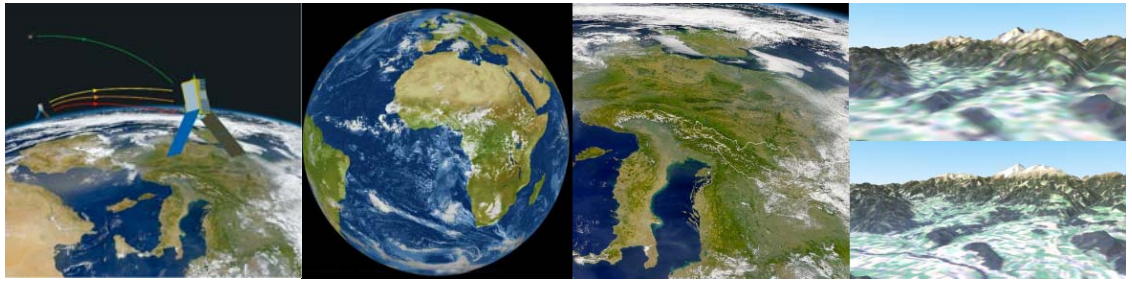
wege entstehen, indem wir sie gehen
ways emerge in that we go them
[1/20]



Wegener Center, University of Graz
Atmospheric Remote Sensing and Climate System (ARSCliSys) Research Group:
Misc. occultation results…
…some slides related to Issue 5 and Issue 9

G. Kirchengast and ARSCliSys Research Group
Wegener Center for Climate and Global Change (WegCenter) and
Institute for Geophysics, Astrophysics, and Meteorology (IGAM)
University of Graz, Austria
(gottfried.kirchengast@uni-graz.at, www.wegcenter.at/arsclisys, www.wegcenter.at, www.uni-graz.at/igam)

Thanks for funds to:

Workshop on Applications of GPS RO to Climate; 17-18 March 2008; UCAR, Boulder, CO, U.S.A.

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…some slides related to Issue 5:
the first six ones related to upper boundary initialization and ionospheric influences

Stratospheric Retrieval Advances

Retrieval Validation – Study Setup (1)

Forward modeling

- **Ionosphere** (NeUoG):
  - 4 ionization levels (no ionosphere, $F_{10.7}$=70, $F_{10.7}$=140, $F_{10.7}$=210)
  - 3 ionospheric a/symmetry types (NICE, NASTY1, NASTY2)
- **Same neutral atmosphere for all occultation events**
- **Receiving system:**
  - idealized (no errors)
  - realistic (GRAS-type errors)

(Gobiet and Kirchengast, 2004)

Retrieval schemes

- **Ionospheric correction:**
  - linear combination of bending angles
- **Statistical optimization:**
  - no optimization (exponential extrapolation)
  - inverse covariance weighting optimization without background profile search in MSIS90)
  - inverse covariance weighting optimization with background profile search in MSIS90)
  - in addition: background bias correction

More information:

Gobiet, A., and G. Kirchengast, Advancements of GNSS RO retrieval in the upper stratosphere for optimal climate monitoring utility, *J. Geophys. Res., 109*, D24110, doi:10.1029/2004JD005117, 2004.

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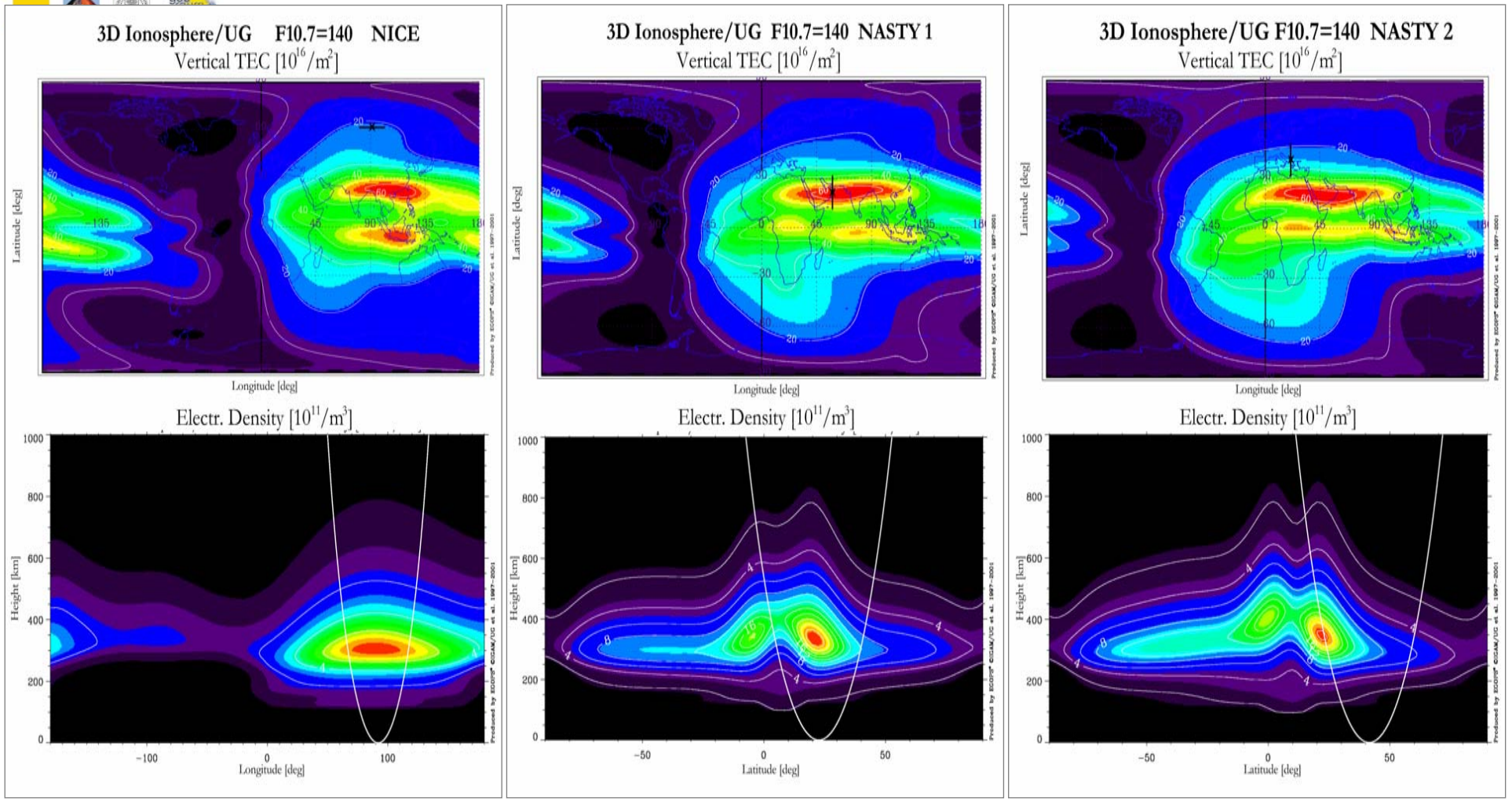
Stratospheric Retrieval Advances

Retrieval Validation – Study Setup (2)

UNI GRAZ



NICE: **low electron dens. grad., near-spherical symmetry**

NASTY1 & NASTY2: high electron density gradients, spherical symmetry assumption violated

(Gobiet and Kirchengast, 2004)

