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InSAR-Based Hydrology of Wetlands

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Wetlands are transition zones where the flow of water, nutrient cycling, and the sun's energy meet to produce a unique and very productive ecosystem. They provide critical habitat for a wide variety of plant and animal species, including the larval stages of many ocean fish. Wetlands also have a valuable economical importance, as they filter nutrients and pollutants from fresh water used by humans and provide aquatic habitats for outdoor recreation, tourism, and fishing. Globally, many such regions are under severe environmental stress, mainly from urban development, pollution, and rising sea level. However, there is increasing recognition of the importance of these habitats and, mitigation and restoration activities have begun in a few regions. A key element in wetlands conservation, management, and restoration involves monitoring its hydrologic system, as the entire ecosystem depends on its water supply. Heretofore, hydrologic monitoring of wetlands are conducted by stage (water level) stations, which provide good temporal resolution, but suffer from poor spatial resolution, as stage stations are typically distributed over several or even tens of kilometers from one another.

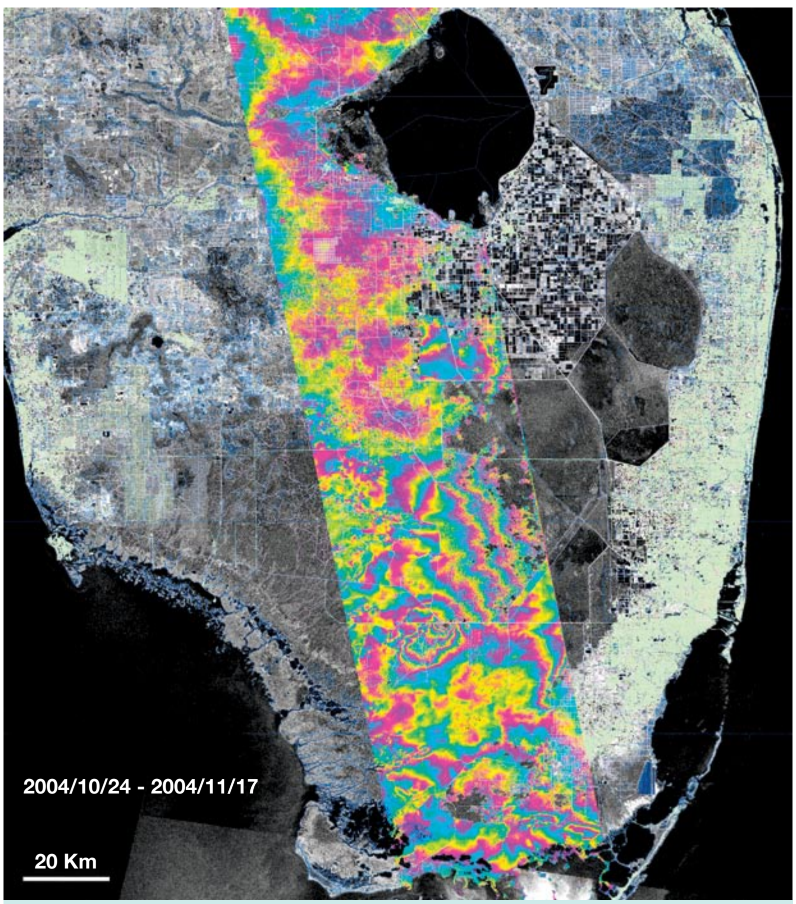

Figure 1. RADARSAT-1 interferogram of central south Florida (2004/10/24-2004/11/17), overlaying a Landsat ETM band8 and vectors maps showing the geographic location of the data. The interferogram shows backscatter phase changes between the two RADARSAT-1 synthetic aperture radar (SAR) acquisitions. The observed phase changes measure cm-level changes in the wetland surface water level.

Wetland application of InSAR provides the needed high spatial resolution hydrological observations, complementing high temporal resolution terrestrial observations. Although conventional wisdom suggests that interferometry does not work in vegetated areas, several studies have shown that both L- and C-band interferograms with short acquisition intervals (one-105 days) can maintain excellent coherence over wetlands. Interferometric coherence is a measurement of how much the complex phase signal of two SAR images is coherent; it reflects a quality measure of an interferogram. In specific cases of wooded wetlands, coherence can be maintained over several years. Interferometric phase is maintained over both woody and herbaceous vegetations, suggesting that double-bounce is the dominant backscatter mechanism in both wetland environments.

In order to evaluate which data type and acquisition parameters are most suitable for wetland application of InSAR, we ordered, acquired, and processed a variety of data collected by the ERS-1/2, JERS-1, RADARSAT-1, and ENVISAT satellites. We explored the use of InSAR for detecting water level changes in various wetland environments around the world, including the Everglades (south Florida), Louisiana coast (southern U.S.), Chesapeake Bay (eastern U.S.), Pantanal (Brazil), Okavango Delta (Botswana), and Lena Delta (Siberia). Our main study area is the Everglades wetland because: (1) it contains various wetlands types (woody, herbaceous, saltwater

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mangrove, and mixed environments), (2) it contains both natural and managed flow areas, and (3) it is hydrologically monitored by a dense network of stage (water level) stations. Our analyses suggest that L-band observations are characterized by higher coherence than C-band observations. We also found that HH polarization with high-resolution and small incidence angle is more suitable to wetland InSAR application.

