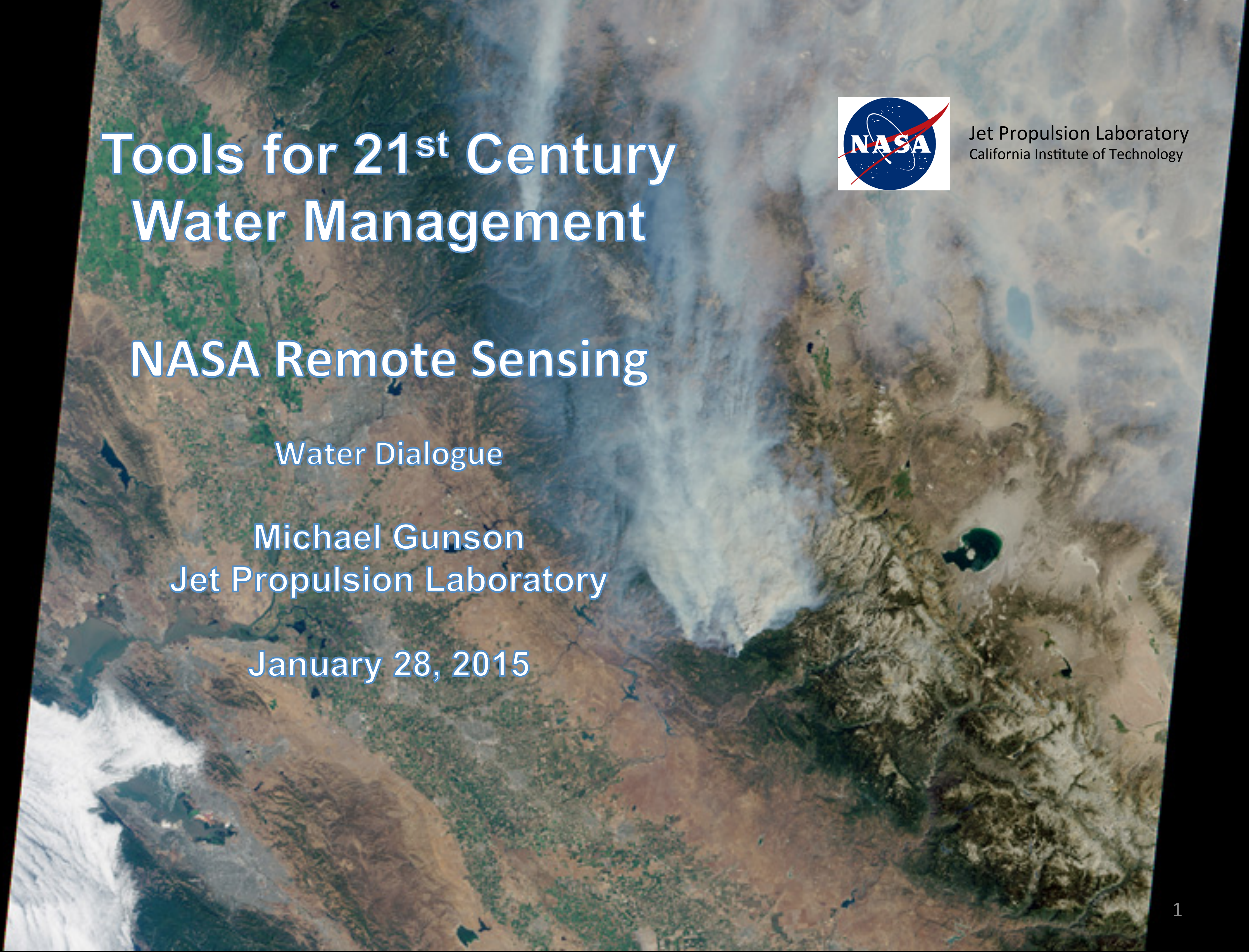


Tools for 21st Century Water Management

NASA Remote Sensing

Water Dialogue

Michael Gunson
Jet Propulsion Laboratory

January 28, 2015

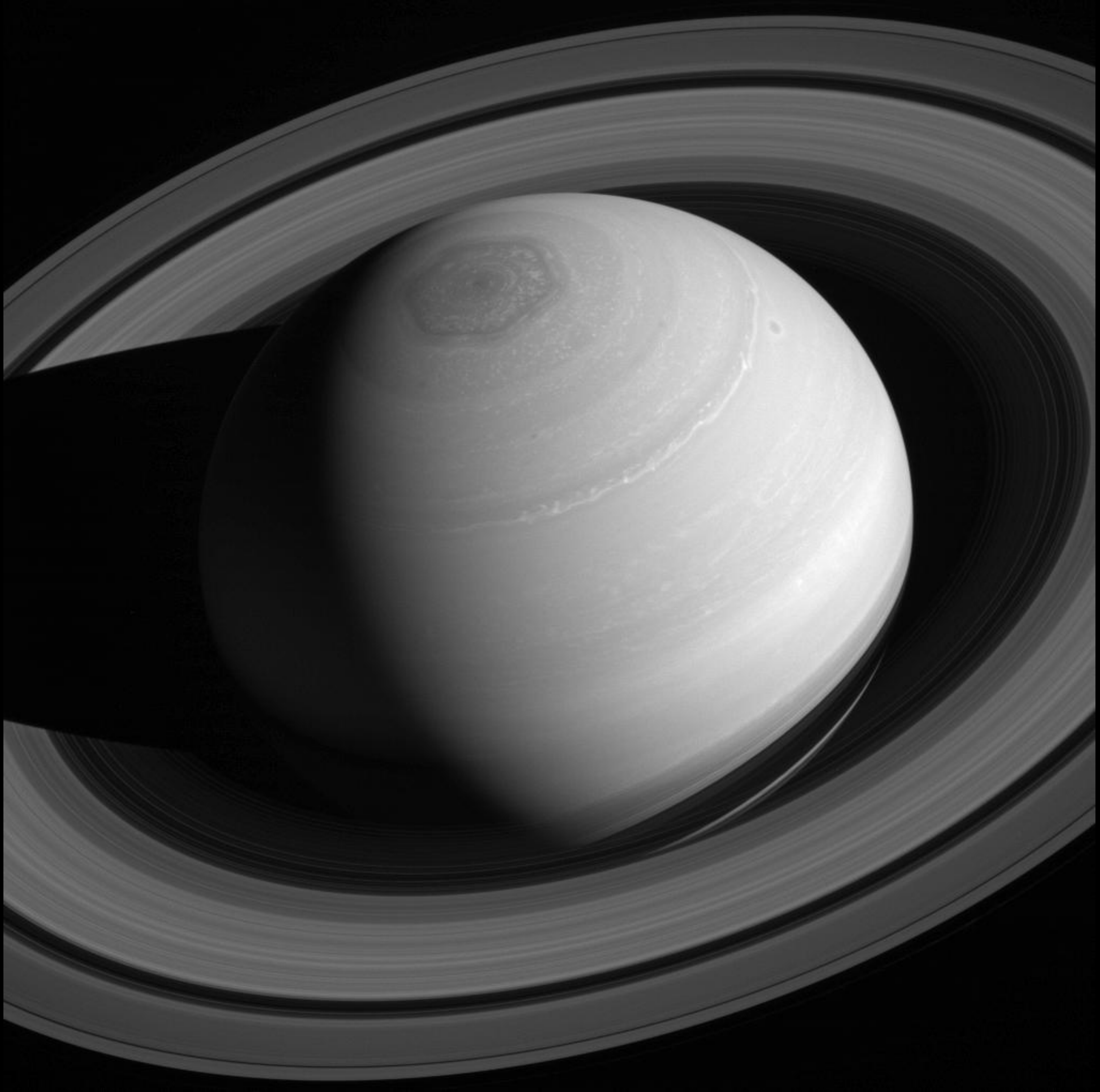
Jet Propulsion Laboratory
California Institute of Technology

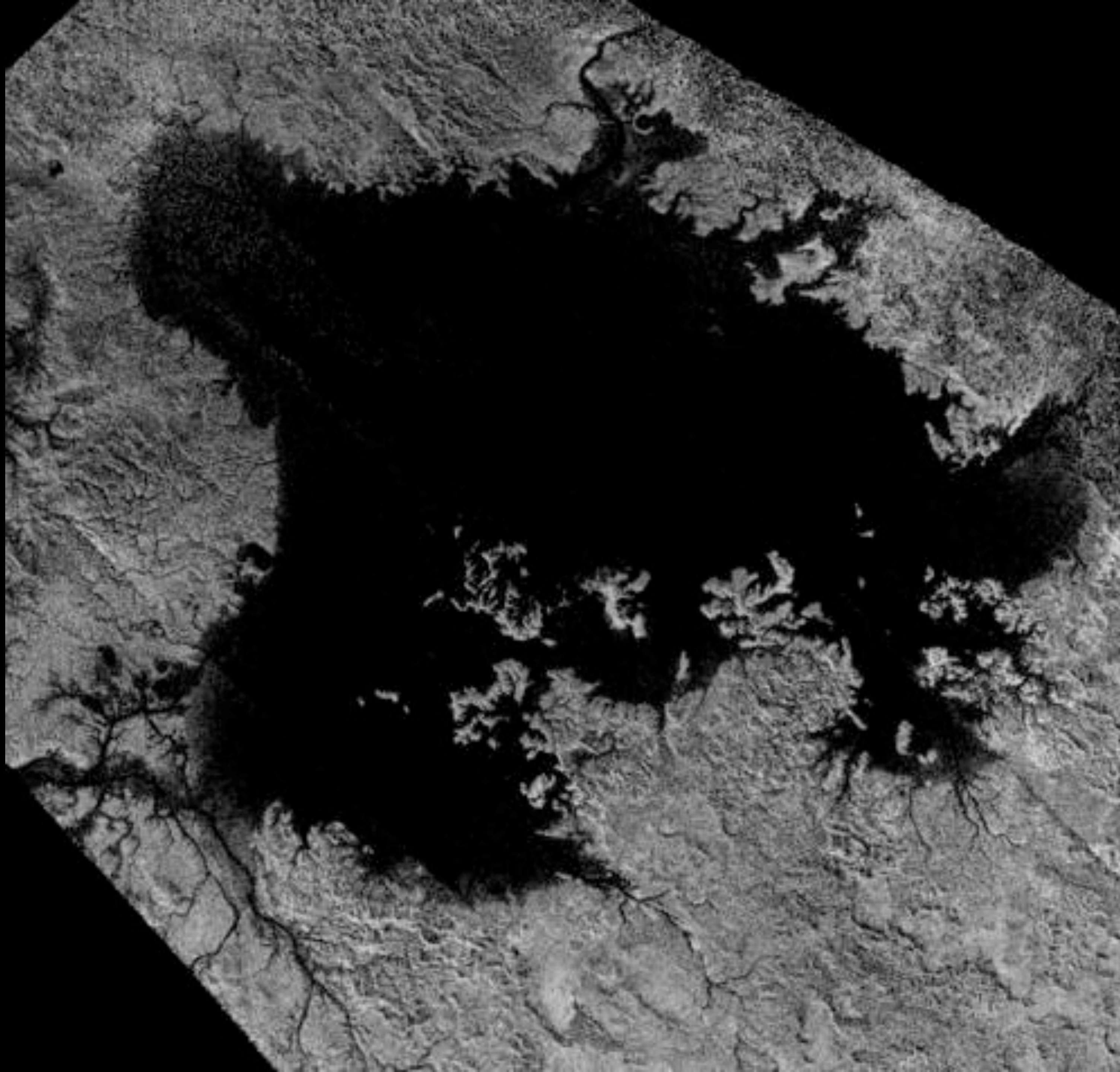
The Beginning of US Space Program

January 31, 1958

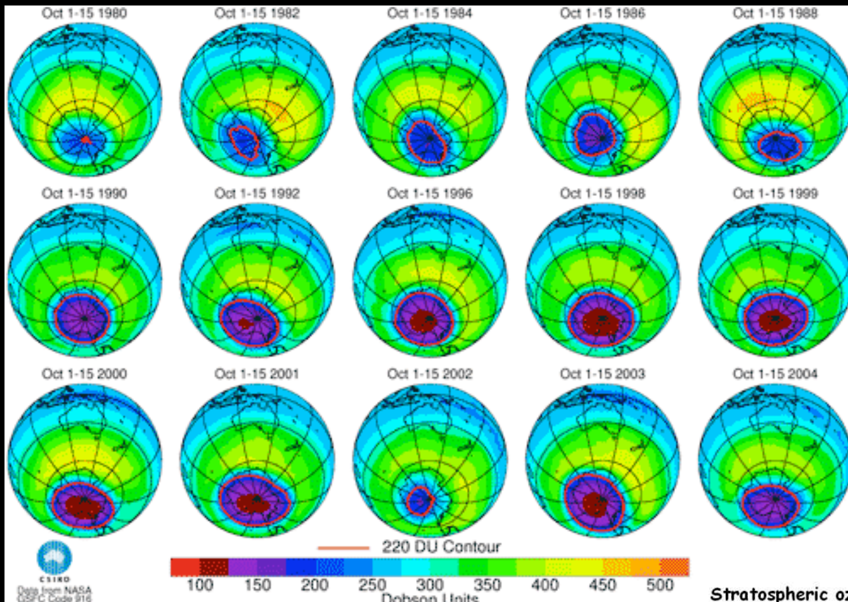
Jupiter C rocket carrying Explorer 1

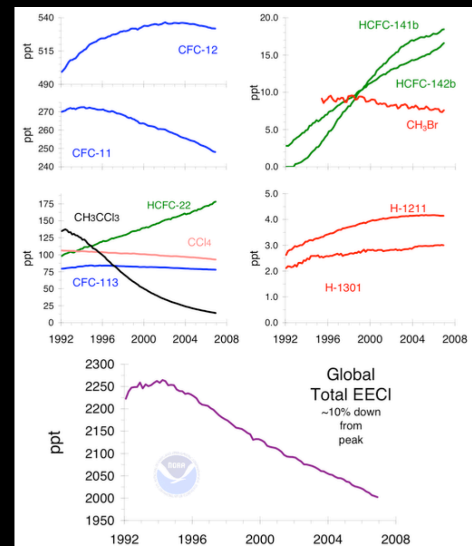
Bill Pickering, James Van Allen and Werhner Von Braun

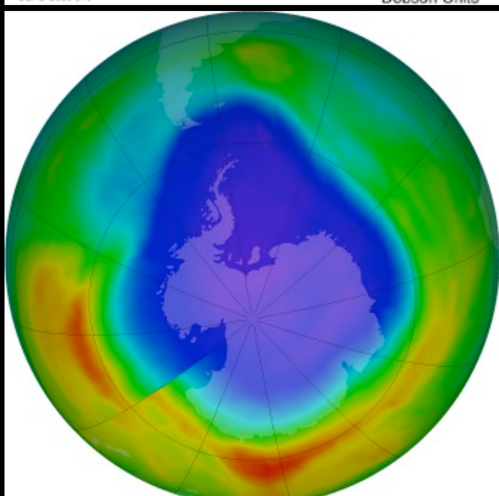




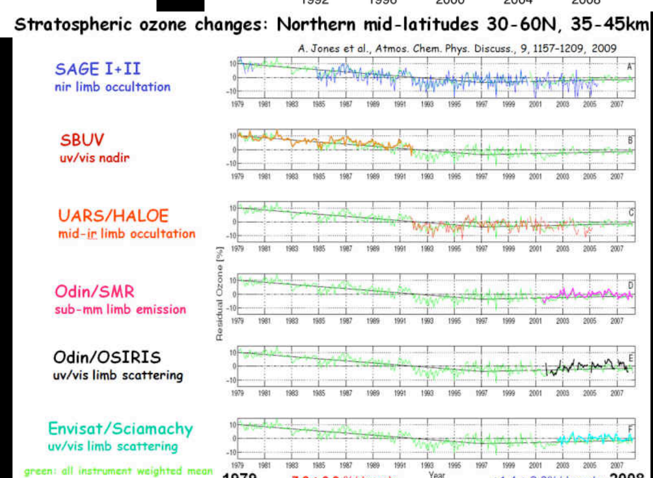
Remote Sensing and Atmospheric Science – The ozone story