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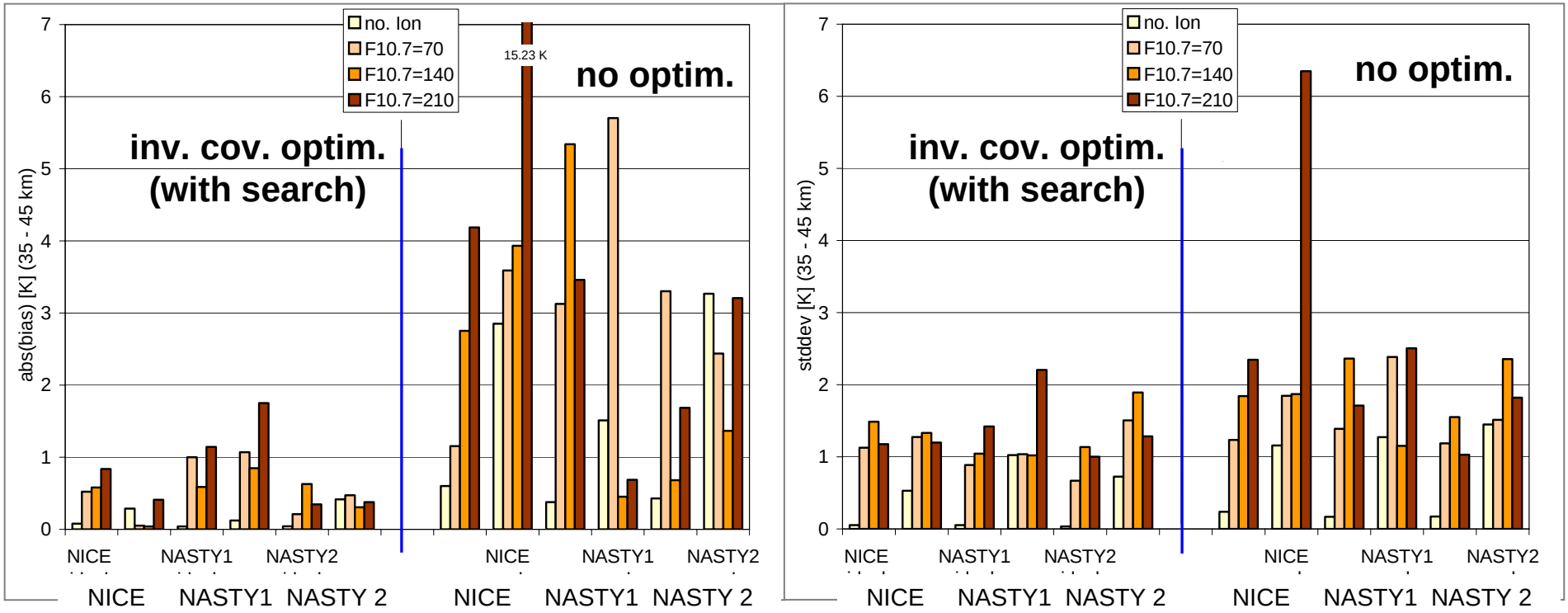
Stratospheric Retrieval Advances

Retrieval Validation – Results (1)

Upper stratosphere temperature bias and standard deviation

(35 km – 45 km height interval)



bias (mean dev. from 'true') [K]

standard dev. (mean fluctuation about bias) [K]

(Gobiet and Kirchengast, 2004)

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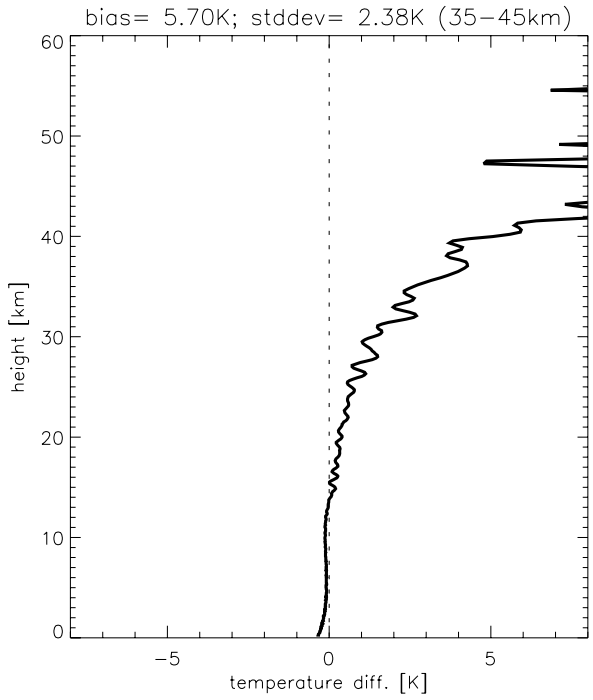
Stratospheric Retrieval Advances

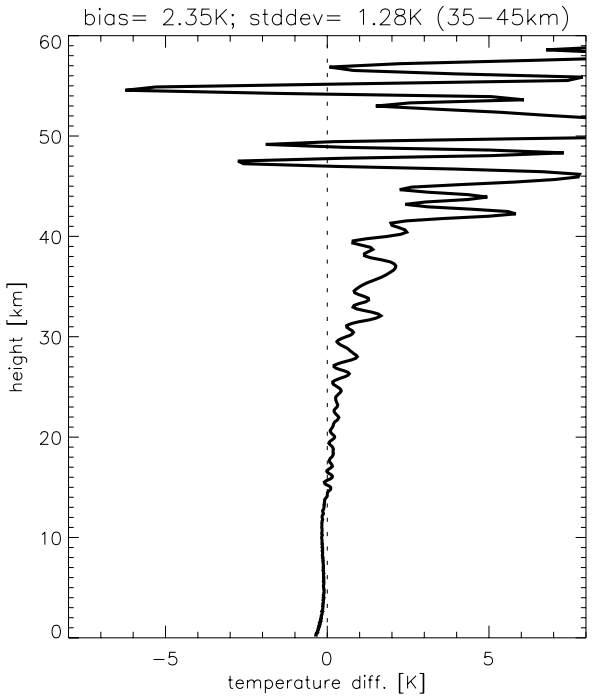
Retrieval Validation – Results (2)

Temperature error profiles [K]

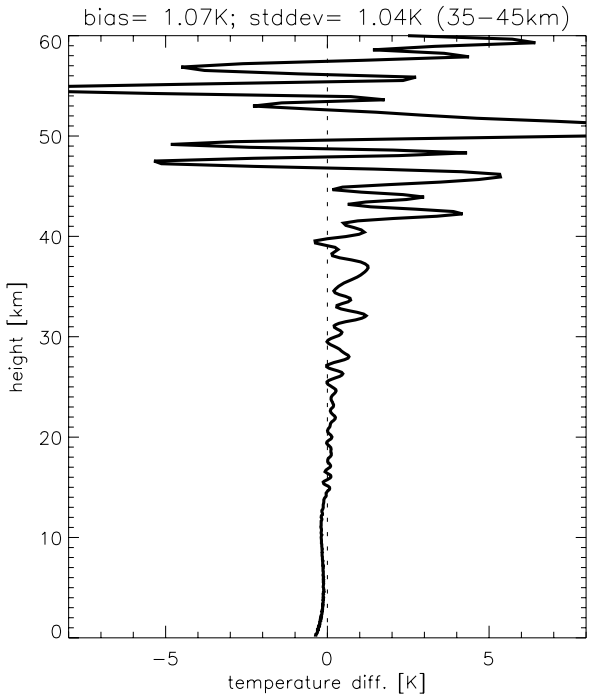
("Nasty 1" event, $F_{10.7}$ = 70, realistic receiving system)



no optimization



inverse covariance optim.
no background search



inverse covariance optim.
incl. background search

(Gobiet and Kirchengast, 2004)

