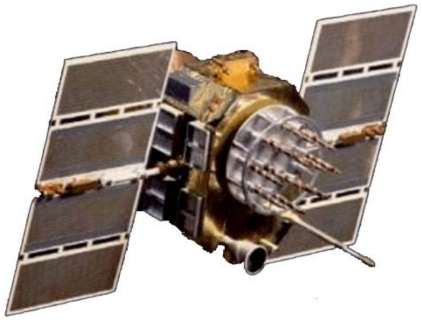
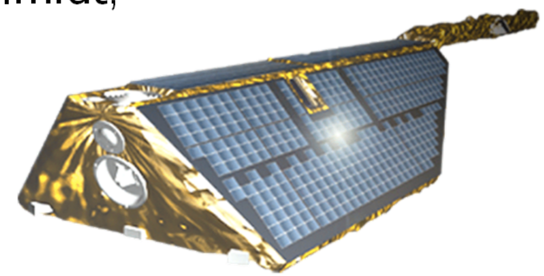



Remote sensing with Navigation Satellites:

Overview and Applications in Polar Regions

J. Wickert

C. Arras, G. Beyerle, M. Bender, Z. Deng, G. Dick,
S. Heise, G. Michalak, M. Ramatschi, T. Schmidt,
H. Schuh, M. Semmling, S. Vey

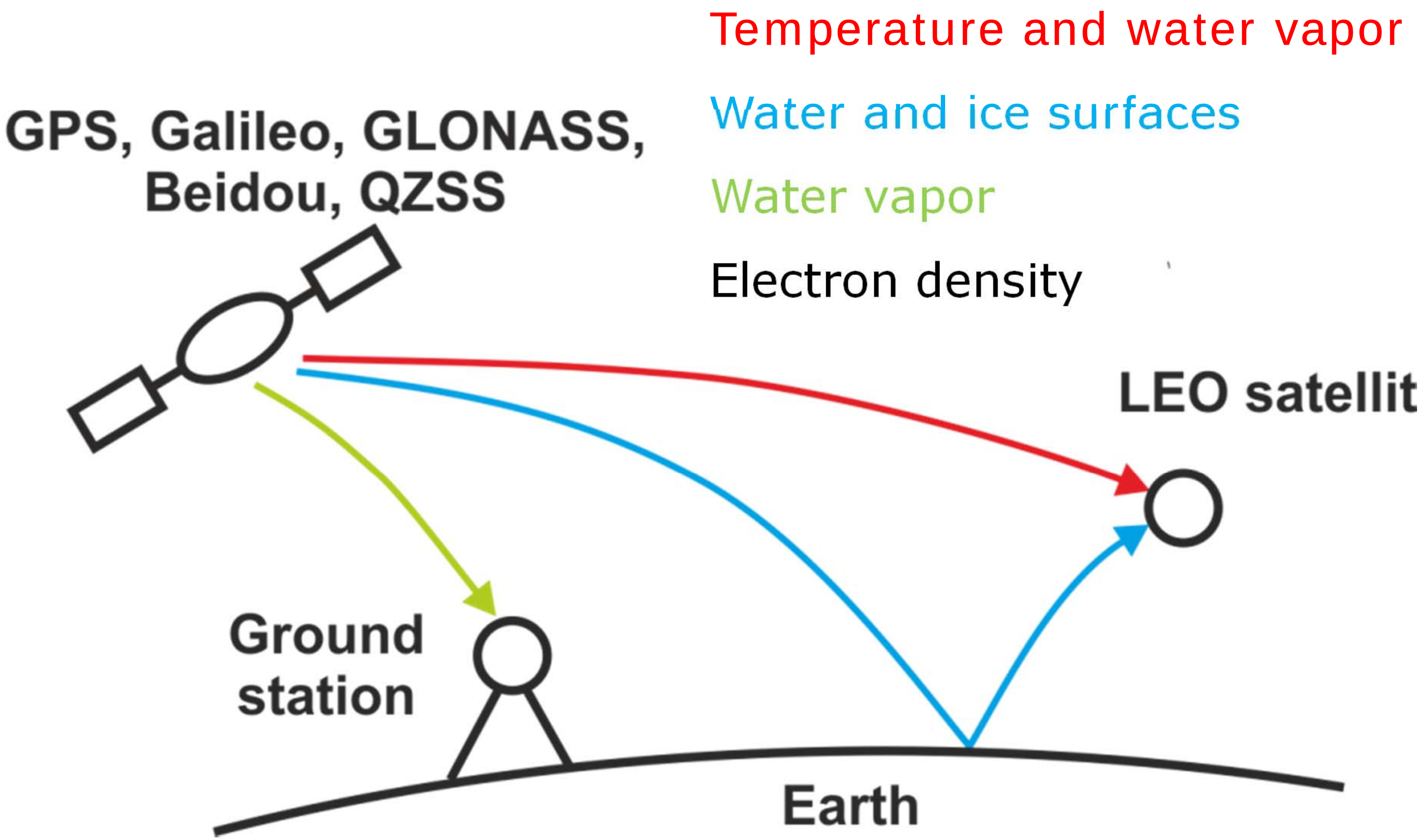



GFZ Helmholtz Centre POTSDAM

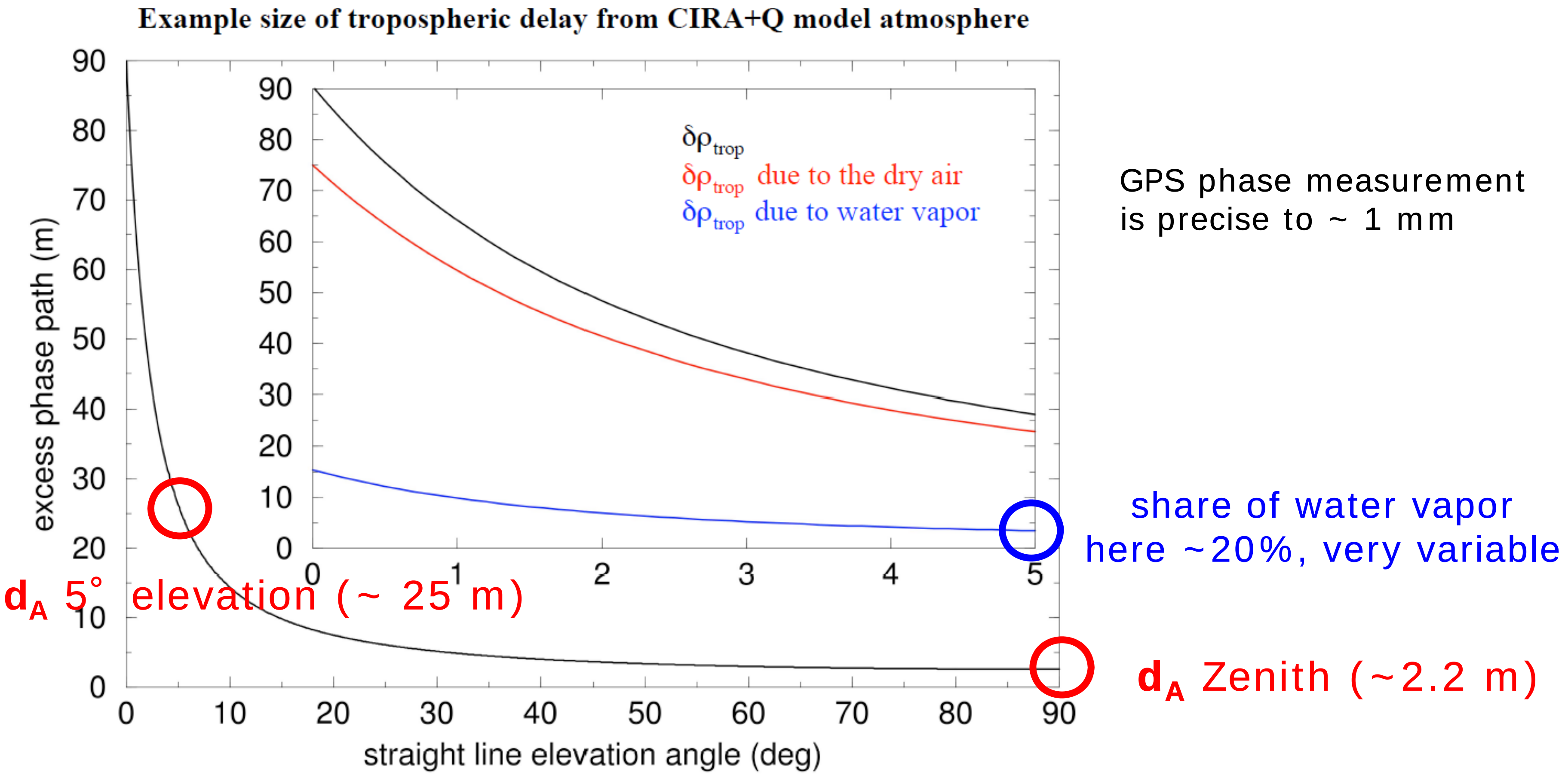
Potsdam Summer School, Arctic in the Anthropocene
June 24, 2014, GFZ

HELMHOLTZ GEMEINSCHAFT

Propagation errors and remote sensing



Example: Ground based measurements, neutral atmosphere delay d_A

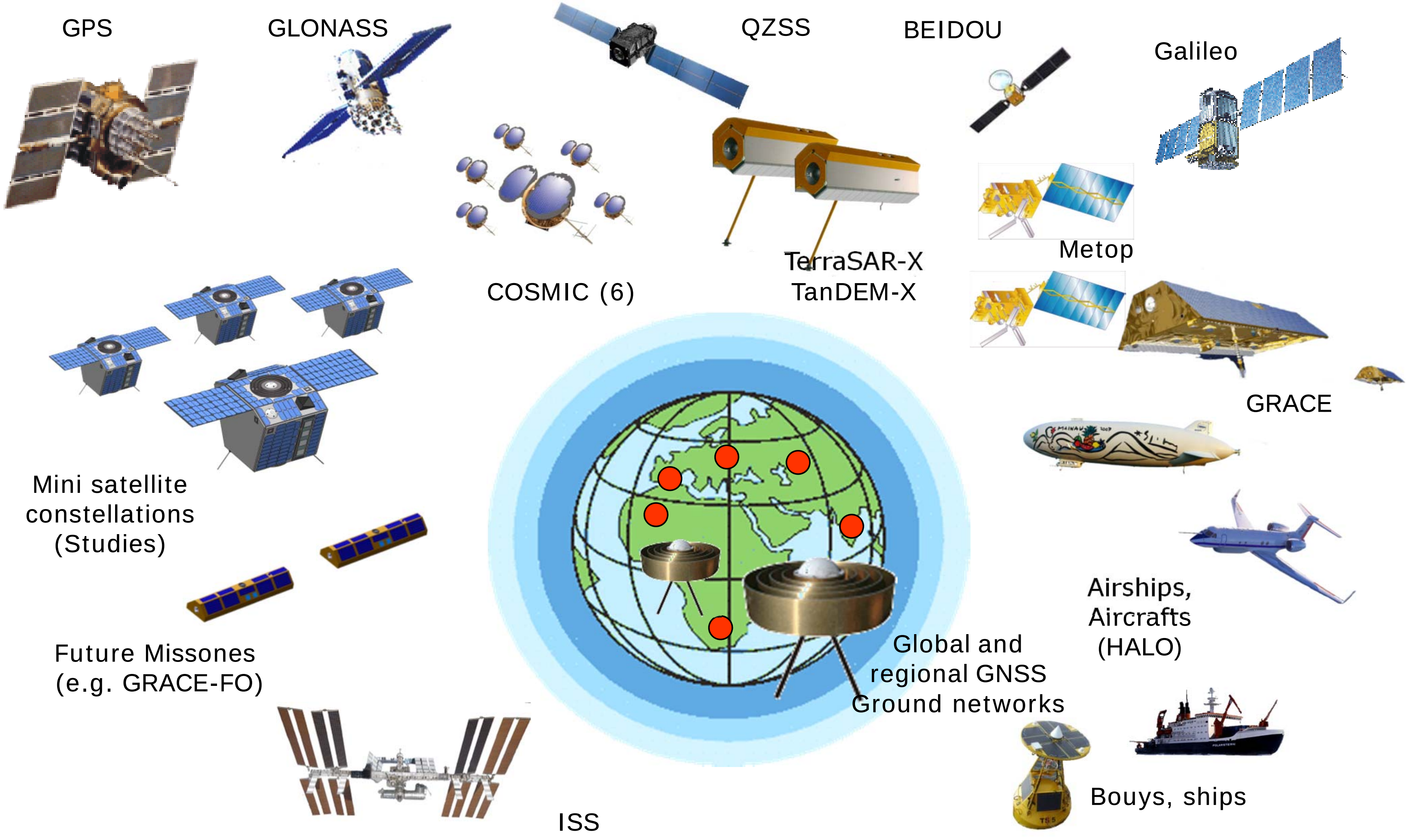


GPS phase measurement is precise to ~ 1 mm

Thanks: C. Rocken, UCAR

GNSS Observation Infrastructure

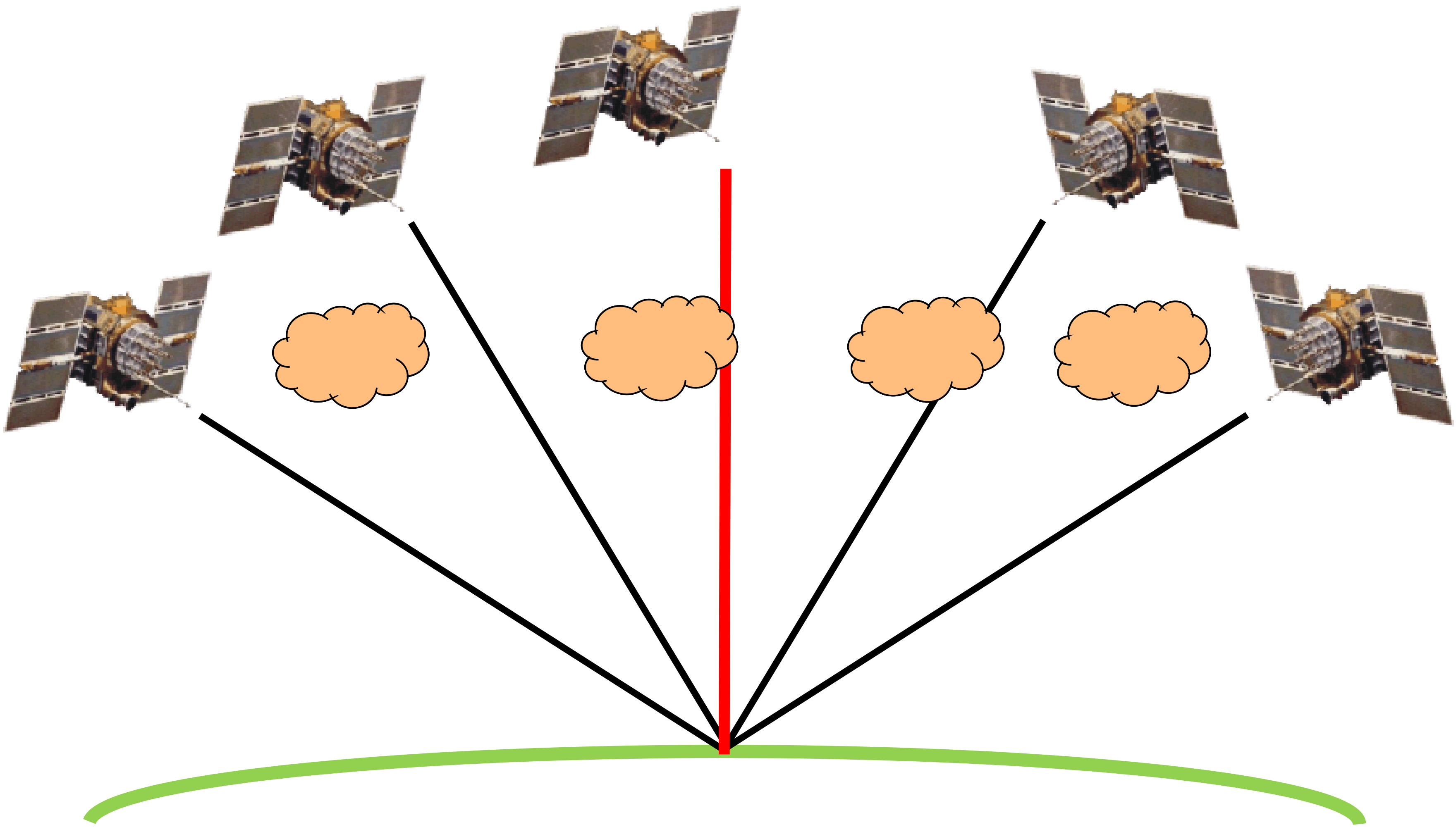
(Observation on different scales in space and time feasible)