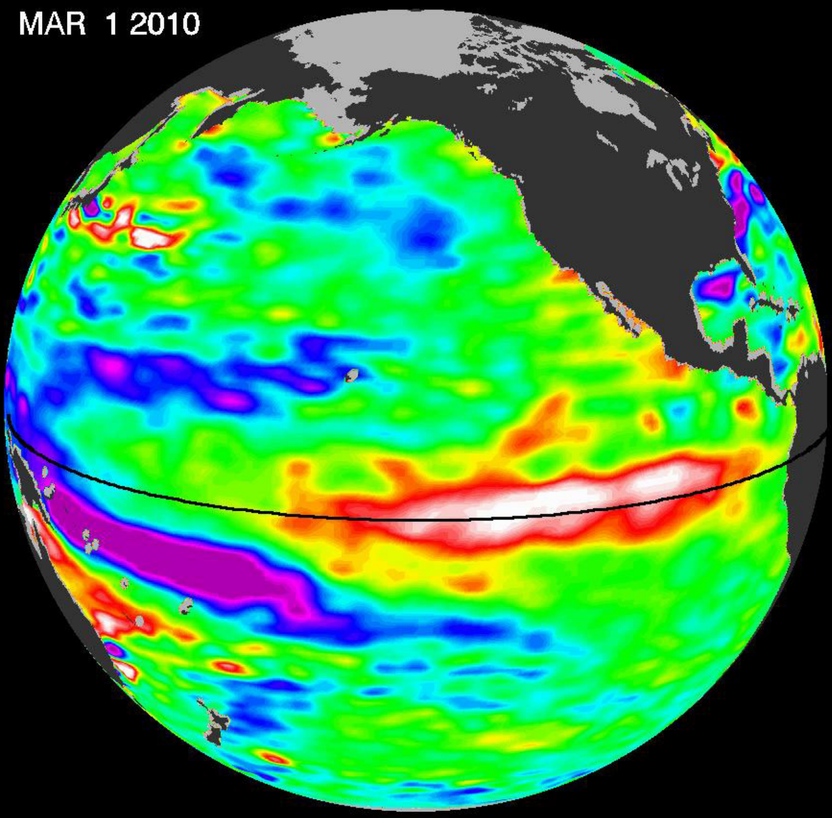


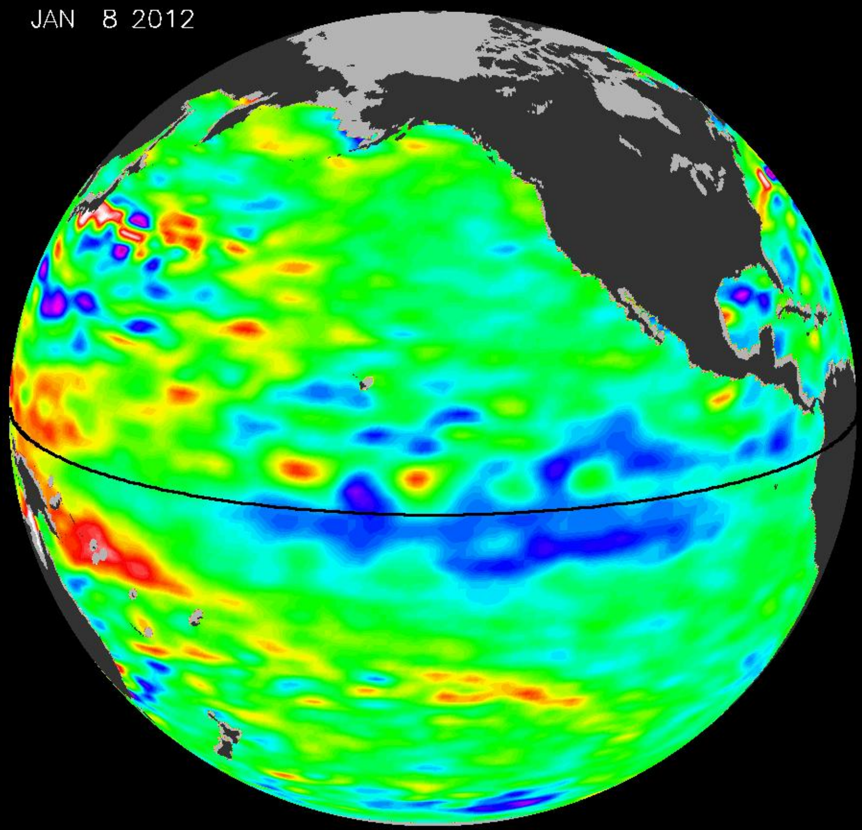


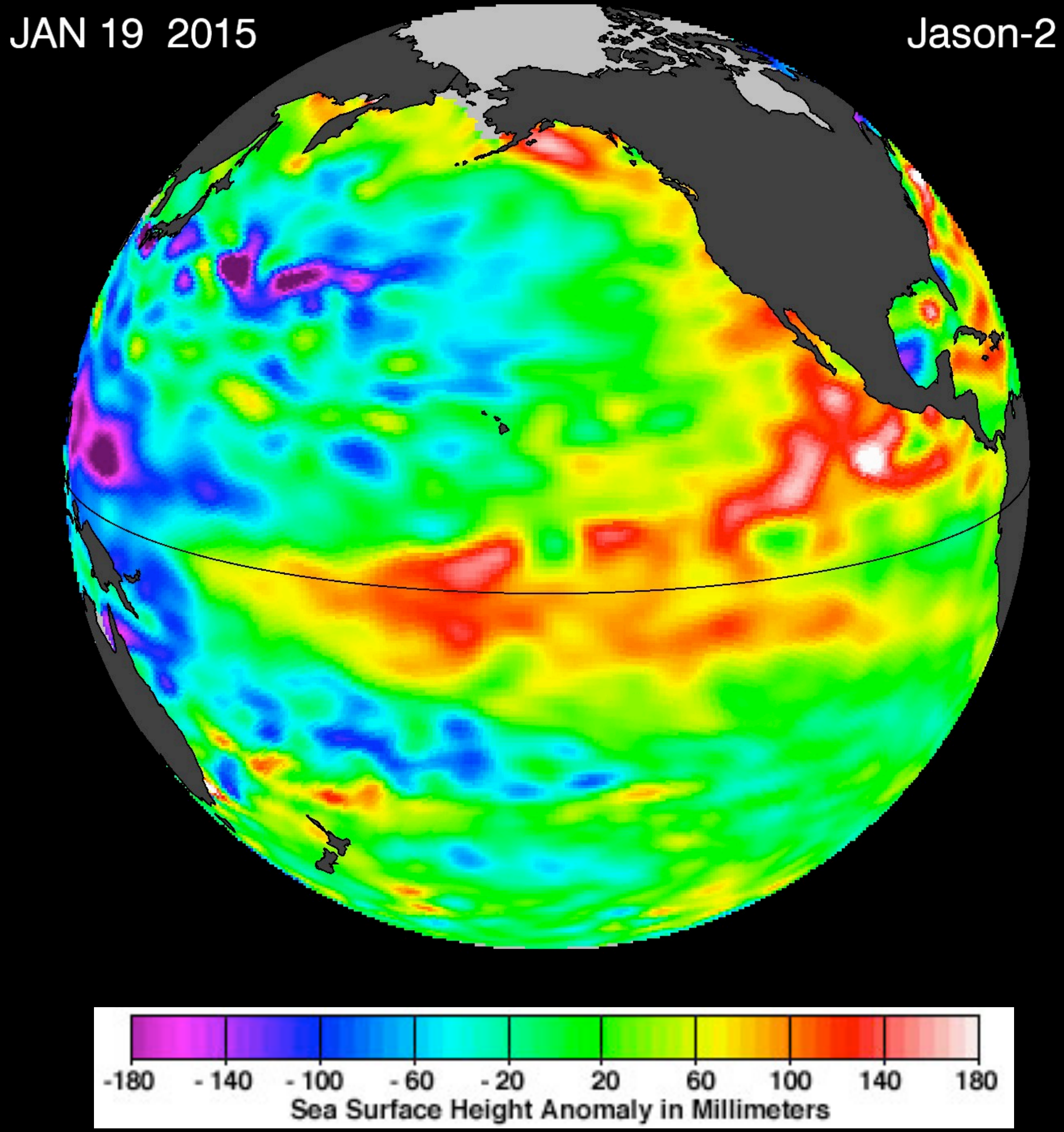
September 2012 [NASA]

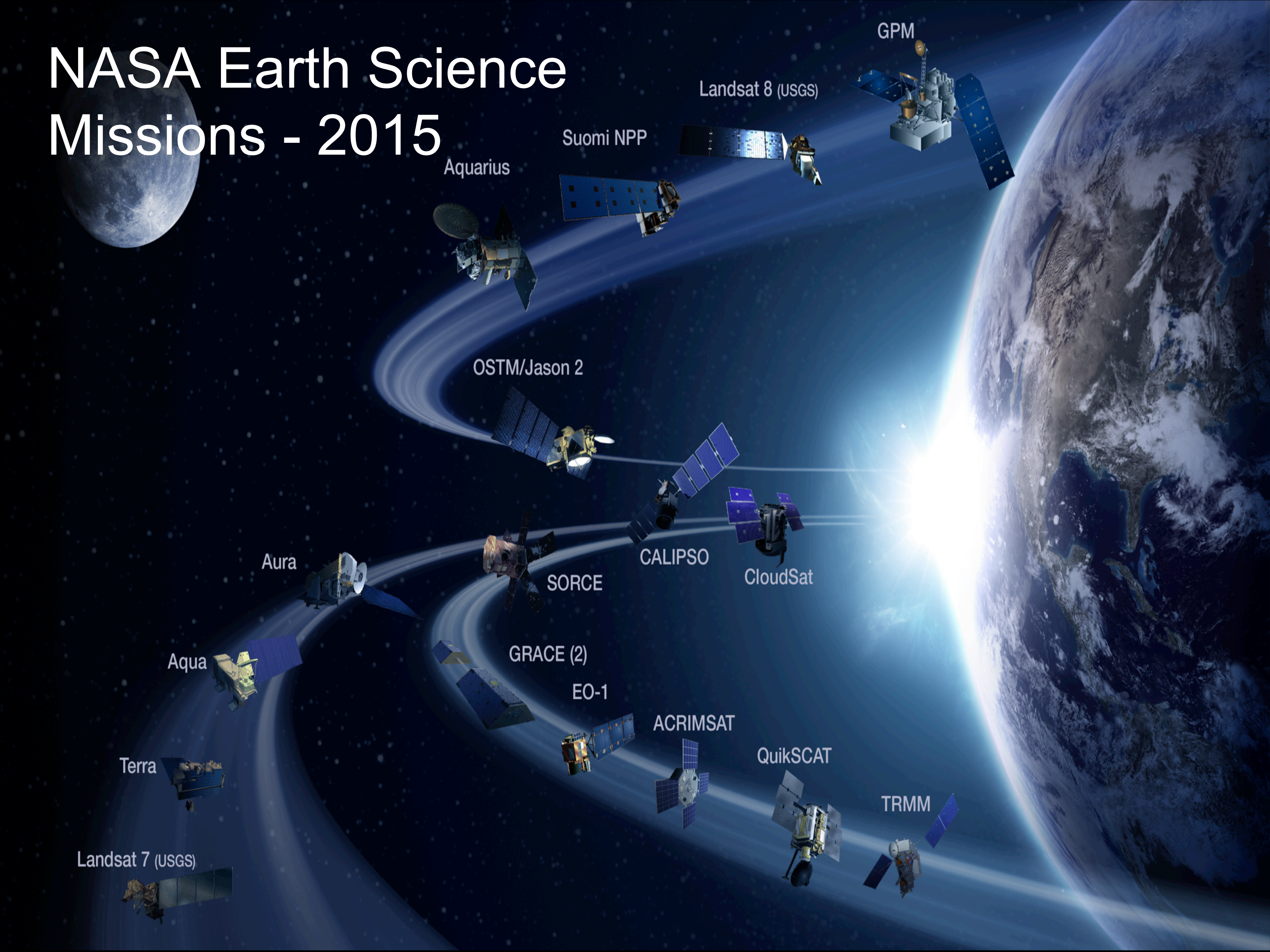


Sea Level Changes - ENSO



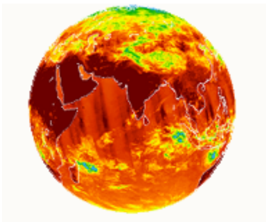



JAN 19 2015
Jason-2
-180
- 140
- 100
- 60
- 20
20
60
100
140
180
Sea Surface Height Anomaly in Millimeters

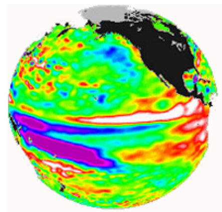

NASA Earth Science Missions - 2015
GPM
Landsat 8 (USGS)
Suomi NPP
Aquarius
OSTM/Jason 2
CALIPSO
CloudSat
Aura
SORCE
Aqua
GRACE (2)
EO-1
ACRIMSAT
Terra
QuikSCAT
TRMM
Landsat 7 (USGS)

JPL Earth Science Observations

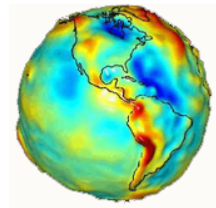
Jet Propulsion Laboratory
California Institute of Technology



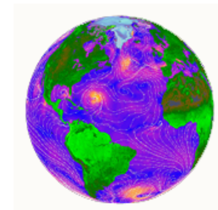
Atmospheric Infrared Sounder **(AIRS)** provides monthly global temperature maps



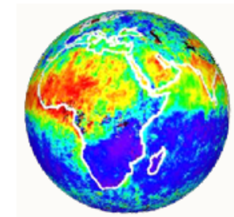
Jason provides global sea surface height maps every 10 days



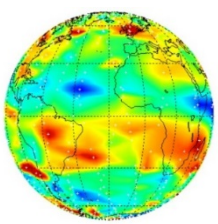
Gravity Recovery and Climate Experiment **(GRACE)** provides monthly maps of Earth's gravity



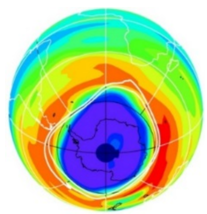
Quikscat collects data over the polar regions, and to support Cal/Val of RapidSCAT



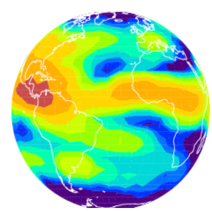
Multi-angle Imaging Spectro Radiometer **(MISR)** provides monthly global aerosol maps



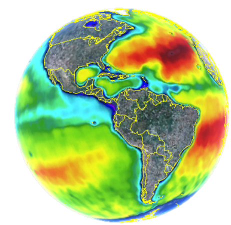
Tropospheric Emission Spectrometer **(TES)** provides monthly global maps of Ozone



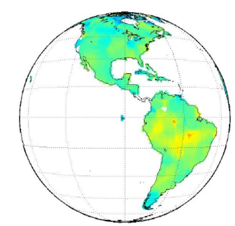
Microwave Limb Sounder **(MLS)** provides daily maps of stratospheric chemistry



