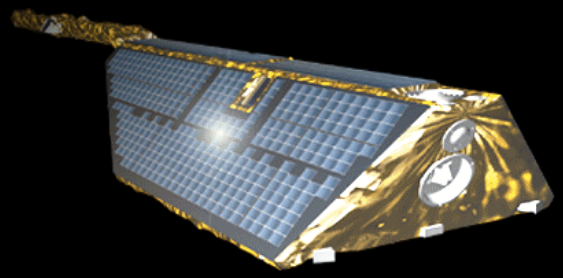
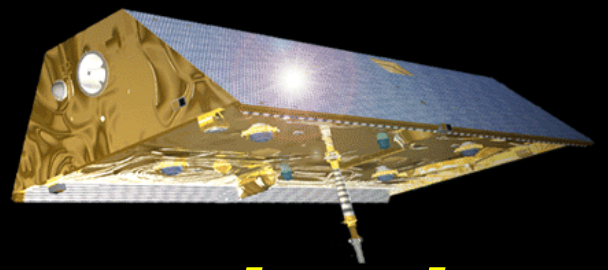




GPS based atmospheric sounding with CHAMP: Recent GFZ activities and results

J. Wickert, G. Beyerle, T. Schmidt, S. Heise, N. Jakowski[1], R. König, M. Rothacher, S.B. Healy[2], D. Offiler[3], W. Wergen[4]

GeoForschungsZentrum Potsdam

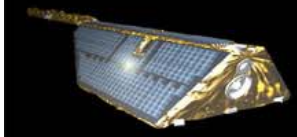
[1] German Aerospace Establishment

[2] European Centre for Medium Range Forecasts

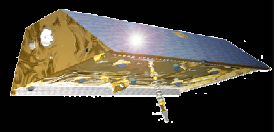
[3] MetOffice

[4] German Weather Service

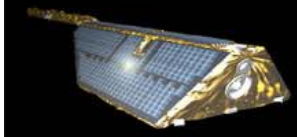
GFZ POTSDAM

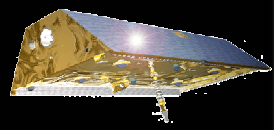


Content



1) Status CHAMP and operational data analysis at GFZ/DLR
2) Near real time activities
3) LT bias and receiver simulations
4) UTLS activities
5) Ionosphere (Space weather in RO data)
6) Zero differencing with GRACE
7) Summary

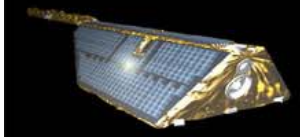




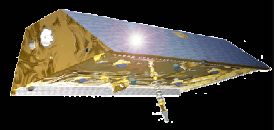
Status CHAMP

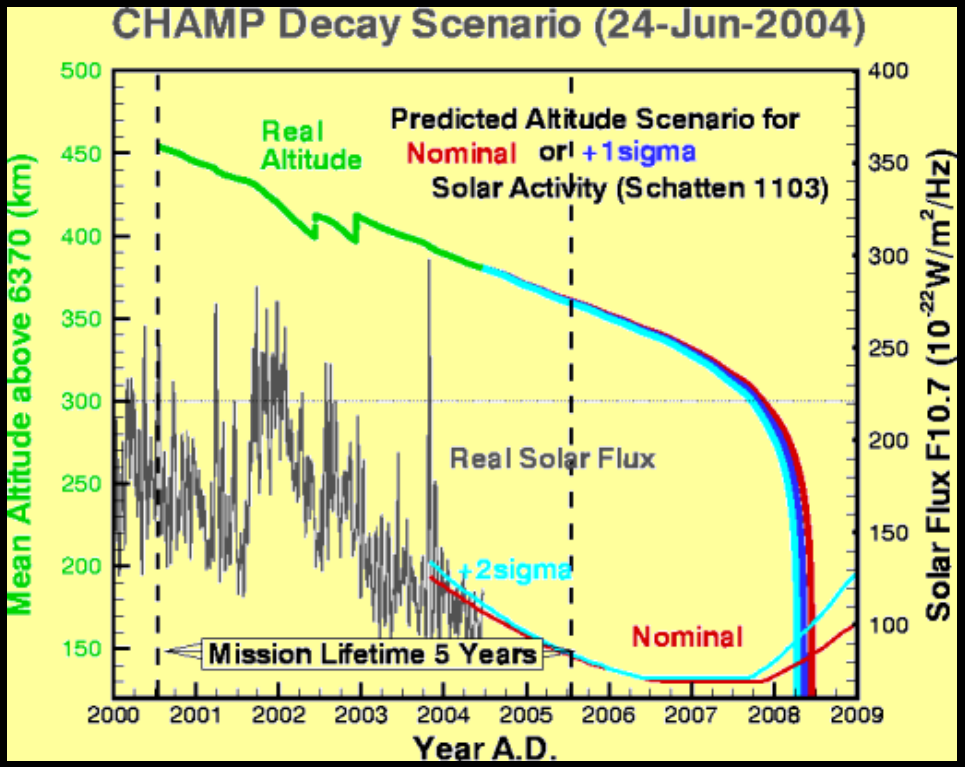
GFZ POTSDAM


5th anniversary of CHAMP in Orbit: July 15, 2005



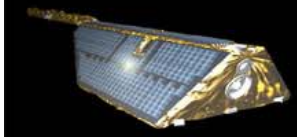
Expected mission duration: end 2007

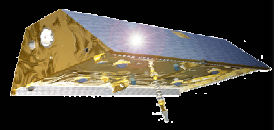




Nominal lifetime of the satellite reached

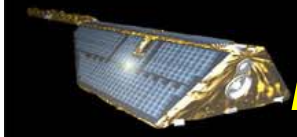
But satellite and instrument status is excellent, further 2 years of operation funded (-2007), then we will see ..



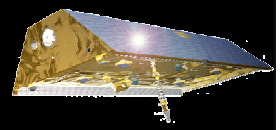


Status CHAMP processing at GFZ

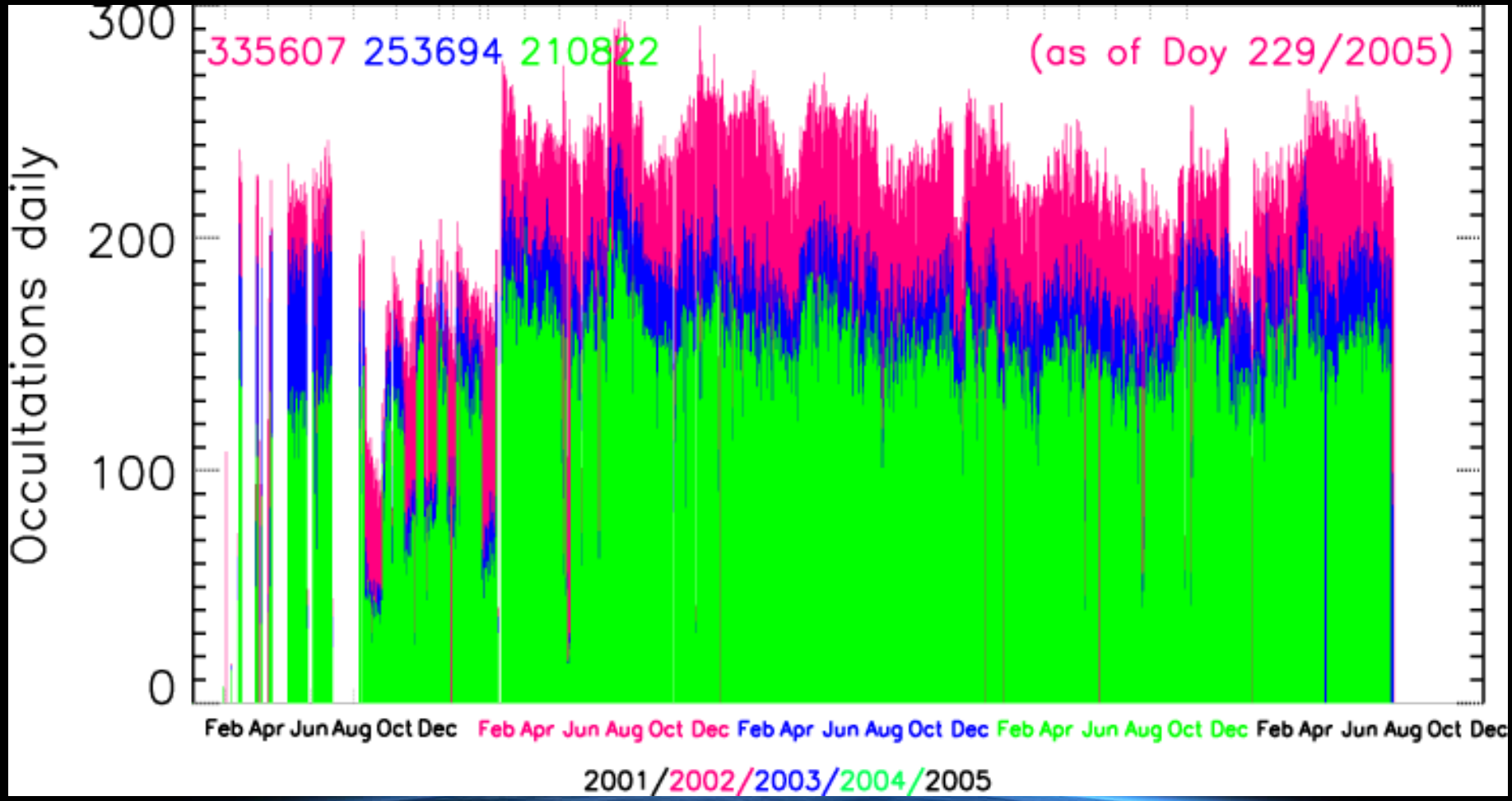
GFZ POTSDAM



Neutral atmosphere: Occultations 2001-2005

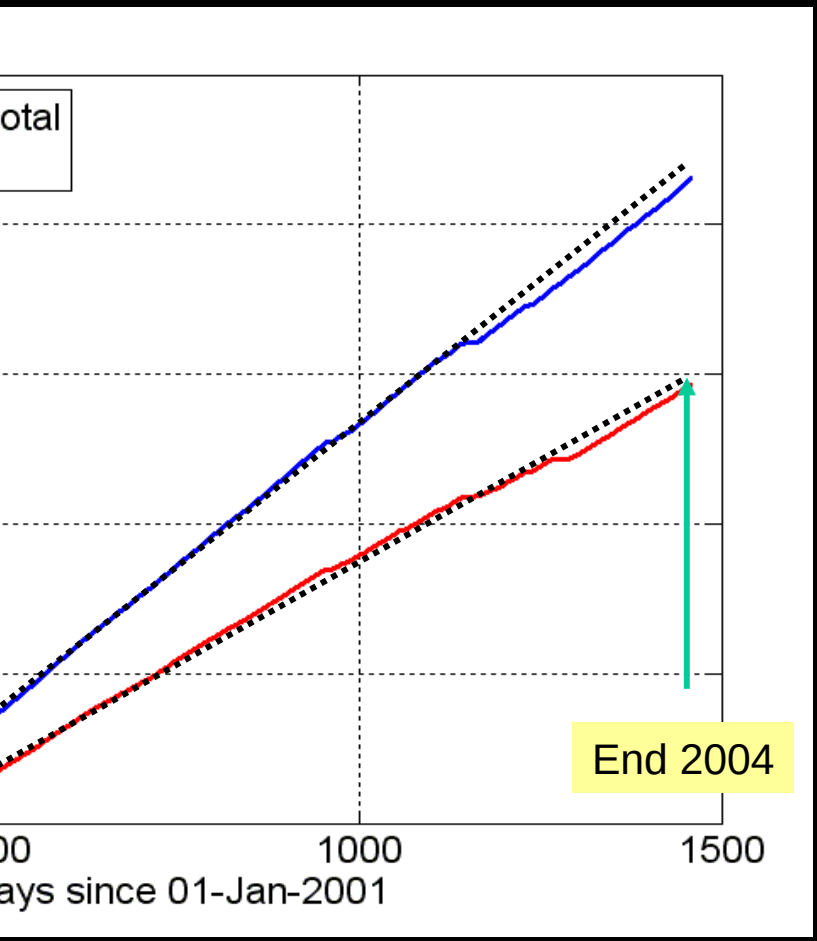


1526 days; 335,607 occultations (~220 daily); Aug 18, 2005
253,694 phase delays (~75 %); 210,822 profiles (~63%); GFZ



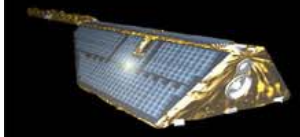
GFZ POTSDAM

Occcultations: Ionosphere (DLR)

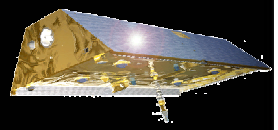


August 2005: ~190 000 electron density profiles
~200 occultations daily (140 profiles)

GFZ POTSDAM



Operational data provison



a) version 005 (POCS), standard since mid 2004
(FSI, Refractivity optimized with MSIS-90E,
T_{dry} with ECMWF at 43 km) 0 .. 35 km

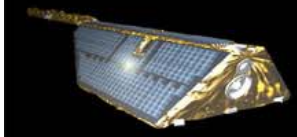
c) 2 operational WVP retrieval techniques (ECMWF as BG):

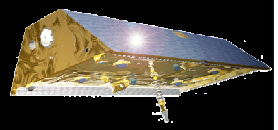
* direct method (DWVP, Heise) up to p_{TP}

* 1Dvar (Healy) p_{surf} .. 122 hPa

b) Continuous validation with ECMWF and RS

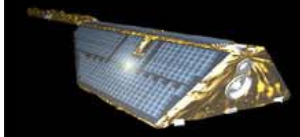
d) Data provision now via FTP possible, WVP on demand



