Validation of modeled plasma density changes during geomagnetic storms

Parameters: TEC, NmF2, hmF2

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Examples: Build-up of plasma and structure at mid-latitudes

- TEC maps from GPS available in some regions and longitude sectors
- RO and in-situ satellite observations
- Point locations with ionosondes

Foster and Coster

Mannucci et al 2005

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Ionosonde NmF2, hmF2 at Millstone Hill (positive and negative response)
Suggested metrics for model validation of storm response

• Challenges
  • Bias in TEC measurements and map - use storm-quiet response
  • hmF2 from ionosondes is an indirect measure
  • Predicting the magnitude of a feature in the wrong place (high RMSE)

• Possible methodologies and metrics
  • Differential validation – used to validate TEC maps from GPS
  • RMSE comparison with regional TEC maps (or difference from normal)
  • RMSE with N/S cuts through TEC maps in well-observed sectors
  • RMSE with ionosonde NmF2 and hmF2 (or +/- phases, divide into low, mid, and high latitude response)
  • RMSE with in-situ satellite $N_e$
Example of regional TEC map

Target Users: Positioning and Navigation community

- Kalman filter over CONUS + ground-based GPS data, IRI background model, solve for receiver biases, 15-minute cadence, 15 to 30 minute latency

- What is accuracy of storm response
Differential Code and Phase

Site = arp3, SV = 1, L1 - L2 Phase, L2 - L1 Pseudorange in Meters

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“Differential” Validation

- Integrate through US-TEC model at two different times.
- Compare directly to the phase difference in the original RINEX data file.
- As time separation increases, errors in US-TEC map become uncorrelated and approach true uncertainty.

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Araujo-Pradere et al. 2006
US-TEC “Differential” Validation

- Validation stations not included in assimilation process
- Build up statistics every 5th day over 6 months
- Daily average RMSE for each site
Validate models against regional TEC maps

- RMSE
- departures from normal

Observational TEC map accuracy:

Slant = 2.4 TEC units
Vertical = 1.7 TEC units
Global TEC data (Goncharenko, Coster)

- GPS TEC, MIT Haystack Observatory:
  - ~2000 GPS receivers, 5 min, 1°x1° resolution
  - Longitudes selected: 75°W, 40°E, 120°E
- Too many gaps for a global RMSE

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GPS TEC cut through 75°W, 12LT

- Hourly or daily RMSE along three longitude sectors
- Departures from normal

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Ionosondes at low, mid, and high latitude
NmF2, hmF2, RMSE, difference from average

Station map and examples of real-time validation:

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Validation Statistics: "differential" TEC

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2.4 TEC units
Process 6
Evolution of neutral composition change

Response and recovery of O/N\textsubscript{2}
Movement of boundaries in O/N\textsubscript{2}
Observations: TIMED/GUVI, SSUSI, GOLD,....

Process 7
Ionospheric negative storm phase at mid latitude

- Validate TEC from GPS maps
- Validate in-situ from satellite
- Validation point with ionosondes
Process 8
Disturbance dynamo

Difficult to validate.
Confused by penetration electric field and its time constants.

Process 2 and 8

- Possibility: Combine penetration and disturbance dynamo at low latitudes

Time series of electric field (e.g., Jicamarca, magnetometers).
Validation of total E at low latitudes, penetration + dynamo + time constants
Validate total EIA response
Suggested process-orientated storm metrics for model validation

Process 1: Quantifying the geomagnetic storm energy dissipation

Process 3: Build-up of plasma and structure at mid-latitudes

Process 4: Gravity wave propagation from high to low latitude

Process 6: Evolution of neutral composition change

Process 7: Ionospheric negative storm phase at mid latitude

Process 2 and 8: Combined penetration and dynamo electric fields