Preliminary Validation of Total Water Vapor Column Production of Scanning Microwave Radiometer Onboard HY-2 Satellite

Xiaoqi HUANG¹,², Jianhua ZHU¹, Yili ZHAO¹, He WANG¹, Chuntao CHEN¹
¹National Ocean Technology Center, State Oceanic Administration, Tianjin, 300112, China
E-mail: 13920046686@163.com

Abstract. The scanning microwave radiometer (RM) was launched on August 16, 2011, onboard HY-2 satellite. As the one of primary parameters retrieved from HY-2 RM, the six-month long from Jan to Jun 2012 global total water vapor column (WV) obtained from HY-2 scanning microwave radiometer were preliminarily validated using other operational space-borne radiometer observations. The gridded water vapor productions of Special Sensor Microwave Imager (SSM/I) were seen as “true data” in this inter-comparison. For the global scale, the bias and RMS difference of the dataset of these space-borne collocated WV observations was respectively -0.24 mm and 1.19 mm during this six-month period. With analysis of global map of mean difference of the collocation between HY-2 RM and SSM/I, the map of bias distribution appeared that there were a positive deviation about 1mm in the tropic ocean where the precipitation and humidity were in relative high level, a negative deviation in the coastal and near-shore regions. The results suggested that accuracy of retrieval algorithm for HY-2 WV productions obviously depends on latitude. There were potential and room for improvement of retrieval accuracy of WV, for correcting overestimation of WV in the tropic sea and underestimation in the inshore regions relative to SSM/I observations.

1. Introduction
So far, there are several space-borne microwave radiometer launched by NASA and ESA in orbit, such as SSM/I F17 aboard the Defense Meteorological Satellite Program (DMSP), WindSat carried on Coriolis mission and so on. As one of primary parameters retrieved by microwave radiometer, precise observation of water vapor are widely used in meteorological observation and forecast. Therefore, it is necessary to validate the accuracy of WV measured by space-borne radiometer. The radiosonde measurements located in some islands, seen as “true data”, are used in assessing columnar water vapor derived by SSM/I for a whole year of 1989 [1]. Furthermore, the inter-comparison of water vapor retrieved from SSM/I and GPS radio occultation were carried out for the evaluation of global distribution of deviation in 2006 [2].

In this research, the main objective of this paper is to perform an evaluation of the WV measured by HY-2 RM, by comparing with SSM/I F17 in the time period from Jan to Jun 2012. Based on this

² Corresponding author: No.219 Jieyuanxidao Nankai District Tianjin P.R.China. 300112
Foundation items: the Marine Public Welfare Project of China under contract No.201105032-5.
inter-comparison between HY-2 RM and SSM/I, quality stability of WV productions will be assessed in the time series, and the characteristic of distribution of global WV deviation will be analyzed.

2. Dataset

2.1. HY-2 scanning microwave radiometer dataset

The scanning radiometer aboard HY-2 is operating at five-frequency of 6.6GHz, 10.7GHz, 18.7GHz, 23.8GHz and 37GHz, which works with horizontal and vertical polarization except for only vertical polarization at 23.8GHz. The antenna of forward viewing maintains an constant incidence angle of 47.7° due to the off-nadir angle of 40°, and rotates equally ±70° relative to the satellite nadir track. This instrument is capable of providing a swath of 1600km on the surface of earth within a period of 3.79s. The two-point method is used to calibrate this scanning radiometer. The parameters of this instrument are listed in Table 1 (Jiang et al., 2012).

In this study, the HY-2 scanning radiometer data used are produced by National Satellite Ocean Application Service (NSOAS) workgroup of SOA with a unified physically based algorithm. The level 2A products of HY-2 RM are selected in the time period from Jan to Jun 2012.

| Table 1. Primary parameters of the HY-2 RM |
|-------------------------------------------|
| Frequency(GHz) | 6.6 | 10.7 | 18.7 | 23.8 | 37.0 |
| Polarization  | V H | V H | V H | V | V H |
| Scan width(km) | 1600 | | | | |
| Footprint size (km) | 100 | 70 | 40 | 35 | 25 |
| Sensitivity(K)  | <0.5 | <0.5 | <0.5 | <0.5 | <0.8 |
| Dynamic range (K) | 3~350 | | | | |
| Calibration precision(K) | 1(180-320) | | | | |

