Center for Southeastern Tropical Advanced Remote Sensing (CSTARS)

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Award #: N00014-00-1-0875
http://cstars.rsmas.miami.edu

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.

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **30 SEP 2006**	2. REPORT TYPE	3. DATES COVERED **00-00-2006 to 00-00-2006**

4. TITLE AND SUBTITLE **Center for Southeastern Tropical Advanced Remote Sensing (CSTARS)**	5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **University of Miami,Rosenstiel School of Marine and Atmospheric Science,4600 Rickenbacker Causeway,Miami,FL,33149-1098**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR’S ACRONYM(S) 11. SPONSOR/MONITOR’S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**7**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

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, ERS-2, ENVISAT ASAR as well as MODIS instruments TERRA and AQUA. In Phase 2 we have begun to add the SPOT-5 terminal and have also received numerous FormoSat-2 imagery. With MDA Geopspatial Services (formerly RadarSat International) we are in discussions for RadarSat-2 and with InfoTerra, GmbH for TerraSAR-X. We are currently exploring the addition of 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. The acquisition of two radomes for the 11.3 m antennas proved to be a good decision during the passage of Hurricanes Katrina and Wilma.

3. CSTARS major hardware and software upgrades included the acquisition of:

   a) Two HDR CORTEX (High Data Rate) receiver systems were installed and fully tested and now are the primary means for capturing data reception of multiple satellites. The configuration is currently set up for 320 Mbps receive capabilities including multi-missions and several standard demodulation options.

   b) A Moving Window Display (MWD) for SAR was added to complement the current SPOT capability and provide instantaneous viewing of SAR images while reception is taking place. This new feature works for RadarSat, ERS-2, Envisat as well as ALOS/PALSAR.

   c) A Trouble Monitoring System (TMS) has been installed to monitor the diverse set of processes of CSTARS. As the complexity of CSTARS functionalities and capabilities increases, a central authority monitoring the health of all vital systems at CSTARS is required.

4. 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 loose their ability to hold the data. The Seasat SAR data will all be digitally processed (many for the first time) and then make the results available to the user community. The hardware and software installation include:

a) Seasat L0 procesor.

b) Data Catalog Ingest.

c) L1 Processor.

d) Data Processing.

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. These images will be used to extract high resolution wind fields using the CMOD-5 algorithm as described in Horstmann et al. (2005). Figure 1 shows two SAR wind fields on 27 and 28 August 2005 of Hurricane Katrina, which were captured and processed in near real time at CSTARS as part of the HurricaneWatch program.

