Improvement metrics for water vapour and temperature profiles retrieved from GPS RO profiles through 1D-Var

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ROM SAF products and activities

The EUMETSAT Radio Occultation Meteorology SAF delivers near real time (NRT) and offline meteorological data for meteorological production and research. The ROM SAF core activity is processing NRT phase shift data from the GRAS instrument (METOP A/B)

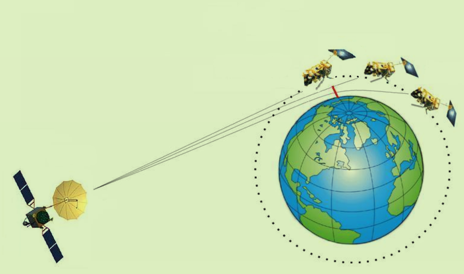
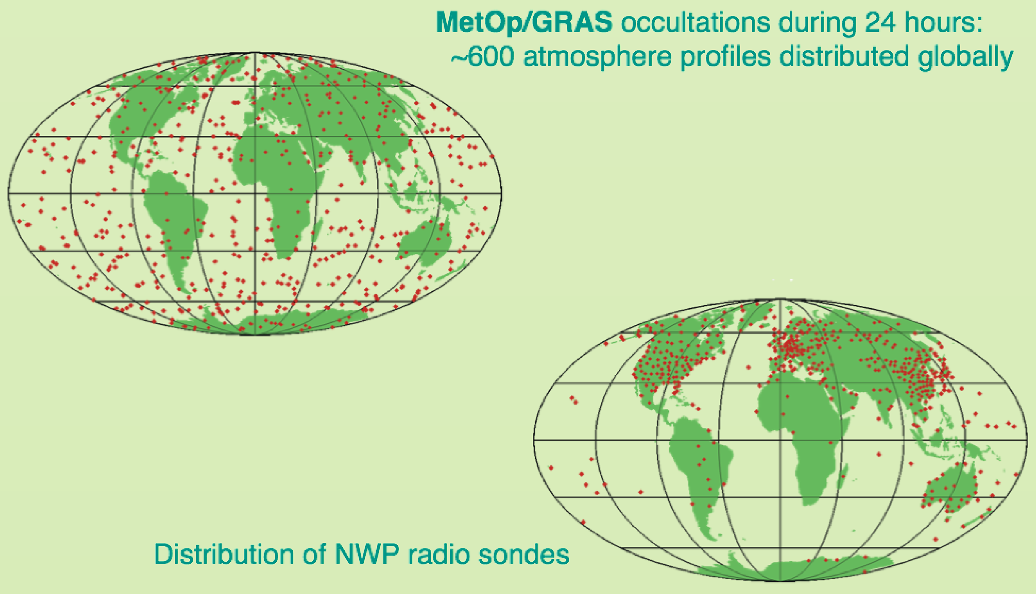
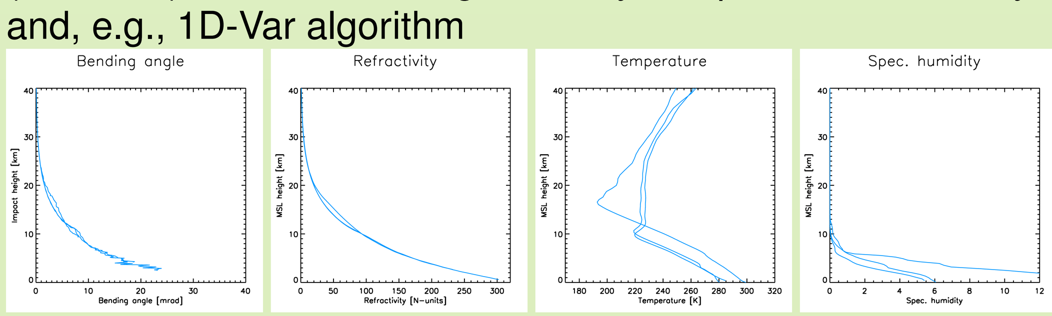