2.2. SSM/I Dataset

For the global scale, the quality of total water vapor production of HY-2 scanning radiometer is investigated using water vapor measured by Special Sensor Microwave Imager (SSM/I) F17 in this study. The instruments are carried aboard the Defense Meteorological Satellite Program (DMSP) on successive polar orbiting platform. To date, DMSP satellites have carried the SSM/I instrument (F08, F10, F11, F13, F14, F15) and the SSMIS instrument (F16, F17, F18), an instrument similar to the SSM/I, but with sounding capabilities. The SSM/I sensor consists of 7 separate total-power radiometers sharing a common feed-horn. These seven radiometers take dual-polarization measurements at 19.35, 37.0, and 85.5 GHz, and just a vertical-polarization measurement at 22.235GHz. In this research, the SSM/I data products are obtained from Remote Sensing System (RSS) via the website http://www.ssmi.com. The dataset including ocean wind speeds, total water vapor, cloud and rain observations are processed in the form of maps of geophysical parameters on 0.25×0.25 degree grid, moreover, the gridded dataset are divided into ascending and descending swath for each day.

3. Collocation

In order to compare HY-2 RM water vapor observations with SSM/I, spatial and temporal collocation must be performed between those two datasets. Therefore, the satellites inter-comparison data pairs are reasonably collocated with following spatial and temporal criteria. First, the distance between location of HY-2 RM and SSM/I observation cell is within 25km. Second, time interval between scan time of HY-2 RM and SSM/I is less than 60 min. For SSM/I gridded data (1440×720 pixels for each map) obtained from RSS, HY-2 RM swath data are transformed into maps of ocean parameters on 0.25×0.25 degree grid. By retrieving the index from the two 1440×720 size gridded maps, the spatial collocation is performed. The HY-2 RM and SSM/I gridded data pairs are suitably collocated
with the same location in those two maps and the scan time difference of less than 30min between those two satellites.

4. Results

4.1. Quality stability in the time series
To assess the stability of WV product data observed by HY-2 RM in the time series, the bias and RMS of collocated WV observation dataset for every day are achieved. Figure 1 shows the bias and RMS for the daily collocated observations, plotted as a function of Julian date. The bias and RMS of total collocated WV data during these six months are -0.24mm and 1.19mm respectively. The curve of bias shown in this figure is generally below zero, except for few days. Furthermore, by the analysis of the curve of RMS, there are relatively stable daily RMS differences within range of 1mm to 1.5mm during the period of Jan to Jun. This indicates that the WV production of HY-2 are under-estimated relative to SSM/I measurements, and the quality of these products is stable and reliable.

![Figure 1](#). Daily bias and RMS of WV difference between HY-2/RM and SSM/I F17 during recent six months (Jan~Jun 2012). In this figure, blue line and marks represent daily global WV RMS difference, green line and marks represent daily WV biases respectively. The starting point of time is Jan 10 2012 on the horizontal axis.

4.2. Global feature from comparison with SSM/I
Comparisons with SSM/I WV observations is capability of extending the regional HY-2 RM WV validation to the most of global ocean, and covering much wider range of water vapor conditions, including cold and tropical zone. Coverage map of the collocated WV difference between HY-2 RM and SSM/I shown in figure 2 indicates the global characterization of regional biases during the period of these six months. For the gridded map, mean of difference were calculated from Jan to June 2012 in each 0.25° grid. With analyzing these WV bias in this global map, it is obviously appeared that there is a negative deviation in the inshore regions, especially in the sea around Europe and North Africa, where WV differences are approximate -1.5mm. In the oceanic regions, the WV differences are between -0.5 and 0.5mm, except for tropic sea area around the equator.
Figure 2. Global map of averaged WV difference between HY-2 RM and SSM/I gridded data for six months taken over the time period between January 2012 and June 2012. The gray part shown in the figure represents continent, the blank area represents absence of collocated data.

To analyze the algorithm of WV productions deeply, monthly SSM/I WV measurements and HY-2 bias relative to SSM/I are separately plotted in figure 3 according to global bias map shown in the above figure. The WV differences between HY-2 and SSM/I are put into bins 10 latitudinal degrees wide. The bias of differences is respectively calculated within each bin. This bias has been negative at mid-high latitudinal sea area, positive at low latitude, especially the equatorial region. Moreover, the trend of WV bias relatively coincides with the curve of SSM/I WV in this figure. This indicates that global map of columnar water vapor is similar to figure 2. Therefore, trend of bias show significant impact of columnar water vapor due to latitudinal dependence of algorithm of HY-2 WV productions.

