The role of representation error in IR and 183 Ghz measurements

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with contributions from

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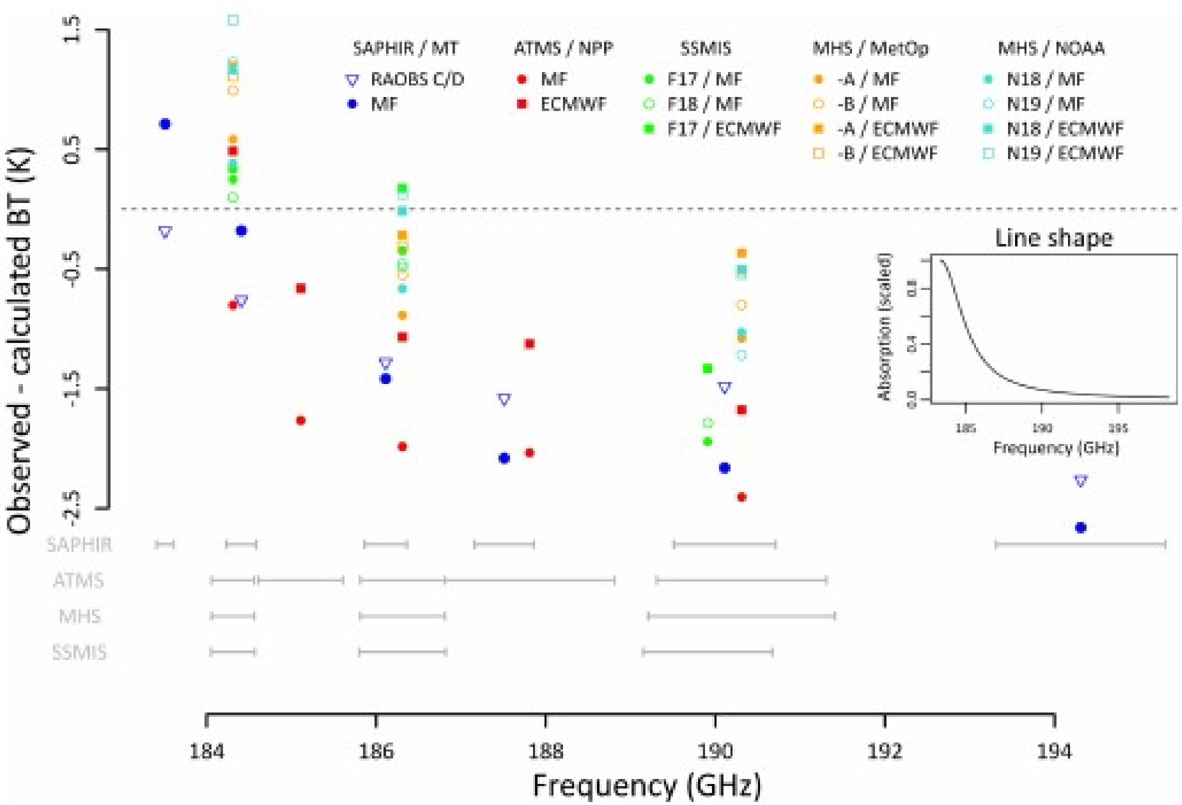
ECMWF/EUMETSAT NWP SAF Workshop on the treatment of random and systematic errors in satellite data assimilation for NWP

Consistency between Measurements

- Different Measurement Systems should give the "same" (consistent) values of the parameter being measured
- For Water Vapour, there are some examples where measurements are consistent and some in which they are not
- Ideally, we need to understand the measurements before using them: assimilation, blended products, climate series, etc.

Examples of NO Consistency

183 GHz OBS – CALC Biases from different NWP and Sondes



Brogniez et al., AMT, 2016

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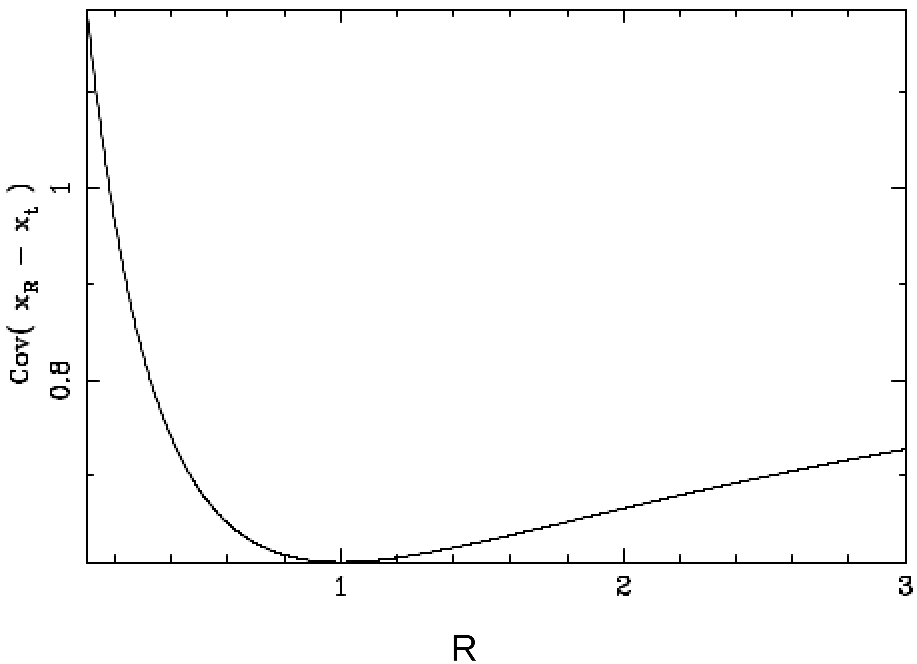
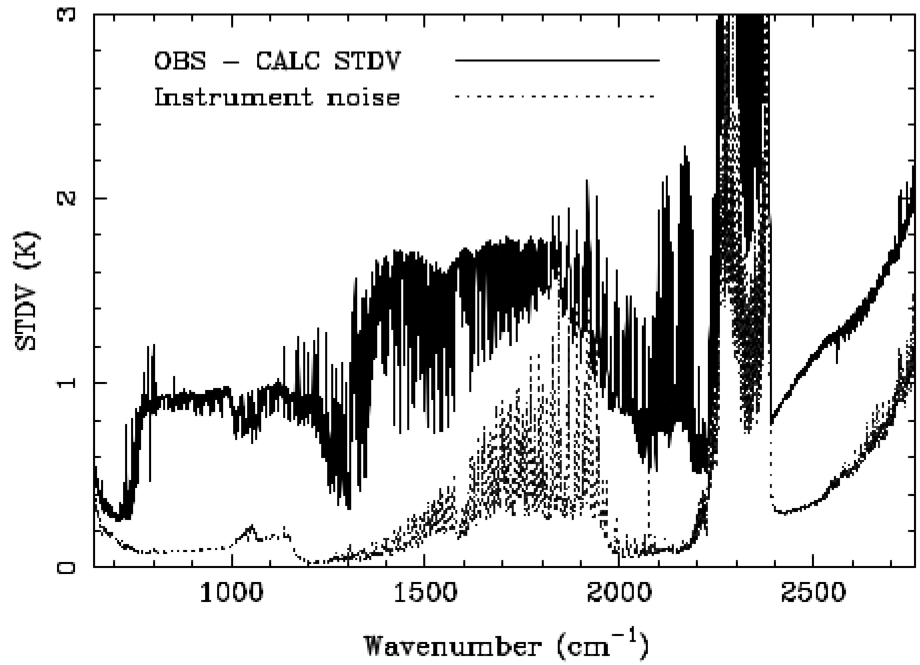
Examples of NO Consistency

