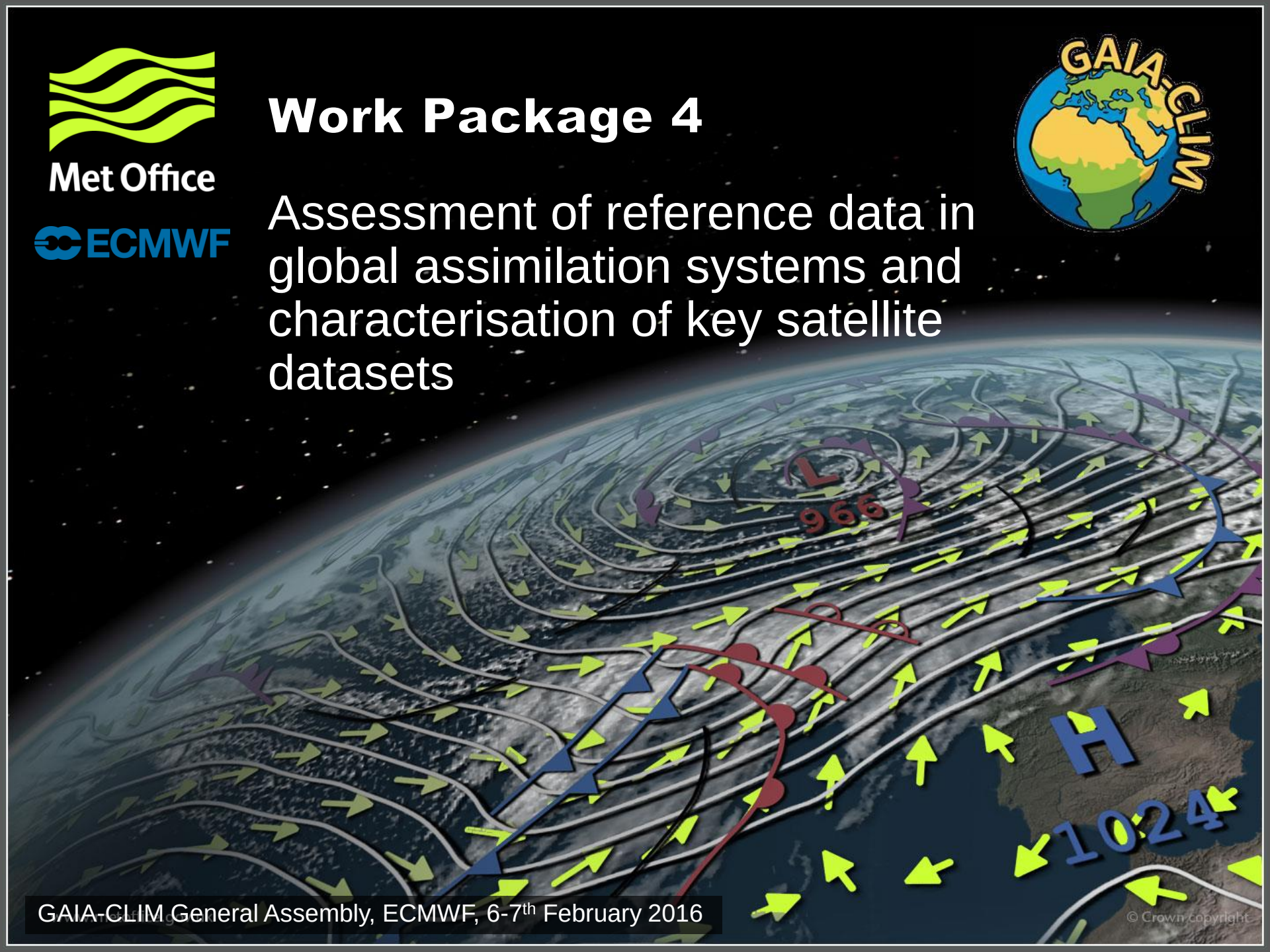
Work Package 4

Assessment of reference data in global assimilation systems and characterisation of key satellite datasets

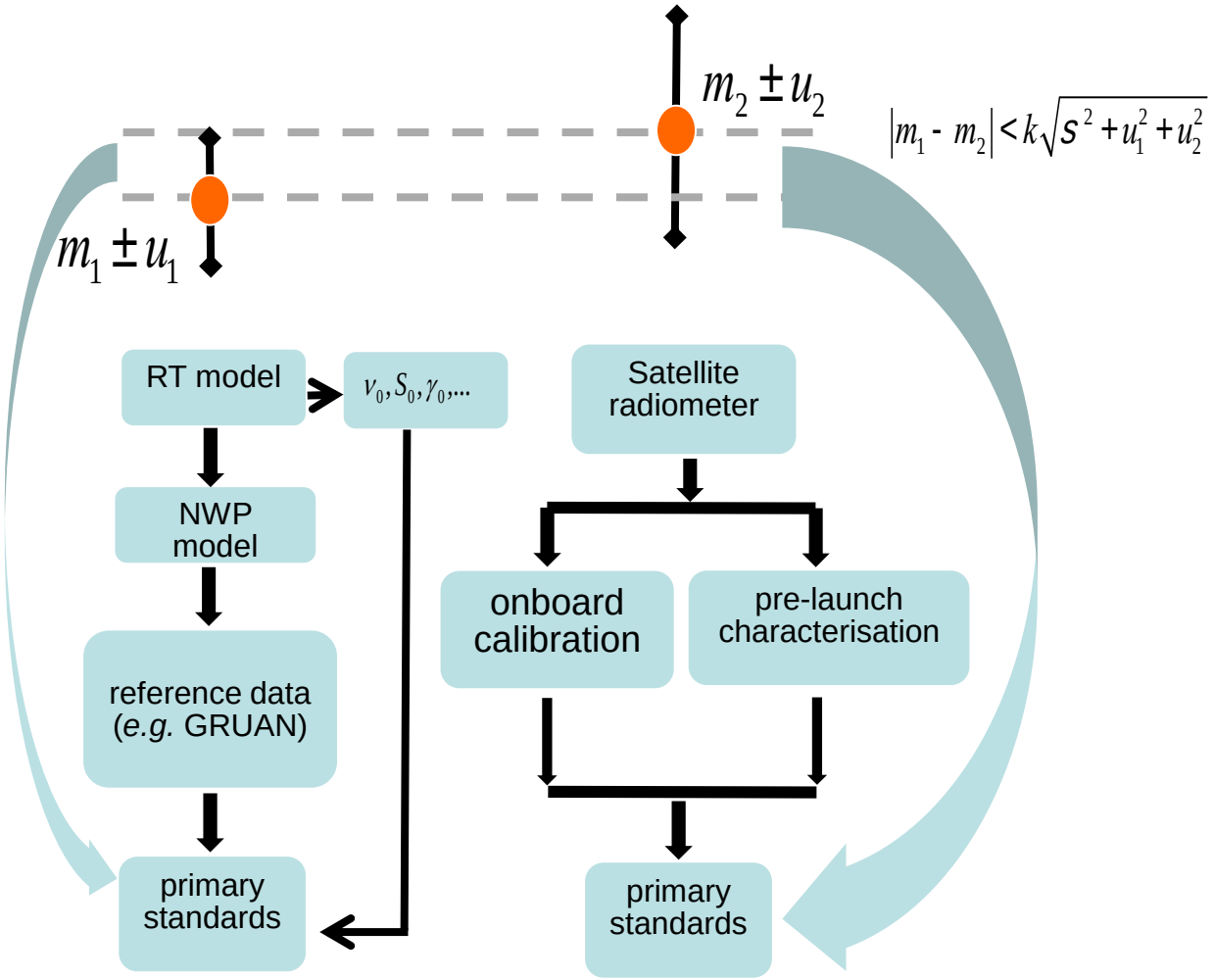


Outline

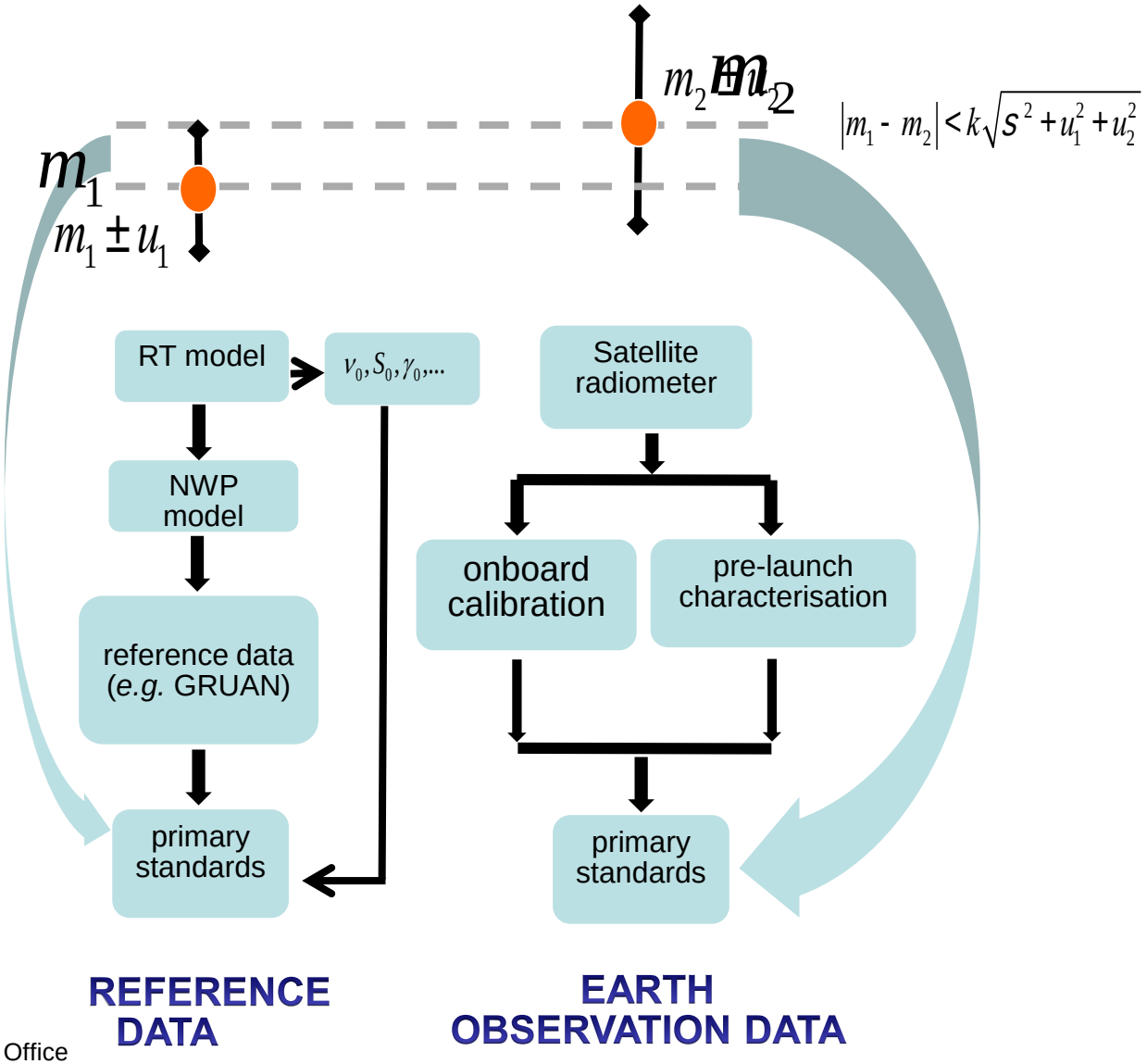
- WP4 Overview (Bill)
- Assessment of FY-3C (Heather)
- The GRUAN processor (Fabien & Bruce)
- Plans for Year 3 (Bill)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 640276.

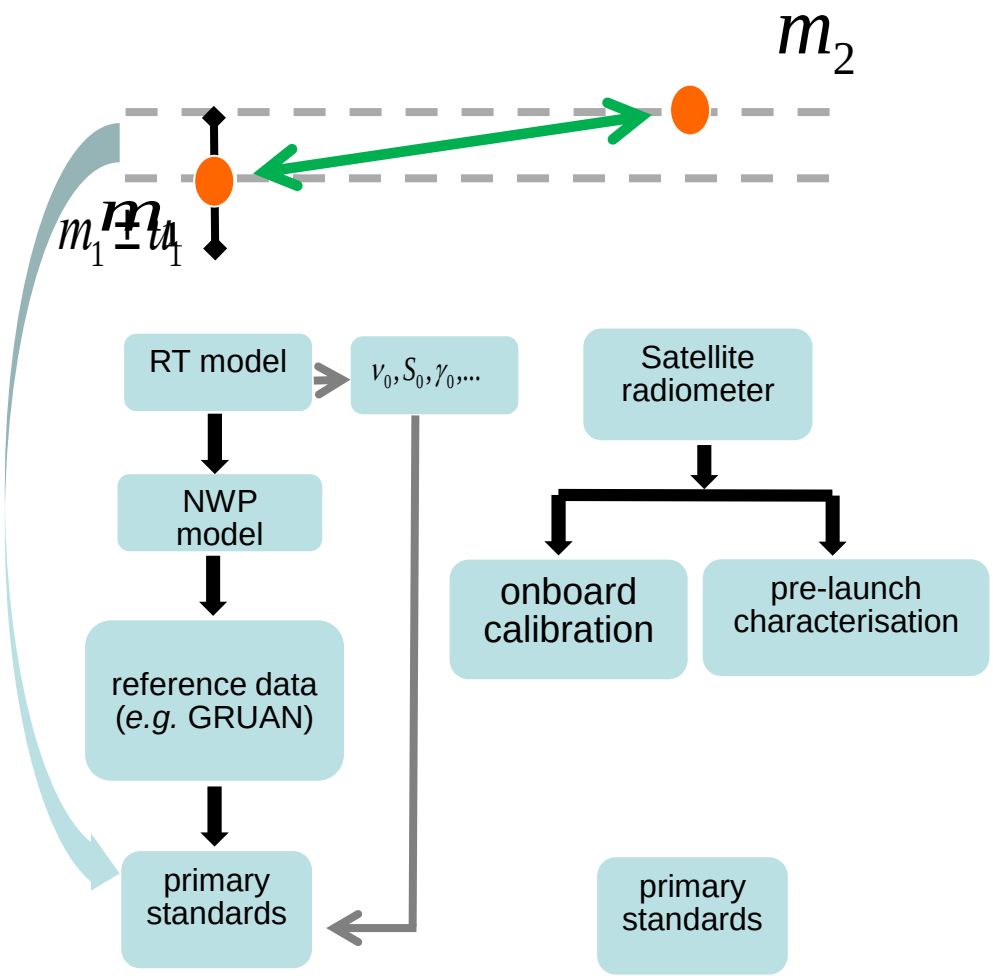
Background:
Validation of EO data: Idealised case



