Multiple Satellite Analysis of the Earth's Thermosphere and Interplanetary Magnetic Field Variations due to ICME/CIR events during 2003–2015

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Content of the study

Estimation of interplanetary coronal mass ejections (ICME) and co-rotating interaction regions (CIR) induced disturbances of the upper Earth atmosphere and the associated orbit decay rate of low Earth orbiting satellites (LEO)

Solar events during 2003 – 2015; covering 196 ICME and 195 CIR events

Satellites of interest: ACE & CHAMP and GRACE

Data basis:

- Magnetic field component B_z (measured at L1 by ACE)
- Accelerometer observations from CHAMP and GRACE
- Various geomagnetic indices (a-indices,kp, Dst, Sym-H, PC, AE)

ICME & CIR observations

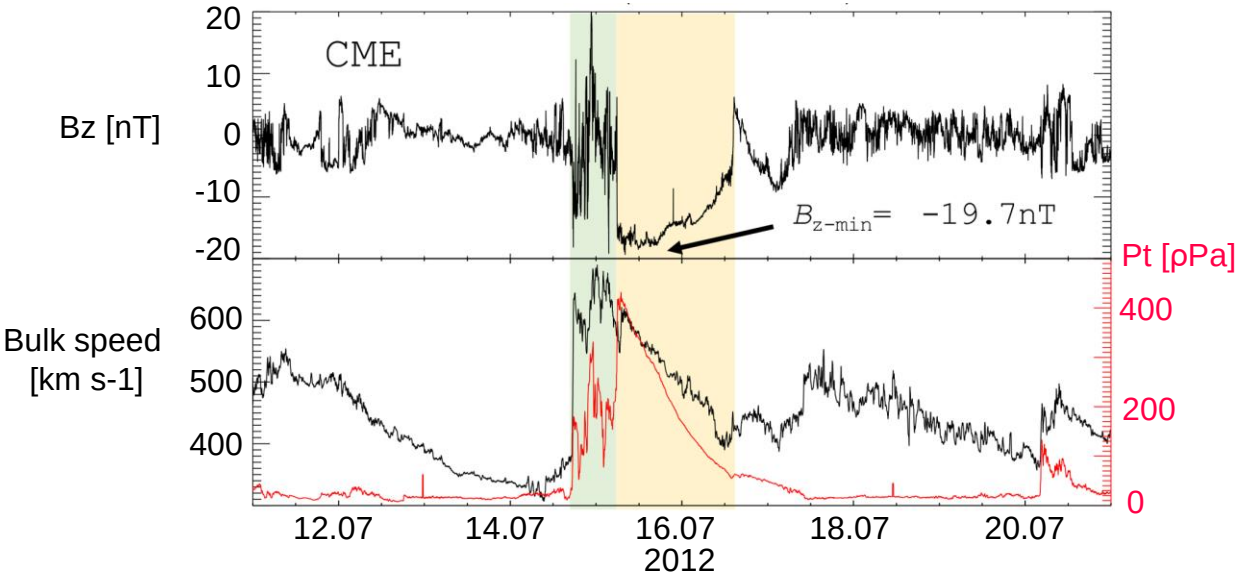
Advanced Composition Explorer (ACE)

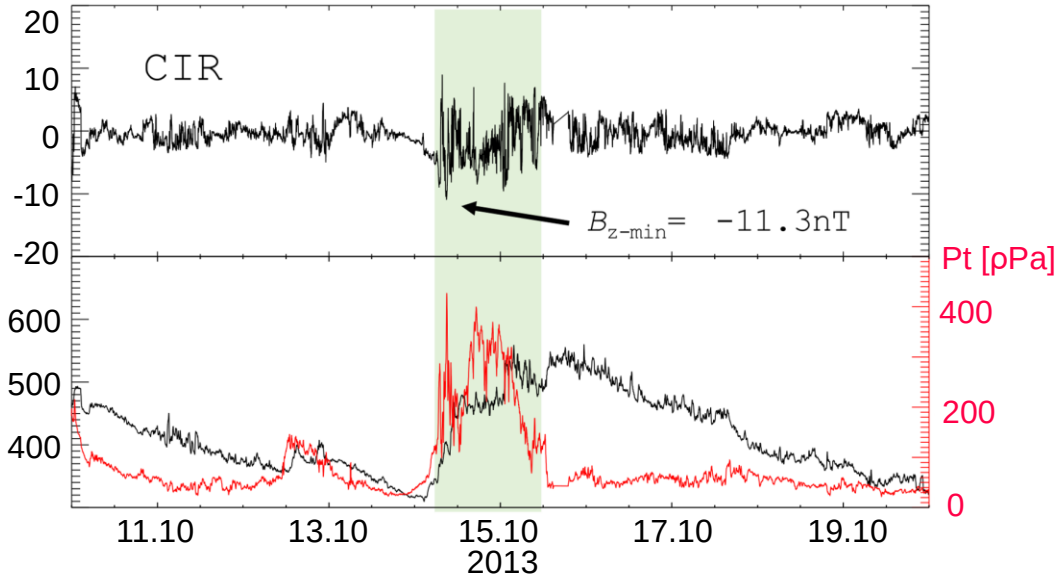
Study comprises 196 ICME and 195 CIR events occurred between 2003 - 2015

Analysis is based on solar wind flow speed (proton bulk speed) and in-situ measurements of the magnetic field component Bz; Level-2 data products, with a time resolution of 4 minutes.

Events: ICME catalogue by Richardson and Cane; CIR-list by Vennerstrom and Jian et al. (2011)

Compression regions of a CIR is less energetic but last longer than that from a ICME.





