wege entstehen, indem wir sie gehen
paths emerge in that we walk them

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Atmospheric Remote Sensing and Climate System Research Group
ARSCliSys

Structural Uncertainty of the CHAMP Climate Record from Different Data Centers

A.K. Steiner [1], S-P. Ho [2], D. Hunt [2], G. Kirchengast [1], A. J. Mannucci [3], B. Scherllin-Pirscher [2,1], H. Gleisner [4], A. von Engeln [5], T. Schmidt [6], C. Ao [3], S. S. Leroy [7], U. Foelsche [1], Y-H. Kuo [2], E. R. Kursinski [8], K. B. Lauritsen [4], S. Syndergaard [4], C. Marquardt [5], C. Rocken [2], W. Schreiner [2], S. Sokolovskiy [2], J. Wickert [6]

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[6] German Research Centre for Geosciences (GFZ), Potsdam, Germany
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OPAC 2010, September 8, 2010, Graz, Austria

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Outline

- Background
- Data and study setup
- Centers and their processing
- Results
- Conclusions and outlook

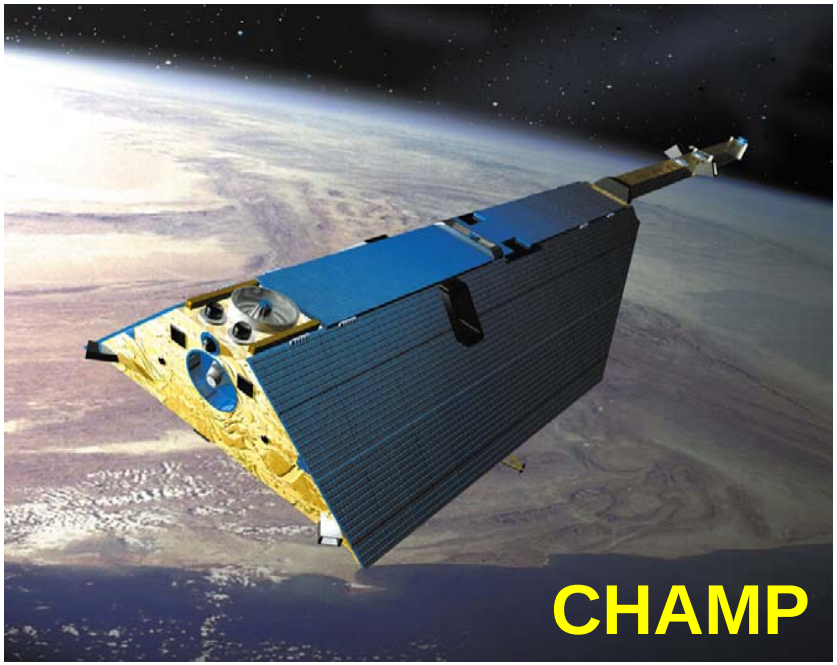
Background

- Aim: Quantifying the structural uncertainty of RO data provided by main RO processing centers

- Background:
  - 1st round study by Ho et al. (GRL, 2009)
  - Intercomparison of refractivity climatologies
  - CHAMP 2002-2006
  - 4 centers JPL, GFZ, UCAR, WEGC
  - Structural uncertainties amongst climatologies of different RO processing centers are < 0.03 %/5years for refractivity trends in large scale means

Data and Study Setup

- 2nd round intercomparison studies
- Profile to profile comparison (PPC) provided by RO processing centers (study by S-P. Ho)
- Intercomparison of zonal monthly mean climatologies (MMCs)
- **CHAMP** record September 2001 to September 2008



Courtesy: J. Wickert

Data and Study Setup

- Resolution/range: 5-degree zonal means, monthly means
- **Latitude regions:** Tropics 20°N–20°S
  Northern/Southern mid-latitudes: 20°N/S–50°N/S
  Northern/Southern high-latitudes: 50°N/S–90°N/S
- **Altitude range:** 8–30 km (200 m)
- **Altitude layers:** 8–12 km (Upper Troposphere UT)
  12–16 km (Tropopause TP)
  16–25 km (Lower Stratosphere LS)
  25–30 km
- Focus region: Tropical UTLS
- **Parameters[a]:** Bending angle $\alpha(z_a)$
  Refractivity N(z)
  Dry pressure $p_d(z)$,
  Dry geopotential height $Z_d(z_p)$
  Dry temperature $T_d(z)$

[a] msl altitude z, impact altitude z_a (z_a = impact parameter – radius of curvature – geoid undulation),
pressure altitude $z_p(p)[m]=(7000\ m) \times \ln(1013.25\ hPa/p[hPa])$

Centers and Processing

Processing Center [b]	Data version	Processing Steps [a]
DMI Copenhagen, DK	OCC 18.9.353	UCAR phase & orbit data, Geometrics optics (GO), CanonTransf. (CT)<25km Optimization of α with MSIS-E90,
EUM Darmstadt, D	YAROS0.1(Beta)	UCAR phase & orbit data, GO, Optimization of N with MSISE-90
JPL Pasadena, CA, USA	v2fo_10Kp1N	Excess phase Double Differencing, CT, exponential function fit of α at 40-50km, extrapol.
UCAR Boulder, CO, USA	2009.2650	Excess phase Single Differencing, Full Spectrum Inversion in troposphere, above GO Optimization with NCAR climatology
WEGC Graz, A	OPSv5.4	UCAR phase & orbit data, GO, Statistical optimization > 30 km with ECMWF forecasts & MSIS above

[a] All centers: Ionospheric correction of bending angles and dry air retrieval but different smoothing routines and quality control

