Electron density profiles of FORMOSAT-3/COSMIC at E-Layer

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- Purpose:
  - Combine 1 Hz and 50 Hz RO data to retrieve to fix electron density bias and quantify electron density profiles.
  - We present a very simple and efficient method (GPSARC) to fix electron density bias for lower ionosphere.
- Outline:
  - Principle of Fixing electron density
  - Results22
  - Conclusion

Principle of Fixing electron density (1/7)

Bending angle equation

$$\alpha(a_0) = \int_{a_0}^{a_{LEO}} \frac{2a_0}{\sqrt{a^2 - a_0^2}} \frac{d\ln(n)}{dr} dr$$

Abel-inversion of Refractive index

$$n(a_0) = \exp\left\{ \frac{1}{\pi} \int_{a_{LEO}}^{\infty} \frac{\alpha(a)}{\sqrt{a^2 - a_0^2}} da + \frac{1}{\pi} \int_{a_0}^{a_{LEO}} \frac{\alpha(a)}{\sqrt{a^2 - a_0^2}} da \right\}$$

Bending Angle Error (2/7)

$$\tilde{\alpha}_{LEO} = \alpha_{obs} + \alpha_{up.LEO} + \alpha_{asy} + \alpha_{diff.path} + \alpha_{clk} + \alpha_{drift} + \varepsilon$$

- $\alpha_{up.LEO}$: above the altitude of LEO satellite orbit,
- α_{asy} : asymmetric spherical distribution of ED,
- $\alpha_{diff.path}$: different path between L1 and L2 signals,
- α_{clk} : clocks error of GPS and LEO satellites,
- α_{drift} : tangent point drift,
- ε : hardware random error.

Observed BA is separated to:

$$\alpha_{obs} = \alpha_{abel} + \Delta\alpha$$

- α_{abel} represents the partial bending angle which satisfy the assumption of Abel-inversion,
- $\Delta\alpha$ represents the residual bending angle

Abel-inversion of Refractive index during 70-85 km

$$\exp\left\{ \underline{\underline{\frac{1}{\pi}\int_{a_0}^{\infty} \frac{\alpha_{abel}(a)}{\sqrt{a^2 - a_0^2}} da}} + \frac{1}{\pi}\int_{a_c}^{a_{LEO}} \frac{\Delta\alpha(a)}{\sqrt{a^2 - a_0^2}} da + \frac{1}{\pi}\int_{a_0}^{a_c} \frac{\Delta\alpha(a)}{\sqrt{a^2 - a_0^2}} da \right\}$$

$$= \exp\{\underline{\underline{0}} + \Delta n(a_0)\}$$

$$\approx \underline{\underline{1}} + \Delta n(a_0)$$

While tangent point Refractive is approximate to 0

Electron Density Bias during 70-85km:

