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Comparative study of ionosphere and plasmasphere electron content variability

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Statement of the problem

Knowledge of the state of the upper atmosphere, especially its ionospheric part and its diurnal and seasonal variations, is very important. Different radio methods and techniques are applied in order to study the ionosphere variability and structure.

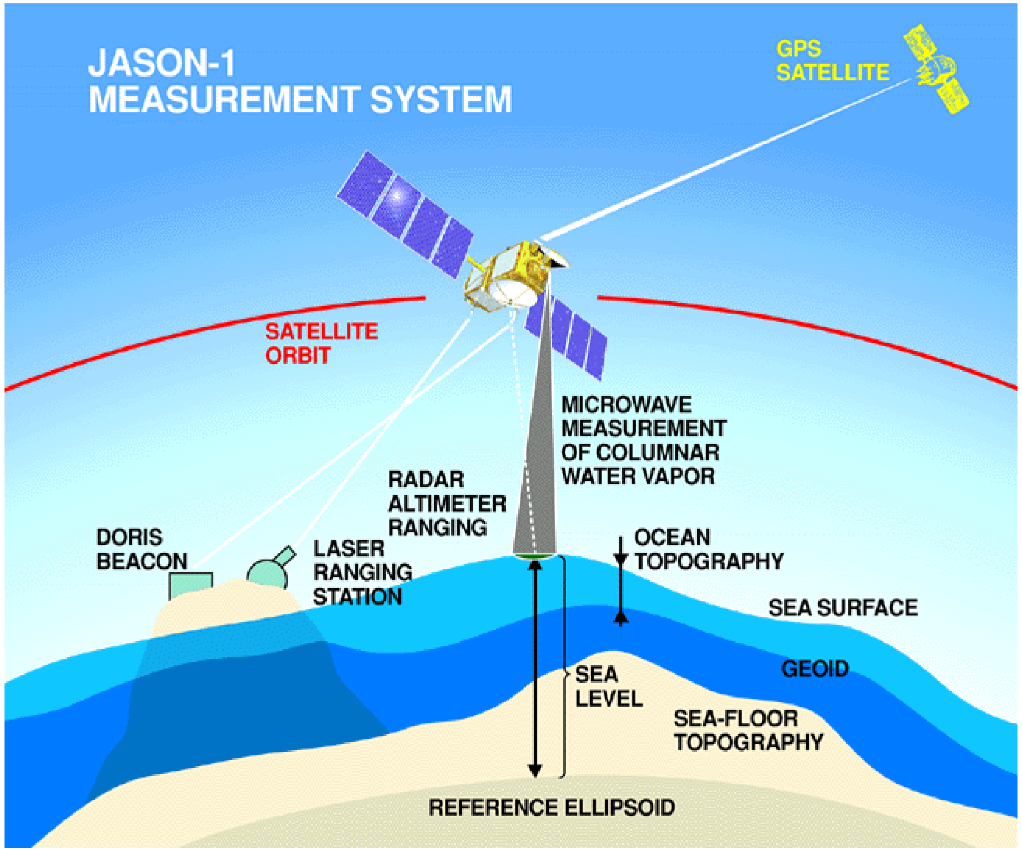
Nowadays the measurements of global navigation satellite systems, such as GPS and GLONASS, are widely used by the scientific community for the Earth's ionospheric studies. The height of GPS/GLONASS orbits is about 20,200 km above the Earth's surface, and so most part of the propagation path of a radio signal from a GPS satellite to ground-based GPS receiver or GPS receiver onboard a Low Earth Orbit (LEO) satellite is mainly within the plasmasphere.

The total number of electrons along a ray path from GPS satellite to ground-based receiver is called total electron content (GPS TEC), this value can be considered as the combined contribution of the ionosphere and overlying plasmasphere.

However one of the main limitations of the GPS technique is that the value of GPS TEC has an integral character and it is difficult to determine the contribution of the concrete ionospheric region to GPS TEC on ground-based GPS measurements only.

Observation source

Lee et al. (2013) compared global plasmaspheric total electron content with the ionospheric TEC simultaneously measured by Jason-1 satellite during the declining phase of solar cycle 23 (2002–2009) to investigate the global morphology of the plasmaspheric density in relation to the ionosphere.



Orbit altitude – 1,336 km

Inclination - 66°

Period – 2h

Lee H.-B., Jee G., Kim Y.H., Shim J.S.. Characteristics of global plasmaspheric TEC in comparison with the ionosphere simultaneously observed by Jason-1 satellite. *Journal of Geophysical Research*: *Space Physics*, V. 118, 1–12, doi:10.1002/jgra.50130, 2013

JASON-1 TEC data

Lee et al. (2013) used TEC data derived under following conditions:

The TEC from sea surface to the satellite orbit of 1,336 km corresponds to the iTEC. The bias of 3 TECU was applied to Jason iTEC.

The TEC between the Jason and the GPS satellites orbiting at 20,200 km altitude corresponds to the plasmaspheric TEC (pTEC).

The slant TEC data in the procedure were included only for the elevation angles above 60° to reduce the error associated with the multipath mapping procedure.

The median height of the plasmasphere (shell height) is assumed to be approximately 2,000 km above the altitude of Jason-1 satellite

IRI Plas

We also used **IRI-Plas** or International **Standard Plasmasphere-Ionosphere Model**, **SPIM** (Gulyaeva et al., 2002; Gulyaeva and Bilitza, 2012), to obtain model-derived estimates of TEC, ECbot, ECtop and ECpl.

Fortran code of the model is available at (**http://ftp.izmiran.ru/pub/izmiran/SPIM/**).

IRI-Plas presents the combination of the **International Reference Ionosphere model**, IRI, with the **Russian Standard Model of the Ionosphere and Plasmasphere**, SMI.

One of the main advantages of the model that it has the plasmasphere extension and is able to provide electron density profiles and total electron content at altitudes of 80 to 35,000 km for any location of the Earth.

