The semi-empirical thermosphere model DTM2013 (Drag Temperature Model)

Sean Bruinsma

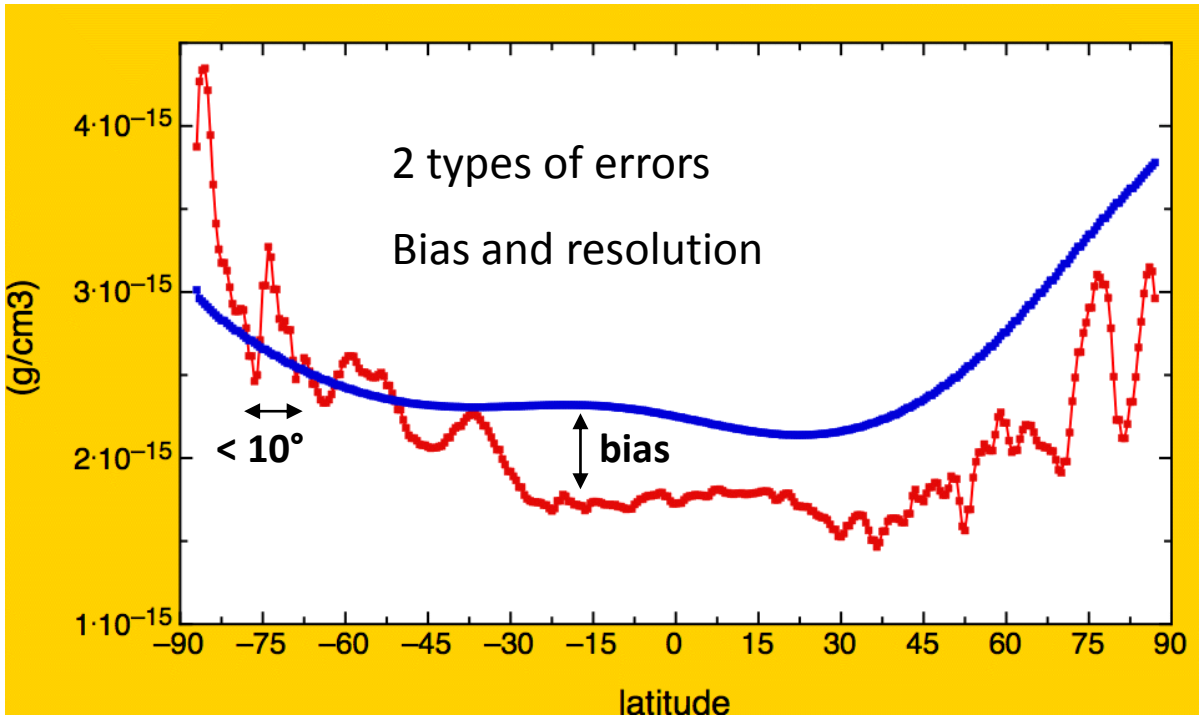
CNES - Department of terrestrial and planetary geodesy

ATMOP (*FP7 project*): objective

To improve the semi-empirical DTM model in the 250-1000 km altitude range of the upper atmosphere and reduce systematic errors in particular (most important for orbit computation), at least to the level of JB2008

ATMOP

SEVENTH FRAMEWORK PROGRAMME



DTM model

The following variations are modeled (temperature and composition)

periodic	**non-periodic**
diurnal	latitude (zonal)
semi-diurnal	***solar activity: F30***
ter-diurnal	geomagnetic activity: kp
annual	
semi-annual	

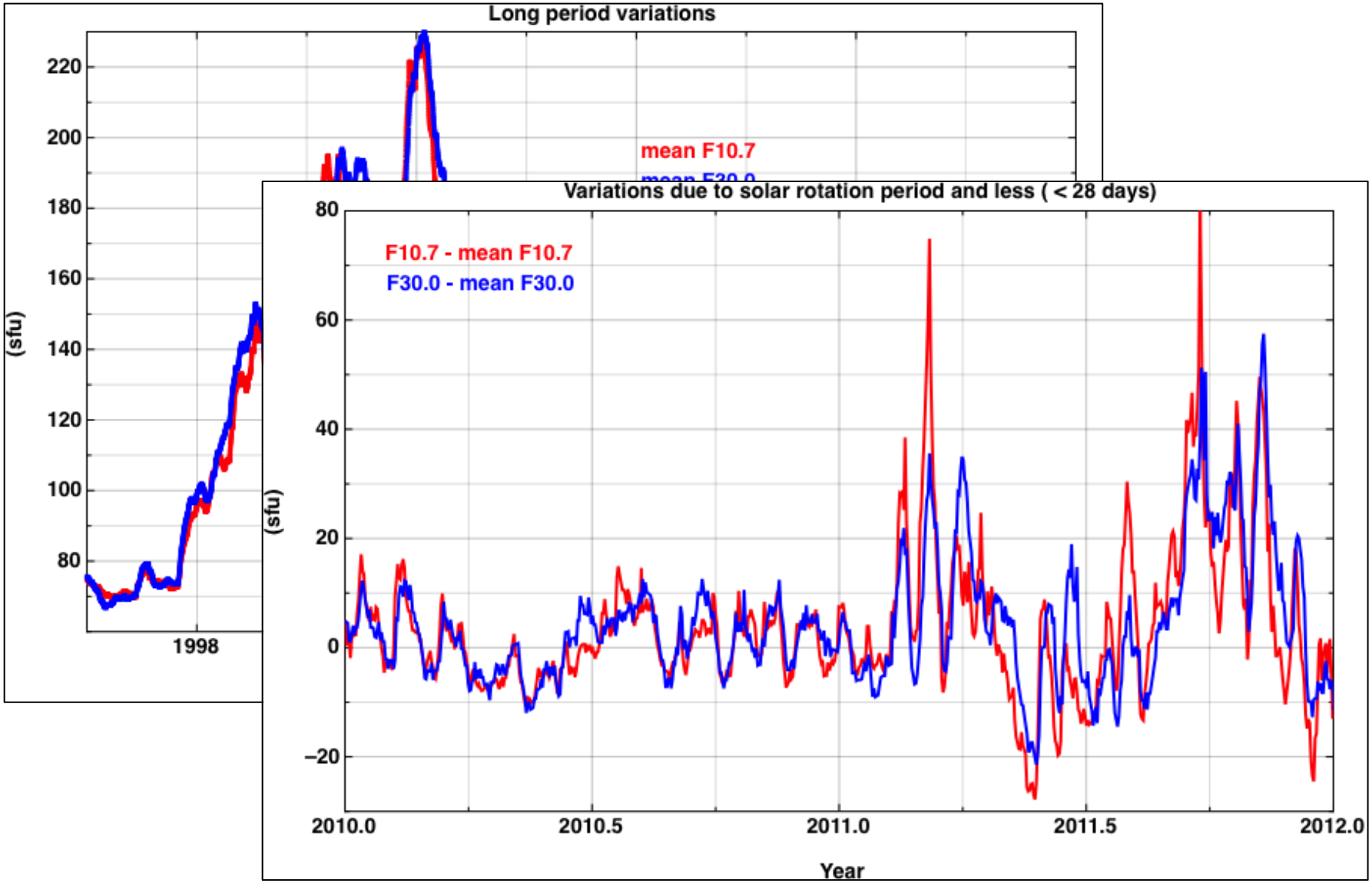
(+ coupling with F30)

