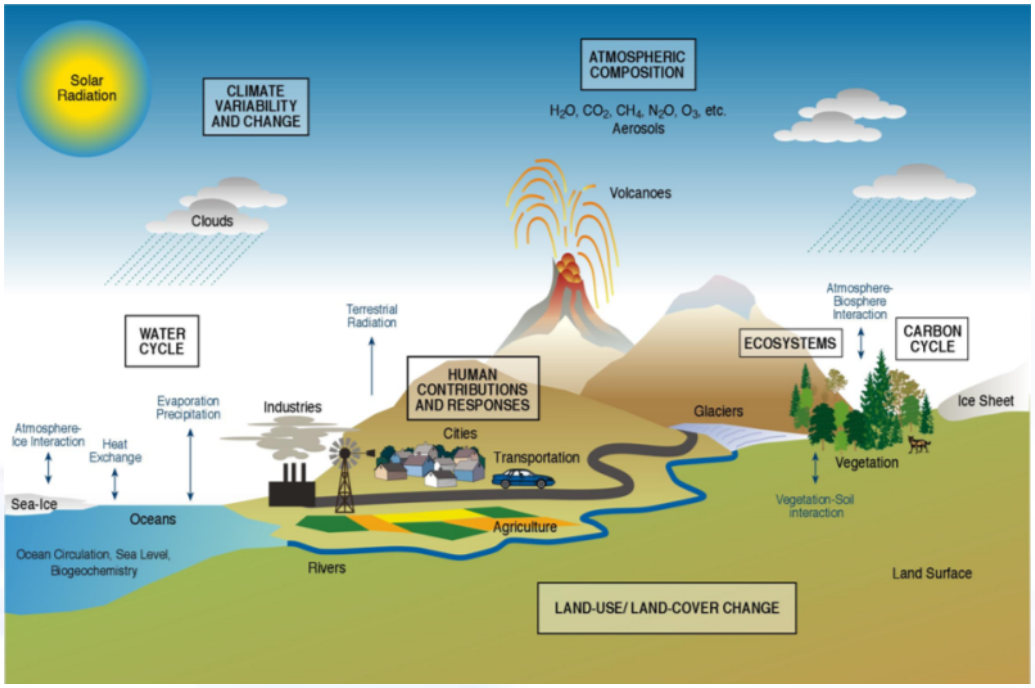
Watching Water in the West:
An Overview of NASA Missions and Applied Science for Water Resources Management

NASA Applied Sciences Program

Bradley Doorn, Program Manager, NASA HQ
Forrest Melton, Associate PM, NASA ARC-CREST
John Bolten, Associate PM, NASA GSFC
Christine Lee, Associate PM, NASA JPL

WESTFAST Webinar
20 August 2015

NASA Earth Science



NASA Earth Science supports basic and applied research on the Earth system and its processes.

Characterize, understand, and improve predictions of the Earth system to advance knowledge and benefit society.

Technology

Flight Missions

Research

Data Systems

Education

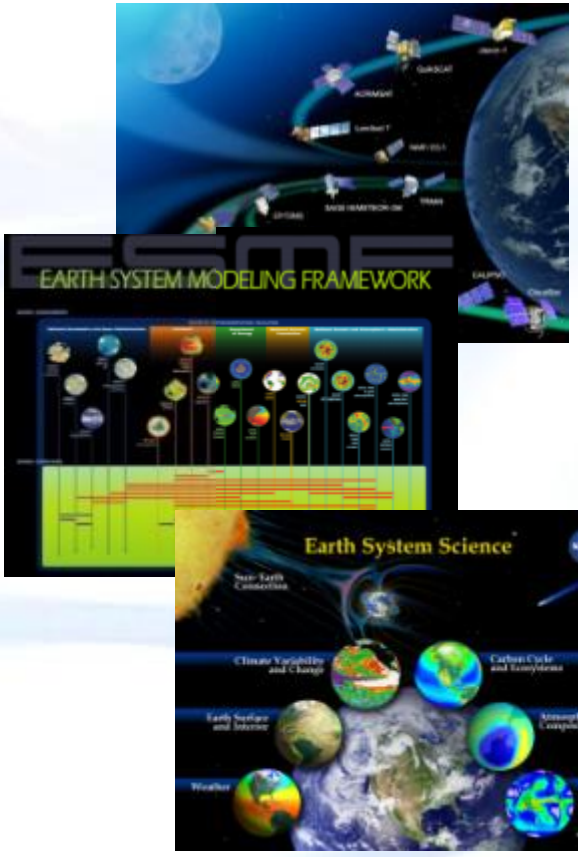
Applications

NASA Applied Sciences Program

A Pathway Between Earth Science & Society

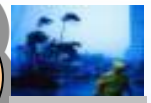
Results of NASA Earth Science Research

Uses by Partners and Stakeholder Communities



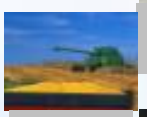
NASA Applied Sciences Program

GEOSS Societal Benefit Areas


Natural Disasters


Water Resources


Ecosystems


Agriculture


Air Quality

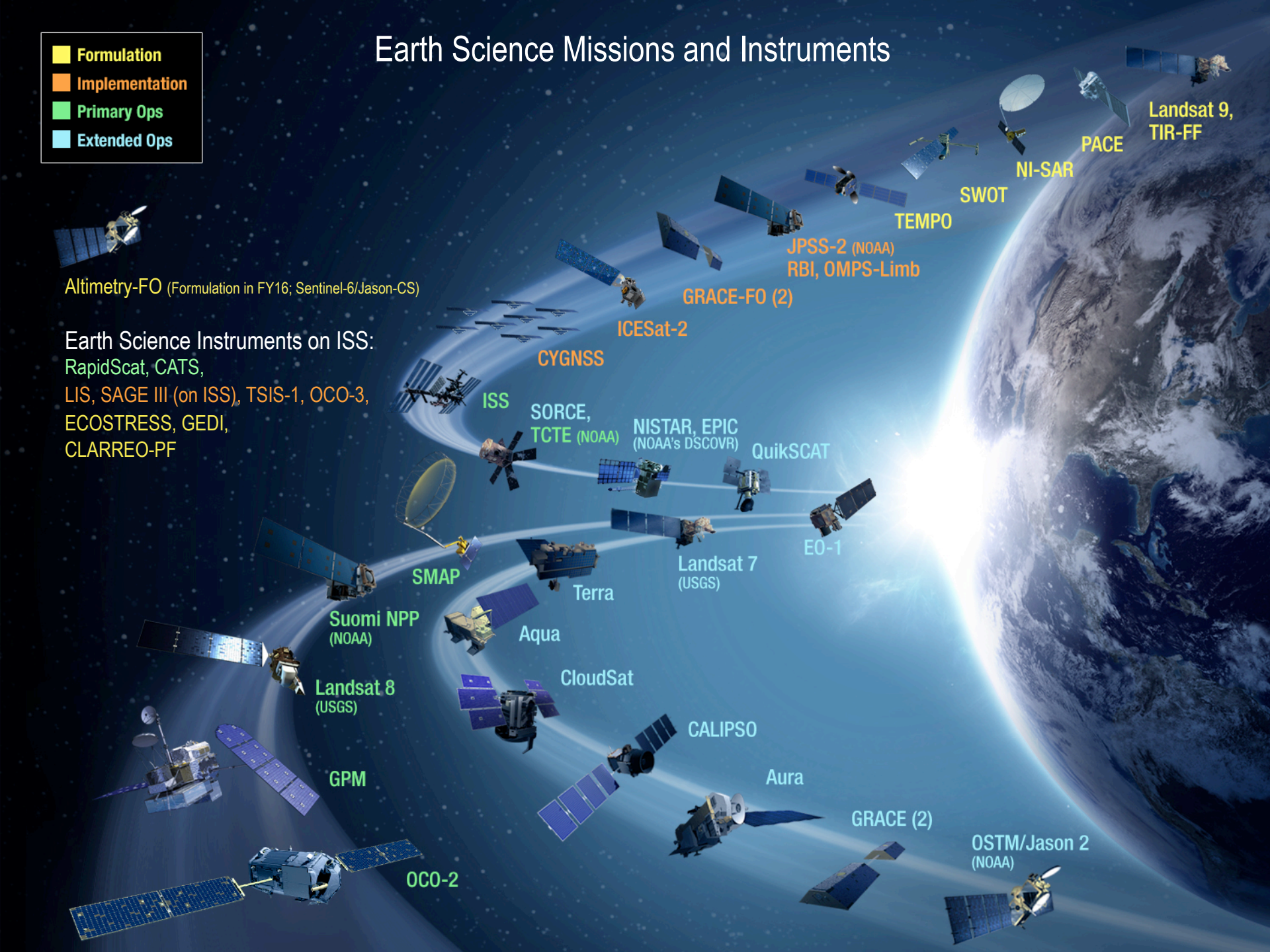

Weather

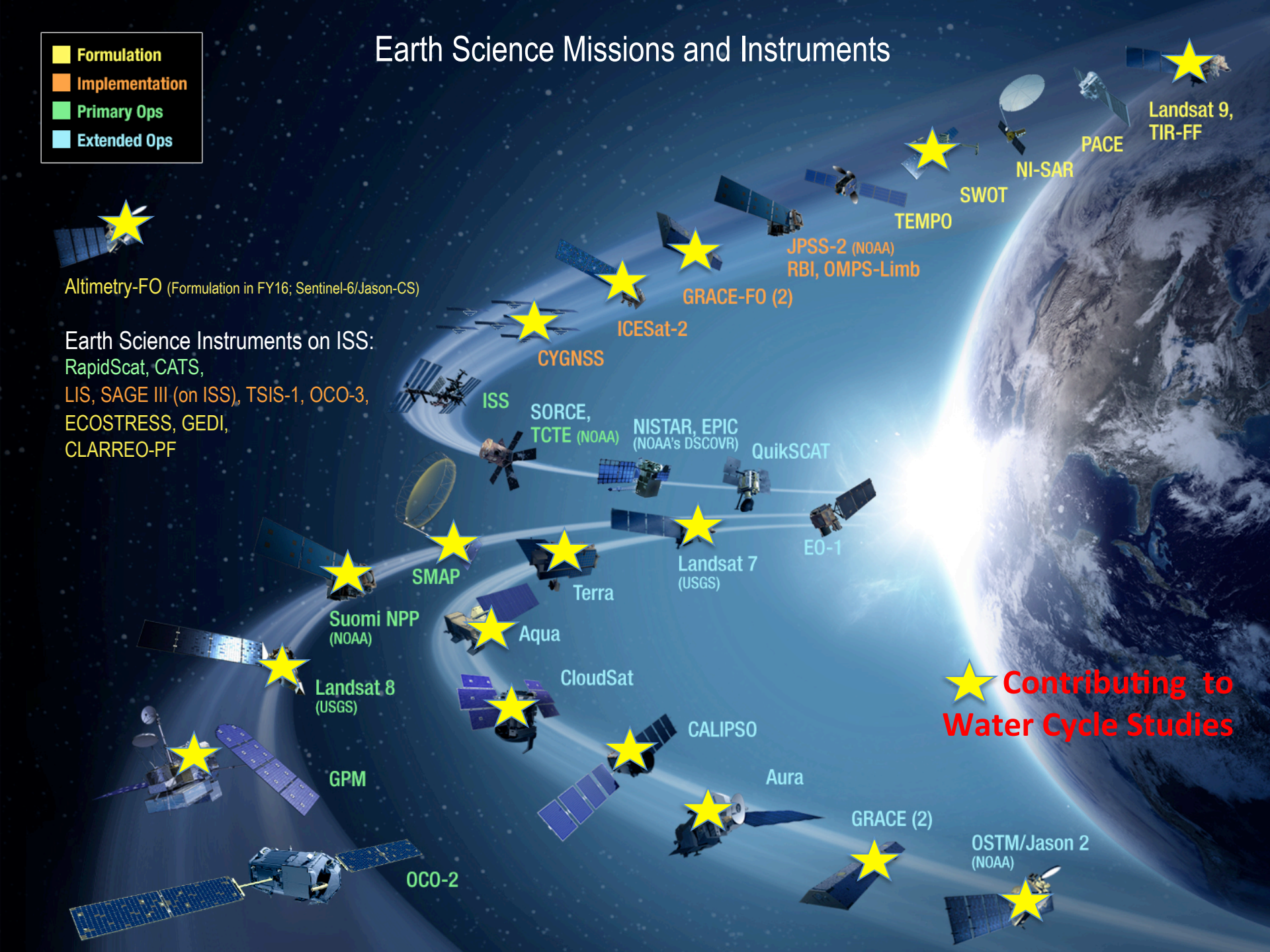

Climate


Public Health

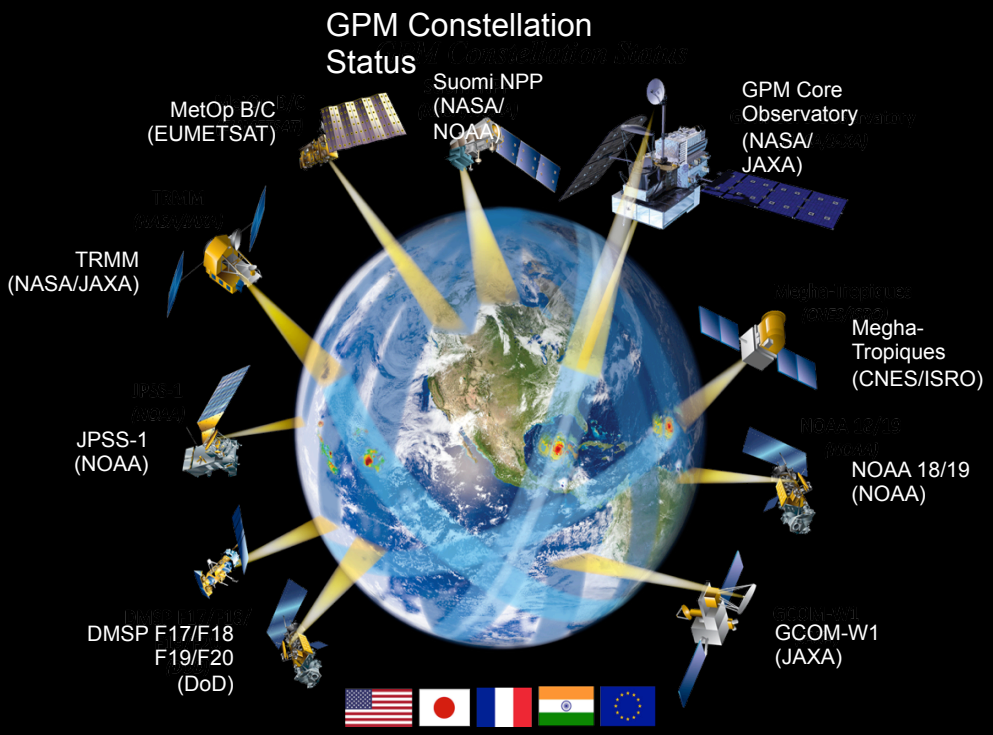
WATER RESOURCE RESEARCH AND APPLICATIONS FROM

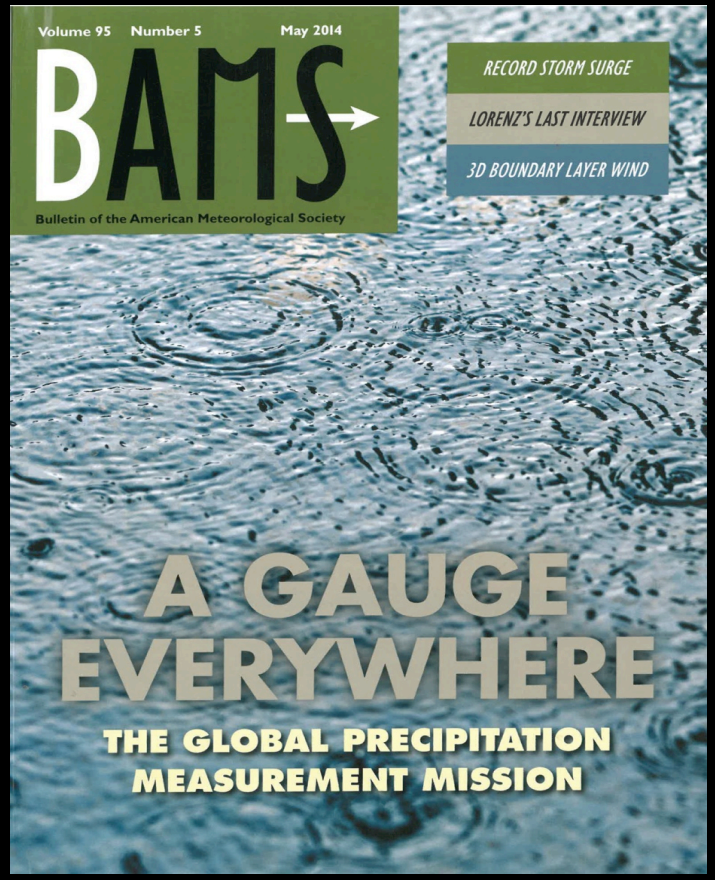
SPACE OBSERVATIONS


Formulation
Implementation
Primary Ops
Extended Ops
Earth Science Missions and Instruments
Altimetry-FO (Formulation in FY16; Sentinel-6/Jason-CS)
Earth Science Instruments on ISS:
RapidScat, CATS,
LIS, SAGE III (on ISS), TSIS-1, OCO-3,
ECOSTRESS, GEDI,
CLARREO-PF
Landsat 9, TIR-FF
PACE
NI-SAR
SWOT
TEMPO
JPSS-2 (NOAA)
RBI, OMPS-Limb
GRACE-FO (2)
ICESat-2
CYGNSS
ISS
SORCE,
TCTE (NOAA)
NISTAR, EPIC
(NOAA's DSCOVR)
QuikSCAT
EO-1
Landsat 7
(USGS)
SMAP
Terra
Suomi NPP
(NOAA)
Aqua
Landsat 8
(USGS)
CloudSat
CALIPSO
GPM
Aura
GRACE (2)
OSTM/Jason 2
(NOAA)
OCO-2


