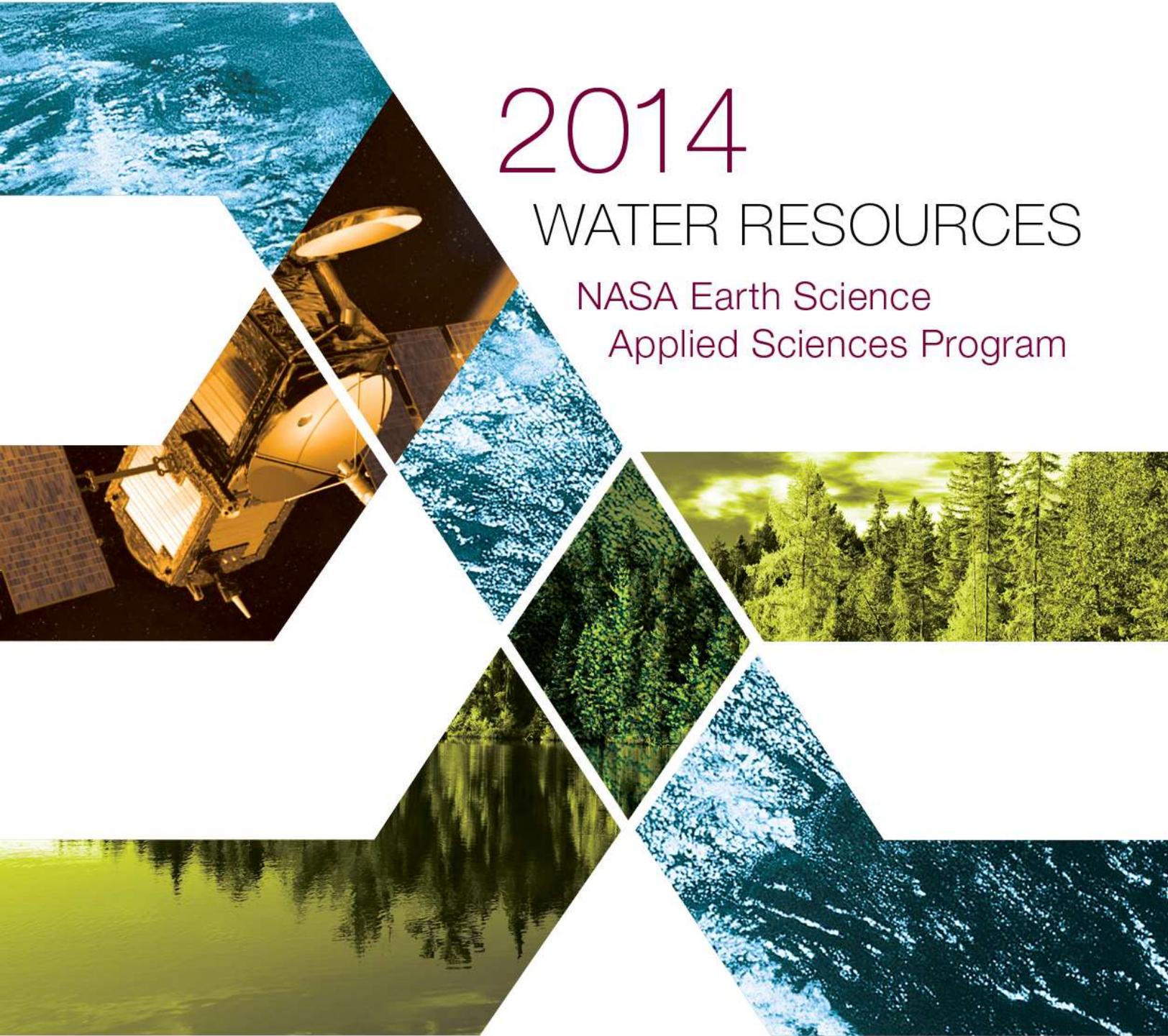




2014

WATER RESOURCES

NASA Earth Science
Applied Sciences Program



Water Resources: 2014 Annual Summary

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<http://AppliedSciences.NASA.gov>

I. Introduction

The ESD Applied Sciences Program promotes efforts to discover and demonstrate innovative and practical uses of Earth observations. The Program funds applied science research and applications projects to enable near-term uses of Earth observations, formulate new applications, integrate Earth observations and related products in practitioners' decision making, and transfer the applications. The projects are carried out in partnership with public- and private-sector organizations to achieve sustained use and sustained benefits from the Earth observations.

The Applied Sciences Program's applications themes are currently focused on four of the nine Societal Benefit Areas of the interagency Group on Earth Observations: Health (including Air Quality), Disasters, Ecological Forecasting, and Water Resources.¹ The Program includes climate-related influences and impacts within each of these themes and has crosscutting elements such as Wildfires and Capacity Building.

The Applied Sciences Water Resources Applications area supports the integration of NASA Earth observations and technologies into management tools for the water resources management community. The Water Resources Applications area currently supports a diverse range of projects in its portfolio, addressing topics including drought monitoring and mitigation, snow monitoring and runoff forecasting, water quality, soil moisture, groundwater change, and climatic and ecological impacts on water resources.

NASA's free and open exchange of Earth observations data helps engage and improve integrated observation networks and enables national and multinational regional water cycle research and applications. Satellite and airborne observations and hydrometeorological models can be applied to enhance information from surface observation networks, and they play a critical role in providing information on water resources, especially in data-sparse regions.

NASA satellite and modeling products provide a huge volume of valuable water resources information extending back more than 50 years across a broad range of spatial (local to global) and temporal (hourly to decadal) scales. Many of these products are also available in near real-time (see <https://earthdata.nasa.gov>).

The primary objective of NASA's Water Resources Applications area is to discover, demonstrate, and transfer innovative uses and practical benefits of NASA's Earth science observations, research, and technologies for improved water management to the water resources management community. To accomplish this objective, NASA partners with public and private groups (e.g., federal agencies, universities, NGOs, and industry) in the United States and internationally to ensure cost-effective and efficacious solutions are provided to water resources managers.

¹ The nine USGEO SBAs are Agriculture, Climate, Disasters, Ecological Forecasting, Energy, Health, Oceans, Water Resources, and Weather.

II. Overview of 2014

Calendar year 2014 was full of activity, including the transition and closing of two ROSES projects, the continued achievement of milestones for continuing projects, and the selection of nine new projects to join the Water Resources Applications Area community. The Water Resources Applications area also pursued several strategic/programmatic areas of development, including continuing to build its international water projects component while leveraging the existing activities and partnerships with Applied Sciences, acting as a critical resource and envoy of NASA Earth observations and information for addressing the drought in the West, and investigating how water quality can play a role in water supply and the potential role of remote sensing in understanding that interaction.

III. Major Accomplishments

Some of the notable Water Resources project achievements this past year include:

Airborne Snow Observatory (PI T. Painter). The NASA JPL Airborne Snow Observatory (ASO) continued to provide rapid assessments of snow conditions in the Tuolumne watershed, conducting weekly flights from March 23 through June 5, 2014. The project made significant contributions to its partner stakeholders, the California Department of Water Resources (CDWR) and the San Francisco Public Utilities Commission, providing sustained monitoring of the winter snowpack during one of the warmest and driest water years on record. In 2014, the project demonstrated a capability for sustained monitoring as well as processing and delivery of data within 24 hours of data collection. The data collected by ASO improved estimates of actual inflow into the Hetch Hetchy reservoir, which serves the city of San Francisco, and enabled water managers to optimize reservoir operations during a critically dry year. The project also developed plans to expand monitoring to include the Merced River watershed and other sites in the Sierra Nevada, as well as the Uncompahgre Watershed in Colorado.

