

# Monitoring Inundated Wetlands Ecosystems with Satellite Microwave Remote Sensing in Support of Earth System Science Research

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**Abstract** - We are constructing a global-scale Earth System Data Record (ESDR) of inundated wetlands to facilitate investigations on their role in climate, biogeochemistry, hydrology, and biodiversity. The ESDR is composed of fine-resolution maps of wetland extent, vegetation type, and seasonal inundation dynamics derived from Synthetic Aperture Radar (SAR) for continental-scale areas covering crucial wetland regions, and global multi-year mappings of inundation extent at coarse resolution derived from multiple satellite data sets. We present details of ESDR construction including remote sensing algorithms, cross-product harmonization, and data system development supporting ESDR construction and product dissemination. This ESDR will provide the first accurate, consistent and comprehensive global-scale data set of wetland inundation and vegetation.

**Key Words:** wetlands, inundation, remote sensing, ESDR

## 1. INTRODUCTION

Wetlands cover less than 5% of Earth's ice-free land surface but exert major impacts on global biogeochemistry, hydrology, and biological diversity. The extent and seasonal, interannual, and decadal variation of inundated wetland area play key roles in ecosystem dynamics. Climate change is projected to have a pronounced effect on global wetlands and freshwater ecosystems through sea level change and alterations in hydrologic regimes. In turn, climate-driven and anthropogenic changes to tropical and boreal peatlands have the potential to create significant feedbacks through release of large pools of soil carbon and effects on methanogenesis. The extent and dynamics of global wetlands remain poorly characterized and modeled, primarily because of the scarcity of suitable regional-to-global remote-sensing data for characterizing their distribution and dynamics.

We are developing an Earth System Data Record (ESDR) of Inundated Wetlands to facilitate a range of global to regional investigations on the role of inundated wetlands in climate, biogeochemistry, hydrology and biodiversity. The ESDR will enable advances in understanding and modeling the role of wetlands in 1) global cycling of carbon and water, 2) interactions among climate, greenhouse-gas emissions, and water exchange, 3) climate change effects and feedbacks, 4) maintaining ecological health and biodiversity of critical habitats, and 5) management of water resources for long-term sustainability. We are employing mature algorithms and

data processing methodologies to produce two complementary ESDR components:

(1) Regional fine-resolution (100m) data sets of wetland extent, vegetation type, and seasonal inundation dynamics at approximately monthly intervals for continental-scale areas covering crucial wetland regions.

(2) Global data sets of fractional inundation at coarse (~25 km) resolution at weekly and monthly intervals for the period 1992-2009, derived from multiple satellite observations including e.g. AMSR-E and SeaWinds-on-QuikSCAT.

Comparison and validation of coarse resolution data sets with the fine-scale regional wetland distributions ensures self-consistency within the ESDR.

## 2. DEVELOPEMENT OF ESDR COMPONENTS

Our objective is assembly of a data set to facilitate global and regional studies of the role of inundated wetlands in studies of climate, biogeochemistry, hydrology, and biodiversity. To achieve this, we construct an Earth System Data Record of natural inundated wetlands consisting of two components, each designed to address specific requirements.

### 2.1 Fine-resolution data sets of wetlands vegetation

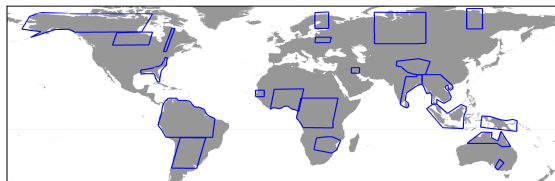
The first ESDR component comprises a regional, fine-scale (100 m) inundated wetlands data set. Assembly of these products focuses on regions covered by the broad, systematic coverage plan developed for the Advanced Land Observing Satellite (ALOS) PALSAR (Fig. 1). Contemporary-era mapping utilizes recent and on-going L-band PALSAR collections while 1990s-era mapping draws on imagery from the Japanese Earth Resources Satellite (JERS) SAR data archives (e.g., Fig. 2).

