Quantification of inhomogenous water vapor concentration effects in IR and MW radiation biases comparing observed versus calculated radiances (sondes + RTTOV)

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ITSC-24

Summary

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Summary

1. Background: Sonde versus Sounders
2. Ongoing: Sonde versus Sounders
3. Theoretical Background
4. Previous results: small sample IR
5. Results: Big sample MW
6. Conclusion and Outlook

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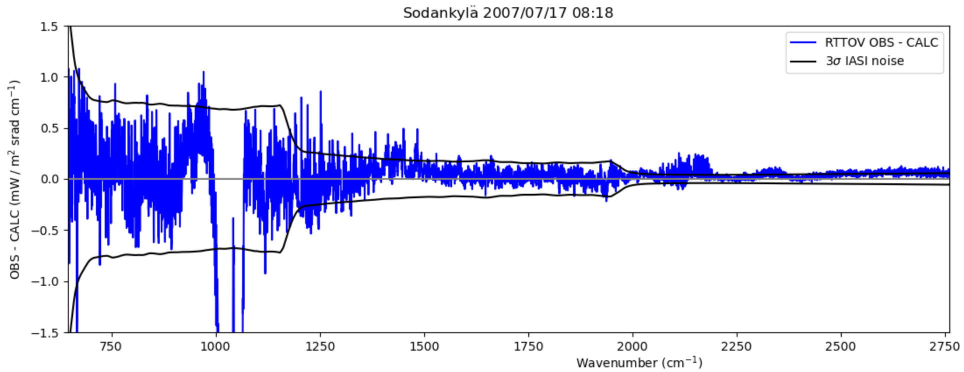
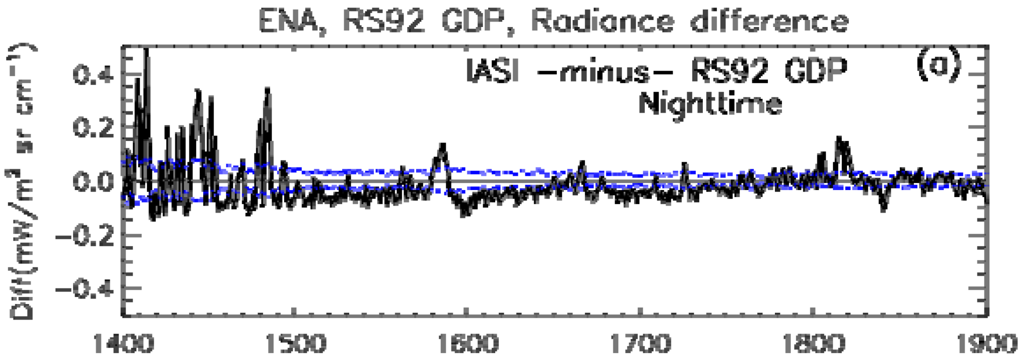
Background: Sonde versus Sounders

- Matching Sonde RTM with IR Hyper
  - Small Samples: Calbet et al. (AMT 2011,2016,2017)



  - Big Samples: Sun et al. (Rem. Sen. 2021)



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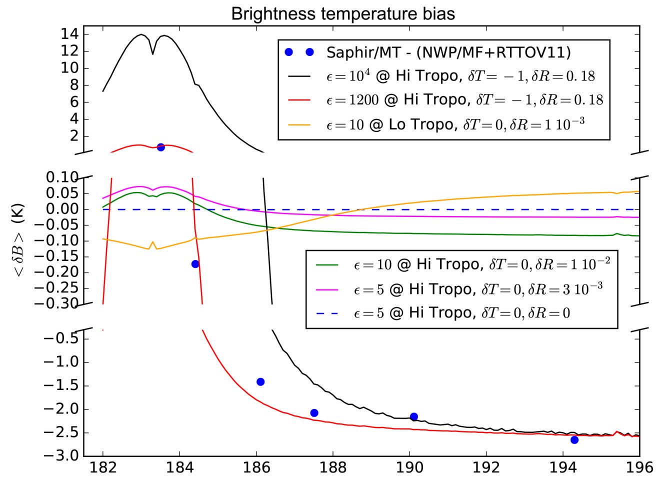
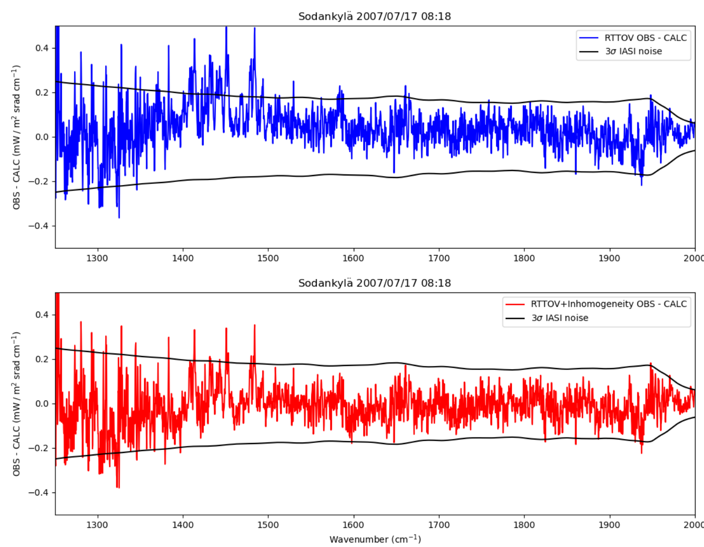
Background: Sonde versus Sounders

- Including WV Inhomogeneities in matching Sonde RTM with Sounders
  - MW Theoretical:
    Calbet et al. (AMT 2018)



  - IR Hyper Small Sample:
    Calbet et al. (ITSC-23 2021)



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Ongoing: Sonde versus Sounders

- Extending to Big Samples MW: Including WV Inhomogeneities in matching Sonde RTM versus Sounders
  - This presentation

- Refining study with Big Samples in IR and MW
  - Future

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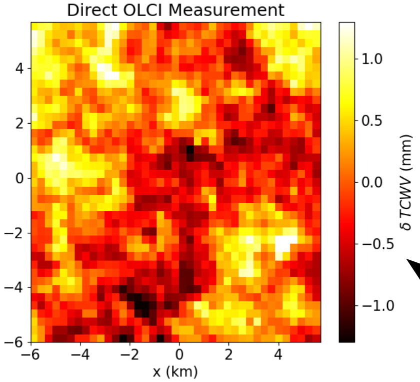
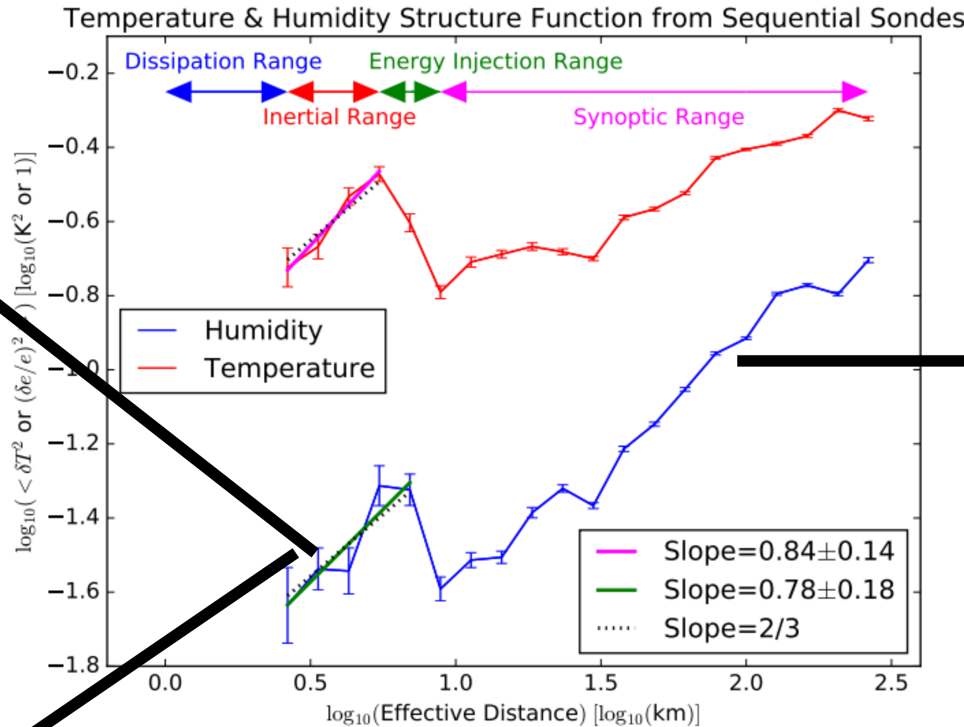
Variability of Water Vapour

