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**NOAA REPORT ON PROGRESS TOWARDS USING SSMIS TO EXTEND
THE SSMI RECORDS ON TOTAL PRECIPITABLE WATER**

In response to CGMS action/recommendation 38.19

Summary of the Working Paper:

The Special Sensor Microwave Imager/Sounder (SSMIS) aboard the Defence Microwave Satellite Program (DMSP) F16/F17/F18 satellites measures the Earth-emitted radiation at frequencies from 19 to 183 GHz. Compared to the Special Sensor Microwave Imager (SSM/I), SSMIS has similar imaging channels except for two at 85.5 GHz replaced by the 91.655 GHz frequency. After the calibration of SSMIS imager channels, the temperature data record (TDR) can be utilized operationally to derive both atmospheric and surface parameters. In this study, total precipitable water (TPW) is retrieved from SSMIS TDR using the SSM/I heritage algorithms by linear remapping of TDR from SSMIS to SSM/I imaging channels. TPW from F-15 SSM/I and F-16 SSMIS is inter-compared to quantify the mean bias and standard deviation. Both the relatively small mean bias and standard deviation indicate that the SSMIS total precipitable water may replace the SSM/I products for operational use.

Action/Recommendation proposed:

**NOAA REPORT ON PROGRESS TOWARDS USING SSMIS TO EXTEND
THE SSMI RECORDS ON TOTAL PRECIPITABLE WATER**
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1 INTRODUCTION

The Special Sensor Microwave/Imager (SSM/I) was developed as part of the Defense Meteorological Satellite Program (DMSP) and first launched in June 1987 aboard DMSP F-8 satellite. The SSM/I measures thermal radiation from the Earth's surface and atmosphere at four frequencies from 19.35 GHz to 85.5 GHz with both vertical and horizontal polarizations, and has provided critical information on global hydrological parameters such as water vapour, cloud water and precipitation. SSM/I data and the retrieved products have been widely used in data assimilation systems with positive impacts

The DMSP F-16 satellite was successfully launched on October 18, 2003, carrying the first Special Sensor Microwave Imager/Sounder (SSMIS) onboard. F-16 SSMIS marks the beginning of a new series of passive microwave conically scanning imagers and sounders to be launched over the next two decades. This instrument provides measurements at 24 channels. Seven include imaging channels, similar to SSM/I, of which two channels have been slightly shifted from the SSM/I 85.5 GHz vertical and horizontal polarizations (V and H will be used to represent vertical horizontal polarizations for simplicity hereafter) to the SSMIS 91.655 GHz V and H. With a larger scan angle, $144°$ versus $102°$ for SSM/I, SSMIS increases the imaging channel scene number to 90 compared with 64 in the SSM/I A-scan and to 180 from 128 in the SSM/I B-scan. This effectively reduces the scan gap area in mid-latitude regions. Based on its ability to measure microwave radiation from a broader spectrum, SSMIS can provide temperature profiles up to 80 km altitude as well as water vapour profiles and surface information under varying weather conditions.

This study will be focusing on the evaluation of the retrieval of TPW heritage environmental parameters from F-16 SSM/I-like channels, which uses 19.35 GHz V/H, 22.235 GHz V, 37.0 GHz V/H, and 91.655 GHz V/H, in the SSMIS. The description of retrieval algorithms and the inter-comparison results of these environmental parameters from F-15 and F-16 measurements will be given in section 2.

2 Retrieval of TPW from SSMIS

2.1 TPW Retrieval Algorithm

The water vapor path retrieval, also known as total precipitable water (TPW), has been made over ocean from passive microwave instruments since 1987 when the first SSM/I was launched on board DMSP F-8 satellite (Alishouse *et al.*, 1990) and have been widely used at NOAA since 1990s, as described in (Ferraro *et al.*, 1996). The algorithm was updated from Alishouse *et al.* (1990) by using brightness temperatures at 19.35V, 22.235V, 37.0V, and 85.5V. As one of the most accurate parameters retrieved by passive microwave sensors, the error is only around 10% on a globally averaged basis compared with radiosondes observations. A slight modification is applied to Alishouse *et al.*'s original algorithm in order to obtain more accurate results partifcularly under extreme weather conditions.

