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# Water Vapour variability at different scales

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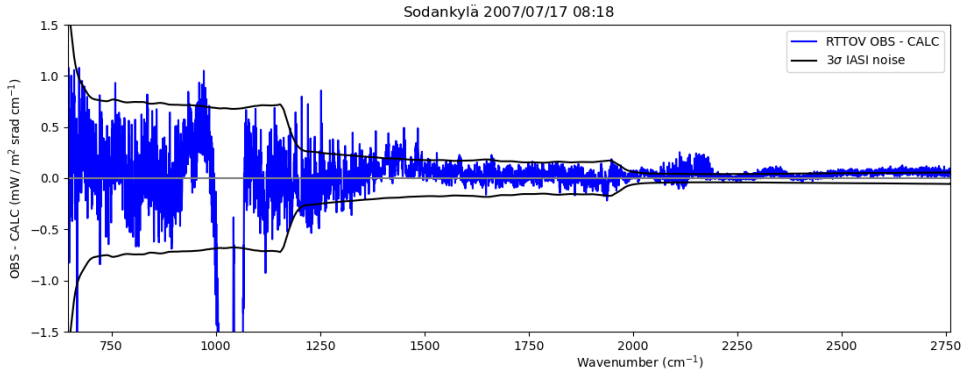
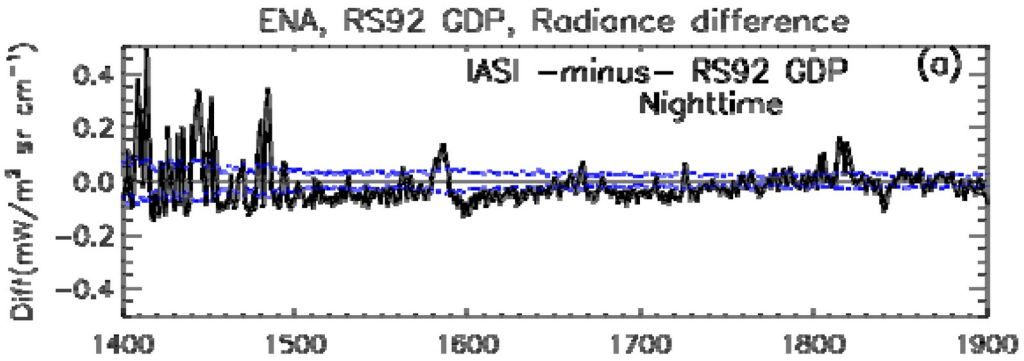
# Background: Sonde versus Sounders

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

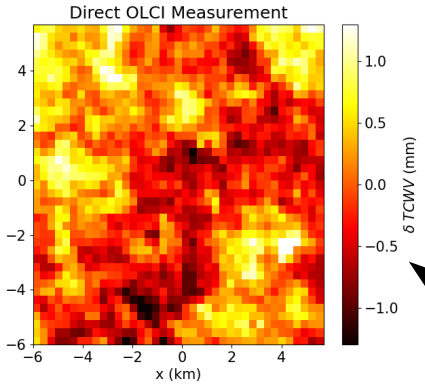



  - Big Samples: Sun et al. (Rem. Sen. 2021)

