

# ***RO-CLIM (SCM-08)***

## **RADIO OCCULTATION BASED GRIDDED CLIMATE DATA SETS**

Hans Gleisner & the RO-CLIM project team

Danish Meteorological Institute

# Outline

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- ▶ Background: RO measurement technique, RO satellite missions, data numbers
- ▶ RO-CLIM project: understanding structural uncertainties & generating CDRs
- ▶ Ongoing project activities and current status
- ▶ Plans ahead

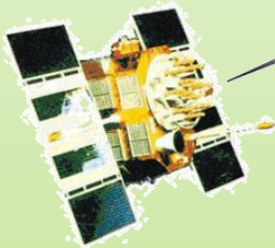
# Atmospheric sounding with GPS RO

– what is measured –

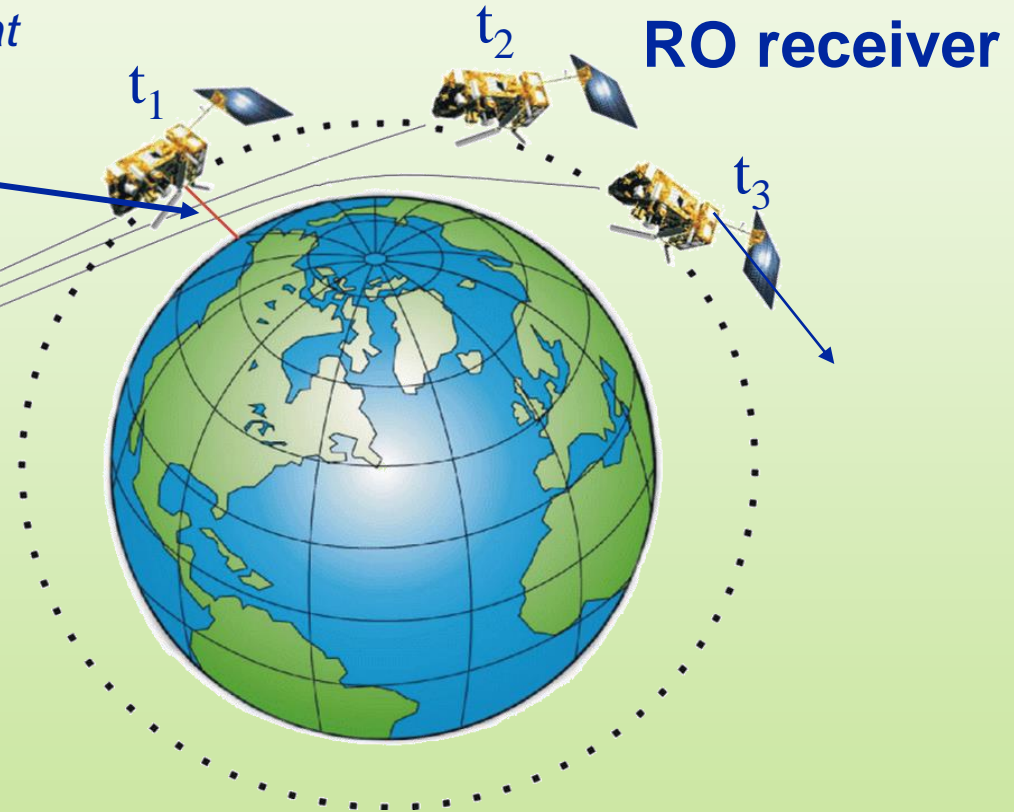
## **Starting point for processing:**

- i. Measurements of phase and amplitude that gives a vertical atmospheric profile at the ray's tangent point.*
- ii. Position and velocity of the satellites.*

**GNSS**



GPS signals:  
L1:  $\approx 19$  cm  
L2:  $\approx 24$  cm



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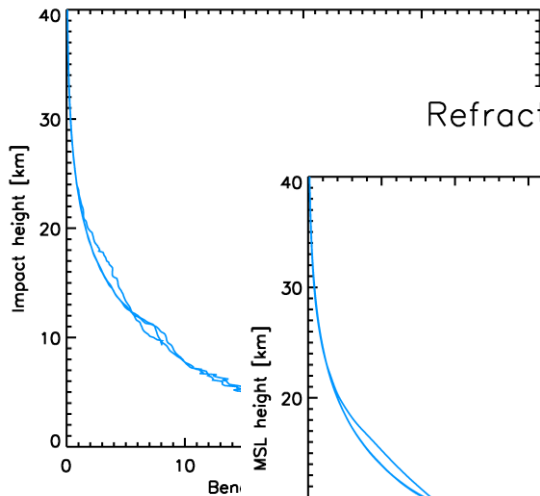


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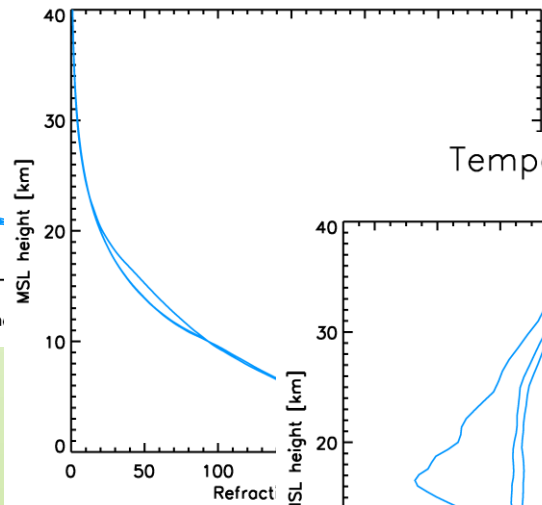
# Atmospheric sounding with GPS RO

