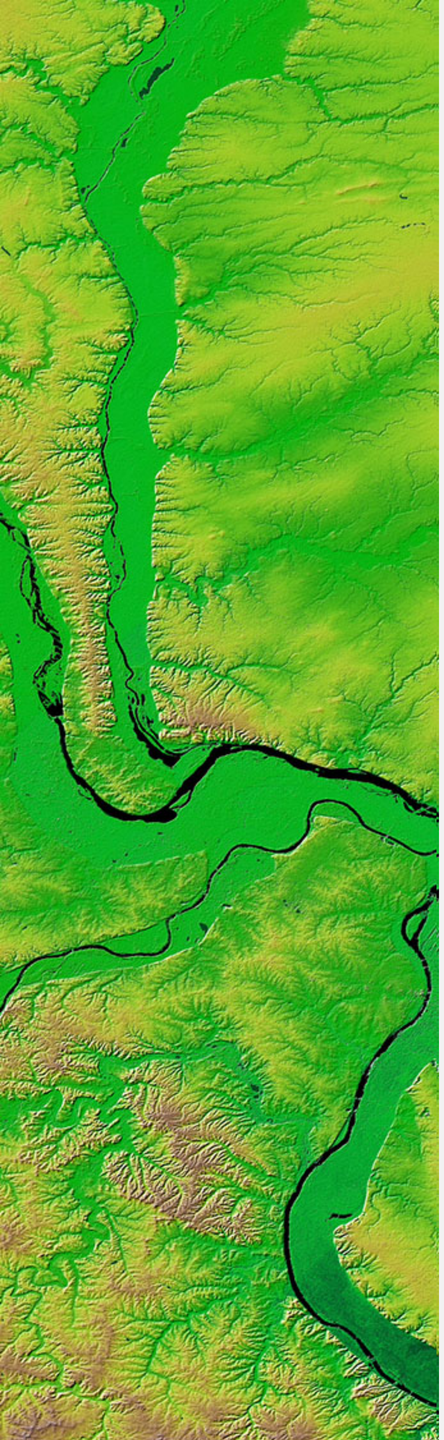


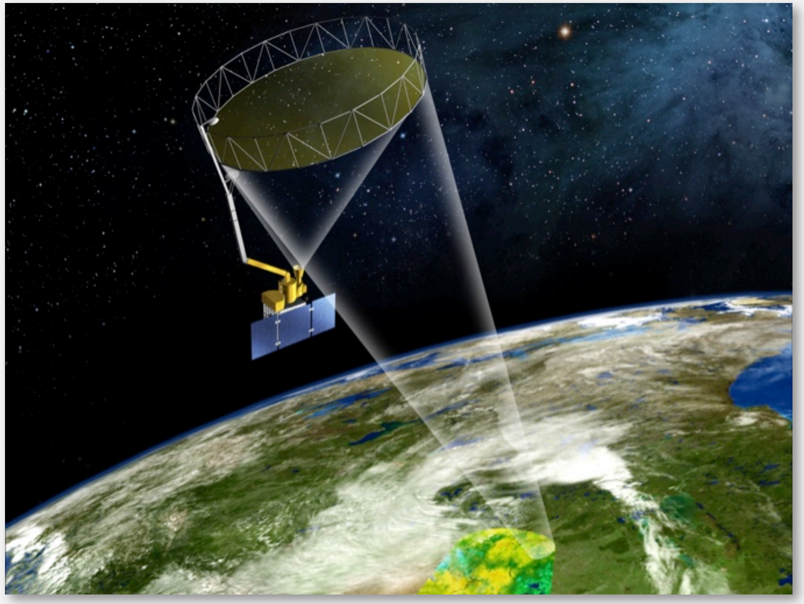
National Aeronautics and
Space Administration

ARSET

Applied Remote Sensing Training

http://arset.gsfc.nasa.gov

@NASAARSET



Applications of SAR

Erika Podest and Amita Mehta

April 19, 2017

Learning Objectives

By the end of this presentation, you will be able to:

- understand how different microwave frequencies support different applications
- understand how different approaches (e.g. interferometry, polarimetry) support different applications

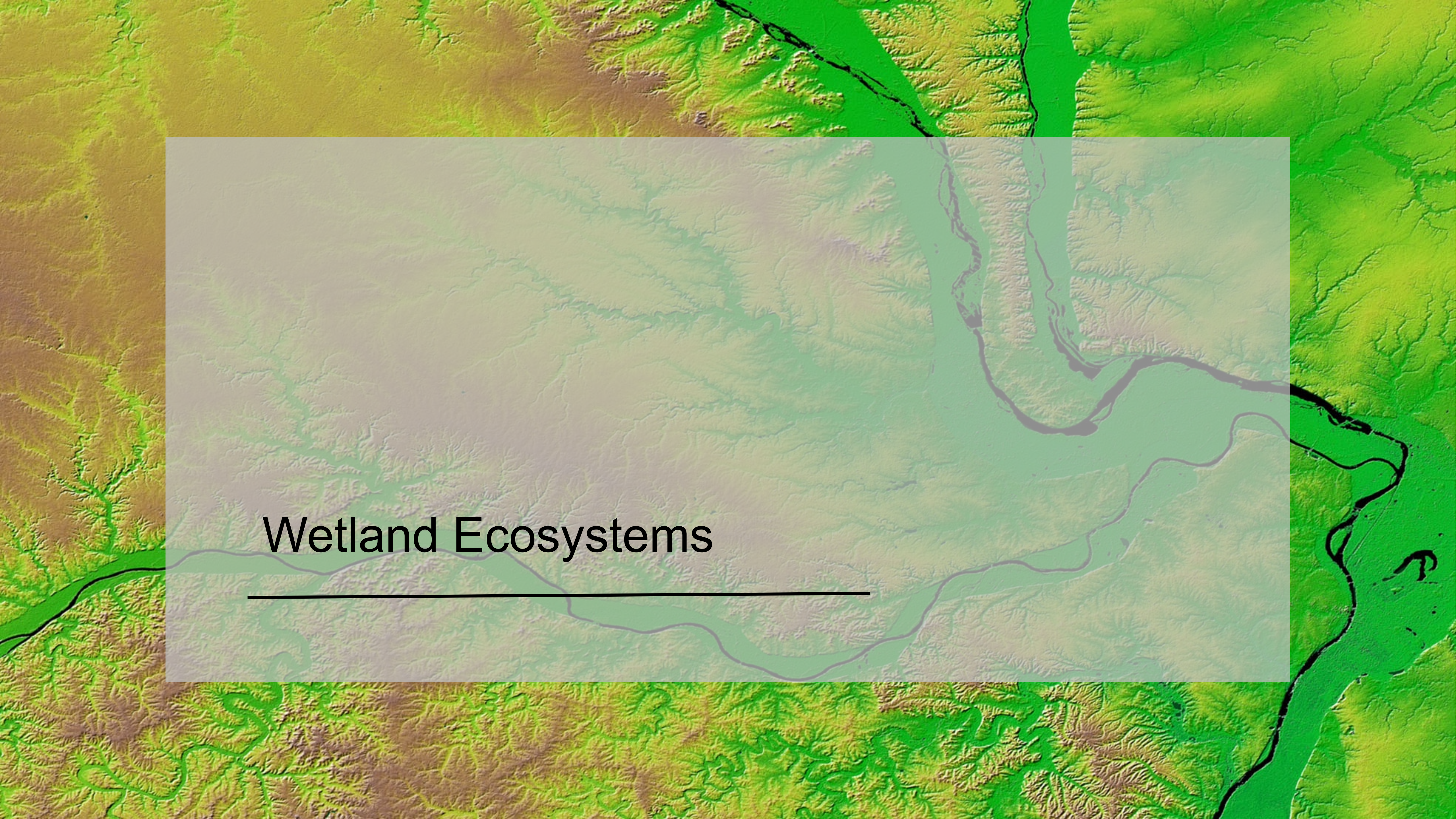
SAR Applications

1. Wetland Ecosystems
2. Vegetation Studies
3. Disaster Monitoring
4. Ground Subsidence
5. Cryosphere
6. Oceans
7. Urban Area/Infrastructure Change

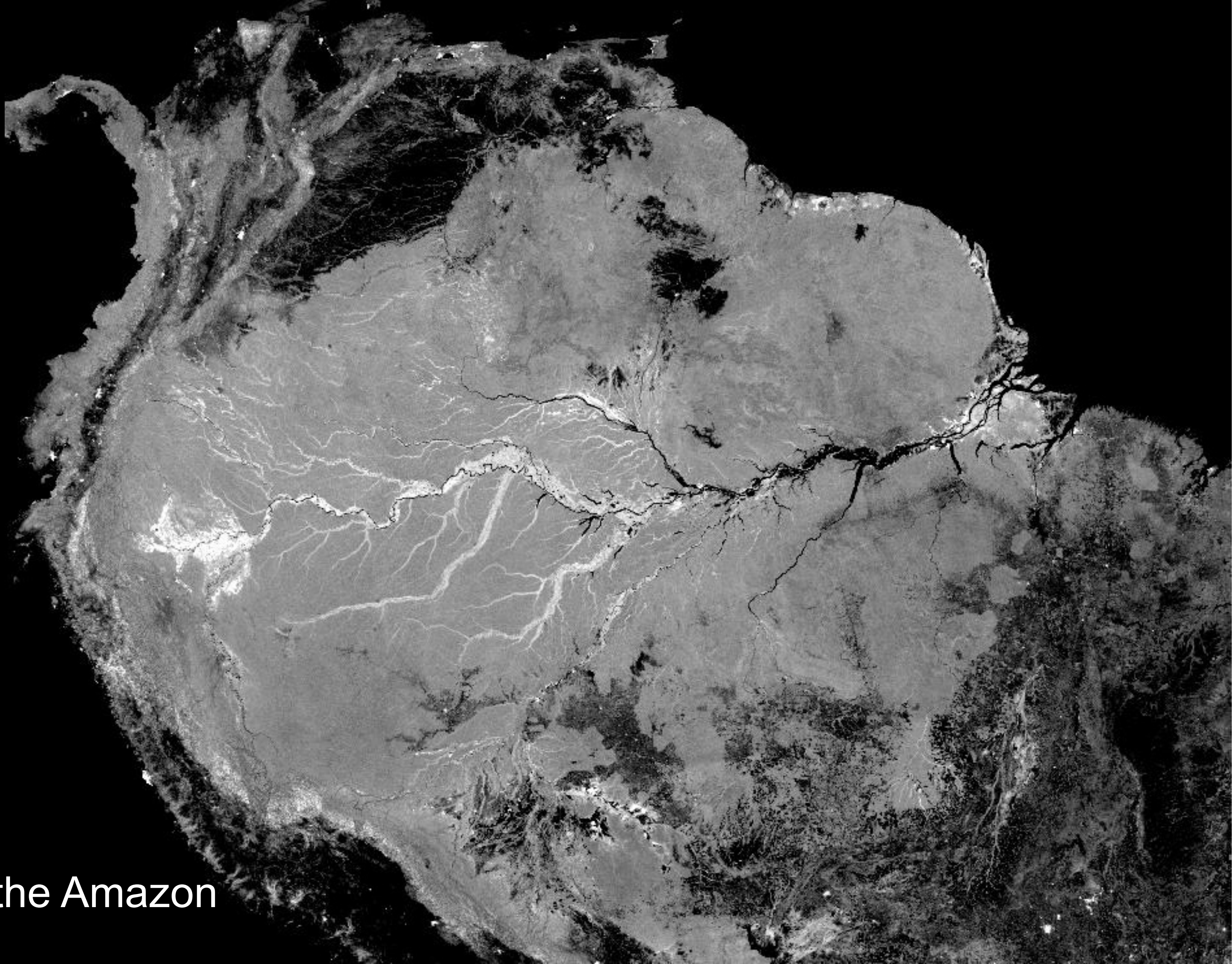
SAR Applications Using Different Frequency Bands

Frequency band	*Frequency range*	*Application Example*
• VHF	300 KHz - 300 MHz	Foliage/Ground penetration, biomass
• P-Band	300 MHz - 1 GHz	biomass, soil moisture, penetration
• L-Band	1 GHz - 2 GHz	agriculture, forestry, soil moisture
• C-Band	4 GHz - 8 GHz	ocean, agriculture
• X-Band	8 GHz - 12 GHz	agriculture, ocean, high resolution radar
• Ku-Band	14 GHz - 18 GHz	glaciology (snow cover mapping)
• Ka-Band	27 GHz - 47 GHz	high resolution radars

