Validation of stratospheric temperatures in ECMWF analyses with CHAMP radio occultation climatologies

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ECMWF Validation with CHAMP

Outline

• CHAMPCLIM Project Overview
• CHAMPCLIM Pre-Operational Status
• ECMWF – CHAMPCLIM Comparison Setup
• Results
• Summary and Outlook
CHAMPCLIM Project Overview
ECMWF Validation with CHAMP

The CHAMPCLIM Project

CHAMPCLIM Project

- Wegener Center / IGAM, University of Graz
- GeoForschungsZentrum (GFZ) Potsdam

CHAMP Mission

- Operated by GFZ Potsdam
- Low earth orbit (~ 370 km), near polar orbit (87.2°)
- Mission objectives: Gravity + magnetic field, atmospheric sounding (radio occultation)
CHAMP radio occultation experiment

- Continuous since March 2002 (August 2001)
- ~250 RO events/day → 130 – 180 atmospheric profiles/day
- Expected lifetime: ~ end 2007

→ First opportunity (starting point) for RO-based climatologies
CHAMPCLIM Major Objective:

“... ensure that the CHAMP/GPS RO data are exploited in the best possible manner, in particular for climate monitoring”

- RO Retrieval Advancement
- Retrieval Validation
- Climatologies & Error Specification

CHAMPCLIM Part I (finished)

CHAMPCLIM Part II (started)
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Retrieval Overview

CHAMPCLIM Retrieval

- **Excess phases** (provided by GFZ Potsdam)
  Operational GFZ

- **CHAMPCLIM bending angle / refractivity retrieval**
  Advanced stratospheric retrieval (EGOPS/CCR v2, geometric optic).
  Background information:
  a) ECMWF operational analyses (IGAM/ECMWF) – for direct climatologies
  b) MSISE–90 based search library (IGAM/MSIS) – for DA use (refractivity)

- **CHAMPCLIM atmospheric parameter retrieval** (temperature, …)
  Dry air/moist air retrieval (EGOPS/CCR v2)
  Virtually no further background information.
# ECMWF Validation with CHAMP

**CHAMPCLIM Retrieval**

<table>
<thead>
<tr>
<th>EGOPS/CCR v2</th>
<th>IGAM/MSIS</th>
<th>IGAM/ECMWF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outlier Rejection and Smoothing</td>
<td>“3σ” outlier rejection on phase delays and smoothing using regularization.</td>
<td>Like IGAM/MSIS</td>
</tr>
<tr>
<td>Ionospheric Correction</td>
<td><strong>Linear combination of bending angles.</strong> Correction is applied to low-pass filtered bending angles (1 km sliding average), L1 high-pass contribution is added after correction. L2 bending angles &lt; 15 km derived via L1-L2 extrapolation.</td>
<td>Like IGAM/MSIS</td>
</tr>
<tr>
<td>Bending Angle Initialization</td>
<td><strong>Statistical optimization of bending angles</strong> 30-120 km. Vertically correlated background (corr. length L = 6 km) and observation (L = 1 km) errors. Obs. error estimated from obs. profile &gt; 60 km. Background error: 15%. Backg. information: MSISE-90 best fit-profile, bias corrected.</td>
<td>Like IGAM/MSIS, but co-located bending angle profile derived from ECMWF operational analysis as background Information (above ~60 km: MSISE-90). No further pre-processing.</td>
</tr>
<tr>
<td>Hydrostatic Integral Initialization</td>
<td>At <strong>120 km</strong>: pressure = p(MSISE-90).</td>
<td>Like IGAM/MSIS</td>
</tr>
</tbody>
</table>
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Data Quality (Temperature)

10 – 30km “RO optimum range”
Temperature bias: < 1 K, std. dev.: < 1 – 3 K, climat. std. dev.: order 0.1 K

CHAMPCLIM – CHAMP GFZ
- Latitude: mid (30°–60°)
- 409 events

CHAMPCLIM - ECMWF
- Latitude: mid (30°–60°)
- 432 events

CHAMPCLIM – MIPAS
- Latitude: mid (30°–60°)
- 41 events

(GFZ operational version 4)
(MIPAS data provided by IMK Univ. Karlsruhe)
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Climatologies Setup

Global Climatologies – Two Modes

Direct climatology
(RO only)

3DVar Analysis
(RO Refractivity + ECMWF MM 3DVar)

Temperature  Humidity  Geopotential

Monthly  Seasonal  Yearly

CHAMPCLIM Primary Products
Vertical Grid: 0-50 km (internal), var-30 km (users), 500 m steps
Horizontal Grid: Direct: 10°lat, zonal means, 10°lat x 60°lon
Analysis: 2.8°x 2.8° (Gaussian T42 grid)

CHAMPCLIM Special Products
Trends (future goal), tropopause height, tropopause temperature, ...
ECMWF Validation with CHAMP

CHAMPCLIM Pre-Operational

- CHAMPCLIM Pre-Operational Status
ECMWF Validation with CHAMP

CHAMPCLIM Pre-Operational

GFZ
(atmospheric excess phases)

IGAM
Operational retrieval
MSIS ECMWF
(atmospheric parameters)

Operational + semi–operational
quality control

ECMWF
Daily and MM analyses

Direct climatologies
Analyses
ECMWF Validation with CHAMP

CHAMPCLIM Pre-Operational

GFZ
(atmospheric excess phases)

