Tenth Year Progress Report for NASA Co-operative Agreement NNX12A05A

December 30, 2021

ARC-CREST (Ames Research Center Co-operative for Research in Earth Science and Technology)

NASA Technical Officer:

Dr. Florian M. Schwandner/florian.m.schwandner@nasa.gov

NSSC Grant Officer:

Morris Hicks/NSSC-Grant-Reporting@mail.nasa.gov

Prepared by:
Dr. Robert W. Bergstrom
Principal Investigator
Bay Area Environmental Research Institute
P.O. Box 25
Moffett Field, CA 94035
707-938-9387

Period of Performance 3/1/21 to 2/28/22

Table of Contents

Introduction

The Cooperative Agreement creating the Ames Research Center Cooperative for Research in Earth Science and Technology ("ARC-CREST") provides on page 16 (Required Publications and Reports) that a progress report is due annually, 60 days prior to the anniversary date of the grant/cooperative agreement. Accordingly, we present this report for the tenth year of this Cooperative Agreement.

The primary task of ARC-CREST is to work cooperatively with NASA Ames Research Center's Earth Science Division and related groups to achieve NASA's strategic Earth Science objectives. These objectives include: (1) the conduct of research into fundamental questions related to the atmosphere, the oceans, the biosphere, and Earth's land masses; (2) the use of informational and computational sciences to visualize, analyze, and interpret Earth Science data; (3) the application of technology necessary for Earth Science research; and (4) the provision of outreach and education to the general public regarding Earth Science. As shown below, in the tenth year of the ARC-CREST cooperative agreement, the current participants, Bay Area Environmental Research Institute ("BAERI") and California State University Monterey Bay ("CSUMB") achieved each of these objectives despite the postponement of many Earth Science mission-related activities due to the COVID pandemic.

Robert W. Bergstrom, Ph.D., J.D.
Director of Research

ARC-CREST Partners

Bay Area Environmental Research Institute
California State University at Monterey Bay
NASA Ames Research Center – Earth Sciences Division

ARC-CREST Participants

BAERI

Alfter, Judy	Hoban, Susan	Pompeii, Alexandria
Allison, Quincy D.	Hoffmann, Gary	Ravindra, Vinay
Ash, Gary	Hu, Terry	Ryan, Leslie
Behan, David	Jacobson, James	Schaller, Emily L.
Bengtsson, Zach	Justice, Erin	Schine, Casey
Bennett, Ryan	Kennedy, Lynn	Schlick, Greg A.
Biggs, Brenna	Ketzner, Ryan	Schmidt, Cindy
Broccardo, Stephen	Kim, Sam	Schoenung, Susan
Bulger, Brad	Kulawik, Susan	Schroeder, Michael
Chang, Cecilia S.	LeBlanc, Samuel	Segal-Rozenhaimer, Michal
Cordova, Lorena	Li, Alan	Shinozuka, Yohei
Das, Puja (former staff)	Liem, Andrian	Sonntag, John
Dean-Day, Jonathan M.	McCullum, Amber Jean	Stern, Kathryn
Dominguez, Rose	McFadden, Susan	Su, Haiping
Drdla, Katja	Moustafa, Samiah	Tan, Qian
Duffy, Kate	Murphy, Caitlin	Tulley, Nikki Rae
Dunwoody, Kent	Myers, Jeffrey	Van den Bergh, Jarrett
Ellis, Thomas	Nag, Sreeja	Vandal, Thomas James
Esch, Conrad	Nicholas, Sommer	Venancio, Scott A.
Esswein, Robert	Padhi, Ayuta	Webster, Adam L.

Finch, Patrick E.	Park, Taejin	Windham, Paul
Fraim, Eric	Perlongo, Kassie	Yates, Emma
Gribschaw, Diane	Phan, Tu	Yip, Wen F.
Grose, Jeff	Phothisane, Stevie	Zheng, Jian
Hartlep, Thomas	Pinsker, Ethan	
Hildum, Edward	Pistone, Kristina M.	

CSUMB

Alexander, Susan	Genovese, Vanessa Brooks	Lopez, Javier
Ambrosia, Vincent	Guzman, Alberto	McCarrell, Samantha
Burroughs, Kristen	Hang, Michael	Melton, Forrest
Carrera, Will	Hansen, Pam	Solymar, Ryan
Cihasky, Andrea	Hashimoto, Hirofumi	Wang, Weile
Doherty, Conor	Johnson, Lee	

NASA

Brosnan, Ian	Iraci, Laura	Oaida, Catalina
Bubenheim, Dave	Jenkins, Amber	Pavlick, Ryan
Bui, Thaopaul	Jenkins, Jon	Podolske, Jim
Chirayath, Ved	Johnson, Matthew	Poulter, Ben
Davidson, Mark	Johnson, Roy	Schwandner, Florian
Dunagan, Stephen	Kacenelenbogen, Meloë	Spackman, Ryan
Dungan, Jennifer	Little, Mike	Tenenbaum, Peter
Eilers, Jim	Luna, Bernadette	Turner, Woody
Fladeland, Matt	McClain, Shanna	Ueyama, Rei
Friedl, Lawrence	Mehrotra, Piyush	Vasques, Marilyn
Gaddis, Keith	Michaelis, Andrew	Wang, Weile

Graczyk, Indrani	Moore, Berrien	Wohler, Bill
Granger, Stephanie	Natraj, Vijay	Yu, Hongbin
Gutman, G.	Nemani, Rama	

Other Partners

InuTeq	DRI	Giordano, Marco
UGA	Caltech	Girona, Tarsilo
JPL	Becker, Jeff	Golston, Levi
OVSICORI Costa Rica	Bledsoe, Brian	Lammers, Rod
Michigan Technological University	Cheung, Kar-Ming	Nelson, Katie
University of Costa Rica	de Moor, Maarten	Payne, Vivienne
Stanford University	Deering, Chad	Sanchez Net, Marc
University of Alaska, Fairbanks	Diaz, Andres	Wilcox, Eric
NPP	Doherty, Conor	Yung, Yuk

Earth Science Focus Areas

4STAR and Satellite Data Analysis

Project Participants

BAERI: Samuel LeBlanc, Kristina Pistone, and Stephen Broccardo

Project Description: 4STAR Project Overview

The 4STAR Sunsat project has multiple tasks associated with it:

- ORACLES (ObseRvations of Aerosols above CLouds and their intEractionS);
- ISFM (Internal Science Funding Model) - Radiation Science Program (RSP);
- ISFM - Atmospheric Composition Program (ACP);
- IRAD (Internal Research And Development) - muSSTAR; and
- Canada's NRC (National Research Council) COSR (Canadian Oil Sands Regions, experiment).

The 4STAR (Sky-scanning, Sun-tracking Atmospheric Research) project quantifies solar light transmission through the atmosphere, including aerosol, trace gases, and clouds. We use airborne measurements obtained from the 4STAR instrument, as well as other airborne and ground-based instruments (e.g., AERONET and Pandora), to study the microphysical properties of the atmospheric constituents and their impact on the radiative environment, and, consequently, on climate.

We analyze measurements from these instruments (4STAR, its predecessor AATS-14) to yield atmospheric aerosol optical depth and extinction spectra, aerosol size distributions, aerosol absorption and refractive index, cloud optical depth and microphysical properties, water vapor columns and profiles, and ozone column density. We have used the sun-photometer instruments to validate measurements from 12 satellite instruments, two airborne simulators of satellite instruments, and several airborne and ground-based LIDARS. The new muSSTAR instrument concept and 5STAR instrument broaden the available platforms, and add the additional measurement capabilities of high accuracy, multi-decade dynamic range filter-photodiode detectors to supplement and increase the stability of spectrometers, while reducing size, weight, and power for greater flexibility.

Accomplishments

Kristina Pistone

- Continued work on processing and optimizing 4STAR sky scans from ORACLES 2017/2018. Initial QC'd ORACLES 2016 sky scans used 5 wavelengths (400, 500, 675, 870, 995nm), and the two subsequent years exhibited irregularities in the 400nm radiances. This was further explored in 2021 to determine whether the 2017/2018 irregularities could be robustly corrected for using theoretical radiance fitting (this

possibility was then eliminated as a course of action). Analysis and processing of sky scan data is ongoing, including QC and collocation with other ORACLES aerosol instrumentation (see below); and

- Drafted paper to describe and then compare the 4STAR sky scan retrievals to the in situ (and SSFR-retrieved) SSAs, spatially and by season, over the three years of deployment. Working title: "Aerosol intensive properties of biomass burning smoke measured by an airborne sun photometer over the southeast Atlantic, 2016-2018"

Samuel LeBlanc

- Led project linked to cloud radiative effects during ORACLES: "Cloud radiative effect changed due to shading from above cloud absorbing aerosol in the southeast Atlantic" by Samuel E. LeBlanc, Jens Redemann, Michal Segal-Rosenheimer, Connor Flynn, Meloë Kacenelenbogen, Kristina Pistone, Yohei Shinozuka, K. Sebastian Schmidt, Hong Chen, and Sabrina Cochrane. In preparation for publication to ACP;
- Supported database creation for 4STAR and AATS data, stored on the Ames' NAS. This is in support of paper led by B. Cornelison: "Airborne Remote Sensing Measurements of Particles in Different Parts of the World";
- Contributed to the publication of the Canadian Oil Sands Region Research led by Konstantin Baibakov: "Airborne and ground-based measurements of aerosol optical depth of freshly emitted anthropogenic plumes in the Athabasca Oil Sands region." Published, with new added analysis of MODIS to 4STAR AOD comparisons;
- Supported muSSTAR / 5STAR design and radiometer testing as well as the preparation of science guidance of muSSTAR and 5STAR design Radiometer testing data analysis for radiometric and thermal stability;
- Supported 4STAR ORACLES aerosol microphysical property retrieval and provided data quality assurance for AOD and input measurements to retrievals.
- Provided support role and science advising on retrievals to Connor Flynn, Logan Mitchell, and Kristina Pistone;
  Supported snow surface retrieval implementation on Ames' NAS for SBG testing and advised on implementation of computational clusters on NAS;
- Built new software for Hyperion geolocation and viewing angle calculations;
- Led project comparing the spatial extent of aerosol intensive and extensive properties during KORUS-AQ: "Airborne observation during KORUS-AQ of consistent aerosol optical depth and less consistent aerosol intensive properties " by Samuel E. LeBlanc, Michal Segal-Rozenhaimer, Jens Redemann, Connor Flynn, Roy R. Johnson, Stephen E. Dunagan, Robert Dahlgren, Jhoon Kim, Myungje Choi, Arlindo da Silva, Patricia Castellanos, Qian Tan, Luke Ziemba, K. Lee Thornhill, and Meloë Kacenelenbogen. Current status: Near submission (within a few weeks), need to address a few co-authors comments;
- Was part of a selected proposal (Including K. Pistone): ROSES 2020, (TASNPP) The Science of Terra, Aqua, Suomi NPP, and JPSS Series Satellites: "Transitioning an

existing near real-time MODIS cloud and above-cloud absorbing aerosol retrieval algorithm into a new MODIS/VIIRS continuity product" PI: Kerry Meyer;

- Published 2 code repositories:
    - 4STAR Team, Samuel LeBlanc, Connor J Flynn, Kristina Pistone, Michal Segal-Rozenhaimer, Meloë Kacenelenbogen, and Stephen Broccardo. (2020). samuelleblanc/4STAR_codes: 4STAR processing codes for 2020 (1.1.0). Zenodo. https://doi.org/10.5281/zenodo.3785745; and
    - Samuel LeBlanc, and millercommamatt. (2021). samuelleblanc/fp: Moving Lines with python3 (v1.27). Zenodo. https://doi.org/10.5281/zenodo.5598279.

Stephen Broccardo

- Mentored Chaitu Nookala (volunteer student intern) to work on the Home-STAR robot prototype, and achieved successful motion compensation using an IMU and inverse-kinematics solver;
- Provided engineering judgement and direction for the 5STAR (next-generation airborne sunphotometer) project based on testing done by student intern Conrad Esch (now a BAERI employee, working at ASF and on SeaSTAR), and plots generated by Sam LeBlanc for temperature stability testing;
- Developed a message-passing software architecture and implementation in LabView for the 5STAR instrument prototype;
- Re-negotiated a ROSES New Investigator Program (NIP) proposal for SeaSTAR with NASA HQ Program Manager Allison Leidner. This is now a funded project and reported under a separate task;
- Analyzed 4STAR NO_2 column measurements from KORUS-AQ in collaboration with Michal Segal-Rosenhaimer. This paper is near completion; and
- Analyzed AERONET and Pandora ground-based data, and comparisons with OMI at Ames & JPL/TMF, and expanded to the global fleet of co-located instruments. Aiming to publish in e.g., Geophysical Research Letters.

Presentations

- Pistone et al featured poster in the Southern Hemisphere working group at the IGAC (International Global Atmospheric Chemistry) online conference, September 2021: "Biomass burning smoke and coincident water vapor over the southeast Atlantic stratocumulus region: results from observations and models."
- LeBlanc S. et al, Aerosol optical depth is more consistent than aerosol size over large distances during KORUS-AQ, in American Geophysical Union Fall Meeting, December 2021, New Orleans and online.

Publications

Baibakov, K., LeBlanc, S., Ranjbar, K., O'Neill, N., Wolde, M., Redemann, J., Pistone, K., Li, S.-M., Liggio, J., Hayden, K., Chan, T., Wheeler, M., Nichman, L., Flynn, C. and Johnson, R.: Airborne and ground-based measurements of aerosol optical depth of freshly emitted anthropogenic plumes in the Athabasca Oil Sands region, Atmos. Chem. Phys., 1–27, doi:10.5194/acp-2020-1218, 2021.

Pistone, K., Zuidema, P., Wood, R., Diamond, M., da Silva, A. M., Ferrada, G., Saide, P. E., Ueyama, R., Ryoo, J.-M., Pfister, L., Podolske, J., Noone, D., Bennett, R., Stith, E., Carmichael, G., Redemann, J., Flynn, C., LeBlanc, S., Segal-Rozenhaimer, M., and Shinozuka, Y.: Exploring the elevated water vapor signal associated with the free tropospheric biomass burning plume over the southeast Atlantic Ocean, Atmos. Chem. Phys., 21, 9643–9668, https://doi.org/10.5194/acp-21-9643-2021, 2021.

Cochrane, S. P., Schmidt, K. S., Chen, H., Pilewskie, P., Kittleman, S., Redemann, J., LeBlanc, S., Pistone, K., Segal Rozenhaimer, M., Kacenelenbogen, M., Shinozuka, Y., Flynn, C., Ferrare, R., Burton, S., Hostetler, C., Mallet, M., and Zuidema, P.: Biomass Burning Aerosol Heating Rates from the ORACLES 2016 and 2017 Experiments, Atmos. Meas. Tech. Discuss. [preprint], https://doi.org/10.5194/amt-2021-169, in review, 2021.

Cochrane, S., Schmidt, K. S., Chen, H., Pilewskie, P., Kittelman, S., Redemann, J., LeBlanc, S., Pistone, K., Kacenelenbogen, M., Segal Rozenhaimer, M., Shinozuka, Y., Flynn, C., Dobracki, A., Zuidema, P., Howell, S., Freitag, S. and Doherty, S.: Empirically-Derived Parameterizations of the Direct Aerosol Radiative Effect based on ORACLES Aircraft Observations, Atmos. Meas. Tech., 14, 567–593, doi:10.5194/amt-14-567-2021, 2021.

Chang, I., Gao, L., Burton, S. P., Chen, H., Diamond, M. S., Ferrare, R. A., Flynn, C. J., Kacenelenbogen, M., LeBlanc, S. E., Meyer, K. G., Pistone, K., Schmidt, S., Segal-Rozenhaimer, M., Shinozuka, Y., Wood, R., Zuidema, P., Redemann, J. and Christopher, S. A.: Spatiotemporal Heterogeneity of Aerosol and Cloud Properties Over the Southeast Atlantic: An Observational Analysis, Geophys. Res. Lett., 48(7), 1–12, doi:10.1029/2020gl091469, 2021.

Choi, Y., Ghim, Y. S., Rozenhaimer, M. S., Redemann, J., LeBlanc, S. E., Flynn, C. J., Johnson, R. J., Lee, Y., Lee, T., Park, T., Schwarz, J. P., Lamb, K. D. and Perring, A. E.: Temporal and spatial variations of aerosol optical properties over the Korean peninsula during KORUS-AQ, Atmos. Environ., (February), 118301, doi:10.1016/j.atmosenv.2021.118301, 2021.

Doherty, S. J., Saide, P. E., Zuidema, P., Shinozuka, Y., Ferrada, G. A., Gordon, H., Mallet, M., Meyer, K., Painemal, D., Howell, S. G., Freitag, S., Dobracki, A., Podolske, J. R., Burton, S. P., Ferrare, R. A., Howes, C., Nabat, P., Carmichael, G. R., da Silva, A., Pistone, K., Chang, I., Gao, L., Wood, R., and Redemann, J.: Modeled and observed properties related to the direct aerosol radiative effect of biomass burning aerosol over the Southeast Atlantic, Atmos. Chem. Phys. Discuss. [preprint], https://doi.org/10.5194/acp-2021-333, in review, 2021.

Gupta, S., McFarquhar, G. M., O'Brien, J. R., Delene, D. J., Poellot, M. R., Dobracki, A., Podolske, J. R., Redemann, J., LeBlanc, S. E., Segal-Rozenhaimer, M., and Pistone, K.: Impact of the variability in vertical separation between biomass burning aerosols and marine

stratocumulus on cloud microphysical properties over the Southeast Atlantic, Atmos. Chem. Phys., 21, 4615–4635, https://doi.org/10.5194/acp-21-4615-2021, 2021.

Norgren, M. S., Wood, J., Schmidt, K. S., Diedenhoven, B. Van, Snorre, A., Ziemba, L. D., Crosbie, E. C., Shook, M. A., Kittelman, A. S., Samuel, E., Broccardo, S., Freitag, S. and Reid, J. S.: Above-aircraft cirrus cloud and aerosol optical depth from hyperspectral irradiances measured by a total-diffuse radiometer, Atmos. Chem. Phys. Discuss., 10(September), 1–36, doi:https://doi.org/10.5194/amt-2021-269, 2021.

Redemann, J., Wood, R., Zuidema, P., Doherty, S. J., Luna, B., LeBlanc, S. E., Diamond, M. S., Shinozuka, Y., Chang, I. Y., Ueyama, R., Pfister, L., Ryoo, J.-M., Dobracki, A. N., da Silva, A. M., Longo, K. M., Kacenelenbogen, M. S., Flynn, C. J., Pistone, K., Knox, N. M., Piketh, S. J., Haywood, J. M., Formenti, P., Mallet, M., Stier, P., Ackerman, A. S., Bauer, S. E., Fridlind, A. M., Carmichael, G. R., Saide, P. E., Ferrada, G. A., Howell, S. G., Freitag, S., Cairns, B., Holben, B. N., Knobelspiesse, K. D., Tanelli, S., L'Ecuyer, T. S., Dzambo, A. M., Sy, O. O., McFarquhar, G. M., Poellot, M. R., Gupta, S., O'Brien, J. R., Nenes, A., Kacarab, M., Wong, J. P. S., Small-Griswold, J. D., Thornhill, K. L., Noone, D., Podolske, J. R., Schmidt, K. S., Pilewskie, P., Chen, H., Cochrane, S. P., Sedlacek, A. J., Lang, T. J., Stith, E., Segal-Rozenhaimer, M., Ferrare, R. A., Burton, S. P., Hostetler, C. A., Diner, D. J., Seidel, F. C., Platnick, S. E., Myers, J. S., Meyer, K. G., Spangenberg, D. A., Maring, H., and Gao, L.: An overview of the ORACLES (ObseRvations of Aerosols above CLouds and their intEractionS) project: aerosol–cloud–radiation interactions in the southeast Atlantic basin, Atmos. Chem. Phys., 21, 1507–1563, https://doi.org/10.5194/acp-21-1507-2021, 2021.

Weston, M., Piketh, S., Burnet, F., Broccardo, S.P., Denjean, C., Bourrianne, T., Formenti, P., Sensitivity analysis of an aerosol-aware microphysics scheme in WRF during case studies of fog in Namibia, in prep for Atmospheric Chemistry and Physics.

Committees and Service

Kristina Pistone

- CLOUD GAZE Science Steering Committee (May 2021-present). Science advisory on development of a new community science platform as part of NASA's GLOBE program;
- NASA ARC Science Directorate Diversity and Inclusion Advisory Committee (April 2021-present);
- Unlearning Racism in Geosciences (URGE), pod leader (January 2021-present), https://urgeoscience.org/pods/earth-scientists-near-hangar-one/ ;
- Earth Science Seminar Committee, NASA ARC (January 2021-present);
- NASA Technical Review Committee for MUREP (Minority University Research and Education Project) Center for Advanced Measurements in Extreme Environments (CAMEE) project (June 2020-present), including review of COVID-related 2y funding extension;
- American Geophysical Union Fall Meeting Program Committee (June 2020-present), Atmospheric Sciences section;

- NASA GLOBE Subject Matter Expert on aerosols and clouds (videos, webinars, and interactive Q&A for educators and students), 2 events in 2021; and
- Paper peer reviews at Atmos Chem Phys, J Geophys Res, and Atmos Res.

Samuel LeBlanc

- Peer reviewer for Atmospheric Chemistry and Physics, Geoscientific Model Development, and Journal of Applied Meteorology and Climatology;
- Virtual Panel member for selecting NASA Postdoctoral Program (NPP); and
- Member of Aerosol Cloud Convection and Precipitation (ACCP) suborbital meetings.

Stephen Broccardo

- Peer reviewer for Atmospheric Measurement Techniques, and South African Clean Air Journal.

5STAR/Eng-Sci

Project Participants

NASA: Stephen Dunagan
BAERI: Samuel LeBlanc, Conrad Esch, Scott Venancio, Stephen Broccardo

Project Description

The ARC (Ames Research Center) Sun-photometer/Satellite group supports a variety of instruments with a specific focus on airborne sun photometers that provide measurements of tropospheric aerosols (i.e. low-level atmospheric particles, such as from smoke, dust, or pollution) and trace gases. ARC maintains existing instruments (4STAR-A and -B), and is developing the next generation instrument: 5STAR (ultra-Stable Spectrometers for Sky-Scanning Sun-Tracking Atmospheric Research). 5STAR depends on precision radiometers and spectrometer detectors, and includes a variety of transmissive, diffractive, and diffusive optical elements, including fiber optic light path technology. Robotics technology is required for sun tracking and sky scanning functionality in the aircraft environment with the detector head exposed to free stream environmental conditions up to the tropopause.

5STAR will be an improvement over the current instruments by reducing measurement uncertainty and improving calibration stability, all with smaller weight and power (SWAP) packaging, which is enabled by modern sensor and digital processing technology. 5STAR adopts a new means of sun-tracking, miniature fiber spectrometers, and custom circuitry. The design includes a camera for sun-tracking purposes in place of a quadrant detector (what its predecessor 4STAR uses). 5STAR also includes custom circuitry to thermally stabilize both silicon and InGaAs photodiodes at discrete wavelengths, and custom boards to amplify the signal.

Accomplishments

- Developed flight instrument mechanical design based on COTS and custom components to scope geometry for loads analysis;
- Performed initial flight instrument loads analysis;
- Benchtop-tested improved A/D converter;
- Benchtop-tested triple-gain radiometer/amplifier circuit to establish thermal drift characteristics;
- Prototyped thermal control design using thermo-electric coolers and a water-cooling circuit;
- Assembled proof-of-concept brassboard to test radiometers, spectrometers, thermal control, and tracking system; and
- Developed initial mechanical design for a miniaturized instrument to fly on a hexcopter.

ACCDAM

Project Participants

Kristina Pistone (BAERI), Eric Wilcox (DRI), and Marco Giordano (DRI)

Project Description

The climatological effects of atmospheric aerosol particles are primarily regional in scale, yet of global importance. Aerosols alter cloud properties by changing cloud microphysics (e.g. droplet size) or macrophysics (e.g. thickness or altitude), the total cloud amount, or the local atmospheric dynamics. Stratocumulus clouds, by covering large regions of the subtropical oceans, are a large component of global albedo, and changes in the reflectivity of these regions may have global impacts. We use observations from the NASA ORACLES airborne campaigns in the southeast Atlantic (SEA) between 2016 and 2018, and the multi-platform VOCALS-REx campaign in the southeast Pacific (SEP) in 2008 to observationally quantify the impact of water vapor under different aerosol conditions. The SEA stratocumulus are seasonally subjected to biomass burning (BB) emissions advected from springtime agricultural fires in southern Africa. In contrast, the SEP is largely influenced by local anthropogenic sulfate aerosol. The regions also differ in water vapor context: while VOCALS saw very low above-cloud water vapor content, ORACLES saw a humid layer co-located with the BB plume. Studies of these two regions together can thus provide valuable insights into the complex radiative and dynamic interactions between water vapor, aerosols, and clouds, in current and future climate.

In this project, we seek to explain how atmospheric water vapor governs aerosol effects on stratocumulus clouds, and establish how cloud-top radiative fluxes vary with above-cloud humidity and aerosol, and how this affects cloud macrophysics (specifically, cloud liquid water and cloud fraction). Our analysis will use a combination of observations from suborbital field campaigns, satellite data, and reanalysis products over two stratocumulus regions. We will use the ORACLES and VOCALS observations of aerosol and cloud properties and atmospheric state to gain a better understanding of the impacts of water vapor on cloud properties in these stratocumulus regimes, how water vapor varies with aerosol loading, and the radiative and dynamic effects of this covariance. We will incorporate vertically-resolved and geostationary satellite observations and large-scale reanalysis to understand the conditions preceding and following aircraft measurements, and to capture the range of variability in water vapor and aerosol conditions over the two regions. Finally, we will use this understanding to quantify the relative radiative effects of atmospheric humidity and aerosol in these regions.

By better understanding the importance of water vapor to the radiative and dynamic processes that control aerosol effects on stratocumulus clouds, we will ultimately be able to better quantify direct, semi-direct, and indirect aerosol effects in the present-day and future climate.

Accomplishments

This is a fairly new project, and we are working towards accomplishments beyond the scheduled AGU talk below.

Presentations

- AGU Fall Meeting 2021: “Variations in radiative heating of humid biomass burning aerosols in the southeast Atlantic from airborne observations and reanalysis.” K. Pistone, E.M. Wilcox, M. Giordano, P. Zuidema, R. Wood https://agu.confex.com/agu/fm21/meetingapp.cgi/Paper/954715.

ACCLIP/COMA

Project Participants

NASA: Laura Iraci, Jim Podolskie, Roy Johnson, and Jim Eilers
BAERI: Emma Yates
NPP: Levi Golston

Project Description

ACCLIP (Asian Summer Monsoon Chemical & CLimate Impact Project) aims to investigate the impacts of Asian gas and aerosol emissions on global chemistry and climate via the linkage of Asian Summer Monsoon (ASM) convection and associated large-scale dynamics. Main deployment: July – August, 2022 – Osan AFB, South Korea. Test flights: July - August 2021, Houston, Texas.

COMA (Carbon mOnoxide Measurement from Ames) will play a valuable role in determining CO and N_2O mixing ratios in the stratosphere, both of which are tracers of surface influence/pollution and will be used in future data analysis.

Accomplishments

- Modified a lab-based CO instrument to one that is capable of flying unpressurized to 50 kft onboard the WB-57;
- Performed laboratory tests and a number of simulated flights in a pressure and temperature controlled chamber to evaluate the instrument's performance;
- Deployed to Houston, Texas in July/August to participate in the ACCLIP test flight series. We integrated the flight payload, tested instrument performance, and conducted an in-flight comparison with the DCOTTS field campaign, which allowed instruments to be compared in flight; and
- Analyzed data post-deployment, and evaluated the instrument's performance and science.

Presentations

- Presentation to Earth Science Division (November 2021 meeting).
- AGU presentation (LG is lead author).

Aerosol Modeling & Data Analysis

Project Participants

NASA: Hongbin Yu
BAERI: Qian Tan

Project Description

Aerosols, small particles suspended in the air, can affect air quality and climate in many ways. As one of the major air pollutants, aerosols not only affect local air quality, but can also travel long distances. In the summer of 2020, a severe dust plume travelled clear across the Atlantic Ocean and degraded air quality in many states in the Southeast of the United States.

We use various NASA satellite measurements to track the movement of this gigantic dust plume. Satellites measure aerosol distribution and properties from different perspectives, and two Lidar systems measure the vertical profile of aerosols. The spatial coverage of these systems' orbits provides a unique opportunity to study the polar-ward transport of aerosols from major aerosol source regions, both man-made and natural, to high latitude. By combining this data with model-simulated aerosol distribution and NASA GMAO's MERRA-2 meteorological fields, we estimated the seasonal and regional averages of aerosol vertical profiles at major aerosol source regions and transport pathways.

Accomplishments

- Studied the evolution of a gigantic dust storm that travelled from North African deserts and caused air quality degradation over the Southeast United States;
- Evaluated seasonal aerosol vertical profiles at different geographic locations; and
- Studied the relationship of aerosol chemical properties and optical properties using NASA aircraft campaign measurements.

Presentations

- Qian Tan, Hongbin Yu, Huisheng Bian, AMS Annual Meeting: Dust Transport to the Arctic Circle Estimated by a Combination of Satellite Measurements and Assimilated Wind Fields, Virtual, Jan 2021.
- Qian Tan, Hongbin Yu, Huisheng Bian, AGU Fall Meeting 2021: Poleward dust transport estimated by a combination of lidar measurements and MERRA-2 wind fields.

Publications

https://doi.org/10.1029/2019JD030822

Yu, H., Tan, Q., Zhou, L., Zhou, Y., Bian, H., Chin, M., Ryder, C. L., Levy, R. C., Pradhan, Y., Shi, Y., Song, Q., Zhang, Z., Colarco, P. R., Kim, D., Remer, L. A., Yuan, T., Mayol-Bracero, O., and Holben, B. N.: Observation and modeling of the historic "Godzilla" African dust intrusion into the Caribbean Basin and the southern US in June 2020, Atmos. Chem. Phys., 21, 12359–12383, https://doi.org/10.5194/acp-21-12359-2021, 2021.