Pros/Cons of empirical models:

Fast computation, easy to use, relatively accurate (10-20%, 1σ)

Low resolution, static response, proxy use, scale/bias problems,….

Solar proxies: *F30* and F10.7



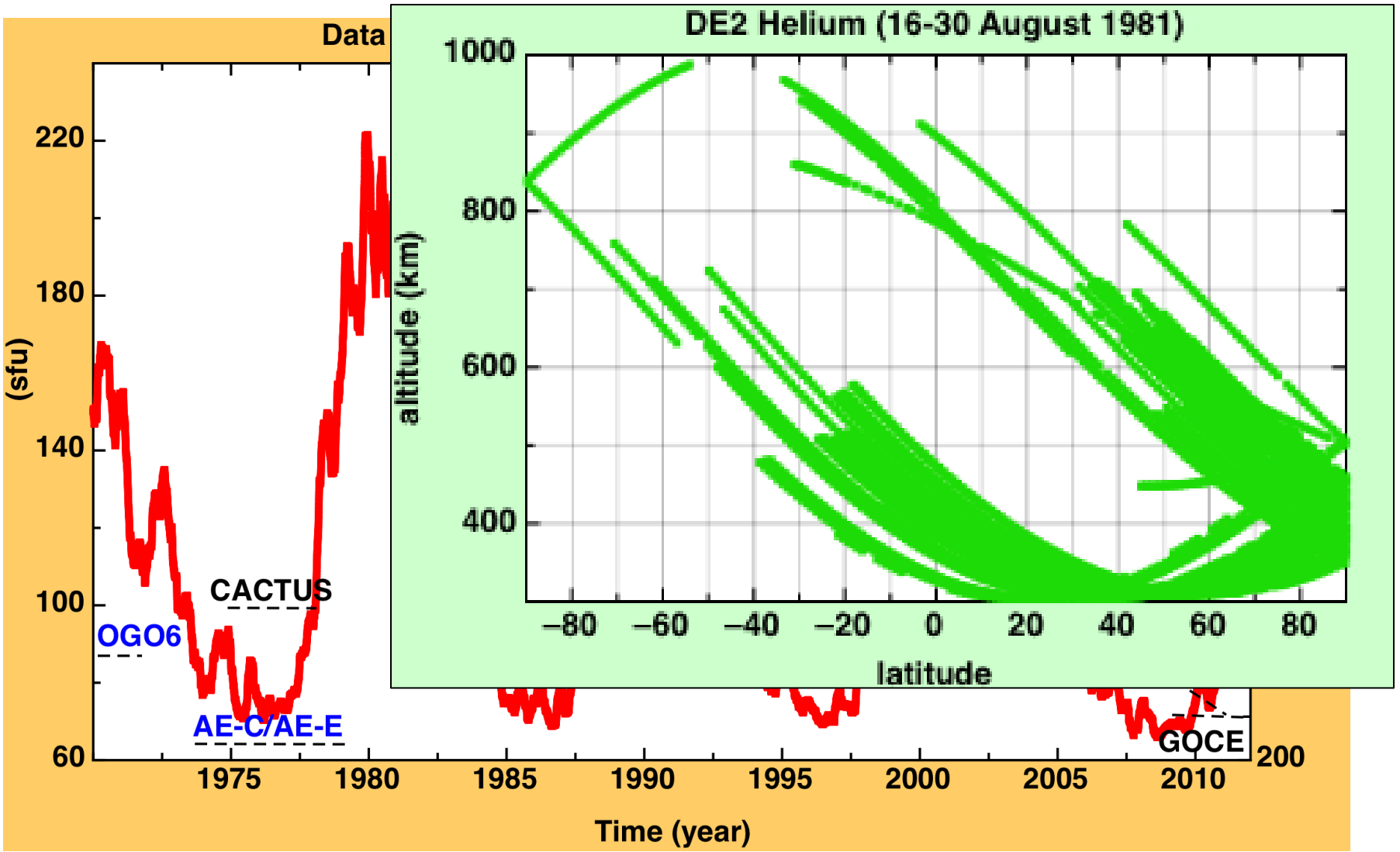
DTM model

Data used in the construction of DTM2013:

✓CHAMP	05/2001 - 08/2010
✓GRACE	01/2003 - 12/2011
✓GOCE	11/2009 - 05/2012
✓Starlette & Stella	01/1994 - 12/2012
✓Deimos-1	03/2010 - 09/2011
✓CACTUS	07/1975 - 01/1979
✓OGO6	06/1969 - 08/1975
✓DE-2 (T, He, O, N2)	08/1981 - 02/1983
✓AE-C (N2)	01/1974 - 04/1977
✓AE-E (T, He, O)	12/1975 - 05/1981

