Modelling of
Ionospheric Perturbation
due to variation in
Interplanetary Magnetic Field

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Modelling ionospheric Perturbation due to IMF Variation

Introduction:

- Space Weather affect the ionospheric plasma density
- Variations in interplanetary magnetic field of the solar wind, interacts with the magnetosphere of the earth
- Electric field induced readily gets penetrated to the equatorial region and causes variations in the transport component of the equatorial ionospheric plasma
- The consequent TEC variation, in turn, affect satellite navigation in this region

Modelling ionospheric Perturbation due to IMF Variation

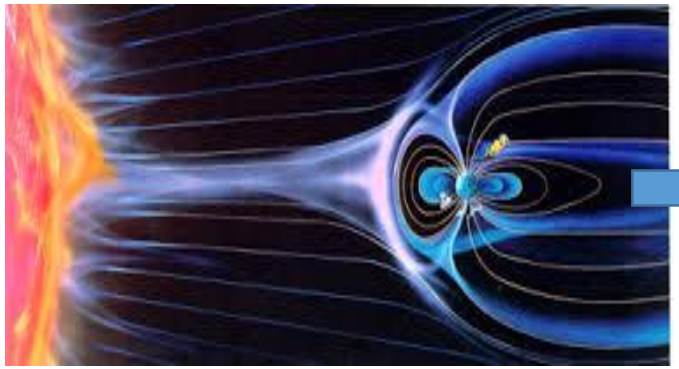
Observation and prior research

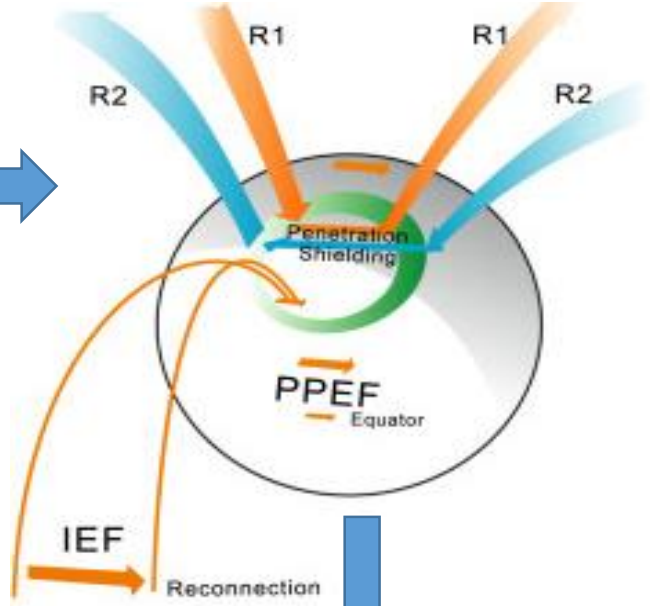
- There exist a definite systematic relationship between the IMF variation and additional induced electric field
- A model can be established between the causal parameters and the effect

