NOAA/STAR 1D-Var Retrieval Algorithm to Process Radio Occultation Data

Stanislav Kireev[1] and Shu-peng Ben Ho[2]

[1]Global Science & Technology, Inc; [2]NOAA/STAR

Introduction

Temperature and water vapor play a crucial role in weather and climate. GPS Radio Occultation (RO) is the first technique that can provide globally a high vertical resolution all-weather refractivity profile, which is a function of pressure, temperature and moisture.

Launched in 2006, COSMIC-1 has demonstrated the great value of RO data for climate, meteorological research, and operational weather forecasting. A follow-up COSMIC-2 was successfully launched on June 25, 2019.

In preparation for COSMIC-2, NOAA STAR RO team is developing 1D-Var retrieval algorithm to derive temperature and water vapor profiles from RO refractivity. In this presentation, we detail the method; analyze sensitivity of RO measurements to tropospheric temperature and water vapor; present comparison of COSMIC-1 and COSMIC-2 retrievals with radiosondes and UCAR retrieval profiles.

Algorithm Key Points

- RO Forward Model: $N = 77.6\frac{P}{T} + 3.73 \times 10^5 \frac{P_W}{T^2}$
- RO Retrieval (optimal estimation):

$$X_{i+1} = X_0 + \left(K_i^T E^{-1} K_i + B^{-1}\right)^{-1} \times K_i^T E^{-1}\{(Y_{OBS} - Y(X_i)) + K_i(X_i - X_0)\}$$

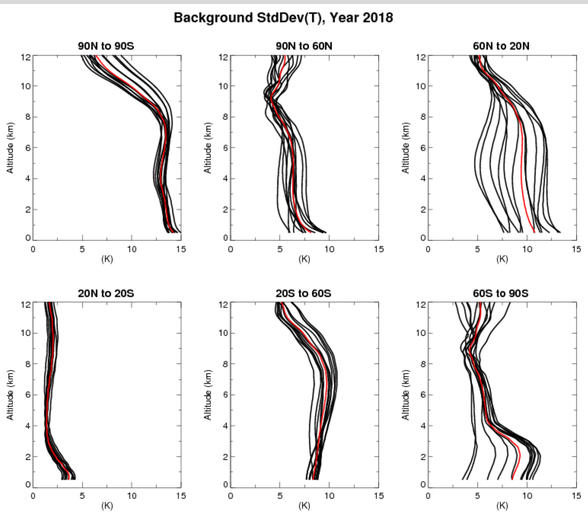
- Background matrix **B**: monthly averaging of GFS in 5 latitude zones to account seasonal and zonal atmospheric variability.
- Measurement noise matrix $E(h) = \{\gamma \cdot \sigma_N(h)\}^2$ with $\gamma = 0.1$ (determined empirically as an optimal value in a trade-off between stability and freedom of the solution)
- The First Guess (FG) X_0: GFS Forecast, collocated with RO observation and timely interpolated in 6 hours window.
- RO observation **Y**: from *wetPrf* files (CDAAC)
- Temperature and water vapor averaging kernels:

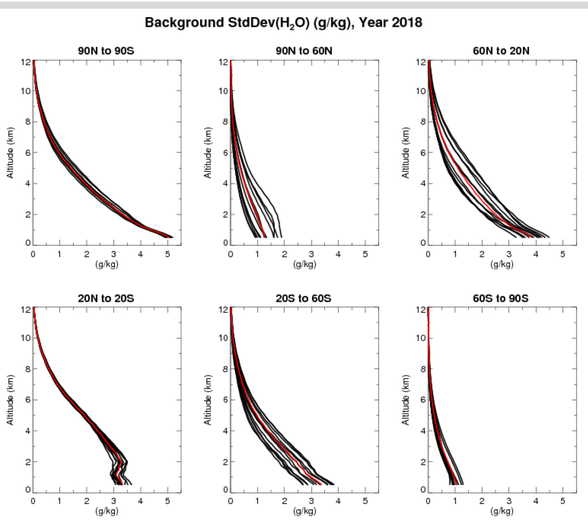
$$A = \left(K^T E^{-1} K + B^{-1}\right)^{-1} K^T E^{-1} K$$

- Altitude levels are processed independently, vertical resolution is 0.1 km.
- Iterations are continued until N-residual is less than 0.1% of observed N-value.
- Retrieval is to be successful if iterations are converged and $H2O_{RTR} > 0$.