Two different scales

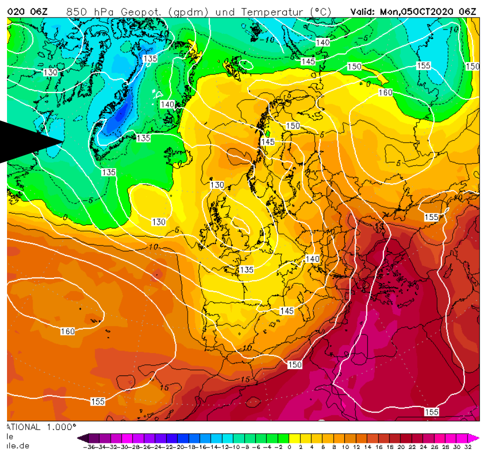
Reality

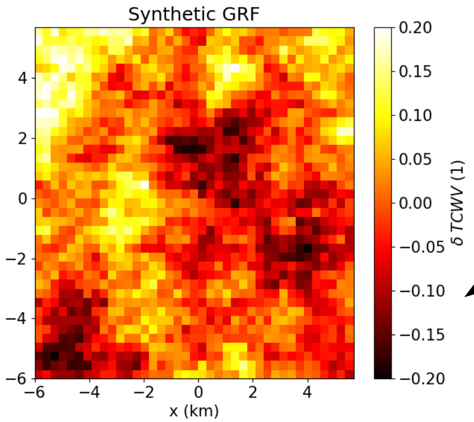


Scales < 6 km
Random
Gaussian Field



Scales > 10km
Smooth Field





Simulation

Calbet et al. 2022, AMT

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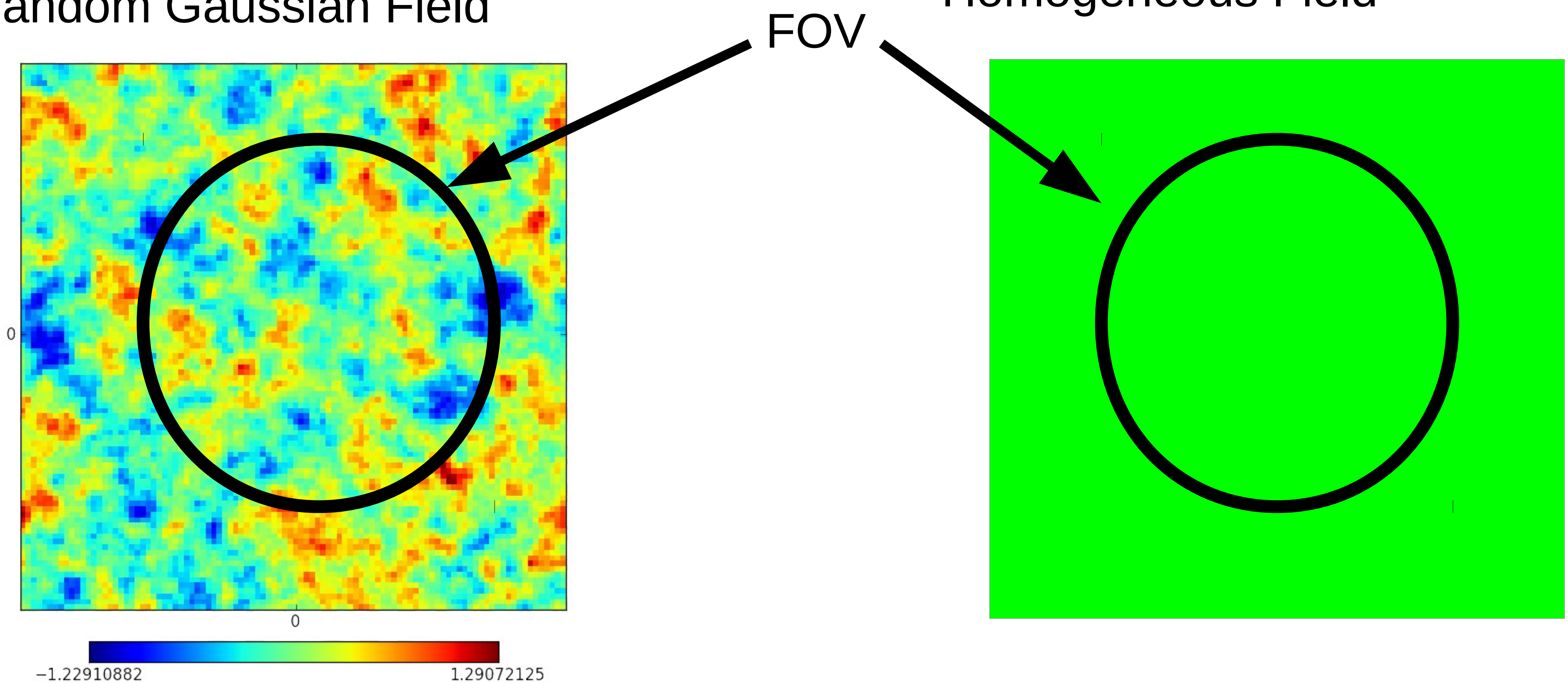
Variability of Water Vapour within FOV