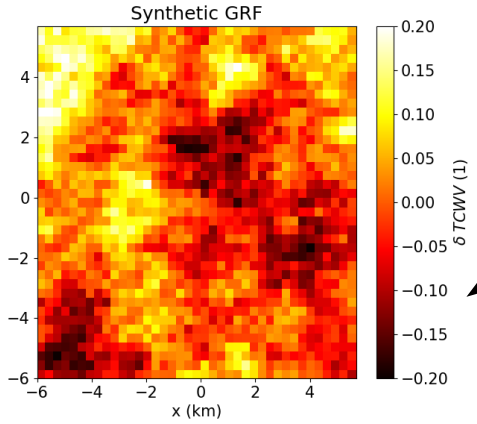


# Variability of Water Vapour

Reality

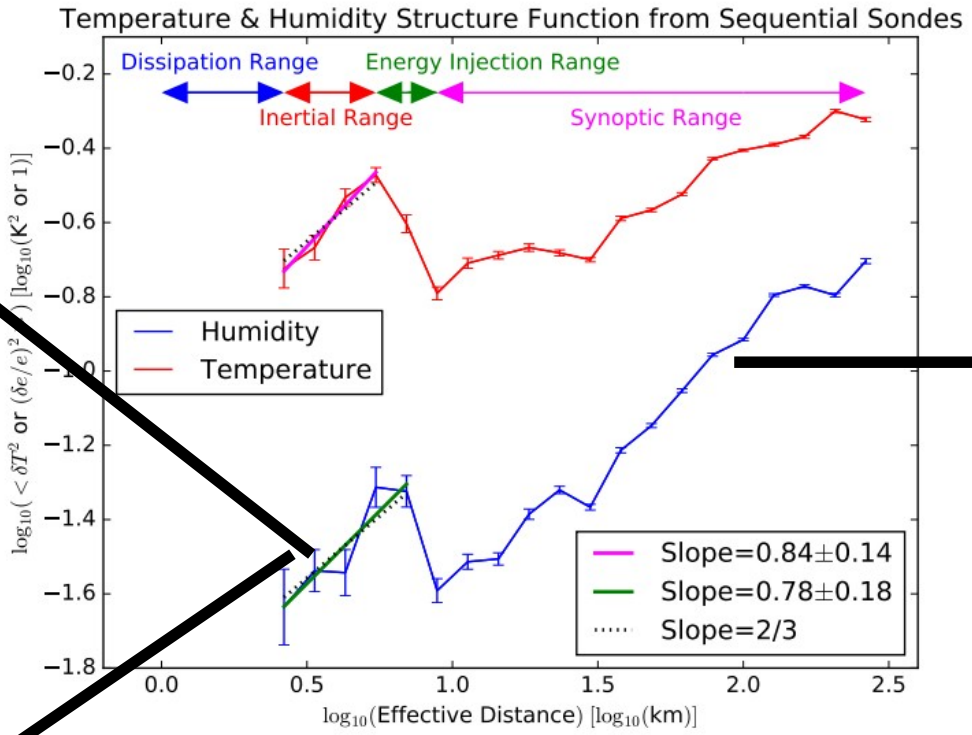



Scales < 6 km
Random
Gaussian Field



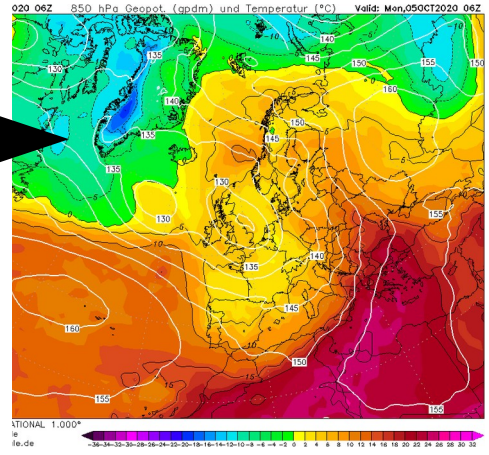

Simulation

## Two different scales




Calbet et al. 2022, AMT

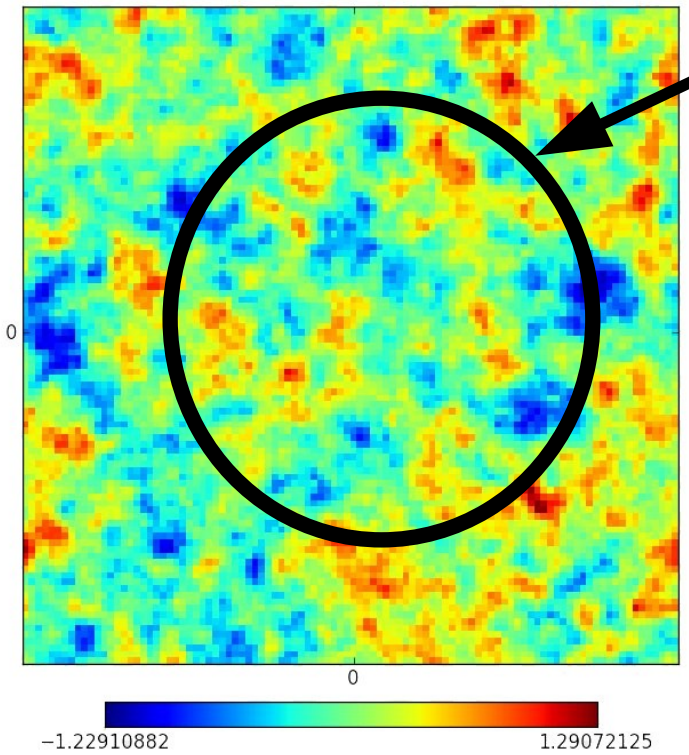
Scales > 10km
Smooth Field



# Variability of Water Vapour within FOV

Reality: Scales < 6 km

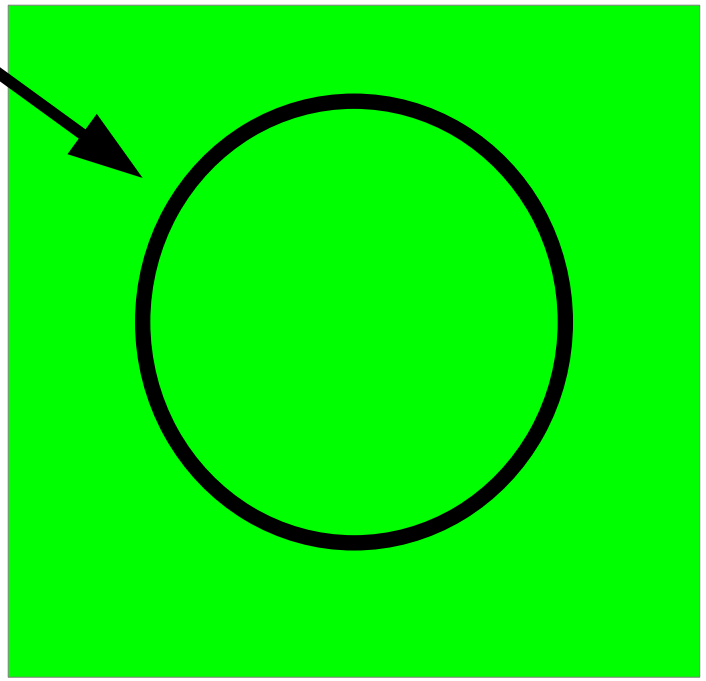
Random Gaussian Field




FOV

Currently assumed:

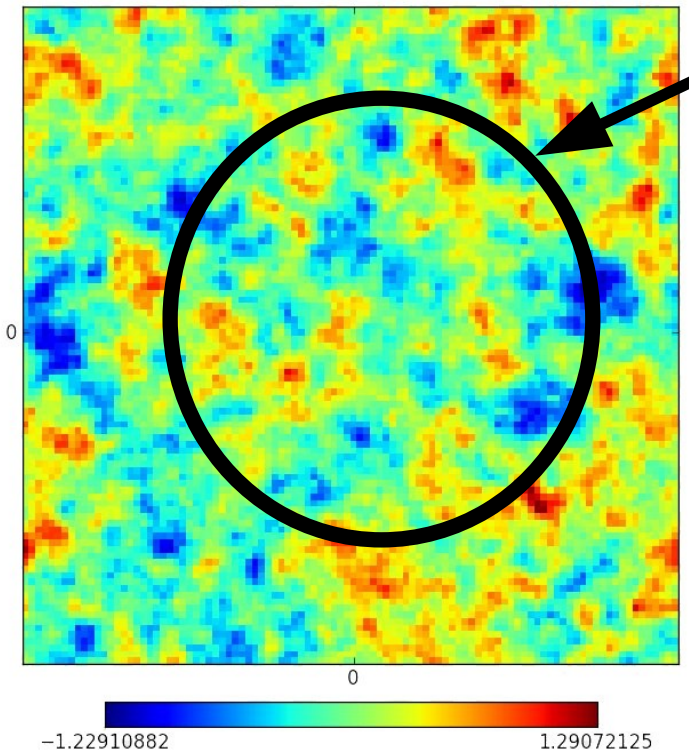
Homogeneous Field



# Variability of Water Vapour within FOV

Reality: Scales < 6 km

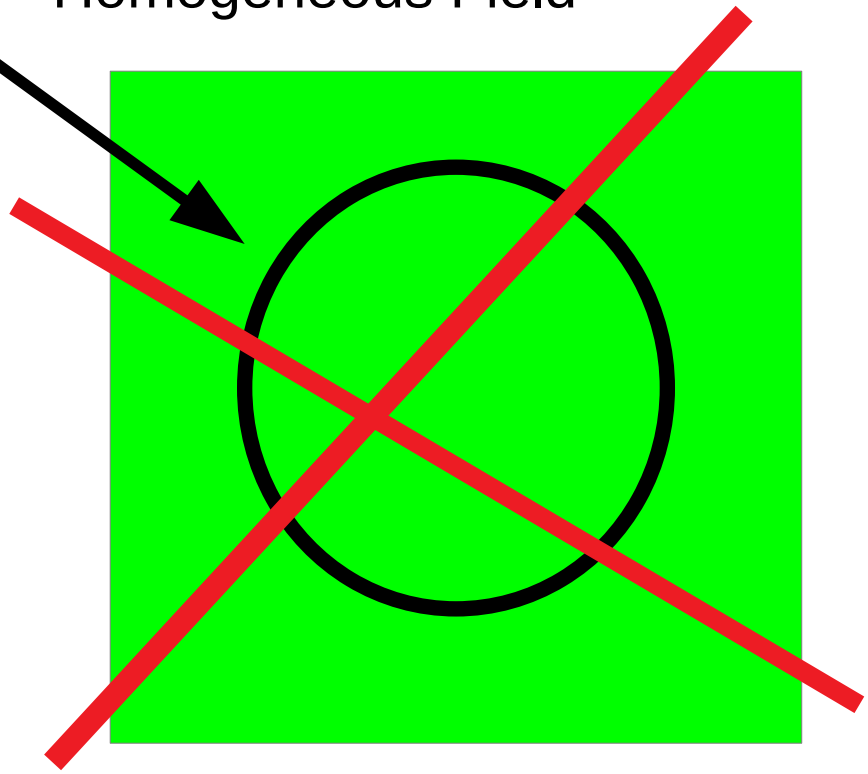
Random Gaussian Field




FOV

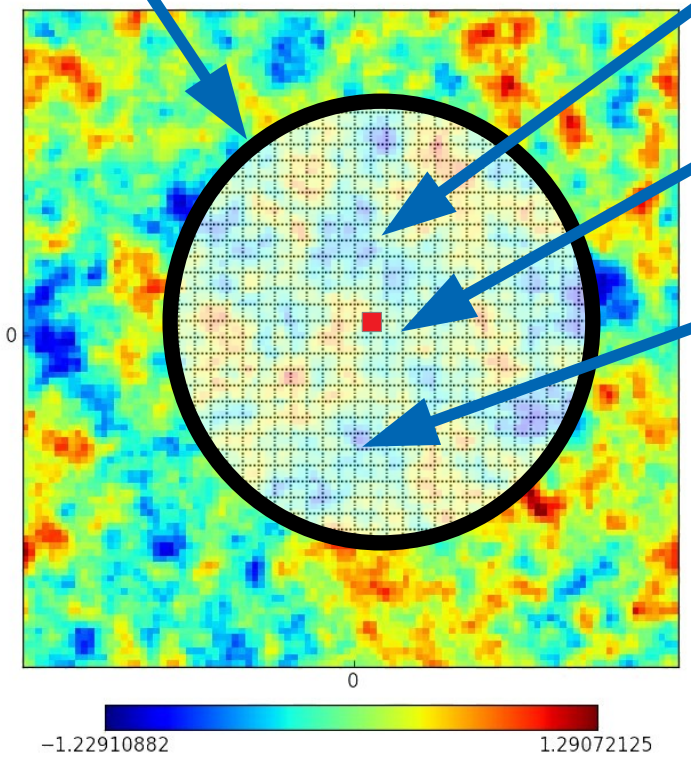
Currently assumed:

Homogeneous Field



# RTM in an inhomogeneous FOV

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:
  $<\delta R>=dR/dw\ <\delta w>+1/2\ d^2R/dw^2\ <\delta w^2>$

- 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

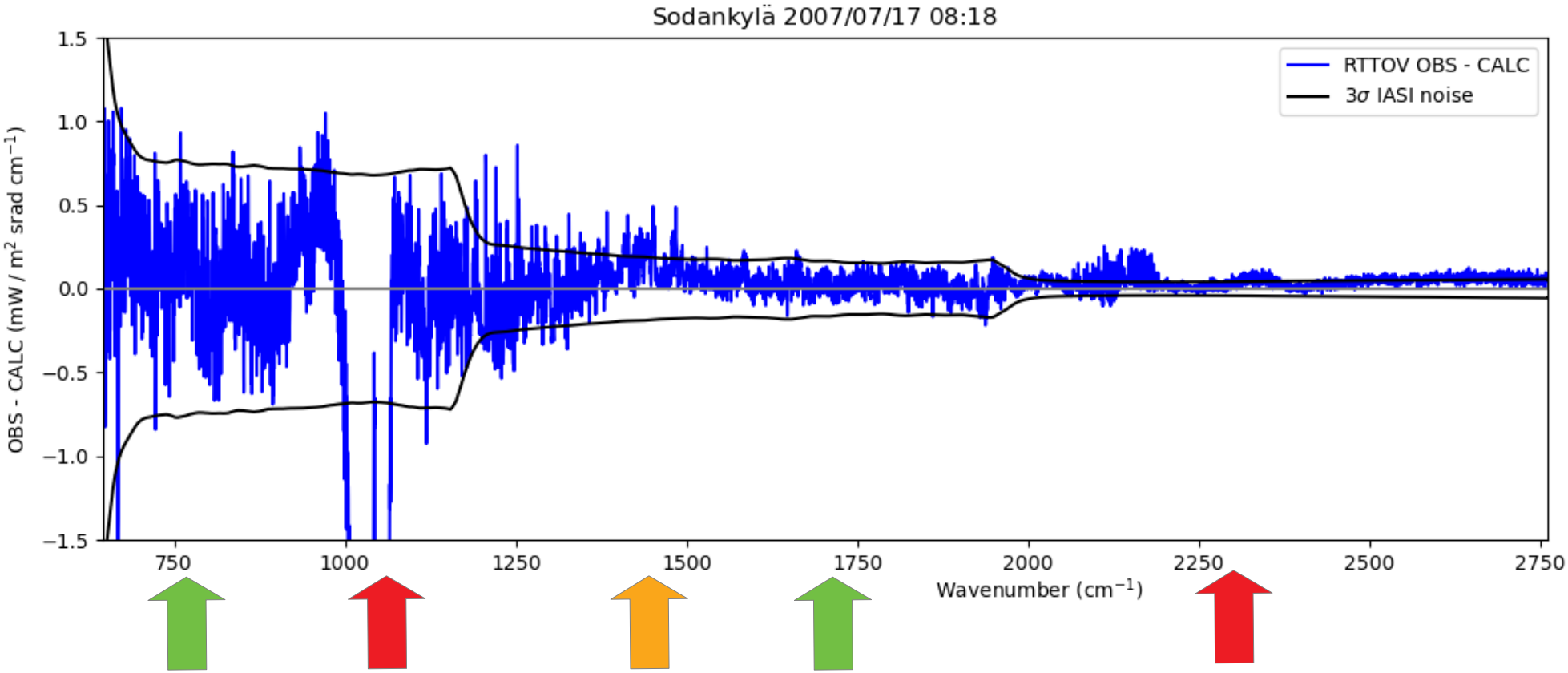
RTM calculation for an inhomogeneous FOV, where:

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

Due to non-linearities: The average of the radiances from different profiles is NOT the radiance of the average of the profiles

