Second GPS RO Data Users' Workshop

Lansdowne, VA, USA, 22 – 24 August 2005

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

ECMWF Validation with CHAMP

CHAMP - CHAMPCLIM

- **CHAMPCLIM Project Overview**

ECMWF Validation with CHAMP

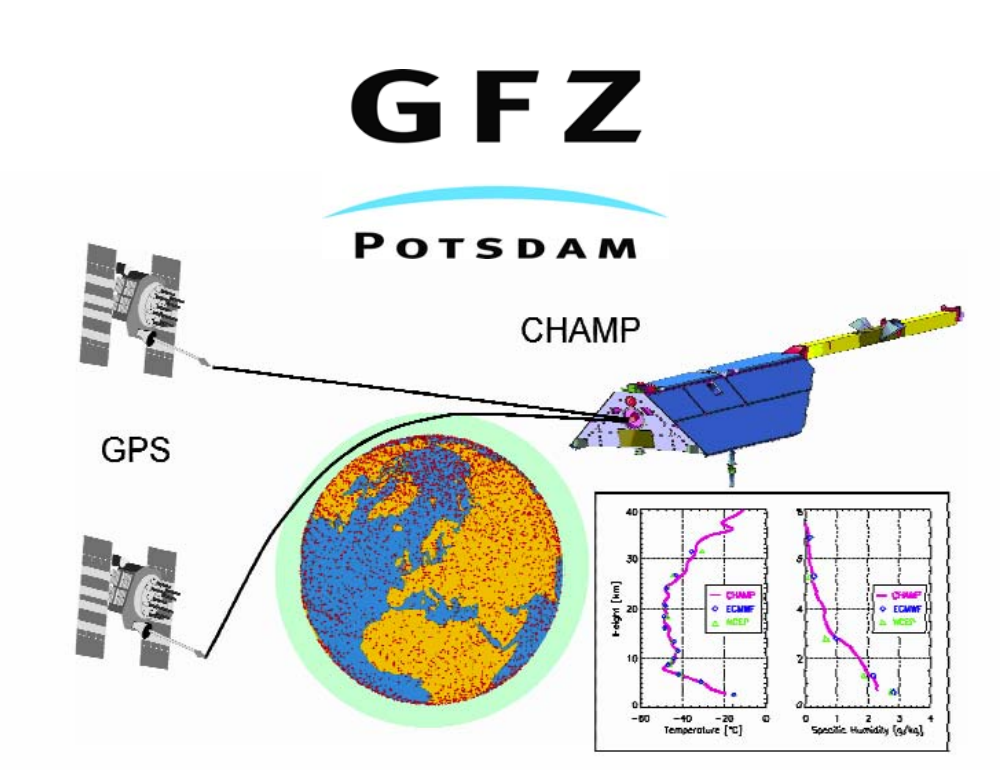
The CHAMPCLIM Project

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)**



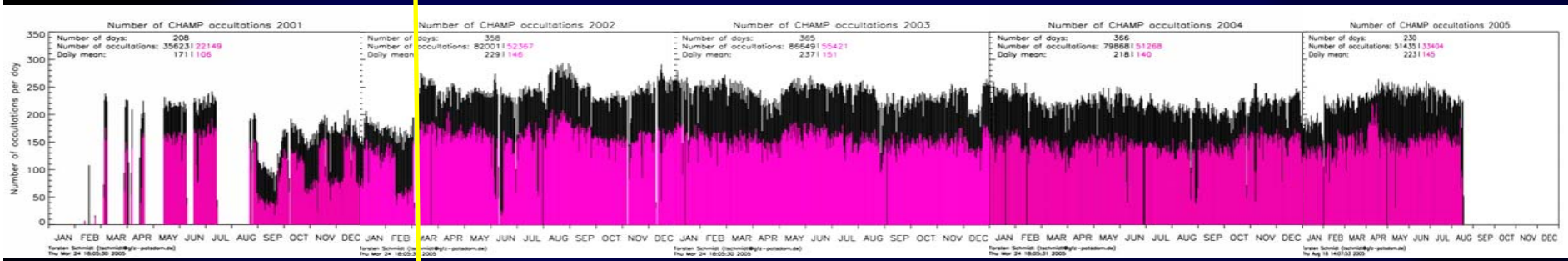
ECMWF Validation with CHAMP

CHAMP

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



2001 **2002** **2003** **2004** **2005...**

CHAMPCLIM

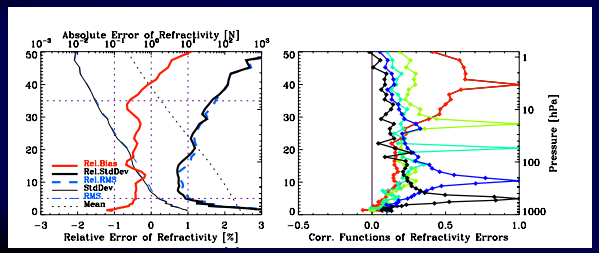
ECMWF Validation with CHAMP

CHAMPCLIM Overview

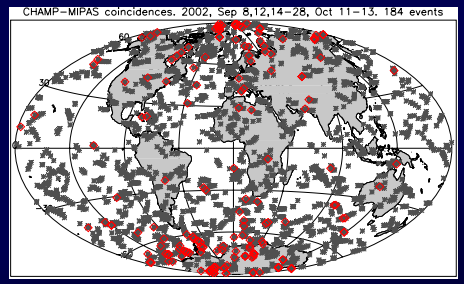
CHAMPCLIM Major Objective:

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

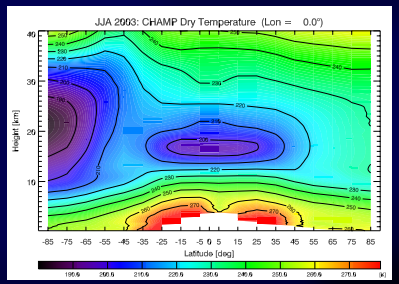
RO Retrieval Advancement



Retrieval Validation



Climatologies & Error Specification



CHAMPCLIM Part I (finished)

CHAMPCLIM Part II (started)

ECMWF Validation with CHAMP

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

EGOPS/CCR v2	IGAM/MSIS	IGAM/ECMWF
Outlier Rejection and Smoothing	"3σ" outlier rejection on phase delays and smoothing using regularization.	Like IGAM/MSIS
Ionospheric Correction	**Linear combination of bending angles**. Correction is applied to low-pass filtered bending angles (1 km sliding average), L1 high-pass contribution is added after correction. L2 bending angles < 15 km derived via L1-L2 extrapolation.	Like IGAM/MSIS
Bending Angle Initialization	**Statistical optimization of bending angles** 30-120 km. Vertically correlated background (corr. length L = 6 km) and observation (L = 1 km) errors. Obs. error estimated from obs. profile > 60 km. Background error: 15%. Backg. information: MSISE-90 best fit-profile, bias corrected.	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.
Hydrostatic Integral Initialization	At **120 km**: pressure = p(MSISE-90).	Like IGAM/MSIS
Quality Control	Refractivity 5 – 35 km: $\Delta N/N$ < 10%; Temperature 8 – 25 km: ΔT < 25 K. Reference: co-located ECMWF profiles.	Like IGAM/MSIS

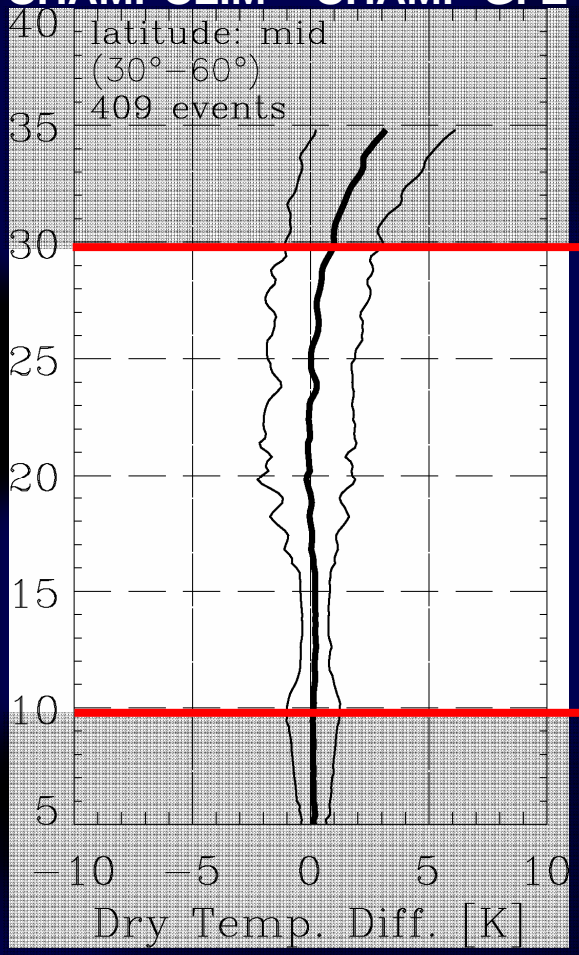
ECMWF Validation with CHAMP

Data Quality (Temperature)