Ground based

GNSS atmosphere sounding

Vertically integrated water vapor

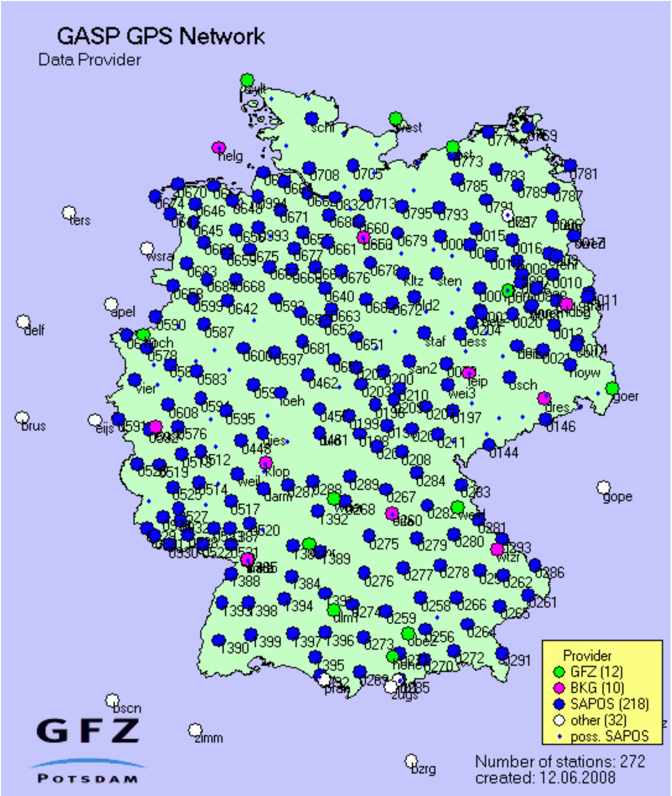


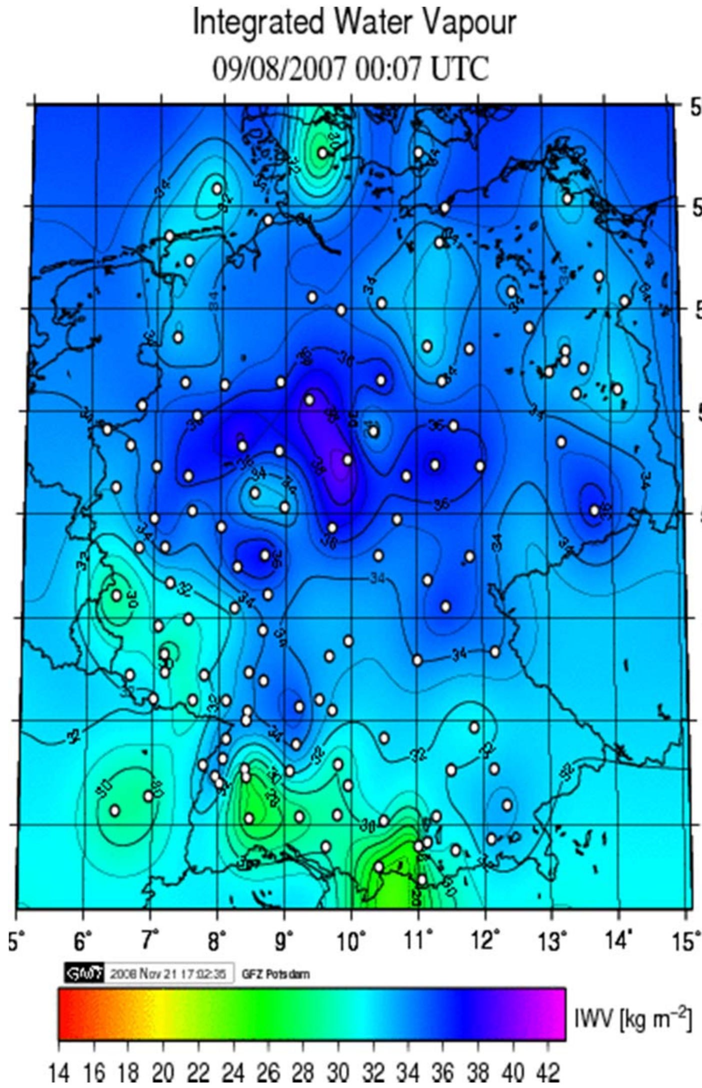
GNSS ground stations

Ny Alesund, Spitsbergen

Potsdam, GFZ,
Geodetic institute

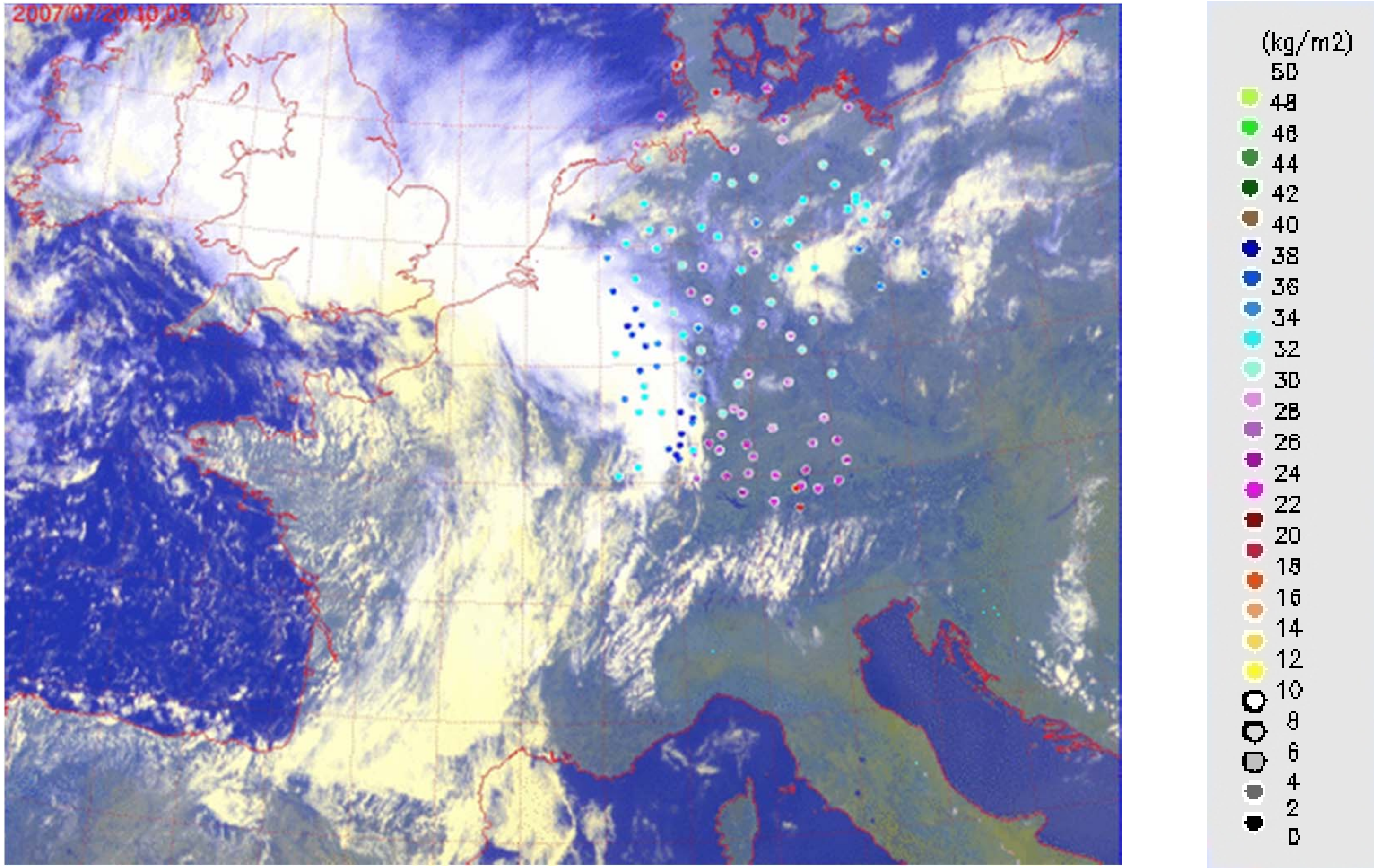
German network (~300 stations)





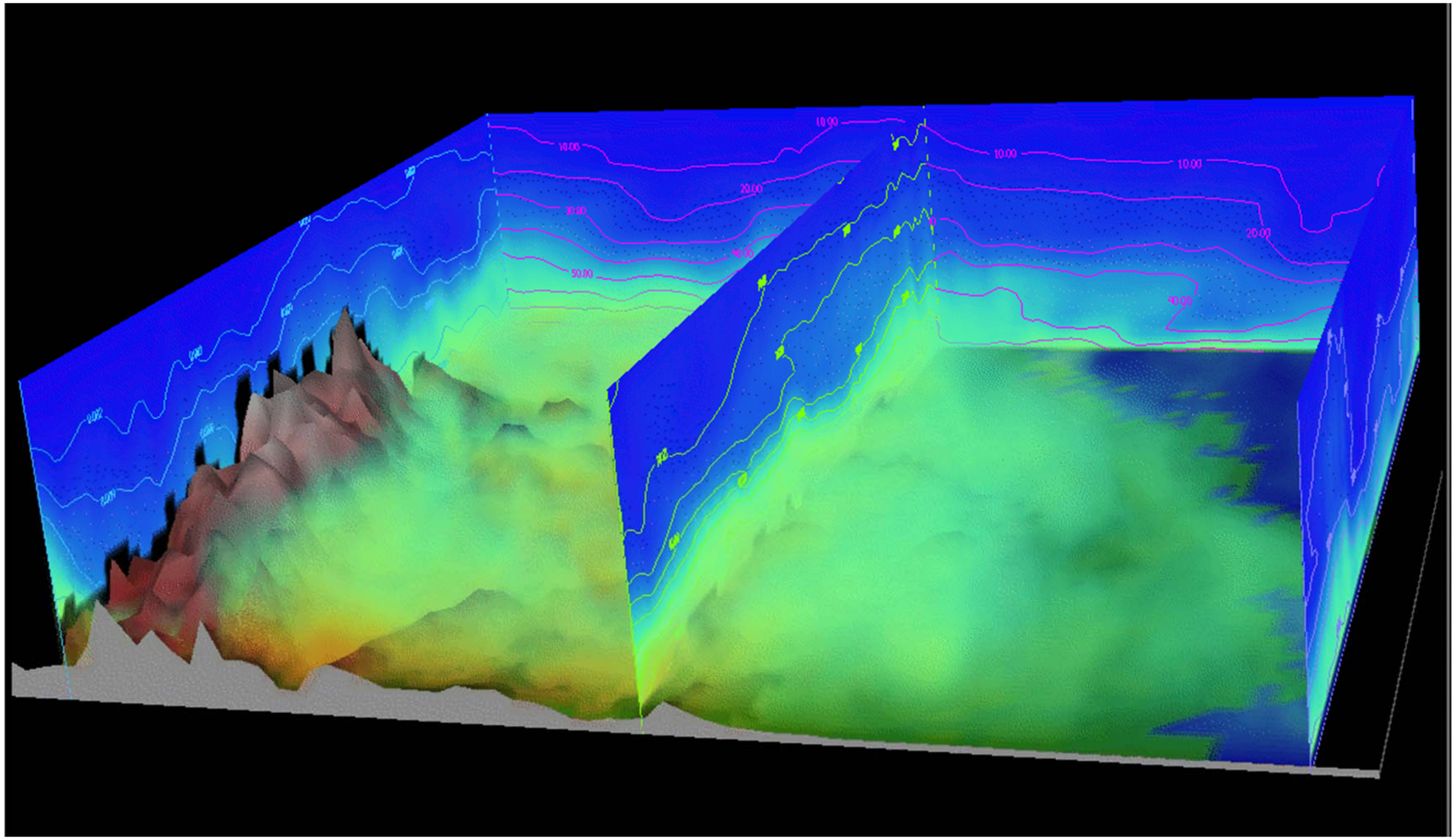
Water vapor monitoring
in Near-Real-Time

Overlay plots with Meteosat-8 images



Overlay plots of Meteosat-8 (multi-channel) and GPS IWV for 20th of July 2007 (Fumiko Aoshima, Uni Hohenheim)

