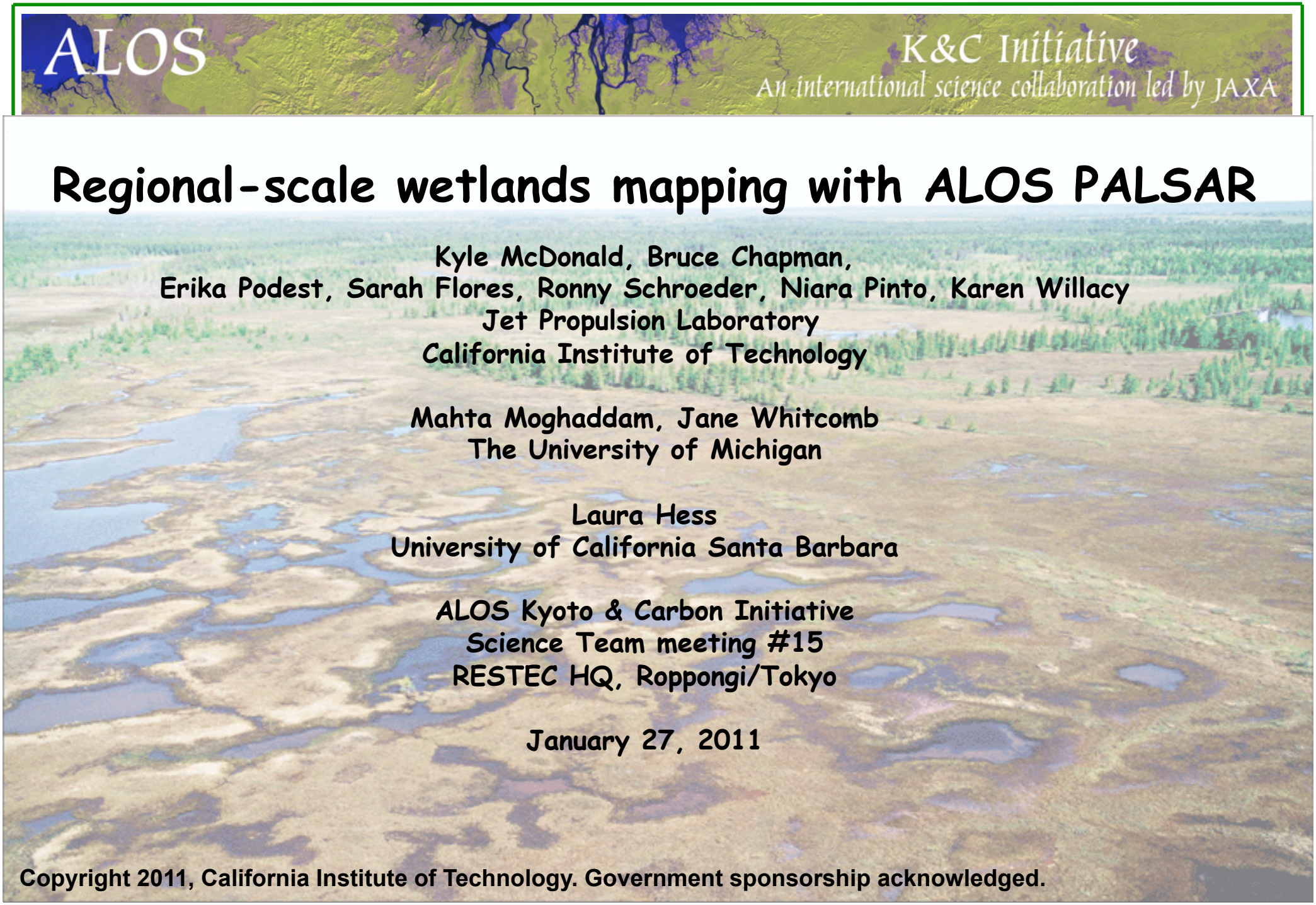

Regional-scale wetlands mapping with ALOS PALSAR

Kyle McDonald, Bruce Chapman,
Erika Podest, Sarah Flores, Ronny Schroeder, Niara Pinto, Karen Willacy
Jet Propulsion Laboratory
California Institute of Technology

Mahta Moghaddam, Jane Whitcomb
The University of Michigan

Laura Hess
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ALOS Kyoto & Carbon Initiative
Science Team meeting #15
RESTEC HQ, Roppongi/Tokyo

January 27, 2011

ALOS

K&C Initiative
An international science collaboration led by JAXA

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

Principal Investigator: Kyle McDonald (JPL/Caltech)

Project Members: Mahta Moghaddam (The University of Michigan)
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Nick Davidson (Ramsar)
Lisa Rebelo
(International Water Management Institute)
Martti Hallikainen
(Helsinki University of Technology)

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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 inundatal 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 (SSMI, ERS scatterometer, AVHRR, AMSR-E, MODIS, QuikSCAT, ASCAT)
- Temporal coverage: Monthly monitoring with annual summaries, 1992-2009 †
1. Globally gridded (0.25º) monthly inundated area fraction
2. Globally gridded (0.25º) 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.

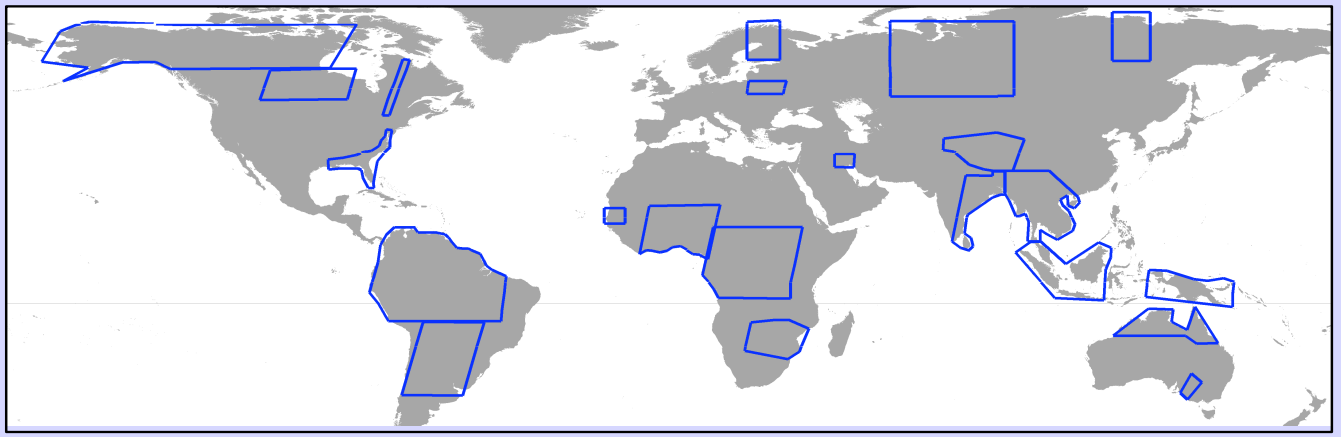
Missions Data

I. Regional inundated wetlands data sets from Synthetic Aperture Radar (SAR)
Primary data sources
• ALOS PALSAR
• JERS SAR
• SRTM DEM
Secondary data sources
• Landsat – using for open water delineation; also to verify consistency with land cover data records

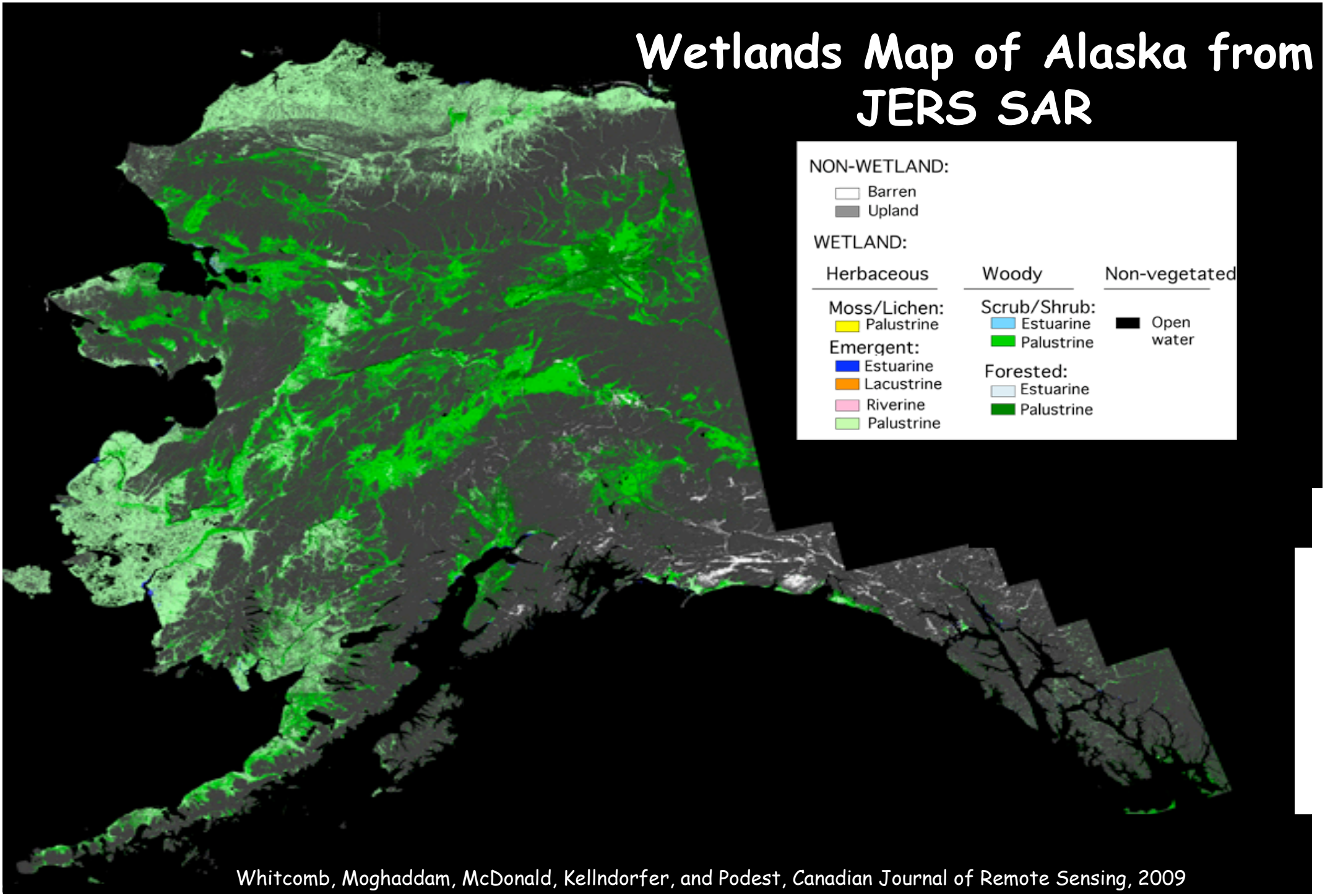
II. Global monthly inundation data sets derived from multiple satellite data sources
Retrospective Data Sets (1992 onward)
• SSM/I
• ERS Scatterometer
• AVHRR
Contemporary Data Sets (2002 onward)
• AMSR-E
• MODIS
• QuikSCAT , ASCAT

PALSAR Regional Coverage: ScanSAR regions

- Inundated wetland area (swath-by-swath)
- Principal wetland vegetation classes (non-vegetated, herbaceous, shrub, woodland, forest),
- Seasonally based summary



Wetlands Map of Alaska from JERS SAR



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

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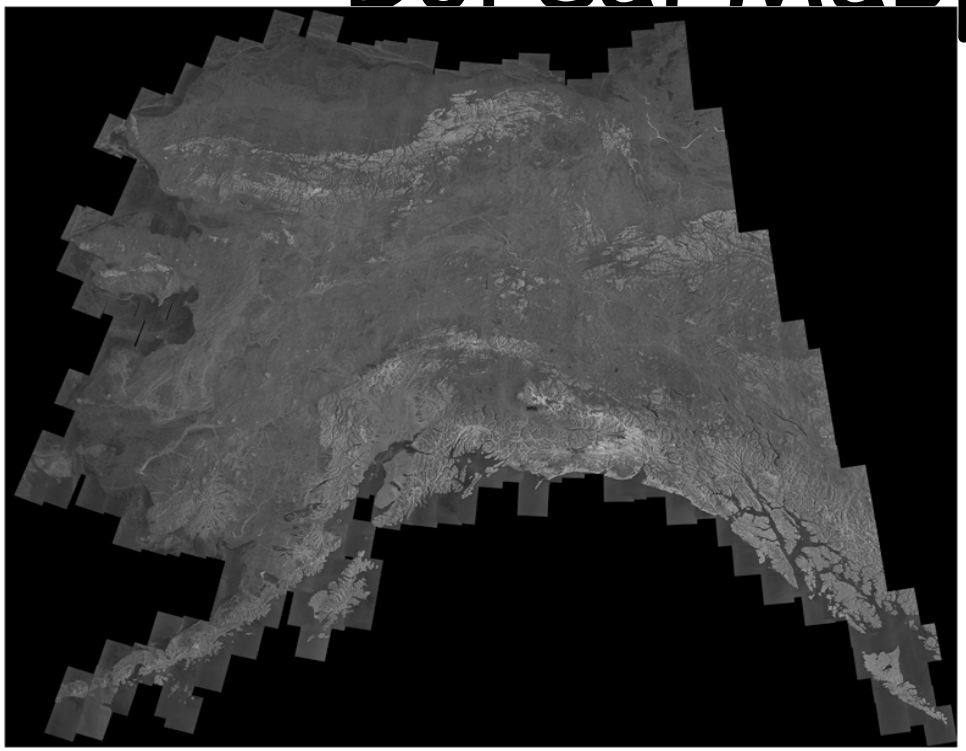
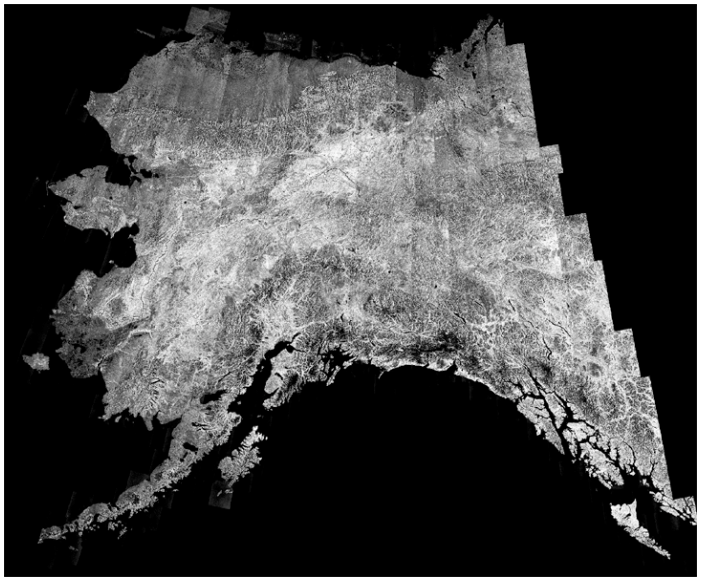
L-band Radar Imagery from JERS-1 Boreal Mapping Mission