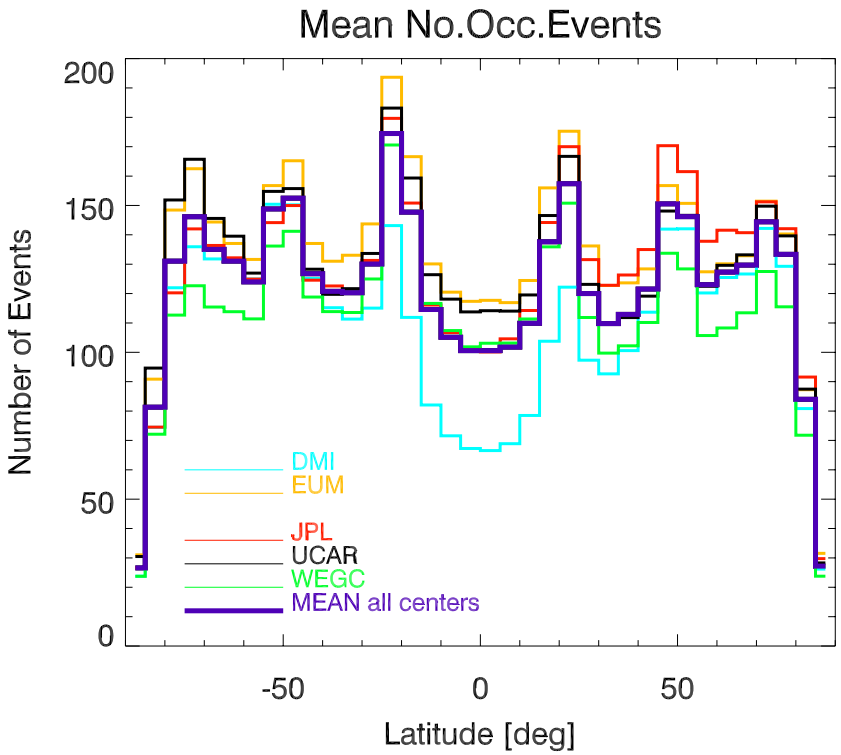
[b] GFZ not yet included

Method

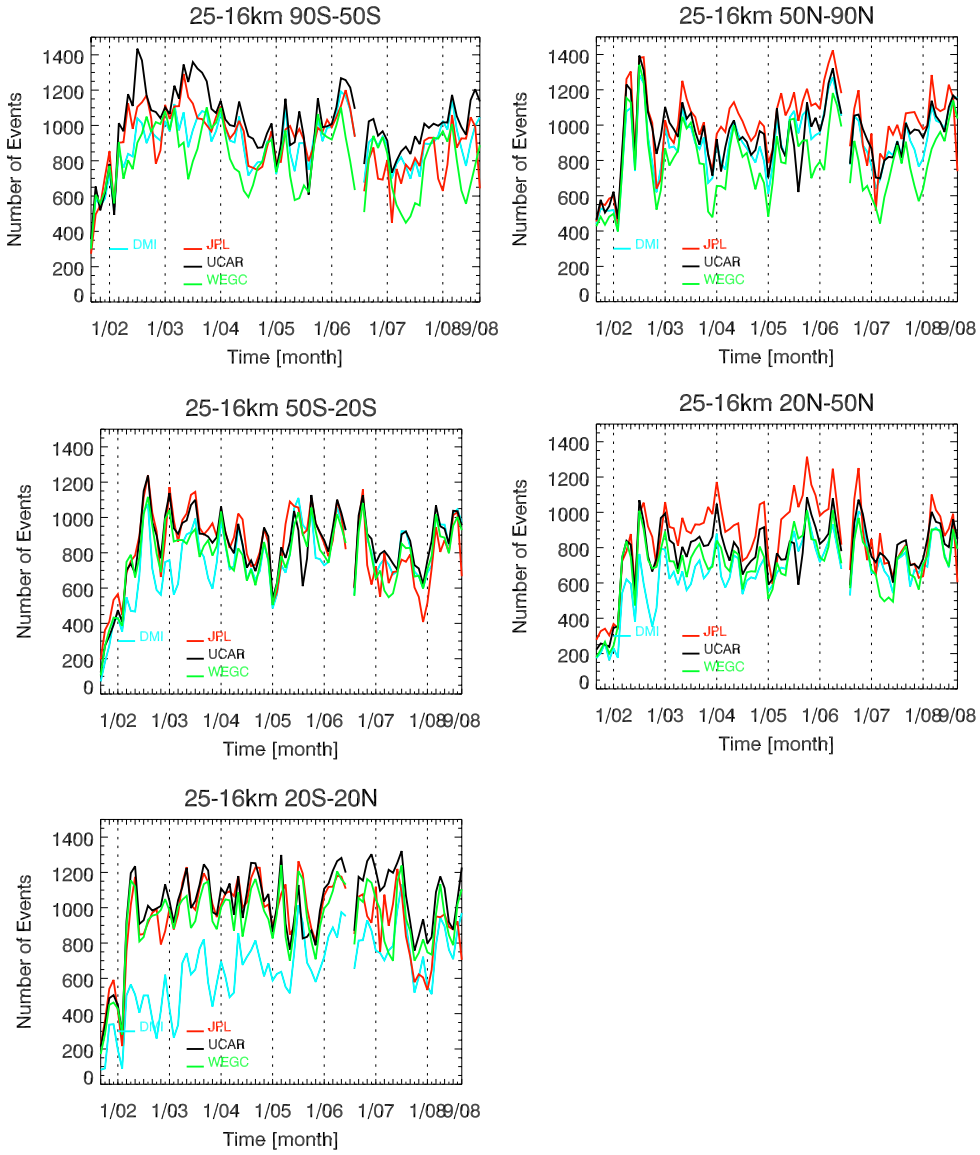
- MMCs based on provided profiles (computed by D. Hunt, UCAR)
- Sampling error estimation based on ERA-Interim for N, p_d, Z_d, T_d for 5-deg latitude bins
- Subtraction of sampling error: "de-sampled" 5-deg MMCs
- MMCs and de-sampled MMCs were used
- Mean difference of each center to the intercenter mean
- Seasonal means: for each center and intercenter seasonal mean
- De-seasonalized anomaly time series
- De-seasonalized anomaly difference time series and trends:
  absolute anomaly differences for Z and T (anomaly – intercenter mean)
  fractional anomaly differences for α, N, p:
  (anomalies - intercenter seas. mean)/intercenter seas, mean*100
- 5 centers, 5 parameters, 5 latitude bins and 4 altitude layers

Number of Occultation Events

Mean no of events per 5-deg bin

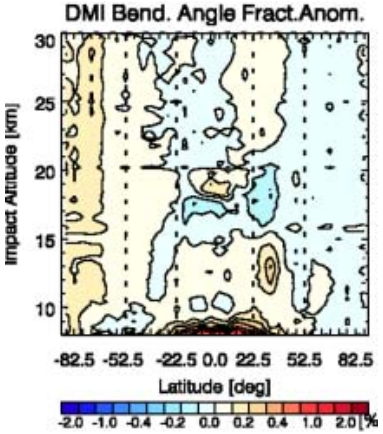


No of events 5 large zonal bins over time

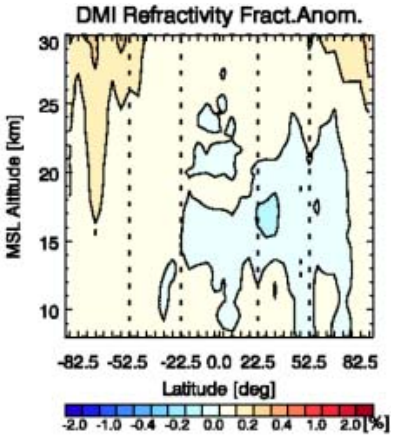


Results: Center's mean difference to intercentermean

DMI

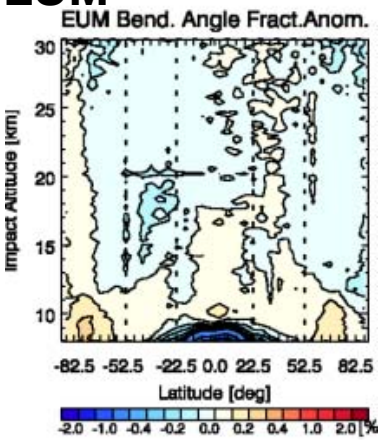


- Bending Angle
- within +/- 0.1 %
- high latitudes:
  DMI <0.2 %
  JPL -0.3 %

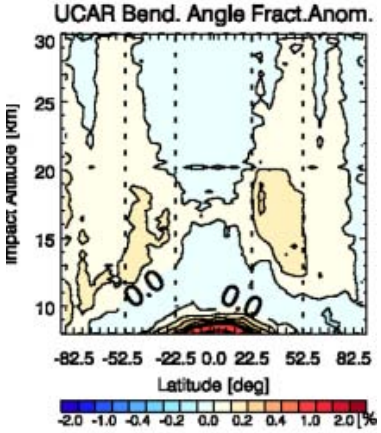


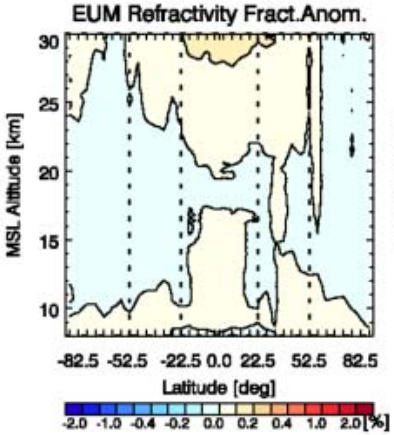
- Refractivity
- within +/- 0.1 %
- high lats > 25 km:
  DMI 0.2 %
  UCAR -0.3 %

