SOLAR ACTIVITY EFFECTS ON THE IONOSPHERIC TOTAL ELECTRON USING GNSS OVER SOUTH AFRICA

D. M. Moeketsi (a), L. A. McKinnell (b,d) & W. L. Combrinck (c)

(a) Centre for High Performance Computing, CSIR Meraka Institute
(b) Department of Physics and Electronics, Rhodes University, SA
(c) Space Geodesy Programme, SA
(d) Hermanus Magnetic Observatory, SA
PART I
OVERVIEW OF CENTRE FOR HIGH PERFORMANCE COMPUTING IN SOUTH AFRICA
Brief History

● 2000  Initiated as a collaborative intervention amongst the scientists.

● 2004  Department of Science and Technology (DST) appointed a steering committee and develop business plan.

● 2005  The CHPC incorporated into CSIR's Meraka Institute.

● 2007  Official launched by the Minister of DST.

● 2008  Dr. H. Sithole appointed as the Director of the CHPC.
Vision and Objectives

Remit is to advance scientific boundaries by enabling world-class research through

- promoting and facilitating the use of computational technologies and techniques amongst researchers
- innovation
- the training of a new generation of computationally skilled researchers

in areas underpinned by high end computing, particularly those of national and continental strategic importance, to the benefit of basic and applied research, commerce and industry
Special Interest Groups

Linking to the technology missions in the National R&D Strategy by working alongside a wide range of stakeholders.
Computational Resource

*e1350: Clustered 160 compute nodes* - each with two dual core AMD Opteron 2.6GHz Rev. F processors (640 CPUs in total at approx. 2.5 Teraflops/s peak performance). Each cluster node is equipped with 16GB of DDR2 667MHz random access and it is interconnected with Infiniband 4X SDR via HTX from Voltaire and PathScale. Eight of the cluster nodes are equipped with ClearSpeed accelerator cards.
The Blue Gene/P cluster consists of 1024 compute nodes plus 16 IO nodes, which provide an approximately 13.6 Teraflops/s computational power. Each node is equipped with four IBM PowerPC cores plus three cache, 2GB memory and 13.6 GFlop/s peak performance.
Computational Resource

Two P690 SMP machines: 32 x 1.9GHz Power4+ CPUs and at least 32GB of RAM each.

GPFS storage cluster consists of three IO nodes attached to the shared storage capacity of 94 Terabytes.
The CHPC is also equipped with a wide range of proprietary and open-source software packages and applications. The centre also hosts a virtual reality visualisation facility and training rooms.
Currently there are five merging research laboratories:

- Advanced Computing Engineering (ACE)
- Space Weather Research (SWR)
- Earth Science Projection and Analysis (ESPA)
- Interactive Visualisation Technology (VIT)
- Specialised Solutions for High Performance Computing Research (S2HPCR)
Africa Initiative

The CHPC seeks partnership with its African peers through the following mechanisms:

- Blue Gene for Africa (BG4A)
- Exchange programme
- Joint research projects using HPC applications
- Joint research project on technical computing
- e-Learning research activities

For more information visit:
http://www.chpc.ac.za/
PART II

SOLAR ACTIVITY EFFECTS ON THE IONOSPHERIC TOTAL ELECTRON CONTENT USING GNSS OVER SOUTH AFRICA
Main Aim

- To validate the University of New Brunswick Ionospheric Modelling Technique (UNB-IMT) (Komjathy, 1997) TEC results using ionosonde TEC (ITEC) measurements over South Africa.

- To investigate midday TEC variability over South Africa during different periods of solar cycle 23: The years 2002 near solar maximum and 2005 near solar minimum.
Outline

- Introduction
- The Global Navigation Satellite System (GNSS) and Total Electron Content (TEC)
- Sunspot and Solar Activity Cycle
- The University of New Brunswick Ionospheric Modelling Technique
- Geographic Map of South African Ionosonde and GNSS stations
- Results
  - Comparison of midday GNSS (GTEC) with ITEC measurements
  - The difference between GTEC and ITEC – (Reinisch et al., 2001; Belehaki and Jakowski, 2002)
  - Variations of equivalent ionospheric total slab thickness parameters
- Some conclusions and Future work
GNSS (e.g. GPS, GLONASS and future GALILEO) signals are transmitted at two L-band frequencies: (L1=1.6 GHz and L2=1.2 GHz)

Because of dispersive nature of the ionosphere:

\[ \Delta I_e = \frac{40.3}{f^2} \frac{Hz^2 m^3}{Et} \]

1 TECU = 1 \times 10^{16} \text{ e/m}^2

**Langley et al. (2002)**
Sunspot and Solar Activity

Solar flare – is a violent explosion in the Sun’s atmosphere.