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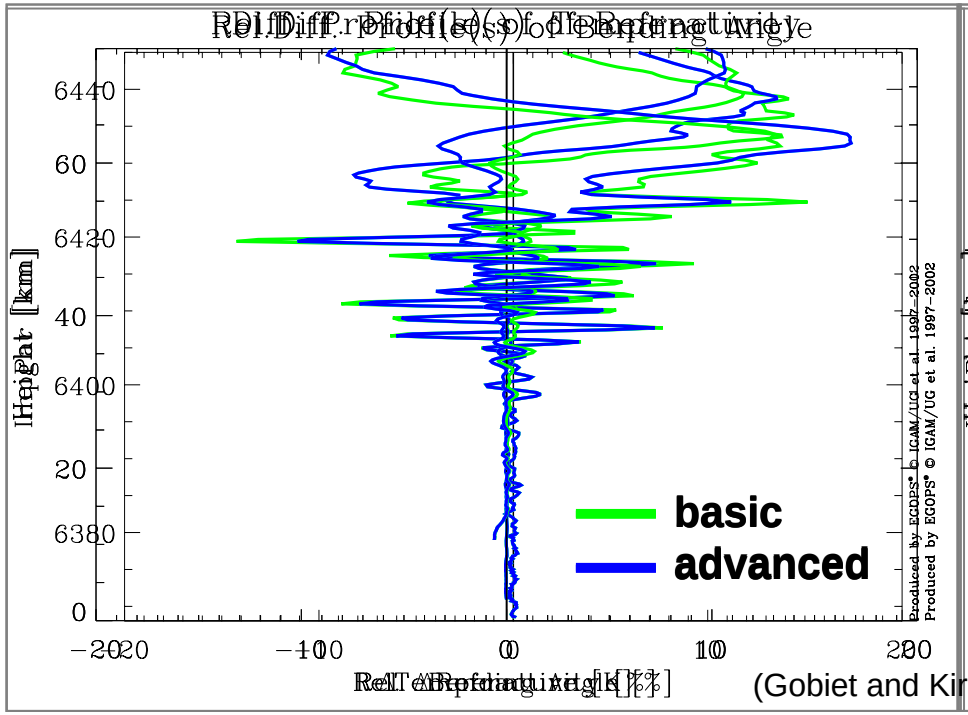
Stratospheric Retrieval Advances

Background Bias Correction

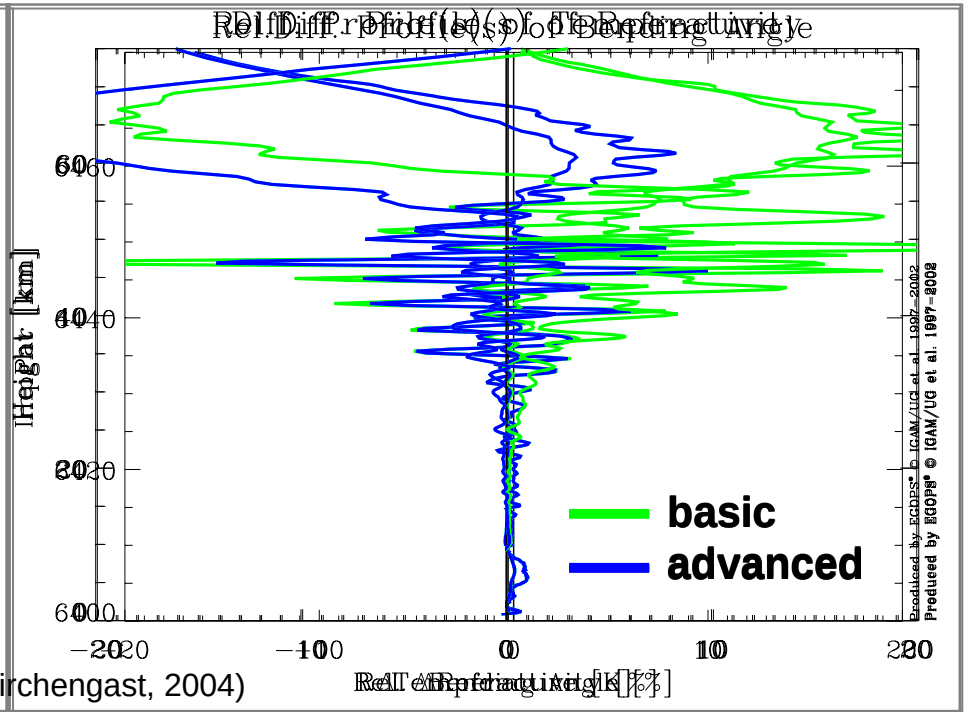
In addition: ENHANCED BACKGROUND BIAS CORRECTION SCHEME

- Optimization of the search algorithm by smoothing of observations
- Additional background bias correction by linearly fitting at high altitude
- Reduce background error to 15% (empirical evaluation done before)
- Background: MSIS90

lat. = 13°S, bias correction: 0.2 %



lat. = 76°S, bias correction: 15.9 %



(Gobiet and Kirchengast, 2004)

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Stratospheric Retrieval Advances

Background Bias Correction – Results

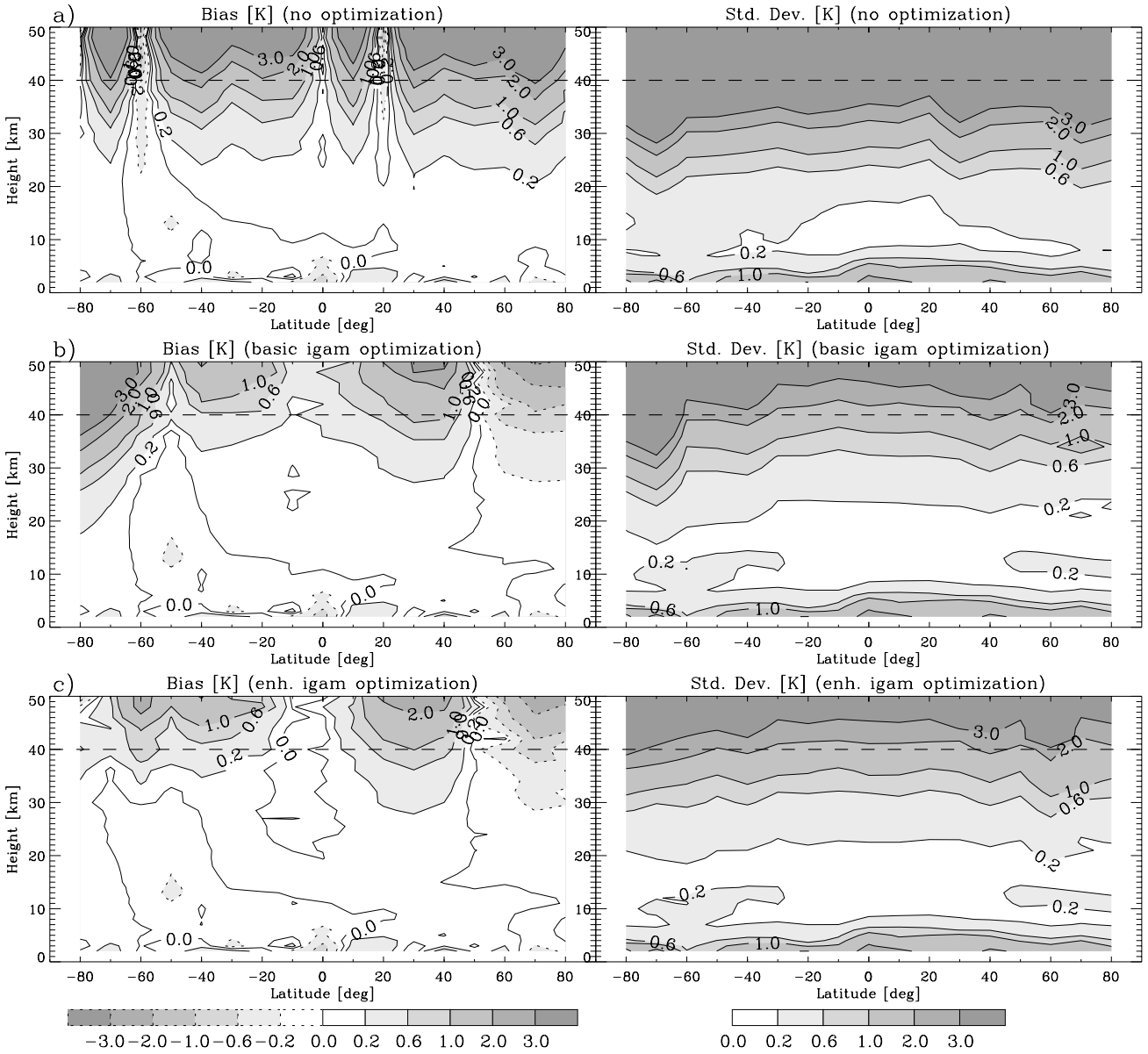
Mean dry temperature
(GNSS-CLIMATCH "testbed"
~1000 occultation events)

No optimization →

Basic IGAM retrieval →
(inverse covariance optim.
& background search)

Enhanced IGAM retrieval →
(inverse covariance optim.
& background search
& background bias corr.)