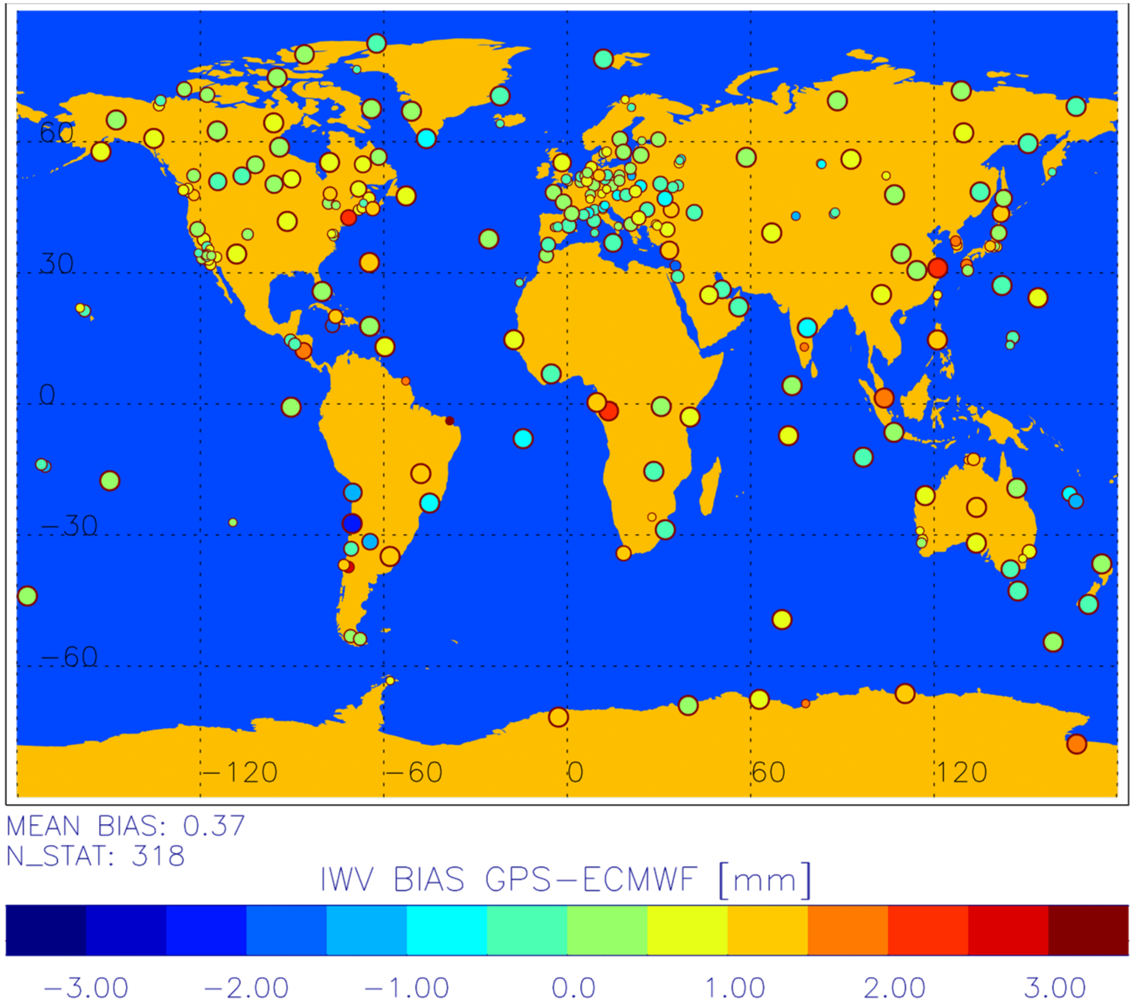
3D water vapor from GNSS above Germany

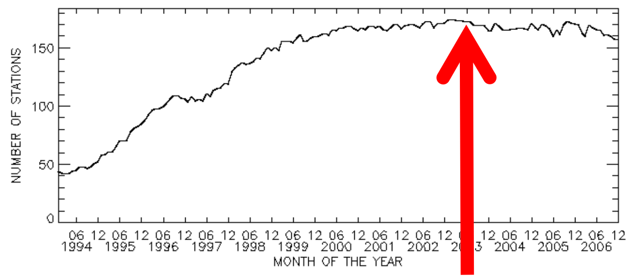


Januar 18, 2007, Low pressure Kyrill

Bender et al. [GFZ], 2010

Water vapor from a global network

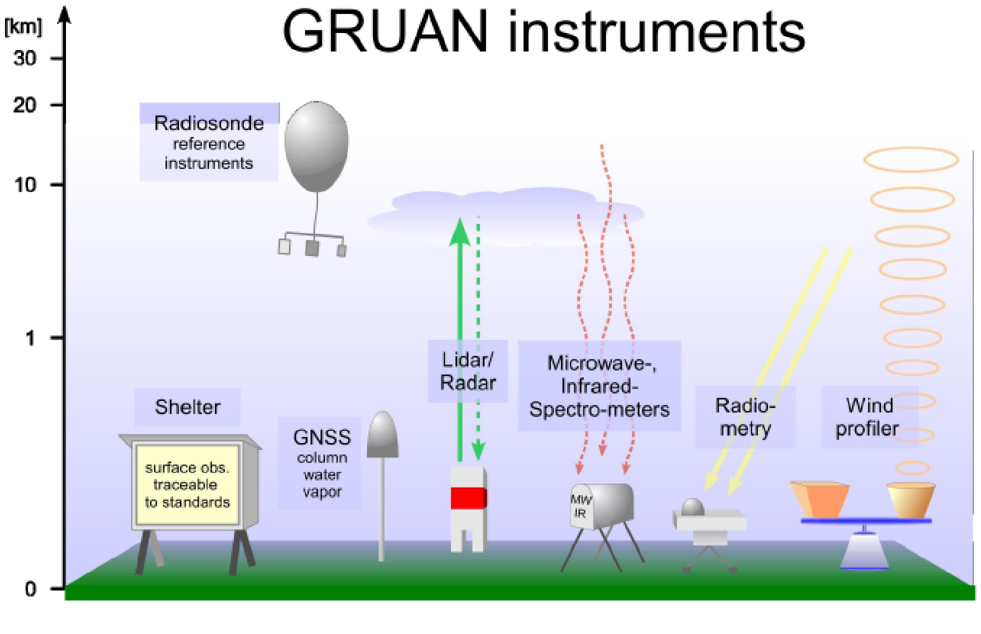




~170 stations globally, some since 1994

GPS IWV results 2004-2008 in comparison (Bias) with ECMWF IWV. Accuracy ~1mm

GNSS for Global Climate Observing System (GCOS, WMO)



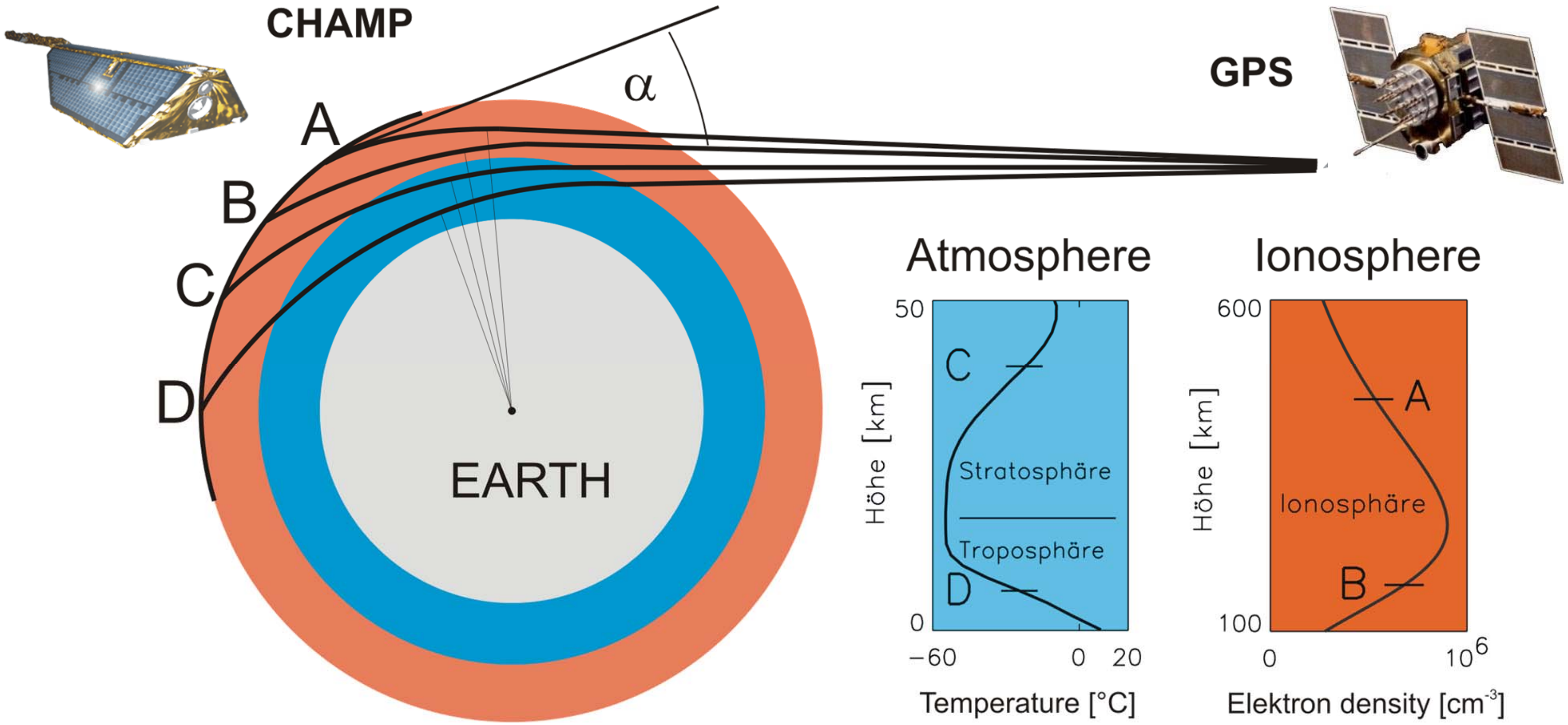
GNSS is standard device for climate monitoring
Data analysis at GFZ

GCOS Reference Upper Air Network

GRUAN polar GNSS station

Satellite based
GNSS atmosphere sounding:
Radio occultation

GNSS radio occultation

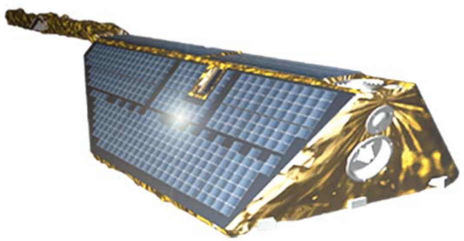


Wickert , 2002

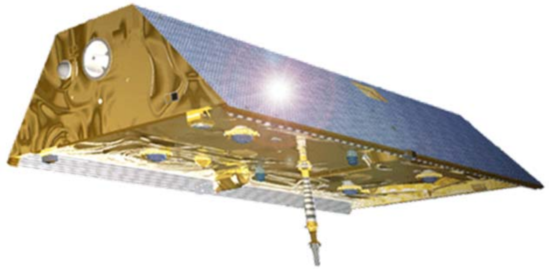
Key properties: global coverage, all-weather, calibration free, very precise, high vertical resolution

Very attractive for weather forecast, Climate and atmospheric research

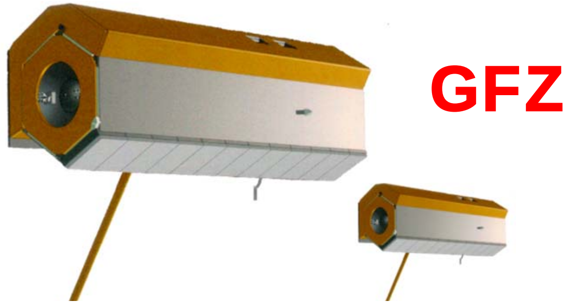
GNSS receivers for occultations on satellites



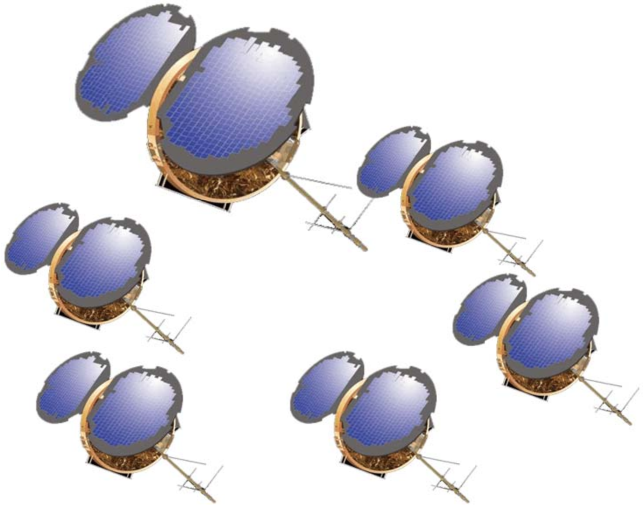
CHAMP (since 2000)



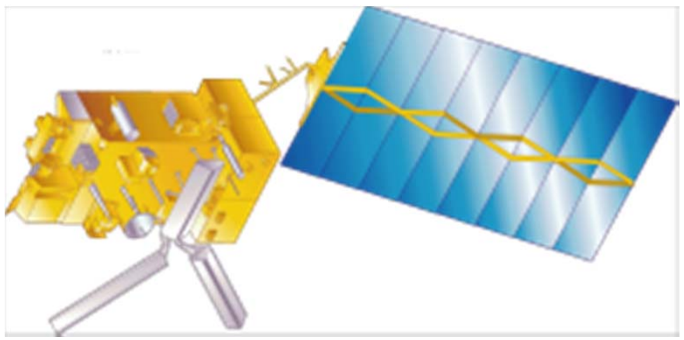
GRACE (since 2002)



