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CCMC Workshop Jan. 25-29, 2010

User Feedback: Ionosphere Models, *D. Rees*

27-01-2010: 8:40 - 9:20 am:

This is something of a personalised view of “Opportunities”!

1. Relevant Current and Planned ESA Projects

2. CIRA and ISO Activities – International Models / Standards

3. Future ESA Earth Observation Missions (possible)

4. Planetary Missions

In case I overlook – these views rest on very many discussions with many other Scientists – and not just those in Europe.

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1. Relevant Current / Planned ESA Projects

(a) Projects needing CCMC Modelling Support for science:-

GOCE – 2009

Swarm - 2011

- - - - - - - - - - -

(b) Projects needing CCMC Modelling Support for “best orbit”:-

Atmospheric Dynamics Mission (Aeolus) 2011

EarthCARE – ATLID - 2011

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1. Current / Planned ESA Projects

Swarm

1. Current and Planned ESA Projects:

CHAMP and GRACE are instrumented with precision accelerometers.

They have provided excellent "Thermospheric Density" results.

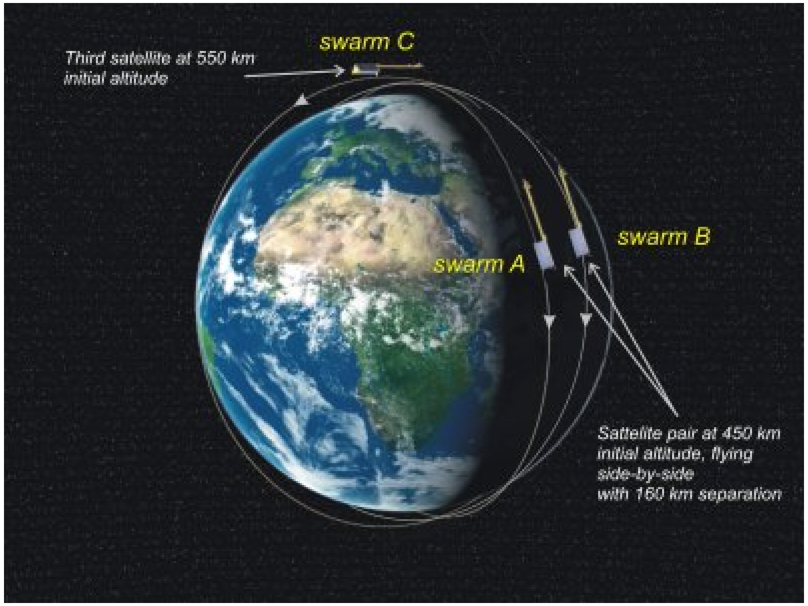
ESA launched GOCE in early 2009 (now fully operational) and will fly the Swarm Constellation in 2011.

➔ Swarm will put three spacecraft into coordinated orbits:

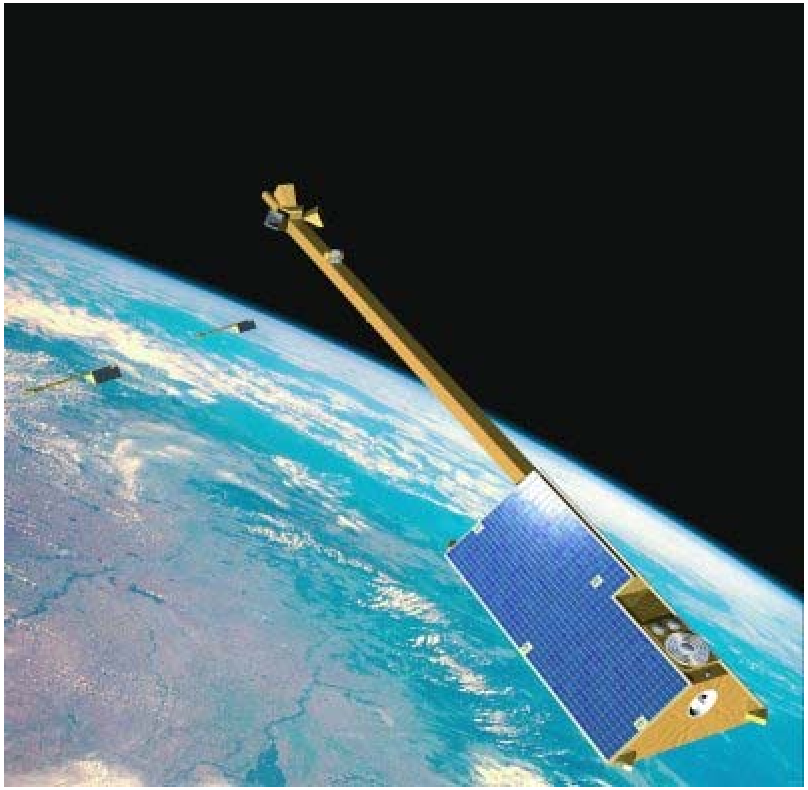
The Swarm S/C are instrumented with:

High Precision / time resolution Accelerometers;
High precision / time resolution Magnetometers;

The orbits will be closely coordinated for measurements of the Ionosphere, Magnetic fields including FAC and the thermosphere.

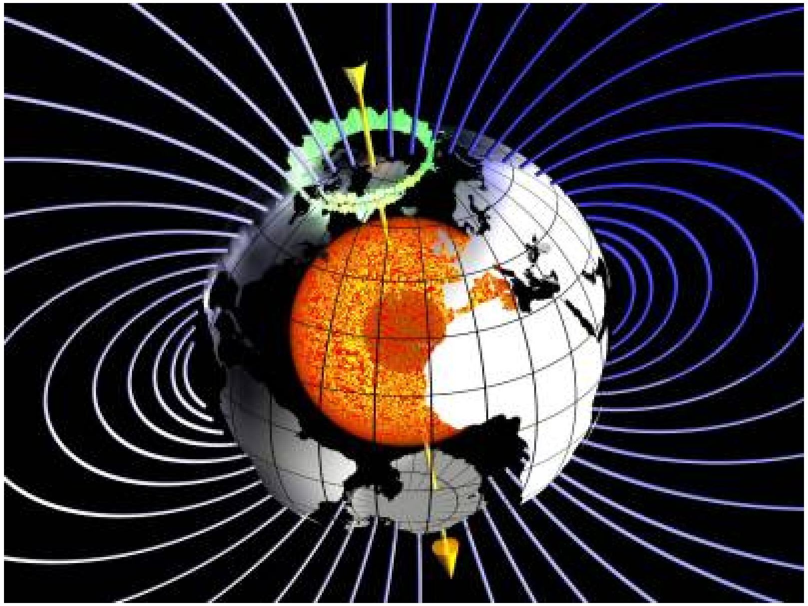


Swarm Spacecraft



Swarm Orbits:
Two “low”
One “high”

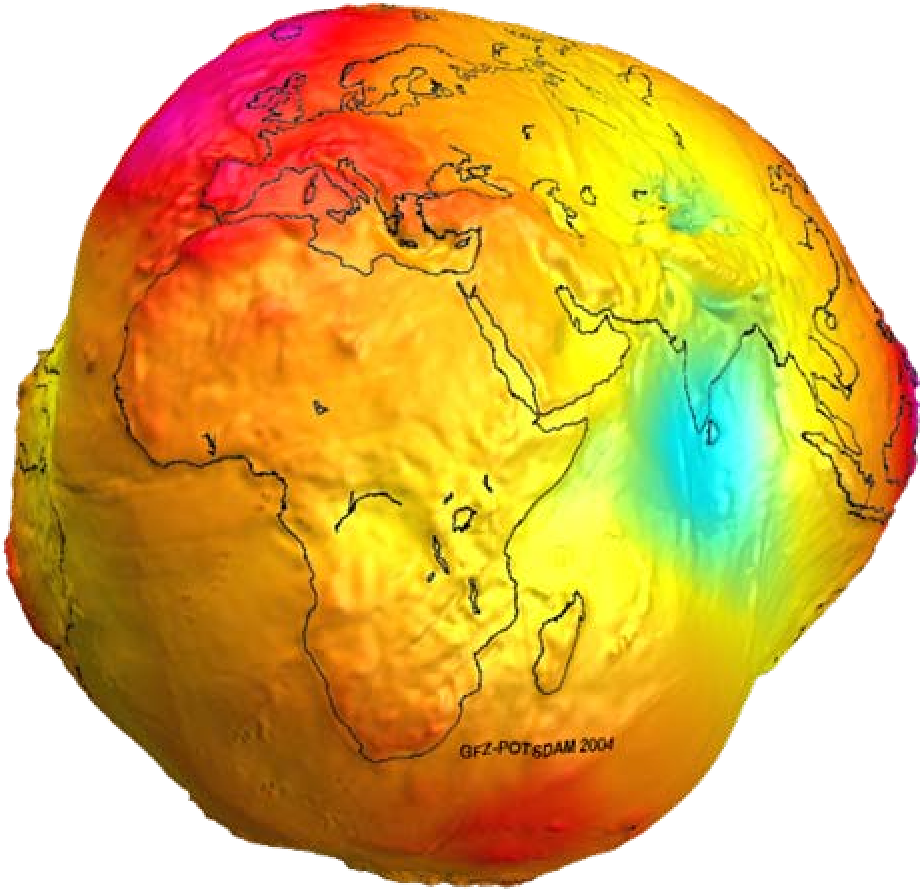
Different precession rates

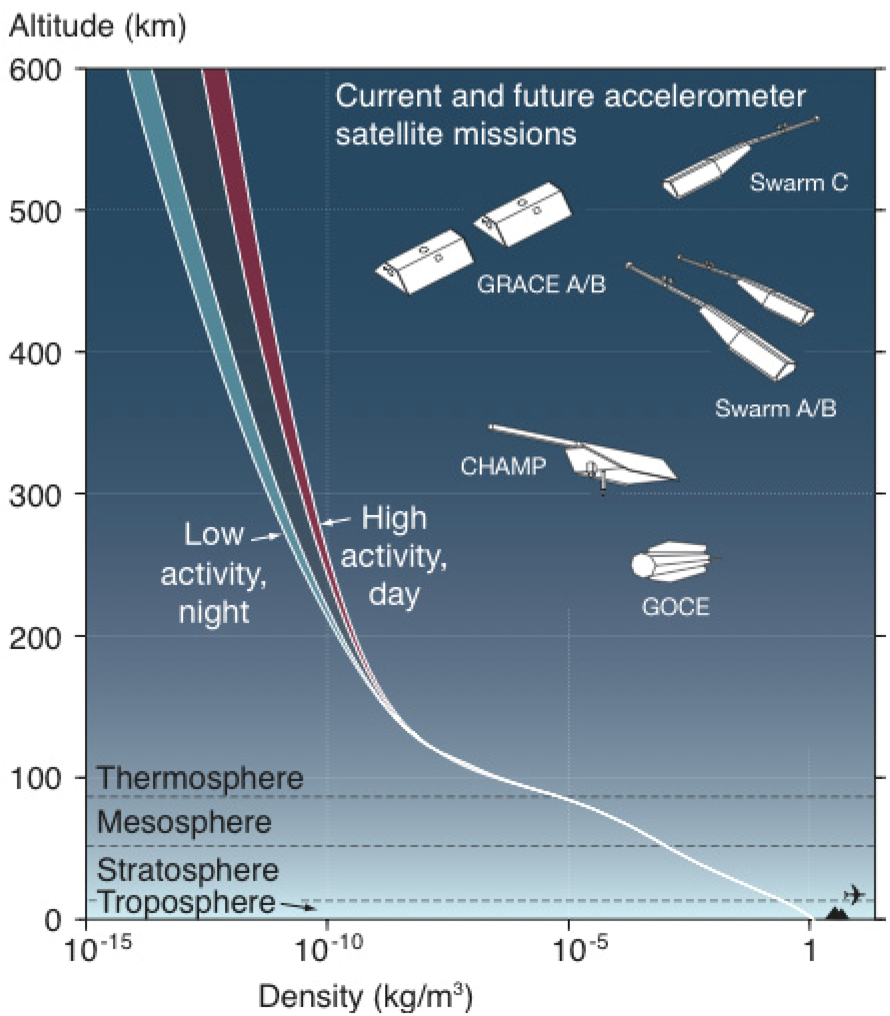


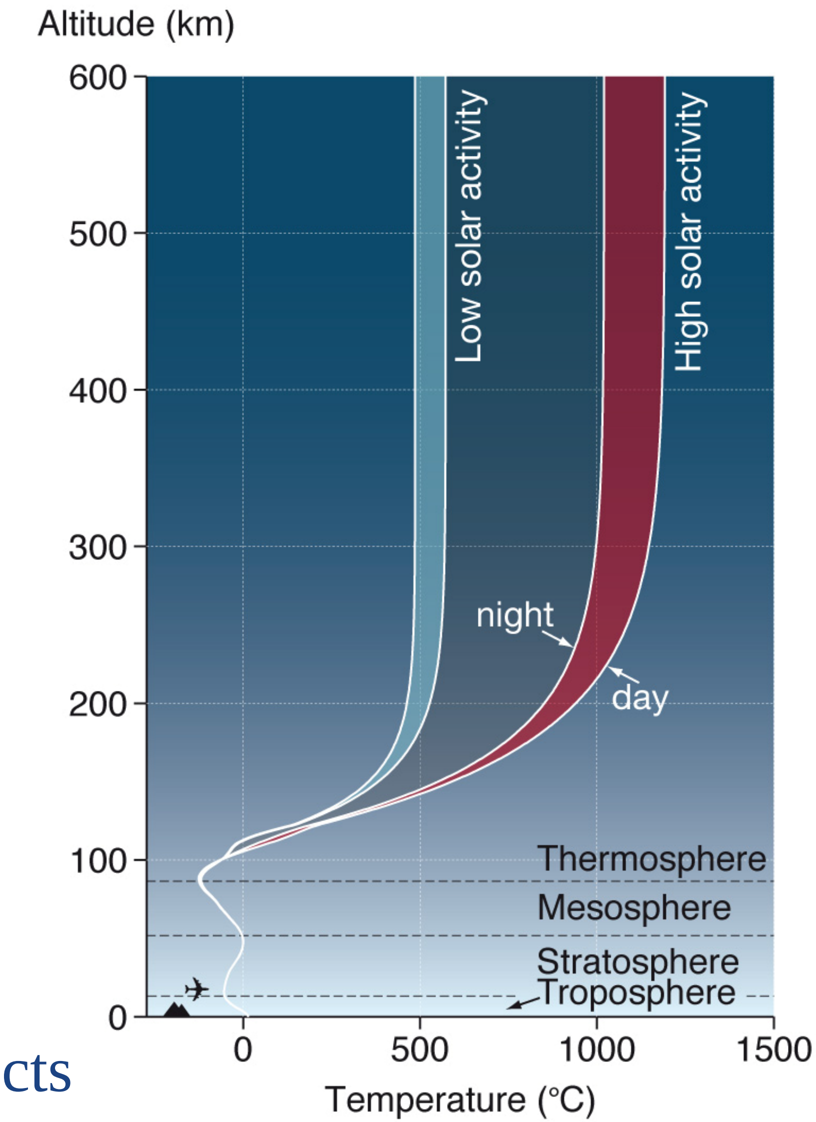
Scenario for magnetic field measurements by Swarm