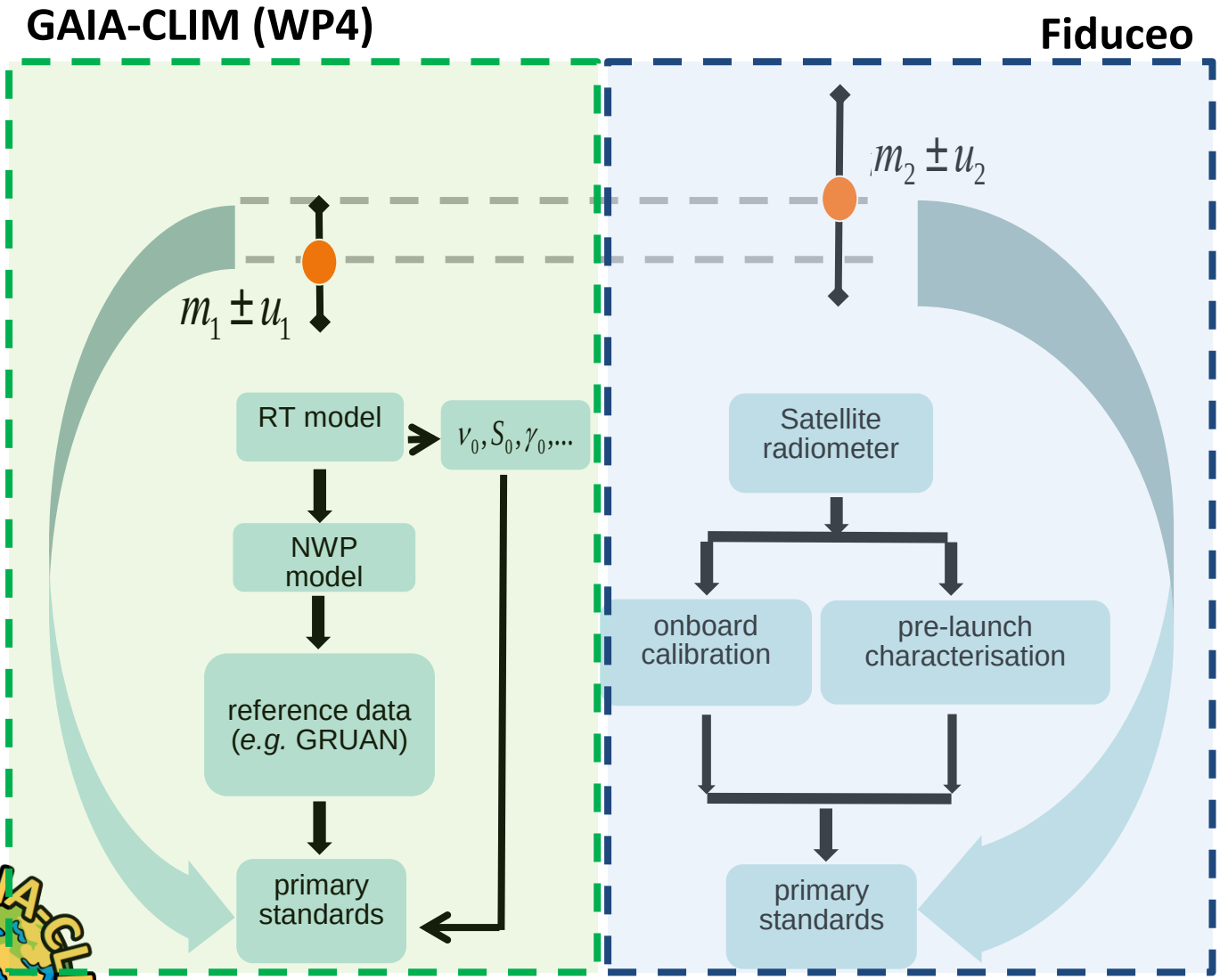
Background:
Validation of EO data: current situation



Background:
The Aim of GAIA CLIM WP4



GAIA-CLIM (WP4) & Fiduceo



- see joint GAIA-CLIM session on wednesday

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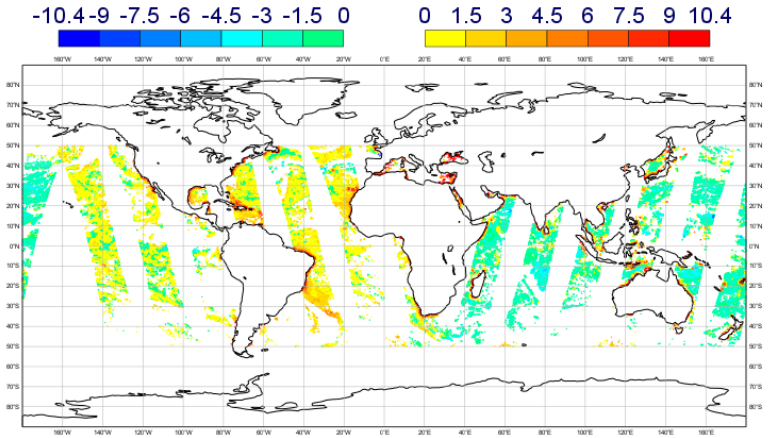
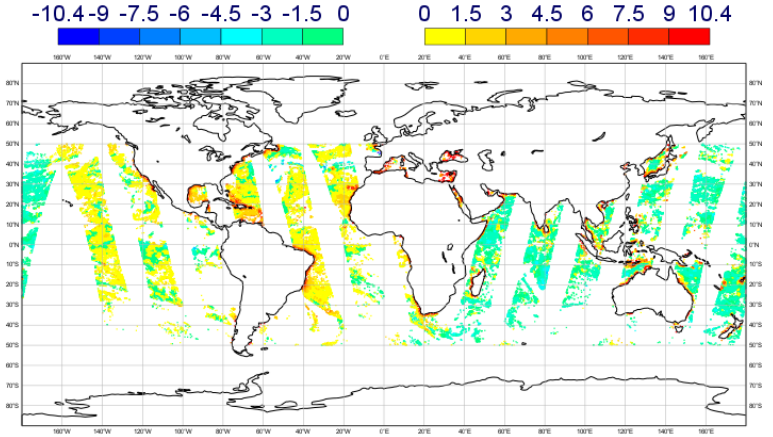
GAIA-CLIM WP4
Demonstrating the value of NWP for EO validation

FY-3C MWRI 10H channel

ECMWF O – B (minus global average)



Met Office O – B (minus global average)



N.B. collocated data → same sample (12 hour period)

Approx. uncertainties in NWP TOA T_B

Temperature sounding radiances	0.1-0.5K
Humidity sounding radiances	1K
Surface sensitive radiances	2-5K

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Aims

• Demonstrating the capability of NWP systems to validate measurements from key new meteorological satellites.

• Developing, as a demonstrator of a general approach, the infrastructure required to monitor reference network data (GRUAN) in NWP (global) models and produce near real-time statistics on the comparison.

• Defining the measurement performance requirements for reference data sources for the validation of NWP and Reanalysis models and hence satellite observations.

• Illustrating how the methods developed in this WP, targeting Level 1 (radiance) datasets for temperature and humidity estimation, extend to a broader range of atmospheric, land surface and ocean ECVs.

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Deliverables (M1-M24)

D4.1 Initial input from WP4 to the gap analysis and impacts document (led by MO; M4)

D4.2 Individual reports on validation of satellites v1 (led by MO; M12, M24, M34)

- *Year 1 (AMSR-2); Year 2 (FY-3C); Year 3 (GMI and MTVZA)*

D4.3 Review of and input to GAID aspects relevant to WP4 (led by MO; M16 & M24).

- *New gaps identified (4.07-4.11)*

D 4.4 Publicly available web-based monitoring pages showing a comparison of GRUAN observations with MO and ECMWF systems as an input to the virtual observatory. (MO; M24)

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GAID V4 - WP4 input

- **G4.01** Lack of traceable uncertainty estimates for NWP and reanalysis fields & equivalent TOA radiances – relating to temperature
- **G4.02** Lack of traceable uncertainty estimates for NWP and reanalysis fields & equivalent TOA radiances – relating to humidity
- **G4.07** Error correlations for reference sonde (GRUAN) measurements
- **G4.08** Estimates of uncertainties in microwave ocean surface emissivity models
- **G4.09** Estimates of uncertainties in land surface microwave emissivity atlases
- **G4.10** Estimates of uncertainties in land surface infrared emissivity atlases
- **G4.11** Geographical sampling of reference in-situ data

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Evaluation of FY-3C MWRI and MWHS-2 at ECMWF and the Met Office

Heather Lawrence, Fabien Carminati, Stuart Newman, Bill Bell, Niels Bormann, Alan Geer

ECMWF, Met Office

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 640276.

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FY-3C Satellite

- China Meteorological Administration (CMA)'s polar-orbiting satellite
- Launched 2013, carries instruments important to NWP and Reanalysis:
- **MWHS-2**: microwave humidity sounder
- MWTS-2: microwave temperature sounder (stopped working 2014)
- **MWRI**: microwave imager
- IRAS: infra-red sounder
- GNOS: GPSRO instrument

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Previous Work:

- Initial Evaluation of MWTS-2
- Evaluation of MWHS-2: generally good quality data

(Lu et al, ECMWF Tech. Memo. 2015)

Year 2 of GAIA-CLIM:

- Evaluate long-term performance of MWHS-2
- Extend evaluation to the MWRI instrument

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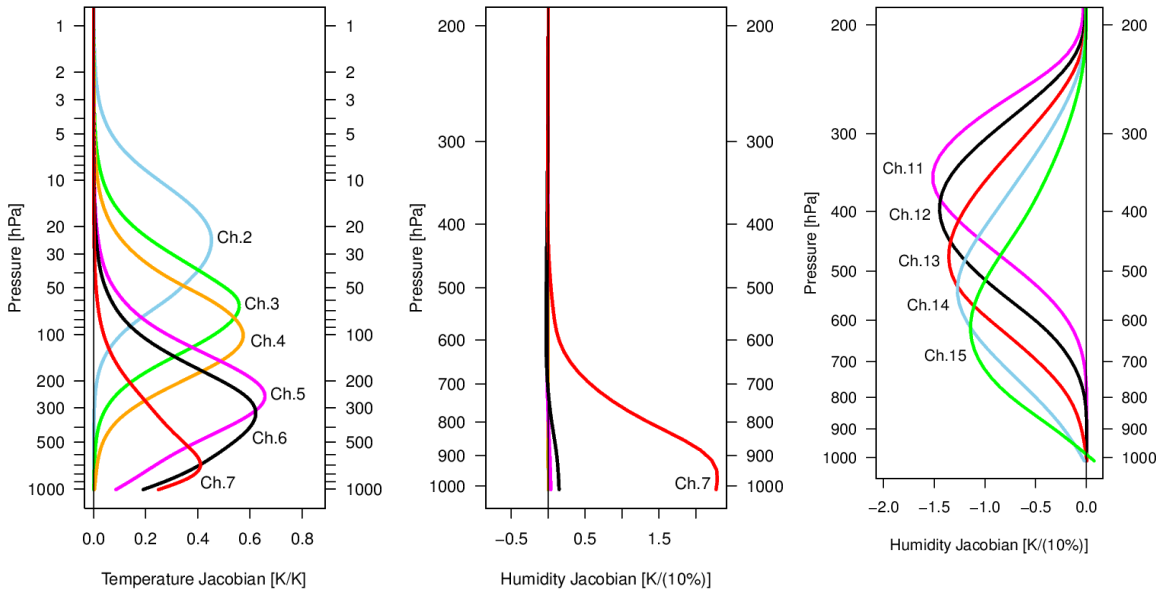
FY-3C MWHS-2

- Humidity sounding channels at 183 GHz
- New temperature sounding channels at 118 GHz
- All channels also very sensitive to cloud



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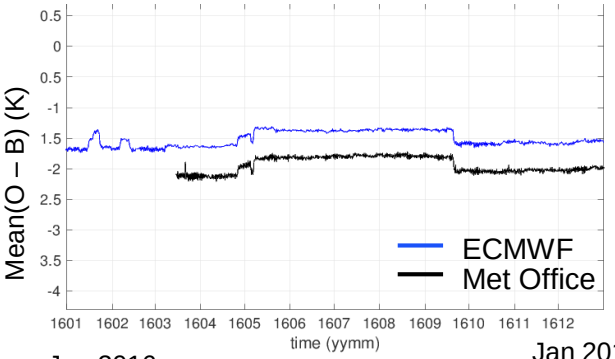
FY-3C MWHS-2

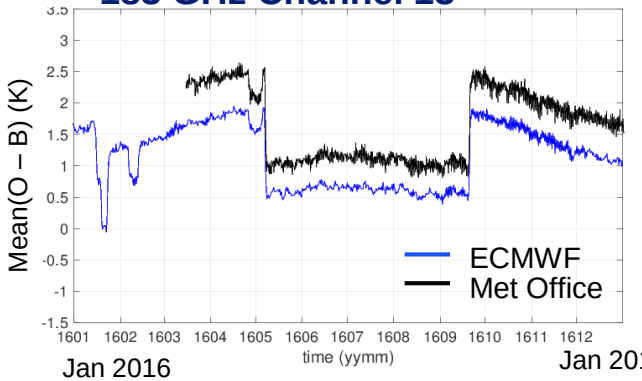
1-year time series for both ECMWF and Met Office data:

118 GHz Channel 4



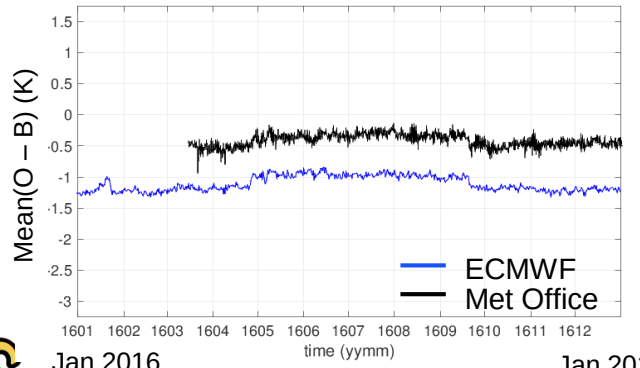
Jan 2016 Jan 2017

183 GHz Channel 13



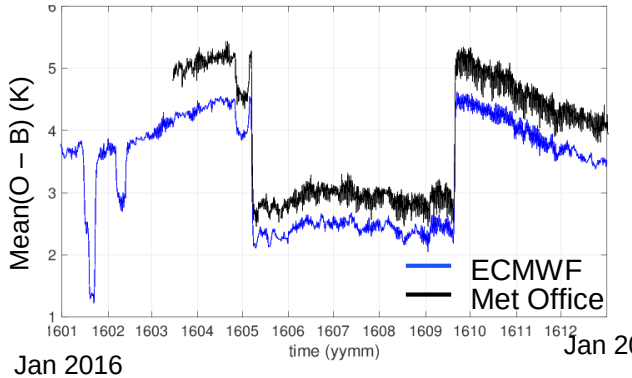
Jan 2016 Jan 2017

183 GHz Channel 11



Jan 2016 Jan 2017

183 GHz Channel 14



Jan 2016 Jan 2017

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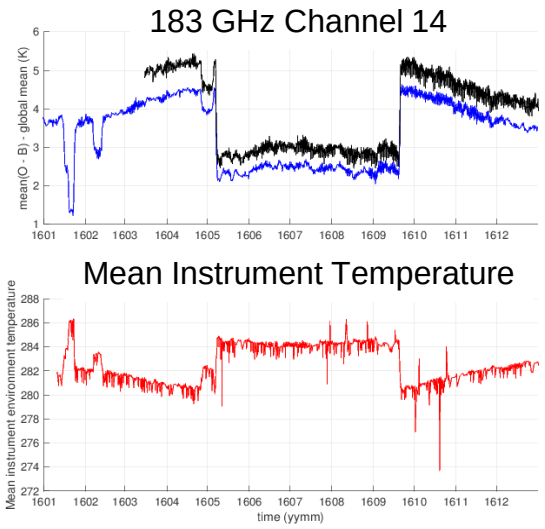
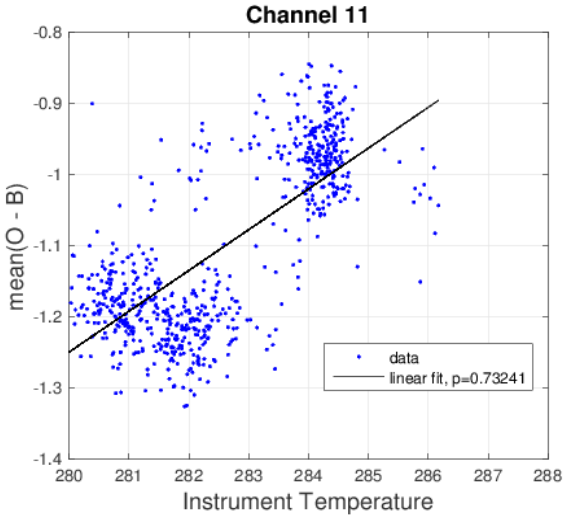
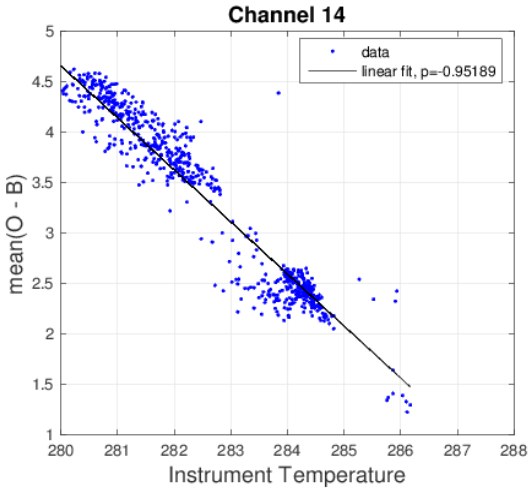
FY-3C MWHS-2

Bias jumps correlated to instrument temperature changes:







Most channels are weakly positively correlated, channels 13 and 14 are strongly negatively correlated

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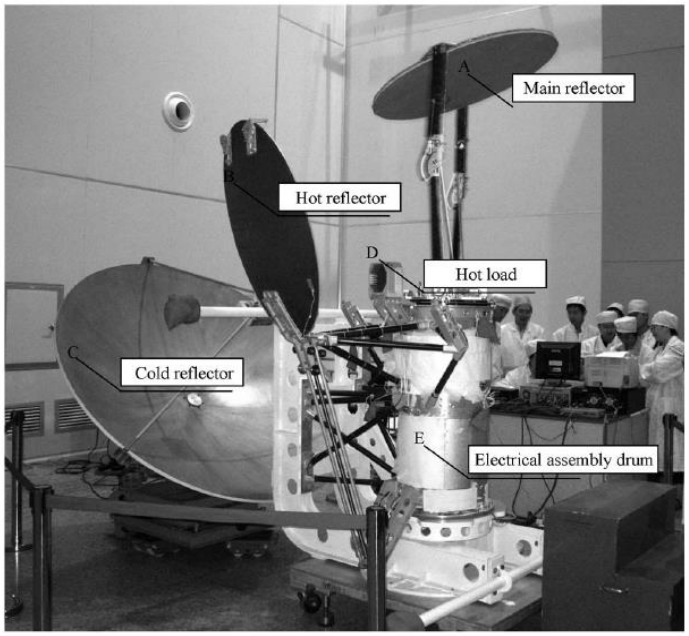
FY-3C MWRI



- Microwave imager channels 10 – 90 GHz
- Sensitive to total column water vapour, cloud and precipitation
- New Calibration procedure with 3 reflectors
- ‘Effective warm load’ must be calculated to include emission received from the back lobes of the reflectors

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FY-3C MWRI

O – B calculations for Met Office and ECMWF

Radiative Transfer Models:

Met Office: RTTOV-11, FASTEM-6
ECMWF: RTTOV-11, FASTEM-6

Cloud Treatment:

Met Office: Clear-sky radiative transfer
ECMWF: All-sky radiative transfer

Cloud Screening:

Screen using the ‘normalised polarisation difference’ at 37 GHz (both observations and background) for both ECMWF and Met Office (threshold 0.05)

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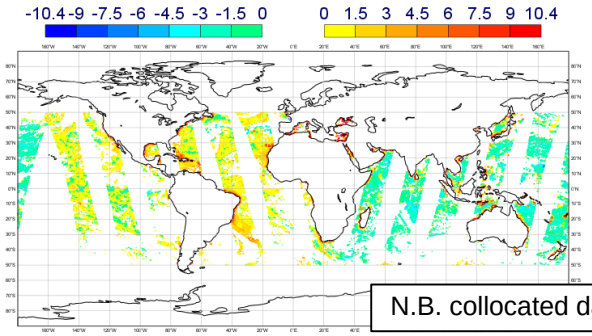
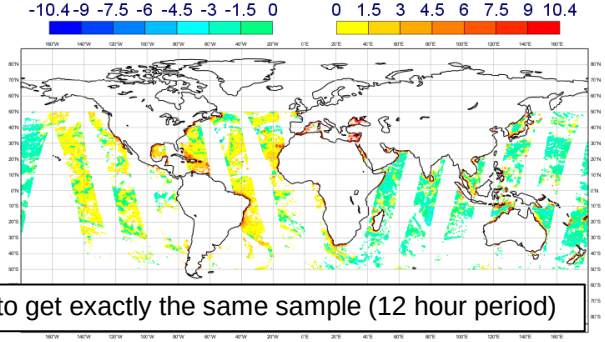
FY-3C MWRI: Ascending/Descending biases

10H channel

ECMWF O – B minus global average

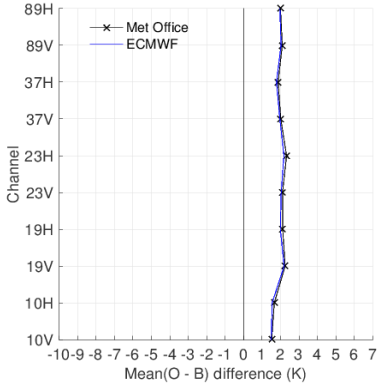


Met Office O – B minus global average

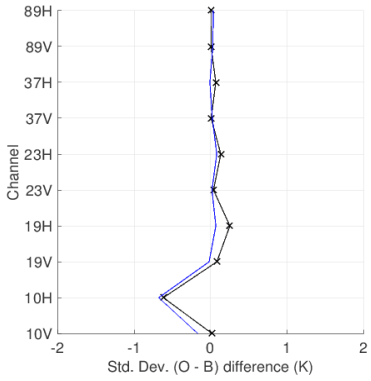


N.B. collocated data to get exactly the same sample (12 hour period)

Mean(O – B): Ascending – Descending:



Stdev(O – B): Ascending - Descending



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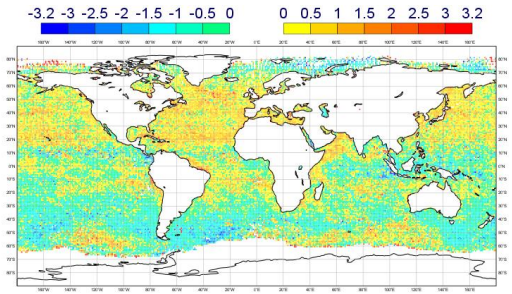
MWRI: Complex solar-dependent biases?

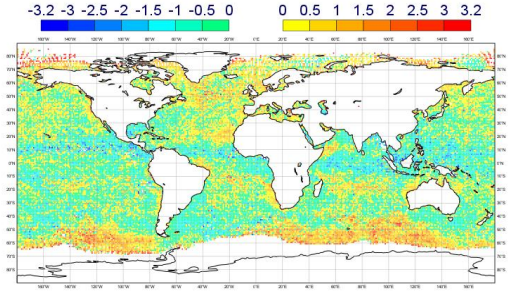
Mean(O – B) minus global average

ascending

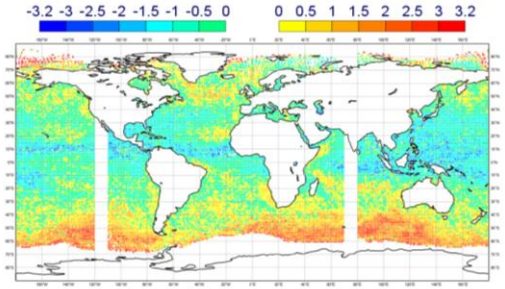
descending

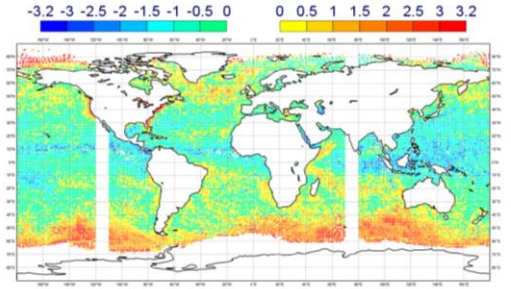
ECMWF
MWRI 37V



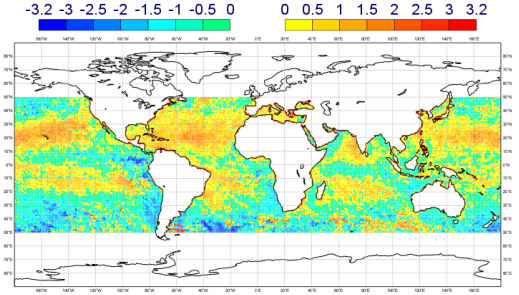


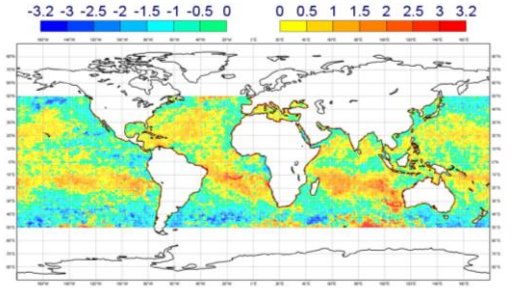
ECMWF
AMSR-2 37V





Met Office
MWRI 37V





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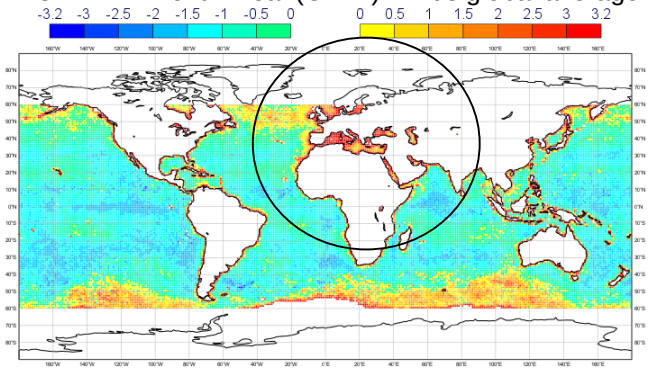
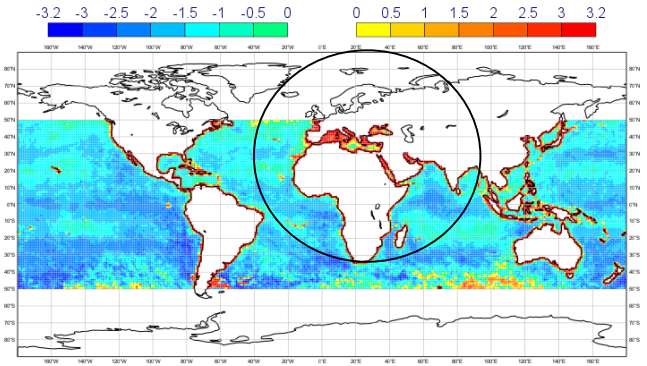
FY-3C MWRI: RFI at 10 GHz