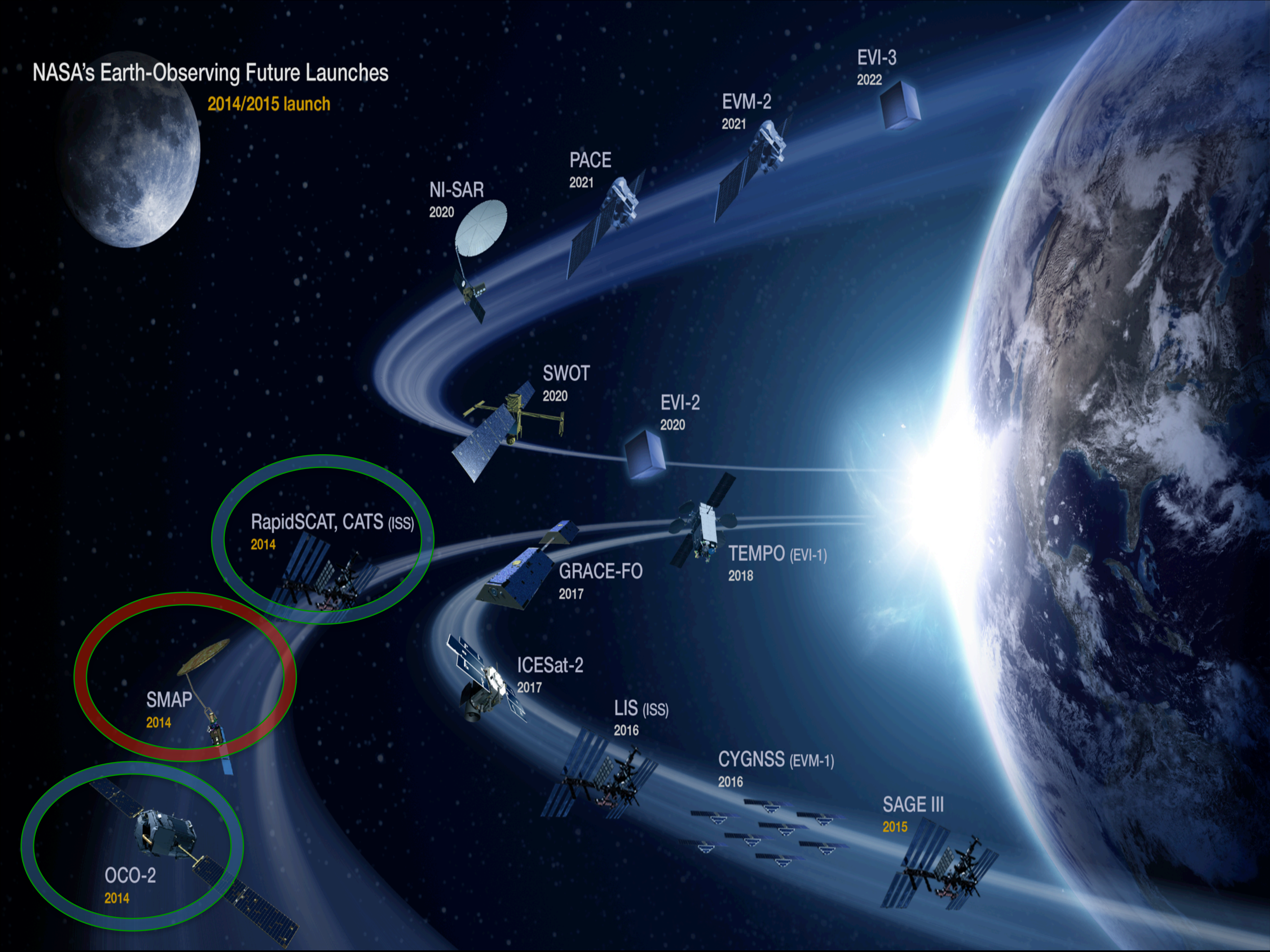
CloudSat provides monthly maps of cloud ice water content



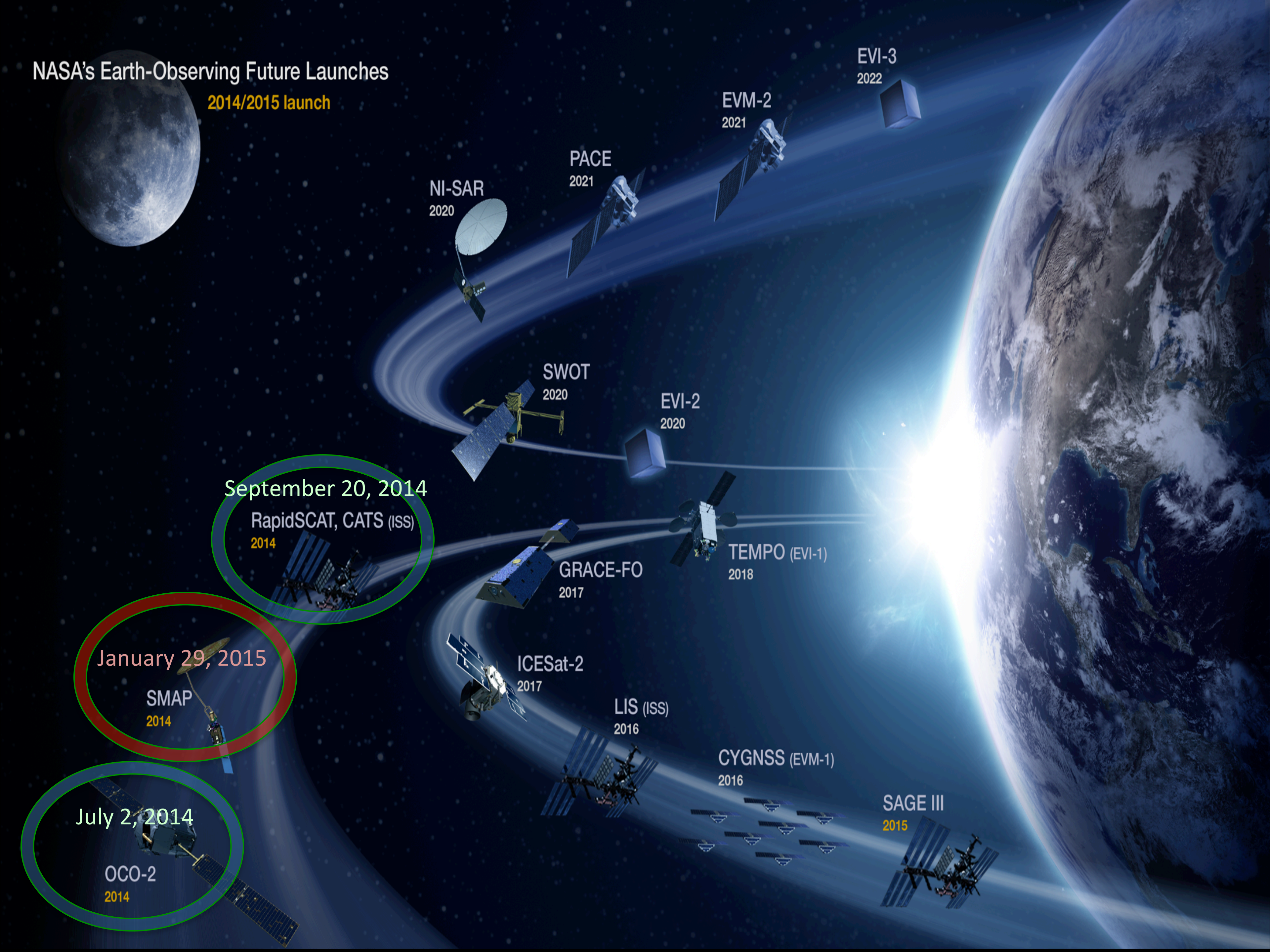
Aquarius provides monthly maps of sea surface salinity



OCO-2 provides monthly maps of carbon dioxide



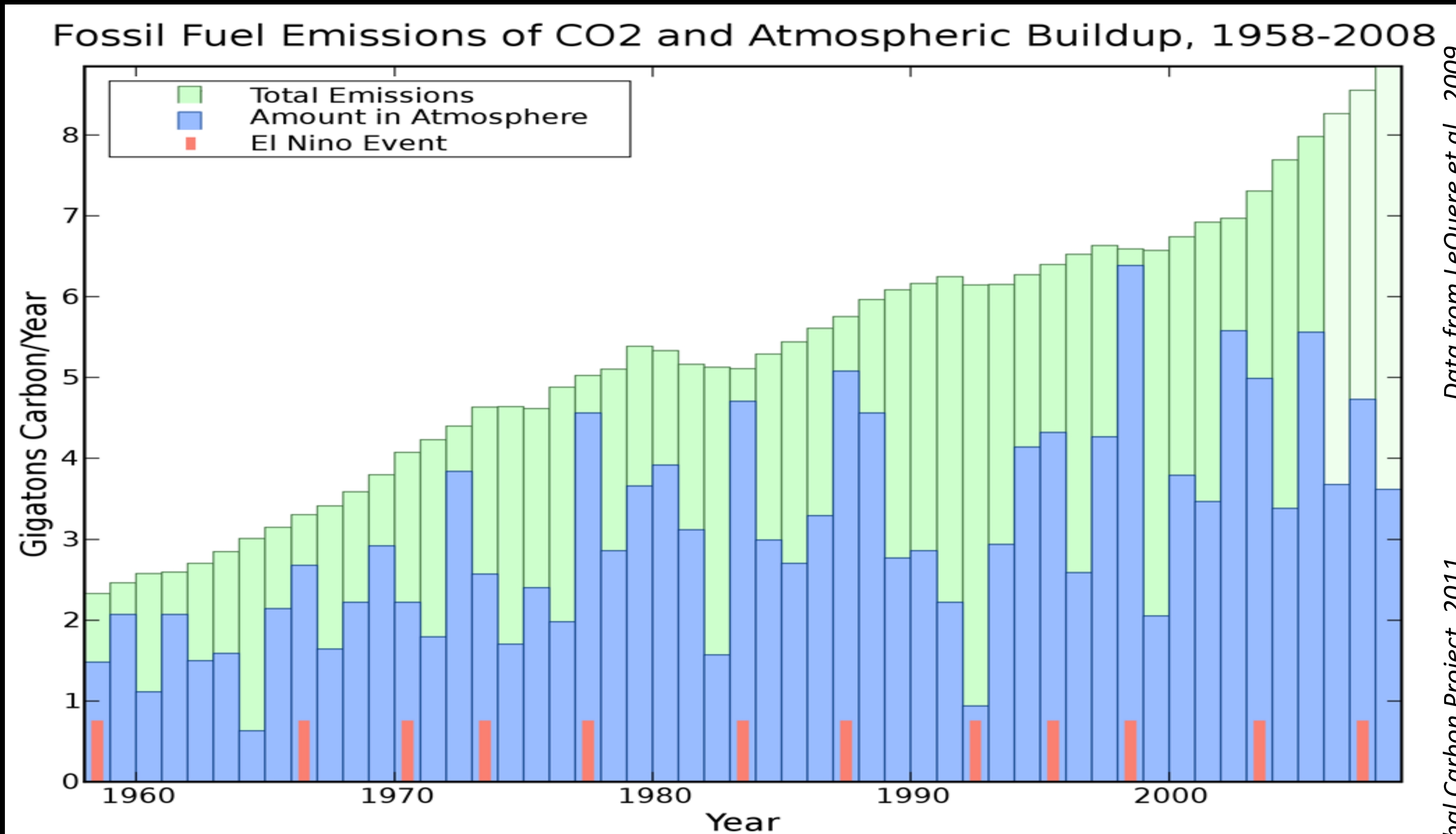
NASA's Earth-Observing Future Launches
2014/2015 launch
EVI-3
2022
EVM-2
2021
PACE
2021
NI-SAR
2020
SWOT
2020
EVI-2
2020
RapidSCAT, CATS (ISS)
2014
GRACE-FO
2017
TEMPO (EVI-1)
2018
SMAP
2014
ICESat-2
2017
LIS (ISS)
2016
CYGNSS (EVM-1)
2016
SAGE III
2015
OCO-2
2014



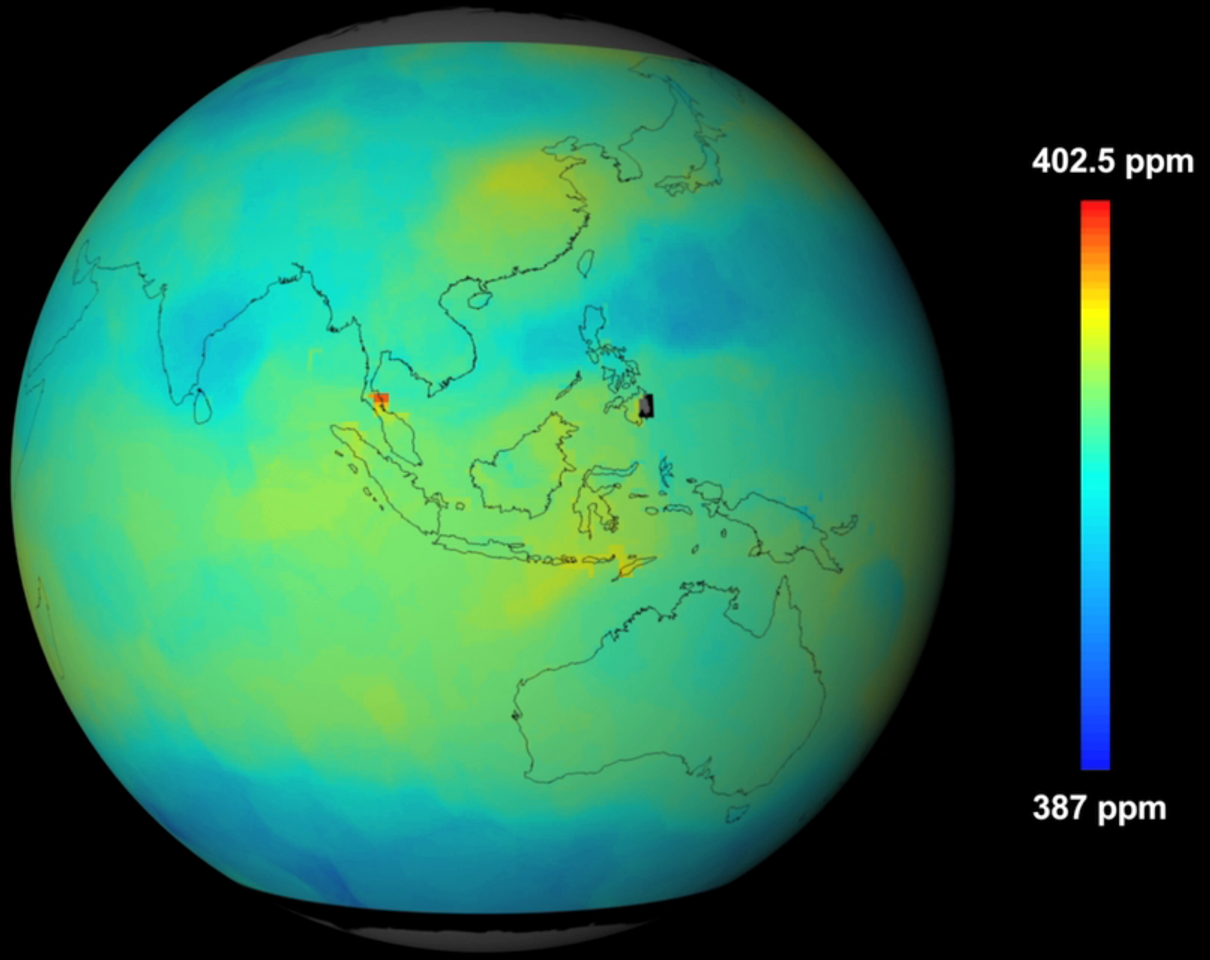
NASA's Earth-Observing Future Launches
2014/2015 launch
EVI-3
2022
EVM-2
2021
PACE
2021
NI-SAR
2020
SWOT
2020
EVI-2
2020
September 20, 2014
RapidSCAT, CATS (ISS)
2014
TEMPO (EVI-1)
2018
GRACE-FO
2017
January 29, 2015
SMAP
2014
ICESat-2
2017
LIS (ISS)
2016
CYGNSS (EVM-1)
2016
July 2, 2014
OCO-2
2014
SAGE III
2015