– atmospheric profiles –

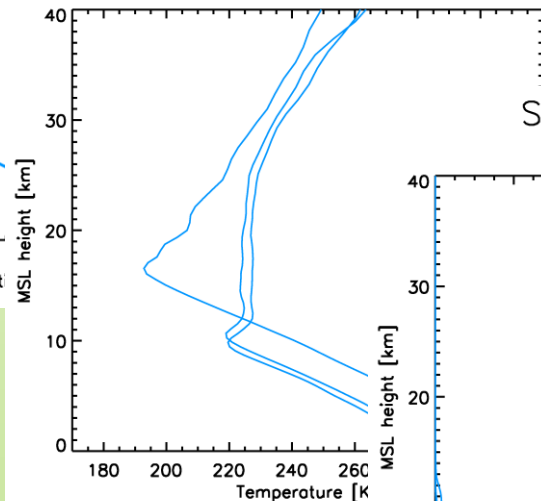
Bending angle



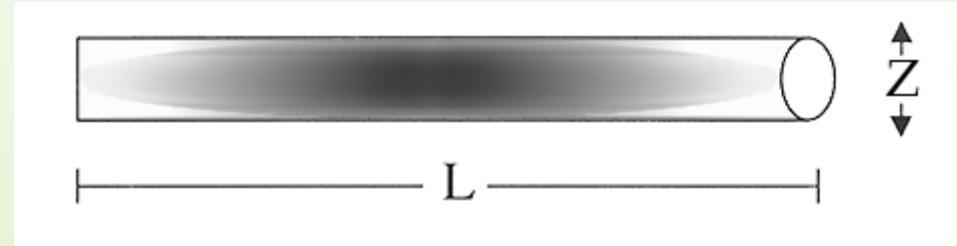
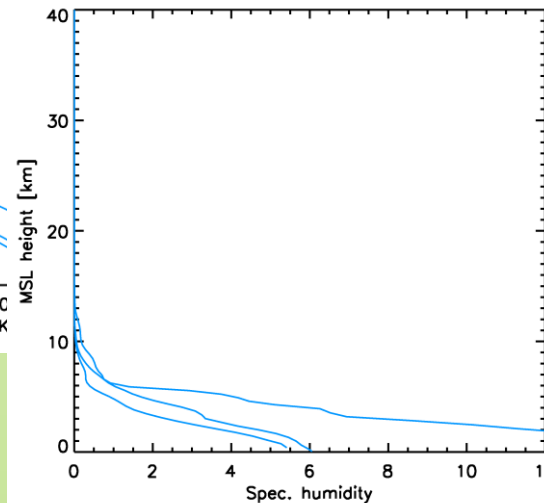
Refractivity



Temperature



Spec. humidity



**$L \sim 300$  kilometers**

**$Z \sim 100$  meters – 1 kilometer**

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# Sampling the atmosphere with GPS RO