10 V channel

ECMWF 1 month mean(O – B) minus global average

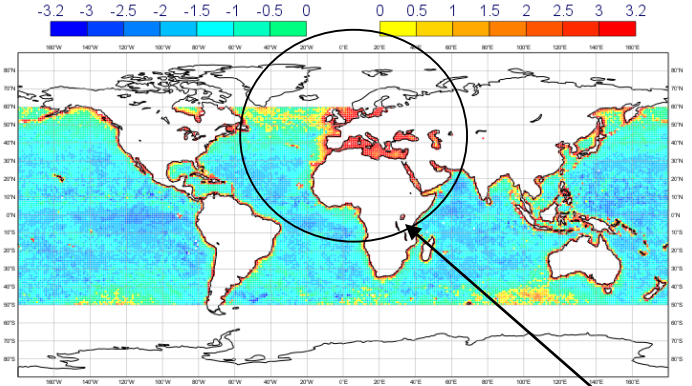


Met Office 1 month mean(O – B) minus global average

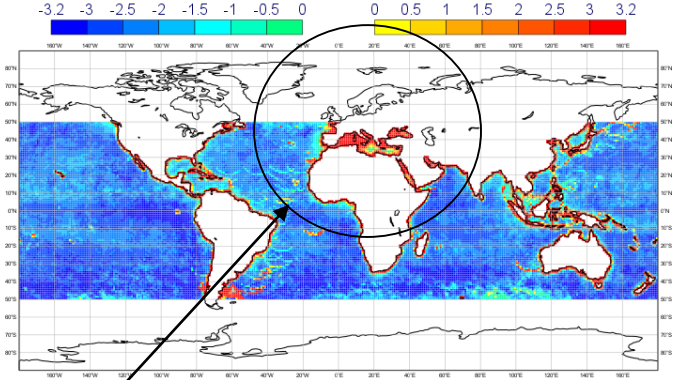


10 H channel

ECMWF 1 month mean(O – B) minus global average



Met Office 1 month mean(O – B) minus global average



Large positive biases over Europe for the 10 GHz H/V channels

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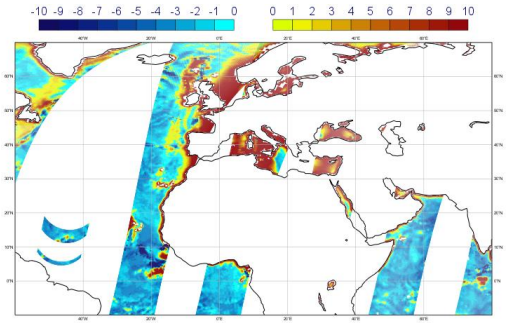
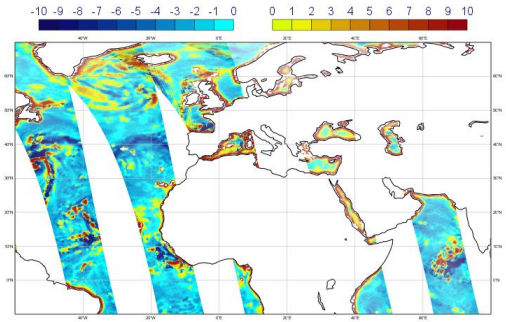
FY-3C MWRI: RFI at 10 GHz

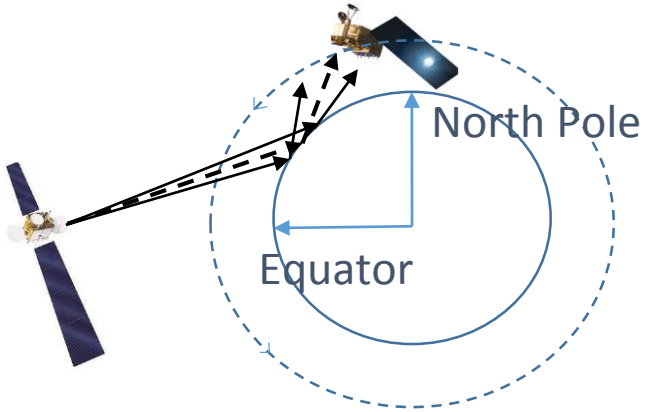
10H descending



10H ascending



Could be interference from a geostationary TV satellite:



But specified passband includes an un-protected region so not necessarily illegal

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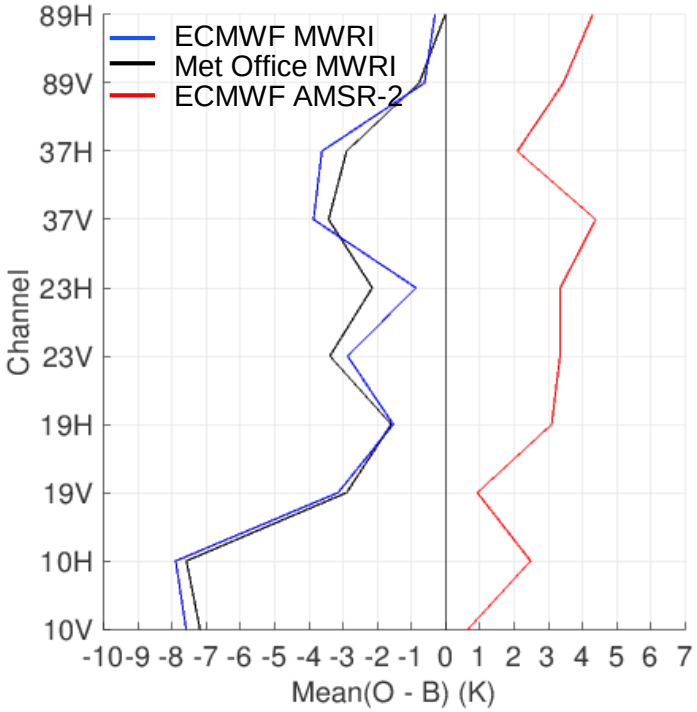
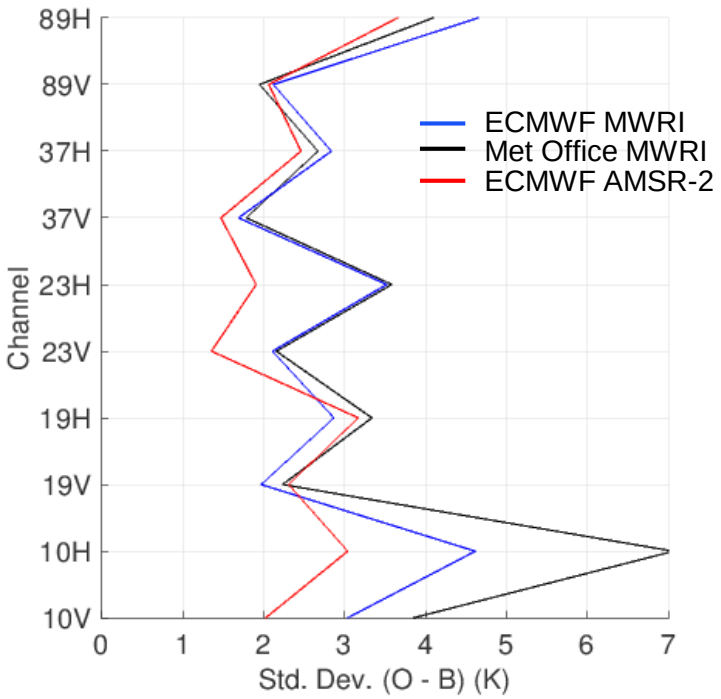
FY-3C MWRI

Mean and Standard Deviation of O - B

Ascending & Descending data, cloud-screened



Descending data only, cloud-screened



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Summary

- MWHS-2 have biases which vary with instrument temperature
- MWRI has a large ascending/descending bias for all channels
- RFI found for the 10 GHz channels
- MWRI has cold biases at both NWP centres, compared to warm biases seen for AMSR-2

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The GRUAN Processor

Fabien Carminati[1], Bruce Ingleby[2], and Bill Bell[1]

[1]MetOffice, [2]ECMWF

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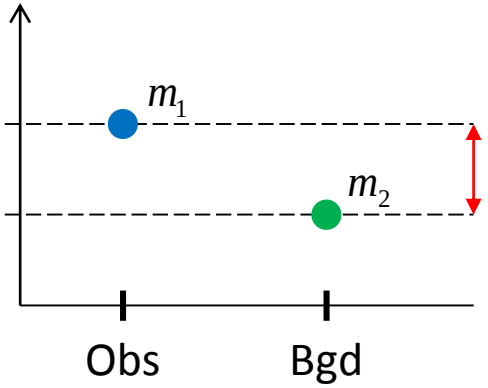
The GRUAN Processor

The aim of the Gap Analysis for Integrated Atmospheric ECV CLImate Monitoring (GAIA-CLIM) project is to improve our ability to use ground-based and sub-orbital observations to characterise satellite observations for a number of atmospheric Essential Climate Variables (ECVs).



What we do:
We compare observations to a proxy of truth, typically a 6-h forecast from a NWP system: $m_1 - m_2$

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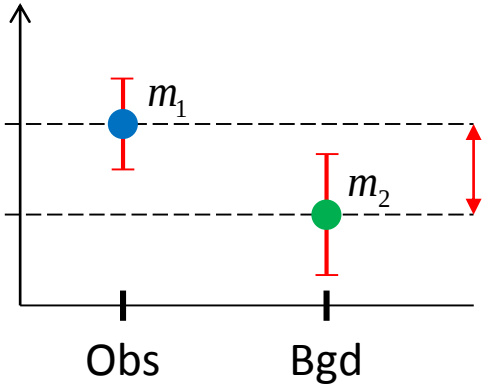

What we should be doing:

Verify $|m_1 - m_2| < k\sqrt{\sigma^2 + u_1^2 + u_2^2}$

with u_1 and u_2 the uncertainties associated to m_1 and m_2, σ the co-location/co-incidence uncertainty, and k a coverage factor.

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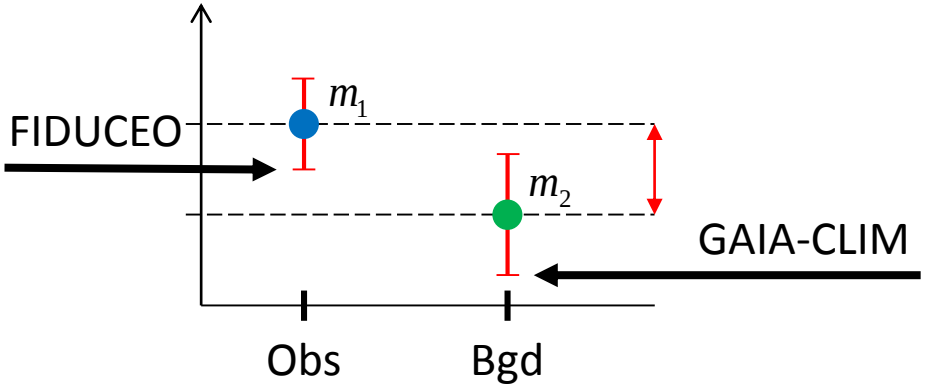
The GRUAN Processor

The aim of the Gap Analysis for Integrated Atmospheric ECV CLImate Monitoring (GAIA-CLIM) project is to improve our ability to use ground-based and sub-orbital observations to characterise satellite observations for a number of atmospheric Essential Climate Variables (ECVs).



1) NWP – GRUAN i.e. GRUAN Processor
2) Spectroscopy
3) Representativeness

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 640276.

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The GRUAN Processor

LEGACY: EUMETSAT Numerical Weather Prediction Satellite Application Facilities NWPSAF Radiance Simulator (http://nwpsaf.eu/).

CAPABILITY: Simulate satellite observations (in Brightness Temperatures or Radiances) from observed or modelled geophysical parameters (Pressure, Humidity, Temperature).

OBJECTIVE: Estimate model uncertainties by comparison with GRUAN observations and uncertainties both in observation and Brightness Temperature (or Radiance) spaces.

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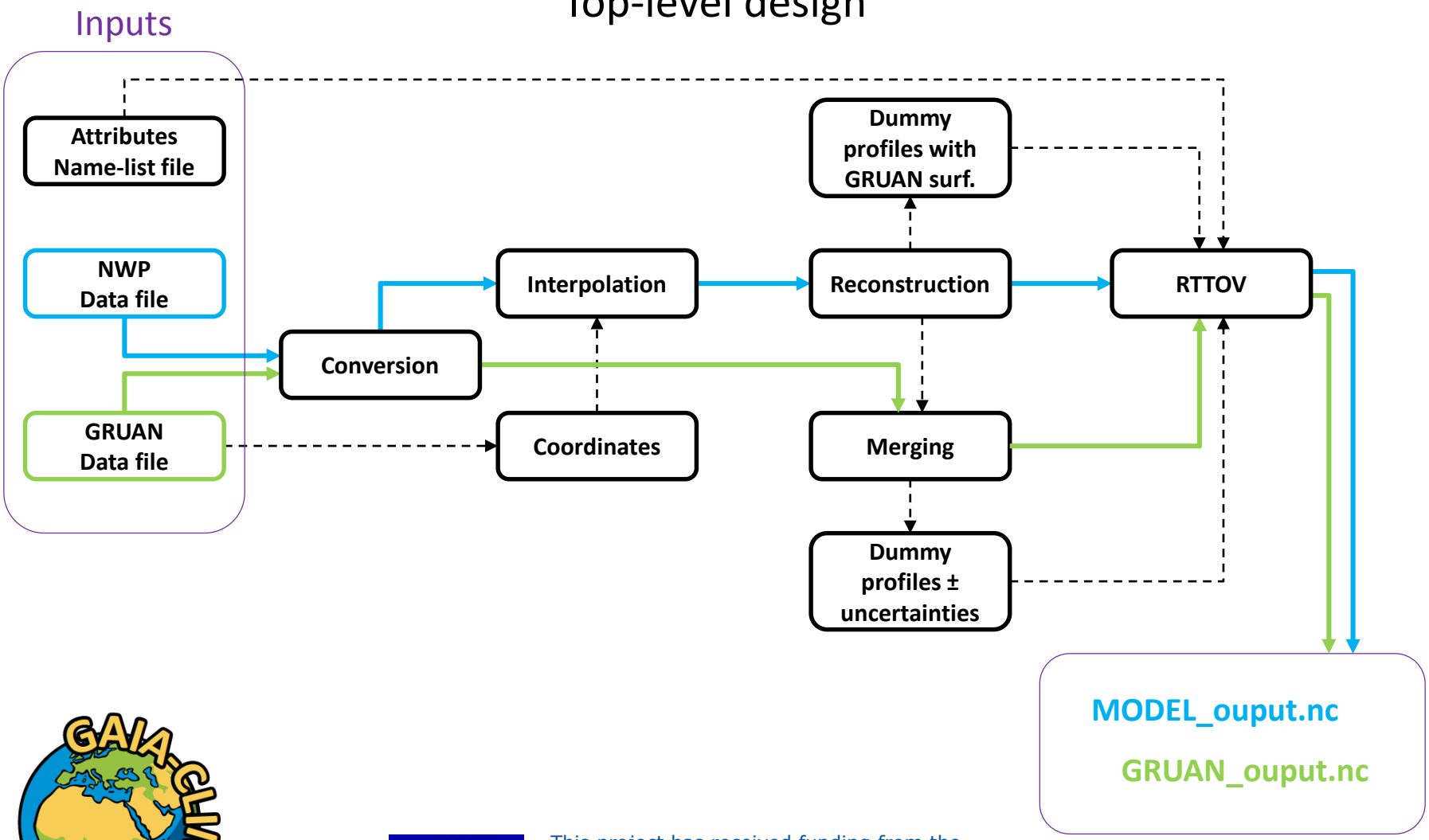
The GRUAN Processor

