ANNUAL REPORT 2016

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, 2015 to February 28, 2016.

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 37 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 2015, 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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INTRODUCTION

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

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

The ARC-CREST scientific team, working closely with the Ames Earth Science Division, participated in over 41 different project areas covering the gamut of Earth Science research. One important theme was the measurement of atmospheric carbon dioxide, first by using the data from the Tropospheric Emission Spectrometer (TES), which is an infrared spectrometer flying aboard the Aura satellite and the Orbiting Carbon Observatory-2 (OCO-2). Closer to home, the Alpha Jet Atmospheric eXperiment (AJAX) continued flights over California and Nevada, measuring carbon dioxide, ozone, and methane over multiple seasons to complement other data collection efforts. Other atmospheric carbon dioxide projects included the Earth Science Data Records (ESDR) project, and the Total Carbon Column Observing Network (TCCON) project.

ARC-CREST scientists used NASA resources to study tropospheric ozone production, coastal ocean biology, space weather, solar physics, plant physiology, and synthetic biology. They also continued to develop and use cutting edge technology to advance Earth Science. The NASA Earth Exchange (NEX) project used NASA's supercomputing capability to provide online collaborative space to researchers around the world, providing dramatically increasing access to vast amounts of data collected by NASA satellites. In the Carbon Monitoring Systems (CMS) project, ARC-CREST scientists used the NEX computing capability and Landsat data to estimate to forest cover in the continental US at a spatial resolution of 1 meter. Through the MEaSUREs project (Making Earth System Data Records for Use in Research Environments), ARC-CREST scientists monitored global croplands in order to ensure sustainable water and food security.

ARC-CREST scientists also worked with NASA to use data collected for Earth Science Research on a range of projects that have practical applications. For example, through the Ecological Forecasting project, there were significant accomplishments in agricultural productivity, water management, earthquake response, and many other important areas. Our scientists also continued to adapt NASA unmanned aerial vehicles (UAVs) for use in fighting forest fires.

INTRODUCTION

The ARC-CREST partners also provided support to critical Earth Science activities at NASA Ames Research Center, including the Earth Science Project Office; the Applied Sciences Program's Water Resources Program; the Meteorological Measurement System; and the Airborne Science Program (including payload integration engineering, data display and networking, and facility instrumentation for NASA's fleet of research aircraft). Development of NASA's capabilities in using Unmanned Aerial Vehicles for Earth Science projects continued to be a particular focus.

Finally, through the Student Airborne Research Program (SARP) and the Digital Earth Virtual Environment and Learning Outreach Project (DEVELOP), ARC-CREST participants worked with the NASA Ames Research Center to provide extensive educational and public outreach opportunities related to Earth Science

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
2. California State University at Monterey Bay
3. NASA Ames Research Center – Earth Sciences Division
4. University of North Dakota – National Suborbital Education and Research Center

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Mehrotra, Piyush
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Nemani, Rama
Pfister, Leonhard
Pierce, Brad
Podolskie, Jim
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Prados, Ana
Rios, Joey
Redemann, Jens
Scargle, Jeff
Vasques, Marilyn
Worden, John

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Delaney, Michael
Katrinak, Karen
Peterson, Jane
Schaller, Emily
Shetter, Rick
Stith, Eric
Van Gilst, David
Webster, Adam
Yang, Melissa

EARTH SCIENCE FOCUS AREAS

4STAR and Satellite Data Analysis

NASA: J. Redemann,
BAERI: C. Chang, M. Kacenelenbogen, Y. Shinozuka, M. Segal-Rozenhaimer, Q. Zhang

The Ames 4STAR (Spectrometer for 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 air instruments and the Ames Airborne Tracking Sun-photometer (AATS-14). Scientists analyze measurements from these instruments to yield atmospheric aerosol optical depth and extinction spectra, aerosol size distributions, water vapor columns and profiles, and ozone columns. They also have used the sun-photometer instruments to validate measurements from 12 satellite instruments, two airborne simulators of satellite instruments, and several airborne and ground-based LIDARS. The AATS instrument has 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 ground and air instruments broaden the types of usable aircraft and add the additional measurement capabilities of sky-scanning and improved wavelength resolution.

2016 Accomplishments

- Produced global seasonal clear-sky aerosol radiative forcing results based on multi-satellite sensor aerosol retrievals; those results were then compared to values derived from a subset of models that participated in the latest AeroCom initiative;
- Developed an alternate retrieval of aerosol above opaque water cloud using the CALIOP/ CALIPSO Depolarization Ratio Technique over the globe;
- Used aerosol retrievals from a combination of MODIS, OMI and CALIOP satellite observations to infer aerosol types over the globe;
- Used the full capacity of the 14-channel Ames Airborne Tracking Sunphotometer (AATS--14) as input to an atmospheric correction model for an improved water color characterization; and
- Assisted in the management of the ORACLES experiment and, more specifically, improved real-time mapping of geostationary and sun-synchronous satellite maps for flight planning purposes.
- **Instrument Development (AITT)**
  Continued working on improving instrument reliability and accuracy through the AITT project. Specifically, we have performed laboratory measurement of temperature dependence under various conditions, for the various instrument parts and revealed that the diffuser on the fiber optic side was the main problem. We have mitigated this by changing the diffuser/fiber-optic connectivity path.

  o Developed initial capability of tracking the sun via a wide FOV visible camera.
  o Developed a procedure to adjusting the Langley calibration using an FEL lamp calibration to improve 4STAR UV measurement signal.
- **Data analysis (SEAC4RS and ARISE)**
  Worked on SEAC4RS data archival and reprocessed the data based on the recent findings of temperature sensitivity. 4STAR SEAC4RS data has been used in several SEAC4RS publications (see for example Jethva et al., 2015).
- Worked on archiving final data for the ARISE 2014 campaign and applied thin cirrus retrievals on the 4STAR instrument to compare with the CERES satellite overpasses during the ARISE campaign (see Smith et al., 2015). In addition, we are working on analyzing multi- sensor data from ARISE to get insights on cloud radiative forcing magnitude and sensitivity over the Arctic Sea-Ice.

- **Flight Operations**
  For the NAAMES deployment in November, adjusted the fiber optic set-up, cleaned the FORJ and all elements in the 4STAR optical path, and performed laboratory calibrations;
- Integrated 4STAR on the C-130 for the NAAMES campain.; and
- Worked logistic aspects in preparation for the KORUS-AQ campaign and participated in the STM held in October.

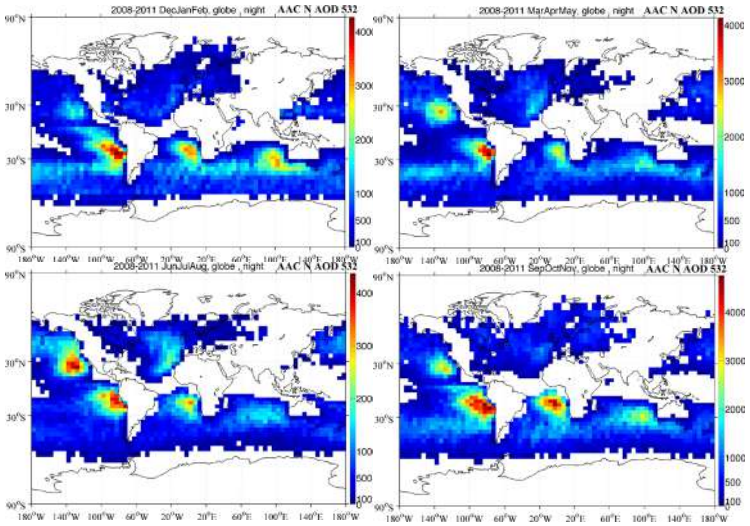


Figure 1: Global seasonal nighttime number of aerosol above cloud cases from 2008 to 2012 using CALIOP and the alternate depolarization ratio method

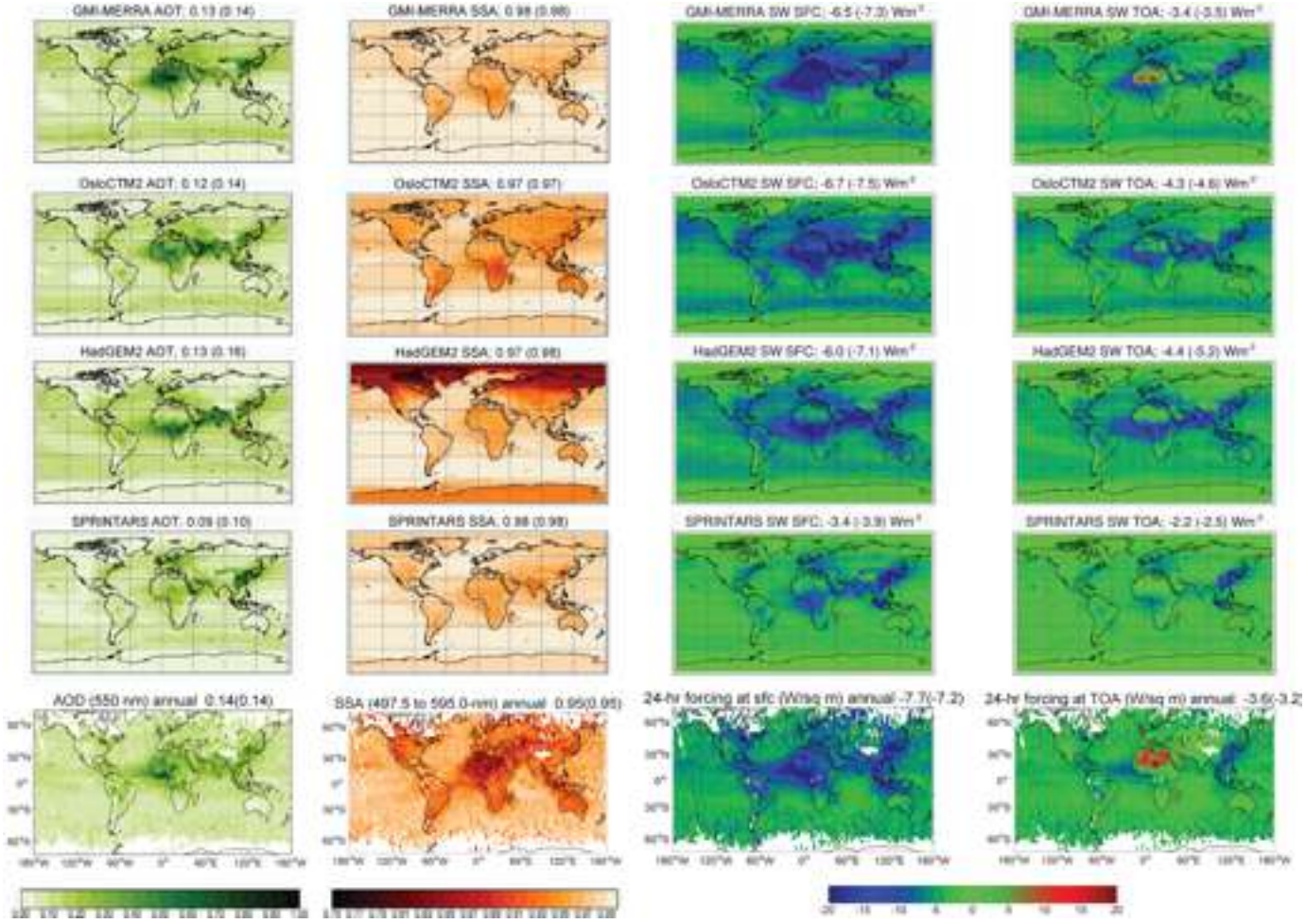


Figure 2: Annually averaged AOD, SSA, surface and TOA shortwave forcing from GMI-Merra, OSLO-CTM, HadGEM2, SPINTARS, compared to MODIS-OMI-CALIOP retrieval results (last row).

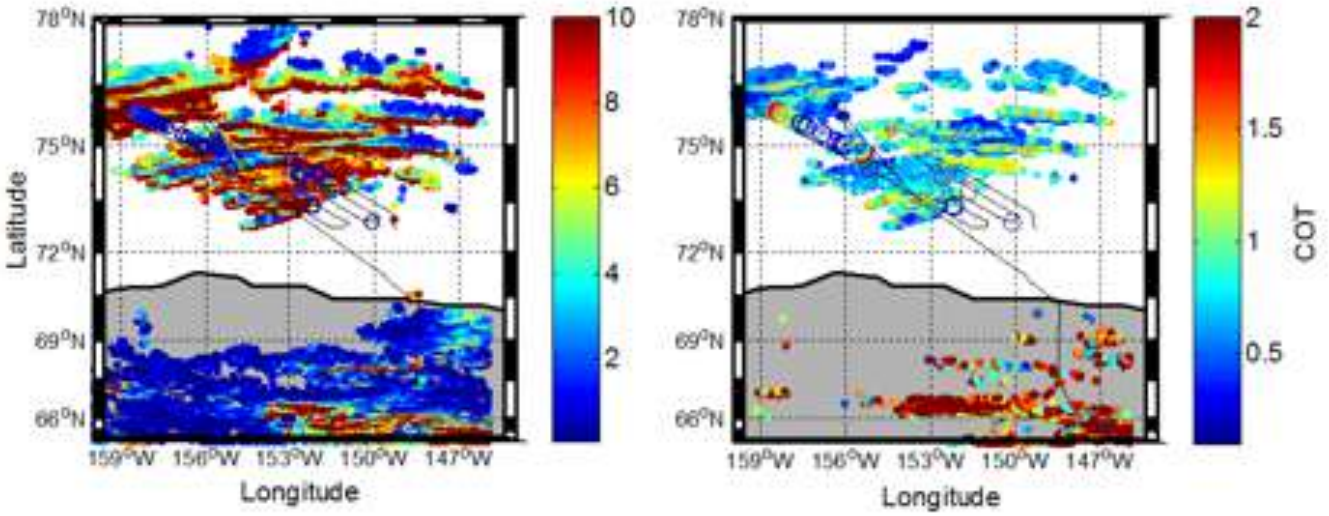


Figure 3: (adapted from Smith et al., 2015, submitted): (a) COT for all multi-layer ice clouds with top above 5 km height derived by CERES (solid circles),overlaid by direct sun cirrus retrievals (based on procedure developed in Segal-Rosenheimer et al., 2013) from the 4STAR instrument on-board C-130 (open circles), and (b) COT for only upper layer clouds, as derived by CERES, overlaid by direct sun cirrus retrievals from 4STAR (open circles) for September-15 flight. Note the different colorbar scales.

Publications and Presentations

Jethva et al., Validating Above-cloud Aerosol Optical Depth Retrieved from MODIS-based 'Color Ratio' Algorithm using NASA's Airborne AATS and 4STAR Direct Measurements, in preparation for GRL, 2015.

Saide, P. E. et al. (Kacenelenbogen, M. and Redemann, J. among 10 authors): Central American biomass burning smoke can increase tornado severity in the U.S. Geophys. Res. Lett., 2014GL062826,10.1002/2014gl062826, 201

Saide, P. E. et al. (Redemann, J. and Shinozuka, Y.) among 26 authors. (2015), Revealing important nocturnal and day-to-day variations in fire smoke emissions through a multiplatform inversion. Geophys. Res. Lett., 42, 3609–3618. doi: 10.1002/2015GL063737.

Smith L. William Jr. et al.s, Arctic Radiation-IceBridge Sea and Ice Experiment (ARISE): The Arctic radiant energy system during the critical seasonal ice transition. Bull. Amer. Meteor. Soc., submitted (August, 2015).

Segal-Rozenhaimer et al., Relative roles of atmospheric state and boundary layer clouds on Arctic cloud radiative forcing forecasts: The ARISE 2014 case study, in preparation for J. of Climate, 2015

Shinozuka, Y., et al. (2015), The relationship between cloud condensation nuclei (CCN) concentration and light extinction of dried particles: indications of underlying aerosol processes and implications for satellite-based CCN estimates, Atmos. Chem. Phys., 15, 7585-7604, doi:10.5194/acp-15-7585-2015.

Flynn et al., 4STAR sky-scanning retrievals of aerosol intensive optical properties including size distribution, coarse mode fraction, complex index of refraction and single scattering albedo: comparisons to AERONET during TCAP I & II and SEAC4RS, American Geophysical Union (AGU),12/14-18 2015.

Redemann et al., Aerosol-cloud interactions in the South-East Atlantic: future suborbital activities to address knowledge gaps in satellite and model assessments, American Geophysical Union (AGU), 12/14-18 2015

LeBlanc et al., Implication of using transmitted vs. reflected light or determining cloud properties, cloud radiative effect and aerosol-cloud-interactions, American Geophysical Union (AGU), 12/14-18 2015

Kacenelenbogen et al., Preparing for ORACLES: A few satellite derived aerosol and cloud properties in the South East Atlantic, Poster, ORACLES Science Team, NASA AMES, USA, September 2015

Kacenelenbogen et al., Aerosol types from spaceborne remote sensing observations over the globe: from clear-sky to above low opaque water clouds, Poster, National Academy of Science, Irvine, USA, 06/23-24 2015.

Palacios S. et al., Bringing the ocean into finer focus, Climate Change and Ecosystems Joint Workshop in College Park, MD, April 20-24, 2015.

Le Blanc S. E. et al., Cloud Properties Retrieved from Airborne Measurements of transmitted and Reflected Shortwave Spectral Radiation, SEAC4RS science team, Boulder, CO, April 2015.

Le Blanc S. E. et al., Cloud shortwave radiative effect and cloud properties estimated from airborne measurements of transmitted and reflected light, EGU, Vienna, Austria, 12-17 April, 2015.

Segal-Rozenhaimer, M. et al., Cloud radiative forcing sensitivity to Arctic synoptic regimes, surface type, cloud phase and cloud properties during the Fall 2014 Arctic Radiation, IceBridge and Sea-Ice Experiment (ARISE). European Geophys. Union General Assembly, 12-17 April 2015, Vienna, Austria.

Segal-Rozenhaimer, M., et al., Investigating cloud radiative effects sensitivity over the marginal ice zone during ARISE 2014, ARISE Science Team Meeting, NASA Goddard Space Flight Center, Greenbelt, Md., 19-20 May 2015

Shinozuka, Y., et al. (2015), The relationship between cloud condensation nuclei (CCN) concentration and light extinction of dried particles: indications of underlying aerosol processes and implications for satellite-based CCN estimates, ORACLES Science Team Meeting.

Shinozuka, Y., et al. (2015), The relationship between cloud condensation nuclei (CCN) concentration and light extinction of dried particles: indications of underlying aerosol processes and implications for satellite-based CCN estimates, NAAMES Science Team Meeting.

Shinozuka, Y., et al. (2015), The relationship between cloud condensation nuclei (CCN) concentration and light extinction of dried particles: indications of underlying aerosol processes and implications for satellite-based CCN estimates, Arthur M. Sackler colloquium on Improving Our Fundamental Understanding of the Role of Aerosol-Cloud Interactions in the Climate System.

Shinozuka, Y., et al. (2015), Airborne observation of aerosol optical depth, Phil Russell Retirement Symposium.

Awards
NASA Group Achievement award for ARISE campaign

Aerosol Modeling

NASA: Mian Chin
BAERI: : Qian Tan

Aerosols are small particles suspended in the air. They can affect the air quality and climate in many ways. The vertical distribution of aerosols and their precursors can largely affect their lifetime and magnitude of their impacts. In 2016, the team continued their study of the vertical distribution of aerosols and their precursors using both a global aerosol transport model and measurements from airborne and space-borne instruments. Multi-model comparison shows very large differences among simulated distribution of aerosols in the upper troposphere and lower stratosphere. This can lead to uncertainty in estimated source attribution and their climate impacts.

2016 Accomplishments

- Compared simulated sulfate aerosols and SO2 by 16 aerosol transport models from the Aerosols Modeling Inter-Comparison project (AEROCOM);
- • Compared vertical distribution of aerosols from two space-borne LIDARs and tracked their transport; and
- • Worked on a project to study the impact of soil moisture measured by a new satellite on the dust emission in Africa.

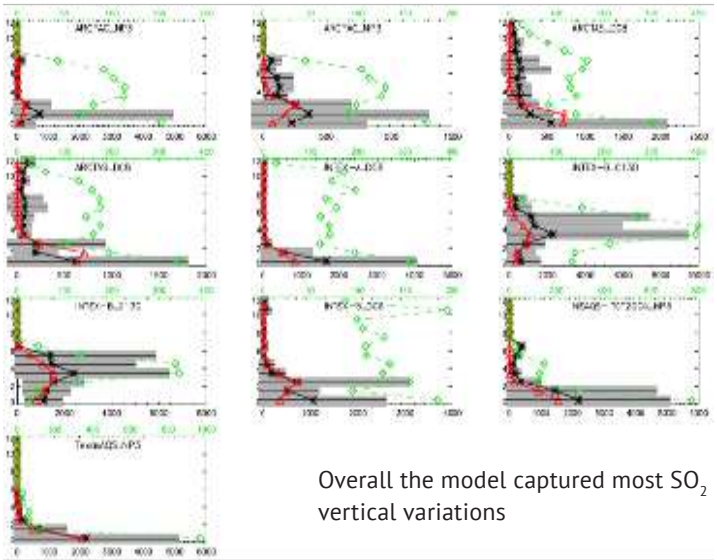
Publications and Presentations

Lau W. K. M., K-M Kim, J. Shi, T. Matsui, M. Chin, Q. Tan, C. Peters-Lidard, W. K. Tao, Impacts of aerosol–monsoon interaction on rainfall and circulation over Northern India and the Himalaya Foothills, Climate Dynamics, doi:10.1007/s00382-016-3430-y, 1-16, 2016.