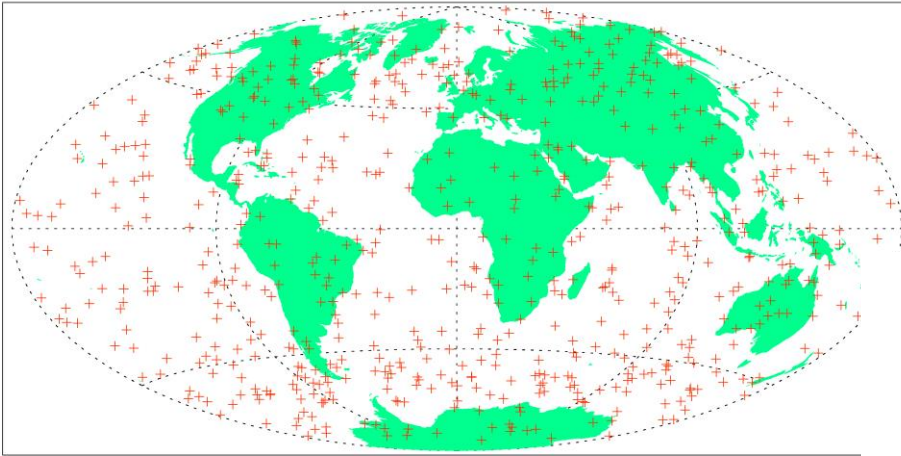
– distribution of profiles –

METOP

Occultations

– one day –

Aug 2009

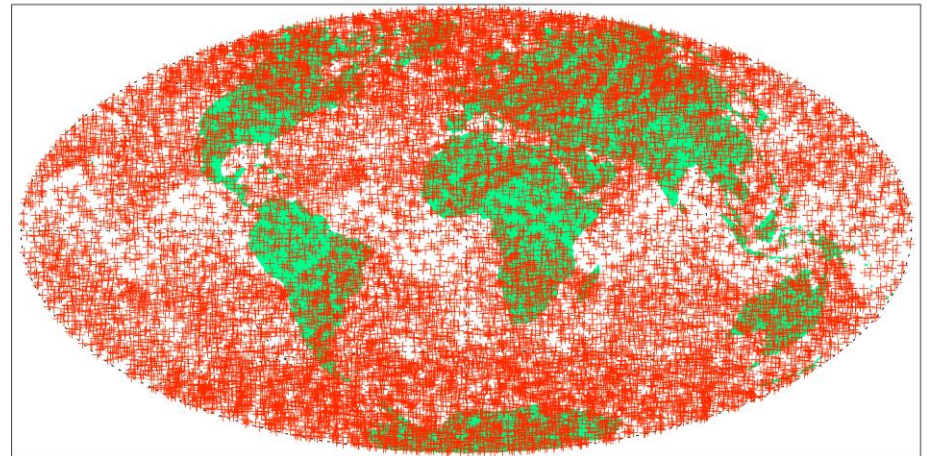


METOP

Occultations

– one month –

Aug 2009

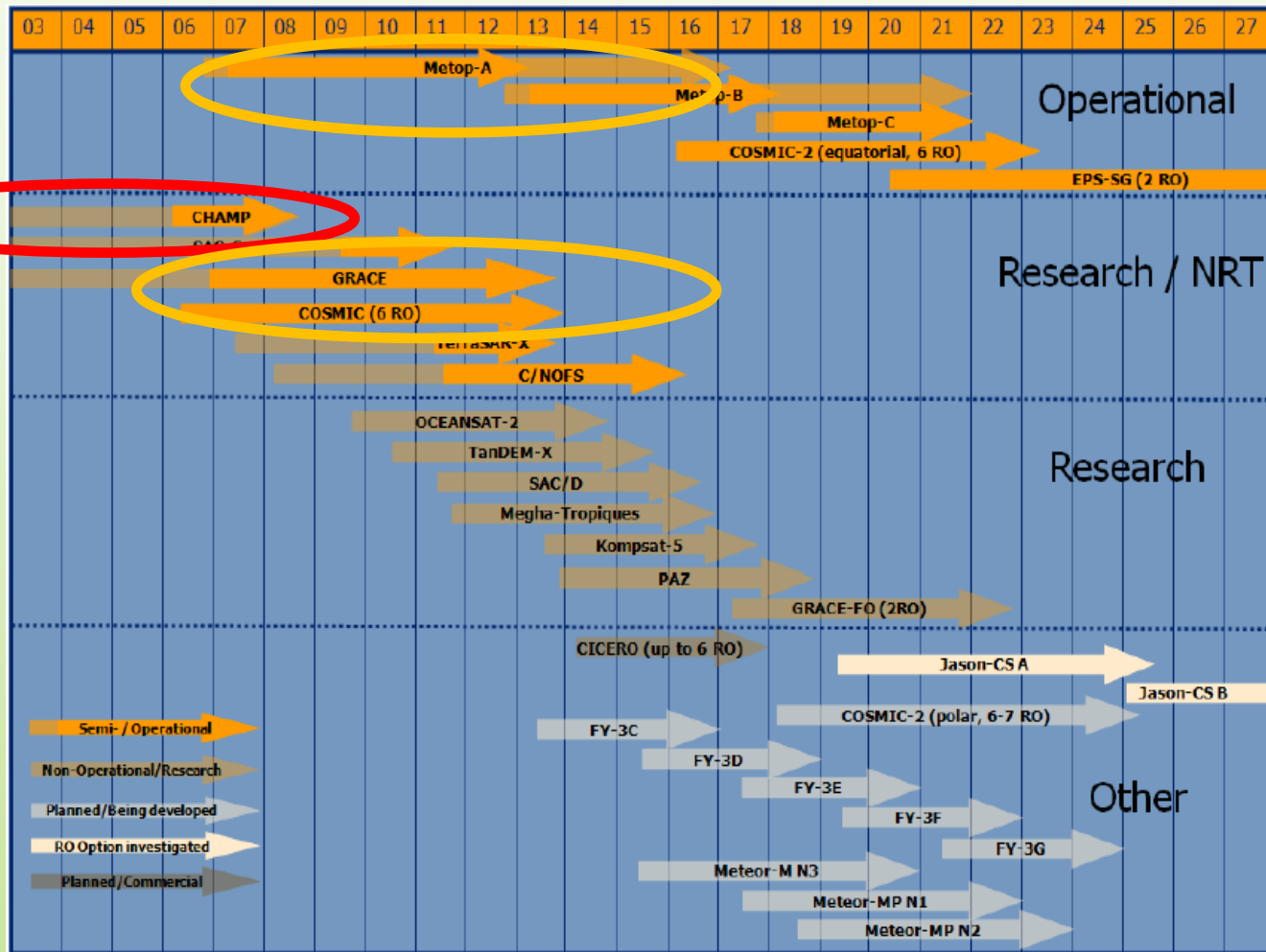


# Characteristics of RO data

- ▶ microwave frequencies, active sounding:  
independent of clouds, surface emissivity, day/night
- ▶ based on time measurements, not radiances:  
intrinsic long-term stability  
no inter-calibration between instruments and missions  
provides “anchor” point in NWP and re-analysis
- ▶ limb sounding:  
high vertical resolution (0.1-1.0 km from lower troposphere to stratosphere)  
low horizontal resolution (300 km along the ray)
- ▶ global coverage:  
sampling all lats & lons, troposphere and stratosphere  
“quasi-random” sampling in space and time

These features make RO ideal for climate monitoring – but errors must be understood. *Residual ionospheric errors* and *structural errors* (impact of algorithmic choices and processing assumptions) are two important limiting factors.

# RO satellite missions



Continuous RO data since August 2001.

Initial RO-CLIM Focus

Extended RO-CLIM Focus

**Note: Figure from proposal, now outdated after 2014!**

See also:

Status of the Global Observing System for Radio Occultation (Update 2013), IROWG/DOC/2013/02, available at:

<http://irowg.org/workshops/irowg-3/>

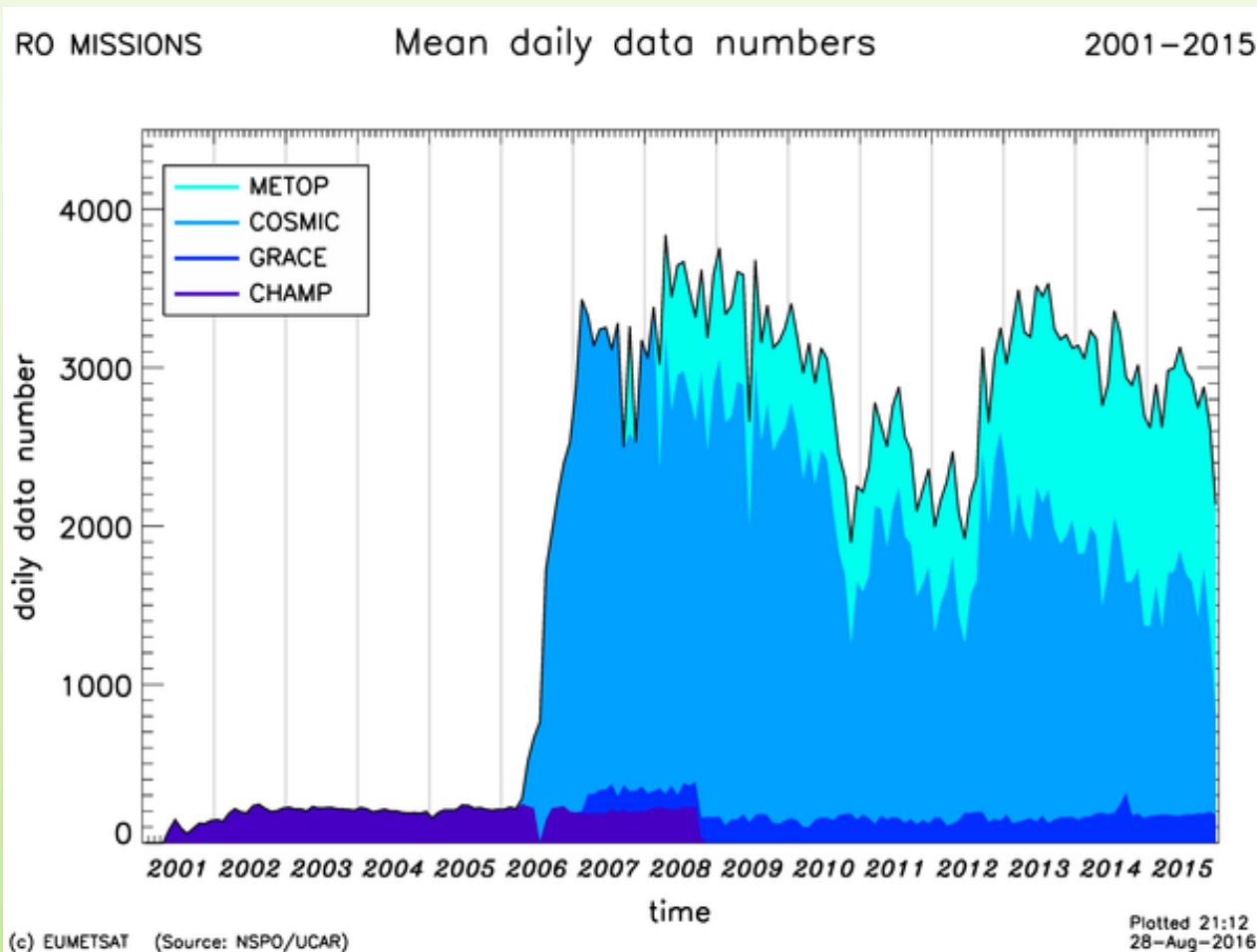
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# RO data numbers

– in current ROM SAF reprocessing –



Daily data numbers for the RO missions included in the ROM SAF reprocessing.

Data from Metop-A available since Nov 2006, from Metop-B since Oct 2012.

COSMIC is declining, but the gap is largely filled by Metop (by numbers, not coverage).



# RO-CLIM project partners

Name and title	Institute	Address
H. Gleisner, K. Lauritsen, S. Syndergaard	ROM SAF / DMI	Danish Meteorological Institute, Copenhagen, Denmark
S. Healy	ECMWF	European Centre for Medium Range Weather Forecasts, Reading, UK
C. Marquardt, R.A. Roebeling, A. von Engeln	EUMETSAT	EUMETSAT, Darmstadt, Germany
T. Schmidt, J. Wickert	GFZ	GeoForschungsZentrum, Helmholtz Centre, Potsdam, Germany
C. Ao, T. Mannucci	JPL	NASA Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California, USA
M. Ringer	Met Office	Met Office, Exeter, UK
R. Kursinski	SS&E	Space Science and Engineering, Boulder, USA
B. Schreiner, S.-P. Ho, D. Hunt	UCAR	COSMIC Program Office, University Corporation for Atmospheric Research, Boulder, Colorado, USA
A. Steiner, U. Foelsche, G. Kirchengast B. Scherllin-Pirscher	WEGC	Wegener Center for Climate and Global Change, University of Graz, Graz, Austria

From RO-CLIM Project Description, available at:

<http://irowg.org/projects/ro-clim-under-scope-cm/>

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# Summary of *RO-CLIM* project goals

## c. Summary of proposed project

While ROTrends provided a very valuable data set over the CHAMP period, an extension of that initial period to include the most recent radio occultation observations and build up a long term climate data record is one focus of this project. It will in addition also make use of the more dense coverage of recent satellites, to provide a shorter duration, higher resolution data set. By including model data from both ECMWF and the Met Office Hadley Centre an assessment of the model performance against radio occultation data is also possible. The SCOPE-CM used maturity matrix provides a very valuable reference for the currently available ROTrends data set, this set will be evaluated and “matured” against that matrix.

From RO-CLIM Project Description, available at:

<http://www.scope-cm.org/projects/scm-08>

# RO-CLIM project

- Main aim is to support the generation of Climate Data Records;
- this is done by identifying sources of structural errors through comparison between data sets independently generated by several RO processing centers, and through other collaborative cross-center studies, leading to improved algorithms and processing methods;
- the 6 processing centers (project partners) use largely independent processing chains – we do not decide on common standard algorithms;
- as a result of this process, we get up to 6 (quasi)-independent CDRs, from which a 6-member ensemble of gridded monthly mean data is obtained;
- we plan to make this ensemble of CDRs publically available with a “SCOPE-CM label”. Version 1, based on CHAMP data only, is currently accessible through the project page on [www.scope-cm.org](http://www.scope-cm.org).

