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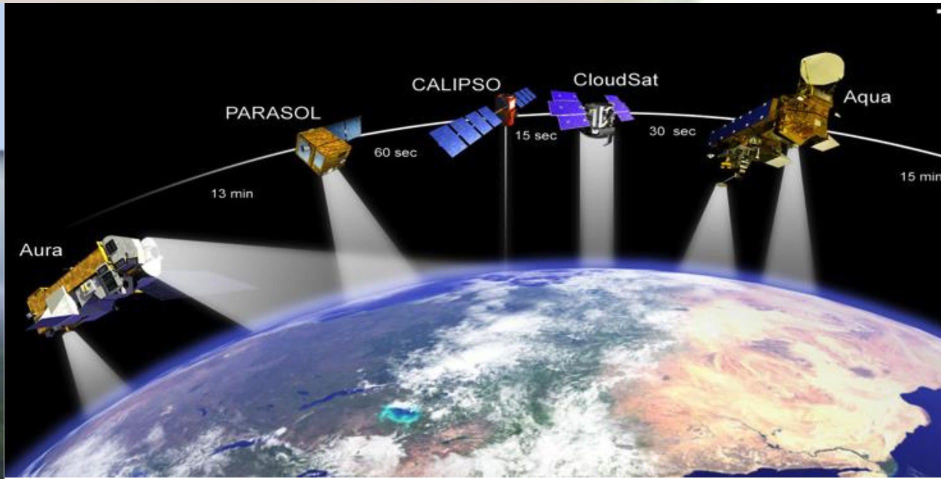
California Institute of Technology

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

Duane Waliser
Chief Scientist
Earth Science & Technology Directorate
Jet Propulsion Laboratory, Caltech
Pasadena, CA



Water from snow melt
Amount & timing of runoff
Precipitation & forecasts
Water conveyance infrastructure
Levee Integrity
Future Water Availability
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

