Parametrizations for the dependence of

radar reflectivity on vertically-variable non-uniformity, Ka-band radar reflectivity on multiple scattering, and sounders on vertical distribution of water

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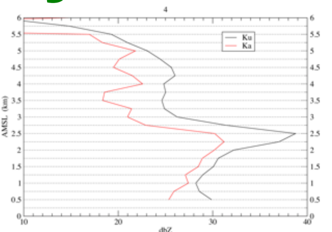
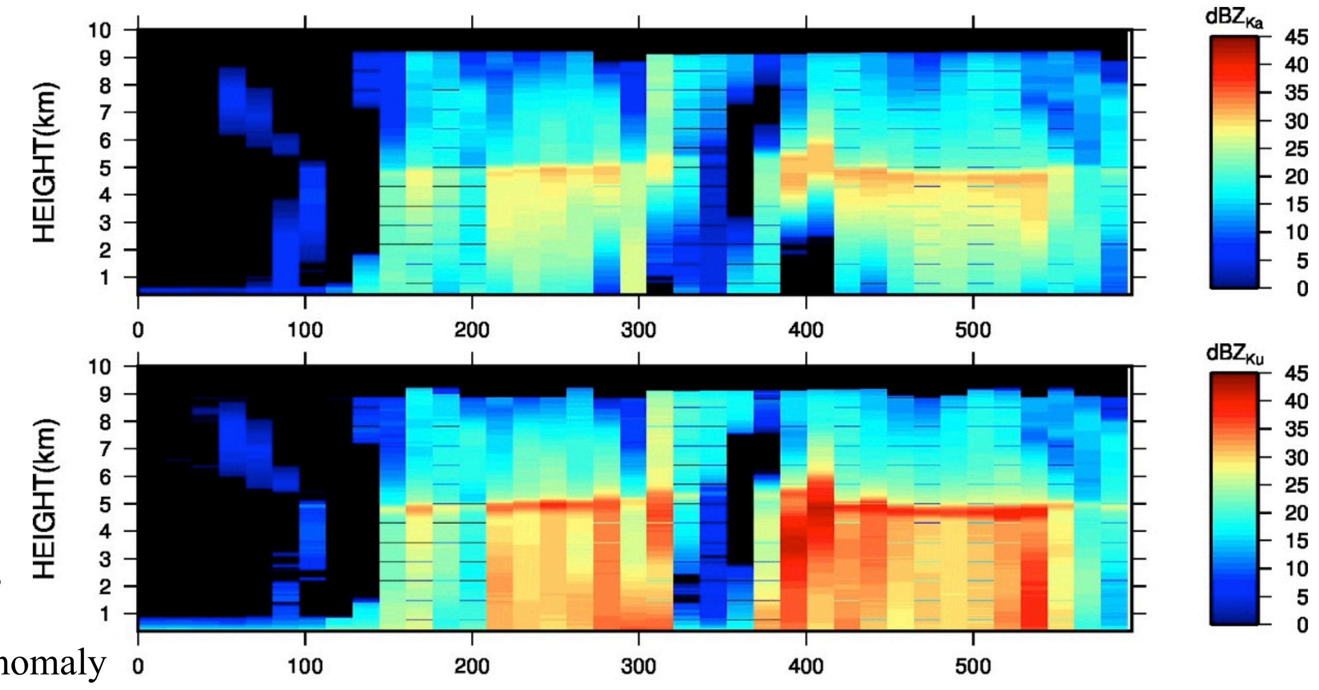
Parametrization for the dependence of radar reflectivity on vertically-variable non-uniformity

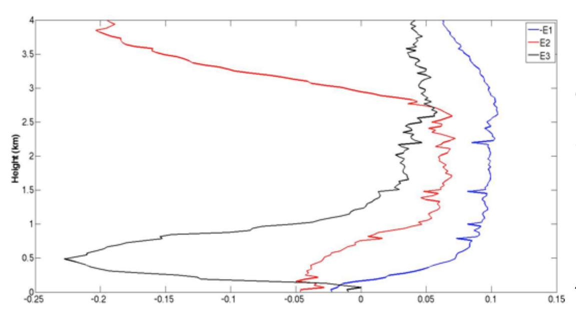


$k_{35GHz} \sim 7\, k_{14GHz}$
and yet all too often DPR measures

Manifestly,
the attenuation is not as efficient as a perfect vertical alignment would suggest. So how to represent verticall-variable changes in the horizontal inhomogeneity?

