White Paper

Trimble IonoGuard™ | Overview and Performance in Applanix POSPac Post-Processing

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https://www.applanix.com/products/pospac.htm

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Trimble IonoGuard™ in POSPac

Trimble's Applanix POSPac™ GNSS-Inertial post-processing Software will incorporate Trimble's IonoGuard™ technology starting with version 9.2. The purpose of the IonoGuard feature is to mitigate the impact of ionospheric disturbances on positioning accuracy. Solar activities reach a peak every 11 years, with the next maximum predicted in 2025 (cycle number 25) - see Figure 1. These solar activities can negatively affect GNSS signals, potentially causing degraded positioning performance and bad ambiguity fixing, thus impacting the GNSS-Inertial trajectory (SBET) quality generated by POSPac.

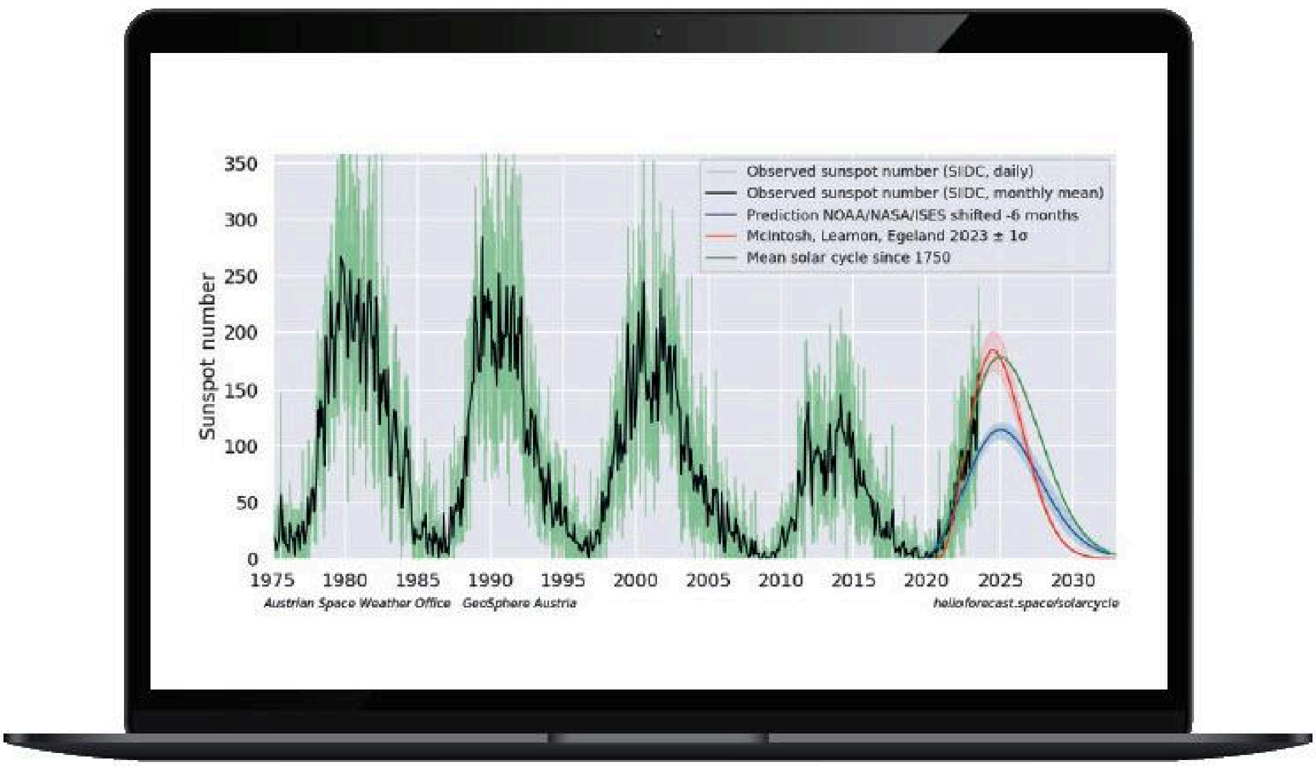

Figure 1: Solar Cycles - 11 years

Ionospheric Disturbances

The ionosphere is a layer in the atmosphere that has a large number of electrically charged atoms and molecules which cause a delay in the GNSS signals passing through it. The delay through the ionosphere is not fixed and will change based on the time of the day, year, and location.