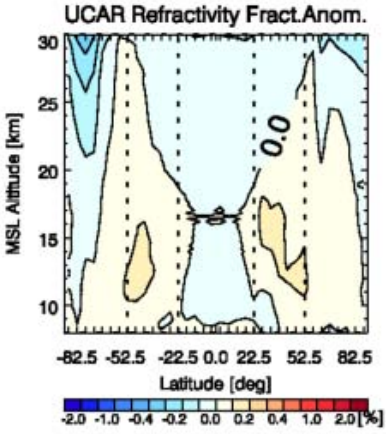
EUM



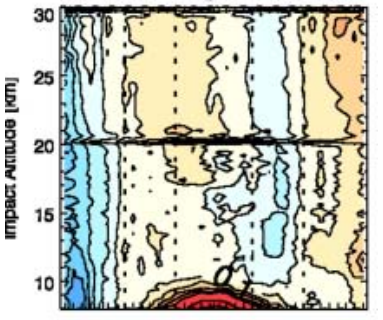
UCAR



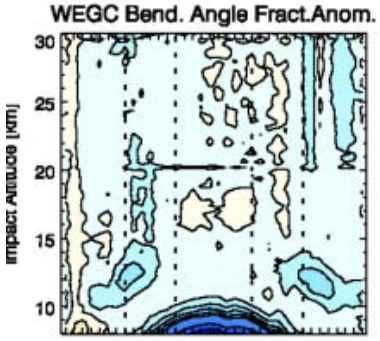


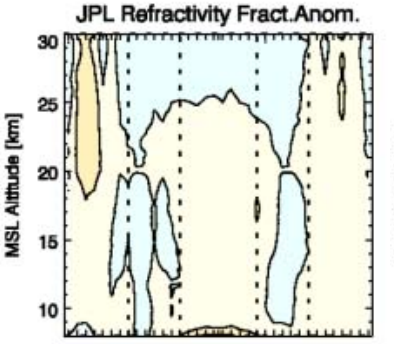


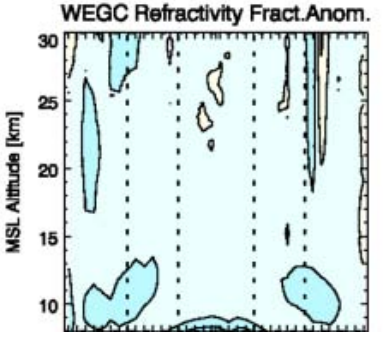
JPL



WEGC

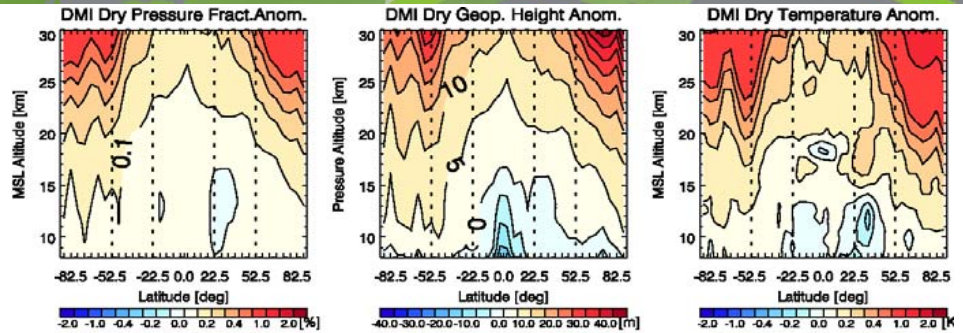




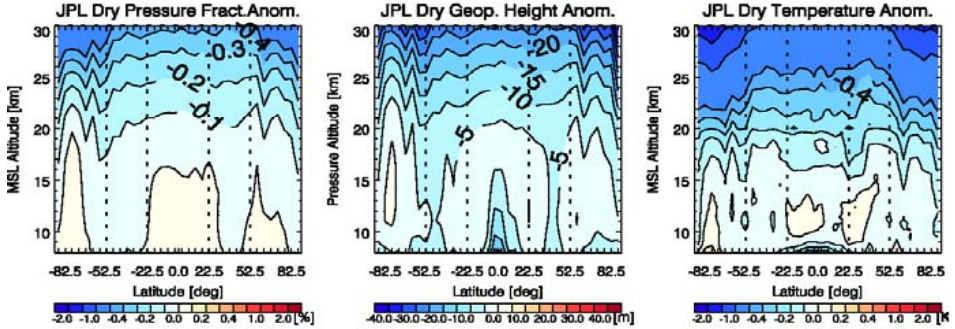


Results: Center's mean difference to intercentermean

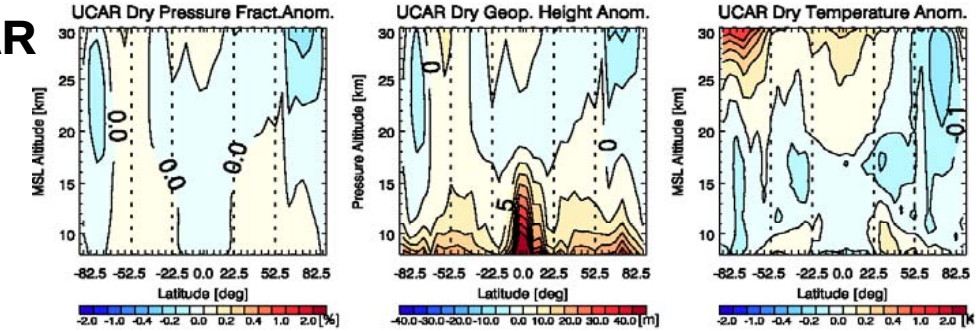
DMI



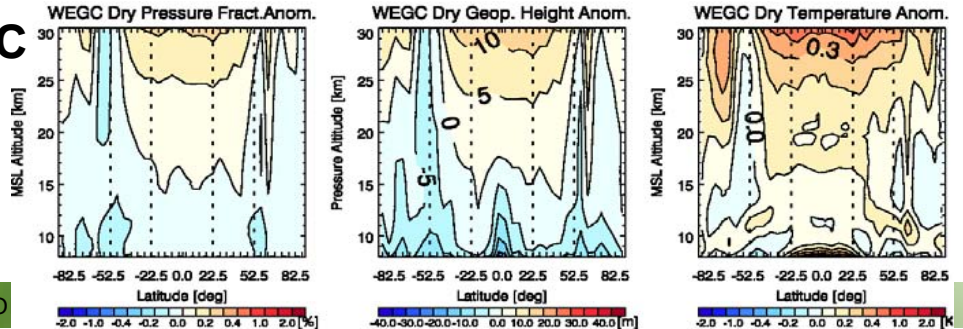
JPL



UCAR



WEGC



Dry Pressure (left)

- DMI: + 0.1% < 20 km (25 km tropics)
- JPL: - 0.1% < 20 km (-0.2%@30km)
- UCAR: within +/- 0.1%
- WEGC: within +/- 0.1% (< 25 km)

Dry Geopotential Height (middle)

- Same pattern as pressure
- UCAR: checks troposphere

Dry Temperature (right)

- DMI: < 0.2 K tropics, 1 K@HL>25km
- JPL: within -0.2 K < 20 km
  up to 0.5 K > 25 km
- UCAR: +/- 0.1 K except HL > 25 km
- WEGC: <0.2 < 25 km