$$TPW = 232.89 - 0.1486(TB_{19v}) - 0.3695(TB_{37v}) - [1.8291 - 0.006193(TB_{22v})]TB_{22v} \quad (1)$$

$$TPW_{corrected} = -3.753 + 1.507(TPW) - 0.1933(TPW)^2 + 0.00219(TPW)^3 \quad (2)$$

In the retrieval process, TPW is firstly calculated using Eq. (1). At the same time, a scattering index is also computed using Eq. (3). Whenever the scattering index is greater than 10K, the additional cubic correction is made to the original TPW as shown in Eq. (2).

The difference between actual and an estimated (through 19.35 GHz V and 22.235 GHz V observation) brightness temperature at 85.5 GHz V, called "scattering index" in [15], is calculated by Eq.(7).

$$SI = EST_{TB_{85v}} - TB_{85v} \qquad (3)$$

Where,

$$EST_{TB_{85v}} = \begin{cases} 438.5 - 0.46(TB_{19v}) + 1.735(TB_{22v}) - 0.00589(TB_{22v})^2, & land \\ 182.7 + 0.75(TB_{19v}) - 2.543(TB_{22v}) + 0.00543(TB_{22v})^2, & ocean \end{cases}$$

2.2 Remapping from SSMIS TDR to SSM/I SDR

As described earlier, two imaging channels at 85.5 GHz in SSM/I have been shifted to 91.655 GHz in SSMIS. To directly use SSM/I heritage retrieval algorithms, a set of empirical linear remapping coefficients are applied to SSM/I-like channels. Eq. (4) is used to make these channels signatures closer to corresponding heritage SSM/I channels.

$$TA'_{ichan} = \alpha_{ichan} + \beta_{ichan}TA_{ichan} \qquad (4)$$

where,

TA'_{ichan} remapped antenna brightness temperature

TA_{ichan} original antenna brightness temperature

$\alpha_{ichan}, \beta_{ichan}$ remapping coefficients

Note that such remapping also includes the mapping of SSMIS 91.655 GHz to F-15 SSM/I 85.5 GHz so as to minimize the effects of the channel frequency shift, thereby allowing existing F-15 SSM/I retrieval algorithms to be used with SSMIS data.

Finally, the TDR to SDR conversion will be implemented by applying the linear APC algorithm to the remapped TDRs, as shown in Eq. (5).

$$TB_{v(h)} = \frac{[TA_{v(h)} - a_{v(h)}TA_{h(v)}]}{\eta_{v(h)}(1 - a_{v(h)})} \qquad (5)$$