Fallowed Area Mapping for Drought Impact Reporting and Decision Making (PI J. Verdin). In 2014, the Fallowed Area Mapping project demonstrated a capability for within-season mapping of drought impacts on agricultural production in California's Central Valley. Monthly data on idle agricultural acreage were delivered to CDWR from March to September 2014, and revealed an increase of 41 percent (500,000 acres) in summer idle acreage relative to 2011, the most recent year with average rainfall. Data were provided within 14 days of the end of each month, and the availability of initial estimates in March represented an improvement of 10 months relatively to previously available information. Field surveys were conducted to quantify the accuracy of the estimates, which exceeded accuracy requirements established by CDWR. Data from the project were presented by CDWR to the California Governor's Drought Task Force, and were used to inform allocation of drought emergency funds to counties to support social services for farmworkers and their families. Project data were also used by the California Department of Food and Agriculture in economic modeling of drought impacts on the agricultural sector, and requested by the *Nature Conservancy* for use in planning for solar power development. In addition, *National Geographic* featured data from the project in an October article on drought in the West.

Satellite Earth Image Products for Regulatory Water Quality Standards (PI J. Lehrter). This project reached its final year of active funding and is an example of a successful applications development, partner engagement, and applications transition project. During 2014, this project was able to successfully use remote sensing information from MODIS, *Landsat*, SeaWiFS, and MERIS to inform the U.S. Environmental Protection Agency (EPA) decision process for establishing nutrient criteria. The project reached ARL 9 in the final project year when the EPA Office of Water and the state of Florida officially adopted the project approaches and methodologies for establishing numeric nutrient criteria in estuarine and coastal waters of the state of Florida. The rulemaking has been completed in Florida, and now EPA is promoting the use of remote sensing for criteria development and assessment in other states. The team is planning to continue working with the Florida Department of Environmental Protection, Florida Keys National Marine Sanctuary, Florida Fish and Wildlife Conservation Commission, and others by implementing the water quality products and the Water Quality Analysis Tool (WQAT) via weekly meetings, Web tutorials, and publications. Several post-project outreach and training activities are planned, including NASA Applied Remote Sensing Training (ARSET).

The GEO Global Agriculture Monitoring (GEOGLAM) Task: Supporting the GEOSS Vision for an Agricultural Monitoring System of Systems (PI: I. Becker-Reshef). The GEOGLAM task continues to make significant contributions through its project and capacity building activities. In 2014, GEOGLAM provided global monthly crop status information to increase the stability of global food markets, at the request of G20 nations. This project integrates in-country assessments with remote sensing data to produce transparent and reliable estimates of the production of major crops (soybeans, wheat, corn, and rice). More than 30 agencies and organizations are involved in the sharing and analysis of this data.

IV. Assessment

Calendar year 2014 was very productive. The nine projects (down-selected from 13) from the Feasibility-to-Decisions Water Resources solicitation in 2011 continued to make progress. The Water Resources Applications area also conducted a panel review to assess 75 proposals that were received in response to the A45 solicitation that was focused on the development of applications with operational partners that would improve 30 to 180-day outlooks for water supply anomalies. A unique component of this solicitation included an option to apply for supplemental funds to conduct an impact assessment, which will provide important insights into the value of funded projects and opportunities. Nine proposals were selected for funding and represent the development of applications across a diverse set of technical capabilities, end users, and geographic extent.

The Water Resources program also provided leadership in expanding and diversifying the Applied Sciences Program partnership with the U.S. Agency for International Development (USAID) through the Partnerships for Enhanced Engagement in Research (PEER) activity. In this first phase of partnership, USAID has made funding available to

developing country investigators to partner with and leverage existing projects/efforts of U.S. government-funded scientists at NASA and other agencies.

In 2014, the Water Resources Applications area further explored how water quality can affect water resources and water supply. Through this effort, the Water Resources Applications area conducted a stakeholder workshop at the National Water Quality Monitoring Conference 2014, which will yield between two to four 10-week pilot project activities with the NASA DEVELOP program and various end users in the water quality community. Furthermore, a two-workshop series about Water Quality Remote Sensing in the Great Lakes, hosted by the Glenn Research Center, was supported. These activities facilitated supporting Glenn's airborne campaign to monitor an algal bloom that affected the water supply of residents in Toledo, Ohio, which drew nationwide attention to water quality issues and NASA capabilities that can be used to study and address them. A ROSES project selected under the A45 solicitation and led by a private sector/engineering firm investigator, with operational partners in New York City; Raleigh, North Carolina; and northern Colorado, will be utilizing remote sensing to assess various water quality constituents impacting water supply, such as turbidity, natural organic matter, nutrients, and algae.

The Water Resources Applications area also continued to provide leadership to address impacts of drought in the western United States, including the continued partnership with the California Department of Water Resources, the Western States Water Council, and NIDIS. Notably, CDWR and NASA hosted a joint workshop on remote sensing of the California drought that received national media attention, and included a presentation from the California Secretary of Natural Resources. The WR program team also continued to develop and refine a letter of agreement that would provide visibility to the working relationships between CDWR and the NASA Applied Sciences Program as well as facilitate continued use of NASA Earth Observations to address drought and water resource challenges.

The Water Resources Applications area also expanded its team of associates to include John Bolten at Goddard Space Flight Center and Christine Lee at the Jet Propulsion Laboratory.

The development of the Water Resources website was completed in 2014, and it includes features that will enable the type of collaboration and community engagement across projects and stakeholders that we seek. We also working with project teams and stakeholders to highlight project successes via the website, and to streamline reporting and communication efforts building upon the quarterly reporting process initiated in 2013. This activity will be integrated with the Applied Sciences Program website as it comes online in 2015.

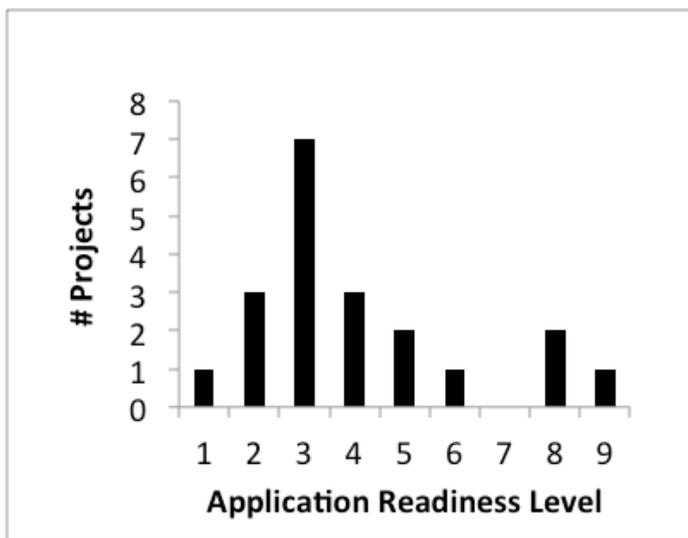
V. Project Portfolio

In 2014, the Water Resources portfolio included a total 20 projects, including two projects that were finalized and nine that were selected from the Feasibility-to-Decisions solicitation in 2011. Another nine projects were selected from the A.45 solicitation to

develop improved forecasts of water supply anomalies in the mid term (30-180 day outlooks).

The table below summarizes the distribution of Application Readiness Levels (ARLs) of the 20 projects that were active during 2014. Half of the projects were selected and initiated in 2014, which is reflected in the distribution of project ARLs in 1-3 range.