OEM IASI WV Retrievals need R matrix values much bigger than instrument noise

$$J = (y - F(x))^T R^{-1} (y - F(x)) + (x - x_a)^T B^{-1} (x - x_a)$$





Calbet, arxiv, 2012

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Examples of NO Consistency

- Different BIASES in TCWV with respect to GPS/GNSS from different instruments
- Attributed to different retrieval algorithms

Instrument	BIAS (kg m^{-2})	RMSE (kg m^{-2})
IASI	− 1.77 ± 0.006	2.74
MIRS	1.36 ± 0.016	3.77
MODIS	1.11 ± 0.021	3.11
MODIS-FUB	− 0.31 ± 0.019	2.52

Carbajal-Henken et al., Remote Sensing, 2020

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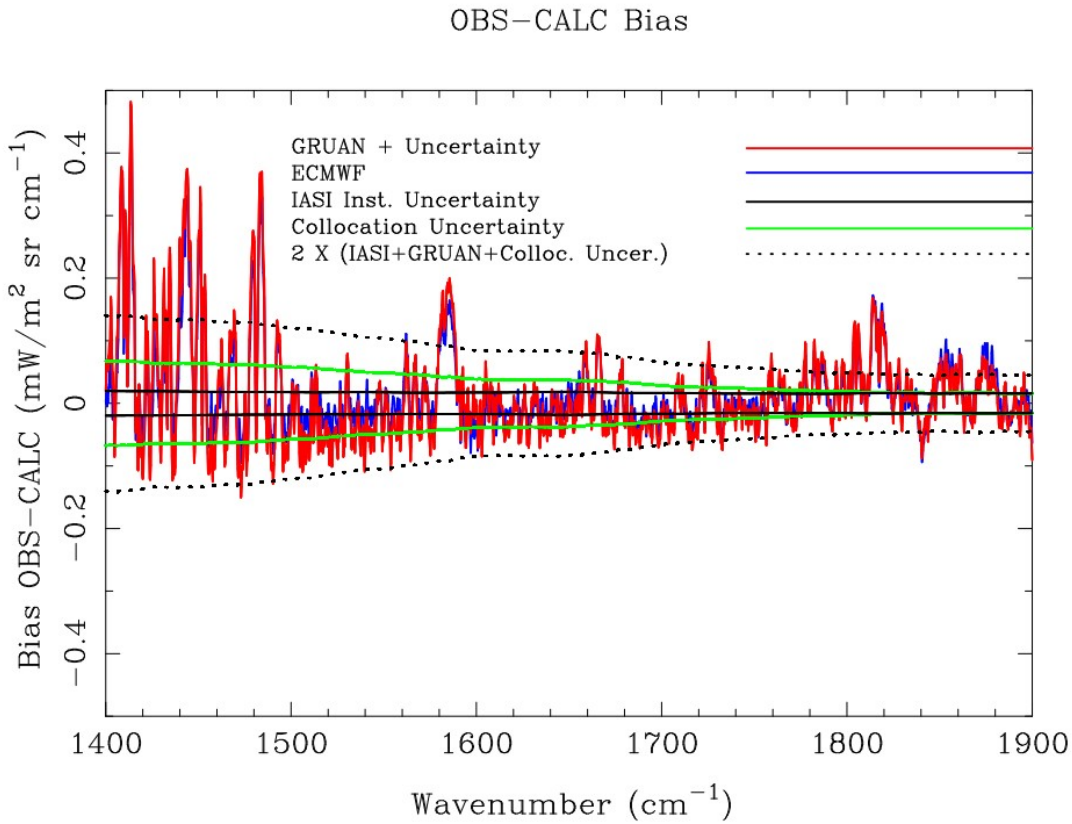
Examples of Some Consistency

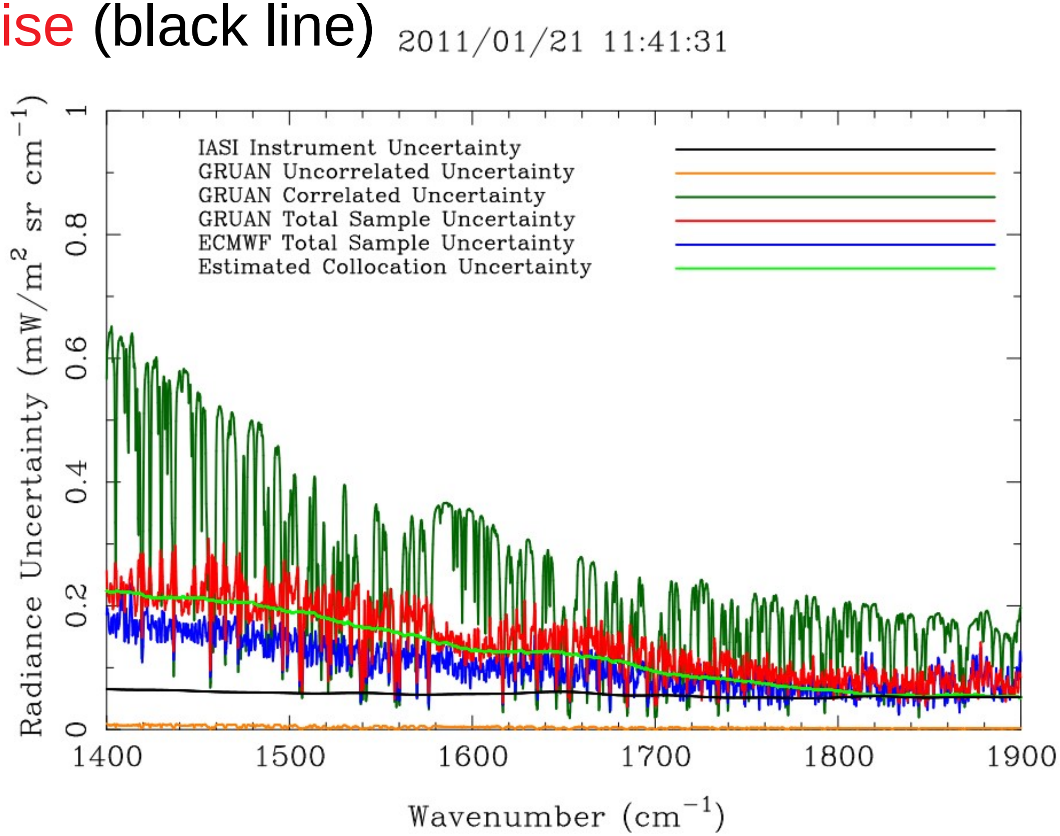
- Individual sonde measurements
- Consistency in BIAS between GRUAN sondes, LBLRTM and IASI