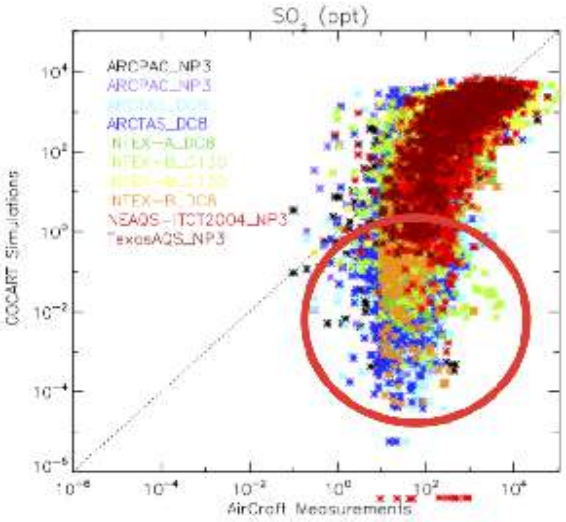
Tan Q., M. Chin, V. Aquila, G. Chen, M. Hoepfner, The vertical profile of SO2 seen by aircraft, satellite and models, Kaufman Symposium, June, 2016, NASA GSFC, Greenbelt, MD (poster)

Tan Q., M. Chin, V. Aquila, G. Chen, Evaluation of modeled vertical distribution of SO2 and sulfate, AeroCom Workshop, Sept 2016, Beijing, China. (poster)

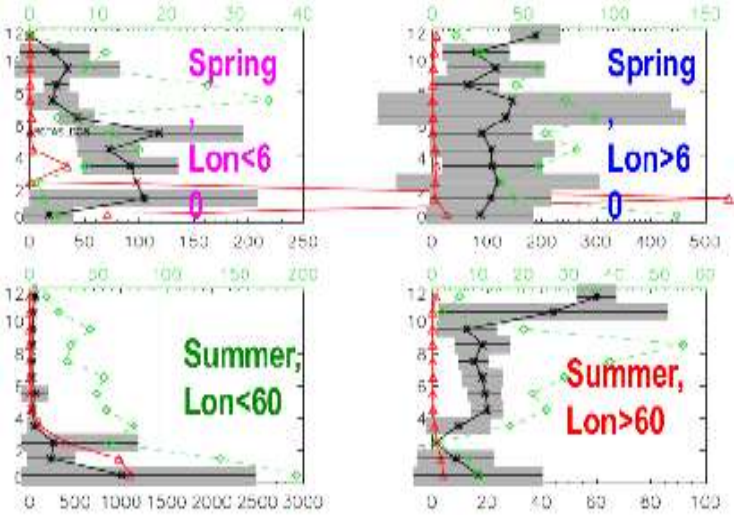
Tan Q., M. Chin, V. Aquila, G. Chen, Evaluation of modeled vertical distribution of atmospheric SO2 and sulfate, AGU Fall Meeting, Dec 2016, San Francisco, CA.



Overall the model captured most SO_2 vertical variations

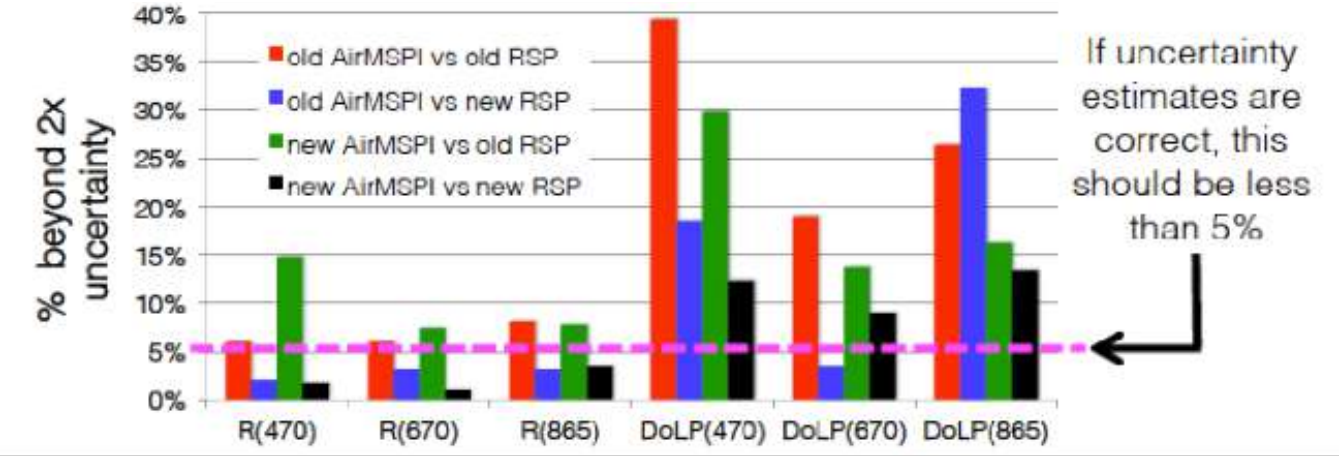


Low [SO_2]: instrument detection limit vs. small numerical value in model



Model underestimated SO_2 in high latitude in spring time.

Figure 4: Evaluation if modeled SO_2 vertical distributions



Agriculture, Health, and Marine Applied Sciences

NASA: Rama Nemani, Jennifer Dungan
CSUMB: Forrest Melton, Lee Johnson, Kirk Post, Alberto Guzman, Carolyn Rosevelt, Isabel Zaragoza, Michael Hang, Dan Muratore, Rachel Spellenberg, Andrew Michaelis

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

The primary objectives of this task are to:

1) Apply satellite data, airborne data, and surface sensor networks to model and map agricultural productivity and crop water demand;

2) Apply satellite data, climate models, and ecological models to map habitat for disease vectors and model vector-borne disease transmission risk; and

3) Apply satellite multispectral and airborne hyperspectral data coupled with field measurements of biological data, to contribute to research on ecosystem health, ecological structure, and benthic habitat biodiversity of coral reefs and associated biotopes (seagrass).

2016 Accomplishments

• Mentored three CSUMB SNS students who worked with the SIMS and Fallowed ARea Mapping projects in 2016 (Rachel Spellenberg, Dan Muratore, Michael Hang). Additional research internships will be offered in 2017;

• Published 1 peer reviewed journal article, submitted 2 peer reviewed journal articles that are in review, and 2 additional articles currently in preparation. Presented more than 15 scientific and technical talks/posters at science conferences and technical meetings;

• Delivered data on land fallowing during the ongoing California drought monthly from April - September to the California Department of Water Resources and the California Department of Food and Agriculture. Data and maps presented to the CA Governor's Drought Task Force by CDWR;

• Presented results at multiple workshops organized by CDWR as well as at scientific conferences and briefings for legislative representatives;

• Continued development of the SIMS data processing system on the NASA Earth Exchange (NEX), including prototype web and mobile interfaces. Delivered data during 2016 to partner growers for evaluation and to support drought mitigation efforts and irrigation optimization. Presented research results to CDWR, partner growers, and at multiple industry and professional conferences. Initiated work on transfer of SIMS framework to Google Earth Engine and Amazon AWS for sustained operation by CA DWR. Successfully completed SIMS API and used API to link the UC Cooperative Extension CropManage irrigation management software and SIMS. Hundreds of Salinas Valley growers are currently able to access data from SIMS via CropManage;

• Deployed successfully and maintained instrumentation on two commercial farms in partnership with growers in the Salinas Valley and Central Valley. Collaborated with partner growers on data analysis. Maintained partnerships with four important growers/ag companies in the Salinas Valley: Dole, Driscolls, Fresh Express and Huntington Farms; and

• Continued work on a project with UC Davis on mapping of potential risk for spread of mosquito vectors for dengue and zika virus in California. Currently mapping land cover from NAIP to provide high resolution maps of land cover as inputs into vector habitat modeling.

Publications and Presentations

Johnson, L.F., Cahn, M.D., Martin, F., Melton, F., Benzen, S., Farrara, B, Lund, C., and K. Post, 2016. Evapotranspiration-based irrigation scheduling of lettuce and broccoli, HortSci 51.7 (2016): 935-940.

Sun, L. et al. (F. Melton and K. Post two of 14 co-authors), 2016. Daily mapping of 30m LAI, NDVI for grape yield prediction in California vineyard. Remote Sensing of Environment (in review).

Fisher, J., Middleton, E., Melton, F., Anderson, M., Hain, C., Allen, R. et al. 2016. The Future of Evapotranspiration: Global requirements for ecosystem functioning, carbon and climate feedbacks, agricultural management, and water resources. Nature (in review).

Medellín-Azuara, J. et al. (F. Melton one of 12 co-authors), 2016). Estimation of Crop Evapotranspiration in the Sacramento San Joaquin Delta for the 2014-2015 Water Year. An Interim Report for the Office of the Delta Water Master, State Water Resources Control Board. Center for Watershed Sciences, University of California, Davis. Last Access September 29 2016 at <http://watershed.ucdavis.edu/DeltaET>.

Select participants of World Bank ET Workshop (F. Melton and L. Johnson among 17 co-authors). Evapotranspiration Mapping for Water Security: Recommendations and Requirements. Whitepaper for National Research Council.

Johnson, L., F. Melton, K. Post, A. Guzman, C. Rosevelt, R. Spellenberg, and I. Zaragoza, 2016. Satellite mapping of crop coefficients and water requirements in California. Sustainable Ag Expo, 14-15 Nov., San Luis Obispo (invited).

Trout, T., F. Melton, L. Johnson, et al., 2016. Satellite mapping of crop coefficients and crop water requirements in California. USCID 9th Int'l Conference/Latest Methods in Evapotranspiration and Supporting Technologies, U.S. Committee on Irrigation & Drainage, 11-14 Oct., Ft. Collins.

Melton, F., L. Johnson, K. Post, A. Guzman, C. Rosevelt, R. Spellenberg, I. Zaragoza, A. Michaelis, J. Huntington, C. Morton, A. Vitale, K. Frame, and B. Temesgen, 2016. Operational mapping of evapotranspiration over agricultural land in the California Central Valley. Water Education Foundation, International Groundwater Conference, 28-30 June, San Francisco.

Johnson, L., M. Cahn, S. Benzen, I. Zaragoza, L. Murphy, T. Lockhart, and F. Melton, 2016. ET-based Irrigation Management in Leaf Lettuce and Cabbage: Results from 2015 Trials. Proceedings USCID Water Management Conference, U.S. Committee on Irrigation & Drainage, (Eds. S. Macaulay, D. Bradshaw, S. Anderson), pp. 81-86, ISBN 978-1-887903-53-0, 17-20 May, San Diego.

Melton, F., L. Johnson, et al., 2016. Towards operational mapping of agricultural drought impacts and evapotranspiration with satellite data, USCID Water Management Conference, U.S. Committee on Irrigation & Drainage, 17-20 May, San Diego.

Melton, F., et al., 2016. Automated approaches for satellite mapping of ET over agricultural land in California at field-scale. UC Davis Evapotranspiration Remote Sensing Wksp, 10 Feb., Davis.

Johnson, L., M. Cahn, S. Benzen, I. Zaragoza, L. Murphy, F. Melton, F. Martin, A. Quackenbush, T. Lockhart, 2015. Testing an irrigation decision support tool for California specialty crops. AGU Fall

Meeting, 14-18 Dec., San Francisco (#H53G-1745).

Rosevelt, C., et al., 2015. Drought Impacts on Agricultural Production and Land Fallowing in

California's Central Valley in 2015. AGU Fall Meeting, 14-18 Dec., San Francisco. (#H53G-1749)

Melton, F., et al., 2015. Mapping Evapotranspiration over Agricultural Lands in the California Central Valley. AGU Fall Meeting, 14-18 Dec., San Francisco. (#H53G-1744)

Johnson, L., M. Cahn, F. Martin, F. Melton, S. Benzen, B. Farrara, and K. Post, 2015. Testing decision tools for irrigation management in California specialty crops. NASA/World Bank International Workshop on ET Mapping for Water Security, 15-17 Sept, Washington DC.

Johnson, L., 2016. Remote sensing of crop development and water use. Guest lecture in CSU Fresno Soil & Water Management.

Rosevelt, C., Melton, F., Guzman, A., Johnson, L. et al., 2016. Drought Impacts on Agricultural Production and Land Fallowing in California's Central Valley in 2015. Central Coast GIS Day 2016, 16 Nov., Marina, CA. (First place award for poster and Certificate of Achievement for Outstanding Presentation)

Alpha Jet Atmospheric Experiment (AJAX)

NASA: Warren Gore, Laura Iraci
BAERI: Emma Yates, Ju-Mee Ryoo, Josette Marrero

AJAX is a public-private partnership between the aircraft owner (H211, LLC) and NASA Ames Research Center. The aircraft is based at and operated from Moffett Field, CA under a Space Act Agreement. It is a tactical strike fighter developed by Dassault-Breguet and Dornier. Carrying a crew of two, it has a ceiling of 51,000 ft, speed of 150 - 500 knots, and a range of approximately 1,200 miles (2.5-hours flight duration). Scientific instruments are housed in externally mounted wing pods. Current scientific payload consists of an ozone monitor, a greenhouse gas (carbon dioxide and methane) sensor, and a meteorological measurement system (MMS). Plans are underway to install a formaldehyde instrument.

In the past six years, AJAX has flown 203 science flights and participated in numerous field campaigns. The AJAX team researches many topics including 1) Satellite and remote sensing validation (OCO-2, GOSAT, TCCON), 2) investigating the transport of ozone from the free troposphere to the surface, impacting air quality, 3) identifying inaccuracies (under-estimations) in methane emission inventories for the State of California and 4) studying emissions from recent California wildfires

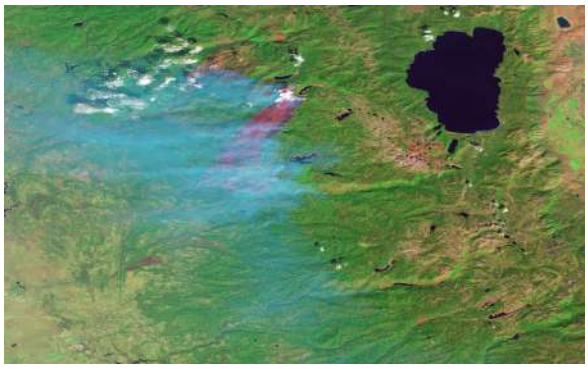


Figure 5: The King fire, burning in El Dorado National Forest as captured by Landsat-8 . ARC-CREST researchers measured CO_2 and CH_4 in the King fire plume from the Alpha Jet platform.

Figure 6: A view of the Alpha Jet research platform, based at NASA-ARC. Instruments are housed in specially designed wing pods.

2016 Accomplishments

- Completed 24 AJAX science flights to date;
- Dedicated 8 flights to sampling ozone inflow and variations in California's boundary layer as part of California Baseline Ozone Transport Study (CABOTS);
- Dedicated 5 flights to sampling emissions from Californian wildfires, particularly the Soberanes megafire;
- Dedicated 5 flights to sampling emissions from urban centers and/or oil and gas structures; and
- Participated in CalWater, CABOTS, SF Bay Area campaign & GOSAT-COMEX campaigns.

Carbon Monitoring Systems (CMS)

NASA: Rama Nemani
BAERI: Sangram Ganguly, Shreekant Gayaka, Subodh Kalia
CSUMB: Andrew Michaelis

The NASA CMS program seeks to characterize, quantify, understand, and predict the evolution of global carbon sources and sinks through improved monitoring of carbon stocks and fluxes. As part of the CMS multi-phase activities, a major effort was to quantify 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) that can alleviate the discontinuity of data in space and time, because field measurement is labor-intensive and thus impractical for large-scale monitoring.

Through the CMS project, forest cover for the continental US is being estimated at spatial resolution of 1-m in support of reducing uncertainties in the AGB estimation. The process involves 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. The process will also be complemented with a LiDAR-derived AGB estimate at the 30-m scale to aid in true validation. This work will substantially contribute to filling gaps in ongoing NASA CMS research and help quantify 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 estimates. The CMS work is data and computer intensive and has extensively used the NASA Pleiades supercomputing platform for doing the simulations and modeling.

2016 Accomplishments

- Developed a robust scalable machine learning algorithm (SegNet) for performing classification/segmentation of 1-m NAIP imagery;
- Developed software for creating labeled training data (matlab module);
- Generated "region of interest" polygon tree mask data for 48 U.S. states;
- Built an automated parallel computing framework for deploying SegNet over Pleiades High Performance Computing cluster;
- Used the Allometric Scaling and Resource Limitations Model (ASRL) to model canopy heights using various geospatial predictors like elevation, long-term monthly precipitation, air temperature, solar radiation, vapor pressure and wind speed;
- Developed theoretical relationships between tree height and available, evaporative, and basal metabolic flow rates using the Allometric Scaling and Resource Limitations model;
- Generated predictions of maximum forest height for forested areas across the continental U.S. and compared these heights to actual reference height data (FIA) by region and accounting for forest age;
- Published in Global Ecology and Biogeography manuscript of ASRL. Manuscript figure also selected for journal cover page (December 2016, Issue 12, Volume 25);
- Worked on Segmentation Neural Network to train a binary classifier to predict forest and non-forest areas in a very high resolution 1-m NAIP imagery;
- Achieved an accuracy of > 93% for the trained model; the model is scalable and can predict accurately for the areas where data is not available.

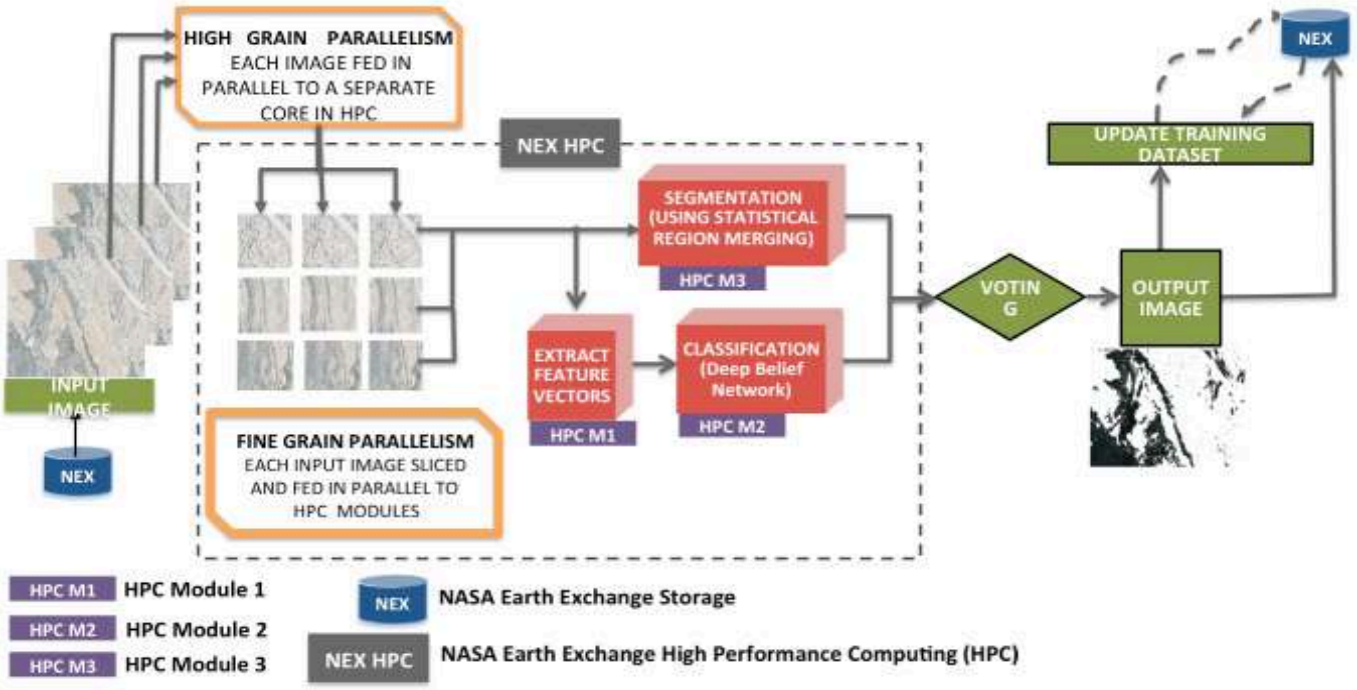


Figure 7: High performance computing architecture for generating very high resolution tree cover map. The processing (classification and segmentation) was performed on a quarter million NAIP image scenes.

Publications and Presentations

Choi. S. et al. (S. Ganguly, one of 17 co-authors). 2016. Application of metabolic scaling theory and water-energy balance equation to model large-scale patterns of maximum forest canopy height. Global Ecology and Biogeography. Wiley Online Library. 25 (12), 1428-1442, doi: 10.1111/geb.12503.