Tom Painter/JPL

The way we want to see it

.... 39 million times more coverage

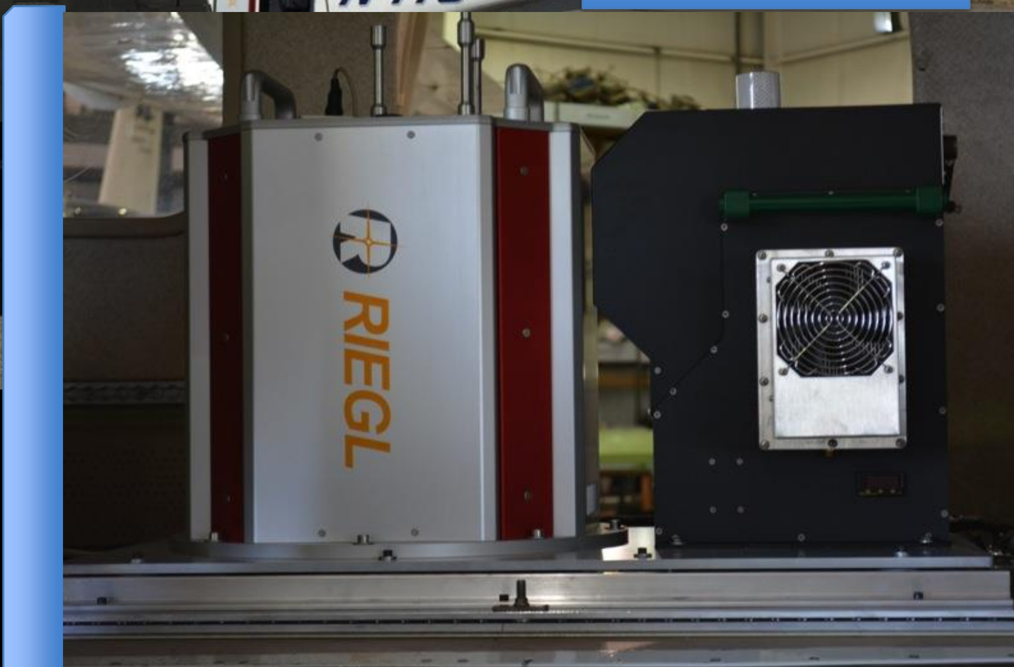
Snow Water Equivalent

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

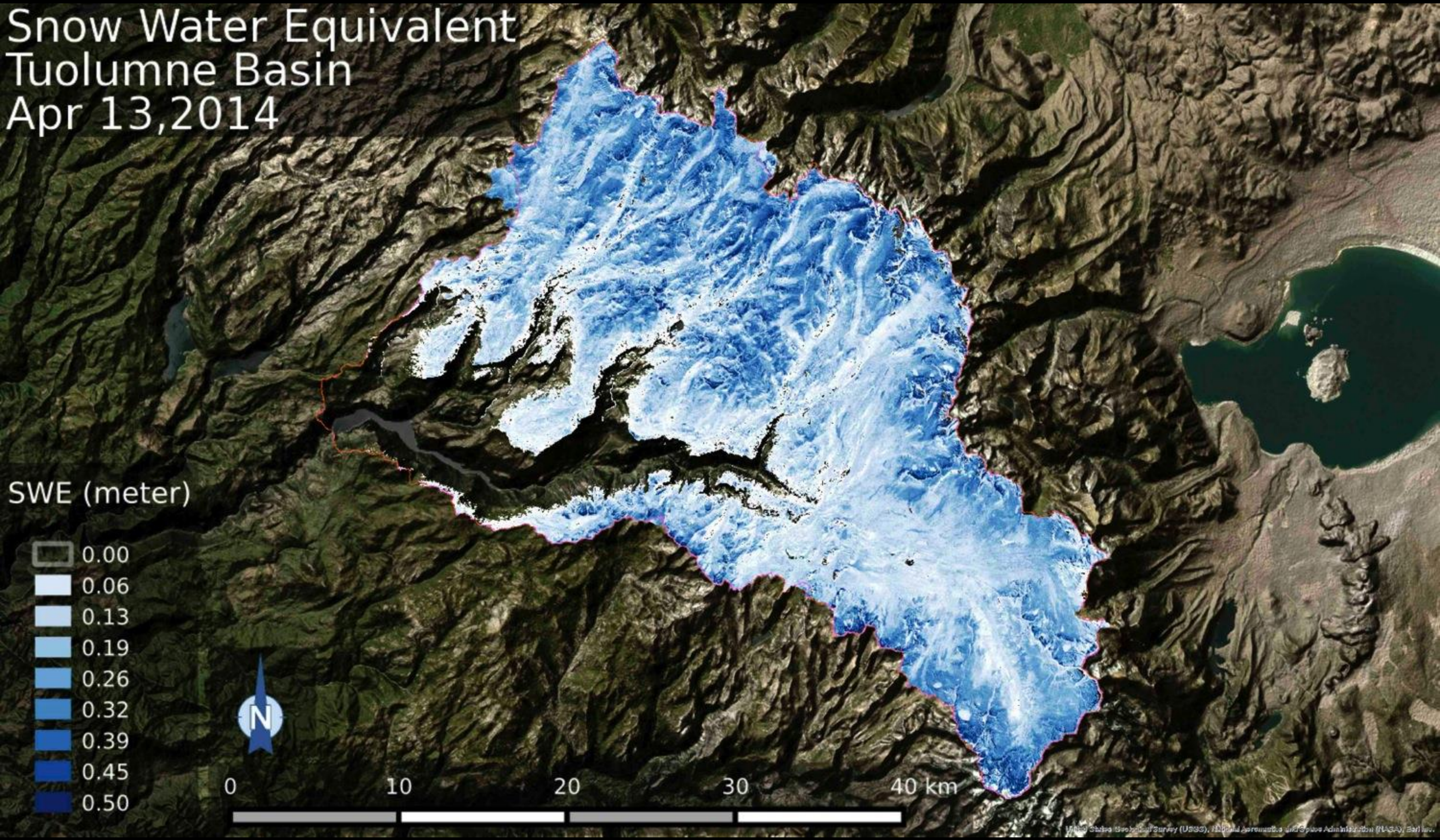
Albedo

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

Tom Painter/JPL



- < 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

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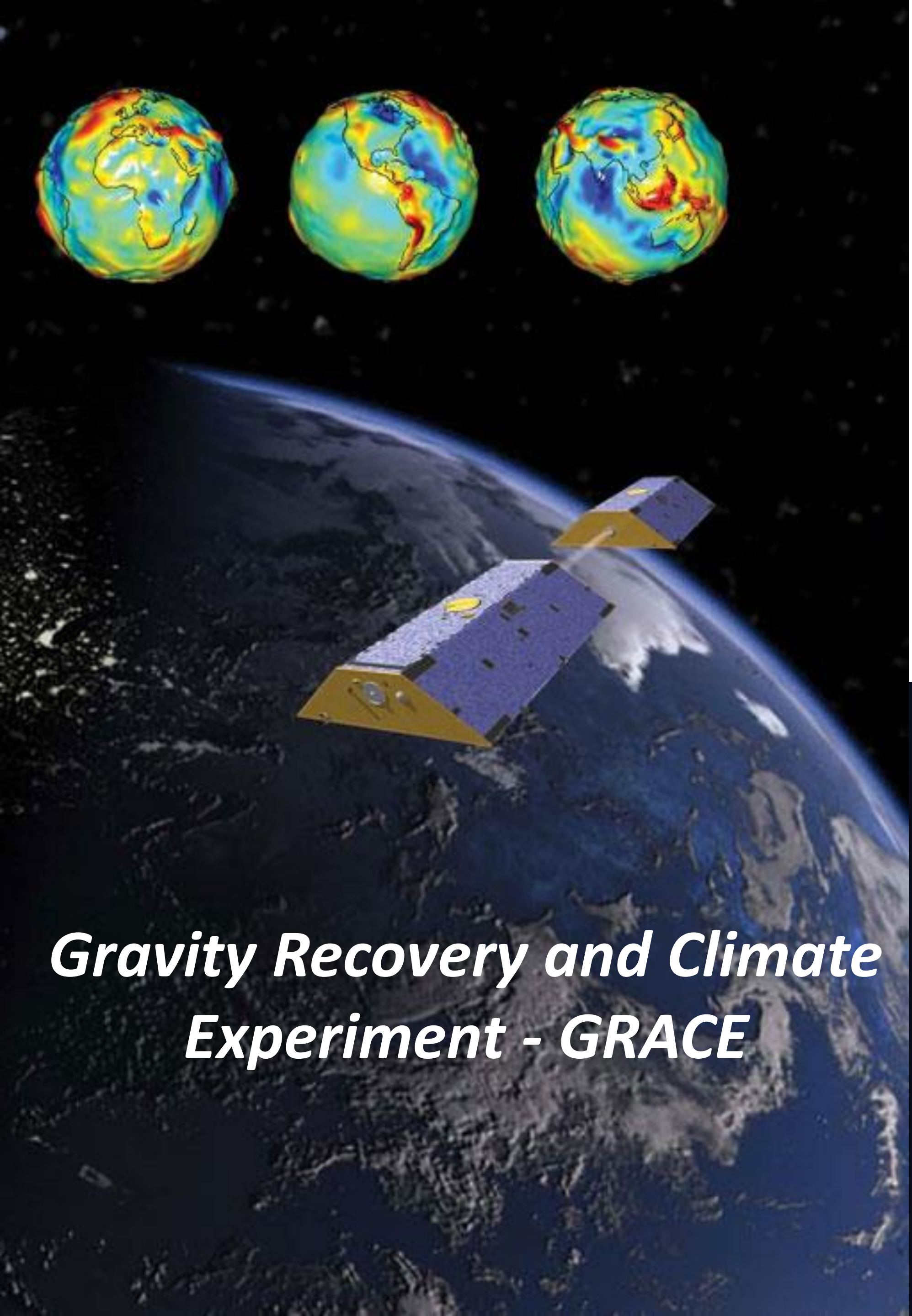
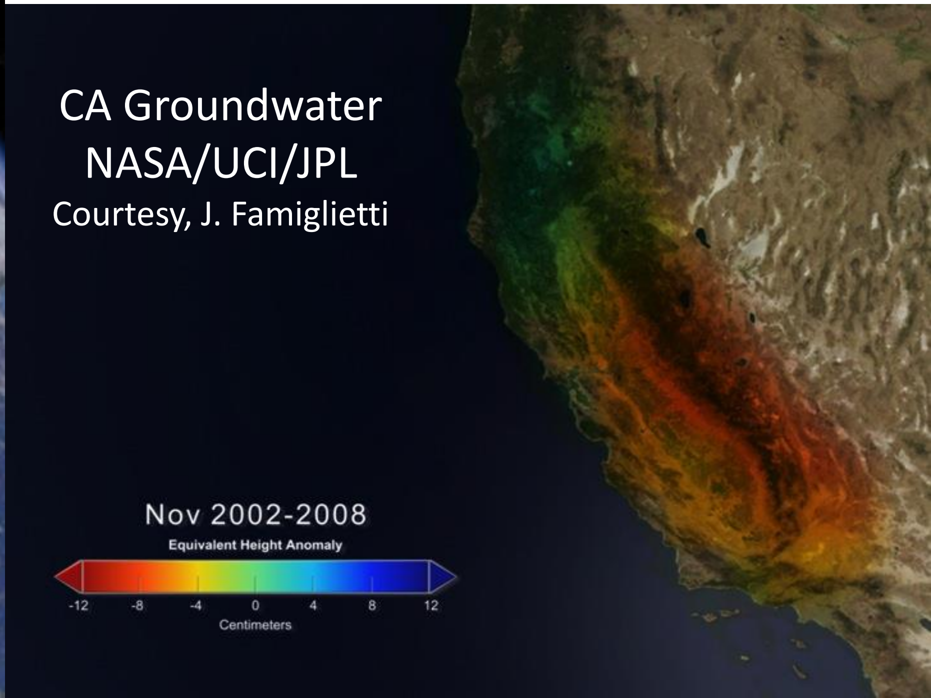


Gravity Recovery and Climate Experiment - GRACE

Measurement: Δx between 2 satellites

Infer: mass change at the surface

Units: represented as cm of H_2O



California's Central Valley 2004 - 2014: Groundwater changes from GRACE

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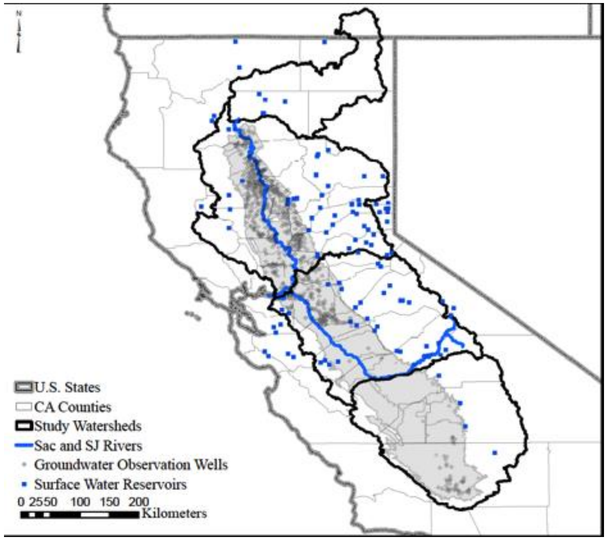
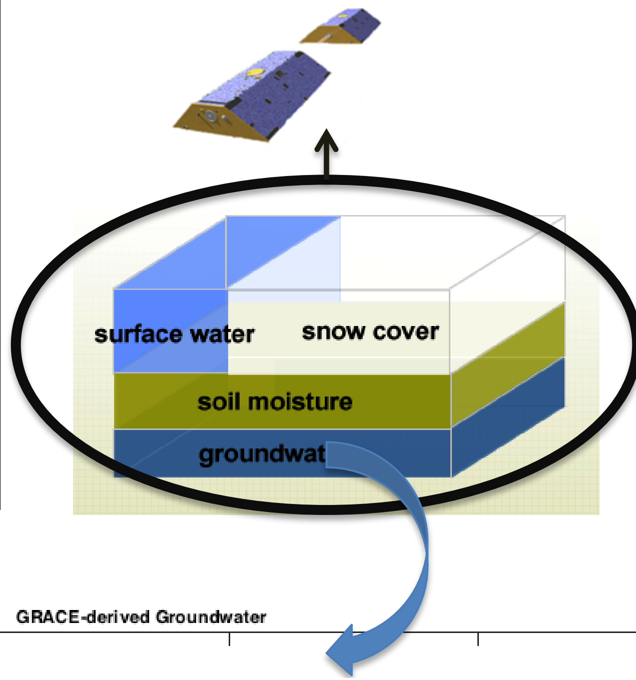
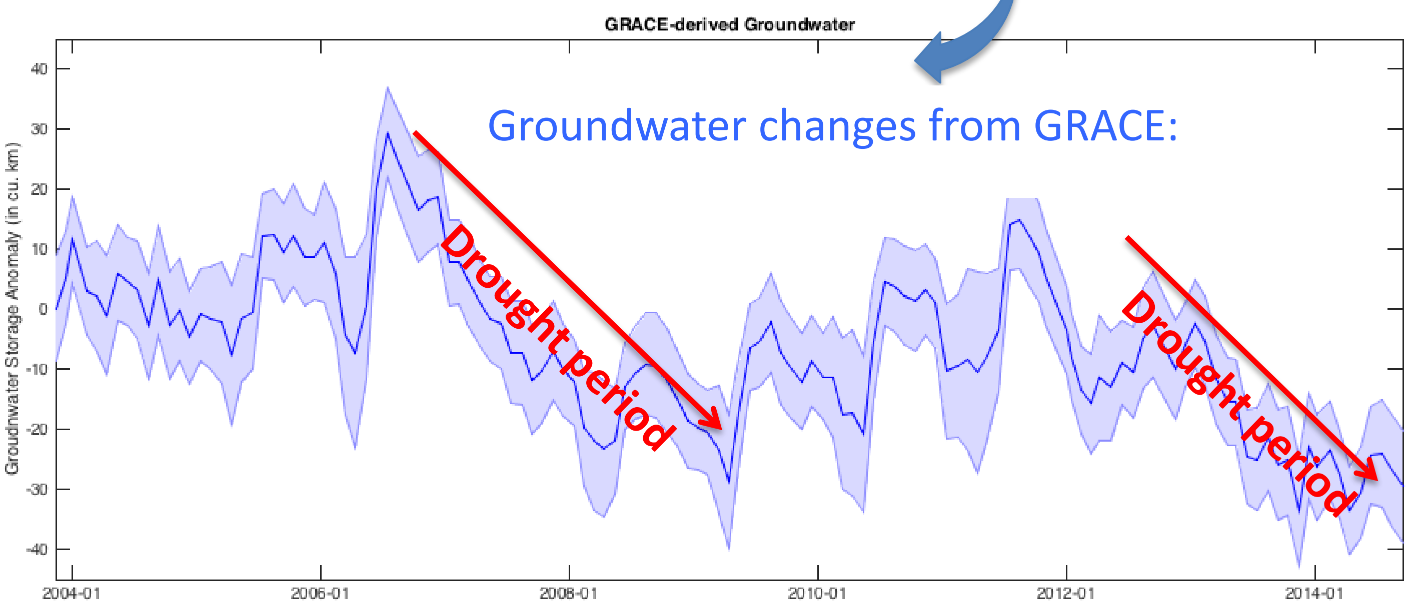