Image Credit: DLR



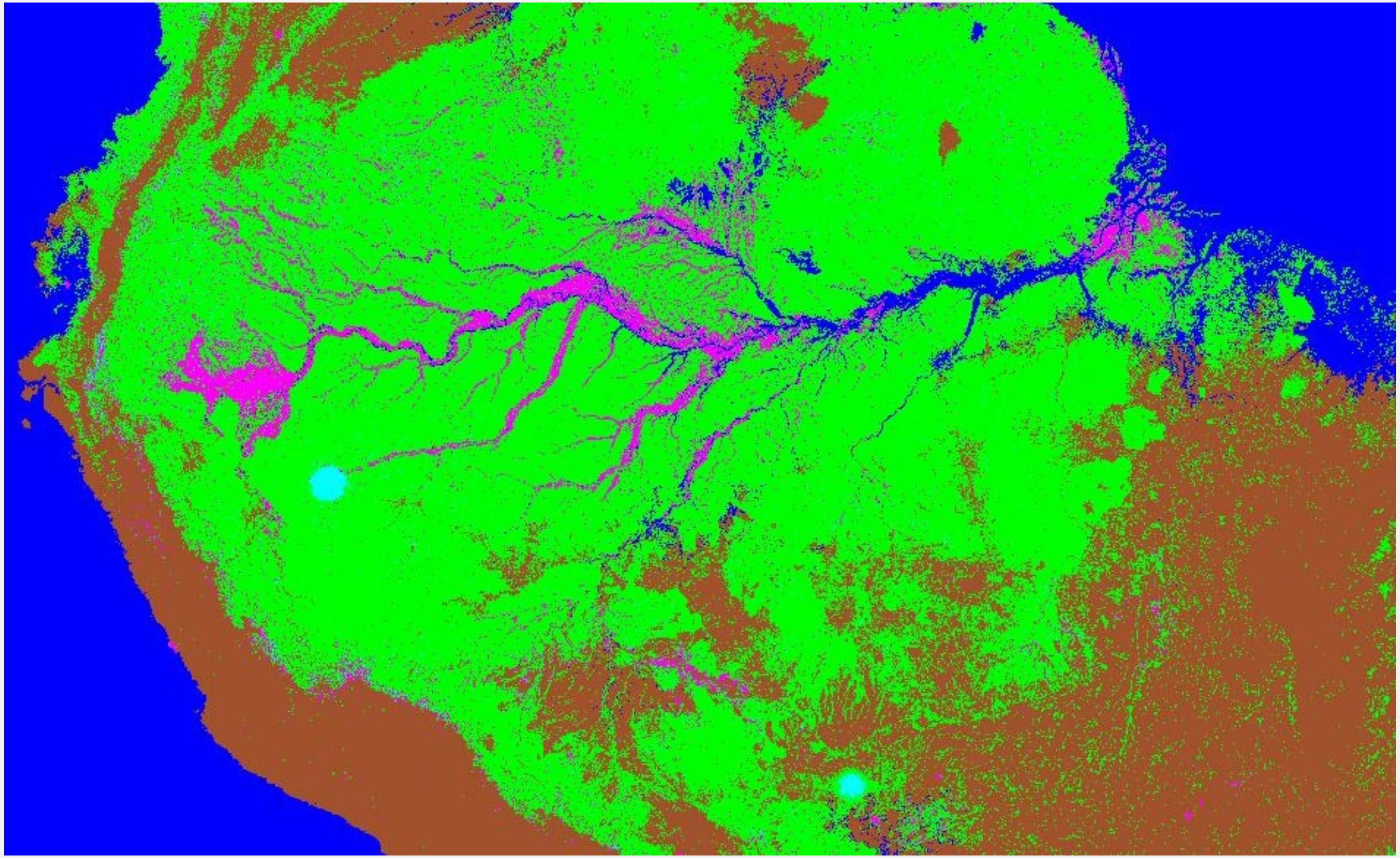
Wetland Ecosystems



SMAP Radar Mosaic of the Amazon

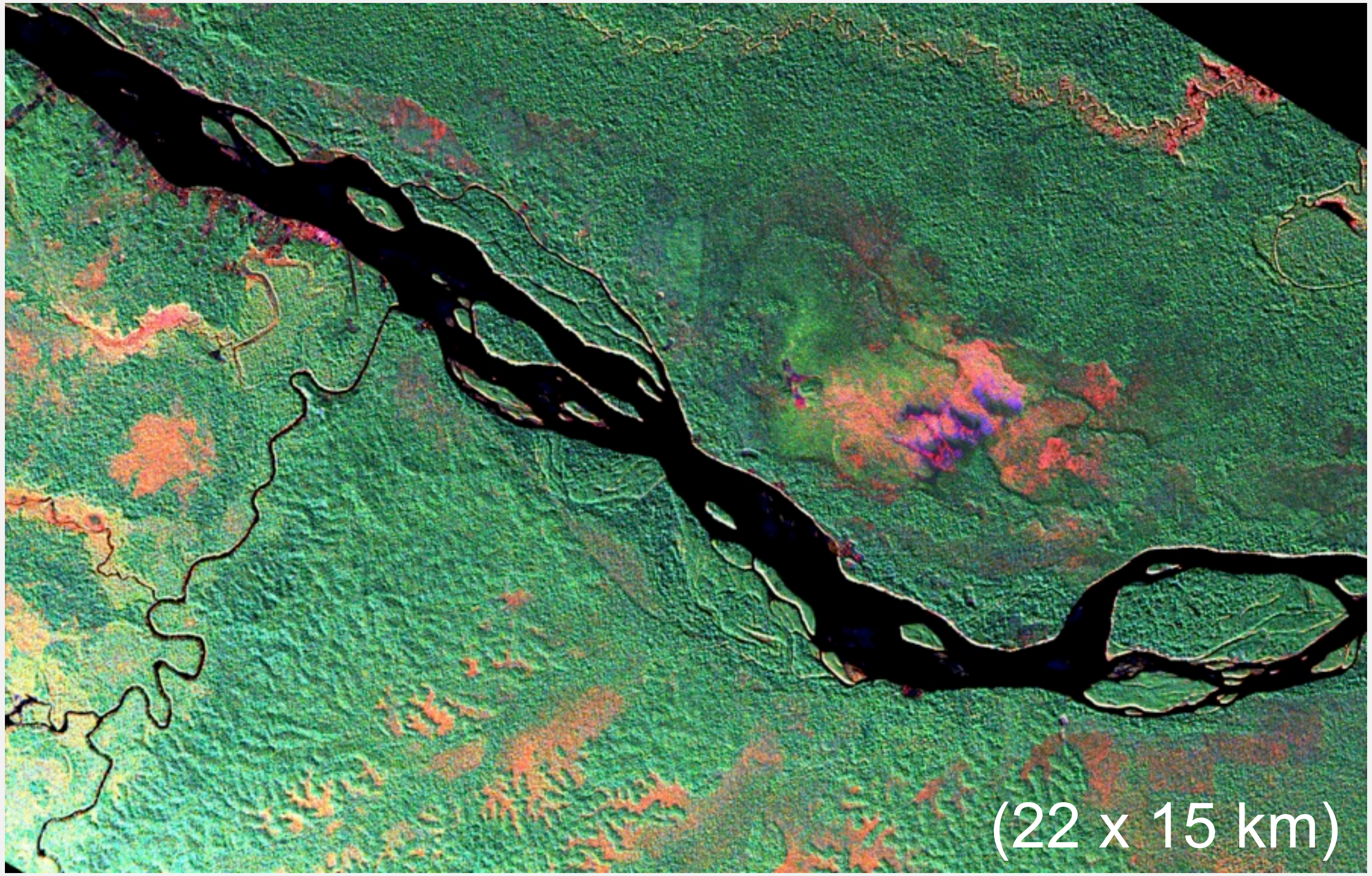
SMAP Radar Mosaic Wetland Classification

- Open Water
- Inundated Vegetation
- RFi
- High Biomass Non-Inundated Forest
- Low Biomass Non-Inundated Forest



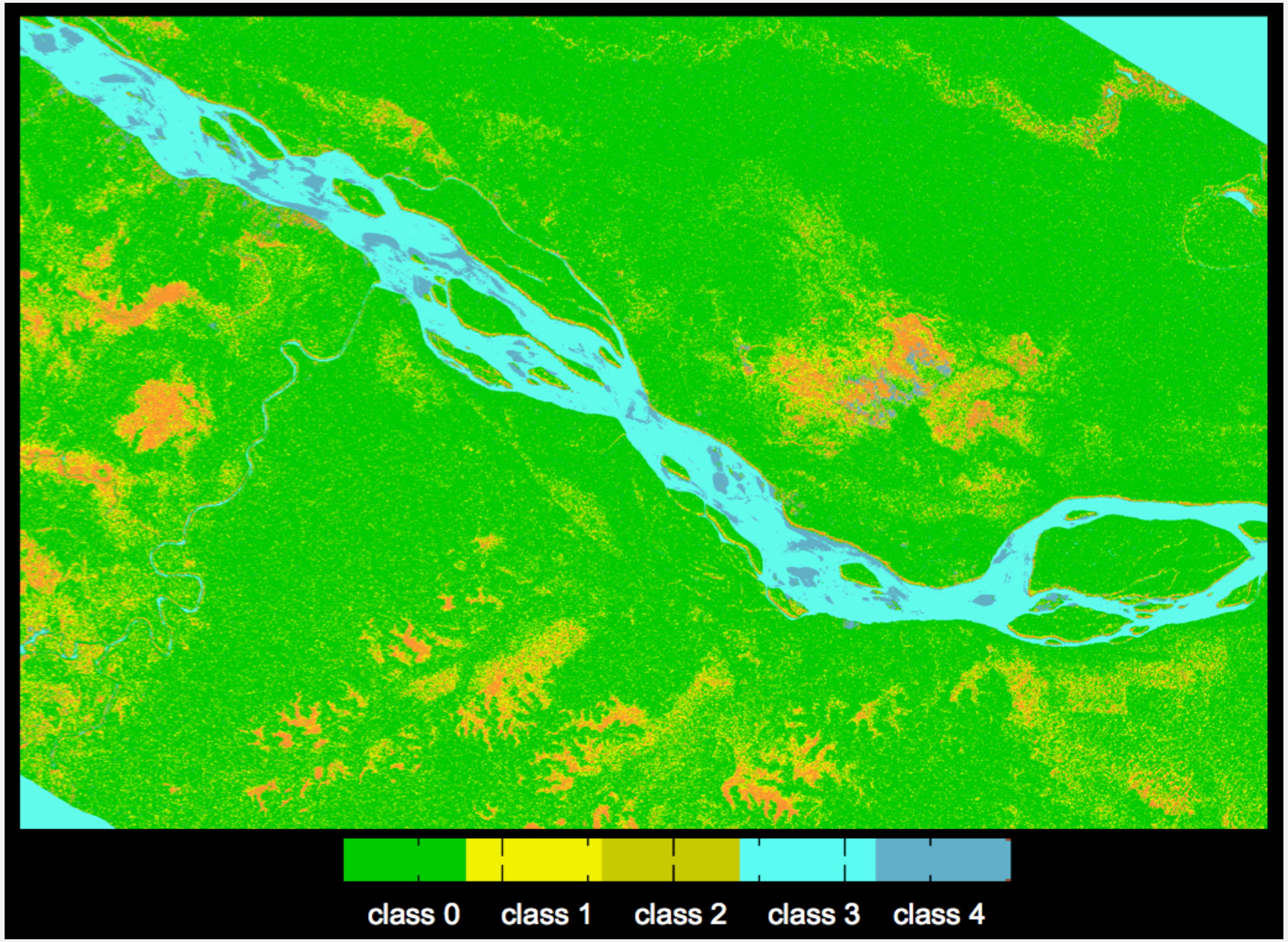
Credit: E. Podest

Mapping Inundation Extent with UAVSAR – Fully Polarimetric



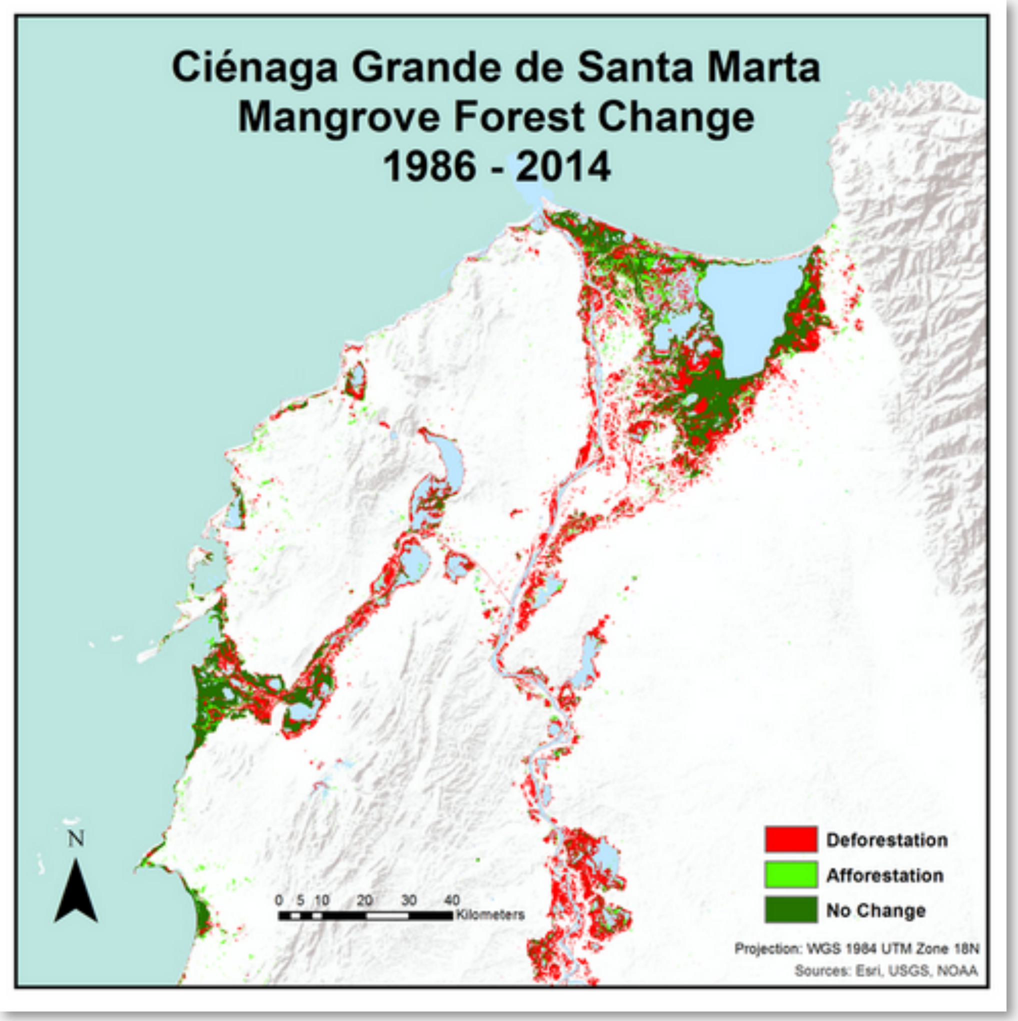
- UAVSAR quad-pol
  Napo River, Ecuador
  March 31, 2013
- Van Zyl decomposition of a subset of the UAVSAR image swath
- Red: double bounce scatter
- Green: volume scatter
- Blue: odd scatter

Classification Based on SAR Observables



- Green: not inundated
- Yellow & Orange: inundated vegetation
- Blue (light & dark): open water

Mangrove Monitoring

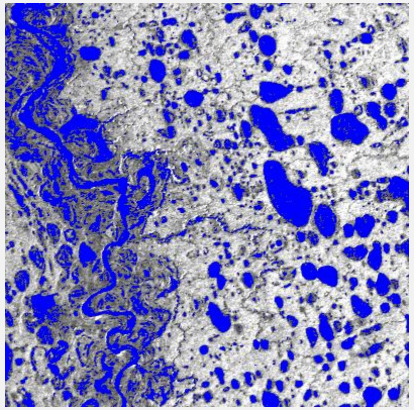


Credit: Marc Simard, JPL

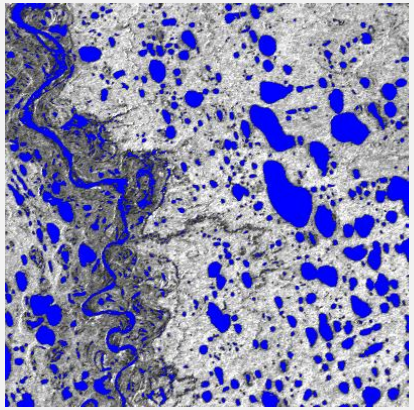
Open Water Change: North Slope, Alaska

	Drier	Wetter
Jul	7.7%	2.7%
Aug	6.9%	3.2%

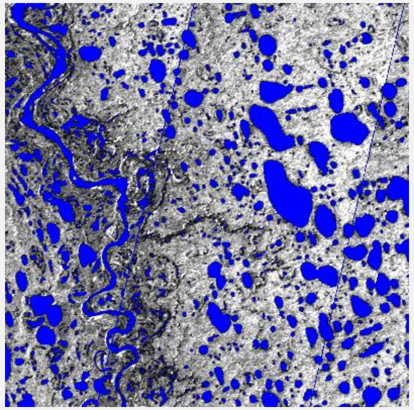
- More open water (red)
- Less open water (white)
- No change (black)



