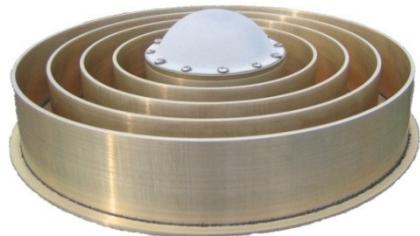




Remote Sensing with Navigation Satellites: Recent Activities and Results

J. Wickert

C. Arras, G. Beyerle, M. Bender, J. Chen, Z. Deng, G. Dick, C. Falck,
F. Flechtner, C. Förste, M. Ge, G. Gendt, A. Haser, S. Heise,
M. Ramatschi, T. Schmidt , M. Semmling, R. Stosius



**German Research Centre for Geosciences
GFZ, Germany**

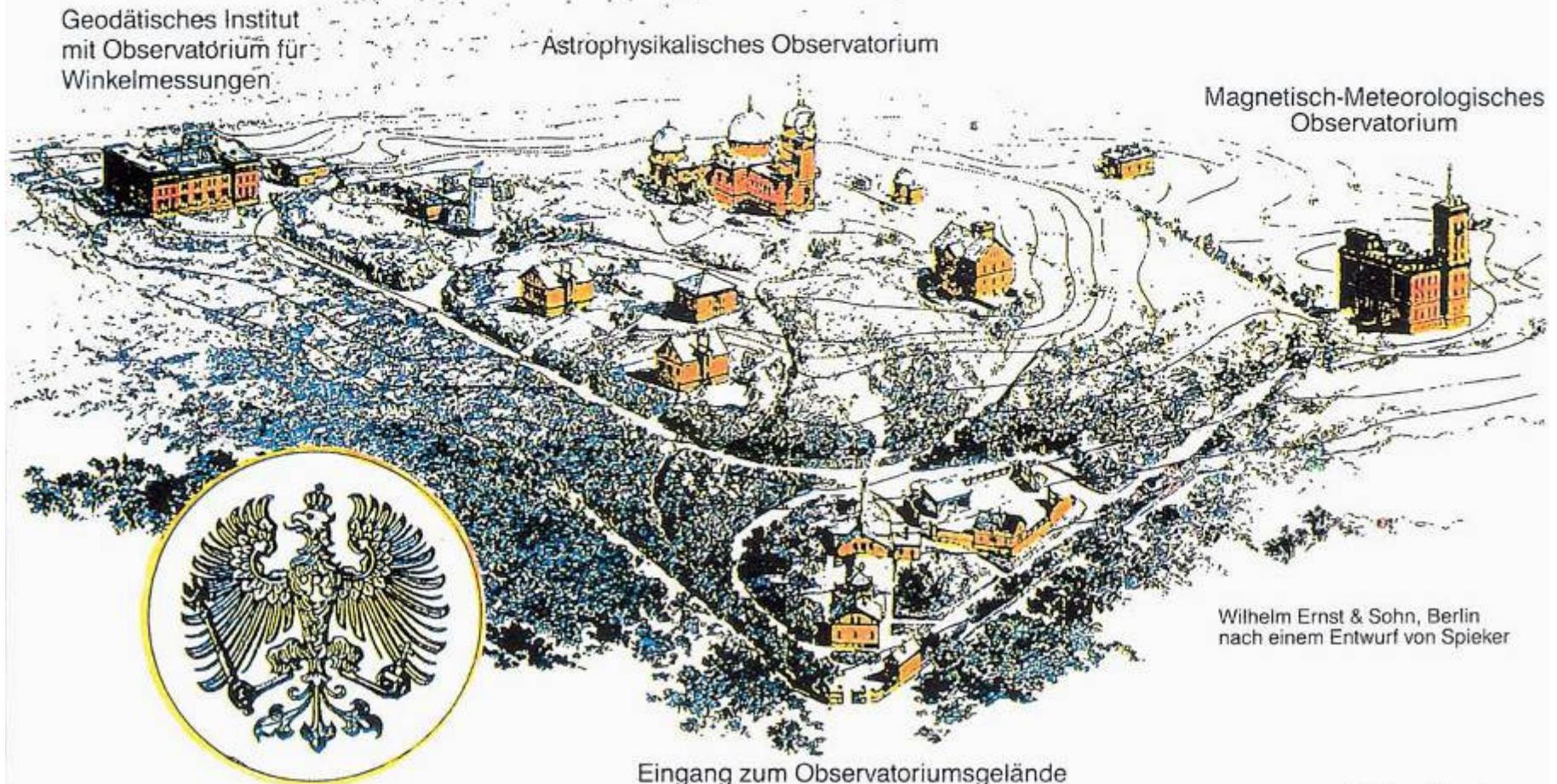
1

The German Research Centre for Geosciences GFZ

The German Research Centre for Geosciences



Die Königlich Preußischen Observatorien bei Potsdam auf dem Telegraphen-Berge (um 1892)





Potsdam Telegrafenberg (GFZ)

Department
Geodesy and
Remote Sensing

2

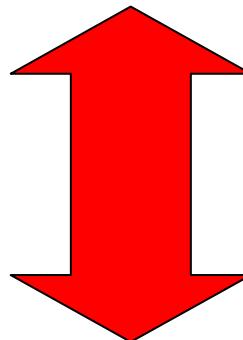
Atmosphere/Ionosphere

Sounding with GPS

GPS: A story of success



Positioning



Remote sensing

1995:

GPS operational

2006:

**operational use of GPS for
numerical weather
forecast**

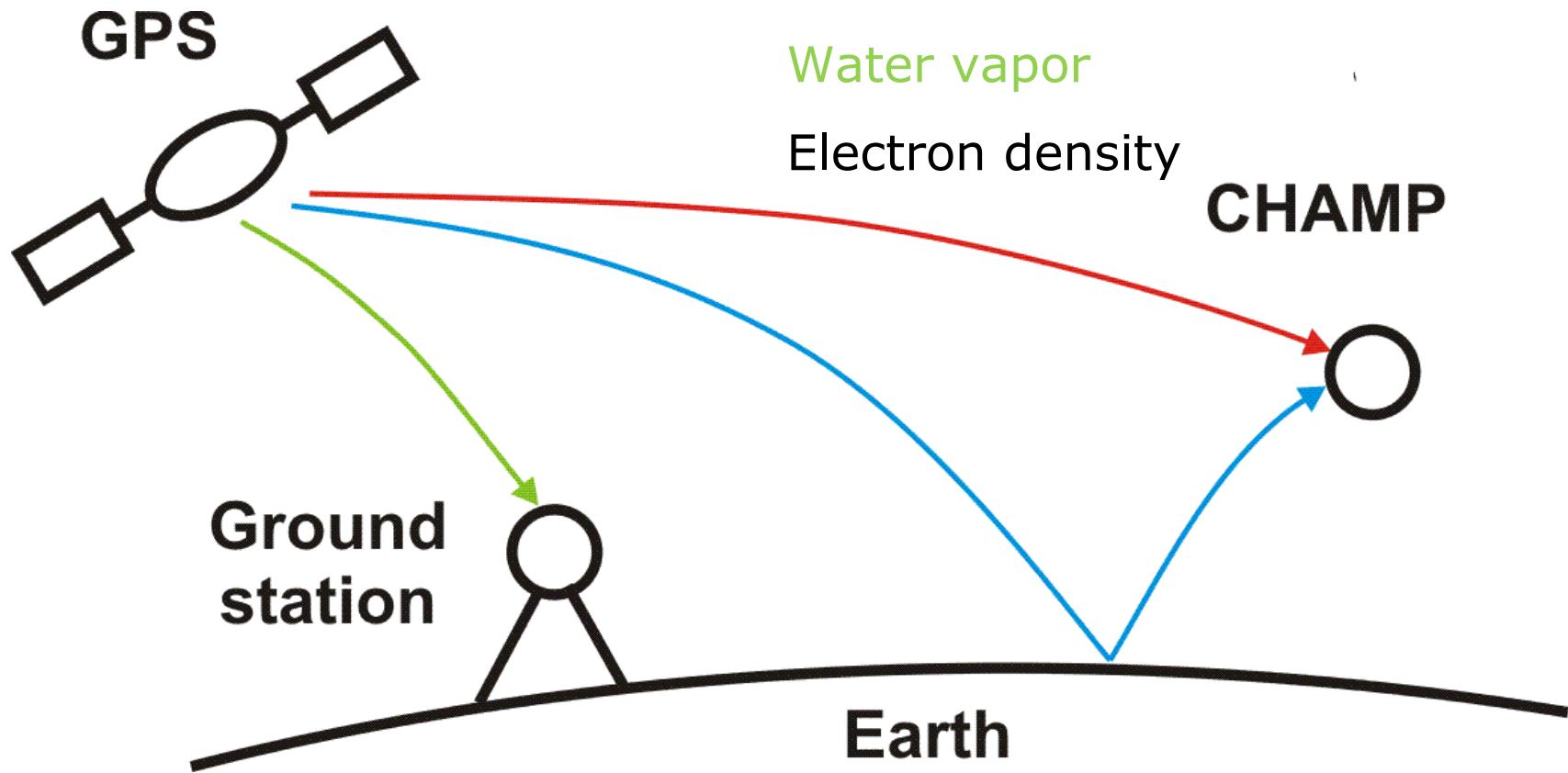
Symbiosis: Positioning and Remote Sensing with GPS

