

## **Center for Southeastern Tropical Advanced Remote Sensing (CSTARS)**

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### **LONG-TERM GOAL**

We wish to establish a high capability satellite data reception and analysis facility for environmental monitoring in the southeastern US, Gulf of Mexico, Caribbean Basin and Equatorial Atlantic. CSTARS will provide a variety of satellite data and support for scientific research in land, atmosphere, ice and ocean sciences, as well as applied applications in the fields of environmental monitoring, natural hazard assessment, civil defense and defense tactical applications.

### **SCIENTIFIC OBJECTIVES**

To achieve these goals we are developing a high capability receiving and analysis facility for X-band satellite data with a subsequent enhanced capability that would include lower frequency L- and S-band reception. Key priorities in the system design will be high reliability data reception to low elevation angles and rapid data access for all scientific, civilian and defense tactical users.

The specific scientific objectives of this proposed project are, but not limited to air-sea interaction and ocean dynamics:

- 1) To explore the further use of SAR imagery for retrieval of high-resolution synoptic wind fields with special emphasis on tropical storms.

- 2) To examine the surface roughness, wave breaking and directional distribution of the wave field in tropical and extra-tropical storm systems.
- 3) To explore and quantify mesoscale flow patterns in synoptic and tropical lows.
- 4) To study in more detail the morphology of hurricanes especially when coupled with information about cloud patterns and precipitation from other sensors.
- 5) To develop algorithms for improved detection of ships and their location, size and type as well as speed and direction characteristics.
- 6) To examine ocean features such as fronts, currents and eddies and combine with measurements of long-range shore-based high-frequency Doppler radars.
- 7) To study a variety of applications on coastal and river flooding and shoreline changes as well as monitoring of water resources and vegetation and hazards arising from volcanoes.

## **APPROACH**

The CSTARS satellite data reception and analysis facility currently operates with dual antennas at X-band (~8 GHz frequency), and is receiving data from a wide variety of low-Earth orbiting satellite (LEOS) systems. Current operational capability includes RADARSAT-1, SPOT 2, 4 & 5, ERS-2, ENVISAT ASAR as well as MODIS instruments TERRA and AQUA. We also have an indirect or virtual capability for FormoSat-2 imagery. With MDA Geospatial Services (formerly RadarSat International) we are in discussions for RadarSat-2, with InfoTerra, GmbH for TerraSAR-X and with the Italian Space Agency for Cosmo-SkyMed. We evaluated a QuickBird capability from DigitalGlobe using a Virtual Ground Terminal (VGT) that allows processing of data to higher levels from Level 0. The facility supports a variety of scientific missions.

CSTARS applications will be quite diverse. They will include a wide range of scientific applications in land, atmosphere, ice and ocean sciences, as well as more applied applications in the fields of environmental monitoring, natural hazard assessment, civil defense and defense tactical applications. High reliability data reception to low elevation angles (~3 degrees above the local horizon) and rapid data access for all scientific and other civilian users will be key priorities in the system operations.

## **WORK COMPLETED**

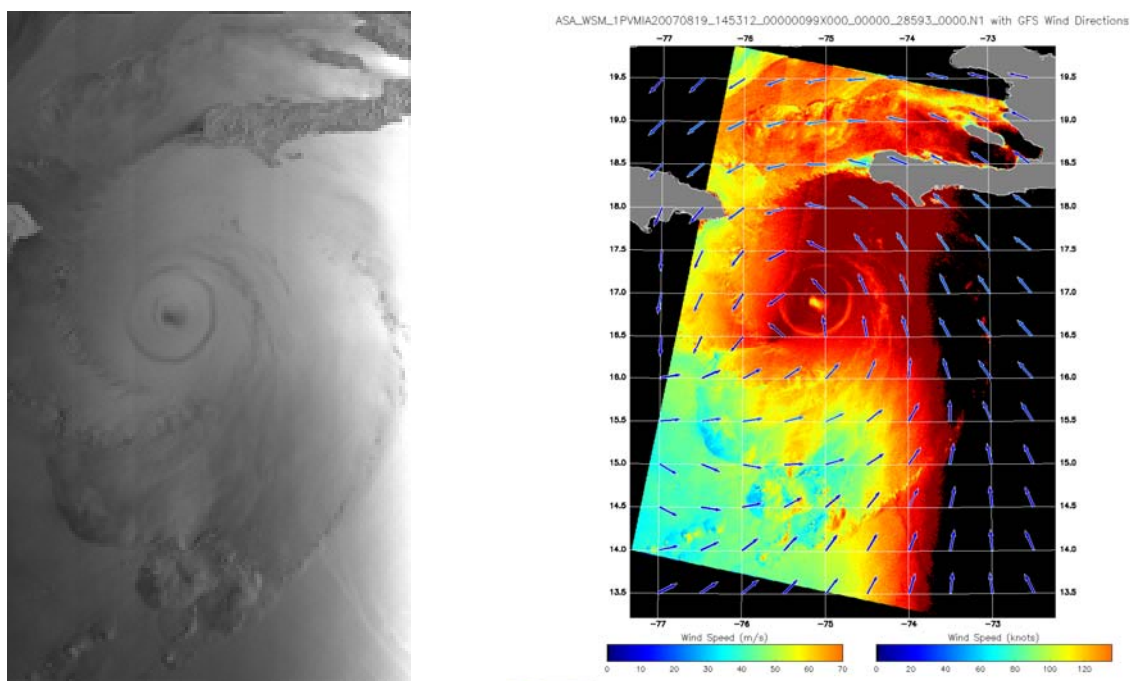
1. Major infrastructure upgrades and modifications are completed at the CSTARS facility.
2. We are completing the acquisition of XTPS processor for both ENVISAT ASAR and MERIS data.
3. All Seasat raw data held at the Alaska SAR Facility at ASF were copied during the summer of 2004. The data were stored on 29 Sony D-2 tapes. These tapes are nearly 6 years old and will begin soon to lose their ability to hold the data.
- 4.

