Modelling of Ionospheric Irregularities during Geomagnetically Disturbed Conditions over the African Low Latitude Region

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Out Line

- Aim of the study
- Geomagnetic Disturbance Effect on Ionospheric Irregularities
- Data Resources, Analysis and Organisation
- Results of Guiding analysis
- The model; Its validation and Error analysis
- Conclusions

Aim

Develop a model that estimates occurrence of ionospheric irregularities at nights of geomagnetically disturbed days,

when given:

- Dst values during the day
- AE indices during the day
- F10.7 flux of the day, and
- Day of the year number

Generation of Ionospheric Irregularities during Geomagnetically Disturbed Conditions

Governing factor is the plasma drift, given by $\vec{E} \times \vec{B}$

- the prompt penetration of high latitude electric fields during day time (10:00 - 17:00 LT) result in to up-ward drift
- dynamo action of storm time winds during day time result in to down-ward drift
- Intensification of ring current during day time result in to reduction of the drift

Data Resources, Analysis and Organisation (1)

- The geomagnetically disturbed days were identified when Dst $\leq$ -50 nT on that day.

  Dst indices were also used to establish the occurrence of day time intensified ring current.

- AE indices during the disturbed days were used to determine the occurrence of D*dyn*.

Data Resources, Analysis and Organisation (2)

- The RINEX data files from the UNAVCO stations shown on the Map on disturbed days were used to derive TEC.

  The GPS-TEC Analysis software that was developed by Dr. Gopi Semala (IIG) was used to process the RINEX files.

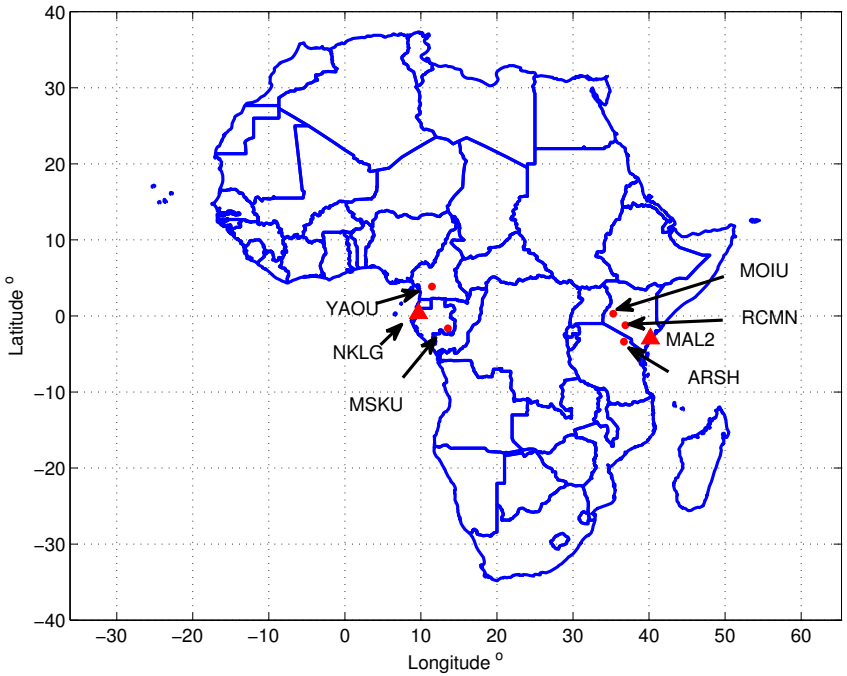

Figure: 1

Data Resources, Analysis and Organisation (3)

- The ROT were computed using

$$\mathrm{rot} = \frac{\mathrm{VTEC}_k^i - \mathrm{VTEC}_{k-1}^i}{t_k^i - t_{k-1}^i}, \tag{1}$$

where VTEC_k^i and VTEC_{k-1}^i are consecutive VTEC values at epochs t_k^i and t_{k-1}^i corresponding to observed satellite i.

ROTI indices were computed from ROT by taking standard deviations over 5 minute interval.