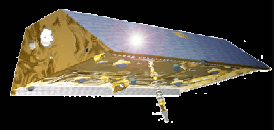


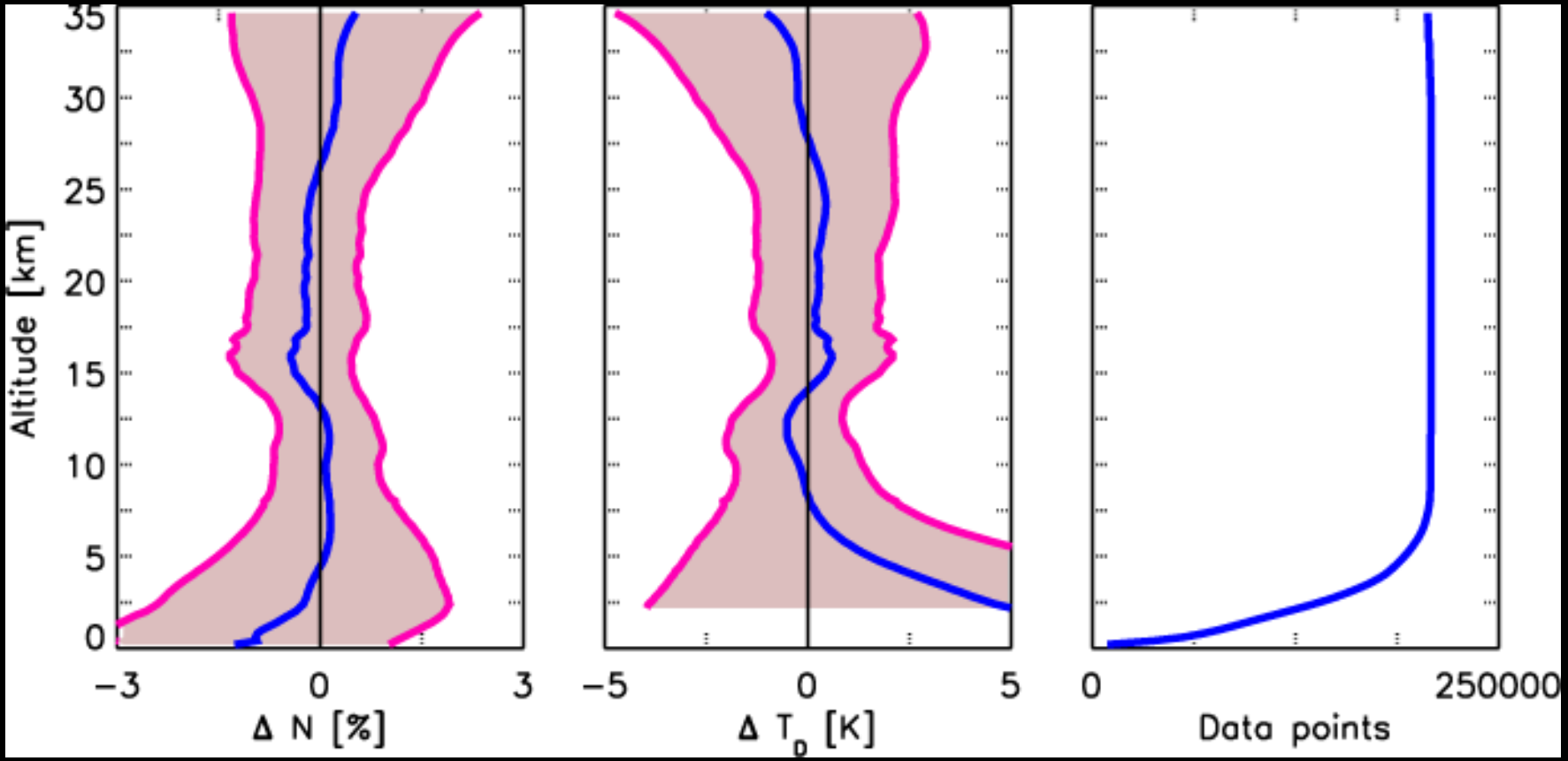
Validation
(only selected examples)

GFZ POTSDAM



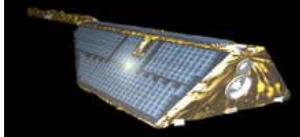
Validation with ECMWF



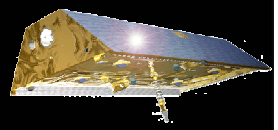


more than 200,000 vertical profiles

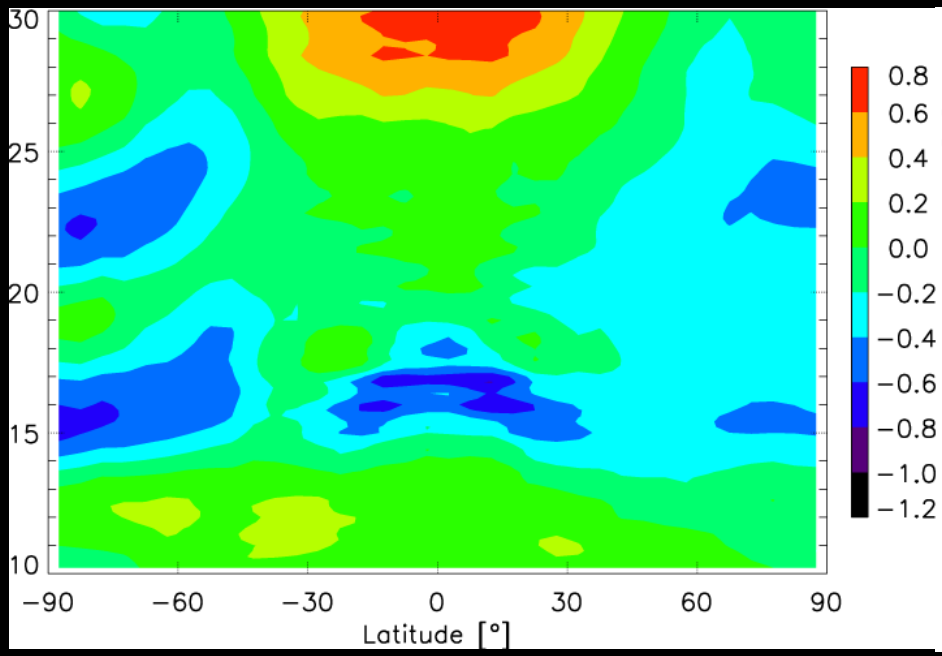
GFZ POTSDAM



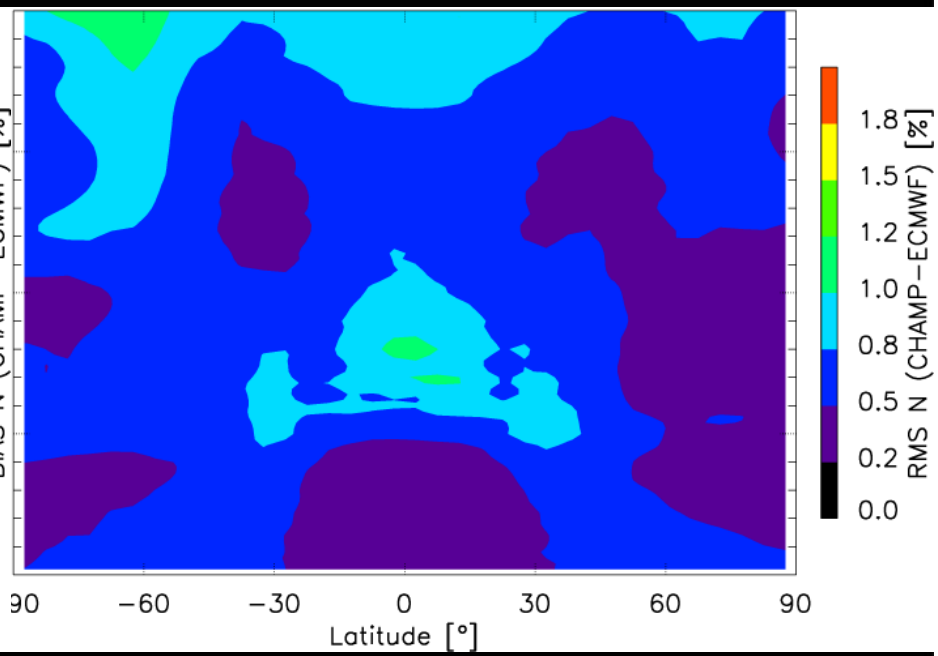
Continuous validation with ECMWF and RS data (example)



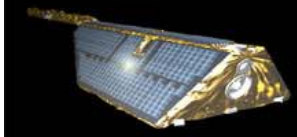
CHAMP-ECMWF (bias)

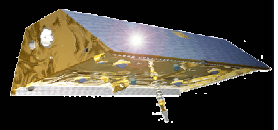


CHAMP/ECMWF (RMS)



~170,000 vertical profiles (May 2001 – November 2004)

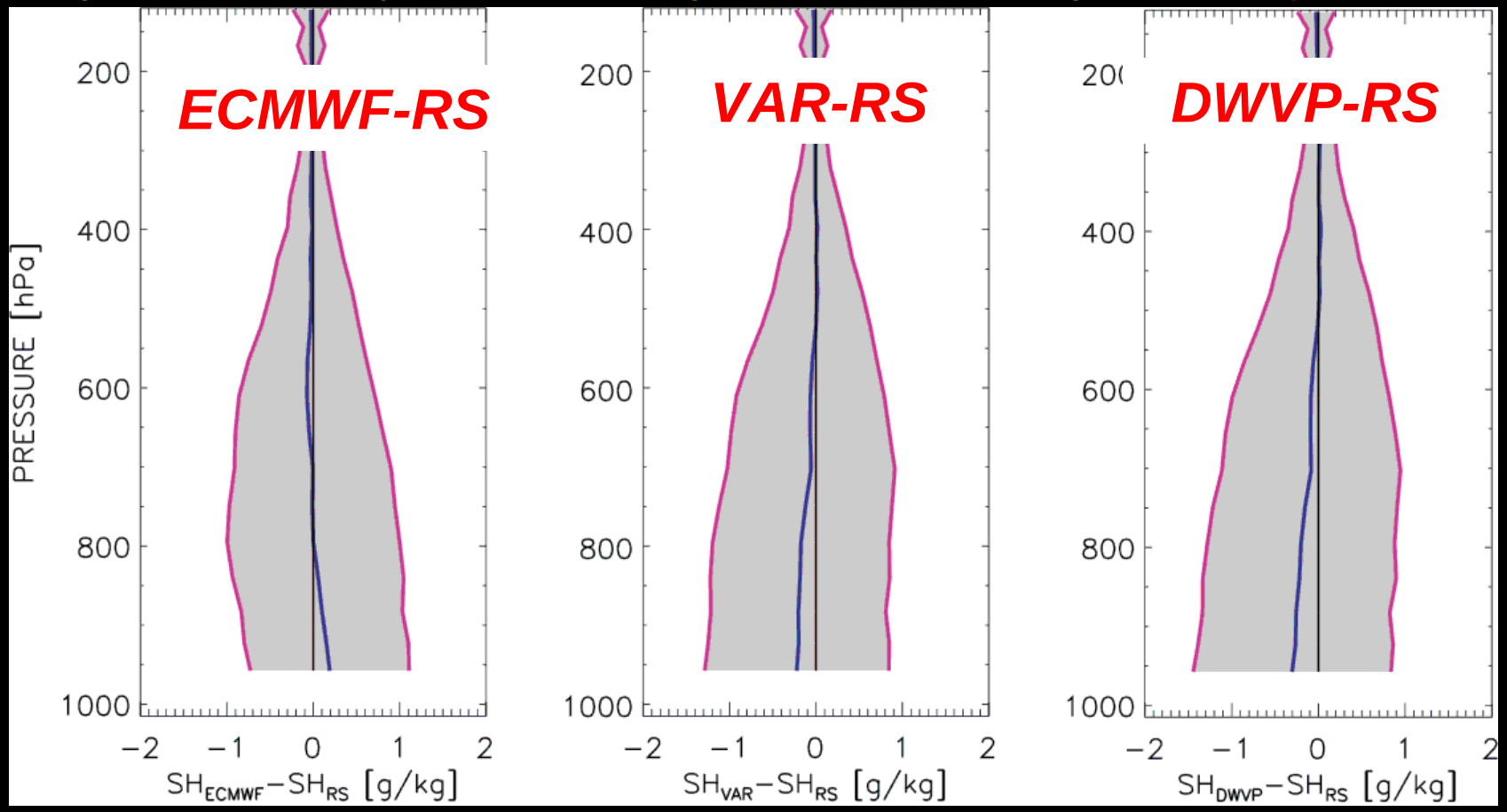




Water vapor retrieval

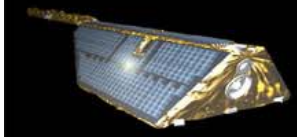
WVP: comparison with RS data

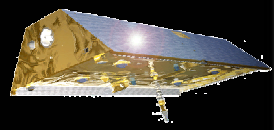
Specific humidity 2002 - 2003 (0° < latitude < 90°) ~14,000 profiles



Δd < 300 km, Δt < 3 h; similar results even if different techniques, 1dvar only slightly modifies the temperature, LT dry bias in DWVP more pronounced, works best in middle troposphere (above: too dry, below: less data); ? Wet bias of ECMWF wrt. RS