Basu, S. et al. (S. Ganguly, one of 7 co-authors). 2016. Learning sparse feature representations using Probabilistic Quadtrees and Deep Belief Nets. Neural Processing Letters. doi: 10.1007/s11063-016-9556-4

Kumar, U. et al. (S. Ganguly, one of 6 co-authors). 2016. Partially and fully constrained least squares linear spectral mixture models for subpixel land cover classification using Landsat data. International Journal of Signal Processing Systems. 4(3), 245-251. doi: 10.18178/ijsps.4.3.245-251

Basu. S.et al. (S. Ganguly, one of 7 co-authors). 2016. A theoretical analysis of deep neural networks for texture classification. International Joint Conference on Neural Networks. arXiv preprint arXiv:1605.02699

Featured speaker at the Nvidia GPU Technology Conference, Washington D. C., Oct 26-27, 2016, Title: DeepSAT: A Deep Learning Framework for Satellite Image Classification

Invited speaker for PlanetOS Webinar Series, Palo Alto, Sep 21, 2016. Title: Easily Analyze Climate Models with Planet OS and OpenNEX

Invited speaker at Supercomputing SC16 Conference, Nvidia GPU Technology Theatre, Nov 16, 2016. Title: DeepSAT: A Deep Learning Framework for Satellite Image Classification

Invited talk at the Ad Hoc Big Data Task Force of the NASA Advisory Council Science Committee, Sep 28-30, NASA Ames, 2016.

Title: NASA Earth Exchange: Helping Scientists Tackle Big Data

Invited talk at the European Geophysical Union General Assembly, Apr 21, Vienna, Austria, 2016.

Title: Very High Resolution of Tree Cover Using Scalable Deep Learning Architectures

Poster presentation at NASA Carbon Monitoring System Annual Meeting 2016, Boulder, CO.

Convener for the special session on "Carbon Monitoring Systems Research and Applications II", American Geophysical Union, December 2015, San Francisco.

Guest Editor for the "Remote Sensing" journal 2016 special issue on "Remote Sensing of Vegetation Structure and Dynamics" - 38 articles published, 3rd most published papers in this special issue.

Cirrus Cloud Modeling

NASA: Eric Jensen
BAERI: Bill McKie

This project provides computer hardware selection, hardware assembly, hardware maintenance, system software installation, system software maintenance, system administration, application programming consulting, documentation, testing, networking, and security in support of atmospheric science cloud studies that include modeling and observed data analysis. Computing platforms include three Beowulf clusters with remote network access to interactive and batch computing under Linux operating systems, a central gateway Linux system for remote access to the clusters, plus support for several versions of the OS-X operating systems configured with add-on software and configurations for use in scientific environments.

2016 Accomplishments

- Completed bi-weekly, weekly, bi-monthly, monthly online, off-line, and off-site user file safety backups;
- Obtained and installed Linux and OS-X system updates;
- Updated online system documentation;
- Kept familiarity with various flavors of Linux systems up-to-date by doing installs and explorations on test bed systems;
- Maintained NASA Certified System Administration credentials by completing the annual coursework and tests;
- Completed annual review of Linux system NASA Ames Code-S and Center for Internet Security controls;
- Installed, tested, and documented the latest OS-X system on test bed hardware;
- Continued with system administration, programming consulting, user OS-X update notifications, backups, hardware maintenance, cluster monitoring, security monitoring, and new OS testing;
- Assembled PC test bed computer, installed latest Scientific-Linux system software, and continued exploring the KVM virtualization system with various Linux and Windows virtual machines;
- Retired the group's oldest Beowulf cluster; and
- Explored the blender program for building 3-D models.

Coastal Ocean Biology

NASA: Liane S. Guild, Kirk Knobelspiesse, Jens Redemann
BAERI: Juan L. Torres-Pérez, Sherry L. Palacios, Meloe Kacenelenbogen

This project aims to understand the effects of humans on the health and resilience of reefs, particularly those in the Caribbean. One of the current projects, **Human Impacts to Coastal Ecosystems in Puerto Rico (HICE-PR)** aims at studying how anthropogenic impacts to watersheds in Puerto Rico eventually cause detrimental effects on the shallow coastal reefs of the Island. This is a highly interdisciplinary project involving scientists from diverse disciplines such as remote sensing, hydrology, geography, coral reef biology and ecology, and sociology. Remotely sensed images are used to study land cover/land use changes in PR along with extensive fieldwork to assess for changes in coral reefs structure through time. Bio-optical techniques are used to study changes in the spectral shape of coral reef benthic components and beach sediments as a tool to validate satellite or airborne images.

The **High-Quality Optical Observations (H-Q2O)** project aims to improve Atmospheric Correction and Remote Sensing of Water Quality in the Coastal Zone. It combines the use of an airborne sensor suite to characterize coastal atmospheric and aquatic properties through an end-to-end assessment of image acquisition, atmospheric correction, and sea-truth observations.

Hyperspectral Infrared Imager (HyspIRI) is being used to understand ocean biodiversity through the development of remote sensing algorithms that enable a synoptic view of phytoplankton community structure using airborne and satellite ocean color observations. Statistical and deterministic approaches are used to define and track water masses in river plume systems and to discriminate among algal taxa in phytoplankton blooms. The team contributed an optical proxy for low salinity water to identify the Columbia River plume on the coastal shelf using satellite imagery, a statistical model to identify and track the evolution of sub-mesoscale features within the larger river plume water mass, and a bio-optical algorithm based on first principles of aquatic optics to discriminate among major phytoplankton taxa within an algal bloom. The phytoplankton discriminator is an important tool for detecting harmful algal blooms and tracing pathways of carbon through different phytoplankton-dominated ecosystems.

2016 Accomplishments

- Conducted assessments at the Manatí study sites (north coast PR);
- Hosted the 3rd Soil and Water Assessment Tool (SWAT) workshop, working with hydrological data from both watersheds under study;
- Continued the collection of additional benthic data from the reefs located in the southwest coast which are associated with the Río Loco watershed. The benthic data collected so far during the past 3 years in both watersheds sums to more than 10,000 photo grids;
- Conducted the first stakeholders meeting in La Parguera, PR where more than 50 people with diverse interests (farmers, dive shop owners, fishers, and representatives from the federal and local agencies, managers) participated. A similar meeting is planned for the Manatí watershed for early 2017;
- Continued expanding their efforts in Puerto Rico to promote the participation of dive shop owners in data collection for validation of satellite imagery at their study sites;
- Participated in a training exercise on the use of wave gliders to collect bio-optical data in Hawaii. The idea is to eventually use these gliders to collect additional water quality bio-optical data on the study sites;
- Participated in field campaigns in Monterey Bay related to the HyspIRI Preparatory Mission and the C-HORSE project, collecting field spectral information at Pinto Lake in Watsonville and the Santa Cruz Wharf with different radiometers;
- Completed an exhaustive sensitivity analysis on the atmospheric correction of coastal waters for the HQ2O project;

•Successfully ported phytoplankton functional type algorithm, PHYDOTax to IDL and streamlined processing so that data processing flows can be more efficient; and

•Applied PHYDOTax to San Francisco Bay remote sensing imagery to evaluate phytoplankton community structure, or "food quality" for higher trophic levels in the bay. Phytoplankton community structure strongly influences pelagic fish populations in the bay, including several endangered species.

Figure 8: 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.

Publications and Presentations

Torres-Pérez, J.L. 2016. Advancing the knowledge of coral reef spectroscopy and human impacts in coastal and marine ecosystems in the Caribbean. Invited speaker. UC Santa Cruz. February 2016.

Barreto, M., N. Cabrera Valentín, I. Caraballo Álvarez, and J.L. Torres-Pérez. 2016. Studying coastal geomorphological changes near the Río Grande de Manatí watershed, Puerto Rico (1977-2015). ASLO AGU Ocean Sciences. New Orleans. February 2016.

Torres-Pérez, J.L. 2016. Status of benthic characterization (Manatí, Guánica, La Parguera). University of PR. San Juan, PR. April 2016.

Torres-Pérez, J.L. 2016. Studying coral reef ecosystems with NASA tools in an age of climate change and coral bleaching: the role of spectroscopy. Invited plenary speaker. NASA Ames Research Center. Ames Contractor Council Awards Ceremony. June 2016.

Torres-Pérez, J.L., L.S. Guild, and R.A. Armstrong. Advancing the knowledge of coral reef spectroscopy and human impacts in coastal and marine ecosystems in the Caribbean. Invited plenary speaker. Percepción Remota y Sistemas de Información Geográfica en Puerto Rico, 2016 Meeting. University of Puerto Rico at Mayaguez. October, 2016.

Torres-Pérez, J.L. 2016. Un vistazo a las zonas llanas de algunos arrecifes asociados a la Cuenca del Río Loco y la plataforma de La Parguera. HICE-PR stakeholders Meeting. La Parguera, PR. October, 2016.

Palacios, SL, DR Thompson, RM Kudela, KK Hayashi, LS Guild, B-C Gao, RO Green, JL Torres-Perez. Seasonal and Inter-Annual Patterns of Chlorophyll and Phytoplankton Community Structure in Monterey Bay, CA Derived from AVIRIS Data During the 2013-2015 HyspIRI Airborne Campaign. 2016 Ocean Sciences Meeting, New Orleans LA.

Palacios, SL, MB Peacock, AN Golini, JE Cloern, DB Senn, LS Guild, RM Kudela. Food Quality and Phytoplankton Community Composition in San Francisco Bay using Imaging Spectroscopy Data from the California HyspIRI Airborne Campaign. 2016 American Geophysical Union Fall Meeting, San Francisco, CA

Invited Talk -- What is it like to work as a Biological Oceanographer? Canada College STEM Speaker Series. September 29, 2016.

NASA Working Group: "Prospects and Priorities for Satellite Monitoring of Global Marine Biodiversity" hosted at National Center for Ecological Analysis and Synthesis (NCEAS), June 2016, Santa Barbara, CA. Publication forthcoming from meeting.

Reviewer for NASA Ecosystem Forecasting Program. Program Manager, Woody Turner.

Awards

NASA Group Achievement Award, UCSC-ARC HyspIRI Team

Earth Science Data Records (ESDR)

NASA: Matt Fladeland
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.

Dr. Kulawik is working on developing and validating long-term records of atmospheric trace gases, including CO2. 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 CO2 and other trace constituents. This data can be used for mitigation of natural hazards, K-12 science education, and other societal benefits.

Publications and Presentations

Kulawik, S. et al. Consistent evaluation of ACOS-GOSAT, BESD-SCIAMACHY, CarbonTracker, and MACC through comparisons to TCCON, Atmos. Meas. Tech., 9, 683-709, doi:10.5194/amt-9-683-2016, 2016.

Frankenberg, C., Kulawik, S. S., Wofsy, S. C., Chevallier, F., Daube, B., Kort, E. A., O'Dell, C., Olsen, E. T., and Osterman, G.: Using airborne HIAPER Pole-to-Pole Observations (HIPPO) to evaluate model and remote sensing estimates of atmospheric carbon dioxide, Atmos. Chem. Phys., 16, 7867-7878, doi:10.5194/acp-16-7867-2016, 2016.

Kulawik, S. et al .HIPPO versus OCO-2, OCO-2 Science Team Meeting, 21-23 March, 2016, Pasadena, CA.

2016 Accomplishments

- Compared measurements of carbon dioxide (CO_2) taken 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);
- Updated comparisons between SCIAMACHY, GOSAT, MACC, and Carbon Tracker to TCCON, with a manuscript in preparation; and
- Focused on incorporating onto the analysis additional aircraft sets, sets co-located at TCCON sites and sets of OCO-2 data.

Ground, Air, and Spaceborne Aerosol Typing

NASA: Jens Redemann
BAERI: Meloe Kacenelenbogen (PI), Yohei Shinozuka, Michal Segal-Rozenhaimer, Qin Zhang, Qian Tan

To improve the predictions of aerosol composition in chemical transport models (CTMs) and global climate models (GCMs), a flexible aerosol classification algorithm (called Specified Clustering and Mahalanobis Classification), (SCMC) assigns an aerosol type to multi-parameter retrievals by spaceborne, airborne, or ground based passive remote sensing instruments [Russell et al., 2014]. SCMC uses Mahalanobis classification [Mahalanobis, 1936; Burton et al., 2012] with pre-specified clusters (or classes). The pre-specified classes were defined using parameters retrieved from AErosol RObotic NETwork (AERONET) stations where a single aerosol type tends to dominate in certain months. The aerosol types identified by this scheme are pure dust, polluted dust, urban-industrial/developed economy, urban-industrial/developing economy, dark biomass smoke, light biomass smoke and pure marine.

This project, begun in March 2015, is a three-year investigation with the following goals: (1) understand the limitations of the Specified Clustering and Mahalanobis Classification (SCMC) method applied to passive spaceborne polarimetry and ground-based sun and sky photometry, (2) improve this method through the addition of mixtures of aerosol types, (3) bridge the gap between remote sensing-inferred aerosol types and their corresponding chemical speciation, (4) use the SCMC method to evaluate aerosol type predictions from the GEOS-Chem CTM, (5) study long-term trends of aerosol types at a few key locations over the globe, (6) attribute various sources to those aerosol types using the GEOS-Chem CTM and (7) provide recommendations for future passive space-borne instrumentation that could yield an improved aerosol classification from space.

2016 Accomplishments

Task #1: Space-borne aerosol types and ground-based evaluation

- Applied the SCMC method to two different total-column datasets of aerosol optical properties: inversions from AERONET and retrievals from the space-borne POLDER (Polarization and Directionality of Earth's Reflectances) instrument. The POLDER retrievals used differ from standard POLDER retrievals [Deuzé et al., 2001] because they make full use of multi-angle, multispectral polarimetric data [Hasekamp et al., 2011]. Their classification algorithm uses three parameters, the Extinction Angstrom Exponent (EAE491,863), the Single Scattering Albedo (SSA670), and the difference between two SSA (dSSA863-491);

- Produced global monthly, seasonal and annual maps of POLDER-derived aerosol type probability of occurrence and most common aerosol type using POLDER or AERONET during the year 2006.

- Found reasonable aerosol features globally using POLDER observations (e.g. pure dust across the Atlantic Ocean or biomass burning dark smoke offshore from the Namibian coast in Jul-Aug-Sept) and POLDER-AERONET EAE, SSA, dSSA as well as SCMC-derived aerosol types compare reasonably well; and

- Recommended more accurate future passive space-borne satellite retrieval of RRI (and other parameters such as particle sphericity or volume concentration) for an improved space-borne aerosol classification over the globe.

- Compared MACC, and Carbon Tracker to TCCON, with a manuscript in preparation; and

- Focused on incorporating onto the analysis additional aircraft sets, sets co-located at TCCON sites and sets of OCO-2 data.

Task #2: Bridge the gap between remote sensing-inferred aerosol types and corresponding chemical speciation

- With Dr Q. Tan's help, filtered, averaged, and collocated airborne measurements of EAE491-863, SSA491 and dSSA863-491 from the airborne NASA Langley Aerosol Research Group Experiment (LARGE) and RRI532 measurements from the Differential Aerosol Sizing and Hygroscopicity Spectrometer Probe (DASH-SP) during the SEAC4RS experiment;

- Inferred airborne SCMC aerosol types based on those optical measurements for every flight and compared those SCMC aerosol types to number fraction measurements of sulfate, organic, nitrate, biomass burning, soot, mineral and sea salt fractions from the Particle Analysis by Laser Mass Spectrometry (PALMS) instrument (present on the same aircraft during SEAC4RS); and

- Compared their airborne SCMC aerosol types to ambient mass concentration measurements of organic, sulfate, ammonium and nitrate from the High - Resolution Time - of - Flight Aerosol Mass Spectrometer (AMS) and mass concentration measurements of black carbon (BC) from the Single-Particle Soot Photometers (HD-SP2).

Publications and Presentations

Kacenelenbogen et al., 2016, "Spaceborne Remote Sensing of Aerosol Type: Global Distribution, Model Evaluation and Translation into Chemical Speciation", Oral, American Geophysical Union (AGU), 12/12-16 2016

Kacenelenbogen et al., 2016, "Spaceborne Remote Sensing of Aerosol Type: Global Distribution, Model Evaluation and Translation into Chemical Speciation", Oral, 97th

American Meteoorlogical Society (AMS) meeting, Conference on Atmospheric Chemistry, Seattle, WA, 01/ 22–26 2017.

Panels or Committees

M. Kacenelenbogen is serving on a NASA ROSES ACMAP panel review, Nov 30-Dec1 2016.

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

NASA: : Jennifer Dungan
BAERI: Pardha Teluguntla, Jun Xiong

The MEaSUREs project 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 this data is important to climate scientists, agricultural scientists, farmers, natural resource managers, and national leaders.

Global Food Security-Support Analysis Data at 30 m (GFSAD30)

The goal of this research is to develop and implement spectral matching techniques (SMTs) and automated cropland classification algorithms (ACCA's) for production of multi-year cropland products that will help address food security issues using MODIS 250m time-series data for Australia.

Specific objectives include:
1. Development of reference cropland products for the year 2014 using novel spectral matching techniques based on ideal spectra of croplands generated using extensive field knowledge applied on MODIS time-series data;

2. Development of automated cropland classification algorithms using the reference data generated to train algorithms and then apply them to reference year 2014, as well as each year from 2000 to 2013;

3. Establish the accuracy of cropland products generated using spectral matching techniques and automated cropland classification algorithms, highlighting the ability of the algorithms to predict drought by applying them to data collected from 2000 to 2014.

Publications and Presentations

Telugunlta et al. "Spectral Matching Techniques (SMTs) and Automated Cropland Classification Algorithms (ACCA's) for Production of Multi-Year Cropland Products to Address Food Security Issues using MODIS 250m Time-series Data for Australia", submitted to International Journal of Digital Earth (IJDE), under review.

Xiong et al. Automated Cropland Mapping of Continental Africa using Google Earth Engine Cloud Computing, submitted to ISPRS Journal of Photogrammetry and Remote Sensing, under review.

Cropland Products of Australia @ MODIS 250 m (GCE V2.0) and Landsat 30m (GCE V3.0) : Current status (Pardhasaradhi Teluguntla et al.). Presented during GFSAD30m January 2016 workshop conducted at W.G.S.C, U.S. Geological Survey, MenloPark, CA

Global Cropland Extent (GCE) 30m Cropland products (aka GCE V3.0) for Australia using: (a) Random forest Algorithm and (b) Google Earth Engine Cloud Computing (Pardhasaradhi Teluguntla et al.) Presented during, GFSAD30m July 2016 workshop conducted at U.S. Geological Survey , Flagstaff

Cropland Products of Africa @ MODIS 250 m (GCE V2.0) and Landsat 30m(GCE V3.0) : Current status (Jun Xiong et al.). GFSAD30m January 2016 workshop conducted at W.G.S.C, U.S. Geological Survey, MenloPark, CA

Global Cropland Extent (GCE) 30m Cropland products (aka GCE V3.0) for Africa using: (a) Random forest Algorithm and (b) Google Earth Engine Cloud Computing (Jun Xiong et al.), GFSAD30m July 2016 workshop conducted at U.S. Geological Survey , Flagstaff, , Arizona

Global Croplands Mapping, Pardhasaradhi Teluguntla, Jun Xiong and Adam Oliphant. Museum of Northern Arizona. Sept 29. 2016, Flagstaff, Arizona.

2016 Accomplishments

- Produced Production of Global Cropland Extent Version 2. 0 (GCE V2.0) at 250 m resolution for the nominal 2014 using MODIS time-series data, ground knowledge and Spectral Matching Techniques(SMT) for Australia/Africa. Products & Documentation were submitted to LP DAAC, under review;

- Produced 30m Cropland extent version 1.0 (GFSAD30CE) cropland products for Australia/Africa. Finalized the methodology/products, released web-access through www.croplands.org; and

- Developed Crop Intensity layer using MODIS Vegetation indices 16-day composite (MODIS/MOD13Q1). The proposed algorithm was deployed in Google Earth Engine to scale to large area. The global 250m crop intensity map was generated for further evaluation.

NASA Earth Exchange (NEX)

NASA: Rama Nemani, Jennifer Dungan, Ved Chirayath, Piyush Mehrotra
BAERI: Sangram Ganguly, Subodh Kalia
CSUMB: Alberto Guzman, Hirofumi Hashimoto, Shuang Li, Forrest Melton, Andrew Michaelis, Petr Votava, Weile Wang

Over the past five years, the Ecological Forecasting task has increasingly focused on development of the NASA Earth Exchange (NEX) project (Nemani et al., 2011).

Under this task, ARC-CREST scientists and software engineers collaborate with scientists and engineers in the NASA Ames Earth Science Division and the NASA Advanced Supercomputing (NAS) Division to develop and support the NEX collaborative supercomputing/cloud computing environment for large-scale Earth Science research.

Since its inception in 2009, the NEX project has evolved from having a sole focus on ecological forecasting to providing access to large Earth science datasets, supercomputing and cloud computing capabilities, and the development of an online collaborative research environment. The primary objective of the NEX project is to accelerate scientific discovery using data from NASA's satellite missions and climate models, and to facilitate scientific collaboration in a way that was not previously possible. NEX maintains a large set of satellite observations and climate model data for use by NASA-supported researchers who are tackling science questions that involve data and computing intensive analyses at regional to global scales. NEX provides the Earth science research community with 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 to analyze long-term and emerging trends in ecosystem conditions, conduct simulations of climate and land use change impacts on terrestrial and aquatic ecosystems, map patterns in biodiversity, and monitor biomass at local to continental scales. The NEX team also supports applied science activities, such as the development of indicators of climate change impacts for Landscape Conservation Cooperatives and NASA Centers, and 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. In addition, NEX supports production of global long-term data records for NASA's MEaSUREs program, as well as large-scale visualizations for data from NASA's Earth Observing System Data and Information System (EOSDIS).