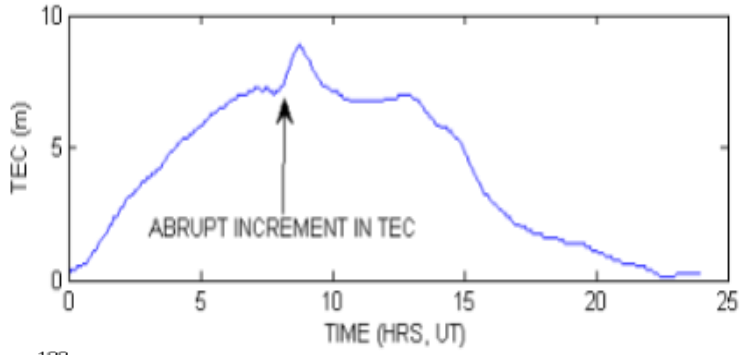
Aim

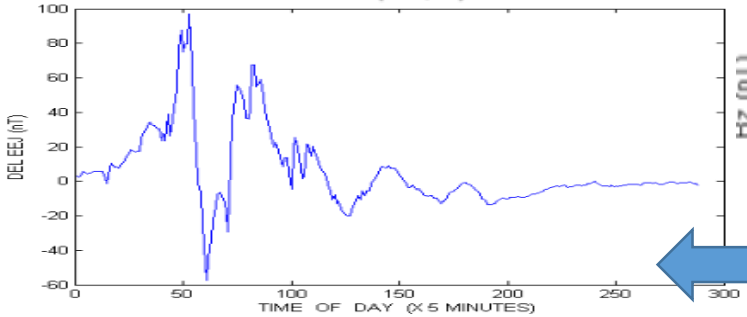
- Study the effects of solar wind and IMF on ionosphere under normal and enhanced solar activity events
- Establish a relation between the IMF and the occurrences of measurable ionospheric TEC variation

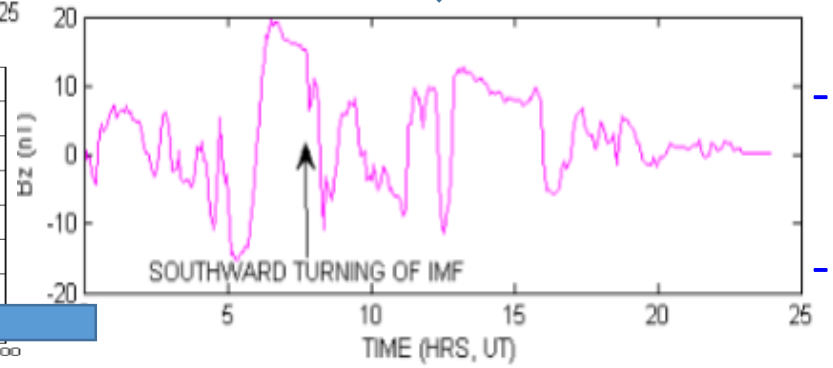
Modelling ionospheric Perturbation due to IMF Variation











Prompt Penetration Electric Field:

- Abrupt and rapid inversion in IMF Bz
- Associated IEF – Ey is derived
- Over shielding and under shielding process occurs
- Excess electric field penetrates from the poles to the equatorial region
- Excess zonal field drives excess plasma up
- Uplifted excess plasma adds to excess TEC

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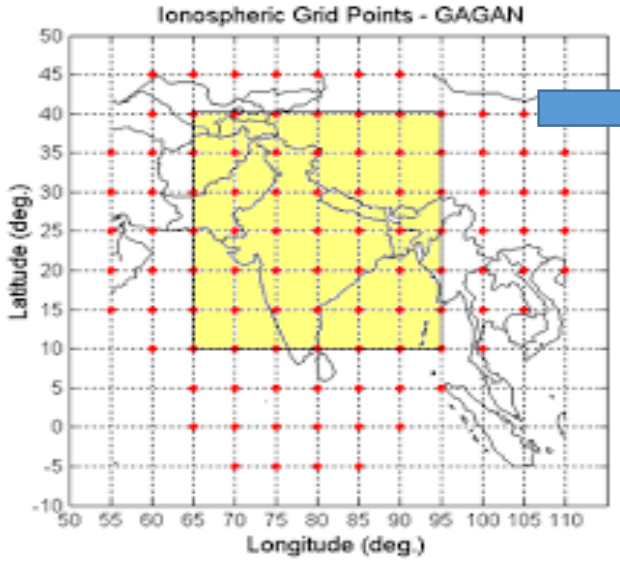
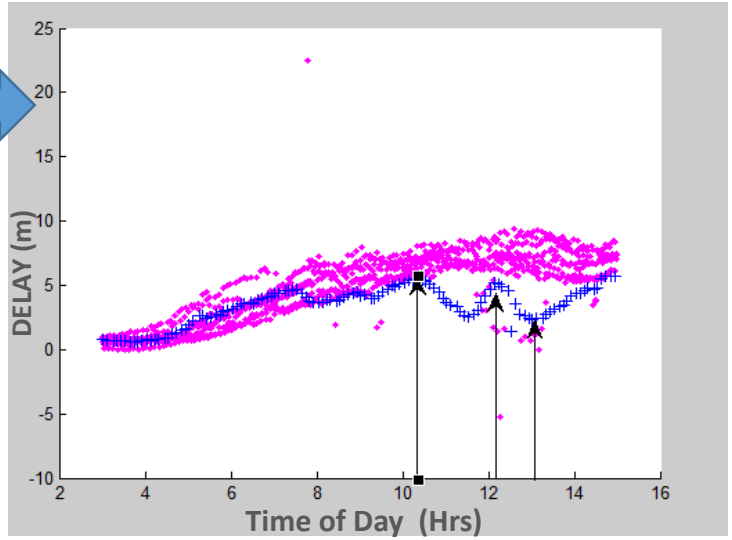
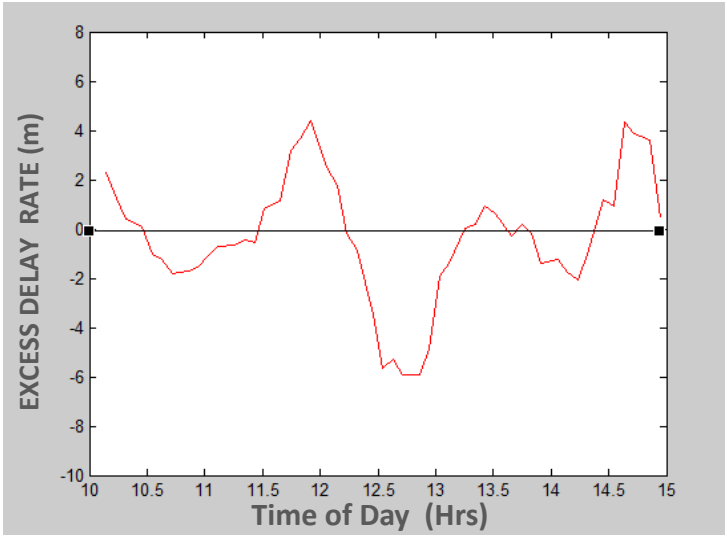