10 – 30km “RO optimum range”

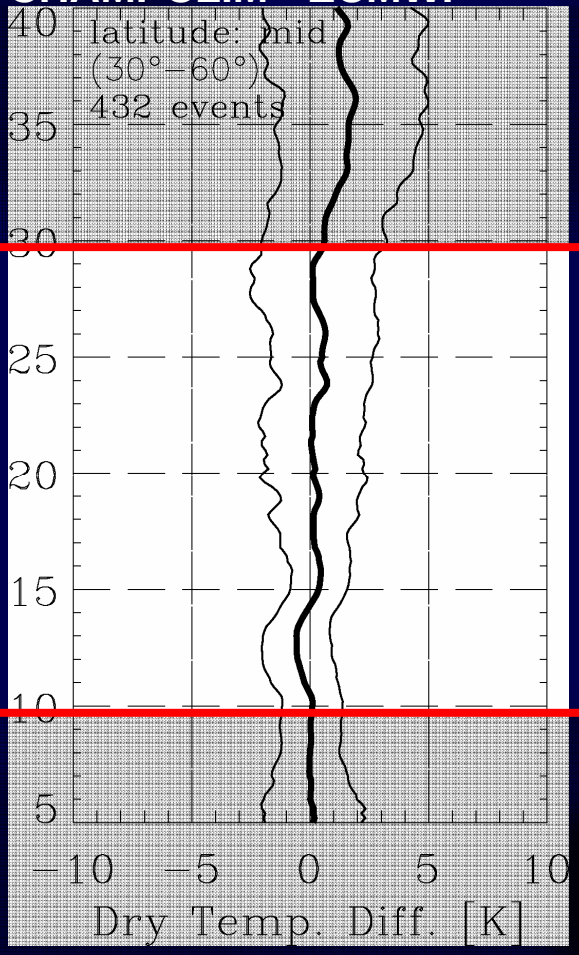
Temperature bias: < 1 K, std. dev.: < 1 – 3 K, climat. std. dev.: order 0.1 K

CHAMPCLIM – CHAMP GFZ

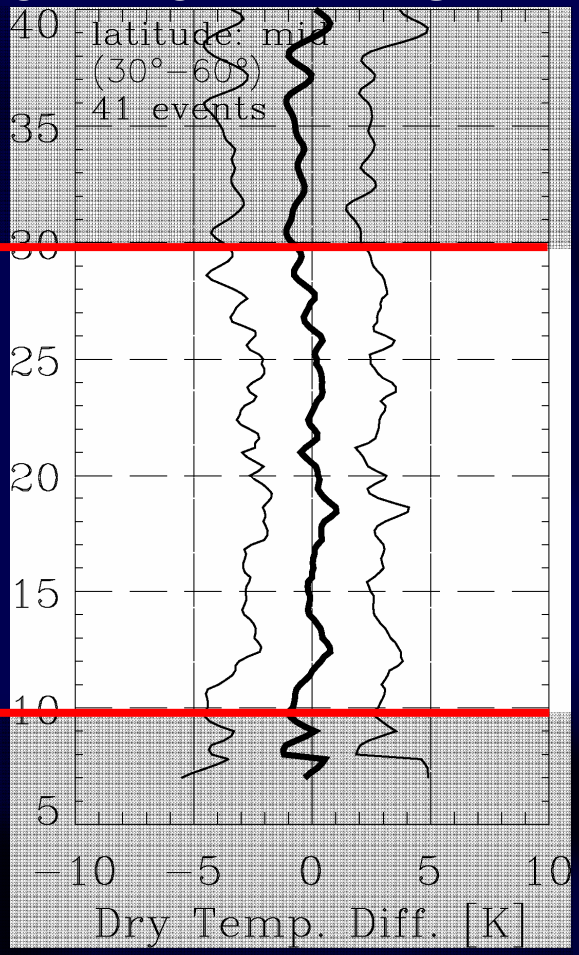


(GFZ operational version 4)

CHAMPCLIM - ECMWF



CHAMPCLIM – MIPAS



(MIPAS data provided by IMK Univ. Karlsruhe)

ECMWF Validation with CHAMP
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, ...

