Thermosphere model evaluation at low altitude with GOCE densities

Sean Bruinsma
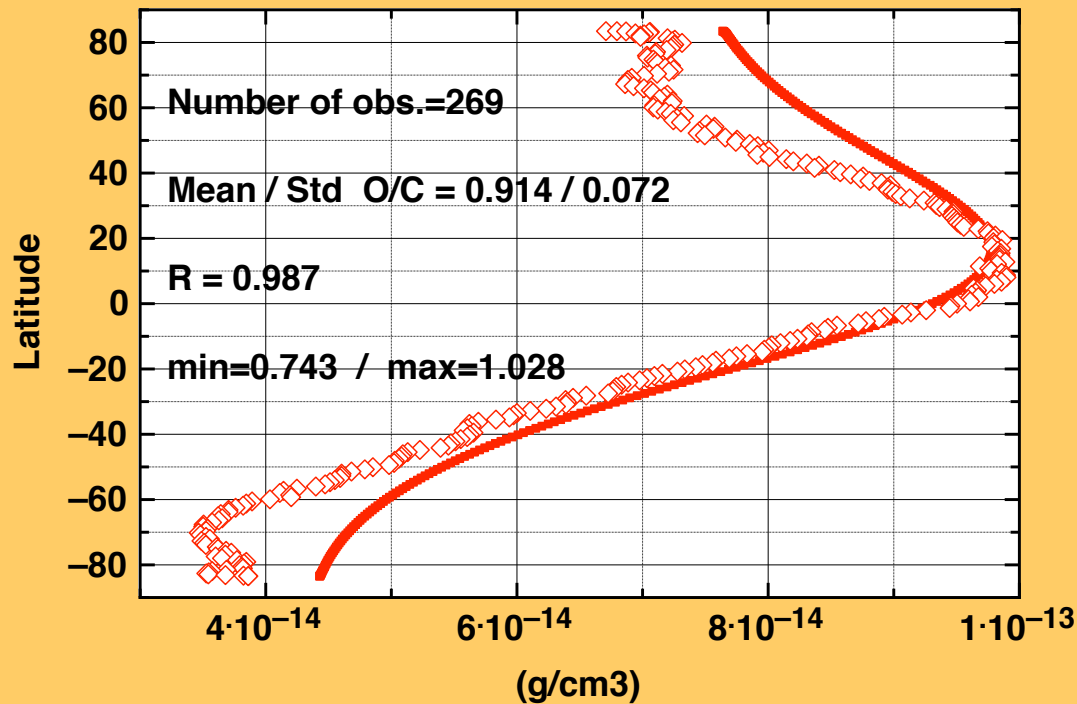
CNES - Space Geodesy

Toulouse, France

Introduction

➢ **CIRA models are evaluated: NRLMSISE-00, JB2008 and DTM2013**

➢ **GOCE density data from 11/2009 – 11/2013 is used (270-170 km), Metric: mean, sigma, RMS and correlation of density ratio O/C**

➢ **Evaluate on long (years), medium (month) and short (day, hours) time scales**

GOCE densities dawn profile (open), and DTM2013 (solid)

Number of obs.=269

Mean / Std O/C = 0.914 / 0.072

R = 0.987

min=0.743 / max=1.028

Y-axis: Latitude (80, 60, 40, 20, 0, −20, −40, −60, −80)

X-axis: $4 \cdot 10^{-14}$ $6 \cdot 10^{-14}$ $8 \cdot 10^{-14}$ $1 \cdot 10^{-13}$ (g/cm3)
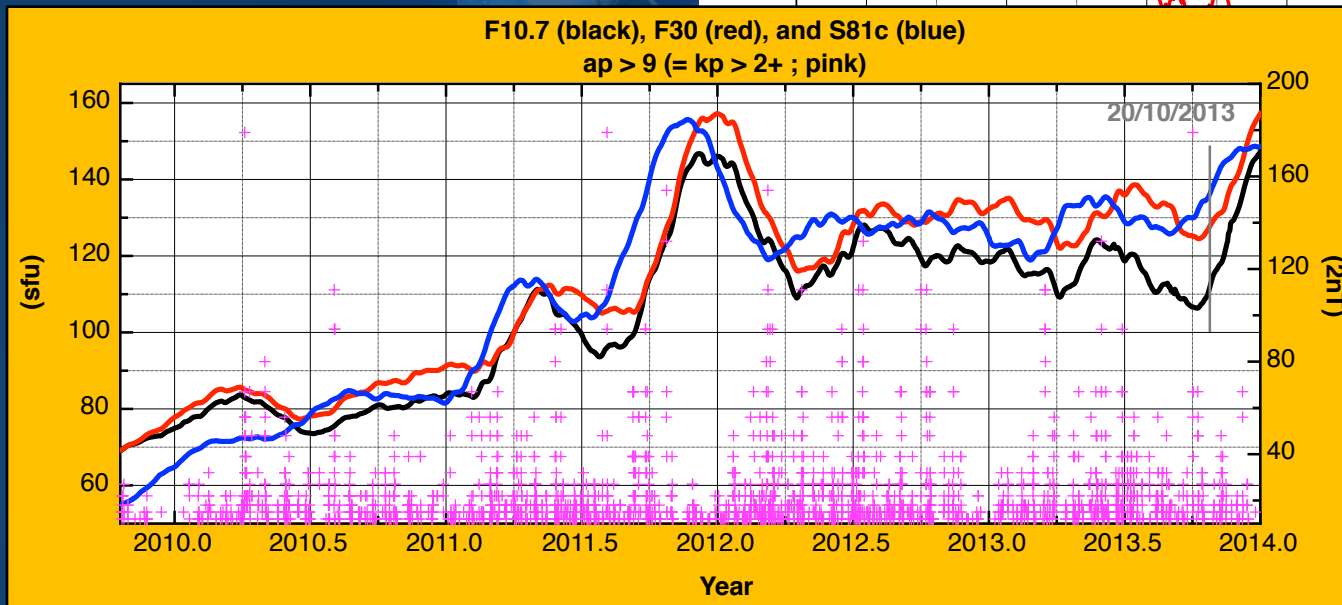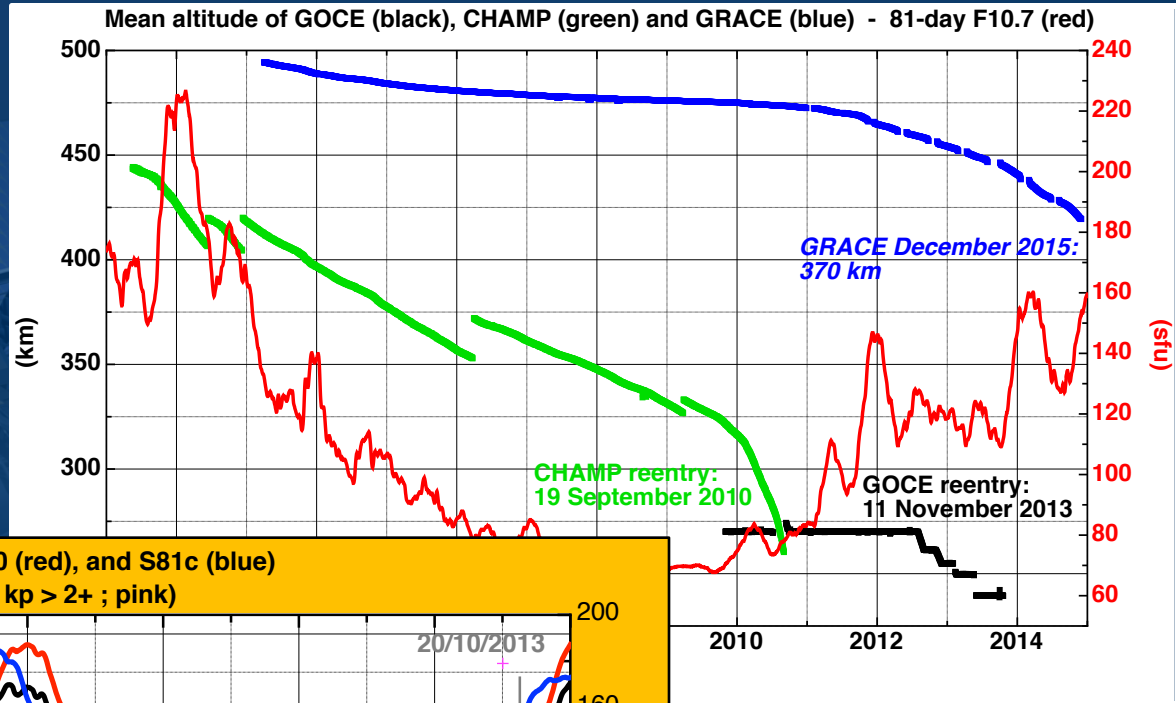
GOCE (2009 – 2013):

