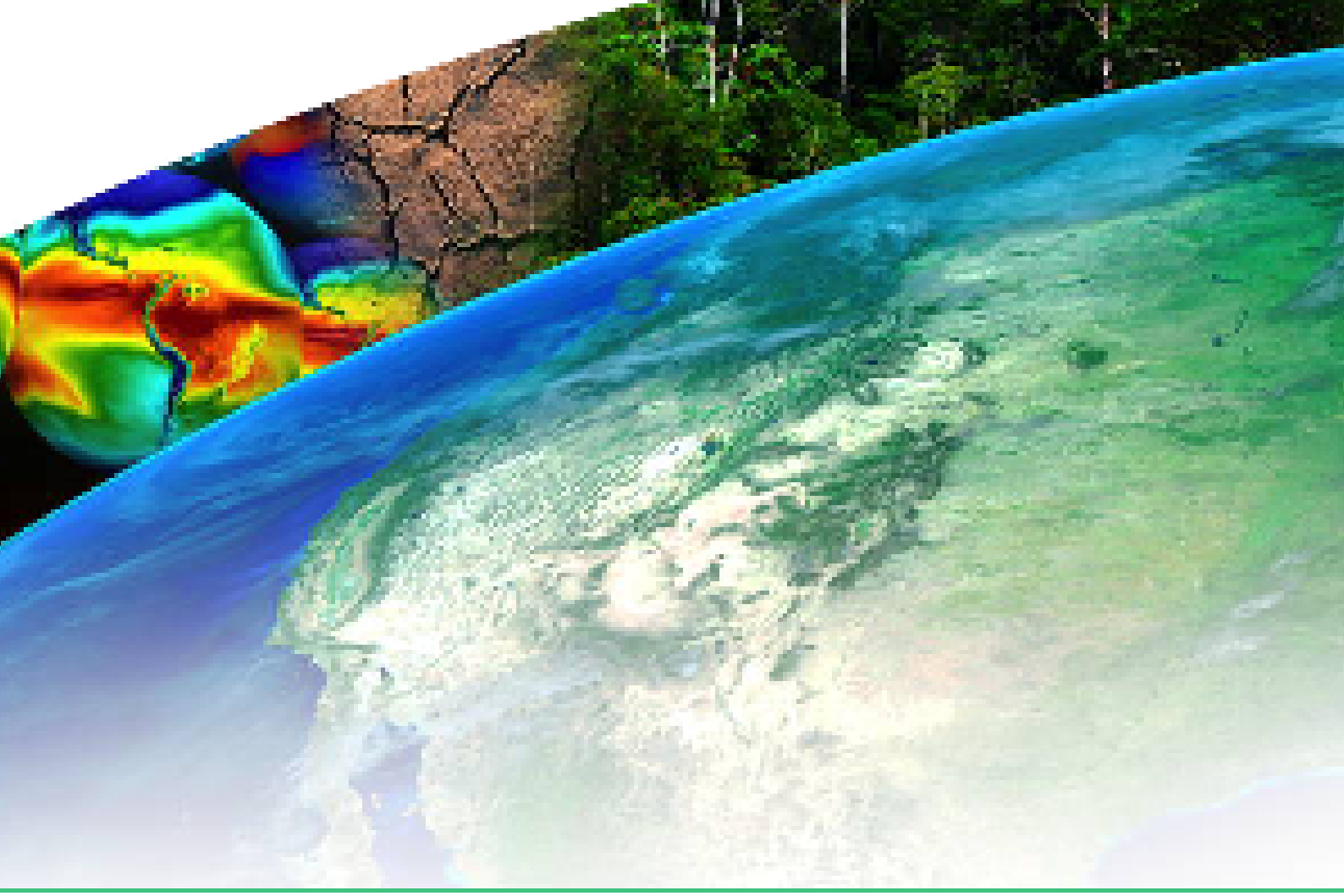

ANNUAL REPORT 2014

Ames Research Center: Cooperative Research in Earth Science and Technology

ARC-CREST

Bay Area Environmental Research Institute

www.baeri.org

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LETTER FROM **THE DIRECTOR**

I am pleased to present the annual report for the Ames Research Center Cooperative for Research in Earth Science and Technology (ARC-CREST). NASA awarded the ARC-CREST cooperative agreement to the Bay Area Environmental Research Institute (BAERI), the California State University at Monterey Bay (CSUMB) and the National Suborbital Education and Research Center at the University of North Dakota (NSERC/UND) in 2012. This report covers the performance period March 1, 2014 to February 28, 2015.

During the period of performance, ARC-CREST staff from the partner institutions worked side by side with their collaborators at NASA Ames Research Center on 39 separate Earth Science research, research support, and education or outreach projects. This report summarizes their accomplishments during that time. Through their hard work and commitment, the ARC-CREST team made many significant achievements to support NASA's Earth Science mission goals. In 2014, ARC-CREST researchers,engineers, staff, and students contributed to the success of over 10 airborne field campaigns, gave presentations to the White House Office and Science and Technology Policy and U.S. Global Change Research Program, conducted three large scale student outreach and education programs, were featured in the award-winning documentary Years of Living Dangerously, and provided key research to California officials dealing with the drought, to name just a few accomplishments.

Congratulations and thank you to the ARC-CREST team and our NASA partners for another great year in this exciting partnership!

Dr. Robert Bergstrom
Director

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NASA Ames Research Center (ARC) awarded Bay Area Environmental Research Institute (BAERI) and partners (University of North Dakota and California State University at Monterey Bay) the ten-year, Ames Research Center Cooperative for Research in Earth Science and Technology (ARC-CREST) in March 2012. NASA ARC-CREST scientists and staff, in collaboration with NASA and other investigators, work cooperatively with NASA -ARC's Earth Science Division (Code SG) 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.

This document describes the progress and achievements made in 2014 of the 39 research, education and support projects within the ARC-CREST cooperative agreement.

For more information please contact Dr. Robert Bergstrom, ARC-CREST Director (bergstrom@baeri.org), or Mark Sittloh, ARC-CREST Business Manager (msittloh@baeri.org).

ARC-CREST **PARTNERS**

1. Bay Area Environmental Research Institute (BAERI)
   http://baeri.org/

2. Department of Science and Environmental Policy at California State University at Monterey Bay (CSUMB)
   https://csumb.edu/sep/research-partnerships

3. National Suborbital Education and Research Center (NSERC) at the University of North Dakota (UND-NSERC)
   http://www.nserc.und.edu/

4. Earth Science Division (Code SG) at NASA Ames Research Center
   https://earthscience.arc.nasa.gov/

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EARTH SCIENCE FOCUS AREAS

4STAR and Satellite Data Analysis

NASA: Jens Redemann, Phil Russell
BAERI: Michal Segal Rosenhaimer, Meloe Kacenelenbogen, Yohei Shinozuka, Qin Zhang

The Ames 4STAR (Sky-scanning, Sun-tracking Atmospheric Research) project uses ground and airborne sun-photometer instruments to study aerosol radiative properties and measure atmospheric trace gases. Instruments currently in use include: the recently developed 4STAR ground and 4STAR air instruments and the Ames Airborne Tracking Sun-photometer (AATS-14). The 4STAR group analyzes these measurements to yield atmospheric aerosol optical depth and extinction spectra, aerosol size distributions, H_2O(g) columns and profiles, and O_3 columns. They also have used the data to validate measurements from 12 different satellite instruments, two airborne simulators of satellite instruments, and several airborne and ground-based lidars. Data taken using the AATS instrument have also been used in studies of aerosol radiative forcing of climate, aerosol light absorption spectra, and consistency (closure) between in situ and radiometric measurements. The 4STAR and Satellite Data Analysis project also analyzes data from prior field missions as well as various satellite data products to better understand global aerosol optical properties and climate forcing.

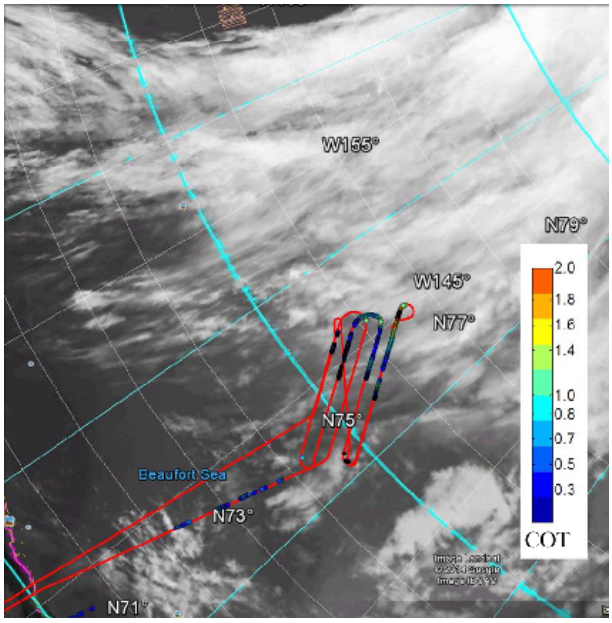

Figure 1: Optical thickness along the flight track for one science flight during the ARISE mission. Optical thickness is determined from direct sun measurements made by the 4STAR instrument. Results are preliminary.

The team has recently been working on the development of the next generation of the AATS instrument, the 4STAR ground, and 4STAR air instruments. The 4STAR instruments broaden the types of aircraft on which the instrument can be deployed, improve the wavelength resolution and introduce a sky-scanning capability. In 2014 the 4STAR instrument flew in a major field campaign, ARISE (Arctic Radiation – Ice-Bridge, Sea and Ice Experiment), with great success. The 4STAR team operated the instrument during approximately 60 science flight hours. Through analysis of the 4STAR data and comparisons with co-located satellite observations (MODIS and CALIPSO), the team is learning more about the properties of thin cirrus clouds in the Arctic and their relationship to Earth's radiative balance.

2014 Accomplishments

- The 4 STAR and Satellite Data Analysis team made improvements in calibration, algorithms, and error reduction in the 4STAR retrievals, especially for trace gases. They applied the new algorithms to previous aerosol optical property and trace gas datasets obtained during the SEAC4RS and TCAP field campaigns and provided continued support to the scientific community using the SEAC4RS datasets.
- The team completed detailed comparisons between Aqua version 5 and the newly released Aqua version 6 parameters. Various aerosol optical property datasets for 2007 were updated to version 6.
- The 4STAR instrument was successfully deployed during the ARISE mission. The team installed the instrument on the C-130 aircraft, operated the instrument in-flight, and developed new MATLAB code for more efficient data processing. As one of 4STAR's initial deployments, this deployment required immediate processing of 4STAR data in order to identify instrument problems prior to the next flight.

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Segal Rosenhaimer, M. "Effects of urban and biomass burning sources on downwind aerosol and ozone distributions: regional scale simulations combined with airborne remote sensing measurements during TCAP and SEAC4RS and their link to spaceborne observations", presented at American Geophysical Union Annual Meeting, San Francisco, CA., December 15-19, 2014).

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Jethva, H. et al. (J. Redemann, Y. Shinozuka, M. Kacenelenbogen, and M. Segal Rosenhaimer among 9 authors)"Validating abovecloud aerosol optical depth retrieved from MODIS using NASA Ames airborne suntracking photometric and spectrometric (AATS and 4STAR) measurements" (A12A-06), (presented at American Geophysical Union Annual Meeting, San Francisco, CA, December 15-19, 2014).

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Alpha Jet Atmospheric Experiment (AJAX)

NASA: Warren Gore, Laura Iraci, Max Loewenstein
BAERI: Quincy Allison, Steven Todorov, Emma Yates, Chris Camacho

The Alpha Jet Atmospheric Experiment (AJAX) project at NASA-ARC makes in situ measurements of the important greenhouse gases, CO_2, CH_4, and O_3 as well as associated meteorological measurements during flight. Using a jet aircraft, the project routinely collects vertical profiles of 3-D wind speeds and gas concentrations from near the surface up to ~ 27,000 ft. and over locations such as: the California Central Valley, Edwards Air Force Base, Railroad Valley, NV, and over the Pacific Ocean. Boundary layer measurements like these can indicate surface sources of greenhouse gases such as fires, oil and gas infrastructure, livestock, and urban pollution.

AJAX project goals are to: 1) study local photochemical smog production, 2) provide data for long-term studies of Pacific transport of pollution, and 3) support the observation of greenhouse gases from satellites through in situ validation measurements. Because of the jet's range and fuel load, measurements are focused along the California coast and locations in the far western United States. However, NASA's flexible relationship with the aircraft provider together with the aircraft's base at Moffett Field allow the AJAX team to collect data on a bi-weekly basis over multiple seasons, and often on demand for specific events such as California wildfires. Further, the long-term and dedicated availability of this platform provides for long term in situ data collection, a unique complement to surface and tower-based observations in the region. Validation data for satellite sensors can also be obtained over months and years with this platform to help assess sensor health and calibration.

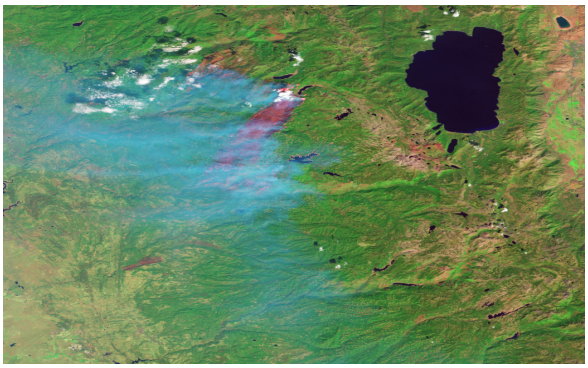

Figure 3: The King fire, burning in El Dorado National Forest as captured by Landsat-8 on September 19, 2014. ARC-CREST researchers measured CO_2 and CH_4 in the King fire plume from the Alpha Jet platform.

AJAX supports NASA's Orbiting Carbon Observatory (OCO-2) Science Team and is developing collaborations with NASA-ARC personnel in the areas of instrument development, systems engineering, science mission development, and project management.

Figure 2: A view of the Alpha Jet research platform, based at NASA-ARC. Instruments are housed in specially designed wing pods.

2014 Accomplishments

- The team completed 31 scientific flights targeting airborne observations of urban outflow, validation of satellite and ground-based remote sensing techniques, emissions from dairies, wildfires and oil fields as well as high altitude flights (to 45,000 feet) with scientific payloads.

- In coordination with JAXA and NASA-JPL, the team conducted the Railroad Valley vicarious calibration mission and the CO_2 and CH_4 experiment (COMEX);

- Working with NOAA researchers, the team continued development of the "AirCore" which takes a sample of air during aircraft descents that can be analyzed in the laboratory post-flight. "AirCore" will be installed with the AJAX instrument payload in 2015.

- The team made flight day determinations of tropopause height using radiosondes and conducted research on historical tropopause heights in the California-Nevada flight areas.

Orbiting Carbon Observatory – 2 (OCO-2) Errors

NASA: Steve Hipskind
BAERI: Susan Kulawik
Colorado State University: Chris O'Dell

ARC-CREST researchers, Susan Kulawik and Chris O'Dell, together with other members of the Orbiting Carbon Observatory-2 (OCO-2) Errors science team, are developing algorithms for analyzing the data from the OCO-2 instrument that is aboard a satellite in Earth orbit. The instrument, consisting of three high resolution grating spectrometers, is acquiring precise measurements of atmospheric CO_2, at high spatial and temporal resolution and with global coverage. OCO-2 was launched from the Vandenberg Air Force Base in California on a dedicated Delta II rocket in July 2014. OCO-2 has a planned operational life of two years and is taking measurements crucial to checking scientists' understanding of the carbon cycle. For example, comparison of OCO-2's measurements of atmospheric CO_2 with carbon model outputs will allow scientists to verify the magnitude of the carbon sink in tropical forests or the amount of carbon released by forest fires.

OCO-2 is unprecedented not only in the sheer number of atmospheric CO_2 measurements it can take each day (~ 1 million measurements across a single swath) but also in the precision of the measurements. OCO-2 acquires data in three different measurement modes. In Nadir Mode, the instrument views the ground directly below the spacecraft. In Glint Mode, the instrument tracks near the location where sunlight is directly reflected on the Earth's surface. Glint Mode enhances the instrument's ability to acquire highly accurate measurements, particularly over the ocean. In Target Mode, the instrument views a specified surface target continuously as the satellite passes overhead.

Target Mode is especially important to data processing because it provides the capability to collect a large number of measurements over sites where ground-based and airborne instruments also measure atmospheric CO_2 and the satellite and ground-based measurement can be compared. Because the changes in atmospheric CO_2 that OCO-2 seeks to measure are so small, the science team takes unusual precautions to ensure the measurements are free of errors. Comparison to ground-based sites such as the Total Carbon Column Observatory network (TCCON), which is fully calibrated and extremely accurate, and an extensive algorithm development and testing process, are critical to ensuring that the Observatory's measurements are error-free. This essential work is currently ongoing and the first maps of global CO_2 developed from OCO-2 measurements were released in December of 2014.

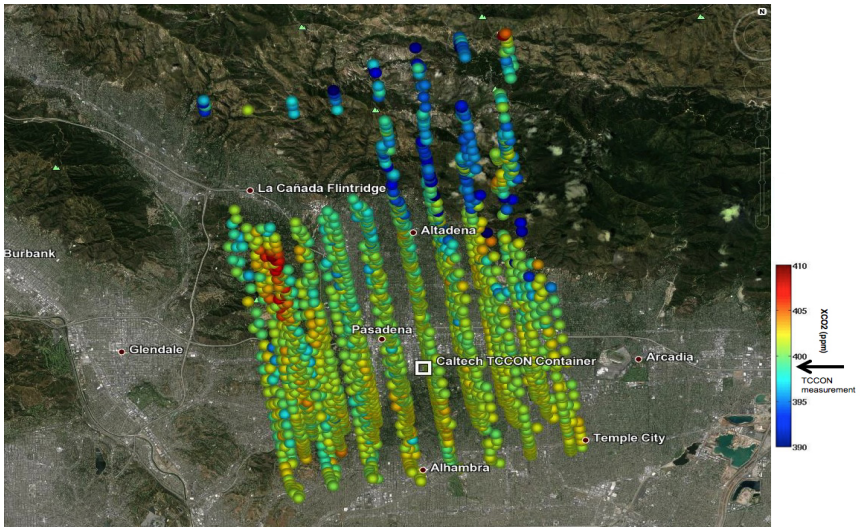

Figure 4: Image Credit: NASA-JPL

The image shows measurements of CO_2 levels over the northern LA Basin on September 5, 2014 made by OCO-2. Each dot is a single CO_2 measurement made during the satellite's 5-minute over-flight of the area. These measurements compared very well to those made by the ground-based TCCON instrument located in Pasadena, CA (402 ppm vs. 399ppm).

