Global 3-D ionospheric electron density reanalysis based on multi-source data assimilation

UCAR/COSMIC: Xin’an Yue (乐新安), Bill Schreiner
Bill Kuo, Doug Hunt,...

NCAR/HAO: Wenbin Wang, Stan Solomon, Alan Burns,...

NSPO: J. Y. (Tiger) Liu

GFZ: Jens Wickert
Content

- Motivation
- Model and Data description
- Reanalysis results and evaluation
Motivation:

- Global atmosphere, ocean, and land fields reanalysis (ECMWF, NCAR/NCEP) has shown great impacts in climate monitoring, related scientific research, and numerical weather prediction.

- For the ionosphere, the main useful parameter is the electron density. RO data, especially the launching of COSMIC, make global electron density reanalysis possible for the first time.

- UCAR/CDAAC processes many data for multi-missions. Doing a reanalysis can make good use and archive of these data. It will benefit the ionospheric weather, climate, variability study, applications (e.g., calibrate ionospheric large scale residuals in neutral atmosphere RO retrievals).
Global ionospheric data assimilation model:

- **Background model:** empirical model (IRI), no time forward of error covariance in this study.

- **Spatial Resolution:** flexible, 2.5 latitude, 5 longitude, 20 km altitude in this study.

- **Background correlation:** Gaussian correlation, cutoff when dlat>10 degrees, dlon>20 degrees, and dalt>60 km.

- **Observation correlation and error:** un-correlated; 1% of background error.

- **Time resolution:** flexible, 1 hour in this study.

- **Altitude range:** flexible, 80-2000 km in this study, plasmasphere is calibrated by a simple H+ model.

- **Method:** Kalman filter.
Data source: Good Coverage
Ground based GNSS sTEC process mainly include:

- cycle slip detection;
- Leveling of phase TEC to pseudo-range TEC;
- Differential Code Bias (DCB) estimation: aided by IGS GIM (Global Ionospheric Map)
LEO based GNSS sTEC process mainly include:

- cycle slip detection;
- Multi path calibration;
- Leveling of phase TEC to pseudo-range TEC;
- Differential Code Bias (DCB) estimation: spherical symmetry assumption
Satellite environmental temperature effects on the Differential Code Bias (DCB) estimation: CHAMP DCB drift agrees well with orbit neutral temperature variation
Reanalysis results: Global 3-D electron density example

NmF2 ($10^5 \text{cm}^{-3}$)

TEC (tecu)
Reanalysis evaluation 1: Compare with IGS GEC

Big improvement over IRI prediction
Reanalysis evaluation 2: Compare with Poker Flat ISR (65N, 147W)
Reanalysis evaluation 3: Compare with global Ionosonde: example (Townsville; 19S, 147E)
Further Evaluation: Aurora Zone Electron Density Enhancements (120km Ne, Left: IRI; Right: Reanalysis)
Further Evaluation: Winter Anomaly (In middle latitude, the daytime electron is higher in Winter than in Summer, disappear in this solar minimum)
Future Plan:

- Publish the preliminary reanalysis data as Level3 product after further evaluation.
- Develop an Accurate Nowcast/Short-Term Forecast system of Ionosphere/Thermosphere based on huge COSMIC-2 data and TIEGCM (or other theoretical) model.

See details from: Yue et al., 2012JA017968