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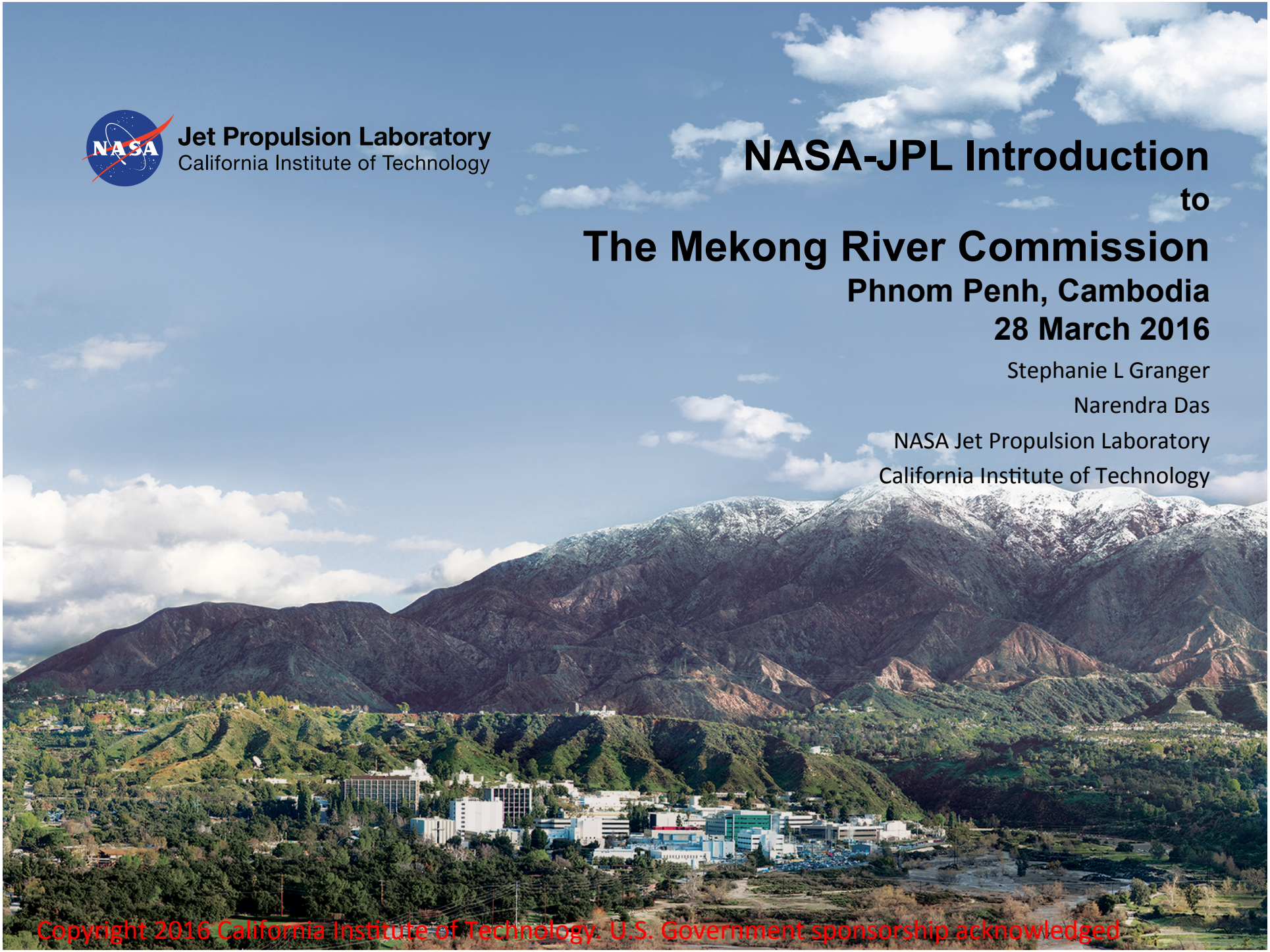
NASA-JPL Introduction to The Mekong River Commission

Phnom Penh, Cambodia
28 March 2016

Stephanie L Granger
Narendra Das
NASA Jet Propulsion Laboratory
California Institute of Technology



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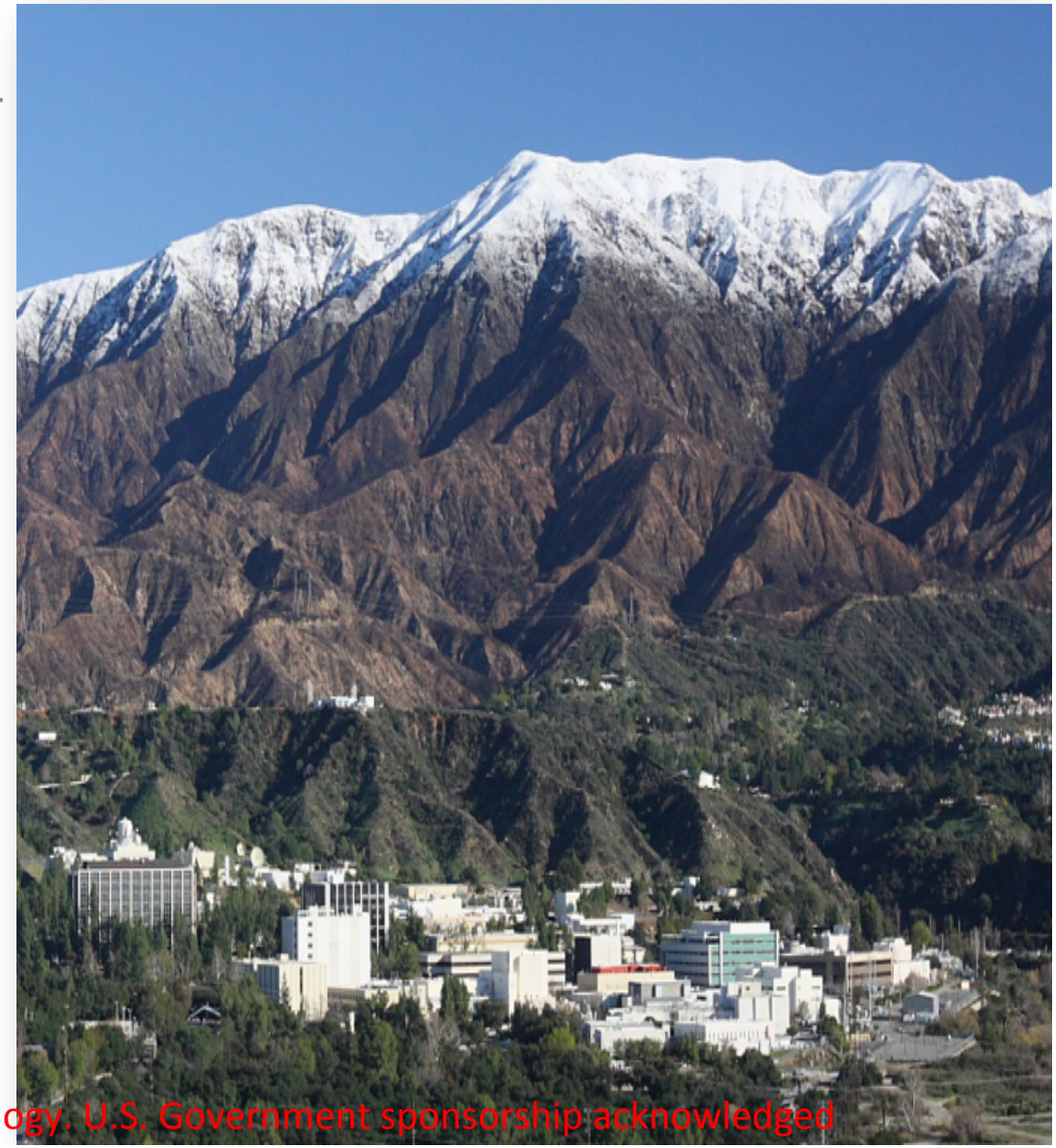
JPL is part of NASA and Caltech

- Federally-Funded (NASA-owned) Research and Development Center (FFRDC)
- University Operated (Caltech)
- 5,000 Employees
- 177 Acres; 139 Buildings; 36 Trailers
- 673,000 Net Square Feet of Office Space
- 906,000 Net Square Feet of Non-Office Space (e.g., Labs)



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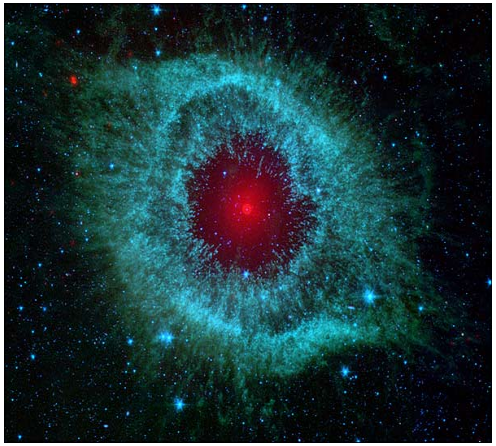
JPL: From Caltech students testing rockets to exploring the planets in our lifetime

Caltech students (1936)

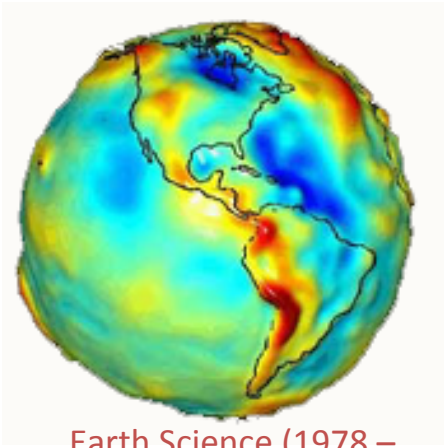
Missiles (1940s)

Explorer 1 (1958)

Mars Exploration Rovers (2004 – present)



Spitzer Space Telescope (2004 – present)



Earth Science (1978 – now)

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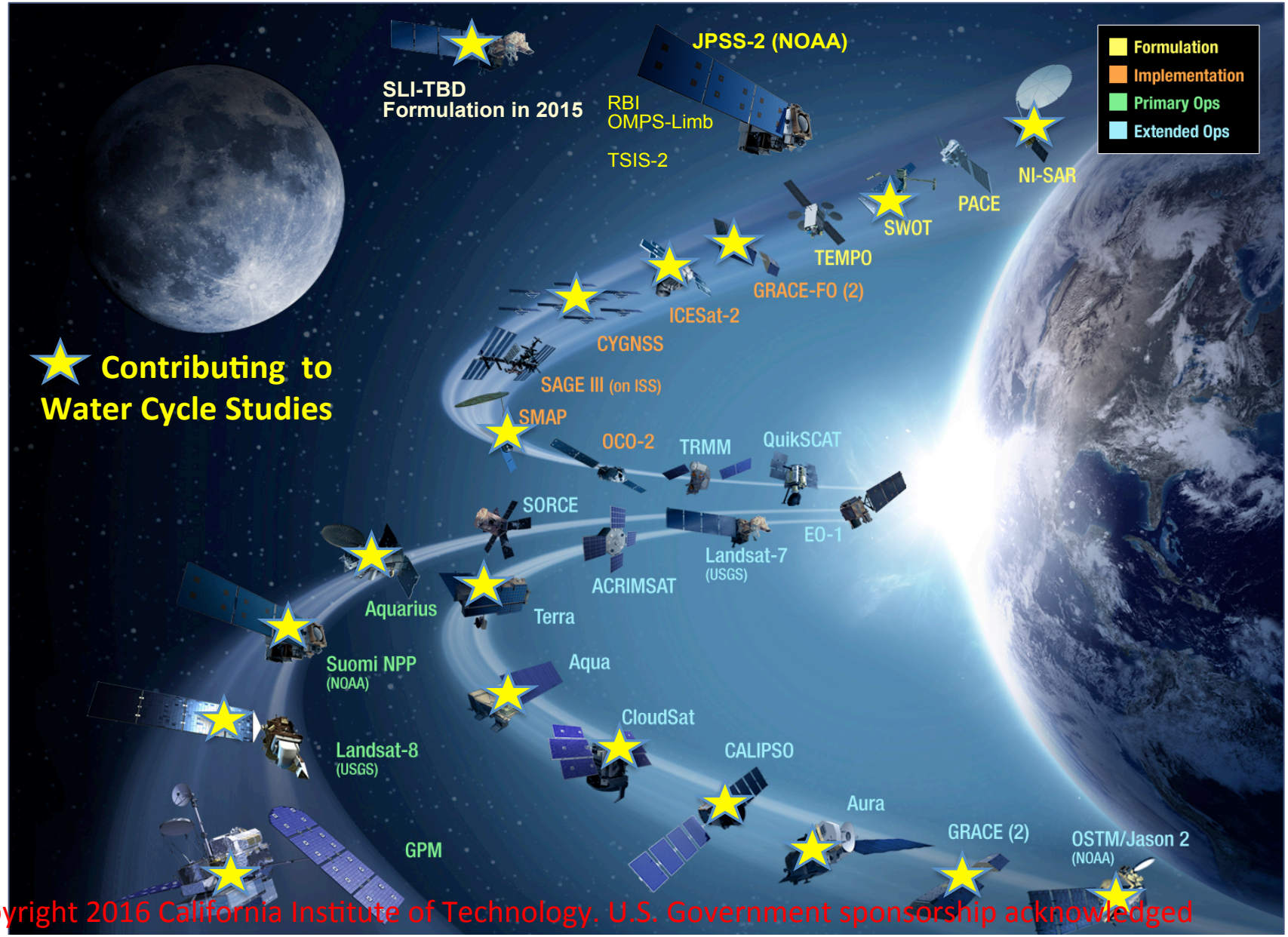
NASA Earth Observing Fleet



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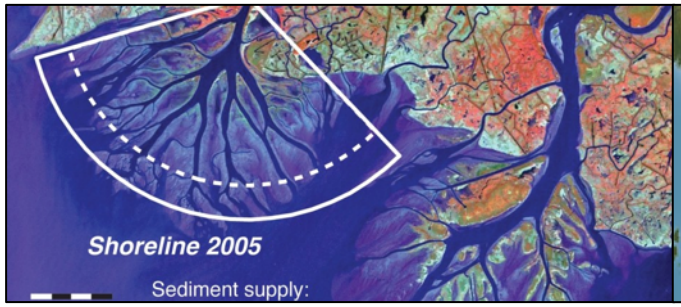
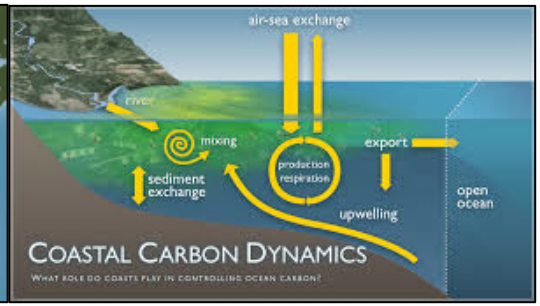
Coastal / Inland Water Science and Applications





Intersection of *sea level rise, subsidence, urban integrity, water quality, carbon storage & transport, infrastructure & security, natural hazards, and climate*

- **Coastal/Inland waters – a critical and emerging science and applications area.**
- **JPL-NASA has activities, assets and expertise to bring to bear on coastal/inland water challenges.**

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Coastal / Inland Water Science and Applications

