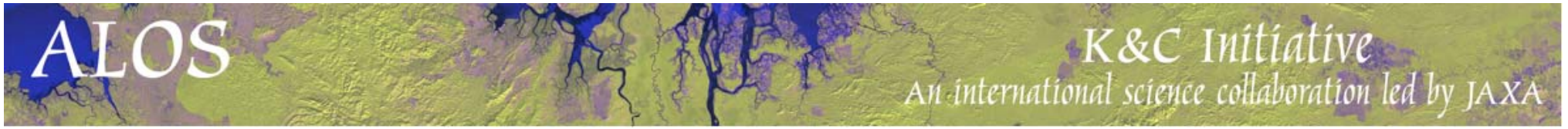


Mapping Global Wetlands and Boreal Freeze/Thaw with ALOS PALSAR

Kyle C. McDonald

Environmental Crossroads Initiative and CREST Institute
Department of Earth and Atmospheric Sciences
The City College of New York
New York, NY 10031 U.S.A.

Science Team meeting #16 – Phase 3 Kick-off
JAXA TKSC/RESTEC HQ, Tsukuba/Tokyo, October 17-21, 2011

Objectives

- A continuation of our wetlands mapping efforts, now extending from boreal to global-scope,
- A development of a new, high resolution time series landscape freeze-thaw state mapping across the domain of the ASF-processed ScanSAR data.

An Inundated Wetlands Earth System Data Record: Global Monitoring of Wetland Extent and Dynamics

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.

An Earth System Data Record for Land Surface Freeze/Thaw State: Quantifying Terrestrial Water Mobility Constraints to Global Ecosystem Processes

Objective: Construction of a consistent, systematic long-term global record of land surface freeze/thaw state dynamics for all vegetated regions where low temperatures are a major constraint to ecosystem processes.

An Inundated Wetlands Earth System Data Record: Global Monitoring of Wetland Extent and Dynamics

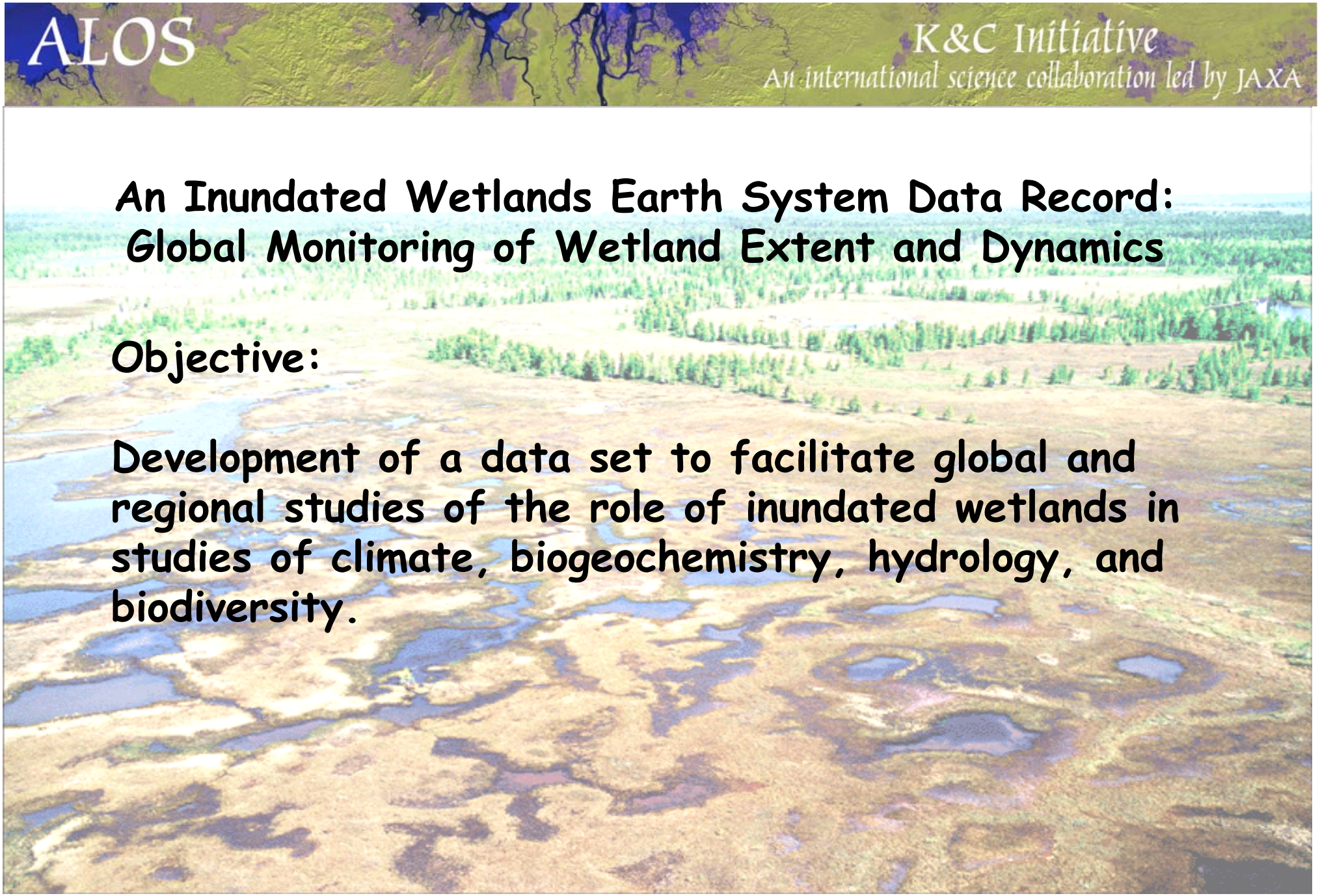
Principal Investigator: Kyle McDonald (City College of New York)

NASA Project Scientist: Diane Wickland (Terrestrial Ecology Program)

Project Members:
Bruce Chapman (JPL/Caltech)
Laura Hess (University of California, Santa Barbara)
John Kimball (University of Montana)
Mahta Moghaddam (The University of Michigan)

Collaborators:
Ake Rosenqvist (JRC- Italy)
Masanobu Shimada (EORC-JAXA – Japan)
Wenjun Chen (Canadian Centre for Remote Sensing
Nick Davidson (Ramsar)
Lisa-Maria Rebello
(International Water Management Institute, Ethiopia)

An Inundated Wetlands Earth System Data Record: Global Monitoring of Wetland Extent and Dynamics



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.

Components of the Inundated Wetlands Earth System Data Record

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, 1992-2009 †
1. Globally gridded (25km) inundated area fraction (10 day intervals)
2. Globally gridded (25km) annual inundation duration

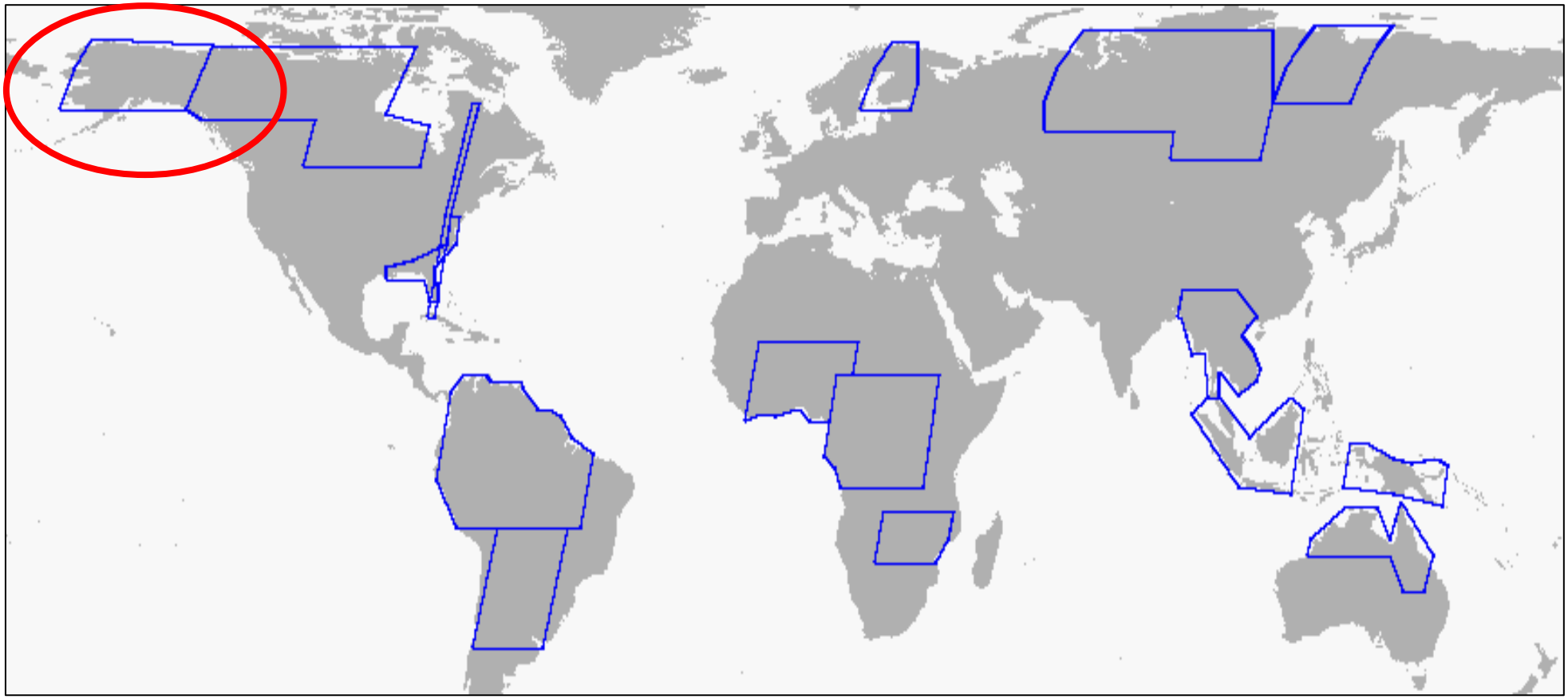
† The domain of the 25-km and 100-m data sets excludes permanently frozen regions and seasonally frozen landscapes during the frozen season, although data from frozen seasons is used to improve classification accuracy.

