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Main content of this newsletter

In this newsletter we outline the current situation of the ionosphere and its impact to GNSS applications.
We further provide useful references to obtain further information and provide recommendation to mitigate the impact of ionosphere activity to your GNSS application.

Introduction

Since a few months the activity of the earth's ionosphere has noticeably increased. The degree of ionosphere activity depends on the amount of sunspots that varies during an 11-years cycle. Currently, we are approaching the next maximum of solar sunspot and thus ionosphere activity. In addition the ionosphere shows short term daily variation as well as high frequent scintillations in some regions.
The influence of the ionosphere on radio signals emitted by GNSS satellites remains one of the main limitations to the accuracy and to the reliability of GNSS applications. Therefore, it is important to be aware of the situation and understand its impact on the daily work.

Sunspots & Ionosphere long-term variation

The amount of sunspots varies over time and follows an approximate 11-year cycle from one maximum to the next. Figure 1 shows the current cycle with the predicted, actually observed and

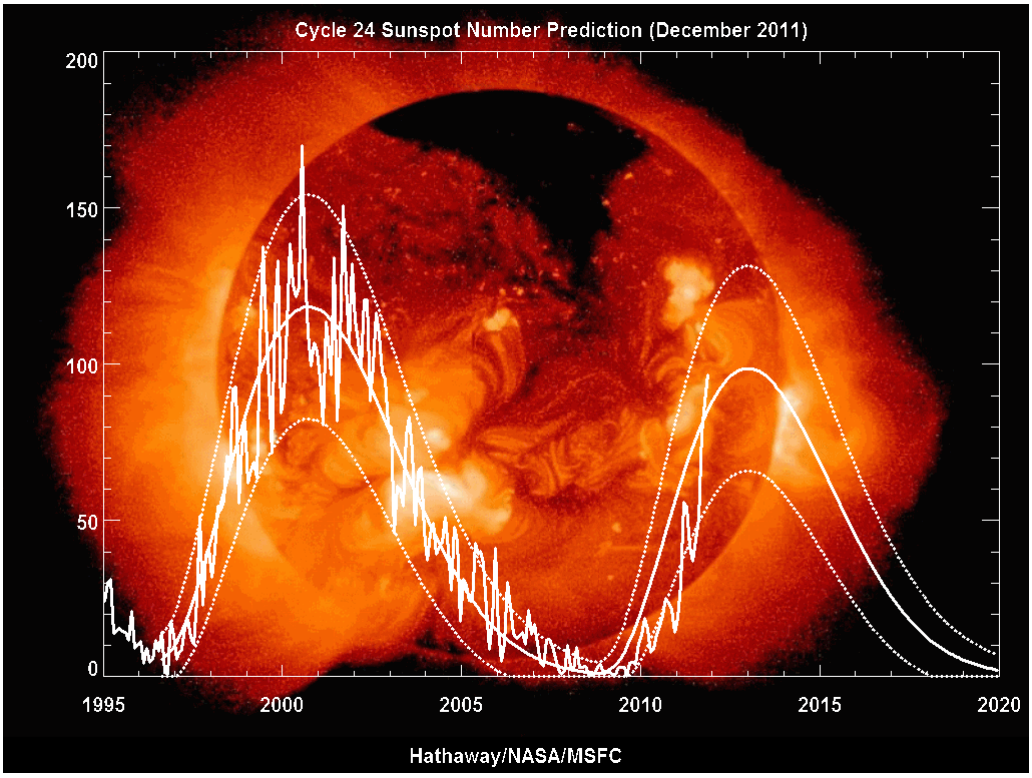

Figure 1 - Solar Cycle no. 24
(source: http://solarscience.msfc.nasa.gov/predict.shtml)

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min/max range of sunspot number. It can well be seen that there was a significant increase of sunspots during the past few months. The next peak is estimated to be reached in 2013.
The number of sunspots correlates with the intensity of solar radiation, which then affects the amount of free electrons in the earth's atmosphere.
Free electrons in the ionosphere perturb the propagation of radio waves. Indeed, the ionosphere is defined as "the atmospheric layer where the free electron concentration is sufficient to affect radio wave propagation". In practice, these so-called Space Weather phenomena are often the origin of disturbed ionospheric conditions which can strongly affect the performances of technological systems based on radio waves.