JPL/Caltech Resources and Assets

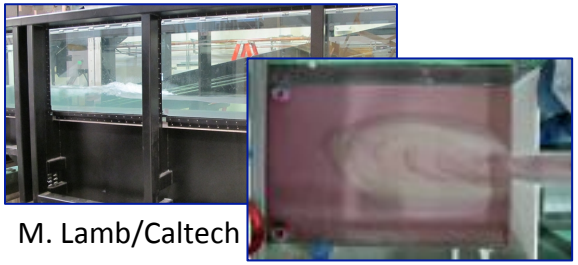
- ***Airborne Observing Systems***
  PRISM – water quality (Chl, turbidity, DOC, methyl mercury), benthic cover
  HYTES – surface temperature (water, land)
  AVRIS-NG – vegetation type
  UAVSAR – levee integrity, ground subsidence, water surface velocity,
  shallow bathymetry structure, earthquake and other hazards
  airSWOT – surface water elevation, river discharge

Horizontal Resolutions
O (1m to 1km)

- ***Satellite Assets***
  SMAP – salinity, soil moisture
  GPM – precipitation
  GRACE – groundwater variations
  Under Development
  SWOT – surface water elevation, river discharge
  NISAR – ground surface deformation, infrastructure, hazard
  ECOSTRESS – surface temperature

Horizontal Resolutions
O (10km to 100 km)

- **Caltech Experimental River Delta Laboratory**



M. Lamb/Caltech

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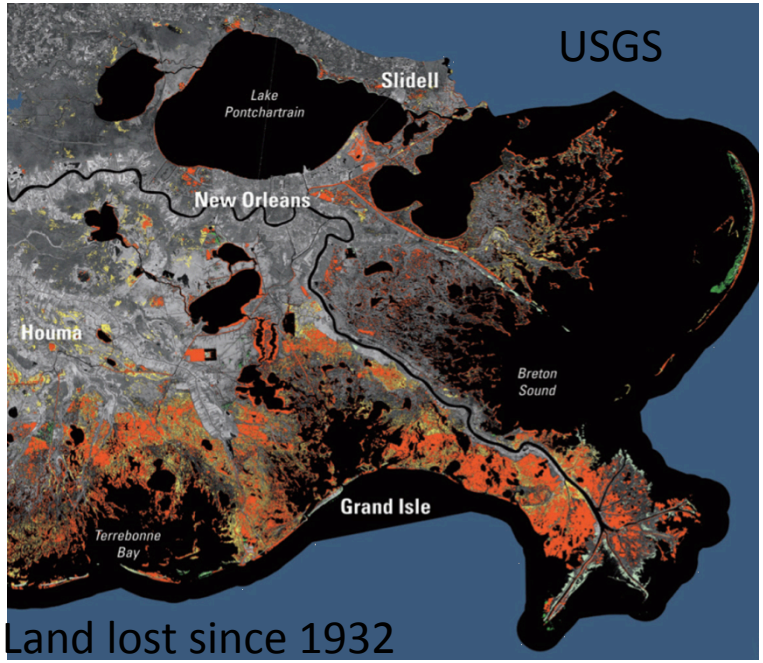
Deltas are in danger

- More than half a billion people inhabit deltas.
- Owing to their low slopes, deltas are susceptible to dramatic land loss and storm inundation due to small imbalances in sediment supply, sea-level rise, and land subsidence.
- We lack synoptic data of high spatial and temporal resolution to understand water flow and sediment transport patterns on deltas.



Land lost since 1932

Hurricane Katrina, 2005
1833 fatalities; $108 billion in damage

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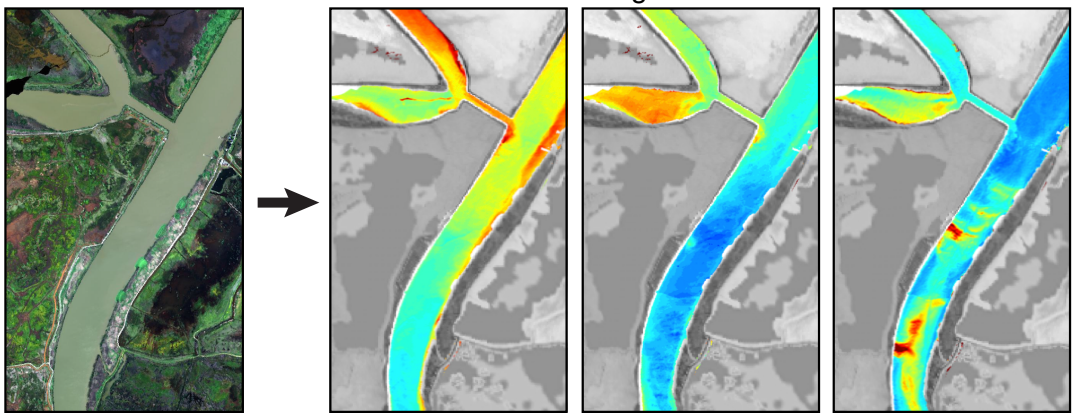
2014 Bay Delta PRISM Campaign

Gierach, Fichot, etc

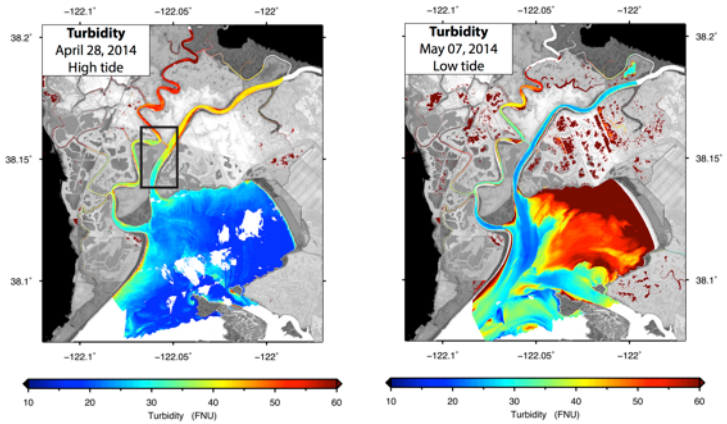
Purpose: Demonstrate PRISM capability for remotely sensing water quality.

Remote Sensing Reflectance | Turbidity | Dissolved Organic Carbon | Chlorophyll-a



PRISM imaging spectrometer can simultaneously map the spatial distributions of several independent water quality indicators – turbidity, DOC, Chlorophyll-a, and also provide inference on methylmercury

Turbidity difference between high tide and low tide.



Environmental Science & Technology
Article
pubs.acs.org/est

High-Resolution Remote Sensing of Water Quality in the San Francisco Bay–Delta Estuary

Cédric G. Fichot,[*,†] Bryan D. Downing,[‡] Brian A. Bergamaschi,[‡] Lisamarie Windham-Myers,[§] Mark Marvin-DiPasquale,[§] David R. Thompson,[†] and Michelle M. Gierach[†]

Regional Dependent Result; Broader Application & Demonstration Required

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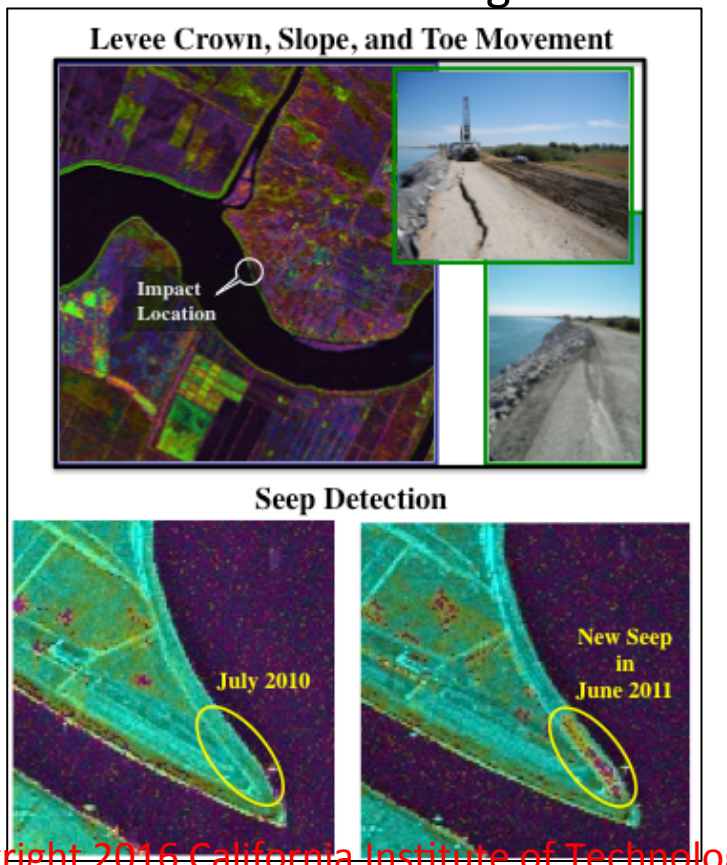
UAVSAR Bay Delta Levee & Subsidence Monitoring

PI: C. Jones
Sponsors NASA, DHS, CA-DWR

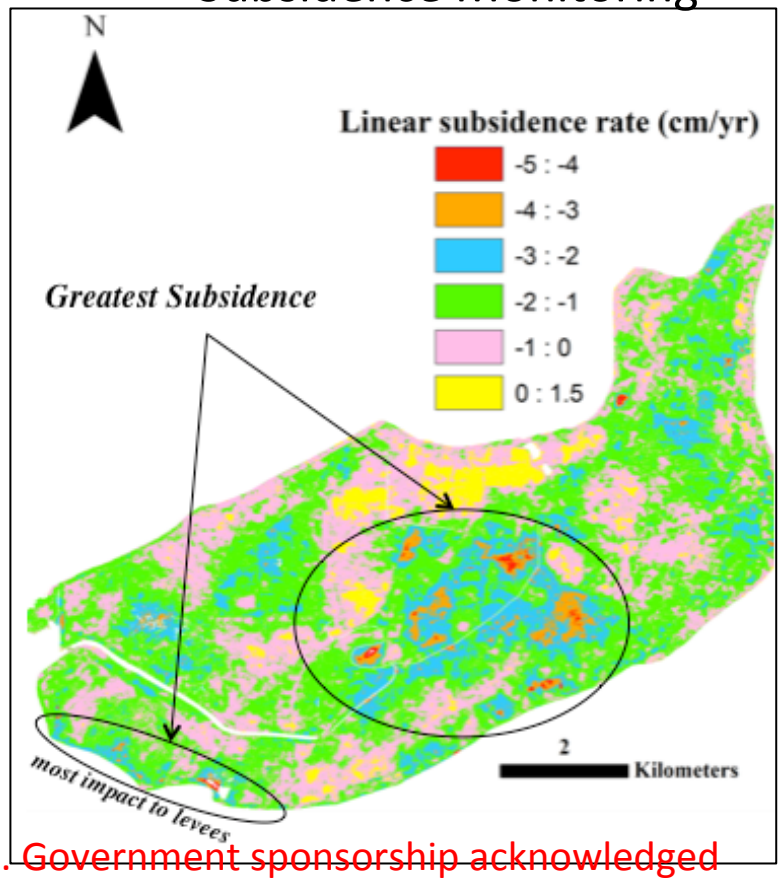
Objectives

Disaster Mitigation/Response: Monitor movement of and seepage through levees.
Water Resource Management: Measure subsidence rates across to inform future long-term solutions to water management.

Levee Monitoring



Subsidence Monitoring



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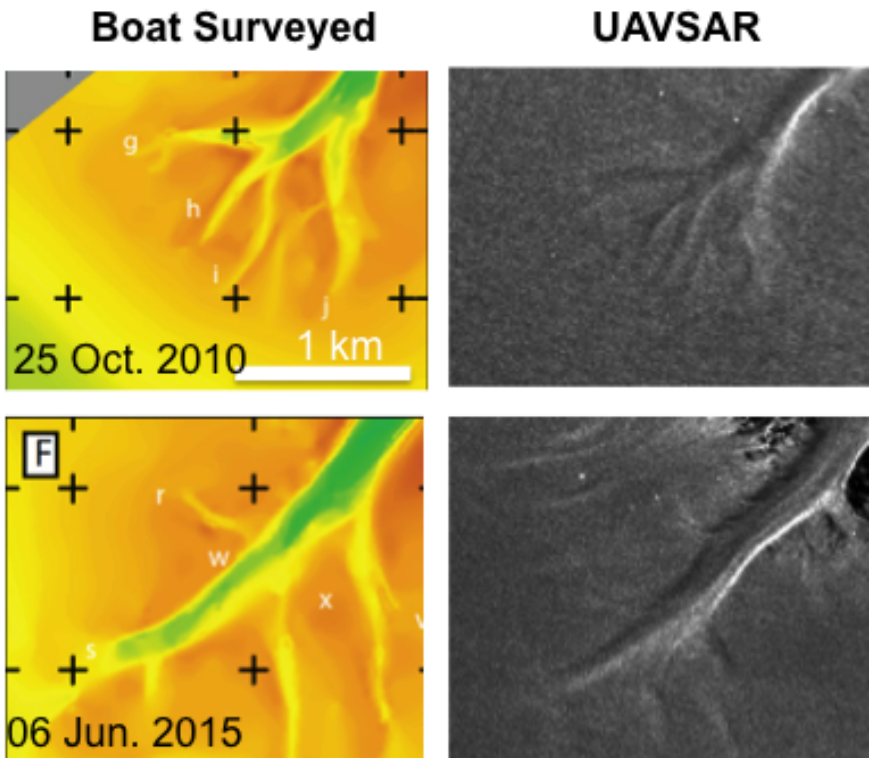
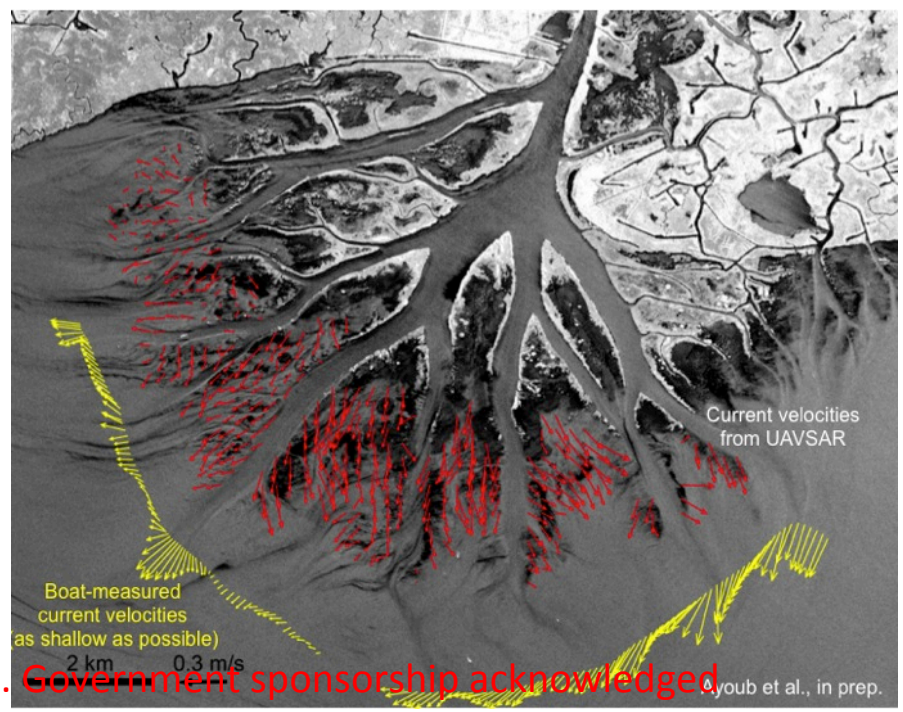
2015 Project for Wax Lake Delta

PIs: Jones & Lamb; Others: Simard, Rodriguez



UAVSAR backscatter can map evolving channel patterns at the submerged delta front – i.e. "see" qualitative bathymetry variations under shallow water.



Repeat-pass UAVSAR using Doppler shift to measure water current velocities within submerged islands; synoptic snapshot and shallow water inaccessible by conventional survey methods.