Formulation
Implementation
Primary Ops
Extended Ops
Earth Science Missions and Instruments
Altimetry-FO (Formulation in FY16; Sentinel-6/Jason-CS)
Earth Science Instruments on ISS:
RapidScat, CATS,
LIS, SAGE III (on ISS), TSIS-1, OCO-3,
ECOSTRESS, GEDI,
CLARREO-PF
Landsat 9, TIR-FF
PACE
NI-SAR
SWOT
TEMPO
JPSS-2 (NOAA)
RBI, OMPS-Limb
GRACE-FO (2)
ICESat-2
CYGNSS
ISS
SORCE,
TCTE (NOAA)
NISTAR, EPIC
(NOAA's DSCOVR)
QuikSCAT
EO-1
SMAP
Landsat 7
(USGS)
Terra
Suomi NPP
(NOAA)
Aqua
Landsat 8
(USGS)
CloudSat
CALIPSO
Aura
GPM
GRACE (2)
OSTM/Jason 2
(NOAA)
OCO-2
Contributing to
Water Cycle Studies

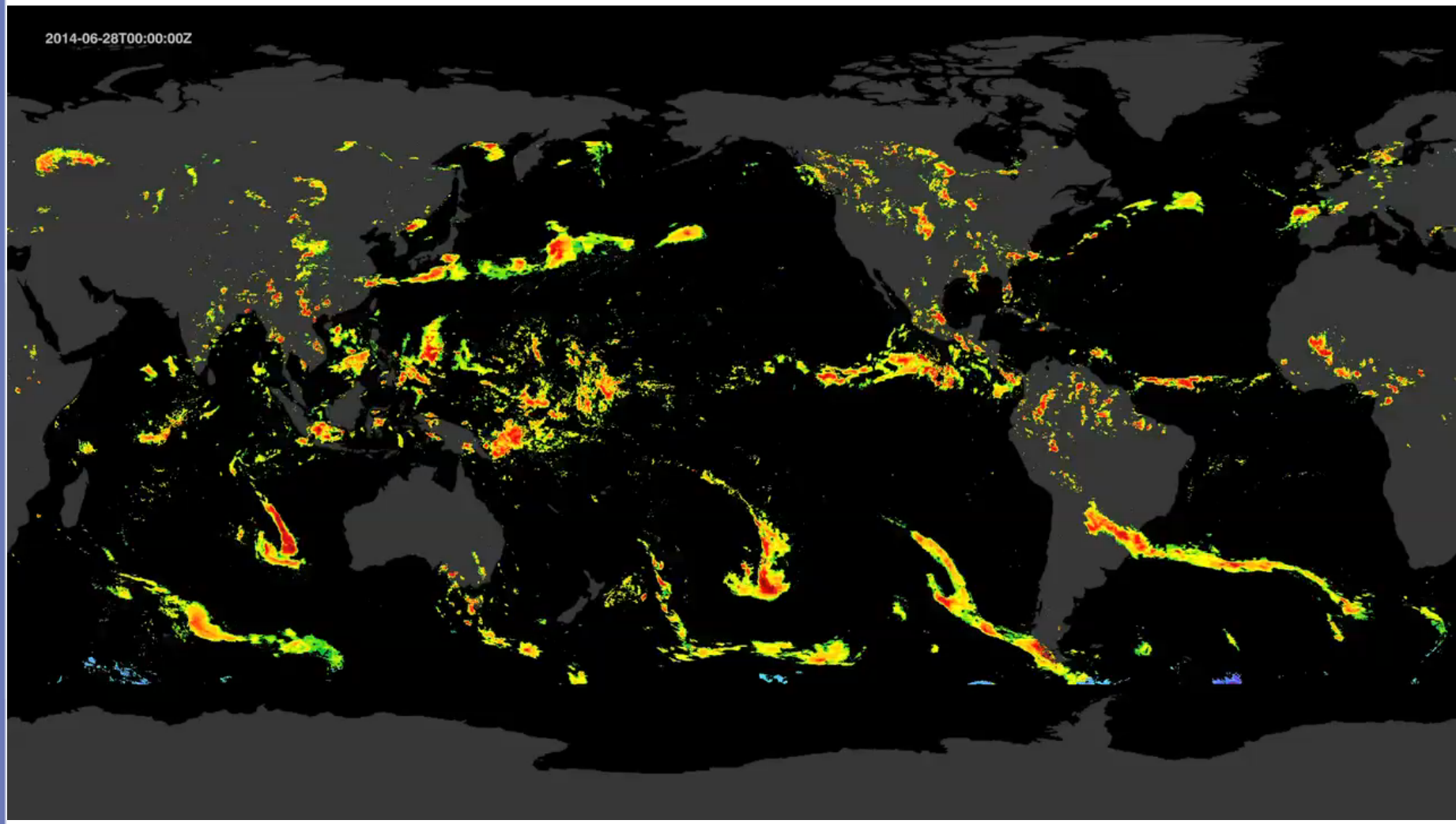
Global Precipitation Measurement Mission





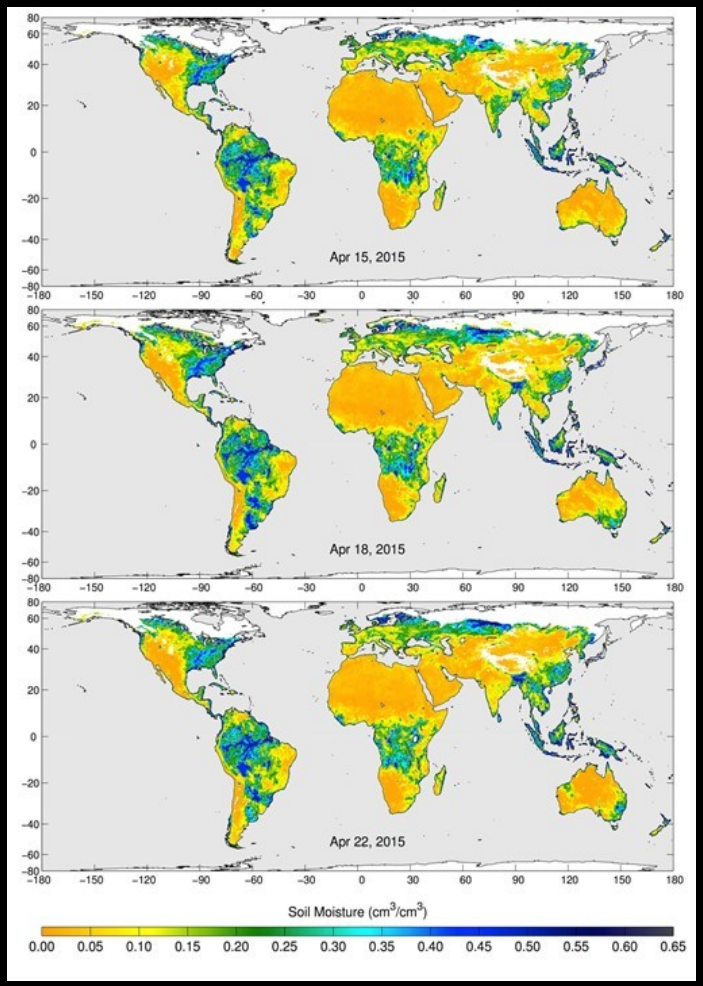
Active Joint Projects (19 PI's from 13 countries)

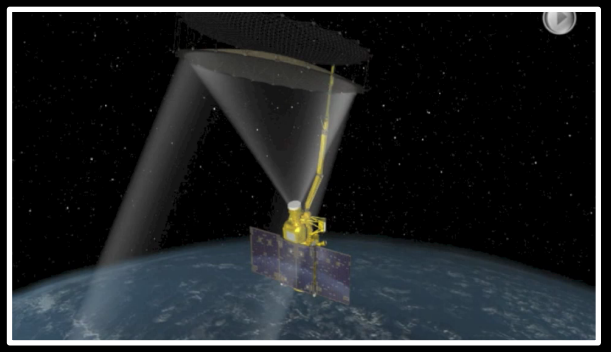
IMERG: Integrated Multi-satellitE Retrievals for GPM

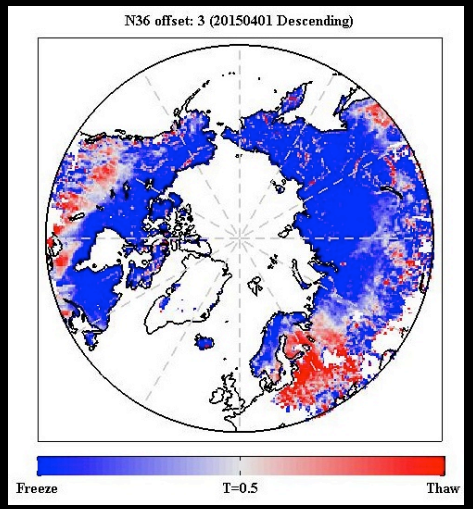


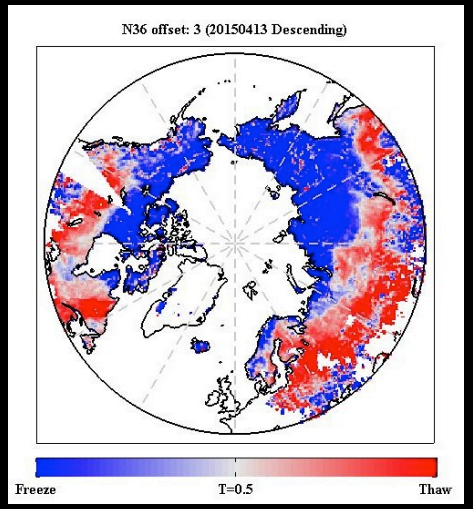
SMAP Measurements

- SMAP is providing moisture content in the top 5 cm of soil, at 10 km resolution, globally every 3 days









SMAP measurements of soil moisture address a wide range of water cycle research and science applications, including weather prediction, drought/ flood monitoring, and food production

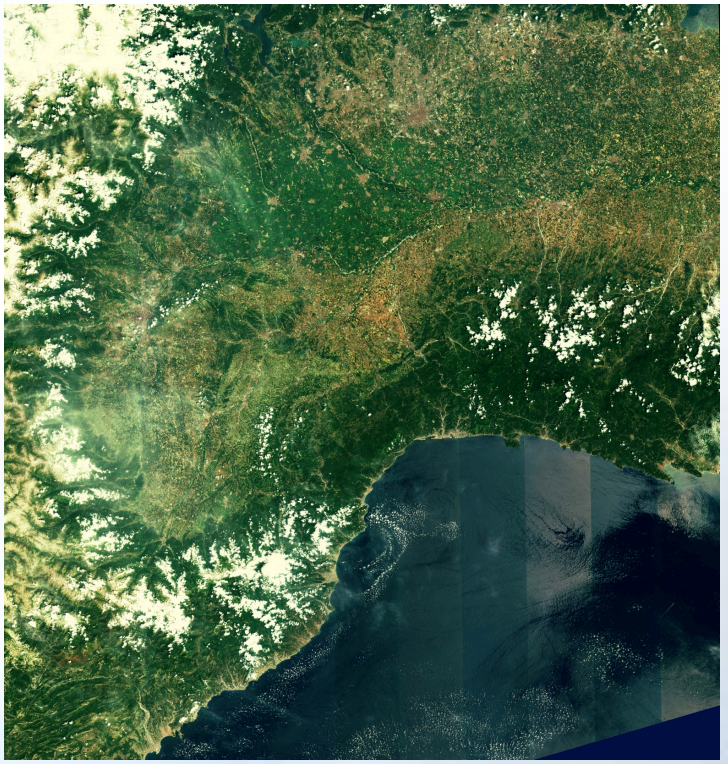
SMAP Mission Update

- Release of first calibrated data on July 31
  - paves way for ground validation
- Radar Instrument Anomaly
  - Radar halted on July 7 and in safe mode
  - All other systems (incl. radiometer, antenna) working nominally
    - Soil Moisture products are being produced albeit at a lower resolution (~40km)
  - Mission team has isolated anomaly to the low-voltage power supply for the high-power amplifier (HPA)
  - Several candidate faults are identified
  - Next scheduled power up attempt may occur in late August

Sentinel-2 – European Multi-Spectral Land Imaging

- Sentinel-2A launched successfully 23 June 2015
  - 13 spectral bands (Landsat-8 bands plus…) – ***NO THERMAL INFRARED***
  - 10 m resolution, 280 km swath – 10-day, single-satellite repeat
  - First imagery and processed products received 27 June 2015
  - Sentinel-2B on schedule for mid-2016 launch – 5-day system repeat

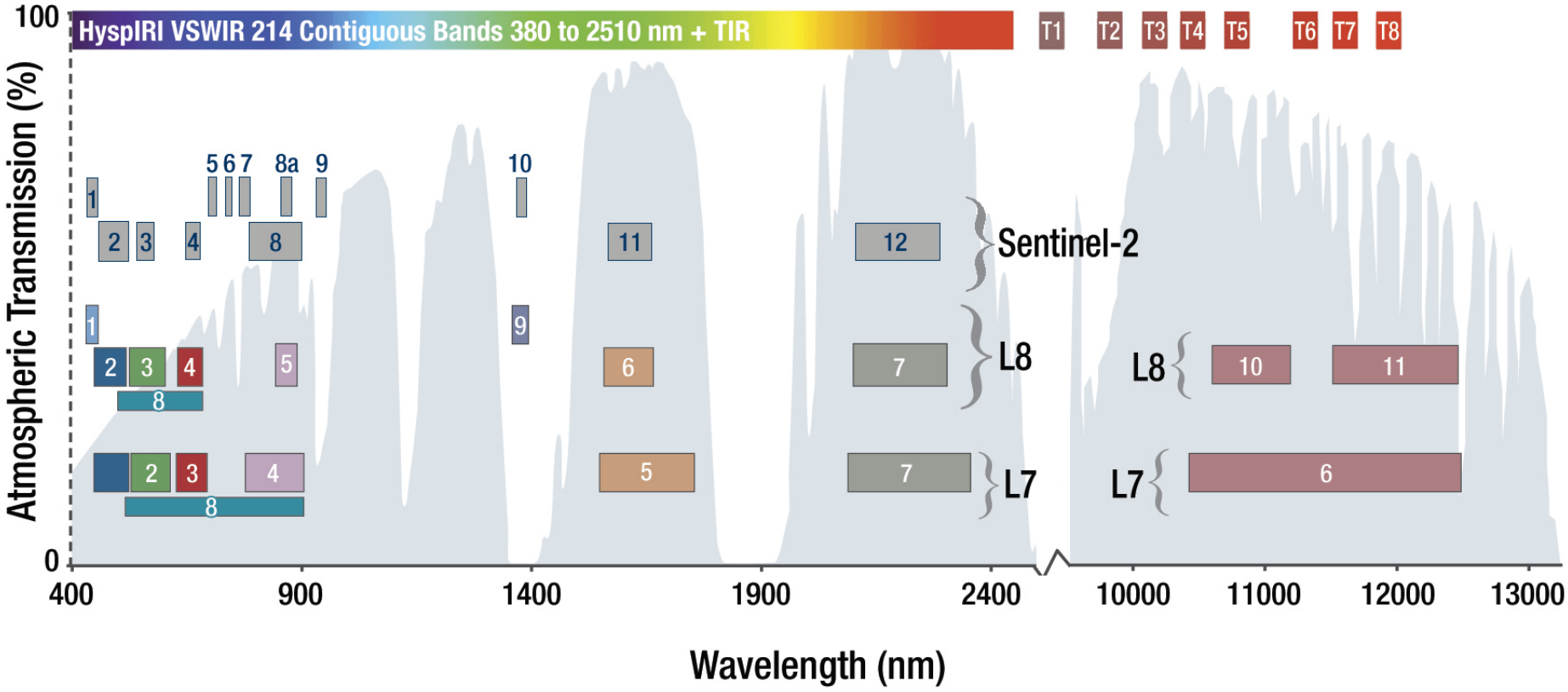
Northwest Sardinia



So. France, No. Italy

- Open data availability agreement w/EU in final stages: NASA, NOAA, USGS; State Dept. signs
- NASA has solicited and selected research investigations for multi-system data fusion products