Measures of ionosphere

The **Total Electron Content** or TEC is a key parameter not only for ionospheric studies but also for the correction of ionospheric effects which degrade GNSS positioning accuracy and reliability.

Another method to illustrate ionosperic activity is the **I95 index**. It can be used to show an index for the average ionospheric activity in a particular region at short time intervalls of e.g. one hour. Although this method shows generally the extend of the ionosphere activity, it does not directly relate to its impact on rover positioning.

Within GNSS networks it is also possible to determine the **residual ionosphere**, which represents remaining ionosphere that has an impact on the postioning quality and reliability. This information can be provided by Leica SpiderQC NOVA maps. Detailed regionally mapped information (figure 3) or a global regional mean can be shown (figure 2).

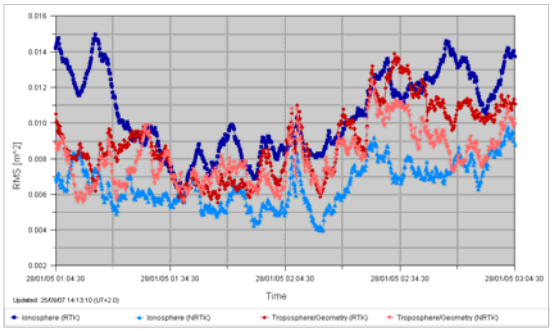

Figure 2 - Leica SpiderQC, Example of Global RMS for Ionosphere & Troposphere, for RTK and NRTK

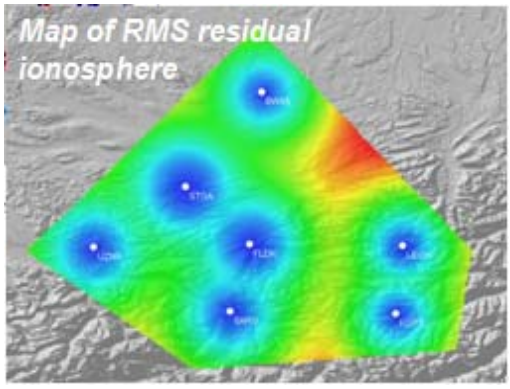

Figure 3: Leica SpiderQC - Example of mapped residual ionosphere

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Ionosphere -
Daily short term variation

Both the I95 index as well as the residual ionospheric estimates show the daily short term variation of ionospheric activity.

Daily peaks are typically observed between 11 a.m. to 2 p.m. local time. The daily rise usually begins around 9 a.m. and ends around 5 p.m. Figure 5 shows this daily varation as I95 index and Figure 4 the global ionopheric residual for the single reference station use case (RTK) and when using network corrections (NRTK).

In sparser networks, typically the residual ionosphere for RTK and NRTK show larger differences, wheras in dense networks they can be quite close and are usually lower overall.

