Ionospheric characterization over Rome during low solar activity years by means of ground and satellite measurements

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Electron density from CHAMP and SWARM satellites

CHAMP and Swarm measurements are considered from 01-01-2007 to 31-12-2009, and from 01-01-2016 to 31-12-2017 at Rome coordinates (41.8° N; 12.5° E). Two different backgrounds have been defined.

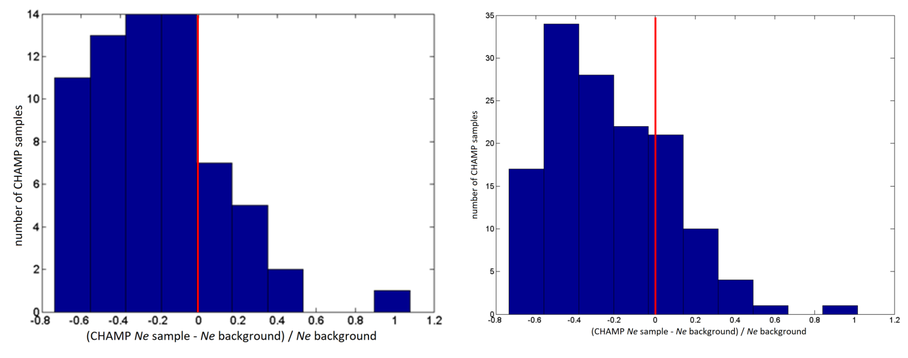
IRI BACKGROUND
Direct IRI-2016 *Ne* output at CHAMP/Swarm altitude.

IONOSONDE BACKGROUND
To estimate the electron density at CHAMP/Swarm altitude, the foF2 monthly median values were reported at the satellites altitude making use of the IRI-2016 model:

$$Ne_{background}(UT, month) = Ne(F2)_{ionosonde}(UT, month) \cdot \frac{Ne(altitude\ CHAMP/Swarm, UT, month)_{IRI}}{Ne(hmF2, UT, month)_{IRI}}$$

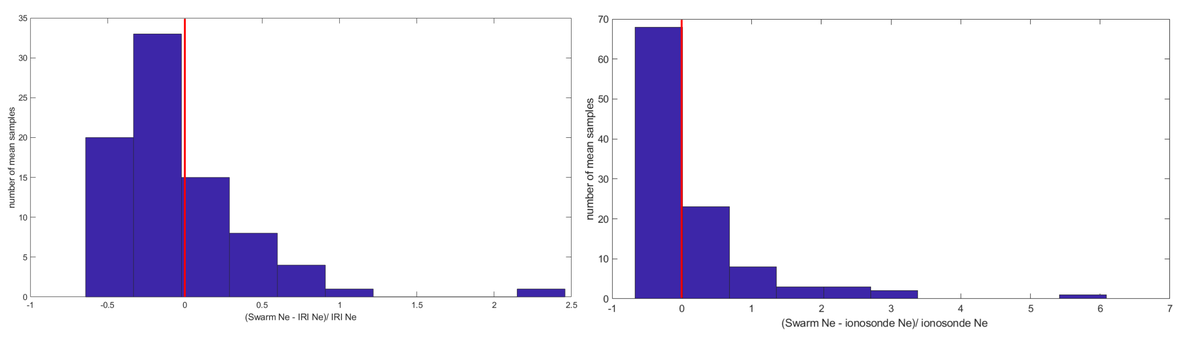
The relative deviation distributions of the CHAMP data with respect to the two backgrounds for 2009 both show a left shift with respect to zero, which indicates that **both backgrounds tend to overestimate the *Ne* data with respect to satellite measurements**, although ionosonde background seems to work slightly better.

IRI BACKGROUND 2009 IONOSONDE BACKGROUND



Indeed, also the number of the Swarm 2016 data which are lower than the corresponding background values is predominant in both cases.

