IROWG Workshop 2012
Estes Park, Colorado

Assessment of Radio Occultation Observations to Improve Space Weather Nowcasts Using the JPL/USC Global Assimilative Ionosphere Model

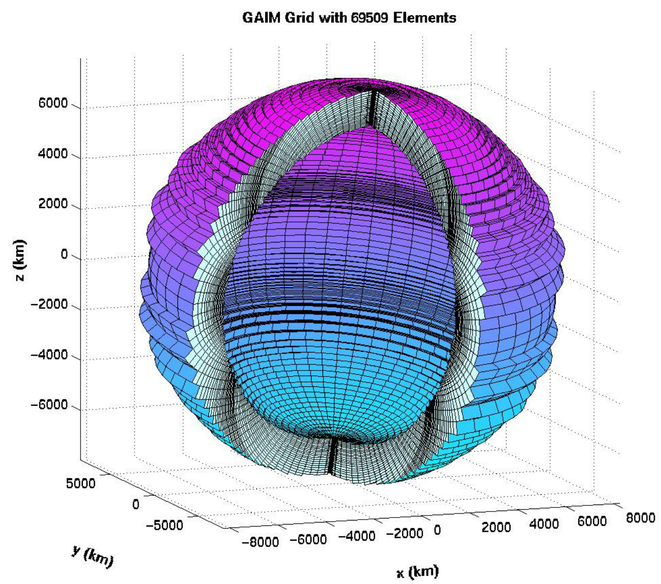
Anthony J Mannucci, Attila Komjathy, Mark Butala, Xiaoqing Pi, Olga Verkhoglyadova, Byron Iijima, Brian D Wilson and Vardan Akopian

Jet Propulsion Laboratory, California Institute of Technology

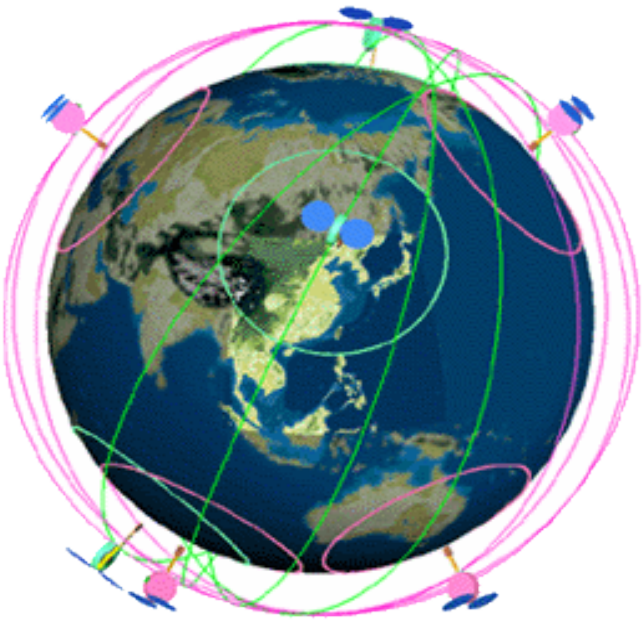
Session 6 "Ionosphere"
Friday March 30, 2012

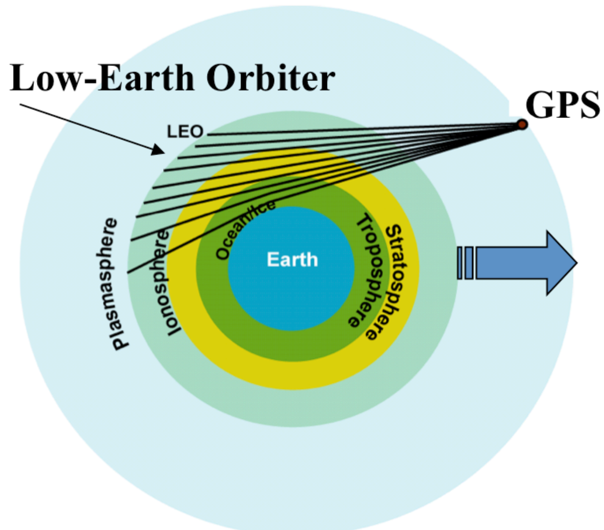
Outline

1. The radio occultation data set
2. Survey of results
   1. Value of radio occultation to ionospheric space weather: electron density profile shape
   2. Benefit of COSMIC-2: more profiles, and filling in geospatial "holes"
   3. Driver estimation ("holy grail")
3. Summary and conclusions

