

ATMOSPHERIC EFFECTS DETECTION BY SHORT BASELINE PROCESSING IN RADARSAT TIME SERIES OVER MANAUS CITY, AMAZON REGION

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ABSTRACT

In this work we present an analysis of RADARSAT-1 and RADARSAT-2 times series acquired from 2006 to 2010 aiming to recognize the presence of atmospheric artefacts in the interferometric phase. The dataset was interferometrically processed using a short-baseline strategy, i.e. all interferometric pairs characterized by the shortest temporal baselines were identified. In this dataset the temporal baseline corresponds to the shortest temporal baseline of 24 days which can be achieved using the Radarsat mission. Interferometric phase was compared to estimates of the atmospheric artefacts obtained from the available measurements of the atmospheric parameters (air temperature, pressure, relative humidity, wind speed and direction, precipitations) over the studied area provided by the Brazilian Aeronautic Center of Meteorology.

1. INTRODUCTION

The preliminary results obtained by the first orbital interferometry study over Amazon region (Solimões Project) indicates an area of crustal movement located adjacently to a circular drainage feature inside Manaus city urban area. It's expected that the final analysis will include an improved understanding of the geological activities and crustal motion in the Amazon Basin that is characterized by an annual cycle of vertical displacement with an amplitude of 50-75 mm measured by a GPS station near the centre of the basin. This is considered a large crustal oscillation and indicates the lithosphere is subsiding and rebounding in response to changes in the weight of the Amazon River system flow. The Amazon River annually cycles through a vertical height range of 10-15 m.

The primary impediment to a wider application of InSAR technology is the moisture in the air column

affecting the SAR signal. Its evidence is presented as false ramps or fringes in the interferograms. In tropical regions, as Amazon area, the depth of the atmosphere and rapid changes in moisture content produces highly variable results. A previous analysis of RADARSAT dataset over Manaus region evidenced important phase artefacts possibly due to the temporal variations of the Precipitable Water Vapour (PWV). Atmospheric artefacts are severe over regions such as Amazon, characterized by an important plant transpiration phenomenon.

In this work we present an analysis of RADARSAT-1 and RADARSAT-2 times series acquired from 2006 to 2010 aiming to confirm the presence of atmospheric artefacts. The dataset was interferometrically processed using a short-baseline strategy, i.e. all interferometric pairs characterized by the shortest temporal baselines were identified. In this dataset the temporal baseline corresponds to the shortest temporal baseline which can be achieved using the Radarsat mission, 24 days. The InSAR processing of those pairs results in SAR interferograms containing the smallest contribution from possible terrain displacements due to geological phenomenon or anthropic activity. The interferometric phase was analysed to detect the presence of atmospheric artefacts. Topography effects were removed using the available SRTM Digital Elevation Model of the region. Besides this analysis, the presence of atmospheric artefacts in SAR interferograms was confirmed by the available measurements of the atmospheric parameters (air temperature, pressure, relative humidity, wind speed and direction, precipitations) over the studied area provided by the Brazilian Aeronautic Center of Meteorology.

2. STUDY AREA

The site of investigation is situated in the Amazonas sedimentary basin and includes the region around

Manaus city, totaling approximately 4,000 km² (see Fig.1). The study area is characterized by a terrain elevation ranging from 50 and 100 m through relief rises and watersheds oriented in NW-SE and NE-SW directions. Manaus has a tropical climate and technically a dry season month, August, where less than 60 mm of precipitation falls. Because of this dry season month, the city's climate falls under the tropical monsoon climate category instead of the tropical rainforest climate category. Average annual temperature is 26.6C, with quite stable temperatures along the year.

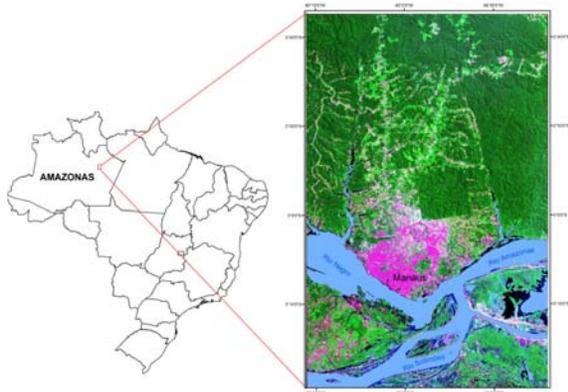


Figura 1: Location of Amazonas state and Manaus region and Landsat image of the study area.

3. DATASET

3.1. InSAR dataset

A stack of 15 RADARSAT-1 images in Fine 2 Far beam mode was collected from 2006 to November 11, 2007. From 2007 to 2010, 24 images of Radarsat-2 were collected in Fine 2 Far beam mode. Figure 2 shows examples of Radarsat SAR image acquired over the study area. All acquisitions were programmed for 22hs and cover Manaus region, including a large portion of forest.