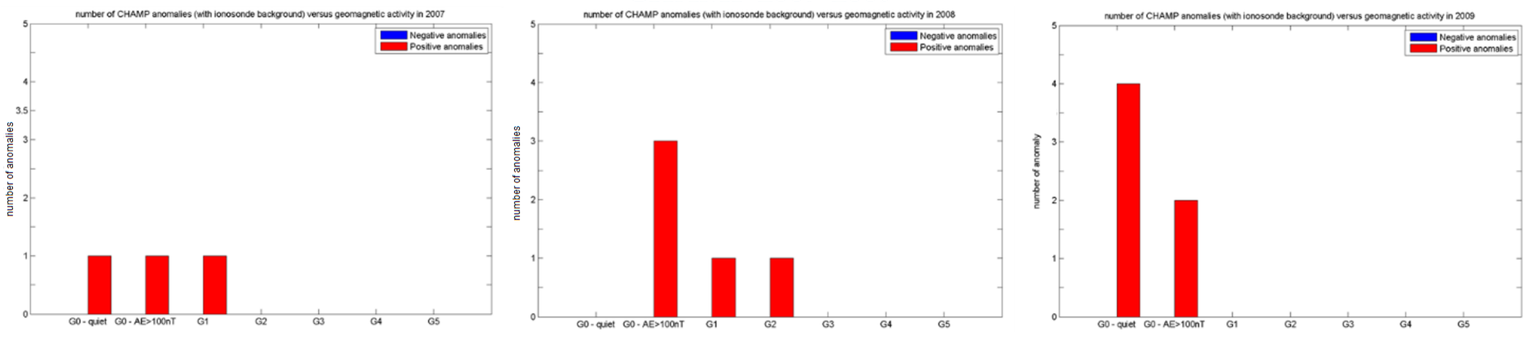
IRI BACKGROUND 2016 IONOSONDE BACKGROUND



ANOMALY
Variation of hourly *Ne* values outside ± 2σ with respect to the background level.

IONOSONDE BACKGROUND

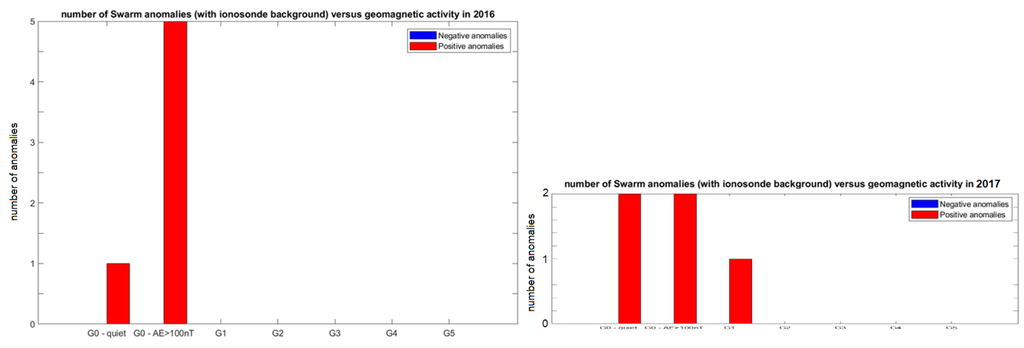
CHAMP 2007-2009



- The number of anomalies found with respect to the ionosonde background are only positive for both periods, and in a small number, particularly in 2007.

- This can be explained by the low solar activity level during 2007-2009 and 2016-2017, as negative storms generally occur only under a significant solar activity.

Swarm 2016-2017



foF2 from Rome ionosonde

Hourly observations recorded by the ionospheric station of Rome have been considered for the years 2007-2009 and 2016-2017.

BACKGROUND
27-day running median hourly values.

