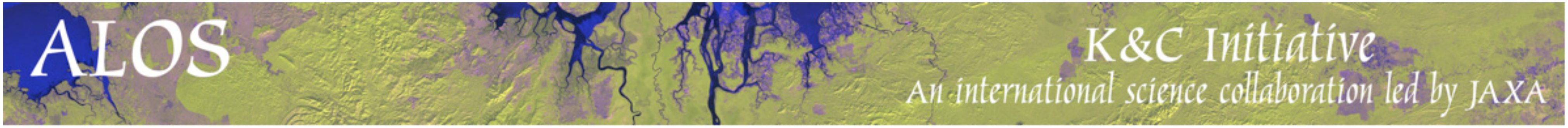


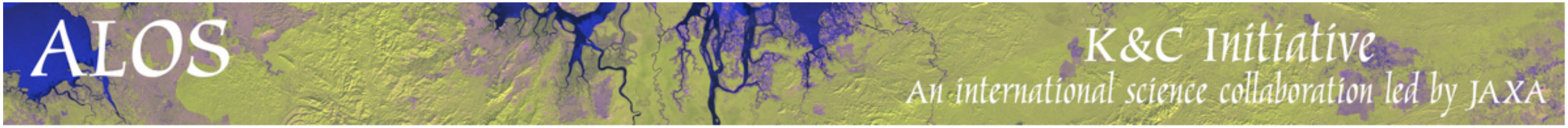
K&C Phase 4 – Status report

Mapping Wetlands, Surface Structural Attributes, and Boreal Freeze/Thaw at Regional Scales with JAXA SAR Datasets

Kyle C. McDonald

Department of Earth and Atmospheric Sciences
City College of New York
City University of New York
New York, NY, USA

Science Team meeting #23
January 18-21, 2017



Mapping Wetlands, Surface Structural Attributes, and Boreal Freeze/Thaw at Regional Scales with JAXA SAR Datasets

Collaborators:

Ana Carnaval, Maria Tzortziou (CCNY)
Laura Chavez (Michigan Tech)
Joel Cracraft (American Museum of Natural History)
Bruce Chapman, Erika Podest (NASA JPL)
Mahta Moghaddam (USC)
Lisa Rebelo (IWMI), Thiago Silva (UNESP)

CCNY Contributors:

Nicholas Steiner, Kat Jensen, Brian Lamb, Aaron Davit, Jessica Rosenqvist, Rehnuma Islam

Science Team meeting #23
January 18-21, 2017

Project Objectives

Wetlands

Extension of on-going wetlands work

- 30-year record: JERS, PALSAR, PALSAR2

Alaska, Canada

South America

Africa

New Wetlands Regions

Chesapeake Bay – Estuarine carbon, Land-ocean exchange

New England – Land-ocean carbon exchange

River Deltas – Carbon & Conservation (Mekong, Indus)

Boreal peatlands - Canada

Project Objectives

<u>Biodiversity and Structure</u>

Amazon and Brazilian Atlantic Coastal Forest

– Biodiversity

– Biome classification, landcover structure

<u>Freeze/Thaw</u>

Alaska, Canada, Northern Europe

– Thermokarst studies

– Permafrost carbon cycle

High Mountain Asia

- Climate change links to economies (hydropower, fisheries)

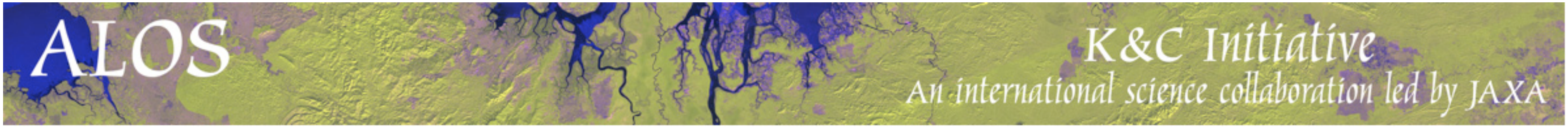
Objective: Development of a data set to facilitate global and regional studies of the role of inundated wetlands in studies of climate biogeochemistry, hydrology, and biodiversity.

I. Regional inundated wetlands data sets from Synthetic Aperture Radar (SAR)
- Spatial coverage: Major global wetland regions, 100m resolution
- Temporal coverage: 1-2 year time series at 17-to-46 day intervals during 2006-2009 † ‡
- Retrospective 1990's-era from archived JERS data covering Alaska, Canada, Amazon
1. Wetland extent (maximum inundatable area, including water bodies).
2. Wetland vegetation type (Non-vegetated, Herbaceous, Shrub, Woodland, Forest).
3. Inundation state (Flooded, Non-flooded; 17-46 day intervals) ‡
4. Annual inundation duration

II. Global monthly inundation data sets derived from multiple satellite data sources
- Spatial coverage: Global, 25 km resolution
- Temporal coverage: Monthly monitoring with annual summaries, 1992-2013 †
1. Globally gridded monthly inundated area fraction
2. Globally gridded annual inundation duration

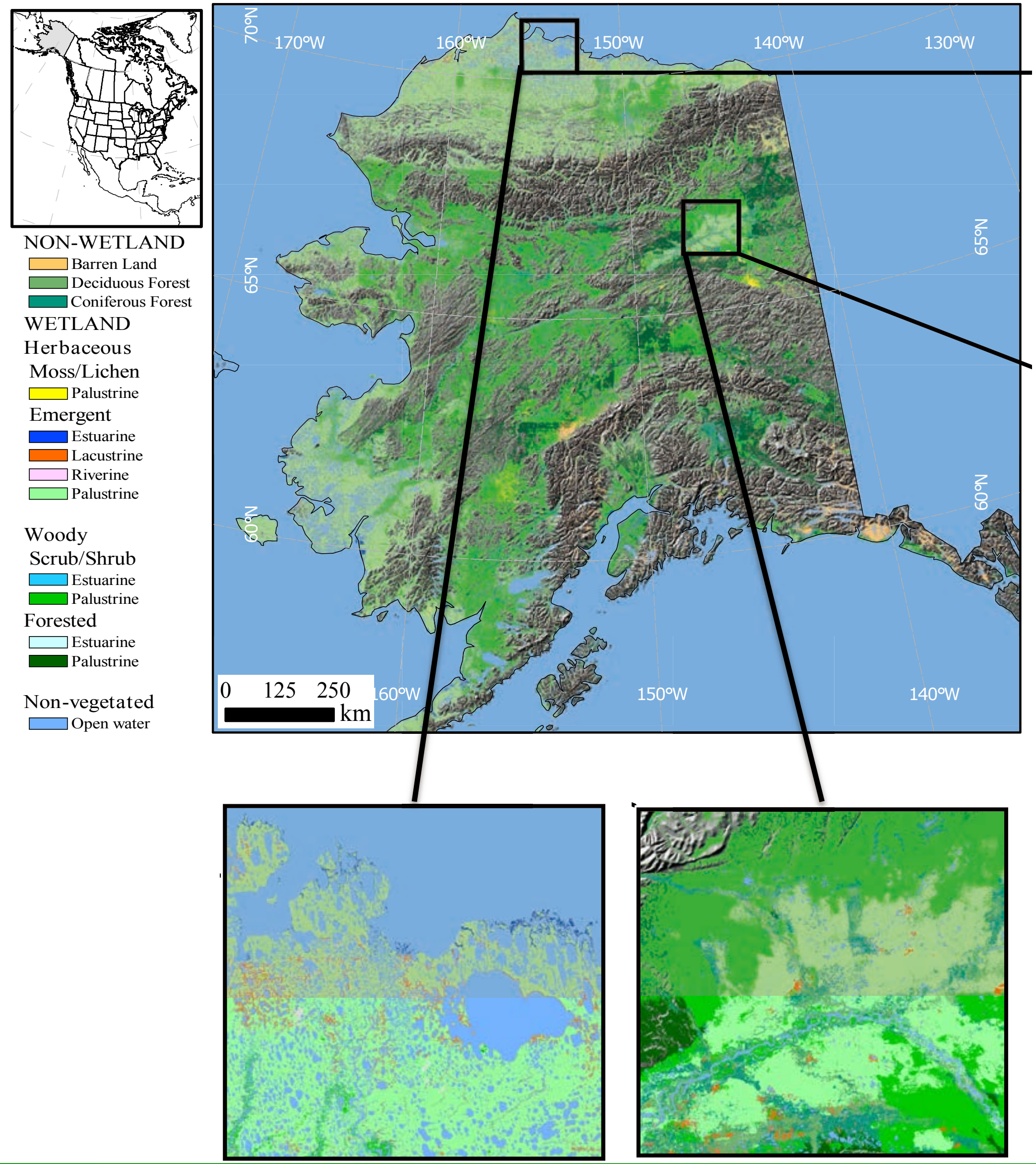
† The domain of the 25-km and 100-m data sets excludes permanently frozen regions and seasonally frozen landscapes during the frozen season, although data from frozen seasons is used to improve classification accuracy.

‡ PALSAR ScanSAR mode has 46-day exact repeat orbit with 17-day sub-cycles.

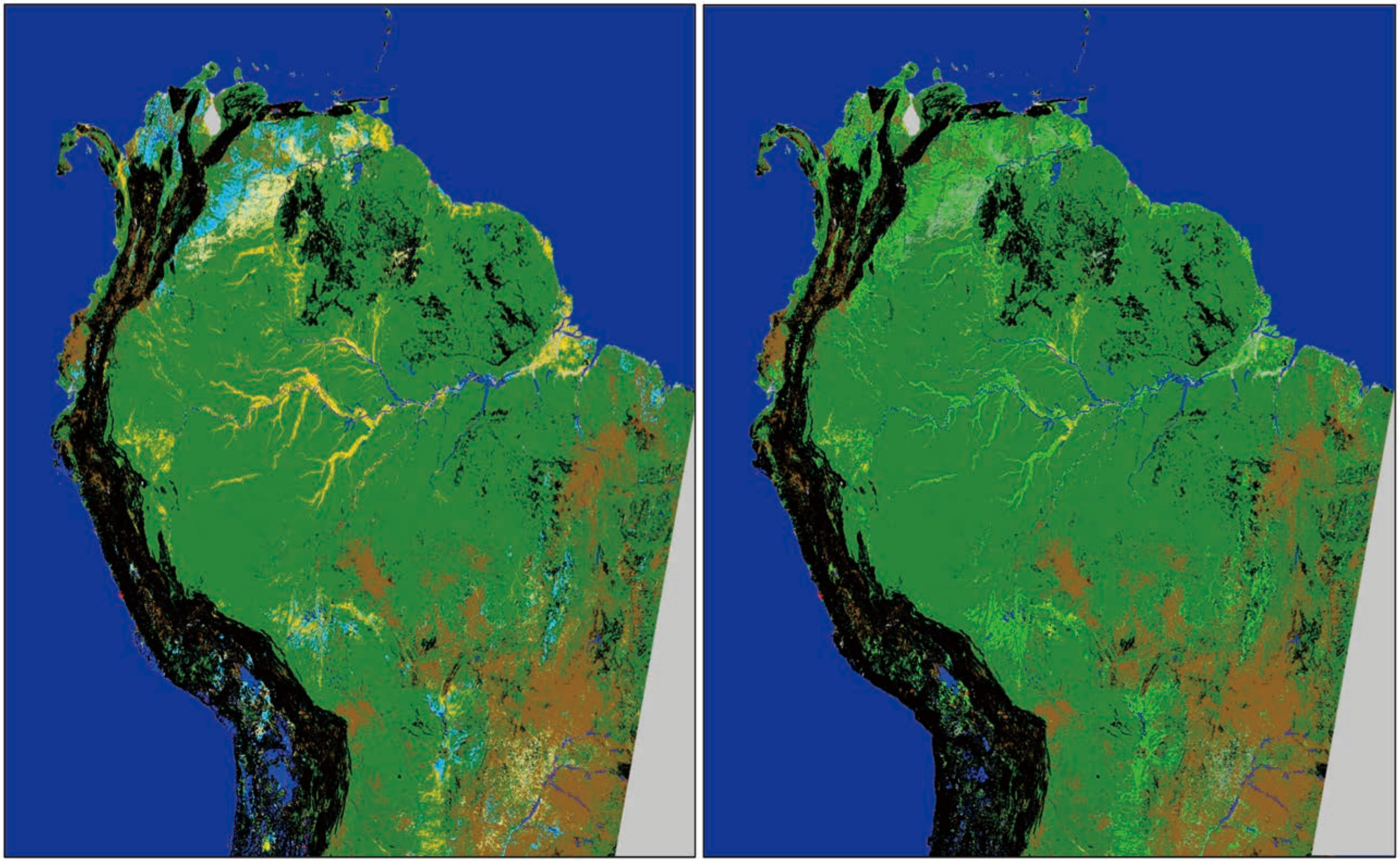


An updated map of wetlands in Alaska from PALSAR data

- 50 m spatial resolution map, using dual-polarization 2007 data
- Trained using National Wetland Inventory (NWI) data.
- Accuracy of geomorphology-vegetation classes 84 %
- Accuracy of wetland / non-wetland discrimination 94 %
- 0.59 million km^2 of wetlands mapped



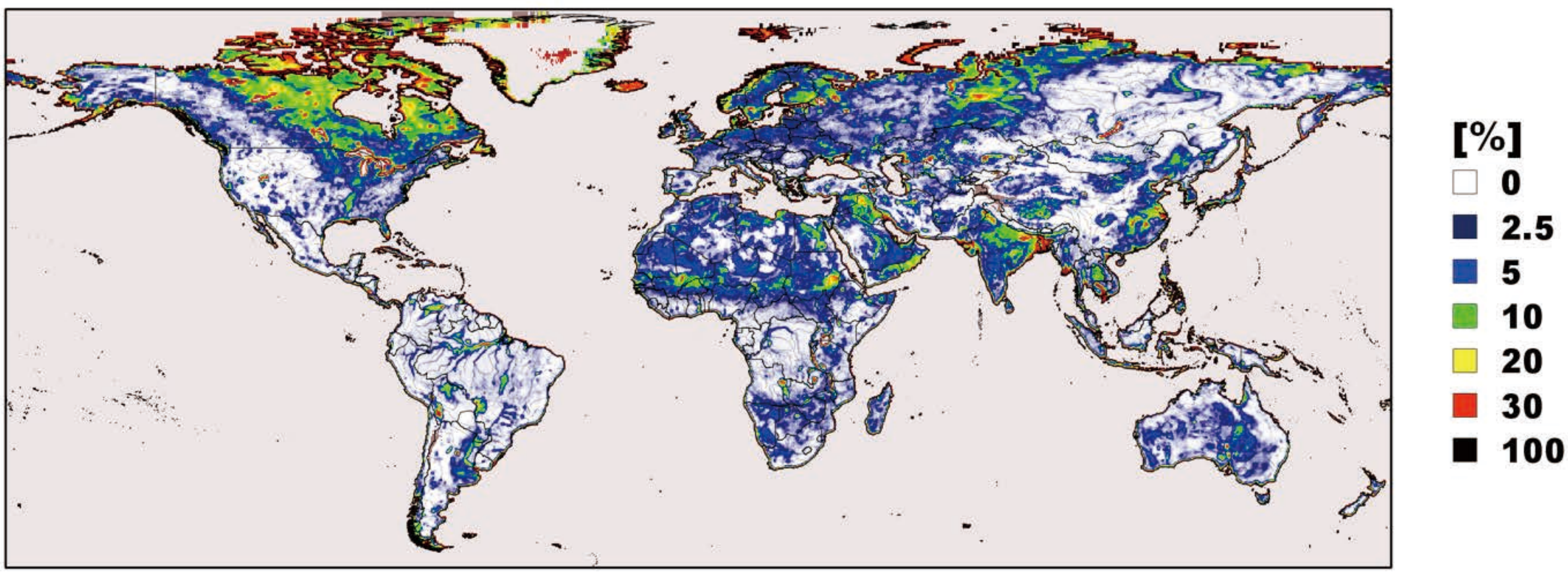
Seasonal Maximum/Minimum Inundation from ALOS ScanSAR



Chapman et al, 2015

Surface Water Microwave Product Series (SWAMPS)

20+ Years of Daily Global Mappings of Inundation Extent at ~25 km Resolution for the Period 1992-2016



Schroeder et al 2015

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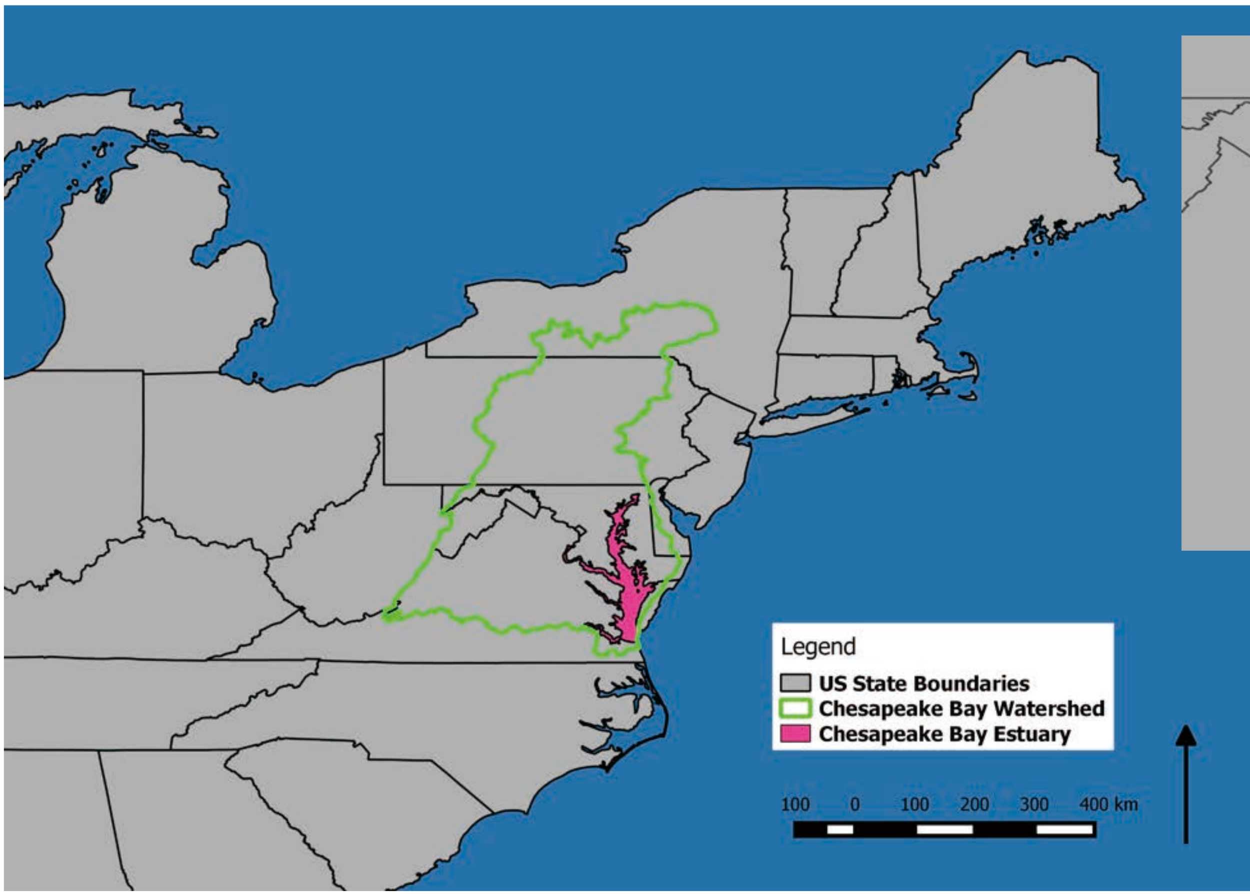
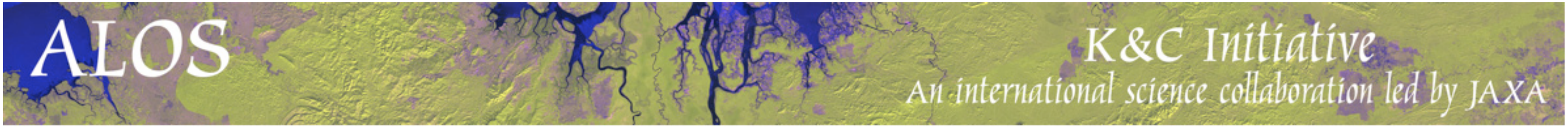
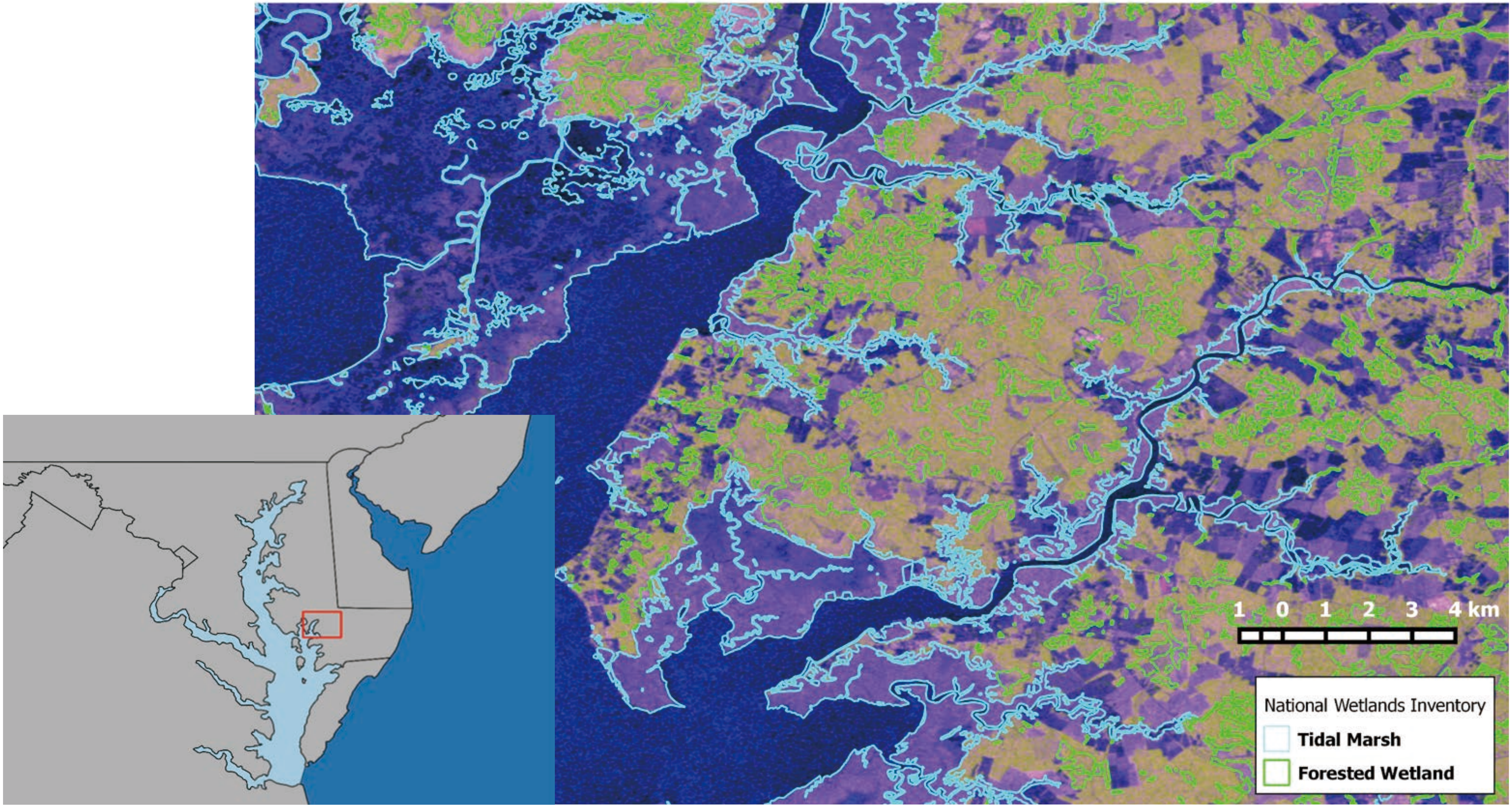
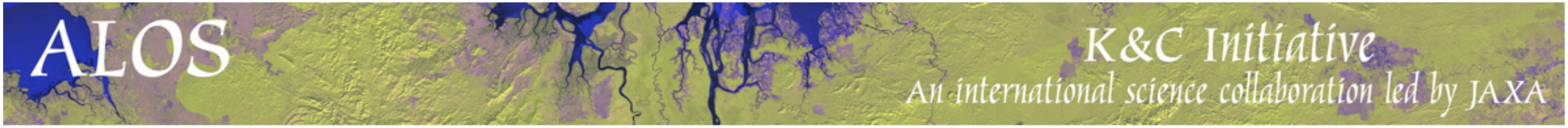
Carbon exchange in tidal estuary systems: Chesapeake Bay