Agriculture, Health, and Marine Applied Sciences

Project Participants

NASA: Ramakrishna Nemani, and Jennifer Dungan
CSUMB: Forrest Melton, Lee Johnson, Alberto Guzman, Will Carrara, Michael Hang, and Ryan Solymar
Student team members: Javier Lopez, Andrea Cihasky, Kristen Burroughs (CSUMB), and Conor Doherty (Stanford University)

Project Description

CSUMB personnel have a long history of participation and support of NASA research and applied science missions that apply satellite data to improve our understanding of environmental conditions and processes that affect agriculture, public health and vectorborne disease, coral reefs, and other marine ecosystems. Under this task, CSUMB conducts research and applied science activities in these areas in collaboration with the Ames Earth Science Division (AESD) and numerous collaborators in government agencies, non-profits and NGOs, and the commercial sector. This task applies remote sensing data, agricultural models, ecological and weather models, and epidemiologic, vector, and pathogen models to advance the ability of U.S. and international institutions to understand and manage these processes. Activities include analysis of satellite data, management of airborne and field campaigns to collect data, and development of models and decision support systems.

Our primary objectives are to:

- Apply satellite data, airborne data, flux towers, and other ground-based instrumentation to model and map agricultural productivity, evapotranspiration and crop water demand;
- Apply satellite data, climate models, and ecological models to map habitat for disease vectors and model vector-borne disease transmission risk; and
- Apply satellite multispectral and airborne hyperspectral data, coupled with field measurements of biological data, to contribute to research on ecosystem health, ecological structure, and benthic habitat biodiversity of coral reefs and associated biotopes.

During 2021, research activities focused solely on the first objective, based on priorities and funding availability from NASA.

Accomplishments

- Published 6 peer reviewed journal articles, with 3 articles currently in final preparation for a total of 9 prepared papers, 6 of which were published in 2021. The team also has two other manuscripts currently in preparation;
- Presented more than 14 scientific and technical talks/posters at science conferences and technical meetings. F. Melton also provided dozens of briefings and presentations leading up to the OpenET public launch in October 2021, including presentations for the American Farm Bureau Federation, the California Farm Bureau, the U.S. Office of Management and Budget, House and Senate Offices and Natural Resources Committee, the California Department of Food and Agriculture, Family Farm Alliance, Kern Farm Bureau, Kern Groundwater Authority, and others;
- Mentored three CSUMB students and one Stanford University student who worked with the SIMS and OpenET projects in 2020 (Javier Lopez, Andrea Cihasky, Kristen Burroughs, Conor Doherty). Additional research internships will be offered in 2022;
- Secured an additional $1.5 million ($8.5 million in total funding to date) for the OpenET project from the Rauner Family Fund and the Walton Family Fund, in addition to $500k from the NASA Applied Sciences Program. The OpenET project is advancing operational mapping of field scale information on evapotranspiration (ET) via open web data services and APIs. The OpenET project is a partnership among 3 NASA Centers (ARC, JPL, MSFC), EDF, Google, the Desert Research Institute, USDA, USGS, and multiple university research teams. F. Melton is the NASA project scientist for OpenET and co-lead for the project, and continues to lead a team of >45 leading experts on remote sensing of ET. Co-Is Guzman, Carrara and Johnson led the implementation of the NASA SIMS ET model on the Earth Engine platform and production of field-scale ET data for 17 western states to date. Carrara and Guzman also led the development of the raster API for the OpenET interface, as well as implementation of the daily data workflows. The team supported the public launch of OpenET in October 2021 — OpenET was featured on nasa.gov, and the launch was announced by the NASA Administrator. All CSUMB team members were co-authors on the manuscript describing the OpenET framework, and the results of Phase I of the OpenET accuracy assessment and intercomparison study, which is the largest accuracy assessment and intercomparison of field-scale ET data conducted to date. Articles on OpenET have been published in hundreds of regional and national newspapers;
- Concluded work on the WesternET project, a ROSES supported project on evapotranspiration (ET) mapping in the western US in collaboration with Univ. Nevada/Desert Research Institute. Co-PI Johnson and Sr. Software Engineer Guzman collaborated with DRI to apply SIMS and METRIC to map ET across four critically impacted basins spanning 6 western states. Project results are currently helping to support the OpenET effort;
- Concluded work on the SIMS-CropManage project for the Western Water Applications Office. This project integrates satellite-derived data products from the NASA Satellite Irrigation Management Support (SIMS) system into the CropManage irrigation and nutrient management software application. CropManage was developed by the University

of California Agriculture and Natural Resources (UCANR) Institute to support data-driven management of irrigation and nutrients for a wide range of high value specialty crops;

- Completed and released an updated Application Programming Interface (API) for SIMS, and used the API to integrate data from SIMS with the UCANR CropManage tool, with support from the NASA Western Water Applications Office. This allows data from SIMS to be used operationally to support irrigation and fertilizer management decisions by more than 3,000 California growers. W. Carrara and A. Guzman also worked with HabitatSeven to redesign the SIMS website. In addition, the project deployed and maintained flux towers in collaboration with Central Coast growers to support expansion of CropManage to include wine grapes and celery. R. Solymar supported the deployment and operation of eddy covariance instrumentation in commercial fields and vineyards. The data from these flux towers are currently being used to evaluate ET data and irrigation recommendations from CropManage for these crops. The SIMS API has also been provided to multiple commercial partners for testing and use in commercial applications;
- Will Carrara supported collaborative work with NASA Goddard Space Flight Center to develop applications of satellite data for Mercy Corps, with support from the NASA Applied Sciences Program. This partnership is leveraging capabilities provided by SIMS to provide smallholder farmers across Africa who lack access to affordable, accessible, data-driven remote sensing products and services which drive higher productivity and income for their households. Digital tools and platforms like SIMS can help overcome these challenges as well as improve farmers' digital literacy and irrigation practices. Carrara is currently serving as the NASA project manager for this activity and is regularly coordinating with NASA HQ and the Agrafin team leadership to advance the project. In his role, Will has given multiple presentations on SIMS to various groups from Nairobi to Ethiopia. Presently, the project is fostering collaboration with the Ethiopian Agricultural Transformation Agency (ATA), and Kenya’s Agricultural & Livestock Research Organisation (KALRO). Both these collaborations and others will continue to advance the SIMS platform internationally;
- Continued to use a DJI Matrice 600 Pro hexacopter UAV platform and Micasense Altum camera to collect multispectral imagery over agricultural fields in the Salinas Valley, in partnership with USDA ARS in Salinas, CA. The project team (F. Melton, PI; M. Hang Co-I) continued joint research with USDA ARS under a five-year cooperative agreement with USDA ARS ($500k total funding) to identify and map plant pathogen presence in strawberries and other high value specialty crops. The project team is currently monitoring multiple strawberry fields for plant pathogens and assessing development of crop canopies and fractional cover across multiple crops to verify and improve the SIMS algorithms. M. Hang used the UAV to map multiple research sites, applied an automated data processing workflow for tens of thousands of UAV images to create timeseries maps, and is currently working with USDA partners to incorporate data on crop yields and pathogen density into the analysis. The ultimate goal of this project is to provide an information tool that will support early detection of disease and targeted applications of fumigants in the strawberry industry;

- Continued field trials and research to quantify the value of SIMS and ET-based irrigation scheduling. We have been continuously collecting data on wine grapes in Soledad, CA and our data set now exceeds 18 months. Additionally, the team deployed and maintained instrumentation to quantify ET rates from sorghum at the West Side Research and Extension Center in collaboration with CSU Fresno. Results to date further confirm the value of SIMS for reducing applied water relative to standard practice, and also demonstrate the ability to reduce nitrate leaching by 50-75% or more. We are currently in the process of planning an additional deployment to capture ET rates from *Arundo donax*, a tall (roughly 10m) perennial cane. A key question in the groundwater sustainability plan for the Salinas Valley is the extent to which efforts to eradicate the invasive species also reduce consumptive use of water in the Salinas River basin; and
- Secured additional funding related to this task, which was available only to non-federal, California institutions as follows:
    - Johnson is Co-I on a project led by UC Cooperative Extension under the 2019 CDFA Specialty Crop Block Grants Program ($333k). He is helping to manage irrigation trials in artichoke and red cabbage being conducted at the USDA research station in Salinas;
    - Johnson is PI of a $386k project awarded by the CDFA-SCBGP in 2020 to work with UC Cooperative Extension offices in Monterey, San Luis Obispo, and Fresno Counties to adapt the CropManage-SIMS decision support tool for use in winegrape and tablegrape vineyards;
    - Johnson is PI of a $445k project awarded under the 2021 CDFA-SCBGP. The project will exercise OpenET and CropManage to address sustainability indicators identified by the State of California in response to declining groundwater levels, seawater intrusion, and degraded water quality; and
    - Melton is a PI on a project awarded by the CSU Agricultural Research Institute in 2020 to apply remotely sensed ET data to support implementation of the Sustainable Groundwater Management Act ($400k). This project is mapping ET from high value specialty crops and invasive plants in the Salinas River Watershed to support implementation of the Groundwater Sustainability Plan for the Salinas Valley Basin.

Presentations

- Melton, F., Johnson, L., Guzman, A., Carrara, W., et al., 2021. OpenET: Operational ET Data for Water Management in the Western U.S. AGU Fall Meeting. 1-17 Dec., New Orleans, (invited).
- Melton, F., Johnson, L., Guzman, A., Carrara, W., et al., 2021. OpenET: Operational ET Data for Water Management in the Western U.S. California Department of Food and Agriculture Nutrient Management Conference, San Luis Obispo, CA, Oct 27-28, 2021 (invited).
- Melton, F., Johnson, L., Guzman, A., Carrara, W., et al., 2021. OpenET: Operational ET Data for Water Management in the Western U.S. United Nations Food and Agriculture

Organization, Webinar Series on Remote Sensing of Evapotranspiration, July 7, 2021 (invited).

- Melton, F., Johnson, L., Guzman, A., Carrara, W., Hang, M., Solymar, R., et al., 2021.The NASA Satellite Irrigation Management Support (SIMS) Framework . United Nations Food and Agriculture Organization, Webinar Series on Remote Sensing of Evapotranspiration, May 26, 2021 (invited).
- Melton, F., Johnson, L., Guzman, A., Carrara, W., Hang, M., Solymar, R., et al., 2021.Applications of remote sensing for irrigation management, California Plant and Soil Science Conference, May 25, 2021 (invited).
- Johnson, L., M. Cahn, F. Melton, 2021. Initial evaluation of CropManage decision-support model for vineyard ET estimation. AGU Fall Meeting. 1-17 Dec.
- Volk, J., et al., 2021. OpenET Satellite-based ET Intercomparisons with Ground-based Measurements: Phase II Results. AGU Fall Meeting. 1-17 Dec.
- Johnson, L., F. Cassel Sharma, J. Harding, J. Herring, and F. Melton, 2021. Derivation and Testing of Consumptive Water Use Fraction for Specialty Crops. Amer Soc. Hort. Sci. Annual Meeting, 5-9 Aug. Hortscience 56:9S.
- Cahn, M., L. Johnson, S. Benzen, T. Lockhart, and D. Chambers, 2021. Using Weather-Based Irrigation Scheduling to Optimize Red Cabbage Production. ASHS Annual Meeting, 5-9 Aug. Hortscience 56:9S.
- Johnson, L., J. Harding, J. Herring, F. Cassel Sharma, 2021. Calculator for agricultural water use fractions in California. ASCE World Environmental & Water Resource Congress 23-26 May.
- Johnson, L., 2021. Using weather-based irrigation scheduling for optimizing red cabbage production. UCCE Irrigation and Nutrient Management Meeting, 23 Feb, Salinas (invited).
- Melton, F., L. Johnson, M. Cahn, A. Guzman, W. Carrara, C. Wang, C. Doherty, R. Solymar, M. Hang, F. Cassel-Sharma, 2021. Applications of remote sensing for irrigation management. Amer. Soc. Agronomy, Calif. Plant and Soil Conference, 1-3 Feb., 2021 (invited).
- Grimm, R., et al., 2021. OpenET: Enabling science-based water management through open data services and user-driven design. Amer. Meteorological Soc. Annual Meeting, 35th Conference on Hydrology 10-15 Jan., 2021 (invited).
- Martin, F., Melton, F., Hang, M., et al., 2021. Site-specific soil pest management in strawberry and vegetable cropping systems. MBAO Fumigation and Alternatives for Production, Storage and Trade Conference, 15 Nov 2021.
- Guzman, A. SIMS-CropManage. Nasa Applied Sciences, WWAO and Water Resources Team Meeting, 10 Oct 2021.

Publications

Melton F., W. Carrara, A. Guzman, C. Doherty, L. Johnson, et al., 2021. OpenET: Filling a critical data gap in water management for the western United States. J. Amer. Water Resources Assn., paper no. JAWR-20-0084-P. http://doi.org/10.1111/1752-1688.12956

Pereira, L., P. Paredes, F. Melton, L. Johnson, M. Mota, T. Wang., 2021. Prediction of crop coefficients from fraction of ground cover and height. Practical application to vegetable, field and fruit crops with focus on parameterization. Special issue: Updates & Advances to the FAO56 Crop Water Requirements Methods, Agricultural Water Management 252, 106663. https://doi.org/10.1016/j.agwat.2020.106663

Wang, T., F. Melton, T. Thao, K. Post, L. Johnson, F. Cassel-Sharma, 2021. Evaluation of crop coefficient and evapotranspiration data for sugar beets from Landsat surface reflectances using micrometeorological measurements and weighing lysimetry. Agricultural Water Management 244, 106533. https://doi.org/10.1016/j.agwat.2020.106533

Laipelt, L., Kayser, R.H.B., Fleischmann, A.S., Ruhoff, A., Bastiaanssen, W., Erickson, T.A. and Melton, F., 2021. Long-term monitoring of evapotranspiration using the SEBAL algorithm and Google Earth Engine cloud computing. ISPRS Journal of Photogrammetry and Remote Sensing, 178, pp.81-96.

Volk, J., Huntington, J., Allen, R., Melton, F., Anderson, M. and Kilic, A., 2021. flux-data-qaqc: A Python Package for Energy Balance Closure and Post-Processing of Eddy Flux Data. Journal of Open Source Software, *6*(66), p.3418.

Ahamed, A., Knight, R., Alam, S., Pauloo, R. and Melton, F., 2021. Assessing the utility of remote sensing data to accurately estimate changes in groundwater storage. Science of The Total Environment, 807, p.150635.

Panels or Committees

- NASA Climate Strategy Working Group (F. Melton);
- California Open Water Data Infrastructure Technical Working Group (F. Melton);
- EWRI ET in Irrigation and Hydrology Committee, member at-large (L. Johnson);
- Western Water Applications Office Capabilities Working Group (L. Johnson);
- IGARSS-2021 Scientific Committee (L. Johnson);
- Journal reviewer for Agricultural Water Management (Johnson, Melton); and
- Participation in multiple NASA review panels (Applied Science, SBIR) by Melton.

Alpha Jet Atmospheric Experiment (AJAX)

Project Participants

NASA: Laura Iraci
BAERI: Emma Yates

Project Description

The Alpha Jet Atmospheric eXperiment (AJAX) team takes airborne measurements of ozone, formaldehyde, CO_2, methane and meteorological parameters. Yates's role includes identifying science questions, designing and planning flights, data analysis (IDL, python), maintaining instruments, and scientific writing and presentations. Since 2016, Yates has been responsible for facilitating collaborations through setting up a new laboratory of atmospheric instruments (CO_2, CO, carbonyl sulphide, C-isotopes) and making them available for use within the wider scientific community. To date the project has successfully been awarded four grants to deploy instrumentation on a UAS in Alaska, and to measure COS uptake from coastal Redwood forests.

Accomplishments

- Co-I on an accepted proposal: NASA EARTH SCIENCE DIVISION, Atmospheric Composition Campaign Data Analysis and Modeling, ROSES 2020 Program Element A.23, NNH20ZDA001N-ACCDAM. Proposal Title: Solving the Mystery of the Disappearing Low Ozone Values: Attributing Ozone Trends over the Eastern Pacific Ocean and Western North America;
- Completed a laboratory move to a ground-floor lab which will allow us easier access when AJAX flights return to move wingpods in/out the laboratory. The lab also has access to the outside air (via inlet ports) which will allow us to set up a trace gas sampling lab to accompany the existing roof-top instruments;
- Maintained, calibrated, and serviced AJAX wing pod instruments to ready them for return to flight status (approvals still needed from Ames/airfield management);
- In progress (near completion): Converting all existing AJAX data to ICARRT format for upload to the DAAC; and
- Participated in a panel for NASA Earth Science call.

Presentations

- In-person presentation in the lab/near aircraft for NASA Earth Science Division Director, Karen St. Germain (May 2021).

Atmospheric Composition: Modeling and Analysis Program (ACMAP)

Project Participants

BAERI: Michal Segal-Rozenhaimer (PI)

Project Description

Our goal is to gain a better understanding of the link between aerosols, Marine Stratocumulus Clouds (MSC), and their radiative effects, and how those interactions impact the capabilities of global climate model prediction by developing a novel technique of cloud type classification.

The project's objectives are to:

- Develop a new algorithm to classify MSC cloud cover and MCC (Meso-scale Cellular convection) cell types from multi-spectral satellite imagery on a finer spatial and temporal scale than what is available to-date, using a powerful image-based machine learning technique (semantic segmentation and texture classification via convolutional neural network);

- Utilize the new algorithm to generate high spatial and temporal cloud mask and MCC cell type maps over the South-east Atlantic and South-east Pacific regions, during the ORACLES and VOCALS airborne campaigns, and compare these two different aerosol-laden regions. Between these two regions, we will compare their MCC type cloud microphysical properties (e.g., cloud droplet number concentrations, effective radius, precipitation rate), and macrophysical properties (e.g., cloud albedo, cloud coverage), as well as their diurnal cycle and radiative effects under comparable meteorological conditions to better assess how MSC cloud cell properties change in response to variations in aerosol conditions; and

- Compare our campaign-derived cloud mask, cell types, and their properties with cloud fields and properties derived by GCM. We will use various sub-grid parameterization schemes to evaluate how these schemes (or lack thereof) affect radiative budget estimations due to MSC clouds in climate models. We will explore the differences in the model's predictions under the different aerosol conditions that prevail in the two selected regions of investigation.

Accomplishments

- Generated training for SE Atlantic using SEVIRI data from 2016-2018;
  Developed several machine learning algorithm approaches to predict MCC cloud types using VIS (visible) and IR (infrared) imagery from Geostationary satellites;

- Performed predictions of MCC cloud fields over the ORACLES domain and improved algorithmic approaches;
- Derived climatology and diurnal cycle of low-level clouds over SE Atlantic from SEVIRI; and
- Evaluated MSC simulations in the CMIP6 GCMs.

Presentations

- Marine Stratocumulus Cloud Type Classification from SEVIRI using Convolutional Neural-Network and their Diurnal Cycle over the South-East Atlantic Ocean during ORACLES. Michal Segal Rozenhaimer, NASA Ames Research Center/BAERI, Mountain View, CA, Israel; Tel-Aviv University, Tel-Aviv, Israel; and D. Nukrai, T. Shalev, Z. Zhang, A. Denagamage, R. Wood, and J. Riedi, Oral Presentation, AMS January 2021.
- Cloud Meso-scale Classification and dynamics from the Geostationary SEVIRI satellite using Convolutional Neural-Network, Michal Segal Rozenhaimer, David Nukrai, Robert Wood, Zhibo Zhang, Accepted as Oral presentation for 21st Conference on Artificial Intelligence for Environmental Science, AMS, January, 2022.

Publications

Cloud Meso-scale Classification and dynamics from the Geostationary SEVIRI satellite using Convolutional Neural-Network, Michal Segal Rozenhaimer, David Nukrai, Robert Wood, Zhibo Zhang, in prep. For Remote Sensing of Environment.

Aura-TES

Project Participants

BAERI: Susan Kulawik

Project Description

The Tropospheric Emission Spectrometer (TES) was an infrared spectrometer on the Aura satellite. Its high spectral resolution enabled it to vertically resolve ozone in the Troposphere and measure concentrations of many chemical constituents in our atmosphere including: temperature, water, HDO, methane, ozone, carbon monoxide, carbon dioxide, methanol, ammonia, formic acid, HCN, and PAN. Based analysis from the GEOCAPE project and other analysis, the TES team developed and routinely processes a combined UV (e.g. from OMI, tropOMI, OMPS) and thermal infrared observations (e.g. TES, AIRS, IASI, or CrIS). Even though AIRS and OMI individually each have 1 or less degree of freedom in the Troposphere, combined OMI+AIRS observations have similar sensitivity to TES and are used to continue the TES record of tropospheric ozone measurements. The TES-heritage processing system, called MUSES, contains the ability to process TES, AIRS, CrIS, OMI, and OCO-2. Dr. Kulawik was one of the key developers of the MUSES system, along with Dejian Fu (JPL), John Worden (JPL), Helen Worden (NCAR), and Kevin Bowman (JPL).

Accomplishments

- Developed, validated, and set the bias correction for the CrIS CH4 product.
- Contributed to the documentation for CH4 for AIRS and CrIS.

Publications

Kulawik, S. S., Worden, J. R., Payne, V. H., Fu, D., Wofsy, S. C., McKain, K., Sweeney, C., Daube Jr., B. C., Lipton, A., Polonsky, I., He, Y., Cady-Pereira, K. E., Dlugokencky, E. J., Jacob, D. J., and Yin, Y.: Evaluation of single-footprint AIRS CH4 profile retrieval uncertainties using aircraft profile measurements, Atmos. Meas. Tech., 14, 335–354, https://doi.org/10.5194/amt-14-335-2021, 2021.

Carbon Monitoring Systems (CMS)

Project Participants

NASA: Ramakrishna Nemani
BAERI: Taejin Park

Project Description

The objective of this research is to implement a machine learning algorithm on the Landsat Web-enabled Landsat Data (WELD) composites to generate a yearly forest cover map for Mexico. In addition, the project will implement algorithms to generate biophysical parameters like Leaf Area Index (LAI), Fraction of Photosynthetically Active Radiation (FPAR), and General Purpose Parameters (GPP) using the Terrestrial Observation and Prediction Systems (TOPS) framework on NEX to model biomass, Net Primary Productivity, and carbon flux.

Accomplishments

- Validated the NEX tree cover product using state-wide Lidar based 1-m tree cover estimates;
- Performed inter-comparison of the NEX tree cover using independent existing tree cover product, i.e., NLCD and MODIS product;
- Disseminated the tree cover product to University of Delaware; and
- Enhanced collaborative research activities with CMS project team members (see publications & presentations).

Presentations

- Park. T., Li, S., Vandal, T., Yu, Y., Saatchi, S., Vargas, R., Nemani, R., Generation of continental scale percent tree cover product using deep-learning and multi-scale remote sensing data, Mar 2021, 2021 7th NACP Open Science Meeting.
- Park, T., Kim, M., Nemani, R., Integrating field measurement, remote sensing, and modeling approach to track forest cover and above ground biomass changes in the Northeast Asian temperate forests, Dec 2021, Online, AGU 2021.
- Vargas, R., Park, T., Nemani, R., Carbon monitoring systems across Mexico to support implementation of REDD+: maximizing benefits and knowledge. NASA Carbon Monitoring System Science Team Meeting 2021. CMS Science Team Meeting. November 16-18, 2021.

Publications

Collier, E., Mukhopadhyay, S., Duffy, K., Ganguly, S., Madanguit, G., Kalia, S., Shreekant, G., Nemani, R., Michaelis, A., Li, S. and Ganguly, A., 2021. Semantic Segmentation of High Resolution Satellite Imagery using Generative Adversarial Networks with Progressive Growing. Remote Sensing Letters, 12(5), pp.439-448.

Duncanson, L., Armston, J., Disney, M., Avitabile, V., Barbier, N., Calders, K., Carter, S., Chave, J., Herold, M., MacBean, N., McRoberts, R., Minor, D., Paul, K., Réjou-Méchain, M., Roxburgh, S., Williams, M., Albinet, C., Baker, T., Bartholomeus, H., Bastin, J.F., Coomes, D., Crowther, T., Davies, S., de Bruin, S., De Kauwe, M., Domke, G., Dubayah, R., Falkowski, M., Fatoyinbo, L., Goetz, S., Jantz, P., Jonckheere, I., Jucker, T., Kay, H., Kellner, J., Labriere, N., Lucas, R., Mitchard, E., Morsdorf, F., Næsset, E., Park, T., Phillips, O.L., Ploton, P., Puliti, S., Quegan, S., Saatchi, S., Schaaf, C., Schepaschenko, D., Scipal, K., Stovall, A., Thiel, C., Wulder, M.A., Camacho, F., Nickeson, J., Román, M., Margolis, H. (2021). Aboveground Woody Biomass Product Validation Good Practices Protocol. Version 1.0. In L. Duncanson, M. Disney, J. Armston, J. Nickeson, D. Minor, and F. Camacho (Eds.), Good Practices for Satellite-Derived Land Product Validation, (p. 236): Land Product Validation Subgroup (WGCV/CEOS), doi:10.5067/doc/ceoswgcv/lpv/agb.001

Hemming, D.L., Garforth, J., O'Keefe, T., Park, T., Richardson, A.D., Rutishäuser, A.D., Sparks, T.H., Thackeray, S.j., 2021. Phenology of primary producers [in "State of the Climate in 2020"]. Bulletin of the American Meteorological Society, 101, pp.S108-S110.

Peano, D., Hemming, D., Materia, S., Delire, C., Fan, Y., Joetzjer, E., Lee, H., Nabel, J.E., Park, T., Peylin, P. and Wårlind, D., 2021. Plant phenology evaluation of CRESCENDO land surface models–Part 1: Start and end of the growing season. Biogeosciences, 18(7), pp.2405-2428.

Data Analysis (Chatfield)

Project Participants

BAERI: Robert F. Esswein

Project Description

GeoCarb, an Earth Venture Class mission, will advance our understanding of the global carbon cycle by mapping concentrations of key carbon gases from a new vantage point: geostationary orbit. The mission, launching in 2022, will measure carbon cycle constituents, carbon dioxide, carbon monoxide, methane, as well as solar induced fluorescence (SIF) to answer key questions about the carbon cycle.

Accomplishments

- Calculated statistics of cloud-free patches over the Amazon region for selected years;
- Created documentation of differences in cloud type classification, between MAIAC-MODIS and MAIAC-GOES16; and
- Kept software development environment stable across two changes of operating system version and various other policy changes.

MAIAC = "Multi-Angle Implementation of Atmospheric Correction"
MODIS = "Moderate Resolution Imaging Spectroradiometer"
GOES = "Geostationary Operational Environmental Satellite"

Publications

Chatfield RB, Esswein RF, Price, V., Kulalwik, S., Pierce RB.Sentinel 5p" Tropomi" Perspectives on FIREX-AQ and WE-CAN: Tracing Emissions over Hours and Days of Development. In AGU Fall Meeting Abstracts 2020 Dec (Vol. 2020, pp. A202-01).

Follow the Photochemistry: Harnessing New Observations of PAN to Learn How Changes in Emissions are Impacting the Global Atmosphere

Project Participants

JPL: Vivienne Payne
BAERI: Susan Kulawik

Project Description

While total anthropogenic NOx emissions have remained approximately constant over the last 15 years, this time period has been marked by dramatic changes in the distribution of these emissions. While there have been large decreases in the emissions of NOx in North America, Chinese emissions have risen and subsequently dropped, and rapid urbanization is creating new emission hot spots in parts of the world where anthropogenic NOx emissions have typically been small. Peroxyacetyl nitrate (PAN) plays a fundamental role in the distribution of tropospheric ozone via its role as a reservoir for NOx. This proposal aims to improve our ability to predict how global oxidation capacity responds to changes in NOx emissions via the new PAN record from the Aura satellite (2004-2013), the CrIS instrument (2012-present), and the GEOS-Chem global model.

Accomplishments

- Generated updated PAN observations for a 45-day period of summer wildfires in 2018, and matched WE-CAN aircraft campaign and PAN observations to ATom aircraft validation data. These results were analyzed by other group members and resulted in two accepted publications; and
- Wrote two accepted publications:
    - "Evolution of Acyl Peroxynitrates (PANs) in wildfire smoke plumes detected by the Cross-Track Infrared Sounder (CrIS) over the western U.S. during summer 2018.", Julieta F. Juncosa Calahorrano, Vivienne H. Payne, Susan Kulawik, Bonne Ford, Frank Flocke, Teresa Campos, and Emily V. Fischer, Geophysical Research Letters, accepted for publication, 2021.
        - This paper compares aircraft and CrIS satellite observations of Acyl peroxynitrates, also known as PANs during the Western Wildfire Experiment for Cloud Chemistry, Aerosol Absorption, and Nitrogen (WE-CAN) field campaign. This paper shows that CrIS is able to detect PANs in smoke plumes from fast-growing fires and able to detect the chemical production of PANs within a given smoke plume.
    - Payne, V. H., Kulawik, S. S., Fischer, E. V., Brewer, J. F., Huey, L. G., Miyazaki, K., Worden, J. R., Bowman, K. W., Hintsa, E. J., Moore, F., Elkins, J. W., and

Juncosa Calahorrano, J.: Satellite measurements of peroxyacetyl nitrate from the Cross-Track Infrared Sounder: Comparison with ATom aircraft measurements, Atmos. Meas. Tech. Discuss. [preprint], https://doi.org/10.5194/amt-2021-353, in review, 2021.

- This paper validates the new of Acyl peroxynitrate (PAN) product from the Cross-Track Infrared Sounder (CrIS) by comparisons to aircraft PAN measurements taken during the Atmospheric Tomography Mission (ATom).

Presentations

- Co-author on presentation at NASA AIRS/Sounder Virtual Science Team Meeting 2021 – Part 2 (virtual meeting), "Multisensor Observations of PAN over megacities", Madison Shogrin, Vivienne Payne, Susan Kulawik, Emily Fischer.

Publications

"Evolution of Acyl Peroxynitrates (PANs) in wildfire smoke plumes detected by the Cross-Track Infrared Sounder (CrIS) over the western U.S. during summer 2018.", Julieta F. Juncosa Calahorrano, Vivienne H. Payne, Susan Kulawik, Bonne Ford, Frank Flocke, Teresa Campos, and Emily V. Fischer, Geophysical Research Letters, accepted for publication, 2021.

Payne, V. H., Kulawik, S. S., Fischer, E. V., Brewer, J. F., Huey, L. G., Miyazaki, K., Worden, J. R., Bowman, K. W., Hintsa, E. J., Moore, F., Elkins, J. W., and Juncosa Calahorrano, J.: Satellite measurements of peroxyacetyl nitrate from the Cross-Track Infrared Sounder: Comparison with ATom aircraft measurements, Atmos. Meas. Tech. Discuss. [preprint], https://doi.org/10.5194/amt-2021-353, in review, 2021.