(Gobiet and Kirchengast, 2004)



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…some slides related to Issue 5:

the next four ones related to the perspectives for improved performance up into the upper stratosphere > 30 km (further decreased dependence on initialization and further improved correction of ionospheric influences)

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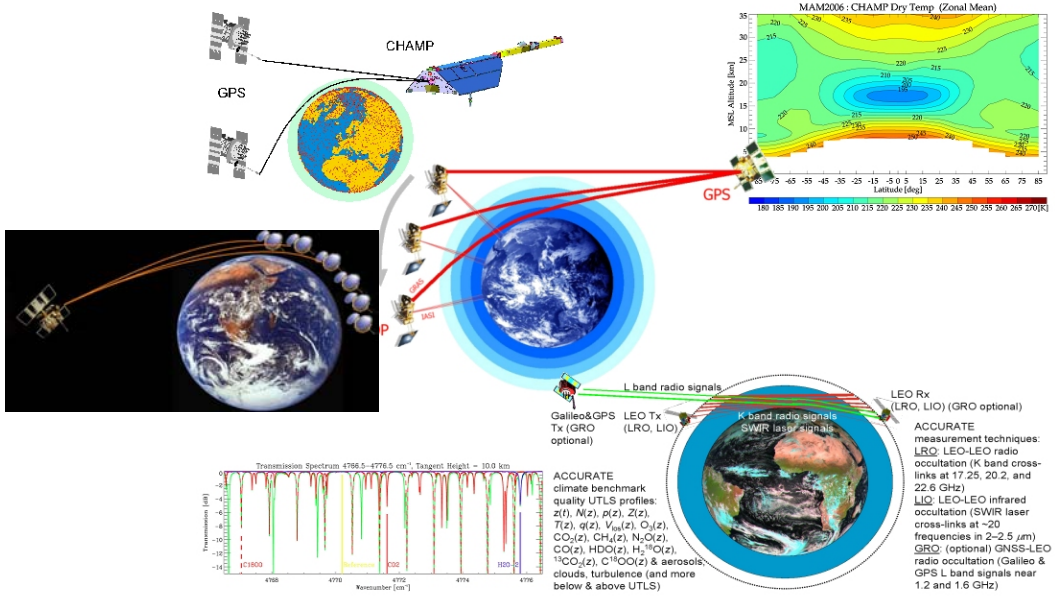
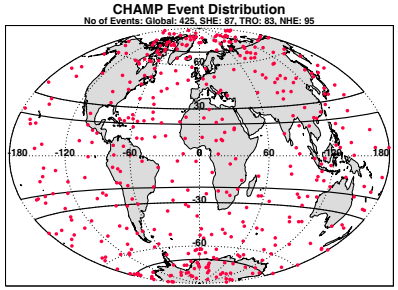
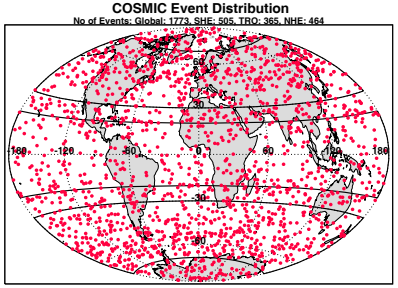
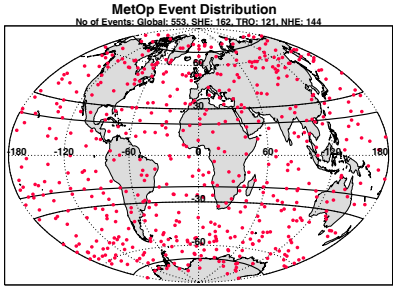
CHAMP -> COSMIC -> MetOp -> …
…maturing RO technology and data quality



CHAMP – COSMIC – MetOp data
6 Sep 2007; CHAMP also 5th and
7th Sep 2007







(WegCenter 2004-08; CHAMP image GFZ 2002; COSMIC image UCAR 2006)

wege entstehen, indem wir sie gehen
ways emerge in that we go them
[11/20]

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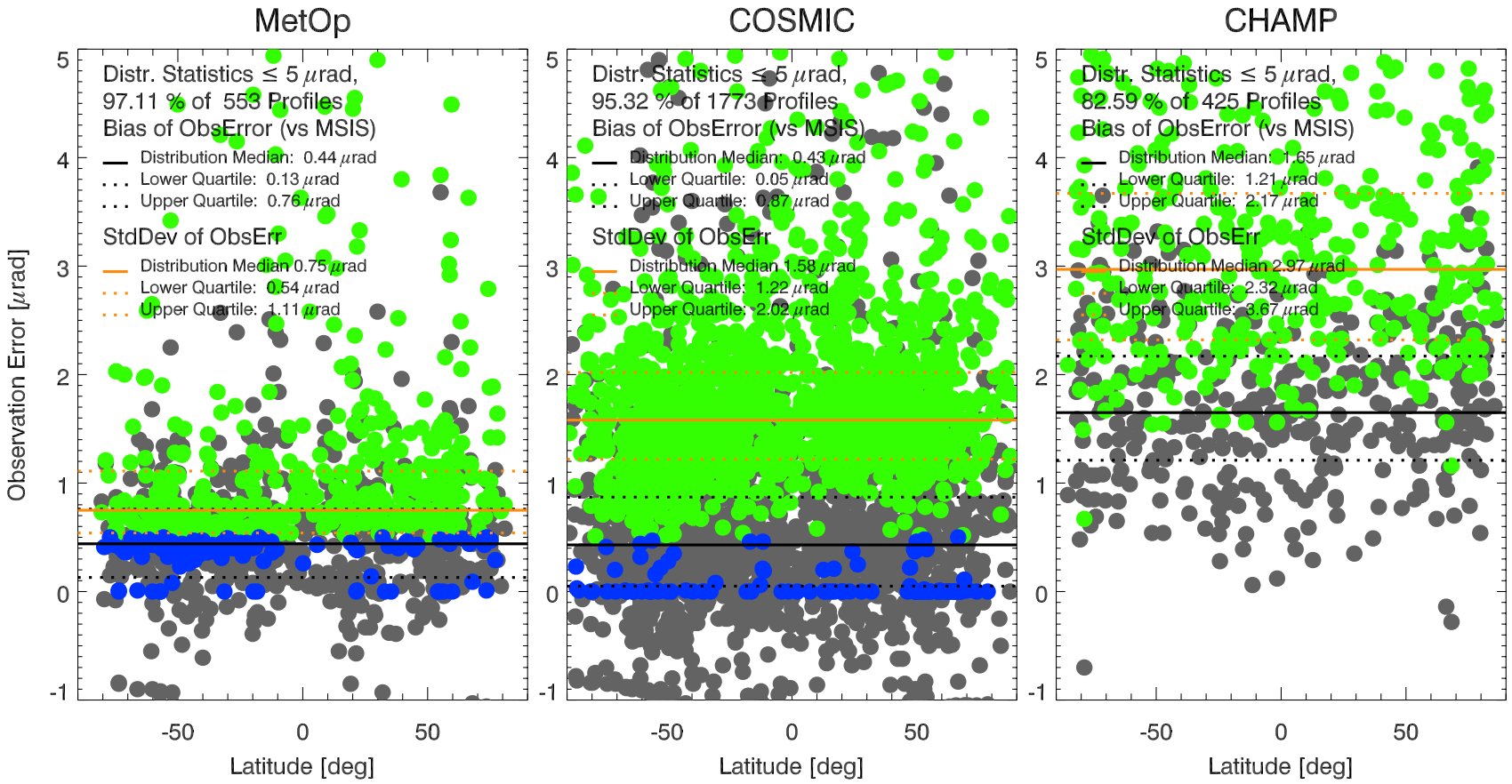
MetOp – COSMIC – CHAMP
Bending Angle Quality Diagnostics
(data of 6 Sep 2007; CHAMP 5-7 Sep 2007)



(Pirscher et al. 2008, on-going work; results noBEC processing, BEC=Bend.angle Error Corr.)

