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Hydrologic Study of Vegetated Wetland Using Retracked Satellite Altimetry

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Introduction

Coastal estuaries, which connect coastal ocean, wetlands and coastal land region, play important roles in ecological environments. Wetlands typically occur in low-lying areas on the edges of lakes, and rivers, or in coastal areas protected from waves and are found in a variety of climates on every continent except Antarctica. Wetlands not only provide habitat for thousands of aquatic/terrestrial plant and animal species but also control floods by holding water much like a sponge by absorbing and reducing the velocity of storm-water. Human activities have so many negative impacts on wetlands and they became main contributing factors to many wetlands loss. Louisiana's wetlands have lost more than 100 km^2 of its area per year (Walker et al., 1987). Synthetic Aperture Radar Interferometry and satellite radar altimetry have been proven to be useful for large lake/river and wetland hydrological studies in terms of measuring geocentric water level changes (Alsdorf, 2003; Birkett, 2002; Lu, 2005). In this study, we use retracked TOPEX/POSEIDON measurements to detect water level changes of Louisiana's wetlands, where the water surfaces are calm resulting in *specular* radar returns, or vegetated, causing irregular radar waveforms. The loss of Louisiana wetlands as a result of ecological erosion or geological subsidence potentially have had significant impacts in slowing down storm surge from the devastating Hurricane Katrina. The ability to quantitatively measure accurate wetland water level changes in Louisiana has impacts on ecology and natural hazards mitigation including improved storm surge modeling resulting from hurricanes.

Data Sets

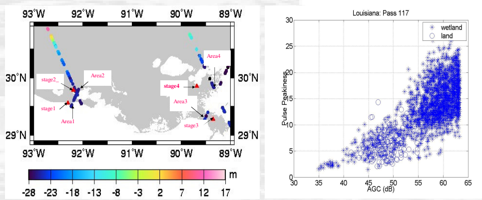
In this study, the TOPEX/POSEIDON Geophysical Data Record (GDR) and the Sensor Data Record (SDR) for cycles 9 to 364 are used. The Ku-band ten-per-frame (10-Hz) surface height data with an along-track spatial sampling interval of ~660 m are available from the GDR/SDR files. We used the data which have been corrected for oscillator drift, track mode, doppler shift, pointing angle/sea state, center of gravity, range acceleration and calibration. In addition, geophysical corrections such as the solid Earth tides, and the media corrections including the dry and wet troposphere delays and ionosphere corrections have been applied to the data. The 10-Hz geodetic coordinates are computed using the Precise Orbit Ephemeris (POE) data provided by NASA Goddard Space Flight Center (GSFC) and 10-Hz time tags are calculated from 20Hz ranges contained in the SDR. The SDR files also contain the ten-per-frame 64-sample waveforms.

Detection of Water Surface

The vegetation type of the study areas is brackish marsh (Visser et al., 2000; Day et al., 2000), and the measured mean mudline elevation of these brackish marshes over Area 1 and Area2 is 28.24 cm (Louisiana Department of Natural Resources, 2002). To identify 'water-covered' surface, we perform a test based on waveform peakiness (Strawbridge and Laxon, 1994) and 10-Hz automatic gain control (AGC) parameter contained TOPEX SDR (Birkett, 1998). The reason using 10-Hz AGC value instead of GDR-contained 1-Hz $\sigma 0$ (Birkett, 1998; Maheu and Cazenave, 2003) is that we have to distinguish individual 10-Hz range measurements of water surface from those of vegetation. The waveforms obtained over the wetland include those of low peakiness and low AGC values, which are the characteristics of the waveforms from land. The waveform from the water surface is defined as those that are single-peaked specular, with 10-Hz AGC>55 dB.

Time Series Construction

To get the best possible set of atmospheric path delay corrections to be applied to the 1-Hz surface height altimeter data, we first calculated the RMS residuals of a linear fit to the 10-Hz surface heights as a by-product of data compression to 1-Hz surface heights for four candidate sets of atmospheric correction data available.