Land Imaging Sensor Spectral Ranges/Bands



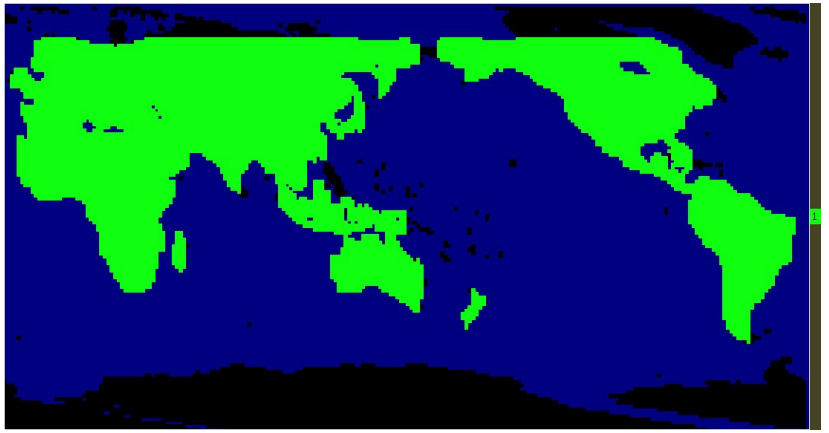
Sentinel-2 and other planned international missions do not acquire Thermal IR measurements

Landsat On-Orbit Status

- Landsat 7
  - Launched in 1999
  - Scan Line Corrector instrument hardware failure in 2003 resulted in a loss of 22% of each Landsat 7 scene
  - Collecting ~475 scenes per day; ~22% of pixels missing per scene (faulty scan-line corrector)
  - L7 collection strategy modified to concentrate on continental coverage (L8 capturing islands and reefs)
  - Expected to be decommissioned in 2020 (potential extension by an additional 24 months beyond 2020 if science is still valuable from data acquired earlier than 0930 MLT)
- Landsat 8
  - Launched in February 2013
  - Operational Land Imager (OLI; the 30m resolution, multi-spectral instrument) operating superbly
  - Thermal Infrared Sensor (TIRS) experiencing a stray light problem in one of two channels; also now operating on redundant hardware
  - Currently collecting 725 scenes/day (exceeding the requirement of 400 scenes/day)
  - Fuel could last ~20 years based on operational consumption to date

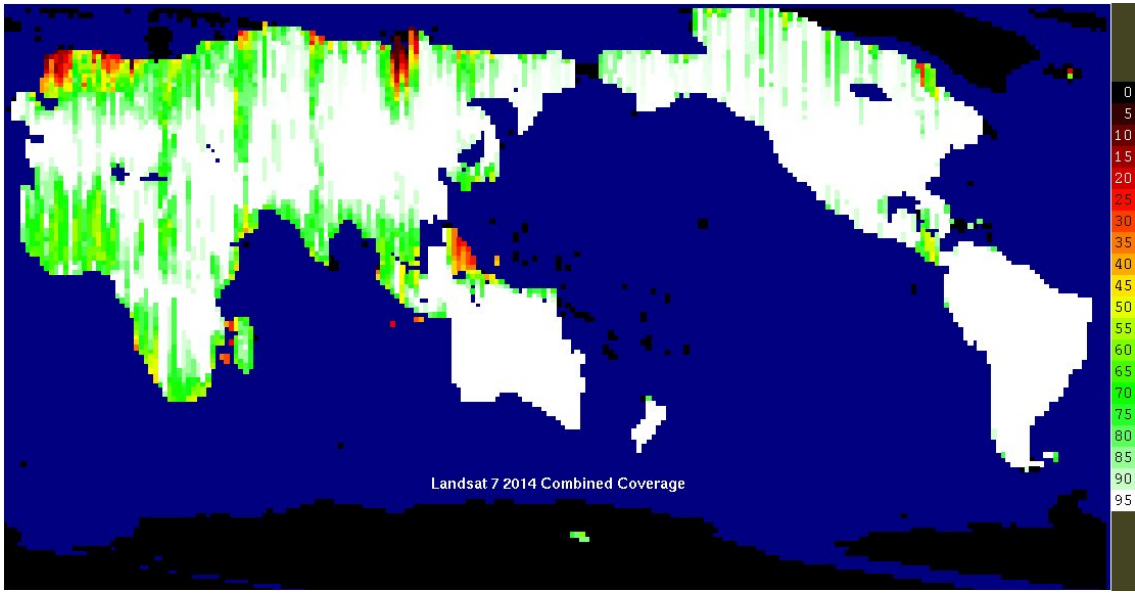
Landsat 7 Current Status

- **Acquire only continental land masses**
  - Minimize revisit time
  - Maximize interval lengths
  - Exclude many islands, Antarctica, Greenland, and row 9 and above



- **No daily limits**

Currently acquiring ~470 scenes/day!

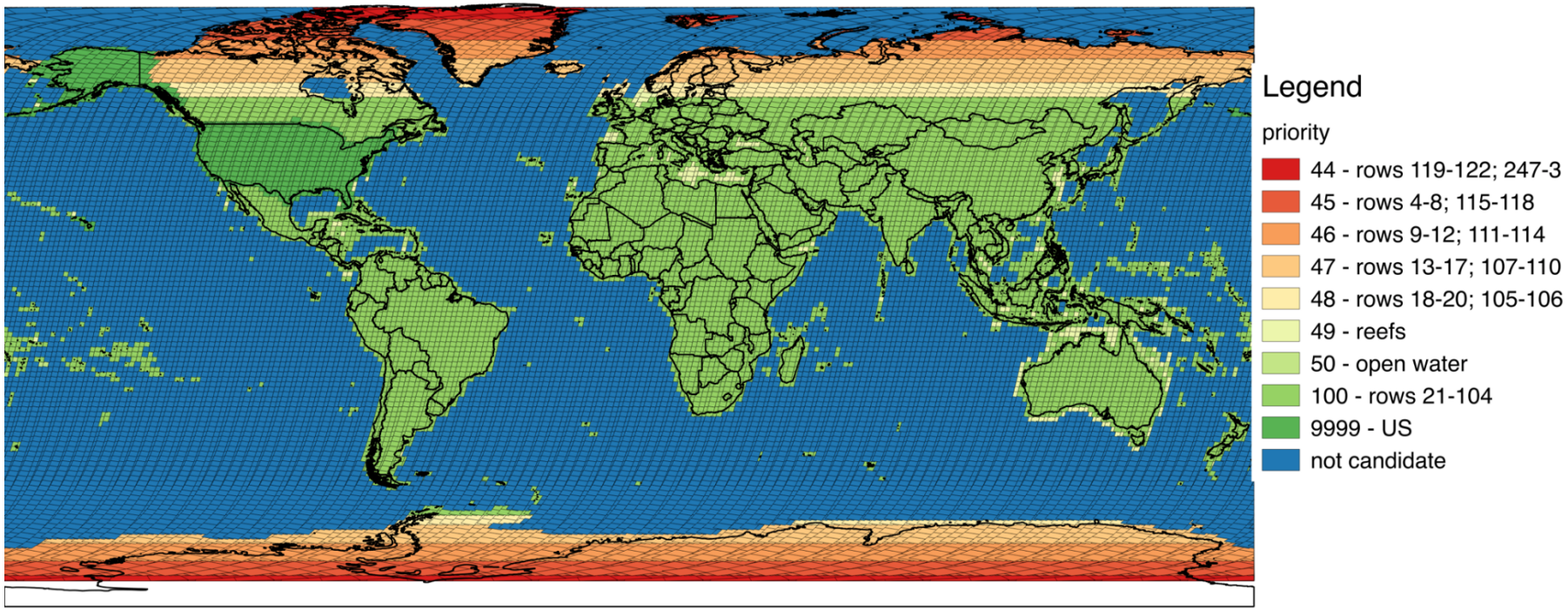


Fraction of CY2014 acquisitions

USGS

Landsat 8 – Acquisition Priorities

Seasonality 6 May 2015

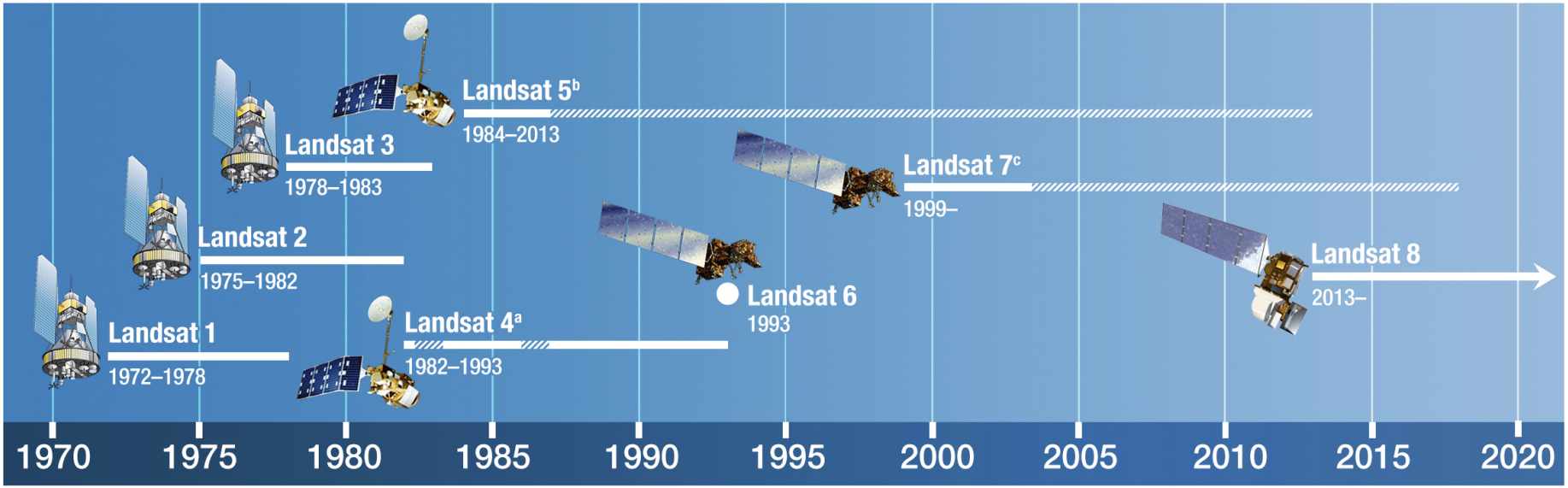


USGS

Sustainable Land Imaging 2016 - 2035

FY14, FY15 President's NASA budgets called for design and initiation of an affordable, ***sustained,*** Land Imaging Satellite System (with USGS) to extend the Landsat data record for decades – not just the "next mission"

NASA (w/USGS) Sustainable Land Imaging report produced 9/2014



[a]Limited data due to transmitter failure soon after launch. Only 45,172 Landsat 4 Thematic Mapper scenes from 1982–1993 available for science users—~10 scenes/day (vs 725 scenes/day from L8)

[b]Data coverage limited to Continental US (CONUS) and International Ground Station sites after a transmitter failure in 1987; Multispectral Scanner turned off in August 1995

[c]Degraded Performance due to Scan Line Corrector failure in May 2003

SLI in FY16 President's Budget Submit

- A 3+1 part program to ensure a world class, sustainable, and responsible land imaging program through 2035:

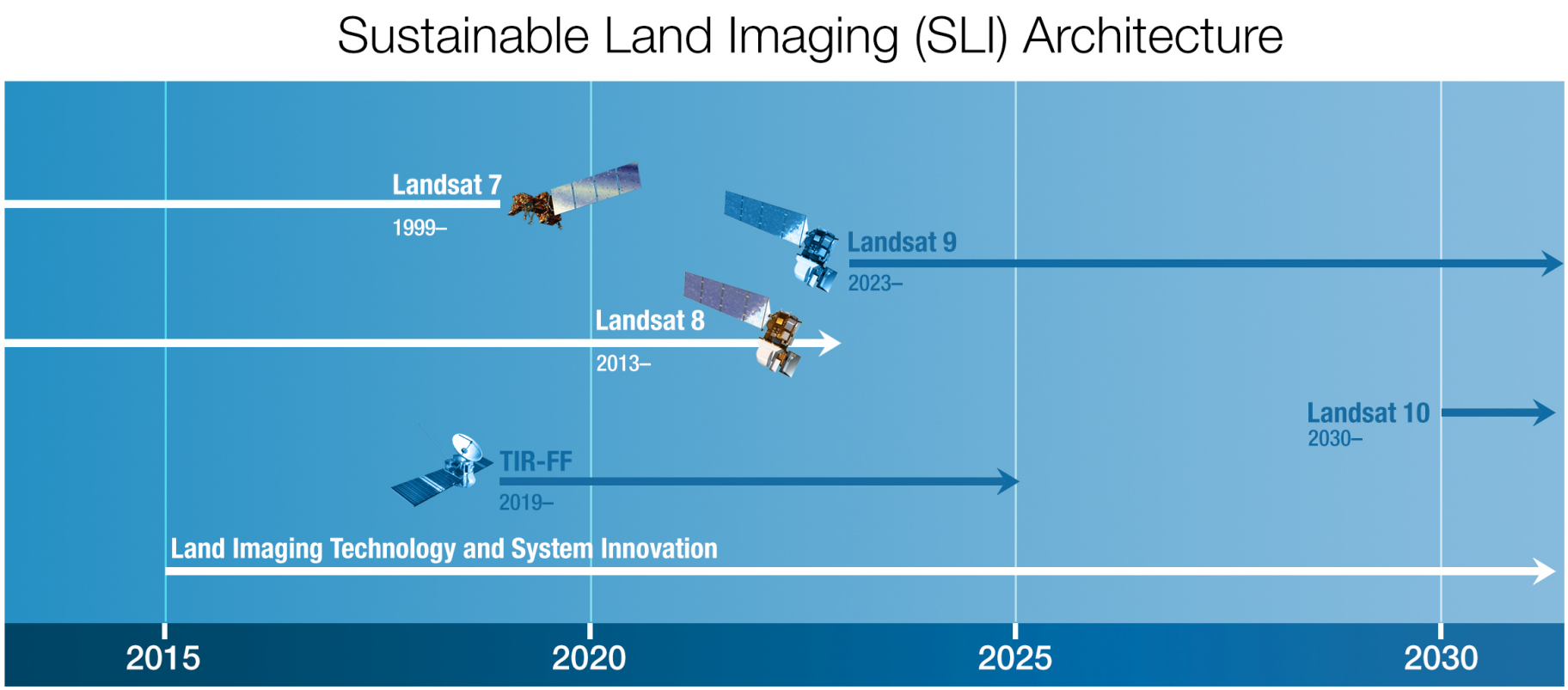
1. **Class D Thermal Infrared Free Flyer** (TIR-FF) to launch ASAP (NLT 2019) and to fly in constellation with a reflective band imager
   - Low cost mitigation against an early loss of the Landsat 8 Class C TIRS, while demonstrating feasibility of constellation flying

2. **Landsat 9** (fully Class-B rebuild of Landsat 8) to launch NLT 2023
   - Low programmatic risk implementation of a proven system with upgrades to bring the whole system to Class B

3. **Land Imaging Technology and Systems Innovation**
   - Hardware, operations, and data management/processing investments to reduce risk in next generation missions

4. **Landsat 10**, Class B full spectrum, to launch ~2030
   - Mission architecture to be informed by the technology investments (2015-), leading to definition ~2020

Landsat Future – FY16 Budget Submit



GRACE Mission Status

GRACE data producing excellent science

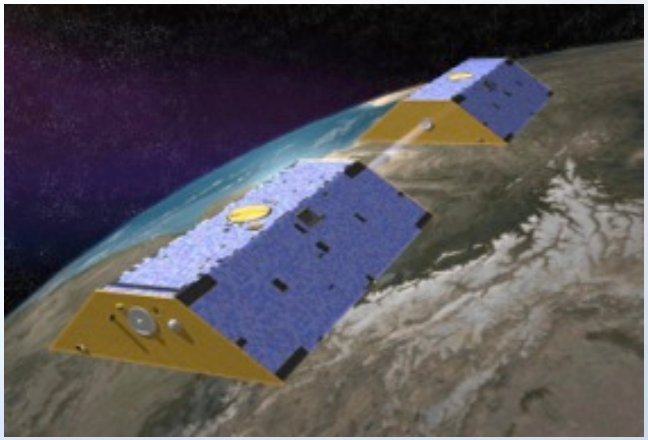
- Launched March 2002, over 12.5 years in orbit
- Time variable gravity observations enable studies in hydrology, oceanography, cryosphere and solid earth sciences.