DTM model

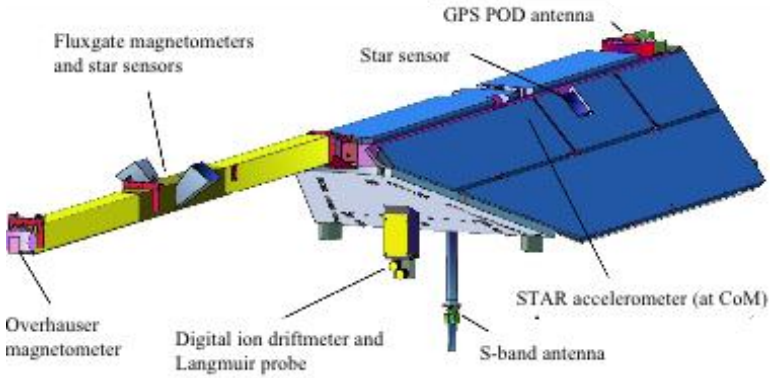
NB: No data above 1000 km; data is sparse at 800 km

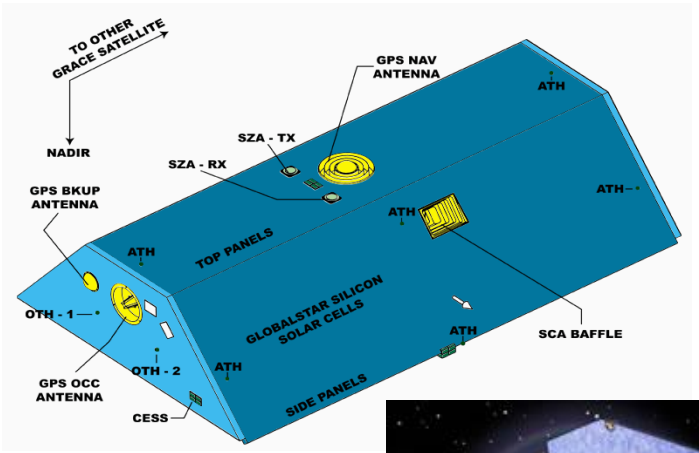


Data: CHAMP, GRACE and GOCE

CHAMP (2000-2010):

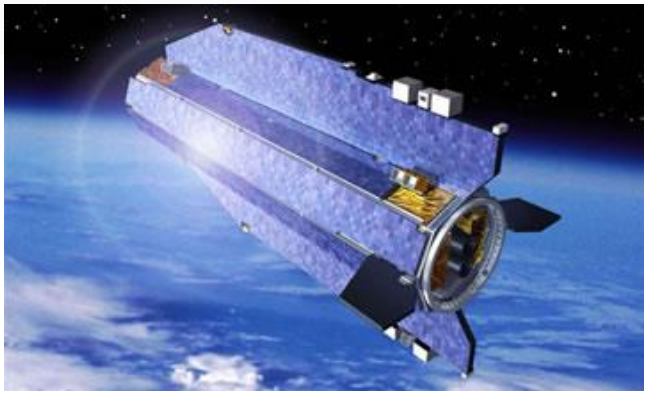
- ***STAR resolution: $3 \cdot 10^{-9}$ m/s^2/Hz$^{0.5}$***
- GPS and SLR
- inclination: 87°
- Altitude: 460-300 km





GRACE (2003-2011):

- ***SuperSTAR resolution: $1 \cdot 10^{-10}$ m/s^2/Hz$^{0.5}$***
- GPS and SLR
- inclination: 90°
- Altitude: 490-450 km



GOCE (11/2009 – 5/2012):

- ***Acc. resolution: $1 \cdot 10^{-12}$ m/s^2/Hz$^{0.5}$***
- ***ion propulsion***
- GPS and SLR
- inclination: 96.5°
- Altitude: 255-225 km

Calculating drag, deriving density

The drag acceleration:

$$a_{drag} = -\frac{1}{2} C_D \frac{A}{m} \rho v^2$$

v **= speed with respect to co-rotating atmosphere**

A **= surface perpendicular to speed (ram area)**

m **= mass**

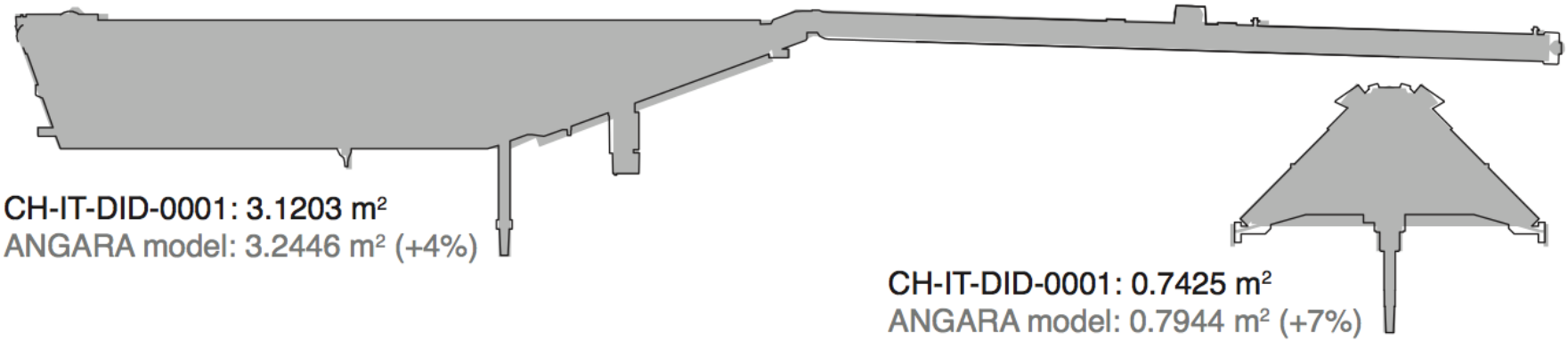
C_D **= aerodynamic (or drag) coefficient**

ρ **= density**

When the drag acceleration is measured/known, *and all other parameters are also known*, atmospheric density can be computed.