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

Science Products:

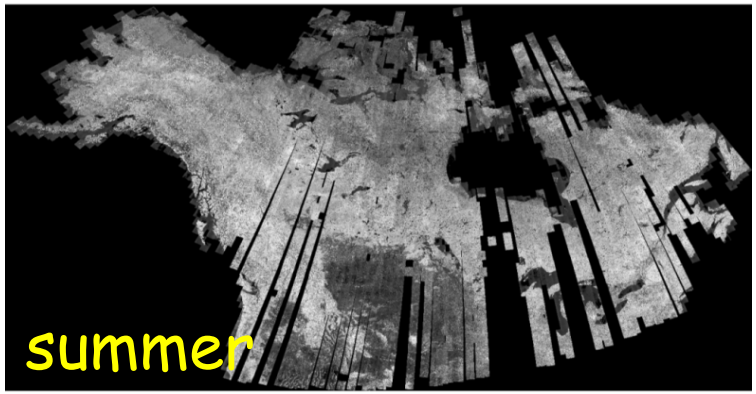
- Inundated wetland area (swath-by-swath)
- Principal wetland vegetation classes (non-vegetated, herbaceous, shrub, woodland, forest)
- Seasonally based summary products describing timing and extent of wetland inundation
- ScanSAR coverage has a 46-day repeat cycle with ~17-day sub-cycles

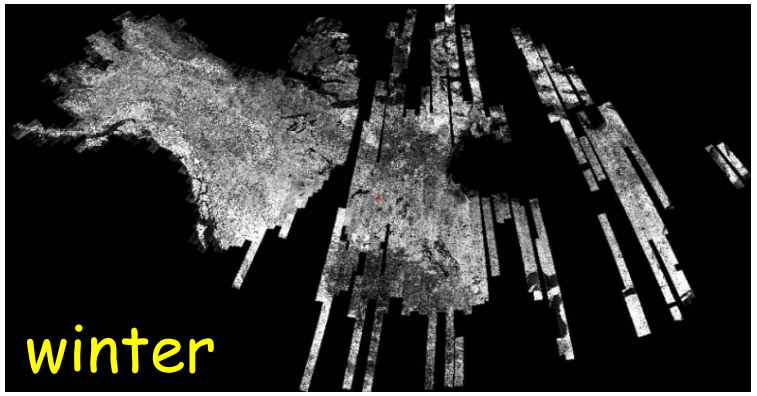
Project Areas: ScanSAR regions



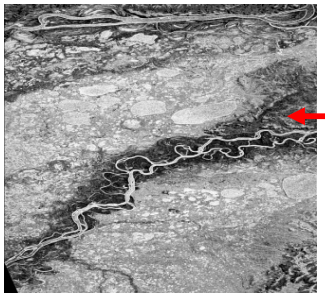
JERS Imagery

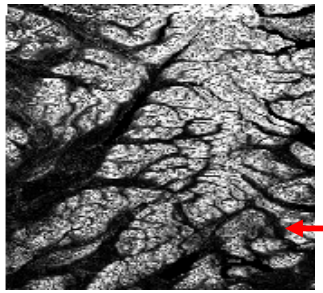
- HH only
- Operational 1993-1998
- Used to develop summer and winter mosaics covering much of North America @ *100 m resolution*
- Less-than-perfect quality …
  - no orthorectification
  - poor geolocation, signal-to-noise performance, radiometric accuracy
  - prominent swath-to-swath variations in mean backscatter amplitude
- Still, imagery captures status in late 1990s time frame
  - is used here to establish temporal variations

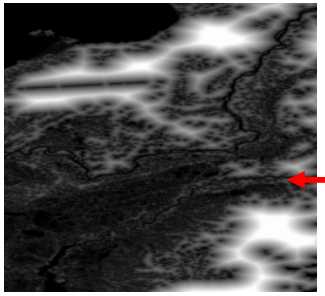




Ancillary Data Used in Wetlands Classification







Data	Purpose	Source
SAR texture	provides measure of SAR brightness variability	Derived from SAR imagery
SAR date-of-collection	allow adjustment for temporal differences between swaths	Provided with imagery
DEM	accounts for local terrain altitude	NED
Slope	masks out areas of high slope (> 3°), provides local surface orientation	Derived from DEM
Open water mask	masks out areas of open water	Derived from SAR imagery
Proximity to water	allows adaptation for waterside ecosystems	Derived from water mask
Latitude	captures effects of geographic location	Generated by GIS software

Ground Reference Data

- Composite ground reference data layer used to train classification algorithm, validate classification results
- Includes ground reference data from:
  - Various wetlands study sites in Canada
    - BOREAS
    - Mer Bleue
    - Ramsar sites
      - e.g., Long Point
    - Ducks Unlimited Canada
  - For locations near US:
    - National Wetlands Inventory (NWI)
      - Cowardin wetlands classification system
    - Alaska Geospatial Data Clearinghouse (AGDC)
    - National Land Cover Database (NLCD)

Classification Technique (1)

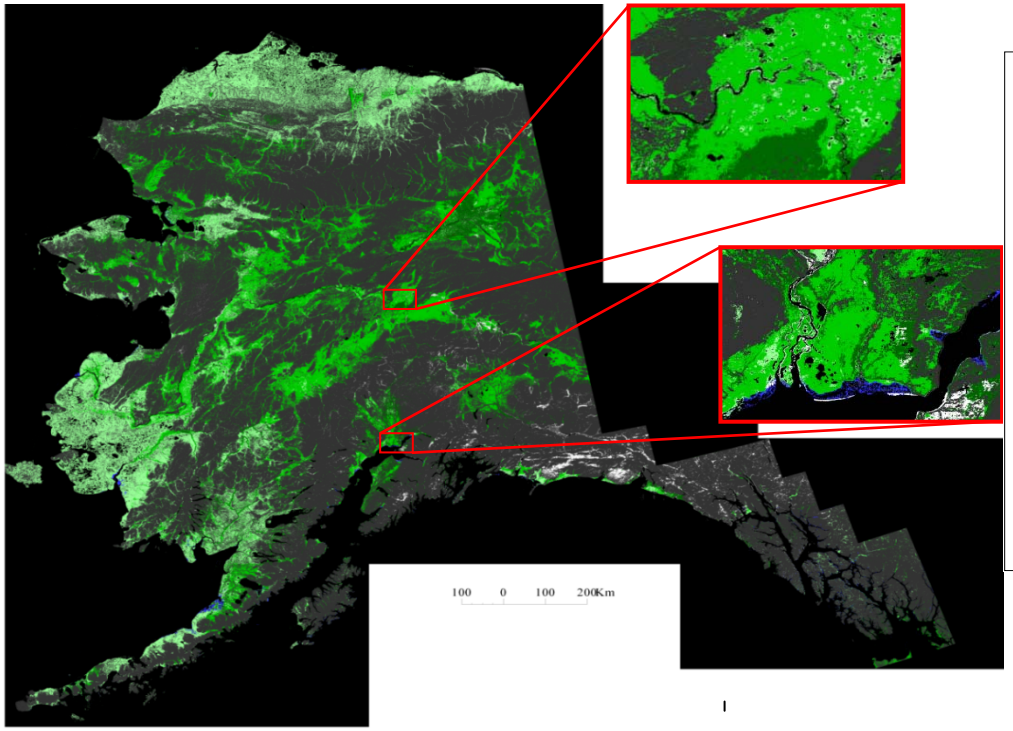
- Standard classification methods (e.g., maximum likelihood estimation, isodata) yield poor results due to swath-to-swath brightness variations
- Current approach based on novel classification algorithm “Random Forests”
  - Statistically based decision tree classifier
  - Accepts input data from variety of imagery, ancillary data sources
  - First constructs a large number, a “forest”, of decision trees
  - Then classifies each pixel by implementing all decision trees in the "forest" and setting the class code of the pixel equal to the class selected by the most decision trees

Classification Processing: Ground Reference Issues

- Regions where ground reference data are unavailable
  - 1) Run Random Forests in a nearby, similar-ecosystem region and save the decision tree forest
  - 2) Run Random Forests based on the saved forest in the region of interest
    - Caveat: Accuracy computation not possible for runs based on saved trees
- Regions where ground reference data are sparse
  - Currently developing capability to classify based on local ground reference pixels plus saved decision trees

Late 1990s Map: Based on JERS-1 Imagery

Previously used summer and winter JERS-1 imagery to develop a thematic map of wetlands throughout Alaska



NON-WETLAND:
- Barren
- Upland

WETLAND:

Herbaceous	Woody	Non-vegetated
Moss/Lichen: Palustrine	Scrub/Shrub: Estuarine	Open water
Emergent: Estuarine	Scrub/Shrub: Palustrine	
Emergent: Lacustrine	Forested: Estuarine	
Emergent: Riverine	Forested: Palustrine	
Emergent: Palustrine		

