

Ionospheric Weather Monitoring by FORMOSAT-3 and ground-based GPS receivers

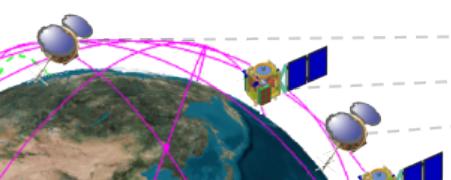
Tiger J.Y. Liu NSPO, TAIWAN

I.T. Lee CWB TAIWAN

Y.Y. Sun, C.Y. Lin, C.T. Hsu NCU TAIWAN

T. Matsuo NOAA, USA

W. Wang NCAR USA



FORMOSAT-3 & FOMORSAT-7

Content

- The 7 January 2015 Dst= **-99nT** magnetic storm
- Ionospheric DA model (F3/C)
- TGIM model (F3/C + gb GPSR)
- Magnetic+ (F3/C + gb GPSR)
- Summary

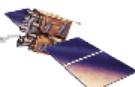




FORMOSAT-3/COSMIC

Global Real-time Weather (Meteorology) Space Weather (Ionosphere) Observation and Prediction

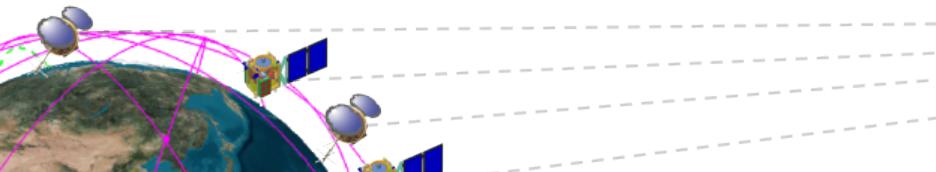
The **FORMOSAT-3/COSMIC** program is an international collaboration between **Taiwan** and **the United States** that will use a constellation of **six** remote sensing **microsatellites** to collect atmospheric data for **weather prediction** and for **ionosphere, climate** and **gravity** research. Data from the satellites will be made freely available to the international scientific community in near **real-time**.



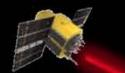
FORMOSAT-3 & FOMORSAT-7

FORMOSAT-3/COSMIC

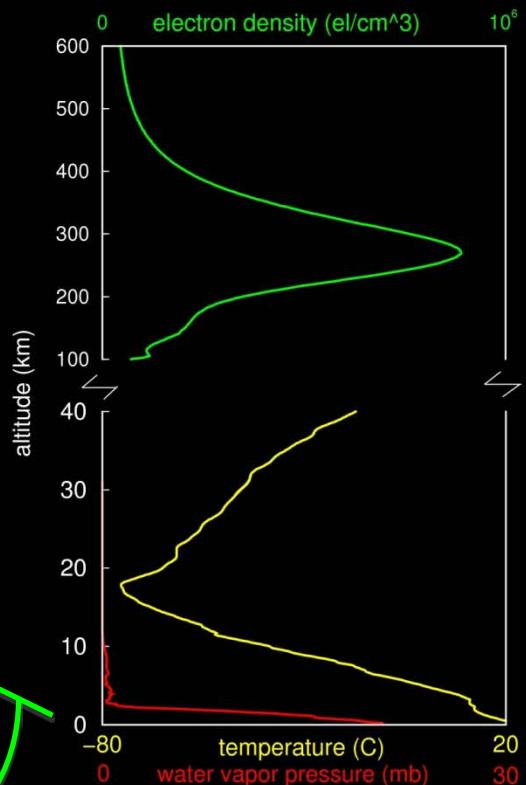
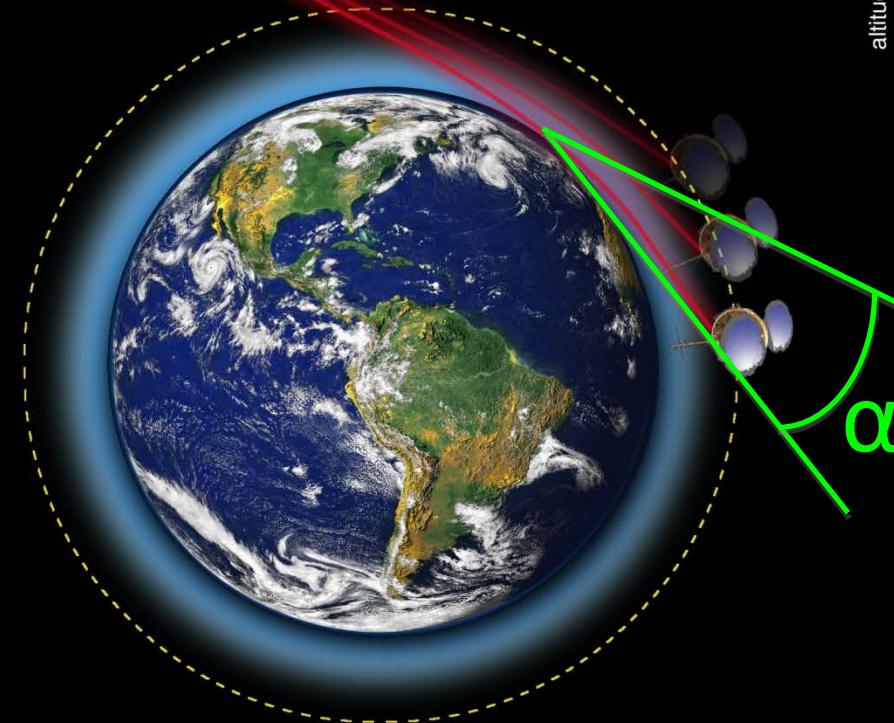
- **FORMOSAT-3/COSMIC Constellation was launch at 01:40 UTC, April 14, 2006 (Taiwan Time: April 15 2006) at Vandenberg Air Force Base, CA. Minotaur Launch**
- **Maneuvered into six different orbital planes (*inclination ~72°*) for optimal global coverage (at ~800 km altitude).**
- **Five out of Six satellites are in good health and providing science data.**



GPS Radio Occultation



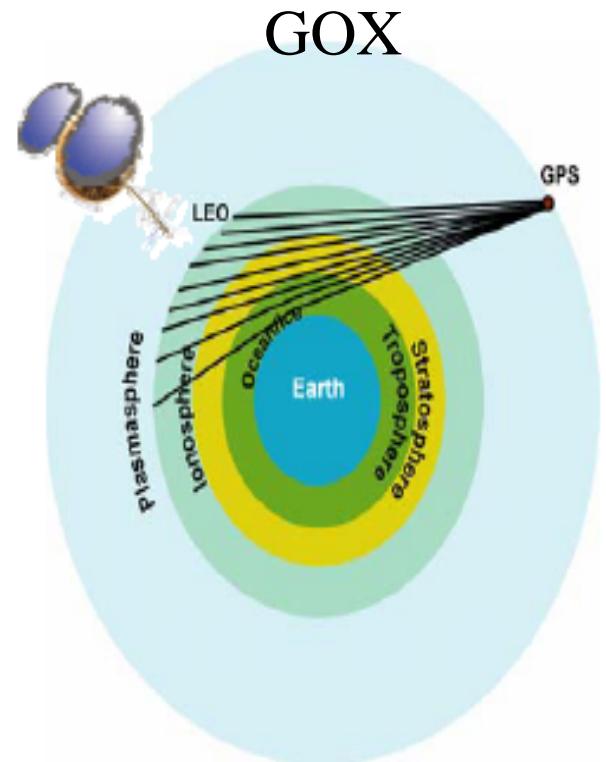
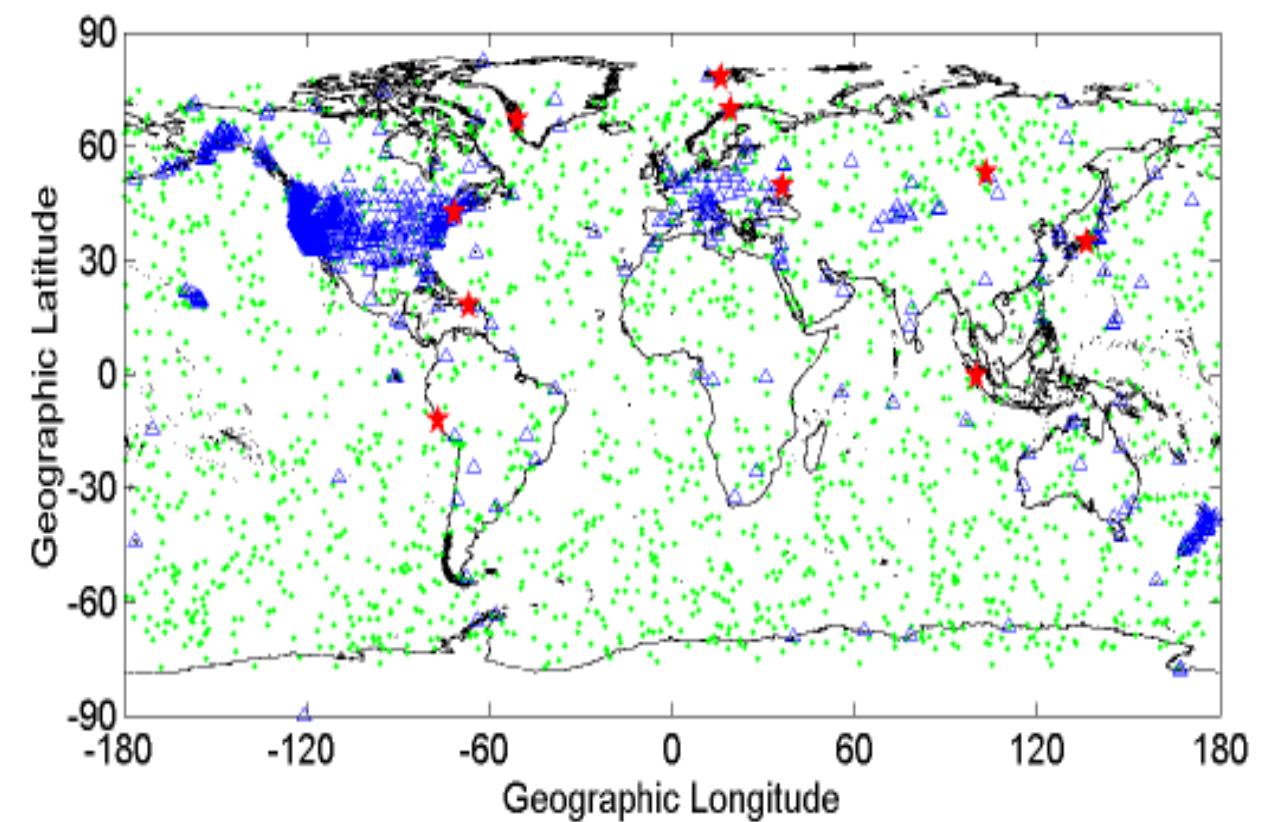
GPS