With the increased solar activity during the peak cycle, ionospheric scintillations are induced. These are rapid fluctuations in the amplitude and phase of radio signals caused by small scale irregularities in the ionosphere. They can lead to complete loss of signal tracking or carrier phase cycle slips. Scintillation is a strong function of local time, season, geomagnetic activity and the solar cycle. The critically impacted territories are the polar regions (high latitude) and areas around the geomagnetic equator - see Figure 2. Particularly, South America, central Africa, and regions in Asia are heavily impacted. In South America, scintillation occurs an hour or two after sunset and will typically last for 4-5 hours. It also follows an annual cycle, with most disturbances between September and March. The severity of these disturbances depends on the 11-year solar cycle.

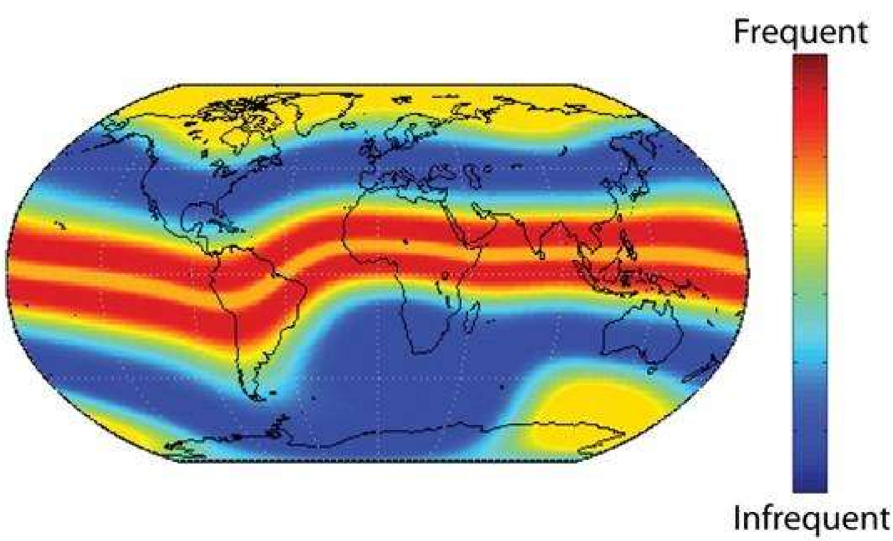

Figure 2: Critical Iono-Scintillation Areas

Ionospheric disturbances can significantly increase the convergence time of phase ambiguities and might lead to biased fixed navigation solutions due to poor ambiguity resolution.

Although most noticeable disturbances occur around the geomagnetic equator and northern latitudes, increases in the ionospheric delay measurements globally have been observed as the solar cycle maximum approaches. The ionospheric gradient provides an indication of how much the ionosphere changes spatially. A high ionospheric gradient can result in a poor GNSS-Inertial post-processing solution. Dual and triple frequency techniques as well as adaptive noise modeling and estimation algorithms are leveraged to mitigate these effects. With the potential for large solar storms to cause disruptions in mid-latitude operations, ionospheric protection has become a critical global requirement for GNSS receivers and hence GNSS-Inertial post-processing.

Mitigation Concept

The Trimble IonoGuard™ technology relies on using carrier phase measurements from ideally all available frequencies, which are supported and logged by the latest generations of Trimble Applanix hardware (e.g. AP+ and APX). While the IN-Fusion processing engine in POSPac does include ionospheric scintillation detection, the new IonoGuard™ technology, integrated into the IN-Fusion+ engine is more advanced due to successful learnings over the last three solar cycles. The IN-Fusion+ processing mode in POSPac ensures the full usage of the tracked signals and can operate with any combination of triple, dual or single frequency measurements.

Using the IN-Fusion+ Single Base mode, POSPac is able to detect ionospheric scintillation and disturbances using the base station data. Three disturbance types are estimated per satellite:

- SNR (Signal-To-Noise Ratio)- based scintillation level detection (= amplitude scintillation)
- Phase-based scintillation level detection and
- Gradient-based ionospheric disturbance detection

The SNR-based and phase-based scintillation detection removes the ionospheric phase delay delta from each phase observation resulting in iono-free phases. In addition, the detected scintillation triggers a scaling of the driving noise of the single-difference iono-delay.

The phase scintillation detection and gradient detection is enabled on all base receiver types while the SNR-based scintillation detection, also known as “amplitude scintillation”, is enabled on Trimble base receivers only.