OCO-2 Launch July 2, 2014

Orbiting Carbon Observatory: The CO_2 Puzzle



October 2014



OCO-2 Measurements Over Pasadena

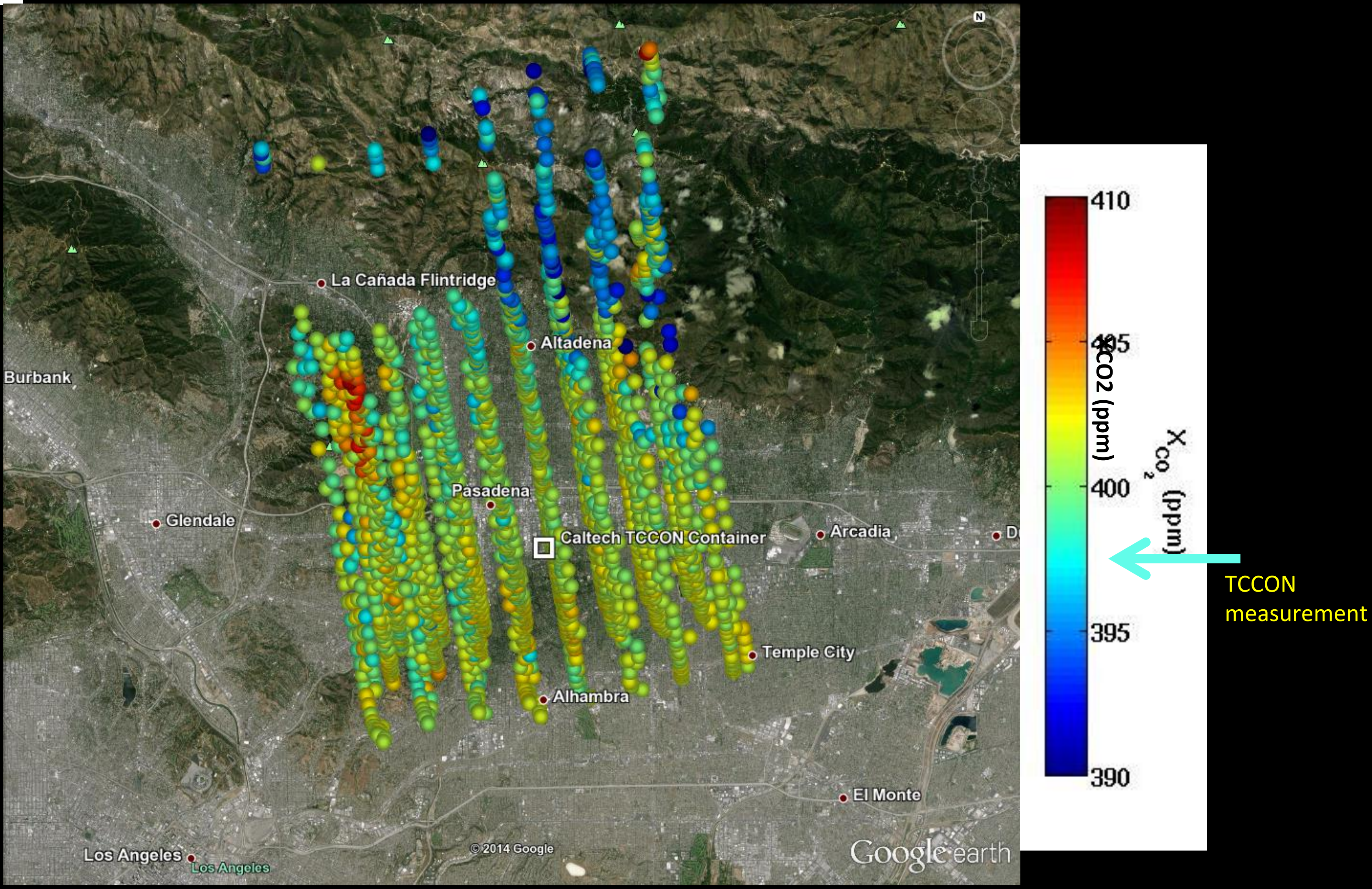
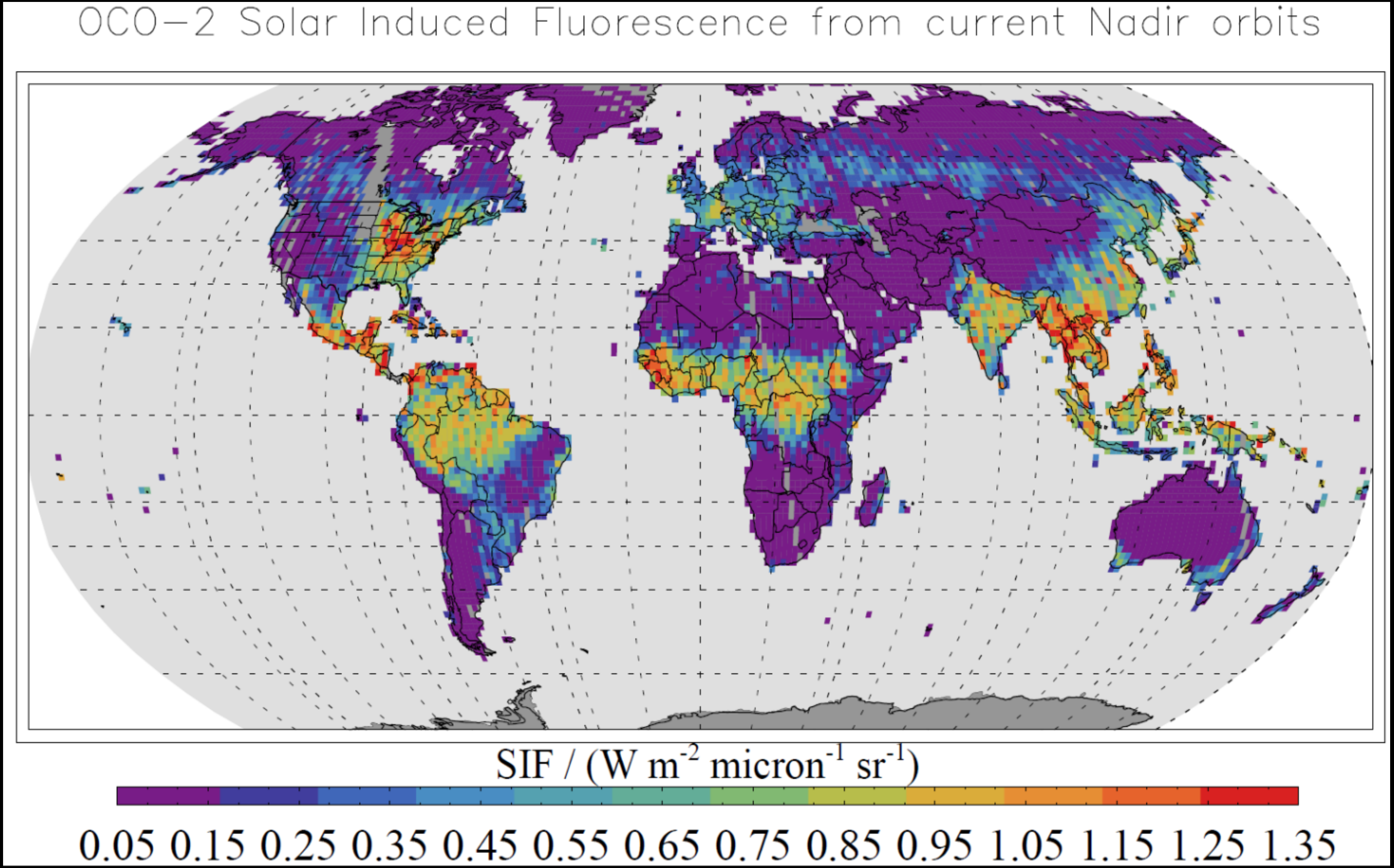
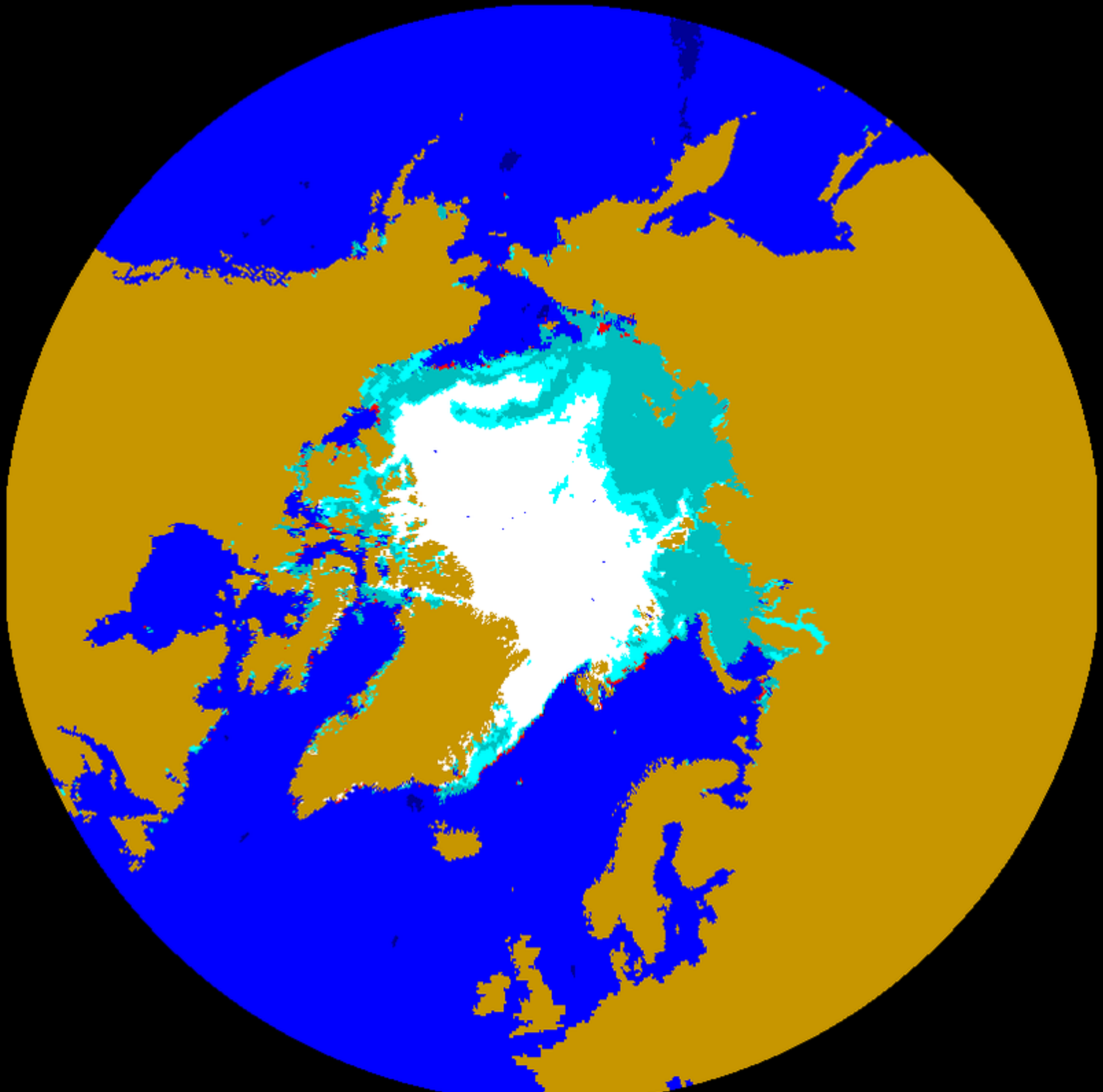