Wavelength and amplitude
of in the vertical direction

Global 3D structure

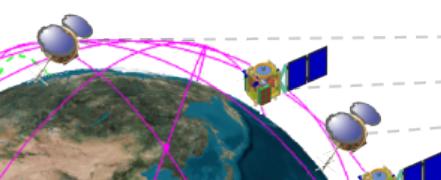
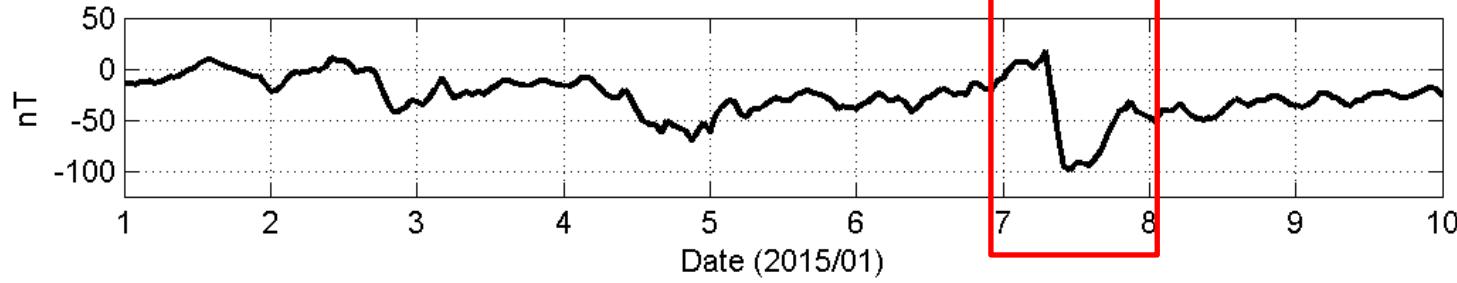
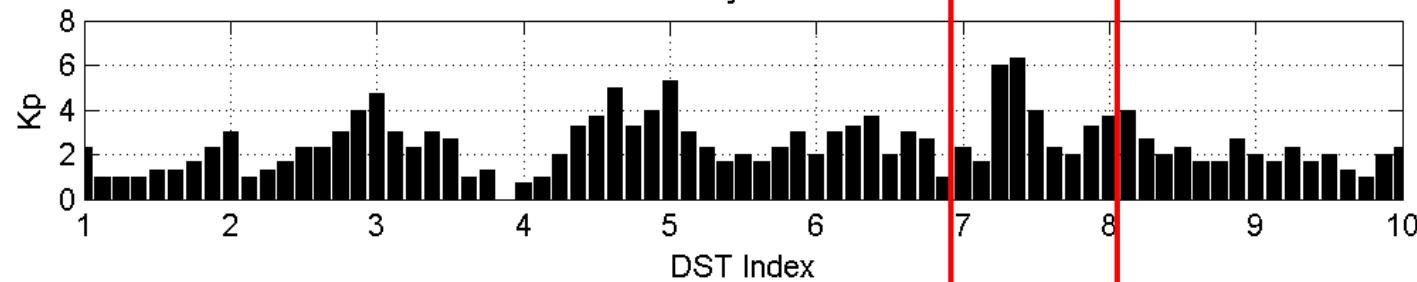
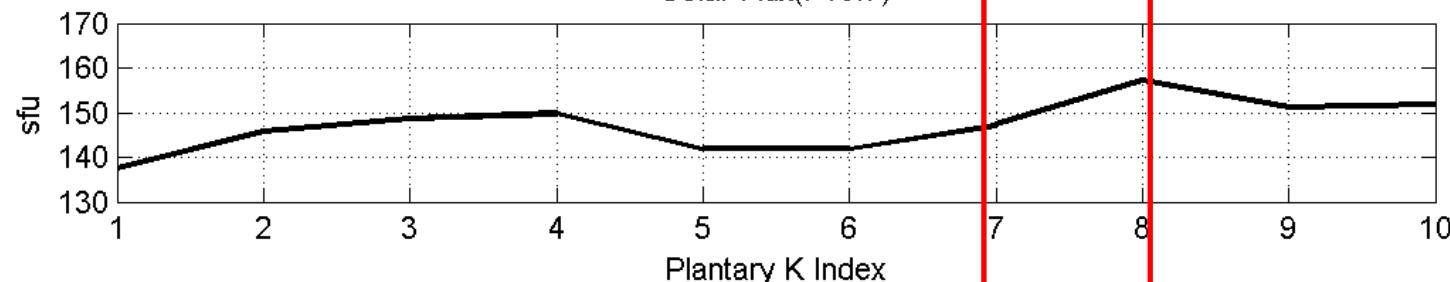
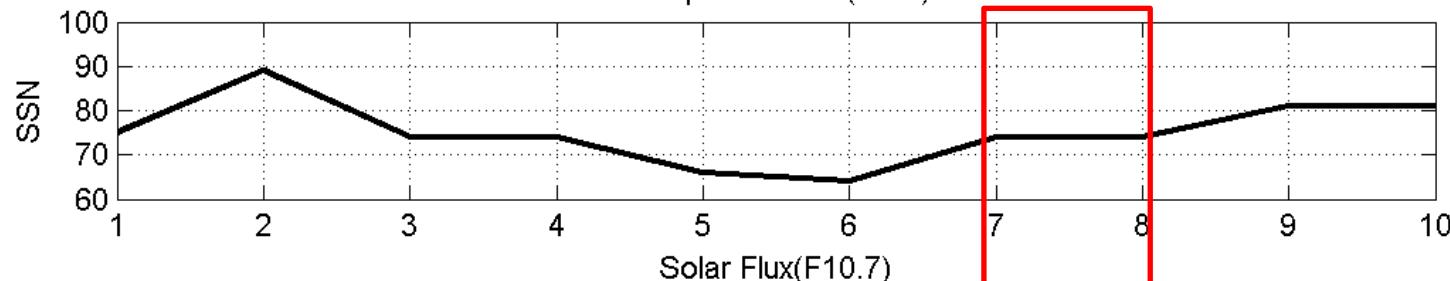
Distribution of occultation events observed by FORMOSAT-3



FORMOSAT-3 & FOMORSAT-7

7 January 2015 storm

Sunspot Number(SSN)



FORMOSAT-3 & FOMORSAT-7

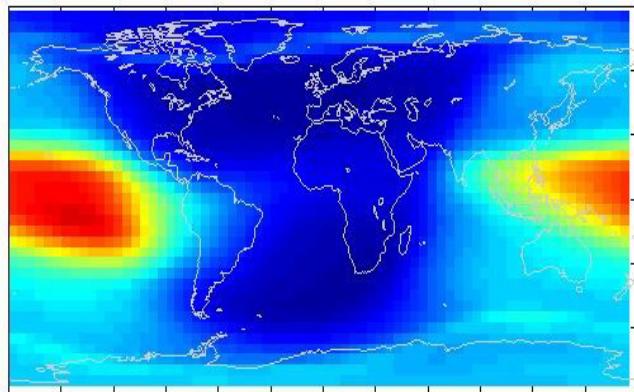
Ionospheric Assimilation Model

NCAR Thermosphere Ionosphere E-GCM
FORMOSAT-3/COSMIC (Electron density profiles)
Data Assimilation Research Testbed

