Introducing GSICS Inter-calibration of Microwave Radiometers for Precipitation

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GSICS Scope

- Global Space-based Inter-Calibration System (GSICS)
  - is an international collaborative effort initiated in 2005
  - by World Meteorological Organization (WMO) and Coordination Group for Meteorological Satellites (CGMS) to

  1) monitor,

  2) improve,

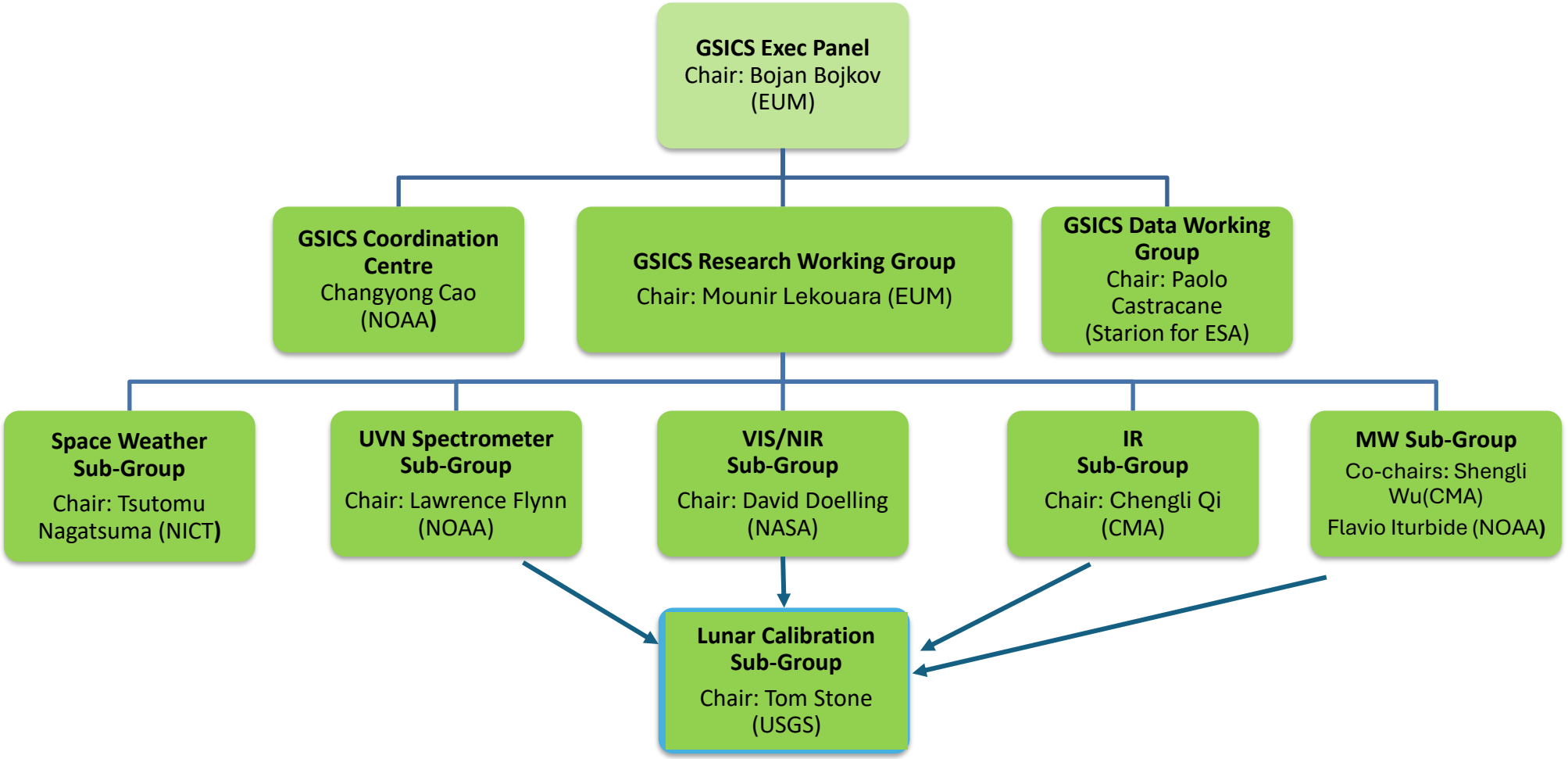
  3) harmonize
  - the quality of observations from operational weather and environmental satellites of the Global Observing System