FIGURE 1: Sketch of a GPS Radio Occultation measurement

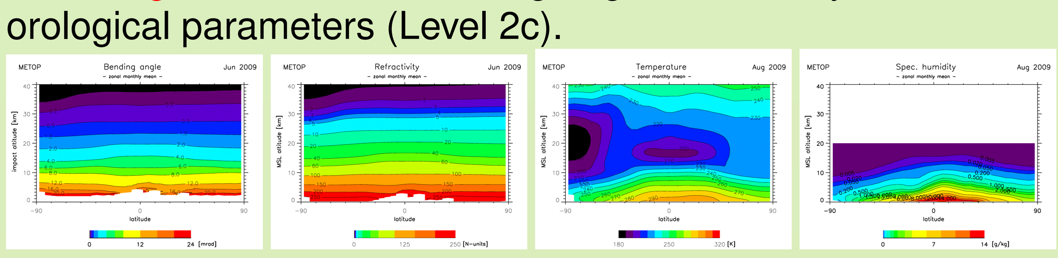


In addition the ROM SAF will produce an GRASS offline archive of meteorological data, and an gridded meteorological dataset for climate research.

Bending angle (Level 1b): obtained from the measured phases and the positions and velocities of the two satellites using Doppler shift and wave optics (canonical transform)
Ionosphere corrected bending angle: obtained by linear combination of the bending angles corresponding to the two GPS frequencies L1 and L2
Refractivity (Level 2a): obtained from the bending angle as a function of height using the Abel Transform inversion (assuming spherical symmetry and statistical optimization)
Pressure, temperature and specific humidity (water vapor) (Level 2b): obtained using ancillary temperature, humidity and, e.g., 1D-Var algorithm



Climate gridded data of bending angle, refractivity and meteorological parameters (Level 2c).



- What would be a good way to characterize the gain of knowledge about the sate of the atmosphere from a single occultation?
- Can we identify a good measure from some examples with known quality differences?

We analyze the Metop-A GNSS dataset from October 2007 retrieved with raw sampling, and processed with both wave optics and geometrical optics.

1D-Var

1D-Var minimizes the costfunction:

$$J(\mathbf{x}) = \frac{1}{2}(\mathbf{x}-\mathbf{x}^b)^T\mathbf{B}^{-1}(\mathbf{x}-\mathbf{x}^b) + \frac{1}{2}(\mathbf{y}^o-\mathbf{H}(\mathbf{x}))^T\mathbf{O}^{-1}(\mathbf{y}^o-\mathbf{H}(\mathbf{x}))$$

Relative entropy

The relative entropy (or information gain) measures the departure of the posterior distribution $p(\mathbf{x}|\mathbf{y}) \propto e^{-}J$ from the prior distribution $p(\mathbf{x}) \propto e^{-0.5(\mathbf{x}-\mathbf{x}^b)^T\mathbf{B}^{-1}(\mathbf{x}-\mathbf{x}^b)}$.

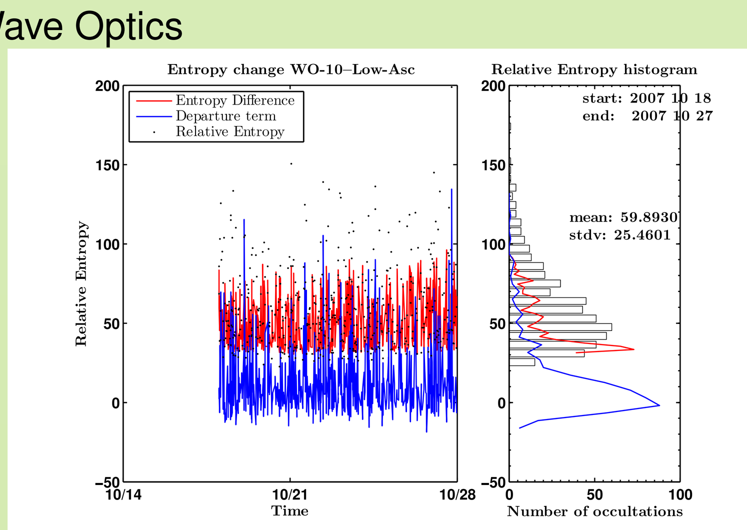
$$d = \int d\mathbf{x} p(\mathbf{x}|\mathbf{y}) \ln \frac{p(\mathbf{x}|\mathbf{y})}{p(\mathbf{x})} = \frac{1}{2}\left(\ln|\mathbf{BS}^{-1}| + (\mathbf{x}_s-\mathbf{x}_b)^T\mathbf{B}^{-1}(\mathbf{x}_s-\mathbf{x}_b) - Tr(\mathbf{I}-\mathbf{SB}^{-1})\right)$$