GEDI

Project Participants

BAERI: Taejin Park
NASA: Ramakrishna Nemani

Project Description

The aim of this project is to map and project current (circa 2020) and future (~ 2100) forest height, aboveground biomass, and carbon sequestration potential over the continental USA (CONUS) using a theory-based integrative approach. This proposed research will synergistically use a biophysical model, called Allometric Scaling and Resource Limitation (ASRL), with spaceborne/airborne remote sensing data, including foundational GEDI lidar altimetry data to generate large-scale and continuous patterns of forest height and aboveground biomass. The model has been developed on the basis of metabolic scaling theory and water-energy balance equations. Local resource availability (i.e., water, light, and temperature) and disturbance history are explicitly implemented in the model to predict maximum forest growth. In contrast to conventional black-box approaches, the biophysical mechanism integrated within the model enables prognostic applications.

The objectives of this proposal are to: (1) refine and expand the current form of the ASRL model to predict tree height, aboveground biomass, and carbon sequestration potential by accounting for specific biophysical parameters in different disturbance histories; (2) test a theory-based integrative approach using independent and comparable measurements; and (3) map and project changes in forest height, biomass, and carbon sequestration potential over the CONUS with different climate scenarios.

In this proposed research, input geo-predictors to the model are topography, climate variables and nutrients. Lidar and optical observations such as NASA's GEDI, ICESat-2, LVIS, MODIS, and Landsat will produce current patterns of forest structure, which are used to initialize model parameters regarding tree metabolism, crown geometry, and resource accessibility and use efficiency. We will utilize NASA's NEX CMIP6 climate projection to project changes in forest height, biomass, and carbon sequestration potential. Model evaluation and uncertainty estimation will also incorporate independent in-situ, FLUXNET, and remote sensing data.

This proposed research directly responds to the 2020 NASA "Global Ecosystem Dynamics Investigation Science Team (NNH20ZDA001N-GEDIST)" call and carbon science program that both aim at characterizing, quantifying, understanding, and predicting the evolution of global carbon sources/sinks through spaceborne, airborne, and field monitoring. The proposed research will not only facilitate the current NASA Carbon Monitoring and Terrestrial Ecology Programs, but also support ongoing NASA space missions including GEDI and ICESat-2.

Accomplishments

- Prepared the input of GEDI L3 (1km gridded forest height), climate (monthly DAYMET and TerraClim), geospatial (SRTM, stand age), and forest inventory data;
- Developed eco-regional and forest type specific stand-age models from forest inventory data, and implementated the developed models in the ASRL model; and
- Completed a test run of the refined ASRL model, and evaluated the modeled forest's maximum height with ground-measured maximum forest height.

Presentations

- Park, T., Nemani, R., Myneni, R. Monitoring and forecasting large-scale patterns of forest structure and carbon dynamics using field, remote sensing, and process-based models. Global Ecosystem Dynamics Investigation (GEDI) Science Team Meeting. 12-15 January 2021.
- Park, T., Nemani, R., Myneni, R. Monitoring and forecasting large-scale patterns of forest structure and carbon dynamics using field, remote sensing, and process-based models: Progress in Year 1. Global Ecosystem Dynamics Investigation (GEDI) Science Team Meeting. 8-10 November 2021.
- Park, T., Kim, M., Nemani, R., Integrating field measurement, remote sensing, and modeling approach to track forest cover and above ground biomass changes in the Northeast Asian temperate forests, Dec 2021, Online, AGU 2021

Publications

Duncanson, L., J. Armston, M. Disney, V. Avitabile, N. Barbier, Kim Calders, S. Carter, J. Chave, M. Herold, N. MacBean, R. McRoberts, D. Minor, K. Paul, M. Réjou-Méchain, S. Roxburgh, M. Williams, C. Albinet, T. Baker, H. Bartholomeus, J. F. Bastin, D. Coomes, T. Crowther, S. Davies, S. de Bruin, M. De Kauwe, G. Domke, R. Dubayah, M. Falkowski, L. Fatoyinbo, S. Goetz, P. Jantz, I. Jonckheere, T. Jucker, H. Kay, J. Kellner, N. Labriere, R. Lucas, E. Mitchard, F. Morsdorf, E. Næsset, T. Park, O. L. Phillips, P. Ploton, S. Puliti, S. Quegan, S. Saatchi, C. Schaaf, D. Schepaschenko, K. Scipal, A. Stovall, C. Thiel, M. A. Wulder, F. Camacho, J. Nickeson, M. Román, and H. Margolis. 2021. Aboveground Woody Biomass Product Validation : Good Practices Protocol. Ed by. Laura Duncanson, Mat Disney, John Armston, JJaime Nickeson, David Minor, and Fernando Camacho. Version 1.0. Land Product Validation Subgroup (WGCV/CEOS). doi:10.5067/doc/ceoswgcv/lpv/agb.001.

Park, T., Kim, M., Nemani, R., Estimation of forest carbon stock changes in North and South Korea using High-resolution remote sensing data and forest carbon dynamic model. In preparation.

GeoCarb

Project Participants

NASA: Berrien Moore, PI
BAERI: Susan Kulawik

Project Description

GeoCarb, an Earth Venture Class mission, will advance our understanding of the global carbon cycle by mapping concentrations of key carbon gases from a new vantage point: geostationary orbit.

The mission, launching in 2022, will measure carbon cycle constituents, carbon dioxide, carbon monoxide, methane, as well as solar induced fluorescence (SIF), to answer key questions about the carbon cycle.

Accomplishments

- Did complex calculations for Railroad Valley validation site to determine GeoCarb's spatial needs for use in Railroad Valley. This was in response to part of this validation site being designated as available for mining activities. The calculations were included in a report to HQ for recommendation of withdrawal area with the response: "Based on what I see here, I don't think we should reduce the withdrawal area – in fact, as I see it, our request is already a compromise. I know that we had previously indicated that we would "scrub" the request and potentially reduce the ask. However, since we started the process two (or more?) years ago, the questions around the carbon cycle and GHGs have only become more pressing, and sustained accuracy of observations is even more critical";
- Looked at and analyzed the "day-in-the-life" GeoCarb retrievals from synthetic observations and provided feedback on file content; and

- At direction from the deputy PI, downloaded and started analyzing TropOMI CH4 observations compared to TCCON.

MiDAR

Project Participants

BAERI: Alan Li, and Ved Chirayath

Project Description

MiDAR is a next-generation remote sensing instrument that provides real-time multispectral video using an array of LED emitters coupled with NASA's FluidCam Imaging System. A MiDAR-integrated multispectral mapping system is currently under development using standard, commercially available, small unmanned aerial systems (sUAS). Both the transmitting and receiver systems work in-tandem to reconstruct a multispectral image from an illuminated target.

Accomplishments

- Secured next stage battery for high power MiDAR implementation; and
- Published work for evaluating the MiDAR algorithm on CPU, GPU and FPGA architectures for future mission planning and space-based design.

Publications

Menon, V. V., Siddiqui, S., Rao, S., Schmidt, A., French, M., Chirayath, V., and Li, A. Design and Performance Evaluation of Multispectral Sensing Algorithms on CPU, GPU, and FPGA, 2021 IEEE Aerospace Conference, Big Sky, MT, March 2021.

NASA Earth Exchange (NEX) / Ecological Forecasting

Project Participants

NASA: Rama Nemani, Jennifer Dungan, Ved Chirayath, Piyush Mehrotra, Andrew Michaelis, and Weile Wang
BAERI: Taejin Park, Thomas Vandal, Wen Yip, Subodh Kalia, and Kate Duffy
CSUMB: Weile Wang (until May 2021), Alberto Guzman, Hirofumi Hashimoto, Forrest Melton, and Will Carrara
InuTeq: Jeff Becker

Project Description

ARC-CREST scientists and software engineers, in collaboration with the NASA Ames Earth Science Division and the NASA Advanced Supercomputing (NAS) Division, continue to develop and support the NASA Earth Exchange (NEX) project (Nemani et al., 2011). The primary objectives of the NEX project are to enable significant scientific discovery using data from NASA's satellite missions, and to foster scientific collaboration across a broad portfolio of researchers supported through Research Opportunities in Space and Earth Science (ROSES). NEX enables a community of researchers to answer meaningful science questions that require data, computing-intensive analyses, and modeling at regional to global scales. By leveraging NASA's advanced supercomputing (NAS) facility at NASA Ames research center, utilizing the NEX virtual collaborative, and having select NASA datasets readily available, scientists and engineers can ask big science questions, execute on large scale research, and share research results and knowledge with minimal burden.

ARC-CREST researchers closely collaborate with scientists in NASA Ames' Earth Science Division, as well as with the broader NASA science community, to apply NEX capabilities to analyze long-term and emerging trends in ecosystem conditions, conduct simulations of climate and land-use change impacts on terrestrial and aquatic ecosystems, map patterns in biodiversity, and monitor biomass at local to continental scales. The NEX team supports applied science activities, such as the development of information products to support land managers, agricultural producers, and water managers throughout the U.S. for the monitoring and modeling of natural disasters, such as wildfires, and emerging public health threats. Additionally, NEX supports the production of global long-term data records for NASA's MEaSUREs program, NASA's Carbon Monitoring System (CMS) program, as well as large-scale visualizations for data from NASA's Earth Observing System Data and Information System (EOSDIS).

The NEX team continues to support the GeoNEX initiative, a collaborative effort among scientists from NASA, NOAA, JAXA (Japan Aerospace Exploration Agency) and KARI (Korean Aerospace Research Institute) in exploring the feasibility of producing operational land surface products similar to those from MODIS/VIIRS using GeoStationary satellites, such as GOES16, and GOES17. Research from this activity not only derives more value from the current operational GeoStationary platforms, it also feeds into NASA's long term goals supporting new geostationary platforms due to launch in the coming years.

The NEX team continues to support the OpenNEX initiative in collaboration with Carnegie Mellon University. OpenNEX strives to support science education through lectures by experts and community challenge events, such as the Space Apps Challenges (https://www.spaceappschallenge.org/).

Accomplishments

- Selected for ROSES: "Quantifying Earth Process Dynamics with Optical Flow on Geostationary Satellite Imagery." NASA Research Opportunities in Space and Earth Science (ROSES), Earth Science Research From Operational Geostationary Satellite Systems (9 of 83 selected). Aug 2020 - July 2023;
- Boston University's paper about greening, with Rama Nemani as contributor, was posted on the online NASA Earth Observatory on March 9th, 2021. Full story link: https://earthobservatory.nasa.gov/images/148026/greening-landscape-changes-air-flow;
- An interview with the NASA Earth Exchange (NEX) led Rama Nemani, "You just go wherever there are interesting patterns," by Katrina Wesencraft on March 29th, 2021, was highlighted by Kassandra Perlongo on StoryCorps. Link: https://archive.storycorps.org/communities/share-your-science-a-collection-of-stories-from-scientists-at-nasa-ames/;
- Kate Duffy, NASA Pathways Intern, was elected as a student member of the American Meteorological Society (AMS) Committee on AI Applications to Environmental Science. Link: https://www.ametsoc.org/index.cfm/stac/committees/committee-on-artificial-intelligence-applications-to-environmental-science/; and
- Taejin Park contributed to a section of the State of the Climate in 2020 report (S108-S110), providing MODIS-based land surface phenology monitoring.

NEX/GeoNEX Accomplishments

- Supported NASA's research calls by facilitating the use of NASA state-of-the-art supercomputing, large data archives, and providing relevant software and support;
- Organized a session on Geostationary Earth Remote Sensing at the AOGS-2021 Meeting;
- Completed a special Issue with the peer-reviewed journal Remote Sensing on the theme of Geostationary Earth Monitoring;
- Formally released NEX-GDM dataset, distributed at data.nas.nasa.gov/geonex;
- Refined, extended and distributed the GeoNEX L1G products, which are radiometric calibration with residual georegistration and topographic errors removed, with accurate illumination/view geometry-dependent bi-directional reflectance factors provided. The products are projected onto a global common grid to facilitate inter-satellite comparisons and are available at data.nas.nasa.gov/geonex (Fig. 1);

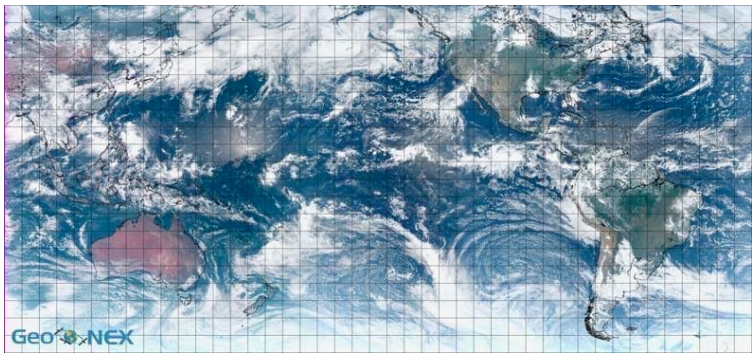


Figure 1
Example of GeoNEX L1G TOA reflectance composited with data from Himawari-8/AHI, GOES-17/ABI and GOES16/ABI.

- Initiated research on the fusion of GEO-LEO satellite datasets across multiple spatial and temporal resolutions that is expected to synergistically leverage advantages of different platforms to improve global land surface monitoring (Fig. 2);

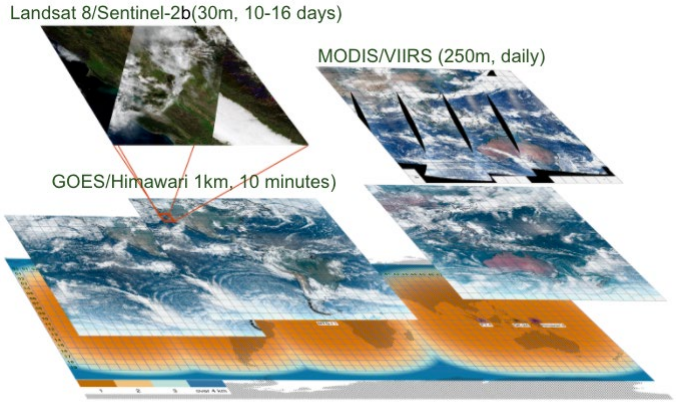


Figure 2
Data fusion of GEO-LEO satellite data across various spatio-temporal resolutions based on the GeoNEX common grid.

- Built, maintained, and developed NASA MAIAC software package for atmospheric correction and the production of aerosol optical thickness (AOT) and surface reflectance (SR) datasets;
- Distributed provisional surface reflectance products with customized MAIAC algorithm to collaborators for science investigations over Asia, Oceania, and North/South America;
- Implemented a machine learning -based framework to generate Landsat-based yearly percent tree cover maps for the conterminous United States and Mexico. Collaborated with the JPL team to produce national scale carbon pool and flux products. An example of the datasets in tree cover estimation over the US and Mexico is shown in Fig. 3;

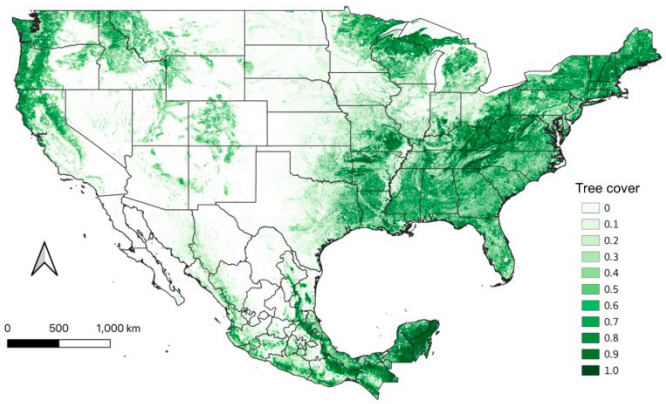
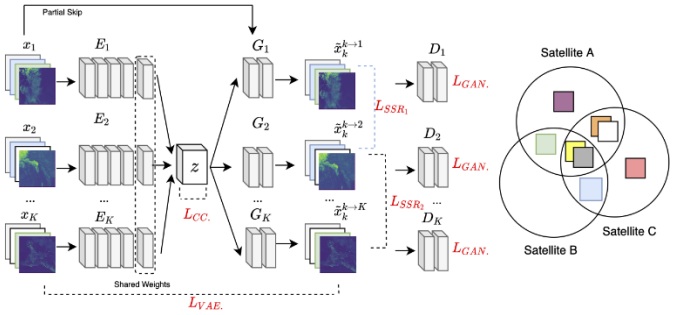


Figure 3

Landsat based tree cover estimate in 2018 over the contiguous United States and Mexico.

- Phenology Product: collaborated with South Dakota State University team on product development;
- Collaborated with University of Michigan and South Dakota State University to create and distribute Global WELD Landsat products;
- Implemented Python and PyTorch software to automatically generate synthetic observations from GOES-16/17 data using unsupervised spectral synthesis for satellite-to-satellite translation method. This approach generalizes across sensors with different spectral bands to produce synthetic observations. [Code: https://github.com/tjvandal/unsupervised-spectral-synthesis]; and



- $L_{VAE.}$

Figure 4

Deep learning architecture for satellite-to-satellite translation

- Implemented GEO to MODIS LST emulation with convolutional neural networks to predict land surface temperature with improved spatial and temporal resolution compared to standard product. This approach is applicable across collocated satellite observations to produce global products.

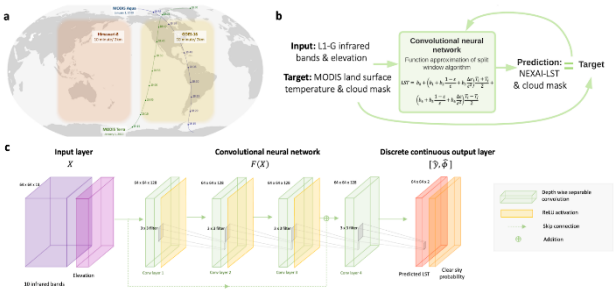


Figure 5

Datasets, problem setup, and deep learning architecture for LEO-GEO algorithm emulation

SBG Accomplishments

- Led Task 4 of the SBG Modeling Group, "Emulating Global Surface Hyperspectral Reflectance from Multi-Band Remote Sensing Data," and developed algorithms to generated global synthetic hyperspectral datasets (Ames Global Hyperspectral Synthetic Data) based on MODIS data and pre-selected spectral libraries (Fig. 4); and

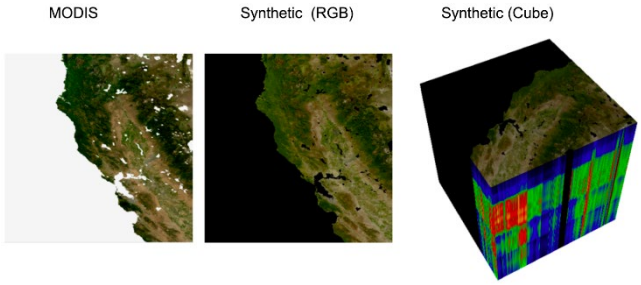


Figure 5

Example of synthetic hyperspectral images generated from broad-band satellite (MODIS) data and a pre-selected spectral library with an algorithm based on non-negative-least-square (NNLS) regressions.

- Obtained and deployed software packages including MODTRAN, LibRadtran, Atrem, ISOFIT, and Hypertrace on NEX for implementing/testing the processing pipeline of the SBG-SISTER project.

Optical Flow and Atmospheric Motion Vectors

- Developed physics-guided optical flow for deriving atmospheric motion vectors by learning from high-resolution numerical simulations and fine-tuning with geostationary observations; and

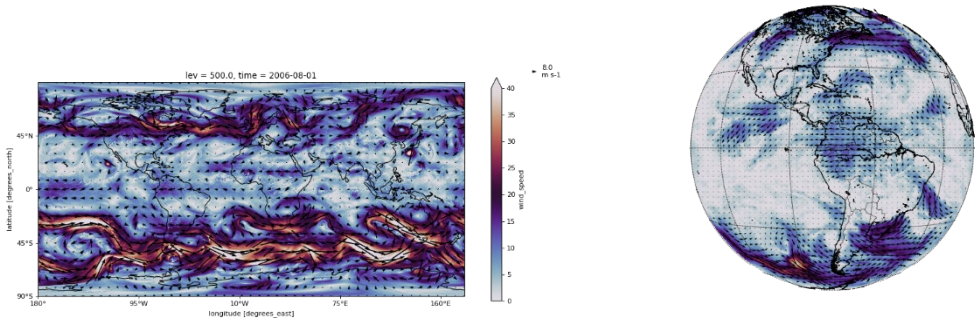


Figure 6
Left) Winds predicted from optical flow model on numerical simulations, Right) Application of optical flow of full-disk geostationary images

- Collocated Calipso observations with GOES-16/17 L1B for cloud height prediction with neural networks.

Data Acquisition & Management

- Acquired and managed several hundred terabytes of Landsat Collection 1 and Collection 2 data for several active NEX projects;
- Acquired and managed several hundred terabytes of MODIS, MAIAC, ECOSTRESS, GEDI data for the GeoNEX activity;
- Acquired and managed GOES16, GOES17, Himawari 8 and GEO-KOMPSAT-2A datasets to enable the GeoNEX activity in support of the Earth Science Research from Operational Geostationary Satellite Systems solicitation (NNH19ZDA001N);
- Improved data acquisition automation, data management, and data distribution for GeoNEX/NEX data products;
- Acquired Hyperion data from USGS for several active NEX projects;
- Acquired NAIP, SSURGO soils data, NLCD land cover data, and SRTM elevation data; and
- Obtained daily surface temperature and precipitation data until 2100 from all climate projection models using the NASA Earth Exchange Global Daily Downscaled Projections (NEX-GDDP) dataset to assist in conducting world-wide climate change studies.

Presentations

- Park, T., Nemani, R., Myneni, R. Monitoring and forecasting large-scale patterns of forest structure and carbon dynamics using field, remote sensing, and process-based models. Global Ecosystem Dynamics Investigation (GEDI) Science Team Meeting. 12-15 January 2021.

- Park, T., Nemani, R., Myneni, R. Monitoring and forecasting large-scale patterns of forest structure and carbon dynamics using field, remote sensing, and process-based models: Progress in Year 1. Global Ecosystem Dynamics Investigation (GEDI) Science Team Meeting. 8-10 November 2021.
- Park, T., Wang, W., Michaelis, A., Hashimoto, H., Yeom, J.M., Nemani, R., Geolocation Accuracy Assessment of Geo-kompsat-2a Ami, Aug 2021, AOGS 2021 Annual Meeting.
- Park. T., Li, S., Vandal, T., Yu, Y., Saatchi, S., Vargas, R., Nemani, R., Generation of continental scale percent tree cover product using deep-learning and multi-scale remote sensing data, Mar 2021, 2021 7th NACP Open Science Meeting.
- Park, T., Kim, M., Nemani, R., Integrating field measurement, remote sensing, and modeling approach to track forest cover and above ground biomass changes in the Northeast Asian temperate forests, Dec 2021, Online, AGU 2021.
- Park, T., Wang, W., Michaelis, A., Hashimoto, H., Yeom, J.M., Nemani, R., Improving Geolocation Accuracy of the Advanced Meteorological Imager on the GEO-KOMPSAT-2A, Dec 2021, Online, AGU 2021.
- Rama Nemani delivered a presentation to Steve Jurczyk on cutting-edge data products from geostationary satellites for wildfire management at the NASA Ames supercomputing facility on 6 April 2021.
- The NEX team presented a flash talk, "The NASA Earth Exchange Global Daily Downscaled Projections." at the European Geophysical Union on 28 April 2021. The authors of this work are Weile Wang (NEX), Bridget Thrasher (NCAR), Andrew Michaelis (NEX), Ramakrishna Nemani (NEX) and Tsengdar Lee (NASA HQ).
- Weile Wang was presenting "Using the Diurnal Variability in GeoNEX TOA Reflectances for Earth Monitoring," an invited paper at Japan Geoscience Union (JPGU) Meeting held virtually on 3 June 2021.
- Kate Duffy presented "A generalizable machine learning approach for prediction of land surface temperature" at 3rd NOAA Workshop on Leveraging AI in Environmental Sciences (13-14 September 2021).
- Kate Duffy presented " Developing a LEO-GEO approach to prediction of high temporal resolution land surface temperature" at the AOGS 2021 Annual Meeting (1 August 2021).
- Thomas Vandal presented "Virtual Sensing with Unsupervised Image-to-Image Translation" at AMS Winter Meeting (January 12, 2021).
- Thomas Vandal presented "Towards Physics Guided Optical Flow for Tracking Atmospheric Motion" at the AOGS2021 Annual Meeting (1 August 2021).
- Thomas Vandal presented "GeoNEX-ML: A Machine Learning System for Geostationary Satellite Imagery" at 3rd NOAA Workshop on Leveraging AI in Environmental Sciences (13-14 September 2021).

Publications

Hashimoto, H.; Wang, W.; Dungan, J.L.; Li, S.; Michaelis, A.R.; Takenaka, H.; Higuchi, A.; Myneni, R.B.; Nemani, R.R. New generation geostationary satellite observations support seasonality in greenness of the Amazon evergreen forests. Nature Communications 12, 684 (2021).

Kai Yan, Jiabin Pu, Taejin Park, Baodong Xu, Yelu Zeng, Guangjian Yan, Marie Weiss, Yuri Knyazikhin, Ranga B. Myneni, Performance stability of the MODIS and VIIRS LAI algorithms inferred from analysis of long time series of products, Remote Sensing of Environment, Volume 260, 2021, 112438, ISSN 0034-4257.

Edward Collier, Supratik Mukhopadhyay, Kate Duffy, Sangram Ganguly, Geri Madanguit, Subodh Kalia, Gayaka Shreekant, Ramakrishna Nemani, Andrew Michaelis, Shuang Li & Auroop Ganguly (2021), Semantic Segmentation of High Resolution Satellite Imagery using Generative Adversarial Networks with Progressive Growing, Remote Sensing Letters, 12:5, 439-448.

Soininen, E. M., Barrio, I. C., Bjørkås, R., Björnsdóttir, K., Ehrich, D., Hopping, K. A., ... & Speed, J. D. M. (2021). Location of studies and evidence of effects of herbivory on Arctic vegetation: a systematic map. Environmental Evidence, 10(1), 1-21.

Chen, Y., Sun, K., Li, W., Chen, C., Li, P., Bai, T., ... & Myneni, R. B. (2021). Prototyping of LAI and FPAR Retrievals From GOES-16 Advanced Baseline Imager Data Using Global Optimizing Algorithm. IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, 14, 6937-6950.

Dunn, R. J., Aldred, F., Gobron, N., Miller, J. B., Willett, K. M., Ades, M., ... & Tye, M. R. (2021). Global climate. Bulletin of the American Meteorological Society, 102(8), S11-S142.

Yan, K., Pu, J., Park, T., Xu, B., Zeng, Y., Yan, G., ... & Myneni, R. B. (2021). Performance stability of the MODIS and VIIRS LAI algorithms inferred from analysis of long time series of products. Remote Sensing of Environment, 260, 112438.

Duncanson, L., Armston, J., Disney, M., Avitabile, V., Barbier, N., Calders, K., ... & Margolis, H. (2021). Aboveground Woody Biomass Product Validation Good Practices Protocol.

Peano, D., Hemming, D., Materia, S., Delire, C., Fan, Y., Joetzjer, E., ... & Zaehle, S. (2021). Plant phenology evaluation of CRESCENDO land surface models–Part 1: Start and end of the growing season. Biogeosciences, 18(7), 2405-2428.

GAR Special Report on Drought 2021. United Nations Office for Disaster Risk Reduction (2021), Contributing Author: Rama Nemani. GAR Special Report on Drought 2021. Geneva. ISBN 9789212320274. Published: 2021.

Vandal, T.J., D. McDuff, W. Wang, K. Duffy, A. Michaelis and R. R. Nemani, (2021) "Spectral Synthesis for Geostationary Satellite-to-Satellite Translation," in IEEE Transactions on Geoscience and Remote Sensing, doi: 10.1109/TGRS.2021.3088686.

Vandal, T.J. and R. R. Nemani, "Temporal Interpolation of Geostationary Satellite Imagery With Optical Flow," in IEEE Transactions on Neural Networks and Learning Systems, doi: 10.1109/TNNLS.2021.3101742.

Wilson, M., Vandal, T., Hogg, T. et al. Quantum-assisted associative adversarial network: applying quantum annealing in deep learning. Quantum Mach. Intell. 3, 19 (2021). https://doi.org/10.1007/s42484-021-00047-9.

Xiao, J., Fisher, J.B., Hashimoto, H. et al. Emerging satellite observations for diurnal cycling of ecosystem processes. Nat. Plants 7, 877–887 (2021). https://doi.org/10.1038/s41477-021-00952-8.

Shen, Y., X. Zhang, W. Wang, and R. Nemani, 2021: Fusing geostationary satellite observations with Landsat- 8 and Sentinel-2 time series for monitoring field-scale land surface phenology. Remote Sensing (in review).

Duffy, K., et al. 2021: A Framework for Deep Learning Emulation of Numerical Models with a Case Study in Satellite Remote Sensing. IEEE Transactions on Neural Networks and Learning Systems (in review).

Stavros, N., et al. 2021 : Designing an Observing System to Study the Surface Biology and Geology of the Earth in the 2020s. Biogeosciences (in review).

Panel or Committees

- Ryan Spackman, Rama Nemani, and the NEX team supported the MEaSUREs Principal Investigators Forum on Webex on 2-3 February 2021.
- Thomas Vandal, program committees: SIAM International Conference on Data Mining, AI for Earth Workshop at NeurIPS, SIGKDD Workshop on Fragile Earth Data Science, and ICDM Workshop on Data Mining in Earth System Science.
- Weile Wang, Co-lead on the Modeling Working Group of NASA Surface Biology & Geology (SBG) Study.
- Weile Wang, Panelist on the NASA Remote Sensing Theory (RST) Proposal Review Panel, May 27-29, 2020.
- Weile Wang, Panelist on the NASA DSCOVR 2021 proposal review panel, Nov. 1-3, 2021.
- Taejin Park & Rama Nemani, conveners of session on “Earth Observations from a New Generation of Geostationary Satellite” at AOGS 2021 Annual Meeting.
- Andy Michaelis has been asked to join the core ESD Open Source Science Initiative (OSSI) architecture study team, representing NASA ARC’s experience with open source science initiatives.
- Andy Michaelis was a member of the convening architecture team for The Open Source Science for Data Processing and Archives Workshop, 14 October 2021.
- Kate Duffy co-chaired a session on neural networks at the DOE Artificial Intelligence for Earth System Predictability (AI4ESP) workshop.

- Kate Duffy, student member of the American Meteorological Society (AMS) Committee on AI Applications to Environmental Science.