In-situ measurements – Earth‘s upper atmosphere

CHAllenging Minisatellite Payload (CHAMP)

Managed by GeoForschungsZentrum Potsdam (GFZ)

Mission duration: Juli 15, 2000 – September 19, 2010

Instrument of interest: Star-Accelerometer ($\pm 3 \times 10^{-9}$ ms^{-2})

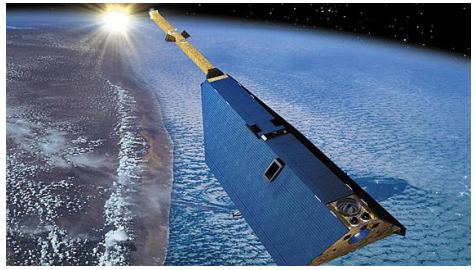
Gravity Recovery And Climate Experiment (GRACE)

Joint mission of NASA and the German Aerospace Center (DLR)

Mission duration: March 17, 2002 – October 27, 2017

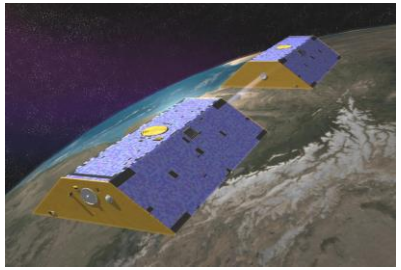
Instrument of interest: SuperStar-Accelerometer ($\pm 1 \times 10^{-10}$ ms^{-2})

CHAMP



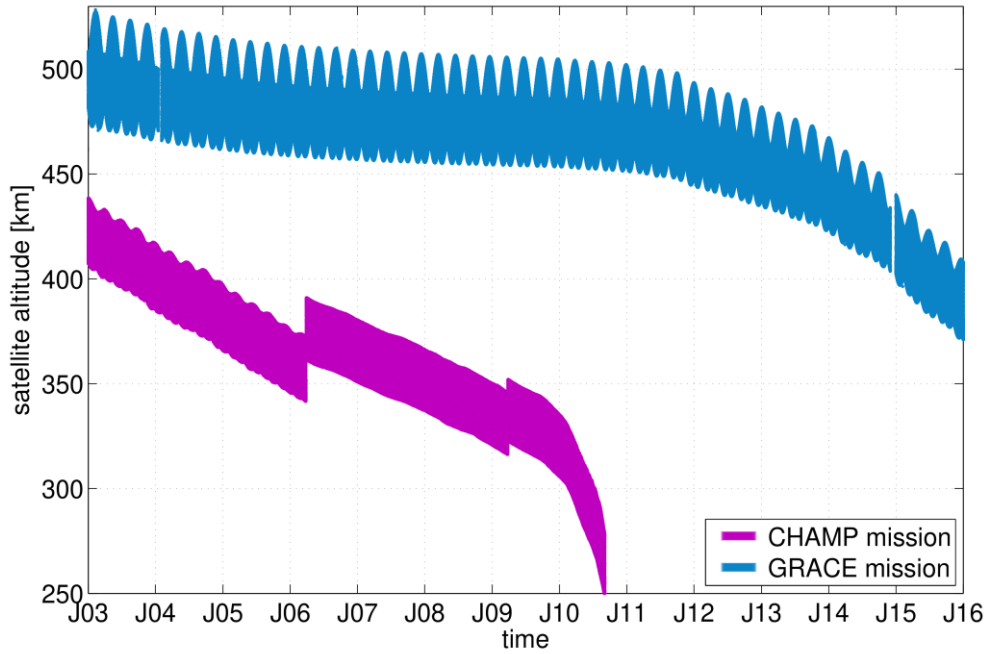
(Source: Astrium GmbH)

GRACE



(Source: DLR)

Course of the orbital altitudes



In-situ measurements – Earth‘s upper atmosphere

Observation

Accelerometer measurements

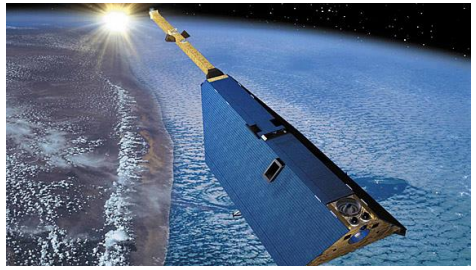
(Bruinsma et al. 2006; Sutton 2008; Dornboos et al. 2009; Krauss et al. 2012, ….)

Neutral mass density

(Chen et al. 2012; Krauss et al. 2015)

Satellite orbit decay

CHAMP



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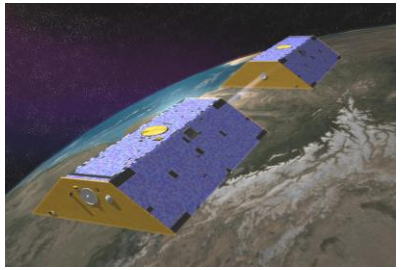
GRACE