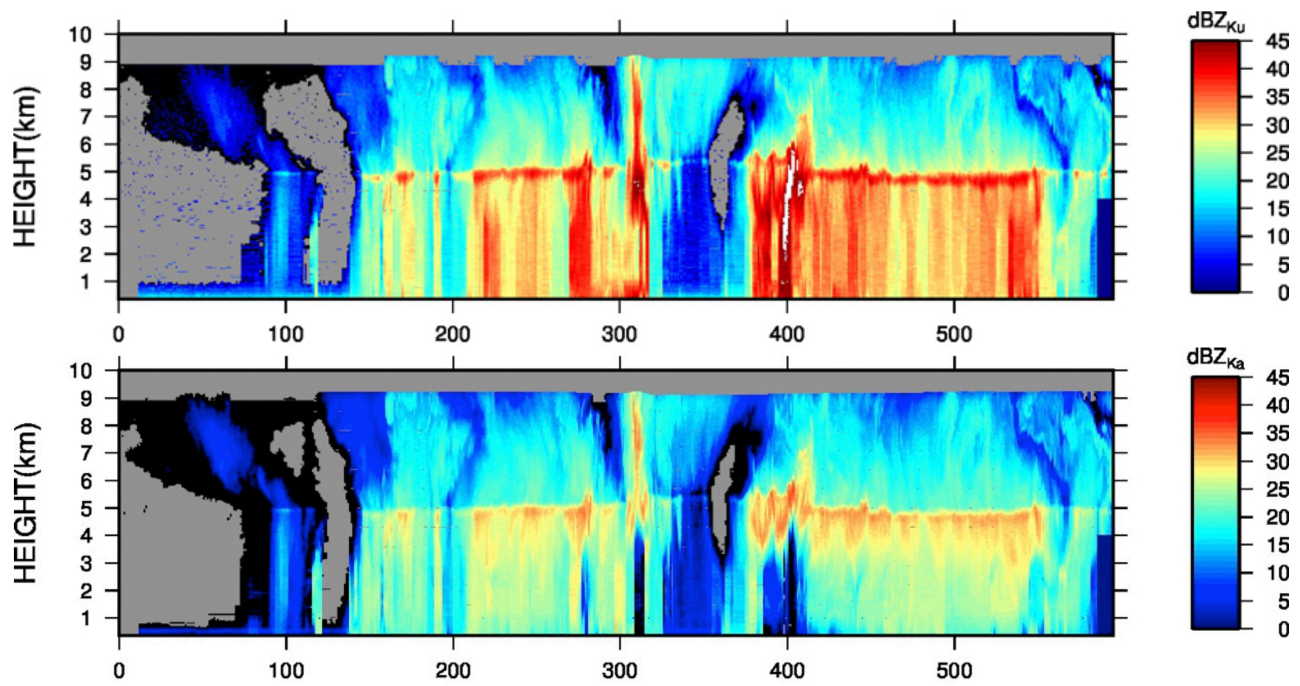
Answer (from high-resolution airborne data):
parametrize it similar to the parametrization of DSD, then try to retrieve the parameters



