Tropopause altitude identification using GPS radio occultation data

Huw Lewis, FORMOSAT-3/COSMIC Data Users Workshop, Boulder. 27 October 2009
Outline

- Tropopause measurements
- Radio Occultation data
- Results
  - Radiosonde validation
  - 2008-2009 analysis
  - Multiple layers
- Summary
The tropopause

- The tropopause region is crucial for NWP

- Denotes transition between moist, convective troposphere and dry, ozone-rich, stable stratosphere
- Puts a lid on tropospheric convection
- Active in the development of large weather systems
- Different chemical processes occur in the stratosphere and troposphere, stratosphere-troposphere exchange is poorly understood
- Tropopause altitude is a useful diagnostic for model performance and validation – an integral measure of tropospheric temperature
- Future potential for assimilating derived height observations
The tropopause

- Observation of the tropopause region on a global scale is crucial for continuous monitoring of global climate change

“The sky is slowly rising”
San Francisco Chronicle, Jan 2003

- Sensitive indicator of climate change
- Cooling stratosphere with warming troposphere leads to rising tropopause
- Climate modeling attributes increase to anthropogenic forcing and ozone

The tropopause

- Thermal lapse-rate tropopause criteria [WMO]
  - lowest level at which temperature lapse-rate is less than 2 K/km and the average lapse-rate in the next 2 km does not exceed 2 K/km.

- Radiosondes
  - high vertical resolution T profiles
  - poor global distribution
  - climate trends complicated by changes in instrumentation over time

- Trends from reanalyses suffer from coarser vertical resolution and model biases
The tropopause

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**The tropopause**

- GPS RO data have been analysed to study the tropopause
  - High vertical resolution, global distribution, all-weather data
- Mainly by analysis of Tdry
  - Retrieved parameter after Abel transform
  - Errors due to humidity considered negligible in tropopause region
  - Hydrostatic assumption
  - Subjective detection criteria required!
- Schmidt et al (2008) use 80 month RO data record to estimate between 4-7 m/yr global average increase of tropopause altitude

\[ T_{dry} \equiv \frac{N}{p} \]

- RO observables are climate benchmark – can we use more fundamental measurements to determine tropopause characteristics?
Radio occultation data

Excess phase $\phi(t)$

Bending angle $\alpha_{L1}(x), \alpha_{L2}(x)$

Bending angle IC $\alpha_{IC}(x)$

Refractivity $N(z)$

Dry temp $T_{dry}(z)$

Orbits $r_G(t), v_G(t), r_L(t), v_L(t)$

Ionospheric correction

A priori BA > 50 km

Abel transform

Spherical symmetry

Neglect q

Hydrostatic approx

A priori pressure

0.02% N

0.5% K < 1.5 K

"Structural uncertainty"
Radio occultation data

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Radio occultation data

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Covariance transforms

\[ W_f(a, b) = \frac{1}{a} \int_{z_b}^{z_a} f(z) h \left( \frac{z-b}{a} \right) dz \]

\[ h \left( \frac{z-b}{a} \right) = f(z) - f(b) \]

\[ W_f(a, b) = 3 + 0 - 1 \]

\[ = 4 + 0 - 2 \]

\[ = 5 + 0 - 3 \]
Covariance transforms

\[ W_f(a,b) = \frac{1}{a} \int_{z_b}^{z_a} f(z) h\left( \frac{z-b}{a} \right) dz \]
Covariance transforms
Results – radiosonde validation

colocated radiosonde and RO profiles, July 2008

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Comparison with colocated sondes – July 2008 [3hr, 300 km]

- \( a = 20 \text{ km} \) : 47 profiles with tropopause identified in lower troposphere, 11 fail QC
- \( a = 10 \text{ km} \) : 56 profiles with tropopause identified in lower troposphere, 16 fail QC
Results – 2008/2009 analysis
Potential for climate monitoring
- consistency between receivers
Potential for climate monitoring - consistency between receivers

RO

Tdry
Potential for climate monitoring
- consistency between processing centres

**RO**

**Tdry**
Multiple tropopause layers

- High vertical resolution information – resolve multiple tropopause layers
Summary

• It is possible to determine global tropopause characteristics directly from GPSRO bending angle data
  • Robust and objective method
  • No need for additional processing or assumptions – directly linked to climate benchmark data
• Analysis of archive data will reveal climate trends over past decade
  • Trends in impact height rather than geometric height
• Potential tool for testing climate model performance
• Potential tool for monitoring NWP model performance
Questions and answers