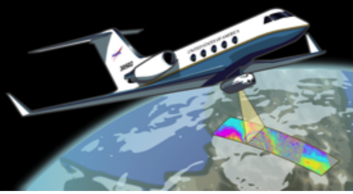
- GRACE measures all the water storage changes on land
- To estimate groundwater, the snow, surface water and soil moisture changes must be subtracted



Brian Thomas & F. Landerer, JPL

UAVSAR

UAVSAR
Uninhabited Aerial Vehicle Synthetic Aperture Radar



UAVSAR

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

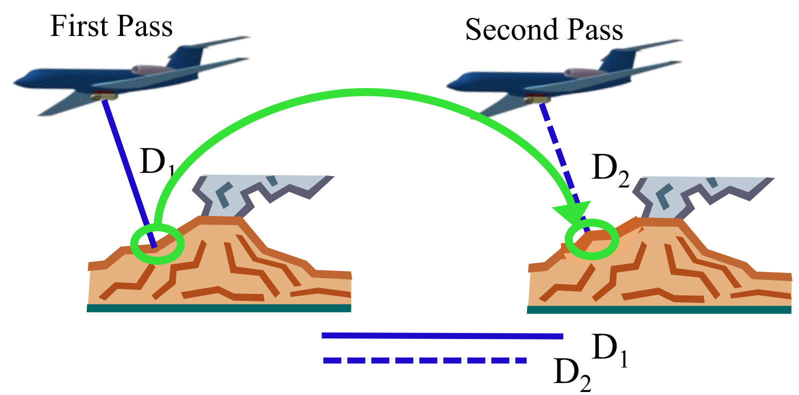
(UAVSAR = Uninhabited Aerial Vehicle Synthetic Aperture Radar)

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

Sacramento Delta / false color UAVSAR POLSAR image / 7 m resolution

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

Differential Interferometry (DINSAR)



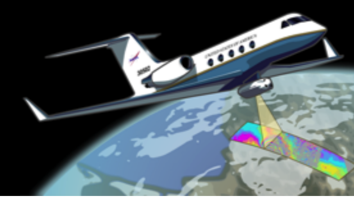
$$\Delta\phi = \frac{4\pi}{\lambda}(D_2 - D_1)$$

$\lambda =$ wavelength of radar

Application: Levee Monitoring

UAVSAR

Uninhabited Aerial Vehicle Synthetic Aperture Radar



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:

<u>Major Findings:</u>

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)

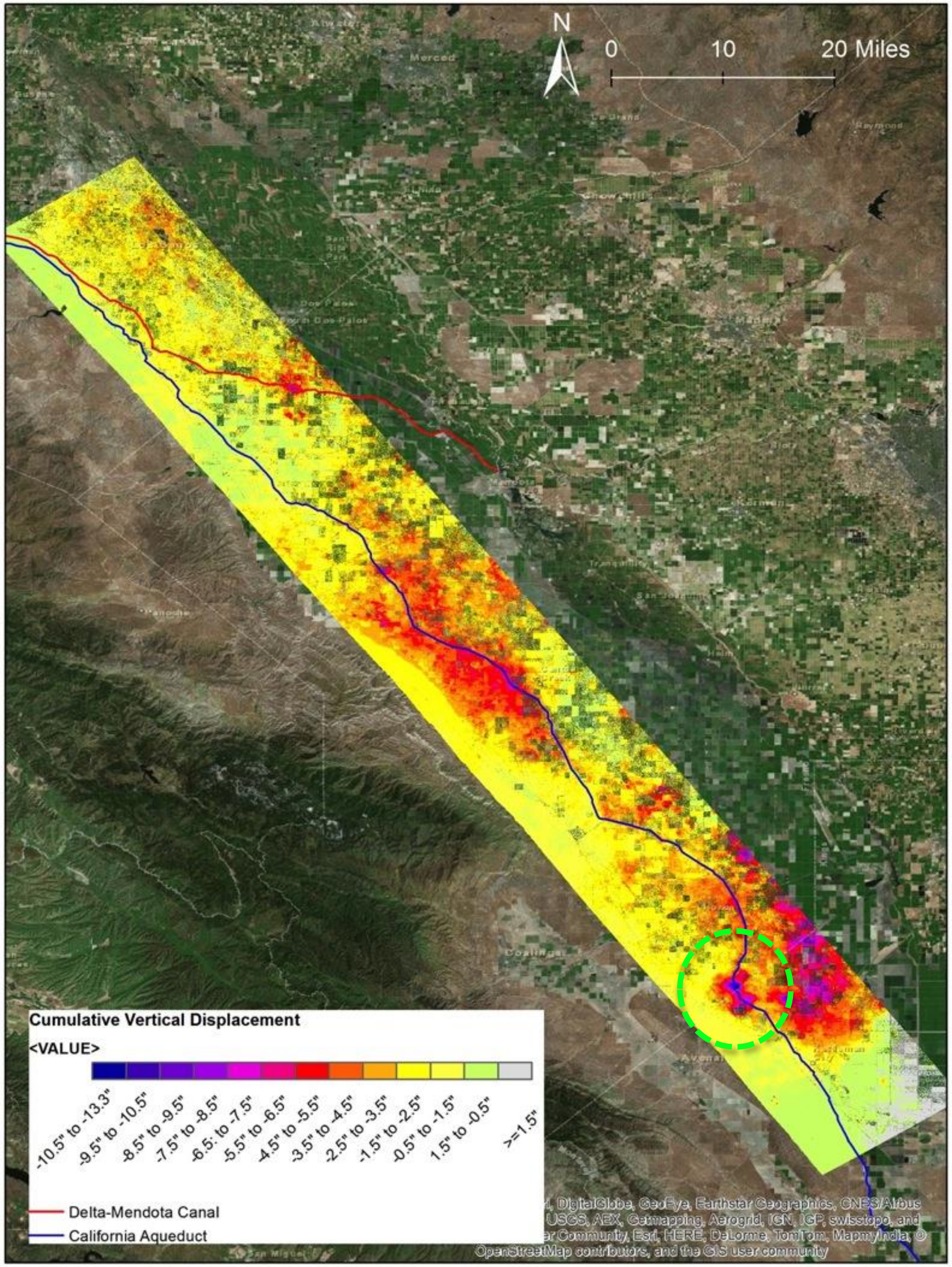
Levee Crown, Slope, and Toe Movement

Seep Detection

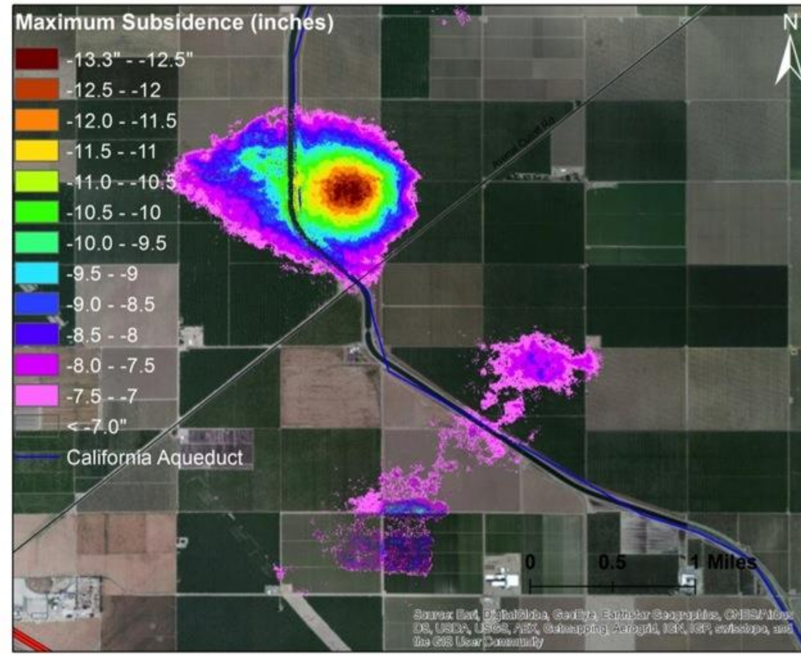
Continuing Subsidence in the Central Valley

PALSAR-1 (Japan)

Zhen Liu, Vince Realmuto, Tom Farr (JPL)



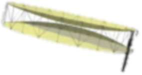
Highest subsidence directly affecting the California Aqueduct:



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

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

Better weather & climate Forecasting

Informing agriculture practices

Drought early warning

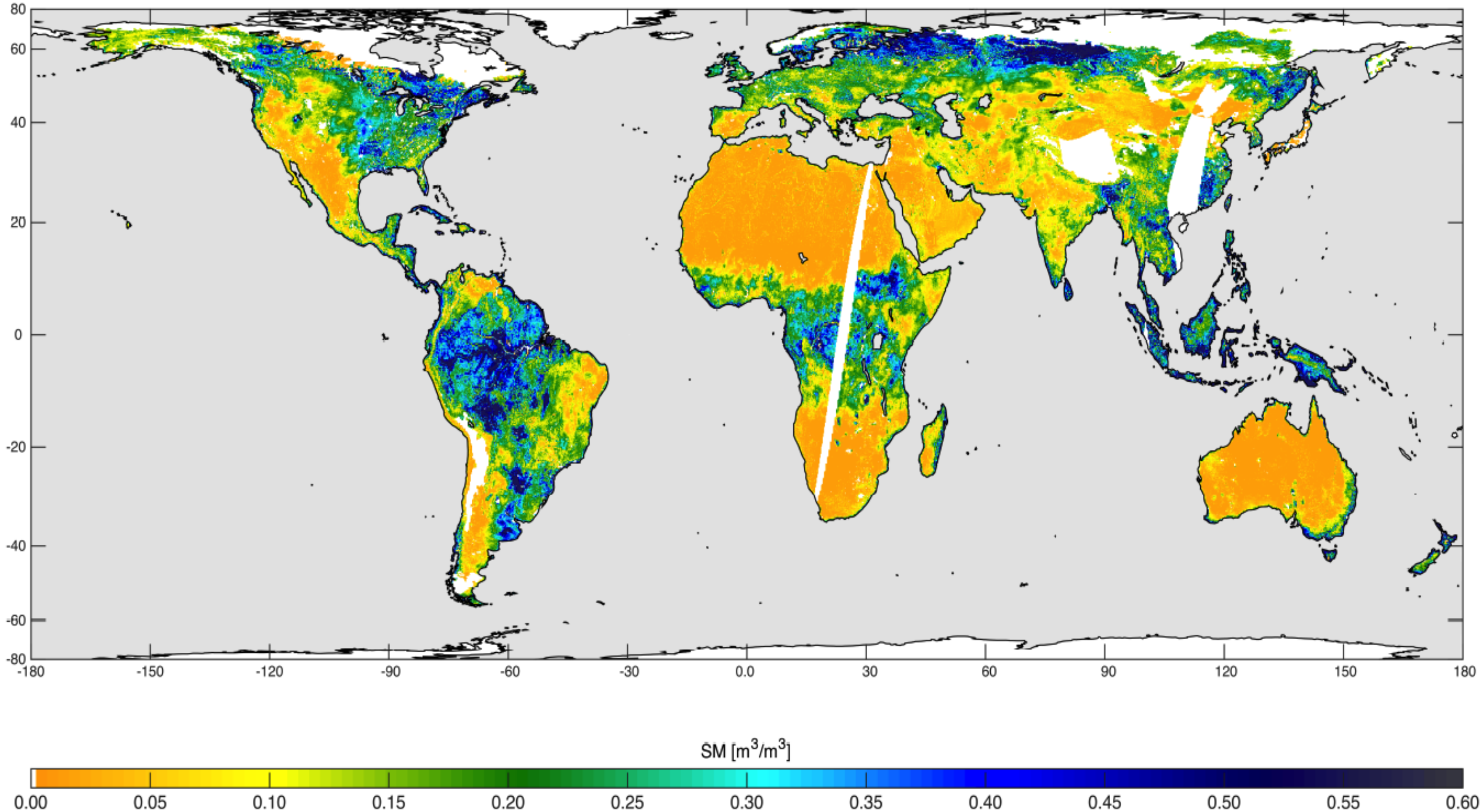
Extent of flooding

Human health: Vector borne disease

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

First SMAP Global Soil Moisture Map

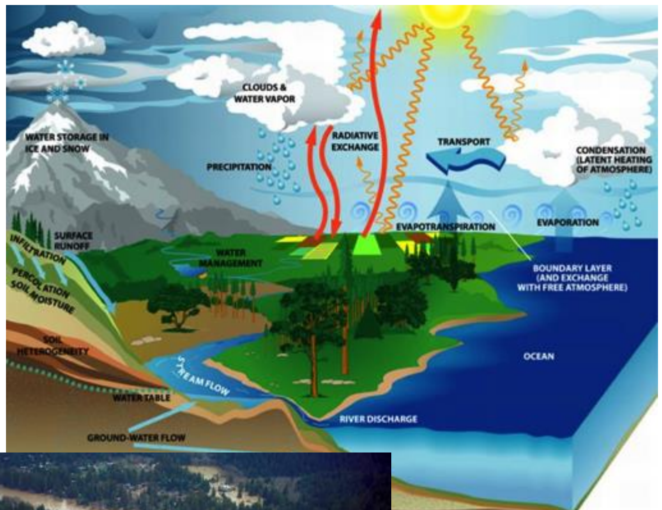
May 4 to May 11, 2015



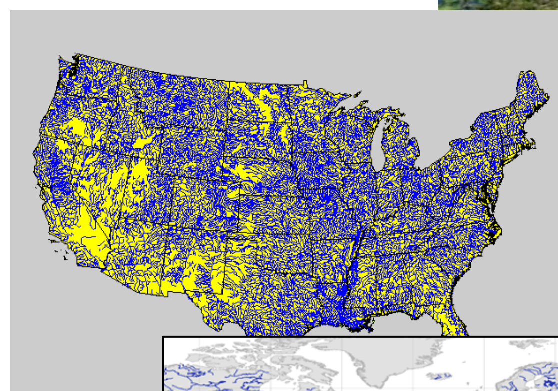
Combined Radar and Radiometer

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

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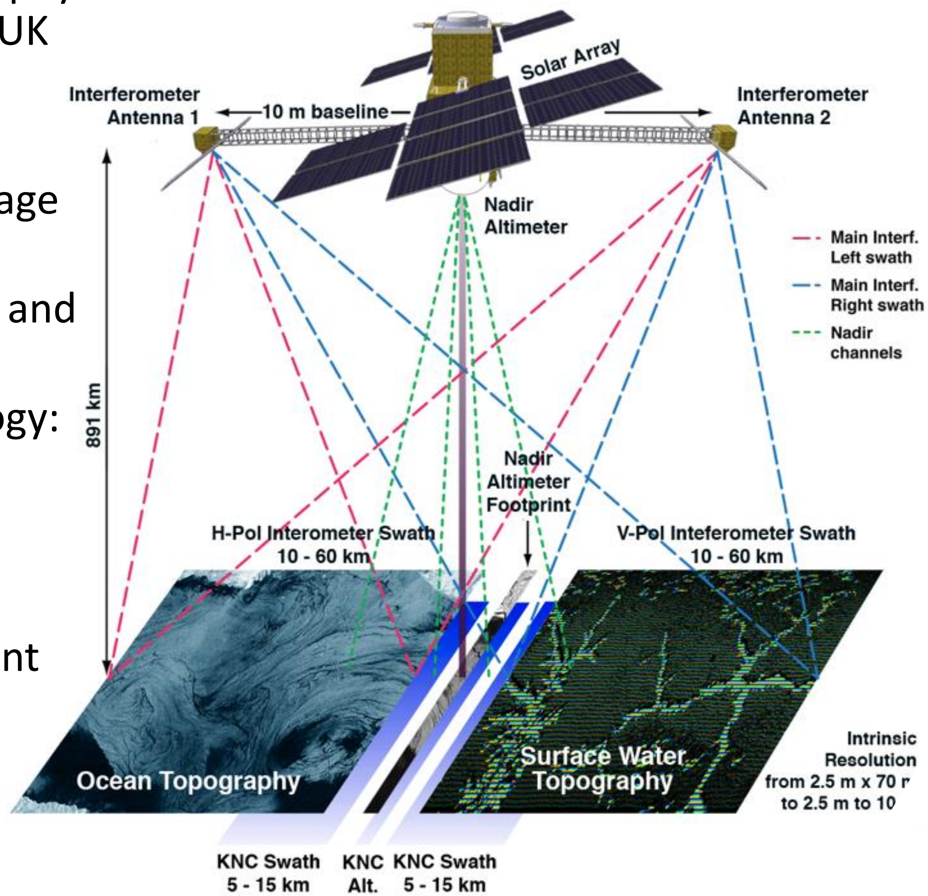
- The Surface Water and Ocean Topography (SWOT) mission is a NASA/CNES/CSA/UK mission scheduled for launch in 2020
- Mission Objectives:
    - Global observation of water storage change and discharge
    - Observation of ocean mesoscale and submesoscale circulation
- Measurement Capabilities for Hydrology:
    - 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