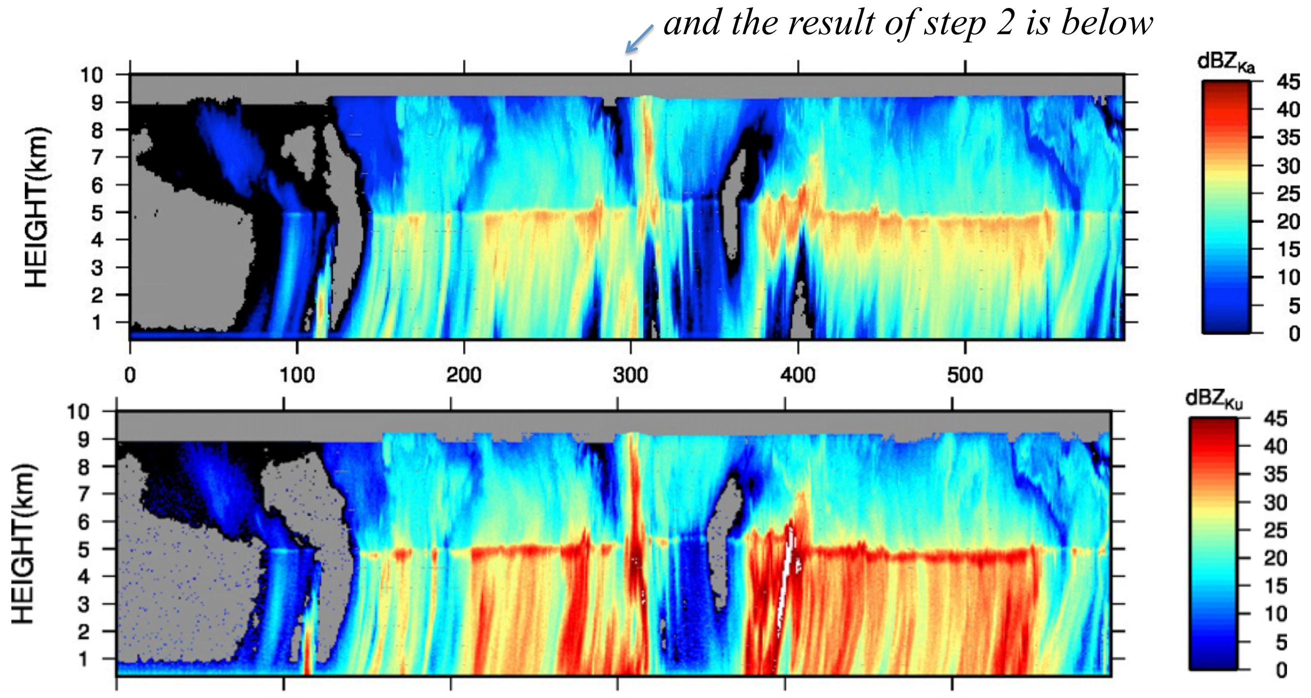


1) From airborne data, determine PCv_1, PCv_2 and PCv_3 of vertical anomaly so that the reflectivity can be written as

$Z_{actual}(x,h) = Z_{average}(h) + a_1(x)\, PCv_1(h) + a_2(x)\, PCv_2(h)$ (and determine the variance of a_1 and of a_2)



The result of step 1 is above, *and the result of step 2 is below*



2) From airborne data, determine the range of values of the parameters for the height-dependent translation

$$x_0(h) = ch^2 - \left(\frac{x_0(0) - x_0(h_0)}{h_0} + ch_0\right) h + x_0(0)$$

$$0 < c < \frac{x_0(0) - x_0(h_0)}{h_0^2}$$

$$0 < x_0(h_0) < \rho/2$$

$$\rho/2 < x_0(0) < \rho$$

to be able to represent realistic shear (as observed)

3) Starting from observed $Z_{average}(h)$, generate ensemble of 25 vertically-aligned columns by varying a_1 and a_2,

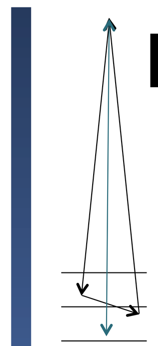
then for every plausible combination of shear parameters (about 50 suffice, and are probably more than sufficient), generate 50 x {25 sheared columns}

then invert each high-resolution pair of columns (i.e. apply retrieval algorithm to each of 25 columns in each of 50 realizations)

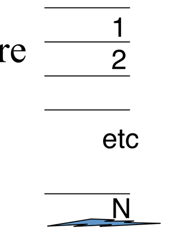
then antenna-convolve the each of the 50 results ⇒ this produce the 50 plausible underlying averages corresponding to the 50 plausible shear scenarios

4) use ancillary data to evaluate each shear scenario or average them with a-priori weight

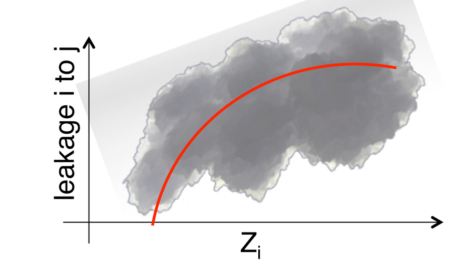
Parametrization for the dependence of Ka-band radar reflectivity on multiple scattering



Number the vertically layered atmosphere from 1 at the top down to N=80 at the surface (to match the DPR's 250m layers)



