Water vapor observations during the METAWAVE Campaign for effect mitigation into satellite Interferometric SAR imaging

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ABSTRACT

Spaceborne Interferometric Synthetic Aperture Radar (InSAR) imaging is a well established technique to derive useful products for several land applications. One of the major limitations of InSAR is due to atmospheric effects, and in particular to high water vapor (WV) variability in troposphere. In general, the atmospheric artifacts are of the same order of magnitude of the ground motions to be measured, at times even much greater. Thus, the WV variability still remains a problem for InSAR processing and any information on its distribution could be useful for mitigating such effect.

This work is related to the ESA project METAWAVE (Mitigation of Electromagnetic Transmission errors induced by Atmospheric Water Vapour Effects) where the above mentioned problematic is being investigated by a team composed of SAR experts, meteorologists, atmospheric remote sensing experts. In the frame of METAWAVE, a month-long field campaign has been conducted in Rome, deploying ground-based instruments as well as radiosondes, and collecting high-resolution mesoscale model outputs and satellite observations.

Herewith we present selected preliminary results from the METAWAVE campaign in Rome on the characterization of the 3 dimensional WV field.

1. INTRODUCTION

Spaceborne Interferometric Synthetic Aperture Radar (InSAR) imaging is based on the measurement of the difference in phase of the signal backscattered by each land surface element observed from different points and/or at different times [1].

The atmosphere, particularly due to the high water vapour spatial and temporal variability, introduces an unknown delay in the signal propagation. The atmospheric artefacts are in general of the same order of magnitude of the motions to be measured, or at times even much greater, but they can be abated using the multi pass technique and time averaging [1]. Conversely, when a long sequence of interferograms does not exists, or sudden movements have been occurred on large areas (such in the case of an earthquake) the water vapour variability still remains a problem for InSAR processing and any information on its distribution could be useful to try to correct, or at least to mitigate such effect [2].

This paper is related to the ESA project METAWAVE (Mitigation of Electromagnetic Transmission errors induced by Atmospheric WAter Vapour Effects), where the above mentioned problematic is investigated by a consortium composed by the Universities of Rome, Perugia and L'Aquila (Italy), the Politechnic schools of Milan and Turin (Italy), and the Colorado State University (USA). The team includes SAR experts, meteorologists and atmospheric remote sensing experts. In the frame of METAWAVE, two field campaigns have been conducted near Como (northern Italy) and in Rome (central Italy).

In this paper, we present preliminary results from the METAWAVE campaign in Rome on the characterization of the 3 dimentional WV field through the deployment of ground-based instrumentation as well as radiosondes and the output of the high-resolution mesoscale model MM5.

During the campaign there were two InSAR observations over Rome, and InSAR Atmospheric Phase Screens (APS) (i.e., time difference of excess path between interferometric acquisitions related to variation in water vapour content along radar line of sight) were collected as well as WV estimation from other satellites (MERIS, MODIS, AMSRE).

Figure 1. *Frame of the MM5 higher resolution domain and location of the operational GPS network.*

2. EXPERIMENTAL SET-UP

The METAWAVE field campaign in Rome last for 15 days (19 Sept-4 Oct, 2008), covering two InSAR observations (20 Sept and 3 Oct) obtained by ASAR on ENVISAT. The instrumentation deployed includes the following:

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- Surface pressure-temperature-humidity (PTU) sensor at anchor station University of Rome La Sapienza (DIESAP)
- 1 dual-channel (23.8 and 31.4 GHz) radiometer (MWR) at DIESAP for Integrated Water Vapor (IWV) retrieval (University of Perugia)
- 3 four-channel (22.12, 22.67, 23.25, 24.50 GHz) radiometers (CMR) for WV tomography (developed by Colorado State University [3])
- 1 LIDAR for WV profiling (University of Rome)
- Portable radiosonde station (Colorado State University) and 10 radiosondes (CETEMPS)

Moreover, the following data of opportunity (operationally available) have been collected:

- IWV from a low resolution network of Global Positioning System (GPS) receivers
- Precipitation coverage from 2 weather radars at C- and X-bands (CETEMPS)
- 4-times a day radiosonde profiles launched from Pratica di Mare (PDM) by the Italian Air Force
- IWV maps from satellite observations (MERIS on ENVISAT, MODIS on AQUA and TERRA)

Finally, the three dimensional (3D) WV distribution has been simulated with the high-resolution numerical weather prediction model MM5. This model, developed by PSU/NCAR, is a limited-area, nonhydrostatic, terrain-following sigma-coordinate model designed to simulate mesoscale atmospheric circulation allowing resolution of the order of 1 km.