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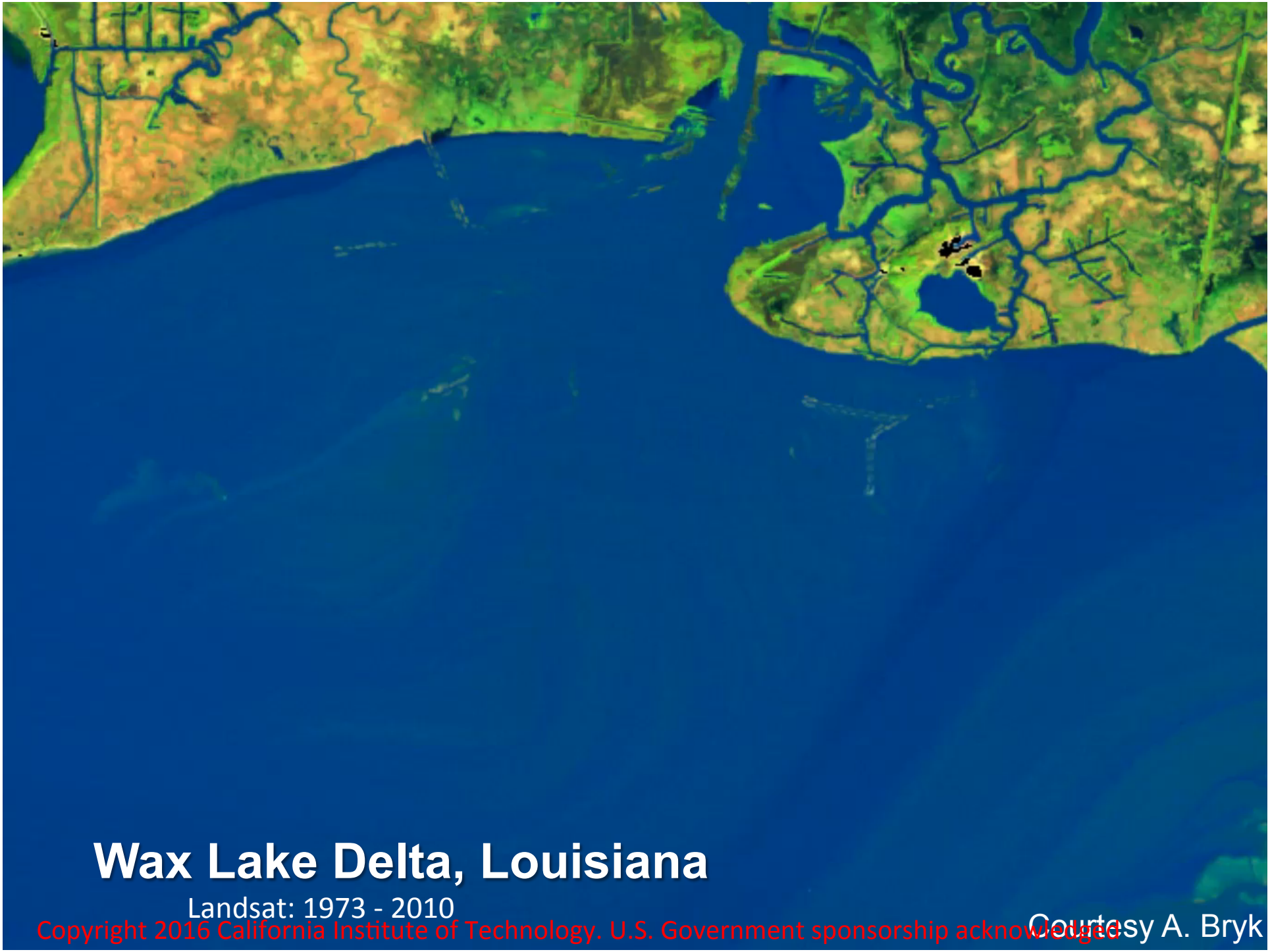

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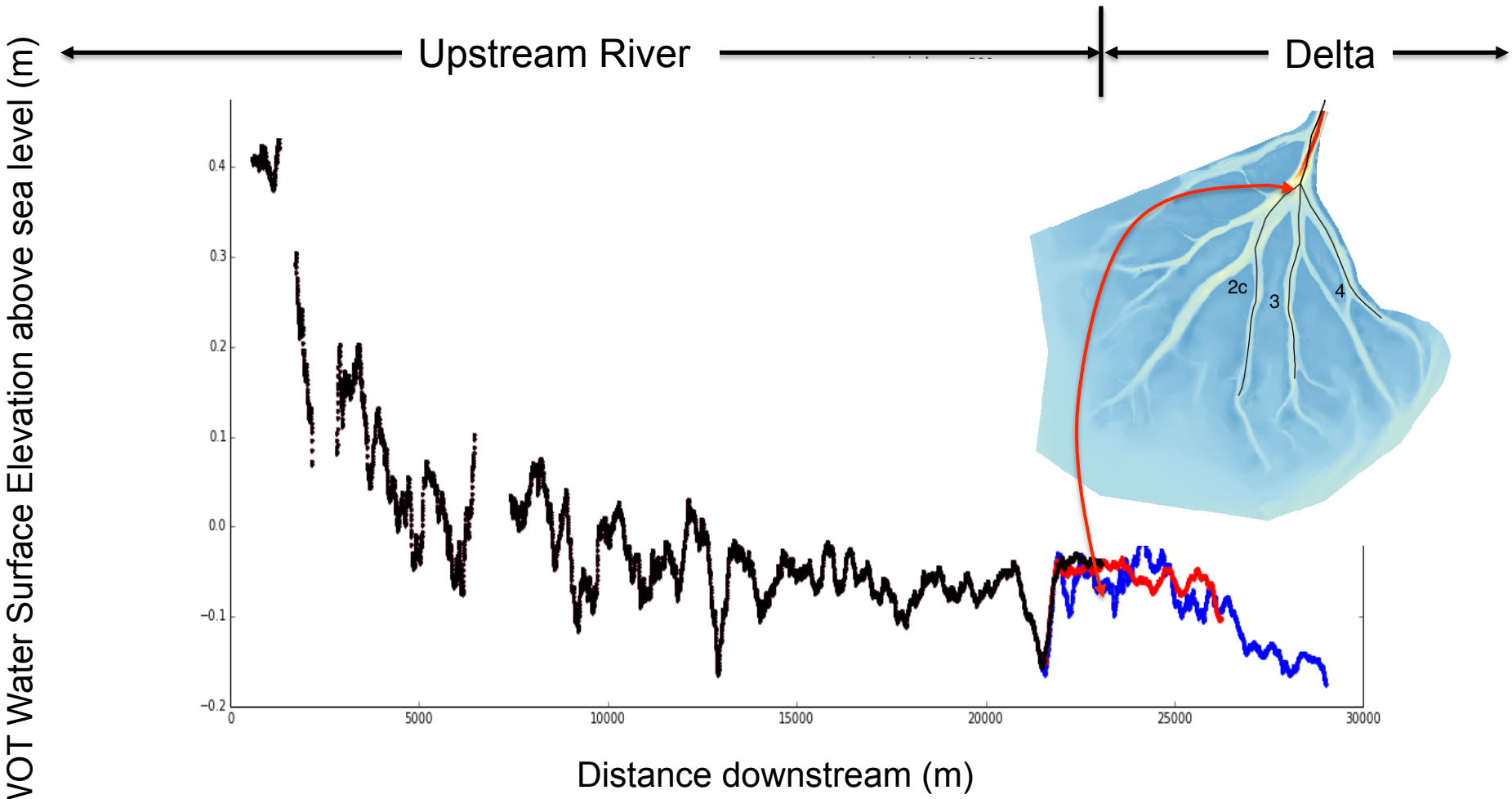
AirSWOT Measures River Water Elevations



Michailovsky &
Rodriguez et al., in prep.

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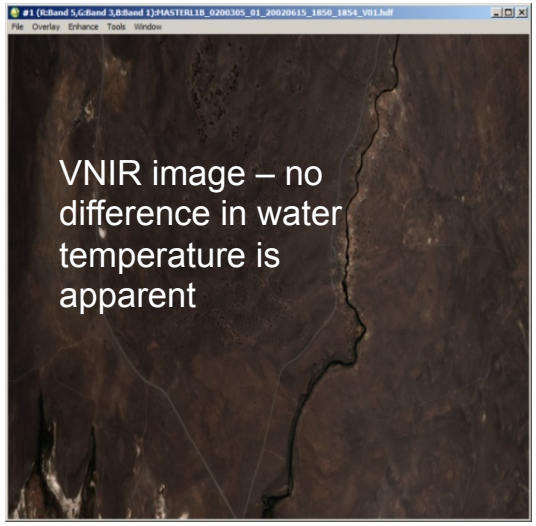
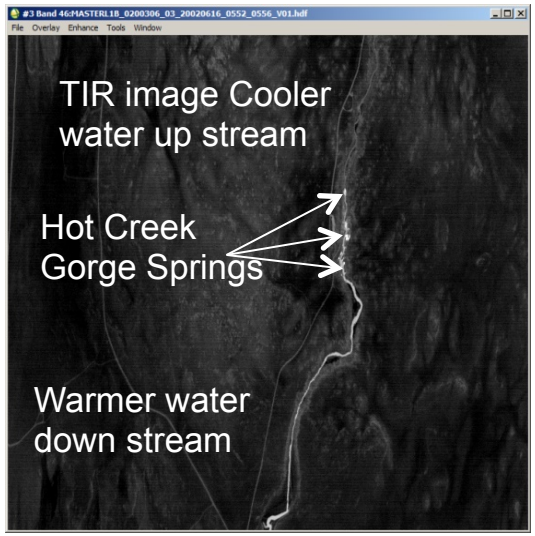
Airborne/Spaceborne Temperature Imagery for Aquatic Studies

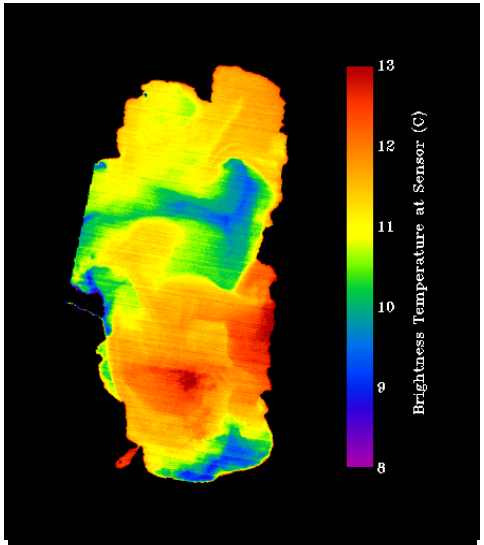
MASTER, ASTER, Landsat

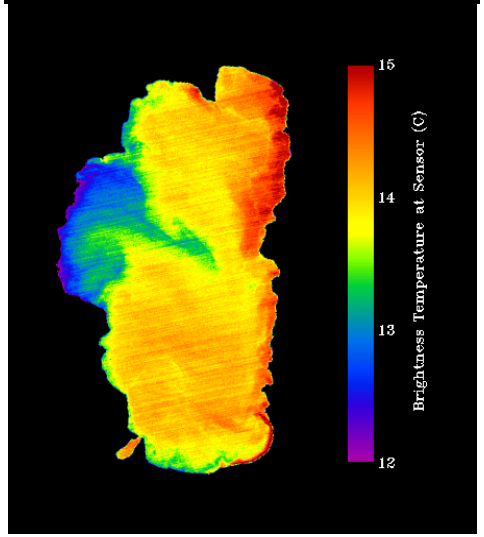
Hot Springs in CA



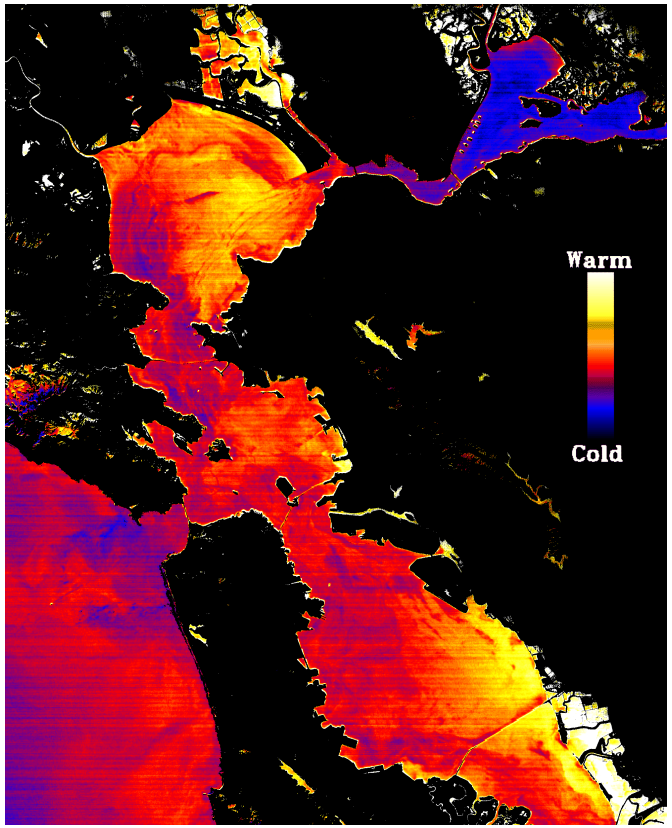


Upwellings in Lake Tahoe CA





Cold snowmelt influx to San Pablo Bay CA



Courtesy S. Hook/JPL

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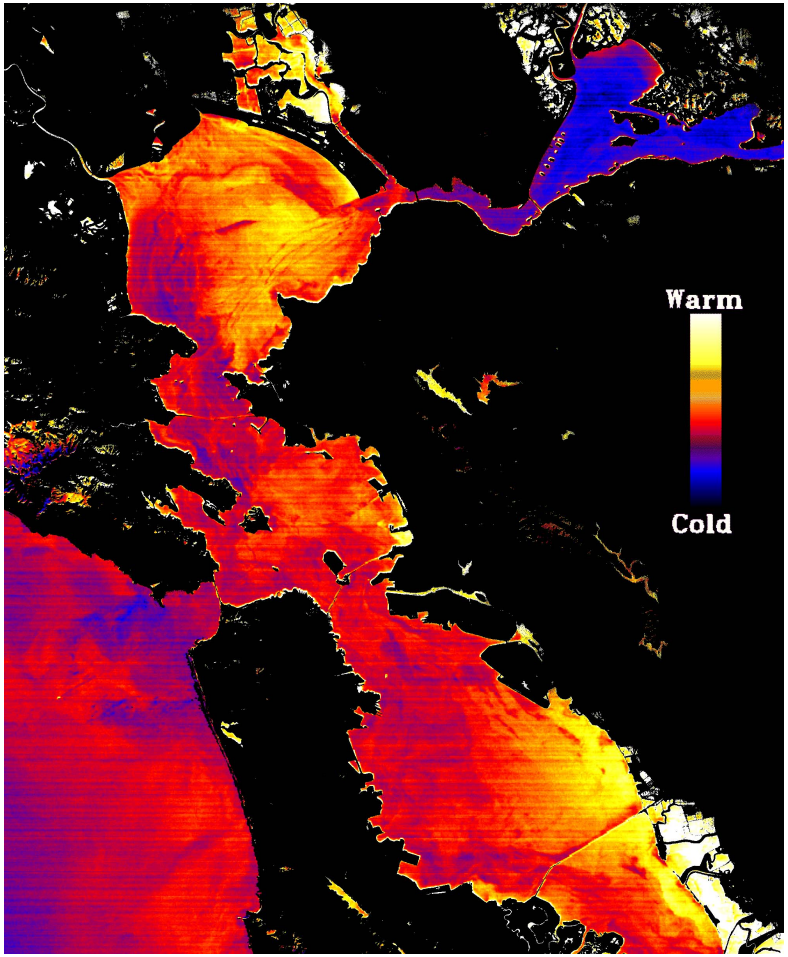
ASTER Satellite Observations