To make excellent data on the "core" magnetic field:- External "noise" must be removed

Gravity Field from CHAMP







The atmosphere changes – many effects

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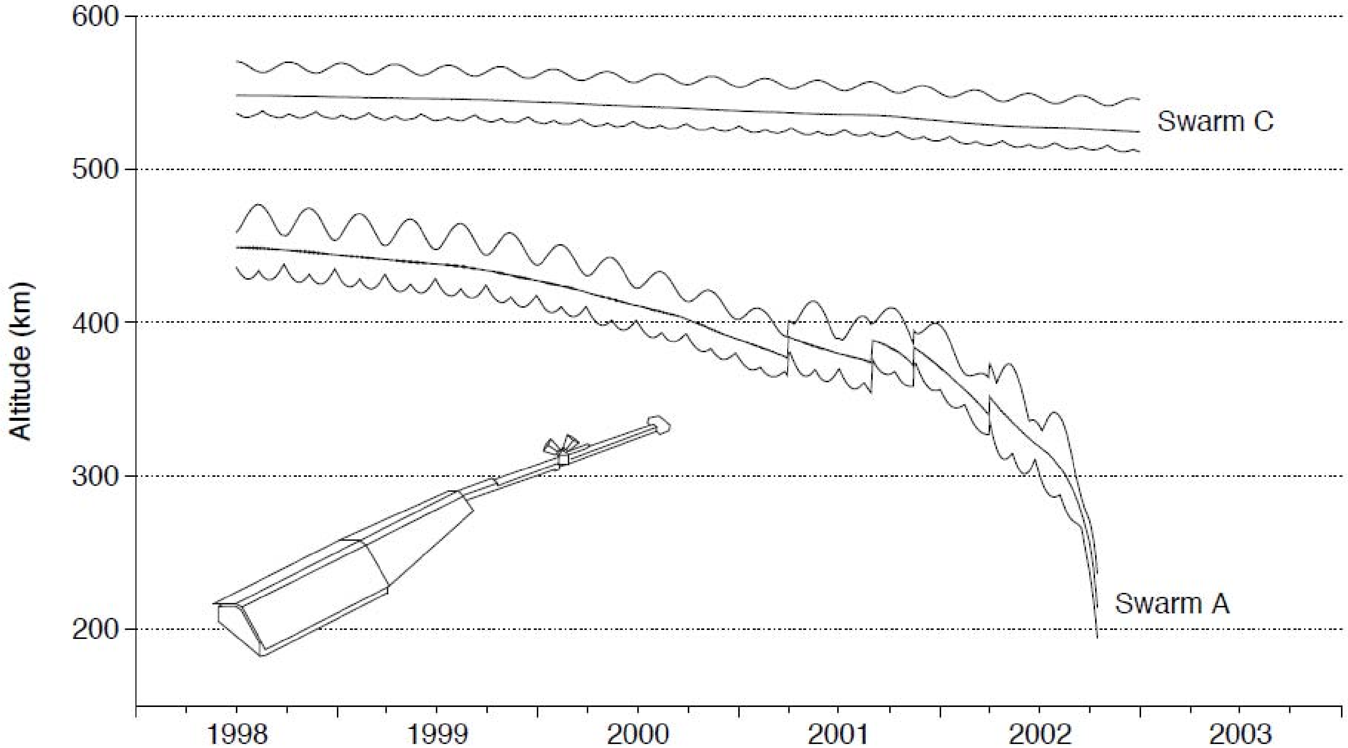
Swarm altitude profile



Actual Swarm launch is 2011 – But – what will the solar activity do?

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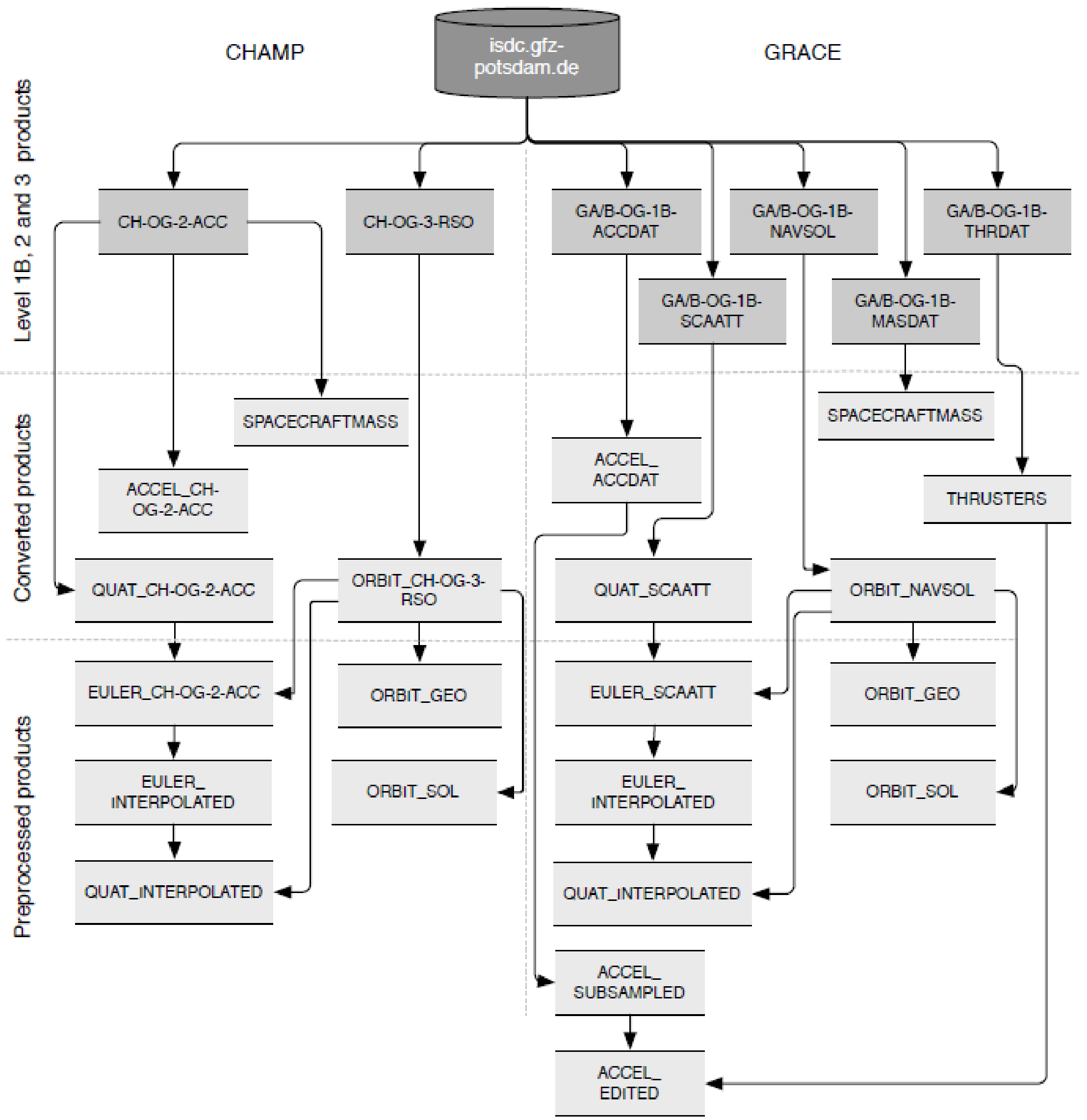

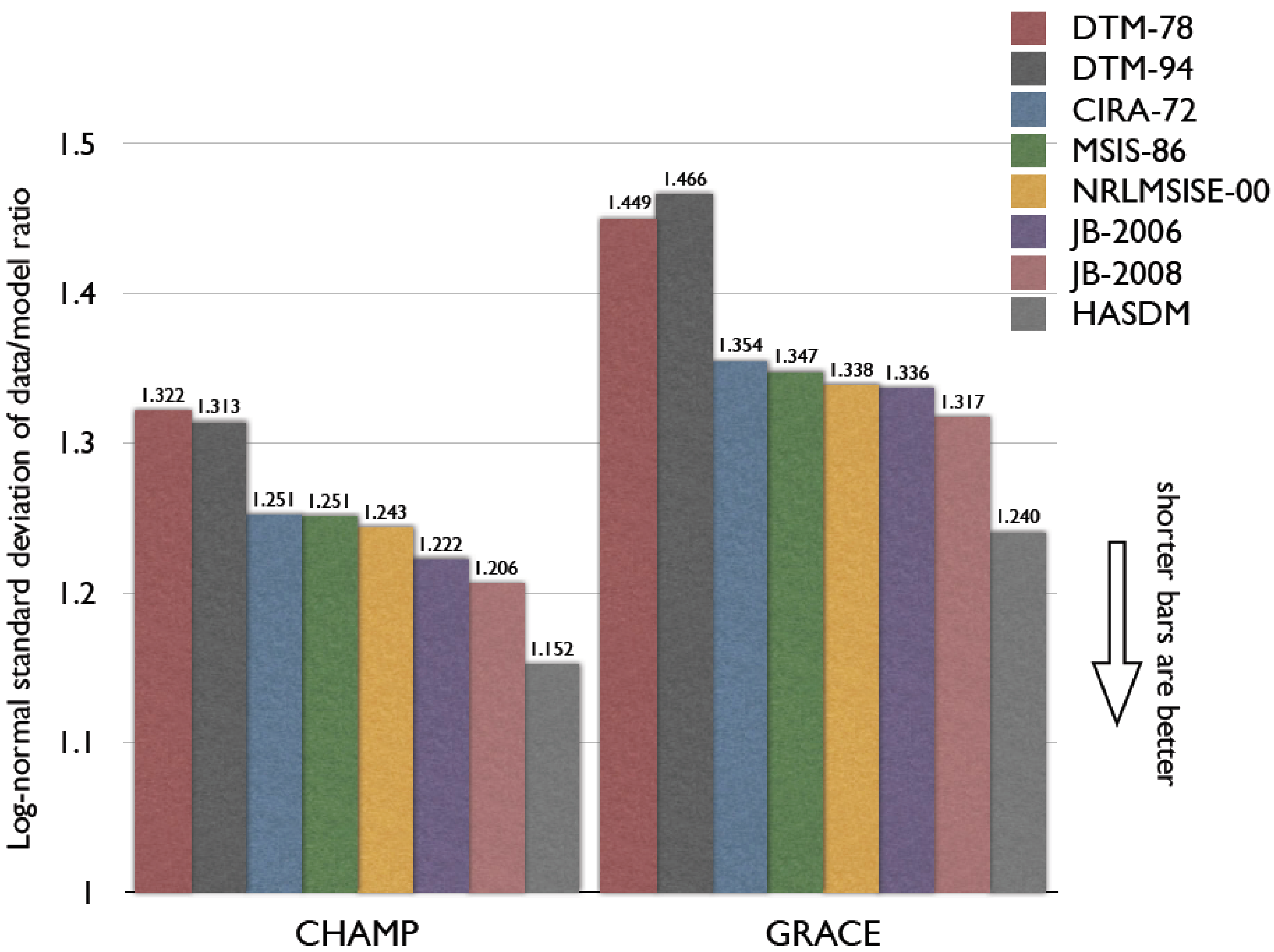
DTM-78
DTM-94
CIRA-72
MSIS-86
NRLMSISE-00
JB-2006
JB-2008
HASDM
Log-normal standard deviation of data/model ratio
1.5
1.4
1.3
1.2
1.1
1
1.322
1.313
1.251
1.251
1.243
1.222
1.206
1.152
1.449
1.466
1.354
1.347
1.338
1.336
1.317
1.240
CHAMP
GRACE
shorter bars are better

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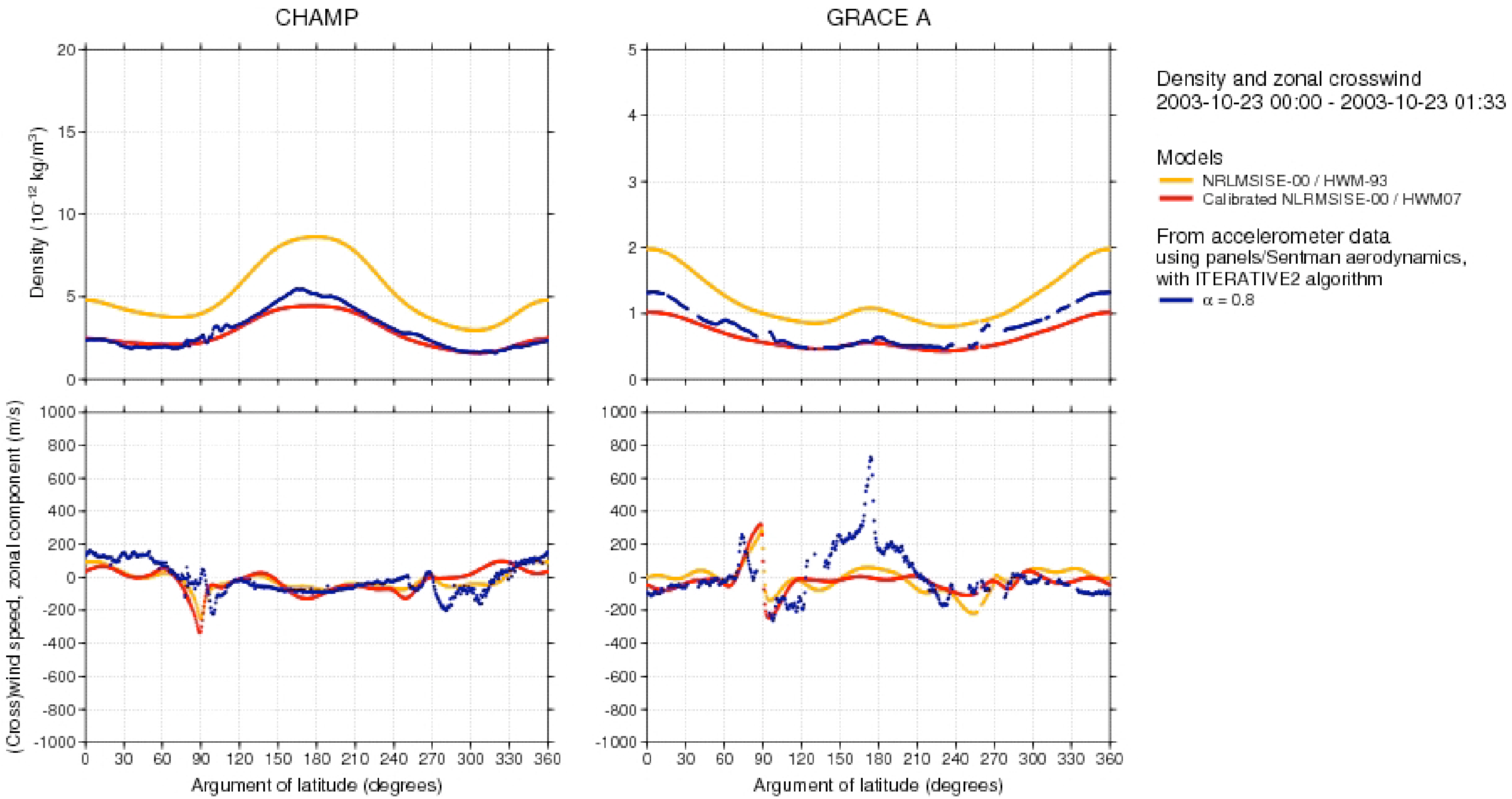