Our analyses of various data types revealed that RADARSAT-1 observations are very suitable for wetland InSAR, because the satellite has a short repeat orbit period (24 days), HH polarization, and ability to acquire high-resolution observations (fine beam with 7-meter pixel resolution). Using the NASA RADARSAT program, we have acquired RADARSAT-1 data systematically, since October 2004, over two large wetland regions, the Louisiana coast and the Everglades (Figure 2). The data are ordered by ASF, downlinked at CSTARS (Center for Southeastern Tropical Advanced Remote Sensing at the University of Miami), and are available for monitoring and research in near real time. We are currently monitoring the south Florida wetlands with five swaths and the Louisiana coast wetlands with four swaths. This acquisition plan provides new SAR observations of each study area every 4-7 days. Such

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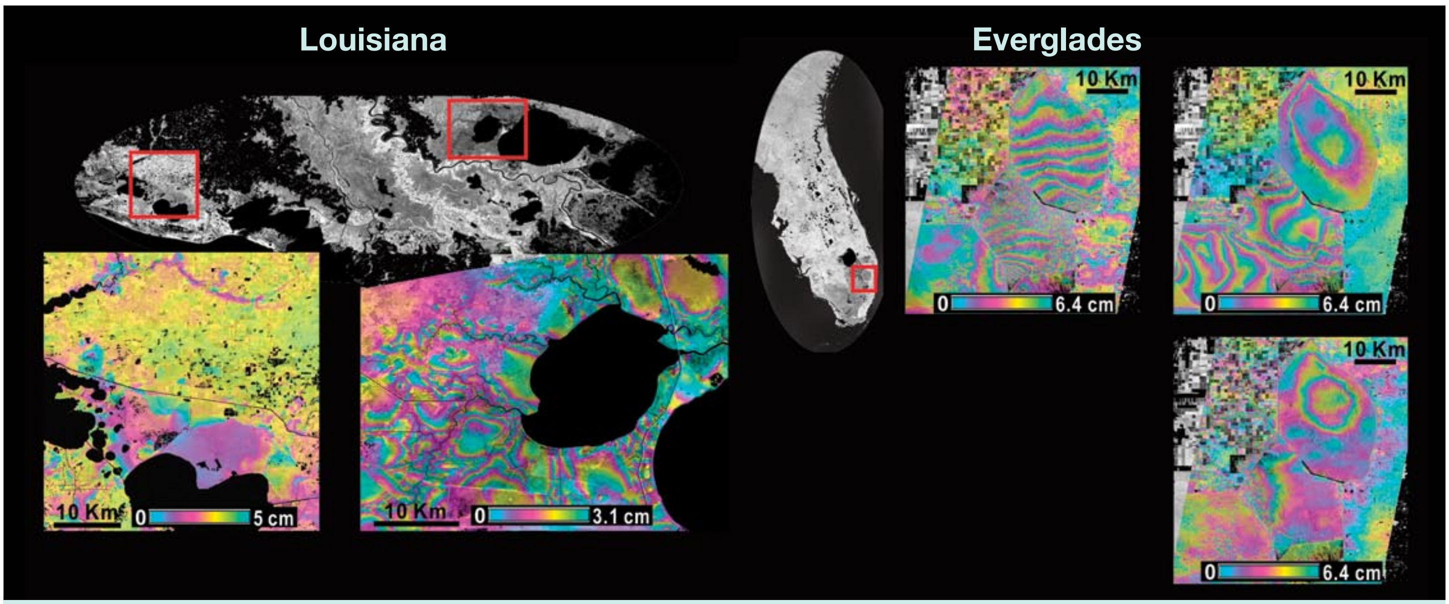

Figure 2: RADARSAT-1 interferograms of Louisiana and south Florida wetlands. The left Louisiana interferograms show constant phase throughout the wetland area. The right Louisiana interferogram show smaller scale phase variations, typically bounded by streams or canals. The south Florida intereferograms show phase changes in the managed section of the Everglades, which are controlled by gate operation. The interferograms show different patterns reflecting various flow conditions.