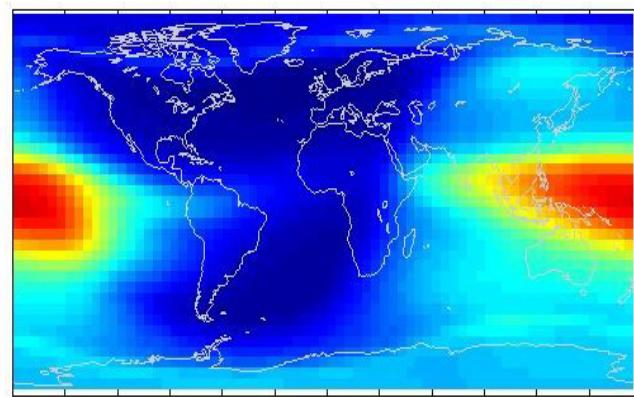
Lee et al. [JGR 2012, JGR 2013] , Hsu et al. [JGR 2015]



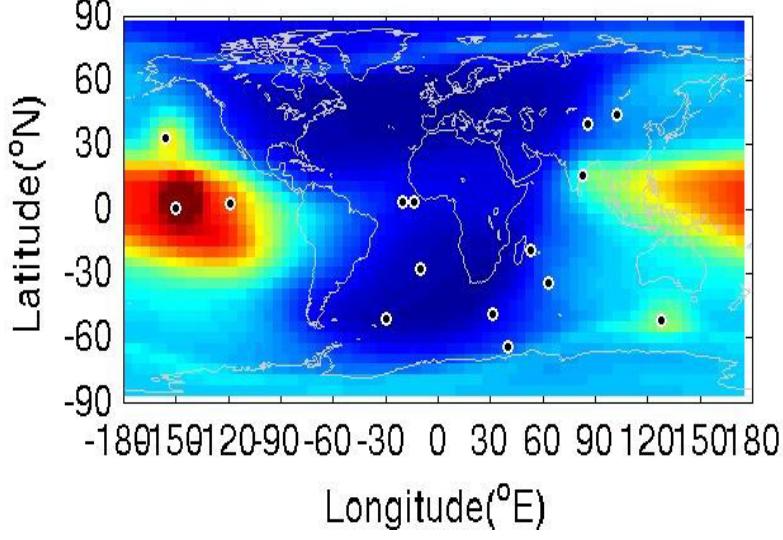
Prior @02:00UT



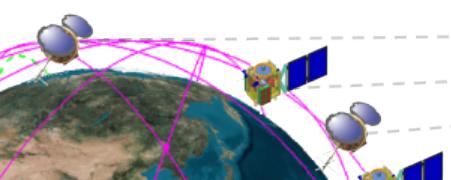
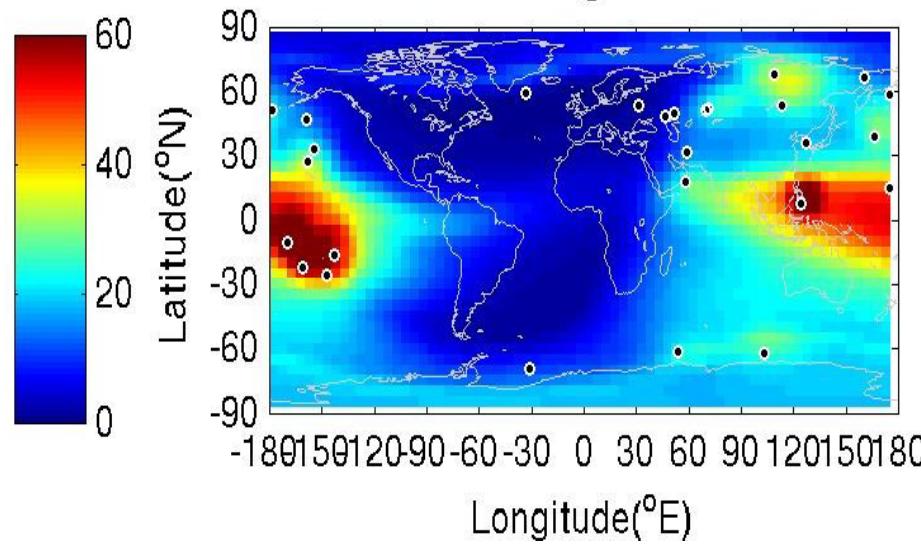
Prior @04:00UT



Posterior @02:00UT

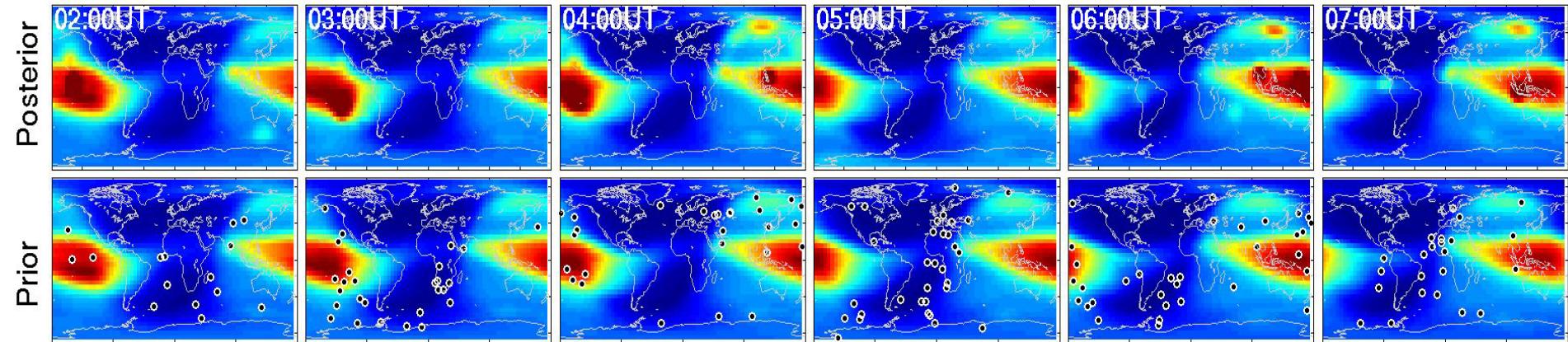


Posterior @04:00UT

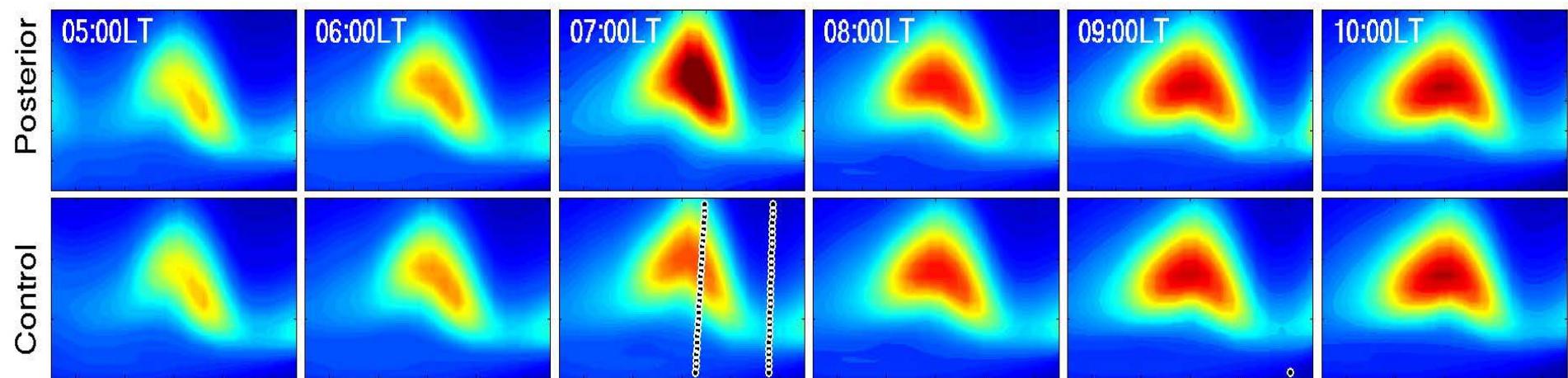


FORMOSAT-3 & FOMORSAT-7

NmF2 map



Along 120°E



FORMOSAT-3 & FOMORSAT-7

Taiwan Global Ionosphere Map (TGIM model)

IGS GPS Receivers (total electron content; TEC)

FORMOSAT-3/COSMIC (vertical TEC)

Spherical harmonic surface functions

Sun et al. [2015]



Magnetic EOF Data Assimilation model

IGS GPS TEC

FORMOSAT-3/COSMIC (Radio Occultation TEC)

International Reference Ionosphere (IRI)

Kalman Filter with a 3-D Error Covariance

Empirical orthogonal functions (EOF)