# Structural uncertainty: differences between centers

Bending angle – difference to all-center mean – July 2008

CHAMP

COSMIC

GRACE

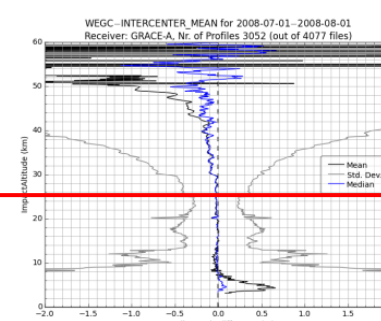
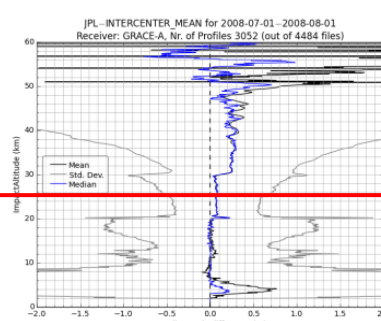
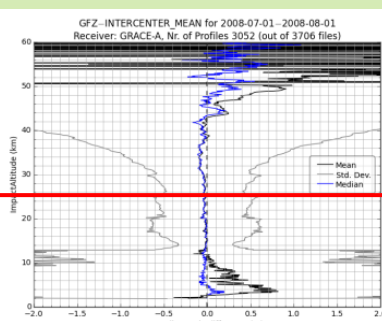
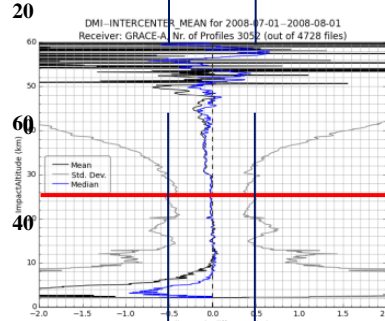
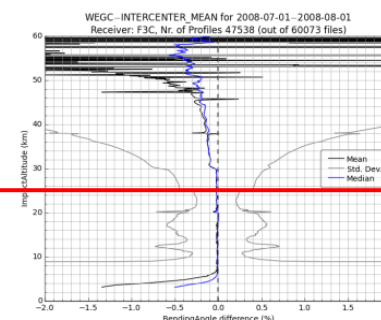
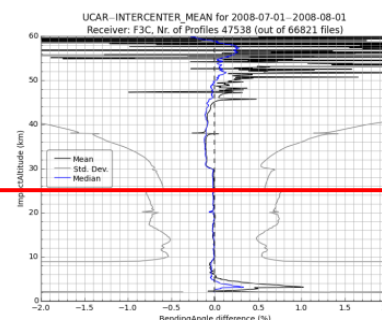
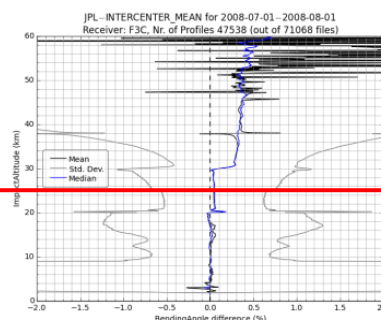
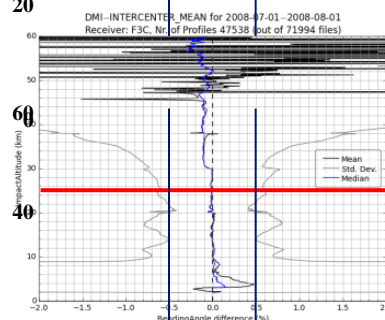
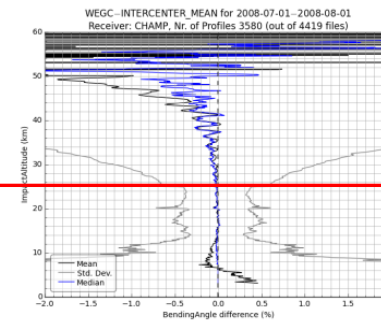
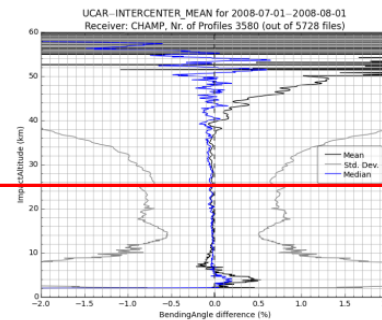
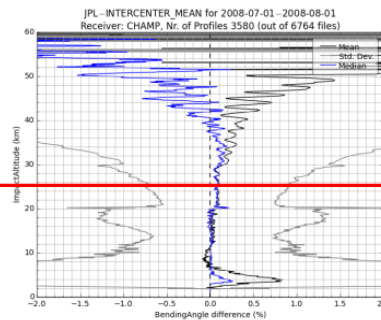
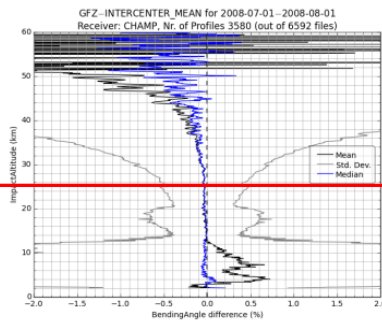
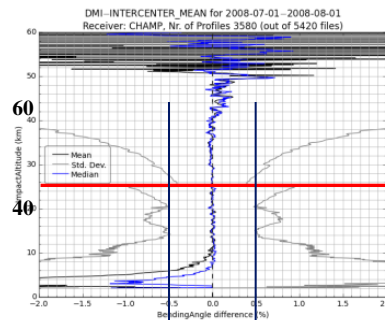
DMI