Data Organisation

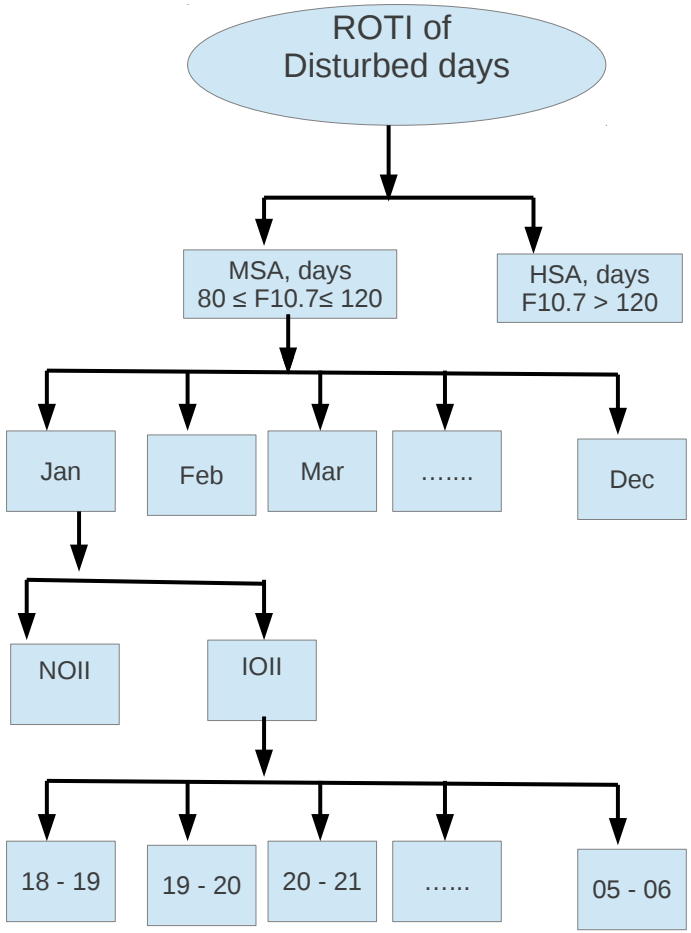

Figure: 2

Data Resources, Analysis and Organisation (5)

Days with day time significant ring current intensification were identified

when Dst remained below -50 nT for $>$3 hours consecutively.

Data Resources, Analysis and Organisation (5)

When one of the conditions,

1. $\triangle \mathrm{AE}(t) \leq 150$, Average AE before 2 - 4 hrs from t is ≤ 300, and $\triangle \mathrm{AE}(t-1) \geq 125$,
2. $|\triangle \mathrm{AE}| \leq 150$, Average AE before 2 - 4 hrs from t is ≥ 200,
3. $\triangle \mathrm{AE}(t) \leq$ -125, Average AE before 2 - 4 hrs from t is ≥ 125
4. $|\triangle \mathrm{AE}| \leq 150$, Average AE before 2 - 4 hrs from t is ≥ 175, $\triangle \mathrm{AE}(t-1) \leq$ -125,

occurred at day time epoch, t, the epoch was termed as delayed dynamo epoch.

Fejer, B. G., L. Scherliess (1995), Time dependent response of equatorial ionospheric electric fields to magnetospheric disturbances, Geophys. Res. Lett., 22 (7), 851-854.

Data Resources, Analysis and Organisation (6)

Night with ionospheric irregularities inhibited was defined as,

$$\mathrm{MDR} + 2\sigma \geq \mathrm{MNR}, \tag{2}$$

where MDR, represents the mean of day time ROTI,

σ, the standard deviation of day time ROTI values, and

MNR is the mean of ROTI values during 20:00 - 03:00 LT.

Results of Guiding Analysis (1)

ROTI data over MAL2 for disturbed 109 nights during 2000 and 2001 were examined for inhibitions.

Effectively, 103 nights clearly indicated either inhibition or occurrence of irregularities.

50 nights indicated inhibitions.

Percentage of inhibitions correctly predicted by ring current intensification = 62

Percentage of ring current intensifications that occur simultaneously with inhibitions = 62

Results of Guiding Analysis (2)

Percentage of inhibitions correctly predicted by $D_{dyn} = 56$

Percentage of D_{dyn} that occur simultaneously with inhibitions $= 61$

Percentage of inhibitions correctly predicted by either ring current intensification or $D_{dyn} = 80$

Percentage of occurrence of either ring current intensification or D_{dyn} occurring simultaneously with inhibitions $= 57$

Results of Guiding Analysis (3)

Therefore, occurrence of ring current intensification or D_{dyn} were used to infer inhibitions of irregularities.

To compensate for the in efficiency in determing inhibitions, lower and upper quartiles of all data in a month were used to represent monthly data with and without inhibitions, respectively.