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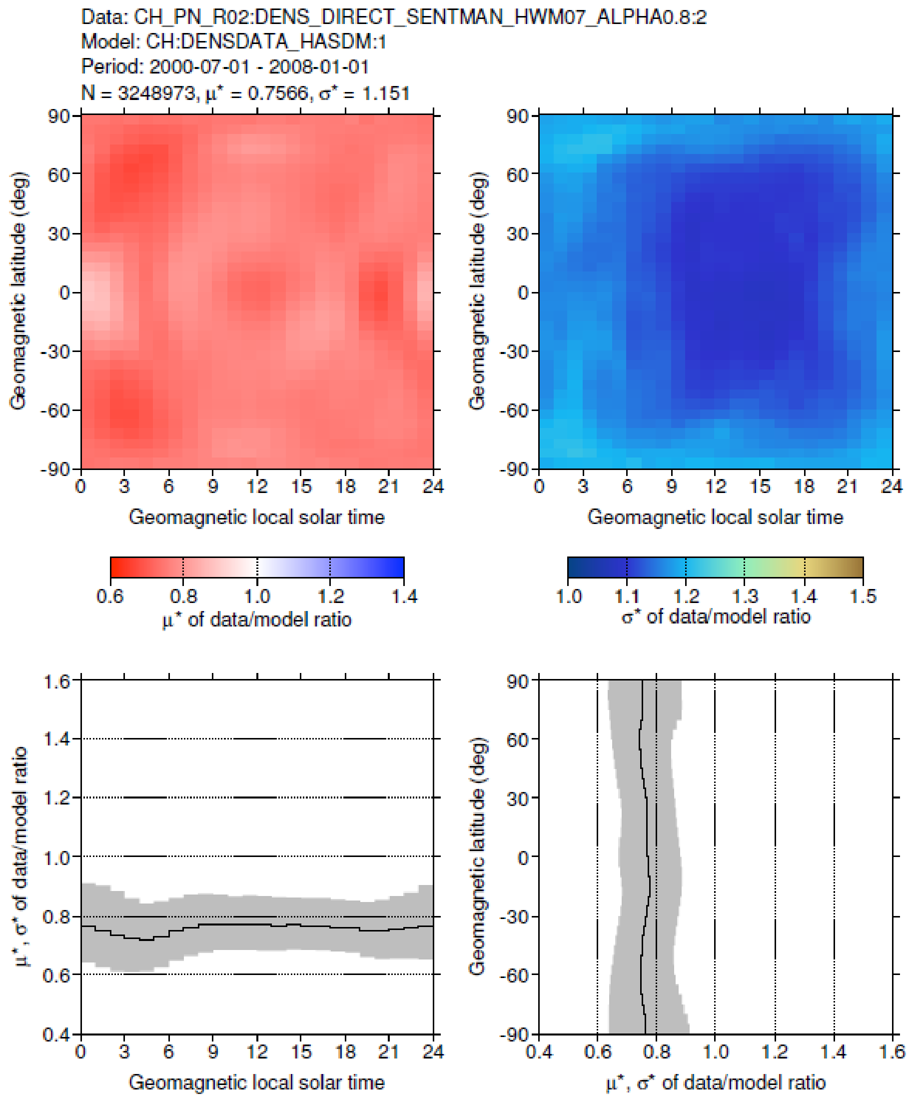

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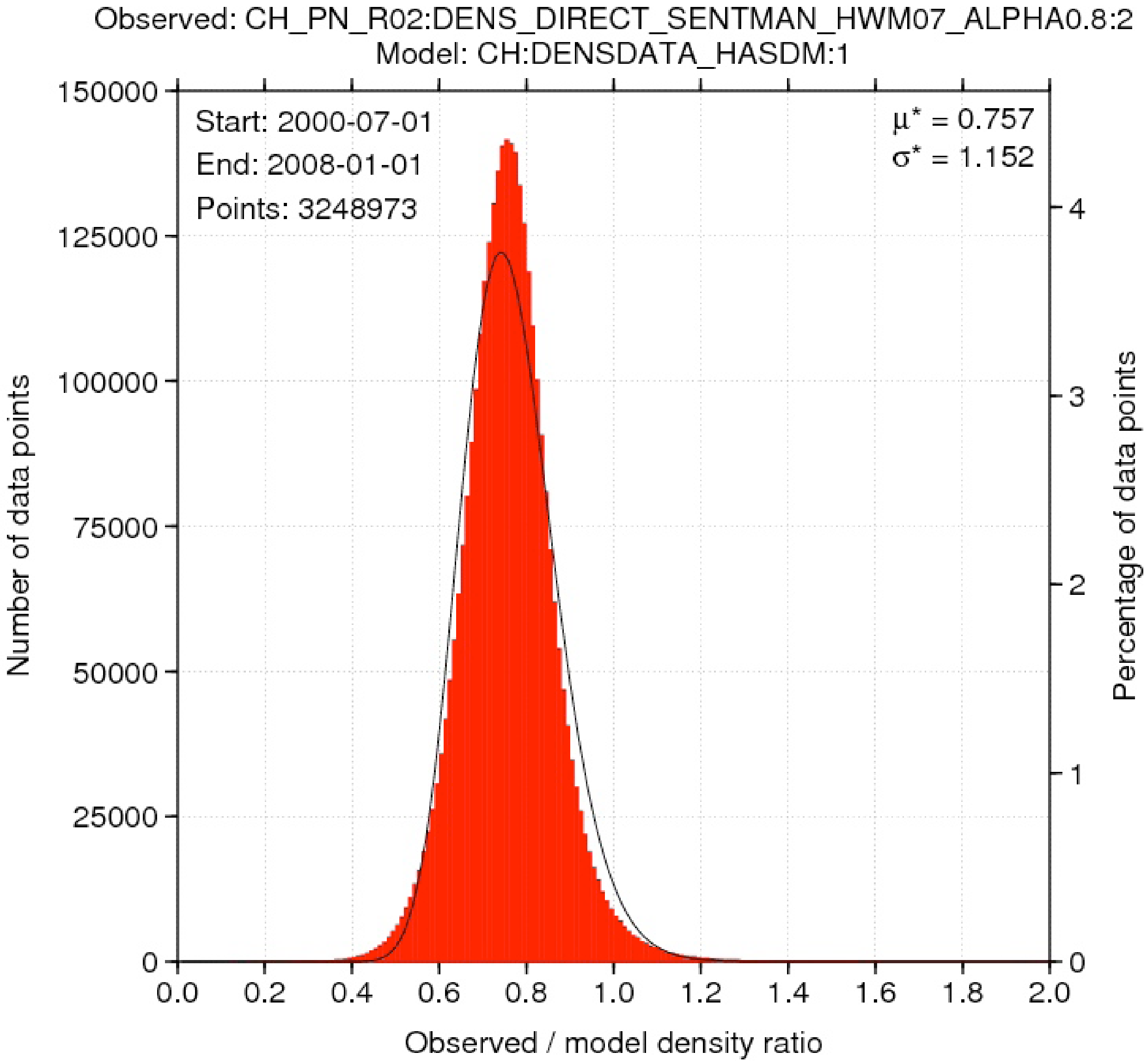

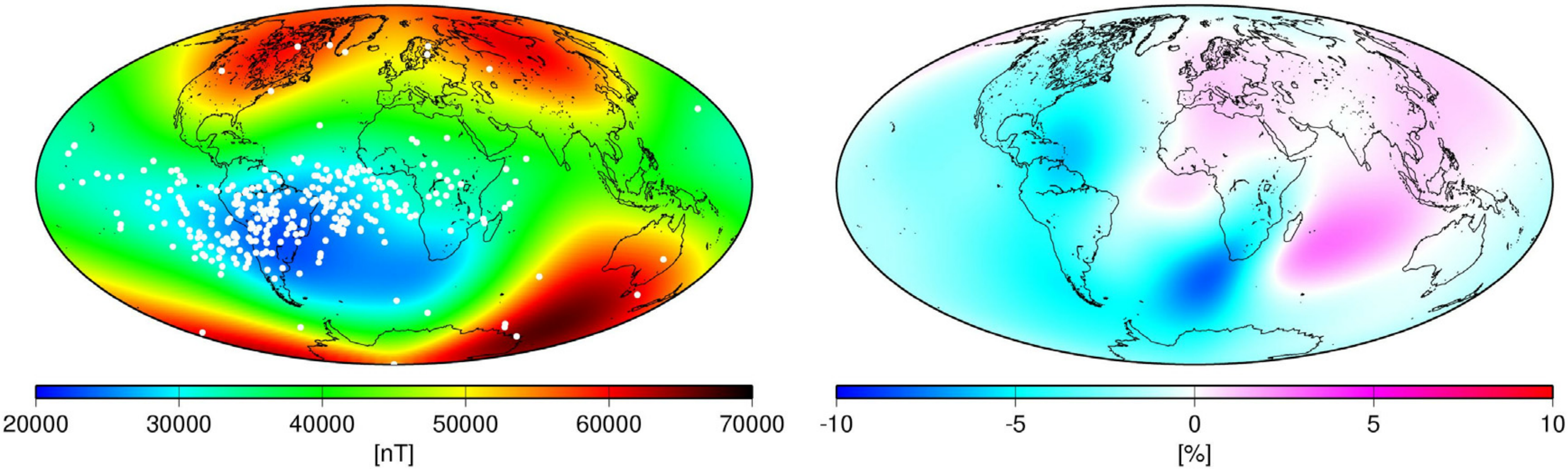

Magnetic Field Measurements and Single-event Upsets:

Important for planning “Mission Logistics”

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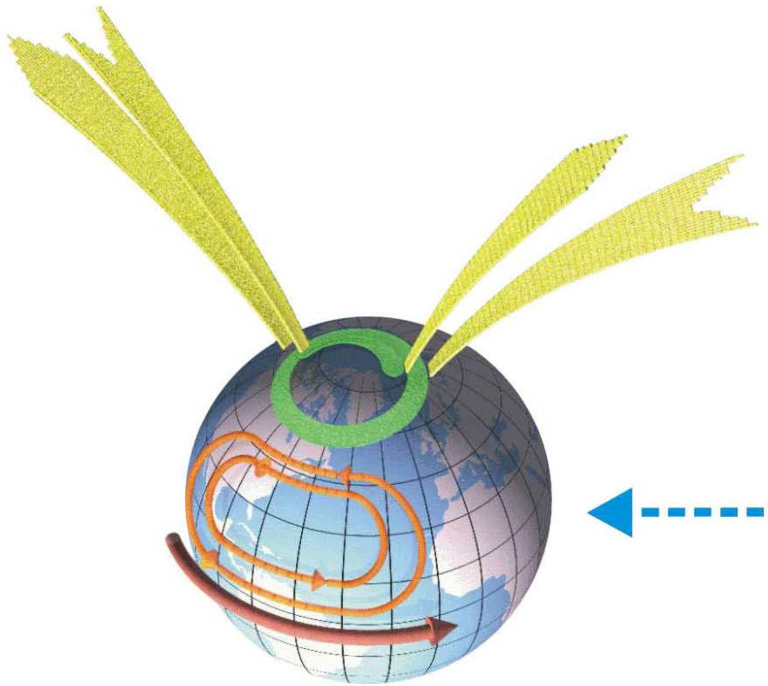

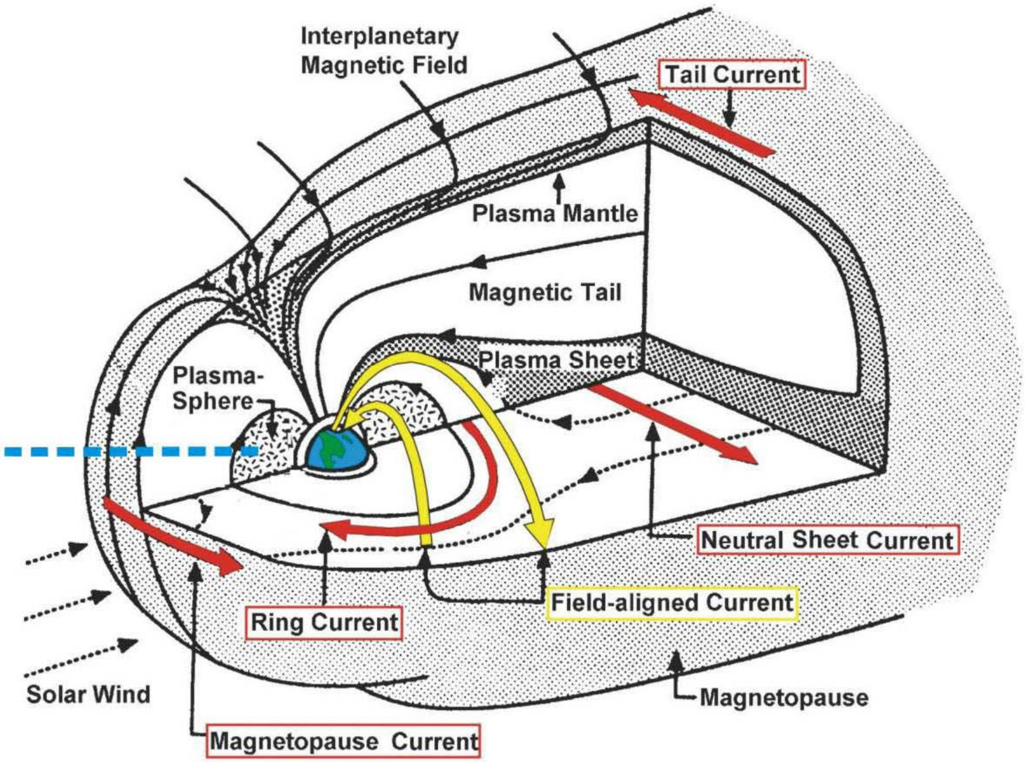

Planning and Modeling for Swarm: Equatorial Electrojets
Mid-latitude “Sq” currents;
Auroral Electrojets;
Field-Aligned Currents