2014 Accomplishments

• The team ran a series of OCO-2 simulations to test the predicted OCO-2 errors. Through these retrievals, they found that the predicted and actual sensitivities were validated by varying the a priori values for CO_2. As part of this exercise, the team characterized the non-linearity of the retrieval system by comparing the results using different initial state values. In total, they performed 16 different kinds of retrievals, involving different prior CO_2 covariance matrices and different first guess CO_2 states, for a total of ~ 752 retrieval-orbits or roughly 400,000 individual retrievals.

• The simulation series described above was further updated by the team to test the propagated errors from aerosols, albedo, and other parameters.

• The NASA-ARC based OCO-2 researchers also coordinated closely with the rest of the OCO-2 team, located at NASA-JPL, on modifications to the retrieval code as necessary.

Publications and Presentations

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Indianapolis Flux Experiment (INFLUX) and Total Carbon Column Observing Network (TCCON)

NASA: Laura Iraci, Jim Podolskie
BAERI: Patrick Hillyard

The Total Carbon Column Observing Network (TCCON) is a network of ground-based Fourier Transform Spectrometers that record spectra of the sun at the Earth's surface in the near-infrared wavelengths. From these spectra, accurate and precise column-averaged abundances of atmospheric constituents including CO_2, CH_4, N_2O, HF, CO, H_2O(g), and HDO, are retrieved. Begun in 2004, TCCON provides important information about regional and global atmospheric levels of carbon-containing gases from many stations worldwide. Measurements of atmospheric gases made by the TCCON instruments are considered to be a highly accurate and thoroughly calibrated dataset and are often used as a standard in inter-comparison studies with other measurements.

As part of the TCCON network, ARC-CREST researchers and NASA-ARC partners deploy a Fourier Transform Spectrometer at NASA-AFRC. The NASA-ARC-based team remotely monitors, assesses, and maintains the hardware deployed at NASA-AFRC and also processes data according to the TCCON protocol, making it available to the scientific community. The TCCON team at NASA-ARC also supports the OCO-2 team by providing critical measurements at the ground-based targets needed for inter-comparison and calibration of the satellite instrument.

The Indianapolis Flux Experiment (INFLUX) was a greenhouse gas quantification experiment that focused on the "urban plume" emanating from the city and that utilized one of the TCCON Fourier Transform Spectrometers. This instrument was installed by ARC-CREST researchers and NASA-ARC partners in Indianapolis and acquired daily CO_2 column measurements through the summer and fall of 2012. The INLFUX team combined these measurements and others with "bottom-up" inventories of CO_2 and CH_4 from urban sources with the goal of evaluating these approaches and measurements in their ability to accurately quantify greenhouse gas emissions from urban sources. Remote sensing of atmospheric greenhouse gases is likely to be an important tool in monitoring global greenhouse gas budgets, including urban emissions.

The TCCON instrument used during INFLUX was re-deployed to NASA-AFRC in late 2012 by the NASA-ARC-based team for continued use in OCO-2 data calibration/validation and other missions. Analysis of the INFLUX data is on-going.

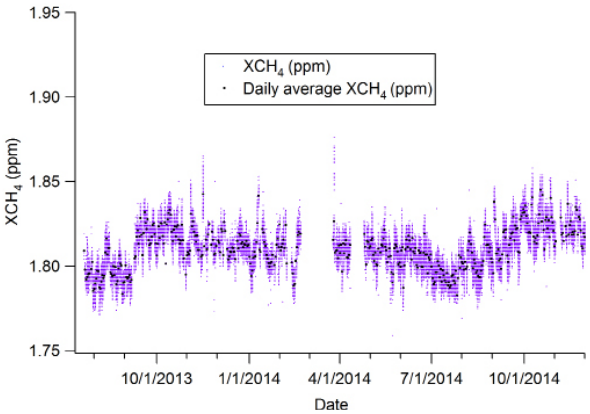

Figure 5: Column averaged, mole fractions of CH_4 in parts per million as measured by the TCCON instrument deployed at NASA-AFRC over the period July 2013 – November 2014. Daily averages are shown in black.

2014 Accomplishments

• The team completed analysis of all greenhouse gas data collected with the TCCON instrument during the fall 2012 field campaign and posted to the INFLUX/TCCON international data archive.

• With these datasets and in collaboration with other university and government scientists, the team studied changes in greenhouse gases around an urban center.

• ARC-CREST researchers supporting the TCCON instrument, located at NASA-AFRC, conducted many tasks related to the support and maintenance of the instrument and access and reliability of the TCCON data. In addition to regular communication and coordination with the TCCON science team, in 2014 project researchers:

o Maintained and managed the Linux workstation that is used for TCCON data processing and storage;

o Downloaded the data from NASA-AFRC, conducted quality control and quality assurance, and processed it according to the TCCON protocol in order to compare the data to other instruments in the network;

- Transferred all complete datasets to California Institute of Technology and archived completed datasets at NASA-ARC; and
- Reprocessed all data taken with this instrument to be consistent with the new TCCON software release (GGG2014);

• With the launch of the OCO-2 satellite instrument in mid-2014, the TCCON instrument began service as a key calibration and validation point for OCO-2. To support calibration and validation of OCO-2 with TCCON, the team:

- Performed close monitoring of the instrument in order to ensure it was operating properly during the OCO-2 inter-comparison, typically with less than 24 hour notice;
- Completed very rapid processing of data following OCO-2 targets for delivery to California Institute of Technology (a total of 7 targets since launch in July 2014); and
- Completed comparisons of TCCON profiles with those obtained from aircraft also being used for calibration and validation (Alpha Jet, DC-8, and ER-2);

• The team examined the ability of TCCON measurements to be used for urban air quality monitoring using data taken during the INFLUX experiment.

Publications and Presentations

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Hardesty, R. et al. (P. Hillyard, and J. Podolske among 24 authors), "One year of Doppler Lidar observations characterizing boundary layer wind, turbulence, and aerosol structure during the Indianapolis Flux Experiment" (A51O-03). Presented at American Geophysical Union Annual Meeting, December 15-19, San Francisco, CA.

Miles, N. et al. (P. Hillyard and J. Podolske, among 20 authors) "Greenhouse gas emissions of Indianapolis using a high-density surface tower network and an atmospheric inversion" (A51O-05). Presented at American Geophysical Union Annual Meeting, December 15-19, San Francisco, CA.

Butterfield, Z. et al. (J. Podolske, L. Iraci, and P. Hillyard, among 10 authors)"Compact Solar Spectroscopic Column CO2, CH4, H2O and HOD Observations: Performance Evaluation at TCCON Sites" (A41I-3174), (presented at American Geophysical Union Annual Fall Meeting, San Francisco, CA, December 15-19, 2014).

Hillyard, P. et al "Calibration of a TCCON FTS at Armstrong Flight Research Center (AFRC) Using Multiple Airborne Profiles" (A41I-3173), (presented at American Geophysical Union Annual Fall Meeting, San Francisco, CA, December 1519, 2014).

Kawakami, S. et al. (P. Hillyard, J. Podolske, L. Iraci, among 9 authors)"The total column of CO2 and CH4 measured with a compact Fourier transform spectrometer at NASA Armstrong Flight Research Center and Railroad Valley, Nevada, USA" (A41I-3171), (presented at American Geophysical Union Annual Fall Meeting, San Francisco, CA, December 15-19, 2014).

Tropospheric Emission Spectrometer (TES)

NASA: John Worden
BAERI: Susan Kulawik

The Tropospheric Emission Spectrometer (TES) is an infrared spectrometer flying aboard the Aura satellite, currently in Earth orbit. Its high spectral resolution enables it to measure concentrations of many chemical constituents in our atmosphere including: ozone (O_3), carbon monoxide (CO), water vapor (H_2O), peroxyacetyl nitrate (PAN), formic acid (CH_2O_2), methanol (CH_3OH), methane (CH_4), and other gases. Measurements made by TES advance our understanding of the atmosphere's chemistry, knowledge that is a prerequisite to addressing air pollution and climate change. TES focuses on the troposphere, the layer of atmosphere that stretches from the ground to approximately 32,000 ft. TES can distinguish concentrations of gases at different altitudes, a key factor in understanding their behavior and impact. It is the first orbiting instrument able to measure ozone profiles, a very important chemical with regard to both global warming and air pollution.

ARC-CREST researchers and their partners at NASA-JPL are analyzing and interpreting TES data, making high quality TES data products available to the scientific community.

Their work requires close coordination with the NASA Distributed Active Archive Center where these large datasets are hosted. Further, they work closely with the TES science team to expand the retrieval algorithms to capture additional atmospheric gas concentrations, to improve existing algorithms by reducing or better quantifying errors, and to conduct comparisons with other satellite or ground-based retrievals.

Publications

Kulawik, S. et al. 2014. Estimating biases and errors of CO2 from satellites (AIRS, GOSAT, SCIAMACHY, TES, OCO-2) and models (CarbonTracker, MACC). 10th International Workshop on Greenhouse Gas Measurements from Space, ESA/ESTEC, May 5-7, Noordwijk, The Netherlands.

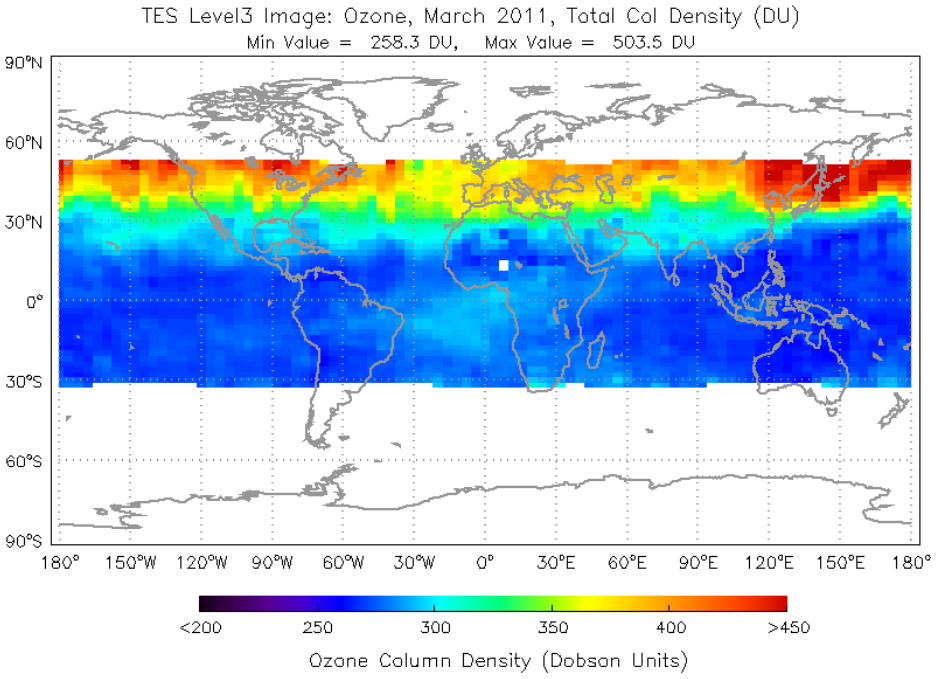

Figure 6: An example of data collected by the TES instrument. The figure is a global image of the total column density of ozone for the month of March in 2011. The ARC-CREST members of the TES team work to continually improve and expand the retrieval algorithms for TES data products.

2014 Accomplishments

• The TES team, led by Dr. Susan Kulawik, implemented and supported the development and launch of several new TES products or capabilities. In 2014, the NASA-ARC-based TES team:

o Implemented a new capability within the TES production code to process data from different and multiple satellites;

o Validated absorption coefficient updates for v005 release;

o Supported OCS and PAN development through prototype runs;

o Tested and evaluated the TES+OMI and AIRS + OMI ozone products;

o Oversaw the implementation of new OCS, HCOOH, and CH_3OH TES products;

o Worked with the software team to transition TES Lite products to produce these for hosting at the DAAC; and

o Contributed to the TES science team with a particular focus on CO_2.

CLIMATE VARIABILTY AND CHANGE

Arctic Radiation-IceBridge Sea and Ice Experiment (ARISE)

NASA: Jens Redemann
BAERI: Michal Segal-Rozenheimer, Yohei Shinozuka

The ARISE mission used aircraft and surface-based sensors to understand the relationship between changes in Arctic ice and regional energy budgets as influenced by clouds. Based out of Eielson Air Force Base, Fairbanks, Alaska, the NASA C-130 completed more than 28 science flights and registered over 200 science flight hours between August and October 2014. The mission had two science teams: 1) a radiation team to measure outgoing and incoming solar and thermal energy and 2) the IceBridge team to measure sea ice coverage and surface albedo (reflectivity). The IceBridge team simultaneously fulfilled requirements of the on-going Operation Ice Bridge (OIB) campaign while also contributing to the ARISE science mission.

Instruments deployed on the C-130 during ARISE were: the Solar Spectral Flux Radiometer (SSFR); the Broad-Band Radiometer (BBR); the Spectrometer for Sky-scanning, Sun-tracking Atmospheric Research (4STAR); the Land, Vegetation and Ice Sensor (LVIS); a geo-located digital camera; the National Polar-orbiting Operational Environmental Satellite System Airborne Sounder Test bed (NAST-I); and various in situ probes.

Figure 8: The C-130 lands at Eielson Air Force base in Fairbanks Alaska after completing a science flight during the ARISE mission in September 2014.

This scientific payload measured spectral and broadband radiative flux profiles, quantified surface characteristics, cloud properties, and other atmospheric state parameters under a variety of Arctic atmospheric and surface conditions (including open water, sea ice, and land ice) and coinciding with satellite overpasses when possible. Long-term monitoring stations, research vessels, and other surface and aircraft in-situ measurement missions providing information on surface conditions, radiation, cloud properties, and atmospheric state were used to complement the data collected by the NASA C-130. ARC-CREST researchers deployed the 4STAR instrument on all science flights and are currently working with the rest of the ARISE science team on data archiving, analysis and interpretation.

2014 Accomplishments

- The ARISE team at NASA-ARC collected aerosol optical property and trace gas data during more than 60 hours of science flight time. During the mission the team performed instrument preparation and calibration, real-time data analysis and development of operational codes.

- The method of comparing thin cirrus retrievals from sun photometers developed by Segal Rosenhaimer et al., 2013 was applied to the 4STAR datasets to produce preliminary cirrus optical depth during ARISE.

- New retrieval algorithms of cloud phase and cloud properties were also applied to the 4STAR measurements taken during ARISE. The team began development of a methodology and framework to perform cloud radiative forcing calculations under the various conditions observed in ARISE. This includes open ocean and sea ice conditions as well as a method to generalize cloud phase derivation from hyperspectral zenith spectra taken by the 4STAR instrument.

- The team continues to coordinate with and provide support to the scientific community utilizing ARISE data products from the 4STAR instrument.

Earth Science Data Records (ESDR)

NASA: Steve Hipskind
BAERI: Susan Kulawik

The ESDR project supports the NASA Earth Science Data Systems Program. The Program's mission is to both manage and expand the many Earth science data records obtained from NASA satellites, airborne platforms, ground stations and other sources. Management of these datasets includes archiving, algorithm development, calibration and validation, processing, quality control, and continued support to the user community. One component of the ESDR Program, the Earth System Data Records Uncertainty Analysis, seeks to extend and enhance Earth system data records used by NASA communities, including climate data records, through rigorous estimation of errors. Projects under the Earth System Data Records Uncertainty Analysis umbrella increase the scientific value of the measurements by identifying and validating systematic uncertainties in input data and physical models and improving error estimations.

ARC-CREST scientists are working on developing and validating long-term records of atmospheric trace gases, including CO_2. They are using multiple remote sensing derived data products, as well as airborne and ground-based data to create long-term, consistent data records of atmospheric CO_2 and other trace constituents. This data can be used for mitigation of natural hazards, K-12 science education, and other societal benefits.

2014 Accomplishments

- The ESDR team, led by Dr. Susan Kulawik, compared measurements of carbon dioxide (CO_2) as measured from satellites (TES, AIRS, GOSAT) and estimated from models (Carbon Tracker, and MACC) to aircraft data, starting with comparisons to the HIAPER Pole to Pole Observations (HIPPO).

- In connection with the work above, the team updated comparisons between SCIAMACHY, GOSAT, MACC, and Carbon Tracker to TCCON to the latest data versions available, with a manuscript in preparation. This next year will focus on additional aircraft sets, including sets co-located at TCCON sites and integrating OCO-2 into the analysis.

- Dr. Susan Kulawik presented at the OCO-2 science meetings (January 28-30, 2014, Pasadena, CA) and IWGGMS-10 (May 5-7, Noordwijk, Netherlands).

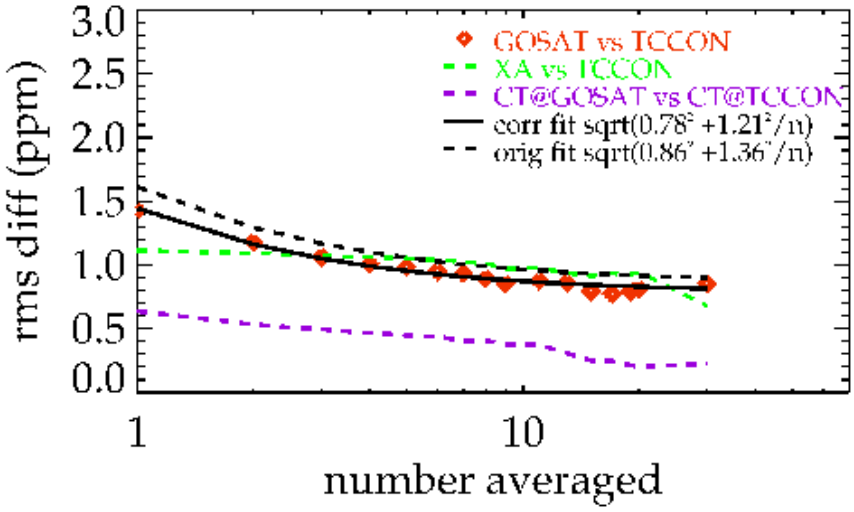

Figure 9: The ARC-CREST ESDR team is working with multiple measurements of CO_2, seeking to optimize the processing of this data for minimum error. In the plot above, the team is comparing the standard deviation in measurements of CO_2 in parts per million from GOSAT satellite to that of those from the TCCON ground network (red) and predictions from the CarbonTracker model (green). This plot shows that averaging only 3 GOSAT observations results in greatly reduced error.