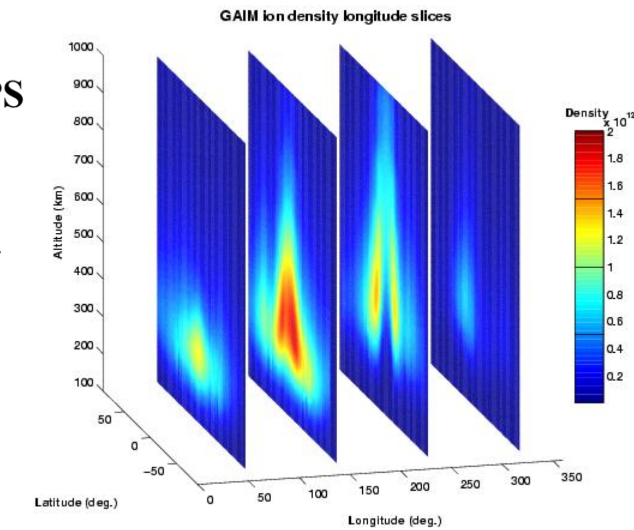


GPS Receivers in Low Earth Orbit: Electron Density Maps



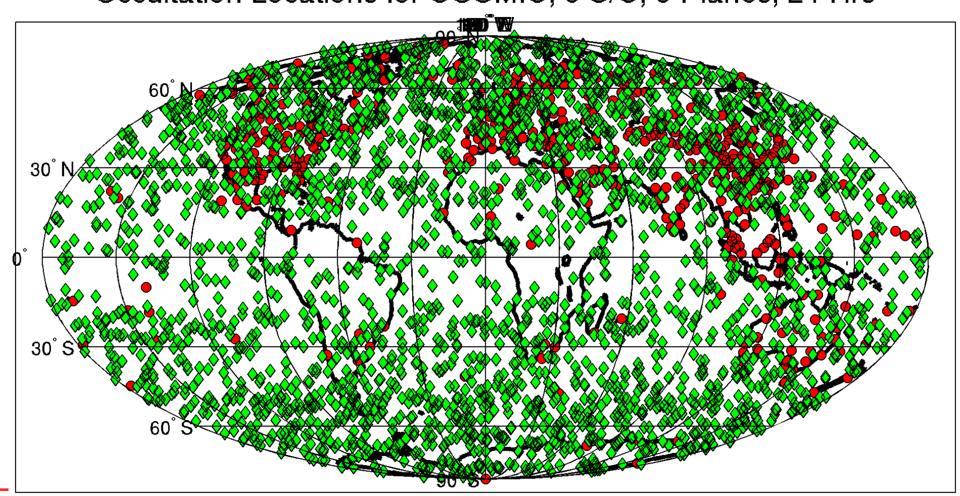


JPL/USC GAIM



COSMIC coverage: 2500 profiles/day

Occultation Locations for COSMIC, 6 S/C, 6 Planes, 24 Hrs



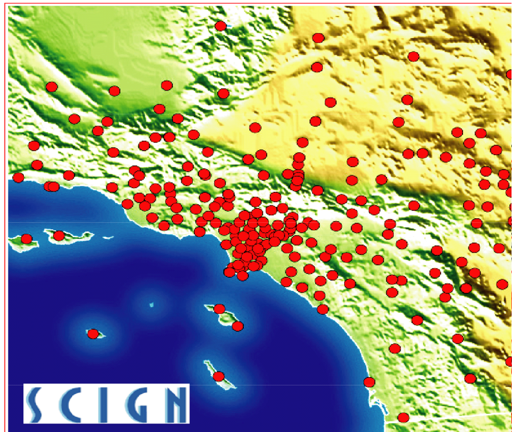
800 km altitude

72° inclination, 6 planes

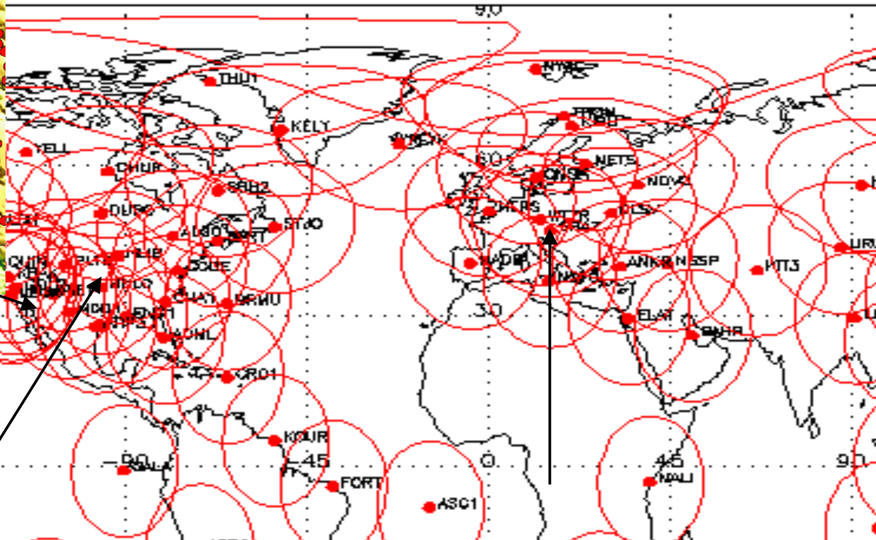
Six-satellite COSMIC constellation
Launched April 14, 2006

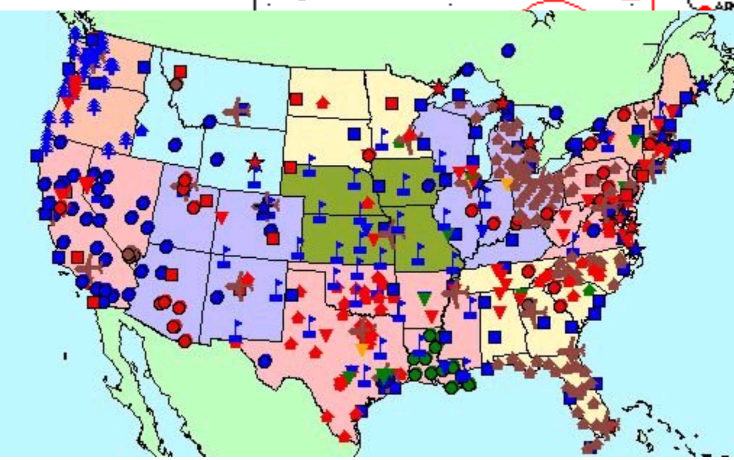
NSF NASA USAF NOAA NSPO ONR

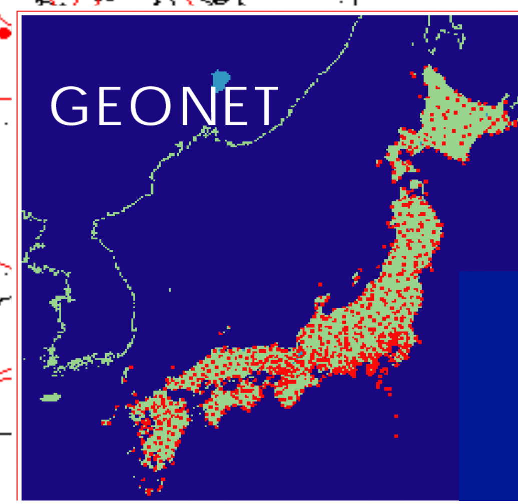
Coverage of Daily IGS Network and Regional Networks