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	Requirement (1σ)	Predicted Performance #	Numerical Simulation Results
Scalar magnetic field down to 20 km scales	Random: 0.15 nT	0.13 nT	0.11 nT
	Stablity: 0.05 nT per 3 months	compliant	n.a.
Vector magnetic field down to 2 km scales	Random: 0.5 nT	0.49 nT*	[0.245, 0.155, 0.22] nT
	Stability: 0.5 nT per year	0.49 nT	n.a.
Vector electric field down to 20 km scales	Random: 1.5mV/m	1.35 m V/m**	[0.22, 0.345, 0.20] mV/m
	Stability 0.5 mV/m per month	compliant	n.a.
Electron density down to 20 km scales	$0.5 \cdot 10^{10}$ m^{-3} RMS precision	compliant	$0.6 \cdot 10^{10}$ m^{-3} RMS***
Air drag down to 200 km scales	Random $2.5 \cdot 10^{-8}$ m s^{-2}	$1.5 \cdot 10^{-8}$ m s^{-2}	$[0.9, 1.6, 1.85] \cdot 10^{-8}$m s^{-2}

 # In the case of a vector, one value is given that is representative for each of the three components.
** Predicted value from analytic assessment is higher because this also includes the expected calibration errors. The latter are considered realistic because they are based upon what is currently possible for single-satellite missions like Ørsted and CHAMP.*
*** Predicted value from the analytical assessment is higher because it includes worst-case values for effects that were not included in the simulator (Technical and Programmatic Annex).*
**** Results based on a simplified model (Technical and Programmatic Annex).*

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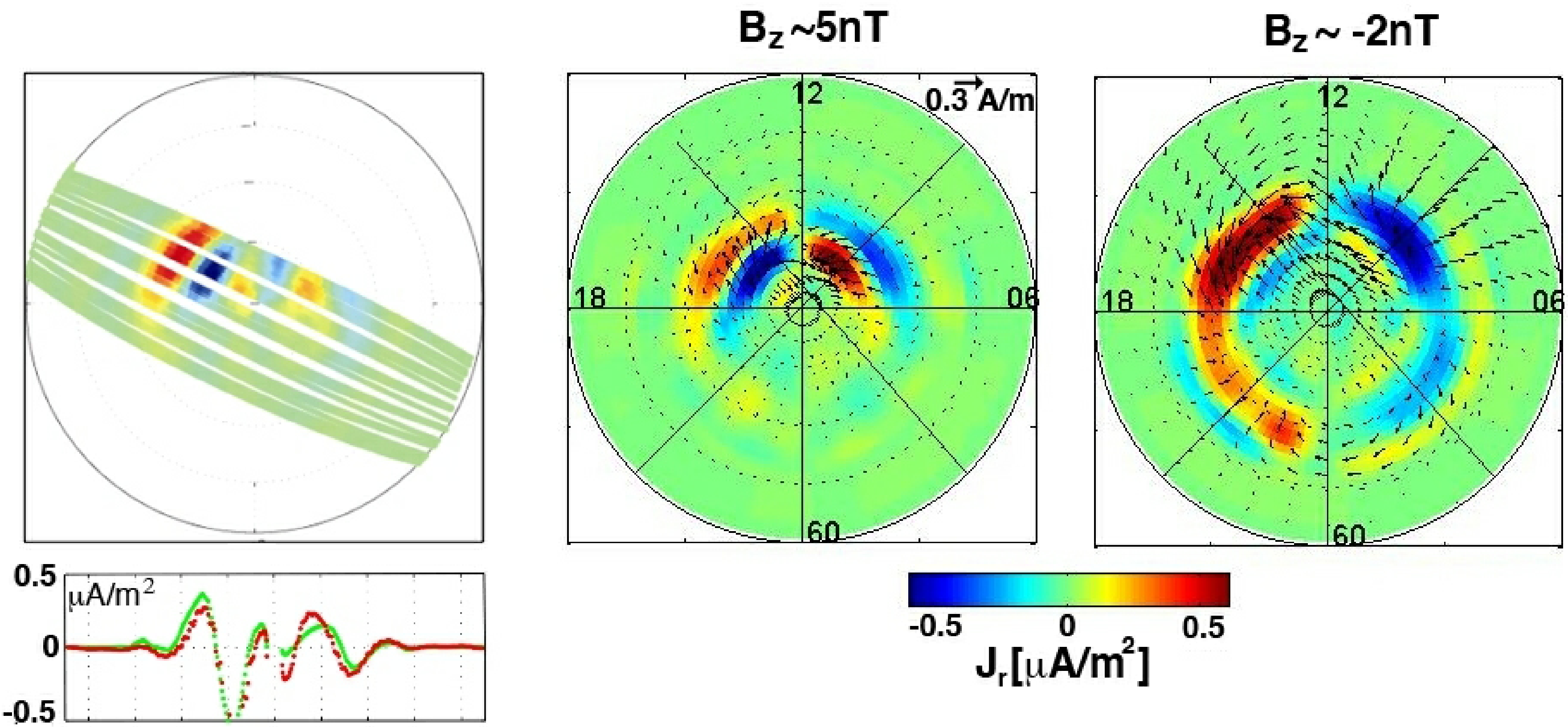

Simulations of the field-aligned currents for Bz +ve and –ve

These should be "easy" to detect with Swarm Magnetometers

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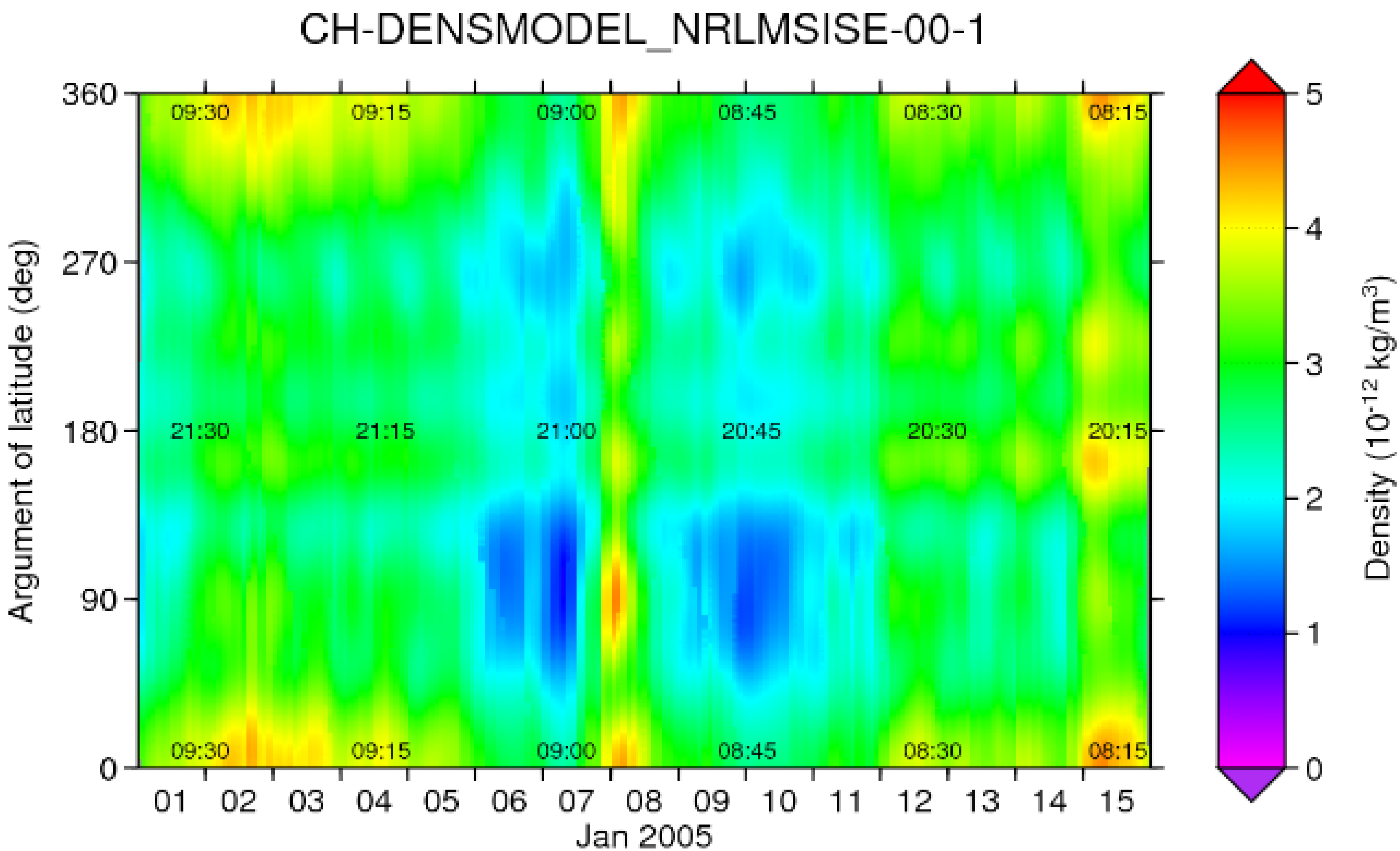
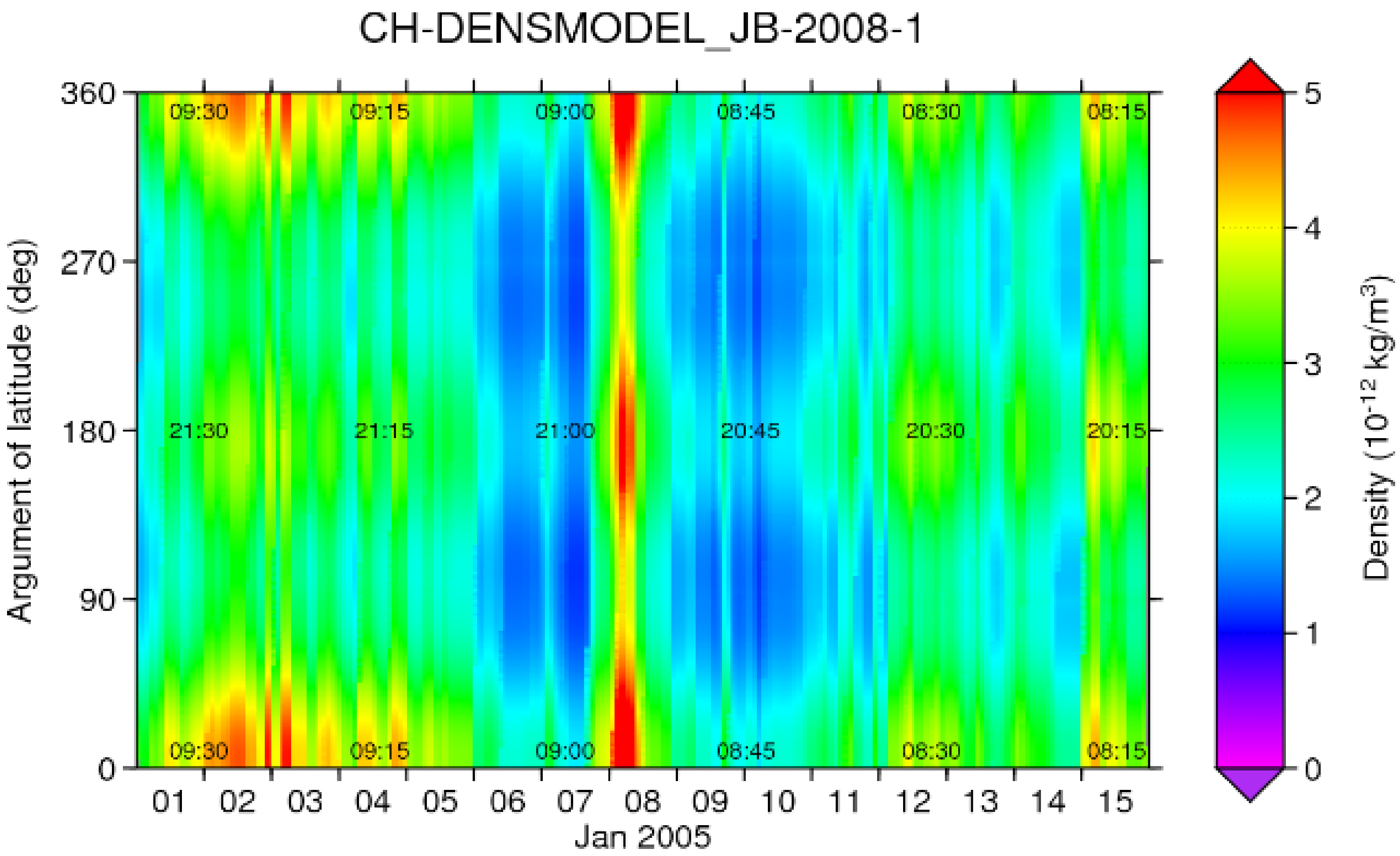


Densities predicted by the NRLMSISE-00 Model for January 1 – 15 2005.
The effects of the geomagnetic disturbance around January 07 / 08 are quite clear.



Densities predicted by the JB-2008 Model for January 1 – 15 2005.

The effects of the geomagnetic disturbance around January 07 / 08 are clear in the JB-2008 density predictions. The JB-2008 model predicts a higher degree of structure, reflecting the higher temporal resolution of the Dst index of geomagnetic activity.