Winter

Significant pass-to-pass striping, pointing to temporal scene variations



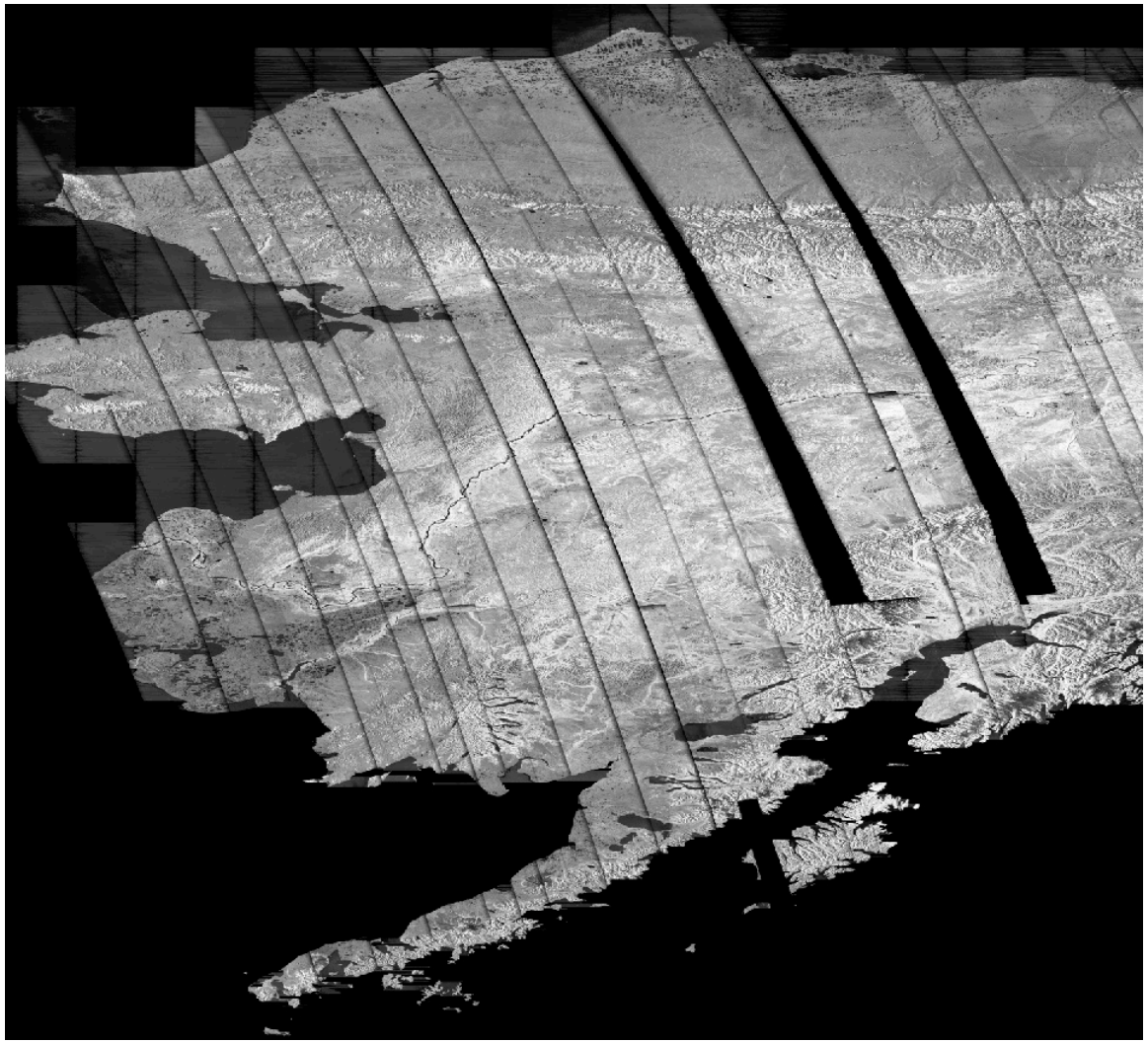
Summer

NASA

JPL

Jet Propulsion Laboratory

Fine-Beam Data Assembly and Mosaics



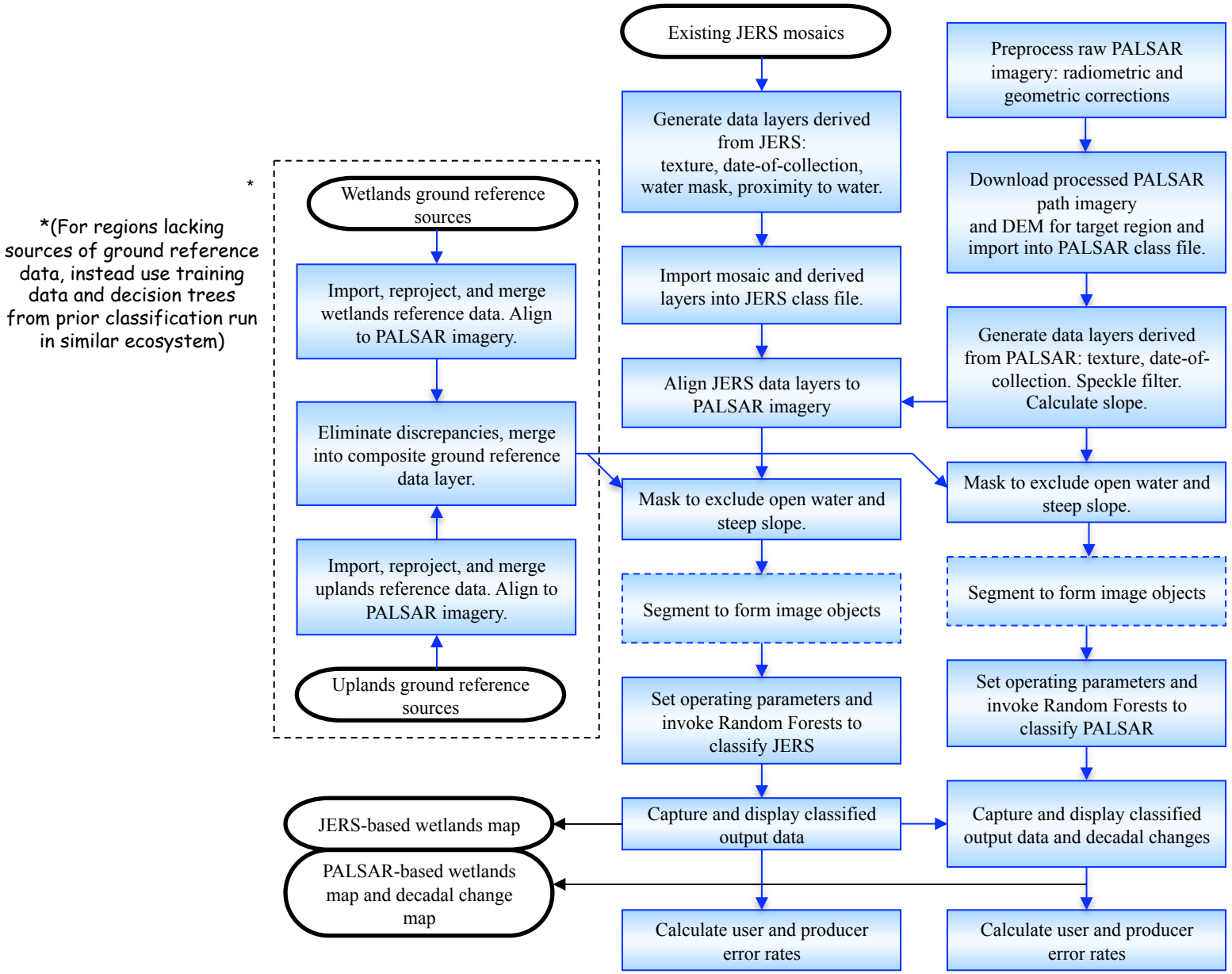
HH

Alaska

Classification Technique

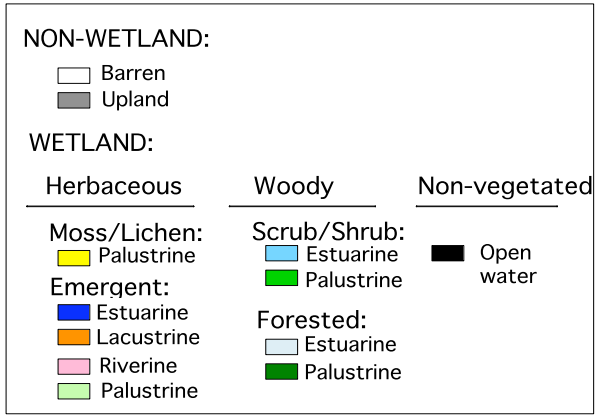
- Standard classification methods (e.g., maximum likelihood estimation, isodata) yield poor results due to swath-to-swath brightness variations
- Current approach based on novel classification algorithm called "Random Forests"
  - Statistically based decision tree classifier
  - Accepts input data from 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
- Developed suite of software to adapt Random Forests to task of classifying satellite imagery
- Classification sorts pixels into narrow wetlands/uplands subclasses according to morphology, vegetation structure, and water regime

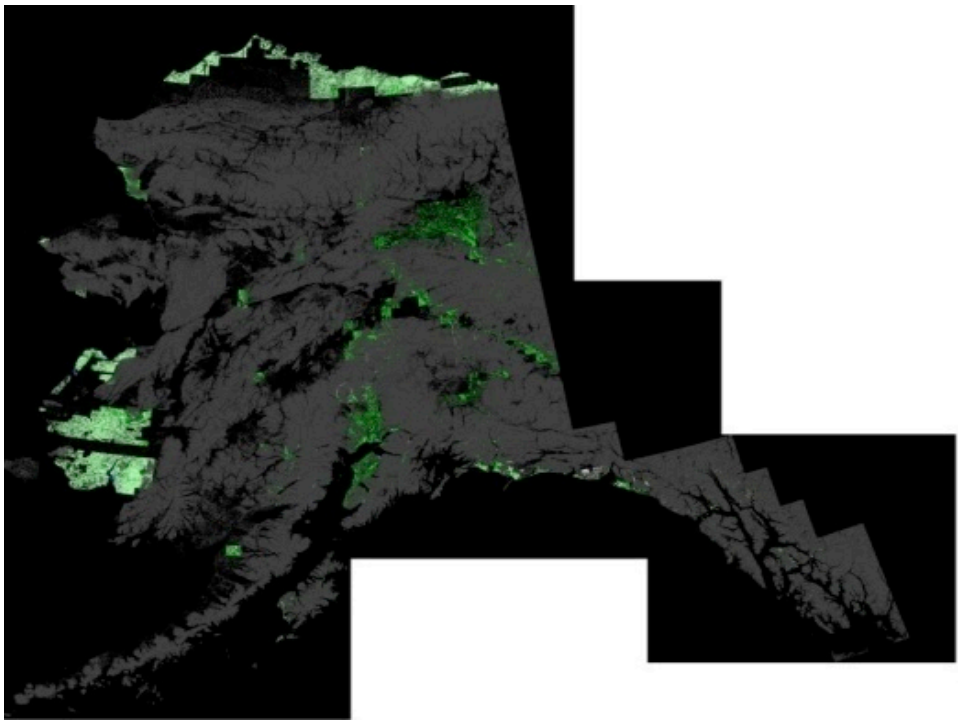
Classification Flowchart



Ground Reference Data (1)

- Composite ground reference data layer used to train classification algorithm, validate classification results
- Assembled from combination of
  - Wetlands ground reference data sources
  - Uplands ground reference data sources
- Areas of discrepancy between different ground reference data sources excluded from composite ground reference data layer

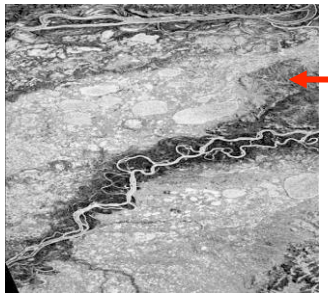


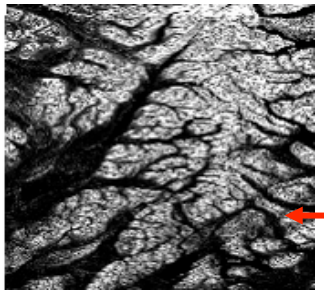


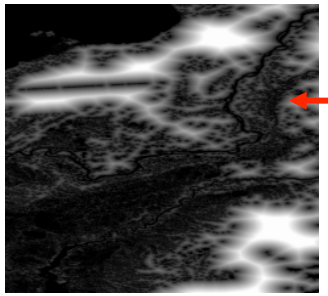
Ground Reference Data (2)

- Wetlands Ground Reference Sources
  - US: National Wetlands Inventory (NWI)
  - Cowardin classification system
  - Most systematic data available
  - Canada: Until more systematic wetlands data product becomes available, base on wetlands study sites (e.g., BOREAS, Mer Bleue, RAMSAR) plus nearby US sources
- Uplands Ground Reference Sources
  - US: Alaska Geospatial Data Clearinghouse (AGDC), National Land Cover (NLCD)
    - *AGDC/NLCD used to categorize regions within NWI quadrangles that are left unlabeled and so assumed to be uplands*
  - Canada: Land Cover Circa 2000 (LCC)
  - Land cover codes aggregated to seven top-level classes for consistency across regions

Ancillary Data Used in Wetlands Classification



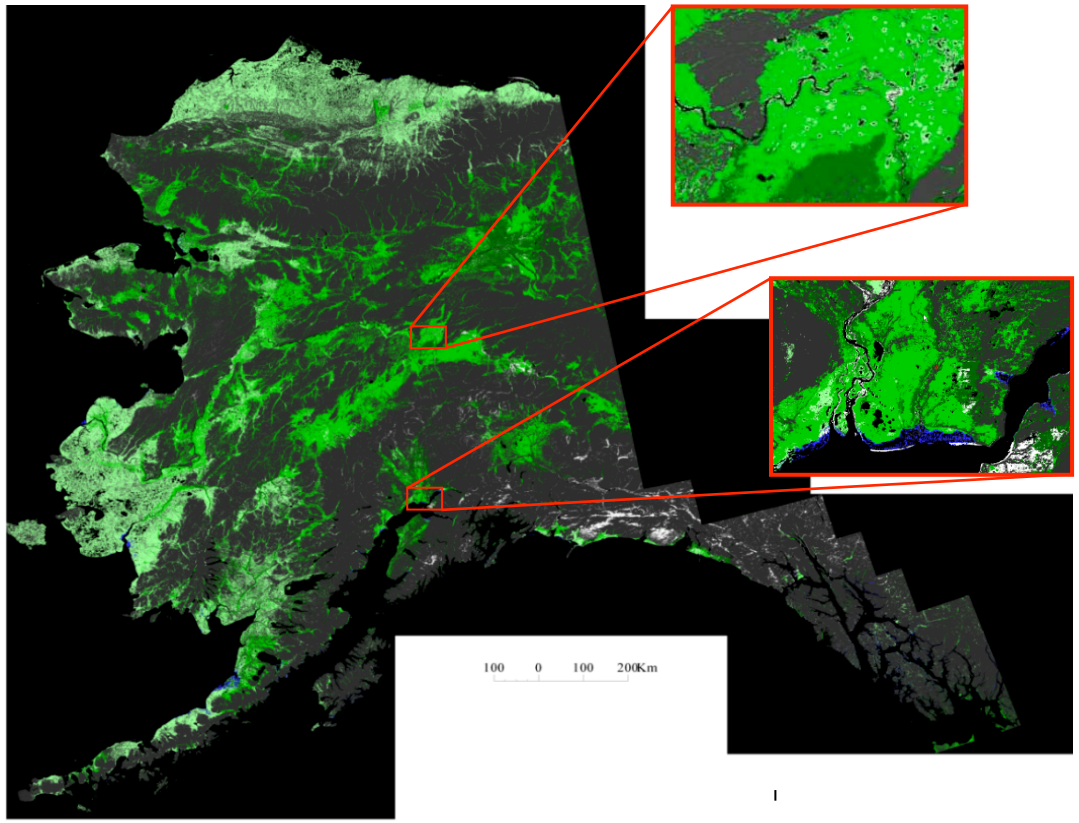




Data	Purpose	Source
SAR texture	provides measure of SAR brightness variability	Derived from SAR imagery (coefficient of variation within 7×7 window)
SAR date-of-collection	allow adjustment for temporal differences between swaths	Provided with imagery
DEM	accounts for local terrain altitude	NED
Slope	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

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		

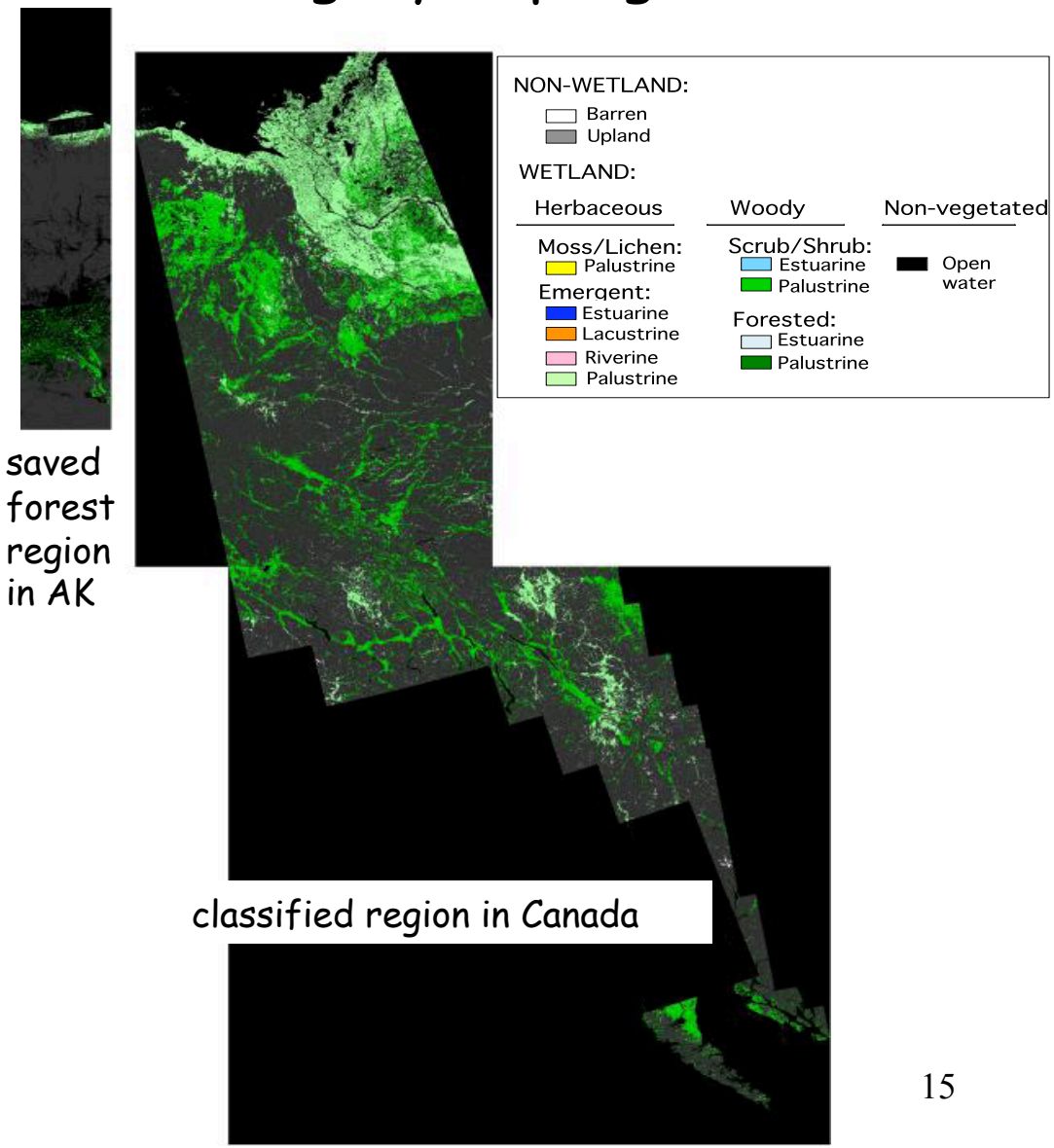
- Aggregate accuracy approximately 89.5%
- Used to generate tally of wetlands for Alaska

