Quantifying the Tropical Upper Troposphere Lapse Rate Feedback Using Radio Occultations

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Joint 6\(^{th}\) ROM SAF User Workshop & IROWG-7 Workshop

Konventum, Helsingør (Elsinore), Denmark, September 19-25, 2019

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Objectives

1. Understand how ROs could complement climate research?

2. What new physics information could we get from GNSS signals?
Climate Feedback Definition:

The climate feedback for a variable, $\lambda_x$, can be expressed as the product of two terms [e.g., Soden et al., 2008]:

$$\lambda_x = \left( \frac{\partial R_x}{\partial X} \right) \cdot \left( \frac{dX}{dT_s} \right)$$

A) One of the radiative transfer

B) One of the climate response

Where $R$ is the net top of the atmosphere (TOA) flux; $X$ is a climate variable (e.g., $T$, $q$, $A$, $C$); and $T_s$ is the surface temperature.
RO-BASED WATER VAPOR FEEDBACK [Vergados et al., 2016]

\[
\frac{dq}{dT_s} = 621.9907 \cdot \frac{P}{(P - e^2)^2} \cdot \frac{T^2}{b} \cdot \left[ \frac{dN}{dT_s} + \frac{1}{T} \left( 2N - \frac{aP}{T} \right) \frac{dT}{dT_s} \right]
\]

$q$ is the specific humidity, $N$ is the refractivity, $T$ is the atmospheric temperature, $T_s$ is the surface temperature, $e$ is the partial pressure of water vapor, and $a$ and $b$ are constant values.
# Methodology

## COMPONENTS OF SOFTWARE

### DATA
- **Data**
  - JPL, GPS-RO
  - ERA-Interim
  - Aqua/AIRS v6.0
  - MERRA v2.0

### METHODOLOGY
- **Analysis**
  - Monthly zonal means
  - 9–year long time series
  - Interannual anomalies
  - 300 – 200 hPa

### ANALYSIS
- **Retrieve**
  - Compare GPS-RO series with ERA-Interim, AIRS, and MERRA data sets.
  - Assess linear trends, seasonal variabilities, their anomalies, and quantify dT/dSST.

### SET UP
- **Set Up**
  - 01/2007–12/2015
  - 30°S–30°N
  - Tropical Zones

### STATISTICS
- **Statistics**
  - Mean climatologies
  - Difference & Std. Dev.
  - Monthly variabilities
  - Seasonal/Annual Trend

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**ERA-Interim**
European Center for Medium-Range Weather Forecasts
Re-Analysis Interim

**Aqua/AIRS**
Atmospheric Infrared Sounder

**MERRA**
Modern-Era Retrospective Analysis for Research and Applications
Results (1/6) ($\pm 30^\circ, 300$ hPa)

Temperature Variability: 300 hPa, 30N/S, 01/2007 – 12/2015

Interquartile Range: 300 hPa, 30N/S, 01/2007 – 12/2015
Results (2/6) \((\pm 30^\circ, 300 \text{ hPa})\)

Temperature Comparisons with respect to JPL climatology

Temperature Anomalies Time Series
Results (3/6) ($\pm 30^\circ$, 200 hPa)

Temperature Variability: 200 hPa, 30N/S, 01/2007 – 12/2015

Interquartile Range: 200 hPa, 30N/S, 01/2007 – 12/2015
Results (4/6) (± 30°, 200 hPa)

Temperature Comparisons with respect to JPL climatology

Temperature Anomalies Time Series
The majority of the climate models show $dT/dSST$ at 250 hPa to have a wide range of values, fluctuating between 1.5 K/K and 2.5 K/K [Minschwaner et al., 2006]
1. All data sets, within their error uncertainty, agree on the temperature variability.

2. The variability captured in the inter-annual anomalies of all data sets are the same.

3. At 200 hPa, all data sets show the same dT/dSST response to surface warming.

4. At 300 hPa, all data sets agree with one another – except from GPS/RO showing 30% weaker signal.

5. All data sets fall within the model range (gray area) and are systematically smaller than the multi-model mean.