GSICS Microwave Subgroup Meeting Minutes

Day 1 (Tuesday January 24th, 2023 - 1100 UTC - 1300 UTC)

Attendees: Mei Yuan, Karsten Fennig, Misako Kachi, Quanhua "Mark" Liu, Qifeng Lu, Shengli Wu, Qifeng Wu, Jun Zhou, Cheng-Zhi Zou, Martin Burgdorf, Ninghai Sun, Y Li, and Manik Bali

Information given in presentations is not reflected in the notes.

1) **(30 min) An Lunar Disk-Averaged Brightness Temperature Database for Microwave Sounder Calibration   Hu (Tiger) Yang and Martin Burgdorf**

Using the moon as a microwave calibration standard for satellite microwave instruments is a goal of calibration scientist. This talk introduces Keihm's lunar RTM model for calculation of disk averaged brightness temperature, and its calibration/validation using the disk-averaged brightness temperature spectrum from the 2-D scan full-Moon observations of NOAA-20 ATMS. The new 2D model was validated by using the LI samples collected on 12/03, 2022. Compared to the 1D model, the accuracy of calculated lunar brightness temperature is improved, especially for W and G band, where the magnitude of LI is more sensitive to the location of the Moon in cold space view FOV.

Questions and Comments:
Tim Hewison

- How representative are the properties of the lunar soil determined from point measurements on the moon's surface as applied to a given spot over the whole moon?
    - Thermal conductivity and dielectric constants are derived from the Apollo mission.
    - Other high-resolution lunar satellite missions have also been conducted that have estimated these parameters.
    - The dielectric constant has found not to vary much in the microwave because the moon has no water or air.
    - We are most interested in the full disk-averaged value, because of the relatively large microwave instrument beam size compared to the moon.

Cheng-Zhi Zou

- 13 Frequencies from 23 – 204 GHz are covered? Does this include individual ATMS channels?
    - Yes, the study was performed using ATMS as a training data set.
    - In this work, we focus on some ATMS bands within each microwave band – e.g., K-, Ka-, V- and W-bands.
    - The most accurate results from the frequencies that cover ATMS, so anything beyond 23 GHz and 183 GHz are extrapolated and not as accurate.
- Do you have the lunar measurements from S-NPP ATMS? There is interest in comparing the stability of the lunar measurements with respect to the corrected earth measurements to see if any instrument calibration drift is revealed from the lunar measurements.
    - The moon is a stable calibration source, so any deviation of the monthly-averaged moon measurements with respect to the moon model for S-NPP could reveal some calibration irregularity
    - Cheng-Zhi is matching S-NPP with RO data set, but that may have its own inherent changes.

2) (30 min) A Lunar Eclipse Observed With AMSU-B and its Relevance for Calibration Martin Burgdorf

Need accurate model and precise measurements of lunar radiance. The precision of moon radiance is 0.5% (MHS) – 1% (AMSU-B) given a 95% confidence bounds (worse for channel H2/17). This is comparable to accuracy achieved with astronomical radio telescopes. A critical parameter is the distance between the deep space view (DSV) and Moon position, and this can be obtained from a light curve and different DSVs/observing times. Characteristics from ground tests are unreliable, so it is necessary to determine diameter (FOV), pointing accuracy, etc. in flight (with Moon). Good agreement between measurements and model radiances suggests that the Moon is a suitable calibration standard.

Questions and Comments:
Cheng-Zhi Zou

- When you look at the moon, you still have the side-lobe affect. How do you deal with that.
    - The sidelobe effect is present whether or not you have the Moon in view. So, we subtract the average cold space views without the Moon in the FOV from those with the Moon in the FOV. This is assumed to identify the Moon signal in the microwave instrument.
    - Tiger
        - When you calibrate lunar observations, you have to consider contamination from the sidelobes.
        - For ATMS, we consider sidelobe and reflector emission. Also, ATMS and MHS have four continuous-scan cold space view measurements, so it is easy to find a scan position where the sidelobe effect is minimized. This is not true for AMSU-A, because it only has one cold space view measurement.
        - There is a need to make sure the gain is valid to be used during the lunar observations.
        - We have performed the study for the AMSU-A drifting orbit. It is a 2016 Remote Sensing journal article regarding how to deal with the AMSU-A lunar samples.
    - Martin uses the AAPP calibration values, where there is a correction factor for sidelobes that can be used to correct the calibration.
    - Cheng-zhi
        - NOAA-15 AMSU-A Ch 5 drift is obvious.
        - Possible due to sidelobe effect on the calibration. Either by sat effective temperature, or sidelobe efficiency, related to reflector degradation.
        - Moon observations may be able to be used to detect and correct for this.

