RETRIEVAL OF ATMOSPHERIC WATER VAPOR FROM AMSR-E AND THE APPLICATION FOR NWP AT JMA

Masahiro KAZUMORI
Takumu EGAWA

Japan Meteorological Agency

1. INTRODUCTION

Atmospheric water vapor is a key geophysical parameter for Numerical Weather Prediction (NWP). For operational forecasts of heavy precipitation and typhoon, accurate moisture analysis fields as the initial conditions of NWP are required. Atmospheric water vapor is a source of clouds, rains and snows, and the distribution and amount play important roles for a representation of latent heat releases and absorptions in NWP model. And the condensation and the energy affect directly the strength of the precipitation and the typhoon intensity. Therefore, numerous moisture observations are required to produce accurate and realistic analyses and forecasts in the data assimilation for NWP.

Measurements of space-borne Microwave instruments contain information on atmospheric water vapor, cloud liquid water and the earth surface. The information of the atmospheric water vapor from various Microwave Imagers such as AMSR-E, SSMIS, and TMI are indispensable to represent a realistic atmospheric state over NWP model domain, and actually these data have been utilized in most operational NWP centers in the form of the retrievals or the brightness temperatures.

Since 2001, an operational Meso Scale NWP Model (MSM) has been operated to provide the disaster prevention information for severe weather events in the Japan Meteorological Agency (JMA). As Japan is surrounded by oceans, the information of atmospheric water vapor over the ocean is essential for the NWP. The operational use of the retrieved atmospheric water vapor from Microwave Imagers such as DMSP F13, F14, F15 SSMI and TRMM TMI in the JMA system was started in October 2003. And in November 2004, AMSR-E data was also added in the system. Use of these retrieved data brought improvement of the NWP, especially for the rain fall forecasts [1].

However, as for DMSP F15 SSMI data, because of a radar calibration beacon for the F15, the 22GHz V pol. of F15 brightness temperatures have biases since August 2006, it got impossible to use them in the retrieval process and the data assimilation. And F14 and F13 SSM/I had discontinued the measurements in August 2008 and November 2009, respectively. Remaining Microwave Imagers, TMI/TRMM and AMSR-E/Aqua have been continuing the measurements beyond their designed life time.

In order to supply more information on atmospheric water vapor from new satellite instruments for the operational data assimilation, development of an atmospheric water vapor retrieval algorithm was required [2] and that was expected to have capability to retrieve the atmospheric water vapor from various Microwave Imagers such as current on-orbit sensor SSMIS on DMSP F16, 17, WindSat on Coriolis, planned future satellite instrument AMSR2 on GCOM-W1 and GMI on GPM core satellite.

In this paper, the outline of the developed retrieval algorithm and the results of product verification and comparison are presented. In addition, some NWP experiment results in JMA Meso-Scale Model data assimilation system were shown as an application example of this algorithm.

2. RETRIEVAL METHODOROGY

The retrieval algorithm is a physical-statistical based algorithm. Forward model of microwave radiative transfer consists of a single atmospheric layer and ocean surface. The single atmospheric layer includes water vapor and cloud liquid water as absorber and emitter at microwave region. The ocean surface is assumed to be Fresnel reflection surface. The original algorithm codes were developed based on Janssen (1993) [3] for AMSR and AMSR-E [4] in 2002. The capability of the algorithm was improved and extended in this study.

In this algorithm, atmospheric transmittance is defined at a frequency and a satellite zenith angle. The satellite zenith angle is the microwave emitting direction. A vertical mean temperature of the atmosphere at the frequency and the satellite zenith angle is defined. The transmittance and mean temperature depend on vertical profile of temperature, water vapor and cloud liquid water. The dependency of the transmittance and the vertical mean temperature to polarization is not considered because the dependency can be detected only in heavy rain condition by measurements of higher frequency. The algorithm is applicable in rain free region (no scattering condition) and other correction algorithm is applied for the rain affected data based on the ratio of observed vertical and horizontal polarized brightness temperature.