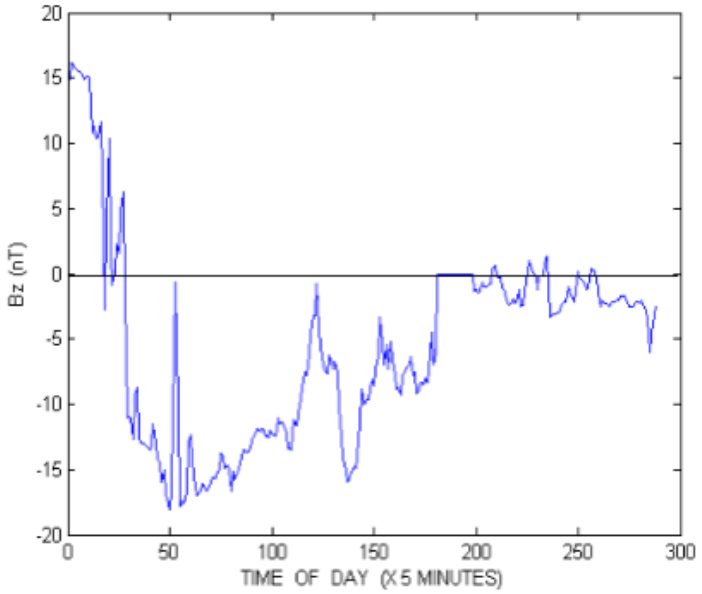


Data and pre processing:

- GAGAN TEC data used at 10°N,75°E
- Normalized by solar flux intensity
- The mean variation of 5 most quiet days of the month taken as nominal reference
- ΔTEC derived as the difference between the current TEC value and the reference value at the current time
- d ΔTEC/dt obtained numerically
- d ΔTEC/dt used as data

Modelling ionospheric Perturbation due to IMF Variation

YEAR	MONTH	DAY
12	3	9
12	4	24
12	7	9
12	7	15
12	10	1
12	10	9
13	3	17
13	6	1
13	10	2
15	**3**	**17**
15	6	22
15	6	23
15	9	11
15	9	20
15	10	7
15	12	20
15	12	21
17	3	27
17	5	28
17	9	7
17	9	8
17	9	28