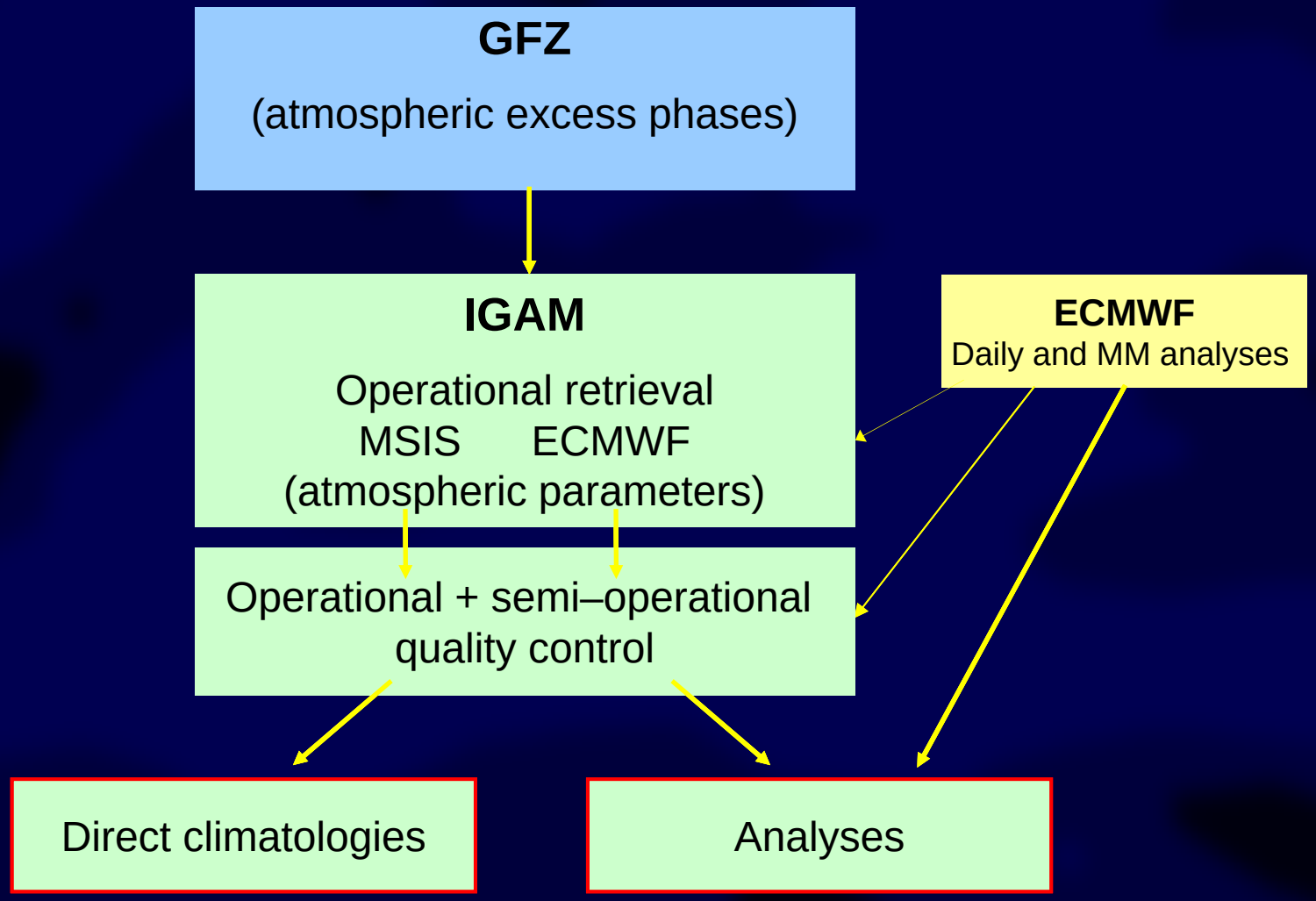
ECMWF Validation with CHAMP

CHAMPCLIM Pre-Operational

- **CHAMPCLIM Pre-Operational Status**

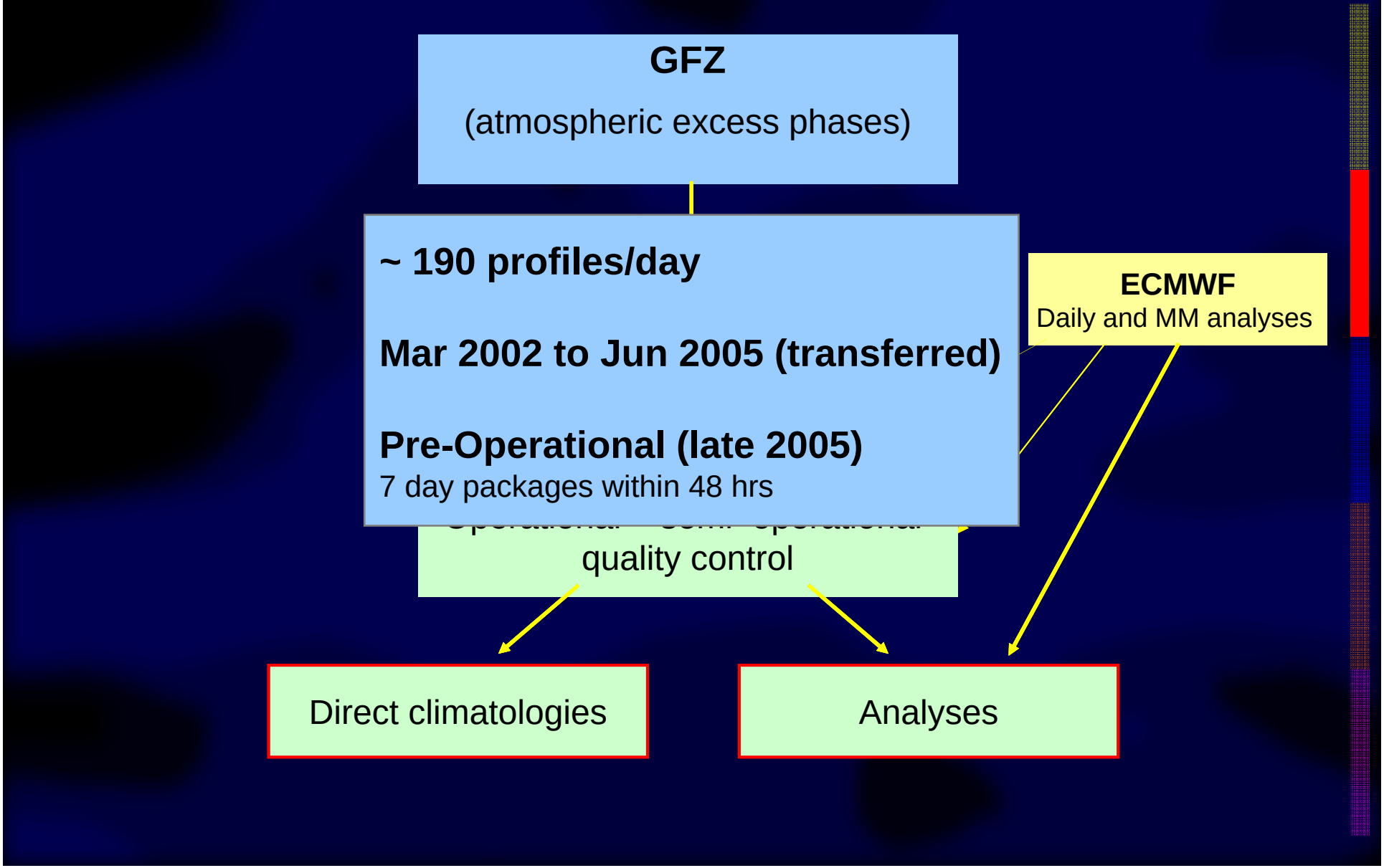
ECMWF Validation with CHAMP

CHAMPCLIM Pre-Operational



ECMWF Validation with CHAMP

CHAMPCLIM Pre-Operational



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

quality control

Direct climatologies

Analyses

ECMWF Validation with CHAMP

CHAMPCLIM Pre-Operational

Implementation Status

Operational timescale

GFZ

(atmospheric excess phases)

IGAM

Operational retrieval
MSIS ECMWF
(atmospheric parameters)

ECMWF
Daily and MM analyses

Operational + semi–operational
quality control

Direct climatologies

Analyses

< 14 days

ECMWF Validation with CHAMP

Validation Setup

- **ECMWF – CHAMPCLIM Comparison Setup**

ECMWF Validation with CHAMP

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

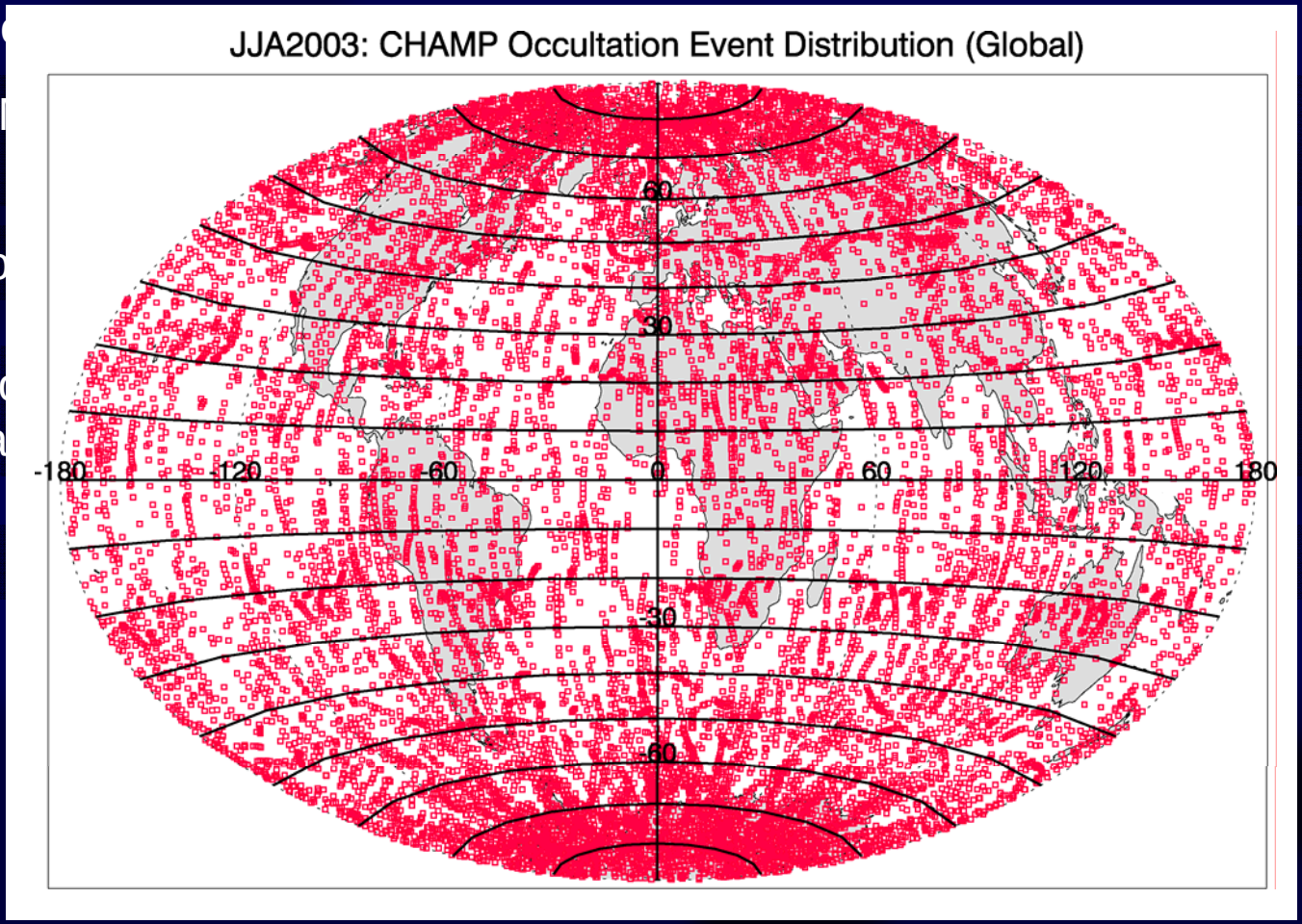
ECMWF Validation with CHAMP

Validation Setup

Spatial- Temporal Characteristics CHAMP

- IGAM/ECMWF r
- Validation period: I profiles)
- Temporal resolutio
- Horizontal resoluti 1000 events per la