GFZ POTSDAM

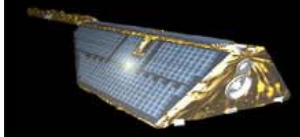


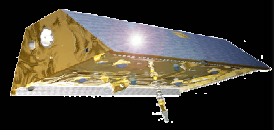


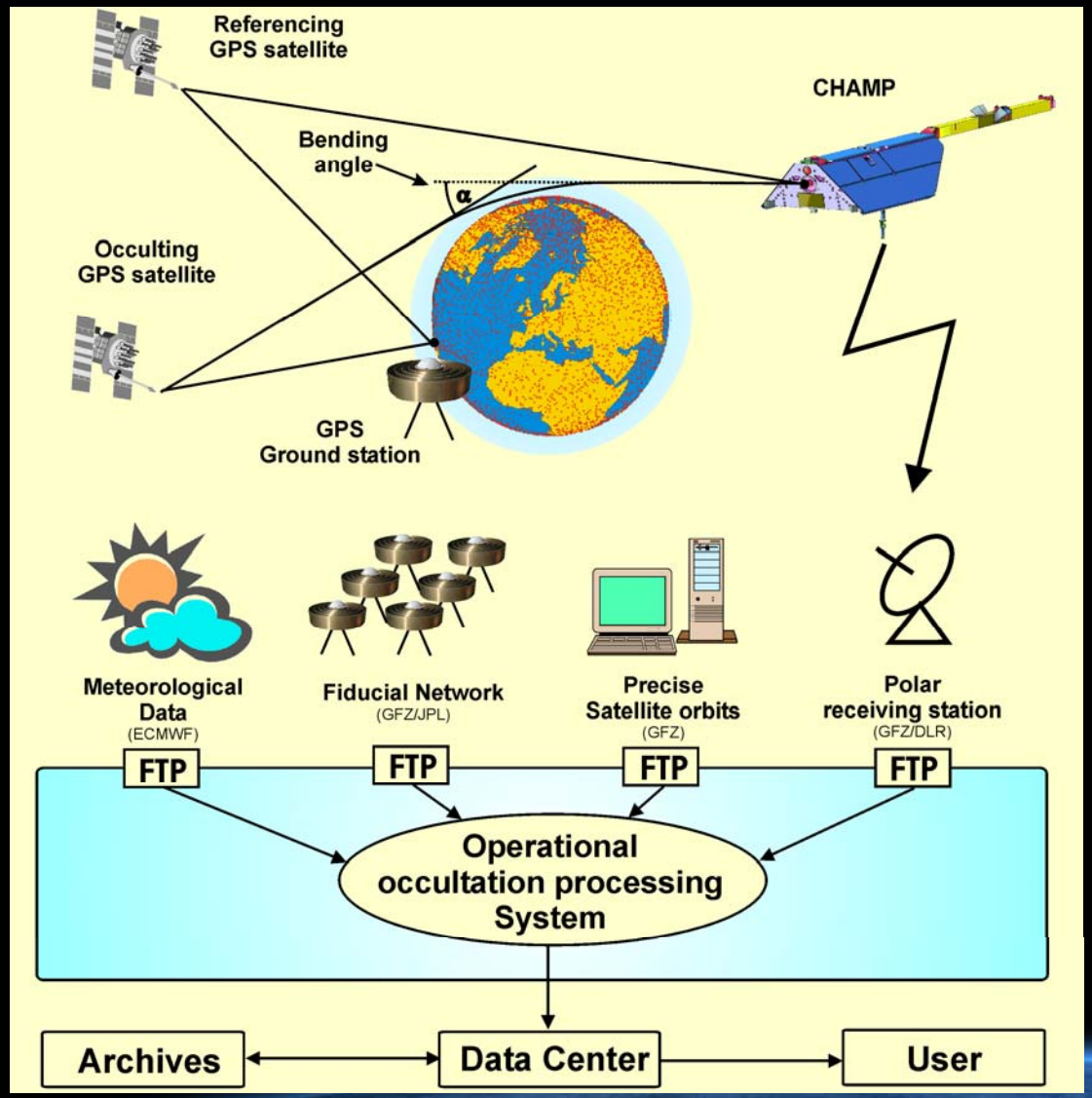
Near real time activities

GFZ POTSDAM

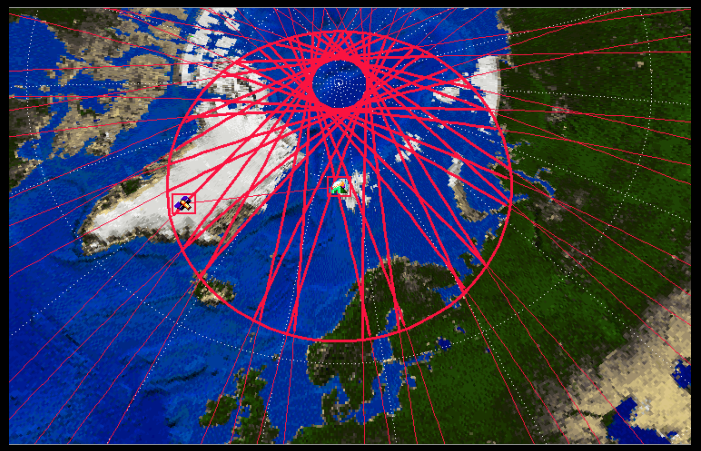
Operational RO infrastructure with polar receiving antenna







Ny Ålesund



Reception area

GFZ POTSDAM

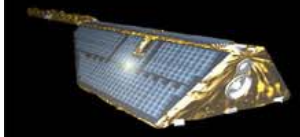
National NRT occultation project

Continuous provision and usage of NRT RO data together with weather prediction centers ECMWF, DWD and MetOffice

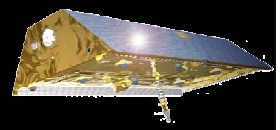
Goals:

- ***provision of NRT RO data (~2h latency***
- ***assimilation to NWP (impact studies)***
- ***real assimilation to NWP planned***

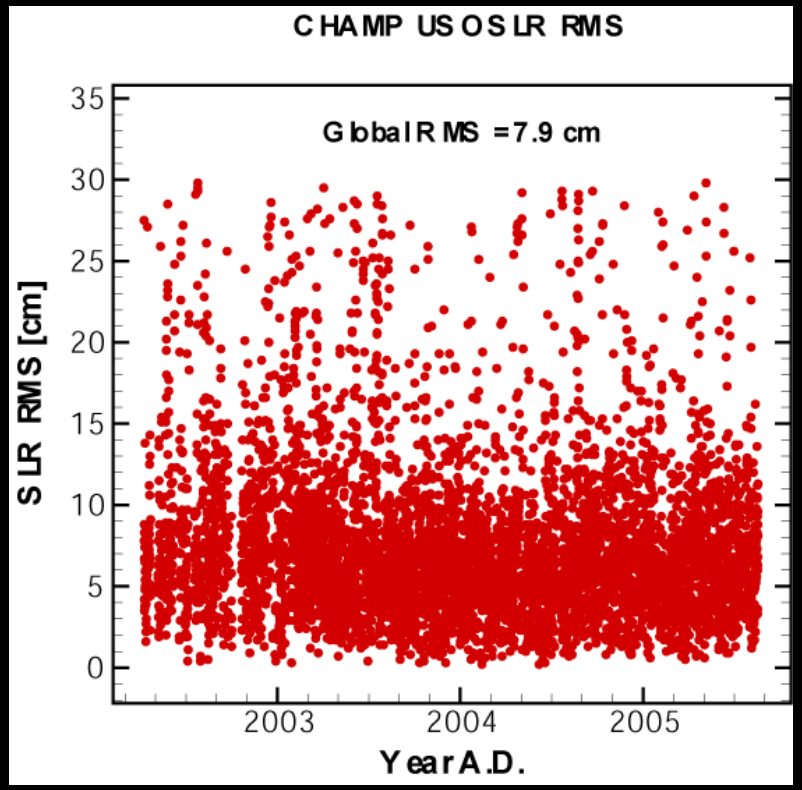
other user are invited to use NRT data



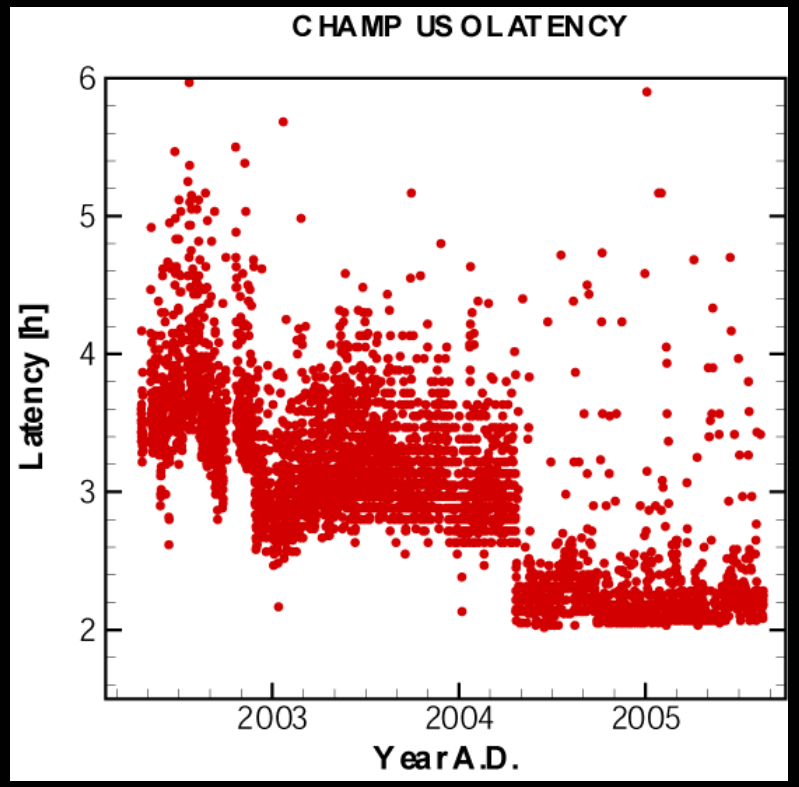
Status: provision of rapid orbit data



RMS USO/SLR

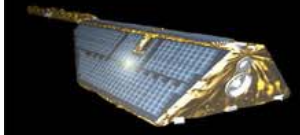


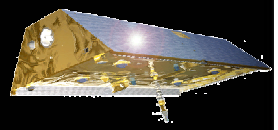
USO latency

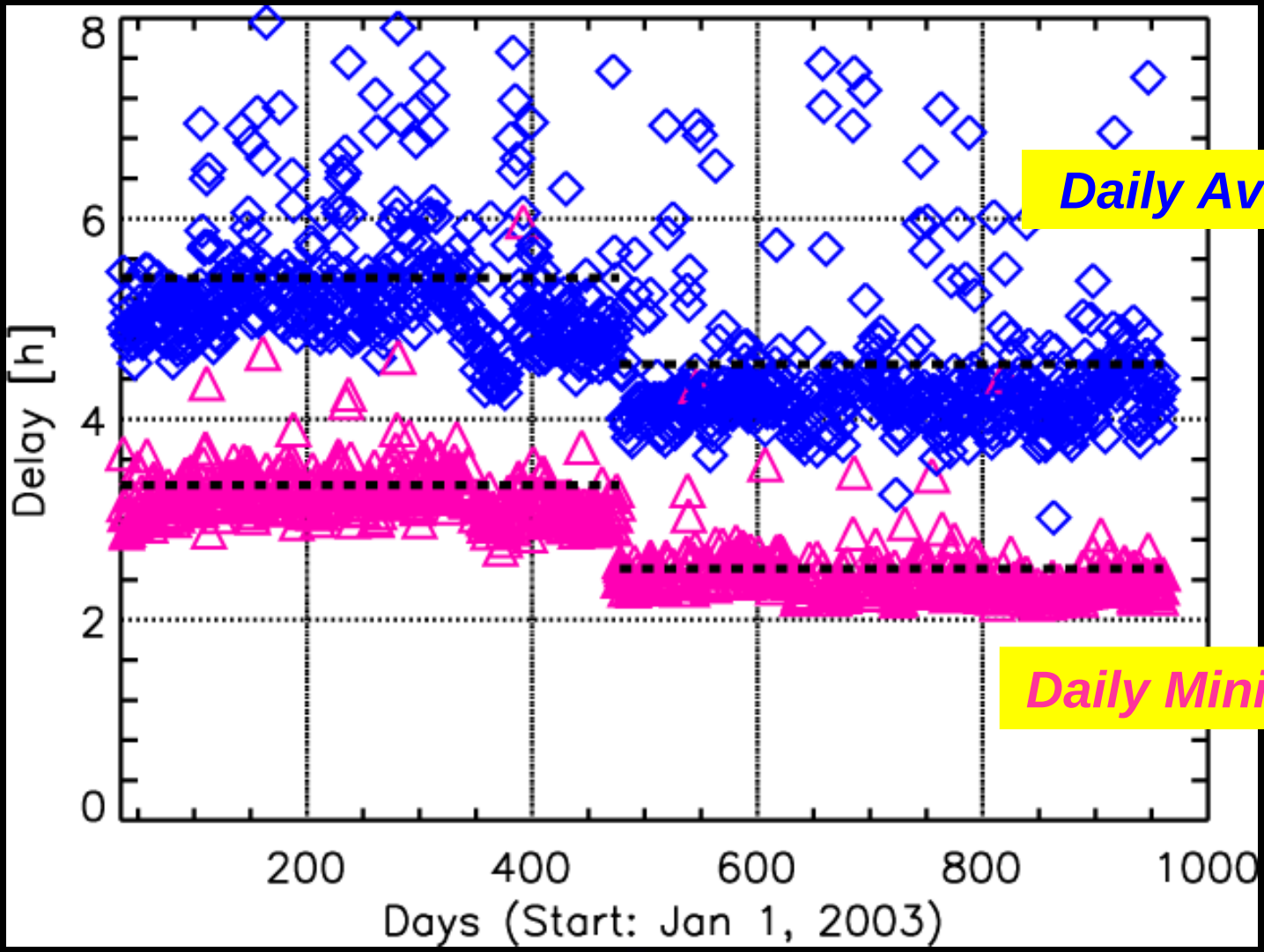


Orbit generation at fixed time grid, latency related to the last data point of the arc (every 3h)