The OpenNEX initiative, a collaboration between NASA and Amazon Web Services, develops cloud-hosted data, tools and solutions for working with satellite and climate data (e.g. virtual labs). Development of these tools and maintenance and administration of the OpenNEX platform are also are performed by ARC-CREST researchers. Additional information about NEX can be found at: https://nex.nasa.gov/nex/

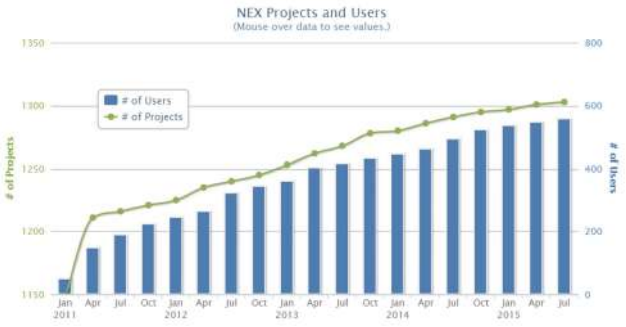


Figure 9: The NEX community of users has grown substantially over the past 3 years. ARC-CREST researchers now provide support for over 1300 projects and nearly 600 users. NEX is a one of its kind virtual platform for studying and collaborating on Earth science projects.

2016 Accomplishments

• Supported NEX Virtual Workshop (2016). Generated an initial series of lectures, hands-on labs and video tutorials on the use of NEX datasets, tools and technologies. This is an evolving workshop that will target different science and technology areas in regular intervals;

• Supported the science community to derive a suite of downscaled high-resolution surface climate scenarios based on the Coupled Model Intercomparison Project Phase 5 (CMIP5) simulations, including the NEX-DCP30, NEX-GDDP, BCCA, and the LOCA datasets. The NEX climate datasets described above were designated as core climate datasets for the Fourth National Climate Assessment, and the NEX-DCP30 and BCCA datasets were selected as the two datasets used in the Climate Explorer, the primary data interface for climate scenarios for the U.S. Climate Resilience Toolkit. NEX team members (W Wang and F Melton) served on USGCRP working groups and provided support to USGCRP in accessing and processing these NEX datasets;

• Prototyped agile production, analytics and visualization pipelines for big-data on the NASA Earth Exchange (NEX), NNH14ZDA001N-AIST (NASA ESTO Advanced Information Systems Technology (AIST) Project)

• Collaborated with Kitware, Inc. to develop a new GeoNotebook technology that enables easy visualization and analysis of large-scale datasets on the Amazon cloud;

• Awarded two NASA ACCESS projects:

  o (Open)NEX: Enabling Code-to-Data Migration between High-Performance Computing, Cloud and Beyond

  o Object Store-Based Data Service for Earth System Science (collaboration with the HDF Group);

• Collaborated with the Making Earth System data records for Use in Research Environments (MEASURES) Project - Web-enabled Landsat Data (WELD), NNH06ZDA001N: Implemented major science improvements in the version 3.0 of the data release that is now available from the USGS EDC data center; completed first large-scale true-resolution visualizations available through NASA EOSDIS GIBS system; and

• Completed the first global, 30-year, daily, 1 km dataset for maximum temperature produced through fusion of satellite and surface temperature observations. Following completion of the dataset for minimum temperature, the datasets will be released and a corresponding publication is being prepared.

Publications and Presentations

Choi, S., C.P. Kempes, T. Park, S. Ganguly, W. Wang, and et al, 2016: Application of the metabolic scaling theory and water-energy balance equation to model large-scale patterns of maximum forest canopy height. Global Ecology and Biogeography, DOI: 10.1111/geb.12503.

Park, T., S. Ganguly, R. Nemani et al., 2016: Changes in growing season duration and productivity of Northern vegetation inferred from long-term remote sensing data. Environmental Research Letters. DOI: 10.1088/1748-9326/11/8/084001.

Wang, W., and R. Nemani, 2016: Dynamics of atmospheric CO2 from 1850 to 2010: a linear approximation. Advances in Atmospheric Sciences. 33, 247-258.

Ito, A., et a. (W. Wang, one of the 33 co-authors), 2016: Decadal trends in the seasonal-cycle amplitude of terrestrial CO2 exchange resulting from the ensemble of terrestrial biosphere models. Tellus B, 68, 28968. http://dx.doi.org/10.3402/tellusb.v68.28968

Herring, J., M.S. VanDyke, R.G. Cummins, and F. Melton, 2016: Communicating local climate risks online through an interactive data visualization. Environmental Communication, doi:10.1080/17524032.2016.1176946.

Melton, F., Xiong, J., Wang, W., Milesi, C., Li, S., Quackenbush, A., et al., 2016. Quantifying Impacts of Climate and Land Use Change on Ecosystem Processes in the Great Northern and Appalachian Landscape Conservation Cooperatives. In Climate change in wildlands: Pioneering approaches to science and management in the Rocky Mountains and Appalachians, A. Hansen, W. Monahan, and D. Theobald (eds.), Island Press.

Nemani, R., Hirofumi Hashimoto, Michael White, Bala Govindasamy, Long Cao, Andrew Michaelis, Sangram Ganguly, Weile Wang, Cristina Milesi, Ryan Eastman, Tsengdar Lee and Ranga Myneni, "A Green Lining to a Warming Earth" – submitted to Science Magazine

Boyda, E., Saikat Basu, Sangram Ganguly, Andrew Michaelis, Supratik Mukhopadhyay, Ramakrishna R. Nemani "Tree Cover Classification on a Quantum Annealing Processor" – submitted to PLOS One

Core NEX datasets had significant impacts that resulted in two high profile papers list here:

Egan, P.J. and M. Mullin, 2016: Recent improvement and projected worsening of weather in the United States. Nature, 532, 357-360.

D'Orangeville, L., L. Duchesne, D. Houle, D. Kneeshaw, B. Côté, and N. Pederson, 2016: Northeastern North America as a potential refugium for boreal forests in a warming climate. Science, 352, 1452-1455.

Melton, F., Mehrortra, P., Nemani, R., Votava, P., Michaelis, A, Wang, W., et al., 2016. The NASA Earth Exchange and OpenNEX: Addressing the challenge of big data in analyses of climate change impacts. The National Council on Science and the Environment 2016 Conference, Washington, DC.

Wang, W., R. Nemani, A. Michaelis et al. 2016: Uncertainty Assessment of the NASA Earth Exchange Global Daily Downscaled Climate Projections (NEX-GDDP) dataset. AGU 2016, San Francisco.

Hashimoto,H. et al. 2016: Observed trend in surface wind speed over the conterminous USA and CMIP5 simulations. AGU 2016, San Francisco.

Votava, P, D. Roy: Big Data Processing: Lessons learned from the Global Web Enabled Landsat Data (WELD) Project. ESA Living Planet Symposium 2016, Prague, Czech Republic.

Chaudhary, A., P. Votava, R.R. Nemani, A. Michaelis, C. Kotfila. 2016. Analytics and Visualization Pipelines for Big Data on the NASA Earth Exchange (NEX) and OpenNEX. AGU 2016, San Francisco.

Ozturk, D., A. Chaudhary, P. Votava, C. Kotfila. 2016. GeoNotebook: Browser based interactive analysis and visualization workflow for very large climate and geospatial datasets. AGU 2016, San Francisco, CA.

Michaelis, A., J. Ready, P. Votava. 2016. Using Cloud-based Storage Technologies for Earth Science Data. AGU 2016, San Francisco, CA.

Votava, P., A. Michaelis, R. Spaulding, J. Becker. 2016. Using Docker Containers to Extend Reproducibility Architecture for the NASA Earth Exchange (NEX): AGU 2016, San Francisco

Votava, P., S. Ganguly. 2016. Supporting Petabyte-scale Science on NASA Earth Exchange (NEX). IEEE Supercomputing 2016, Salt Lake City, UT.

Nemani. R., P. Votava, S. Ganguly. 2016. Helping Scientists Tackling Big Data. NASA Big Data Task Force Meeting, Mountain View, CA.

Votava, P. 2016. Supporting Science at Petabyte Scale. NASA-NJIT Workshop in Computational Heliophysics, Mountain View, CA.

Awards

2016 NASA Group Achievement Award

ORACLES Radiative Transfer Algorithm Development

NASA: Kirk Knoblespeisse, Jens Redemann
BAERI: M. Segal-Rozenhaimer,

The primary goal of this research is to develop new algorithms to retrieve atmospheric aerosol and cloud optical properties from observations by polarimetrically sensitive instruments. These algorithms are intended for the analysis of aerosols lofted above clouds, the main target of ORACLES (ObseRvations of Aerosols Above CLouds and their IntEractionS). The ORACLES experiment will consist of 3 deployments in 2016, 2017, and 2018 offshore from Namibia involving 2 airplanes with numerous ground-based and airborne remote sensing and in-situ instruments. ORACLES provides multi-year airborne observations over the complete vertical column of the key parameters that drive aerosol-cloud interactions in the South-East Atlantic, an area with some of the largest inter-model differences in aerosol forcing assessments on the planet. Algorithms will be applied to observations by the Research Scanning Polarimeter (RSP) and the Airborne Multiangle SpectroPolarimetric Imager (AirMSPI).

An algorithm will be created to retrieve the optical properties of Aerosols Above Clouds (AAC), observed during ORACLES concurrently with some of the optical properties of the underlying clouds. The basis of this algorithm is the ability that multiviewing angle, polarimetrically sensitive instruments have to separate the effects of aerosols and (liquid phase) clouds. Since the polarimetric expression of the liquid phase cloudbow is very distinct, observations of the spectral and geometric expression of this cloudbow can be used to accurately determine the droplet effective radius and variance at the top of the cloud. Observations at scattering angles away from the cloudbow can then be used to determine aerosol characteristics because the underlying reflectance properties of the cloud have already been constrained (polarized reflectance is only sensitive to the top three cloud optical depths, so additional information such as overall cloud optical thickness and physical dimensionality are not needed).

Vertical distribution of the aerosols and clouds must either be assumed or specified by external data. Standard polarimetric retrievals are often performed using some version of optimal estimation, whereby a radiative transfer model representing the scene is tuned until its output matches observations. This can be very computationally expensive. The proposed algorithm uses a trained neural-network (NN) scheme that captures the various scenes expected to be observed during the campaign (with varying properties of both aerosol and cloud layers). NN allows the training (i.e., optimization) of a large dataset of options, using simulated inputs (i.e., polarimetric measurements of various scenes) that link (i.e., creates the best possible modeled coefficients) inputs (measurements) to outputs (retrieved properties of aerosol and clouds). After the training process is completed, retrievals are achieved by inputting sets of measurements, using the obtained coefficients from the training process.

2016 Accomplishments

- Worked on developing low level liquid cloud NN retrieval algorithm using RSP polarized simulated data; this enticed generating simulated data that can be used as a training set for the ORACLES campaign, coding up NN scheme framework, performing sensitivity studies on various input combinations and performing network parameter selection and optimization through cross-validation and training/test runs;

- Retrieved cloud properties from ORACLES 2016, comparing with other RSP algorithms to assess their method; and

- Summarized all the algorithm development, sensitivity studies, and retrieval ability and results in a manuscript.

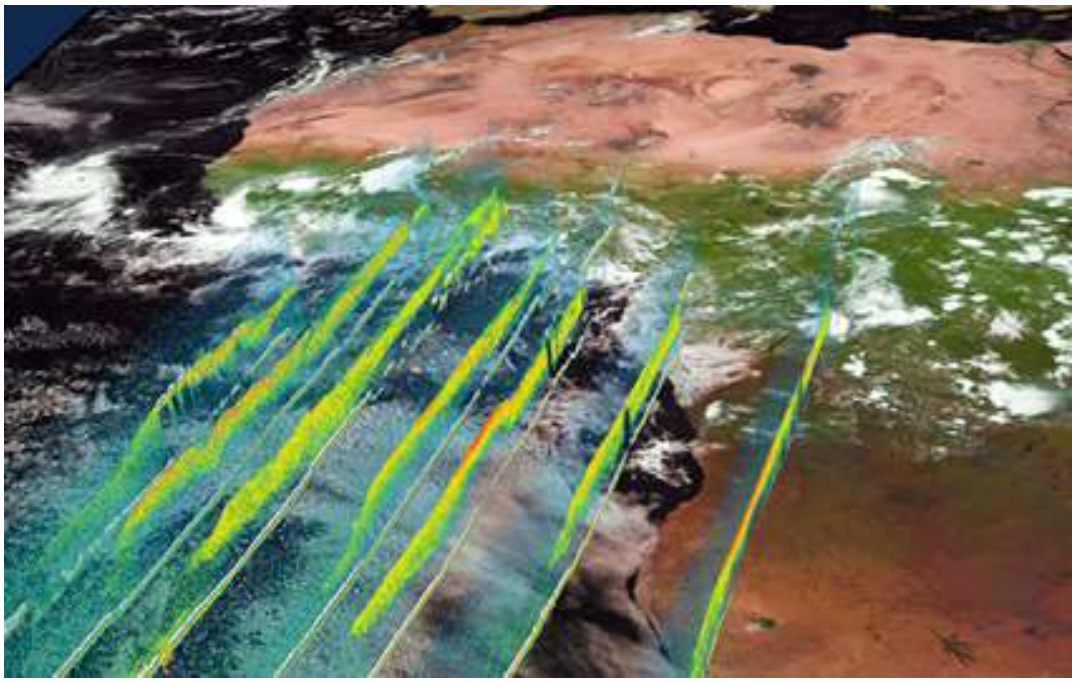


Figure 10: Composite CALIPSO lidar backscatter curtains show pervasive transport of BB aerosol transport during the first week of September 2008 as well as the underlying cloud tops over the South-East Atlantic (region of the ORACLES field campaign)

Publications and Presentations

Segal-Rozenhaimer, M., Kirk Knobelspiesse, Jens Redemann, Brian Cairns, Retrievals of liquid cloud properties from polarimetric measurements using Neural Network, in prep. for Remote Sensing of Environment

Segal-Rozenhaimer, M., Kirk Knobelspiesse, Jens Redemann, Brian Cairns, Neural Network (NN) retrievals of Stratocumulus cloud properties using multi-angle polarimetric observations during ORACLES, Oral presentation at AGU fall meeting A33L-06

Orbiting Carbon Observatory – 2 Errors/Profiles (OCO-2 E/ OCO-2 P)

NASA: Matt Fladeland
BAERI: Susan Kulawik
Colorado State University: Chris O'Dell

The goal of this project is to develop vertically resolved GOSAT and OCO-2 products. Solving the carbon cycle to estimate locations and amounts of emitted carbon dioxide (e.g. from fires, combustion) and locations and amounts of carbon dioxide uptake (e.g. forests, oceans) is a complex problem utilizing satellite observations, ground based measurements, and transport modeling. Separation of satellite carbon dioxide measurements into lower and upper partial columns provides better constraint on model transport errors and uncertainties, and better information on whether variations in carbon dioxide result from nearby (lower partial column) versus transported (upper partial column) sources. Previous studies have shown that model transport error results in uncertainties in the carbon dioxide emissions and uptakes on continental scales and that vertically resolved observations can identify and constrain transport error.

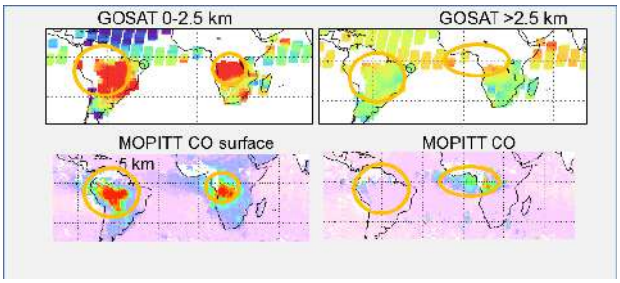


Figure 11: MOPITT multi-spectral CO is used to validate the partitioning between LMT-XCO_2 and U-XCO_2 in the tropics where the GOSAT prior is constant vertically. In the burning season, high values are seen at the surface in South America for GOSAT LMT-XCO_2 and MOPITT. Outflow shows up in the free troposphere in later months.

Publications and Presentations

Kulawik, Susan S., O'Dell, C., Deng, F., Payne, V., Kuai, L., Worden, H.M., Jones, D.B.A., Sweeney, C., Biraud, S., Iraci, L.T., Yates, E.L., and Tanaka, T., Lower-tropospheric CO2 from near-infrared ACOS-GOSAT observations, AGU Fall Meeting, 12-16 December, 2016, San Francisco, CA

Kulawik, Susan S., O'Dell, C., Deng, F., Payne, V., Worden, H.M., Jones, D.B.A., Dlugokenck, E., Sweeney, C., Biraud, Wennberg, P., Lower troposphere CO2 from OCO-2 and GOSAT, OCO-2 Science Team Meeting, 25-27 October, 2016, NCAR Table Mesa Lab, Boulder, CO

Kulawik, Susan S., Chris O'Dell, Vivienne H. Payne, Le Kuai, Feng Deng, Colm Sweeney, Sebastien C. Biraud, Ed Dlugokencky, Laura Iraci, Emma Yates, Tomoaki Tanaka, "Lower-tropospheric CO2 from near infrared GOSAT observations", 12th International Workshop on Greenhouse Gas Measurements from Space, Kyoto University, Kyoto, Japan

2016 Accomplishments

- Produced lowermost and upper partial columns for the GOSAT v3.5 data record (the current version);
- Validated the new products versus aircraft and surface observations and published in the ACPD paper, "Lower-tropospheric CO2 from near-infrared ACOS-GOSAT observations" (in review);
- Applied the technique to OCO-2 data, resulting in good preliminary results presented at the OCO-2 Science Team Meeting in October, but the OCO-2 results have not been validated; and
- Assimilated the new products by Feng Deng of Dylan Jones' group. The results of the assimilation were presented at the 2016 AGU Fall Meeting.

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 investigation is especially important because the range of many plant species is expected to shift 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. This project is currently focused on the Yellowstar Thistle and Cheatgrass, invasive species to California.

The team uses a variety of techniques including: forward osmosis for determining toxicity thresholds; growth chambers, and experiments to induce phenology changes; 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.

2016 Accomplishments

Water Hyacinth (WH) Mapping

• Developed a new methodology for generating bi-weekly WH percent cover maps from (30 meter) Landsat satellite imagery for the SF Bay and Delta;

• Created and shared with CA-DBW a new SF Bay and Delta online map viewer for 30 meter WH percent cover layers from the past five years (http://cquest.arc.nasa.gov:8399/flexviewers/sf_wetlands/) ;

• Acquired and processed AVIRIS (15 meter) airborne hyperspectral imagery and classified pure stands of WH in the Delta for Landsat product verification; and

• Conducted on-water, field verification of mapping tool accuracy and relevance to directing field management practices such as herbicide application.

Submerged Aquatic Plant Mapping

• Acquired and processed AVIRIS (15 meter) airborne hyperspectral imagery and tested classification methods for Egaria densa; and

• Acquired and processed (2 meter) airborne hyperspectral imagery and tested classification methods for Egaria densa.

Delta Ecosystem Modeling

• Set-up successfully the USDA Soil and Water Assessment Tool (SWAT) for the Legal Delta area and tested agricultural drainage water quality simulations; and

• Overlaid actual agricultural drainage return pumping locations for Delta Island tracts.

Plant Environmental Response Testing

• Collected reviewed Water Hyacinth growth models;

• Developed environmental response input structure for model development; and

• Initiated controlled environment response studies with Water Hyacinth and Egaria densa.

Pointing Schedules of Agile Spacecraft

NASA: Kimberly Hines
BAERI: Sreeja Nag, Alan Li

Distributed Space Missions (DSMs) such as formation flight and constellations, are being recognized as important solutions to increase measurement samples over space and time. Given the increasingly accurate attitude control systems emerging in the commercial market, small spacecraft now can slew and point within few minutes of notice. In spite of hardware development in CubeSats at the payload (e.g. NASA InVEST) and subsystems (e.g. Blue Canyon Technologies), software development for tradespace analysis in constellation design (e.g. Goddard's TAT-C), planning and scheduling development in single spacecraft (e.g. GEO-CAPE) and aerial flight path optimizations for UAVs (e.g. NASA Sensor Web), there is a gap in open-source, open-access software tools for planning and scheduling distributed satellite operations in terms of pointing and observing targets. This project will demonstrate results from a tool being developed for scheduling pointing operations of narrow field-of-view (FOV) sensors over mission lifetime to maximize metrics such as global coverage and revisit statistics. Past research has shown the need for at least fourteen satellites to cover the Earth globally everyday using a Landsat-like sensor. Increasing the FOV three times reduces the need to four satellites, however adds image distortion and BRDF complexities to the observed reflectance. If narrow FOV sensors on a small satellite constellation were commanded using robust algorithms to slew their sensor dynamically, they would be able to coordinately cover the global landmass much faster without compensating for spatial resolution or BRDF effects. Our algorithm to optimize constellation satellite pointing is based on a dynamic programming approach under the constraints of orbital mechanics and existing attitude control systems for small satellites. As a case study for our algorithm, we minimize the time required to cover the ~17000 Landsat images with maximum signal to noise ratio fall-off and minimum image distortion among the satellites, using Landsat's specifications. Attitude-specific constraints such as power consumption, response time, and stability were factored into the optimality computations. The algorithm can integrate cloud cover predictions, specific ground and air assets and angular constraints.