$$\Delta n_e(a_0) \cong \frac{-f_1^2}{40.3} \Delta n(a_0)$$

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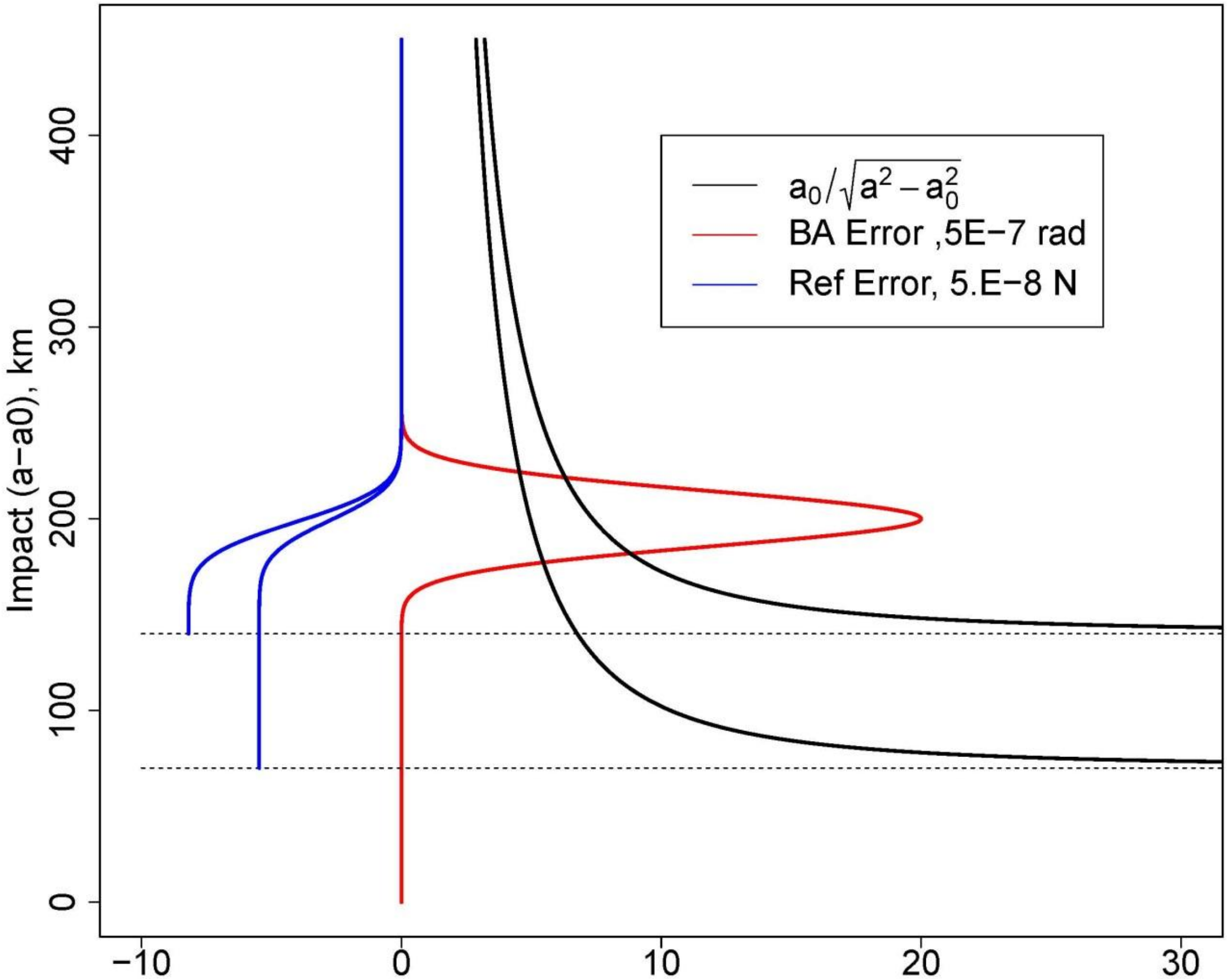
Concept of fix EDB method (4/7)



- Contributed function while tangent points locate at 70 km and 140 km respectively.
- Assume a Gaussian BA bias which center at 200 km .

The assumptions in GPSARC method (5/7)

- The contribution from bending angle bias converge to constant during higher ionosphere, due to the convergence of contributed function. (easy to satisfied).
