In response to EUMETSAT Invitation Tender ITT 22/224312

Update on the VIcarious Calibration tool for MWI and ICI using RadioSoundings

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Aims

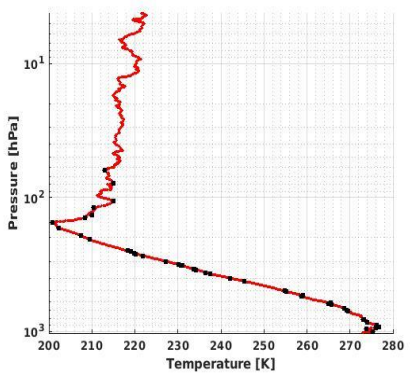
Develop a SW tool for vicarious calibration of MWI and ICI

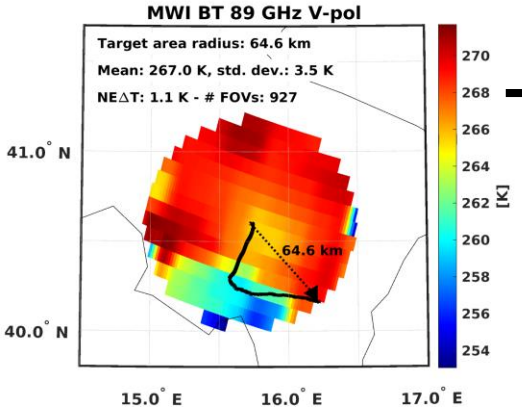
- **MWI**: MicroWave Imager
- **ICI**: Ice Cloud Imager
- To be launched with MetOp-SG-B (2026+)

- **Vicarious calibration**: post-launch calibration based on reference targets
  - E.g., other sat observations (well calibrated)
  - Simulated observations from radiosonde
  - Crucial for unprecedented channels (i.e., ICI-4 to ICI-11, MWI-9 to MWI-12)

Aims

INPUT





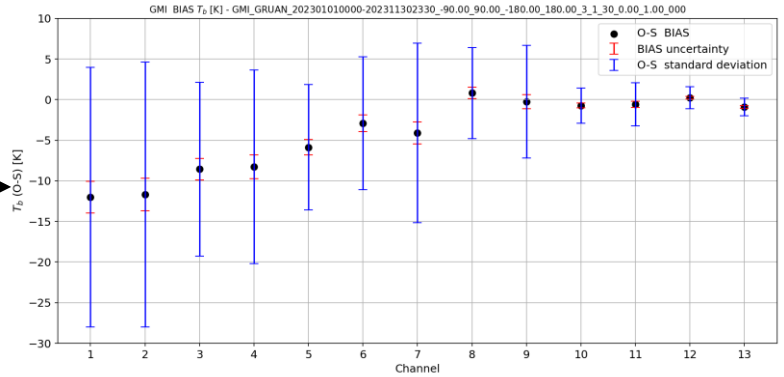
VICIRS TOOL

Colocation

Uncertainty

OUTPUT

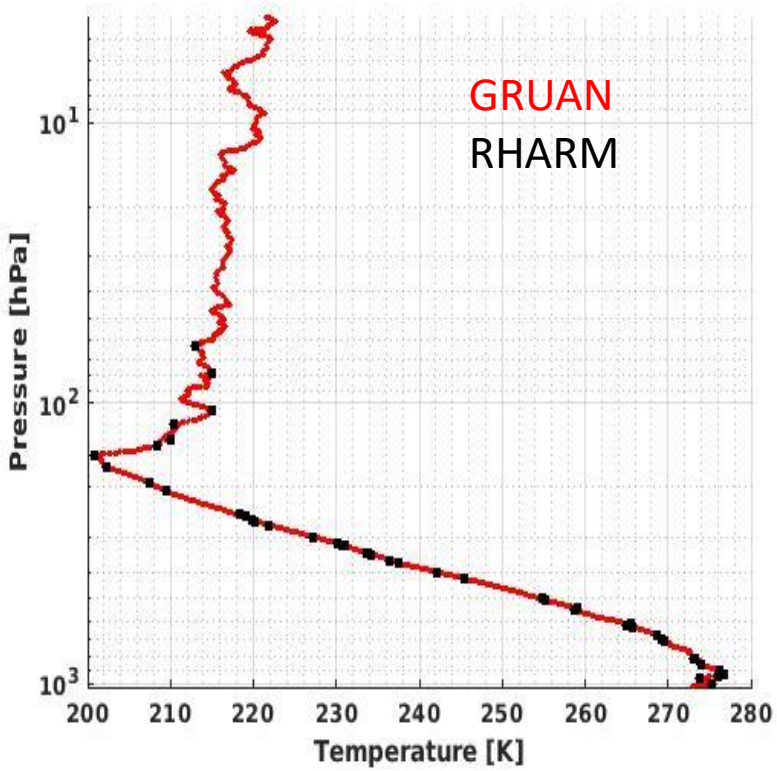
BIAS & UNCERTAINTY

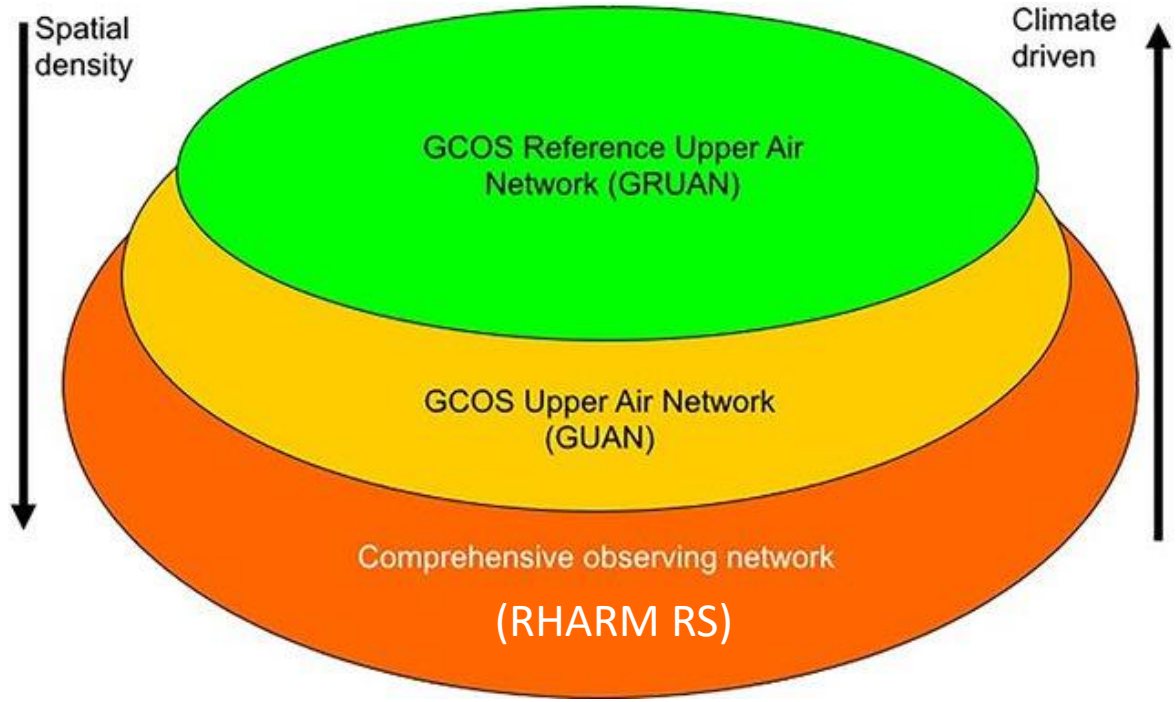


CHANNEL #

Radiosondes

- Need for RS uncertainty





GCOS tiered-network concept

Radiosounding HARMonization (RHARM)