- Primary focus of GSICS is the development of methodologies and tools for NRT operational monitoring and improvement of the radiometric calibration performances by the member agencies.
- Aim for all* providers to implement common algorithm to inter-compare data from their constellations

  (* including commercial satellite operators)
  - Working towards an inter-operable system
- All GSICS tools/methods are open and freely available

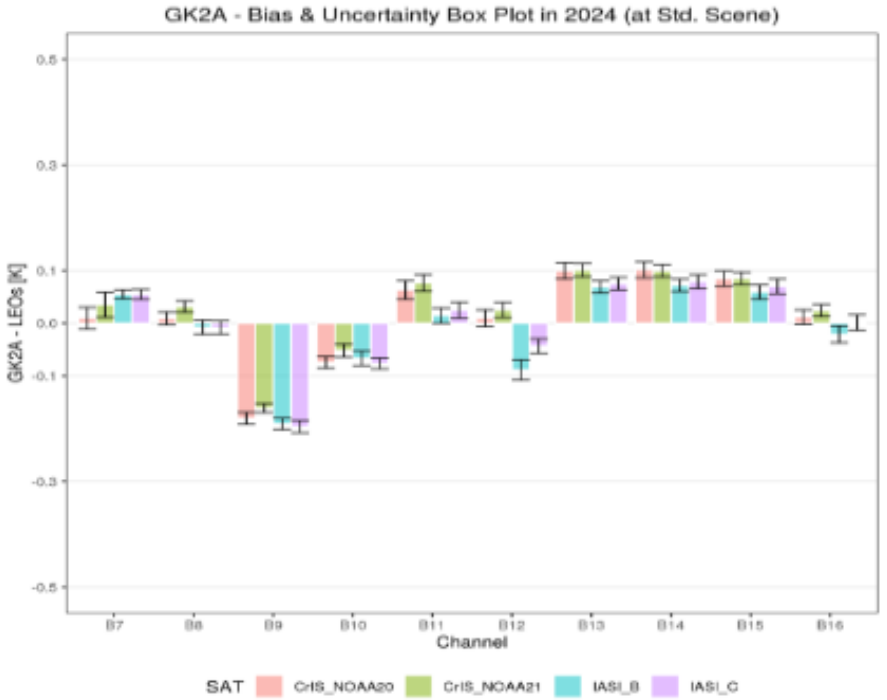
Current GSICS Members
https://gsics.wmo.int/

