CGMS-44 EUM-WP-13
V2, 13th May 2016

Prepared by SST-VC
Agenda Item: 6
Discussed in WPIII

CGMS WORKING PAPER

Passive Microwave Radiometer Constellation for Sea Surface Temperature

The use of Passive Microwave radiometers (PMW) for Sea Surface Temperature (SST) retrievals is an essential component of the global constellation of SST sensors, providing information on the temperature of the ocean under clouds, where SST measurements from infrared sensors are not possible. Recent research has shown that large sampling error due to cloud masks at high latitudes compromise the SST CDR if only derived from IR SSTs. The PMW SSTs provide essential measurements in the high latitude regions where cloud persistence can prevent IR SST retrievals for significant periods of time (Liu et al, 2016) and where the climate change impacts are occurring first. While the IR SSTs provide accurate data in the Tropics, a large volcanic event could significantly impact the availability and accuracy of the SSTs in this region, further compromising any SST CDR that is derived from IR SST only. Additionally, SST from PMW is a crucial contribution providing input to ocean modelling and weather forecasting models. This capability is particularly important in synoptically active regimes where knowledge of the ocean surface temperature under low pressure systems, hurricanes and storms is needed. SST from PMW provide important, observations of the ocean surface temperature.

There is a risk to the current and continued PMW constellation for SST and a need for a redundant capability of PMW with ~7 GHz. The issue was raised at the CEOS SIT Technical Workshop 2015 and followed with a presentation to CEOS SIT-31 in April 2016.

This paper summarises the current constellation of PMW for SST with a view to the likely future constellation. Coordination and assistance is requested from CGMS for continuation of the existing capability and to facilitate redundancy of PMW for SST, particularly with access to current and future operational data streams. The paper follows on from a joint Group for High Resolution SST (GHRSST) / CEOS SST-Virtual Constellation (SST-VC) presentation to CGMS-42, WG III, agenda item 3 in 2014 on the current status of the SST constellation.

Action/Recommendation proposed:

Coordination and assistance is requested from CGMS for continuation of the existing capability and to facilitate redundancy of PMW for SST, particularly with access to current and future operational data streams.

PASSIVE MICROWAVE RADIOMETER CONSTELLATION FOR SEA SURFACE TEMPERATURE

1 INTRODUCTION

The current situation of the PMW constellation for SST is summarised in this section.

This paper summarises the current constellation of PMW for SST with a view to the likely future constellation. Coordination is requested for continuation of the existing capability and to facilitate redundancy of PMW for SST, particularly with access to current and future operational data streams. The desirability of an overlap is also an important consideration.

Figure 1 illustrates the current and planned constellation.