Publications and Presentations

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Oetjen, H. et al. (Susan Kulawika among 10 authors). "Extending the Satellite Data Record of Tropospheric Ozone Profiles from Aura-TES to MetOp-IASI" (A33I-3313). Presented at American Geophysical Union Annual Meeting, December 15-19, San Francisco, CA.

Fu, D. et al. (Susan Kulawik among 16 authors). "Improved Ozone Profile Retrievals Using Multispectral Measurements from S-NPP and NASA "A Train" Satellites" (IN13C-3664). Presented at American Geophysical Union Annual Meeting, December 15-19, San Francisco, CA.

Deng, F. et al. (Susan Kulawik among 7 authors). "Quantifying Regional Sources and Sinks of CO_2 Using Data From GOSAT and TES" (A41G-3141). Presented at American Geophysical Union Annual Meeting, December 15-19, San Francisco, CA.

Luo, M. et al. (Susan Kulawik among 9 authors). "Introducing and Validating the New Aura CO Product Derived from Joined TES and MLS Measurements" (A33I-3319). Presented at American Geophysical Union Annual Meeting, December 15-19, San Francisco, CA.

Kuai, L., John Worden, Meemong Lee, J Elliott Campbell, Susan Kulawik, Richard Weidner. "Optimal Estimation of the Carbonyl Sulfide Surface Flux Through Inverse Modeling of TES Observations" (A13L-3334). Presented at American Geophysical Union Annual Meeting, December 15-19, San Francisco, CA.

Making Earth System Data Records for Use in Research Environments (MEaSUREs)

NASA: Cristina Milesi
BAERI: Pardha Teluguntla

The MEaSUREs project is also is part of NASA's Earth Science Data Systems Program, the mission of which is to both manage and expand the many Earth science data records obtained from NASA satellites, airborne platforms, ground stations, and other sources. The MEaSUREs project monitors global croplands to ensure sustainable water and food security. Development and maintenance of these data records are important to climate scientists, agricultural scientists, farmers, natural resource managers, and national leaders.

The currently available cropland products suffer from major limitations such as:
• Absence of precise spatial location of the cropped areas;
• Coarse resolution of the map products with significant uncertainties in areas, locations, and detail;
• Uncertainties in differentiating irrigated areas from rainfed areas;
• Absence of crop types and cropping intensities; and
• Absence of a dedicated web/data portal for the dissemination of cropland products.

Using MODIS data, Landsat data and three different cropland mapping algorithms to create the Global Cropland Area Database at a nominal spatial resolution of 30m (GCAD30) products, ARC-CREST researchers working on the MEaSUREs project are closing these gaps by producing four products: 1) Cropland extent/area, 2) Crop types with focus on 8 crops that occupy 70% of the global cropland areas, 3) Irrigated versus rain fed areas, and 4) Cropping intensities: single, double, triple, and continuous cropping.

The data and products will be disseminated through the USGS Powell Center Global Croplands Working Group web portal (https://my-beta.usgs.gov/wggc/). The MEaSUREs team is also creating GCAD products for 1990 and will characterize global cropland dynamics since the 1980s using AVHRR, MODIS and other available data. Similar to the ESDR project, MEaSUREs has a strong focus on assessing the accuracy and uncertainties of the data products.

MEaSUREs, through creation of the GCAD30 database, is making significant contributions to Earth System Data Records, the Group on Earth Observations, Agriculture and Water Societal Beneficial Areas, the Global Agricultural Monitoring Initiative, and the recent "Big Data" initiative by the White House. The project has the support of USGS Working Group on Global Croplands.

2014 Accomplishments

• The team produced the first Global Cropland Extent (v1) maps at a nominal 1 km resolution and released the maps through Google Earth Engine and through the Land Processes Distributed Active Archive Center.

• The team began work, focusing on Australia, on version 2 of the Global Cropland Extent (GCE) maps at a higher resolution of 250 m. The team began development of the Automated Cropland Classification Algorithm for Australia and completed an extensive field campaign in Australia to collect Ground Reference data points for different crop types.

• The team presented methods and approaches for mapping GCEV1.0 and GCEV2.0 at conferences in Menlo Park, CA and Sioux Falls. IA.

NASA Earth Exchange (NEX)

NASA: Rama Nemani
BAERI: Sangram Ganguly, Gong Zhang, Abishek Rajkumar, Lisa Waring, Parker Abercrombie, Ed Maurer, Bridget Thrasher, Ed Boyda, Hengyue Zhang, Supratik Mukhopadhyay, Ranga Myneni, Andrew Kumler and Felicia Chiang
CSUMB: Forrest Melton, Petr Votava, Alberto Guzman, Hirofumi Hashimoto, Andrew Michaelis, John Shupe, Weile Wang
University of California, Berkeley: Maggi Kelly,

Under the NASA Earth Exchange (NEX) project (Nemani et al., 2011), ARC-CREST scientists and software engineers collaborated with scientists and engineers in the NASA Ames Earth Science Division and the NASA Advanced Supercomputing (NAS) Division to implement a first of its kind, collaborative supercomputing environment for global change research.

ARC-CREST researchers support the further development of NEX. They build and incorporate new technologies and extend NEX capabilities for research and applied science. Since its inception in 2011, the NEX project has evolved from having a single focus on ecological forecasting to providing access to large datasets, supercomputing capability, and the support of online collaborative space, thereby maximizing the scientific output of NASA's satellite data products and climate models and greatly facilitating collaboration in a way that was not previously possible. NEX maintains a large set of satellite observation and climate model data for use by NASA-supported researchers who are tackling science questions over large regional or global areas. NEX brings the Earth science community members into a virtual collaborative, where scientists can process large data sets, run model codes, and share the results and knowledge. As the data products and models available within NEX and the community utilizing NEX grow, the support needed to maintain this unique collaborative environment also grows.

ARC-CREST researchers collaborate closely with scientists in NASA Ames Earth Science Division, as well as the broader NASA Earth science community to apply NEX capabilities in assessing 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 also supports applied science activities, such as development of indicators of climate change impacts for Landscape Conservation Cooperatives and NASA Centers, development of information products to support land managers, agricultural producers, and water managers throughout the U.S. NEX also supports monitoring and modeling of natural disasters and emerging public health threats.

NEX is currently funded by NASA as an "Enabling Tool" to support the National Climate Assessment (related research and "Sustained Assessment" activities). NEX is now also part of the Big Data and Climate Data initiatives that aim to promote the use of government data for creating new solutions for climate change. The OpenNEX initiative, a collaboration between NASA and Amazon Web Services, develops cloud-hosted tools and solutions for dealing with satellite and climate data (e.g. virtual labs) and also climate science through lectures by experts and challenges. Development of these tools and maintenance and administration of the OpenNEX platform are also done by ARC-CREST researchers. Additional information about NEX can be found at: https://nex.nasa.gov/nex/

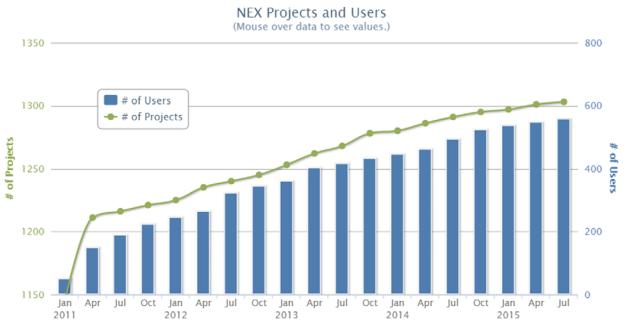

Figure 10: The NEX community of users has grown substantially over the past 3 years. ARC-CREST researchers now provide support for over 1300 projects and nearly 600 users. NEX is a one of its kind virtual platform for studying and collaborating on Earth science projects.

2014 Accomplishments

• ARC-CREST researchers working on the NEX project launched the OpenNEX2014 Virtual Workshop and OpenNEX2014 Virtual Challenge. For the workshop and challenge, the team created original web content in three areas, all centered on the Open-access NEX datasets, which are housed on the Amazon Web Service. The team created:

1. Keynote lectures given by over 10 experts in the field and speaking on various aspects of climate change assessments and data analyses;

2. A series of six hands-on labs, equipped with video instructions and companion Amazon Web Service virtual computers; the labs demonstrate how to access Open NEX datasets and computational tools;

3. A two-phase (ideation and implementation, respectively) competition or 'challenge' inviting the National Climate Assessment (NCA) community as well as the general public ("citizen scientists") to compete for prizes by designing and implementing solutions for climate assessment applications, new data access technology, or data visualization tools. Since the launch of the workshop on June 21st, 2014, the team's video lectures and virtual labs have attracted more than 4,000 viewers and more than 500 registered participants for the OpenNEX challenges. The winners were announced at the annual AGU meeting in December 2014.

• The team expanded the climate downscaling capability of NEX by building a set of on-demand downscaling tools that allow users to interactively produce daily climate projections based on CMIP5 simulations for any grid point or region over the coterminous United States at a 1km spatial resolution.

• The team collaborated with Showtime, Google, and the University of Maryland to film an episode of the Emmy-winning Showtime series "Years of Living Dangerously" (http://yearsoflivingdangerously.com/). NEX datasets were featured in the first episode of the 8-part series.

• Under the newly awarded NASA ACCESS project, the team set up a prototype analytics infrastructure using SciDB (an array database developed by Paradigm 4) and started testing the system using MODIS and AVHRR datasets on OpenNEX.

• In collaboration with HabitatSeven, NEX team members developed visualization tools for NEX-Downscaled Climate Predictions at 30m resolution (NEX-DCP30). Each projection includes monthly averaged maximum temperature, minimum temperature, and precipitation for the periods from 1950 through 2005 (Retrospective Run) and from 2006 to 2099 (Prospective Run). HabitatSeven and NEX team members were invited to the White House to present the interface to the OSTP and the USGCRP;

• In collaboration with researchers at University of Maryland, College Park, the team developed a physical algorithm for large-scale retrieval of leaf area index (LAI) and Vertical Foliage Profile from the Spaceborne Waveform Lidar (GLAS/ICESat);

• In support of the North American Carbon Program's North American Forest Dynamics project and in collaboration with the U.S. Forest Service, U.S. Department of Agriculture (USDA) and the University of Maryland (Goward et al., 2008 and Goward et al. 2012) the team produced time series maps of forest disturbance and regrowth in 55 unique areas in the U.S. Data products produced from this project http://dx.doi.org/10.3334/ORNLDAAC/1077;

• The team participated in an international effort to compare various models to better understand global carbon cycling at various temporal and spatial scales (Huntzinger et al. 2013; Zscheischler et al. 2014);

• The team continued to support the NEX platform and growing NEX community through the following activities:

1. Organized three NEX User Working Group meetings;

2. Completed the NEX data management plan;

3. Integrated the new provenance capture system with NEX and made it accessible to all supercomputing users at NASA;

4. Completed two rounds of NEX data system requirements;

5. Continued testing of the new web portal and content moderation component for the portal;

6. Built a complete Landsat data processing pipeline and completed the first 3-year epoch of global Landsat products under the WELD (Web-enabled Landsat Data) project together with our collaborators from South Dakota State University and U.S. Geological Survey (USGS);

7. Completed testing of the interface between Pleiades computer nodes and NEX database infrastructure;

8. Continued development of ticketing user support system for NEX that is integrated with NAS user support services; and

9. Supported 181 active NEX science platform users (up from 158 in FY13, and 503 registered members for the NEX portal (up from 420).

Figure 11: A screenshot of the OpenNEX Challenge portal. The Challenge conducted and completed in 2014, provided virtual lectures by climate experts, computational tools and virtual labs for using and accessing data and a challenge inviting participants to compete for prizes designing and implementing solutions for climate change impacts. Winners were announced at the Fall AGU Meeting in December 2014.

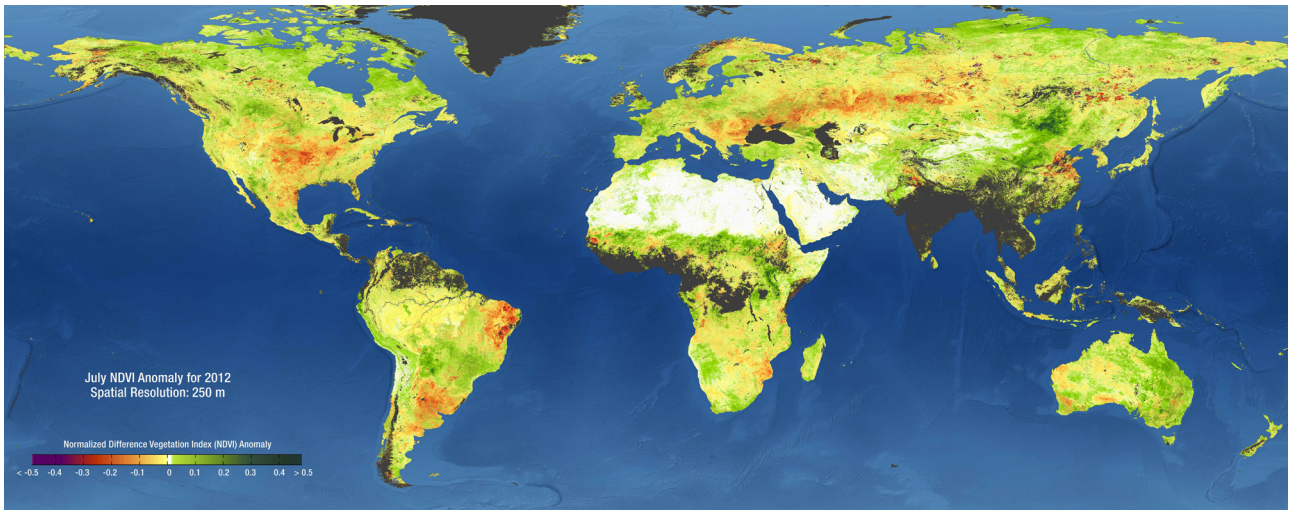

Figure 12: A map showing global drought for July 2012 as indexed by the Normalized Differential Vegetation Index Anomaly or NDVI Anomaly. NDVI is determined from measurements made by the satellite-based AVHRR instrument. Red areas indicate areas with lower than normal growing conditions, most likely due to drought. This image, developed by the NEX team, was featured in the Showtime Movie, 'Years of Living Dangerously'.

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Votava, P., Andrew Michaelis, Sangram Ganguly, and Ramakrishna Nemani. "Using Analytics to Support Petabyte-Scale Science on the NASA Earth Exchange (NEX)" (IN53A-3788, Invited). Presented at American Geophysical Union 2014 Annual Meeting, San Francisco, CA.

Milesi, C. et al. "Mapping Urban Expansion Across North America Using Multi-Temporal Landsat and Nighttime Lights Data" (B43E-0286). Presented at American Geophysical Union 2014 Annual Meeting, December 15-19, San Francisco, CA.

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Mukhopadhyay, S., Subhajit Sidhanta, Samrat Ganguly, Sangram Ganguly, and Ramakrishna Nemani. "Cost Optimal Elastic Auto-Scaling in Cloud Infrastructure" (IN31B-3719B, Invited). Presented at American Geophysical Union 2014 Annual Meeting, December 15-19, San Francisco, CA

Saatchi, S. et al. (Sangram Ganguly, Ramakrishna Nemani, and Gong Zhang among 13 authors). "Geography of Global Forest Carbon Stocks & Dynamics" (B54G-02). Presented at American Geophysical Union 2014 Annual Meeting, December 15-19, San Francisco, CA.

Boyda, E. et al. "A Semi-Automated Machine Learning Algorithm for Tree Cover Delineation from 1-m Naip Imagery Using a High Performance Computing Architecture" (IN21A-3698). Presented at American Geophysical Union 2014 Annual Meeting, December 15-19, San Francisco, CA.

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Ganguly, S., et al. "Long-Term Data Records of Biophysical Parameters from Multiple Satellite Systems" (B53G-01, Invited). Presented at American Geophysical Union 2014 Annual Meeting, December 15-19, San Francisco, CA.

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CARBON CYCLE AND ECOSYSTEMS

Carbon Monitoring Systems (CMS)

NASA: Rama Nemani
BAERI: Sangram Ganguly, Sungho Choi

The NASA CMS program, initiated and directed through a 2010 Congressional Appropriation, is a forward-looking initiative, the goal of which is to make significant contributions in characterizing, quantifying, understanding, and predicting the evolution of global carbon sources and sinks through improved monitoring of carbon stocks and fluxes. Accurate monitoring of carbon sources and sinks from space-borne measurements and modeling techniques is key to reducing carbon emissions and abating climate change due to carbon-induced warming of the atmosphere.

A major piece of the larger CMS program is the quantification of regional-to-continental forest Aboveground Biomass (AGB) and forest canopy height using a host of satellite-derived data, ground data, and physical models. Forest canopy height and AGB are key biophysical parameters needed to understand local, regional, and global carbon cycles and serve as an important input to a variety of climate and ecosystem models. Satellite-based observation and/or geospatial predictors (e.g., climate variables) represent a vast improvement over existing AGB and forest canopy height datasets derived from ground measurements. Because these measurements are extremely labor-intensive to make, they are limited in spatial and temporal coverage and impractical for large-scale monitoring.

ARC-CREST and NASA researchers are estimating forest cover for the continental U.S. at spatial resolution of 1-m, greatly reducing uncertainties in the AGB estimation. The team is using a state-of-the art machine learning algorithm and segmentation algorithms to delineate tree cover from the USDA National Agricultural Imagery Program (NAIP) Imagery. The generated 1-m forest cover map will be aggregated to the Landsat spatial grid to demonstrate differences in AGB estimates (pixel-level AGB density, total AGB at aggregated scales like eco-regions and counties) when using a native 30 m forest cover map versus a 30 m map derived from a higher resolution dataset. A LiDAR-derived AGB estimate at the 30 m scale is being used to aid in true validation. This work is necessary for quantifying errors and uncertainties in NASA CMS products. This work is an extension of previous CMS Phase II work which demonstrated the use of Landsat-based estimates of Leaf Area Index and ICESat Geoscience Laser Altimeter System (GLAS) derived canopy heights for estimating AGB at a 30 m spatial resolution and which compared relatively well with inventory-based plot level (ground-based) estimates.

2014 Accomplishments

- The team developed a first of its kind map of aboveground carbon stocks for California at 30 m spatial resolution. The team used a combination of remote sensing products combined with ground inventory data to create and share the map via the NEX platform.

- The team developed additional map products showing the change in carbon stocks in California from 2001 to the present, primarily using MODIS time series. Unique to this analysis was the construction of a parallel computing framework to accommodate the massive time series analysis. With this framework the team detected the magnitude of disturbance in forested pixels and estimated the corresponding date of disturbance for two golden tiles covering the east coast and the west coast of the coterminus United States.