To make comparison with Jason-1 data possible, some changes in the default parameters were done: the ionosphere was considered within altitudes' limits of 100-1,336 km, plasmasphere – from 1,336 km (Jason-1 orbit) up to 20,000 km (GPS orbit). IRI-Plas results were retrieved for different seasons and different solar activity conditions.

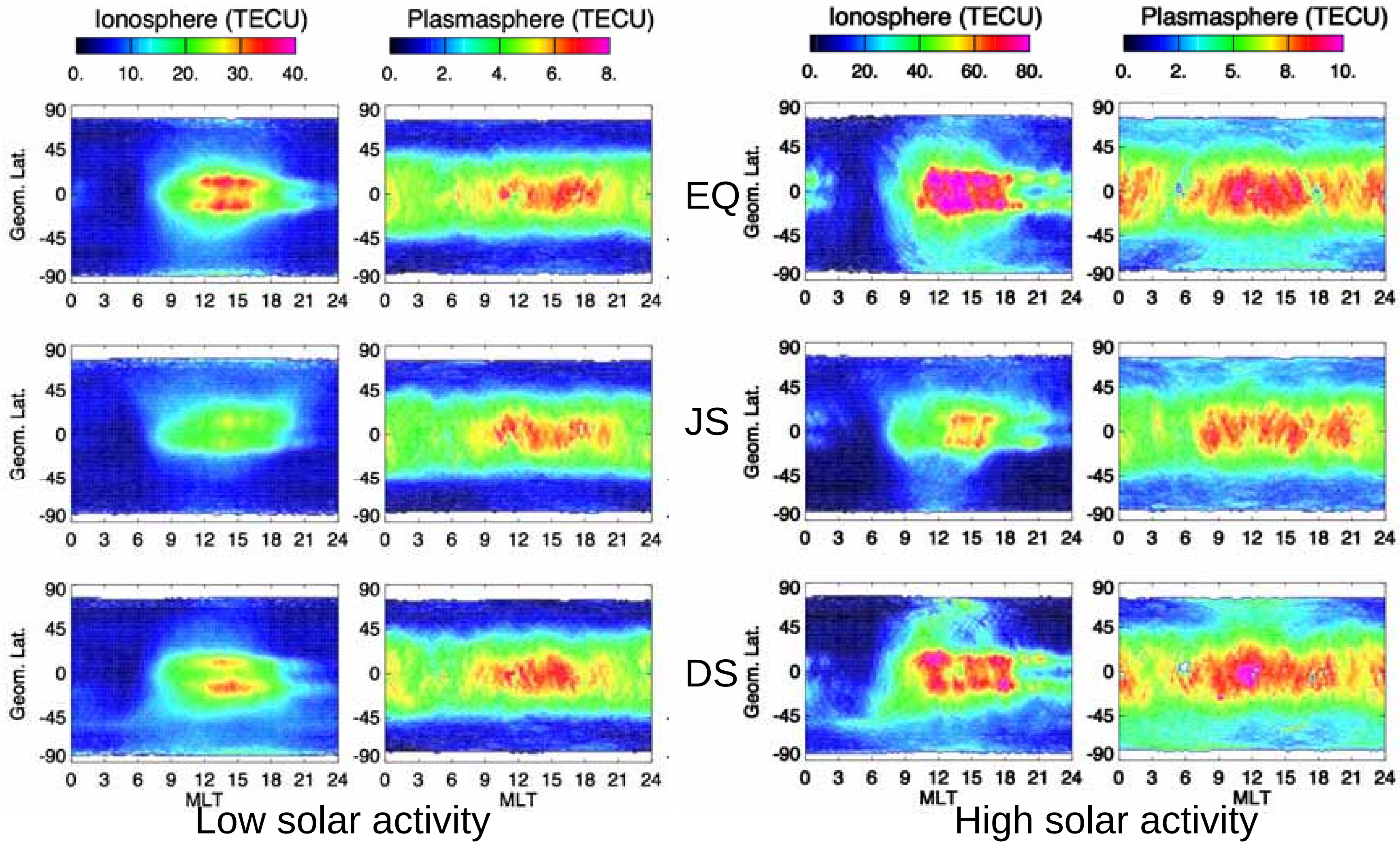
Gulyaeva, T.L., Huang, X., Reinisch, B. Ionosphere-Plasmasphere Model Sowtware for ISO.

Acta Geod. Geoph. Hung., 37 (2-3), 143-152, 2002.

Gulyaeva, T.L., Bilitza, D. Towards ISO Standard Earth Ionosphere and Plasmasphere Model.

In: "New Developments in the Standard Model", NOVA Publishers, 2012, https://www.novapublishers.com/catalog/product_info.php?products_id=35812