Water Resources Projects	
ARL	# Projects
9	1
8	2
7	
6	1
5	2
4	3
3	7
2	3
1	1
Total	20



VI. Program Management

The Water Resources Applications area also directed support for three missions in various stages of development: *Soil Moisture Active Passive (SMAP)*, *Gravity Recovery and Climate Experiment Follow-On (GRACE-FO)*, and *Surface Water Ocean Topography (SWOT)*. *SMAP* efforts continued with early applications development of *SMAP* test data as the *SMAP* mission team prepared for launch. The *SWOT* mission team developed applied science tasks for AirSWOT campaigns and collaborated with CNES to establish an international applied sciences team for the mission. *GRACE-FO* and *SWOT* application teams established applications websites for their missions, facilitated presentations and discussions at Science Team meetings, and continued to develop applications plans.

Workshop on Remote Sensing Applications for Water Resources Management and Drought

February 25–26, 2014

The California Department of Water Resources and the NASA Water Resources Applications area held a workshop in Sacramento, California, to highlight ongoing efforts to apply remote sensing to support water managers in responding to evolving drought conditions in the state. The workshop provided information about projects supported by NASA and the department to apply remote sensing and other NASA technologies to monitor drought conditions, quantify drought impacts, and support water

management agencies in California in planning for drought response and mitigation. The primary objective of these joint projects is to integrate remote sensing data with existing information systems and decision support tools, enhancing the value of information from ground-based sensor networks and hydro-meteorological models currently used by water managers in monitoring and responding to drought.

LEARN MORE

<https://c3.nasa.gov/water/resources/2/>

The Water Resources Applications area was active in multiple interagency partnerships: USGS–NASA Water Resources quarterly coordination meetings; U.S. Water Partnership; Western States Federal Agency Support Team (WESTFAST) to the Western States Water Council (WSWC); the Climate Change and Water Working Group (CCAWG); the Group on Earth Observations (GEO); U.S. GEO; and Committee on Earth Observation Satellites. The next two sections of this report describe Water Resources activities with these organizations.

The Water Resources team for CY 2014 was comprised of program manager Brad Doorn, assisted by Forrest Melton, Karen Mohr, John Bolten, and Christine Lee.

VII. Community Leadership

Highlights of Water Resources Applications area activities and leadership in 2014 include:

AGU Fall Meeting

December 15–19, 2014 Moscone Center, San Francisco

The Water Resources program was well represented at the 2014 Fall American Geophysical Union Meeting. The Water Resources Applications area sponsored and convened three sessions on applications of remote sensing for water resource management, which featured several PIs from the portfolio and was among the most heavily subscribed session topics in the Hydrology section. The sessions highlighted recent applications of satellite, airborne, and ground platforms for improved management and monitoring of water resources. The Water Resources team also presented two hyperwall presentations, “Earth Observations for Global Water Knowledge” and “Remote Sensing of the Western Drought.” The hyperwall talks featured recent results and demonstrations from the portfolio and provided an opportunity for the team to answer questions from the audience about the featured projects, program objective, and goals.

National Water Quality Monitoring Council Conference

April 28–May 2, 2014

This meeting brought together water quality monitoring researchers and practitioners to exchange information, share best management practices, and discuss new tools, technologies, and approaches related to water quality science. The NASA Water Resources Applications area held a workshop, How Can Remote Sensing Address

Information Needs and Gaps in Water Quality and Quantity Management? This workshop provided an overview of satellite remote sensing for water quality, featured case studies, and strengthened communication between water quality managers and the applied remote sensing research community. Outcomes of this event included improved understanding of water quality information needs and data gaps, development of pilot project concepts for evaluating potential applications, and publication of a workshop briefing in *Eos*, the journal of the American Geophysical Union.

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<http://acwi.gov/monitoring/conference/2014/index.html>

WHO-HABITAT-UNEP EO-Novel Data- Data Integration Task Team Meeting
NOAA Center for Weather and Climate Prediction; University of Maryland, College Park
August 11–12 2014

The objective of the meeting was to develop a framework and ideas for a proposal using Earth observations, novel data, data integration, and data analysis and interpretation tools for a Monitoring System for the proposed U.N. Water Sustainable Development Goal with a focus on wastewater, water quality and water resources management. The meeting also provided a platform to review with key national and international agencies the importance of use of data from Earth Observations (satellite and *in situ*), integrate them with other traditional and non-traditional data sources (including Big Data) in monitoring Sustainable Development Goals for water, and explore opportunities for inclusion of this in the SDG discussions at the political level. The meeting also reviewed the cost effectiveness of such monitoring approaches and finding the need for required resources, financial and otherwise, for making such monitoring sustainable. The Water Resources team helped convene the meeting and lead discussions on Water Resources Indicators and monitoring tools and strategies. The outcomes of the meeting are focused towards the next U.N. Global Development Agenda (post 2015) to develop a water monitoring system covering drinking water, wastewater, and water resources management.

G-WADI and International Drought Initiatives: Data and Product Working Meeting
April 22–23, 2014

The Center for Hydrometeorology and Remote Sensing held a meeting at the University of California, Irvine, to discuss the UNESCO program for Water and Development Information for Arid Lands: A Global Network (G-WADI) geoserver with colleagues and collaborators from UNESCO and NASA, and end users from the Namibia National Hydrological Services, AGRHYMET Regional Centre in Niger, UNESCO Santiago, the Water for Sustainable Development and Adaptation to Climate Change Center in Serbia, and the Ministry of Regional Municipalities and the Ministry of Water Resources in Oman. The meeting provided an opportunity for attendees to discuss recent advances in developing precipitation products that rely on NASA and NOAA Earth observations as well as discuss how end users use this data, along with ground-based data, for decision making. Outcomes of this meeting included connecting attendees with potential end users and collaborators in SERVIR regions as well as in South America, which supports activities of GEOSS in the Americas.

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<http://www.gwadi.org/news/249>

Great Lakes Workshop on Remote Sensing of Water Quality

March 12–13, 2014

This workshop convened the Great Lakes scientific and operational community to discuss the current state of science and operations for monitoring water quality in the Great Lakes. The keynote speaker, Cameron Davis, senior advisor to the EPA administrator, provided an overview of activities in the Great Lakes, and highlighted the partnership with NASA (which was the product of NASA DEVELOP projects in the Great Lakes region). NASA Applied Sciences' Lawrence Friedl and Christine Lee both presented at this meeting. Friedl's presentation shared information about NASA Earth science, water missions, and the upcoming Earth Science Decadal Survey. Lee presented on NASA Applied Sciences and water quality applications. Kenton Ross from NASA DEVELOP also attended this meeting and discussed the DEVELOP program and their activities in the Great Lakes.

LEARN MORE

<http://mtri.org/workshops/nasagreatlakes2014/>

Western States Water Council Remote Sensing Workshop

August 25–27, 2014

The purpose of this meeting, which was co-hosted by the NASA Jet Propulsion Laboratory and the Western States Water Council (WSWC), was to improve understanding of water resources challenges in the West and the information needs of water managers from western states. Highlights of the meeting included discussion of information needs such as water availability from snowmelt, runoff, and precipitation; water availability forecasts; water infrastructure; water use for agriculture; and water quality. Water managers and applied researchers gave presentations. Outcomes of this workshop included stakeholders' continuing to work together to better understand and prioritize collaborations, such as high impact issues relevant to WSWC membership that NASA can help address; identification of specific federal agencies and divisions or personnel to integrate efforts and identify partnerships for future opportunities; supporting linkages with the Water Data Exchange effort led by WSWC, and potential integration with the NASA Applied Remote Sensing Training program, where appropriate.