- Using the Allometric Scaling and Resource Limitations model, the team developed theoretical relationships between tree height and available, evaporative, and basal metabolic flow rates. These relationships were then used to generate predictions of maximum forest height for forested areas across the continental U.S. and to compare them to actual reference height data by region and accounting for forest age.

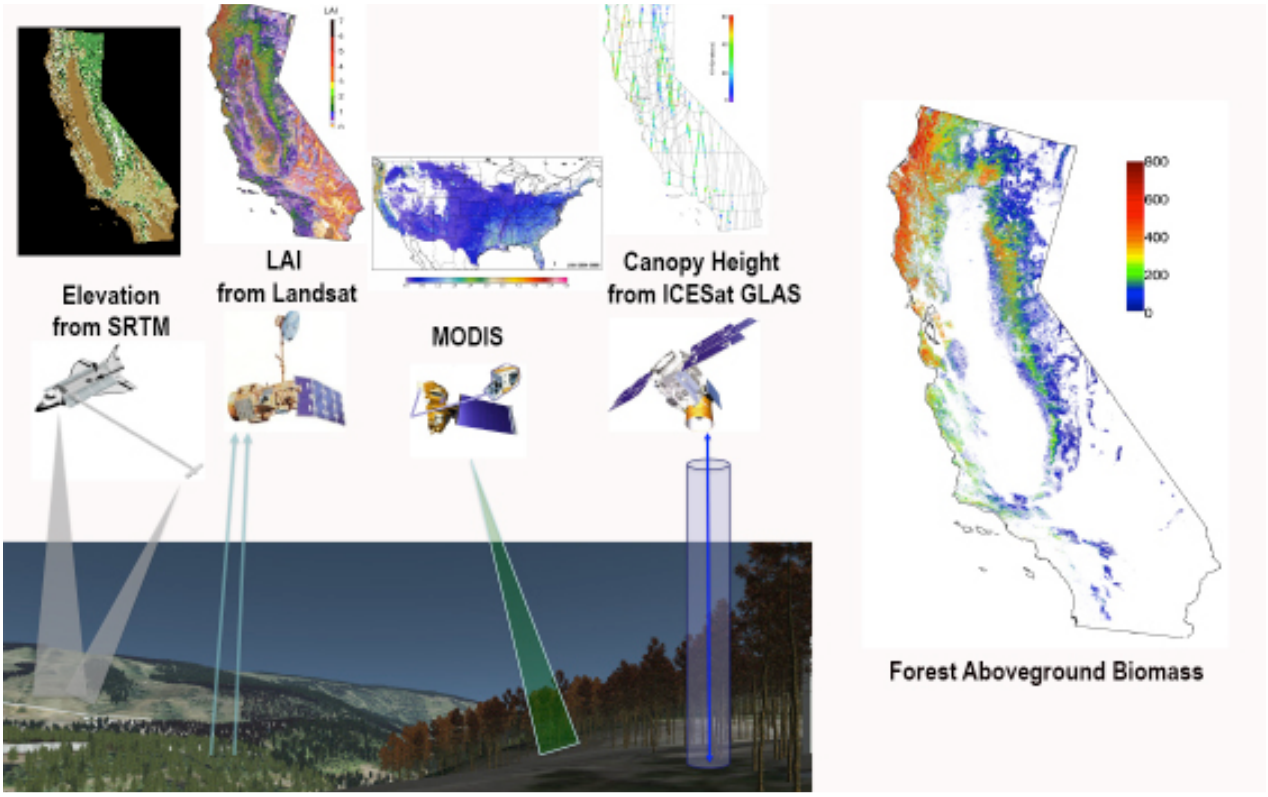

Figure 13: Maps of above-ground forest biomass like the one on the right for the state of California are created by the CMS team using data products from several satellite based sensors shown above.

Publications and Presentations

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Plant Physiology

NASA: Dave Bubenheim
BAERI: Dave Wilson, Greg Schlick

ARC-CREST researchers on the Plant Physiology team are studying the ecophysiology of biological systems in both synthetic and natural environments. In natural environments, the team is investigating how plants respond to environmental toxicity, bioremediation, and adaptation to climate change, as well as how invasive plant species impact ecosystem functions. This is especially important as the range of many plant species is expected to change with changing climate and associated changes in resource availability. As the climate changes, different types of plants may be co-located that were not historically within the same ecosystem.

The team uses a variety of techniques including: forward osmosis for determining toxicity thresholds; growth chambers and experiments to induce phenology changes; and soil water dynamic studies and remote sensing techniques (e.g. hyper-spectral imaging to view accumulation of toxins). These techniques are also used to investigate carbon flux and plant physiology.

Finally, the Plant Physiology team is developing "Sustainable, Closed Ecology Systems" to provide life support for space travel and other planetary habitats. Using plants to produce food, oxygen, and water while removing CO_2 from the air and recovering nutrients from wastes is important to achieving sustainable, self-sufficient human settlements in space or on other planets.

2014 Accomplishments

- Continuing work begun in 2013 to set up and initiate this project, the team built culture tanks for native and invasive aquatic plants from the Sacramento/San Joaquin Delta region and developed culture techniques for these species.

- In support of the Controlled Ecological Life Support System Antarctic Analog Project, the team began retrofiting large walk-in chamber for aquatic plant culture and for use in spectral analysis. The team also tested and identified water quality issues affecting aquatic plant culture in the new chamber.

- The team worked with California Boating and Waterways personnel to map and identify regions of aquatic plant populations in an 8-mile tract area and collected multiple species of plants, including plants of primary interest, Egeria densa and Potamogeton crispus.

Figure 14: Potamegon crispus, or curlyleaf pondweed is an invasive species in California and can become problematic in managed waterways such as irrigation canals. The team worked with California officials in 2014 to map areas of this and other invasives.

Image Credit: Chris Evans, Illinois Wildlife Action Plan, Bugwood.org

Terrestrial Ecosystem and Carbon Simulation Modeling

NASA: Chris Potter
CSUMB: Steven Klooster; Vanessa Brooks Genovese, John Shupe

The ARC-CREST Terrestrial Ecosystem and Carbon Simulation Modeling group studies the movement of carbon through, and the storage of carbon within terrestrial ecosystems. The primary goal of this research is the accurate quantification of the carbon fluxes and storage pools under current conditions and how they might change in response to external forcing such as global climate warming, and changing land use patterns. The NASA-CASA Ecosystem modeling framework, developed by this research group, has been implemented to estimate historical as well as current monthly patterns in plant carbon fixation, living biomass increments, and long-term decay of woody (slash) pools before, during, and after land cover disturbance events such as fire or clearing for agriculture.

The team also supports the SilvaCarbon program, the United States' contribution to the Global Earth Observation System of Systems (GEOSS). GEOSS is a U.S.-led technical assistance program for resource managers, decision makers, and emergency managers around the world and provides data and information about a variety of Earth observations.

The ARC-CREST team is also involved in the U. S. Agency for International Development's Forest Carbon, Markets and Communities (FCMC) program. This program's core mission is to build technical capacity by developing tools and training that support USAID and SilvaCarbon contributions to the Reducing Emissions from Deforestation and Forest Degradation (REDD+) program. The team provides technical support to users of SilvaCarbon and FCMC by posting user guides (in English and Spanish) on their website accompanied by methods for using the CASA-CQUEST model's annual change in forest carbon. This model output defines the upper limit for the amount of harvested wood products that can be removed and still avoid degradation (net loss) of the total wood carbon stock over that same time period. One of the first products the team developed was used for a REDD+ project in Borneo, Indonesia.

The ARC-CREST Terrestrial Ecosystem and Carbon Simulation Modeling group has also been working for the past 3 years under the federally funded National Climate Assessment project. As part of this assessment the team is determining which variables are most closely associated with high sustained forest production and CO_2 sinks in the U.S. over the past decade and which variables are most closely associated with unsustainable forest production and large annual CO_2 emissions. Also, in support of the National Climate Assessment, the CASA model is being used to predict changes in forest net primary productivity and to quantify annual carbon sinks or source fluxes from all forested lands in the continental U.S. This work is important for an accurate United States' greenhouse gas inventory and understanding the potential for forest carbon sequestration within the U.S.

Figure 15: The team provides support to users of SilvaCarbon, a technical assistance program sponsored by U.S. agencies and intended for forest managers around the world who use SilvaCarbon's models and outputs to understand changes in forest carbon.

2014 Accomplishments

• The team improved the NASA-CASA model algorithms, allowing a more accurate representation of environmental processes in specific regions of interest.

• For the SilvaCarbon project, the team continued to evaluate degradation of the forests in Vietnam, Indonesia, Peru, and Gabon using Landsat 8 imagery inputs to the CASA model.

• Landsat ETM+ images for the study sites were processed and region-wide estimates of forest net primary production (NPP) at 30 meters spatial resolution were generated, also for the SilvaCarbon project.

• The team continued their support of the National Climate Assessment, updating the results of this analysis with the recent years' satellite data.

• For the National Climate Assessment, the team ran the model with several different scenarios representing a "normal" scenario and a "removal" scenario where the forests are harvested and removed and the by-products are spatially redistributed.

• The team completed several computer server updates and development projects such as adding additional data output options to the CASA model like GeoTIFF.

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Potter, C. "Regional analysis of NASA satellite greenness trends for ecosystems of arctic Alaska", Intl. Journal of Geosciences 5(2014): 997-1006.http://dx.doi.org/10.4236/ijg.2014.59085

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Coastal Ocean Biology

NASA: Liane Guild
BAERI: Juan Torres-Perez, Sherry Palacios

The Coastal Ocean Biology project is using remote sensing tools and analysis techniques to assess the health of coastal and marine ecosystems (CMEs) in Puerto Rico. The CMEs in Puerto Rico have been severely impacted in recent decades by human activities including: the construction of river dams; urban expansion, continuing agricultural activities, intensive deforestation, and sand extraction. These activities affect the supply of sediment, nutrients, and contaminants to coastal waters. In particular, the coverage of mangroves that provide a variety of critical ecosystem services has diminished.

Figure 16: ARC-CREST researcher Dr. Juan Torres-Perez takes measurements of corals off of Puerto Rico's south coast to better understand changes to this environment from riverine inputs.

ARC-CREST researchers are using remote sensing capabilities to define the changes in CME spatiotemporal distribution over the period 1936-2015. Airborne and satellite sensors (multi and hyperspectral) used include: Landsat ETM+, Landsat 8 OLI, MODIS, AVIRIS, and HICO. The goals of this research are: 1) to conduct an interdisciplinary study using sound mapping technologies and hydrological modeling in order to infer how anthropogenic activities related to land cover/land use changes have modified riverine inputs into the CMEs of two priority watersheds located on the north and south coasts of Puerto Rico and 2) to combine outputs from field measurements within CMEs, ecological modeling, and economic valuation methods to assess the degradation of the selected watersheds.

2014 Accomplishments

• ARC-CREST staff person and Coastal Ocean Biology projects team lead, Dr. Juan Torres-Perez got the project off to a successful start by: 1) leading monthly coordination meetings with University of Puerto Rico collaborators; 2) creating schedules and staffing matrices for field work and other major deliverables as well as other project management tools for the team; 3) presenting the project in the annual Biodiversity and Ecological Forecasting/Ocean Color Research Team meeting in Washington DC; 4) connecting with teams of other related, NASA-funded research projects and 5) establishing collaborations with NGOs and other federal agencies at the 32nd US Coral Reef Task Force Meeting in Maui.

• The team collected benthic coral reef data for multiple sites on the southwest coast of Puerto Rico and installed multiple underwater sediment traps at the study sites.

• The team collected around 3,000 photo grids, characterizing six different reefs along the southwest coast of Puerto Rico.

• For the HyspIRI Preparatory Mission in Monterey Bay, the team collected field spectral information at Pinto Lake in Watsonville and at a white target site in Moss Landing for the validation of airborne images obtained with the AVIRIS and MASTER sensors on-board the ER-2 aircraft.

Publications and Presentations

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Palacios, S. et al. "Bringing the ocean into finer focus through the NASA COAST, HyspIRL and OCEANIA suborbital missions" (OS41A-1176). Presented at American Geophysical Union Annual Meeting, December 15-19, San Francisco, CA.

Disaster Management

NASA: Jim Brass
CSUMB: Vince Ambrosia, Robert Dahlgren

NASA and the U.S. Forest Service (USFS) have collaborated since the 1990's in the development and use of unmanned aircraft systems (UAS) and improved remote sensing systems to better support the observations of wildfires. ARC-CREST researchers are part of this on-going collaboration. Over the past decade, the team has progressed from mission design concepts to conducting actual UAS emergency support data collection flights over wildfires in California and the western US in 2006-2009. During these flights, NASA and USFS successfully demonstrated the UAS as a wildfire sensing platform, and the payload and associated data analysis and communications suite as a much improved tool for wildfire decision support.

Since 2010, this work has evolved with the primary objective of NASA and ARC-CREST researchers being to improve how remote sensing data is used and to analyze data acquired by manned aircrafts and UASs for environmental monitoring and management.

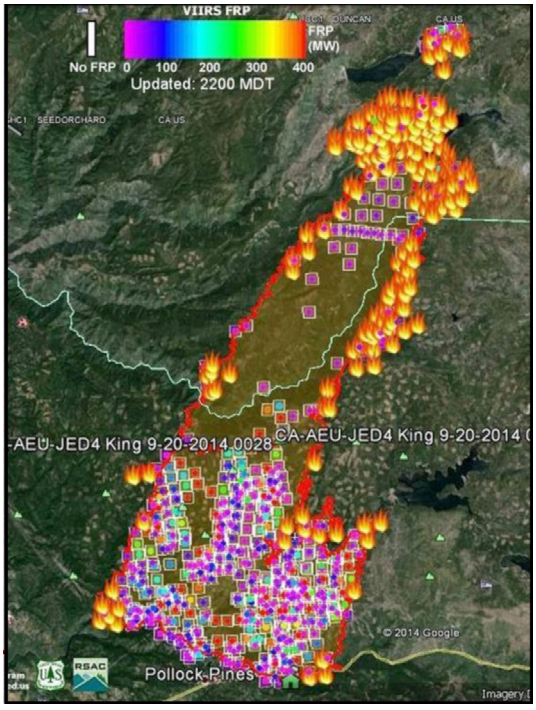

Figure 17: At the October 2014 Tactical Fire Remote Sensing Advisory Committee Meeting, CalFire representatives reported that California Fire Agencies used remote sensing on 55 incidents in 2014 with 348 flights. Remote sensing data for the King Fire in September 2014 is shown above.

2014 Accomplishments

• The team made recommendations to the NASA Applied Science Program for 9 Phase II wildfire projects. These projects, if conducted, would build upon highly successful Phase I work where ARC-CREST scientists and NASA partners developed payloads for measuring and imaging forest fires from an airborne platform and demonstrated the use of UAS to gather, analyze, and display fire data in real time to fire fighters on the ground. To make recommendations, the team organized and managed a two-day peer review panel of 13 members from the fire science community.

• The team attended the NASA Wildfire Program meeting, made presentations, and worked to develop collaborations for future wildfire focused projects between NASA, other government agencies, and NGO's (such as the Joint Fire Science Program, National Research Council, OSTP Sub-Committee on Disasters, and others).

• The team organized and led two meetings in May 2014 (NASA-Ames Research Park) and October 2014 (Reno, NV) of the Tactical Fire Remote Sensing Advisory Committee. The meetings included participation from various fire management agencies and focused on facilitating improved observational capabilities for wildfire occurrences;

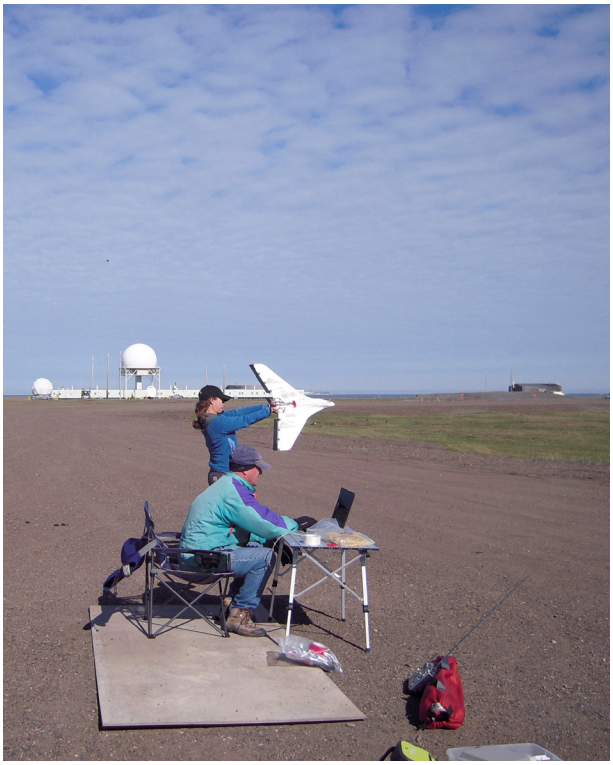

Figure 18: Pre-flight checks on the DataHawk UAS being conducted at Crows Landing, California.

• The team participated and/or represented NASA-ARC at the following events in the wildfire science community: 1) International Union of Forest Research Organizations (IUFRO) in Salt lake City, UT, Oct. 2014; 2) Pecora Conference, Denver, CO, Nov. 2014 (special session on NASA Wildfire Applications); 3) NASA Wildfire program on Interagency Arctic Research Policy Committee (IARPC), Wildfire Implementation Team; 4) American Society of Photogrammetry and Remote Sensing UAS for Natural Resources Workshop, Reno, NV (Oct. 2014) and 5) USGS Innovation Center for Earth Sciences Workshop.

• The team, now recognized for excellence in wildfire science applications, served on the following review panels: National Science Foundation, International Journal of Remote Sensing, Remote Sensing of Environment Journal, Remote Sensing Journal, IGARSS-TGRS Journal, Journal of Field Robotics, Geocarto International Journal, AIAA Journal of Aircraft, NASA SBIR Proposals, and USDA SBIR Proposal, as well as NASA Peer Review Science Program Panels.

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Hinkley, E.A., V.G. Ambrosia, S. Wegener (2014), "Unmanned Aircraft Systems in Environmental Monitoring Applications," In W. Messnew (Ed.), Autonomous Technologies: Applications That Matter, Society of American Engineers International, Warrendale, PA., Chapter 8, pp. 138-156.

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Vanderbilt, V., C. Daughtry, L. Biehl, and R. Dahlgren.B51F-0078. Optical Polarization of Light from a Sorghum Canopy Measured under both a Clear and an Overcast Sky. Presented at American Geophysical Union Annual Meeting, December 15-19, San Francisco, CA.