NeMO-NET (Neural Multimodal observation and training network for global coral reef assessment)

Project Participants

NASA: Mike Little, Woody Turner, Ved Chirayath
BAERI: Alan Li, Michal Segal Rozenhaimer, Jarrett Van Den Bergh, Puja Das (former staff),

Project Description

NeMO-Net is a single player iPad game where players help NASA classify coral reefs by painting 3D and 2D images of coral. Players can rate the classifications of other players and level up in the food chain as they explore and classify coral reefs and other shallow marine environments and creatures from locations all over the world. Data from the NeMO-Net game is fed to NASA NeMO-Net, the first neural multi-modal observation and training network for global coral reef assessment. NeMO-Net is an open-source deep convolutional neural network (CNN) that leverages NASA's Supercomputer, Pleiades, to use game data to classify and assess the health of coral reefs around the world.

Due to the massive amounts of sample data required to train machine learning algorithms, NeMO-Net includes an online classification application for mobile and desktop, which leverages the power of citizen science and active learning to generate accurate, high-resolution classification datasets. This application trains users to accurately identify coral reef families and semantically segment 3D coral reef scenes. The application also acts as an active learning framework, allowing users to rate and build off of other users' classifications.

NeMO-Net was released this April for desktop and iOS. To date, the application has had over 43,000 downloads and over 71,000 unique coral reef classifications, each filtered through a user-based rating and expert evaluation system. It is available to download at www.nemonet.info.

Accomplishments

- Released a web-based citizen science application. So far, there have been about 43,000 downloads with more than 71,000 image classifications completed for Pacific and Caribbean coral reefs. The user App Store ratings are 4.9/5.0 showing the success of this app with citizen scientists;
- Gave multiple presentations, mostly by the project PI, in different venues including IEEE and AGU;
- Acknowledged by NASA HQ, the Ocean Biology and Biochemistry Program, the Biodiversity and Ecological Forecasting Program, among others;
- Released public iOS version of NeMO-Net game on app store and online;
- Finalized partnership with Living Oceans Foundation (LOF) for additional coral data;

- Starting ingestion of data of 65,000 km2 from Living Oceans Foundation, slated to be completed by the end of the year;
- Completed code refactor to allow for public-facing components;
- Built out the NeMO-Net architecture in understandable modules, packaging the entire codebase in easy setup mode;
- Rebuilt certain sections of the workflow, particularly the KNN post-processing modules; and
- Created habitat maps for sample islands with successful initial ingestion of LOF data.

Presentations

- CitSciCon (2021) – NASA NeMO-Net: https://scistarter.org/nasa/NASA-NeMO-Net-nasa.
- IEEE (2020) International Geoscience and Remote Sensing Symposium - NASA NeMO-Net – A Neural Multimodal Observation & Training Network for Marine EcosystemMapping at Diverse Spatiotemporal Scales.
- Asanjan, A.A., K. Das, A. Li, V. Chirayath, J. Torres-Perez, and S. Sorooshian. 2020. Learning instrument invariant characteristics for generating high-resolution global coral reef maps. KDD '20: Proc. 26th ACM SIGKDD Int. Conf. Knowledge Discovery and Data Mining. August 2020.
- AGU Presentation: "Expanding NeMO-Net Machine Learning Capabilities for Citizen Science."

Publications

Van Den Bergh, J., Chirayath, V., Li, A., Torres-Perez, J., and Segal-Rozenhaimer, M. NeMO-Net - Gamifying 3D Labeling of Multi-Modal Reference Datasets to Support Automated Marine Habitat Mapping, in Frontiers in Marine Science (2021), doi: 10.3389/fmars.2021.645408.

A. S. Li, V. Chirayath, M. Segal-Rozenhaimer, J. L. Torres-Pérez and J. van den Bergh, "NASA NeMO-Net's Convolutional Neural Network: Mapping Marine Habitats with Spectrally Heterogeneous Remote Sensing Imagery," in IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, vol. 13, pp. 5115-5133, 2020, doi: 10.1109/JSTARS.2020.3018719.

Asanjan, A.A., K. Das, A. Li, V. Chirayath, J. Torres-Perez, and S. Sorooshian. 2020. Learning instrument invariant characteristics for generating high-resolution global coral reef maps. KDD '20: Proc. 26th ACM SIGKDD Int. Conf. Knowledge Discovery and Data Mining. 2617-2624.

Michal Segal-Rozenhaimer, Alan Li, Kamalika Das, Ved Chirayath, Cloud detection algorithm for multi-modal satellite imagery using convolutional neural-networks (CNN), Remote Sensing of Environment, Volume 237, 2020, 111446, ISSN 0034-4257, https://doi.org/10.1016/j.rse.2019.111446.

OCO-2 Profile

Project Participants

BAERI: Susan Kulawik

Project Description

This work is in support of the ROSES 17-OCO2-17-0013 project, “Reducing the impact of model transport error on flux estimates using CO2 profile information from OCO2 in concert with an online bias correction,” Sourish Basu, PI.

Accomplishments

- Analyzed and corrected the effects of bias correction on the sensitivity (averaging kernel);
- Developed initial v10 bias correction; and
- Generated the lowermost tropospheric product for the v10 record, delivered to Sourish Basu, PI.

Presentations

- “ReFRACtor / MUSES OCO-2/3 analysis”: talk at OCO2/3 OCO 2/3 Algorithm Breakout, March 8, 2021.
- Contributed to PI talk by Sourish Basu at OCO2/3 Science Team meeting, October 19, 2021.

PICOGRAM

Project Participants

BAERI: Alan Li, and Jarret van den Bergh
NASA: Ved Chirayath
NOAA: Thomas Oliver, and Courtney Couch

Project Description

Reef managers are turning to resilience-based management to support coral reefs through the combined crises posed by global and local human impacts. This broad strategy, at its core, aims not only to improve reef conditions, but also to develop a reef ecosystem's physiological and adaptive capacity to meet the environmental challenges that are coming. Picogram was initiated to help support such efforts, so that reef managers could visualize and ascertain how a reef changes over time, what pressures it may be sensitive towards, and how it may recover from environmental disturbances. At its core, we aim to repurpose the successful NeMO-Net framework to the task of local coral prediction, using in-situ measurements and photogrammetry (in addition to specialized sites such as the Saipan Coral Nursery), to build a responsive system to the global climate challenges of today.

Accomplishments

- Brought together all stakeholders for PICOGRAM kickoff meeting in October; and
- Began evaluation of NOAA coral reef data at specific sites.

Reducing OCO-2 regional biases through novel 3D cloud, albedo, and meteorology estimation

Project Participants

BAERI: Susan Kulawik

Project Description

The project seeks to improve OCO-2/3 regional biases by adding 3-d clouds, additional albedo parameters, and temperature and water vapor vertical parameters to the OCO-2 retrieved state. We hope/expect to improve regional biases from ~0.6 to ~0.4 ppm, which should reduce OCO-2/3 flux errors by about 30%.

Accomplishments

- Updated the ReFRACtor radiative transfer to add the additional 3-d cloud and albedo parameters;
- Studied the ECOSTRESS albedo spectral library and AVIRIS albedos to characterize albedo variations by surface type and by wavelength;
- Processed OCO-2 overpasses with the EAR3T system to estimate 3-d cloud properties using MODIS; and
- Set up simulated test cases.

Presentations

- PI talk at the OCO-2/3 Science Team meeting, October 19, 2021, “3d-clouds, meteorology, and albedo updates for OCO-⅔.”

RUMMBL

Project Participants

BAERI: Stephen Broccardo (PI),
NASA Ames: Meloe Kacenelenbogen, Matthew Johnson, Roy Johnson, Florian Schwandner
NASA JPL: Vijay Natraj, Ryan Pavlick
Caltech: Yuk Yung
University of Alaska, Fairbanks: Tarsilo Girona
Michigan Technological University: Chad Deering, Katie Nelson
University of Costa Rica: Andres Diaz
OVSICORI Costa Rica: Maarten de Moor

Project Description

This project is funded by a 2020 ROSES Interdisciplinary Science (IDS) proposal, and aims to make measurements of degassing fluxes from a volcano in Costa Rica (i.e. Turriabla), from the OCO-3 and ECOSTRESS instruments on the International Space Station. These will be combined with ground-based measurements made during intensive observation periods (IOP's) to inform a geophysical sub-surface model of magma evolution within the volcano. JPL/Caltech will lead the development of a new XCO2 retrieval, as well as an SO2 column retrieval. Michigan Technological University will perform field measurements. University of Alaska will do the geophysical modeling. NASA Ames and BAERI will lead the deployment of an AERONET sunphotometer to Costa Rica, and interpret flux measurements.

Accomplishments

- Conducted a field measurement campaign in Costa Rica, led by staff and students from Michigan Technological University;
- Measured ground-degassing fluxes of CO2 over an extensive area around the Turrilaba volcano in Costa Rica;
- Shipped a sunphotometer to Costa Rica, in collaboration with the Goddard AERONET group. Travel restrictions associated with the COVID-19 pandemic precluded anybody from traveling there to assist with the setup; and
- Applied a state-of-the art XCO2 retrieval (developed by JPL/Caltech) to selected OCO-3 measurements over Turrialba.

Presentations

- Girona, T., Caudron, C., Lundgren, P.R., Bato, M.G.P., Schwandner, F.M., Broccardo, S.P., Natraj, V., Kacenelenbogen, M.S., Yung, Y., Johnson, R., Deering, C., De Moor, M., Pavlick, R.P., Nelson, K., Benavente, D.: The stop-and-go mechanism: towards an integrated approach to model seismicity, outgassing, deformation and thermal unrest at active volcanoes, in AGU Fall Meeting 2021, New Orleans, USA.

SeaSTAR

Project Participants

BAERI: Stephen Broccardo (PI), and Conrad Esch

Project Description

The project aims to develop a ship-based robotic sun/sky photometer for the quantification and characterization of marine aerosol particles. We will integrate radiometer technology that was developed for Ames' next-generation airborne sunphotometer (5STAR) with a new high-performance robot platform developed using Ames Innovation Fair funds from 2018, and the efforts of two student interns (Saketh Muvva in 2019 and Chaitu Nookala in 2020/1).

We aim to develop an instrument which will make direct-sun absorption measurements, as well as polarized sky radiance measurements, to allow retrieval of aerosol particle optical properties. A third aim is to be able to make measurements of upwelling radiances from the sea surface. The robot will incorporate inertial measurement to enable compensation for the movement of the vessel while making sky- and ocean radiance measurements.

Accomplishments

- Began initial design (schematic capture and circuit board artwork layout) of an analog-to-digital converter interface board for the radiometers; and
- Began initial mechanical design of the robot to incorporate a third axis servomotor, and selectable polarization filters.

Presentations

- Broccardo, S.P., Esch, C., Johnson, R., Dahlgren, R.P., Dunagan, S.E., Palacios, S.L., Wang, J., Flynn, C: SeaSTAR - sunphotometer platform diversification for aerosol characterization over the ocean, in American Geophysical Union Fall Meeting 2021, New Orleans.

Surface Biology and Geology (SBG)

Project Participants

NASA Ames: Ian Brosnan, Jon Jenkins, Peter Tenenbaum, Bill Wohler, Andrew Michaelis, Jennifer Dungan, Weile Wang, Ben Poulter
CSUMB: Vanessa Brooks Genovese
BAERI: Yohei Shinozuka

Project Description

The NASA Surface Biology and Geology (SBG) study proposes a new set of missions to study the Earth with the following priorities:

- Terrestrial vegetation physiology, functional traits, and health;
- Inland and coastal aquatic ecosystems physiology, functional traits, and health;
- Snow and ice accumulation, melting, and albedo;
- Active surface changes (eruptions, landslides, evolving landscapes, hazard risks);
- Effects of changing land use on surface energy, water, momentum, and C fluxes; and
- Managing agriculture, natural habitats, water use/quality, and urban development.

The study has been broken into four Research & Applications working groups: Applications, Algorithms, Modeling and Calibration / Validation. Our group at NASA Ames is working as sub-tasks of the modeling working group (MEET-SBG) and the Space-based Imaging Spectroscopy and Thermal pathfinder (SISTER).

Accomplishments

SISTER Accomplishments

- Ingested data and applied workflows from the EO-1/Hyperion 17-year mission archive;
- Reprocessed the entire 55 TB Hyperion data set;
- Developed an infrastructure for pipelines that process large volumes of science data, building upon a predecessor for the Kepler and TESS exoplanet mission;
- Completed the reprocessing of Hyperion data going from the L0 data (55 TB) to L1R (26TB) using the Ziggy infrastructure; and
- Prepared to process the L1R data into L2. The preparation has involved the transformation of the Hyperion L1R and meta data for a nascent atmospheric-surface retrieval algorithm (ISOFIT); modifications of an ISOFIT utility module; the configuration of Python environment and multi-thread computation; small-scale test-runs; the inspection and the verification of the output; and the estimate of memory usage and data volume.

MEET-SBG Accomplishments

- Released Version 1.0 of the Ames Global Hyperspectral Synthetic Dataset (AGHSD), and made it available to the community on the data portal of NASA's Advanced Supercomputing Division at ARC. The URL is https://data.nas.nasa.gov/aghsd.

Earth Science
Applied Sciences Program

Disaster Management

Project Participants

NASA: Lawrence Friedl (NASA HQ) and G. Gutman (NASA HQ)
CSUMB: Vincent Ambrosia

Project Description

The Disaster Task is composed of two principal elements: 1) Staffing to support the NASA Applied Science Program (ASP) as Associate Program Manager - Wildfires, and 2) Supporting the development of airborne UAS and related sensor system technologies to enable improved science and applications data collection mission for NASA and partnering agencies and organizations. This element encompasses UAS systems development (and sensors) optimized for disaster support within the overall context of earth science mission support.

Since 2013, Ambrosia has served as a Associate Program Manager and managed a portfolio of projects within the ASP-Wildland Fire Program. Portfolio management includes development of NASA Applied Science Wildland Fire topical solicitations, as well as organizing and managing review panels and selection of NASA proposals to those solicitations; scientific oversight of the program goals and objectives; budgetary management of the funded efforts of disparate organizations and investigators; metrics monitoring for the investigations; interactions with partner agencies involved in the projects; and serving as the NASA representative on regional, national, and international wildfire science and applications panels and boards. Additional activities include organization and planning of national and international symposia and forums, as well as participating and collaborating in workshops and webinars, highlighting the ASP-Wildfire program and access / use of EO data to support wildfire science and applications by the community.

In 2019, Ambrosia assumed an additional role / task as the NASA Coordinator of the NASA Land-Cover/Land-Use Change Program, Mediterranean Regional Information Network (MedRIN). The tasks include coordination of annual meetings and workshops with regional coordinators from the Mediterranean countries with a focus on dynamic land / biosphere changes common to the area, and also to participate in the NASA LCLUC Annual Team Meeting (virtual in 2021).

Accomplishments

- Supported briefings of the U.S. House Science Committee (February 2021), and participated in briefing the Office of Management and Budget (OMB) Science & Space Branch on the NASA ASP Wildland Fire Program (28 June 2021), in preparation for the re-introduction of the Applied Science Program – Wildland Fire Program element in FY22;

- Organized a series of working group meetings with the U.S. Wildland Fire Management / Wildfire Science community to assist / advise in structuring the new (FY22) NASA Applied Science Program, Wildland Fire Program;
- Managed the NASA ROSES16 A.50-Group on Earth Observations (GEO) Work Programme; 3.8 Global Wildfire Information System (GWIS) projects (2018-2022), including development of the solicitation, organizing and managing the peer-review panel for selection, and serving as Associate PM of the GWIS program projects (3) in that solicitation. Management includes development of project progress metrics, organizing and participating in workshops and trainings on GWIS and NASA EO tools / data uses to organizations in Paraguay, Columbia, Bolivia, Guatemala, Greece, Turkey, India, and the Disaster Risk Reduction- Central America group;
- Co-led the 2021 Tactical Fire Remote Sensing Advisory Committee (TFRSAC), which also entails co-hosting the twice-annual workshop in Spring (May) and Fall (November) meetings. Management efforts included planning agendas, budgetary control of the meeting expenses, contracting services, organizing speakers, development of breakout sessions, securing meeting facilities and securing A/V support to meetings, and archiving / sharing of meeting presentations;
- Advised and participated as Panelist at the 13 May 2021 "NASA Aeronautics Research Mission Directorate (ARMD) Wildfire Management Workshop (Virtual)";
- Continued management of the NASA LCLUC Program (HQ PM: G. Gutman), Mediterranean Regional Information Network (MedRIN). As NASA Lead of MedRIN, developed collaborations with international EO partners in the eastern Mediterranean region with the NASA Earth Sciences Program. Worked with two European MedRIN Chairs to facilitate collaborative science, and organize regional workshops that enhance the use of NASA Earth System data for land change dynamics;
- Co-organized the Joint MedRIN / SCERIN (South Central Europe Regional Information Network) Joint Virtual Capacity Building Workshop on Earth Observations, Thessaloniki, Greece (15-17 June 2021);
- Report Author Member: UN Office for Disaster Risk Reduction, Global Assessment Report (UN-GAR) on Disaster Risk Reduction (DRR) Assessment Report; 2020-2022;
- Committee Member: Committee on Earth Observation Satellites (CEOS) Disasters Working Group, Wildfire Pilot Sub-Committee (2020-2022);
- Author Member: *UN* Office for Disaster Risk Reduction, Global Assessment Report (UN-GAR) on Disaster Risk Reduction (DRR) Assessment Report;
- Represented NASA Applied Science Program on inter-agency, regional, national, and international science panels focused on wildfire assessment, including the USGEO / GEO Global Wildfire Information System (GWIS) Committee;
- Briefed NASA HQ management on programmatic goals and metrics of the Wildfire Program during quarterly ASP Programmatic Reviews;
- Served on numerous journal peer-review panels and provided scientific peer review of ten (10) manuscripts submitted to journals in 2021;

- Science Advisor (2020-2021): NASA Idaho Space Grant Consortium (ISGC) Research Grant to Idaho State University (K. Weber, PI) entitled: *"Effect of Weather and Climate on Biomass Production and Wildfire Susceptibility across the Western US*";
- Co-Guest Editor: Special Issue, International Journal of Applied Earth Observations, *Earth Observations for World Heritage Sites*, 2021-2022;
- Proposal Peer Review Panel Reviewer for *USDA-NIFA 2021 (February, '21) Small Business Innovative Research (SBIR-STTR), Forests and Related Resources*; (Winter / Spring 2021);
- Collaborated with NASA HQ Communications Department on a series of wildfire science features and web documentaries in 2021, related to EO support to the wildland fire management community;
- Contributed to NASA Applied Science Program – Disaster Program, Wildland Fire element 2020 Annual Program Report;
- Authored GEO-GWIS component and NASA Fire Applications elements of the NASA Applied Science Program – Disaster 2020 Annual Report; and
- Served as external Advisory Board Member of the *"EXCELSIOR" (ERATOSTHENES: Excellence Research Center for Earth Surveillance and Space-Based Monitoring Of the Environment)*, Center of Excellence (CoE) at the Cyprus Technology University (CTU), Limassol, Cyprus.

Presentations / Seminars

- Ambrosia, V.G., 2021. *Wildland Fires: How Can We Be Better Informed Through New Observation Capabilities and Modeling Strategies*? Commercial Space Lecture Series, Space Portal Office, NASA-Ames Research Center. (https://www.nasa.gov/ames/partnerships/spaceportal/commercial-space-lecture-series), 7 April 2021;
- Speaker and Mentor*: Wildfire Communications Challenge: Linking Firefighters with Information Quickly and Efficiently*; AngelHacks 2.0, 26-28 February 2021; https://www.angelhacks.org; and
- Invited Panel Member / Workshop Presentation*: Lightning Talk: NASA Wildfire Program Directions*; "Real Time Detection and Tracking of Fires That Matter: What Is Needed, What Is Possible, How Do We Build It?", Keck Institute for Space Studies (KISS), CalTech, JPL, Pasadena, CA. (virtual meeting), 11-12 March 2021.

Panels or Committees

- USGEO Committee / NASA Lead for GEO-GWIS, 2021-22;
- Member: Committee on Earth Observation Systems (CEOS) -Working Group Disasters (WGDisasters), Wildfire Pilot Stakeholders Committee; 2020-2023;

- External Advisory Board (EAB) Member, *EXCELSIOR (ERATATOSTHENES: Excellence Research Center for Earth SurveiLlance and Space-Based MonItoring Of the EnviRonment)*, WIDESPREAD-01-2018-2019: Teaming Phase 2, Horizon 2020 Program, Cyprus University of Technology (CUT), Lemasos, Cyprus;
- Panelist: *Current and Future Contributions of Aviation and Space to Wildfire Management,* Panelist**,** National Academy of Sciences, Aeronautics and Space Engineering Board, Fall Meeting of the Aeronautics and Space Engineering Board, 168th Meeting, 20 October 2021;
- Panelist: *Real Time Detection and Tracking of Fires that Matter: What is Needed, what is possible, how do we build it?* NASA-JPL Keck Institute for Space Studies Workshop, 20-21 March 2021;
- Panelist: *The History and Future of the Tactical Fire Remote Sensing Advisory Committee (TFRSAC)*, Fireside Chat at: NASA Aeronautics Research Mission Directorate (ARMD) Wildfire Management Workshop, 13 May 2021;
- Member of Scientific Forum Board: *FirEURisk- A Holistic Approach For Risk-Wise Adaptation of the Wildfire Management in the EU the Global Changes;* PI**:** Domingos Xavier Viegas (ADAI (Associacao Para o Desenvolvimento Aerodinamica Industrial), University of Coimbra, Portugal); Horizon 2020 - Work Programme 2018-2020 "Climate action, environment, resource efficiency and raw materials", Call name: "Building a low-carbon, climate resilient future: climate action in support of the Paris Agreement; LC-CLA-15-2020: "Forest Fires risk reduction: towards an integrated fire management approach in the E.U." 2021-2025;
- Advisor / SME: *Fire Danger Prediction Using Satellite Remote Sensing*; PI: Dr. Diofantos Hadjimitsis (CUT) / Maria Prodromou (CUT) 'EXCELLENCE-HUBS", a Programme of the Research and Innovation Foundation for Research, Technological Development and Innovation, "RESTART 2016 – 2020"; 2021-2023; and
- Advisor / SME*: Copernicus-based Predictive Modelling for Timely Landslide Risk Detection (Cop-LANDRISK);* PI: Dr Marios Tzouvaras (Cyprus University of Technology (CUT)); EXCELLENCE-HUBS, a Programme of the Research and Innovation Foundation for Research, Technological Development and Innovation, "RESTART 2016 – 2020" (Cyprus Govt.); 2021-2023.

Scientific Panel Reviews

- Proposal Panel Reviewer: USDA-National Institute of Food & Agriculture; SBIR 8.1, Forests and Related Resources (23-25 February 2021);
- 2021 Scientific Peer-Review Journal Reviewer: International Journal of Wildland Fire, Remote Sensing, Remote Sensing of Environment, Science of Remote Sensing, Remote Sensing Applications, Fire Journal, International Journal of Applied Earth Observations,

Forests, GEOCARTO Journal, Sensors Journal, Natural Hazards & Earth Systems Science, International Journal of Disaster Risk Reduction; and

- Co-Chair: NASA Tactical Fire Remote Sensing Advisory Committee (TFRSAC); a USFS / NASA committee focused on technology development and EO in support of wildland fire management (since 2003).

Other Information

Community Outreach

Vince Ambrosia is an External Advisory Board member for the Cyprus University of Technology (CUT), EXCELSIOR Center of Excellence (CoE) (2018-2027). The EXCELSIOR CoE is designed to create a new Mediterranean region remote sensing, earth observations, and Geomatics Center to develop research, applications, and technology transfer of geospatial tools to greater use in the community. The European Commission (EC) supports the EXCELSIOR CoE effort.

Professional Societies, Committees, and Boards

- NASA Representative on the Group on Earth Observations (GEO), Global Wildfire Information System (GWIS) committee; GEO Work Plan 2011-2015, 2016-2020, and 2020-2022.
- American Society for Photogrammetry and Remote Sensing (ASPRS).
- European Assoc. of Remote Sensing Laboratories (EARSeL) Forest Fires Special Interest Group (FF-SIG), Science Team Member (2001-present); Technical Committee (2009-present).
- American Geophysical Union (AGU).

Ecological Forecasting

Project Participants

NASA: Woody Turner, Keith Gaddis
BAERI: Cindy Schmidt

Project Description

As an Associate program manager for the NASA Applied Science Ecological Forecasting program, Schmidt tracks projects in the Ecological Forecasting portfolio, supports strategic planning activities, helps coordinate annual program review meetings, and participates in interagency activities and meetings as required by the Program Managers. She currently manages 14 projects for the program.

Accomplishments

- Participated in Applied Science program reviews in January, March, May, July, September and November. Participation included presenting on Ecological Forecasting projects and contributing to the Applied Science strategic planning process;
- Participated in ROSES Ecological Forecasting proposal review panel in January and a FINESST review panel in April;
- Attended the Belize Sustainable Development Goals Virtual Technical Workshop in April. This workshop focused on the use of Earth observations for assessing coral reef health in Belize;
- Conducted a 2-day remote sensing training for conservation as part of the Society for Conservation GIS annual conference in July. This training was co-taught with a colleague from UC Berkeley's Geospatial Innovation Lab;
- Member of review committee for the Applied Sciences Guidebook. The Guidebook is being developed to help current and new potential Applied Science scientists, stakeholders, end users and the general public;
- Acquired 4 new projects recently funded under the A.39 ROSES solicitation which received initial funding Fall 2021;
- Participated on the planning committee for Earth Science Applications week, which included organizing content for the Ecological Forecasting program. Earth Science Applications week occurred Aug. 2021; and
- Worked with Natalie Tarbox (intern) and Argie Kaavada (NASA HQ) to develop one-page hand-outs and story maps for nine SDG projects.

Presentations

- “Remote Sensing for Biodiversity and Conservation”, ASPRS Pacific Southwest Spring meeting, April 2021; and
- “Remote Sensing for Biodiversity and Conservation”, UC Berkeley GIS class, November 2021.

Indigenous Peoples Capacity Building Initiative

Project Participants

NASA: Lawrence Friedl
BAERI: Cindy Schmidt, Amber McCullum

Project Description

The NASA Applied Science Indigenous Peoples Capacity Building Initiative seeks to better understand the needs and data gaps in the use of geospatial data, particularly NASA Earth science data and products, within Indigenous communities globally, but particularly tribes in the United States. This program also builds the capacity of indigenous communities and organizations to use geospatial data through in-person and online trainings and workshops. In addition to better understanding the needs and data gaps of Indigenous groups, this effort also seeks to understand how indigenous knowledge can inform NASA Earth Science activities.

The pillars of this work include community engagement and the co-production of place-based remote sensing trainings specific to indigenous lands and territories. We aim to strengthen the relationships between NASA and indigenous communities through meetings and knowledge-sharing activities, as well as co-developing a global indigenous geospatial community of practice through the Group on Earth Observations (GEO), particularly the GEO Indigenous Alliance, US GEO and AmeriGEO.

Through dialogue and discussion focused on indigenous needs and priorities, our remote sensing trainings provide participants with the data and resources needed to address specific natural resource issues facing their lands. https://appliedsciences.nasa.gov/indigenous-peoples-pilot

Accomplishments

- Participated in the Indigenous Mapping Workshop (IMW 2020), held online from November 17-19th, 2020, and offered 9 training sessions as part of the Indigenous Mapping workshop. This workshop was organized by the indigenous-led and owned Firelight Group out of Canada, and featured training sessions by other collaborators such as Google, ESRI, and Mapbox. The workshop had over 800 people registered and included panels and presentations from Indigenous leaders and elders from Canada, Australia, New Zealand and the US. Additional information can be found here: https://www.indigenousmaps.com/2020imw/;
    - Held meetings and gathered materials for the Indigenous Mapping Workshop: Turtle Island (IMW 2021), to be held Nov 1-5, 2021. We will be offering 14 training sessions in collaboration with the Canadian Space Agency (CSA) and ESRI Canada. Training details and outcomes will be included in the FY22 BAERI report.
- The Indigenous Peoples Capacity Building Initiative was featured in a Space.com article that highlighted the initiative objectives and the recent remote sensing trainings. The

article also featured quotes from our collaborators: James Rattling Leaf of the Rosebud Sioux Tribe and Nikki Tulley of the Navajo Nation. The article can be found here: https://www.space.com/earth-observation-for-native-american-tribes.html;

- Cindy Schmidt and Amber McCullum assisted in the organization of a training titled "Engaging with Indigenous Peoples" on February 9-11, 2021. This training is being offered through the Inter-American Academy of Geosciences and Applications (AmeriGEO) and will also be offered in Spanish. This training is provided by our partners with Conservation International (CI), the Firelight Group, and the GEO Indigenous Alliance. This training will focus on the 2007 United Nations Declaration on the Rights of Indigenous Peoples, recognizing their rights and the practice of Free, Prior and Informed Consent (FPIC) as a prerequisite for any activity that affects their ancestral lands, territories and natural resources. More information about this training can be found here: https://academy.amerigeoss.org/;
- The IP team participated in the Earth Science Applications Week event in August 2021. Organized by the NASA Earth Applied Sciences Program, Earth Science Applications Week highlighted experts and end users from within and outside the agency, speaking about everything from space-borne to boots on the ground solutions to our planet's most pressing concerns;
- The IP team assisted in the organization of a IUCN World Conservation Congress (WCC) Campus Session titled "Supporting Indigenous peoples in defending nature and traditions with geospatial technologies. Here is the session description: Indigenous peoples frequently lack consistent and timely access to the data, technologies, and resources necessary to effectively gain official recognition of and to uphold their land rights, as well as to monitor new threats to nature and their livelihoods. In this campus session, participants exchanged experiences gleaned from applying innovative approaches to support indigenous peoples' access to relevant technologies and resources and receive hand-on training to use geospatial tools introduced by the session organizers. One key outcome of this session was an action plan to improve knowledge-exchange of ideas, capacity building resources, and accessible geospatial technologies appropriate for indigenous-led mapping and monitoring; and
- The IP team conducted collaborative meetings for the US Group on Earth Observations (US GEO) on Indigenous representation and strategic alignment with other federal agencies such as NOAA and the USGS.