But: errors in A, and no standard for C_D → « Density? »

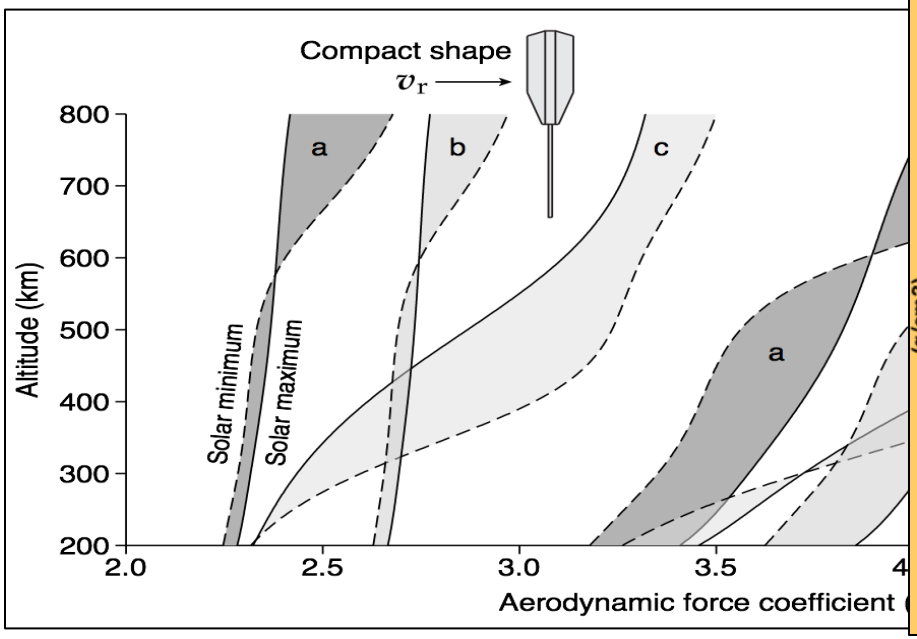
Calculating drag, deriving density

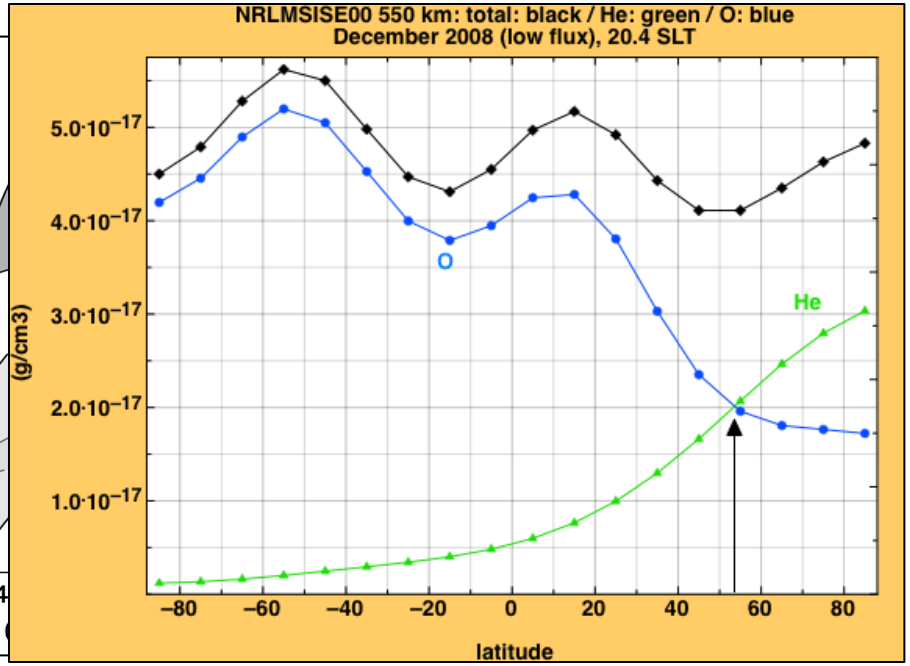


CH-IT-DID-0001: 3.1203 m²
ANGARA model: 3.2446 m² (+4%)

CH-IT-DID-0001: 0.7425 m²
ANGARA model: 0.7944 m² (+7%)