Climate Adaptation Science Investigators (CASI)

NASA: Cristina Milesi, Max Loewenstein
BAERI: Felicia Chiang

Climate variability and climate change pose a range of hazards, including rise in sea level, increased frequency and intensity of wildfire, increased duration and intensity of drought in some regions, changes in precipitation patterns in other regions, increased frequency and duration of extreme heat events and changes in the ranges of flora and fauna. Many of these climate impacts will impede or greatly challenge federal agencies in fulfilling their missions. In 2009, President Obama issued an executive order to federal agencies to develop Agency Adaptation Plans to evaluate the most significant climate change related risks to, and vulnerabilities in, agency operations and missions, both short term and long term. The Climate Adaptation Science Investigators (CASI) Workgroup, a partnership between Earth scientists and institutional stewards, is tasked to assist in the development of Climate Change Adaptation strategies for NASA and for individual NASA Centers.

In addition to working on the most recent release of the NASA Climate Risk Management Plan (http://www.nasa.gov/sites/default/files/files/NASA_2014_Climate_Risk_Mgmt_Plan.pdf) , ARC-CREST researchers on the CASI Workgroup are working on the following: developing climate projections with associated uncertainties for each Center; inventorying climate data, climate impact data and climate project activities within NASA; assessing adaptation approaches and Center level planning strategies; making recommendations for future research initiatives that fill gaps; and leading thematic, region specific workshops. At NASA-ARC, some of this work builds on previous work conducted by ARC-CREST scientists showing the potential for using the Northern Oscillation Index (NOI) as a predictor of drought for California and the larger Southwest region. In California, a large fraction of annual precipitation arrives in just a few storms (generally, fewer than 10 storms per year). Therefore, the ability to predict storm likelihood and by proxy drought, would be a very powerful management tool affecting millions of people.

2014 Accomplishments

- The CASI team continued to build and improve their model that predicts extreme precipitation events and storm water runoff in California using NOI and Specific Atmospheric Humidity (HUS) as predictors. They completed a variety of statistical analyses on precipitation data and model return values.

- The team examined differences in model output when using precipitation data downscaled using either the BCCA (Bias-Correction Constructed Analogs) or BCSD (Bias Correction Spatial Disaggregation) downscaling method.

- The team presented these analyses at the Bay Delta Science Conference in October 2014. The Bay Delta Science Conference is a forum for presenting technical analyses and results relevant to managing the San Francisco Bay and San Joaquin and Sacramento River Delta using the best possible science. The goal of the conference is to provide new information and syntheses to the broad community of scientists, engineers, resource managers, and stakeholders working on this unique, vulnerable and vitally important ecosystem. Changes in precipitation are especially important to the health and management of this resource.

- ARC-CREST Researchers and their NASA counterparts on the CASI team continue to support the fulfillment of Executive Order 13514 Federal Leadership in Environmental, Energy and Economic Performance. In October 31, NASA's 2014 Climate Risk Management Plan was released. The CASI team has begun related work in sea-level rise impacts at NASA-ARC.

Figure 19: Projected high tide water levels in south San Francisco Bay with a 50cm rise in global mean sea level rise. The NASA-ARC facility can be identified by the airfield (2 runways oriented vertically) located just left of center.

Publications and Presentations

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Ecological Forecasting

NASA: Jim Brass
BAERI: Cindy Schmidt

The Ecological Forecasting program is one sub-program within NASA's Applied Science Program whose larger goal is to advance innovative and practical uses of Earth observations and modelling in order to enhance stewardship of natural resources and decision making of public and private organizations. The Program, new to the ARC-CREST cooperative agreement in 2014, solicits proposals and includes a portfolio of projects in the Ecological Forecasting area. ARC-CREST staff are managing the Program, reviewing proposals and will be working with the research teams that submit successful proposals in coming years.

The project manager is responsible for overseeing the following projects, selected in 2014:

• Bayesian Data-Model Synthesis for Biological Conservation and Management in Antarctica. Project PI: Dr. Heather J. Lynch (Stony Brook University)

• Snapshot Wisconsin: Bringing wildlife management into focus through integration of camera traps, remote sensing and citizen science to improve population modeling. Project PI: Dr. Philip A. Townsend (University of Wisconsin)

• Projecting Effects of Climate Change on River Habitats and Salmonid Fishes: Integrating remote sensing, genomics and demography to inform conservation. Project PI: Dr. Gordon Luikart, Flathead Lake Biological Station, University of Montana

• Snow, Montane Wildflowers and Citizen Scientists. Project PI: Dr. Janneke Hille Ris Lambers (University of Washington)

2014 Accomplishments

• As director of the Ecological Forecasting Program, Cindy Schmidt managed the conduct of the program by:

1) attending bi-weekly conference calls to discuss project progress as well as strategies for the program;

2) reviewing and approving required reports from project PIs;

3) presenting project summaries at the bi-monthly NASA Applied Science Program reviews; and

4) communicating frequently with principal investigators of projects within the program to ensure projects are making adequate progress.

Geostationary Coastal and Air Pollution Events Mission (GEO-CAPE)

NASA: Laura Iraci
BAERI: Susan Kulawik

The GEOstationary Coastal and Air Pollution Events (GEO-CAPE) mission was recommended by the National Research Council's Earth Science Decadal Survey to measure tropospheric trace gases and aerosols as well as coastal ocean phytoplankton, water quality and biogeochemistry from geostationary orbit. Multiple observations per day are required to determine tropospheric composition and air quality over spatial scales ranging from urban to continental, and over temporal scales ranging from diurnal to seasonal. High frequency satellite observations are also critical to studying and quantifying biological, chemical, and physical processes within the coastal ocean and beyond.

ARC-CREST researchers are involved in mission planning and the development of instrument concepts for this upcoming satellite mission. GEO-CAPE is planned to be in orbit in the 2020 time frame. At this preliminary stage, several instrument concepts are being studied to ensure that a range of potential instruments can meet GEO-CAPE requirements.

2014 Accomplishments

- In support of the alternative mission implementation concepts, the team simulated multi-spectral ozone retrievals. They ran 4,050 simulations for 17 different surface sites, with different wavelengths and with different netcdf products. The team was then able to characterize sensitivity as a function of the atmospheric state for different simulated instruments.

Figure 20: ARC-CREST researchers are contributing to the planning and development of the GEO-CAPE Mission. Planned to be in orbit ~ 2020, GEO-CAPE will measure tropospheric trace gases and aerosols and coastal ocean phytoplankton, water quality and biogeochemistry from geostationary orbit, providing multiple daily observations within the field of view.

Agriculture, Health and Marine Studies

NASA: Jim Brass
CSUMB: Forrest Melton, Lee Johnson, Alberto Guzman, David Hamblin, Gwen Miller, Andrew Michaelis, Kirk Post, Carolyn Rosevelt, John Shupe, Aimee Teaby, Sean Windell

Agriculture, Health and Marine Studies encompass various efforts by ARC-CREST researchers that fall within NASA's Applied Sciences Program. These projects generally apply NASA Earth observations and remote sensing technologies to improve understanding of environmental conditions and ecological processes that affect agriculture, public health and vector borne disease, and marine ecosystems. The goal is for these observations to enhance policy and decision-making capabilities. ARC-CREST researchers are working mainly on agricultural issues, promoting innovation in public and private sector organizations by bringing NASA satellite data, model products, and scientific findings to agricultural management and policy activities. Currently, ARC-CREST researchers are working with the California Department of Water Resources and farmers throughout California to support decision making associated with the severe drought. They are creating maps, projections, and tools that can be used for water and agriculture management using satellite and airborne-based data. Communication with the management and policy community as well as mentoring of students are also critical to this work.

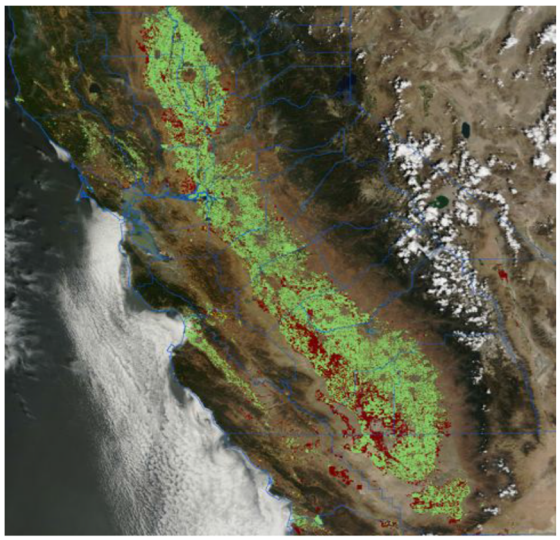

Figure 21: Fallowed crop areas in California's Central Valley during summer 2014. Fallowed areas were determined from measurements made by various vegetation mapping instruments on board the Landsat 7 ,Landsat 8, Terra and Aqua satellites and are being used by California water managers as one drought monitoring index.

2014 Accomplishments

•Researchers developed algorithms for mapping drought impacts on agricultural production and land fallowing due to drought in California. They demonstrated the ability to deliver this type of data monthly with a time lag of 1-2 weeks and with an accuracy of better than +/-15%.

• The team delivered data of this type to the California Department of Water Resources (CDWR), the California Department of Food and Agriculture (CDFA), and the CA Governor's Drought Task Force for the months of April through October in 2014.

• Data from the Fallowed Area Mapping project was featured in National Geographic magazine in the pullout map in the October 2014 issue on Drought in the West available at http://www.nationalgeographic.com/west-snow-fail/draining-california/index.html

• The Satellite Irrigation Management System (SIMS) data processing system underwent continued development on the NEX, including prototype web and mobile interfaces and gathering feedback from growers in California using this data.

• The team presented results of the use and utility of the SIMS system to CDWR and expanded the network of growers using the system in Fresno and Salinas Valley.

Publications and Presentations

Johnson, L., M. Cahn, F. Martin, F. Melton, S. Benzen, B. Farrara, and K. Post. Evapotranspiration-based irrigation scheduling of lettuce and broccoli. *HortScience* (in prep).

AghaKouchak, A. et al. (Melton, F.S. among 7 authors) Remote Sensing of Drought: Progress, Challenges, and Opportunities. *Geophysical Research Letters, (in review).*

Medellin-Azuara, J. et al (Melton, F. among 10 authors) Hydro-economic analysis of groundwater pumping for California's Central Valley irrigated agriculture. *Hydrogeology (in review).*

Wu, Z. et al. (F. Melton, L. Johnson, and C. Rosevelt among 10 authors). 2014. Seasonal cropland mapping using the Automated Cropland Classification Algorithm (ACCA). J. Applied Rem. Sens. 8(1):083685. doi:10.1117/1JRS.8.083685.

Johnson, L. et al. 2014. Results from 2012-2013 Salinas irrigation trials – further development of decision support tools for cool season vegetable production. *Proceedings, US Committee on Irrigation & Drainage, Water Management Conference,* 4-7 March, Sacramento.

Melton, F. et al. 2014. Remote Sensing of California Agriculture for Drought Impact Assessment and Mitigation, Sustainable Water Resources Roundtable Meeting, 20 Nov 2014, Mountain View, CA.

Melton, F. et al. 2014. Satellite Mapping of Agricultural Water Requirements in California. Amer. Soc. Agric. Bio. Engrs., Evapotranspiration Conference, 7-11 April, Raleigh, NC.

Post, K., Melton, F., Lund, C., and Johnson, L. 2014. A Sensor Network Application for Measuring Crop Evapotranspiration in California's Central Valley. ASA, CSSA, and SSSA International Meeting 2-5 Nov 2014. Long Beach, CA.

Melton, F. et al. 2014. Satellite Mapping of Agricultural Water Requirements in California. USCID Water Management Conference, U.S. Committee on Irrigation & Drainage, 4-7 March, 2014, Sacramento, CA.

Post, K. et al. 2014. Application of a prototype system for irrigation scheduling based on satellite mapping of agricultural water requirements in California vineyards. Annual ASEV Meeting, 23-27 June 2014, Austin, Texas.

Melton, F., L. Johnson, K, Post, et al., 2014. Satellite Mapping of Agricultural Water Requirements in California. UC Water Resources Law Symposium, 8 Feb 2014, San Francico, CA.

Johnson, L. and F. Melton, 2014. Satellite-based Calculator for Estimation of Crop Consumptive Use Fraction, USCID Water Management Conference, U.S. Committee on Irrigation & Drainage, 2-5 Dec., Phoenix, AZ.

Johnson, L., F. Cassel-Sharma, D. Goorahoo, and F. Melton, 2014. Landsat-based calculation of agricultural water use fractions in California. 19th ASPRS 18th William T. Pecora Memorial Remote Sensing Symposium, 17-20 Nov., Denver, CO.

Johnson, L. 2014. Remote sensing of crop development and evapotranspiration. 22nd Annual Fertilizer Research & Education Program Conference, 29-30 Oct., Modesto, CA (invited).

Johnson, L., F. Cassel-Sharma, D. Goorahoo, and F. Melton, 2014. Calculator for water sustainability metrics in California Agriculture, Amer. Soc. Civil Engrs, World Environmental & Water Resources Congress, 1-5 June, Portland, OR.

Melton, F. et al. "Mapping drought impacts on agricultural production in California's Central Valley" (Invited). Presented at American Geophysical Union Annual Meeting, December 15-19, San Francisco, CA.

Johnson, L., F. Cassel-Sharma, D. Goorahoo, and F. Melton, "Calculator for evaluation of crop water use fractions in California" (Poster). Presented at American Geophysical Union Annual Meeting, December 15-19, San Francisco, CA.

Goorahoo, D., F. Cassel-Sharma, L. Johnson, and F. Melton, "An integrated lysimeter and satellite imagery approach for estimating crop evapotranspiration" (Poster). Presented at American Geophysical Union Annual Meeting, December 15-19, San Francisco, CA.

Water Quality Monitoring for National Geospatial Agency (NGA)

NASA: Jim Brass
BAERI: Cindy Schmidt, Chase Mueller

This NGA project is creating water quality geospatial products of the Niger River Basin. The project involves three phases: creation of the dataset, validation of the dataset and sharing via the NASA Earth Exchange (NEX). As part of this work, ARC-CREST and NASA scientists are using remote sensing data including land cover, climate, topography, and soils, as well as demographic and socio-economic data for the region. The team is also evaluating existing tools and models for water quality assessments and needs for new functionalities. By using an analog river site, researchers will define and create the method for producing the temporal maps of water quality in the Niger basin. Data products will ultimately be prepared in a format suitable to be incorporated in the NGA online hydro visualization tool and also shared via the NASA Earth Exchange (NEX).

Figure 22: The Niger River Basin in West Africa from highlands in Guinea, through Mali, Niger and Nigeria. ARC-CREST researchers are evaluating remote sensing data and available tools and models for assessing water quality in the region. Data products will eventually be shared via the NEX platform.

2014 Accomplishments

• The team completed several activities directly related to the project kick-off meeting held in November in Washington, D.C. These were:

1. Held several project meetings with the NGA PI;
2. Prepared maps of land cover, tree cover, evapotranspiration, temperature, irrigation, water management, water withdrawal, population, cattle distribution, and infrastructure within the Niger River Basin and surrounding areas for presentation at the kick-off meeting;
3. Established chlorophyll, turbidity, temperature, and salinity as the target indicators of water quality going forward and presented these at the kick-off meeting;
4. Determined to expand the study area to Lake Chad and identified a U.S. analog study area to be presented at the kick-off meeting;
5. Completed initial literature reviews of data and models available for water quality research in the study area to be presented at the kick-off meeting; and
6. Tested the current limits of the GEO narrative dashboard created by RadiantBlue and identified areas requiring future work for presentation at the kick-off meeting.

• The team acquired Aqua MODIS products for temperature, chlorophyll a, colored dissolved organic matter, and the absorption coefficient for dissolved and detrital material for the Gulf of Guinea. The team also acquired cloud free Landsat 8 - OLI data to analyze the temperature, Floating Algal Index, and turbidity of the Kainji Reservoir.

• The team re-charted Flood Observatory data to allow a customized display of the Niger River discharge data.

• Crop and vegetation tolerances to salinity within the Inland Niger Delta were investigated as an alternative way of tracking salinity.

• For the collaboration with the DEVELOP program which will be working at the U.S. analog site at Lake Erie, target deliverables were laid out.

Water Resources Program

NASA: Jim Brass
CSUMB: Forrest Melton

ARC-CREST researchers working on water resources projects apply NASA satellite data to improve the decision support tools of the various user groups that manage water resources in the U.S. and elsewhere. Projects within the water resources program address key concerns in the decision making processes surrounding water availability, water forecast, and water quality. The projects bring together Federal agencies, academia, private firms, and international organizations and are organized into several categories: water quality, water delivery and irrigation, flow and flood forecasting, drought, snowpack, and climate and water resources. ARC-CREST staff oversee the program, completing the following general activities: 1) tracking a portfolio of NASA ASP funded projects, including the project progress and funding status; 2) enhancing coordination among funded projects and enhancing communication with project partners and stakeholders in the water resource management community; and 3) planning and convening workshops, meetings, and workshop sessions to enhance visibility of the program's projects and activities.

Publications

AghaKouchak, A. et al. (Melton, F.S. among 7 authors). Hain, C.R. Remote Sensing of Drought: Progress, Challenges, and Opportunities. *Geophysical Research Letters, (in review).*

2014 Accomplishments

• CSUMB staff Forrest Melton did the following in 2014:

1. Organized the annual NASA Applied Sciences Program - Water Resources PI meeting held at the National Drought Mitigation Center in Lincoln, NE and helped organize the 2015 PI meeting held in March in Washington, DC;

2. Developed and authored the Applied Science Program Water Resources website http://c3.nasa.gov/water;

3. Tracked and coordinated 10 Applied Science Program Water Resources projects including monitoring financial and technical progress, engaging with partners and stakeholders, communicating regularly with project PIs to identify and resolve issues, and reporting progress during 6 Program Reviews.

• Forrest Melton worked with the Bureau of Reclamation, NOAA, USGS, and EPA to organize a 2015 workshop on climate change and water resources and organized a joint workshop and press conference between NASA and the CDWR on the subject of Applications of Remote Sensing for Drought Monitoring and Mitigation. The workshop was covered by Sacramento and Bay Area television stations, multiple radio stations, and national print media.

• Forrest Melton jointly organized and chaired 3 hydrology sessions (H33P, H34D, H41E) at the 2014 Fall AGU Meeting on Remote Sensing Applications for Water Resources Management and delivered a hyper wall presentation for the NASA booth at AGU with Dr. Bradley Doorn, the program manager for Water Resources.

• In collaboration with other scientists in the NASA Applied Sciences Program, Melton authored a review of Remote Sensing Applications of Drought, published in the journal Geophysical Research Letters.