San Francisco Bay

Turbidity

Surface Temperature



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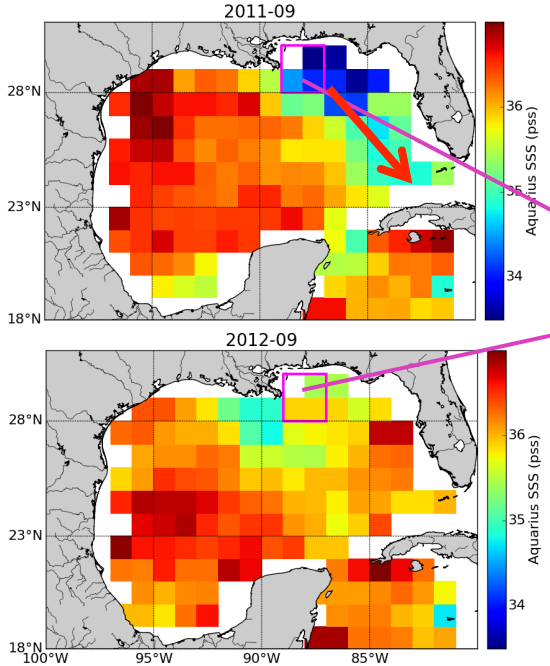
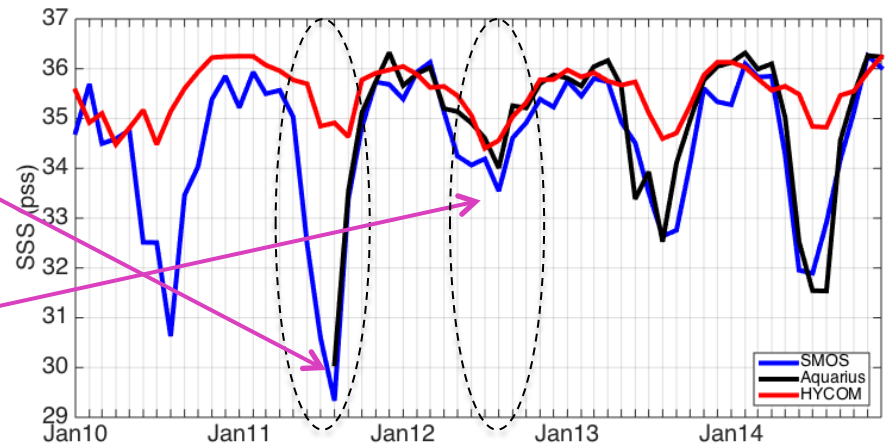
Satellite Observations Reveal Large Variations Of Sea Surface Salinity Associated With The Mississippi River Plume

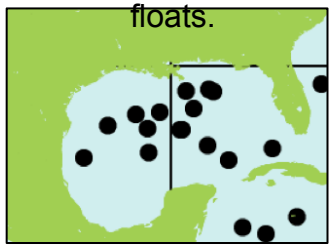




2010-2015 monthly time series of SMOS (blue), Aquarius (black) and HYCOM (red) SSS near the Mississippi mouth.

Aquarius SSS maps in September, near the time when the SSS in the magenta square region reaches a minimum in 2011 and 2012 and 4 months after the peak discharge. The red arrow symbolizes the direction of the plume pathway.

For Reference: Number and location of Argo floats.



In-situ useful for ground truth but inadequate for plume detection

Problem: Lack of knowledge of salinity variations associated with large rivers that are important to air-sea and land-sea interactions.

Finding: Aquarius & SMOS detected large interannual changes of SSS in the Mississippi river mouth that state-of-the-ocean high-resolution global ocean assimilation products (e.g., US Navy's HYCOM operational analysis) failed to capture.

Significance: Aquarius/SMOS/SMAP salinity data provide valuable resources to constraint ocean analysis and forecast to study the linkage of ocean and regional water cycle.

Fournier, S., T. Lee and M. Gierach (2016): Seasonal and Interannual variations of sea surface salinity associated with the Mississippi River plume observed by SMOS and Aquarius. *Accepted to Remote Sensing of Environment.*

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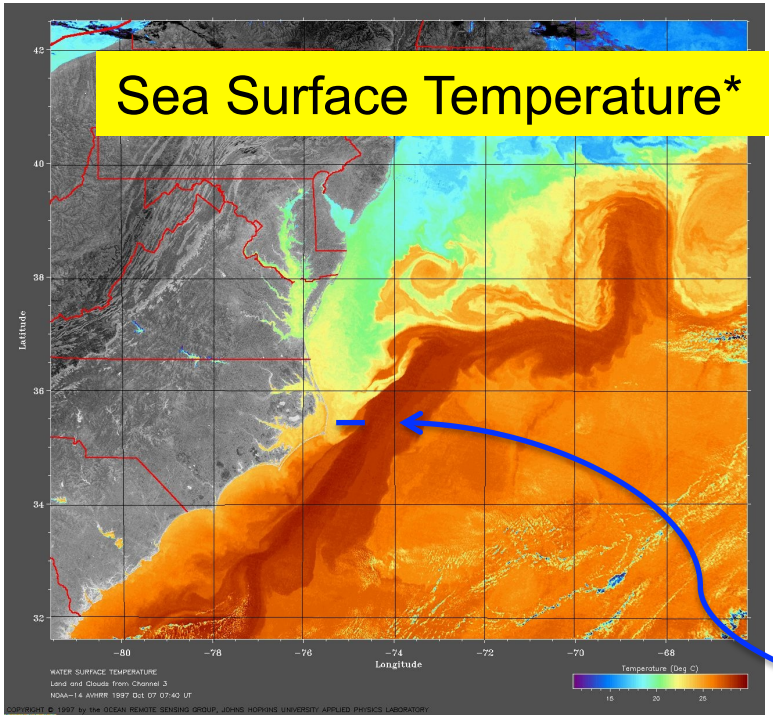
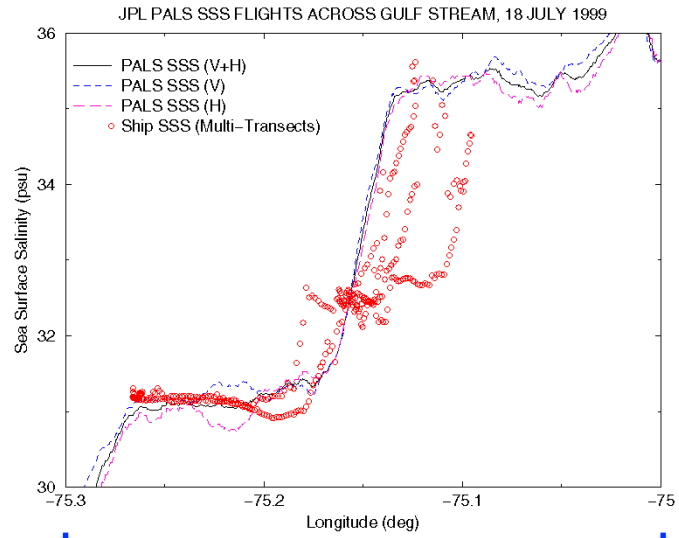
PALS Airborne Salinity Observations



*Arbitrary day and map for spatial reference

JPL PALS Salinity



~30km flight path with > 100 samples

PALS airborne radar obtains robust salinity observations with spatial resolution of O (100m)

S. Yueh (JPL)

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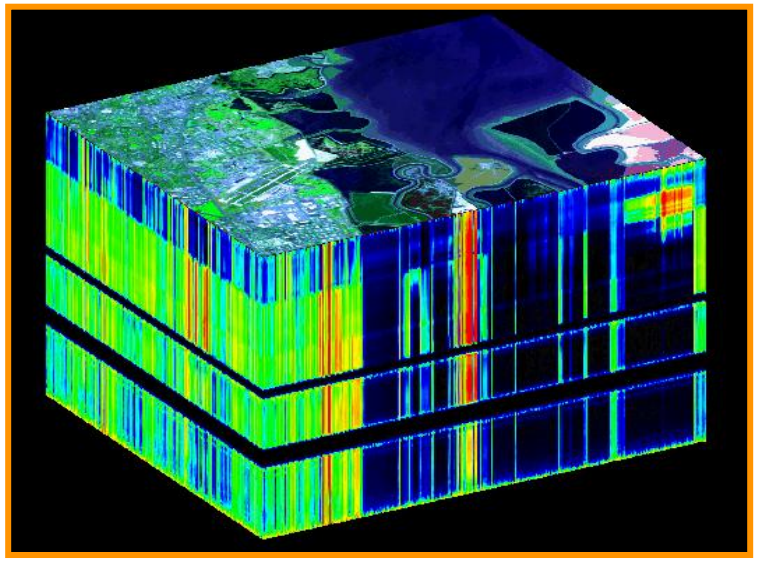
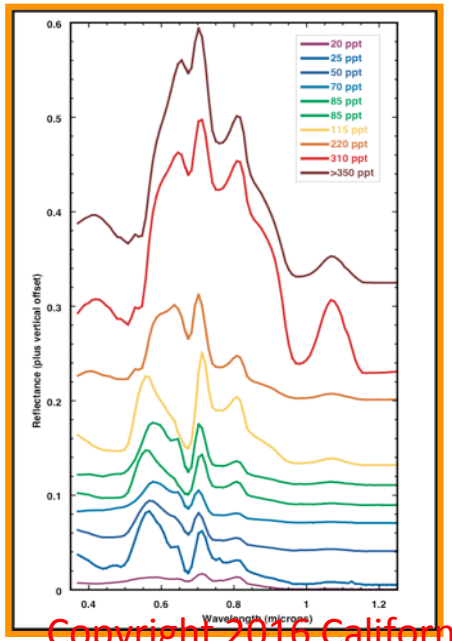
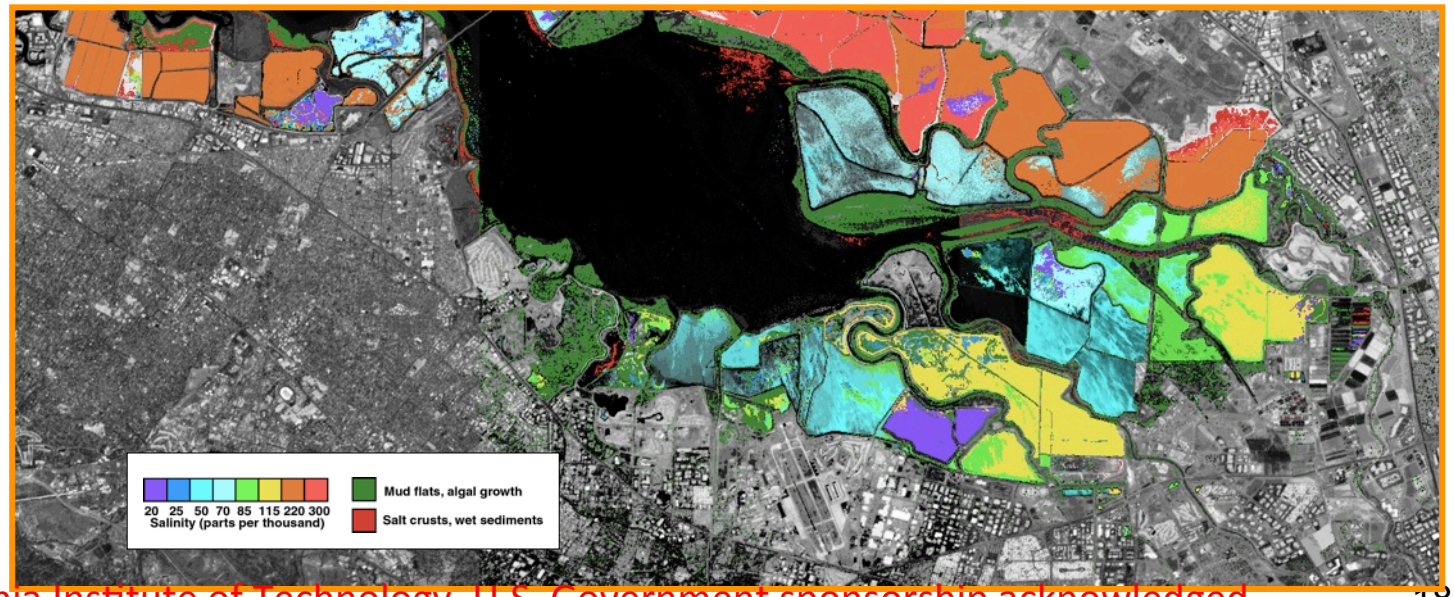
AVIRIS Airborne Observations

Salinity Characterization of South San Francisco Bay Salt Ponds

- 16500 acres of salt ponds scheduled for remediation over 25 years
- AVIRIS >10 year baseline
- Field work + IR Spectroscopy
- Developed a Remote Monitoring Protocol
- Dalton et al., Int. J. Rem. Sens., 2009
- Used spectra of microbe communities as proxy for salinity; approached 10 ppt precision







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Status of NASA's SMAP mission and Soil Moisture Observations from space

Narendra Das (JPL, NASA)
Dara Entekhabi (MIT)
Simon Yueh (JPL, NASA)
Andreas Colliander (JPL, NASA)

MSU

Date: 02-10-2016

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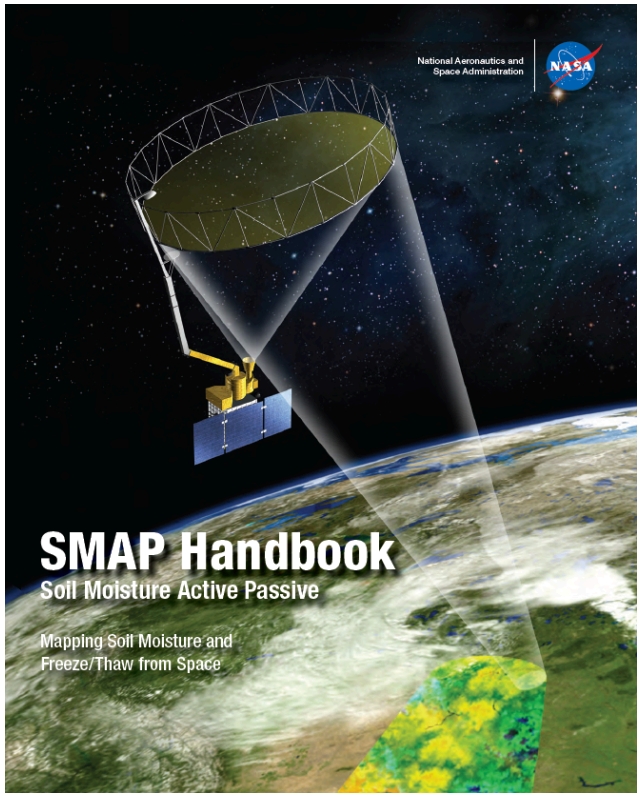
Outline

Contents:

1. Overview and Mission Objectives
2. Instruments (radar and radiometer)
3. Data Products
4. SMAP high resolution product

- Details provided in SMAP Handbook

- Credits: *SMAP Project Team*
  SMAP Science Team



http://smap.jpl.nasa.gov/mission/description

Entekhabi, D. et al., "SMAP Handbook," *JPL Publication JPL 400-1567*, Jet Propulsion Laboratory, Pasadena, California, 182 pages, July 2014.

