Modelling ionospheric TEC changes over Southern Africa using the neural network method

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Aim of the study and outline

Objective: To develop a model that will nowcast and forecast TEC over Southern Africa

Outline

- Introduction
- Data sources
- Results
- Conclusion

Introduction

- The nowcasting and forecasting of parameters that don't have linear behavioural patterns is a rather difficult task through analytical modelling.
- It is known that the ionosphere has a non-linear behaviour.
- There are several ionospheric parameters that do not vary linearly such as foF2, the ionospheric slab thickness, TEC etc
- TEC is the integral number of electrons in a unit cross sectional area (1 m^2) along a signal path from the GPS satellite to the receiver on the ground.
- First results from a national neural network based model over the entire South Africa are presented.
- There are about 40 GPS receiver stations distributed over the whole country.

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Introduction cont'd

Neural networks

- A technique used to learn the relationship between data using input-output mapping process
- Data (consisting of both inputs and outputs) under consideration is divided into training and validating patterns
- Also a testing dataset is prepared to assess the overall performance of the trained neural net.

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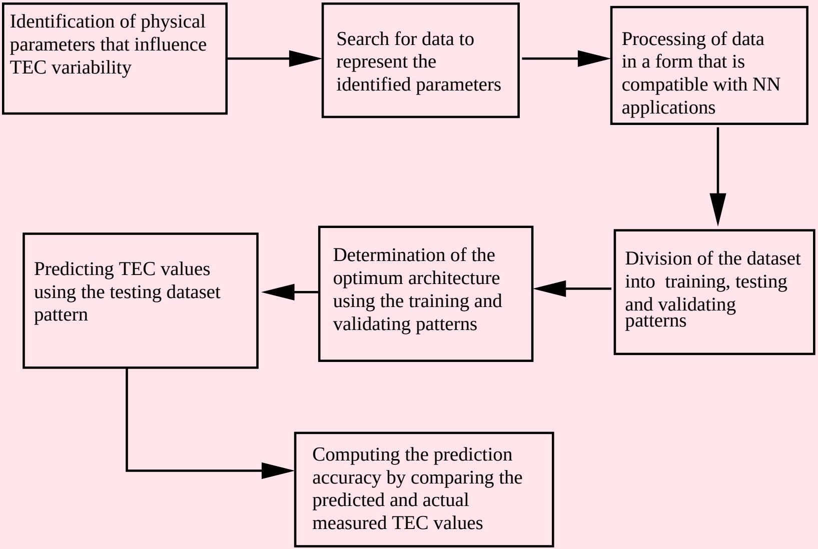
Procedure


Identification of physical parameters that influence TEC variability
Search for data to represent the identified parameters
Processing of data in a form that is compatible with NN applications
Division of the dataset into training, testing and validating patterns
Determination of the optimum architecture using the training and validating patterns
Predicting TEC values using the testing dataset pattern
Computing the prediction accuracy by comparing the predicted and actual measured TEC values

Data sources

- GPS TEC was derived from GPS observations at intervals of 1 minute.
- Solar activity represented by sunspot number
- Magnetic activity represented by magnetic A index values
- Diurnal variation === Hour of the day
- Seasonal variation === Day number of the year
- Geographic position of GPS receivers === Latitude and Longitudes

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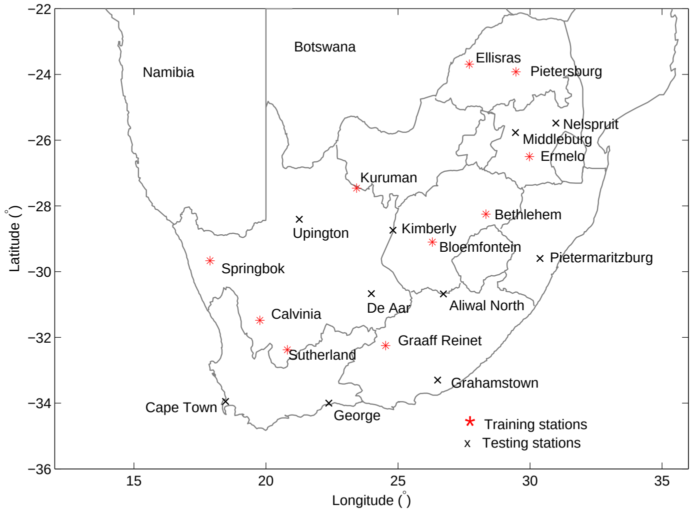
South African map showing training and testing stations



