EVALUATION OF SPACE-BASED WETLAND INSAR OBSERVATIONS OVER THE CIENAGA GRANDE DE SANTA MARTA (CGSM), COLOMBIA

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Abstract

The Cienaga Grande de Santa Marta (CGSM) is vast wetland and upland area located along the Caribbean coast of Colombia. It is sadly remembered as one of the ecological catastrophes of the Americas. A road construction along the wetland's perimeter blocked the natural hydrologic flow between sea and fresh water required for the natural functioning of the wetland's ecosystems [1-2]. This caused hyper saline conditions resulting in massive mortality of mangroves at the end of the 20th century. Recent restoration efforts at CGSM have shown some recovery of the mangrove forest. Due to the large extent and the remoteness of the CGSM wetlands, ecological and hydrological assessments of the area require the use of remote sensing observations.

In this study we use wetland Interferometric Synthetic Aperture Radar (InSAR) observations, which have the capability to detect water level changes in aquatic environments with emergent vegetation over wide areas [3-5]. Our study is based on both L-band ALOS PALSAR and C-band RADARSAT-2 data. The ALOS PALSAR data consists of 44 images acquired over two tracks between 2007/01/01 and 2011/03/16. The RADARSAT-2 data consists of 20 Fine Quad polarization mode scenes acquired over three tracks between 2014/09/14 and 2015/01/05. These data were provided by RADARSAT-2 Science and Operational Applications Research Education International (SOAR-EI) initiative. The data were processed using the Repeat Orbit Interferometry PACkage (ROI_PAC) software, which generates differential interferograms eliminating topographic effects with a digital elevation model (DEM). We used 3 arc-seconds Shuttle Radar Topography Mission (SRTM) DEM for topographic phase removal in this study. Multi-looking was applied to reduce undesirable phase noise. The interferograms processing contains phase filtering to enhance the signal to noise ratio of the phase, and phase unwrapping.

We can evaluate the interferometric results in terms of interferometric coherence and fringe pattern. Our results yielded a different success level between the two datasets in extracting coherent phase over the CGSM wetlands. The L-band ALOS interferogram show mostly coherent phase changes across the entire wetland area, whereas the C-band RADARSAT-2 interferograms show only patchy areas with coherent phase. The low coherence of the RADARSAT-2 interferograms suggest that the mangrove forest at CGSM is tall and massive, because small and intermediate height mangrove forests yield coherent phase, as we observed in the Everglades wetlands [6].

The higher coherence ALOS interferograms show the following two types of fringe patterns: (1) low gradient fringes over some flood plain wetland with herbaceous vegetation, and (2) high gradient fringes over some of the mangrove forests. We detected at most one or two fringes over flood plain wetland was detected showing very low water level change, possibly due to sheetflow conditions. High gradient fringes were detected over mangrove forests, located near the CGSM lagoon. Based on our experience from the Everglades wetlands, we attribute these fringes to temporal changes in tidal flooding. The most significant and coherent interferometric phase related to water level changes was detected over mangrove forest area, which is located near the CGSM lagoon rather than flood plain wetland area. It is interesting to note that coherent phase is better maintained over dead or rehabilitated mangrove areas than over live mangrove areas. It might be resulted from that leafy and heavy mangrove forest prevents the radar signal from maintaining coherence. Because volume scattering in heavy vegetated area does not allow maintaining coherence over time. However, the leafless vegetation provides better conditions for double bounce scattering, which has been regarded as the main mechanism of wetland InSAR.

Overall, our results indicate that wetland InSAR works well over the CGSM wetlands and provide us new understanding of the hydrological condition at the entire wetland scale. Furthermore, coherence values can be used for classification of dead or alive mangrove regions, which would be useful for a base map for restoration plan of the CGSM wetland.