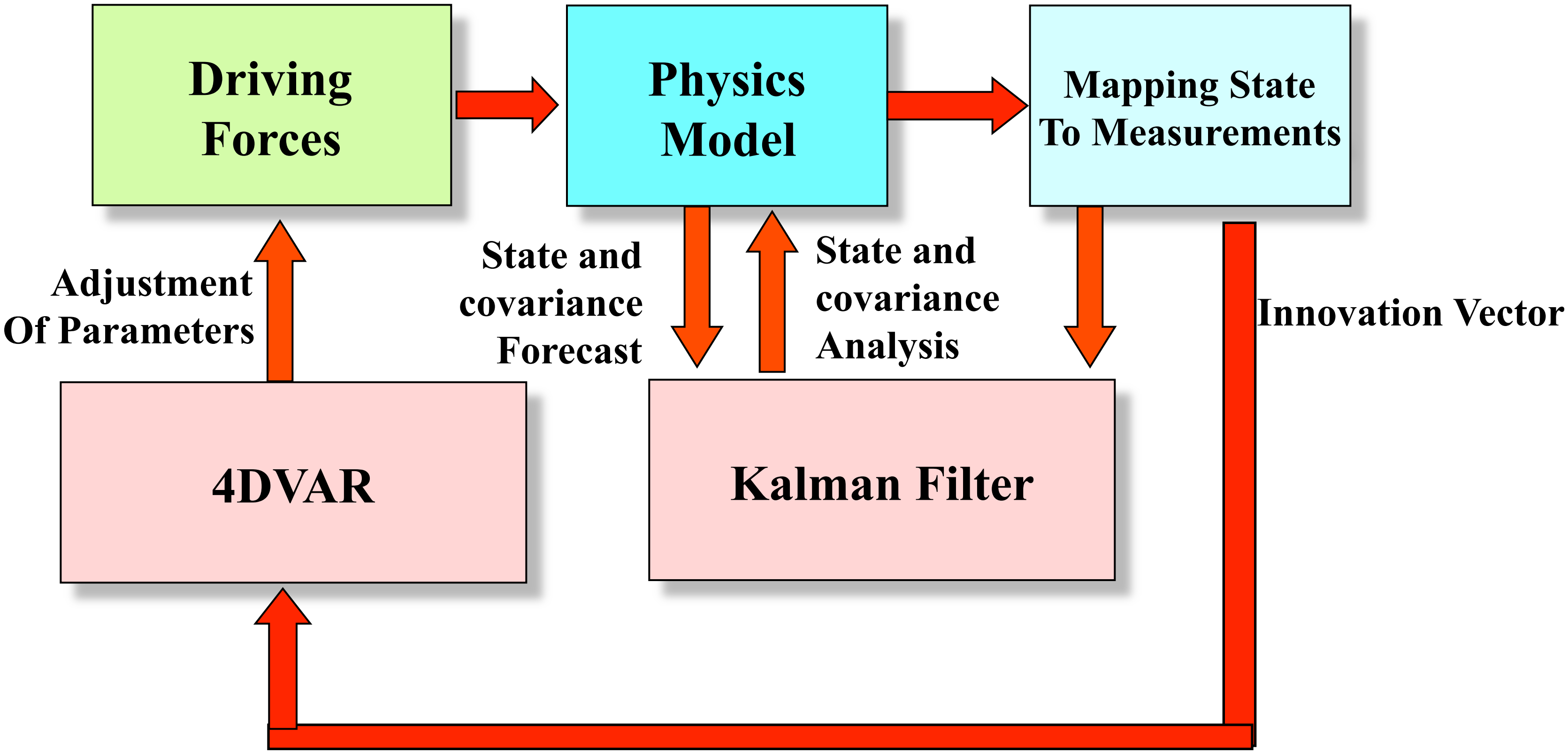
(10 degree elevation mask; 450 km shell height)







Global Assimilative Ionospheric Model Data Assimilation Process

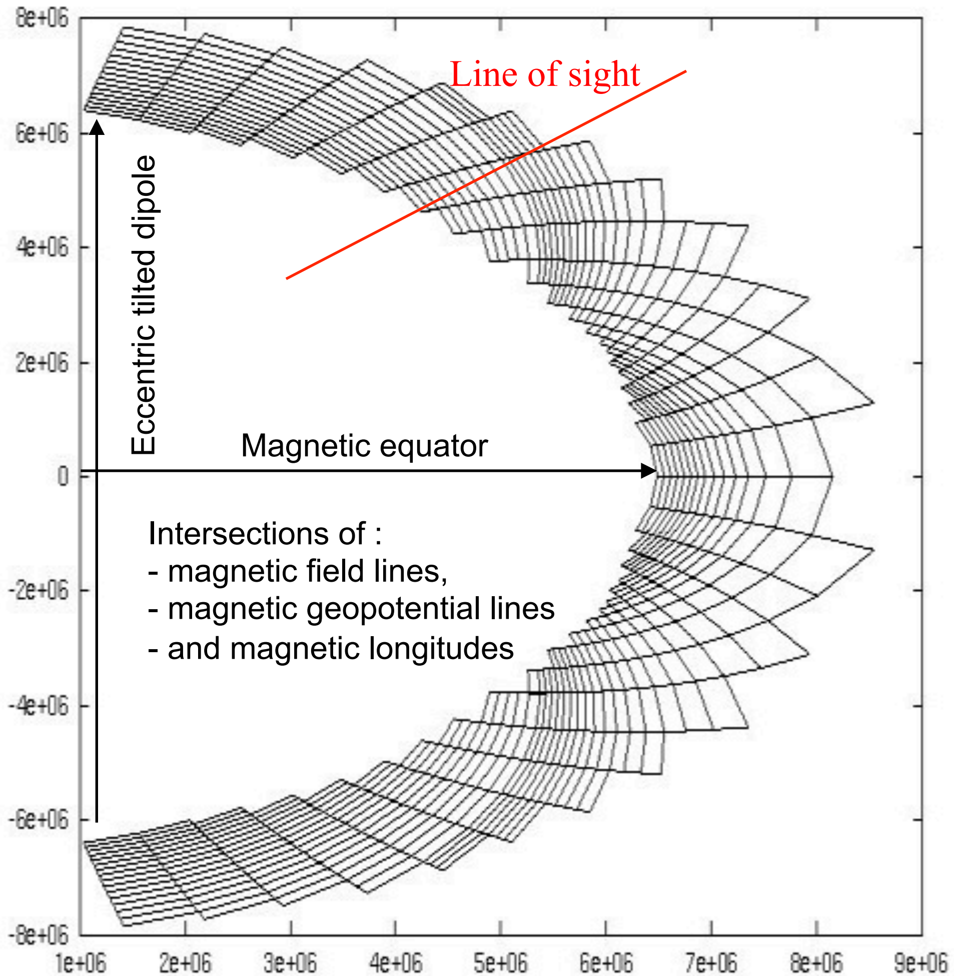


- 4-Dimensional Variational Approach
  - Minimization of cost function by estimating driving parameters
  - Non-linear least-square minimization
  - Adjoint method to efficiently compute the gradient of cost function
  - Parameterization of model "drivers"
- Kalman Filter
  - Recursive Filtering
  - Covariance estimation and state correction