Results: De-seasonalized Anomaly Time Series

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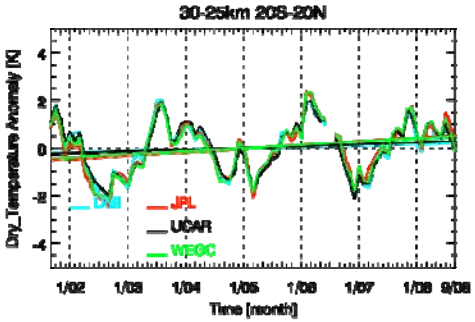
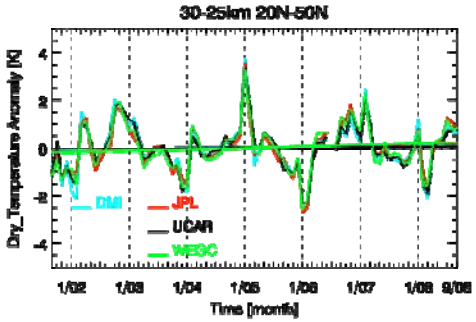
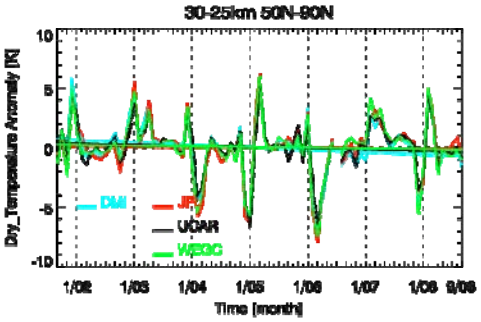
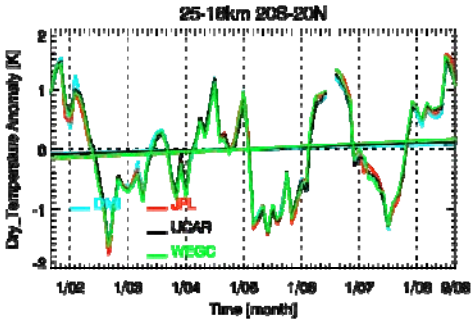
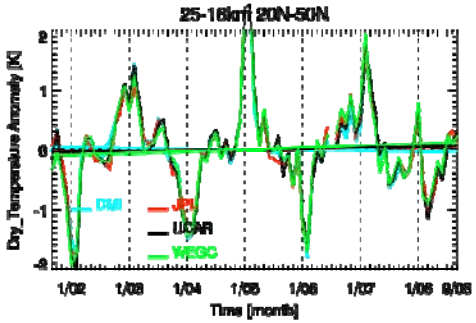
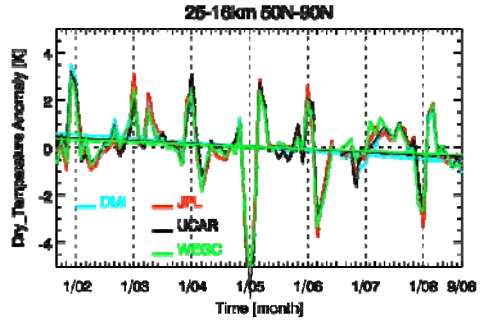
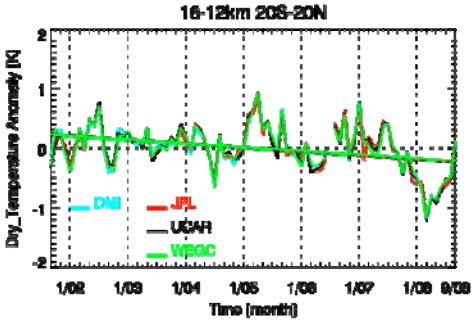
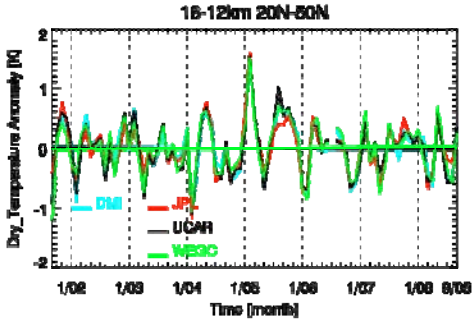
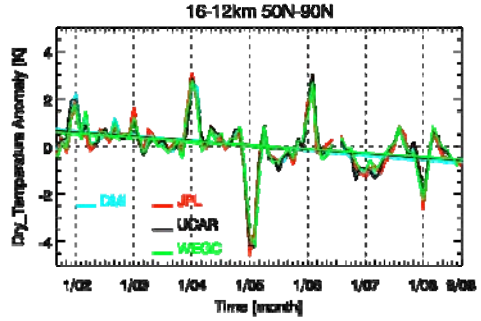
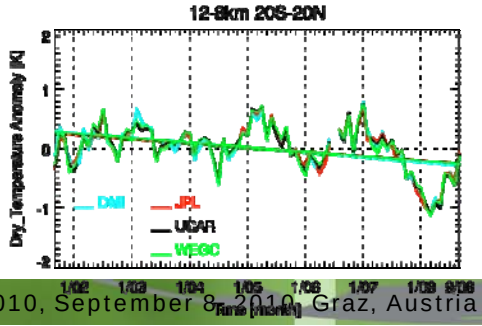
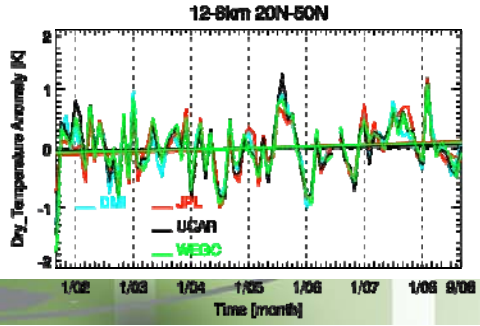
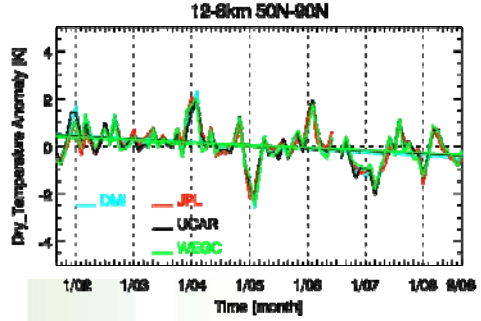
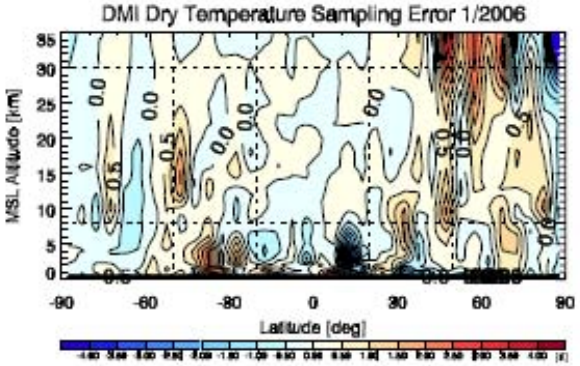
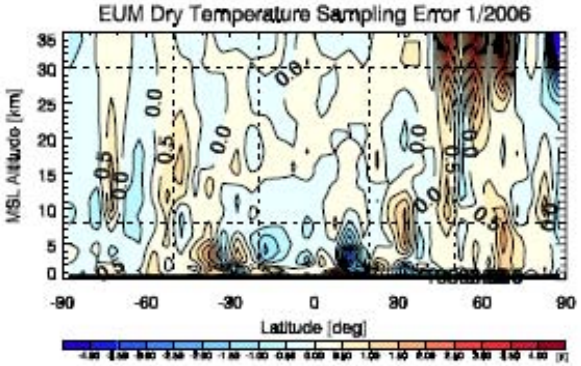
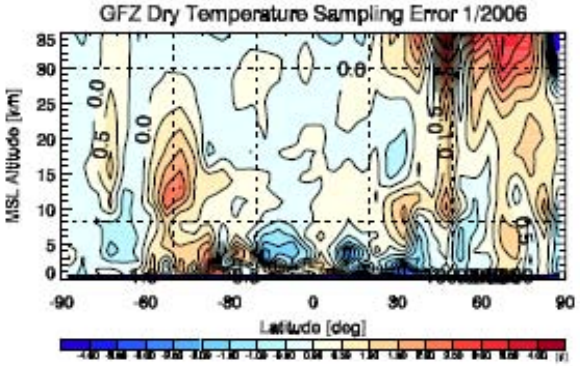
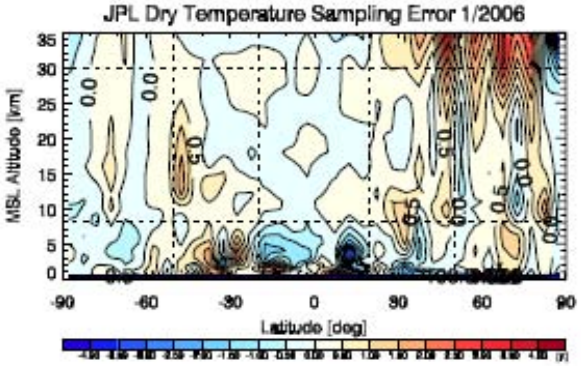
	Tropics	NH mid-latitudes	NH high latitudes
30-25 km			
16-25 km			
12-16 km			
8-12 km			