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

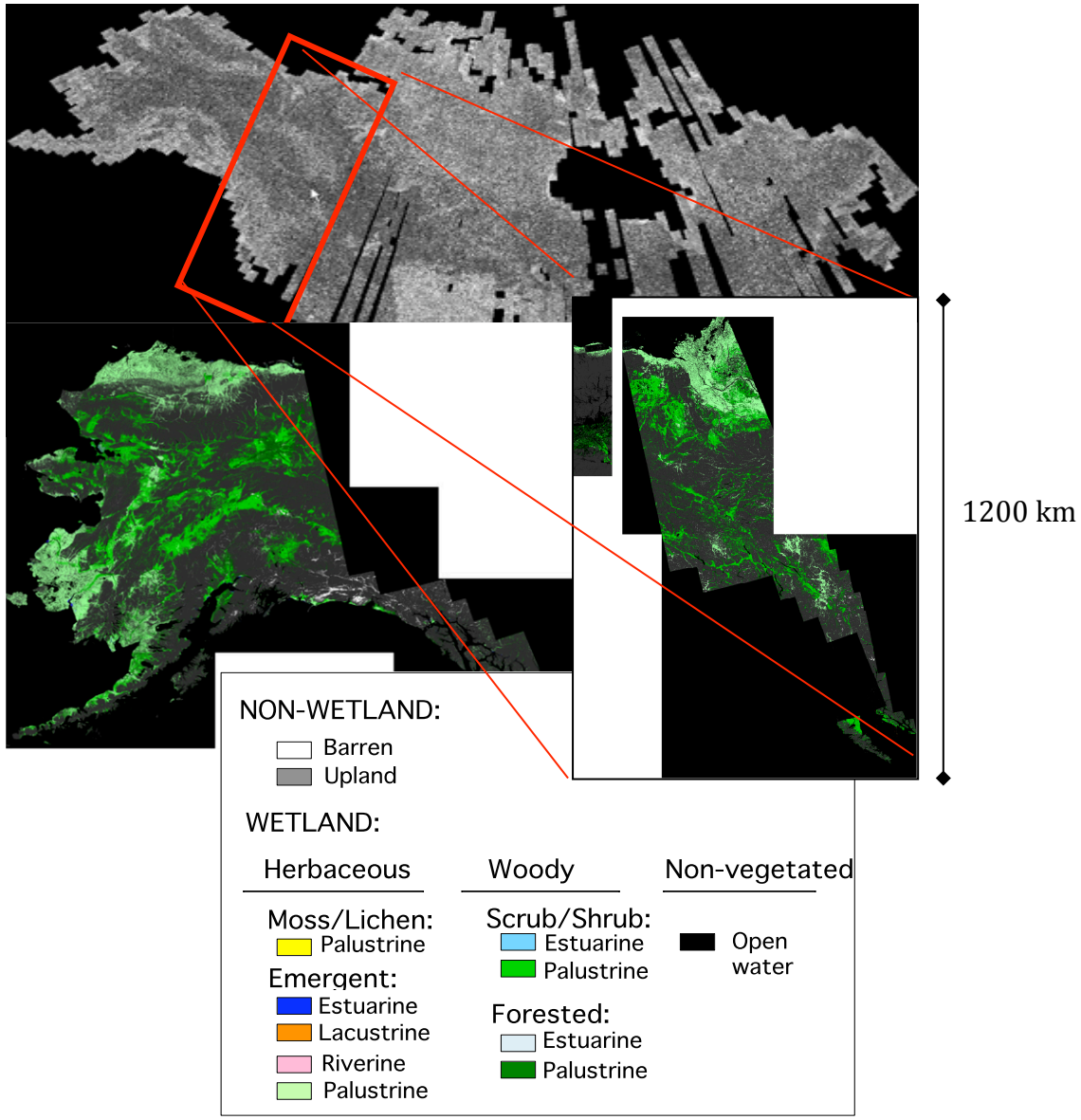
- Classification of Canadian JERS-1 imagery in progress

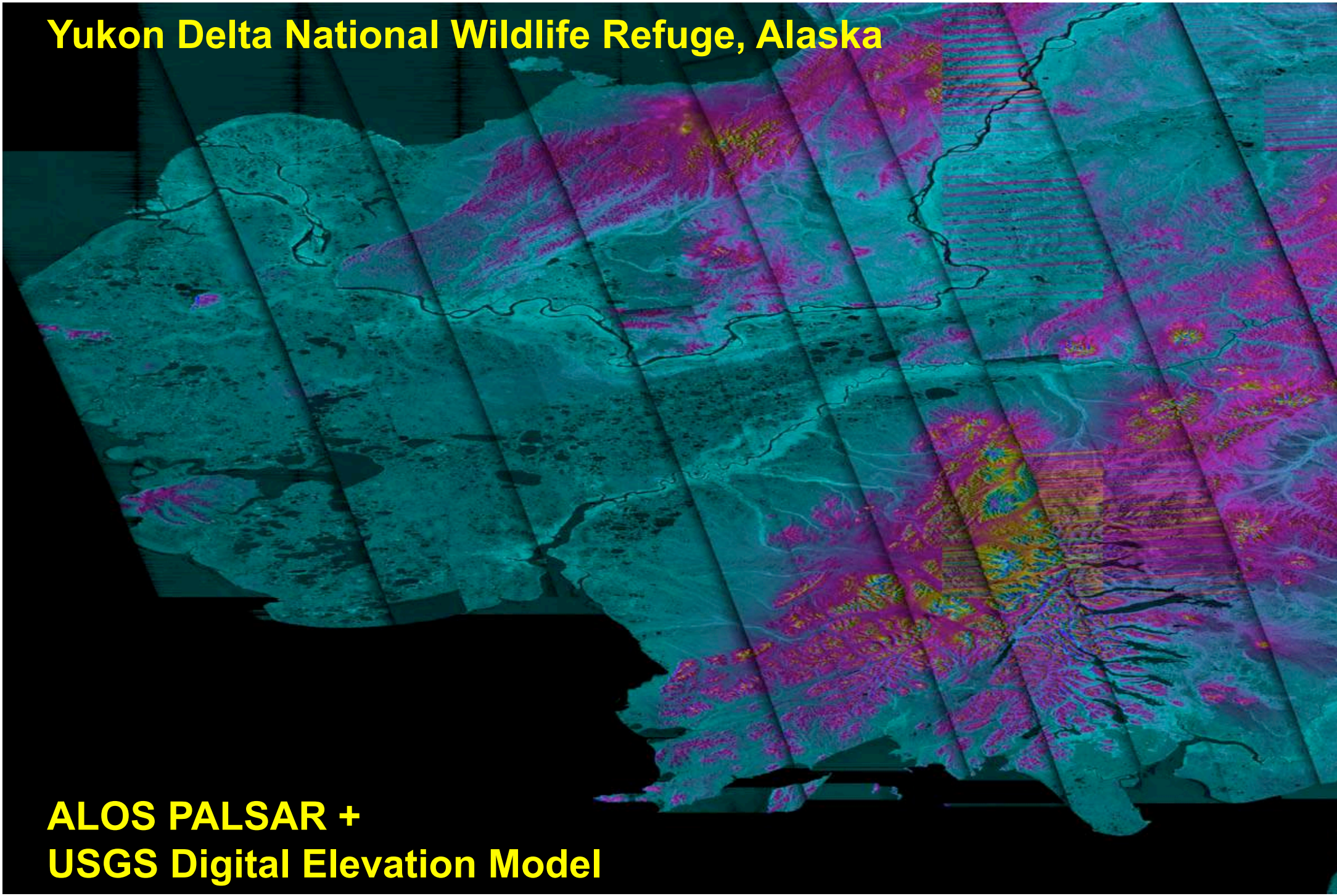
  - First section based on saved decision tree forest from nearby region in Alaska
  - Large-scale ecosystem maps confirm ecosystem of saved forest region in Alaska very similar to that of location of interest in Canada
  - Classification accuracy for saved forest 85%



Another view

- Shown on right: Wetlands map of Alaska from 1997-98 JERS is complete; 89% accuracy
- Canada ~20% complete
- Resolution: 100m
- Planned for integration with wetland carbon models (wetland-DNDC; other models welcome)




Yukon Delta National Wildlife Refuge, Alaska
ALOS PALSAR +
USGS Digital Elevation Model

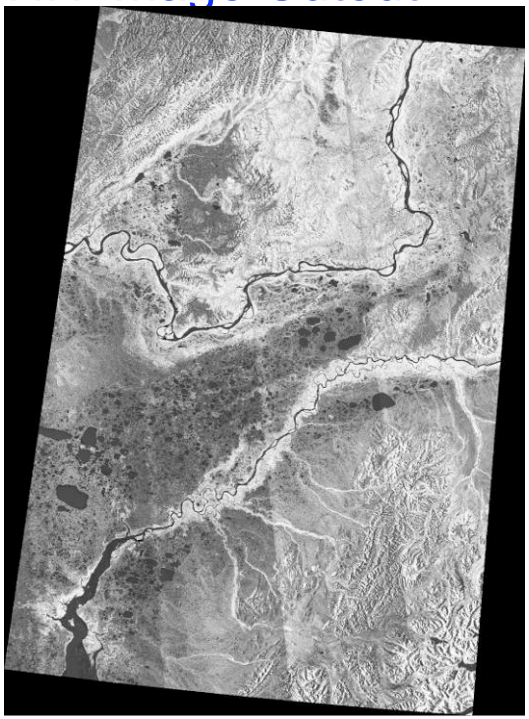
Yukon Delta Wetlands from PALSAR

NON-WETLAND:
- Barren
- Upland

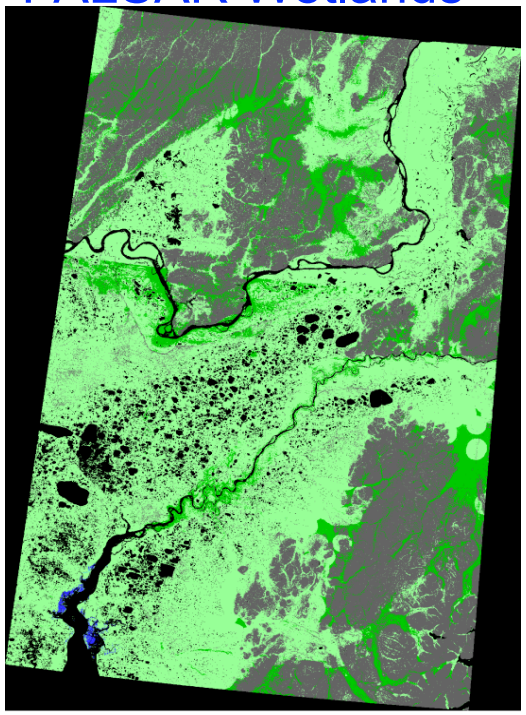
WETLAND:

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

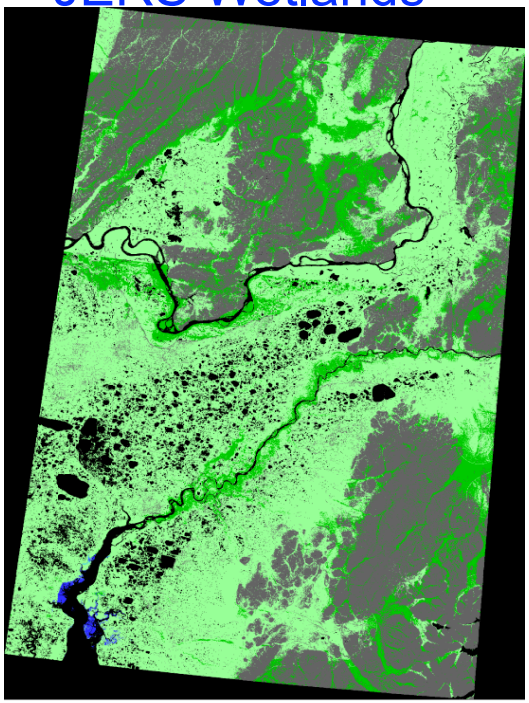
HH Image Cutout



PALSAR Wetlands



JERS Wetlands



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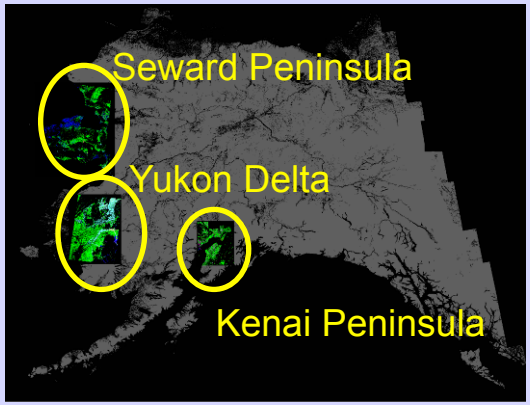
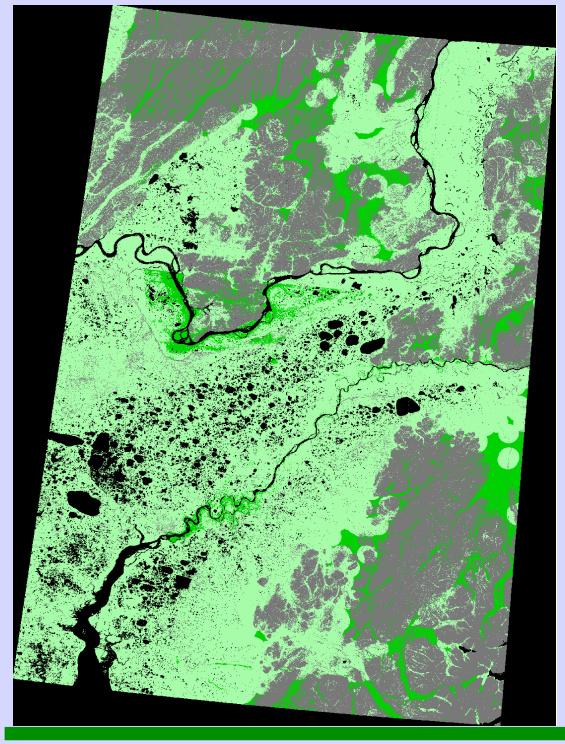
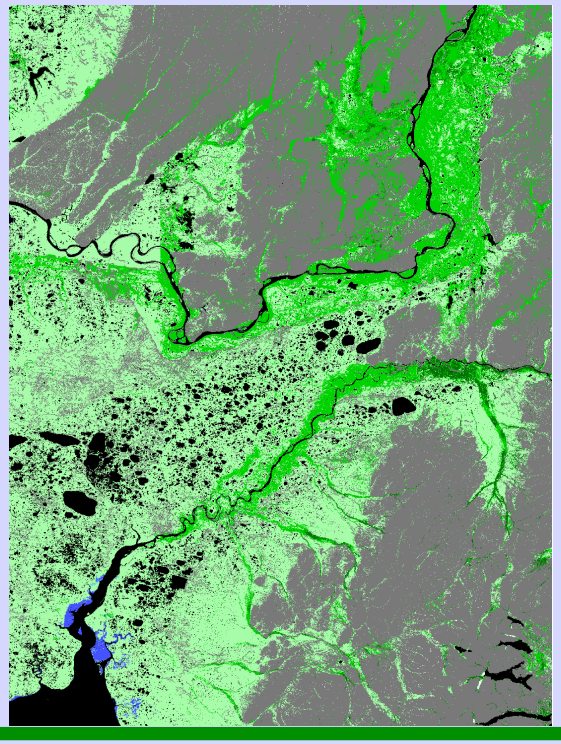


Yukon Delta Wetlands from JERS and PALSAR

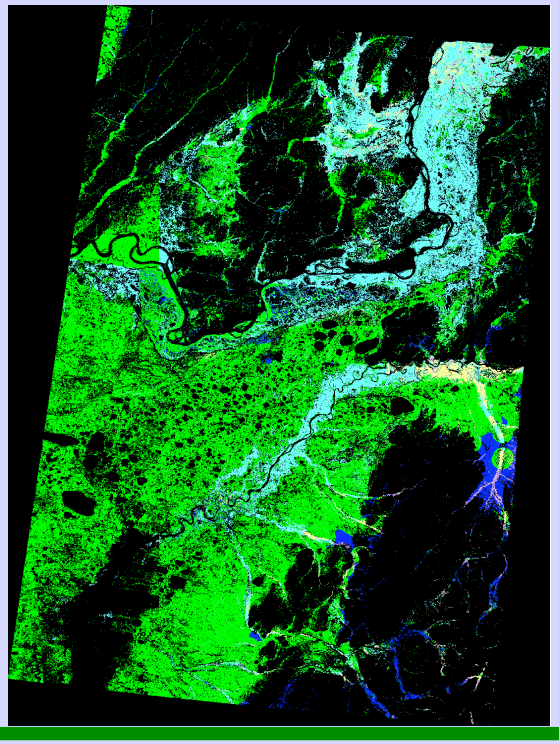
PALSAR Wetlands



JERS Wetlands

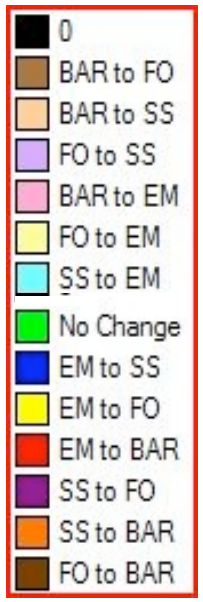


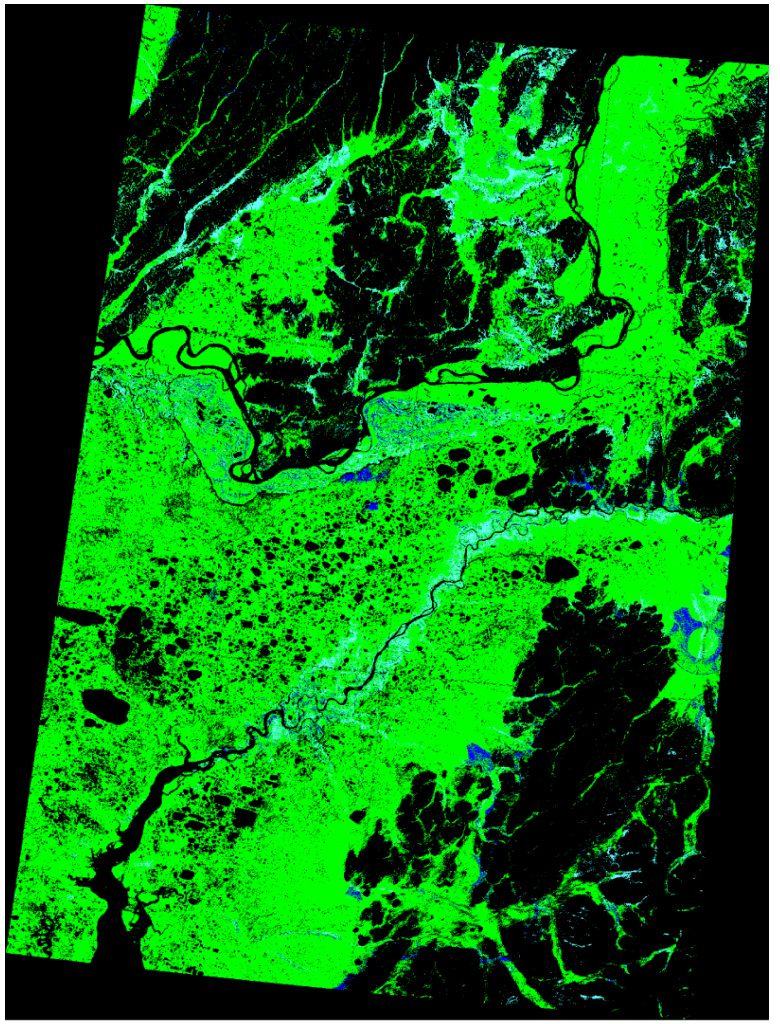
Change Map



Yukon Delta Wetlands
Decadal Change

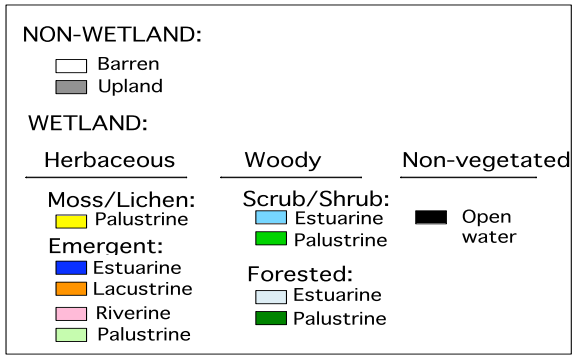
- Region mostly unchanged, observable transitions of:
  - Scrub/shrub to Emergent
  - Emergent to Scrub/shrub