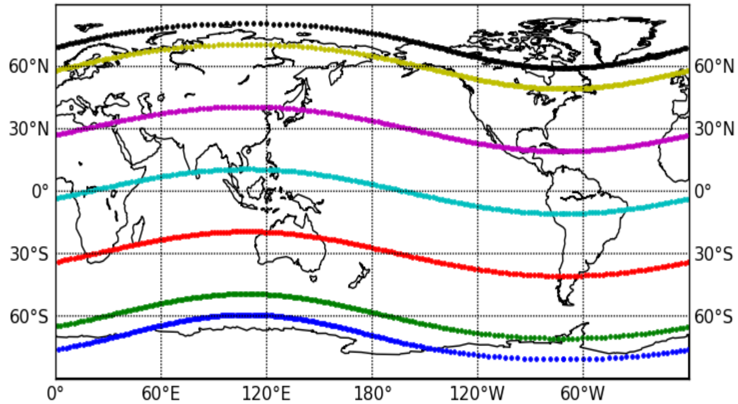
  Optimal interpolation

  Band-Limited Kalman filter

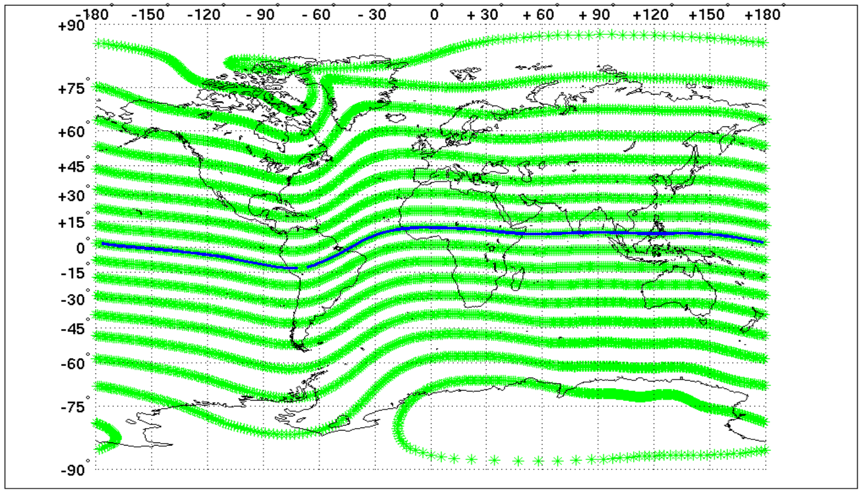
GAIM Magnetic Aligned Grids



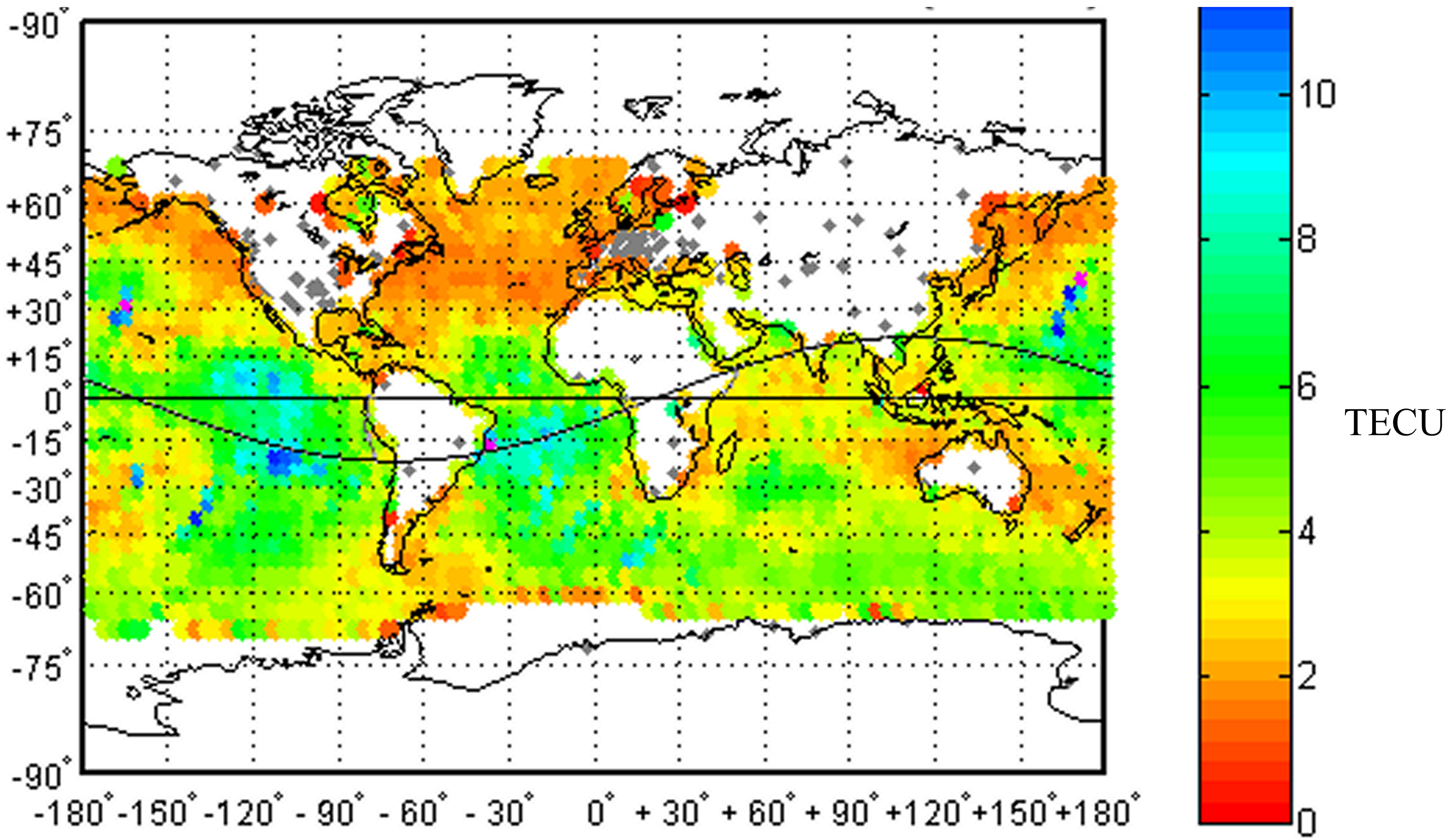
Single Dipole GAIM++



Multiple Dipole GAIM++

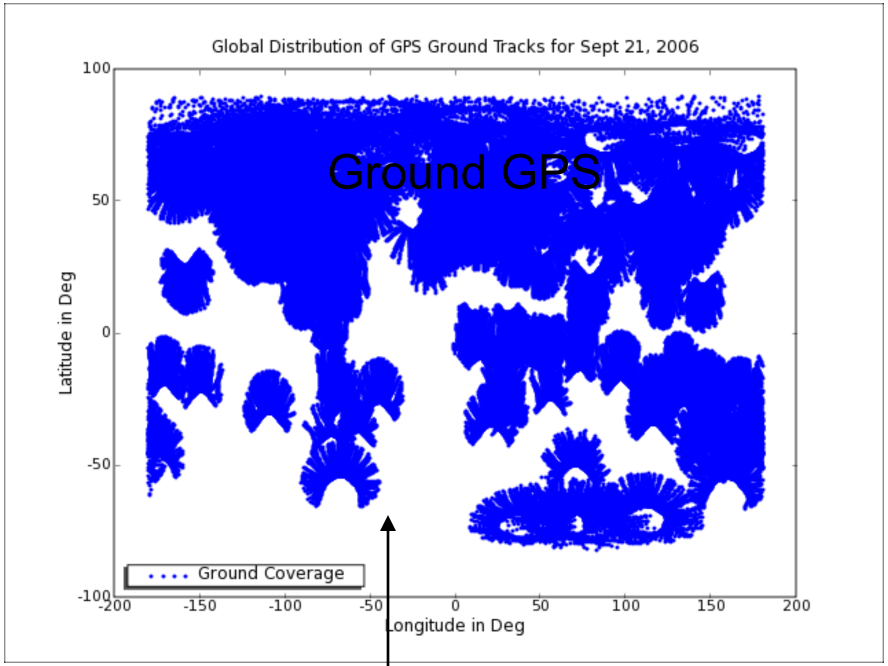


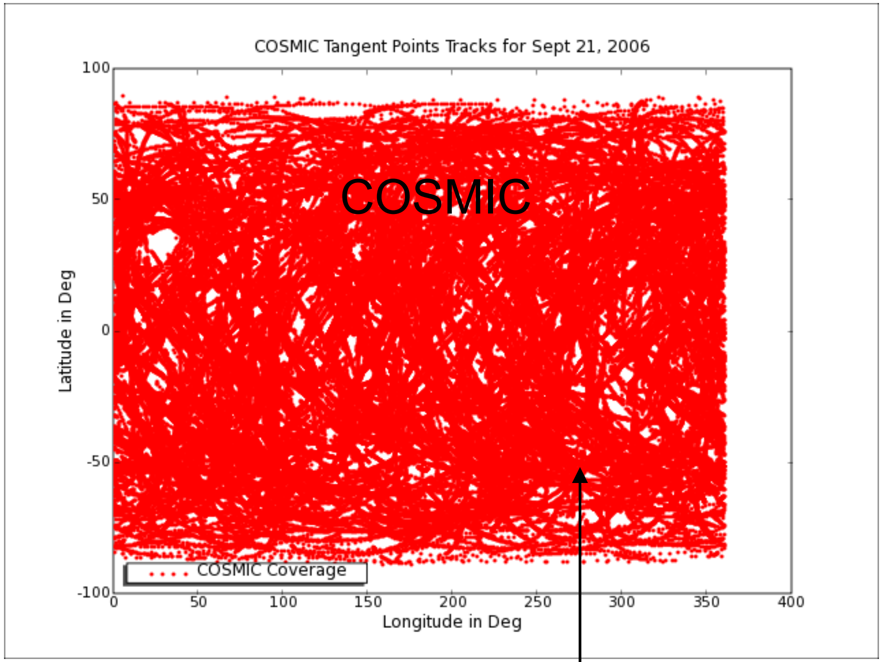
GAIM VTEC RMS Difference Versus JASON Altimeter



06/01/2004 to 11/08/2004 200 stations/day 137 days

Ground and COSMIC Coverage Example (Sept 21, 2006)