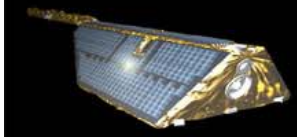
Current latency of phase delays

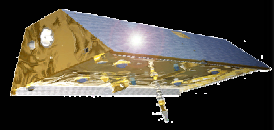






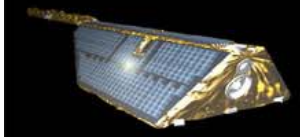
Further reduction to ~2h as first step of NRT RO project



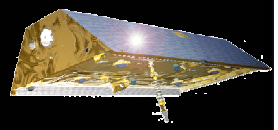


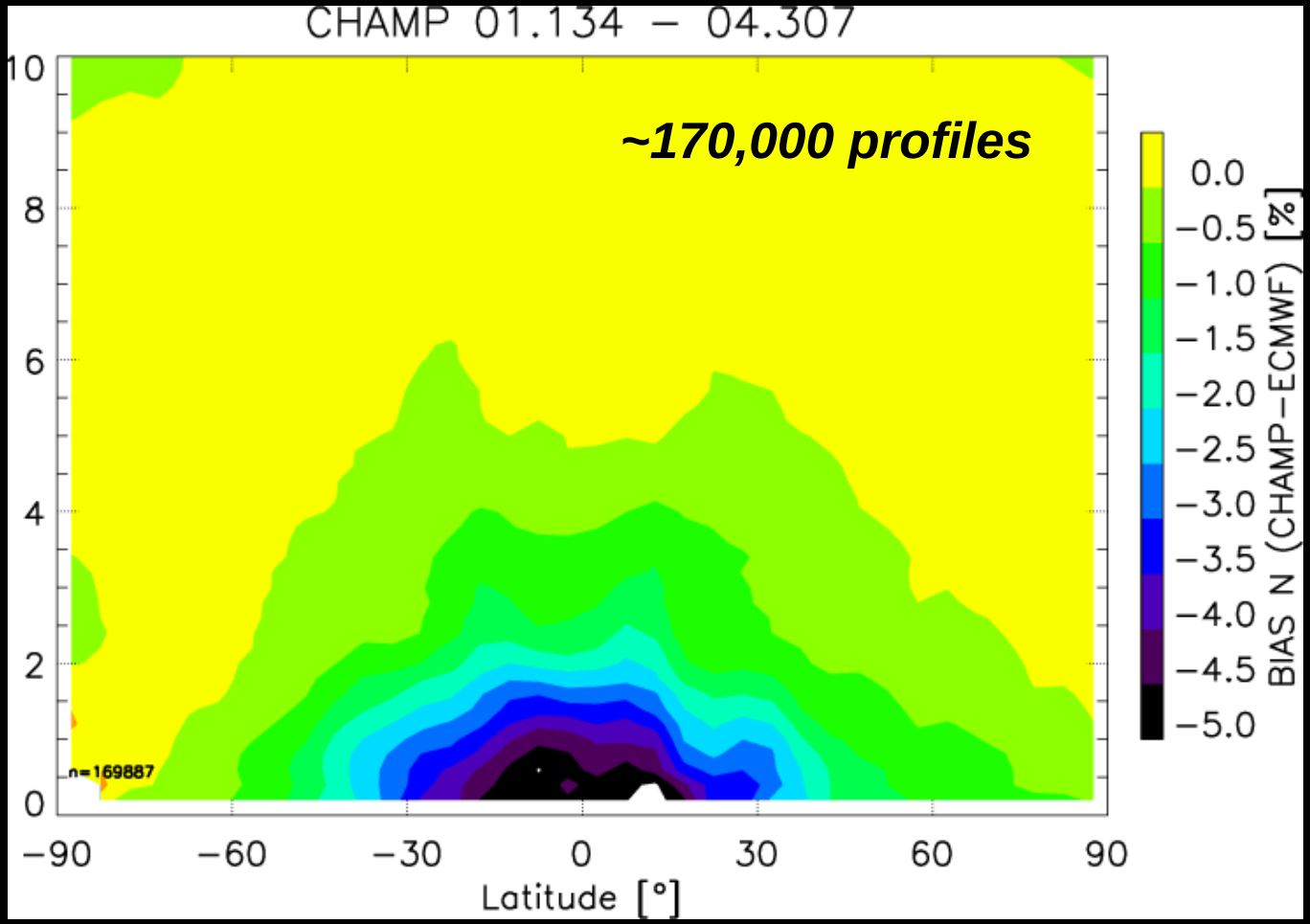
Negative bias and receiver simulations

GFZ POTSDAM



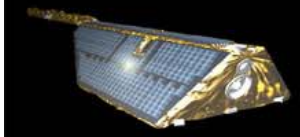
Negative refractivity bias



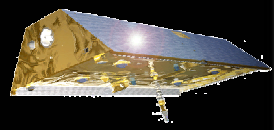


together with data loss in the LT

GFZ POTSDAM



End to end simulations



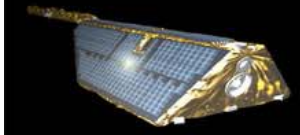
Recent study by Beyerle et al. (2005)

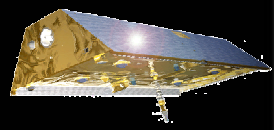
* Investigate the known negative bias using end2end simulations based on tropical RS data using different receiver tracking modes

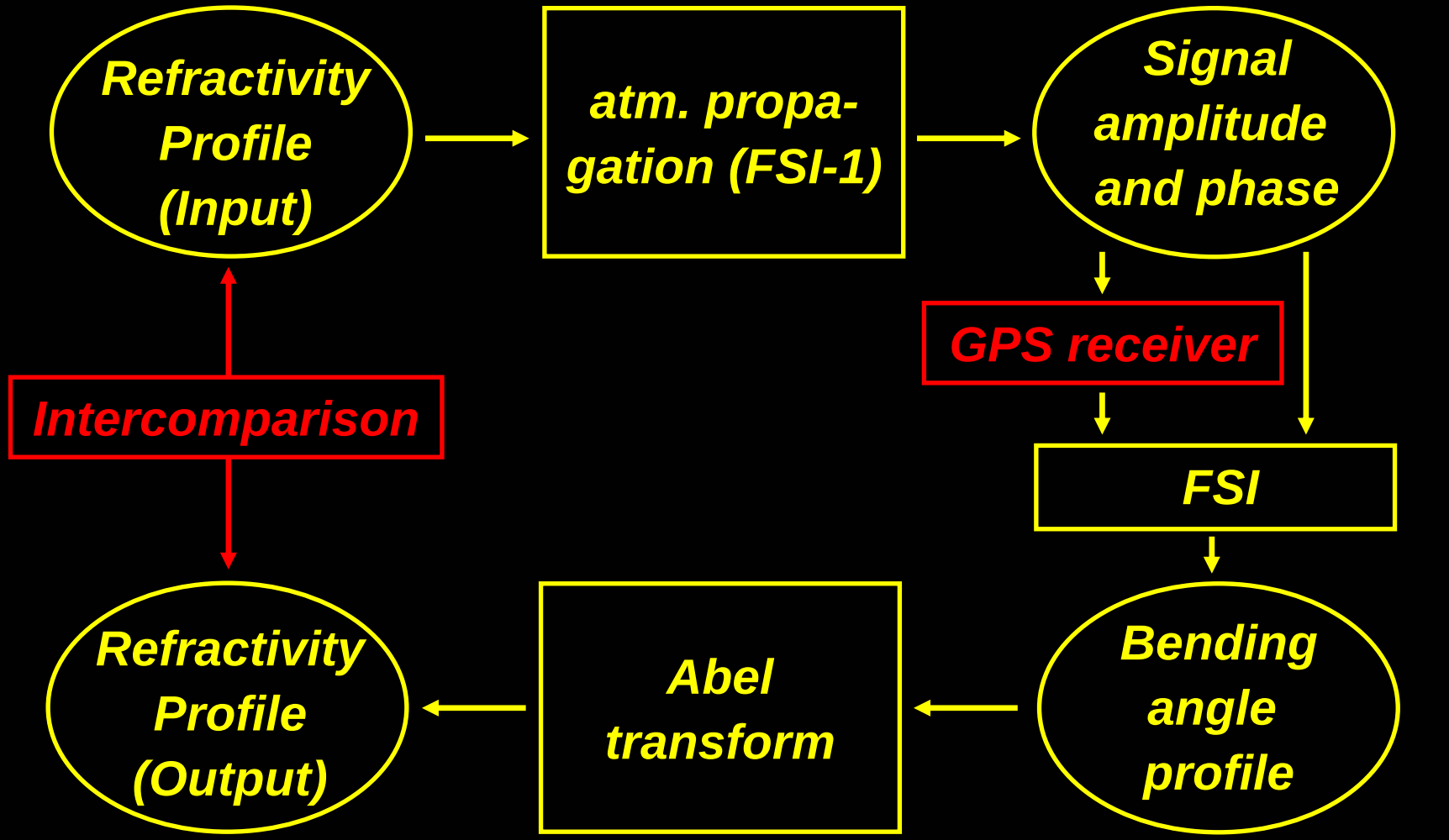
- 5 different GPS receiver tracking modes (@3 SNR)
  - A ideal receiver (reproduces input, without noise)
  - B „CHAMP“like (3th order loop BW 30Hz; FW)
  - C Open-loop (output: I, Q and model)
  - D Closed loop (3th order loop, red. BW 5 Hz)
  - E Closed loop (2th order loop, BW 30 Hz)

* 2th order closed-loop tracking (E) is considered as a viable alternative to open-loop tracking

End to end simulations (Beyerle)