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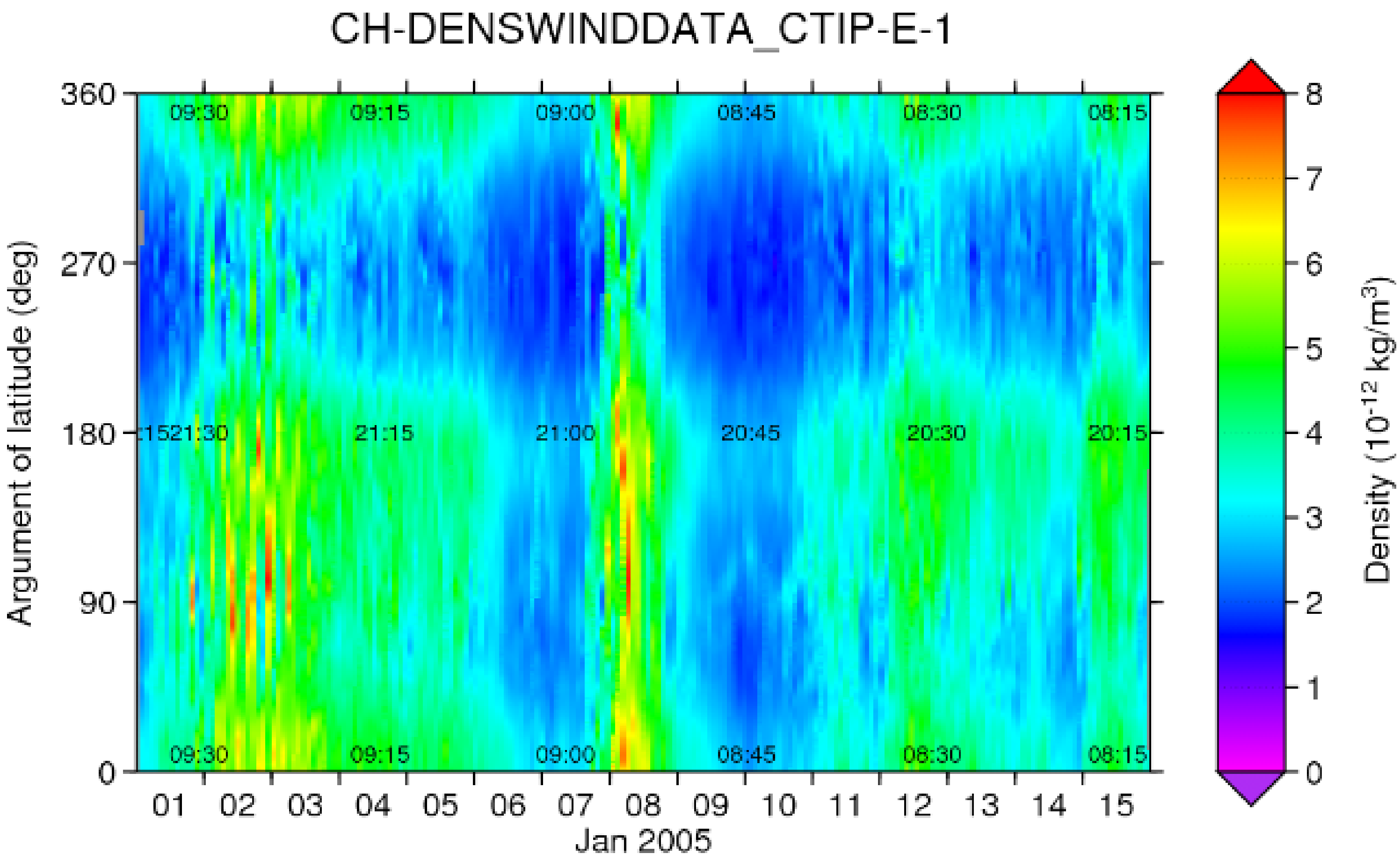
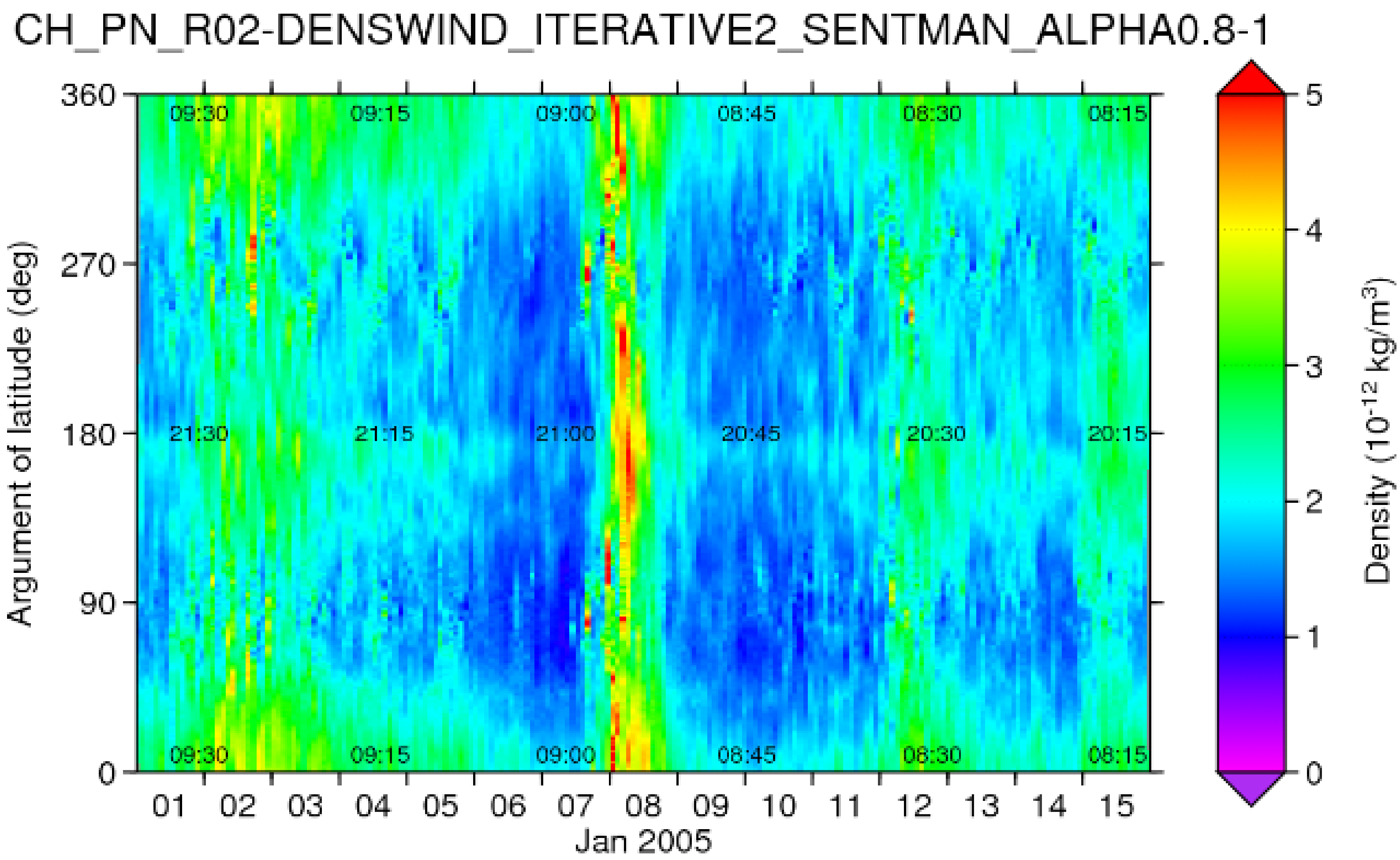


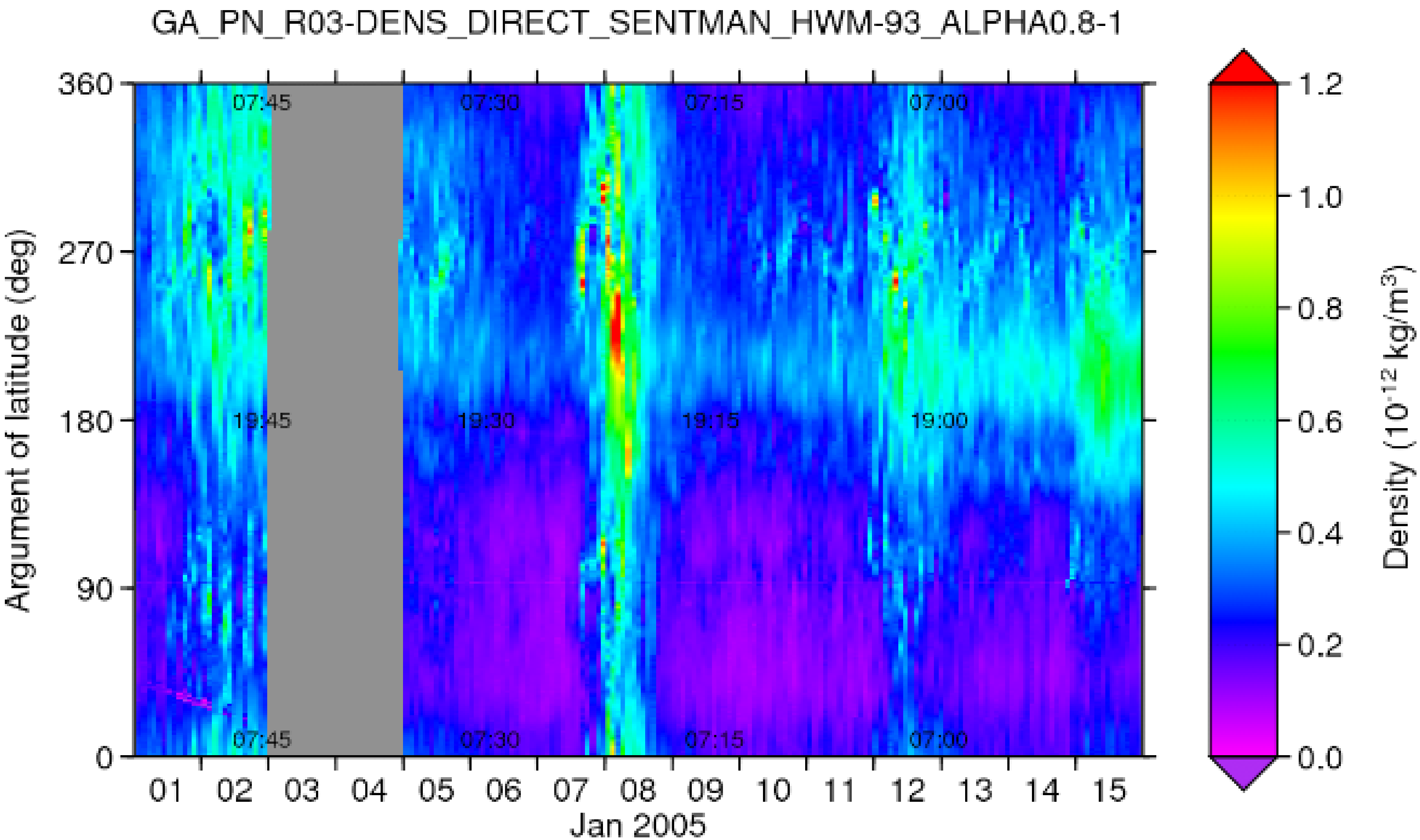
Densities predicted by the CTIPe Model for January 1 – 15, 2005.

The effects of the geomagnetic disturbance around January 07 / 08 are also quite clear in the CTIPe Predictions. The temporal and latitudinal structures are very similar to JB-2008. One significant difference is in the absolute density values, where CTIPe is order 40% higher than either the NRLMSISE-00 or the JB-2008 model.

➔ **This issue will be considered in extended work with the authors of the CTIPe model.**



Densities measured by CHAMP for January 1 – 15, 2005.
The effects of the geomagnetic disturbance around January 07 / 08 are also quite clear in the CHAMP data – as are many of the other latitudinal and temporal structures.



Densities measured by GRACE for January 1 – 15, 2005 (Sentman-HWM-93).

The effects of the geomagnetic disturbance around January 07 / 08 are also clear in the GRACE data – as are many of the other latitudinal and temporal structures. In this figure, the data are now taken closer to 500 km altitude. (data bite-out 02 – 04 Jan.)

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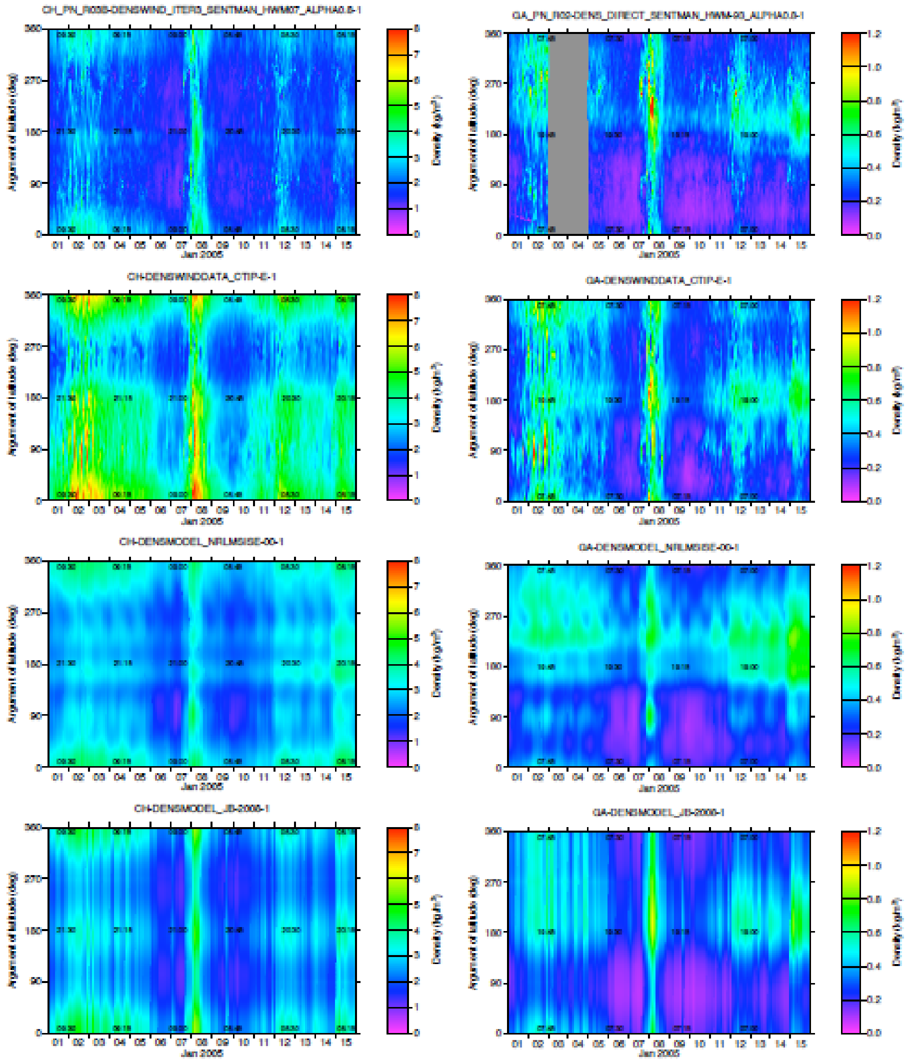

Figure 1.3 Comparisons of total neutral densities along the tracks of CHAMP (left) and GRACE-A (right), as computed (from top to bottom) from accelerometer data, the CTIPe model, the NLRMSISE-00 model and the JB-2008 model.