Publications and Presentations

Nag,S., C.K. Gatebe, D.W. Miller, O.L. de Weck, "Effect of Satellite Formation Architectures and Imaging Modes on Global Albedo Estimation", Acta Astronautica 126 (2016), 77-97, DOI:10.1016/j.actaastro.2016.04.004

Nag, S., A.S. Li, "Optimizing the Attitude Control of Small Satellite Constellations for Rapid Response Imaging", American Geophysical Union Fall Meeting, California USA, December 201

2016 Accomplishments

- Developed capability to scheduling pointing operations for NFoV sensors, for imaging, calibration and downlink, on Single spacecraft in known orbits and Satellite constellations and demonstrated value through a case study - Single and multiple satellites in the Landsat orbits with the existing FOVs;
- Set up computer simulations to mimic and predict interactions of UAS communications so as to stay in touch UAS operators and potentially serve as vehicles to make responsive and valuable measurements for Earth Science;
- Reviewed the commercially available transponders for UAS communication and compare them quantitatively; and
- Completed software development of Executive Driver and Data Computation modules of TAT-C. This included completing its system architecture design and the development of the system Interface Control Document.

Sentinel-2

NASA: Jennifer Dungan, Ramakrishna Nemani
BAERI: Sangram Ganguly

Sentinel-2 (S2) is a land monitoring constellation of two satellites that provides high resolution optical imagery by European Space Agency (ESA). Sentinel-2A is the first of two satellites was successfully launched in June 2015. Its MultiSpectral Instrument (MSI) capitalizes on the technology and the vast experience acquired with SPOT and Landsat over the past three decades. The S2 MSI samples 13 spectral bands: four bands at 10 meters, six bands at 20 meters and three bands at 60 meters spatial resolution.

NASA Earth Exchange (NEX) team has been working on radiometric cross-calibration of the S2MSI and Landsat-8 OLI sensors based on the latest released sample S2 images from ESA. An S2 processing pipeline has also been developed to provide research ready S2 imagery to the remote sensing community. The algorithm used for S2 atmospheric correction is consistent with standard Landsat OLI product, which provides potential data harmonization between Landsat 8 and S2. NEX supercomputing facility will be used to process daily-acquired S2 images.

Publications and Presentations

Huang, S., H. Liu, D. Dahal, S. Jin, S. Li, and S. Liu (2016). Spatial variations in immediate greenhouse gases and aerosol emissions and resulting radiative forcing from wildfires in interior Alaska. Theoretical and Applied Climatology. 123(3): 581-592.doi:10.1007/s00704-015-1379-0

Li, S., S. Ganguly, J. Dungan, W. Wang, R.R. Nemani (2016). Sentinel-2 MSI Radiometric Characterization and Cross-Calibration with Landsat-8 OLI. Ready to submit for review

BOOK CHAPTER:

Hansen, A.J. et al., 2016. Climate Change in Wildlands - Pioneering Approaches to Science and Management. Chapter 7, Forrest Melton, Jun Xiong, Weile Wang, Cristina Milesi, Shuang Li, Ashley Quackenbush, David M. Theobald, Scott J. Geotz, Patrick Jantz, and Ramakrishna Nemani, 119-150.

2016 Accomplishments

- Deployed S2 atmospheric correction tool (ESA) on NASA NEX;
- Processed all the released sample S2 data and compared with Landsat 8 images;
- Determined that the atmospheric correction tool (developed by ESA) is not reliable in its current status. Abnormal pixel values from derived S2 L2A products (surface reflectance) occur in all land cover types;
- Planned for the preparation of a process chain (scale codes from NASA's Goddard Space Flight Center) - the process chain involves multiple modules related to BRDF correction, georegistration, atmospheric correction, and regridding/reprojection routines;
- Prepared for the deployment of process codes to provide research-ready data (Surface Spectral Reflectance production) to MuSLI PIs; and
- Prepared to implement LAI algorithm for higher level product demo.

Terrestrial Ecosystem and Carbon Simulation Modeling

NASA: Chris Potter
CSUMB: Steven Klooster; Vanessa Brooks Genovese

The main focus of this group is the study of trace gas fluxes (CO_2, CH_4, N_2O, and NO) and plant production at global and regional scales using the NASA-CASA (NASA-Carnegie-Ames-Stanford Approach). This model simulates controls over terrestrial production processes, interactions of trace gas flux components through nutrient substrate availability, soil moisture availability, temperature stress, soil texture, and microbial activity.

The NASA-CASA model is used for predicting ecosystem responses to global climate warming and changes resulting from land use patterns, understanding influences on terrestrial net primary productivity, quantifying carbon pools, and understanding biosphere-atmosphere interactions.

The NASA-CASA model has been used to generate maps of annual net primary production (NPP) and aboveground biomass carbon stocks or pools in forests over various regions of the world. An advantage of NASA-CASA results over most other available map products for forest carbon accounting is that NASA-CASA can cover an entire country at a relatively high resolution using a consistent method.

The team works on two USDA-ARS funded projects. The Area-wide Management of Aquatic Weeds in the Delta and the Hawaii Coffee Berry Borer Modeling Project. The Delta project is designed to control the spread of water hyacinth and other invasive aquatic plants in the Delta. The main objectives of the Hawaii CBB project are to track and predict the spread of the coffee berry boring beetle which is causing widespread damage and destruction of coffee fields in the state of Hawaii.

2016 Accomplishments

The Area-wide Management of Aquatic Weeds in the Delta

- Focused on using satellite and areal imagery to predict where water primrose and water hyacinth were growing and moving.;
- Worked on a weed growth model to simulate where the invasive plants will spread; and
- Focused on obtaining and analyzing new SPECTIR (2 meter) airborne hyperspectral imagery to assess and verify the invasive maps. The goal of the Delta area-wide project is to reduce or eliminate the economic and environmental damage caused by large populations of water hyacinth and other invasive aquatic plants.

The Hawaii Coffee Berry Borer Modeling

- Worked with the USDA office in Hawaii to map coffee fields over the Big Island for several years to analyze the land cover change caused by the coffee berry borer; and
- Classified coffee fields in Maui.

Figure 12: 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.

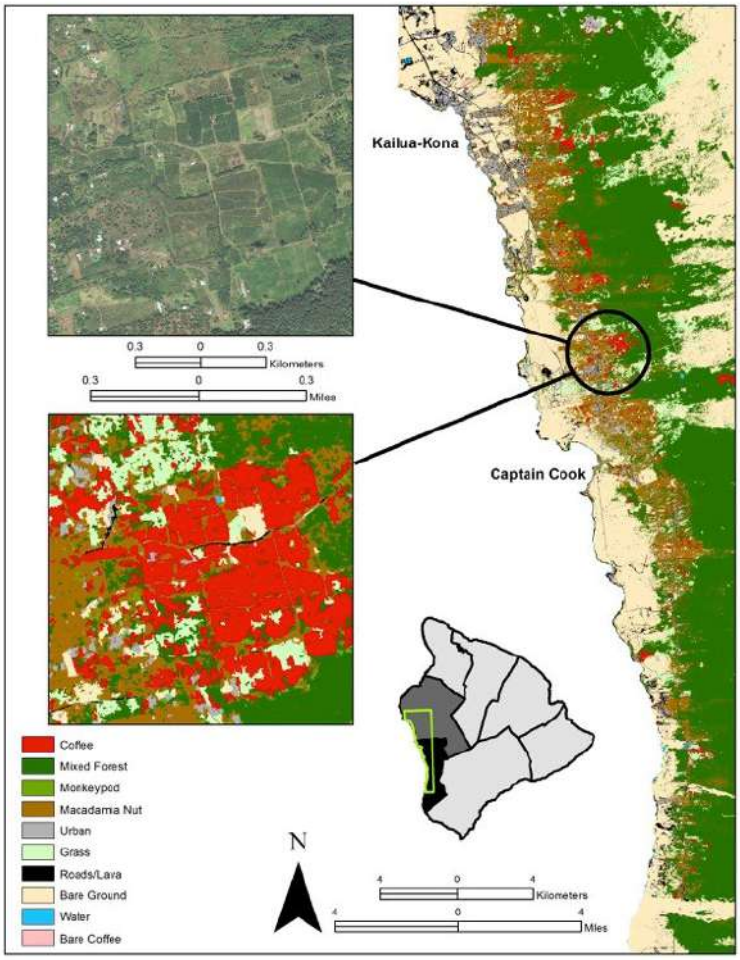


Figure 13: The Hawaii CBB project main objectives are to track and predict the spread of the coffee berry boring beatle which is causing widespread damage and destruction of coffee fields in the state of Hawaii. The Carbon team has been working with the USDA office in Hawaii to map coffee fields over the Big Island for several years to analyze the land cover change caused by the coffee berry borer

Total Carbon Column Observing Network (TCCON)

NASA: Laura Iraci, Jim Podolskie
BAERI: Patrick Hillyard

NASA Ames deployed a Fourier Transform Spectrometer (FTS) as part of the Total Carbon Column Observing Network (TCCON) to the Armstrong Flight Research Center (AFRC) in July 2013. The TCCON FTS is a solar-looking spectrometer that captures solar interferograms throughout the course of the day. After post-processing and converting the interferograms into spectra, fitting routines and further processing can be performed to obtain column-averaged dry-air mole fractions for gases of interest by looking at specific spectral regions. Currently, TCCON provides mole fractions for CO_2, CH_4, CO, N_2O, HF, H_2O, and HDO. The TCCON data can be used alone, as part of the international TCCON network, or in conjunction with other instrumetation to perform studies that relate to the above-mentioned gases.

Furthermore, the launch of the OCO-2 satellite has brought with it the need for highly accurate data with which calibrations can be performed. The NASA Ames TCCON has provided a great deal of data for the purpose of OCO-2 calibration. It has additionally been utilized for comparison with GOSAT data, in conjunction with aircraft in-situ measurements, and for comparision of data from the relatively new, portable Bruker EM27 solar spectrometer.

Publications and Presentations

M. Inoue, et al. (L. Iraci, J.R. Podolske and P. Hillyard are among 46 co-authors). Bias corrections of GOSAT SWIR XCO_2 and XCH_4 with TCCON data and their evaluation using aircraft measurement data, Atmospheric Chemistry and Physics.

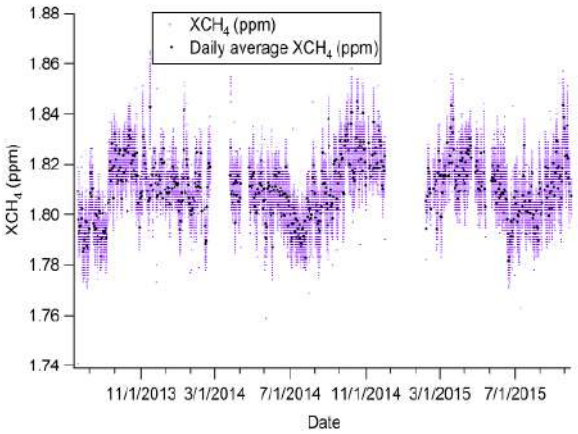


Figure 14: Column averaged, mole fractions of CH_4 in parts per million as measured by the TCCON instrument deployed at NASA-AFRC. Daily averages are shown in black.

2016 Accomplishments

- Maintained and managed the Linux workstation that is used for data processing and storage;
- Downloaded the data from the Armstrong Flight Research Facility (AFRC), and processed it according to the TCCON protocol in order to be comparable to other instruments in the network;
- Analyzed data including the processing of FTS interferograms as well as the fitting of the spectra in spectroscopic regions of interest for a given gas;
- Managed quality control, transferred the data to the California Institute of Technology, and safely archived the data at NASA Ames; and
- Used the FTS data in conjunction with GOSAT data and in-situ data taken at a network of sites around Indianapolis.
- Finished the analysis of the 2012 deployment to Indianapolis as part of the INFLUX campaign and worked with researchers from Penn State to submit the results for publication; and
- Continued to build collaborations with OCO-2 and GOSAT teams and also those working on studying urban emission in the Los Angeles area

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.

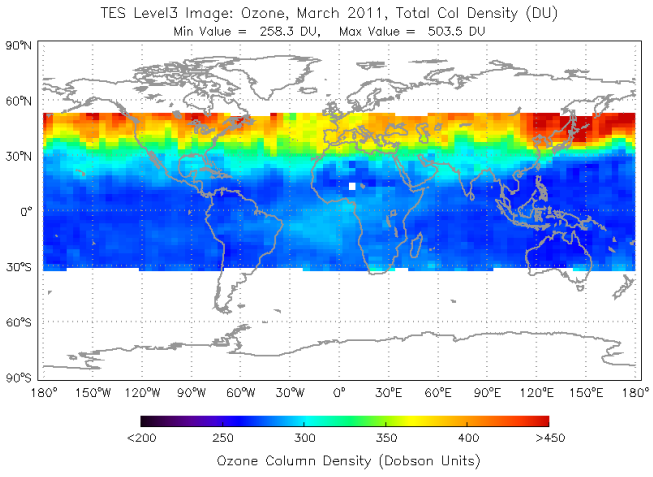


Figure 15: An example of data collected by the TES instrument. The figure is a global image of the total column density of ozone for the month of March in 2011. The ARC-CREST members of the TES team work to continually improve and expand the retrieval algorithms for TES data products.

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 and Presentations

Kulawik, S., Vivienne Payne, Emily Fischer, Dejian Fu, "Acetone and Hydrogen Cyanide from Aura-TES", August 30-Sept 1, 2016, Rotterdam, The Netherlands.

Kulawik, S., Vivienne Payne, Emily Fischer, Dejian Fu, "Using TES retrievals of HCN to determine fire influence of Aura-TES footprints", AGU Fall Meeting, 12-16 December, 2016, San Francisco, CA

2016 Accomplishments

- Worked with the software team to transition the multi-satellite retrieval code to an operational code being run by the software team on OMI and AIRS data to continue the A-Train ozone record begun by TES;
- Developed TES ozone time series products for the Total Ozone Assessment Report (TOAR); and
- Continued to support TES "Lite" products which are easier for first time users, and continued development of the TES-heritage multi-satellite retrieval code.

EARTH SCIENCE APPLIED SCIENCES PROGRAM

Disaster Management

NASA: Jim Brass
CSUMB: Vince Ambrosia, Robert Dahlgren, Lee Johnson

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

A. Disaster Task Element 1: Since 2013, Dr. Ambrosia has supported a portfolio of funded project efforts within the ASP-Wildfire Program. That responsibility includes scientific oversight of the project goals and objectives, budgetary management of the funded efforts of disparate organizations and investigators, metrics monitoring for the projects, interactions with partner agencies involved in the projects and serving as a representative on regional, national, and international wildfire science and applications panels and boards. Additional activities include organization and planning of national and international symposia and forums, as well as participating and collaborating in workshops and webinars, highlighting the ASP-Wildfire program and access and use of EO data to support wildfire science and applications by the community

B. Airborne systems (UAS for Environmental and Disaster Monitoring and Science Support)
(1) Research directed at lowering the cost of remote sensing using small unmanned aerial systems (sUAS), aka small drones, as stable low-altitude platforms to host payloads such as sensing instruments. What is unique about this research is the concept of modularity that allows UAS airframes that can be assembled Lego*-like and scaled such that they are holistically optimized to maximize performance for a given remote sensing mission. As a demonstration concept, components from surplus military sUAS are converted into modular aircraft capable of a variety of configurations, which are in development and scheduled for flight testing at the end of 2016. Some of the applications of these mass-customized aircraft will be volcanic plume observation, magnetometer surveys, wildlife census, marsh erosion, post-wildfire recovery, landslide hazard mapping, geological survey, inundation mapping, mudflat quality and quantity, and other data collection campaigns.

(2) Applied research and improvement of sensors and instruments for onboard manned and unmanned aircraft. This includes development and construction of specific instruments such as n-STAR, sun glint sensor, and polarimetric sensors. This work also includes the integration of payloads such as MicroDOAS and MFAM that often require significant effort for suspension system, aerodynamics, electromagnetic compatibility (EMC), and system engineering development.

(3) Electrical engineering of avionics and telemetry systems for commercial sUAS and larger military surplus unmanned aerial systems (UAS) at the NASA Ames Research Center. Subject matter expert in optical sensor physics, gyroscopes/accelerometers, lasers, and EMC testing.

(4) Education and outreach activities supporting several undergraduate and graduate interns at NASA Ames Research Center. Provide mentorship and focused sUAS projects for intern teams during the summer, and individuals throughout the school year, via a variety of programs.

*Lego is the trademark of the LEGO Group, Billund, Denmark.

Figure 16: Airborne systems (UAS for Environmental and Disaster Monitoring and Science Support)

2016 Accomplishments

Disaster Element Task 1 (Ambrosia)

• Organized a series of meetings and workshops in support of the NASA Applied Science Program - Wildfire Program. These workshops and meetings included planning agendas, budgeting meeting expenses, contracting services, organizing speakers, developing breakout sessions, securing meeting facilities, and securing A/V support to meetings;

• Provided support for a portfolio of 9 NASA ASP-funded Wildfire projects, including metrics tracking, budget maintenance and reporting, investigator interface, partnership / co-agency development and maturation and review / evaluations of work accomplished by those 9 teams;

• Served on a number of interagency, regional, national, and international science panels focused on wildfire assessment, including the Office of Science & Technology Policy (OSTP) Wildland Fire Science and Technology Task Force (WFST TF); USGEO / GEO Global Wildfire Information System (GWIS) Committee; OSTP - National Science & Technology Council (NSTC) Subcommittee on Disaster Reduction (SDR); Interagency Arctic Research Policy Committee (IARPC) - Wildfire Implementation Team (WIT); National Research Council (NRC), Div. of Earth & Life Sciences, Wildfire Study Team; JFS Program, Fire and Smoke Model Evaluation Experiment (FASMEE) Team;

• Briefed NASA HQ management on programmatic goals and metrics of the Wildfire Program during quarterly ASP Programmatic Reviews;

• Served on Planning Committees for upcoming scientific symposia;

• Sat on numerous journal peer-review panels; Provided scientific peer review of 7 manuscripts submitted to journals in 2016;

• Served on NASA ASP proposal review panels, including leading review panels on solicited proposal efforts in wildland fire;

• Reviewed for two USDA SBIR submissions for fire science support;

• Worked with NASA HQ Public Affairs on program descriptions and development of press releases and video of wildfire program project highlights;

• Served as scientific content manager of the NASA ASP-Wildfire website;

• Performed an ASP-Wildfire Quarterly report videoblog on the NASA website; and

• Supported a 2017 NASA ROSES solicitation on Axx Group on Earth Observations Work Programme; 3.3.7 Global Wildfire Information System, GWIS

Disaster Element Task 2 (Dahlgren/Pinsker)

• Harvested, as a demonstration concept, parts from surplus military sUAS to serve as raw materials for "Franken-craft" having new configurations and enhanced performance. NASA ARC has a number small unmanned aerial systems (sUAS) namely RQ-11A and RQ-11B Ravens, donated by the Department of the Interior for zero dollars. The Raven is designed to be easily disassembled and reassembled for field use, which presents ideal feedstock to develop modular, more complex aircraft. A new staff member was hired to support the FrankenRaven and other projects. One setback was that the Autonomous Systems Development Lab (ASDL) which is in the basement of ARC Building N245 experienced minor flooding and needs to be abandoned while remediation takes place.

• Worked on Modular UAS Framework for Customizable Autonomy Research

o This ARMD-funded LEARN-2 project has picked up the momentum from the 2015 work and is developing modular aircraft capable a variety of configurations that can be scaled, in this case by changing the wingspan or payload placement. The advent of modular aircraft opens a new tradeoff space which can be explored to holistically optimize the platform to maximize mission performance. This project that is headed by Prof. Alonso at Stanford held a workshop on modular UAS in February 2016 and an industry survey in September 2016.

o One demonstration vehicle developed by this project will be a single fuselage FrankenRaven design, and this aircraft is scheduled for flight testing at the end of 2016. Stanford and collaborators are also developing a modular rotorcraft.

o In 2016 the student interns converted all the CAD from SolidWorks to Creo format. The mechanical errors in the splice ware characterized, and the mechanical design was iterated to reduce misalignment. A weight and CG budged was developed for all the modules, and aerodynamic analysis was performed to estimate veloc

ity, endurance time, distance, and other parameters. Electrical schematics were generated and consolidated with mechanical drawings and other documents to form a Technical Construction File (TCF) for the modular aircraft. Three meetings were held with the NASA ARC Airworthiness and Flight Safety Review Board (AFSRB) as part of the process to fly the modular aircraft.

• Continued on work on FrankenRaven: A modular subscale platform for autonomy research. This proposal was initially declined, but subsequently funded by the ARC Center Innovation Fund (CIF) in July 2016 at a fraction of the proposed amount, therefore the project was significantly descoped and delayed. Once the project was re-started, work commenced on demonstrating the common avionics architecture (CAA) based on the Pixhawk autopilot in an unmodified Raven aircraft.

• Worked on integrating Volcanic Gas Sensing on to UAS Platforms

o The USGS Innovation Center for Earth Science (ICES) funded project met a major milestone with the construction of the 3DP/FDM wing splice subcomponent in 2015. One or more of these splices is used in an extended-wing dual-fuselage FrankenRaven, designed to carry a 1.5 kg payload. The so-called TwinRaven design features a lightweight carbon fiber instrument pod that is centrally-mounted below the wing, in between the two fuselages. The payload consists of a miniature spectrometer and zenith-facing telescope having a narrow field of view. This instrument permits spectroscopic analysis of the atmospheric column above the UAS and can be used for characterization of volcanic gas plumes and other aerosols. Both the TwinRaven and payload integration are in the construction phase. We expect to fly this aircraft in early 2017 and ultimately use this platform to observe a volcanic plume during a mission at Kilauea summit, Hawaii in spring 2017.