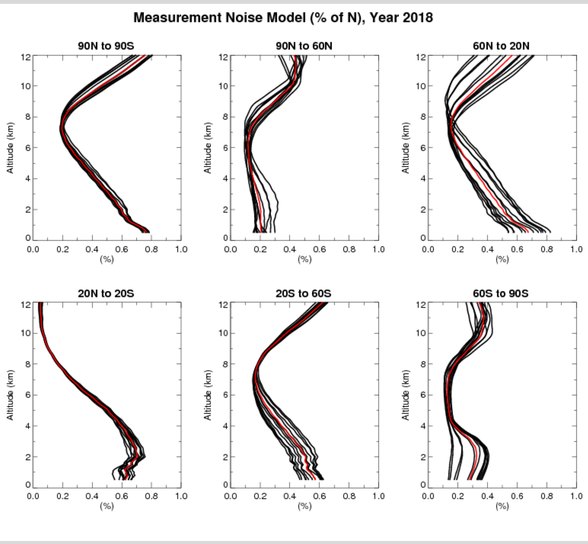
Background State Covariance

12 months × (5 latitude zones + globally) from GFS-2018

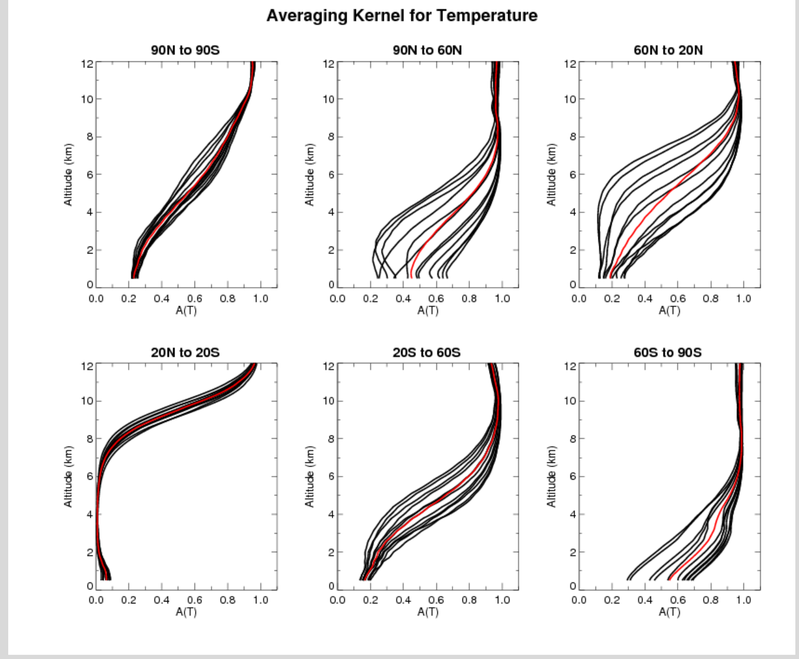


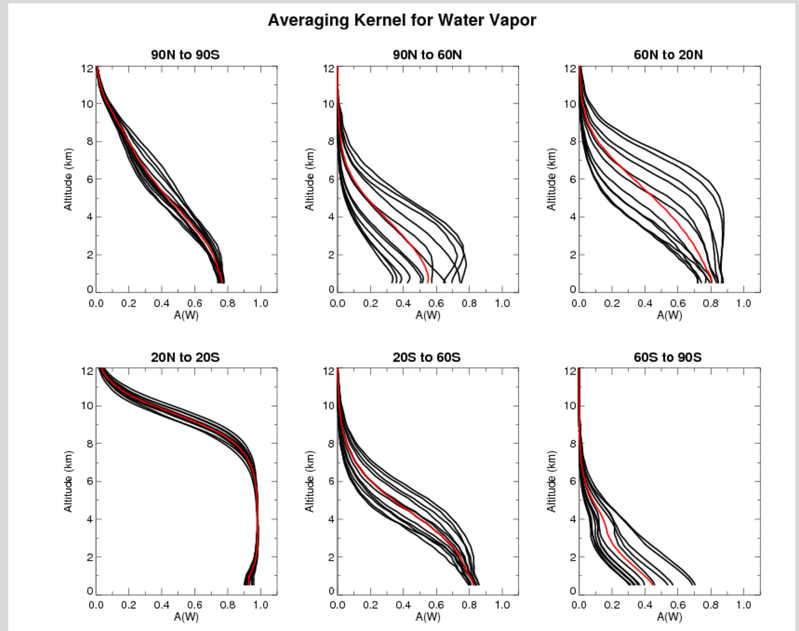


Measurement Noise Model



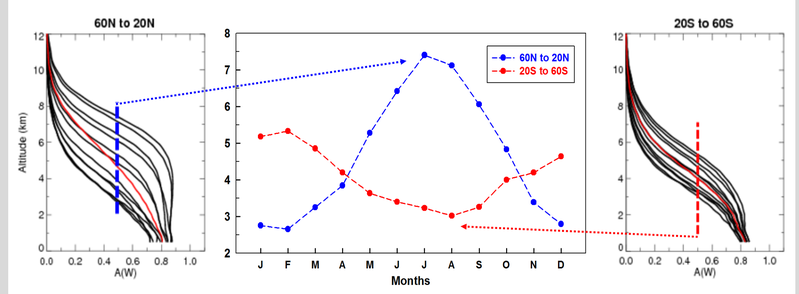
RO Sensitivity: Averaging Kernels



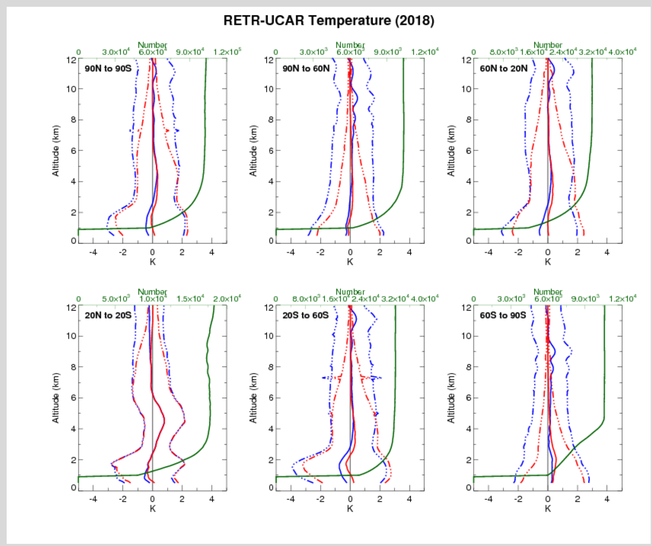


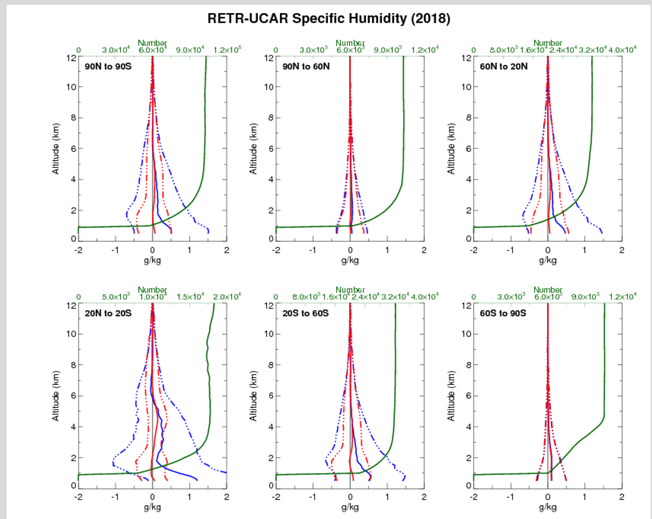
Above: Averaging kernels for temperature and water vapor depict seasonal and zonal variability of RO measurements sensitivity. The following relation is observed: $A_T(h) + A_W(h) \cong 1$, i.e. off-diagonal elements of AK $A_{T,W}$ and $A_{W,T}$ are small enough in comparison with diagonal elements.

Under: Altitudes where water vapor averaging kernels reach value 0.5 for Northern and Southern mid-latitudes monthly. Max/min altitude values correspond to Hemisphere's summer/winter seasons respectively.