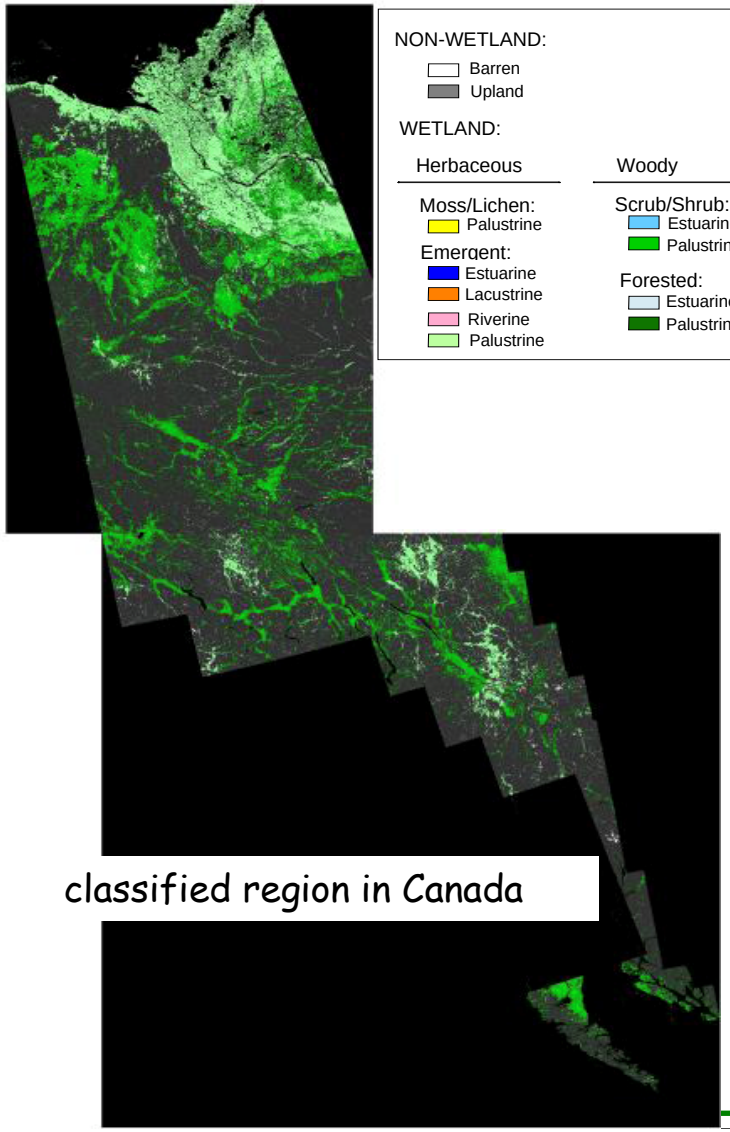
- Aggregate accuracy approximately 89.5%
- Used to generate tally of wetlands for Alaska

Whitcomb, J., Moghaddam, M., McDonald, K., Podest, E., Kellndorfer, J., Wetlands Map of Alaska Using L-Band Radar Satellite Imagery, Canadian Journal of Remote Sensing, 2009, Vol. 35, pp. 54-72 (winner of Best-Paper-of-Year award)

JERS-1 for Canada

- First section based on saved decision tree forest from nearby region in Alaska
- Large-scale ecosystem maps confirm ecosystem of saved forest region in Alaska very similar to that of location of interest in Canada
- Classification accuracy for saved forest 85%

saved forest region in AK



classified region in Canada

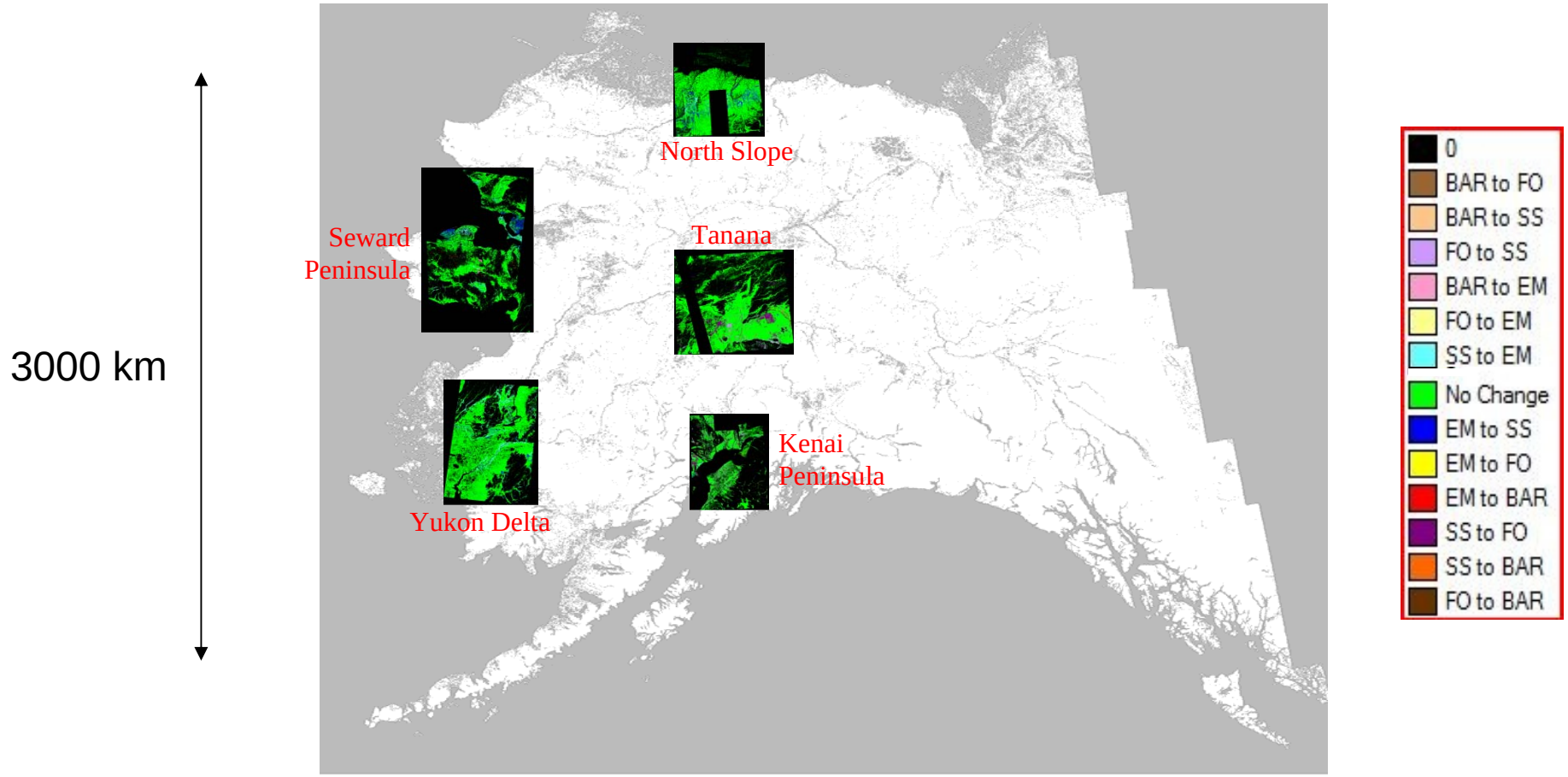
Accuracy Assessment

- **Error analysis based on confusion matrices generated during each classification procedure**
  - **Reflects performance for validation pixels**
  - **Aggregate 47 original wetlands and uplands classes into several top-level classes to derive aggregate error rate**
  - **Typical confusion matrix:**

Wetlands Code:	E2EM	E2EM	PEM	PEM	PEM	PSS	PSS	PFO	BAR
Wetlands Type:	2	4	31	33	35	38	40	46	47
Class Number:	1	2	3	4	5	6	7	8	9
1	21021	3964	0	1646	20	0	0	0	1895
2	2456	65546	28	8047	79	201	0	0	890
3	0	15	4861	498	625	823	17	79	12
4	819	8786	4903	233491	31210	19486	106	84	1627
5	78	176	12601	60764	374403	23835	2092	2020	1303
6	0	362	4781	21333	12211	232844	2855	4618	76
7	0	0	90	219	340	768	3843	2	0
8	0	0	13	23	31	193	0	778	0
9	104	107	2	55	9	1	0	0	1268
Total in Class:	24478	78956	27279	326076	418928	278151	8913	7581	7071
Correct in Class:	21021	65546	4861	233491	374403	232844	3843	778	1268
Class Error Rate:	14.12	16.98	82.18	28.39	10.63	16.29	56.88	89.74	82.07
Total in Superclass:					875717		287064	7581	7071
Correct in Superclass:					836037		240310	778	1268
Superclass Error Rate:					4.53			89.74	82.07

Change Mapping Based on PALSAR Imagery

- Classification of Alaskan PALSAR imagery
- So far, generally good classification accuracy (79-94%); classification parameters being optimized for increasingly better results



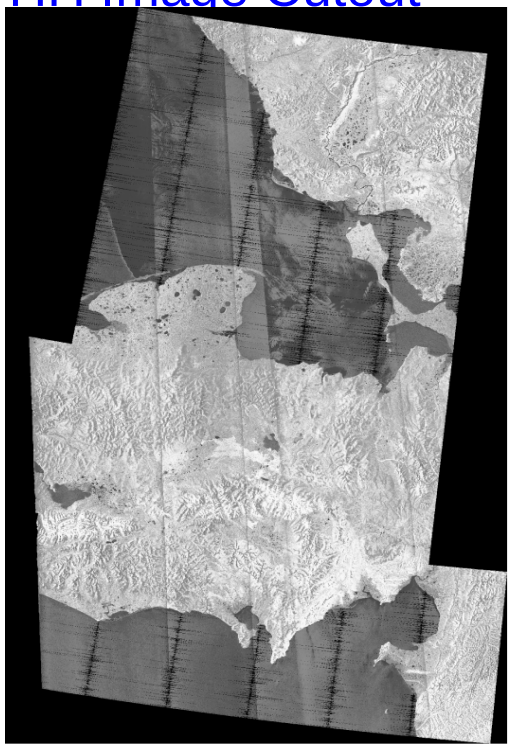
Seward Peninsula Wetlands from PALSAR

NON-WETLAND:
- Barren
- Upland

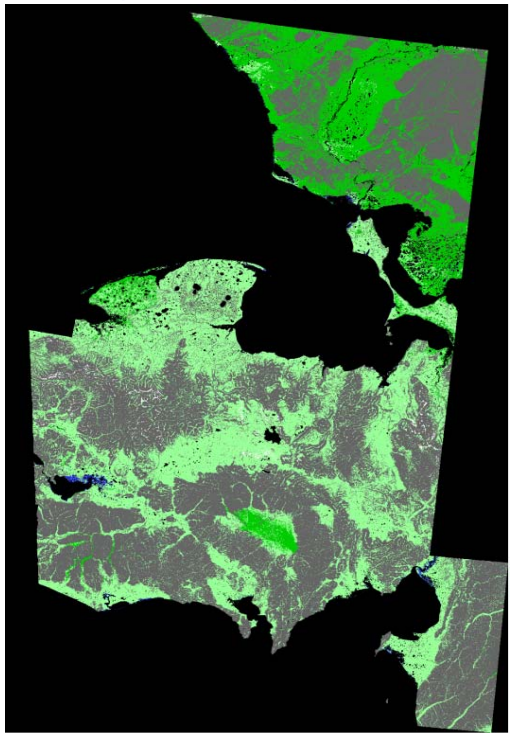
WETLAND:

Herbaceous	Woody	Non-vegetated
Moss/Lichen: Palustrine	Scrub/Shrub: Estuarine, Palustrine	Open water
Emergent: Estuarine, Lacustrine, Riverine, Palustrine	Forested: Estuarine, Palustrine	

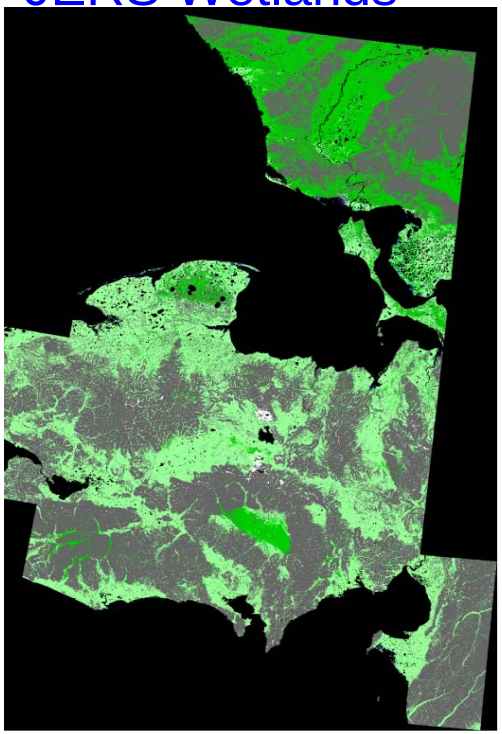
HH Image Cutout



PALSAR Wetlands

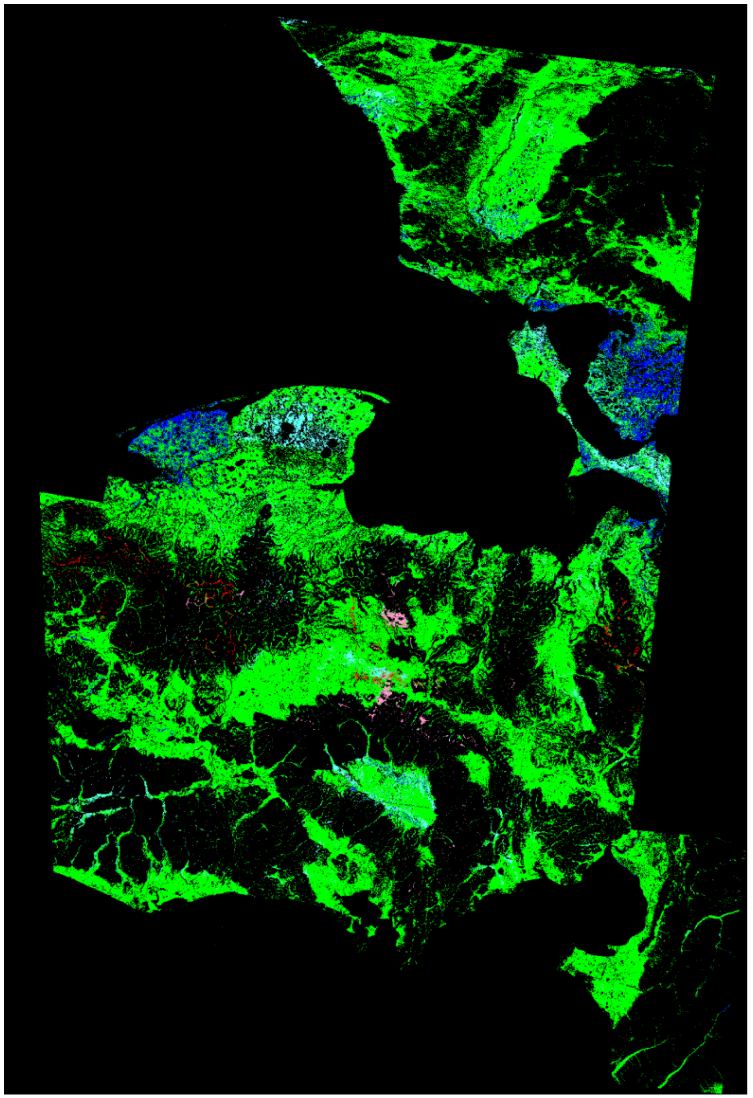


JERS Wetlands



Seward Peninsula Wetlands Decadal Change

- Region shows quite a bit of change, with most significant being transitions of:
  - Emergent to Scrub/shrub
  - Some Scrub/shrub to Emergent
  - Small amounts of:
    - Barren to Emergent
    - Emergent to Barren



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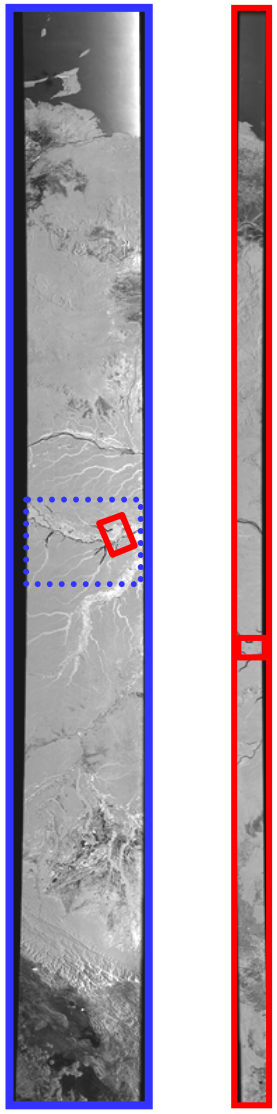
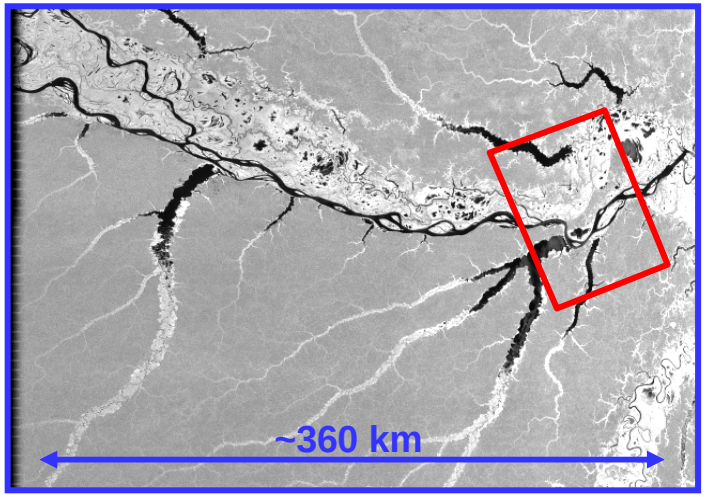
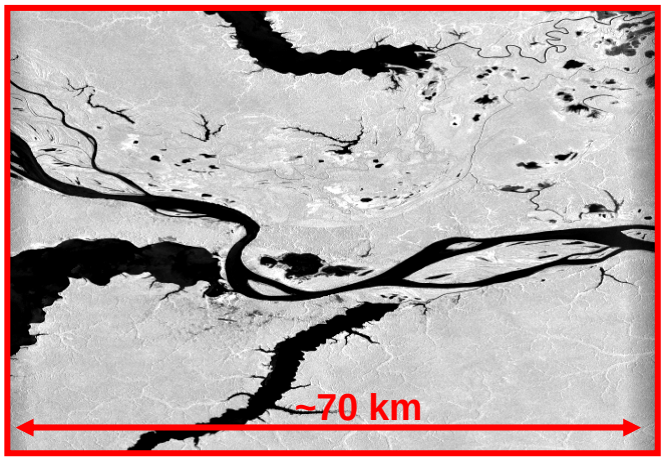


