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

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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, scientific research, and numerical weather prediction.

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

- UCAR/CDAAC processes many data for multi-missions. Reanalysis can make good use and archive of these data. Will benefit the ionospheric weather, climate, variability study, applications.

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✓ Global ionospheric data assimilation model:

- **Background model:** empirical model (NeQucik, IRI), easy to add other(theoretical) models
- **Space Resolution:** flexible, 2.5 latitude, 5 longitude, 20 km altitude in this study.
- **Background correlation and error:** Gaussian correlation, cutoff when dlat>10, dlon>20, and dalt>60; square of background Ne.
- **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.

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✓ Global ionospheric data assimilation model （cont.）:

- **Solve method:** Kalman Filter.
- **Inversion of innovation covariance:** restarted GMRES (generalized minimal residual) iteration method.
- **Input:** GNSS rinex files, IGS GIM, LEO orbit, GNSS orbit, navigation of Glonass (to get the frequency number). flexible to add different kind observations.
- **Data down-sampling and quantity control:** flexible. TEC range restriction; remove duplicate GPS ray.
- **Output:** global 3-D grid electron density.

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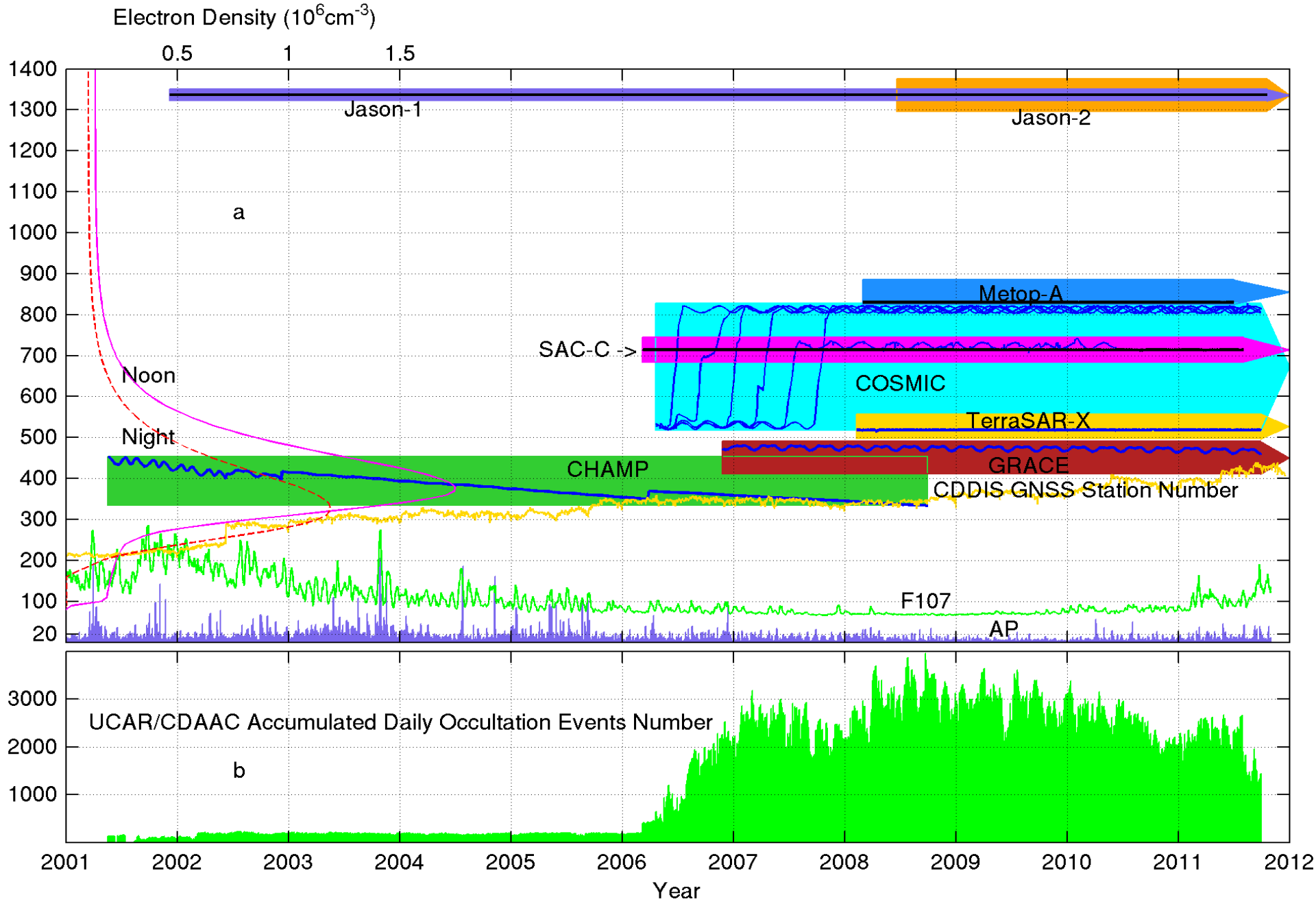
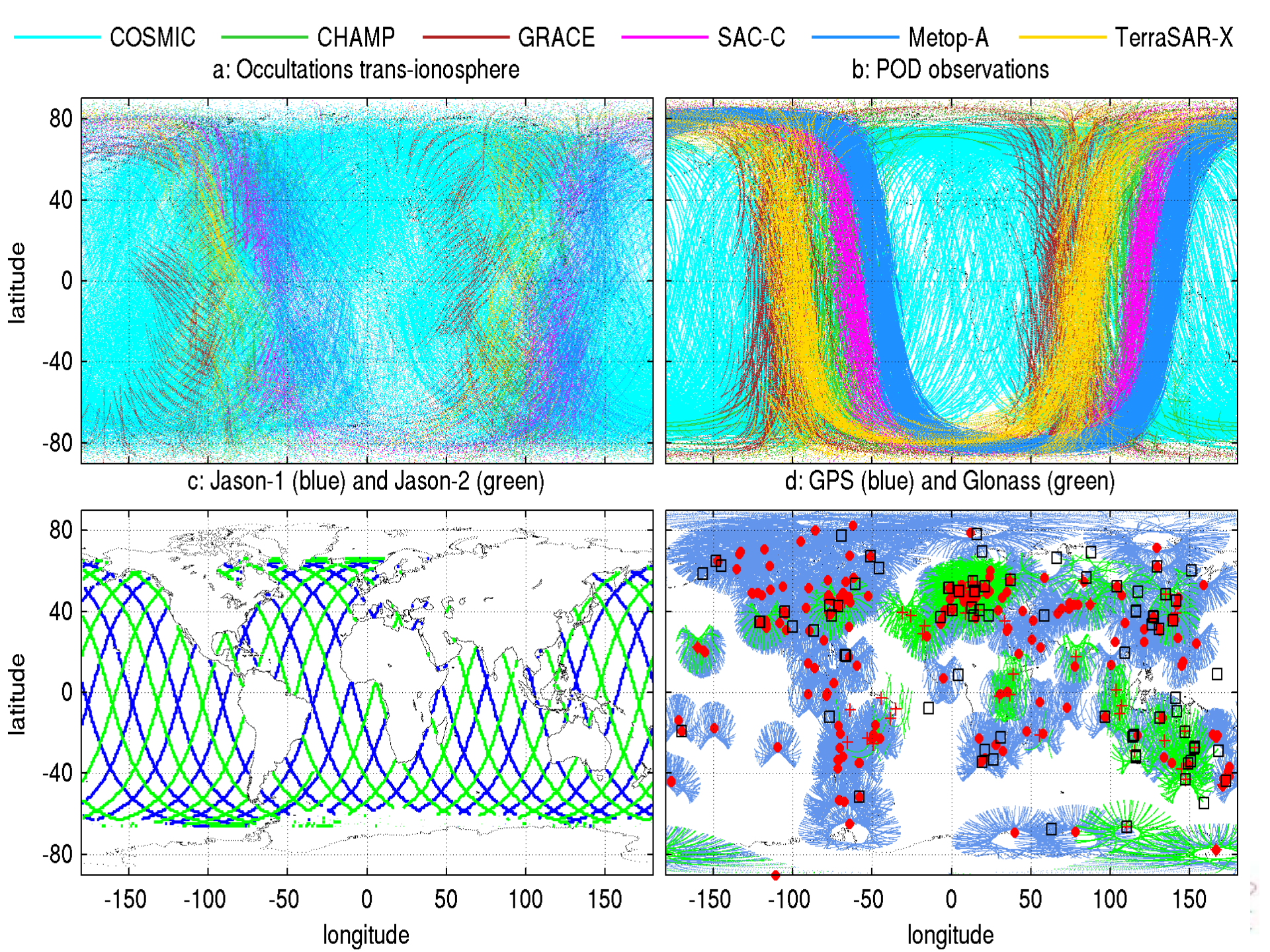
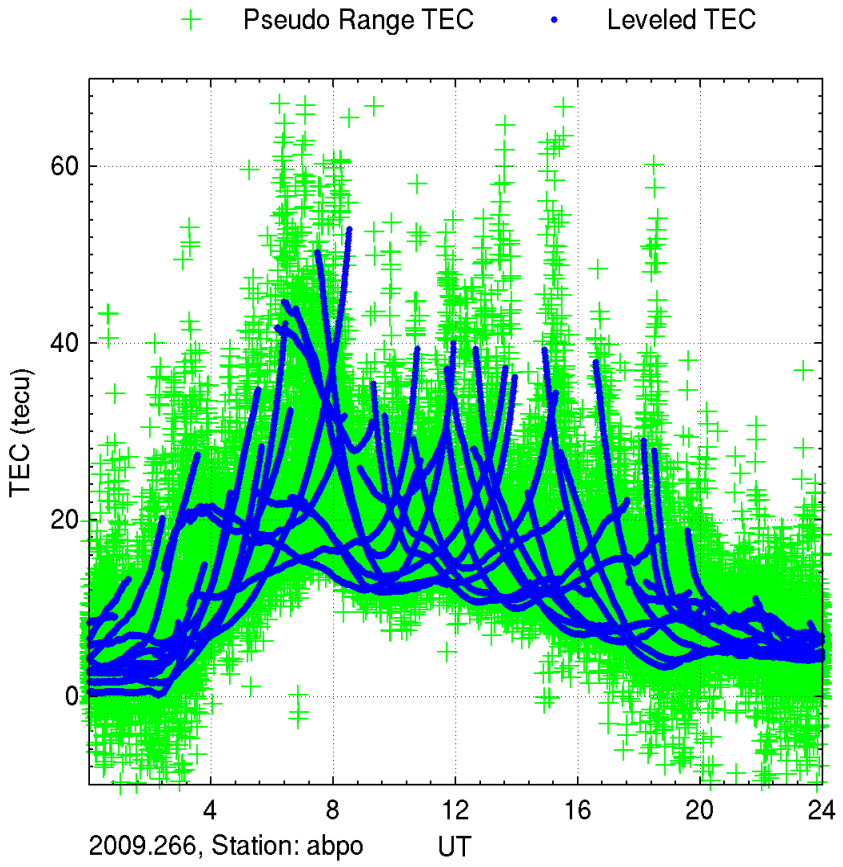
Data source:

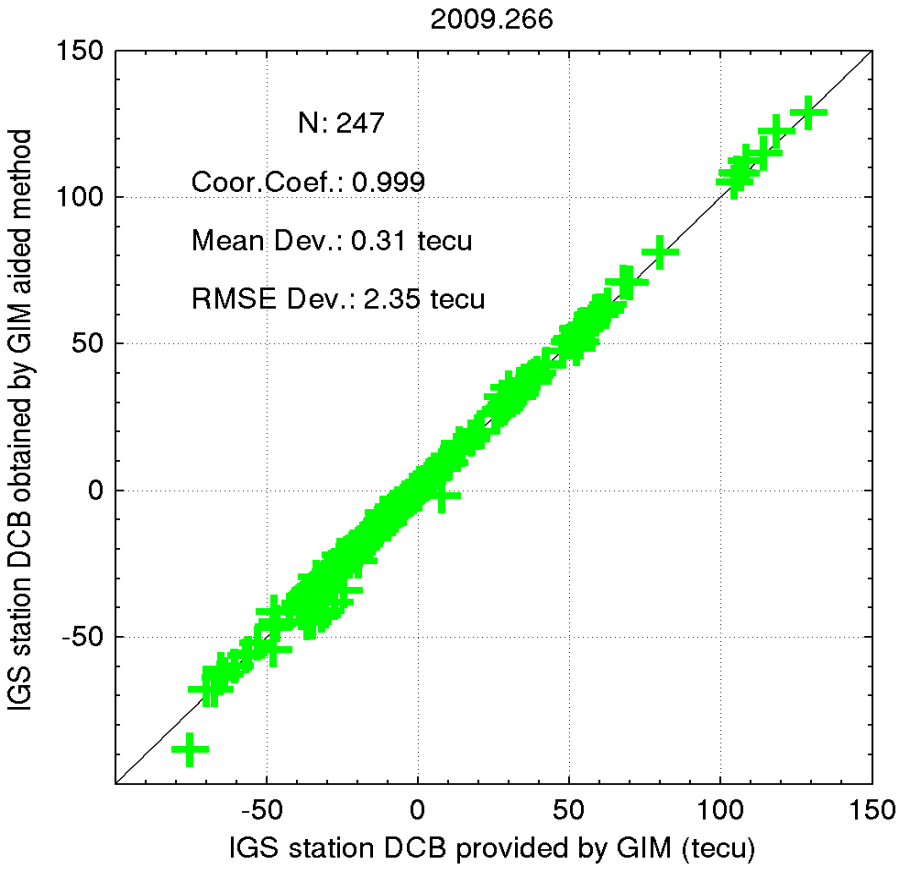

Electron Density ($10^6 cm^{-3}$)
0.5
1
1.5
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
20
Jason-1
Jason-2
a
Metop-A
SAC-C ->
COSMIC
Noon
Night
TerraSAR-X
CHAMP
GRACE
CDDIS GNSS Station Number
F107
AP
3000
2000
1000
UCAR/CDAAC Accumulated Daily Occultation Events Number
b
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
Year