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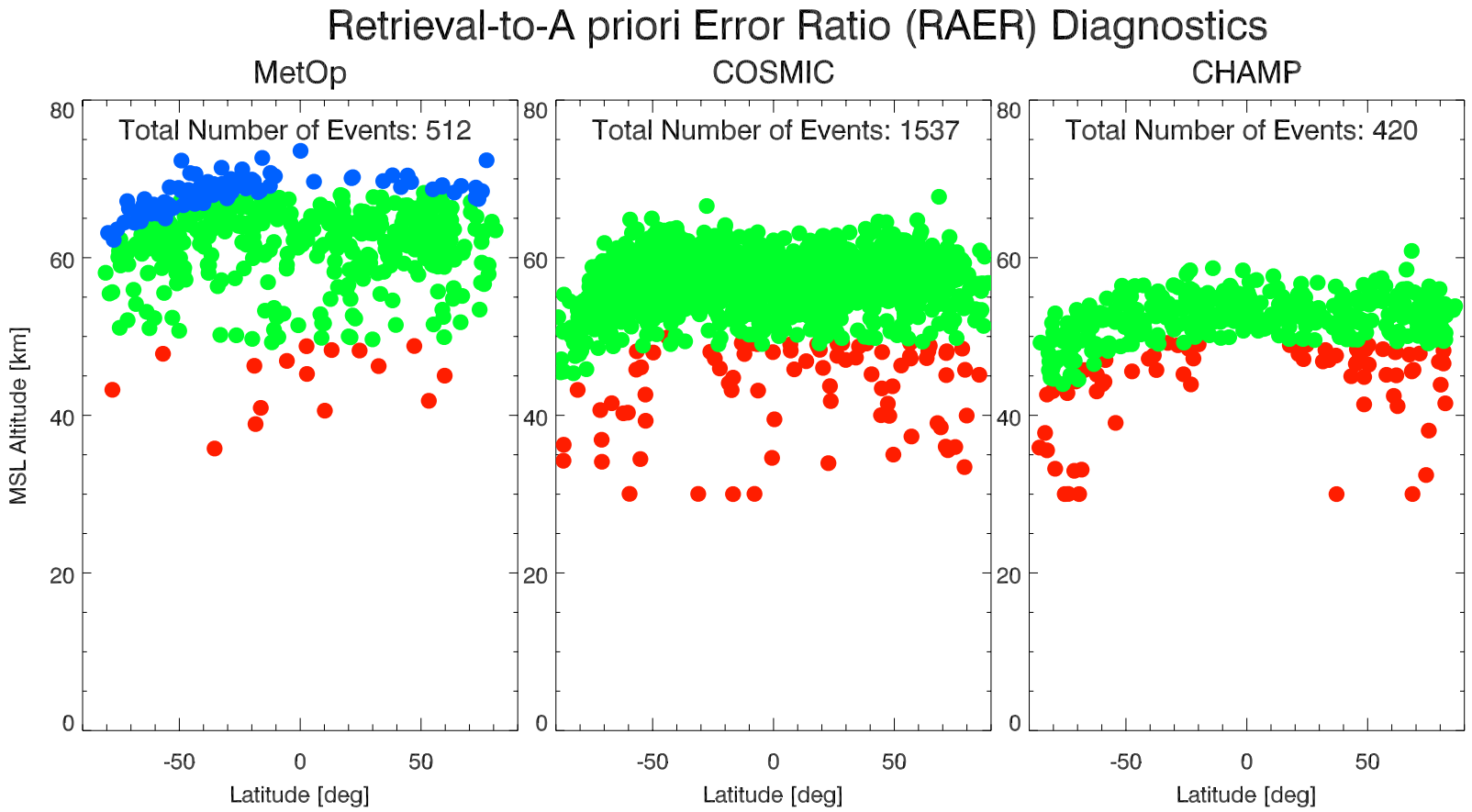
MetOp – COSMIC – CHAMP
zRAER-50% diagnostics
(data of 6 Sep 2007; CHAMP 5-7 Sep 2007)



(Pirscher et al. 2008, on-going work; results noBEC processing, BEC=Bend.angle Error Corr.)

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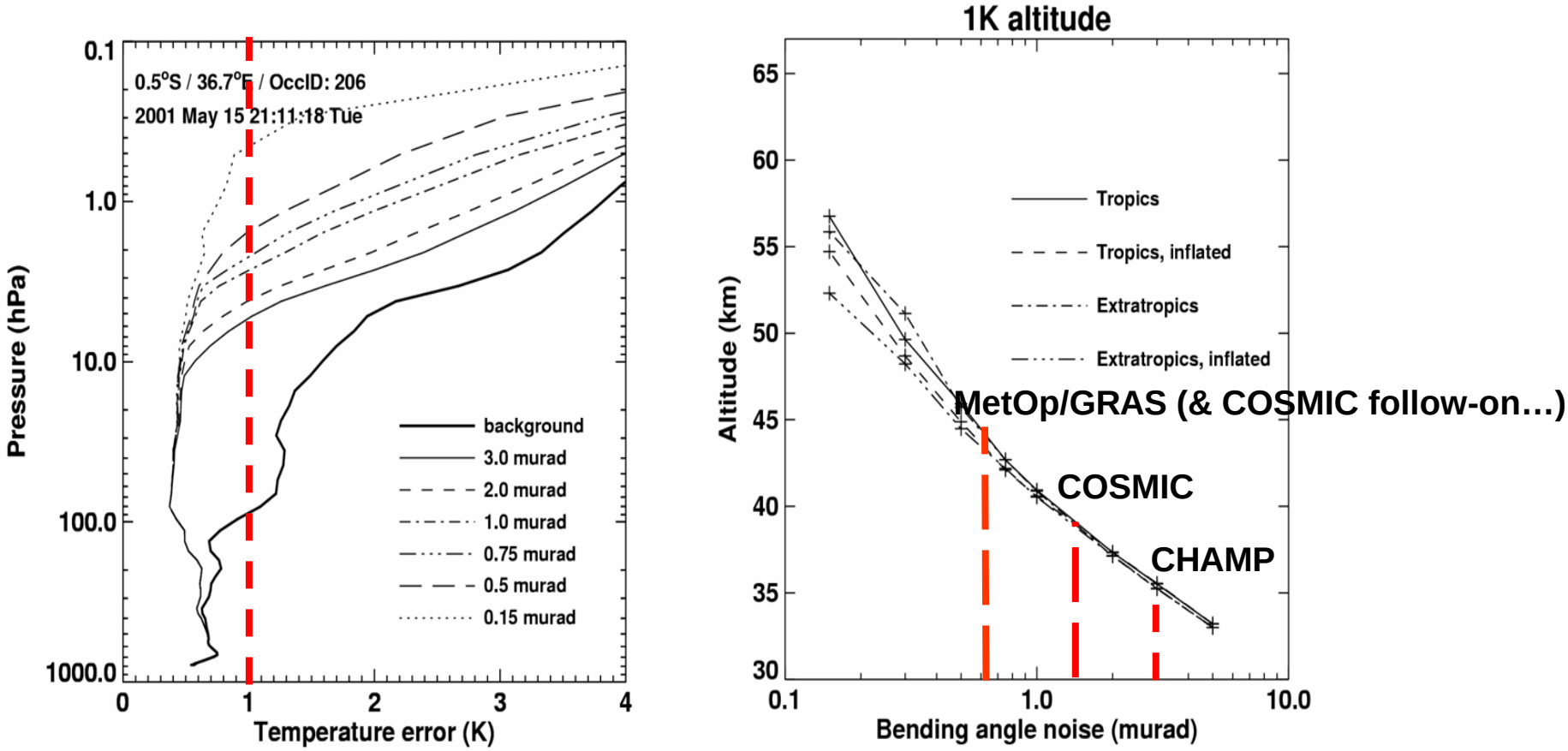
CHAMP -> COSMIC -> MetOp -> …
…future GNSS RO obs system can be benchmark over full LS/up to ~35 km