Temperature and water vapor

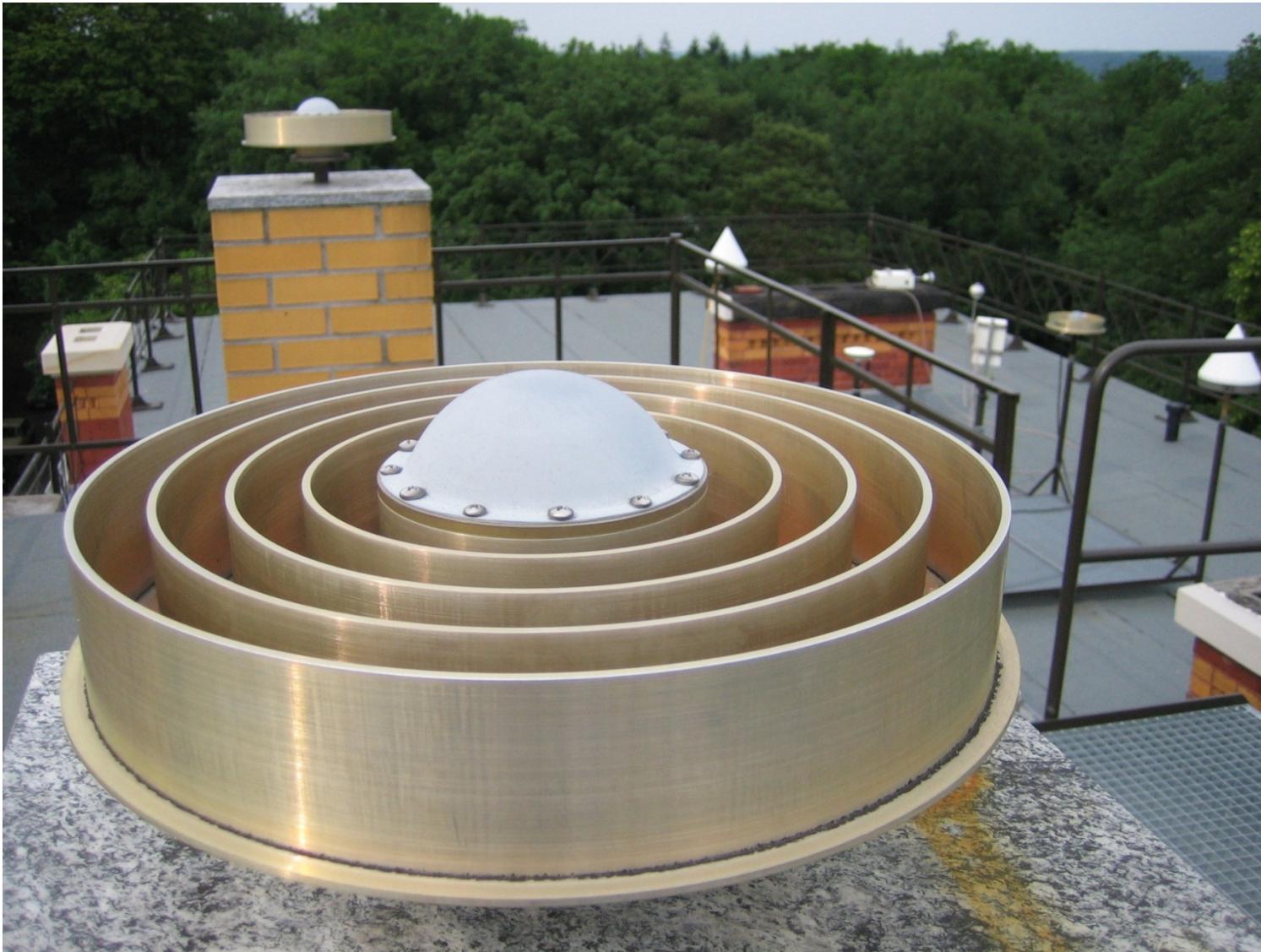
Water and ice surfaces

Water vapor

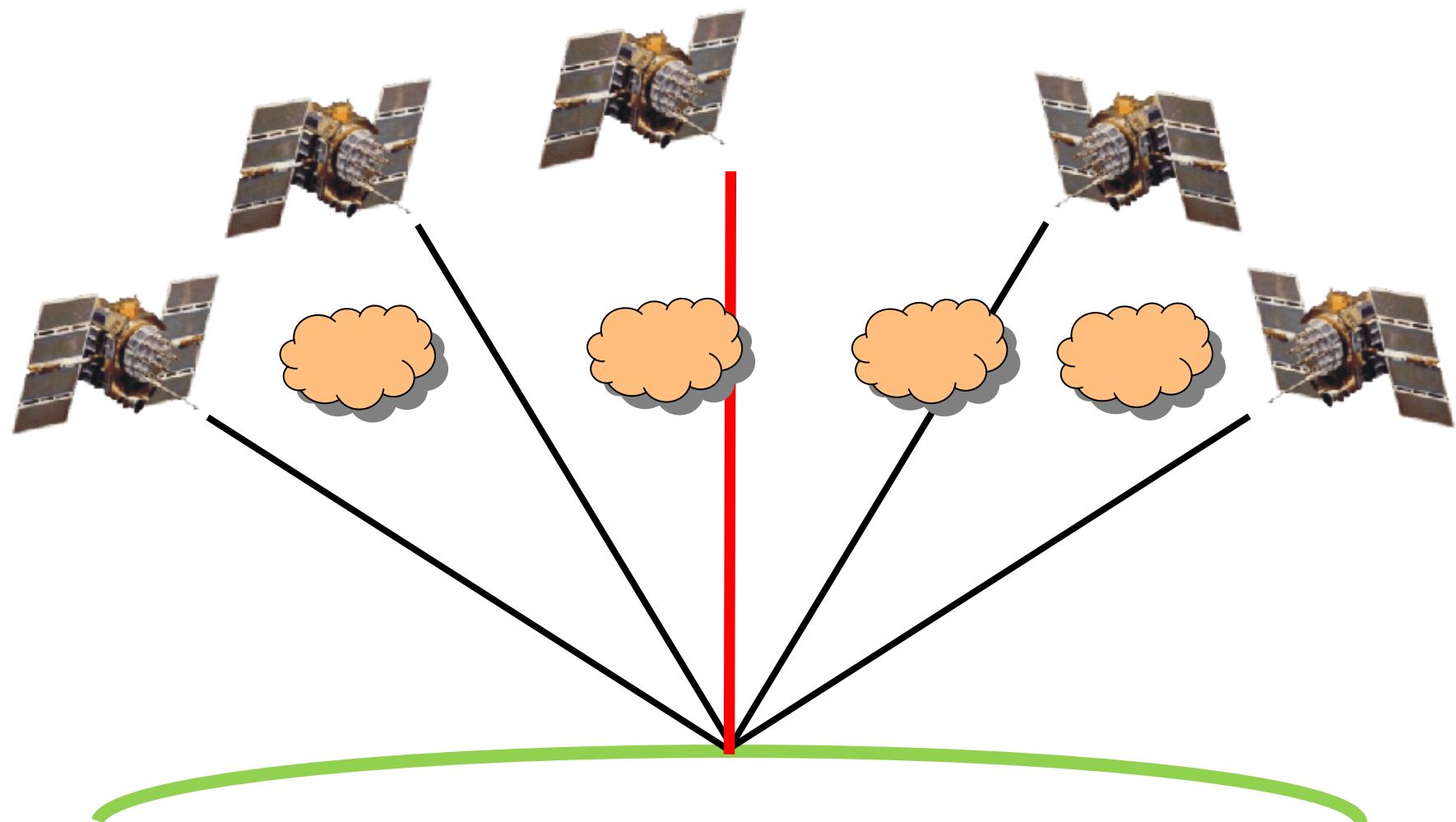
Electron density



GPS ground station Potsdam

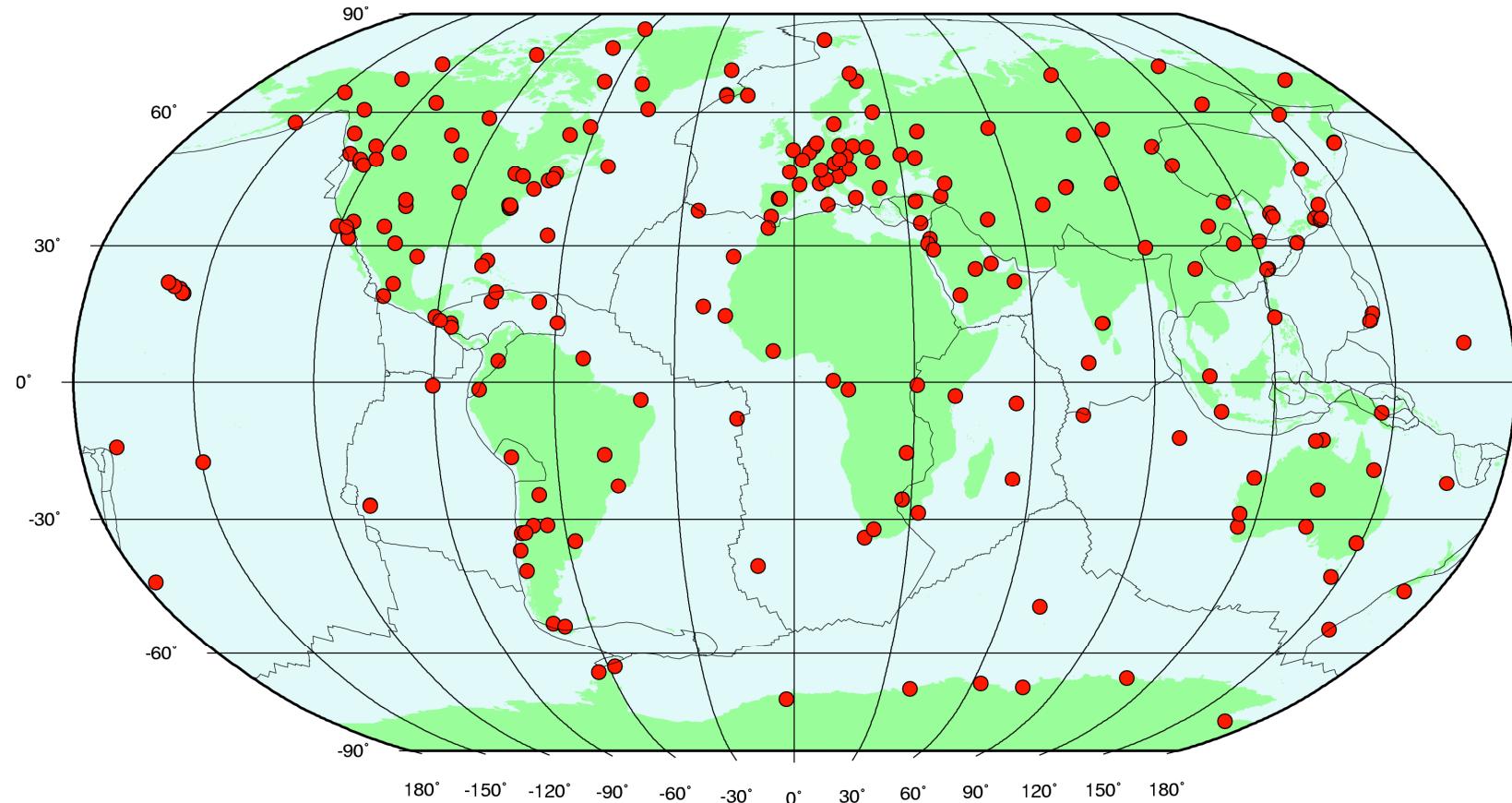


Vertically integrated water vapor



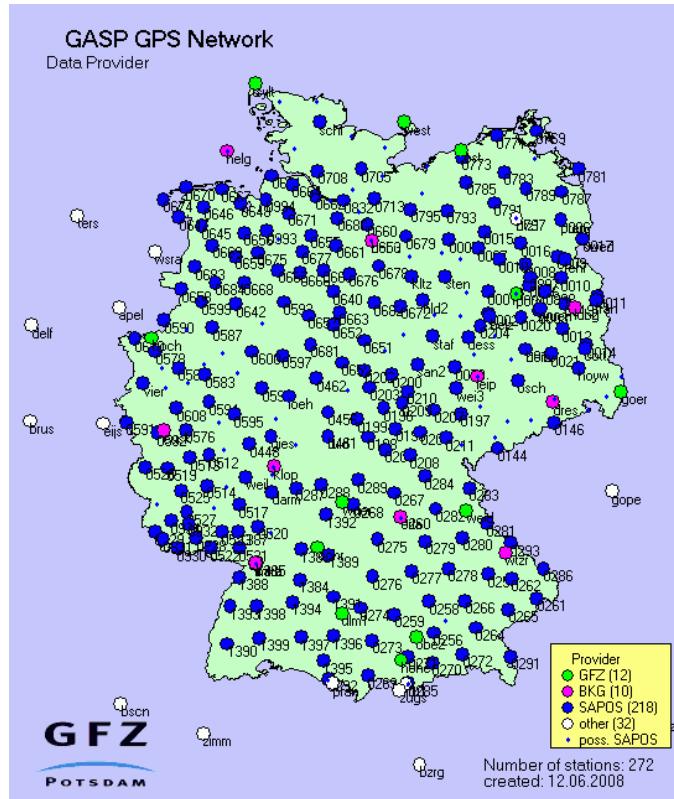
Global GPS ground network

~200 stations analyzed at GFZ

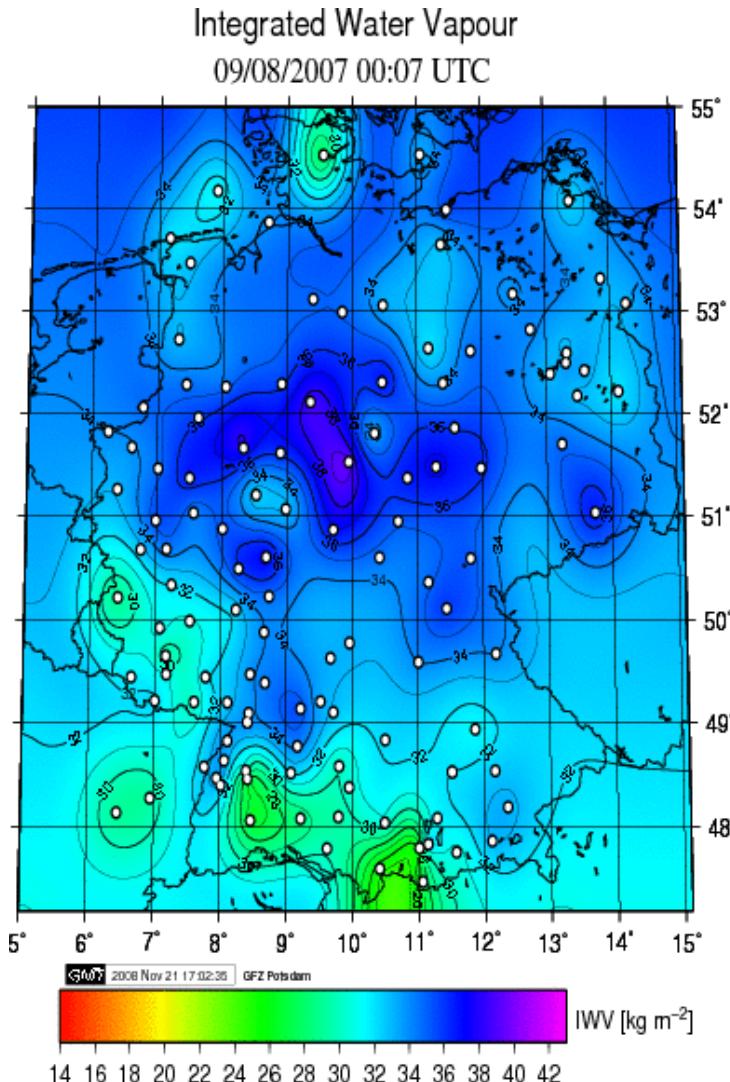


Some stations since 1993, different climate zones

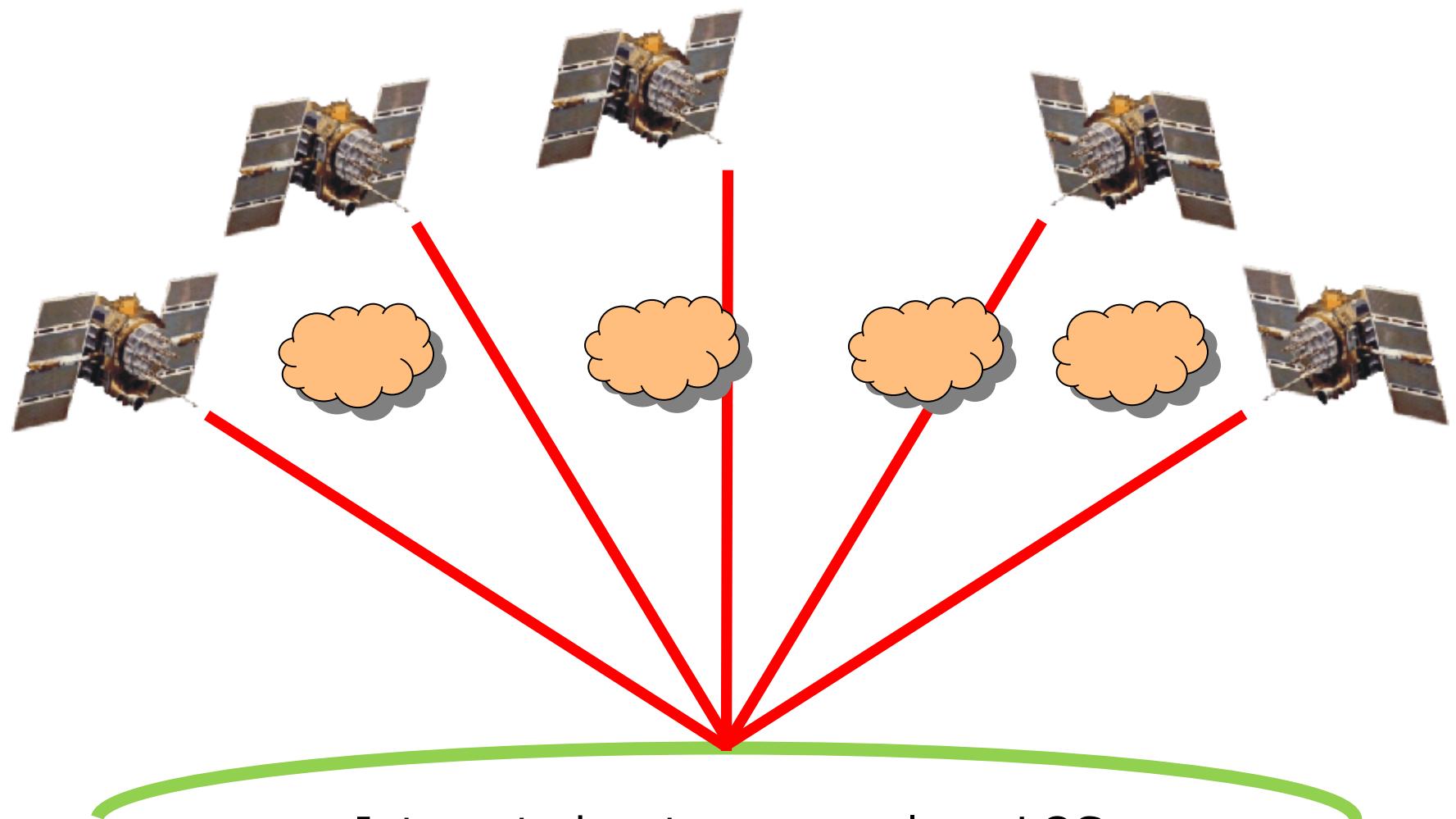