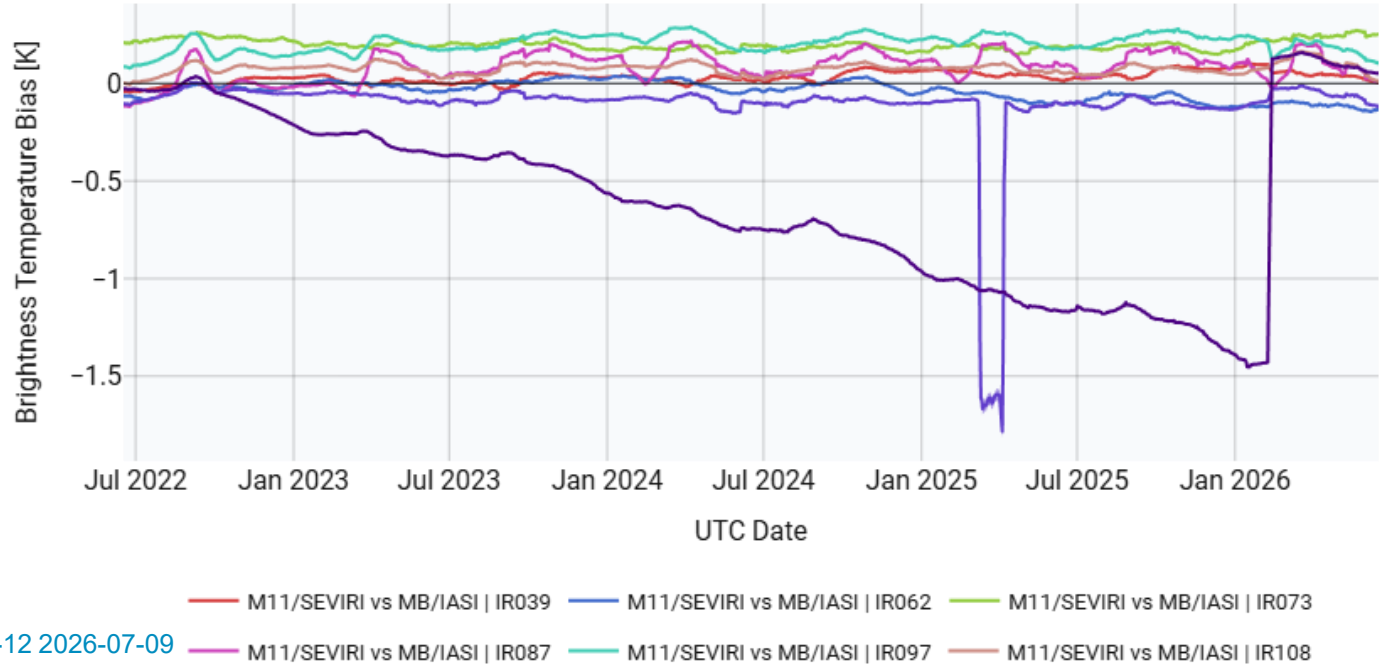
GSICS Structure

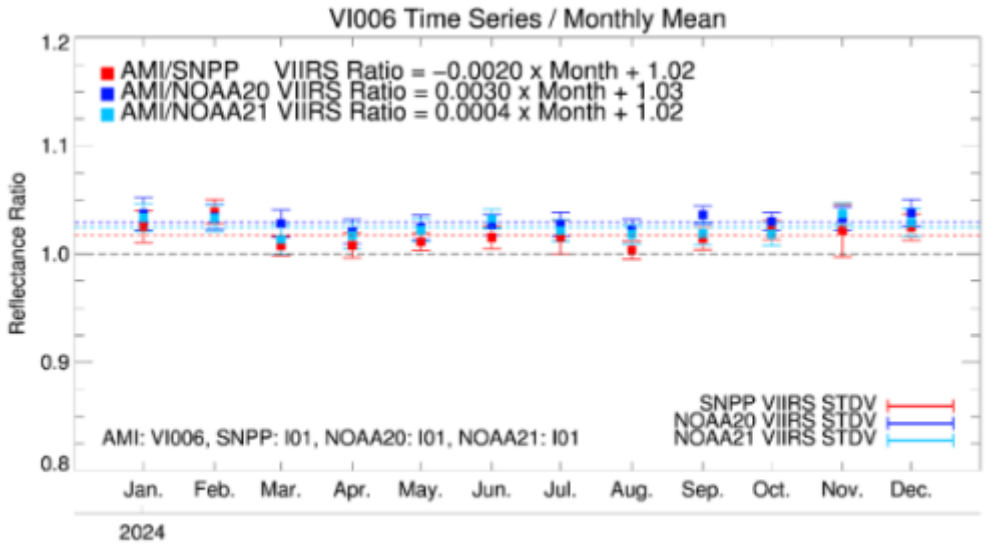


GSICS Products

- Common Inter-Calibration Algorithms
  - For various instrument classes
- Calibration Monitoring
  - Examples from EUMETSAT, KMA, JMA
- Tools
  - e.g. Spectral Band Adjustment Functions
- Calibration Corrections
  - Empirical adjustments to align radiance with reference







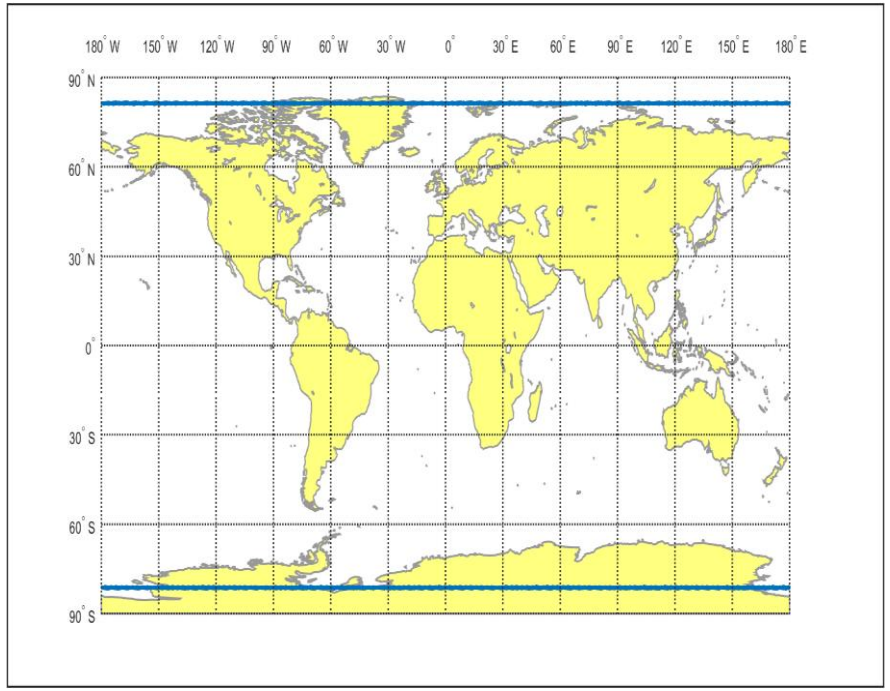
GSICS to the Rescue!