Mission Life

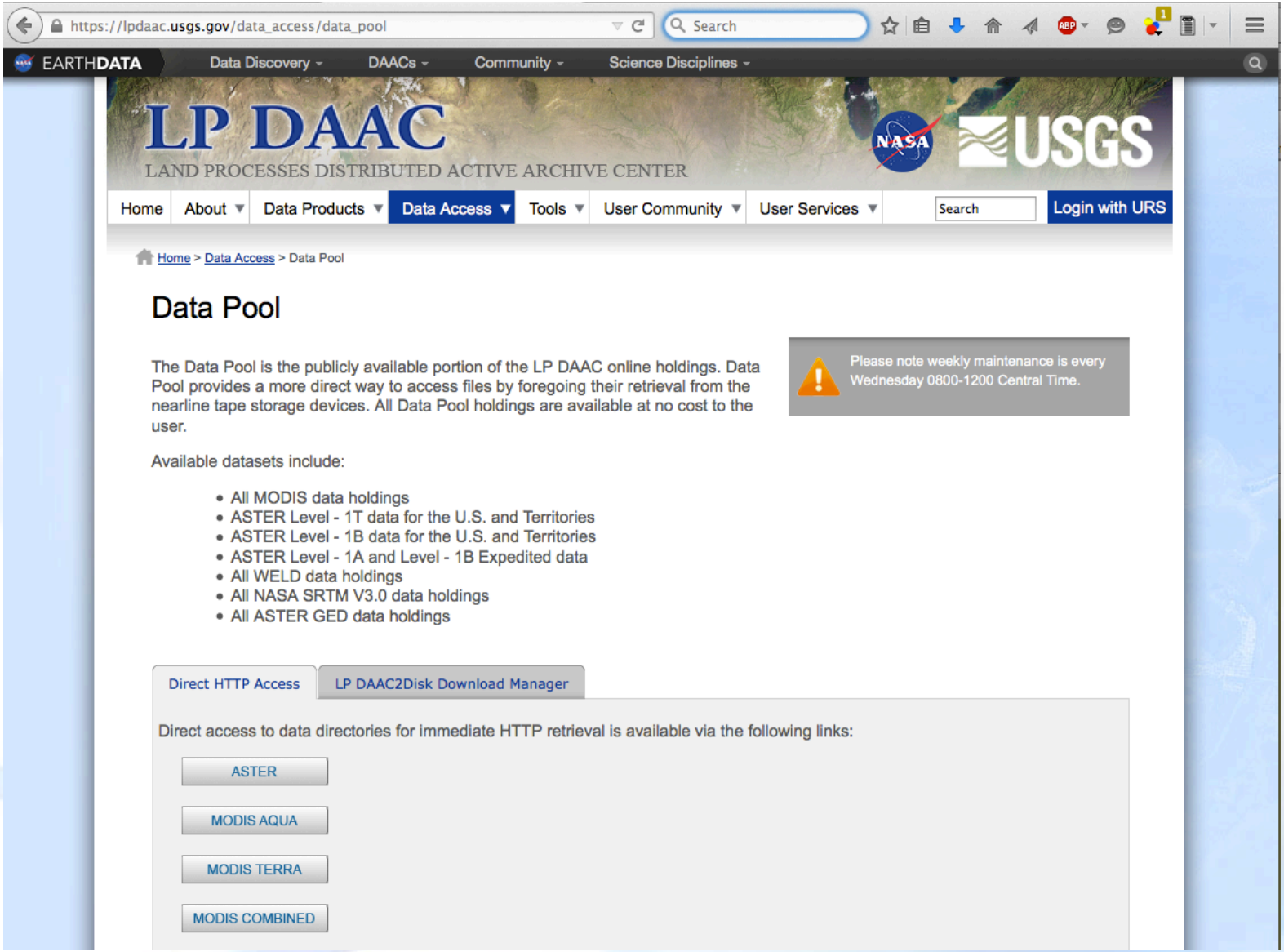
- Adequate satellite resources for continued mission
- Aging components a concern
  - » Recent improvements to battery management strategy have reduced yearly data loss from ~50 days to less than 40 days

Measurement Continuity Prospects

- NASA GRACE FO - 2017
- GRACE 2 - future



Data from NASA Mission Freely Available via Range of Data Services



WATER RESOURCE RESEARCH AND APPLICATIONS FROM

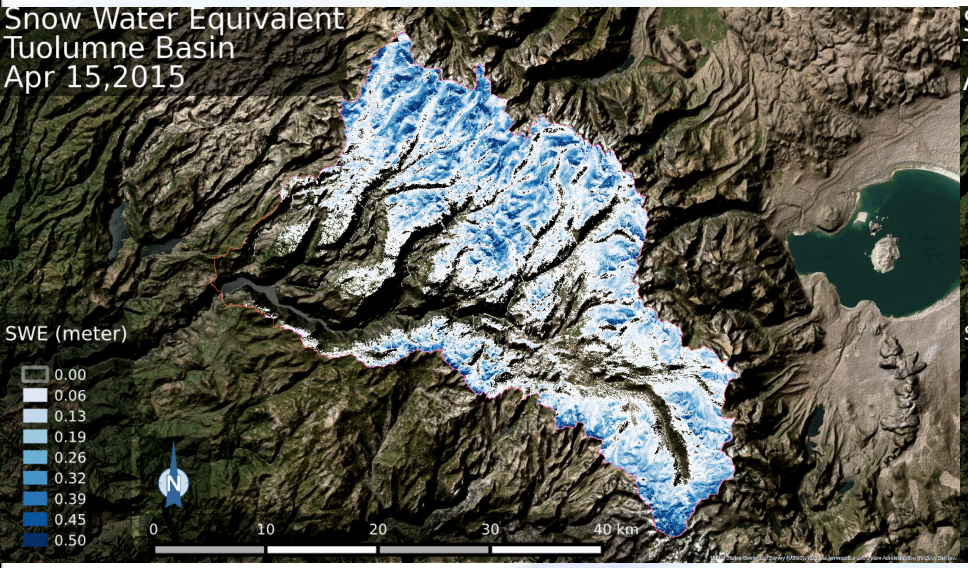
AIRBORNE OBSERVATIONS

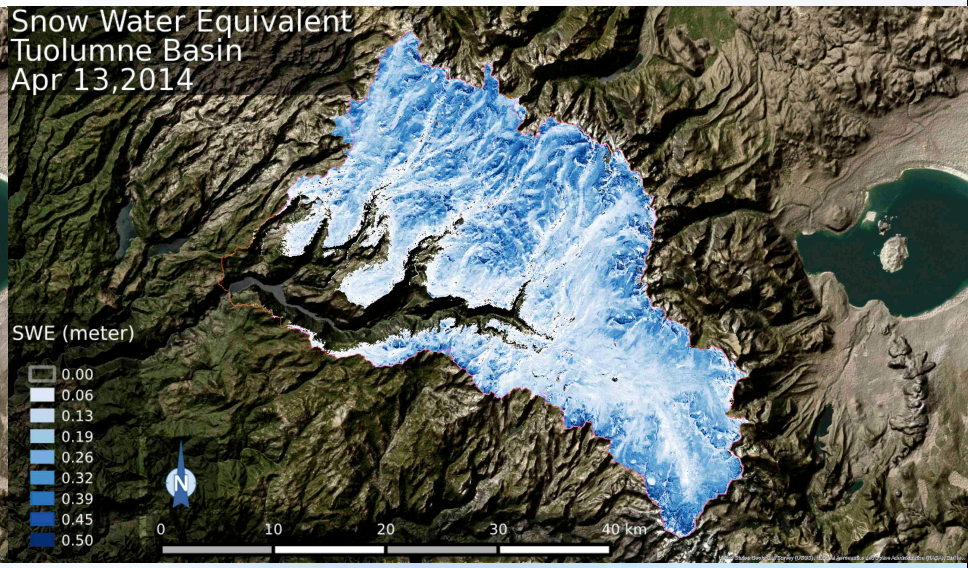
Forecasting Snowmelt Inflow and Timing Airborne Snow Observatory (LiDAR & spectrometer)

Airborne Snow Observatory: fusion of imaging spectrometer and scanning lidar for studies of mountain snow cover

Snow Water Equivalent and albedo at meter-scale resolution for a 300k acre watershed with 24hr latency

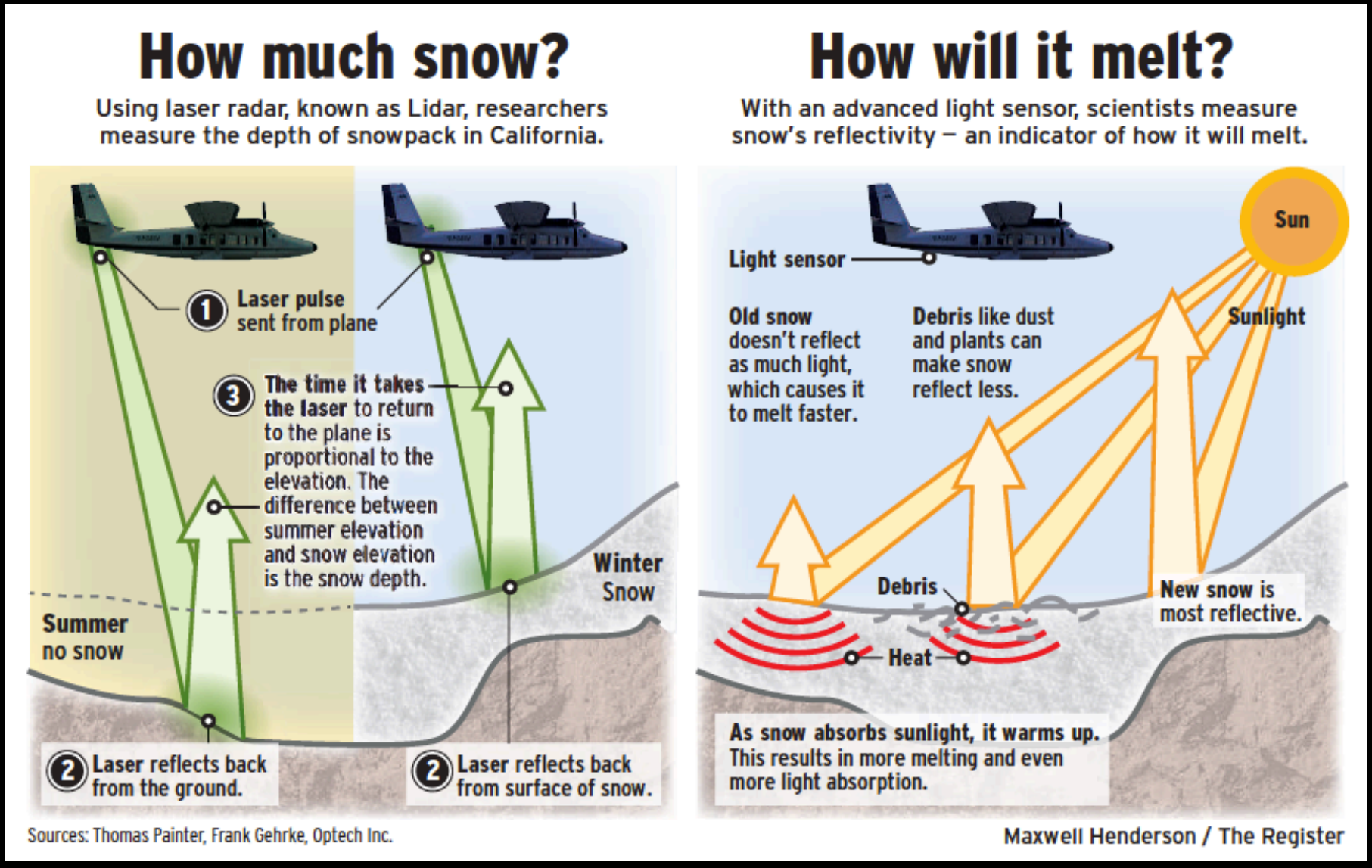
California Tuolumne Snowpack 40 Percent of Worst Year





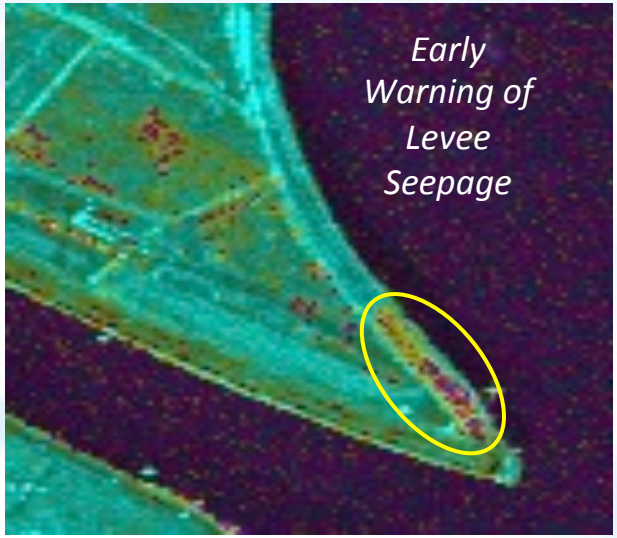
Tom Painter, JPL

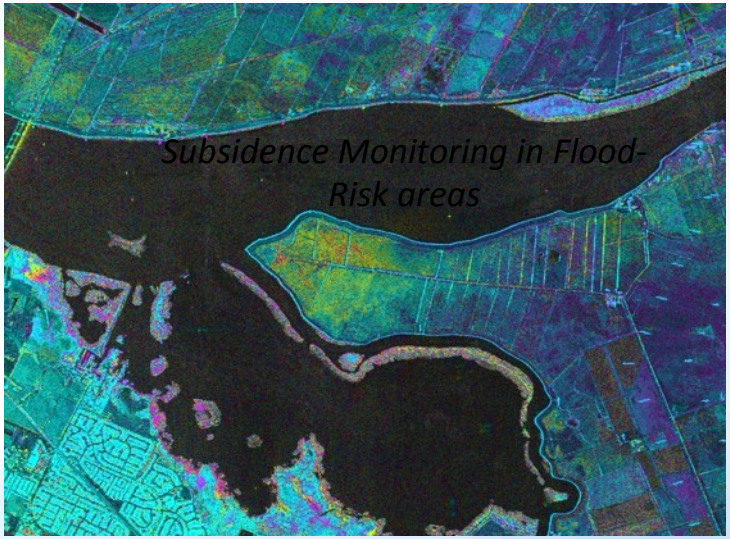
How ASO works



Infrastructure Monitoring & Emergency Response
UAVSAR (L-band Synthetic Aperture Radar)

UAVSAR flights image the Sacramento-San Joaquin Delta every ~6 weeks to monitor levy integrity and measure subsidence



