**GSICS Annual Meeting: Microwave Subgroup Breakout Session**

 **1100-1500 UTC March 31 , 2021**

**Attendees:**

CMA: Qifeng Lu, Wu Shengli, Jian Shang, Banghua Yan, Dawai An

China NIM: Xiaohai Cui

NOAA: Mark Liu, Robbie Iacovazzi, Tiger Yang, Cheng-Zhi Zhou, Yong Chen, Lin Lin, Banghua Yan, Fred Wu, John Yang

ECMWF: Niels Bormann

EUMETSAT: Tim Hewison, Viju John, Timo Hanschmann, Vinia Mattioli, Paul Poli

KMA: Jun Park

JAXA: Misako KACHI, Kazutaka YAMADA, Marihito KASAHARA

JMA: Arata Okuyama, Kazutaka Yamada

UK Met Office: Fabien Carminati

Hamburg University: Martin Burgdorf

ESA: Raffaele Crapolicchio

MIT: Phillip Rosenkranz

SRC Planta/ROSHYDROMET: Unknown Participant

Unknown Affiliation: Hujy, Hu Yong

**1.** **MW Subgroup Way-Forward (Qifeng LU, CMA)**

Tim - Encourage the group to be more active in working towards producing inter-calibration products to improve the inter-operability of current microwave instruments. GPM X-Cal was a start, and a way forward was created for that. There was to be a workshop on this, but that was delayed. Constellations of microsatellites will increasingly require methods of inter-calibration to make the data more readily usable.

Qifeng – We do think it is important, and we are doing the following:

* Shared Wiki links to the agency satellite instrument monitoring systems
* Implemented GSICS methods such as those related to Simultaneous Nadir Overpass (SNO) and observed (O) minus background (B) simulated brightness temperature.
* Developing FCDR’s that will adopt GSICS chosen standard instruments.

Mark – Important activity will be done this year by the group that relate to inter-calibration and comparison between sensors, and coordinating FCDR work. The main challenge is this: The microwave has made good contributions to NWP, but we see large, but stable, measurement difference between sensors. We still need to work on that … to find out what the root cause for these differences are.

**2.** **Development of the 3rd Generation of AMSR series (AMSR3) (Misako Kachi)**

**Summary:** Describes the characteristics and specifications of the AMSR-3 instrument to be launched on GOSAT-GW in Japan Fiscal Year 2023.

Mark – Dual 10 GHz channel. This should be useful for SST. High spatial resolution for the water vapor channels will also be helpful. You mention that JAXA is aware that there may be 5G radio frequency interference for some of the bands. If band affected by 5G what will you do?

Misako – Changed the 36 GHz bandwidth from 1000 MHz to 840 MHz, so it will not be affected by 5G. We can avoid the risk this way. JAXA is looking forward to the new capabilities as well to improve SST and water vapor retrievals. For the new higher frequency channels, inter-comparisons with GMI and operational microwave sounders can be done.

Tiger – Do you have RFI in AMSR-3? You have 6 GHz and 11 GHz and 18 GHz channels, which can be prone to RFI. Do have new approaches to address this interference?

Misako –

* Using nearby but not overlapping channel for 6 GHz RFI. One will be influenced by RFI and one not, and using this information we can estimate RFI in this channel.
* Using 10 GHz may help to detect RFI in 11 GHz, and an algorithm may be created to remove it.
* For the 18 GHz channel there is no nearby channel. There can be large RFI in coastal regions. New data assimilation system can remove the RFI from the natural signal, but we cannot take advantage of this for L1 data processing for AMSR-3. Perhaps when we compare channel signals from 23 GHz or 36 GHz to remove RFI.

**3.** **Summary of outcomes from the ECMWF/NWP-SAF workshop on the treatment of random and systematic errors in satellite data assimilation. (Niels Bormann, ECMWF)**

**Summary:** A synopsis of findings from this workshop focuses on three areas: Estimating uncertainties; Correcting observational and model biases in data assimilation; and Representing random observational errors in data assimilation.

Several outcomes were reported that could be distilled into overarching points, and treatment of random and systematic errors.

Tim – There were recommendations to coordinate between GSICS and NWP. Two main points:

1) There is already bilateral work between GSICS and ECMWF on diurnal variation in GEO imagers

2) Sensitivity of NWP to measurement biases. Is it possible to estimate the sensitivity to NWP if you inject artificial measurement biases into the forecast? What can be learned from them?