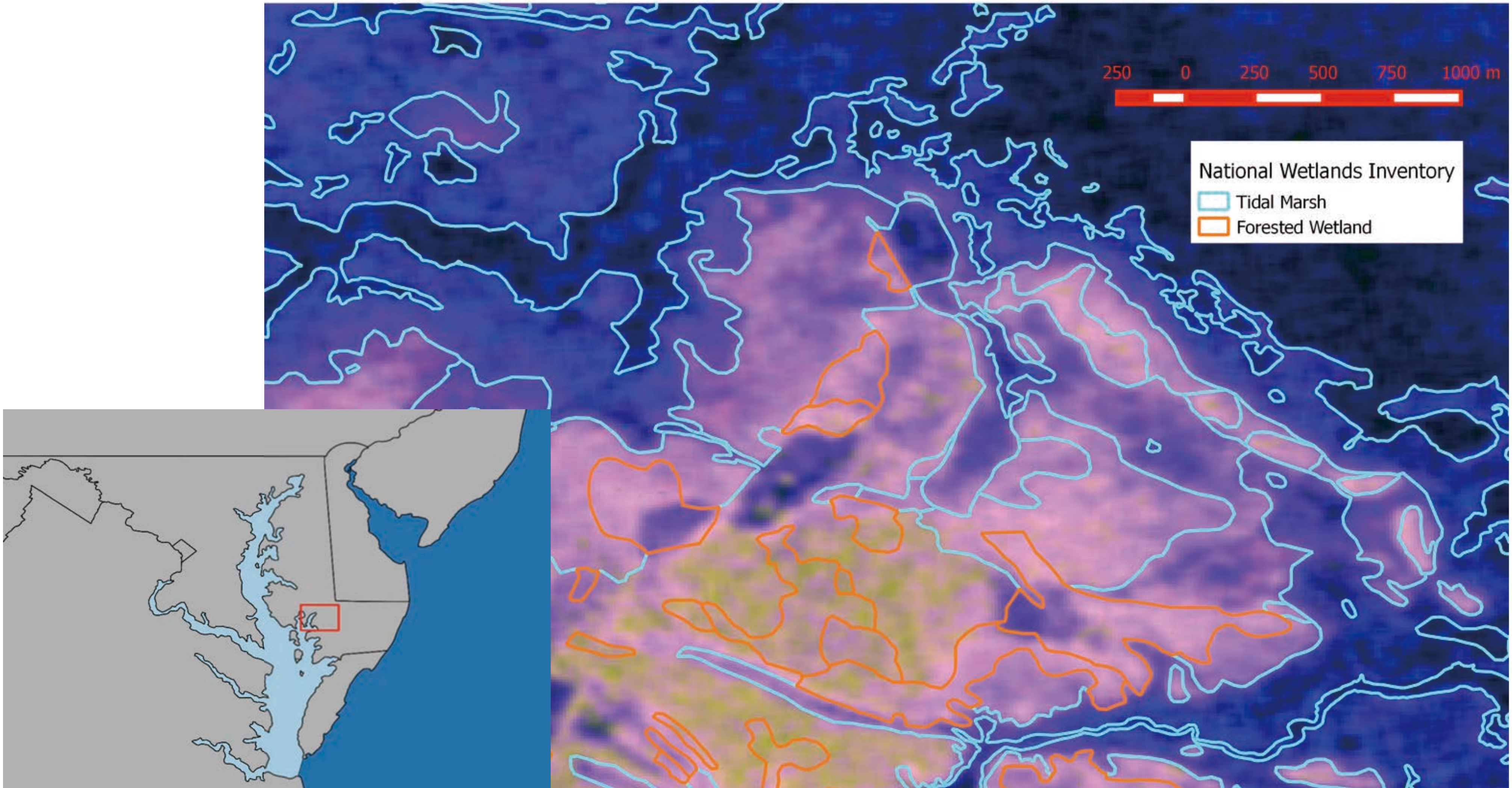


PALSAR-1 False Color RGB (HH, HV, HH-HV). July 2009. Maryland, Eastern Shore



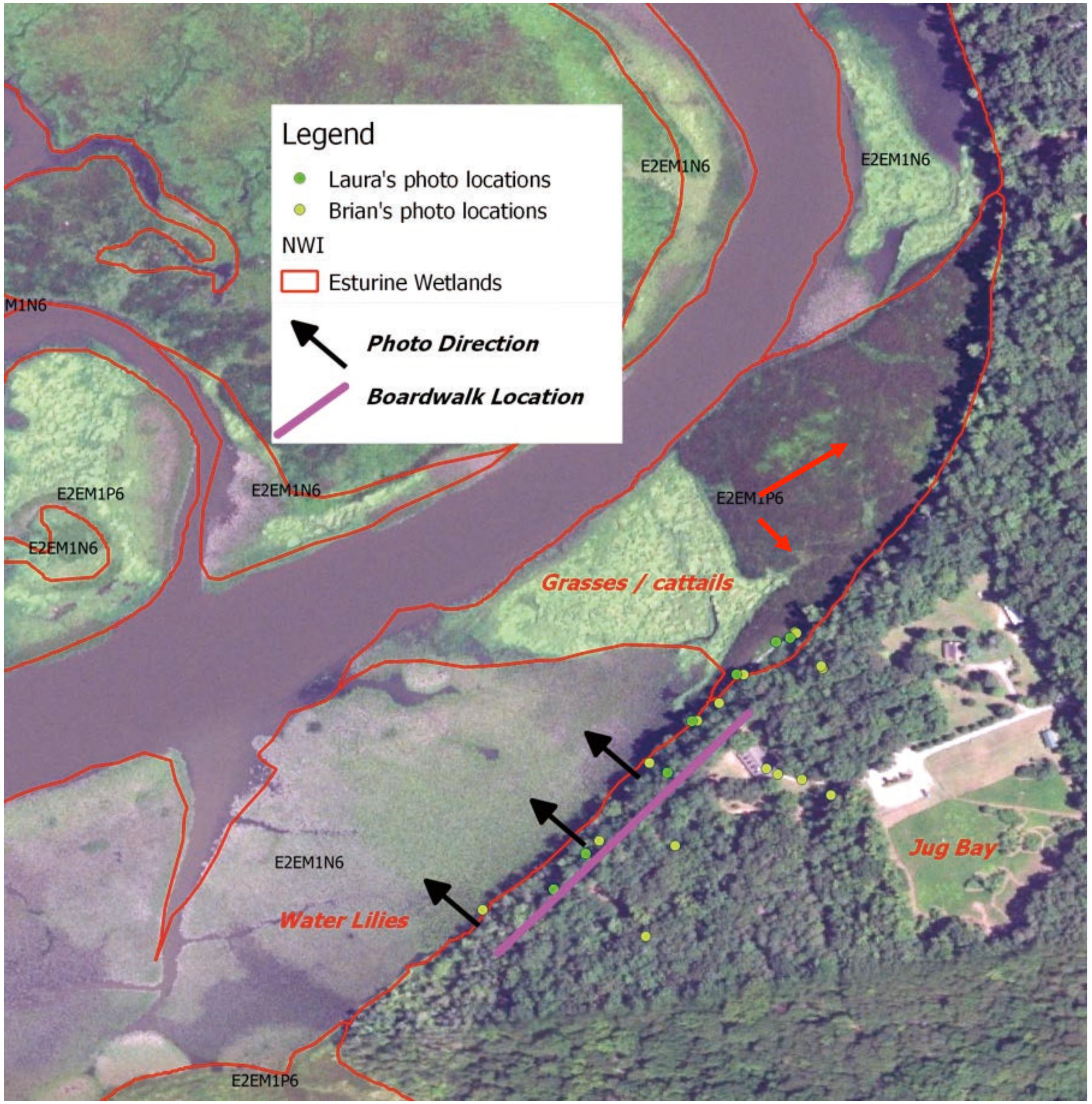


PALSAR-1 False Color RGB (HH, HV, HH-HV): Blackwater National Wildlife Refuge



Jug Bay Vegetation Mapping updates

- Compared photos taken July 2016 to photos taken Jan. 2017
- Water lilies and cattails have substantial differences in phenologies
- This appears in radar signatures



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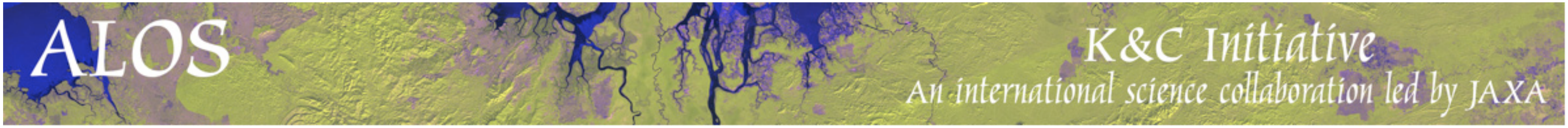
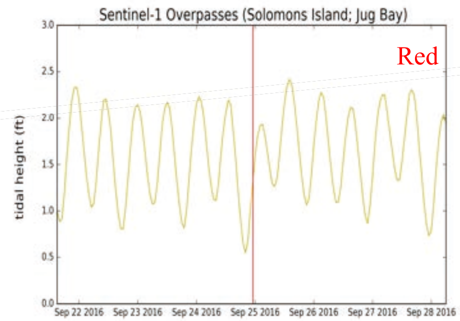
Jug Bay: January 2017 (left) vs. July 2016 (right): Non-permanent vegetation (Water Lilies) Yellow circle is reference point (bird nesting platform)

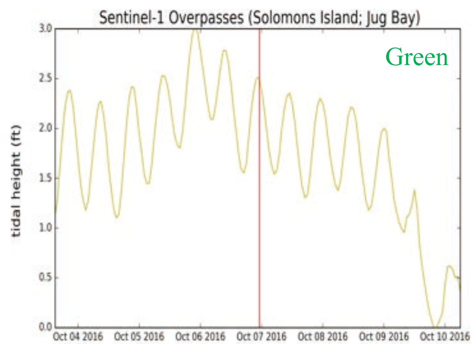
Jug Bay: January 2017 (left) vs. July 2016 (right):
Non-permanent vegetation (Water Lilies)
Yellow circle is reference point (bird nesting platform)

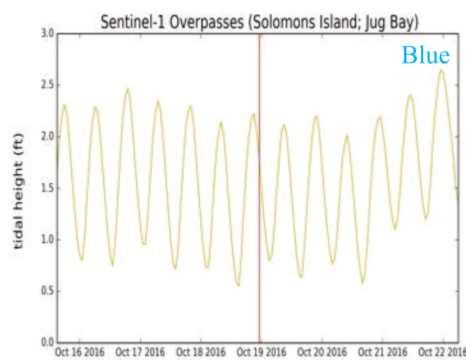
Jug Bay: January 2017 (left) vs. July 2016 (right): Permanent vegetation in foreground (Cattails)

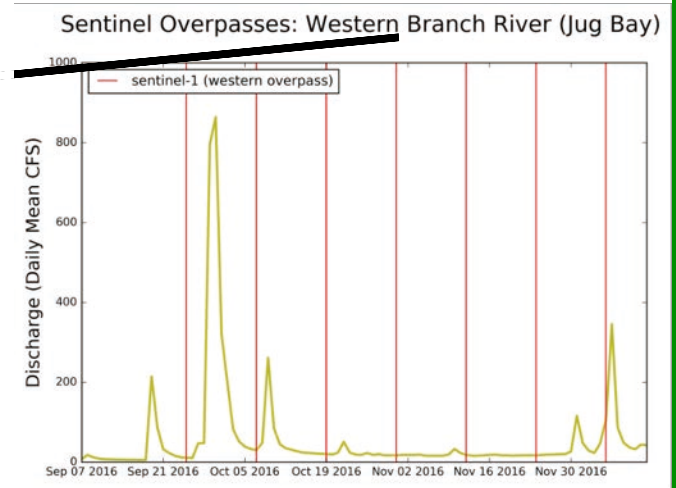


Sentinel-1 backscatter RGB timeseries images: September 24th (Red), October 6th (Green), October 18th (Blue)



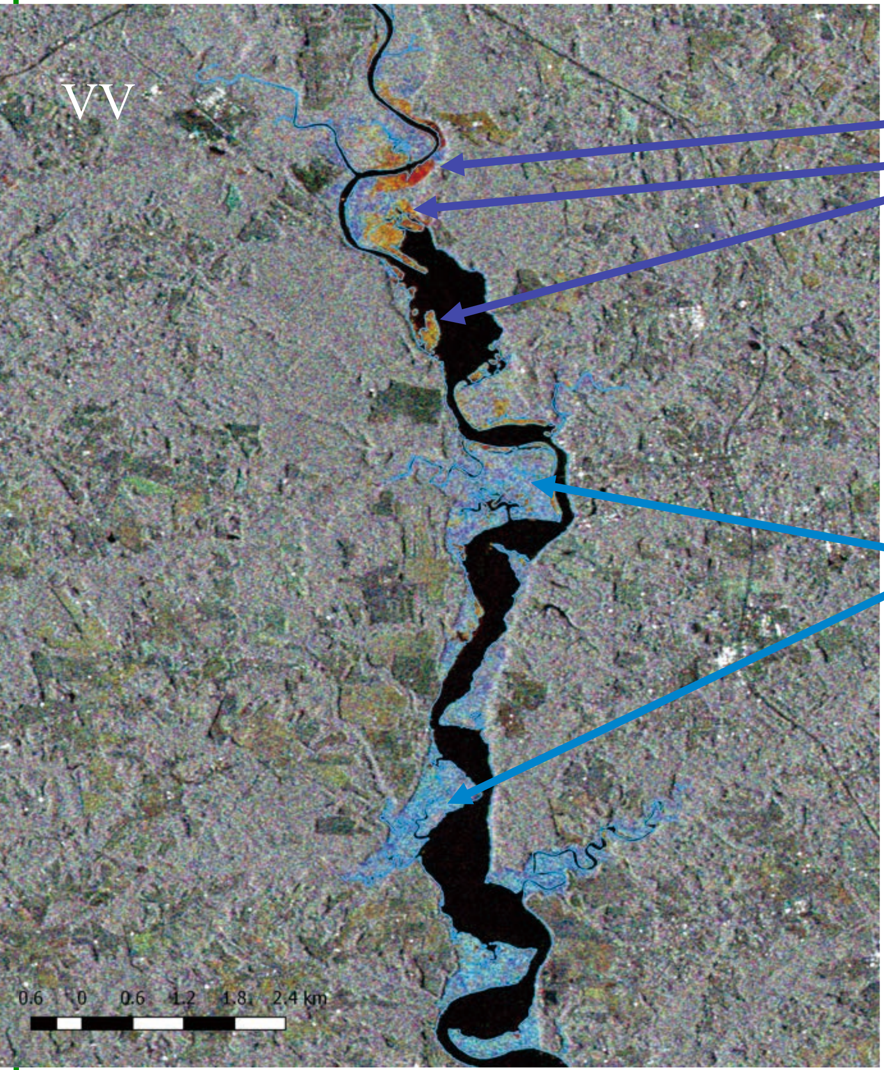






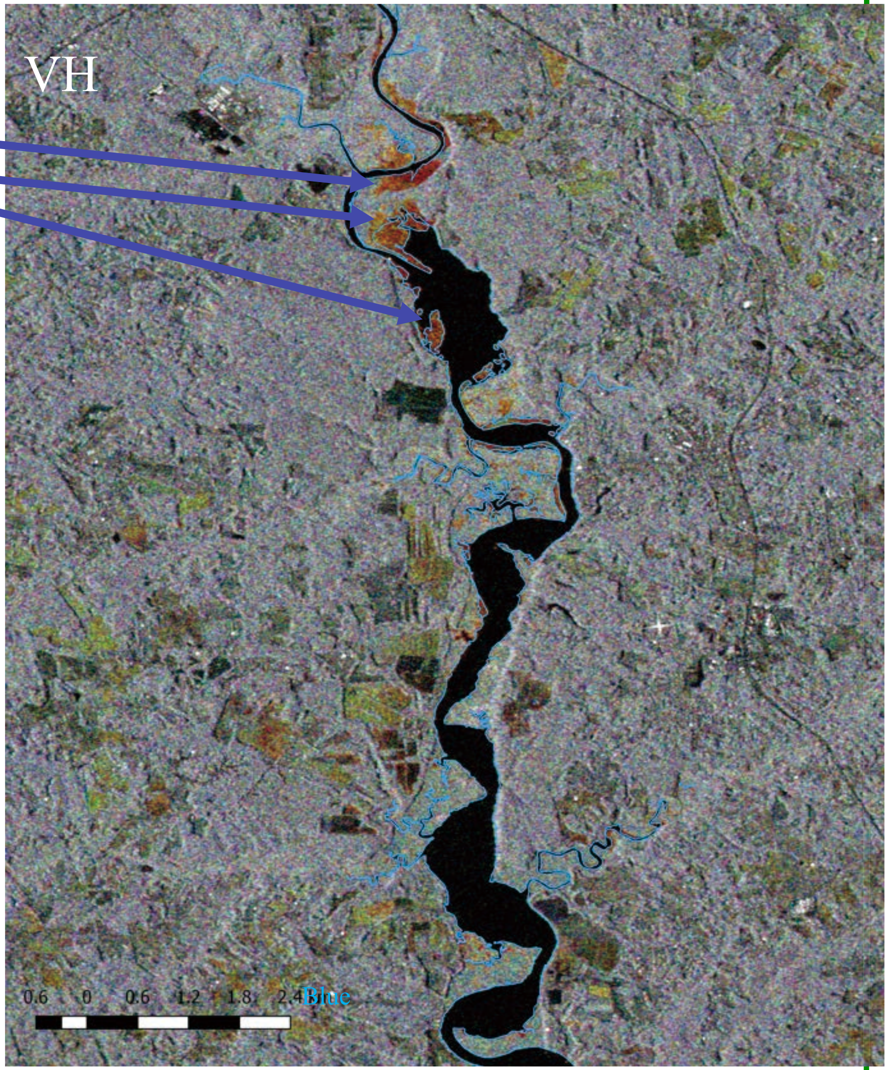
Tides vs. discharge: October 18th image is brightest presumed due to inundation underlying marsh grasses causing double bounce scattering. But it remains unclear whether tides or lagged discharge is the source of the inundation.