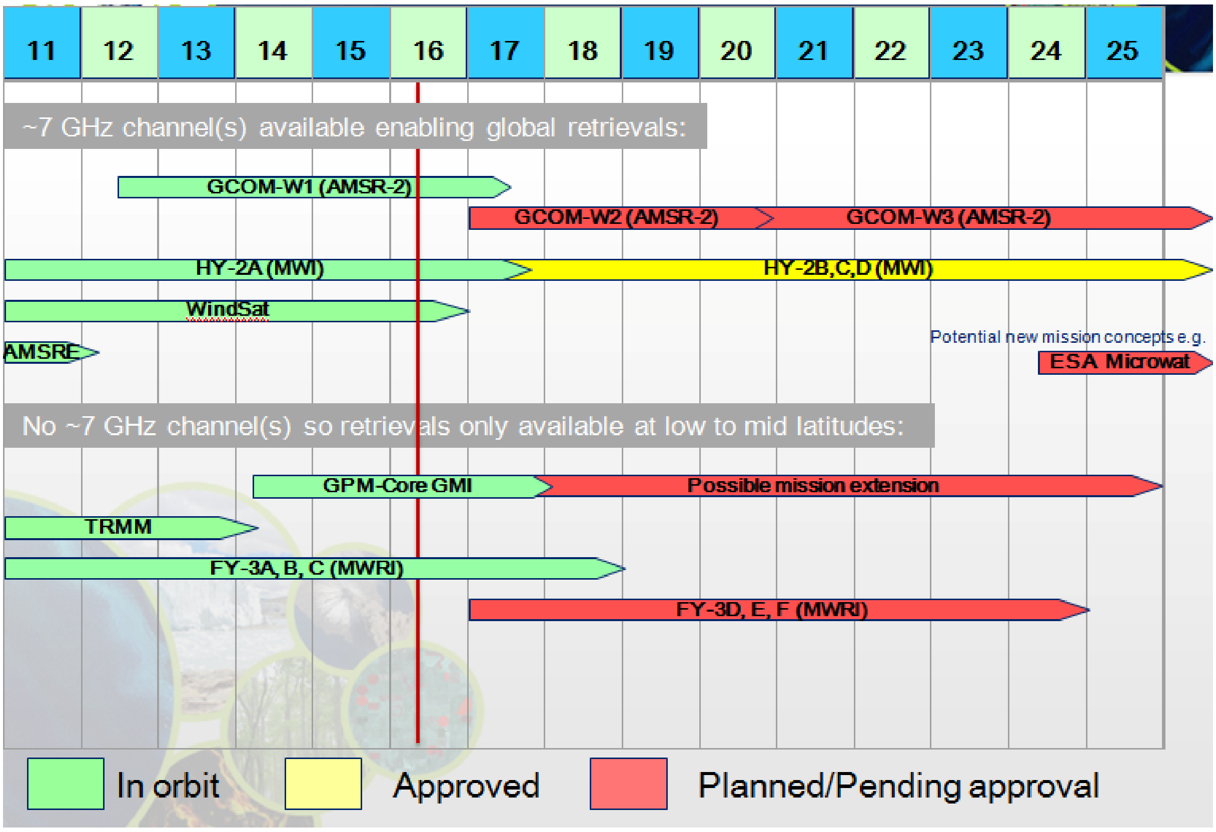

Fig.1. Passive Microwave Radiometer constellation for Sea Surface Temperature

There is no follow-on plan to GCOM-W1 AMSR2 by JAXA at present. However, it is understood that discussions on a potential follow-on mission will be accelerated in Japan in 2016.

If GMI continues well, it is thought that the mission may be possible up to 2026. There are limitations, as the radiometer is not able to provide measurements at high latitudes or cool SSTs, since it is in a high inclination orbit and only has a 10.65 GHz channel but not in the 7GHz range. However, the mission does provide an important climate PMW SST bridge, at least in the Tropics where it measures. This includes reference to the continuity of non sun-synchronous observations and the tropical diurnal cycle, however, the measurements are also important for other climate aspects.

Two letters of intent have been received by ESA to the Earth Explorer 9 (EE9) call that propose missions that can retrieve SST from passive microwave instruments in the 2024 timeframe if selected. Extensive studies conducted by ESA on the Microwat concept (a multi-frequency passive microwave radiometer operating in C- and X-bands) highlighted the importance of flying an EE9 type SST mission in tandem with METOP-SG as one of the METOP-SG satellites will carry a scatterometer (SCA) and the second a microwave radiometer (MWR) providing a suite of higher frequency channels. Such an approach maximises the opportunity to work in synergy and provide the best SST and sea ice edge information in the polar regions as well as SST from a global perspective.

The China FY-3 series with MWRI (Microwave Radiation Imager) has a 10.7 GHz channel allowing warmer SST retrievals, but there is no 6.9 GHz channel so retrievals < 12˚C or above, typically pole-ward of ~40˚ latitudes. More coordination with China would be beneficial to work on scientific and calibration issues leading to possible sharing of data.

There is a 6.6 GHz channel on the NSOAS HY-2 series, and ROSCOSMOS are planning to add a 6.9 GHz channel to future Meteor series (maybe 2020 onwards). The SST-VC and the GHRSST Project Office has made some contact with both NSOAS and ROSCOSMOS through CGMS but further coordination is needed.

2 THE BENEFIT TO SST RETRIEVAL USING ~7GHZ AND 11~GHZ CHANNELS

Figure 2 shows the difference in SST error when using 7 GHz SST retrievals and when only using 11 GHz in the SST retrieval. While the 7 GHz SST retrievals are accurate for all ocean temperatures, the 11 GHz SST retrievals have significant errors above 40 deg latitude in both hemispheres. These errors are also correlated in some cases with high wind-speed regions.

Figure 3 shows cloud persistence and highlights regions where IR SST retrievals are prevented due to cloud cover. There is a remarkable coherence between where the 11 GHz retrievals are not accurate and the IR SST retrievals not available, emphasizing the need for a 7GHz SST retrieval. Figure 4 shows the increase in error as a function of SST for both the 7 and 11 GHz SST retrievals.

