**GSICS Microwave Subgroup Web Meeting**

 **1100-1400 UTC March 18, 2021**

**Attendees:**

CMA: Qifeng Lu, , Wu Shengli, Hongyi Xiao

NOAA: Mark Liu, Robbie Iacovazzi, Cheng-Zhi Zou, Yong Chen, Tiger Yang, Xi Shao

EUMETSAT: Tim Hewison, Christophe Accadia, Viju John, Timo Hanschmann, Ali Mousivand, Vinia Mattioli, Paul Poli

JAXA: Misako Kachi

UK Met Office: Fabien Carminati

ECMWF: Bill Bell

DWD: Karsten Fennig

Hamburg Univ: Martin Burgdorf

MIT: Phillip Rosenkranz

Others: John Yang, Constanze Siebert

This GSICS Microwave Subgroup meeting focused on application of microwave radiometer data on numerical weather prediction and associated reanalysis. There were three presentations that tracked closely to this topic. The session also include a presentation on the application of AI to radiative transfer modeling.

Announcement: ESA Copernicus Imaging Radiometer Science to Operations Meeting. WebEx May 10-12. *Abstract Dues 21 March.*

1. **The Assimilation of Microwave Data in ECMWF Reanalyses: Aspects of ERA5 and Future Plans (William Bell – ECMWF)**

*Summary:*

This presentation introduced the ECMWF ERA-5 reanalysis product, and the associated impacts of integrating microwave data. Microwave sounder radiometer data, after being introduced in 1979, has greatly improved the reanalysis, especially in the Southern Hemisphere. All sky data sets from SSMI, SSMIS, TMI, and GMI microwave imagers, and more recently MHS microwave sounder, have also brought some improvements. A bias correction of the radiometer data with respect a background model simulated brightness temperatures is always needed before integrating microwave radiometer data into the reanalysis, but these bias corrections has less magnitude and uncertainty as instruments improve and their orbits have been stabilized.

*Question and Answer:*

*Mark* – Bias correction includes instrument, model data, and radiative transfer parts. If there are improvements in radiative transfer model, how will we know because improvements could be hidden by bias correction?

*Bill* - We hope that we have to apply ever smaller corrections to the data as we improve the RT modeling and as we improve the observations themselves. If RT is dominant, then as they are improved the bias correction has to do less work. There are many cases, such as with MSU, that instrument issues drive the bias and not the RT model. Generally the hope is the corrections get smaller.

*Mark* – New analysis ERA-6. At NOAA we have reprocess ATMS from 2011. Would you consider using this new reprocessed data?

*Bill* – Have been working with EUMETSAT to work with ATMS data reprocessed by them. We have been working especially with humidity sounding channels 18 – 22. The results are promising. Encourage you to talk with Timo Hanschmann.

*Tim* – In the discussion from disentangling the bias between the observations and the model, you did not mention the role of anchor observations that could be assimilated without bias correction. Currently, the calibration of instruments such as IASI and CrIS are quite good. In the future, there may be CLARREO observations that have SI traceable measurement that may be used to inter-calibration the microwave constellation after we apply the GSICS correction to them. Any thoughts about this using such “anchor” dataset?

*Bill* – The radiometer performance of CrIS and IASI are radiometrically good with documented uncertainties. It is worth testing the idea. If there are reprocessed data sets with well understood and documented accuracy and uncertainty, it is definitely worth exploring. Reanalysis is vulnerable to the bias correction, and these bias corrections can be quite large. To explore this idea of anchor data sets we would need reliable data that spans over multiple years.

*Tim* – One critical functions of GSICS is to determine the bound of the biases and uncertainties of these important data sets and communicate them to users.

*Qifeng* - Slide 4 - Satellite data contributes to forecast skill. For users of 1950-1979 data, it’s quite different than after 1979. What is the recommendation to users in creating a long-term time series?