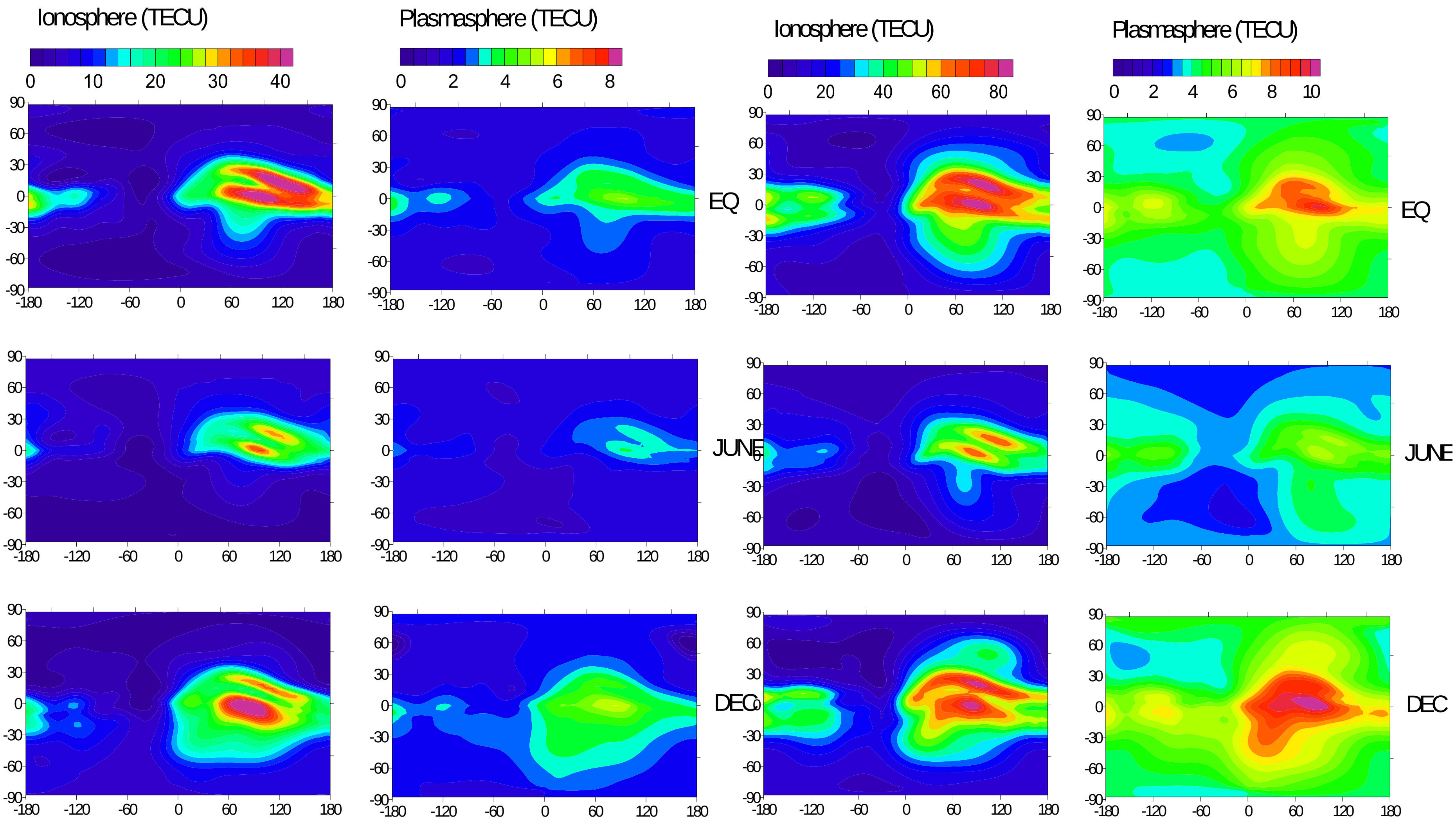
Ionosphere/Plasmasphere TEC – Jason 1



The diurnal variation of plasmaspheric TEC is much weaker than that in the iTEC, although they are in phase (maximum at around 12-16 LT and minimum at around 03-06 LT). The hemispheric asymmetry for solstices exists, but it is barely noticeable for high solar activity.

The ionospheric TEC increases with increasing solar activity. The plasmaspheric density enhances to a certain level as solar activity increases from the minimum, than density in the plasmasphere not go up although the ionospheric density continues to increase.