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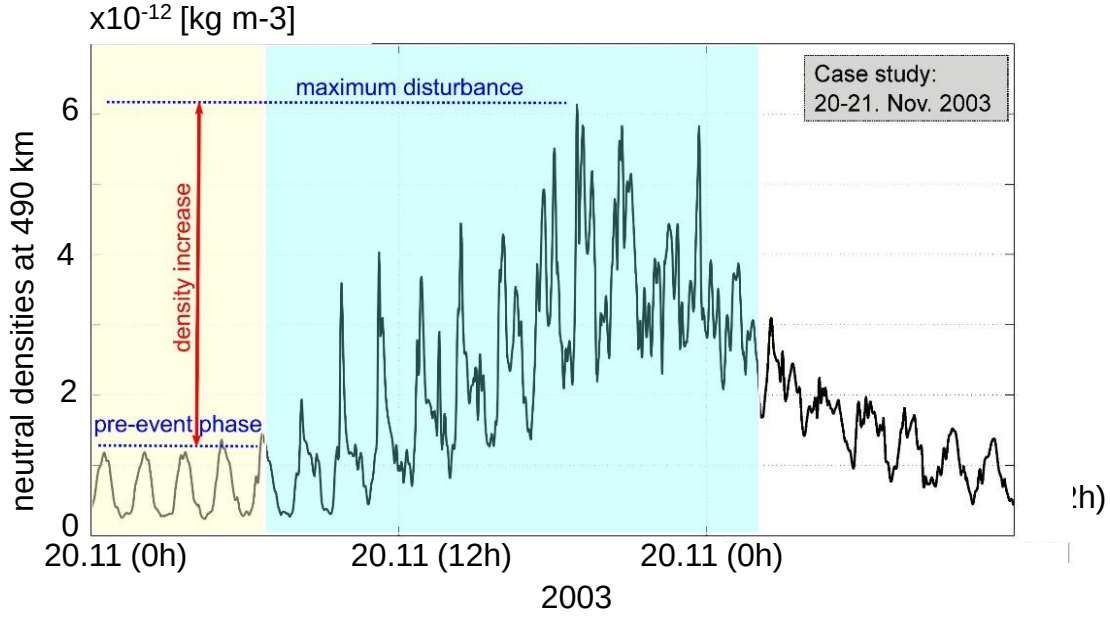
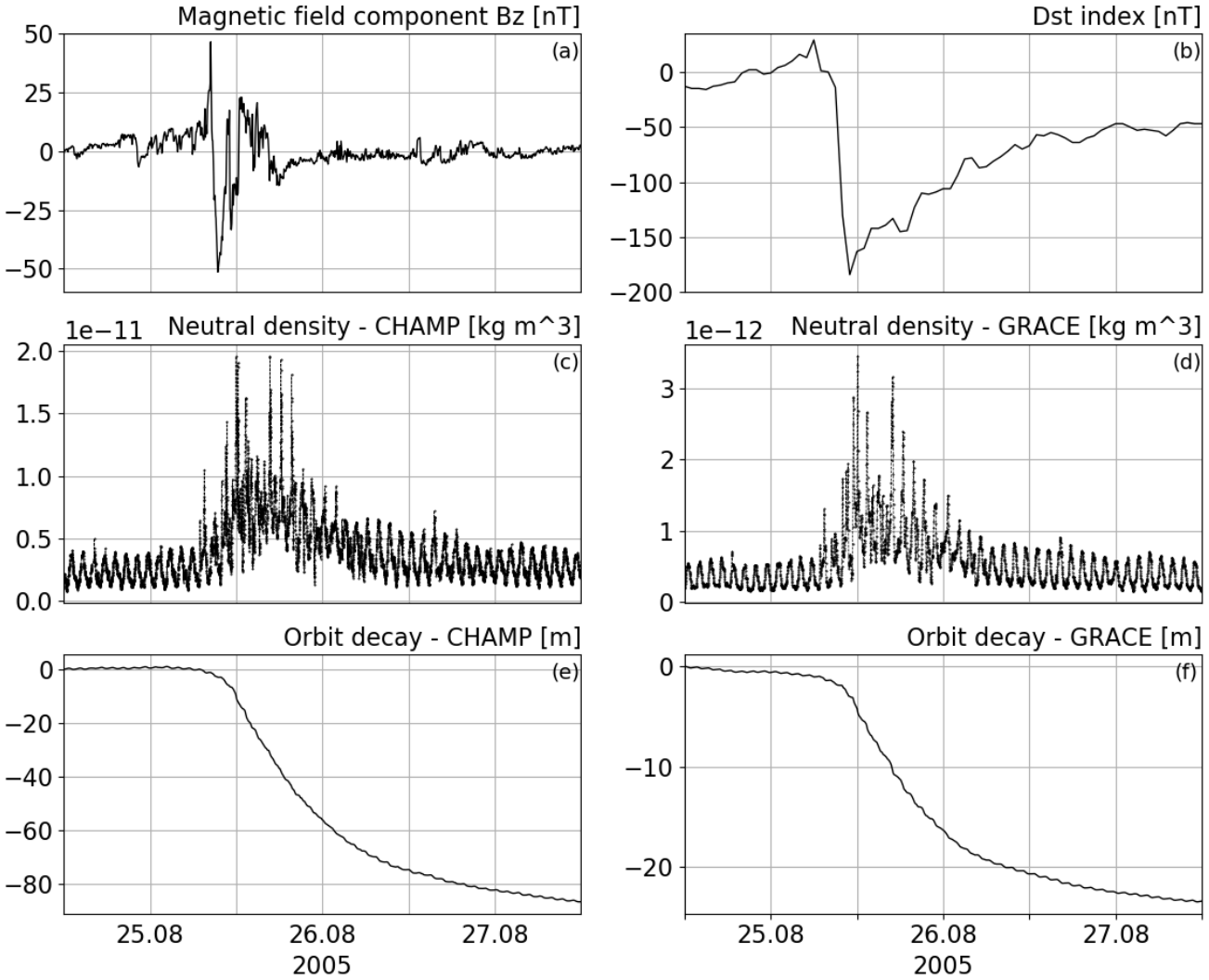