- The bending angle bias is not too big during lower ionosphere, the contribution could converge to constant (little critical). We define an index (VEDB) to quantify the level of convergence.
- The refractivity is very small compared to electron density in E layer. The CIRA86 annual mean refractivity at northern hemisphere are approximate to

  $N=1.2\times10^{-2}$ N-unit (0.05mb, 201K, 70km,),

  $\boldsymbol{n_e = -1.2\times10^9}$ **#/m^3**

  $N=1.2\times10^{-3}$ N-unit (0.005mb, 210K, 85km),

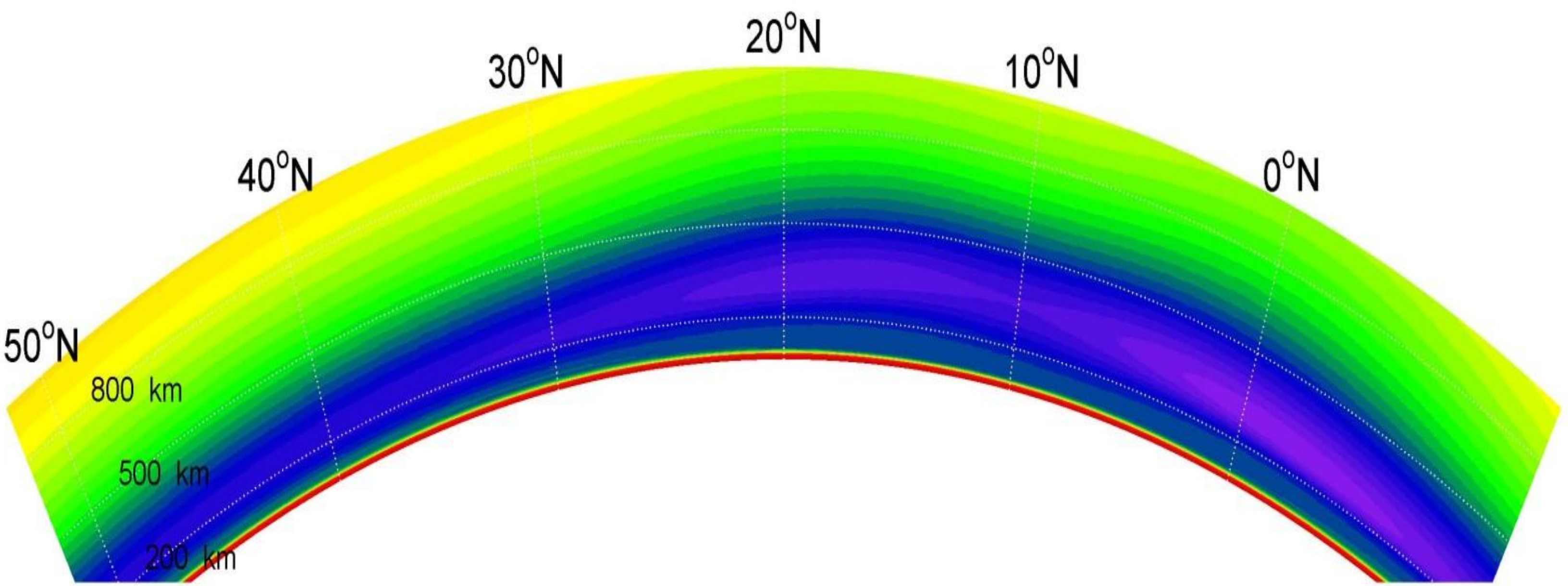
  $\boldsymbol{n_e = -1.2\times10^9}$ **#/m^3**