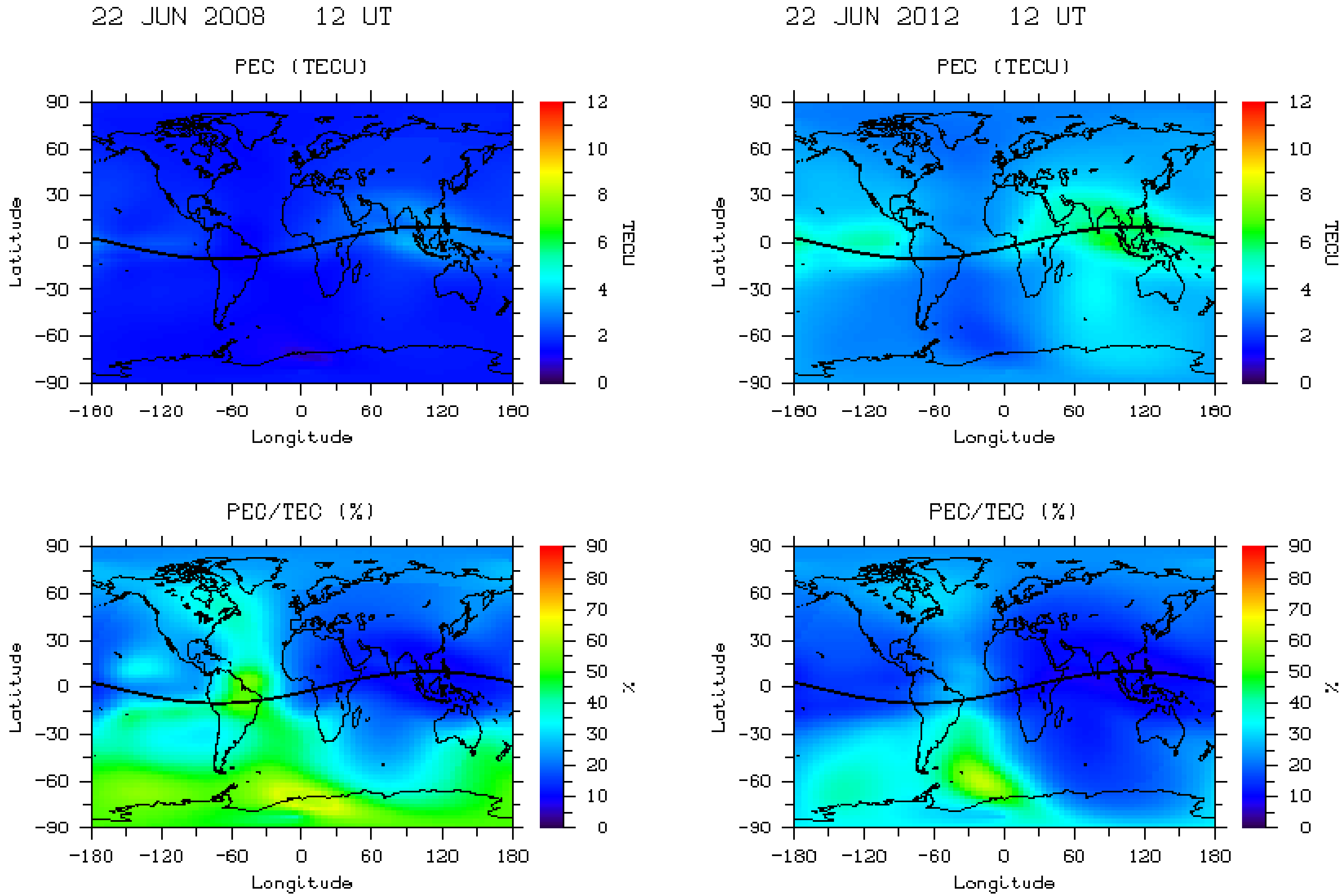
Ionosphere/Plasmasphere TEC – IRI plas



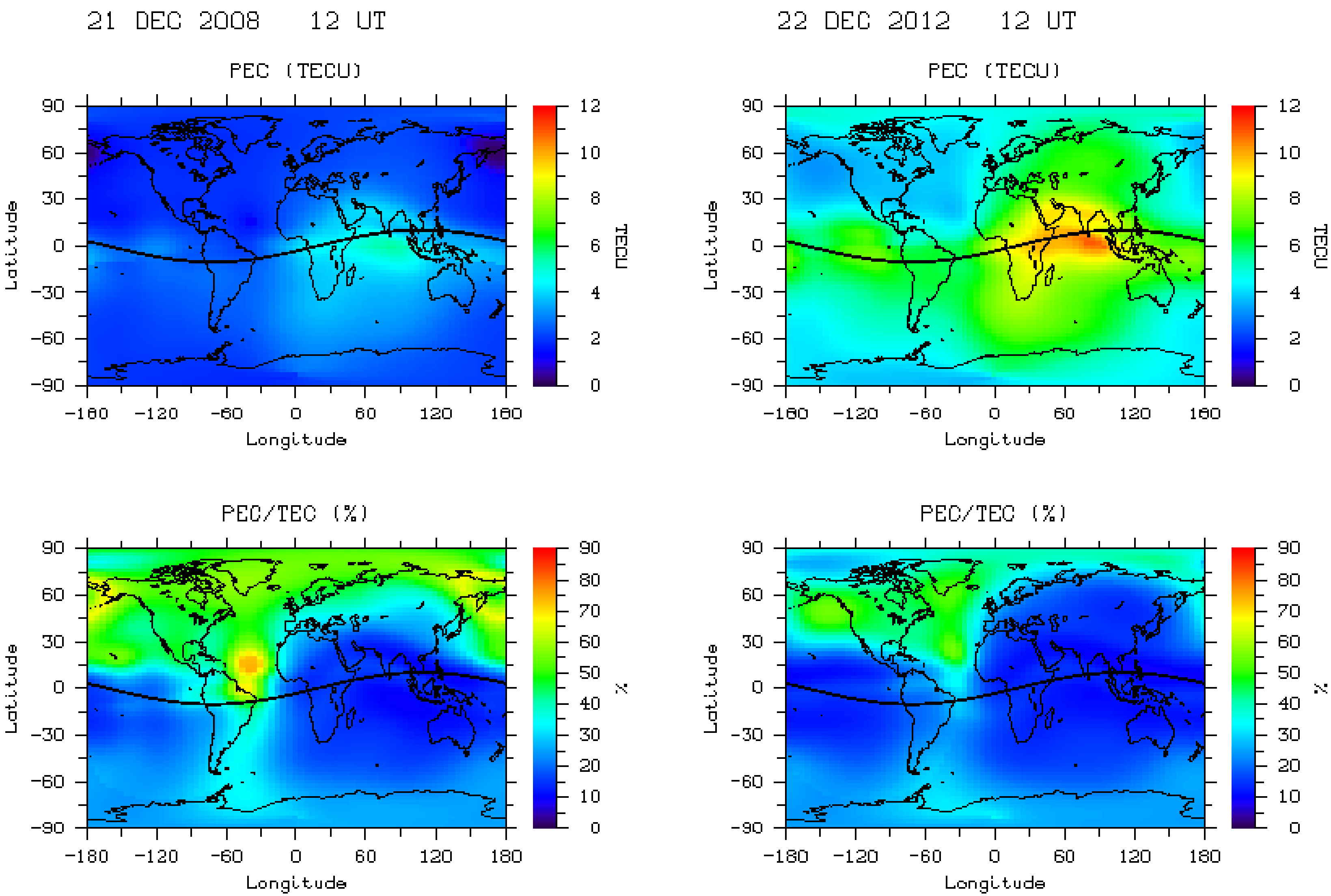
Low solar activity

High solar activity

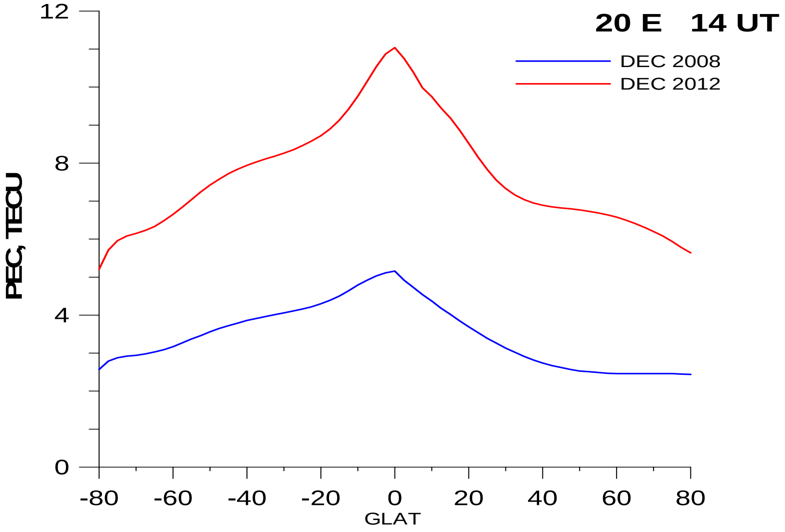
Global maps of PEC and PEC/TEC (%) distribution for 12 UT and summer solstice