• Participated in the Naval Research Enterprise Internship Program (NREIP), and one excellent student was placed into the project for the summer of 2016 and requested and was granted an extended stay. Additionally, four ROTC interns were hosted during the summer for short-term tasks. The 2016 NASA internship alumni are:

o Lowell Jones (NREIP), Tuskegee University

o Corbin Mosser (ROTC), University of Kentucky

o John Jasionowicz (ROTC), Temple University

o Matthew Pscheid (ROTC), Michigan Tech

o Nick Weidow (ROTC), Purdue University

Additionally, a UCSC senior project was supported in conjunction with Prof. Steve Petersen at the electrical engineering department. This was to design and demonstrate an encrypted command and control (C&C) line for UAS, and the team included:

o Ethan Pinsker, Senior

o Randall Robinson, Junior

o Harry Jackson, Senior

Summer Intern Lowell Jones and Jr. Engineer Ethan Pinsker represented NASA Ames Research Center and the Earth Science Division at the City of Mountain View's Technology Showcase. The Technology Showcase was held on August 11th, 2016 at Civic Plaza in downtown Mountain View. At the event, they met with the general public, answered questions about NASA, and handed out NASA bags and posters. The event was well attended and was mentioned in the local press and television media. www.mountainview.gov/techshowcase

• Provided general electrical engineering support for the Sierra-B project, and medium-class UAVs. A schematic review has been performed on a large drawing set for the Sierra-B aircraft, and a number of issues were addressed.

• Evaluated opto-mechanical impairments in the 4STAR instrument and advised the science and engineering teams on photonics matters. Developed, inspected and redesigned the wiring for the sun photometer while keeping the previous wiring drawing standards and methods. Designed placement of operating modules in the system.

Figure 17: Summer Intern Lowell Jones and Jr. Engineer Ethan Pinsker representing NASA Ames Research Center and the Earth Science Division at the City of Mountain View's Technology Showcase.

Publications and Presentations

Dahlgren, R Ambrosia, V. G. and L. Friedl, 2016. Keynote Address: NASA Applied Science Program: Building Capacity in the Community. Fourth International Conference on Remote Sensing and Geoinformation of Environment, Paphos, Cyprus, 4 April 2016.

Ambrosia, V. G., L. Friedl, and A. Soja, 2016. NASA Applied Science Program: Wildland Fire and Disasters. Fourth International Conference on Remote Sensing and Geoinformation of Environment, Paphos, Cyprus, 6 April 2016.

Soja, A., V.G. Ambrosia, and L. Friedl, 2016. NASA Fire Science and Applications: Technology, Satellites, Airborne Data and Models, International Association of Wildland Fire (IAWF): 5th International Fire Behavior and Fuels Conference, Portland, OR., 11-15 April 2016.

Ambrosia, V.G., 2016. NASA Applied Science Wildfire Program. ESRI User Conference, San Diego, CA, 29 June 2016.

Ambrosia, V. G., L. Friedl, and A. Soja, 2016. NASA Applied Science Wildfire Program. IAWF Second International Smoke Symposium -- Workshop, Long Beach, CA, 14 November 2016.

Dahlgren, R., J. Alonso and M. Fladeland "Progress on Modular Unmanned Aircraft Technology" (Invited Talk), ASPRS UAS Mapping Conference, (Palm Springs).

Dahlgren, R., "The Value of Volunteering in Science & Engineering," UCSC Electrify Your Career: Get Involved! 9-1-2016.

Dahlgren, R., M. Fladeland, E. Pinsker, et al., "FrankenRaven: A New Platform for Remote Sensing," AGU 2016 NH11B-1726 (San Francisco).

Gentry D., M. Guarro, I. Demachkie, I. Stumfall and R. Dahlgren, "A UAV-Based Fog Collector Design for Fine-Scale Aerobiological Sampling," AGU 2016 A21L-05 (San Francisco).

Vanderbilt, V., C. Daughtry, R. Dahlgren, "Leaf Relative Water Content Estimated from Leaf Reflectance and Transmittance," MISR, 18-19 February 2016.

Vanderbilt, V., C. Daughtry, R. Dahlgren, "Leaf Relative Water Content Estimated from Leaf Reflectance and Transmittance," IGARSS.

Vanderbilt, V., C. Daughtry, R. Dahlgren, "Estimating the Relative Water Content of Single Leaves from Optical Polarization Measurements," AGU 2016 P11C-1874 (San Francisco).

Abstract Accepted
Dahlgren, R., E. Pinsker, O. Dary, J. Ogunbiyi, A. Mazhari, "3D scanning and printing of airfoils for modular UAS," SPIE Photonics West, 10095-16 (San Francisco)..

Ecological Forecasting

NASA: Jim Brass
BAERI: Cindy Schmidt

The Ecological Forecasting program is a 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. ARC-CREST staff are part of the Program management team. In this capacity, they track the projects in the Ecological Forecasting portfolio, support strategic planning activities, help coordinate annual program review meetings and participate in interagency activities and meetings as required by the Program Manager for Ecological Forecasting. ARC-CREST staff help manage the following projects:

1. Projecting Effects of Climate Change on River Habitats and Salmonid Fishes, PI: Gordon Luikart, University of Montana

2. Bayesian Data-Model Synthesis for Biological Conservation and Management in Antarctica, PI: Heather Lynch, Stony Brook University

3. Bringing Wildlife Management into Focus: Integrating Camera Traps, Remote Sensing and Citizen Science to Improve Population Modeling, PI: Phil Townsend, University of Wisconsin.

Publications and Presentations

"Using NASA data for Earth Science Applications", Key Note Presentation, Florida GIS Conference, Daytona Beach, Florida (September).

Proposal review panel for NASA Citizen Science solicitation, Washington DC (November)

Proposal review panel for NASA Ecological Forecasting solicitation, Washington DC (November

2016 Accomplishments

- Attended Arctic Boreal Vulnerability Experiment meeting to represent NASA Applied Sciences program, Anchorage, AK (January);
- Helped organize and attended NASA Ecological Forecasting PI meeting, Washington DC (May);
- Helped organize and attend NASA Applied Sciences Associates Retreat, Washington DC (October);
- Worked with PIs to ensure they comply with all Applied Science requirements;
- Conducted site visit to University of Wisconsin, Madison to meet with the "Snapshot Wisconsin" team;
- Presented project summaries during bi-monthly Applied Sciences program reviews; and
- Participated in monthly NASA citizen science conference calls organized by NASA's Senior Policy Advisor.

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

NASA: Laura Iraci, Vijay Natraj, Brad Pierce
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.

Publications and Presentations

Natraj, V., Brad Pierce, Allen Lenzen, Susan Kulawik, Helen Worden, Xiong Liu, Mike Newchurch, Konstantin Vinnikov, "Ozone and NO2 OSSEs on a Regional/Urban Scale for GEO-CAPE", GEMS Science Team Meeting, October 11, 2016, Yonsei University, Seoul, Korea.

Natraj, V., B. Pierce, A. Lenzen, S. S. Kulawik, "NO2 OSSEs on a Regional/Urban Scale for the GEO-CAPE Mission", AGU Fall Meeting, 12-16 December, 2016, San Francisco, CA

2016 Accomplishments

- Focused on real-time simulated retrievals; and
- Performed the first simulated NO2 retrievals in November.

Figure 18: 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.

Indigenous Knowledge

NASA: Jim Brass
BAERI: Cindy Schmidt, Sherry Palacios

The NASA Applied Science Capacity Building program seeks to better understand the needs and data gaps in the use of geospatial data, particularly NASA Earth science data and products, within Indigenous communities in North America. Tribal members and other long-term residents of particular areas have developed extensive knowledge bases that include deep understanding of local environments and adaptive processes passed down through generations. That knowledge, referred to as "indigenous knowledge" or "traditional ecological knowledge (TEK)" is typically orally passed down through generations, and holistic in having cultural and spiritual components. TEK encompasses the relation of living beings with each other and the surrounding environment. In addition to better understanding the needs and data gaps of Indigenous groups, this effort also seeks to understand how TEK can inform NASA Earth Science activities.

The proposed activities in FY16 to meet these objectives included:

1) Determine what other federal agencies are doing with Native American tribes;

2) Identify NASA activities with tribal organizations; and

3) Interact with key national/state/regional/local tribal organizations to understand needs

Publications and Presentations
Using NASA Data for Earth Science Applications", National Indian Timber Symposium, San Carlos Apache Reservation, Arizona (April)

"Using NASA Data for Earth Science Applications", Intertribal Environmental Summit, Dallas, TX (April)

"Using NASA Data for Earth Science Applications", Tribal GIS conference, Albuquerque, NM (November).

2016 Accomplishments

- Attended Conferences:
    - o National Indian Timber Symposium, San Carlos Apache Reservation (April)
    - o Intertribal Environmental Summit, Dallas, TX (April)
    - o Tribal GIS Conference, Albuquerque, NM (November)
- Conducted hands-on workshop on the use of a Drought Monitoring Tool, Navajo Nation (April);
- Attended Bureau of Indian Affairs (BIA) GIS training, Sacramento, CA (September);
- Visited Sault tribe of Chippewa Indians, Sault Ste Marie, MI (August);
- Conducted 1-day, hands-on Introduction to Remote Sensing workshop, Tribal GIS Conference, Albuquerque, NM (November); and
- Participated in monthly communications with: Pacific Northwest Tribal Climate Change Network, the Southwest Tribal Climate Change Network, and the NASA American Indian/Alaskan Native Education Working Group.

Water Resources Program

NASA: Jim Brass
CSUMB: Forrest Melton

The primary objectives of this task are to:

1) Support the NASA Applied Sciences Program, Water Resources application area by serving as an Associate Program Manager for Water Resources, and a Deputy Program Manager for the Suomi NPP satellite mission.

2) Monitor progress across the project portfolio, engage and support project teams in identifying and resolving project issues, and coordinate the ASP Water Resources science community.

3) Engage and support the NASA Applied Sciences stakeholder community.

2016 Accomplishments

• Co-organized the annual NASA Applied Sciences Program (ASP) Water Resources PI Meeting held at the NOAA Center for Weather Prediction in College Park, MD. Co-authored the meeting report;

• Led the organization of a joint workshop with the World Bank on the topic of Remote Sensing of Evapotranspiration for Food and Water Security, held at the World Bank in Washington, DC. The meeting was attended by more than 150 scientists, water resource managers, World Bank staff, and stakeholders from around the world. Co-authored the meeting report and a whitepaper submitted to the NRC Decadal Survey request for information;• Co-organized the Climate Change and Water Resources Working Group interagency workshop at the NOAA Fisheries Science Building in Seattle, WA, attended by 60 scientist and water resource managers;

• Maintained the ASP Water Resources website (http://c3.nasa.gov/water);

• Co-authored the 2016 ROSES Water Resources solicitation and jointly organized the review panel with the Program Manager for Water Resources;

• Tracked and coordinated 9 ASP Water Resources projects. Monitored financial and technical progress and engagement with partners and stakeholders. Communicated regularly with project PIs to identify and resolve issues. Reported project progress to ASP PMs and Associates at 6 ASP Program Reviews;

• Served as the NASA Representative to WESTFAST and the Climate Change and Water Working Group, which are federal interagency coordinating organizations;

HELIOPHYSICS

Collaborative Space Weather Modeling

NASA: Jeff Scargle, Nagi Mansour
BAERI: Bob Stein, Thomas Hartlep

The goal of Collaborative Space Weather Modelling is to model the emergence of active regions and sunspots through the upper layers of the solar convection zone by numerically solving the magneto-hydrodynamic conservation equations of mass, momentum, energy, and magnetic field. The results of global solar dynamo calculations are used to impose bottom boundary conditions on the vertical velocity and horizontal magnetic field. The magnetic field entering the computational domain at the bottom is accelerated upward by buoyancy (due to lower density where the magnetic field is strong) and advected upward by rising convective motions. These two processes bring the magnetic flux to the solar surface. Convective motions not only carry the magnetic field toward the solar surface, but also shred the rising magnetic field into thin filaments which emerge as small mixed polarity magnetic bipoles at the surface, while at the same time the large-scale, supergranule, convective motions confine the filament bundles into omega-shaped loops that emerge as the active regions. Modeling active region emergence process as realistically as possible provides a synthetic data set which can be used to compare with solar observations to develop techniques for predicting the emergence of active regions before they appear at the visible solar surface. This is one step in the chain of understanding and being able to predict the impact on the Earth of events on the Sun

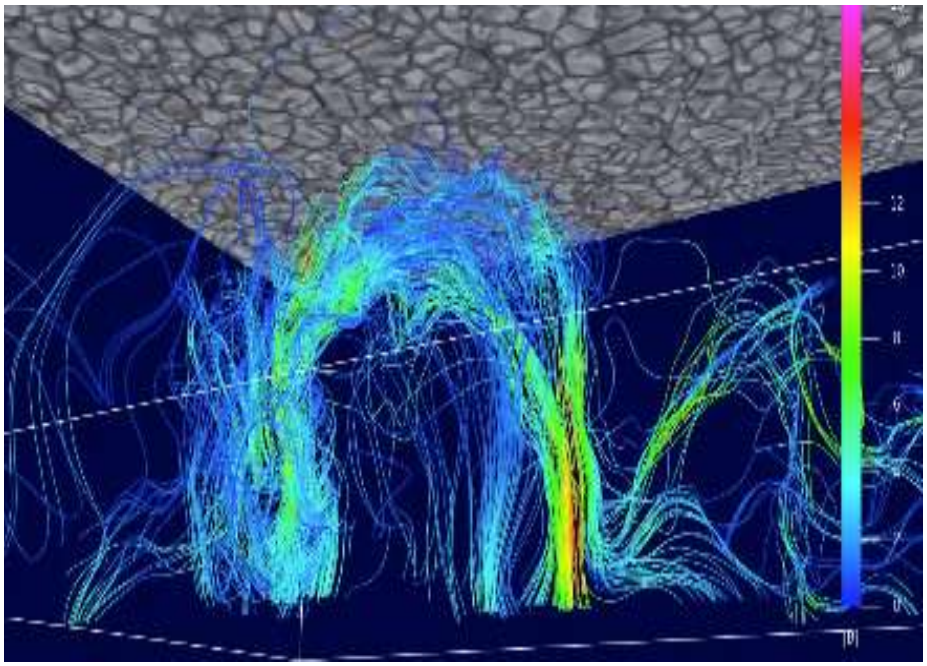


Figure 19: Magnetic field lines of an emerging Omega-loop. Color indicates magnetic field magnitude with scale on the right in kG. Gray scale image at the top is the surface continuum radiation intensity showing the granulation pattern. Convection shreds the magnetic field into multiple filaments, but 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).

2016 Accomplishments

• Enlarged 96 Mm wide by 20 Mm deep computational domain to 192 Mm wide and began the process of relaxing it to develop larger-scale convective cells near the bottom of the domain. This has run for a time slightly longer than the time for typical surface down flows to reach the bottom of the computational domain;

• Developed and tested new bottom boundary conditions to incorporate spatially and temporally varying velocity and magnetic field values determined from global dynamo calculations;

• Caught and fixed a bug in the bottom magnetic field boundary condition that led to instability when the field became very strong;

• Investigated a problem near the visible surface that inhibited running the simulation at very low resolution, needed in order to speed up the relaxation in deep levels; and

• Continued small-scale (48 Mm wide) simulation of magnetic flux emergence, which resulted in merging of smaller magnetic flux concentrations into a small sunspot. During the merger process, light bridges formed and disappeared and incipient penumbra appeared.

Publications and Presentations

"Oscillations and Convection Simulations", Robert Stein, SCORE16 (Stellar Convection and Oscillations and their Relationship) workshop, Aarhus University, Denmark, October 2016

"Active Region Formation and Subsurface Structure", Robert Stein, SDO16, Burlington, VT, October 2016

"Sun's Weather Controls Earth's Space Weather", Robert Stein, Supercomputing 2016, Salt Lake City, UT, November 2016.

Heliophysics Modeling and Simulation (HMS)

NASA: Nagi Mansour, David Hathaway
BAERI: Thomas Hartlep

In this project, we study the structure and evolution of the solar interior and surface using numerical simulations. There are two efforts in this project: One goal is the modeling of the magnetic field on the entire surface of the Sun. This is challenging because only part of the Sun is visible at any given time. However, knowledge of the entire surface is crucial for space weather modeling and forecasting. Using observational data and a surface flux transport model, we want to estimate the current state of the solar magnetic field on the entire solar surface and predict its state in the future.

Another effort in this project is aimed at improving our knowledge of the solar interior flows. Signatures of sound waves are visible on the solar surface and allow us to probe the interior similar to earth seismology. Using numerical simulations of wave propagation in the solar interior, we aim to improve helioseismic measurement and inversion techniques.

Publications and Presentations

Roth, M.; Doerr, H.-P.; Hartlep, T. 2016. Verification of the helioseismic Fourier-Legendre analysis for meridional flow measurements. Astronomy & Astrophysics, Volume 592, id.A106. doi:10.1051/0004-6361/201526971.

Díaz Alfaro, M.; Pérez Hernández, F.; González Hernández, I.; Hartlep, T. 2016. Seismic Holography of the Solar Interior near the Maximum and Minimum of Solar Activity. Solar Physics, Volume 291, Issue 5, pp.1323-1340. doi: 10.1007/s11207-016-0912-3.

2016 Accomplishments

Surface Flux Transport Effort

- Wrote scripts for retrieving magnetic field data from the Helioseismic and Magnetic Imager (HMI)/ Solar Dynamics Observatory (SDO) and prepared it for ingestion into the surface flux transport code;
- Prepared hourly data ready to be ingested for 2010 through 2016; and
- Added capability to the flux transport code "SURF" to assimilate observed magnetic field data.

Helioseismic Effort

- Set-up and performed simulations of wave propagation through localized flow perturbations in the solar interior (ongoing) that are being used to derived numerical sensitivy kernels for flows in the solar interior;
- Devised code for calculating 2-D sensitivty kernels given measuements of travel times of helioseismic wave in above simuations; and
- Derived preliminary 2-D kernels for horizontal flows for select distances and single frequency.

BIOLOGY

Synthetic Biology

NASA: Michael Flynn
BAERI: Rocco Mancinelli

This project aims to generate the knowledge required to engineer a potentially broad range of space biotechnology applications employing synthetic organisms and microbial bioreactors for in situ resource utilization and biological life support systems. The project focused on two missions this year: Euglena and Combined Regenerative Organic-food Production in Space (Eu:CROPIS) and Synthetic BioMembranes.

Eu:CROPIS: A significant part of using biological systems (synthetic or naturally occurring) in space is to understand the function of gravity from the gene level to the ecosystem level. Eu:CROPIS will elucidate the nitrogen cycle of an ecological system during spaceflight. Because Earth has a 1 x g environment, understanding how the nitrogen cycle operates as a function of gravity is key to sustaining life off Earth. To change the gravity levels, the spacecraft will be maneuvered (by spinning) to produce three different gravity regimes during the mission. The three gravity regimes will be 0.01 x g - 0.1-x g (essentially microgravity); 0.16 x g (Moon gravity) and 0.38 x g (Mars gravity). Each gravity regime will last for six months. The Eu:CROPIS core element is a microbiological trickling filter of lava rock – the habitat of a multitude of microorganisms that purify and decontaminate water. It will be the first time nitrogen- transformation reactions will be measured as a function of gravity.

Publications and Presentations

Mancinelli, R.L. , Hauslage, J, Bornemann, G, and Richter, P. Elucidating the nitrogen cycle of Eu:CROPIS: Euglena: Combined Regenerative Organic-food Production In Space. International Society for Gravitational Physiology. Annual Meeting Abt. Book 2015, Igor B. Mekjavic (ed) pg. 120. ISBN 978-961-93848-0-0. Flynn, M.T., D. Loftus, and R.L. Mancinelli, et al., 2016. Synthetic Biological Membrane. AIAA #269. In press.

2016 Accomplishments

• Eu:CROPIS: The flight unit is in its final phase of construction and testing.

• Grew successfully, using the ground simulation unit at the DLR in Cologne, Germany, tomato plants whose nitrogen source was from synthetic urine placed in the lava trickling filter via the transformation of urea to NH_4+ and then to NO_3- through nitrification;

• Constructed an additional test module that isolates each component of the system (i.e., greenhouse for Euglena, tomato growing section, trickling filter, etc.), such that they can function independently. This module is fitted with gas inlets/outlets and sampling ports so that they can control the atmosphere in the system. This allows them to test each system at various O_2 levels in a controlled manner. The tests from this system indicate that it is highly sensitive to changes in O_2 levels. Upon the addition of synthetic urine, the microbial activity in the trickling filter initially uses all the available oxygen quickly, outstripping the rate of production by Euglena. However, when the urea from the synthetic urine is depleted, microbial activity slows and the oxygen production from Euglena replenishes the system. When more synthetic urine is added to the system the O_2 level falls;

Membranes

NASA: Michael Flynn
BAERI: Rocco Mancinelli

Membranes are a vital component of biological processes. Lipid-based membranes are also used commercially in separation and purification processes. Membranes are used extensively in modern spacecraft for separations, sensors, space suits, and structural components. Man-made membranes created using current technologies have short lifespans due to a susceptibility to chemical, physical, and radiation-exposure damage, resulting in a sizable resupply penalty for long-duration missions. The mission proposes to develop biomimicry capabilities critical for long-duration missions using principles of synthetic biology.