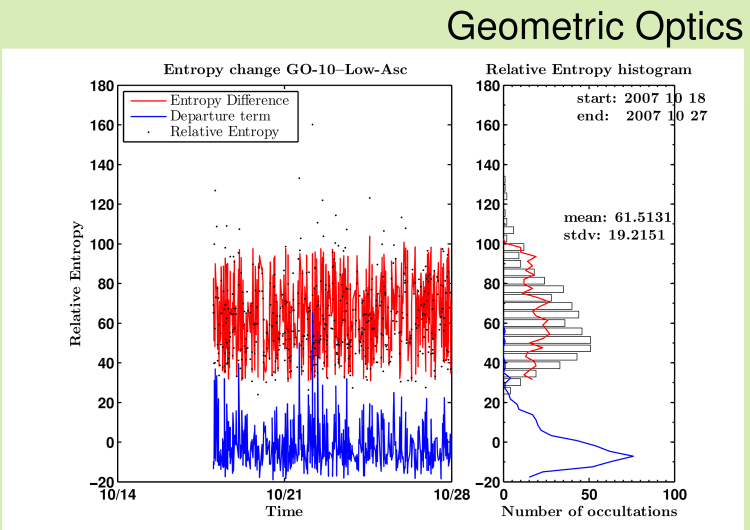
$$\mathbf{S}^{-1} = \mathbf{B}^{-1} + \mathbf{K}^T\mathbf{O}^{-1}\mathbf{K}, \quad \text{where} \quad \mathbf{K} = \frac{\partial \mathbf{H}}{\partial \mathbf{x}}$$

1st term: Entropy difference. $S(|\mathbf{B}|) > S(|\mathbf{S}|)$ Measures how much the prior error covariance $\mathbf{B}$ is reduced by 1D-Var
2nd term: Solution-Background distance measured in Background metrics
3rd term: This term is related to the number of well measured variables, but it is also mean of the second term. So the second and third term in combination measures the departure from the expected increment of a specific retrieval.

Wave Optics | Geometric Optics

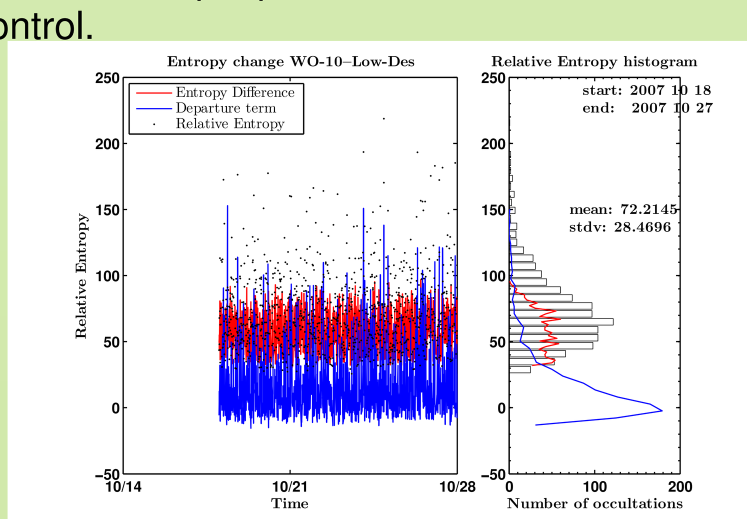
Ascent

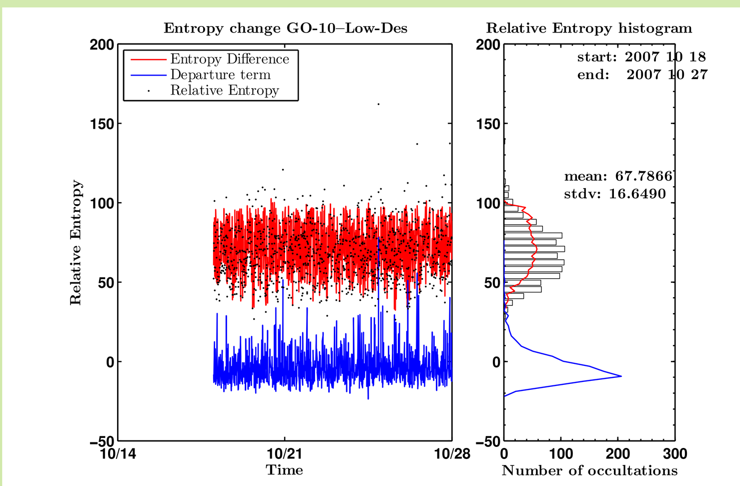




The 4 relative entropy diagrams corresponds to the 4 prior fraction plots on the right. The most pronounced difference is found between ascending and descending profiles, where the descending profiles track the signal deeper in the tropical troposphere. Apparently geometrical optics seems to gain slightly more information (not necessarily correct information) about specific humidity in the lowest troposphere. This is because the wave optical method depends on a more strict quality control.