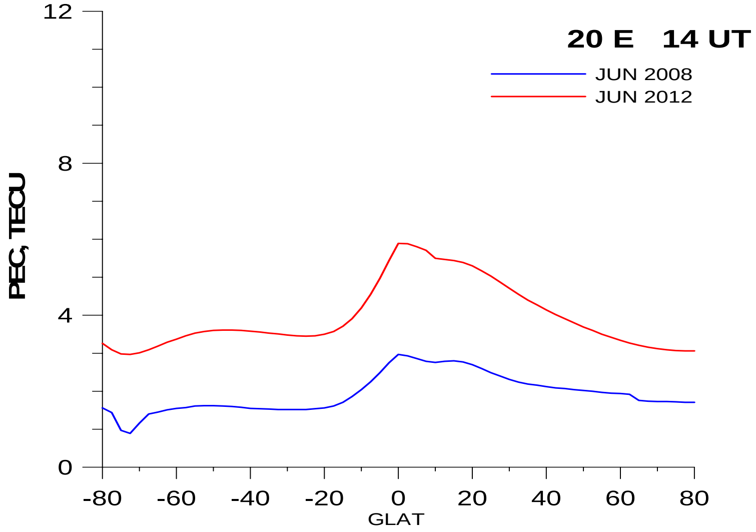


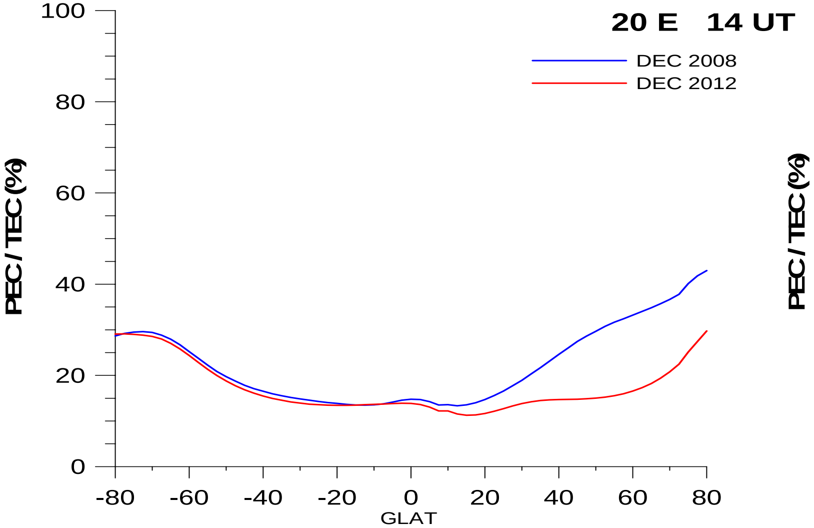
Global maps of PEC and PEC/TEC (%) distribution for 12 UT and winter solstice

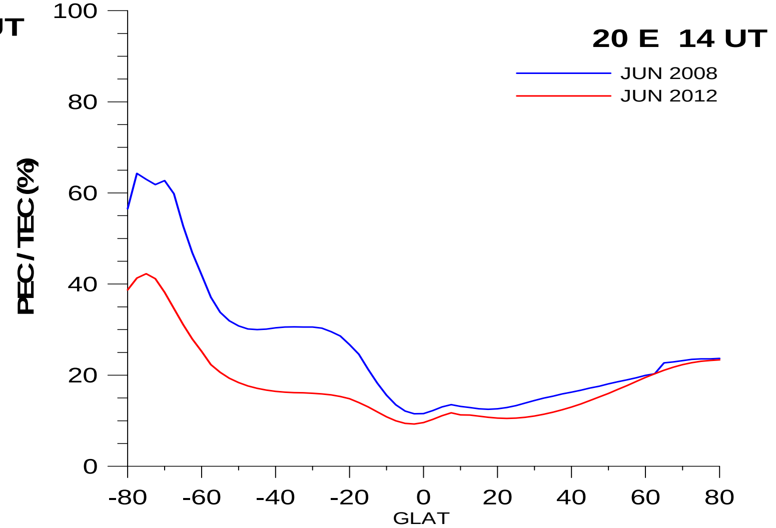


Latitudinal slice - comparison between PEC and percentage contribution PEC/TEC for summer and winter conditions