Problem: no standard for drag computation



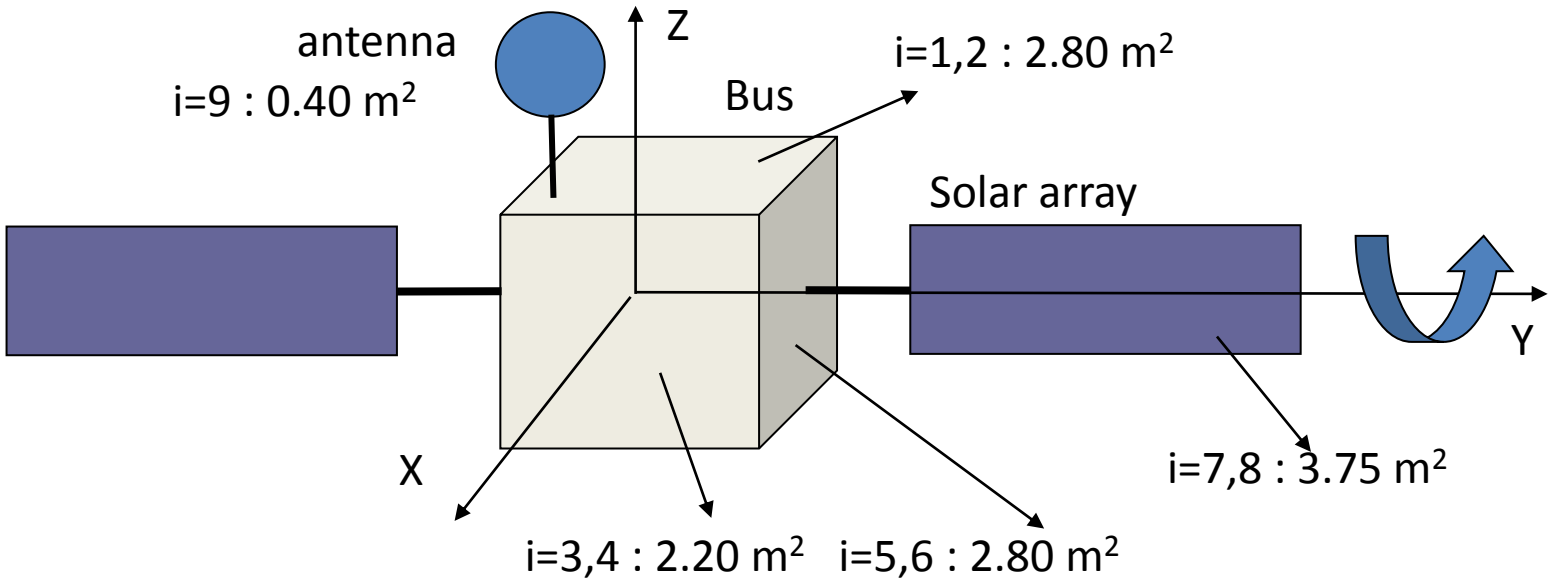


- **Drag coefficient (different models and hypotheses)**

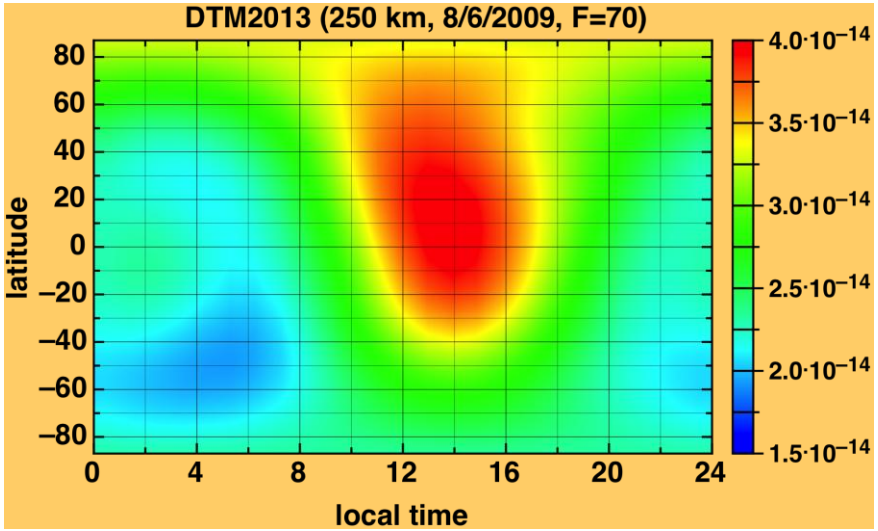
Calculating drag, deriving density

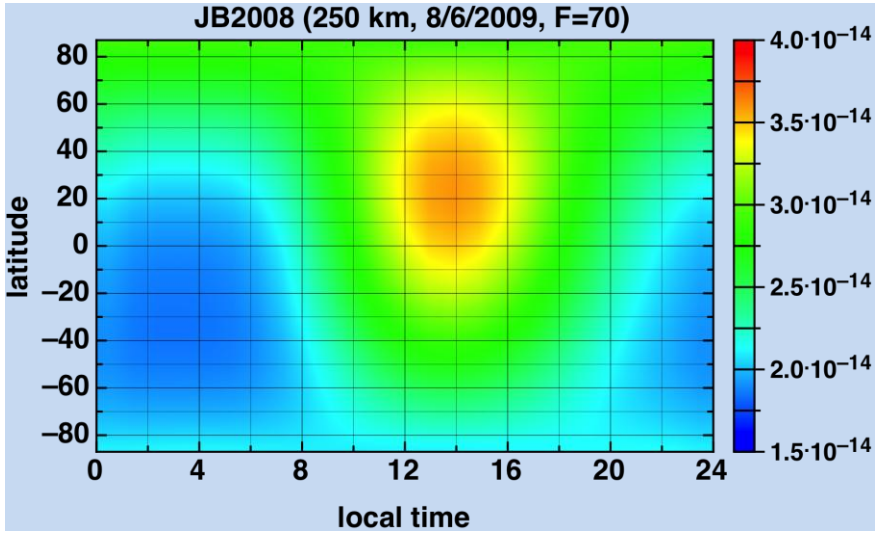
For EO satellites, the situation is much worse than for CHAMP