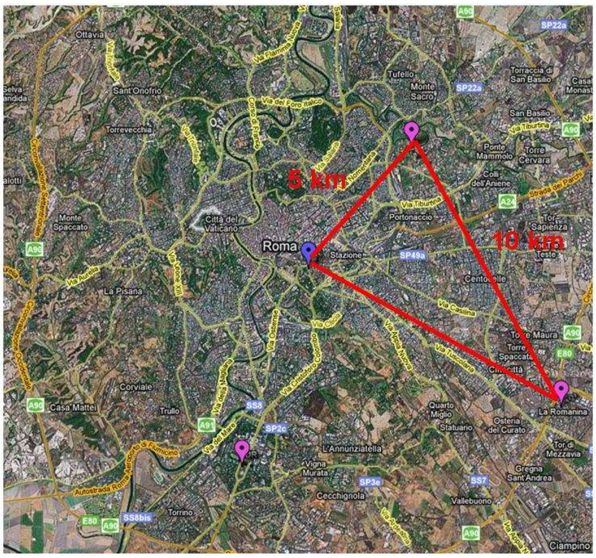

Figure 2. *The network of microwave radiometers. The MWR is located on the DIESAP anchor site (marked in blue) while the 3 CMR are located on the vertices of the red triangle. Radiosondes were launched from DIESAP.*

Fig. 1 shows the higher resolution domain of MM5 products together with the location of the GPS network operationally available in the area. Fig.2 shows the local scale with the network of microwave radiometers. The dual-channel MWR was located on the DIESAP anchor site, from which also the radiosondes were launched. The three CMR were located on the vertices of a triangle with roughly 5-10 km distance between each other. MWR and CMRs scanned both in elevation and in azimuth. The CMRs were operated in synchronization for looking simultaneously at the same portion of the atmosphere to allow the application of tomographic techniques [3].

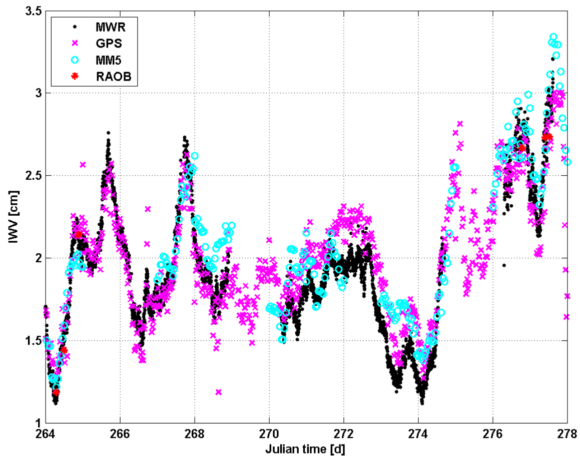

Figure 3. *Time series of IWV observed and simulated over DIESAP site during the campaign. Different colors indicate different sources of data.*

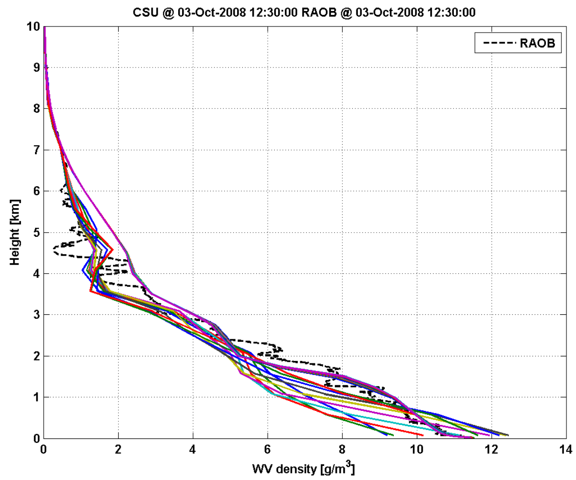

Figure 4. *WV profiles as measured by a radiosonde, estimated by the CMR, and predicted by MM5 (3 Oct 2008 12:30 UTC).*

3. PRELIMINARY RESULTS

Water vapour observations and simulations collected during the campaign have been qualitatively compared in terms of IWV, WV profiles, and 3-D WV distribution.