- accelerometer
- ion propulsion
- GPS and SLR
- inclination: 96.5°
- Altitude: 270-170 km

➢ 10-s densities, precision 1-2%

Introduction

GOCE densities:

- *Low altitude*

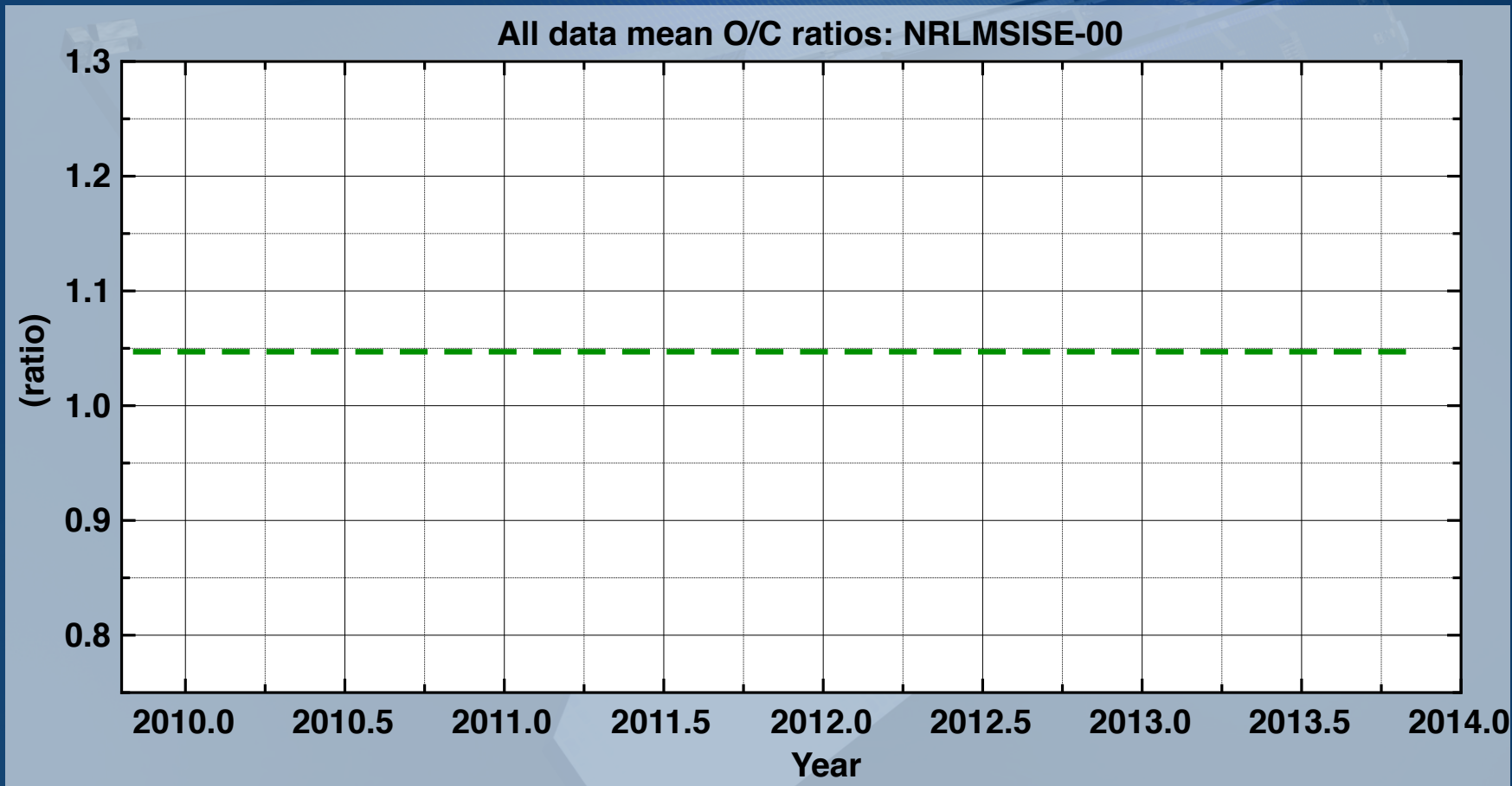- *Low-medium solar activity*

- *6-8am/pm local solar time*

Mean altitude of GOCE (black), CHAMP (green) and GRACE (blue) - 81-day F10.7 (red)

GRACE December 2015: 370 km

CHAMP reentry: 19 September 2010

GOCE reentry: 11 November 2013

F10.7 (black), F30 (red), and S81c (blue)
ap > 9 (= kp > 2+ ; pink)

20/10/2013

Models: solar proxies:

NRLMSISE-00: F10.7

JB2008: S, F10.7, M, Y

DTM2013: F30

Download F30 here: ftp://ftpsedr.cls.fr/pub/previsol/solarflux/final

Density ratios O/C: NRLMSISE-00

All data mean O/C ratios: NRLMSISE-00

Mean and StD (of O/C time series): 1.05 / -   *(All data)*

Density ratios O/C: NRLMSISE-00

All + Yearly mean O/C ratios: NRLMSISE-00
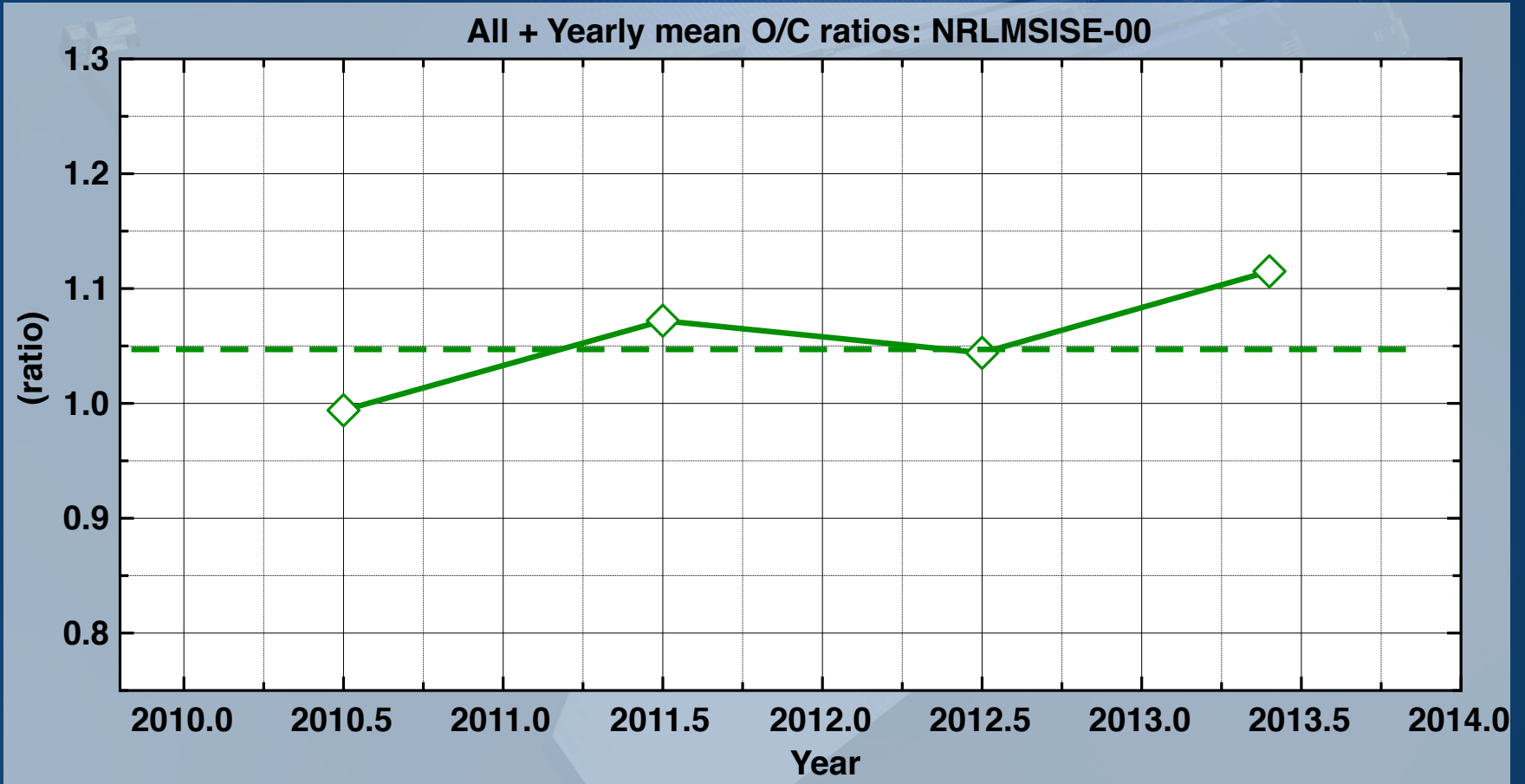
Mean and StD (of O/C time series): 1.05 / 0.051   *(Per year)*