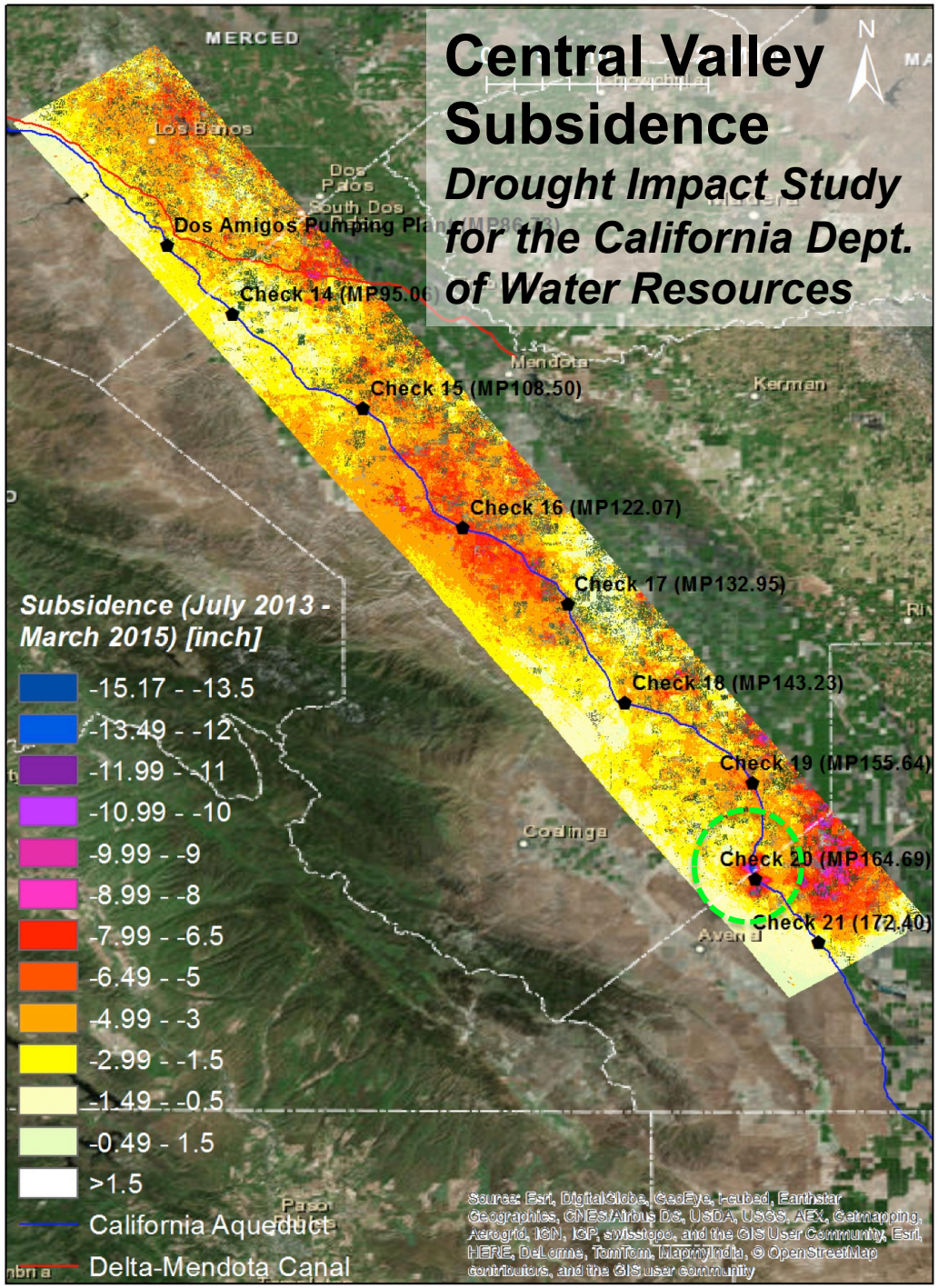


Pixel size ~ 20 ft

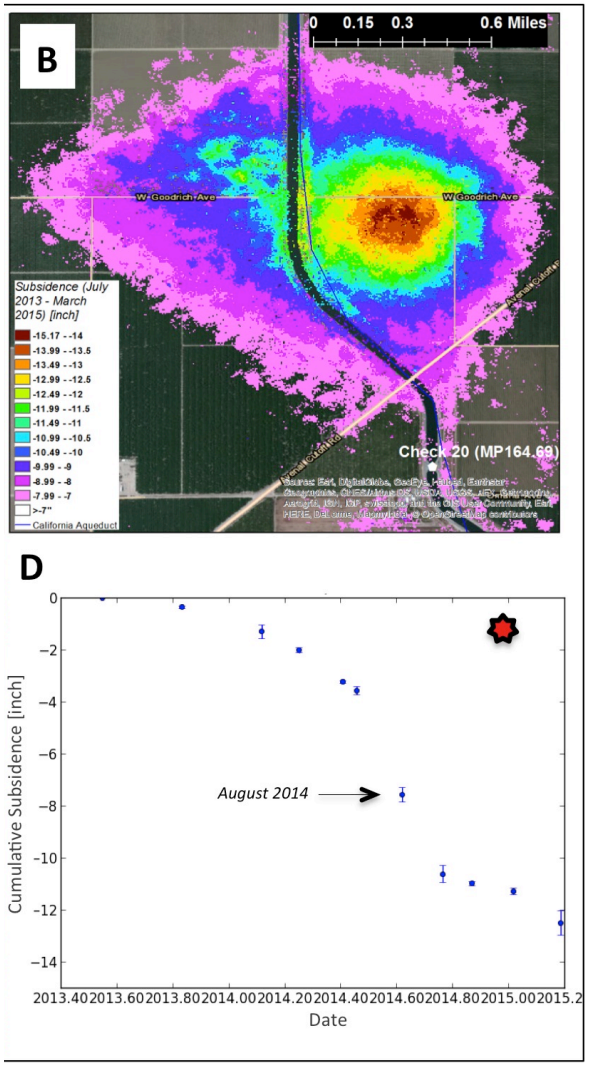
Cathleen Jones, JPL

Central Valley Subsidence

Drought Impact Study for the California Dept. of Water Resources



Highest subsidence directly affecting the California Aqueduct:

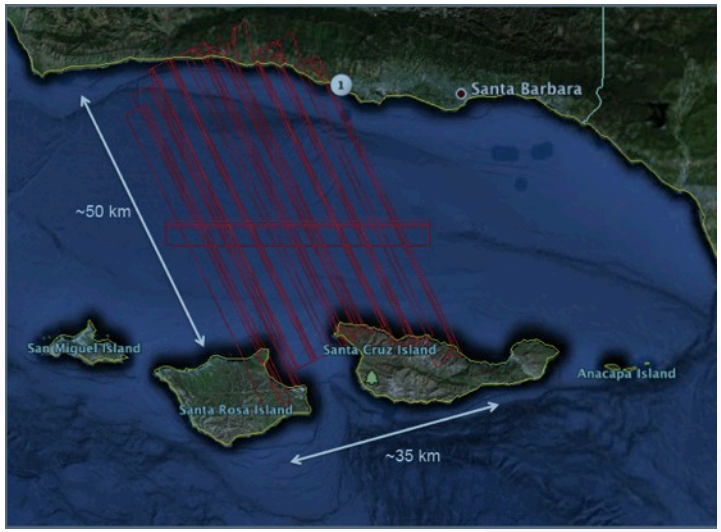


A 1.3 mile stretch of the California Aqueduct experienced >8" of subsidence, with maximum of 13" at the stretch closest to the center of the subsidence feature.

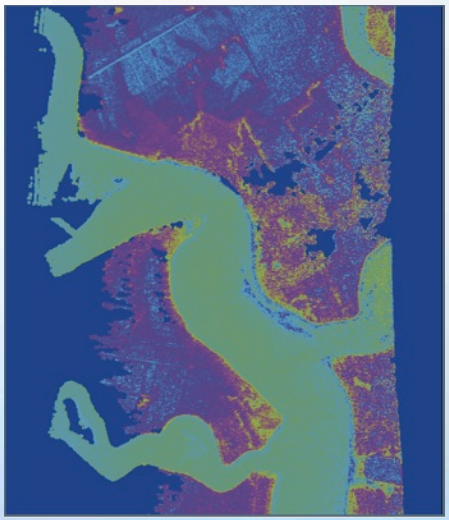
Mission Studies (Applications Oriented)

AirSWOT: Successful campaigns

- First flight; April 2013 – system check
- Second flight; May 2013, 2 days each at;
  - Santa Barbara Channel
  - Sacramento River
  - Sacramento-San Joaquin River Delta
  - AltiKa underflight
  - Yosemite/Hetch Hetchy reservoirs
- Large amount of data collected with supporting ground truth.
- Will provide invaluable information for SWOT
- Data system; encourage development to support/ promote applications
- Future AirSWOT planned campaigns are:
  - French hydrology deployment (2014)
  - Alaska rivers & lakes (2015)
  - Early discussions on Mekong River campaign



Santa Barbara Channel

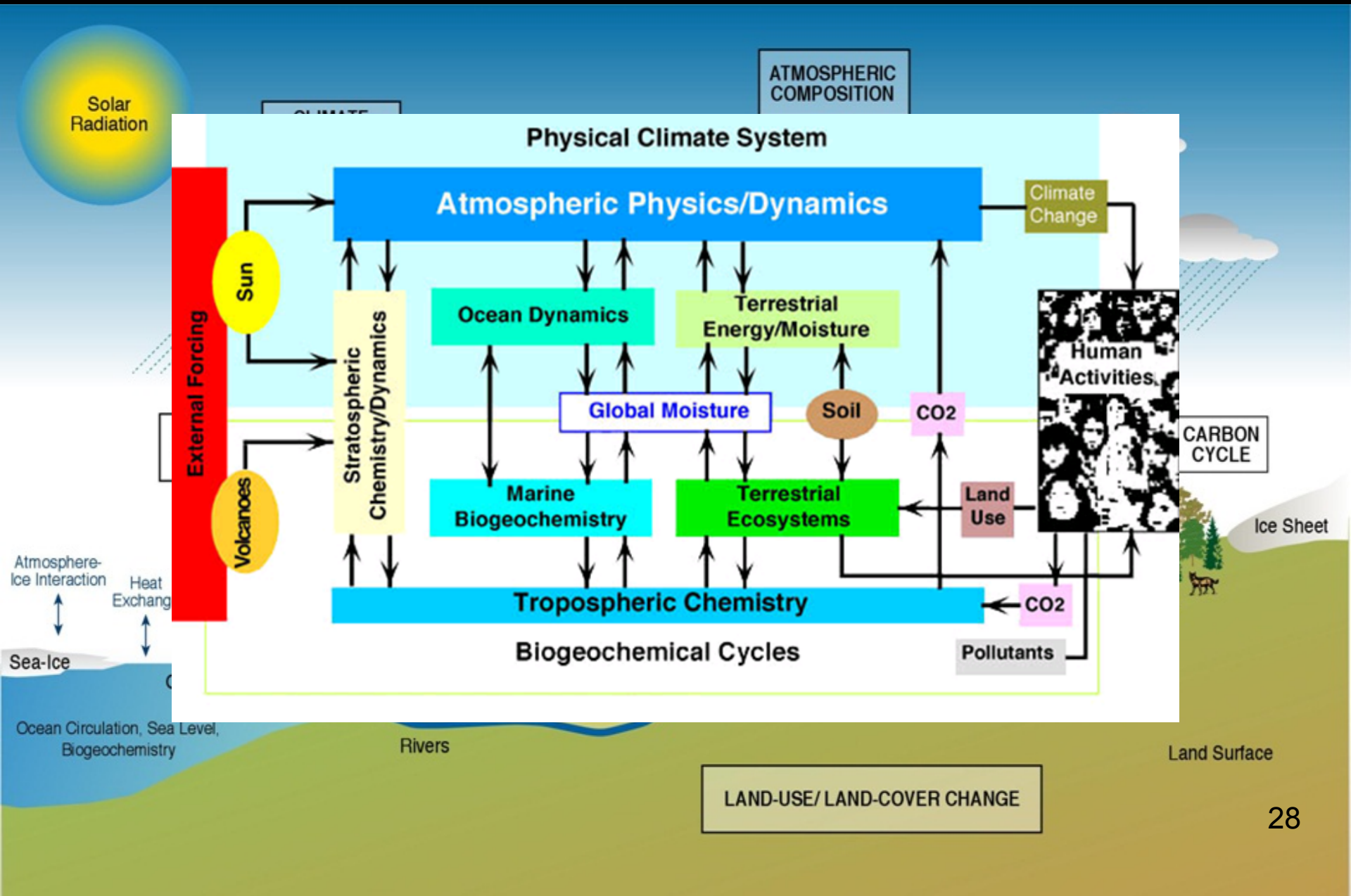


Sacramento Delta

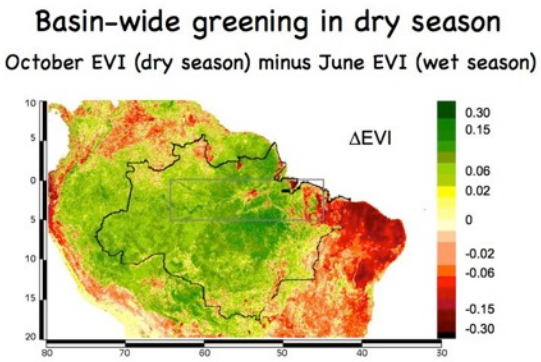
WATER RESOURCE RESEARCH AND APPLICATIONS FROM

RESEARCH AND ANALYSIS PROGRAM

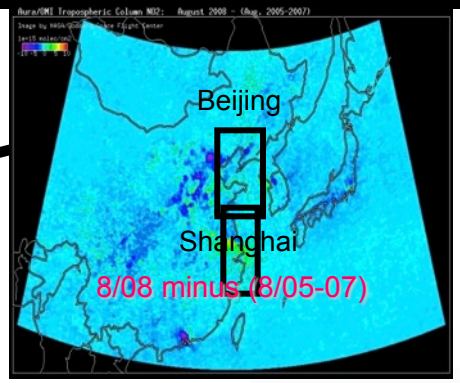
Earth as a Complex Inter-related System



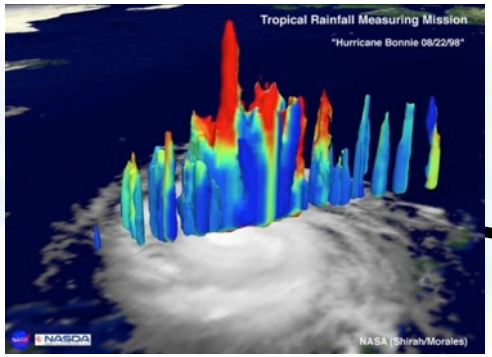
Earth Science Focus Areas



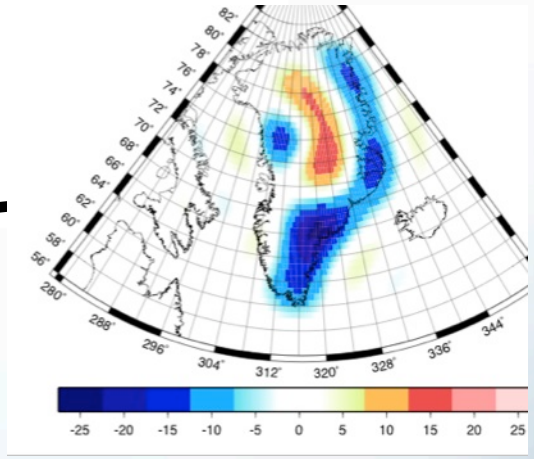
Atmospheric Composition



Carbon Cycle and Ecosystems

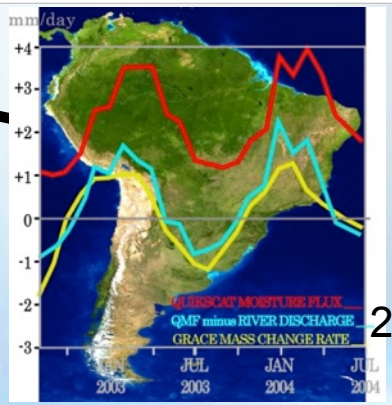


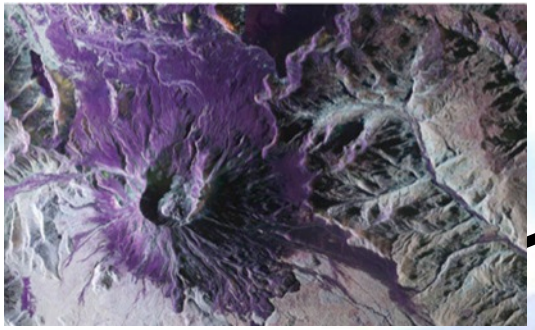
Climate Variability and Change



Weather

Water and Energy Cycle





Earth Surface and Interior

WATER RESOURCE RESEARCH AND APPLICATIONS FROM

APPLIED SCIENCES PROGRAM

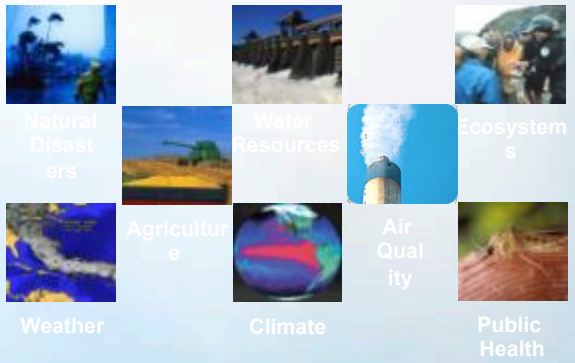
NASA Applied Sciences Program
A Pathway Between Earth Science & Society

Results of NASA Earth Science Research

Uses by Partners and Stakeholder Communities

NASA Applied Sciences Program

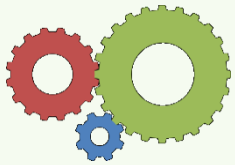
GEOSS Societal Benefit Areas



Applied Sciences: Lines of Business

Applications in Mission Planning

Identify applications early and throughout mission lifecycle, integrate end-user needs in design and development, enable user feedback, and broaden advocacy.



Societal & Economic Applications

Generate, test, develop, enable adoption, and extol applications ideas for sustained uses of Earth obs. in decisions and actions.