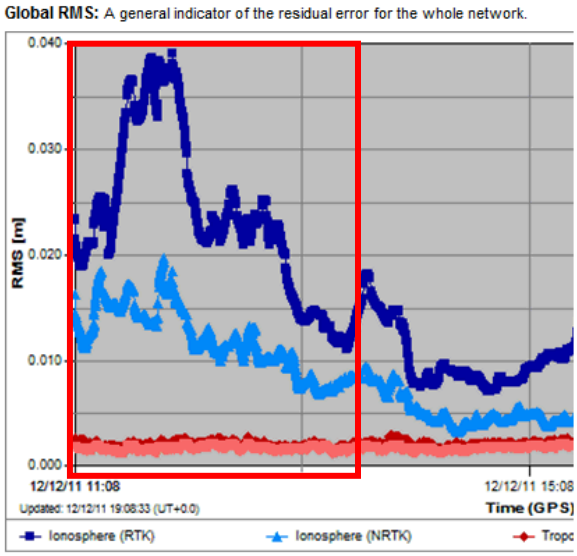

Figure 4 - Leica SpiderQC NOVA Global Ionosphere RMS

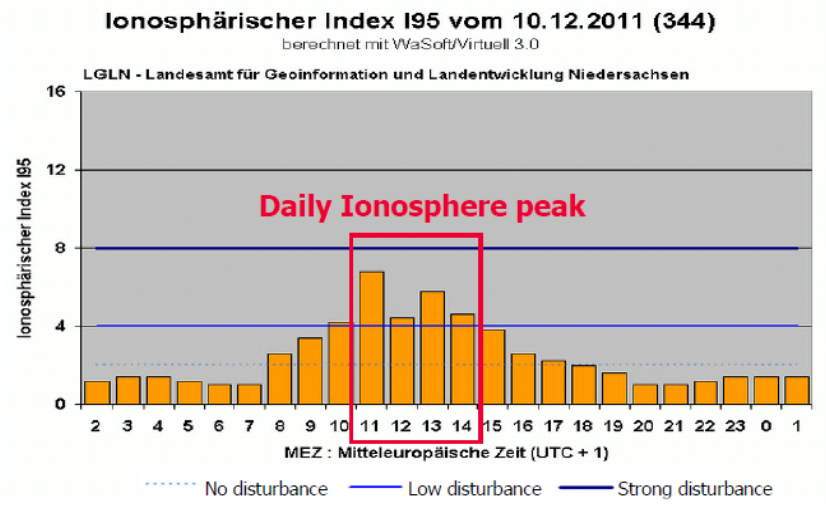

Figure 5 - Ionospheric Index I95

(source: http://www.lgnapp.niedersachsen.de/sapos/iono_index.htm)

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Ionosphere - Global regional variation

The global TEC is regularly determined by the IGS (International GNSS Service) tracking network and published in a standard format **IONEX** (IONosphere map EXchange). It provides a global grid map of TEC information. This information allows illustrating that the ionosphere activity also varies regionally. Depending on the user's location the intensity can be very different. In general, regions closer to the equator are more affected but still underlie the daily variation, shown above. Figure 6 shows the global TEC distribution for a particular day and time.

This IONEX data can also be plotted using Leica SpiderQC software. It allows to animate the 24h global change of the ionosphere. This feature is available in the free version of Leica SpiderQC.