Regional ground networks: E.g., Germany



Water vapor information
in near-real time, operational
use in weather forecast

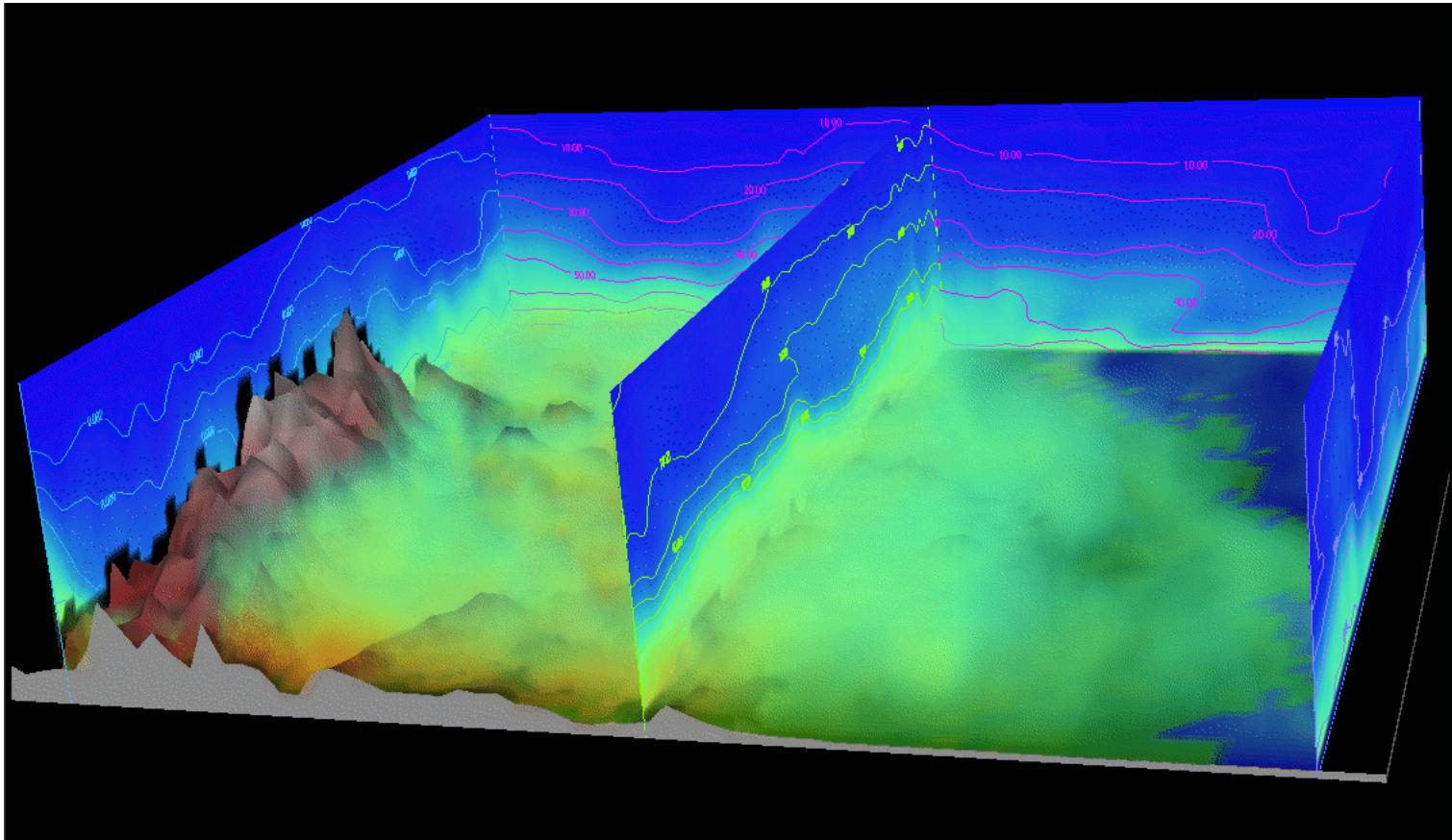


Recent extension: Slants and 3D water vapor



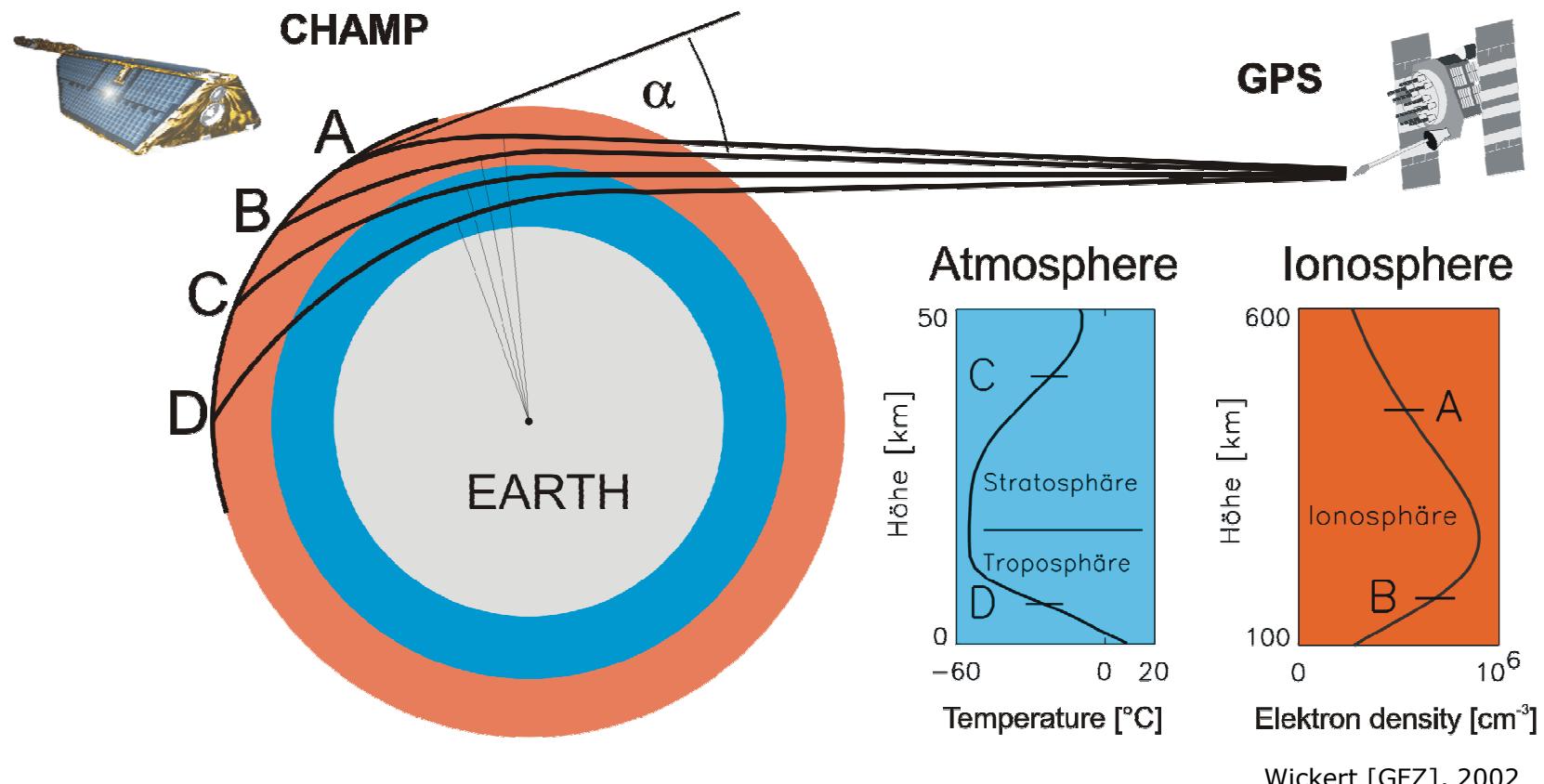
Integrated water vapor along LOS
is the base for 3D reconstructions

GPS tomography: Towards 3D water vapor



3D water vapor distribution above Germany

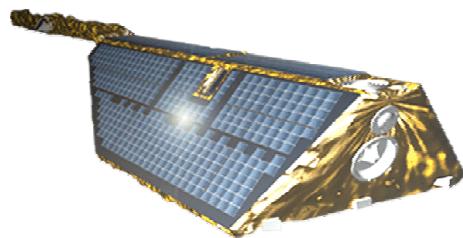
GPS radio occultation



Key properties: global coverage, all-weather, calibration free,