  $\boldsymbol{n_e \approx 10^9}$ **#/m^3** in D-region at day at equator.

  $\boldsymbol{n_e \approx 10^{11}}$ **#/m^3** in E-region at day at equator

Horizontal gradient error simulation by IRI-2007 (6/7)

- Lat = 20°N
- Signal Azi = 0°N
- yyyydoy = 2010.140



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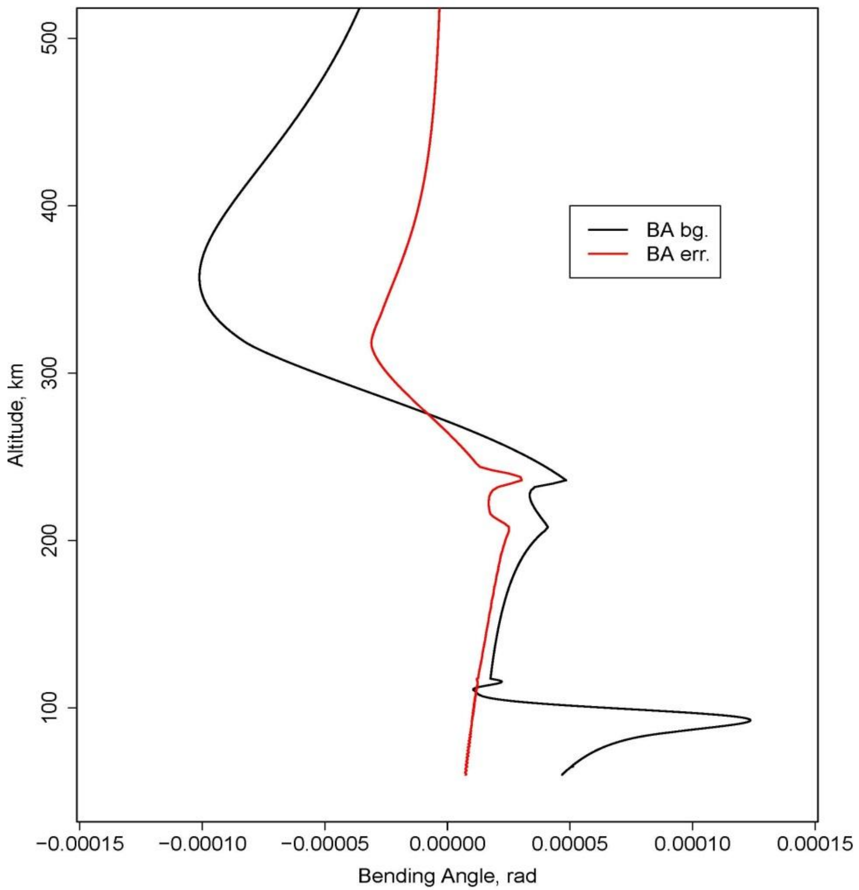
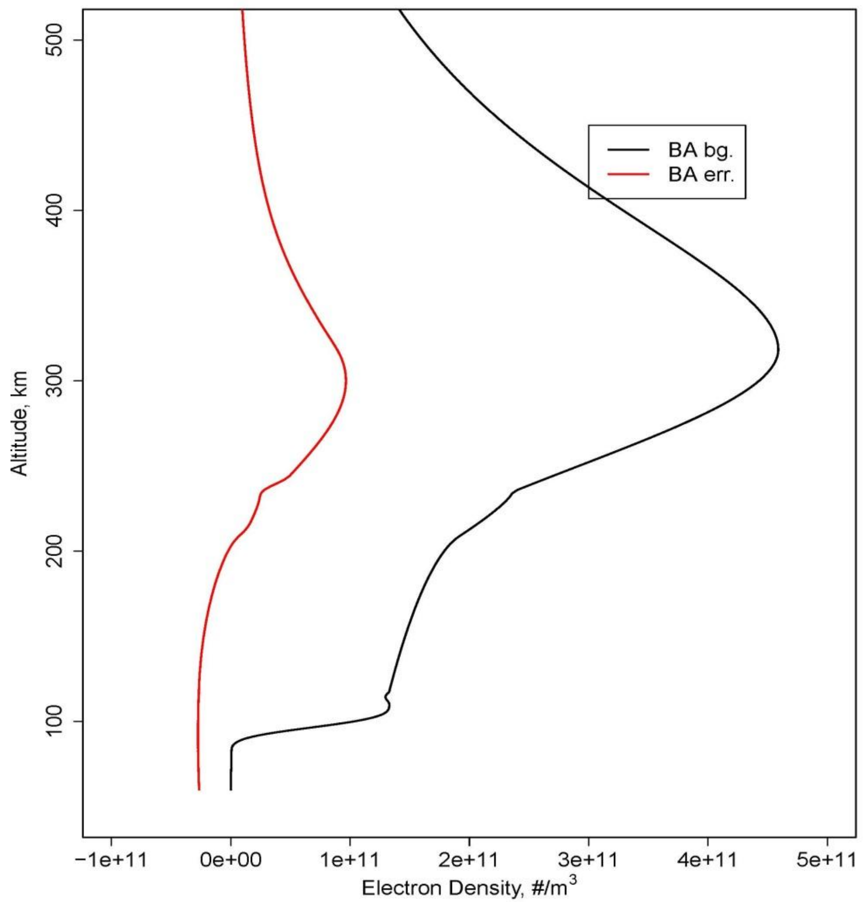
BA Bias and ED Bias (7/7)