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

# RTTOV IASI Radiances from Best State Estimate




Good fit in the CO2 and Window channels

Wrong Ozone profile

Not so good fit in the “low” WV channels

Extremely good fit in the “high” WV channels

Bad fit in the “solar” channels

Calbet 2016, AMT

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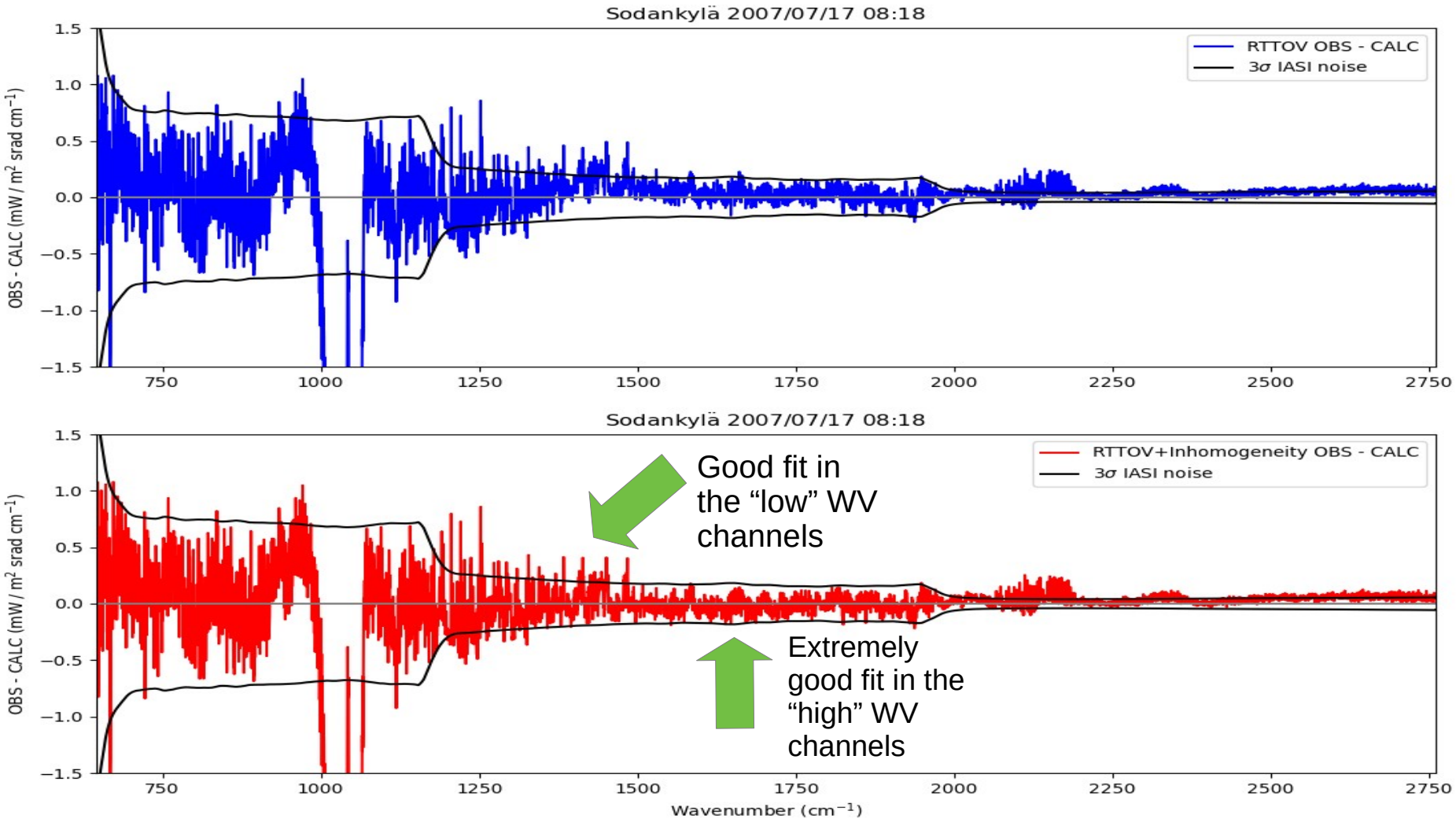
# Previous result (ITSC-23): small sample for IASI