very precise, high vertical resolution

very attractive for weather forecast, climate and atmospheric research

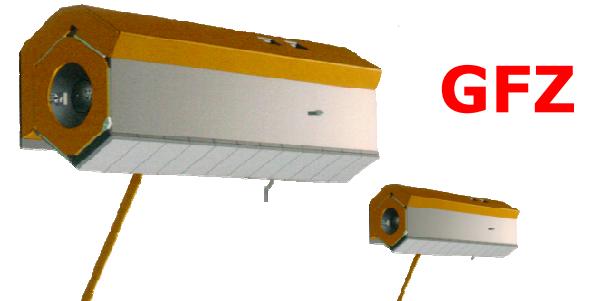
Navigation receivers for occultations on satellites



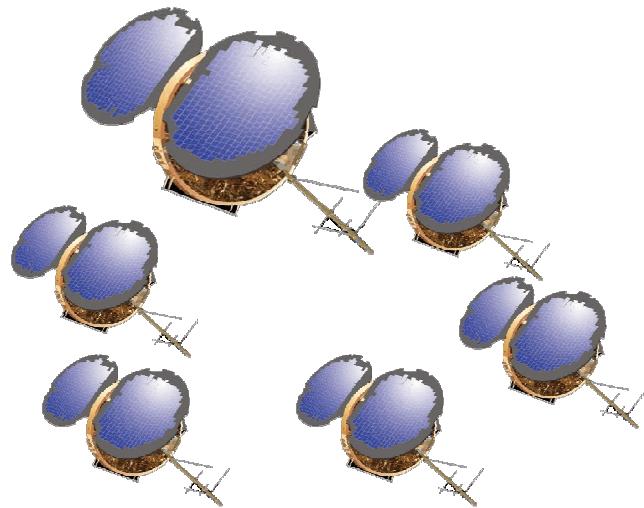
CHAMP (since 2000)



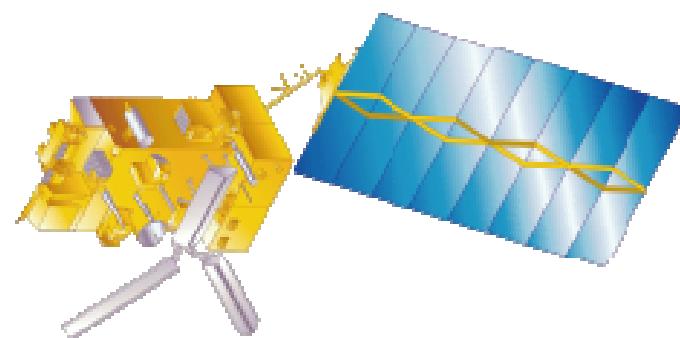
GRACE (since 2002)



TerraSAR/TanDEM-X

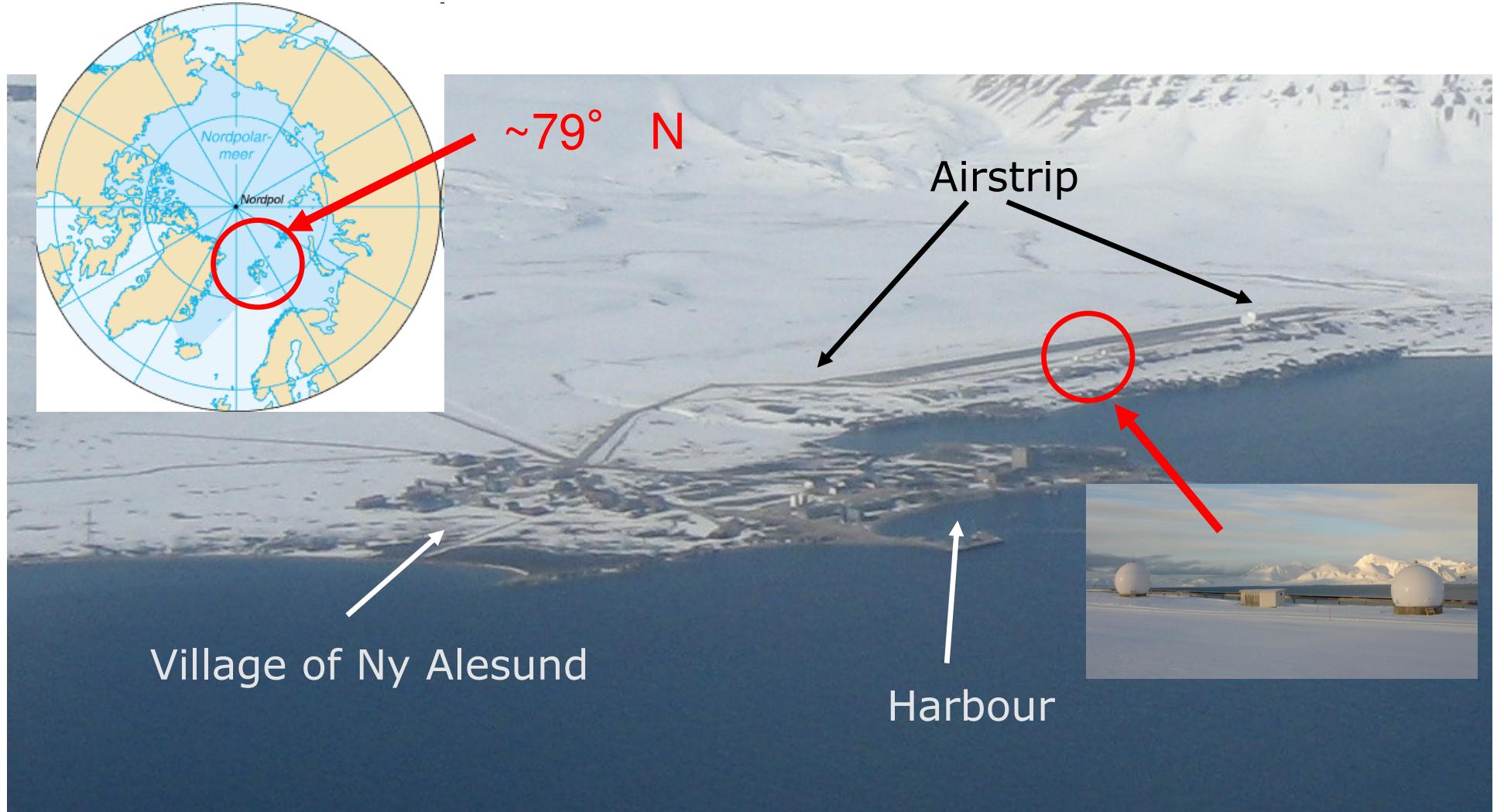


FORMOSAT-3/COSMIC
(6; since 2006)



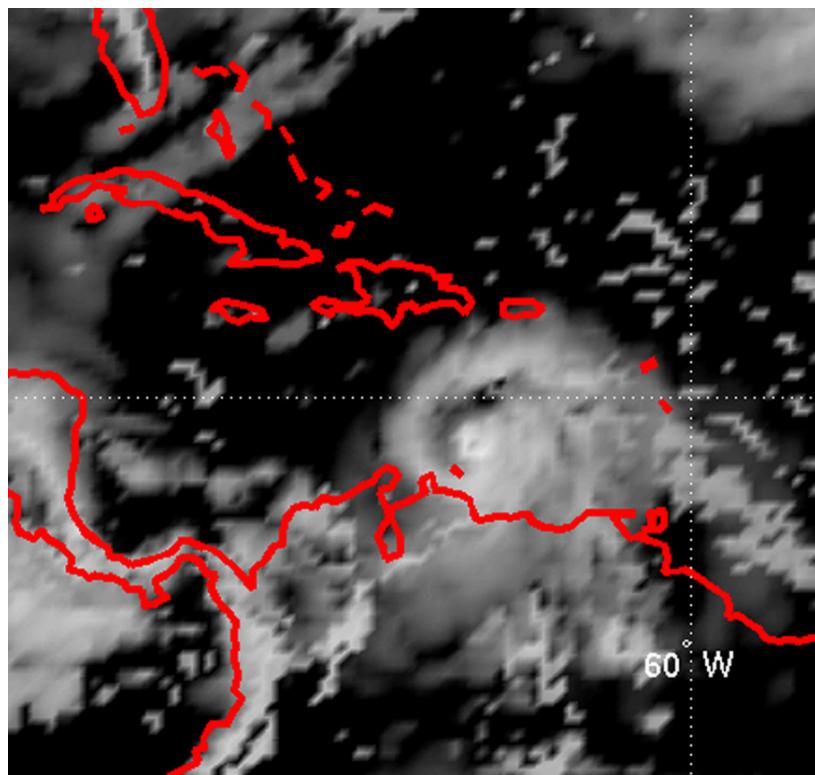
Metop (since 2006)