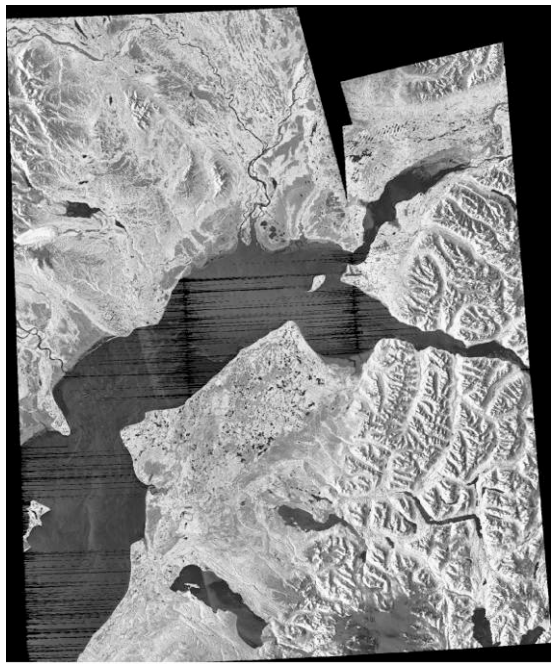


Kenai Wetlands from PALSAR

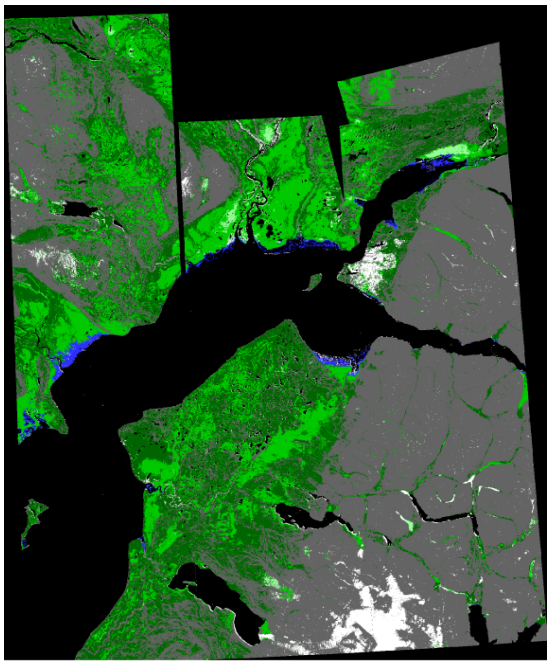
- Followed same general methodology as for JERS; had to become creative about memory management and processor multiple core usage to be able to handle dual-pol and higher-res data



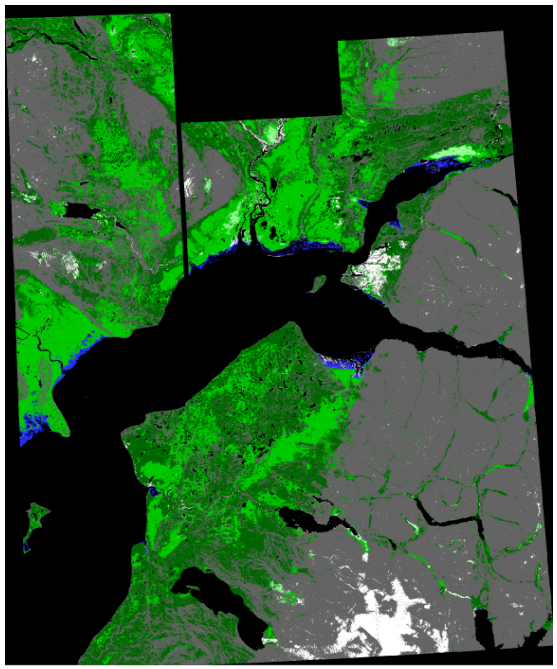
HH Image Cutout



PALSAR Wetlands

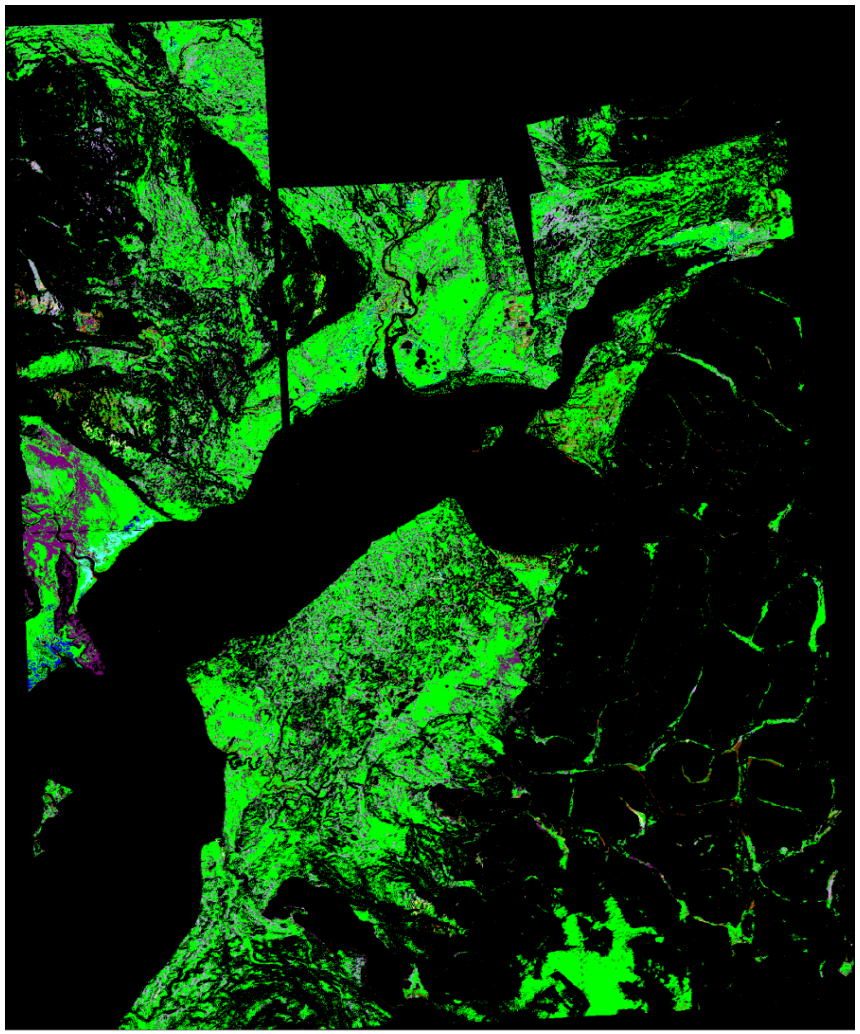


JERS Wetlands



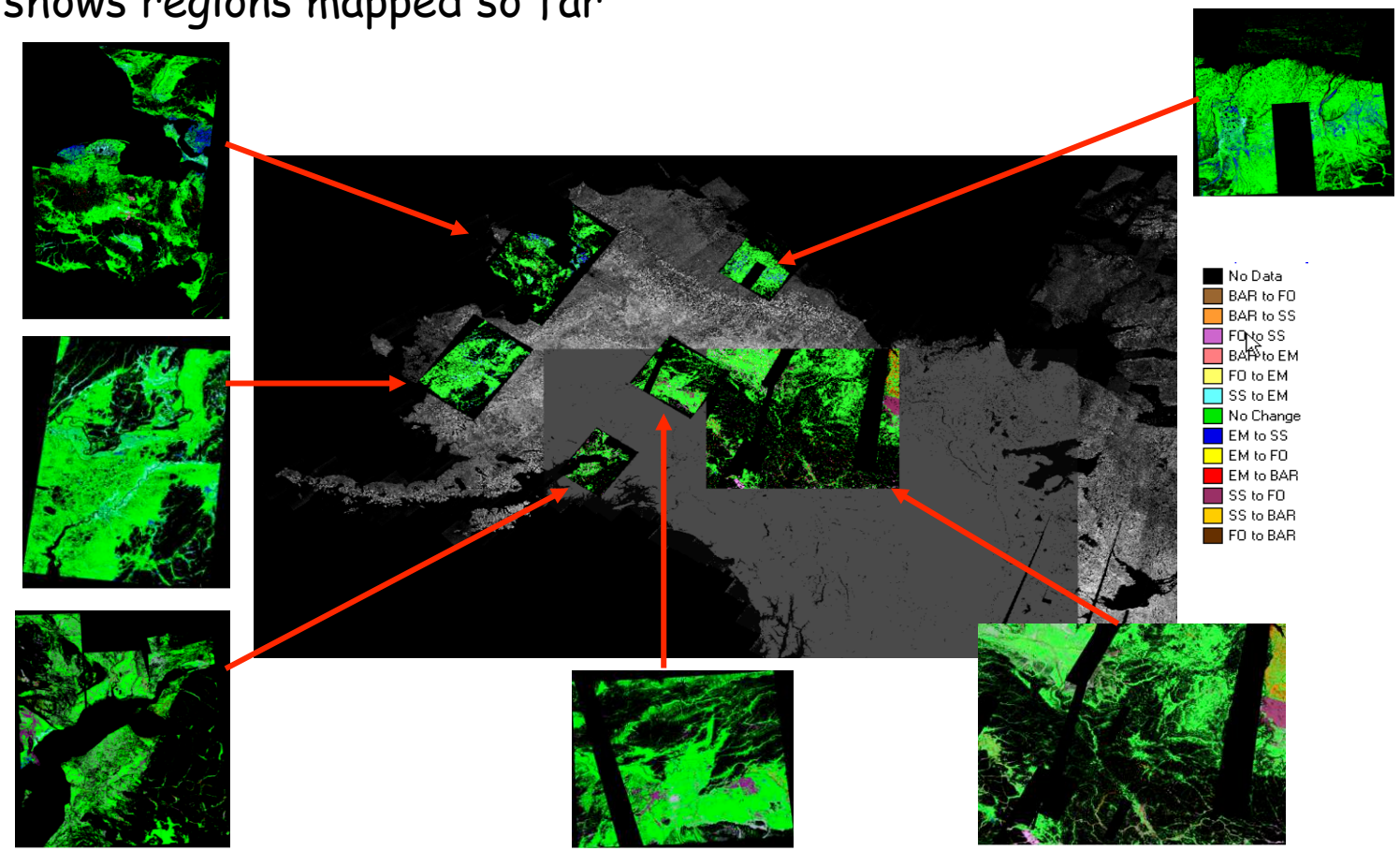
Kenai Wetlands
Decadal Change

- Region mostly unchanged, but there ARE significant transitions of:
  - Scrub/shrub to Forested
  - Some forested to Scrub/shrub
  - Smaller amounts of:
    - *Forested to Barren*
    - *Scrub/Shrub to Emergent*
    - *Emergent to Scrub/shrub*



Change Mapping Based on PALSAR Imagery

- Classification of Alaskan PALSAR imagery (from 2007) in progress
- So far, generally good classification accuracy (79-94%); classification parameters being optimized for increasingly better results
- Figure shows regions mapped so far



Overall Accuracy for Classified Regions

From:	EM	SS	FO	BAR	Total Classified into Superclass:
To: EM	1488051	77797	4986	7488	1578322
SS	75433	1155237	82836	15263	1328769
FO	31209	111410	510363	11898	664880
BAR	1419	4692	5143	30770	42024
al in Superclass:	1596112	1349136	603328	65419	

Composite error rates for JERS

producer

From:	EM	SS	FO	BAR
To: EM	93.23	5.77	0.83	11.45
SS	4.73	85.63	13.73	23.33
FO	1.96	8.26	84.59	18.19
BAR	0.09	0.35	0.85	47.04
al in Superclass:	100	100	100	100

user

From:	EM	SS	FO	BAR	Total Classified into Superclass:
To: EM	94.28	4.93	0.32	0.47	100.00
SS	5.68	86.94	6.23	1.15	100.00
FO	4.69	16.76	76.76	1.79	100.00
BAR	3.38	11.17	12.24	73.22	100.00

oducer error rate	EM	SS	FO	BAR
	6.77	14.37	15.41	52.96

user error rate	EM	SS	FO	BAR
	5.72	13.06	23.24	26.78

Unaggregated

Total Correct	2789586
Total Pixels	3618374
Total Accuracy	77.10

Aggregated

Total Correct	3184421
Total Pixels	3618374
Total Accuracy	88.01

From:	EM	SS	FO	BAR	Total Classified into Superclass:
To: EM	1510053	69309	4685	5596	1589643
SS	87604	1231595	77022	14335	1410556
FO	29708	98109	507389	11806	647012
BAR	1855	5452	5333	33238	45878
al in Superclass:	1629220	1404465	594429	64975	

Composite error rates for PALSAR

producer

From:	EM	SS	FO	BAR
To: EM	92.69	4.93	0.79	8.61
SS	5.38	87.69	12.96	22.06
FO	1.82	6.99	85.36	18.17
BAR	0.11	0.39	0.90	51.16
al in Superclass:	100	100	100	100

user

From:	EM	SS	FO	BAR	Total Classified into Superclass:
To: EM	94.99	4.36	0.29	0.35	100.00
SS	6.21	87.31	5.46	1.02	100.00
FO	4.59	15.16	78.42	1.82	100.00
BAR	4.04	11.88	11.62	72.45	100.00

oducer error rate	EM	SS	FO	BAR
	7.31	12.31	14.64	48.84

user error rate	EM	SS	FO	BAR
	5.01	12.69	21.58	27.55

Unaggregated

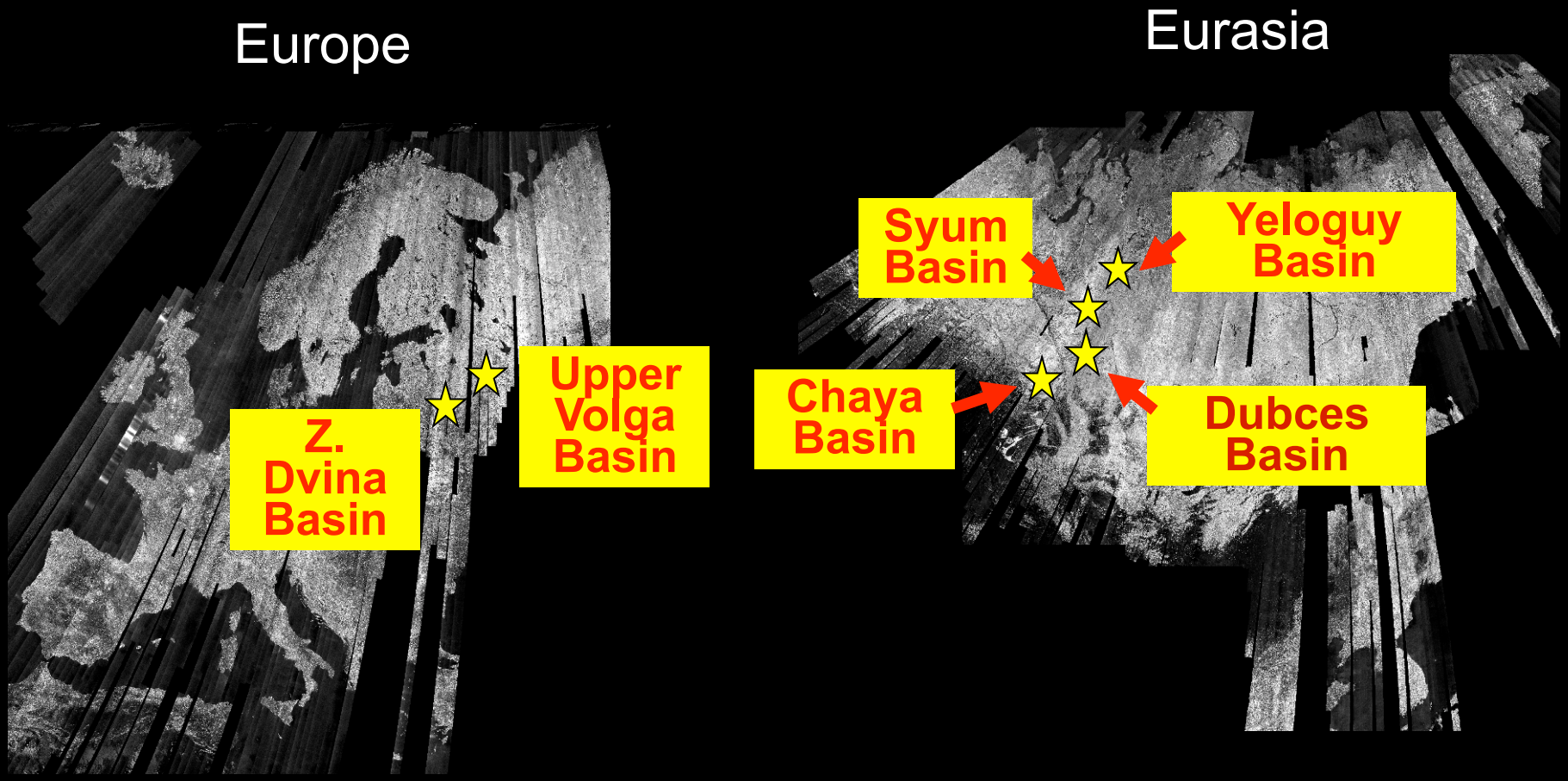
Total Correct	2874769
Total Pixels	3700260
Total Accuracy	77.69