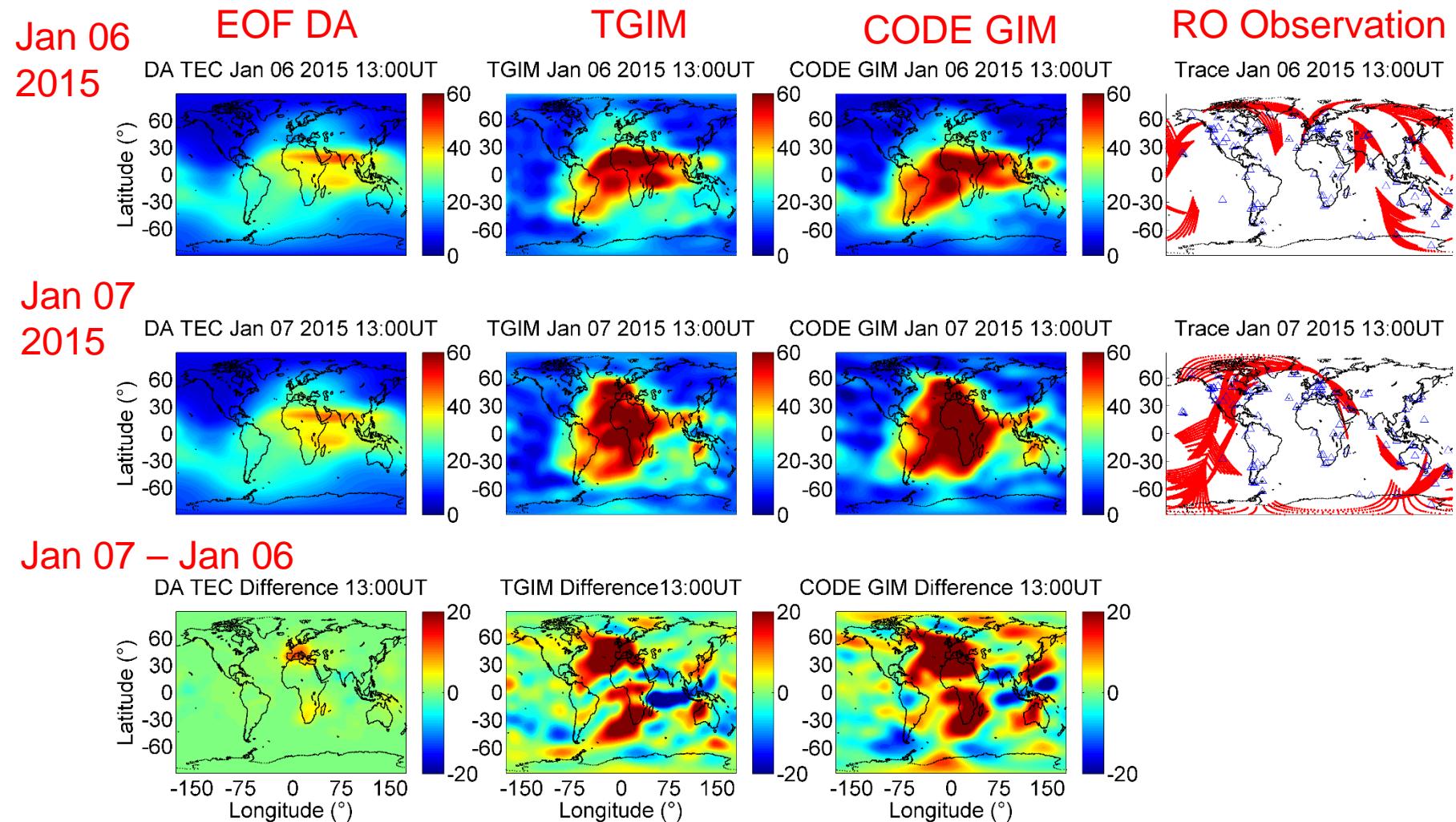
Lin et al. [AMT 2015]