Top-level design



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Preliminary results

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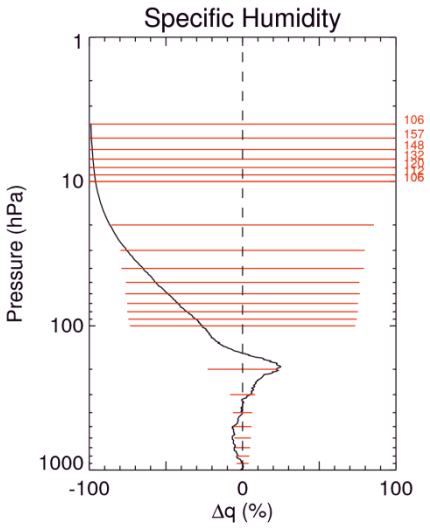
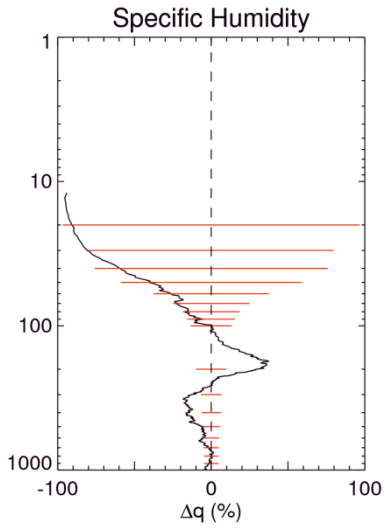
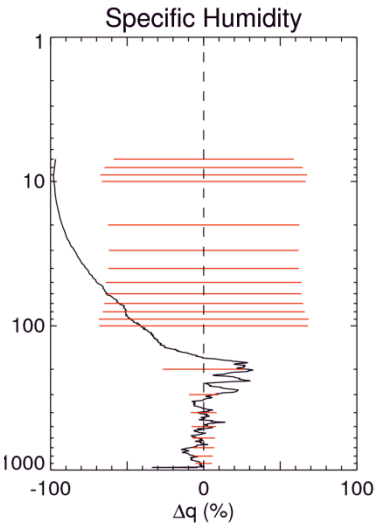
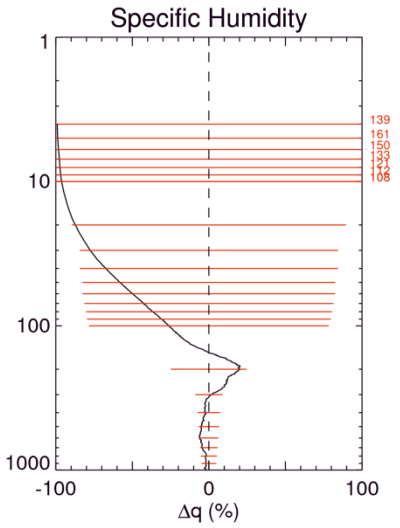
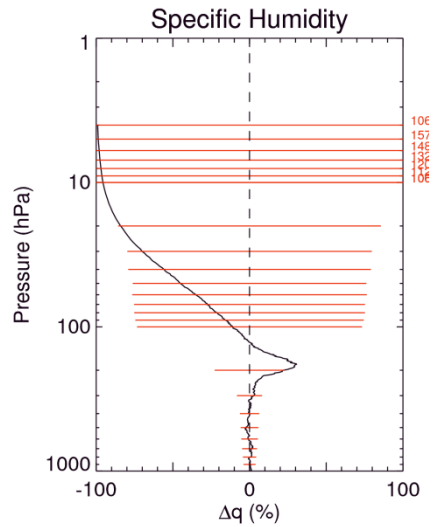
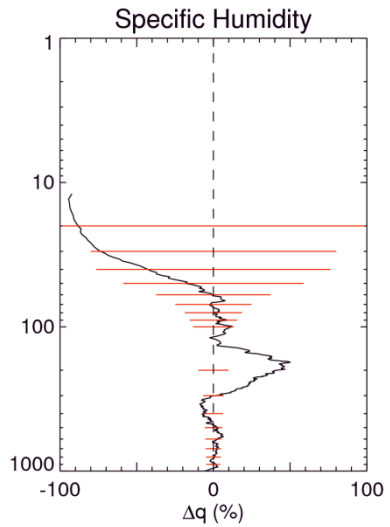
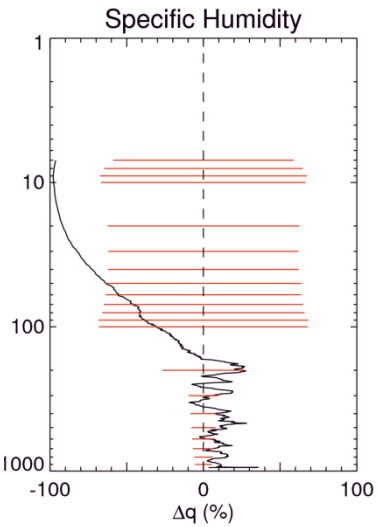
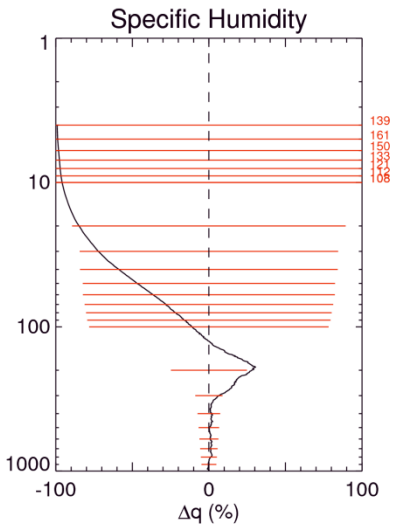
NWP-GRUAN

The GRUAN Processor

– Mean total uncertainty

Humidity

	LIN (NH)	MAN (Trop)	LAU (SH)	All sites*
	1297 profiles	82 profiles	32 profiles	3895 profiles
ECMWF				
MetOffice				

NWP-GRUAN

The GRUAN Processor

Temperature

– Mean total uncertainty

ECMWF

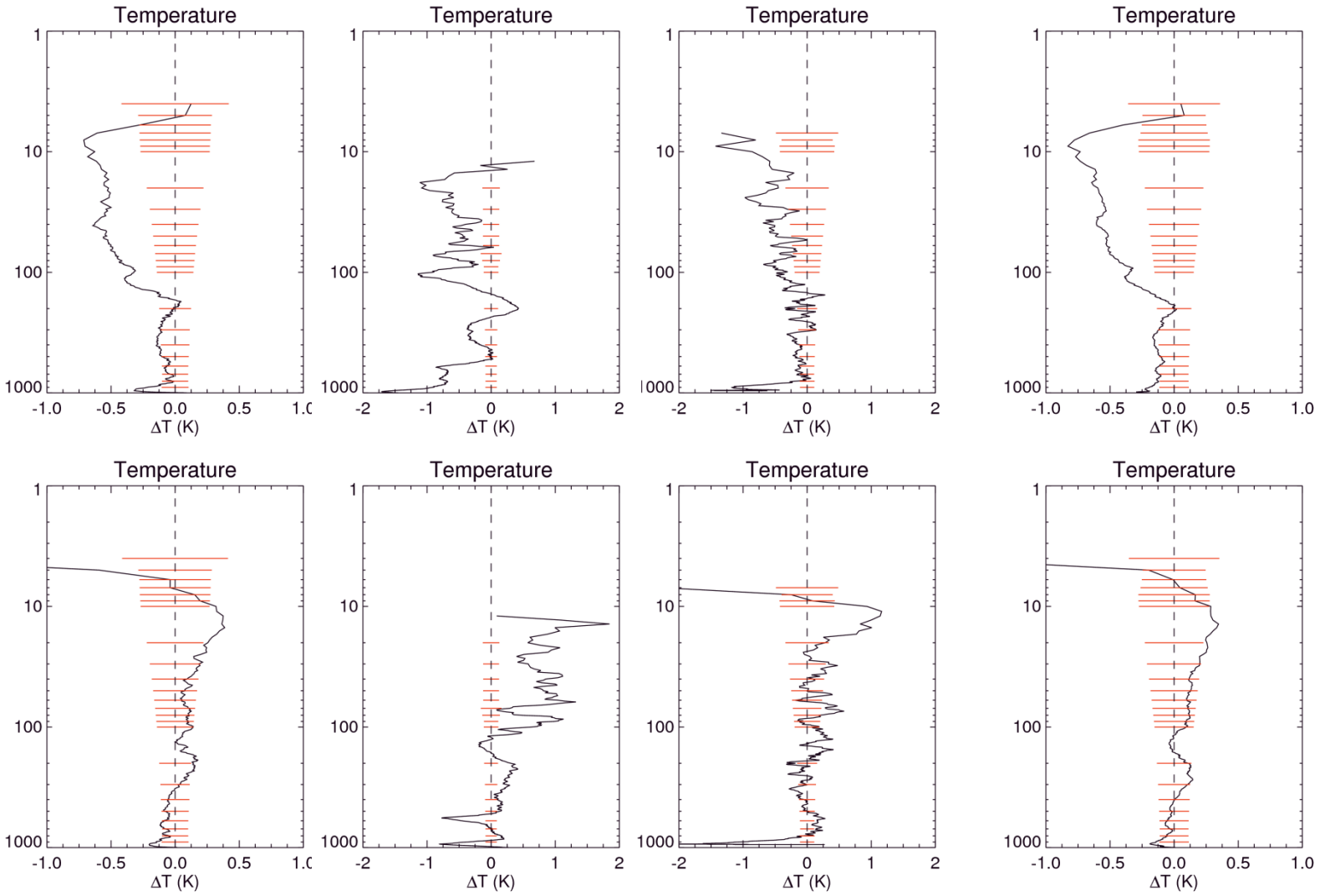
MetOffice

LIN (NH)
1297 profiles

MAN (Trop)
82 profiles

LAU (SH)
32 profiles

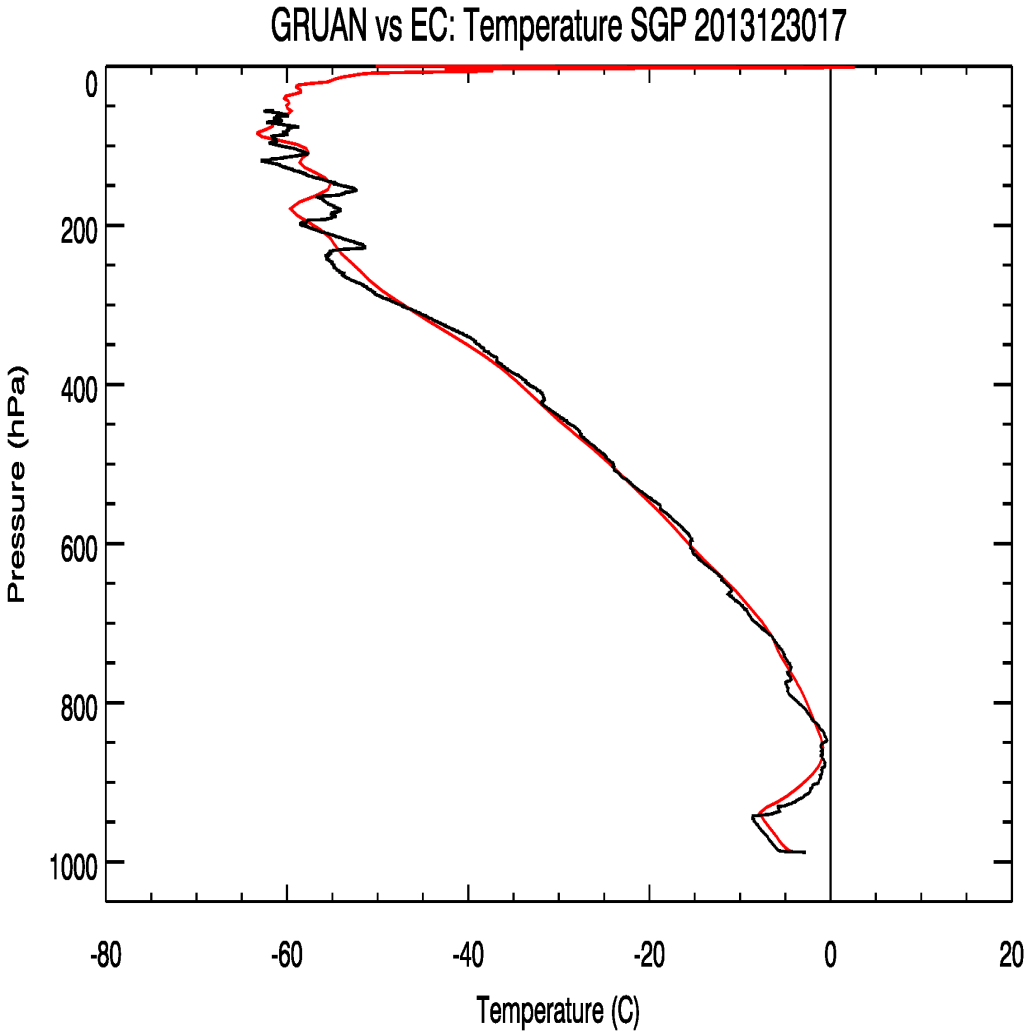
All sites*
3895 profiles



Intermittent ‘noise’ from stratospheric gravity waves

Current NWP models cannot represent details of gravity waves: worse fit to radiosondes (but little effect on mean) – partly smoothed out by satellite weighting functions.

The waves can be seen at all latitudes, but most frequent at low latitudes, Alexander et al (2002).