Copernicus Climate Change Service (C3S) - (Madonna et al, 2022)

- Builds on Integrated Global Radiosonde Archive (IGRA)
- bias-adjusted & estimated uncertainties
  - based on GRUAN expertise and intercomparison data
- 700 sites

GRUAN radiosondes

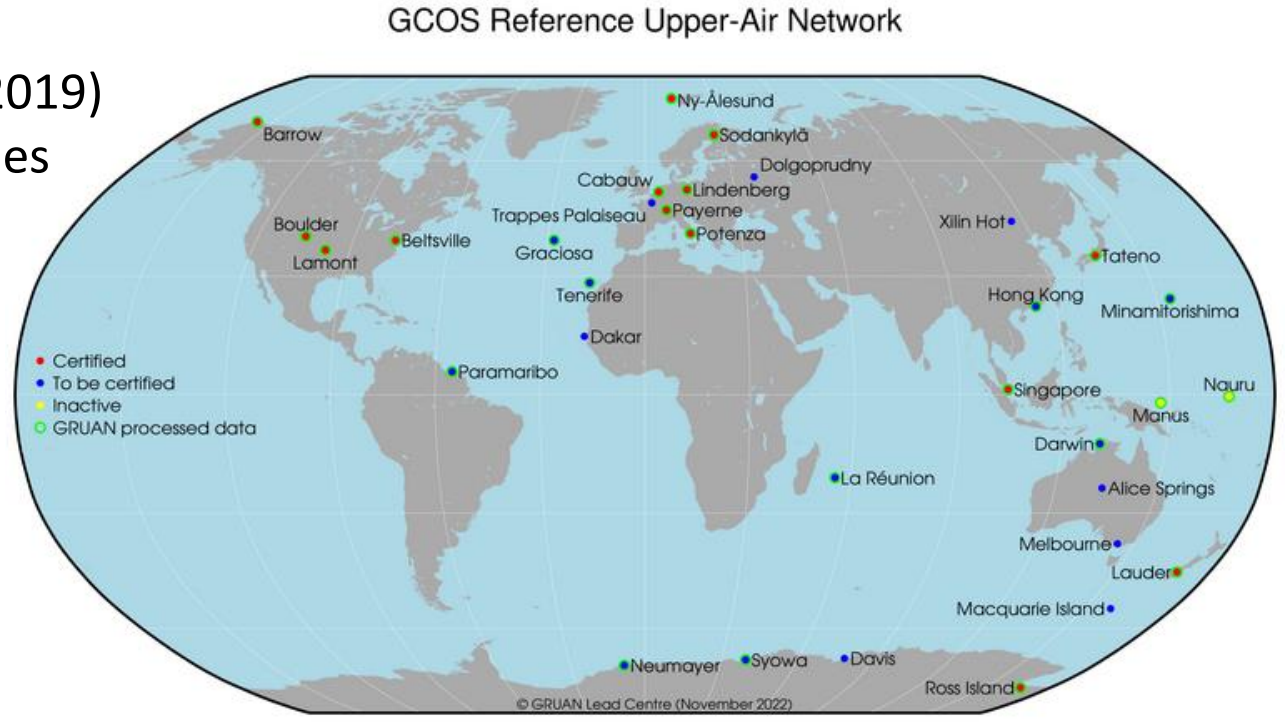
- Homogeneous and fully traceable - with quantified uncertainties
- 31 sites
  - 14 GRUAN certified
  - 23 with active data streams

GRUAN Processor

- developed within **GAIA-CLIM** (Carminati et al, 2019)
- simulates sat obs from GRUAN RS & uncertainties
- based on RTTOV and RadSim (NWP-SAF)

Upgraded (v6.3.b.0.1) to work with

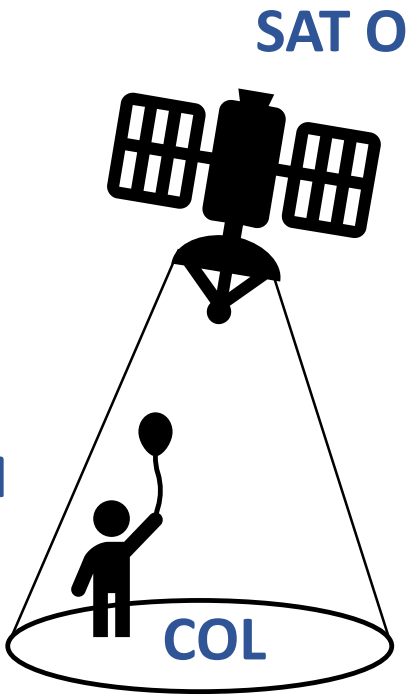
- latest RTTOV (v13.2)
- latest emissivity model (SurfEm)
- GRUAN RS41 & RHARM RS



Uncertainty analysis

- Total uncertainty

$$u_{all} = \sqrt{\sum u_i^2} = \sqrt{u_{i_{OBS}}^2 + u_{i_{SIM}}^2 + u_{i_{COL}}^2}$$



How many radiosonde are needed?