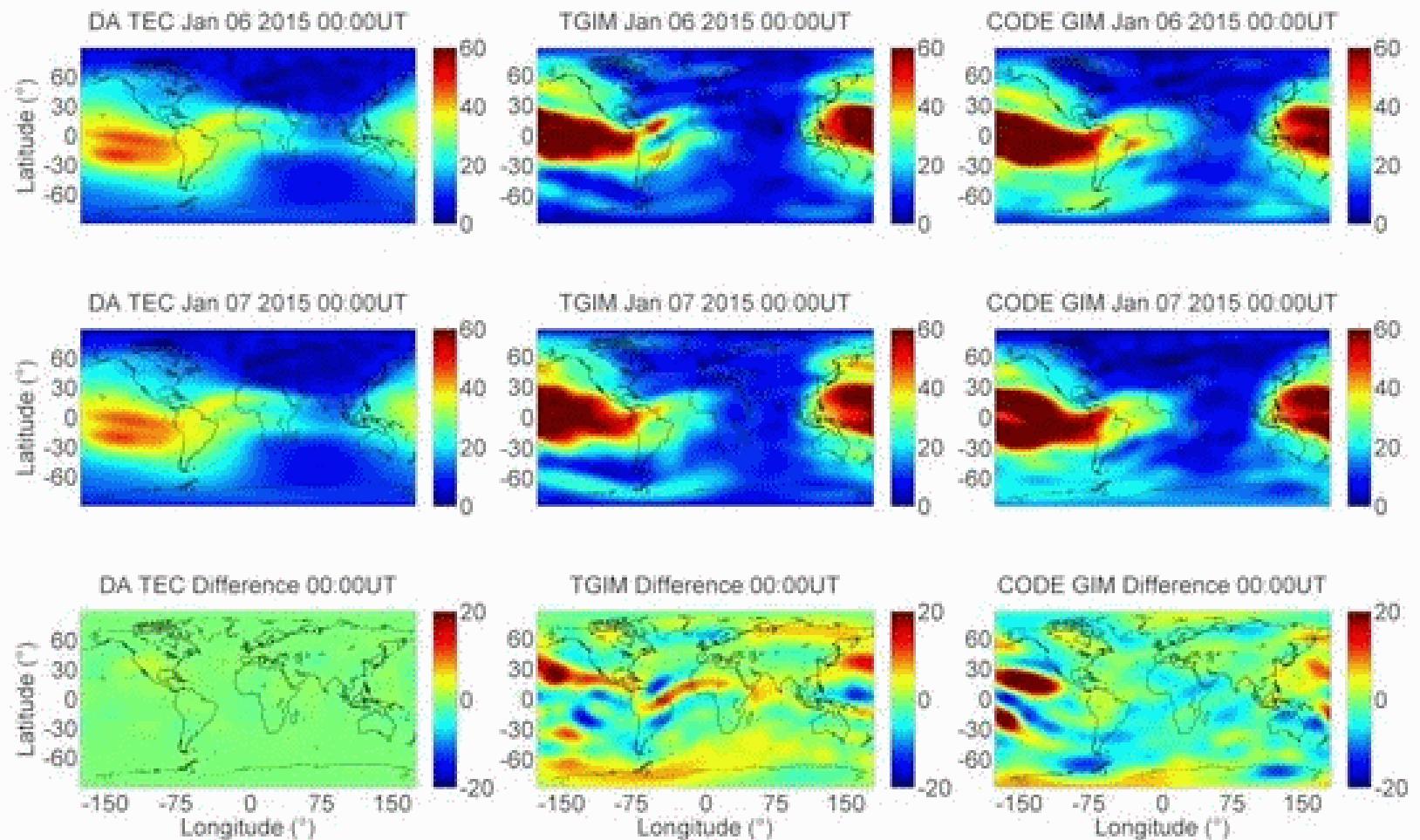


FORMOSAT-3 & FOMORSAT-7

Storm signatures in TGIM and EOF DA

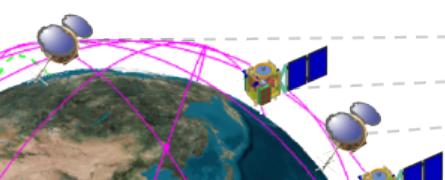
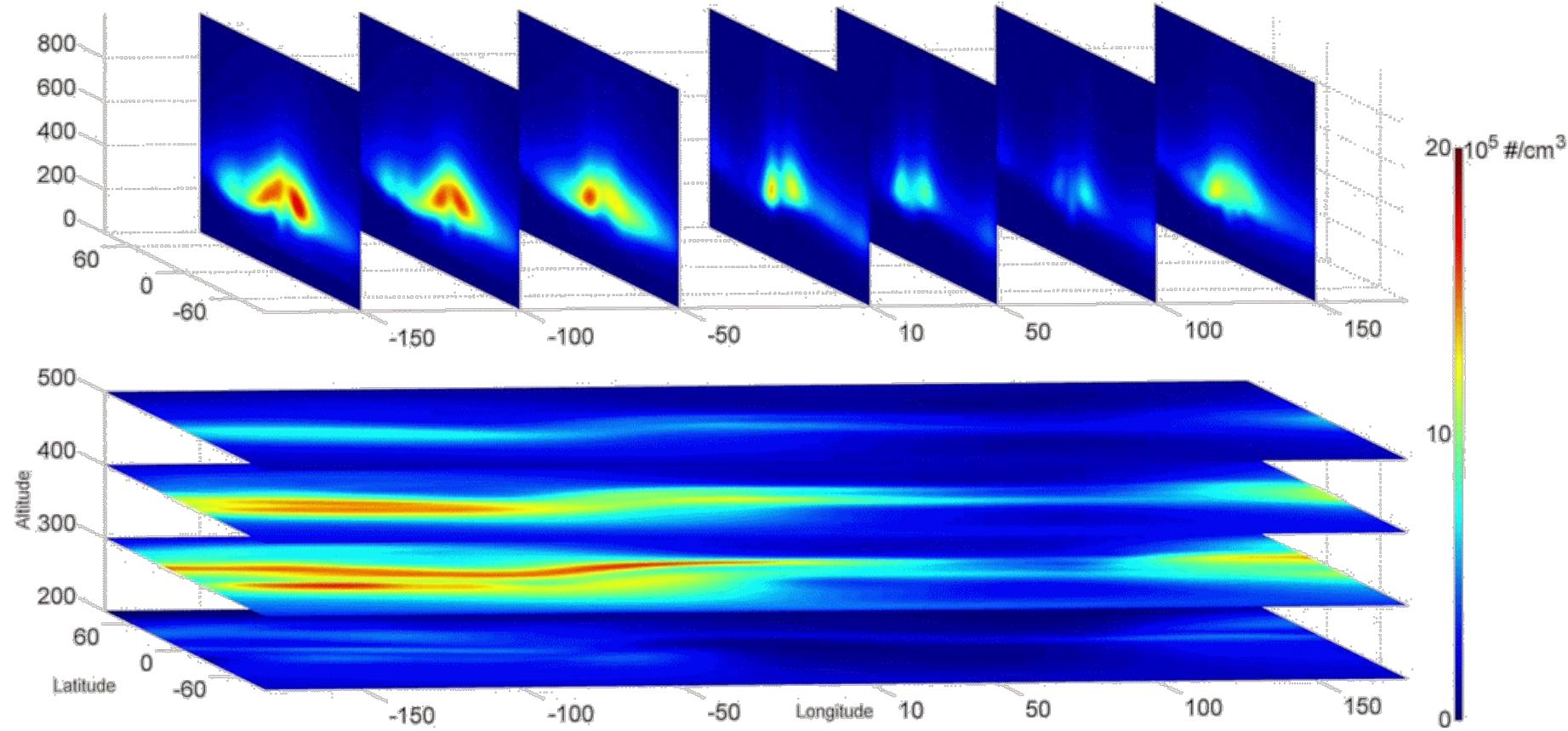
13:00 UTC Jan 07 2015





FORMOSAT-3 & FOMORSAT-7

DA 00:00UTC Jan 07 2015

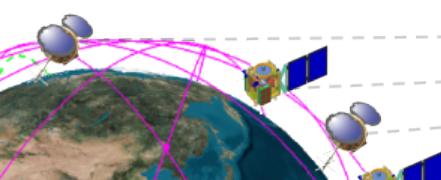
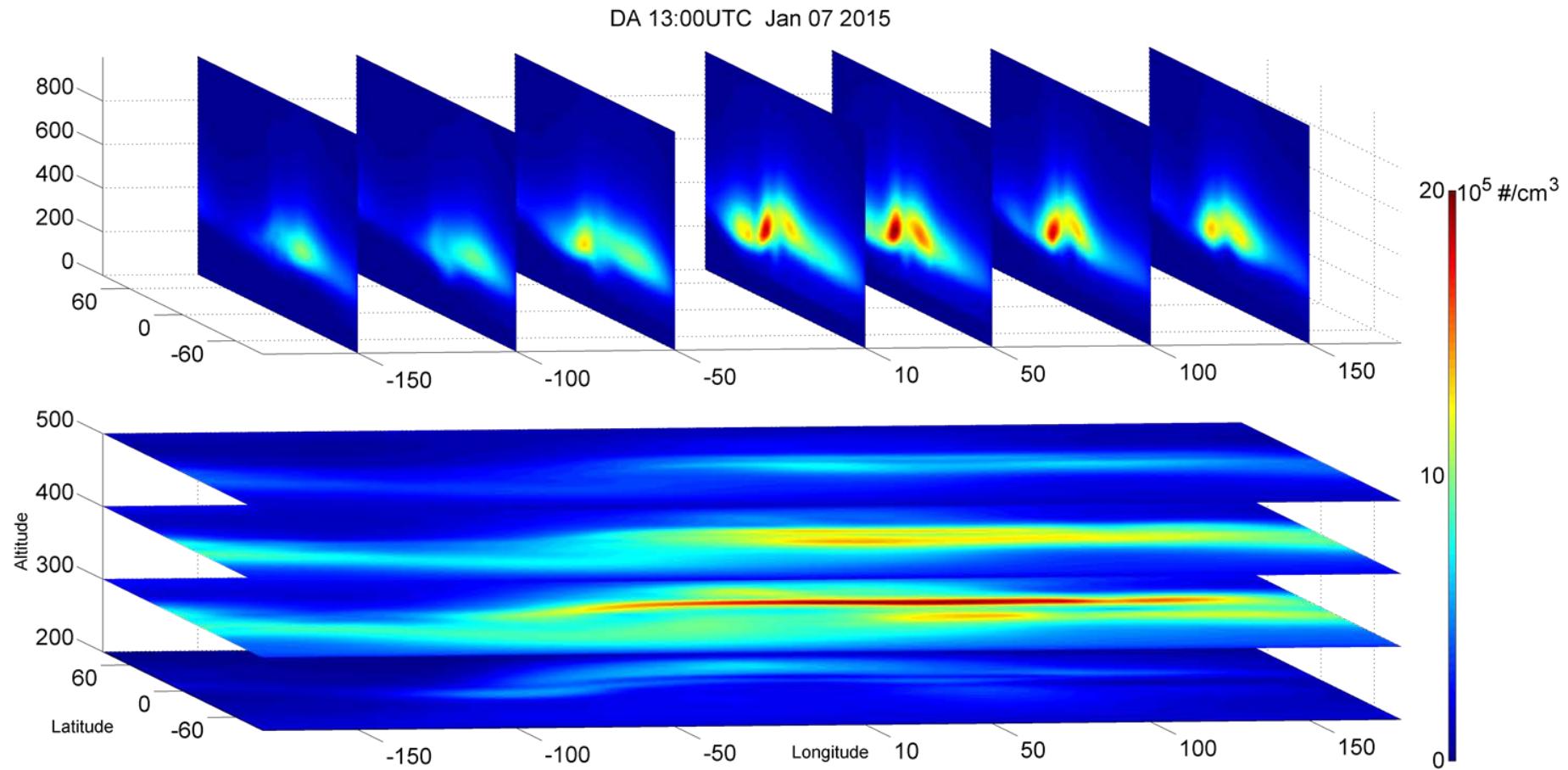


FORMOSAT-3 & FOMORSAT-7



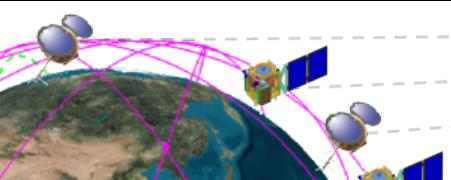
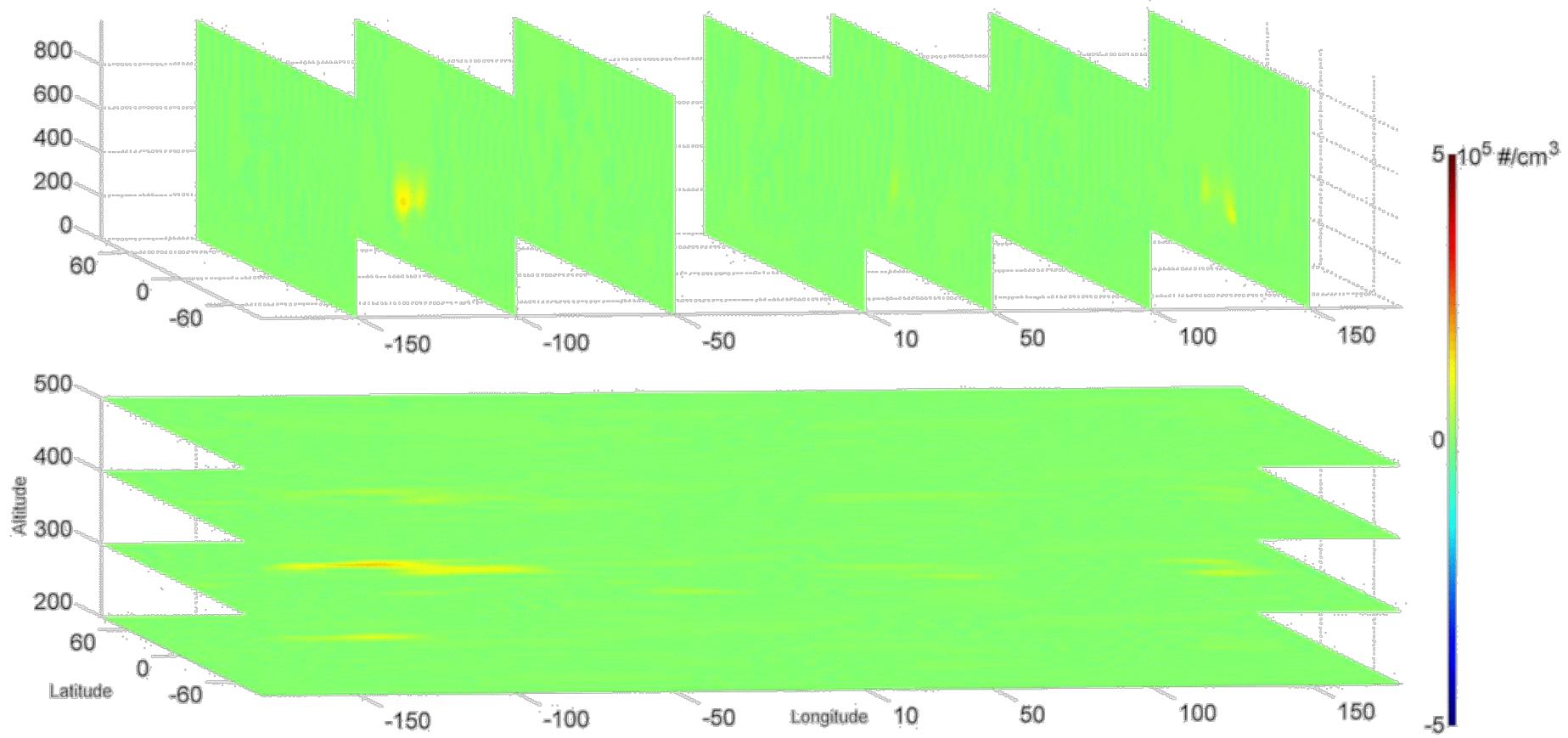
Ionospheric Data Assimilation 3-D structure