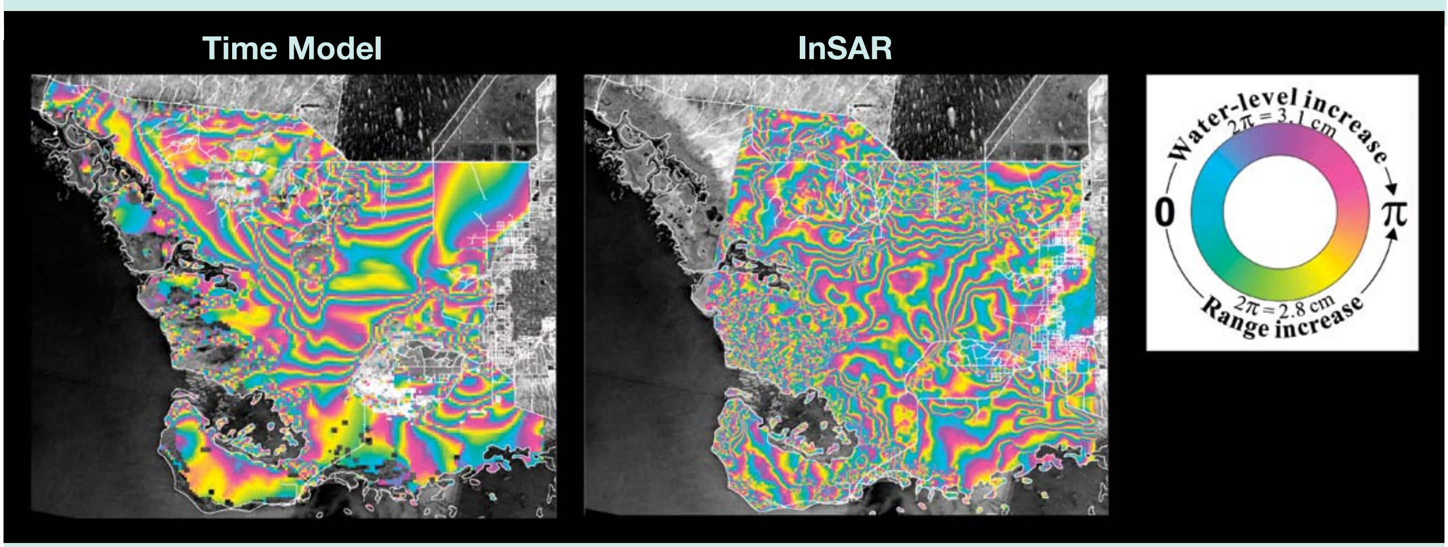

Figure 3: Comparison between synthetic (TIME model) and observed (InSAR) interferograms describing water level changes occurring between the two RADARSAT-1 acquisition dates on 1997/07/13 and 1997/08/06. The comparison shows similarities in the orientation and shape of the longer wavelength fringes, but many differences in the shorter wavelength features.

frequent acquisitions are essential for wetland monitoring because of fast changes (days) in wetland surface water levels.

Wetland InSAR observations provide high special resolution maps of water level changes of the dynamic wetland environment. Because InSAR observations are relative in both space and time, it is important to tie the space-based observations with ground observations of water level (stage monitoring). The dense stage (water level) monitoring network in the Everglades (more than 200 stations, located 5-10 Km from one another) allows us to calibrate and validate the InSAR observations and tie them to an absolute reference frame. Our calibration studies suggest an accuracy level of 5-10 cm. High-resolution wetland interferograms provide direct observations of flow patterns and flow discontinuities, as shown in the figures. The observations also serve as excellent constraints for high-resolution flow models, which are important tools for wetland management and restoration. Preliminary studies that compare InSAR observations with flow models indicate that the models predict well longer wavelength water levels, which are constrained by the stage data, but miss many of the shorter wavelength features (Figure 3).

ASF Open House

By Vicky Wolf • Photos by Dave Lokken

The Alaska Satellite Facility celebrated its 15th Anniversary of the first SAR downlink at the facility with a reception and an Open House. The President of the University of Alaska addressed the group gathered for the reception which provided an opportunity for ASF staff, both past and present to reminisce of ASF's successes. The Open House provided an opportunity for ASF to reach out to the community and explain why a big blue antenna occupies a prominent part of the Fairbanks skyline. A variety of activities showcased different applications of SAR data and the science possible with the data.

Celso Reyes demonstrated different volcanic eruptions to large groups of visitors. The demonstration ended in a fog created by combining liquid nitrogen and dish soap.

ASF Director, Nettie La Belle-Hamer with President of the University of Alaska, Mark Hamilton, and Director of the Geophysical Institute, Roger Smith.

Guided tour to the ASF 11-m antenna.

John Miller, the first Operations Manager of ASF with Nettie La Belle Hamer.

Rebecca Sanches explains earthquakes and SAR to interested visitors.

Creating water spouts to illustrate wave patterns visible in SAR images.

SAR Training Processor Available From ASF

The SAR Training Processor (STP) is an ASF-developed SAR processor with an integrated graphical user interface built for use in the ASF SAR training courses. The STP assists users who are either new to SAR or who want a more in-depth knowledge of SAR processing to learn what happens when a raw SAR image is processed from Level 0 raw data to a Level 1 image via the range-Doppler technique. The STP has built-in hooks that allow images to be written at each processing stage, giving the user an insider's view of intermediate steps in the process. The graphical interface allows the user to choose important parameters as well as which SAR processing steps to perform, to see the effects of each. It explains each step and displays the imagery produced. With this capability at their fingertips, users are able to better understand the significance of each step in the range-Doppler SAR processing technique. The STP is available to all interested users via the web at http://www.asf.alaska.edu/softwaretools/.

Submissions and Subscriptions

This newsletter, published by the Alaska Satellite Facility, was created to provide detailed information about special projects and noteworthy developments, as well as science articles highlighting the use of ASF data.

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