WB

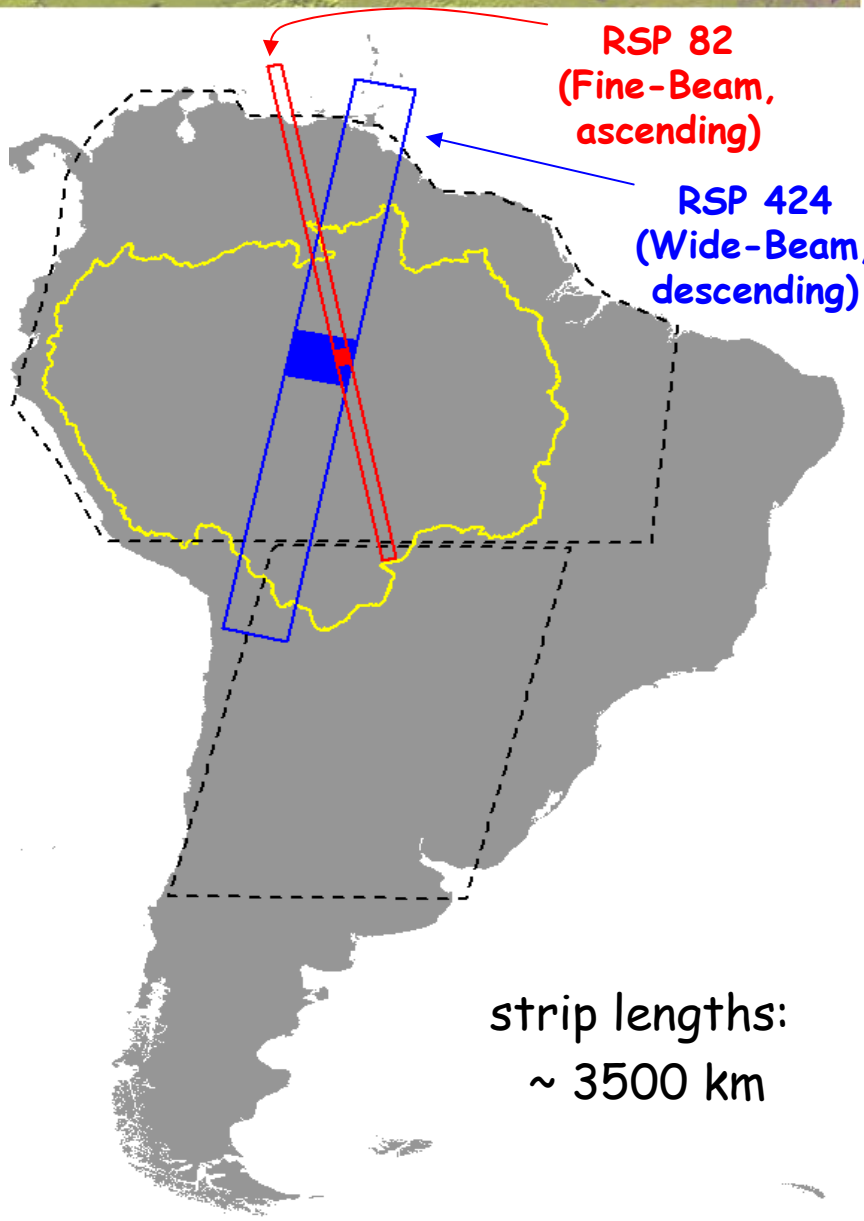
FB



Wide-Beam, slant range, ~100 m



Fine-Beam, slant range, ~50 m



strip lengths:
~ 3500 km

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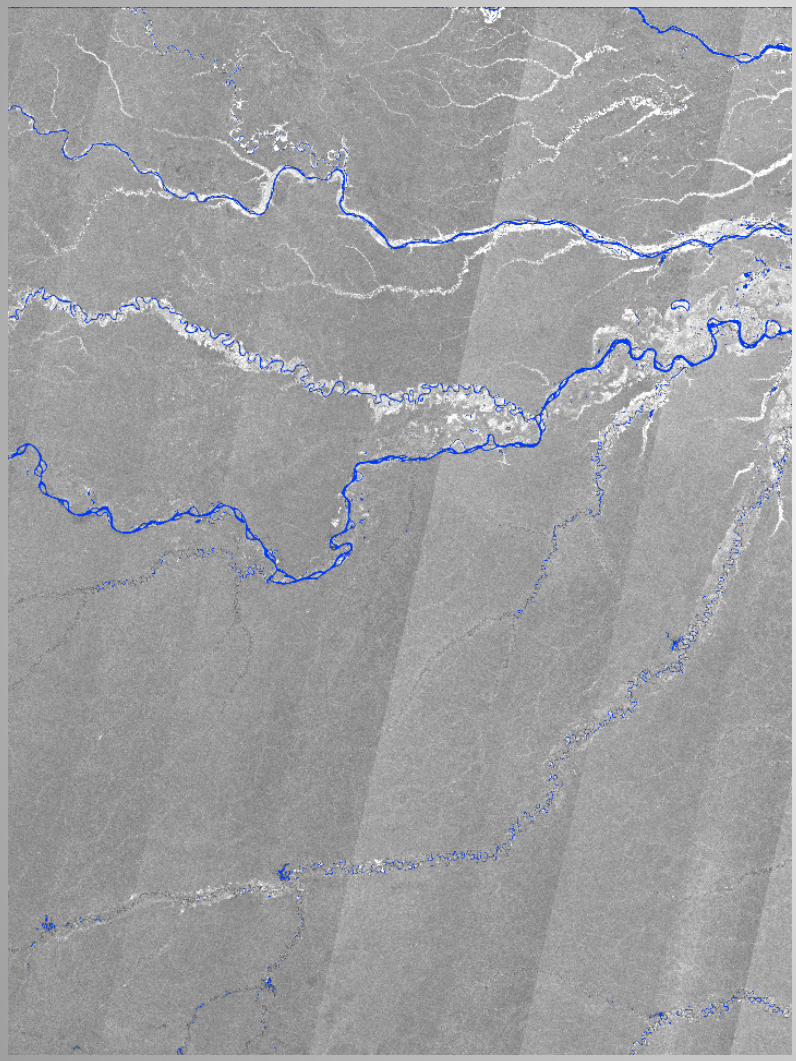
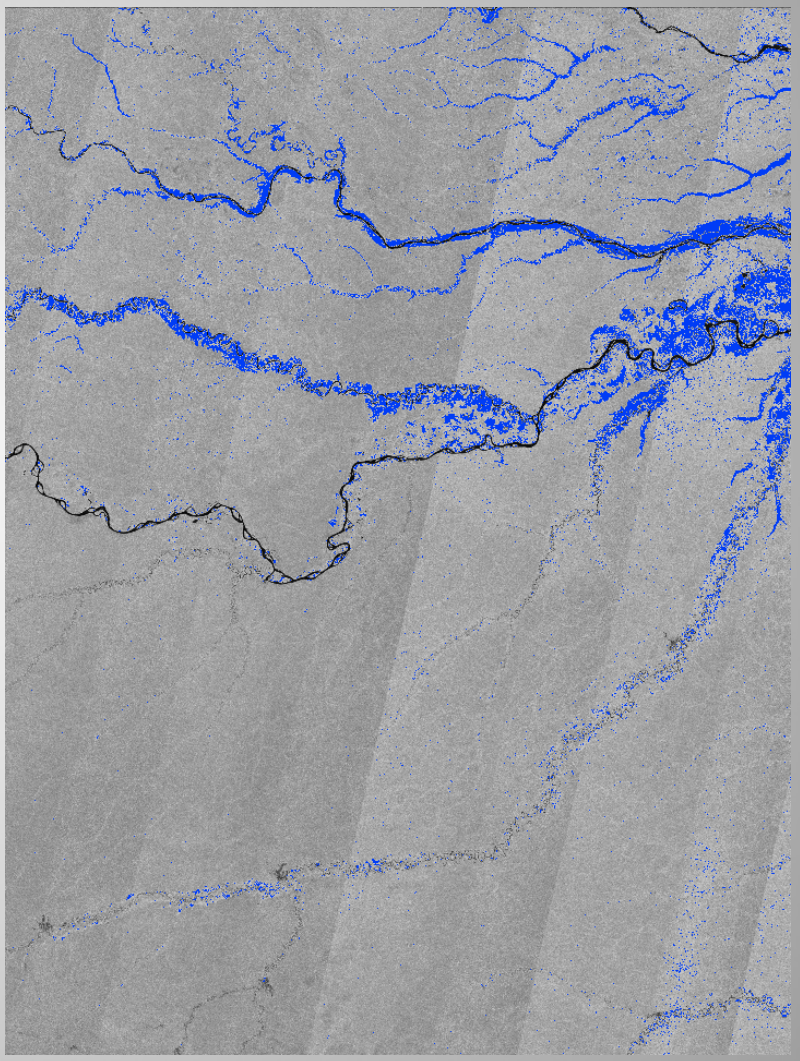
Simple thresholds for identifying open water and inundated vegetation