LEARN MORE

<http://www.westernstateswater.org/remote-sensing-applications-workshop/>

VIII. International Activities

U.S. GEO Water Strategy

Significant progress has been made with respect to the U.S. GEO Water Strategy. The draft strategy has been circulated among interagency component leads and will be distributed for broader comment to the international water resources community. Within

the timeline established, the strategy will be finalized in early to spring of 2015 and may be presented at the World Water Forum (April 2015).

PEER Water

The Applied Sciences partnership with USAID is expanding to include PEER Water (PEER SERVIR is another element of this partnership that interlinks with Capacity Building). The solicitation for this activity was launched on October 1, 2014 and it is expected to produce and seed multiple collaborations in international water resources activities across the Earth Science Division.

IX. Looking Ahead

The Water Resources Applications area looks ahead to 2015 as a year of growth, expansion, and strengthening of impact analysis across the program. The portfolio of projects expanded in 2014 following the selection of funded work for the A.45 solicitation. Furthermore, a unique element has been added to this solicitation that focuses specifically on impact assessment and economic analysis. Projects selected under A.45 will have the opportunity to apply for funding to perform a full impact analysis with a multidisciplinary team.

Other opportunities for growth include the Water Resources Applications area looking towards understanding and supporting user needs, especially in the area of water quality. The Water Resources Applications area plans to explore use of Innovation Challenges in collaboration with the U.S. Bureau of Reclamation, and to collaborate with CCAWWG on a joint workshop on Climate Change and Water Resource Management. Additional opportunities include increased engagement in international water resources challenges through the PEER Water partnership with USAID, planning for a joint workshop with the World Bank on the topic of International Applications of Remote Sensing of Evapotranspiration for Water and Food Security, the U.S. Water Partnership, and through the U.S. GEO Water Strategy.

The Water Resources Applications area also anticipates continued and integrated participation and leadership in ESD mission support, and looks forward to opportunities to leverage NASA science results from the *GPM* and *SMAP* missions to develop new applications to enhance water resources management using these exciting new water-oriented missions.

X. Appendix

Water Resources Project Highlights from 2014

Project: The Global Reservoir and Lake Monitor (GRLM): Expansion and Enhancement of Water Height Products

Principal investigator: Charon Birkett, University of Maryland

Project year: 2

Year-end ARL: 3

Description: The objective of this project is to provide lake level products in a near real-time framework and expand the current timeline of merged products via integration of historical and future data sets. This includes the historical ESA ERS/ENVISAT data set, and the NRL data set. It also includes the future ISRO/SARAL, ESA/*Sentinel-3* and NASA/NOAA *Jason-3* data sets.

End users: USDA Foreign Agricultural Service (FAS)

Data sources, models, technology: *Jason-1*, *Jason-2/OSTM*, *TOPEX/Poseidon*, *Sentinel-3* SARAL GDR

Major accomplishments in CY 2014

- Acquisition and ingestion of new SARAL GDR data set (2013 to present)
- Revision of the 10-day target list with non-USDA end user requirements. Allowed products with shortened time periods (e.g., 2008 to present) to be made available. Potential for current 10-day target list (~70 lakes/reservoirs) to be expanded to ~200.
- Began exploration and validation of preliminary SARAL products for greater accuracy, greater number of targets (~500), and acquisition of much smaller lakes/reservoirs.

Plans or expectations for 2015:

- Receipt of continued funding for second and third stages of envisioned work.
- Perform one more upgrade of the current 10-day products, historically extend and upgrade the 35-day products, and bring online three new near real-time products. Two of the near real-time products will extend the 10- and 35-day timeline across the 2013–2020 period. The third product will increase the number of lake/reservoirs to stakeholders.

* * *

Project: Enhancing the USDA Global Crop Production Decision Support System with the NASA Land Information System and Water Cycle Satellite Observations

Principal investigator: Wade Crow, USDA ARS

Project year: 3

Year-end ARL: 8 (final)

Description: The central objective of this project was enhancing the U.S. Department of Agriculture (USDA) Foreign Agricultural Service (FAS) global crop assessment decision support system via the integration of NASA soil moisture data products and/or the adoption of NASA land surface modeling and data assimilation tools.

End users: USDA FAS

Data sources, models, technology: *AMSR-E, TRMM, LIS, SMOS*

Major accomplishments in CY 2014:

- Soil moisture products have been operationally delivered to USDA FAS since late 2013 and fully incorporated into the USDA FAS Crop Explorer decision support system since April 2014.
- Using the NASA Land Information System (LIS), a global ensemble of the land surface runs have been completed between 2002 and 2010. Using this ensemble, an intercomparison of the value of simple, soil moisture accounting models (like the 2-layer Palmer model used operationally at USDA FAS) to more complex land surface models embedded in the NASA LIS system was performed.
- Benchmarking of the system was completed through independent evaluation by the USDA World Agricultural Outlook Board (WAOB), which concluded that the root-zone soil moisture product created by this project is superior to the existing USDA WAOB root-zone soil moisture product.

* * *

Project: Satellite Earth Image Products Applied to Development of Regulatory Water Quality Standards

Principal investigator: John Lehrter, EPA

Project year: 3

Year-end ARL: 9

Description: This project utilizes satellite ocean color data products to inform two water quality decisions: 1) the development of numeric nutrient criteria for the state of Florida;

and 2) rezoning of a marine protected area, the Florida Keys National Marine Sanctuary (FKNMS).

End users: EPA Office of Water, the state of Florida, the state of Alabama, and Florida Keys National Marine Sanctuary

Data sources, models, technology: Two years of monthly optical data collected in Florida Panhandle estuaries (Pensacola Bay, Choctawhatchee Bay, St. Andrews Bay, St. Joseph's Bay);

Two extensive optical surveys of the Florida Keys, SeaWiFS, Bio-Optical Archive and Storage System (SeaBASS)

Major accomplishments in CY 2014:

- Both EPA Office of Water and the state of Florida adopted the approaches from this project for establishing numeric nutrient criteria in estuarine and coastal waters of the state of Florida.
- The rulemaking has been completed in Florida; EPA is now promoting the use of remote sensing for criteria development and assessment in other states.
- Coastal remote sensing products were added to the suite of data products hosted by the Florida Fish and Wildlife Commission to support the rezoning of the FKNMS.

Project: Assessing Water Resources in Remote, Sparsely Gauged, Snow-Dominated Mountain Basins

Principal investigator: Jeff Dozier, University of California at Santa Barbara

Project year: 2

Year-end ARL: 5 (final)

Description: Utilizing MODIS data and GDAS/GLDAS assimilations, this project estimated seasonal snow volumes, relative to historical trends and extremes, in snow-dominated mountains that have emerging or enduring insecurity related to water resources, to support government operations and analysis for aid organizations. It aimed to identify, on regional and local bases, "crisis" and near-crisis events compared against historical data.

End users: U.S. Army Staff, U.S. Army Corps of Engineers, U.S. Embassy (Islamabad and Kabul), California Department of Water Resources (CDWR)

Data sources, models, technology: MODIS (VIIRS in future), SSM/I assimilations from GDAS and GLDAS. Own models and from NOHRSC.

Major accomplishments in CY 2014:

- Completed reconstruction of time series of snow water equivalent for the 8 basins in Afghanistan.
- Demonstrated that retrievals of SWE from passive microwave have close correspondence to reconstructed SWE during drought conditions.
- Project continuing to collaborate with USACE CRREL and USAF 14th Weather Squadron to review results and develop transition strategy.

