Ionospheric Vertical Correlation Distance Calculation Based on COSMIC Electron Density Profile Data

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DATA-11

Introduction & Background

Background error covariance contains error information of the model background field and determines the influence degree of observations on models. The vertical component of background error covariance matrix shapes the assimilated electron density profile, which requires the information about the vertical ionospheric correlations.

Motivation:

1. The settings for vertical correlation distances (VCD) remain unclear and lack data support.
2. The full-day and global-distribution ionospheric detection provided by COSMIC contains a wealth of vertical ionospheric information that can be used to study the vertical correlation of the ionosphere.

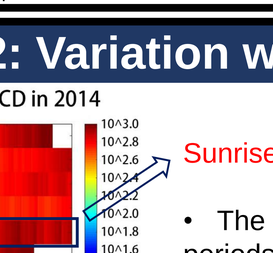
cost function

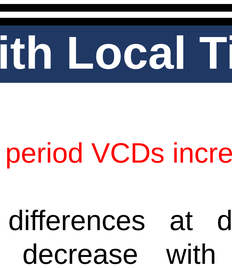
$$J = \frac{1}{2}[y - Hx_b]^b R^{-1}[y - Hx_b] + \frac{1}{2}[x - x_b]^T B^{-1}[x - x_b]$$

$$B = \overline{\varphi\varphi^T} \quad \varphi = x_b - x_t$$

$$B_{ij} = V_{ij} C_{ij}^{ver} C_{ij}^{hor}$$ → Horizontal & Vertical component

Local time variation of correlation distances





Altitude variation factor of vertical correlation distances

[Yue et al., 2011]

Data Processing

DATA: COSMIC occultation electric density profiles data in 2008 & 2014

1.Fitting: fit the Chapman function with profile data between 200-750 km to obtain profiles of 200-2000 km.

Fig.1 COSMIC satellite

$$N_e(h) = N_m F_2 \exp\left\{0.5\left[1 - \frac{h - h_m F_2}{H(h)} - exp\left(-\frac{h - h_m F_2}{H(h)}\right)\right]\right\}$$

$$H(h) = A_1(h - h_m F_2) + H_{m1}$$

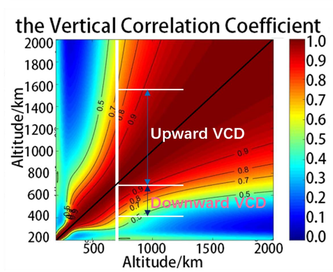
$$H(h) = A_2(h - h_m F_2) + H_{m2}$$

2.Binning: choose profiles within the 3σ, the binning with altitude at 5-km, LT at 4-hour, Mlat at 10°

3.Correlating: calculate the corresponding electric density profiles of IRI model and the correlations in each bin

4.Converting: the correlation converted into the upward and downward correlation distance with a truncation value of 0.7

$$X = \Delta_{h1}[COSMIC - IRI]$$
$$Y = \Delta_{h2}[COSMIC - IRI]$$
$$r_{h1,h2} = \frac{Cov(X,Y)}{\sqrt{Var(X) \cdot Var(Y)}}$$



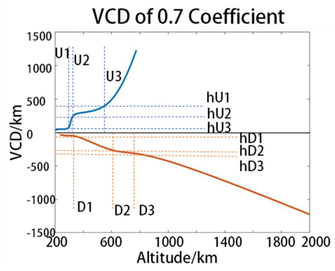


Fig.2 An example of transformation of distribution of VCD

Result 1: Variation with Geomagnetic Latitude

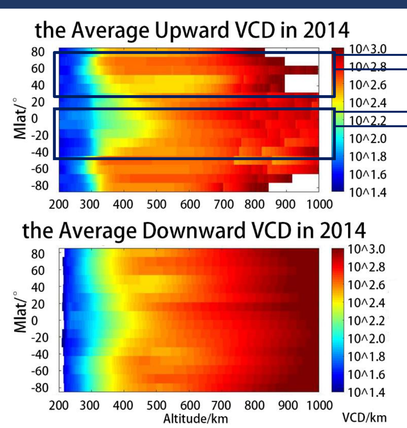


Fig.3 Statistical results of correlation distance variation with MLAT for 2014

Increase faster at middle and high latitudes

Increase slower at the equator and low latitudes

- not identical between the upward and downward directions
- north–south hemisphere trend symmetrical variation
- in high-solar activity years are greater than that in low-solar activity years
- not a continuous increase, the main difference is concentrated under 800km

Result 2: Variation with Local Time

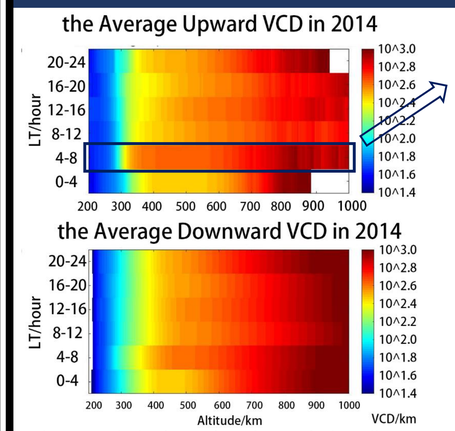


Fig.4 Statistical results of correlation distance variation with LT for 2014

Sunrise period VCDs increase fastest.

- The differences at different LT periods decrease with increasing MLAT
- The variation in the distances associated with sunrise is most dramatic in the equatorial low MLAT region.
- The LT variation trend in the middle MLAT region is lower than that in the equatorial low MLAT region.

Result 3: Variation with Altitude

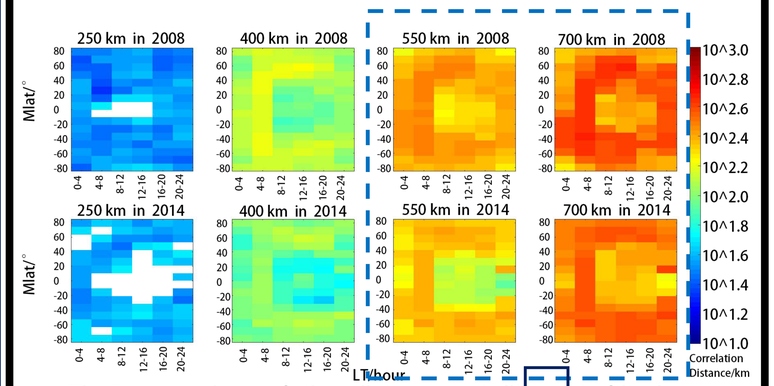


Fig.5 Upward correlation distances at different altitudes

Smallest: in the daytime low latitude region
Largest: in the daytime mid-latitude region and at sunrise

- The U1 height may be correlated with hmF_2.
- U2 to U3 usually remain stable may be due to the maintenance of the bipolar diffusion balance.
- U3 may be related to the upper transition height.

Conclusion

1. The VCDs are not identical between the upward and downward directions. VCDs in high-solar activity years are greater than that in low-solar activity years.
2. The VCD increase faster with increasing altitude at middle and high latitudes, while they grow more slowly at the equator and low latitudes. The VCD associated with sunrise is most dramatic in the equatorial low-latitude region.
3. The largest differences are found during the different time periods in the low-latitude region, while the differences at different LT periods decrease with increasing MLAT.
4. The turning point of VCD growth rate may be related to hmF_2 and upper transition height.

Future work: Compare the assimilation results using the new background error covariance matrix with the original assimilation results.

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