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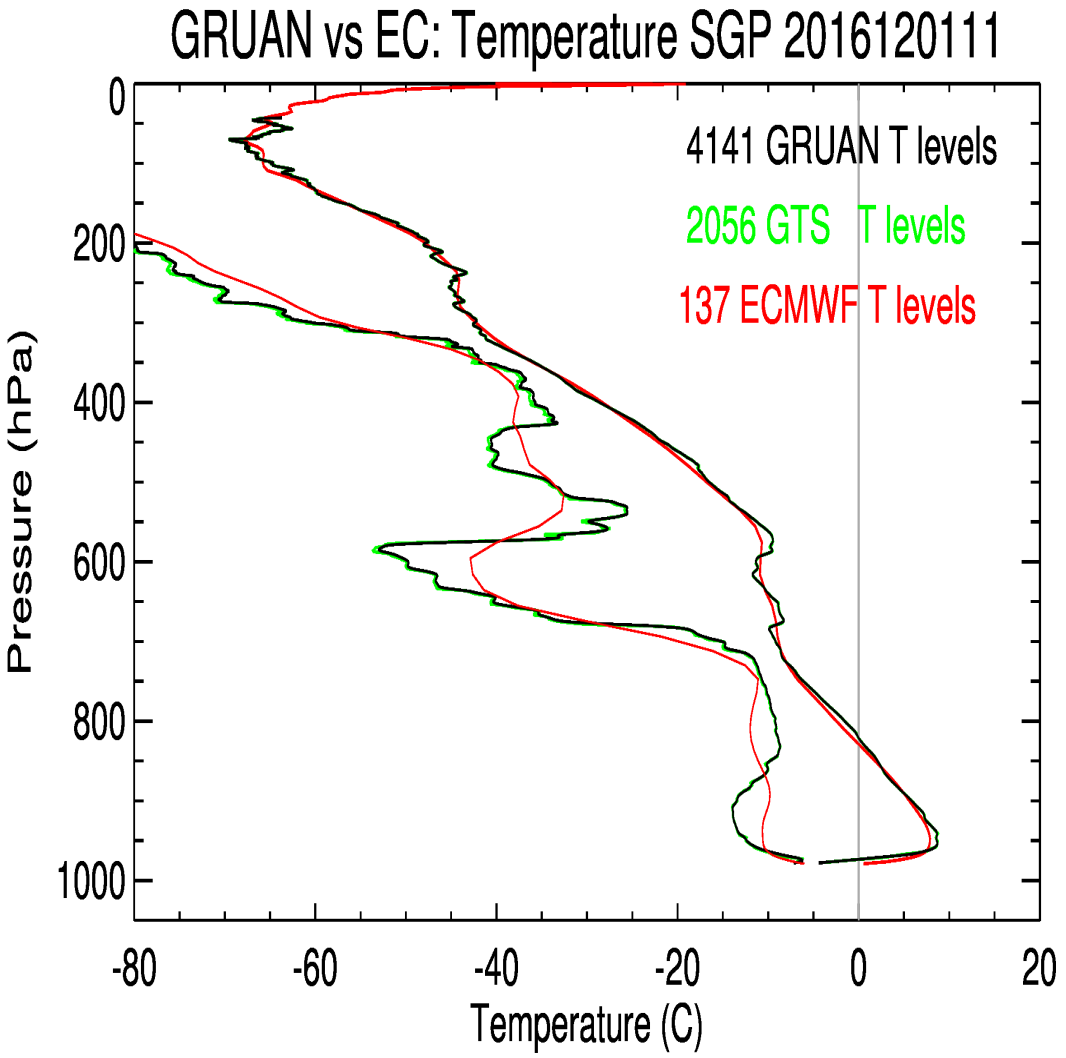
Real time data from most GRUAN sites

Some provide high-resolution BUFR data now (green).
GRUAN and Vaisala processing very similar for temperature, more difference for humidity.

If we can use operational RS92 (and other selected types of similar accuracy for T) reports then the sample size and geographical range are much better.
Use mean GRUAN uncertainties?



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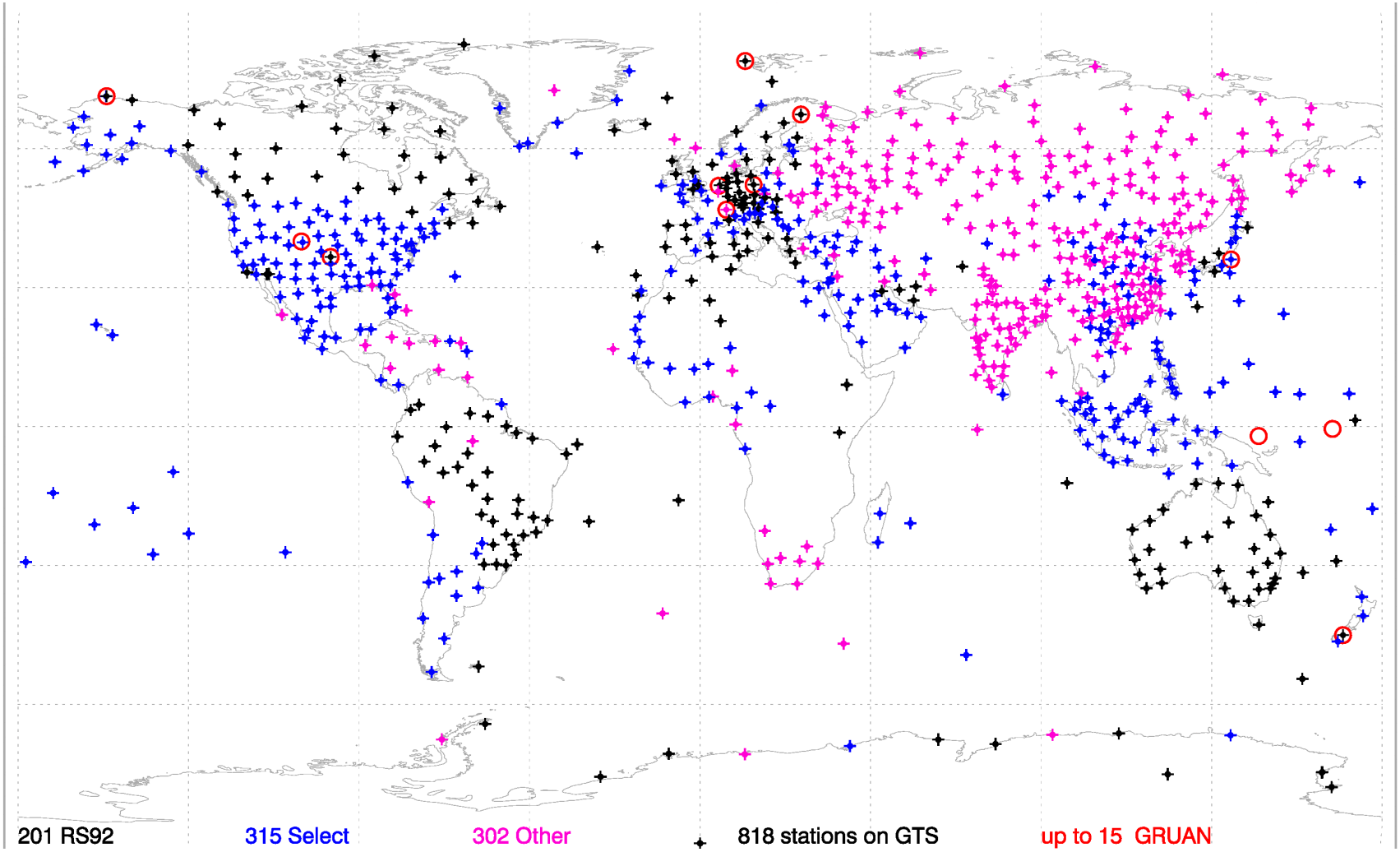
Radiosonde categories, December 2016



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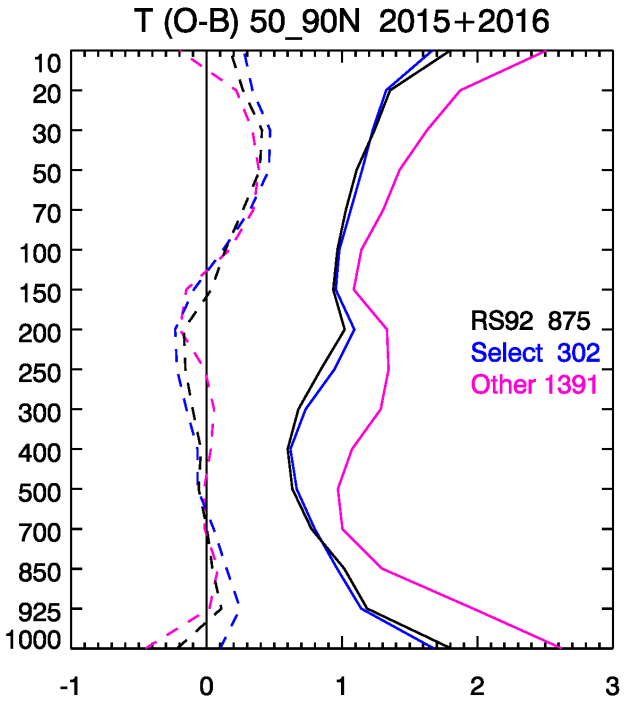
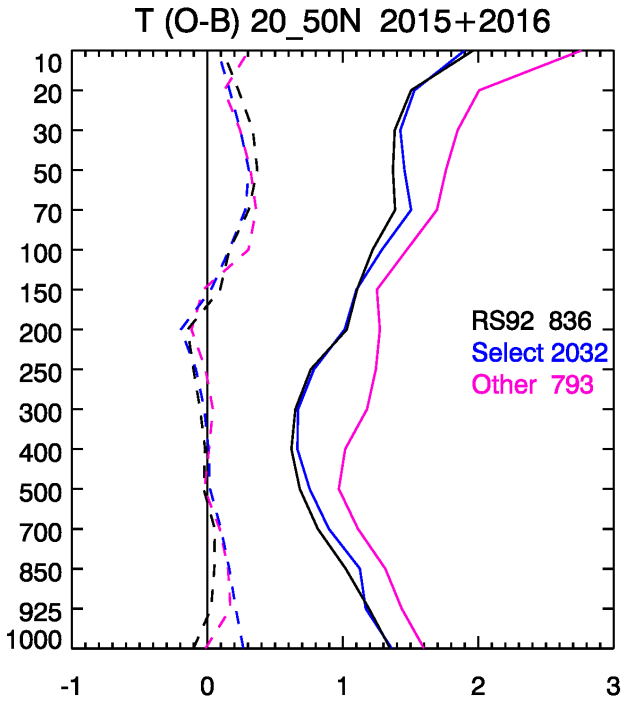
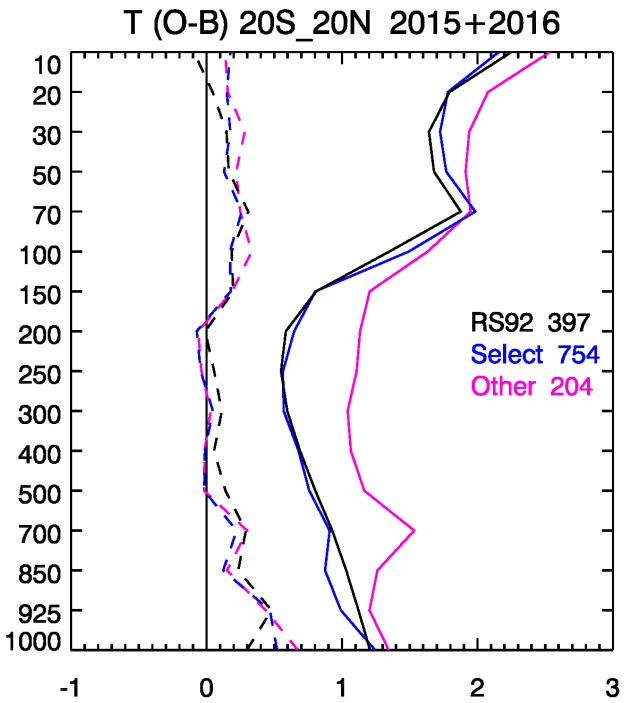
GTS statistics vs ECMWF for 2015+2016

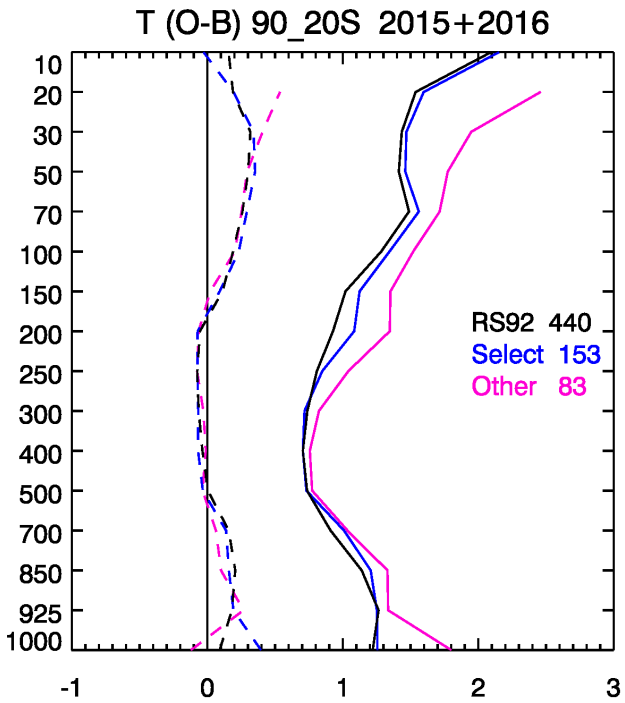
Mean and rms O-B split by four latitude bands.
Show stratospheric bias as seen vs GRUAN (2013) also low level tropical bias.

"Good" temperature reports from ~500 stations, but some others have problems.
ECMWF report in preparation.