3) (40 min) Agency Status Reports

a) (10 Min) JAXA (Misako KACHI)

Questions and Comments:
None

b) (10 Min) EUMETSAT (Tim Hewison)

Questions and Comments:
Siena Iacovazzi

- Sentinel has two MW channels. Why?

    - Provide information on tropospheric humidity to remove the altimeter "wet path delay" on Sentinel 3 and 22 GHz and 36 GHz. Future versions, on Sentinel 6, channel added for wind speed effect on the wet path delay.

Mark Liu

- What is the EPS Sterna instrument?
    - The EPS-Sterna mission would enable the provision of atmospheric temperature and humidity profiles. The mission would significantly benefit medium and short-range weather forecasting globally, as well as enhancing very-short-range forecasting regionally at high latitudes.
    - The microwave radiometer will have channels in the 50-57 GHz O2 band, and 89 GHz window channel, and 183 GHz and 325 GHz water vapor bands.
- Does EUMETSAT for microwave hyperspectral?
    - No.

c) (10 Min) CMA (Shengli Wu)

Questions and Comments:

Mark Liu - Microwave on GEO how many channels?

- Cannot give a clear answer. Maybe next year.

d) (10 Min) NOAA (Quanhua Liu)

Questions and Comments:

None

4) (20 Min) Breakout Meeting Planning for the GSICS Annual Meeting on March 1, 2023.

Questions and Comments:

- Algorithm Collaboration
    - Tim Hewison
        - Consider to work together for inter-calibration. Collaboration on GPM X-Cal method was done in the past, but it was reliant on participation from GPM, and now Wes Berg has retired.
        - Common algorithms that can bring our instruments together
    - Siena Iacovazzi - Create on one hour discussion of the four hours
    - Tiger Yang
        - Yes, a good idea about common algorithms. For example, use of lunar brightness temperature data set to compute disc-average brightness temperature for each GSICS partners lunar observations. From this, a lunar model for inter-satellite calibration may be able to be developed.
        - In NOAA, we collect the lunar samples from the microwave instruments, and use them to check the calibration consistency between the instruments.
    - Tim Hewison
        - Supports the proposal.
        - This is the same model that followed for the 1st lunar workshop. The lunar images from each agency were extracted. Then they are processed using a common algorithm to produce lunar irradiances for each instrument. Inter-satellite inter-sensor comparison then can be performed between sensors
    - Tiger Yang
        - When you do lunar calibration, you need to involve the different parameters of the instruments, for example antenna pattern.

        - This activity will both encourage agencies to do lunar calibration, and also will help to improve the lunar calibration method.
    - Mark Liu
        - We can have an open discussion regarding data sharing, and discuss what we can do.
    - Shengli Wu
        - For XCal, CMA plans to launch next year its first rainfall mission (FY-3G) as a continuity to the Global Precipitation Measurement program. This satellite will be in a drift orbit. This will create opportunities for simultaneous nadir overpasses with other instruments, as well as lunar observations from different LTAN's.
        - We can discuss what we can do with the data from their platform on FY-3G as a source of comparison.

Status report

- Need to work with Manik to understand what is to be presented in the plenary session, and what needs to be presented in the Subgroup Breakout meeting.
- Friday morning there is an outbrief from the Subgroups, but there is no plan to have Subgroup reports in the plenary sessions.