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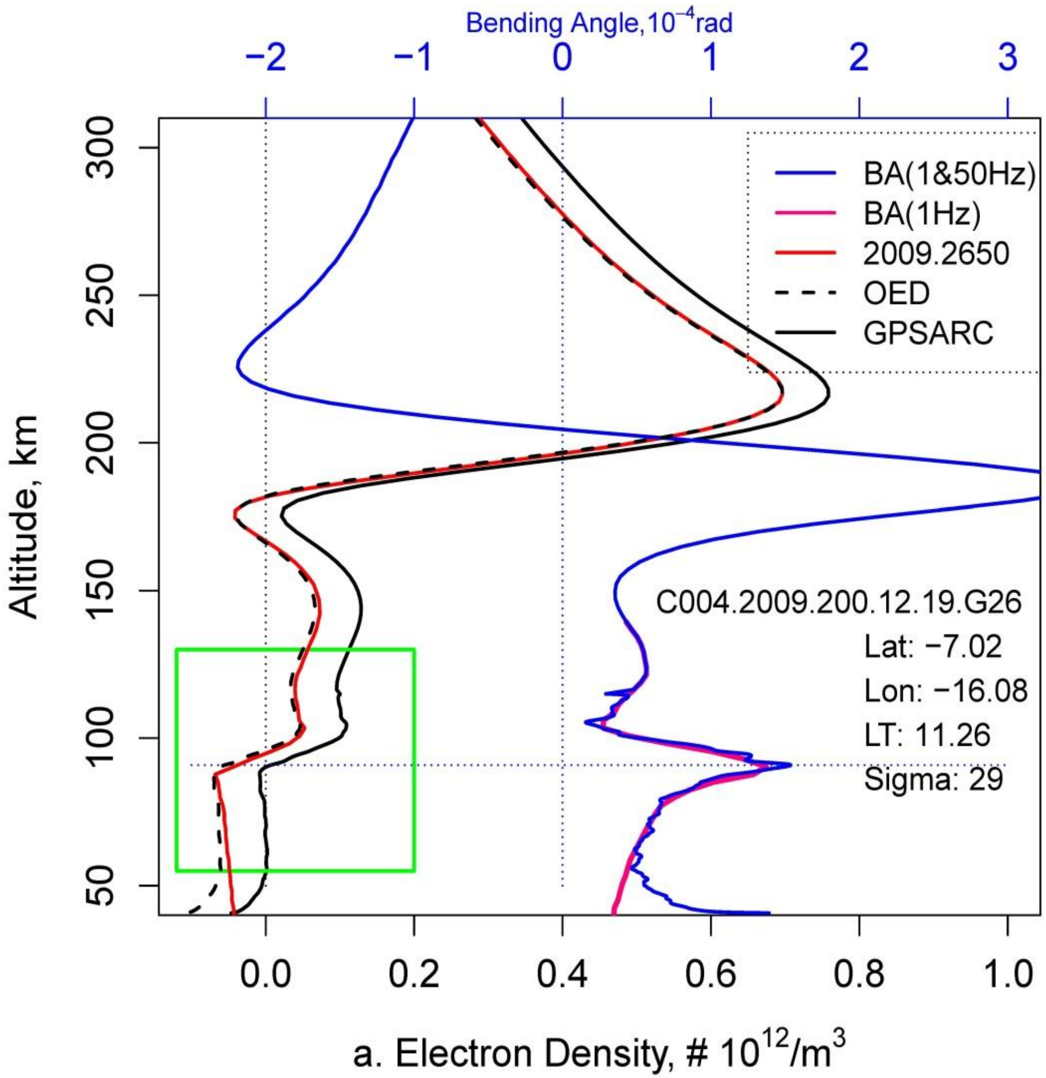
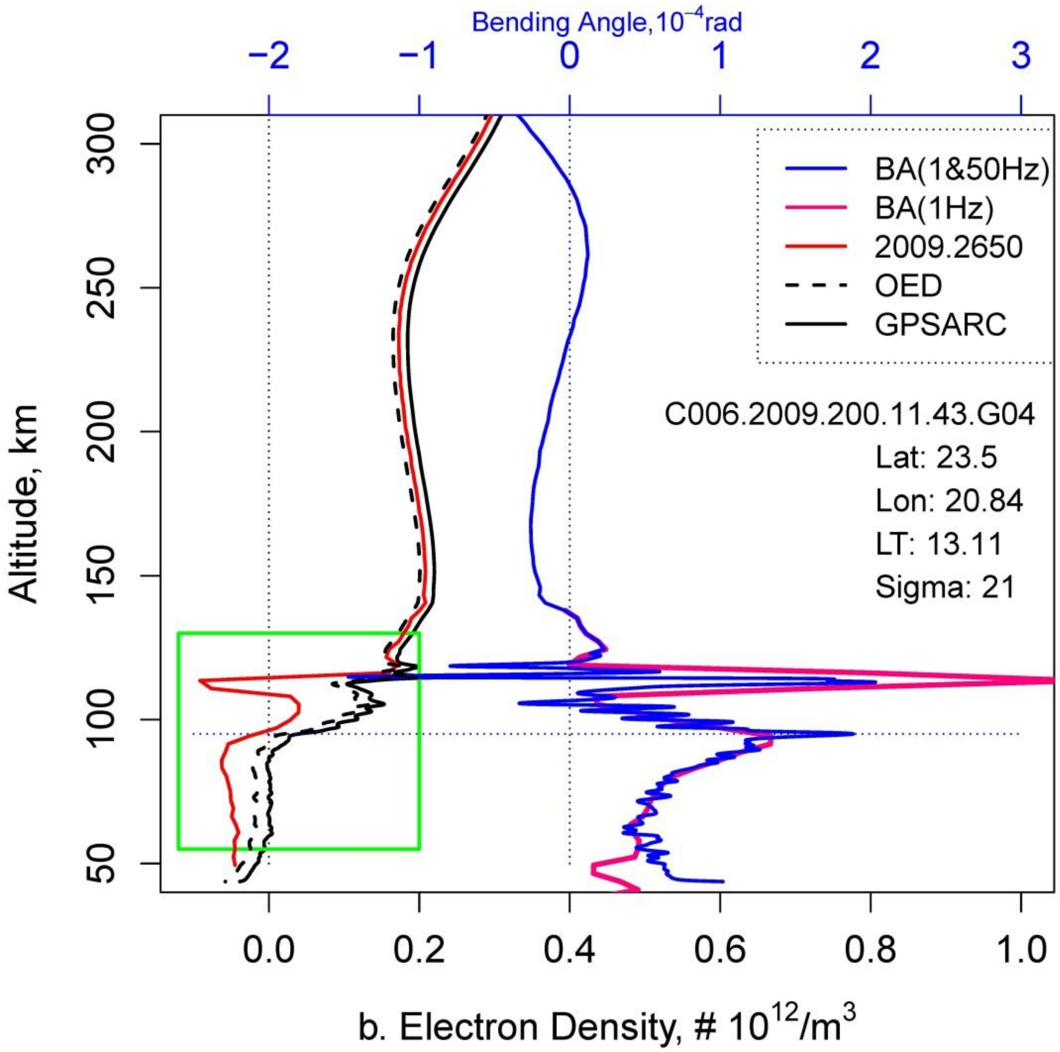
Results: RO Case I (1/5)