Simple satellite model (macro model): box and wing(s), antenna



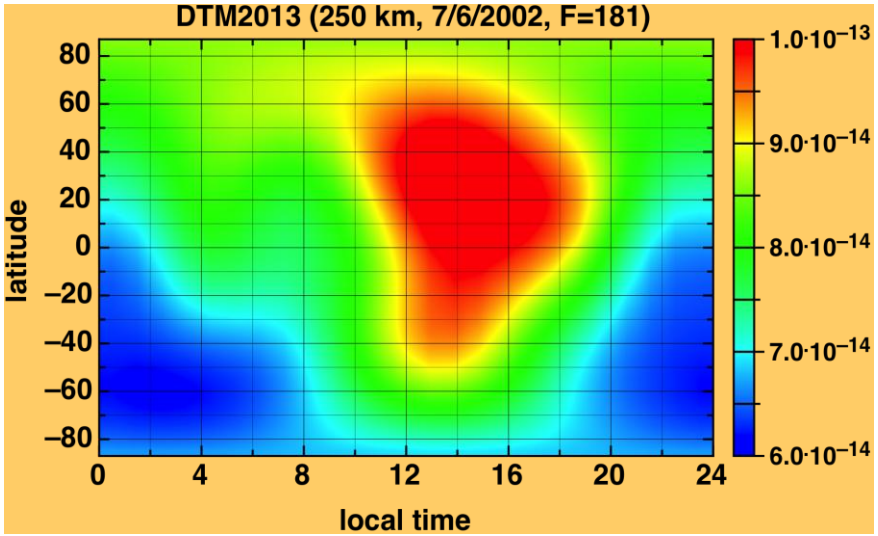
Model evaluation

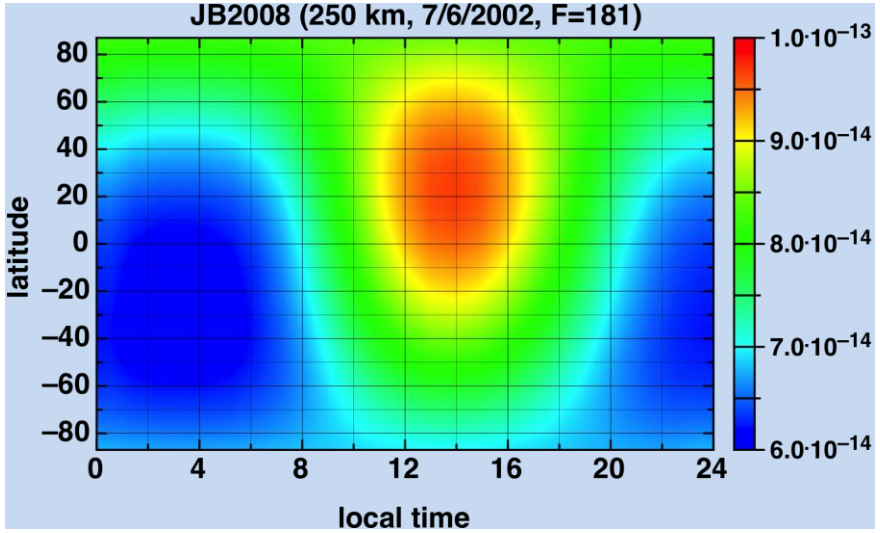




DTM: CIRA optional model

JB2008: CIRA model





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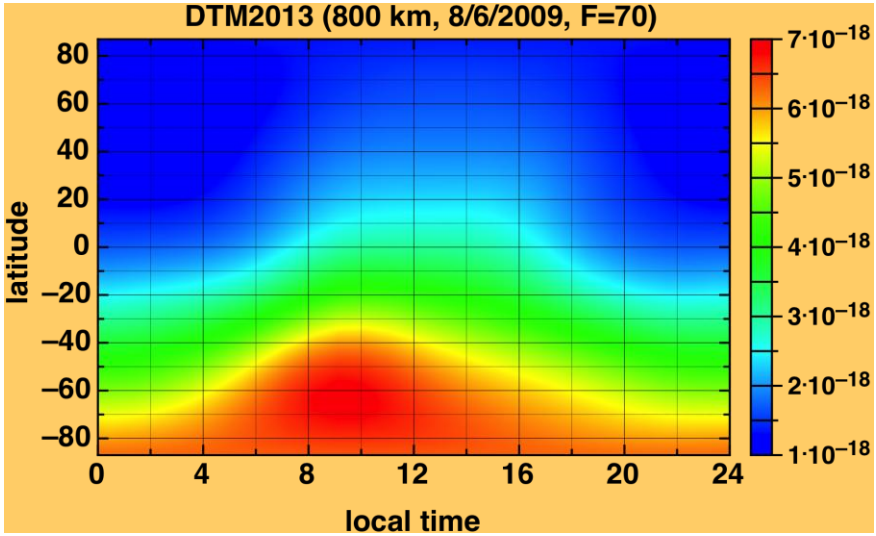