→ Robust statistics



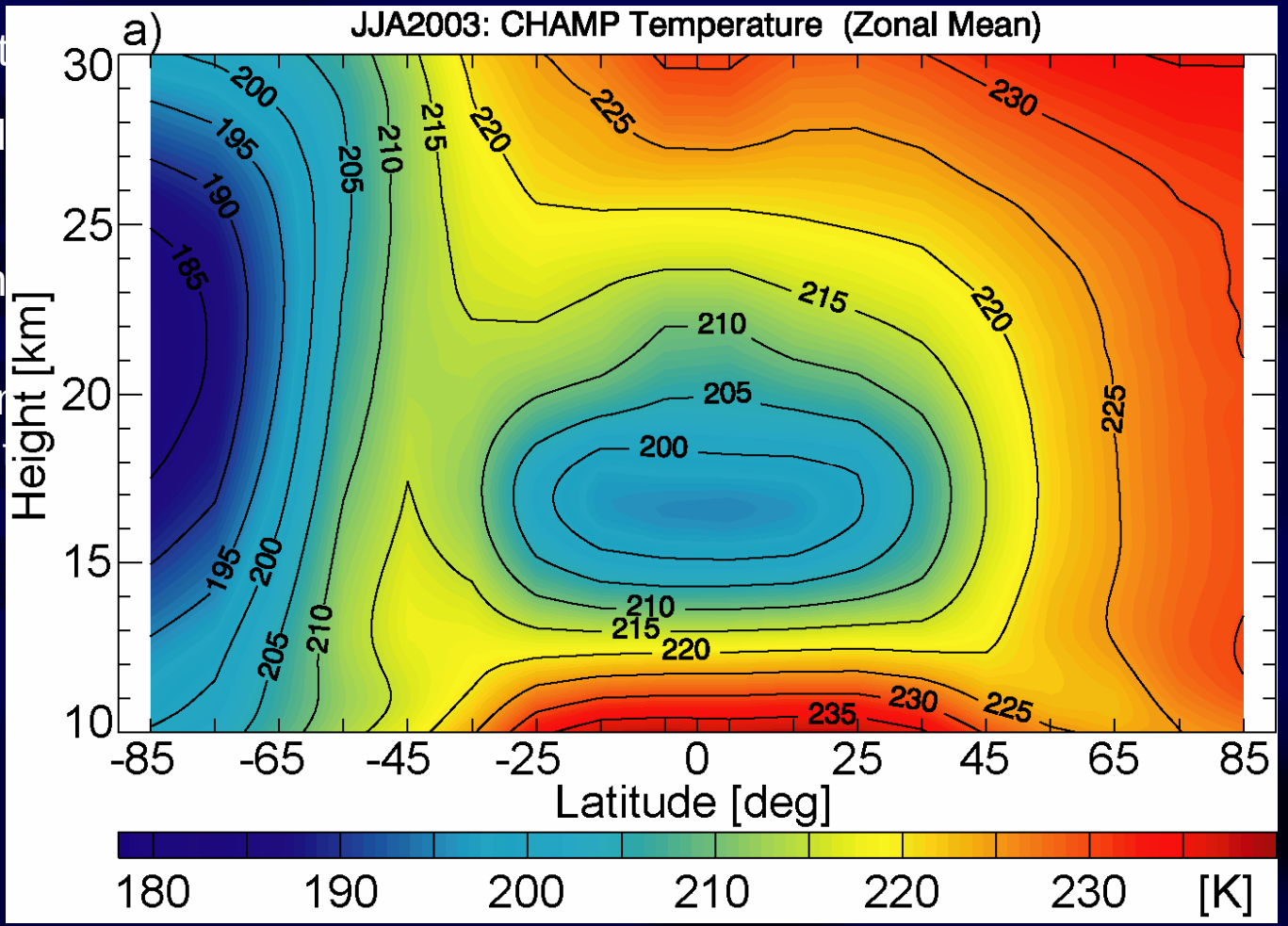
ECMWF Validation with CHAMP

Validation Setup

Spatial- Temporal Characteristics CHAMP

- IGAM/ECMWF ret
- Validation period: M
  profiles)
- Temporal resolution
- Horizontal resolution
  1000 events per lati

→ 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

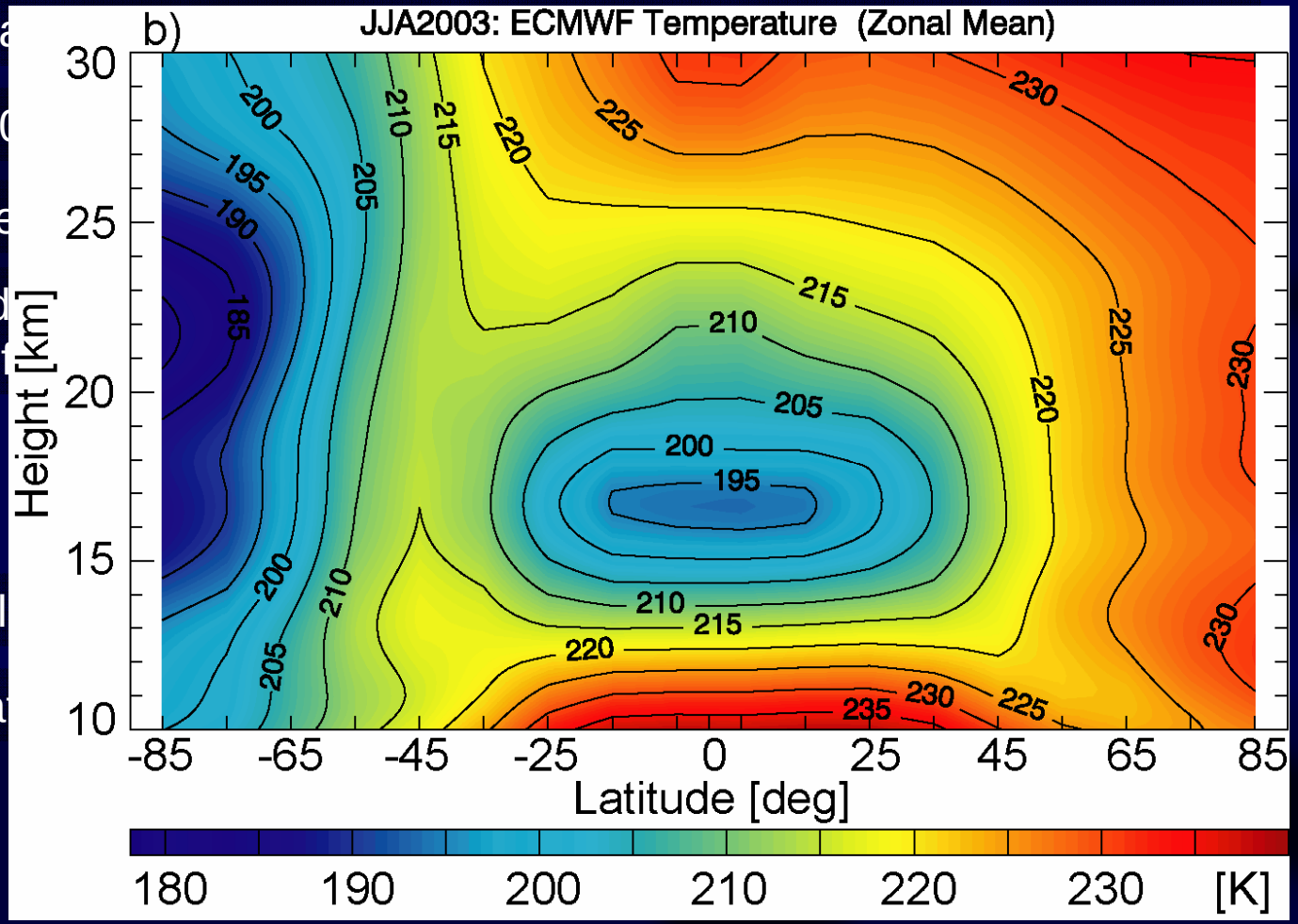
- Reduced horizontal resolution (T42L60, ~ 300 km)
- Profiles extracted at positions of occultation events (to avoid sampling errors)