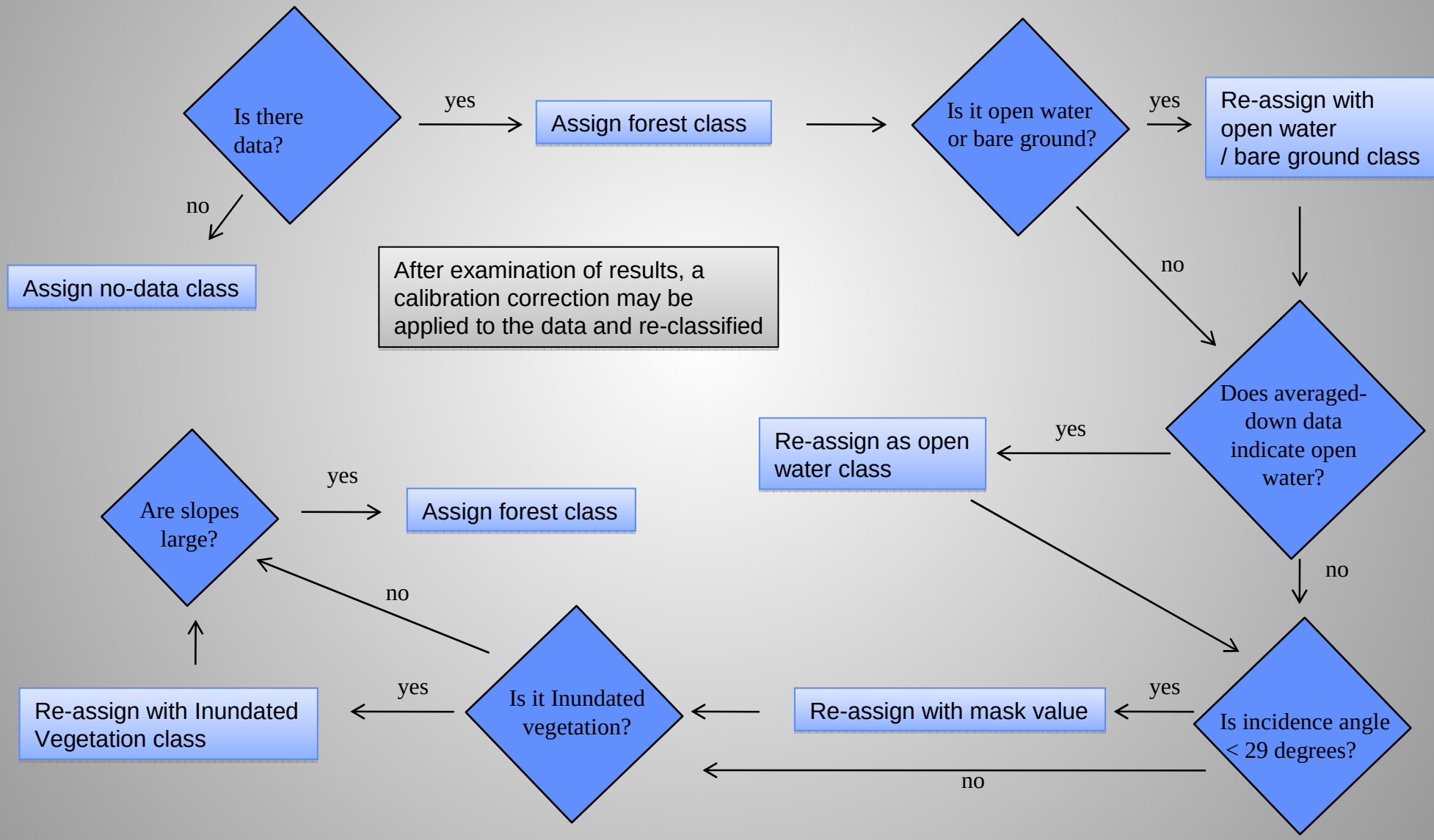
Open water → less than -10dB

19M



Inundated Vegetation → greater than -6 dB

Simple threshold-based classification



AMSR-E+QSCAT and SSM/I+QSCAT

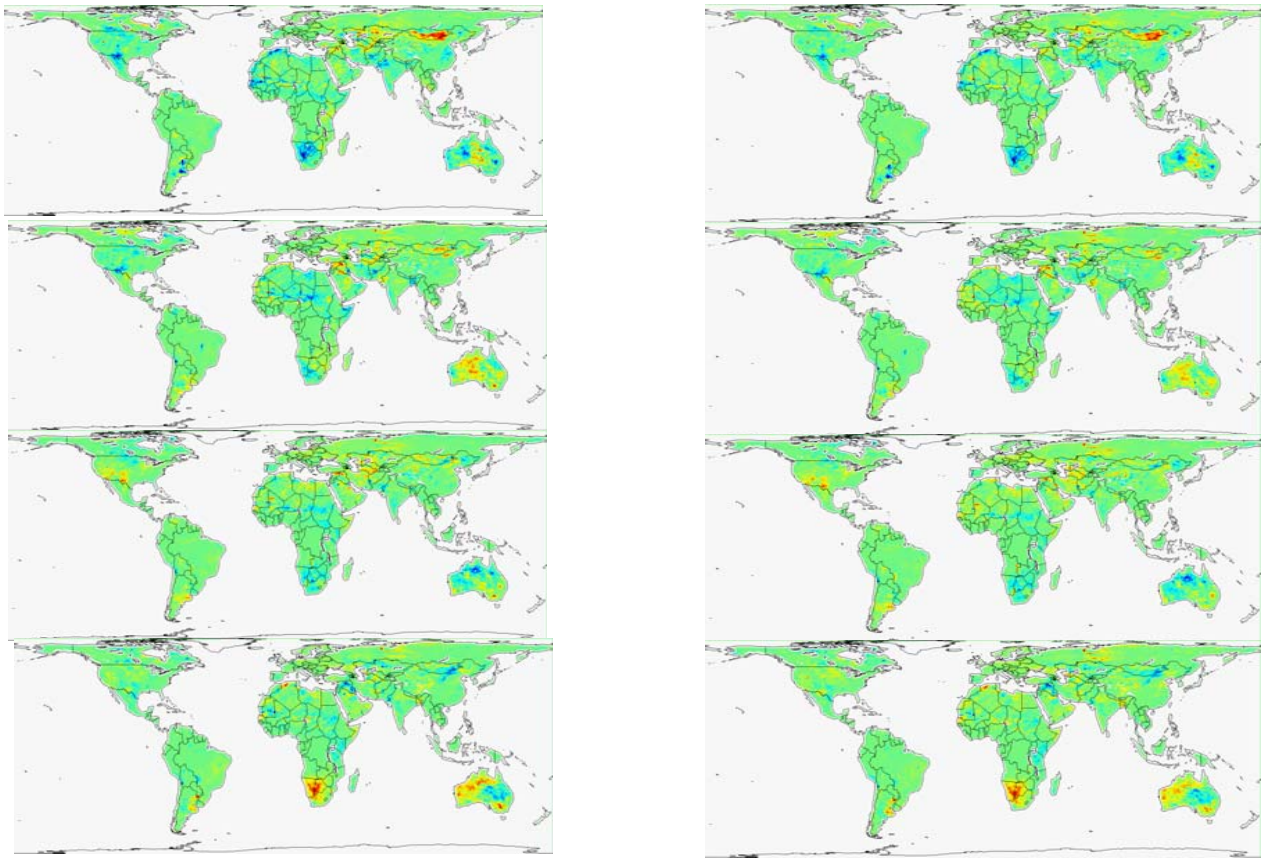
Global Anomalies 2003-2006

2003

2004

2005

2006



Surface Water Fraction [%]

-5 -2.5 0 2.5 5

QSCAT-AMSR-E 18.7 GHz

QSCAT-SSM/I 19.35 GHz

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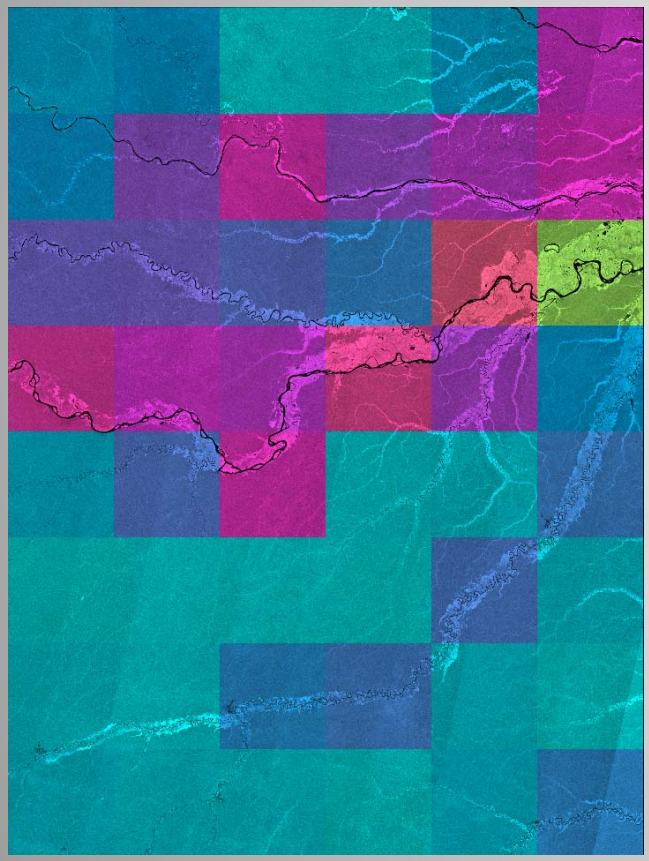
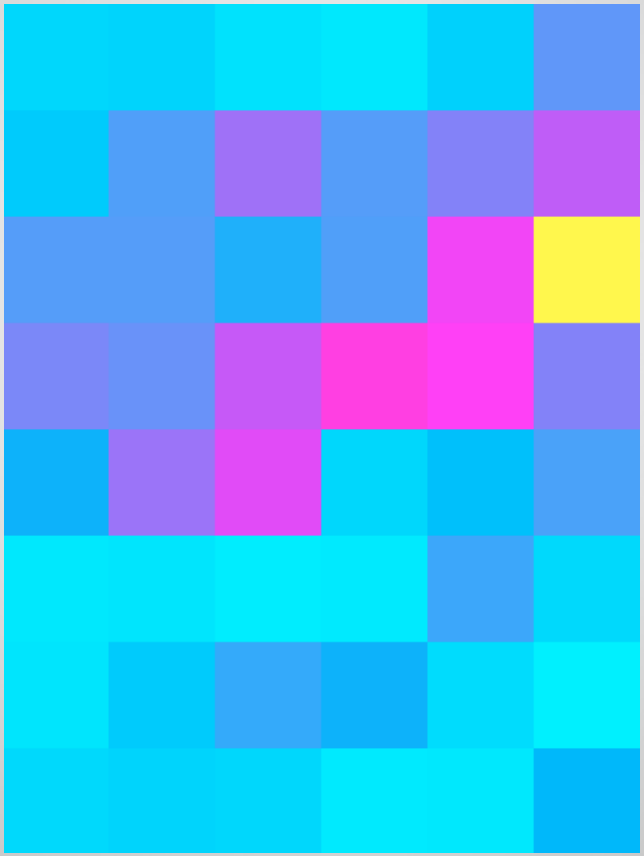
May-June 2007