3.2. Meteorological data

A set of measurements of the atmospheric parameters (dry and wet bulb temperature, minimum and maximum temperature, pressure, relative humidity, wind speed and direction, precipitation) over the Manaus area was provided by the Brazilian Aeronautic Center of Meteorology. Figure 3 displays a map with the location of meteorological stations located within the study area. There is a meteorological station inside the Manaus city and three further stations, inside the Amazon watershed, within a distance of about 200 km.

4. MODELLING OF ATMOSPHERIC DELAY

The water vapor pressure is a fundamental quantity in radio wave propagation in atmosphere. In addition to the water vapor pressure many other variables are used by meteorologists to express the water vapor content of moist air. In this section, we define some of those variables. The dry-bulb temperature, t_{dry} , is the ambient temperature of moist air, shielded from radiation, as measured by a standard thermometer. The wet-bulb temperature, t_{wet} , is the lowest temperature obtainable by ventilating a standard thermometer, whose bulb is covered with a wetted wick.

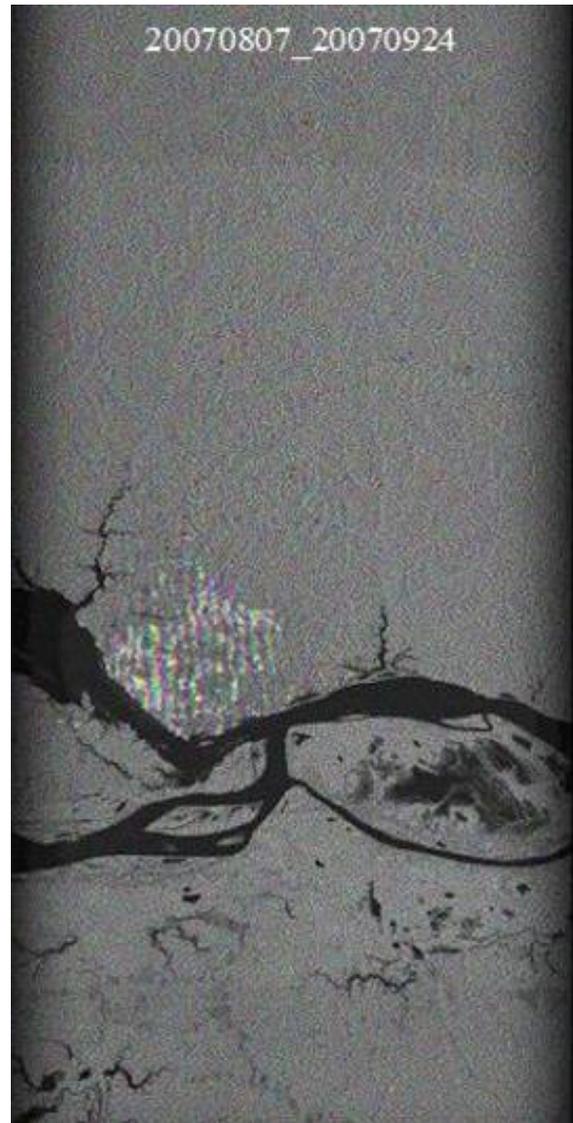


Figura 2: Example of Radarsat SAR image acquired over the study area. The location of Manaus city close to the Amazon river can be easily recognized.

At constant pressure and within a closed thermodynamic system, this happens when saturation is reached. The dew-point depression, t_{dew} , which is the difference between the dry-bulb temperature and wet-bulb temperature. The dew-point temperature T_d of moist air, at a certain temperature, pressure, and mixing ratio, is the temperature to which the air must be cooled, keeping the pressure and mixing ratio constant, for it to reach saturation with respect to liquid water. Dew-point temperature can be obtained using a dew-point hygrometer and constitutes therefore a direct measure of the water vapor pressure, as this quantity can be defined as the saturation vapor pressure at the dew point.



Figura 3: Location of meteorological stations and the footprint of the SAR image.

The water vapor pressure can be computed from the wet-bulb temperature and dew-point depression using the following recommended psychrometer formula [1]

$$e = e_{sw} - 0.000646 (1 + 0.000944 t_{wet}) P t_{dew}$$

with t_{wet} and t_{dew} in °C, e_{sw} is the saturation vapor pressure over water (moist air), measured in hPa, and P is the total pressure, also measured in hPa. There is experimental evidence that the saturation vapor pressure is a function of temperature only and the functional model defining this relationship is given by the Clausius-Clapeyron equation [3],[4]

$$e_{sw} = e_{s0} \cdot \exp \left[\frac{L_v}{R_w} \cdot \left(\frac{1}{T_0} - \frac{1}{T} \right) \right]$$

where $L_v = 2.50 \cdot 10^6 J \cdot kg^{-1}$ at the reference temperature $T_0 = 273.15K$ and $e_{s0} = 6.11hPa$ is the reference saturation vapor pressure at the same reference temperature.

