Stratospheric Temperature Trends from AIRS and GPS RO

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Background

• Multiple data types sensitive to the same atmospheric variables should yield same trends and anomalies.
  — Both are highly accurate...and ”stable”.
  — Bias in a retrieval system is acceptable; a time-dependent bias is not.

• Time-dependent biases can be identified by a comparison of trends in anomalies in two different data types.
  — Biases have structures that can be fingerprinted.
  — GPS RO and AIRS stratospheric temperature are good starting candidates for comparison.
Data

• Atmospheric Infrared Sounder (AIRS)
  – Thermal IR, near-IR, 2378 channels, ascending node at 13:30
  – Temperature retrievals, 1 km resolution in troposphere, 2 km in stratosphere
  – Data since June, 2002, to present
  – Version 6, infrared-only products, combined infrared and microwave products

• GPS Radio Occultation, JPL
  – COSMIC mission, 6 satellites, ~2400 soundings daily, SNR ~700, separated 30° in ascending node, June 2006 to the present
  – Bayesian interpolation to generate level 3

Intra-comparison: AIRS

AIRS (IR+MW) – AIRS (IR)
Intra-comparisons: GPS RO

27 months overlap, CHAMP and COSMIC

Different SNR, different upper boundary for Abel transform...

COSMIC – FM1, 1 month

Sampling error for Bayesian mapping...
Trends

(a) AIRS (IR)
(b) AIRS (IR+MW)
(c) GPS RO
(d) MERRA
(e) MERRA-2
(f) ERA-Interim

Pressure [hPa]

Latitude

Temperature trend [K/yr]

-0.10 -0.06 -0.02 0.02 0.06 0.10
Time-series: QBO

QBO upper, QBO lower

(a) QBO upper: 0.0N, 20hPa
(b) QBO lower: 0.0N, 70hPa
(c) North Stratosphere: 20.0N, 20hPa
AIRS QBO Error

(a) AIRS (IR)  (b) AIRS (IR+MW)  (c) GPS RO
(d) MERRA  (e) MERRA-2

Pressure [hPa]

90N 60N 30N Eq 30S 60S 90S
Latitude

Temperature difference [K]

-1.5 -1.0 -0.5 0.0 0.5 1.0 1.5
Time-series: Stratosphere Differences

Northern stratosphere

Southern stratosphere
Seasonal Cycle Differences

(a) AIRS (IR)  
(b) AIRS (IR+MW)  
(c) GPS RO  
(d) MERRA  
(e) MERRA-2

Pressure [hPa]

Latitude

ΔΔT, JJA-DJF [K]

16 May 2018
Leroy et al.: Stratospheric Temperature Trends
Conclusions

- Infrared-only AIRS retrieval introduces a trend bias compared to AIRS combined infrared and microwave retrieval of approximately 0.2 K/decade. The combined retrieval is preferable, but slightly.

- AIRS retrievals contain null-space error of ~3 K in realizations of QBO and annual cycle in Antarctic stratosphere. The responsible priors or retrieval constraints are unknown. Theoretically should not affect determination of longwave feedbacks.

- GPS RO seasonal cycle error in upper troposphere points to flaws in humidity prior.

- Broad disagreement in stratospheric trends of 2 K/decade.
  - AIRS and MERRA most realistic, but even they disagree on trends in the Brewer-Dobson circulation.
  - GPS RO and ERA-Interim show no cooling at all; GPS RO probably overly influenced by ECMWF initialization of hydrostatic integral.

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Recommendations

• AIRS and infrared generally:
  — Explore cause of drift between retrievals including microwave and those without over the lifetime of AIRS.
  — Discover and fix causes of null space error over the equator and in the Antarctic stratosphere.

• GPS RO:
  — Implement an algorithm that corrects for ionospheric residual.
  — Implement an algorithm that reduces sensitivity to initialization of Abel and hydrostatic integrals.

In review at J. Geophys. Res.
Independent retrievals

GPS RO (CHAMP) refractivity from four different retrieval centers

(Ho et al., JGR, 2009)
Truncate COSMIC data

\[ \chi^2 = \beta (d - M(w))^2 + \alpha w^2 \]

Sampling error for Bayesian mapping!
Assimilating the GPSRO measurements improves the r.m.s. fit to radiosonde temperature measurements in the SH upper troposphere and lower stratosphere over the day 1 to day 5 forecast range, as illustrated in Fig. 7. The r.m.s. values do not increase smoothly as a function of forecast day because of the differences in radiosonde coverage at 00 and 12 UTC. The improvement introduced by the GPSRO measurements may appear small, but they are statistically significant. Table 1 provides the statistical

Null-space Error (2)

Foelsche et al., Climate Dynamics, 31, 49–65, 2008.