Image by Debra Wunch, Caltech

The unexpected observation: solar induced fluorescence

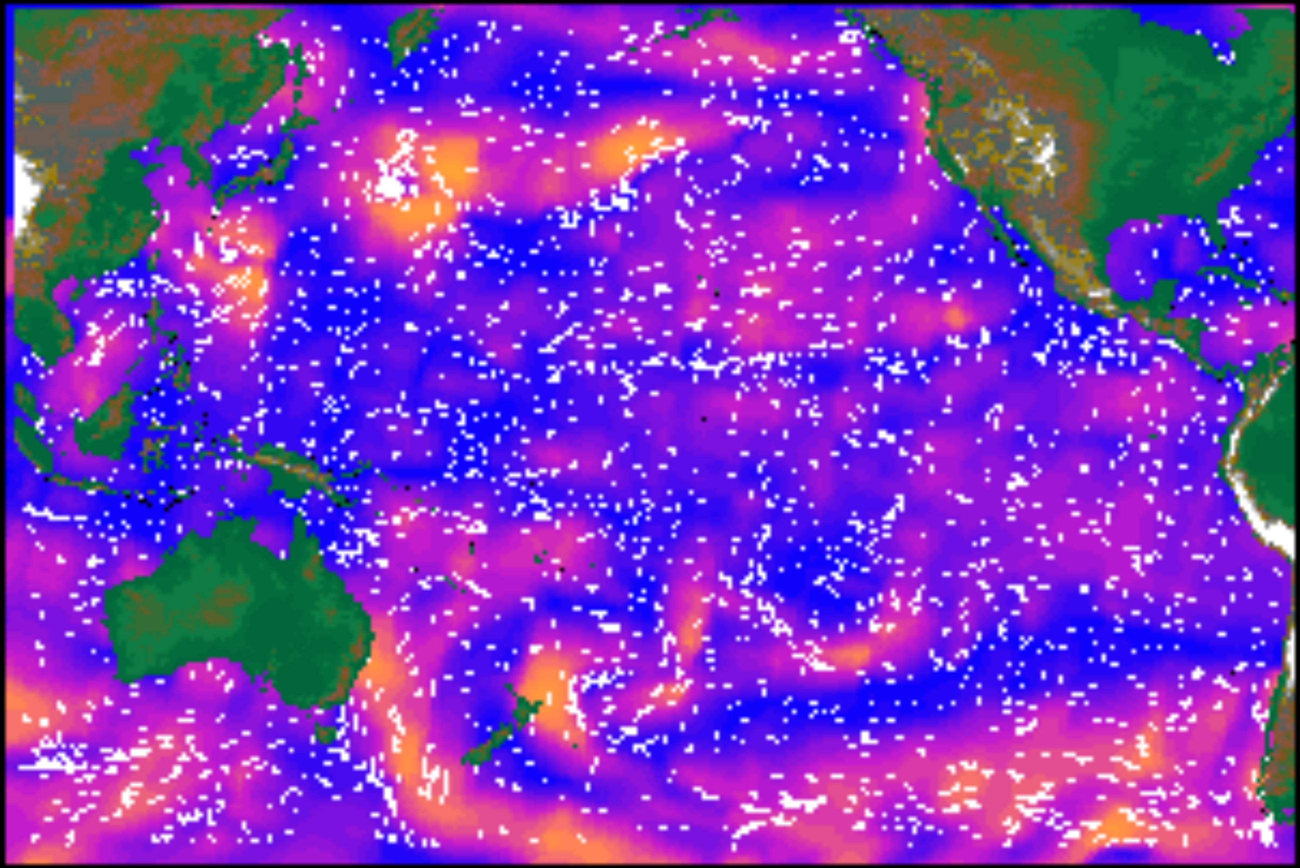


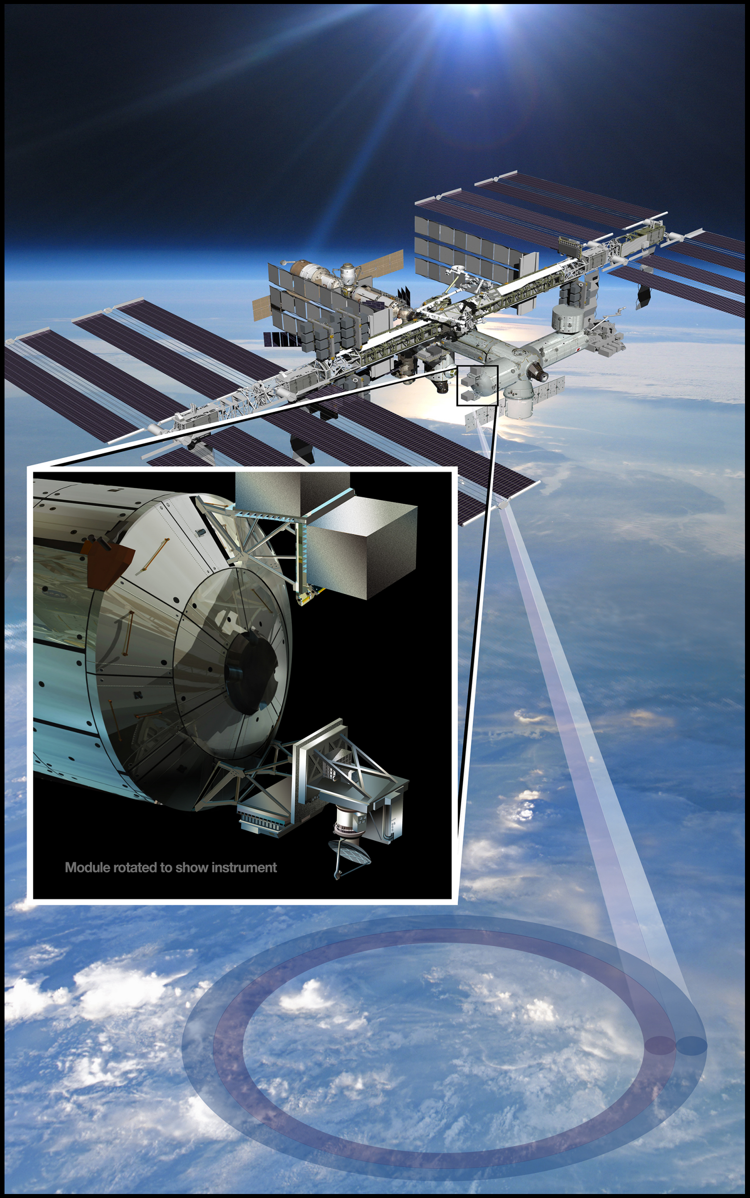
Scatterometry: sea ice changes



2006-11-01

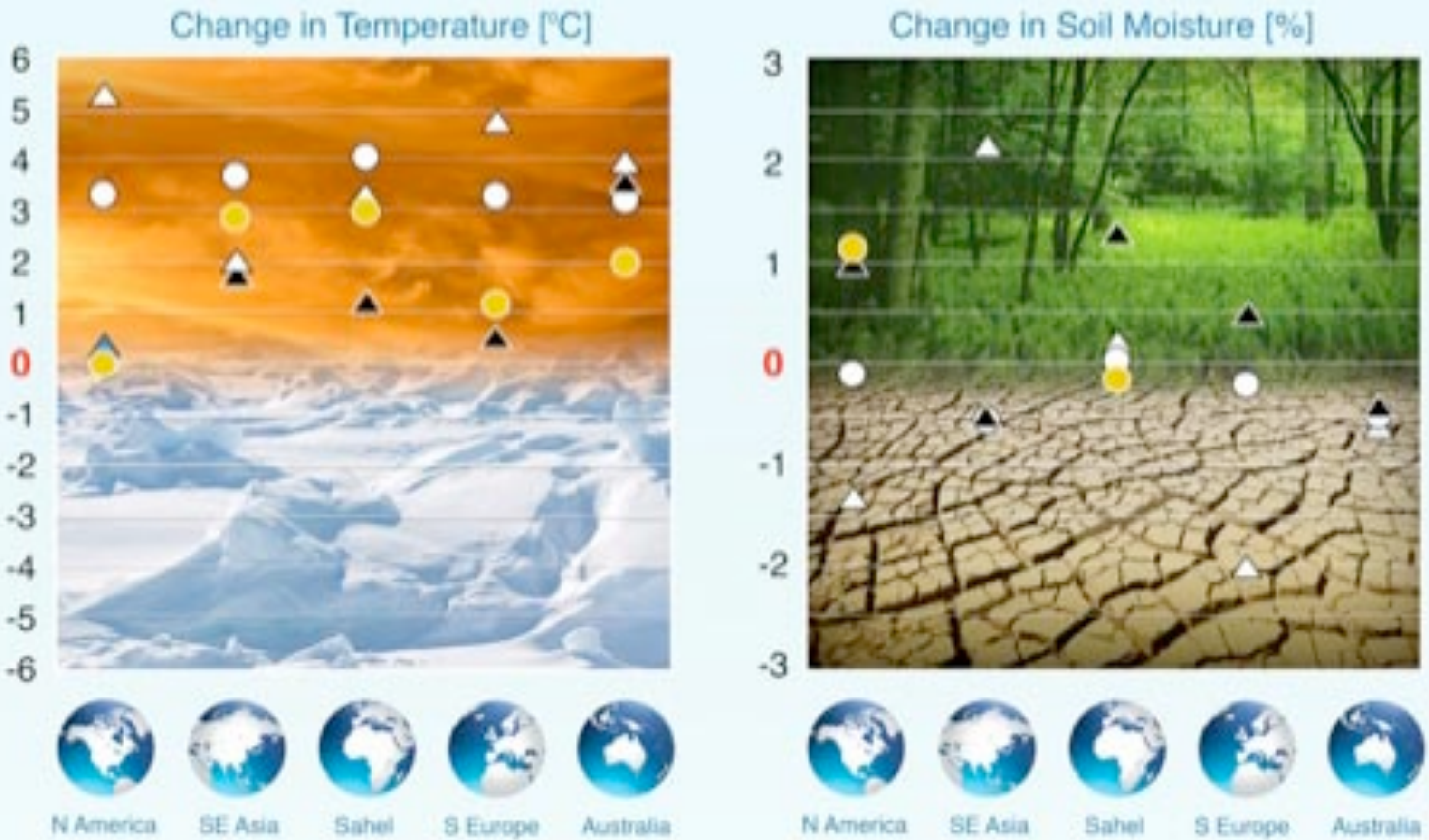
Scatterometry: ocean surface winds





The spare parts scatterometer

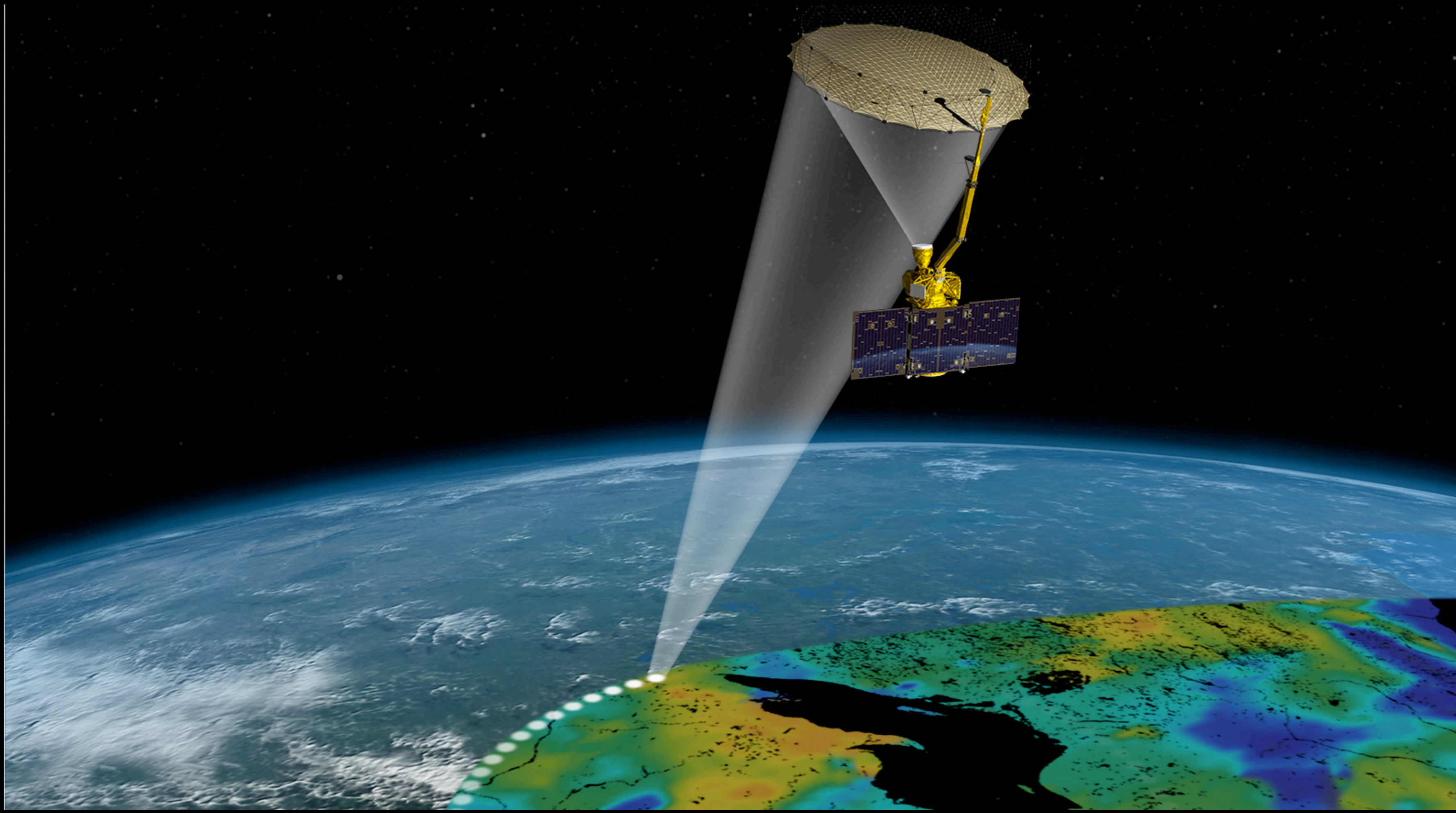
Intergovernmental Panel on Climate Change (IPCC) climate model projections by region:



Models agree on direction of temperature increase

Models disagree on whether there will be MORE or LESS water compared to today

SMAP - Soil Moisture Active Passive



Launch January 29 at 6:23 a.m. (PST)

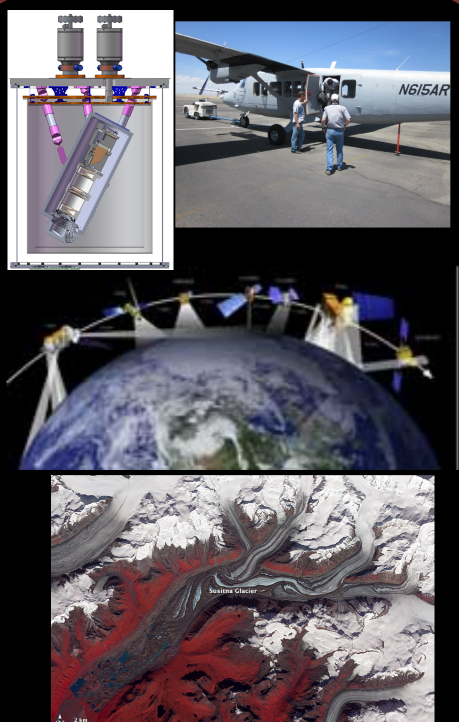
STOP FOR ANIMATION

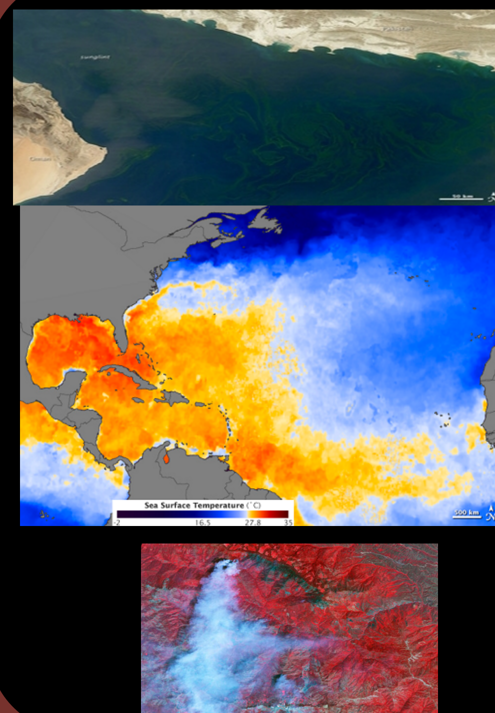
http://www.jpl.nasa.gov/news/news.php?release=2014-444

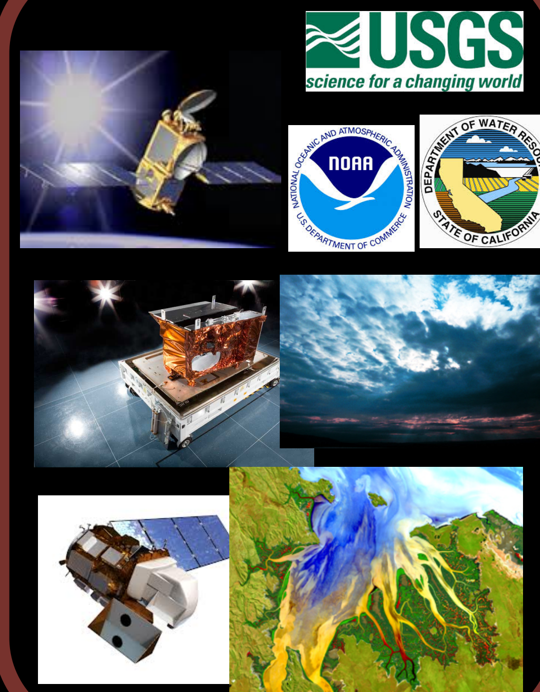
Can Remote Sensing Improve Water Resource Management?