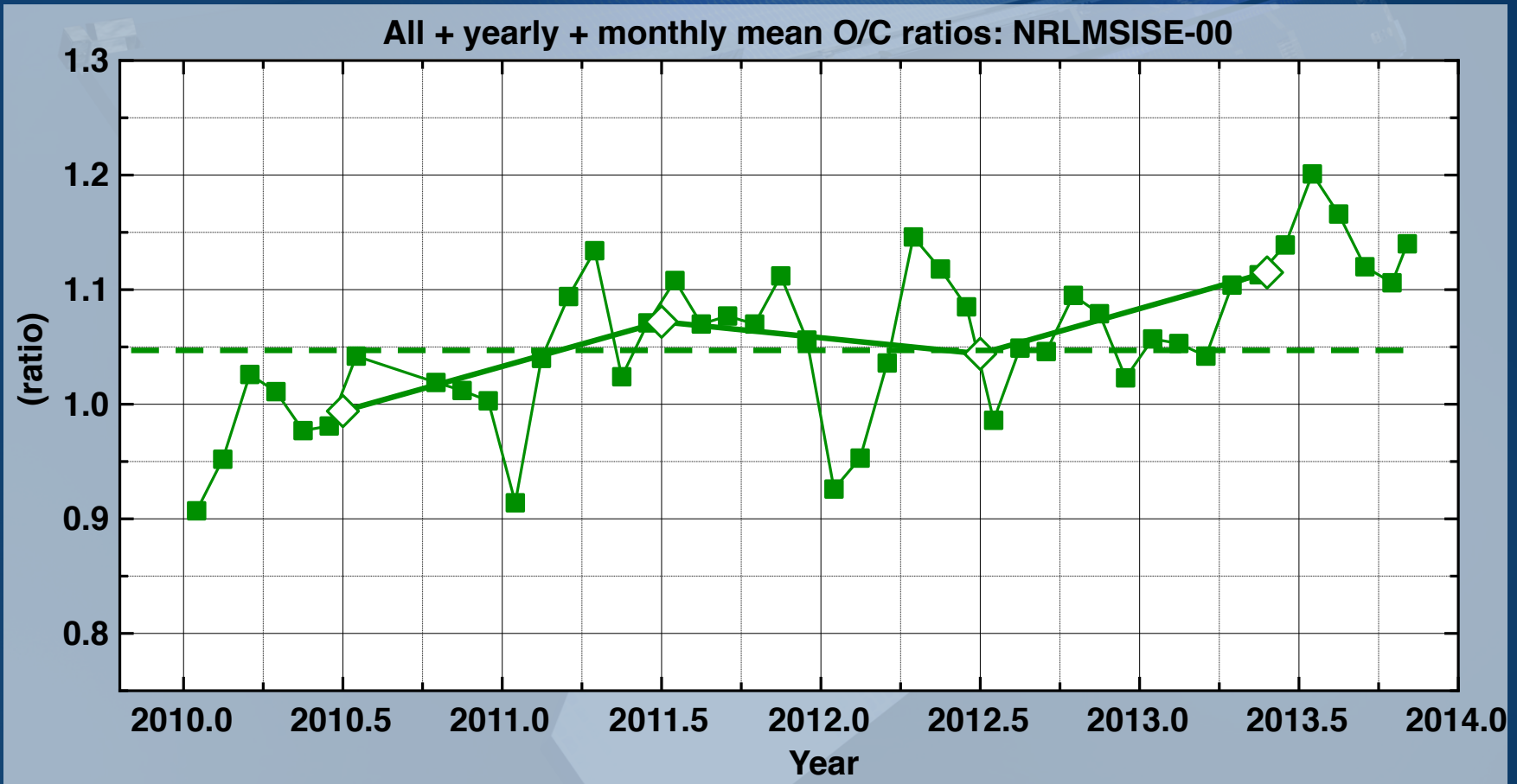# Density ratios O/C: NRLMSISE-00

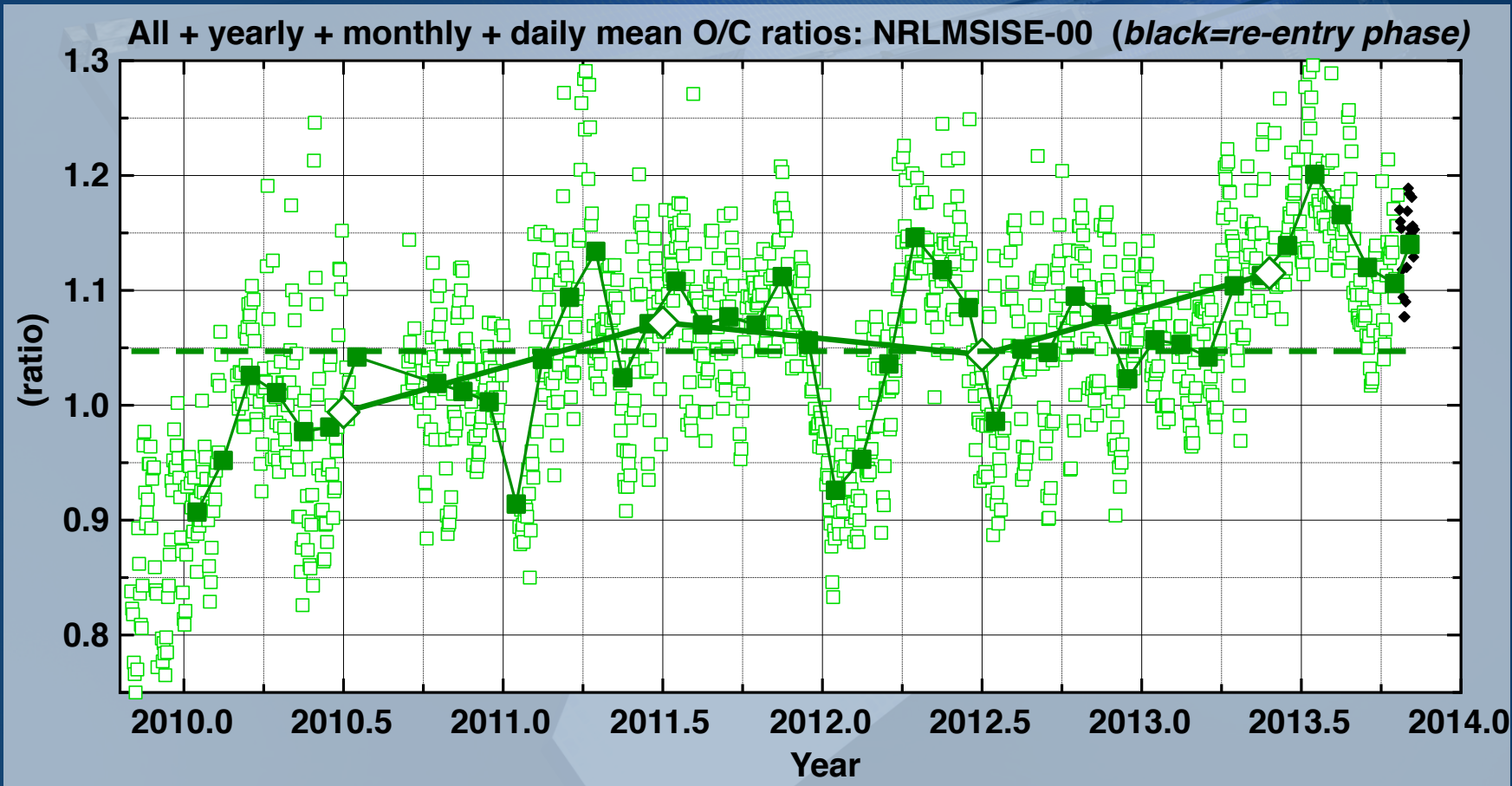

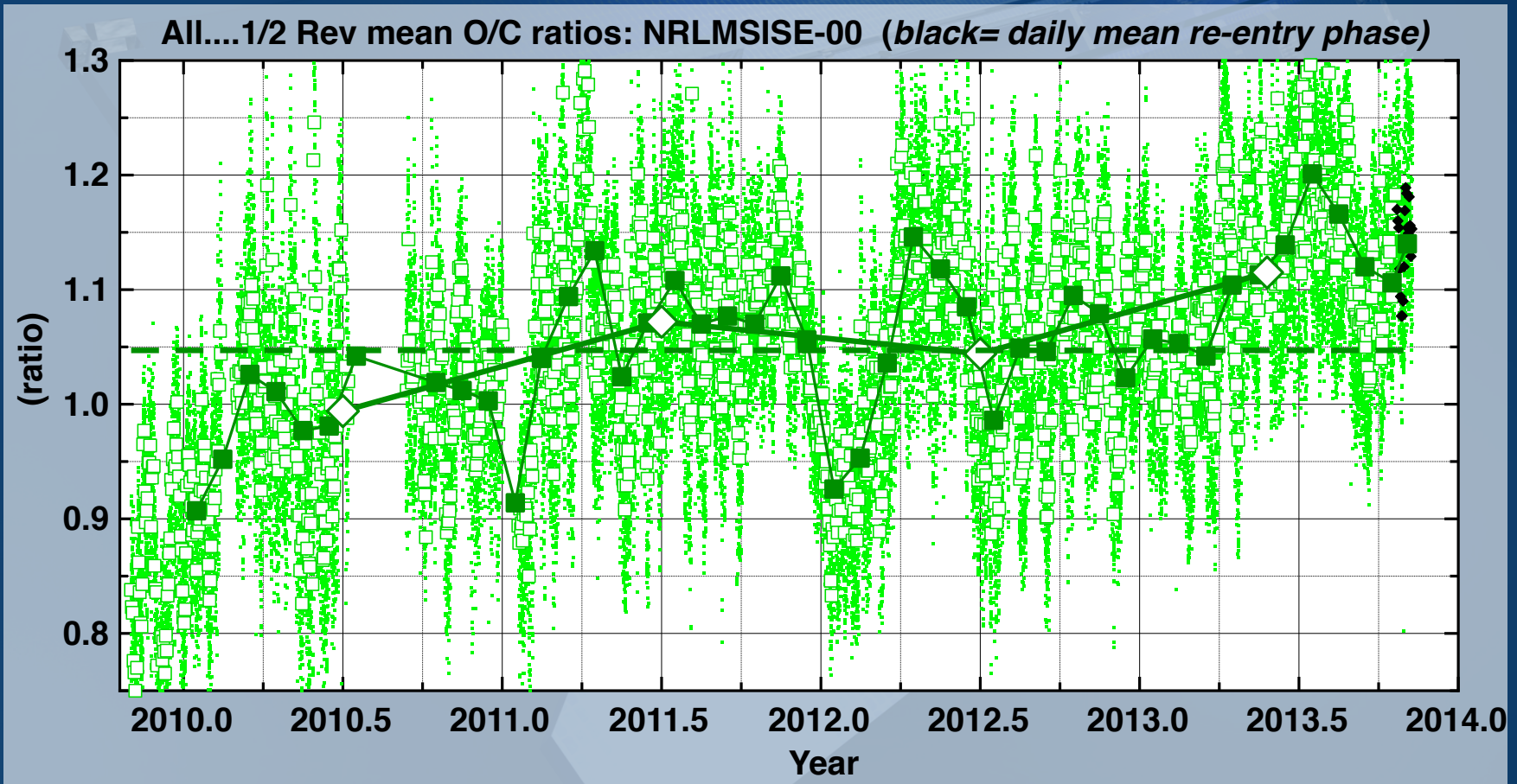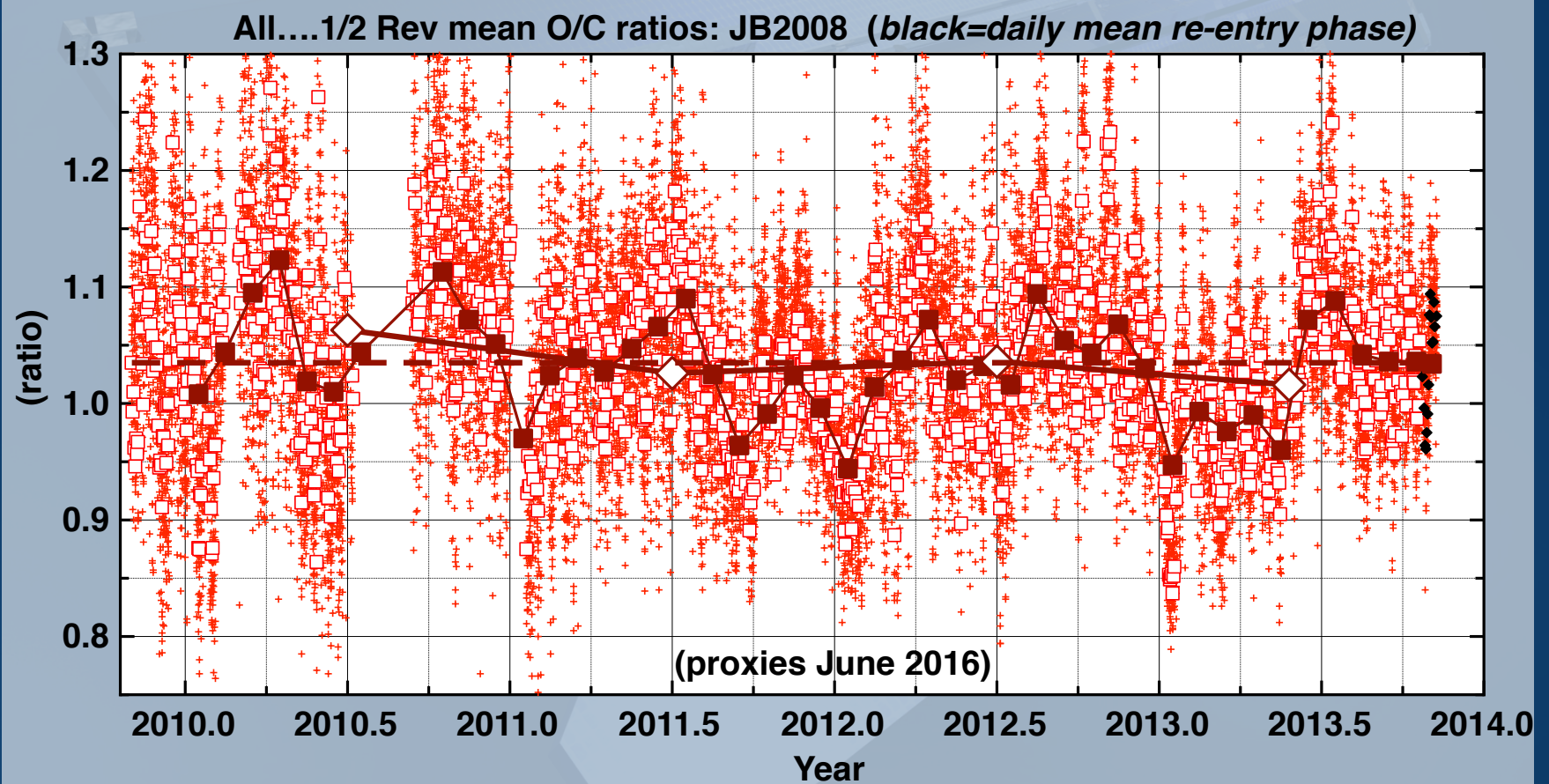All + yearly + monthly mean O/C ratios: NRLMSISE-00