1. Study area

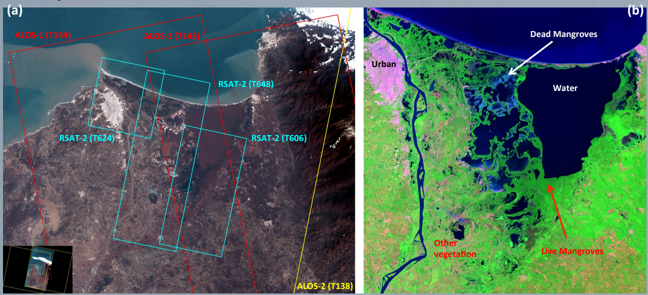

Figure 1. (a) Location map of the study area along the Caribbean coast of Colombia using a Landsat-8 image of January 11th, 2015 with true color composite (Landsat Data Continuity Mission: LDCM, http://landsat.usgs.gov). The frames mark the swath locations of data acquired by C-band Radarsat-2 (cyan) and L-band ALOS-1 (red) / ALOS-2 (yellow) SAR satellite. (b) Landsat-8 multispectral pseudo color composite image with bands of 7 (red), 5 (green), and 1 (blue) over the study area. The bright blue color shows dead mangroves, while the green color represents mangrove as reported in [2].

2. Wetland InSAR

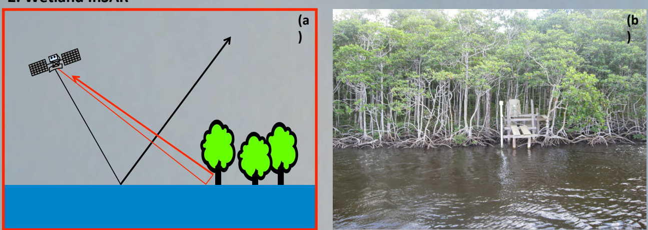

Figure 2 (a) Schematic illustration showing the double bounce concept that enables the detection water level changes in InSAR applications. (b) Typical woody wetland showing flat water surface and emergent vegetation that enable wetland InSAR.

3. Interferogram: RADARSAT-2

- Total 20 Fine Quad polarization mode scenes acquired over three tracks between 2014/09/14 and 2015/01/26.
- Temporal baselines: 24 – 96 days
- Perpendicular baselines: 19 – 269 m
- The ROI_PAC and GAMMA software were used to calculate repeat pass interferograms.
- The Pauli decomposition shows that the volume scattering is dominant over all over mangrove areas.
- Patch-like coherence phase can be detected where double bounce scattering is dominant.
- The low coherence indicates that the mangrove forest at CGSM is tall and massive, because small and intermediate height mangrove forests yield coherent phase, as we observed in the Everglades wetlands [6].

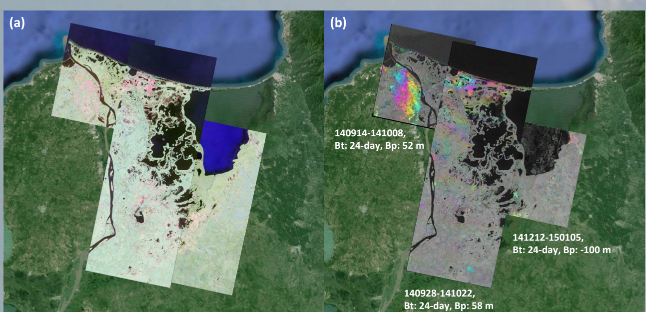

Figure 3 (a) Pauli decomposition of RADARSAT-2 SAR image as color composite image: HH-VV (red), HH+VV (blue), and HV (green). (b) Interferograms over three tracks: low coherence was found despite of small temporal and perpendicular baselines.