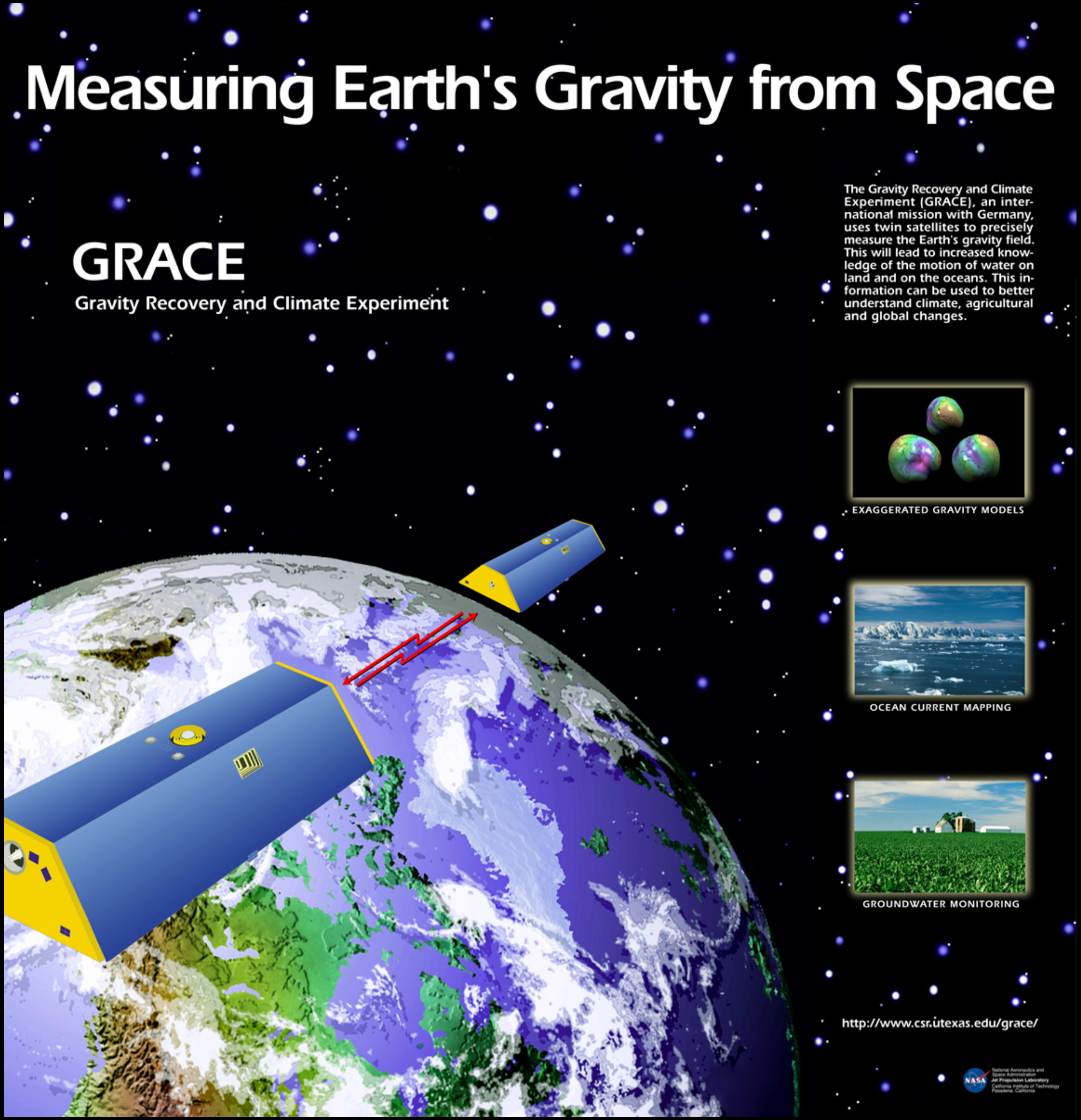
NASA

Operational Entities

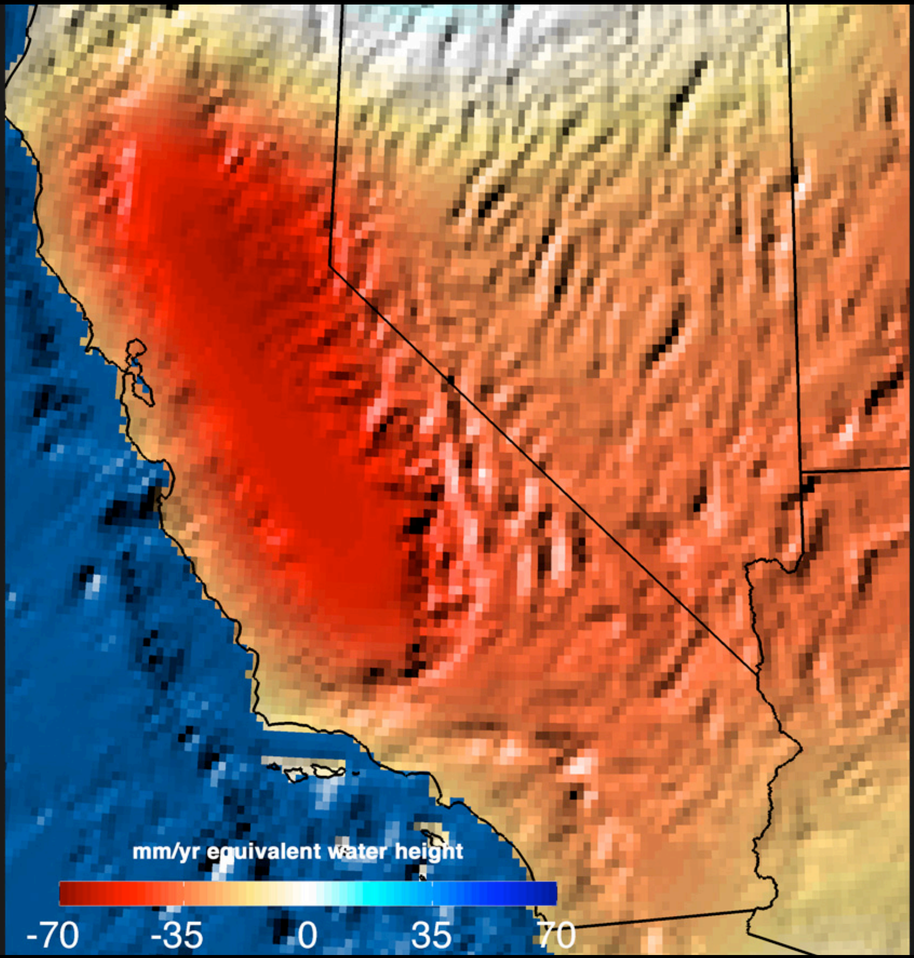







Measuring Earth's Gravity from Space
GRACE
Gravity Recovery and Climate Experiment
The Gravity Recovery and Climate Experiment (GRACE), an international mission with Germany, uses twin satellites to precisely measure the Earth's gravity field. This will lead to increased knowledge of the motion of water on land and on the oceans. This information can be used to better understand climate, agricultural and global changes.
EXAGGERATED GRAVITY MODELS
OCEAN CURRENT MAPPING
GROUNDWATER MONITORING
http://www.csr.utexas.edu/grace/
National Aeronautics and Space Administration
Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

California Drought: Overall changes in water

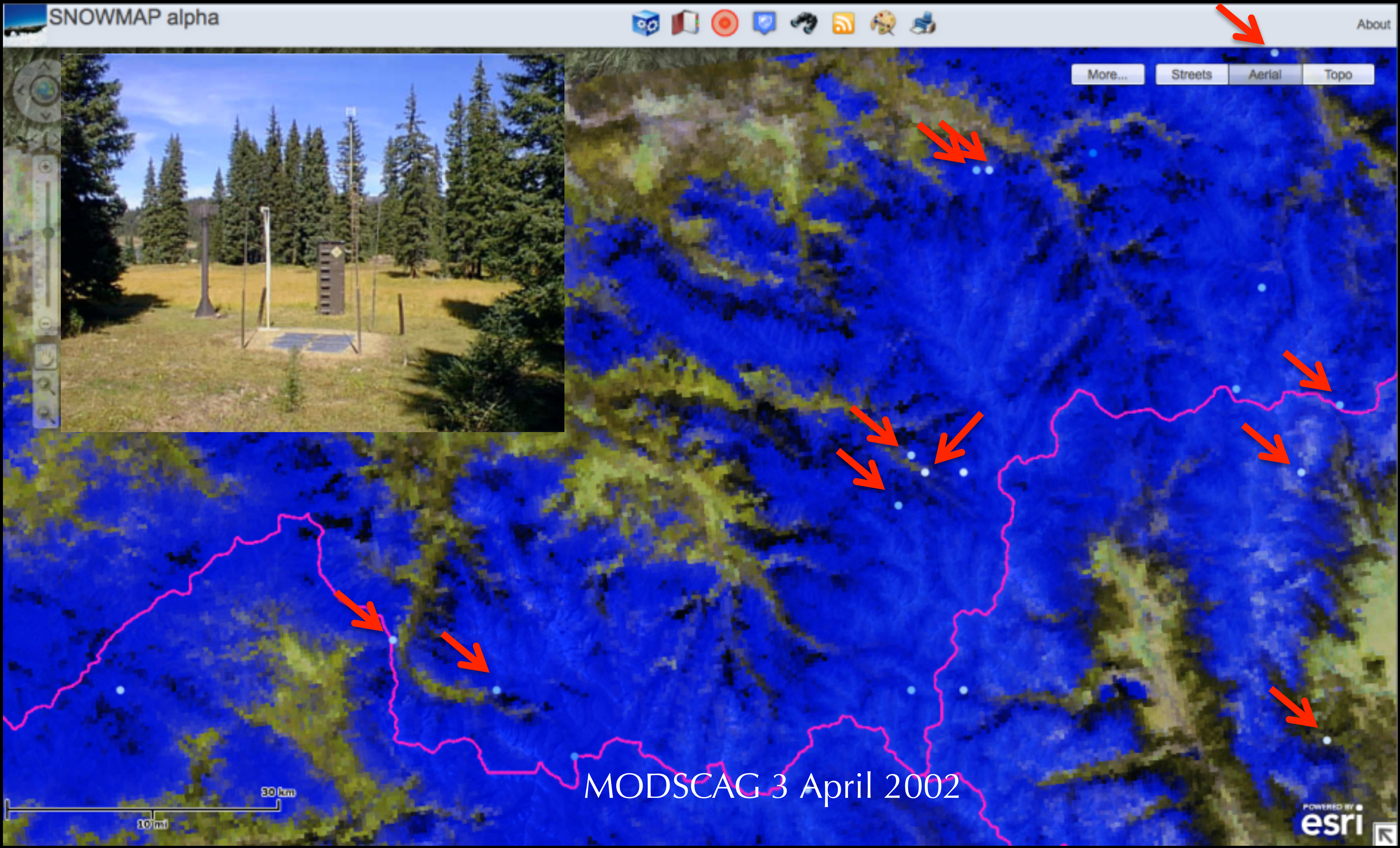


Airborne Snow Observatory

Imaging snow water equivalent, snow albedo, and predicting runoff for water management

Principal Investigator: Thomas H. Painter, JPL/Caltech
Bruce J. McGurk, McGurk Hydrologic, and Frank Gehrke, CA DWR

Snow pillows melt, we go blind

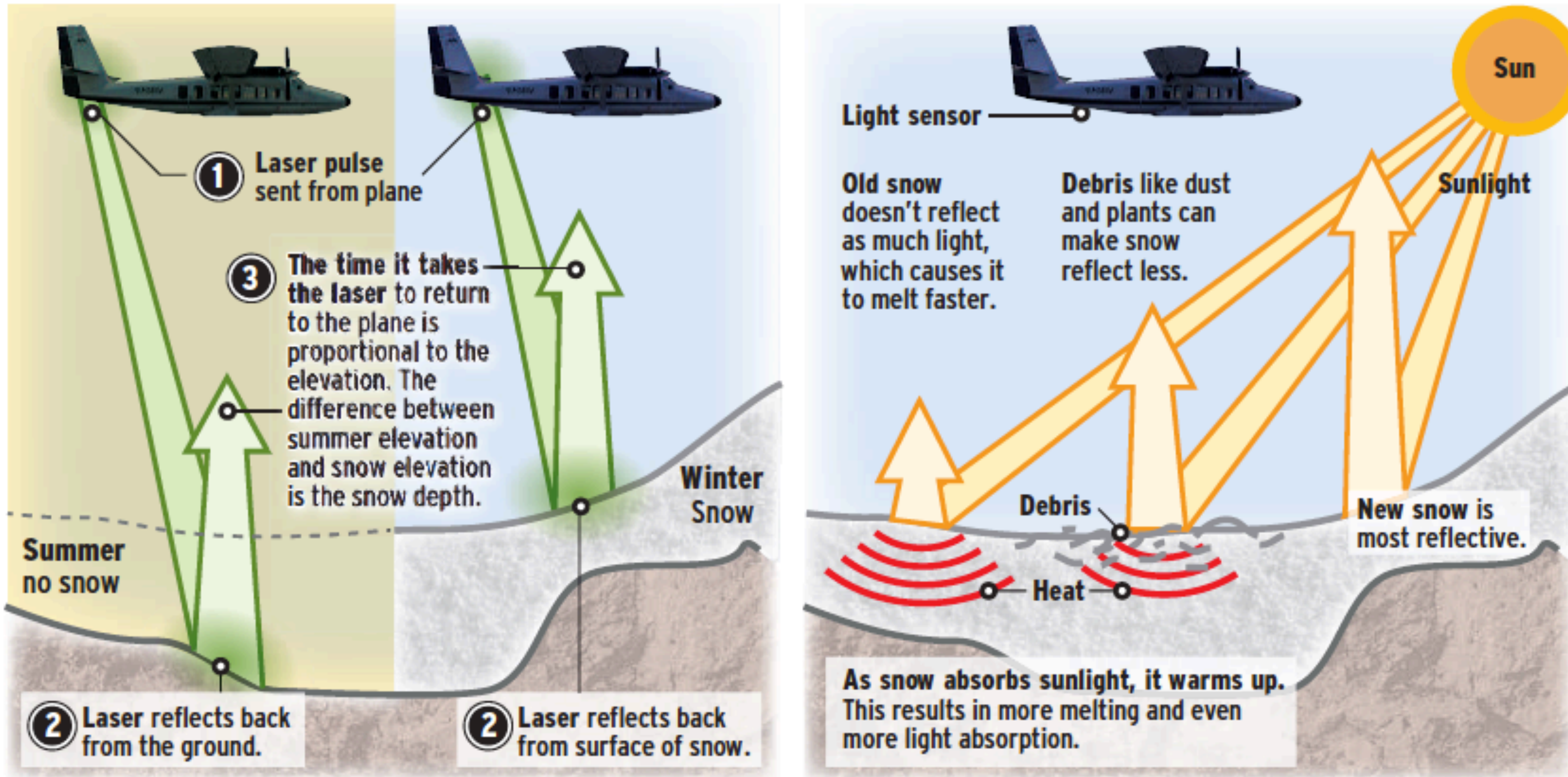


How much snow?

Using laser radar, known as Lidar, researchers measure the depth of snowpack in California.

How will it melt?

With an advanced light sensor, scientists measure snow's reflectivity – an indicator of how it will melt.



Sources: Thomas Painter, Frank Gehrke, Optech Inc.