Meeting Type

- This will be a hybrid meeting

Other

- CMA will be remote, because of COVID.
- ESA will give a report

Day 2 (Wednesday January 25th, 2023 - 1100 UTC - 1300 UTC)

Attendees: Misako Kachi, Quanhua "Mark" Liu, Qifeng Lu, Fabien Carminati, Jian Shang, Shengli Wu, Cheng-Zhi Zou, Paul Poli, Rachael Kroodsma, Timo Hanschmann, Vinia Mattioli, Viju John, Manik Bali, Juyang Hu, Ed Kim, and Stephen English

This is an introduction into the GeoSTAR Geostationary Microwave Sounder technology, and its applications. It reveals that a geostationary microwave sounder is now feasible, and that it could provide unprecedented capabilities, such as significant advances in regional weather forecasting and real-time monitoring of severe storms and hurricanes. The projected instrument performance readily meets our needs, as the performance matches that of current LEO sounders (AMSU, ATMS), including spatial resolution, and is commensurate with that of an IR sounder, but without limitations due to clouds. The flexible system can adapt to changing needs and conditions. The instrument design has a large trade space – e.g., size, mass, and cost versus overall field of view, spatial resolution and performance. The technology is ready, following years of NASA-funded development.

Information given in presentations is not reflected in the notes.

1) (40 min) Geo MW talk (TBD - Bjorn Lambrightsen - NASA)

Question and Comments:

- Steve English
  - How does this concept compare in cost and performance compared to a constellation of small or cubesats in LEO e.g. TROPICS?
    - I don't know the cost of TROPICS (nor will JPL allow me to give out GeoSTAR cost numbers), but I can point out that we proposed GeoSTAR (a mission called GeoStorm) to the same NASA EV-I call as Bill Blackwell proposed TROPICS to. Ours was proposed under a cost cap of around $105M and his under a $30M cost cap
    - The smaller versions of GeoSTAR have similar spectral coverage as TROPICS (pretty much the same channel set), but spatial and temporal sampling and coverage are very different. TROPICS revisit times are considerably greater than those of GeoSTAR
    - You might think of GeoSTAR as a regional sensor, while TROPICS is a global sensor. A cubesat constellation would need to be much greater to provide adequate spatial and temporal coverage as a regional system, while we would need a constellation of 5-6 GeoSTARs to achieve adequate coverage as a global system. Sort of apples and oranges
- Tiger Yang
  - Any word about calibration ?
    - Since GeoSTAR is an interferometer, phase calibration is most important. We cover that by characterizing the antenna array before launch; positioning a calibration beacon (which emits noise in a given channel) in a few places on the ground, typically on mountain tops to minimize opacity; and by looking at the Earth's limb and the moon and correcting for geometric distortions
    - We do radiometric calibration with a few dedicated receivers that operate as correlation receivers and measure the mean brightness temperature within the FOV, which we can compare with data from LEO sounders and models; and we

will do cross-calibration against LEO sounders with near-identical channels during very frequent underpasses.

- Jian Shang
    - High radiometric sensitivity is achieved by averaging over 15 min. Does the hypothesis reasonable? The atmosphere can vary greatly in 15 minutes.
        - It depends on the scene. The temperature field typically changes very little in 15 minutes. Water vapor changes more rapidly than temperature, but it will also typically not change much in 15 minutes. Cloud dynamics may be faster, and precipitation is probably the most rapidly changing parameter. So, there is a range of time scales here, and averaging over some time interval introduces a geophysical variance that will look like a random error. We can think of this as total-variance = instrument-variance + geophysical-variance. By shortening the averaging time, the first one increases and second one decreases. I haven't studied this in detail, but I expect that for a given target there may be an optimal averaging time. It seems likely that under ordinary situations, with slowly varying thermodynamics, 15 minutes is perfectly fine. If we are looking at high-intensity precipitation or TC eyewall dynamics, no averaging would be fine. For convective rain, for example, the signal is typically tens of degrees, and an NEDT of 1 K is perfectly adequate
- Tim Hewison
    - Could the concept be readily applied to the 50-60GHz band?
        - Indeed it can, and that is really one of our major achievements, since it allowed us to satisfy the requirements of the PATH mission that was part of the first NASA earth science decadal study and which was the basis for the NASA funding of the GeoSTAR development.
        - As I mentioned in my talk, a number of different design implementations are possible (we have a large trade space), and doing T-sounding at 50 GHz is one of them. That is listed in Table II of the attached paper, also shown below:
        - By the way, as I mentioned in my talk, the GeoSTAR design uses a software-defined receiver system. We use a digital synthesizer to generate the LO, and we mix the signal down to baseband. We define a channel set by tuning the LO to a corresponding set of frequencies. We cycle through them very rapidly (a matter of milliseconds for each) and accumulate the cross-correlations for each of them for a total of 90 seconds. The totals are then sent down to the ground for further processing and possibly averaging. All of this - channel set, time allocation, cycling period, etc. - is under software control and can be changed by command on-orbit. We can implement an AMSU channel set for legacy capabilities, or we can concentrate more channels in the lower troposphere for enhanced PBL sounding, or we can cycle through a large number of interleaved channels to achieve hyperspectral sounding. Very flexible!
- Cheng-Zhi Zhou
    - please confirm you will only have 118 and 183 GHz frequency, right?
        - This is an implementation question, it is not inherent in our design or architecture. As my answer above indicates, we can implement 50 + 183 GHz. For the performance assessment we did for NOAA that I described in my talk, we chose to use 118 + 183 GHz. We used to believe that 50 GHz is necessary to