Calbet et al., AMT, 2017 (small sample)
Sun et al., Remote Sensing, 2020 (big sample)

Examples of Some Consistency

- Individual sonde measurements
- NO consistency in STDV (red line) between GRUAN sondes, LBLRTM and IASI noise (black line)



Calbet et al., AMT, 2017 (small sample)
Sun et al., Remote Sensing, 2020 (big sample)

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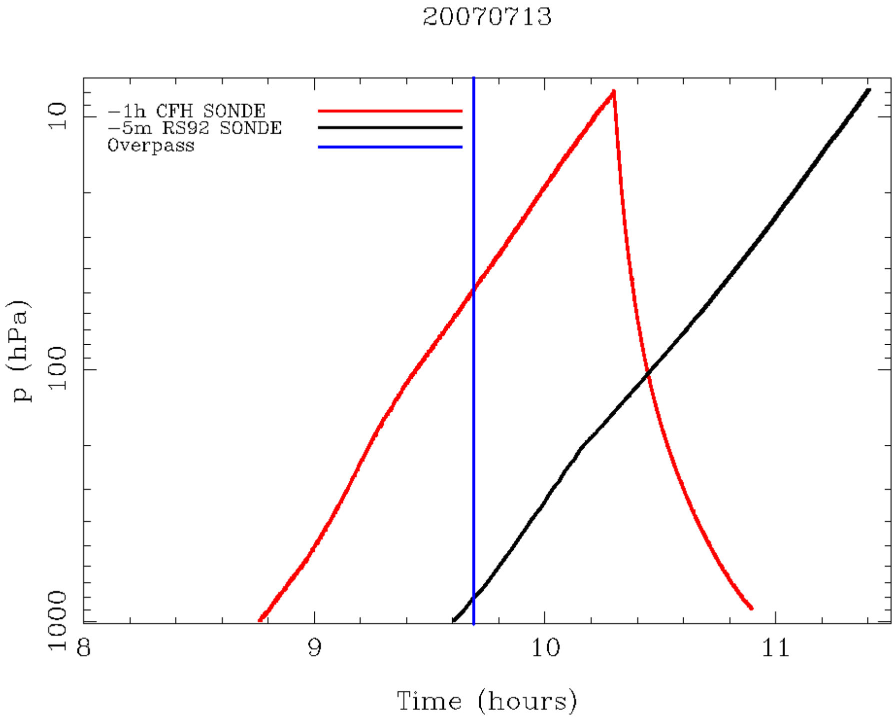
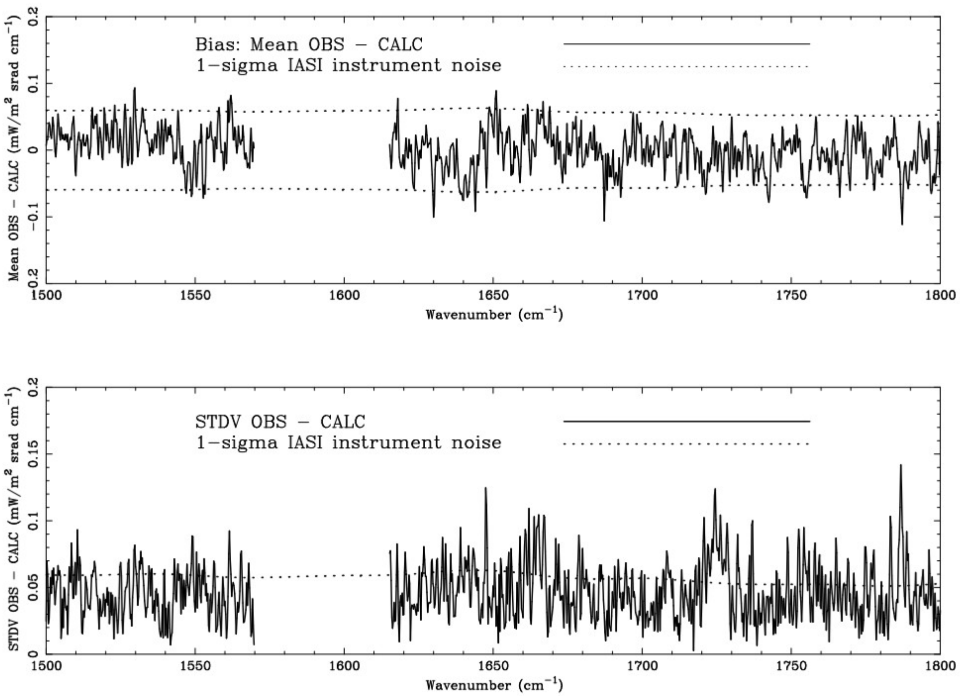
Examples of Consistency

- Two sequential sonde measurements
- Consistency in BIAS and STDV (solid line) between GRUAN sondes, LBLRTM and IASI noise (dashed line)

"Tobin" interpolation





Calbet et al., AMT, 2011 (small sample)

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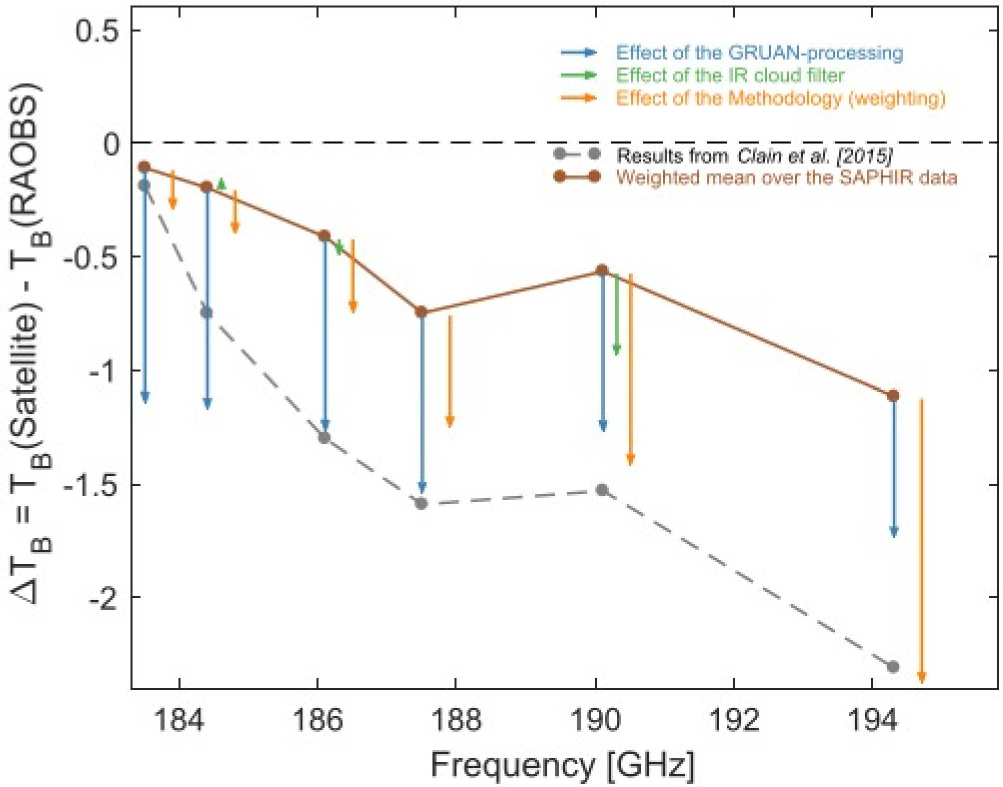
Examples of Consistency