13:00 UTC Jan 07 2015



FORMOSAT-3 & FOMORSAT-7

DA Difference 00:00UTC Jan 07 - Jan 06 2015

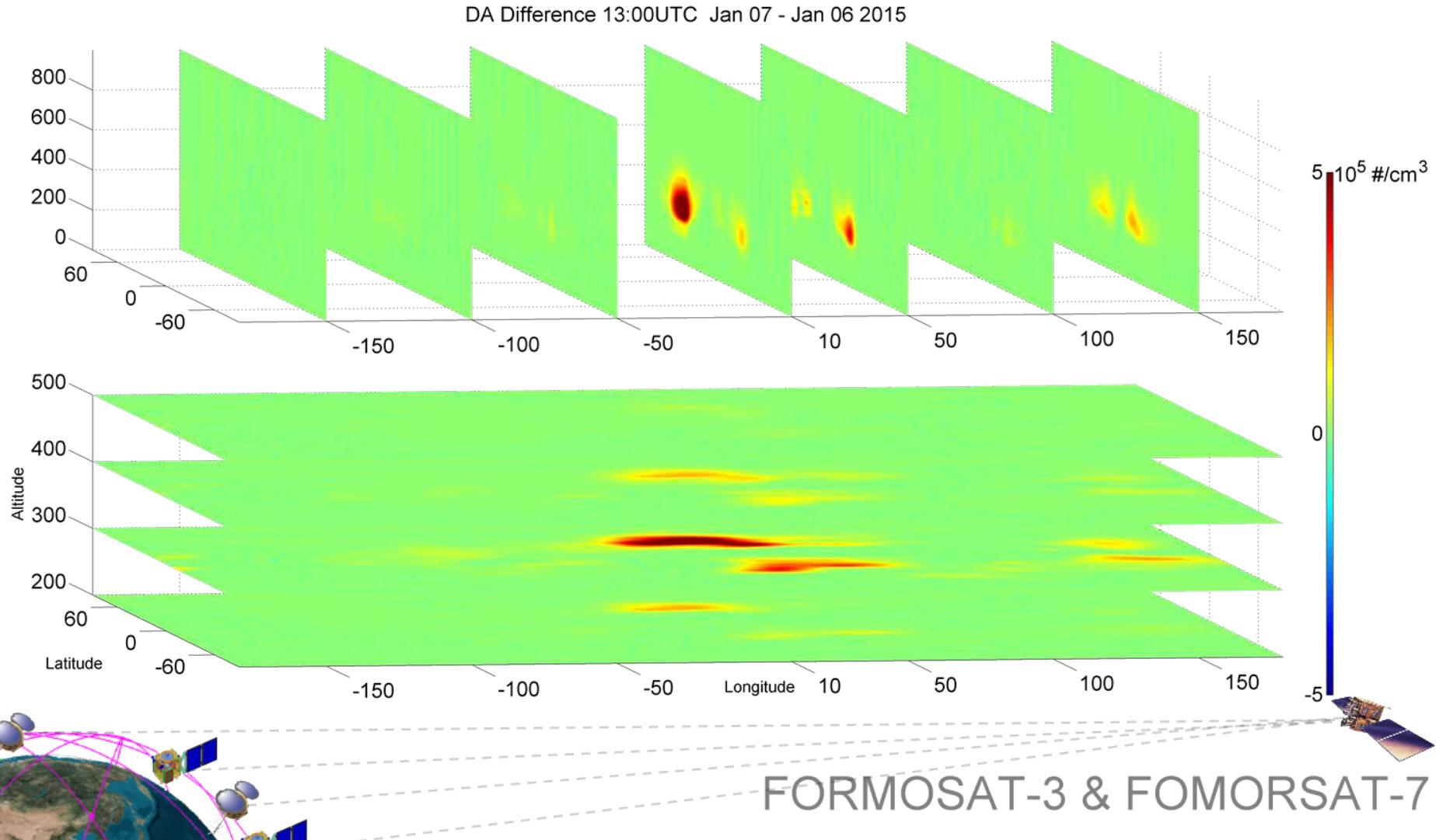


FORMOSAT-3 & FOMORSAT-7

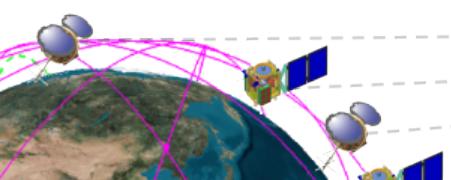
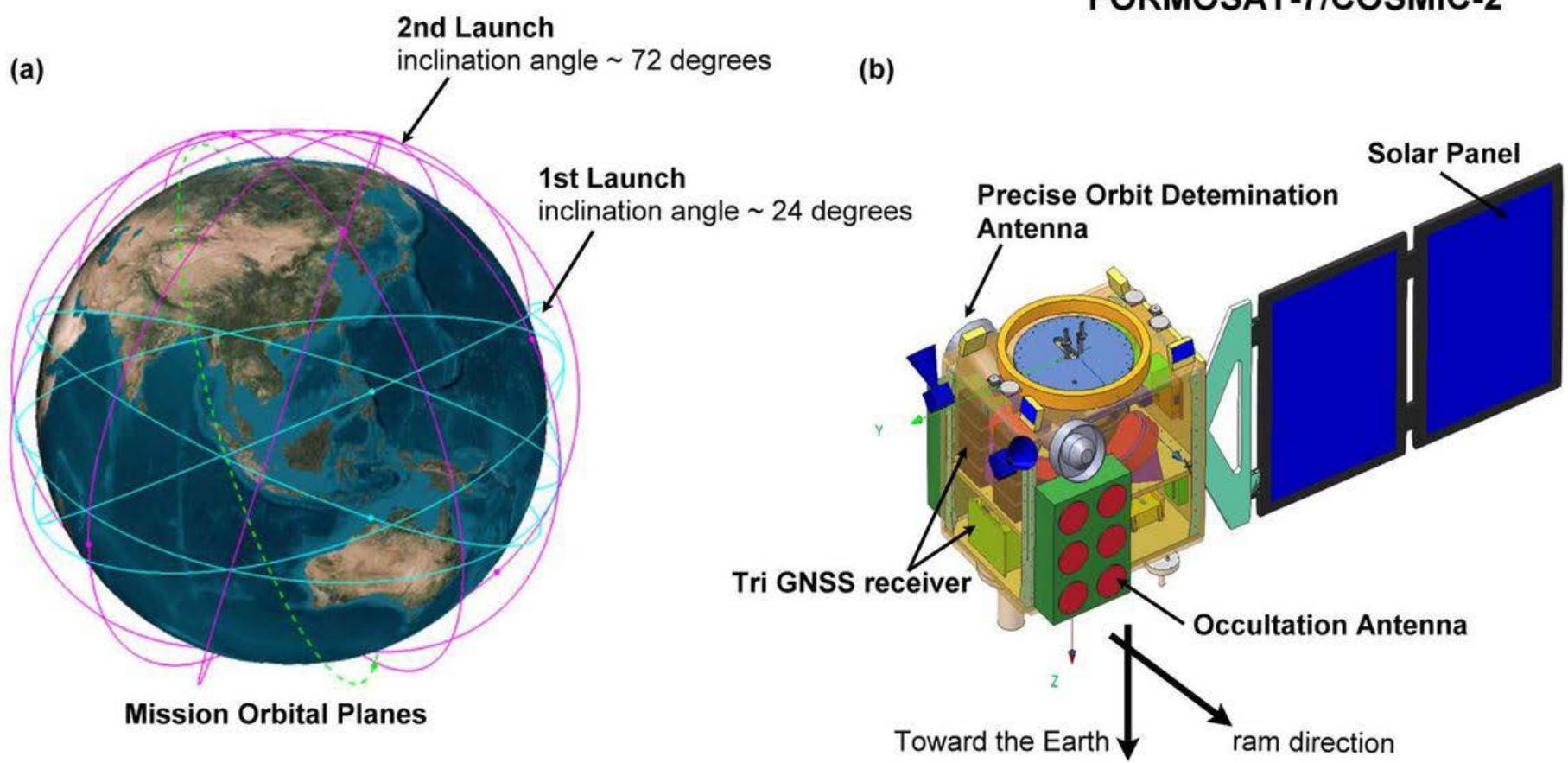
Ionospheric Data Assimilation