get adequate measurements in the lower troposphere under opaque conditions, but we have come to the conclusion that the difference in performance is very minor. We explored that in our NOAA study, and we show some of those results in the attached paper.
    - The large trade space I've been talking about has a number of dimensions: spatial resolution, temporal resolution, spatial coverage, NEDT, physical size and mass, cost, etc. We think that one of the most attractive options is the one we used in our study, which is the one called "GeoStorm" in the table above. Although it has a relatively small FOV, a little over 1000 km, it can be mounted on a steerable mechanism, which makes it possible to track a storm through its entire life cycle, for example, or jump from one storm to another. The entire earth disc is reachable. This is also a low-cost option, especially since it is perfect for hosting on a commercial communications satellite. It would be suitable as a demonstration mission
  - What is the frequency resolution
    - See my answers above. Our "GeoStorm" implementation has 10 channels: 6 in the 118-GHz band with weighting functions nominally identical to the tropospheric channels of ATMS, and 4 in the 183-GHz band identical to the ATMS channels there. This is all controlled by the on-board software, so it can be changed by command.

2) (20 min) CRTM-simulated MW Sounder Brightness Temperature Uncertainties and their Relation to NOAA Operational Calibration Anomaly Detection and Analysis Siena Iacovazzi, Quanhua Liu, Hu Yang, James Fuentes, and Ninghai Sun

CRTM-simulated satellite MW sensor Tb uncertainties are estimated to better understand our ability to track NOAA MW sounder data quality, and analyze their calibration anomaly mechanisms. Uncertainties are estimated with CRTM-simulated Tb generated separately with ECMWF ENS and GNSS RO soundings collocated with NPP and N20 ATMS, and MEA, MEB, MEC, N18 and N19 AMSU-A, operational MW sounder data locations. Global-average ECMWF ENS and GNSS RO temperature and water vapor soundings can differ as a function of mean sea level altitude and season, which translate directly to single-sensor Tb difference variability between these simulations that have an all-channel NSF value of 10^{-3} (~0.3 K). ATMS-to-AMSU-A inter-sensor simulated Tb differences, derived from the double difference of single-sensor simulated Tb differences, reduce all-channel NSF to a value of 10^{-4} (~0.03 K). It is found that CRTM-simulation Tb uncertainty can be on the same scale as MW instrument calibration anomaly mechanisms for single sensor O-B Ta bias data, but much smaller for many inter-sensor Ta biases.

Questions and Comments:
Tim Hewison

- Are you currently getting the full ECMWF 51-member ensemble of soundings? If so, could you perform a Monte-Carlo analysis using this ensemble? You might see a similar dispersion.
  - Siena Iacovazzi
    - I have used the ECMWF data sets that are provided to NOAA/NESDIS/STAR. To my knowledge, there is only on set of sounding parameters provided, and not 51.
  - Steve English

        - NOAA currently receives a low volume data stream from ECMWF that contains no ensemble information. However, discussion is at an advanced stage for NOAA to receive a new high volume (3.5Tb of data from ECMWF a day) data stream that will contain ensemble information. Note the ECMWF ensemble resolution will increase to 9km in next cycle later this year.