COSMIC
CHAMP
GRACE
SAC-C
Metop-A
TerraSAR-X
a: Occultations trans-ionosphere
b: POD observations
c: Jason-1 (blue) and Jason-2 (green)
d: GPS (blue) and Glonass (green)
latitude
longitude
80
40
0
-40
-80
-150
-100
-50
0
50
100
150

✓ Ground based GNSS process mainly include:

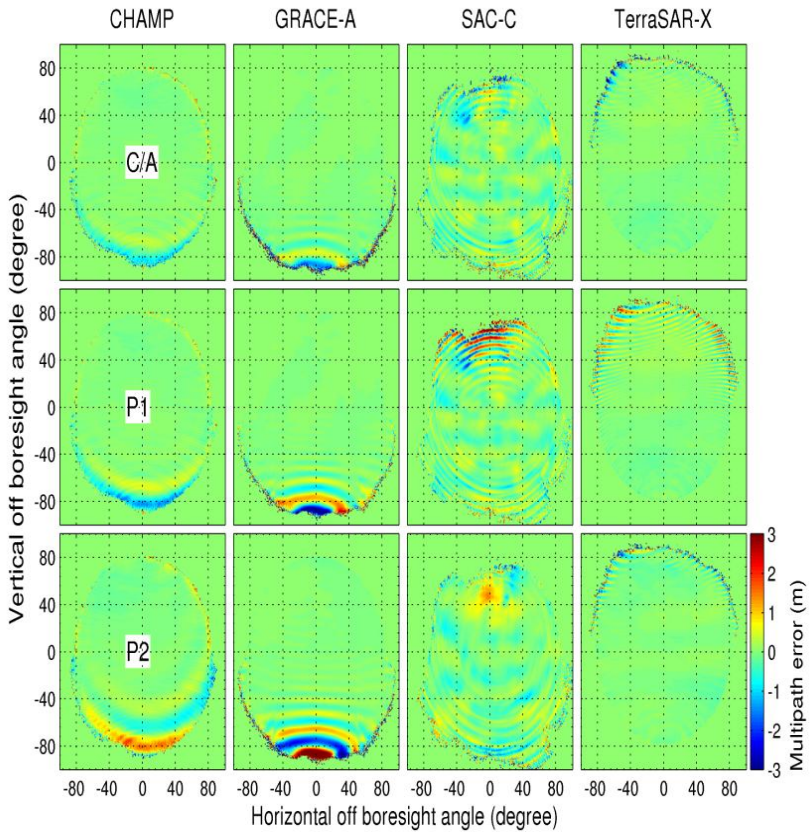
- **cycle slip detection;**
- **Leveling of phase TEC to pseudo-range TEC;**
- **Differential Code Bias (DCB) estimation: aided by IGS GIM**





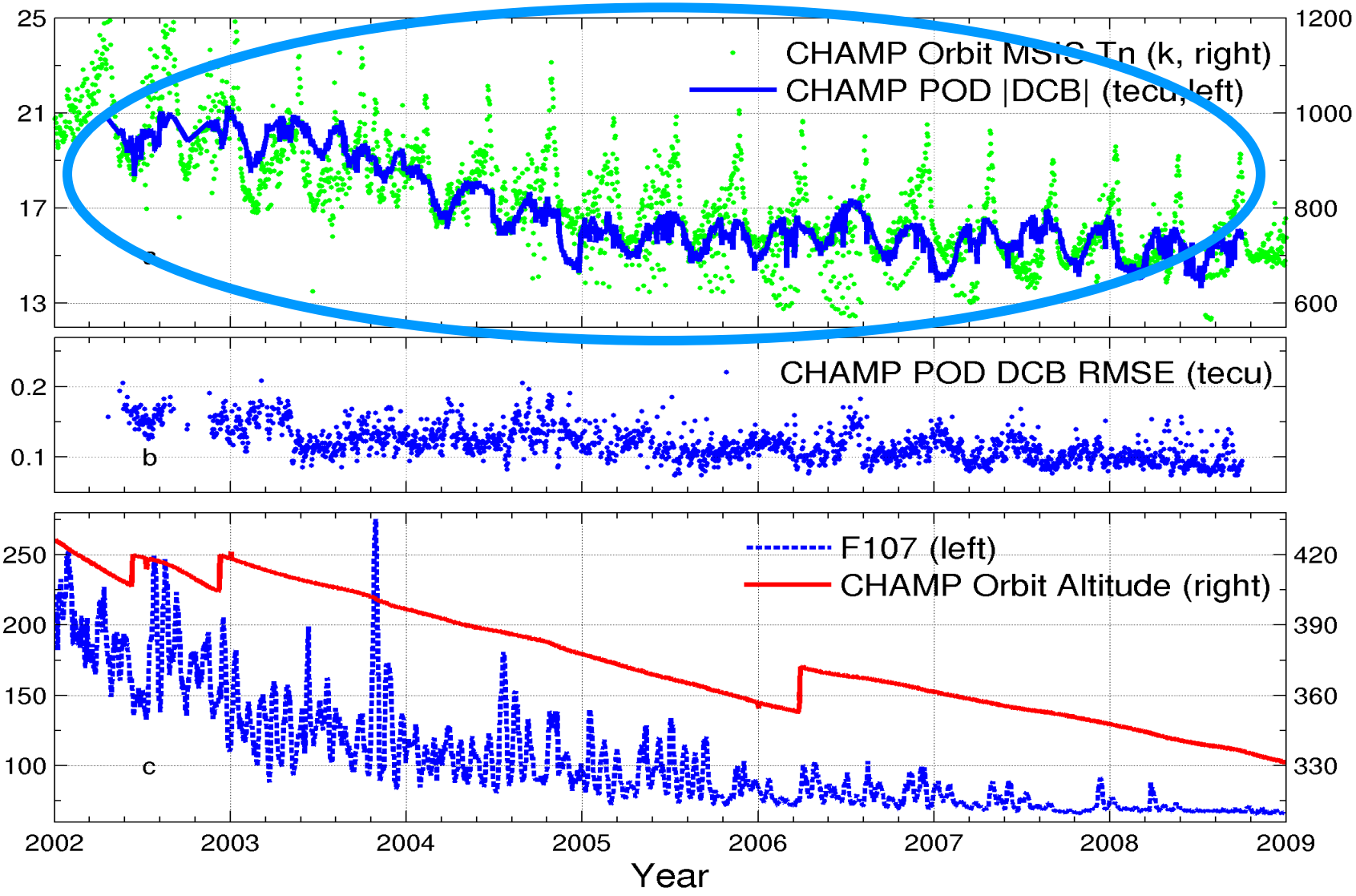
✓ LEO based GNSS process mainly include:

- cycle slip detection;
- **Multi path calibration;**
- Leveling of phase TEC to pseudo-range TEC;
- **Differential Code Bias (DCB) estimation: spherical symmetry assumption**

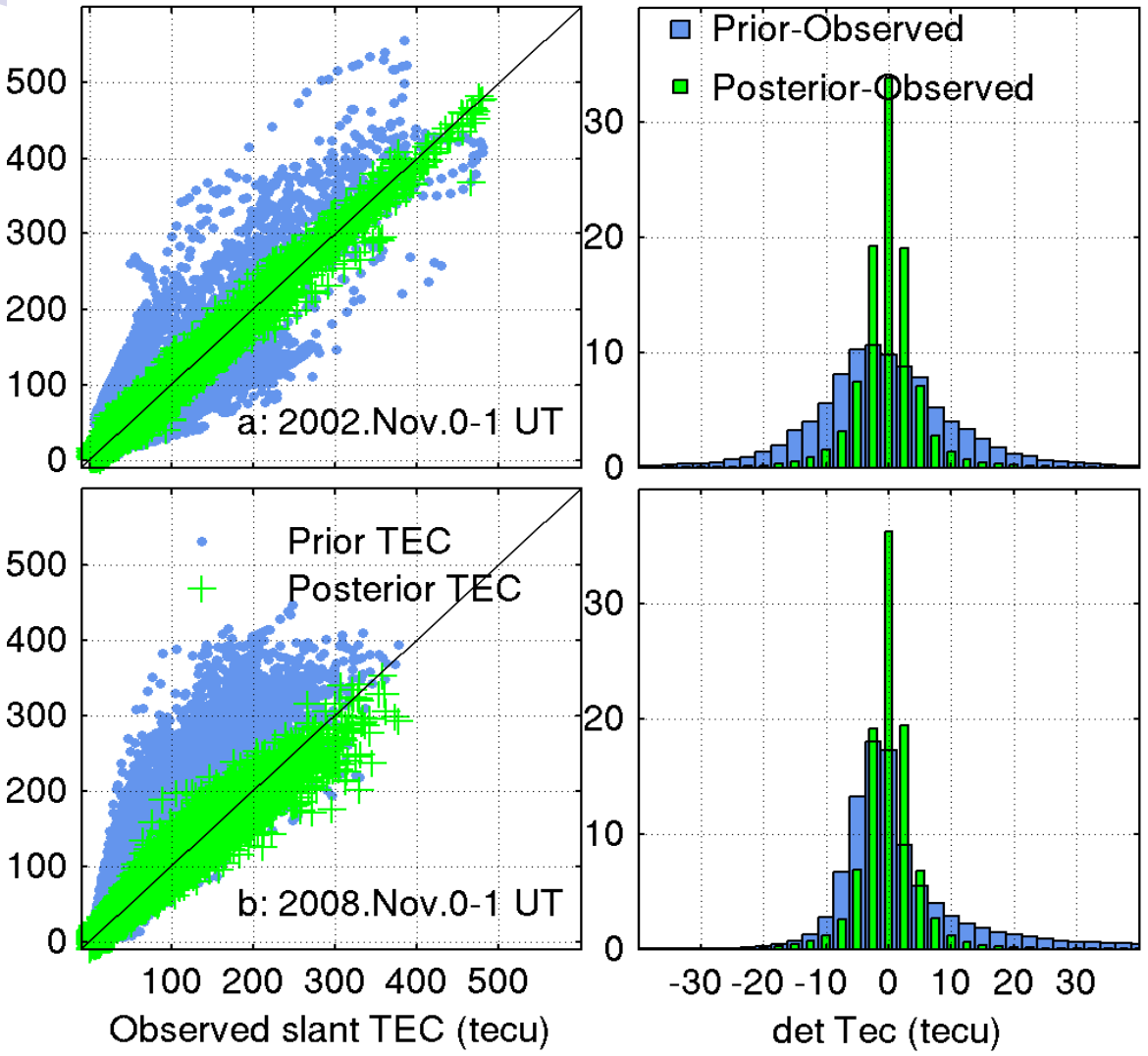


Mission	Inclination (°)/Altitude(km)/mass(kg)	GPS Receiver type	Operation years	POD antenna normal	Multipath RMSE (C/A, m)	Leveling error mean (tecu)	DCB RMSE mean (tecu)
COSMIC FM4	72/700-800/70	Blackjack	2006-	75° off the zenith	0.30	0.12	0.69
CHAMP	87.3/460-330/522	Blackjack	2000-2009	zenith	0.20	0.19	0.11
GRACE-A	89/~495/432	Blackjack	2002-	zenith	0.42	0.31	0.14
SAC-C	98.2/~710/467	Blackjack	2000-	zenith	0.42	0.60	0.87
TerraSAR-X	97.44/~514/1230	IGOR	2007-	zenith	0.29	0.15	0.09
Metop-A	98.7/~820/4093	GRAS	2006-	zenith	0.15	0.09	0.16

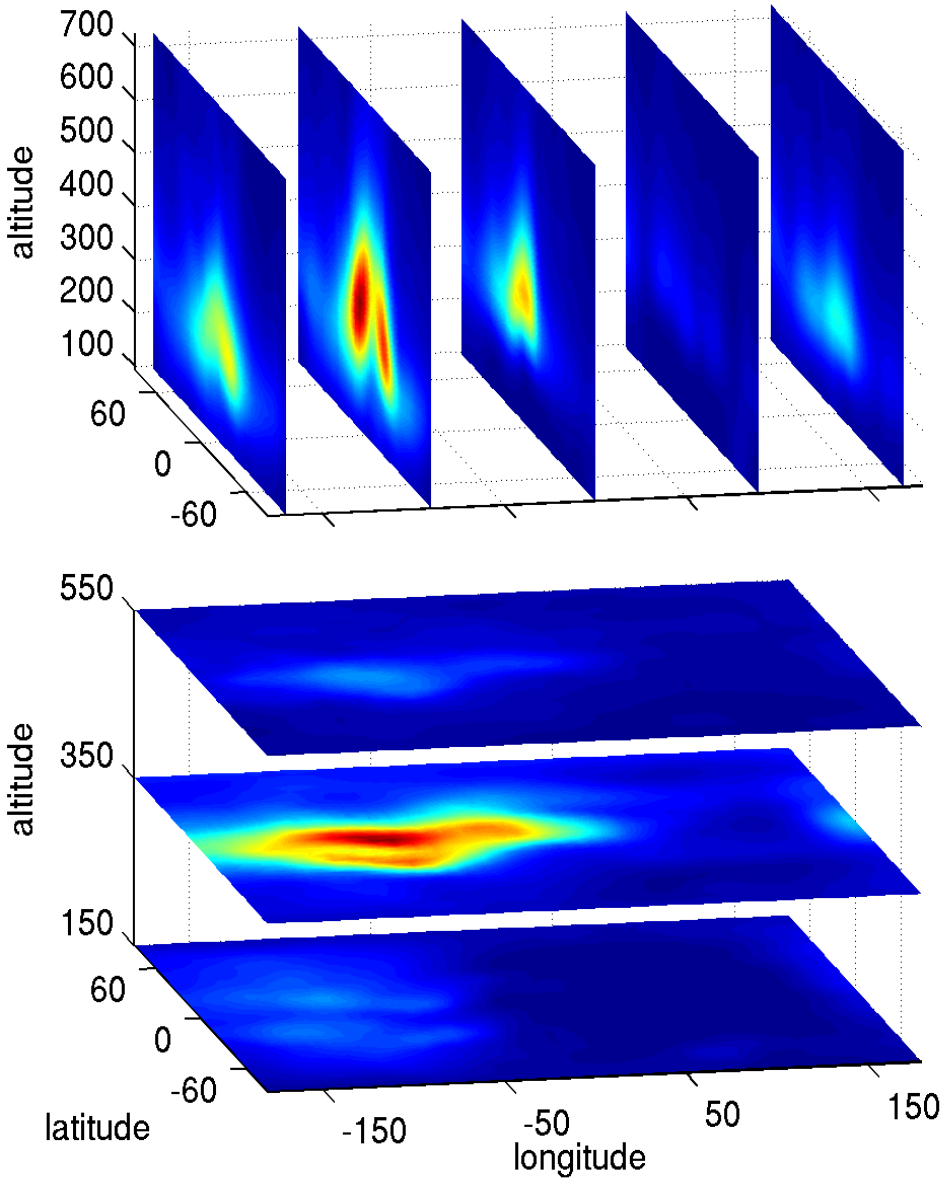
Satellite environmental temperature effects on the Differential Code Bias (DCB) estimation: CHAMP DCB drift aggress well with orbit neutral temperature variation