## **RESULTS**

### **Tropical Cyclone and Oceanic Winds from SAR Imagery**

Jointly with the Canadian Space Agency, CSTARS operates a HurricaneWatch program to acquire in near real time SAR imagery of tropical cyclones in the Atlantic and Caribbean Basins as well as the Gulf of Mexico. For the 2006 and 2007 hurricane season we came to a similar agreement with ESA using a carpet planning approach to cover the annual hurricane season. For these and other activities CSTARS now has access to 120,000 seconds of ESA satellite data. These images will be used to

extract high resolution wind fields using the CMOD-5 algorithm from JHU/APL ANSWR system and the WiSAR system as described in Horstmann et al. (2005). Figure 1 show the ENVISAT ASAR image of Hurricane Dean south of Puerto Rico on 19 August 2007 at 14:43 UTC and the corresponding wind field derived from the ANSWR system.



**Figure 1:** ENVISAT ASAR image of Hurricane Dean on 19 August 2007 at 14:43 UTC (left). High resolution wind vector field of Hurricane Dean derived from ENVISAT WideScan image captured at CSTARS (right passing south of Puerto Rico).

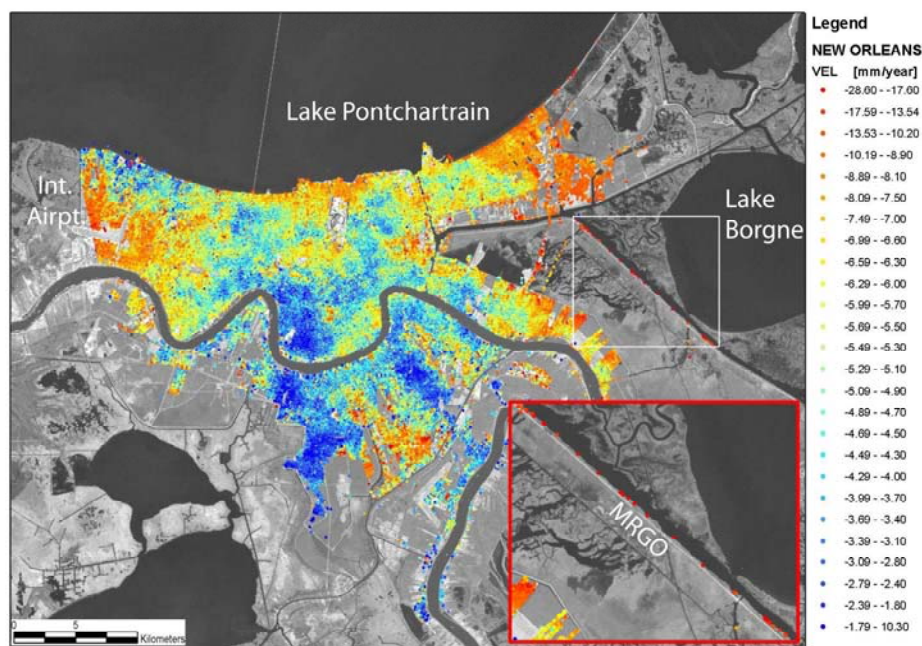
### The InSAR and PSInSAR Techniques

Apart from cycle ambiguity problems, the main limitations for standard InSAR are related to temporal and geometrical decorrelation (low signal to noise ratio in the phase change estimate), and variable tropospheric water vapor, which can generate variable path delay for microwave signals unrelated to surface motions. In sub-tropical and tropical regions, the tropospheric delay may be as high as 10 cm over several weeks (Dixon and Kornreich 1990; Dixon *et al.* 1991). This constitutes a significant potential error source for InSAR, and has tended to restrict most InSAR studies to relatively dry regions.