Expected error for bias (at 95% C.I.):

$$u_b = \left|\hat{b} - b\right| \leq 2\frac{\sigma(m_1 - m_2)}{\sqrt{N}} \sim 2\frac{\sqrt{u_{i_{OBS}}^2 + u_{i_{SIM}}^2 + u_{i_{COL}}^2}}{\sqrt{N}}$$

$$N \geq \left(2\sqrt{u_{i_{OBS}}^2 + u_{i_{SIM}}^2 + u_{i_{COL}}^2}/u_b\right)^2$$

FROM: Analysis of GRUAN METOP-SG-B1 MWI/ICI matchup statistics: executive summary

Assumptions:

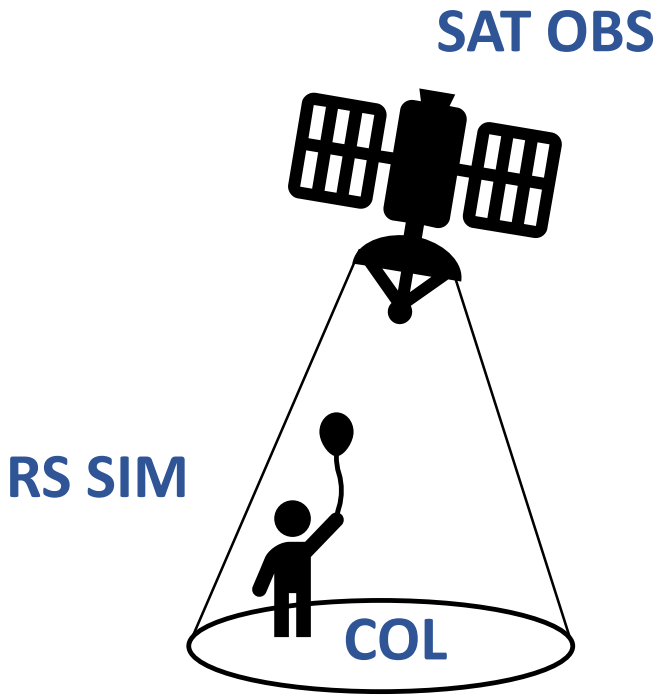
- u_{OBS}=0.5 K (for typical uncertainty of satellite observations)
- u_{SIM}=0.5 K (as in Buelher et al, 2004)
- four typical values of u_{COL} (*)

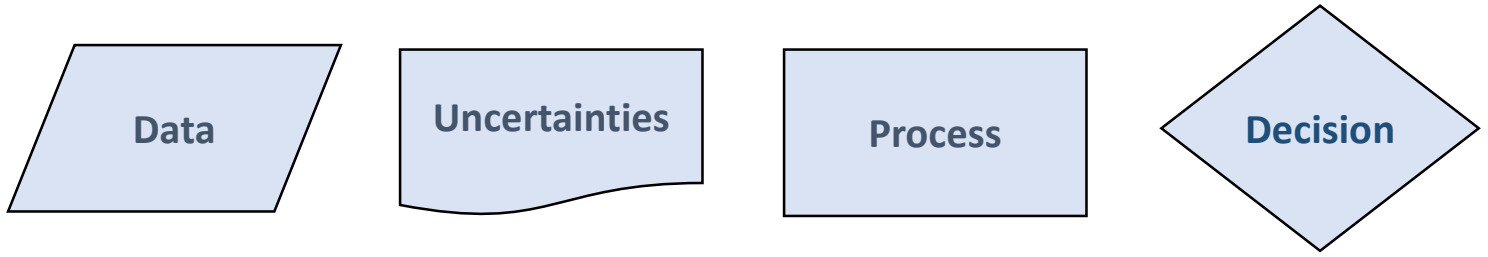
u_{COL}(K)	$\sigma(m_1-m_2)$ (K)	N(u_b=0.1 K)	N(u_b=0.15 K)	N(u_b=0.2 K)
0.75	1.03	425	189	106
1.00	1.22	600	267	150
1.25	1.43	825	367	206
1.50	1.65	1100	489	275

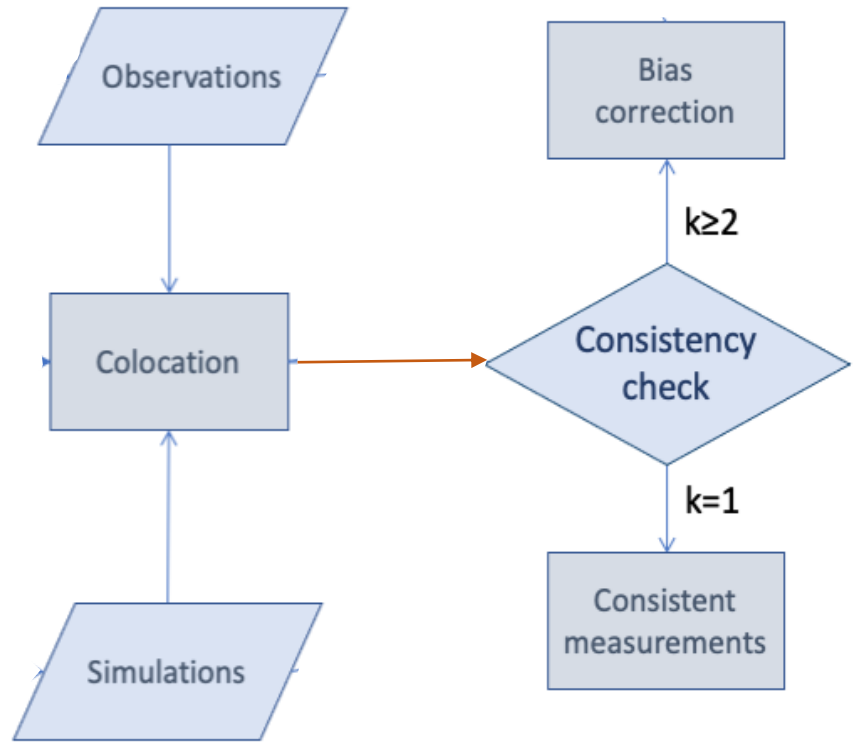
(*) corresponding to the values of the maximum of the histograms in Figure 7 of Buelher et al, 2004

Uncertainty analysis

- Review of uncertainty sources
- Uncertainty model diagram
- Identify knowledge gaps

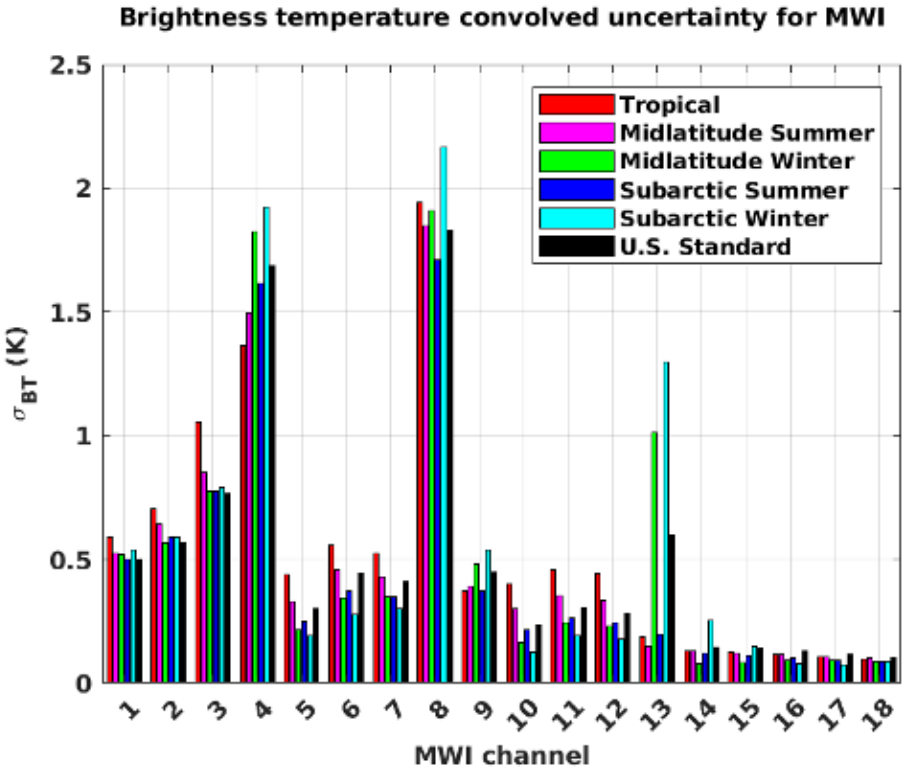





Observations
Colocation
Simulations
Consistency check
k≥2
Bias correction
k=1
Consistent measurements