*Bill* – In most regions of the Northern Hemisphere, there is a dense conventional network and changes show a relatively gentle improvement. In the Southern Hemisphere this is more abrupt. This is inevitable, because of the sparseness of the data before 1979 in this part of the globe. You cannot create data where there is none. The 1950 analysis will never be as good as one in 2020.

*Qifeng* - Slide 5 – In the middle period, there is an improvement (1980-2000) then it gets worst afterwards. What is going on here?

*Bill* – Anomalies relative to a 1980 to 2010 period are shown here, so we expect them to be closes to zero. There is a trend, which is near zero from we choose as the mean state.

*Qifeng* - Slide 11 – Different instruments dominate bias reduction. The GNSS-RO data is quite impressive. These show quite a stark improvement.

*Bill* - They are spread in the ensemble, so we get 10 independent analyses. This spread is just the standard deviation in the 10 members. When you have observations that constrain the state, it affects all 10 members of the ensemble, so it reduces the spread. GNSS-RO increased dramatically the observations in the Stratosphere. That is why spread goes down. This plot does not show bias reduction, which may be much different.

*Tiger* – GSICS communities uses reanalysis to evaluate instrument bias. The instrument and model bias has already been corrected in reanalysis data. Using this as a benchmark may not be independent. What is your suggestion in using reanalysis for instrument quality, and comparing the quality between satellites?

Model observing system analysis are quite good for many parameters, because so many different types of observing systems are represented. If one system is slightly biased or noisy, its effect is swamped by the completeness of the observing system. When you go back to a period there were not many observations, then you need to be more careful. The ability to diagnose biases also depends on the size of the biases you are looking for. Large biases (~1K) are easier to diagnose than smaller ones (~0.01K). In general terms, when a new instrument is added, this can reveal instrument issues or biases. You have to be intelligent about how you assign quality to the estimates, based on robustness of reanalysis for a given time period. There needs to be communication between instrument and reanalysis folks.

1. **Current and future use of MW data at the Met Office (Fabien Carminati – UK Met Office)**

*Summary:*

The UK Met Office NWP model input data is composed of about 25% microwave radiometer data, which is rivaled only by infrared sounder data. A series of microwave sounder and imager data denial experiments in the model revealed that forecasts degrade with respect to observations and ECMWF analysis by about 1.3% and 2.6%, respectively. More recently, improvements have been made using “all sky” measurements from instruments such as MHS. Measurements from 118 GHz are also shown to have a positive impact as well, which is promising for future radiometers that may need smaller antenna size. Finally, under study is a newly proposed hyperspectral microwave radiometer with bands mainly in the 60 GHz oxygen and 183 GHz water vapor absorption bands.

*Question and Answer:*

*Bill* – Did you use the Forecast Sensitivity to Observation Impact (FSOI) analysis as a metric of verification for your all-sky experiments as it is commonly done at ECMWF?

*Fabien* - I have not done the experiment with MHS, maybe Stefano has (*It was later reported the he is not*). To run FSOI, you need a special setup, and unless one is focused on performing experiments with FSOI, then it cannot be easily done. So, for the “All-Sky” experiments we have not looked at FSOI.

*Bill* - Who is working on the channel optimization and configuration of the hyperspectral microwave? It really could fill and important gaps in the observing system.

*Fabien* – Not sure who is working on this aspect of the instrument design. The slides were given to Fabien to present, and understands the content on the slides, but he does not know the whole back story.

ACTION: Fabien to provide information to Bill about who is performing channel optimization and configuration of the Hyperspectral Microwave Sounder.

Action completed (3/19/2021)

*Tiger* – Did you have to do test when to be able to conclusively determine if you combine 118 GHz and 50 GHz observations if there is any additional benefit?