Whereas the hydrostatic component of the tropospheric delay can be determined very accurately as a function of the surface pressure, assuming the condition of hydrostatic equilibrium, the non-hydrostatic component requires a water vapor profiles, which generally shows no strong dependence on the surface conditions. Due to the difficulty of handling this problem, a large number of wet and zenith non-hydrostatic delay models have been attempted. In this work we modeled the atmospheric vertical delay using the Saastamonien and Hopfield models.

5. PROCESSING AND PRELIMINARY RESULTS

The datasets of 14 RS1 and 5 RS2 images were interferometrically processed following the schemes represented in

Figura 4 in order to facilitate the recognition of atmospheric phase delay artefacts.

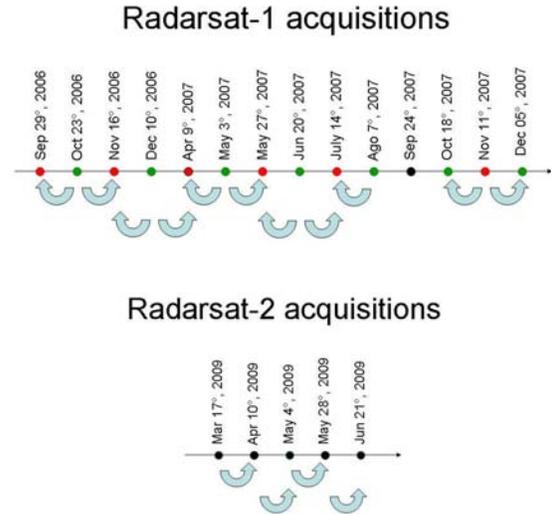


Figura 4. Processing of RS-1 and RS-2 SAR images used to study the atmospheric phase delay artefacts

Figura 5 and 6 display, respectively, the interferograms obtained by processing the RS2 images acquired on May, 4th and May, 28th 2010 and May, 28th and June, 21st 2010. In both cases, the interferometric phase signal measured is almost surely related to changes in the atmospheric phase delay properties occurred in the time interval of 24 days. since the terrain deformation in this area is not expected to generate such an interferometric phase.

Furthermore, it has been computed the wet zenith delay on each acquisition day. Figura 7 shows the case corresponding to RS1 acquisitions of April, 9th and May 3rd, 2007 and obtained from the meteorological data

acquired at station of Manaus.. At the top it is shown the wet zenith delay, computed using both Saastamonien and Hopfield models, at 00:00, 12:00, 18:00 and 24:00 during the acquisition day of the master image. In the middle, it is shown the same quantity by the acquisition day of slave image.

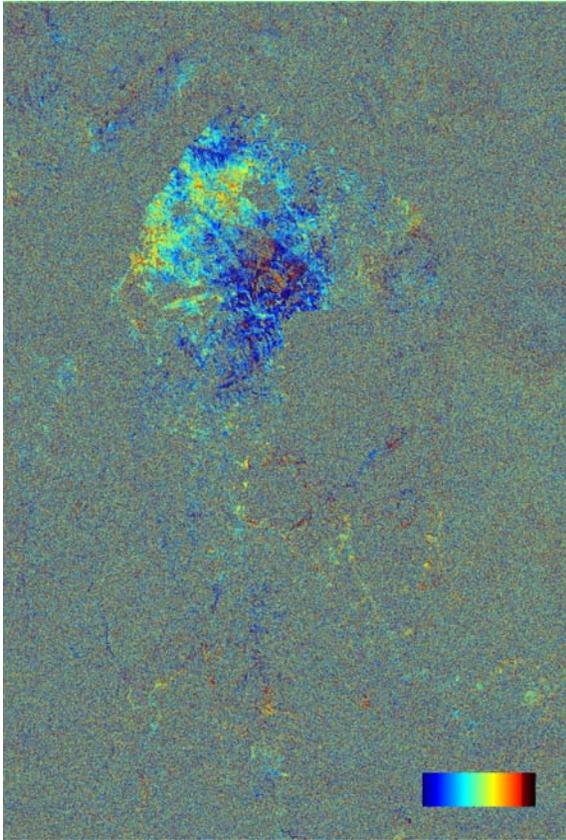


Figura 5: *RS-2 SAR interferogram, master: May, 4th 2010, slave: May, 28th 2010. Temporal baseline: 24 days, perpendicular baseline: 350 m.*

At the bottom, it is shown the difference between these two estimated of the wet zenith delays. The analysis of this last plot emphasizes how the temporal difference between the wet zenith delay close to the acquisition time of SAR images is quite high, in the range of 45-50 cm. Of course we cannot directly compare this estimate with phase signals since SAR interferograms measure the spatial difference, within the area imaged by the Radarsat. To carry out this comparison we need to process the data of other meteorological station close to that of Manaus. Unfortunately, at the moment we have not access at this dataset but we plane to process these data in the near future.