Mean and StD (of O/C time series): 1.05 / 0.067   *(Per month)*

Density ratios O/C: NRLMSISE-00

Mean and StD (of O/C time series): **1.05 / 0.098**   *(Per day)*
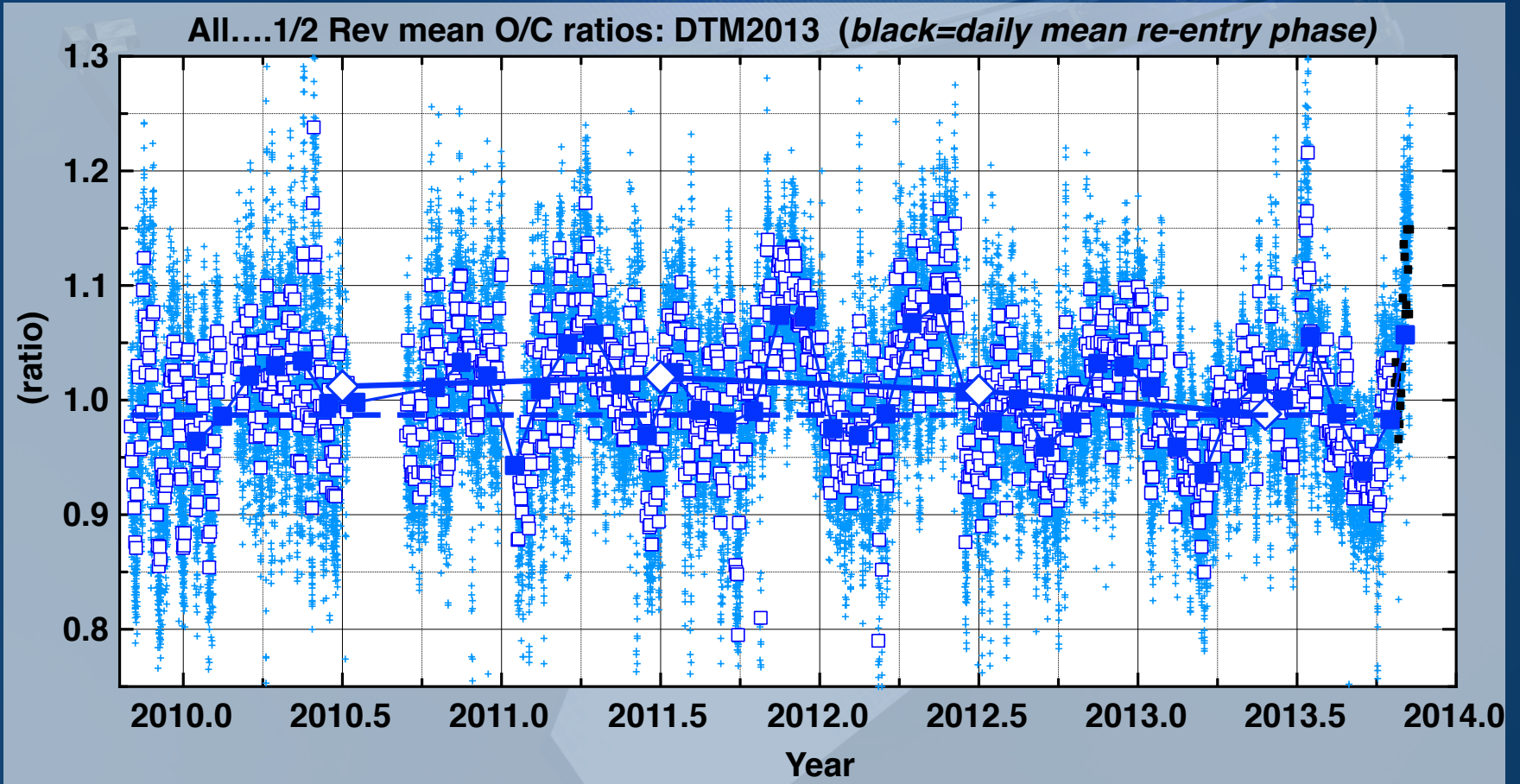
Density ratios O/C: NRLMSISE-00

All....1/2 Rev mean O/C ratios: NRLMSISE-00 (*black= daily mean re-entry phase*)

Mean and StD (of O/C time series): 1.05 / 0.109   *(Per asc/desc arc)*

Density ratios O/C: JB2008

All….1/2 Rev mean O/C ratios: JB2008 (*black=daily mean re-entry phase*)