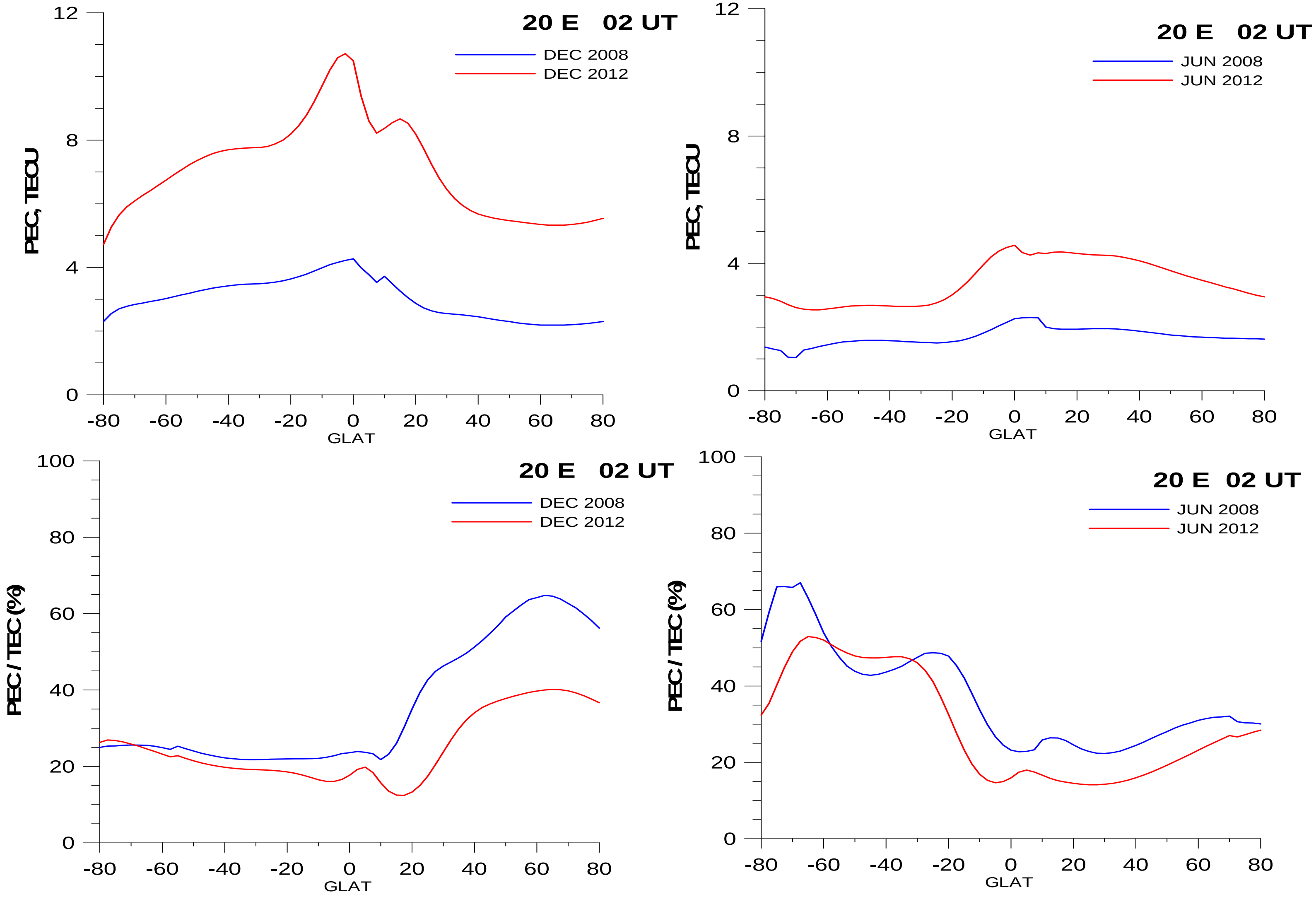








Latitudinal slice - comparison between PEC and percentage contribution PEC/TEC for summer and winter conditions



COSMIC/FORMOSAT-3 is the Constellation Observing System for Meteorology, Ionosphere and Climate and Taiwan's Formosa Satellite Mission #3, a joint Taiwan-U.S. project.

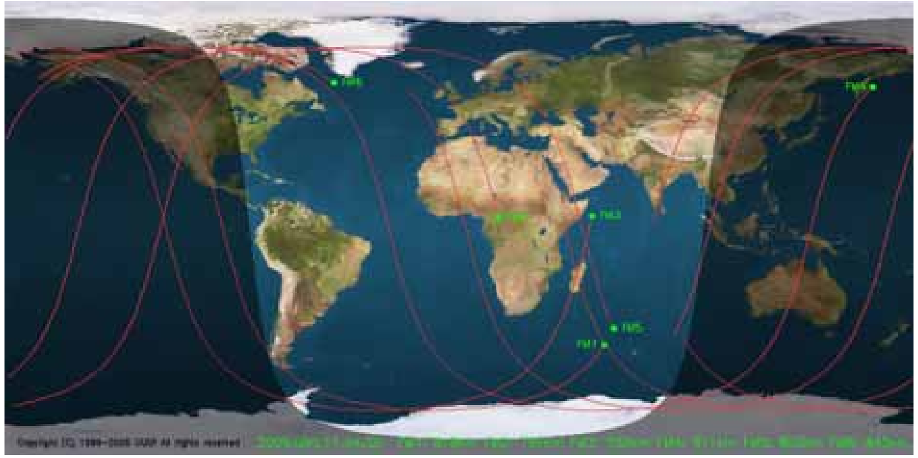
- The COSMIC constellation was launched on April 14, 2006