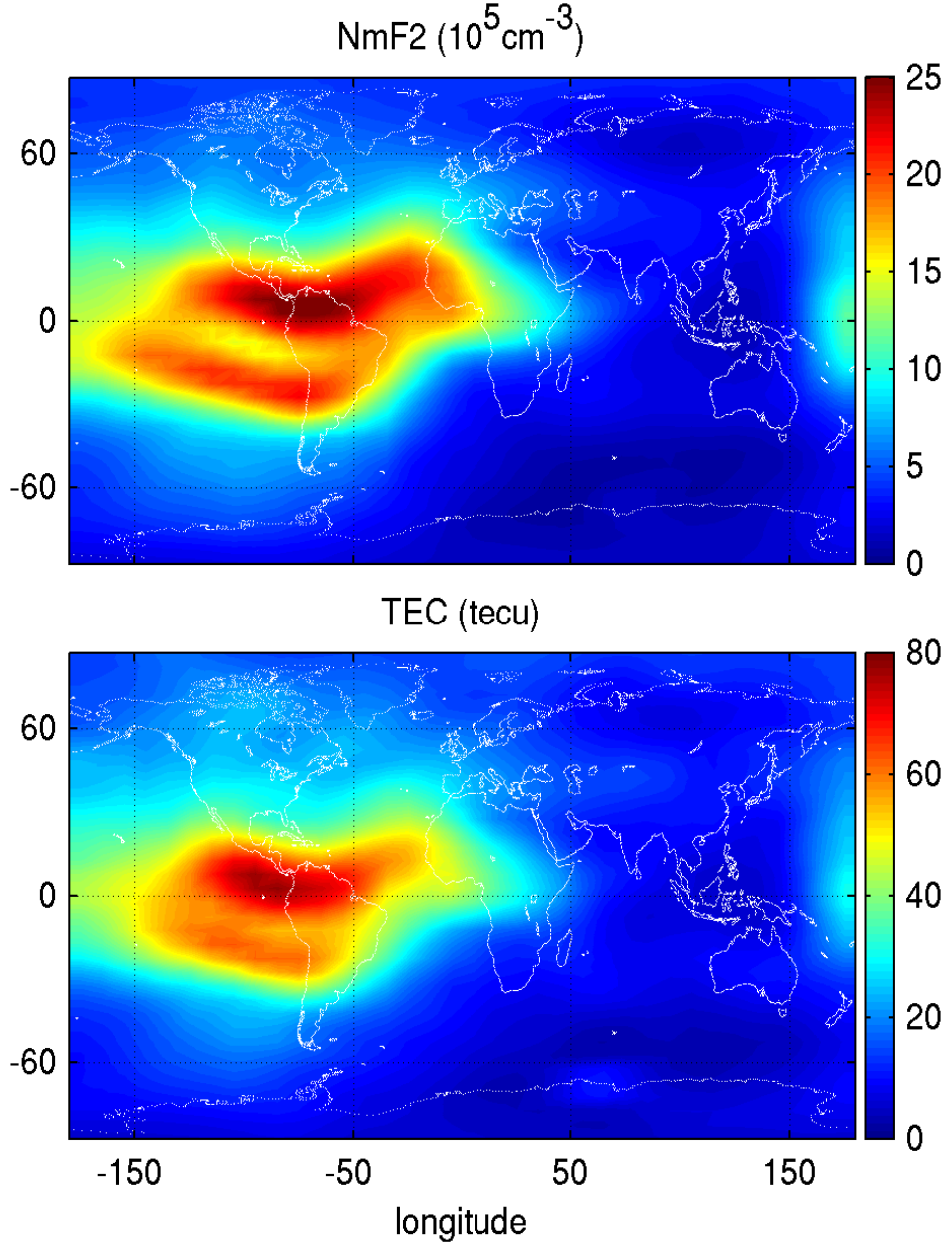


✓ Reanalysis results 1: Comparison the slant TEC before and after assimilation

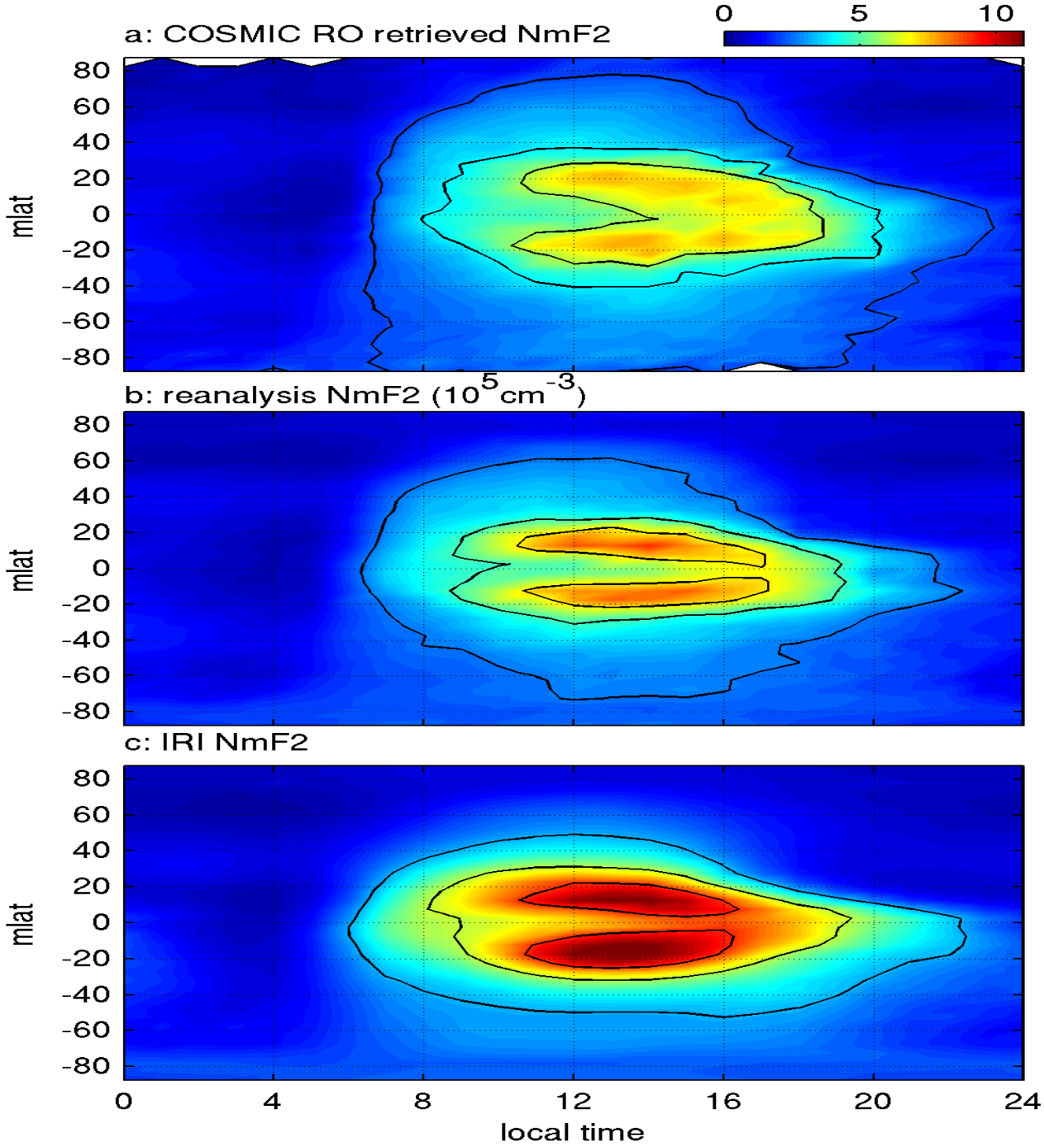