Aggregated

Total Correct	3282275
Total Pixels	3700260
Total Accuracy	88.70

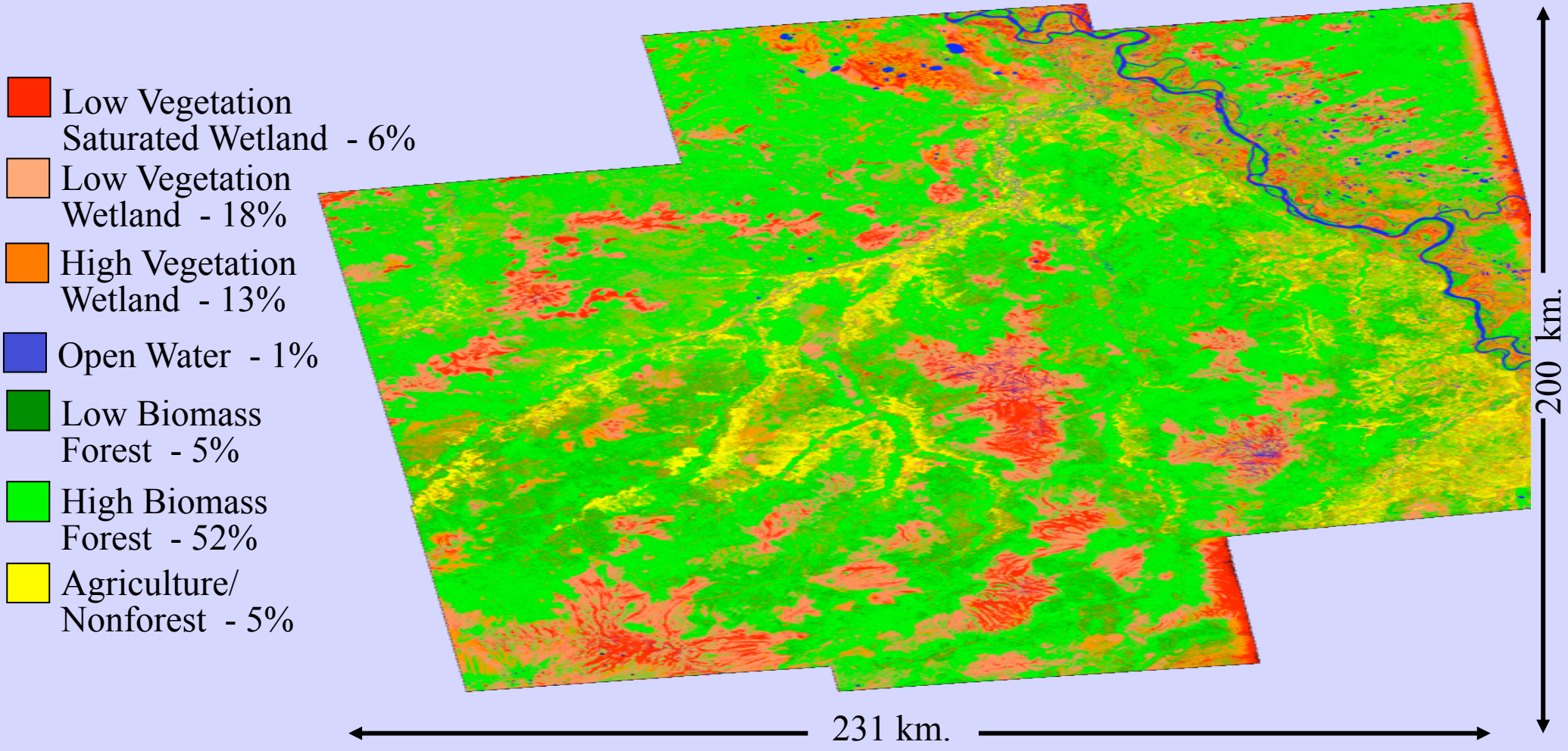
- All six regions completed to date
- Overall producer accuracy
  - JERS: 88.0%
  - PALSAR: 88.7%

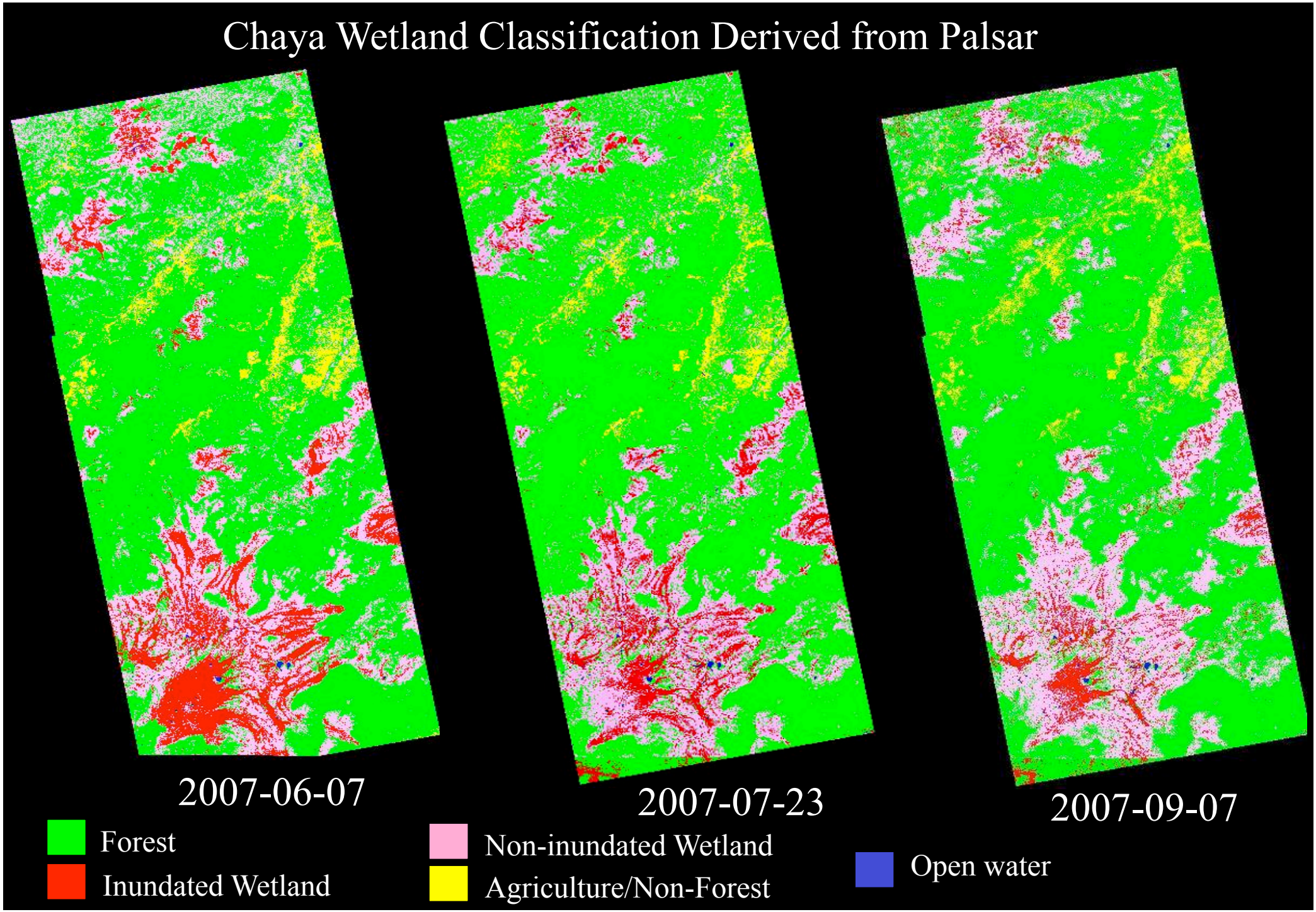
Eurasia 100m JERS-1 Mosaics: Northern Eurasia



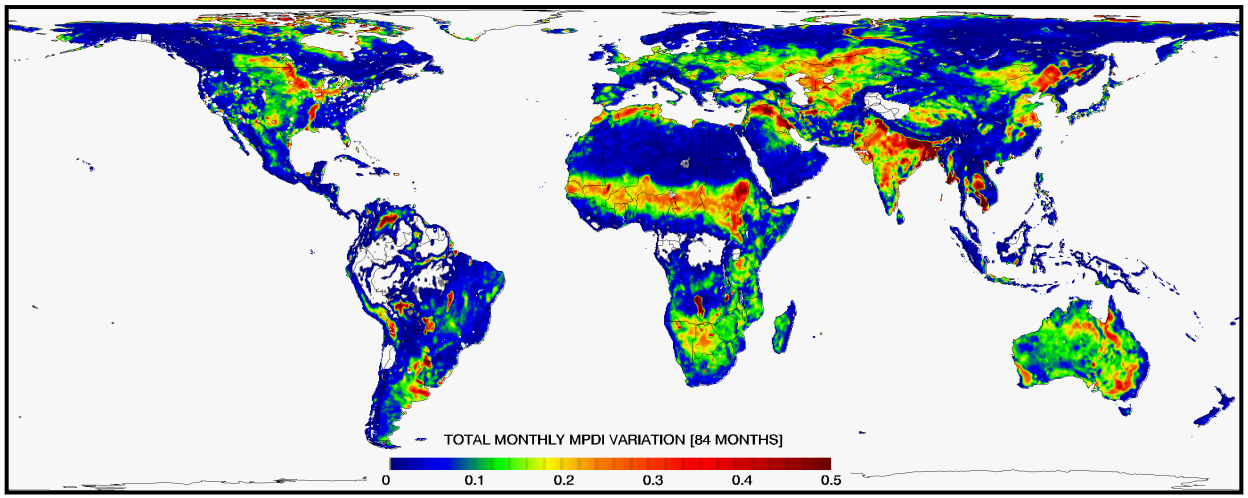
Wetland Classification of the Chaya Basin

Accuracy assessment was based on validation pixels not used for training. Accuracy varied between 2% and 20% according to class. However, because of limited ground truth data, these values may vary.



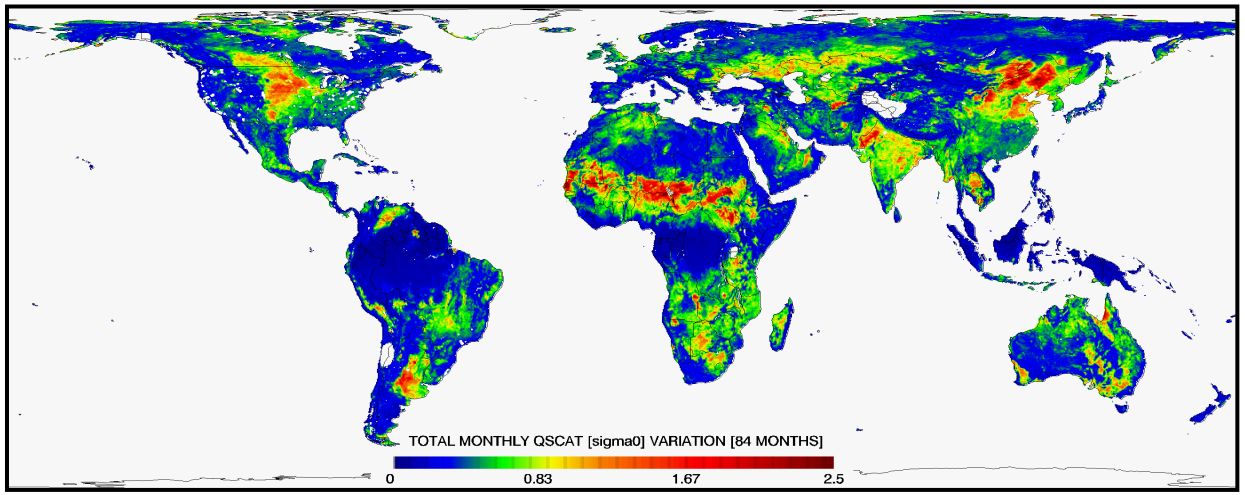

Chaya Wetland Classification Derived from Palsar
2007-06-07
2007-07-23
2007-09-07
Forest
Inundated Wetland
Non-inundated Wetland
Agriculture/Non-Forest
Open water

Passive and Active Microwave Data (2002-2010)



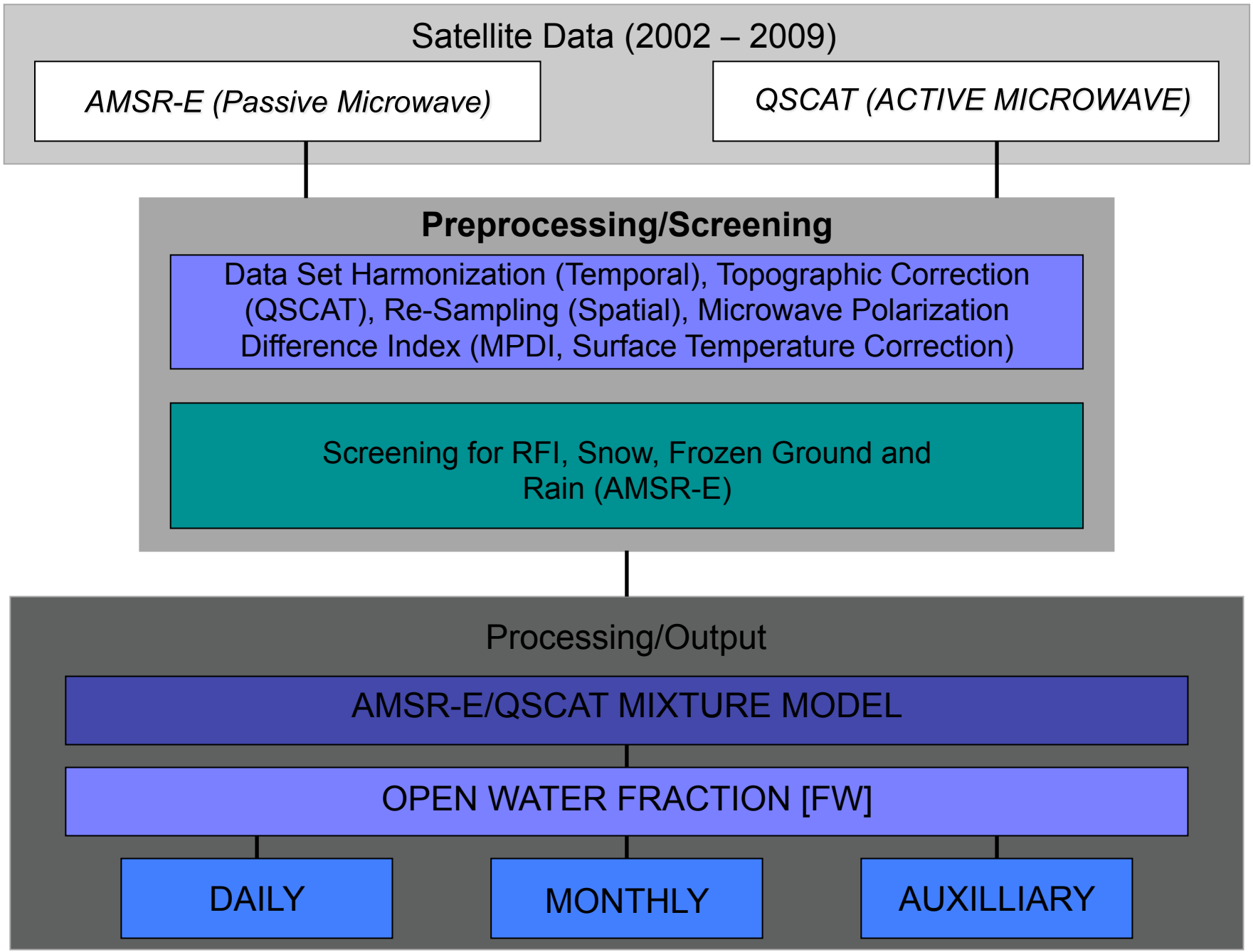
Daily AMSR-E brightness temperature

sensitive to inundation, soil moisture and vegetation changes (warm tones on map)

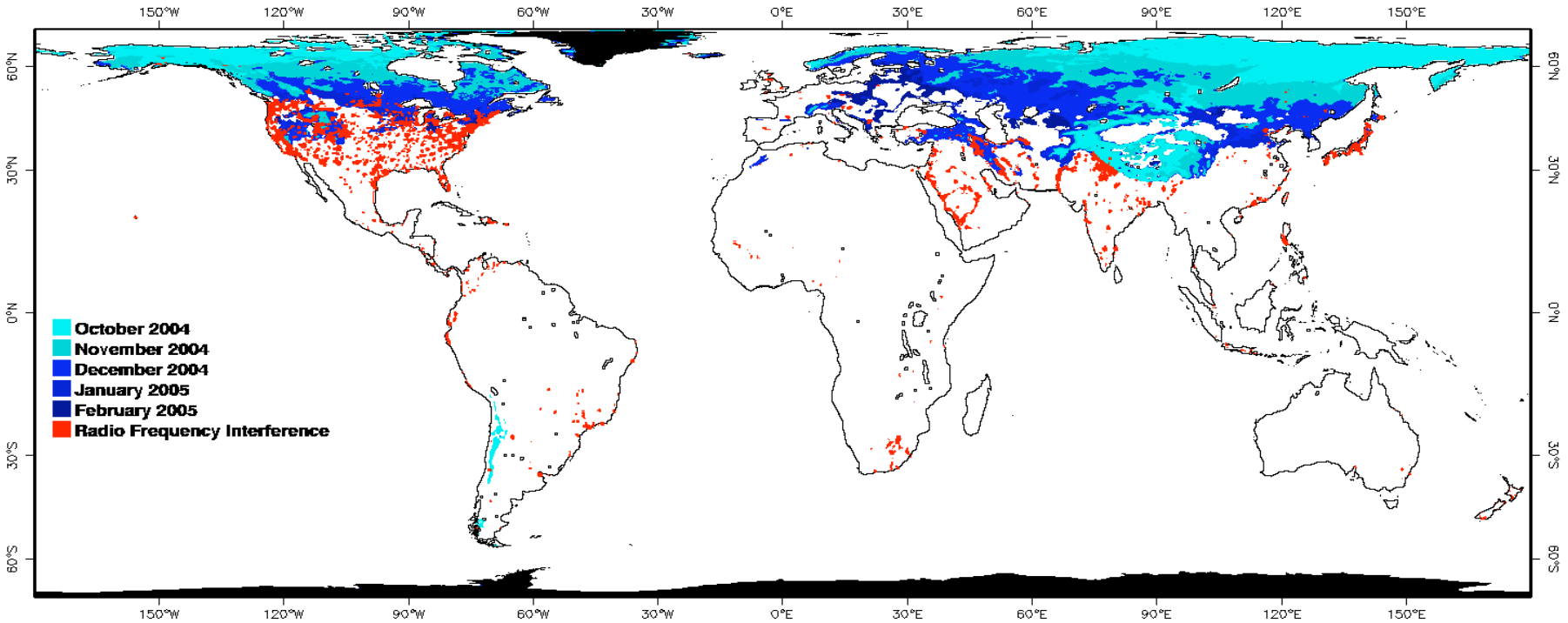


Daily QuikSCAT backscatter

sensitive to vegetation structure and surface roughness changes incl. inundation (warm tones on map)