Data and pre processing:

- Data obtained from the OMNIWeb repository of SPDF https://spdf.gsfc.nasa.gov/pub/data/omni/high_res_omni/
- data at 5 minutes interval used
- $-dE_y/dt$ data used as input
- Variation in dB_z/dt >12 nT/5min considered as event
- $-dE_y/dt$ values where the gradient is less is clipped to zero
- A temporal array of 1hour is used

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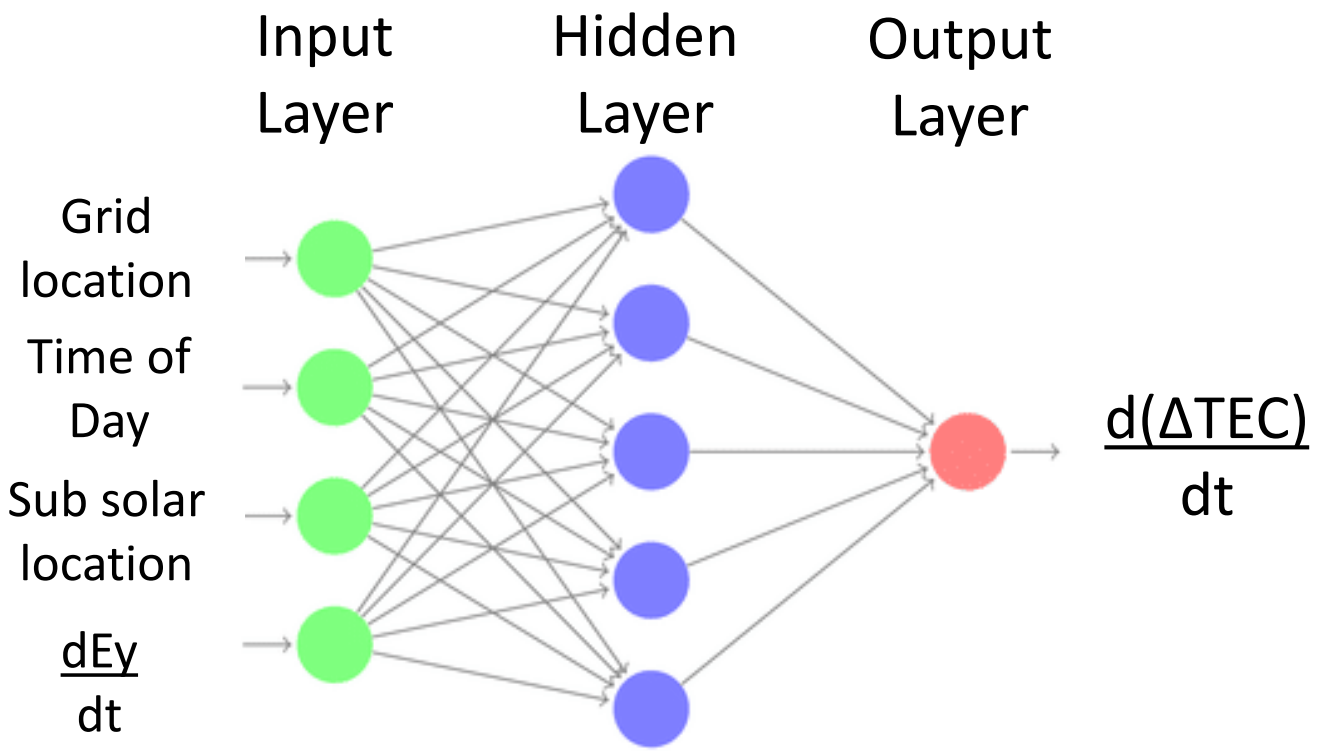

Neural Network Architecture:

- Neural Network of 1 hidden layer of 50 neurons designed
- Sigmoid non-linearity used
- Back propagation used for learning /weight adjustment
- Least mean error used as reference

