B2 thickness parameter response to Equinoctial geomagnetic storms

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Introduction
Base Point and B2 definitions
Introduction

**Thickness Parameters**
Most of the ionospheric empirical models make use of thickness parameters to characterize the shape of an electron density profile.

These thickness parameters are generally defined by empirical relations related to ionogram characteristics.

**Purpose**
In this study we analyze the behavior of the B2 thickness parameter during three CME events that occurred during Equinox of years 2013 and 2015.
Base Point and B2 Concepts

**Base Point (BP)**
- Inflection point of Ne below the F2 peak.
- Where the height gradient is maximum.

(Mosert de Gonzalez and Radicella., 1990)

BP is not related to any given type of analytical profile and can be experimentally derived from any Electron Density Profile (EDP).

**The NeQuick model**
- Uses this BP as an anchor point to define a thickness parameter of the F2 bottomside of the EDP, which is named B2.

**The B2 thickness parameter**
- Describes the shape of an Epstein Layer EDP below the F2 region peak. It can be derived analytically as:

\[
B2 = 0.385 \text{NmF2} / dN/dh_{max}
\]

(Nava et al., 2008)
B2 parameter study
Analysis of B2 variation during geomagnetic storms
Three ionospheric storms caused by CME occurring during the same season (Equinox) selected. All of them developed after a magnetic quiet period and with an onset time between 02 and 06 UT. The events are those of March 17th, 2013; October 2nd, 2013 and March 17th, 2015.

The experimental maximum dN/dh gradient values, \((dN/dh)_{\text{max}}\), were obtained from hourly ionograms from about 20 digisondes at middle and low latitudes from GIRO network (Reinisch and Galkin, 2011).

B2 behavior was analyzed before, during and after the aforementioned events, together with vertical TEC (VTEC) and NmF2 variations for different longitude sectors.

The response time of the different measurements according to location were subsequently analyzed by means of cross correlation.
Geographical Locations of digisonde stations used

GIRO network (Reinisch and Galkin, 2011)
GNSS station
### Storms parameters

<table>
<thead>
<tr>
<th>Storm/Onset Date &amp; Time</th>
<th>Mar 2013 06 UT</th>
<th>Oct 2013 02 UT</th>
<th>Mar 2015 04.45 UT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Min Bz southward</td>
<td>-20 nT</td>
<td>-30 nT</td>
<td>-23 nT</td>
</tr>
<tr>
<td>Vz max after SSC</td>
<td>300 km/s =&gt; 700 km/s</td>
<td>250 km/s =&gt; 600 km/s</td>
<td>120 km/s =&gt; 520 km/s</td>
</tr>
<tr>
<td>SYMH min</td>
<td>-130 nT</td>
<td>-90 nT</td>
<td>-234 nT</td>
</tr>
<tr>
<td>AE max</td>
<td>2000 nT</td>
<td>2000 nT</td>
<td>2300 nT</td>
</tr>
</tbody>
</table>
The three storms occurring on Equinox and beginning between 02.00 UT and 6.00UT highlights a similar pattern:

1) VTEC decreases in the Asia and increases in Europe and Africa during the day of the storm.
2) VTEC decreases, in all the longitude sectors, the day after the storm.
Storms Overview

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Results B2, NmF2 and VTEC variations

Profiles and Variations of B2, NmF2 and VTEC at Ebro station before and during the storm March 17, 2015.
Results B2, NmF2 and VTEC variations

Variations of B2, NmF2 and VTEC at Ebro station during the three equinoctial storms March 17, 2013, October 2, 2013 and March 17, 2015.
Results B2, NmF2 and VTEC variations

Variations of B2, NmF2 and VTEC at Austin and Boulder stations during the three equinoctial storms March 17, 2013, October 2, 2013 and March 17, 2015.
Results  B2, NmF2 and VTEC variations

Variations of B2, NmF2 and VTEC at Jicamarca station during the three equinoctial storms March 17, 2013, October 2, 2013 and March 17, 2015.

LT = UT – 5
Results

B2, NmF2 and VTEC variations

LT = UT + 7

Variations of B2, NmF2 and VTEC at Jeju and Wuhan stations during the three equinoctial storms
March 17, 2013, October 2, 2013 and March 17, 2015.

Asia – mid-latitudes
Results B2, NmF2 and VTEC variations

Variations of B2, NmF2 and VTEC at Sanya station during the equinoctial storms October 2, 2013 and March 17, 2015. No available data for March 15, 2013.