Review of uncertainty sources

- Instrument uncertainty
  - Calibration
  - NEΔT
- Radiosonde uncertainty
  - GRUAN
  - RHARM
- Radiative transfer model (RTM) uncertainty
  - Absorption model



Gallucci et al, ACPD, egusphere-2023-3160

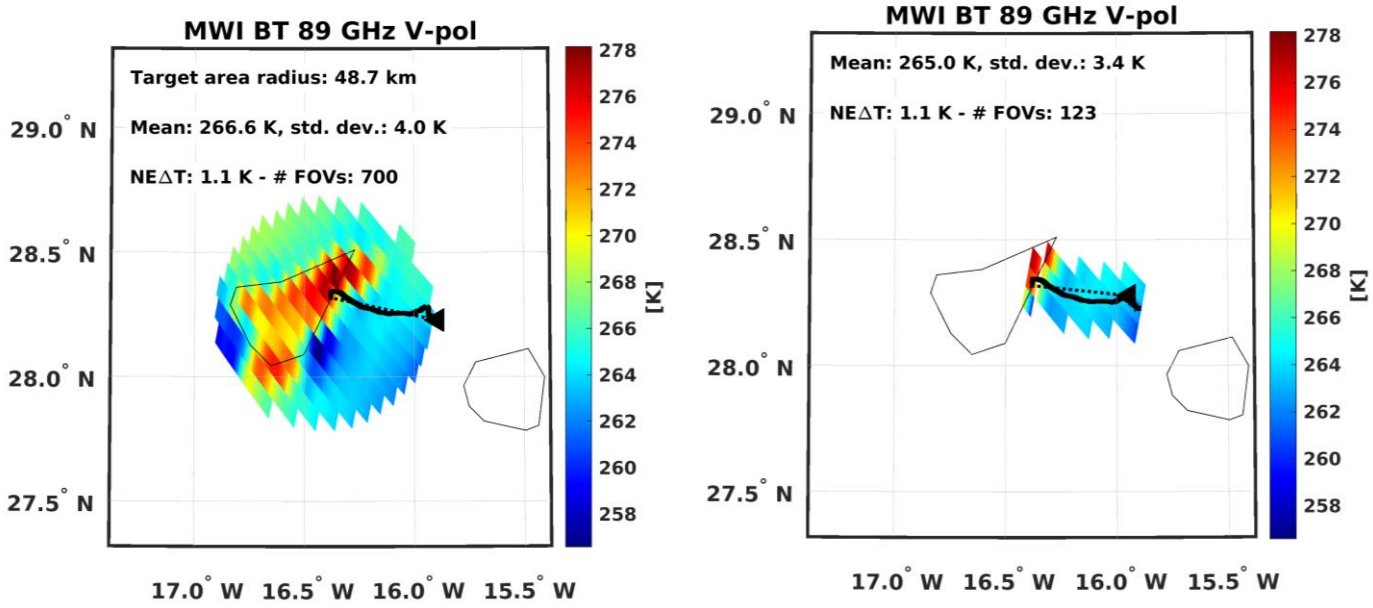
Knowledge gap analysis

- Spatial colocation
- Geolocation
- RTM contribution of:
  - Surface emissivity model
  - Atmospheric model
    - Optimization
    - Discretization

Knowledge gap analysis

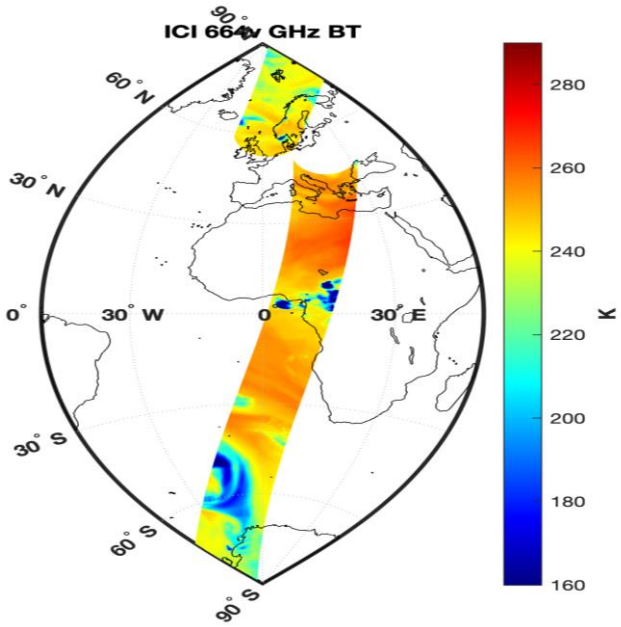
Spatial colocation

- Target area (TA) approach[1]
- $u_{BT} = STD(BT_{TA})$
- Circular, RS-driven



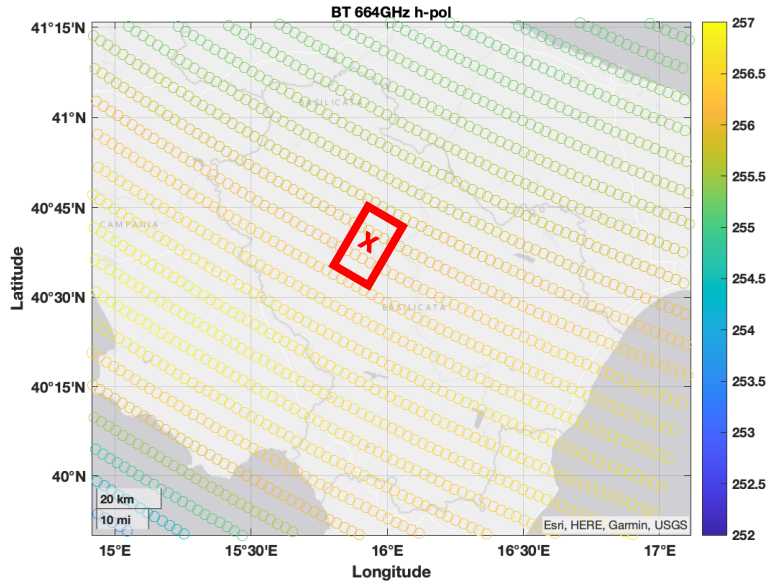
[1]Buehler et al, 2004; Moradi et al, 2010

