New and Future Remote Sensing Capabilities for Monitoring Earth’s Fresh Water

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• Water from snow melt
• Amount & timing of runoff
• Precipitation & forecasts

• Water conveyance infrastructure
• Levee Integrity

• Ecosystem health
• Salinity intrusion
• Integrated modeling/prediction

• Evapotranspiration
• Groundwater storage
• Soil Moisture
The way we’ve measured snow in the West since 1910

Tom Painter/JPL
The way we see SWE now

The way we want to see it

... 39 million times more coverage
Snow Water Equivalent

Riegl Q1560 3D Scanning lidar
1064 nm, canopy penetration
1 m spatial resolution

Albedo
CASI-1500 Imaging Spectrometer
0.35-1.05 μm
2 m spatial resolution from 4000 AGL

• < 24 hour turnaround of products
• Quantification of snow volume
• Quantification of snowmelt timing
• Quantification of snowfall
• Much improved allocations
• Much improved runoff forecasting

Tom Painter/JPL
Snow Water Equivalent
Tuolumne Basin
Apr 13, 2014

SWE (meter)

0.00
0.06
0.13
0.19
0.26
0.32
0.39
0.45
0.50

0 10 20 30 40 km

Tom Painter/JPL
**Measurement:** Δx between 2 satellites

**Infer:** mass change at the surface

**Units:** represented as cm of H₂O
California’s Central Valley 2004 - 2014: Groundwater changes from GRACE

- GRACE measures all the water storage changes on land
- To estimate groundwater, the snow, surface water and soil moisture changes must be subtracted

Groundwater changes from GRACE:

Brian Thomas & F. Landerer, JPL
UAVSAR

A High Resolution, Low Noise, Fully Polarimetric L-band SAR

(UAVSAR = Uninhabited Aerial Vehicle Synthetic Aperture Radar)

Designed for repeat track differential interferometry & optimized for change detection.

Differential Interferometry (DINSAR)

First Pass

Second Pass

$\Delta \phi = \frac{4\pi}{\lambda} (D_2 - D_1)$

$\lambda$ = wavelength of radar

POC: Cathleen E. Jones (cathleen.jones@jpl.nasa.gov)
Project Overview

Monitoring Levees and Subsidence in the Sacramento-San Joaquin Delta

NASA Program: Applied Science - Natural Disasters
Collaboration: JPL, Ca. Dept. of Water Resources, USGS, HydroFocus
Instrument: UAVSAR, near-monthly collections over the entire Sacramento-San Joaquin Delta since July 2009

Objectives:
1. Disaster Mitigation and Response: Use DINSAR to monitor movement of and seepage through levees.
2. Water Resource Management: Measure subsidence rates across the entire area to inform future long-term solutions to water management issues in the area.

Scientific Impact:

Major Findings:
1. Cracks in levees identified with DInSAR.
2. Post-repair settlement along levees detected and monitored.
3. Seeps identified with coherence change detection; detection methodology developed.
4. Subsidence rates within the islands show general subsidence trends in the region.

POC: Cathleen E. Jones (cathleen.jones@jpl.nasa.gov)
Continuing Subsidence in the Central Valley

PALSAR-1 (Japan)  Zhen Liu, Vince Realmuto, Tom Farr (JPL)
Highest subsidence directly affecting the California Aqueduct:

Subsidence bowl immediately north of the junction of the Ca. Aqueduct with Avenal Cutoff Rd.

A 1.3 mile stretch of the aqueduct experienced >7” of subsidence, with maximum reaching 11.5” closest to the center of the subsidence feature.

Courtesy, Cathleen Jones/JPL
Soil Moisture

Soil Moisture Active Passive Mission

SMAP
2015 Launch

Better weather & climate Forecasting

Informing agriculture practices

Drought early warning

Extent of flooding

Human health: Vector borne disease

Transportation: Air (Dust), Sea (Ice), Land (Mud)

Combined Radar and Radiometer

3km Radar footprint
40km Radiometer footprint
6am/6pm orbit
2-3 Day Revisit

Products
Soil Moisture
Freeze-Thaw State
Vegetation Water Content
Surface Temperature
First SMAP Global Soil Moisture Map

May 4 to May 11, 2015

Combined Radar and Radiometer
How much “surface water” do we have?