- Following a hardware failure on the Meteosat-12 FCI in January 2024, the instrument resumed observation mode in May 2024 without on-board calibration.
- Since then, the anomaly is well mitigated using GSICS GEO-LEO (inter-calibration with Metop-B/C IASI) to estimate FCI IR gains.
- This is a clear example of the GSICS cooperation benefiting the quality and lifetime of a key operational mission.

- EUMETSAT's team responsible for imager calibration was able to quickly develop a fix, based on a GSICS algorithm
  - Thanks to Mounir Lekouara, Ali Mousivand, Alessandro Burini

Microwave Radiometer Inter-calibration Algorithms

- Simultaneous Nadir Overpass
  - Compare observations of spectrally matched channels
  - near-nadir – at similar times
  - 1000s of match-ups per year
  - Typ. in polar areas for sun-synchronous satellites



Geographic distribution of 1 year's predicted matchups between EPS-Sterna and Metop-C with 23:30 and 21:30 local equator crossing times
for 5° max viewing angle, 15min max time difference

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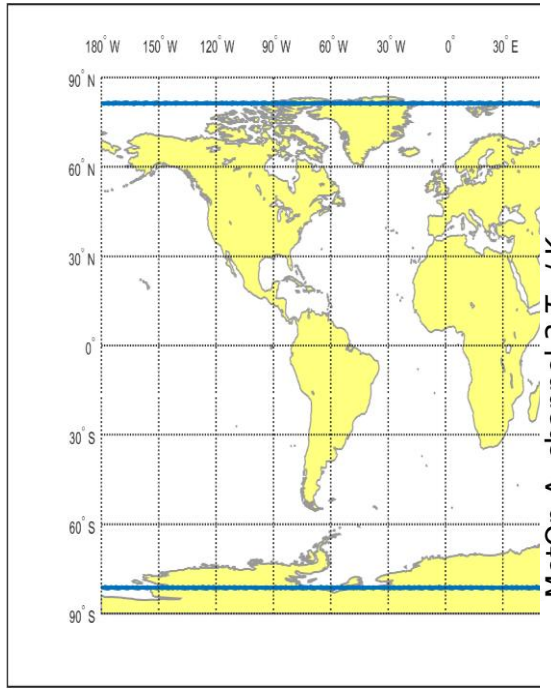
- Opportunistic Constant Target Matching (“Warm SNO”)
  - Aims to improve dynamic range of
  - By identifying stable conditions
  - where time window can be extended
  - Based on geostationary imager data