HELIOPHYSICS

Collaborative Space Weather Modeling

NASA: Jeff Scargle, John Marmie, Nagi Mansour
BAERI: Jean Paul Rabanal, Bob Stein, Thomas Hartlep

The Collaborative Space Weather Modelling project is one of three projects under the ARC-CREST umbrella that support NASA's larger Heliophysics Modeling and Simulation (HMS) and Living With a Star (LWS) initiatives. ARC-CREST researchers working on the Collaborative Space Weather Modeling project are focused on building a high-fidelity, physics-based model of solar flux and transport. Models like these provide a predictive understanding of the Sun's system, specifically of the space weather conditions near Earth and in the interplanetary medium. Space weather affects the Earth's geophysical systems and technological infrastructure. For example, many power-grid disturbances, satellite anomalies, and positioning errors are attributable to the coupling of solar magnetic activity into the electrical, electronic, or electromagnetic components of modern everyday life.

2014 Accomplishments

•As part of the larger collaborative Heliophysics Modeling and Simulation community, the NASA-ARC based team continued to work towards an accurate, physics-based model of solar magnetic flux and transport.

•In 2014, ARC-CREST researchers were succeeding in conducting model runs of over 83 solar hours and achieving near constant entropy. However, the model did not accurately capture solar flux.

•The team continues to work on this issue within the model.

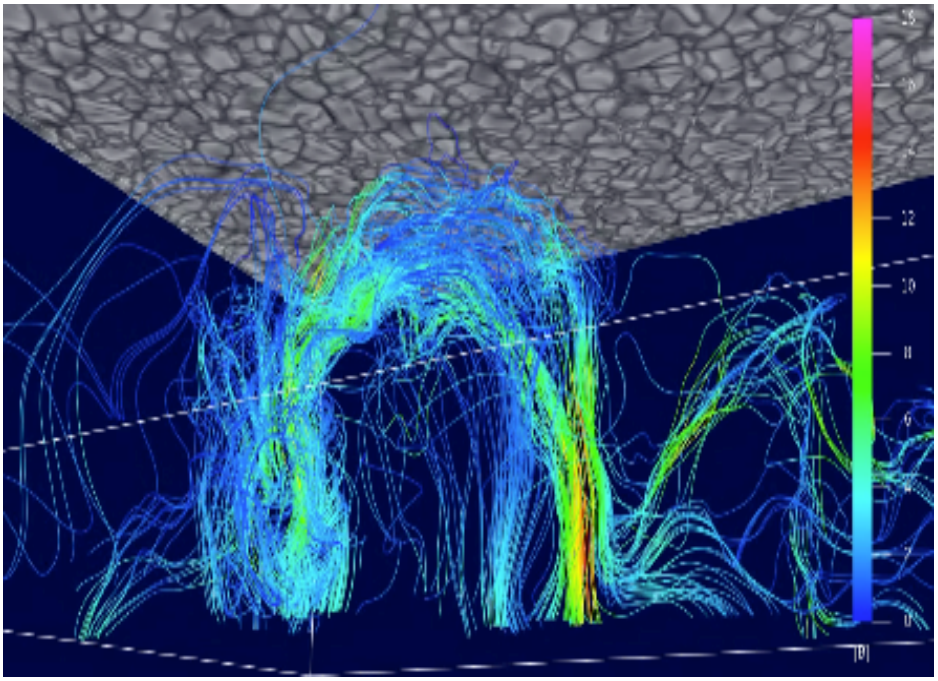

Figure 23: Magnetic field lines of an emerging Omega-loop. Color indicates magnetic field magnitude with scale on the right in kG. Gray scale image at the top is the surface continuum radiation intensity showing the granulation pattern. Convection shreds the magnetic field into multiple filaments, but also confines the large-scale loop topology. The length of the loop is that of a typical supergranule diameter. The team is now working on modeling a larger version of the image above (only 48 Mm wide with weak 1 kG horizontal input magnetic field at 20 Mm depth).

Heliophysics Modeling and Simulation (HMS)

NASA: Nagi Mansour
BAERI: Thomas Hartlep

The Heliophysics Modeling and Simulation (HMS) project is the second of three projects under the ARC-CREST umbrella that support NASA's larger Heliophysics Modeling and Simulation (HMS) and Living With a Star (LWS) initiatives. This team is developing and conducting numerical simulations of the 3-D helioseismic wave field in the whole solar interior and under the influence of magnetic fields, flows, and thermal perturbations. They are generating synthetic data to test and calibrate helioseismology methods. The team seeks to advance our understanding of detection and measurement of large-scale magnetic structures in the deep solar convection zone and also to determine thresholds on detectable magnetic fields. Together with other projects within NASA's HMS/LWS program, models like these advance our progress towards a predictive understanding of the Sun-Earth system..

Presentations

Kitiashvili, I., Alexander G Kosovichev, Nagi N Mansour, Alan A Wray. Multiscale Properties of the Local Dynamo on the Sun (224). Presented at American Astronomical Society Meeting. June 2014.

Zhao, J., Ruizhu Chen, and Thomas Hartlep. "Detection of Fast-Moving Waves Propagating from Penumbra to Outside of Sunspots in the Photosphere" (SH41B-4138). Presented at American Geophysical Union 2014 Annual Meeting, San Francisco, CA.

Hartlep, T. and Jeffrey Cuzzi. "Statistical modeling of preferential concentration of heavy particles in turbulence" (A21I-3135). Presented at American Geophysical Union 2014 Annual Meeting, San Francisco, CA.

2014 Accomplishments

• As part of the larger collaborative HMS community, a second of three NASA-ARC-based team continued to work towards an accurate, physics-based model of solar magnetic flux and transport.

• In 2014, the team made progress on development of a new non-linear force free field extrapolation method, a new technique allowing for modeling the entire sphere and not just small sections of the corona.

• The team collaborated with Dr. Junwei Zhao at Stanford University on possible explanations for recent observations of fast moving waves originating from sunspots as observed using Solar Dynamics Observatory Helioseismic and Magnetic Imager (SDO/HMI) data.

• ARC-CREST researchers working on this aspect of HMS developed a numerical code for computing acoustic wave propagation in the sun and in the ray approximation that takes sound speed and magnetic fields into account. The code uses a numerical model of a sunspot (developed by Dr. Matthias Rempel), and propagated rays through this model to test different hypotheses of where the fast waves observed at the surface could have originated.

Solar Physics Modeling

NASA: Helen Yee
BAERI: Dmitry Kotov

The Solar Physics Modeling project is the third of three projects under the ARC-CREST umbrella that support NASA's larger Heliophysics Modeling and Simulation (HMS) and Living With a Star (LWS) initiatives. This team is using numerical simulations to better understand the following: (a) magnetic reconnection in the sun and its effect on the structure of the solar wind, (b) interaction of the solar wind and the Earth's magnetic field and (c) formation of planetesimals in protoplanetary disks. Accurate and reliable modeling and simulation are the primary tools available for studying solar physics and for predicting associated geophysical phenomena. High performance computing employing the proper numerical methods is a very powerful complement to theory and observation. However, one of the important challenges involved is the sensitivity and stability of the numerical simulation to the accuracy of the numerical scheme employed. ARC-CREST researchers working on the Solar Physics Modeling project and their NASA-ARC collaborators are building on previous work showing that high order non-linear filter schemes can improve the accuracy and stability of the computations involving both gas dynamics and MHD governing equations.

2014 Accomplishments

- As part of the larger collaborative HMS community, a third of three NASA-ARC-based team continued to work towards an accurate, physics based model of solar magnetic flux and transport.

- In 2014, ARC-CREST researcher Dmitry Kotov examined the performance of the Yee & Sjogreen scheme for Direct Numerical Simulation (DNS) and Large Eddy Simulation (LES) of low-speed flows.

- Dr. Kotov performed a comparative study of the DNS and LES to reduce the loss of accuracy at the shock within the framework of the model using a canonical shock-turbulence interaction problem and confirmed the loss of accuracy within the model.

- Dr. Kotov then began development of a new method for solving one-sided filtered governing equations in the vicinity of the shock based on sub-cell resolution approach.

Publications and Presentations

Kotov, D., H. C. Yee, A. Hadjadj, A. Wray, and B. Sjogreen. High-order numerical methods for LES of turbulent flows with shocks. Annual Research Briefs, Center for Turbulence Research, Stanford, 2014.

Kotov, D., H. C. Yee, A. Wray, and B. Sjogreen. On LES of low-speed flows by high-order shock capturing schemes with flow sensors. Annual Research Briefs, Center for Turbulence Research, Stanford, 2014.

Kotov, D., H. C. Yee, A. Wray, and B. Sjogreen. Numerical dissipation control in high order shock capturing schemes for LES of low speed flows. In Proceedings of the ICOSAHOM 14. Salt Lake City, UT, USA, June 23-27 2014.

Kotov, D., H. C. Yee, A. Hadjadj, A. Wray, and B. Sjogreen. High order numerical methods for LES of turbulent flows with shocks. In Proceedings of the ICCFD8. Chengdu, Sichuan, China, July 14-18, 2014.

Synthetic Biology

NASA: Michael Flynn
BAERI: Rocco Mancinelli

ARC-CREST researchers are studying the function and response of the nitrogen cycle, fundamental to life processes here on earth, under different gravity conditions. This research furthers basic understanding of the nitrogen cycle, but is also affiliated with the German Aerospace Center's (DLR's) Eu:CROPIS Mission. The Eu:CROPIS mission will put a lightweight greenhouse satellite into low earth orbit, replicating lunar and Martian gravity conditions.

In the Eu:CROPIS satellite greenhouse, combined life-support systems will utilize waste products to manufacture fertilizer and help grow tomatoes for a lunar and Mars habitat, as well as for long duration missions. ARC-CREST researchers' examination of the effects of gravity on the nitrogen cycle are part of mission planning and buildup and the results relevant to the ability to support life whether it is on Earth, in space, or on other planets or moons. This important work contributes to NASA's larger SynBio efforts. SynBio technologies could allow space travelers to use microbes to produce their own fuel, food, medicines and building materials from raw feedstock readily available on Mars or the moon, instead of carrying all supplies aboard the spacecraft or making them at the destination with conventional methods. Scientists calculate that using biological production could reduce the mass of supplies and equipment sent with the expedition by between 26 and 85 percent, depending on the application, which would significantly reduce the cost of the mission.

2014 Accomplishments

- The team successfully demonstrated Euglena growth on NO3- as well as on NH4+ and also demonstrated Euglena growth on NH4+ produced by cyanobacteria in co-culture and on 2 different media types.

- The team completed colorimetric assays for the various nitrogen species, and based on these results decided to use ion-chromatography for the ground controls and flight experiment; the team also confirmed the decision to use gas sensors to measure atmospheric gases in the primary payload instead of a gas chromatograph.

- The team developed the first phase of a computer model to simulate the microbial and nitrogen species changes in the Eu: CROPIS system.

Publications

Mancinelli, R. L. The effect of the space environment on the survival of Halorubrum chaoviator and Synechococcus (Nägeli): data from the Space Experiment OSMO on EXPOSE-R. International Journal of Astrobiology, available on CJO2014. doi:10.1017/S147355041400055X.

AIRBORNE SCIENCE AND MISSION SUPPORT

Atmospheric Chemistry Data Analysis

NASA: Hanwant Singh, Bob Chatfield
BAERI: Bob Esswein, Dan Olsen

This project, composed of two research teams, utilizes airborne-, ground-, and satellite based measurements to understand aspects of atmospheric chemistry and transport. The first team, led by NASA scientist Dr. Robert Chatfield, is examining tropospheric O_3 production in urban and remote areas, with a special focus on the Western U.S., as well as emissions of chemical constituents from forest fires. The second team led by Hanwant Singh is focused on chemistry and transport of PAN, CH_4 and other short lived constituents. The work done by these teams is unique because it improves the utility of NASA satellite measurements in the understanding of global tropospheric O_3 and aerosols, including their precursors and transformation processes in the atmosphere. Further, the researchers study air quality and oxidation efficiency in the troposphere, how pollution-sourced aerosols affect cloud properties, stratospheric chemistry, and O_3 depletion, and the very important interactions between atmospheric chemistry and climate. Multivariate and time-series statistical analysis, primarily of retrieved satellite data and aircraft exploratory missions are used as well as various atmospheric chemical and transport models.

2014 Accomplishments

- Researchers created a merged dataset of measurements taken from the Dragon aircraft, the AERONET network, and the MODIS-MAIAC satellite instrument. This merged dataset was used to calculate column H_2O, PM2.5 AOD, and PBL height for selected sites, including those in the San Joaquin Valley.

- SSFR data taken during the SEAC4RS mission was processed for select atmospheric constituents and parameters.

- The team created an R-HDF interface in Linux to accommodate updated MAIAC data and made numerical fits to MODIS data.

Publications and Presentations

Fischer, E. et al. (H. Singh, among 12 authors). 2014. Atmospheric peroxyacetyl nitrate (PAN): a global budget and source attribution. Atmos. Chem. Phys., 14: 2679-2698. doi: 10.5194/acp-14-2679-2014. http://www.atmos-chem-phys.net/14/2679/2014/acp-14-2679-2014.html

Law, K. et al. (H. Singh, among 15 authors). 2014. Arctic Air Pollution: New Insights from POLARCAT-IPY. Bull. American Meteorological Soc. In Press.

Wells, K. et al. (H.B. Singh. among 10 authors) 2014. Quantifying global terrestrial methanol emissions using observations from the TES satellite sensor. Atmos. Chem. and Physics, 14: 2555-2570; doi:10.5194/acp-14-2555-2014. http://www.atmos-chem-phys.net/14/2555/2014/acp-14-2555-2014.html

Liss, P. et al. (H. Singh, among 14 authors). 2014. "Short-lived trace gases in the surface ocean and the atmosphere." In Ocean-Atmosphere Interactions of Gases and Particles. Berlin/Heidelberg: Springer Verlag. 1-54. doi: 10.1007/978-3-642-25643-1_1. http://link.springer.com/chapter/10.1007/978-3-642-25643-1_1

Singh, H. 2014. "Tropospheric Composition and Analysis: Peroxyacetyl Nitrate." In Encyclopedia of Atmospheric Sciences, 2nd Edition, edited by G. North, J. Pyle, F. Zhang. Oxford: Academic Press.

Chatfield, R. and R. F. Esswein. 2014. True Emission factors for western forest fires: Better estimation and usage. Air and Waste Management Association Annual Conference, June 24-26, Long Beach, CA. 1-5. http://www.eventscribe.com/2014/AWMA/assets

Chatfield, R. 2014. True Emission Factors for SEAC4RS Smoke and Gases Compared to OLD NERM (difference/Regression) estimate, SEAC4RS Science Team Meeting, Apr. 15-18, Boulder, CO.

Chatfield, R. B., Michal Segal-Rosenheimer, and SEAC4RS, DC3, and ARCTAS Science Teams, "Revised (Mixed effects) estimation for forest burning emissions of gases and smoke, fire/emission factor typologies, and potential remote sensing classification of types for use in ozone and absorbing-carbon simulation" (A33G-3281). Presented at American Geophysical Union Annual Meeting, December 15-19, San Francisco, CA.

Singh, H. 2014. SEAC4RS 2013 airborne mission: biogenic and wildfire emissions and oxidation products over continental United States. 4th Integrated Land Ecosystem – Atmosphere Processes Study (iLEAPS) Science Conference, May 12-16 Nanjing, China.

Airborne Science Advanced Planning

NASA: Matt Fladeland
BAERI: Susan Schoenung, Gailynne Bouret, Pat Finch, Justin Humphrey

The NASA Airborne Science Program (ASP) conducts on the order of 30 missions per year utilizing a fleet of manned and unmanned aircraft. ARC-CREST staff support the Program by maintaining and updating the 5-year mission plan for the ASP fleet used by NASA's Earth Science community. Scheduling and maintenance of the airborne research assets is extremely complex as the fleet is utilized to its maximum extent, used for a variety of scientific research missions, and at numerous remote locations. Costs associated with aircraft operations can quickly build and impact scientific budgets if scheduling and operations are not optimized. Missions are planned over the course of several years and involve hundreds of scientists and technical staff.

The ASP Advanced Planning team, composed in part by ARC-CREST staff, communicates with the NASA Earth Science program scientists to discuss upcoming and changing requirements for NASA assets, including aircraft and supporting infrastructure. The team includes representatives from the six R&A science areas, the Earth Science Technology Office, and the Applied Science Program. They attend project team meetings for field and space missions, maintain the Science Operations Flight Request System, give briefings on the ASP capabilities, and prepare the ASP newsletter and annual report. The ASP Advanced Planning team provides ongoing support to scientists utilizing assets for science presentations and proposals. Additionally, the team provides specialized electrical and mechanical support for aircraft as needed, specifically for development of new UAV assets based at NASA-ARC.

Publications

NASA Airborne Science Program 2013 Annual Report. Available at: https://airbornescience.nasa.gov/sites/default/files/documents/ASP13_AnnualRept_v8.pdf

NASA Airborne Science Program Fall 2014 Newsletter. Available at: https://airbornescience.nasa.gov/sites/default/files/documents/ASP_Fall2014_nsltr_v3.pdf

2014 Accomplishments

- ARC-CREST staff updated the ASP mission plan and the briefing materials related to the capabilities for the ASP fleet of manned and unmanned aircraft used by NASA's Earth Science community.

- The team communicated regularly with the NASA Earth Science program scientists (across six R&A areas), ESTO, and the Applied Science Program to discuss upcoming and changing requirements for NASA assets, including aircraft and supporting infrastructure.

- The team created and distributed monthly newsletters and the 2014 ASP Annual Report as well as a new briefing highlighting how ASP supports NASA Earth satellites by collecting data for algorithm development, collecting data for satellite instrument cal/val activities, providing test flight opportunities for new instruments in development, and carrying out complementary field missions.

- The team attended meetings with all Earth Science and Space Science project teams to gather information on upcoming requirements and needed access to ASP assets.

- The NASA-ARC based ASP Advanced Planning team participated in and made presentations at the annual Applied Sciences Missions Applications review and at IGARRS.

Figure 24: The NASA Airborne Science Program Annual Report details the activities and achievements of the many manned and un-manned aircraft in NASA's research fleet. The report is available at https://airbornescience.nasa.gov/

Figure 25: Pre-flight checks are completed on the SIERRA aircraft, one of several UAS managed by the Airborne Science Advanced Planning team.

Earth Science Project Office (ESPO)

NASA: Mike Craig, Marilyn Vasques
BAERI: Erin Czech, Dan Chirica, Erin Justice, Michaela Herman, Quincy Allison, Sue Tolley, Steven Todorov

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 O_3 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.