Left: TOPEX cycle 11 ground tracks over Louisiana with retracked ellipsoidal height

Right: Waveform peakiness versus AGC for pass 117 passing over Chenier Plain covered with brackish marsh and water

Then the spatially averaged RMS surface height residuals over each selected study site is again averaged from TOPEX cycles 9-364 to represent the uncertainty of candidate sets of atmospheric corrections. For all of the four study areas, FMO wet tropospheric and DORIS ionospheric corrections yield the optimal corrections we have to use, i.e., showed minimum variance. Furthermore, except Area1, all of the study regions showed that retracked surface heights using Center of Gravity (COG) or 50% threshold retracker yield results better agreeing with the in-situ measurement. Finally, TOPEX time series is generated using the spatially averaged 1-Hz retracked measurements. The river gauge data provided by US Army Corps of Engineers (http://www.mvn.usace.army.mil/eng/edhd/Wcontrol) is daily (8 AM) data. Therefore, the river gauge data measured at the time closest to the time of TOPEX measurements are chosen to be compared.

Average of RMS surface height residuals (cm)

	FMO wet + DORIS iono	Rad wet + DORIS iono	FMO wet + dual iono	Rad wet + dual iono
AREA1	**5.76**	6.00	6.03	6.21
AREA2	**4.98**	5.06	5.14	5.13
AREA3	**4.54**	4.55	4.56	4.56
AREA4	**5.27**	5.3	5.94	5.89

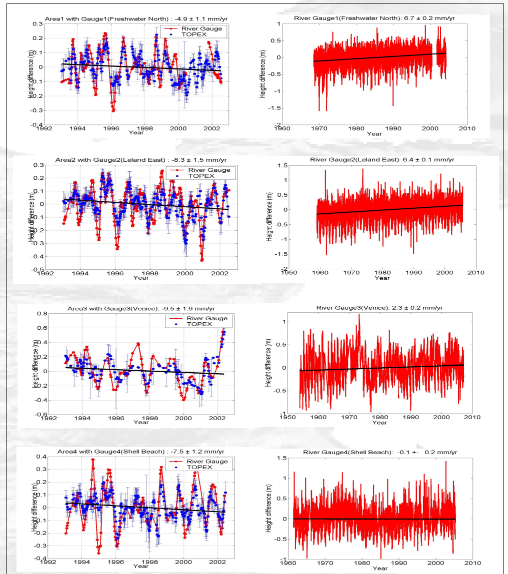
RMS differences (cm) and correlation coefficients between TOPEX and river gauge time series

Retracker	COG		50% Threshold		No retracking	
	RMS	CC	RMS	CC	RMS	CC
AREA1	9.40	0.59	9.26	0.60	**8.67**	**0.64**
AREA2	**10.02**	**0.67**	10.10	0.66	10.11	0.66
AREA3	13.29	0.76	**12.91**	**0.78**	13.49	0.76
AREA4	11.96	0.63	**11.41**	**0.67**	11.75	0.65

Standard deviation of the variations in time series (cm)

	Before gradient correction	After gradient correction
AREA1	13.8	**8.3**
AREA2	15.3	**9.9**
AREA3	27.2	**15.9**
AREA4	17.1	**8.7**

One issue that must be considered in generating a time series from altimeter measurements is the effect of the surface height gradient due to the orbital drifts of the satellite. Since the identified water surface is flat, we model the surface as a plane and the surface height gradient is computed from the satellite observation itself. TOPEX secular trends observe both the land subsidence, if any, and wetland water level increase/decrease.



If we assume that the TOPEX and the river stage measurements are at the same location, then the difference in the two trends represents land subsidence. It is speculated that, although the linear trend estimates are poorly determined (because of short data span), the difference in linear trends between TOPEX and river stage water level could be due to land subsidence. This agrees with the fact that the subsidence, one of the major causes of wetland loss, naturally occurs in Louisiana.

Conclusion

In this study, we demonstrated the use of *retracked* TOPEX/POSEIDON radar altimetry to measure decadal water level changes over Louisiana vegetated wetlands, to our knowledge, for the first time. Altimetry measurements generally agree well with the river stage data, which are available near some of our study sites. However, as river stage data are usually located in open water and near river banks which are not necessarily, or should not, be agreeing with altimeter measured wetland water level changes. Seasonal and inter-annual variations are quantified, which could be used towards understanding the underlying flow dynamics. Four of the selected study sites, indicating land subsidence, will be further studied for hydrologic interpretation including flow dynamics. Analysis shows that ionosphere corrections using DORIS and model troposphere corrections, which are usually not considered for land hydrology studies, reduces variances of the water level measurements. The study also intends to contribute to the proposed WATER HM satellite mission (http://www.geology.ohio-state.edu/water) in terms of demonstrating the feasibility of retracking altimeter measurements for accurate vegetated wetland water level changes and studying the modeling of various media and geophysical corrections.

Acknowledgements

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