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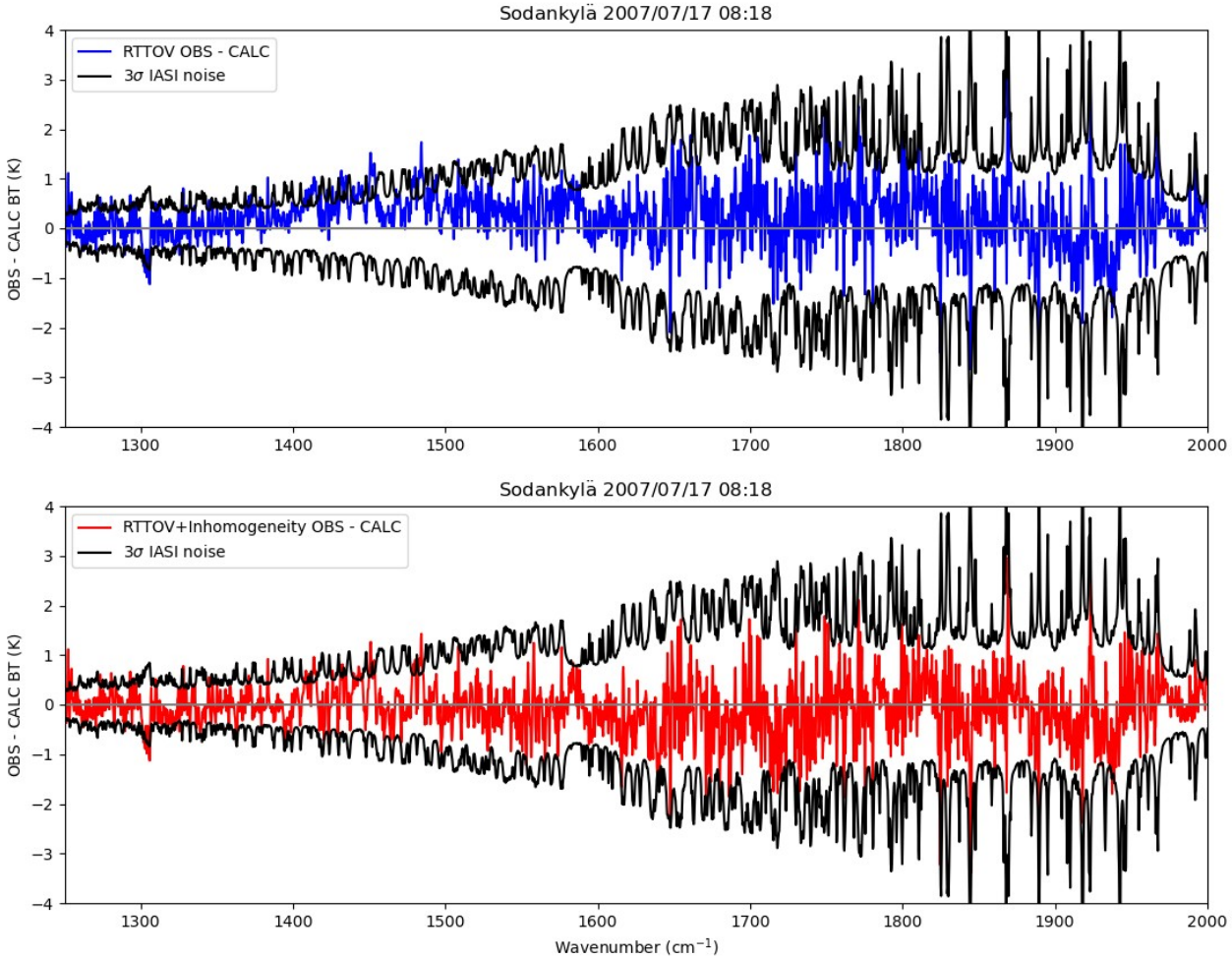
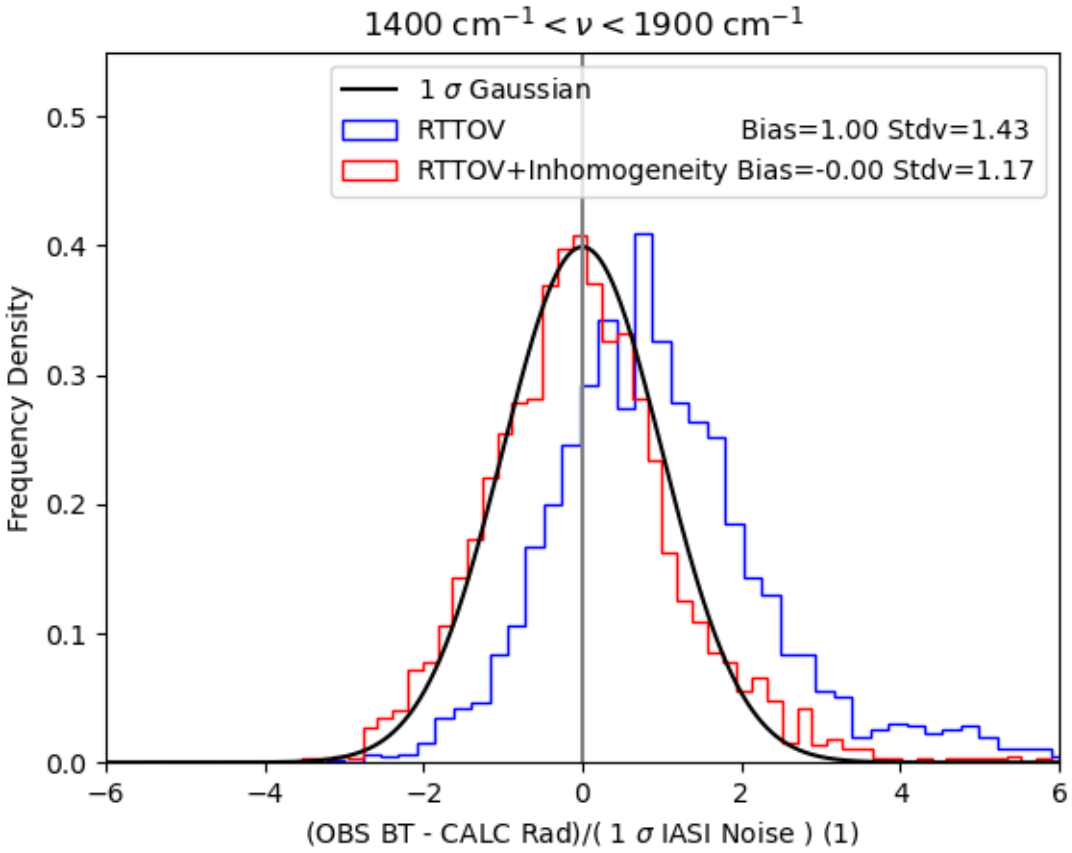