GFZ satellite receiving station at Ny Alesund, Spitsbergen

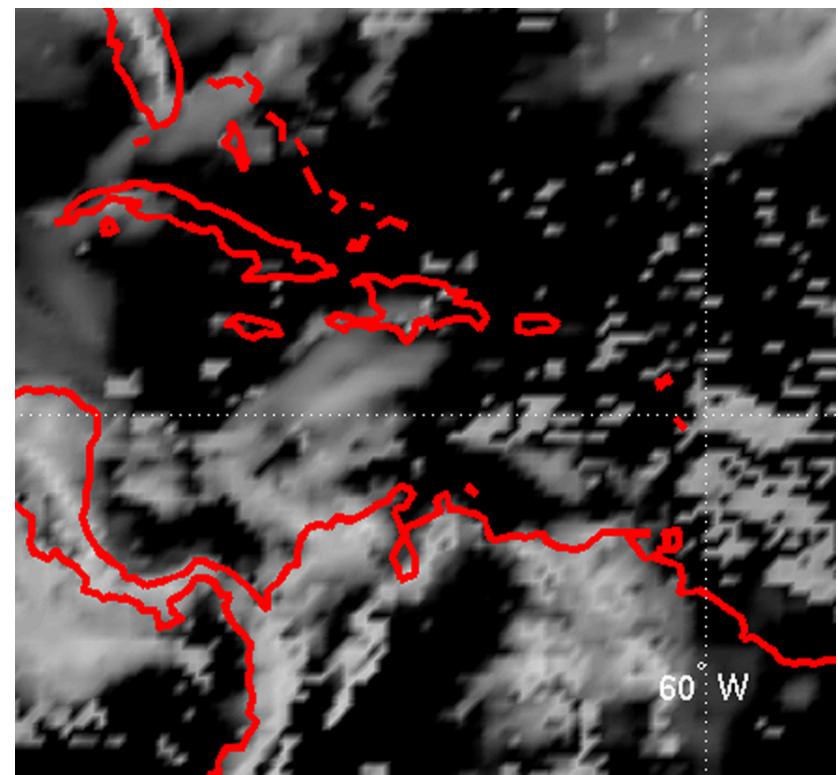


Improvements of typhoon forecasts with GPS: e.g., Ernesto (2006)