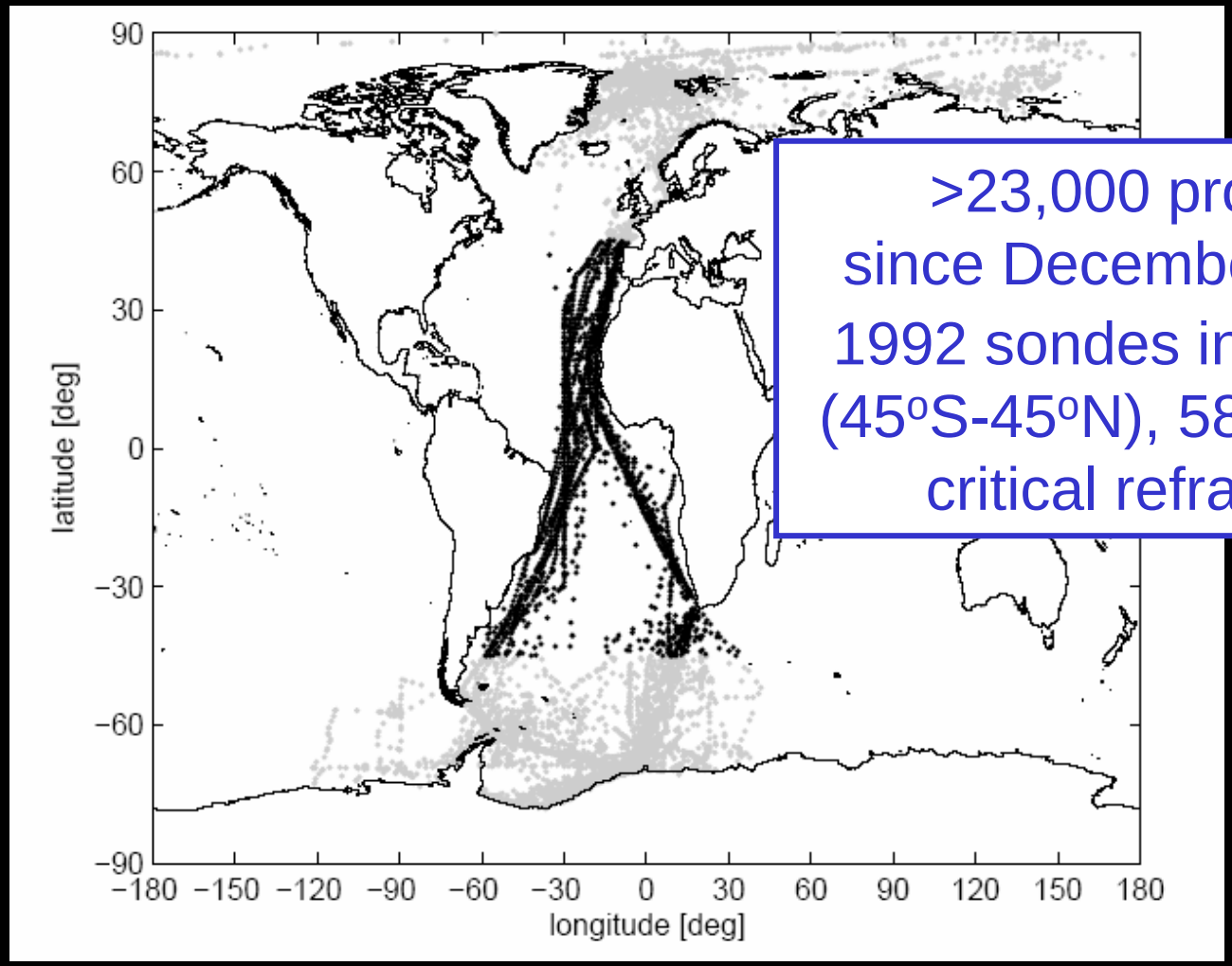






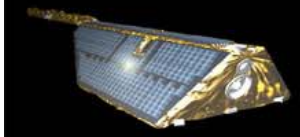
GFZ POTSDAM

„POLARSTERN“ radio sonde data set

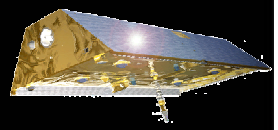


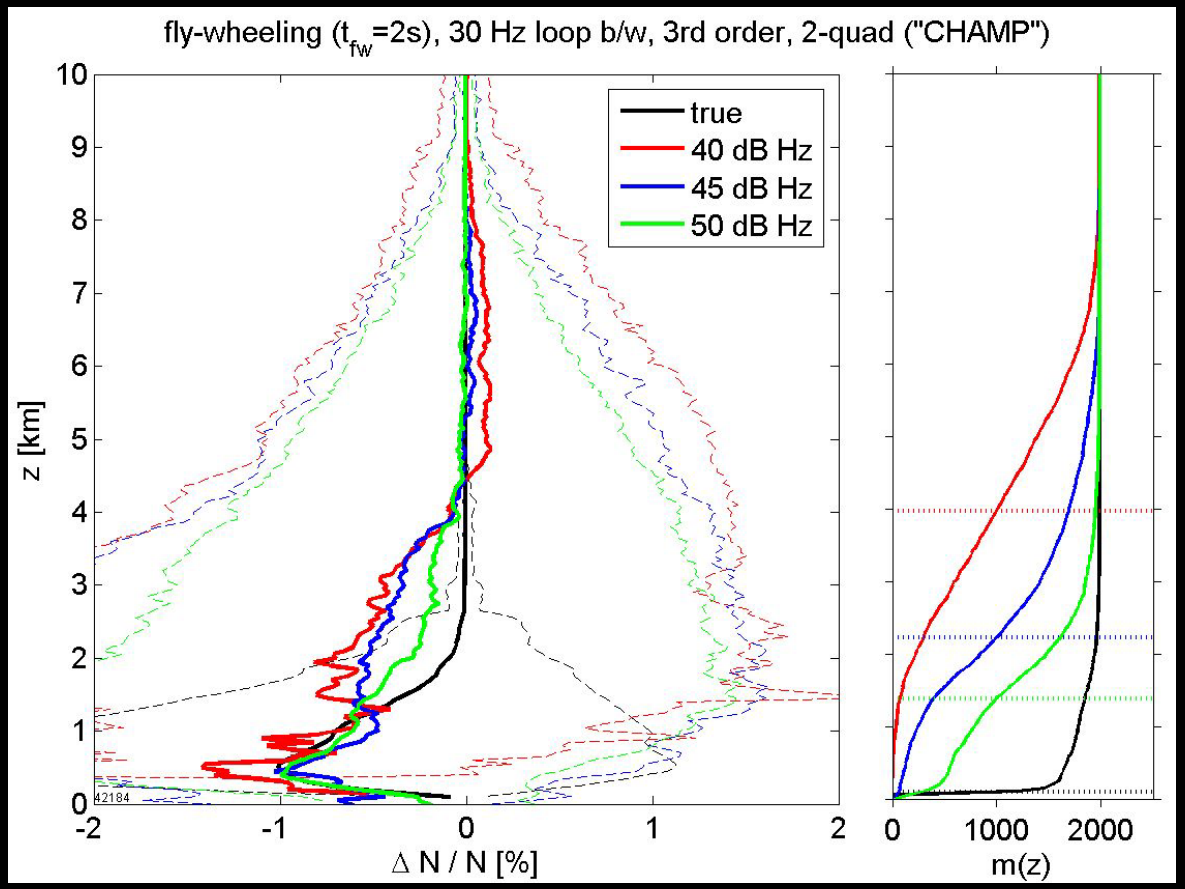
>23,000 profiles
since December 1982,
1992 sondes in Tropics
(45°S-45°N), 58.3% with
critical refraction

GFZ POTSDAM



„CHAMP like“ Model B

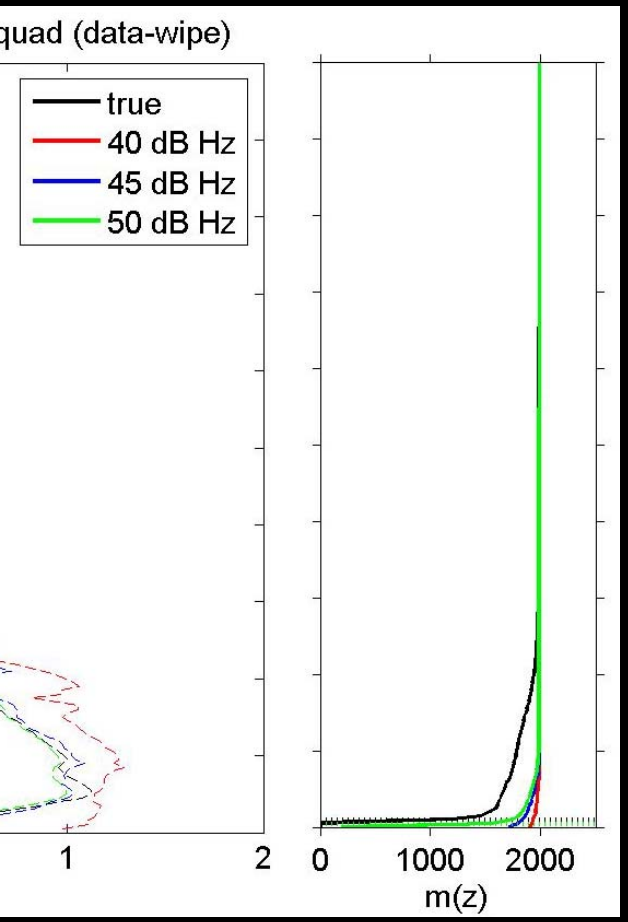




Results correspond to the observed bias in CHAMP observations, above 3 km receiver induced bias most likely

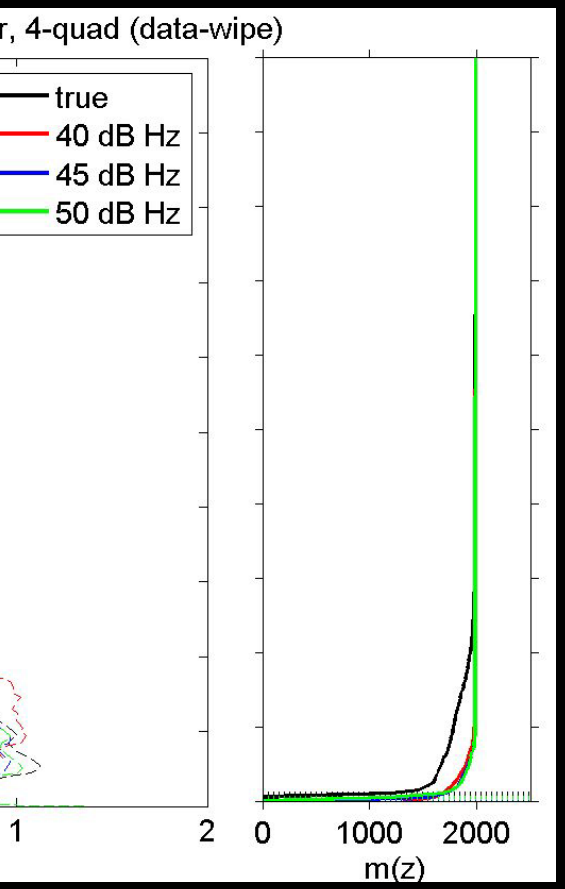
GFZ POTSDAM

Open loop (model C)



OL data exhibit almost no bias and significanly reduced standard deviation

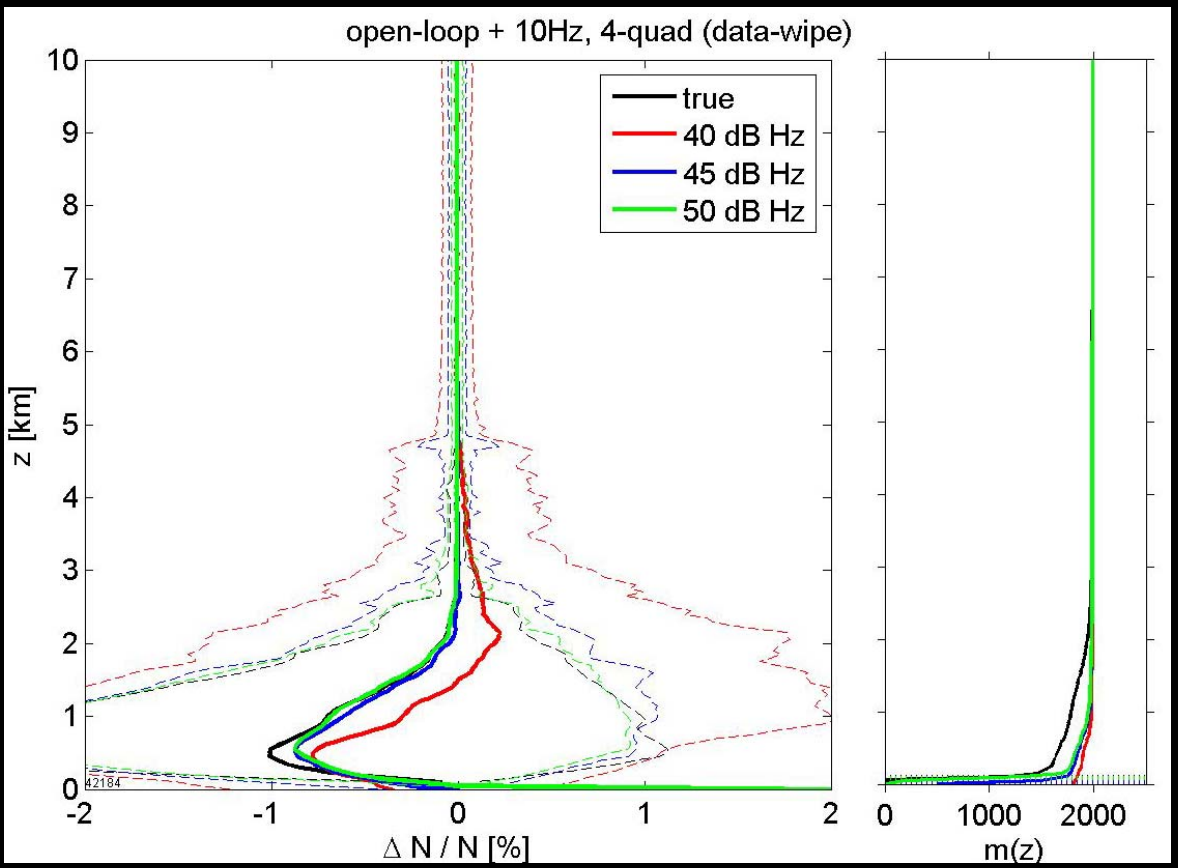
Closed loop with 2th order (Model E)



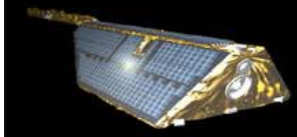
Results compare favourable with OL data with respect to bias, RMS and lock of loss altitude, 2th order loop less sensitive wrt phase accelarations, closed loop design simpler as OL (only 2 parameters), but navigation data modulation must be removed onboard (predictable for ~98% of the subframes, 12.5 min repetition rate)

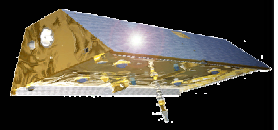
GFZ POTSDAM

OI data with biased Doppler model

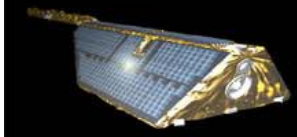


If a biased Doppler model is used, for low SNR in mid and lower troposphere bias is introduced, however of less practical relevance, since such low SNR is not expected in future RO data

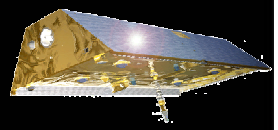




Upper troposphere/ lower stratosphere



UTLS region

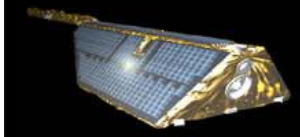


Recent study by Schmidt et al (ACP, 2005)

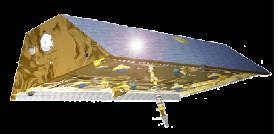
a) Unique long term data set (in part with SAC-C), first long term investigations in UTLS possible

b) Global characteristics of tropopause and gravity waves

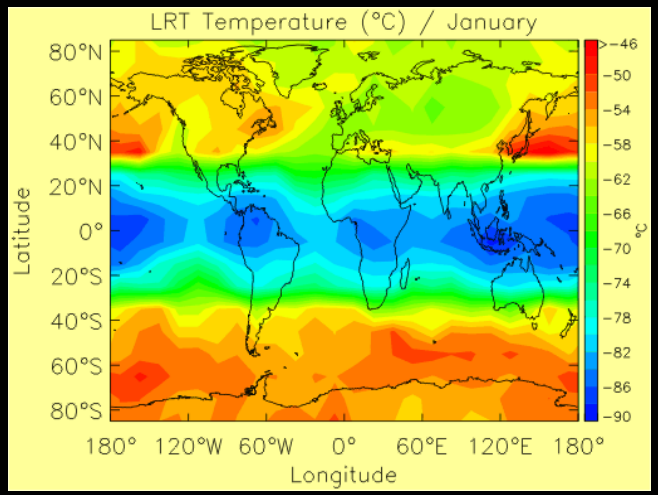
c) Participation in national research programme related to CAWSES (Climate and Weather of the Sun Earth system) program of SCOSTEP (Scientific Committee on Solar-Terrestrial Physics)