COSMIC-1: Comparison of STAR retrievals *vs* UCAR



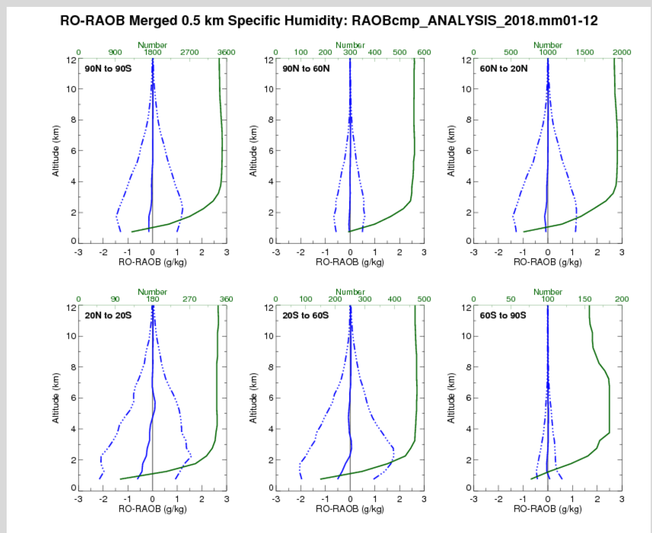


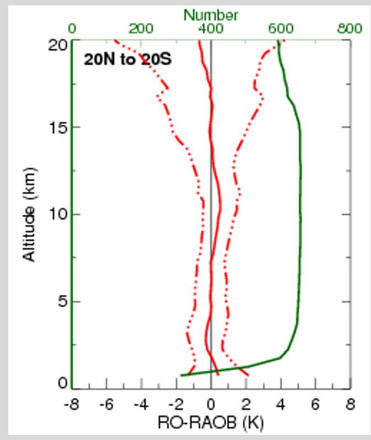
Blue = $X_{FG} - X_{RTR}^{UCAR}$

Red = $X_{RTR}^{STAR} - X_{RTR}^{UCAR}$

Green = sample size

COSMIC-1: Comparison of STAR retrievals with RAOB





COSMIC-2 First Results

COSMIC-2 first test data set is processed:

- 30 days from July 16 to August 27, 2019,
- 50,000+ profiles

Left and under: Temperature and water vapor comparison with collocated RAOBs (2 hours, 300 km) averaged over 30 days; only RAOB type RS92 is taken for comparison. Negative bias is observed for water vapor in the lower troposphere.

Right: Daily averaged comparison (August 11 and 12) for N-residual and STAR water vapor retrievals:

blue = FG – UCAR

red = RETR - UCAR