* * *

Project: Development of a Multi-Scale Remote Sensing-Based Framework for Mapping Drought over North America

Principal investigator: Christopher Hain, University of Maryland

Project year: 1

Year-end ARL: 6

Description: The project has developed a multi-scale drought monitoring tool for North America based on remotely sensed estimates of evapotranspiration (ET) derived from thermal infrared retrievals of land surface temperature (LST): the Evaporative Stress Index (ESI). The expanded ESI domain was evaluated with respect to drought metrics used in the United States Drought Monitor (USDM) and the North America Drought Monitor (NADM), along with commonly used drought indicators.

End users: NADM, Agriculture and Agrifood Canada, Meteorological Service of Canada, National Meteorological Service of Mexico

Data sources, models, technology: ALEXI ESI, MODIS LAI

Major accomplishments in CY 2014:

- The project successfully transitioned our current ESI capabilities over the continental United States (CONUS) to a domain covering most of North America (NA: 0°N to 60°N).
- To facilitate the expansion of the ESI domain, the system was migrated to ingest GOES Imager products in place of the GOES Sounder products, which provide spatial coverage only over the CONUS.
- The modified NA ESI processing system was implemented at NOAA/NESDIS/STAR; the retrospective ESI climatology and drought products were generated over the period of 2000-2012. The near real-time system began generating ESI products over NA in March 2013 (CONUS generation of ESI products have been produced in near real-time since 2012).
- NA ESI outputs are generated daily at a spatial resolution of 10 km with this fully automated processing system.

- The project team has been working with NOAA to develop the GOES Evapotranspiration and Drought Product System (GET-D) that will provide operational ESI analyses over North America (12 km) and CONUS (4 km).
- A completely new pre-processing system has been developed to produce all necessary inputs to ALEXI for operational use. The new GET-D system has passed its first "stress-test" and has shown to produce identical results to the previous system. The next step will be a Critical Design Review within NOAA in late summer where the system will be presented to operational IT staff to prepare for operational transition in 2015.
- 4-km ESI maps are currently being provided to end-users at CPC for their monthly drought briefings.
- The data sets generated with the NA ALEXI/ESI system have already demonstrated significant measurable impact for a number of end users who rely on actionable drought information.
 - NOAA has identified satellite-based estimates of ET and drought as a critical requirement for meeting several agency strategic goals. NOAA-NCEP has recognized the need for diagnostic remote sensing estimates of ET for independent regional validation of prognostic NLDAS land surface model (LSM) output, as these data are critical to improving land surface representations in numerical weather and climate forecasts (EMC).
 - Satellite-based drought information has also become an important component in the monthly North American Drought Briefing (CPC), providing independent confirmation of rapidly evolving drought signals.
 - NOAA will provide support to transition the North America ALEXI/ESI system to operations by 2015, with continuing operational support beyond 2015.
 - ESI products are currently available in near real-time to authors for both the NADM and the USDM, working closely with collaborator Svoboda to ensure operational needs and timelines are met. The ESI products are routinely provided to NCEP-CPC for their monthly North American Drought Briefing.
 - The project team is also actively working with researchers in the USDA National Agricultural Statistics Service (NASS) to investigate integration of ESI time series into operational projections of state agricultural yields. NASS has identified ESI as a potentially high-impact tool which could be integrated into yield forecasts in the future and have requested the need for higher-resolution ESI data (4 km ESI products) to better understand the relationships between ESI and specific crop yields.

* * *

Project: Global Monitoring of Agricultural Drought: A Contribution to GEOGLAM

Principal investigator: Inbal Becker-Reshef, University of Maryland

Project year: 1

Year-end ARL: 4

Description: The objective of this project is to coordinate international efforts to prototype the GEOGLAM crop outlooks for the G-20 AMIS Initiative. These are transparent, timely, qualitative crop condition assessments in primary agricultural production areas that reflect an international consensus.

End users: GEOGLAM Global Agricultural Monitoring Community of Practice; G20 Agricultural Market Information System; USDA

Data sources, models, technology: MODIS Vegetation Indices, anomaly-based indicators, temperature, precipitation, agricultural statistics, crop calendars, cropland masks, GIS web systems

Major accomplishments in CY 2014:

- Established an operational relationship with the G20-AMIS initiative and international colleagues to produce a monthly global agricultural assessment.
- Provide operational monthly reports on crop conditions published within the AMIS Market Monitor.
- Designed and implemented a web interface for global partners to provide agricultural crop outlooks every month.
- Initiated dialogue with international partners for development of country specific crop monitoring and stress GLAM system and initiated prototype development.
- Secured U.S. partnerships with USDA leadership.
- Secured international partnerships with over 30 agencies and organizations.
- Developed categories of crop conditions.
- Developed customized products (maps and charts) that are understandable for policy makers and economist communities.
- Developing global crop calendars and crop type masks for the AMIS countries with the help of international partners.

Plans or expectations for 2015:

- Research Earth observations-based methods for assessing crop production prospects as the growing season progresses for primary agricultural production/export countries of wheat, soy, and corn that are prone to droughts and have significant impacts on international markets. Wheat: Russia, Ukraine, Kazakhstan, Australia, Canada, USA, Argentina. Soy: Argentina, USA, Brazil, China. Corn: USA, Argentina, Brazil, China, Ukraine, Russia.
- Work with Vienna University of Technology (TU WIEN) to integrate their monthly and 10-day soil water index products into the interface as an additional EO data layer available for the GEOGLAM analysts.

* * *

Project: Mitigation of Drought Impacts on Agriculture through Satellite Irrigation Monitoring and Management Support

Principal investigator: Forrest Melton, NASA Ames Research Center and California State University at Monterey Bay

Project year: 2

Year-end ARL: 5

Description: The Satellite Irrigation Management Support (SIMS) project is a NASA-supported effort to apply publicly available data from Earth-observing satellites to map crop cover, crop coefficients, and crop evapotranspiration. The long-term goal of the project involves developing information products and tools to provide decision support for water managers and agricultural producers. The primary focus of the effort is to expand the applicability of Terrestrial Observation and Prediction System (TOPS) to support the use of satellite data for rapid assessments of current crop conditions and translate satellite data into formats that are useful to agricultural producers in irrigation scheduling and water management.

End users: Western Growers Association, University of California Cooperative Extension, USDA Agricultural Research Service, NOAA National Weather Service, Tanimura & Antle, Farming D Ranch, Pereira Bros. & Sons, Booth Ranches, Fresh Express, Ryan Palms Farms, Del Monte, Inc., Constellation Wines, E. & J. Gallo, Dole, Inc., Driscoll's Farms, Meyer Farms

Data sources, models, technology: TOPS, MODIS, *Landsat*

Major accomplishments in CY 2014:

- The SIMS web interface was publicly available during 2014. Reports were generated on a weekly basis for partner growers, with combined management of more than 100,000 acres.
- Feedback from grower experience using the system is currently being collected, and will be incorporated into software development plans for the coming year.
- APIs are also being developed to facilitate integration of data with additional irrigation management and agricultural water management decision support tools.
- Integrated UCCE CropManage and NASA SIMS framework identified by CDFA as top candidate for standard tool for irrigation and nutrient management in California.
- Three years of validation studies completed in collaboration with CDWR. Results currently being compiled and prepared for publication.
- Initial regional estimates of regional ET for the critical California Delta region provided to CA DWR for review.
- Two years of field studies performed to quantify potential for reductions in applied water and associated changes in crop yield. Studies conducted to date demonstrate potential for reductions in applied water of 22-34 percent or more, without any

statistically significant changes in yield, and no measurable reductions in yield. Additional funding from CDFA secured for two additional years of yield trials.