With GPS

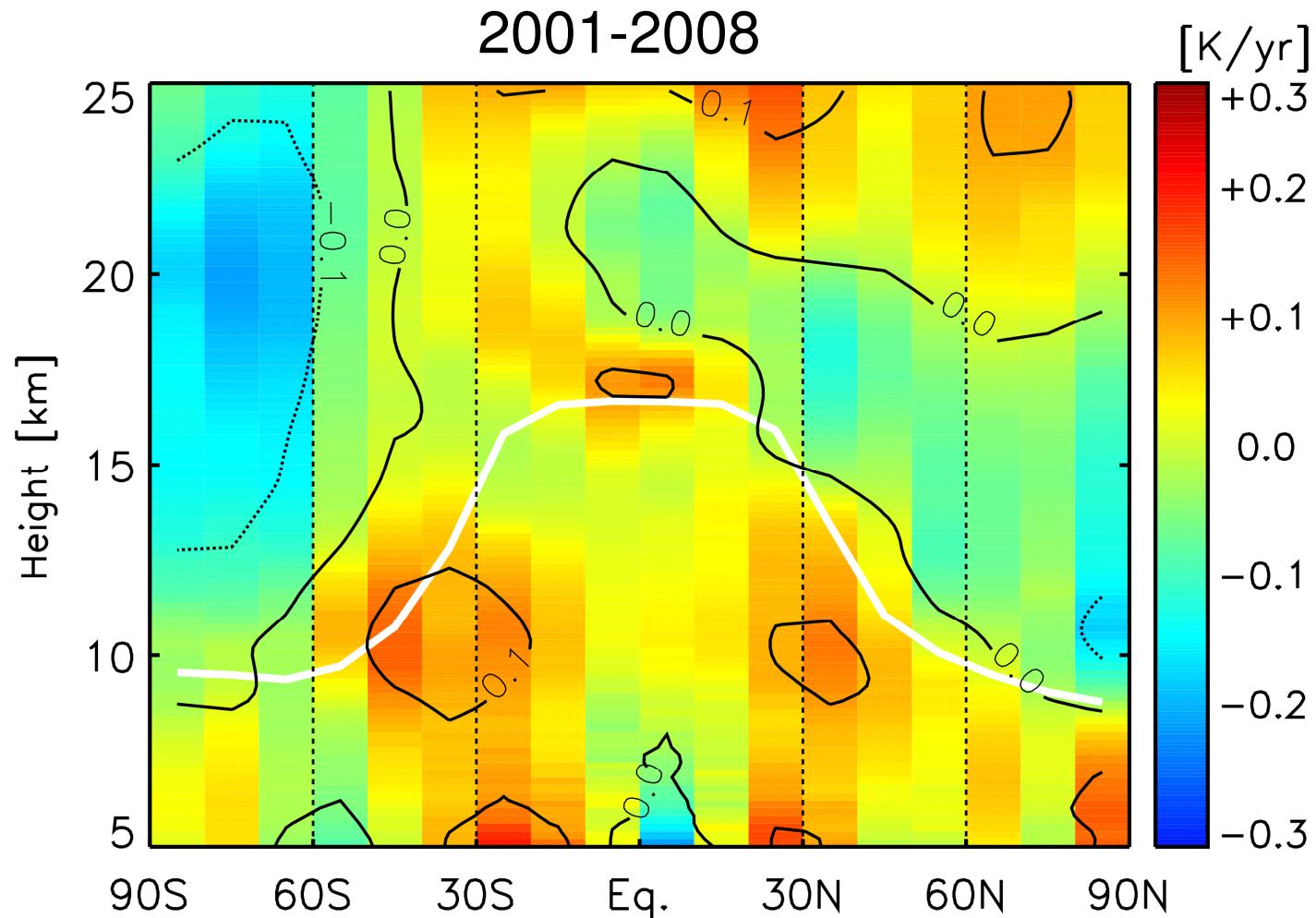


Without GPS



Liu, NCAR

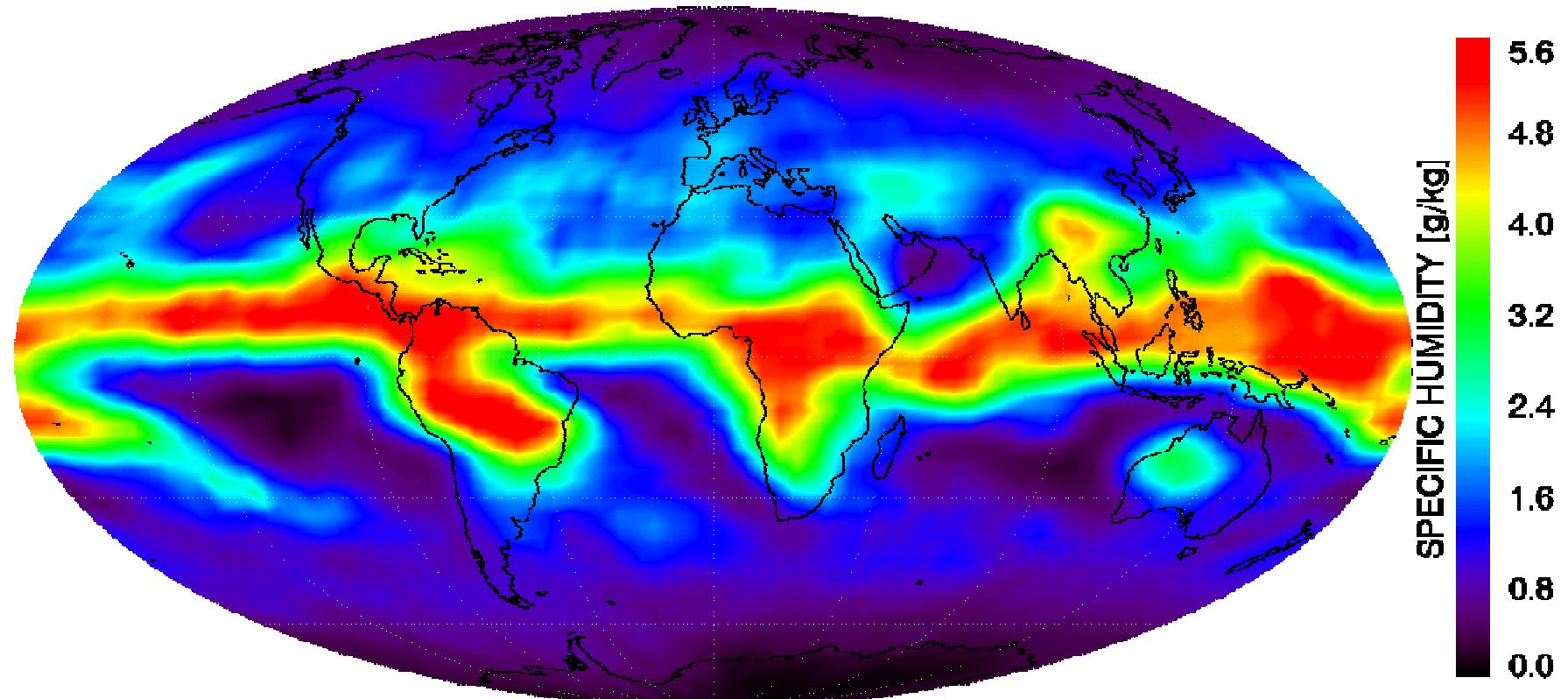
Global Temperature Trends from GPS data



Schmidt [GFZ] et al., 2010

Global water vapor distribution from GPS data

CHAMP + GRACE + COSMIC



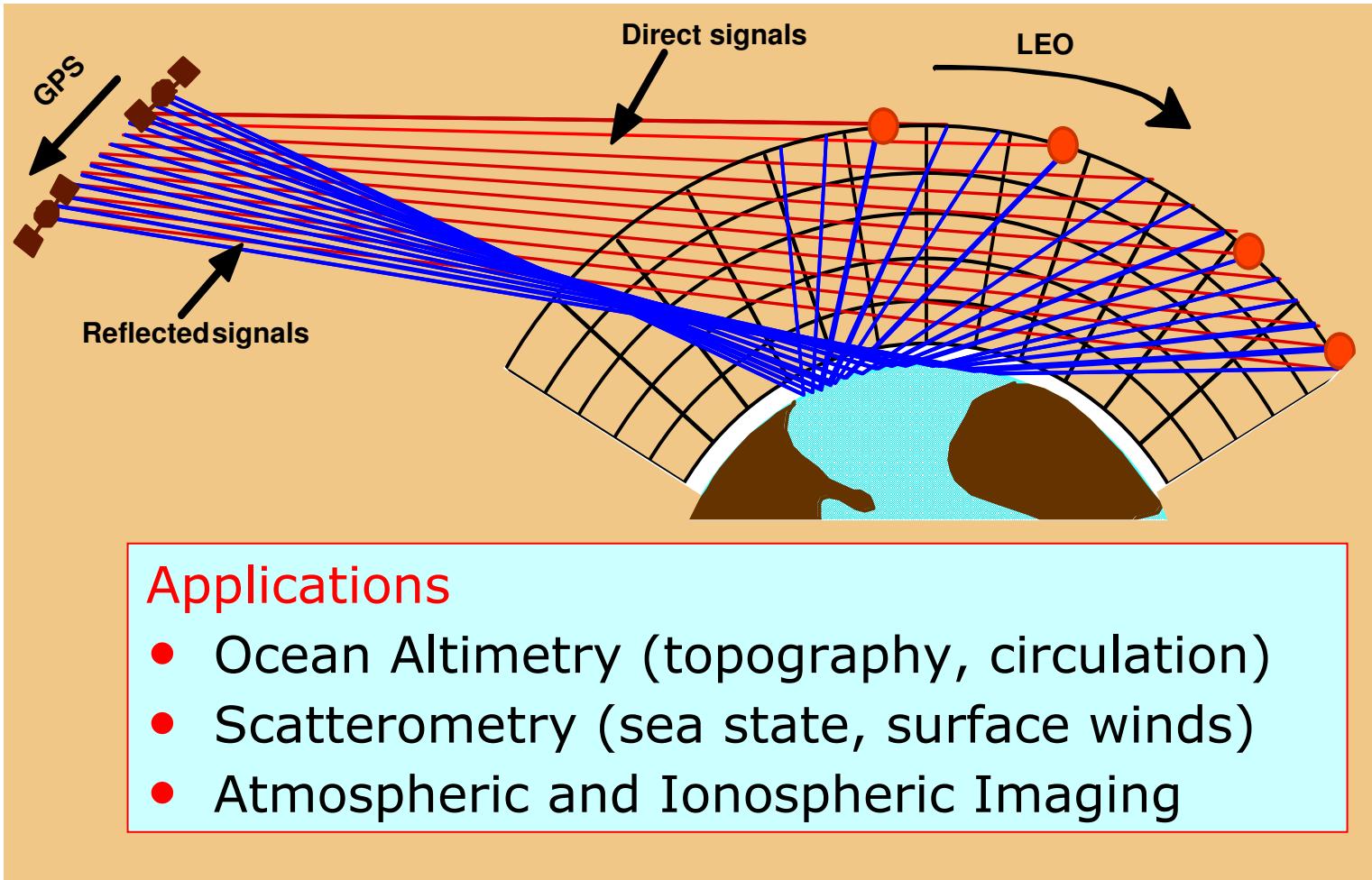
Mean specific humidity at 4 km altitude October 2006

Heise [GFZ] et al., 2008

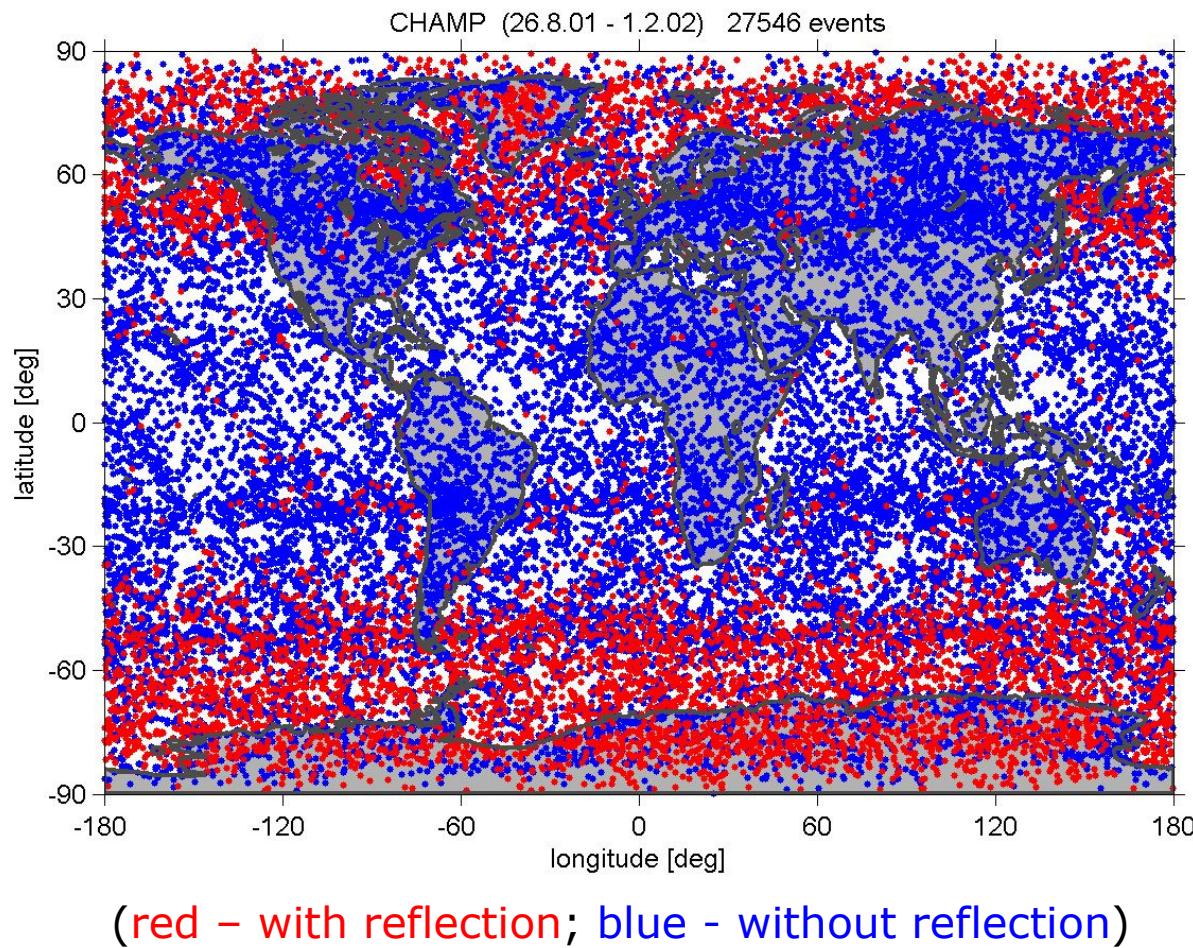
3

GPS reflections

Remote Sensing with Reflected GNSS



Space based ocean and ice reflections (as seen by CHAMP)



5 months of CHAMP occultation data (Beyerle et al. 2002, JGR)

Recent ESA-Project:

Reflections over sea ice

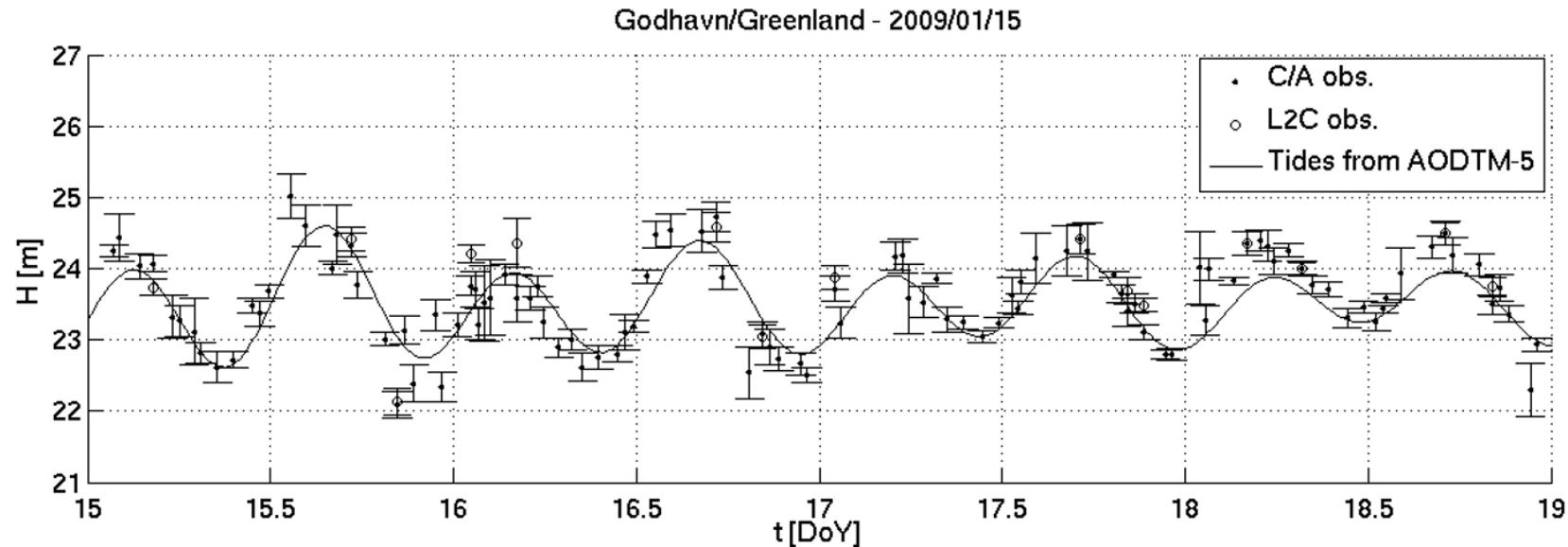
in Greenland

Disco bay, West Greeland
View from GPS reflectometry measuring place



Photo: M. Soerensen (DMI)

Monitoring of tides in Greenland with GPS

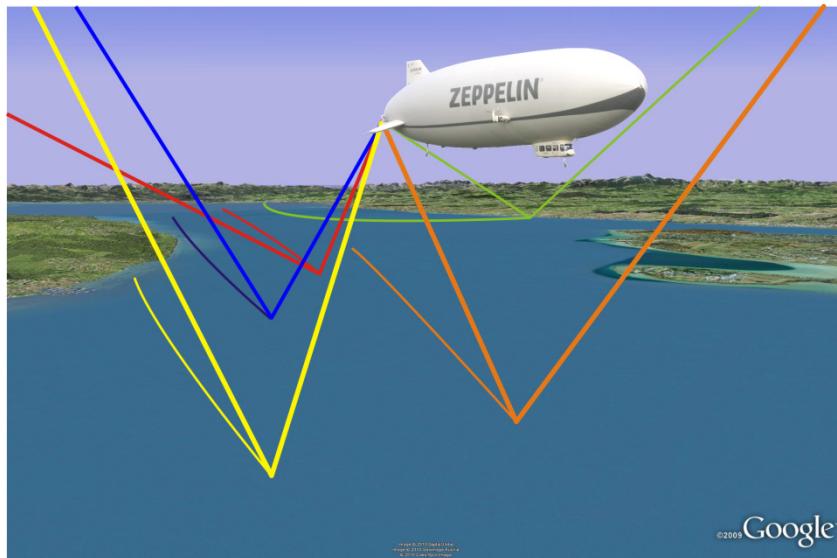


- Very promising results
- max. tide amplitude 2 m
- Tide model in coastal region not optimal