A source of the 3-D WV distribution is available through the MM5 simulations over the whole domain in Fig.1; moreover, the 3-D WV distribution within the triangle in Fig.2 was estimated by the Colorado State University (CSU) team from their ground-based CMR observations, using a tomographic approach based on elevation and azimuth scanning at 4 frequency channels near the water vapour absorption channel at

22.238 GHz [4]. WV profiles over the DIESAP site were also observed in-situ by the Vaisala radiosondes launched during the campaign. Finally, IWV data is available from a variety of sources; in fact, IWV is directly retrieved from MWR and GPS observations and it is also obtained integrating radiosonde and MM5 profiles. Fig.3 shows the time series of IWV from different sources during the whole experiment. Note the pick-to-pick variation over the 15-day campaign is exceeding 2.2 cm. Assuming the radiosonde IWV as the reference value, the rms error of MWR and GPS observations was found to be ~0.1 cm, while about 0.2 cm for the MM5 simulations.

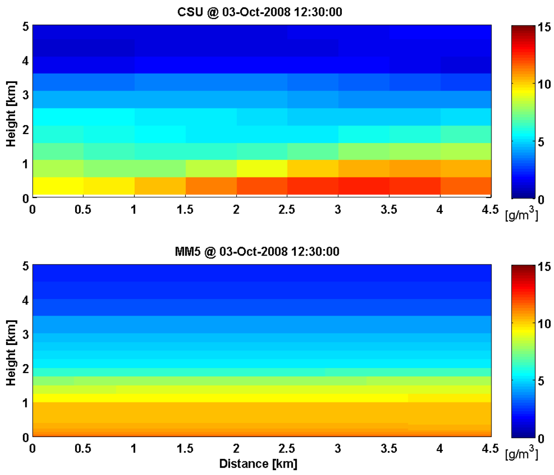

Figure 5. *Distance-height cross section of WV density as estimated by CMR (top) and predicted by MM5 (bottom) (3 Oct 2008 10:10 UTC).*

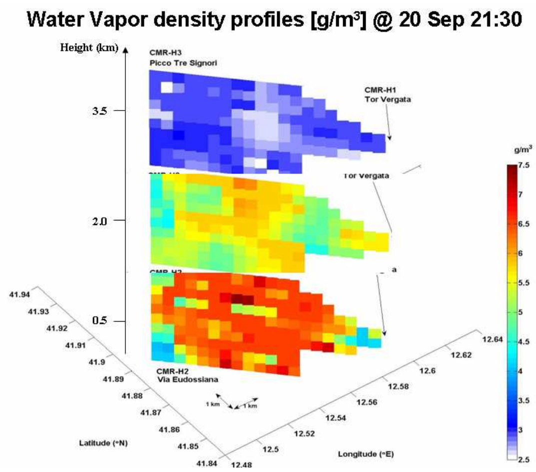

Figure 6. *3D WV distribution as estimated from CMR. Only 3 selected vertical levels are shown for clarity (20 Sept 2008 21:30 UTC)*

Concerning the WV profiles, a qualitative comparison of RAOB in-situ measurements, CMR retrievals, and MM5 simulations is given in Fig.4. The radiosonde was launched from DIESAP, while the CMR and MM5 profiles correspond to grid cells distributed along the short side of the triangle in Fig.2. Note that the MM5 profiles show much less variability than CMR profiles. This is also evident in the distance-height cross sections in Fig.5. The accuracy of these profiles is hard to determine since there's no other reference than the radiosonde profile, which is assumed a point measurement. However, the 2-D horizontal variability of WV can be investigated in terms of IWV by comparing with high-resolution satellite IWV images, which is currently under study using MERIS and MODIS observations.

An example of the 3-D WV distribution retrieved by the tomographic approach based on CMR observations is shown in Fig.6. Only three selected vertical levels are shown for clarity, though the profiles are retrieved in 20 levels up to 10 km. For the 3-D field, the only source of comparison would be the MM5 simulations. The quantitative comparison of WV profiles and 3-D distribution between CMR estimates and radiosonde observations or MM5 modeling is currently on going.

4. SUMMARY

The METAWAVE field campaign in Rome gave the opportunity to investigate a variety of sources of WV horizontal and vertical variability information. These includes in-situ observations, ground-based and spaceborne remote sensing, and numerical modeling. The dataset is currently under investigations for validating the accuracy of as many sources as possible with respect to standards. The validation of WV observations and simulations will play a key role in the demonstration of feasibility for WV effect mitigation in InSAR satellite imagery.

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