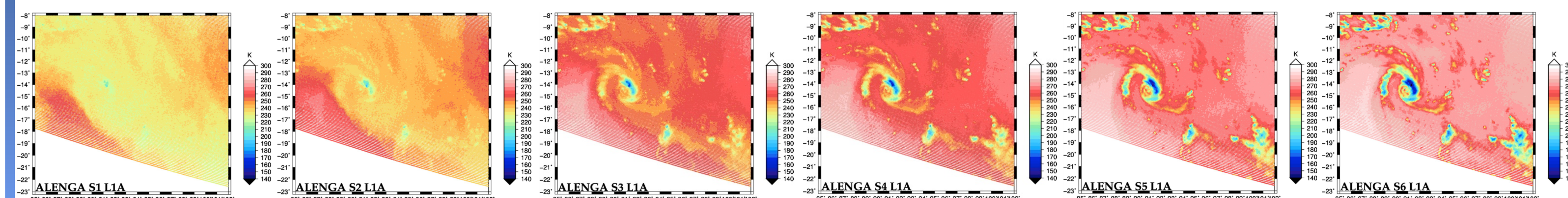
If we call z_{ij} the multiple-scattered leakage from layer i to layer j (and let's stick with i above j, i.e. i < j) we can use a forward-simulation database to fit a power law $z_{ij} = a_{ij}\, Zss_i^{\,b_{ij}}$



Then back to each beam, and keeping b_{ij} fixed, solve for a_{ij} and determine how the actual a_{ij} (solved for by recursion) are distributed about the mean "profile" (of a_{ij}), including vertical correlations, and spatial clustering: $Z_j = Zss_j + \mathrm{sum}_{\text{over } i<j}\; a_{actual,ij}\, Zss_i^{\,b_{ij}}$

- hypothesis 1: a_{ij} is highly correlated with a_{kl} if j-I = l-k (if true, $a_{ij} = c_{j-i}$)
- hypothesis 2 : $a_{actual,ij}$ is correlated with Zss_n for all n between i and j

Quantifying the vertical distribution of water from sounders using data assimilation



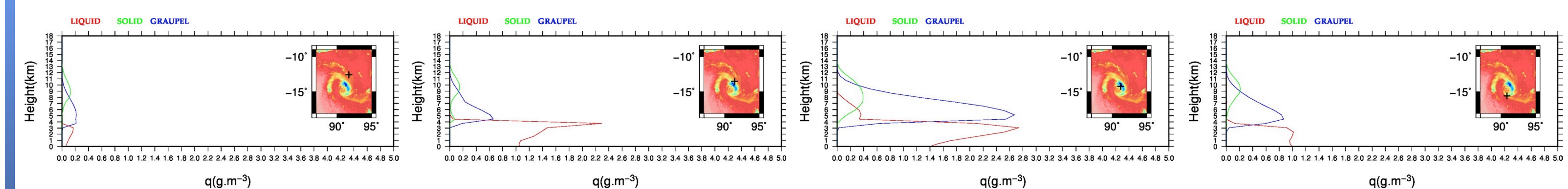
1) Construct a forward database with **several different** forward-calculated brightness temperatures **for each column condensed water** (corresponding to different scattering assumptions)

2) Derive the Bayesian forward operator (mean and covariance) after a dimensionality reduction based on canonical correlation, as is described in Z. S. Haddad, J. L. Steward, H.-C. Tseng, T. Vukicevic, S.-H. Chen, and S. Hristova-Veleva, 2015: A data assimilation technique to account for the nonlinear dependence of scattering microwave observations of precipitation. *J. Geophys. Res. Atmos.* **120**, 5548-5563

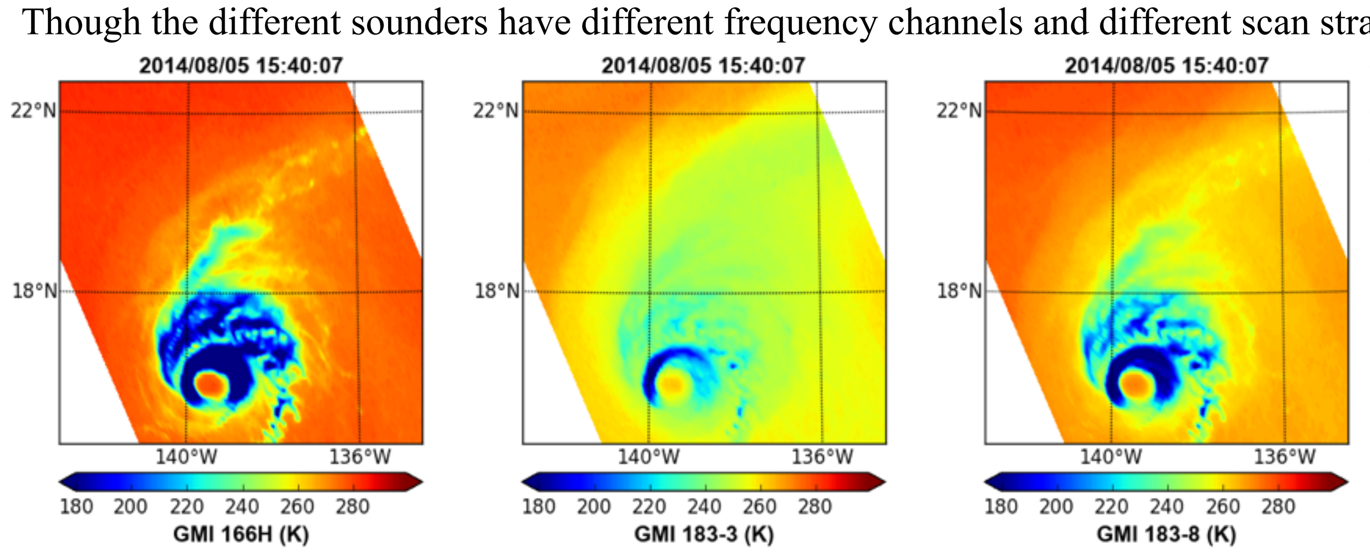
$$T_{b3} = K^{-1} \sum_{i=1}^{10000} Tb_3^{(i)} \cdot \exp\left(-(cwm_{bg1} - cwm_1^{(i)})^2 - \dots - (cwm_{bg40} - cwm_{40}^{(i)})^2\right)$$