GFZ

JPL

UCAR

WEGC



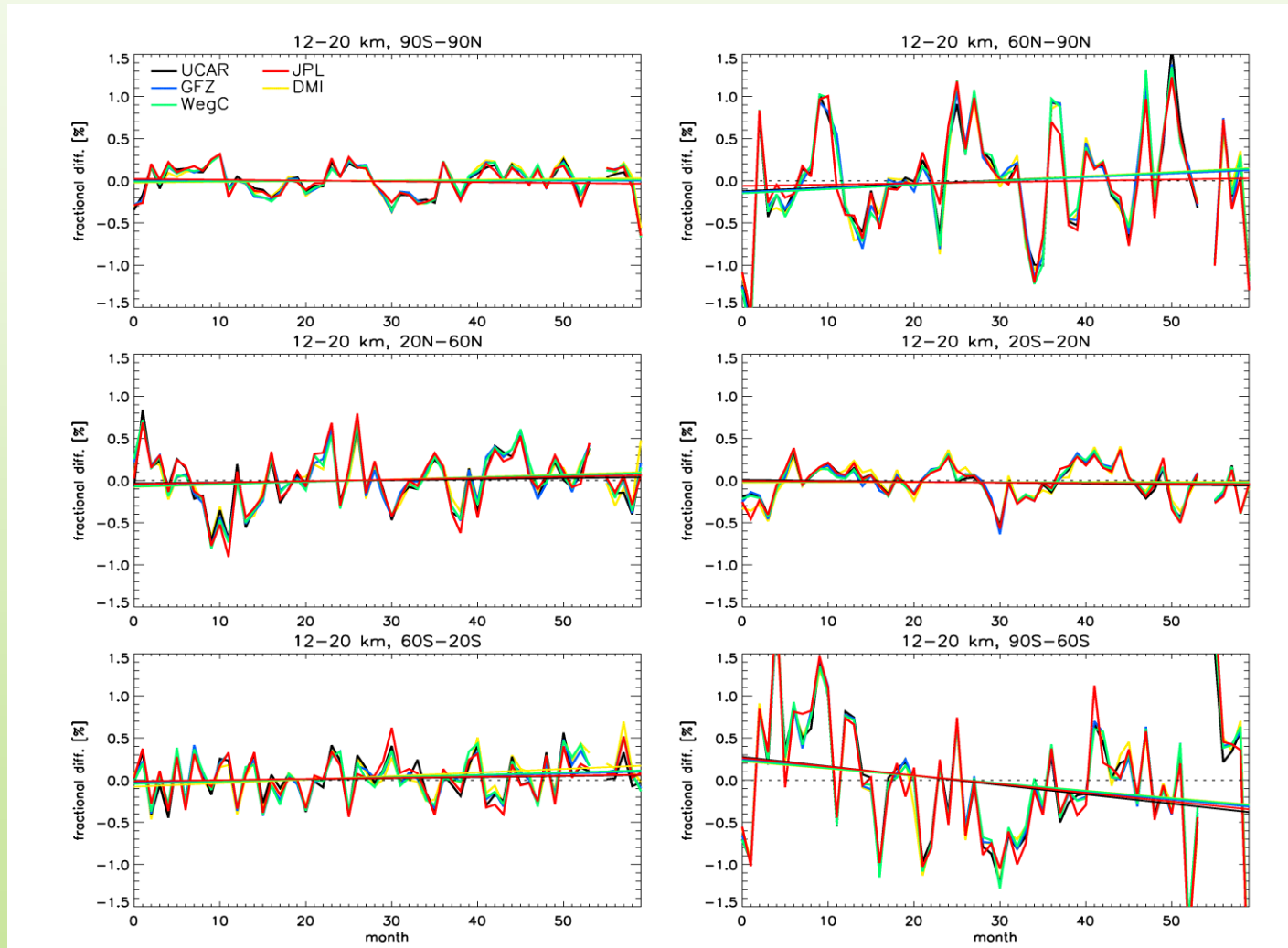
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# Structural uncertainty: differences between centers

## Refractivity trends in latitude zones – CHAMP data

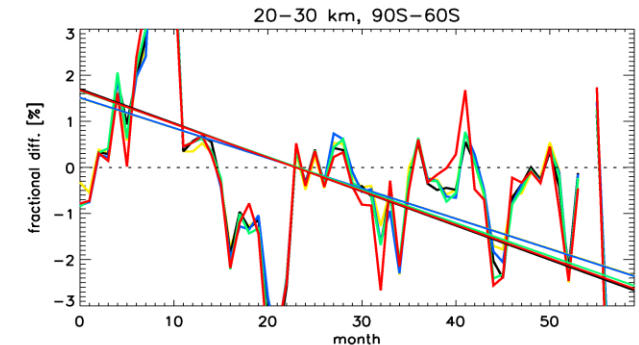
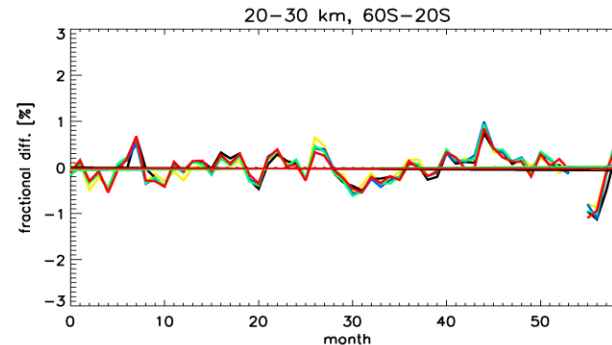
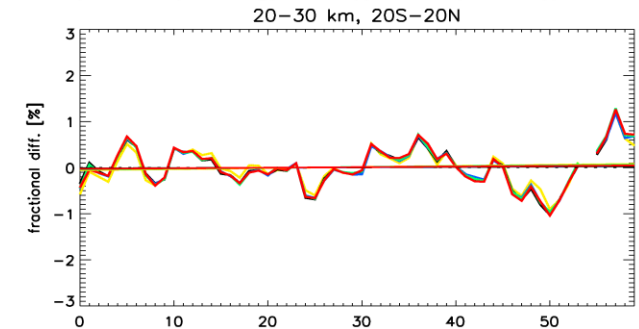
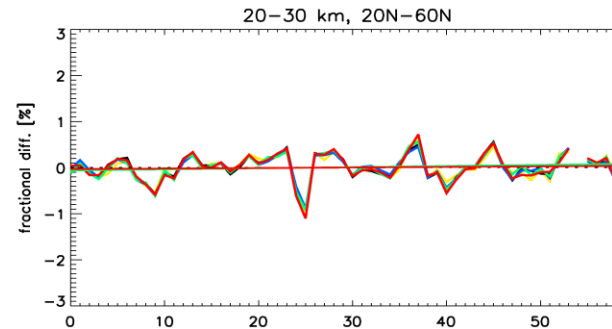
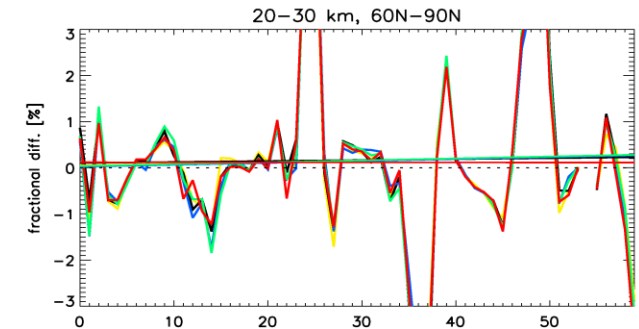
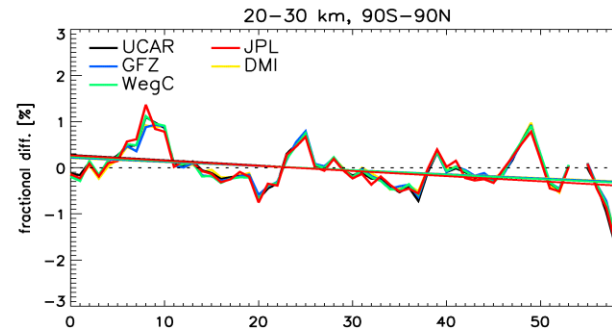
- Common CHAMP data
- DMI, WEGC, UCAR, JPL, GFZ
- Refractivity anomalies
- 12-20 km
- 6 latitude bands
- Data within  $\pm 0.2\%$
- Trends within  $\pm 0.02\%/10\text{yr}$