- Solar Energetic Particles (e.g., protons, electrons, etc.)
- Mass flow
- Electromagnetic radiation (e.g., X-ray and EUV) – GOES and SOHO etc.
Uses single layer ionospheric model (Komjathy, 1997; Feddrizi et al., 2005; Moeketsi et al., 2007a,b):

\[ I(t) = M(e)[a_0(t) + a_1(t)dl + a_2(t)df] + b_r + b_s \]

- \( I(t) : L_1 - L_2 \) Phase-levelled ionospheric measurement in TECU,
- \( M(e) : \) elevation angle mapping function,
- \( [a_0(t) + a_1(t)dl + a_2(t)df] : \) spatial linear approximation of TEC,
- \( b_r + b_s : \) Receiver plus Satellite instrumental differential delays.

- Solar-geomagnetic reference frame.
- 5 by 5 longitude/latitude degree grid spacing maps.
- TEC at each grid node computed using the 4 closest stations.
Comparison of GTEC and ITEC for near Solar Maximum

(a) Madimbo
- PBWA
- PTBG
- ERAS

(b) Grahamstown
- PELB
- ELDN

(c) Louisvale
- UPTN
- KMAN

Day of 2002
Comparison of GTEC and ITEC for near Solar Minimum

Graphs showing TEC (TECU) vs. Day of 2005 for Madimbo, Grahamstown, and Louisvale.

- (a) Madimbo: PBWA, PTBG, ERAS
- (b) Grahamstown: PELB, ELDN
- (c) Louisvale: UPTN, KMAM
Difference between GTEC and ITEC for near Solar Maximum
Difference between GTEC and ITEC for near Solar Minimum

(a) Madimbo

(b) Grahamstown

(c) Louisvale
Calculation of equivalent midday ionospheric total slab thickness parameters

- **Slab thickness:** can be defined as the depth of an imaginary ionosphere, which has the measured TEC and electron density equal to the maximum electron density of the ionosphere (e.g. Breed and Goodwin, 1997; Forster and Jakowski, 2000):

\[
\tau_t = \frac{GTEC}{N_m F2} = \alpha \cdot \frac{GTEC}{f_o F2^2}
\]

\[
\tau_i = \frac{ITEC}{N_m F2} = \alpha \cdot \frac{ITEC}{f_o F2^2}
\]

\[
\alpha = 806.45
\]

\[
N_m F2/1 \text{ m}^{-3} = \frac{1}{80.6} \left( \frac{f_o f_2}{1 \text{ Hz}} \right)^2
\]
Equivalent midday ionospheric total slab thickness parameters for year 2002 near solar Maximum.
Equivalent midday ionospheric total slab thickness parameters for year 2005 near solar minimum

(a) Madimbo

(b) Grahamstown

(c) Louisvale
Some conclusions

- Variation Trends of midday GTEC and ITEC over all stations showed a good agreement.
- Both GTEC and ITEC showed a pronounced seasonal variations for the period near solar maximum.
- Variation trend of the plasmaspheric electron content for period near solar minimum display a complicated picture, compared to the period near solar maximum.
- This study verified the use of UNB-IMT for future Ionospheric research over SA.
- The work has been accepted for publication in IRI/COST 296 special issue of JASR.
Future work

- Investigate in details the seasonal variations of plasmaspheric electron content over South Africa with more data sets.
- Develop data assimilation model for southern Africa in collaboration with University of Colorado, NOAA Space Weather Prediction Centre (Dr. Eduardo A. Ajauro-Pradere).
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