3-D structure Difference

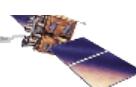
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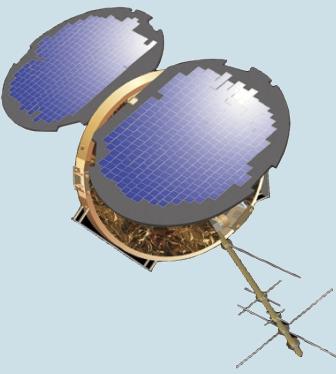
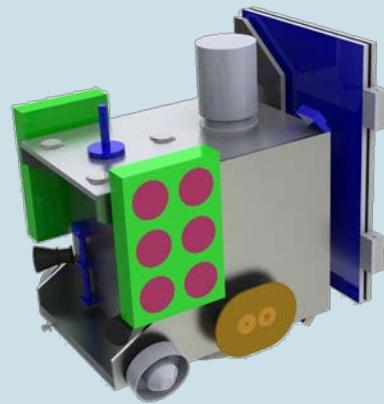


FORMOSAT-7/COSMIC-2



FORMOSAT-3 & FOMORSAT-7

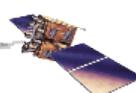


	FORMOSAT-3/COSMIC	FORMOSAT-7/COSMIC-2	
Exterior Design			
Sequence		1 st Launch	2 nd Launch
Constellation	6	6	6
Mission Orbit Altitude	800 km	520-550 km	720-750 km
Inclination Angle	72°	24-28.5°	72°
Mission Payload	GOX	TriG	
RO Signals	GPS	GPS, GLONASS, Galileo	
Launch Schedule	Launched in 2006	2016	2018

- Descriptions are provided by NSPO (<http://www.nspo.org.tw>).
- F7/C2 is illustrated by Surrey Satellite Technology LTD.

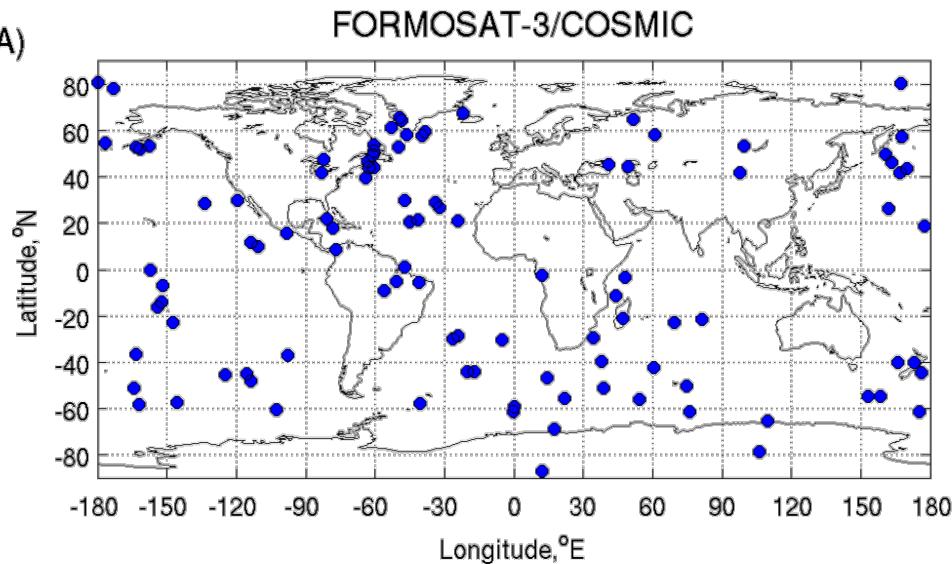


FORMOSAT-3 & FOMORSAT-7



F7/C2 vs F3/C

(A)

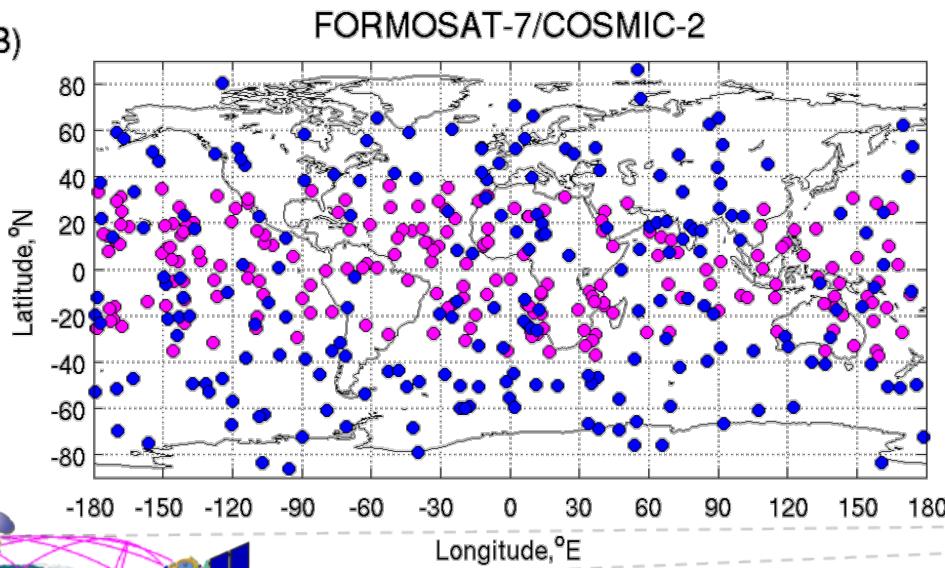


With 6 satellites + GPS, 60 minutes

About 80-100 profiles per hour

F3/C

(B)