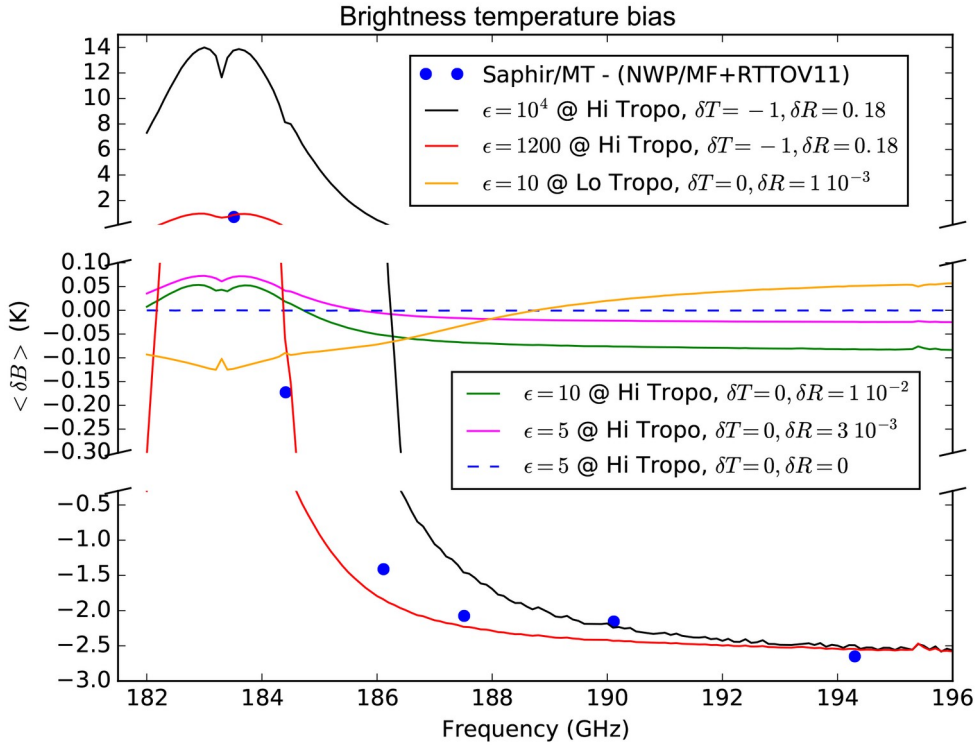

Comparison in Brightness Temperature Space → Improvement of around 0.5K

# IASI Radiances with and without WV Inhomogeneities

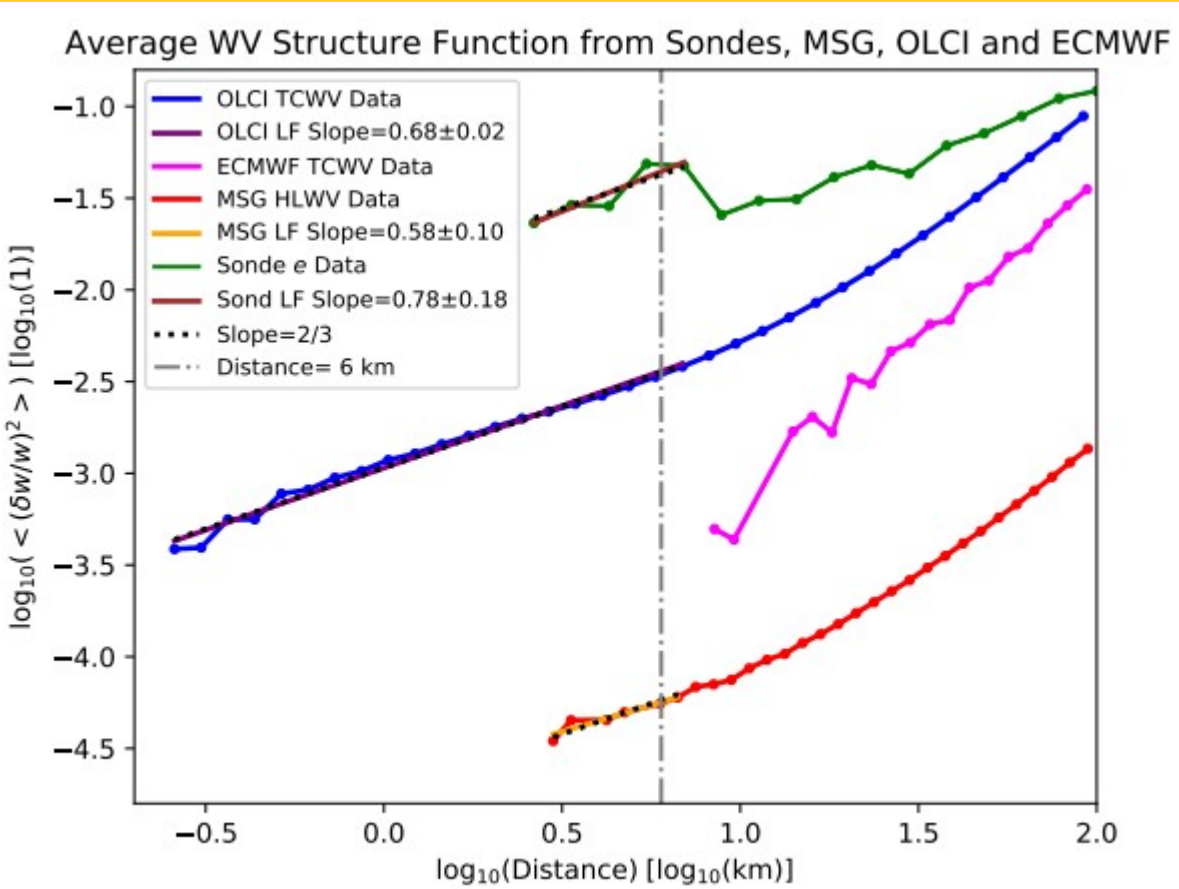


# Background: Sonde versus Sounders

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



# Structure Function of WV from Sondes, MSG and OLCI




Calbet et al. 2022, AMT

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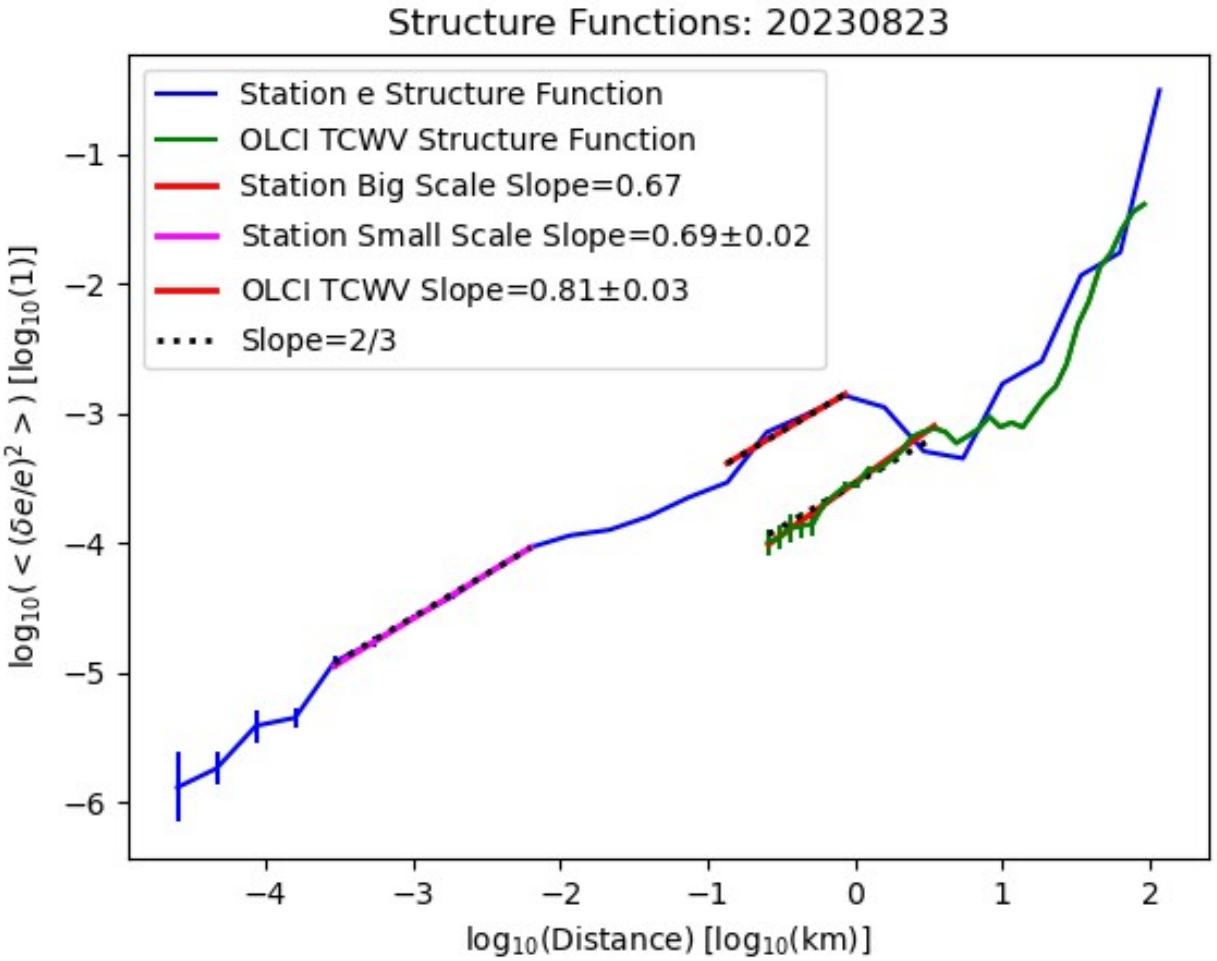
# Structure Function of WV from Ground Station and OLCI




New

# Discussion

- Critical: sequential sondes (launches), reference CFH measurement (or GRUAN processing)
- Structure function will be extended to GNSS measurements
- A comparison of NWP, GNSS, Ground Station and OLCI will be done, studying the effect of different spatial resolutions
- After this an extension to bigger samples is necessary:
  - Current technique requires sequential sondes
  - Perhaps a different solution should be sought (Lidars??)
- Perhaps GNSS biases comes from WV inhomogeneities within the field of regard of GNSS

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