Figure 26: The RV Endeavor departing Narragansett, RI for the SABOR Mission.

Figure 27: The NASA P3-B aircraft and Operation IceBridge (OIB) team in Thule Greenland during the OIB field campaign.

2014 Accomplishments

• In 2014, the NASA-ARC-based ESPO team supported 10 NASA-funded, air or ship-based, field missions. ESPO supported the following missions:

1. OIB (Spring 2014 Thule, Greenland)
2. OIB (Fall 2014 Punta Arenas, Chile)
3. ARISE (Summer 2014 Thule, Greenland)
4. ATTREX (Winter 2014 Guam)
5. DISCOVER-AQ (Summer 2014, Colorado)
6. HS3 (Summer and Fall 2014, Wallops Island, VA)
7. SABOR (Summer 2014 Narragansett, RI)
8. COMEX (Summer 2014 Bakersfield, CA)
9. ORACLES (planning phase)
10. AJAX (Ongoing, Moffett Field, CA)

• For each of these missions, ESPO provided logistical support for the deployment including: managed deployment sites (facilities, lodging, transport, Customs); interfaced between mission managers, instrument teams, NASA Program Managers, and aircraft crew; coordinated all shipping of equipment and materials (NASA-ARC shipping, university shipping, freight forwarders, customs, local transportation); and deployment setup and on-site support for duration of mission.

• For select missions, the ESPO team provided additional and specialized support related to instrument integration and operation, data systems support, and communications support for mission teams.

• For many of these missions, ESPO provided programming and IT support such as: provided in-field IT support for website, system and network setup, printer access, local ISPs, and user support for deployments; created new websites for missions beginning in 2014; improved or added features to existing websites including ESPO, ESD, ASP and SOFRS; processed requests through SOFRS; maintained archives of all older websites; stayed abreast of internet technologies and security options for deployment sites.

• For many of these missions, ESPO provided education, outreach, and communications support including: attending conferences, supporting sat communications between teachers and in-flight scientists; supporting open-house events at facilities hosting field deployments.

• Due to the nature of the field missions, the ESPO team participates in advance planning for missions occurring several years out in the future. In support of this effort the ESPO team did the following: assumed management of the SUAS program (Summer 2015) and supported the CARTA project; provided full logistical support for ATom; assisted AFRC with badging for the ATTREX mission and contributed to early planning meetings for the KORUS-AQ mission.

Figure 28: 2014 Missions supported by the NASA-ARC based ESPO team

Meteorological Measurement Systems (MMS)

NASA: Thaopaul Bui
BAERI: Jon Dean-Day, Cecilia Chang

The Meteorological Measurement System (MMS), developed at NASA-ARC, is a proven airborne instrument package for measuring high resolution in situ state parameters like pressure, temperature, turbulence index, and 3-dimensional wind vectors. Accurate measurements of these quantities from a variety of airborne platforms require judicious choices of sensor locations, repeated laboratory calibrations, and proper corrections for compressibility, adiabatic heating, and flow distortion.

The MMS is used to investigate atmospheric mesoscale phenomena (gravity and mountain lee waves) as well as microscale phenomena (turbulence). An accurate characterization of the turbulence phenomenon is important for the understanding of dynamic processes in the atmosphere, such as the behavior of buoyant plumes within cirrus clouds, diffusion of chemical species within wake vortices generated by jet aircraft, and microphysical processes in breaking gravity waves. Additionally, the MMS is deployed in conjunction with other airborne, or satellite-based sensors so that the MMS data can provide a critical piece of the data interpretation. ARC CREST researchers supporting the MMS system provide on-going support to the scientific community accessing these measurements. The MMS team also works with scientists developing new instruments or payloads to modify the MMS system for each new platform and mission.

Figure 29: An MMS payload is installed on the DC-8.

2014 Accomplishments

- The MMS team maintained the MMS payload on the Alpha Jet and Global Hawk airborne platforms.
- The team provided field support for AJAX science flights in California and ATTREX science flights in Guam.
- The team performed MMS data processing and archiving for all AJAX science flights in California and ATTREX science flights in Guam including calibrations and decoding of the Alpha Jet's internal Garmin for comparison.
- By simulating the Alpha Jet's flight system in the laboratory, the team was able to greatly improve the MMS on this unique platform.
- For the 4STAR Instrument, the MMS team developed new LabVIEW based acquisition system to allow for rapid viewing of field of view (FOV) data and also developed LabVIEW acquisition system for the ground-based instrument.
- In continued support of the SEAC4RS mission, the MMS team: calibrated, revised, and archived various datasets from the DC-8, devised methods to correct for high frequency analog noise, remove cold spike errors in the temperature data, and adjusted altitude angle offsets.

Publications and Presentations

Ueyama, R., Eric J. Jensen, Leonhard Pfister, Glenn S. Diskin, T. P. Bui and Jonathan M. Dean-Day. Dehydration in the tropical tropopause layer: A case study for model evaluation using aircraft observations. Journal of Geophysical Research – Atmospheres, 119 (9). May 2014.

Rollins, A., T. Thornberry, R.-S. Gao, S. Woods, T. Bui, and D. Fahey, "Relative humidity distributions in the Tropical Tropopause Layer measured during NASA ATTREX" (A42D-02). Presented at American Geophysical Union Annual Meeting, December 15-19, San Francisco, CA.

Wolfe, G. et al. (Thaopaul Bui among 15 authors). "Airborne Eddy Covariance Fluxes Provide Novel Constraints on Sources and Sinks of Reactive Gases in the Planetary Boundary Layer" (A32A-08). Presented at American Geophysical Union Annual Meeting, December 15-19, San Francisco, CA.

Bergman, J., Eric Jensen, Leonhard Pfister, Thaopaul Bui. "Trajectory dispersion by unresolved wind variability in the UTLS" (A32K-3396). Presented at American Geophysical Union Annual Meeting, December 15-19, San Francisco, CA.

Thornberry, T., Andrew Rollins, Ru-Shan Gao, David Fahey, Thaopaul Bui, Sarah Woods. "In Situ Observations of Water Vapor and Cirrus IWC in the Pacific TTL During ATTREX" (A23L-3417). Presented at American Geophysical Union Annual Meeting, December 15-19, San Francisco, CA.

Meteorological Support

NASA: Leonhard Pfister
BAERI: Patrick Hillyard, Bill McKie

The NASA-ARC-based Meteorological Support group provides meteorological support during planning, execution and research phases of NASA airborne missions in both the troposphere and stratosphere. This support covers a range of forecasting tasks such as preparing historical climatological and meteorological summaries for proposed airborne mission field sites, providing detailed flight day forecasts, and creating specific meteorological data products during and post mission. This support needs to be coincident to a specific place and time of scientific measurements and requires forecasting knowledge, familiarity with meteorological data archives, and attendance at mission planning meetings and during field missions. It also requires continual interfacing and support to scientists in the community utilizing mission data in the years following the mission. The ability to provide these met-based mission tools in a timely manner is critical to mission success.

2014 Accomplishments

• In 2014, the team of Dr. Patrick Hillyard and Bill Mc Kie provided meteorological support to 4 NASA funded field missions: ATTREX, SEAC4RS, OIB, and ARISE. For these missions, the team did the following:

1. Analyzed and plotted meteorological forecast data from NCEP GFS and NASA GEOS-5 model products multiple times per day;

2. Managed websites for meteorological data dispersal including integration of satellite data and from multiple instrument groups;

3. Visualized data from multiple satellites (as relevant to the particular mission) and data analysis from the missions, including visible, IR, and water vapor imagery and made it available to the mission community;

4. Visualized data from multiple satellites, relevant to both the ATTREX-2 and ATTREX-3 missions and data analysis from the missions, including visible, infrared, and water vapor imagery.

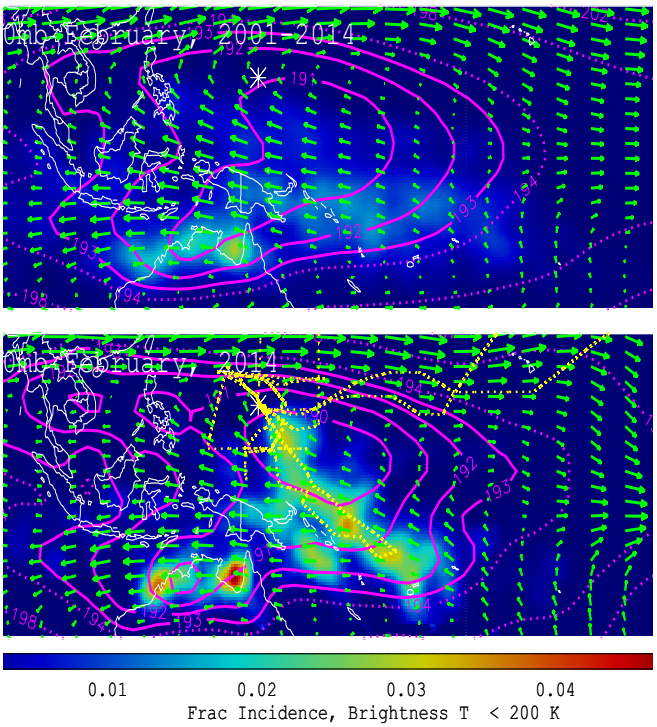

Figure 30: The ARC-CREST team prepared detailed meteorological products specific to the needs of the ATTREX field campaign in 2014. The figure compares the fractional incidence when the brightness temperature is less than 200K for an average time period (2001-2014) to the time of the ATTREX mission. Also shown are temperatures and winds at the 100 mbar level where the ATTREX aircraft sampled.

National Suborbital Education and Research Center (NSERC) Mission Operations

NASA: Matt Fladeland
UND/NSERC: Rick Shetter, Adam Webster, David Van Gilst, Eric Stith, Michael Delaney, Eric Buzay, Karen Katrinak, Emily Shaller, Jane Petersen

The University of North Dakota's National Suborbital Education and Research Center (NSERC) is a partner in the ARC-CREST cooperative agreement. NSERC works with the NASA Airborne Science Program and is responsible for two tasks:

Task 1: Science Mission Operations and
Task 2: Education and Training

In support of Task 1, NSERC addresses all data, satellite communications, engineering and maintenance needs for the following manned NASA airborne science platforms: DC-8, C-130, B-200, ER-2 and P3-B. In addition, in 2014, NSERC supported the following field missions: ATTREX, DISCOVER-AQ, HS3, GHOC, OIB, ASCENDS, SARP, HyspIRI, and ARISE. Accomplishments related to specific airborne platforms are listed. NSERC accomplishments specific to missions are discussed in their respective sections in this document.

In support of Task 2, the NSERC team conducts education and training activities around select fields. Separately, the NSERC team leads outreach programs missions designed to build capacity with science students and teachers. In 2014, NSERC conducted the following education and training activities: SARP, HS3 Outreach, ATTREX Outreach, Ice Bridge Outreach, outreach to K-12 science teachers, and general outreach. The latter two are described below. SARP and mission-specific education and outreach are discussed in their respective sections.

Figure 31 : DC-8

2014 Accomplishments

• The NSERC team provided critical data, satellite communications, and engineering maintenance and support to the DC-8, ER-2, C-130 and B-200 aircrafts, making the conduct of airborne scientific measurement and experiment possible. For all aircraft, the team provides engineering for payload integration, data display and networking support, and instrumentation permanent to the platform. Each aircraft encounters different maintenance issues from year to year. Data, satcom, and engineering highlights are listed by aircraft below .

DC-8

• The team supported the DC-8 Heavy Check in Roswell, NM, by creating design drawings for many permanent installations and completing wiring for various components.

• For the Air Force, the team prepared a summary brief of the DC-8's capabilities to measure cloud microphysics as a potential support partner for the Air Force's Airborne Icing Tanker Program.

• The team finalized the mechanical design of the second generation Multi-Channel assembly, modified the new Multi-Channel computers with locking UNC helicoil mounting, replaced the tapped aluminum metric holes and assembled the bulk of the new Multi-Channel enclosure for the DC-8.

• The team designed, fabricated, and installed the new integration of tablets on the yokes; and set up the new cockpit tablet PC's with VNC, Falconview Firefox, and Xchat.

ER-2 Aircraft

• The team worked with the NASA Alaska Satellite Facility (ASF) to identify and correct the causes of persistent problems with the INMARSAT communications package on board the ER-2. To address this problem, the team worked closely with the INMARSAT electrical systems team to design, fabricate, and install replacement components on the aircraft.

• Also, in cooperation with the ASF team, NSERC staff designed and installed a Wi-Fi system for the ER-2.

C-130

• In 2014, the NSERC team worked closely with NASA-WFF on a variety of tasks related to bringing the C-130 up to the standards required for a science-class platform including: identifying and obtaining quotes for all hardware needs; working with manufacturers to obtain specifications and drawings on certain existing aircraft components; configuring various IT items and developing needed software; and testing iridium and GPS systems.

B-200

•The NSERC team designed and fabricated a new optical window adaptor and re-assembled and tested the new optical window. The team prepared the stress analysis report for this B-200/DC-8 window installation and submitted to Code RS for review.

• For specific airborne science missions in any given year, the NSERC team provides critical data, satellite communications and engineering support unique to the payloads and purpose for that mission. The team is on-site at each field mission, and does everything from setting up ground-based networks, to fabricating components for inlet repair or instrument integration. The team is integral in developing the data communication capabilities between instrument payloads to allow for real-time viewing of various data products by the entire science team. The NSERC team are invaluable to scientists in developing the mission payloads. They provide drawings, specifications and other engineering data needed for fabrication of payload components. In 2014, the team supported the following airborne science missions: ATTREX (Guam), OIB (Greenland), ASCENDS (Virginia), HyspIRI (California), ARISE (Alaska), DISCOVER-AQ (Colorado), and HS3 (Virginia).

• For each of the airborne science missions, the NSERC team also coordinates education and outreach activities around the missions. In 2014, these activities included: regular updates to mission websites, blogs and twitter feeds; staffing the NASA booth at the National Science Teachers' Association Annual Meeting and the AGU Annual Meeting; The team gave giving presentations to science teachers during summer workshops; giving a total 41 presentations to K-12 students; the team coordinatinged in-flight chats with classrooms reaching over 3200 students; collected video footage for documentaries; and also produced a 3 minute video on upcoming missions.

• The team provides support throughout the year to all science teams preparing proposals for upcoming airborne missions. The NSERC team is a partner in design, concept, and feasibility of all airborne science experiments proposed.

Figure 32: ER-2

Figure 33: B-200

Program Management Analysis of Airborne Science Program (ASP)

NASA: Matt Fladeland
BAERI: Jim Weber

ARC-CREST staff are conducting a management analysis of the ASP at NASA-ARC. This includes an assessment of current and historical staff skill sets, major achievements, and major challenges of the program. The team is conducting interviews with NASA and NASA partners involved with the program since its inception. A summary report and all documentation of the program assessment will be delivered to NASA HQ. As a second task, ARC-CREST staff are also acting as liaison between NASA-ARC Applied Science Program and national and international governmental and non-governmental organizations such as the International Society of Photogrammetry and Remote Sensing, The Group on Earth Observations, The Committee on Earth Observations, as well as U.S. and foreign space science and applications agencies.

2014 Accomplishments

• In 2014, Jim Weber completed interviews with the following senior NASA staff: Andrew Roberts (Former Pilot and Director of ASP); Frank Newman (Former Mission Manager at NASA-JSC); Steve Hipskind (Former Earth Sciences Division Director at NASA-ARC); and Jarrell Priess (Current Flight Operations Engineer at NASA-JSC)

• Jim Weber participated in the following coordination meetings:

1. Washington, D.C., NASA Headquarters (Director of the Office of Applied Science);

2. San Francisco, CA., Annual meeting of AGU (President of the International Center for Remote Sensing of Environment);

3. Denver, Colorado (Secretary General of the International Society of Photogrammetry and Remote Sensing), Berlin and Oberfaffenhofen, Germany (Chairman of the International Committee on Remote Sensing of Environment and the German Space Agency or DLR);

4. Paris, France (Director of the Division of Ecology and Earth Sciences of UNESCO).

Earth Science Division Support

NASA: Matt Fladeland
BAERI: Patrick Finch

ARC-CREST staff are providing a variety of data systems and communication support to the Earth Science Division and more specifically to the Airborne Science Program at NASA-ARC. Much of this work involves research and development of the electronics, computing, and communications systems needed for tracking of airborne platforms, including UAS. ARC-CREST staff also interface with numerous investigators and support many different instruments utilizing a variety of airborne platforms.

2014 Accomplishments

In 2014, the team provided critical and 'one of its kind' type electronics, satellite communications, engineering and data support to existing and new ASP assets, including:

1. Assumed control and managements of all ASP tracking devices;

2. Deployed one of the ASP trackers, for the first time, on a research ship in the Atlantic;

3. Developed a system for receiving data from disparate trackers over low bandwidth;

4. Wrote servo-control software for the SIERRA-B UAS;

5. Provided on-site support during the HS-3 mission;

6. Set up streaming services for ASP video; and

7. Acquired, tuned, and integrated an after-market fuel injection system in one of NASA-ARC UAS engines and completed engine testing on a custom-built engine stand.

EDUCATION AND OUTREACH ACTIVITY

Applied Remote Sensing Training (ARSET)

NASA: Jim Brass, Ana Prados (GSFC)
BAERI: Cindy Schmidt, Amber Kuss

NASA's Applied Remote Sensing Training program (ARSET) in NASA's Applied Sciences program provides professional training in the application of NASA Earth Science data for water resources, disaster, and land and air quality management. ARSET builds the skills needed to integrate NASA Earth Science into national and international organizational decision-making activities. The program staff work directly with governmental and non-governmental end users to develop courses that teach end users how to access, visualize, and apply NASA Earth Science data in their professional area. Course modules are publicly available on the program website. The program has reached over 1,600 participants world-wide using the combined online and interactive approach.

ARC-CREST staff conducts online webinars entitled "Introduction to Remote Sensing for Conservation Management" and "Introduction to Remote Sensing for Wildfire Management.". The staff also conducts wildfire training at Idaho State University and collaborates with Navajo Nation representatives on water resources and land management issues.

Presentations

Prados, A., P. Gupta, A. Mehta, C. Schmidt, B. Blevens, A. Carelton-Hug and D. Barbato. " A Multi-step Approach to Improving NASA Earth Science Data Access and Use for Decision support through Online and Hands-on Training." (GC53A-0510). Presented at American Geophysical Union Annual Meeting, December 15-19, San Francisco, CA.

2014 Accomplishments

• ARC-CREST researchers working on the ARSET project produced webinars in Ecoforecasting and Disaster Management areas and created live demonstration videos for the webinars.