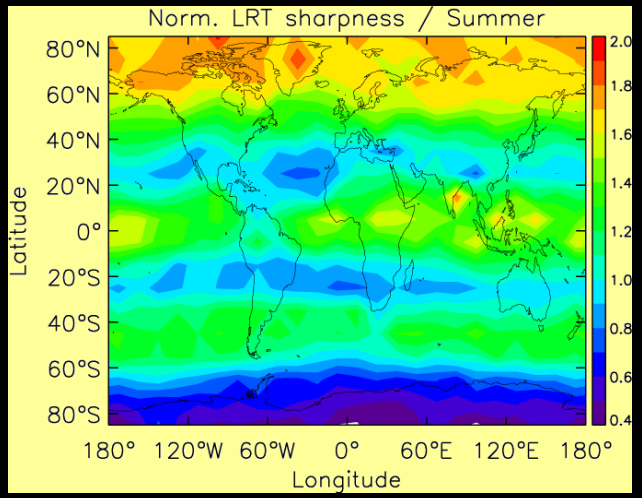
CHAMP/SAC-C UTLS (examples)



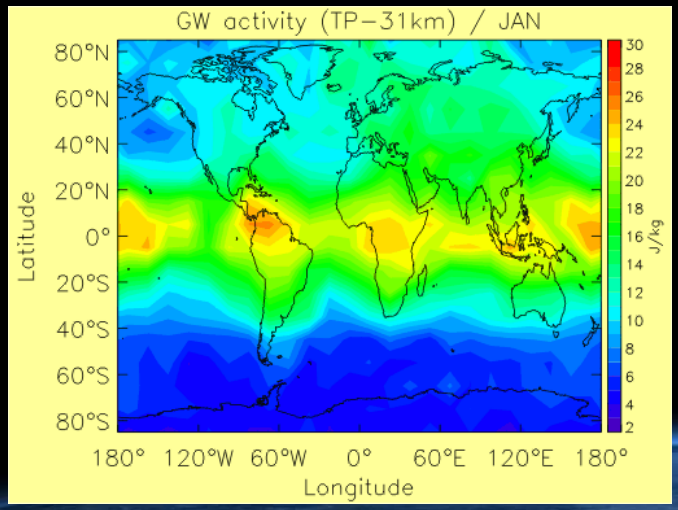
Global tropopause T



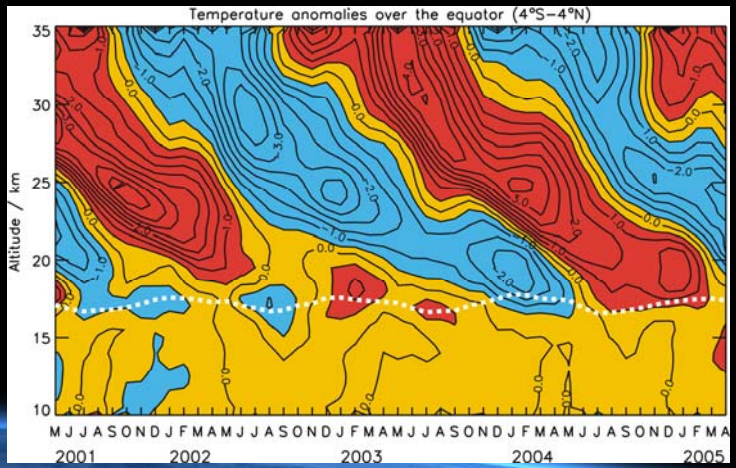
Global tropopause sharpness



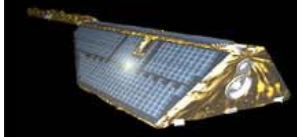
Initial „in-house“ GW analyses

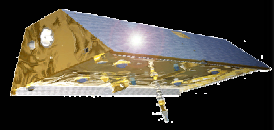


QBO

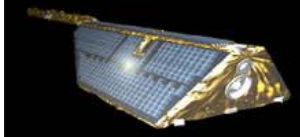


GFZ POTSDAM

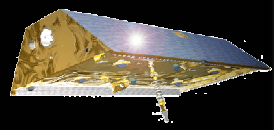




Recent results: Ionosphere



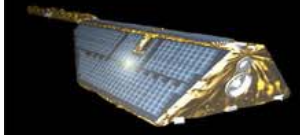
Occultation analysis ionosphere



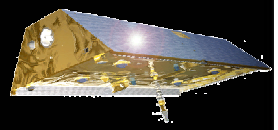
a) Operational data analysis at DLR Neustrelitz (N. Jakowski), ~190,000 profiles available via CHAMP data center

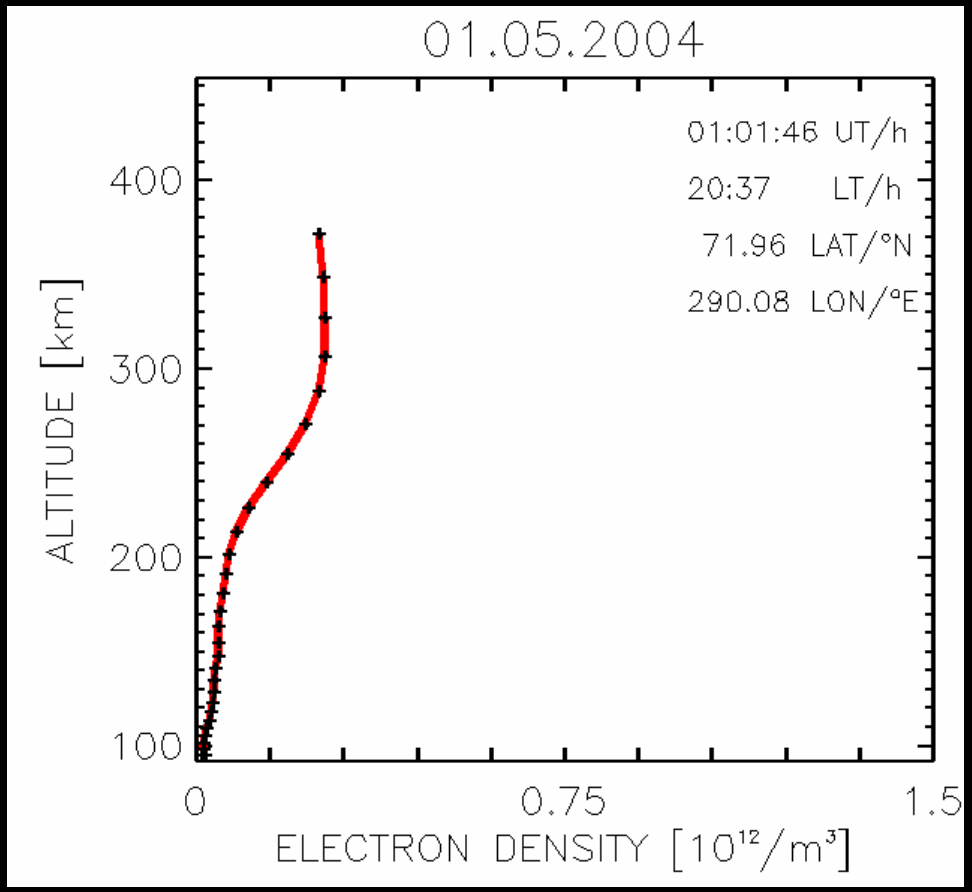
b) Continuous validation with models (e.g. IRI, Nequick) and ground based vertical sounders (e.g., ionosondes)

c) Several applications for ionospheric research demonstrated, here some examples only for the monitoring of SPACE weather events in the profile data

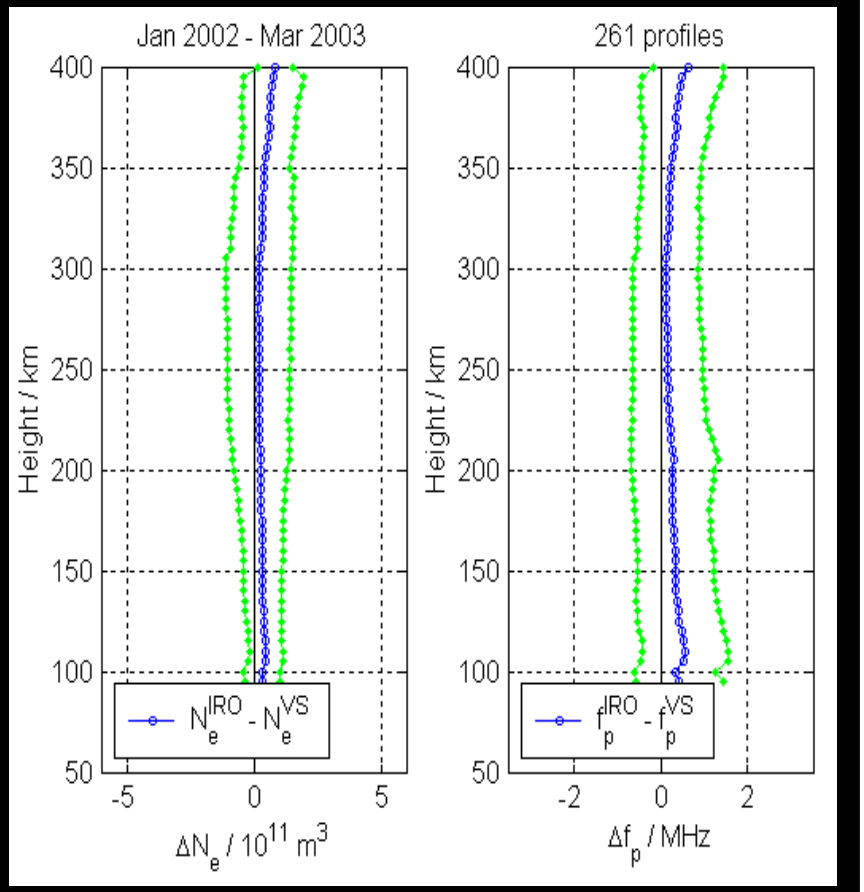


Electron density profiles continously





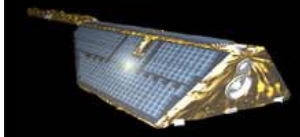
136 CHAMP profiles (May 1, 2004)

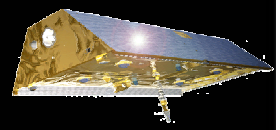


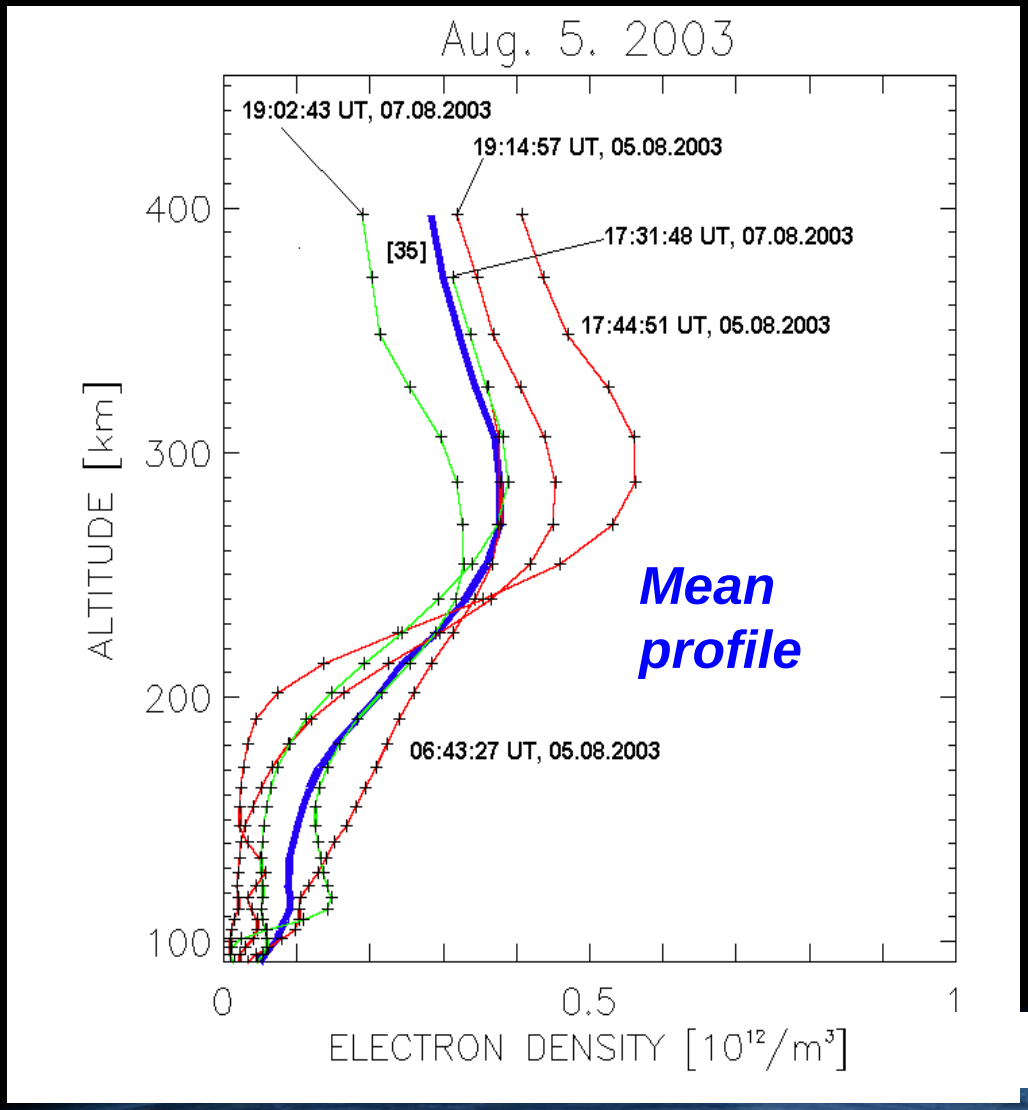
Validation with 261 ionosonde profiles at Juliusruh (Northern Germany)

