Mapping Global Wetlands and Boreal Freeze/Thaw with ALOS PALSAR

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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)

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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**

<table>
<thead>
<tr>
<th>I. Regional inundated wetlands data sets from Synthetic Aperture Radar (SAR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Spatial coverage: Major global wetland regions, 100m resolution</td>
</tr>
<tr>
<td>- Temporal coverage: 1-2 year time series at 17-to-46 day intervals during 2006-2009 †‡</td>
</tr>
<tr>
<td>- Retrospective 1990’s-era from archived JERS data covering Alaska, Canada, Amazon</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>II. Global monthly inundation data sets derived from multiple satellite data sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Spatial coverage: Global, 25 km resolution</td>
</tr>
<tr>
<td>- Temporal coverage: Monthly monitoring with annual summaries, 1992-2009 †</td>
</tr>
</tbody>
</table>

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

McDonald et al.  An Inundated Wetlands Earth System Data Record
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

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

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

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%

Classification accuracy for saved forest 85%
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:

<table>
<thead>
<tr>
<th>Wetlands Code:</th>
<th>E2EM</th>
<th>E2EM</th>
<th>PEM</th>
<th>PEM</th>
<th>PEM</th>
<th>PSS</th>
<th>PSS</th>
<th>PFO</th>
<th>BAR</th>
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<tbody>
<tr>
<td>Wetlands Type:</td>
<td>2</td>
<td>4</td>
<td>31</td>
<td>33</td>
<td>35</td>
<td>38</td>
<td>40</td>
<td>46</td>
<td>47</td>
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<tr>
<td>Class Number:</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>9</td>
</tr>
<tr>
<td>1</td>
<td>21021</td>
<td>3964</td>
<td>0</td>
<td>1646</td>
<td>20</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1895</td>
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<tr>
<td>2</td>
<td>2456</td>
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<td>8047</td>
<td>79</td>
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<td>0</td>
<td>0</td>
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<td>3</td>
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<td>15</td>
<td>4861</td>
<td>498</td>
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<td>1303</td>
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<td>4618</td>
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<tr>
<td>Total in Class:</td>
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<td>78956</td>
<td>27279</td>
<td>326076</td>
<td>418928</td>
<td>278151</td>
<td>8913</td>
<td>7581</td>
<td>7071</td>
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<tr>
<td>Correct in Class:</td>
<td>21021</td>
<td>6554</td>
<td>4861</td>
<td>233491</td>
<td>374403</td>
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<td>3843</td>
<td>778</td>
<td>1268</td>
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<tr>
<td>Class Error Rate:</td>
<td>14.12</td>
<td>16.98</td>
<td>82.18</td>
<td>28.39</td>
<td>10.63</td>
<td>16.29</td>
<td>56.88</td>
<td>89.74</td>
<td>82.07</td>
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<tr>
<td>Total in Superclass:</td>
<td>875717</td>
<td>287064</td>
<td>7581</td>
<td>7071</td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>Correct in Superclass:</td>
<td>836037</td>
<td>240310</td>
<td>778</td>
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</tr>
<tr>
<td>Superclass Error Rate:</td>
<td>4.53</td>
<td>89.74</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
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

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
Fine-Beam, slant range, ~50 m

~70 km

Wide-Beam, slant range, ~100 m

~360 km

Fine-Beam, slant range, ~50 m

strip lengths:
~ 3500 km

RSP 82
(Fine-Beam, ascending)

RSP 424
(Wide-Beam, descending)

K&C Initiative
An international science collaboration led by JAXA
Simple thresholds for identifying open water and inundated vegetation

Open water $\rightarrow$ less than -10dB

Inundated Vegetation $\rightarrow$ greater than -6 dB

19M
Simple threshold-based classification

Is there data?
- no → Assign no-data class
- yes → Assign forest class

Is it Inundated vegetation?
- yes → Re-assign with Inundated Vegetation class
- no → Is it open water or bare ground?
  - yes → Re-assign with open water / bare ground class
  - no → Are slopes large?
    - yes → Assign forest class
    - no → Re-assign with mask value

Does averaged-down data indicate open water?
- no → After examination of results, a calibration correction may be applied to the data and re-classified
- yes → Re-assign as open water class

Is incidence angle < 29 degrees?
- yes → Re-assign with mask value
- no → Assign forest class

yes

no
AMSR-E+QSCAT and SSM/I+QSCAT
Global Anomalies 2003-2006

<table>
<thead>
<tr>
<th>Year</th>
<th>Surface Water Fraction [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>2003</td>
<td>[Map showing global anomalies]</td>
</tr>
<tr>
<td>2004</td>
<td>[Map showing global anomalies]</td>
</tr>
<tr>
<td>2005</td>
<td>[Map showing global anomalies]</td>
</tr>
<tr>
<td>2006</td>
<td>[Map showing global anomalies]</td>
</tr>
</tbody>
</table>

QSCAT-AMSR-E 18.7 GHz
QSCAT-SSM/I 19.35 GHz
Fraction for each 1deg x 1deg cell

ALOS Open Water

AMSR-E/QSCAT Open Water

ALOS Inundated Vegetation

May-June 2007

19M

Fraction open water

0% 5%

Fraction inundated vegetation

0% 40%
Fraction for each 1deg x 1deg cell

ALOS Open Water

AMSR-E/QSCAT Open Water

ALOS Inundated Vegetation

Fraction open water

Fraction inundated vegetation

19M
Fraction for each 1deg x 1deg cell

ALOS Open Water

AMSR-E/QSCAT Open Water

ALOS Inundated Vegetation

Aug-Sept 2007

19M Fraction open water

Fraction inundated vegetation

0% 5% 0% 40%
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 km² 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

- Apr 10
- Jul 19
- Dec 26

**Source:** [http://freezethaw.ntsg.umt.edu](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