Single event analysis

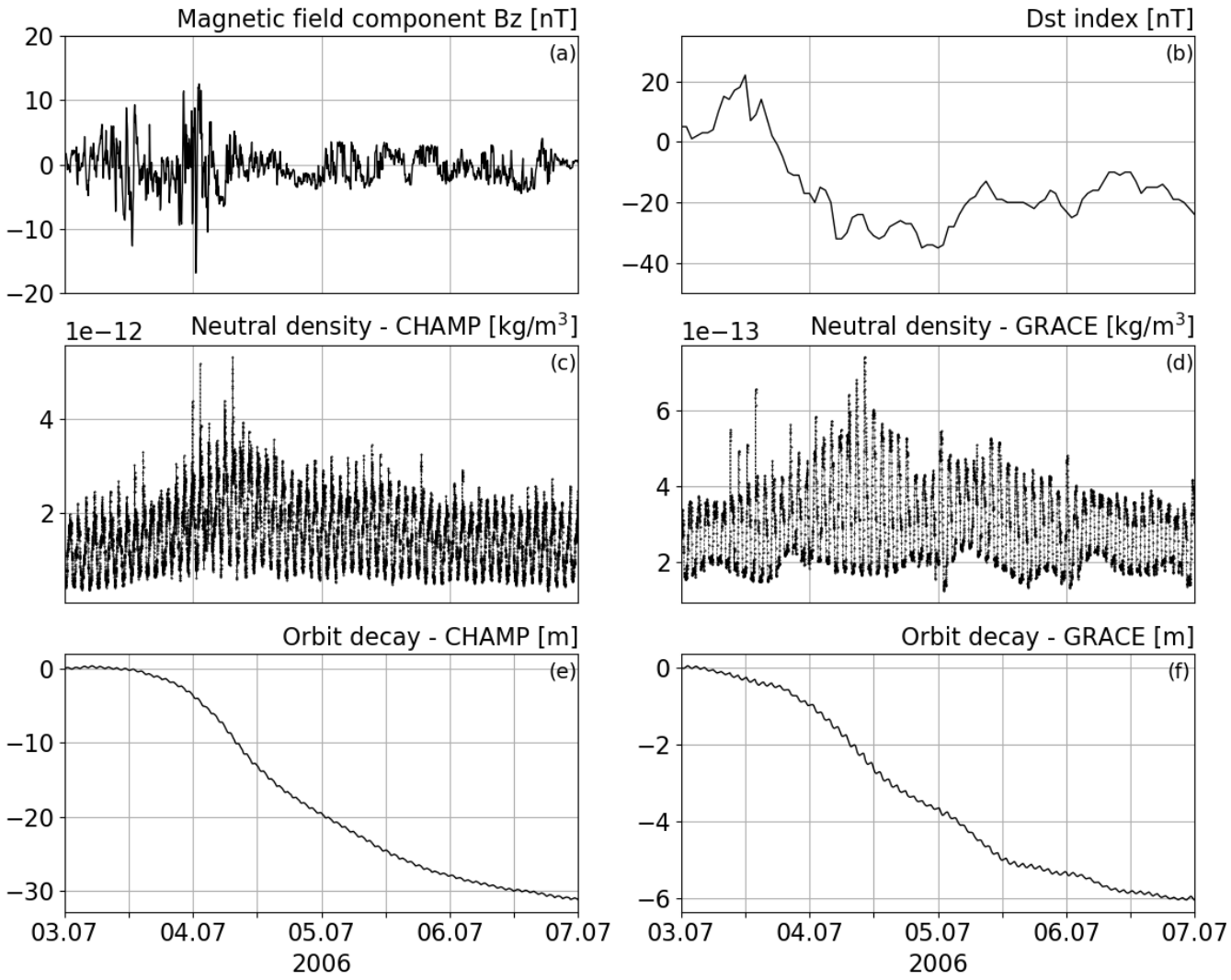
ICME



Krauss et al. 2018

Single event analysis

CIR



Krauss et al. 2018

Overall statistics

Correlation Coefficient Between the Various Parameters and the Increase in Neutral Density $\Delta\rho_{490}$ (Column 2) as well as the B_z Component Measured by ACE (Column 3)—Time Period 2003–2015

	$\Delta\rho_{490}$	B_z
$\Delta\rho_{490}$	1.00	−0.89
B_z	−0.89	1.00
v_{max}	0.65	−0.60
E	−0.85	0.86
S	0.78	0.77
Dst index	−0.89	0.85
AE index	0.71	−0.73
a_a index	0.89	−0.87
a_m index	0.89	−0.88
a_p index	0.84	−0.83
k_p index	0.67	−0.75
PC_{north} index	0.80	−0.80
PCS_{south} index	0.76	−0.78
Sym-H index	−0.88	0.89

Krauss et al. 2018

High correlations for most of the parameters

Not shown here:

- *CHAMP vs. GRACE: cc = 0.97*

Minor correlations for:

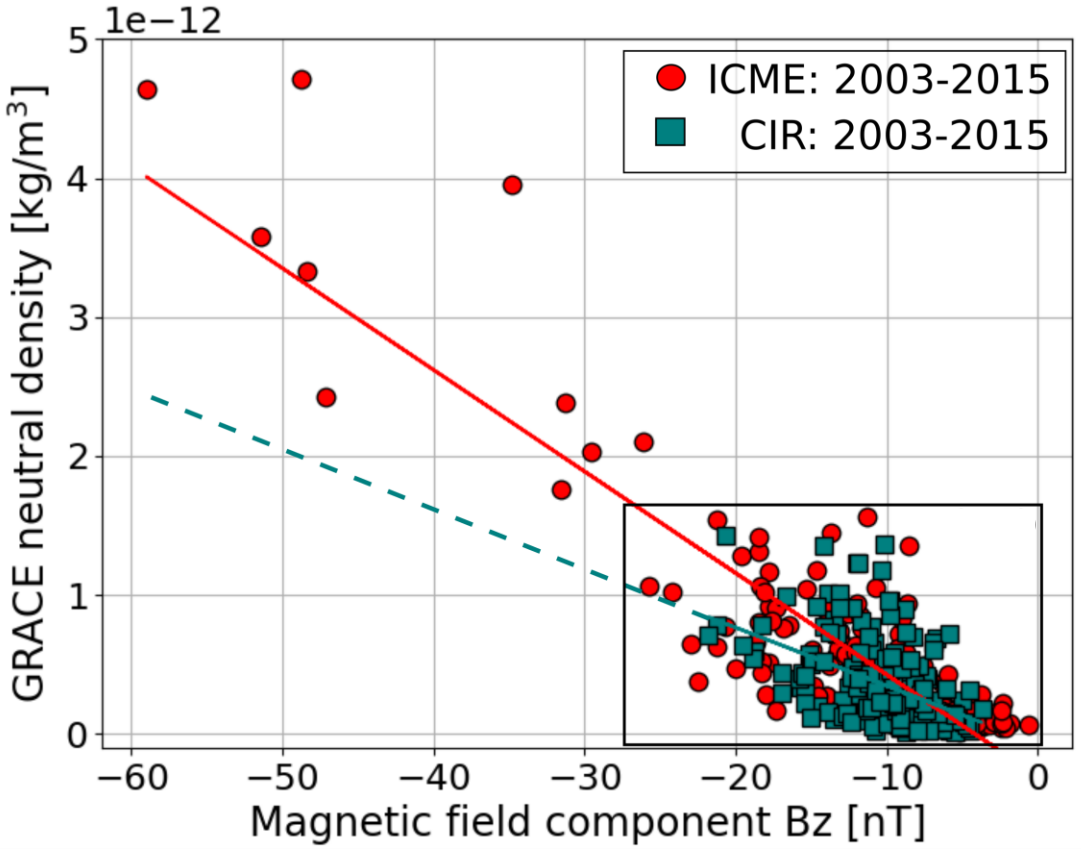
- *ICME velocity*
- *auroral electrojet*
- *kp index*

in accordance with Krauss et al. 2015
study of 104 ICME events and their impact on the thermosphere

Comparison ICME and CIR

Comparison of ICME and CIR induced variations in the neutral mass density

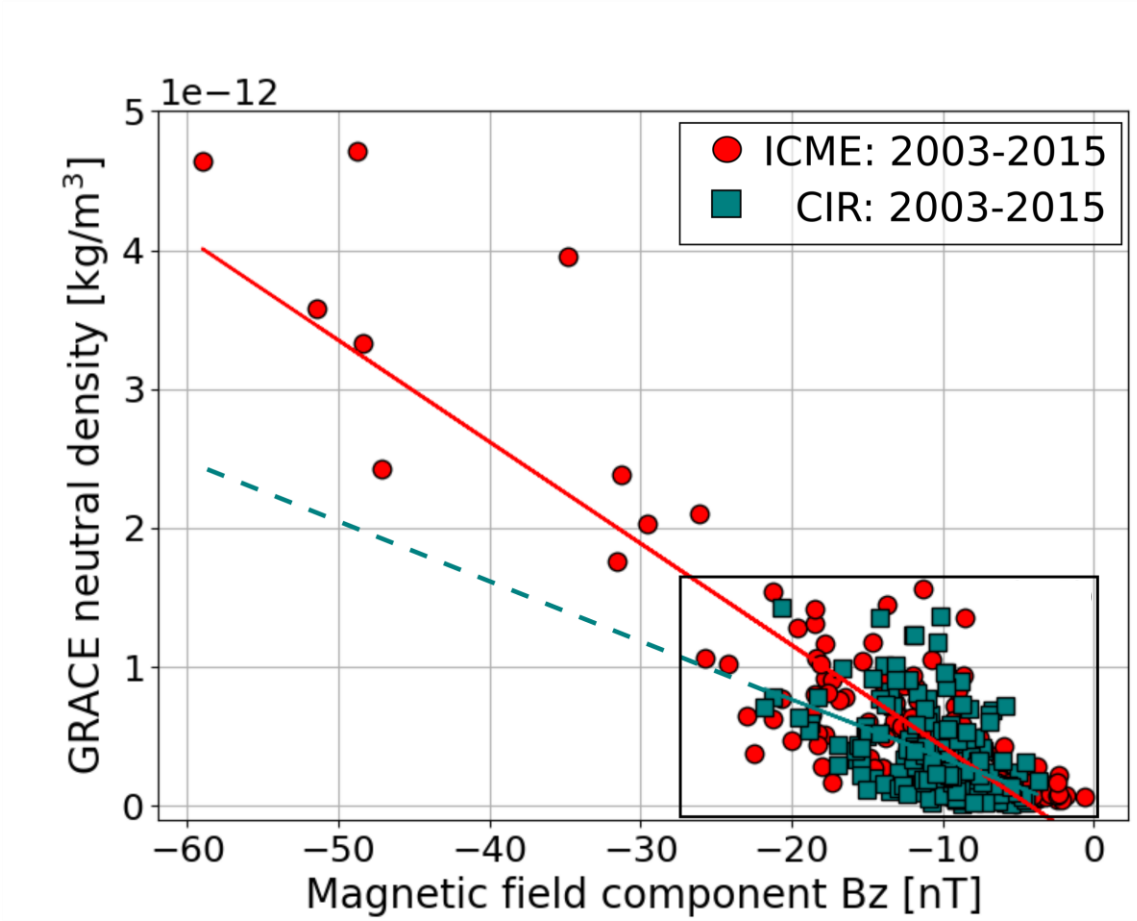
Do CIR‘s fit into the ICME analysis ?