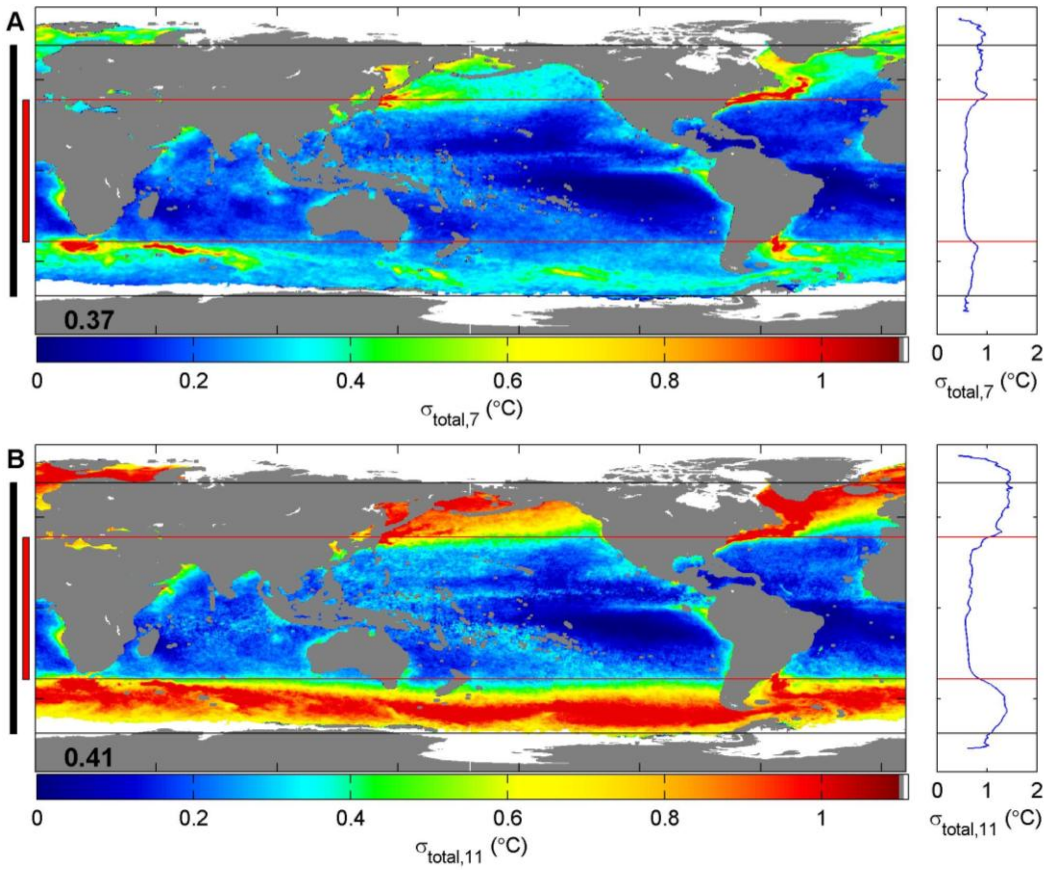

Fig.2. The standard deviation of AMSR-E minus Reynolds SST for the (A) 7 GHz AMSR-E SSTs and (B) 11 GHz AMSR-E SSTs. The latitudes measured by TMI (red) and GMI (black) are shown on the left side of each panel. The latitudinal average is shown to the right of panels. An estimate of the collocation error (0.37 and 0.41) given in the lower left corner, was subtracted from each image. From Gentemann et al. (2010).