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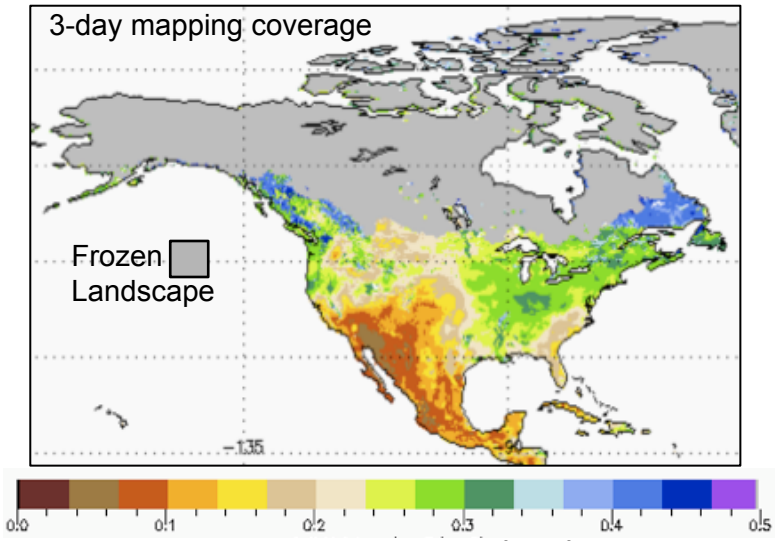
What Is SMAP?

- SMAP is the Soil Moisture Active Passive mission, a NASA Earth science mission
- SMAP's science objective is to provide high-resolution, frequent-revisit, global observations of soil moisture and freeze/ thaw state to:
  - Link terrestrial water, energy, and carbon-cycle processes
  - Estimate global water and energy fluxes at the land surface
  - Quantify net carbon flux in boreal landscapes
  - Extend weather and climate forecast skill
  - Develop improved flood and drought prediction capability

Soil moisture is defined in terms of volume of water per unit volume of soil

Freeze/thaw state is defined as the phase of the water contained within the landscape including soil and vegetation



Surface soil moisture [cm^3 /cm^3]

SMAP was initiated in 2008 in response to recommendations of the NRC Earth Science Decadal Survey (2007) and was launched in January 31, 2015

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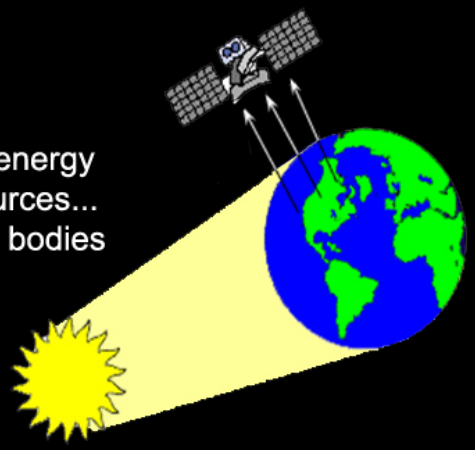
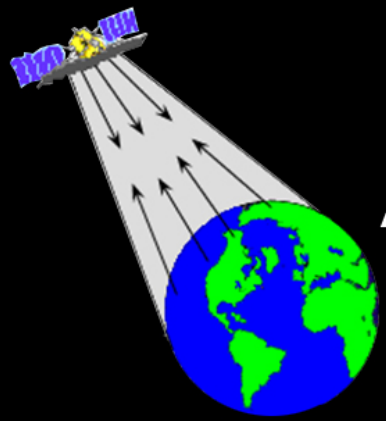
Why Active and Passive?

SMAP uses both "Passive" and "Active"
Remote Sensing to measure Soil Moisture

Passive Sensors:

The source of radiant energy
arises from natural sources...
Sun, Earth, other "hot" bodies





Active Sensors:

Provide their own artificial radiant energy
source for illumination... **RADAR,**
Synthetic Aperture Radar (SAR), LIDAR

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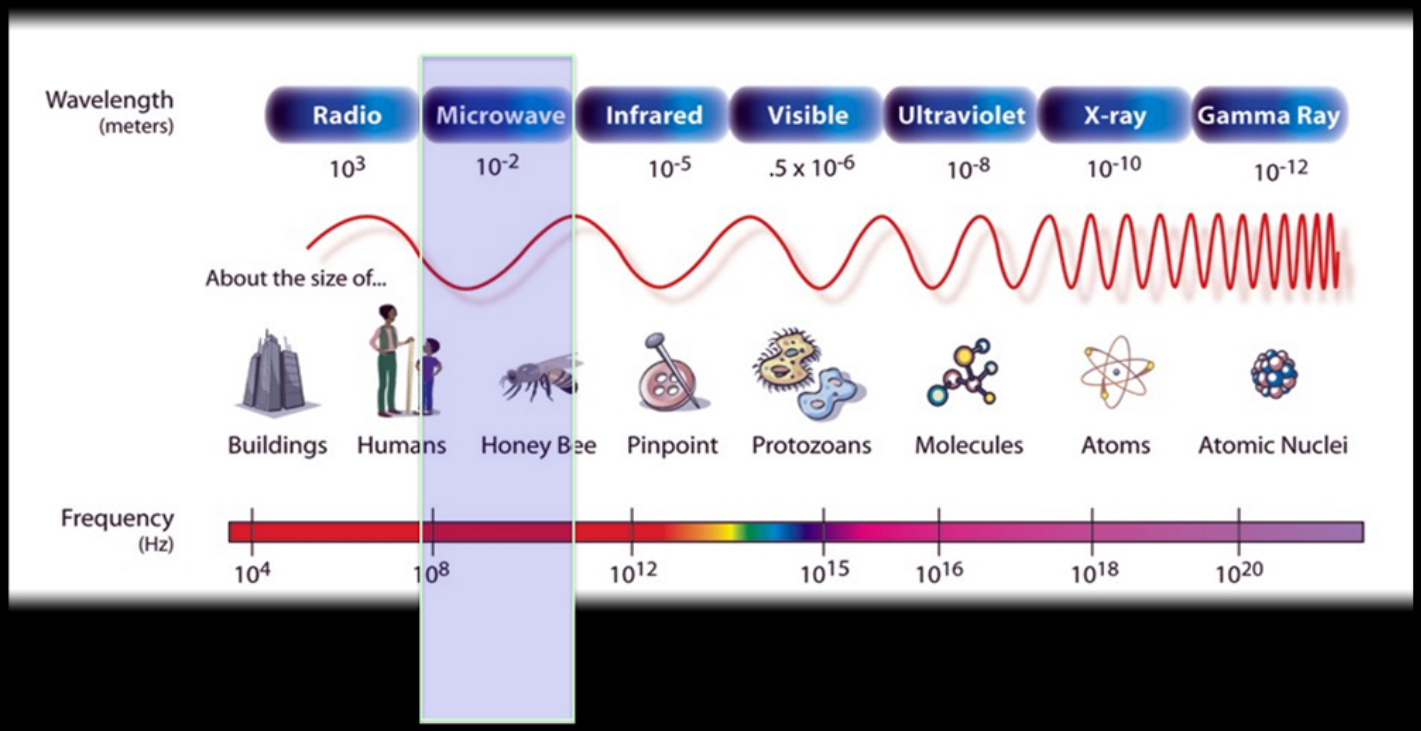
Measurement Frequency

SMAP Views the Earth in the Microwave Region of the Electromagnetic Spectrum



- With optical and infrared wavelength sensors the soil is masked by clouds and vegetation Also, optical sensors operate by measuring scattered sunlight and are “daytime only”
- Microwaves can penetrate through clouds and vegetation, operate day and night, and are highly sensitive to the water in the soil due to the change in the soil microwave dielectric properties

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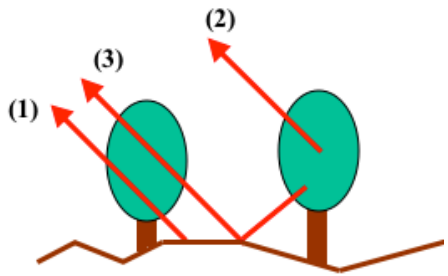
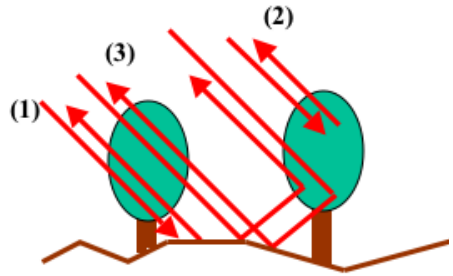
Retrieval of Soil Moisture



Emission (Radiometer)

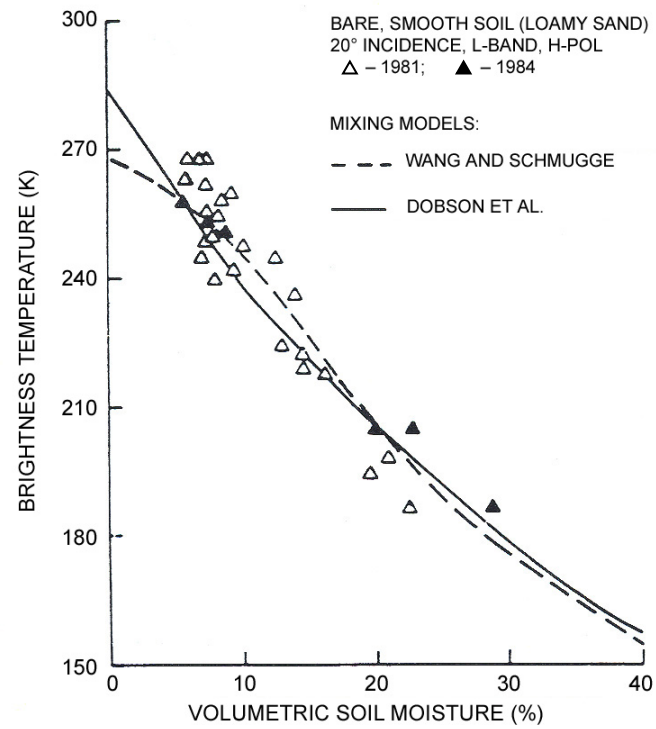


Backscatter (Radar)

$$T_{Bp}^{t} = T_{Bp}^{s} L_p + T_{Bp}^{v} + T_{Bp}^{sv} \qquad \text{(Emission)}$$

$$\sigma_{pq}^{t} = \sigma_{pq}^{s} L_{pq}^{2} + \sigma_{pq}^{v} + \sigma_{pq}^{sv} \qquad \text{(Backscatter)}$$

- Radiometers measure "brightness temperature", T_B (K)
  Radars measure "backscatter cross-section", s_o (dB)
- Contributions to emission and backscatter include three terms: soil, vegetation, and soil-vegetation interaction
- Soil moisture is the dominant contributor to the signal
- L is the vegetation attenuation factor, $\exp(-\tau_o / \cos\theta)$



Experimental data showing brightness temperature sensitivity to soil moisture for bare, smooth soil

Retrievals invert these equations to obtain soil moisture, with corrections for vegetation, roughness and surface temperature

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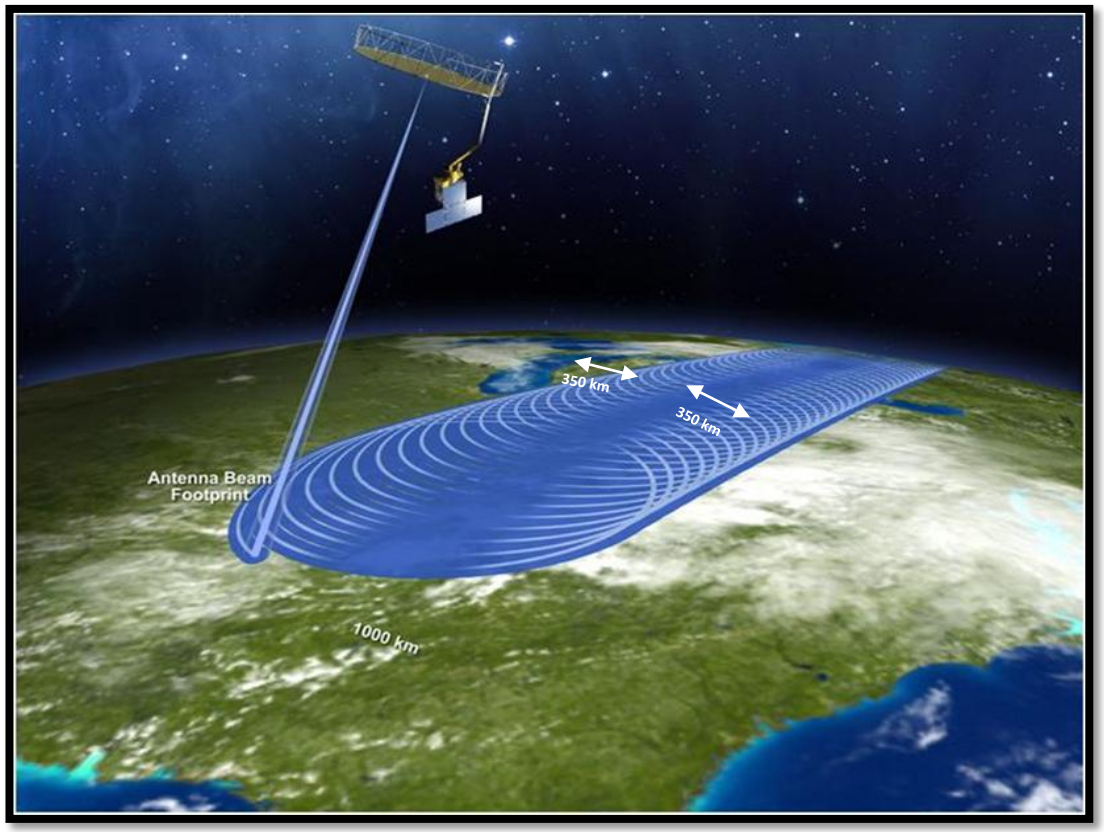
SMAP Instrument and Operating Characteristics

SMAP's objective is to provide high-resolution and frequent-revisit global mapping of soil moisture and landscape freeze/thaw state



Instrument Configuration

Radar
Frequency: 1.26 GHz
Polarizations: VV, HH, HV
Resolution: 1-3 km
Relative Accuracy: 1.0 dB (HH, VV); 1.5 dB (HV)

Radiometer
Frequency: 1.41 GHz
Polarizations: H, V, 3rd & 4th Stokes
Resolution: 40 km
Relative Accuracy: 1.3 K

Shared Antenna
6-m diameter deployable mesh antenna
Conical scan at 14.6 rpm
Constant incidence angle: 40 degrees
1000 km-wide swath
Swath and orbit enable 2-3 day global revisit

Orbit

Sun-synchronous, 6 am/pm, 685 km altitude

Mission Operations

3-year baseline mission

- ***Radar*** - High spatial resolution (1-3 km) but more influenced by surface roughness and vegetation
- ***Radiometer*** - High accuracy (less influenced by roughness and vegetation) but coarser spatial resolution (40 km)
- ***Combined Radar-Radiometer –*** Soil moisture product (9 km) provides optimal blend of resolution and accuracy

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SMAP Data Products

Data Product Short Name	Description	Grid (Resolution)	Granule Extent
L1A_Radar	Parsed Radar Instrument Telemetry		Half Orbit
L1A_Radiometer	Parsed Radiometer Instrument Telemetry		Half Orbit
L1B_S0_LoRes	Low Resolution Radar σ_o in Time Order	(5x30 km) (slices)	Half Orbit
L1C_S0_HiRes	High Resolution Radar σ_o on Swath Grid	1 km	Half Orbit
L1B_TB	Radiometer T_B in Time Order	(39x47 km)	Half Orbit
L1C_TB	Radiometer T_B	36 km	Half Orbit
L2_SM_A	Radar Soil Moisture (includes Freeze-Thaw)	3 km	Half Orbit
L2_SM_P	Radiometer Soil Moisture	36 km	Half Orbit
L2_SM_AP	Active-Passive Soil Moisture	9 km	Half Orbit
L3_FT_A	Daily Global Composite Freeze/Thaw State	3 km	North of 45° N
L3_SM_A	Daily Global Composite Radar Soil Moisture	3 km	Global
L3_SM_P	Daily Global Composite Radiometer Soil Moisture	36 km	Global
L3_SM_AP	Daily Global Composite Active-Passive Soil Moisture	9 km	Global
L4_SM	Surface & Root Zone Soil Moisture	9 km	Global
L4_C	Carbon Net Ecosystem Exchange	9 km	Global