1. **Surface Water** is key to the global water cycle, regional water availability, and flood/drought risk and prediction.

2. **The Problem** In-situ observations cannot address global, or even regional, surface water information needs.
SWOT Mission Overview

• The Surface Water and Ocean Topography (SWOT) mission is a NASA/CNES/CSA/UK mission scheduled for launch in 2020

• Mission Objectives:
  • Global observation of water storage change and discharge
  • Observation of ocean mesoscale and submesoscale circulation

• Measurement Capabilities for Hydrology:
  • Observation period: ~10 days
  • Imaging resolution: ~50 m
  • Physical observations:
    • Water body shape and extent
    • Water surface elevation
    • Water surface slope
  • Derived quantities:
    • Water extent
    • Storage change
    • River discharge
Water Cycle and Freshwater Availability

Next Challenge: Adding Integrated Value to the Measurements

FRESHWATER STORAGE IN ICE AND SNOW
Airborne Snow Observatory (ASO)

CLOUDS
CloudSat, MODIS

WATER VAPOR
AIRS, MLS, GPS-RO
Tempest (2017)

PRECIPITATION
GPM
RainCube (2017)

RIVERS & LAKES
SWOT (2020)

EVAPOTRANSPIRATION
ECOSTRESS (2017)

GROUND-WATER
GRACE, GRACE-FO (2017)

SOIL MOISTURE
SMAP

WATER STORAGE IN OCEANS
Jason Series, SWOT (2020)

EVAPORATION
Aquarius
Importance of Atmospheric Rivers

Key to our water supply & Responsible for our floods

Working with National & International Programs to improve the accuracy and lead times of predictions of Atmospheric Rivers with
Comprehensive Capabilities for Monitoring Earth’s Fresh Water

- New Instruments
- Airborne Science & Prototype Monitoring
- Routine Satellite Mapping
- Research, Synthesis & Modeling
- Deliver Capabilities for Operational Entities
• backup
Progress in Subseasonal Weather/Climate Forecasting

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Drought Response Workshop
February 25-26, 2015
Irvine, CA
ARs : Key to Beneficial & Hazardous Water Delivery

25% - 45% of annual precipitation in the west coast states fell in association with atmospheric rivers.

Atmospheric Rivers are to the west what Hurricane Hazards are to the Southeast.

An average AR transports the equivalent of 7.5 times the average discharge of the Mississippi River, or about 10 Million acre feet per day. Of this, 20-40% may become precipitation.
Forecast Models Need to Improve their Forecasts of Landfall Location

For example: at 5-6 day lead time, global weather forecasts cannot determine if it will hit LA or San Francisco

Wick et al. 2013
The Unusually Snowy Winter of 2010/2011

2010/2011 winter
- Largest total seasonal snow (~170% above normal)
- Largest number of AR dates (twice normal)
- Largest AR-related snow accumulation

On average 9 AR dates per winter contribute 37% total snow
December 18 to 22 – Five Straight Days of AR

- >13 feet of snow in the Sierras
- >6 inches of rain in LA and >21 inches in parts of the foothills
- Spread into Nevada/Arizona/Utah; Zion NP evacuated
14 out of the season’s 20 AR dates occurred in one month

No. of ARs in Dec. 2010 well above normal range

Observed precipitation from 12 UTC 8 Dec to 12 UTC 22 Dec 2010

Widespread areas received more than 10 inches of rain or melted snow in 14 days

Max storm total >20 inches of rain (>10 feet of snow)

Right: Ralph and Dettinger 2012,
Climate Conditions of the 2010/2011 Winter

AO and PNA tend to be associated with more stormy weather in California.
When the AO and PNA are both in the negative phase, ARs are significantly more likely to occur.