(proxies June 2016)

Density ratios O/C: DTM2013

All....1/2 Rev mean O/C ratios: DTM2013 (*black=daily mean re-entry phase*)

StD of density ratio time series –vs– time scale

NRLMSISE-00 (green) / JB2008 (red) / DTM2013 (blue)
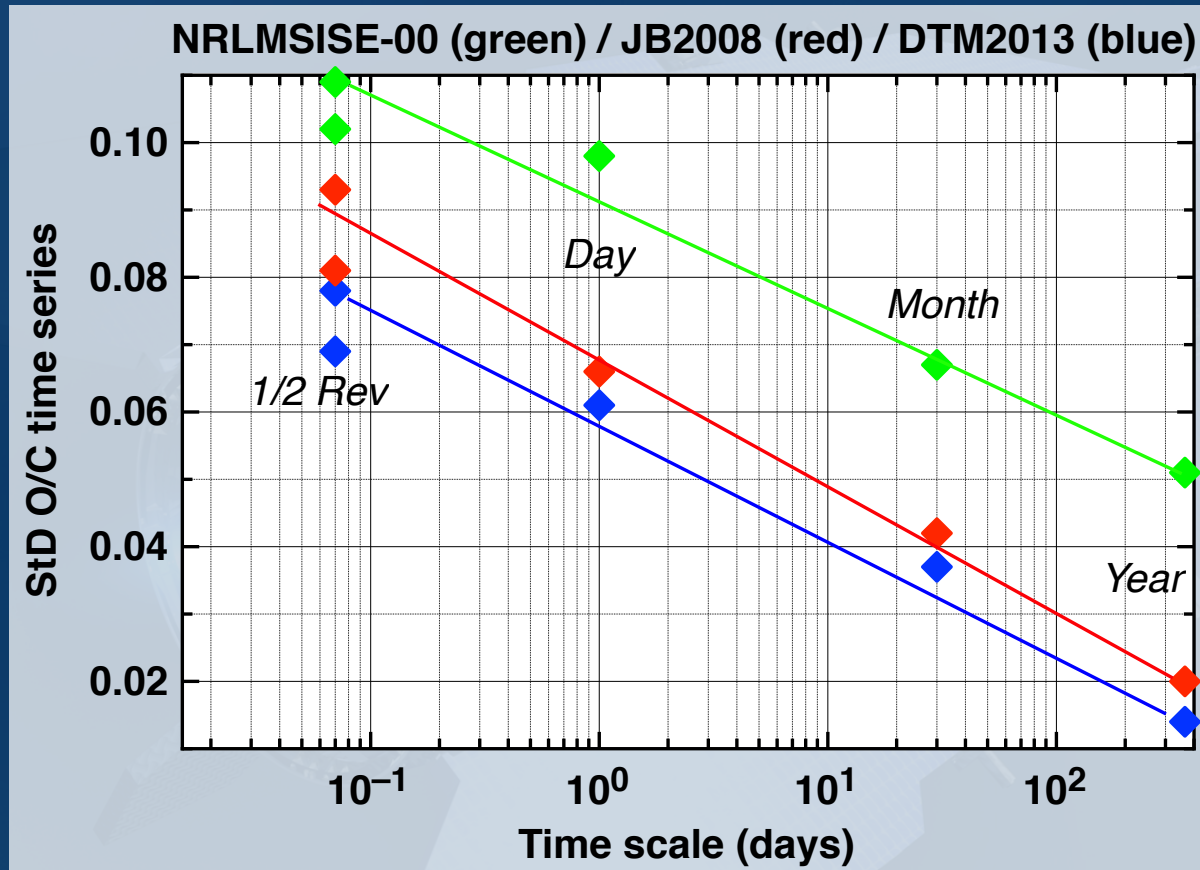
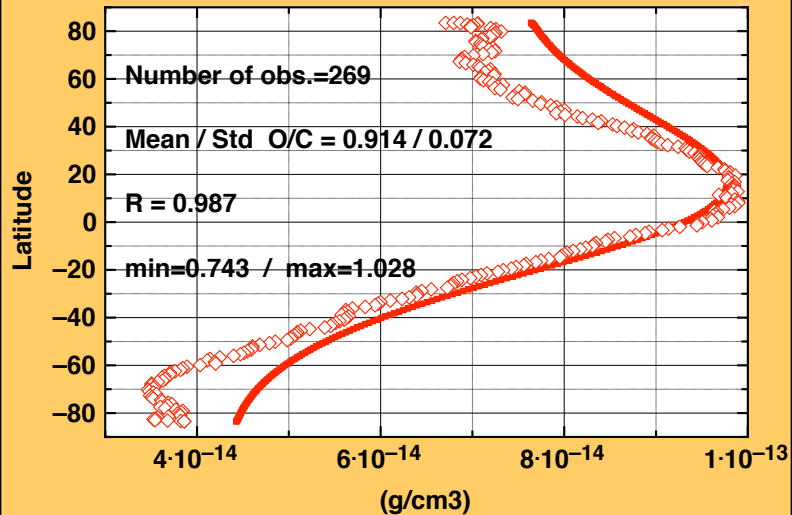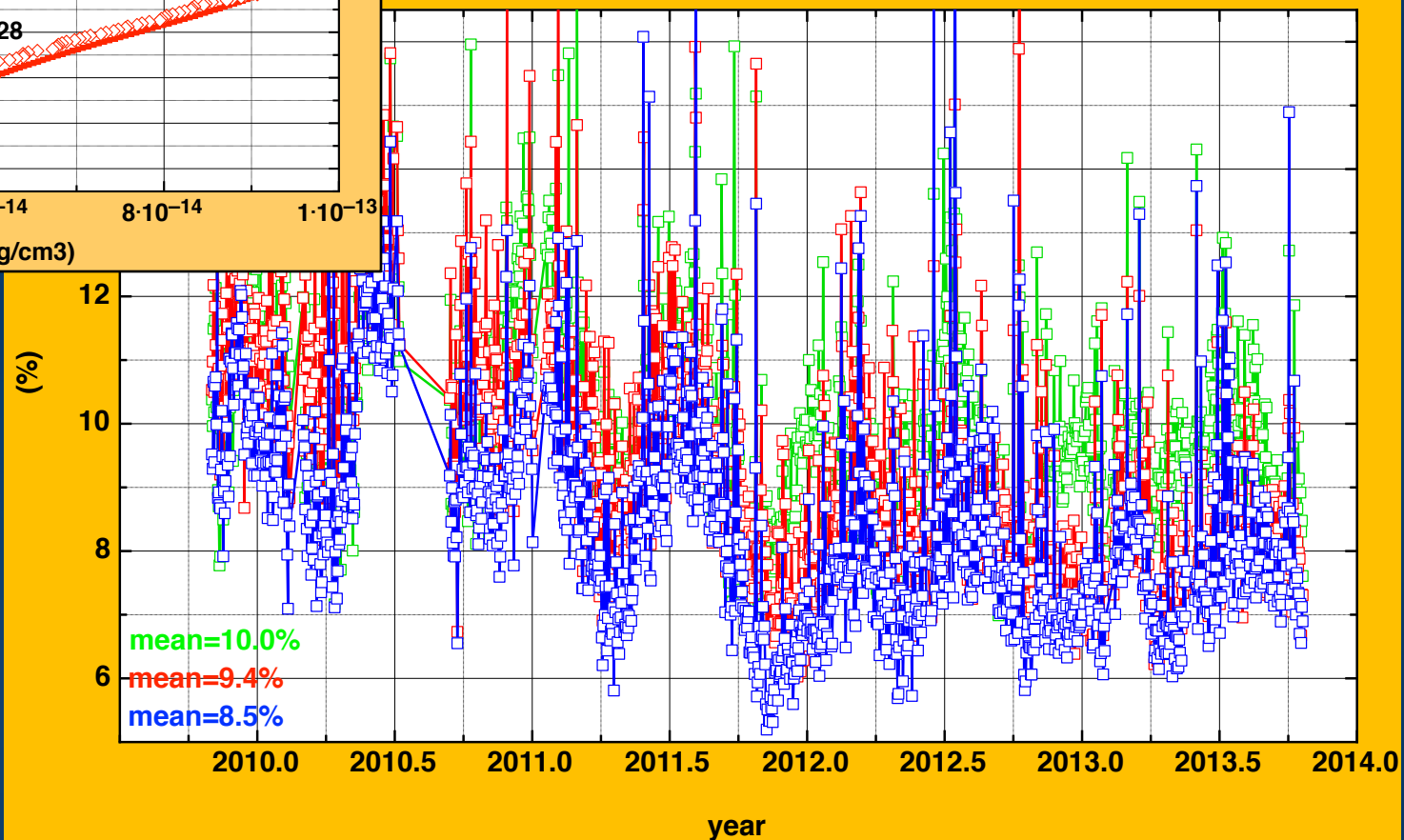|	
σ of annual time series:	0.014
of monthly time series:	0.037
of daily time series:	0.061
of ½ rev time series:	0.069 / 0.078 *(dusk / dawn)*