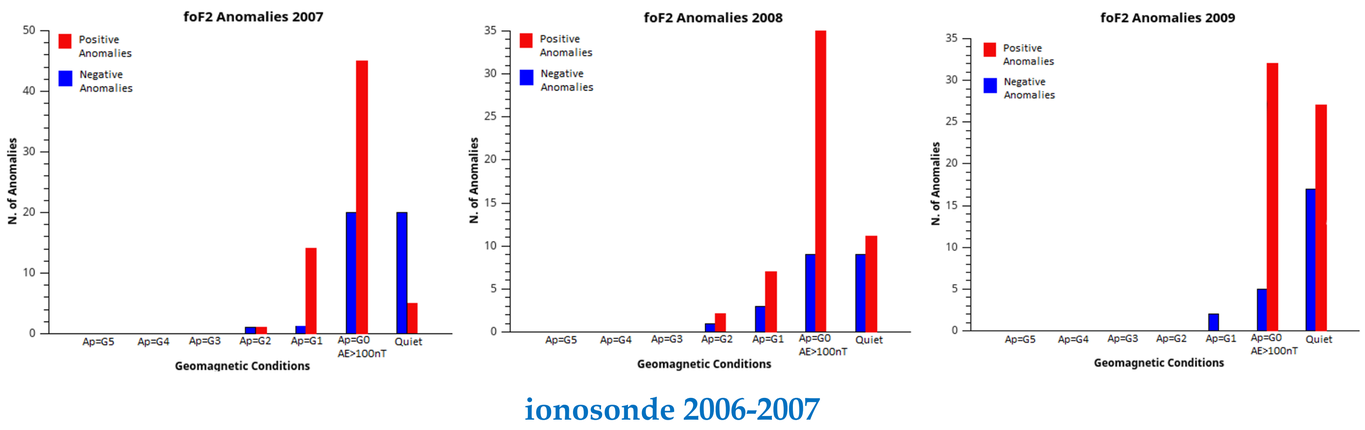
ANOMALY
Variation of hourly foF2 values outside ± 15% with respect to the background level

- The number of positive anomalies is greater than the number of negative ones, but they are with the same order of magnitude.

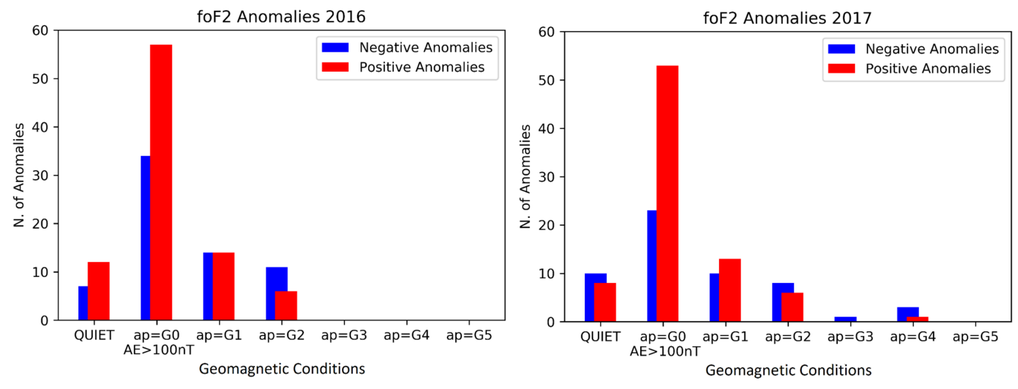
- The anomalies found in quiet conditions are more numerous. This is due to the higher number of days with AE <100 nT.

- During 2016-2017 from G2 to higher levels of geomagnetic activity the negative storms are more numerous with respect to the positive.

ionosonde 2007-2009



ionosonde 2006-2007



vTEC from Rome single station GNSS

Hourly observations recorded by the single station GNSS of Rome have been considered for the years 2007-2009 and 2016-2017.

BACKGROUND
Monthly median hourly values.