TerraSAR/TanDEM-X



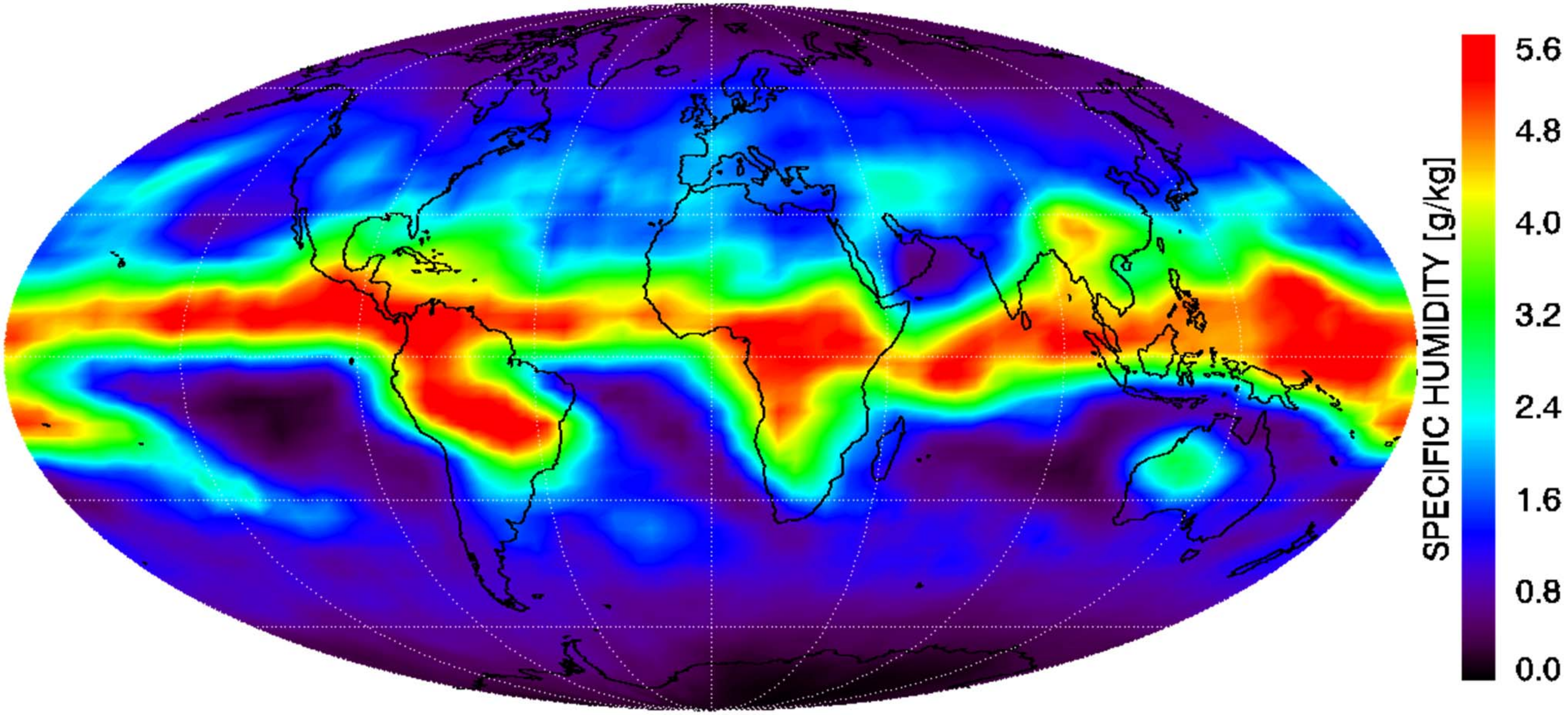
FORMOSAT-3/COSMIC
(6; since 2006)



Metop (since 2006)

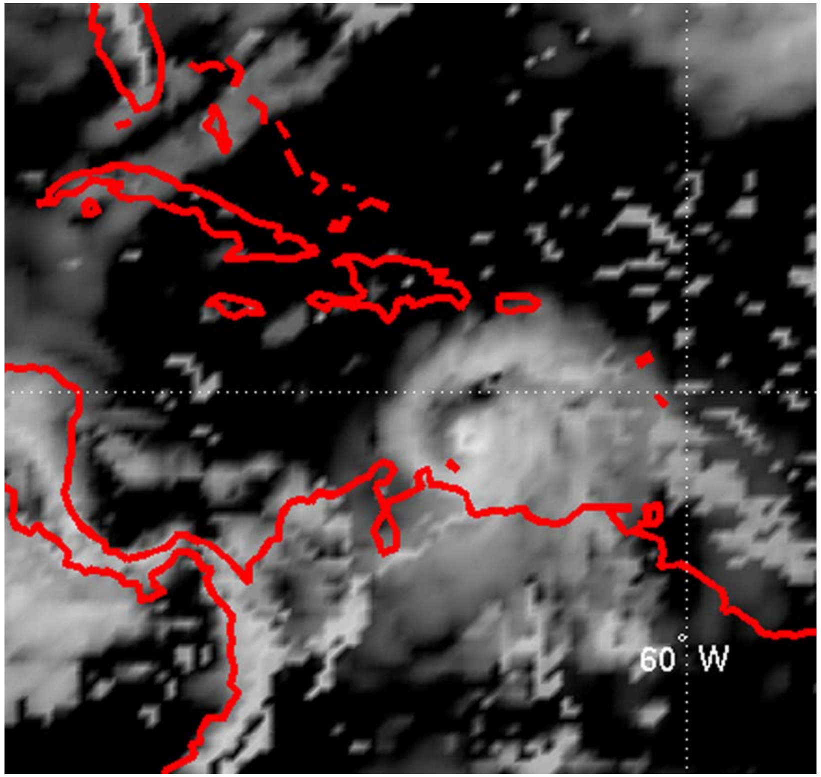
Global water vapor from satellite GPS data

CHAMP + GRACE + COSMIC

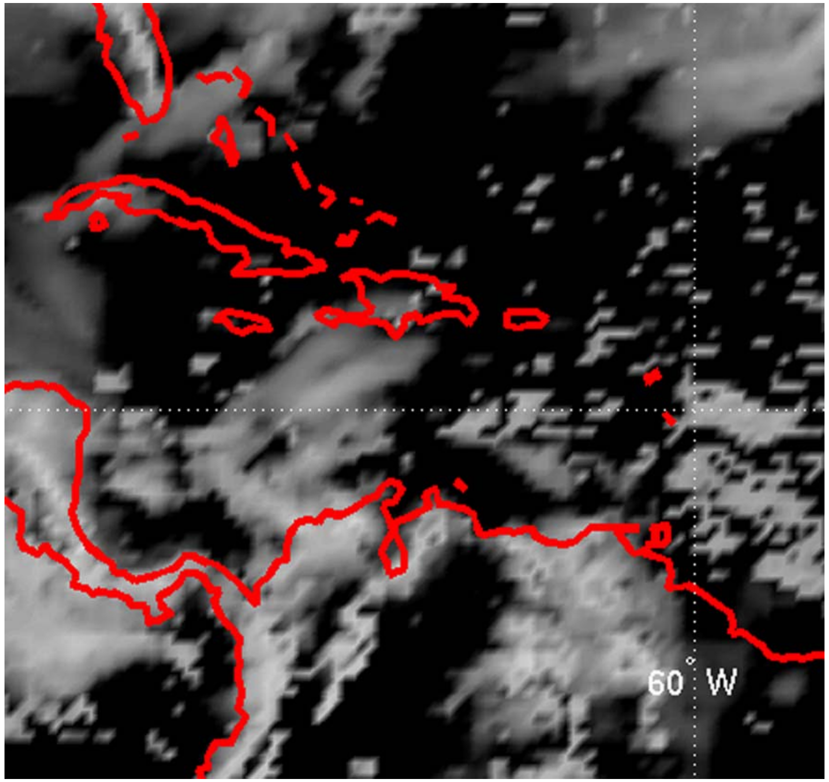


e.g., Improvements of Typhoon forecasts with GPS: Ernesto (2006)

With GPS



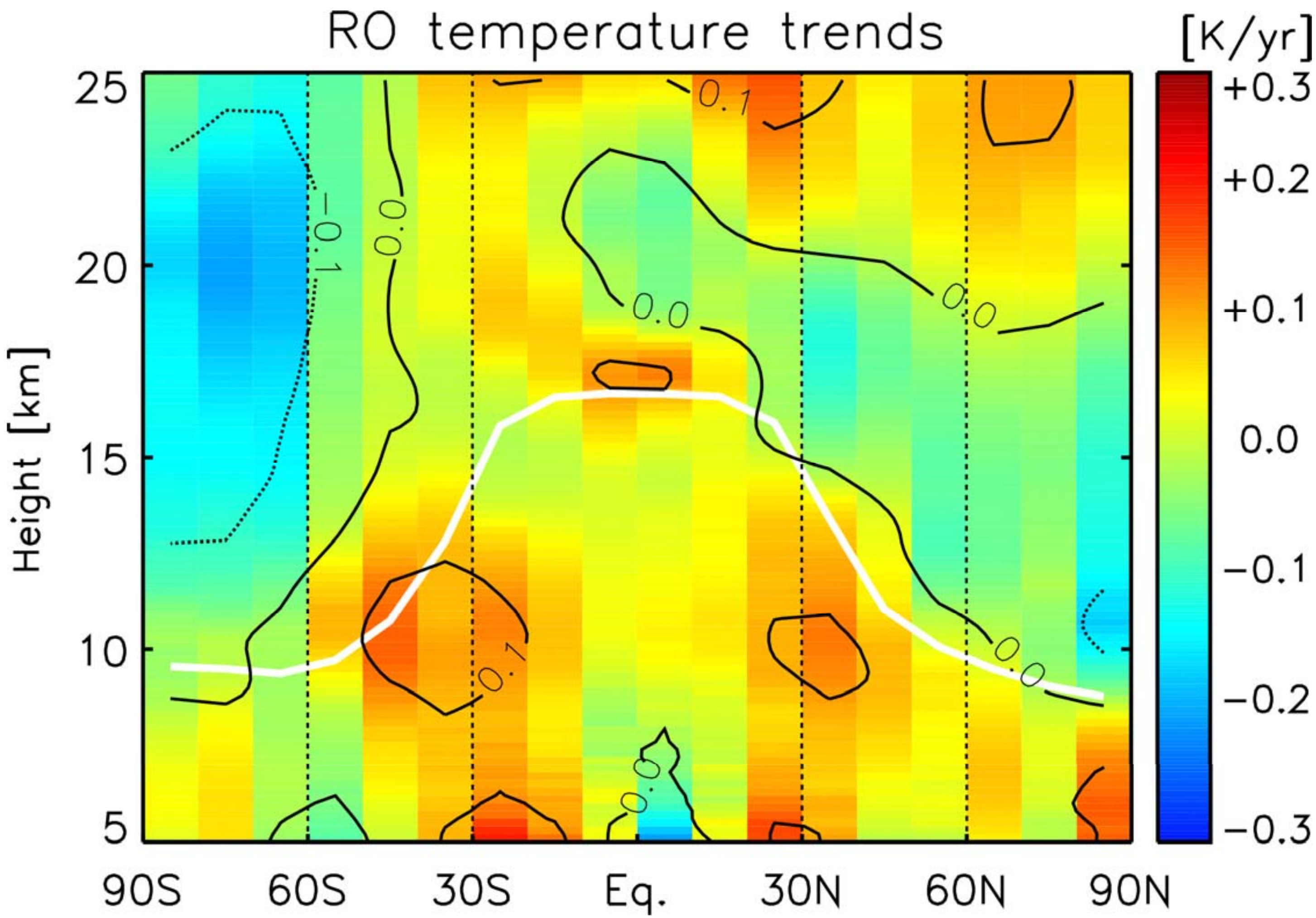
Without GPS



GPS data used for weather forecasts since 2006!

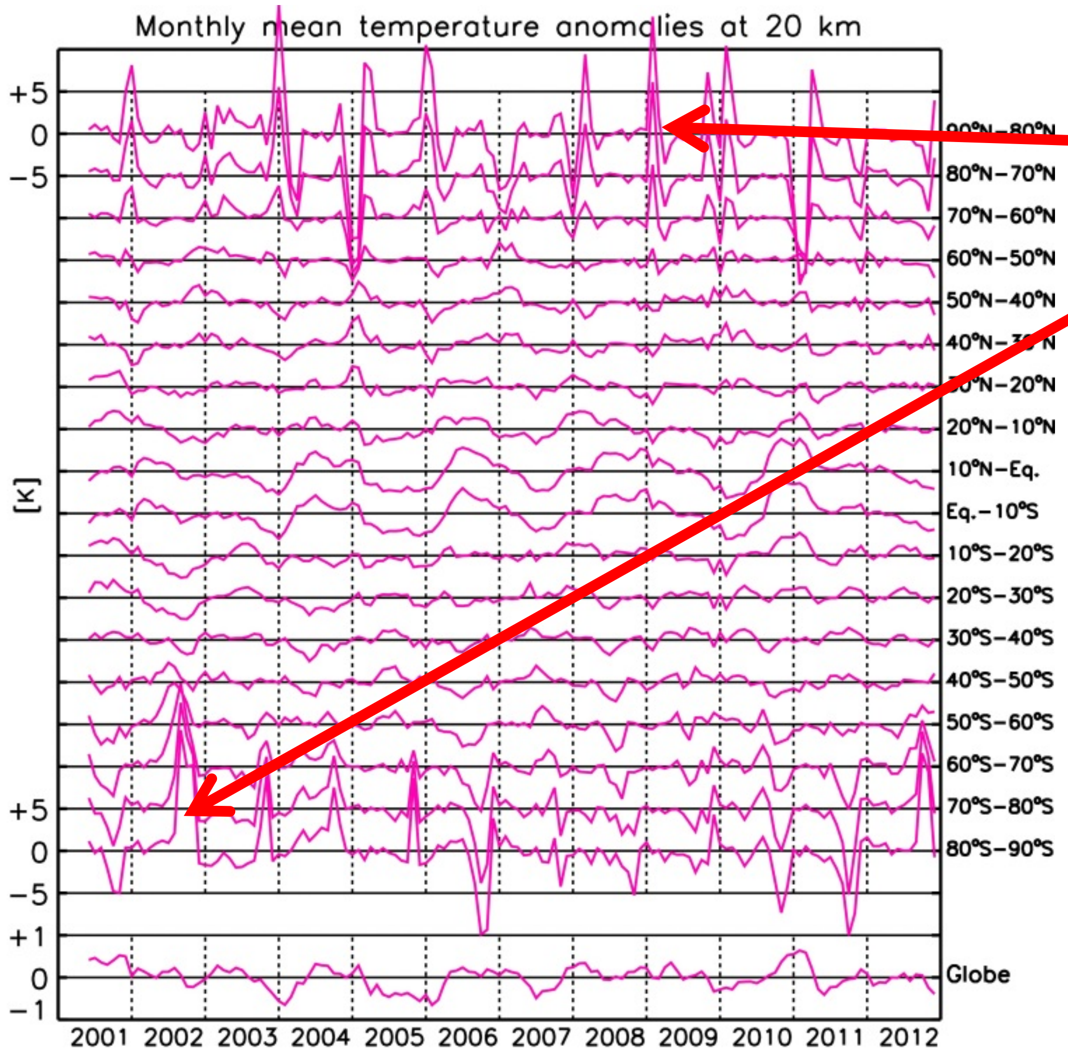
Liu, NCAR

Climate: Global temperature variations Observed with GPS und CHAMP/GRACE (10 years)