Figure 3. WV bias and columnar water vapor as a function of latitude. The blue marks represent WV bias in each bin of latitude, the green marks represent mean of SSM/I WV observations.
The collocated observations are binned into 5mm wide bins using the WV measured by SSM/I. The mean and standard deviation of difference between HY-2 and SSM/I is respectively calculated within each bin, and the results are plotted in figure 4. The error bars represent one standard deviation on each side of the mean in these bins. In this figure, the curve of means shows relatively flat trend in the total water vapor range from 0mm to 70mm. It is found that there is an upturn in this curve of the figure as a function of WV. Within WV range of 0 to 28mm, the means of difference are below zero, and the means are above zero within WV range 28 to 70mm. The standard deviation of difference is almost below 1mm, except at 2.5mm and 62.5mm due to the absence of collocation observations at low and high WV respectively.

![Figure 4](image-url) Figure 4. WV difference (bias) as a function of WV observations from SSM/I. The error bars represented as vertical red line are standard deviation of each bin.

5. Conclusion
This is the first relatively systematic assessment of accuracy of WV observations from HY-2 RM after the HY-2 test on orbit. We have performed a preliminary comparison between WV productions derived by HY-2 RM and SSM/I F17 during the period from Jan to Jun 2012. The bias and RMS difference of this inter-comparison is less than -0.24 mm, respectively approximate 1.19 mm. In my opinion, those results could be acceptable relative to accuracy of SSM/I WV observations.

Furthermore, the inter-comparison between HY-2 RM and SSM/I measurements is carried out, as well, for the purpose of investigation of feature of global deviation distribution. With the analysis of this inter-comparison, the results suggest that accuracy of the WV retrieval algorithm obviously depends on latitude. Besides, there are considerable potential for development of capability of WV observation in the coastal and near-shore regions. As development of retrieval algorithm of HY-2 RM geophysics parameters, there is a large room for retrieval accuracy improvement.

References
[1] Jackson D L and Stephens G L 1995 A Study of SSM/I-Derived Columnar Water Vapor over the Global Oceans J. Clim. 8 2025
[2] Wick G A, Kuo Y H, Martin Ralph F, Wee T K and Neiman P J 2008 Intercomparison of integrated water vapor retrievals from SSM/I and COSMIC Geophys. Res. Lett. 35 L21805, doi:10.1029/2008GL035126
[3] Li J, Wolf W W, Paul Menzel W, Zhang W J, Huang H L and Achtor T H 2000 Global Soundings of the Atmosphere from ATOVS Measurements: The Algorithm and Validation J. Appl. Meteor. 39 1248
[4] Jiang X W, Lin M S, Liu J Q, Zhang Y G, Xie X T, Peng H L and Zhou W. 2012 The HY-2 satellite and its preliminary assessment. Int. J. Digi. Earth. 5 266
[5] Sohn B J and Smith E A 2003 Explaining sources of discrepancy in SSM/I water vapor algorithms J. Climate. 16 3229–55
[6] Wentz F J 1997 A well-calibrated ocean algorithm for Special Sensor Microwave/Imager J. Geophys. Res. 102 8703–8718
[7] Noel S, Buchwitz M, Bovensmann H and Burrows J P 2005 Validation of SCIAMACHY AMC-DOAS water vapour columns Atmos. Chem. Phys. Discuss. 5 1925–42
[8] Divakarla M G, Barnet C D, Goldberg M D, McMillin L M, Maddy E, Wolf W, Zhou L H and Liu X P 2006 Validation of Atmospheric Infrared Sounder temperature and water vapor retrievals with matched radiosonde measurements and forecasts J. Geophys. Res. 111 D09S15
[9] Trenberth K E Fasullo J and Smith L 2005 Trends and variability in column-integrated atmospheric water vapor Clim.Dyna. 24 741-58

Acknowledgments
The authors would like to thank the Remote Sensing Systems at www.ssmi.com, for providing water vapor gridded data of SSM/I, which were produced by F. Wentz, Z. Jelenak, M. Bettenhausen, P. Gaiser. They were also thankful to the NSOAS for providing HY-2 level-2 data. The investigation was supported from the Marine Public Welfare Project of China under contract No. 201105032-5 in this paper.