Tools for 21st Century Water Management

NASA Remote Sensing

Water Dialogue

Michael Gunson
Jet Propulsion Laboratory

January 28, 2015
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

Sea Level Changes - ENSO
NASA Earth Science Missions - 2015
JPL Earth Science Observations

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
Orbiting Carbon Observatory: The CO$_2$ Puzzle

Fossil Fuel Emissions of CO$_2$ and Atmospheric Buildup, 1958-2008

- Total Emissions
- Amount in Atmosphere
- El Nino Event

Data from LeQuere et al., 2009
Global Carbon Project, 2011

OCO-2 Measurements Over Pasadena

Image by Debra Wunch, Caltech

The unexpected observation: solar induced fluorescence

OCO–2 Solar Induced Fluorescence from current Nadir orbits

SIF / (W m² micron⁻¹ sr⁻¹)

0.05 0.15 0.25 0.35 0.45 0.55 0.65 0.75 0.85 0.95 1.05 1.15 1.25 1.35
Scatterometry: sea ice changes
Scatterometry: ocean surface winds
The spare parts scatterometer
Intergovernmental Panel on Climate Change (IPCC) climate model projections by region:

Change in Temperature [°C]

Models agree on direction of temperature increase

Change in Soil Moisture [%]

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

Can Remote Sensing Improve Water Resource Management?

NASA

Operational Entities

NASA Operational Environments

USGS

Science for a Changing World
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.

http://www.csr.utexas.edu/grace/
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.

**Steps:**
1. Laser pulse sent from plane
2. Laser reflects back from surface of snow.
3. The time it takes the laser to return to the plane is proportional to the elevation. The difference between summer elevation and snow elevation is the snow depth.

**Sources:** Thomas Painter, Frank Gehrke, Optech Inc.

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**How will it melt?**

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

**Diagram:**
- Old snow doesn’t reflect as much light, which causes it to melt faster.
- Debris like dust and plants can make snow reflect less.
- As snow absorbs sunlight, it warms up. This results in more melting and even more light absorption.
- New snow is most reflective.

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Maxwell Henderson / The Register
Spring Data Collection - Weekly
ASO time series of snow water equivalent
Tuolumne Basin 2013
USGS PRMS Hydrologic Budget
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.
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 ✔

• Ecosystem health
• Levee integrity ✔
• Salinity intrusion

Future Water Availability

• 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 Famiglietti, Tom Farr, Duane Waliser, and many more whose work and efforts these slides represent

THANK YOU!!
Orbiting Carbon Observatory: The CO₂ Puzzle

- Humans have added >200 Gt C to the atmosphere since 1958
- Less than half of this CO₂ is staying in the atmosphere
- Where are the sinks that are absorbing over half of the CO₂?
  - Land or ocean?
  - Eurasia/North America?
- Why does the CO₂ 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 CO₂ sinks respond to climate change?