Schmidt et al. [GFZ], 2010

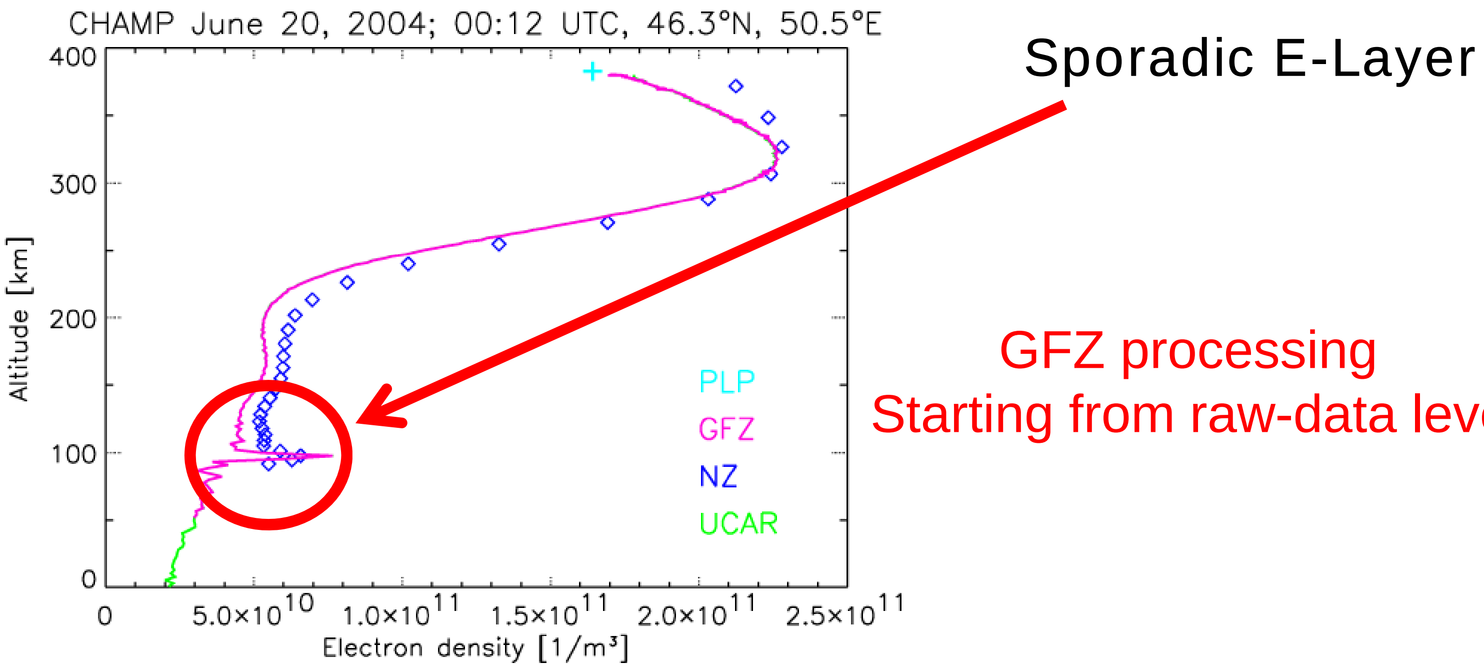
Example: Stratospheric temperature variability



sudden stratospheric warmings in polar regions

- Disturbance of polar vortex, more often in Arctic
- Relevant for Ozone Chemistry
- GNSS RO excellent observation tool

Ionosphere: Vertical electron density profiles and detection of disturbances

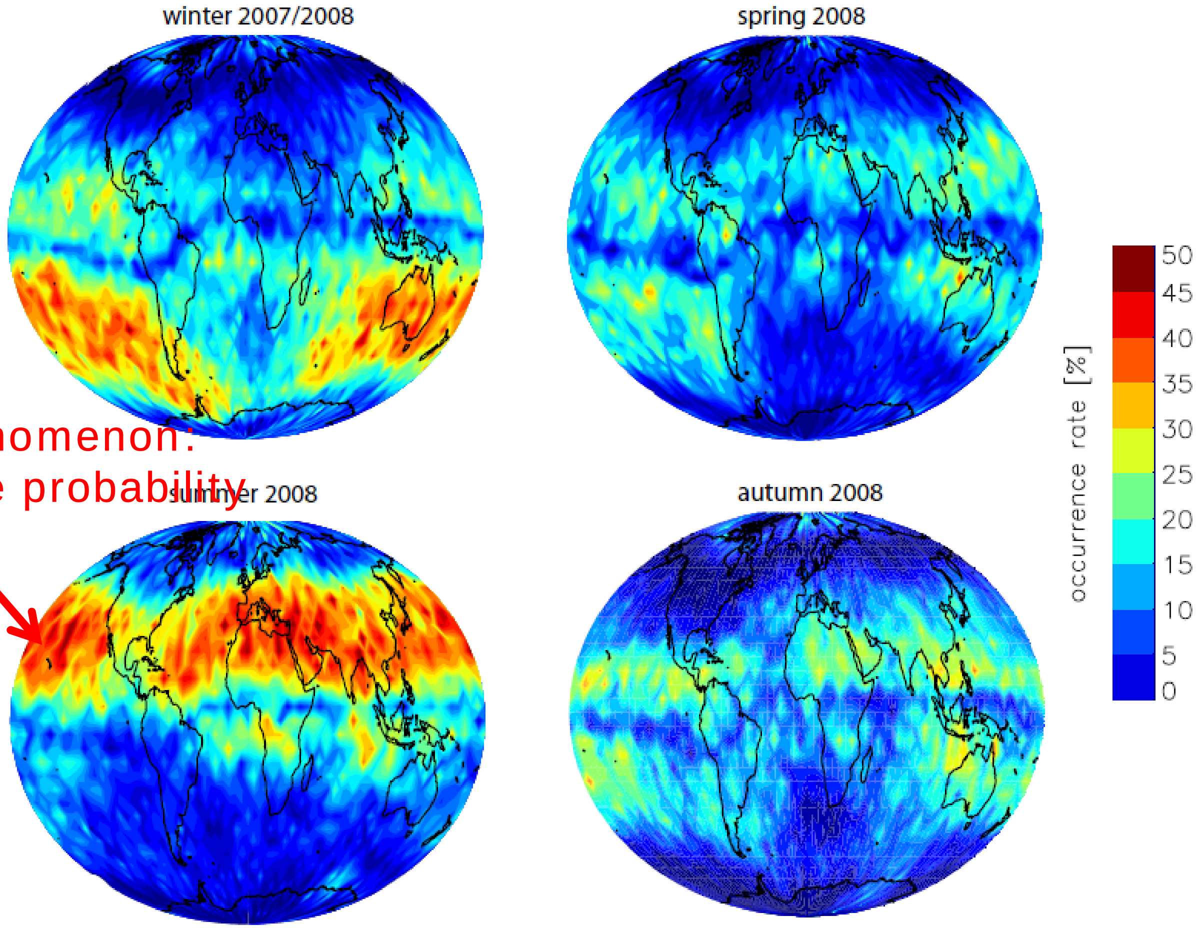


GFZ processing
Starting from raw-data level

Relevant for navigation, communication,
Studies of atmospheric coupling processes

Wickert et al., 2009

Global ionosphere monitoring mit GPS



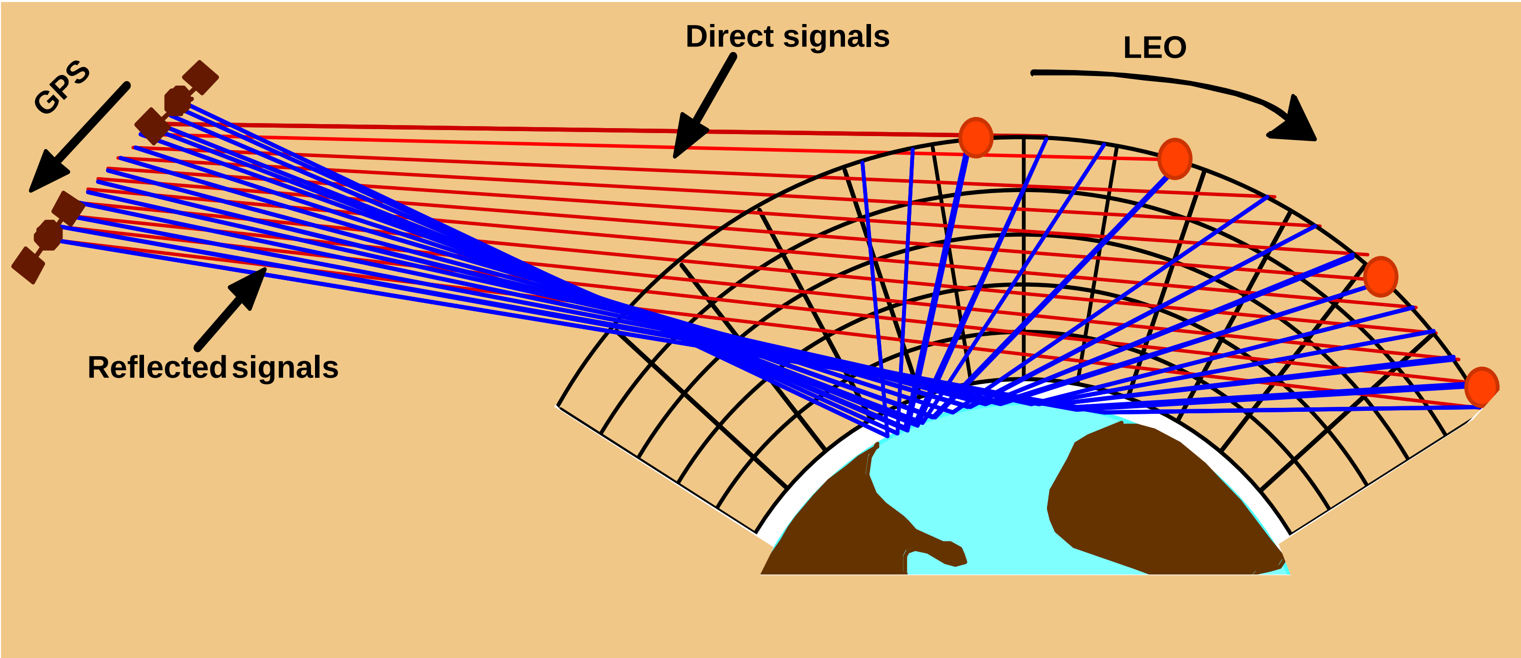
Important phenomenon:
~50% occurrence probability

Sporadic-E Results from CHAMP, GRACE, FormoSAT-3/COSMIC 2007/2008

Arras, PhD finished, available in english

A major challenge in GNSS remote sensing: Reflectometry

Remote Sensing with Reflected GNSS



Thanks: T. Yunck

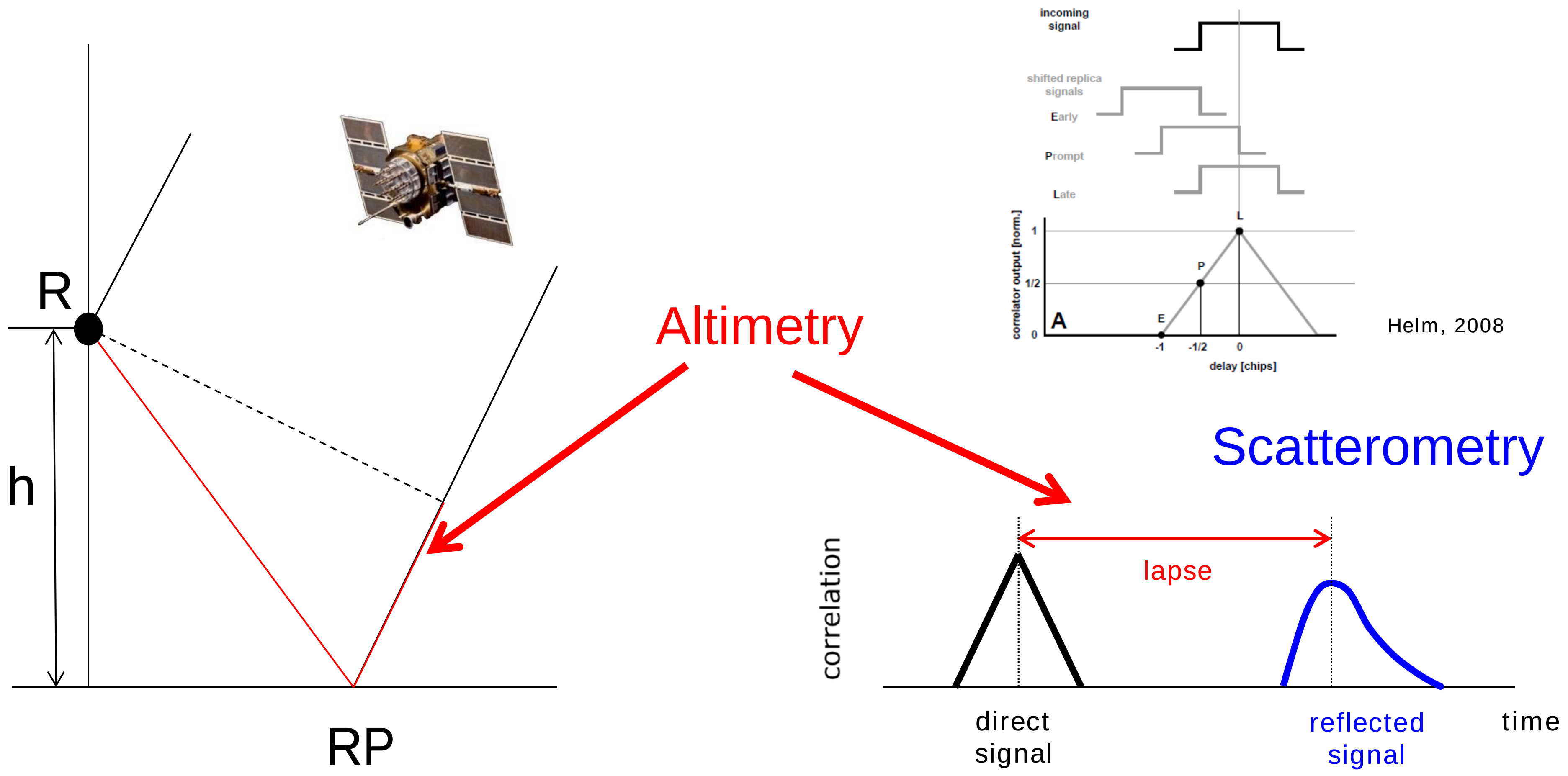
Potential applications of GNSS reflectometry

- Weather: Wind direction and velocity; Specific humidity, Tomography Refractivity
- Climate: Ocean: Sea level, Sea Ice Coverage; Ice shelf altitude monitoring, Tide gauges in coastal regions, Salinity
- Ionosphere and Space Weather: Electron content imaging
- Disasters: Tsunami Early warning, Flood monitoring
- Soil moisture: land classification, biomass monitoring
- Snow: cover and depth, humidity content of snow