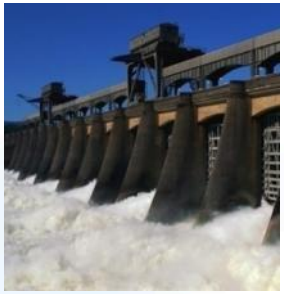
Capacity Building

Build skills, workforce, and capabilities in US and developing countries to apply Earth obs. to benefit society and build economies.

Application Program Elements

Emphasis in 4 Applications Areas

Health & Air Quality



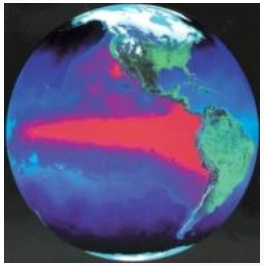
Water Resources

Disasters

Ecological Forecasting

Support opportunities in 5 additional areas

Agriculture



Climate

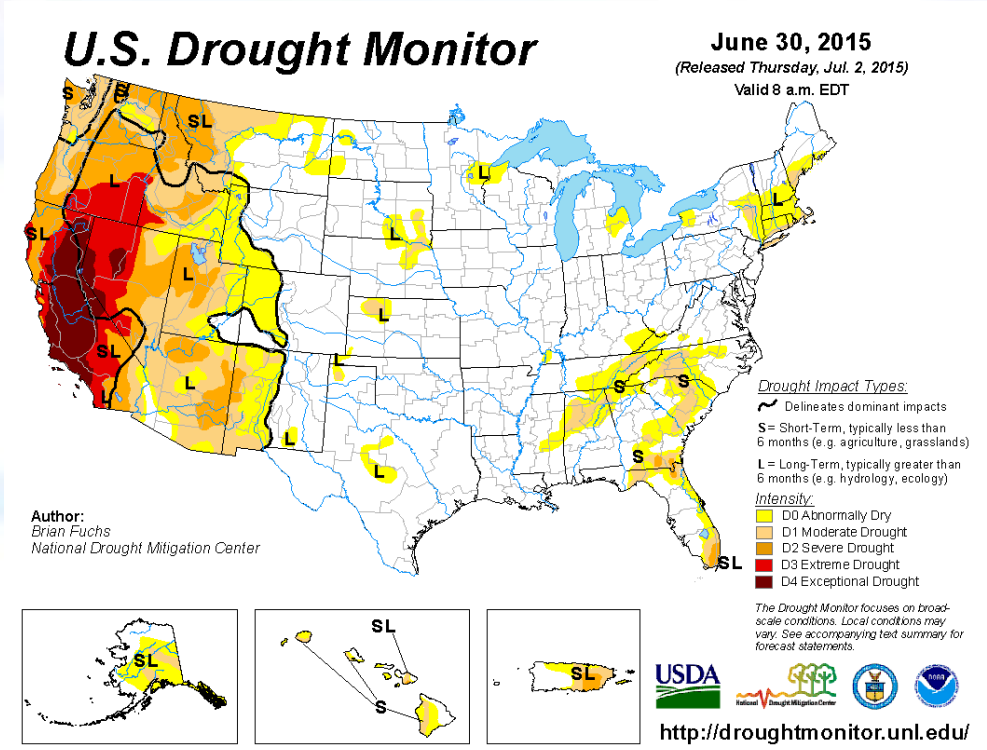
Weather

Energy

Oceans

NASA Water Resource Applied Sciences

The NASA Water Resources Program Element:
The Water Resources Program Element addresses concerns and decision processes that are related to water availability, water forecast, and water quality. The goal of the Water Resources Program Element is to apply NASA satellite data to improve the Decision Support Tools (DSTs) of user groups that manage water resources. Implementation requires close and enduring partnerships with Federal agencies, academia, private firms, and international organizations.



Water Resources Projects:

Projects are tactical implementations led by Principal Investigators, driven by water management challenges, and ultimately sustained by water resource information stakeholders.

Programmatic Activities:

National and international activities to improve skills, share data and applications, and broaden the range of users who apply satellite data and Earth science in water resource decisions.

NASA Water Resource Applied Sciences

Applied Sciences Program

Home (Start here) | About (Our Mission) | News (What's happening) | Projects (Learn more) | Community (Collaborate) | Resources (More info) | Events | Login / Register

NASA Applied Sciences Program
Water Resources

Earth Science Serving Society

The goal of the ASP Water Resources application area is to apply NASA satellite data to improve the decision support systems of organizations and user groups that manage water resources. The ASP Water Resources application area partners with Federal agencies, academia, private firms, and international organizations.

LEARN MORE

https://c3.nasa.gov/water/

Welcome to the NASA Applied Sciences Program Water Resources Application Area

NASA-USDA MOU signing at Ames

On July 16, 2015, USDA Deputy Secretary Krysta Harden and NASA Deputy Administrator Dava Newman announced a collaboration to improve agricultural and Earth science research and its application in agricultural decision-making, and inspire young people to pursue careers in science, technology, engineering, mathematics and agriculture.

This agreement will help facilitate partnerships to:

- provide the USDA with increased access to NASA satellite data to assess agriculture threats (e.g. fire, drought),
- expand cooperation on space-borne remote sensing efforts to gather soil moisture data,
- promote sharing of NASA satellite data for crop health and harvest estimates,
- improves data sharing between USDA and NASA for disasters such as drought and floods,
- promotes STEM and agriculture to younger generations,
- among other on-going and new activities.

ROSES 2011& 2013 NASA Water Resources Projects

PI	Title	Parter Organization
AGHAKOUCHAK	Advancing Drought Onset Detection and Seasonal Prediction Using a Composite of NASA Model and Satellite Data	CA Department of Water Resources
BOLTEN	Enhancing the USDA Global Crop Production Decision Support System with NASA Soil Moisture Active Passive (SMAP) Satellite Observations	USDA FAS
DAY	Advancing Water Supply Forecasts in the Colorado River Basin for Improved Decision Making	NOAA NWS, Colorado Basin RFC
GEBREMICHAEL	Optimizing Reservoir Operations for Hydropower Production in Africa through the use of Remote Sensing Data and Seasonal Climate Forecasts	National Meteorological Agency of Ethiopia
HOSSAIN	Towards Operational Water Resources Management in South Asia Exploiting Satellite Geodetic and Remote Sensing Technologies	Multiple stakeholders in region
JACOBS	Satellite Enhanced Snowmelt Flood Predictions in the Red River of the North Basin	NOAA NWS, North Central RFC
PETERS-LIDARD	Predicting Middle Eastern and African Seasonal Water Deficits using NASA Data and Models	USAID, FEWS NET, USACE
RODELL	Integrating GRACE and GRACE Follow On Data into Flood and Drought Forecasts for the Continental U.S.	US Drought Monitor
STANFORD	Decision Support System (DSS) to Enhance Source Water Quality Modeling and Monitoring using Remote Sensing Data	Multiple US Agencies
BIRKETT	The Global Reservoir and Lake Monitor (GRLM): Expansion and Enhancement of Water Height Products.	USDA
DOZIER	Assessing Water Resources in Remote, Sparsely Gauged, Snow-Dominated Mountain Basins	US Army Corps of Engineers
HAIN	Development of a Mult-Scale Remote Sensing Based Framework for Mapping Drought over North America	NOAA / US Drought Monitor
BECKER-RESHEF	Global monitoring of agricultural drought: A contribution to GEO GLAM	USDA FAS
MELTON	Mitigation of Drought Impacts on Agriculture through Satellite Irrigation Monitoring and Management Support	CA Dept. of Water Resources, Western Growers Assoc.
PAINTER	Integration of precision NASA snow products with the operations of the Colorado Basin River Forecast Center to improve decision making under drought conditions	Colorado Basin RFC
ROSENZWEIG	Adaptation Planning for Climate Change Impacts using Advanced Decision Support and Remote Sensing: Irrigated Agriculture in California's Central Valley	USBR
VERDIN	Fallowed Area Mapping for Drought Impact Reporting and Decision Making	USGS, NIDIS
WARDLOW	The Quick Drought Response Index (QuickDRI): An Integrated Approach for Rapid Response Agricultural Drought Monitoring	US Drought Monitor

Snow from Satellite Observations in the Red River of the North Basin

Carrie Vuyovich, CRREL and Jennifer Jacobs, University of New Hampshire

Highlight:

•Satellite instruments show that most of the Red River of the North Basin had lower than average snow water equivalent (SWE) during the winter 2015, but a few areas had higher than typical values.

Relevance:

•SWE data from space are able to differentiate which parts of the watershed might have flood hazards due to large snowpacks.
•Very low snowpacks may indicate drier than normal soils in the spring and challenging growing conditions in agricultural regions.
•Long-term NASA Earth system science observations from space can provide information that allows year to year comparison of snowpacks that will improve flood predictions.

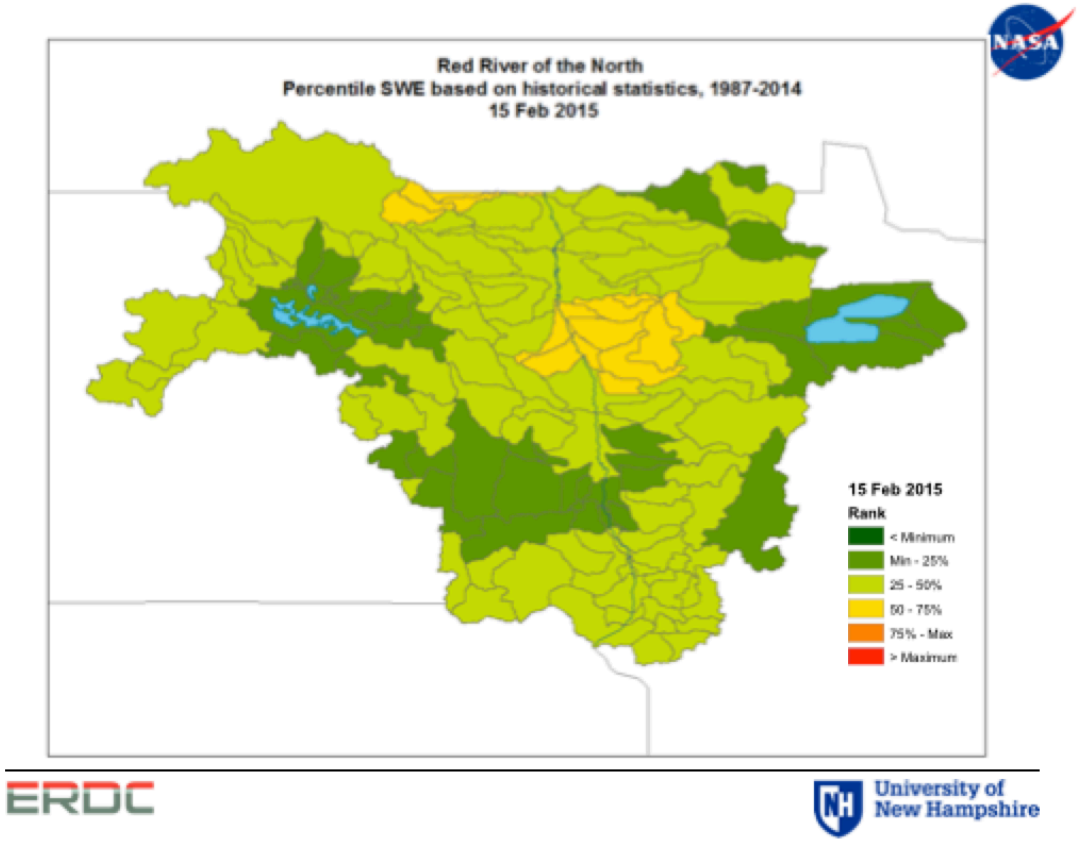


Figure 2: The snow water equivalent (SWE) in the Red River of the North Basin from SSM/I instrument on February 15, 2015 relative to previous years (1987 to 2014) on the same date. Mid-February is typically has the highest snowpack for the season.

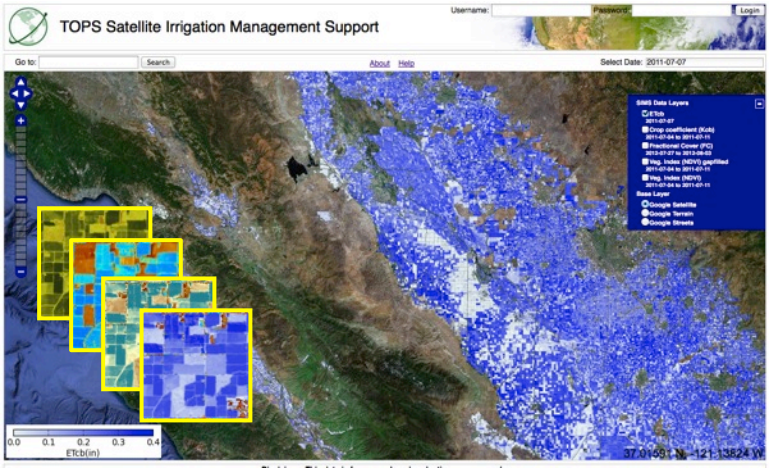
NASA Satellite Irrigation Management Support: Mapping Crop Water Requirements to Assist Growers in Optimizing Water Use

PROJECT TEAM: NASA Ames Research Center, California Dept. of Water Resources, Western Growers Association, California State University, Univ. of California Cooperative Extension, Desert Research Institute, USDA Ag. Research Service, USGS, Booth Ranches, Chiquita, Constellation Wines, Del Monte Produce, Dole, E & J. Gallo, Farming D, Fresh Express, Pereira Farms, Ryan Palm Farms

Terra Satellite

Landsat 8

California agricultural sector produced $46.4b In 2013



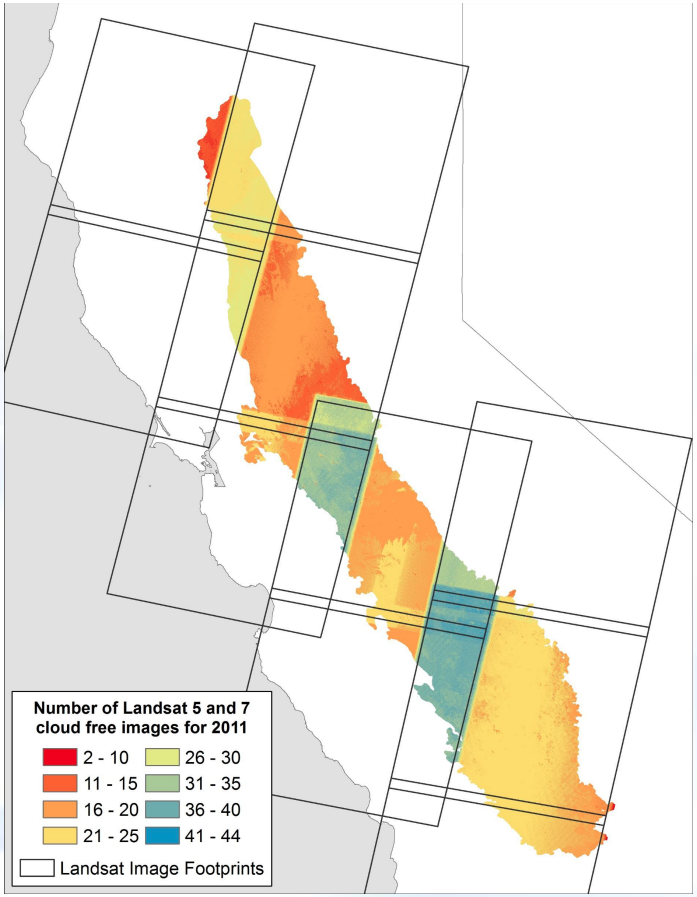
NASA SIMS web and mobile data services puts irrigation demand across 8 million acres of farm land directly into the hands of farmers and water managers

Students work hand in hand with growers to validate the system and quantify benefits

For more information, contact forrest.s.melton@nasa.gov, or visit https://c3.nasa.gov/water/projects/1/

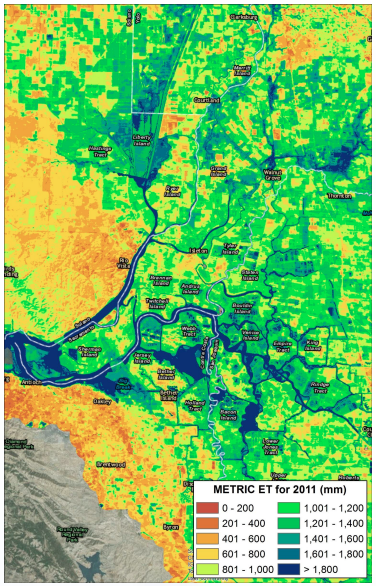
Mapping Crop Consumptive Use (ETa) with METRIC on the NASA Earth Exchange

PROJECT TEAM: Desert Research Institute, NASA Ames Research Center, California State University Monterey Bay