Data range and TEC predictability

1. Training and validating consisted of 2000-2004 data
2. Testing was done using
   - 2002 — during equinoxes and solstices
   - 2005 — during the magnetic storms of 8, 15 May
3. $T_{pred} \equiv f(DNC, DNS, HRC, HRS, R, A, lat, long)$
4. Note: In cases where the data for equinox and solstice days was not available, the closest days with data to this period was used to test the NN model

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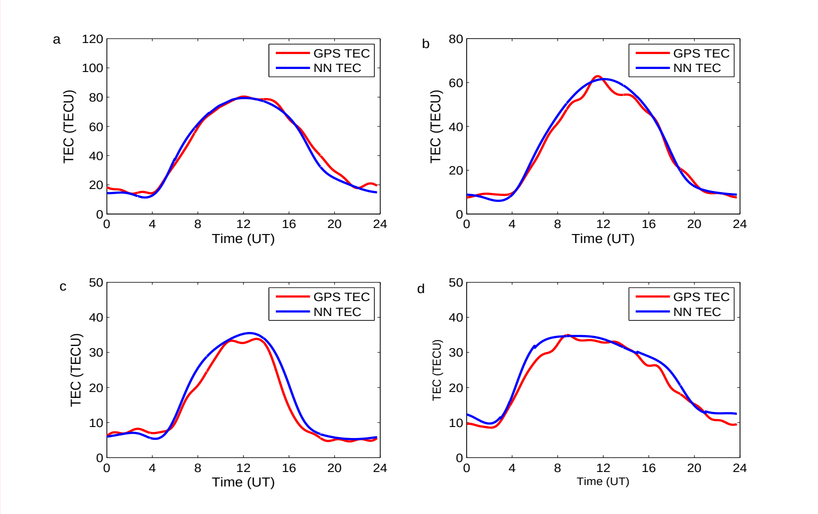
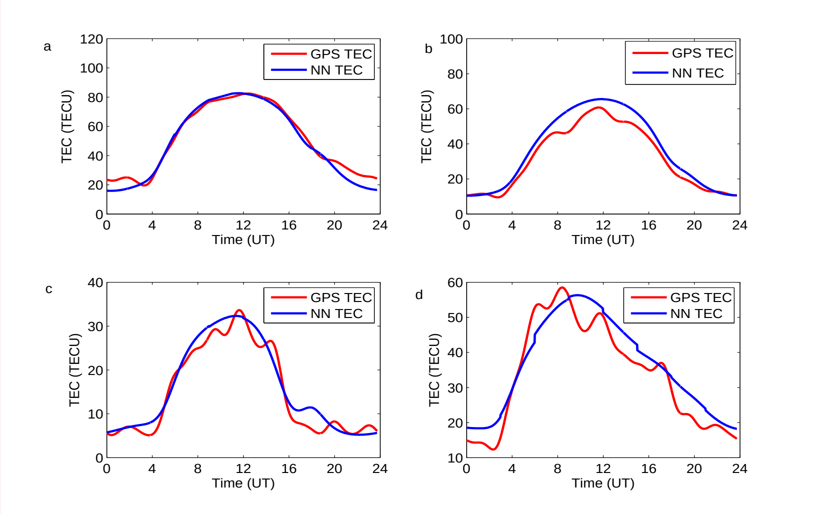
Results; Cape Town (33.95°S, 18.47°E) – 2002