Wickert et al., EU-project report GfG², 2012

Few basics GNSS-R Altimetry/Scatterometry

Path delay (lapse) Correlation and waveform



Advantages of GNSS vs. Radar Altimetry

* Signals are „free of charge“

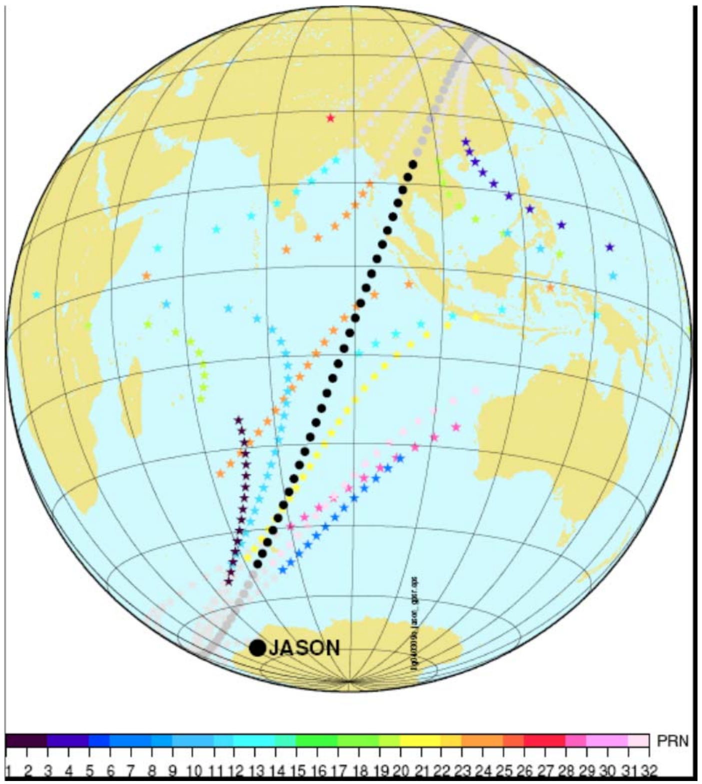
* Many reflection points

  2018: ~100 GNSS satellites

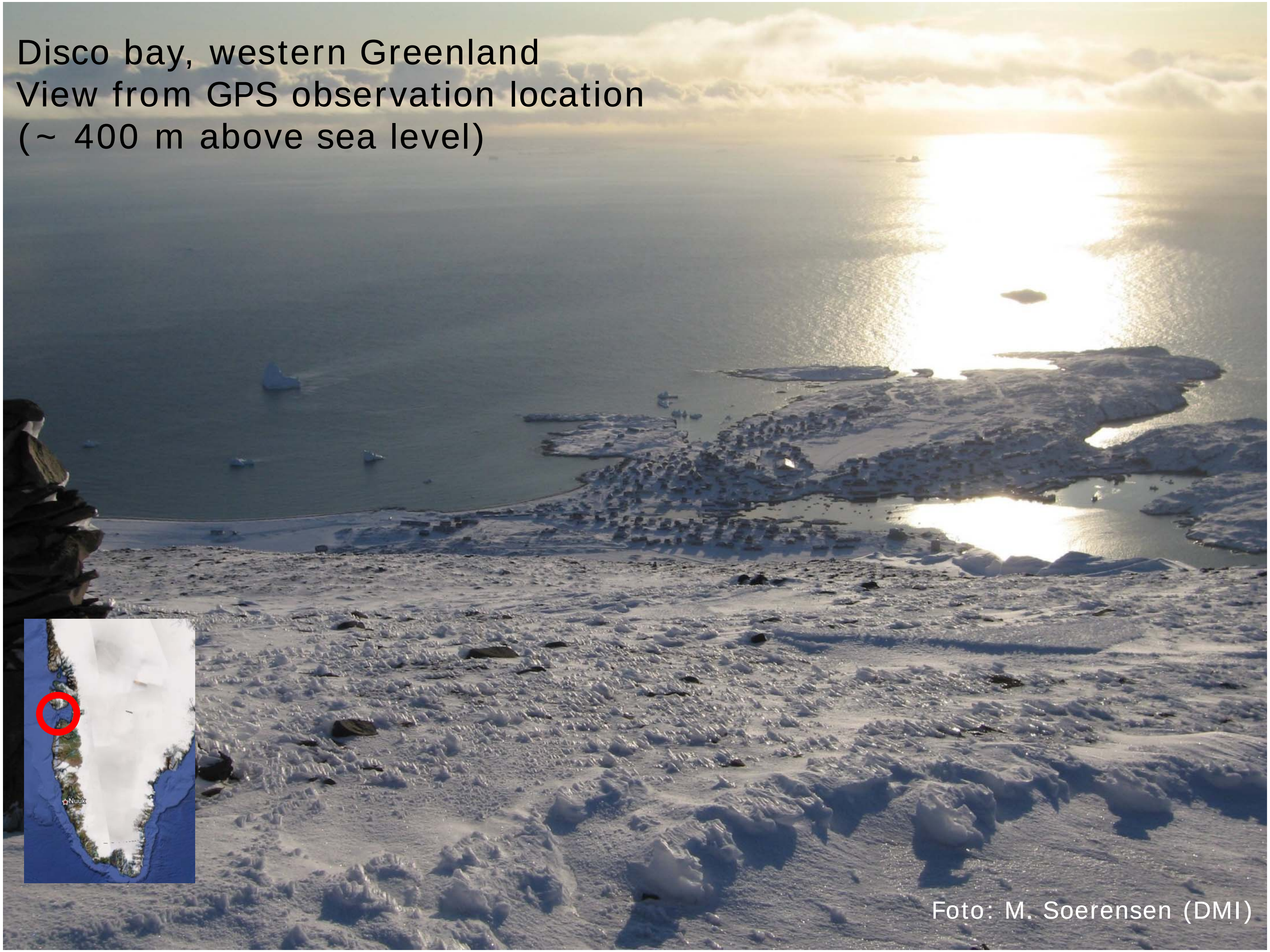
* High transmissivity at high rain rates (100 mm/h and more)

* Low-cost sensors aboard small satellites feasible (make future constellations feasible, sustainability of measurements)

2004 sumatra tsunami detected by JASON and simulated GNSS-R (GPS)

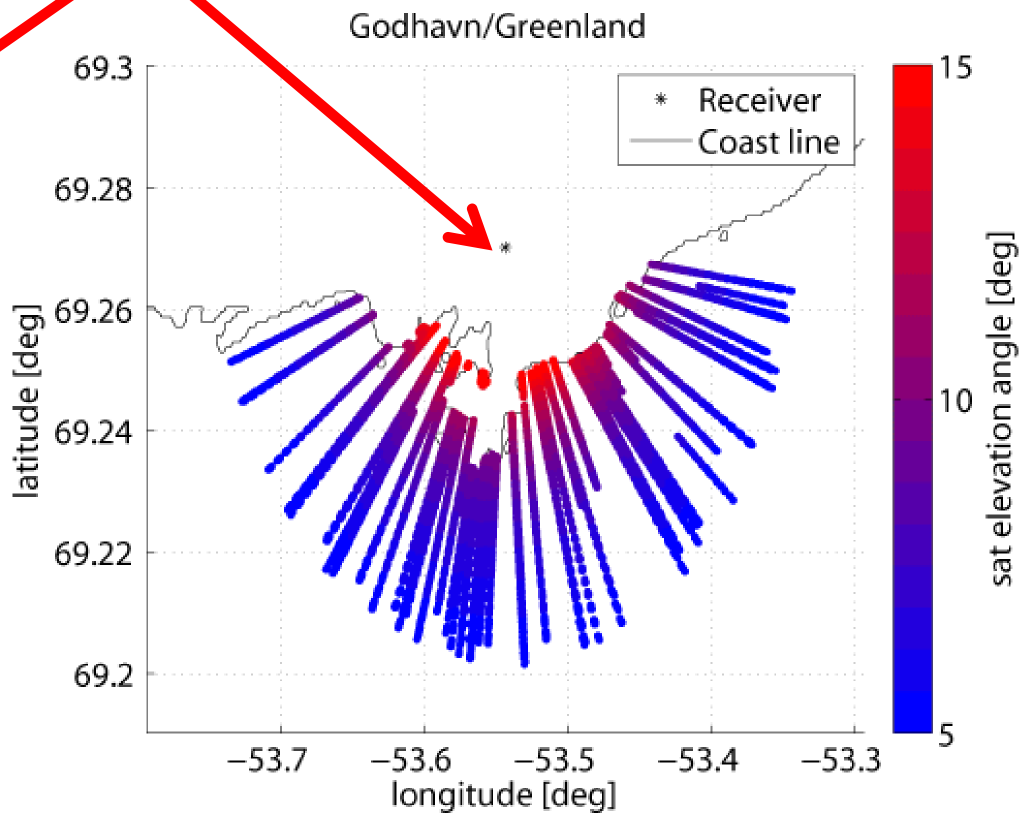


Some examples:
GNSS reflectometry
at GFZ


Disco bay, western Greenland
View from GPS observation location
(~ 400 m above sea level)
Nuuk
Foto: M. Soerensen (DMI)

Ground based GNSS-R at Greenland

GPS antenna (ca. 600 m above water/ice)

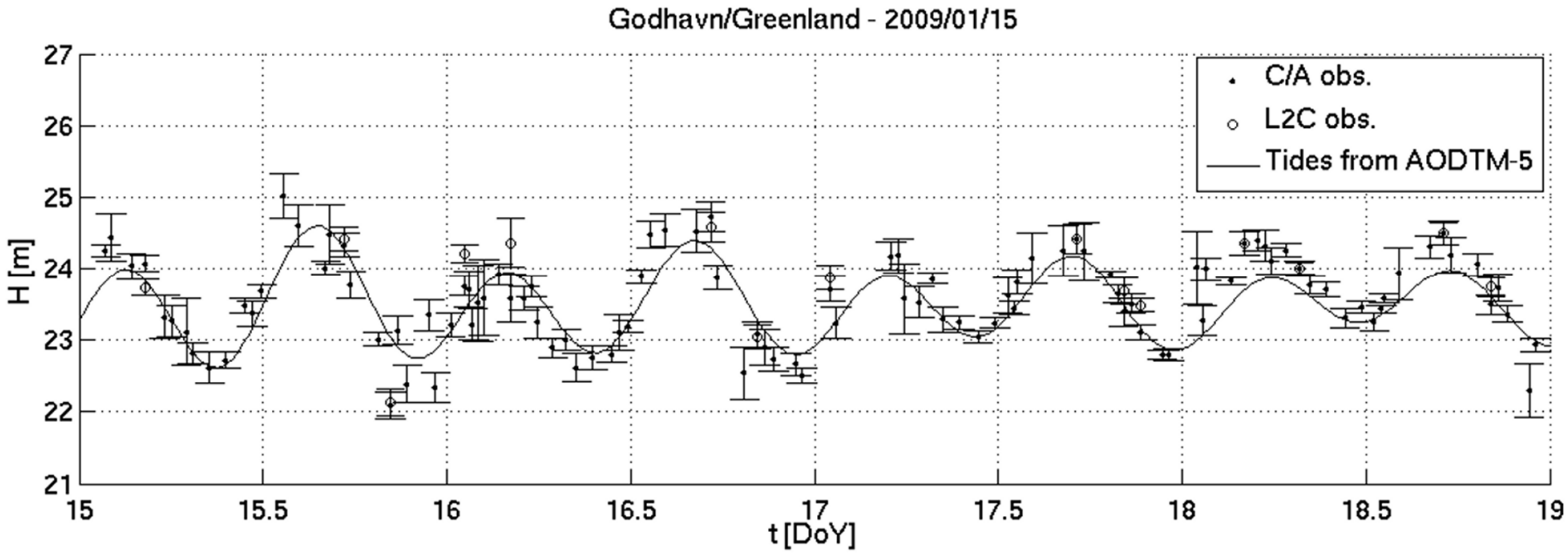


Measurements November 2008 until January 2009

Data set for potential sea ice remote sensing

Cooperation with IEEC Barcelona within ESA project (GPS-SIDS)

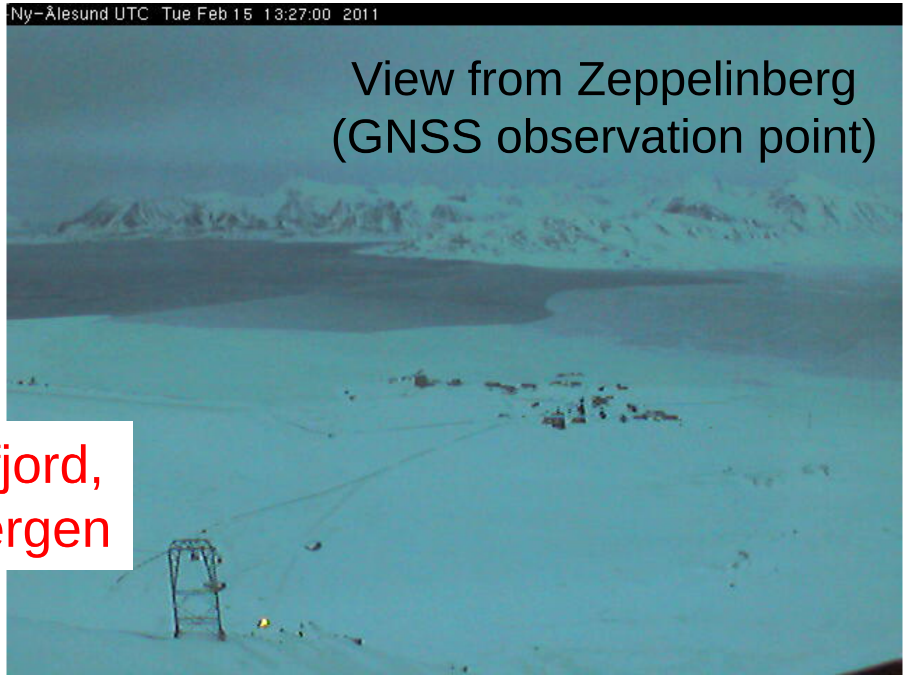
Monitoring of tides at Disco Bay with GPS



- Very promising results
- max. tide amplitude ~ 2 m
- Tide model in coastal region not optimal
- Accuracy closely related to knowledge of atmospheric state (Synergy Atmosphere sounding/Reflectometry)