2016 Accomplishments

• Examined and narrowed the current list of potential candidate fatty acids to a few candidate FA/FALCs that are produced by available engineered organisms;

• Obtained a strain of Synechococcus PCC7002 that has been genetically modified to produce their candidate fatty acids (stearic, palmitic and myristic);

• Demonstrated that the organism will produce these FAs in the OA. They have also determined that strains of E. coli capable of producing the candidate FA/FALCs may be obtained through a contract. Because E. coli are heterotrophic, they require a source of nutrients that may not be met by the nutrients (organic, nitrogen, phosphorous and trace mineral compounds) present in the feed side and that diffuse through to the OA side of the membrane;

• Evaluated the transport of metabolic requirements across the bio-membrane and their ability to support E. coli growth and determined that their growth requirements are not met by transport across the membrane from the feed-side to the OA side of the membrane. This was undertaken to investigate this potential requirement for supplying or resupplying these nutrients. The study is designed to determine if the addition of marine cyanobacteria (photoautotrophs) that produce and excrete sugars to the OA side of the system will alleviate a resupply requirement. This study is in progress;

• Developed a protocol to quantify the diffusivity of FA/FALCs into and through the membrane to the feed-side to form a layer;

• Demonstrated the fabrication of bio-membranes with structural lipids and fusion FA/FALCs leading to the production of a set of membranes with a range of FA/FALC permeation rates;

• Conducted a full-scale FO system test with human urine and determined the OA concentration required to achieve the targeted 87% water recovery ratio (3.0 -3.5%);

• Began a trade study to evaluate the best method to deliver and control oxygen and remove and control carbon dioxide in the OA. The study is continuing by measuring oxygen and carbon dioxide fluxes across the bio-membrane. As part of this study an assessment of the ability of cyanobacteria to provide oxygen from photosynthesis and to be a sink for carbon dioxide was conducted and it was shown that cyanobacteria do indeed provide sufficient oxygen to keep the system aerobic. The studies to quantify the ability of the cyanobacteria to act as CO_2 sink are still in progress.

AIRBORNE SCIENCE AND MISSION SUPPORT

Airborne Science Support

NASA: Matt Fladeland
BAERI: Patrick Finch, Ron Instrella

The goal of this task is to provide software support to the NASA Airborne Science Program. There are currently three projects:

MTS (Mission Tools Software) Aircraft Tracking: The team has created and is maintaining and improving the software used as the back-end service to the Mission Tools Suite for tracking aircraft. The team makes use of multiple hardware devices, some portable, some less so, which leverage the Iridium network to pass data from a moving vehicle to our server. The team has written software for this data and have made it retrievable over the web for display in MTS. The software infrastructure will be built out to support a new handheld device (Iridium 9575 Extreme handset) offering not just tracking services, but also emergency communication services.

MTS Network Infrastructure: The team is building out a Virtual Private Network to communicate directly with the FAA to effect the tracking of all civilian aircraft over the United States. This effort supplements the individual tracking of specific NASA assets by allowing NASA to track aircraft near its specific assets in real-time. Storing this data will allow users to see how air traffic and weather affect data collection missions.

Airborne Science Data Repository: The team is building a software and storage system to automate the task of uploading data from NASA Airborne Science facilities instruments. At present, all data must be QC'd, uploaded, and made available by hand. This software and storage system will reduce the amount of time between data collection and dissemination.

2016 Accomplishments

- Deployed Iridium Extreme handsets for the MTS Aircraft Tracking project; thus, initial configurations are completed and any further development can be pushed to the platform remotely;

- Made the initial VPN connection for the MTS Network Infrastructure project, so the data machine behind the VPN is live and accessing data. We are in the process of moving out of R&D to the FAA staging network and are using FAA data to track aircraft; and

- Finished initial experimentation for the Airborne Science Data Repository, and a path forward has been identified to automate QC and file uploads.

Airborne Science Advanced Planning

NASA: Matt Fladeland
BAERI: Susan Schoenung, Patrick Finch, Randy Berthold

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

Figure 20: Pre-flight checks are completed on UAS managed by the Airborne Science Advanced Planning team.

2015 Accomplishments

- Updated the ASP 5-year plan, monthly, for ASP management;
- Prepared a monthly map of all ESD airborne missions for ASP management;
- Completed preliminary briefing: "Airborne Science Support for NASA Earth Science Satellite and International Space Station Missions";
- Prepared the ASP 2016 Annual Report and two semi-annual newsletters; and
- Participated in various science team meetings related to NASA Earth Science missions to gather airborne requirements data.

Aircraft Remote Sensing

NASA: Joey Rios
BAERI: Sreeja Nag, Karishma Inamdar

The Communications and Navigation (CN) Team of NASA's Unmanned Air Systems (UAS) manages a Traffic Management Project, also called UTM. UTM is a NASA effort, entirely in the public and open-source domain, to enable Civilian Low-Altitude Airspace and Unmanned Aircraft System Operations. These operations are very essential for high resolution airborne remote sensing. Alongside many committed government, industry and academic partners, NASA is leading the research, development and testing that is taking place in a series of activities called "Technology Capability Levels (TCL)," each increasing in complexity. Our role is to assist in research and development of TCL 2. We will identify commercially available technologies for UAS-to-UAS and UAS-to-ground communication, compare them to one another quantitatively, help the team procure select technologies for laboratory testing and assist in ground testing.

2016 Accomplishments

- Assisted the CN team in their holistic goal of setting CN requirements for UTM operations such that ground operators can monitor the state of their UAS and can be operated in a safe environment for remote sensing operations.

Earth Science Project Office (ESPO)

NASA: Marilyn Vasques
BAERI: Erin Czech, Dan Chirica, Erin Justice, Quincy Allison, Sommer Beddingfield, Elizabeth Juvera

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

Figure 22: The NASA P3-B aircraft and Operation IceBridge (OIB) team in Thule Greenland during the OIB field campaign.

[1] The ESPO team supported additional missions through EVS-1 (Earth Venture Sub-orbital-1) and EVS-2 (Earth Venture Sub-orbital-2) projects that were not under the ARC-CREST agreement. These included: ATTREX, HS3, ORACLES, and ATom. Information about these missions can be found at https://espo.nasa.gov/.

2016 Accomplishments

• Supported the following airborne missions under the ARC-CREST agreement :

o ATOM (Atmospheric Tomography Mission

o KORUS-AQ (Korea – US Air Quality)

o ORACLES (ObseRvations of Aerosols above CLouds and their intEractionS)

o OIB (Operation Ice Bridge)

o POSIDON (Pacific Oxidants, Sulfur, Ice, Dehydration, and cONvection Experiment

o SHOUT (Sending Hazards with Operational Unmanned Technology)

• Provided, for all missions, logistical support for the deployment, including: management of deployment sites (facilities, lodging, transport, customs); interface between mission managers, instrument teams, NASA Program Managers and aircraft crew members; coordination of all shipping of equipment and materials (NASA-ARC shipping, university shipping, freight forwarding, customs, local transportation); and deployment setup and on-site support for the duration of mission;

• Managed, for all missions, the Science Operations Flight Request System or SOFRS. SOFRS manages and tracks the allocation of NASA's fleet of scientific aircraft and sensors. In 2015, ESPO team members trained new team members on the management and administration of the system and upgraded the system to allow NASA Headquarters to use the flight request process for tracking of their aircraft use;

• Provided, for select missions, additional and specialized support related to instrument integration and operation, data systems support, and communications support for mission teams.

• Provided, for many missions, programming and IT support such as: in-field IT support for website, system and network setup, printer access, local ISPs, and user support for deployments; creation of new websites for missions beginning in 2015; improvement or additions to existing websites including ESPO, ESD, and ASP; maintenance of the ESPO Mission Database, ESPO Data Archive, and ESD Publications Database; maintenance of archives of all older websites; monitoring of internet technologies and security options for deployment sites; improvement of file sharing options for mission participants; and

• Provided, for many of the missions, education, outreach, and communications support including: attendance at conferences, support for SAT communications between teachers and in-flight scientists; and support for open-house events at facilities hosting field deployments.

Figure 23: 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) provides in situ measurements of static pressure, static temperature, and 3-D winds on several NASA airborne research platforms, including the Global Hawk UAV, Sierra UAV, DC-8, ER-2, WB-57F, as well as the H211 Alpha Jet. These measurements are useful to chemistry studies which rely on our basic state measurements to compute reaction rates of atmospheric pollutants, to microphysical studies which focus on the formation and growth of ice crystals in cirrus clouds, and large scale transport studies which rely on our data to initialize back trajectories. The data are also useful for characterizing advection of pollutants in the planetary boundary layer and the structure and morphology of mesoscale waves which modulate the freeze-drying process of air rising through the tropical tropopause layer into the lower stratosphere.

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

2016 Accomplishments

• Monitored Alpha Jet MMS data quality and reviewed calibration procedures. Investigated sources of error in temperature probe data and GPS altitude accuracy. Processed 1 Hz and 20Hz pressure, temperature and wind measurements for AJAX research flights;

• Calibrated and processes MMS data from the Volcano-plume Investigation Readiness and Gas-phase and Aerosol Sulfur (VIRGAS) mission based at Ellington Field, TX. Compared time delays of GPS measurements with C-MIGITS and RACAL data from SEAC4RS. Calibrated MMS flight maneuvers. Reprocessed and submitted final data for a portion of the mission for which air data measurement were available;

• Co-authored the paper, "Ubiquitous Influence of Waves on Tropical High Cirrus Cloud" by J. Kim et al. Reviewed the manuscript, providing feedback and suggestions for improvement;

• Reviewed an existing temperature time delay algorithm for Global Hawk MMS data from ATTREX, for comparison with recent research for estimating the two time-constant delay in Rosemount temperature probe measurements. Investigated small timing errors in attack angle measurements. Re-processed 1 Hz and 20 Hz MMS data from ATTREX-2014/15 in order to remove time delay artifacts, improving vertical wind spectra during quiescent flight;

• Continued DC-8 MMS preparation for the Atmospheric Tomography (ATom) project. Performed moist true air speed calculations using both simulated and SEAC4RS flight data to estimate changes to mixed layer temperatures and winds relative to dry air values. Investigated utility of speed runs for data quality monitoring and calibration. Developed plan for flight maneuvers and performed initial calibrations from field data during ATom-1; and

• Provided data calibration and processing support during the NASA Pacific Oxidants, Sulfur, Ice, Dehydration and cONvection experiment (POSIDON). Compared 858-y probe and flush differential pressure measurements to determine optimum flow angle values. Provided code updates to utilize secondary measurements due to sensor failures.

Figure 24: An MMS payload is installed on the DC-8.

Meteorological Support

NASA: Leonhard Pfister. Eric Jensen
BAERI: Patrick Hillyard, Bill McKie, Rei Ueyama, John Bergman

The NASA-ARC based Meteorological Support group provides meteorological and flight planning support for NASA airborne missions that mainly address upper tropospheric and lower stratospheric (UTLS) composition. A successful field campaign requires a good understanding of the climatological mean and variability of relevant atmospheric fields (to select the most favorable time and location of the mission), an ability to quickly and comprehensively develop flight plans (to support effective data collection), a science team that is well informed of when and how meteorology can stymy aircraft operations (to facilitate smooth operation), and a detailed meteorological overview of the mission and knowledge of the origin and history of sampled air parcels (to maximize the scientific return from aircraft measurements).

Their work involves four tasks, which follow the time sequence of a typical field campaign from beginning to end: campaign conception and planning, detailed campaign preparation, in-field support, and post-campaign analysis. Campaign planning includes formulating the science questions about UTLS processes we seek to answer and deciding on times and places where a certain set of measurements can provide the answers. They advise the science team on the meteorological conditions relevant for a given science question, which are key to identifying where and when the best measurements can be made. They also develop conceptual flight plans that, along with the specific measurements, are needed to answer the science questions. The second phase, detailed preparation, involves assembling the meteorological and flight planning team, ensuring the availability of meteorological data (e.g., model forecast products, contextual satellite data), designing a meteorological website, and organizing forecasting and flight planning dry runs. For in-field support, they provide meteorological guidance to the science team in the field (usually in the form of daily weather briefings), provide the software infrastructure for systematic and efficient flight planning, and participate actively in flight planning discussions. During the post-campaign analysis phase, they provide the science team with the foundational meteorological information needed to interpret their data and trajectory-based analysis of convective influence which has been widely used by the science community to analyze the measurements of past field experiments.

Their analysis of past campaign data has primarily focused on understanding the role of convection in driving tropical UTLS composition.

2016 Accomplishments

- Provided meteorological and flight planning support for POSIDON and ORACLES field missions;
- Provided plots of meteorological analysis and forecast fields from NCEP GFS and NASA GEOS-5 model products;
- Provided satellite (IR, visible, water vapor) imagery animations with planned and real-time flight tracks;
- Managed the central meteorological support website with links to various sites useful for flight planning;
- Produced convective influence forecast plots to determine target regions for sampling air parcels recently influenced by convection;
- Gave weather briefings and flight planning presentations every 2-3 days during the POSIDON mission; and
- Monitored the weather and development of deep convection along POSIDON flight tracks.

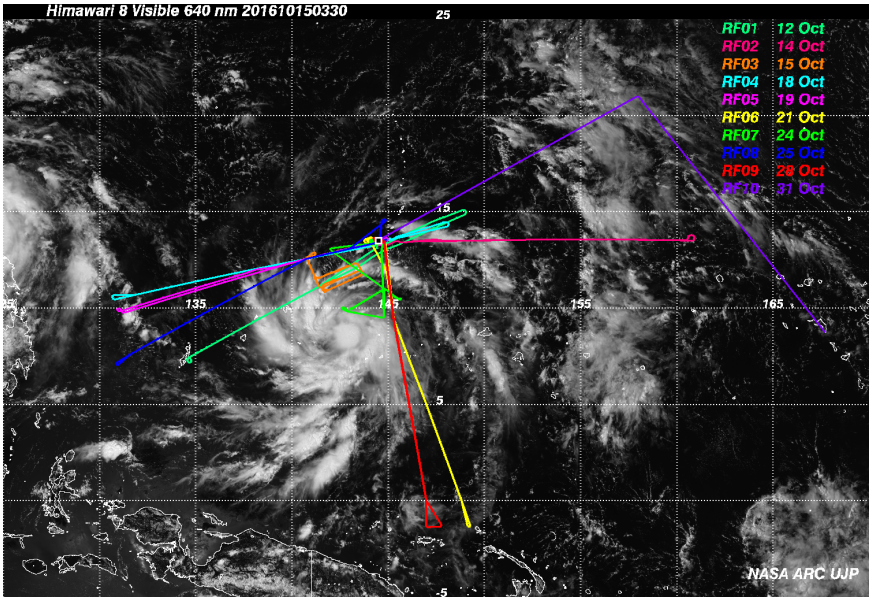


Figure 25: Himawari 8 Satellite Imagery to understand the role of convection in driving tropical UTLS composition.

Publications and Presentations

Jensen, E. J., R. Ueyama, L. Pfister, T. V. Bui, M. J. Alexander, A. Podglajen, A. Hertzog, S. Woods, R. P. Lawson, J.-E. Kim, and M. Schoeberl. 2016. High-frequency gravity waves and homogeneous freezing ice nucleation in cold cirrus clouds, Geophys. Res. Lett., 43, 6629-6635; doi:10.1002/2016GL069426.

Jensen, E. J., R. Ueyama, L. Pfister, T. V. Bui, R. P. Lawson, S. Woods, T. Thornberry, A. W. Rollins, G. S. Diskin, J. P. DiGangi, and M. A. Avery. 2016. On the susceptibility of cold tropical cirrus to ice nuclei abundance, J. Atmos.Sci.; doi:10.1175/JAS-D-15-0274.1.

Jensen, E. J., and co-authors (R. Ueyama). 2016. The NASA Airborne Tropical TRopopause EXperiment (ATTREX): High altitude aircraft measurements in the tropical western Pacific, Bull. Am. Meteor. Soc.; doi:10.1175/BAMS-D-14-00263.1.

Ueyama, R., E. Jensen, and L. Pfister. 2016. Convective influence on the lower stratospheric water vapor in the boreal summer monsoon regions, AMS Annual Meeting.

Ueyama, R., E. Jensen, and L. Pfister. 2016. Convective influence on the lower stratospheric water vapor in the boreal summer Asian monsoon regions, Workshop on Dynamics, Transport and Chemistry of the UTLS Asian Monsoon.

Ueyama, R., E. Jensen, L. Pfister, and M. Schoeberl. 2016. Convective influence on the lower stratospheric water vapor in the boreal summer Asian monsoon regions, Aura science team meeting.

Ueyama, R., E. Jensen, L. Pfister, and M. Schoeberl. 2016. Convective influence on the lower stratospheric water vapor in the boreal summer Asian monsoon regions, AGU Fall Meeting.

Awards

NASA Group Achievement Award for ATTREX

National Suborbital Education and Research Center (NSERC) Mission Operations

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

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

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

In support of Task 1, NSERC addresses all data, SATCOM, engineering and maintenance needs for the following manned NASA airborne science platforms: DC-8, C-130, and the ER-2. In addition, in 2015 NSERC supported the following field missions: CalWater, ATV-5, OIB, HIWC, ATom, KORUS-AQ, ATTREX/CAST, PECAN, Keflavik Polar Winds, NAAMES, ACT-America, OLYMPEX, HsypIRI, SHOUT, and RADEX. Accomplishments related to specific airborne platforms are listed below. 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 field missions. Separately, the NSERC team leads outreach program missions designed to build capacity with science students and teachers.

In 2016, NSERC conducted the following education and training activities: SARP, ATTREX/CAST, OIB, NAAMES, 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 26 : DC-8

2016 Accomplishments

DC-8 Specific Engineering and Data and Satcom System Accomplishments

- Conducted extensive environmental testing of instrument components for the DC-8 aircraft as per Armstrong's new regulations;
- Began preliminary planning for the potential ECLIF mission;
- Looked at the details of an avionics tray to accommodate a new TCAS electronics box for the DC-8;
- Coordinated with Armstrong and QuickCrate to get some rack shipping crates made for the medium and low racks;
- Created a new design for a replacement for the original composite radar altimeter antenna panel (which was delaminating), created a detail/assembly drawing to send to the shop for fabrication, and performed a structural analysis of the design;
- Did a minor redesign of time server cooling fan installation to accommodate Meinberg time server;
- Began work on a facility improvement project:
- Installed new window clips for the DC-8 modified viewports that will seat the windows on the O-ring seals in the port;
- Rebuilt and installed FalconView VM on server; and
- Wired up the VectorNav and Serial Converter in the AIMMS-20 canister.

ER-2 Specific Engineering and Data and Satcom System Accomplishments

• Configured real-time data API for all ER-2 campaigns for use on MTS and the Airborne Science tracker;

• Designed a connector bracket for ER-2 Inmarsat router console connectors (VGA and USB), had them made, and reassembled the second canoe after successful electrical/operation checkout;

• Provided backup data systems support;

• Wrote software to facilitate HSRL using data from their instrument on the ER-2 and publishing it to MTS and for display on the P-3 for ORACLES;

• Trained mission managers in the use of the data download laptop; and

• Trained Caitlin Barnes (ASF) in the configuration of the data download laptop.

Specific Engineering and Data and Satcom System Accomplishments (P-3)

• Reintegrated P-3 data system in new rack;

• Reinstalled and verified facility instrumentation;

• Updated systems software and firmware to catch up from re-wing period;

• Installed new fast-syncing time server;

• Integrated 10 instrument teams with real-time data streams; and

• David Van Gilst traveled out to Waco, TX to check on housekeeping wiring in the P-3 to evaluate status of housekeeping wiring after re-wing. This allowed NSERC to be prepared for integration once the P-3 returned to WFF.

Specific Engineering and Data and Satcom System Accomplishments (C-130 (436))

• Designed and constructed new facility instrument suite to accommodate ACT-AMERICA Mission;

• Augmented the Air Data System to meet ACT-America Mission Requirements;

• Installed supplemental high precision transducers on copilot pitot-static system;

• Installed supplemental Rosemount TAT with high precision digital signal conditioner;

• Designed and processed calibration maneuvers;

• Installed 3-Stage Hygrometer (This will need to be moved due to contamination from other air sources);

• Sourced surplus APN-232 Radar Altimeter, allowing provision of radar altitude through the full range of aircraft altitudes at approximately 10% of new cost;

•Installed forward tracking camera;

• Completed design of port for Nadir tracking camera;

• Designed and constructed housekeeping data system, network, and Satcom facilities.

• Implemented gigabit network in cooperation with Pinnacle;

• Designed and constructed system patch panel for power control and signal concentration;

• Designed and constructed wiring harnesses for interface to aircraft avionics and facility instrumentation;

• Integrated NASDAT with aircraft systems and facility instrumentation;

Figure 27: ER-2

Figure 28: B-200

• Designed and implemented UPS backed DC power system allowing system to run on 400Hz power, stay up through power switch over and provide long-endurance support of aircraft GPS splitter;

• Designed and implemented filtered GPS Network for housekeeping system and experimenter use;

• Designed and implemented filtered Iridum antenna system for use with NASDAT.

• Assembled the cockpit Ethernet switch installation and shipped it out to Andalusia with the GPS splitter and WiFi access point assemblies for installation on the aircraft;

• Assembled the radar altimeter R/T adapter;

• Fabricated misc. components for the shelf assemblies and built up the main data system component shelves; and

David Van Gilst traveled out to Andulusia, AL, to install antenna and instrument wiring harnesses on the C130 (436);

• Integrated LN251 into N439NA Data System;

• Designed and constructed wiring harnesses, patch panel and system interfaces;

• Developed software to drive the LN251 startup sequence, diagnose faults and distribute data to the NASDAT and other data system components;

• Developed software to facilitate transfer of satellite data and quick look products without disrupting IRC/xChat communications;

• Mount permanently remaining data system components (UPS, AIS, Network Switch).