StD of daily-mean density ratios

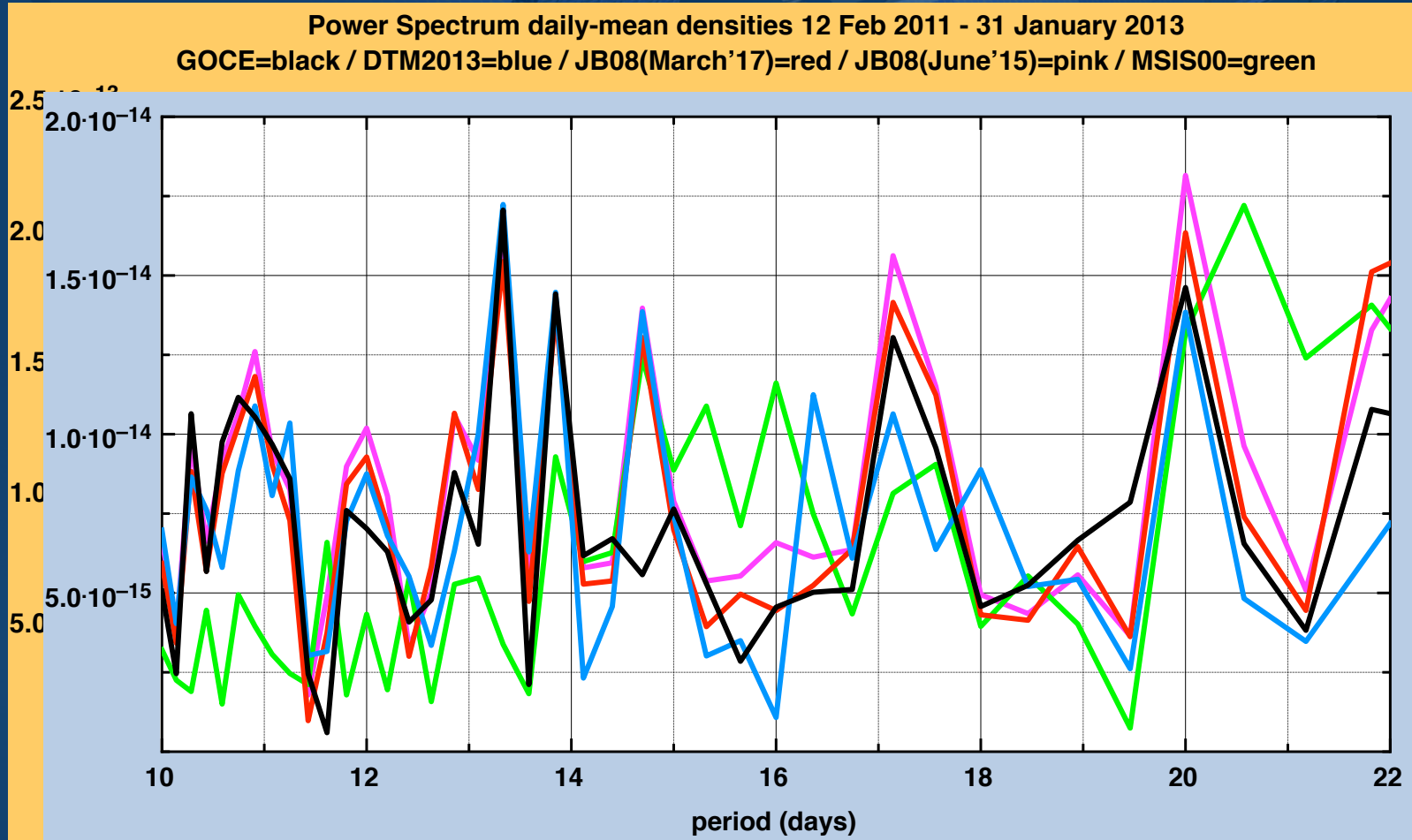GOCE densities dawn profile (open), and DTM2013 (solid)

Number of obs.=269

Mean / Std O/C = 0.914 / 0.072

R = 0.987

min=0.743 / max=1.028

(normalized) standard deviation of O/C ratios
...E-00 (green), JB2008 (red), DTM2013 (blue)
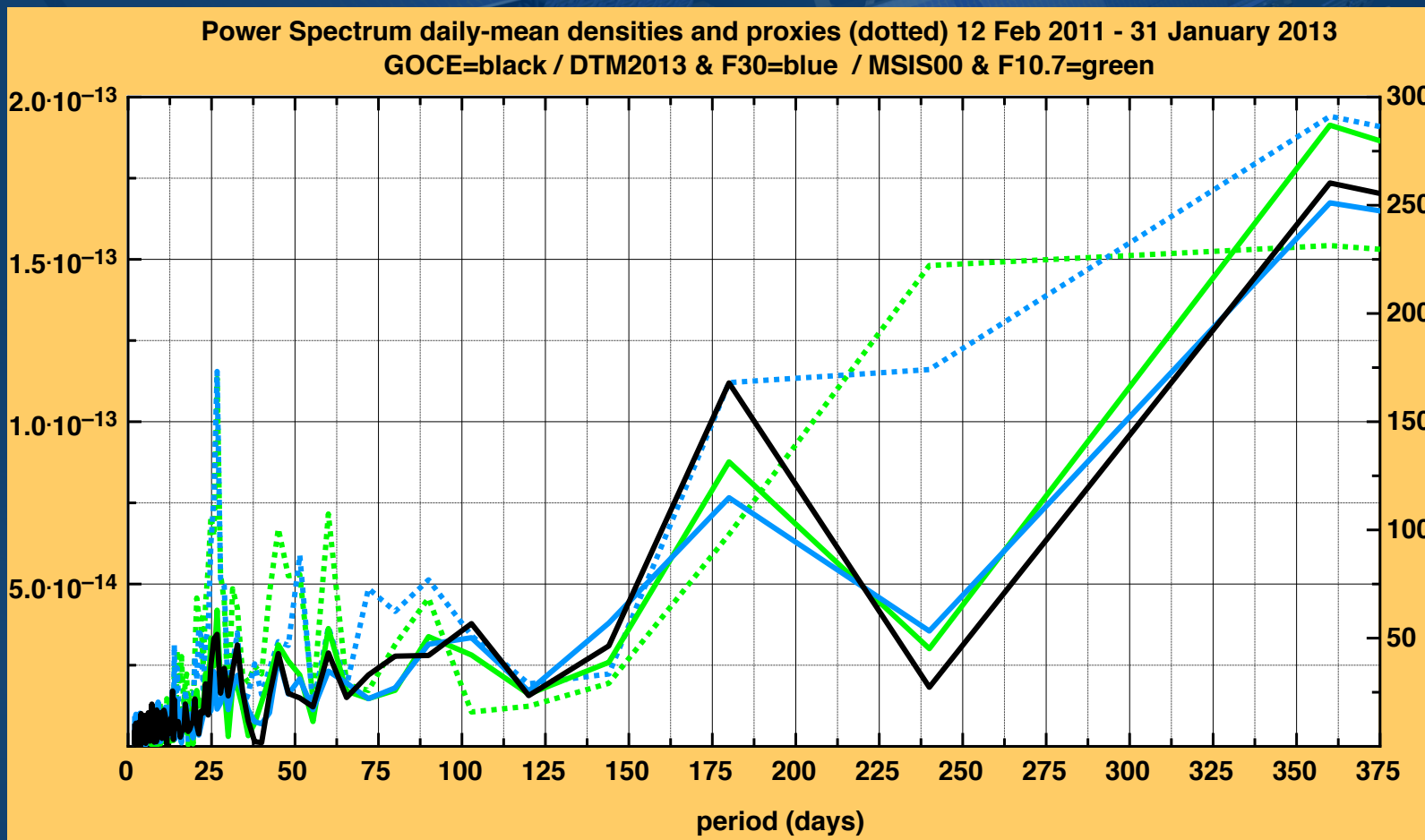
mean=10.0%
mean=9.4%
mean=8.5%

