Inter-comparison of wet trpospheric corrections applied in Coastal Altimetry

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Abstract

The range measurements from the altimeter are associated with a large number of geophysical corrections which needs special attention near coasts and the shallow water regions. The corrections due to ionosphere, dry and wet troposphere and that due to sea state are of primary importance in altimetry. Water vapor dominates the wet tropospheric corrections by several factors which is more complex with higher spatio-temporal variations and thus needs a careful attention near coasts. In this piece of work the corrections due to water vapor estimated from radiosonde measurements near the coastal regions are compared with the model estimated corrections applied in the altimeter range measurements. Analysis has been performed for the Coastal Altimeter products provided by the PISTACH to observe these corrections.

1. Introduction

Atmospheric water vapor is a major source of uncertainty in satellite ranging measurements through the Earth's atmosphere due to its effect on the index of refraction. Signal propagation due to water vapor is highly variable with time and location thereby producing range measurement errors of ~3-45cm if uncorrected. In particular satellite radar altimeter measurements of sea surface height and topography needs higher accuracies since the instrument related errors are now reduced down to 2-4 cm level. Thus precise estimates of the vapor induced range corrections are clearly required to fully utilize the current altimeter technology.

The wet troposphere correction is the most difficult part to model because the water vapor in the air is highly variable spatially and temporally, ranging from a correction of nearly zero over the cold, dry poles to over 300 mm in the warm, humid tropics. The wet tropospheric delay, can be estimated by measuring the atmospheric brightness near the water vapor line at 22.2356 GHz and providing suitable removal of the background. The modern satellite altimeter missions, TOPEX/Poseidon (T/P), ERS-1, ERS-2, and GFO-1, derive the wet troposphere correction to their range measurements by using onboard microwave radiometers[1]. On homogenous ocean surfaces the radiometer wet tropospheric corrections applied are satisfactory in terms of accuracy and resolution [2]. However the problem arises over sea/land transistion areas. This is due to the fact that the algorithms used to retrive the wet path delay from the brightness temperatures are only valid on homogeneous ocean surfaces since they are based on sea surface emissivity models. Nevertheless, the exploitation of altimer measurements in coastal areas becomes necessary for oceanography, and studies are in progress to exploit altimetry for hydrological budgets over large continental basins. Untill now, the different tests performed to retrieve the wet tropospheric correction near coasts are empirical and give poor results.

In the present study an attempt is made to to evaluate the feasability of an operational retrieval of the wet troposphere correction over these transition areas.using radiosonde measured wet delays near coastal regions surrounding peninsular India. . For this study high resolution COASTALT products from JASON-2, which is a follow-on mission to Jason-1data was used

2. Methodology

The algorithm for reducing the radiosonde measurements is based on the fact that the wet tropospheric range correction is proportional to the water vapor (mass/unit area) present in the atmosphere[3]. The atmospheric water vapor, measured from sea level to an altitude h*, is given by the following expression

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$$W = \int_0^{h^*} \rho(h)dh \quad (1)$$

where W is the integrated water vapor, p(h) is the water vapor density, and h is the path length from sea level to the maximum altitude, h*, above which no significant atmospheric water vapor is present. The wet tropospheric range correction Δh_w can be expressed as using[3]

$$\Delta h_w = \Omega \int_0^{h^*} \rho(h)dh + \eta \int_0^{h^*} \frac{\rho(h)}{T(h)} dh \quad (2)$$

where T(h) is the atmospheric temperature at the altitude h and Ω and η are constants used to approximate the dielectric constant for water vapor in the atmosphere at frequencies below 30 GHz. The values for Ω and η are 0.331cm^3/gm and 1.731 x 10^3 ^{o}K cm^3/gm, respectively.

3. Data used

The OSTM/Jason-2 satellite flies on the same ground-track as Jason-1 and the original T/P with a 254 pass, 10-day exact repeat cycle. Jason-2 has three frequency microwave radiometer, named the Advanced Microwave Radiometer (AMR), consists of three separate channels at 18.7, 23.8 and 34 GHz. The radiometer is functionally equivalent to the Jason Microwave Radiometer found on Jason-1. The Jason-2 Microwave Radiometer (AMR) measures the brightness temperatures in the nadir path at 18.7, 23.8 and 34.0 GHz: the water vapor signal is sensed by the 23.8 GHz channel, while the 18.7 GHz channel removes the surface emission (wind speed influence), and the 34 GHz channel removes other atmospheric contributions (cloud cover influence) [4]. Measurements are combined to obtain the path delay in the satellite range measurement due to the water vapor content. The uncertainty is less than 1.2 cm RMS [5]. The ECMWF numerical weather prediction model provides also a value for the wet tropospheric delay. The model values will prove useful when sun glint, land contamination, or anomalous sensor behavior makes the AMR measurement of the wet tropospheric delay unusable.