Fraction for each 1deg x 1deg cell

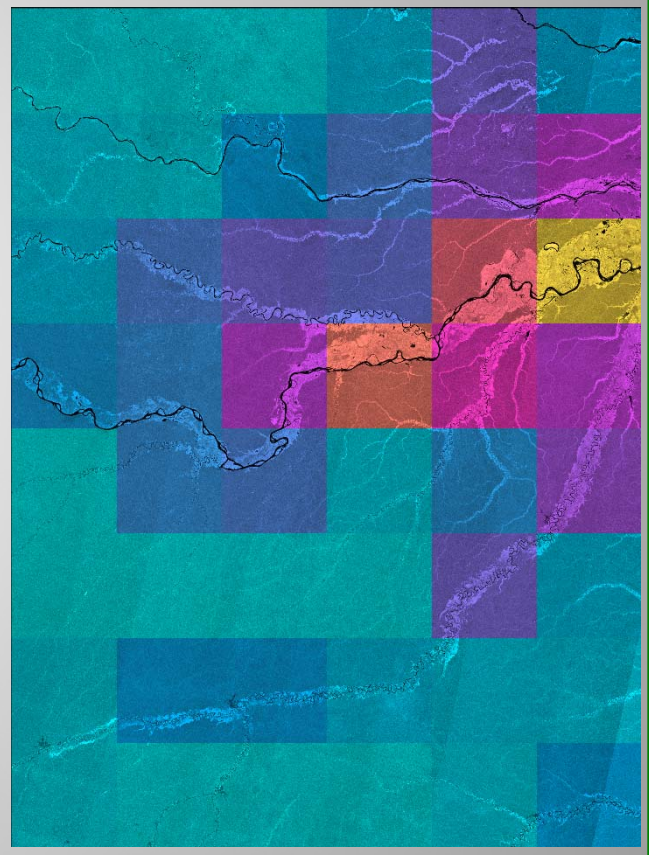
ALOS Open Water



AMSR-E/QSCAT Open Water



ALOS Inundated Vegetation



19M

Fraction open water

0% 5%

Fraction inundated vegetation

0% 40%

ALOS

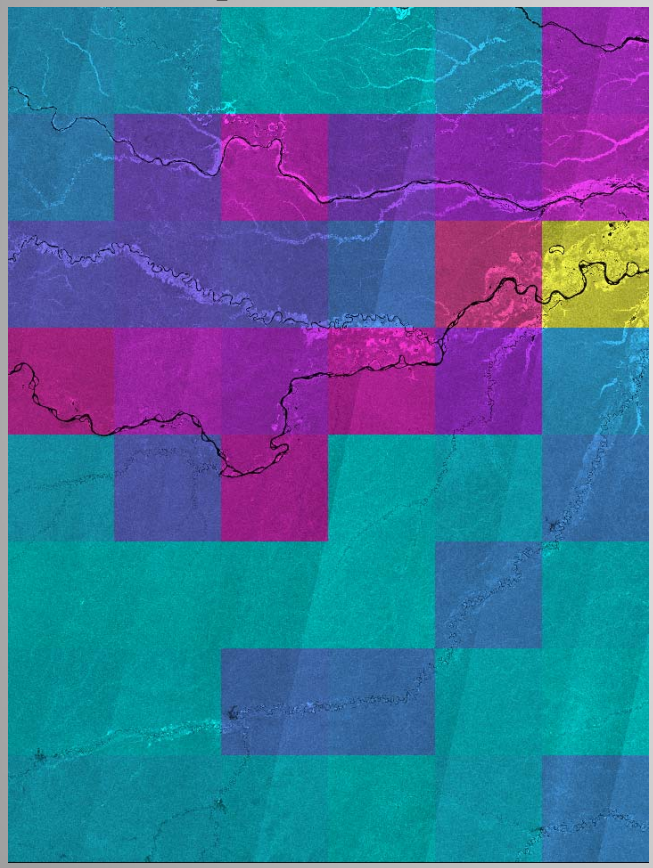
K&C Initiative

An international science collaboration led by JAXA

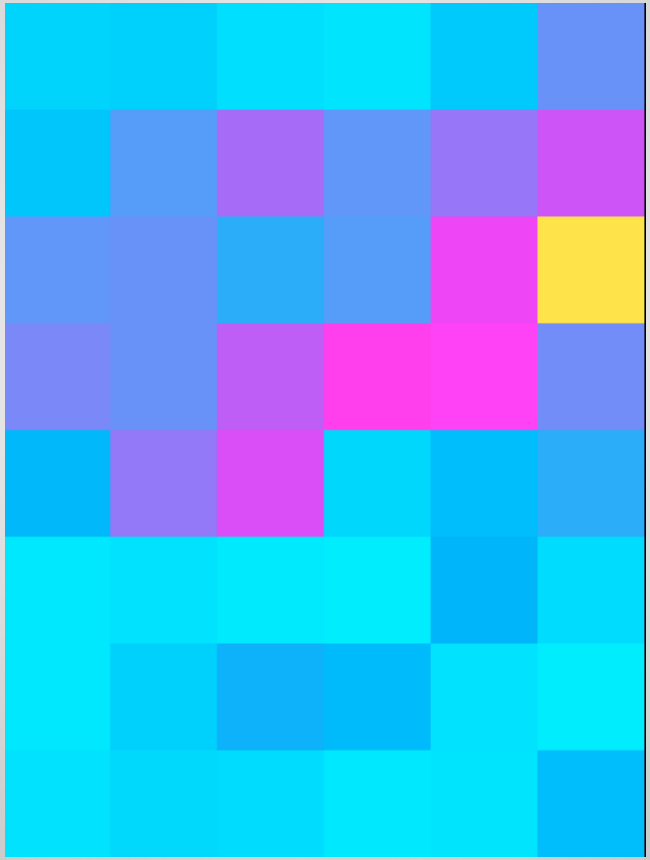
Fraction for each 1deg x 1deg cell

July 2007

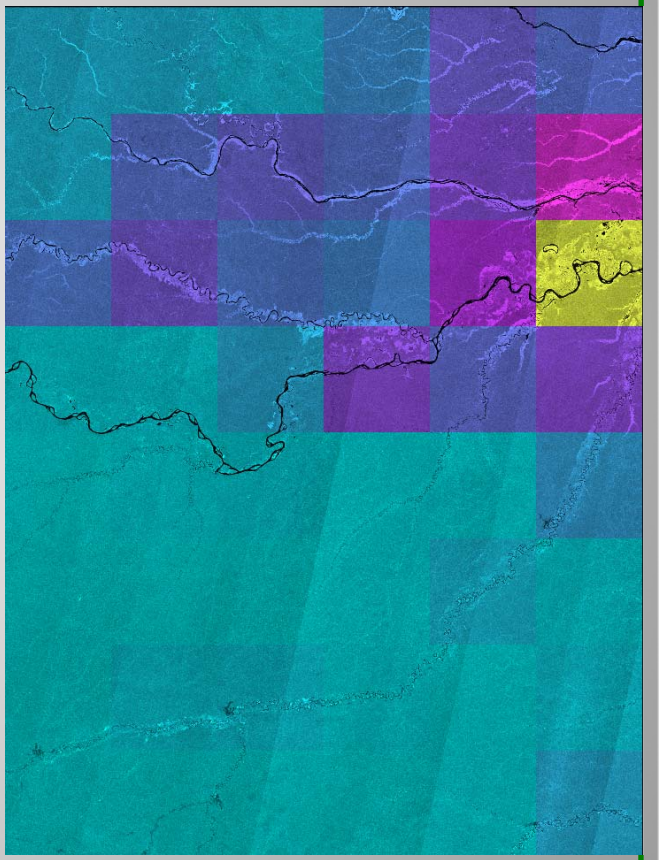
ALOS Open Water



AMSR-E/QSCAT Open Water



ALOS Inundated Vegetation



Fraction open water

0%

5%

Fraction inundated vegetation

0%

40%

19M

ALOS

K&C Initiative

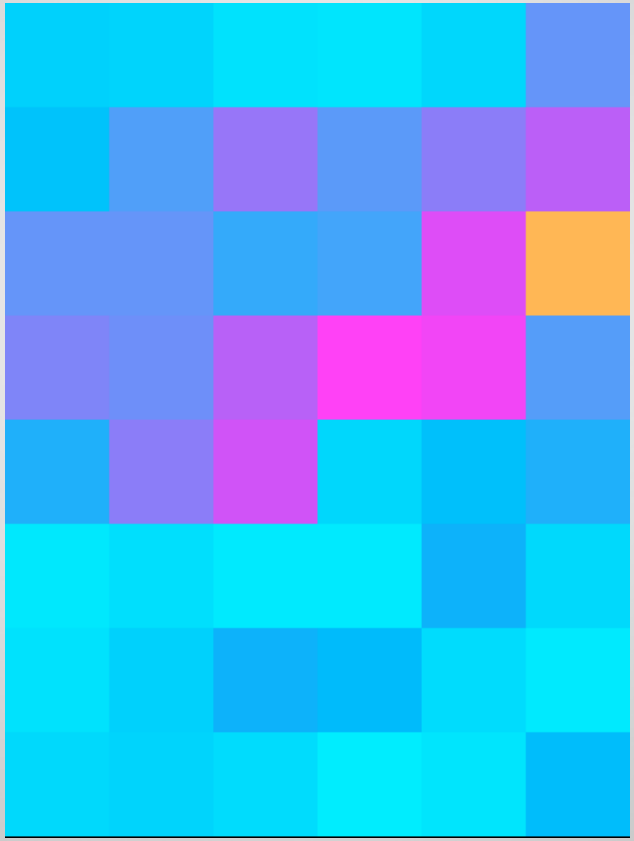
An international science collaboration led by JAXA