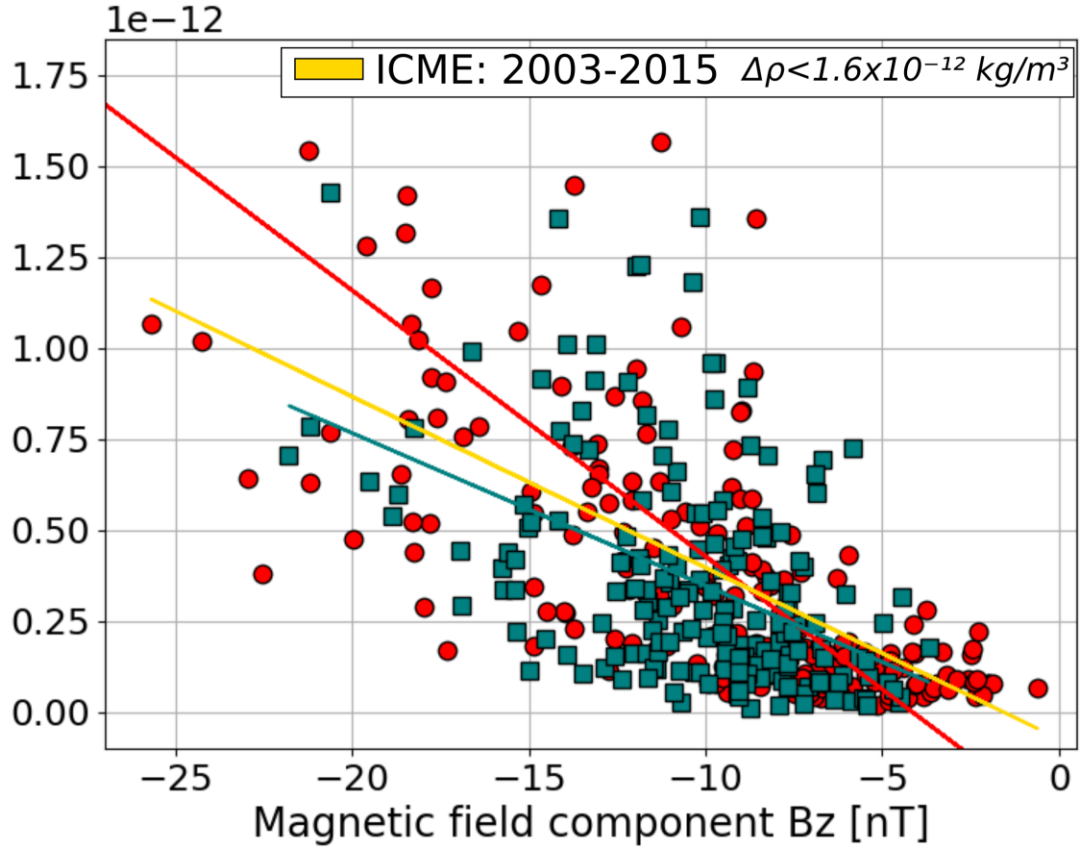


Comparison ICME and CIR

Comparison of ICME and CIR induced variations in the neutral mass density

Do CIR‘s fit into the ICME analysis ? Yes, fit pretty well in the overall picture.