The vertical mean temperature also depends slightly the direction of radiation transfer, i.e. upward or downward direction, due to inhomogeneity of temperature and water vapor. The vertical mean temperature is defined as the average of upward and downward temperature and assumed as the same for waver vapor and cloud liquid water to simplify the calculation. Ocean surface emissivities depend on frequency, sea surface temperature, ocean surface wind and satellite zenith angle. The sea surface temperature can be obtained from operational JMA global SST analysis. Emissivities are calculated by Fresnel law and the dependency on sea surface temperature and sea surface wind speed is included in a correction table for the modification of Fresnel reflectivity. Once the vertical mean temperature is given appropriately, atmospheric transmittance is calculated. The atmospheric transmittance is a function of atmospheric water vapor, cloud liquid water, absorption coefficients of water vapor and cloud liquid water. As the absorption coefficients depend on temperature and moisture vertical profiles, combination of more than two channels allows the retrieval of atmospheric water vapor and cloud liquid water. Frequencies 19GHz and 37GHz data are mainly used in the algorithm. And the vertical mean temperature was calculated as a function of temperature at 850hPa and square of atmospheric transmittance by using pre-defined look up tables (LUTs). All LUTs used in the algorithm were newly created by using 3-year radiosonde collocated data set. The algorithm was extended the capability to retrieve atmospheric water vapor under strong wind condition such as ocean surface wind speed beyond 20 m/s.

3. PRELIMINARY RESULTS

The retrieved atmospheric water vapors were verified against radiosonde observations. The satellite data were collocated with radiosonde observations within 150km in the location difference and within 60 minutes in the time difference. Fig. 1 shows the verification results for AMSR-E. The biases of the new products were largely reduced in high water vapor condition. The improvement of the bias error was also confirmed in comparisons with products from other retrieval algorithm. Fig. 2 shows the comparison results between the atmospheric water vapor products from current JAXA level 2 algorithm, new algorithm and Remote Sensing System (RSS) products. It is clear that the new products showed similar feature with RSS products in the convective area around the maritime continent.

In the mean time, JMA has been operating a 4-dimensional variational (4D-Var) data assimilation system for MSM. In the 4D-Var system, various observation data such as conventional data (surface observation, ocean buoy data, radiosonde observation, wind profiler data, aircraft observation), and satellite data (atmospheric motion vectors from MTSAT-1R, atmospheric water vapor from microwave imagers and ground based GPS observation, wind vector data from radar, and rain rate from radar and microwave imagers) are assimilated operationally. The data cut off time for the operational use is strict (50 min. after the analysis time). On top of the data set, the atmospheric water vapor retrieved from DMSP F16 and F17 SSMIS data from new algorithm were incorporated. The data acquisition and decoding were performed in the same time schedule as operational.

In Fig. 3, each panels show the operational analysis increment of total atmospheric water vapor for 3-hourly 4D-Var analysis on June 9, 2009. The increment was limited along the satellite orbits. DMSP F13 SSMI data was used in 00UTC and 09 UTC analyses. AMSR-E data was used in 06UTC and 18UTC. Little increment was found in other analysis times because there were no available atmospheric water vapor products in the region. Fig. 4 shows the preliminary experimental results. The atmospheric water vapor from DMSP SSMIS F16 and F17 were retrieved by the new algorithm and assimilated in the 00, 09, 12, 21 UTC analyses. It was clear that the data brought much analysis moisture increment over the ocean.

4. SUMMARY

In this study, a retrieval algorithm of atmospheric water vapor for AMSR-E was developed. The algorithm is physical and statistical algorithm and applicable for other Microwave Imagers (TMI and SSMIS) and future planned instrument AMSR2 on GCOM-W1. Improvement of bias errors was confirmed in the verification against radiosonde observations and the comparison with other algorithm products.