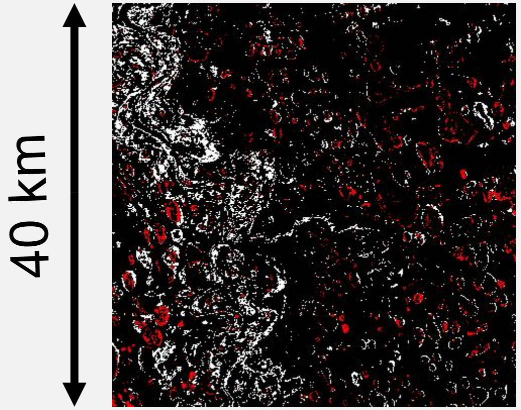
June 1998



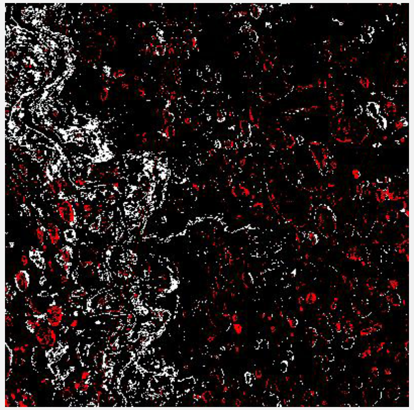
July 1998



August 1998



Open water change Jun/Jul



Open water change Jun/Aug

Credit: E. Podest

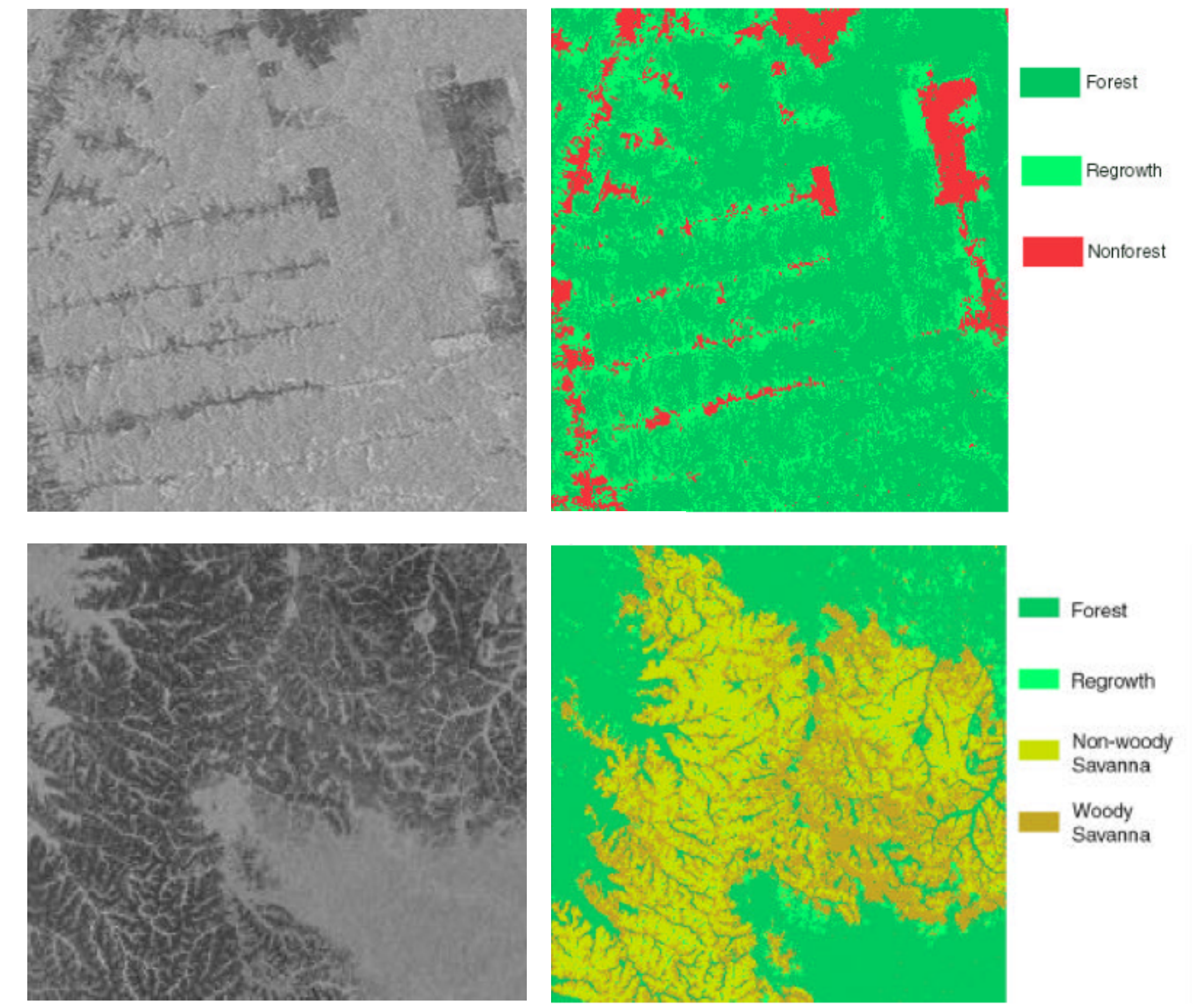
Vegetation Studies

Land Cover and Land Use Change in Brazil: Single Polarization

Brazil

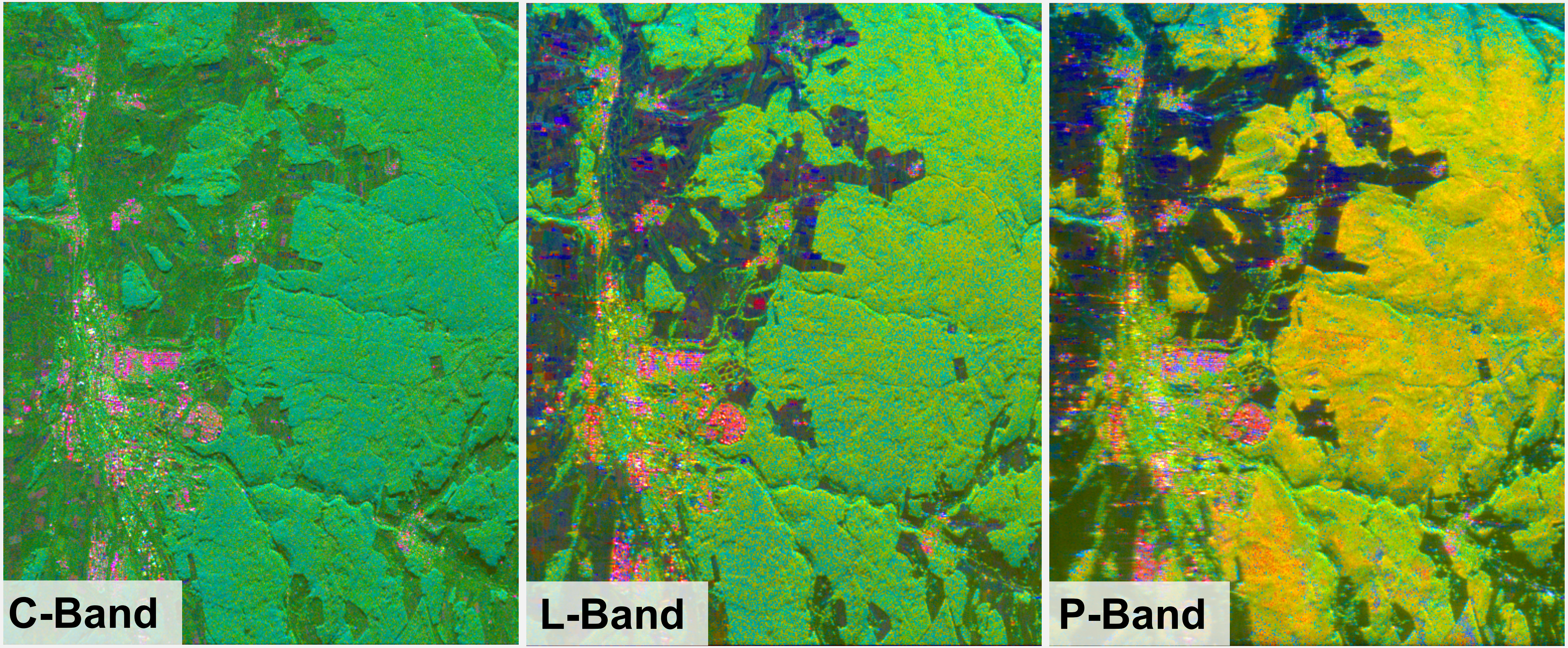
JERS-1 L-band

100 m resolution



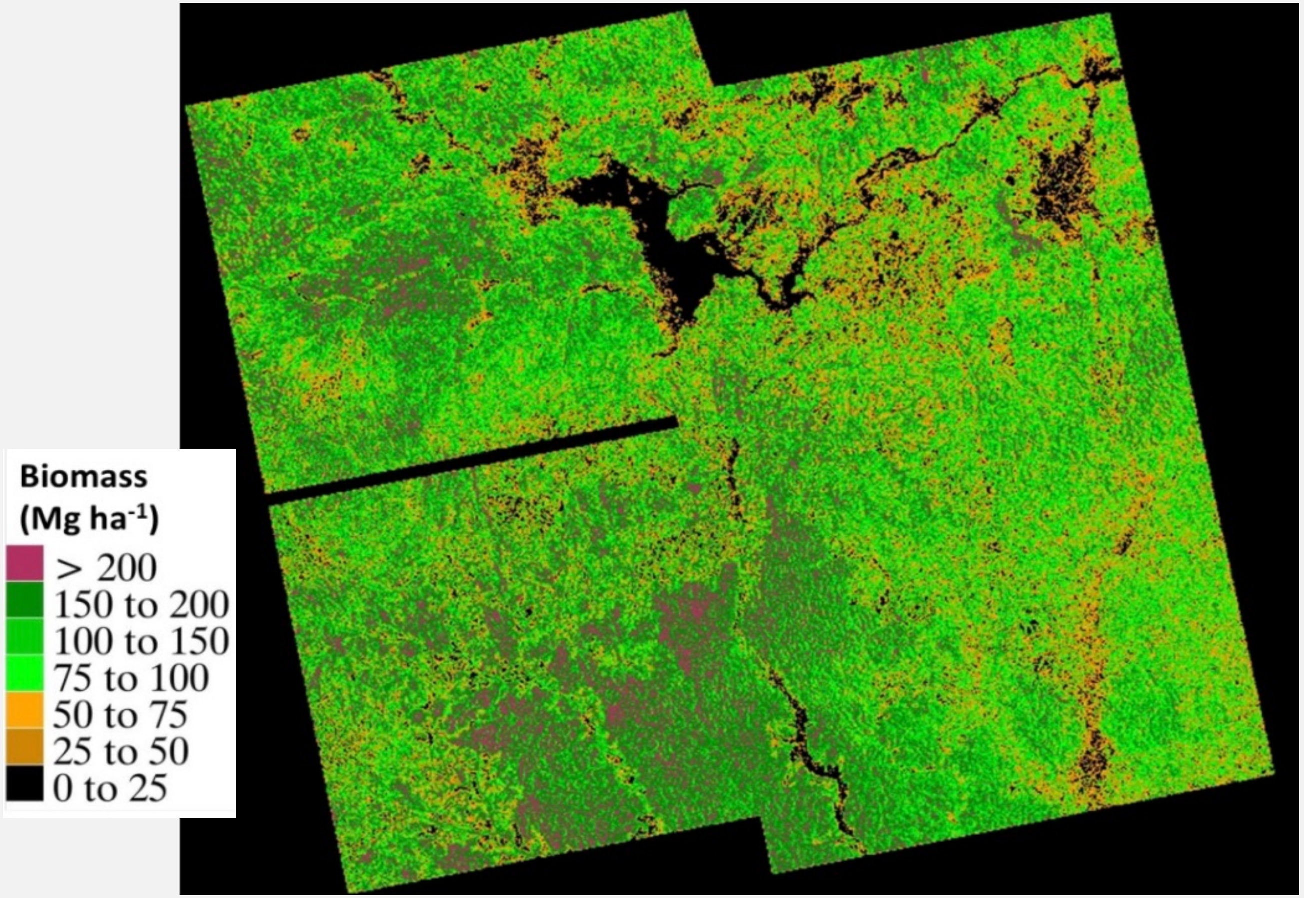
Credit: E. Podest

Land Cover and Land Use: Multiple Polarizations



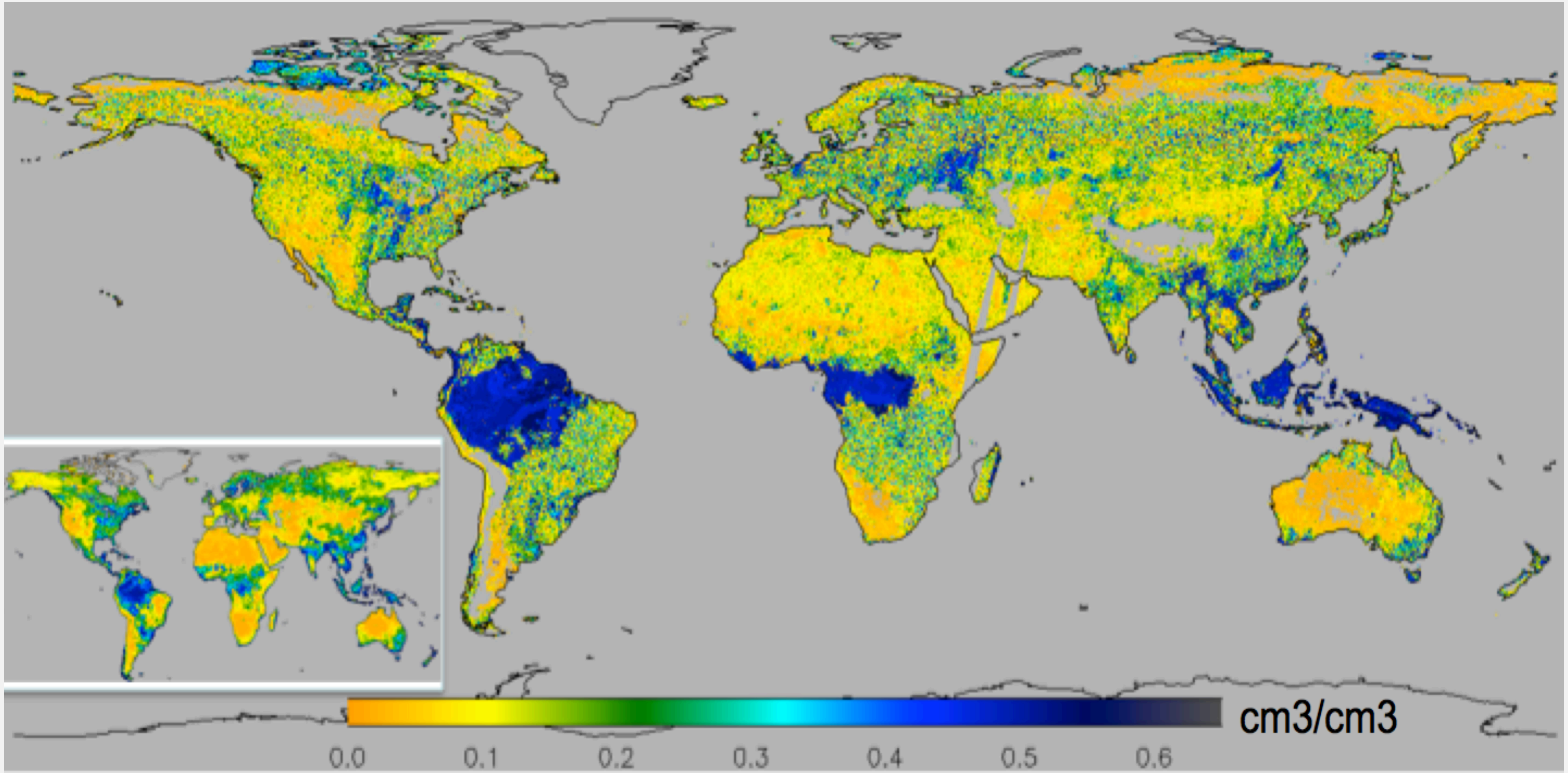
Above Ground Biomass Mapping

- Biomass map over Mbam Djerem National Park in Cameroon
- Derived from ALOS PALSAR data from 2007 and local field plot calibration