~ 190 profiles/day
Mar 2002 to Jun 2005 (transferred)
Pre-Operational (late 2005)
7 day packages within 48 hrs

quality control

Direct climatologies
Analyses

ECMWF
Daily and MM analyses
ECMWF Validation with CHAMP
CHAMPCLIM Pre-Operational

**Products**
T, Z, ln(SP), q

**Resolution**
T42L60, 4 time layers

**Daily analysis**
Operational download every day with 12 hrs delay

**Monthly means**
Monthly download with 24 hrs delay

**ECMWF**
Daily and MM analyses

**Direct climatologies**

**Analyses**

Quality control
ECMWF Validation with CHAMP
CHAMPCLIM Pre-Operational

Implementation Status

GFZ
(atmospheric excess phases)

Operational timescale

IGAM
Operational retrieval
MSIS ECMWF
(atmospheric parameters)

Operational + semi–operational
quality control

Direct climatologies

Analyses

< 14 days

ECMWF
Daily and MM analyses
ECMWF Validation with CHAMP

Validation Setup

- ECMWF – CHAMPCLIM Comparison Setup
Validation Setup

Spatial- Temporal Characteristics CHAMP

- IGAM/ECMWF retrieval
- Validation period: MAM 2002 – DJF 2004/05 (3 years, ~150,000 temperature profiles)
- Temporal resolution: seasonal mean (3 month, ~12,500 profiles per season)
- Horizontal resolution: Zonal means (10° latitude bands, several hundred to > 1000 events per latitude band)

→ Robust statistics
ECMWF Validation with CHAMP

Validation Setup

Spatial- Temporal Characteristics CHAMP

- IGAM/ECMWF retrieval
- Validation period: MAM 2002 – JJA 2004 (2.5 years, 124,355 temperature profiles)
- Temporal resolution: seasonal mean (3 month, ~12,500 profiles per season)
- Horizontal resolution: Zonal means (10° latitude bands, several hundred to > 1000 events per latitude band)

→ Robust statistics

JJA2003: CHAMP Occultation Event Distribution (Global)
**ECMWF Validation with CHAMP**

**Validation Setup**

**Spatial- Temporal Characteristics CHAMP**

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→ Robust statistics
## ECMWF Validation with CHAMP

### Validation Setup

**Characteristics ECMWF operational analyses**

- 4DVar data assimilation combining short range forecast with observations
- Resolution T511L60 (~40 km horizontal, 60 levels up to 0.1 hPa)
- Provided 4 times per day (00, 06, 12, 18 UT)
- Used as initial conditions for ECMWF’s IFS, for many atmospheric process studies, often as reference dataset in validation studies
- Reduced horizontal resolution (T42L60, ~ 300 km)
- Profiles extracted at positions of occultation events (to avoid sampling errors)
ECMWF Validation with CHAMP

Validation Setup

Characteristics ECMWF operational analyses

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ECMWF Validation with CHAMP

Validation Setup

Statistics

- Based on temperature difference profiles ECMWF - CHAMPCLIM
  - seasonal/zonal mean difference ("bias")
  - seasonal/zonal std. deviation of differences
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Results

- Results
ECMWF Validation with CHAMP

Results

ECMWF – CHAMP Seasonal Zonal Bias: <0.5 K, 2 features
ECMWF Validation with CHAMP

Results

Tropopause Bias

Cold low latitude tropopause bias in ECMWF (1 – 2 K)
ECMWF Validation with CHAMP

Results

ECMWF Tropopause Bias

[Graph showing ECMWF Tropopause Bias with temperature standard deviation in JJA2003]
ECMWF Validation with CHAMP

Results

ECMWF Polar Vortex Bias (JJA 2003)

wavelike structure (−2.5 to 3.5 K), Deficiencies in representation of Antarctic polar vortex in ECMWF
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Results

Polar Vortex Bias

2002:
warmer, polar vortex vortex split late Sep.

2004:
wave pattern: >20 km red. magnitude, rev. sign
Below: shape more pronounced than in 2002, 2003
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Results

Upper Stratosphere Bias
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Summary

• Summary and Outlook
Summary

• Generally good agreement of ECMWF analysis and RO seasonal zonal mean stratospheric temperatures (bias < 0.5 K) but:

  • ECMWF polar vortex bias (-2.5 to +3.5 K) (related to DA scheme, AMSU, bias adjustment, ?)

  • Cold low latitude tropopause bias in ECMWF (1 – 2 K), probably related to weak tropopause height variability in ECMWF (work ongoing)

  • Cold upper stratosphere bias (-1 to -3 K) (work ongoing)

• CHAMPCLIM: Accurate seasonal climatologies (10° zonal mean, 10°x60°) obtainable from a single RO receiver
ECMWF Validation with CHAMP

Outlook

• Tropopause study (variability)
• Further CHAMPCLIM retrieval advancement (troposphere, moist air)
• Detailed CHAMPCLIM error characterization (sampling error, local time sampling, …)
• Detailed CHAMPCLIM vertical resolution characterization
• Include more (future) RO data (SAC-C, GRACE, Metop/GRAS, COSMIC, …)
• Open (web-based) access to CHAMPCLIM products