GFZ POTSDAM

Electron density profiles during the geomagnetic storm on August 5, 2003





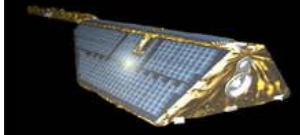


Storm onset:
5 August 2003, 05:00 UT

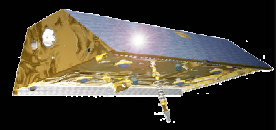
Latitude range: 55-70° deg
Longitude range: 20°W – 40°E

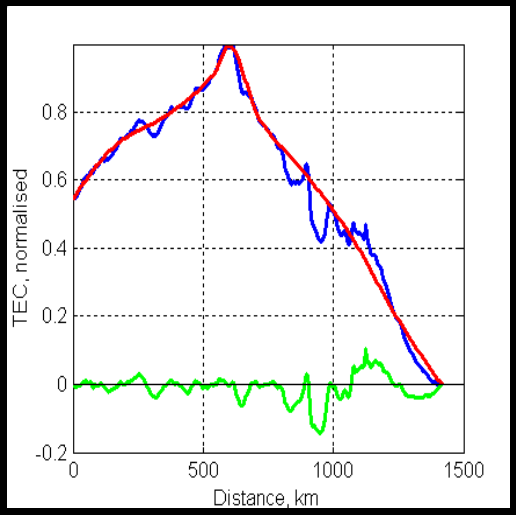
Deformation of profile shape probably due to winds (positive phase)
Enhanced plasma loss on second day (negative phase)

GFZ POTSDAM

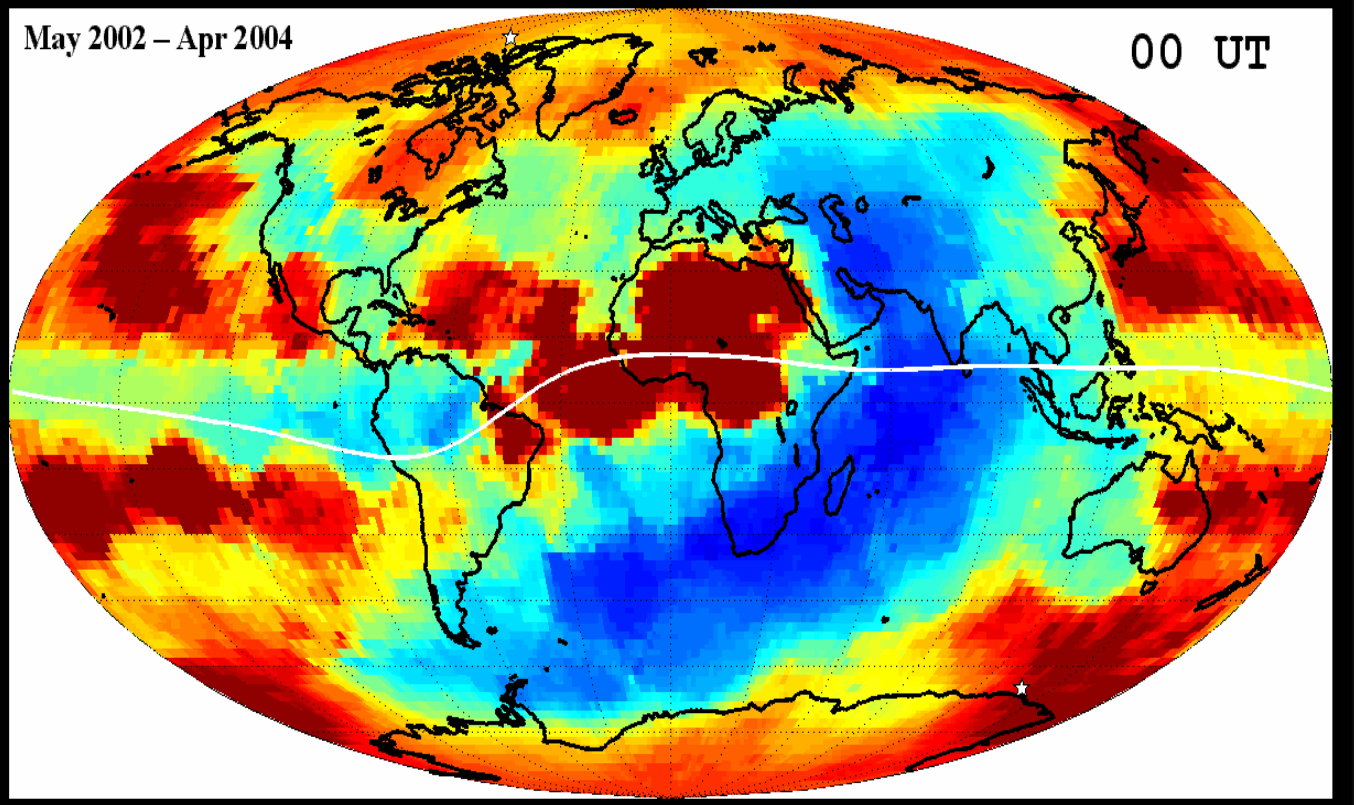


Monitoring ionospheric irregularities



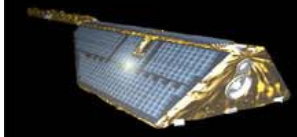


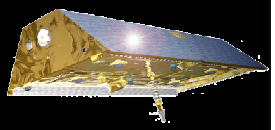
Disturbance Activity



CHAMP measurements from May 02 – April 04 (occultations)

Tsybulya and Jakowski; Geophys. Res. Lett., 2005



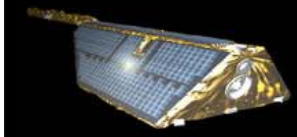


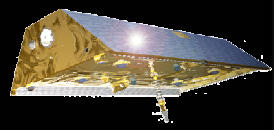
First GRACE measurements: Zero Differencing

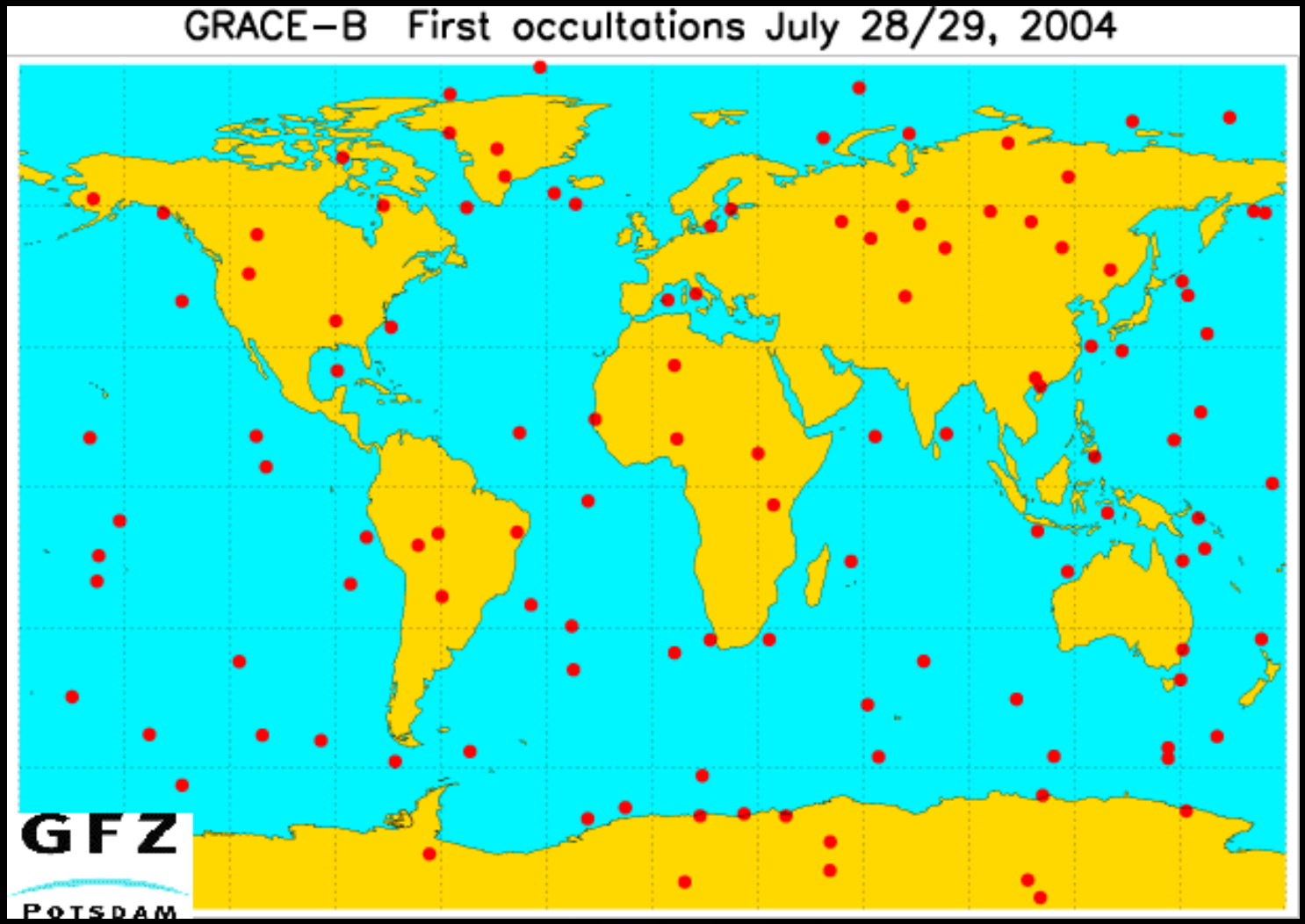
For details: Beyerle et al., 2005; Wickert et al., 2005

GFZ POTSDAM

GRACE –B occultations





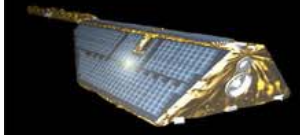


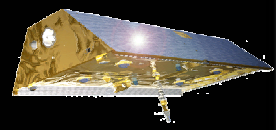
Global distribution (120 events)

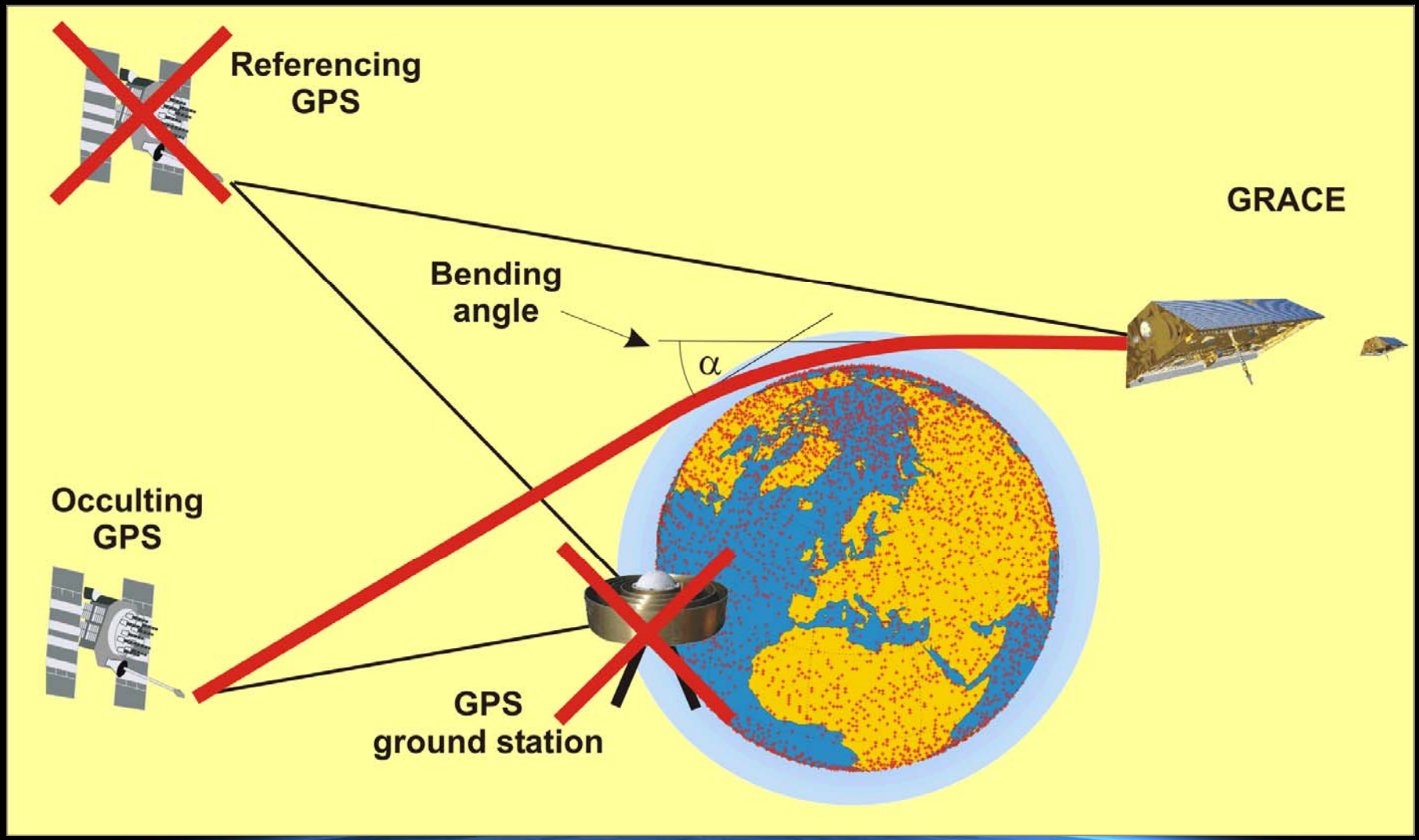
Radio Occultation User Workshop, August 22, 2005