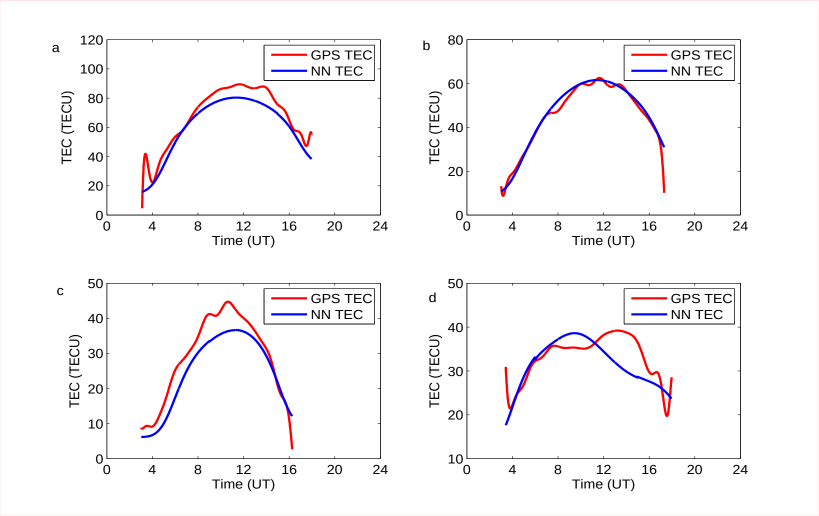


(a) March 20, (b) Sept. 23, (c) June 22 and (d) Dec. 21



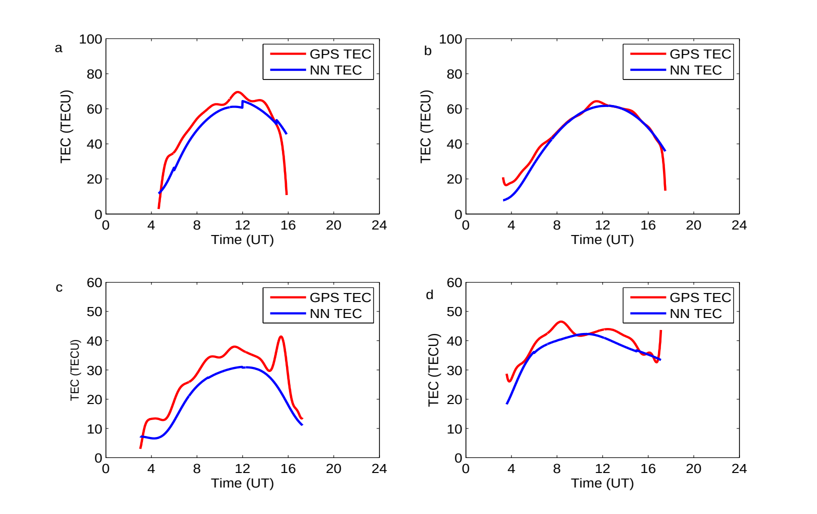
(a) March 20, (b) Sept. 22, (c) June 21 and (d) Dec. 22

Pietermaritzburg (29.60°S, 30.38°E) – 2002



(a) March 18, (b) Sept. 26, (c) May 31 and (d) Dec. 22

Upington (28.41°S, 21.26°E) – 2002.



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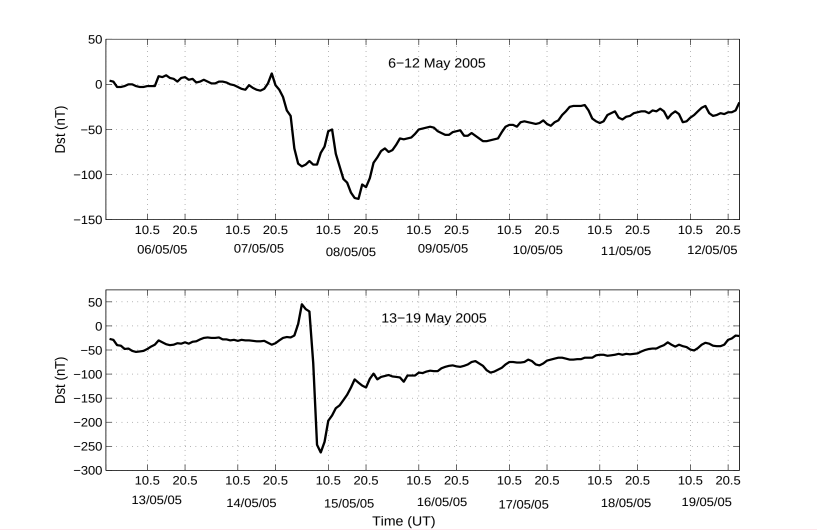
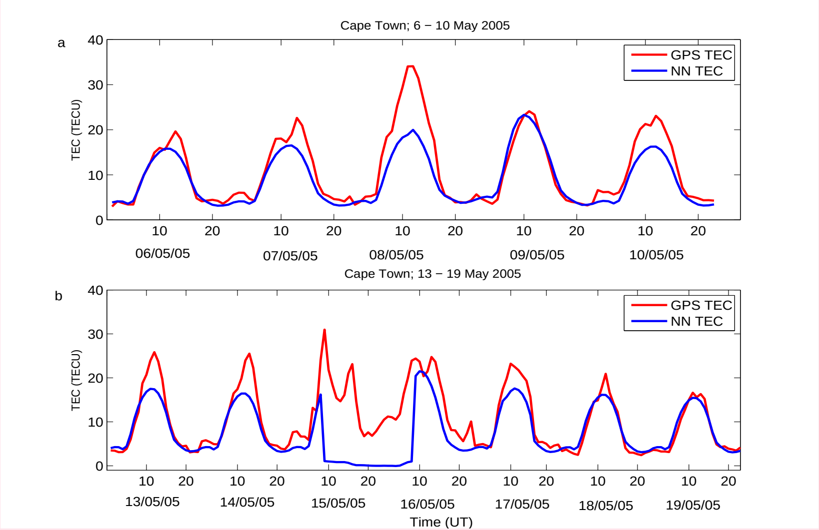
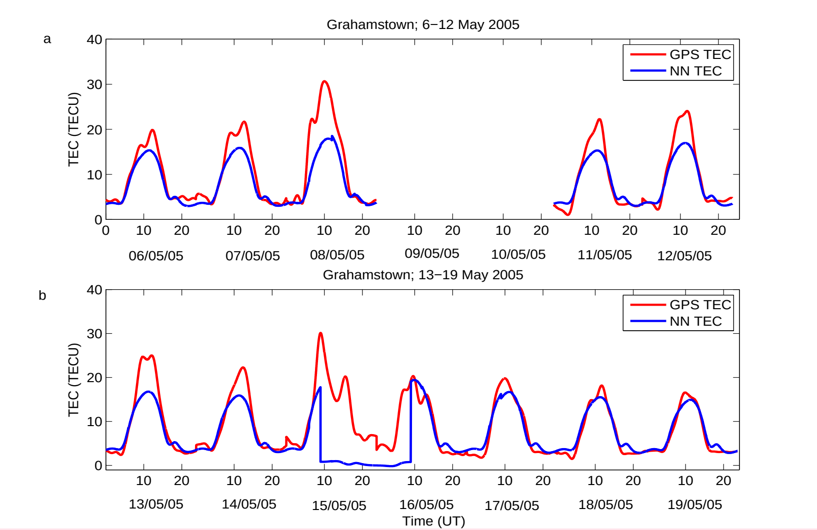
TEC predictions during magnetic storms