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Current Status

Date	Milestone
January 31, 2015	SMAP launch
February 24	Antenna reflector deployed
March 26	Antenna spin-up to 14.6 RPM
March 31	Radiometer begins routine science operation
April 13	Radar begins routine science operation
July 7	Radar stops transmitting (traced to low-voltage power supply of radar amplifier) Radiometer continues to operate normally
July 31	Beta data for L1 Radiometer and Radar released to public
September 2	NASA official announcement that all efforts to restart the radar are unsuccessful
September 9	Beta data for L2/3 Soil Moisture Passive (radiometer) released to public
Early November	Validated data for L1 Radiometer and Radar released to public
Early November	Beta data for L2-L3 Soil Moisture and Freeze/Thaw , L4 Soil Moisture and L4 Carbon released to public
Through April 2018 (nominal mission)	Science data available through data centers are used to demonstrate SMAP science and applications

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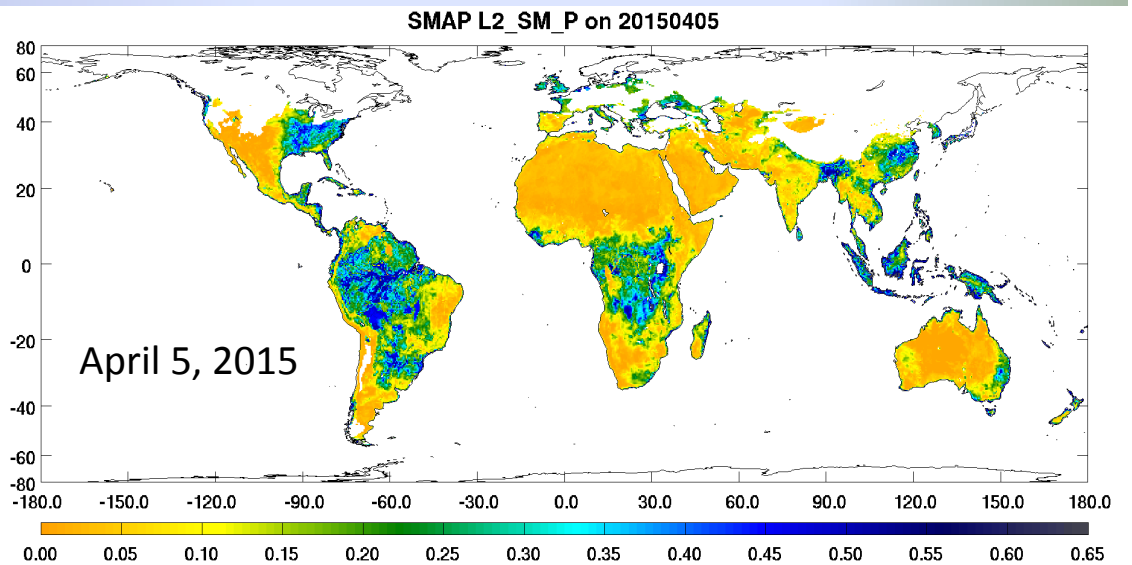
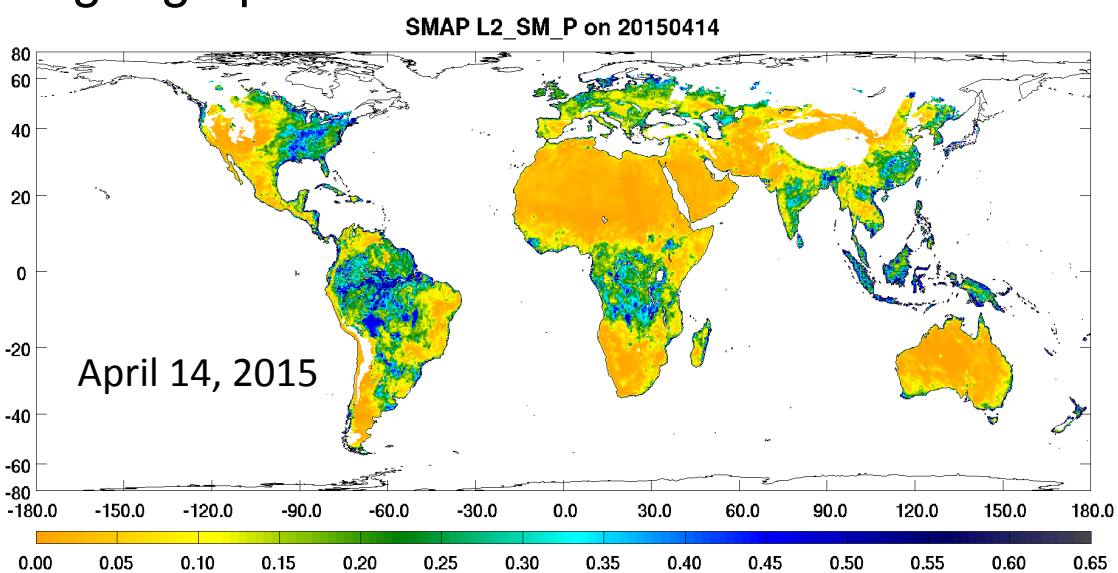
Soil Moisture - Observed Changes

- Passive (36 km) data processed into soil moisture 3-day global images centered on April 5 and 14, 2015
- Soil moisture patterns agree with expected geographical soil moisture





- Soil moisture changes are evident in the time-sequence
- Rainfall in India, Bangladesh, and Vietnam
- Dry-down in eastern Australia and Argentina

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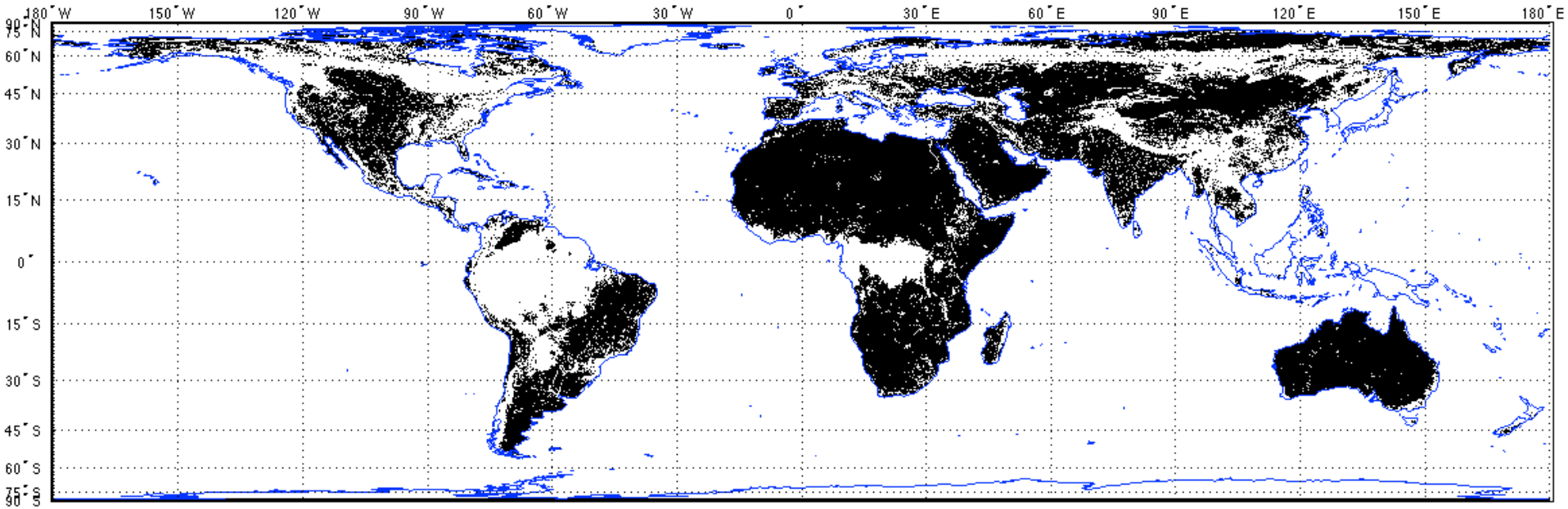
Soil Moisture - Expected Accuracy

- Regions where SMAP soil moisture retrievals are expected to meet L1 accuracy requirement of 0.04 m^3/m^3



- Retrieval expected quality mask (black colored pixels indicate good quality) with following specifications:
  a) Vegetation water content ≤ 5 kg/m^2
  b) Urban fraction ≤ 0.25
  c) Water fraction ≤ 0.1
  d) DEM slope standard deviation ≤ 3 deg

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Characteristics of SMAP Soil Moisture Products

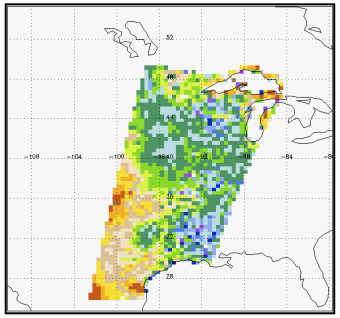
SMAP provided soil moisture products a three different resolutions:

Radiometer only (36 km spatial resolution):
- Higher accuracy
- coarse resolution
- Soil moisture for ~5 cm depth

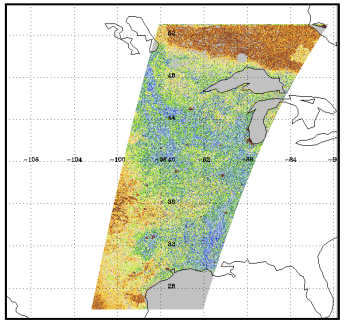
Radar only (3 km spatial resolution):
- Lower accuracy
- Higher resolution
- Soil moisture for ~5 cm depth

Combined (Radiometer – Radar) product (9 km spatial resolution):
- optimal accuracy
- moderate resolution
- Soil moisture for ~5 cm depth

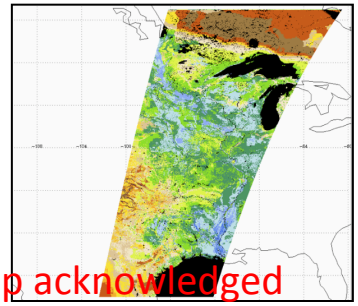
L2_SM_P (36 km)



L2_SM_A (3 km)



L2_SM_AP (9 km)



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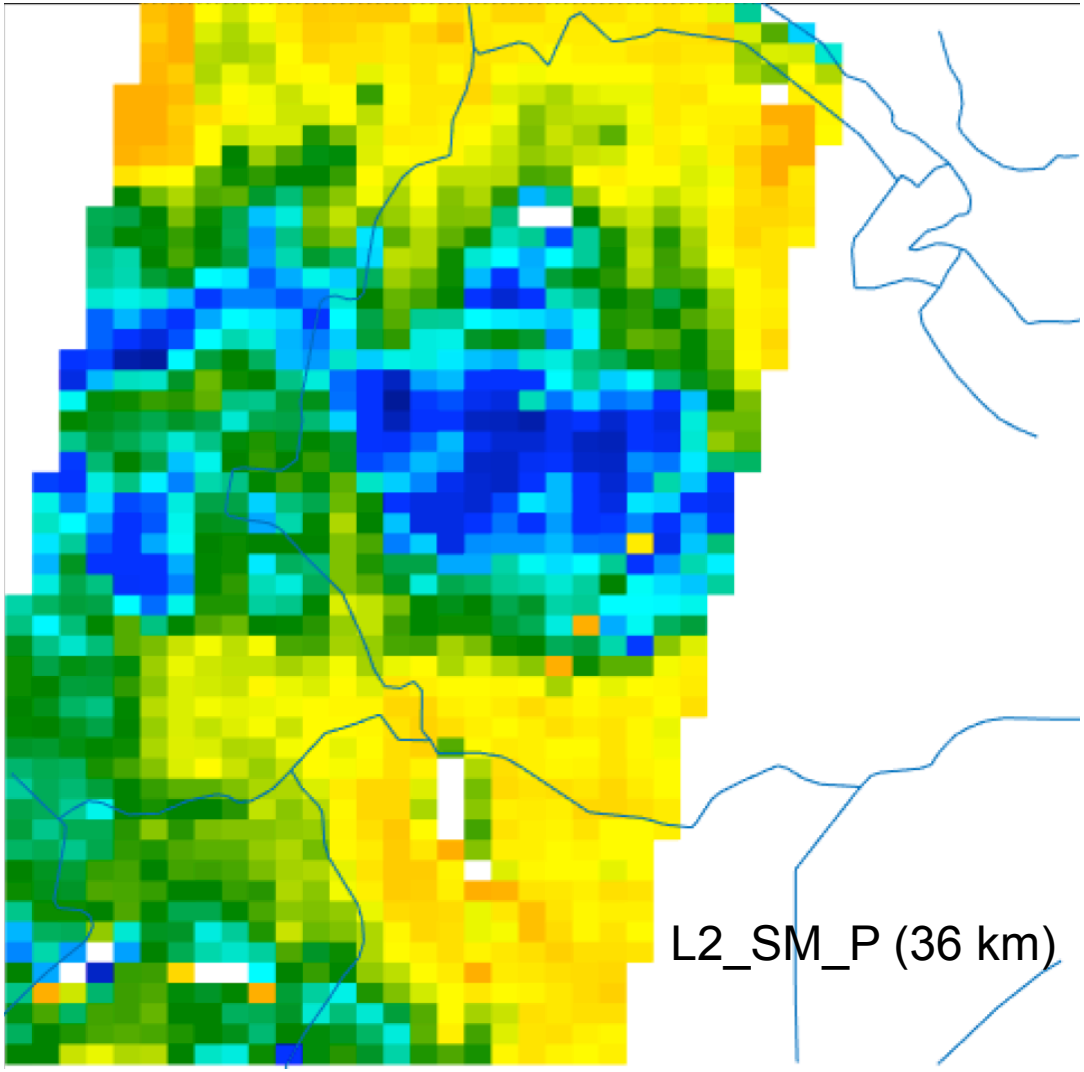
SMAP Active-Passive Approach

Additional detail captured



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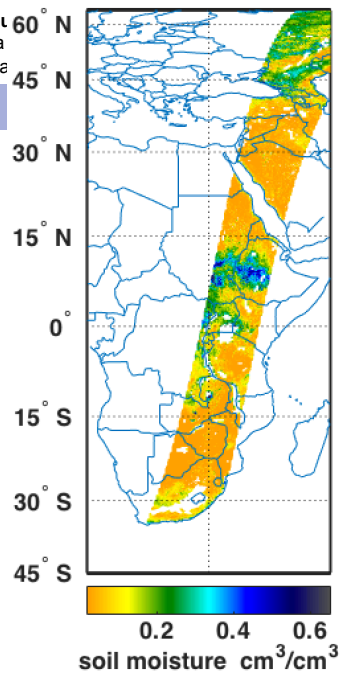
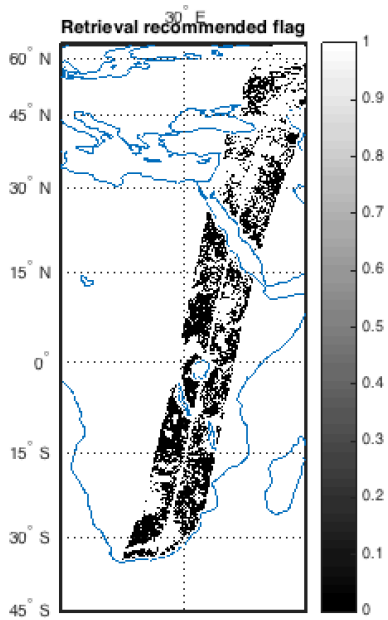
Quality Flags in Active-Passive Soil Moisture Products