The Model (1)

The ionospheric irregularity strength (hourly ROTI) was expressed as a tensor product as follows:

$$\mathrm{ROTI}(t, m, F, E) = \sum_{i=1}^{12}\sum_{j=1}^{12}\sum_{k=1}^{2}\sum_{l=1}^{2} a_{i,j,k,l} N_{i,4}(t) N_{j,2}(m) N_{k,2}(F) N_{l,2}(E), \tag{3}$$

- $N_{i,4}(t)$ is a cubic B-spline of order four applied to LT dependence (t).
- $N_{j,2}(m)$, $N_{k,2}(F)$, and $N_{l,2}(E)$ are cubic B-splines of order two applied to monthly (m), solar flux (F), and storm effect (E) dependences, respectively.

The model; Its validation and Error analysis (2)

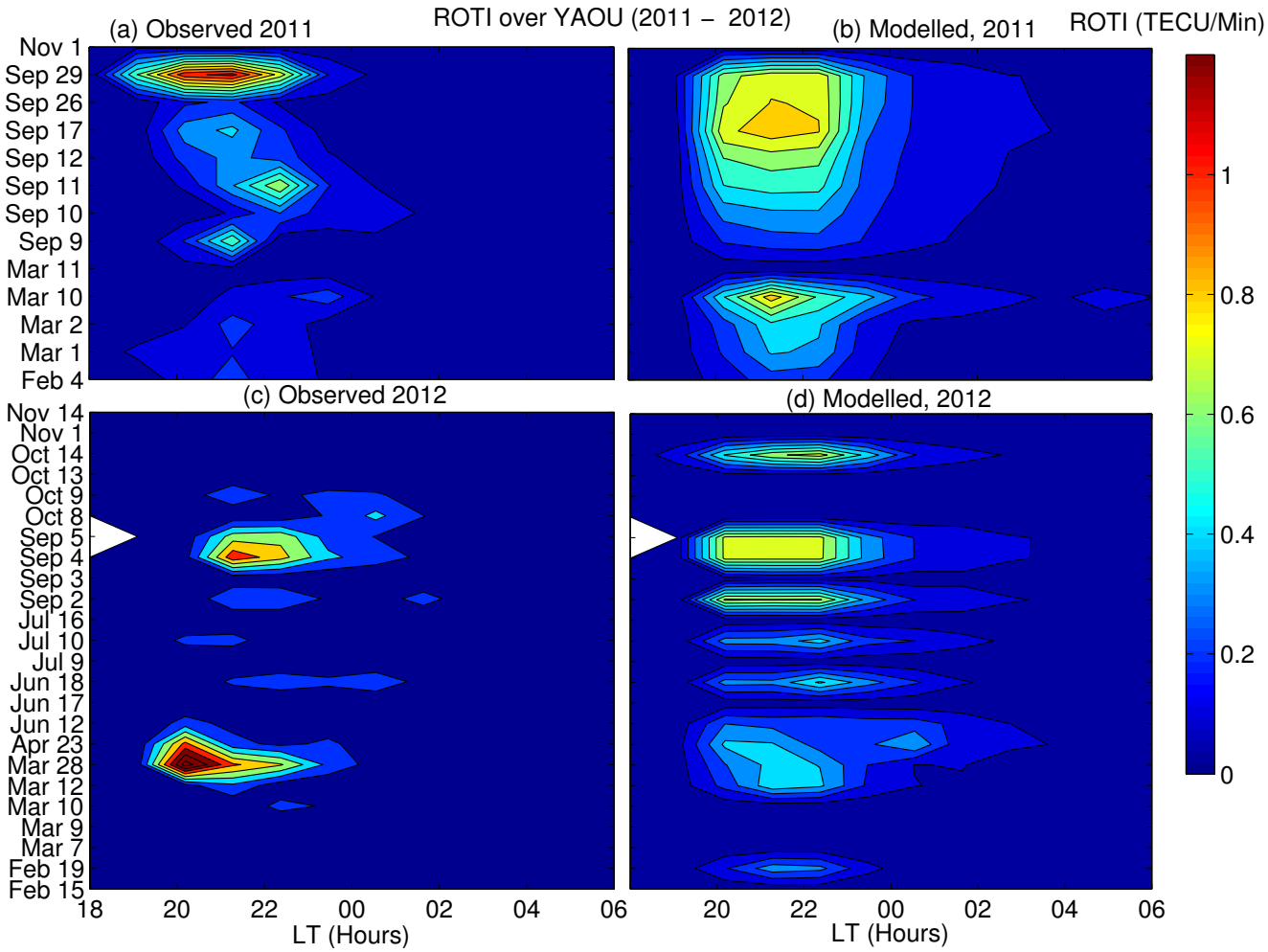

Figure: 3

The model; Its validation and Error analysis (3)