Spectral analysis

Due to many, sometimes long, data gaps, the analysis was done on a 720-day interval from 12 February 2011 – 31 January 2013.

Data gaps, short and few, are interpolated linearly.

Power Spectrum daily-mean densities 12 Feb 2011 - 31 January 2013
GOCE=black / DTM2013=blue / JB08(March'17)=red / JB08(June'15)=pink / MSIS00=green

Spectral analysis

Observed density, NRLMSISE-00 and F10.7 (green), and DTM2013 and F30 (blue)

Power Spectrum daily-mean densities and proxies (dotted) 12 Feb 2011 - 31 January 2013
GOCE=black / DTM2013 & F30=blue / MSIS00 & F10.7=green

Spectral analysis

Errors are due to model and proxies; <u>nrt data assimilation can correct both (HASDM)</u>

Density data inferred from radar tracking on 60-70 objects are assimilated every 3 hours

Power Spectrum daily-mean densities 12 Feb 2011 - 31 January 2013
GOCE=black / HASDM=grey /DTM2013=blue / JB08(March'17)=red
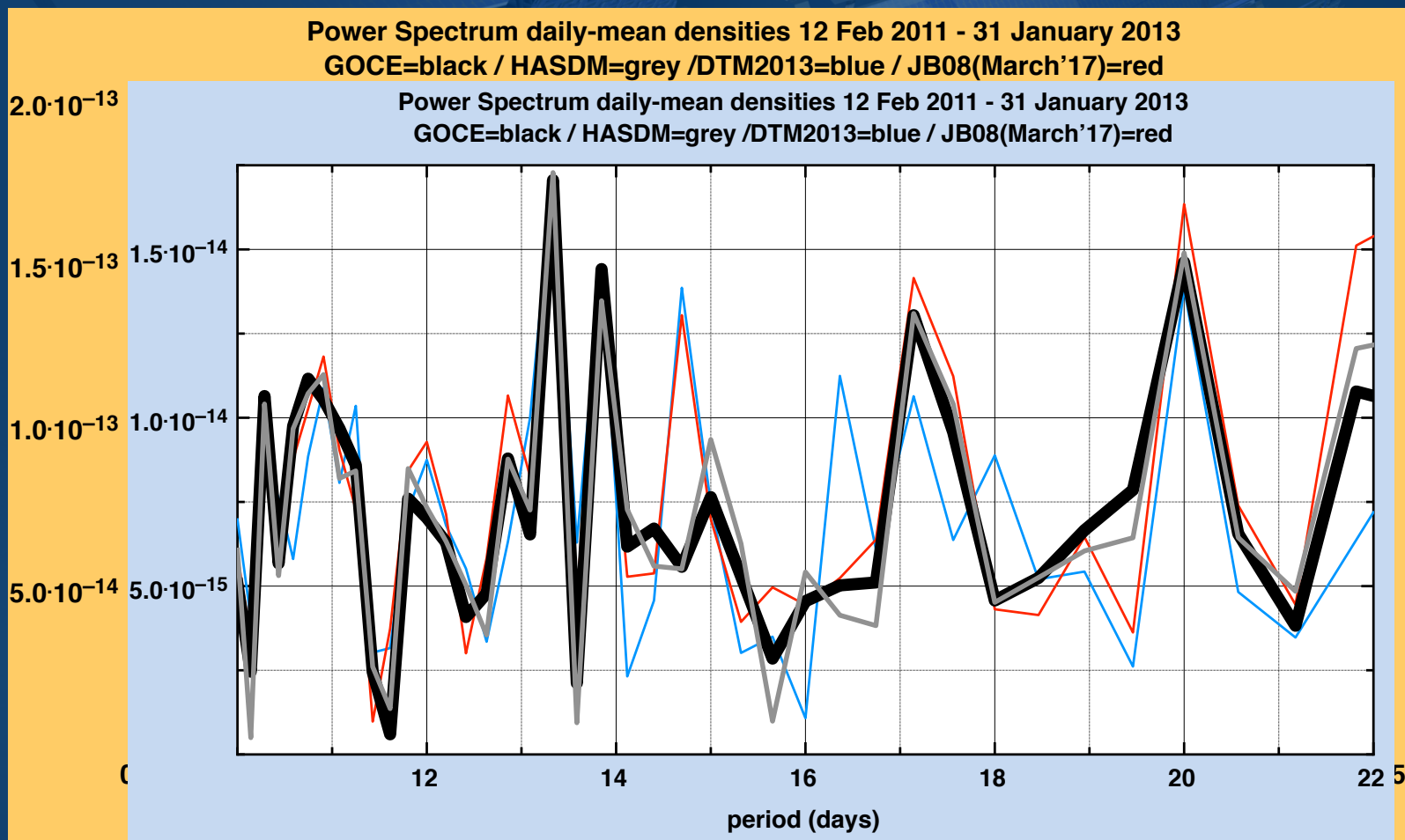
Summary and Conclusions

- ✓ **High resolution GOCE densities available**

- ✓ **CIRA models evaluated in the 270-170 km altitude range**

- ✓ **DTM2013 and JB2008 (_NB: proxies_!) most accurate and precise**

- ✓ **NRLMSISE-00 biased (_database and solar activity_)**

- ✓ **Models biased for lowest activity in 2009-10, most NRLMSISE-00**

- ✓ **_Standard deviation_ of CIRA models at the 2-10% level (1-σ)**

- ✓ **High correlation, most solar variations reproduced**

- ✓ **Representative results for all local times (using CHAMP, not shown)**

- • _Model errors on time scales of weeks-months: proxies & database_

- • _Model error is not white (see density ratios)_