Presentations

- Cindy Schmidt presented at the International GEO Indigenous Summit in December, 2020 to discuss NASA's Indigenous Peoples Pilot and the two training virtual training sessions we conducted this fall: (1) Introduction to Remote Sensing for Tribal Lands in partnership with the United Tribes Technical College (UTTC) and (2) Remote Sensing with NASA data as part of the Indigenous Mapping Workshop (IMW) 2020. This session focused on education and intergenerational knowledge transfer of geospatial data with Indigenous communities. A link to the recording can also be found at the GEO Indigenous Summit website here: http://www.earthobservations.org/indigenoussummit2020.php?t=full_programme;

- Amber McCullum and Nikki Tulley presented for the University of Arizona's Water Resources Research Center on January 20th, 2021. The presentation title was: *Collaborative Capacity Building and Sovereign Science with NASA and the Navajo Nation* and highlighted the Indigenous Peoples Initiative and the Navajo Drought and OpenET projects;
- Cindy Schmidt and Amber McCullum presented in collaboration with David Borger (LARC), Dan Slayback (GSFS), and Frederick Policelli (GSFS) from the Disasters Program on *NASA Data and Tools for Floods, Wildfires, and Droughts* to the Institute for Tribal Environmental Professions Disasters Cohort meeting on July 21st. This presentation featured demonstrations of multiple NASA resources including the Indigenous Peoples Pilot and associated training resources, NASA Disasters Flood Dashboard, Worldview, the Drought Severity Evaluation Tool (DSET) and more;
- Cindy Schmidt and Amber McCullum presented on NASA Data for Land and Water Management to the Inter-Tribal Environmental Council on July 29th. The training featured the Indigenous Peoples Pilot and associated training resources, the Drought Severity Evaluation Tool (DSET) and OpenET; and
- Cindy Schmidt presented for the First Virtual Forum or Science, Technology, and Indigenous Peoples organized by the Inter-American Development Bank and the Guatemala Secretariat of Technology on August 5th, 2021. The presentation provided an overview of the Indigenous Peoples Initiative and opportunities to collaborate on an international scale.

Partnerships

Project Participants

NASA: Shanna McClain, Keith Gaddis
BAERI: Cindy Schmidt, Amber McCullum

Project Description

NASA's Earth Science Division and Conservation International are collaborating on approaches for the assessment and monitoring of ecosystem health and natural capital flows to amplify the role of Earth observations, and drive more sustainable decision making at national and regional scales. The partnership deepens the impact and application of NASA ESD remote sensing data and research and advance natural resource management, including natural capital accounting and ecosystem health assessment. Efforts under this collaboration include development of ecosystem accounts for Liberia, Botswana, and Gabon which contribute to the Gabarone Declaration for Sustainability in Africa (GDSA), as well as development of the Freshwater Health Index in the Mekong region (southeast Asia), and the Okavango (Africa).

Accomplishments

GDSA

- Developed ecosystem maps for Liberia, which will be combined with measurements of environmental assets developed by Conservation International. The government of Liberia has officially sanctioned the use of the ecosystem map for use in National Capital Accounting. Cindy Schmidt is working with Conservation International to develop a Capacity Building plan for Liberia, Botswana and Gabon. In-person trainings have been postponed due to COVID travel restrictions. The NASA/CI team meets bi-weekly, the NASA team meets monthly and Schmidt and McCullum present project updates at quarterly reviews with NASA ESD leadership.

FHI

The team currently has three study regions where they are facilitating the use of the Freshwater Health Index (FHI) to assess ecosystem functions, services, and health: the Mekong Delta (Vietnam), the Okavango Delta (Botswana), and the Rupununi Watershed (Guyana).

- In the Mekong, where the team has been working for some time, they are finalizing a manuscript and they have conducted virtual capacity building trainings with their partners;
- Signed a memorandum of agreement (MOU) with CI and the Okavango River Basin Water Commission (OKACOM). This is an exciting step forward as the MOU outlines intentions to collaborate on projects for monitoring, protecting, and restoring ecosystem

health to support the sustainable and equitable long-term provision of ecosystem services.; and

- Held a kick-off meeting for the Rupununi work, and are working with the Guyana government agency, called Hydromet, to establish a formal relationship for data sharing and analysis.

Plant Physiology

Project Participants

BAERI Greg Schlick
NASA: David Bubenheim

Project Description

Invasive aquatic plants impact waterways throughout the world with ecological, economic, and social impacts. The California Delta, involving the San Francisco Bay and San Joaquin and Sacramento River watersheds, is seriously affected by the increasing presence of aquatic invasive plants, which threaten the ecological integrity of the region and water management. Invasive aquatic plants are affecting resource management, ecosystem services, aquatic habitats and food webs, and economic pursuits in the Delta region, as well as primary agricultural production and water supply to 25 million people in California. Added challenges include unpredictable climate and environmental variations, unknown biological response to those variations, and changing regulatory rules, stakeholder needs, and regional US water resource distribution and management policy.

The Delta Region Areawide Aquatic Weed Project (DRAAWP) was initiated in response to these challenges, as a comprehensive and multi-disciplinary effort to develop science-informed, adaptive management support systems. The DRAAWP provided for the development, gap filling science, and demonstration of how science and remote sensing-based tools can be fused to support adaptive management decisions in a complex aquatic ecosystem with a wide range of stakeholder pressures and regulatory oversight.

DRAAWP includes the USDA-ARS, NASA-Ames Research Center, University of California Davis, and State of California – Division of Boating and Waterways (DBW). NASA-ARC focuses on remote sensing to map and track floating aquatic invasive plant communities in the Delta, including the validation of location and estimation of biomass, and definition of invasive aquatic species to environmental variations, including water quality and flow as impacted by land use and climate change.

Accomplishments

- Received the Outstanding Technical Contribution to the Field Award for 2020 from the Society of Aquatic Plant Management; and
- Awarded the 2020 Outstanding Federal Agency Collaboration from The Federal Lab Consortium.

Water Resources Program

Project Participants

CSUMB: Forrest Melton, Pam Hansen

Project Description

The primary objectives of this task are to:

- Support the NASA Applied Sciences Program, Water Resources application area by serving as an Associate Program Manager for Water Resources, and as the Program Scientist for the NASA Western Water Application Office;
- Monitor progress across the project portfolio, engage and support project teams in identifying and resolving project issues, and coordinate the ASP Water Resources science community; and
- Conduct outreach and engage and support the NASA Applied Sciences Water Resources stakeholder community.

Accomplishments

- Tracked and coordinated 9 ASP Water Resources projects. Monitored financial and technical progress and engagement with partners and stakeholders. Communicated regularly with project PIs to identify and resolve issues. Reported project progress to ASP PMs and Associates at five ASP Program Reviews;
- Served as a representative for Earth Science and Applied Sciences on the NASA Climate Strategy Working Group and contributed content to the NASA Climate Strategy released in October, 2021;
- Participated in weekly meetings with WWAO and bi-weekly meetings with NASA HQ. Supported the project formulation process for multiple projects being supported by WWAO in the Columbia River Basin. Co-led the development of the WWAO Program Strategy for FY22. Supported the WWAO Needs Assessments for the Rio Grande River Basin and the Missouri River Basin. Co-authored the WWAO RFI for the Columbia River Basin and co-managed the project selection process. Oversaw technical progress on six project supported by WWAO;
- Organized and co-led the annual NASA Applied Sciences Program (ASP) Water Resources and Western Water Applications Office Annual Team Meetings. P. Hansen planned all logistics for the meeting to be held in Salt Lake City, UT and P. Hansen and F. Melton reorganized the meeting and agenda to allow the meeting to be held virtually over four days from Oct 5-8, 2021. P. Hansen organized all meeting logistics, web conferencing support, and agenda for a meeting with over 90 participants. F. Melton organized panels on special topics for the NASA WWAO and Water Resources Community;

- Contributed to the development of the NASA Water Resources 2021 solicitations (NASA ROSES element A.34), including the introduction of a 3-phase approach to applied sciences projects. Reviewed more than 140 Phase I proposals with the Water Resources program manager and co-chaired two NASA review panels for the 68 Phase II proposals received;
- Served as the NASA Representative to WESTFAST and the NIDIS Applications Working Group, which are federal interagency coordinating organizations; and
- Co-led the organization of the WWAO Technology Transition Workshop with the Western States Water Council (WSWC) and WestFAST in Irvine, CA, scheduled for May, 2020. Worked with the WWAO team and the WSWC to develop the workshop objectives and agenda. This workshop has been postponed until 2022; and

Presentations

- During 2021, Forrest Melton provided briefings for more than 10 briefings for U.S. House and Senate Offices, staff for 2 House Committees, and the American Farm Bureau Federation and the California Farm Bureau.

Publications

Schmidt, G., Sengupta, M., Melton, F. et al. (2021). NASA Climate: Advancing NASA's Climate Strategy -- A whole of NASA approach, October 2021, NASA, Washington, D.C.

Panels or Committees

- NASA Climate Strategy Working Group;
- Western Federal Agency Support Team (WESTFAST);
- California Department of Water Resources Open Water Information Architecture Technical Committee; and
- NIDIS Applications Working Group.

Western Water Applications Office (WWAO)

Project Participants

BAERI: Amber McCullum
JPL, CSU Monterey Bay, etc: Indrani Graczyk, Forrest Melton, Stephanie Granger, Dr. Catalina Oaida, Dr. Amber Jenkins, Mark Davidson. Full team link here.

Project Description

The Western Water Applications Office (WWAO) is a NASA program focused on all things water. While physically headquartered at NASA's Jet Propulsion Laboratory in Pasadena, California, it is a cross-NASA initiative with a team representing all of the NASA centers. WWAO is part of a larger effort within NASA's Applied Sciences Program to help society through NASA's data, tools, and technology. It is part of NASA's Applied Sciences Program, which covers Earth science and encompasses five application areas: Health and Air Quality, Ecological Forecasting, Disasters, Wildfires, and Water Resources. WWAO forms a core part of the latter of these thrusts – water resources. WWAO leverages decades of NASA investment in science and technology to deliver useful, actionable information to those on the ground making water decisions and shaping policies that potentially affect millions of people. Amber McCullum serves as the Impact and Transition Lead for the WWAO Program Office.

Accomplishments

- **Impact assessment guidelines document augmentations:** This was conducted through interviews with WWAO project leads and included documenting best practices and lessons learned. This was a valued contextualization of the impact assessment process and will serve as a resource for new project leads to design and/or revise their assessments. This included the creation of a reporting guide for new project leads to become familiar with the process and to conduct quarterly impact assessments in a timely manner. This increased the communication of project impacts and successes to a variety of audiences.
- **Continued and sustained project support:** This portion of the role centers around relationships with project leads and the WWAO program office to design, document, and communicate project impacts. The primary focus was to support project leads to ensure the completion of their impact assessment and transition goals. The process for completing impact assessments and transition plans was established as a flexible and adaptable workplan for future projects. This included participation in quarterly project updates with project leads and the WWAO program office to monitor progress on technology transfer and impact assessment. Finally, this portion of the role involves continuing and increasing communications among WWAO, the VALUABLES consortium, and the Applied Sciences community about best practices, lessons learned, and effectively creating impact assessments and communicating project successes.
- **Applications transitions coordination:** Assisting with the transition of a successful project application into the public or private sector, this portion of the role focuses on

working with project leads to create a business model proposal for transitions and economic assessments. Successful models used as guidance for this work included the Airborne Snow Observatory, outcomes from the R2O workshops, and more.

- **Coordination with the Applied Sciences Program (ASP) and the Capacity Building Program (CBP):** Established an ongoing strategic initiative to communicate and coordinate with other ASP projects and CBP element. This included connecting the DEVELOP Program with potential stakeholders to conduct pilot projects that could serve as an entryway into larger WWAO projects, and linking WWAO and other ASP Water Resources projects to the ARSET program to help feature project outcomes and tools in online and in-person trainings. Benefits of this include promotion of the WWAO program to a broad audience, and increasing the use of WWAO-developed tools and products among stakeholders. Finally, engagement with the Indigenous Peoples Capacity Building Initiative assisted in ensuring equitable engagement with Indigenous groups of the western U.S., in particular with the WWAO Stakeholder Engagement process.
- Assisted with the launch of the Navajo Nation Drought Severity Evaluation Tool (DSET) User guide on the Western Water Applications Office (WWAO) website. This user guide offers guided demonstrations of the water insights that the DSET can deliver to the Navajo Nation region. The videos and manuals below offer step-by-step instructions for making maps and time series to: evaluate drought conditions, perform crop analysis, monitor the status of lakes and meadows, and to gauge the state of snowpack. Each focus area provides a demonstration video and a written user guide. See the user guide here: https://wwao.jpl.nasa.gov/water-programs/water-projects/nasa-navajo-drought-severity-tool-user-guide/
- Assisted with a series of communications activities centered around the launch of the WWAO Navajo Nation DSET USerguide, including:
    - A feature on our project team member, Nikki Tulley, on what inspires her to focus on water issues within her community. This feature was posted on the NASA's Applied Sciences website.
    - A related feature about the DSET project and Nikki's work on the Western Water Applications Office (WWAO) website here: https://wwao.jpl.nasa.gov/news-insight/articles/connecting-drops-nikki-tulley-navajo-nation/

Presentations

- Amber McCullum and Nikki Tulley organized and moderated a panel for the American Water Resources Association (AWRA) Virtual Summer Conference: Connecting Land and Water for Healthy Communities on July 21st, 2021. This panel, "Collaborative Approaches for the use of Earth Observations in Indigenous Communities" highlighted cloud-based water and land management tools that have been co-developed to meet the needs of Indigenous communities, such as the Navajo Nation Drought Severity Evaluation Tool (DSET) and the OpenET data portal. Panel speakers included: James Rattling Leaf Sr. (The Geo Indigenous Alliance), Crystal Tulley-Cordova and Carlee McCllean (Navajo Nation Department of Water Resources), Forrest Melton (CSU Monterey Bay/NASA Ames), and Dawn White (Great Lakes Indian Fish and Wildlife Commission).

- Amber McCullum presented for the International Precipitation Working Group (IPWG) and Global Precipitation Measurement (GPM) Applications Training on September 15, 2021. This three-part webinar series hosted by the International Precipitation Working Group (IPWG) and Global Precipitation Measurement (GPM) Applications Program focused on the use of GPM data products for applications. Specifically, the participants learned more about how to access GPM data and were provided demonstrations on precipitation data access and analysis using NASA's Giovanni tool and Google Earth Engine, and featured the Navajo Drought Severity Evaluation Tool (DSET);
- Participated in the Earth Science Applications Week event in August 2021 and presented on behalf of the WWAO office and the DSET project. Organized by the NASA Earth Applied Sciences Program, Earth Science Applications Week highlighted experts and end users from within and outside the agency, speaking about everything from space-borne to boots on the ground solutions to our planet's most pressing concerns; and
- Participated in the Applied Sciences Water Resources Annual Meeting on Oct 5-8, 2021. Presented on behalf of the Western Water Applications Office (WWAO) on topics of impact assessment and research to operations (R2O) within Applied Sciences projects and beyond. She also presented as the team lead for the Navajo Nation Drought Severity Evaluation Tool (DSET).

Airborne Science and Mission Support

Airborne Science Advanced Planning

Project Participants

NASA: Matt Fladeland
BAERI: Susan Schoenung

Project Description

The Airborne Science Advanced Planning activity seeks to collect information on the needs of the NASA Earth Science community for support from NASA's Airborne Science Program (ASP). ASP provides flight services for Earth Science using NASA aircraft platforms, both manned and unmanned, operating out of several NASA Centers. ASP also provides payload integration services and mission assistance, including flight planning, data management, and communications. To ensure that the right capabilities are available and will be available for future science activities, Advanced Planning maintains an out-year schedule of mission plans and the assets and services required. Information is gathered from NASA's Earth Science program and from the science community through workshops, conferences, and ongoing interactions.

Accomplishments

- Updated the ASP 5-year plan, monthly, for ASP management;
- Prepared a monthly map of all ESD airborne missions for ASP management;
- Prepared an Airborne Science Program Needs Assessment, which is currently in final publication;
- Prepared the ASP 2020 Annual Report and two ASP newsletters;
- Developed Quad charts to illustrate Airborne Science support for NASA Earth Science space missions, especially upcoming Decadal Survey activities;
- Participated in various science team meetings related to NASA Earth Science missions to gather airborne requirements data;
- Participated in ASP strategic planning with ASP deputy directors by sharing archived data; and
- Initiated preparations for High Altitude Long Endurance (HALE) science workshop and related white paper.

Airborne Science Program (ASP)

Project Participants

BAERI: Dr. Gary Hoffmann, Kent Dunwoody, Ali Pompeii, James Jacobson, and Diane Gribschaw

Project Description

The Airborne Sensor Facility (ASF) at NASA Ames supports a variety of airborne research activities for the NASA Earth Science Division. It conducts engineering development of remote sensing instrumentation and real-time payload communications systems, and supports their operational use on science field campaigns. The ASF maintains a suite of facility instruments that are made available for use by NASA-approved research projects, with all resulting data being made available free of charge through public archives. These data are typically used for fundamental earth science process studies, satellite calibration and validation, development of retrieval algorithms, and disaster response. The sat-com based payload communications systems are deployed on most of the NASA science aircraft, and are a key element of the larger NASA Airborne Sensor Network, which allows scientists to view data from multiple instruments in real-time during science campaigns.

The ASF includes elements for sensor engineering, optical and infrared sensor calibration, and data processing. (see https://asapdata.arc.nasa.gov/)

The ASF and NSRC have historically worked closely together to support the Airborne Science Program (ASP). Earlier this year, the ASF and ASP have refocused their budgets and equipment in order to allow the ASF to concentrate on the primary function of maintaining the N-259 Calibration Laboratory as well as the EOS facility instruments: MASTER, eMAS, and PICARD. This report will cover the ASF/ASP joint activities from 5/30/2021 to 10/1/2021, after which ASP is no longer a contributor to the ASF budget.

As of October, 2021, Kent Dunwoody and Ali Pompeii have fully transitioned to ASP work in support of NASA aircraft, with all other ASF staff remaining as fully supported EOS personnel.

Accomplishments

- NASDAT/Aircraft Network support of the DCOTTS mission;
- NASDAT/Aircraft Network support of the ACTIVATE mission;
- NASDAT/Aircraft Network support of the CPEX mission;
- Delivery and acceptance of the XCube system from Cal Poly SLO;
- Applanix support for DAGR;
- Engineering support of the DC-8 onboard instrumentation;

- Successful first deployment of the PTZ (Pan-Tilt-Zoom) camera system on the ER-2;
- IRIS Camera and Console delivered to The Smithsonian Institute for preservation and display;
- Supported handoff of material, equipment, and documentation of the NASDAT and EIP systems to NSRC/ASP; and
- Ongoing work towards PICARD integration on the NASA G-V/III in anticipation of ARCSIX in FY2024.

Autonomous Scheduling of Earth-orbiting Satellite Constellations

Project Participants

BAERI: Sreeja Nag, Vinay Ravindra, Alan Li
JPL: Marc Sanchez Net, Kar-Ming Cheung
UGA: Rod Lammers, Brian Bledsoe

Project Description

Distributed Space Missions (DSMs), such as formation flight and constellations, are being recognized as important Earth Observation solutions to increase measurement samples over multiple spatio-temporal-angular vantage points. Larger numbers of smaller spacecraft also minimize launch and operational risks, and maximize evolution with time and technology. Small spacecraft (Cubesats up to 27U, ~40 kg in development) have the capability to host imager payloads and can slew to capture images within short notice, given the precise attitude control systems emerging in the commercial market. When combined with appropriate software, this can significantly increase response rate, revisit time, and coverage. In prior work, we have demonstrated an algorithmic framework that combines orbital mechanics, attitude control, and scheduling optimization to plan the time-varying, full-body orientation of agile, small spacecraft in a constellation, such that they maximize observations for given imaging requirements and spacecraft specifications. The proposed schedule optimization would run autonomously at the ground station, and the resultant schedules would be uplinked to the spacecraft for execution. The algorithm is generalizable over small steerable spacecraft, control capability, sensor specs, and regions of interest.

In this project, we will modify the algorithm to run onboard small spacecraft, such that the constellation can make time-sensitive decisions to slew and capture images autonomously, without ground control. Upcoming technologies such as inter-satellite links, onboard processing of images for intelligent decision making, and onboard orbit prediction, will be leveraged for reaching consensus and coordinated execution among multiple spacecraft. Specifically, we will develop a communication module based on Delay/Disruption Tolerant Networking for onboard data management and routing among the satellites, which will work in conjunction with the other modules to optimize the schedule of agile communication and steering. We will then apply the developed software (for both ground-based and onboard autonomy) on representative constellations to simulate targeted measurements of multiple phenomena, organized by relevancy scenarios: (1) episodic precipitation events and subsequent floods, with varying requirements for data latency and reaction time; (2) cloud property assessment by tracking specific multi-angular geometries; and (3) Monitoring the spread of wildfires. The autonomous command and control efficiency of our agile algorithm, compared to static sensors, will be quantified with a very simplified observing system simulation per use case.

The proposed algorithms, partially tested on simulation software, will be integrated with University of Hawaii's COSMOS ground operations tool for software-in-the-loop verification. The onboard version of the algorithms will be integrated with NASAs Core Flight Software -

open source, project-independent framework, used on flight missions such as MMS and GPM. This project will serve NASA's technical and scientific areas of emphasis by delivering an Algorithm driven Information System (ADIS) capable of optimizing agile spacecraft constellation operations, which enables new types of measurements, is validated on flight software, and applied to relevancy scenarios of recognized importance in Earth Science. This project addresses the NRC recommendations for low-cost, small satellites, miniaturized instruments, and robust constellations for meeting Decadal Survey goals. The chosen relevancy scenarios address SMD's research and analysis areas: Water and Energy Cycle (precipitation, floods), Climate Variability and Change (clouds), Carbon Cycle and Ecosystems (fire) and the Applied Science program (flood, fire).

Publications

R. Lammers, A.S. Li, V. Ravindra, S. Nag, "Prediction Models for Urban Flood Evolution for Satellite Remote Sensing", Journal of Hydrology, accepted.

Awards

- NASA AIST Grant for a New Observing Strategy study for ocean color monitoring as Principal Investigator, May-December 2021.

Panels/Committees

- Planning Committee Member, IWPSS - International Workshop on Planning and Scheduling for Space (peer-reviewed), to review and select papers for publication in IWPSS bi-annually

D-SHIELD: Distributed Spacecraft with Heuristic Intelligence to Enable Logistical Decisions

Project Participants

BAERI: Sreeja Nag & Vinay Ravindra & Ryan Ketzner

Project Description

D-SHIELD is a suite of scalable software methods and frameworks to help schedule payload operations of a large constellation, with multiple payloads per and across spacecraft, such that the collection of observational data and their downlink, constrained by the constellation constraints (orbital mechanics), resources (e.g., power) and subsystems (e.g., attitude control), results in maximum science value for a selected use case. Constellation topology, spacecraft, and ground network characteristics can be imported from design tools or existing constellations, and can serve as elements of an operations design tool. The framework includes a science simulator to inform the scheduler of the predictive value of observations or operational decisions.

As a part of the D-SHIELD project, we have developed the Earth Observation Simulator (EOSim), a software framework which facilitates the mission analysis of remote-sensing satellites. EO-Sim allows exploration of observing strategies by facilitating users to configure and simulate heterogenous satellite constellations. The simulations can generate a set of potential observation opportunities and the associated observation metrics during mission-operations. EO-Sim also incorporates an observation simulator to mock the operation of instruments, taking into consideration the instrument specifications and observation geometry. The software has been made available to the public in a GitHub repository.

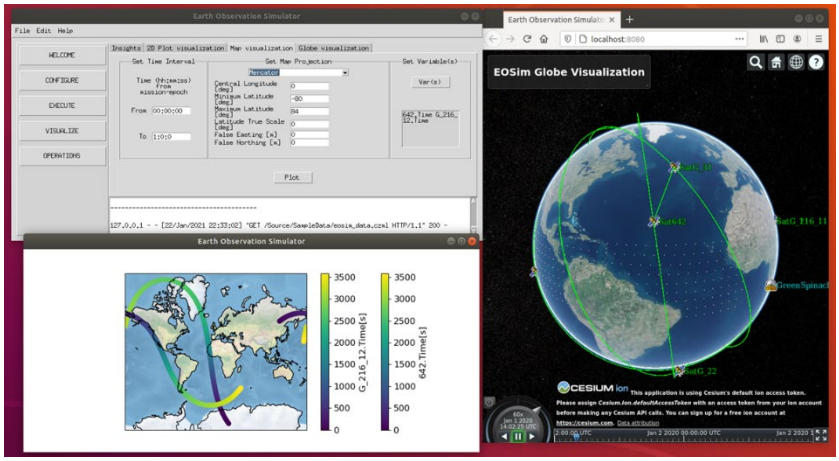


Figure: Screenshot of the EOSim software.

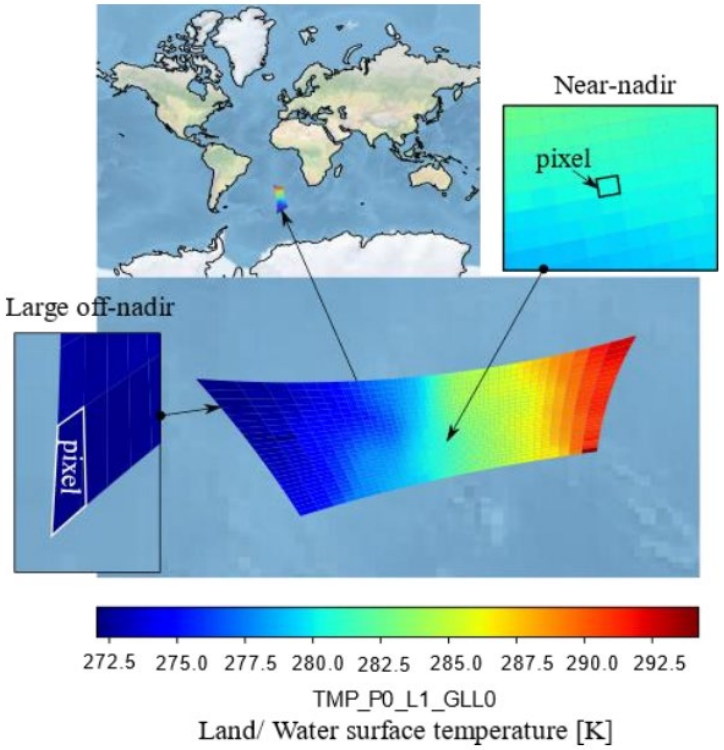


Figure: Example of simulated imagery of an instrument observing the surface temperature. The simulation is of a satellite at 500km Sun-synchronous orbit making observation at 10deg off-nadir using an instrument with field of view 60 deg along-track and 120 deg cross-track. The non-homogeneity of the pixel shapes can be seen.

Accomplishments

- Released open-source software EOSim on GitHub. https://github.com/EarthObservationSimulator/ ;
- Developed a novel algorithm to enable faster, reliable, and accurate satellite-coverage calculations for the purpose of remote-sensing mission analysis;
- Prepared for upcoming release of satellite Attitude Determination and Control System (ADCS) software module on GitHub, which can be used to analyze satellite maneuvers;
- Contributed to the NOS Oceans study that uses D-SHIELD components in an oceans monitoring use case; and
- Passed all annual and quarterly reviews with ESTO, and the project team has been encouraged to submit a follow-on proposal for the next AIST solicitation.

Presentations

- S. Nag, et al., “D-SHIELD: Distributed Spacecraft with Heuristic Intelligence to Enable Logistical Decisions", NASA Earth Science Technology Forum, January 2021.

- V. Ravindra, R. Ketzner, S. Nag, “EO-Sim: An open-source library for design and evaluation of space observation systems; a discussion on the software design and development.”, AGU Fall Meeting 2021.
- A. Kannan, et al., “Forecasting global geophysical states using a deep learning model for Spacecraft constellation scheduling and planning”, AGU Fall Meeting 2021.
- S. Nag, et al., "Simulating the Impact of Agile, Heterogeneous, Distributed Spacecraft with Intelligent Scheduling (D-SHIELD) to reduce global Soil Moisture Uncertainty", AGU Fall Meeting 2021.

Publications

R. Ketzner, V. Ravindra and M. Bramble, “A Robust, Fast, and Accurate Algorithm for Point in Spherical Polygon Classification with Applications in Geoscience and Remote Sensing,” Computers & Geosciences, under review, 2021.

R. Lammers, A.S. Li, V. Ravindra, S. Nag, "Prediction Models for Urban Flood Evolution for Satellite Remote Sensing", Journal of Hydrology, accepted, 2021.

V. Ravindra, R. Ketzner, S. Nag, “”Earth Observation Simulator (EO-SIM): An Open-Source Software for Observation Systems Design”, IEEE International Geoscience and Remote Sensing Symposium, Brussels Belgium, July 2021.

R. Levinson, S. Nag, V. Ravindra, “”Agile Satellite Planning for Multi-Payload Observations to aid Earth Science”, International Workshop on Planning and Scheduling for Space, Virtual Forum, July 2021.

S. Nag, M. Moghaddam, D. Selva, J. Frank, V. Ravindra, R. Levinson, A. Azemati, B. Gorr, A. Li, R. Akbar, "Soil Moisture Monitoring using Autonomous and Distributed Spacecraft (D-SHIELD)", IEEE International Geoscience and Remote Sensing Symposium, Brussels Belgium, July 2021.

B. Gorr, A. Aguilar, D. Selva, V. Ravindra, M. Moghaddam, S. Nag, "Heterogeneous Constellation Design for a Smart Soil Moisture Radar Mission", IEEE International Geoscience and Remote Sensing Symposium, Brussels Belgium, July 2021.

E. Sin, M. Arcak, A. S. Li, V. Ravindra, S. Nag, "Autonomous Attitude Control for Responsive Remote Sensing by Satellite Constellations", AIAA Science and Technology Forum and Exposition (SciTech Forum), Nashville, January 2021.

Earth Observing System (EOS)

Project Participants

BAERI: James Jacobson, Diane Gribschaw, Dr. Edward Hildum, Rose Dominguez, Paul Windham, Thomas Ellis, Jeff Grose, Ethan Pinsker, Conrad Esch, Dr. Stephen Broccardo, Roy Vogler, Eric Fraim, Dr. Gary Hoffmann, Dr. Haiping Su, Jian Zheng, David Behan, and Jeffrey Myers.

Project Description

The Airborne Sensor Facility (ASF) at NASA Ames supports a variety of airborne research activities for the NASA Earth Science Division. It conducts engineering development of remote sensing instrumentation and real-time payload communications systems, and supports their operational use on science field campaigns. The ASF maintains a suite of facility instruments that are made available for use by NASA-approved research projects, with all resulting data being made available free of charge through public archives. These data are typically used for fundamental earth science process studies, satellite calibration and validation, development of retrieval algorithms, and disaster response. The sat-com based payload communications systems are deployed on most of the NASA science aircraft, and are a key element of the larger NASA Airborne Sensor Network, which allows scientists to view data from multiple instruments in real-time during science campaigns.

The ASF includes elements for sensor engineering, optical and infrared sensor calibration, and data processing. (see https://asapdata.arc.nasa.gov/). This report covers the time period from 5/31/2021 to 11/11/2021.