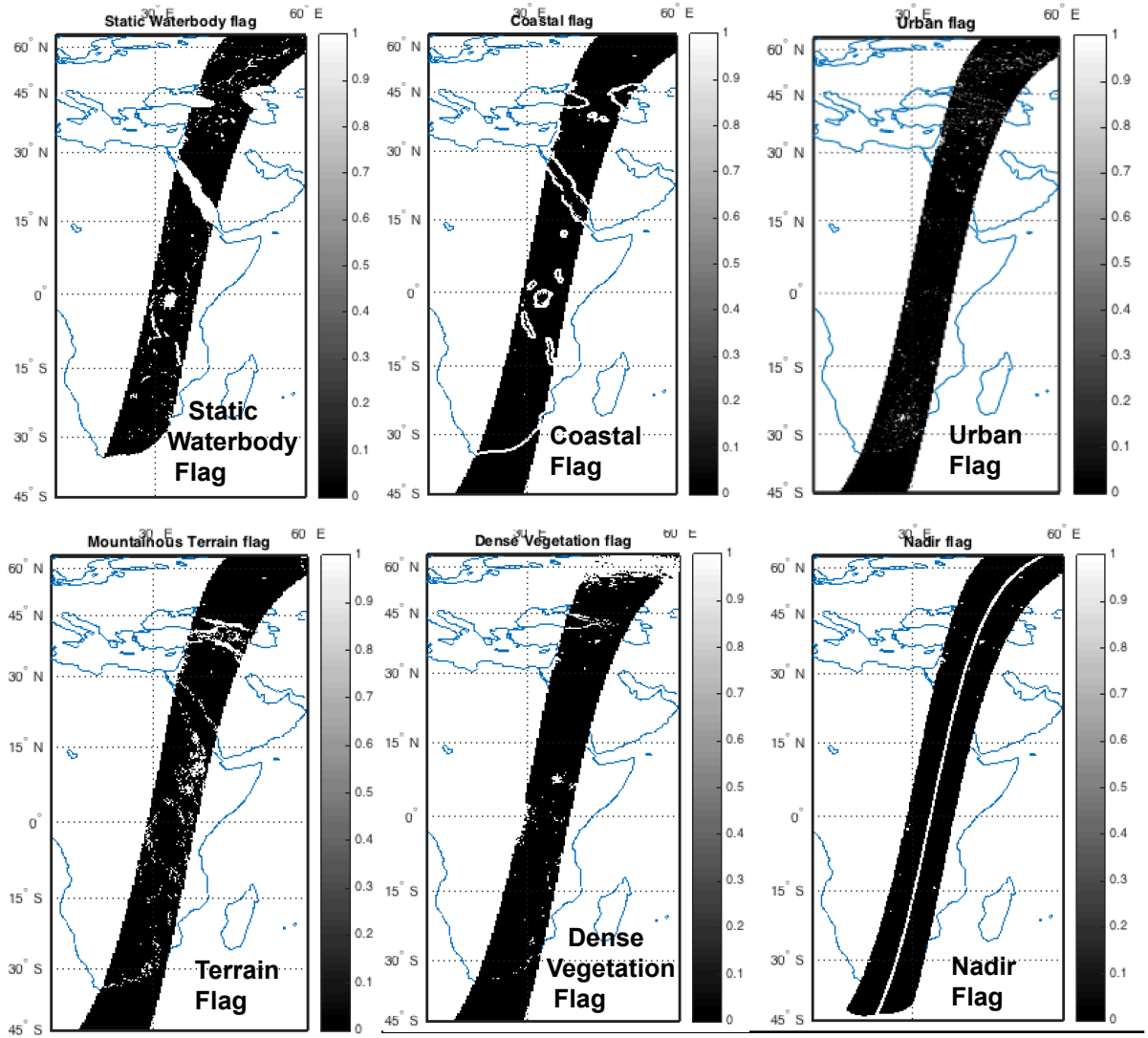
Soil Moisture Orbit 2202_D July 1st, 2015



Retrieval Recommended Flag



Surface Flags



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SMAP Data Portal

- SMAP data will be available in public domain.
- National Snow and Ice Data Center (NSIDC) a NASA Data Archive Center (DAAC) will host SMAP Data (http://nsidc.org/daac/projects/)
- Early Adopters are given preferred access to prelaunch Cal/Val and simulated dataset
- SMAP data will be available in HDF5 format with requisite metadata information. Super easy to read the data file in ESRI GIS and Matlab.
- The data comes at simple EASE2 projections. Typically at 9 km resolution the data array has 1624 rows and 3856 columns
- The data comes with latitude and longitude information that make it easy to render on GIS software.

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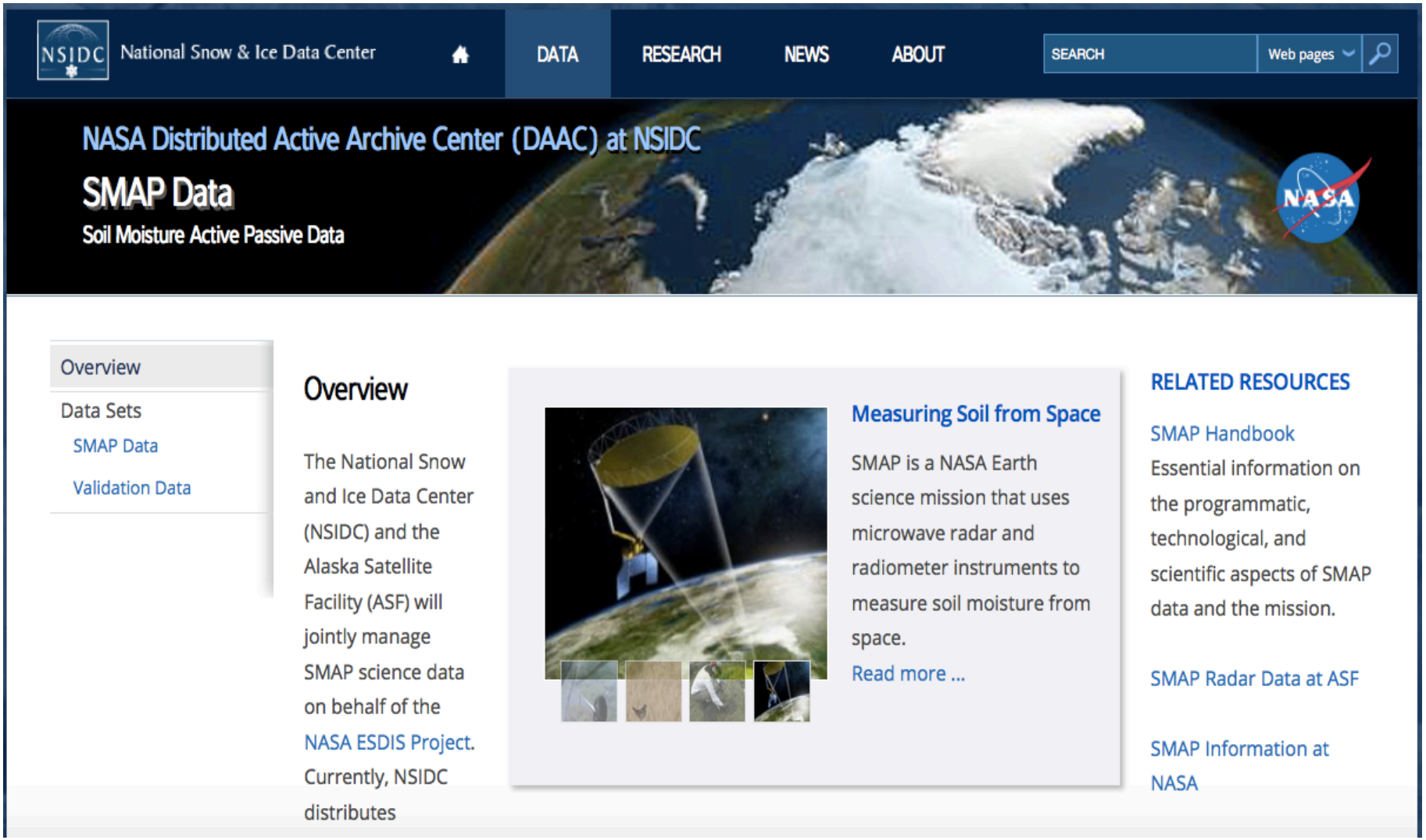
SMAP Portal at the U. S. National Snow and Ice Data Center Archive



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Recovery Effort for the Lost Potential of the SMAP Mission After the Radar Failure on July 7th, 2015

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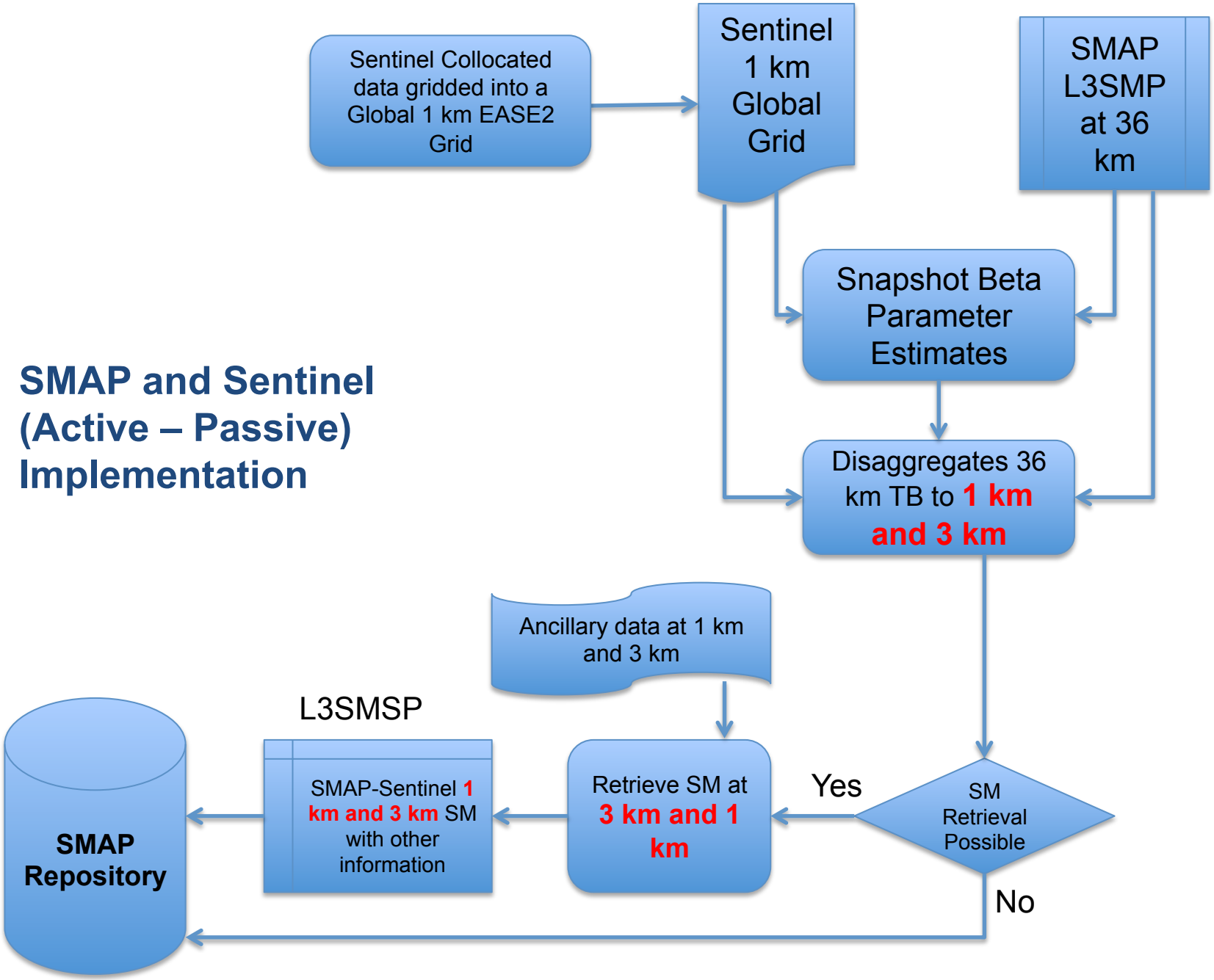
SMAP and Sentinel (Active – Passive) Implementation



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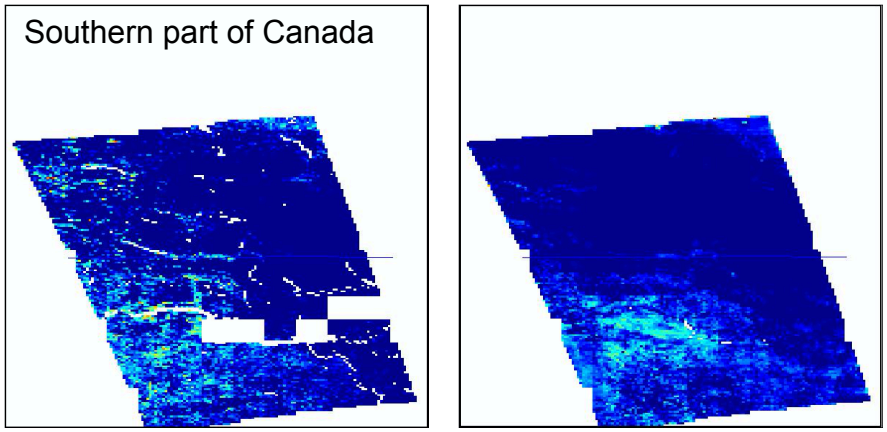
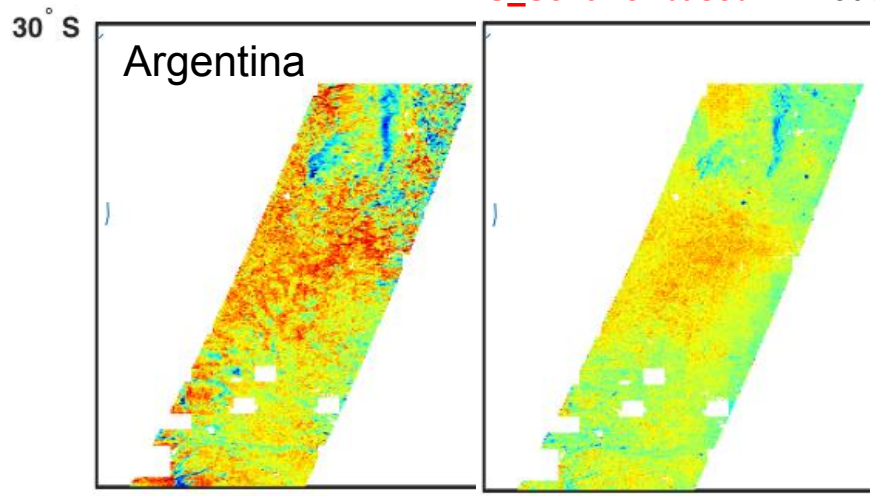
SMAP-based TBV at 3 km **S_Sentinel-based** TBV at 3 km