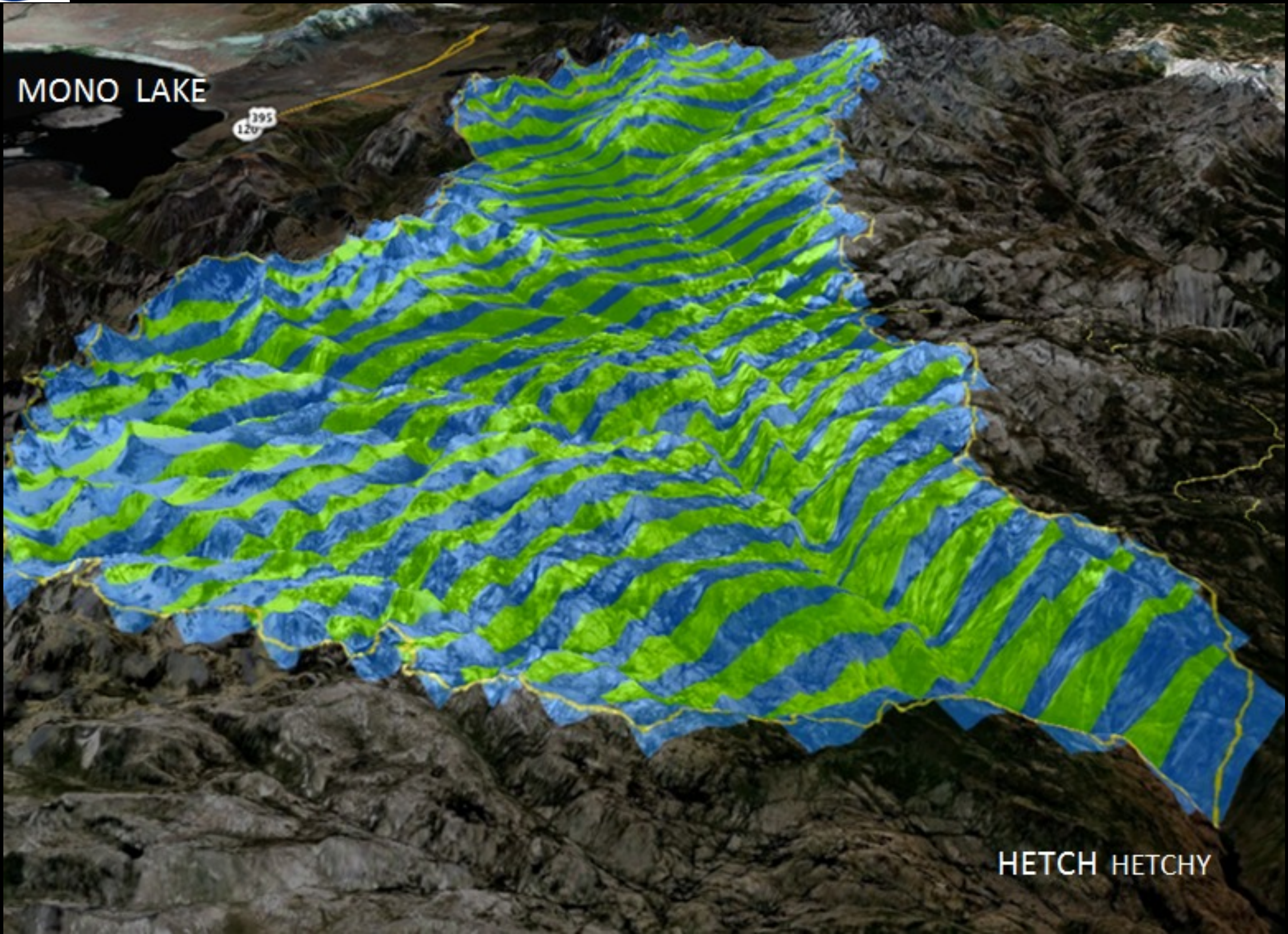
Maxwell Henderson / The Register

of Mt. Lyell,

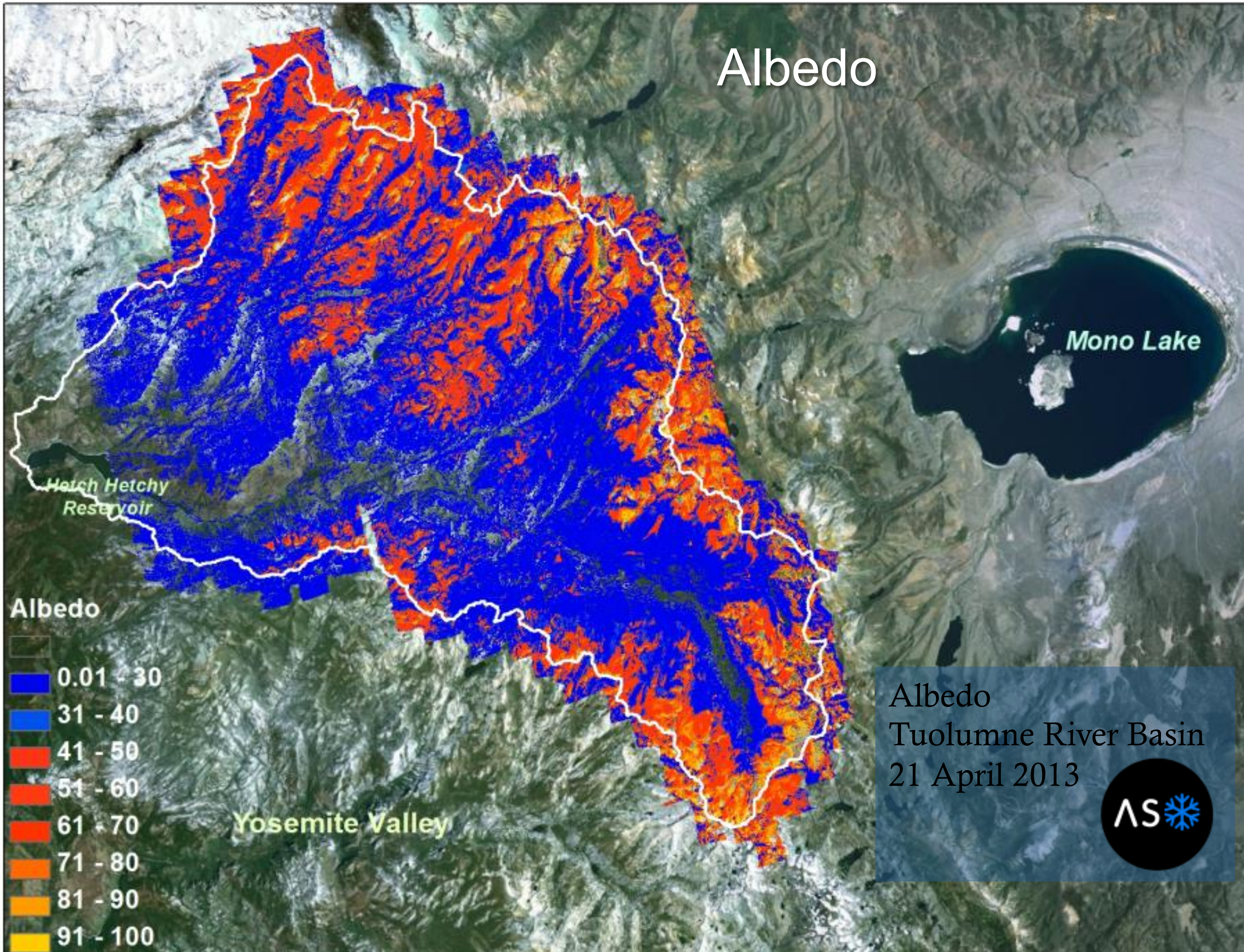
climate change dries out the mountains.

20th annual

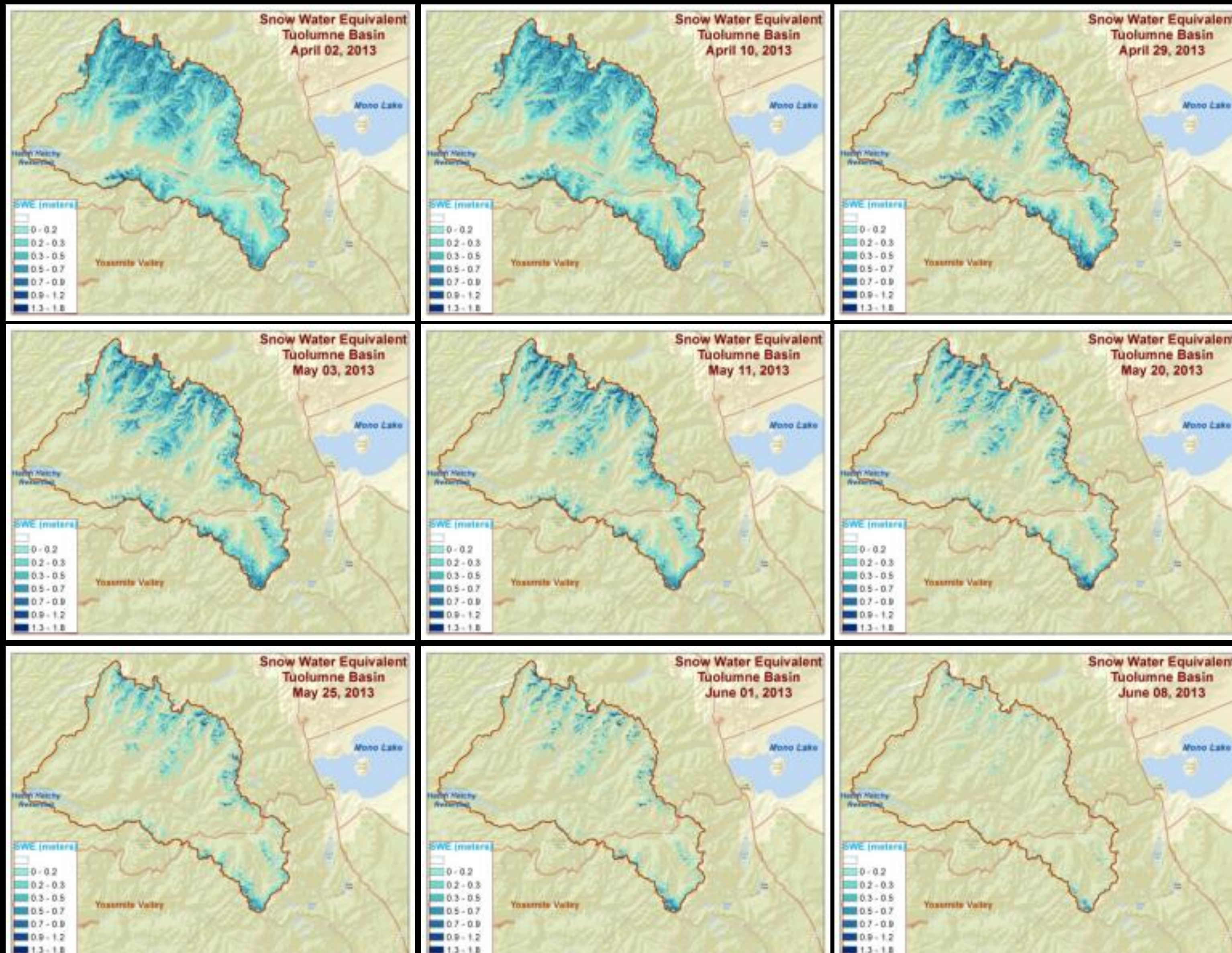
Spring Data Collection - Weekly



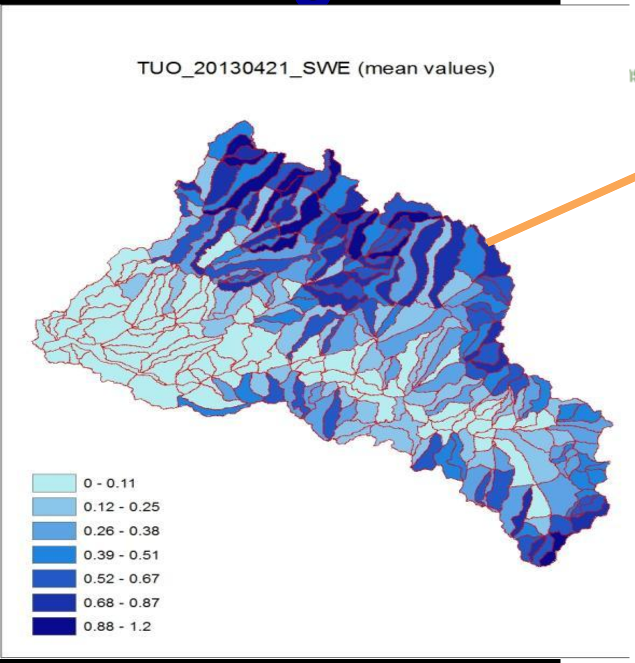

Snow Water Equivalent
Cherry Reservoir
Lake Eleanor
Hetch Hetchy Reservoir
Upper Tuolumne River
Hetch Hetchy Reservoir
SWE (m)
0 - 0.2
0.2 - 0.3
0.3 - 0.5
0.5 - 0.7
0.7 - 0.9
0.9 - 1.2
1.3 - 1.8
Yosemite Valley
SWE
Tuolumne River Basin
21 April 2013

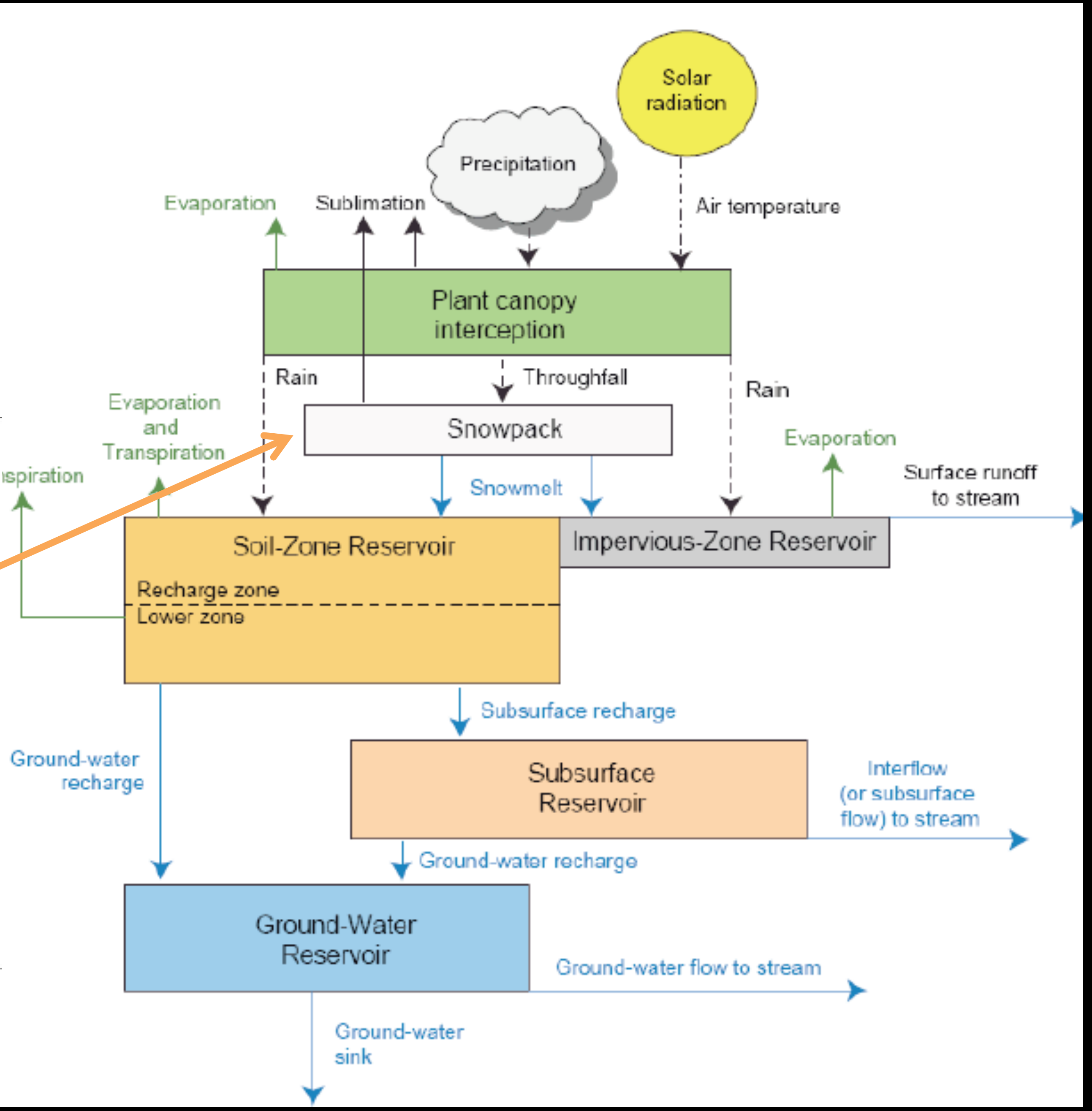

Albedo
Mono Lake
Hetch Hetchy Reservoir
Yosemite Valley
Albedo
0.01 - 30
31 - 40
41 - 50
51 - 60
61 - 70
71 - 80
81 - 90
91 - 100
Albedo
Tuolumne River Basin
21 April 2013
ΛS