# Structural uncertainty: differences between centers

## Refractivity trends in latitude zones – CHAMP data

- Common CHAMP data
- DMI, WEGC, UCAR, JPL, GFZ
- Refractivity anomalies
- 20-30 km
- 6 latitude bands
- Data within  $\pm 0.5\%$
- Trends within  $\pm 0.03\%/10\text{yr}$





# Structural uncertainties

Low structural uncertainty in tropics and at mid-latitudes, 8-25 km

Larger at high latitudes above 25 km

Primarily due to different upper altitude initialization (Abel integral)

Uncertainty in trends over the CHAMP period meets GCOS requirements:

- < 0.02% in bending angle, refractivity

- < 0.03% in pressure

- < 3 m geopotential height

- < 0.02 K (UT), < 0.1 K (LS)

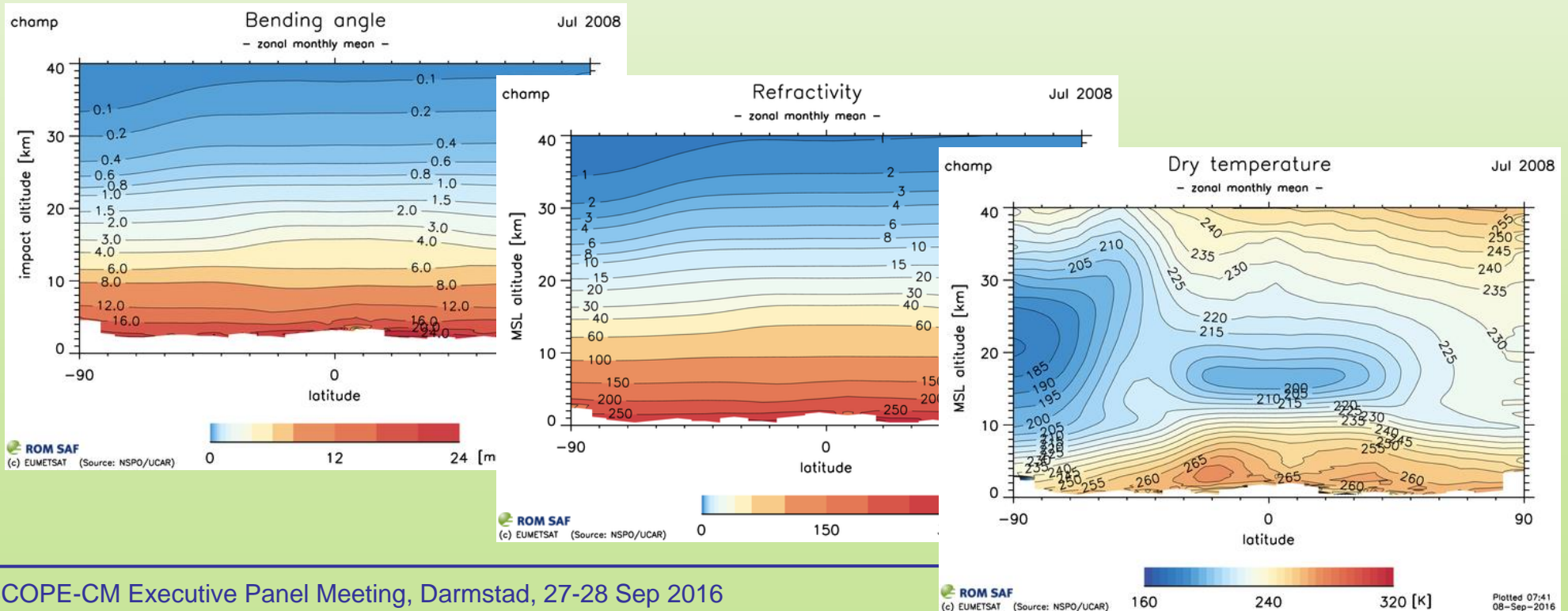
- over 7-year period

Persistent and seasonal biases found at high latitudes, and have lead to software updates at several centres, including the implementation of a new climatology (BAROCLIM [Scherllin-Pirscher et al. [2015]] for upper-level initialization of bending angle profiles.