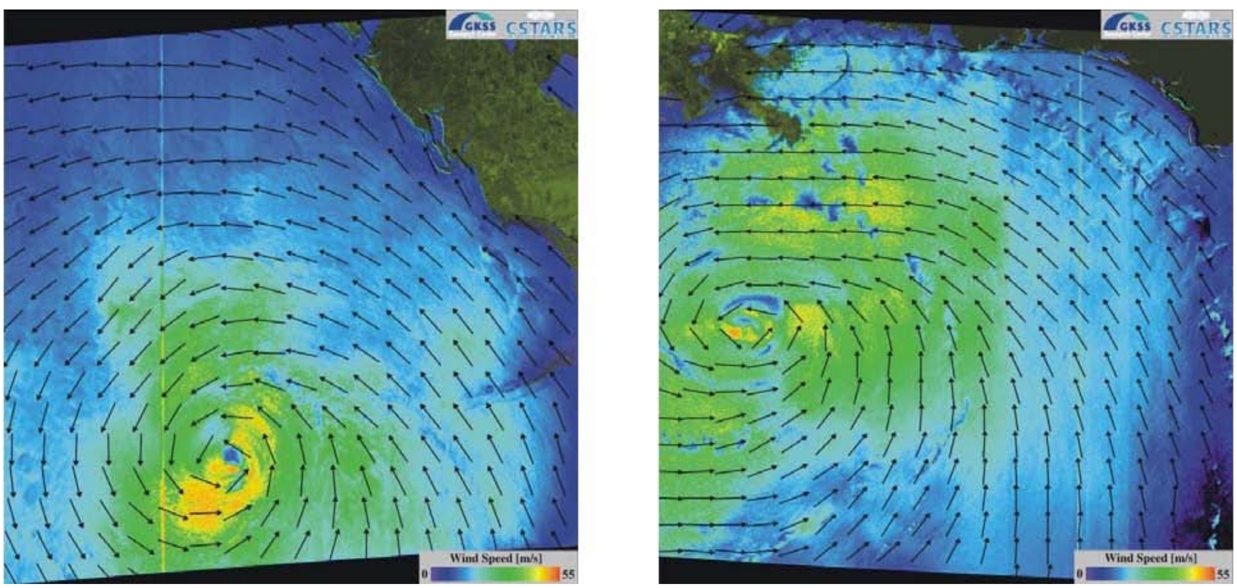

Figure 1: High resolution wind vector fields of Hurricane Katrina derived from RadarSat-1 ScanSAR images captured at CSTARS on 27 August 2005 at 11:28 UTC (left) leaving Florida and 28 August 2005 at23:49 UTC (right) approaching New Orleans.

Hurricane Katrina

On August 30, 2005, CSTARS received the very first image of the devastating flooding in New Orleans caused by Hurricane Katrina. During the late morning hours a SPOT-2 image (Figure 2) was captured and processed by CSTARS and with the assistance of scientists from LSU rapidly distributed to local and state emergency personnel for assistance in disaster response.

Figure 2: SPOT-2 image of 30 August 2005 (right) showing the extent of flooding in New Orleans as outlined by dashed white lines. Locations of levee breaks are shown by dashed yellow lines. Some areas of interest (AOIs) are highlighted. On the left is an image of New Orleans taken on 24 May 2005.

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 3) 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.

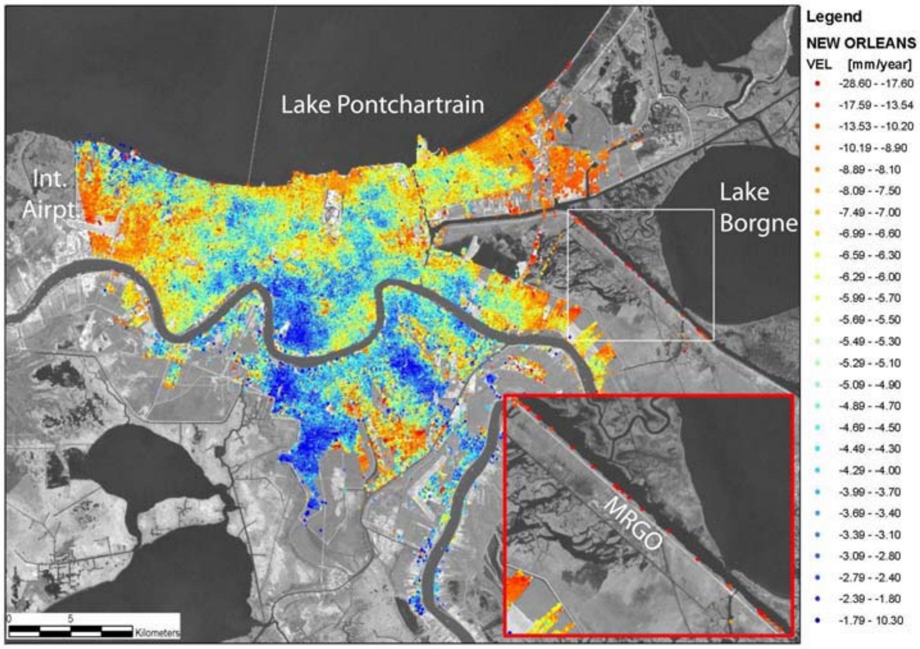

Figure 3: Velocity map for permanent scatterers in New Orleans and vicinity. Values are range change in direction of radar illumination. Negative values indicate motion away from satellite, consistent with subsidence. Int. Airpt. is the location of International Airport, MRGO is Mississippi River-Gulf 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 1.8x105 radar targets were identified in this region that retained some phase coherence over the three year study period. Of these, ~3.9x104 targets had coherence in excess of 0.6, and ~3.1x104 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±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±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.

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