- Only L1 signals are used in 50 Hz, due to the poor quality of L2.
- The altitude of BA peak at E region is very close to the E layer bottom.

RO Case II (2/5)



- 1 Hz and 50 Hz Both catch the cycle slip, due to the higher spatial resolution.
- 50 Hz observe the tendency more better.

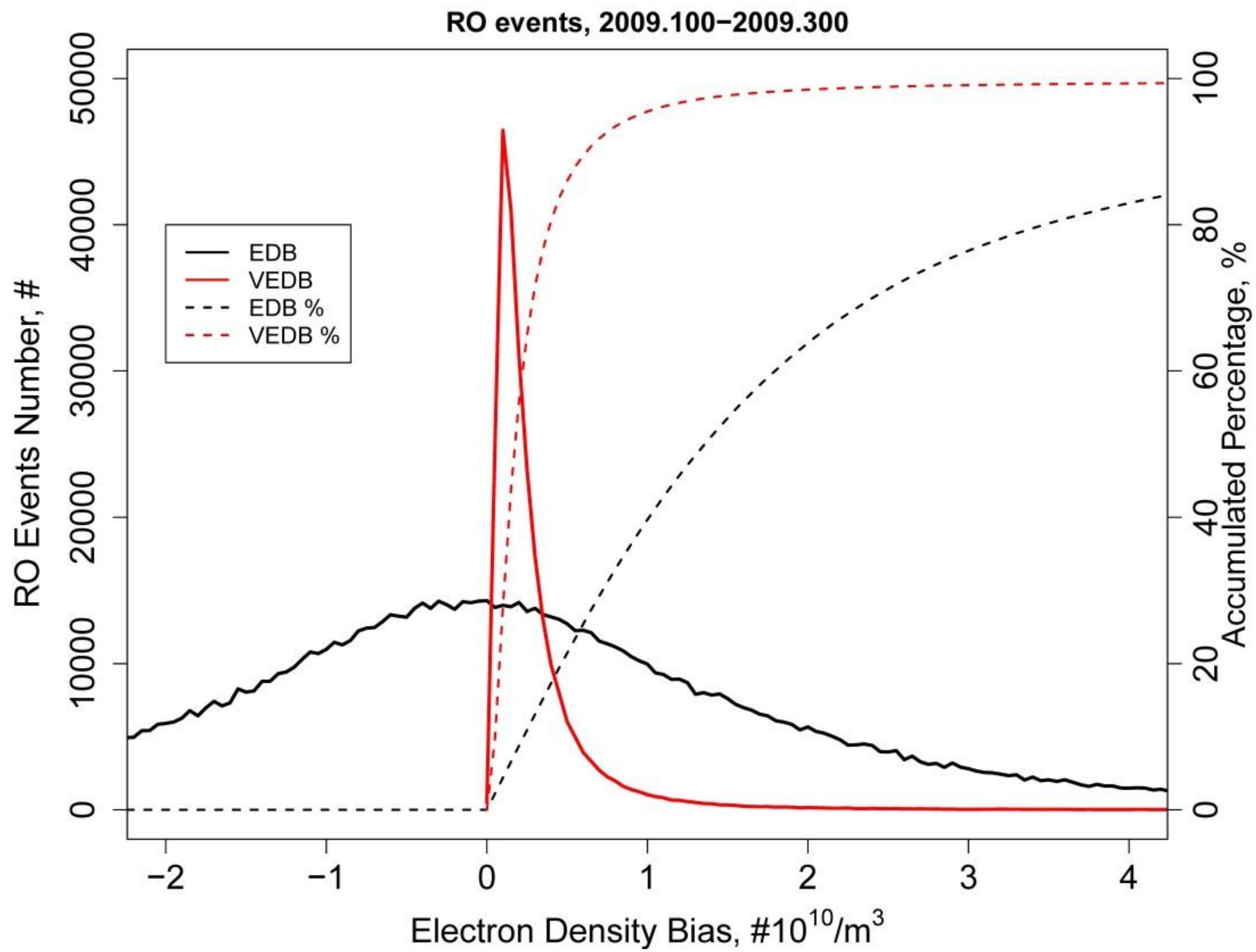
Electron Density Bias (EDB) & Variance of EDB (VEDB) (3/5)

- **EDB**: The mean electron density bias during 70-85 km
- **VEDB**:The variance of electron density bias during 70-85 km. Qualify the contribution from BA bias at lower ionosphere.