Accomplishments

- Continued testing of the new eMAS vacuum system to prepare for return-to-flight activities;
- Continued testing of the PICARD instrument to prepare for return-to-flight activities;
- Conducted Calibration Lab Characterization in joint effort with the NASA GSFC RCL laboratory;
- Provided support for redesigning the PICARD exterior to accommodate new airborne platforms: the NASA G-V and NASA G-III;
- Supported the Autonomous Modular Sensor (AMS) instrument for wildfire related work through the USFS;
- Supported the NIRVSS CLIPS 19C spectrometer calibration; and
- Transferred Applanix GPS/POS 610 systems to JPL, JSC, GSFC for intra-agency use and cooperation.

Earth Science Project Office (ESPO)

Project Participants

NASA: Marilyn Vasques, Bernadette Luna
BAERI: Judy Alfter, Quincy Allison, Brad Bulger, Lorena Cordova, Katja Drdla, Erin Justice, Lynn Kennedy, Sam Kim, Andrian Liem, Susan McFadden, Caitlin Murphy, Sommer Nicholas, Ayuta Padhi, Stevie Phothisane, Leslie Ryan, Michael Schroeder, and Katie Stern.

Project Description

The Ames Earth Science Project Office (ESPO) provides project management for NASA's Science Mission Directorate field research. ESPO provides planning, implementation, and post-mission support for large, complex, multi-agency, national and international field missions, especially airborne missions. ESPO has a long history of managing successful field missions, beginning in 1987 with the Stratosphere-Troposphere Exchange Project and the Airborne Antarctic O3 Expedition experiments. More recently, ESPO's NASA customers have included the Atmospheric Chemistry and Modeling Analysis Program, the Tropospheric Chemistry Program, the Radiation Sciences Program, Atmospheric Dynamics and Remote Sensing, the Suborbital Science Program, and the EOS satellite validation program.

Annually, the ESPO team manages the deployment of between six and ten major field missions and continues to provide support to the science team, airplane team, and the larger scientific community for previous years' missions. Finally, the ESPO team plays a critical role in planning for future missions, interfacing with NASA Headquarters, NASA and university scientists, crew members of airborne platforms, local support staff, and the larger scientific community. The unique work done by the ESPO team makes NASA Earth Science's core mission of collecting Earth Science data from airborne platforms with global coverage possible.

Accomplishments

In 2021, the NASA-ARC-based ESPO team supported the following research campaigns under the ARC-CREST agreement:

- **EXPORTS (EXport Processes in the Ocean from RemoTe Sensing)** is a five year ocean biology project. The field campaign is designed to advance the capability of satellite-based NASA ocean color products to predict how changes in ocean primary production will impact the global carbon cycle. The first very successful deployment took place in August and September of 2018. Data submission and planning for the 2020 deployment continued, but the deployment was ultimately delayed until the spring of 2021. The final EXPORTS deployment was a great success amidst extraordinary logistical challenges due to global supply chain disruptions created in the wake of the pandemic.

- **ACCLIP (Asian Summer Monsoon Chemical & CLimate Impact Project)** is a joint venture between NASA and NCAR. Two aircraft (the NASA WB-57 and the NCAR G-V), outfitted with state-of-the-art sensors, and approximately 80 scientists from the US and other international research organizations, will participate in the ACCLIP deployment from Osan Air Base in South Korea in the summer of 2022. Integration and test flights were successfully completed at NASA JSC in the summer of 2021. The field campaign was initially planned for Naha, Okinawa in the summer of 2020, but was postponed because of the COVID-19 pandemic.

- **CPEX-AW (Convective Processes Experiment – Aerosols & Winds)** is a joint effort between NASA and ESA with the primary goal of conducting post-launch calibration and validation activities of the Atmospheric Dynamics Mission-Aeolus (ADM-AEOLUS) Earth observation wind Lidar satellite in Sal, Cabo Verde. CPEX-AW is a follow-up to the Convective Processes Experiment (CPEX) field campaign which took place in the summer of 2017. In addition to joint calibration/validation of ADM-AEOLUS, CPEX-AW will study the dynamics and microphysics related to the Saharan Air Layer, African Easterly Waves and Jets, Tropical Easterly Jet, and deep convection in the InterTropical Convergence Zone (ITCZ). The field campaign was initially planned for Sal, Cabo Verde in the summer of 2020, but was postponed because of the COVID-19 pandemic. The team deployed to St. Croix in the summer of 2021 and completed seven research flights, but the campaign was suspended after a tragic accident. The team is currently planning to deploy to Sal, Cabo Verde in the summer of 2022.

ESPO is managing the following Earth Venture Suborbital-3 (EVS-3) Missions:

- **IMPACTS (Investigation of Microphysics and Precipitation for Atlantic Coast-Threatening Snowstorms)** is a multi-NASA center project studying the formation of snow bands in East Coast winter storms in order to improve forecasts of extreme weather events. This study will involve flights of NASA's ER-2 and P-3 aircraft over the northeastern United States. Deployments were successfully completed out of Hunter AFB and Wallops Flight Facility from January-March, 2020. The second year field campaign was scheduled to resume in fall 2020 but was postponed until fall 2021 because of the COVID-19 pandemic. The team is currently planning to deploy the ER-2 out of Pope Army Airfield in NC, and the P-3 will operate out of NASA WFF in early 2022.

- **S-MODE (Sub-Mesoscale Ocean Dynamics Experiment)** is a multi-year project exploring the potentially large influence that small-scale ocean eddies have on the exchange of heat between the ocean and the atmosphere. The experimental region is located in the San Francisco Bay Area, with NASA aircraft operations based at Moffett Field at Ames Research Center. The first deployment was recently completed in November 2021. The participating platforms were the NASA AFRC B-200, a Twin Otter, the Research Vessel Oceanus, as well as ocean surface drifters, wave gliders, and Saildrones. Most of the mission planning and control center operations were done remotely, showcasing the team's resiliency. The team is excited to analyze the data collected during the Pilot campaign, and is planning for the next deployment in the Fall

of 2022.

- **DCOTSS (Dynamics and Chemistry of the Summer Stratosphere)** is a five year NASA project investigating how strong summertime convective storms over North America can change the chemistry of the stratosphere. Aircraft operations are based in Salina, Kansas with the NASA ER-2 aircraft. The first deployment was successfully completed in the summer of 2021 after a yearlong postponement because of the COVID-19 pandemic. The team is working to analyze the data and is preparing for the second and final deployment in the spring and summer of 2022.

In 2021, the NASA-ARC-based ESPO team supported the following virtual meetings:

- CAMP^{2}Ex (Cloud, Aerosol and Monsoon Processes Philippines Experiment) Meeting;
- S-MODE (Sub-Mesoscale Ocean Dynamics Experiment) Science Team Meeting;
- NASA ESD Virtual Visit to Howard University;
- NASA UAS Workshop;
- Biodiversity and Ecological Forecasting Science Team Meeting;
- Hybrid meeting: IMPACTS (Investigation of Microphysics and Precipitation for Atlantic Cost-Threatening Snowstorms);
- DCOTSS (Dynamics and Chemistry of the Summer Stratosphere) Team Meeting;
- AGAGE 62 (Advanced Global Atmospheric Gases Experiment) Technical Session;
- TEMPO (Tropospheric Emissions: Monitoring Pollution) Science Team Meeting;
- ORM 11 (Ozone Research Managers of the parties to the Vienna Convention for the Protection of the Ozone Layer Eleventh Meeting, part II);
- NDAAC (Network for the Detection of Atmospheric Composition Change) Steering Committee Meeting; and
- MACIE (Measurements of Aerosols, Clouds and their Interactions for ESMs) meetings.

Meteorological Measurement Systems (MMS)

Project Participants

NASA: T. Paul Bui
BAERI: Jonathan M. Dean-Day, Cecilia S. Chang

Project Description

The Meteorological Measurement System (MMS) provides in situ measurements of static pressure, static temperature, and 3-D winds on a number of NASA airborne research platforms, including the Global Hawk UAV, Sierra UAV, DC-8, ER-2, WB-57F, and the H211 Alpha Jet. These measurements are useful to chemistry studies which rely on our basic state measurements to compute reaction rates of atmospheric pollutants, to microphysical studies which focus on the formation and growth of ice crystals in cirrus clouds, and large scale transport studies which rely on our data to initialize back trajectories. The data are also useful for characterizing advection of pollutants in the planetary boundary layer, and the structure and morphology of mesoscale waves which modulate the freeze drying process of air rising through the tropical tropopause layer into the lower stratosphere.

The MMS is a fast-response (20 Hz) system capable of measuring fine scales of turbulence, and thus is useful for computing fluxes of heat and momentum, as well as chemical contaminants when high-rate in situ chemistry instruments are also operating. It is also highly accurate (P, T, and 3-D winds are accurate to +/- 0.3 hPa, 0.3K, and 1 m/s), making it superior to the usual "facility" type navigation instruments which may provide some similar data, but with much degraded accuracy and reliability. Mr. Dean-Day's research focuses on maintaining the scientific validity of the MMS data, and in performing some basic research with the measurements as time and opportunity allow.

Accomplishments

- Developed MMS processing software for the Dynamics and Chemistry of the Summer Stratosphere (DCOTSS) experiment. Adapted code from prior aircraft campaigns to produce an algorithm capable of analyzing and reducing ER-2 MMS measurements. Performed initial instrument calibration using dedicated maneuvers from test flights flown from Palmdale, CA;
- Evaluated laboratory data obtained from immersed bath calibration of a Rosemount fast temperature probe/amp assembly at an Armstrong Flight Research Center (AFRC) test facility. Checked experimental data for self-consistency and discussed results with PI and lab personnel. Obtained and analyzed corrected bath values and applied curve fits to produce an accurate voltage to temperature conversion suitable for later data reduction;
- Generated sample DCOTSS data files to adhere to new ICARTT format standards and to ensure compatibility with additional requirements for multi-dataset file merging;

- Monitored MMS data quality during the 2021 DCOTSS campaign, assessing both accuracy of static pressure sensors, and frequency response of both inertial navigation system (INS) variables and end data products including static pressure, temperature, and wind;
- Examined several pressure sensor configurations on the WB-57F aircraft in preparation for test flights of the Asian Monsoon Chemical and Climate Impact Project (ACCLIP). Evaluated data quality and calibrated MMS measurements from the 2021 test flight series;
- Finalized calibration and correction of ER-2 #809 MMS data from the DCOTSS 2021 mission. Used redundant measurements to reconstruct errant values. Corrected clock errors in field data resulting from GPS reception dropouts and aircraft engineering issues. Reprocessed final MMS data and archived 1 Hz and 20 Hz files;
- Performed an initial evaluation of WB-57 MMS test flight data from the Stratospheric Aerosol processes, Budget and Radiative Effects (SABRE) mission. Combined maneuver calibrations from 2021 ACCLIP and 2022 SABRE flights to evaluate similarities and differences in results;
- Responded to questions from researchers about the strengths and limitations of MMS turbulence data and turbulence calculation methods from prior aircraft campaigns, including FIREX-AQ;
- Updated the MMS Data Acquisition Software for DCOTSS and ACCLIP 2021 science missions;
- Participated in and supported the DCOTSS 2021 Summer campaign and ACCLIP 2021 Test Flight campaign; and
- Developed MMS next generation data acquisition software system with new INS LN251, new pressure transducers, and new operating system.

National Suborbital Research Center (NSRC)

Project Participants

BAERI: Adam Webster (Interim Acting Director, 11/20-1/21 and 5/21-9/21), John Sonntag (Director, 1/21-5/21), Gary Ash (Director, 10/21), Alexandria (Ali) Pompeii, Kent Dunwoody, Ryan Bennett, and Pat Finch

Project Description

The National Suborbital Research Center (NSRC) is a partner in the ARC-CREST cooperative agreement with NASA Ames Research Center. NSRC is responsible for two tasks for the Airborne Science Program: Task 1) Science Mission Operations, and Task 2) Communications and Training. Below is a summary of the NSRC staff's accomplishments for the period November 2020 through October 2021.

NSRC went through several staff transitions in the Cooperative Award period of November 2020 through October 2021:

- January 2021: John Sonntag begins work as the NSRC Program Director;
- February 2021: Senior Software Engineer Sebastian Rainer leaves NSRC;
- April 2021: Terry Hu begins work as Software Engineer;
- May 2021: Program Director John Sonntag leaves NSRC;
- July 2021: Tu Phan begins work as Mechanical Design Engineer; and
- October 2021:
    - Gary Ash begins work as NSRC Program Director.
    - Senior Instrument Technician Kent Dunwoody transfers from ASF to NSRC.
    - Instrumentation Engineer Ali Pompeii transfers from ASF to NSRC.

Accomplishments

Misc. Staff Accomplishments

- All NSRC employees completed the SATERN training to be considered Certified Systems Administrators (CSA) at NASA. This gives each NSRC employee the administrative rights of their non-ACES/EUSO machines. Terry Hu is performing additional duties as an assistant CSA;
- Numerous staffing changes have resulted in extensive required training for data system operations. Pat Finch, Terry Hu, Ryan Bennett, Ali Pompeii (and JSC civil servant Daniel West) have now all received refresher or initial training on DC-8, ER-2, P-3, Gulfstream, KingAir, and/or Falcon systems; and

- Three NSRC employees completed AFRC fiber optic training.

Aircraft Specific Engineering Accomplishments

DC-8 Specific Engineering and Data/Satcom System Accomplishments

- Removed data system equipment from aircraft in advance of heavy maintenance check;
- Ordered, received, and checked new DC-8 Network switches;
- Created detailed design of new Ethernet network switch enclosures and fabricated prototype;
- Reinstalled DC-8 network components, housekeeping rack equipment, facility instrumentation and other wiring and hardware following heavy maintenance check;
- Created a permanent installation of the IR/Visible camera pod;
    - Performed design/drawings/analysis to relocate the aircraft DME #2 antenna in order to free up an appropriate camera installation location;
    - Performed design/drawings/analysis/fabrication/installation for camera pod installation and associated electronics control box; and
    - Performed electrical design/drawings/fabrication for camera system and video capture.
- Provided documentation in support of various structural repairs during heavy maintenance, including the Nadir #5 port modification, overhead bins, and FS1530 frame;
- Provided documentation in support of structural review of "legacy" modifications/installations, including the Housekeeping Rack and the Nadir #2 port; and
- Installed improved DC-8 Multi-Function Display (MFD) and engine gauge camera replacements.

ER-2 Specific Engineering and Data/Satcom System Accomplishments

- Modified the ER-2 Inmarsat and network router systems to incorporate WiFi and LTE connectivity by providing design/drawing/analysis/fabrication for the required mechanical modifications and wiring/hardware/software/security development for new electronics;
- Worked with ASF Staff to integrate the MVIS nadir-pointing camera, creating a recording and monitoring software solution;
- Worked with ASF staff to integrate the AVS Pan-Tilt-Zoom (PTZ) Camera, which required substantial reverse engineering to develop positioning control and pilot display software;
- Worked with ASF staff to define future requirements for the PTZ camera;
- Worked to correctly identify and apply ER-2 network switch firmware updates;

- Provided support for ER-2 network troubleshooting; and
- Worked with ASF personnel to perform check out of X-Cube functionality, resulting in identification of numerous faults and determination of a path to address them.

P-3 Specific Engineering and Data/Satcom System Accomplishments

- Created designs for P-3 permanent data system overhead bin & load center location installations and began working with WFF/LaRC staff on approval processes NSRC Permanent Data System installation on the P-3 aircraft.

Gulfstream Specific Engineering and Data/Satcom System Accomplishments

- Built up data system servers for installation on the LaRC G-III, JSC G-III, and GV;
- Tested and reconfigured a NASDAT for use aboard the JSC G-III;
- Expanded on LaRC CPL installation (developed for the MOOSE mission) to adapt it to the GV as well. In support of this, a GV optical window adapter and aircraft-specific floorboard adapter rings were designed and fabricated; and
- Completed preliminary work to accommodate GV window installations in the AFRC "cabin simulator" to perform environmental testing of optical windows.

Legacy NASDAT

- Demonstrated feasibility of using Ubuntu 18.04 32-bit OS on existing hardware;
- Began implementation of automatic testing procedures; and
- Configured the DC-8 data system to host a second NASDAT for in-flight testing of new software images.

NextGen NASDAT

- Continued to lead the Next Generation NASDAT development effort, developing a detailed outline of requirements;
- Performed extensive research into various COTS component options, resulting in identification of a likely system architecture. Began detailed planning for physical layout and configuration;
- Acquired and began evaluation of a Curtiss-Wright Duraworx 8042 with associated network switch to evaluate as the core of the system, along with an Alta DT board to ingest the primary avionics databuses;
- Identified additional components to support avionics ingest, timing and communications services, including avionics databuses, Analog/Digital, GPS, IRIG, WiFi, SBD Iridium, LTE; and

- Developed various software technologies including provision of integrated WiFi access points from the server, IPSec VPN tunneling over satcom, and remote management technologies.

Satellite Communications (Satcom)

- Repaired failed Inmarsat components to bring all four pooled systems (DC-8/P-3/ER-2) back to functionality;
- Worked with JSC and ARC staff to move the JSC GV Inmarsat system to the DISA contract; and
- Acquired two BlueSky Iridium Certus systems for testing and eventual integration into the ASP fleet, providing major improvements in bandwidth and reliability over the existing Iridium systems.

SP IT System Security Plan

- Continued to support the development of the ASP System Security plan;
- Compiled comprehensive hardware and software inventories for the DC-8, ER-2s, P-3, and Gulfstream aircraft; and
- Completed a first draft ASP SSP in cooperation with additional ARC staff.

Ground Infrastructure Upgrades

- Set up a locally hosted Jira container in our new container infrastructure, allowing the deactivation of the NSRC cloud hosted ticketing system, mitigating potential concerns about SBU data;
- Brought up a NASA-hosted version of the Jira ticketing software with custom workflows configured to match group requirements;
- Moved all projects from Bitbucket to GitLab; and
- Set up an NSRC Sharepoint to replace the BAERI Google Drive for storage of NASA Documents and Data.

Mission Tools Suite Support

- Specified, acquired, and installed a new server for MTS with upgraded memory and storage; and
- Created architectural advances on MTS backend via containers, including rendering operations.

Overall ASP Development Work

- Created detailed design/drawings/analysis for installation of the OPALS instrument on the DC-8;
- Provided design data and guidance to the AirMASTR instrument team in support of their effort to fly the instrument on the DC-8;
- Facilitated manufacture/assembly of a heated gas-phase inlet for the Korean B1900 aircraft team;
- Performed evaluations of the feasibility of installing the AirMSPI and RSP instruments on the DC-8; and
- Provided input/guidance in determining the most appropriate DC-8 successor platform and desired modifications. Created approximate models of cabin fuselage comparisons and main cabin/cargo compartment layouts for several aircraft models.

Missions Supported by SMO Staff

IMPACTS II (P-3 and ER-2) — November 2020 - February 2021
Impacted by the COVID-19 Pandemic
The Project made a "no-go" decision on Nov 2, 2020, and postponed the mission deployment to winter 2021/2022.

- Gathered new science team data system requirements for the upcoming science campaign;
- Redesigned TAMMS sideslope flow angle sensor probe installation, fabricated parts and performed final assembly of components;
- Virtually attended IMPACTS Data Conference meeting; and
- Prepared upgraded server for P-3 Rack install.

SHARC (JSC G-III and LaRC G-III) — November 2020 - December 2020

- Designed/built/tested a 6-channel Iridium satcom system with a standard NSRC data server for the JSC G-III;
- Installed a standard NSRC Data server on LaRC G-III;
- Developed software to provide SHARC science team a real-time satcom solution to push files from the ground to the aircraft and vice-versa; and
- Provided remote data/satcom support for flight activities.

ACTIVATE (HU-25 and UC-12) — December 2020 - June 2021

- Modified and installed UC-12 and HU-25 data system hardware/software to accommodate requirements for the second year of deployments;

- Supported integration of instruments, and integrated their instrument interfaces with data system and satcom telemetry requirements;
- Provided, installed, and maintained forward-looking Axis F44 cameras on both the HU-25 and UC-12 aircraft;
- Developed mission support documentation;
- Provided general data system and satcom support to science team personnel, and supported flights remotely; and
- Submitted navigation data to ACTIVATE archive.

WDTS (ER-2) — February 2021 - March 2021

- Provided general data system and satcom support to science team personnel and supported flights.

S-MODE (AFRC B-200) — April 2021 - May 2021

- Created design for MOSES optical window test fixture adapter ring;
- Provided guidance to the AFRC B200 team regarding issues with the MOSES optical window test; and
- Provided some design guidance for installation of an Iridium antenna.

MOOSE (LaRC G-III) — May 2021 - July 2021

- Performed engineering design/drawing work and fabrication to integrate the Cloud Physics Lidar (CPL) instrument onto the LaRC G-III and JSC GV. This included design of a customized new optical window cell assembly, transceiver shutter assembly, and a transceiver mounting adapter design that provides commonality between the aircraft. The adapter design has applications beyond CPL and has subsequently been used for support equipment;
- Supported/presented CPL installation during LaRC Preliminary Engineering Review (PER) and Final Engineering Review (FER);Developed telemetry configuration based on science team requirements; and
- Provided general data system and satcom support to science team personnel and supported flights remotely.

SARP 2021 (DC-8 and Dynamic Aviation B-200) May to December 2021

***Impacted by the COVID-19 Pandemic*

Since 2009, the NASA Student Airborne Research Program (SARP) internship has brought ~30 outstanding undergraduate STEM students majors from across the United States to California to participate in a unique internship experience, exposing them to NASA's Earth Science research and allowing them to participate in a short airborne

science mission. In 2020 and 2021, the COVID-19 pandemic prevented travel for the program during the summer. Although SARP was effectively "grounded," it continued to the fullest extent possible, and was able to provide the students with a virtual research experience like none other. This included at-home data collection dispersed across the country, as well as the analysis of previously collected aircraft, ground, and satellite data. Although past SARP programs were 8 weeks long, the SARP 2021 program was a 9-week virtual program that took place from June 14th to August 13th. In December 2021, SARP 2020 and SARP 2021 students will travel to AFRC to participate in SARP science flights on the NASA DC-8.

- Terry Hu and Pat Finch provided continued support throughout the program during the summer;
    - Configured/imaged and supported 32 laptops for SARP participants; and
    - Found solutions to ensure that each student had access to an adequate internet connection in their lockdown locations, including deploying/supporting Wi-Fi hotspots.
- Planned the delayed SARP 2020 and SARP 2021 flight sequences for December 2021, which will occur December 6 - December 10, 2021;
- Ryan Bennett continued to provide meteorological support and data analysis support for the duration of SARP;
    - Enrichment lecture to students demonstrating use of the NOAA HYSPLIT model to determine air mass trajectories/transport/dispersion/etc;
    - Supplemental enrichment lectures covering topics including California climate variability, Saharan Air Layer, data access and availability (highlighting the SARP archive and the 2020 ground sample dataset);
    - Office hour sessions, several times each week;
    - Individual meetings with more than 10 students working on projects;
    - Meeting with Gao Chen to discuss hosting archive products on ASDAC;
    - Updated the SARP remote sensing archive with 2020 and 2021 flight data, compiled external disks that were delivered to each remote sensing student;
    - Performed data retrieval from ASF/JPL, as requested by students and faculty;
    - Contributed to SARP 2020 project overview, data analysis, and visualization of the SARP 2020 ground samples, a cooperative effort with Emily Schaller (in progress);
    - Continued data analysis in support of the Fall AGU meeting, and completed groundwork for a SARP advertisement Arc-GIS story to show guests at the exhibit hall;
    - Program support for the 2021 December SARP flights, including meteorological briefings, flight planning, and aircraft data system operation; and

    - Provided meteorology support for the April 2021 AVIRIS - NG flights on the B200 from JPL.
- Facilitated at-home data collection using WAS canisters (University of California, Irvine) and CEAMS sensors (Colorado State University);
- Contributed to SARP Project Overview article for the Bulletin of the American Meteorological Society (BAMS);
- Completed archival and submission of WAS Airborne Data Sets;
- Completed cleanup of archive for past and current SARP data sets;
- Supported B-200/AVIRIS-NG flights with meteorological briefs and daily coordination meetings;
- Provided general instrument integration support, including development of aircraft layout and upload schedule;
- Emily Schaller trained Brenna Biggs as the new SARP Program Manager; and
- SARP final presentations on August 11th and 12th. Attendees included SARP alumni, Research Faculty, NASA personnel and NSRC staff. Four student research projects were chosen to present at the 2022 Fall AGU meeting.

DCOTTS I (ER-2) — May 2021 - August 2021

- Supported integration of 12 instruments, working their instrument interfaces with data system, extensive satcom telemetry requirements, command & control;
- Provided general data system and satcom support to science team personnel and supported flights onsite at deployment location; and
- Provided support for MetNav files and data/video archive.

QUAKES (GV) — June 2021

- Configured NASDAT to provide specialized data format required.

CPEX-AW (DC-8) — July 2021 - September 2021

- Provided general instrument integration support, including development of aircraft layout and upload schedule;
- Provided design/drawing support and structural analysis for the APR-3 instrument to incorporate a new W-band radar horn;
- Provided design/drawing support and structural analysis for the AVAPS instrument to incorporate a GPS signal re-radiation device inside a dropsonde tube and a telemetry antenna preamplifer;

- Integrated the new AIRO instrument, providing instrument design guidance and satcom connectivity/control/testing;
- Created numerous quicklook and supporting data products as requested by the science team to meet mission goals;
- Staffed all flights with data system/satcom and mission director support;
- Deployed a file server to provide local access to video data in St. Croix; and
- Provided support to the root cause analysis of a cabin depressurization event.

TRACER-AQ (GV) — July 2021 - September 2021

- Completed development to integrate the existing GV Inmarsat system with the onboard data system;
- Developed various quick-look products and integrated instrument packet streams for the HSRL and GCAS instruments;
- Provided general data system and satcom support to science team personnel and supported flights remotely; and
- Configured an archive for housekeeping data.

IMPACTS III (P-3 and ER-2) — November 2021 - February 2022

- Surveyed science team for new requirements;
- Staged equipment at NASA WFF for integration activities; and
- Attended "Virtual" Science Team Meeting, briefing ER-2 and P-3 data system capabilities.

ACTIVATE (HU-25 and UC-12) — November 2021 - June 2022

- Modified and installed UC-12 and HU-25 data system hardware/software to accommodate requirements for the third year of deployments; and
- Supported integration of instruments, working their instrument interfaces with data system and satcom telemetry requirements.

Education and Outreach Activities

Applied Remote Sensing Training (ARSET)

Project Participants

BAERI: Amber McCullum, Juan Torres-Pérez (a NASA Civil servant as of Summer 2021), Zach Bengtsson (for FY21, but no longer a BAERI employee as of Sept, 2021)

Project Description

As part of the Capacity Building Program, the Applied Remote Sensing Training Program, or ARSET, conducts online and in-person trainings that are designed with the user in mind. We have a variety of application areas, such as trainings focused on water resources, disasters, health and air quality, and land management. The team here at NASA Ames focuses on land and wildfire trainings. We have trainings on change detection, wildfire detection, tracking deforestation, freshwater monitoring, time series analysis, and many more. Participants can build skills and grow through ARSET. Participants are introduced to the fundamentals of remote sensing, learn how to find and download NASA data, and learn to process and analyze data using geospatial software to aid in decision-making. All of our materials are freely available in both English and Spanish on the ARSET website: https://arset.gsfc.nasa.gov/

These courses are for beginners and advanced practitioners alike. Since 2009, the program has reached over 40,000 participants from 170 countries and more than 8,500 organizations worldwide. The ARSET team at NASA Ames focuses on the application area of Land Management. Because of COVID-19, all trainings in 2021 were conducted remotely.

Accomplishments

We conducted six trainings in FY21:

Introductory Webinar: Hyperspectral Data for Land and Coastal Systems — Jan/Feb 2021 This three-part training series demonstrated applications of hyperspectral data including plant species identification, invasive species management, assessment of phytoplankton functional types, mapping of wetlands and shallow benthic communities, and detection of harmful algal blooms (HABs). In attendance were 1,935 participants from 109 countries and 49 US states. Approximately 950 unique organizations were represented. You can learn more about the training and access the materials in both English and Spanish at: https://appliedsciences.nasa.gov/join-mission/training/english/hyperspectral-data-land-and-coastal-systems

Intermediate Webinar: Satellite Observations and Tools for Fire Risk, Detection, and Analysis — May 2021 This six-part training was ARSET's longest-running training in program history. The training covered the use of Earth observations pre-fire (fire types, conditions, & fire danger), during-fire (thermal anomalies and smoke mapping), and post-fire (burned area, landscape changes, & regrowth) and the content spanned air quality, disasters, and land applications. In attendance were 2,544 participants from 110 countries and 47 US states. Approximately 1,200 unique organizations were represented. You can learn more about the

training and access the materials in English at: https://appliedsciences.nasa.gov/join-mission/training/english/arset-satellite-observations-and-tools-fire-risk-detection-and

Advanced Webinar: Google Earth Engine Applications for Land Monitoring — June 2021 This three-part training series focuses on the use of the GEE Code Editor for hands-on exercises on change detection, time series analysis, land cover classification, and accuracy assessment of optical imagery. Attendees are provided with scripts for conducting these analyses in GEE and instructed on how to execute these scripts to produce maps and visualizations of environmental data. In attendance were 2,745 participants from 123 countries and 50 US states. Approximately 1,350 unique organizations were represented. You can learn more about the training and access the materials in both English and Spanish: https://appliedsciences.nasa.gov/join-mission/training/english/arset-using-google-earth-engine-land-monitoring-applications

Intermediate Webinar: Species Distribution Modeling with Remote Sensing — August 2021 This intermediate-level training covered species distribution models, remote sensing of predictor variables, a walkthrough of the Wallace tool, and an overview of other tools and methods including the Mapping Applications for Penguin Populations and Projected Dynamics (MAPPPD) and the Fisheries and Climate Toolkit (FaCeT). Amber McCullum (BAERI/ARC), Juan Torres-Pérez (BAERI/ARC), and Zach Bengtsson (BAERI/ARC) delivered the training with guest speakers Erica Johnson (Wallace), Andrea Paz Velez (Wallace), and Mary Blair (Wallace). The training reached 2,150 participants from ~1,000 unique organizations across 116 countries and 47 U.S. States. You can learn more about the training and access the materials in both English and Spanish: https://appliedsciences.nasa.gov/join-mission/training/english/arset-species-distribution-modeling-remote-sensing

Campus Learning Session: Earth Observations in Support of Land Degradation and Sustainable Cities SDGs — September 2021 Land management SDGs call for consistent tracking of land cover metrics. These metrics include productivity, land cover, soil carbon, urban expansion, and more. This half-day training took place at the World Conservation Congress as part of their campus sessions, and utilized materials from the advanced FY19 webinar. In this training, attendees learned to use a freely-available QGIS plugin, Trends.Earth, created by Conservation International and co-developed with United Nations Convention to Combat Desertification (UNCCD), and UN Habitat, custodian agencies of SDG 15.3.1 and 11.3.1 respectively, in support of country reporting needs. The results included a greater understanding of the data tools that exist, their utility, and how it fits into the overarching IUCN policies and programs.