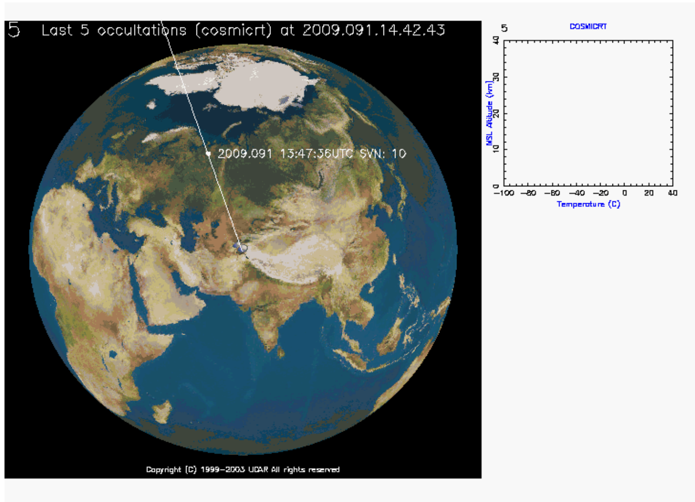
- Altitude ~700-800 km

- six spacecrafts

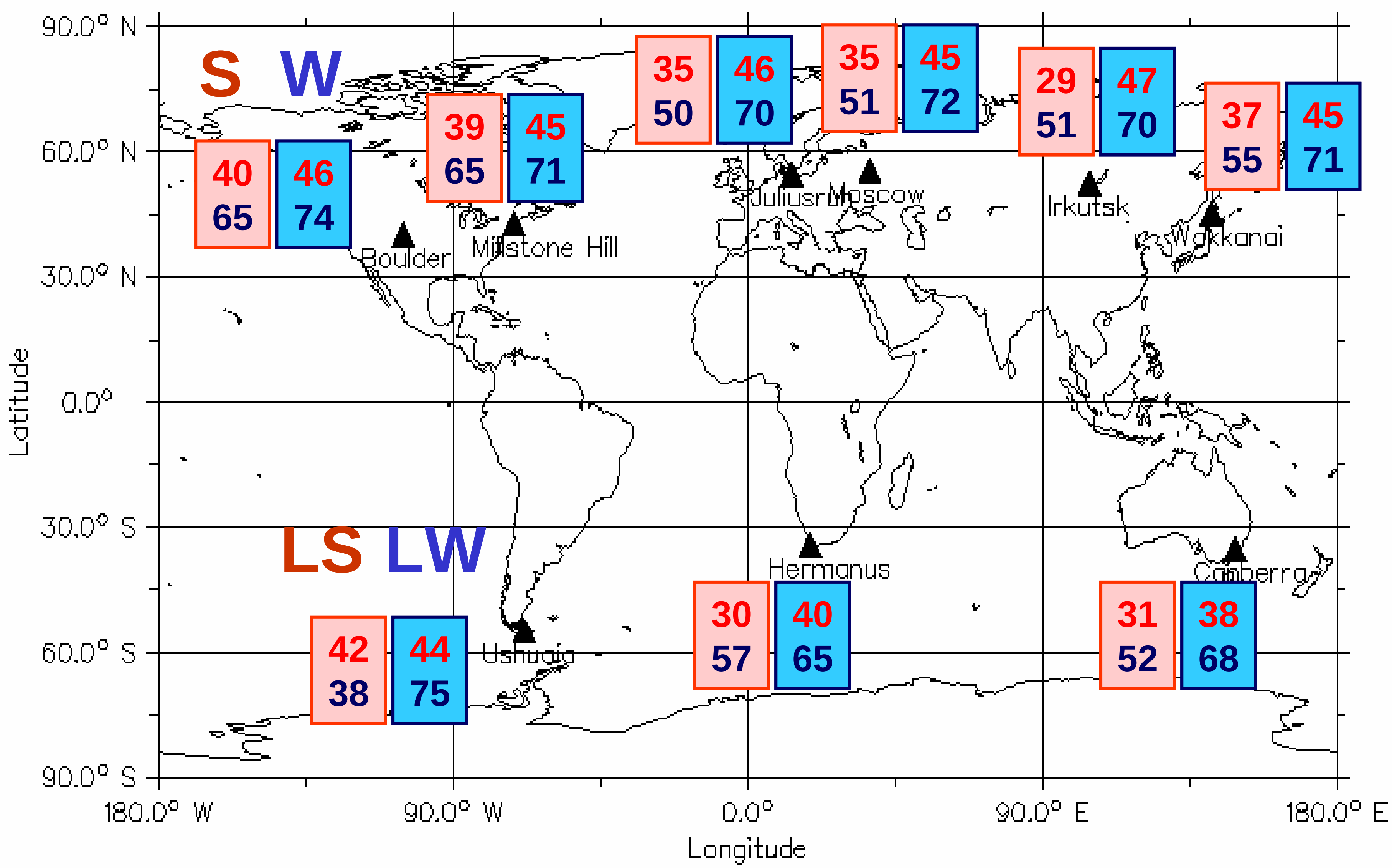
- each with three instruments, including GPS radio occultation receiver, tiny ionospheric photometer, and tri-band beacon

- Depending on the state of the constellation between 1,500 – 2,500 good soundings are obtained per day