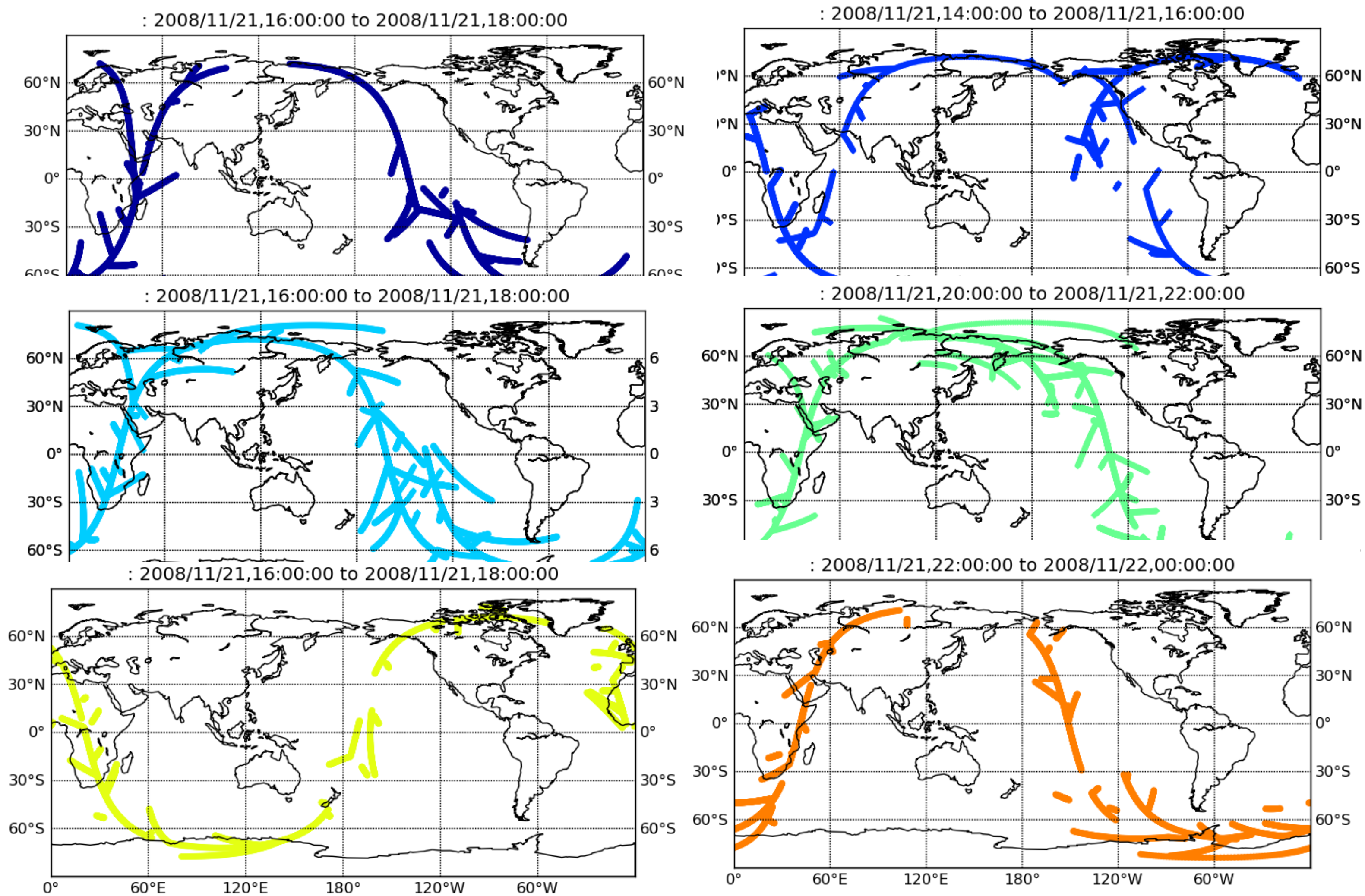




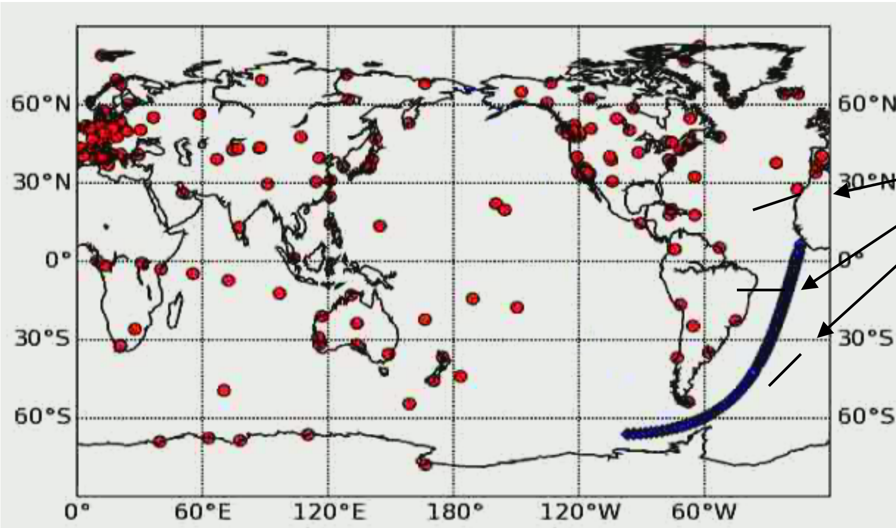
dense but
unevenly distributed
coverage

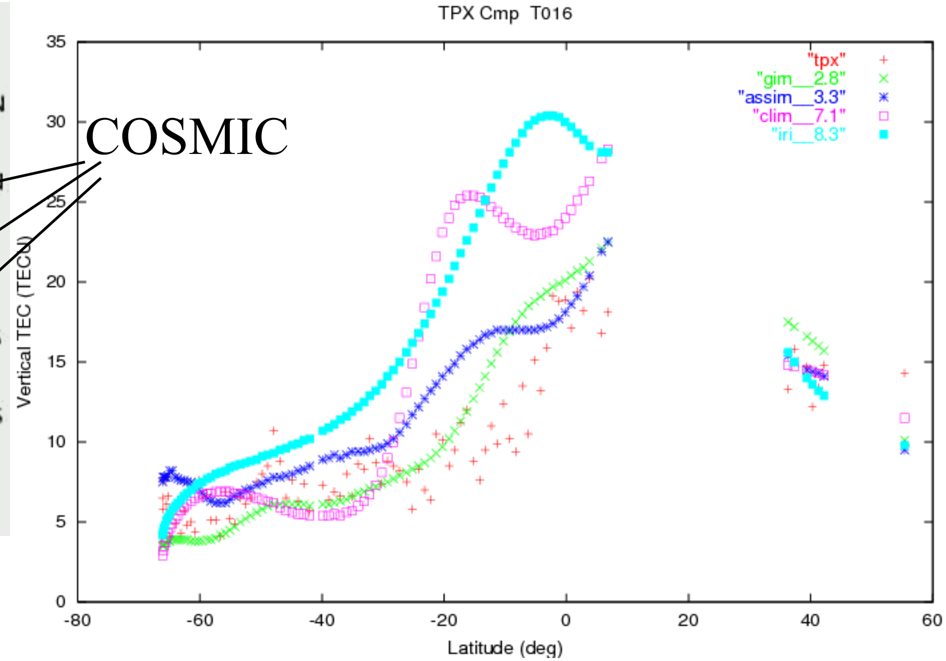
less dense yet
evenly distributed
coverage

COSMIC Coverage on Nov 21, 2008