- Two trials were conducted on commercial farms demonstrating water savings of 30-45 percent, and additional trials scheduled for 2015.
- Ongoing work with CDWR to develop strategy to quantify statewide benefits of using ET-based irrigation management strategies.

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Project: Integration of Precision NASA Snow Products with the Operations of the Colorado Basin River Forecast Center to Improve Decision Making

Principal investigator: Thomas Painter, NASA Jet Propulsion Laboratory

Project year: 2

Year-end ARL: 8

Description: The project developed and delivered MODIS data products, which the Colorado Basin River Forecast Center integrated into its operations in 2013. CBRFC, which is run by the National Weather Service, generates daily and seasonal streamflow forecasts for the Colorado River Basin and eastern Great Basin.

End users: water managers, reservoir managers, government officials

Data sources, models, technology: MODSCAG, MODDRFS

Major accomplishments in CY 2014:

- Ongoing use and refinement of use of near real-time MODSCAG by CBRFC.
- Introduction of near real-time canopy-adjusted MODSCAG fractional snow covered area into CBRFC operations.
- New use of near real-time MODDRFS dust radiative forcing to update snowmelt rates in CBRFC operations.
- Evaluation of CBRFC SNOW-17 forecasting errors across Colorado River Basin relative to dust radiative forcing anomalies from near real-time MODDRFS.
- Modeling of runoff at forecast points with VIC and MODSCAG.
- WRF modeling of snowmelt and dust-accelerated snowmelt in Colorado River Basin.

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Project: Fallowed Area Mapping for Drought Impact Reporting and Decision Making

Principal investigator: James Verdin, USGS

Project year: 2

Year-end ARL: 6

Description: Using MODIS and *Landsat* data, the project demonstrated the feasibility of a remote sensing fallowed land monitoring service. This was a joint effort by USGS EROS, USDA NASS, CDWR, and NASA Ames Research Center to improve the timeliness of fallowed area information products to support within-season decision making on drought disaster declarations and proposed water transfers, and gauge impacts on local economies and employment.

End users: CDWR, U.S. Bureau of Reclamation, California Farm Water Coalition, Western Growers Association, National Integrated Drought Information System

Data sources, models, technology: Expedited and specialized processing of MODIS 250m data, *Landsat 5 TM*, *Landsat 7 ETM+*, and *Landsat 8 OLI*

Major accomplishments in CY 2014:

- Successfully demonstrated capability for within season mapping of idle acreage (advanced delivery of information >10 months).
- Monthly estimates generated by the project team for March – September 2014 and delivered to DWR within two weeks of the end of the month.
- Overall accuracy has been approximately +/- 15 percent or better in all months, exceeding CDWR-specified targets for accuracy.
- Good agreement between USDA/NASA year-to-date idle estimates.
- Data presented to Governor's Drought Task Force by CDWR.
- Data used by CDFA in 2014 modeling of economic impacts of drought on agriculture.
- Data used in allocation of emergency drought relief funds to food banks in impacted counties.
- Project data featured in 5-page poster in National Geographic issue on Drought in the West (Oct 2014).
- Data highlighted in CDWR 2014 Public Update for Drought Response (Nov 2014).
- Project maps of idled acreage in 2014 appeared as NASA Earth Observatory Image of the Day (1/30/2015)

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Project: The Quick Drought Response Index (QuickDRI): An Integrated Approach for Rapid Responses Agricultural Drought

Principal investigator: Brian Wardlow, University of Nebraska at Lincoln

Project year: 2

Year-end ARL: 4

Description: The project is investigating the development of a rapid-response drought monitoring tool prototype called the Quick Drought Response Index (QuickDRI) that integrates satellite-based vegetation, evapotranspiration, and soil moisture data with climate index and biophysical data. QuickDRI will be designed to map and monitor early-stage and rapid-onset vegetation flash drought stress, which is critical information needed to enhance the targeted application of the U.S. Drought Monitor (USDM) and associated key decision-making activities such as the multimillion-dollar USDA Livestock Forage Disaster Program that use the USDM.

End users: USDA Farm Service Agency, Livestock Forage Disaster Program, NWS

Data sources, models, technology: Multiple NASA Earth science products characterizing key components of the hydrologic cycles affecting vegetation drought stress will be integrated into QuickDRI, including MODIS vegetation index data, *GRACE* and NLDAS soil moisture anomalies, and a *GOES*-based Evaporative Stress Index (ESI). Models will subsequently be applied to gridded data to generate maps of short-term vegetation stress patterns across the continental United States.

Major accomplishments in CY 2014:

- USDM authors have been given initial QuickDRI map outputs for the CONUS for selected periods of the growing season during the 2012 drought for the review and comment. USDM authors have also been engaged to define specific time periods and geographic areas of the CONUS during recent drought events (2011 and 2012) where information from current indicators used in the USDM process lagged or did not show early stage and rapid onset drought development. These benchmarking locations will be used to 1) evaluate if QuickDRI provided an early indication of drought; and 2) understand the behavior and response of the various input variables available for QuickDRI, which will allow for a down selection of these variables to a final set for the operational QuickDRI models that will be developed.
- Code for the SPEI calculations was updated to produce weekly index calculations. Initial testing of the new code has shown favorable results in the index values being calculated. Testing of index output from the new code will continue during the next quarter with validation and integration in the QuickDRI calculations at that point.
- The NASA/GSFC team is testing a new *GRACE* data assimilation approach that makes use of the 1 degree *GRACE* terrestrial water storage anomaly grids directly rather than averaging over river basins first. If testing is successful and improvements validated; then reprocessed *GRACE* soil moisture data would be include in the QuickDRI data base for testing and possible integration into the final operational QuickDRI models at the end of this project.

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Project: Predicting Middle Eastern and African Season Water Deficits using NASA Data and Models

Principal investigator: Christa D. Peters-Lidard, Goddard Space Flight Center

Project year: < 1 year

Year-end ARL: 3

Description: In 2014, this project was selected for four-year funding as part of the A.45 Water Resources solicitation. The objective of this work is to develop a season water deficit forecasting system that is relevant for USAID and U.S. Army Corps of Engineers in the Middle East and Africa. These activities will be based on existing/mature NASA and NOAA Earth science capabilities. The primary work has two goals (1) align and improve the USAID's Famine Early Warning Systems Network (FEWS NET); and (2) describe water supply and water supply anomalies in the region of interest through a suite of indicators.

End users: managers at USAID, USACE, and International Center for Biosaline Agriculture

Data sources, models, technology: GEOS-5, CFS seasonal forecasts, LIS, AMSR-E, ASCAT, SMOS, *SMAP*, *GRACE*, LDAS, DSSAT

Major accomplishments in CY 2014:

- Project was selected in late CY 2014.

