A filtering method to improve the global gravity wave activity calculation in the troposphere and stratosphere from radio occultations

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The importance of gravity waves (GW) and their adequate representation

- GW play an important role in the general atmospheric circulation.

- GW drag in general circulation models (GCM) has been usually treated with parameterizations, because a significant part of the spectrum cannot be numerically resolved.

- A limitation for the development and validation of these representations has been up to now the lack of observational constraints on GW.
The importance and limitations of GPS RO in the study of GW

- The GPS RO technique provides global, all-weather, high vertical resolution temperature profiles in the troposphere and stratosphere.

- However, any technique has limitations. Regarding observed GW properties by GPS RO:
  - instrumental sensitivity to certain portions of the wave spectrum (coarse horizontal resolution)
  - operational height interval (e.g. observations in the lower troposphere are less reliable)
  - geometrical factor: the angle between the line of sight, the line of tangent points and the wavefronts (not intrinsic to the technique itself).
GPS RO data

- 200 daily RO 2001-2006 (SAC-C, CHAMP and GRACE)
  2000 daily RO as from 2006 (CHAMP, GRACE and COSMIC).

- GPS RO coverage exhibits irregular patterns.

- Due to the sparse sampling, only monthly or longer processes could be studied before 2006.

Monthly number of RO in cell = 5°x5°

June 2004       June 2010
Calculation of GW activity

- GW activity is quantified by the potential energy \( E_p \) of the waves, which is calculated from temperature \( T \) profiles after decomposing them into background \( T_B \) and wave \( T' \) components, i.e. \( T = T_B + T' \).

\[
E_p = \frac{1}{2} \left( \frac{g}{N} \right)^2 \frac{\left( \frac{T'}{T_B} \right)^2}{z_2 - z_1} \int_{z_1}^{z_2} d\zeta
\]

in a vertical column between heights \( z_1 \) and \( z_2 \), \( g \) is gravity and \( N \) is the Brunt-Väisälä frequency.

- The adequate separation of \( T' \) and \( T_B \) is crucial in GW analysis.
Possible methods to separate background and waves

- by averaging a large number of $T$ profiles binned in lat-lon-time cells
- by applying a high-pass filter to each individual profile
- by applying a polynomial fitting function to each individual profile

Each method has its weaknesses and advantages. The Achilles heel of the filtering procedure is in the tropopause kink, where wave amplitudes become artificially magnified, leading to exaggerated $E_p$ values.
A first approach to improve the filtering procedure

\[ T' = T - T_B \]
The double filtering procedure

First filtering  

Biased perturbations and second filtering  

\( T_c' = \text{corrected } T' \)

\[ T' = T - T_B \]

\[ T_c' = T' - B \]
The double filtering procedure applied to refractivity

Apparent advantages of refractivity: no knee in the tropopause and it is a lower level product of RO
A test for the double filtering procedure

- We created synthetic temperature profiles (background + waves) to compare different filtering procedures.
- Non-dimensional $E_p$ was calculated using different filtering procedures and compared with the reference value.
Improvements in wave climatologies due to COSMIC

-80<lon<-60  -40<lat<-30  monthly mean

Ep [J/kg]

E p [J/kg]

E p [J/kg]

-10 < lat < 10
-40 < lat < -30
30 < lat < 40
Filtering methods comparison with COSMIC RO data

June 2008

$Z_1 = 5\text{ km}$

$Z_2 = 35\text{ km}$

Complete Filtering

Double Filtering

$J/\text{kg}$
$E_p$ climatology with COSMIC RO data: 2007

Ep. Δz=5-35km. 1km<λ<12km. cell=5°×5°
$E_p$ climatology with COSMIC RO data: 2008

Ep. $\Delta z=5$-35 km. $1 \text{km} < \lambda < 12 \text{km}$. cell=$5^\circ \times 5^\circ$

DJF  JJA

MAM  SON

J/kg

0  1  2  3  4
$E_p$ climatology with COSMIC RO data : 2009

$E_p$, $\Delta z = 5-35\text{km}$, $1\text{km} < \lambda < 12\text{km}$, cell $= 5^\circ \times 5^\circ$

DJF  

JJA  

MAM  

SON
Conclusions

- The results obtained with the double filtering method indicate an improvement in the determination of wave activity around the tropopause with respect to previous filtering techniques, specially at low and middle latitudes.

- The significant increase of RO data since 2006 due to COSMIC allows, in addition, to perform more reliable wave climatologies.

- These factors may help us to improve our understanding of the generation, propagation and dissipation of GW in the lower and middle atmosphere, which may lead to a better representation of these processes in GCM.
Work in progress with COSMIC RO data

- A study of the significant increase of GW activity near the Southern Andes and the Antarctic Peninsula during winter and spring.

- A study of global, synoptic and regional climatological patterns related to temperature, specific humidity, pressure and dew point (see poster).
The End