Mitchard, E., et al. (2011). Measuring biomass changes due to woody encroachment and deforestation/degradation in a forest–savanna boundary region of central Africa using multi-temporal L-band radar backscatter. Remote Sensing of Environment, 115(11), 2861-2873. doi:10.1016/j.rse.2010.02.022

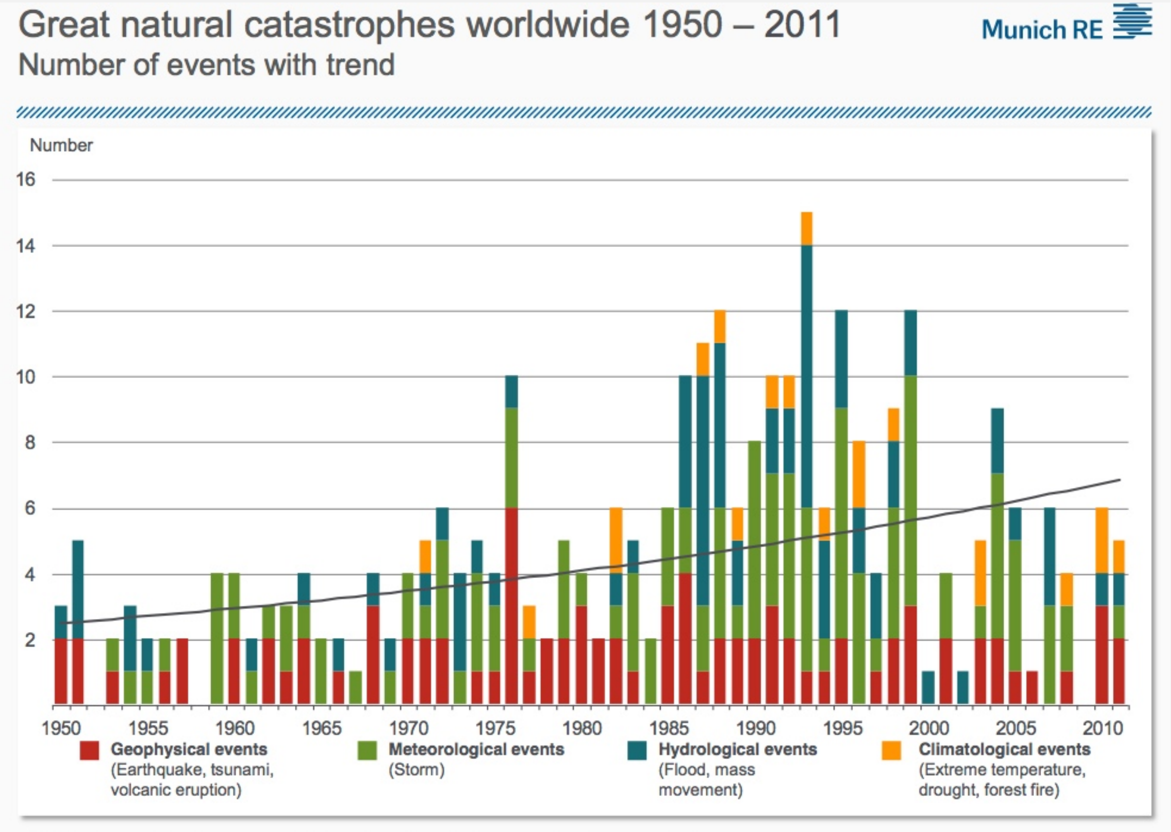
Soil Moisture from SMAP Radar: June 19-26, 201



Disaster Monitoring

SAR for Natural Disaster Monitoring

- Major natural disasters (loss of life in thousands or major economic loss) since 1950 broken down by category
- Geophysical meteorological, and hydrological events are the bulk of the events
- No single radar will meet all disaster monitoring needs
- Choice of frequency, resolution, swath width, interferometric capability, etc. varies depending on the type of the disaster



Credit: Münchener Rückversicherungs-Gesellschaft, Geo Risks Research, NatCatSERVICE

Platform/Sensor Requirements Matrix

Disaster	Information Requirements	Platform/Sensor Requirements
Flood	• Daily flood extent maps (50 m) • Flood level (20 cm vertical accuracy)	• Polarimetric radar (5-25 cm) wavelength with moderate resolution & a wide swath • Single pass interferometer (0.5-5 cm) wavelength
Volcano	• Daily deformation at 0.5 cm accuracy • Map extent of lava flows, lahars, etc. at 5-10 m resolution	• Repeat pass radar capability at suitable wavelengths (12-40 cm). Requires platform trajectory control and suitable antenna • Polarimetric imaging and combination of coherent and incoherent change detection. Need sufficient bandwidth to get looks for a 10 m product

Platform/Sensor Requirements Matrix

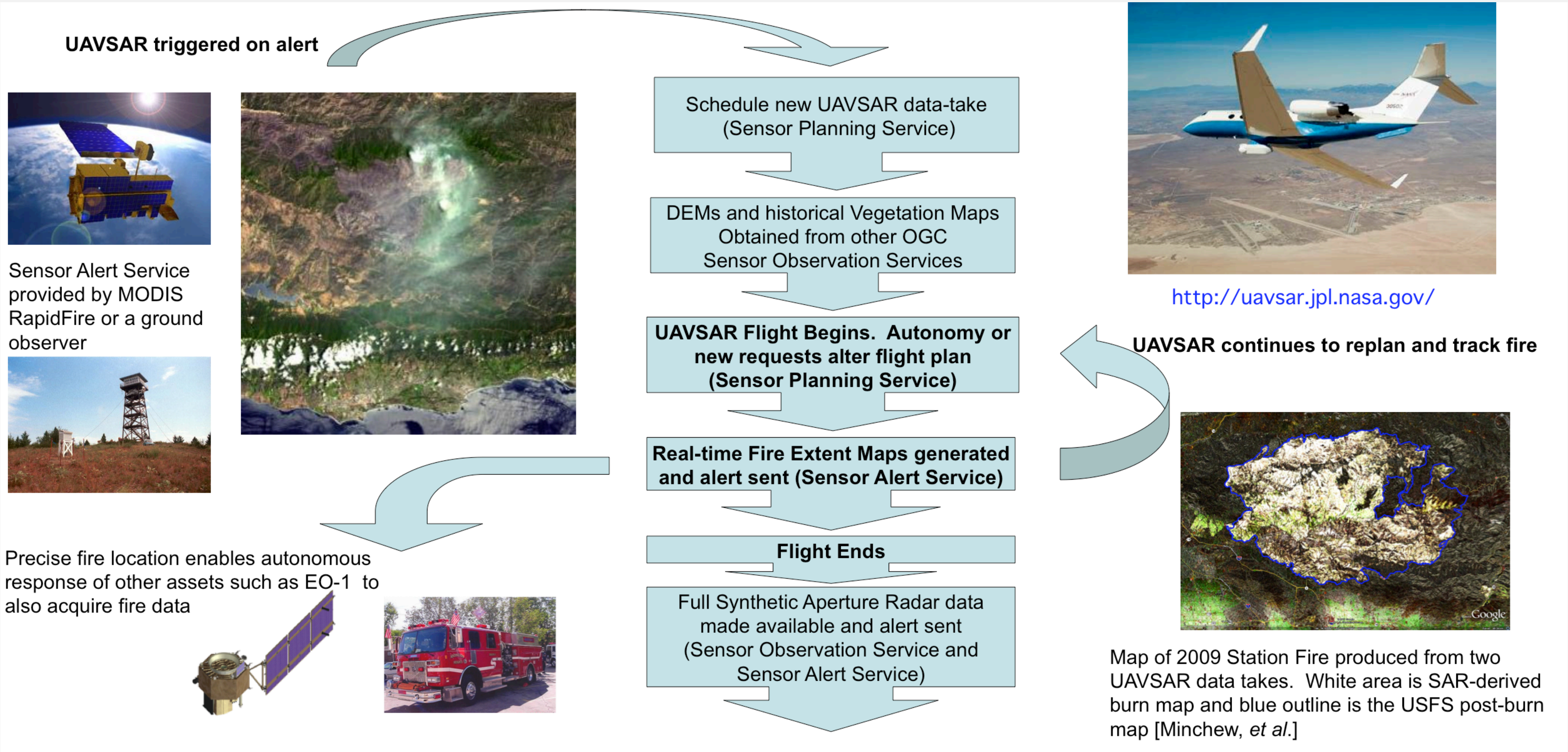
Disaster	Information Requirements	Platform/Sensor Requirements
Earthquakes	• Persistent deformation observations for 48-72 hrs after event (0.5 cm) • Damage assessment from reference images (5-10 m resolution)	• Repeat pass radar capability at suitable wavelength (12-40 cm) • Use correlation changes with different polarizations
Oil Spill	• Daily or more frequent spill extent and thickness maps (20 m resolution)	• Polarimetric with excellent noise equivalent and σ^0 and wide swath
Fire	• Hourly fire extent maps (10 m)	• Wide swath polarimetric radar with good resolution and platform capable of persistent observations

Example Platform/Sensor System: UAVSAR

- L-band, fully polarimetric SAR
- Employs an electronically scanning antenna
- Design incorporates:
  - Precision autopilot so the platform can fly repeat trajectories mostly within a 5 m tube
  - Compensates for attitude angle changes during and between repeat tracks by electronically pointing the antenna based on changes measured by the Inertial Navigation Unit

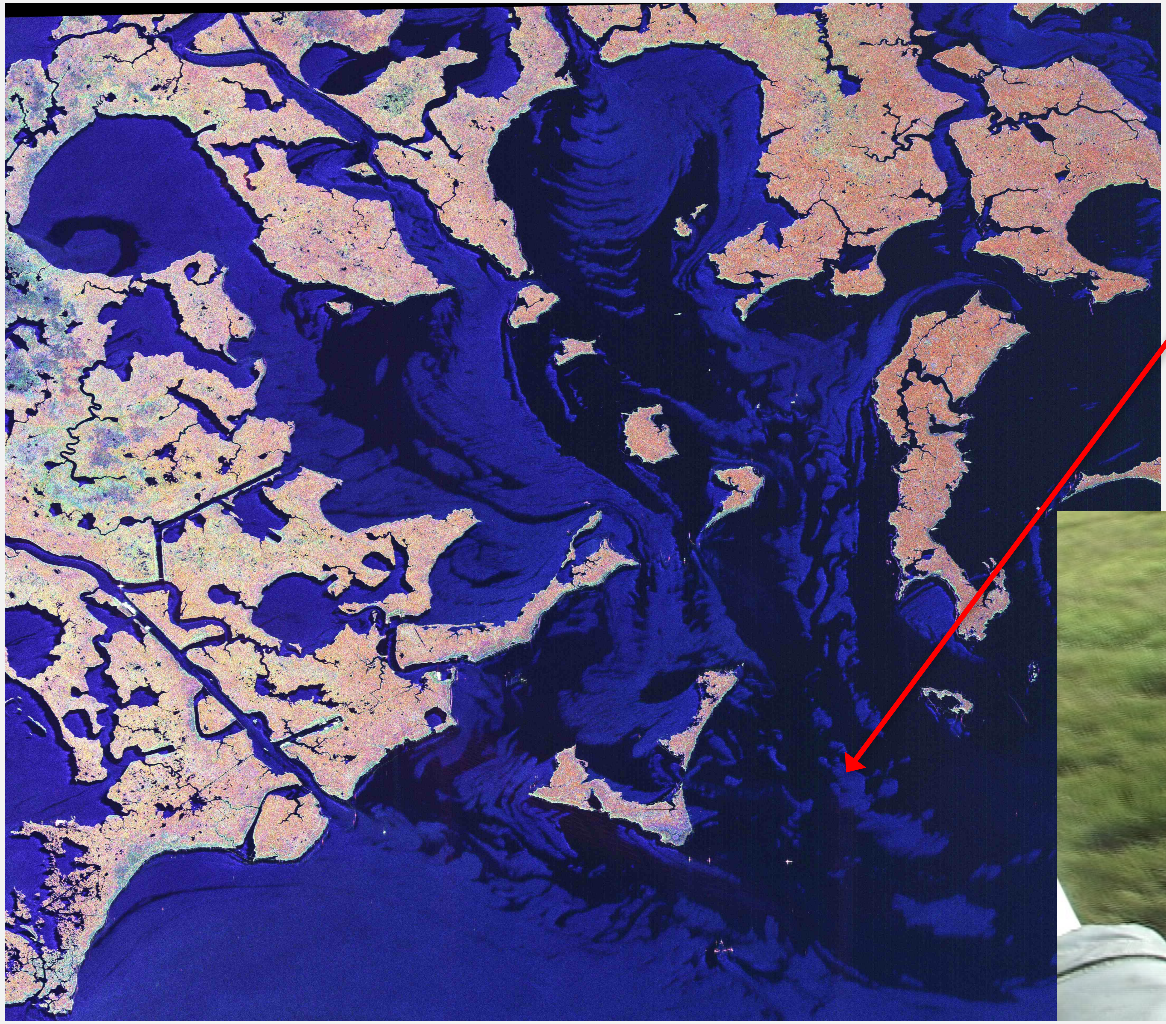
Parameter	Value
Frequency	L-Band 1217.5 - 1297.5 MHz
Bandwidth	80 MHz
Resolution	1.67 m Range, 0.8 m Azimuth
Polarization	Full Quad-Polarization
Azimuth Steering	Greater than ± 20° (± 45° goal)
Transmit Power	> 3.1 kW
Swath Width	> 23 km