With 12 satellites + GPS, 60 minutes

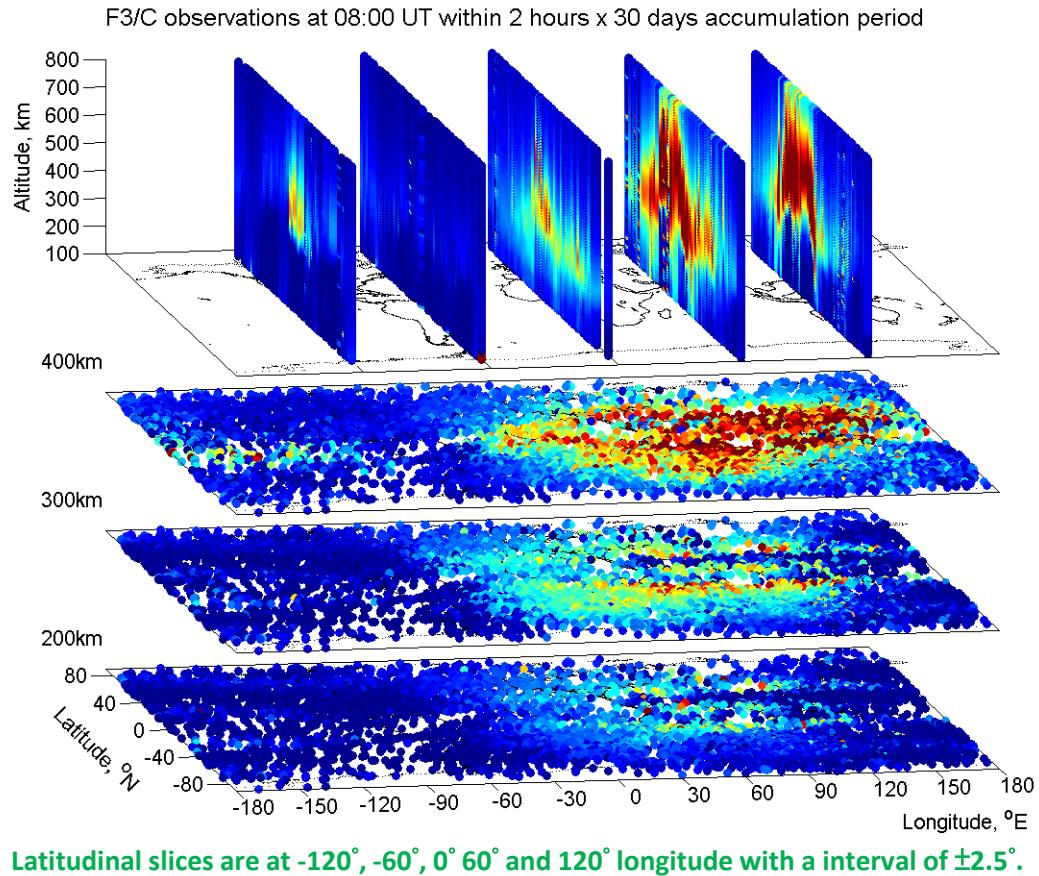
About 400 profiles per hour

1 st
2 nd



FORMOSAT-3 & FOMORSAT-7

Ionospheric Weather Monitoring



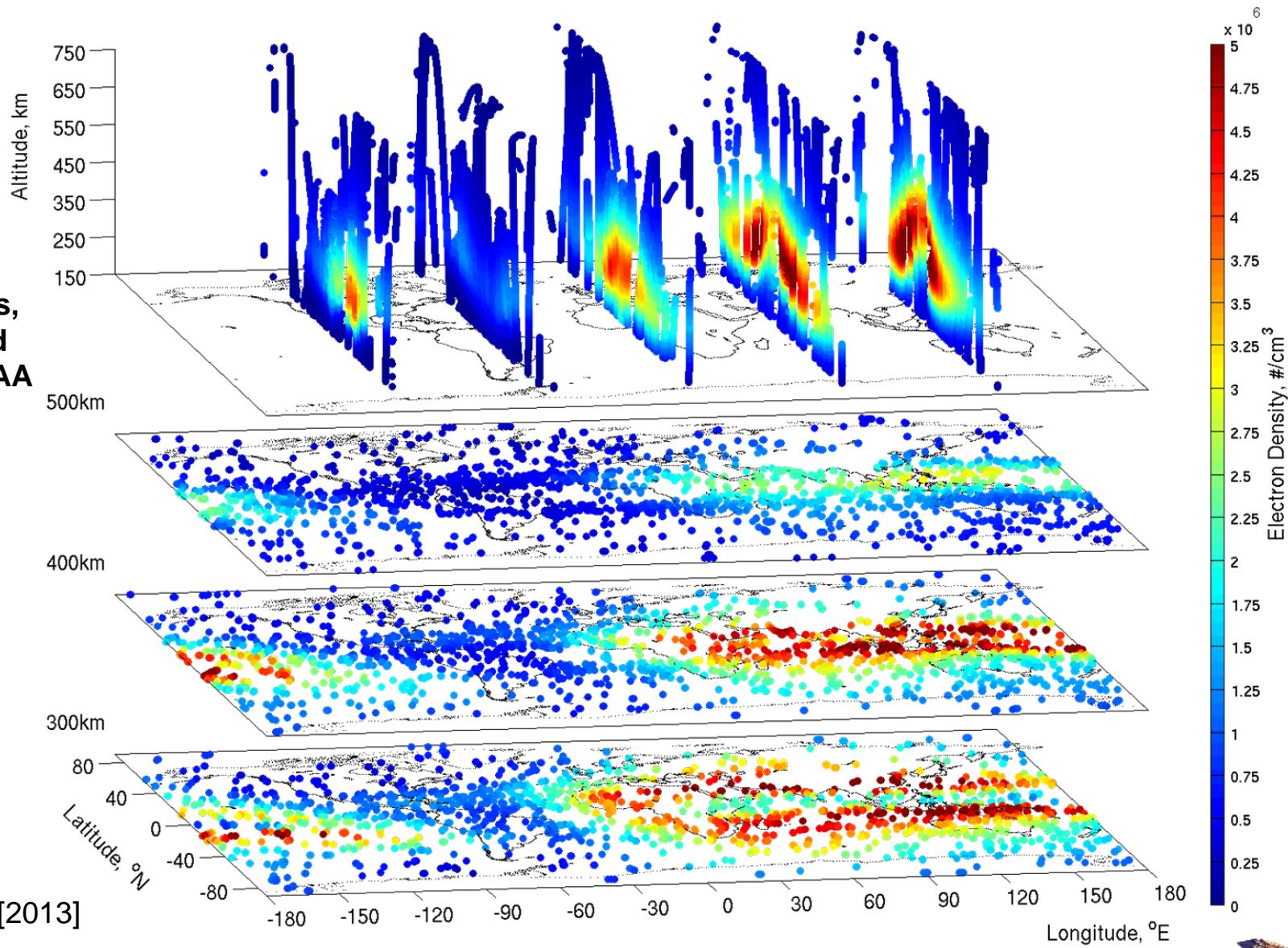
- Solar activity variations
- Seasonal variations
- Monthly variations
- Tidal effects
- Diurnal variations
- Semi-diurnal variations
- Disturbed period effects
- Other temporal variations
- Irregularities

Could it be advanced by F7/C2 ?

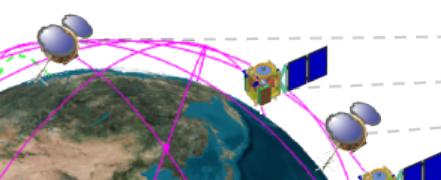


Simulated F7/C2 observations at 08:00 UT within 1 hour x 1 day accumulation period

12 satellites,
28 GPS and
24 GLONAA



Lee et al. [2013]



FORMOSAT-3 & FOMORSAT-7

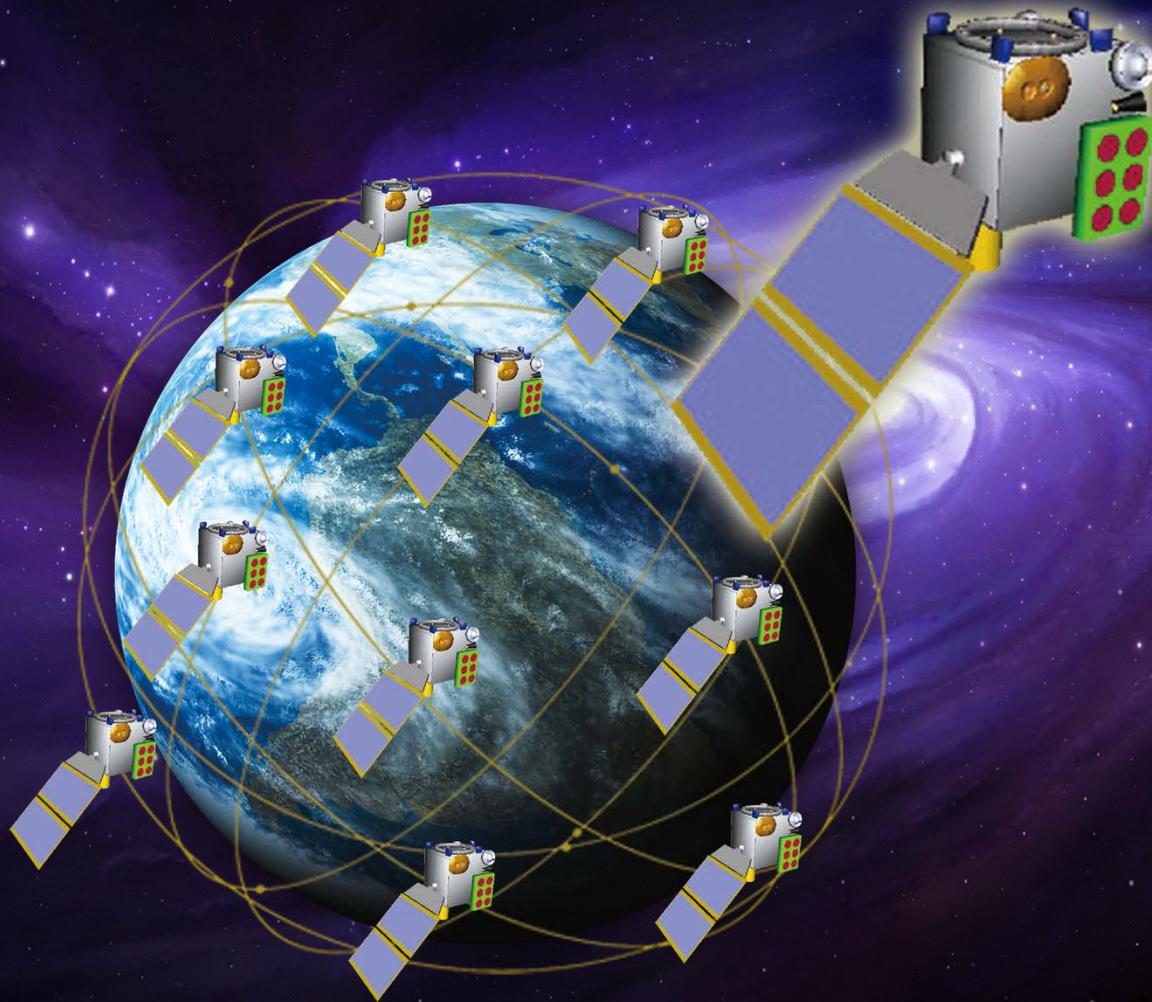
Summary

- TIEGCM DA for the first time includes the neutral atmosphere which can be used to carry out the long term ionospheric weather prediction.
- TGIM issues the global TEC map every 10 minutes currently with a 4-hour time delay.
- EOF DA provides the global 3D electron density structure.
- The three models detect the ionospheric signatures of the 7 January 2015 storm.
- TGIM+EOF DA will be the next product for the short term ionospheric weather prediction.
- FORMOSAT-7/COSMIC-2 shell open a new chapter for the ionospheric weather monitoring and Prediction.



FORMOSAT-3 & FOMORSAT-7

Thank you



FORMOST-7/COSMIC-2