For the present study, wet tropospheric corrections from Interim IGDR- PISTACH high frequency Coastal dataset for two years 2009 and 2010 were used. The data is available in the AVISO (Archiving, Validation and interpretation of Satellite Oceanographic) data. The altimeter products were produced and distributed by Aviso(http://www.aviso.oceanobs.com/), as part of the Ssalto ground processing segment The model wet troposopheric correction, radiometer wet troposphere correction and composite of model and radiometer wet troposphere correction available as IGDR products were used in the present study. The precipitable water vapor was calculated from meteorological parameters like temperature, pressure and water vapor profiles measured using radiosonde soundings near coastal stations. Both 00UTC and 12UTC radiosonde data were used to estimate the wet troposphere delay. The location of IMD stations along with Jason-2 passes used for the present study is given in Table 1.

Table 1 The radiosonde stations used in the present study

S.No	Station Name	Latitude	Longitude	Pass no
1	Port Blair	11.6	92.7	205
2	Visakapatnam	17.7	83.3	116
3	Mumbai	19.1	72.8	105

The wet delay due to water vapor was estimated using equations (1) and (2) over the above said IMD stations and the estimated wet delay were compared with model wet delay applied to the altimeter range measurements. In order to compare the radiosonde measurements with Jason-2 measurements stringent selection criteria was applied. The satellite pass with in 50 km radius of the radiosonde site and time interval of ±3 hours between satellite pass and radiosonde flights were chosen for the present work.

4. Discussions and Summary

The precipitable water vapor present in the atmosphere was estimated using meteorological parameters which in turn was used to estimate the wet tropospheric delay. The comparison between the wet delays estimated using radiosonde measurements, ECMWF model, onboard AMR measurements and composite of both model and AMR were discussed in this short paper. Figure 1 shows the wet delays measured using radiosonde (solid line with inverted triangles), ECMWF model (solid line with squares), radiometer (dashed line with triangles) and composite of both model and radiometer wet delays (dashed line with open circles) over three radiosonde sites for the years 2009 and 2010. As it is seen that there were larger data gaps since the stringent criterion was applied in both spatial and temporal domain. It is to noted that the radiosonde measurements were not available in the monsoon seasons which makes the comparison difficult during monsoon seasons over all stations. The wet tropospheric delays measured over these sites were in the range of ~ 10 to 60 cm. Also the wet delay measured by the radiosonde measurements was found to be higher than the model and radiometer measured wet delay except for mumbai.