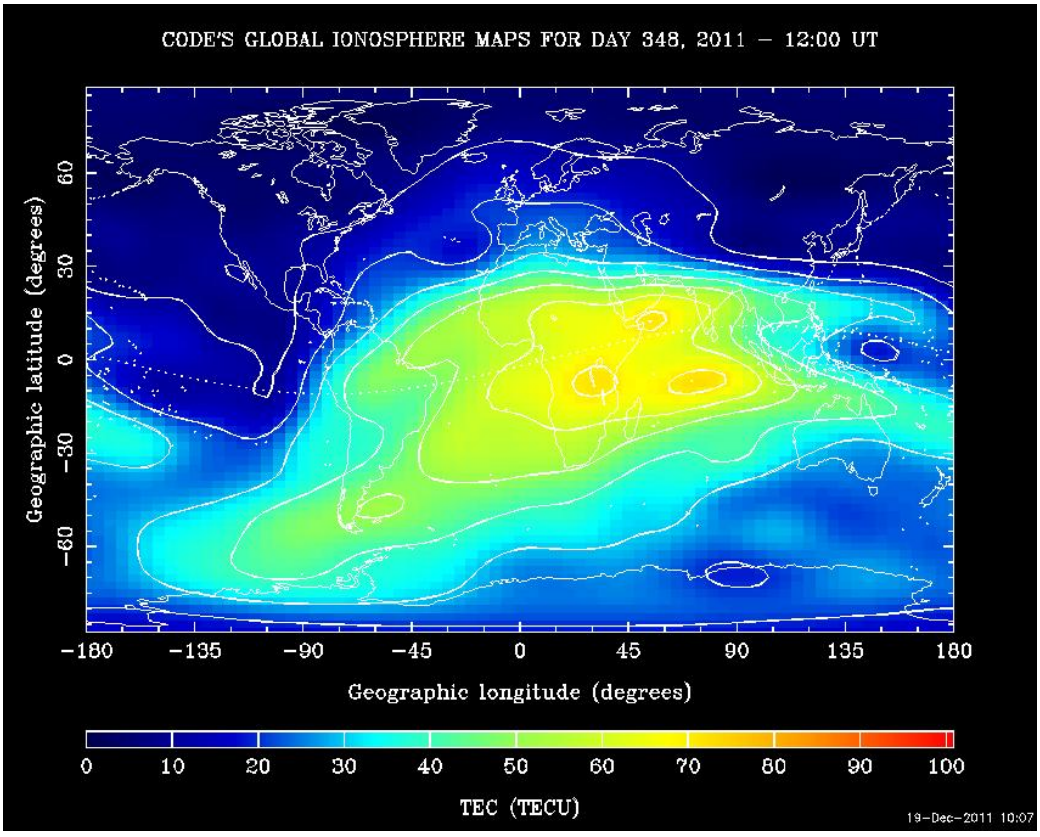

Figure 6 - CODE Global Ionosphere

(source: http://aiuws.unibe.ch/ionosphere/gim_12ut.jpg)

Impact of Ionosphere activity

The influence of the ionosphere on GNSS measurements depends on GNSS wave frequency and on Total Electron Content which is the integral of the electron concentration on the GNSS satellite-to-receiver path. As such, it affects everyone in the GNSS industry, though with different magnitude (e.g. L1 handhelds, car navigation, high precision GNSS receivers). L1 code only receivers are generally less affected due to the fact that ambiguities do not have to be fixed and due to the lower accuracy needs. Wheras dual frequency receivers typically used for high accuracy recognise a more significant impact.

Impact on Reference Station Networks

The ionospheric activity affects all Reference Station Networks. However this largely depends on the design of the network.

- Dense networks, e.g., with 35-50 km station spacing observe a low to medium impact on network correction quality.
- Sparse networks, e.g., up to 70 km station spacing observe a larger impact on network correction quality as well as availability.
- During increased ionospheric activity (e.g. daily peaks) the modeled network correction data may contain higher residual ionophere.

The large impact on the sparser networks is due to the increased difficulty to estimate the integer amibituities reliably, which results usually in longer fixing times and thus less availability. Then, due to the large spacing the modelling of the ionospheric errors more likely does not perfectly match the reality. Both lead to increased difficulty for precise rover positioning.

Impact on GNSS RTK Rovers

The ionospheric activity affects all GNSS RTK rovers in the following ways:

- Short distances (<10 km) - none to low impact on RTK performance
- Medium distances (10 – 20 km) medium impact on RTK performance
- Network RTK Rover performance impact depends on network spacing. ➔ dense networks deliver significantly better rover performance

Summary

- RTK network & rover performance can be affected during the daily ionosphere peaks
- Daily ionospheric activity can vary greatly from day to day.
  - Weeks can go by without high ionospheric activity but the next day the performance can vary due to high ionospheric activity
- Advanced algorithms are applied in our RTK networks to correctly determine the athmospheric errors.
- Sophisticated methods exist in all our RTK networks and rovers to model the ionospheric errors. However, …
  - extreme variations in the ionosphere cannot be modelled well by even the best algorithms, which leads to increased residual ionospheric errors that remain and impact the positioning.
- During the daily ionosphere peaks RTK networks may provide modeled correction data with a higher residual ionosphere or may not be able to continously provide a complete set of network corrections.
  - Without network corrections the RTK Rover will revert to a single baseline solution.
  - RTK rover performance can be affected during these periods if the rover is >10 km from the Master station.

