GPS radio occultation as part of the global observing system for atmosphere

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Overview of Today’s Talk

• The Measurement
  – Physical retrievals based on time standards
• GPS Retrieval Products
• Retrievals and Radiances: CLARREO Mission
• GPS RO and AIRS
• GPS RO and Microwave
• GPS RO and Radiosondes
• GPS/GNSS Science
• Conclusions
The Radio Occultation Measurement

Geometry of an acquisition

$N = a_1 \frac{P}{T} + a_2 \frac{P_W}{T^2}$
GPS RO Retrievals

Temperature

Smoothing of Sharp Tropopause

Water Vapor

2006-09-29-12:59cosmic1_gps45_61976-2006092911

GPS

ROAB

January 21, 2007

GPS And Global Observing System

12th Conf IOAS-AOLS
Retrieval Products

- Refractivity vs altitude
- Density vs altitude (> 7 km)
- Temperature vs altitude
  - Assumes hydrostasis
- Pressure vs altitude
  - Assumes hydrostasis
- Water vapor
  - Assumes T/P

- Climate benchmarks:
  - Refractivity above PBL
  - Temperature 8-25 km

\[ N = a_1 \frac{P}{T} + a_2 \frac{P_W}{T^2} \]

COSMIC-to-COSMIC

COSMIC3 - COSMIC2

Window:
30 km
10 minutes
June 4-16, ‘06
224 pairs

Inter-quartile Range
Contains central 50% of differences

Median

Temperature difference [K]

Height [km]
Objective: *SI-traceable* measurements to compare with climate model output and improve climate predictions

**Requirements Driver: “Societal benefit”**

Infrared radiance – *Forcing*
- Annual mean brightness temperature
- 15-degree grid
- 0.1 K accuracy
- Spectrally resolved (1 cm⁻¹)

GPS refractivity profiles – *Response*
- Refractivity profiles
- 0.1 K equivalent temperature accuracy
  - 0.05% absolute accuracy
“How does a particular observing system mesh with others?”
Retrieval Comparisons
AIRS – ECMWF – GPS

- AIRS-ECMWF-GPS temperatures
- Common set of 3-way match-ups
- For all of 2003 (Champ, SAC-C)

First comparisons:
30°-60° North
(“Mid North”)

Match-up criteria: <200 km, <2 hrs apart
Pair wise RMS deviations

A Puzzle

Mid North Pairwise RMS Deviations, 2003

- AIRS-ECMWF
- GPS-ECMWF
- GPS-AIRS
- GPS Model Deviation

Match-ups: 766
AIRS Quality: 0, 1

Resolution: If AIRS-ECMWF profiles are correlated.
Discernable difference in anomaly trends:
CHAMP (RO)
RSS
UAH
2001-2006

Temperature Comparison To Sonde

- Multi-year statistical profile comparison
- IGRA database
- CHAMP RO

Continents:
USA
Russia
Australia
India
• Statistically significant difference in daytime versus nighttime means
GNSS Science Team

- PBL height climatology
- Small-scale variability (waves) UTLS
  - Combine GPS RO and A-Train
- Improved understanding of turbulence
  - Troposphere, stratosphere, ionosphere
- Wave dynamics in the tropical tropopause

- Improve weather predictions and analyses in the tropics
  \textit{COSMIC data in cloudy regions}
- Cyclones over the West Antarctica ice sheet
  \textit{COSMIC polar coverage}
- Ocean/Ice/Land remote sensing
  \textit{New techniques}

\url{http://nspires.nasaprs.com} \textit{GNSS Remote Sensing Science Team}
Summary and Conclusions

• **Accuracy**: physical retrievals based on time measurement
  – Refractivity near PBL up to ~30 km
  – Temperature 8-25 km
  – (Water vapor probably not SI-traceable accurate)

• **CLARREO**: complements radiances
  – Retrievals and radiances needed to test climate models

• **Integrated into broader observing system**
  – AIRS, Radiosonde, Microwave

• **GNSS science**

• **COSMIC/FORMOSAT-3** (6 satellites) and follow on constellations continuously deployed to the long-term benefit of the Earth science community

• **GPS continues to evolve ⇒ GNSS**