Reality: Scales < 6 km
Random Gaussian Field

Currently assumed:
Homogeneous Field



Variability of Water Vapour within FOV

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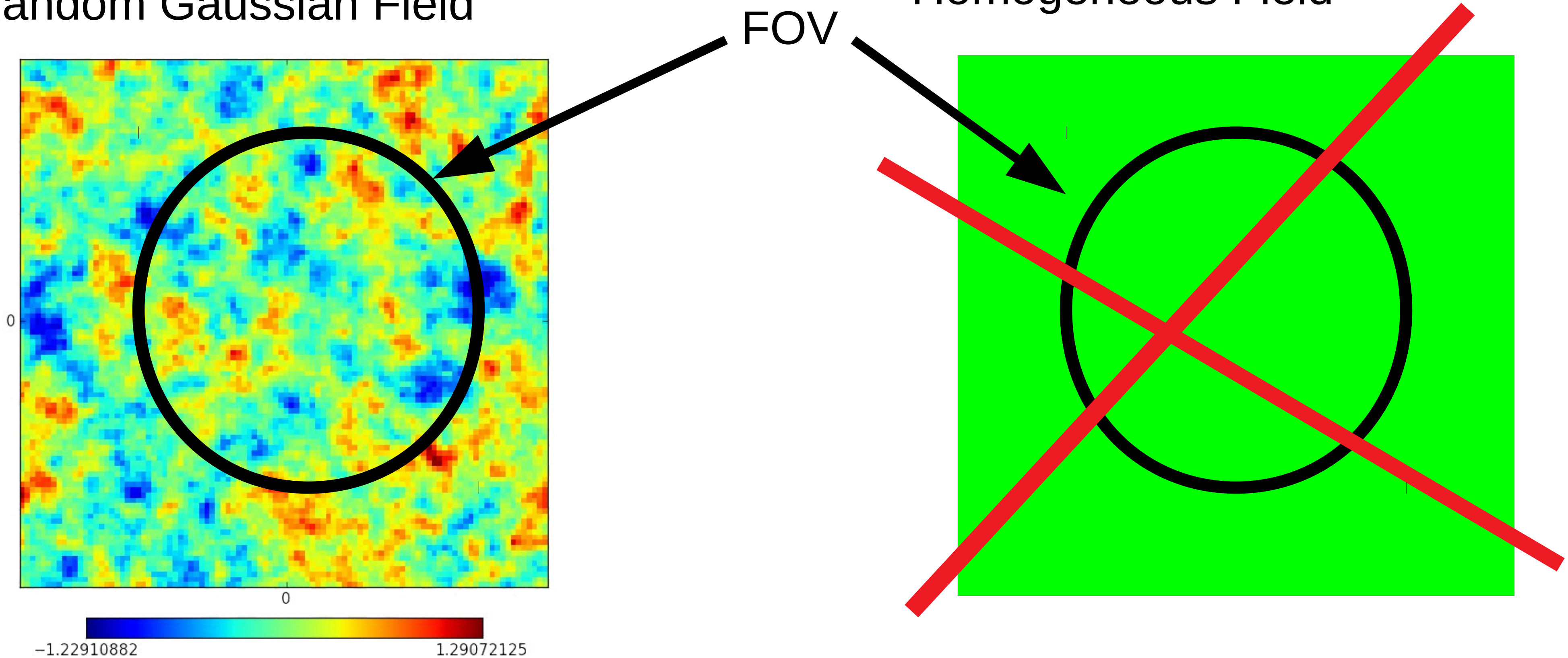

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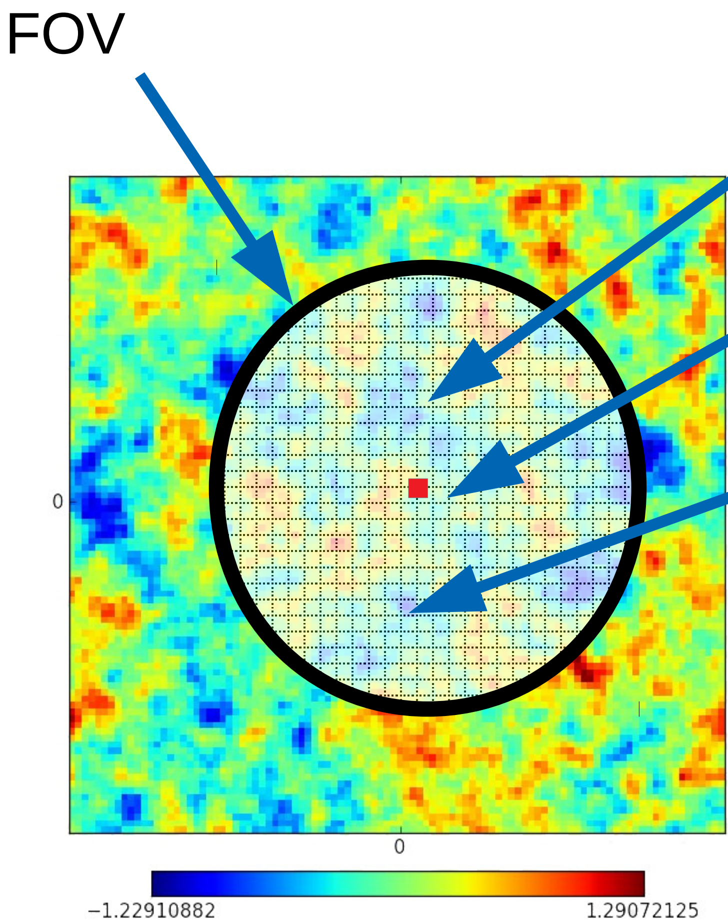
RTM in an inhomogeneous FOV



- Subdividing the FOV in small parcels, we can calculate the radiance R using the RTM at each parcel as a function of the WV profile w:
  $R = RTM(w)$

- We now calculate the RTM for a parcel in the center (marked as a red square) which we call w_0 :
  $R_0 = RTM(w_0)$

- For all the other parcels, w_j, we assume a Taylor expansion with respect to R_0 is enough:
  $R_j=R_0+ dR/dw\,(w_j-w_0)+1/2\, d^2R/dw^2 (w_j-w_0)^2$

- Changing notation by defining: $\delta R_j = R_j-R_0$ and $\delta w_j=w_j-w_0$ we have:
  $\delta R_j=dR/dw\, \delta w_j+1/2\, d^2R/dw^2\, \delta w_j^2$

- The space sensor will detect the integral, or equivalently, the average of all the radiances. Doing the spatial average, <>, over the j indices, we get:
  $\langle\delta R\rangle=dR/dw \langle\delta w\rangle+1/2\, d^2R/dw^2 \langle\delta w^2\rangle$

- Finally, if we take the effects of all the vertical profile levels, we get the equation from the following slide

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RTM in an inhomogeneous FOV

RTM calculation for an inhomogeneous FOV, where:

- < > means spatial average
- R are radiances
- w is humidity
- i, j are the vertical level indices

$$< \delta R > \approx \sum_{i=1}^{All\ Levs} \frac{dR}{dw_i} < \delta w_i > + \sum_{i=1}^{All\ Levs} \sum_{j=1}^{All\ Levs} \frac{1}{2} \frac{d^2 R}{dw_i dw_j} < \delta w_i \delta w_j >$$