Mitigation steps

- Users of GNSS Systems (network operators as well as rover users) should be aware of the current situation concerning the ionosphere.
- The public services should be used to obtain information on the global change of ionospheric activity.
- RTK network operators can provide network specific information, such as, e.g., Leica SpiderQC NOVA maps to inform their users. They may also consider densifying the network with additional stations to optimize station spacing.
- GNSS rover users must be aware of the reduced performance at times of high ionospheric activity.
- In order to maintain reliability and quality of their survey work, GNSS rovers should:
  - o Plan survey work to minimise working at times of high ionosphere (typically around noon time)
  - o Stay close to the nearest reference station where possible.
  - o Complement the RTK network by a temporary local base station to optimize the working distance e.g. to <10 km.
  - o Repeat measurements at different times of the day.
- Both network providers and rover users should make sure to use the latest software and firmware versions to ensure they benefit from the latest advancements in development.

Also to remember

GNSS positioning requires the modelling and handling of many different error sources and not just the ionosphere - i.e. RTK communication (latency, data gaps,…) , environment (multipath), obstructions, jamming, etc.

Therefore, not every performance decrease can now be attributed to ionosphere and still the general parameters for RTK and Network RTK must be considered.

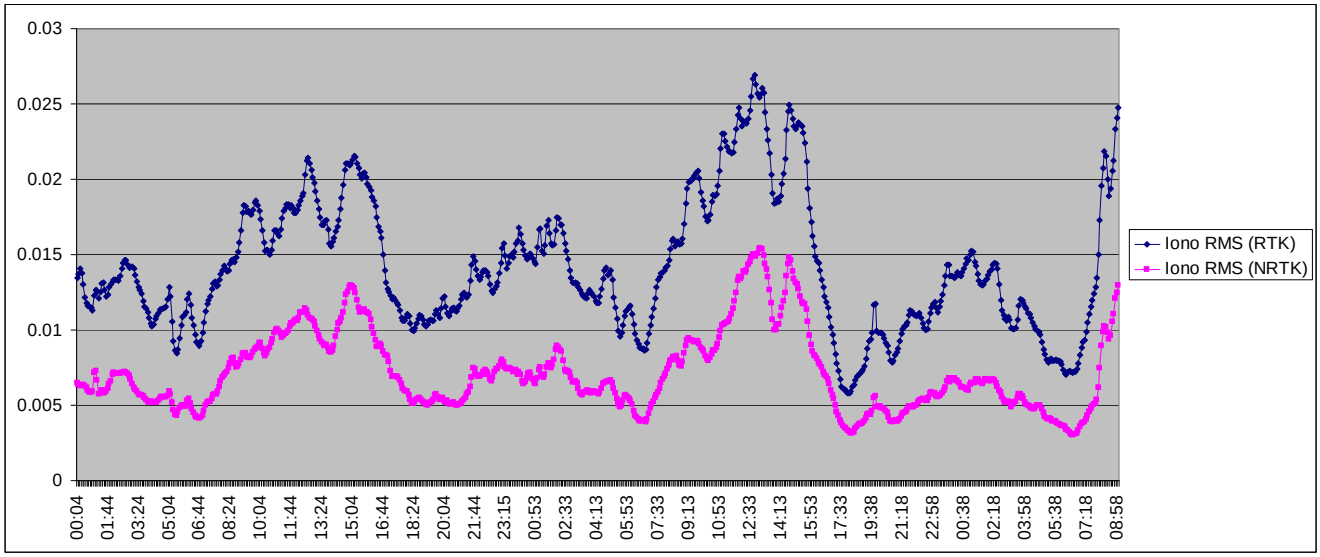

Figure 7 - Ionospheric Residual Variation 17.-19.12.2011

For Single baseline (RTK) and Network (NRTK) application.

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