Knowledge gap analysis



Geolocation

- Analysis based on 183-GHz channels[1]
  - Average geolocation error ~6 km
  - ~113 km^2
- Same order of magnitude of MWI/ICI IFOV distances
  - ~2x9 km (cross-track x along-track)
- u_{GEOL} = STD($BT_{(3x5\text{-}IFOV)}$)
  - ~144 km^2
  - Based on simulated MWI & ICI lev1b data



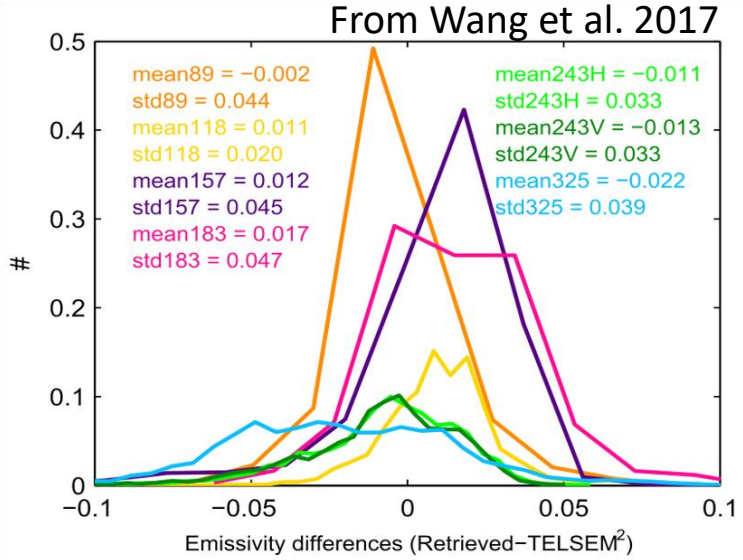
[1]Papa et al, 2021 doi: 10.1109/TGRS.2020.3024677

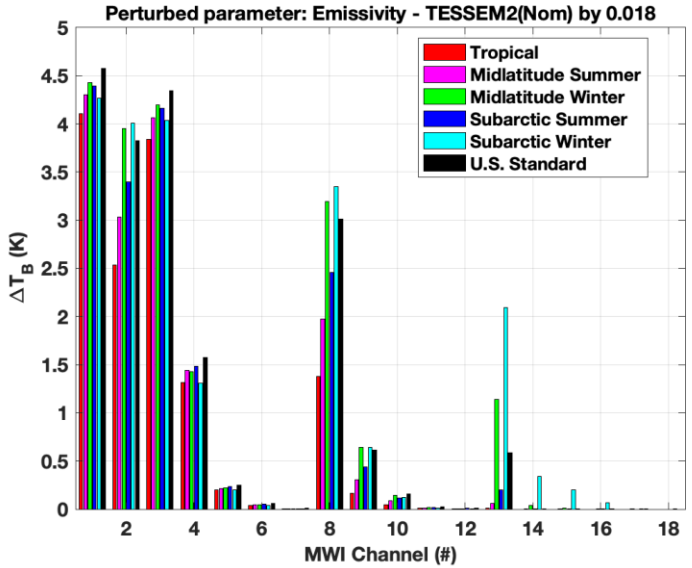
Knowledge gap analysis

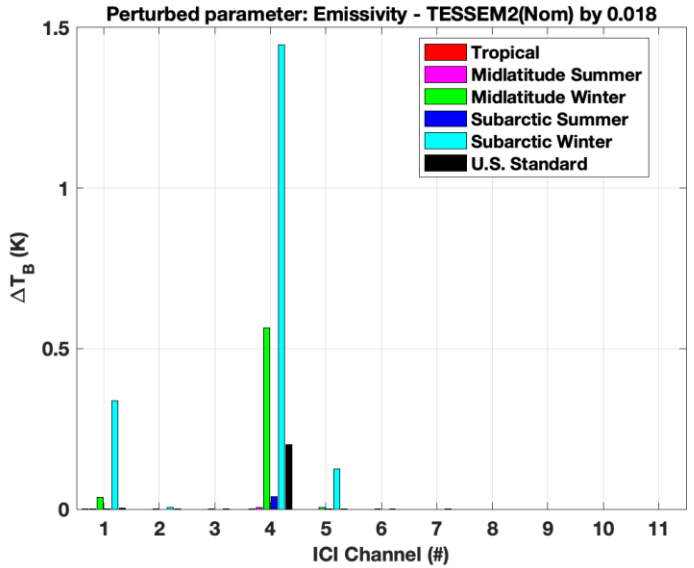
RTM contribution of surface emissivity

- RTM perturbation
- According to land/sea surface uncertainty estimate
  - σ_e = 0.05 (over land) [1]
  - σ_e = 0.018 (over ocean) [2]