Reanalysis results 2: Global 3-D electron density example

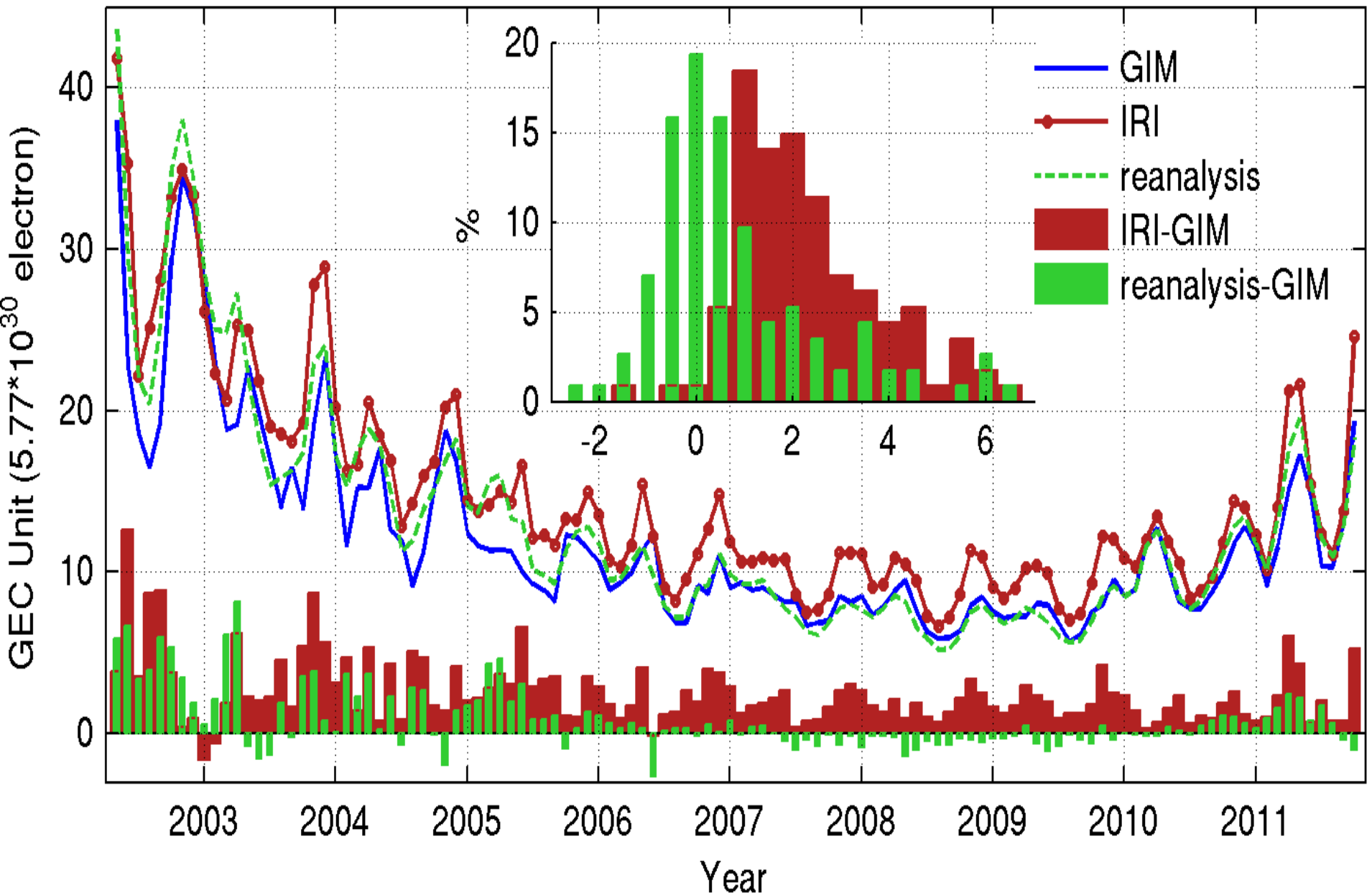




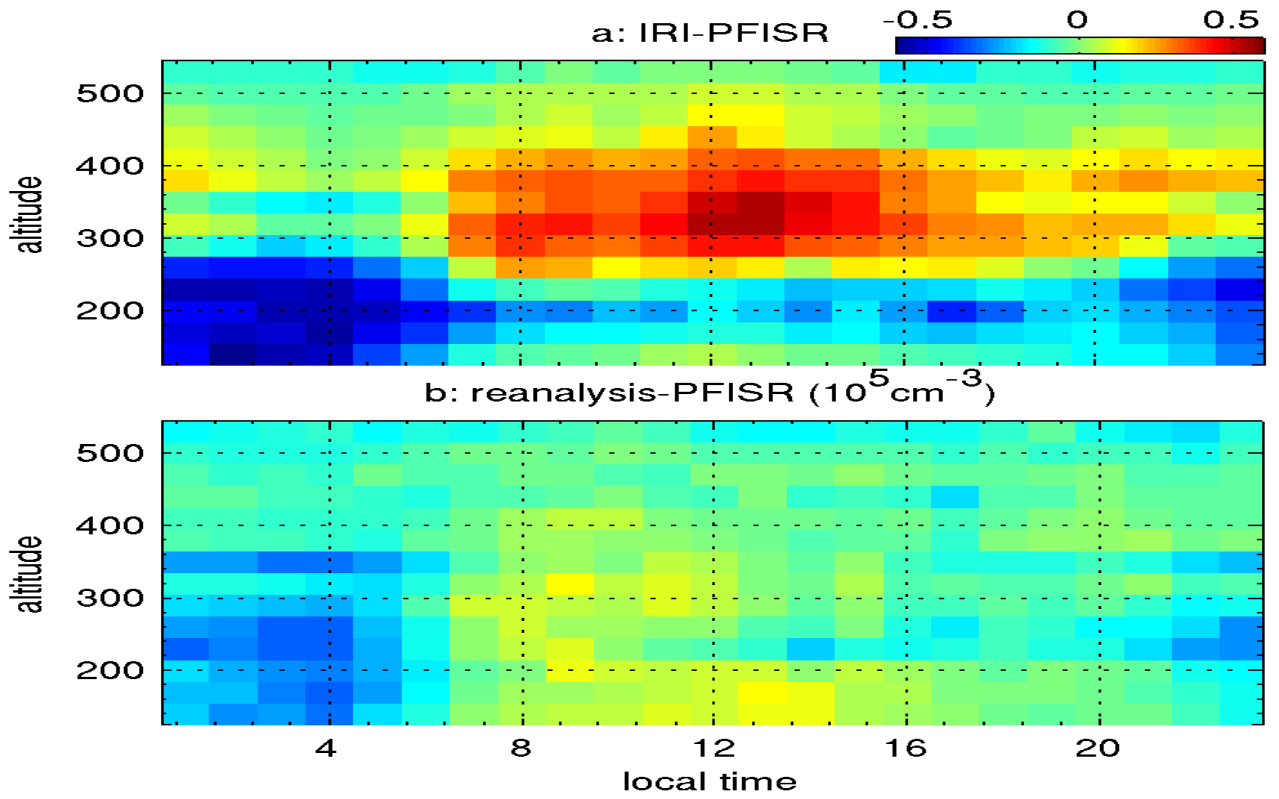
✓ Reanalysis evaluation 1: Compare with RO retrieved results