ECMWF Validation with CHAMP

Validation Setup

Characteristics ECMWF operational analyses

- 4DVar data assimila
- Resolution T511L6
- Provided 4 times pe
- Used as initial cond
  studies, often as re
- Reduced horizontal
- Profiles extracted a



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

ECMWF Validation with CHAMP

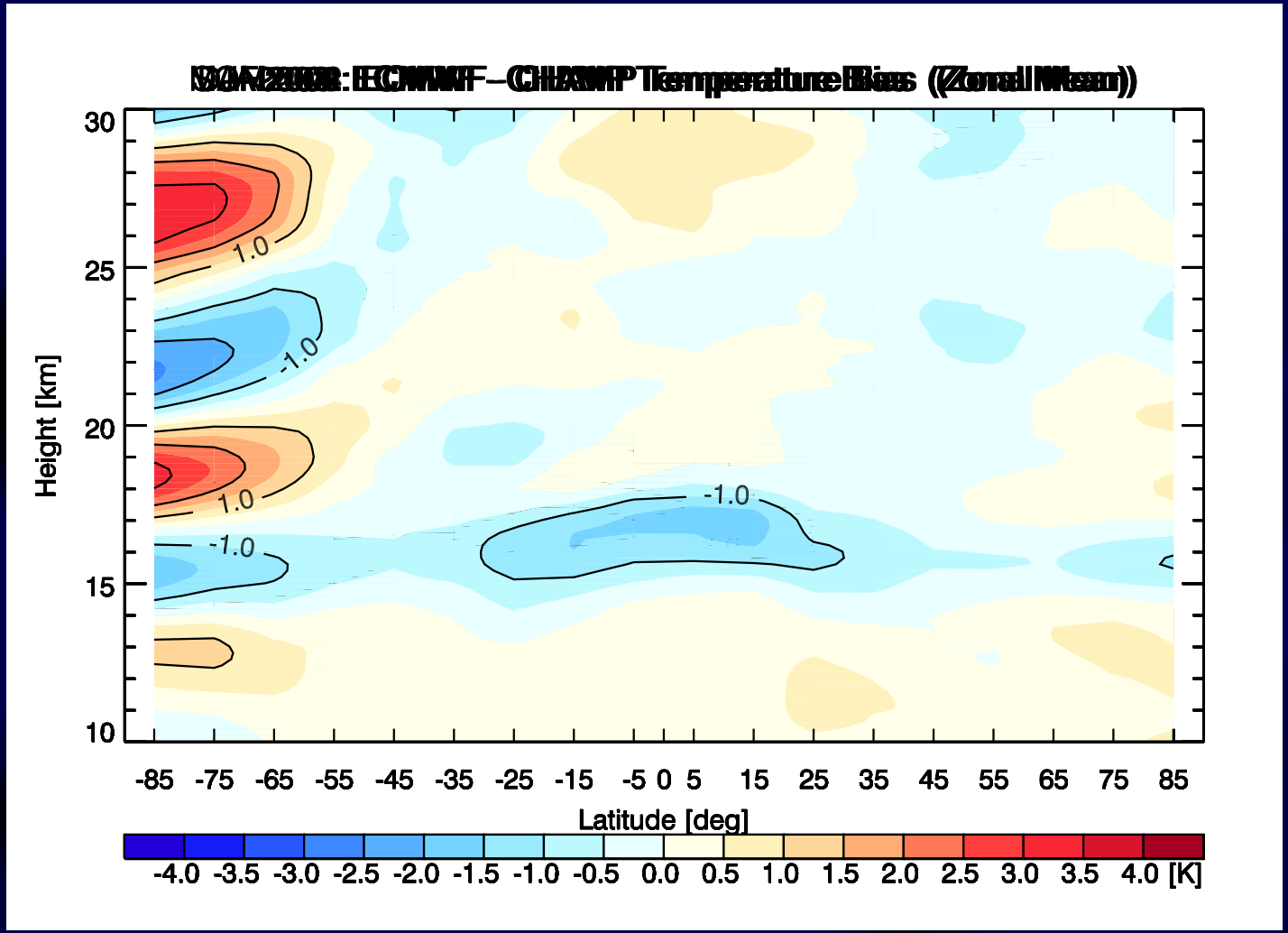
Results

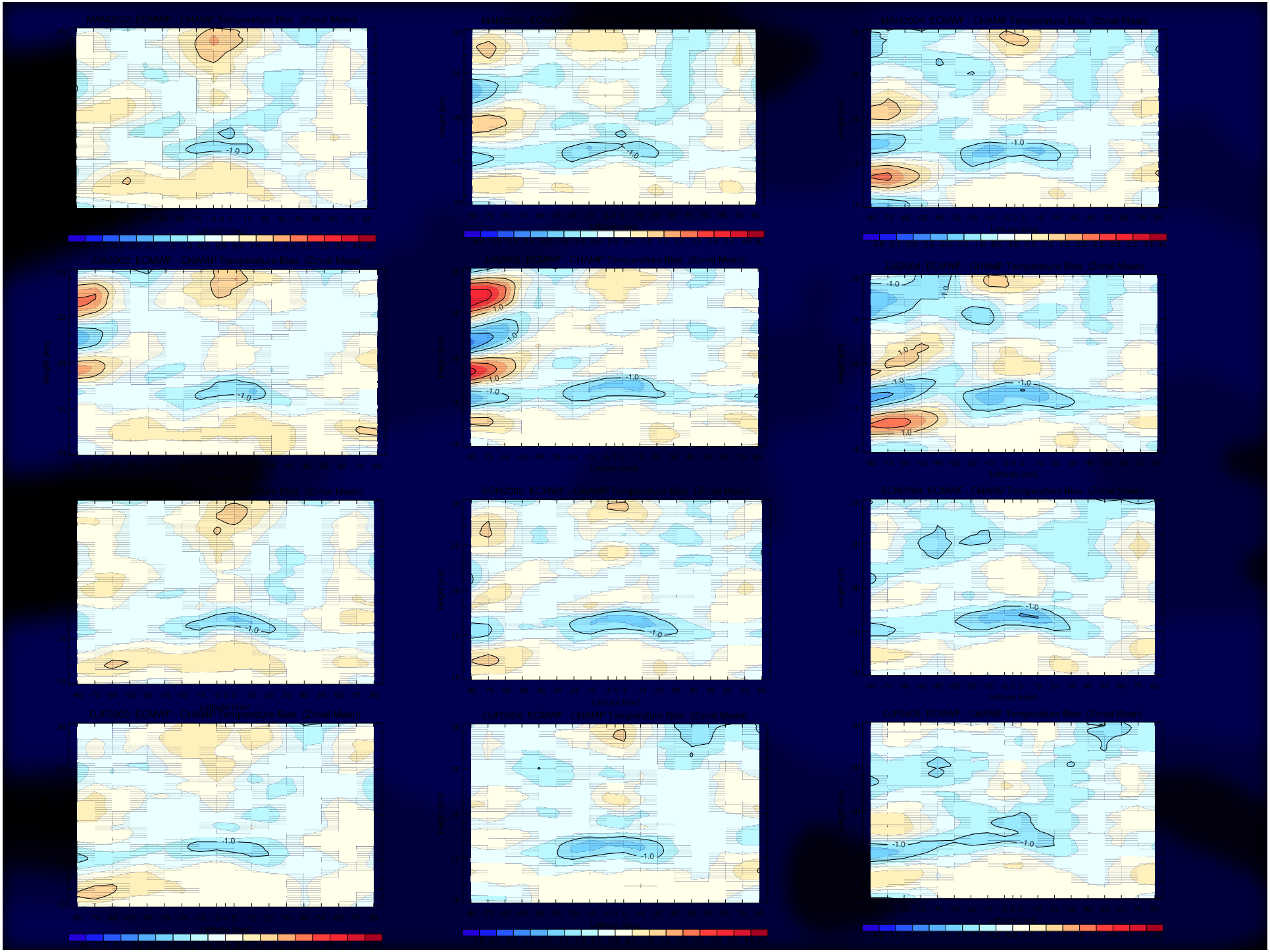
- **Results**

ECMWF Validation with CHAMP

Results

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

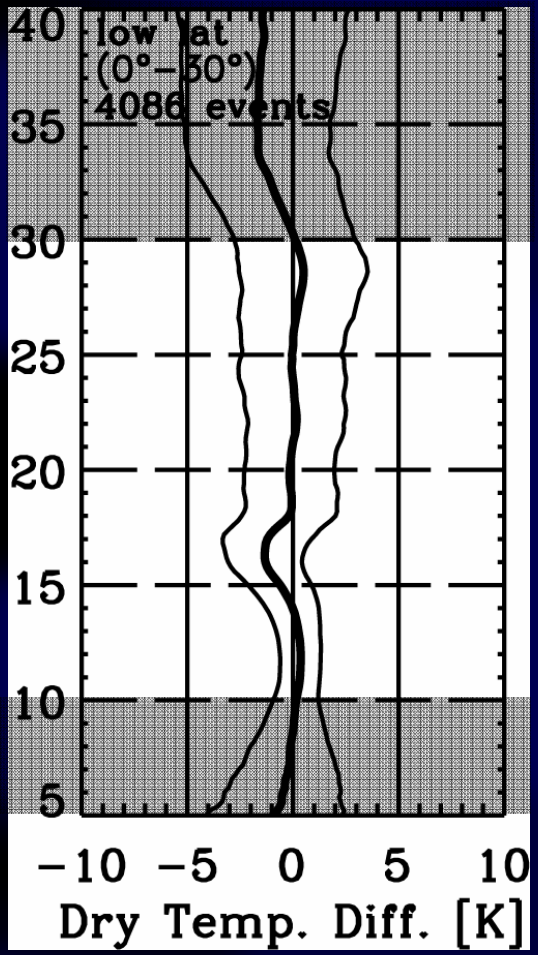


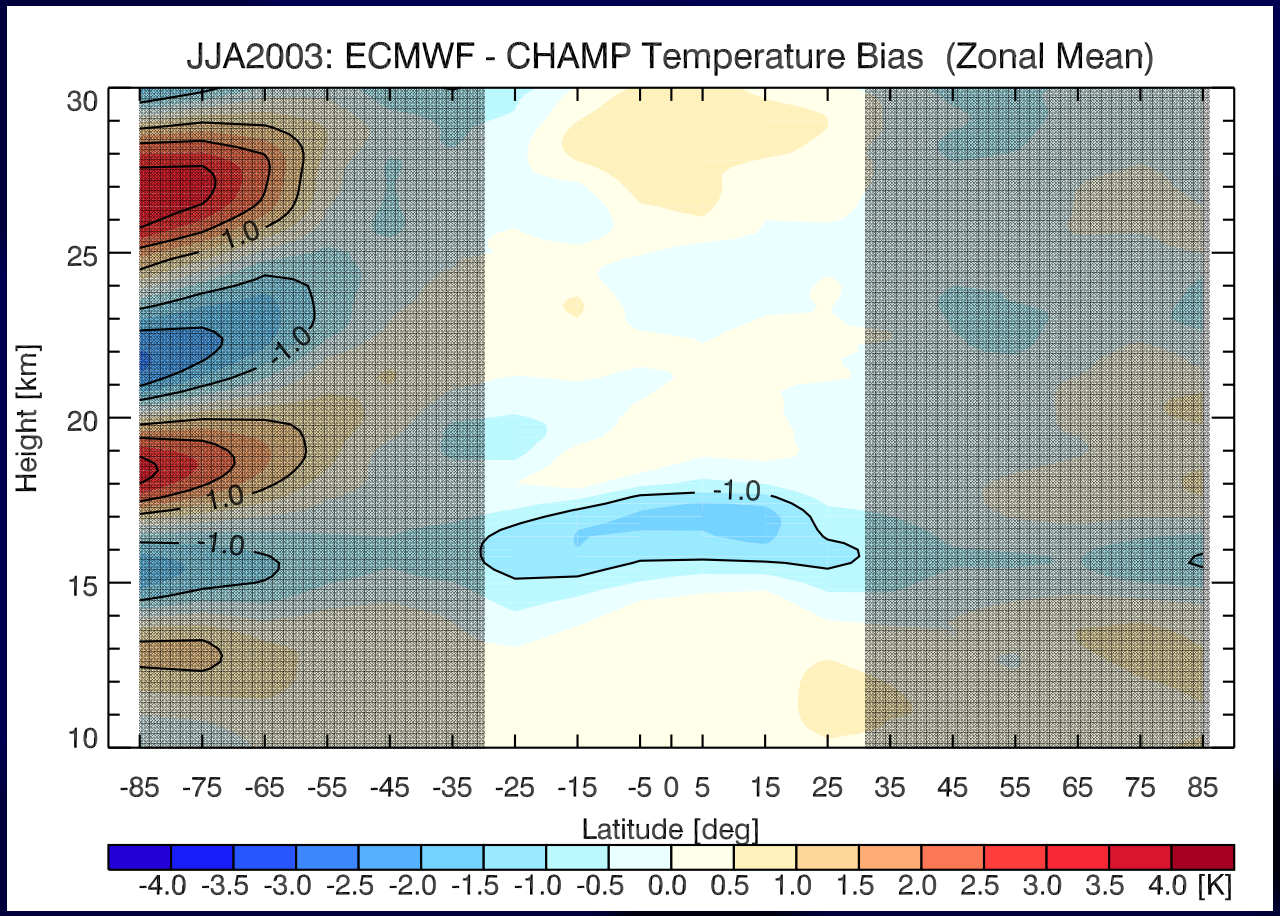

MAM2002: ECMWF - CHAMP Temperature Bias (Zonal Mean)
MAM2003: ECMWF - CHAMP Temperature Bias (Zonal Mean)
MAM2004: ECMWF - CHAMP Temperature Bias (Zonal Mean)
JJA2002: ECMWF - CHAMP Temperature Bias (Zonal Mean)
JJA2003: ECMWF - CHAMP Temperature Bias (Zonal Mean)
JJA2004: ECMWF - CHAMP Temperature Bias (Zonal Mean)
SON2003: ECMWF - CHAMP Temperature Bias (Zonal Mean)
SON2004: ECMWF - CHAMP Temperature Bias (Zonal Mean)
DJF0203: ECMWF - CHAMP Temperature Bias (Zonal Mean)
DJF0304: ECMWF - CHAMP Temperature Bias (Zonal Mean)
DJF0405: ECMWF - CHAMP Temperature Bias (Zonal Mean)
Height [km]
Latitude [deg]
-1.0
[K]