(Marquardt and Healy, 2005, unpublished; adapted G.Kirc., 2008)

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…and a few slides related to Issue 9:

related to analysis of water vapor aliasing into dry temperature time series and comments on potential long-term ionospheric residual influences

(analyses in the context of a climate signal detection study utilizing the complete time period covered by GPS RO data so far; GPS/Met 1995-97; CHAMP 2001-2007.
Also, upper boundary initialization and water vapor aliasing check in (A)MSU TLS synthetic time series from CHAMP RO data spanning 2001-2006)

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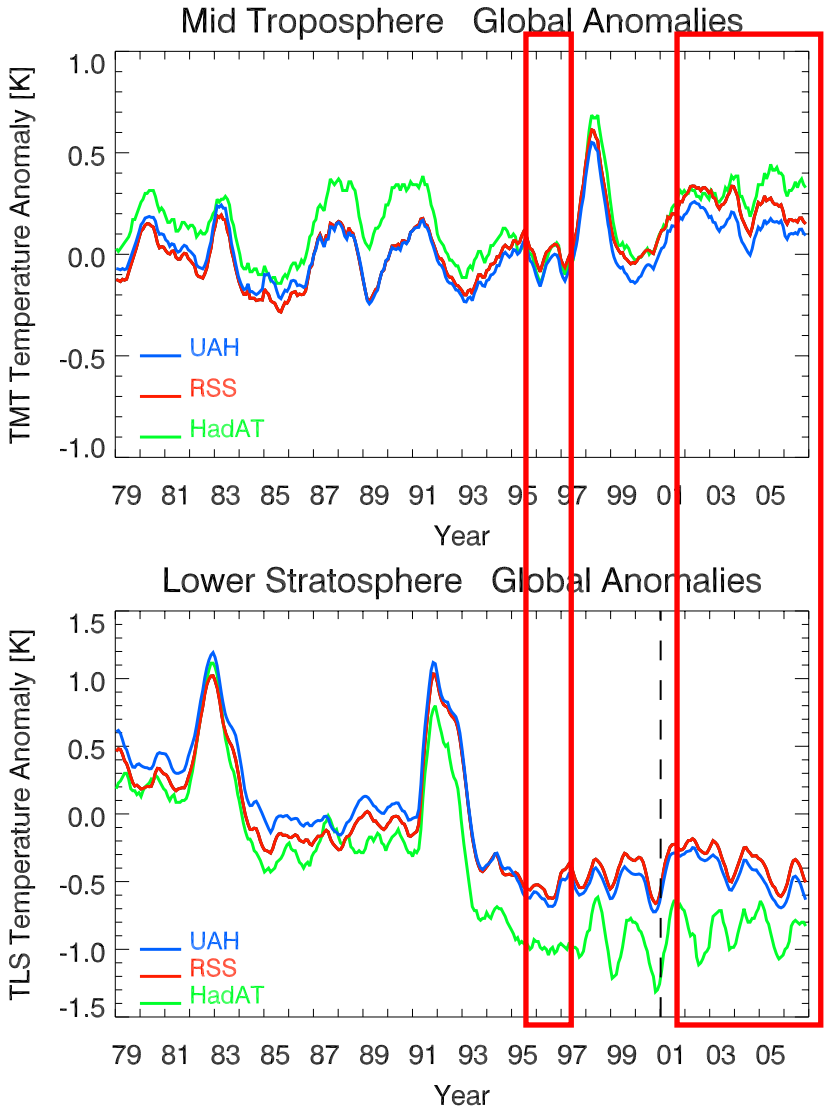
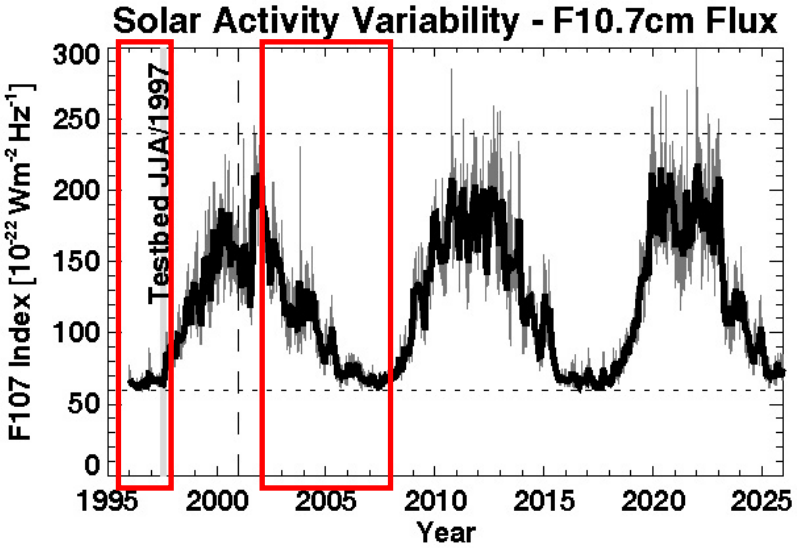
1997-2007 GPS/Met+CHAMP GPS RO obs time intervals: on internal climate var. and iono.var.





(based on Foelsche et al., JGR, in press, 2008)

(left; based on Steiner et al., (A)MSU work, 2007)

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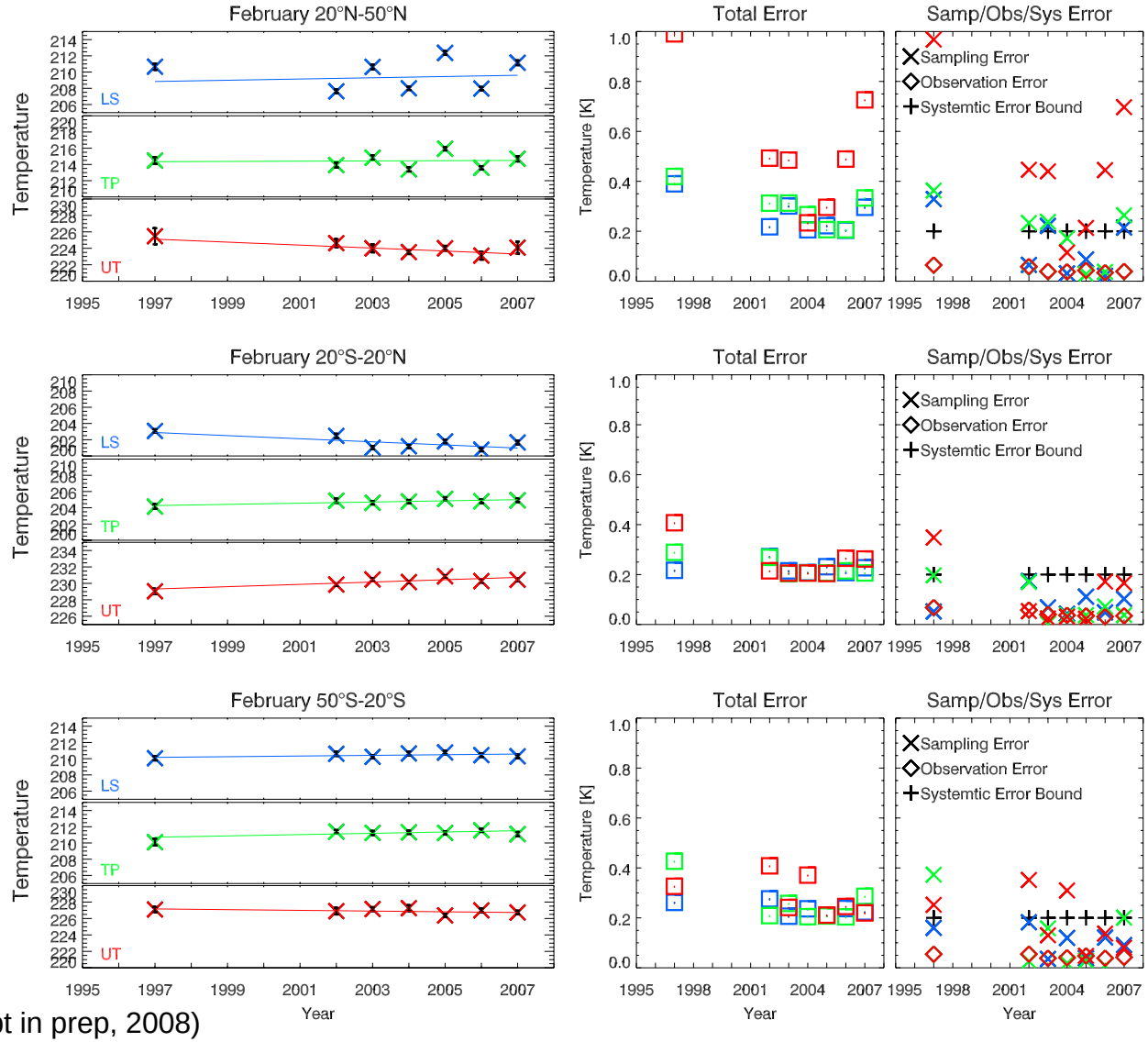
Temperature (T_{dry}) Trends and Uncertainties Feb 1997-2007 (1997 GPS/Met, 2002-07 CHAMP)