Construction of the regional data sets relies on classification algorithms developed under prior efforts utilizing image segmentation and statistically based decision tree classification schemes (Fig. 3; Hess et al. 1995, 2003; Whitcomb et al, 2009). Regional data sets include inundated wetland area on a swath-by-swath basis as defined by the SAR acquisitions delineating principal wetland vegetation classes (non-vegetated, herbaceous, shrub, woodland, forest), as well as seasonally-based summary products describing timing and extent of wetland inundation.

The ALOS data used in this work is obtained directly through the Earth Observation Research Center of the Japan Aerospace Exploration Agency (EORC/JAXA), through existing agreements with the ALOS Kyoto & Carbon science team.

## 2.2 Coarse-resolution inundated area fraction

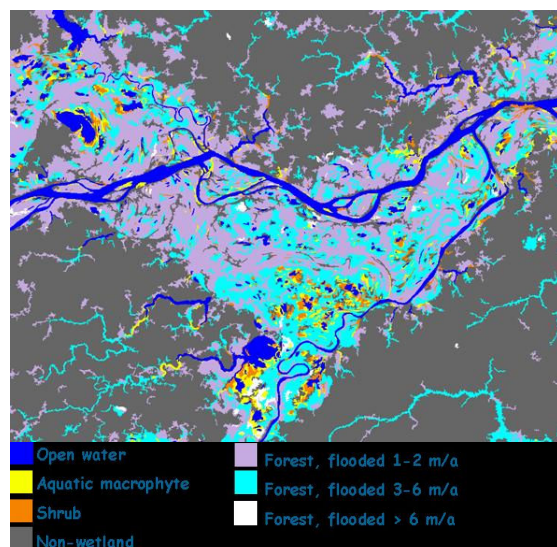
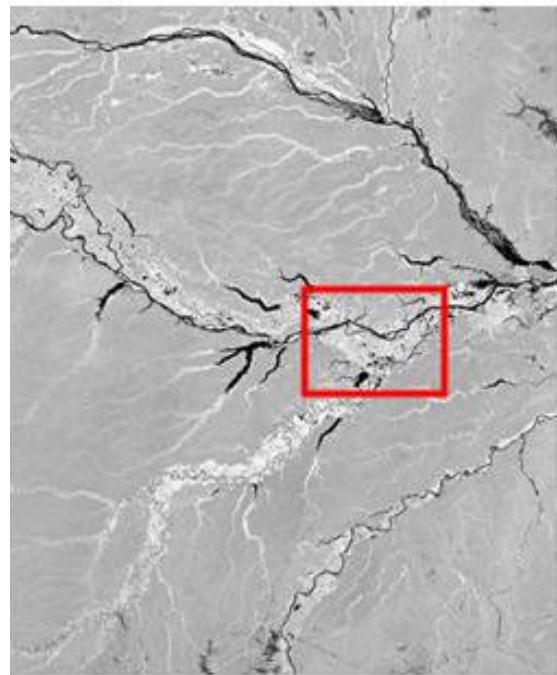
The second ESDR component is a global, multi-decade data set of inundation dynamics at ~25 km resolution. This data set quantifies the multi-temporal (weekly-to-monthly) distribution of land surface inundated area and is derived from observations by multiple satellite sensors. The estimation of land surface inundation relies on application of a spectral mixture model to a combined active/passive microwave remote sensing data set obtained from daily SeaWinds-on-QuikSCAT backscatter and AMSR-E brightness temperature polarization difference ratios (Schroeder et al 2010). The QuikSCAT/AMSR-E product quantifies seasonal and spatial dynamics of inundated wetlands for 2002-2009. Incorporating additional time series data from SSM/I and the ERS and ASCAT scatterometers will extend this time series across nearly two decades, extending from 1992.