A Wildfire Sensor Web with UACSAR Fire Alert

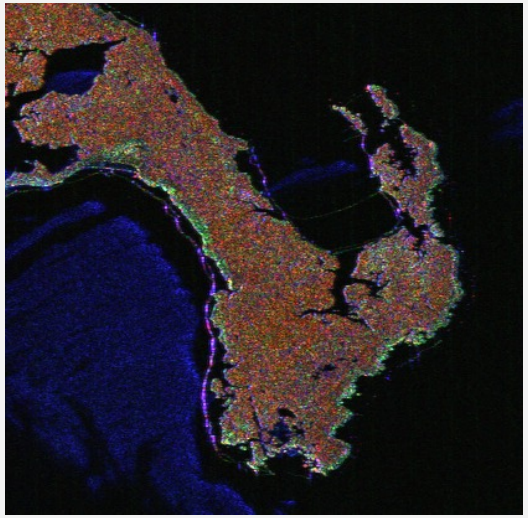


UAVSAR Deepwater Horizon Oil Spill

Oil Intrusion Into Wetlands

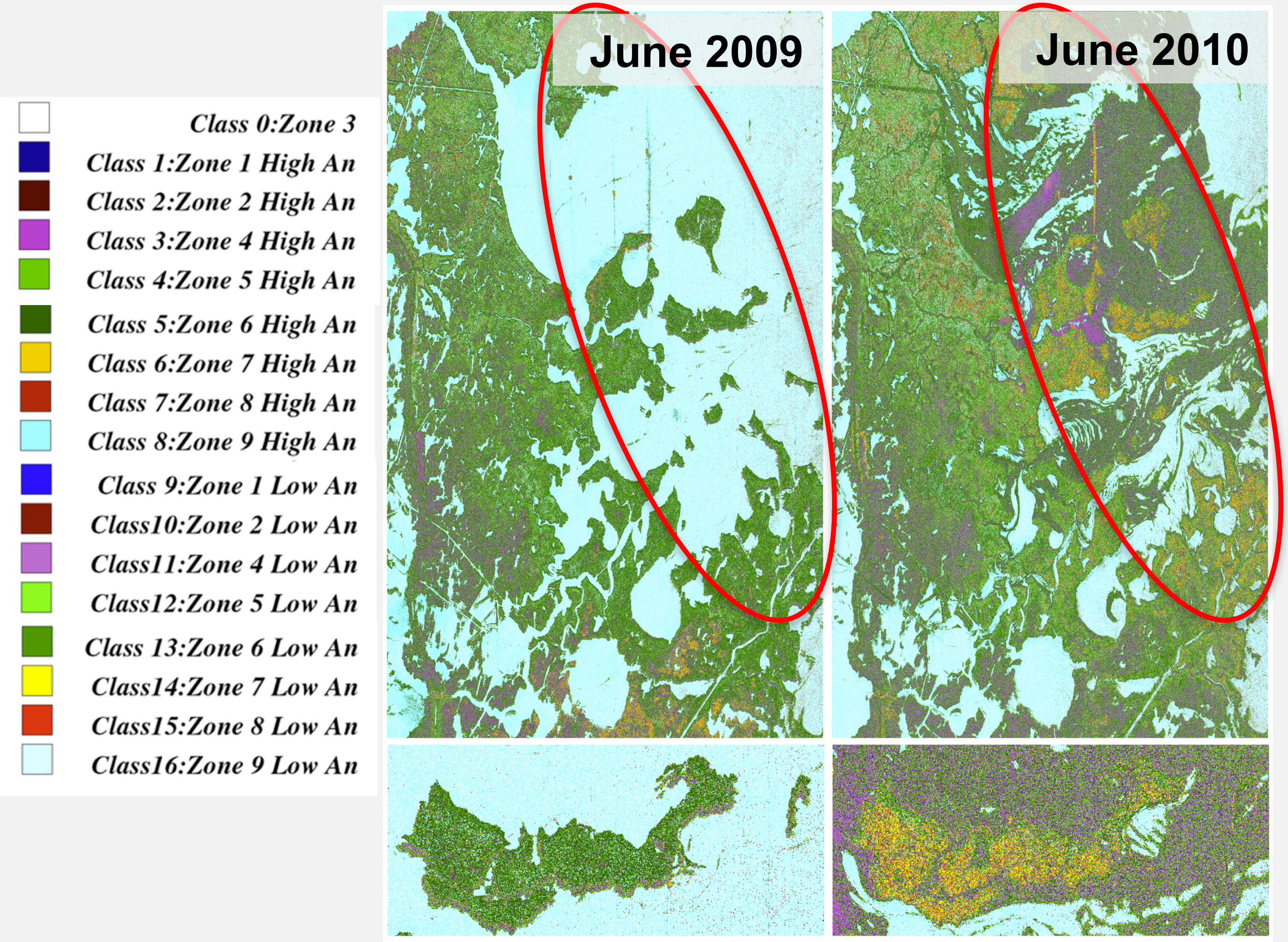


Ground truth from boats and helicopters were used to validate POLSAR-based algorithms for oil detection on vegetation and inland waterways

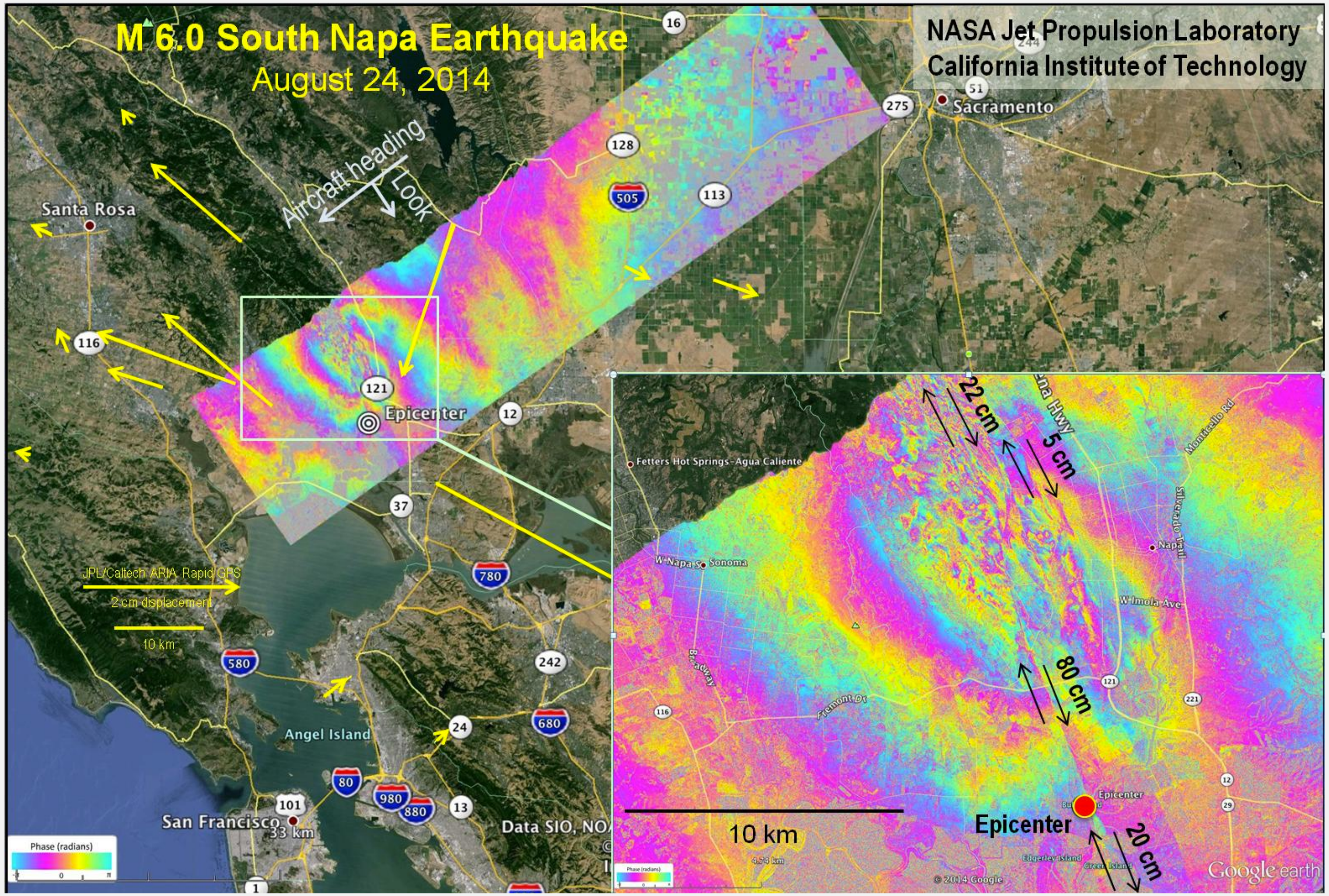


Impact on Wetlands

Cloude-Pottier Decomposition (H,α,A)

