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 humidity.

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: $N = 77.6e^{-3} + 3.73 \times 10^{12} \frac{b}{T}$
• RO Retrieval (optimal estimation):
  $x_{RO} = x_0 + \frac{K(\tilde{Y} - \tilde{X})}{\delta}$
• Background matrix is monthly averaging of GPS in 5 latitude zones to account seasonal and zonal atmospheric variability.
• Measurement noise matrix $E(k) = \gamma \cdot \sigma(k)^2$, 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) $x_0$, GPS forecast, collocated with RO observation and timely interpolated in 6 hours window.
• RO Observation $Y$: from wRF files (CDAC).
• Temperature and water vapor averaging kernels:
  $\delta = \frac{(\delta^2 - E^2)^{\frac{1}{2}}}{\delta E^2}$
• Altitude levels are processed independently, vertical resolution 0.5 km.
• Iterations are continued until $\delta$ residual is less than 0.1% of observed $\delta$ value.
• Retrievals is to be successful if iterations are converged and RO residuals $\| \delta \| < 0$. 

Background State Covariance

12 months ($5 \times 5$ latitude zones) from GFS-2018

Measurement Noise Model

Measurement Noise Model $\delta$, from RO, vertical resolution 0.5 km

RO Sensitivity: Averaging Kernels

COSMIC-1: Comparison of STAR retrievals vs UCAR

COSMIC-2 First Results

COSMIC-2 first test data set is processed:

- 30 days from July 25 to August 27, 2019;
- 50,000+ profiles

Left and under: Temperature and water vapor comparison with collocated RAOBs (2 hours, 500 km) averaged over 30 days; only RAOB type R092 is taken for comparison. Negative bias is observed for water vapor in the lower troposphere.

Right: Daily averaged comparison (August 11 and 12) for RO retrieval and STAR water vapor retrievals: blue = FG - UCAR
red = RETR - UCAR

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