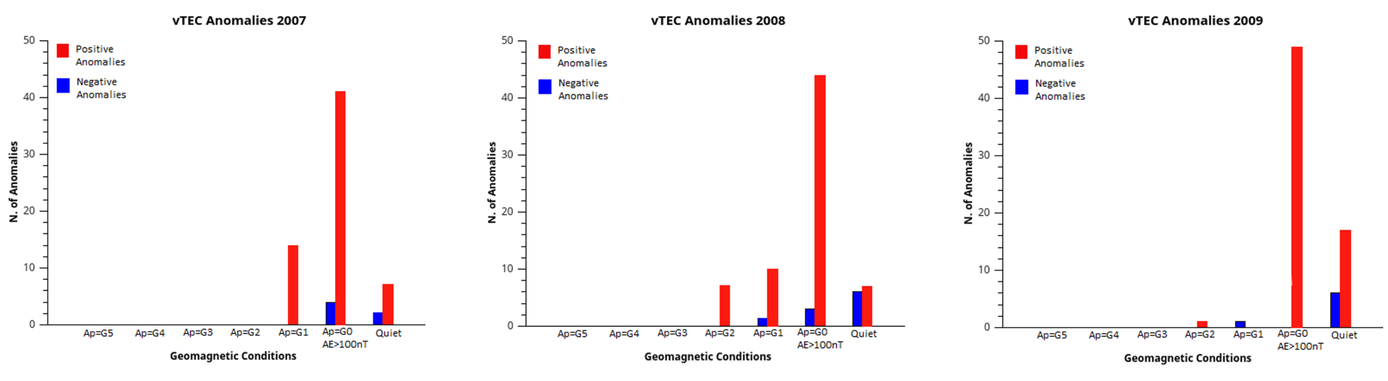
ANOMALY
•Variation of hourly vTEC values outside ± 2σ with respect to the background level.

- The number of positive vTEC anomalies is greater in 2009. This is in agreement with what observed for ionosonde data. Concerning level G0, G1 and G2 the number of detected anomalies is comparable for the years 2007, 2008 and 2009

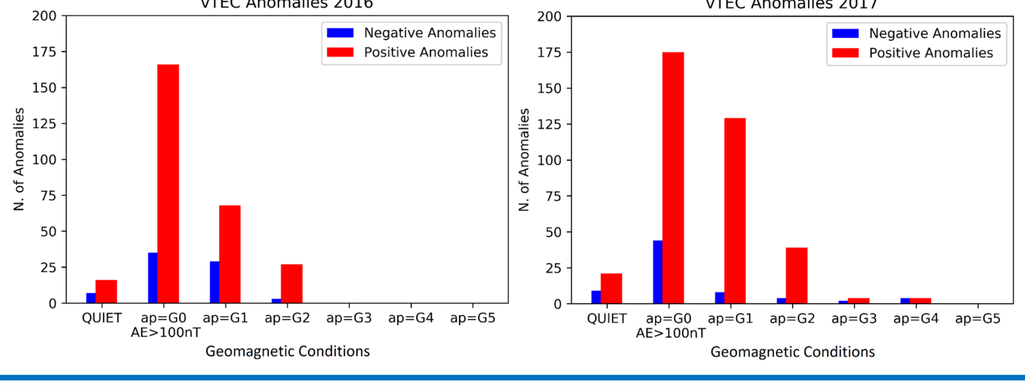
- In 2016 the maximum level of geomagnetic activity is G2, while in 2017 the geomagnetic activity reached the level of G4.

- The number of positive ionospheric anomalies are significantly more numerous than negative ones, particularly for geomagnetic activity between G0 and G2.

Single station GNSS 2007-2009



Single station GNSS 2016-2017



Conclusions

1. During the deep solar minima from ground and satellite observations the number of positive anomalies is greater than the number of negative ones. This low number of negative anomalies is due to the very low solar and geomagnetic activity, as at mid-latitude they generally appear during strong geomagnetic activity.
2. The comparison between CHAMP and Swarm satellite data and two *Ne* backgrounds defined by IRI-2016 model and ionosonde data respectively, shows that both backgrounds tend to overestimate the *Ne* data, although better results have been obtained for ionosonde background.

Acknowledgments

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