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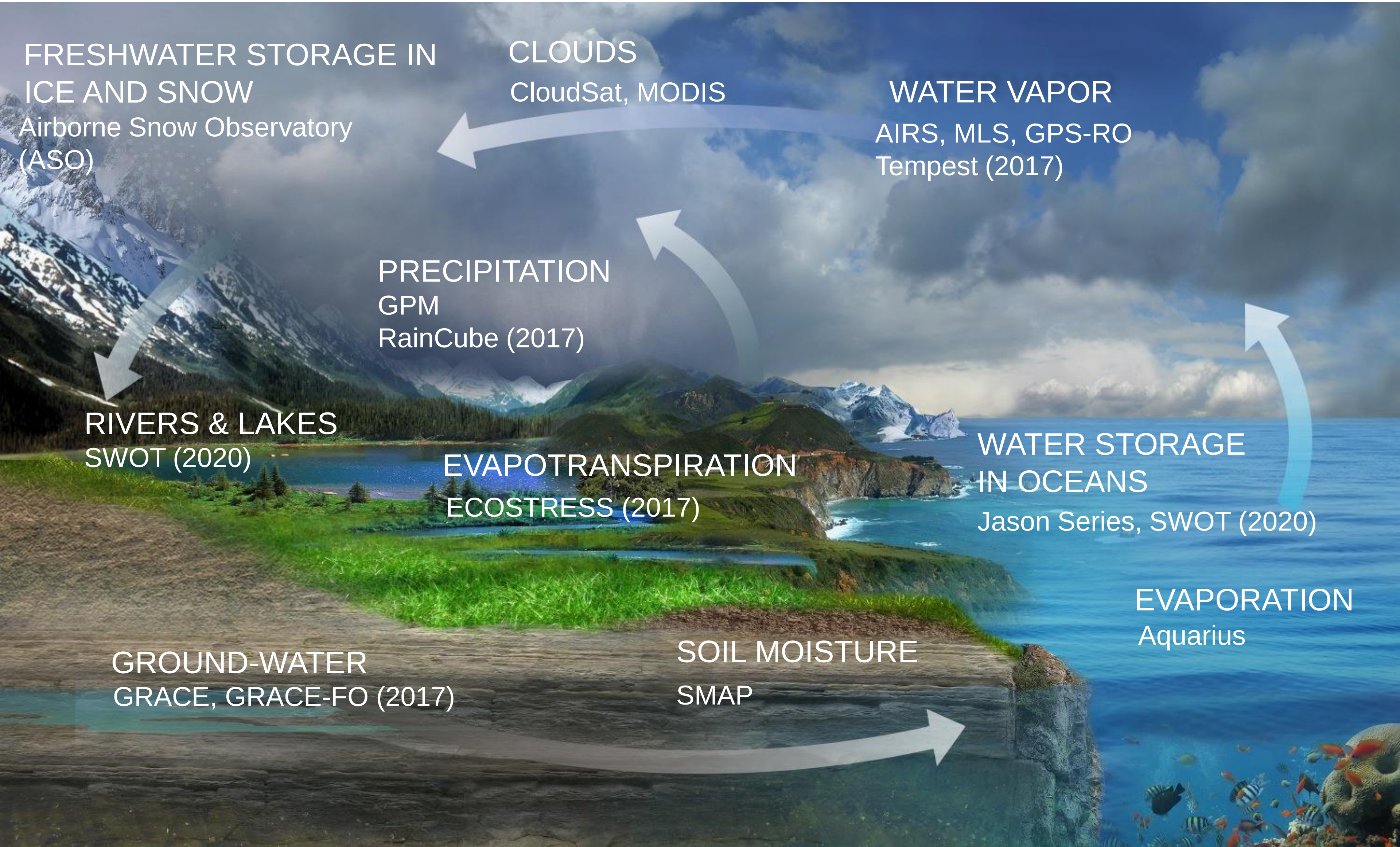
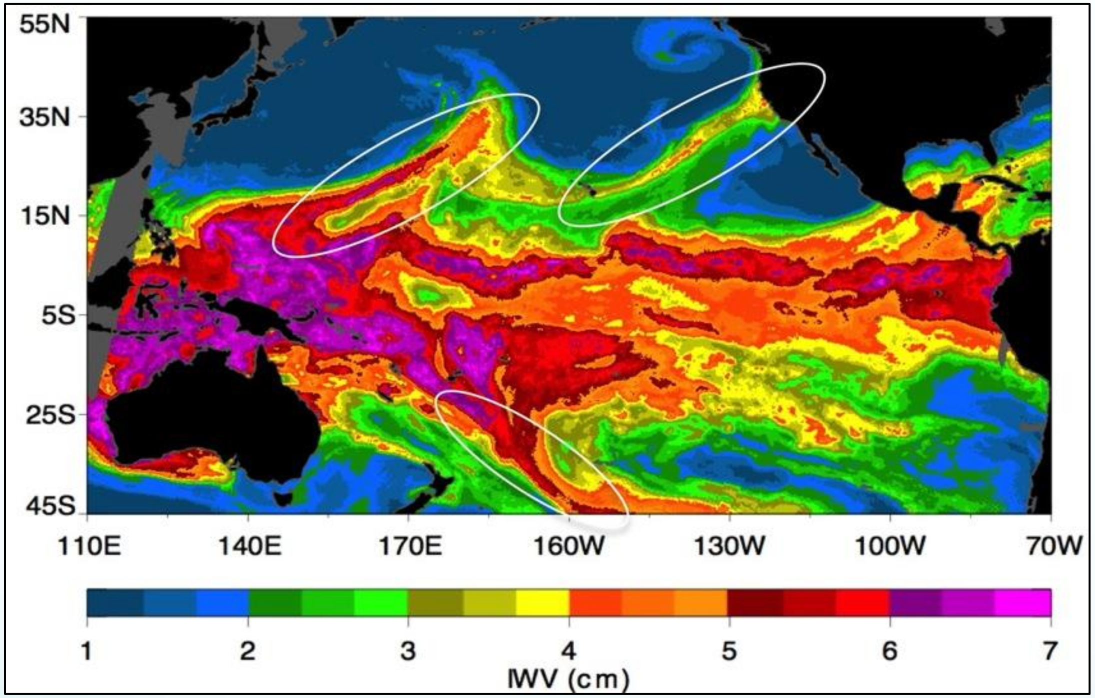
Next Challenge : Adding Integrated Value to the Measurements



Importance of Atmospheric Rivers

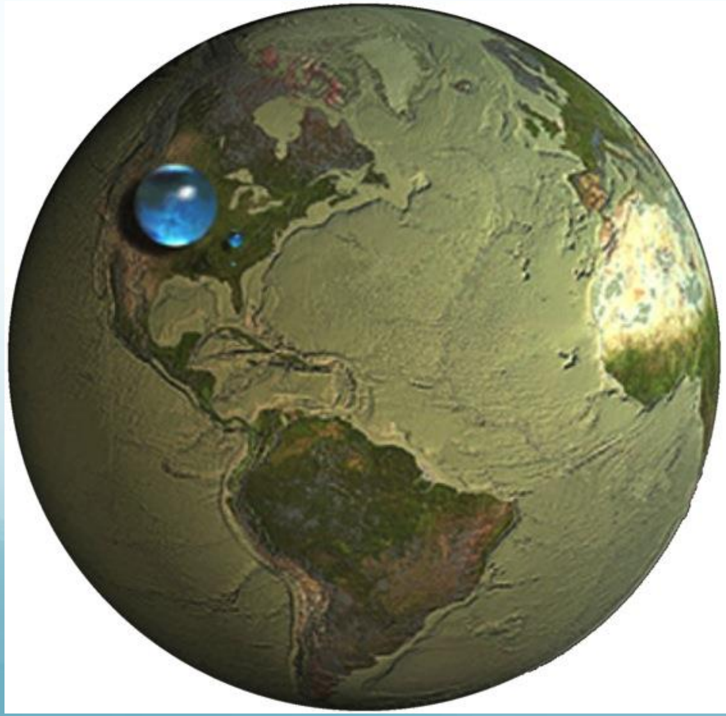
Key to our water supply &
Responsible for our floods



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

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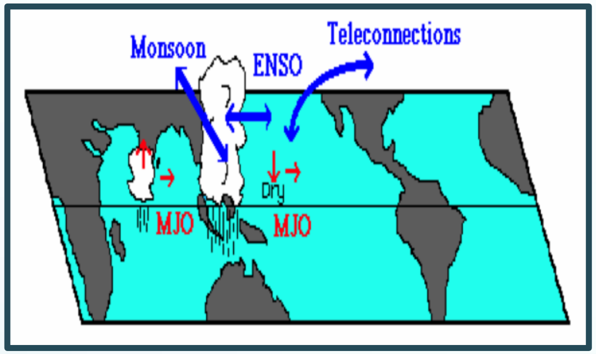
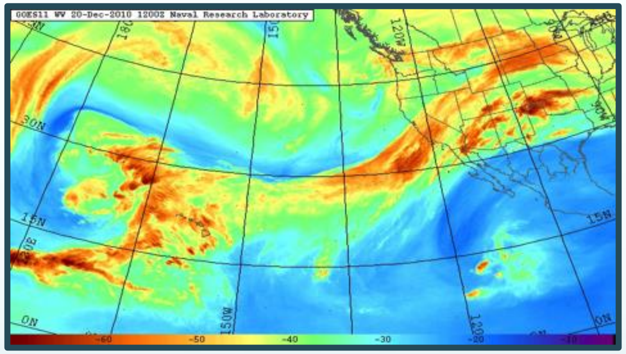
Progress in Subseasonal Weather/Climate Forecasting

Duane Waliser
Jet Propulsion Laboratory/Caltech
Pasadena, CA





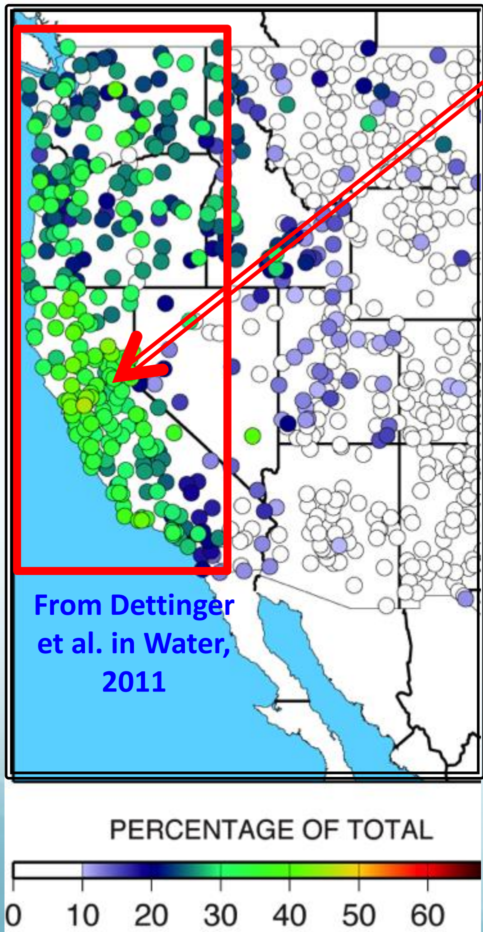
Drought Response Workshop
February 25-26, 2015
Irvine, CA