Semmling [GFZ] et al., 2011, GRL

Flight experiments

Zeppelin NT

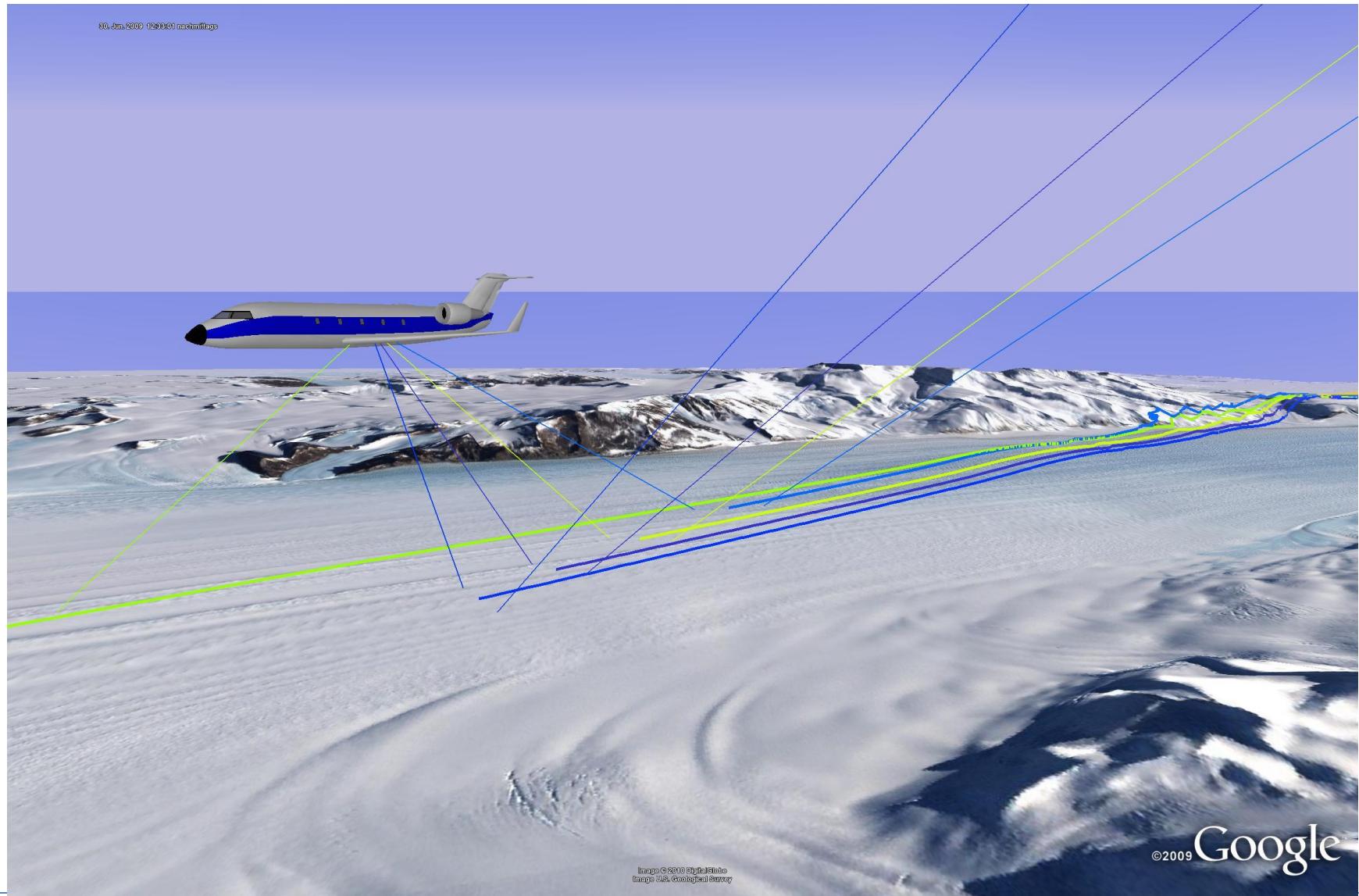


Research aircraft HALO

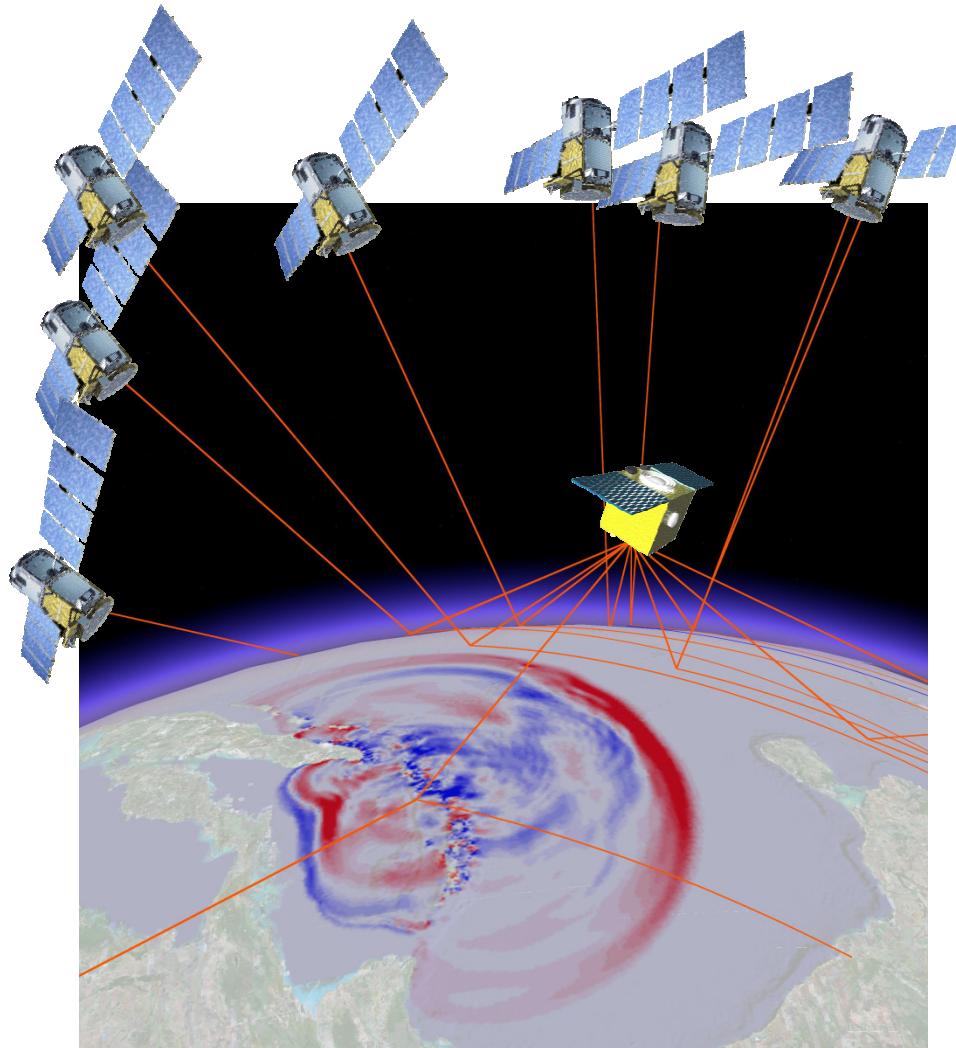


GPS reflectometry; occultations

Example: GPS-Reflektometrie mit HALO



GNSS reflectometry for Tsunami detection with satellites in Low Earth Orbit (LEO)

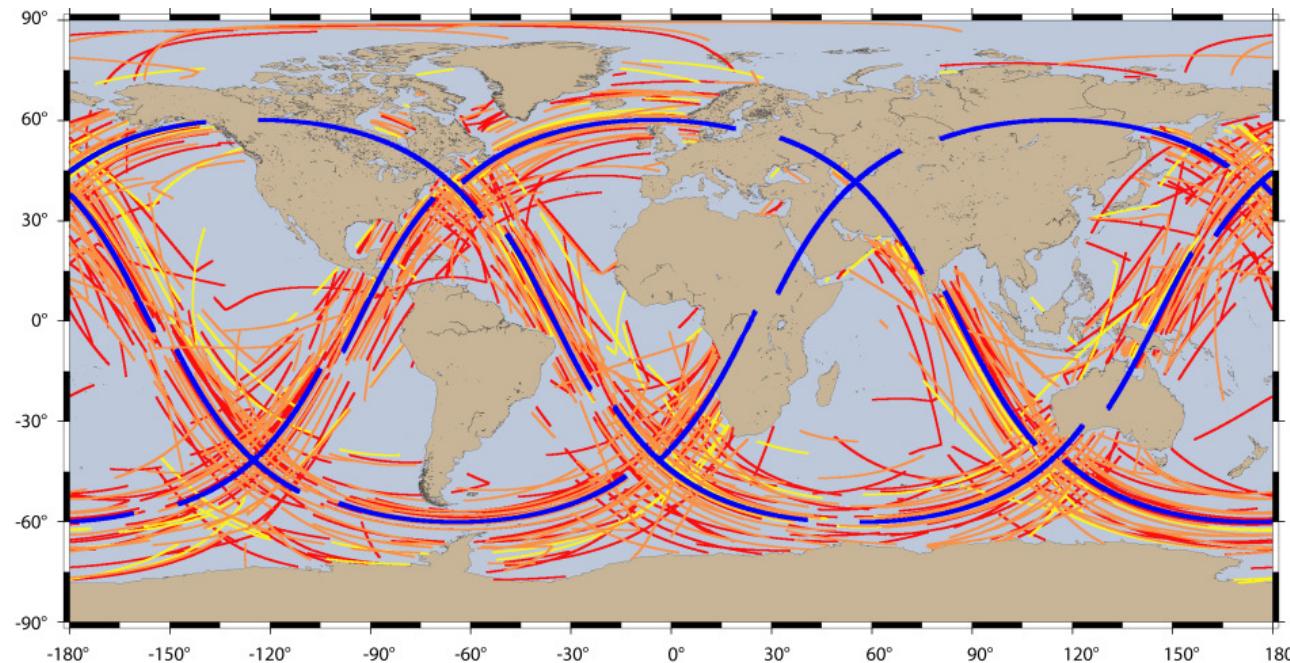


GITEWS
German-
Indonesian
Tsunami Early
Warning System
(2005-2009)

GNSS Research
project for next
generation
satellite based
system (receiver
+ simulations)

Satellite constellation for GNSS reflectometry (Simulation study)

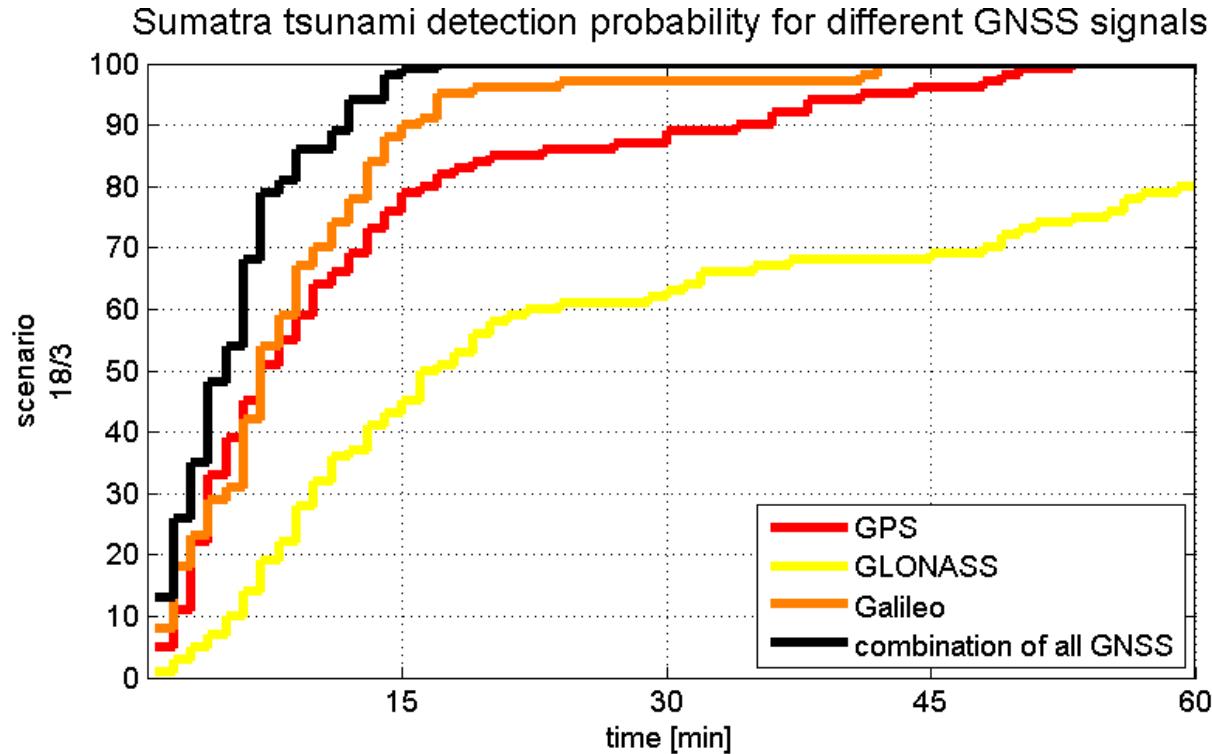
Satellite ground (450 km orbit altitude, 60° inclination)