*Fabien* – A test was carried out with Chinese instruments MWTS and MWHS was performed by first adding 183 GHz in all sky, then adding the 118 GHz to 183 GHz, and then adding the 50 GHz to the 118 and 183 GHz. Not much improvement when adding everything in the “All-Sky” configuration. This may be due to adding only the MWTS stratospheric channels, and these are not sensitive to cloud in an “All-Sky” configuration. Later on with future versions – e.g. FY-3E – we might find a different result if we are able to assimilate the deeper penetrating channels. Studies assimilating the 118 GHz data show that the upper peaking channels have a bias that is too large for assimilation. The main benefit of the 118 GHz has been found with the lower peaking channels. This is similar to what was found with IASI, when they incorporated surface and lower peaking sounding channels.

*Tiger* – Hyperspectral – Major concern is instrument noise. The instrument parameters are a 10 MHz band width and 0.4 K NEDT. ATMS Channel 14 has a 10 MHz band width and its noise is greater than 1 K. So, are the requirements values that you give here the actual requirements? A 0.4 K specification probably would require a technology change.

*Fabien* - These are the requirements for the test flight, which is an airborne instrument. I am not sure it will be for the space borne instrument. Attaining a noise of 0.4 K NEDT is a challenge, but that is the plan for the airborne instrument. This is close to the final version, so would be surprise by a substantial change to the requirements for the space-borne instrument.

*Mark* – Clarified that the microwave sensor narrow-band (10 MHz to 14 MHz) band with such low noise could be achievable with new technology. The analogy was given of the IR. There were concerns about IR instrument noise as the band width diminished from 100 wavenumber to 40 wavenumber to 1 wavenumber over the course of 20 years. Yet, the noise of instruments such as IASI and CrIS have proved that technical challenges can be overcome if there is a real need for the instrument.

*Qifeng* – Is it possible to discriminate 118 GHz channel contributions to forecast skill into contributions from the temperature sounding information and the cloud information?

*Fabien* – An observation error in model experiments was set to be large – e.g., 3K. This large error is not conducive to adding temperature information. So, most of the skill from the 118 GHz is coming from cloud information. To find the best possible configuration, the observation error could be reduced. This may then find some skill coming from 118 GHz temperature information.

1. **Assimilation of Microwave Sounding Observations in Chinese NWP system (Hongyi Xiao - CMA/NWPC)**

*Summary:*

The China Meteorological Agencies Global/Regional Assimilation and PrEdiction System (GRAPES) Global Forecast System (GFS) model processing architecture, and MWRI and AMSR-2 microwave radiometer data quality control measures are presented first. Bias corrections are presented as a function of channel, polarization, scan angle and satellite orbital node. The presentation closes by showcasing the impacts of incorporating MWRI and AMSR-2 data on GRAPES\_GFS forecast skill, as well as a brief summary of future work.

*Shengli* – CMA has created a decade-long MWRI FCDR for FY-3B, -C, and –D. This FCDR accounts for antenna backlobe, hot-load efficiency, and non-linearity effects. If you are interested in using FCDR data we can share it with you.

*Hongyi* – Is interested in using this.

*Qifeng* – You are using MWRI data with clear sky assimilation?

*Hongyi* - Yes only clear sky

*Qifeng* - Do you plan to use imager with all sky?

*Hongyi* – Yes, work is already underway.

*Mark* – What is the RFI detection limit that you have set? Is it 1K or 0.1K ?

*Hongyi* – We set the threshold value to zero. RFI is OK. Most RFI happens over land. There was a comment about the clear sky assimilation over land that was not clear. It has small influence on our assimilation.

1. **AI-based Radiative Transfer Model (Mark Liu - NOAA/STAR)**

*Summary:*

The use of AI to replace radiative transfer modeling in forecasts models and numerous other applications is attractive because of its potential to immensely increase modeling efficiency. The presentation first discusses the role of the Community Radiative Transfer Model to NOAA activities, especially NWP model radiance assimilation. It then presents the AI-based Fully Connected Deep Neural Network (FCDN) CRTM data flow, algorithm and input/output data. Training of the FCDN\_CRTM is discussed with focus on batch normalization and minimizing the loss function, mean and standard deviation. Comparisons show relatively good skill of the FCDN\_CRTM with respect to the CRTM that diminishes over the period of months. Also discussed is the role of applying physics to the input data during method training, and the positive effect this step can have on results. The presentation ends with a discussion of future work.