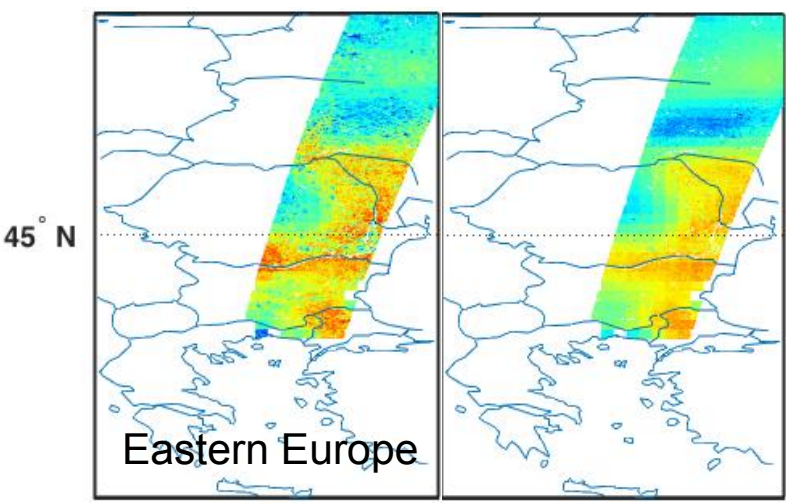


SMAP-based TBV at 3 km **S_Sentinel-based** TBV at 3 km

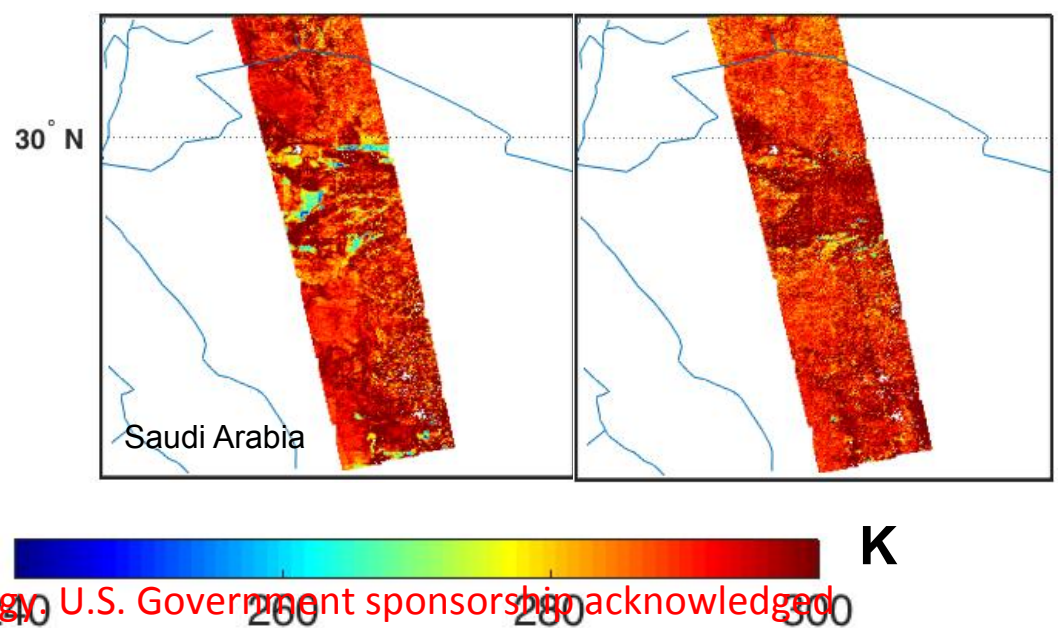


Comparison of SMAP-based and S_Sentinel-based disaggregation for 05-17-2015

SMAP-based TBV at 3 km **S_Sentinel-based** TBV at 3 km



SMAP-based TBV at 3 km **S_Sentinel-based** TBV at 3 km



S_Sentinel = SMAP and Sentinel Combined product

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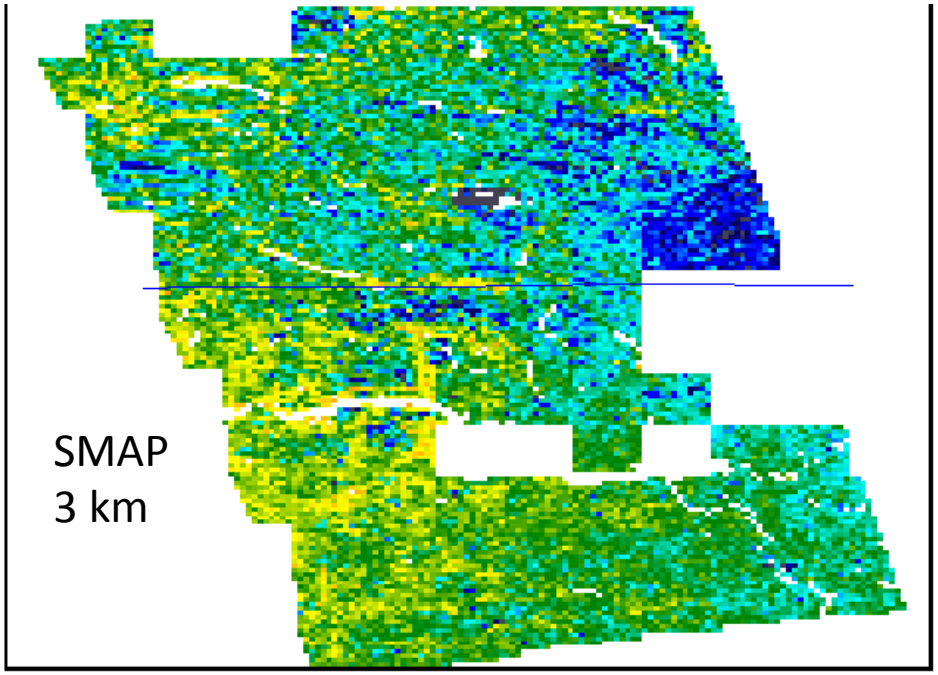
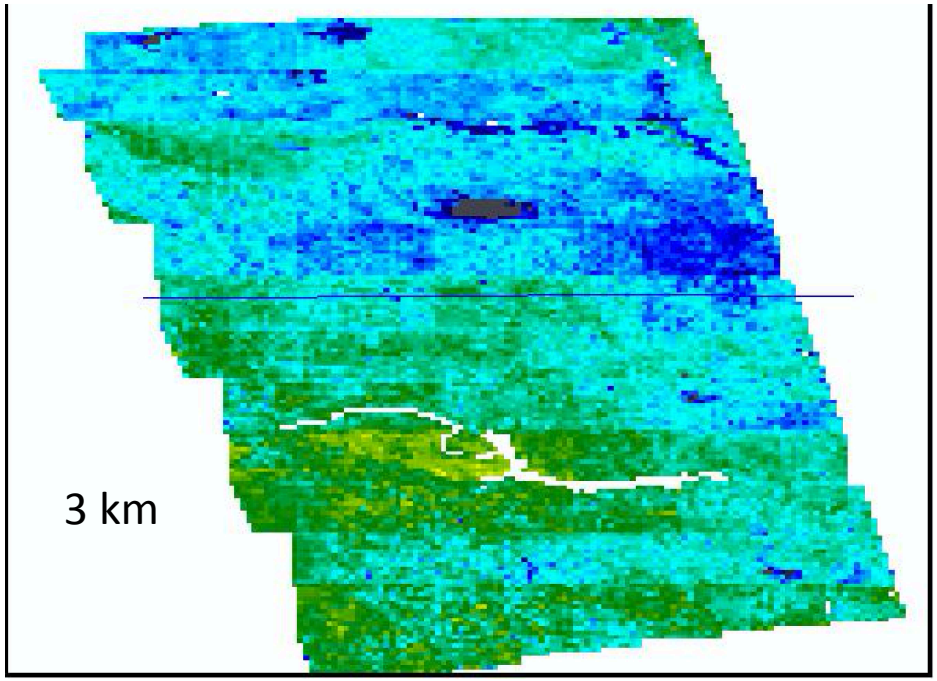
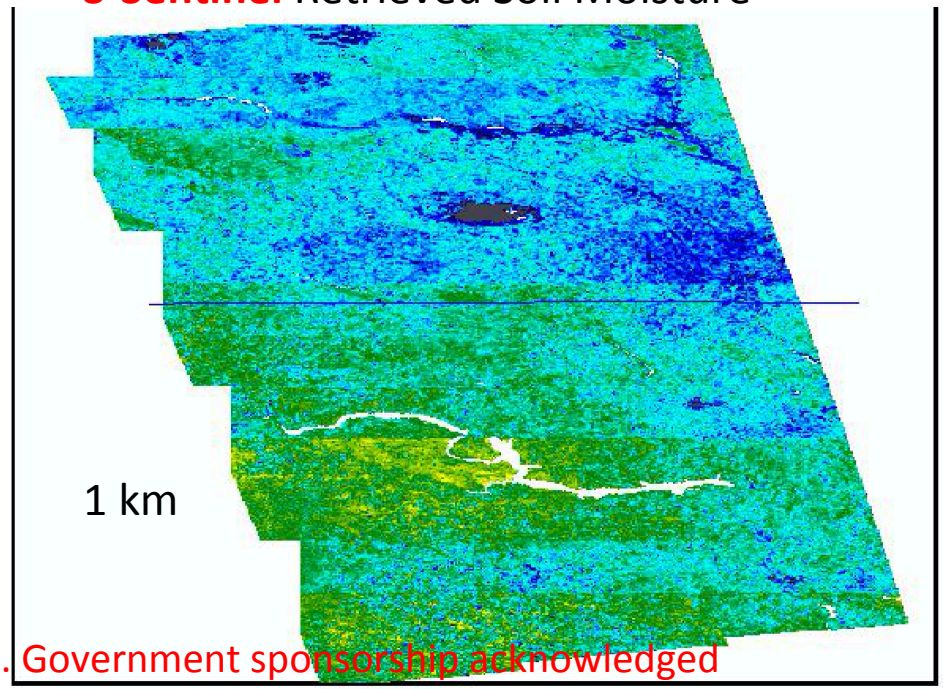


cm^3/cm^3



S-Sentinel Retrieved Soil Moisture



Southern part
of Canada

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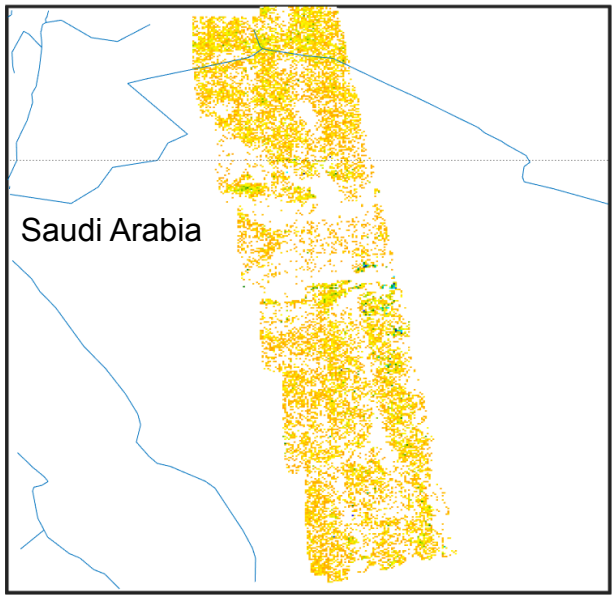
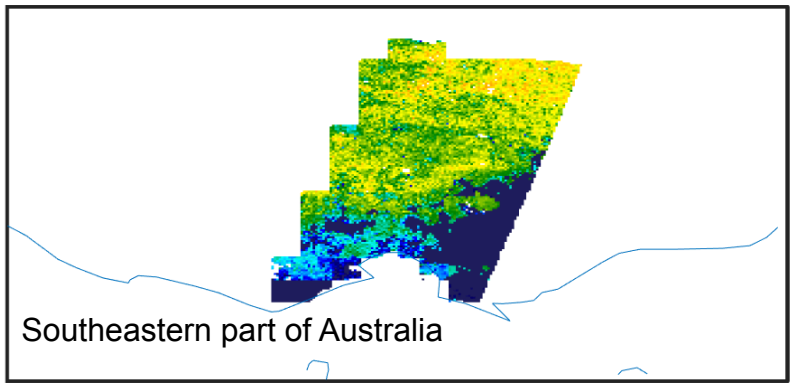
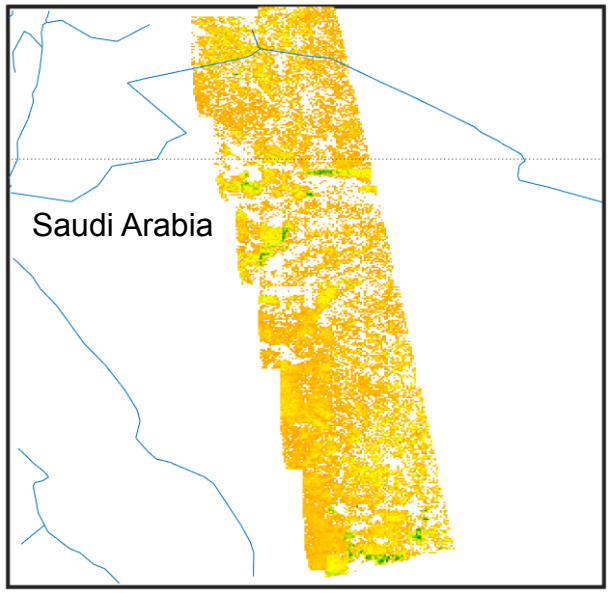
Impacts of Spatial Resolution

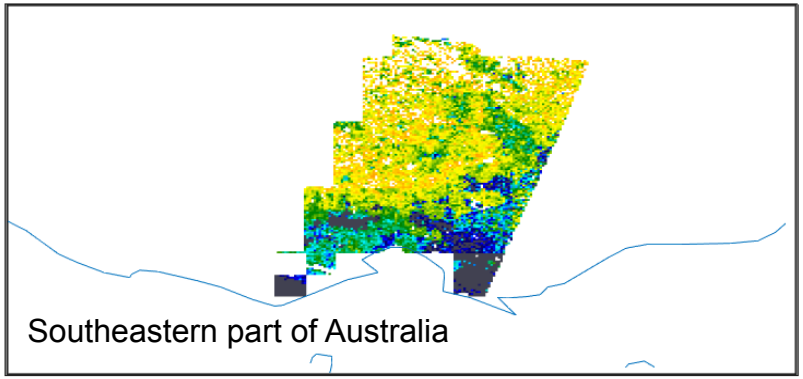
S_Sentinel-based



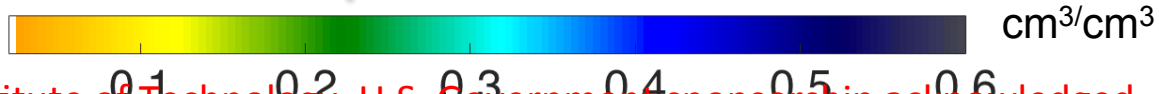


SMAP-based





Retrieved Soil Moisture



cm^3/cm^3

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Summary

- ✓ JPL-NASA has activities, assets and expertise to bring to bear on coastal/inland water challenges, including Deltas
- ✓ SMAP radiometer is performing satisfactorily.
- ✓ SMAP radar stopped operation on July 7th, 2015.
- ✓ The ~2.5 months of the SMAP Active and Passive data shows importance of having radar and radiometer data for improved resolution of soil moisture observation from space.
- ✓ The SMAP beta released data is now available for free at the National Snow and Ice Data Center (NSIDC)
- ✓ The SMAP validated products will be released to public through NSIDC on April 30th, 2016.
- ✓ Efforts are on in JPL to use Sentinel data that will replace the dysfunctional SMAP Radar for the Active-Passive algorithm.

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Thanks!!!

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