Permanent Scatterer InSAR (PSInSAR) (Ferretti *et al.* 2000; Ferretti *et al.* 2001; Colesanti *et al.* 2003a; Colesanti *et al.* 2003b; Hilley *et al.* 2004) exploits several characteristics of radar scattering and atmospheric decorrelation to measure surface displacement in otherwise non-optimum conditions, including humid regions. Atmospheric phase contributions are spatially correlated within a single SAR scene, but are generally uncorrelated in time. Conversely, surfaced motion is usually strongly correlated in time. Thus, atmospheric effects can be estimated and removed by combining data from long time series of SAR images, in effect averaging the temporal fluctuations. Scatterers that are only slightly affected by temporal and geometrical decorrelation are used, allowing exploitation of all available images regardless of imaging geometry. In this sense the scatterers are “permanent”, i.e.,

persistent over many satellite revolutions. In our recent study in New Orleans subsidence (Figure 2) inspection of the individual points (“scatterers”) indicates that many of the scatterers are located at the intersection of a street or sidewalk and vertical structure such as the side of a building, or a roof. Parks and other vegetated areas in contrast have no or few permanent scatterers.

**Figure 2: Velocity map for permanent scatterers in New Orleans and vicinity. Values are range change in direction of radar illumination. Negative values indicate motion away from satellite, consistent with subsidence. Int. Airpt. is the location of International Airport, MRGO is Mississippi River-Gulf Outlet**



**Canal. Inset (location marked by white rectangle) shows close up of PS velocity map for eastern St Bernard's parish and western Lake Borgne. Note high rates of subsidence on levee bounding MRGO Canal. Large sections of the MRGO levee were breached during Hurricane Katrina in August 29, 2005.**

For the New Orleans study, we used 33 RADARSAT (6 cm wavelength) scenes acquired between April 2002 and July 2005. We focused on greater New Orleans, where urbanization provides a number of well-defined radar targets. A total of more than  $1.8 \times 10^5$  radar targets were identified in this region that retained some phase coherence over the three year study period. Of these,  $\sim 3.9 \times 10^4$  targets had coherence in excess of 0.6, and  $\sim 3.1 \times 10^4$  targets had coherence in excess of 0.8, providing excellent phase fidelity and spatial resolution for our space-derived surface velocity

The mean and standard deviation range change rate for all the point targets is  $-5.6 \pm 2.5$  mm/yr. Using just the point targets where coherence is greater than 0.9, the corresponding rate and standard deviation is essentially identical,  $-5.4 \pm 2.2$  mm/yr. Subsidence rates in excess of 20 mm/yr are observed in several areas, including the town of Kenner, near the International airport in west New Orleans, which was marshland prior to the 1920's, when it was drained for construction. Former marshlands that are drained are subject to enhanced subsidence due to compaction, desiccation and oxidation of organic soils. Another area of high subsidence is the levee adjacent to the MRGO canal in east New Orleans near Lake Borgne (inset in Figure 3). The high subsidence rates on this levee correlate with the parts of the levee that breached during Hurricane Katrina (Figure 2). This suggests that the levee may have failed due to overtopping (the levee subsided below design criteria and hence was lower than the storm

surge height), or that the substrate beneath the levee may be anomalously weak, subject to compaction, and possibly erosion during high water conditions.

## **IMPACT/APPLICATION**

The CSTARS facility readily exploits the frequent SAR and EO passes inside its extensive coverage from Hudson Bay in the north to the equator in the south. In particular, CSTARS has made significant contributions to state and local response in hurricane and flood emergencies, especially during Hurricane Katrina in New Orleans and Hurricane Stan in Guatemala. By rapidly providing state and local officials with up-to-date, high-resolution, day or night images of affected areas and by providing quantitative flood extent and qualitative flood and wind damage information, this new system greatly improves the transmission of critical information to emergency response personnel in support of relief efforts after natural disasters.

## **TRANSITIONS**

A variety of operational products are provided to the National Geospatial-Intelligence Agency (NGA) for evaluation.

## **RELATED PROJECTS**

Numerous projects have been spawned from the existence of CSTARS and the availability of electro-optical and microwave satellite data. These projects include:

- HurricaneWatch program over the Atlantic and Caribbean Basins and the Gulf of Mexico with the Canadian Space Agency and the European Space Agency.
- Subsidence monitoring in New Orleans with the Louisiana Department of Transportation.
- Several projects on volcano monitoring in the Galapagos Islands, Hawaii and Central America.
- Coastal erosion and sediment transport studies in the Bahamas.
- Support studies for Office of Naval Research.
- Disaster response projects for USSOUTHCOM in the Caribbean Basin.

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