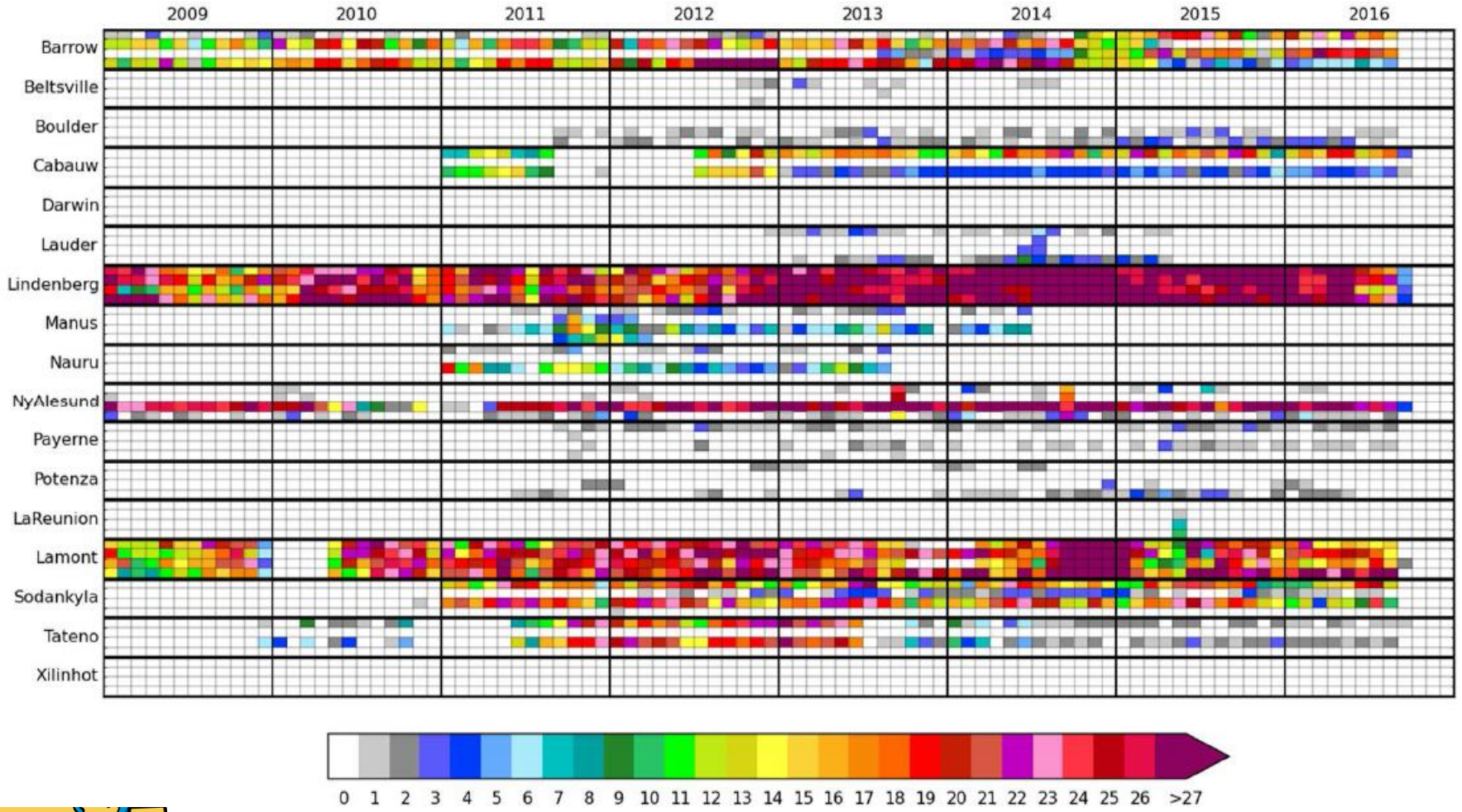






GRUAN data availability (from Bodecker, 2016)

Mainly Northern Extratropics.
Started with 2013 to include tropical data from Manus and Nauru.



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The GRUAN Processor

Brightness Temperature

– Mean total uncertainty*

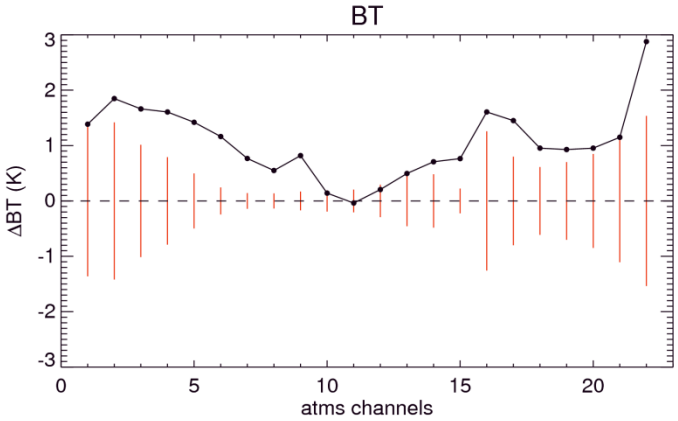
*Total uncertainty for BTs is defined as: $\sqrt{u\_surf\_bt^2 + u\_total\_bt^2}$

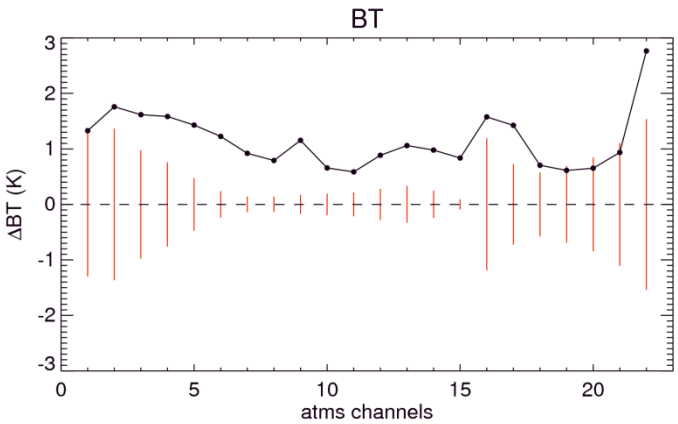
NWP-GRUAN
Lindenberg
1297 profiles

ECMWF

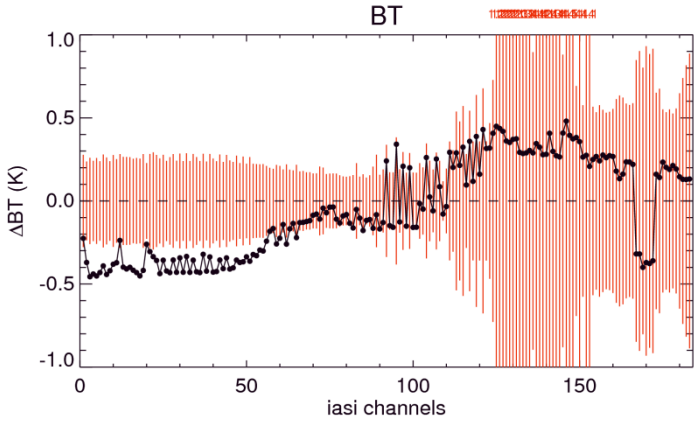
MetOffice

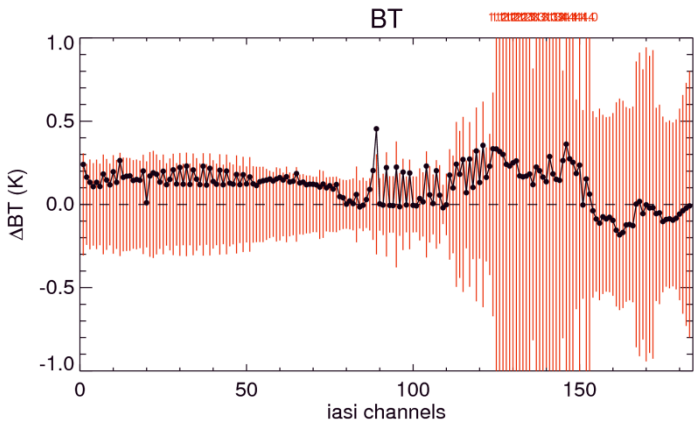
ATMS





IASI





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The GRUAN Processor

Brightness Temperature

Inconsistencies in BT

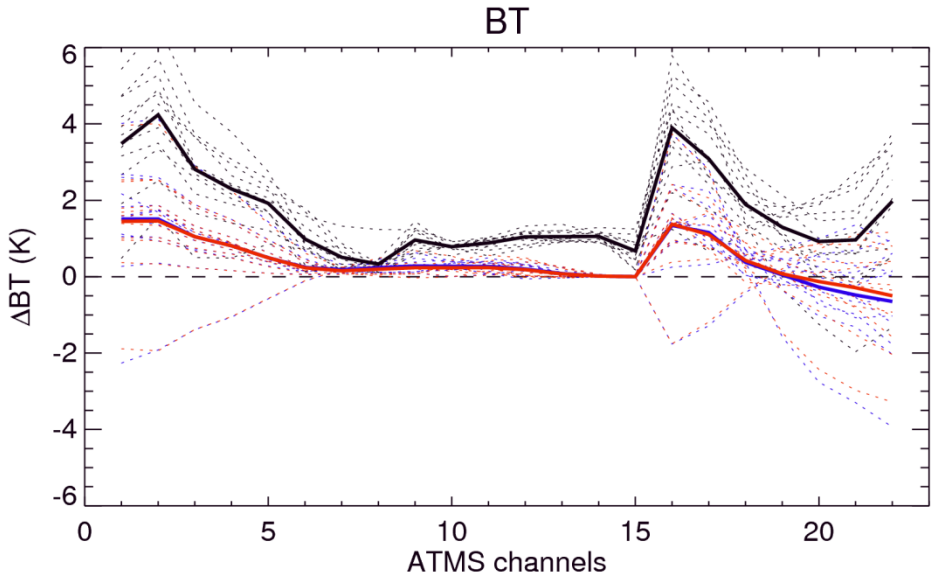
ΔBT larger than expected given ΔQ and ΔT and larger in MW than in IR.

Rationale :

1) Optical depth calculated on 54 layers for MW, 101 for IR.

2) RT equation applied to highly different vertical grid (coarse for model, very fine for GRUAN).

→ Profiles need to be on the same vertical grid.



Single profile no interpolation
Mean profile no interpolation
Single profile on model levels
Mean profile on model levels
Single profile on sonde levels
Mean profile on sonde levels

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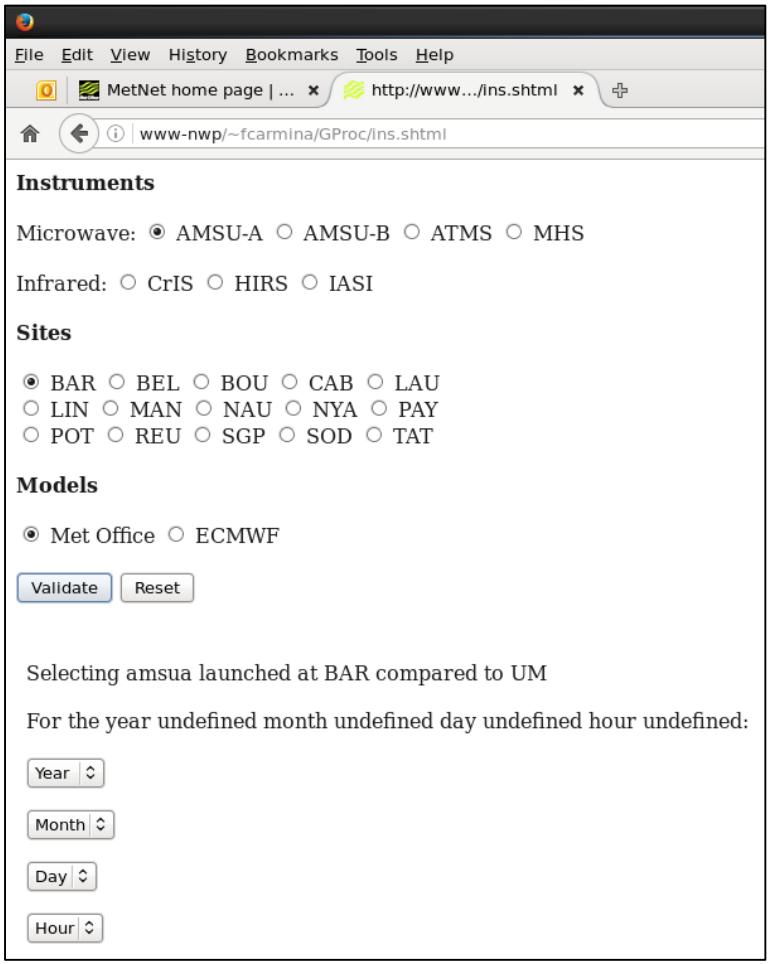
The GRUAN Processor

Webpage

- GRUAN Processor outputs available via a webpage.
- Difference NWP-GRUAN for all available profiles in 2013 and mean annual differences per site. More to come.
- Available at:

https://nwpsaf.eu/GProc_test/fab/ins.shtml



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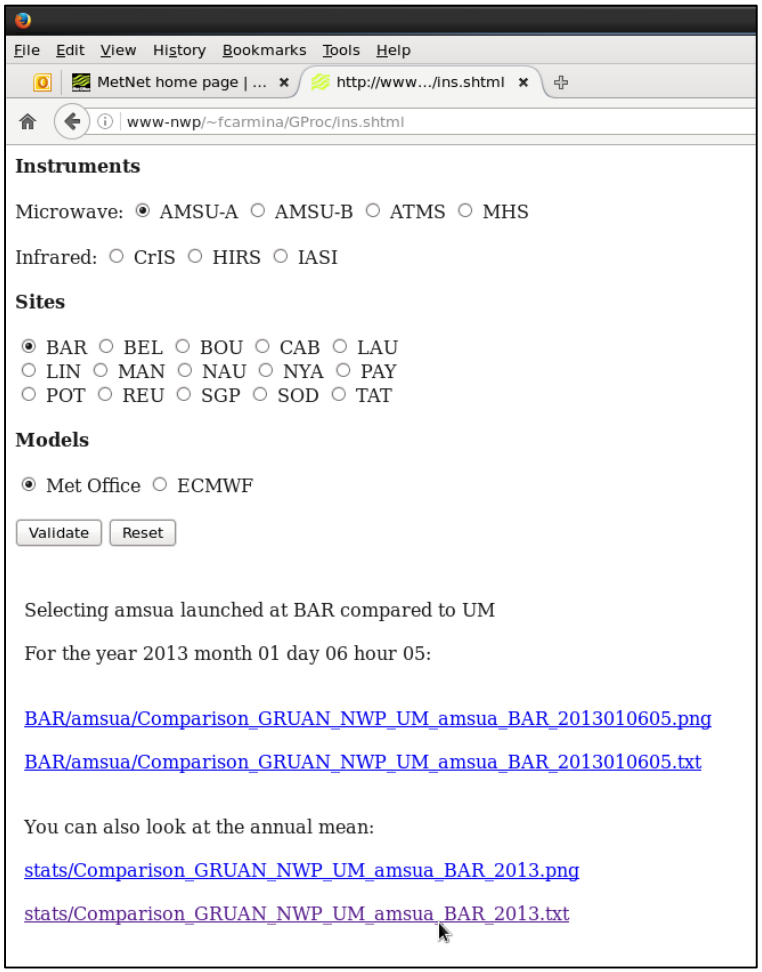