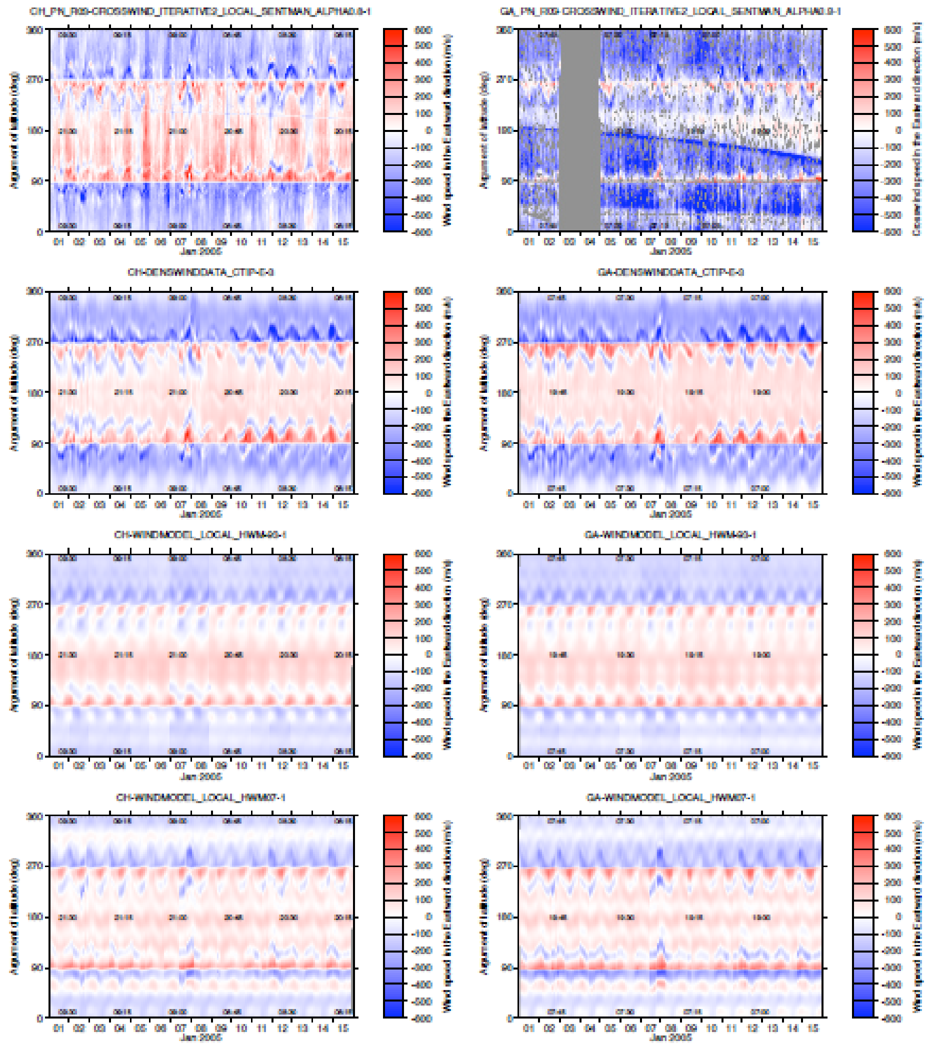

Figure 1.4 Comparisons of Eastward wind speed along the tracks of CHAMP (left) and GRACE-A (right), as computed (from top to bottom) from accelerometer data, the CTIPe model, the HWM-93 model and the HWM07 model.

For the most recent ESA “pre-Swarm” Study:

It was possible to inter-compare all available Empirical Models!

It was only feasible to use CTIP-e as a Theoretical Model!

For Analysis of GOCE and Swarm Data:-

The use of an ensemble of Theoretical Models is a MUST!!

NOTE: initially – this can be brutal – to run “blind tests” against real data and other models – “WITHOUT TWEAKING”!

Current / Planned ESA Projects

GOCE

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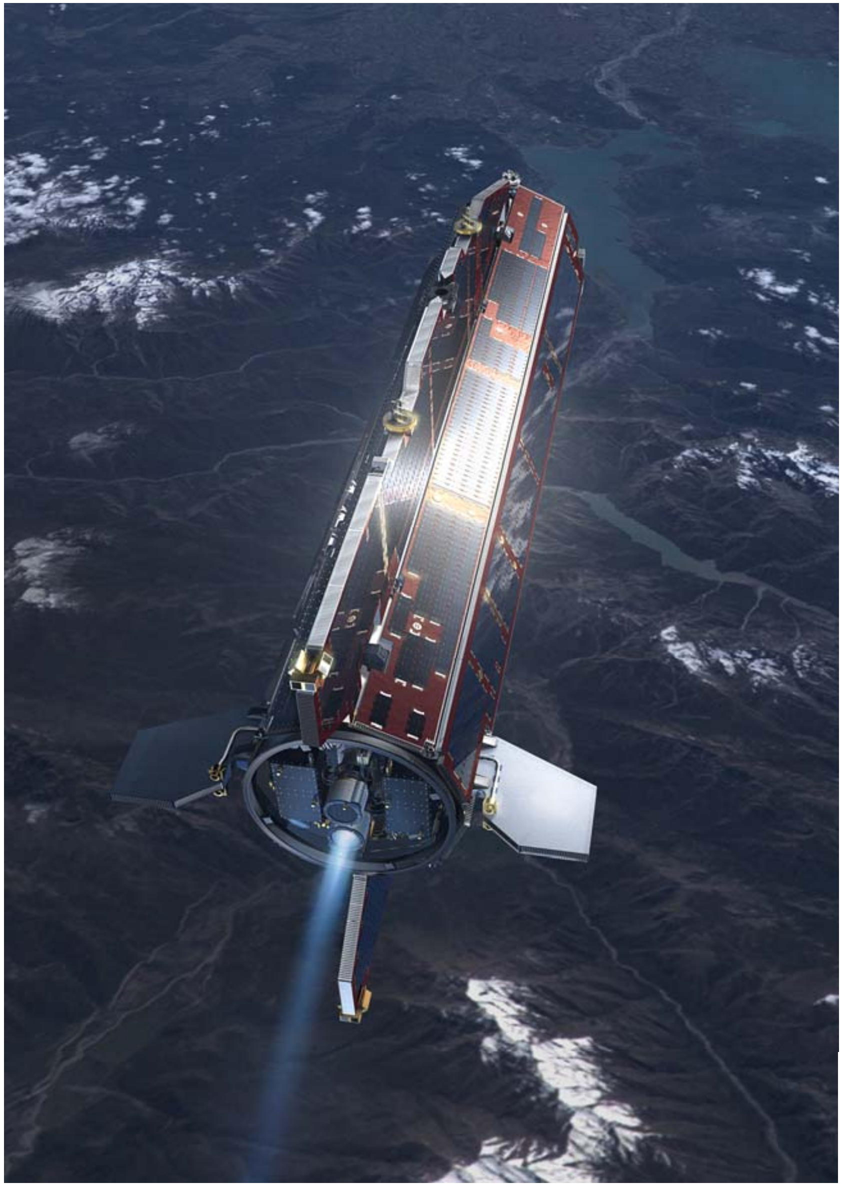


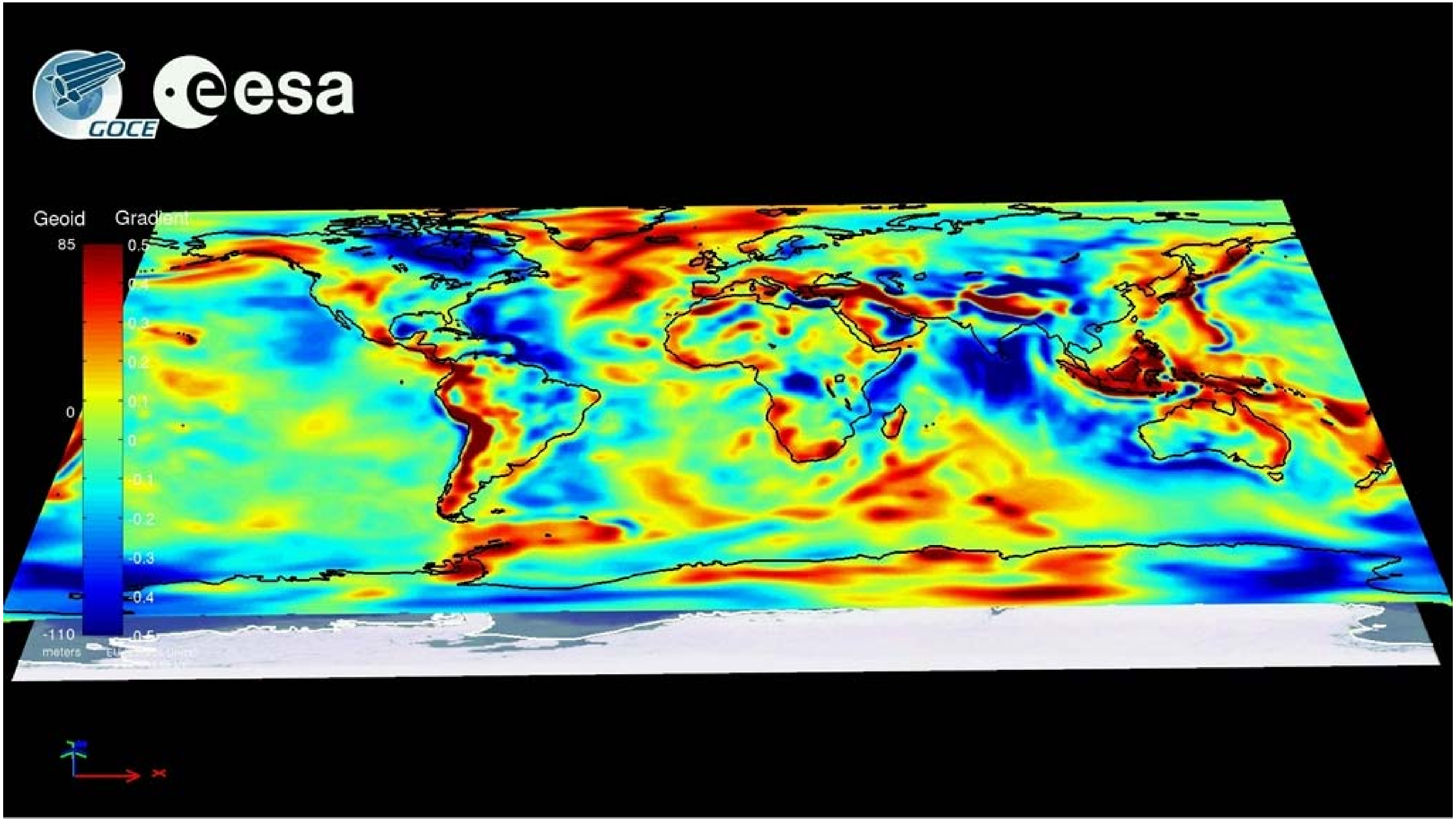
GOCE

GOCE maps the global variations in Earth's gravity with extreme detail.

It will provide a unique model of the gravity field and geoid.

The geoid is the surface of equal gravitational potential defined by the gravity field and is crucial for improving our understanding of ocean circulation, sea-level change and terrestrial ice dynamics, all of which are affected by climate change. GOCE-derived data will also provide new insight into processes occurring in the lithosphere and upper mantle.

In addition, GOCE data will be used for practical applications such as surveying and levelling.



Very early GOCE Data (Density Field)

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GOCE

GOCE flies in a low orbit – literally as low as is feasible.

This means that it has to compensate for the atmospheric drag it experiences at this exceptionally low altitude.

➔ A special sensor system tracks the "proof mass".

The ion-propulsion assembly keeps the satellite in a smooth trajectory:–

Free from all effects – except those of gravity itself.

Those effects include drag due to air density, and also the effects of Thermospheric Winds!

Air Density and Thermospheric Winds can thus be derived from the GOCE data, thruster operations etc. – just what CCMC people need!

Atmospheric Dynamics Mission (Aeolus) 2011

This ESA Mission has no direct connection with CCMC:–

➔ Troposphere and low stratosphere winds by Space Doppler Lidar.

However – it needs predictions of Solar and Geomagnetic activity;

+

Predictions of Thermospheric Density;

All of these are critical for final orbit selection!!!

➔ For any Space Lidar – lower is MUCH better – but drag can win!!!

EarthCARE – ATLID – 2011

This ESA mission also has no direct connection with CCMC:–

"Earth Cloud and Aerosol Radiation Explorer"

Troposphere and low stratosphere aerosols and density by Space Lidar + radar and a number of other "troposphere instruments to investigate the detailed tropospheric radiation budget.

However – predictions of Solar and Geomagnetic activity;

+

Predictions of Thermospheric Density;

are both critical for final orbit selection – same reason as for ADM!!

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2. CIRA, ECSS and ISO Activities

(i) A new version of CIRA (CIRA-08) is very close to publication.

(ii) The ECSS-10-04 was published in late 2008, providing updated "Near-Earth" models – intended for European Space Industry.

(iii) There are a range of activities within ISO (WG-4) for preparation and adoption of "near-Earth" models for the international community. These include models of the atmosphere, ionosphere, plasmasphere and magnetosphere.

To relieve your anxiety – Dr. Kent Tobiska, Bruce Bowman and others are heavily involved in these activities, which are also regularly reviewed at successive COSPAR Symposia (and JGR meetings)

Application of the ECSS and the ISO standards:- "Quote from ESA"

"There should be a way of advising mission analysts what assumptions to use in solar/geomagnetic activity proxy forecasts for:-

- (a) checking compliance with the 25 year lifetime rule, and
- (b) dimensioning a propulsion system for orbit maintenance;
- (c) the labels "min", "mean" and "max" for solar activity forecasts should be expressed in percentiles (e.g. 95%, 50%, 5%) to be realistic;

Moreover, the "mean" value should be a "most probable" value.

This is not the same for the non-Gaussian frequency distribution of F10.7 occurrences.

This might be adopted when trying to define a mean effective density rather than a mean proxy value."

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Major Issues with Thermospheric Densities (absolute):

(i) Changes since 1960's – due to CH_4 and CO_2 in the mesosphere and lower thermosphere (radiative cooling – collapsing the thermosphere)

(ii) Satellite drag data – still affected by the universal assumption of:

➔ **Cd = 2.2** (many thanks to Luigi Jacchia – circa 1960!)

It is not – it is dependent on altitude, eccentricity and the shape and attitude of the Satellite – and it also varies with solar activity.

(iii) Incorrect published data on Satellite Mass, Area etc!

➔ This is an ongoing activity involving a number of people, including Kent Tobiska, Bruce Bowman, Ken and Millie Moe, Eelco Doornbos

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3. Future ESA Earth Observation Missions (possible)

The Terrestrial Mesosphere is still very close to being called:

“The Ignorosphere” (CIRA 1986)

There is a proposal to fly a “Mesosphere-Lower Thermosphere Lidar Mission within the ESA Earth-Explorer-8 opportunity.

This mission should measure winds, temperatures, species densities with 100 metre vertical resolution, on a global scale.

Such measurements would get at some of the “hidden parameters” of GCMs – Gravity Waves, Eddy diffusion and dissipation.