ECMWF Validation with CHAMP

Results

Tropopause Bias



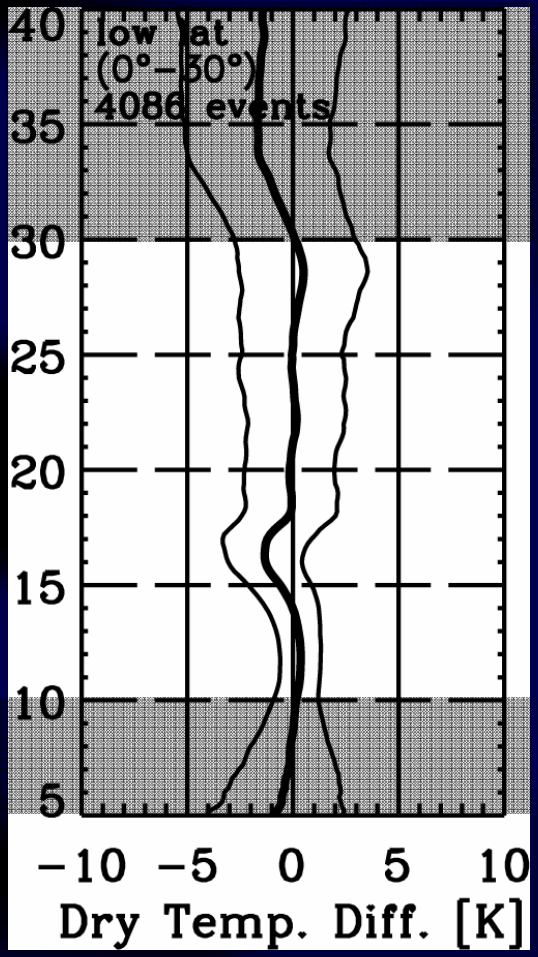


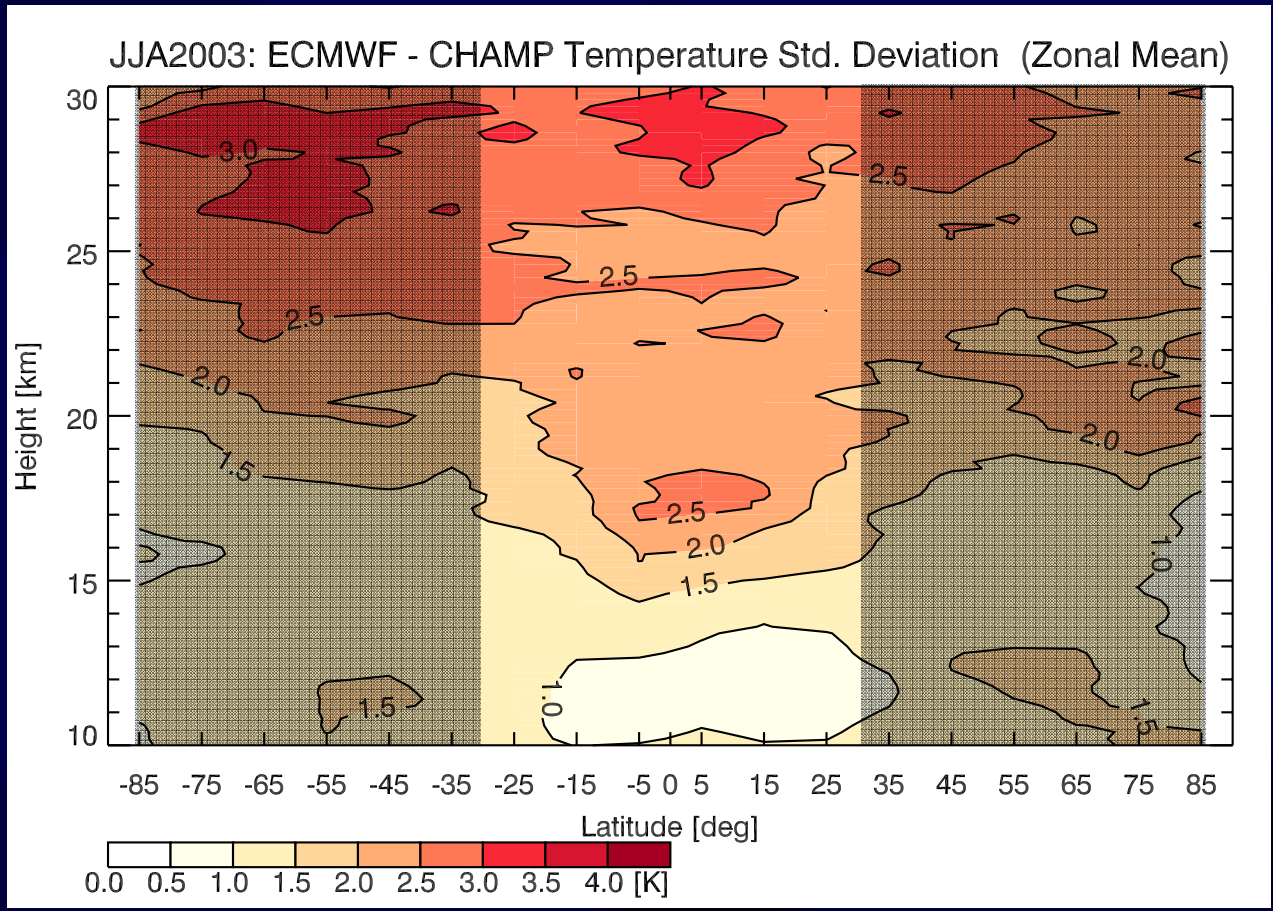
Cold low latitude tropopause bias in ECMWF (1 – 2 K)

ECMWF Validation with CHAMP

Results

ECMWF Tropopause Bias

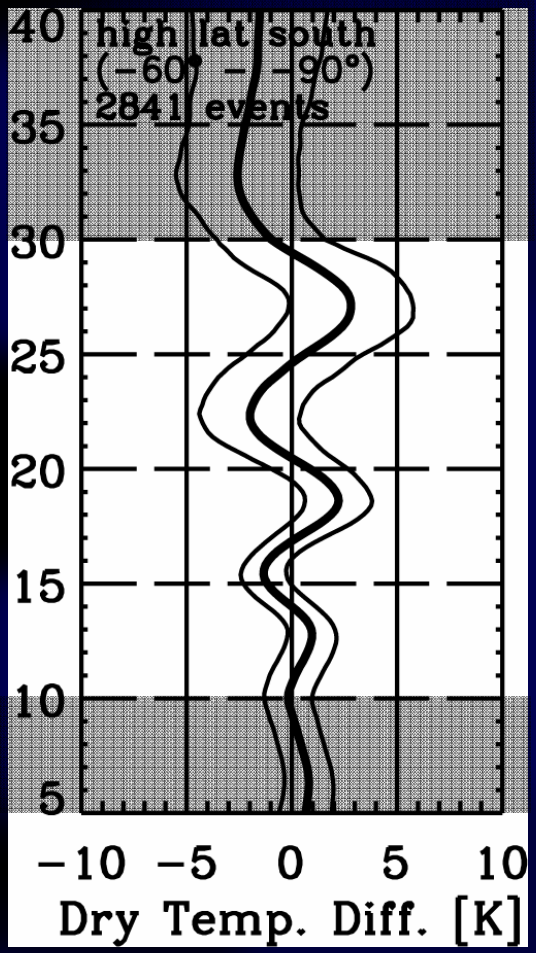


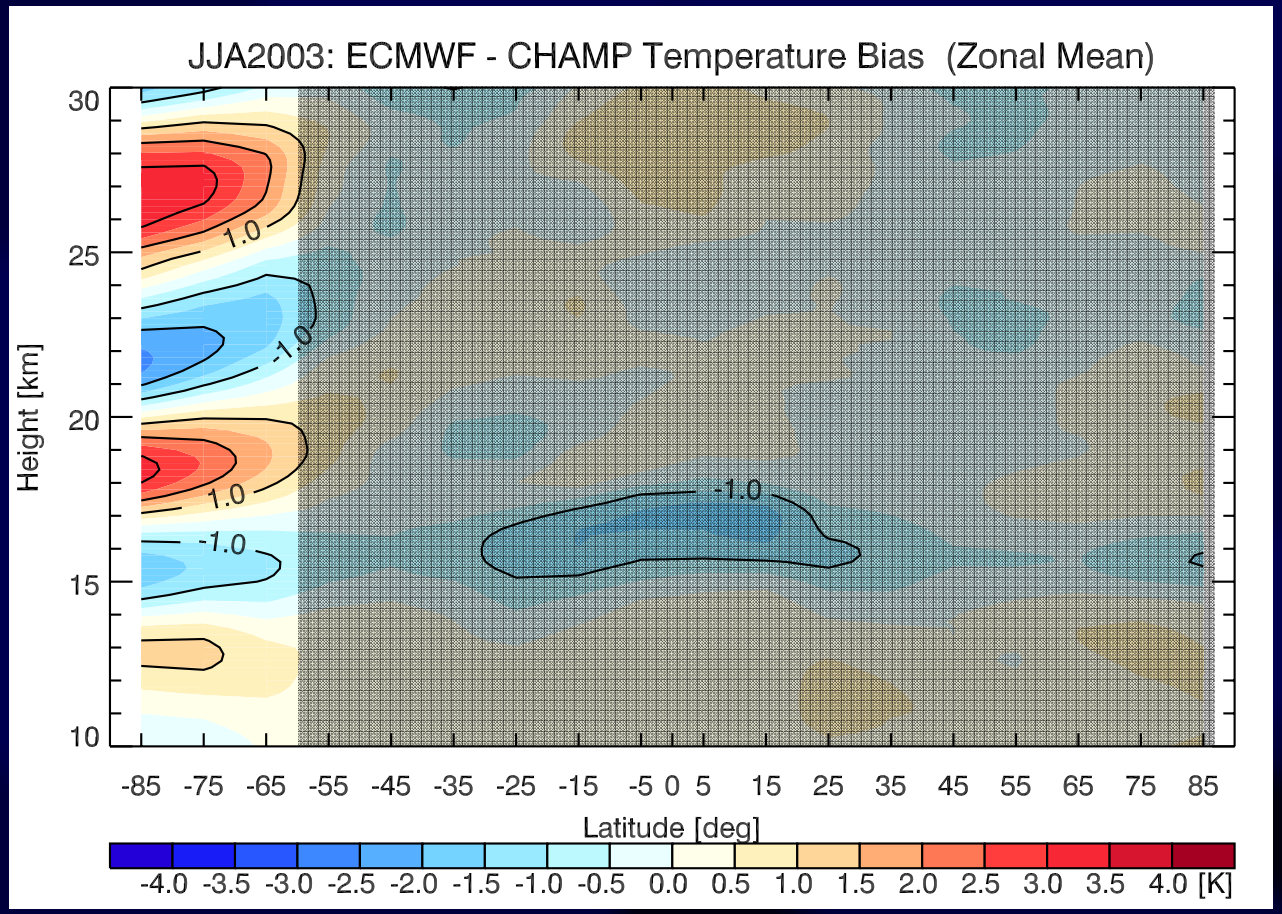


ECMWF Validation with CHAMP

Results

ECMWF Polar Vortex Bias (JJA 2003)