Sentinel-1 backscatter RGB timeseries images: September 24th (Red), October 6th (Green), October 18th (Blue)

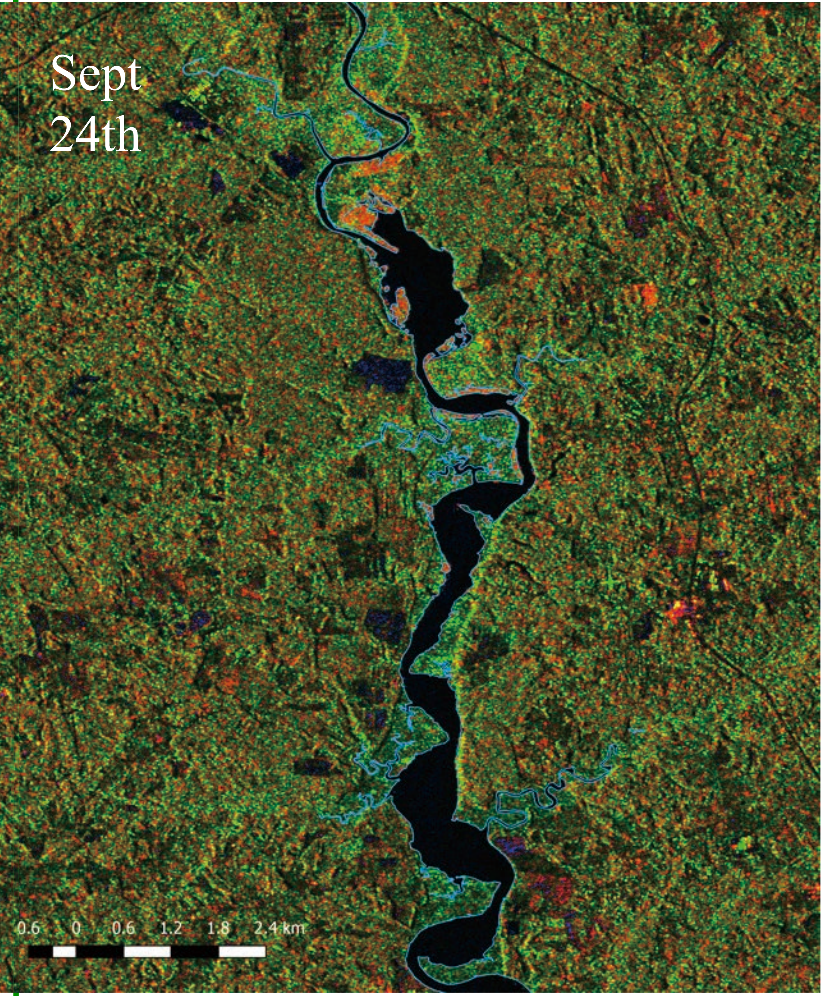


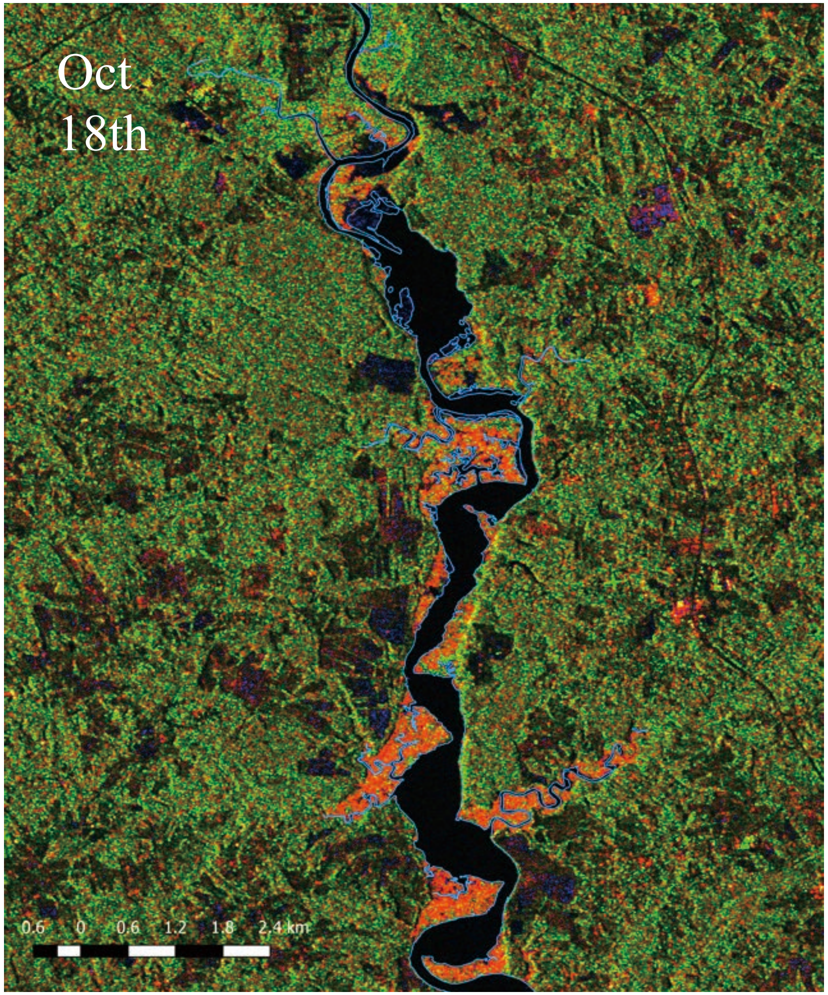
VV and VH backscatter both picking up non-permanent vegetation seasonality

VV backscatter picking up changes in hydrology



Scattering mechanism classification (Jug Bay)





- Red: VV (if VH*3 > open water value)
  - ➪ Non-volume vegetation scattering, corner reflectors
- Green: VH*3
  - ➪ Volume scattering
- Blue: VV (if VH*3 < open water value)
  - ➪ Non-volume scattering

Next steps

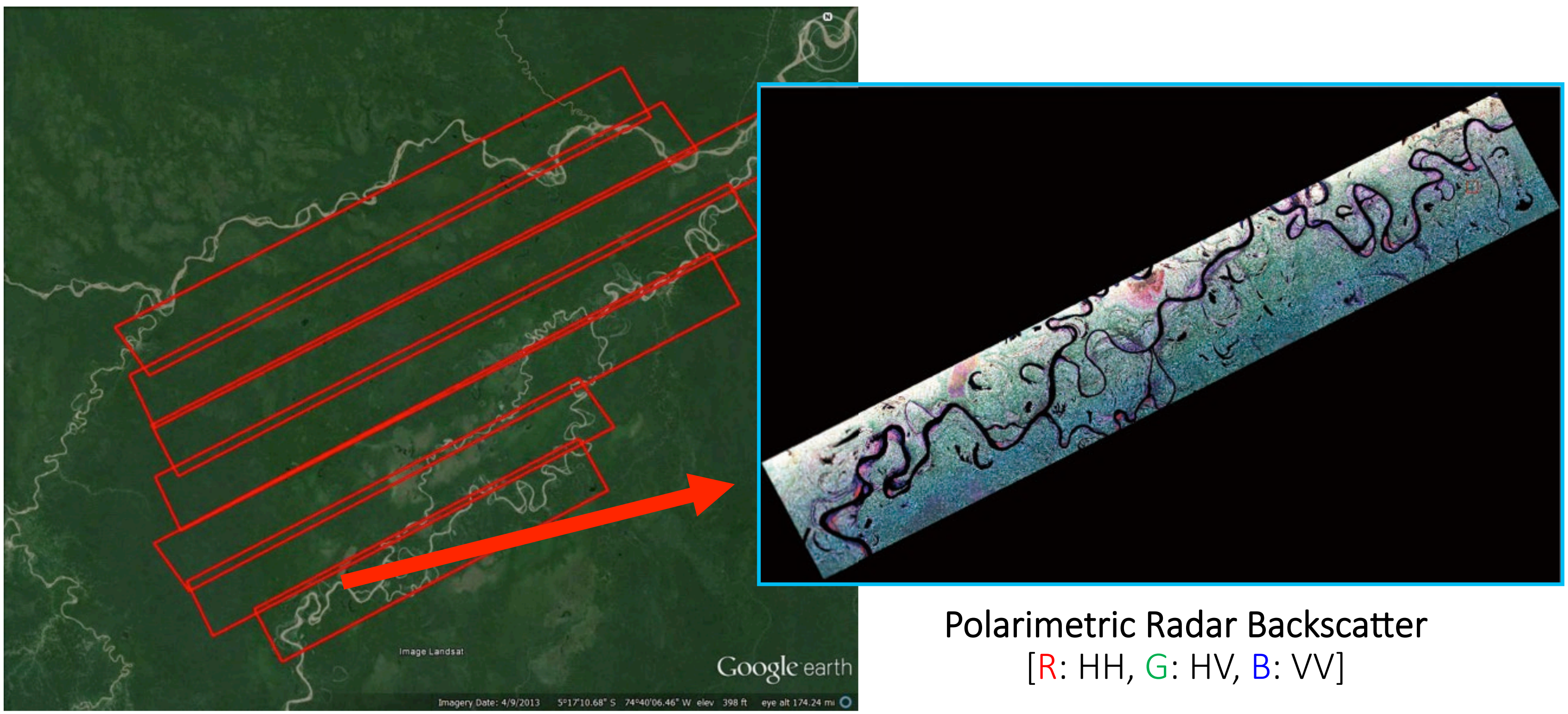
- Continue working on re-projection/geolocating PALSAR-2 data
  - ➪ Compare with previous Sentinel-1 results
- Comparison with MIMICS model outputs

Pacaya-Samiria National Reserve, Peru

- Most extensive tropical flooded forest in the Peruvian Amazon
- Spans area of more than 20,000 km^2
- Hosts rich biodiversity!
- Significant regions of palm swamp wetlands

Assessment with NASA UAVSAR Datasets

Classify and analyze high resolution imaging radar from the NASA UAVSAR mission, identifying wetlands components



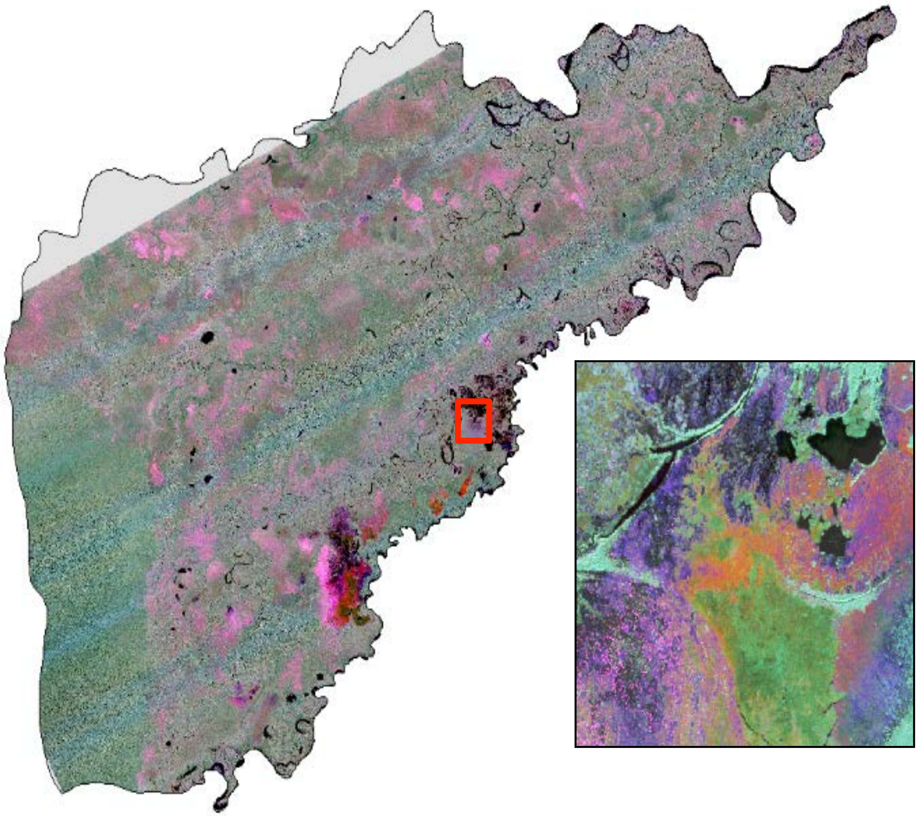
Polarimetric Radar Backscatter
[R: HH, G: HV, B: VV]

UAVSAR False Color Mosaic, normalized for incidence angle

March 17 2013

R: HH, G: HV, B: VV

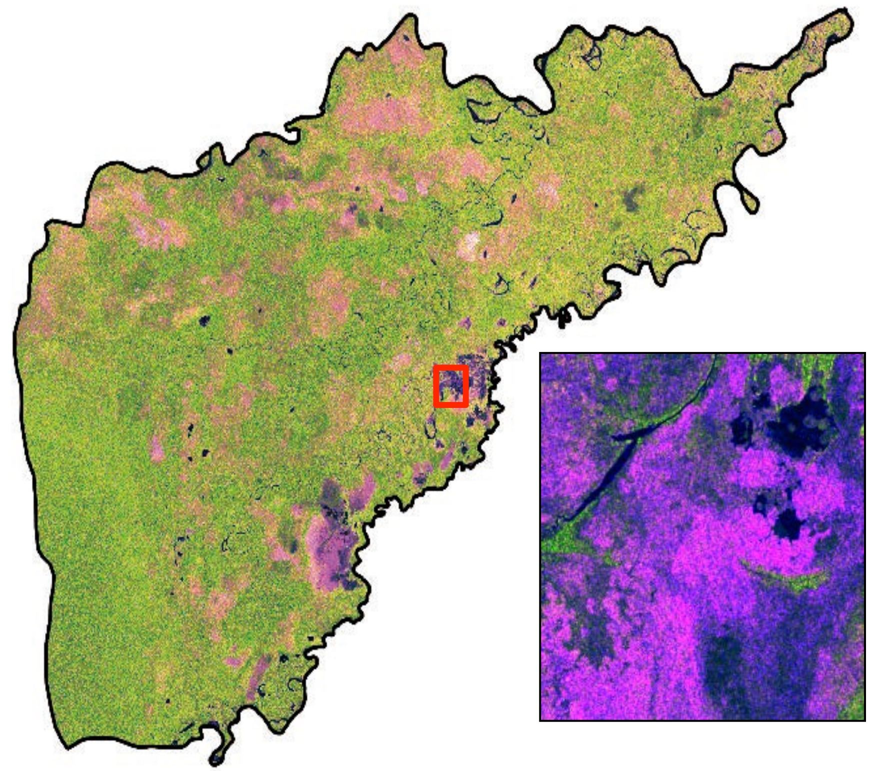
(grey indicates no data collected)



ALOS PALSAR False Color Fine Beam Mosaic

March - April 2009

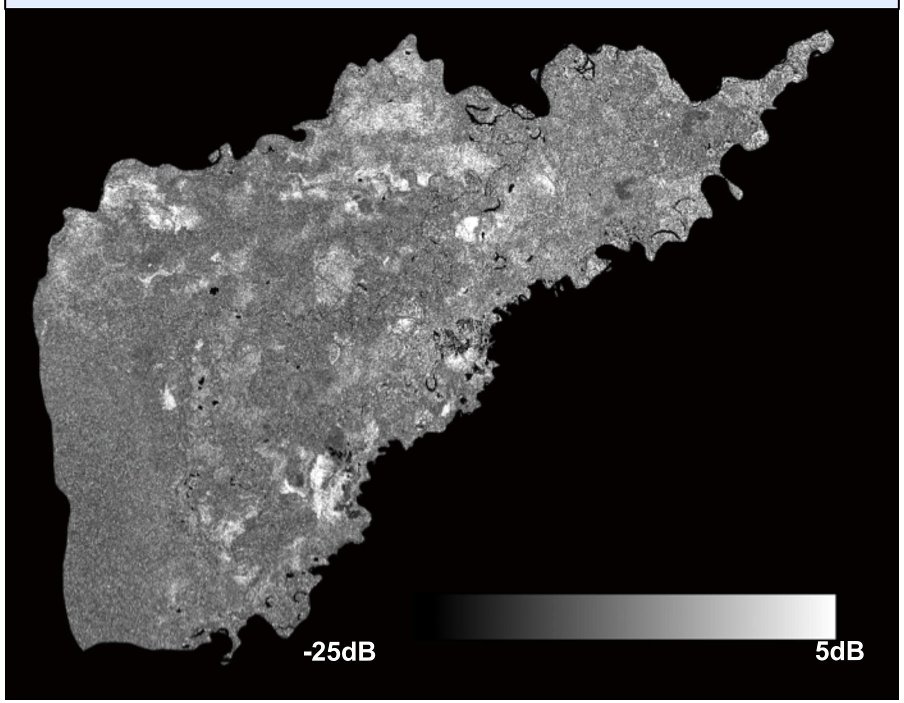
R: HH, G: HV, B: HH/HV



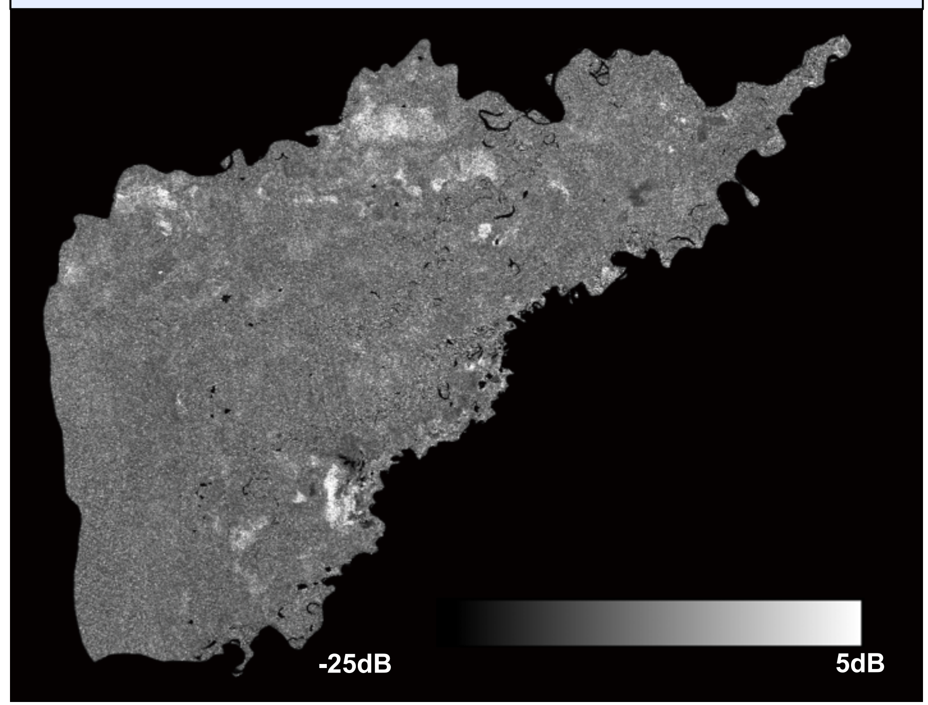
Mapping of wetlands in Pacaya Samiria Reserve, Peru

Seasonality of inundation patterns

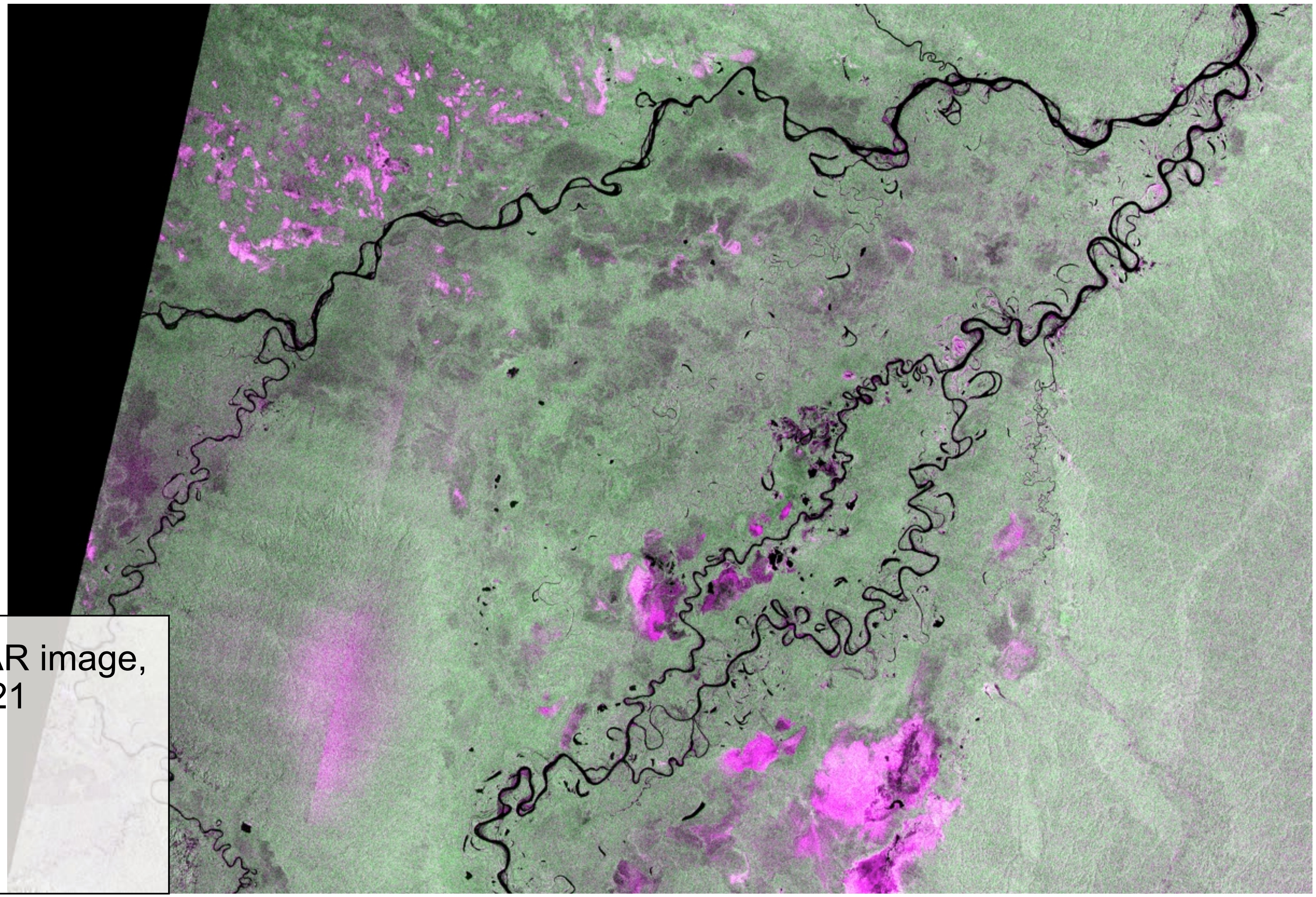
Wet Season [Mar-Apr 2009]
HH-polarized ALOS PALSAR Fine-Beam