Consistency between GRUAN and MW over homogeneous scenes



Bobryshev et al., IEEE Trans. Geo. Rem. Sen., 2018

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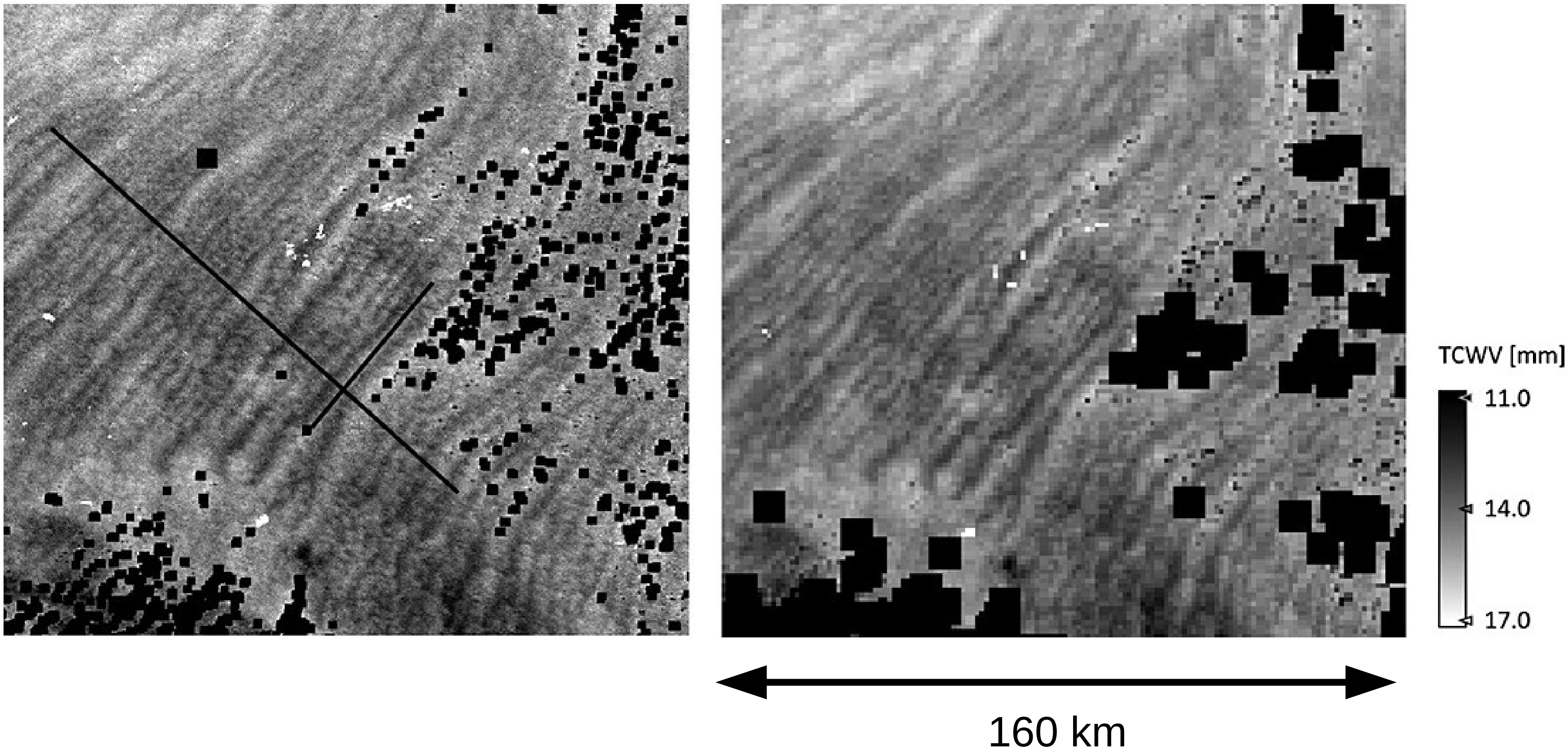
What is going on?

- Is there or is there NOT consistency?
- Are we missing anything?
- Perhaps the difference is in the homogeneity or inhomogeneity of the scenes → How much water vapour varies within the Field of View of the instrument
- We have to realize that usually when we look at cloud free scenes we are usually also implying homogeneous scenes, both with visually or with automatic cloude detection