**Figure 1.** Regions for which ALOS PALSAR repeat acquisition ScanSAR HH-polarization (descending) mode data collections have been targeted to support wetlands studies. Targeted areas include major wetland regions to receive at least one year of coverage with a 17-46-day repeat cycle, allowing consistent monitoring at 100 m spatial resolution. All areas have received PALSAR coverage in fine-resolution (ascending) dual-pol (HH+HV) mode at least once, with the bulk of those data acquired during summer 2007. This coverage constitutes the Wetlands Theme of JAXA's ALOS Kyoto & Carbon (K&C) Initiative (ALOS K&C Science Panel 2006). The data are available to our project directly from JAXA/EORC through the ALOS K&C Initiative.

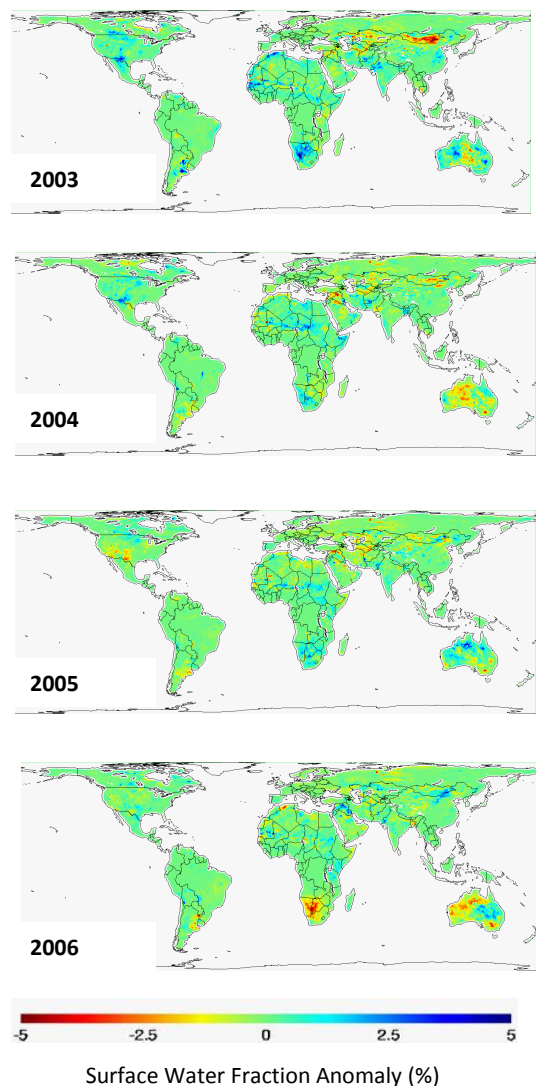


**Figure 2.** Wetlands map of Alaska derived from L-band JERS SAR backscatter imagery. The 1990's-era JERS data set constitutes a pathfinder for application of satellite-borne SAR for mapping global wetlands. (Whitcomb et al., 2009).



**Figure 3.** Top: ALOS PALSAR ScanSAR image of a region of the Amazon basin in Brazil. Dark regions correspond to open water areas while bright areas correspond to inundated vegetation. Bottom: Sample product for Piagaçu-Purus Reserve, Brazil, corresponding to the region enclosed by the red box in the top panel. Multi-temporal ScanSAR imagery allows delineation of inundation duration as well as classification of vegetation type.

This effort relies on systematic, sustained, global, daily satellite measurements to accomplish consistent, large-area characterization of wetland inundation. This data set is unique not only in thematic content (inundated wetlands) but also in terms of its domain (global), high temporal resolution (weekly to monthly), and multi-year coverage. These data are also employed to construct annual summary products, including maximum spatial distribution and area, and annual inundation duration, and to examine annual anomalies in inundated area (Figure 4).