where,

$TB_{v(h)}$ SDR at vertical (horizontal) polarization

$TA_{v(h)}$ TDR at vertical (horizontal) polarization

$\eta_{v(h)}$ Feedhorn spillover factor

$a_{v(h)}$ Cross-polarized coupling coefficient

2.3 Results and Analysis

Plotted in Fig. 1(a) and (b) are the TPW retrieved from F-16 SSMIS and F-15 SSM/I, respectively. Please note that no TPW is retrieved over sea ice due to its high and variable emissivity. From both figures, we can observe many similar features and phenomena associated with the Inter-tropical Convergence Zone (ITCZ), South Pacific Convergence Zone (SPCZ) and South Atlantic Convergence Zone (SACZ). Fig. 5(a) is a statistical comparison between TPW retrievals from F-16 and F-15. The mean bias and standard deviation are -0.753 mm and 0.629 mm, respectively. It seems that the preprocessing of F-16 SSMIS data produces a good quality of the TPW from its imager channels at 19.35 GHz, 22.235 GHz and 37.0 GHz.
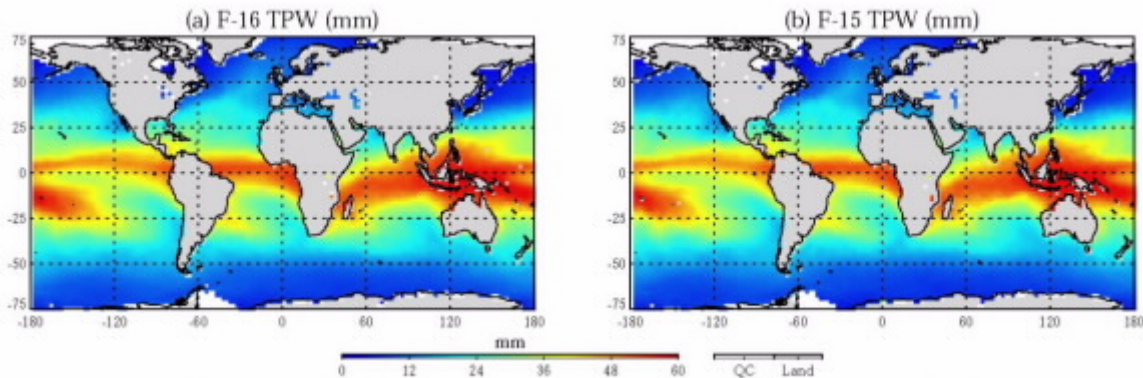

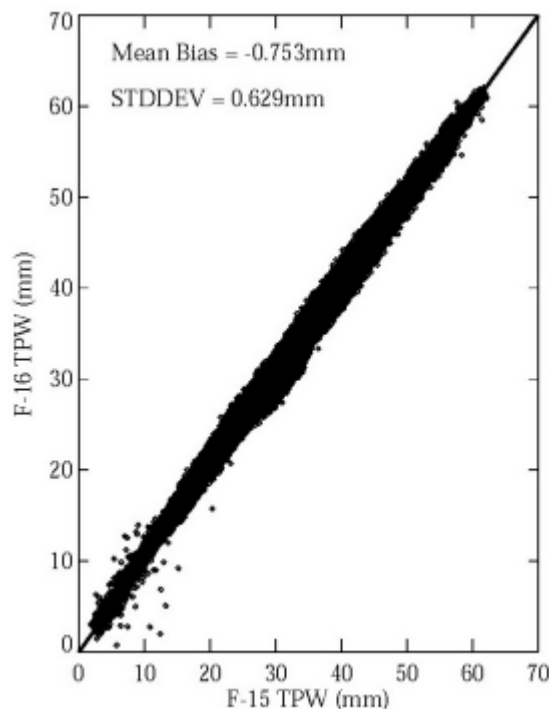**Figure 1. TPW Retrieval from F-16 SSMIS (left) and F-15 SSM/I (right)**

Figure 2. Scatter Plot of TPW retrieved from F-16 SSMIS and F-15 SSM/I

The application of SSM/I TPW heritage retrieval algorithm on SSMIS observations makes DMSP microwave datasets good candidates for the global hydrological climate change study. For example, shown in Fig. 3 is the 5-year DMSP F-16 SSMIS global oceanic TPW anomaly time series. During this period, it seems that the global water vapour content decreases with time. This trend may be due partially to single satellite instrument whose orbit drifts with time. Therefore, a longer observation, inter-sensor calibration of DMSP instruments, and diurnal correction for orbit drifts must be performed prior to the product used for climate change study.
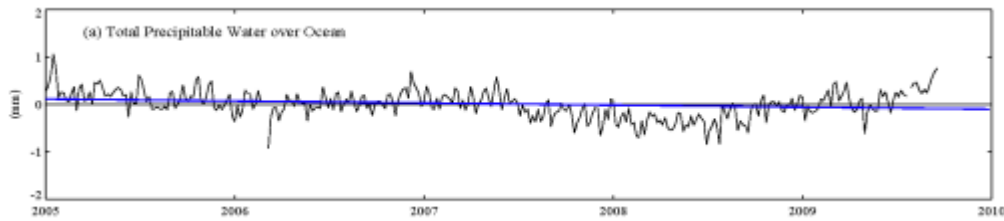
Figure 3. Time series of TPW retrieved from F-16 SSMIS from 2005 to 2009

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