Plans or expectations for 2015:

- Major technical milestone is to test soil moisture and terrestrial water storage data assimilation and seasonal forecasts from *GEOS-5* and CFS in the FEWS NET Land Data Assimilation System

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Project: Towards Operational Water Resources Management in South Asia Exploiting Satellite Geodetic and Remote Sensing Technologies

Principal investigator: Faisal Hossain, University of Washington

Project year: < 1 year

Year-end ARL: 2-3

Description: In 2014, this project was selected for four-year funding as part of the A.45 Water Resources solicitation. The objectives of this project are to develop and transition multiple tools to respective end users. These tools include: (1) Satellite Precipitation and

GCM-based forecasting of anomalies of water availability using hydrologic model for Ganges-Brahmaputra and Indus basins for IRSA and IWM-WRP; (2) GRACE and Altimetry (*JASON-2/3*, *AltiKa*, *Cryosat-2*, *Sentinel-3*, *ICESat-2*), ERA-Interim/MODIS based monitoring of glacier mass balance, elevation change for selected glacier and snow extent/depth change; (3) Satellite Altimetry based monthly-to-3-monthly monitoring of storage anomalies of surface water artificial reservoirs for IRSA; (4) *GRACE*-based monthly-to-seasonal monitoring of groundwater storage anomalies with sub-monthly frequency of updating for PCRWR and IWM-WRP; (5) Satellite Altimetry-based river level forecasting in the Ganges, Brahmaputra and Indus basins in near real-time made available at a Web portal.

End users: Department of Hydrology and Meteorology (DHM-Nepal), Department of Hydromet Services (DHMS-Bhutan), Pakistan Council for Research on Water Resources (PCR WR-Pakistan), Indus River System Authority (IRSA-Pakistan), Institute of Water Modeling-Water Resources and Planning (IWM-WRP-Bangladesh), Flood Forecasting and Warning Center (FFWC-Bangladesh)

Data sources, models, technology: *GRACE*, *JASON-2/3*, *AltiKa*, *Cryosat-2*, *Sentinel-3*, MODIS, GCMs

Major accomplishments in CY 2014:

- Project was selected in late CY 2014.

Plans or expectations for 2015:

- Major milestones include advancing tools #1, 2, 4, and 5 to ARL levels 4, 3, 3-4, and 7, respectively.

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Project: Enhancing the USDA Global Crop Production Decision Support System with NASA Soil Moisture Active Passive (SMAP) Satellite Observations

Principal investigator: John Bolten, NASA Goddard Space Flight Center

Project year: < 1 year

Year-end ARL: 3

Description: The primary goal of this project is to provide NASA products, tools, and information to the USDA Foreign Agricultural Service to advance agricultural productivity forecasting ability of the CADRE crop forecasting system.

End users: USDA FAS

Data sources, models, technology: *SMAP*, *ASCAT*, *GPM*, *SMOS*

Major accomplishments in CY 2014:

- Project was selected in late CY 2014.

Plans or expectations for 2015:

- Complete pre-processing of *GPM* data to USDA Palmer soil moisture model.
- Begin to modify ASCAT/SMOS data assimilation system to ingest *GPM* observations.

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Project: Decision Support System to Enhance Water Quality Modeling and Monitoring using Remote Sensing Data

Principal investigator: Ben Stanford, Hazen and Sawyer

Project year: < 1 year

Year-end ARL: 2-3

Description: In 2014, this project was selected for four-year funding as part of the A.45 Water Resources solicitation. The goal of this project is to develop a decision support system for partners that utilize remote sensing information to predict anomalies in source water quality, looking at parameters such as haloacetic acids, nutrients, and organic matter.

End users: New York Department of Environmental Protection, Colorado Water Conservancy District, and City of Raleigh, NC

Data sources, models, technology: *SMAP*, *GPM*, ASTER, MODIS, Giovanni, *TRMM*, TMPA, NLDAS-VIC

Major accomplishments in CY 2014:

- Project was selected in late CY 2014.

Plans or expectations for 2015:

- Major milestones include collection of various types of *in situ* data from water treatment plants and development/testing of processing algorithms that utilize remote sensing data.

Project: Integrating GRACE and GRACE Follow On Data into Flood and Drought Forecasts for the Continental U.S.

Principal investigator: Matt Rodell, NASA GSFC

Project year: < 1 year

Year-end ARL: 3

Description: In 2014, this project was selected for four-year funding as part of the A.45 Water Resources solicitation. The objective of the project is to build upon a current suite of soil moisture and groundwater wetness indicators employed by the project team and end users to develop 30-90 day, 0.125° gridded predictions of water storage conditions and runoff for the continental U.S. using *GRACE* and *GRACE-FO*, and to test them as inputs to existing drought, river flow, and flood decision support systems at the NDMC, NWS/NCRFC, and USACE.

End users: National Drought Mitigation Center

Data sources, models, technology: *GRACE*, *GRACE-FO*, Catchment Land Surface Model, *GEOS-5*

Major accomplishments in CY 2014:

- Project was selected in late CY 2014.

Plans or expectations for 2015:

- Major milestones include transitioning LIS7 with gridded *GRACE* Terrestrial Water Storage Anomaly data and assess *GRACE* DAS output utility for river flow forecasting.

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Project: Satellite Enhanced Snowmelt Flood Predictions in the Red River of the North Basin

Principal investigator: Jennifer Jacobs, University of New Hampshire

Project year: < 1 year

Year-end ARL: 1

Description: In 2014, this project was selected for four-year funding as part of the A.45 Water Resources solicitation. The objective of the project is to improve the NCRFC's operational flood prediction in the Red River Basin by using NASA products to update the NWS's operational forecasting models (SNOW-17 model and Sacramento SAC-SMA) with spatially distributed estimates of state variables including snow water equivalent, snow melt phase, and snow covered area, and meltwater partitioning parameters based on antecedent soil moisture.

Once proven on the RRB, the same techniques will be available for use elsewhere within the NCRFC area of responsibility and at the remaining 12 RFCs.

End users: North Central River Forecast Center

Data sources, models, technology: SMM/I, AMSR-E, AMSR2, SMOS, *SMAP*, MODIS, SNODAS

Major accomplishments in CY 2014:

- Project was selected in late CY 2014.

Plans or expectations for 2015:

- Develop the data sets needed for the flood forecast application.
- Demonstrate satellite observations value for improving forecasts of snowmelt in the Red River Basin.

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Project: Optimizing Reservoir Operations for Hydropower Production in Africa through the use of Remote Sensing Data and Seasonal Climate Forecasts

Principal investigator: Mekonnen Gebremichael, UCLA

Project year: < 1 year

Year-end ARL: 3

Description: In 2014, this project was selected for four-year funding as part of the A.45 Water Resources solicitation. This project aims to improve reservoir operations for hydropower production for multiple utilities in East Africa by utilizing remote sensing data and seasonal climate forecasts in respective Decision Support Systems.

End users: Ethiopian Electric Power Corporation, Tanzania Electric Company

Data sources, models, technology: TMPA, CMORPH, emerging *GPM*, ASCAT, AMSR2, SMOS, MODIS, *Landsat*, *JASON*, *ENVISAT*, MIKE BASIN, MERRA, CFS, NMME

Major accomplishments in CY 2014:

- Project was selected in late CY 2014.

Plans or expectations for 2015:

- Major milestones within the first year include archiving and preparing all climate forecasts and hindcasts to be used in model development; collect/pre-process hydrology and water resource data and developing the hydropower optimization model for various systems.
- Other plans for 2015 includes co-hosting a joint climate outlook forum which will include capacity building/training for partner institutions.

Project: Advancing Drought Onset Detection and Seasonal Prediction Using a Composite of NASA Model and Satellite Data

Principal investigator: Amir AghaKouchak, UC Irvine

Project year: < 1 year

Year-end ARL: 1

Description: In 2014, this project was selected for four-year funding as part of the A.45 Water Resources solicitation. The overarching goal is to improve drought monitoring and prediction in California through: (a) Using NASA's Atmospheric Infrared Sounder (AIRS) relative humidity and water vapor to improve drought early onset detection and prediction; (b) developing a multivariate modeling framework for composite drought assessment; and (c) developing a framework for quantitative and probabilistic assessment of drought by integrating satellite data into an analog-based drought prediction model. The project will be conducted with investigators from the California Department of Water Resources (CDWR).