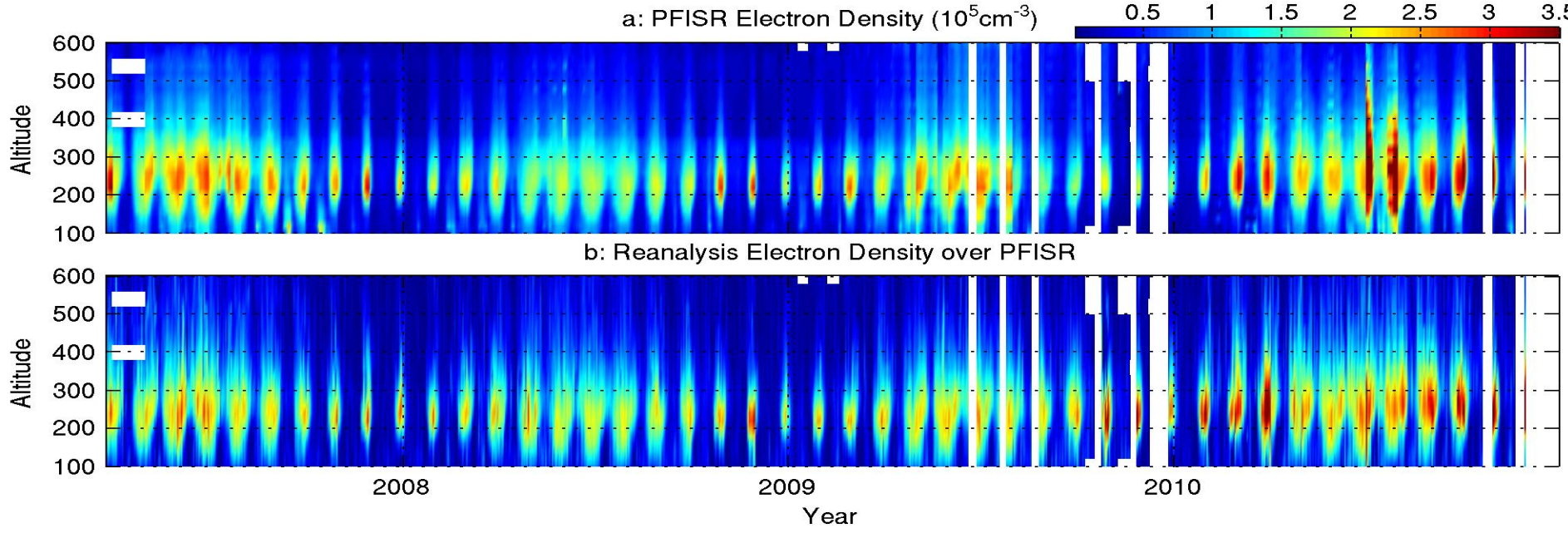


✓ Reanalysis evaluation 2: Compare with IGS GEC

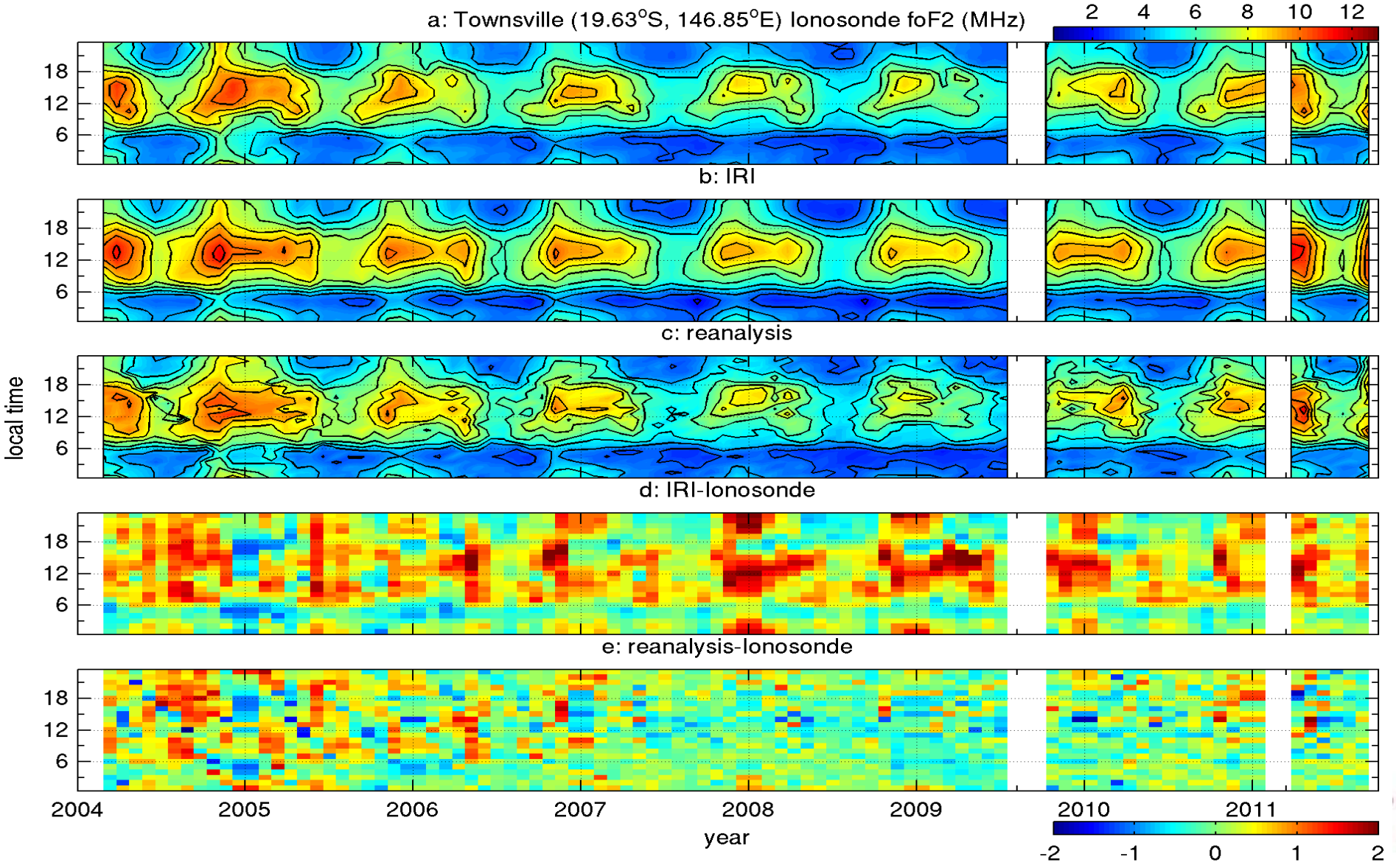


✓ Reanalysis evaluation 3: Compare with Poker Flat ISR （65N，147W）

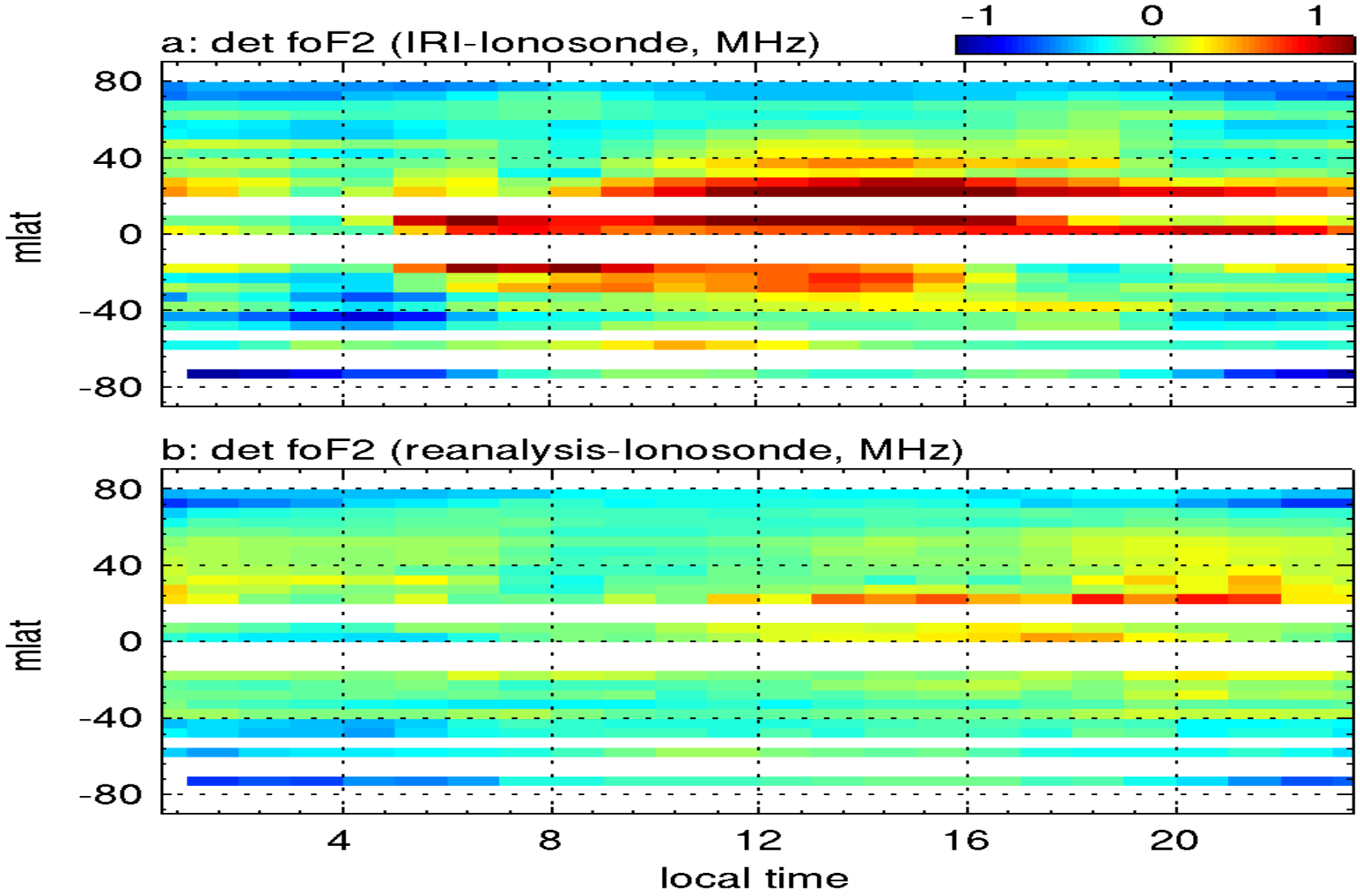




✓ Reanalysis evaluation 4: Compare with global Ionosonde: example （Townsville; 19S, 147E）



✓ Reanalysis evaluation 4: Compare with global Ionosonde: Statistical Results



Conclusion:

- ✓ A global ionospheric data assimilation model is constructed.
- ✓ Ionospheric electron density reanalysis during 2002-2011 have been done in UCAR/DAAC.
- ✓ Preliminary evaluations show reasonable results.