From Wang et al. 2017





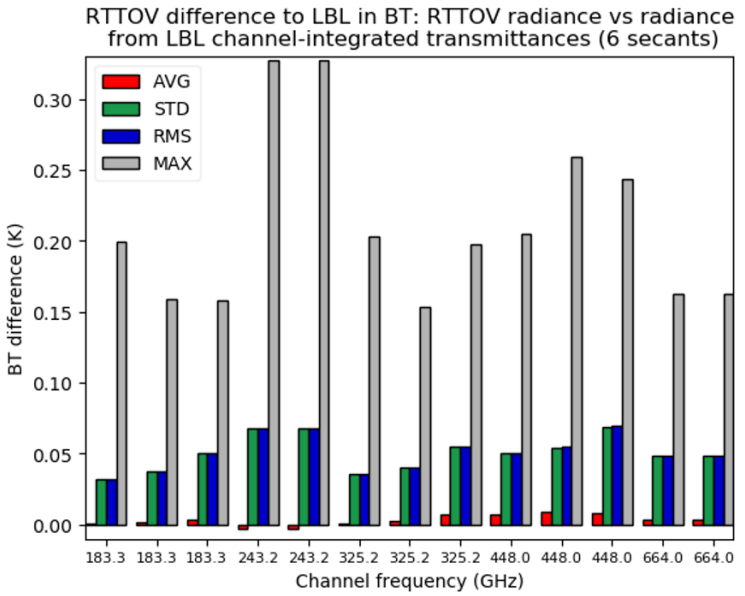


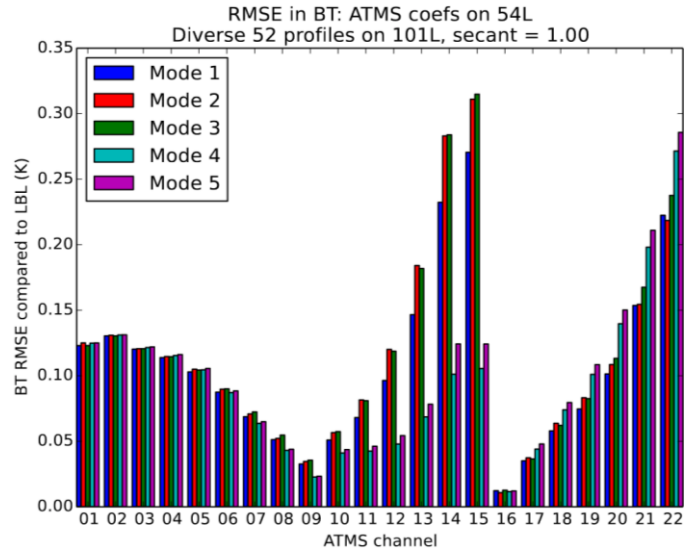
[1]Wang et al. 2017, doi: 10.1175/JTECH-D-16-0188.1
[2]Kilic et al. 2023, doi: 10.1029/2022EA002785

Knowledge gap analysis

RTM contribution of atmospheric model

- RTM optimization[1]
  - Fast parameterized (RTTOV) vs. accurate line-by-line (LBL)
  - RTTOV vs LBL BT
    - diverse 83 profile set and six zenith angles
- Vertical interpolation[2]
  - Discrete levels vs. dense atmosphere
  - $N_{user\ lev} > N_{coef\ lev}$
  - Adapted to MWI/ICI from ATMS channels



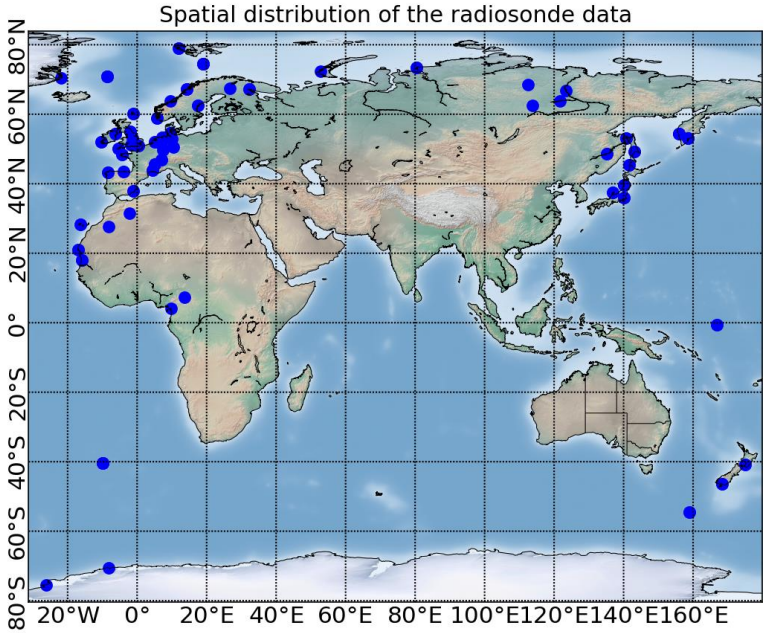


[1]Hocking, NWPSAF, LBL vs RTTOV v13
[2]Hocking 2014, NWPSAF Techl Rep No: 590

Demonstration of VICIRS tool

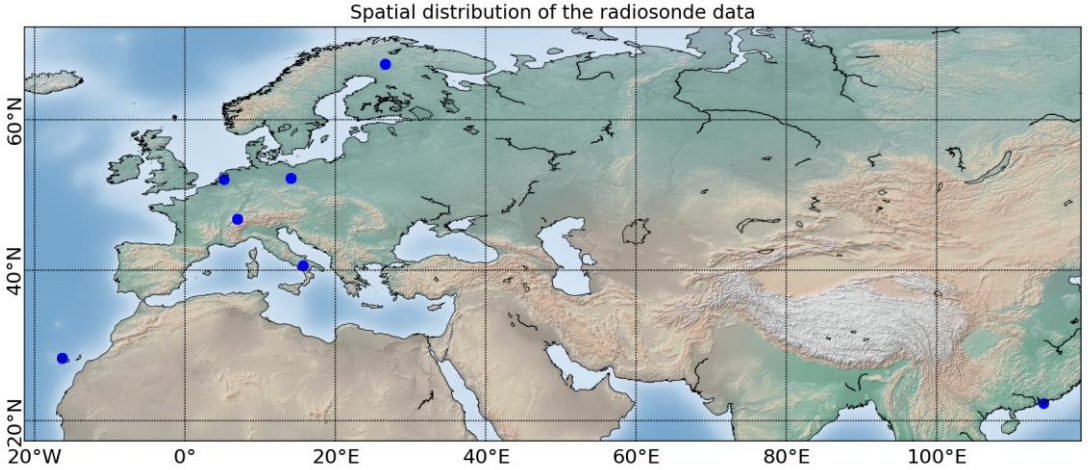
Simulated dataset (112 match-ups)

- **MWI** and **ICI L1B** simulated dataset
- Colocated **RHARM** RS
  - 2007-09-12 08:00 to 2007-09-12 12:00
  - 2008-02-23 08:30 to 2008-02-23 10:30



Real observations (65 match-ups)