Dry Season [Jul-Aug 2010]
HH-polarized ALOS PALSAR Fine-Beam



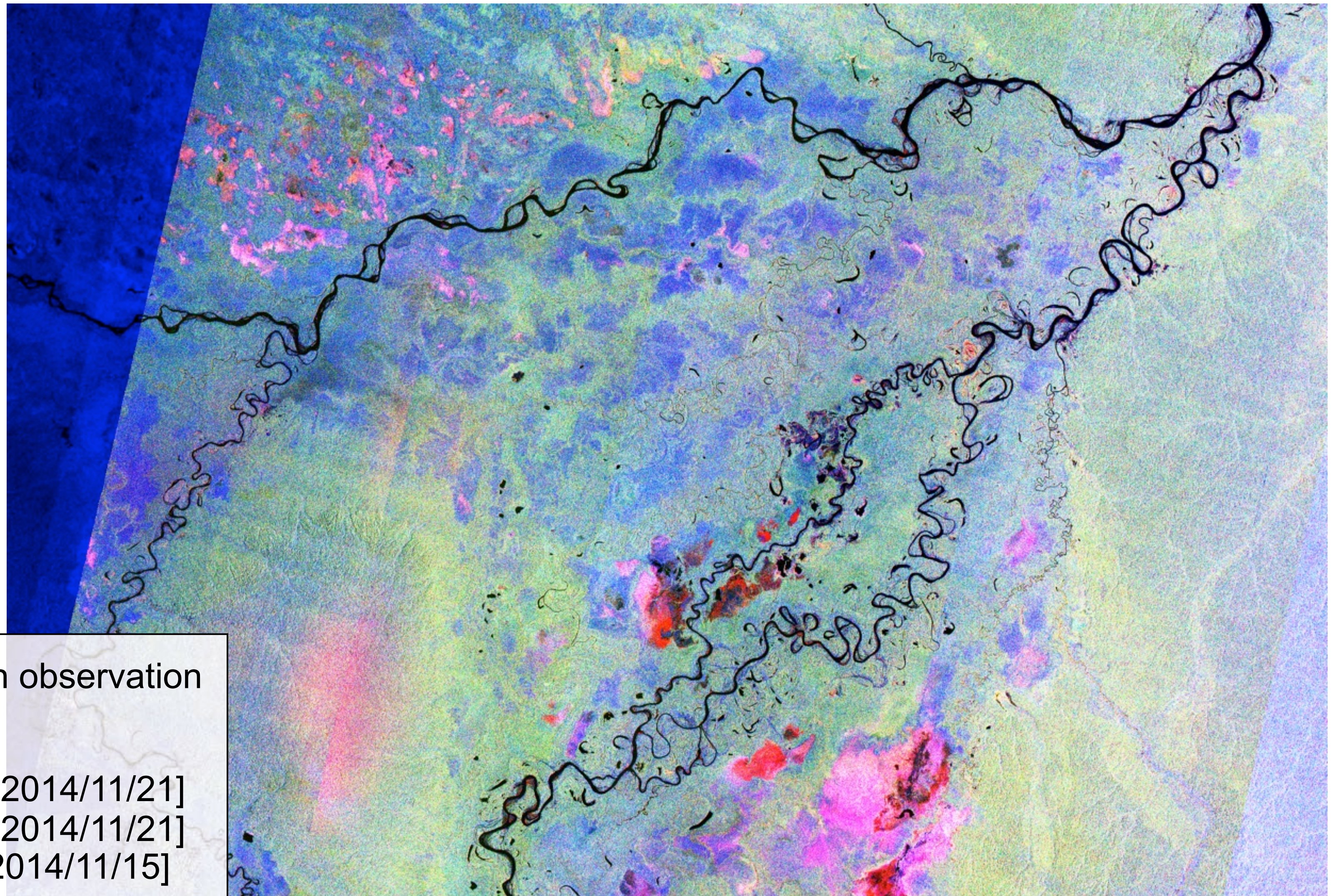
Wetlands Mapping in Pacaya Samiria Reserve, Peru



PALSAR-2 ScanSAR image, observed 2014/11/21

R: HH
G: HV
B: HH

Wetlands Mapping in Pacaya Samiria Reserve, Peru

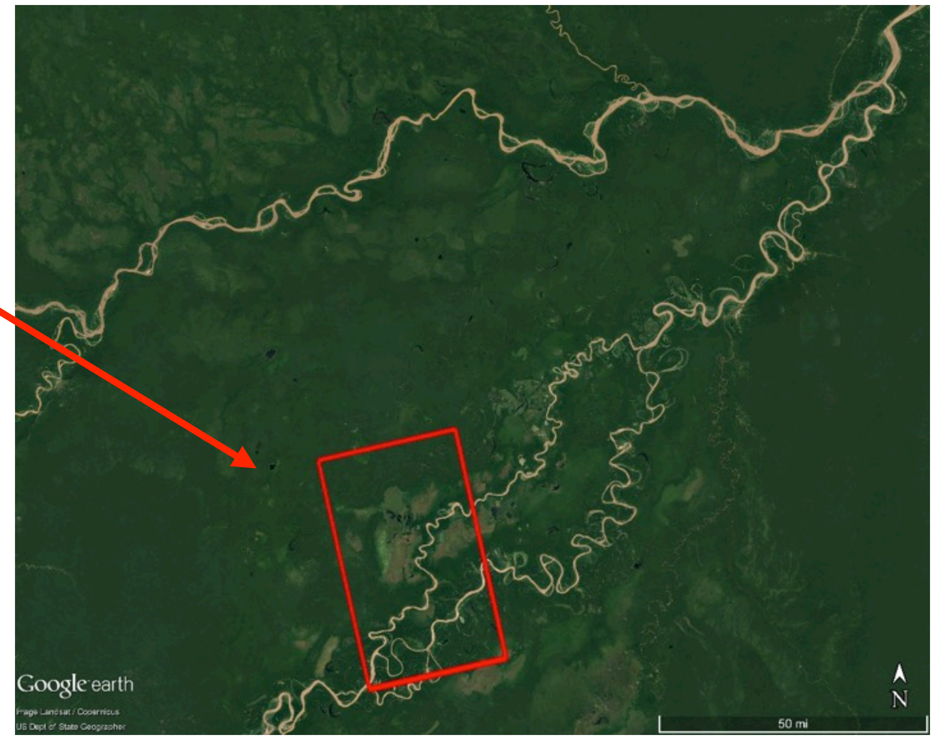


Complemented with observation from Sentinel-1A

R: HH [PALSAR-2, 2014/11/21]
G: HV [PALSAR-2, 2014/11/21]
B: VV [Sentinel-1, 2014/11/15]

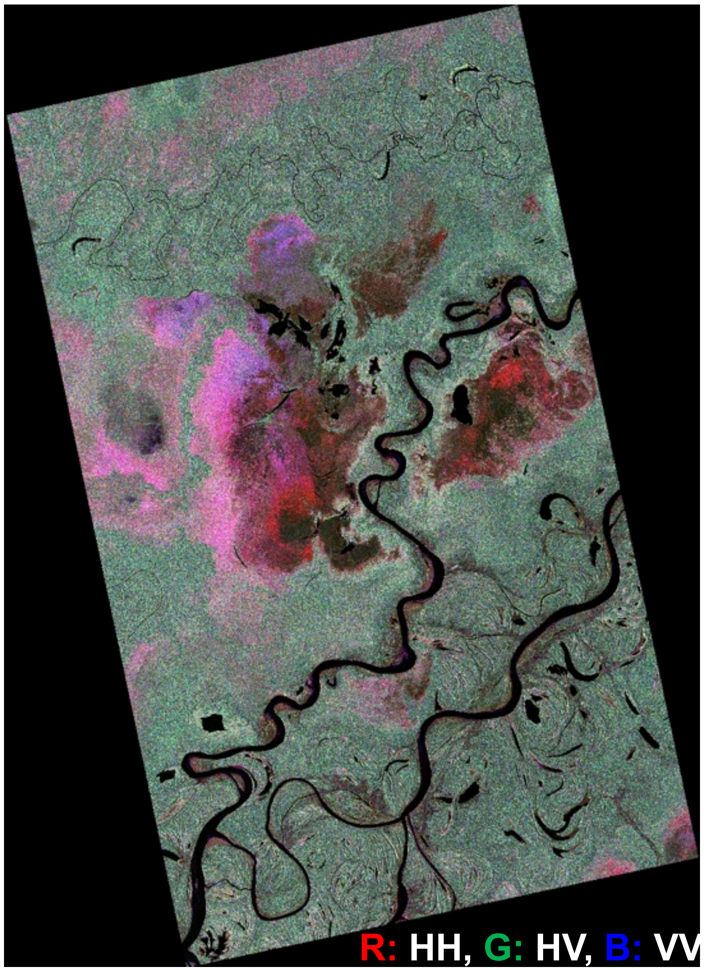
Wetlands Mapping in Pacaya Samiria Reserve, Peru

- Two PALSAR-2 strip map acquisitions, looking at study area:
- 3m spatial resolution
- Fully polarimetric (quad pol)
- **Limited use with Lev 1.5 → need Lev 1.1 for polarimetric analysis**
- Can use to study sub-pixel homogeneity in coarse-resolution products (e.g. SWAMPS)

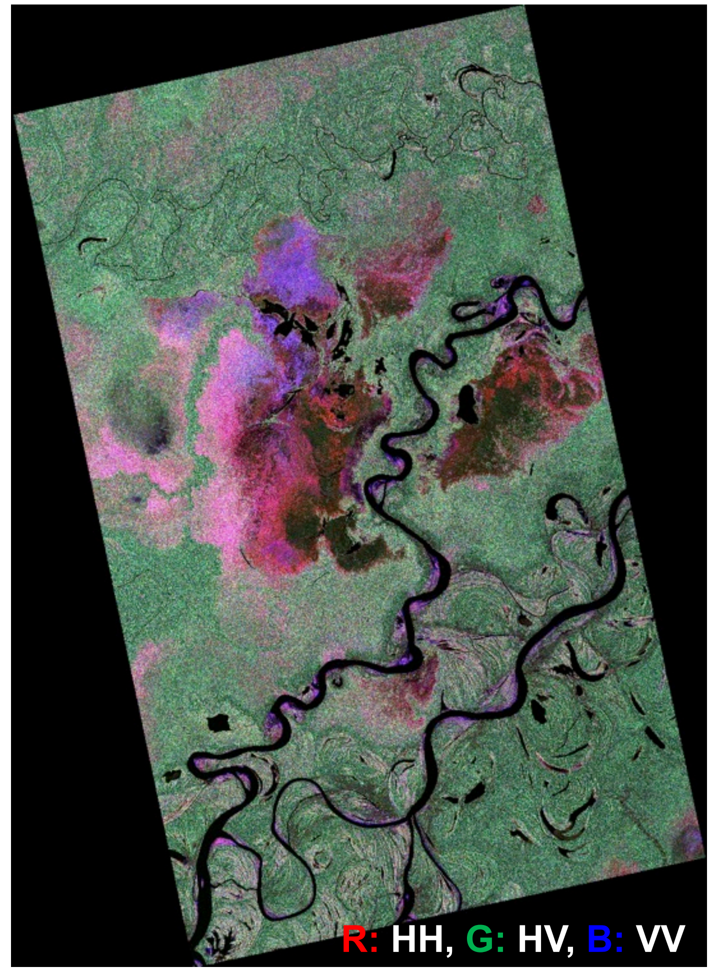


Wetlands Mapping in Pacaya Samiria Reserve, Peru

Aug 13, 2015 [dry season]



Mar 10, 2016 [wet season]



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Monitoring change and threat to River Deltas Systems: Mekong Delta

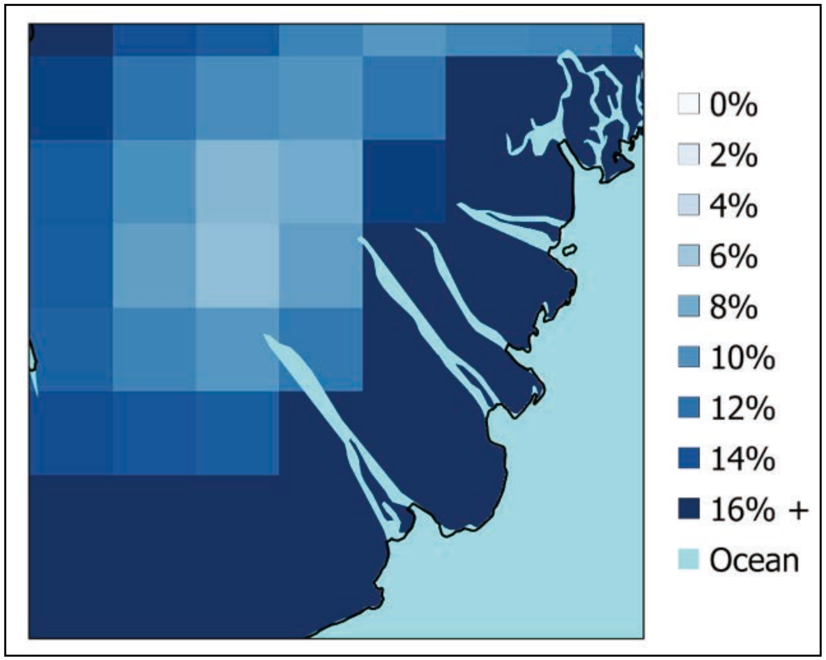
- **The Mekong River delta is the world's 3rd largest delta**
  - ➪ **densely populated**
  - ➪ **considered as Southeast Asia's "most important food basket"**
  - ➪ **rich in biodiversity at the world scale**
- **Increasingly affected by human activities and exposed to subsidence and coastal erosion**
- **Several dams have been constructed upstream of the delta and many more are now planned**
- **GOAL: Can we link landcover/land-use changes with inundation patterns using remote-sensing?**

Mekong Delta in **red**

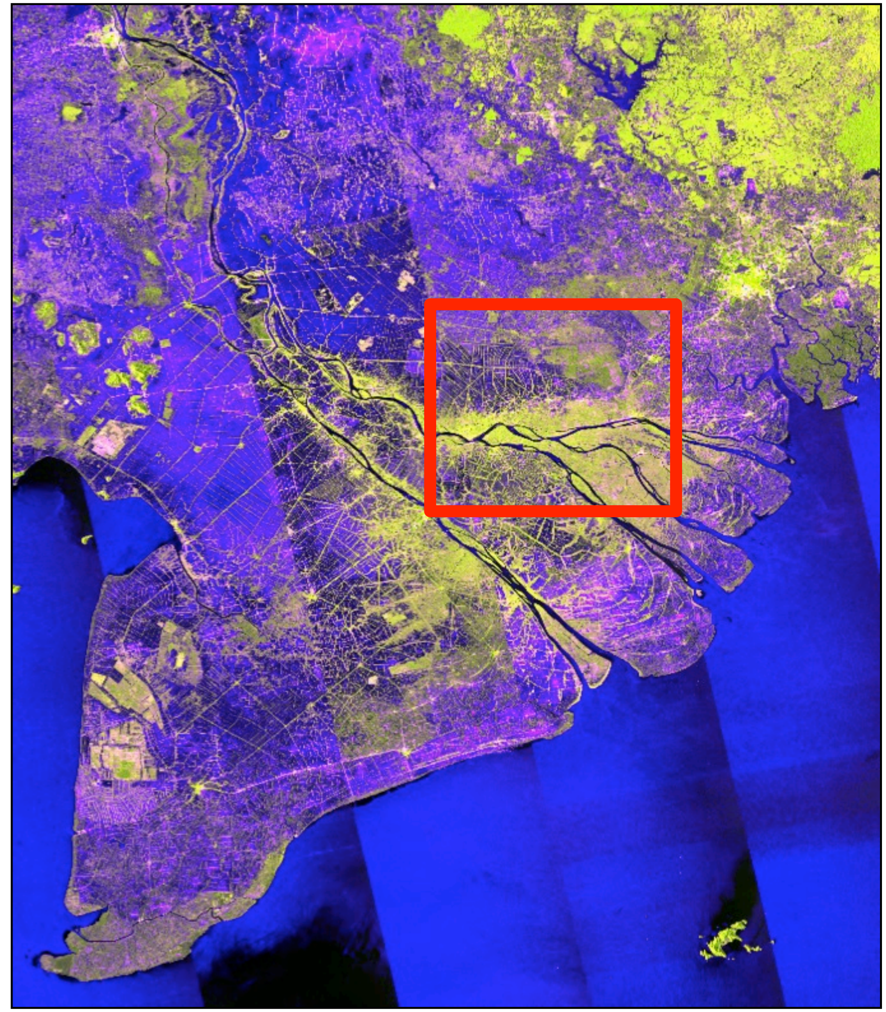
Source: National Geographic

Source: National Geographic

Mekong River Delta, Indochina



SWAMPS 25km f_w, Mekong River Delta, Jul 1-8 2009

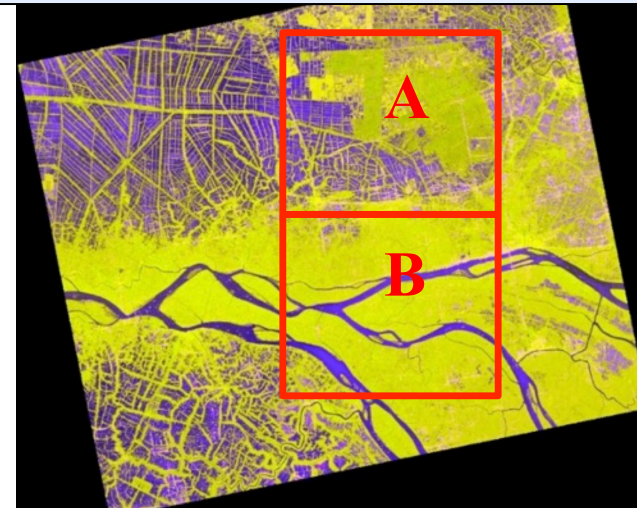


ALOS PALSAR RGB backscatter mosaic, Jun – Aug 2009. R: HH, G: HV, B: HH-HV. 30m spatial resolution. Red box indicates region used in this study.