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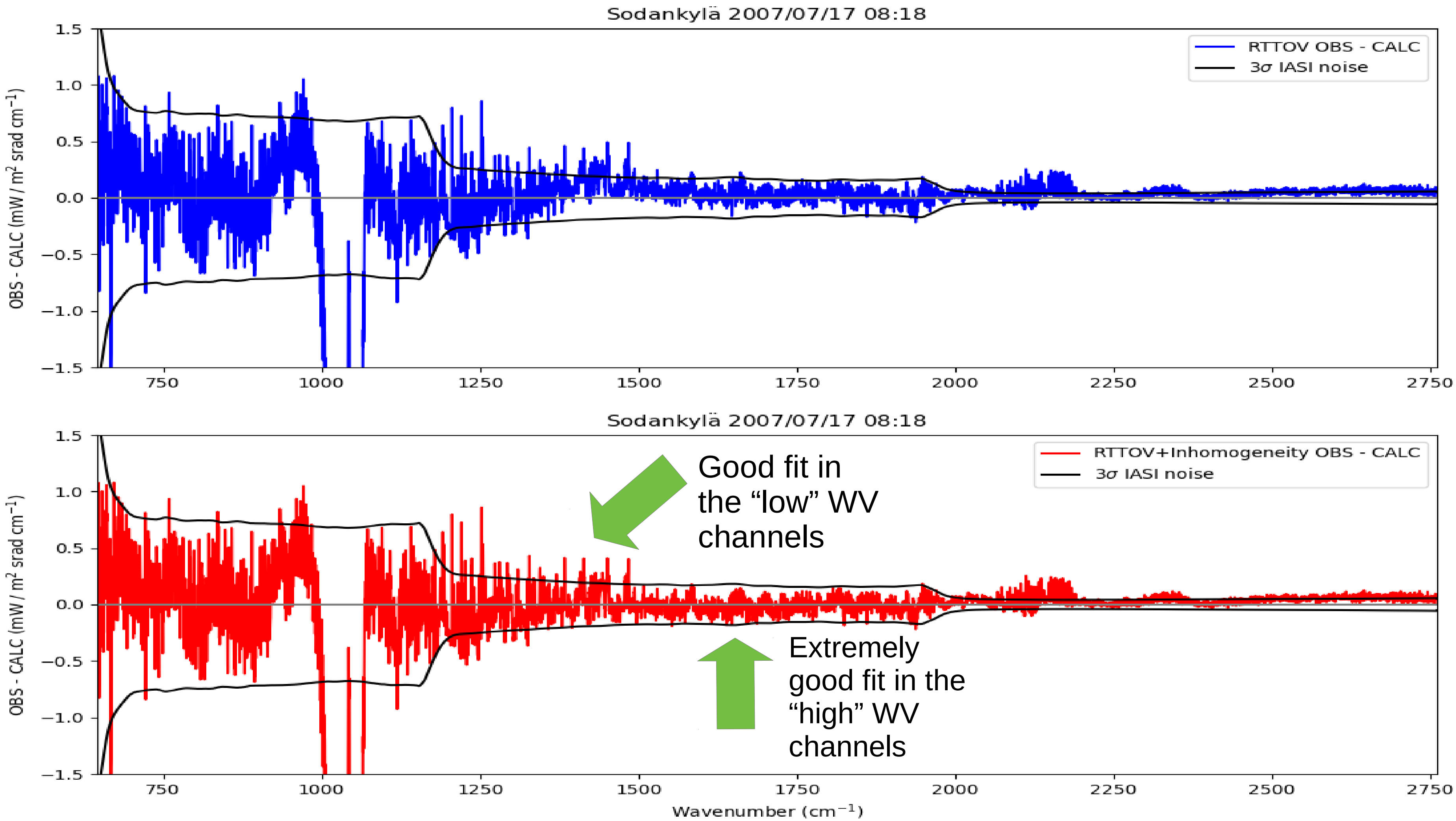
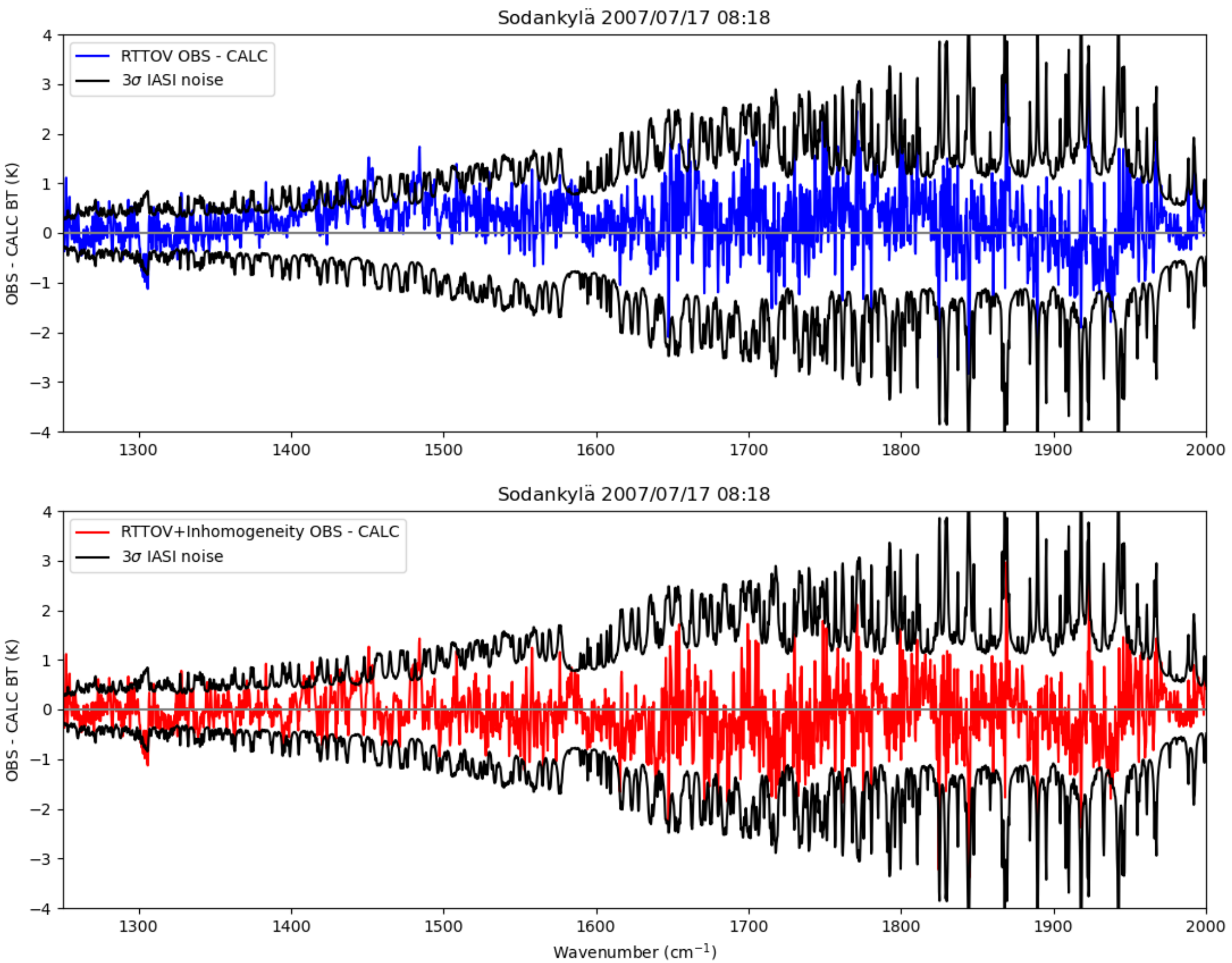
Previous result (ITSC-23): small sample for IASI



Previous result (ITSC-23): small sample for IASI



Comparison in Brightness Temperature Space → Improvement of around 0.5K

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Results: Big sample MW

- Sonde sample from Metop campaign 2007 over Lindenberg: 134 sequential sondes
- Sequential sondes = two consecutive sondes launched 50 min and 5 min before satellite overpass time
- GRUAN processed sondes
- MW data from Metop MHS
- RTM from RTTOV 13
- Skin Temperature retrieved approximately from MHS Channel 2 only
- Simple precipitation screening:
  BT(89 GHz) – BT(157 GHz) < 5 K
- No further cloud processing
- Final sample size 119 sequential sondes