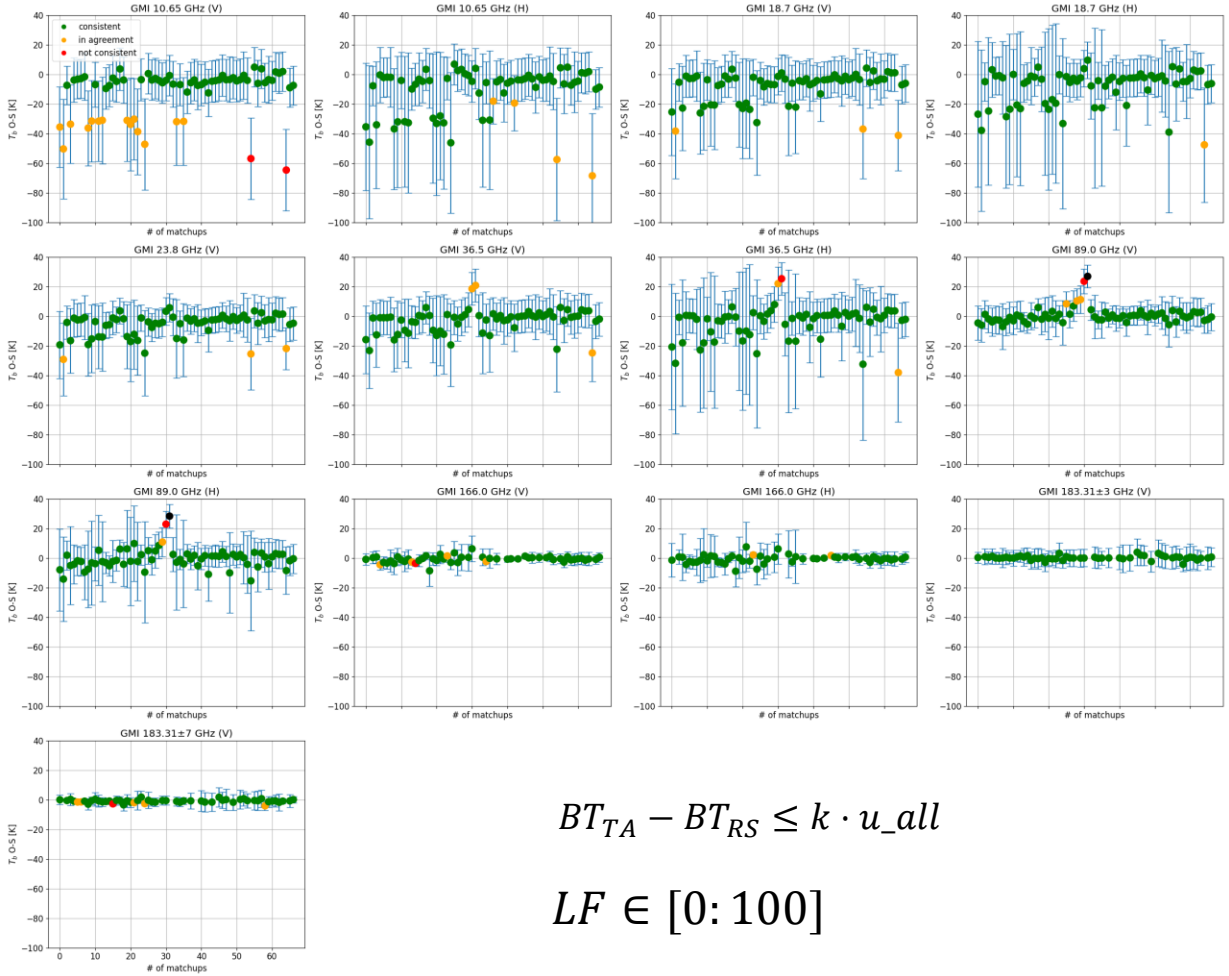
- **GMI:** NASA Global Precipitation Measurement Microwave Imager
- Colocated **GRUAN** RS
  - 2023-01-01 00:00 to 2023-04-30 23:59
  - 2023-09-01 00:00 to 2023-11-30 23:59



PRELIMINARY RESULTS WITH REAL OBS

GMI – GRUAN

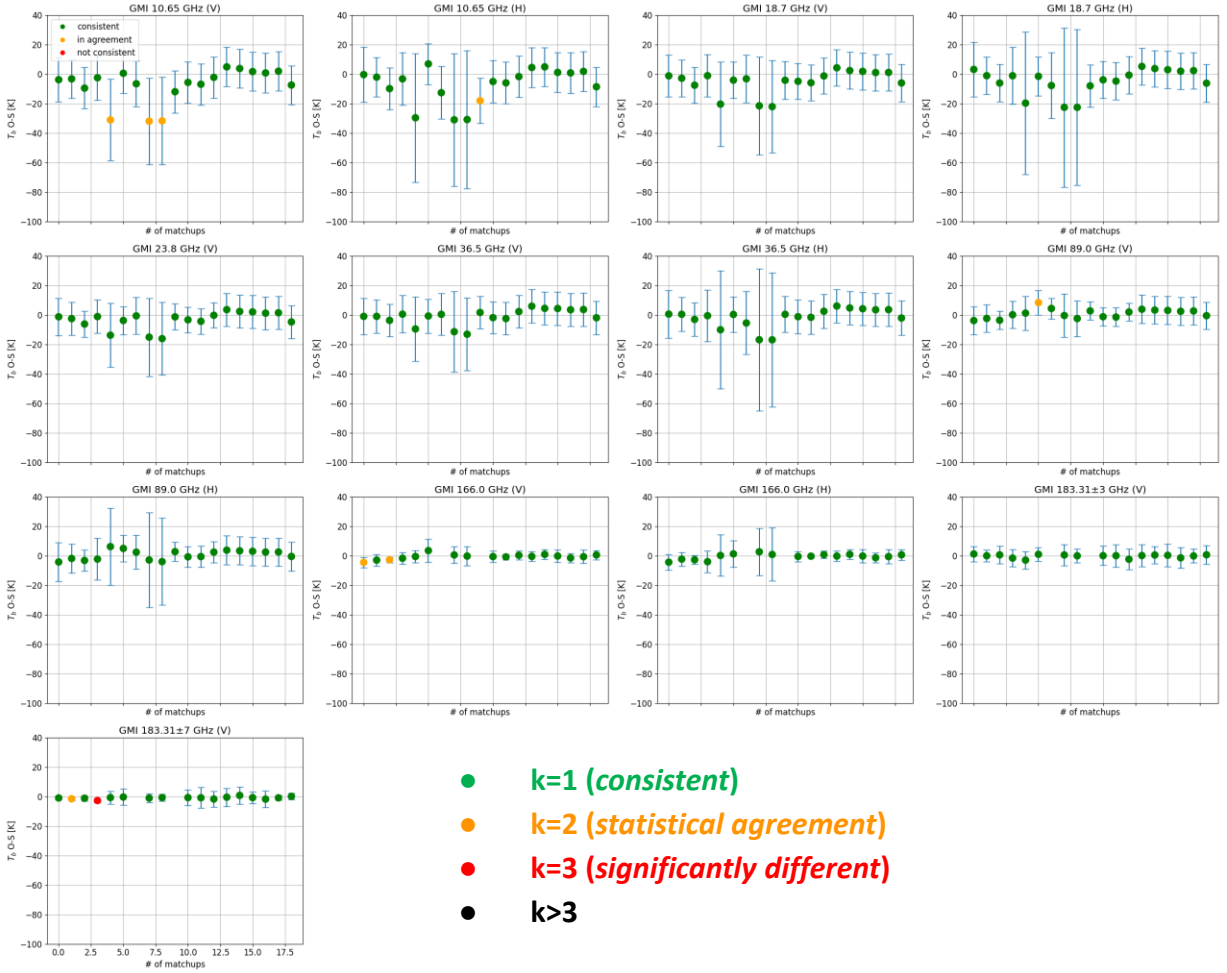
GMI-GRUAN 60 match-ups, $temporal\ distance = 3$



$$BT_{TA} - BT_{RS} \leq k \cdot u\_all$$

$$LF \in [0:100]$$

GMI-GRUAN 19 match-ups, $temporal\ distance = 1$



- **k=1 (*consistent*)**
- **k=2 (*statistical agreement*)**
- **k=3 (*significantly different*)**
- **k>3**