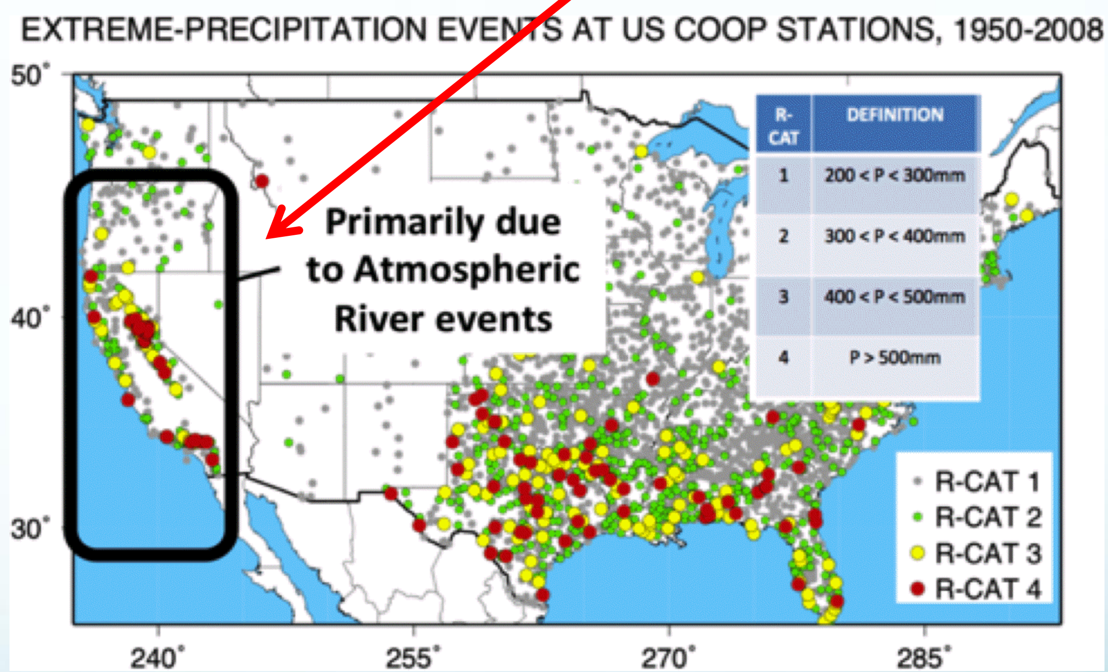
ARs : Key to Beneficial & Hazardous Water Delivery

ARs Provide beneficial rain and snow for water supply

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



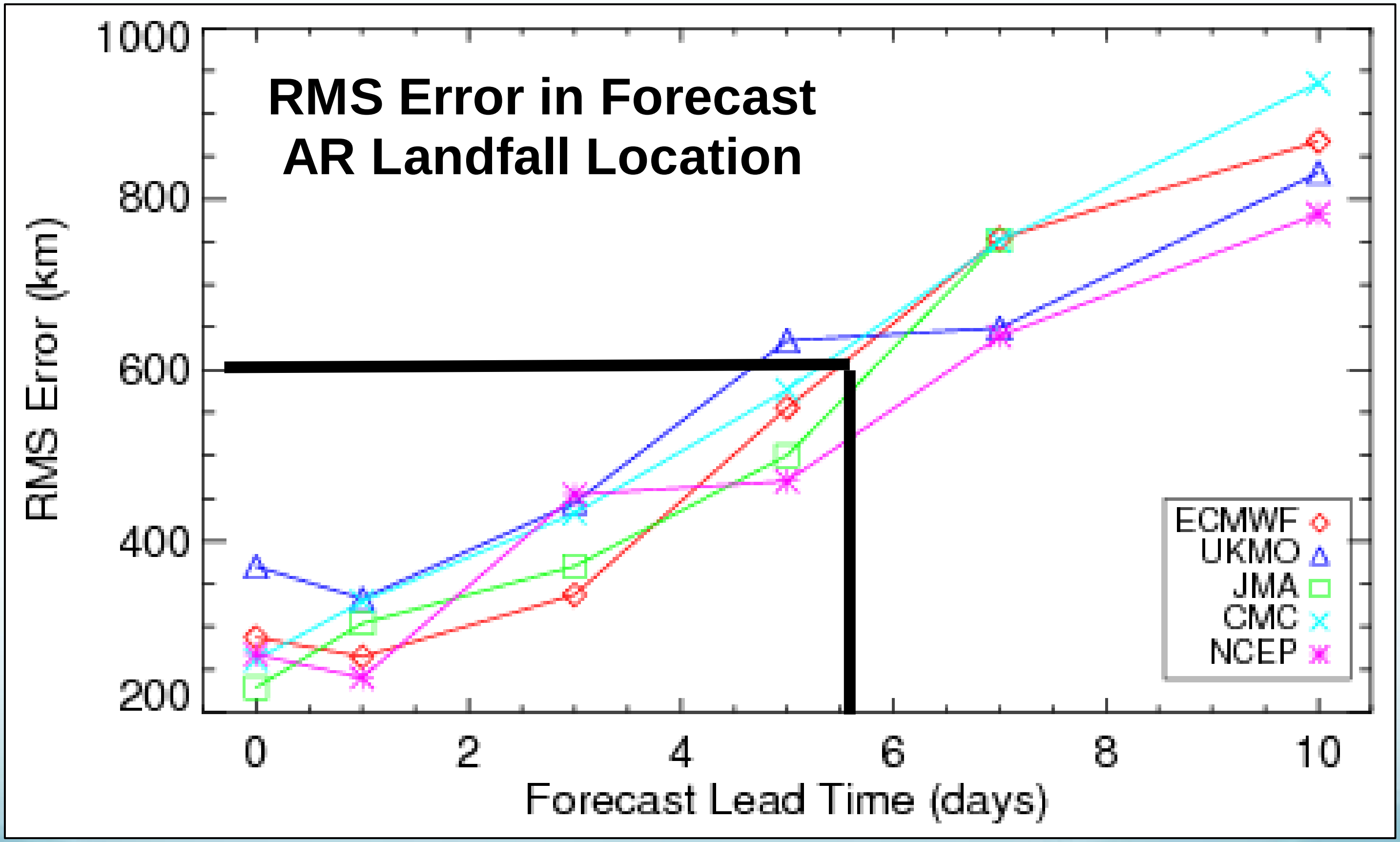


Ralph & Dettinger, 2012

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.

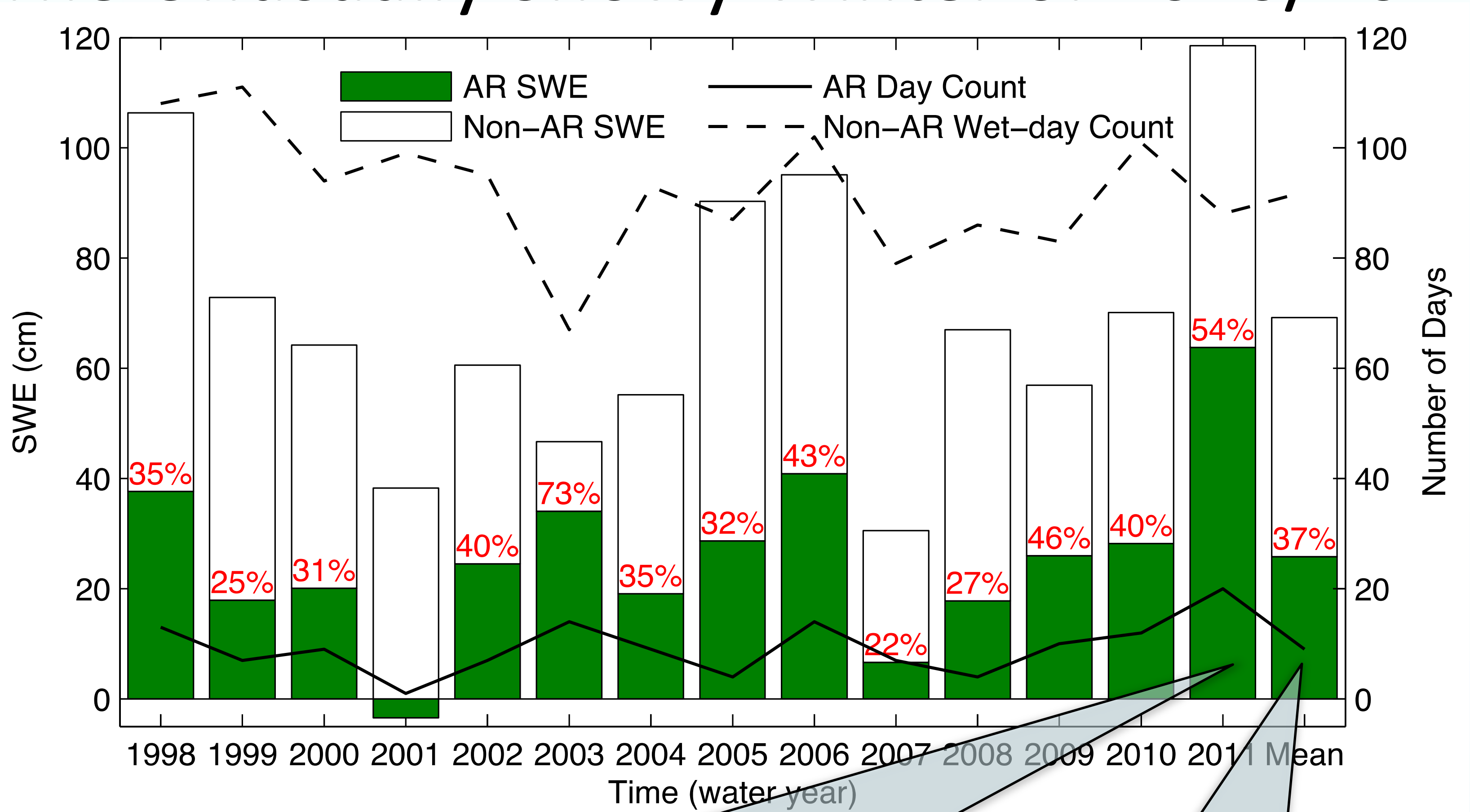
Forecast Models Need to Improve their Forecasts of Landfall Location