Fraction for each 1deg x 1deg cell

Aug-Sept 2007

ALOS Open Water

AMSR-E/QSCAT Open Water



ALOS Inundated Vegetation

Fraction open water

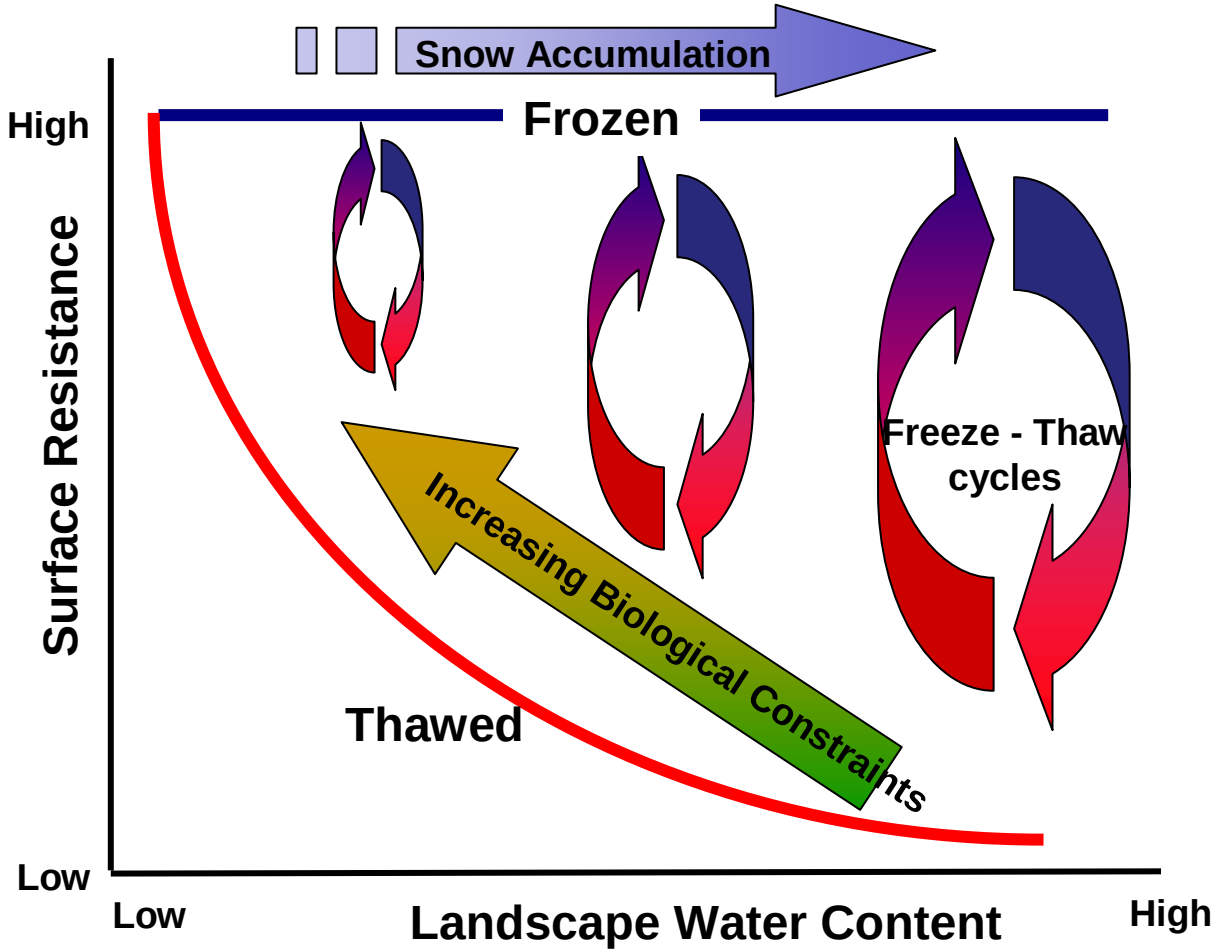
0% 5%

Fraction inundated vegetation

0% 40%

19M

Terrestrial Water Mobility Constraints to Ecosystem Processes

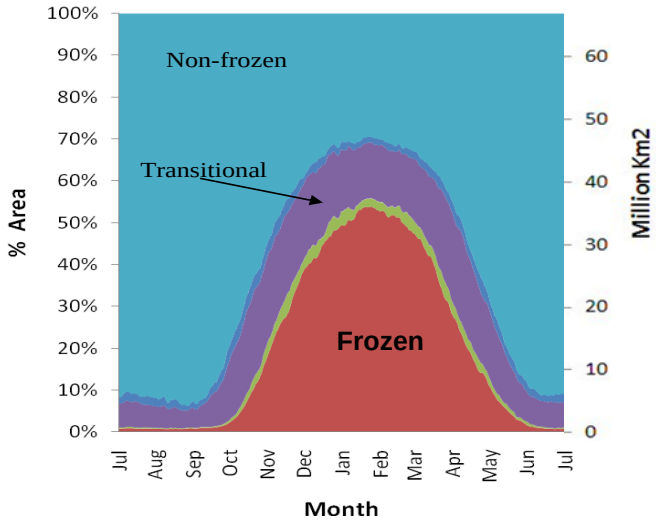


Conceptualization of the relationship between landscape water content and the bulk surface resistance to land-atmosphere latent energy and water exchange, vegetation productivity and sequestration of atmospheric CO_2. Decreasing water content imposes increasing constraints to CO_2 exchange, as do seasonal and episodic freezing. Accumulation of snow during cold seasons allows for increased water availability (high water content) for growth processes after snow melt and landscape thaw.

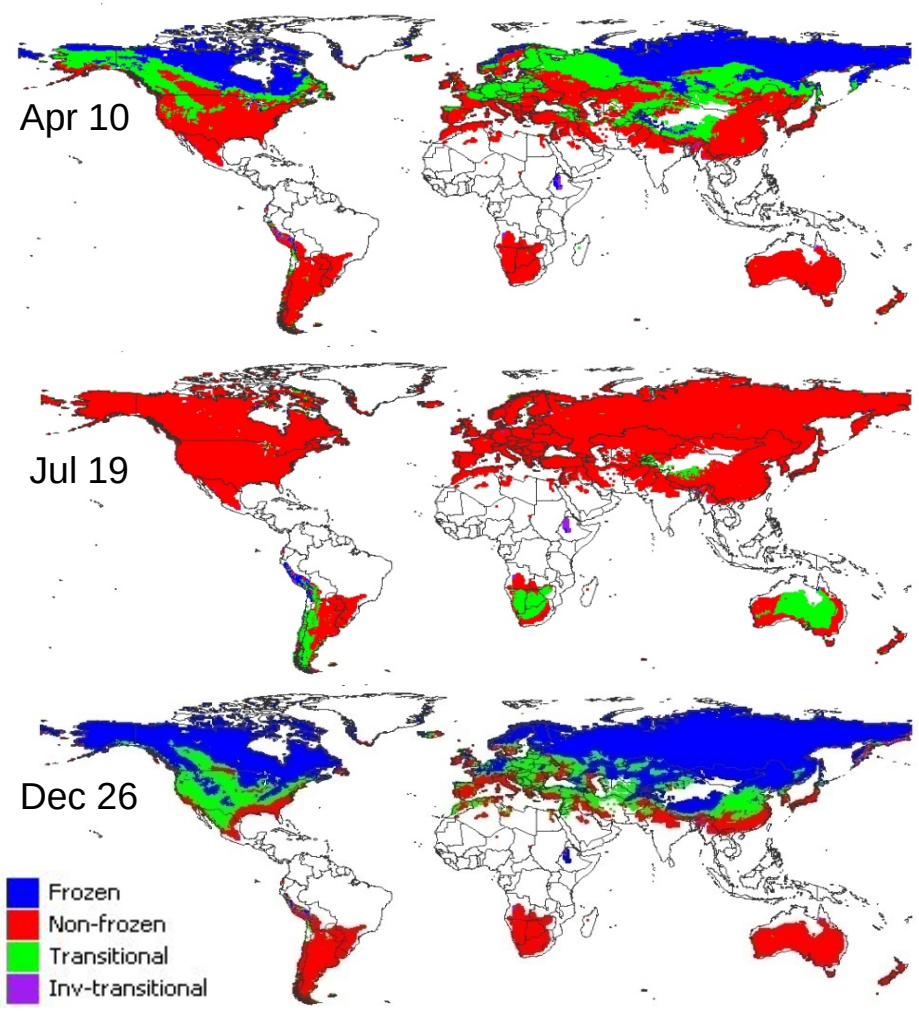
L2/3_FT AM-PM Combined Product Prototype

- **Daily F/T state maps:**
  - 4 classes: Frozen (AM & PM), Thawed (AM & PM), Transitional (AM frozen, PM thaw), Inverse-Transitional (AM thaw, PM frozen);
- **Global domain encompassing F/T affected areas:**
  - 66 million km^2 or 52% of global vegetated area);

Mean Seasonal F-T Progression
SSM/I 1988-2007



Daily Freeze-Thaw Status
SSM/I (37GHz, 25km Res.) 2004



Source: http://freezethaw.ntsg.umt.edu

Support to JAXA's global forest mapping effort

Incorporate our error assessment protocols within the context of the PALSAR global forest product generation scheme to support time series and area scaling assessment of errors

These protocols should ensure improved global forest products, or as a minimum, an improved understanding of the global forest product accuracy.

Ground data utilized in generation of our wetlands and freeze-thaw products.

In the USA, this includes data sets from the National Wetlands Inventory and other associated archives.

Complete data sources or references to publically-available data sources will be provided sufficient for an investigator to generate the wetlands and freeze/thaw products independently, and to adapt these data sources to development of similar data sets associated with e.g. the generation of the global forest products.

Deliverables and Schedule

- Year 1
  - Wetlands vegetation maps of Alaska from PALSAR FBD data
- Year 2
  - Wetlands vegetation maps of Canada from PALSAR FBD data
  - Wetlands vegetation maps of Eurasian sub-regions
  - Initial Freeze/thaw products over ASF region
- Year 3
  - Wetlands inundation dynamics for North America from ScanSAR
  - Freeze/Thaw products from ASF region
- Year 4
  - Wetlands inundation dynamics for other boreal ScanSAR regions
  - Global inundated area fraction maps from coarse resolution sensors with accuracy assessments based on PALSAR