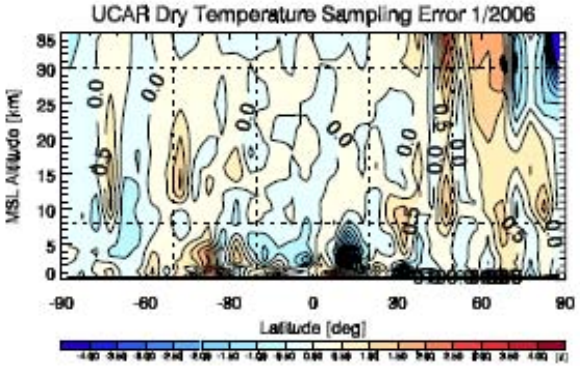
Sampling error estimation

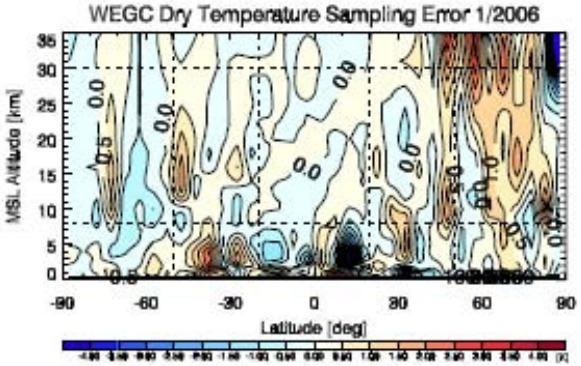


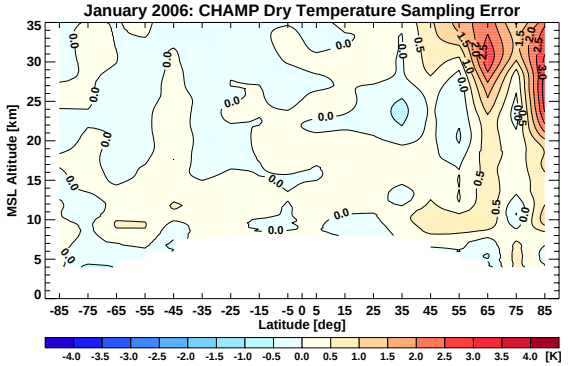












ERA-Interim, 5-deg zonal bins

ECMWF-analyses, 10-deg zonal bins

Results: Refractivity – Fract. Anomaly Differences

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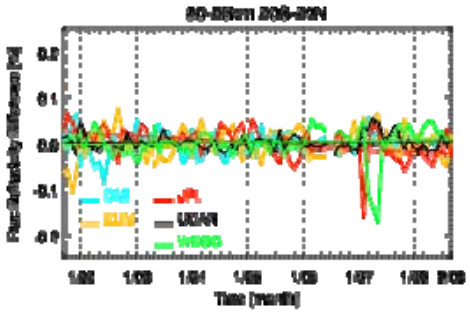
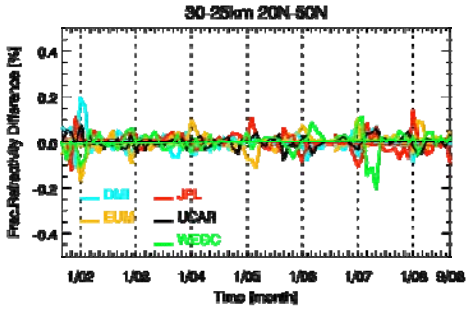
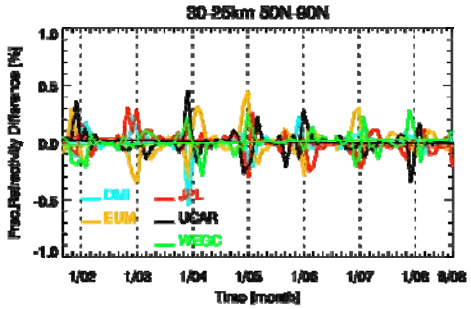
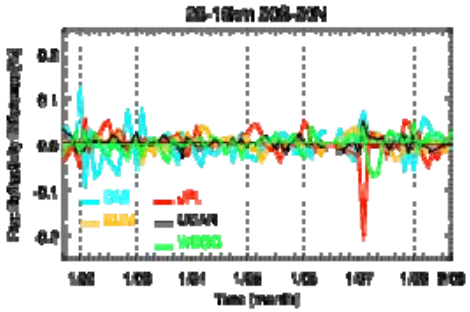
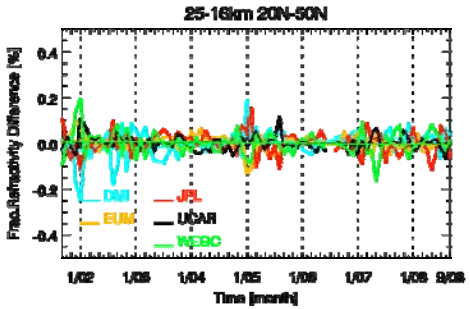
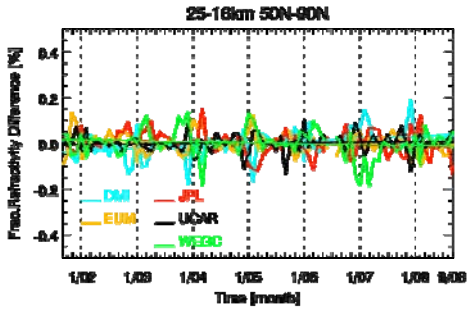
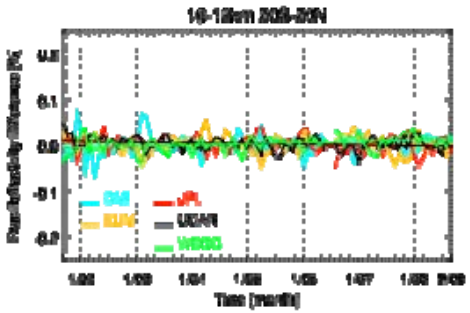
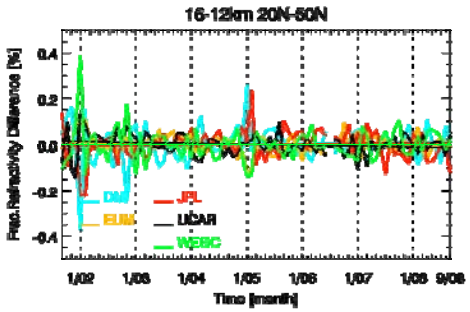
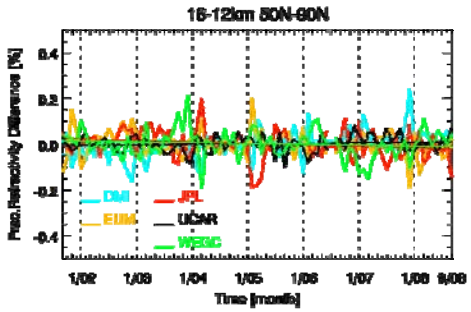
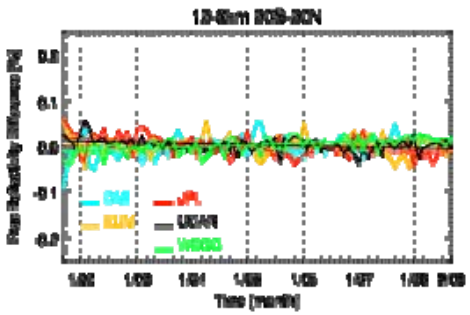
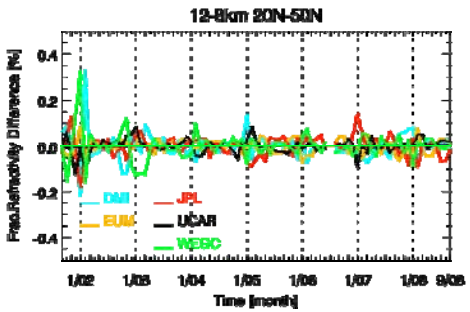
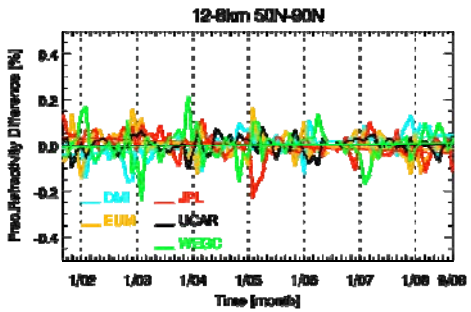
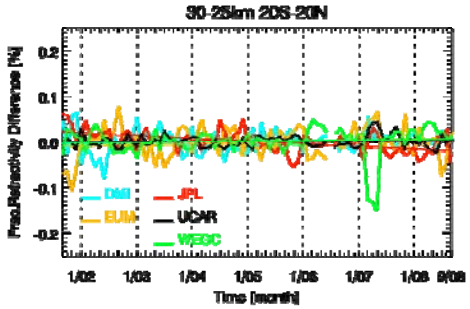
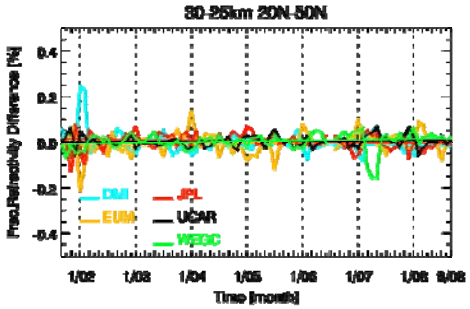
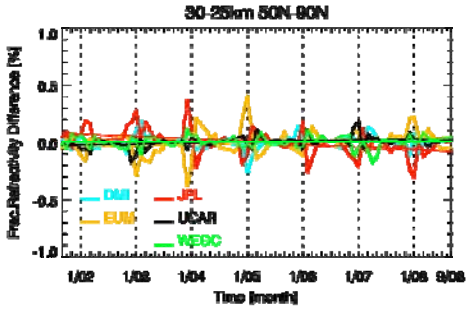
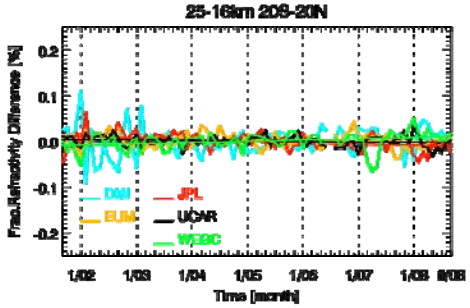
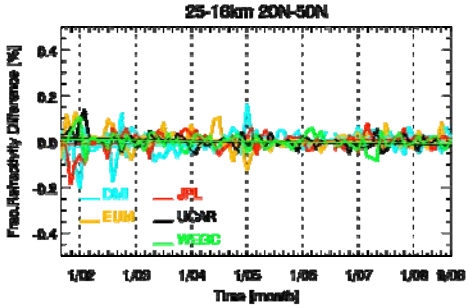
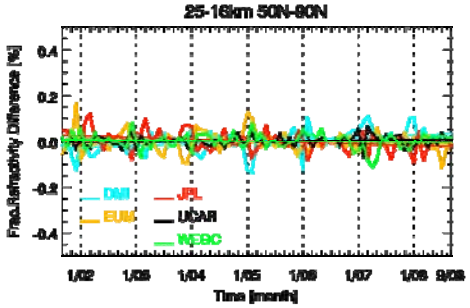
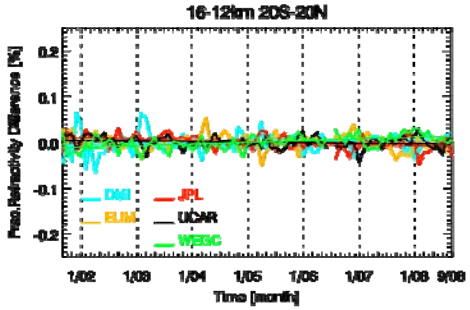
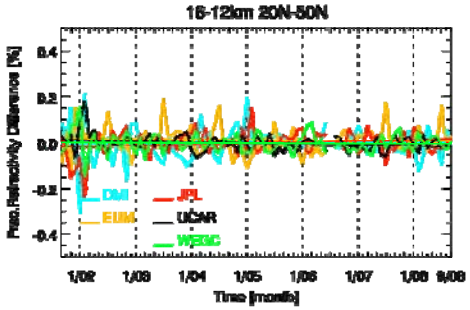
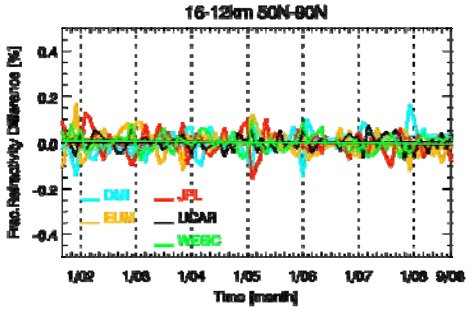
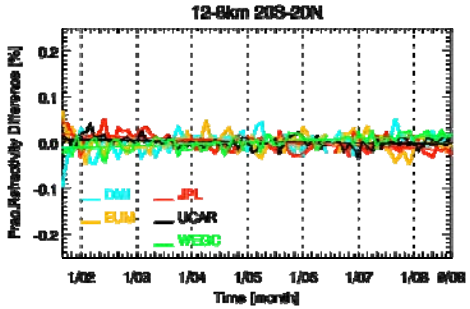
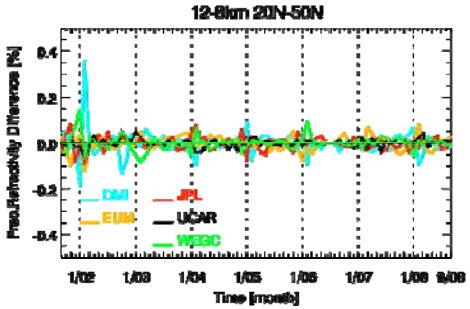
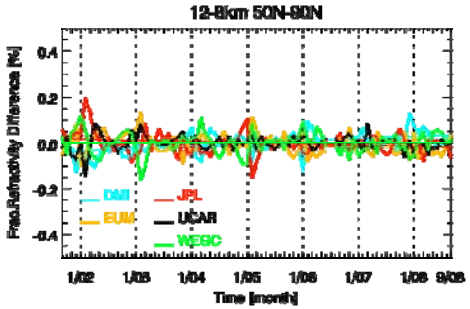
UNI GRAZ