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

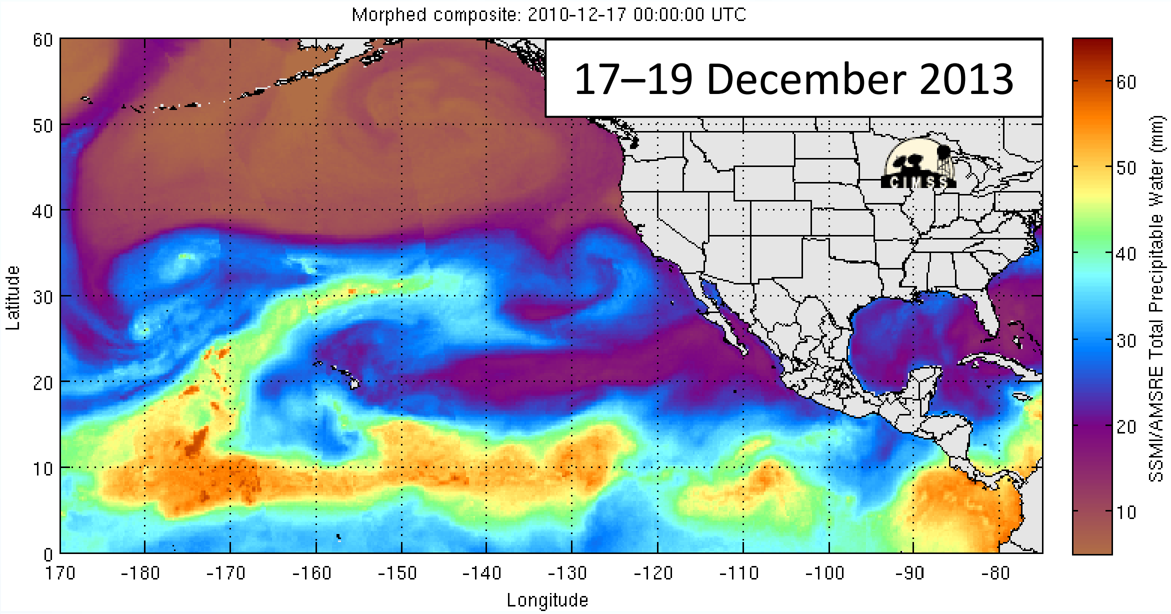


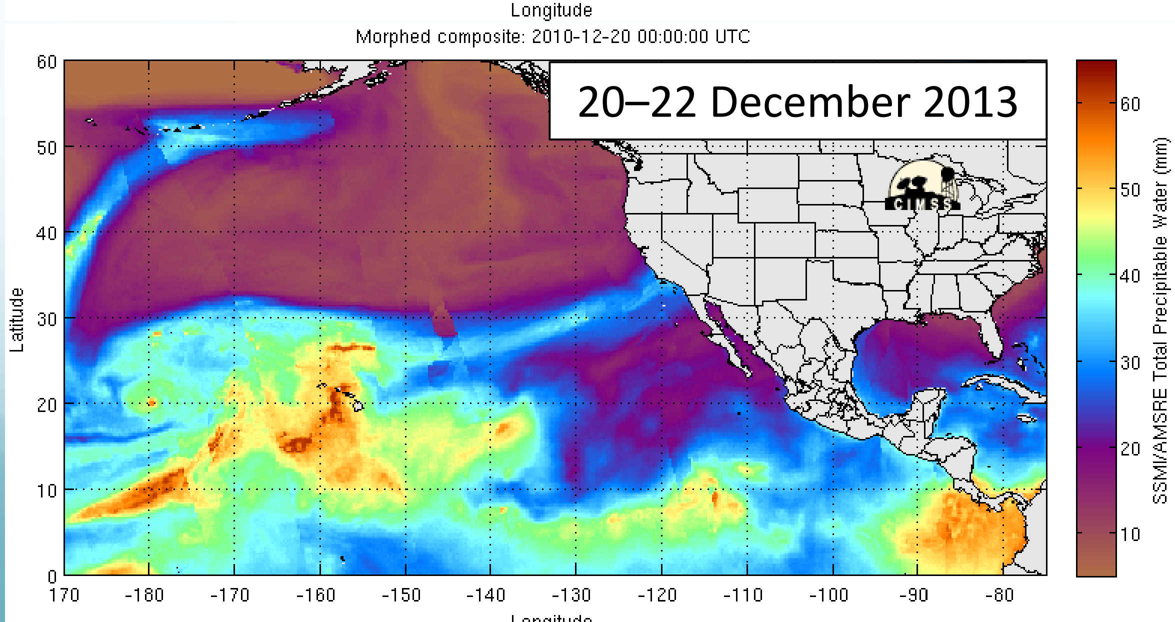
2010/2011 winter

- 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

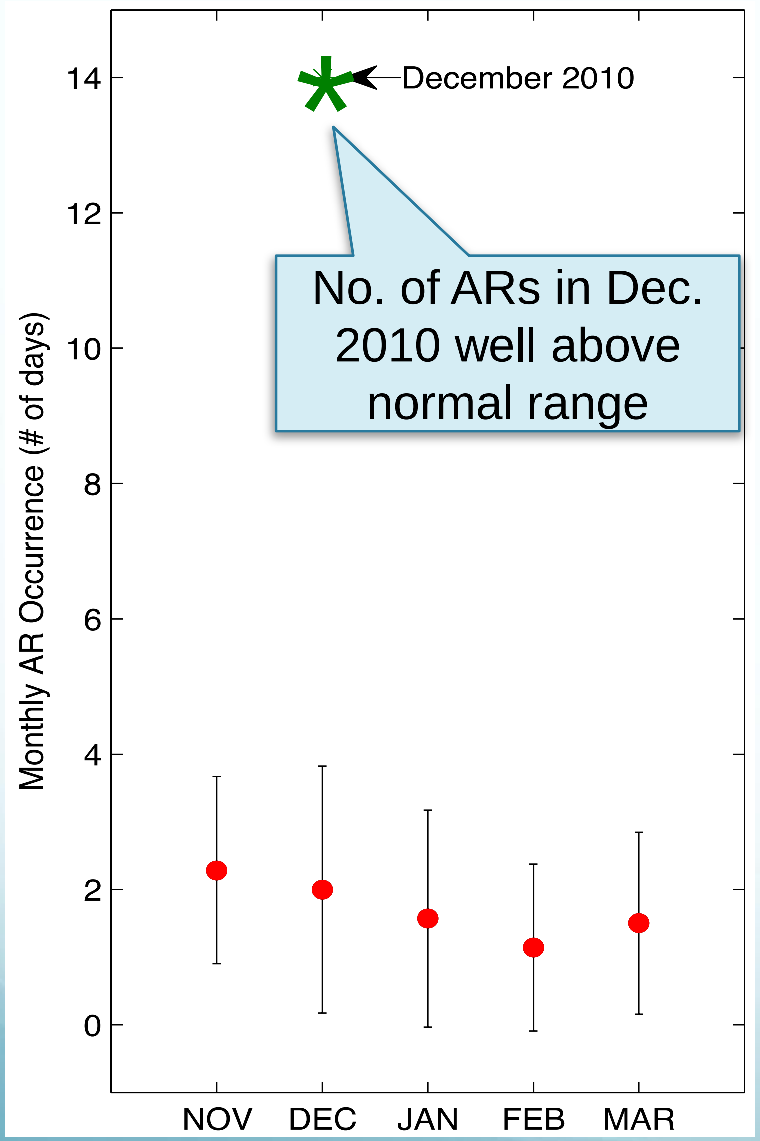
December 18 to 22 – Five Straight Days of AR