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A Mesosphere-Lower Thermosphere Space Lidar Investigation

An opportunity to exploit ISS for investigations of the decadal changes of the Mesosphere-Lower Thermosphere Region

Team led by:

Hovemere (UK) and Athena SPU (Greece)

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Proposing Team:

Prof John Plane – U. Leeds, UK   Prof. Xinzhao Chu – U. Colorado, Boulder, USA
Dr. Elsayed Talaat – APL, Johns Hopkins U., USA   Dr. Dave Fritts – U. Colorado
Prof. Alain Hauchecorne and Dr. Philippe Keckut – LATMOS, France
Prof. Nick Mitchell – U. Bath, UK.   Prof. Mike Damzen, Imperial College London
Prof John Burrows; P.D. Dr. Christian von Savigny; Dr. Miriam Sinnhuber – U. Bremen, Germany
Prof. Franz-Josef Lübken; Dr. Gerd Baumgarten – IAP Kühlungsborn, Germany
Prof. William Ward, U. New Brunswick, Canada

Representatives of European Space Industry (sub-contractors to the MLM Studies)
Chris Saunders – QinetiQ UK   Dr. Phil Davies - SSTL (Astrium) UK


July 23, 1999 Finland, photo by Timo Leponiemi

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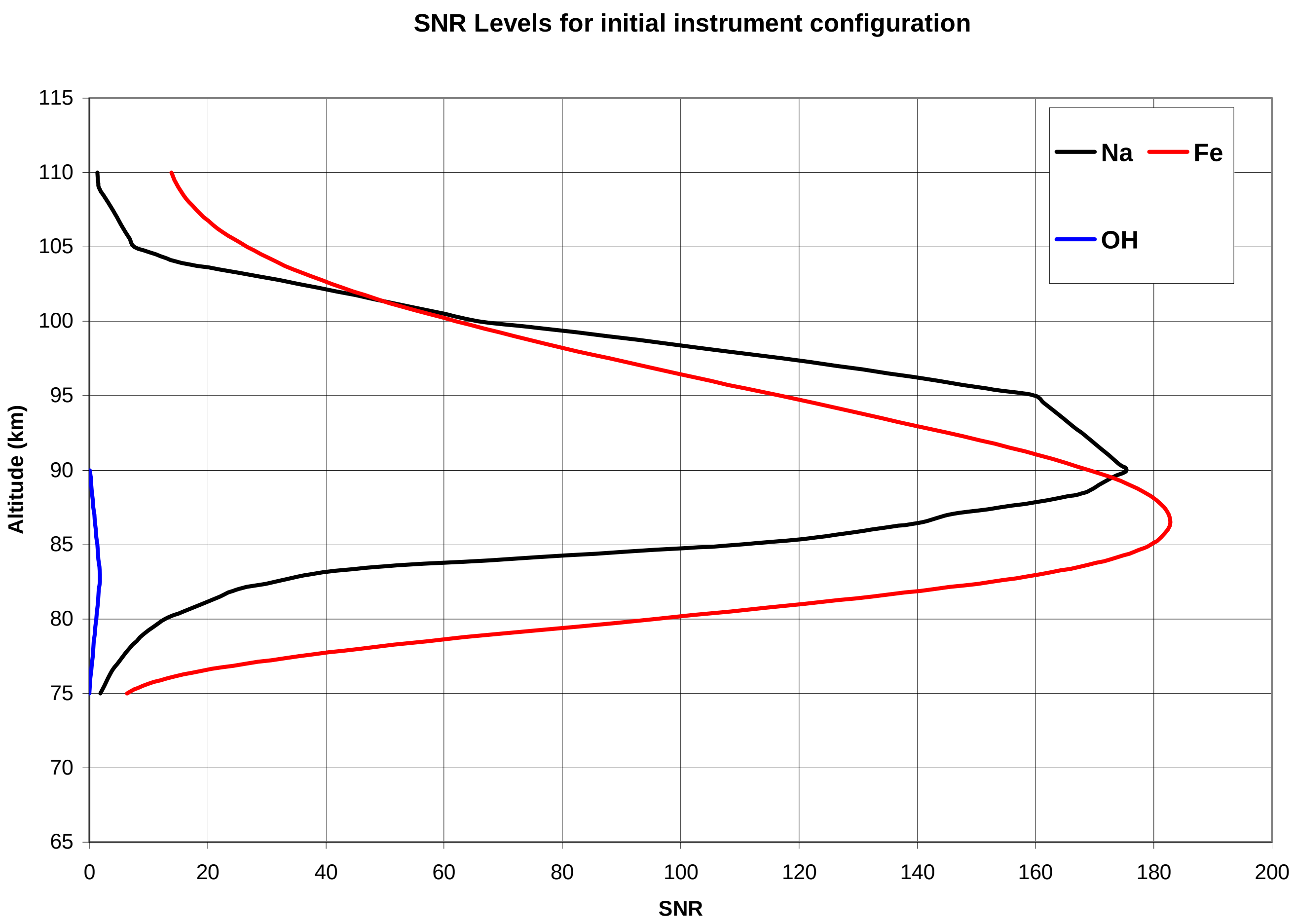
SNR versus altitude.

Black line=Sodium, Red Line = Iron (248 nm), Blue line = OH



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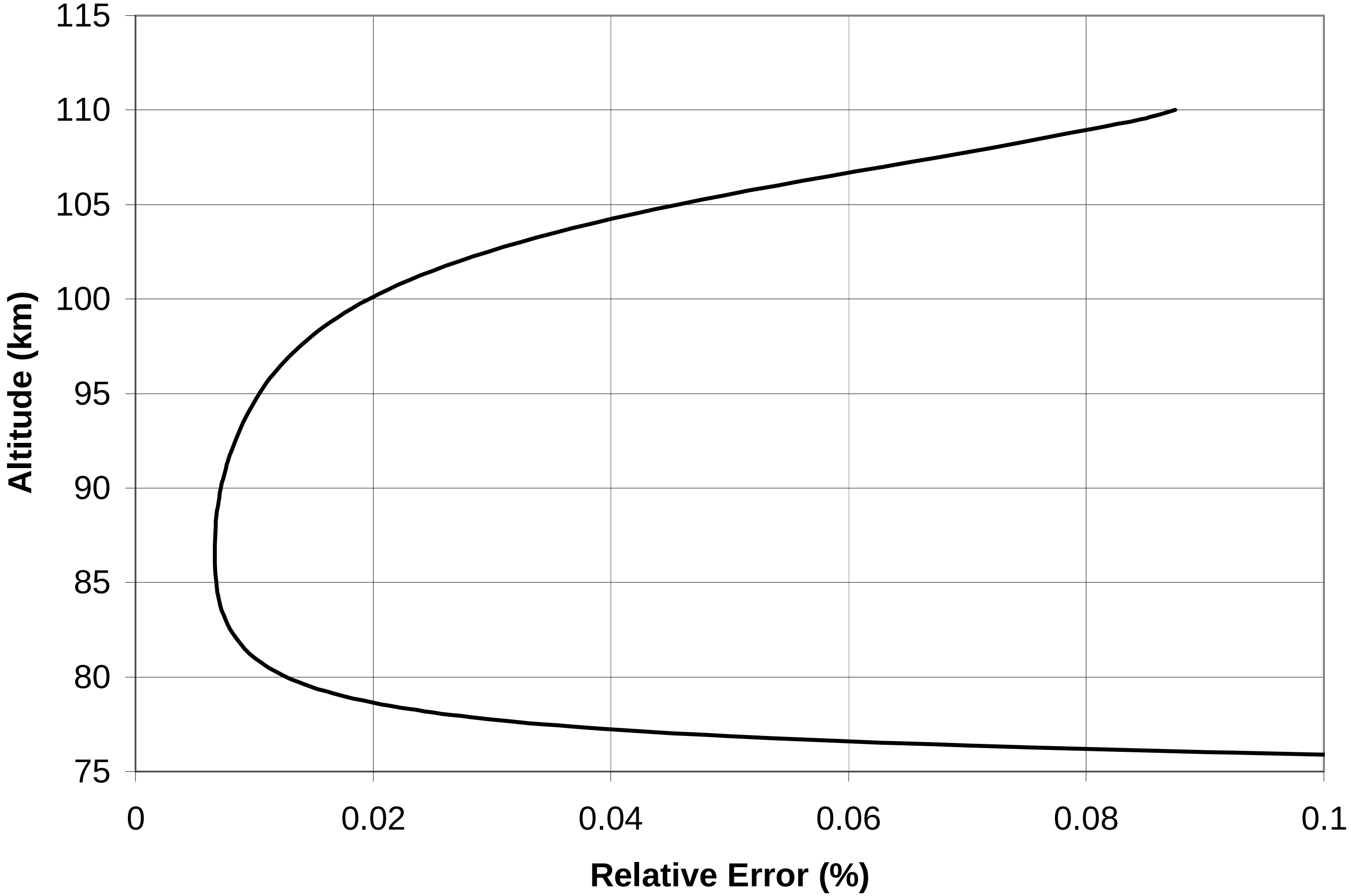
Relative Density Error for Fe as a function of altitude (100 m range gate)



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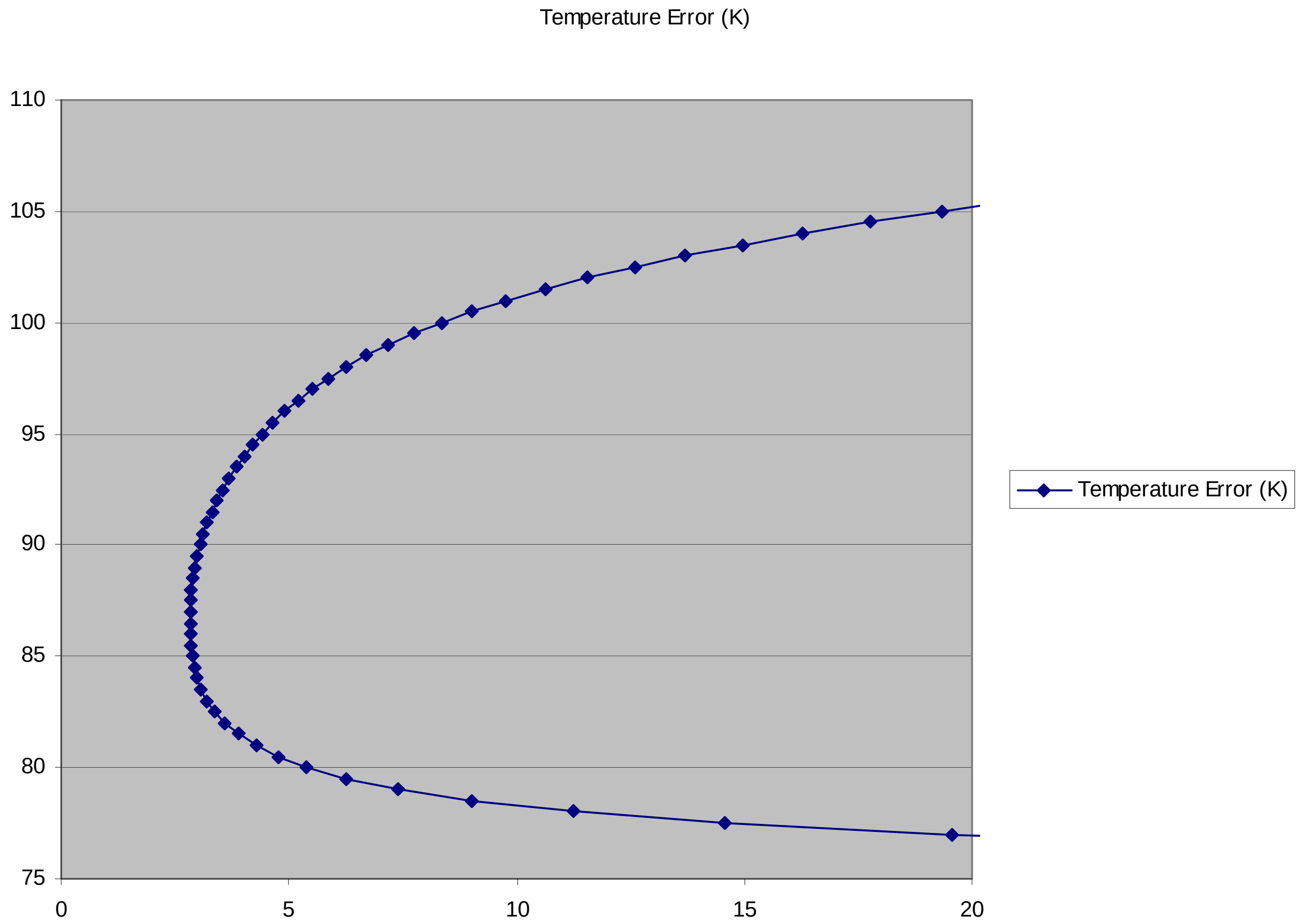
Temperature Measurement Error – from 350 km altitude



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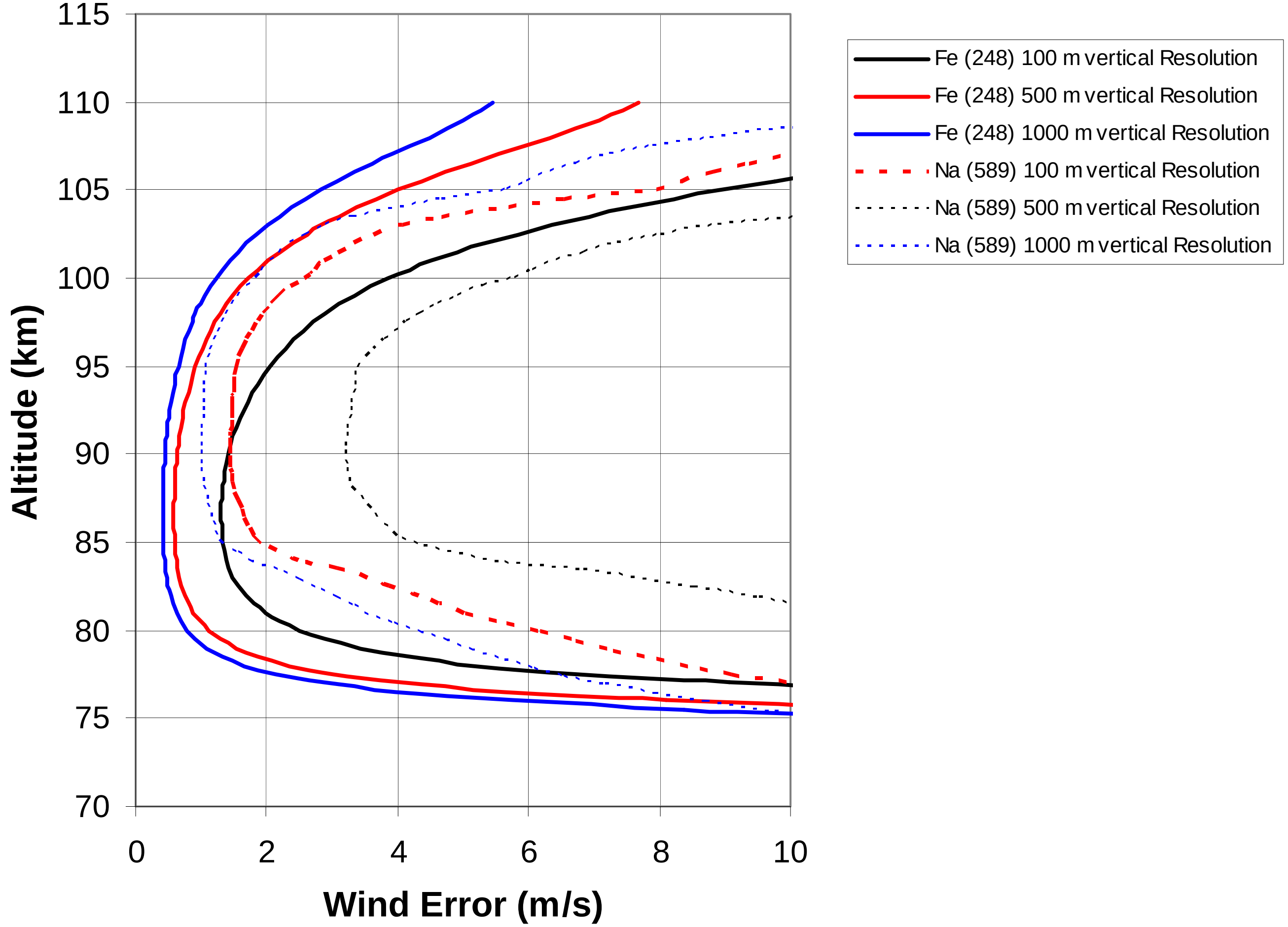
Wind Measurement Error – from 350 km altitude