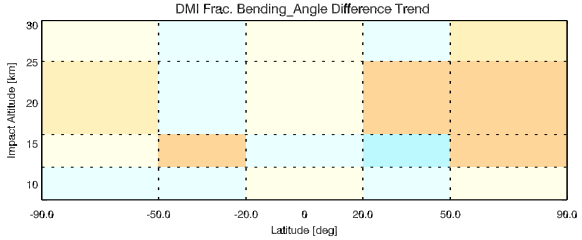
	Tropics	NH mid-latitudes	NH high latitudes
30-25 km			
16-25 km			
12-16 km			
8-12 km			

Results: Refractivity De-sampled Frac.Anom. Differences

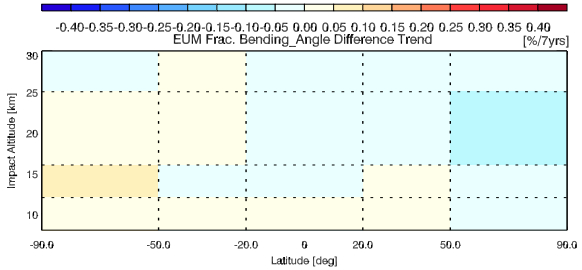
	Tropics	NH mid-latitudes	NH high latitudes
30-25 km			
16-25 km			
12-16 km			
8-12 km			