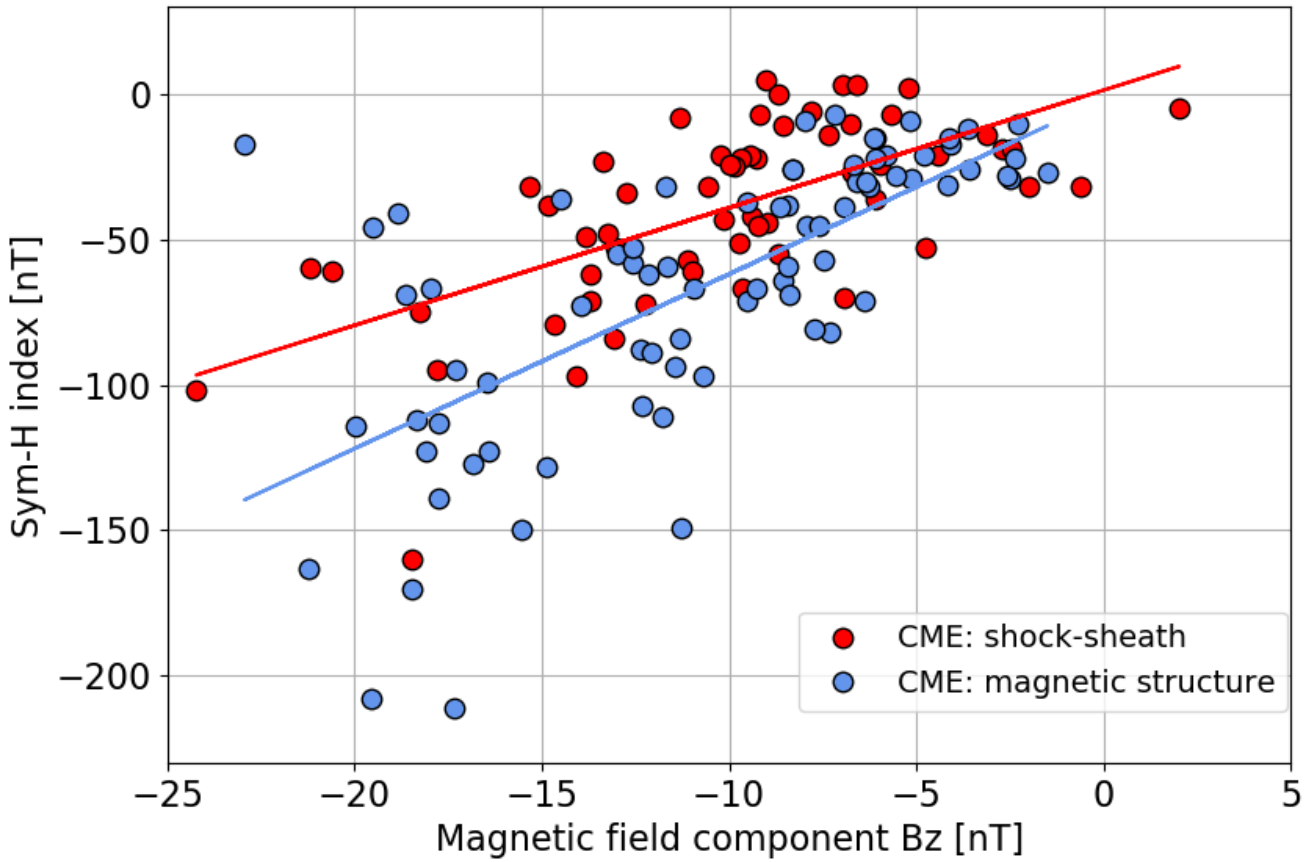




Comparison ICME and CIR

Comparison of ICME and CIR induced variations in the neutral mass density

Is the statistical distribution from a CIR comparable with that of a ICME comprising a shock-sheath region ?

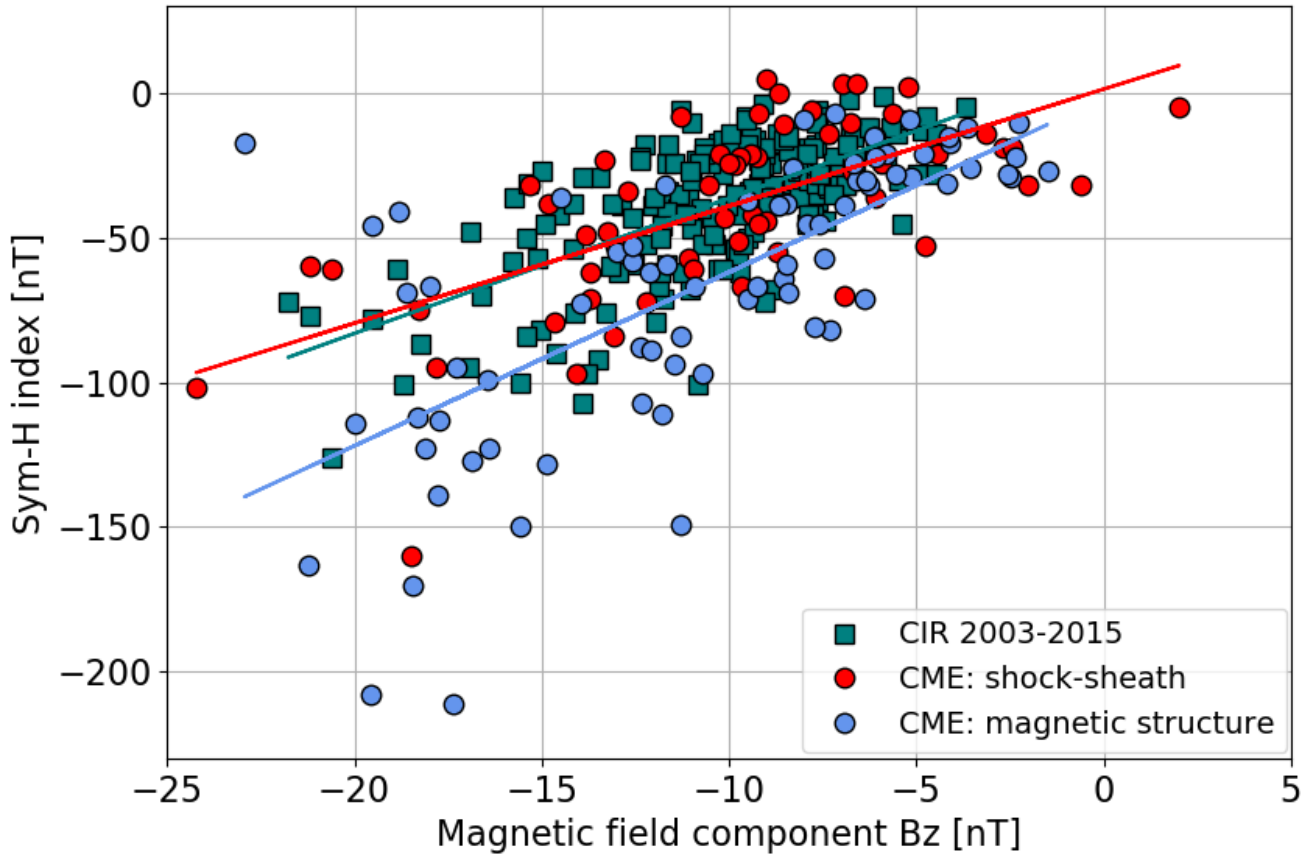


Krauss et al. 2015

Comparison ICME and CIR

Comparison of ICME and CIR induced variations in the neutral mass density

Is the statistical distribution from a CIR comparable with that of a ICME comprising a shock-sheath region ? Yes it fits .