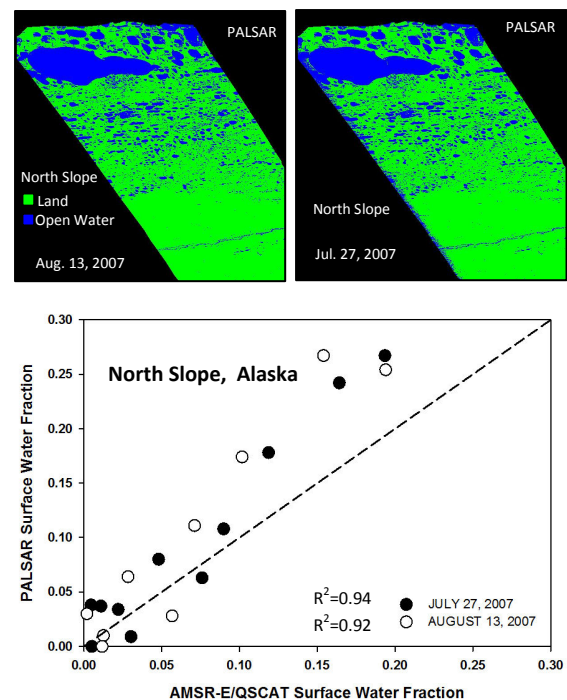


**Figure 4.** Annual anomalies in surface water inundation (%) derived from AMSR-E and SeaWinds-on-QuikSCAT for 2003-2006. These global data sets are derived using a mixture model applied to daily AMSR-E 19GHz brightness temperature polarization difference ratios and 14 GHz backscatter series from QuikSCAT (Schroeder et al., 2010). Data are provided on a 25 km global EASE Grid posting.

### 2.3 Harmonization of ESDR components

The cross-calibration of the multi-year coarse resolution inundation data sets and the regional fine-scale inundated wetlands data sets will ensure consistency across multiple scales and sensors. We compare the fine-scale SAR-based wetlands maps with contemporaneous 25 km

resolution inundated area fraction mappings to assess differences and similarities between these ESDR components. Figure 5 shows an example of a comparison carried out over the North Slope of Alaska. Open water maps of this tundra-dominated region are derived from ALOS PALSAR imagery collected on July 27 and August 13, 2007. The PALSAR-based open water map was aggregated to a 25 km EASE Grid projection to facilitate comparison with the coarse resolution surface water fraction products. The product comparison demonstrates high correlation ( $R^2 = 0.94$  and  $0.92$  for July 27 and August 13, respectively) between the data sets with the higher resolution PALSAR product showing greater presence of open water at higher levels of surface inundation.



**Figure 5. Top:** Open water maps derived at 30 meter resolution from PALSAR for two dates in 2007. **Bottom:** The PALSAR maps are aggregated to 25 km and compared with contemporaneous coarse resolution inundated area fraction derived from AMSR-E and QuikSCAT for the region covered by the PALSAR products.

### 3. DISSEMINATION OF DATA SETS

Derivation and utilization of these large-scale products from data sources spanning multiple resolutions necessitates establishment of a large product database and development of effective software tools supporting manipulation and regional-scale analysis. To this end, we are constructing a user-accessible data system available through a World Wide Web portal to facilitate assembly, analysis and distribution of ESDR components. This framework includes powerful and flexible software tools for mosaic assembly of SAR images and derived ESDR products, and for data product display, assessment, and distribution to the science community. Data products will be accessible via this interface through integrated web sites at collaborating institutes and an appropriate NASA DAAC.

#### 4. CONCLUSIONS

The Inundated Wetlands ESDR will provide the first accurate, consistent and comprehensive global-scale data set of wetland inundation and vegetation, including weekly to monthly inundation dynamics at multiple scales. Both components of the ESDR have been designed to facilitate a range of studies by addressing critical gaps in data and understanding of the role of inundated wetlands in important cycles and processes. The regional fine-scale seasonal inundated wetlands data sets derived from SAR provide key environmental and ecological information needed for regional- to continental-scale studies focusing on biogeochemistry, hydrology, plant and animal biodiversity, water resource management, and long-term sustainability of wetland ecosystems. The global, inundated area data set, spanning almost two decades, represents a unique, comprehensive source of quantitative information supporting analyses and modeling of wetlands in the global cycling of methane, carbon dioxide, and water, as well as simulations of the interactions among climate, greenhouse-gas emissions, and water exchange for past, current and future time periods.

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