If VEDB is too big

➔ Oh! My God

➔ need more correction



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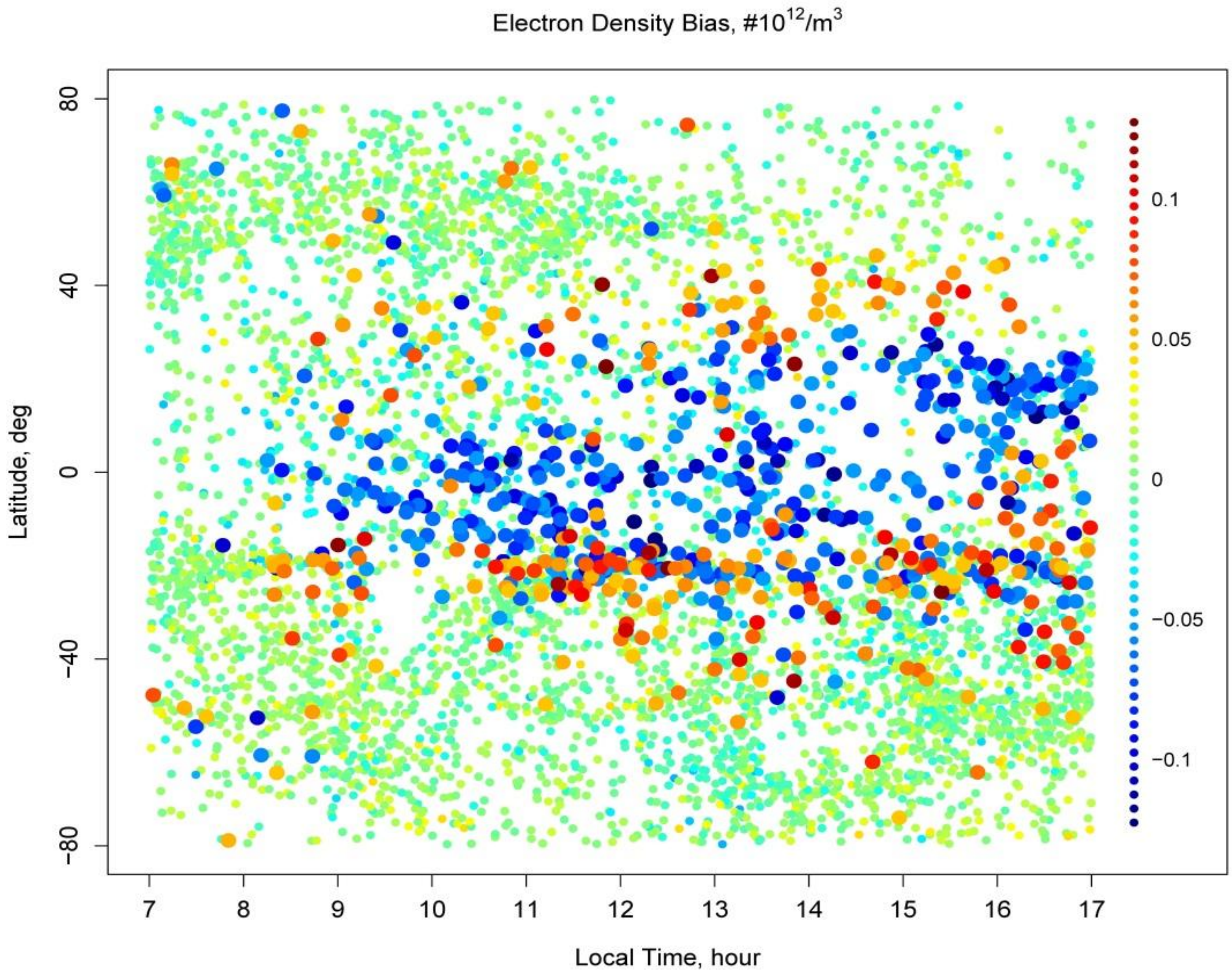
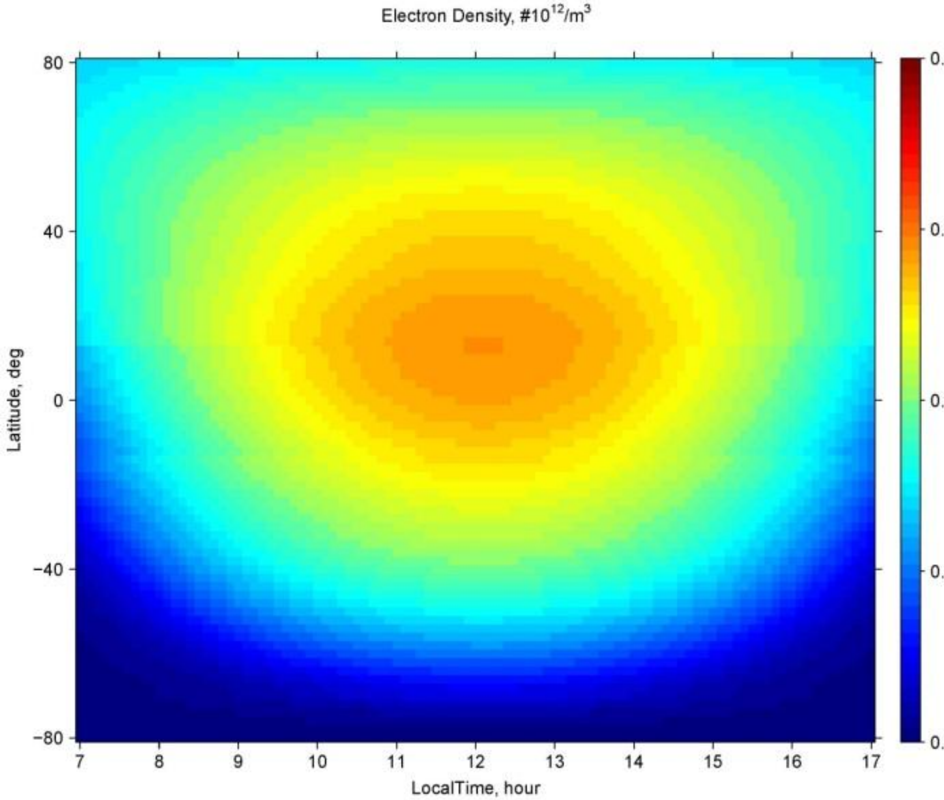
EDB Distribution (4/5)