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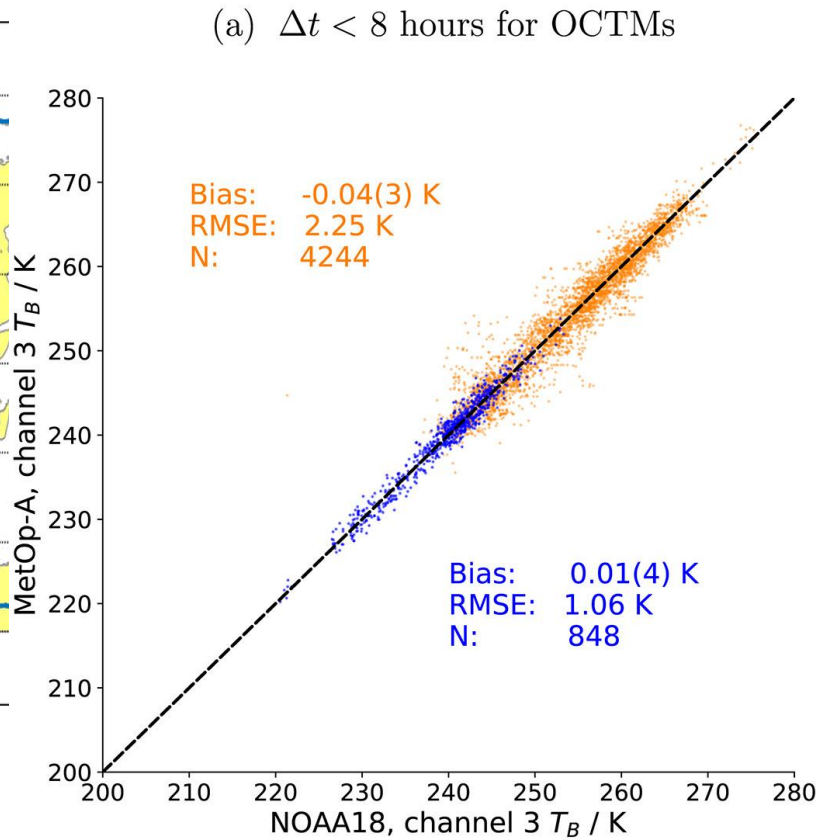
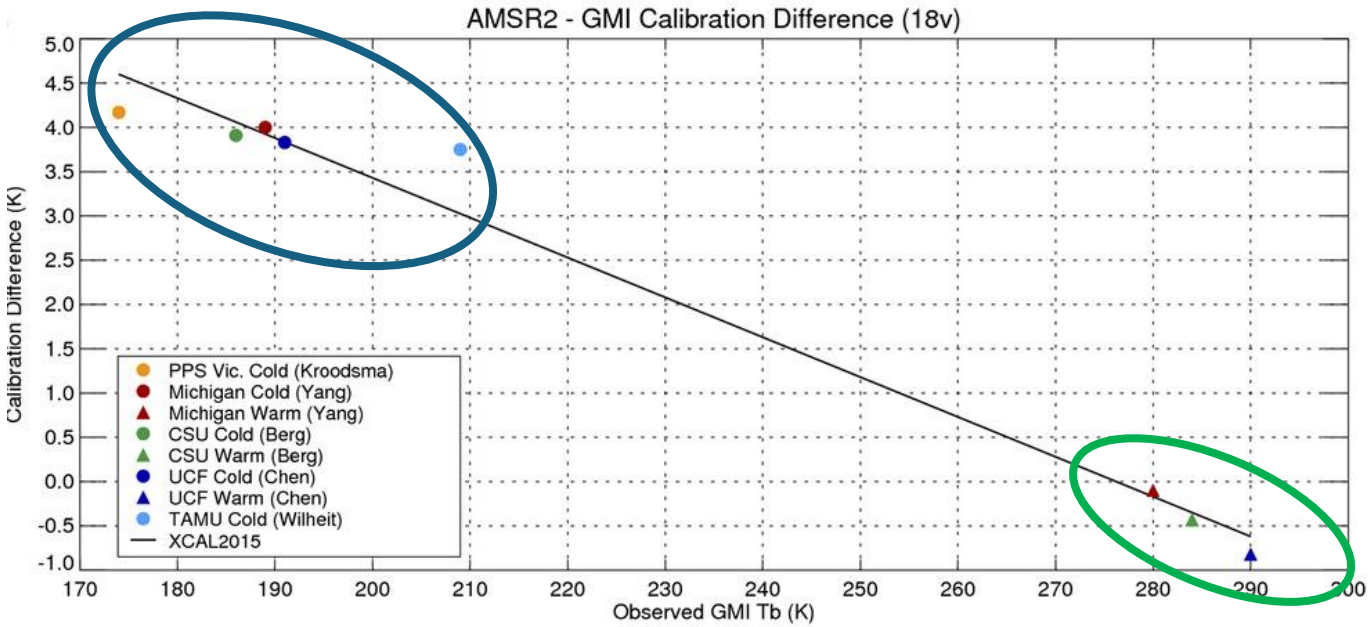


Matchup scatterplot of MHS 183±1GHz on NOAA 18 v. Metop A
Orange points mark OCTMs.
Blue points mark classic SNO matchups. (From Buehler et al. 2020)