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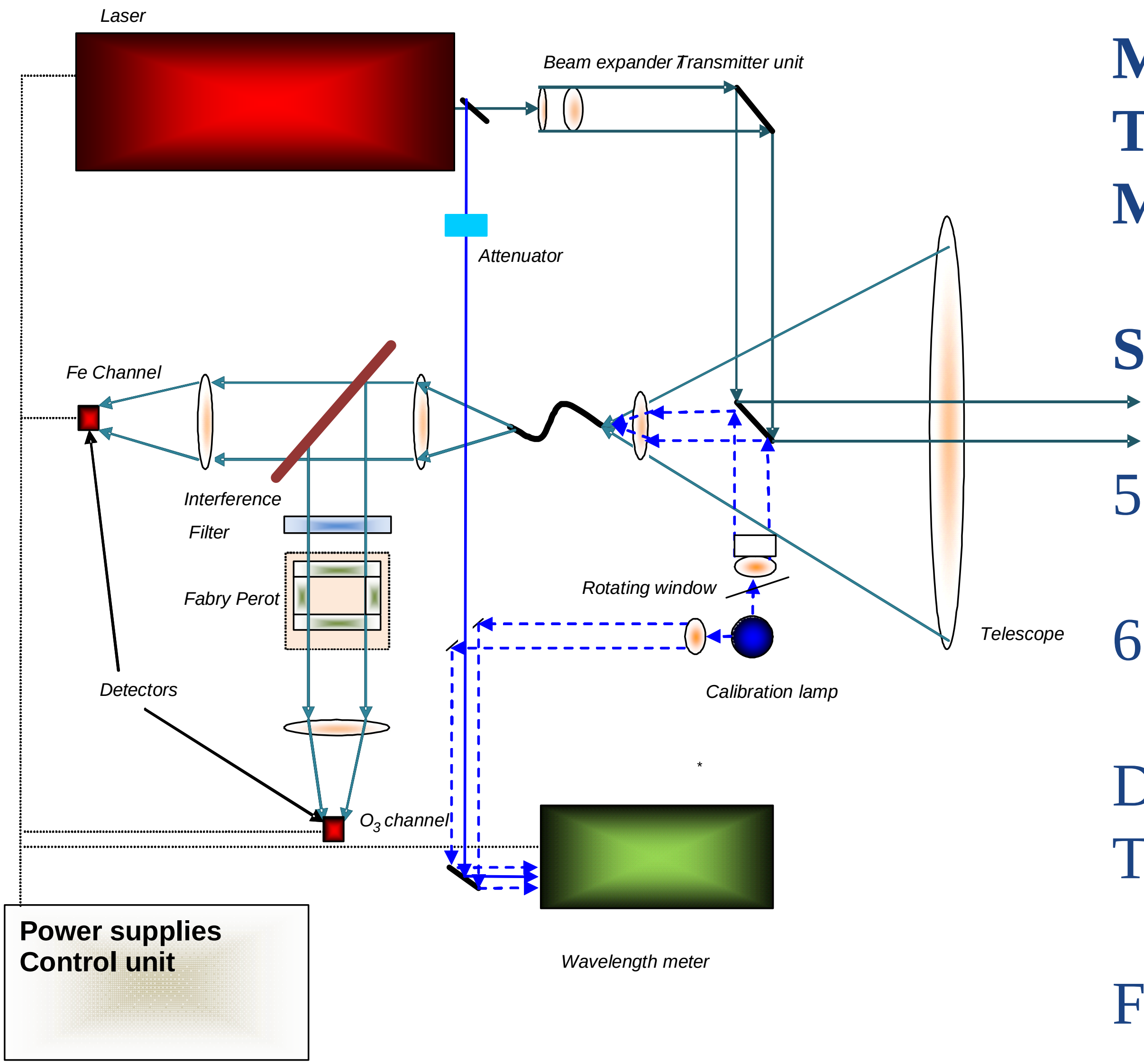

Mesosphere – Lower Thermosphere Lidar Mission:

Schematic Layout:

5 W laser @ 248 nm

600 – 800 mm Rcvr.

Doppler wind and Temperature

Fe (iron) distributions

4. Future ESA / JAXA Planetary Mission (s)

In ~2014, ESA and JAXA will send the Bepi-Colombo Mission to Mercury via an Arianne-5 launcher.

There are two Spacecraft components:

Mercury Planetary Orbiter: – built by ESA

Mercury Magnetospheric Orbiter: – built by JAXA

Both S/C are extremely well instrumented (cf Messenger)

➔ The MSASI Instrument is a key part of the Mercury Magnetospheric Orbiter Science Payload (JAXA).

PI for MSASI is Prof. Ichiro Yoshikawa, Tokyo University.

MSASI will image sodium emissions from the Mercury Atmosphere

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Bepi-Colombo – MMO (JAXA) MSASI

Mercury Sodium Atmosphere Spectral Imager

MSASI will map the 3-D structure of sodium around Mercury with an imaging Fabry-Perot Interferometer combining a 1-D scanner and the spin of the MMO spacecraft.

PI – Prof. Ichiro Yoshikawa (Tokyo University)

I. Yoshikawa, O. Korablev, S. Kameda, D. Rees, H. Nozawa, S. Okano, V. Gnedykh, V. Kottsov, K. Yoshioka, G. Murakami, F. Ezawa, G. Cremonese.

MSASI can resolve ~ 10 km at the Mercury surface – study craters

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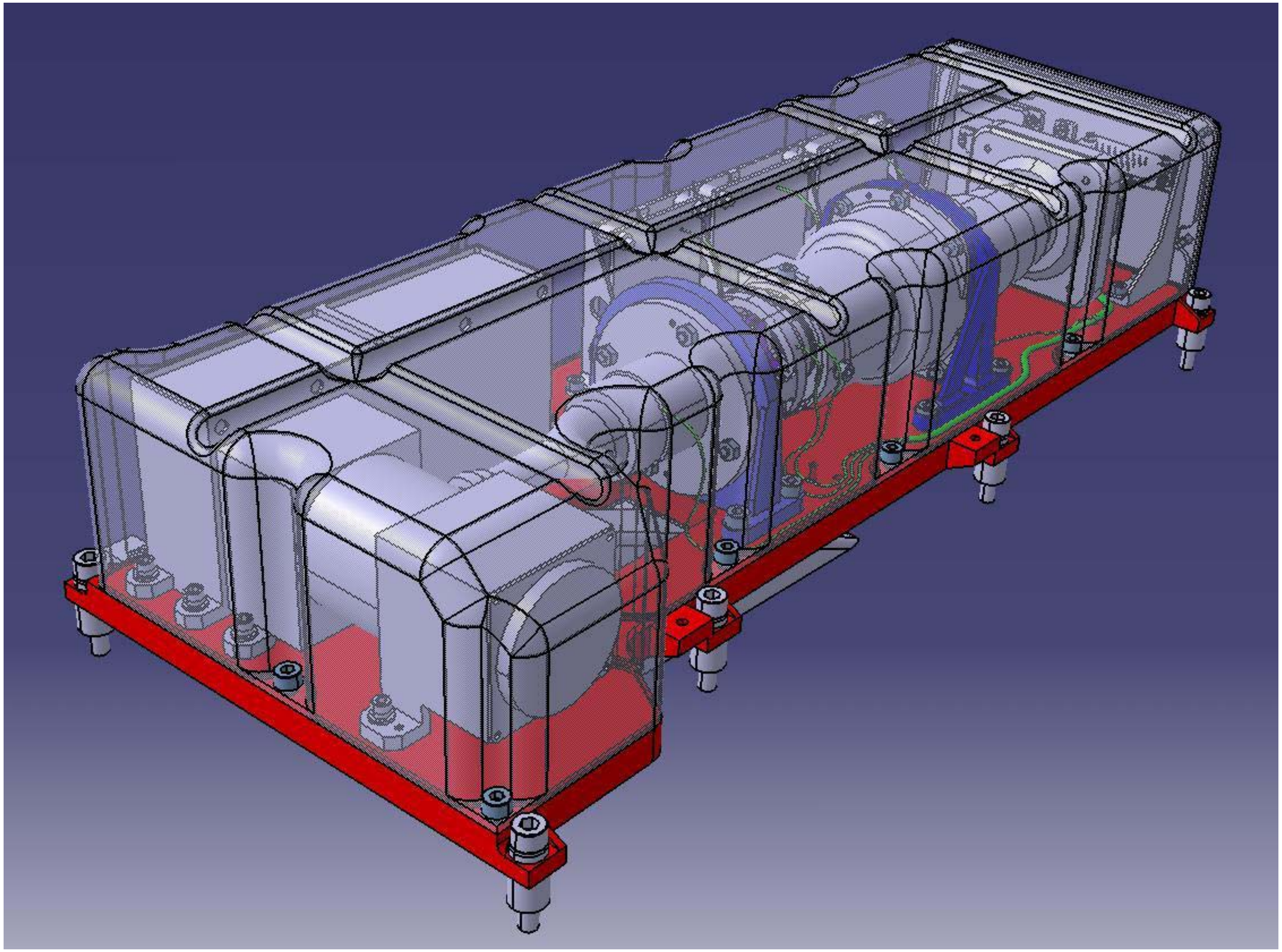

Mercury Sodium Atmosphere Spectral Imager – MSASI

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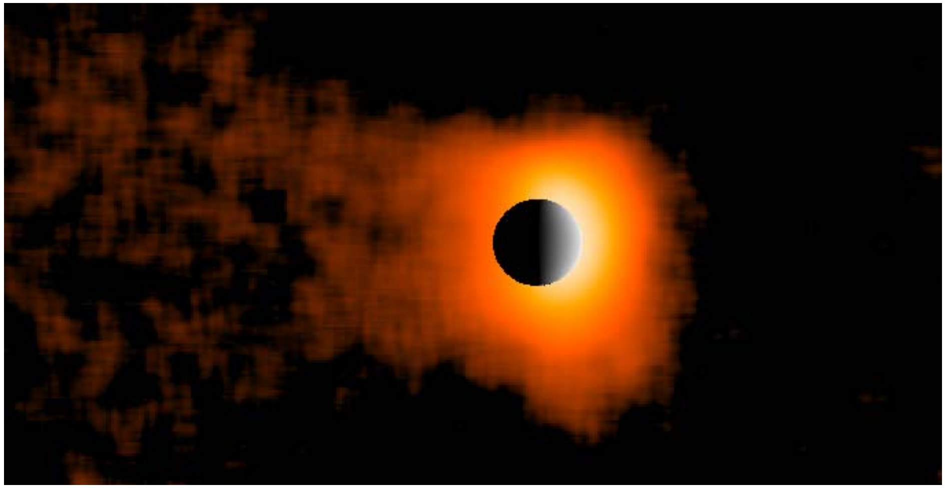
Mercury’s Extended Sodium tail

Kameda et al 2008



Baumgardner et al., 2008

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Mercury – Sodium

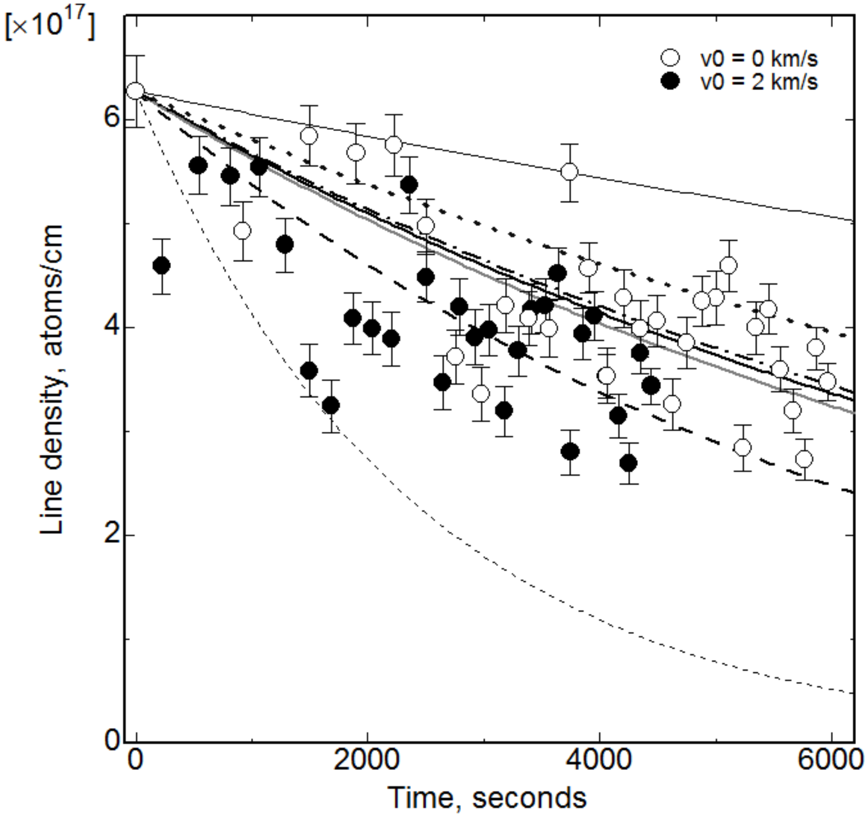
Sources – comet impacts?
– asteroid impacts?

Ion Sputtering – or photons?

Losses:

Photon acceleration?

Pick-up ion acceleration?



Loss of Mercury's sodium atoms in the tail region. The thick solid line and the thick dashed line show least-squares fits assuming $v_{@10000km}$ = 0 km/s and $v_{@10000km}$ = 2 km/s.

[Cremonese et al., (1997) (thin solid line), Hunten et al., (1988) (thick dotted line), Huebner et al., (1992) (thick dot-dashed line), Carlson et al., (1975) (thick gray line), and Potter et al., (2002) (thin dashed line)]

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Future Planetary Missions

What is next:

- ➔ Sodium and other metals in the Jovian System
- ➔ Sodium and other metals in the Saturnian System???

Certainly these alkali metals are present in “halos” or “tori” around the satellite orbits.

They are created by the combination of the satellites being heated by gravitational stresses from the parent planets –

However, the alkali halos are very deeply embedded within the Planet’s magnetic field – and thus are so different to Mercury

Do the very strong magnetic fields have a heating role?

➔ Very many thanks to CCMC!

Many thanks for the invitation to attend your meeting!

I've enjoyed the presentations and discussions this week:

I hope it will be possible to encourage further scientific cooperation and collaboration between European modelling people and the contributors to CCMC.

I also hope it is possible to encourage the extended exploitation of CCMC capabilities as new data become available to test the validity of models in new and extended environments.

champ_yaw_nominal 2_qthigh.mov