Results

This section provides the IN-Fusion+ Single Base performance test results with the new IonoGuard feature in POSPac. Figure 3 and Figure 4 show the POSPac v9.1 and v9.2 IN-Fusion+ Single Base GNSS-Inertial horizontal position with respect to the reference for the stationary data collected during the ionospheric scintillation periods at Peru and Kearl Lake respectively. It can be seen that with the new IonoGuard feature POSPac v9.2 has delivered the robust and precise GNSS-Inertial position solution for both datasets during the ionospheric scintillation periods. Table 1 lists the POSPac v9.1 and v9.2 IN-Fusion+ Single Base GNSS-Inertial 3 sigma (99.7%) horizontal position error for both datasets. With the new IonoGuard feature in POSPac, the robust and precise GNSS-Inertial position solutions with a few cm lever accuracy are achieved in the presence of the ionospheric scintillation and disturbances.

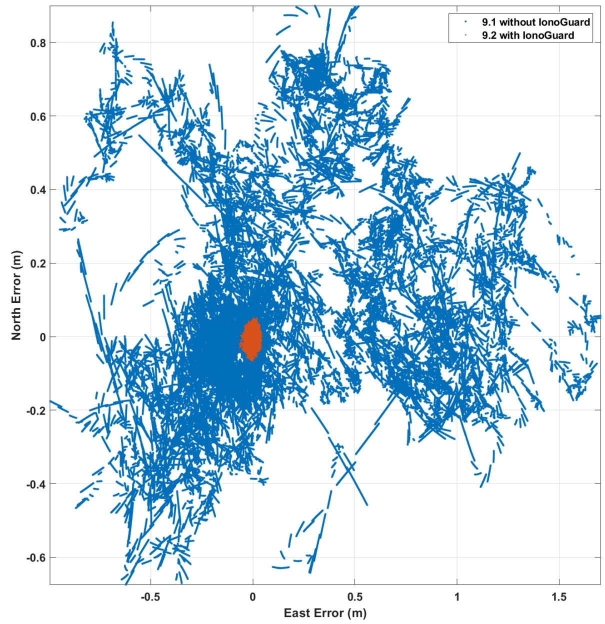

Figure 3: GNSS-Inertial Horizontal Position w.r.t. Reference (Peru)

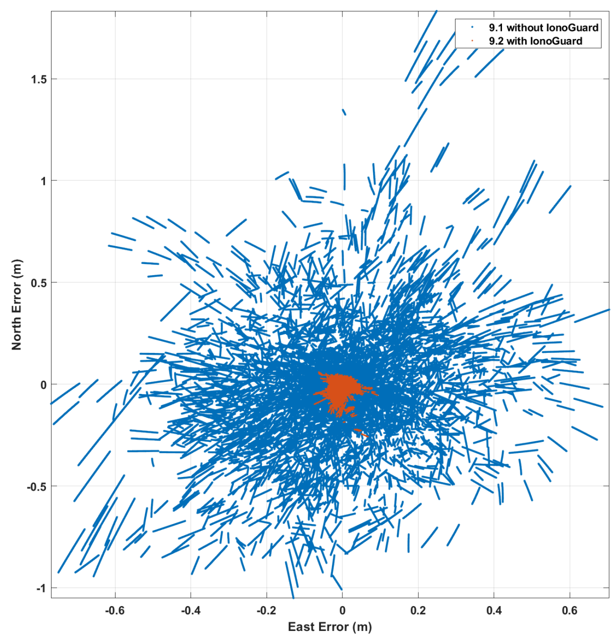

Figure 4: GNSS-Inertial Horizontal Position w.r.t. Reference (Kearl Lake)

Dataset	Horizontal Position Error (99.7%)	
	9.1 without IonoGuard	9.2 with IonoGuard
Peru	144.54 cm	4.23 cm
Kearl Lake	66.97 cm	6.95 cm

Table 1: GNSS-Inertial Horizontal Position Error

Conclusion

Ionospheric scintillation and disturbances are expected in equatorial and polar regions, with peak activities occurring during solar storms and the maximums of the 11-year solar cycle. High-precision GNSS-Inertial post-processing data are affected by these disturbances, especially with increased solar activity. Trimble IonoGuard™ is our latest technology to mitigate the three types of disturbances and Trimble Applanix is leveraging this feature with POSPac v9.2 using the IN-Fusion+ post-processing engine. Currently limited to Single Base (or RTK) post-processing, it will be expanded for PP-RTX processing in the very near future.