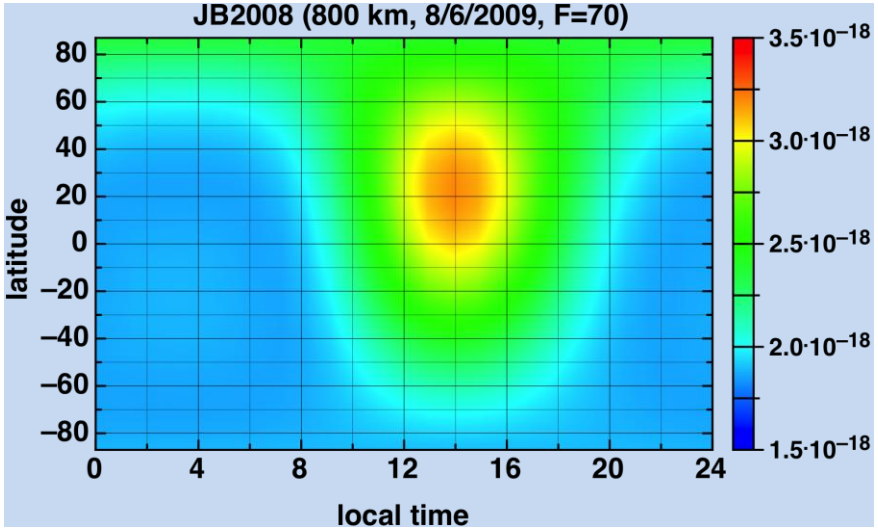

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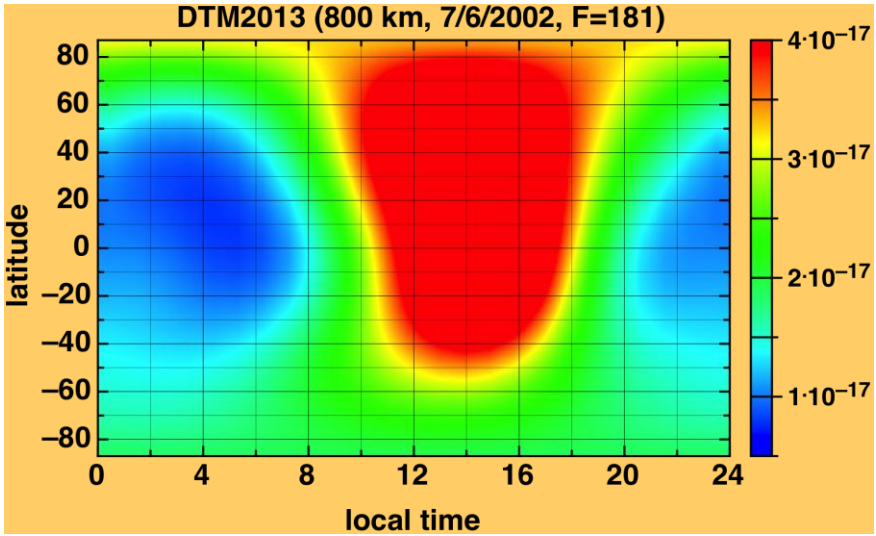
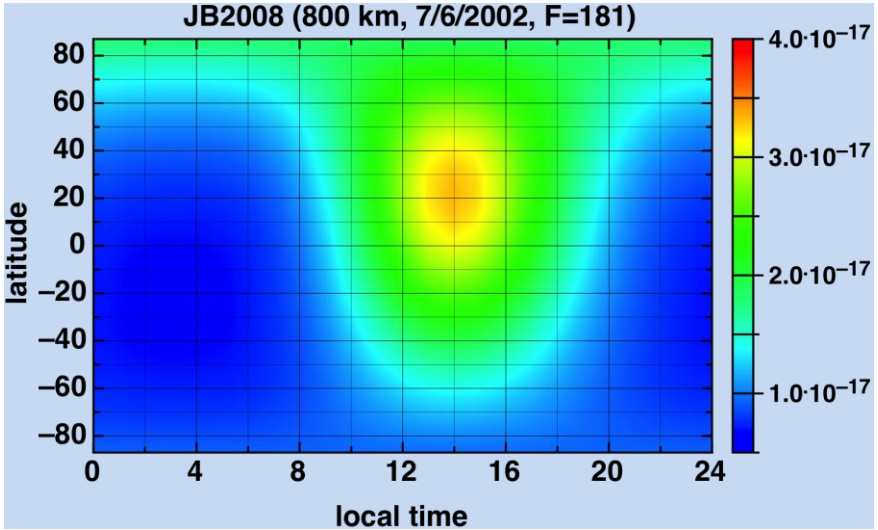
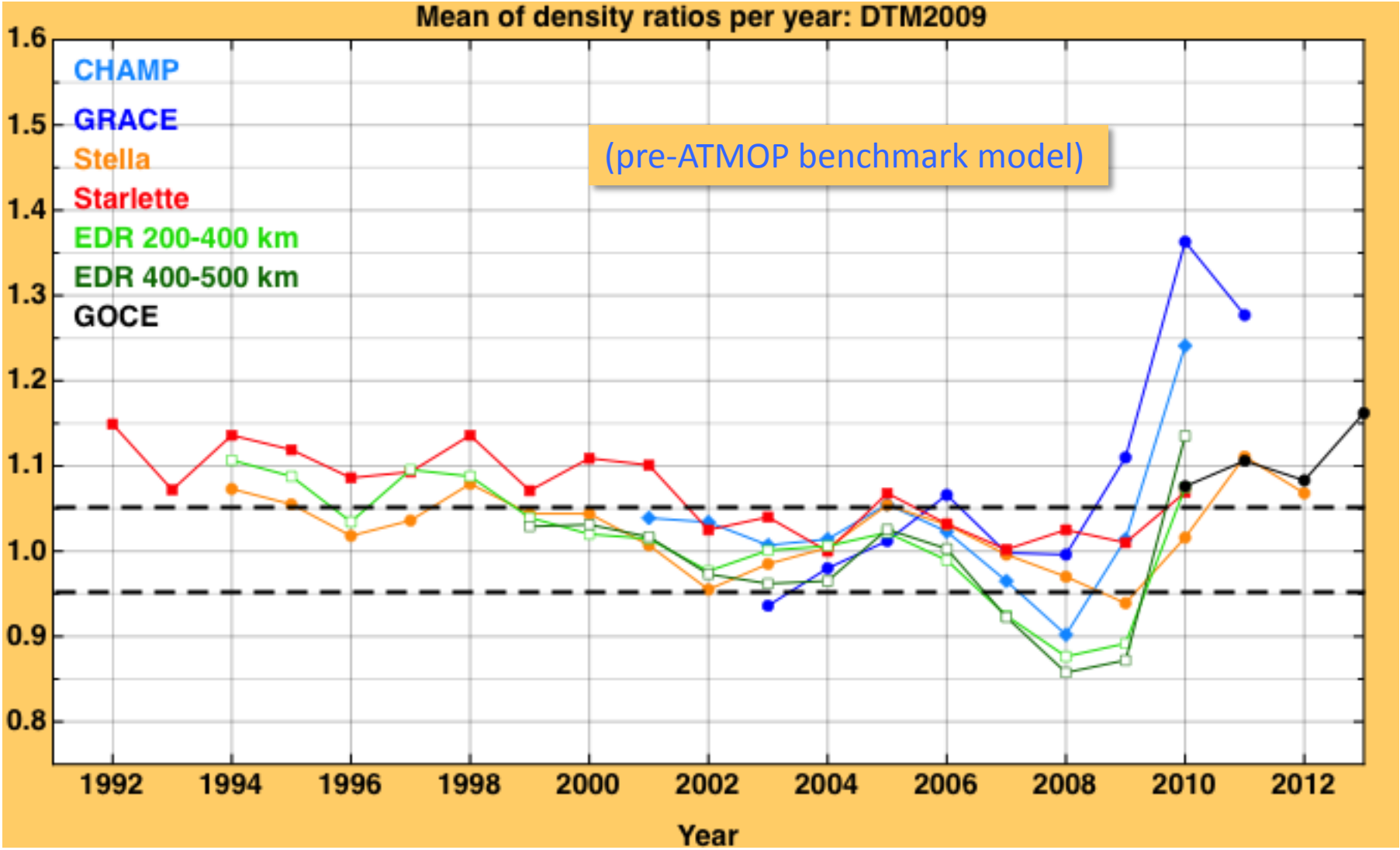




Model evaluation

O/C = Observed-to-Modeled ratio (ideally: O/C = 1.00)



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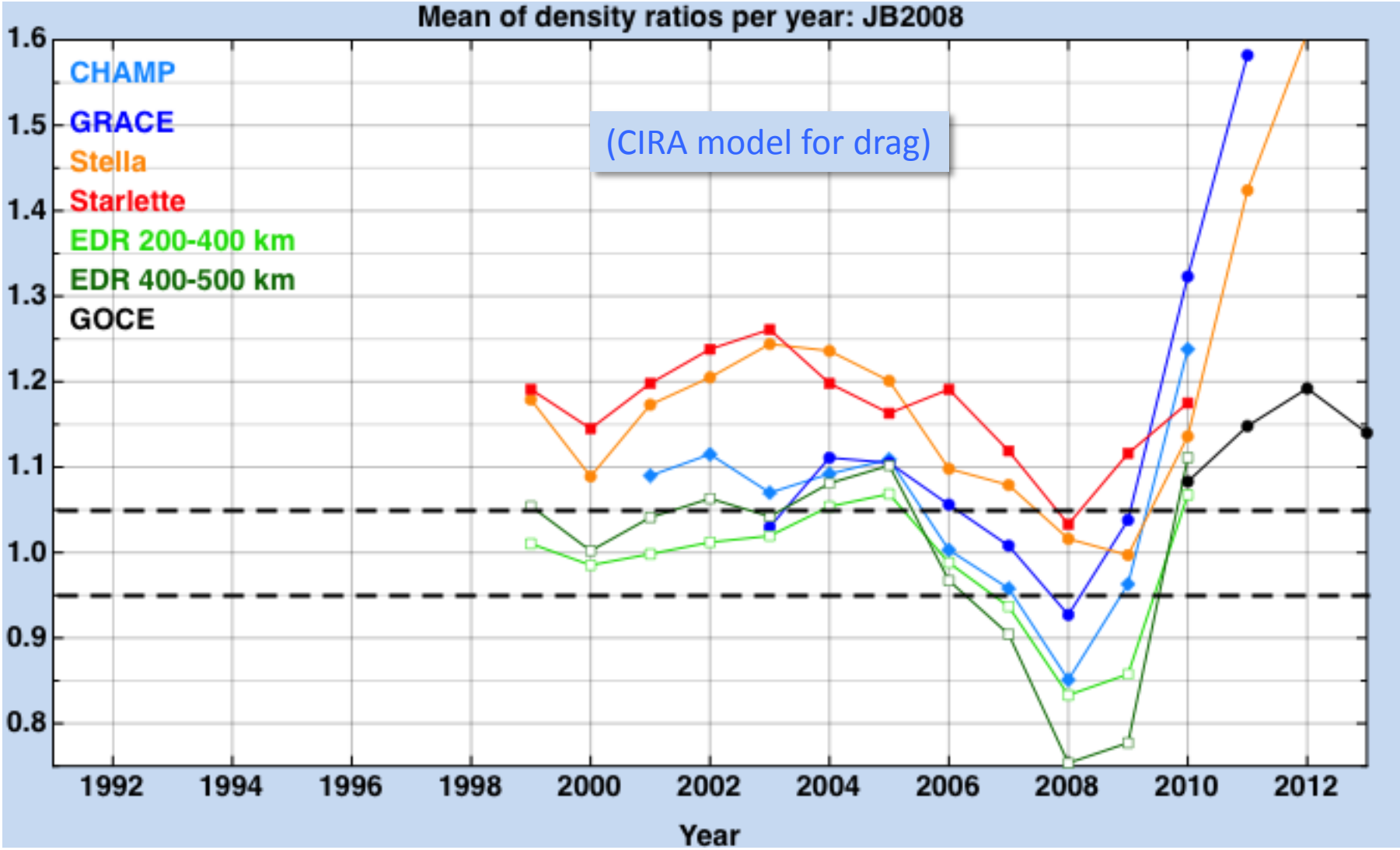