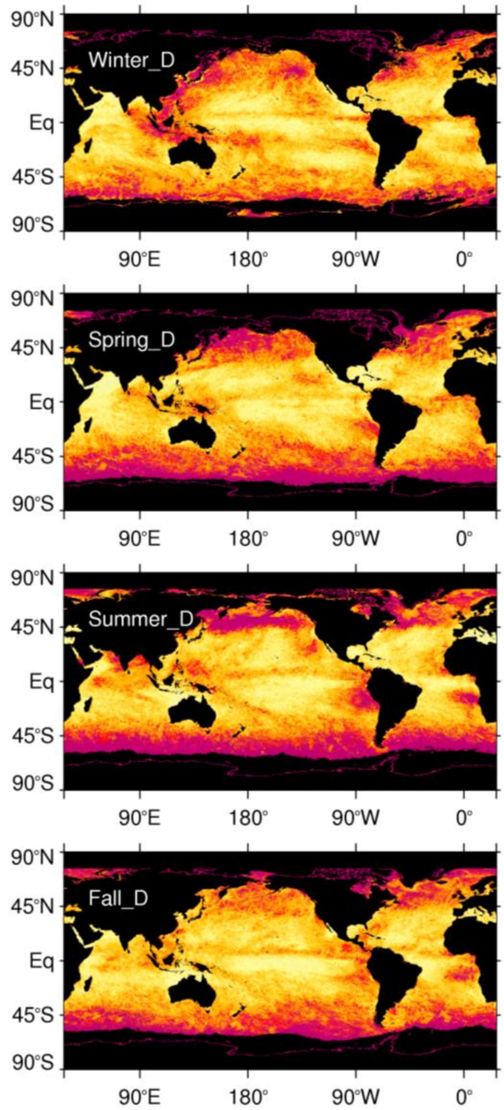

Fig 3. Maximum cloud persistence (days) from MODIS v6 daytime cloud mask data. Season names are for the Northern Hemisphere. From Liu and Minnett (2016).

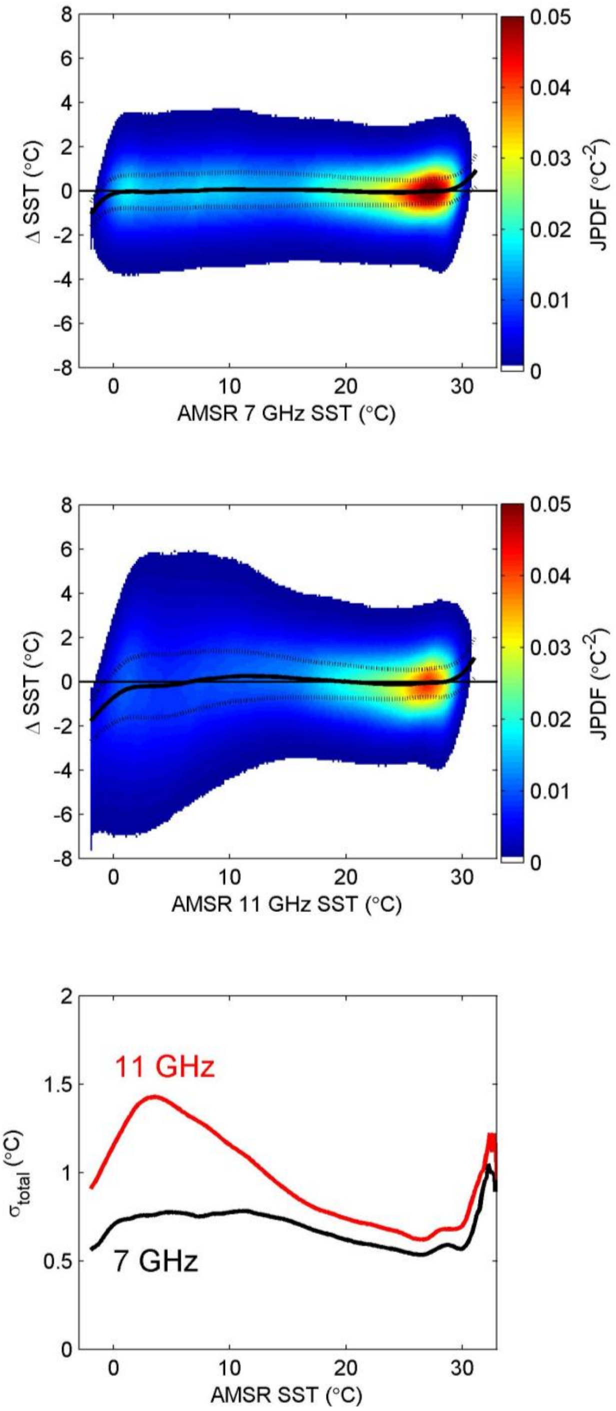

Fig. 4. AMSR-E minus Reynolds SST, ΔSST, as a function of AMSR-E (A) 7 GHz SST, (B) 11 GHz SST, and (C) the standard deviation of ΔSST as a function of AMSR-E SST. From Gentemann et al. (2010).

RFI remains problematic for 7GHz SST retrievals. While onboard RFI filters are possible, their utility is still unproven. There have been improvements in masking geo-stationary and ground-based RFI from the PMW SST retrievals, but the more difficult problem remains satellite-satellite RFI. The source of this RFI is the satellite phone network of satellites, which are numerous and increasing. At this point, the only method for removing these contaminated SST retrievals depends on having a joint 6.9/7.3 GHz channel (Gentemann et al, 2015).