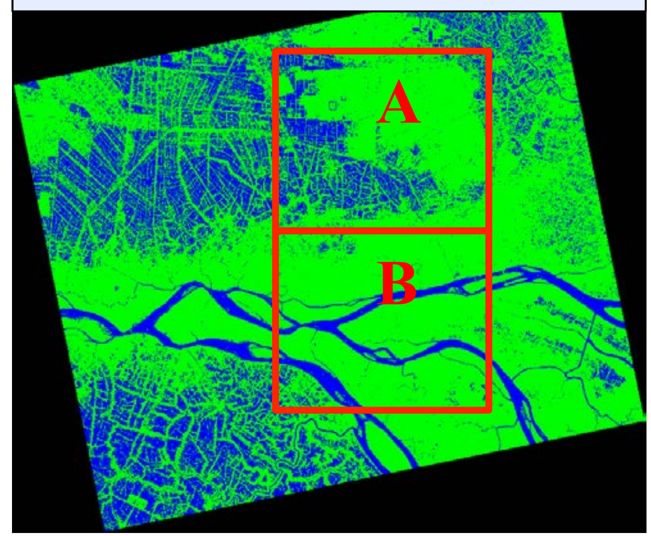
Re-scaling of coarse resolution inundation area fraction

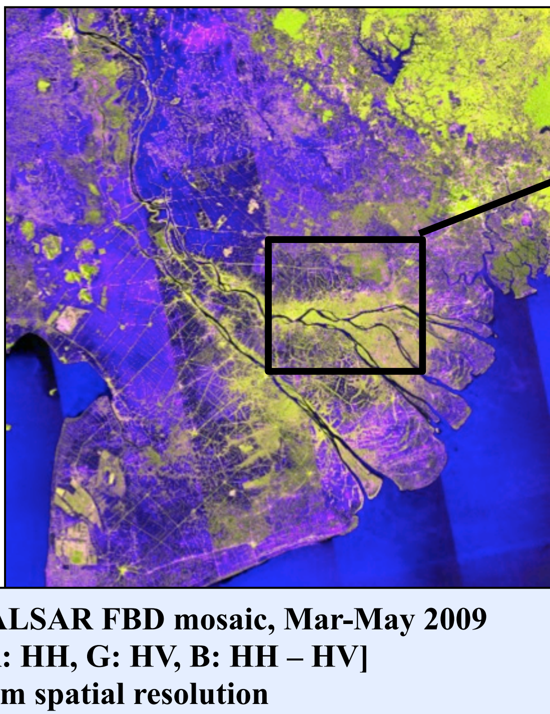
- **Static physical information (e.g. topography) alone is not enough for accurate downscaling**
- **Use of ALOS PALSAR observations as ancillary input:**
  - **Identify biases in SWAMPS data product**
  - **Combine with machine learning algorithms to “learn” from SAR observations**

PALSAR FBD, 11/18/10 [R: HH, G: HV, B: HH – HV]



Decision Tree Classification
Blue= Open Water, Green = Non-Inundated





PALSAR FBD mosaic, Mar-May 2009
[R: HH, G: HV, B: HH – HV]
30m spatial resolution

Classified open water in 24 reoccurring ALOS PALSAR fine-beam images (Feb 2007 – Jan 2011)

Aggregated 30m values of % classified as open water within <u>two</u> ease-grid cells (A & B) that are completely contained in image

Inundation in Mekong Delta

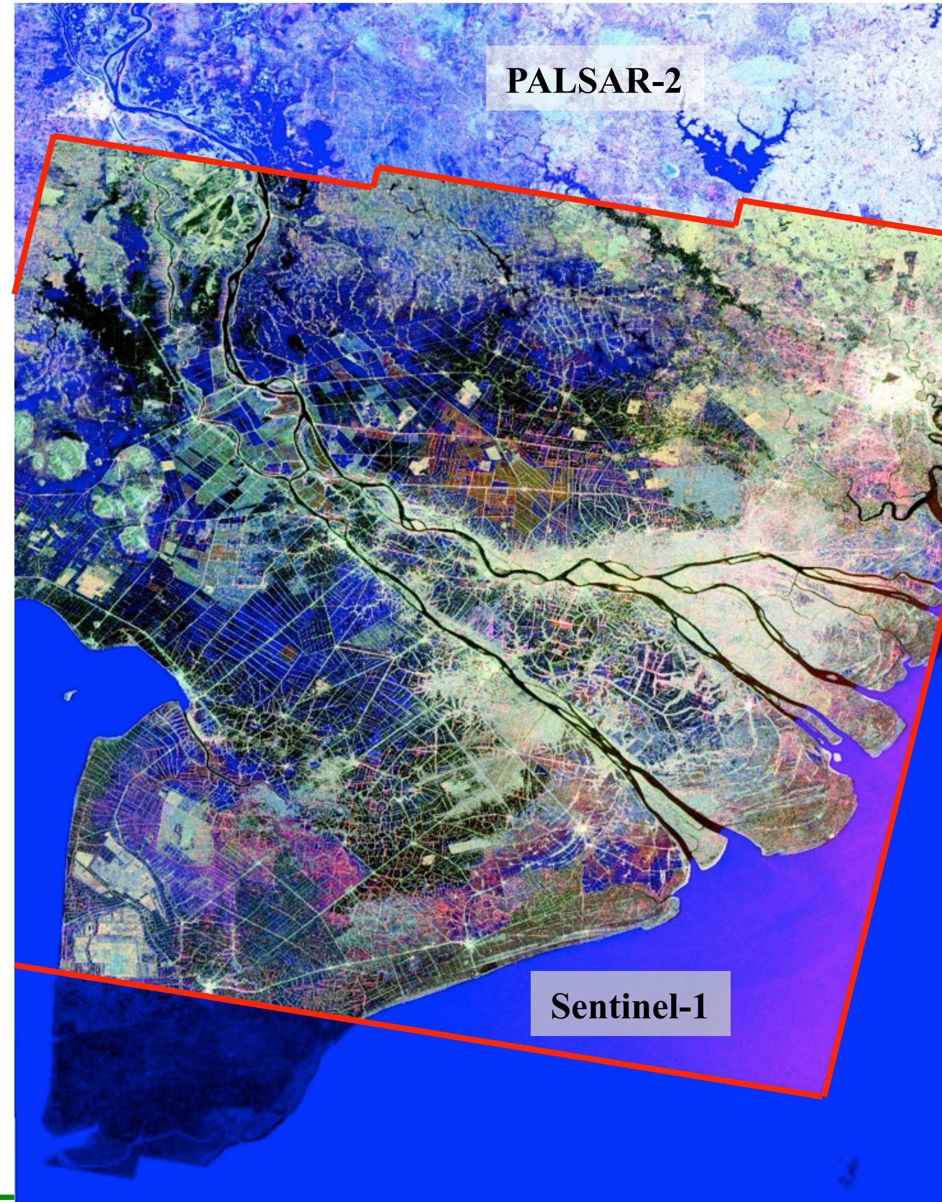
Concurrent observations:

1. **PALSAR-2 ScanSAR**
   - 100m spatial resolution
   - HH + HV pol

2. **Sentinel-1 Interferometric Wide Swath**
   - 30m spatial resolution
   - VV + VH pol

Overlap between Sentinel-1 & PALSAR-2 →

R: HH [PALSAR-2, Dec 12 2014]
G: HV [PALSAR-2, Dec 12 2014]
B: VV [Sentinel-1A, Dec 12 2014]



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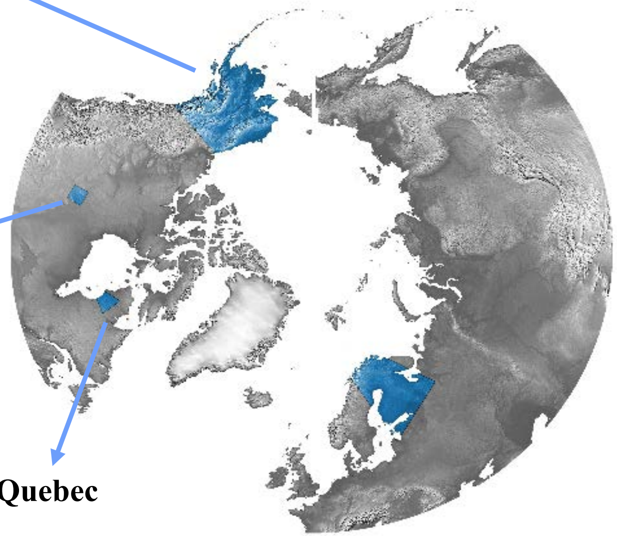
Boreal/Arctic Freeze-Thaw

SMAP F/T Domain



BERMS (Saskatchewan)

Old jack pine (OJP) at (53.92 N, 104.69 W)

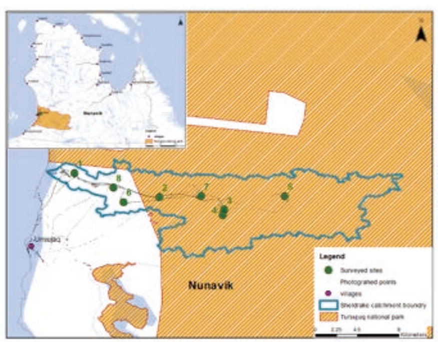
Young jack pine (YJP) also called H02 at (53.95 N, 104.65 W)

Old black spruce (OBS) at (53.99 N, 105.12 W)

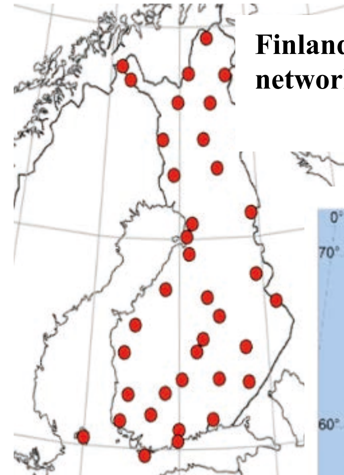
Fen (Fen) at (53.78 N, 104.62 W)

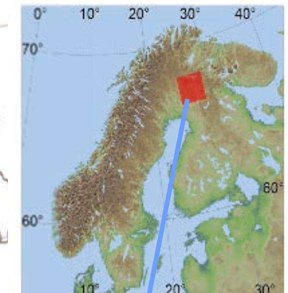
Mixed forest (Temp7) at (53.90 N, 104.88 W)

Umiujaq, Quebec

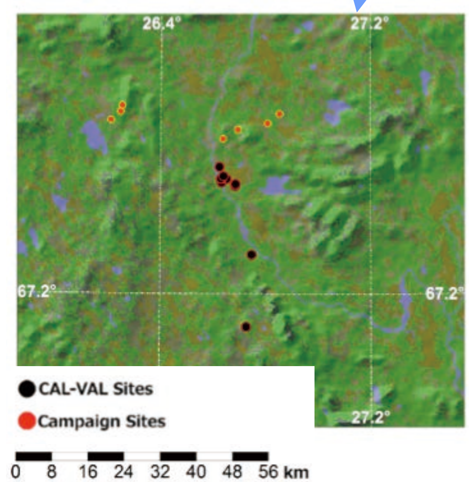


Finland frost tube network

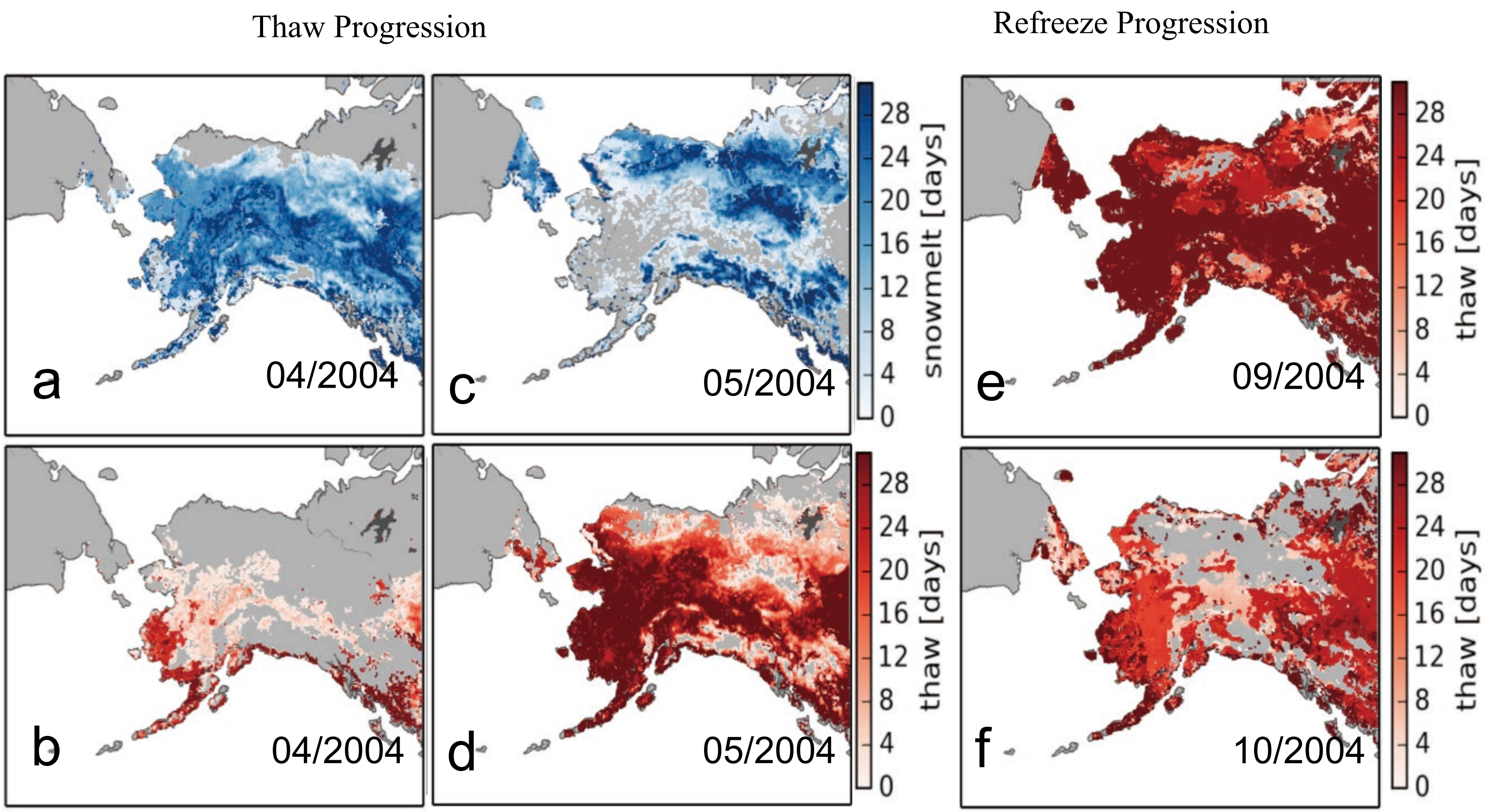




Sodankylä, Finland



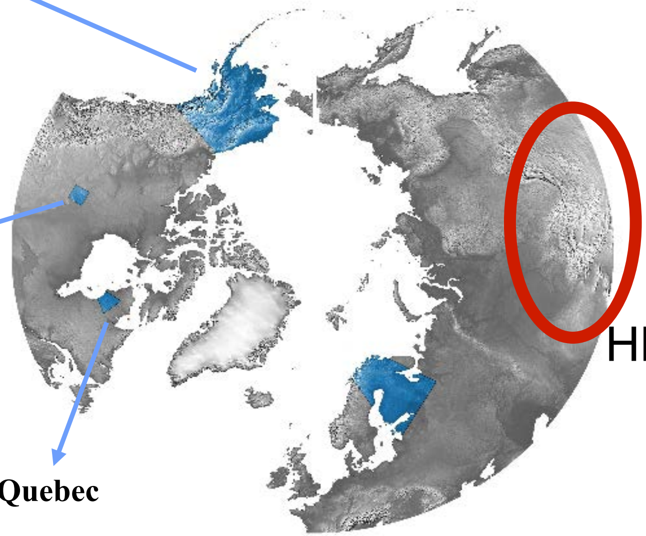
Multi-frequency Freeze/Thaw algorithm development



Boreal/Arctic Freeze-Thaw

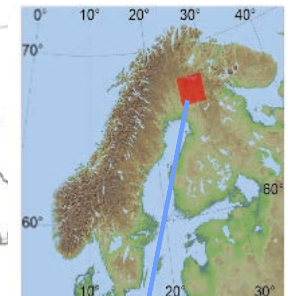
Alaska

SMAP F/T Domain



HMA

Finland frost tube network



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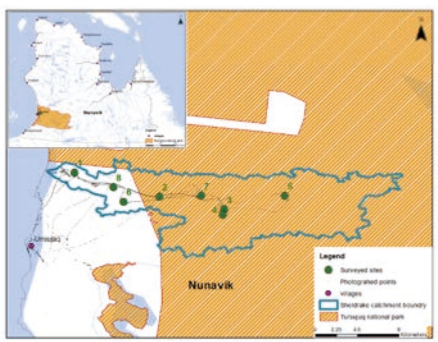
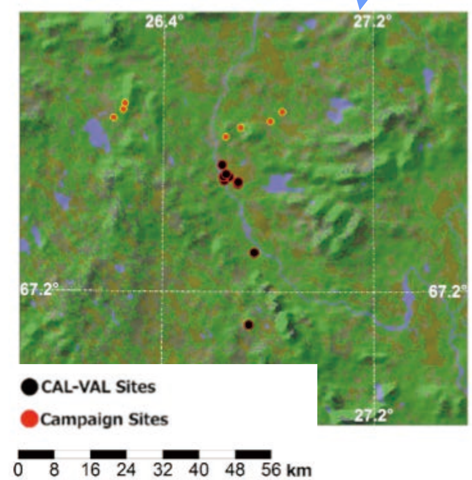
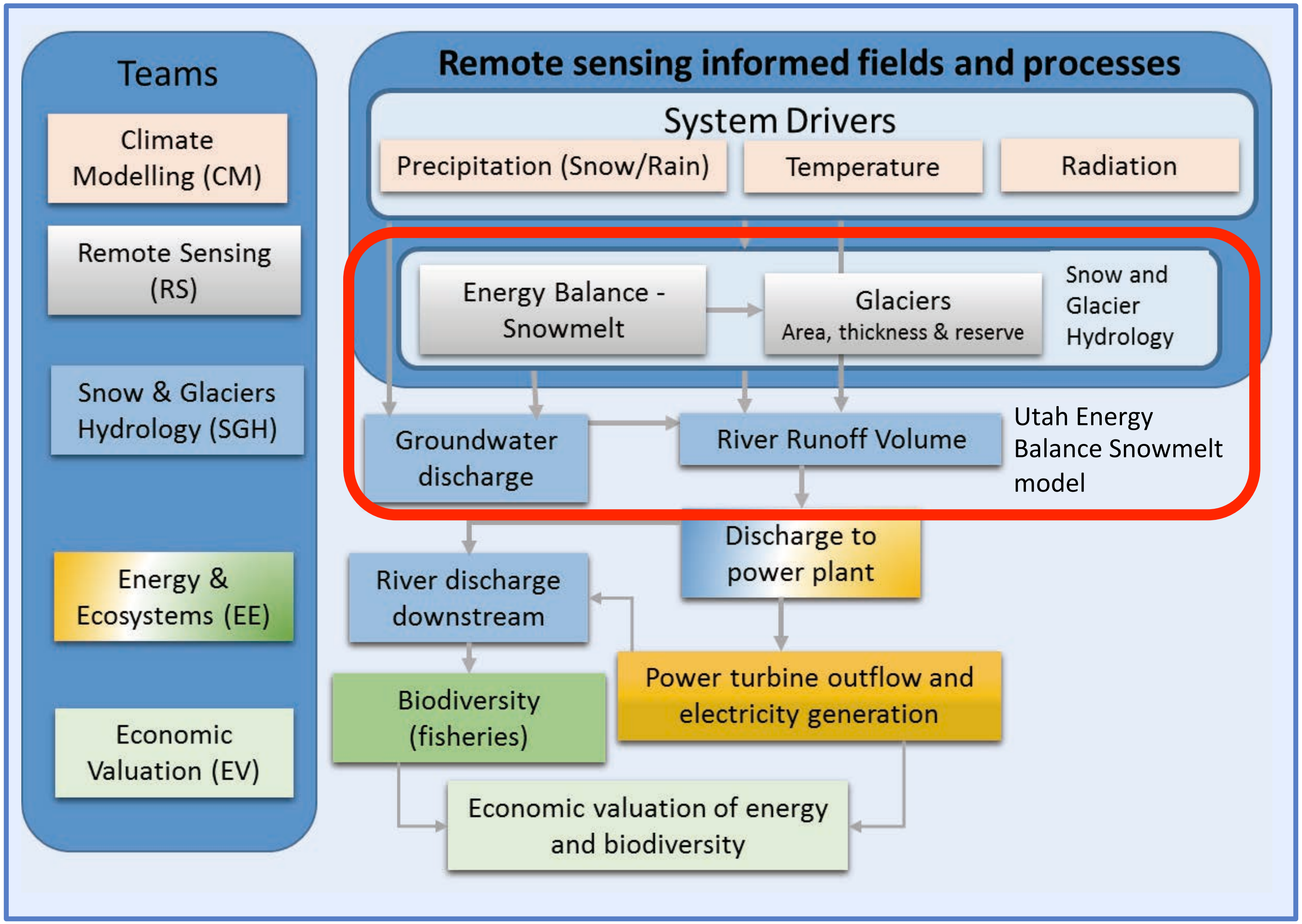


Sodankylä, Finland



Integrated assessment framework



<u>Remote Sensing & Snow and Glacier Hydrology:</u>
multiple datasets to characterize system environmental drivers and surface processes (Snowpack and freeze/thaw state) providing observational data to SGH for melt runoff assessments.

<u>Climate Modeling:</u>
generate historical reconstructions and projections of precipitation (rain and snow) and temperature.

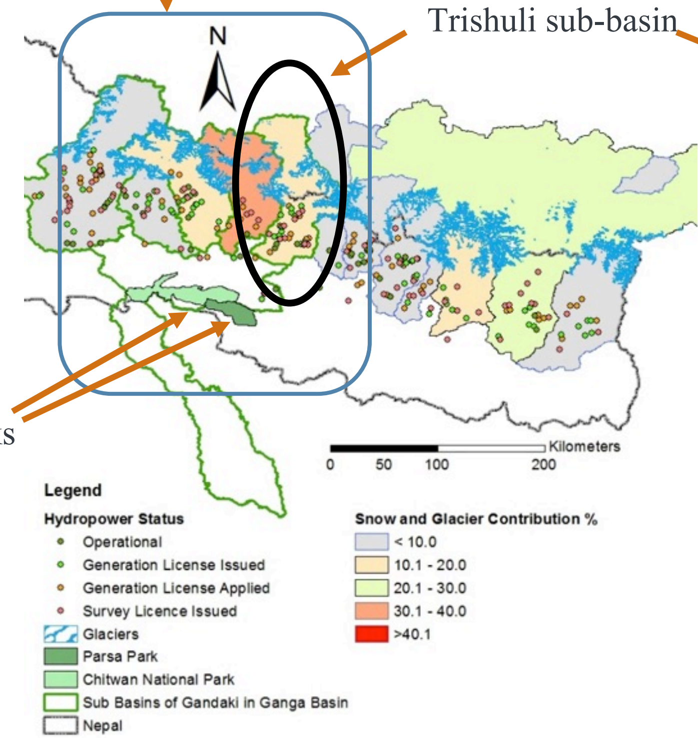
<u>Hydrologic forecasting</u> provides information required to evaluate effects on power generation and ecosystem services.