Descent



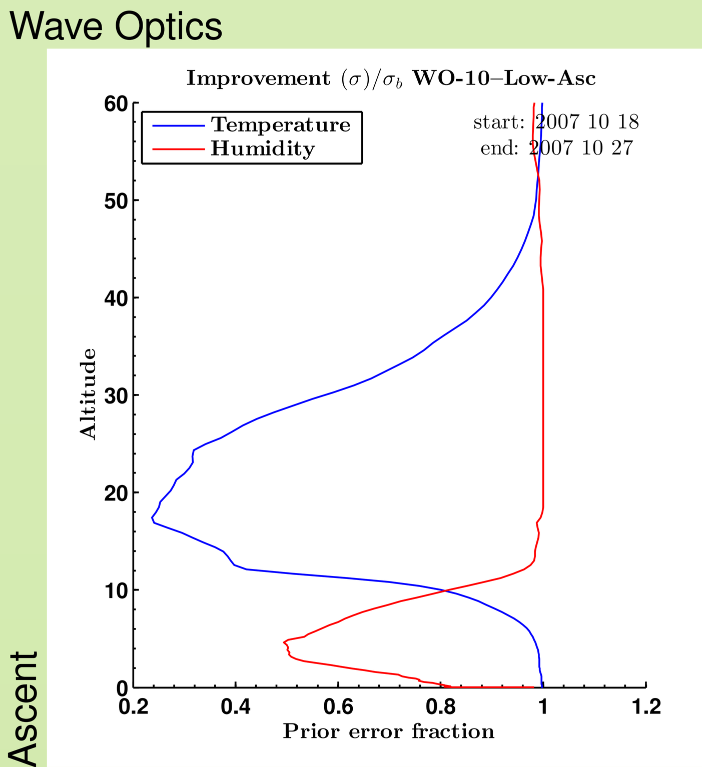


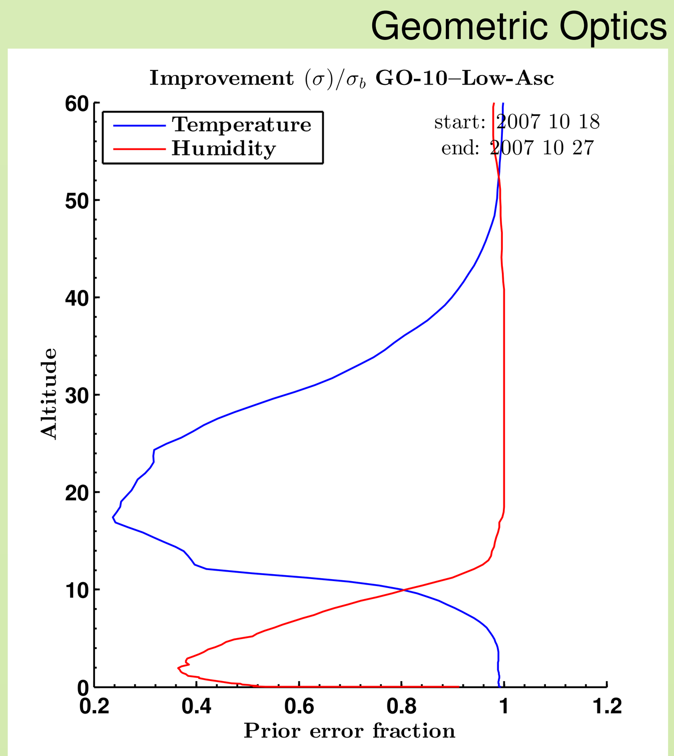
Conclusions

- There are differences in the retrievals between the geometric and the wave optical method.
- The largest relative entropy change in this data set is found in the descending profiles processed with wave optics.
- The relative entropy measure gives high credits to the wave optical method in the descending profiles, while the prior fraction measure (for the specific humidity) favors geometric optics method.

Wave Optics | Geometric Optics

Ascent





Descent