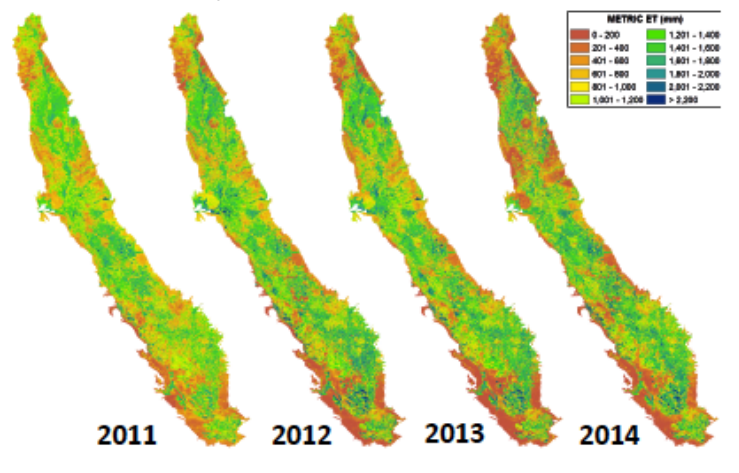


Landsat Scenes over the California Central Valley

California Delta ETa, 2011

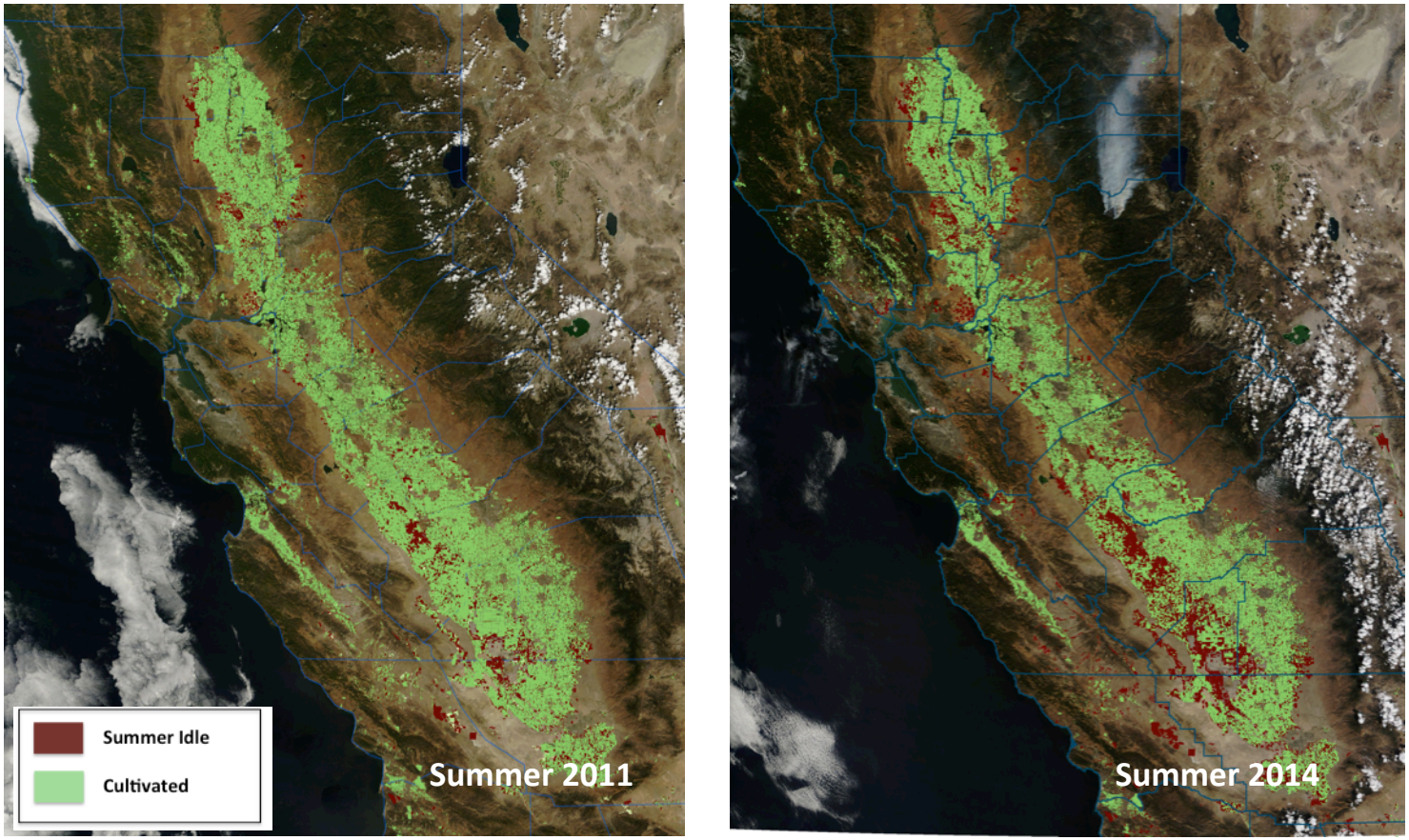


Central Valley ETa, 2011-2014



- Fully automated, python-based implementation on NEX
- Testing Monte Carlo based simulation for hot-cold pixel calibration
- Validating against surface flux measurements collected in CA

Determining the Extent of Fallowed Land with Satellite Imagery

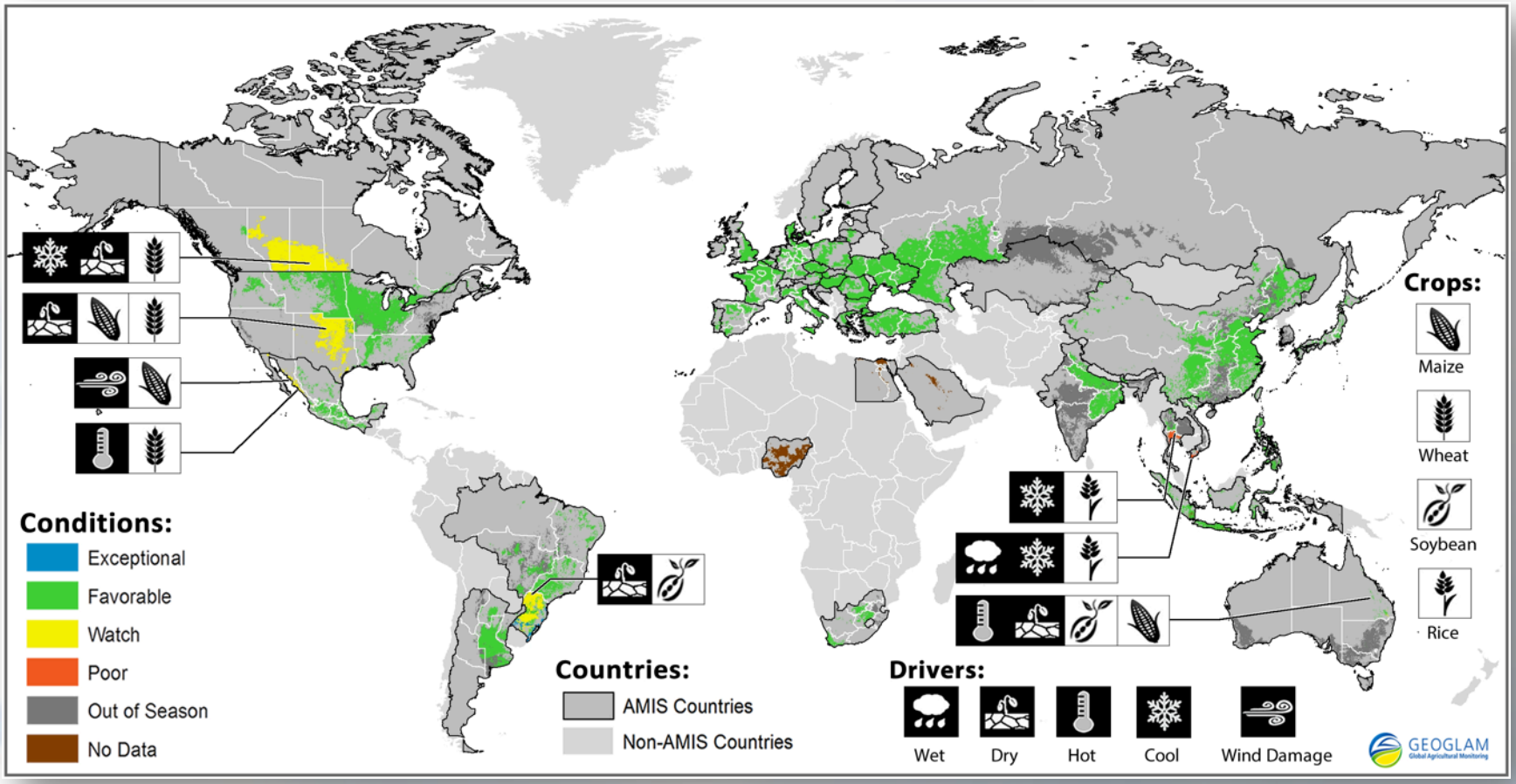


The maps above are based on data from the Landsat 5, Landsat 7, Landsat 8, and Terra and Aqua satellites and show changes in crop cultivation and idle agricultural lands in California in the summers of 2011 and 2014. Brown pixels depict farms and orchards that have been left fallow or "idled" since June 1st in each year. Green pixels are lands still being farmed during the summer growing season. Using 2011 as a baseline, a total increase of 500,000 acres were idled during the summer of 2014 during the drought.

GEO – Global Agriculture Monitoring (GEOGLAM)
PI: Justice/Becker-Reshef (UMD)

Crop Conditions as of April 28th, 2014

Crop Type & Drivers



Crop condition map synthesizing information for all four AMIS crops

Crops that are in other than favorable conditions are displayed on the map with their crop symbol and associated climatic drivers affecting conditions

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

Jeff Dozier, University of California, Santa Barbara &
Robert E. Davis, US Army ERDC

Highlight: Scientists at University of California, Santa Barbara, combine data on snow-cover depletion from MODIS with an energy balance model driven by NLDAS data to reconstruct snow water equivalent (SWE).

- SWE estimates from Reconstruction are more accurate than from the SNODAS model, as shown by comparison with snow pillows and streamflow.
- However, Reconstruction is possible only after the snow is gone, whereas SNODAS analyses are in near real-time.

Relevance: Analyses of the Reconstruction and the model results will enable:

- statistical estimation of patterns similar to Reconstruction, in real-time;
- identification of sources of error in the SNODAS and similar models, and thereby help improve them.

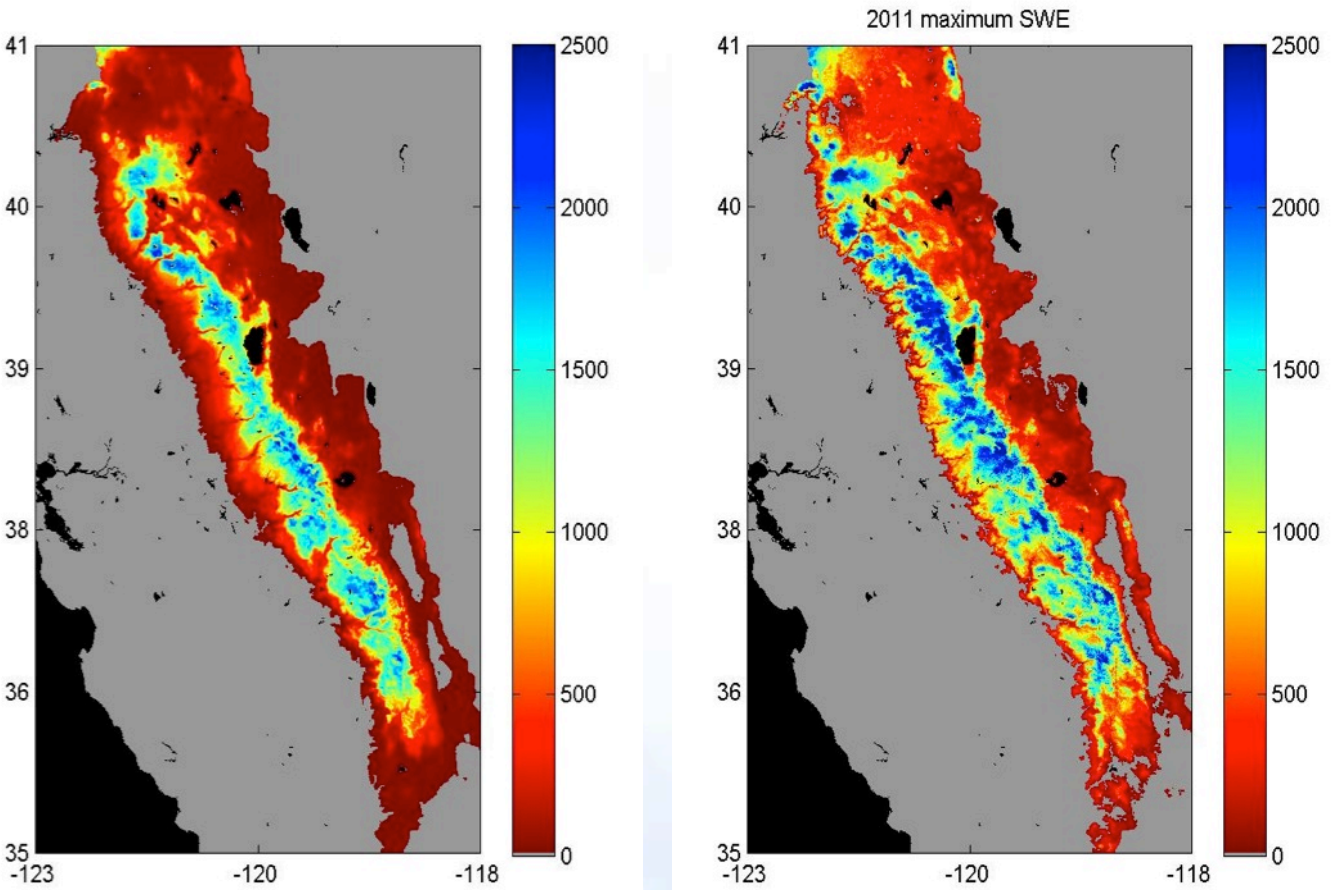


Figure 2. Snow water equivalent (mm) for the Sierra Nevada, California, from (left) SNODAS and (right) reconstruction from MODIS imagery and energy balance modeling.

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

Jeff Dozier, University of California, Santa Barbara &
Robert E. Davis, US Army ERDC

Highlight: Scientists at US Army CRREL analyzed snow water equivalent data from SSM/I, showing the paucity of water in the snowpack before April.

- The official drought warning from UN/IRIN was issued on 21 September, after the harvest had failed.
- An earlier warning would have helped plan humanitarian efforts.

Relevance: Droughts, unlike floods, should not sneak up on us. Earlier warnings of droughts would improve humanitarian operations by the US Army, international organizations, and non-profits.

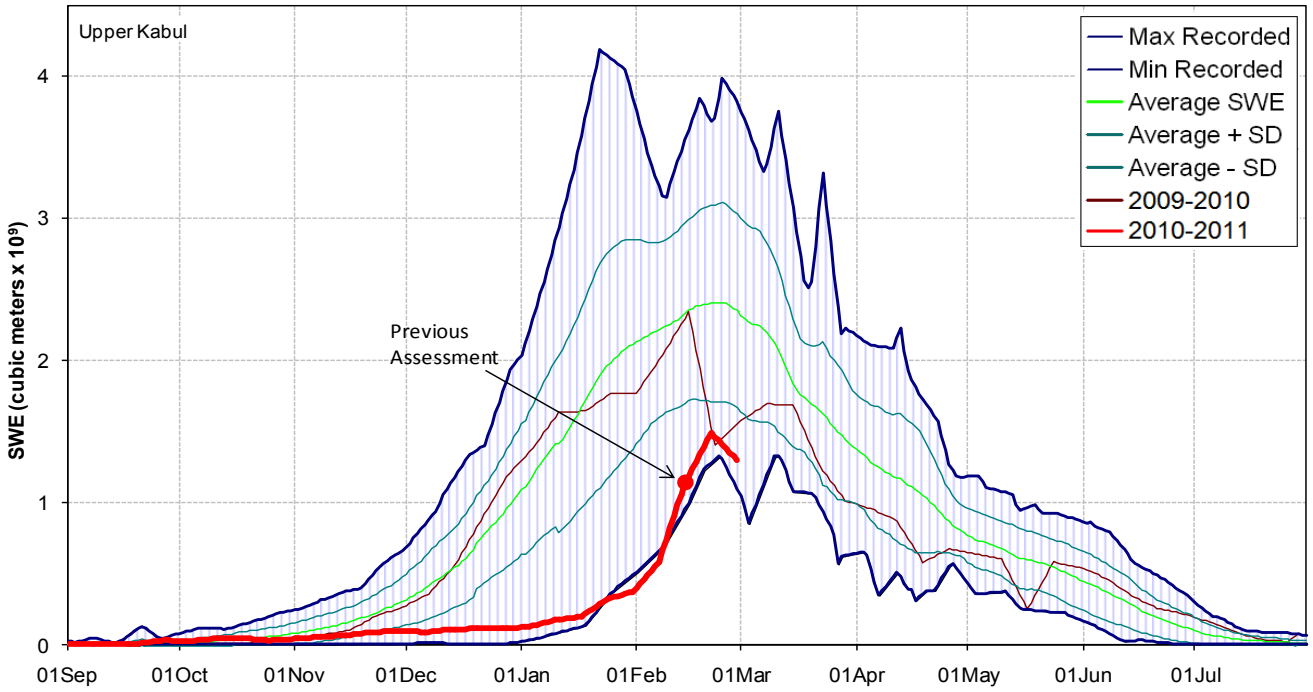


Figure 1. Snow water equivalent for the Upper Kabul watershed, Afghanistan, from SSM/I imagery. The lines show the range of historical values (1978-present), the average ± one standard deviation, and the real-time 2010-2011 data into March. The 2010-2011 data are near the historical minimum, and there was a severe drought in September 2011.