Microwave Radiometer Inter-calibration Algorithms

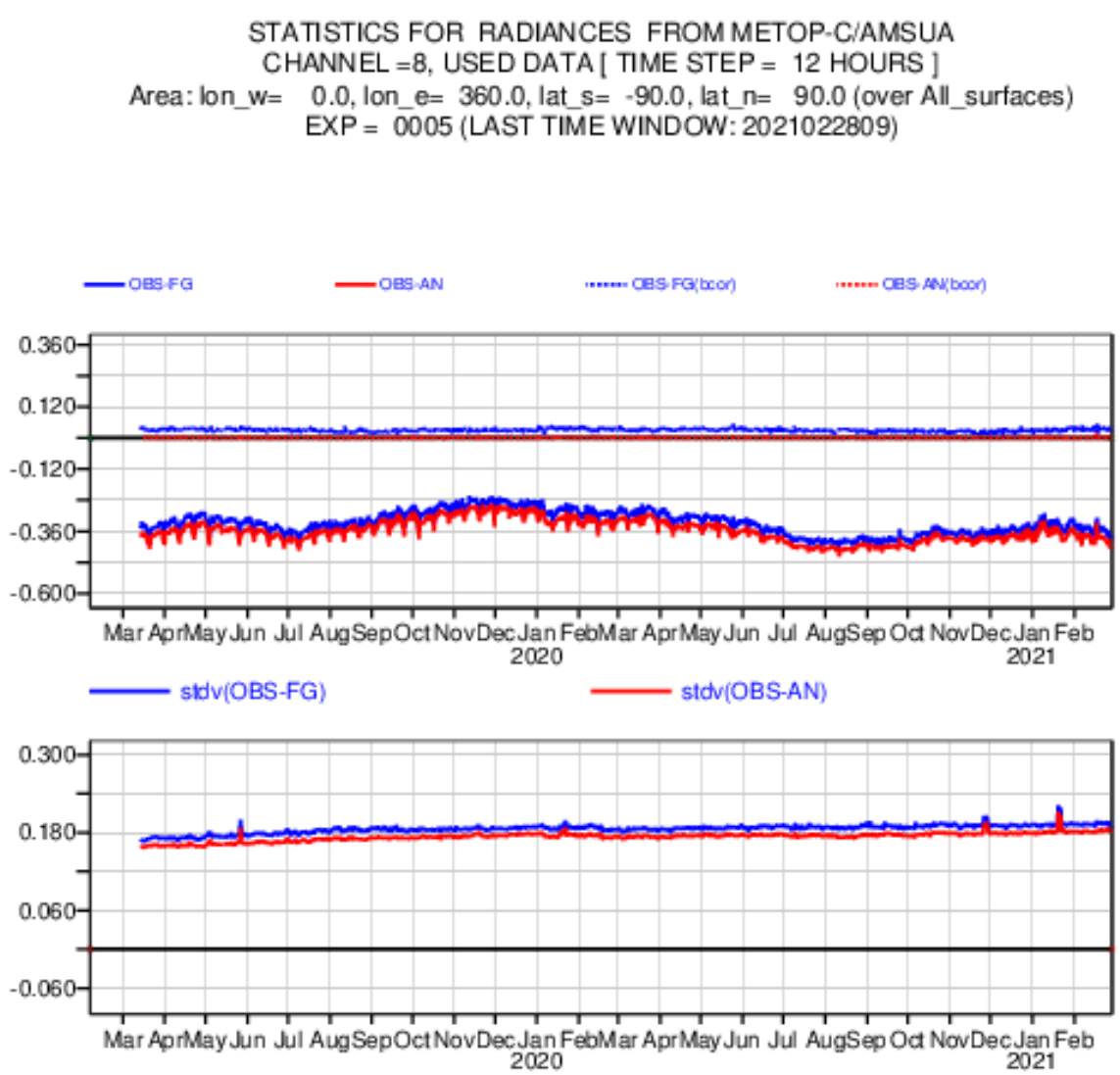
- Vicarious calibration
- Uses natural targets
  - With low temporal
  - and spatial variability
  - Ocean in cold, dry conditions
  - Tropical Rainforests
- TOA radiance can be modelled
  - With low uncertainty
  - Need to filter precipitation and cloud
- Extended to inter-calibration
  - Using double-differencing
  - Accounting for sensor differences
    - Spectral, geometric, polarisation, …
- Popular for window channels of microwave imagers