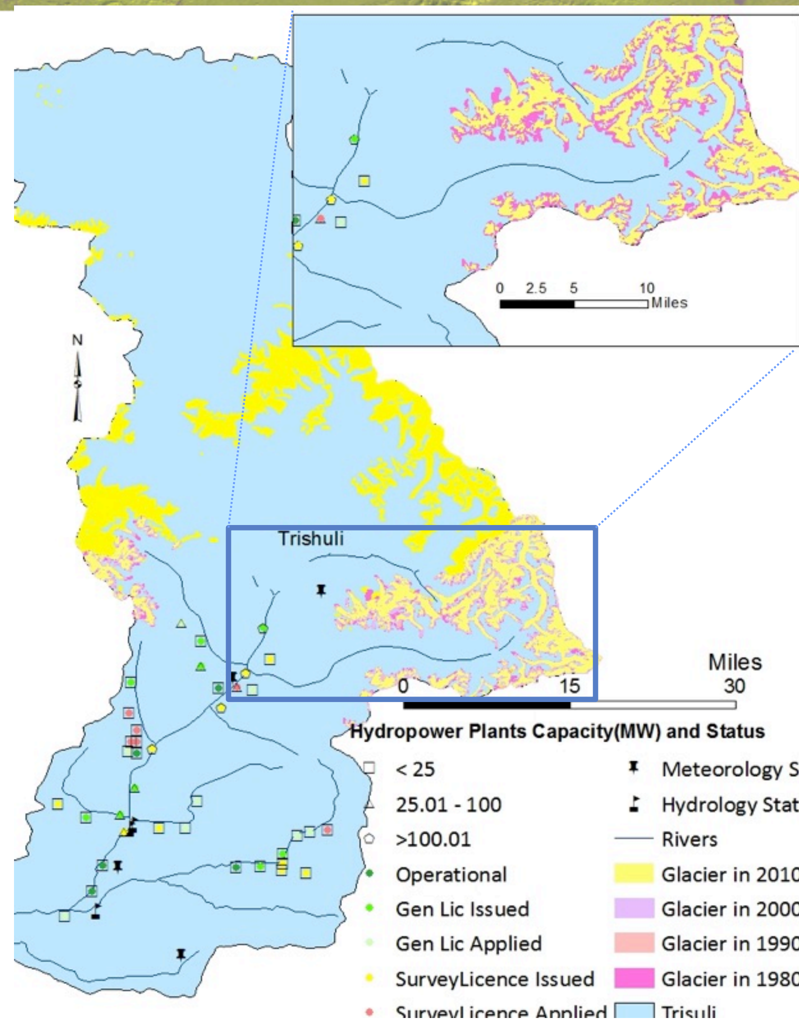
Outputs will be used to evaluate EV of impacts of climate change.

Gandaki basin (36,450 km^2)

Trishuli sub-basin

National Parks





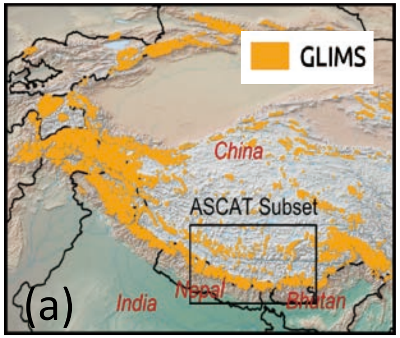
<u>Trishuli Sub-basin</u>:

- 5 operational hydropower plants, 70 Megawatts capacity
- 17 generation licenses, capacity of 422 Megawatts.
- Survey licenses: additional 16 plants, 620 MW total capacity

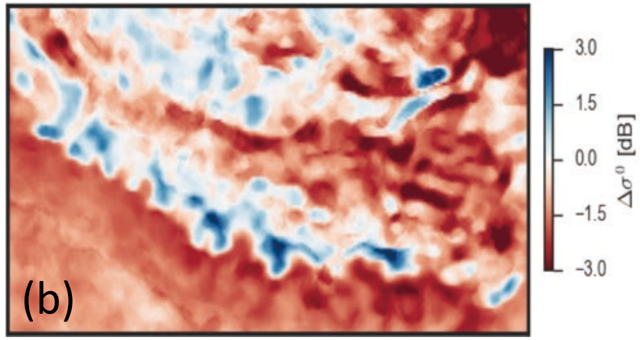
Assessing Climate-Induced Change in River Flow and Economic Output

Regional-scale Remote Sensing Datasets

HMA Glacier Extent



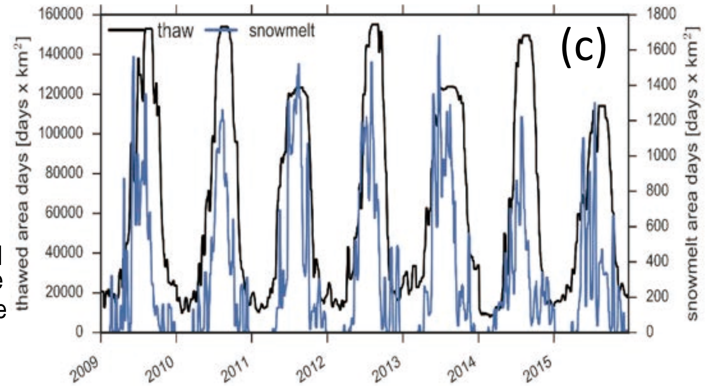
ASCAT Seasonal σ^0 Difference



Scatterometer observations from ASCAT (A+B) characterize seasonal transitions and surface state at a regional scale (a). The enhanced resolution C-Band scatterometer product is close to 5 km. The seasonal response of ASCAT over glaciers is dictated by absorption in the snow volume and increased surface scattering over land (b).

Using ASCAT backscatter, seasonal patterns in snowmelt and landscape freeze/thaw area and timings can be determined and combined with passive microwave observations that have a longer observational record (c).

ASCAT Derived Freeze/Thaw and Snowmelt Area

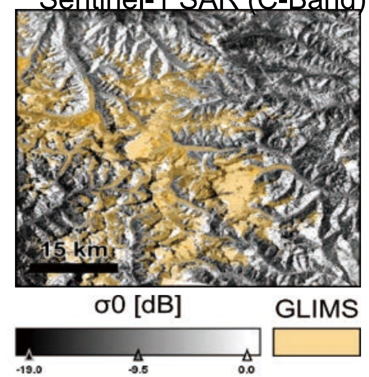


Multi-frequency active and passive microwave data from ASCAT, AMSR-E/2, SMAP and SSM/I to assess snowpack and surface FT state to support characterization of surface hydrology (~5km).

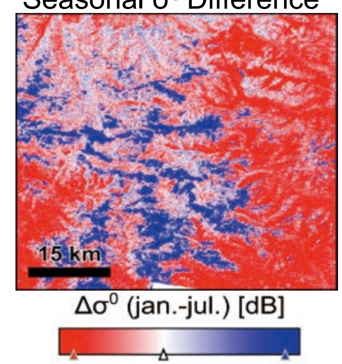
Sentinel-1 SAR datasets (at right) to characterize snow and FT state at high resolution (10-m) to assess effects of surface heterogeneity on surface snow and FT state.

Arun Basin Glaciers

Sentinel-1 SAR (C-Band)



Seasonal σ^0 Difference



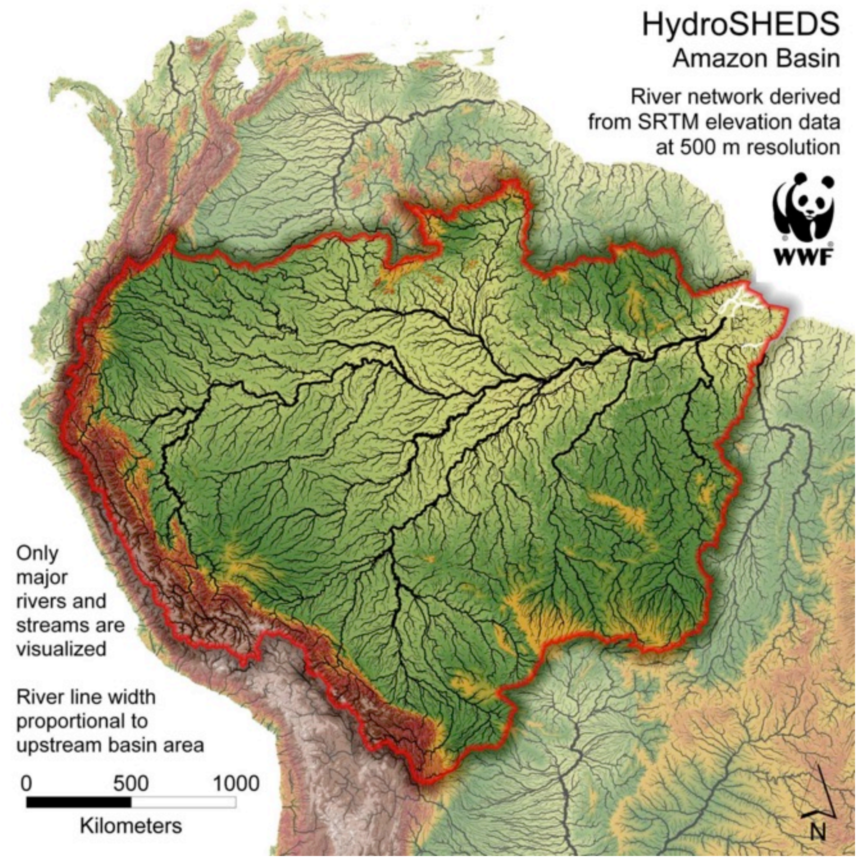
Fine-scale SAR

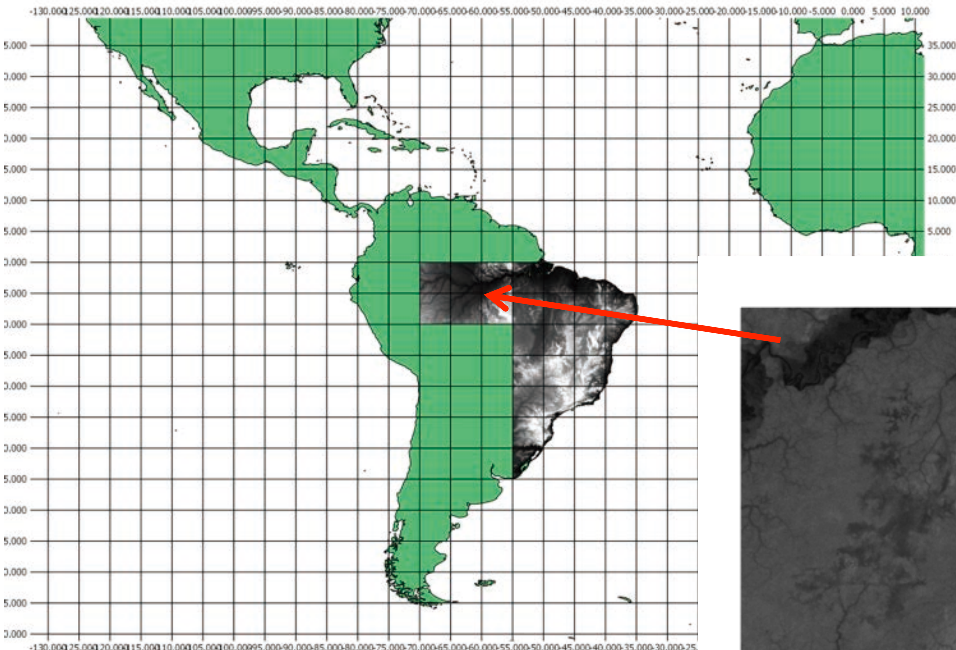
Characterization of the geological and environmental history of Amazonia

- What has been the history of environmental change across Amazonia from the late Neogene to present?

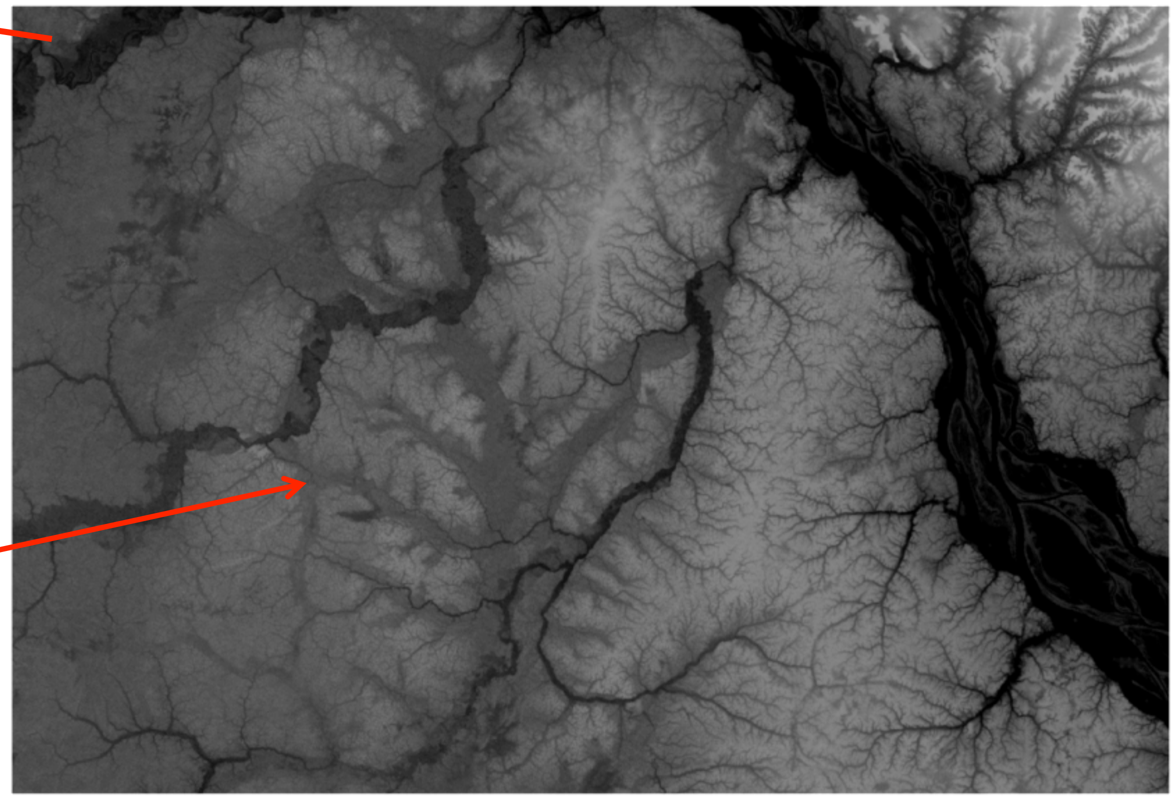
- When did the Amazonian river drainage form?

- What was the Amazonian landscape like before the Amazon river formed and how did it change after the river formation?





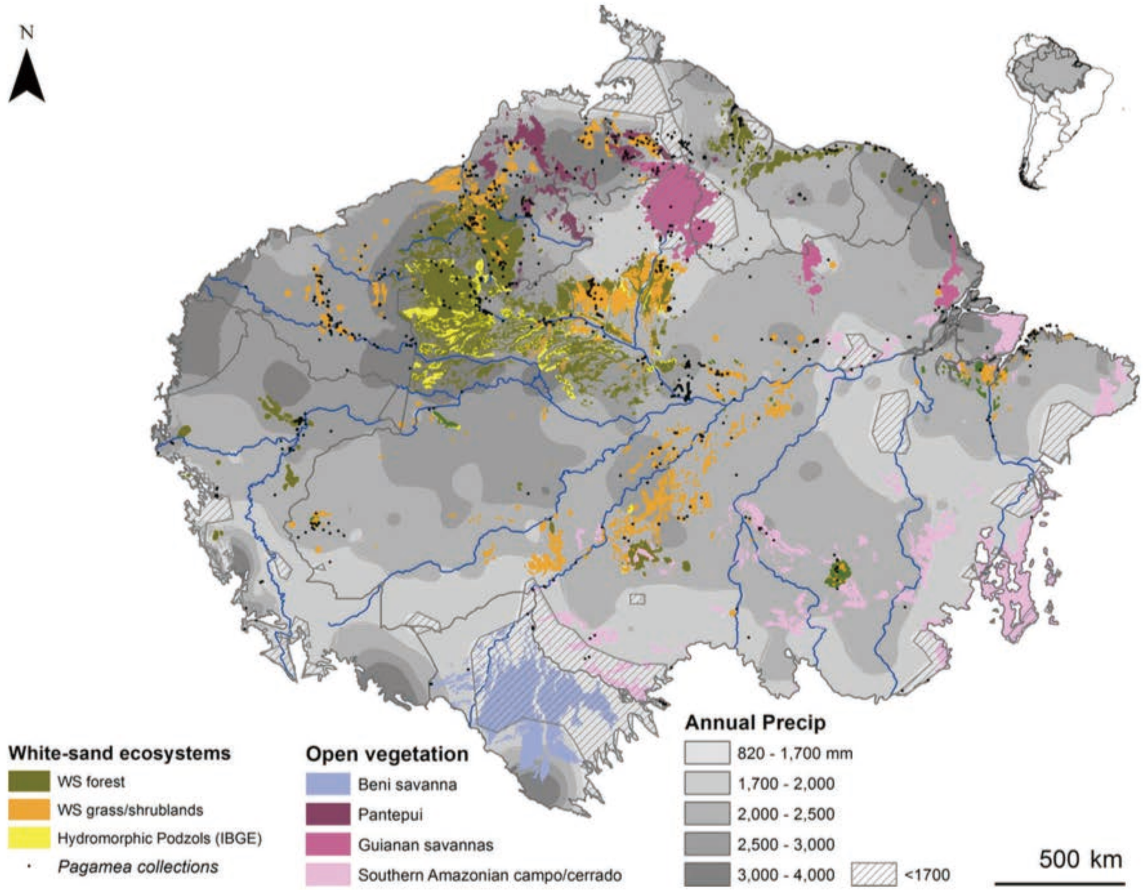
Integration using SRTM DEM: Amazon and the Atlantic Forest



Ancient river system

based on Almeida-Filho & Miranda. 2007. *Remote Sensing Environ.* 110:387-392

White Sand Communities Locations

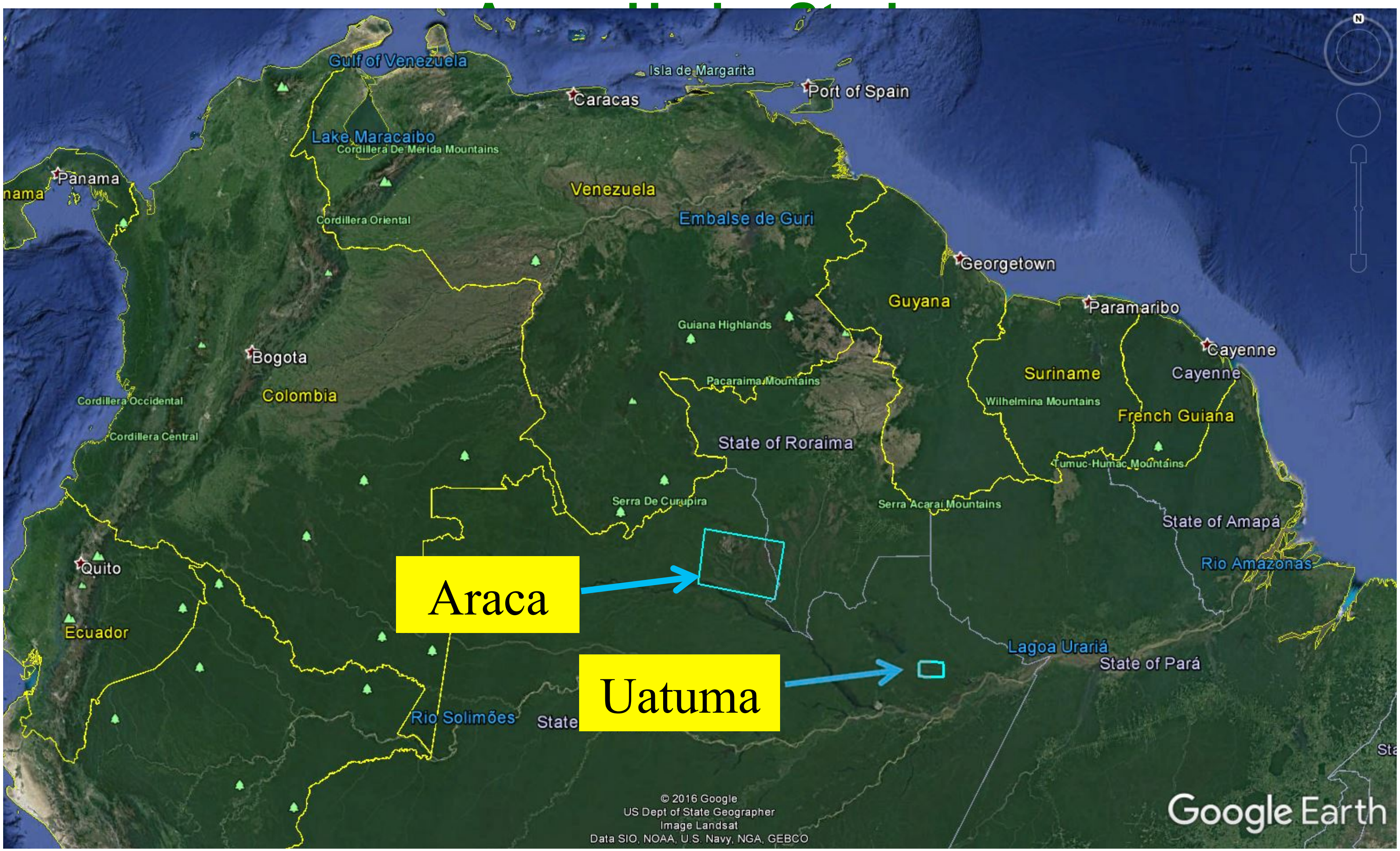


Most up-to-date map showing the locations of all the known white sand communities [Source: Adeney et al. 2016]