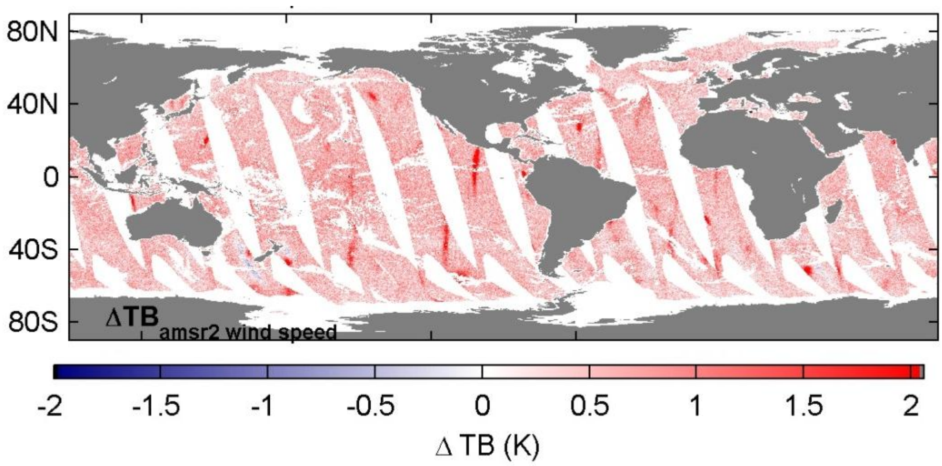

Fig. 5. 26 May 2013 double difference of the brightness temperatures minus radiative transfer model simulated brightness temperatures, TB6.9-RTM6.9 – (TB7.3-RTM7.3), showing the many vertical red streaks where satellite-satellite RFI is affecting SST retrievals.

It is important to also consider the spatial resolution since PMW low frequency channels have larger field of views compared to infrared instruments. Of the current PMW radiometers, AMSR-2 has the largest antenna size of 2m giving a ~50km resolution of retrieved SST with the ~6GHz channel and ~30km resolution with the 10GHz channel. Windsat has an antenna size of 1.8m antenna so its spatial resolution is almost comparable to AMSR2. GMI has an antenna size of 1.2m but its satellite altitude is 400km. Therefore, the spatial resolution of GMI’s 10GHz channel is comparable to AMSR-2 10GHz. HY-2A and FY-3A have spatial resolutions of ~65km for the ~11GHz channel, and HY-2A of ~100km at ~7Ghz.

3 CGMS AND GHRSST / SST-VC

The previous presentation from GHRSST / CEOS SST-VC to CGMS-42 has had a direct benefit on international coordination of SST including collaboration and participation of new partners in GHRSST and the SST-VC. For example, in November 2015, CMA participated in the GHRSST/SST-VC Satellite Oceanography Workshop hosted by the Bureau of Meteorology in Melbourne. CMA have been invited to the next GHRSST science team meeting in June 2016, although participation will be more feasible in 2017 when the GHRSST science team meeting will be in Qingdao, hosted by the Ocean University of China. The participation of CMA is important especially with regard to the geostationary missions. It would also be beneficial for NSOAS participation with regard to the HY-2 series. Roshydromet have also been invited to participate in GHRSST science team meetings and contact has been established. The CGMS links and coordination have also facilitated ISRO participation to GHRSST and the SST-VC.

4 SUMMARY

Concerns regarding the continuity of PMW have been previously raised by GHRSST and SST-VC. These concerns are now heightened with no confirmed continuity of plans for AMSR-2 available. There is a very uncertain future for PMW SSTs, especially at high latitudes where the PMW SSTs provide valuable through-cloud data in the region where the climate is changing most rapidly. The current outlook means there is a high risk of a gap between the current AMSR2 and GMI capabilities.

The GHRSST science team meeting will be in Qingdao in June 2017 and should facilitate closer collaboration with China on the HY-2 and FY-3 series towards PMW SST capabilities. There is a need to work together on lower level data to ensure sensors are well calibrated and to tie in to existing records.

Given the current risk to the current and continued PMW constellation for SST and the need for a redundant capability of PMW with ~7 GHz, coordination and assistance is requested from CGMS for continuation of the existing capability and to facilitate redundancy of PMW for SST, particularly with access to current and future operational data streams.

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