The operational JMA Meso scale analysis utilizes retrieved atmospheric water vapor to obtain moisture information over the ocean. Currently, the atmospheric water vapor from AMSR-E and TMI are only available and are assimilated operationally. Because the cut-off-time of the data receiving is strictly limited for the operational schedule, numerous moisture data from various Microwave Imagers are required for the assimilation and the incorporated data are expected to bring more improvement in heavy rain fall and typhoon forecast.

In the preliminary experiments, the atmospheric water vapors retrieved from SSMIS on DMSP F16 and F17 by the new algorithm were assimilated in the JMA 4D-Var Meso scale Analysis system. The moisture analysis increment over the ocean from SSMIS on DMSP F16, 17 was increased. The impact of the precipitation and typhoon forecast has been investigating and the results will be presented in the IGARSS 2010 conference.

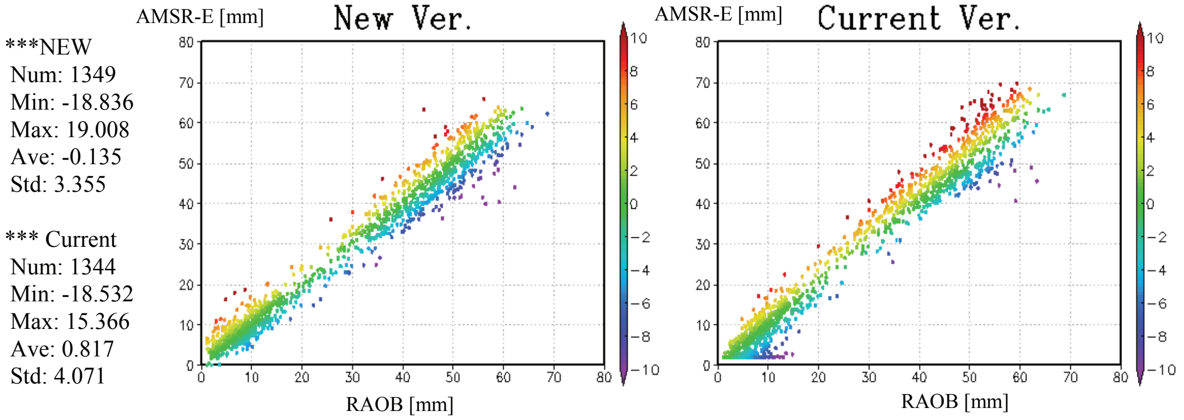
5 REFERENCES

[1] Sato, Y., Y. Takeuchi, T. Tauchi, "Use of TMI and SSM/I data in the JMA operational meso analysis," *CAS/JSC/ WGNE Res. Activ. Atmos/ Oceanic Modell.*, 34, 1.27-1.28, 2004

[2] Kazumori, M, "Development of retrieval algorithm of Total Precipitable Water and Cloud Liquid Water for GCOM-W1 AMSR2", *GCOM Workshop*, Yokohama, Japan, 2009

[3] Janssen M.A., Atmospheric Remote Sensing by Microwave Radiometer, *John Wiley & sons. Inc.*, pp. 572, 1993

[4] Takeuchi, Y., "Algorithm theoretical basis document (ATBD) of the algorithm to derive total water vapor content from ADEOS-II/AMSR," *EORC Bulletin/Technical Report*, 2002



***NEW
Num: 1349
Min: -18.836
Max: 19.008
Ave: -0.135
Std: 3.355

*** Current
Num: 1344
Min: -18.532
Max: 15.366
Ave: 0.817
Std: 4.071

Fig. 1. Results of verification against radiosonde observation. Statistical Period is from January to May 2009. The left panel is for new algorithm and the right panel is for current JAXA level 2 algorithm.