18 Sat., 3 planes, 15 min

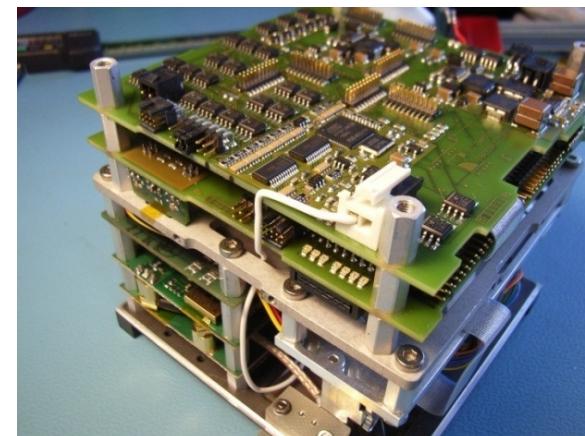
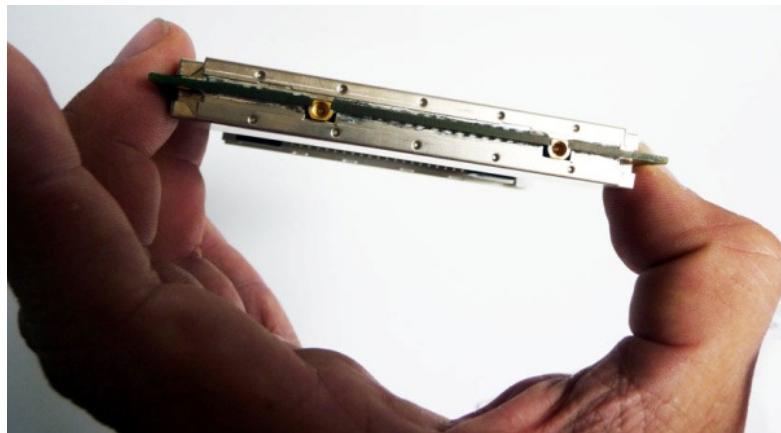
GPS GLONASS GALILEO

Detection results for Sumatra tsunami

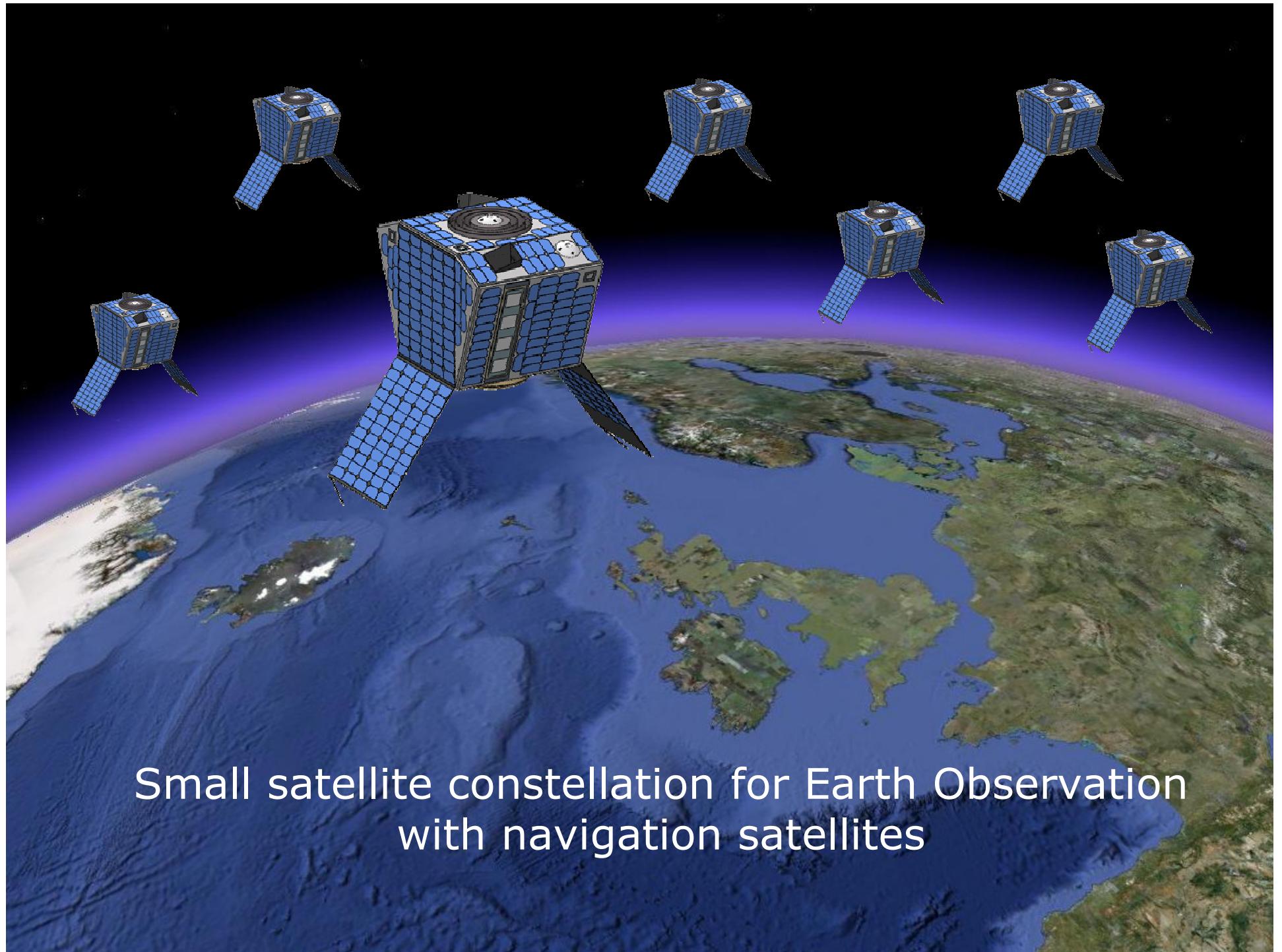


- GPS and Galileo alone show similar detection performance
- GLONASS performance worse because incomplete in 2004
- Best performance when all GNSS signals can be received simultaneously

New and small GPS receivers aboard small satellites



Understanding of the GPS receiver as a
scientific „remote sensing“ sensor

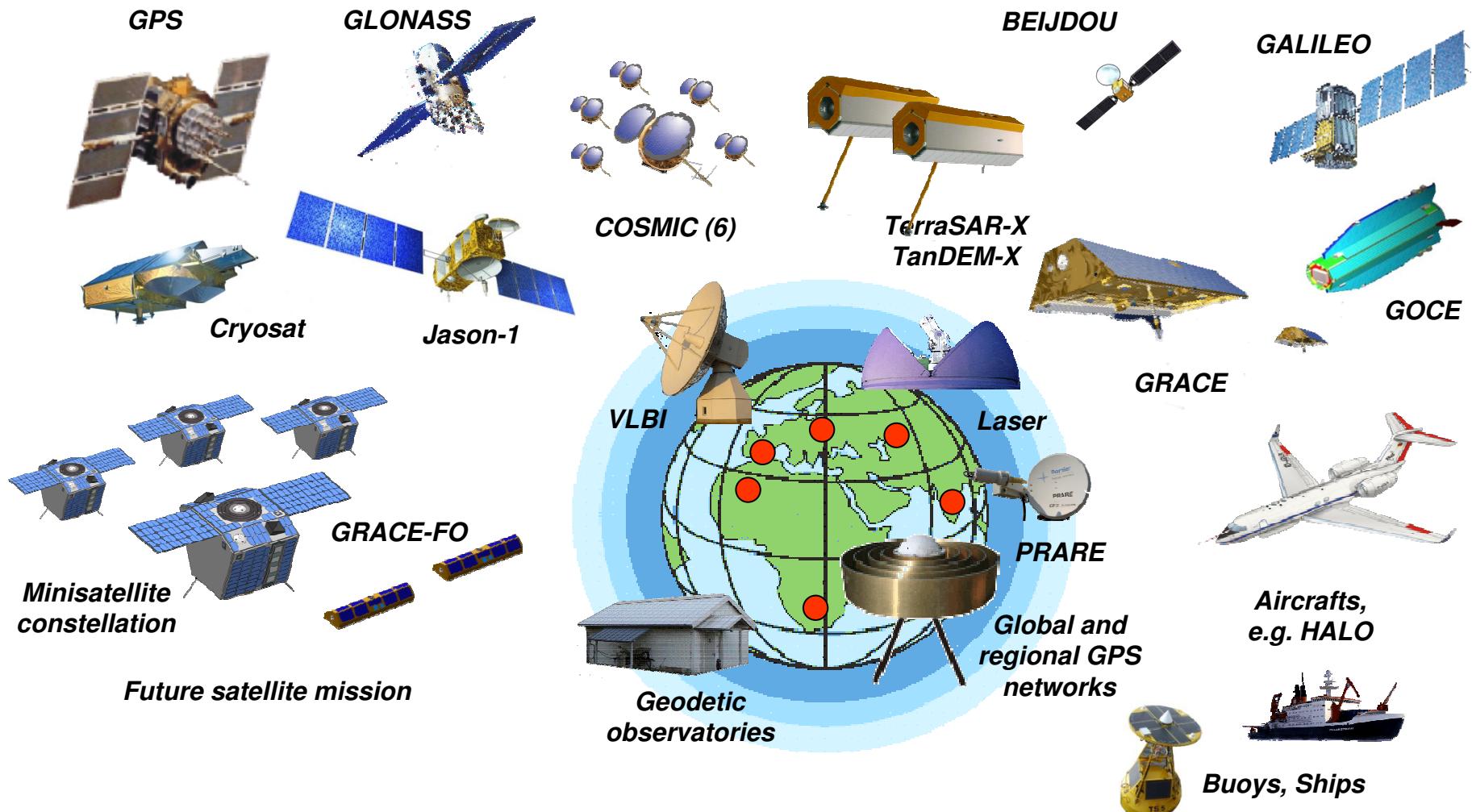


Small satellite constellation for Earth Observation
with navigation satellites

4

Vision and outlook

Geodetic based Global Change Monitoring (key component GNSS)



Global Change Monitoring with GNSS