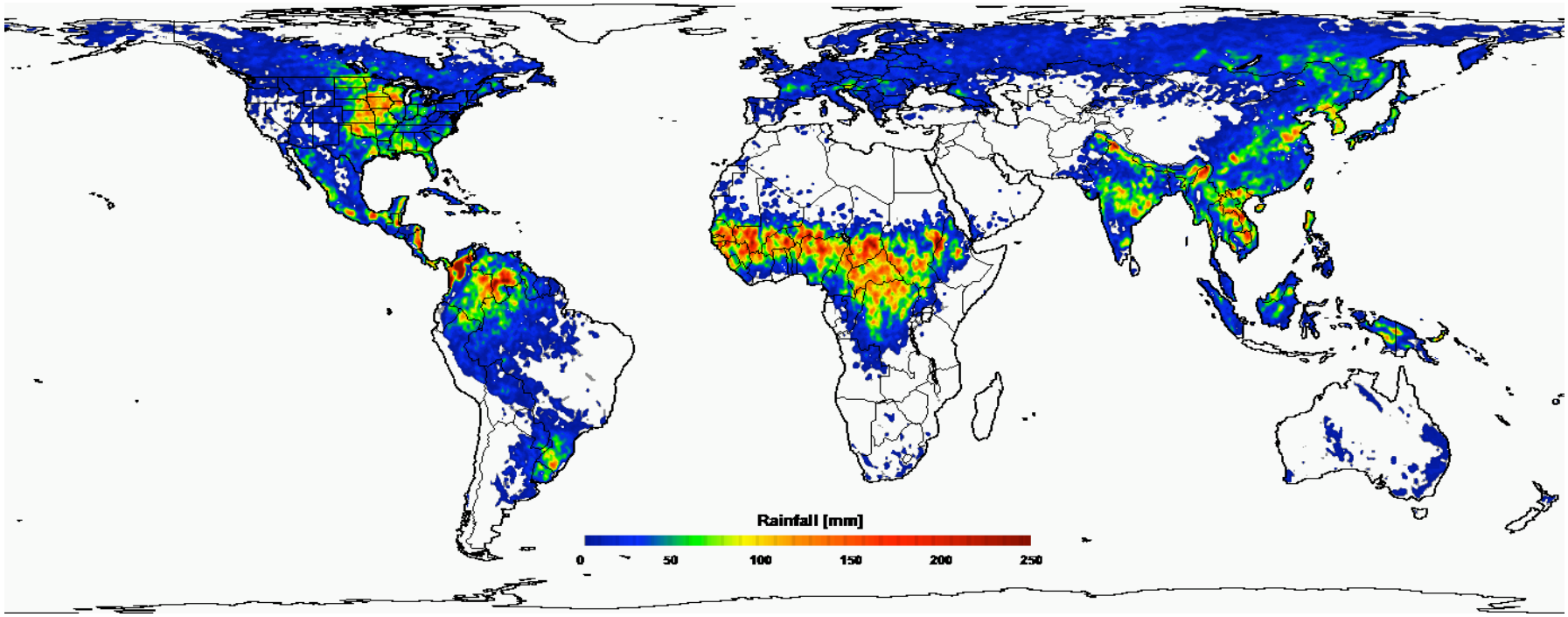

Satellite Data (2002 – 2009)
AMSR-E (Passive Microwave)
QSCAT (ACTIVE MICROWAVE)
Preprocessing/Screening
Data Set Harmonization (Temporal), Topographic Correction (QSCAT), Re-Sampling (Spatial), Microwave Polarization Difference Index (MPDI, Surface Temperature Correction)
Screening for RFI, Snow, Frozen Ground and Rain (AMSR-E)
Processing/Output
AMSR-E/QSCAT MIXTURE MODEL
OPEN WATER FRACTION [FW]
DAILY
MONTHLY
AUXILLIARY

Preprocessing/Screening



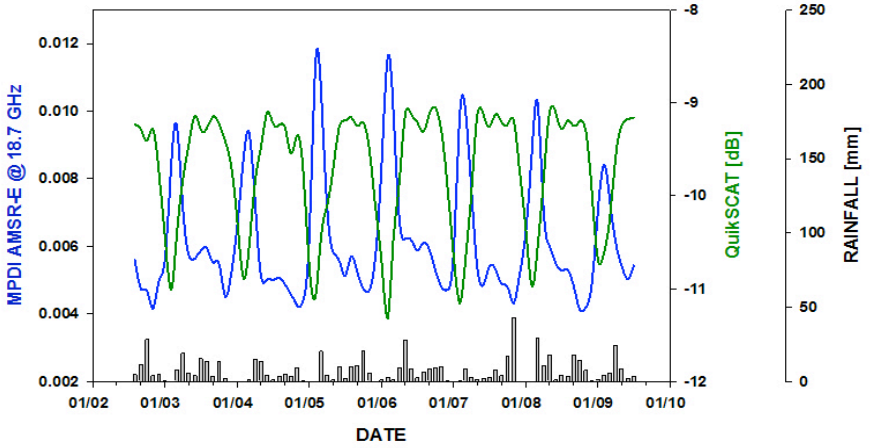
Passive Microwave Screening for SNOW - Winter 04/05

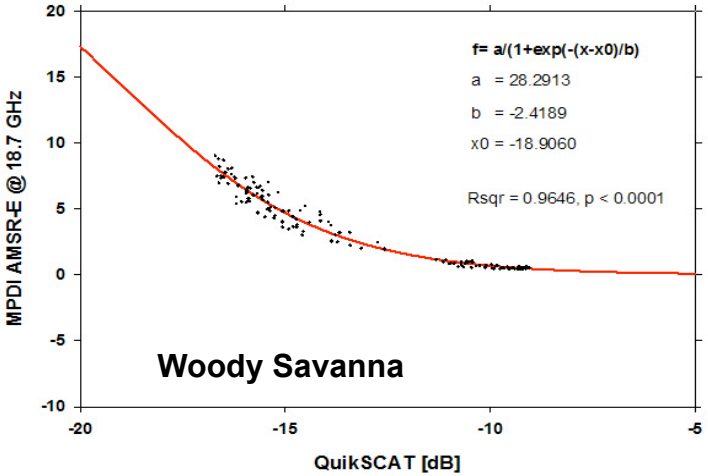
Preprocessing/Screening

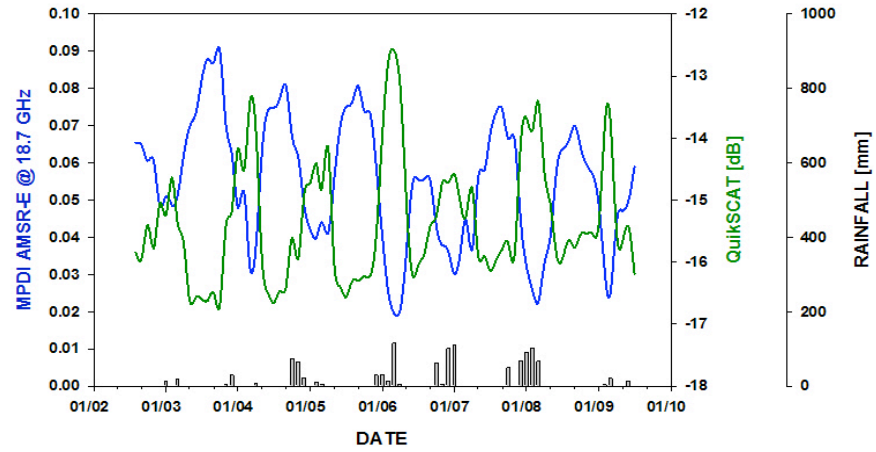


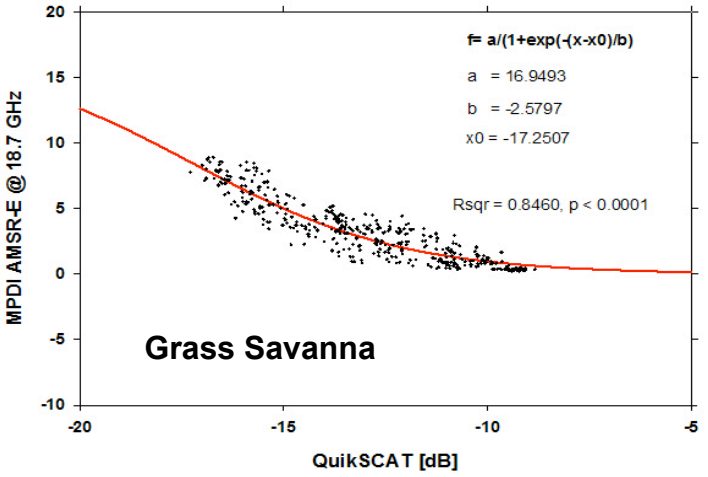
Passive Microwave Screening for RAIN July 02-09