Niels – ECMWF has looked at that, adding bias and trying to retrieve the results, but is not clear about the details of how they were carried out. Depends on what kind anchor observations are present, and how biased the model is. One conclusion is that if the model is not biased, and we have good coverage of anchor observations, then determining the nature of the response to a given bias can be seen because we know that is the cause. But if the model is biased, and we don’t have good anchor observations, then it becomes harder. The process of assimilation find compromises between model and instrument bias, which makes it harder to discern which uncertainties are driving what responses.

Tim – Request literature references.

Neils – They typically are in ECMWF reports.

e.g. how VarBC recovers an imposed bias (caused by frequency shift): <https://www.ecmwf.int/en/elibrary/11662-study-spectral-and-radiometric-specifications-post-eps-microwave-imaging-mission>

Niels also provided the following references after the meeting:

Auligné, T., McNally, A.P. and Dee, D.P. (2007), Adaptive bias correction for satellite data in a numerical weather prediction system. Q.J.R. Meteorol. Soc., 133: 631-642. <https://doi.org/10.1002/qj.56> (appendix)

Auligné, T. and McNally, A.P. (2007), Interaction between bias correction and quality control. Q.J.R. Meteorol. Soc., 133: 643-653. <https://doi.org/10.1002/qj.57>

Experiments with imposed biases in a full assimilation system: <https://cimss.ssec.wisc.edu/itwg/itsc/itsc14/proceedings/8_11_Auligne.pdf>

Mark – O-B bias is composed of instrument, RTM and model input errors. How can we tease out the impacts of each of these components on forecast errors?

Niels – We need independent uncertainty information, then we can give a range for each one. Then constraints can be given to the errors. But this is the challenge.

Cheng-zhi – Climate reanalysis. When you simulate different data set – radiosonde and microwave observation – you may use radiosonde as an anchor with no bias correction. We know there is bias and long term drift between these. I originally thought that you use radiosonde as the anchor, but now know that you use variational bias data assimilation to correct the radiosonde biases. Do you have a comment on this?

Niels –

* We use radiosonde and GNSS-RO.
* The radiosondes are not free from bias. Sunglint and radiation exposure affects are considered, but is not included in VarBC, because we think we have a handle on that. There are other constraints as well. We can constrain things through what think errors in our background typically look like.
* Have done some work with ERA-5.
	+ Before RO, there were structures in the bias estimates that did not look quite right, and that related to a structure in the background errors. When we apply background error structures for when a period when RO is present to a time when they are not present, then the spatial scales were not quite right.
	+ Simplistic to say that radiosondes anchor the system. At least the ECMWF system.
	+ There is a system in Environment Canada that uses only anchor observations that are considered unbiased, and does not give the best estimate of the atmosphere, but is an estimate they believe is largely unbiased.
* So, there are various approaches can be used together.

Qifeng – Small satellites represent a challenge to the observing system, since the quality may not be as good as the current observing system. How do you think that will affect the bias?

Niels –

* Do not have experience with small satellite, but some have looked at TEMPEST-D data.
* Would encourage people building instruments to have robust pre-launch characterization of these instruments. Cutting corners in pre-launch characterization to save money could be problematic.
* Inter-calibration and inter-comparison will be important.

Qifeng - FY3-E will be launched in July of this year, and also another instrument that will give ocean wind. Will you be assimilating such data?

Niels – Interested in FY3-E data.

**4. FCDR Progress Summaries ( Viju John - EUMETSAT (AMSU-B/MHS/MWHS); Paul Poli - EUMETSAT (SSMT2); Shengli Wu - CMA (FY-3/MWRI), Dawei An– CMA (TBD); Cheng-Zhi Zou – NOAA (MSU/AMSU-A/ATMS) )**

**Summary:** Overall progress summaries for FCDR developments within the agencies participating in the GSICS Microwave Subgroup

***Viju John***

Cheng-Zhi – Metop-A, Metop-B and S-NPP is stable compared to ERA-5. This is consistent with recent analysis that Metop-A AMSU-A and S-NPP ATMS have high radiometric stability. ERA-5 shows bias correction shows some trends in biases. Bias correction would be more reliable for stable instruments.

Viju - But we need to understand bias between FCDRs – e.g., MHS and ATMS.

Cheng-Zhi – Instruments often have inherent bias. We cannot expect bias-free FCDRs, but we want them to be stable. Which version of S-NPP data did you use? Reprocessed or operational?

Viju – We used S-NPP using our own calibration. We need to continue to work to understand these biases to maybe reduce them.