Variability of Water Vapour

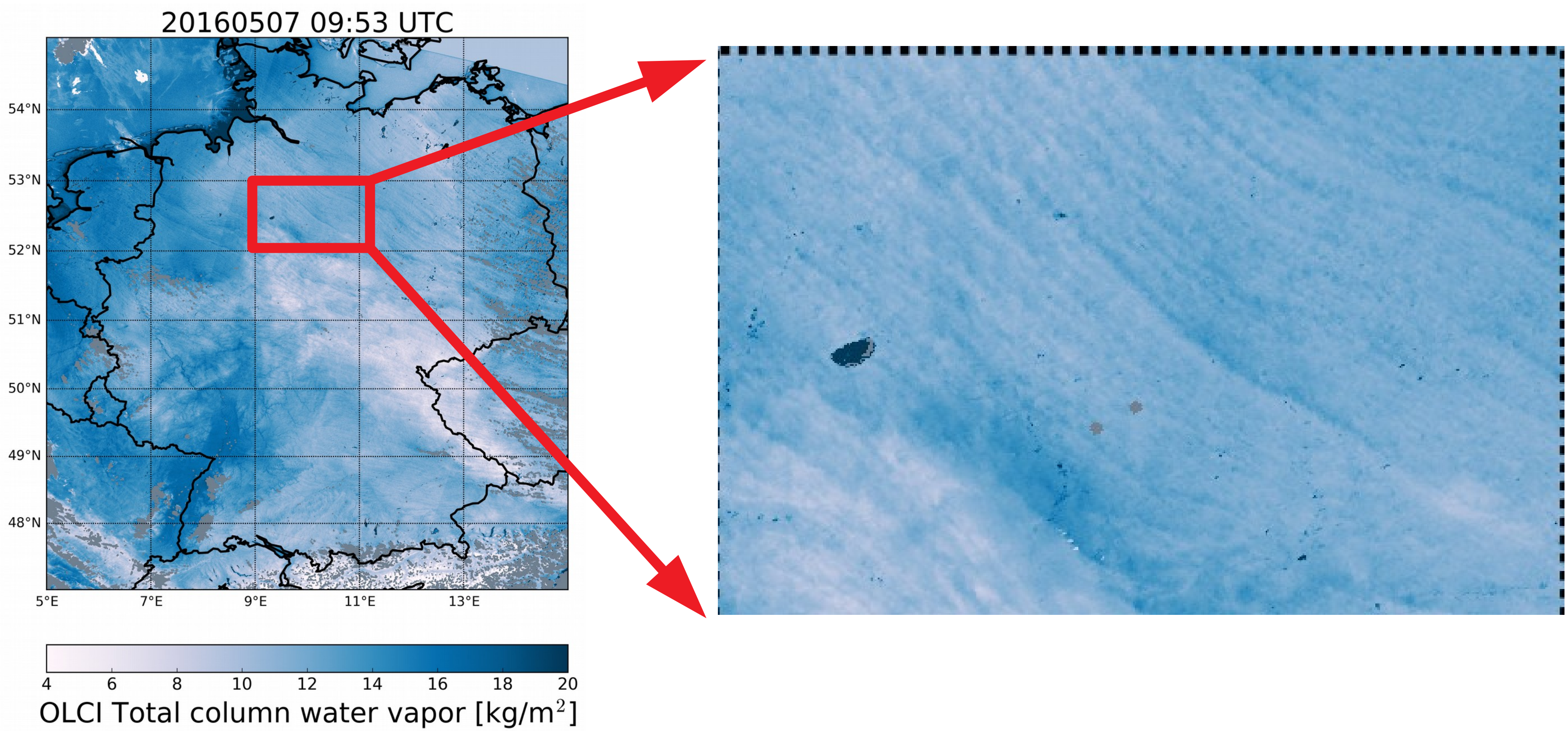
Features, water vapour rolls, of about 5 km from MERIS



Carbajal-Henken et al., GRL, 2015

Variability of Water Vapour

Small scale TCWV features from OLCI



Carbajal-Henken, private comm., 2020

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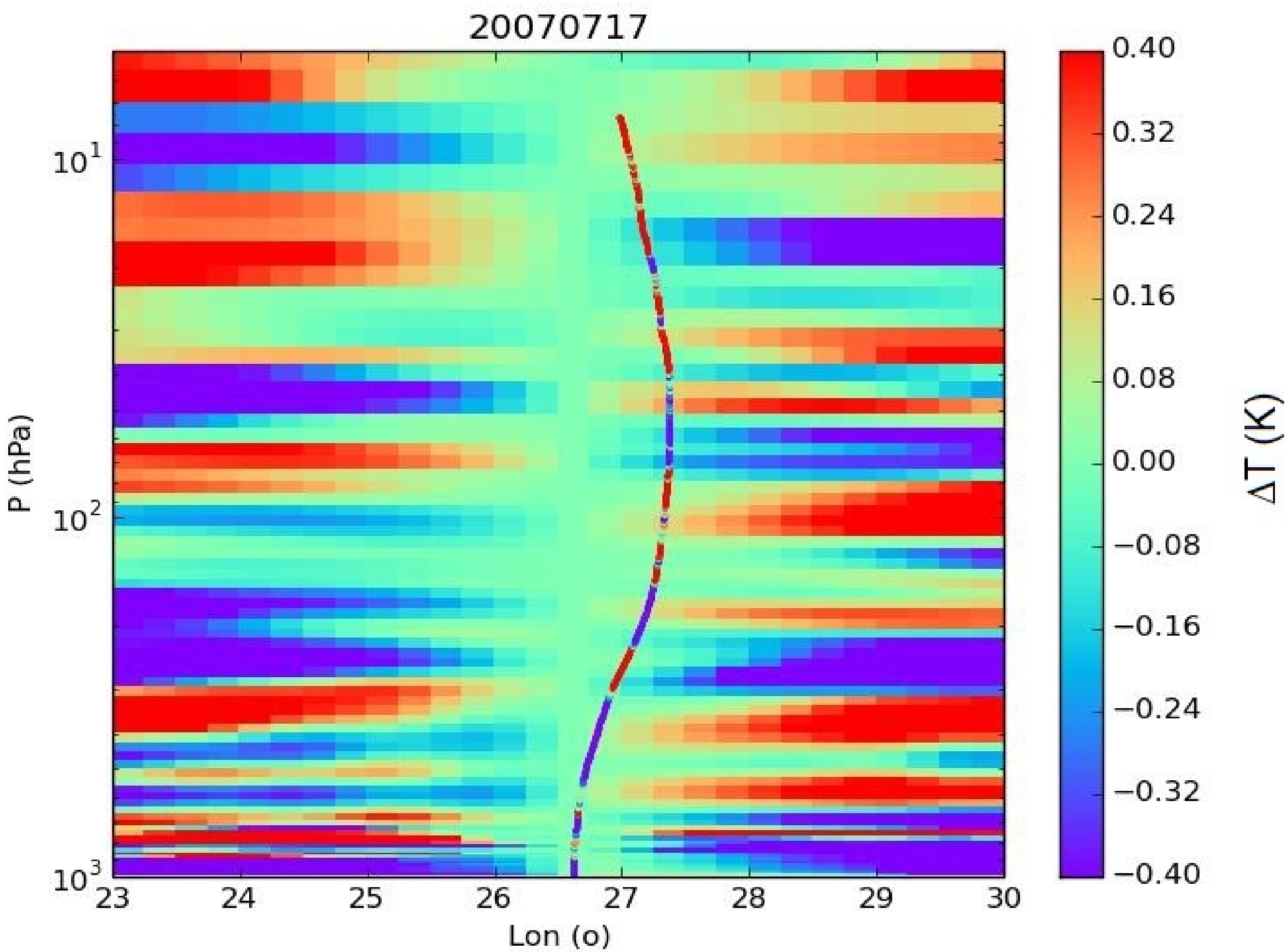
Sonde versus NWP comparison



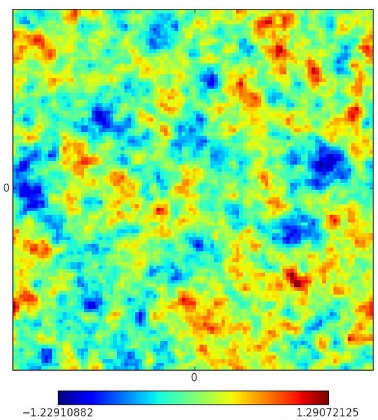
Complete Field: NWP Field relative to NWP Vertical over Observatory