*Ali Mousivand* – Suggestion – Used batch normalization, which is a good technique. You mentioned that you use if because the dynamic range of radiance is large. We find when there is large dynamic range batch normalization may not work so well. When seeing the loss function that you use, it may be helpful to use a relative loss function. If you are using CRUST or MAPE, in this case a mean absolute relative error, you would be giving equal weights to all different wavelengths. It may be good to combine this loss function approach with batch normalization.

*Mark* – For the IR, we use Tb, and their ratios are smaller. So, the dynamic range is much smaller and we don’t need to normalize the measurements. For the visible channel we need to normalize radiance, because Visible and UV can have a dynamic range where measurements vary by 2-3 orders of magnitude.

*Qifeng* – In order to train the method, did you use information from real profiles, or some specific set of training profiles?

Mark - Training data taken from global data and from different months. Every two months we use global data to consider seasonal changes. For an AI-based model, you can do two things:

1) Base the training on a reference model

2) Train model for specific sensor measurement. Bias correction would be much different. Directly simulate based on your measurements.

Still investigating to see which one is better

*Qifeng* – Are you using the Line-by-Line Radiative Transfer Model?

*Mark* - Yes we use the Line-by-Line model, but for this study we use the CRTM. The CRTM is a fast model relative to the Line-by-Line model. We could use Line-by-Line model in the next phase. We did a test using neither the Line-by-Line Model nor the CRTM. We just used collocated measurements as a reference, in order to try to fit the input soundings directly to the observations. Don’t know which way is more benefit.

*Qifeng* – So, you don’t use pre-defined predictors, you just push the input profiles into the system and train those to observations.

*Mark* – This is what I show you. If you use temperature, moisture and ozone profile, and don’t create pre-defined predictors like in the transmittance model, then you will get a result. On the other hand, we showed that the result improved if the secant of the zenith angle is used instead of the zenith angle by itself. This means that applying some physical constraints to you input to create a new predictor may actually be helpful. This is still under investigation.

Another example of adding physics - For thermal radiation, the temperature depends on the Planck function. Temperature can be useful, because it is only one parameter. The Planck function on the other hand has more physics in it – e.g., wavelength. Using the Planck function instead of just temperature may have a benefit. This is good with an instrument with a few channel, but an instrument such as IASI with more than 8000 channels would require 8000 parameters. This is not efficient.

*Qifeng* – Based on the input for the model fit. So that case for data assimilation from different systems, the radiative transfer coefficients will be different.

*Mark* – For a sensor based radiative model, you use different coefficients that are unique to each sensor. AI is the same thing, one training is valid for one sensor. So, to the user, each sensor having its own unique radiative transfer aspects represents no change at all. What we hope to do in the future though is to add more physics inside the black box.

1. **GSICS Annual Meeting Plan (Qifeng LU and Mark Lui)**

There was a discussion based on the current agenda for the GSICS Annual Meeting Microwave Subgroup Breakout Session.

ACTION: (Qifeng, Mark, Shengli, and Robbie) The Plenary Presentation is Only 15 Minutes Total. So, we need to be mindful of how we present our information.

ACTION: (Robbie) Write Jun Park and Ram Rattan to see if they plan to give KMA and ISRO microwave remote sensing activity updates.

ACTION: (Robbie) Update the Microwave Subgroup Breakout Session agenda.

ACTION: (Robbie) Populate the meeting 3 summary and overview slides of the Microwave Subgroup Plenary talk. On the overview slide, what have we achieved in the last year, especially feedback from the users.

ACTION: (Mark) Contact Timo Hanschmann to discuss the use of reprocessed ATMS data in ERA-6.