Tiger – The S-NPP bias is difference with respect to our ICVS monitoring system. Are you using TDR or SDR?

Viju - We did our own calibration based on information in the raw data files. We use the one from the NASA ATBD.

Tiger – We recommend to use JPSS Algorithm Development Library (ADL), as the calibration technique and coefficients are maintained and updated in this software. For NASA, it is developed during the early period before S-NPP launch.

Viju – We are happy to do this, but to be clear, we did not use the software from NASA, we just used NASA calibration approach. We are having a meeting with Mark to discuss this and are welcome to join that discussion.

Cheng-Zhi - Agrees. There are many corrections that have been made – emissivity and antenna corrections. This changes the bias, and this may not be in the NASA ATBD.

Viju – We have not implemented these.

Cheng-Zhi – We have a reprocessed data set that would be more accurate bias estimate. It is available to you.

***Paul Poli***

Qifeng – Are there plans to fit or correct difference between different satellite trends?

Paul - Piecewise approach by instrument. Want to understand how each instrument is performing and its uncertainties, and then we can piece together an FCDR. That is the goal.

Qifeng – From FIDUCEO we are trying to correct instrument bias.

Paul - FIDUCEO is giving us error bars in which the bias may be. If we have error bars from source of uncertainty, then we can use this knowledge to align biases that are consistent with constraints. So it is about using these constraints.

Cheng-Zhi – You have NOAA-16 and a long term trend, but you only show a five year period. Moisture channel also has this trend, but if you look at a longer period, you can clearly show the trend. Are you going to look at this?

Paul - Yes, we have not dealt with this. We are considering only SSMT2 time period, so we truncated it at 2005.

Martin – Shouldn’t the errors on the upper and lower panels be the same? It is especially evident in the large uncertainty near the end of the record.

Paul - We are not able to close the error budget … yet. The timing does match, but the magnitude does not yet. We have a way to create the average uncertainty, but this may not be correct. Any suggestions, I am interested.

***Shengli Wu***

Cheng-Zhi – Question on the calibration equation. What parameter represent the blackbody emissivity? Epsilon is emissivity? So, the blackbody emissivity is usually 0.999. Do you consider the change of emissivity?

Shengli – Our instrument had a reflector dedicated to the hot load, and corrections to the emissivity of the reflector and hot load itself become a “hot load emissivity efficiency” parameter, which is epsilon. We correct using on-orbit data.

Tiger - Last term looks like a noise term. Why did you include this noise term in the calibration equation?

Shengli - This noise term cannot be physically corrected. We just put it here, as it may be some bias.

Tiger – You cannot correct noise. Second slide from last one. In the table … before you do the recalibration it looks like the bias here. How is determined … from GMI? At 10 GHz, 5K is quite large. What is the major error source for this large bias?

Shengli - The major error source is for the hot load. For measurements near the hot load temperature – e.g. jungle – there is a very large bias.

Tiger – If it error in warm load, it seems that it would be scene dependent. Will talk offline.

***Dawei An***

No questions

***Cheng-Zhi Zou***

Tim – Interested in the definition of radiometric stability. You use K/year linear trend, but Phil Rosencrantz used more of stochastic approach, where change is represented by K/SQRT(year). With his approach, the uncertainty is a blend of linear drift and other random effects. It may be that including this random walk portion may be better. What are your thoughts about that?

Cheng-Zhi – Need long enough period to determine this. What is meant by “long enough” is the uncertainty of stability to be small enough over the trend that random changes are relatively small and high frequency compared to long-term trend. This typically is five years. Noise cancellation would be important as well. Global statistics are better to cancel out some noise. When you calculate the trend, you will know whether you can trust it or not.

For the Phil Rosencrantz method, a reference satellite is also needed to determine the calibration stability of microwave radiometers (in his case, the GPSRO data was used as a reference which has ambiguity issues in tropospheric temperature retrievals). It is good that his representation of calibration stability requirement includes random effects, but the linear trend plus trend uncertainty approach is easy to be applied in stability assessment. When observations become longer, say 10 years, the random effects become smaller in the linear trend approach in stability assessment. In this situation, the two approaches give similar calibration stability requirement [0.04K/Decade in the linear trend approach, 0.03K/Sqrt (10 year) in Phil Rosencrantz approach].

Tim - Got into discussion while writing the out brief of the workshop on the SI traceable climate observing system in 2019. It became clear that it can be difficult to find requirements on stability. Your 4 mK per year stability requirement … to what channels does it apply and how did you arrive at the value?