Assimilating COSMIC: Comparisons to Altimeter TEC Over Oceans



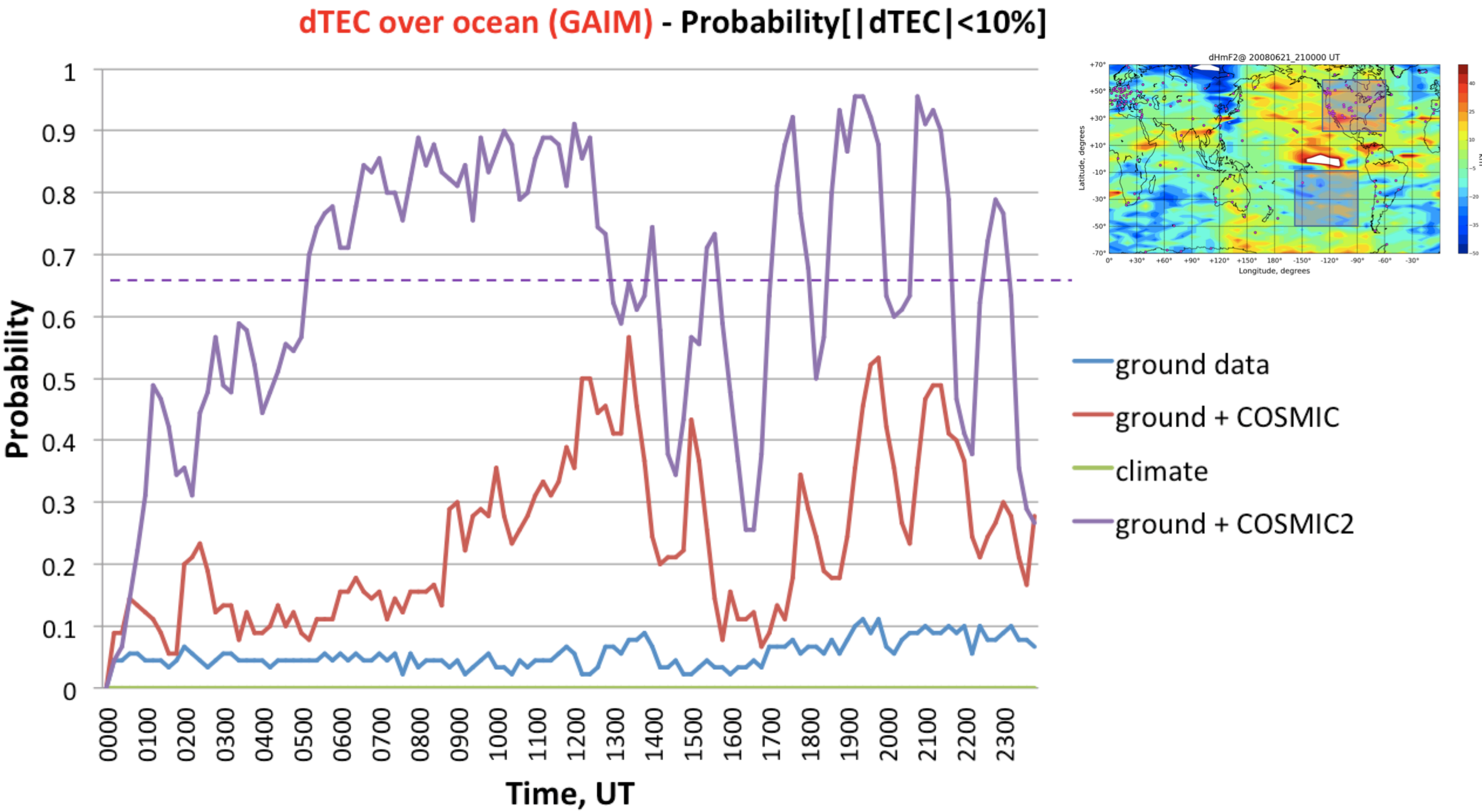


		Mean	Sigma	RMS	Min	Max
	GIM	-1.61	2.88	3.31	-12.5	9.1
06/26/06	**Ground**	-0.24	3.26	3.27	-17.26	11.7
	Ground+COSMIC	-0.29	2.26	***2.28***	-10	8.72