6. CONCLUSIONS AND FUTURE WORK

We processed a set RS-1 and RS-2 SAR images and processed using a short-temporal baseline approach. The resulting interferograms show a clear atmospheric signature due to phase delay artefacts. A first modelling of the atmospheric wet zenith delay based on the available meteorological data acquired at the station of Manaus city show that in the 24 days temporal baseline typical of Radarsat acquisitions atmospheric delay artefacts can reach values up to 50 cm.

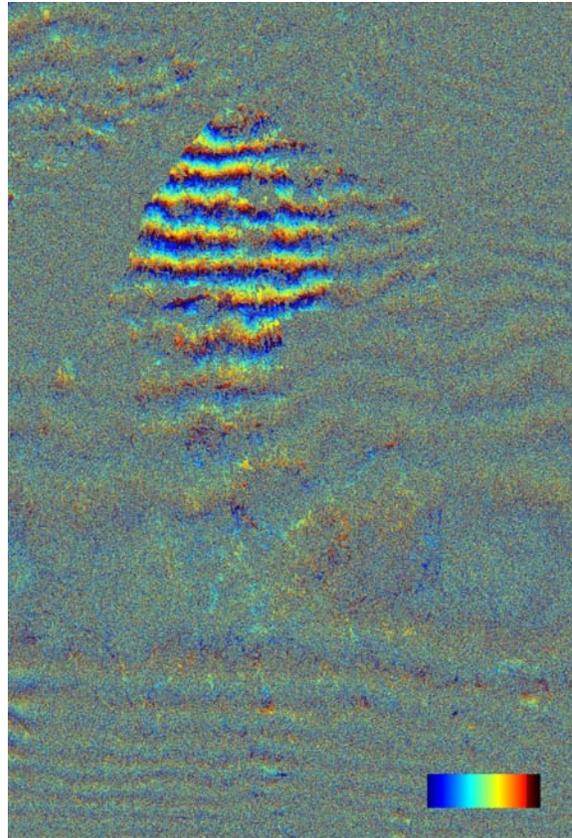


Figura 6: *RS-2 SAR interferogram, master: May, 28th 2010, slave: June, 21st 2010. Temporal baseline: 24 days, perpendicular baseline: 150 m.*

In the future we expect to process data acquired at other meteorological station located within the Amazon watershed and if possible GPS data. We also plan to assess the usefulness of EUMETSAT's Infrared Atmospheric Sounding Interferometer data to extract information about the atmospheric water vapor.

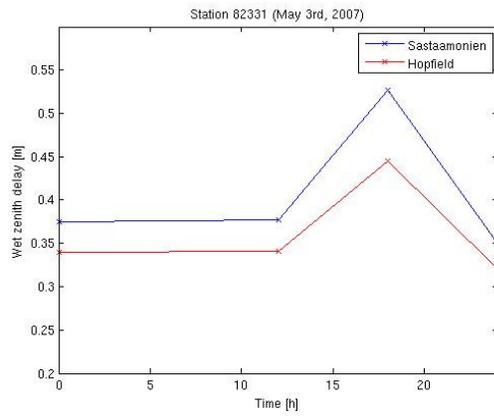
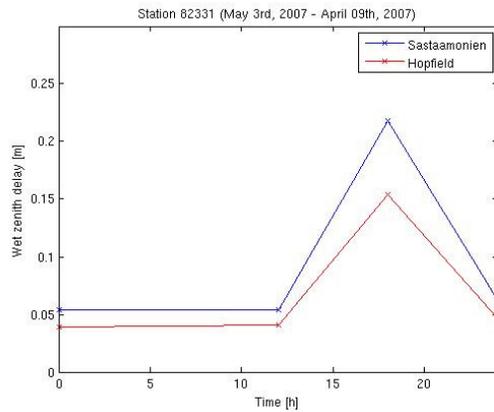


Figure 7: RS-1 Atmospheric wet vertical delay modelled using the Saastamonien and Hopfield models using the data acquired meteorological station available in Manaus area: (top) on April, 9th 2007, (middle) May, 3rd 2007; (bottom) their difference.

7. References

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