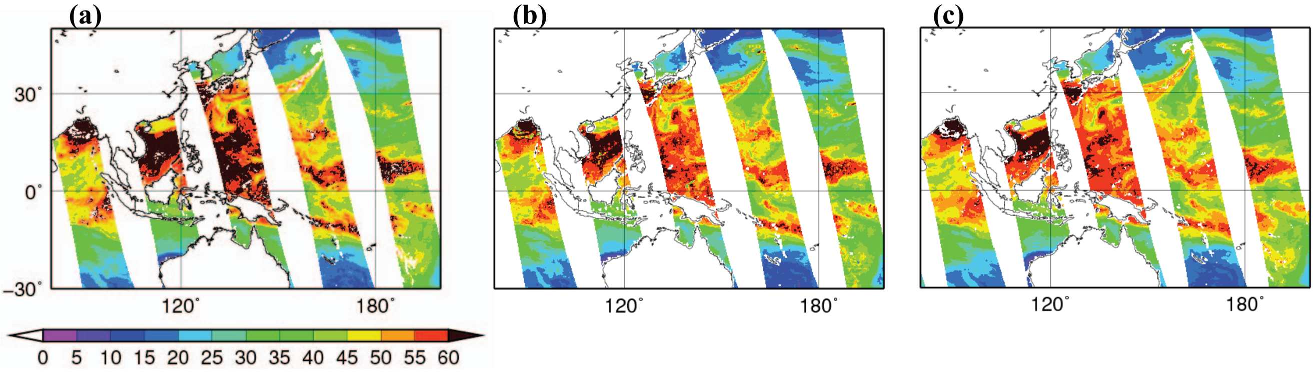


Fig. 2. Comparison of retrieved total atmospheric water vapor (August 15, 2008) for (a) current JAXA level 2 products, (b) products by new algorithm, and (c) Remote Sensing System products.