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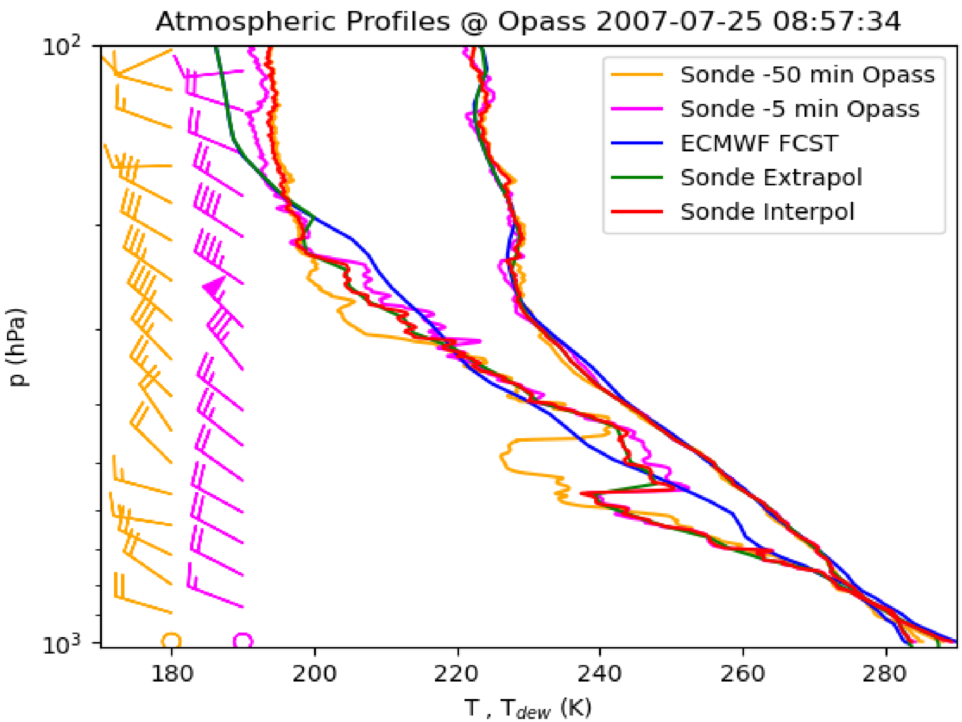
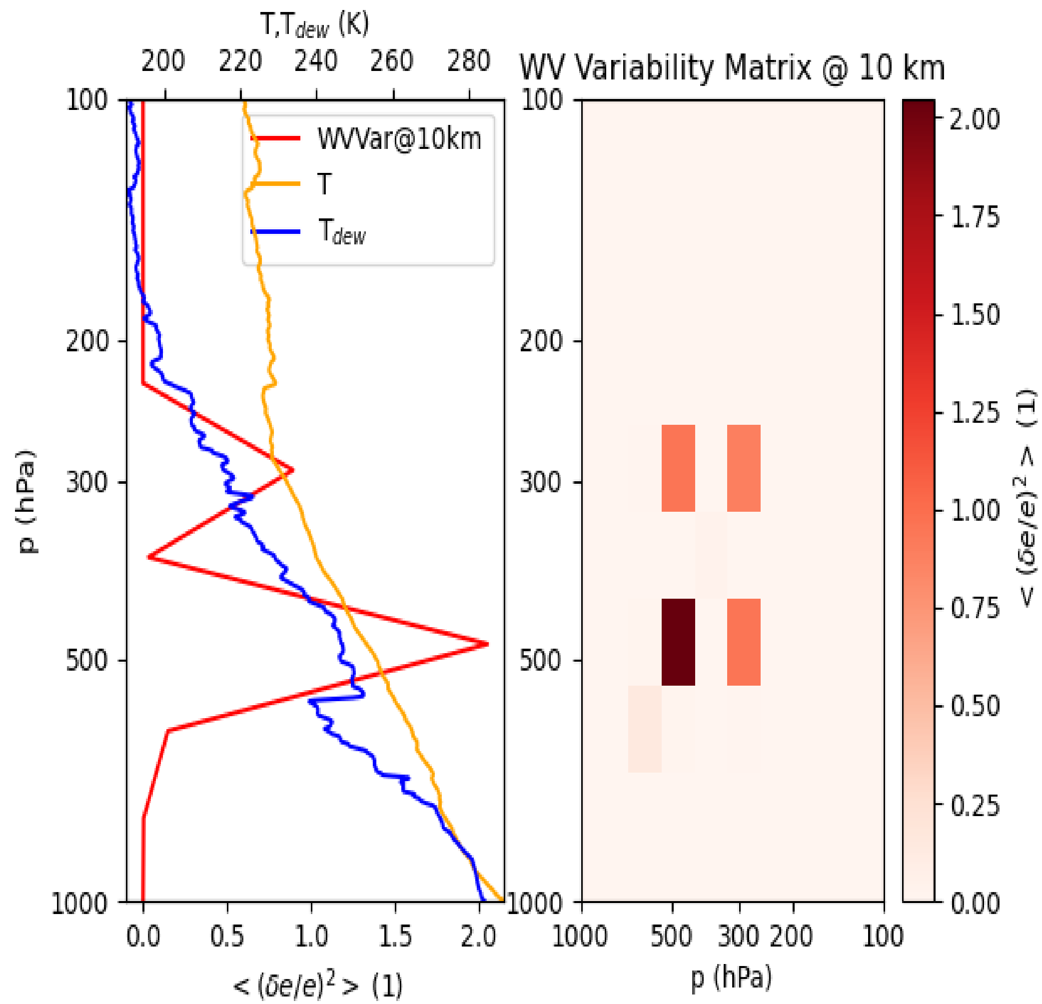
WV Variability matrix from Sequential Sondes





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RTM in an inhomogeneous FOV

- RTM calculations done with RTTOV 13
- Base profile from time interpolation of sequential sondes
- First and second derivatives calculated numerically (34425 RTM calculations for each profile)
- Radiance modified with inhomogeneities corrections from second derivatives and WV variability matrices

$$< \delta R > \approx \sum_{i=1}^{All\ Levs} \frac{dR}{dw_i} < \delta w_i > + \sum_{i=1}^{All\ Levs} \sum_{j=1}^{All\ Levs} \frac{1}{2} \frac{d^2 R}{dw_i dw_j} < \delta w_i \delta w_j >$$

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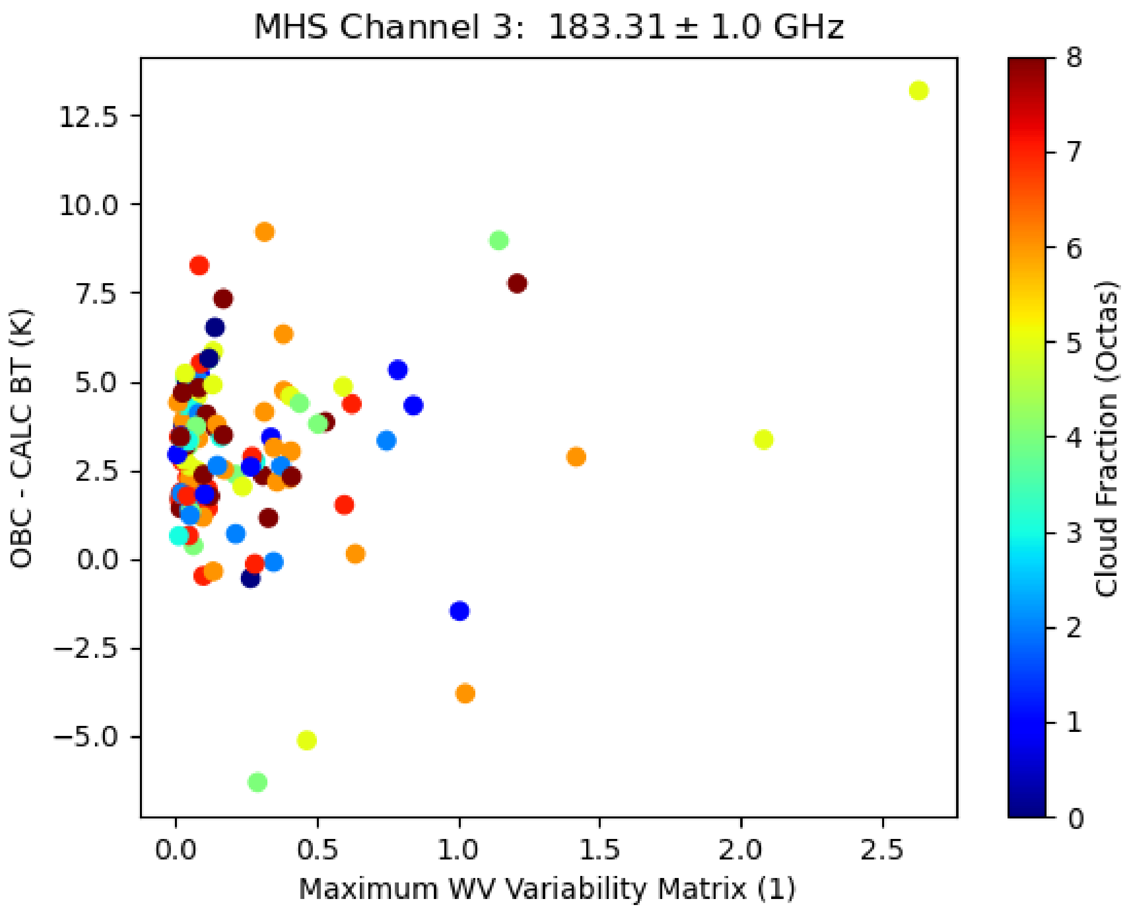
Comparison WITHOUT any Inhomogen. RTM