NHE20-50

Tropics

SHE20-50



(Steiner et al., manuscript in prep, 2008)

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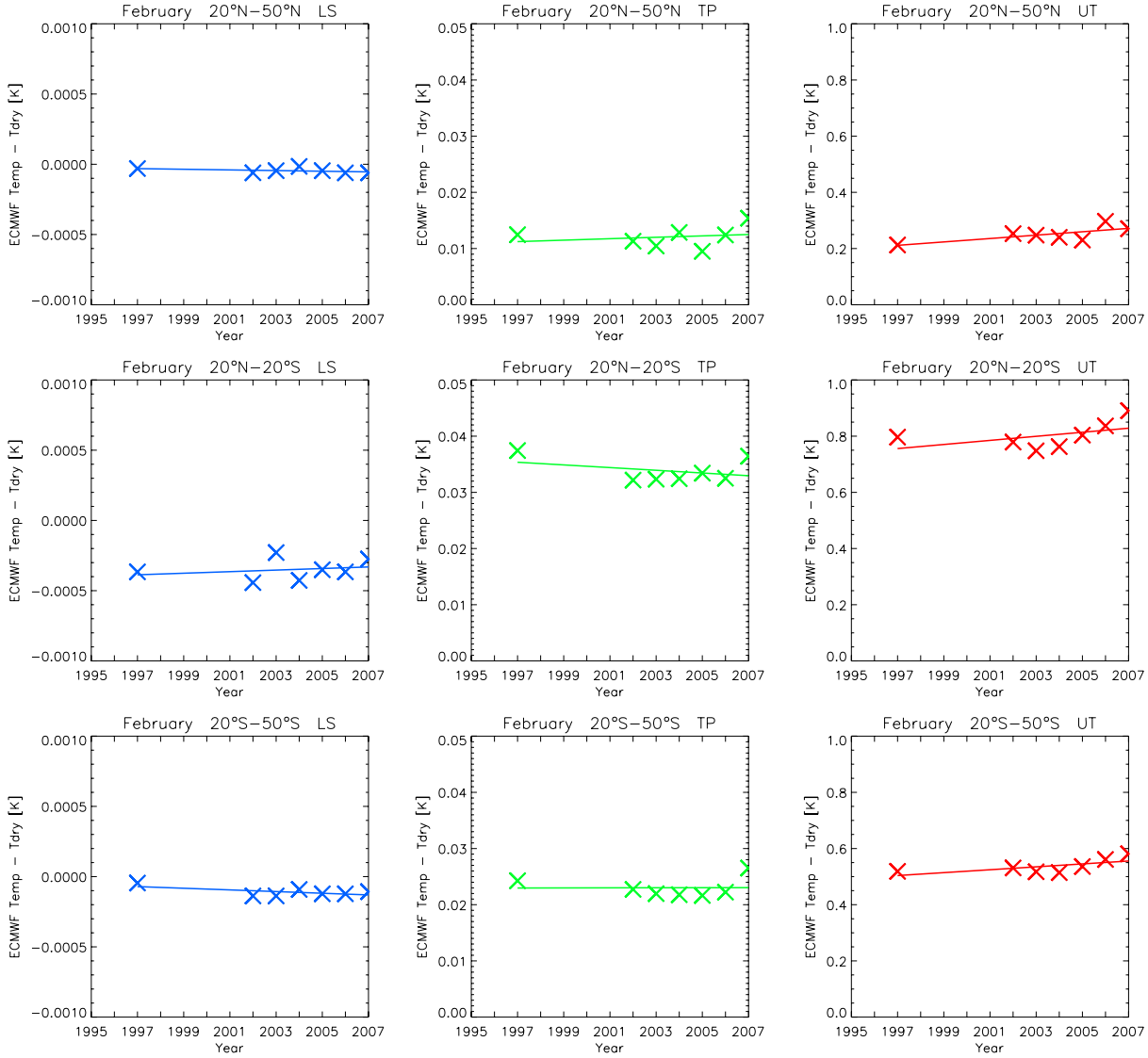
Trend Differences T_{phys}–minus–T_{dry}, Feb 1997-2007 (estimated based on ECMWF analyses)

NHE20-50

Tropics

SHE20-50



(Steiner et al., side work to manuscript in prep/suppl. information, 2008)

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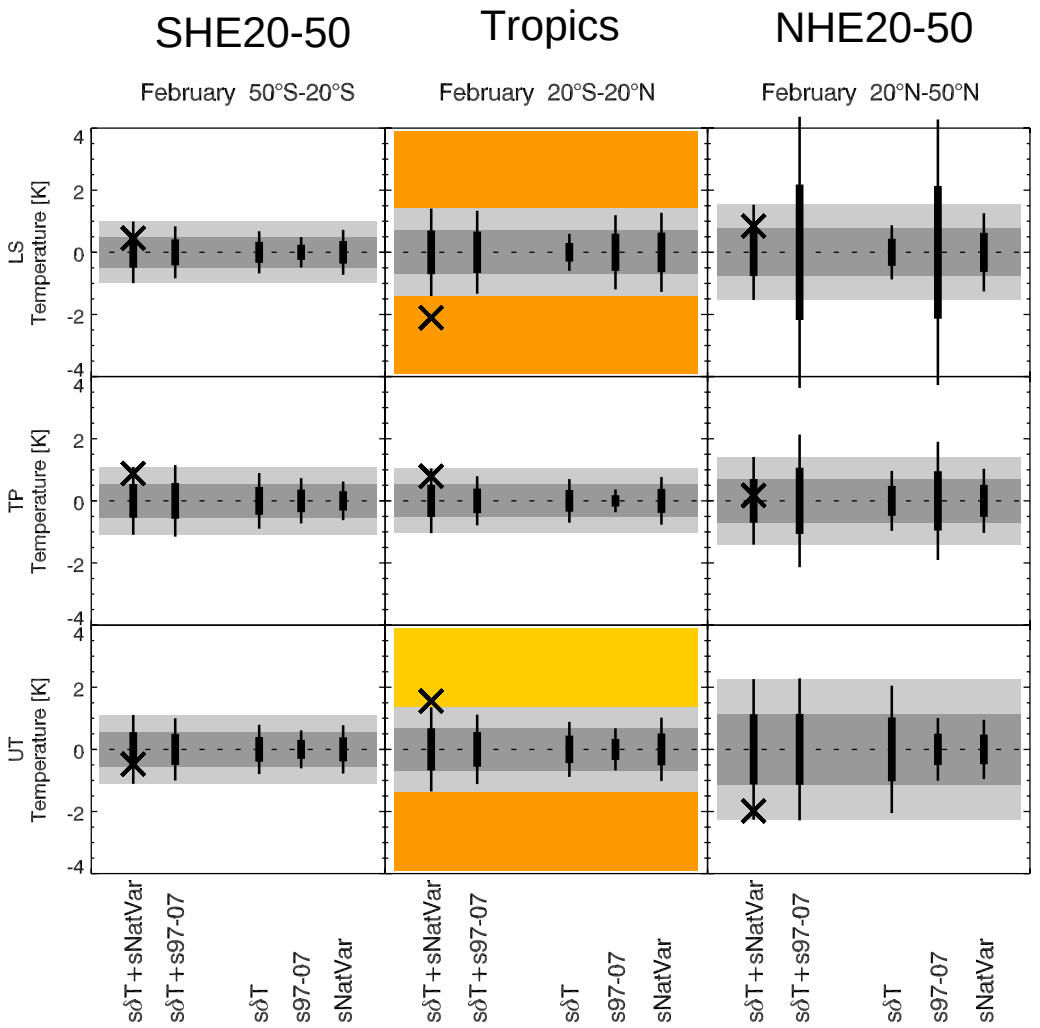
GPS RO Temp (T_{dry}) trends compared to key uncertainties: δtrend, interann.var, nat.var; Feb 1997-2007 (1997 GPS/Met, 2002-07 CHAMP)