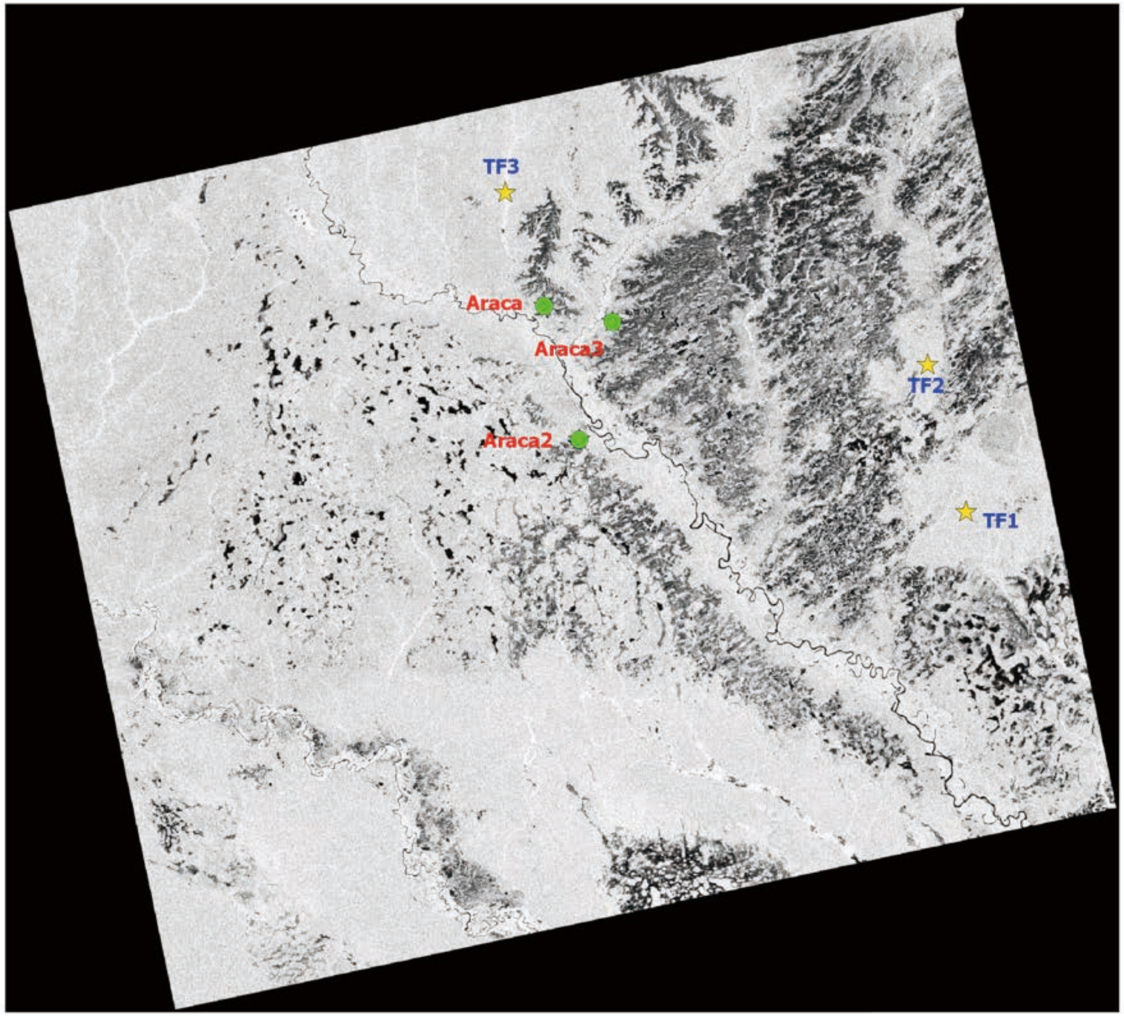
White Sands Forests:

- Not much is known about them (Adeney et al. 2016)
- Their origin is under debate with 3 different theories:
  - Fluvial deposits from the Guiana shield and Roraima Sandstone
  - Aeolian deposits
  - Fluvial deposits by ancient rivers
- Support endemic plant and animal species
  - Some bird species are only exclusively found in a campinas and not campinaranas
- Although extensive areas have already been located, not all of them have been identified due to the large scale of the Amazon Basin.

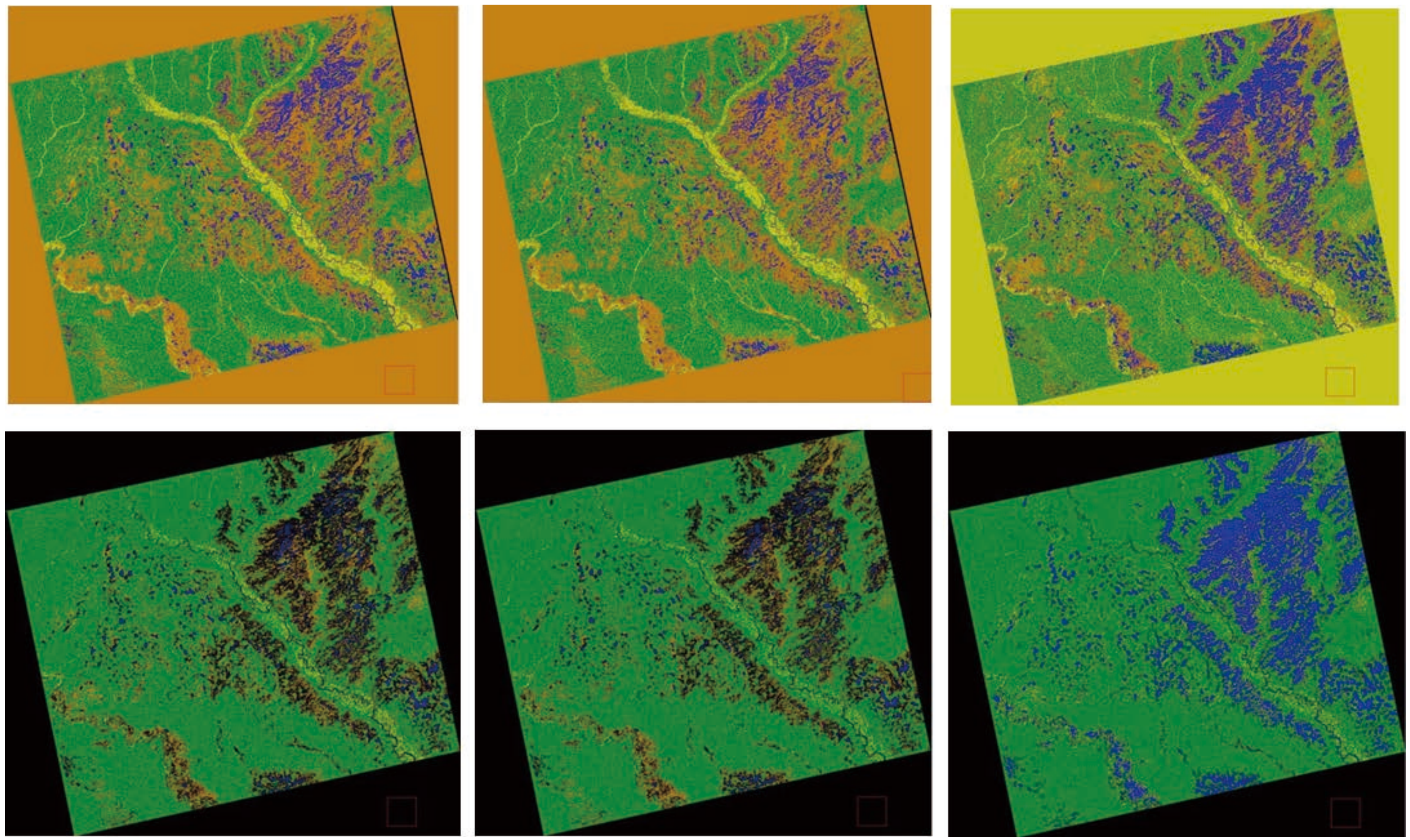
- Photo credits: Eduardo Prata (INPA, Brazil)


Gulf of Venezuela
Isla de Margarita
Caracas
Port of Spain
Lake Maracaibo
Cordillera De Mérida Mountains
Panama
Venezuela
Embalse de Guri
Cordillera Oriental
Georgetown
Guyana
Paramaribo
Guiana Highlands
Bogota
Cayenne
Suriname
Cayenne
Pacaraima Mountains
Colombia
Cordillera Occidental
Wilhelmina Mountains
French Guiana
Cordillera Central
State of Roraima
Tumuc-Humac Mountains
Serra De Curupira
Serra Acarai Mountains
State of Amapá
Quito
Rio Amazonas
Araca
Ecuador
Lagoa Uraria
State of Pará
Uatuma
Rio Solimões
State
© 2016 Google
US Dept of State Geographer
Image Landsat
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Google Earth

ALOS PALSAR HH-polarization High-res terrain corrected FBD Acquisition date: Oct-16 2010

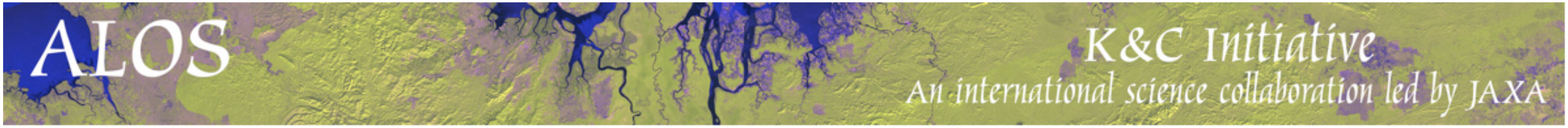


White sand Vegetation
Terra Firme
7190_25177_HH (dB)
-30.603
-0.261416



Classified maps over Araca region. Layers used from left to right in both rows: All 12 scenes (wet and dry season), only wet season (HH- and HV-pol) and only dry season (HH-pol).

Top row used ML classification and the bottom row used parallelepiped classification



Project Deliverables

- Updated wetlands maps from SAR datasets, providing 30-year record (Alaska, South America, Africa)
- Global 25km resolution inundated area maps over 1992-2013 and updated annually, validated and assessed using PALSAR, PALSAR 2 and JERS SAR
- Tidal wetlands map of the Chesapeake Bay estuary region.
- Biome maps of the Amazon basin and Brazilian Atlantic Coastal Forest.
- Prototype multi-sensor freeze/thaw state algorithm and maps for boreal study areas, including ***HMA study domain***.
- Delineation of contemporary land cover (vegetation) related to carbon and climate zonation for focused regions of the Amazon basin and the Brazilian coastal rain forest based on PALSAR and PALSAR 2.

PALSAR/PALSAR-2 dataset issues

We have been concentrating on use of the fine beam Level 1.5 format data.

- geolocation errors are difficult and tedious to correct for co-registration purposes supporting data fusion.

- We would like to utilize Level 1.1 data to support geolocation and potential InSAR work.

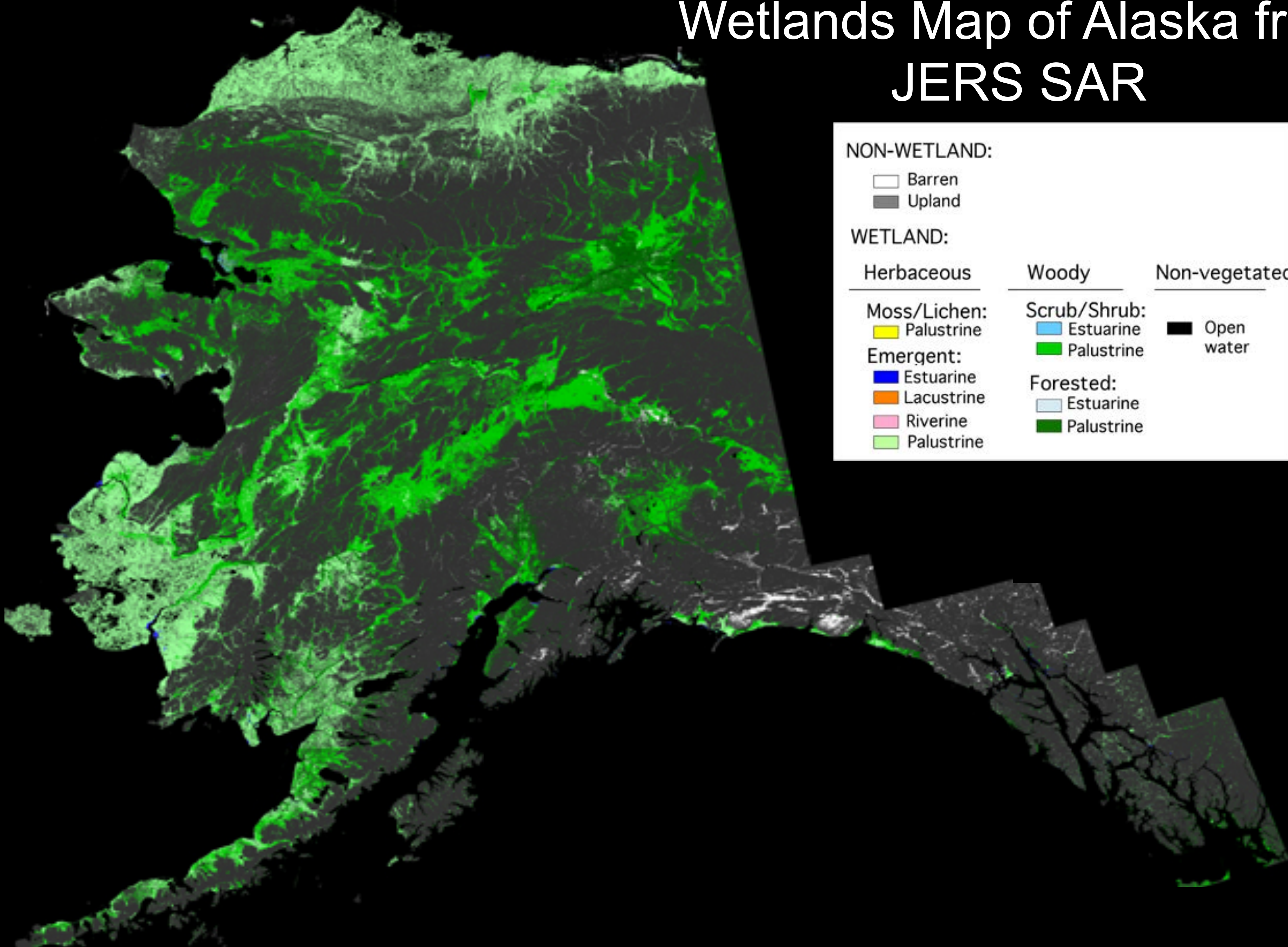
- Can we re-acquire L 1.1 data for the scenes we have already have without using additional data credits?

Large scale mosaics across Amazon will support biodiversity projects.

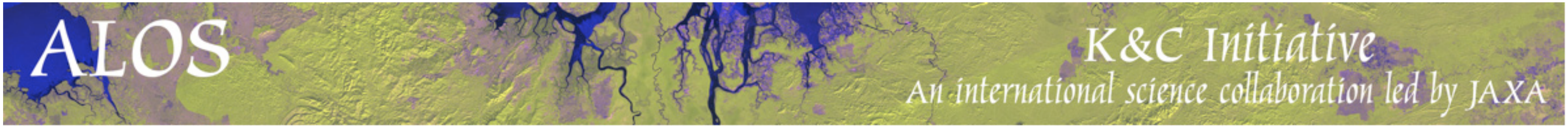
New data/regions needed: High Mountain Asia

Issue: 50 scene per year limit is severely constraining our use of PALSAR-2 across these projects.

Wetlands Map of Alaska from JERS SAR



Whitcomb, Moghaddam, McDonald, Kellndorfer, and Podest, Canadian Journal of Remote Sensing, 2009

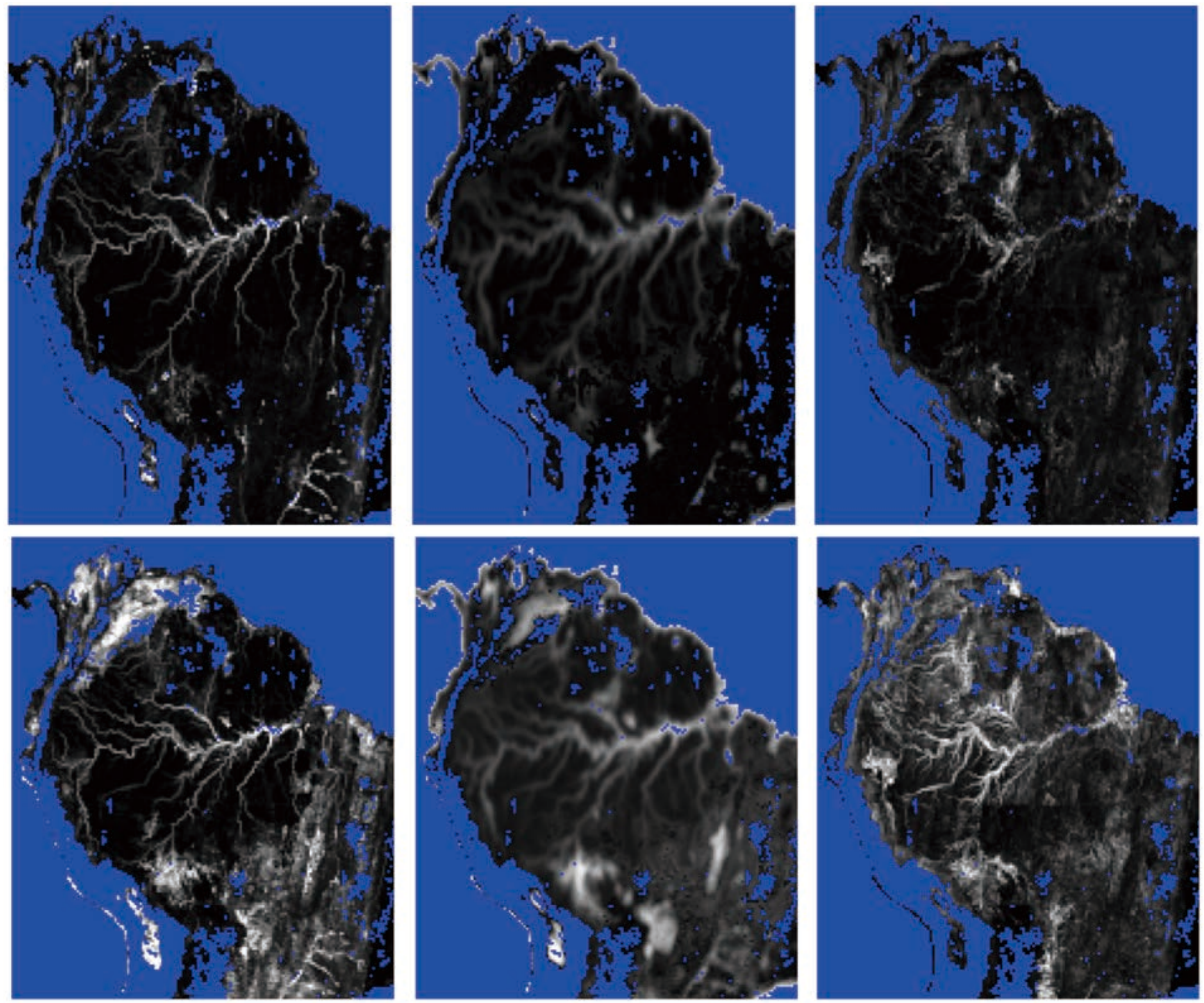


Cross-Product Verification

Comparison of fractional open surface water area from coarse resolution sensors with ALOS SCANSAR open surface water fraction and inundated vegetation fraction