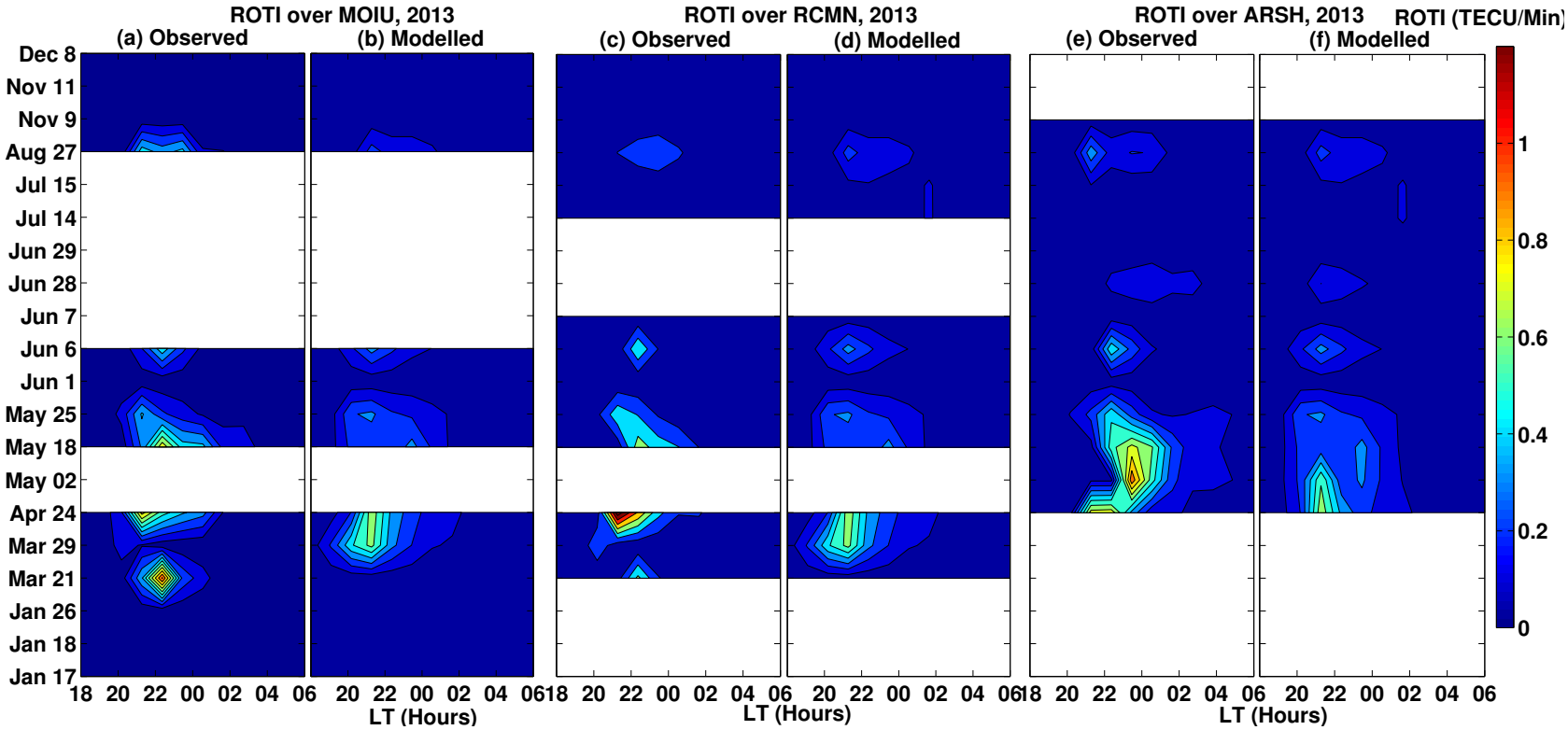

Figure: 4

The model; Its validation and Error analysis (4)