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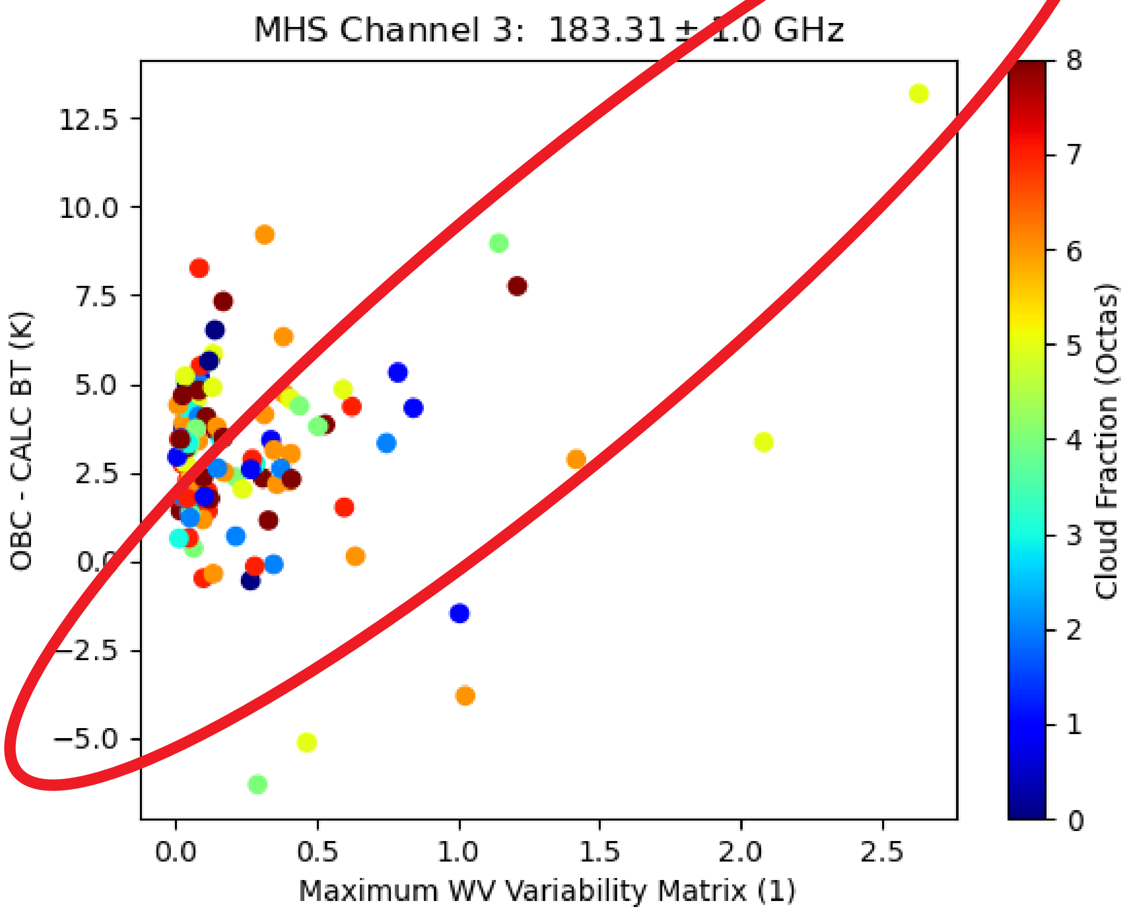
Comparison WITHOUT any Inhomogen. RTM



Good correlation points

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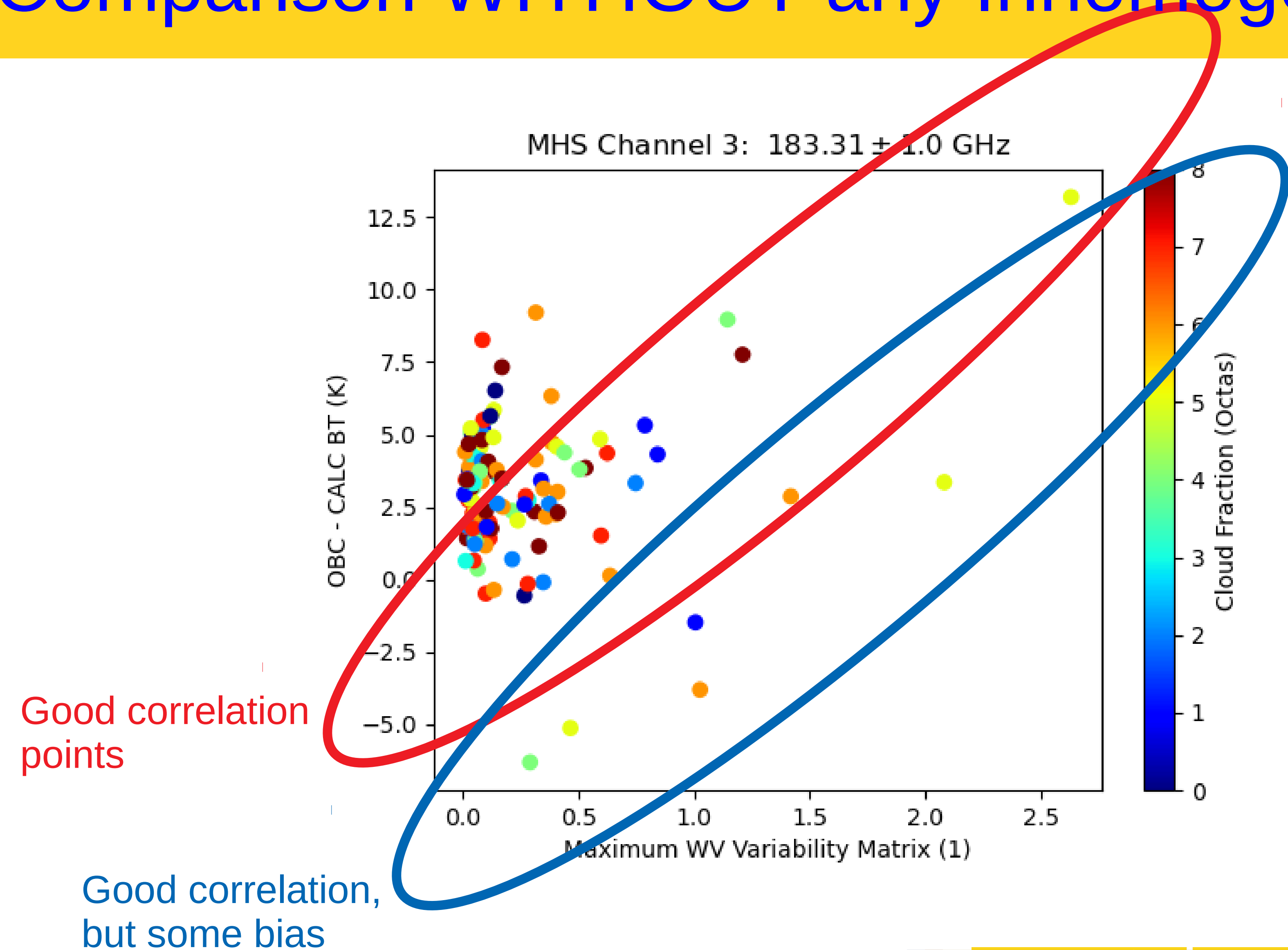
Comparison WITHOUT any Inhomogen. RTM