• Integrated NAAMES Payload with C-130 Data System; and

• Created a simple blank off plate design for the 102 TAT probes, so that the aircraft can fly without them, if needed.

Overall ASP Development Work (Total Air Temperature Measurement)

• Finalized the details for the pressure bulkhead connector pass-through for the new DC-8 TAT sensor wiring;

• Finalized the TAT sensor signal conditioner mechanical design assembly/installation, ordered parts, coordinated with the shop for fabrication, and assembled the box. The TAT sensor on the DC-8 worked well in KORUS-AQ. The design assembly/ installation was completed prior to deployment with the build-up of the new TAT sensor signal conditioner mechanical assembly;

• Continued work on TAT signal conditioner software;

• High-accuracy digital signal capture system based on Laurel Electronics resistance transmitter

  o Completed thermal stability testing at AFRC Environmental Lab;

  o Completed Packaging and Heating system design; and

  oAnticipated reduction of signal capture error by 50-60%;

• Reduced TAT error from ~ 1°C to .2 - .3 °C.

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 (ARSET) Program offers satellite remote sensing training that builds the skills to integrate NASA Earth Science data into an agency's decision-making activities. The project's goal is to increase the utility of NASA Earth Science data for applied resource management professionals, policy makers, and regulatory agencies.

ARSET operates with a gradual learn approach, where they often conduct basic introductory webinars followed by more in-depth advanced webinars or in-person trainings. Their webinars consist of multi-week sessions about a specific topic and can be a combination of lectures, live demos of tool, and tutorials. Recordings of the live webinars are freely available. Most webinar materials are available in Spanish and English. Many courses need no previous experience with remote sensing, but there are prerequisites for advanced webinars. The ARSET program regularly partners with organizations to host two to four day in-person workshops with regionally specific curricula. Conducted in a computer lab, workshops provide a combination of lectures and hands-on activities and frequently feature guest speakers from NASA and other organizations. Attendees learn how to access, interpret and apply NASA data on local and global scales, with an emphasis on case studies.

ARSET conducts trainings in the focus areas of Health and Air Quality, Water Resources, Land Management, Wildfires, and Disasters. The ARSET team is located at multiple NASA centers and consists of scientists with backgrounds specific to the topic area they teach. The Ames team focuses on trainings in the Land Management and Wildfires areas. Since 2009, ARSET has had over 4,000 participants from more than 1,400 organizations and 130 countries. All ARSET materials are free and available for participants to access, use, and adapt.

Publications and Presentations

Wildfire PI meeting, Boise, ID, March

Hyperwall presentations on the use of NASA data for Wildfire applications, IUCN World Conservation Congress, Hawaii, September

From Remote Sensing Dud to Stud: NASA's ARSET Program, AGU Annual Fall Meeting, NASA Booth Presentation, December 2016

2016 Accomplishments

- Conducted advanced webinar: Creating and Using Normalized Difference Vegetation Index (NDVI) from Satellite Imagery (February-March);
- Conducted introductory webinar: Remote Sensing of Forest Cover and Change Assessment for Carbon Monitoring (June);
- Conducted introductory webinar: Introduction to Remote Sensing for Coastal and Ocean Applications (July);
- Conducted in-person workshop: From Earth Observations to Earth Applications: Satellite Applications for Biodiversity Conservation, IUCN World Conservation Congress, Hawaii, (September)
- Conducted in-person workshop: Application of Satellite Remote Sensing Data for Fire & Smoke Monitoring, International Smoke Symposium, Long Beach, CA (November);
- Organized and attended a best practice meeting with the USDA Forest Service Remote Sensing Applications Training Center, Salt Lake City, UT (March); and
- Participated in annual programmatic retreat to assess and refine the ARSET mission and vision, Goddard Space Flight Center (November).

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 (ESTP) and a Master of Science degree program in Applied Marine and Watershed Science (AMWS). These interdisciplinary programs emphasize the critical thinking and technical skills necessary to develop workable solutions to complex environmental problems. The curriculum integrates training in science, technology, economics, and policy that focus on marine, coastal, and watershed systems.

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

The M.S. in AMWS offers two degree options: PSM and thesis. Within their chosen option, students elect an emphasis in marine or watershed science. Advanced technology training is integrated throughout the applied environmental science and policy curriculum.

Figure 29: 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

The PSM option within AMWS emphasizes professional skill sets that will distinguish students as they enter the workforce, including: advanced technologies for acquiring, analyzing, modeling and visualizing spatially explicit environmental data; professional and scientific communication; scientific ethics; and environmental economics and policy analysis. Within the PSM option, skills learned in the classroom are matured by students through professional internships. The program satisfies a demand for highly skilled professionals within environmental technology and applied science-based companies, governmental agencies, and non-profit organizations.

The team applies its educational, scientific, and technological expertise to train the next generation of Earth System scientists and to reach out to the public about the project. Specifically, we work to:

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

- Provide hands-on training for undergraduate and graduate students in Earth Science research activities including participation in field campaigns, internships, apprenticeships, and other research experiences;

- Lead educational activities aimed at K-12 students, college and graduate students, and the general public utilizing NASA-developed technologies and results; and

- Communicate results of scientific activities through community outreach events, conferences, publications, and other venues.

2016 Accomplishments

The California State University at Monterey Bay (CSUMB) Educational Program continues to facilitate research collaborations between AMWS graduate students, ESTP senior undergraduate students, Cooperative Agreement Research Scientists, and NASA PIs at Ames Research Center on the following projects:

• AMWS students (or recent graduates) David Hamblin, Andrew Hill, Daniel Muratore, Rachel Spellenberg, Erin Stanfield, Aimee Teaby, John Urness, Sean Windell, and Isabel Zaragosa conducted research and assisted with field activities under the mentorship of ARC CREST Senior Scientist Forrest Melton and Research Scientist Kirk Post (within the Ecocast and Ag/Health/Marine tasks);

• CSUMB Faculty Member Dr. Dan Fernandez collaborated with NASA PI Dr. Chris Potter on local fog research;

• CSUMB Faculty Members Dr. Arlene Haffa and Dr. Timothy Miles collaborated with ARC CREST Senior Scientist Forrest Melton on local agricultural research;

• They promoted student research opportunities at NASA Ames Research Center related to the Cooperative Agreement (e.g. DEVELOP) and will continue to facilitate student involvement in the Cooperative Agreement.

Support Products and Benefits:

• Provided hardware/software support and mentoring for 15+ students participating in the DEVELOP Summer 2016 session and year-round support for permanent DEVELOP staff and project teams during the fall and spring sessions. DEVELOP support activities are expected to continue in 2017 at the same level;

• Planned/coordinated acquisition (from another NASA Ames organization) and installation of 7 Dell C2100 servers to support additional system backup services and to upgrade/replace aging systems supporting the NASA Airborne Sciences aircraft asset tracking system. This included physical installation of a new 19-inch computer rack, and associated electrical power and network connectivity;

• Acquired/installed/configured a Netbotz 450 environmental monitoring system to provide real-time monitoring and alert notifications (via email and text messaging) for computer systems providing critical functionality to Code SGE programs; and

• Provided year-round large-format poster graphics output support for scientific meetings with large effort prior to the AGU Fall Meeting.

DEVELOP

NASA: James Brass

BAERI: Juan L. Torres-Pérez

The Applied Sciences' DEVELOP National Program addresses environmental and policy issues through interdisciplinary research projects that apply NASA Earth Observations to community concerns around the globe. DEVELOP bridges the gap between NASA Earth Science and society, building capacity in both its participants and partner organizations to better prepare them to handle the challenges that face our society. DEVELOP creates capacity for young professional from diverse academic backgrounds (undergraduate, graduates and recent graduates) on the use of remote sensing and GIS to assess environmental problems. As such, the Ames projects during the past year have comprehended a wide range of themes such as drought, decision support systems for the Navajo Nation, impacts of methane concentrations on the air quality of the San Francisco Bay Area, assessment of the invasive seaweed Sargassum in the Caribbean and the Gulf of Mexico, and environmental factors that influence the presence/absence of disease vectors (e.g., mosquitoes) in tropical countries.

Dr. Juan L. Torres-Pérez began working with DEVELOP as the Center Mentor in 2014. Since then, he has mentored multiple teams of participants in about 20 different projects

2016 Accomplishments

• Provided advice on the use of different imagery available for analysis, methodologies, results, and comments/edits on the deliverables of each project (technical paper, posters presentations, oral presentations, lightning talks, Earthzine videos, etc.);

• Participated each week in staff meetings and seminars;

• During the interim periods between terms they conducted multiple interviews with the applicants. In total, they reviewed about 150 different applications for all three terms. Usually they expect to recruit six participants on each of the Fall and Spring terms and 12-15 for the Summer term to work on two-three different projects during each term. Throughout the year, they are continuously looking for project partners and ideas for new projects. They usually submit about 7-8 different project proposals per year to the National Program Office for their approval.

Figure 30: A Geospatial Evaluation of Drivers, Occurrences, and Distribution of Hypoxic Events within the Grijalva-Usumacinta River Delta System and the Southern Coast of the Gulf of Mexico

Student Airborne Research Program (SARP)

NASA: Jack Kaye
UND/NSERC: Rick Shetter, Emily Schaller, Jane Peterson, 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.

Figure 31: SARP students with the DC-8.

2016 Accomplishments

- Management of the 2016 Student Airborne Research Program including program design, faculty recruitment, participant recruitment, selection and logistics;
- Completed selection of 32 students from over 200 applications;
- Provided logistics for 32 students;
- Organized all science flights;
- Selected the top student presentations for participation at the AGU conference;
- Organized the conclusion of SARP 2016 with final student presentations, the final graduation meeting, collection of student evaluations and SARP laptops, and checkout from the UCI housing, return of the students for their flights home to the John Wayne airport, and return of SARP equipment and staff to Armstrong Building 703;
- Distributed flyers about SARP at the NASA Airborne Science table at AGU 2016;
- Assisted the 13 SARP 2016 students attending AGU with preparing their presentations; and
- Organized SARP alumni reunion dinner during AGU.

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GLOSSARY

ASPRS – American Society of Photogrammetry and Remote Sensing

ASRL– Allometric Scaling and Resource Limitations Model

ASTER – Advanced Spaceborne Thermal Emission and Reflection Radiometer

ATTREX – Airborne Tropical Tropopause Experiment

AATS – Ames Airborne Tracking Sunphotometer ATom – Atmospheric Tomography Mission

AVAPS – Advanced Vertical Atmospheric Profiling System

AVHRR – Advanced Very High Resolution Spectroradiometer

AVIRIS – Airborne Infrared Imaging Spectrometer

AWS – Amazon Web Services

BAER or BAERI – The Bay Area Environmental Research Institute

BCCA – Bias Correction/Constructed Analogs

BCSD – Bias Correction/Spatial Downscaling

BGAN – Broadband Global Area Network

CAAP – CELSS Antarctic Analog Project

CALIPSO – Cloud Aersol Lidar and Infrared Pathfinder Satellite Observations

CAN – Cooperative Agreement Notice

CARVE – Carbon in Arctic Reservoirs Vulnerability Experiment

CASA – Carnegie-Ames-Stanford Approach

CASI – Climate Adaptation Science Investigators

CDWR – California Department of Water Resources

CELSS – Controlled Ecological Life Support System

CERES – California Environmental Resources Evaluation System

CH_4 – Methane

CHAART – Center for Health Applications of Aerospace Related Technologies

CIMIS – California Irrigation Management Information System

CME – Coastal and Marine Ecosystems

CMIP5 – Coupled Model Intercomparison Project Phase 5

CMS – Carbon Monitoring Systems

CO – Carbon Monoxide

COAST – Coastal and Ocean Airborne Science Testbed

COMEX – Carbon Dioxide (CO_2) and MEthane eXperiment

COMPASS – Common Operations and Management Portal for Airborne Science Systems

CQUEST – Carbon Query and Evaluation Support Tools

CRUSH – Canopy Remotesensing for Uniformly Segmented Harvest

CSIRO – Commonwealth Scientific and Industrial Research Organisation

CSC – Climate Science Center

CSGC – California Space Grant Consortium

CSTARS – The Center for Spatial Technologies and Remote Sensing

CSUMB – California State University Monterey Bay

CWSP – Coastal and Watershed Science and Policy

DAAC – Distributed Active Archive Center

DAYMET – Daily Surface Weather and Climatological Summaries

DB AOD – Deep Blue Aerosol Optical Depth

DC3 – Deep Convective Clouds and Chemistry Experiment

DFRC – Dryden Flight Research Center (NASA)

DLR – Deutsches Zentrum für Luft- und Raumfahrt (the German Aerospace Center) DNS – Direct Numerical Simulation

DRI – Desert Research Institute

DRECP – Desert Renewable Energy Conservation Plan

DEVELOP – Digital Earth Virtual Environment and Learning Outreach Project

GLOSSARY

DISCOVER-AQ – Deriving Information on Surface conditions from Column and Vertically Resolved Observations Relevant to Air Quality

DPM – Department of Payment Management

Dropsondes – Advanced Vertical Atmospheric Profiling System

DSEP – Division of Science and Environmental Policy

EARSeL – European Association of Remote Sensing Laboratories

EF – Ecological Forecasting

eMAS – Enhanced MODIS Airborne Simulator

EOS – Earth Observing System

EOS-PSO – EOS Project Science Office

ER-2 – Earth Resources 2 (Single-engine,high-altitude aircraft)

ESDR – Earth Science Data Record

ESTP – Environmental Science, Technology, and Policy

ETM – Enhanced Thematic Mapper

Eu:CROPIS – Euglena: Combined Regenerative Organic-food Production In Space

EVS-2 – Electronic Vibration Switch

FAI – Floating Algal Index

FCMC – Forest Carbon, Markets and Communities

FEL – Field Emission Lamp

FFSIG – Forest Fire Special Interest Group

FIA – Forest Inventory and Analysis

FOV – Field Of View

FPAR – Fraction of Photosynthetically Active Radiation

FRET – Forecast Reference Crop Evapotranspiration

FSun – Total Solar Flux

FTS – Fourier Transform Spectrometer

GCAD30 – Global Cropland Area Database at Nominal 30m

GCEV 1.0 – Global Cropland Extent Version 1.0

GEE – Google Earth Engine

GEO – Group on Earth Observations

GEO Ag. SBAs – Agriculture and Water Societal Beneficial Areas

GEO-CAPE – GEOstationary Coastal and Air Pollution Events

GEO GLAM – Global Agricultural Monitoring Initiative

GEOS-5 – Goddard Earth Observing System Model, Version 5

GEOSS – Global Earth Observation System of Systems

GeoTIFF – Public domain metadata standard which allows geo-referencing information to be embedded within a TIFF file.

GFS – Global Forecast Model

GH – Global Hawk

GHOC – Global Hawk Operations Center

GIS – Geographic Information System

GLAS – Geoscience Laser Altimeter System GOSAT – Green house gases Observing SATellite GPD – Generalized Pareto Distributions

GSFC – Goddard Space Flight Center

HAMSR – High Altitude MMIC Sounding Radiometer HICO - Hyperspectral Imager for the Coastal Ocean HDF – Hierachical Data

HIAPER – High-performance Instrumented Airborne Platform for Environmental Research

HIRAD – Hurricane Imaging Radiometer

HIWRAP – High-Altitude Imaging Wind and Rain Airborne Profiler

HS3 – Hurricane and Severe Storm Sentinel HYDRA – Hydrological Routing Algorithm HyspIRI – Hyperspectral Infrared Imager

IARPC – Interagency Arctic Research Policy Committee

ICCAGRA – Interagency Coordinating Committee for Airborne

GLOSSARY

Geoscience Research and Applications

ICESat – Ice, Cloud and Land Elevation Satellite

IGARRS – International Geoscience and Remote Sensing Symposium iGEM – International Genetically Engineered Machine

INMARSAT – International Maritime Satellite Organization

INPE – Instituto Nacional de Pesquisas Espaciais

INTEX – Intercontinental Chemical Transport ExperimenT

ISE – Information System for the Environment

ISPRS – International Society for Photogrammetry and Remote Sensing

ISRSE – International Symposium on Remote Sensing of Environment

IT – Information Technology

IUFRO – International Union of Forest Research Organizations

IWGADTS – Interagency Working Group for Airborne Data and Telecommunications Systems

KORUS-AQ – An International Cooperative Air Quality Field Study in KoreA LAI – Leaf Area Index (LAI)

LES – Large Eddy Simulation

Lidar – Light Detection and Ranging

LMSAL – Lockheed Martin Solar & Astrophysics Laboratory

LPDAAC – Land Processes Distributed Active Archive Center

LSAMP – Louis Stokes Alliance for Minority Participation program

MACC – Monitoring Atmospheric Composition & Climate

MAIAC – Multi-Angle Implementation of Atmospheric Correction

MASMODIS – Airborne Simulator

MASTER – MODIS/ASTER (airborne simulator)

MATLAB – Material Laboratory

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

MERIS – Medium Resolution Imaging Spectrometer (on Envisat satellite)

MHD – Magnetohydrodynamic

MILAGRO – Megacity Initiative: Local and Global Research Observations

MMS – Meteorological Measurement System

MODIS – Moderate Resolution Imaging Spectroradiometer

MTS – Mission Tools Suite

MWIR – Mid-wavelength infrared

NAIP – National Agricultural Imagery Program

NASA – National Aeronautics and Space Administration

N_2O – Nitrous Oxide

NACP -North American Carbon Program

NAFD – North American Forest Dynamics

NAS – NASA Advanced Supercomputing

NASDAT – NASA Airborne Science Data and Telemetry

NCAR – National Center for Atmospheric Research

NCEP – National Center for Environmental Prediction

NEX – NASA Earth Exchange

NGA - National Geospatial-Intelligence Agency

NGO – Non-Governmental Organization

NIDIS – The National Integrated Drought Information System

NIST – National Institute of Standards and Technology

NLFFF – Non-Linear Force Free Field

NOAA – National Oceanic and Atmospheric Administration

GLOSSARY

NOI – Northern Oscillation Index

NPP – NASA Postdoctoral Program

NPP – Net Primary Production

NPR – NASA Procedural Requirements

NSERC – National Suborbital Education and Research Center

NSF – National Science Foundation

NSSC – NASA Shared Services Center

NWS – National Weather Service

OCO-2 – Orbiting Carbon Observatory

OCS – Carbonyl Sulfide

OIB – Operation IceBridge

OLI – Operational Land Imager

ORACLES – Observations of Aerosols Above Clouds and their Interactions

OSTP – Office of Science and Technology Policy

PANAK – PAN/Aldehyde/Ketone (instrument)

P3 – Four-Engine Turboprop

PAO – Public Affairs Office

PBL – Planetary Boundary Layer

PM2.5 – Particulate Matter less than 2.5 Microns in Diameter

PMS – Particle Measuring System

RDAS – Rotating Disk Analytical System

REDD+ – Reducing Emissions from Deforestation and Forest Degradation

RESA – Renewable Energy Study Areas

RSAC – Remote Sensing Applications Center

SABOR – Ship-Aircraft Bio-Optical Research Experiment

SAFARI 2000 – Southern African Regional Science Initiative

SARP – Student Airborne Research Program

SCIAMACHY – Scanning Imaging Absorption Spectrometer for Atmospheric CHartographY

SEAC4RS – Southeast Asia Composition, Cloud, Climate Coupling Regional Study

SEAGRASS – High Resolution Assessment of Carbon Dynamics in Seagrass and Coral Reef

SGS – Sub-Grid Scale

S-HIS or SHIS – Scanning High-resolution Interferometer Sounder

SIERRA – Sensor Integrated Environmental Remote Research Aircraft

SIMS – Satellite Irrigation Management Support

SIPS – Science Investigator-led Processing Systems

SOFRS – Science Operations Flight Request System

StareWAI – Staring Wide Area Imager

STEM – Science, Technology, Engineering, or Mathematics

STEP – Stratosphere-Troposphere Exchange Project

sUAS – small Unmanned Aerial Systems

SWIR – Short Wavelength Infrared

TARFOX – Tropospheric Aerosol Radiative Forcing Observational eXperiment

TCAP – Two Column Aerosol Project

TCCON – Total Carbon Column Observing Network

TES – Tropospheric Emission Spectrometer

TFRSAC – Tactical Fire Remote Sensing Advisory Committee

TMAS – Thermal Mapping Airborne Simulator

TOP – Terrestrial Observation and Prediction System

GLOSSARY

TOPS-SIMS – Terrestrial Observation and Prediction System-Satellite Irrigation Management

TPI – Task Principal Investigator

TTL – Tropical Tropopause Layer

TWiLiTE – Tropospheric Wind Lidar Technology Experiment

UAS – Unmanned Aerial Systems

UAV – Uninhabited Aerial Vehicles

UC-12B – Military Version of a Beechcraft B200 King Air.

UCD – University of California at Davis

UND – University of North Dakota

UROC – Undergraduate Research Opportunities Center

USAID -United States Agency for International Development

USCRTF – United States Coral Reef Task Force

USFS – United States Forest Service

USGS – United States Geological Survey UV – Ultraviolet

VIIRS – Visible Infrared Imaging Radiometer Suite

VINTAGE – Viticultural Integration of NASA Technologies for Assessment of the Grapevine Environment

VSIM – Vineyard Soil Irrigation Model

WAI -Wide Area Imager

WRAP – Wildfire Research and Applications Partnership