Mixture Model Concept



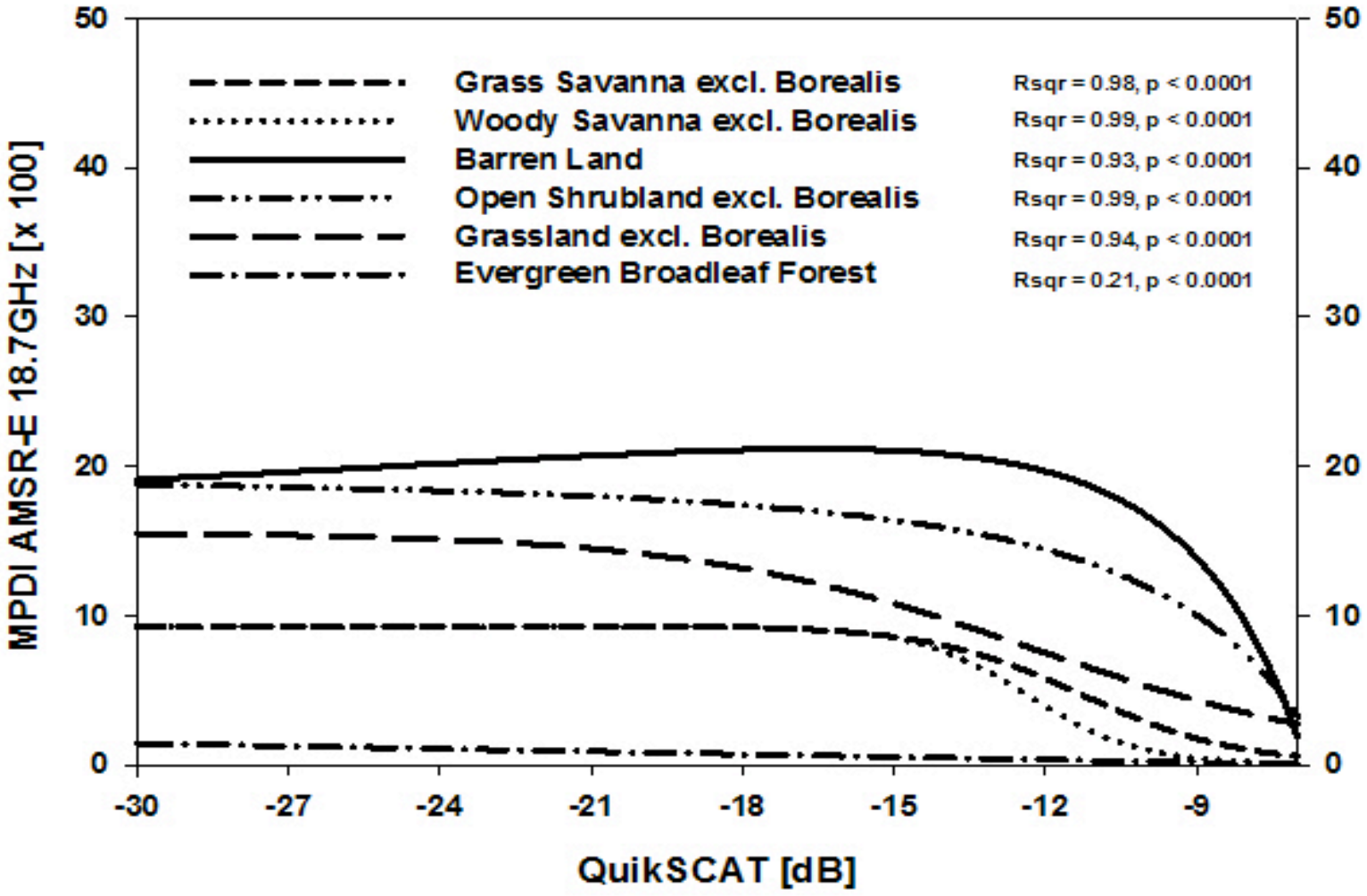






Savanna

Mixture Model

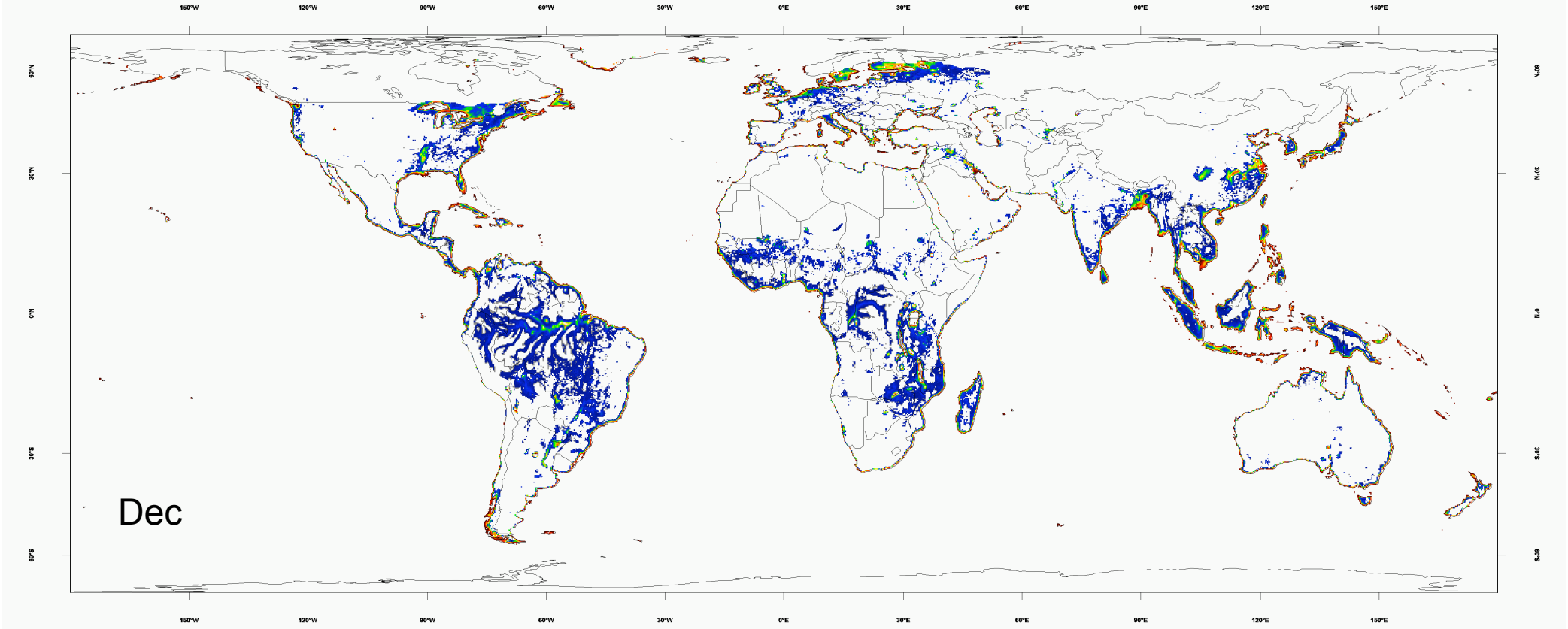


ALOS

K&C Initiative

An international science collaboration led by JAXA

Inundated Area Monthly Composites

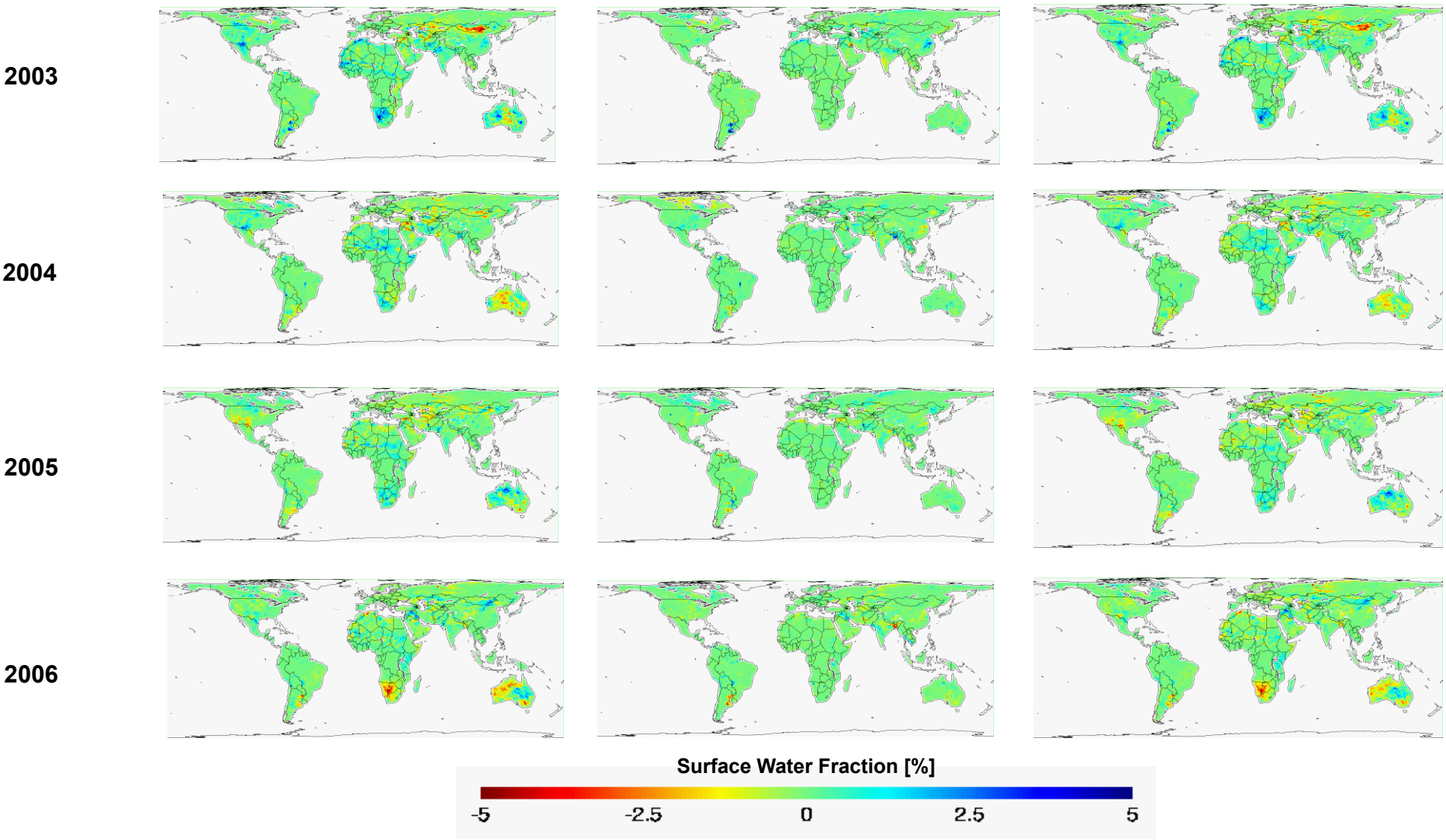


Inundated Area Fraction

0 0.1 0.2 0.3

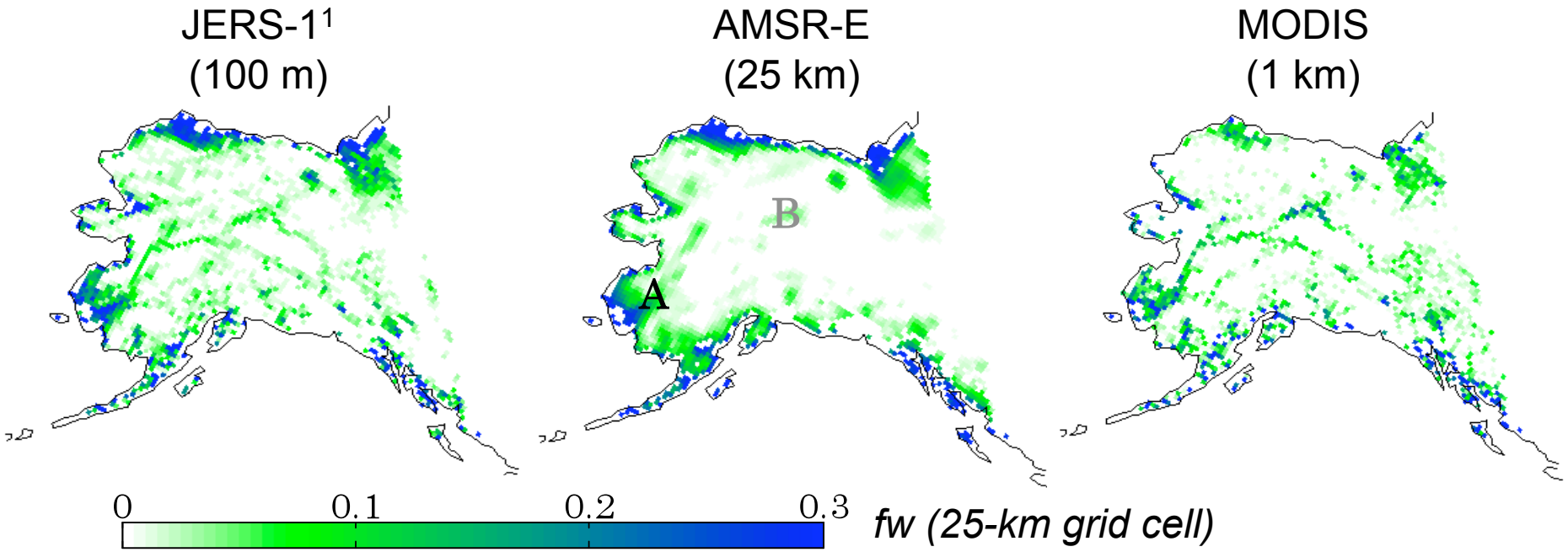
AMSR-E/QSCAT, AMSR-E, SSM/I QSCAT

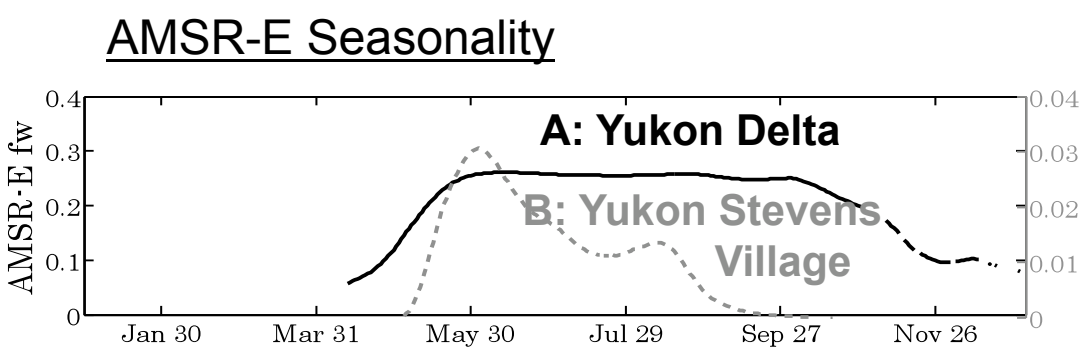
Global Anomalies 2003-2006

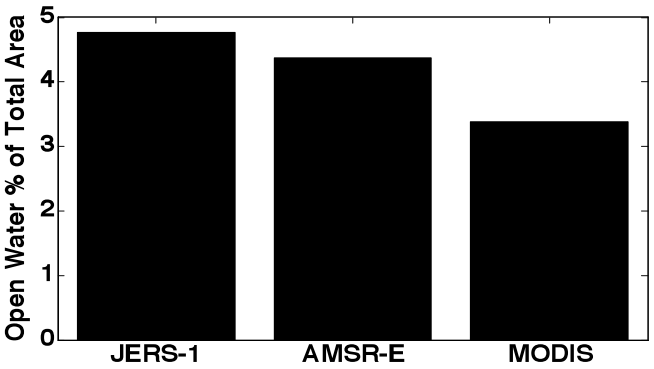


Courtesy of
Lucas Jones

Comparison for Alaska







[1] Whitcomb, J., *Can. J. Rem. Sens.* (2009)

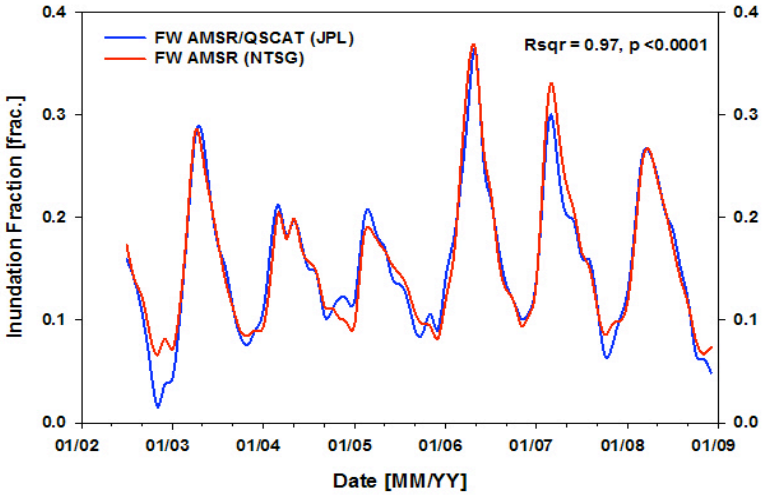
List of Selected Global Reference Sites

Site	Location [Lat, Lon], [EASE X, EASE Y]
EB-1	Peru/Madre de Dios[-11.60/-69.89], [424, 353]
EB-2	Peru/Ucayali[-10.40/-72.49], [414, 347]
EB-3	Brazil/Amazonas[-5.67/-69.89], [424, 323]
EB-4	Brazil/Para'[0.19/-55.05], [481, 293]
EB-5	Cameroon[2.54, 13.15], [743, 281]
EB-6	Congo [0.20, 26.16], [793, 293]
EB-7	Borneo/Sarawak [1.56, 113.36], [1128, 286]
EB-8	Burma [26.51, 97.48], [1067, 163]
EN-1	Russia/Komi [62.79, 47.25], [874, 33]
EN-2	USA/Idaho [45.97, -115.44], [249, 83]
EN-3	Russia/Komi [61.95, 58.44], [917, 35]
DN-1	Russia/Sakha [61.13, 130.54], [1194, 37]
DN-2	Russia/Sakha [60.73, 132.36], [1201, 38]
DB-1	USA/W.Virginia [38.58, -81.34], [380, 111]
DB-2	USA/Pensylvania [41.64, -77.96], [393, 99]
DB-3	Bolivia/Chuquisaca [-20.55, 62.34], [453, 397]
MF-1	Russia/Khabarovsk [47.10, 135.75], [1214, 79]
MF-2	Russia/Altai Rep. [52.55, 87.33], [1028, 61]
MF-3	Russia/Kostroma [57.67, 44.38], [863, 46]
CS-1	Argentinia/Rio Negro [-39.33, -65.21], [442, 480]
CS-2	Somalia [3.71, 44.12], [862,275] !!
CS-3	Somalia [3.52, 43.86], [860,276] !!
OS-1	Lybia [29.38, 12.36], [740,150]
OS-2	Niger [17.24, 5.86], [715,207]
OS-3	Jemen [16.84, 48.55], [879,209]
WSB-1	AK [64.55, -141.21], [150, 29]
WSB-2	Canada [65.95, -140.95], [151, 26]
WSB-3	Canada [64.10, -133.67], [179, 30]
SVB-1	Russia/Amur [55.30, 123.43], [488, 278] N-Hem
GRB-1	Rissia/Sakha [68.96, 117.26], [444, 319] N-Hem

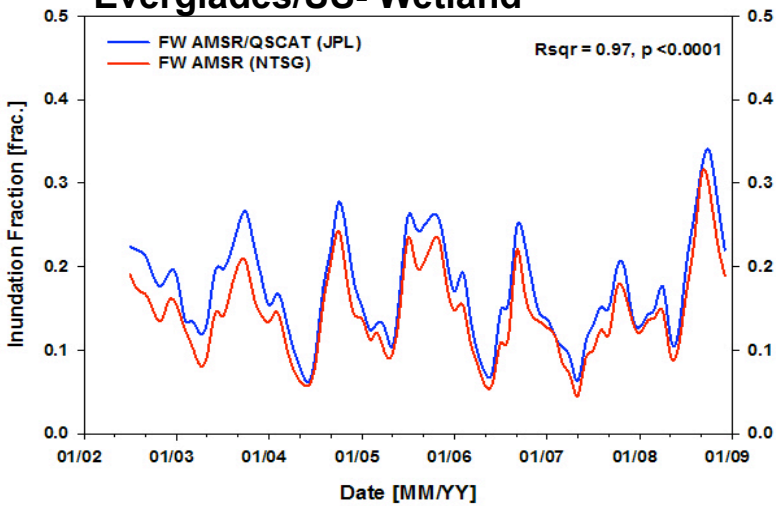
Site	Location [Lat, Lon], [EASE X, EASE Y]
OST-1	Canada/NW Territories [65.47, -139.65], [156, 27]
OST-2	Russia/Koryakskiy [64.10, 164.12], [1323, 30]
OST-3	Russia/Evenkiyskiy [66.43, 98.00], [1069, 25]
OST-4	Russia/Magadan [64.10, 162.04], [1315,30]
OST-5	Russia/Chukotka [63.65, 172.45], [1355, 31]
OST-6	Russia/Magadan [61.95, 155.79], [1291, 35]
WS-1	Congo [-4.89, 25.90], [792,319]
WS-2	Congo [3.32, 30.07], [808, 277]
WS-3	Sierra Leone [9.81, -11.58], [648, 244]
WS-4	Ethopia [9.22, 35.27], [828,247]
WS-5	Zimbabwe [-24.35, 22.52], [779, 415]
SV-1	Mali [12.40, -9.50], [656, 231]
SV-2	Australia [-17.65, 141.74], [1237, 383]
SV-3	Botswana [-19.3, 21.73], [776,391]
SV-4	Botswana [-22.01, 22.78], [780,404]
SV-5	Botswana [-21.38, 22.78], [780, 401]
GR-1	Chad [14.81, 20.43], [771,219]
GR-2	Chad [14.40, 20.95], [773,221]
GR-3	Burkina Faso [13.60, 0.13], [693, 225]
GR-4	Mali [15.21, -7.16], [665,217]
GR-5	Sudan/Northern Kordufan [12.80,27.72], [799,229]
CR-1	Illinois [40.86, -88.11], [354,102]
CR-2	Iowa [43.23, -94.36], [330, 93]
CM-1	Wisconsin [43.76, -90.71], [344, 91]
CM-2	North Dakota [46.82, -101.39], [303, 80]
BL-1	Saudi Arabia [22.65, 46.20], [870, 181]
BL-2	Oman [20.55, 56.10], [908, 191]
BL-3	Egypt [24.13, 31.63], [814, 174]
BL-4	Egypt [28.94, 27.46], [798,152]

Site Comparison AMSR-E and AMSR-E/QSCAT

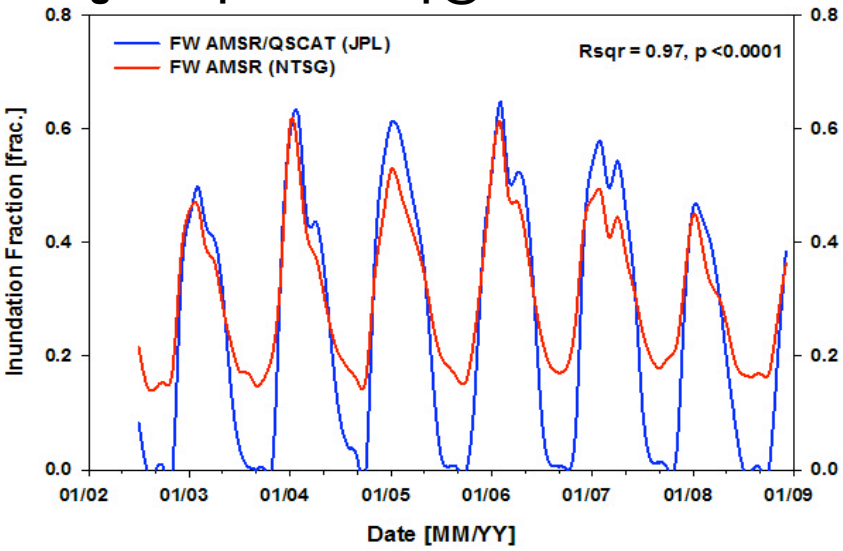
Pantanal/Brazil - Wetland



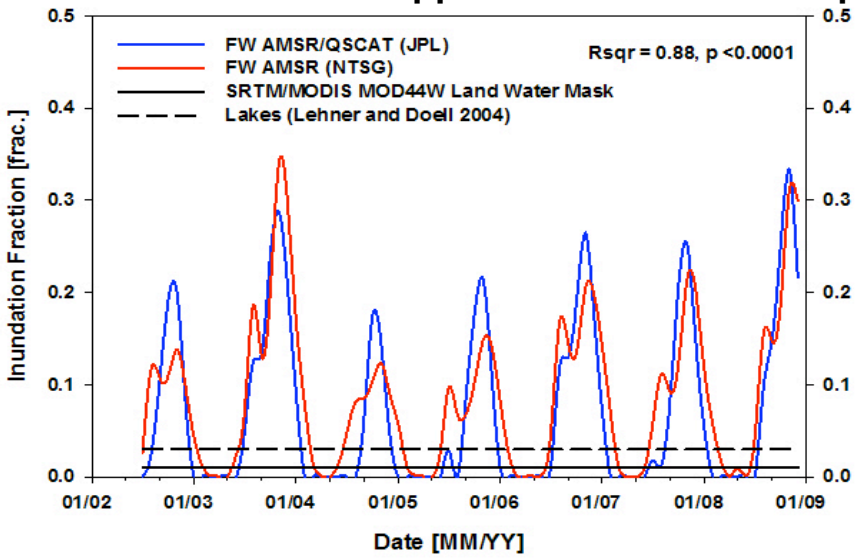
Everglades/US- Wetland



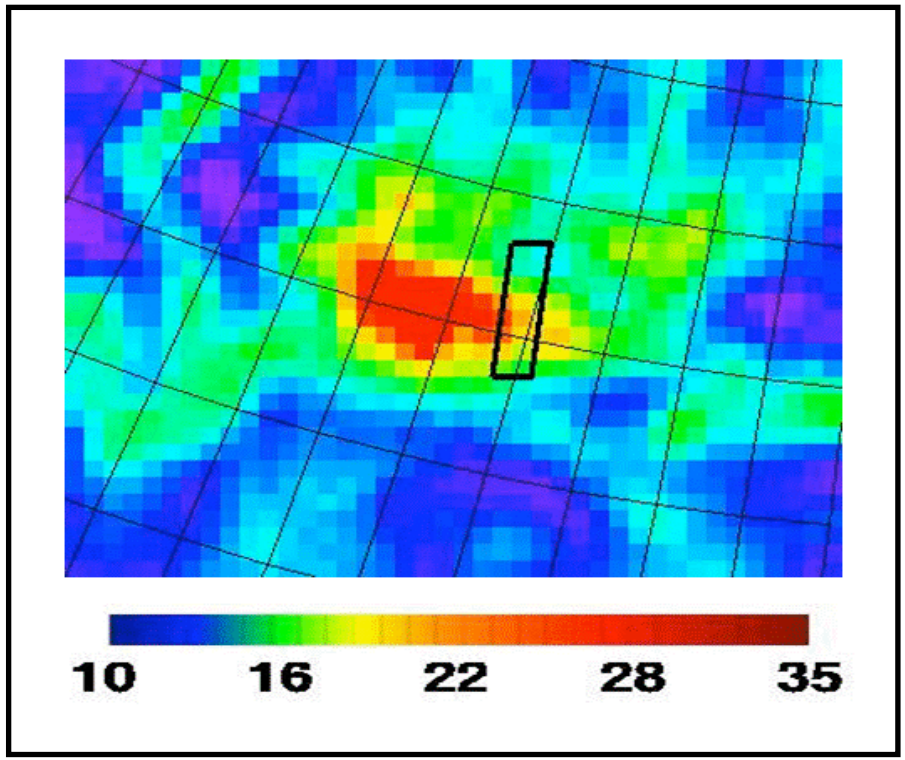
Tigris-Euphrates/Iraq @ Basra - Inundation