Results: Bending Angle Fract. Anomaly Difference Trends

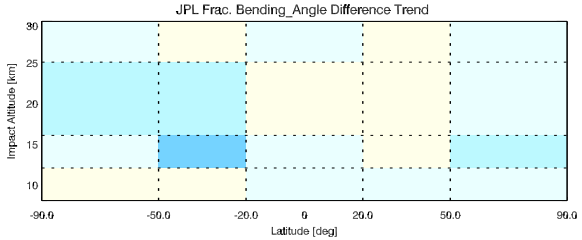
DMI



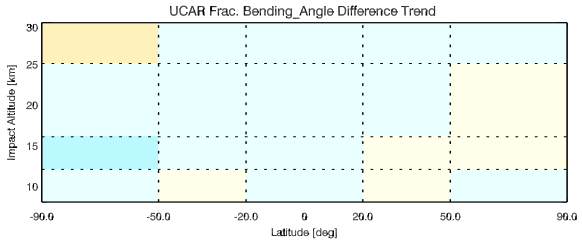
EUM



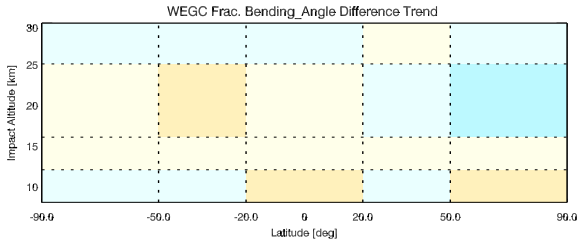
JPL



UCAR



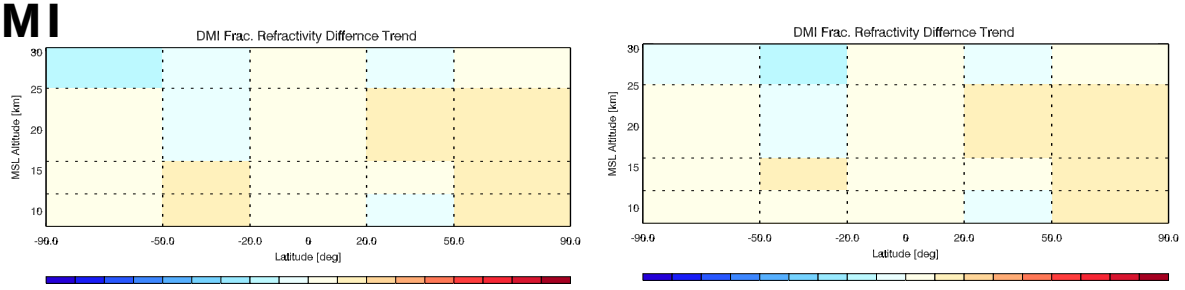
WEGC



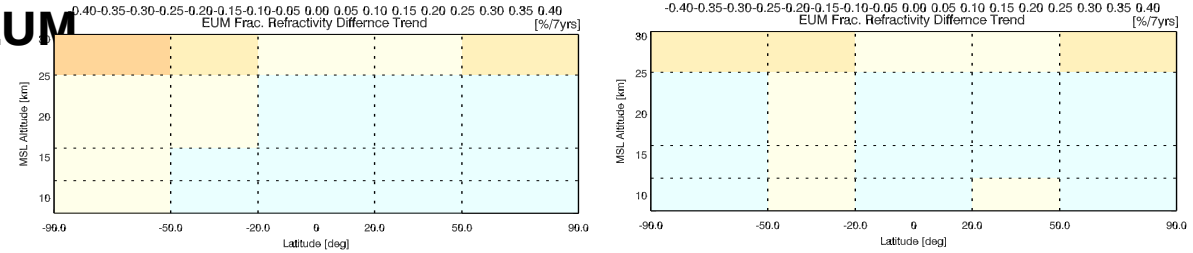
- Tropics: ~ +/- 0.02 %/7yrs
- Mid-lats: ~ 0.02 %/7yrs
- TP: ~ 0.04 %/7yrs
- Hi Lats < +/- 0.05 %/7yrs
  up to +/0.15 %/7yrs (DMI)

Results: Refractivity Fractional Anomaly Difference Trends

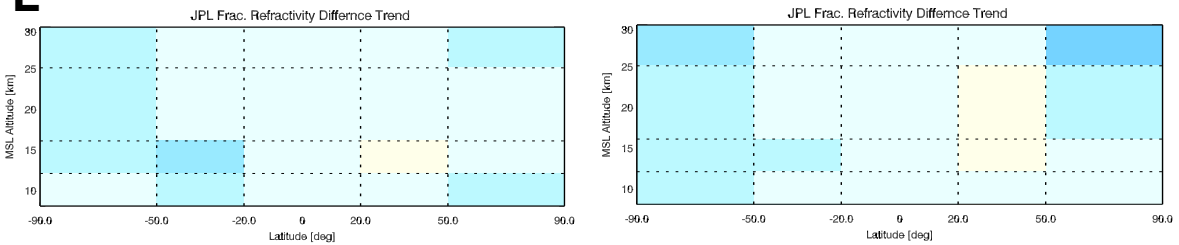
DMI



EUM



JPL



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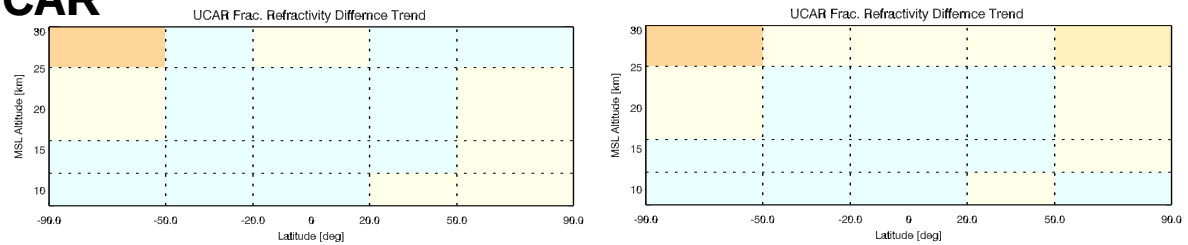

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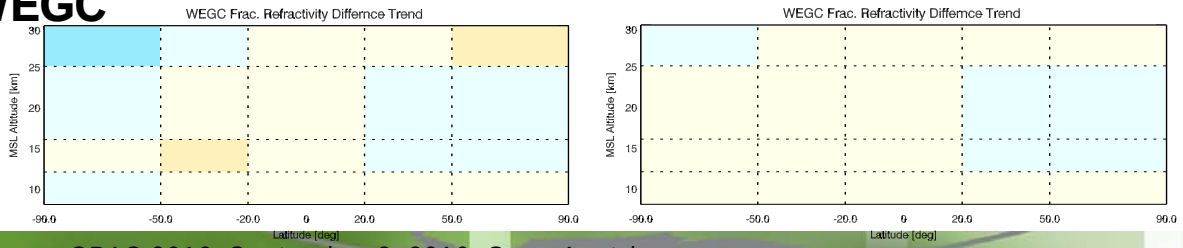
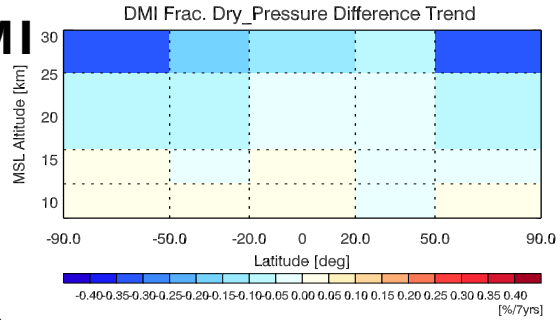
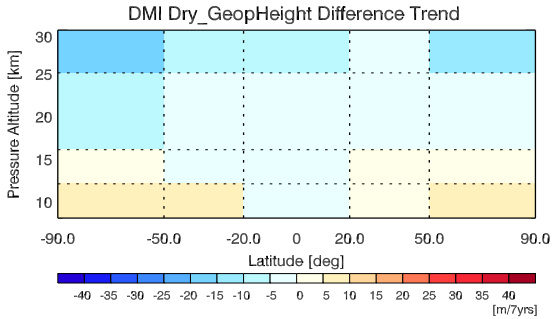
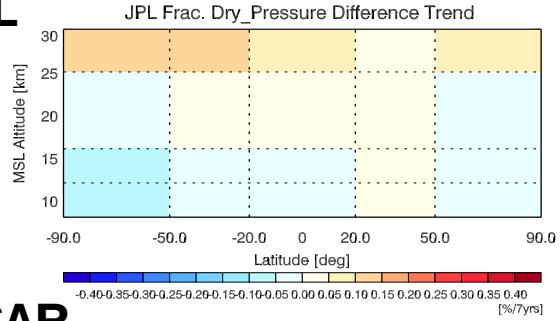
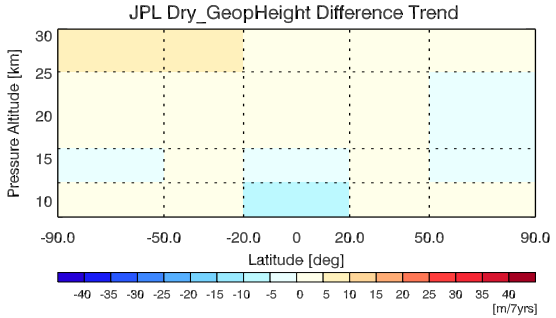
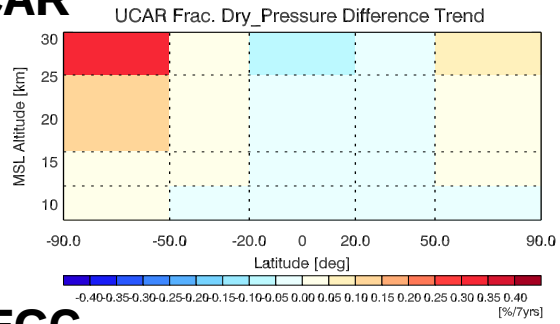
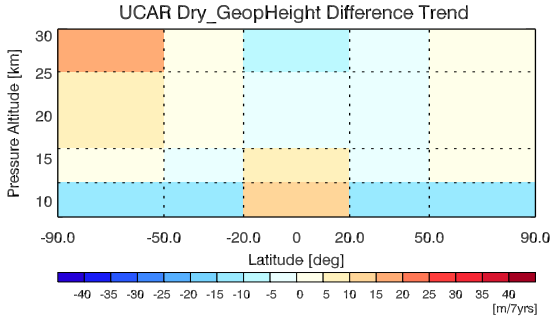
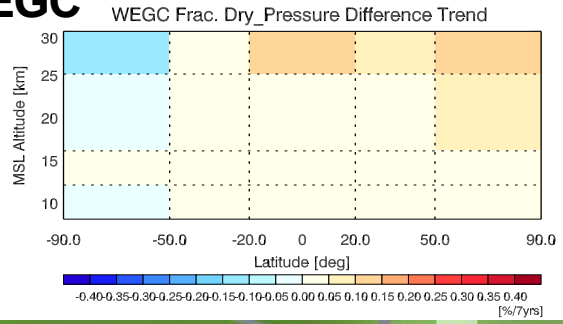
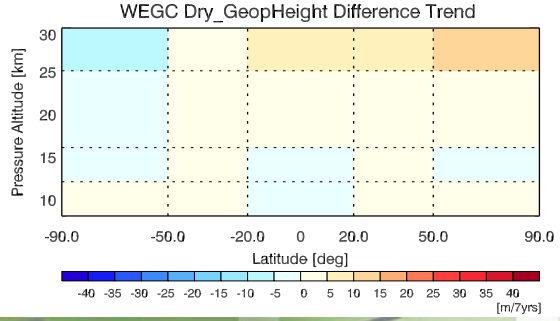