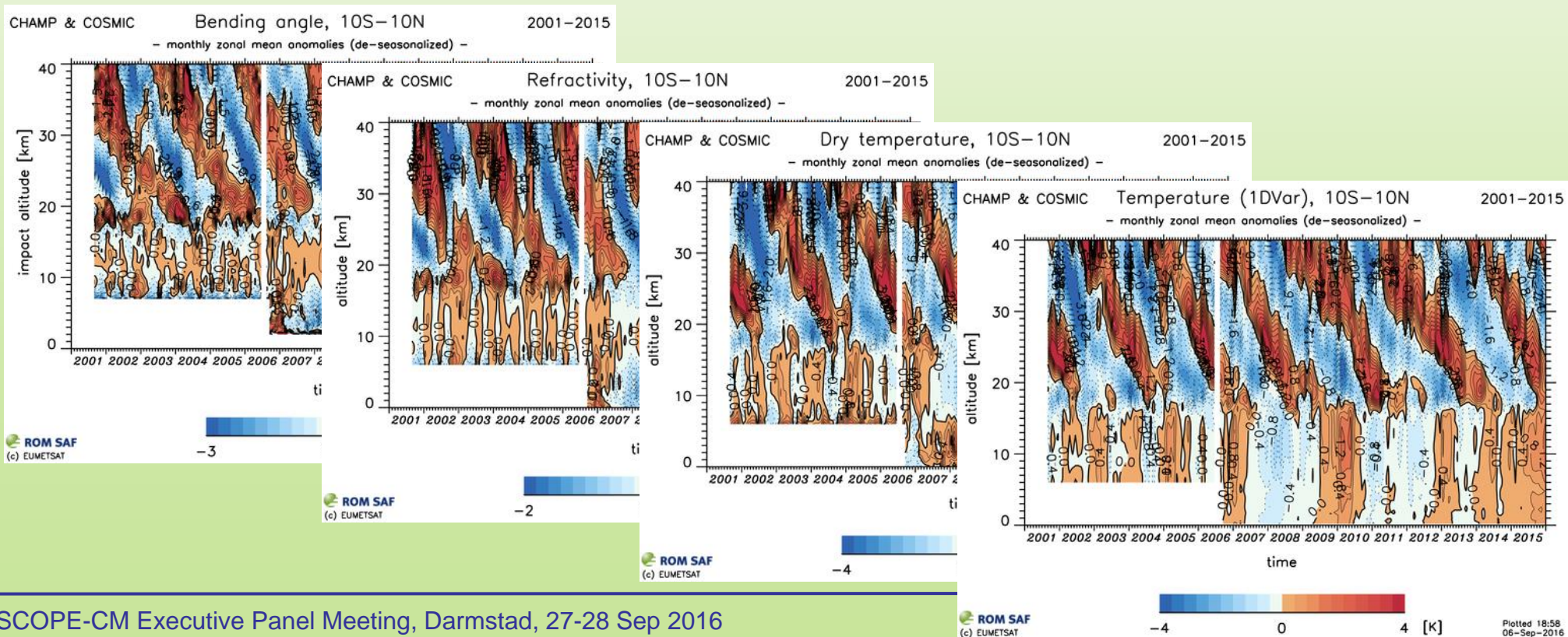
# Initial *RO-CLIM* data set

CHAMP zonal monthly mean data: 5 deg x 200 m, 8-30 km, global coverage.  
Provided with error characteristics and sampling-error corrected means.  
Provided as an ensemble of 6 data sets.  
Made publically available through SCOPE-CM web site.  
Includes a User Guide + web links to RO processing documentation.



# Extended *RO-CLIM* data set

- CHAMP, GRACE, COSMIC, Metop, SAC-C, ...
- Continuous since Aug 2001 (lower resolution), since Aug 2006 (higher resolution).
- Reprocessing currently ongoing at some of the 6 centers.
- Will be made publically available as a 6-member ensemble of RO gridded monthly mean data.



# Self-assessed maturity levels

Software readiness	Metadata	User documentation	Uncertainties Characterisation	Public access, feedback and update	Usage
Coding Standards 4	Coding Standards 4	Formal description of scientific methodology 4	Standards 4	Public access/Archive 4	Research 4
Software Documentation 6	Collection level	Formal validation report 4	Validation 6	Version 4	Decision support system
Numerical reproducibility and portability 4	File level 6	Formal product user guide 6	Uncertainty quantification 4	User feedback mechanism	
Security 4		Formal description of operations concept	Automated quality monitoring	Update to record	
Legend					
1	2	3	4	5	6

# RO-CLIM project status

- RO-CLIM project roughly proceeding according to plan;
- A first version of an RO-CLIM data set is available at the project web page;
- A User Guide for the RO-CLIM RO Climate Data Record is available;
- Documentation of the RO data processing is made available through web links to document repositories at the processing centers;
- Multi-mission/multi-centre inter-comparisons are being done, and will continue during next year (WEGC);
- Reprocessing activities aimed at generation of an extended RO CDR are currently ongoing at several centers;
- Work towards generation of data sets for *Obs4MIPs* (JPL, DMI) ongoing.

# Plans ahead

## Up to 2018

- Make an extended RO CDR available, covering the full length of the RO time period 2001-2016, consisting of an ensemble with 5 or 6 members;
- Improve on documentation, populate the RO processing document repository
- Work towards an *Obs4MIPs* version of the extended RO-CLIM data set.

## After 2018 – potential continuation of RO-CLIM - considerations

- New processing centers, perhaps make changes to project consortium;
- Consider how to optimize usage of data for the climate modelling community (*Obs4MIPs*, *COSP* or other ‘simulators’) and for climate services;
- .....



# STOP

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