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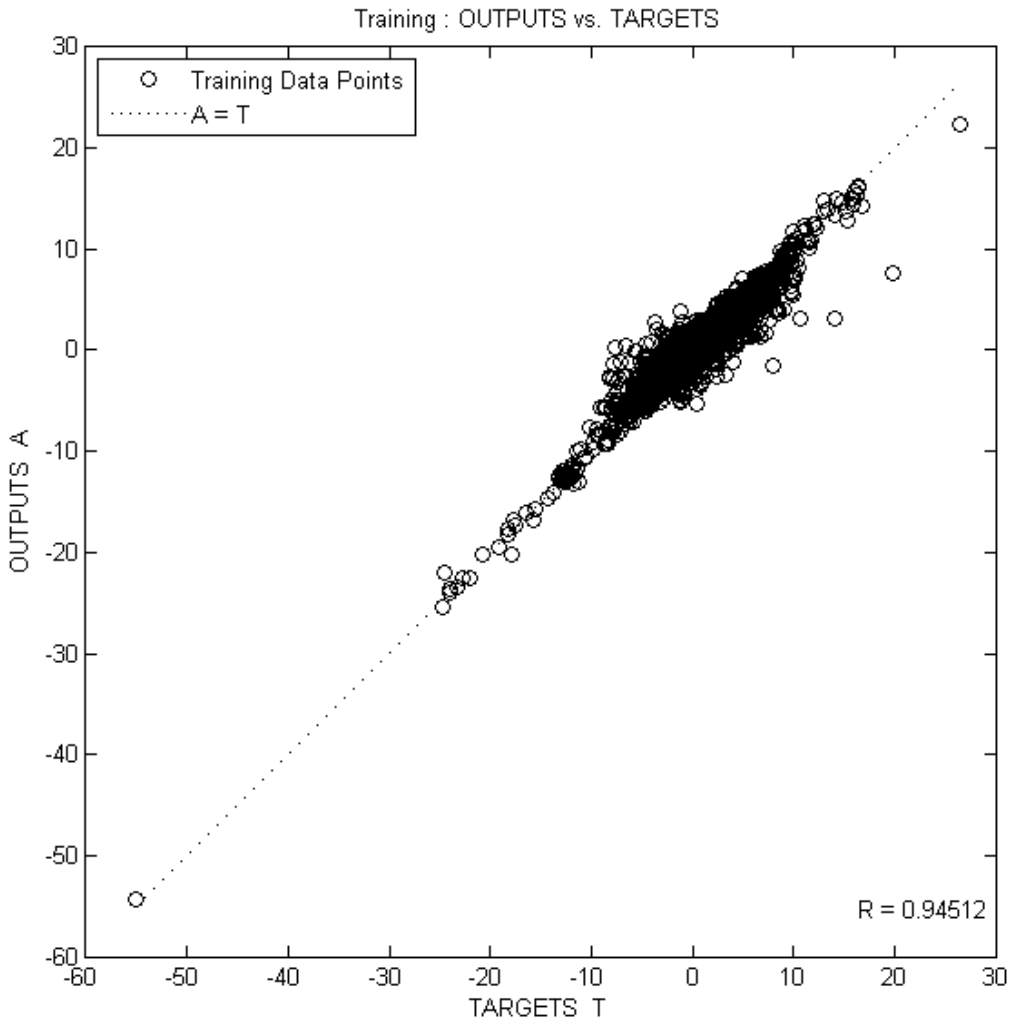

Approach and Training:

- Model is attempted for data only for the daytime
- dBz/dt, sub solar location, local time are taken as input
- Network trained for d ΔTEC/dt output
- LME based training with back propagation used
- Training done with >5000 samples
- Training r = 0.95 obtained
- Very good fit was obtained during training