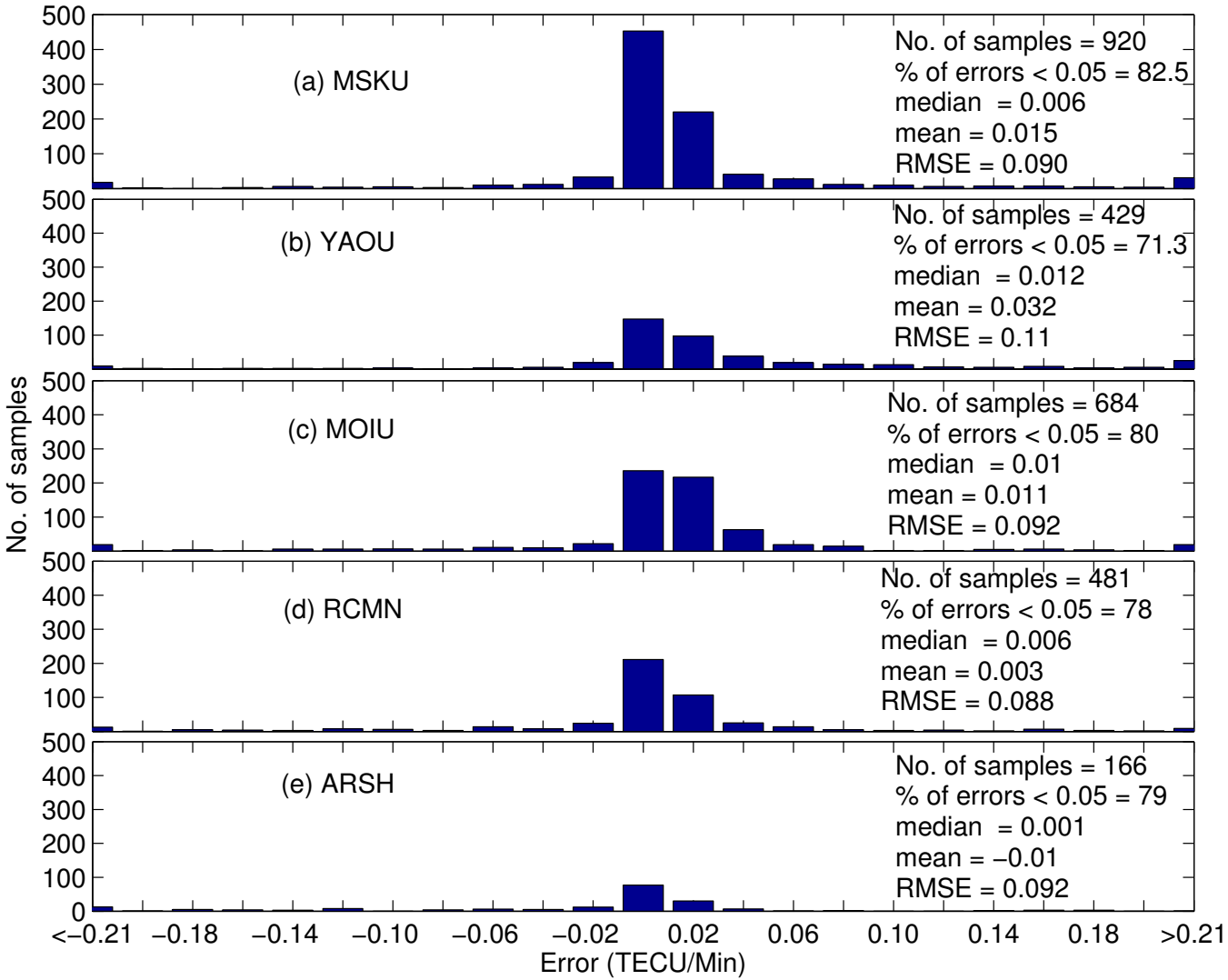

Figure: 5

Conclusions (1)

- The models that were developed reproduced the inhibitions and occurrences of ionospheric irregularities during disturbed geomagnetic conditions over the stations where validations were done.
- The models emulated these patterns in the various seasons during medium and high solar activity conditions.
- The RMSE values for the validations were mostly < 0.1 TECU/Min.

Conclusions (2)

- During validations of the models, the percentages of the number of errors <0.05 TECU/Min were all > 70 %.
- To improve the performance of these models, the problems of in-efficiency in predicting inhibitions and the predicted inhibitions not always occurring need to be addressed.
- This might be achieved by incorporating information on meridional winds in the prediction of inhibitions.
- The in-adequate number of days in some cases used to derive monthly ROTI which in turn were used in model development might be another limitation of the current models.

Acknowledgement

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