Introductory Webinar: Monitoring Coastal and Estuarine Water Quality: Transition from MODIS to VIIRS — September 2021 This bilingual (English and Spanish), three-part training series provided an overview of recent satellites and sensors used for extending the MODIS long-term water quality time series, specifically focusing on VIIRS image processing using the NASA Ocean Color software, SeaDAS. This training also pointed out similarities and differences between MODIS and VIIRS and demonstrated water quality monitoring procedures using these sensors in selected coastal and estuarine regions. In attendance were 802 participants from 93 countries and 24 U.S. states. Approximately 400 unique organizations were represented. You can learn more about the training and access the materials at: https://appliedsciences.nasa.gov/join-mission/training/english/arset-monitoring-coastal-and-estuarine-water-quality-transitioning

Upcoming Trainings

We are currently planning the FY22 portfolio of ARSET trainings, which will include webinars on Using Earth Observations to Map Fire Risk and Burn Severity, Using UN Biodiversity Lab to Monitor the Pulse of the Planet (trilingual), Monitoring Aquatic Vegetation with Remote Sensing (bilingual), and Evaluating Ecosystem Services with Remote Sensing.

California State University at Monterey Bay (CSUMB) Educational Program

Project Participants

CSUMB: Susan Alexander

Students: Kristen Burroughs, Andrea Cihasky, Conor Doherty, Javier Lopez, Samantha McCarrell

Project Description

The Department of Applied Environmental Science at CSUMB offers a Bachelor of Science degree in Environmental Science, Technology, and Policy (ESTP) and a Master of Science degree in Environmental Science (ENSCI). These interdisciplinary programs emphasize the critical thinking and technical skills necessary to develop workable solutions to complex environmental problems. Our curriculum integrates training in science, technology, economics, and policy that focuses on marine, coastal, and watershed systems.

Among its many components, the CSUMB mission emphasizes an educational approach that fosters in students distinctive technical and educational skills, the experience and abilities to start a successful career, the critical thinking abilities to be productive citizens, and the entrepreneurial spirit needed for innovation and success. Because our knowledge and understanding of the Earth system and its processes are increasingly dependent on advanced technologies for acquiring, analyzing, and visualizing geospatial information about our planet, expertise in geospatial applications is one of the most sought after skill sets for students pursuing Earth system science careers.

The M.S. in ENSCI offers two degree options: PSM and thesis. Within their chosen option, students elect an emphasis in marine or watershed science. Advanced technology training is integrated throughout the applied environmental science and policy curriculum. The PSM option within ENSCI emphasizes professional skill sets that will distinguish students as they enter the workforce, including: advanced technologies for acquiring, analyzing, modeling and visualizing spatially explicit environmental data; professional and scientific communication; scientific ethics; and environmental economics and policy analysis. Within the PSM option, students build on skills learned in the classroom through professional internships. The program satisfies a demand for highly skilled professionals within environmental technology and applied science-based companies, governmental agencies, and non-profit organizations.

The team will apply its educational, scientific, and technological expertise to train the next generation of Earth System scientists and to reach out to the public about the project. We will:

- Offer programs and career development opportunities within the Science, Technology, Engineering, and Mathematics fields that specifically foster the identification, recruitment, and success of Hispanic and other under-represented and low-income students;

- Provide hands-on training for undergraduate and graduate students in Earth Science research activities including participation in field campaigns, internships, apprenticeships, and other research experiences;
- Lead educational activities aimed at K-12 students, college and graduate students, and the general public utilizing NASA-developed technologies and results; and
- Communicate results of our scientific activities through community outreach events, conferences, publications, and other venues.

Accomplishments

We continue to facilitate research collaborations between ENSCI graduate students, ESTP and Biology senior undergraduate students, Cooperative Agreement Research Scientists, CSUMB faculty, and NASA PIs at Ames Research Center on the following projects:

- ESTP and ENSCI students Kristen Burroughs, Andrea Cihasky, Javier Lopez, and Samantha McCarrell conducted research and assisted with field activities under the mentorship of ARC CREST Senior Scientists Forrest Melton, Lee Johnson, and ARC CREST Research Scientists;
- The team provided mentorship of students who worked with the SIMS and OpenET projects (described in detail in the Agriculture / Health / Marine Applied Science Task report) in 2021. Ryan Solymar (former student research assistant) is now a field and GIS technician with NASA ARC-CREST. Additional internships will be offered in 2022;
- Johnson is Co-I on a project led by UC Cooperative Extension under the 2019 CDFA Specialty Crop Block Grants Program ($333k). He is helping to manage irrigation trials in artichoke and red cabbage being conducted at the USDA research station in Salinas. The project employs a student assistant (Javier Lopez); and
- ENSCI graduate student Liana Solis was a member of the Spring 2021 DEVELOP intern team at NASA ARC working on the project: “Using Earth Observations to Enhance Flood Monitoring on Tribal Lands in the Northern Great Plains.”

Presentations

- Melton, F., Johnson, L., Guzman, A., Carrara, W., et al., 2021. OpenET: Operational ET Data for Water Management in the Western U.S. AGU Fall Meeting. 1-17 Dec., New Orleans (invited).
- Melton, F., Johnson, L., Guzman, A., Carrara, W., et al., 2021. OpenET: Operational ET Data for Water Management in the Western U.S. California Department of Food and Agriculture Nutrient Management Conference, San Luis Obispo, CA, Oct 27-28, 2021 (invited).
- Melton, F., Johnson, L., Guzman, A., Carrara, W., et al., 2021. OpenET: Operational ET Data for Water Management in the Western U.S. United Nations Food and Agriculture

Organization, Webinar Series on Remote Sensing of Evapotranspiration, July 7, 2021 (invited).

- Melton, F., Johnson, L., Guzman, A., Carrara, W., Hang, M., Solymar, R., et al., 2021.The NASA Satellite Irrigation Management Support (SIMS) Framework . United Nations Food and Agriculture Organization, Webinar Series on Remote Sensing of Evapotranspiration, May 26, 2021 (invited).
- Melton, F., Johnson, L., Guzman, A., Carrara, W., Hang, M., Solymar, R., et al., 2021.Applications of remote sensing for irrigation management, California Plant and Soil Science Conference, May 25, 2021 (invited).
- Melton, F., L. Johnson, M. Cahn, A. Guzman, W. Carrara, C. Wang, C. Doherty, R. Solymar, M. Hang, F. Cassel-Sharma, 2021. Applications of remote sensing for irrigation management. Amer. Soc. Agronomy, Calif. Plant and Soil Conference, 1-3 Feb., 2021 (invited).

Publications

Melton F., W. Carrara, A. Guzman, C. Doherty, L. Johnson, et al., 2021. OpenET: Filling a critical data gap in water management for the western United States. *J. Amer. Water Resources Assn*., paper no. JAWR-20-0084-P. http://doi.org/10.1111/1752-1688.12956

Div Outreach — Science Communications for Code S

Project Participants

Kassie Perlongo
Sandy Dueck

Project Description

We work to facilitate science communication across Code S, and lead and coordinate the Citizen Science Accelerator project 'Planet Hunters Coffee Chat.'

Accomplishments

Science Directorate

- Developed new SaSa NASA website, https://www.nasa.gov/sasa ;
- Created new applications section for first 2022 cohort https://www.nasa.gov/prospective-sasa-applicants;
- Managed social media for SaSa, and assisted with the first October SaSa information session on WebEx; and
- Created two science nuggets every week, and sent to Michael Hesse for SMD submission.

Citizen Science Accelerator

- Initiated a collaboration with Rob Zellum (JPL) and his Citizen Science Project Exoplanet Watch. We plan on working together on future videos and Live Office Hours. Andrea Decker from Be WISE (San Diego) would like Kassie Perlongo and Nora Eisner to hold a workshop on Planet Hunters Coffee Chat in the future, still being planned;
- Conducted weekly strategy meetings to brainstorm ideas for videos and accomplishments. Latest suggestions for engagement include: setting up an online science fair for citizen scientists, poster session, having future video episodes with citizen scientists who regularly attend and have contributed to scientific papers;
- Held larger strategy meeting with creator of Zooniverse platform, Chris Lintoff, and Zooniverse platform supporters to expand and create future resources and materials with Planet Hunters Coffee Chat and Planet Hunters TESS. Resources will include tutorial videos, live office hours with citizen scientists, creating future talks and presentations with citizen scientists, and what 'waiting room' resources can we provide for people to check if they have spotted a potential exoplanet and are not sure; and

- Created 23 videos with Kassie (as host) and Nora (as co-host). Videos have received 100% positive rating on YouTube. We have 280+ subscribers to our channel and citizen scientists are suggesting episode ideas and topics and attending our bi-weekly Live Office Hours.

Presentations

- Nora Eisner to present 3-minute talk about Planet Hunters Coffee Chat at AGU during the “Science and Society” panel discussions.

Student Airborne Science Activation (SaSa)

Project Participants

BAERI: Susan Hoban, Samiah Moustafa, and Kristina Pistone

Project Description

The overarching goals of the Student Airborne Science Activation (SaSa) project are to increase the number of STEM degrees from Minority Serving Institutions (MSIs), and prepare students from MSIs to enter the STEM workforce. To achieve these goals, the SaSa project will engage students through NASA-related airborne campaigns. Providing authentic engagement to students promises to raise the profile of the geoscience departments in MSIs among the relevant academic, research, and local communities. This will help raise science literacy in minority institutions and align them perfectly with one of the primary NASA SciAct objectives: *Improve U.S. Scientific Literacy.*

To contribute to reaching the overarching goals, the specific objectives of the SaSa project are:

- Create a student geoscience learning ecosystem (GLE) to enable effective student engagement with NASA scientists & engineers, academic advisors, peers, and the local communities;
- Provide students with new skills to work with NASA science equipment and real data from field/airborne campaigns and satellite imagery; and
- Provide students with the opportunity to participate in the full life-cycle of a research project, from conception, to data collection and analysis, to synthesis and reporting.

BAER Institute participants are involved in SaSa's Project Management and Project Evaluation.

Accomplishments

Project Management

- K. Pistone led the first SaSa info session on 5 November 2021. 5 participants from previous years of SARP spoke about their experiences in NASA airborne summer programs and answered audience questions;
- Finalized and opened the application portal for the first year of SaSa (summer 2022). Both the info session and the application are being advertised at the universities and on social media, and the nasa.gov/sasa website has been updated;
- Finalized the graduate student mentor application, which will be released to university co-Is shortly for distribution to their grad students. We anticipate hiring four graduate mentors to work with the undergrad SaSa students; and

- K. Pistone continues working on logistics while S. Moustafa is on parental leave, including running biweekly meetings and discussing potential piggyback opportunities to bring other instruments (HYPPOS at LaRC) and expertise into the SaSa experience for summer 2022.

Project Evaluation

- Dr. Susan Hoban is the evaluator for SaSa. Hoban attended all SaSa Bi-weekly Leadership meetings, NASA Science Activation program monthly meetings, and monthly meetings of the NASA SciAct evaluators;
- In collaboration with SaSa PI, Dr. Gatebe, Hoban prepared the SaSa Evaluation Plan, which was submitted to the NASA Science Activation program on 3/31/2021 and approved;
- Hoban met with Ms. Kristi Manseth of Pacific Research & Evaluation (PRE) on 3/30/2021 to discuss the role of PRE in the NASA Science Activation program, and potential opportunities for PRE to assist in the evaluation of of SaSa -- for example, helping to identify common measures among the Science Activation projects;
- Developed two instruments to measure the impact of the SaSa Geosciences Learning Environment (GLE) component of the project. The GLE encompasses the ongoing efforts of SaSa during the academic year (in contradistinction to the SaSa summer intern component), to raise minority students' awareness of NASA Earth science research and NASA educational opportunities. NASA content is being infused into courses at the participating universities, in some cases by SaSa-funded faculty, and in other cases by faculty members who are not directly associated with SaSa. During the Fall 2021 semester, 572 students were taking 21 courses associated with the SaSa GLE, taught by 15 faculty members, 5 of whom are funded by SaSa and 10 who are not;
- The first instrument is a pre-survey to assess students' level of awareness of and interest in NASA (MLOs 1b, 2a, 3b). This instrument was distributed to each participating faculty member and administered in October, 2021. Since the faculty members decided individually when to request that their students complete the survey, the results are being collected at differing times. As of this writing, the results are not yet finalized. This instrument was submitted to the Pacific Research & Evaluation (PRE) data call required by the NASA SciAct Program Office on 9/29/2021. The survey will be re-administered as a post-survey at the end of the Fall 2021 semester to assess the degree of change in students' level of awareness of and interest in NASA; and
- The second instrument is intended to assess to what degree the awareness of NASA-content as an undergraduate teaching tool has increased amongst the non-SaSa faculty offering GLE-affiliated courses (MLOs 1b, 1c, 3b). This survey will be administered at the end of the Fall 2021 semester, in December, 2021. This instrument was submitted to the PRE data call on 9/29/2021.

Presentations

- AGU Fall Meeting, December 2021: U35A-2229 - “Assimilating Lessons Learned – From URGE to NASA's Student Airborne Science Activation (SaSa) Project” K. Pistone, M. Friberg, S. E. Craig, R. Delgado, C. K. Gatebe. https://agu.confex.com/agu/fm21/meetingapp.cgi/Paper/972787.

Publications and Presentations

Publications

“Evolution of Acyl Peroxynitrates (PANs) in wildfire smoke plumes detected by the Cross-Track Infrared Sounder (CrIS) over the western U.S. during summer 2018.”, Julieta F. Juncosa Calahorrano, Vivienne H. Payne, Susan Kulawik, Bonne Ford, Frank Flocke, Teresa Campos, and Emily V. Fischer, Geophysical Research Letters, accepted for publication, 2021.

A. S. Li, V. Chirayath, M. Segal-Rozenhaimer, J. L. Torres-Pérez and J. van den Bergh, “NASA NeMO-Net’s Convolutional Neural Network: Mapping Marine Habitats with Spectrally Heterogeneous Remote Sensing Imagery,” in IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, vol. 13, pp. 5115-5133, 2020, doi: 10.1109/JSTARS.2020.3018719.

Ahamed, A., Knight, R., Alam, S., Pauloo, R. and Melton, F., 2021. Assessing the utility of remote sensing data to accurately estimate changes in groundwater storage. Science of The Total Environment, 807, p.150635.

Asanjan, A.A., K. Das, A. Li, V. Chirayath, J. Torres-Perez, and S. Sorooshian. 2020. Learning instrument invariant characteristics for generating high-resolution global coral reef maps. KDD ‘20: Proc. 26th ACM SIGKDD Int. Conf. Knowledge Discovery and Data Mining. 2617-2624.

B. Gorr, A. Aguilar, D. Selva, V. Ravindra, M. Moghaddam, S. Nag, "Heterogeneous Constellation Design for a Smart Soil Moisture Radar Mission", IEEE International Geoscience and Remote Sensing Symposium, Brussels Belgium, July 2021.

Baibakov, K., LeBlanc, S., Ranjbar, K., O’Neill, N., Wolde, M., Redemann, J., Pistone, K., Li, S.-M., Liggio, J., Hayden, K., Chan, T., Wheeler, M., Nichman, L., Flynn, C. and Johnson, R.: Airborne and ground-based measurements of aerosol optical depth of freshly emitted anthropogenic plumes in the Athabasca Oil Sands region, Atmos. Chem. Phys., 1–27, doi:10.5194/acp-2020-1218, 2021.

Chang, I., Gao, L., Burton, S. P., Chen, H., Diamond, M. S., Ferrare, R. A., Flynn, C. J., Kacenelenbogen, M., LeBlanc, S. E., Meyer, K. G., Pistone, K., Schmidt, S., Segal-Rozenhaimer, M., Shinozuka, Y., Wood, R., Zuidema, P., Redemann, J. and Christopher, S. A.: Spatiotemporal Heterogeneity of Aerosol and Cloud Properties Over the Southeast Atlantic: An Observational Analysis, Geophys. Res. Lett., 48(7), 1–12, doi:10.1029/2020gl091469, 2021.

Chatfield RB, Esswein RF, Price, V., Kulalwik, S., Pierce RB.Sentinel 5p" Tropomi" Perspectives on FIREX-AQ and WE-CAN: Tracing Emissions over Hours and Days of Development. In AGU Fall Meeting Abstracts 2020 Dec (Vol. 2020, pp. A202-01).

Choi, Y., Ghim, Y. S., Rozenhaimer, M. S., Redemann, J., LeBlanc, S. E., Flynn, C. J., Johnson, R. J., Lee, Y., Lee, T., Park, T., Schwarz, J. P., Lamb, K. D. and Perring, A. E.: Temporal and spatial variations of aerosol optical properties over the Korean peninsula during KORUS-AQ, Atmos. Environ., (February), 118301, doi:10.1016/j.atmosenv.2021.118301, 2021.

Cloud Meso-scale Classification and dynamics from the Geostationary SEVIRI satellite using Convolutional Neural-Network, Michal Segal Rozenhaimer, David Nukrai, Robert Wood, Zhibo Zhang, in prep. For Remote Sensing of Environment.

Cochrane, S. P., Schmidt, K. S., Chen, H., Pilewskie, P., Kittleman, S., Redemann, J., LeBlanc, S., Pistone, K., Segal Rozenhaimer, M., Kacenelenbogen, M., Shinozuka, Y., Flynn, C., Ferrare, R., Burton, S., Hostetler, C., Mallet, M., and Zuidema, P.: Biomass Burning Aerosol Heating Rates from the ORACLES 2016 and 2017 Experiments, Atmos. Meas. Tech. Discuss. [preprint], https://doi.org/10.5194/amt-2021-169, in review, 2021.

Cochrane, S., Schmidt, K. S., Chen, H., Pilewskie, P., Kittelman, S., Redemann, J., LeBlanc, S., Pistone, K., Kacenelenbogen, M., Segal Rozenhaimer, M., Shinozuka, Y., Flynn, C., Dobracki, A., Zuidema, P., Howell, S., Freitag, S. and Doherty, S.: Empirically-Derived Parameterizations of the Direct Aerosol Radiative Effect based on ORACLES Aircraft Observations, Atmos. Meas. Tech., 14, 567–593, doi:10.5194/amt-14-567-2021, 2021.

Collier, E., Mukhopadhyay, S., Duffy, K., Ganguly, S., Madanguit, G., Kalia, S., Shreekant, G., Nemani, R., Michaelis, A., Li, S. and Ganguly, A., 2021. Semantic Segmentation of High Resolution Satellite Imagery using Generative Adversarial Networks with Progressive Growing. Remote Sensing Letters, 12(5), pp.439-448.

Doherty, S. J., Saide, P. E., Zuidema, P., Shinozuka, Y., Ferrada, G. A., Gordon, H., Mallet, M., Meyer, K., Painemal, D., Howell, S. G., Freitag, S., Dobracki, A., Podolske, J. R., Burton, S. P., Ferrare, R. A., Howes, C., Nabat, P., Carmichael, G. R., da Silva, A., Pistone, K., Chang, I., Gao, L., Wood, R., and Redemann, J.: Modeled and observed properties related to the direct aerosol radiative effect of biomass burning aerosol over the Southeast Atlantic, Atmos. Chem. Phys. Discuss. [preprint], https://doi.org/10.5194/acp-2021-333, in review, 2021.

Duncanson, L., Armston, J., Disney, M., Avitabile, V., Barbier, N., Calders, K., Carter, S., Chave, J., Herold, M., MacBean, N., McRoberts, R., Minor, D., Paul, K., Réjou-Méchain, M., Roxburgh, S., Williams, M., Albinet, C., Baker, T., Bartholomeus, H., Bastin, J.F., Coomes, D., Crowther, T., Davies, S., de Bruin, S., De Kauwe, M., Domke, G., Dubayah, R., Falkowski, M., Fatoyinbo, L., Goetz, S., Jantz, P., Jonckheere, I., Jucker, T., Kay, H., Kellner, J., Labriere, N., Lucas, R., Mitchard, E., Morsdorf, F., Næsset, E., Park, T., Phillips, O.L., Ploton, P., Puliti, S., Quegan, S., Saatchi, S., Schaaf, C., Schepaschenko, D., Scipal, K., Stovall, A., Thiel, C., Wulder, M.A., Camacho, F., Nickeson, J., Román, M., Margolis, H. (2021). Aboveground Woody Biomass Product Validation Good Practices Protocol. Version 1.0. In L. Duncanson, M. Disney, J. Armston, J. Nickeson, D. Minor, and F. Camacho (Eds.), Good Practices for Satellite-Derived Land Product Validation, (p. 236): Land Product Validation Subgroup (WGCV/CEOS), doi:10.5067/doc/ceoswgcv/lpv/agb.001

Duncanson, L., J. Armston, M. Disney, V. Avitabile, N. Barbier, Kim Calders, S. Carter, J. Chave, M. Herold, N. MacBean, R. McRoberts, D. Minor, K. Paul, M. Réjou-Méchain, S. Roxburgh, M. Williams, C. Albinet, T. Baker, H. Bartholomeus, J. F. Bastin, D. Coomes, T. Crowther, S. Davies, S. de Bruin, M. De Kauwe, G. Domke, R. Dubayah, M. Falkowski, L. Fatoyinbo, S. Goetz, P. Jantz, I. Jonckheere, T. Jucker, H. Kay, J. Kellner, N. Labriere, R. Lucas, E. Mitchard, F. Morsdorf, E. Næsset, T. Park, O. L. Phillips, P. Ploton, S. Puliti, S. Quegan, S. Saatchi, C. Schaaf, D. Schepaschenko, K. Scipal, A. Stovall, C. Thiel, M. A. Wulder, F. Camacho, J. Nickeson, M. Román, and H. Margolis. 2021. Aboveground Woody Biomass Product Validation : Good Practices Protocol. Ed by. Laura Duncanson, Mat Disney, John Armston, JJaime Nickeson, David Minor, and Fernando Camacho. Version 1.0. Land Product Validation Subgroup (WGCV/CEOS). doi:10.5067/doc/ceoswgcv/lpv/agb.001.

E. Sin, M. Arcak, A. S. Li, V. Ravindra, S. Nag, "Autonomous Attitude Control for Responsive Remote Sensing by Satellite Constellations", AIAA Science and Technology Forum and Exposition (SciTech Forum), Nashville, January 2021.

Gupta, S., McFarquhar, G. M., O'Brien, J. R., Delene, D. J., Poellot, M. R., Dobracki, A., Podolske, J. R., Redemann, J., LeBlanc, S. E., Segal-Rozenhaimer, M., and Pistone, K.: Impact of the variability in vertical separation between biomass burning aerosols and marine stratocumulus on cloud microphysical properties over the Southeast Atlantic, Atmos. Chem. Phys., 21, 4615–4635, https://doi.org/10.5194/acp-21-4615-2021, 2021.

Hemming, D.L., Garforth, J., O'Keefe, T., Park, T., Richardson, A.D., Rutishäuser, A.D., Sparks, T.H., Thackeray, S.j., 2021. Phenology of primary producers [in "State of the Climate in 2020"]. Bulletin of the American Meteorological Society, 101, pp.S108-S110.

https://doi.org/10.1029/2019JD030822

Kulawik, S. S., Worden, J. R., Payne, V. H., Fu, D., Wofsy, S. C., McKain, K., Sweeney, C., Daube Jr., B. C., Lipton, A., Polonsky, I., He, Y., Cady-Pereira, K. E., Dlugokencky, E. J., Jacob, D. J., and Yin, Y.: Evaluation of single-footprint AIRS CH4 profile retrieval uncertainties using aircraft profile measurements, Atmos. Meas. Tech., 14, 335–354, https://doi.org/10.5194/amt-14-335-2021, 2021.

Laipelt, L., Kayser, R.H.B., Fleischmann, A.S., Ruhoff, A., Bastiaanssen, W., Erickson, T.A. and Melton, F., 2021. Long-term monitoring of evapotranspiration using the SEBAL algorithm and Google Earth Engine cloud computing. ISPRS Journal of Photogrammetry and Remote Sensing, 178, pp.81-96.

Melton F., W. Carrara, A. Guzman, C. Doherty, L. Johnson, et al., 2021. OpenET: Filling a critical data gap in water management for the western United States. J. Amer. Water Resources Assn., paper no. JAWR-20-0084-P. http://doi.org/10.1111/1752-1688.12956

Melton F., W. Carrara, A. Guzman, C. Doherty, L. Johnson, et al., 2021. OpenET: Filling a critical data gap in water management for the western United States. J. Amer. Water Resources Assn., paper no. JAWR-20-0084-P. http://doi.org/10.1111/1752-1688.12956

Menon, V. V., Siddiqui, S., Rao, S., Schmidt, A., French, M., Chirayath, V., and Li, A. Design and Performance Evaluation of Multispectral Sensing Algorithms on CPU, GPU, and FPGA, 2021 IEEE Aerospace Conference, Big Sky, MT, March 2021.

Michal Segal-Rozenhaimer, Alan Li, Kamalika Das, Ved Chirayath, Cloud detection algorithm for multi-modal satellite imagery using convolutional neural-networks (CNN), Remote Sensing of Environment, Volume 237, 2020, 111446, ISSN 0034-4257, https://doi.org/10.1016/j.rse.2019.111446.

Norgren, M. S., Wood, J., Schmidt, K. S., Diedenhoven, B. Van, Snorre, A., Ziemba, L. D., Crosbie, E. C., Shook, M. A., Kittelman, A. S., Samuel, E., Broccardo, S., Freitag, S. and Reid, J. S.: Above-aircraft cirrus cloud and aerosol optical depth from hyperspectral irradiances measured by a total-diffuse radiometer, Atmos. Chem. Phys. Discuss., 10(September), 1–36, doi:https://doi.org/10.5194/amt-2021-269, 2021.

Park, T., Kim, M., Nemani, R., Estimation of forest carbon stock changes in North and South Korea using High-resolution remote sensing data and forest carbon dynamic model. In preparation.

Payne, V. H., Kulawik, S. S., Fischer, E. V., Brewer, J. F., Huey, L. G., Miyazaki, K., Worden, J. R., Bowman, K. W., Hintsa, E. J., Moore, F., Elkins, J. W., and Juncosa Calahorrano, J.: Satellite measurements of peroxyacetyl nitrate from the Cross-Track Infrared Sounder: Comparison with ATom aircraft measurements, Atmos. Meas. Tech. Discuss. [preprint], https://doi.org/10.5194/amt-2021-353, in review, 2021.

Peano, D., Hemming, D., Materia, S., Delire, C., Fan, Y., Joetzjer, E., Lee, H., Nabel, J.E., Park, T., Peylin, P. and Wårlind, D., 2021. Plant phenology evaluation of CRESCENDO land surface models–Part 1: Start and end of the growing season. Biogeosciences, 18(7), pp.2405-2428.

Pereira, L., P. Paredes, F. Melton, L. Johnson, M. Mota, T. Wang., 2021. Prediction of crop coefficients from fraction of ground cover and height. Practical application to vegetable, field and fruit crops with focus on parameterization. Special issue: Updates & Advances to the FAO56 Crop Water Requirements Methods, Agricultural Water Management 252, 106663. https://doi.org/10.1016/j.agwat.2020.106663

Pistone, K., Zuidema, P., Wood, R., Diamond, M., da Silva, A. M., Ferrada, G., Saide, P. E., Ueyama, R., Ryoo, J.-M., Pfister, L., Podolske, J., Noone, D., Bennett, R., Stith, E., Carmichael, G., Redemann, J., Flynn, C., LeBlanc, S., Segal-Rozenhaimer, M., and Shinozuka, Y.: Exploring the elevated water vapor signal associated with the free tropospheric biomass burning plume over the southeast Atlantic Ocean, Atmos. Chem. Phys., 21, 9643–9668, https://doi.org/10.5194/acp-21-9643-2021, 2021.

R. Ketzner, V. Ravindra and M. Bramble, “A Robust, Fast, and Accurate Algorithm for Point in Spherical Polygon Classification with Applications in Geoscience and Remote Sensing,” Computers & Geosciences, under review, 2021.

R. Lammers, A.S. Li, V. Ravindra, S. Nag, "Prediction Models for Urban Flood Evolution for Satellite Remote Sensing", Journal of Hydrology, accepted

R. Lammers, A.S. Li, V. Ravindra, S. Nag, "Prediction Models for Urban Flood Evolution for Satellite Remote Sensing", Journal of Hydrology, accepted, 2021.

R. Levinson, S. Nag, V. Ravindra, “”Agile Satellite Planning for Multi-Payload Observations to aid Earth Science”, International Workshop on Planning and Scheduling for Space, Virtual Forum, July 2021.

Redemann, J., Wood, R., Zuidema, P., Doherty, S. J., Luna, B., LeBlanc, S. E., Diamond, M. S., Shinozuka, Y., Chang, I. Y., Ueyama, R., Pfister, L., Ryoo, J.-M., Dobracki, A. N., da Silva, A. M., Longo, K. M., Kacenelenbogen, M. S., Flynn, C. J., Pistone, K., Knox, N. M., Piketh, S. J., Haywood, J. M., Formenti, P., Mallet, M., Stier, P., Ackerman, A. S., Bauer, S. E., Fridlind, A. M., Carmichael, G. R., Saide, P. E., Ferrada, G. A., Howell, S. G., Freitag, S., Cairns, B., Holben, B. N., Knobelspiesse, K. D., Tanelli, S., L'Ecuyer, T. S., Dzambo, A. M., Sy, O. O., McFarquhar, G. M., Poellot, M. R., Gupta, S., O'Brien, J. R., Nenes, A., Kacarab, M., Wong, J. P. S., Small-Griswold, J. D., Thornhill, K. L., Noone, D., Podolske, J. R., Schmidt, K. S., Pilewskie, P., Chen, H., Cochrane, S. P., Sedlacek, A. J., Lang, T. J., Stith, E., Segal-Rozenhaimer, M., Ferrare, R. A., Burton, S. P., Hostetler, C. A., Diner, D. J., Seidel, F. C., Platnick, S. E., Myers, J. S., Meyer, K. G., Spangenberg, D. A., Maring, H., and Gao, L.: An overview of the ORACLES (ObseRvations of Aerosols above CLouds and their intEractionS) project: aerosol–cloud–radiation interactions in the southeast Atlantic basin, Atmos. Chem. Phys., 21, 1507–1563, https://doi.org/10.5194/acp-21-1507-2021, 2021.