except use linear combinations of PCs of cwm and PCs of Tb, matched to maximize their correlation

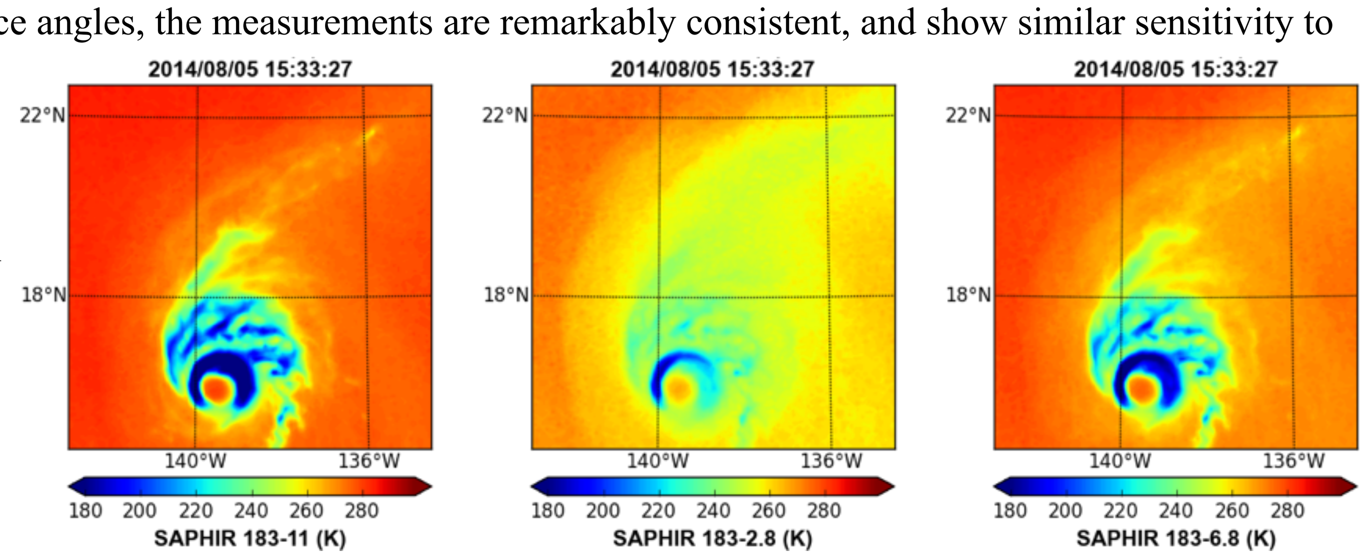
3) Assimilate, for example 1Dvar onto an archival mean background:



Though the different sounders have different frequency channels and different scan strategies resulting in different incidence angles, the measurements are remarkably consistent, and show similar sensitivity to



- the extent of ice in the outflow
- the depth of the convection
- the specific humidity (which contributes differently to the different channels, depending on their distance from the center of the water-vapor absorption line



Result on the data from the satellite "measurements" at the top: the retrievals as in 3) before antenna convolution (left), the retrievals after antenna convolution (center), ... and ... the retrievals directly from the satellite "measurements" at the satellite resolution (by-passing 1 through 3)