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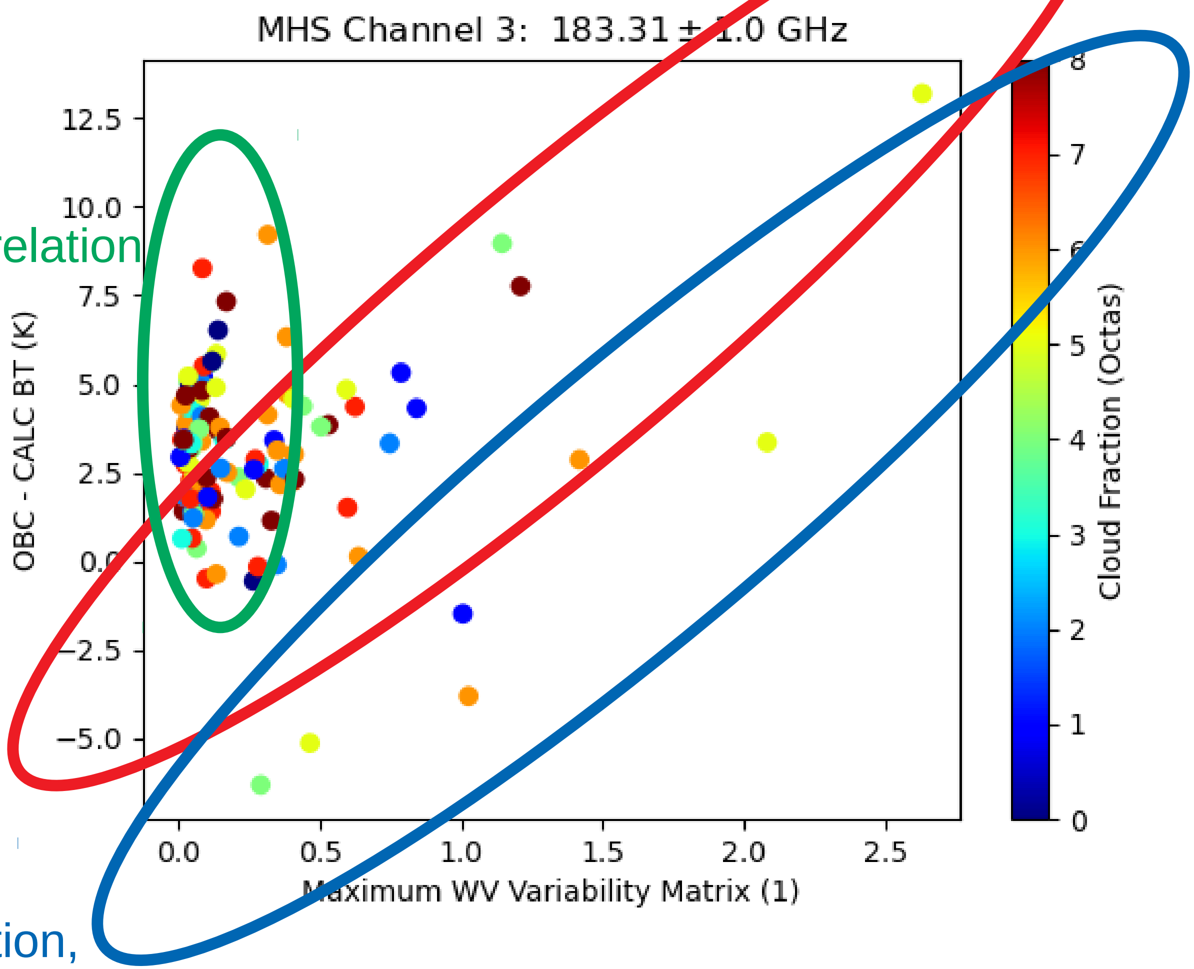
Comparison WITHOUT any Inhomogen. RTM

No Correlation



Good correlation points

Good correlation, but some bias

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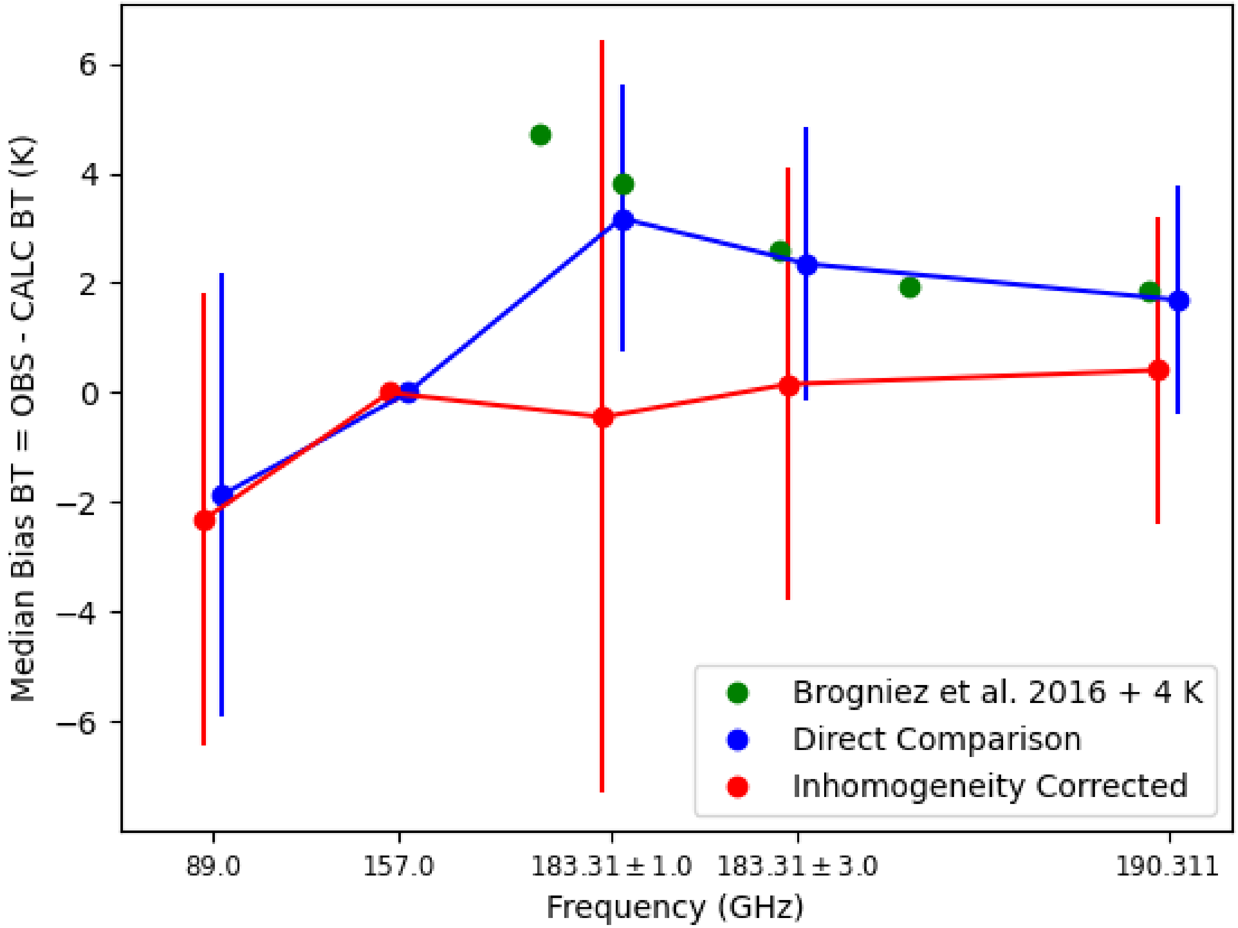
OBS – CALC MHS Biases



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Summary

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Conclusions and Outlook

Conclusions

- WV Inhomogeneity does push the MW radiances in the right direction
- WV Inhomogeneity does push the MW radiances the right amount
- WV Inhomogeneity does affect significantly the MW radiances <~ 4K
- Biases can be corrected using WV inhomogeneities
- But STDV becomes higher → Something not well modelled: Clouds??, Inaccurate WV Var matrices?? Microturbulence effects?? Spectroscopy??