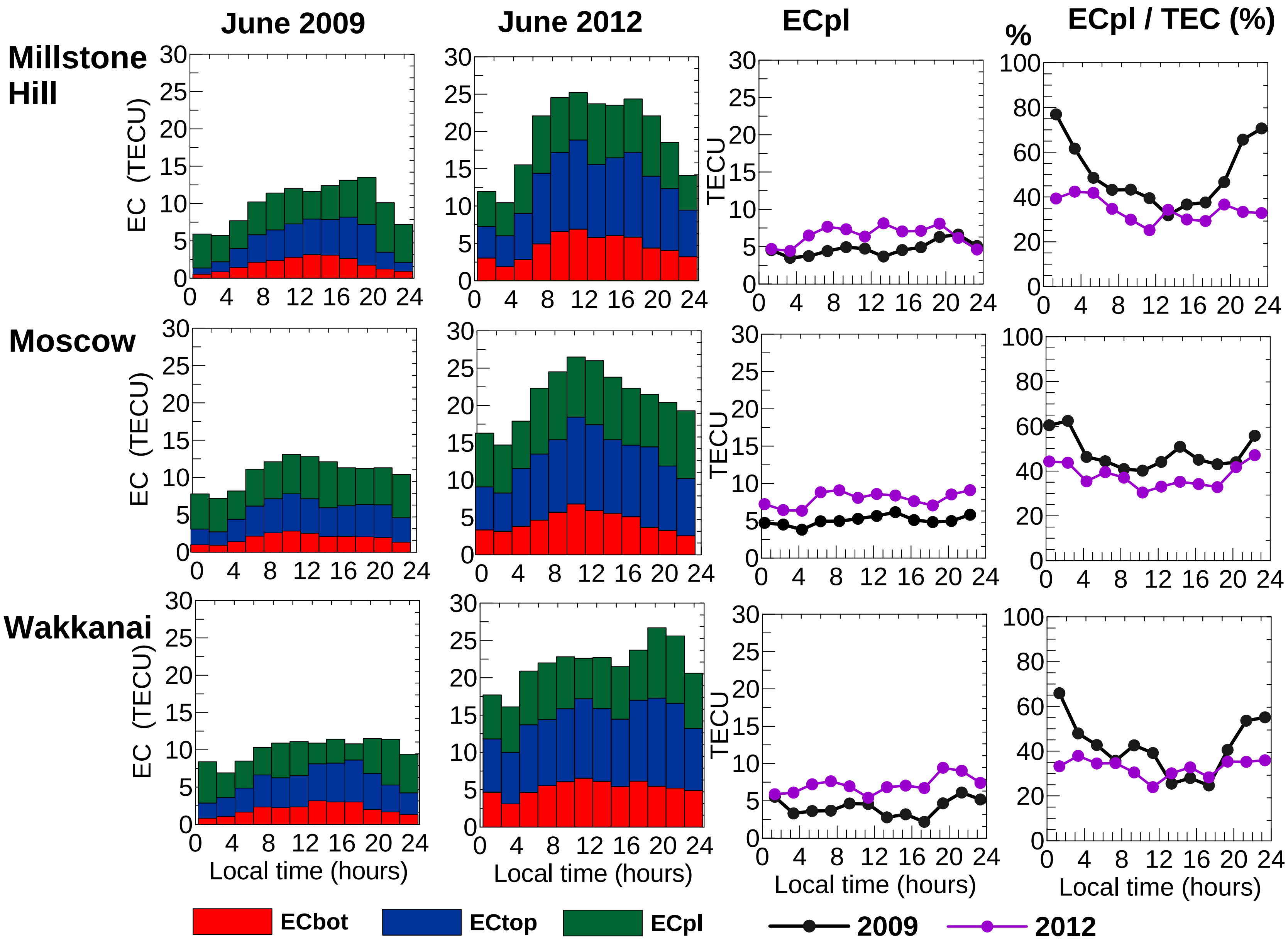




PEC estimates (%) for specific points: summer vs. winter (2009)



Comparison of daily variations of ionosphere/plasmasphere electron content for June 2009 and June 2012 – GPS and FORMOSAT-3 COSMIC data



Lunt N, Kersley L, Bailey G.J. The influence of the protonosphere on GPS observations: Model simulations // Radio Science, V. 34, N. 3, PP. 725-732, 1999

The SUPIM model has been used to estimate the contribution of the electron content arising from the protonosphere along ray paths from GPS satellites. Results have been presented simulating effects for stations at midlatitudes in Europe.

It was shown that during the **night in winter** the protonospheric contribution can exceed **50%** at the lower latitudes and be more than **30%** at the highest latitude considered here. The **daytime** percentages are generally in range **10-30% in winter**, with a slightly smaller upper limit for the lowest latitudes at other seasons.

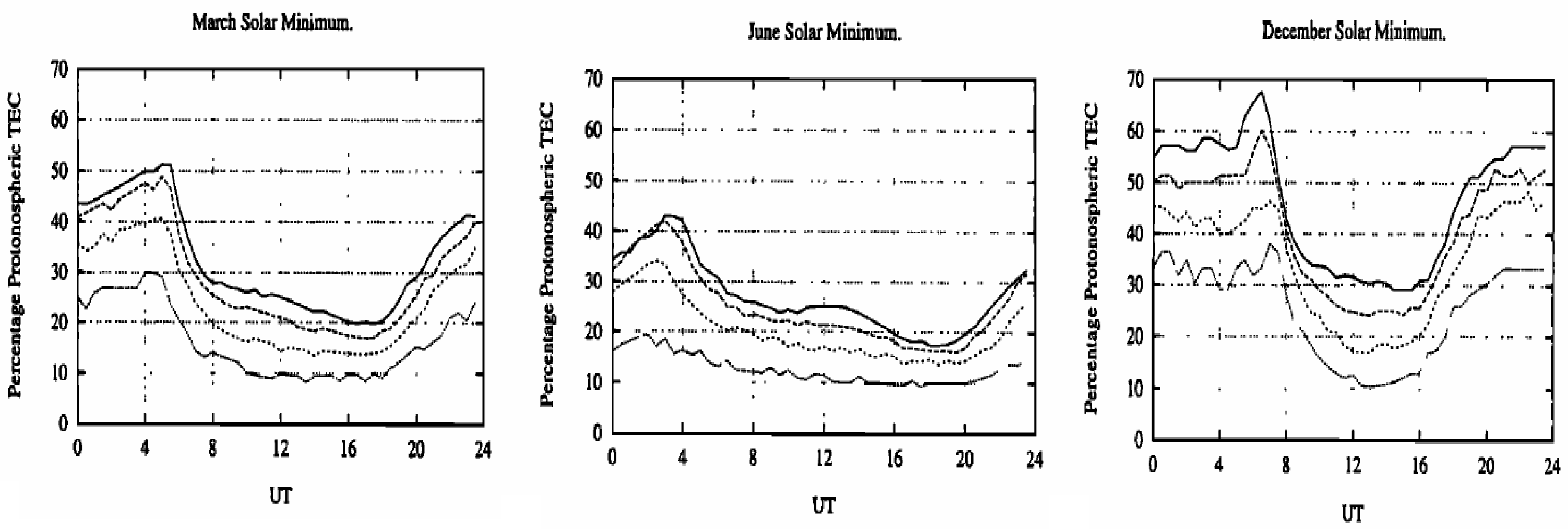


Fig. Percentage diurnal variations of the protonospheric electron content on vertical ray paths, for observations at European longitudes at **solar minimum** for the three months labeled. Station latitudes are designated as follows: solid lines, 40N; long-dashed lines, 45N; short-dashed lines, 50N; and dotted lines, 55N.

SUMMARY

Results of JASON-1data analysis, that reported by Lee at all.:

- The diurnal variation of plasmaspheric TEC is much weaker than that in the iTEC, although they are in phase.
- The plasmaspheric densities at mid and higher latitudes are overall smaller in the winter hemisphere than those in the summer hemisphere.
- The result of the comparison shows that the relative plasmaspheric contributions to the nighttime ionosphere (via downward plasmaspheric flux) mostly decreases with an increasing solar activity

Analysis of COSMIC RO and GPS TEC data and IRI-plas model results has shown that:

- For mid-latitudinal points PEC estimates varied weakly with the time of a day and reached the value of several (**1-6**) TECU for the condition of solar minimum
- Contribution of PEC to GPS TEC becomes most significant at **night** in **all** seasons.
- The contribution has greater values at winter season in comparison with summer.
- The **day-time** percentages are generally in range **30-40%** at **all** seasons.
- The **night-time** percentages are generally in range **50-70%** at **all** seasons.
- These estimates are in a good agreement with results obtained by SUPIM simulation for solar minimum conditions.
- On average for mid-latitudinal region bottom-side IEC contributes about **5-10%** of GPS TEC during night and about **20-27%** during day-time. Topside IEC contributes about **15-20%** of GPS TEC during night and about **35-40%** during day-time.