(orange: > 95% significance level for 11-yr trend over nat.var. and interann.var.)



(Steiner et al., manuscript in prep, 2008)

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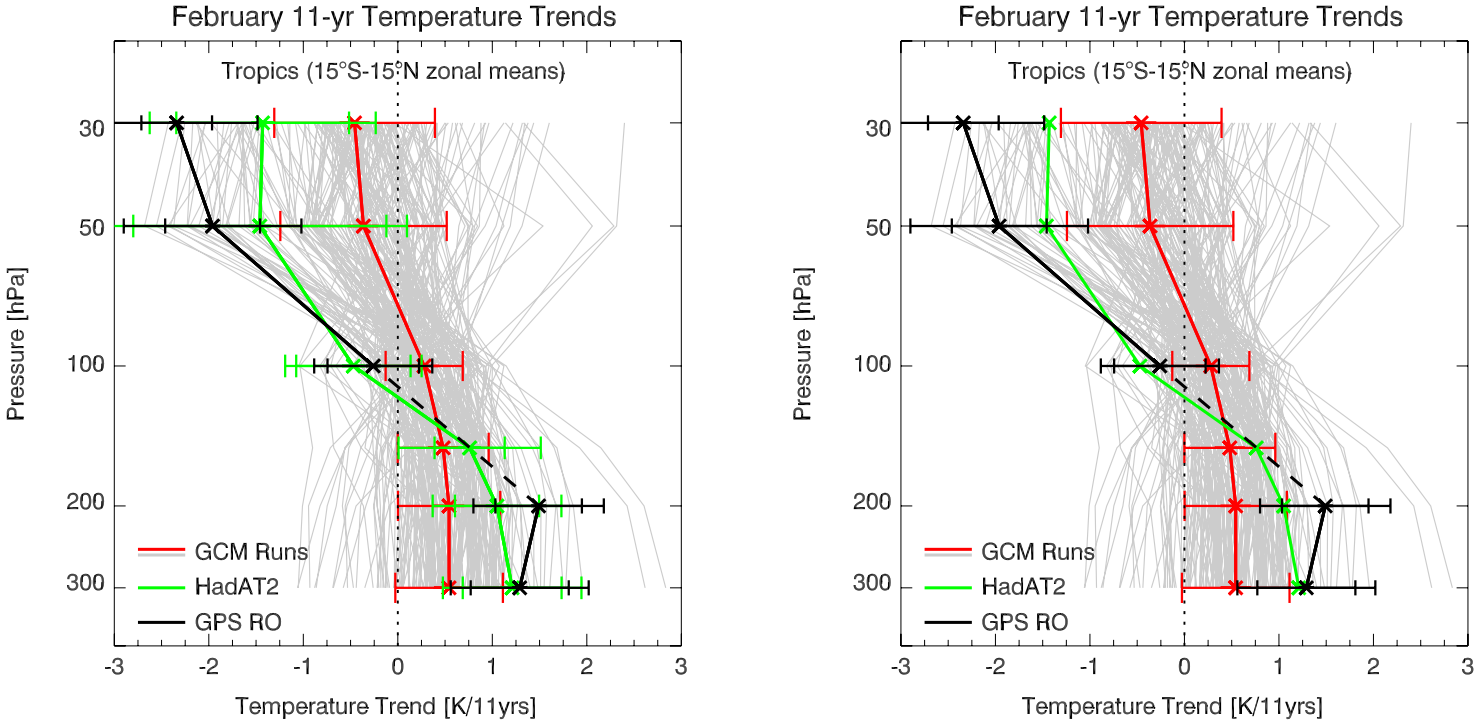
GPS RO Temp (T_{dry}) trends compared to trends from IPCC AR 4 GCM runs, and HadAT2 Raobs; Feb 1997-2007 (GCM trends sampled from 2001-2020)

(GPS RO: 1997 GPS/Met, 2002-2007 CHAMP; HadAT2: Raobs climate dataset/ same years; GCM runs: IPCC AR4 A2 and B1 scenario runs of ECHAM5+HadCM3+CCSM3, 11-yr trends sampled from 2001-2020 period)



(Steiner et al., manuscript in prep, 2008)

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[20/20]

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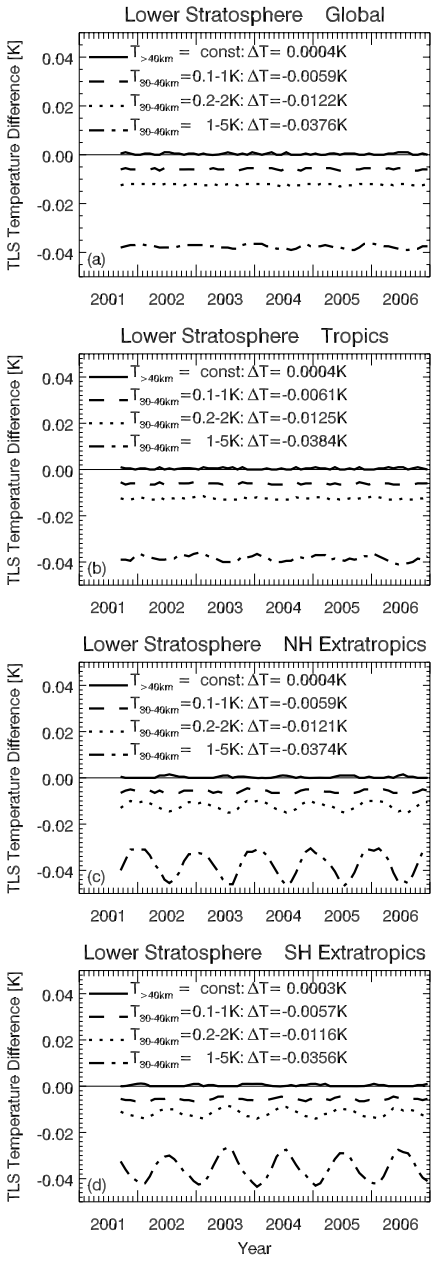
Synthetic MSU/AMSU TLS (T4) time series from CHAMP GPS RO: *Sensitivities to upper-bound initialization* and *to use of Tdry for Tphys*

(Steiner et al., OPAC-3 Springer book, in rev., 2008)

…on TLS upper bound initialization sensitivity



…on TLS T_{phys} - T_{dry} sensitivity (ECMWF analyses)