Cheng-Zhi Zou

- Why is there such a big difference between ECMWF and GNSS RO soundings in the Mesosphere? It seems that GNSS RO is assimilated into the ECMWF model input, and there may not be many other data sets with information in this region of the atmosphere.
    - Mark - ECMWF assimilates the bending angle, while Siena is using the retrieved temperature profiles. This may make a difference.

3) (20 min) Summary of STAR V5.0 Layer Temperature CDR Derived from Satellite Microwave Sounder Observations with Backward Merging Approach. Cheng-Zhi Zou

Question and Comments:

Martin Burgdorf

- Is a second-order polynomial adequate to describe the non-linearity term, and is it valid only over a limited range of earth counts or the full range?
    - The non-linear term is applicable to the whole range of counts. It is a known response of the instrument related to tested. We assume that the non-linear term is relating linearly over time as the instrument degrades or its thermal environment changes due to LTAN drift.

Tim Hewison

- Another possible cause of calibration drift could be changes in the Local Oscillator frequency - e.g. caused by their operating temperature drifting (their frequency/temperature coefficients should be known). This could be investigated by using RTM method. Qifeng Lu and Steve English have looked at this.
    - We have looked into this for the particular microwave sounder channels we analyze. Local Oscillator frequency change will cause the channel to measure different layers of the atmosphere. Because of lapse rate changes over time and space, SNO scattering patterns due to frequency difference would be very different from those due to other causes. This was analyzed in detail in Zou and Wang (2011). In other words, the regression pattern associated with the SNO results can be used as a means to detect local oscillator change. We found the SNO changes linearly with scene temperature. If there is frequency difference, this would have a different pattern. We don't find this.
- Why do you think the largest trend in the difference was observed for SNPP-Metop-A (0.033K/decade)?
    - We calculated difference trends for all satellite pairs with available overlaps. 0.033 K/Dec was the maximum we obtained, and it was from the SNPP and MetOp-A overlaps. We don't have too many overlaps for the four satellites Aqua, Metop-A, SNPP, and NOAA-20. But we did our best to estimate the trend differences between these satellite pairs.
    - The 0.033 K/decade trend between SNPP and Metop-A is actually quite small. This small trend can be interpreted as that both SNPP and Metop-A were very stable. In our 2018 studies, we consider if the trend difference between two satellites are within 0.04 K/decade, then both satellites achieved high radiometric stability performance. With

that criteria, both Metop-A and SNPP have high radiometric stability. For many other satellite pairs, one can easily see relative trends up to 0.2 K/decade. So, 0.033 K/decade was quite small

4) (20 min) FY-3E MW Sounder and Imager Juyang Hu

This presentation discusses the latest developments regarding FY-3 MW Imager and Sounder Instrument.

Questions and Comments:
Tiger Yang

- FY-3E undergoes a very large on-orbit instrument temperature change of about 20 K from May to August. FY-3F has only 20 K dynamic range for TVAC test. Since the non-linear calibration term is sensitive to instrument temperature, can the non-linearity correction handle this large instrument change?
    - The satellite is in the terminator orbit (1800 LTAN) and often goes between sun exposure to being in the earth shadow. This is expected to happen every year.
    - Siena – There are cases where instruments get direct sunlight on them, because the sun can shine at oblique angles onto the instruments.
    - JuYang – Based on your recommendation, we will focus more on nonlinear correction.
    - Tiger – Also recommend to increase the dynamic range of TVAC test to encompass such a large instrument on orbit temperature range.
    - Tiger – Is there a sun shield on FY-3E?
        - Shengli - There is a sunshield to protect the sensor from direct sunlight. MWTS is in the middle of the platform though, and it is very difficult to control the temperature.
        - There is a technology improvement expected for this issue for FY-3F.
        -

Steve English

- Nice talk, very encouraging. I may have missed it - what is the latest launch date for FY3F? Is it still planned for a morning (10:00) ECT?
    - Juyang Hu – yes it is 10:00 ECT morning orbit

5) (20 min) FY-3E WindRad Shang Jian

This talk discusses validation results related to the FY-3E WindRad.

Questions and Comments:
Steve English

- With the C and Q band, will you create separate products with these bands, or some merged product?
    - There will be three products. One using C-band, one using Q-band, and one using both.