Semmling et al., 2011, GRL

Outlook: Sea ice monitoring Kongsfjord, Spitsbergen



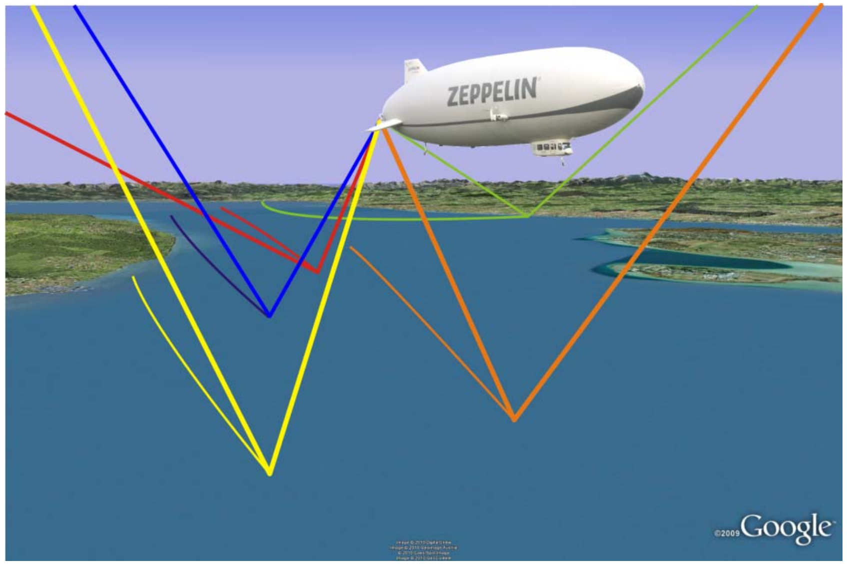
Installation of long-term GNSS reflectometry at Spitsbergen

Monitoring of water level and sea-ice

Comparison with in-situ and other satellite data (optical, SAR)

Flight experiments GNSS reflectometry

Airship Zeppelin NT



Sucessful campaigns September 2012, May 2014

- Nearly identical setup as GEOHALO
- Reflectometry for Geoid determination at Bodensee region

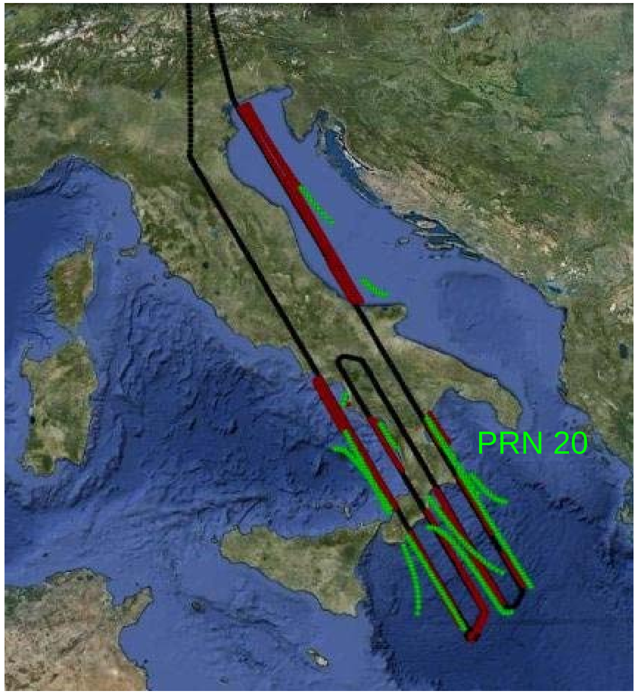
Research aircraft HALO

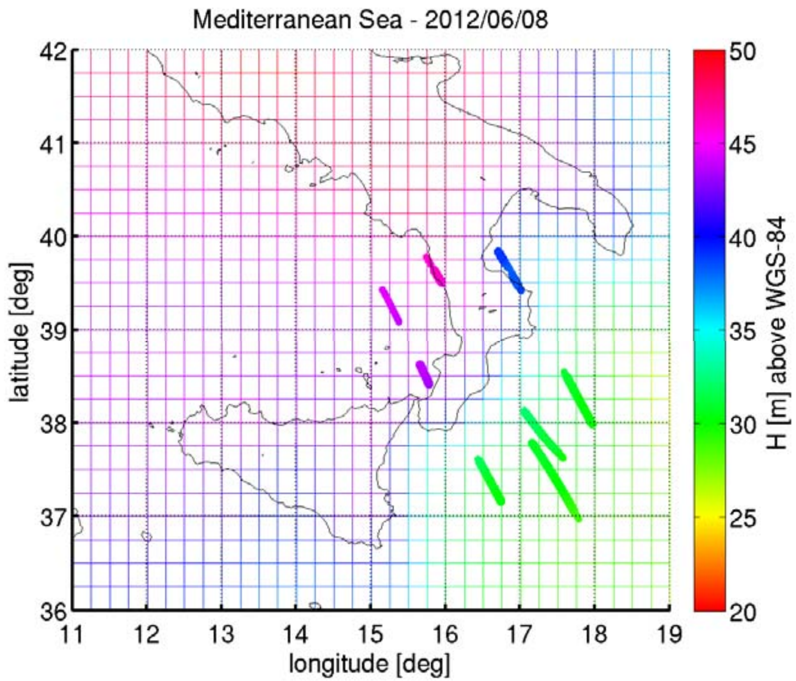
June 2012 within the GEOHALO campaign

- Reflectometry for ocean altimetry

Intial results: Semmling et al. (2013, 2014)

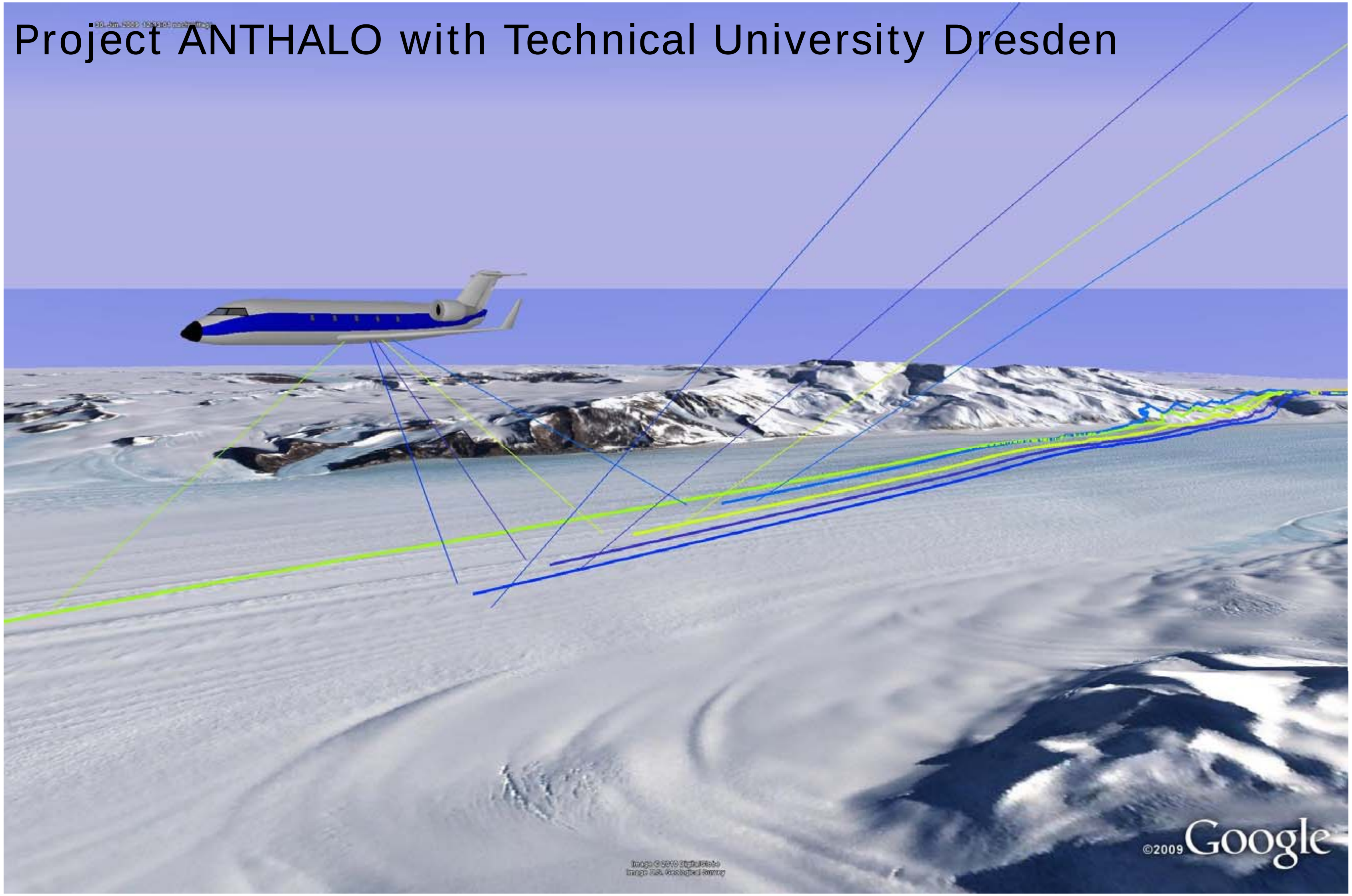
Airborne GNSS reflectometry: GEOHALO



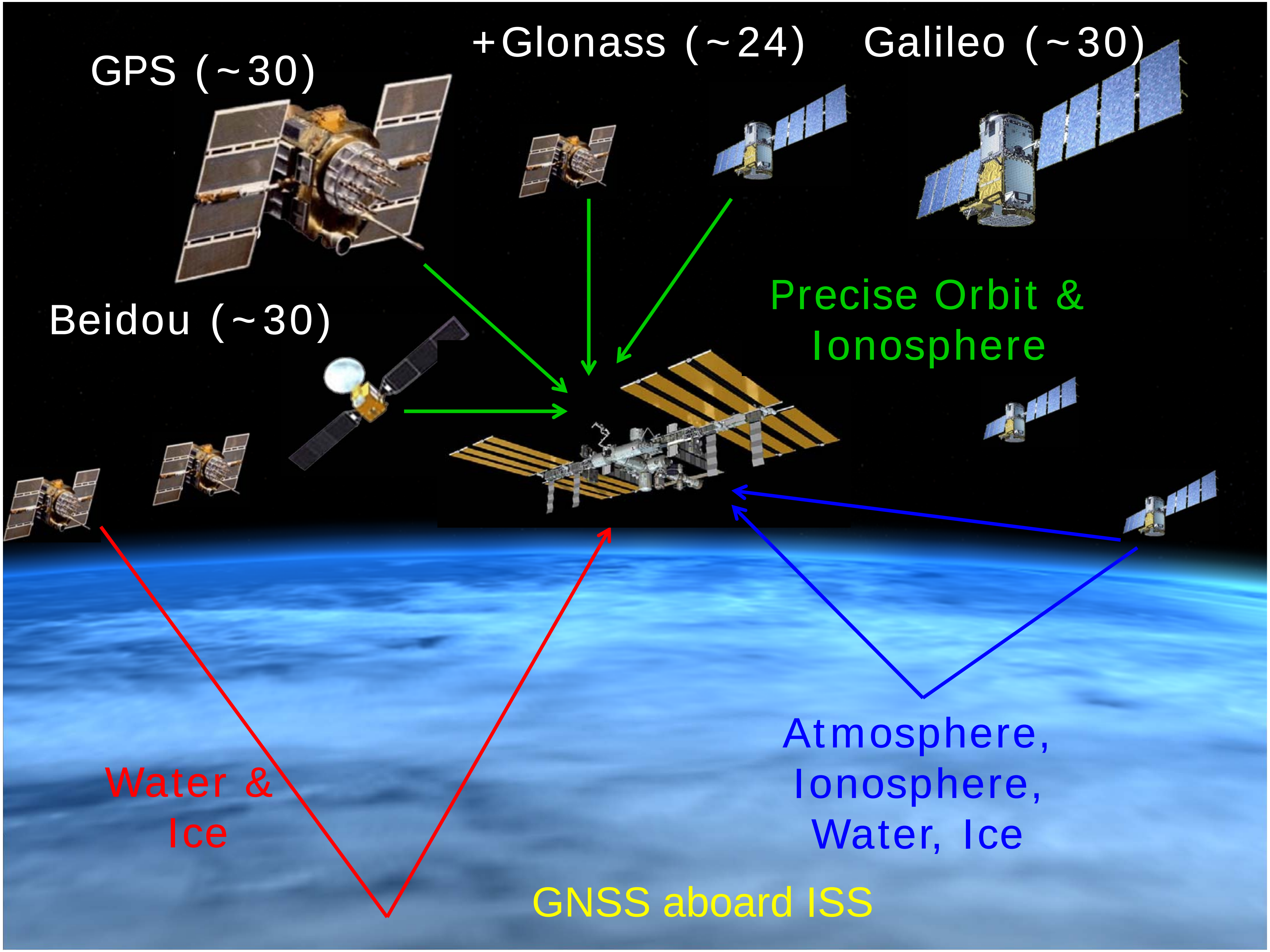


RMS zum Geoid 5 .. 25 cm, depends on track,
Comparison with radar altimetry planned

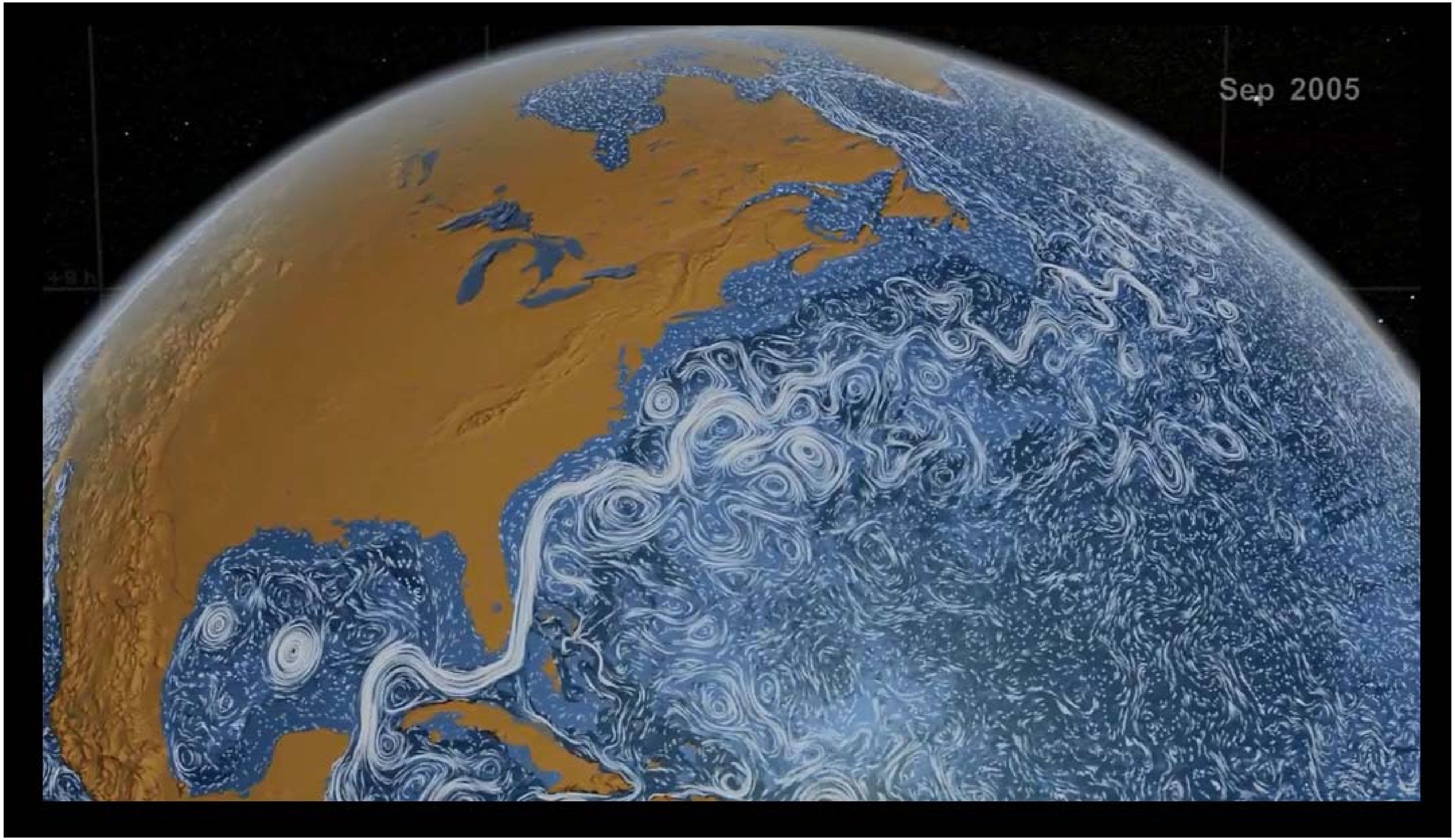
Vision: GNSS reflectometry with HALO in Antarctica