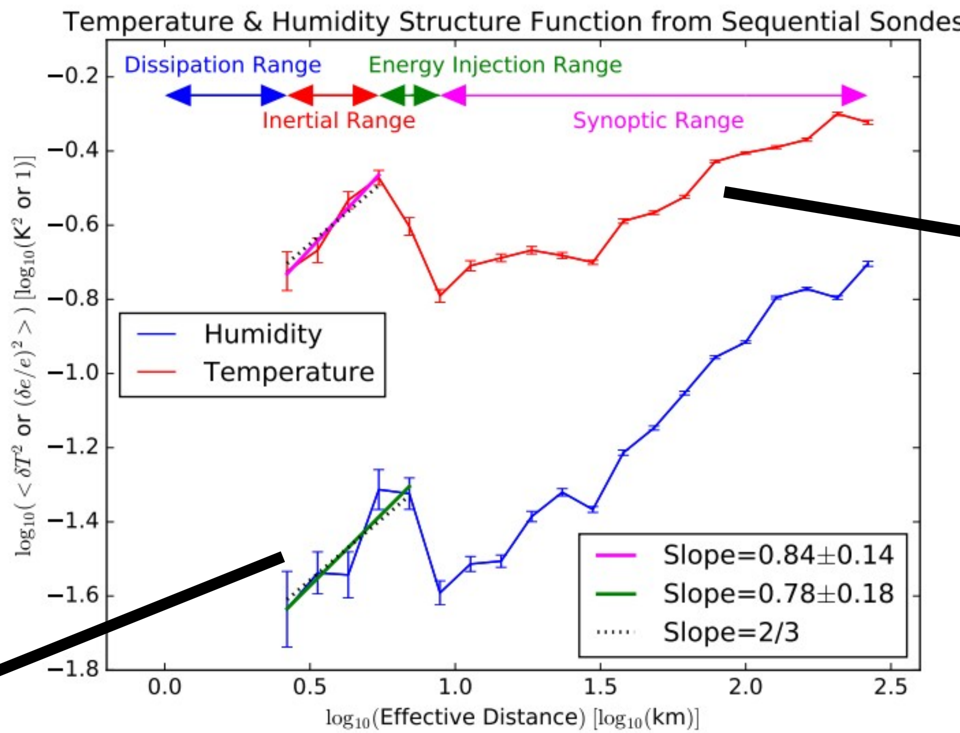
Dots at Center: Radiosonde relative to NWP Vertical over Observatory

Variability of Water Vapour

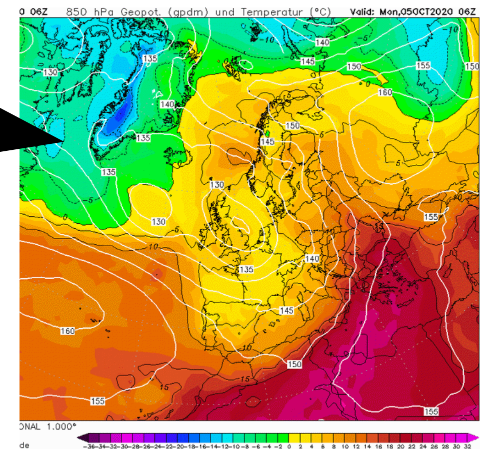
Two different scales → Implications for Nowcasting!

Scales < 6 km
Random
Gaussian Field





Scales > 10km
Smooth Field



Calbet et al. 2018, AMT

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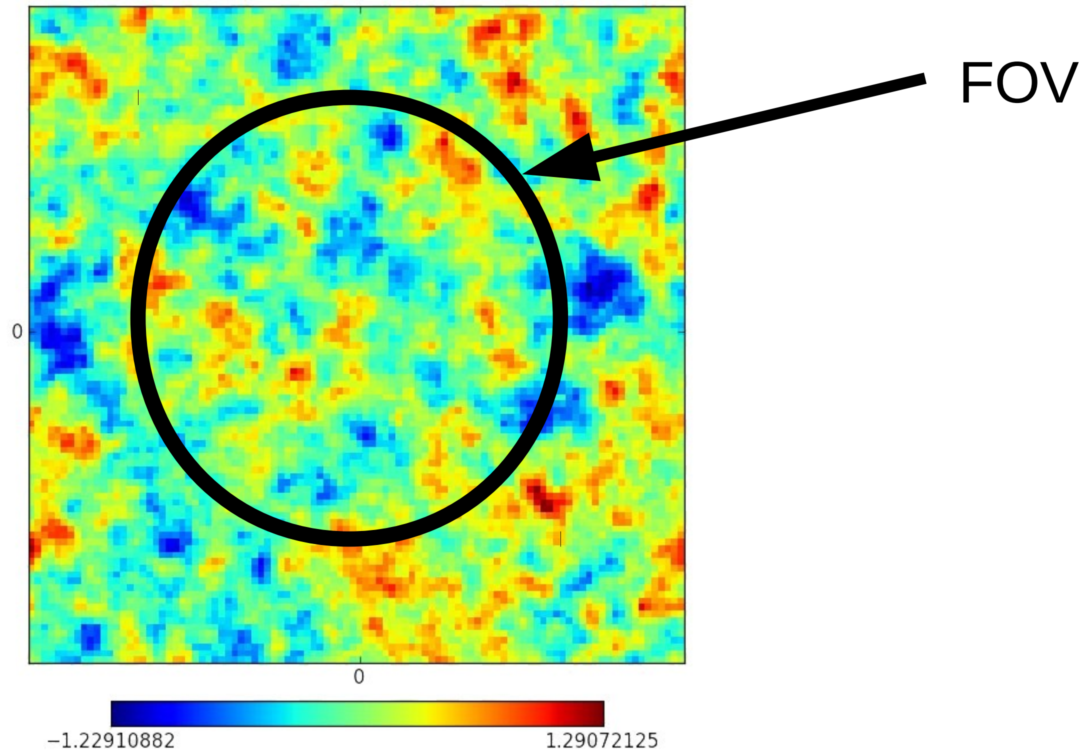
Variability of Water Vapour within FOV

