



## Impact of Ionospheric Scintillation on GPS Applications during Severe Geomagnetic Storms

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### 1. Introduction

Variations of magnetospheric-ionospheric electrodynamics and charged particle precipitations in the polar region become very dramatic during extreme space weather disturbances and severe geomagnetic storms. Associated with auroral electrojet activity, ionospheric irregularities can develop and cause scintillation in GPS signals in the auroral zone and polar cap. The signal phase measurements under scintillation conditions appear to be very noisy, which are often excluded from the data used in GPS applications such as precise positioning. In this presentation observations of ionospheric scintillation in the polar region during very severe geomagnetic storms will be shown, and their impact on GPS-based precise positioning will be demonstrated.

### 2. Major Events Since 2000

Severe geomagnetic storms can occur during extreme space weather events. Table 1 shows samples of such events since 2000. In these events the geomagnetic planetary Ap index exceeds 100 and maximum Kp index reaches 9 or 8. During these storms, magnetospheric-ionospheric electrodynamics and charged particle precipitations in the polar region are significantly enhanced. Ionospheric irregularities can develop under such conditions and cause scintillation in GPS signals in the polar region. Characterization of the impact of ionospheric scintillation on GPS data quality under the severe storm conditions has been conducted using the rate of TEC index (ROTI) measurements [1][2], which can be readily obtained using thousands of dual-frequency geodetic GNSS receivers that are already deployed globally.

<b>Date</b>	<b>Ap</b>	<b>Max. Kp</b>
07/15/2000	152	9
08/12/2000	109	8
03/31/2001	155	9
11/06/2001	112	8
11/24/2001	108	9
10/29/2003	189	9
10/30/2003	162	9
11/20/2003	117	9
07/25/2004	122	8
07/27/2004	162	9
11/08/2004	189	9
11/10/2004	181	9
05/15/2005	105	9
08/24/2005	110	9
09/11/2005	105	9
12/15/2006	104	8
03/17/2015	117	8

### 3. Impact on GPS Precise Positioning

GPS-based precise positioning and related applications take advantage of signal phase measurements. However, the phase measurements appear very noisy during scintillation. Studies have shown that ionospheric scintillation can result in significant degradation in positioning accuracy if the positioning processing and algorithm is not designed to deal with scintillation [2]. This presentation will describe the impact of ionospheric scintillation on GPS data and the accuracy of GPS-based precise positioning. Examples of such impact will be given for extreme space weather conditions and severe geomagnetic storms.

### 4. References

1. X. Pi, A. J. Mannucci, U. J. Lindqwister, and C. M. Ho, "Monitoring of global ionospheric irregularities using the worldwide GPS network," *Geophys. Res. Lett.*, **24**, 1997, p.2283, DOI: 10.1029/97GL02273.
2. X. Pi, B. A. Iijima, W. Lu, "Effects of Ionospheric Scintillation on GNSS-Based Positioning," *Proc. ION GNSS+*, Tampa, Florida, September 2014, pp. 1090-1100.