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

J. K. Nielsen <jkn@dmi.dk>, Kent B. Lauritsen and Kjartan Kinch
Danish Meteorological Institute, Copenhagen, Denmark.

## Geometric Optics

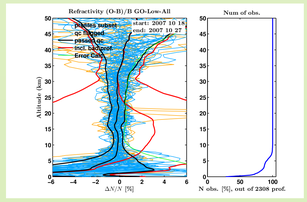


FIGURE 1: (Observed - Background)/Background refractivity.

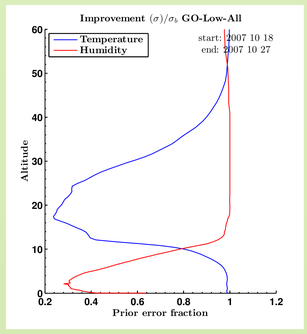


FIGURE 2: Improvement vector all profiles

## Introduction

Wave optical retrieval of GPS RO profiles are known to give a better estimate of bending angle and refractivity profiles in the lower troposphere than geometric optics can provide. Here we analyze the GRAS raw sampling dataset from METOP from October 2007, with good representation of the lower troposphere. We process all profiles in the -30 to 30 deg. latitude range with both the wave optics and geometric optics methods. The resulting refractivity profiles are inverted to temperature, humidity and surface pressure state vectors by using the 1D-Var method, with background states interpolated from the ECMWF forecast. In order to describe the difference in performance of wave optics versus geometric optics we investigate standard information measures to quantify the partitioning of information from observation and background data in the solution profiles.

## 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 KL-distance) measures the departure of the posterior distribution $p(\mathbf{x}|\mathbf{y}) \propto e^{-}J$ from the prior distribution $p(\mathbf{x}) \propto e^{-0.5(\mathbf{x}-\mathbf{x}^b)^T\mathbf{B}^{-1}(\mathbf{x}-\mathbf{x}^b)}$.

$$\begin{aligned} d &= \int d\mathbf{x} p(\mathbf{x}|\mathbf{y}) \ln \frac{p(\mathbf{x}|\mathbf{y})}{p(\mathbf{x})} \\ &= \frac{1}{2}\left(\ln|\mathbf{B}\mathbf{S}^{-1}| - Tr(\mathbf{I}-\mathbf{S}\mathbf{B}^{-1}) + (\mathbf{x}_s-\mathbf{x}_b)^T\mathbf{B}^{-1}(\mathbf{x}_s-\mathbf{x}_b)\right) \\ \mathbf{S}^{-1} &= \mathbf{B}^{-1} + \mathbf{K}^T\mathbf{O}^{-1}\mathbf{K}, \quad \text{where} \quad \mathbf{K} = \frac{\partial \mathbf{H}}{\partial \mathbf{x}} \end{aligned}$$

Entropy difference $S(|\mathbf{B}|) > S(|\mathbf{S}|)$ Number of well measured variables Solution-Background distance

## Conclusions

- Differences in the retrievals between the geometric and the wave optical method are partly due to different quality control.
- The largest relative entropy change is found in the descending profiles processed with wave optics, and is mainly attributed to larger departure of the solution from the background.

## Wave Optics

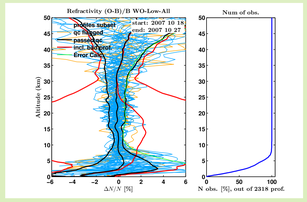


FIGURE 3: (Observed - Background)/Background refractivity.

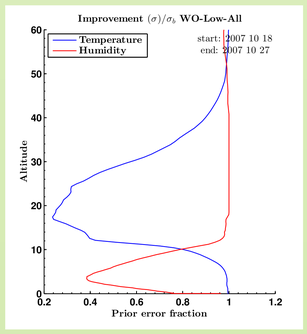


FIGURE 4: Improvement vector all profiles

## Ascending Profiles

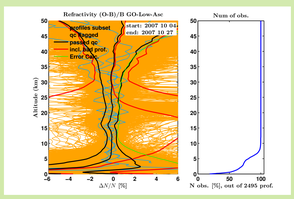


FIGURE 5: (Observed - Background)/Background refractivity.

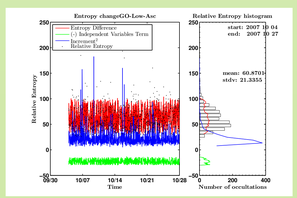


FIGURE 6: Entropy difference

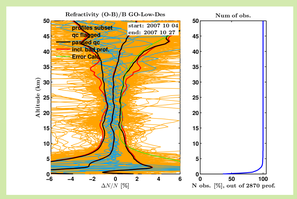


FIGURE 7: (Observed - Background)/Background refractivity.

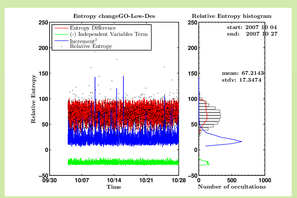


FIGURE 8: Entropy difference

## Descending Profiles

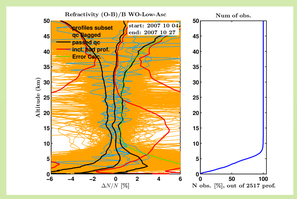


FIGURE 9: (Observed - Background)/Background refractivity.

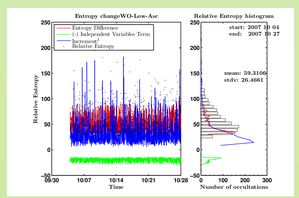


FIGURE 10: Entropy difference

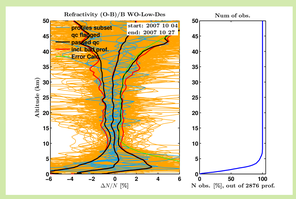


FIGURE 11: (Observed - Background)/Background refractivity.

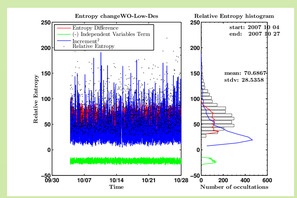


FIGURE 12: Entropy difference