Scales < 6 km

Random Gaussian Field



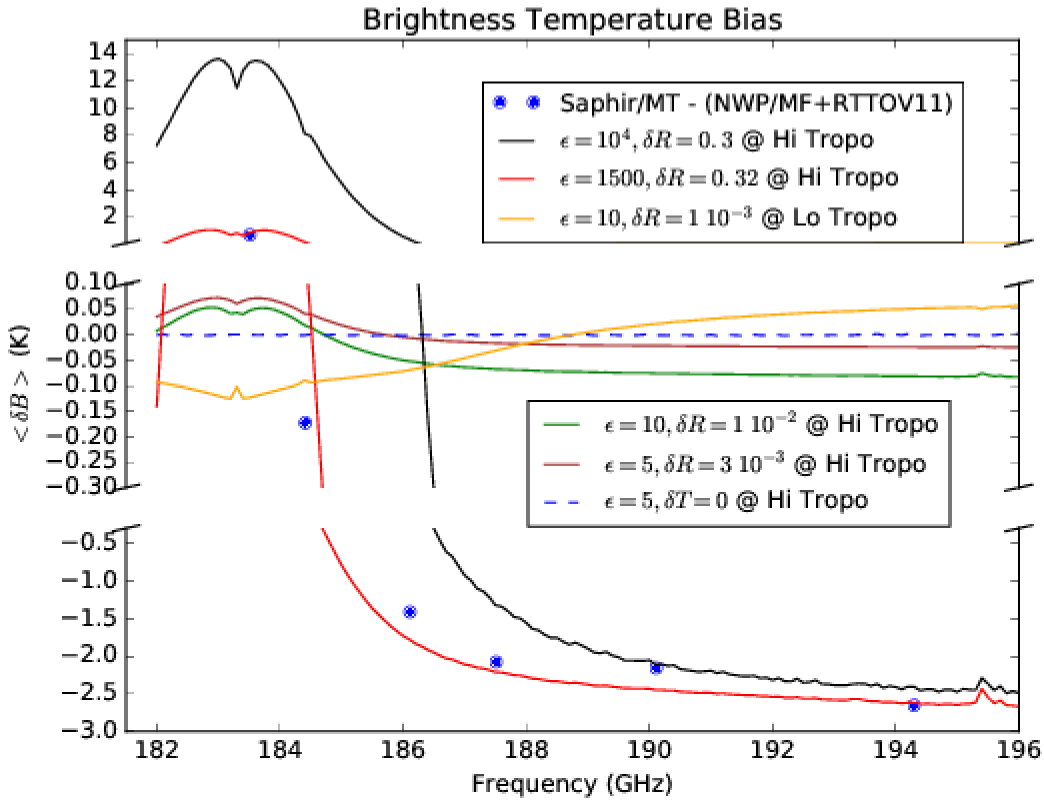
Effect of FOV inhomogeneity

Can turbulence=inhomogeneity within the Field of View cause significant biases in radiative transfer modelling in MW or IR?

$$< \delta B > \approx \sum_{i=1}^{\text{All Levels}} \frac{dB}{dR_i} < \delta R_i > + \frac{1}{2} \frac{d^2 B}{dR_i^2} < (\delta R_i)^2 >$$

Effect of FOV inhomogeneity

Can turbulence (= inhomogeneity) within the field of view cause significant biases in radiative transfer modelling at the 183 GHz band?



Calbet et al., AMT, 2018

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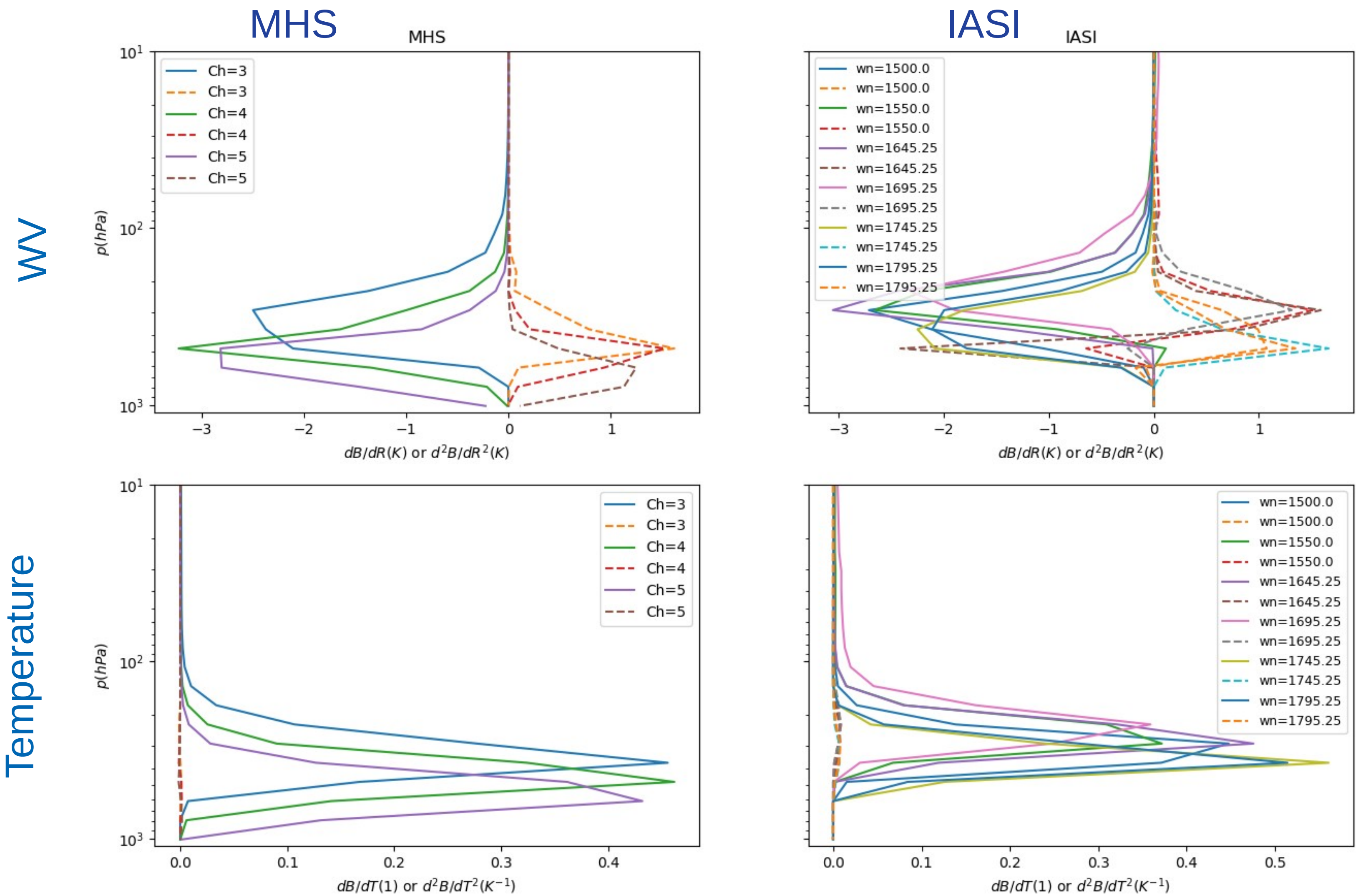
Effect of FOV inhomogeneity

MHS and IASI Jacobians (solid lines) and 2nd Derivatives (dashed lines)



Retrieving Turbulence?

- We can try Optimal Estimation Method (OEM) like techniques to retrieve the T and WV profiles and also WV Turbulence (= FOV inhomogeneity)

- We try OEM with an R exactly equal to instrument noise → We know this has failed before = too unconstrained system

- We use as background ECMWF analyses

- What happens when retrieving also turbulence? Do we retrieve anything reasonable?