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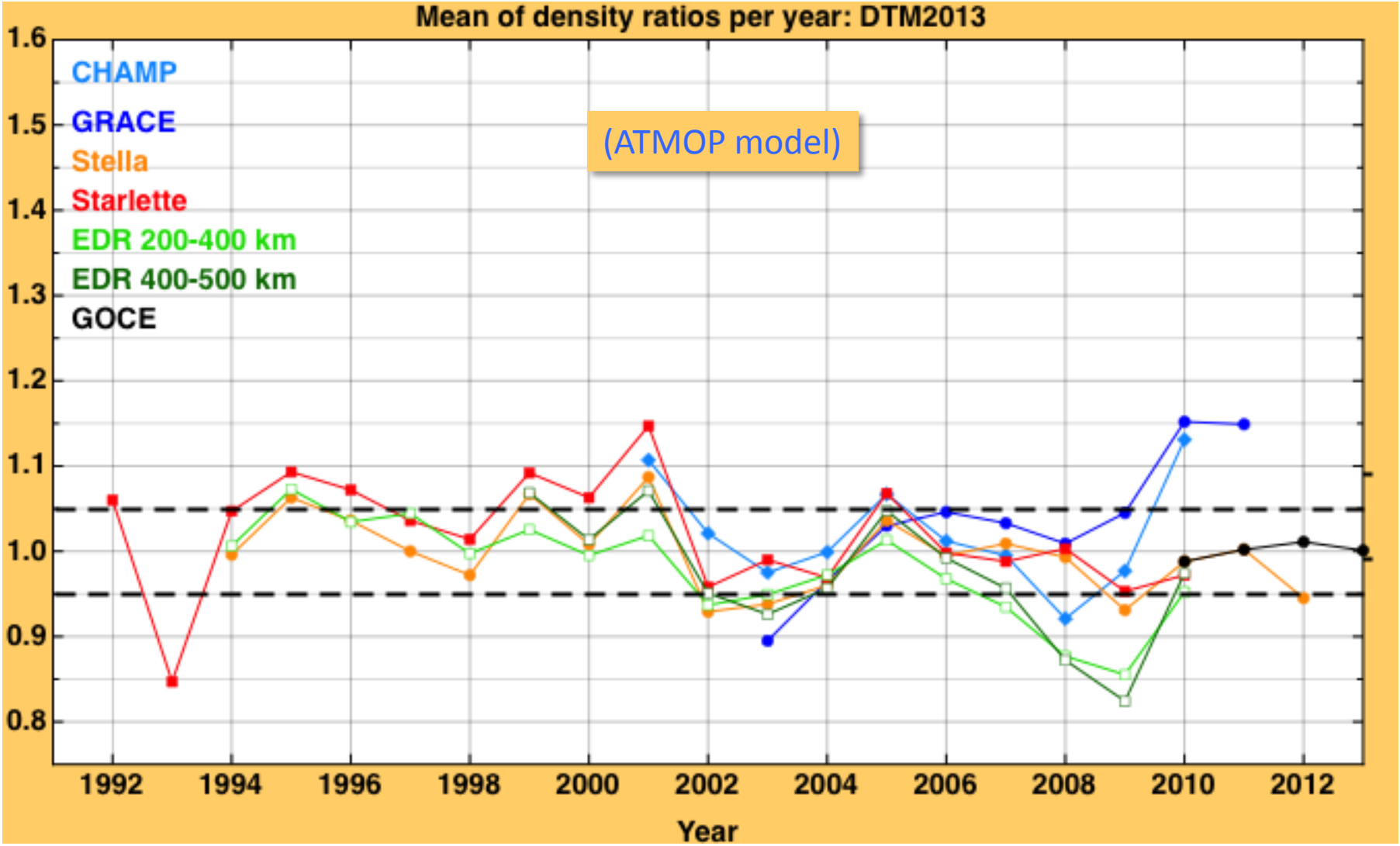

Summary and outlook

- ✓ **DTM2013 constructed with CHAMP, GRACE, GOCE and historical data**
- ✓ **F30 solar proxy is used; better results than with F10.7**
- ✓ **Most precise and least-biased model for GOCE, CHAMP, GRACE, Stella and Starlette**
- ✓ **Fortran90 code**

- *No standard for drag calculation* → *model bias & error*
- *No data above 1000 km* → *pb. TOPEX, Jason*
- *Sparse data above 500 km* → *pb. ERS, Sentinel,..*

(not easy to derive from POD)

Information: sean.bruinsma@cnes.fr / www.atmop.eu