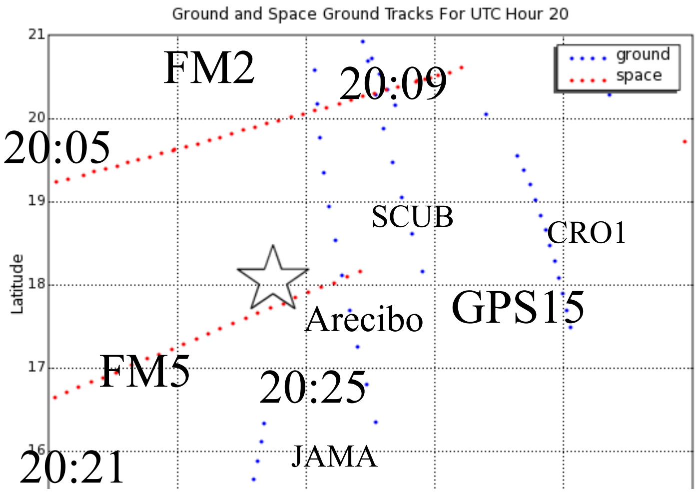
The use of COSMIC+ground-GPS data over ground-GPS only significantly improved TEC predictions for all 3 days processed: 30, 28 and 44% respectively.

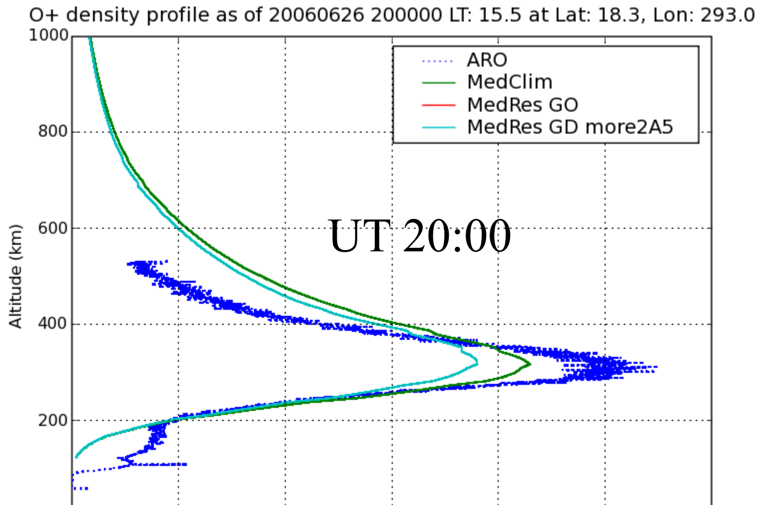
Attila Komjathy, Brian Wilson, Xiaoqing Pi, Vardan Akopian, Miguel Dumett, Byron Iijima, Olga Verkhoglyadova and Anthony J. Mannucci, "JPL/USC GAIM: On The Impact of Using COSMIC And Ground-Based GPS Measurements To Estimate Ionospheric Parameters," JGR 2011

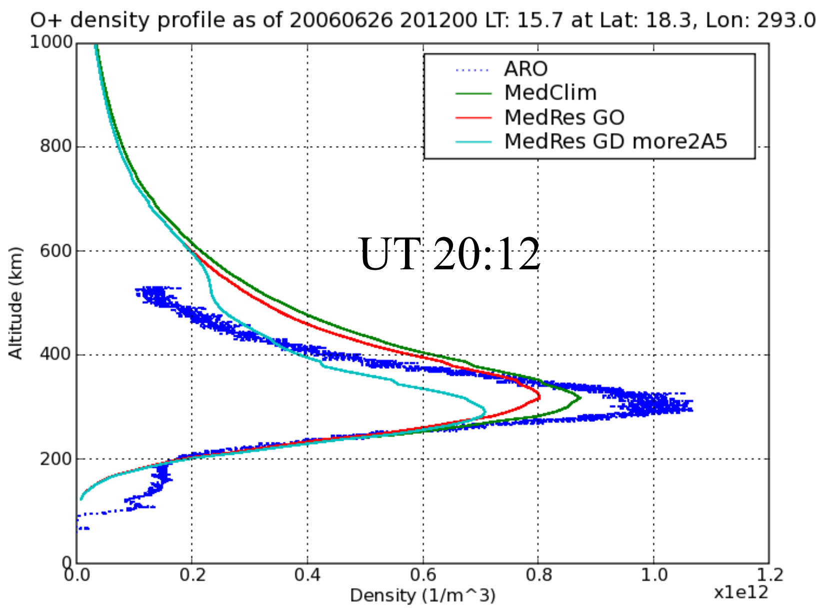
Regional Coverage and COSMIC-2 Simulation Experiment