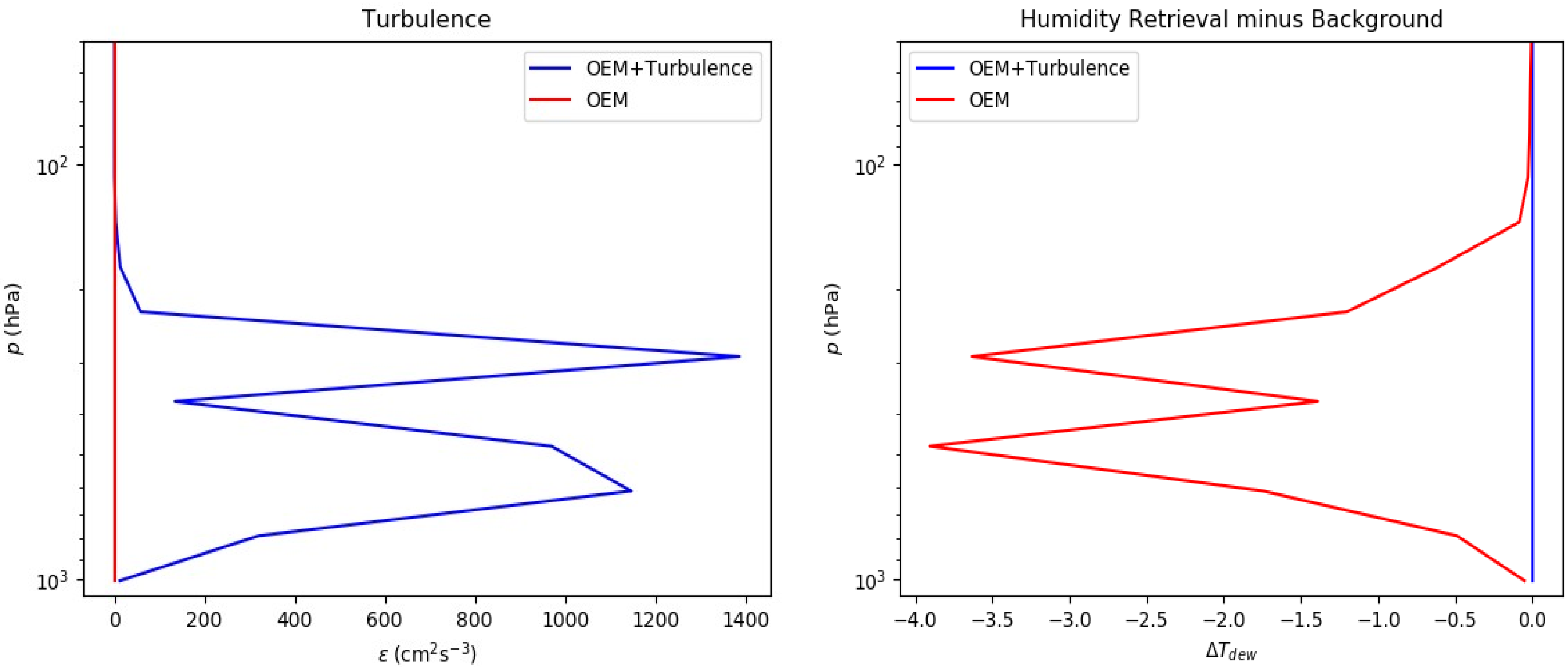
Retrieving Turbulence?

- We try OEM with an R exactly equal to instrument noise → We know this has failed before = too unconstrained system

- We use as background ECMWF analyses

- What happens when retrieving also turbulence?

Retrieving Turbulence?



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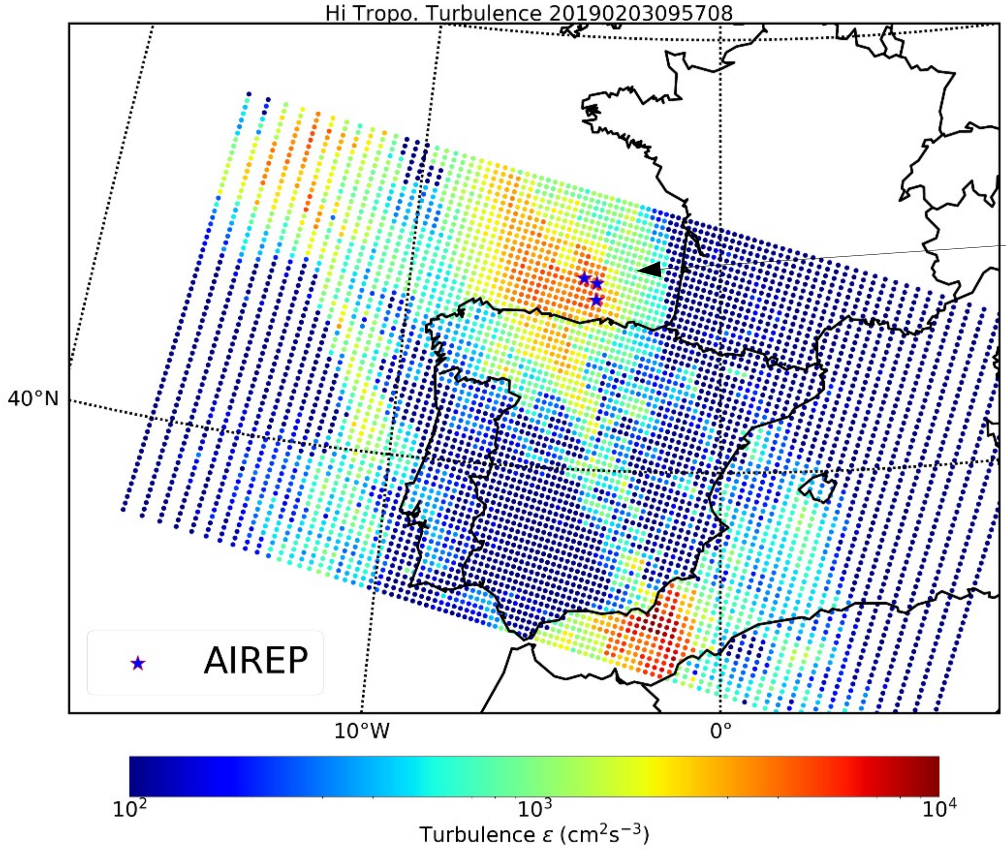
Retrieving Turbulence?

How does it look spatially?

Turbulence product obtained from retrieving water vapour inhomogeneities from MHS



Comparison with three AIREPs reports

Summary

- Ideally we should strive for consistency before combining different measurements
- There are still some remaining inconsistencies between different WV measurements
- Inhomogeneities within the FOV (turbulence) might explain the remaining inconsistencies
- Retrievals with turbulence (inhomogeneities) provide different humidity values with respect to OEM
- This would potentially allow the retrievals of turbulence, but would also complicate retrievals
- High spatial resolution humidity fields would help in this puzzle

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Future

- Can we characterize a FOV (random Gaussian field) with few parameters?

- How many (sonde) measurements do we need inside a FOV?

- What is the vertical and fine scale structure of turbulence? Do we need to look at LIDAR data?

- Can we see the inhomogeneities in high resolution imagers? Can they help?

- Can we retrieve turbulence from Satellite Sounders?