S. Nag, M. Moghaddam, D. Selva, J. Frank, V. Ravindra, R. Levinson, A. Azemati, B. Gorr, A. Li, R. Akbar, "Soil Moisture Monitoring using Autonomous and Distributed Spacecraft (D-SHIELD)", IEEE International Geoscience and Remote Sensing Symposium, Brussels Belgium, July 2021.

Schmidt, G., Sengupta, M., Melton, F. et al. (2021). NASA Climate: Advancing NASA's Climate Strategy -- A whole of NASA approach, October 2021, NASA, Washington, D.C.

V. Ravindra, R. Ketzner, S. Nag, ""Earth Observation Simulator (EO-SIM): An Open-Source Software for Observation Systems Design", IEEE International Geoscience and Remote Sensing Symposium, Brussels Belgium, July 2021.

Van Den Bergh, J., Chirayath, V., Li, A., Torres-Perez, J., and Segal-Rozenhaimer, M. NeMO-Net - Gamifying 3D Labeling of Multi-Modal Reference Datasets to Support Automated Marine Habitat Mapping, in Frontiers in Marine Science (2021), doi: 10.3389/fmars.2021.645408.

Volk, J., Huntington, J., Allen, R., Melton, F., Anderson, M. and Kilic, A., 2021. flux-data-qaqc: A Python Package for Energy Balance Closure and Post-Processing of Eddy Flux Data. Journal of Open Source Software, 6(66), p.3418.

Wang, T., F. Melton, T. Thao, K. Post, L. Johnson, F. Cassel-Sharma, 2021. Evaluation of crop coefficient and evapotranspiration data for sugar beets from Landsat surface reflectances using micrometeorological measurements and weighing lysimetry. Agricultural Water Management 244, 106533. https://doi.org/10.1016/j.agwat.2020.106533

Weston, M., Piketh, S., Burnet, F., Broccardo, S.P., Denjean, C., Bourrianne, T., Formenti, P., Sensitivity analysis of an aerosol-aware microphysics scheme in WRF during case studies of fog in Namibia, in prep for Atmospheric Chemistry and Physics.

Yu, H., Tan, Q., Zhou, L., Zhou, Y., Bian, H., Chin, M., Ryder, C. L., Levy, R. C., Pradhan, Y., Shi, Y., Song, Q., Zhang, Z., Colarco, P. R., Kim, D., Remer, L. A., Yuan, T., Mayol-Bracero, O., and Holben, B. N.: Observation and modeling of the historic "Godzilla" African dust intrusion into the Caribbean Basin and the southern US in June 2020, Atmos. Chem. Phys., 21, 12359–12383, https://doi.org/10.5194/acp-21-12359-2021, 2021.

Presentations

"ReFRACtor / MUSES OCO-2/3 analysis": talk at OCO2/3 OCO 2/3 Algorithm Breakout, March 8, 2021.

"Remote Sensing for Biodiversity and Conservation", ASPRS Pacific Southwest Spring meeting, April 2021; and

"Remote Sensing for Biodiversity and Conservation", UC Berkeley GIS class, November 2021.

A. Kannan, et al., "Forecasting global geophysical states using a deep learning model for Spacecraft constellation scheduling and planning", AGU Fall Meeting 2021.

AGU Fall Meeting 2021: "Variations in radiative heating of humid biomass burning aerosols in the southeast Atlantic from airborne observations and reanalysis." K. Pistone, E.M. Wilcox, M. Giordano, P. Zuidema, R. Wood

https://agu.confex.com/agu/fm21/meetingapp.cgi/Paper/954715.

AGU Fall Meeting 2021: Poleward dust transport estimated by a combination of lidar measurements and MERRA-2 wind fields, Qian Tan, Hongbin Yu, Huisheng Bian.

AGU Fall Meeting, December 2021: U35A-2229 - “Assimilating Lessons Learned – From URGE to NASA's Student Airborne Science Activation (SaSa) Project” K. Pistone, M. Friberg, S. E. Craig, R. Delgado, C. K. Gatebe. https://agu.confex.com/agu/fm21/meetingapp.cgi/Paper/972787.

AGU Presentation: “Expanding NeMO-Net Machine Learning Capabilities for Citizen Science”.

Ambrosia, V.G., 2021. Wildland Fires: How Can We Be Better Informed Through New Observation Capabilities and Modeling Strategies? Commercial Space Lecture Series, Space Portal Office, NASA-Ames Research Center. (https://www.nasa.gov/ames/partnerships/spaceportal/commercial-space-lecture-series), 7 April 2021;

AMS Annual Meeting: Dust Transport to the Arctic Circle Estimated by a Combination of Satellite Measurements and Assimilated Wind Fields, Qian Tan, Hongbin Yu, Huisheng Bian, Virtual, Jan 2021.

Asanjan, A.A., K. Das, A. Li, V. Chirayath, J. Torres-Perez, and S. Sorooshian. 2020. Learning instrument invariant characteristics for generating high-resolution global coral reef maps. KDD ‘20: Proc. 26th ACM SIGKDD Int. Conf. Knowledge Discovery and Data Mining. August 2020.

Broccardo, S.P., Esch, C., Johnson, R., Dahlgren, R.P., Dunagan, S.E., Palacios, S.L., Wang, J., Flynn, C: SeaSTAR - sunphotometer platform diversification for aerosol characterization over the ocean, in American Geophysical Union Fall Meeting 2021, New Orleans.

Cahn, M., L. Johnson, S. Benzen, T. Lockhart, and D. Chambers, 2021. Using Weather-Based Irrigation Scheduling to Optimize Red Cabbage Production. ASHS Annual Meeting, 5-9 Aug. Hortscience 56:9S.

CitSciCon (2021) – NASA NeMO-Net: https://scistarter.org/nasa/NASA-NeMO-Net-nasa.

Cloud Meso-scale Classification and dynamics from the Geostationary SEVIRI satellite using Convolutional Neural-Network, Michal Segal Rozenhaimer, David Nukrai, Robert Wood, Zhibo Zhang, Accepted as Oral presentation for 21st Conference on Artificial Intelligence for Environmental Science, AMS, January, 2022.

Co-author on presentation at NASA AIRS/Sounder Virtual Science Team Meeting 2021 – Part 2 (virtual meeting), “Multisensor Observations of PAN over megacities”, Madison Shogrin, Vivienne Payne, Susan Kulawik, Emily Fischer.

Contributed to PI talk by Sourish Basu at OCO2/3 Science Team meeting, October 19, 2021.

Girona, T., Caudron, C., Lundgren, P.R., Bato, M.G.P., Schwandner, F.M., Broccardo, S.P., Natraj, V., Kacenelenbogen, M.S., Yung, Y., Johnson, R., Deering, C., De Moor, M., Pavlick, R.P., Nelson, K., Benavente, D.: The stop-and-go mechanism: towards an integrated approach to model seismicity, outgassing, deformation and thermal unrest at active volcanoes, in AGU Fall Meeting 2021, New Orleans, USA.

Grimm, R., et al., 2021. OpenET: Enabling science-based water management through open data services and user-driven design. Amer. Meteorological Soc. Annual Meeting, 35th Conference on Hydrology 10-15 Jan., 2021 (invited).

Guzman, A. SIMS-CropManage. Nasa Applied Sciences, WWAO and Water Resources Team Meeting, 10 Oct 2021.

IEEE (2020) International Geoscience and Remote Sensing Symposium - NASA NeMO-Net – A Neural Multimodal Observation & Training Network for Marine Ecosystem Mapping at Diverse Spatiotemporal Scales.

In-person presentation in the lab/near aircraft for NASA Earth Science Division Director, Karen St. Germain (May 2021).

Invited Panel Member / Workshop Presentation: Lightning Talk: NASA Wildfire Program Directions; “Real Time Detection and Tracking of Fires That Matter: What Is Needed, What Is Possible, How Do We Build It?”, Keck Institute for Space Studies (KISS), CalTech, JPL, Pasadena, CA. (virtual meeting), 11-12 March 2021.

Johnson, L., 2021. Using weather-based irrigation scheduling for optimizing red cabbage production. UCCE Irrigation and Nutrient Management Meeting, 23 Feb, Salinas (invited).

Johnson, L., F. Cassel Sharma, J. Harding, J. Herring, and F. Melton, 2021. Derivation and Testing of Consumptive Water Use Fraction for Specialty Crops. Amer Soc. Hort. Sci. Annual Meeting, 5-9 Aug. Hortscience 56:9S.

Johnson, L., J. Harding, J. Herring, F. Cassel Sharma, 2021. Calculator for agricultural water use fractions in California. ASCE World Environmental & Water Resource Congress 23-26 May.

Johnson, L., M. Cahn, F. Melton, 2021. Initial evaluation of CropManage decision-support model for vineyard ET estimation. AGU Fall Meeting. 1-17 Dec.

LeBlanc S. et al, Aerosol optical depth is more consistent than aerosol size over large distances during KORUS-AQ, in American Geophysical Union Fall Meeting, December 2021, New Orleans and online.

Marine Stratocumulus Cloud Type Classification from SEVIRI using Convolutional Neural-Network and their Diurnal Cycle over the South-East Atlantic Ocean during ORACLES. Michal Segal Rozenhaimer, NASA Ames Research Center/BAERI, Mountain View, CA, Israel; Tel-Aviv University, Tel-Aviv, Israel; and D. Nukrai, T. Shalev, Z. Zhang, A. Denagamage, R. Wood, and J. Riedi, Oral Presentation, AMS January 2021.

Martin, F., Melton, F., Hang, M., et al., 2021. Site-specific soil pest management in strawberry and vegetable cropping systems. MBAO Fumigation and Alternatives for Production, Storage and Trade Conference, 15 Nov 2021.

Melton, F., Johnson, L., Guzman, A., Carrara, W., et al., 2021. OpenET: Operational ET Data for Water Management in the Western U.S. AGU Fall Meeting. 1-17 Dec., New Orleans (invited).

Melton, F., Johnson, L., Guzman, A., Carrara, W., et al., 2021. OpenET: Operational ET Data for Water Management in the Western U.S. AGU Fall Meeting. 1-17 Dec., New Orleans (invited).

Melton, F., Johnson, L., Guzman, A., Carrara, W., et al., 2021. OpenET: Operational ET Data for Water Management in the Western U.S. California Department of Food and Agriculture Nutrient Management Conference, San Luis Obispo, CA, Oct 27-28, 2021 (invited).

Melton, F., Johnson, L., Guzman, A., Carrara, W., et al., 2021. OpenET: Operational ET Data for Water Management in the Western U.S. California Department of Food and Agriculture Nutrient Management Conference, San Luis Obispo, CA, Oct 27-28, 2021 (invited).

Melton, F., Johnson, L., Guzman, A., Carrara, W., et al., 2021. OpenET: Operational ET Data for Water Management in the Western U.S. United Nations Food and Agriculture Organization, Webinar Series on Remote Sensing of Evapotranspiration, July 7, 2021 (invited).

Melton, F., Johnson, L., Guzman, A., Carrara, W., et al., 2021. OpenET: Operational ET Data for Water Management in the Western U.S. United Nations Food and Agriculture Organization, Webinar Series on Remote Sensing of Evapotranspiration, July 7, 2021 (invited).

Melton, F., Johnson, L., Guzman, A., Carrara, W., Hang, M., Solymar, R., et al., 2021.Applications of remote sensing for irrigation management, California Plant and Soil Science Conference, May 25, 2021 (invited).

Melton, F., Johnson, L., Guzman, A., Carrara, W., Hang, M., Solymar, R., et al., 2021.Applications of remote sensing for irrigation management, California Plant and Soil Science Conference, May 25, 2021 (invited).

Melton, F., Johnson, L., Guzman, A., Carrara, W., Hang, M., Solymar, R., et al., 2021.The NASA Satellite Irrigation Management Support (SIMS) Framework . United Nations Food and Agriculture Organization, Webinar Series on Remote Sensing of Evapotranspiration, May 26, 2021 (invited).

Melton, F., Johnson, L., Guzman, A., Carrara, W., Hang, M., Solymar, R., et al., 2021.The NASA Satellite Irrigation Management Support (SIMS) Framework . United Nations Food and Agriculture Organization, Webinar Series on Remote Sensing of Evapotranspiration, May 26, 2021 (invited).

Melton, F., L. Johnson, M. Cahn, A. Guzman, W. Carrara, C. Wang, C. Doherty, R. Solymar, M. Hang, F. Cassel-Sharma, 2021. Applications of remote sensing for irrigation management. Amer. Soc. Agronomy, Calif. Plant and Soil Conference, 1-3 Feb., 2021 (invited).

Melton, F., L. Johnson, M. Cahn, A. Guzman, W. Carrara, C. Wang, C. Doherty, R. Solymar, M. Hang, F. Cassel-Sharma, 2021. Applications of remote sensing for irrigation management. Amer. Soc. Agronomy, Calif. Plant and Soil Conference, 1-3 Feb., 2021 (invited).

Nora Eisner to present 3-minute talk about Planet Hunters Coffee Chat at AGU during the “Science and Society” panel discussions.

Park, T., Kim, M., Nemani, R., Integrating field measurement, remote sensing, and modeling approach to track forest cover and above ground biomass changes in the Northeast Asian temperate forests, Dec 2021, Online, AGU 2021

Park, T., Kim, M., Nemani, R., Integrating field measurement, remote sensing, and modeling approach to track forest cover and above ground biomass changes in the Northeast Asian temperate forests, Dec 2021, Online, AGU 2021.

Park, T., Nemani, R., Myneni, R. Monitoring and forecasting large-scale patterns of forest structure and carbon dynamics using field, remote sensing, and process-based models: Progress in Year 1. Global Ecosystem Dynamics Investigation (GEDI) Science Team Meeting. 8-10 November 2021.

Park, T., Nemani, R., Myneni, R. Monitoring and forecasting large-scale patterns of forest structure and carbon dynamics using field, remote sensing, and process-based models. Global Ecosystem Dynamics Investigation (GEDI) Science Team Meeting. 12-15 January 2021.

Park. T., Li, S., Vandal, T., Yu, Y., Saatchi, S., Vargas, R., Nemani, R., Generation of continental scale percent tree cover product using deep-learning and multi-scale remote sensing data, Mar 2021, 2021 7th NACP Open Science Meeting.

PI talk (Kulawik) at the OCO-2/3 Science Team meeting, October 19, 2021, “3d-clouds, meteorology, and albedo updates for OCO-⅔”

Pistone, et al featured poster in the Southern Hemisphere working group at the IGAC (International Global Atmospheric Chemistry) online conference, September 2021: “Biomass burning smoke and coincident water vapor over the southeast Atlantic stratocumulus region: results from observations and models.”

S. Nag, et al., "D-SHIELD: Distributed Spacecraft with Heuristic Intelligence to Enable Logistical Decisions", NASA Earth Science Technology Forum, January 2021.

S. Nag, et al., "Simulating the Impact of Agile, Heterogeneous, Distributed Spacecraft with Intelligent Scheduling (D-SHIELD) to reduce global Soil Moisture Uncertainty", AGU Fall Meeting 2021.

Speaker and Mentor (Ambrosia): Wildfire Communications Challenge: Linking Firefighters with Information Quickly and Efficiently; AngelHacks 2.0, 26-28 February 2021; https://www.angelhacks.org; and

V. Ravindra, R. Ketzner, S. Nag, “EO-Sim: An open-source library for design and evaluation of space observation systems; a discussion on the software design and development.”, AGU Fall Meeting 2021.

Vargas, R., Park, T., Nemani, R., Carbon monitoring systems across Mexico to support implementation of REDD+: maximizing benefits and knowledge. NASA Carbon Monitoring System Science Team Meeting 2021. CMS Science Team Meeting. November 16-18, 2021.

Volk, J., et al., 2021. OpenET Satellite-based ET Intercomparisons with Ground-based Measurements: Phase II Results. AGU Fall Meeting. 1-17 Dec.

Glossary

4STAR — Sky-scanning, Sun-tracking Atmospheric Research

5STAR — ultra-Stable Spectrometers for Sky-Scanning Sun-Tracking Atmospheric Research

AATS — Ames Airborne Tracking Sun-photometer

ACCDAM — Atmospheric Composition Campaign Data Analysis and Modeling

ACMAP — Atmpsheric Composition: Modeling and Analysis Program

ACP — Atmospheric Composition Program

ACTIVATE — Aerosol Cloud meTeorology Interactions oVer the western ATlantic Experiment

ADAI — Associacao Para o Desenvolvimento Aerodinamica Industrial

ADCS — Attitude Determination and Control System

ADIS — Algorithm Driven Information System

ADM-AEOLUS — Atmospheric Dynamics Mission-Aeolus

AERONET — AErosol RObotic NETwork

AESD — Ames Earth Science Division

AFB — Air Force Base

AFRC — Armstrong Flight Research Center

AGAGE — Advanced Global Atmospheric Gases Experiment

AGHSD — Ames Global Hyperspectral Synthetic Dataset

AGU — American Geophysical Union

AI – Artificial Intelligence

AirMSPI — Airborne Multi-angle SpectroPolarimeter Imager

AIRO — The Antarctic Infrared Observatory

AIRS — Atmospheric Infrared Sounder

AIST — Advanced Information Systems Technology

AJAX — Alpha Jet Atmospheric eXperiment

AMS — American Meteorological Society

AMS — Autonomous Modular Sensor

AOGS — Oceania Geosciences Society

AOT — Aerosol Optical Thickness

API – Application Programing Interface

ARC – Ames Research Center

ARC—CREST — Ames Research Center Cooperative for Research in Earth Science and Technology

ARCSIX — Arctic Radiation- Cloud-Aerosol - Surface-Interaction Experiment

ARSET — Applied Remote Sensing Training

ASF — Airborne Sensor Facility

ASP — Applied Sciences Program

ASPRS — American Society for Photogrammetry and Remote Sensing

ASRL — Allometric Scaling and Resource Limitation

ATA — Ethiopia's Agricultural Transformation Agency

ATom — Atmospheric Tomography Mission

AVAPS — The Advanced Vertical Atmospheric Profiling System

AVIRIS — Airborne visible/infrared imaging spectrometer

BAMS — Bulletin of the American Meteorological Society

CAMP2Ex — Cloud, Aerosol and Monsoon Processes Philippines Experiment

CBP — Capacity Building Program

CDFA — California Department of Food and Agriculture

CEAMS — Citizen Enabled Aerosol Measurements for Satellites

CEOS — Committee on Earth Observation Satellites

CI — Conservation International

CMIP6 — Coupled Model Intercomparison Project Phase 6

CMS — Carbon Monitoring Systems

COMA — Carbon mOnoxide Measurement from Ames

CONUS – Continental United States

COSR – Canadian Oil Sands Region

COTS — Commercial Off-The-Shelf

CPEX — Convective Processes Experiment

CPEX-AW — Convective Processes Experiment - Aerosols & Winds

CPU — Central Processing Unit

CrIS – Cross-track Infrared Sounder

CSA — Canadian Space Agency

CSA — Certified Systems Administrators

CSA — Citizen Science Accelerator

CSU — California State University

CSUMB — California State University at Monterey Bay

CUT — Cyprus University of Technology

D-SHIELD — Distributed Spacecraft with Heuristic Intelligence to Enable Logistical Decisions

DAAC – Distributed Active Archive Center

DAYMET — Daymet is a dataset of estimates of gridded surfaces of minimum and maximum temperature, precipitation occurrence and amount, humidity, shortwave radiation, and snow water equivalent.

DBW – Division of Boating and Motorways

DCOTSS — Dynamics and Chemistry of the Summer Stratosphere

DCOTTS — Dynamics and Chemistry of the Summer Stratosphere

DEVELOP — Digital Earth Virtual Environment and Learning Outreach Project

DRAAWP – Delta Region Area-wide Aquatic Weed Project

DRI — Desert Research Institute

DRR — Disaster Risk Reduction

DSET — Drought Severity Evaluation Tool

DSMs — Distributed Space Missions

EC — European Commission

ECOSTRESS – ECOsystem Spaceborne Thermal Radiometer Experiment on Space Station

EDF — Environmental Defense Fund

ENSCI — Environmental Science

EOS – Earth Observing System

EOSDIS — Earth Observing System Data and Information System

EOSim — Earth Observation Simulator

ESPO — Earth Science Project Office

ESRI — Esri is an international supplier of geographic information system software, web GIS and geodatabase management applications.

ESROGSS — Earth Science Research on Operational Geostationary Satellite Systems

ESTO – Earth Science Technology Office

ESTP – Environmental Science, Technology and Policy

ET — Evapotranspiration

EWRI — Environmental & Water Resources Institute

EXCELSIOR – ERATOSTHENES: Excellence Research Center for Earth Surveillance and Space-based Monitoring of the Environment

EXPORTS — EXport Processes in the Ocean from RemoTe Sensing

FHI — Freshwater Health Index

FINESST — Future Investigators in NASA Earth and Space Science and Technology

FIREX-AQ — Fire Influence on Regional to Global Environments and Air Quality

FLUXNET — LUXNET is a global network of micrometeorological tower sites that use eddy covariance methods to measure the exchanges of carbon dioxide, water vapor, and energy between the biosphere and atmosphere.

FPAR – Fraction of Absorbed Photosynthetically Active Radiation

FPGA— Field-programmable Gate Array

FPIC — Free, Prior and Informed Consent

GCMs — Global Climate Models

GDSA — Gabarone Declaration for Sustainability in Africa

GEDI – Global Ecosystem Dynamics Investigation

GEE — Google Earth Engine

GEO-KOMPSAT — Geostationary - Korea Multi-Purpose Satellite

GEO-LEO — GEO-LEO is a virtual library for the specialty fields of mining, geography, maps, Earth sciences, and astronomy.

GEOCAPE — The GEOstationary Coastal and Air Pollution Events

GeoNEX — A collaborative effort for generating Earth monitoring products from the new generation of geostationary satellite sensors

GHG – Greenhouse Gas(es)

GLE — Geoscience Learning Ecosystem

GMAO — Global Modeling and Assimilation Office

GOES – Geostationary Operational Environmental Satellite

GPM — Global Precipitation Measurement

GPP – General Purpose Parameters

GSFC — Goddard Space Flight Center

GWIS — Global Wildfire Information System

HABs — Harmful Algal Blooms

HALE — High Altitude Long Endurance

HCN – Hydrogen cyanide

HYPPOS — The HyMap Airborne Hyperspectral Sensor

HYSPLIT — The Hybrid Single-Particle Lagrangian Integrated Trajectory

IASI — Infrared Atmospheric Sounding Interferometer

ICAART — International Consortium for Atmospheric Research on Transport and Transformation

ICARTT — The ICARTT file format standards were developed to fulfill the data management needs for the International Consortium for Atmospheric Research on Transport and Transformation (ICARTT) campaign

ICESat-2 — ICESat-2, part of NASA's Earth Observing System, is a satellite mission for measuring ice sheet elevation and sea ice thickness, as well as land topography, vegetation characteristics, and clouds.

IDL — Interactive Data Language

IDS — Interdisciplinary Research

IEEE – Institute of Electrical and Electronics Engineers

IGARRS — International Geoscience and Remote Sensing Symposium

IMPACTS — Investigation of Microphysics and Precipitation for Atlantic Coast-Threatening Snowstorms

IOP – Intensive Observation Period

IPWG — International Precipitation Working Group

IR — Infrared

IRAD — Internal Research and Development

IRIS – Interface Region Imaging Spectrograph

ISFM — Internal Science Funding Model

ITCZ — InterTropical Convergence Zone

IUCN — International Union for Conservation of Nature and Natural Resources

IWPSS — International Workshop on Planning and Scheduling for Space

JAXA – Japan Aerospace Exploration Agency

JPL – Jet Propulsion Laboratory

JSC – Johnson Space Center

KALRO — Kenya's Agricultural & Livestock Research Organization

KARI — Korean Aerospace Research Institute

KDD — Knowledge Discovery in Databases

KNN — K-Nearest Neighbors is a machine learning technique and algorithm that can be used for both regression and classification tasks

LAI – Leaf Area Index

LaRC — Langley Research Center

LCLUC — Land-Cover and Land-Use Change

LIDAR — Light Detection and Ranging

LOF — Living Oceans Foundation

MACIE — Measurements of Aerosols, Clouds and their Interactions for ESMs

MAIAC – Multi-Angle Implementation of Atmospheric Correction

MAPPPD — Mapping Applications for Penguin Populations and Projected Dynamics

MASTER — The MODIS/ASTER Airborne Simulator

MASTR — Multi Application Smallsat Tri-band Radar

MBAO — Methyl Bromide Alternatives Outreach

MCC — Meso-scale Cellular Convection

MEaSUREs — Making Earth System Data Records for Use in Research Environments

MedRIN — Mediterranean Regional Information Network

MERRA — Modern Era Retrospective-Analysis for Research and Applications

METRIC – Mapping EvapoTranspiration at high Resolution with Internalized Calibration

MFD — Multi-Function Display

MMS — Meteorological Measurement System

MODIS – Moderate Resolution Imaging Spectroradiometer

MODTRAN — MODTRAN is a computer program designed to model atmospheric propagation of electromagnetic radiation for the 100-50,000 cm−1 spectral range.

MOOSE — Michigan-Ontario Ozone Source Experiment

MSC — Marine Stratocumulus Clouds

MSFC — Marshall Space Flight Center

MSIs — Minority Serving Institutions

MTS — Mission Tools Software

MUSES — Multi-Spectra, Multispecies, Multi-sensors

MuSSTAR — Miniature unmanned airborne Sunphotometer for Sun-Tracking Atmospheric Research

MVIS — Miniature Video Imaging System

NACP — North American Carbon Program

NAIP — National Agriculture Imagery Program

NAS — Network Attached Storage

NASA ACCES – Advancing Collaborative Connections for Earth System Science

NASA GSFC RCL — The NASA Goddard Space Flight Center (GSFC) Radiometric Calibration Laboratory (RCL)

NASDAT — NASA Airborne Science Data and Telemetry System

NCAR — National Center for Atmospheric Research

NDAAC — Network for the Detection of Atmospheric Composition Change

NeMO-NET — Neural Multimodal observation and training network for global coral reef assessment

NEX — NASA Earth Exchange

NEX — NASA Earth Exchange

NEX-GDM — NASA Earth Exchange Gridded Daily Meteorology

NIDIS — National Integrated Drought Information System

NLCD — National Land Cover Database

NOAA — National Oceanic and Atmospheric Administration

NOx — Nitrogen Oxides

NRC — National Research Council

NSRC — National Suborbital Research Center

OCO-2/3 — Orbiting Carbon Observatory 2/3

OKACOM — Okavango River Basin Water Commission

OMB — Office of Management and Budget

OMI — Ozone Measuring Instrument

OMPS — Ozone Mapping and Profiler Suite

OPALS — Optical PAyload for Lasercomm Science

ORACLES — ObseRvations of Aerosols Above CLouds and their IntEractionS

ORM — Ozone Research Managers

PAN – Peroxyocetyl nitrate

Pandora — A small commercially available spectrometer

PER — Preliminary Engineering Review

PICARD — Pushbroom Imager for Cloud and Aerosol Research

PICOGRAM

PRE — Pacific Research & Evaluation

PTZ — Pan-Tilt-Zoom

R2O — Research to Operations

REDD+ — A voluntary climate change mitigation approach that has been developed by Parties to the UN Framework Convention on Climate Change (UNFCCC). It aims to incentivize developing countries to reduce emissions from deforestation and forest degradation, conserve forest carbon stocks, sustainably manage forests and enhance forest carbon stocks

ROSES – Research Opportunities in Earth and Space Science

RSP — Radiation Science Program

RST — Remote Sensing Theory

S-MODE — Sub-Mesoscale Ocean Dynamics Experiment

SABRE — Stratospheric Aerosol processes, Budget and Radiative Effects

SARP — Student Airborne Research Program

SaSas — Student Airborne Science Activation

SATERN – System for Administration, Training, and Educational Resources for NASA

SBG – Surface Biology and Geology

SBIR – Small Business Innovation Research

SCBGP – Specialty Crop Block Grant Program

SCERIN — South Central Europe Regional Information Network

SDGs — Sustainable Development Goals

SDMWG — Strategic Data Management Working Group

SEA — SouthEast Atlantic

SEP — SouthEast Pacific

SEVIRI — The Spinning Enhanced Visible and InfraRed Imager

SHARC — SCIFLI-Hayabusa Airborne Re-entry observation Campaign

SIF — Solar Induced Flourescence

SIMS – Satellite Irrigation Management Support

SIMS – Satellite Irrigation Management Support

SISTER — Space-based Imaging Spectroscopy and Thermal pathfinder

SRTM — Shuttle Radar Topography Mission

SSURGO — Soil Survey Geographic Database

sUAS — Small Unmanned Aerial Systems

SWAP — Smaller Weight And Power

TAMMS — Turbulent Air Motion Measurement System

TCCON — Total Carbon Column Observing Network

TEMPO — Tropospheric Emissions: Monitoring Pollution

TES — Tropospheric Emission Spectrometer

TESS – Triennial Earth Sun Summit

TFRSAC – Tactical Fire Remote Sensing Advisory Committee

TOPS – Terrestrial Observation and Prediction Systems

TRACER-AQ — TRacking Aerosol Convection ExpeRiment – Air Quality

UAS – Unmanned Air Systems

UAV – Unmanned Aerial Vehicle

UCANR — University of California Agriculture and Natural Resources

UCCE – University of California Cooperative Extension

UN-GAR — UN Office for Disaster Risk Redution, Global Assessment Report

UNCCD — United Nations Convention to Combat Desertification

USDA — U.S. Department of Agriculture

USDA-ARS — U.S. Department of Agriculture, Agricultural Research Services

USDA-NIFA — National Institute of Food and Agriculture

USFS — The United States Forest Service

USGS — United States Geological Survey

UTTC — United Tribes Technical College

VALUABLES — a collaboration with NASA to measure how satellite information benefits people and the environment when it is used to make decisions.

VIIRS – Visible Infrared Imaging Radiometer Suite

VIS — Visible

VOCALS — VAMOS Ocean-Cloud-Atmosphere-Land Study Regional Experiment

WAS — Whole Air Sampling

WCC — World Conservation Congress

WDTS — Western Diversity Time Series

WELD — Web-enabled Landsat Data

WESTFAST — Western States Federal Agency Support Team

WFF – Wallops Flight Facility

WSWC — Western States Water Council

WWAO – Western Water Applications Office