PRELIMINARY RESULTS WITH REAL OBS

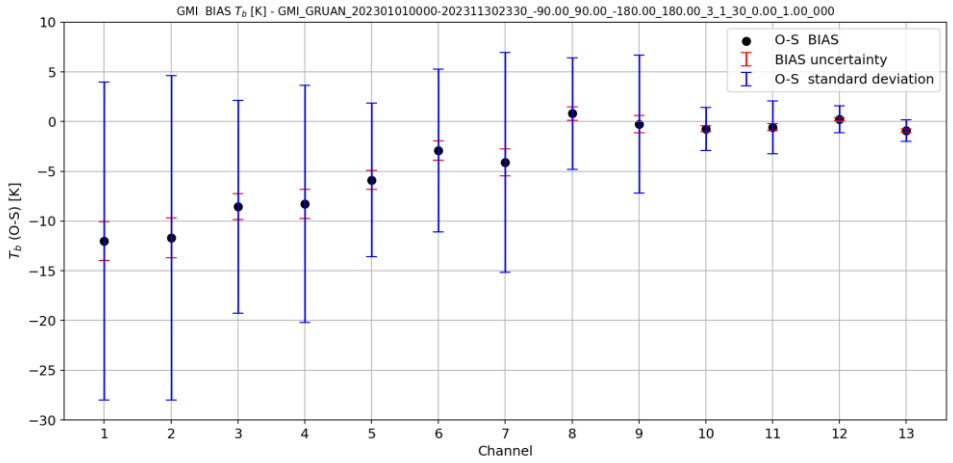
GMI – GRUAN

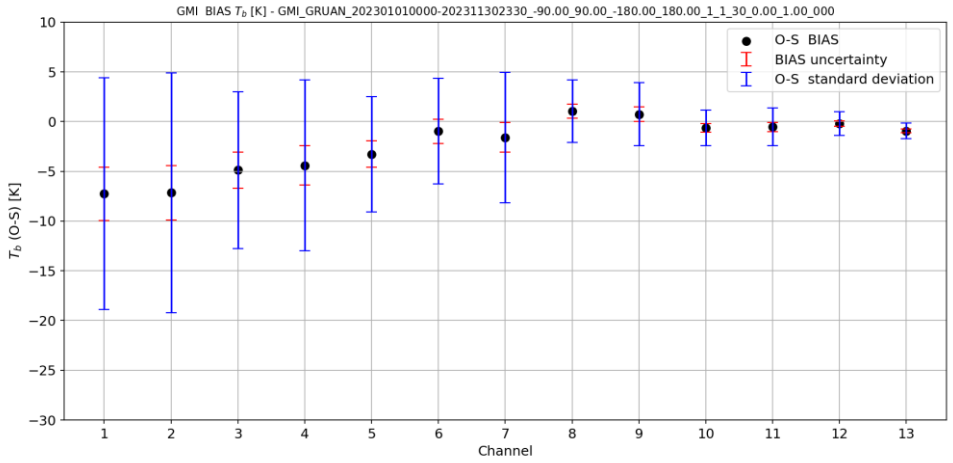
TA $\%cloudy = 0$,
$LF \in [0:100]$

GMI-GRUAN 67 match-ups, $temporal\ distance = 3$ h

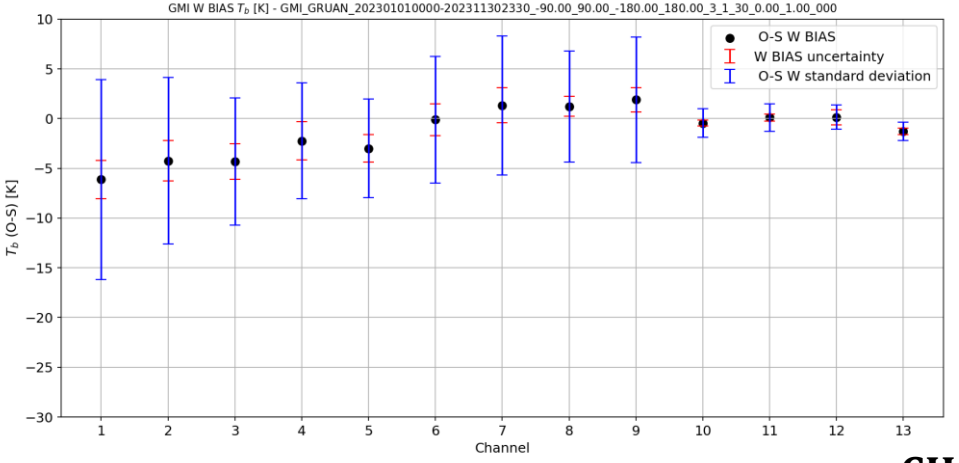
GMI-GRUAN 19 match-ups, $temporal\ distance = 1$ h

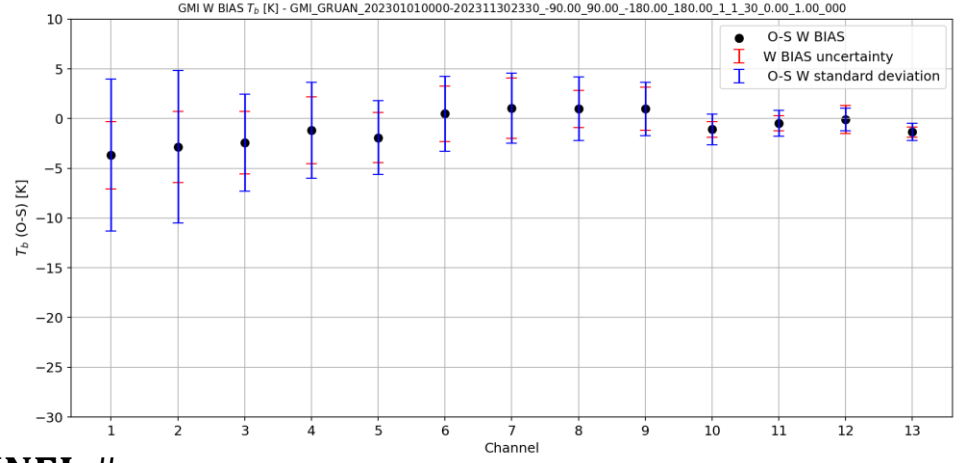
BIAS





weighted BIAS





CHANNEL #

Summary and outlook

- VICIRS tool has been developed
  - Flexible & user friendly
  - Handles GRUAN and RHARM RS
  - Tested with simulated (MWI/ICI) and real (GMI) observations

- Current limitations
  - RHARM v1 archive (n_{lev} & P_{min})
  - land fraction not available for GMI

  will be resolved with RHARM v2 & MWI/ICI land fraction

- Future work
  - Further and refined uncertainty characterization
    - e.g., temporal collocation, NWP,…
  - Assess overall quality of estimated bias and accuracy
    - vs. RS quantity and quality
  - After launch, adopt VICIRS tool within the MWI/ICI Cal/Val activities