- right panel:
  sampl. error subtracted
- improvement after subtraction
- Tropics: ~ +/- 0.02 %/7yrs
  means eg.,
  for LS anomalytrend=
  -0.44+/-0.02 %/yrs
- < 25 km: < +/- 0.05 %/7yrs
  except DMI at NHL
- > 25 km: < +/- 0.1 %/7yrs
- Basically consistent with Ho et al. (2009)

Results: Dry Pressure/Geop. Height Anomaly Diff. Trends

Wegener Center www.wegcenter.at

UNI GRAZ

	Dry Pressure	Dry Geopot. Height
DMI		
JPL		
UCAR		
WEGC		

- Left panels: Dry pressure
- Right panels: Dry geopotential height

- Tropics & Mid-lats UTLS & High lats UT:
  p: < 0.05 %/7yrs
  Z: < +/- 5 m/7yrs
  (except UCAR for Z)

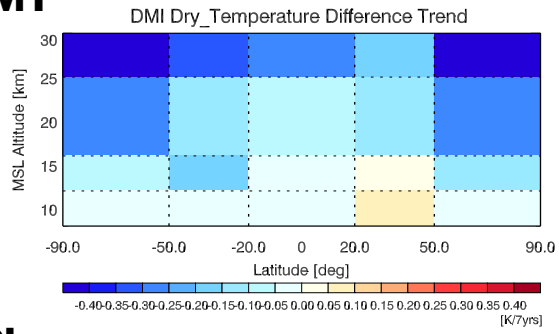
- Tropics & Mid-lats 25-30 km
  p: < 0.1 %/7yrs
  Z: < +/- 10 m/7yrs

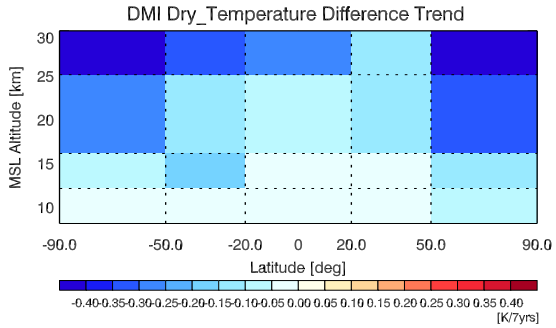
- High lats 25-30 km
  p: < 0.2 %/7yrs
  Z: < +/- 15 m/7yrs

- E.g. LS Anomalytrend in the tropics: -0.23+/-0.03 %/yr

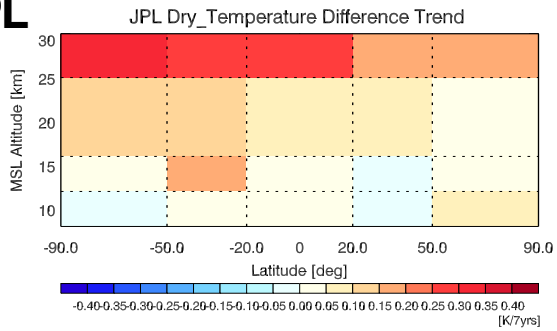
Results: Temperature Anomaly Difference Trends

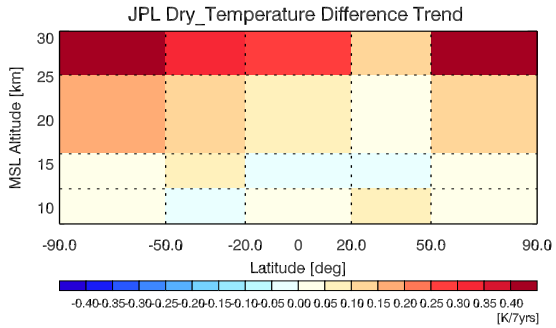
DMI



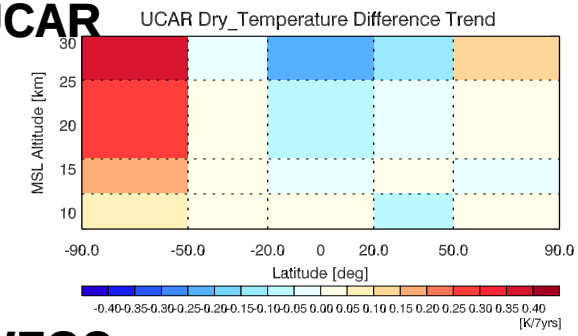


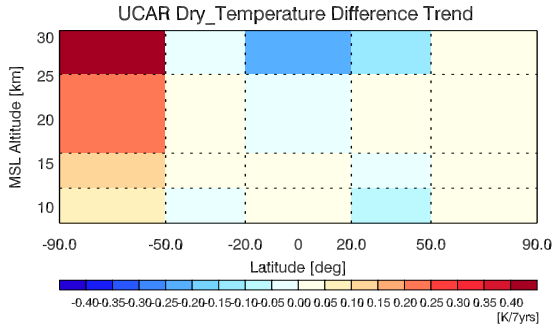
JPL



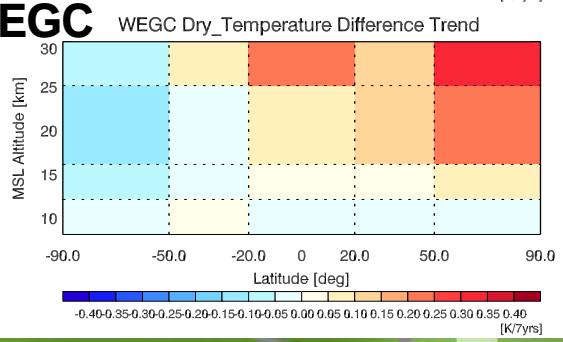


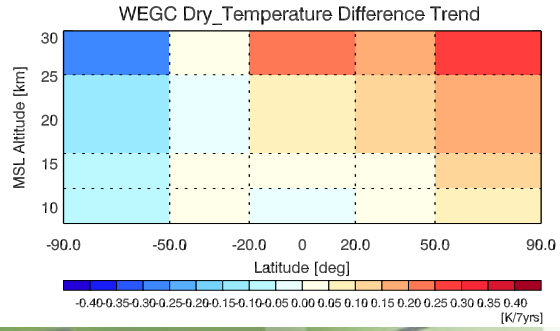
UCAR





WEGC





- right panels: sampl. error subtracted
- Tropics UT: ~ +/- 0. 02 K/7yrs
  LS: < +/- 0. 08 K/7yrs
- UT global & Mid-lats LS:
  < +/- 0.1 K/7yrs
- 25-30 km & High lats LS:
  < +/- 0.25 K/7yrs
  (DMI -0.35 K/7yrs)
- High lats 25-30 km:
  ~ 0.5 K/7yrs
- Best performance:
  tropics to mid-latitudes UTLS
- Anomalytrends:
  tropical LS: 0.25+/-0.08 K/7yrs
  tropical UT: -0.54+/-0.02 K/7yrs

Conclusions and Outlook

CONCLUSIONS

- Structural uncertainty of RO data from 5 processing centers
- Low structural uncertainty for α and N at 8-30 km
- Consistency with Ho et al. (2009)
- Low structural uncertainty for p, Z, T in UTLS in tropics & mid-latitudes
- Higher structural uncertainty > 25 km and at high latitudes
- Reflecting different initialization methods

OUTLOOK

- Check WEGC MAM 2007
- Include GFZ data
- Estimate sampling error for 10-deg zonal bins & its uncertainty
- Estimate level 3 uncertainty – different climatology computation methods