End users: CDWR

Data sources, models, technology: NASA Atmospheric Infrared Sounder

Major accomplishments in CY 2014:

- Project was selected in late CY 2014.

Plans or expectations for 2015:

- Analysis of AIRS data and climate teleconnections to develop prototype predictive models.
- Present initial model and predictive accuracies to CDWR for review.

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Project: Advancing Water Supply Forecasts in the Colorado River Basin for Improved Decision Making

Principal investigator: Gerald Day, Riverside Technologies

Project year: < 1 year

Year-end ARL: 2

Description: In 2014, this project was selected for four-year funding as part of the A.45 Water Resources solicitation. The project team is working with the CBRFC Community Hydrologic Prediction System (CHPS) operational forecast framework to deploy a

distributed modeling environment that will accept gridded precipitation estimates (e.g., *GPM*) and facilitate the assimilation of a variety of sensors including SNOTEL point data, as well as MODIS-based snow products. The project will implement the NWS distributed Hydrologic Model (HL-RDHM), which utilizes the Snow-17 and SacSMA models as a first step for transitioning to operational distributed modeling at the CBRFC. Distributed snow modeling will provide more accurate representation of the spatial distribution of the snowmelt process and should lead to improved forecasts even before advanced data assimilation is introduced. In parallel, the Utah Energy Balance (UEB) model will be implemented in pilot watersheds to address the difficulties and assess the potential value of incorporating an energy balance snow model in an operational environment. CHPS will provide a flexible environment that will support the management of gridded forcing and measurement data sets, allow the use of multiple models in parts of the basin, and facilitate the incorporation of future advancements. In addition, CHPS will provide a framework that will enable the research team to assess the performance of different components of the forecasting process, i.e., forcing data sets, models, and data assimilation procedures. CBRFC has provided a letter of support for the project, recognizing this provides a low-risk approach to transition to an environment that will support improved process modeling and the incorporation of advanced observations.

End users: Colorado Basin River Forecasting Center, Denver Water, Dolores Water Conservancy District

Data sources, models, technology: NASA MODIS, *GPM*

Major accomplishments in CY 2014:

- Project was selected in late CY 2014.

Plans or expectations for 2015:

- Develop initial satellite precipitation integration.
- Select key watersheds for joint implementation.
- Configure HL-RDHM with a-priori parameters, calibrate for key watersheds.
- Assess decision support at agencies.

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Abbreviations

AGU: American Geophysical Union
ALERTS: Automated Land Evaluation, Reporting and Tracking System
ALEXI: Atmosphere-Land Exchange Inverse
AMIS: Agricultural Market Information System
AMSR-E: Advanced Microwave Scanning Radiometer - Earth Observing System
ARL: Application Readiness Level
ASCAT: Advanced Scatterometer
ASO: Airborne Snow Observatory
ASTER: Advanced Spaceborne Thermal Emission and Reflection Radiometer
AVIRIS: Airborne Visible/Infrared Imaging Spectrometer
BASINS: Better Assessment Science Integrating point & Non-point Sources
CADRE: Crop Condition Data Retrieval and Evaluation
CASA: Carnegie-Ames-Stanford Approach
CBRFC: Colorado Basin River Forecast Center
CDWR: California Department of Water Resources
CFS: Climate Forecast System
CIA: Central Intelligence Agency
CIMIS: California Irrigation Management Information System
CMORPH: Climate Prediction Center Morphing Model
CPTEC: Center for Weather Forecasting and Climate Research
CY: calendar year
DoS: Department of State
DSS: decision support system
DSSAT: Decision Support System for Agrotechnology Transfer
ENVISAT: Environmental Satellite
EPA: U.S. Environmental Protection Agency
EROS: Earth Resources Observation and Science
ESD: Earth Science Division
ETM+: Enhanced Thematic Mapper Plus
EVI: Enhanced Vegetation Index
FAS: Foreign Agricultural Service
FEWS NET: Famine Early Warning System Network
FLDAS: FEWS NET Land Data Assimilation System
FY: fiscal year
G20: Group of 20
G8: Group of Eight
GDAS: Global Data Assimilation System
GEO: Group on Earth Observations
GEOGLAM: GEO Global Agricultural Monitoring
GEOS-5: Goddard Earth Observing System Model, version 5
GEOSS: Global Earth Observation System of Systems
GLDAS: Global Land Data Assimilation System
GMAO: Global Modeling and Assimilation Office
GOES: Geostationary Operational Environmental Satellite

GPM: Global Precipitation Measurement Mission
GPP: gross primary productivity
GRACE: Gravity Recovery and Climate Experiment
GRLM: Global Reservoir and Lake Monitor
GSFC: Goddard Space Flight Center
GWLF: Generalized Water Loading Function
IRIN: Integrated Regional Information Networks
JPL: Jet Propulsion Laboratory
LIS: Land Information System
LPRM: Land Parameter Retrieval Model
MERIS: MEdium Resolution Imaging Spectrometer
MERRA: Modern Era Reanalysis for Research and Applications
MOD16: MODIS Global Evapotranspiration Project
MODDRFS: MODIS Dust Radiative Forcing in Snow
MODIS: Moderate Resolution Imaging Spectroradiometer
MODSCAG: MODIS Snow Covered Area and Grain size
NADP: National Atmospheric Deposition Program
NASA: National Aeronautics and Space Administration
NASS: National Agricultural Statistics Service
NCRFC: North Central River Forecast Center
NDMC: National Drought Mitigation Center
NDVI: Normalized Difference Vegetation Index
NEIWPCC: New England Interstate Water Pollution Control Commission
NGA: National Geospatial-Intelligence Agency
NLCD: National Land Cover Database
NLDAS: North American Land Data Assimilation System
NNME: North American Multi-Model Ensemble
NOAA: National Oceanic and Atmospheric Administration
NOHRSC: National Operational Hydrologic Remote Sensing Center
NYCDEP: New York City Department of Environmental Protection
OLI: Operational Land Imager
OSTM: Ocean Surface Topography Mission
PI: project investigator
PSI: Planetary Skin Institute
RZSM: root zone soil moisture
SeaWiFS: Sea-viewing Wide Field-of-view Sensor
SIMS: Satellite Irrigation Management Support
SMAP: Soil Moisture Active Passive
SMOS: Soil Moisture and Ocean Salinity
SNODAS: Snow Data Assimilation System
SPARROW: SPATIally Referenced Regressions On Watershed Attributes
SSM/I: Special Sensor Microwave Imager
SWAT: Soil and Water Assessment Tool
SWE: snow water equivalent
TM: Thematic Mapper
TMPA: TRMM Multi-satellite Precipitation Analysis

TOPEX: Topography Experiment
TRMM: Tropical Rainfall Measurement Mission
TRMM: Tropical Rainfall Measuring Mission
U.N.: United Nations
UCCE: University of California Cooperative Extension
USACE: United States Army Corps of Engineers
USAID: United States Agency for International Development
USDA: United States Department of Agriculture
USGS: United States Geological Survey
VIC: Variable Infiltration Capacity
VIIRS: Visible Infrared Imaging Radiometer Suite
WAOB: World Agricultural Outlook Board
WSWC: Western States Water Council

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