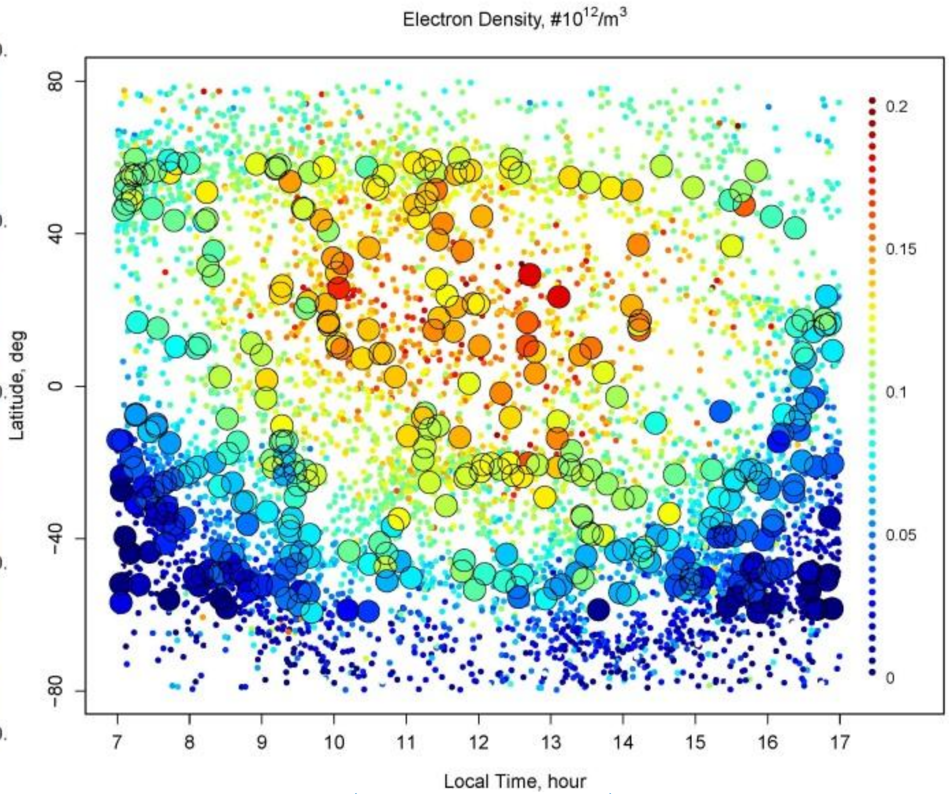
- ➢ We could reduce the EDB by same order at the equator at noon

Fixed ED Comparison with IRI-2012 (5/5)

- One day RO events have show same pattern with IRI-2012.



Nm (IRI2012) on 19 July 2009



Mean ne (GPSARC)
during 110-120km
on 19 July 2009 – 29 July 2009

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Conclusion

- Due to lack of information on bending angle in E region, it is hard to say how accuracy of fixed ED, but the results show we have improved the accuracy of electron density greatly at E-layer.

- Say Good-Bye to Average?

~~Sure!~~

Very Close.