ASO time series of snow water equivalent Tuolumne Basin 2013

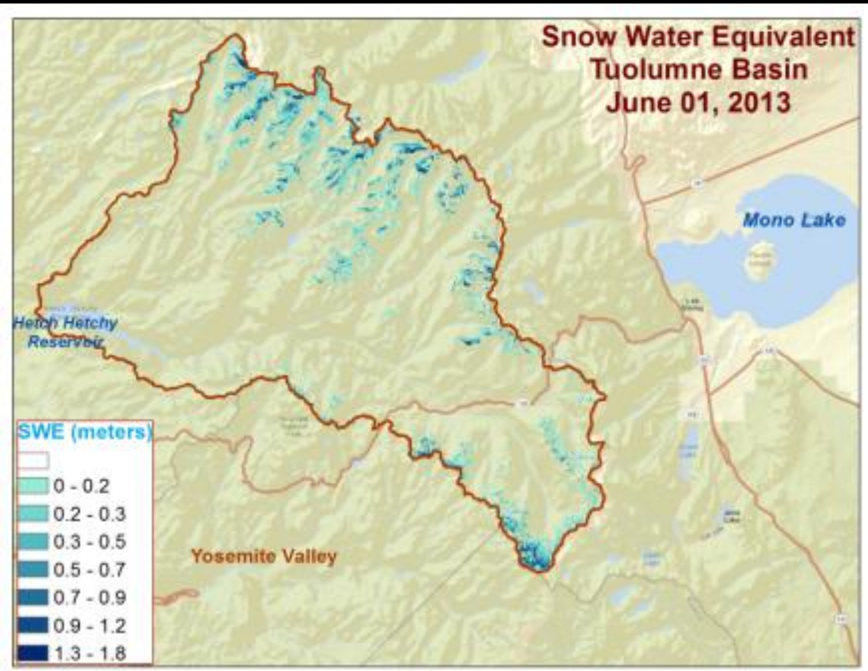


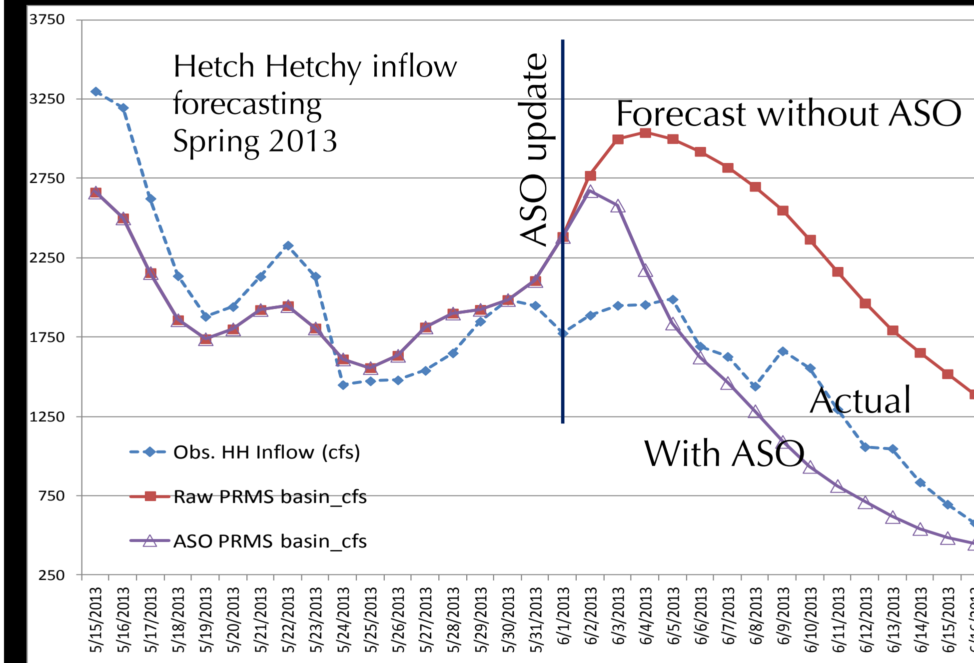
USGS PRMS Hydrologic Budget





Improved Estimates for Water Management in California



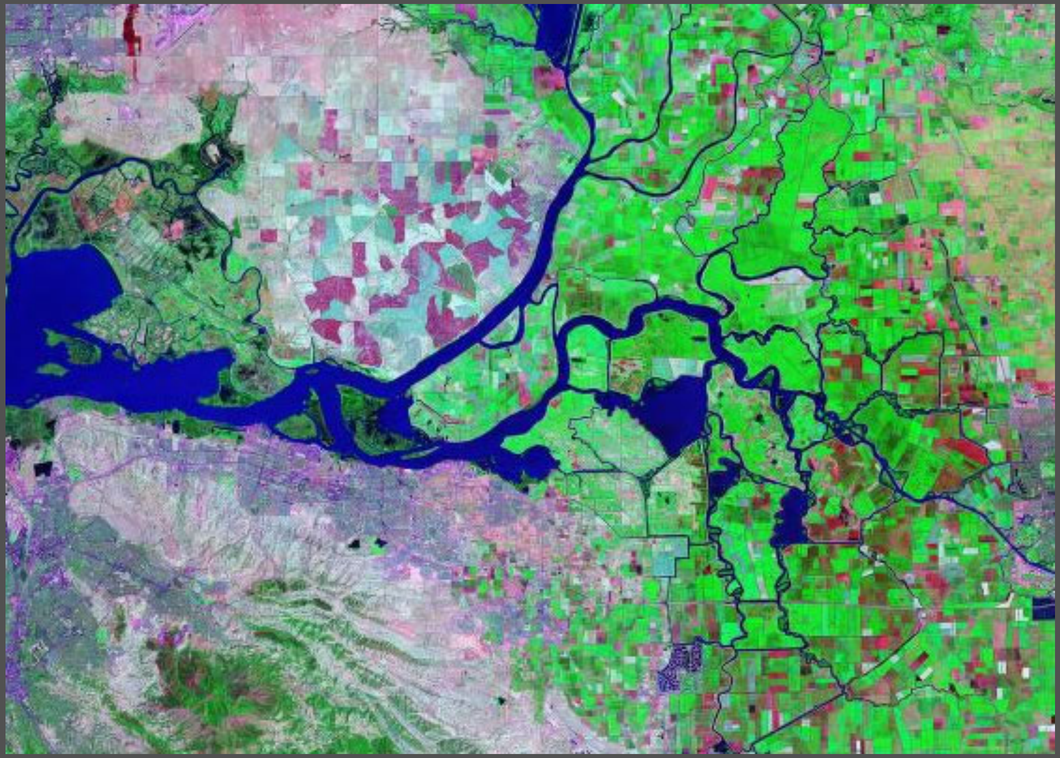


The JPL ASO team's prediction of water inflow into Hetch Hetchy Reservoir in cubic feet per second(shown in red) was modified on June 1, 2013 based on snow water equivalent (SWE) data from the NASA/JPL Airborne Snow Observatory. The new forecast (shown in purple) provided a factor of 2 better estimate of the actual inflow (shown in blue) and enabled water managers to optimize reservoir operations in its first year.

Tom Painter, JPL

Airborne Monitoring of the Sacramento-San Joaquin Delta

Critical Infrastructure: The Levees



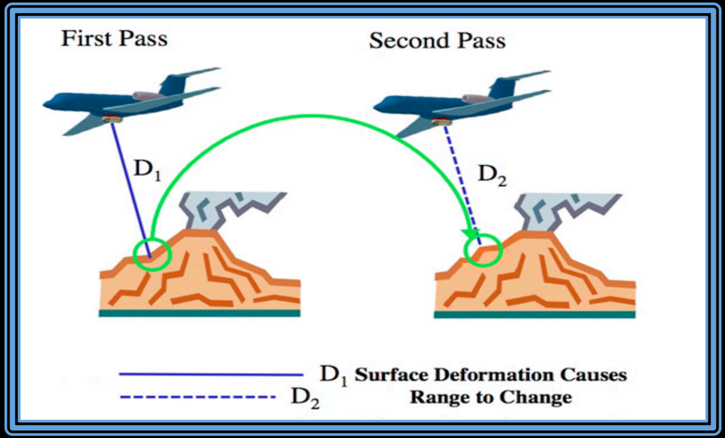
- Over 60 reclaimed islands surrounded by 1100 miles of levees
- Most islands lie below mean sea level.
- Collects run-off from approximately 2/3 of the state via the Sacramento and San Joaquin rivers.
- Supplies water to ~2/3 of the residents of California and to almost all of the agriculture of the Central Valley.

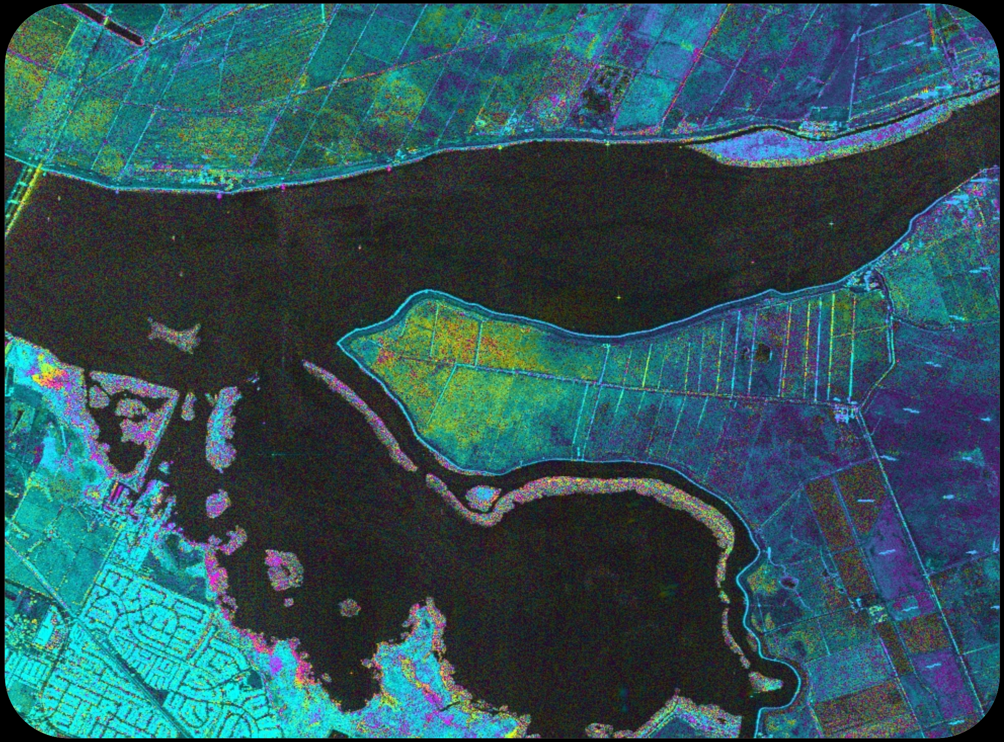
THE DELTA IS THE MOST CRITICAL WATER RESOURCE IN CALIFORNIA.

Airborne Monitoring of the Sacramento-San Joaquin Delta

UAVSAR: Uninhabited Aerial Vehicle Synthetic Aperture Radar

We conduct UAVSAR flights to image the Delta every ~6 weeks from 3 different directions to detect changes in the levees and measure subsidence rates.



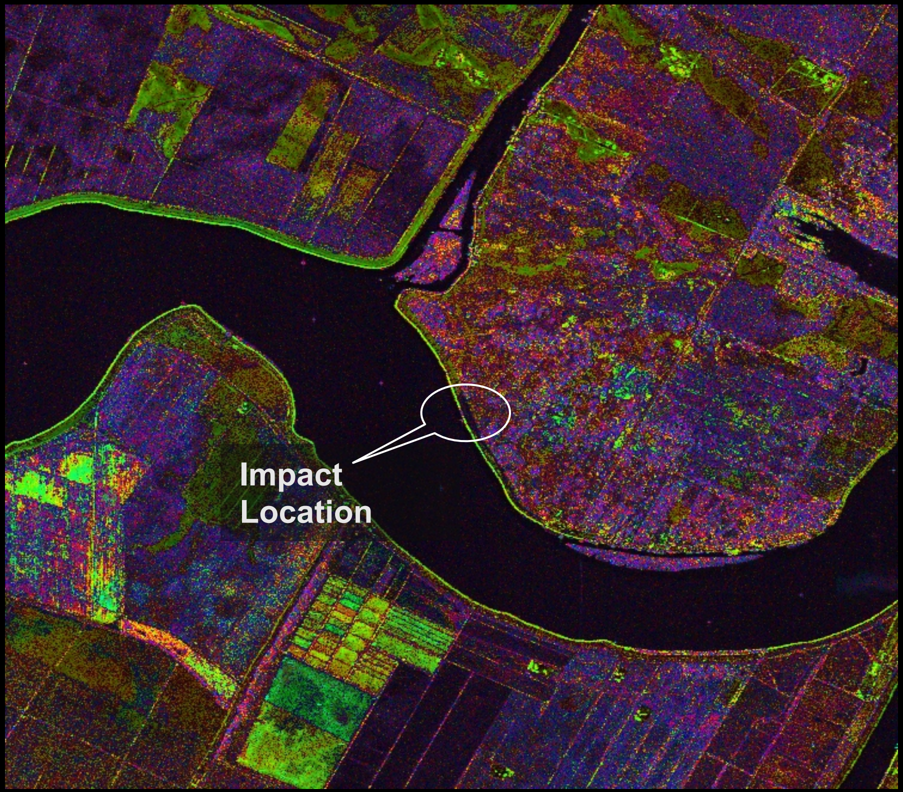


Airborne Monitoring of the Sacramento-San Joaquin Delta

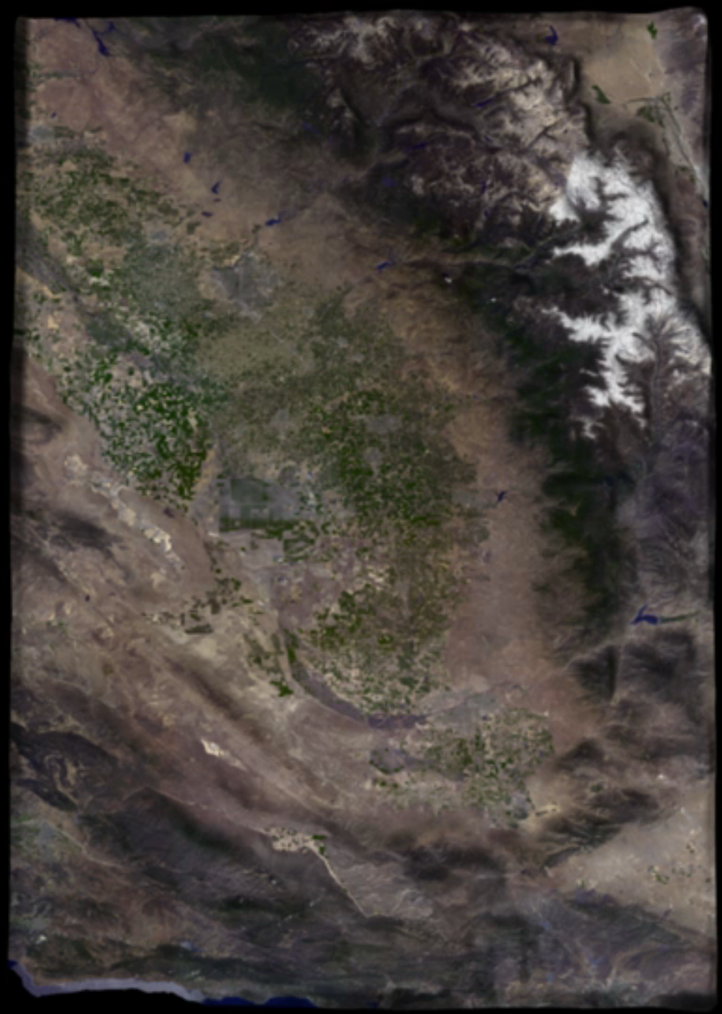
Post-Impact Levee Monitoring

Bradford Island damaged levee:

On August 28, 2009 a ship rammed the north levee on Bradford Island. This image showing the impact location was made using UAVSAR data collected on 7/17/09 and 9/10/09. We have been using the UAVSAR radar to monitor the repaired levee for changes since the damage occurred.



Continuing Subsidence in the Central Valley 2007-2011



Zhen Liu, Vince Realmuto, Tom Farr, JPL

• Water from snow melt ✔
• Timing of runoff
• Precipitation forecasts
• Water conveyance infrastructure ✔
Future Water Availability
• Ecosystem health
• Levee integrity ✔
• Salinity intrusion
• Evapotranspiration
• Groundwater storage ✔
• Integrated modeling/prediction

Bridging the gap from Science to Information

- Satellite and airborne remote sensing technologies has matured from discovery science to monitoring

- How can they be used to improve water resource management, for food security, health, and more?
  - Applications are a key component for all NASA Earth science missions

- Where are the information gaps?
- Who needs the information?
- How should the information be conveyed?

And finally……

- JPL is investing to integrate these data into California and Western US water information products – stay tuned

- Special mention for JPL colleagues: Cathleen Jones, Tom Painter, Jay Famigietti, Tom Farr, Duane Waliser, and many more whose work and efforts these slides represent

THANK YOU!!

Orbiting Carbon Observatory: The CO_2 Puzzle

- Humans have added >200 Gt C to the atmosphere since 1958
- Less than half of this CO_2 is staying in the atmosphere
- Where are the *sinks* that are absorbing over half of the CO_2?
  - Land or ocean?
  - Eurasia/North America?
- Why does the CO_2 buildup vary from year to year with nearly uniform emission rates?
- How are variations driven by large scale drivers of atmospheric variability (e. g., ENSO)?
- Can we reduce the uncertainty on each key system within the carbon cycle?
- How will these CO_2 sinks respond to climate change?