4. Interferogram: ALOS-1/PALSAR

- Total 44 Fine Beam Single Polarization (FBS) / Fine Mode Duel Polarization (FBD) mode scenes are acquired over two tracks between 2007/01/01 and 2011/03/16.
- Temporal baselines: 46 – 1334 days
- Perpendicular baselines: 24 – 1447 m
- The ROI_PAC and GAMMA software were used to calculate repeat pass interferograms.
- The higher coherent interferograms were generated thanks to longer wavelength of the L-band SAR images.
- Low gradient fringe pattern can be found over some flood plain wetland with herbaceous vegetation.
- High gradient fringe pattern showing clear water level change over some of the mangrove forests.
- It is interesting that patch-like coherent phase are found showing local hydrologic dynamics.

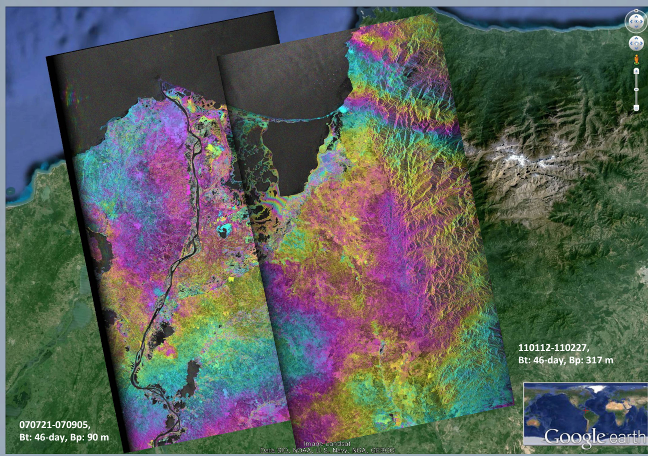

Figure 4. The L-band ALOS PALSAR Interferograms over two tracks: higher coherence was found despite of longer temporal and perpendicular baselines. Each fringe cycle represents about 12 cm change w.r.t. line of sight direction.

5. Interferogram: ALOS-2/PALSAR-2

- Total 4 five-beam ScanSAR (Normal mode) over two tracks between 2014/09/14 and 2015/01/18.
- Perpendicular baselines: 2 – 176 m
- No coherence could be found due to 0 % burst overlap from the spectral analysis.
- It would be great if the burst overlap information is available for choosing ScanSAR interferometric pairs.

Table 1. List of ALOS-2/PALSAR-2 L-band ScanSAR (Normal mode) interferometric pairs

Path/Frame	Date	Azimuth offsets (orbital estimation, pixels)	Perpendicular Baseline (m)	Burst overlap (%)
138 / 3400	2014-12-02 / 2015-01-13	~470	81 ~ 117	0
139 / 3400	2014-09-14 / 2014-10-26	~671	140 ~ 174	0
139 / 3400	2014-09-14 / 2015-01-18	~1218	2 ~ 11	0
139 / 3400	2014-10-26 / 2015-01-18	~547	151 ~ 176	0

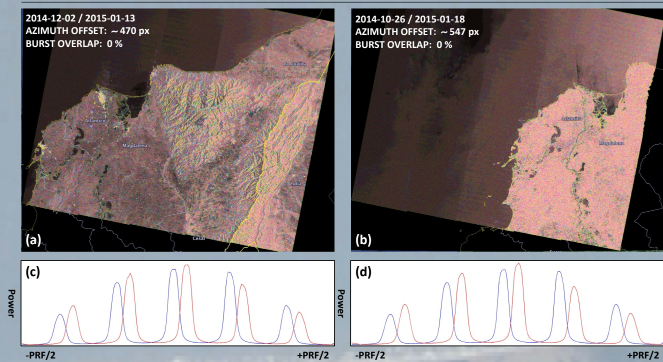

Figure 5. (a, b) ScanSAR interferograms are showing no coherence due to non-overlap of the burst. (c, d) Spectral analysis to show the burst overlap.

6. Summary

- The wetland InSAR works well over the CGSM wetlands, which can provide new understanding of the hydrological condition.
- The L-band SAR signal works better compared with the C-band SAR acquisition over CGSM.
- The wide ScanSAR interferometry can be useful to monitor the hydrological condition, once the burst overlap issue is resolved.

Acknowledgement

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