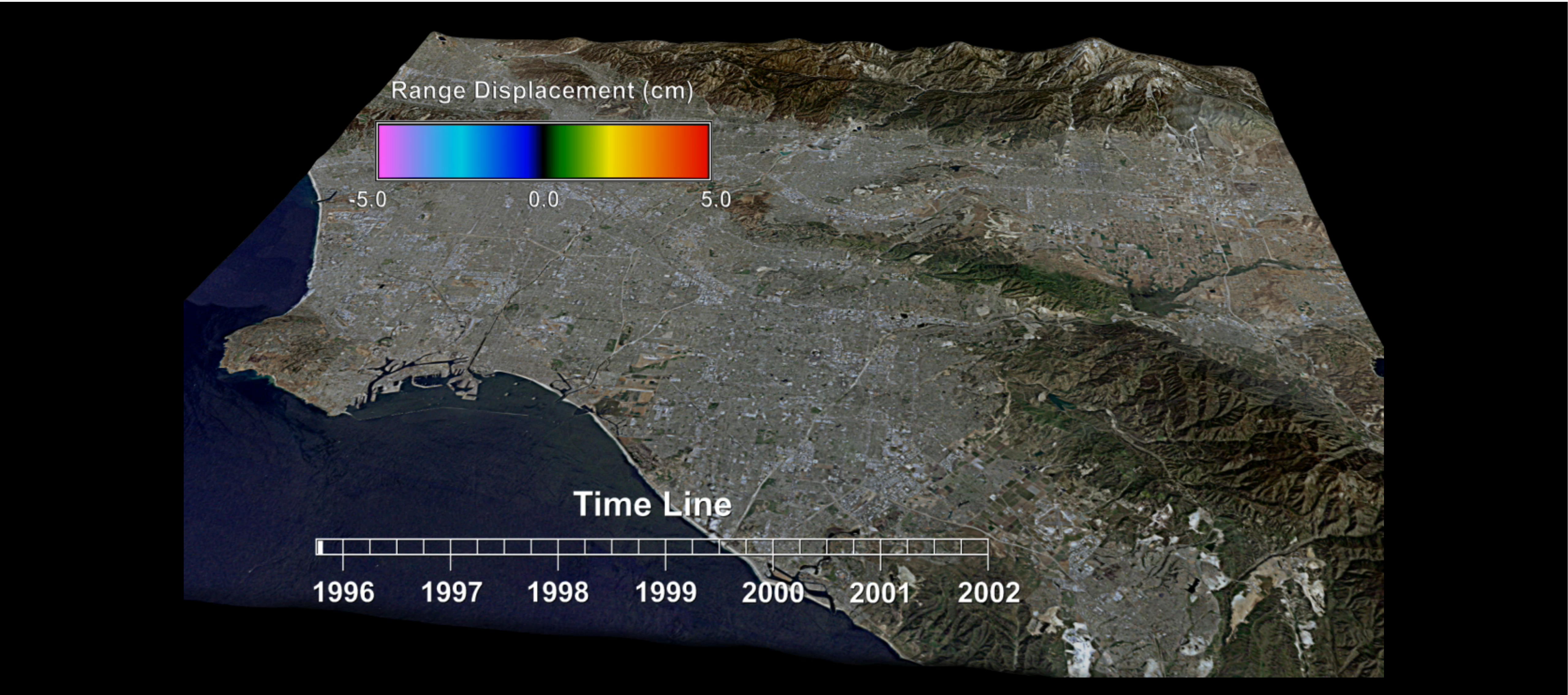


UAVSAR Earthquake Rapid Response

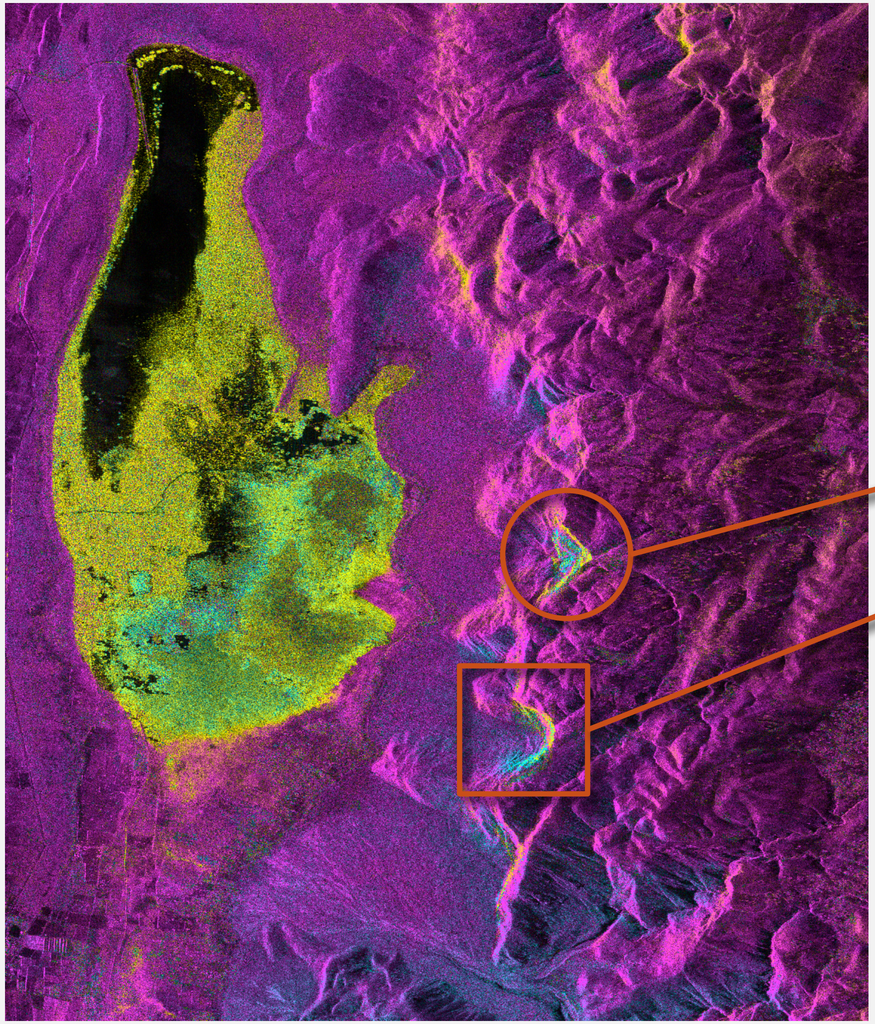


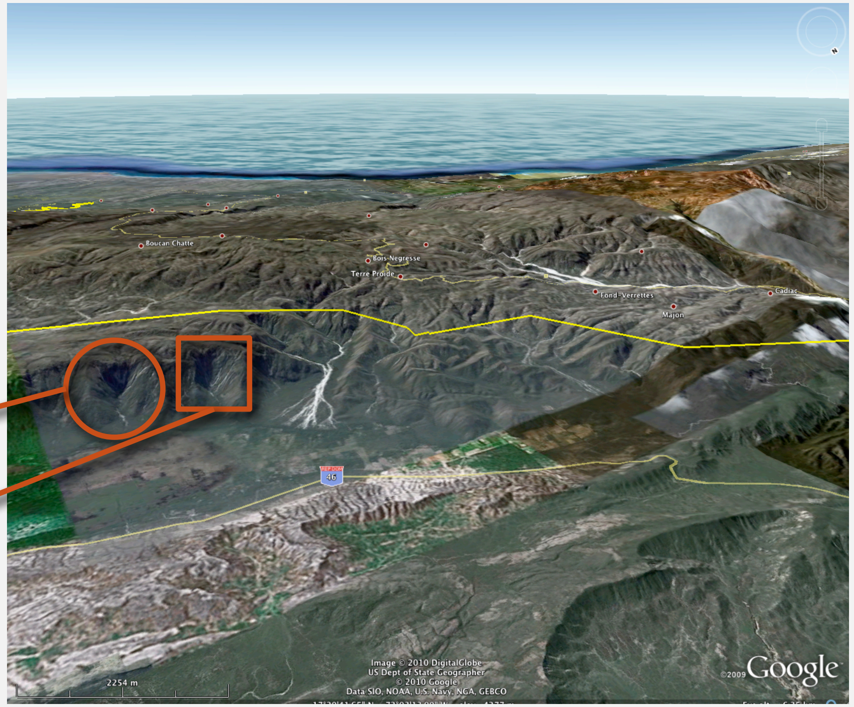
Ground Subsidence

Monitoring the Los Angeles Basin



Identifying Potential Landslides: 16-Day Repeat





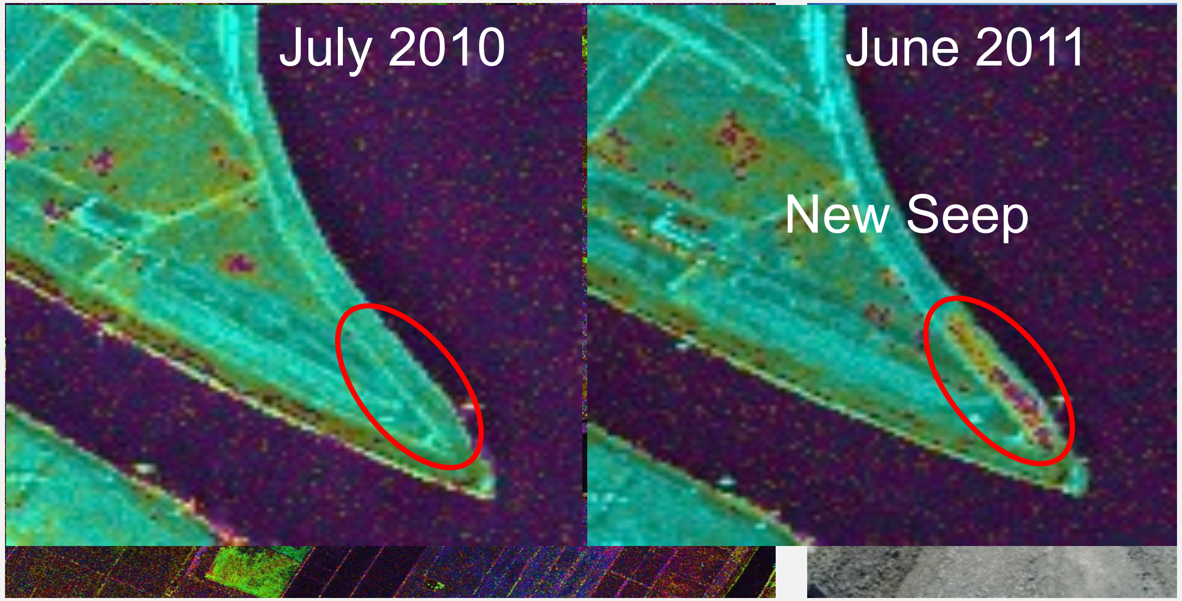
- Potential landslide areas detected by UAVSAR
- Data is approximately 2.5 m in range and 3.6 m in azimuth resolution

Identifying Cracks in Levees

Cracks identified with DInSAR:

1. Post-repair settlement along levees detected and monitored
2. Seeps identified with coherence change detection; detection methodology developed
3. Subsidence rates within the islands can be measured despite temporal decorrelation and show general subsidence on sub-island scale

Levee Crown, Slope, and Toe Movement
Seep Detection



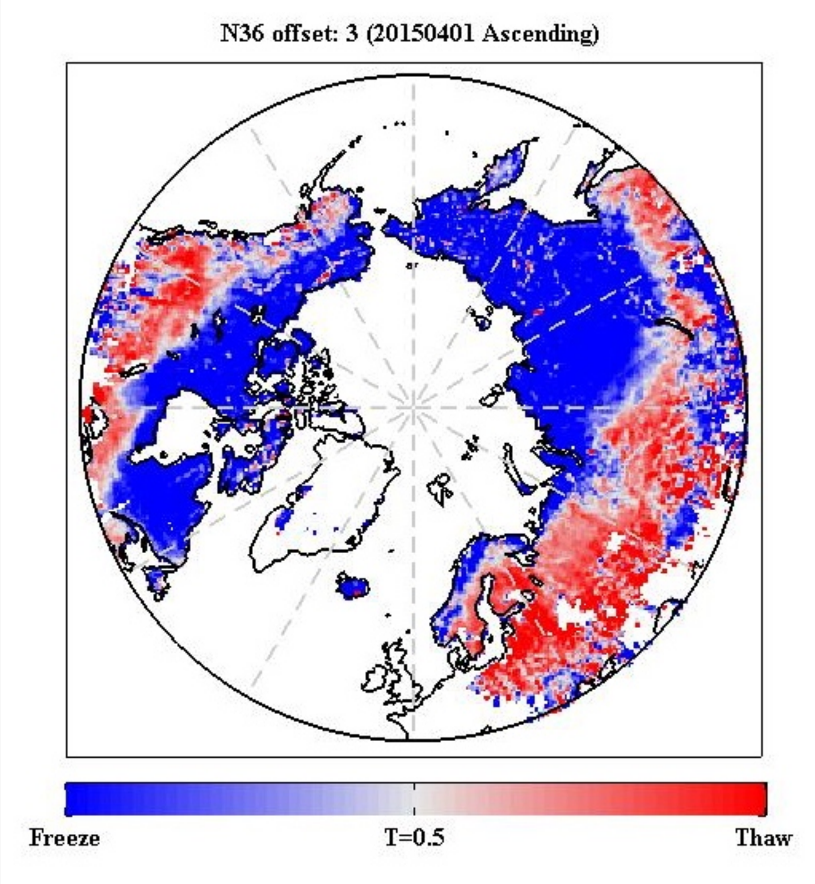
Reference: Cathleen E. Jones, G. Bawden, S. Deverel, J. Dudas, S. Hensley (2012). Study of movement and seepage along levees using DINSAR and the airborne UAVSAR instrument, Proc. SPIE 8536, SAR Image Analysis, Modeling, and Techniques XII, 85360E (November 21, 2012); doi:10.1117/12.976885.

Cryosphere

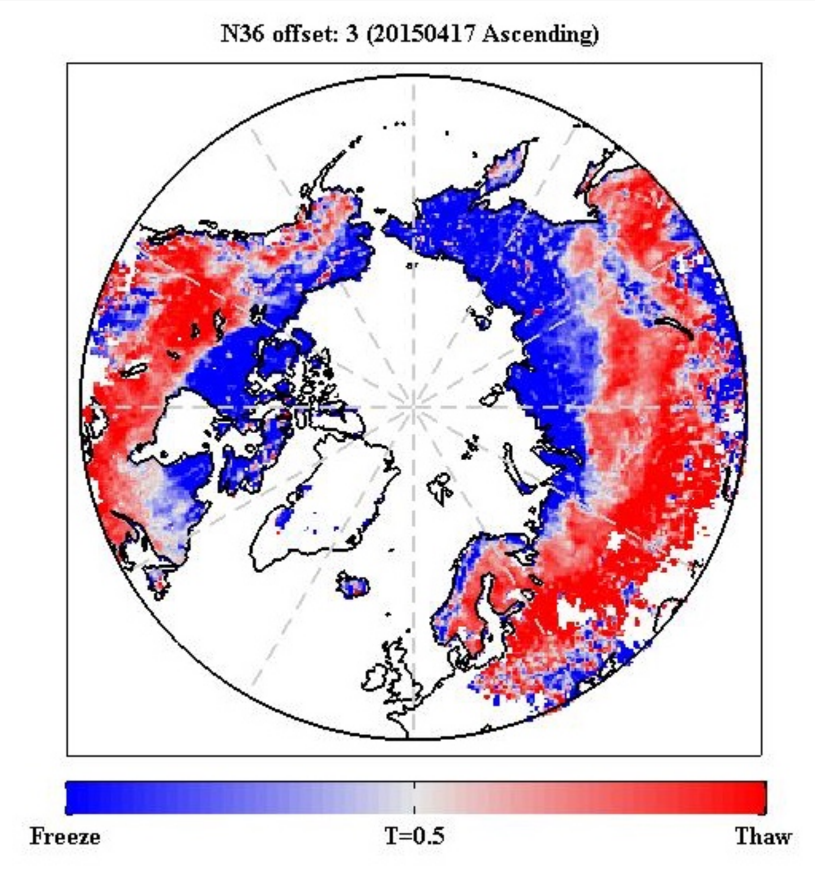
Freeze/Thaw State of the Land Surface: SMAP Radar

- Normalized backscatter ratios, computed using Aquarius references, indicate the freeze to thaw change in the northern hemisphere
- Backscatter references to be replaced with SMAP values