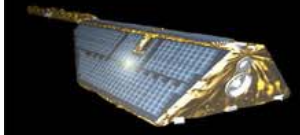
GFZ POTSDAM

Zero differencing

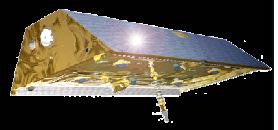




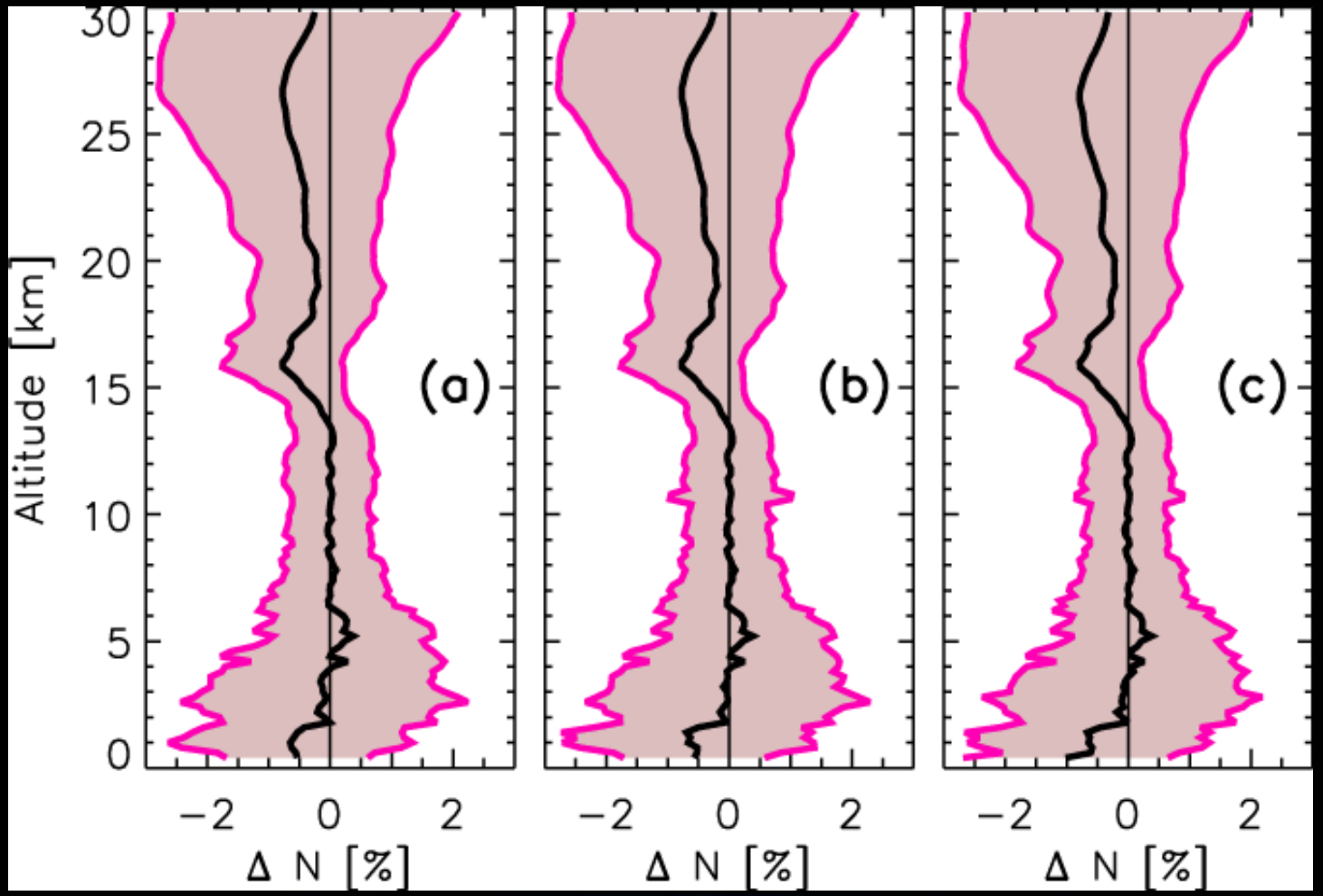




Zero Differencing: GRACE

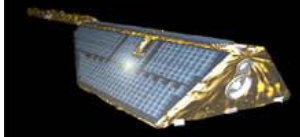


Deviations in relation to ECMWF (96 profiles)



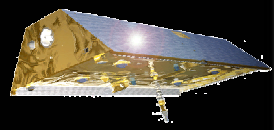
Differencing a) double b) single c) zero

GFZ POTSDAM

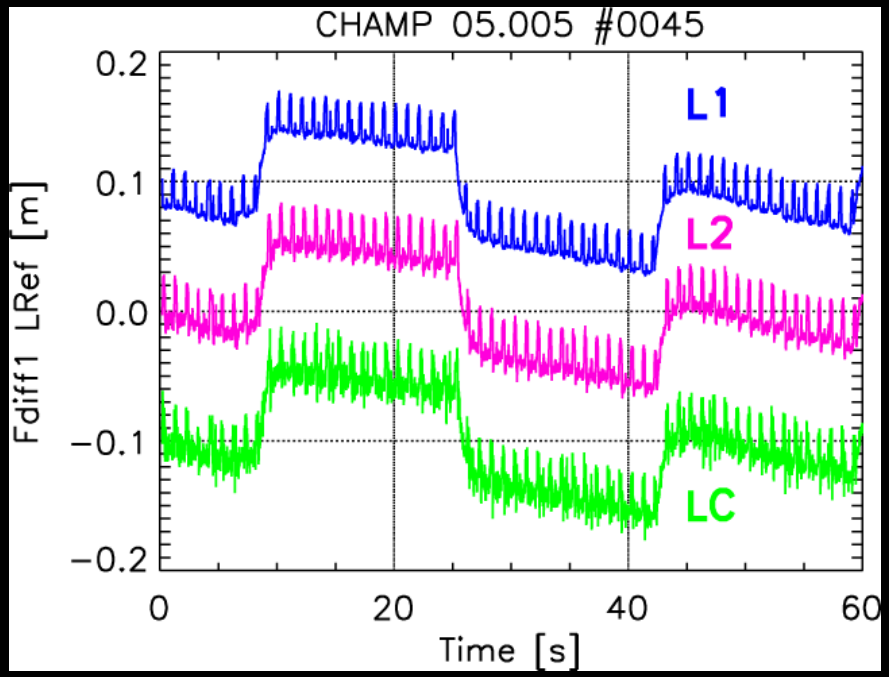


LEO clock rates

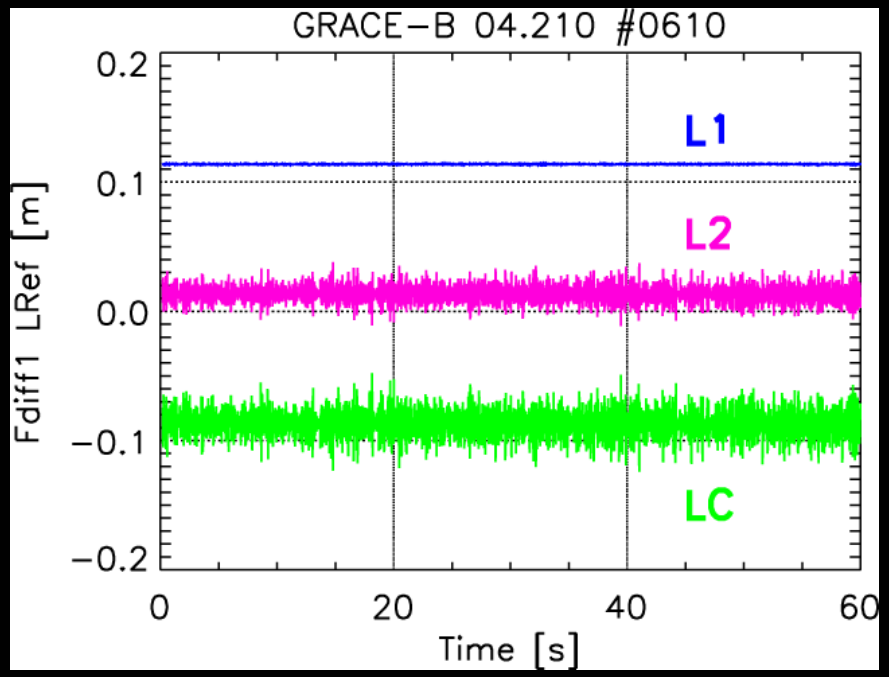
(as can be seen in the phase forward differences)



CHAMP

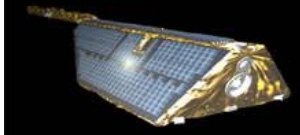


GRACE

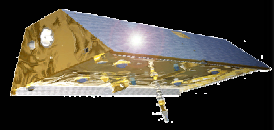


1 and 18 s irregularities induced by clock adjustments

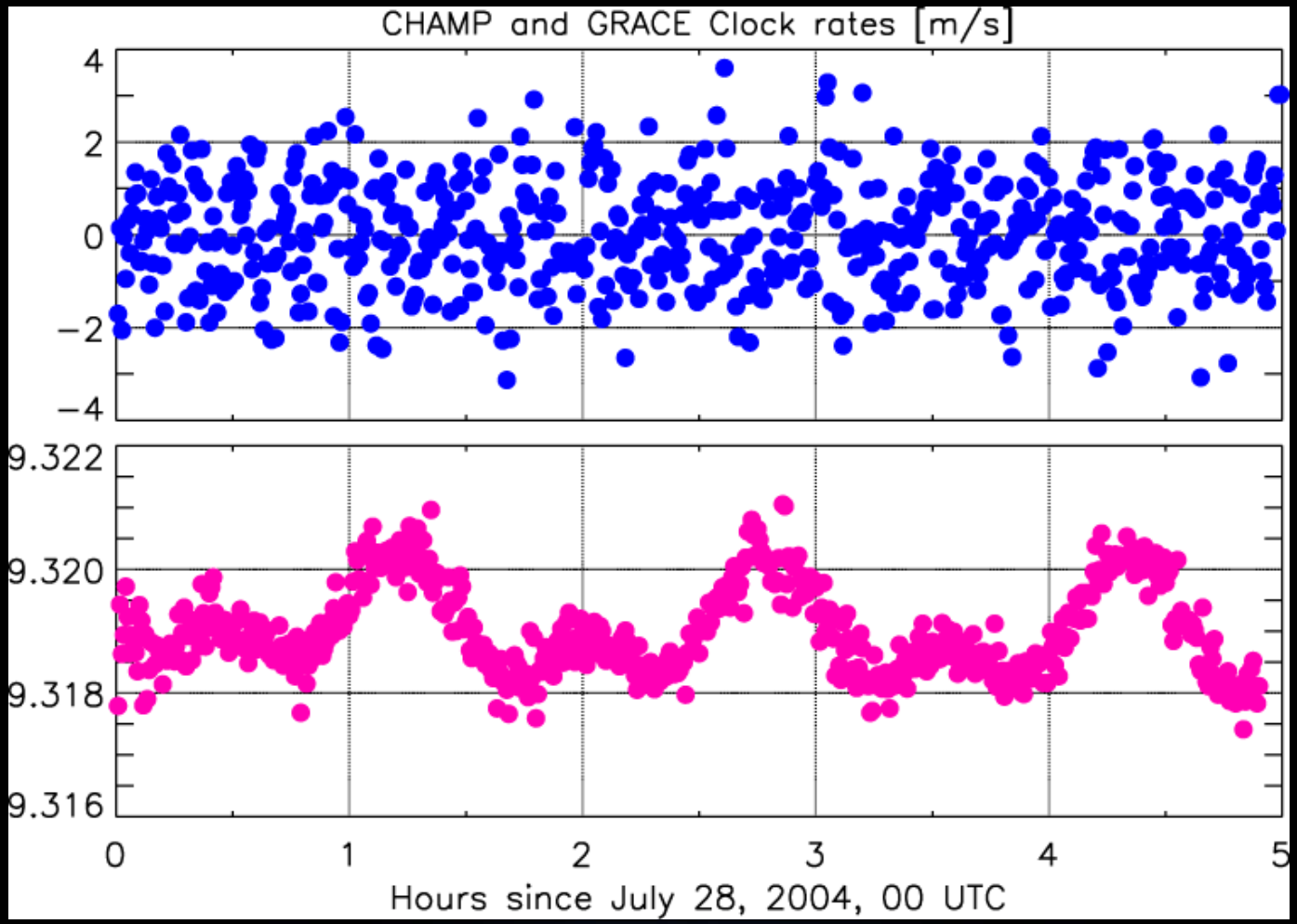
GFZ POTSDAM



30s clock solutions from POD

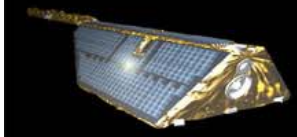


Significant more stable 30s GRACE clock solutions

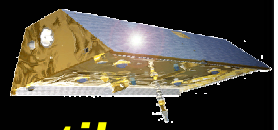


Causes for the period structures still not explained

GFZ POTSDAM



Summary



- *The operation of the CHAMP mission is funded at least until 2007. The first long term set of occultation measurements is expected. Currently ~210,000 profiles available, (~190,000 ionosphere) . Operational data analysis at GFZ*
- *Near real time activities are further stimulated by a national funded research project with weather services (ECMWF, MetOffice, DWD)*
- *End2end simulations to investigate negative refractivity bias*
- *Activities to apply the RO data in the UTLS region (tropopause, gravity waves, QBO; ionospheric profiles can be used to detect space weather events (e.g. storms, irregularities)*
- *First GRACE measurements indicate the feasibility of advantageous zero differencing*
- *We wish successful launches and look forward to COSMIC and Metop!*