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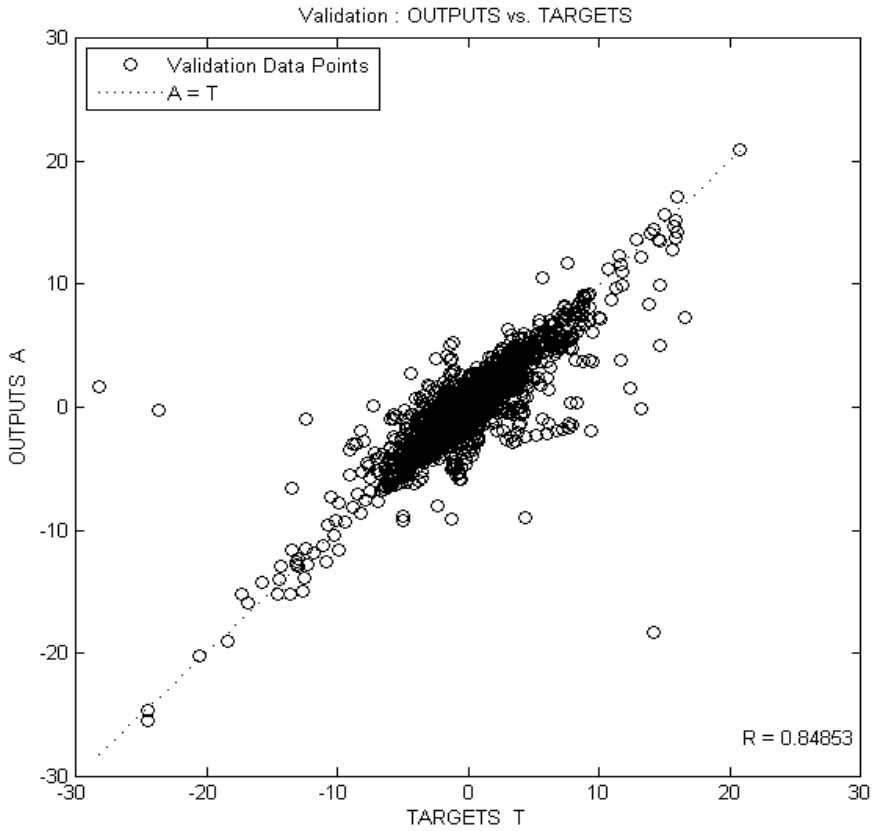
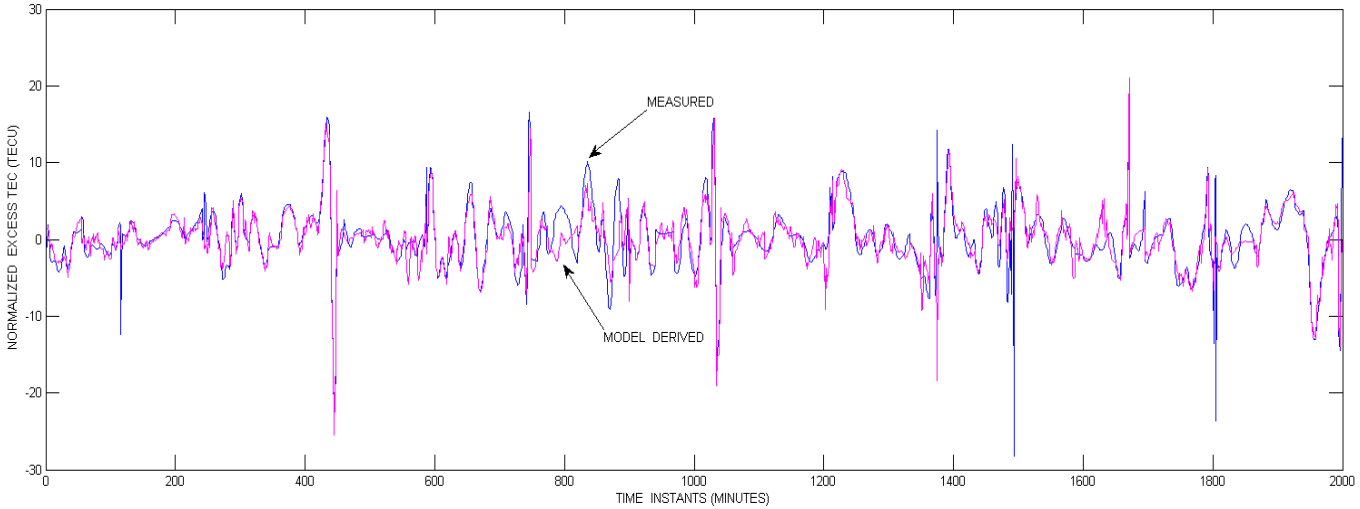