New GNSS reflectometry experiment aboard the ISS


GPS (~30)
+Glonass (~24)
Galileo (~30)
Beidou (~30)
Precise Orbit &
Ionosphere
Water &
Ice
Atmosphere,
Ionosphere,
Water, Ice
GNSS aboard ISS

One focus of GEROS: Mesoscale Ocean Currents (Eddies)



Mission objectives GEROS

Primary (Mission driving):

Long-term GNSS based remote sensing of sea surface applying coherent and incoherent reflectometry in the tropics and mid-latitudes, Unique combination of coherent and incoherent reflectometry with the use of „large“ antennas,

Secondary:

Atmosphere sounding with GNSS

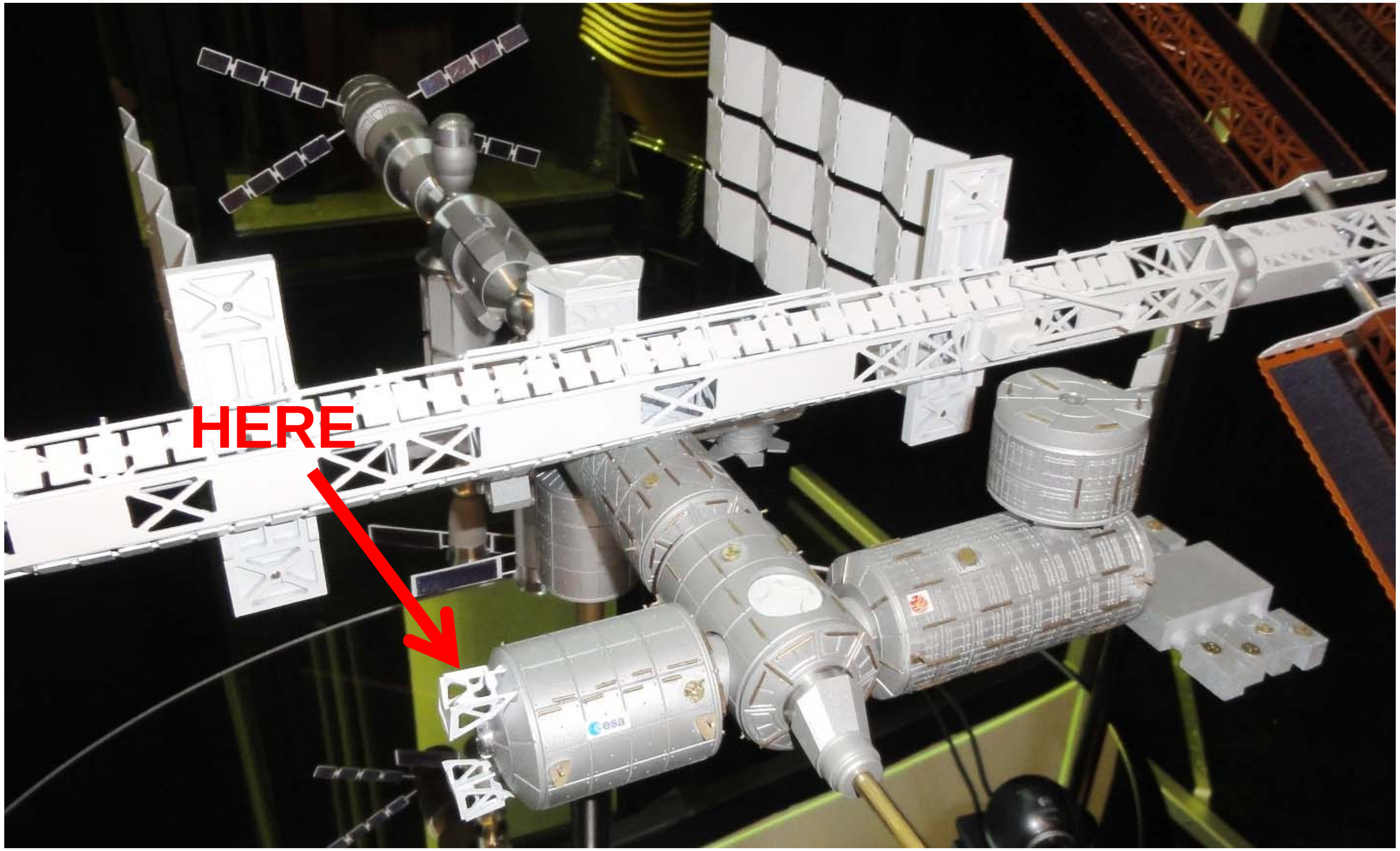
several advantages compared to other missions:

low inclination orbit (high SNR values Equator),polarimetriy occultations, Multi-GNSS, additional information for reflectometry

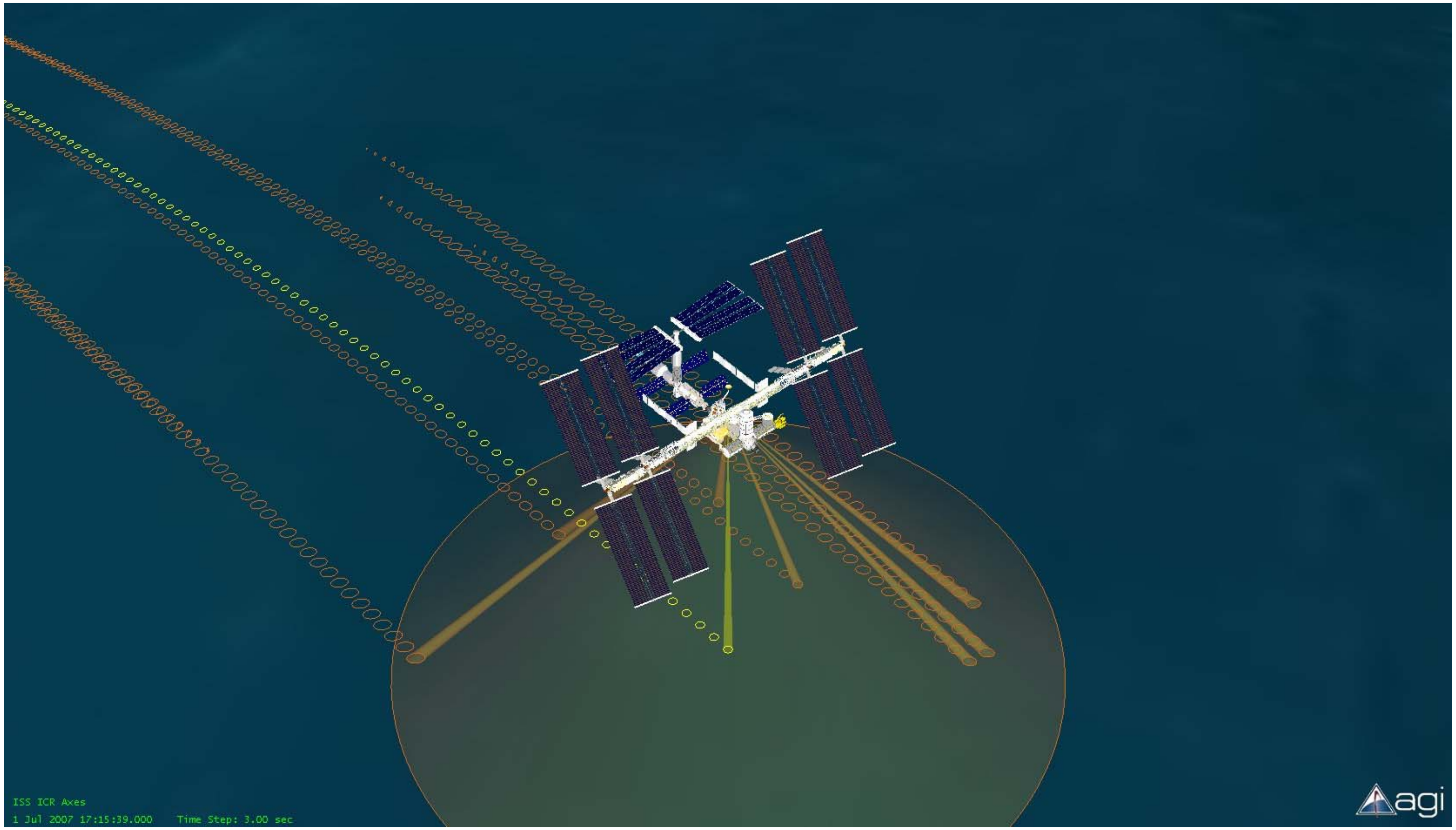
Land surface remote sensing with GNSS

Soil moisture, snow, vegetation

GEROS: Where to mount?

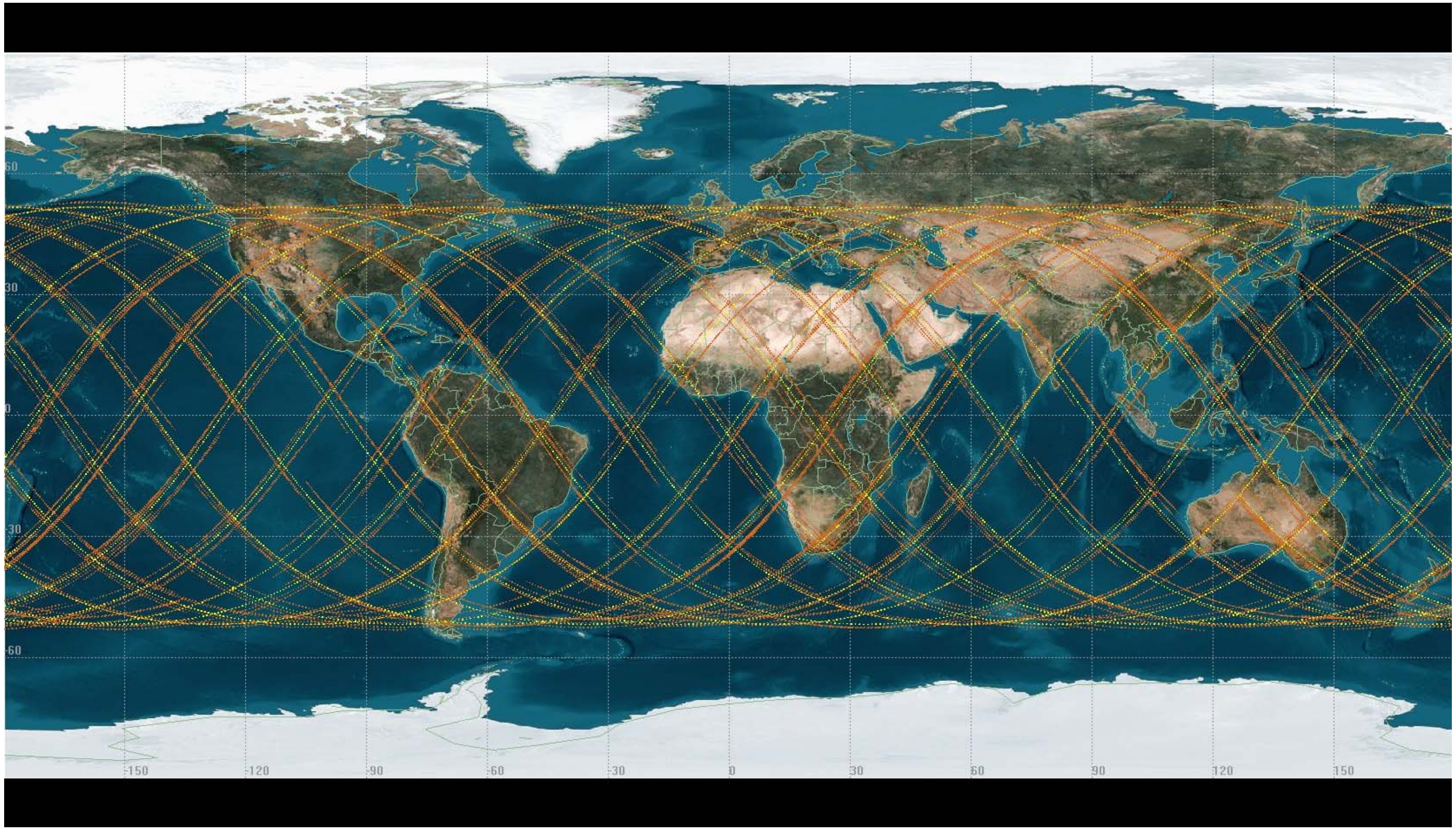


GEROS-ISS: Animation



Thanks: S. D‘Addio (ESA)

GEROS-ISS: Coverage 24h



Thanks: S. D‘Addio (ESA)

Main conclusions

- GNSS Remote Sensing (RS) has evolved to a powerful and versatile remote sensing method for numerous applications in weather/atmosphere research and climate change related investigations also in the polar regions

- A complex and operational GNSS infrastructure can be used to enable operational GNSS RS applications

- Atmosphere sounding reached operational application level, reflectometry is in focus of recent research

- GNSS RS has even more potential (e.g. new GNSS systems), numerous interdisciplinary challenges are waiting, international cooperation will increase effectiveness to meet these challenges

- Young scientists are very welcome to contribute to these challenging and fascinating developments!

Thank you!

wickert@gfz-potsdam.de