Forecasting and Monitoring Harmful Algal Blooms in Lake Erie

Rick Stumpf, NOAA

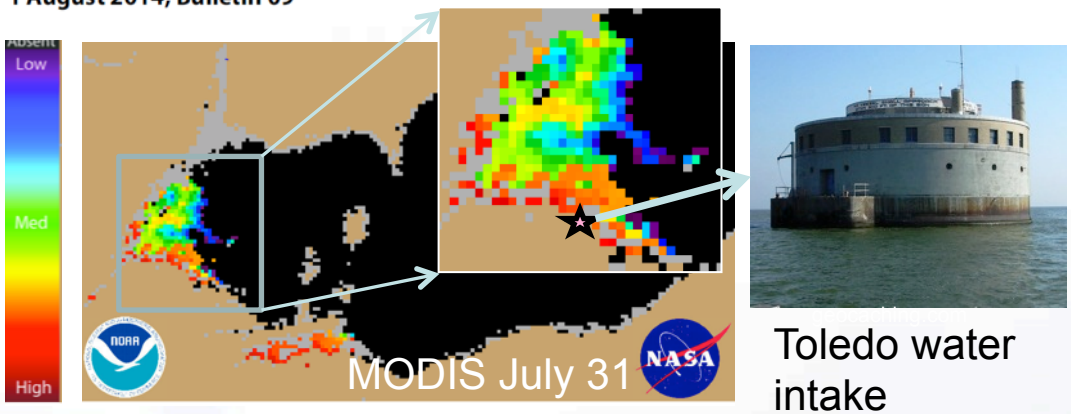
On August 2, 2014, City of Toledo issued "do-not-drink" order for 400,000 people

This project gave Toledo warning to monitor for toxic drinking water and adjust water treatment

Satellite data provide bloom areal extent and density

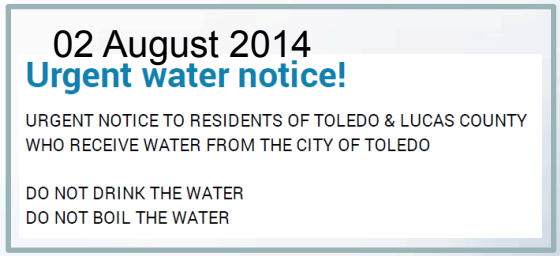
Timeline

Jul 10 Seasonal forecast issued
Jul 17 Bulletin: identifies small bloom
Jul 18 Extra bulletin to OH EPA
Jul 21 OH EPA closes Maumee Bay beaches
Jul 28 Bulletin: bloom along OH coast
Aug 1 Bulletin: bloom intensifies
Aug 2 Toledo finds microcystin in finished water, issues "do not drink"
Aug 4 Bulletin: Bloom further intensifies
Aug 5 Toledo adjusts treatment, reopens water supply

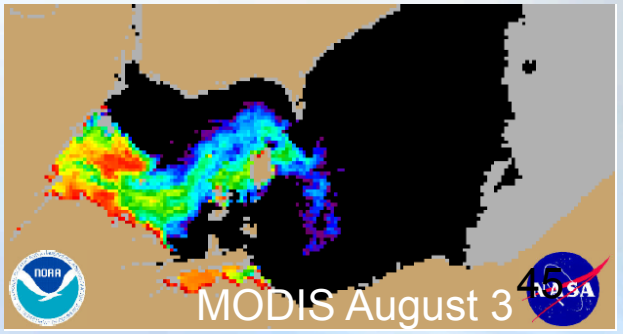


"[The August 1 Bulletin] *put everyone on their toes. The extra vigilance is important for catching blooms in the vicinity of our intakes and beaches."*

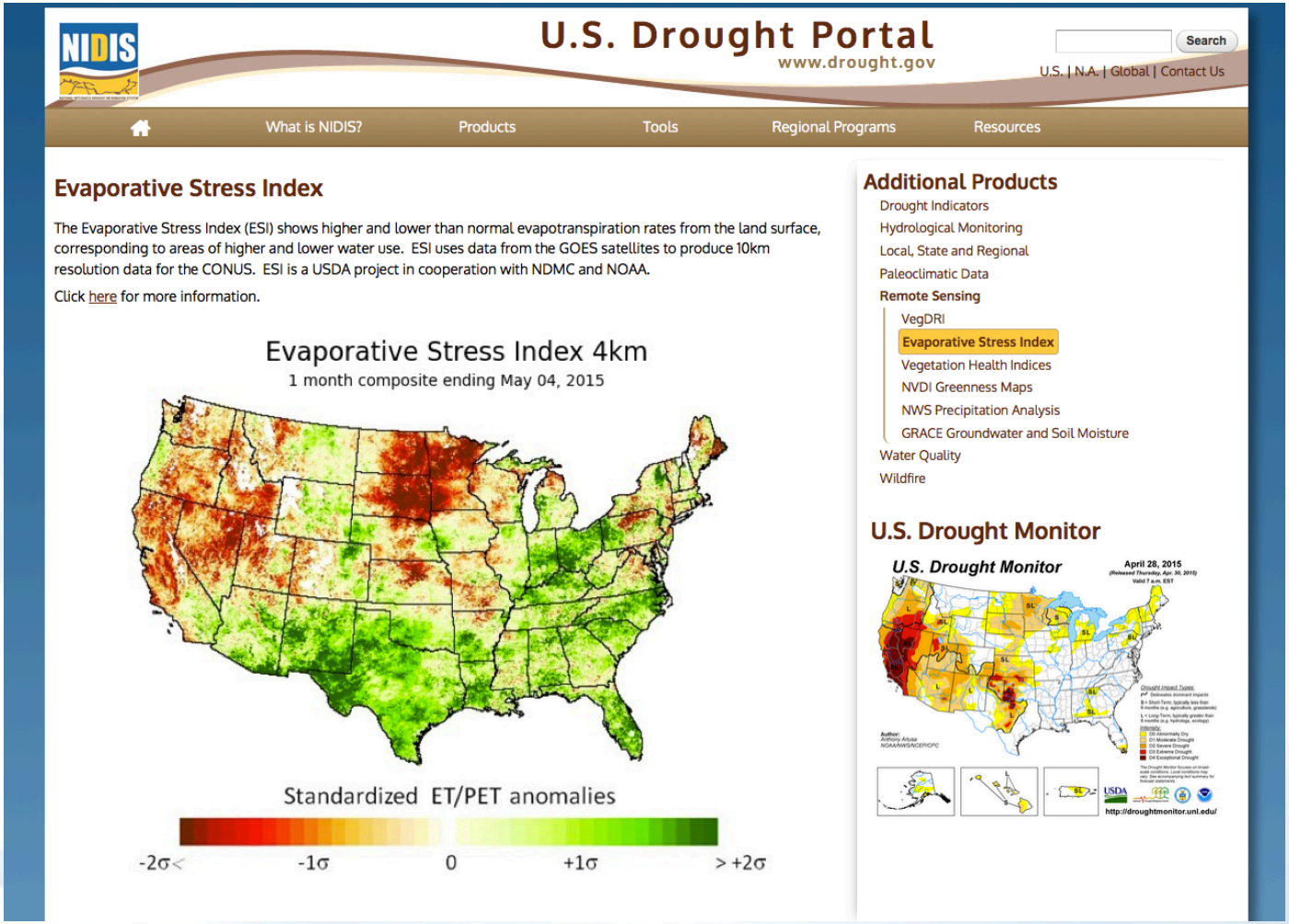
Ohio EPA, August 4, 2014



The bloom has just started: will issue Bulletin twice weekly until end of season in October.



New Data Products for the US Drought Monitor: Evaporative Stress Index



https://www.drought.gov/drought/content/products-current-drought-and-monitoring-remote-sensing/evaporative-stress-index

GRACE Data Assimilation for Drought Monitoring

Rodell / NASA-GSFC

National Drought Mitigation Center

Thursday, August 14, 2014

About Us | News & Outreach | Drought Basics | Monitoring Tools | Planning | Drought for Kids | International | NDMC Photo Gallery

National Drought Mitigation Center

Monitoring Tools 〉 NASA GRACE Data Assimilation

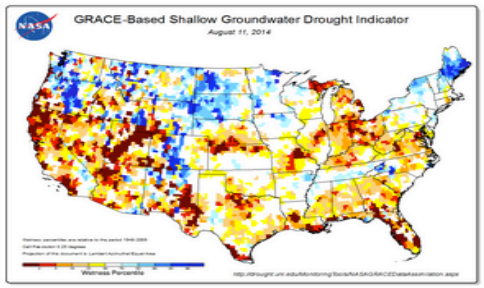
Login

Groundwater and Soil Moisture Conditions from GRACE Data Assimilation

These are experimental products that are still being evaluated and improved. We encourage your specific, constructive feedback as this phase of development proceeds.

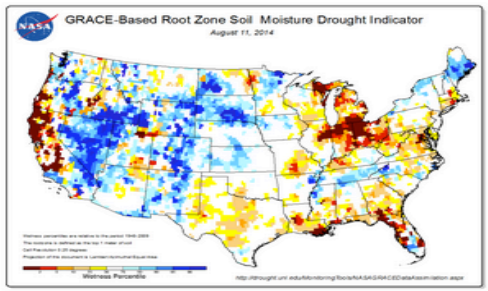
Scientists at NASA's Goddard Space Flight Center generate groundwater and soil moisture drought indicators each week. They are based on terrestrial water storage observations derived from GRACE satellite data and integrated with other observations, using a sophisticated numerical model of land surface water and energy processes. The drought indicators describe current wet or dry conditions, expressed as a percentile showing the probability of occurrence within the period of record from 1948 to the present, with lower values (warm colors) meaning dryer than normal, and higher values (blues) meaning wetter than normal. These are provided as both images and binary data files.

Groundwater Percentile



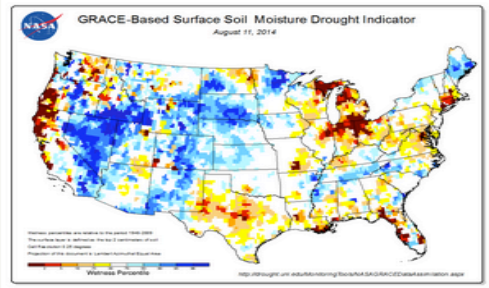
Download image: PDF | PNG

Root Zone Soil Moisture Percentile



Download image: PDF | PNG

Surface Soil Moisture Percentile



Download image: PDF | PNG

47

Non-Technical Description

The maps are based on data from NASA's Gravity Recovery and Climate Experiment (GRACE) satellites, which detect small changes in the Earth's gravity field caused by the redistribution of water on and beneath the land surface. The paired satellites travel about 137 miles (220 km) apart and record small changes in the distance

NASA Support to the Massive Soda Fire, Idaho

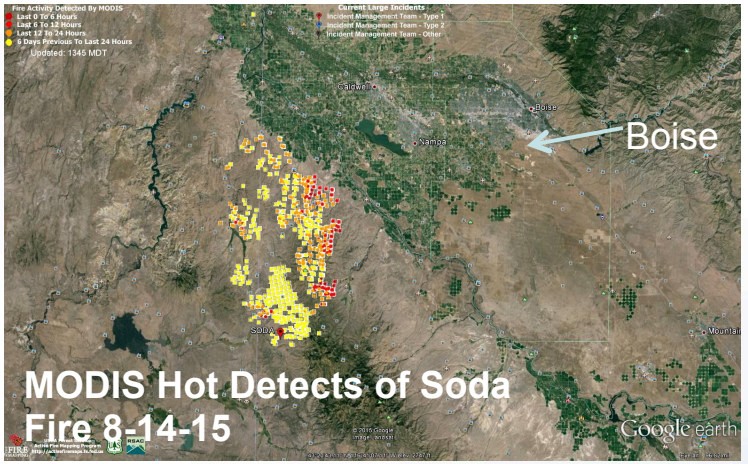
NASA ASP-Funded Project Team – RECOVER, supporting 24/7 operations on Mega-Fire in ID with Fire Modeling Capabilities!!!

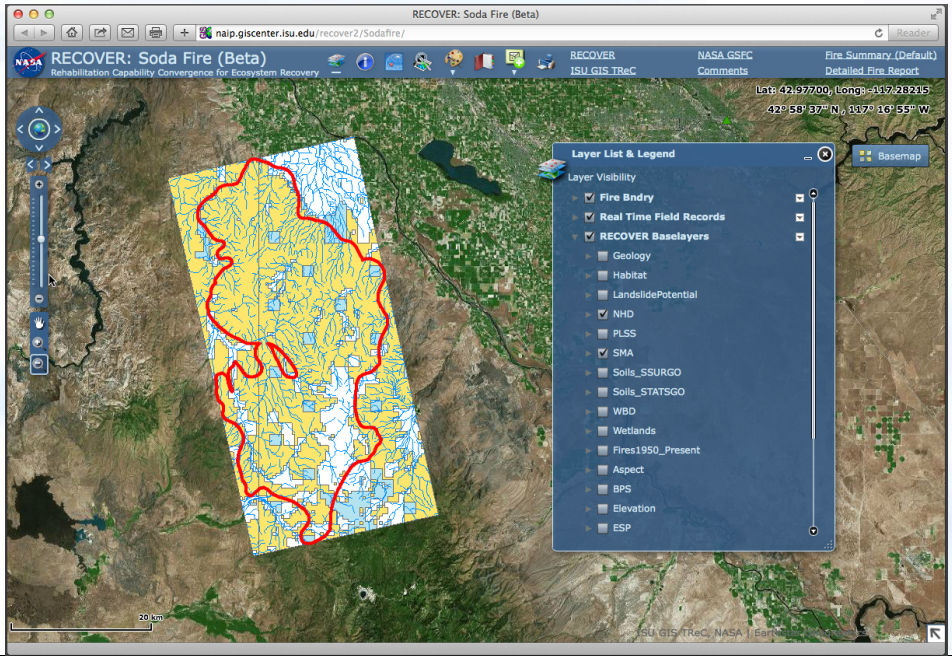
Soda Fire started on 8-10-15

Grew to 78,000 acres by 8-12-15 morn.

Soda Fire grew 586% from 8-12-15 to 8-13-15 (to 218,000 acres)!!!!

RECOVER team requested to support with modeling and geospatial mapping efforts on 8-13-15; continued since.





- **NASA RECOVER supporting Incident managers with real-time tools (NASA satellite data, cloud-enabled, geospatial modeling tools, critical data layers, etc.) to shorten burn area assessments for remediation operations from multiple days to minutes!!**
- **NASA efforts are helping to pinpoint active fire mitigation strategies and post-fire burn conditions for rapid remediation by modeling vegetation cover, terrain, soil, etc.**
- **Team making huge impact on fire management strategy efficiencies and post-burn planning.**


Formulation
Implementation
Primary Ops
Extended Ops
Earth Science Missions and Instruments
Landsat 9, TIR-FF
PACE
NI-SAR
SWOT
TEMPO
JPSS-2 (NOAA)
RBI, OMPS-Limb
Altimetry-FO (Formulation in FY16; Sentinel-6/Jason-CS)
GRACE-FO (2)
ICESat-2
Earth Science Instruments on ISS
RapidScat, CATS,
LIS, SAGE III (on ISS), TSIS-1, OCO-3,
ECOSTRESS, GEDI,
CLARREO-PF
THANK
YOU
SMAP
Suomi NPP
(NOAA)
Aqua
Landsat 8
(USGS)
CloudSat
CALIPSO
Aura
GPM
GRACE (2)
OSTM/Jason 2
(NOAA)
OCO-2
Contributing to
Water Cycle Studies