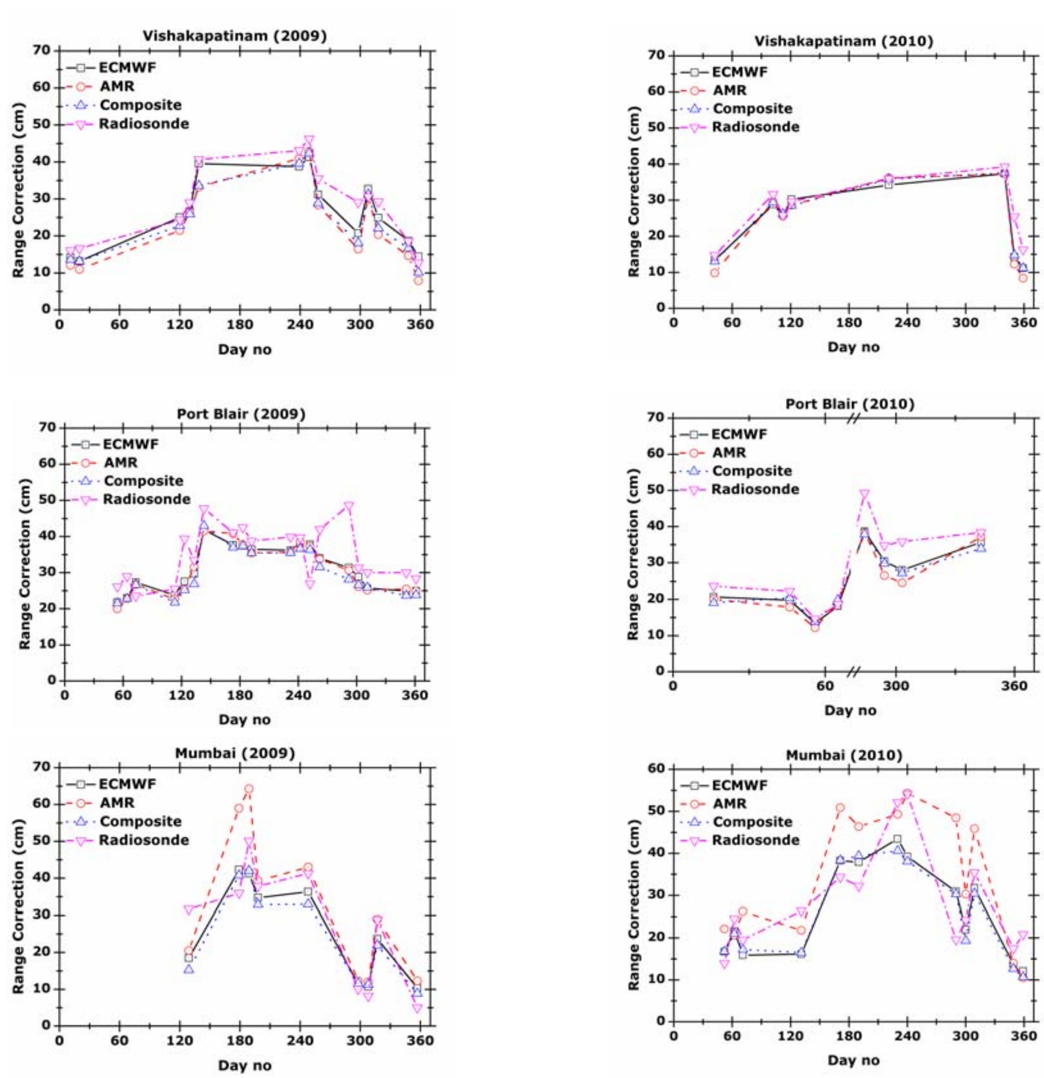

Figure 1 Wet tropospheric delays measured using radiosonde (solid line with inverted triangles), ECMWF model (solid line with squares), radiometer (dashed line with triangles) and composite of both model and radiometer wet delays(dashed line with open circles) for Vishakapatinam, Port Blair and Mumbai

Figure 2(a) shows the scatter plot between the radiosonde measured wet delay versus model wet delay over three stations. It can be seen that wet delay measured by the radiosonde were always higher than the ECMWF model estimated and model corrected composite wet delay. The deviation is found to be ~5.24 cm. Figure 2(b) shows the scatter plot between radiosonde wet delay and the composite of ECMWF model corrected radiometer wet delays. The deviation in this case is also found to be ~ 5.67 cm.

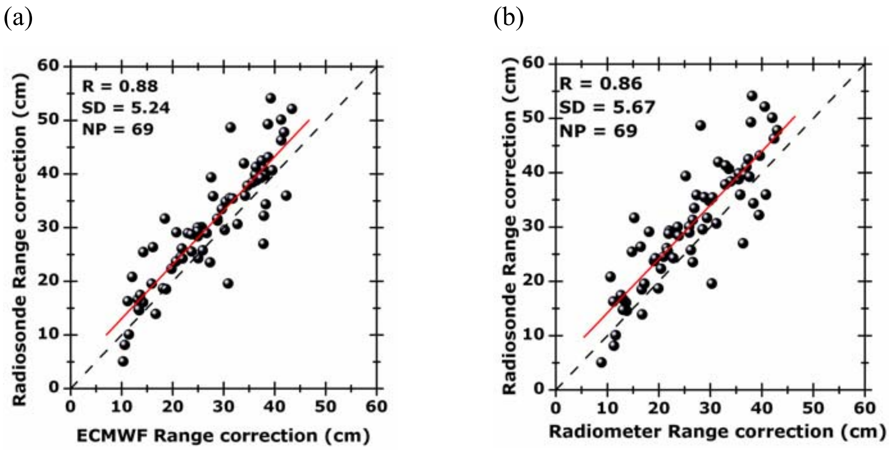

Figure 2 Scatter plot between (a) range correction estimated by ECMWF model and radiosonde and (b) Composite range correction and radiosonde respectively

From the present study it is observed that altimeter wet range correction estimated using ECMWF model values were found to be less than the radiosonde measured wet corrections. The feasibility of the model corrected wet delay applied in the altimeter range correction could be evaluated with more number of collocated observations and will be communicated in the future.

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