Validation Results:

- Data for date used as input
- Testing done with >3000 samplers
- r = 0.84 obtained during validation
- Fair accuracy observed in temporal variation



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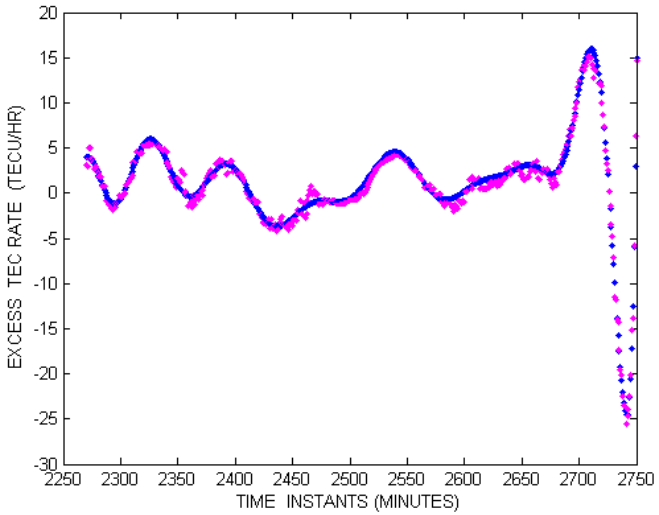

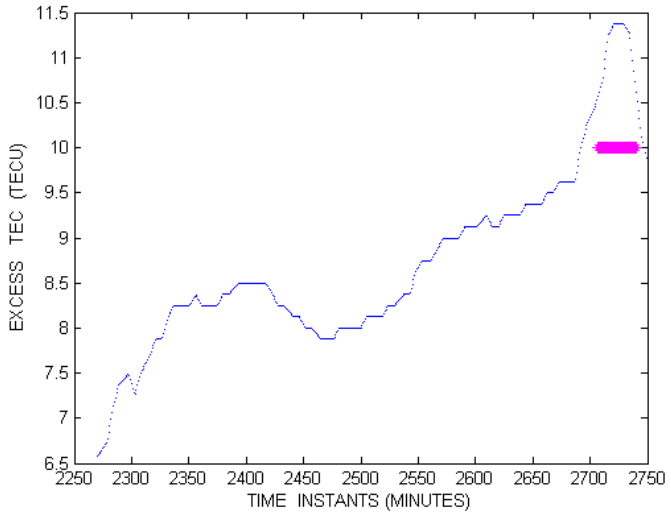

Results:

- d ΔTEC/dt compared with actual measurements on data of an arbitrary storm day
- d ΔTEC/dt integrated to obtain the variation of excess TEC, i.e. ΔTEC with time of day
- Arbitrary threshold of 10 TEC taken as alert level
- Alert generated when the derived excess TEC exceeded 10 TEC
- When tested with many other days, there were considerable amount of false alarm and missed event
- This needs improvement

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Essence of Work done:

- SW variable dBz/dt is used as the driving parameter for equatorial TEC variations
- Neural network based model developed between dEy/dt and dΔTEC/dt
- Storm data from more than 4 years (22 storm events; 8000 samples) used
- Excess TEC (ΔTEC) is obtained from derived values
- Alert generated for excess of 10 TEC over quiet day variation
- IMF at L1 point takes about an hour more to impact on the magnetosphere and cause the ionospheric variations
- The measurements data done at the L1 point can be transmitted to earth in few seconds
- Therefore, about an hour of lead time can be obtained from the impact predicted from the derivation of this data and the actual impact

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Final Outcome:

- Model to identify the ionospheric perturbation due to IMF variation
- Can alert the user in advance and add to integrity for single frequency GNSS receivers
- Provide further insight into solar and heliospheric influence on ionosphere

Limitations and Issues

- Need to obtain PP event which are isolated from any DDEF
- Isolated events are sparsely occurring: Hard to distinguish penetration from neutral wind effect

Future plans

- Improve the obtained model with other sophisticated training algorithms
- Add more auxiliary data which factors the variation to get better accuracy


Thank You