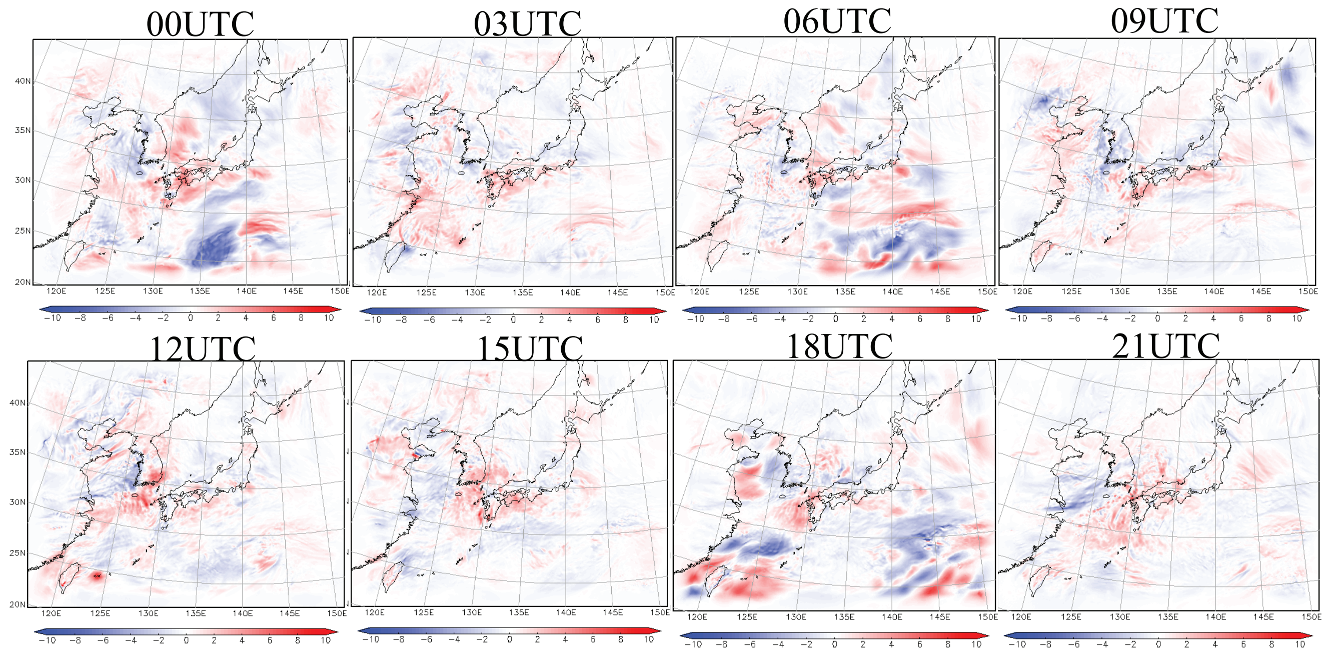


Fig. 3. Analysis increment of total atmospheric water vapor in the JMA operational meso scale analysis on June 9, 2009.

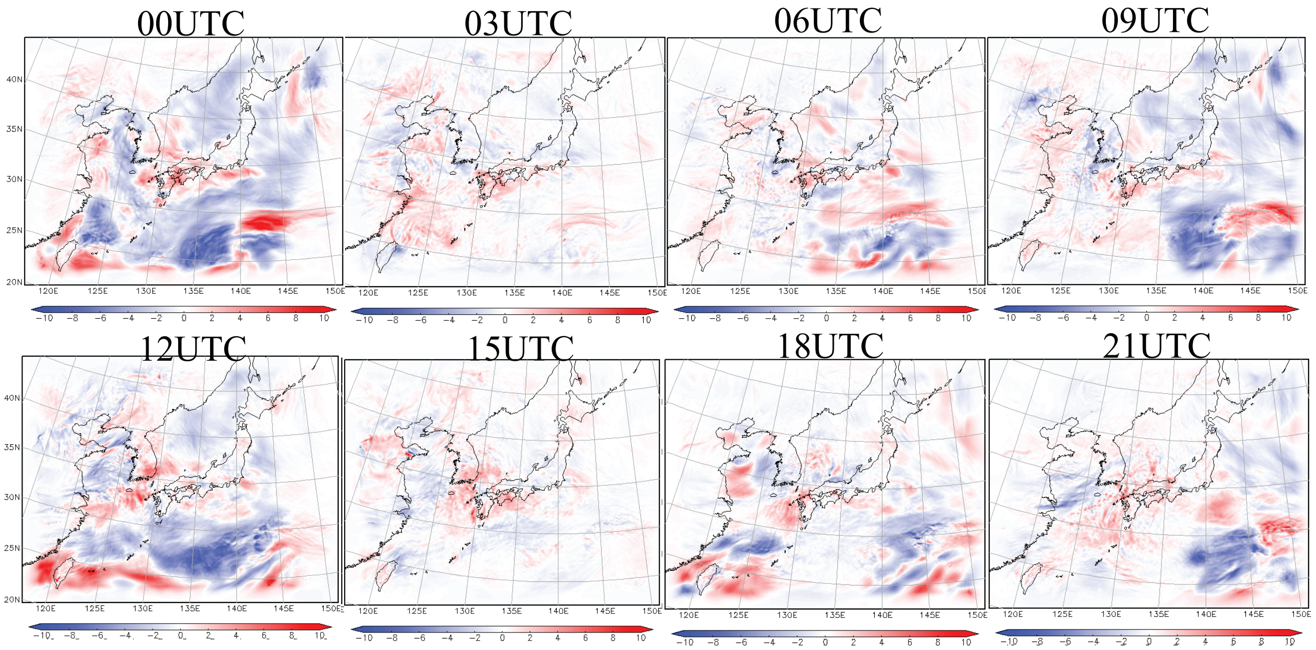


Fig. 4. Analysis increment of the atmospheric water vapor in the JMA operational meso scale analysis on June 9, 2009. The retrievals from DMSP F16 and F17 SSMIS were incorporated in 00UTC, 09UTC, 12UTC and 21UTC analyses.