Outlook

- Work will be extended to the IR (IASI)
- Work will be extended with RS41 sequential sonde data together with MW and IR instruments from NOAA
- Project to fit Sonde+RTM to IR+MW Observations individually within instrument noise
- Code in https://gitlab.aemet.es/xcalbeta/Sonde2RTM.git

- Questions, comments, contributions welcome!!

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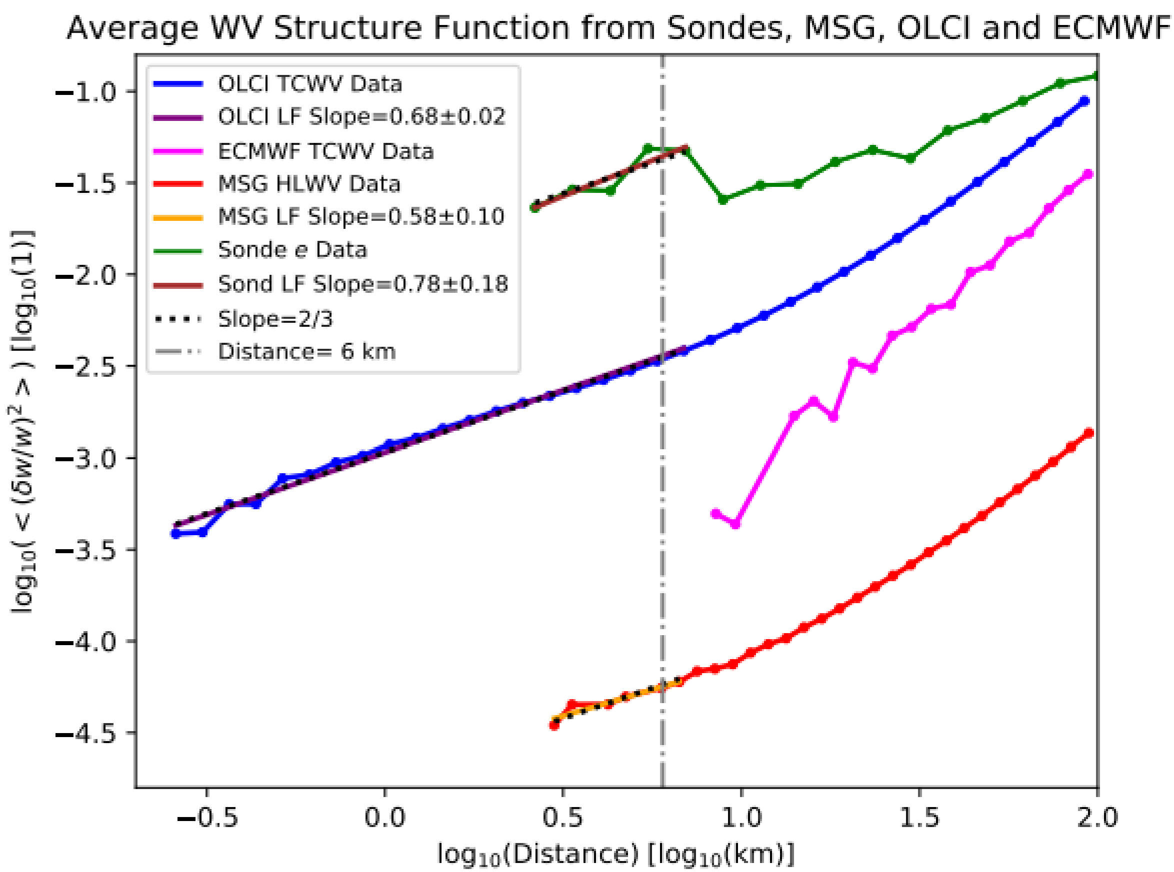
Backup Slides

Structure Function of WV from Sondes, MSG and OLCI



Calbet et al. 2022, AMT

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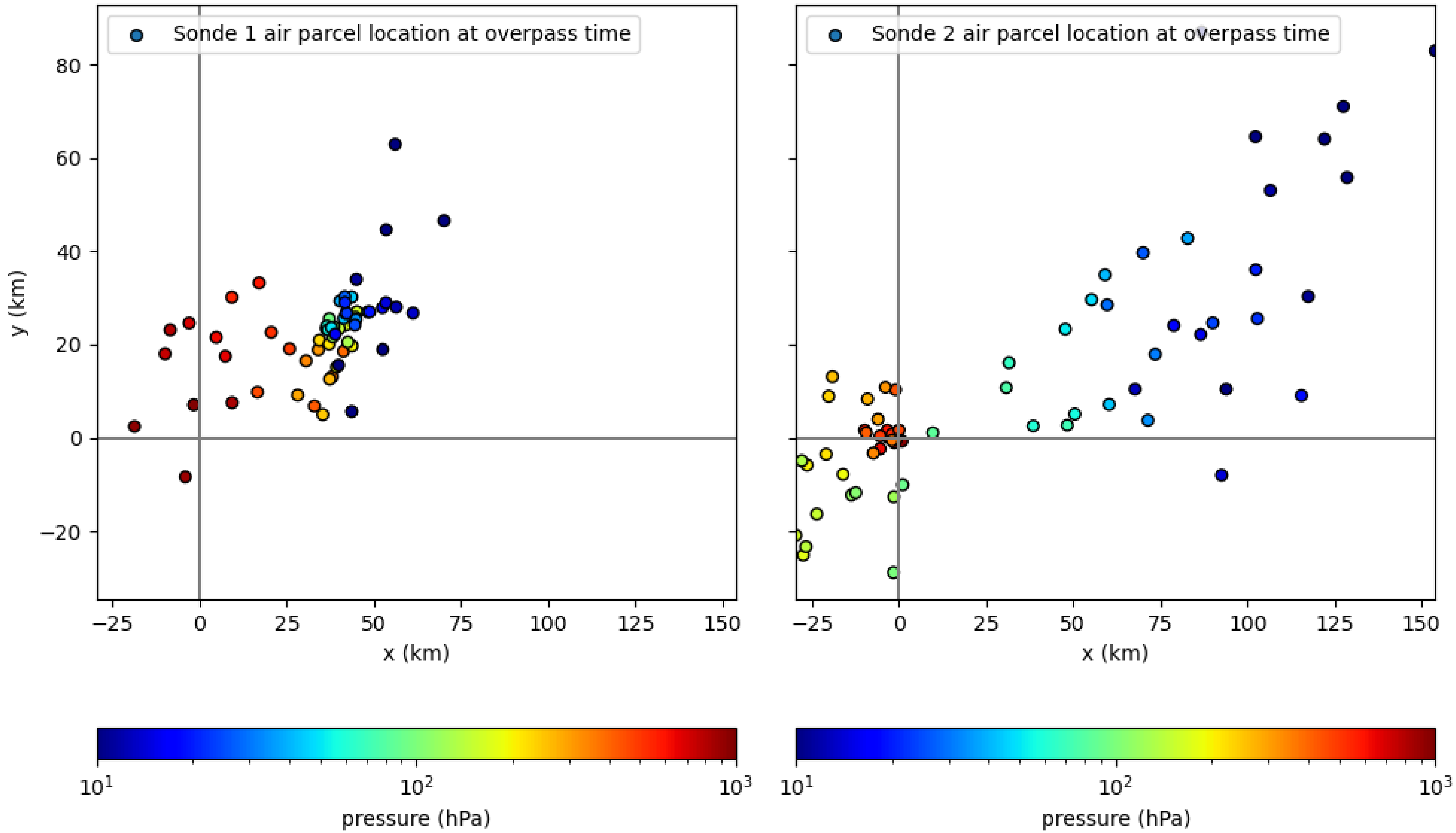
Position of sondes at Satellite Overpass Time



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