Cheng-Zhi - Workshop in 2005 that is represented in BAMS paper, and George Ohring’s book. The specifications were laid out then for certain products – e.g., Ozone and moisture. This applies to tropospheric channels, while for the stratospheric channel it can be larger because this region has larger changes. With that said, for Metop-A AMSU-A and S-NPP ATMS all tropospheric and stratospheric channels satisfy the 0.004 K/decade stability requirement.

Tim – Question about mapping physical atmospheric temperature change directly to brightness temperature of the instrument, but will take that offline.

**5. SI Traceability References Summaries (Xiaohai Cui, China NIM)**

**Summary:** Introduced basic SI traceability concepts, and addressed the type of microwave measurements that exist and to which SI standards they trace to.

No questions

**6a. Updates on Microwave Lunar Geolocation and Calibration (Tiger Yang, NOAA)**

**Summary:** Communicates three main research areas regarding microwave lunar geolocation and calibration studies. The evaluation of NOAA-20 ATMS on-orbit geolocation error by using 2-D lunar observations. Retrieving lunar microwave brightness temperature spectrum from satellite observations. Validating of satellite derived unresolved lunar disk Tb spectrum with model simulations.

Martin - You used the Keihm model. There is another model by Liu & Jin (doi: 10.1109/TGRS.2020.3000230). Did you compare to this model?

Tiger - There is no fundamental difference between the Keihm and Liu models, except for Liu’s model uses different parameter for dielectric constants, and also some other parameters that are satellite based. No fundamental difference. Major part of the problem is surface emissivity calculation part. The Liu model uses the Fresnel approach, which could be a weakness.

Martin – Liu’s model gives slightly lower brightness temperature, and since your satellite results show a lower brightness temperature than the model, this might constitute some of the difference.

Tiger - The reason for the lower is the lower emissivity because they use Fresnel approach for surface emissivity. This may not be proper lunar regolith.

Mark – Slide on model versus satellite Lunar Tb. For V-band, model and satellite observations are very close. The problem may not only be from surface emissivity model. Indicate that lunar surface emissivity is close to 1.

Tiger – There is some uncertainty in satellite observation part. The magnitude of emissivity does not follow the frequency trend especially for the V-band. This may be due to the high noise in V-band. It may be due to some uncertainty on the satellite side. Want to combine model and satellite.

Tim – Would be interesting to include thermal infrared channel in analysis of brightness temperature v Moon phase – would expect the maximum Tb to occur at Full Moon – due to negligible penetration depth into lunar regolith

Martin and Tiger posted messages – for Tb as function of phase angle in the thermal IR, see Fig. 8 in https://arxiv.org/pdf/2103.13721.pdf

**6b. NOAA Operational Microwave Sounder Data Quality Monitoring Update (Robbie Iacovazzi, NOAA)**

**Summary:** Briefly describes the two methods used to track and trend NOAA operational microwave sounder data, the Simultaneous Nadir Overpass (SNO) and Observation minus Background Simulated Brightness Temperature Method using Global Navigation Satellite System (GNSS) Radio Occultation (RO) soundings. It then introduces updates and resulting performance outcomes related to these updates.

Tim – One of the screening techniques you use in the SNO technique is to eliminate matchup data with large local variability. Instead of screening in this manner, you could use the information on local scene variability to weight the individual matchup brightness temperature bias measurements used to estimate the SNO event brightness temperature bias – and associated uncertainty. This weighting for instance could be related to the inverse of the standard deviation. This has been developed by Dave Tobin, and was adopted by the IR subgroup in their version of the SNO method.

Robbie – Will look at the ATBD for the IR Subgroup’s SNO products.

**7. SMOS-SMAP Inter-comparison Activities over Antarctica and Wind Measurement (Raffael Crapolicchio)**

**Summary:** This briefing offered overviews of the Soil Moisture Ocean Salinity (SMOS) mission and the Microwave Imaging Radiometer using Aperture Synthesis (MIRAS) instrument calibration. After introducing DOMEX – an experiment to track long-time stability of L-band microwave emission by using ground data collected at the Antarctic DOME Concordia station – the presentation reported the results of brightness temperature comparisons between MIRAS with DOMEX. Inter-comparisons between the Soil Moisture Active/Passive (SMAP) Mission and MIRAS parameters of DOME-C brightness temperature and wind speed over ocean were also shared.

No questions

ACTION-Admin: Robbie to bundle the last three slides about future subgroup plans in Qifeng’s talk and distribute them to the group, and request feedback from the group by Friday.