Vicarious Inter-calibration results for AMSR2 vs GMI 18.7 GHz V-pol. Independent results from each of the contributing groups shown for radiometrically cold scenes (non-precipitating oceans) and warm scenes (vegetated non-polarized land). (From *Berg et al., 2016*)

RTM-based Inter-Calibration

- NWP: *Best Estimate* of atmosphere/surface
- Observations – First Guess = Calibration Monitoring
  - Typical biases ~1K (AMSU/MHS/ATMS)
  - STD ~0.15K for 52-58GHz oxygen channels (~noise)
  - STD ~3K for water vapour channels (~atm variability)
  - STD ~7K for window channels (surface variability)
- Extension to Inter-Calibration by Double-Differencing
  - Cancel out residual biases e.g. surface emissivity, cloud
  - May need precipitation screening
- Big Data!
  - Can diagnose sensitivity to many variables
- Other RTM-based methods:
  - GNSS Radio Occultation – good for high-peaking temperature channels
  - Forward-modelled Radiosondes – useful for sub-mm WV channels



NWP Bias Monitoring Statistics
For Metop-C/AMSU-A Ch 8 over 2 years
(From ECMWF)

MW Inter-calibration Requirements for Precipitation

- Seeking feedback from IPWG as important GSICS “users”

- Target satellites, instruments, channels
- Dynamic range
- Reference
  - Identification of suitable reference instrument(s)
  - Definition of Spectral Band Adjustment Functions
- Inter-calibration uncertainty, traceability
  - What uncertainty is needed for different channels?
- Timeliness – lead time and update frequency
  - Depends on stability and application
- Monitoring, Reporting
- Form of inter-calibration product:
  - Algorithm, Calibration Coefficient updates,
  - Radiance Corrections, Re-calibration, …
  - Ability to incorporate into L2 pipelines

Channel Type	Expected Dynamic Range	Threshold Uncertainty	Breakthrough Uncertainty	Objective Uncertainty
Window or pseudo-window	90K	2.0K	1.0K	0.5K
Temperature-sounding	30K	0.5K	0.2K	0.1K
Humidity-sounding	50K	1.0K	0.5K	0.2K

Example Uncertainty Requirements (k=2) for Inter-Calibration Algorithm defined per channel type based on requirements for monthly calibration monitoring
Traceability is to Reference Instruments’ calibration

Initial Feedback from C. Kummerow

- Reviewed Draft White Paper ***IPWG's approach to sensor intercalibration***
  - *Follow-up questions to C. Kummerow by email and responses below*
- Which instruments and channels you want to cover?
  - *"We tend to use all instruments that measure between 10 - 183 GHz (and 325 GHz in future)" – both imagers and sounders*
  - *"We have thus far not used the temperature sounding channels but might do so in the future." – also small/cubesats*
- Over what dynamic range?
  - *"We've always done the whole dynamic range of the sensors as precipitation can create both really high and low Tbs"*
- With what inter-calibration uncertainty?
  - *"Precipitation is inherently a bit noisy*
  - *so that noise of ±1 or even 2K is acceptable but biases should be in the 0.1-0.2K range."*
- At what lead times and update frequency?
  - *"Our real time products are dominated by noise and occasional sensor errors.*
  - *Our climate products need to really careful calibration but well after the fact is acceptable"*
- What form of inter-calibration product?
  - *"procedure" rather than a product - a process to follow and would report on what was done (rather than an "algorithm")*
  - *Concerns about using NWP bias correction – due to possible model biases.*

IPWG-GSICS Cooperation

- IPWG represents important potential users
  - of GSICS inter-calibration for Microwave Radiometers

- GSICS focus is on L1 calibration
  - We assume consistent calibration of L1 data among the constellation of satellite instruments is important in the generation of L2 precipitation products
  - How to provide feedback on from L2+ products?

- How to cooperate further?
  - Invite IPWG to consolidate requirements
  - GSICS MW Sub-Group would compare these requirements with capability of current algorithms and propose a way forward
  - Invite IPWG members to a dedicated GSICS meeting to discuss
  - 2027 GSICS Annual Meeting: March/April at EUMETSAT, Germany

Happy to Discuss!

Thank You!