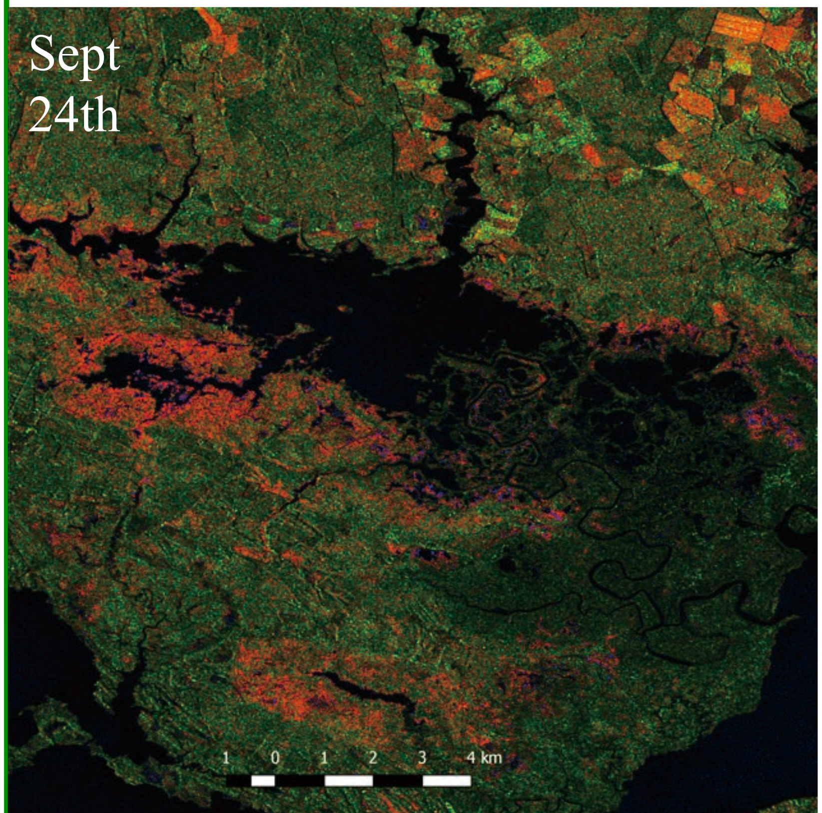
Fractional open surface water area | Open water from ALOS ScanSAR classification | Inundated vegetation from ALOS ScanSAR classification

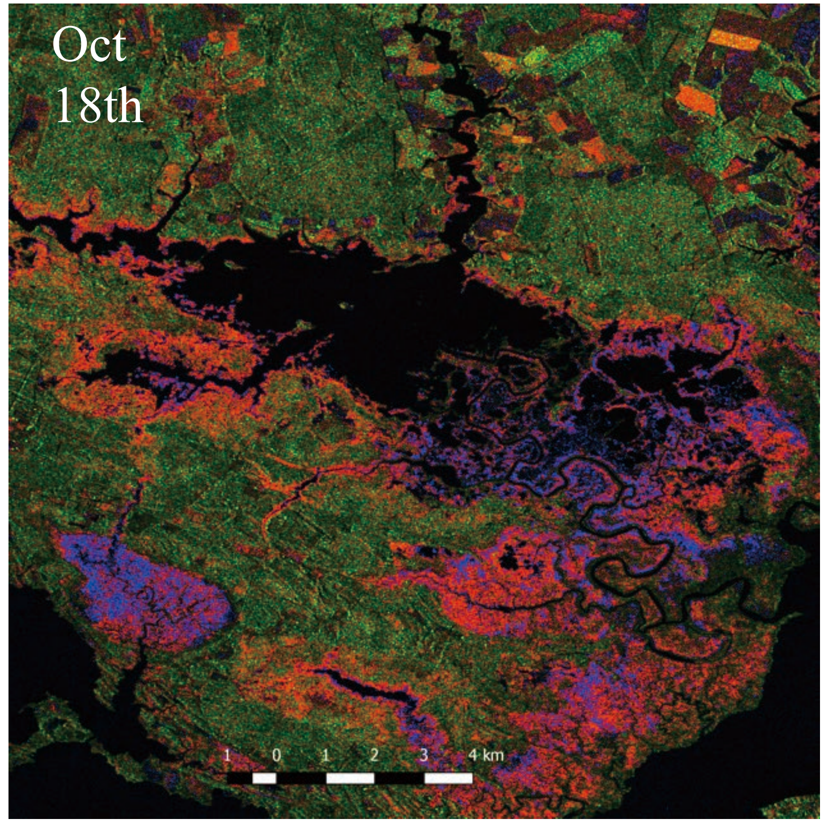
Minimum



Maximum

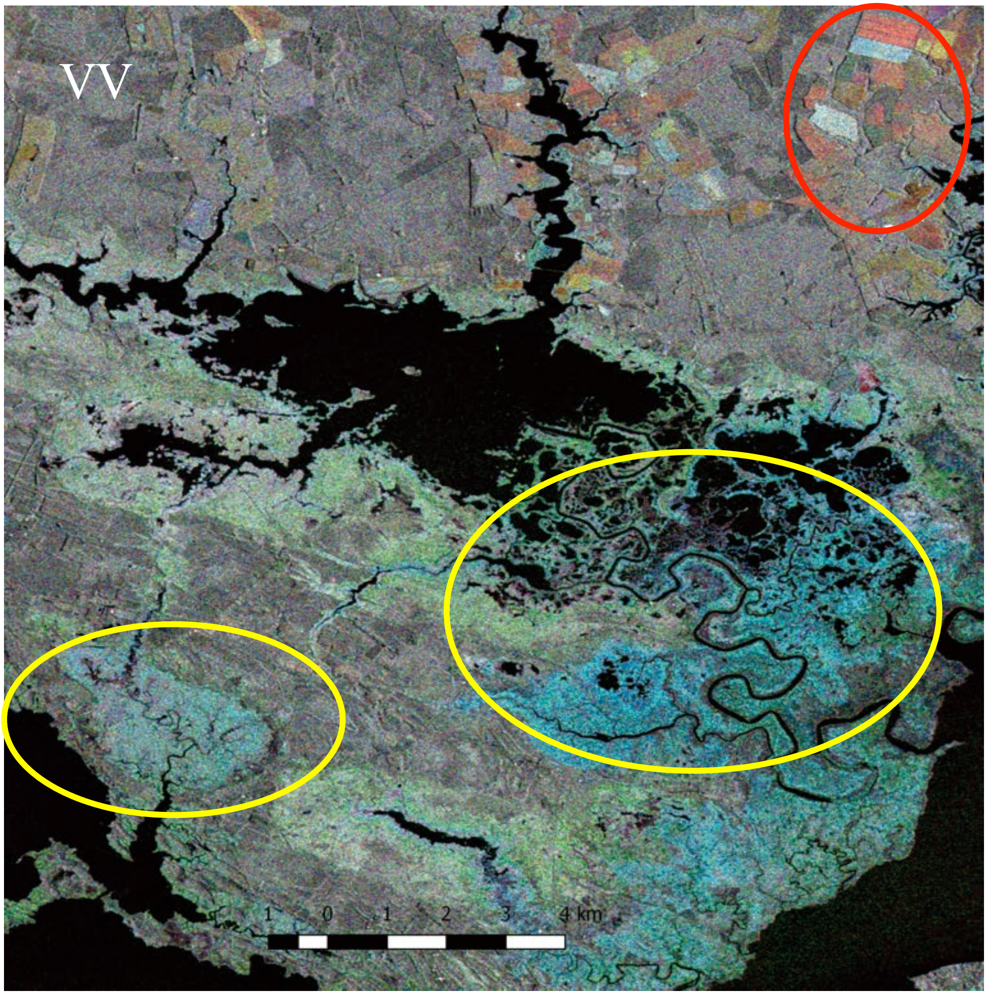
Scattering mechanism classification (Blackwater NWR)

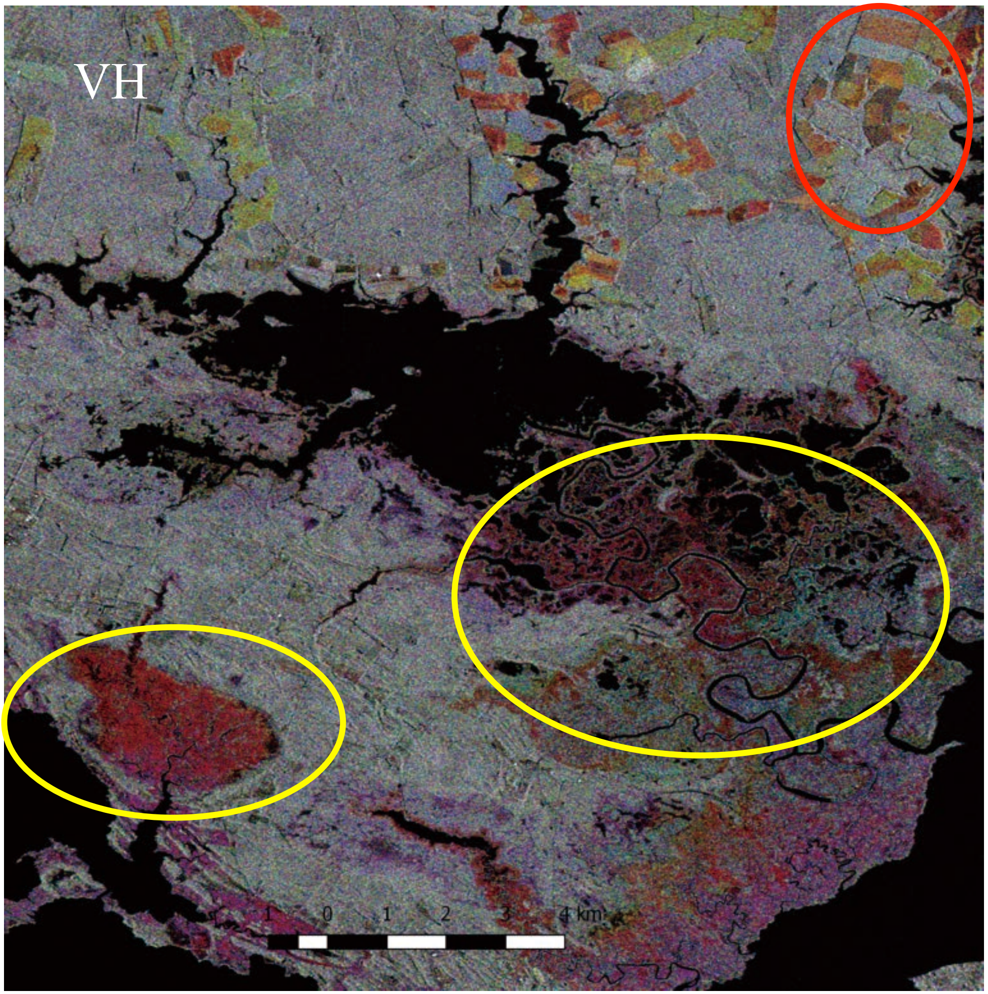




- Red: VV (if VH*3 > open water value)
  - Non-volume vegetation scattering, corner reflectors
- Green: VH*3
  - Volume scattering
- Blue: VV (if VH*3 < open water value)
  - Non-volume scattering

Blackwater timeseries: September 24th, October 6th, October 18th Note the similarities between VV and VH timeseries imagery for agricultural regions in red, and differences in tidal marshes in yellow





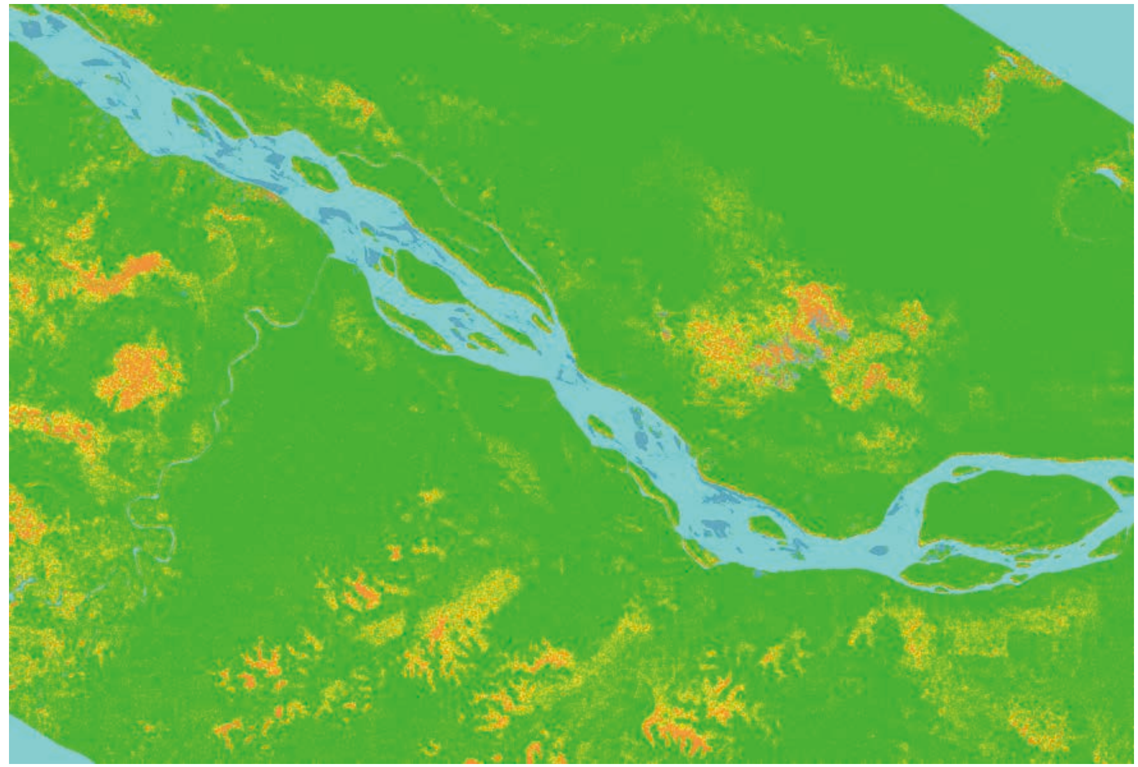
Classification of UAVSAR data over Napo River in Peru (2013)

Vegetation inundation state determined along two transects within 2 days of UAVSAR data acquisition

Classification derived from Van Zyl decomposition of L-band Quad Pol data UAVSAR

Classification verified along field transects

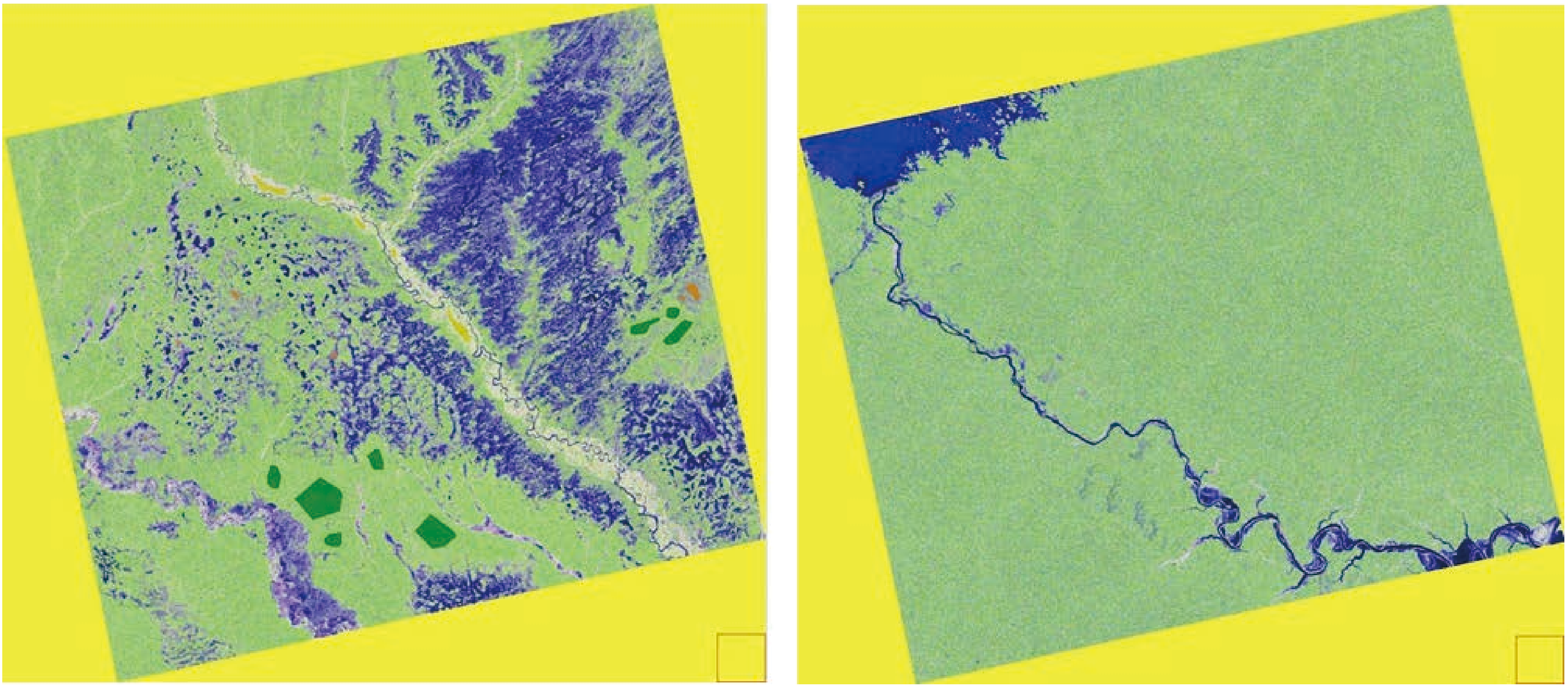
This image spans incidence angles from 20° to over 60° (as determined from the SRTM DEM)



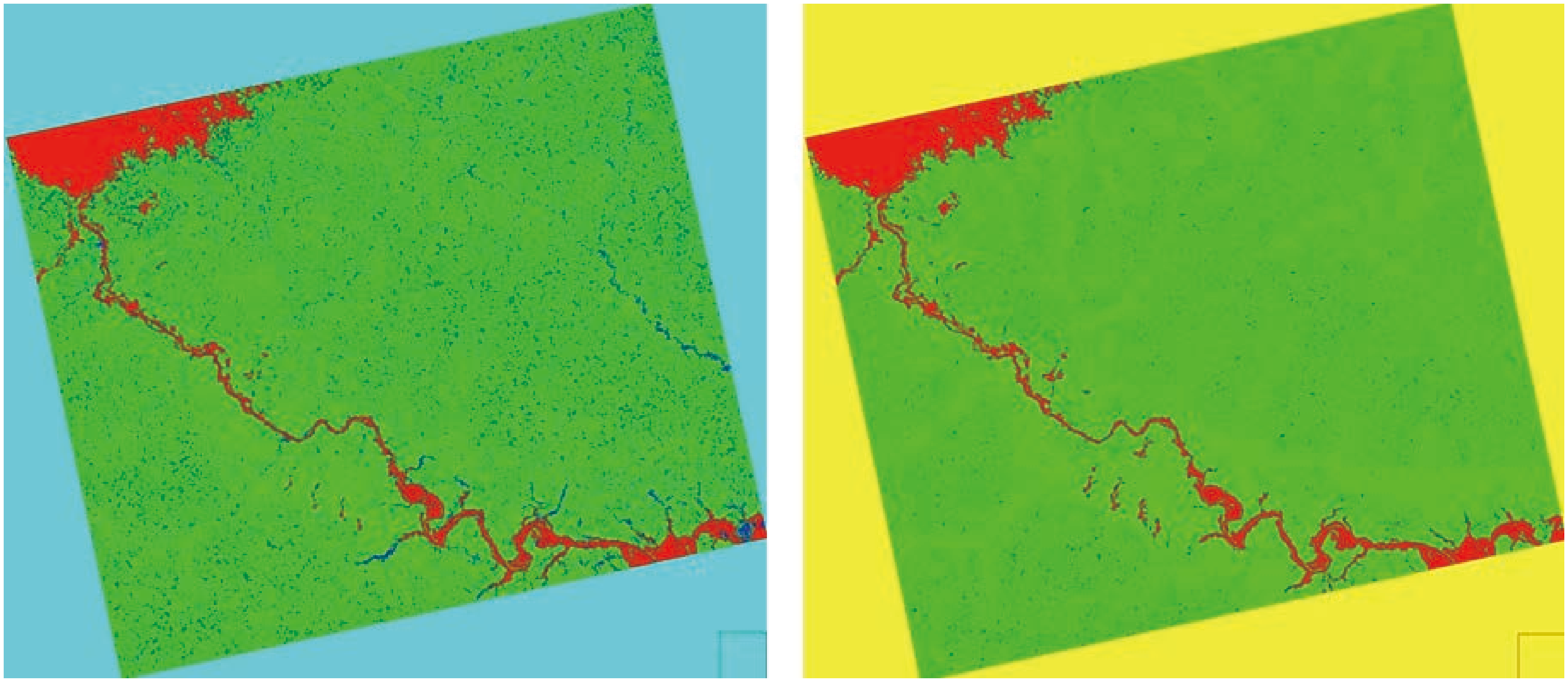
UAVSAR Inundation Classification : Green: not inundated
Yellow and Orange: inundated vegetation
Light and Dark Blue: open water/bare ground

UAVSAR data acquired
March 31, 2013

Chapman et al, "Validation of forested inundation extent revealed by L-band polarimetric and interferometric SAR data", IGARSS 2014, Quebec, Canada July 2014



RGB image of PALSAR tile over Araca (left) taken during the wet season in Aug 2007 with ROIs superimposed and Uatuma (right).
Red channel: HH-polarization Green channel: HV-polarization Blue channel: HH/HV ROIs: Green: Terra Firme; Orange: Other vegetation; Blue: Open Water



Classified maps over Uatuma region. Layers used from left to right: All 12 scenes (wet and dry season), only wet season (HH- and HV-pol).
K-means unsupervised classification method used with 4 classes.