April 1, 2015

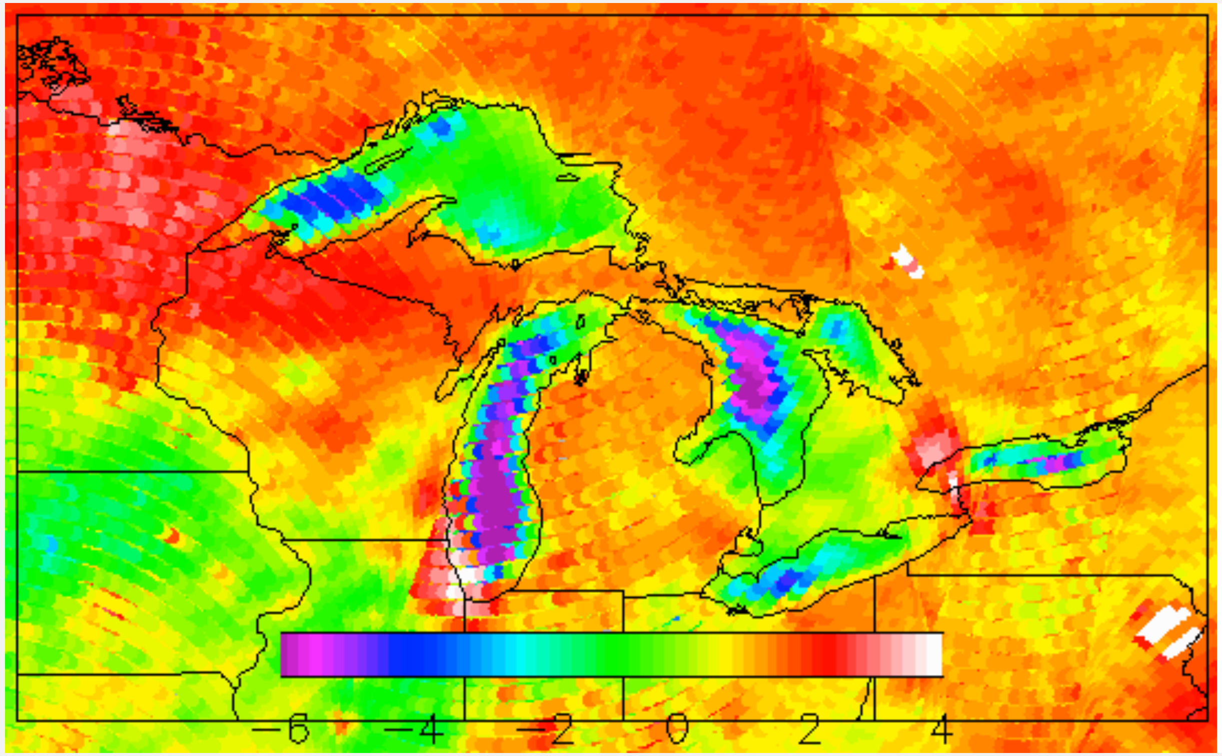


April 17, 2015

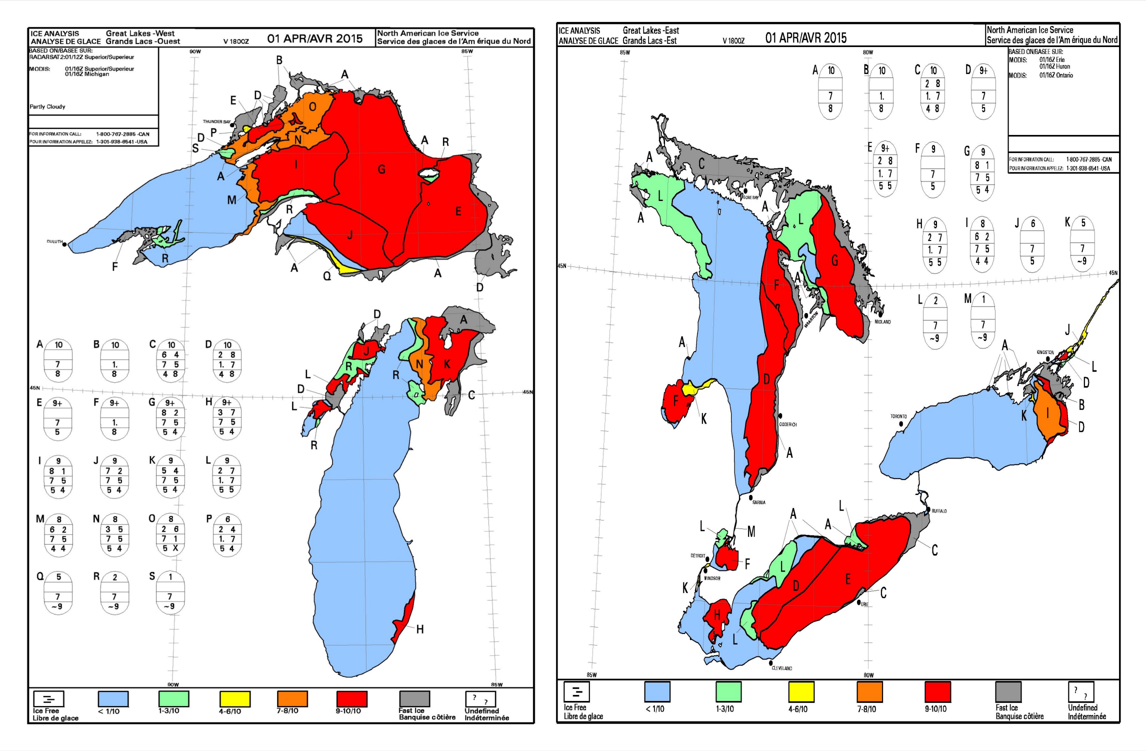


SMAP Radar: Lake Ice Melt from HH/VV Ratio

Indicates Melting of Lake Ice in the Great Lakes



North American Ice Analysis

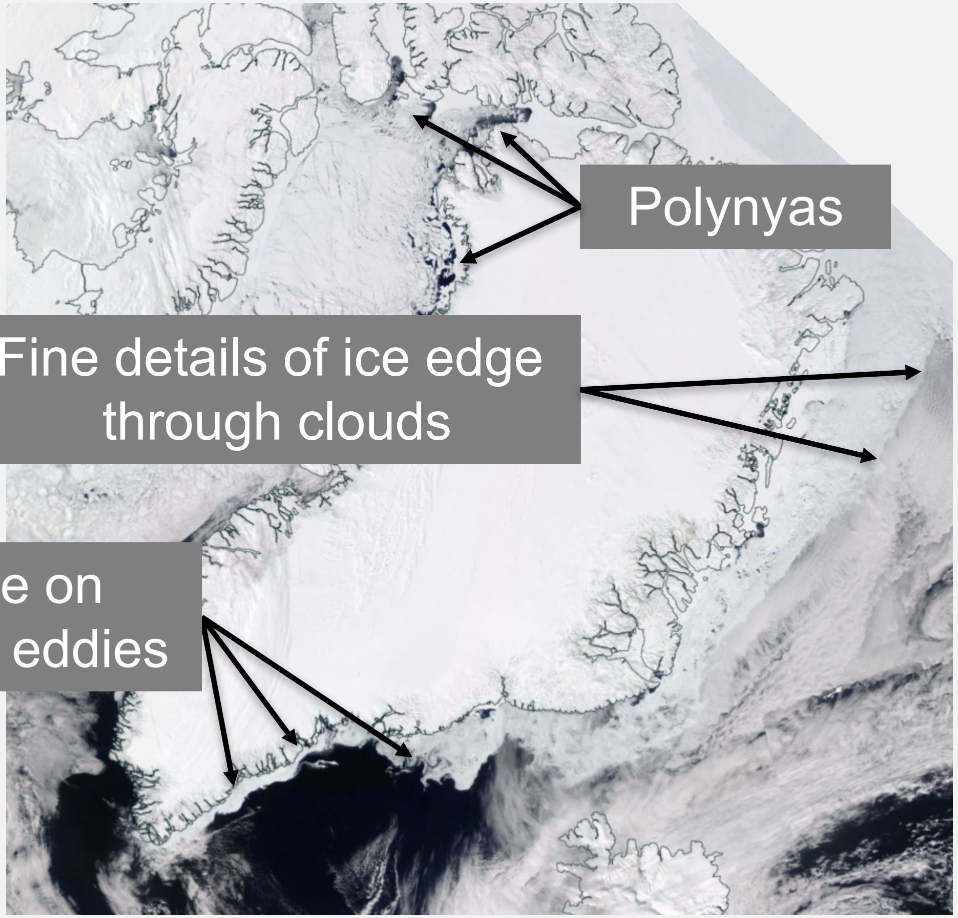


No SMAP requirements to generate lake ice melt products

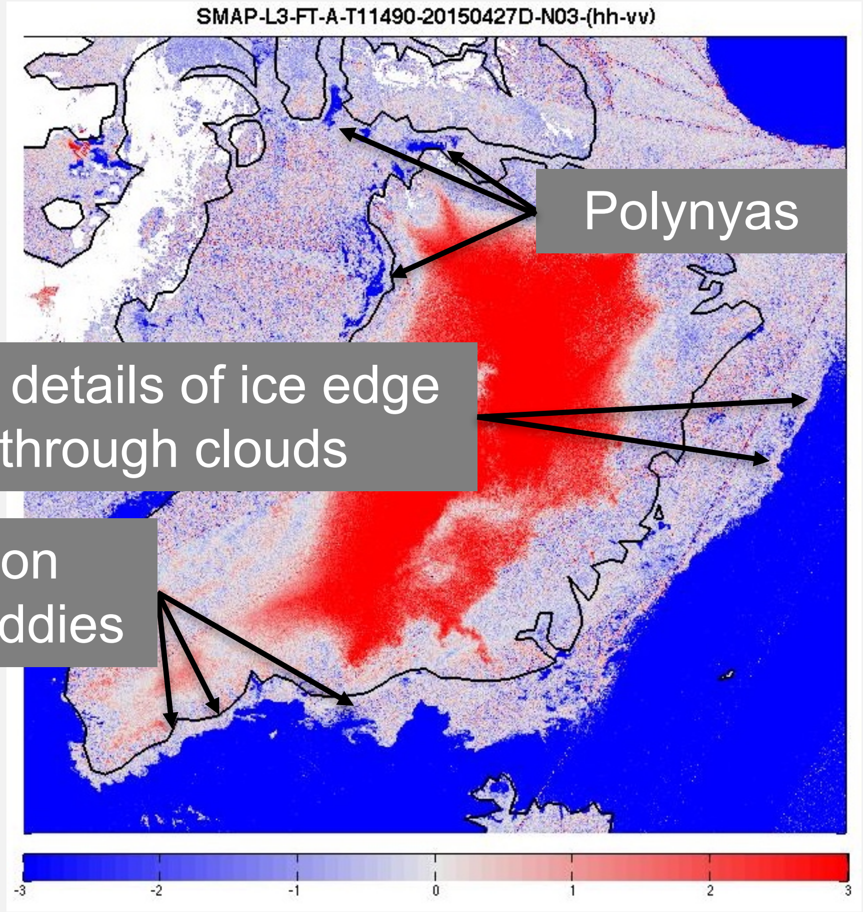
Sea Ice Cover- SMAP Radar

HH/VV Ratio

Aqua (MODIS) Corrected Reflectance (True Color)