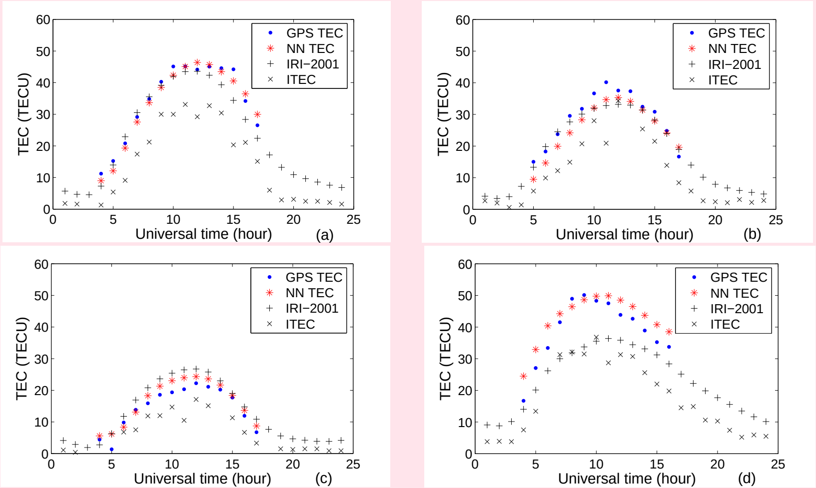
During magnetic storms



During magnetic storms, Grahamstown (33.3°S, 26.5°E)



Comparison of GPS TEC, IRI TEC, ITEC and NN TEC



Upington; (a) March 19, (b) September 22 and solstices: (c) June 22, (d) January 2; all in 2003

Conclusion

1. A national NN model to predict TEC over South Africa has been developed
2. Tested during quiet and disturbed conditions and based on results obtained it is,
    1. Relatively effective during quiet conditions
    2. Ineffective during magnetic storms
3. Therefore we need to do more to represent TEC realistically during strong magnetic storms.
4. Studying more on the inclusion of a solar wind parameter to see whether we shall be able to capture these variations.

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1. International Union of Radio Science secretariat for awarding me the Young Scientist Award which made it possible for me to be part of this conference.

2. The Chief Directorate of Surveys and Mappings, Cape Town, South Africa for GPS data provision.

3. Thanks to all of you for the audience

4. The End!!!!