Krauss et al. 2018

Satellite orbit decay

Depending on:

Current satellite altitude (CHAMP < GRACE)

Severity of the solar event (indicator Bz measurement)

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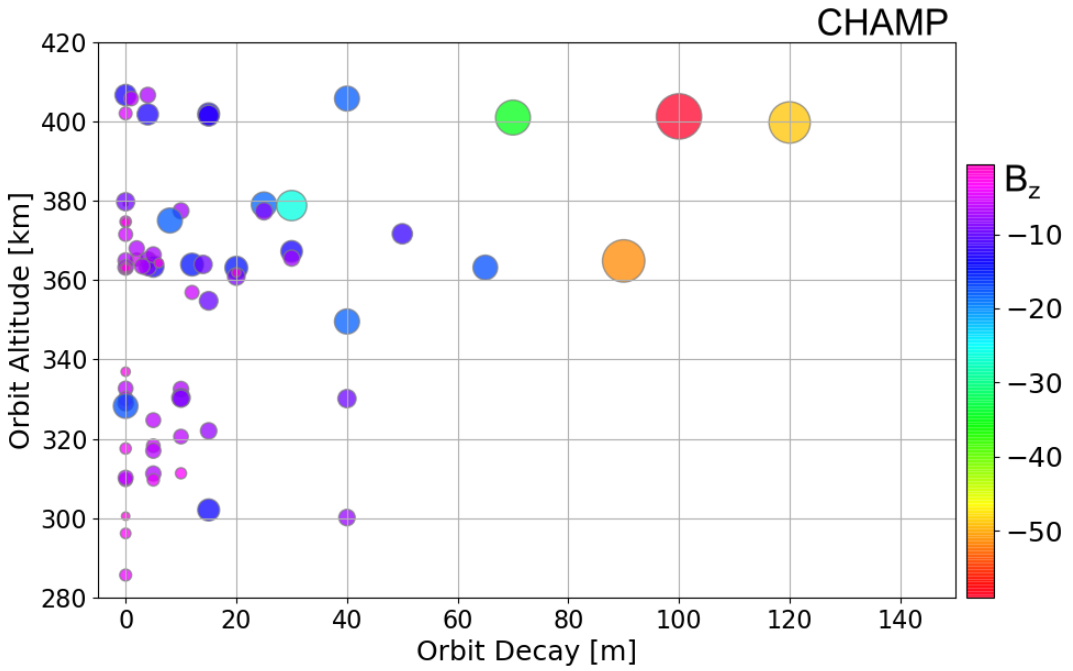

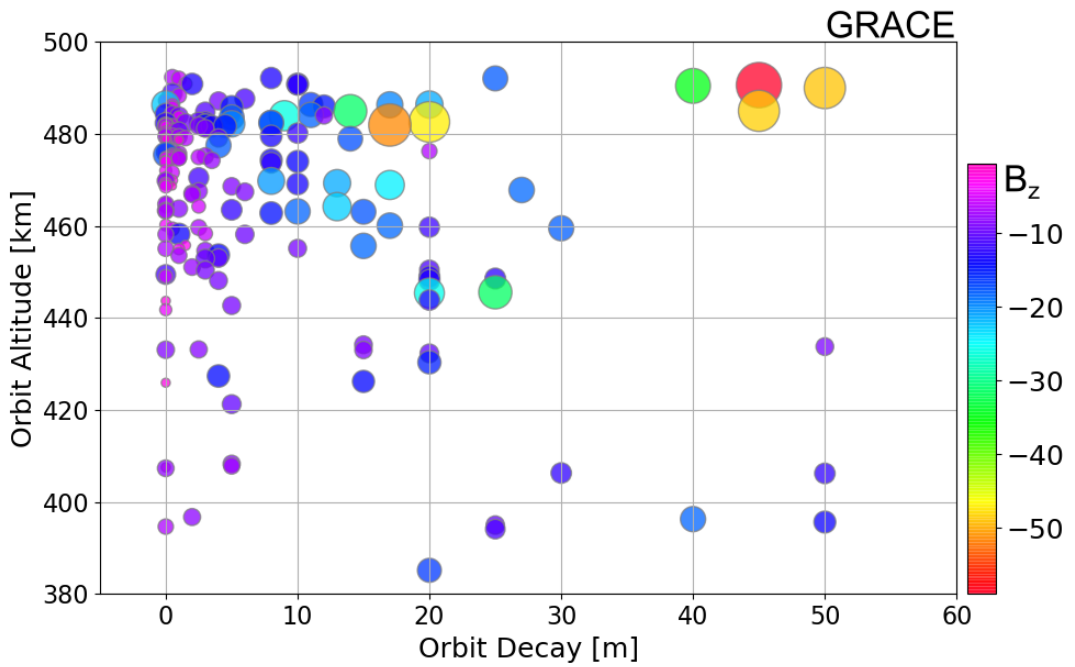

Next steps

- We may achieve a forecast (30-40min) of satellite orbit decays based on these statistical results
- Investigate the impact of cooling mechanism in the Earth’s atmosphere
- Extend the analysis to further satellites at different altitudes (orbit information)

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For further information

- see:

  Multiple Satellite Analysis of the Earth's Thermosphere and Interplanetary Magnetic Field Variations due to ICME/CIR events during 2003–2015, J. Geophys. Res., Space Physics 123, Krauss et al. (2018)

- Expert Service Groups on Solar & Heliosphere Weather (University of Graz)

  swe.uni-graz.at