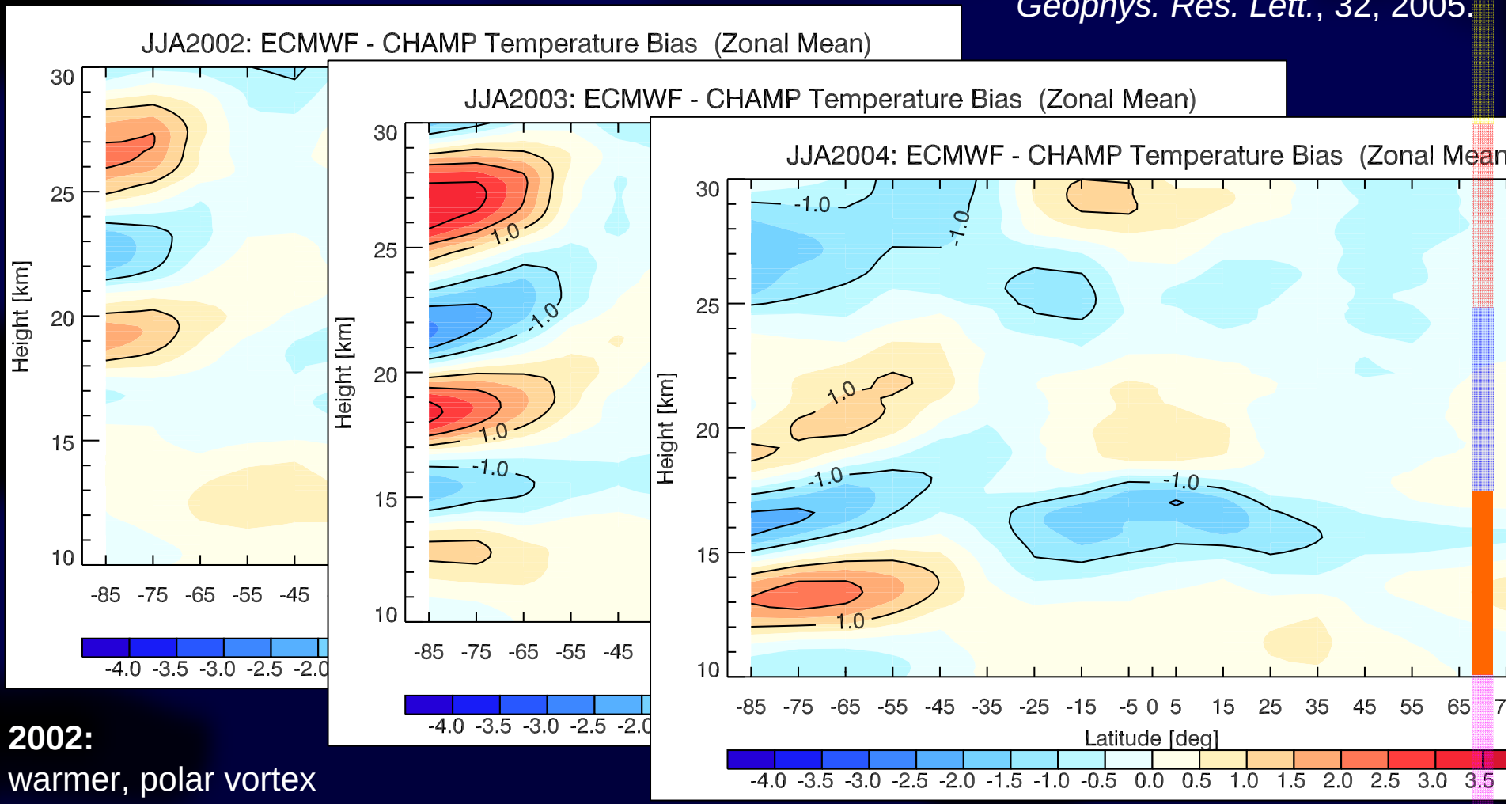
wavelike structure (– 2.5 to 3.5 K), Deficiencies in representation of Antarctic polar vortex in ECMWF

ECMWF Validation with CHAMP

Results

Polar Vortex Bias

Gobiet et al.,
Geophys. Res. Lett., 32, 2005.



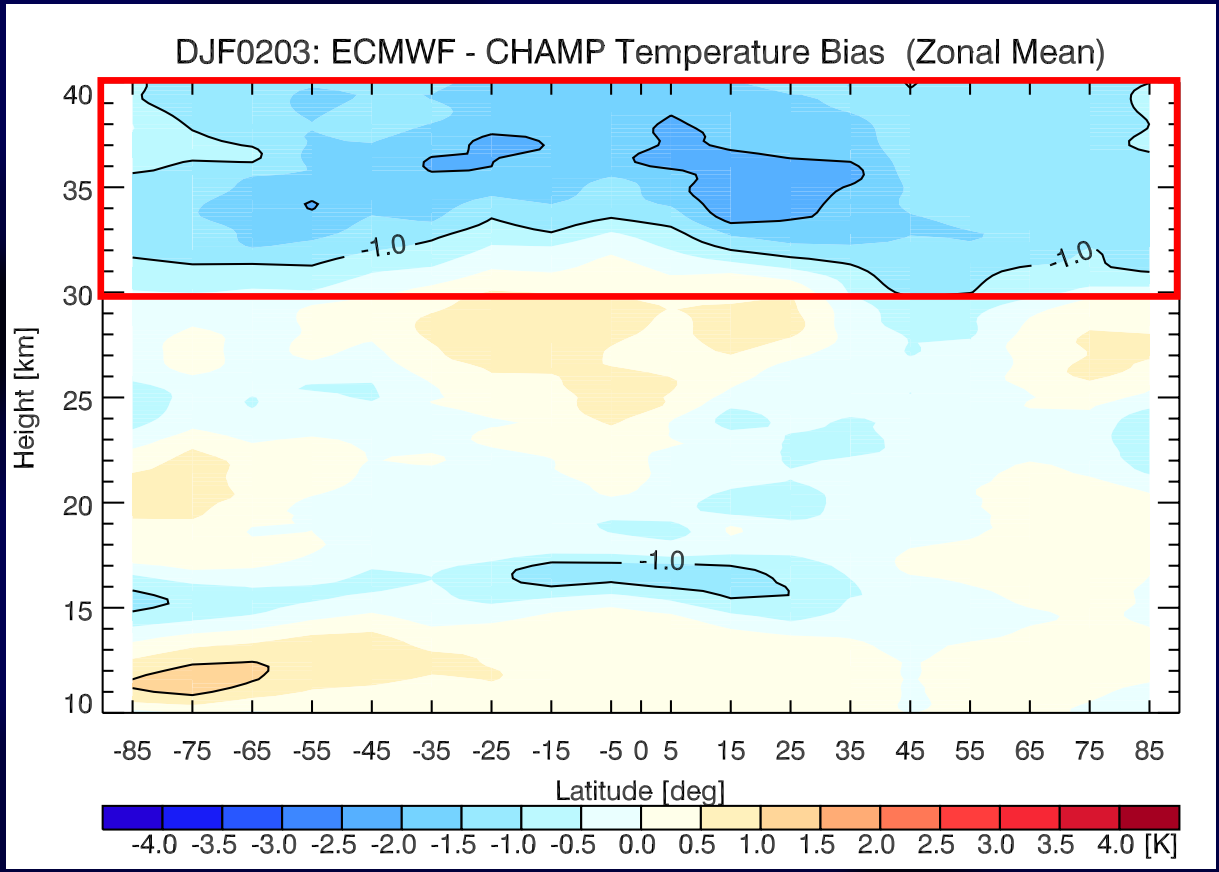
2002:
warmer, polar vortex
vortex split late Sep.

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

ECMWF Validation with CHAMP

Results

Upper Stratosphere Bias



ECMWF Validation with CHAMP

Summary

- **Summary and Outlook**

ECMWF Validation with CHAMP

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