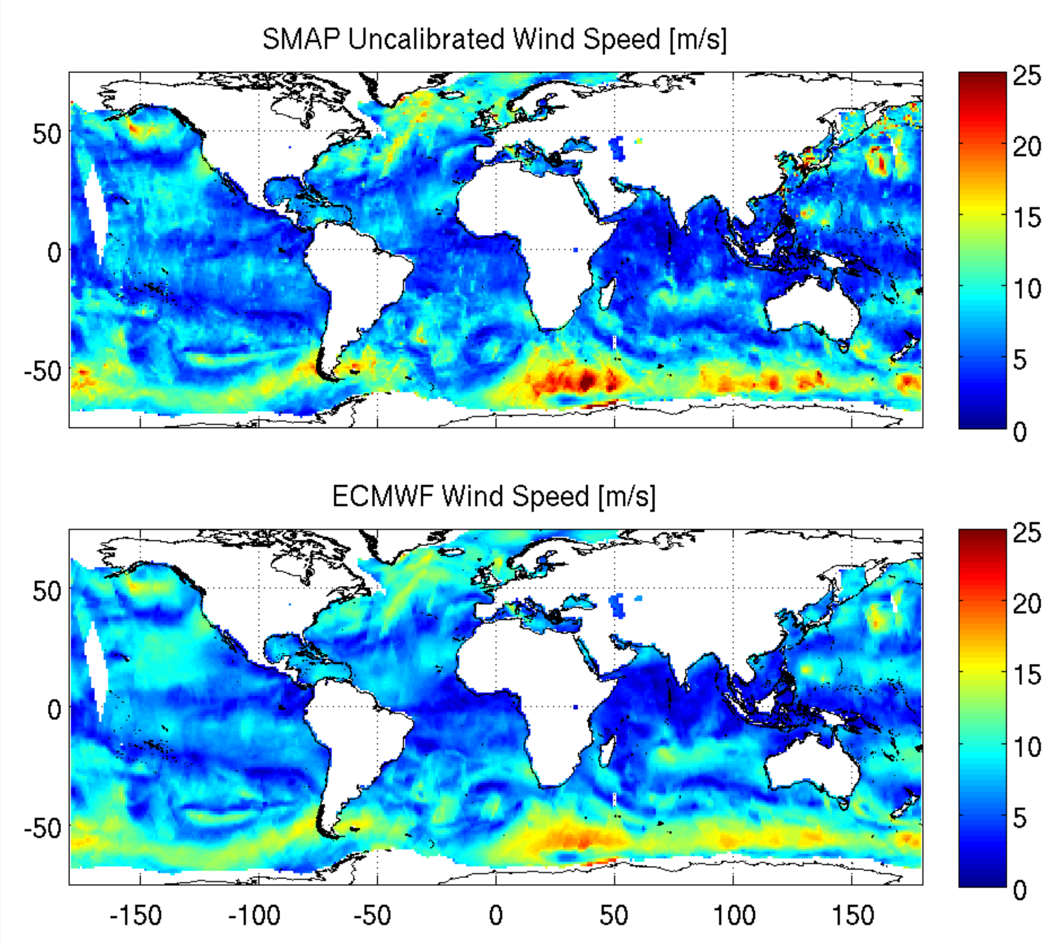
April 27, 2015

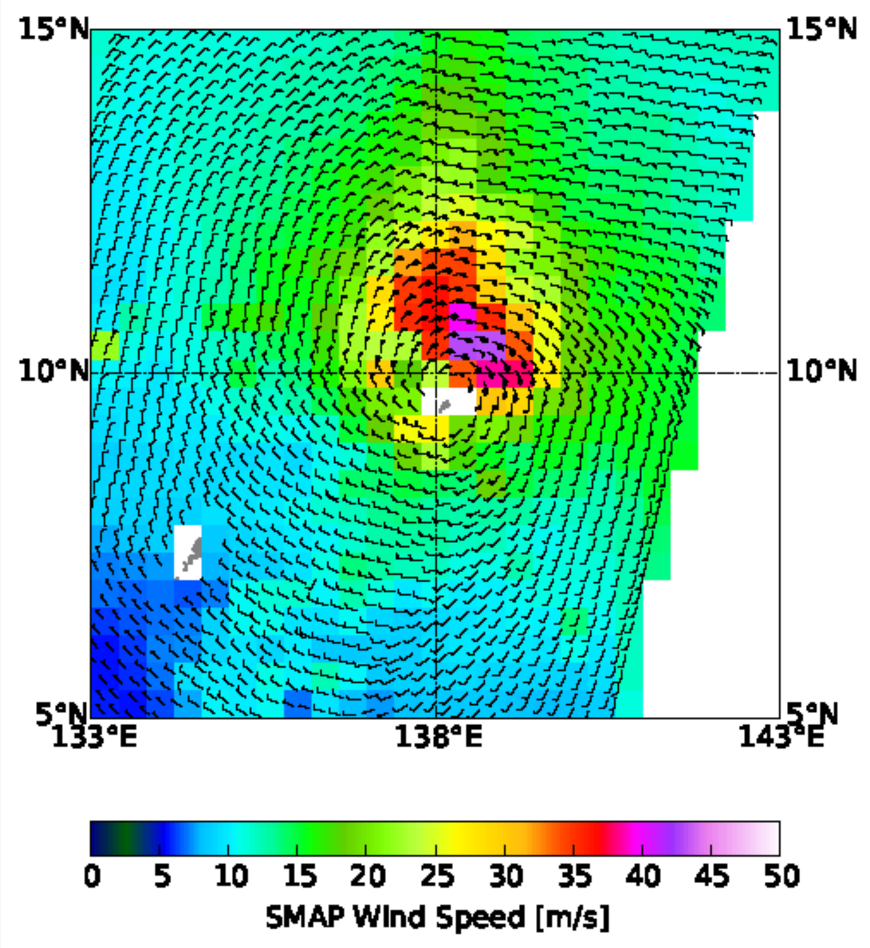


Oceans

Ocean Surface Winds

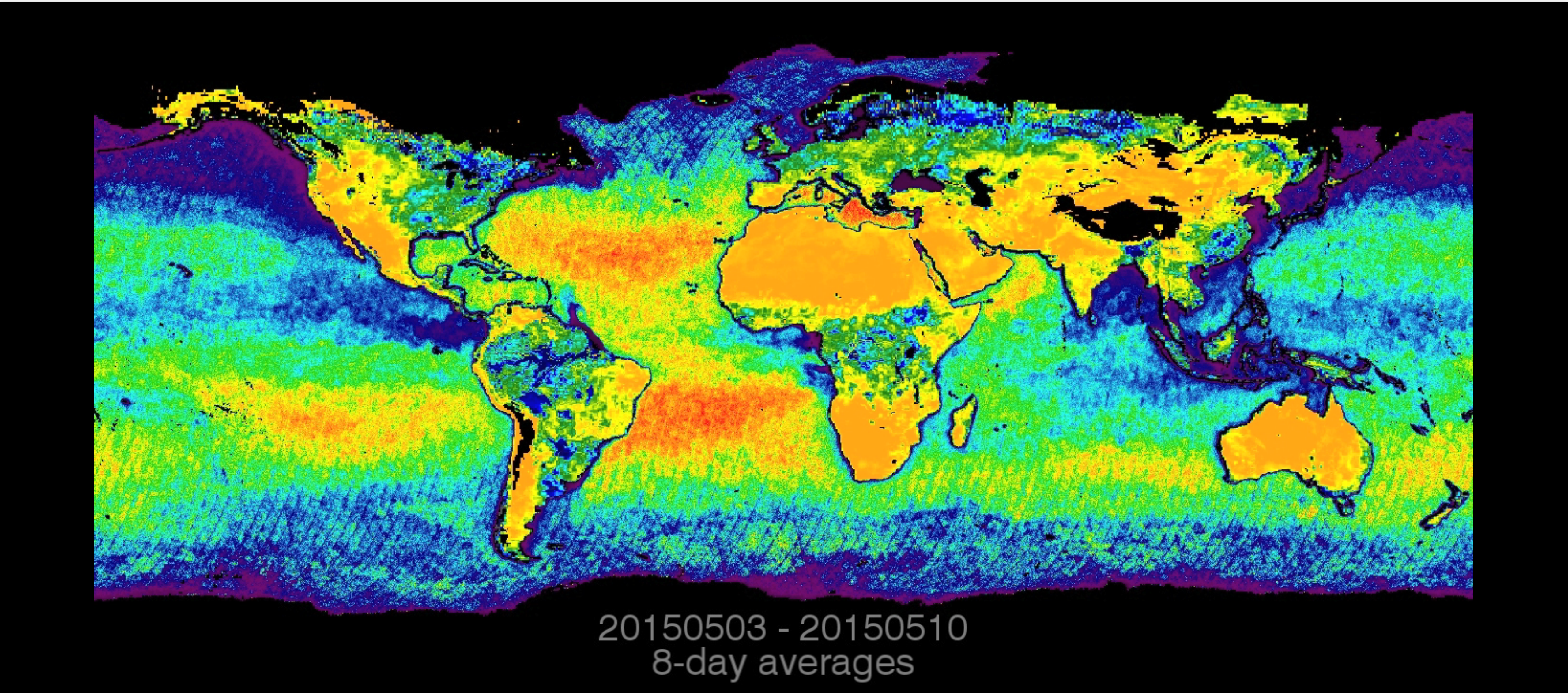
SMAP Radar Wind for Super Typhoon Maysak, March 31, 2015

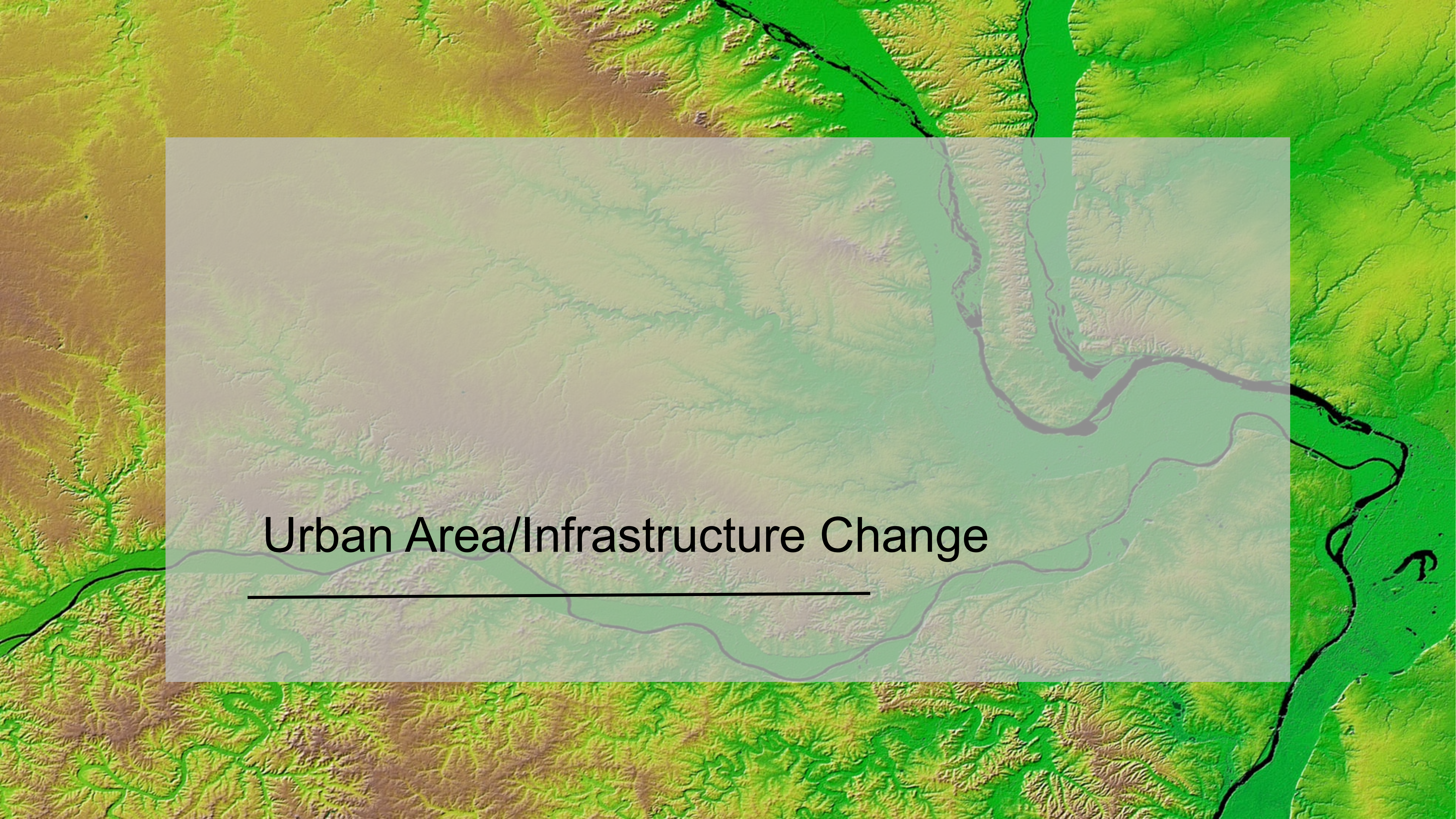




Courtesy of Lindstrom's Oceanography Program

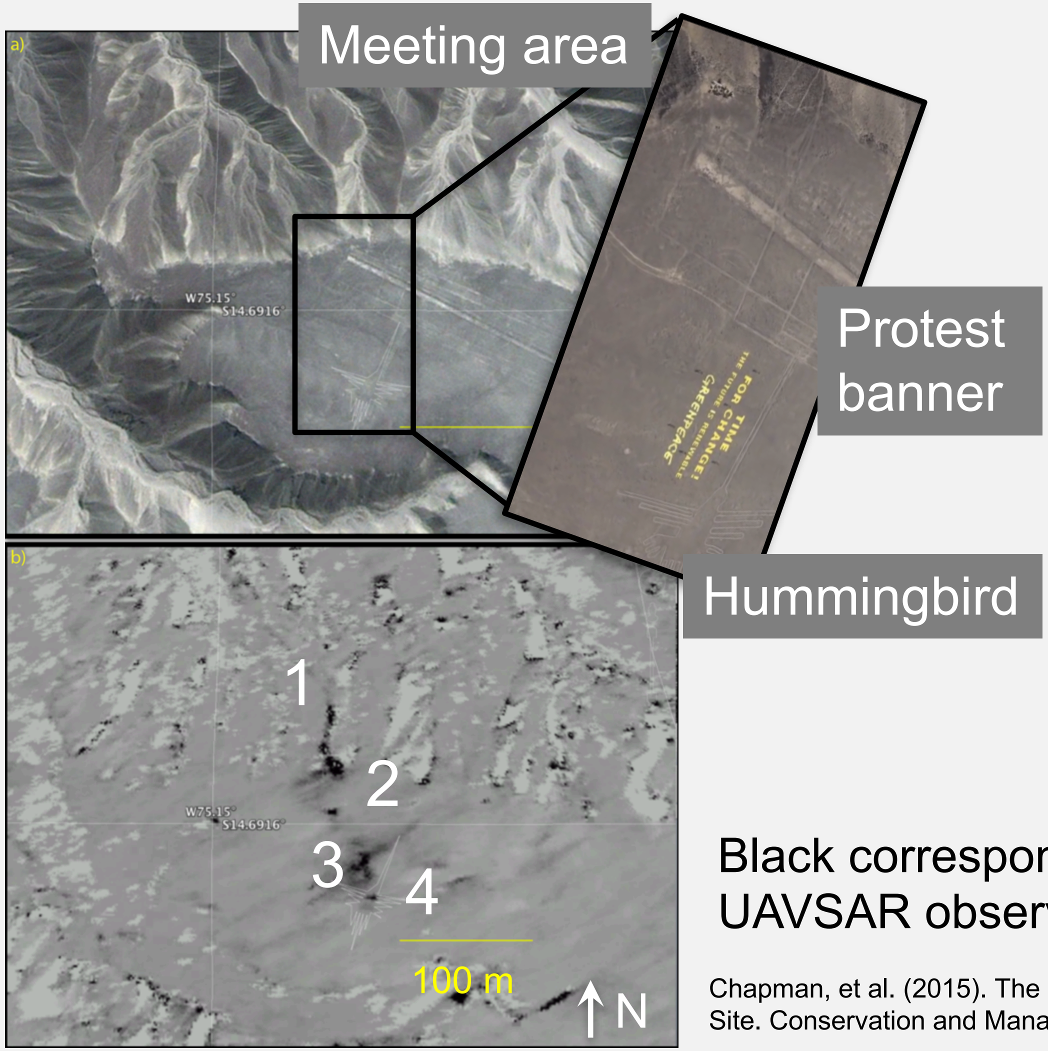
SMAP Radar: Sea Surface Salinity





Urban Area/Infrastructure Change

Nazca Lines: Peru



Five indications of disturbance are observed:

1. Path from the unpaved road to the North
2. An area as one enters the pampa from below, where the protestors congregated and kept equipment
3. The area near the hummingbird geoglyph
4. Decorrelation within the head of the hummingbird itself
5. Ridgeline areas of decorrelation where the slope is large and natural erosion may be occurring

Black corresponds to decorrelation between the two UAVSAR observations (March 2013 – March 2015)

Chapman, et al. (2015). The Measurement by Airborne Synthetic Aperture Radar (SAR) of Disturbance Within the Nasca World Heritage Site. Conservation and Management of Archaeological Sites, 17(3), 270-286. doi:10.1080/13505033.2015.1129801

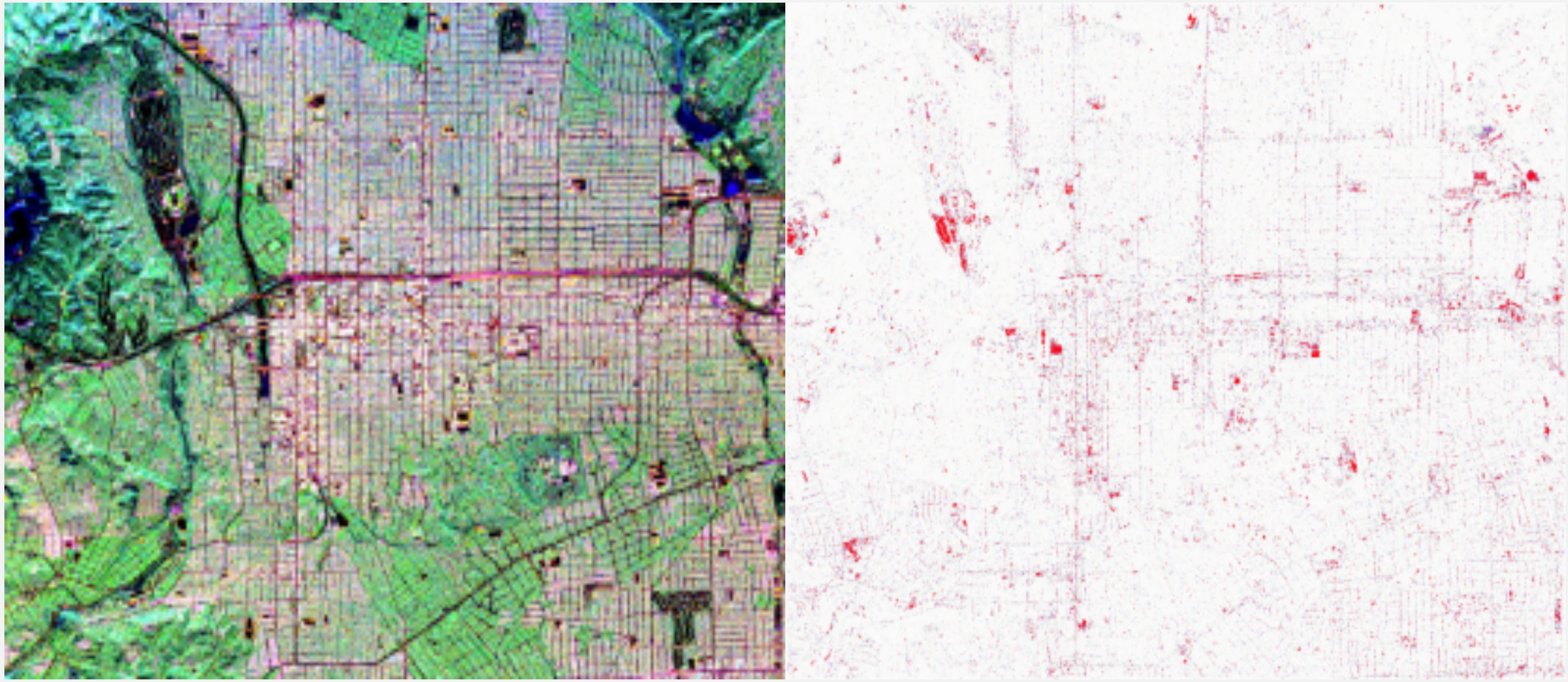
Change Detection in Pasadena, CA

Multi-Temporal and Polarimetric UACSAR Data

(Left) Study site represented by Freeman-Durden decomposition

- red: double bounce
- green: volume scattering
- blue: odd bounce

(Right) Detected changes using a maximum-likelihood ratio (in red)



Kim, D., et al. (2016). Detection of Durable and Permanent Changes in Urban Areas Using Multitemporal Polarimetric UAVSAR Data. IEEE Geoscience and Remote Sensing Letters, 13(2), 267-271. doi:10.1109/lgrs.2015.2509080