• From November 3rd to December 1, 2014, the team hosted the Land Management webinar series (5 weeks) for over 300 attendees. For this series the team implemented webcasting software Adobe Connect to set up the event, manage participants, and upload and broadcast content.

• The team updated all user instructions, datasets, and outreach materials to better engage audiences.

• The team further coordinated with the Navajo Nation on joint projects including on-site meetings with professors and students at Navajo Technical University and governmental personnel at the Navajo Nation Department of Water Resources.

• To increase awareness of the ARSET program and better serve its user community, the team did the following: conducted outreach to target audiences; gave presentations at professional conferences; sent over 400 invites to agency land managers and academics; and interfaced with state, federal, NGO, and academic institutions to identify the needs of the user community.

California State University at Monterey Bay (CSUMB) Educational Program

NASA: James Brass
CSUMB: Susan Alexander, Kenneth Weinstock

The Division of Science and Environmental Policy at CSUMB offers a Bachelor of Science degree program in Environmental Science, Technology, and Policy and a Master of Science degree program in Applied Marine and Watershed Science. ARC-CREST staff work closely with CSUMB staff to support students and mentors associated with this program, particularly in the area of technology.

Advanced technology training is integrated throughout the applied environmental science and policy curriculum emphasizing 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. Professional internships enhance the skills learned in the classroom. 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 supports the program by: providing hardware/software technical support to visiting scientists, including summer faculty; providing hardware/software technical support to students during the DEVELOP program; coordinating production of video and graphic displays of research conducted by students for presentation at conferences; facilitating internships and collaborations between students and ARC-CREST senior scientists that develop advanced skills in remote sensing, image processing, geographical information systems, computer modeling, simulation and analyses, data acquisition and visualization, and communications technology.

2014 Accomplishments

- CSUMB AMWS Master's Student Sean Castorani completed his thesis under the direction of Lee Johnson at NASA Ames Research Center.

- CSUMB AMWS students (or recent graduates) David Hamblin, Shane Keefauver, Gwen Miller, Erin Stanfield, Aimee Teaby, John Urness, and Sean Windell conducted research under the mentorship of Forrest Melton.

- CSUMB AMWS students David Minovitz and Aimee Teaby participated in the NASA DEVELOP student internship program at Ames Research Center in summer 2014.

- AMWS student Gwen Miller participated in the NASA DEVELOP student internship program at JPL in summer and fall 2014.

- Through this program, CSUMB Faculty member Dr. Dan Fernandez collaborated with NASA PI Dr. Chris Potter on local fog research.

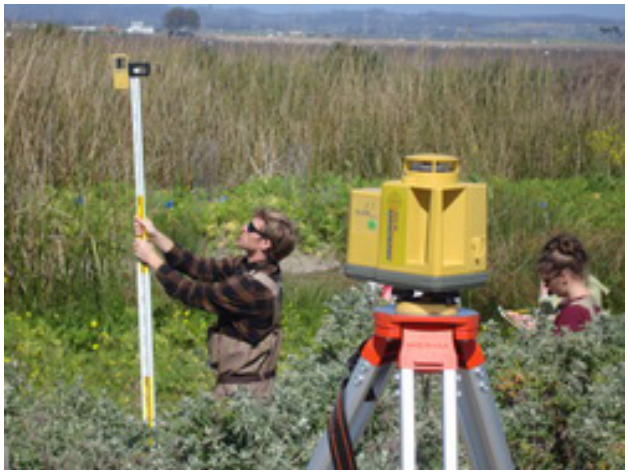

Figure 34: CSUMB students in the Environmental Science, Technology and Policy Department survey wetlands in the Elkhorn Slough area, near Monterey California.

Photo credit: CSUMB Environmental Science, Technology and Policy Department

DEVELOP

NASA: James Brass
BAERI: Cindy Schmidt

The DEVELOP National Program is a capacity building internship sponsored by NASA's Applied Sciences Program that provides young professionals and interns the opportunity to learn about NASA Earth Science and the practical applications of Earth observations. The two main activities of this project are to provide in-person and on-line courses, workshops ,and other capacity building activities throughout the year and to disseminate via the web course materials and other information to enable training in applied air quality and remote sensing.

Project courses are a combination of lectures and computer hands-on activities that teach professionals how to access, interpret, and apply NASA aerosol and trace gas data at regional and global scales with an emphasis on case studies. Course topics include (1) Case studies in air quality analysis tailored to end-user needs, such as urban air pollution, dust, and fires; (2) Satellite aerosol and trace gas products, their application and relationship to in situ monitoring of data; (3) long-range Transport of atmospheric aerosols (or particulate matter) and trace gases; and (4) satellite and regional air quality model comparisons.

Skills taught include:
• Search, access, and download of NASA data products and imagery;

• Appropriate use and interpretation of satellite imagery;

• Visualization and analysis of NASA imagery using NASA, EPA, and NOAA web tools and other resources such as Google Earth, Panoply, RSIG, HDFLook, and MISRView.

2014 Accomplishments

• The DEVELOP team, led by Cindy Schmidt, interviewed over 50 students, selected from an applicant pool of hundreds, and selected 20 students for the summer 2014 program.

• The team created 3 distinct summer projects for students: 1) Climate change in the Great Basin; 2) Water quality and coral reef health in American Samoa; and 3) Developing a web-based decision support tool for the Region 5 USFS for forest health assessment.

• In addition to conducting the program, including coordination between universities and federal agencies, the DEVELOP team mentored students throughout the program until final presentations at NASA Ames Research Center.

• The DEVELOP team traveled to the Navajo Reservation in New Mexico and Arizona to develop a relationship with the Navajo Technical University in Crownpoint, New Mexico, the Navajo Water Resources Department in Fort Defiance, Arizona, and the NASA DEVELOP program.

Early Career Collaborators

NASA: Steve Hipskind
BAERI: Sreeja Nag, Ronnie Instrella

Early career researchers are conducting specialized projects in collaboration with NASA civil servants, ARC-CREST staff and/or agency and university staff on topics directly related to NASA's Mission. These collaborations provide mentoring for early career scientists working on cutting edge projects while at the same time injecting new talent and energy into the NASA work force. Furthermore, early career collaborations initiate new and strengthen existing ties between NASA scientists and the broader research community whereby unique NASA assets such as remote sensing data products, airborne assets or super-computing can be accessed and leveraged for maximum scientific return. Collaborations are currently focused on projects that integrate fluid lensing cameras to airborne platforms, design distributed small satellite systems, and examine applications of small satellite systems to earth monitoring and measurement.

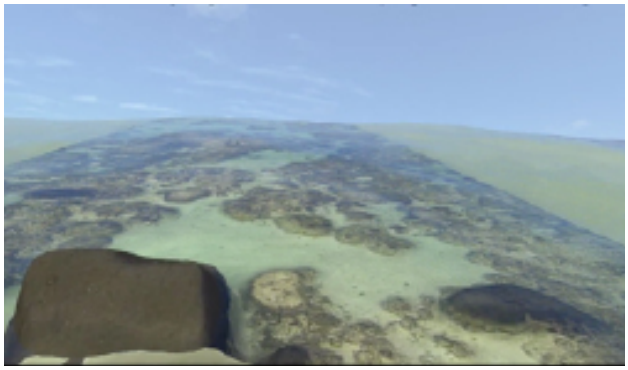

Figure 35: An example of a 3D visualization of a coral reef created by the team from geo-referenced aerial data, fluid lensing and various software techniques. The goal is to gain a basic understanding of the types of fluid distortions seen along shallow coastlines so that scientists can better interpret remotely sensed data.

2014 Accomplishments

• In 2014, early career collaborator Sreeja Nag, worked with NASA-ARC scientists in the Earth Science Division and Mission Design Center to examine the feasibility of using small satellite constellations for certain types of Earth Science observations:

1. Developed software for analyzing the imaging modes for multiple satellites in a multi-angular mission;

2. Developed software for analyzing maintainability of a satellite constellation; and

3. Developed software for generating architectures for a satellite cluster in formation flight.

• An early career collaborator, Ronnie Instrella, worked with NASA Pathways intern Dr. Ved Chirayath to develop fluid lensing algorithms, determine effective methods to correct for image distortions observed through fluid surfaces and enhance these images for making Earth observations. Ronnie Instrella and Ved Chirayath made progress on creating visualizations of coral reefs with this technique from aerial footage captured from a UAS and collaborated with a team at the University of Miami on ongoing research on stromatolite taxonomy.

Earth Science Division Outreach

NASA: Steve Hipskind, Michael Bicay, Jim Brass, Warren Gore
BAERI: Julie Nottage, Nikki Issac, Jennifer Kenworthy, Gailynne Bouret, and Michaela Herman

The Division Outreach project provides a broad range of both internal research support and external communications activities for the Earth Sciences Division at NASA-ARC. The team provides specialized research support to civil servant and ARC-CREST researchers at NASA-ARC and their collaborators. The team interfaces with Center management, Division leadership, Headquarters, ARC-CREST partners, the media, and the general public.

2014 Accomplishments

• The Division Outreach team provides various types of support to the Earth Sciences Division at NASA-ARC. Major accomplishments in 2014 included but were not limited to:

1. Completing a major overhaul of the Division's website and movement to a cloud based system;

2. Providing support to staff as they updated web content;

3. Managing travel and conference requests and attendance for Division staff;

4. Organizing several conferences hosted by the Earth Science Division including lodging, meals, badging, programs and registration;

5. Producing weekly news highlights for the Division.

FrankenEye

NASA: Jim Brass
CSUMB: Robert Dahlgren

The FrankenEye program provides summer students and interns the opportunity to design, build, and test new UAS platforms for scientific use. In 2014, the project team used 3D printers at NASA-ARC and Stanford University to create prototypes and make conceptual models. They also custom-built aircraft by repurposing surplus UAS. The name FrankenEye is a reference to "Frankenstein" ; the student teams participating in summer activities harvested parts from surplus aircraft and re-animated those parts using new 3D printed parts with the goal of increasing payload capacity and endurance in Earth Science missions. Students conducted test flights of the Frankeneye aircraft at Crows Landing flight facility in August of 2014.

Figure 36: Students in the FrankenEye program used the DragonEye aircraft shown above as a basis for design. Students modified and reassembled DragonEye UAS, including newly designed pieces. The DragonEye has proven a useful and robust UAS platform for dangerous environments such as volcanoes and fires.

2014 Accomplishments

• Mentoring 10 NASA summer intern students, the ARC-CREST team led by Robert Dahlgren repurposed several surplus UAVs for scientific experiments.

• The team and the summer interns demonstrated design-to-flight of 2 aircraft in 6 weeks, including airworthiness certification and completed 9 flights of the "FrankenEye" aircraft at Crow's Landing, California.

https://www.youtube.com/watch?v=Hjuq9XertJ4

http://www.nasa.gov/ames/its-alive-ames-engineers-harvest-and-print-parts-for-new-breed-of-aircraft/

• In support of this project, the team constructed a UAS stress-testing frame, a test stand, a UAS catapult carriage, and a propeller dynamometer in a machine shop.

Student Airborne Research Program (SARP)

NASA: Jack Kaye
UND/NSERC: Rick Shetter, Emily Schaller, Jane Peterson, and Karen Katrinak

The Student Airborne Research Program (SARP) is an eight-week summer program for junior and senior undergraduate and early graduate students to acquire hands-on research experience in all aspects of a scientific mission using NASA's DC-8 or P-3 airborne science laboratories. The DC-8 and P-3 are major NASA resources for studying Earth system processes, calibration/validation of space-borne observations, and prototyping instruments for possible satellite missions. Participants assist in the operation of instruments on board the aircraft to sample atmospheric chemicals and to image land and water surfaces in multiple spectral bands.

Along with airborne data collections, students participate in taking measurements at field sites. The program culminates with formal presentations of research results and conclusions. Students participating in the program have a strong academic background in disciplines relevant to the Earth system, including the physical, chemical, or biological sciences or engineering. Many have experience with image processing and GIS systems.

2014 Accomplishments

- The UND-based team reviewed over 200 applications in 2014 and selected 32 students and also selected the top presentations to be presented at the AGU Annual Meeting.
- The team provided all logistics including travel, lodging, final graduation meeting, laptop use and return, science flights, lectures, and final student evaluations.
- The team produced the 2015 SARP recruiting video, sent the 2015 recruiting flyer to over 1000 colleges and universities, and organized the 2014 Reunion Dinner.

Figure 37: 2014 SARP students with the DC-8.

PUBLICATIONS AND PRESENTATIONS

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ACRONYMS

4STAR	Sky-scanning, Sun-tracking Atmospheric Research
AATS-14	Ames Airborne Tracking Sun-photometer
AERONET	Aerosol Robotic Network
AIRS	Atmospheric Infrared Sounder
AGB	Aboveground biomass
AGU	American Geophysical Union
AJAX	Alpha Jet Atmospheric Experiment
AIAA	American Institute of Aeronautics and Astronautics
AMWS	Applied Marine and Watershed Science Program at CSUMB
ARISE	Arctic Radiation, IceBridge, Sea and Ice Experiment
ARC-CREST	Ames Research Center Cooperative for Research in Earth Science and Technology
ARSET	Applied Remote Sensing Training
ASCENDS	Active Sensing of CO_2 Emissions over Nights, Days and Seasons
ASP	Airborne Sciences Program
ATom	Atmospheric Tomography Mission
AVHRR	Advanced Very High Resolution Radar
AVIRIS	Airborne Visible/Infrared Imaging Spectrometer
BBR	Broadband Radiometer
BCCA	Bias-correction Constructed Analogs
BCSD	Bias-correction Spatial Disaggregation
CARB	California Air Resources Board
CALIPSO	Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation
CARTA	Costa Rican Airborne Research and Technology Application
CASI	Climate Adaptation Science Investigators
CDFA	California Department of Food and Agriculture
CDWR	California Department of Water Resources
CH_2O_2	Formic acid
CH_3OH	Methanol
CH_4	Methane
CMEs	Coastal Marine Ecosystems
CMIP5	Coupled Model Inter-comparison Project5
CMS	Carbon Monitoring System
COMEX	Carbon dioxide and methane experiment
CO_2	Carbon dioxide
CSUMB	California State University at Monterey Bay
DAAC	Distributed Active Archive Center
DLR	Deutsches Zentrum für Luft und-Raumfahrt (German Aerospace Center)
DNS	Direct Numerical Simulation
EOS	Earth Observing System
EPA	Environmental Protection Agency
ESDR	Earth Science Data Records
ESD	Earth Science Division Database
ESPO	Earth Science Project Office
Eu:CROPIS	Euglena: Closed Regenerative Organic

ACRONYMS

FCMC	Forest Carbon, Markets, and Communities
GCAD	Global Cropland Area Database
GCAD30	Global Cropland Area Database at 30 m resolution
GCE	Global Cropland Extent
GCM	Global Climate Model
GEO-CAPE	Geostationary Coastal and Air Pollution Events
GEOS-5	Global Earth Observing System Model version 5
GEOSS	Global Earth Observation System of Systems
GFS	Global Forecast System
GOSAT	Greenhouse gases Observing Satellite
$H_2O(g)$	Water vapor
HDO(g)	Deuterium substituted water vapor
HDF	Hierarchical Data Format
HIAPER	High-performance Instrumented Airborne Platform for Environmental Research
HICO	Hyperspectral Imager for the Coastal Ocean
HIPPO	HIAPER pole to pole observations
HMS	Heliophysics Modeling and Simulation
HUS	Specific Atmospheric Humidity
IGARSS	International Geoscience and Remote Sensing Symposium
INFLUX	INdianapolis FLUx eXperiment
IWGGMS	International Workshop on Greenhouse Gas Measurements from Space
KORUS-AQ	International Cooperative Air Quality Field Study in Korea
Landsat ETM+	Landsat Enhanced Thematic Mapper +
Landsat 8 OLI	Landsat 8 Operational Land Imager
LES	Large Eddy Simulation
LVIS	Land, Vegetation and Ice Sensor
MACC	Monitoring Atmospheric Composition and Climate
MAIAC	Mulit-angle implementation of atmospheric correction for MODIS
MASTER	MODIS/ASTER Simulator (Advanced Spaceborne Thermal Emission and Reflection Radiometer)
MEaSUREs	Making Earth System data records for Use in Research EnvironmentS
MMS	Meteorological Measurement Systems
MODIS	Moderate Resolution Imaging Spectro radiometer
MODIS-MAIAC	Multi-angle implementation of atmospheric correction for MODIS data
N_2O	Nitrous oxide
NASA-AFRC	NASA Armstrong Flight Research Facility
NASA-ARC	NASA Ames Research Center
NASA-CASA	NASA Carnegie Ames Stanford Approach
NASA-JPL	NASA Jet Propulsion Laboratory
NAST-I	National Polar Orbiting Operational Environmental Satellite System Airborne Sounder Testbed
NCA	National Climate Assessment
NCEP	National Center for Environmental Prediction
NEX	NASA Earth Exchange
NGA	National Geospatial Agency

ACRONYMS

NO_3^-	Nitrate
NOAA	National Oceanographic and Atmospheric Administration
NOI	Northern Oscillation Index
NSERC	National Suborbital Education and Research Center
OCO-2	Orbiting Carbon Observatory 2
OCS	Carbonyl sulfide
OIB	Operation Ice Bridge
OMI	Ozone Monitoring Instrument
OSTP	Office of Science and Technology Policy (White House)
PAN	Peroxyacetyl nitrate
R	R is a free, open-source programming language and software environment for statistical computing, bioinformatics and graphics
REDD+	Reducing Emissions from Deforestation and Forest Degradation (REDD+)
RSIG	Remote Sensing Information Gateway
SARP	Student Airborne Research Program
SBIR	Small Business Innovation and Research
SCIAMACHY	Scanning Imaging Absorption Spectrometer for Atmospheric Chartography
SEAC4RS	Studies of Emissions and Atmospheric Composition, Clouds and Climate Coupling by Regional Surveys
SIERRA	Sensor Integrated Environmental Remote Research Aircraft
SIMS	Satellite Irrigation Mapping System
SOFRS	Science Operations Flight Request System
SSFR	Solar Spectral Flux Radiometer
SUAS	Small Unmanned Aircraft Systems
TCAP	Two Column Aerosol Project
TCCON	Total Carbon Column Observing Network
TES	Tropospheric Emission Spectrometer
TGARS	Transactions on Geoscience and Remote Sensing
UAS	Unmanned aircraft systems
UAV	Unmanned aerial vehicle
UND	University of North Dakota
UNESCO	United Nations Educational Scientific and Cultural Organization
USDA	United States Department of Agriculture
USCRTF	United State Coral Reef Task Force
USGCRP	United States Global Climate Research Program
USFS	United States Forest Service
USGS	United State Geological Survey