LT = UT + 7
<table>
<thead>
<tr>
<th>Storm Location</th>
<th>March 17, 2013</th>
<th>October 2, 2013</th>
<th>March 17, 2015</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Intense storm</td>
<td>Moderate storm</td>
<td>Great storm</td>
</tr>
<tr>
<td></td>
<td>Max SYMH =&gt; -130 nT</td>
<td>Max SYMH =&gt; -90 nT</td>
<td>Max SYMH =&gt; -234 nT</td>
</tr>
<tr>
<td>Europe Mid-latitudes</td>
<td>Positive storm +NmF2 +B2 spike</td>
<td>Positive storm +NmF2 +B2 spike</td>
<td>Positive storm +NmF2 +B2 spike</td>
</tr>
<tr>
<td>America Mid-latitudes</td>
<td>Positive storm+NmF2 +B2 spike</td>
<td>Positive storm + NmF2 Decrease of B2 Particular case</td>
<td>Negative storm Complex case</td>
</tr>
<tr>
<td>America Low latitudes</td>
<td>Positive storm +NmF2 +B2 spike</td>
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<tr>
<td>Asia Mid-latitudes</td>
<td>No effects</td>
<td>Positive storm +NmF2 +B2 spike</td>
<td>Negative storm Complex case</td>
</tr>
<tr>
<td>Asia Low latitudes</td>
<td>No data</td>
<td>Positive storm +NmF2 Decrease of B2 Particular case</td>
<td>Negative storm Complex case</td>
</tr>
</tbody>
</table>
Results
Results
Results
Results
<table>
<thead>
<tr>
<th>Location/ Station Code</th>
<th>March 17, 2015 Min SYMH =&gt; -234nT</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>America Mid-latitudes Eglin EG931</strong></td>
<td>Positive storm +NmF2 +B2 spike</td>
</tr>
<tr>
<td><strong>America Mid-latitudes Ramey PRJ18</strong></td>
<td>Positive storm +NmF2 +B2 spike</td>
</tr>
<tr>
<td><strong>America Mid-latitudes Port Stanley PSJ5J</strong></td>
<td>Positive storm +NmF2 +B2 spike</td>
</tr>
<tr>
<td><strong>Europe Mid-latitudes San Fernando EA036</strong></td>
<td>Positive storm +NmF2 +B2 spike</td>
</tr>
<tr>
<td><strong>Europe Mid-latitudes Athens AT138</strong></td>
<td>Positive storm +NmF2 +B2 spike</td>
</tr>
<tr>
<td><strong>Europe Mid-latitudes Grahamstown GR13L</strong></td>
<td>Both Positive storm +NmF2 +B2 spike Followed by Negative storm Complex case</td>
</tr>
<tr>
<td><strong>Asia Mid-latitudes Beijing BP440</strong></td>
<td>Negative storm Complex case</td>
</tr>
</tbody>
</table>

St Patrick 2015, Mid-latitudes
<table>
<thead>
<tr>
<th>Storm Location</th>
<th>Station Code</th>
<th>March 17, 2015</th>
<th>Great storm Min SYMH =&gt; -234nT</th>
</tr>
</thead>
<tbody>
<tr>
<td>America Low latitudes</td>
<td>Ramey PRJ18</td>
<td>Positive storm +NmF2</td>
<td>+B2 spike</td>
</tr>
<tr>
<td>America Low latitudes</td>
<td>Boa Vista BVJ03</td>
<td>Positive storm +NmF2</td>
<td>+B2 spike</td>
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<tr>
<td>America Mid-latitudes</td>
<td>Sao Luis SAA0K</td>
<td>Positive storm +NmF2</td>
<td>+B2 spike</td>
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<tr>
<td>America Low-latitudes</td>
<td>Fortaleza FZA0M</td>
<td>Positive storm +NmF2</td>
<td>+B2 spike</td>
</tr>
<tr>
<td>Asia Mid latitudes</td>
<td>Wuhan WU430</td>
<td>Negative storm Complex case +B2</td>
<td></td>
</tr>
<tr>
<td>Asia Low latitudes</td>
<td>Sanya SA418</td>
<td>Negative storm Complex case +B2</td>
<td></td>
</tr>
</tbody>
</table>
Results – Cases Observed

Cases Observed over a total of 26

- +B2: 18 (69%)
- Complex: 5 (19%)
- No Effects: 3 (12%)

Total: 26 cases observed
To investigate the time of response of the different measurements according to location, data series were subsequently analyzed and correlated.
Results – B2 response time Analysis

Evaluation of cross correlations between experimental B2bot and GPS VTEC during the 24 hours (UT) of the main phase of the storm of St Patrick 2015 by Regions.
Discussion & Conclusions

Analysis of B2 variation during geomagnetic storms
B2 Analysis

Summary

The results show 2 main types of behavior of B2, NmF2 and VTEC: +B2 spike and complex cases.

Simple Cases

The cases of +B2 spike [~70% of observations] with a peak of B2 prior to the increases of NmF2 and VTEC corresponds to ionospheric positive storms.

Complex Cases

The complex case [~20% of observations] with a fluctuated B2 associated with a decay of NmF2 and VTEC has been observed during negative ionospheric storms.

The 2 kind of behaviors found correspond to the action of different dominant factors

Negative storm -> modification due to changes in composition
Positive storm -> modifications due to transport of ionization
The analysis on the response time of the different measurements according to location for all the storms studied shows, in general, that B2 reacts before NmF2 and VTEC after the SSC.

A detailed evaluation of the response time of B2 with respect to VTEC after SSC done with the St Patrick 2015 storm shows that times go from 45 min to ~3 hours depending on the sector and latitude.

Due to the sensitiveness shown during storms, experimentally derived thickness parameters, like B2, can be entered to empirical models in order to adapt them to storm situations.
Thank You