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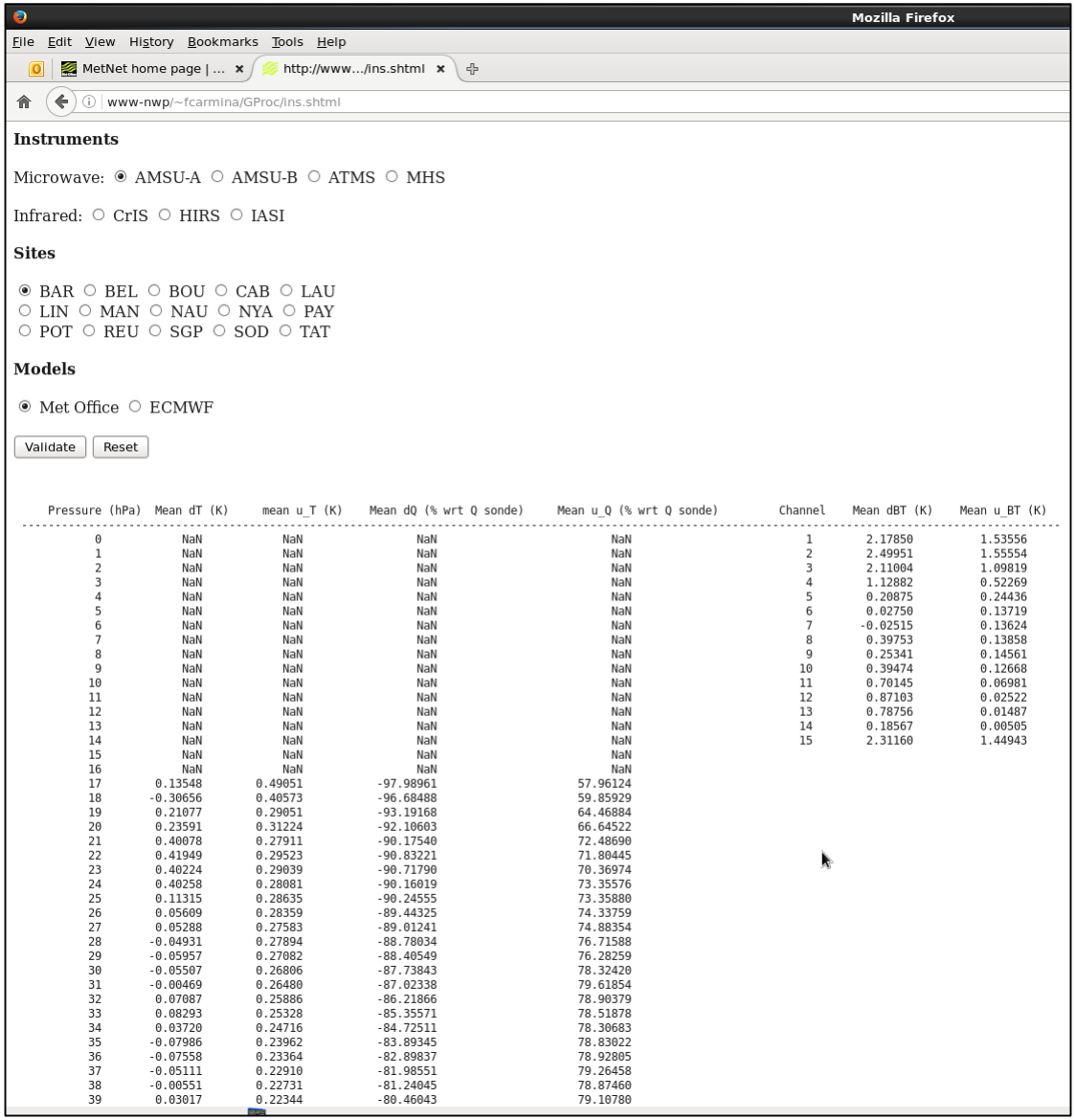

Pressure (hPa)	Mean dT (K)	mean u_T (K)	Mean dQ (% wrt Q sonde)	Mean u_Q (% wrt Q sonde)	Channel	Mean dBT (K)	Mean u_BT (K)
0	NaN	NaN	NaN	NaN	1	2.17850	1.53556
1	NaN	NaN	NaN	NaN	2	2.49951	1.55554
2	NaN	NaN	NaN	NaN	3	2.11004	1.09819
3	NaN	NaN	NaN	NaN	4	1.12882	0.52269
4	NaN	NaN	NaN	NaN	5	0.20875	0.24436
5	NaN	NaN	NaN	NaN	6	0.02750	0.13719
6	NaN	NaN	NaN	NaN	7	-0.02515	0.13624
7	NaN	NaN	NaN	NaN	8	0.39753	0.13858
8	NaN	NaN	NaN	NaN	9	0.25341	0.14561
9	NaN	NaN	NaN	NaN	10	0.39474	0.12668
10	NaN	NaN	NaN	NaN	11	0.70145	0.06981
11	NaN	NaN	NaN	NaN	12	0.87103	0.02522
12	NaN	NaN	NaN	NaN	13	0.78756	0.01487
13	NaN	NaN	NaN	NaN	14	0.18567	0.00505
14	NaN	NaN	NaN	NaN	15	2.31160	1.44943
15	NaN	NaN	NaN	NaN			
16	NaN	NaN	NaN	NaN			
17	0.13548	0.49051	-97.98961	57.96124			
18	-0.30656	0.40573	-96.68488	59.85929			
19	0.21077	0.29051	-93.19168	64.46884			
20	0.23591	0.31224	-92.10603	66.64522			
21	0.40078	0.27911	-90.17540	72.48690			
22	0.41949	0.29523	-90.83221	71.80445			
23	0.40224	0.29039	-90.71790	70.36974			
24	0.40258	0.28081	-90.16019	73.35576			
25	0.11315	0.28635	-90.24555	73.35880			
26	0.05609	0.28359	-89.44325	74.33759			
27	0.05288	0.27583	-89.01241	74.88354			
28	-0.04931	0.27894	-88.78034	76.71588			
29	-0.05957	0.27082	-88.40549	76.28259			
30	-0.05507	0.26806	-87.73843	78.32420			
31	-0.00469	0.26480	-87.02338	79.61854			
32	0.07087	0.25886	-86.21866	78.90379			
33	0.08293	0.25328	-85.35571	78.51878			
34	0.03720	0.24716	-84.72511	78.30683			
35	-0.07986	0.23962	-83.89345	78.83022			
36	-0.07558	0.23364	-82.89837	78.92805			
37	-0.05111	0.22910	-81.98551	79.26458			
38	-0.00551	0.22731	-81.24045	78.87460			
39	0.03017	0.22344	-80.46043	79.10780			

The GRUAN Processor

On-going & Future developments

- Separate treatment for GRUAN correlated and random uncertainties (currently all included in the total uncertainty).
  - → Need GRUAN v3!
- Estimation of GRUAN co-variance matrices.
- Processing capability extended to reanalyses and other NWP centres.
- Post processing analyses.
- Manuscript.

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Work Package 4 : Year 3

- Error budget & closure
- Evaluation of new satellites
  - GMI
  - MTVZA
  - FY-3D
  - JPSS-1
- The general case : extending to full ECV set
- GAID v5 – towards '*SoW-like*' completeness & persuasiveness
- VO

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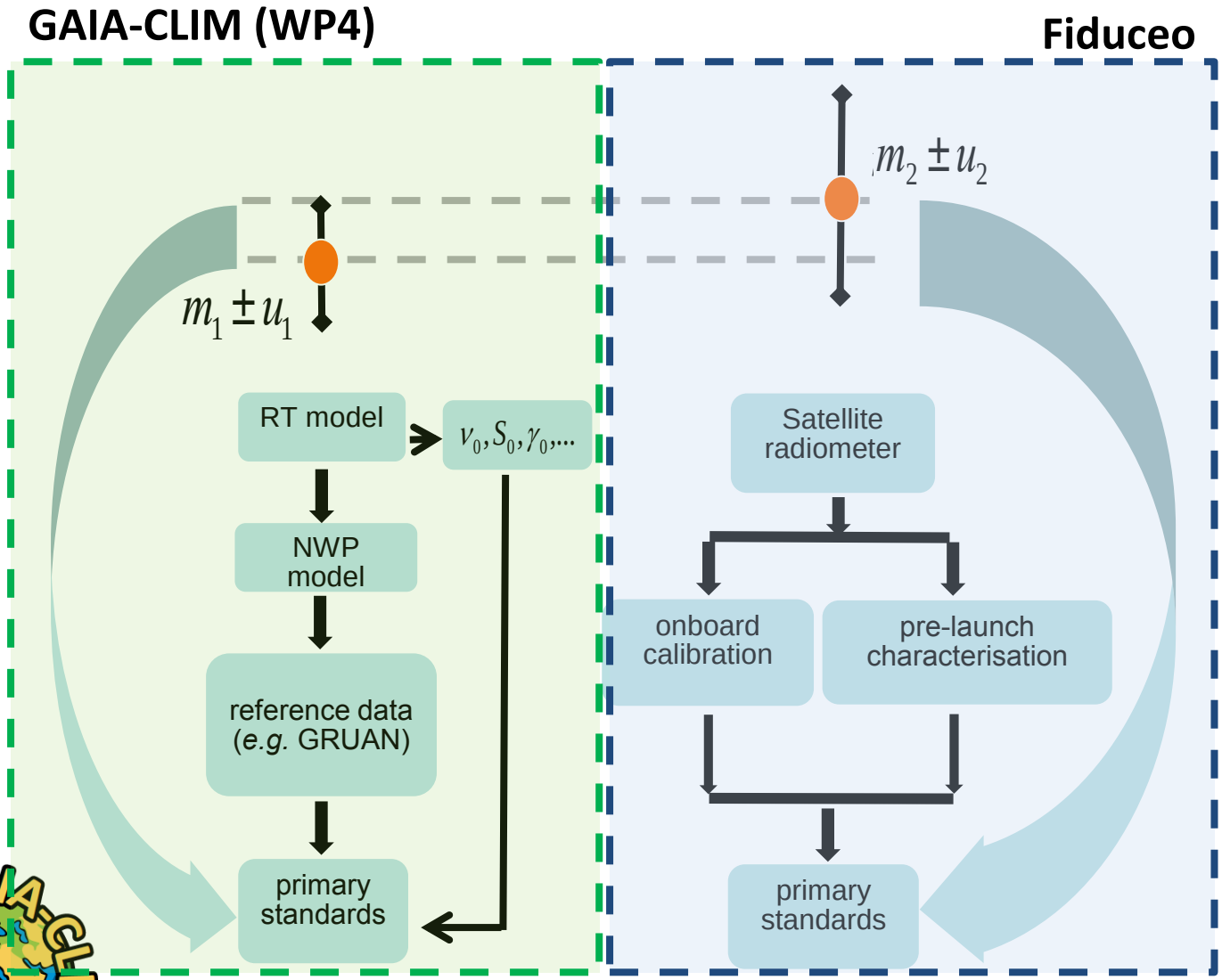
GAIA-CLIM (WP4) & Fiduceo



- see joint GAIA-CLIM session on wednesday

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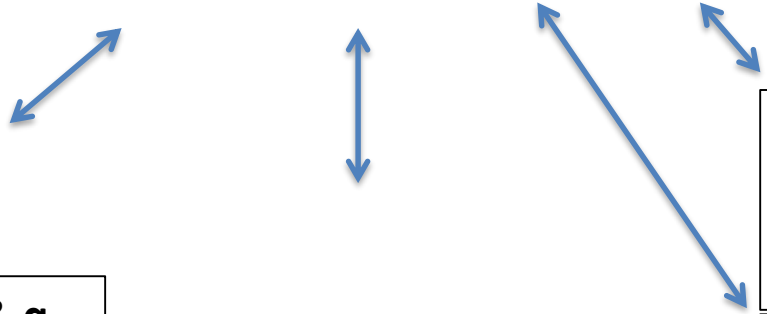
Uncertainties in simulated TOA brightness temperatures $U(T_B)$

$$u(T_B) = f(u(x_{NWP}), u(H), u(\Delta x), u(z, z'))$$



Uncertainties in NWP T & q (in brightness temperatures)

- Estimated from (NWP-GRUAN)
- Consistency check: **~ √(HBH^T)** ?

Uncertainties in RT modelling

- *Line-by-line* to *fast* model
- Spectroscopic uncertainties

Uncertainties due to vertical interpolation

- GRUAN-processor

Uncertainties due to scale mismatch

- Observation scale ≠ model scale

AND

- Natural scale << obs & model

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WP4 Year 3: New Satellites

- Evaluation of new satellites:
  - **GMI** (MW Imager: 10-183 GHz)
  - **MTVZA** (MW Imager: 10-183 GHz, incl. 50 GHz)
  - **FY-3D** (MWTS-2, MWHS-2, MWRI)*
  - **JPSS-1** (ATMS, CrIS)*

  (* pending data availability)

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WP4 Year 3: The wider set of ECVs

TABLE 1. The essential climate variables (for qualifying details, see GCOS 2010a).		
Atmospheric	Surface:[a]	Air temperature, wind speed and direction, water vapor, pressure, precipitation, surface radiation budget
	Upper air:[b]	Temperature, wind speed and direction, water vapor, cloud properties, Earth radiation budget (including solar irradiance)
	Composition:	Carbon dioxide, methane, other long-lived greenhouse gases,[c] ozone and aerosol supported by their precursors[d]
Oceanic	Surface:[e]	Sea surface temperature, sea surface salinity, sea level, sea state, sea ice, surface current, ocean color, carbon dioxide partial pressure, ocean acidity, phytoplankton
	Subsurface:	Temperature, salinity, current, nutrients, carbon dioxide partial pressure, ocean acidity, oxygen, tracers
Terrestrial		River discharge, water use, groundwater, lakes, snow cover, glaciers and ice caps, ice sheets, permafrost, albedo, land cover (including vegetation type), fraction of absorbed photosynthetically active radiation, leaf area index, above-ground biomass, soil carbon, fire disturbance, soil moisture

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