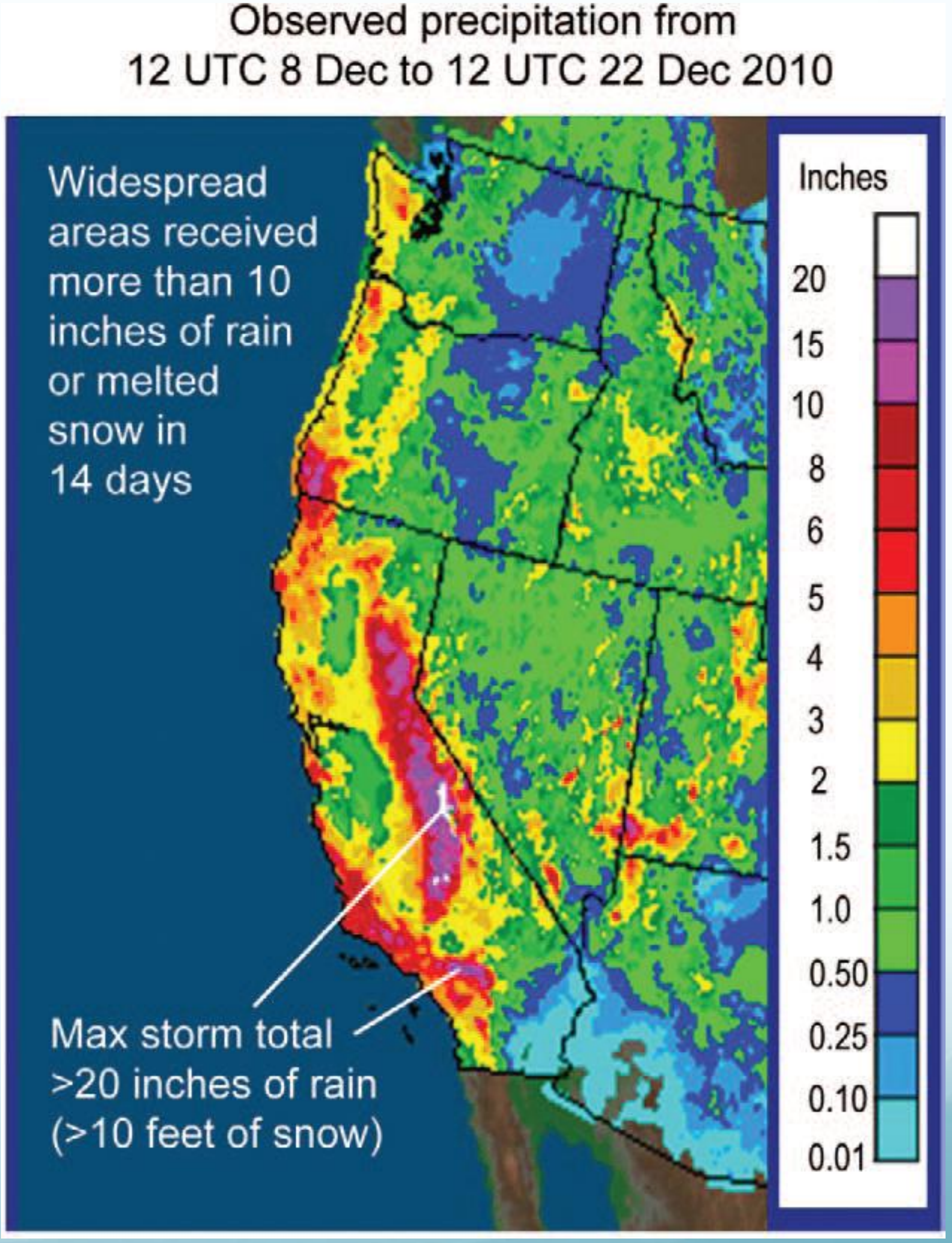




- >13 feet of snow in the Sierras
- >6 inches of rain in LA and >21 inches in parts of the foothills
- Spread into Nevada/Arizona/Utah ; Zion NP evacuated

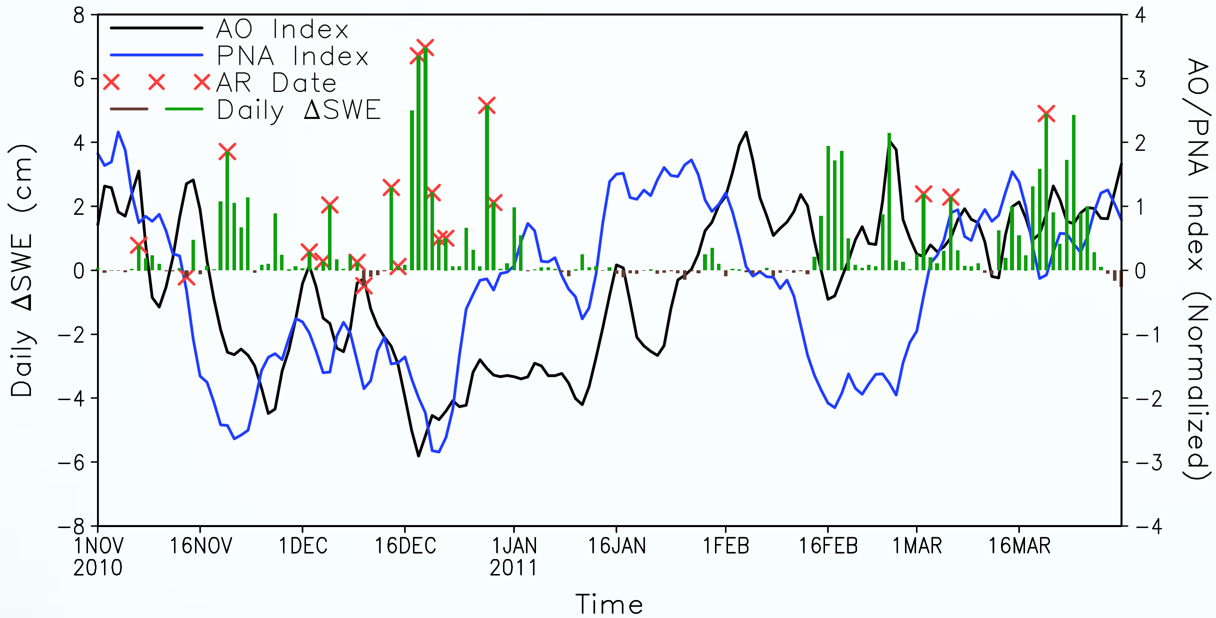
14 out of the season's 20 AR dates occurred in one month



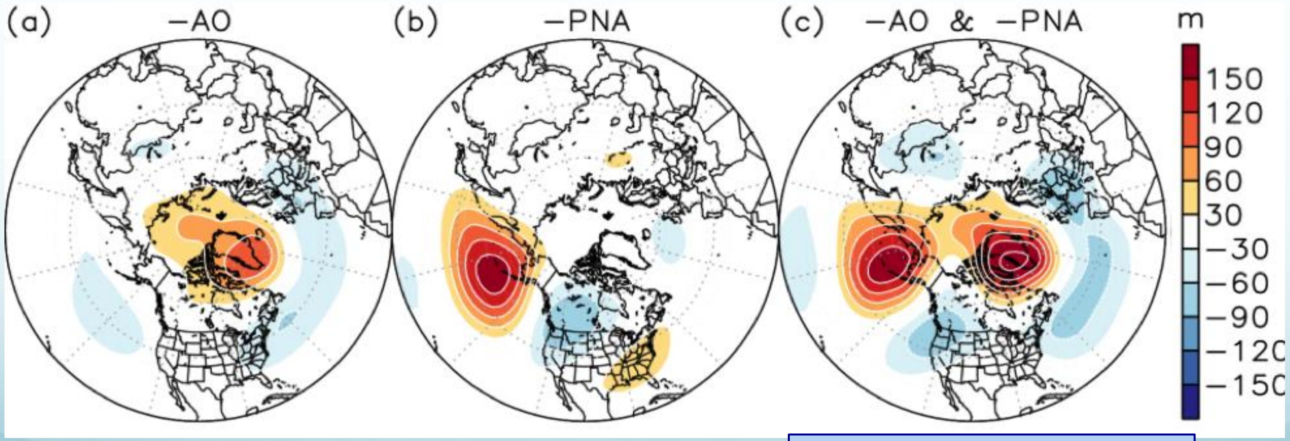


Right: Ralph and Dettinger 2012,

Climate Conditions of the 2010/2011 Winter



–AO and –PNA tend to be associated with more stormy weather in California



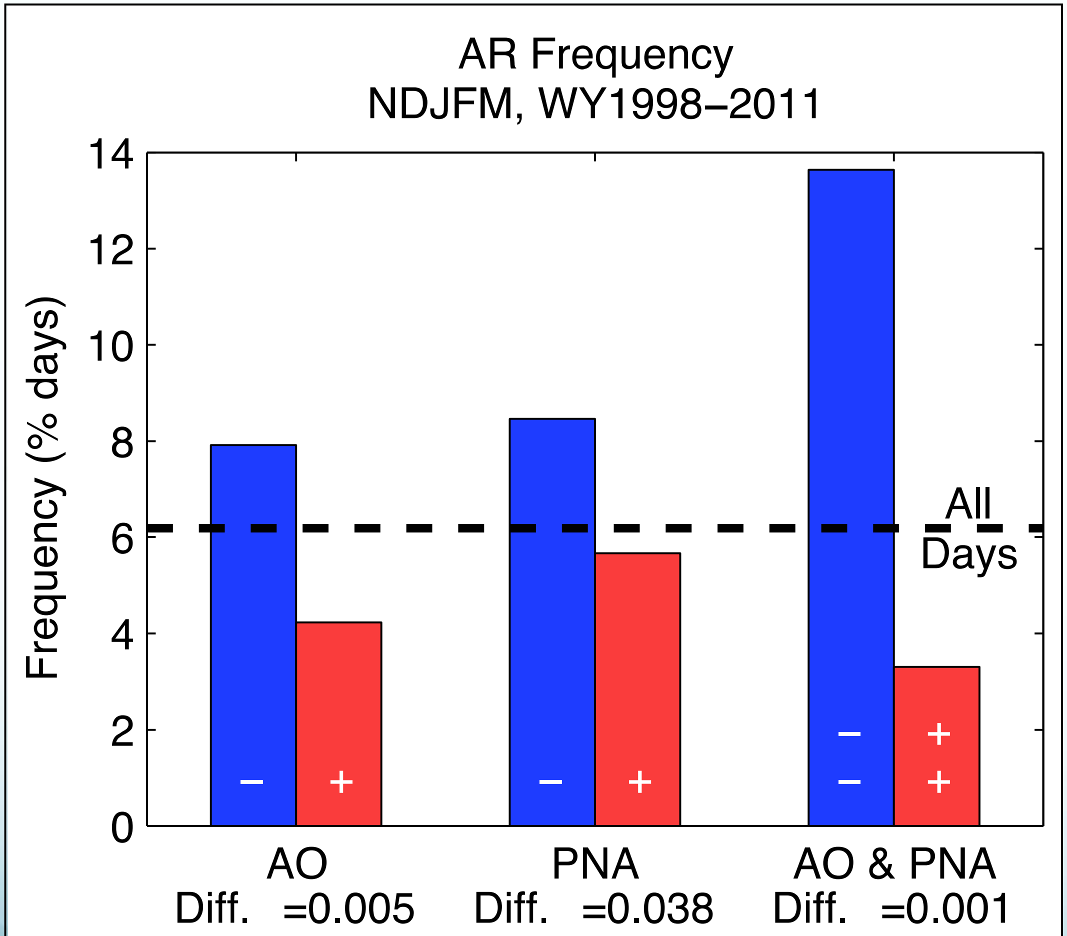
500 mb Geopotential Height Anomalies

"Arctic Oscillation" (AO)

"Pacific North American" (PNA)

Circulation anomaly when both PNA and AO in "negative" phase

Phasing of AO/PNA vs.
AR Frequency in California



When the AO and PNA are both in the negative phase, ARs are significantly more likely to occur.