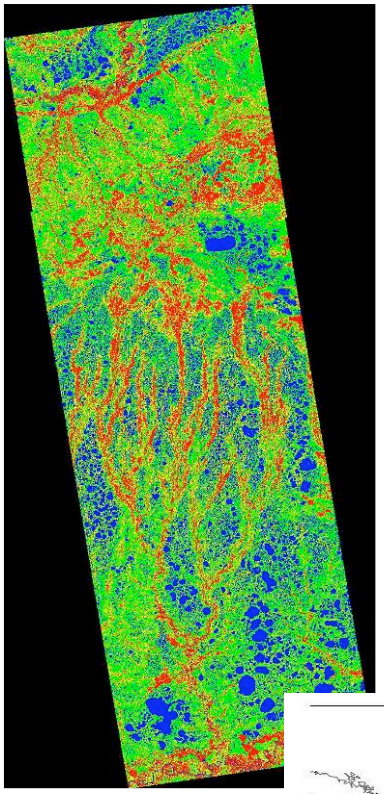
Cleveland/Mississippi/US – Inundation/Crops



Comparison with a high-resolution (30 m) wetland map derived from ALOS PALSAR in the Western Siberian Lowland



AMSR-E/QSCAT (25 km) wetland fraction [%] across Western Siberian Lowland for July 11 -20, 2006



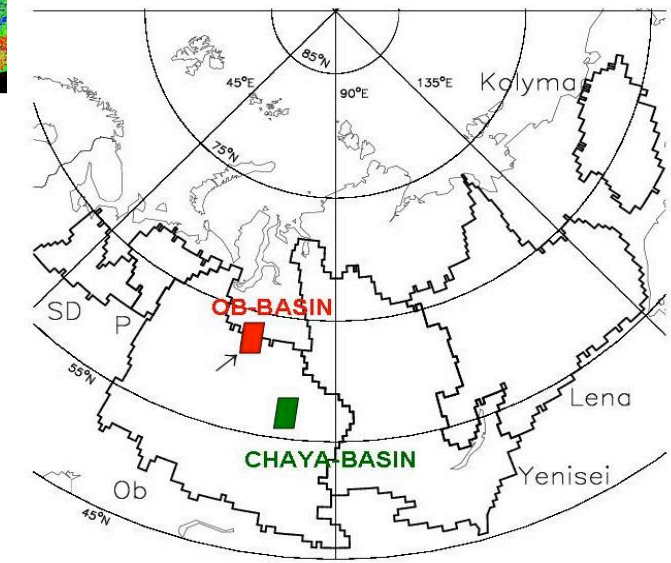
Open water

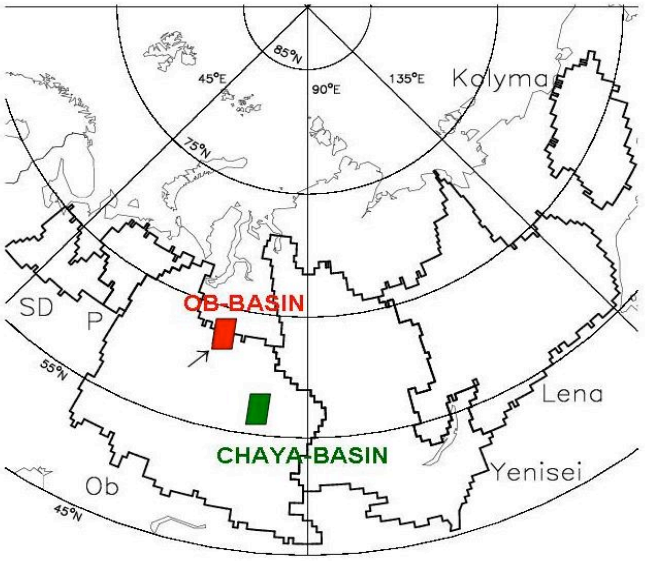
Saturated Soil

Vegetation

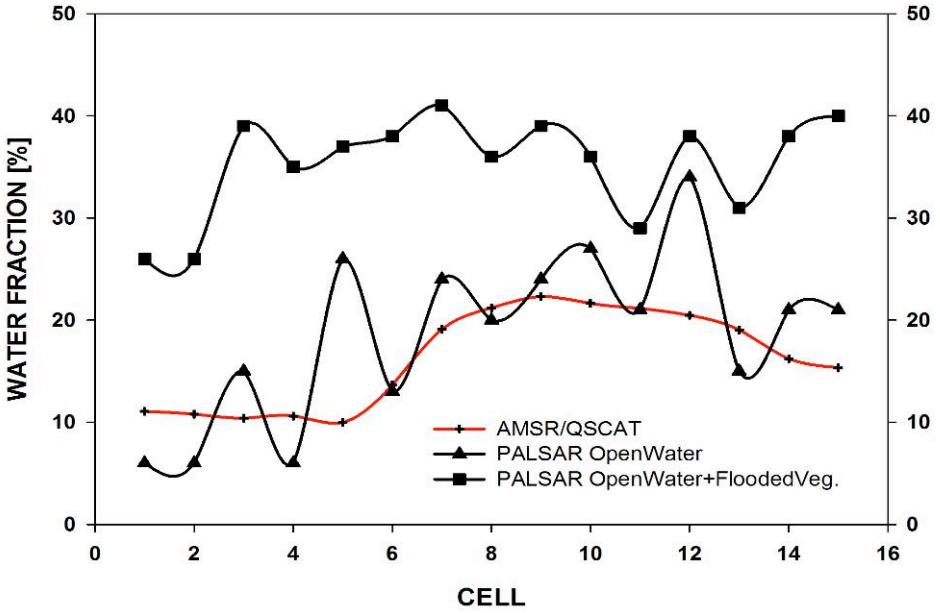
Inundated Vegetation

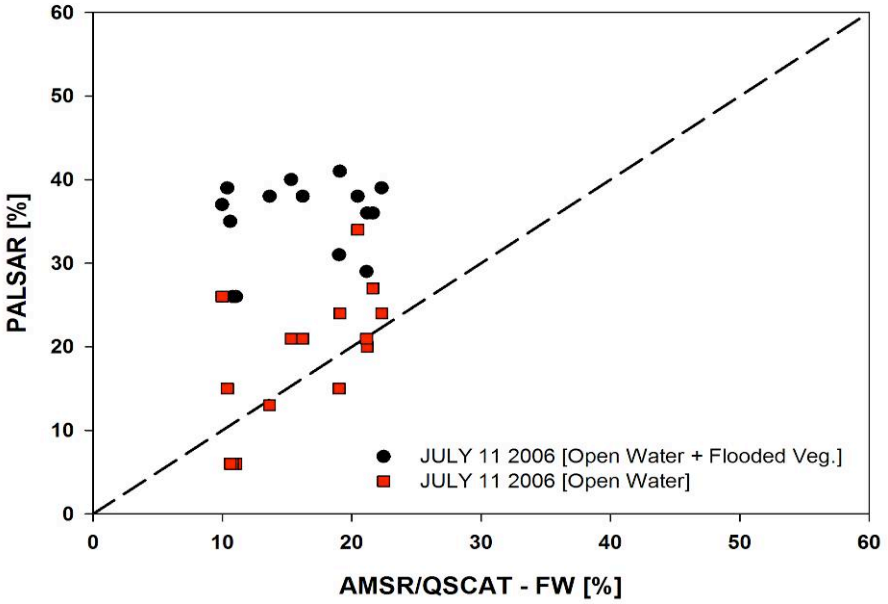
ALOS PALSAR wetland classification Western Siberian Lowland for July 11, 2006.



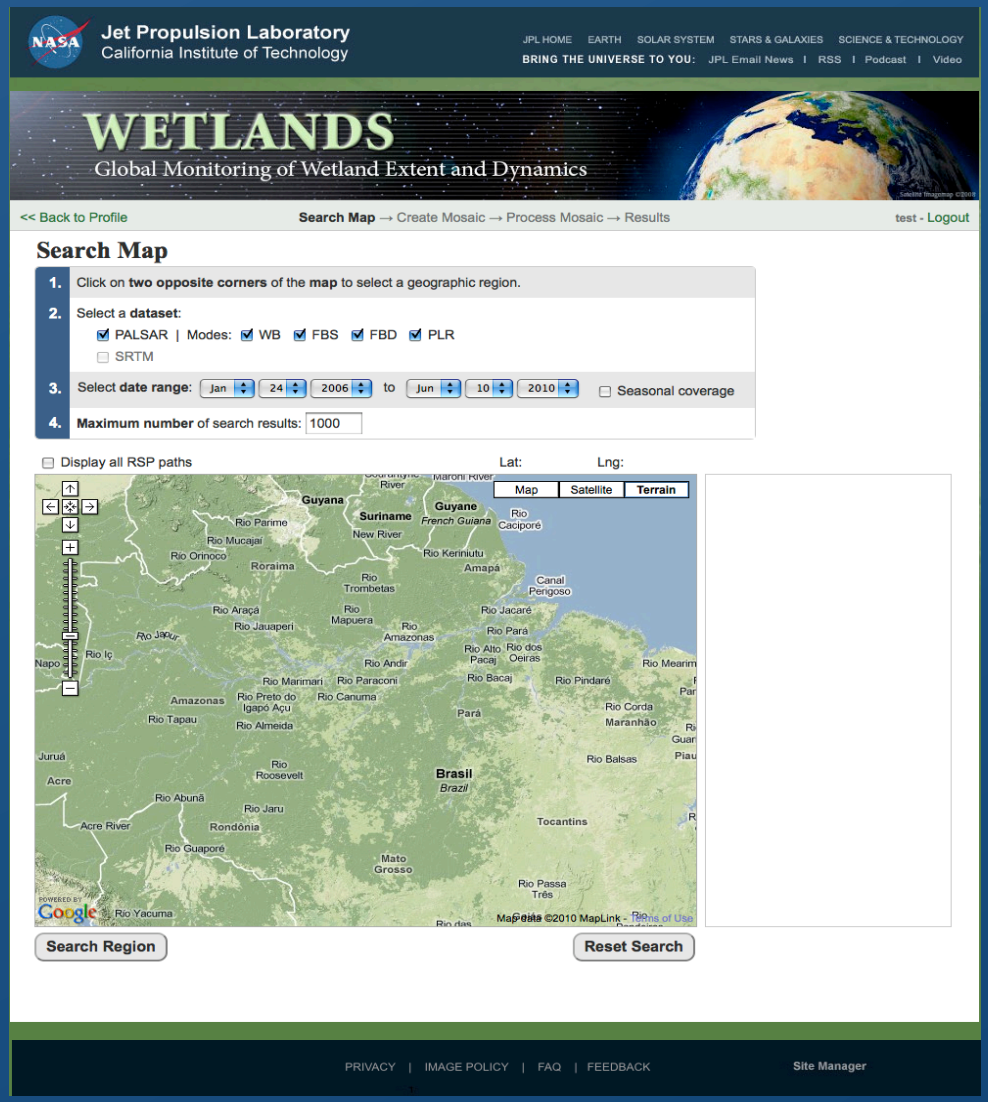


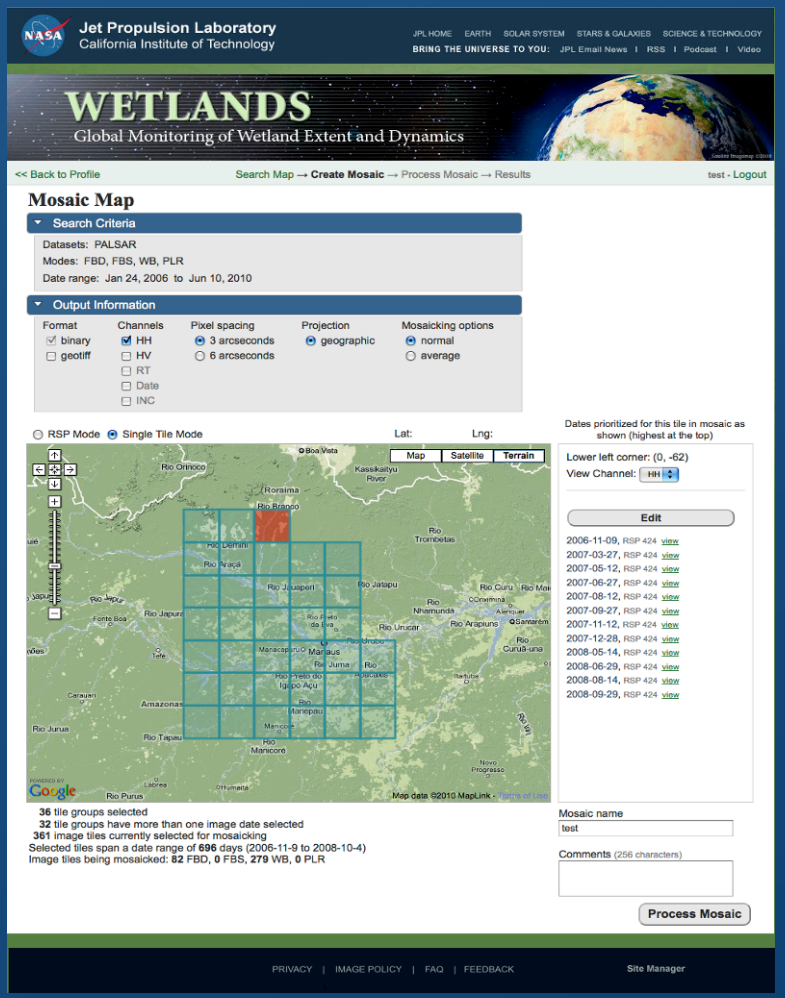
OB-BASIN [JULY 11, 2006]



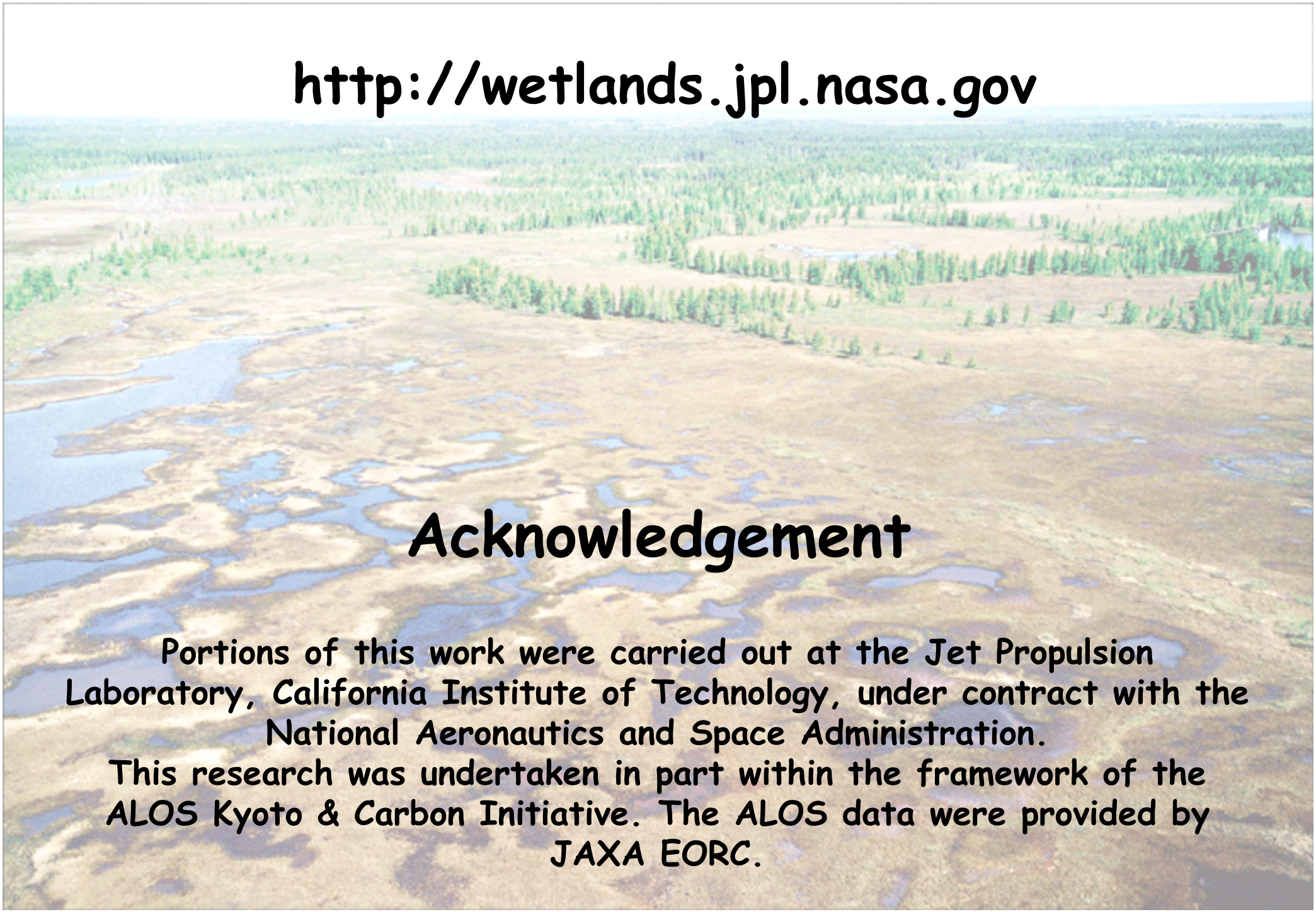


Wetlands Website: Navigation





Search & mosaic pages



http://wetlands.jpl.nasa.gov

Acknowledgement

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This research was undertaken in part within the framework of the ALOS Kyoto & Carbon Initiative. The ALOS data were provided by JAXA EORC.