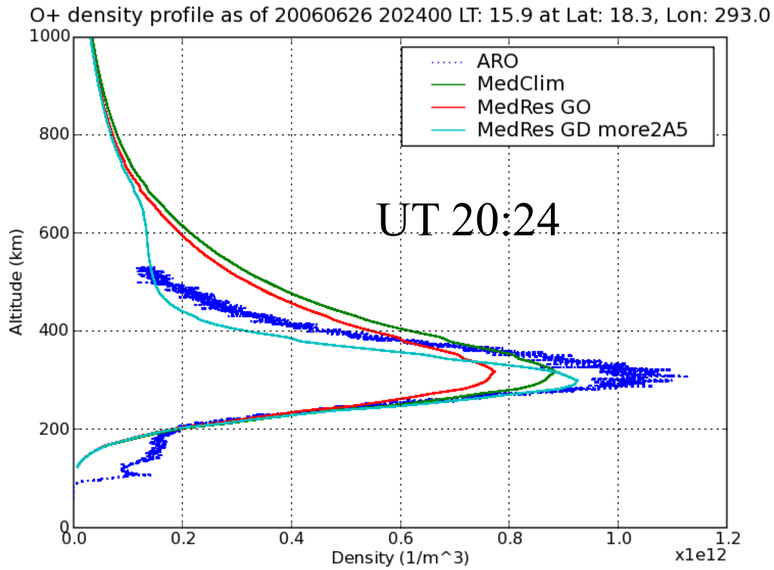


Arecibo ISR Study for June 26, 2006

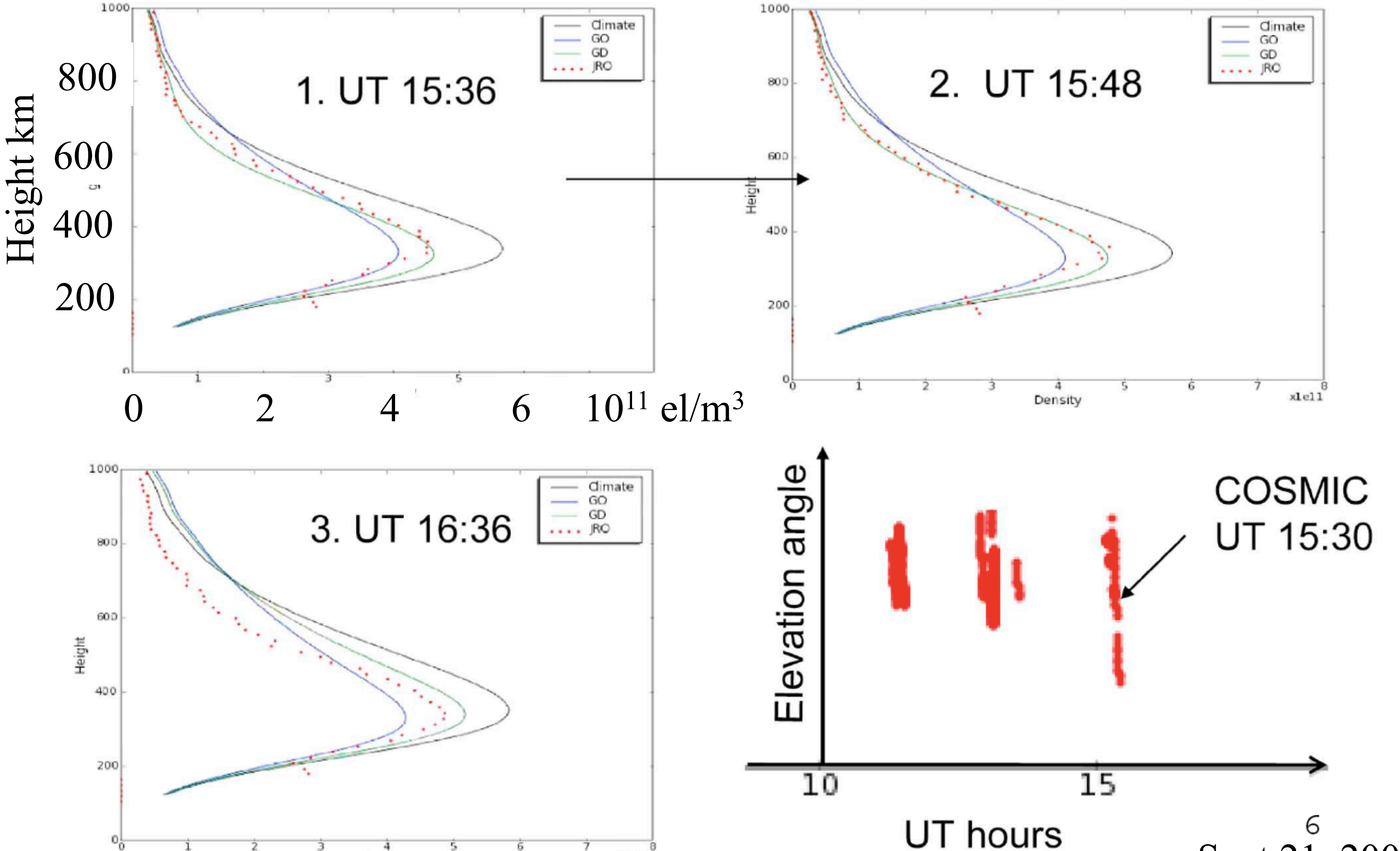








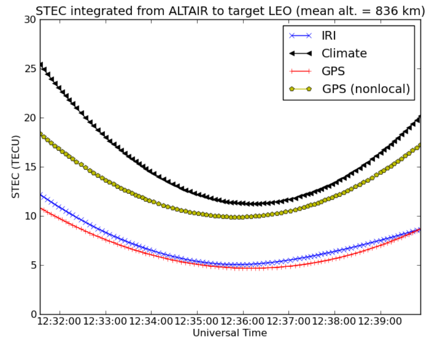
COSMIC Overflight Jicamarca Radio Observatory



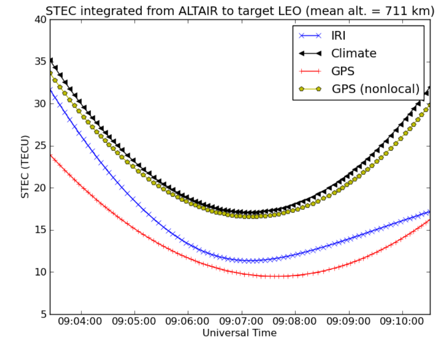
Sept 21, 2006

IRI and GAIM TEC Integrated from ALTAIR to LEOs

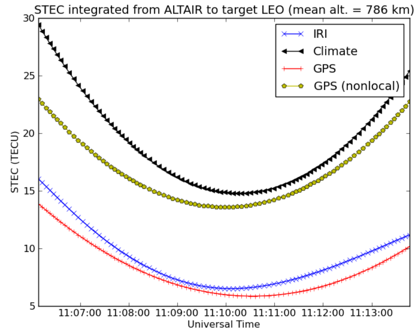
LEO altitude: 836 km
Time of pass: 12:30 UT



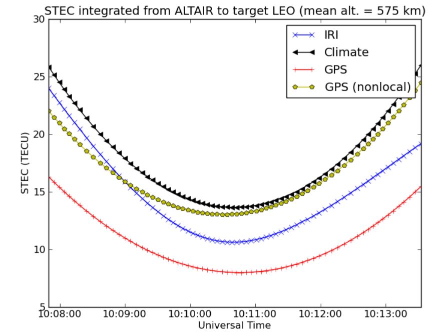
711 km
9:10 UT



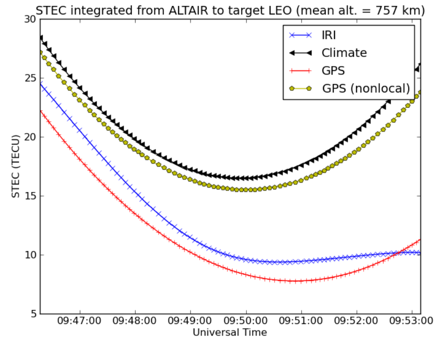
786 km
11:10 UT



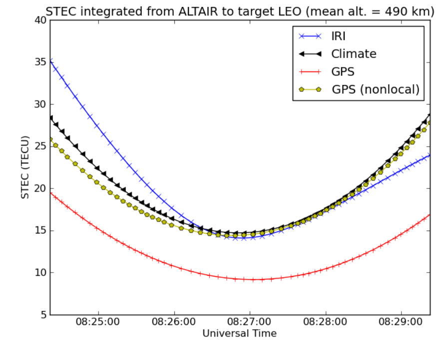
575 km
10:10 UT



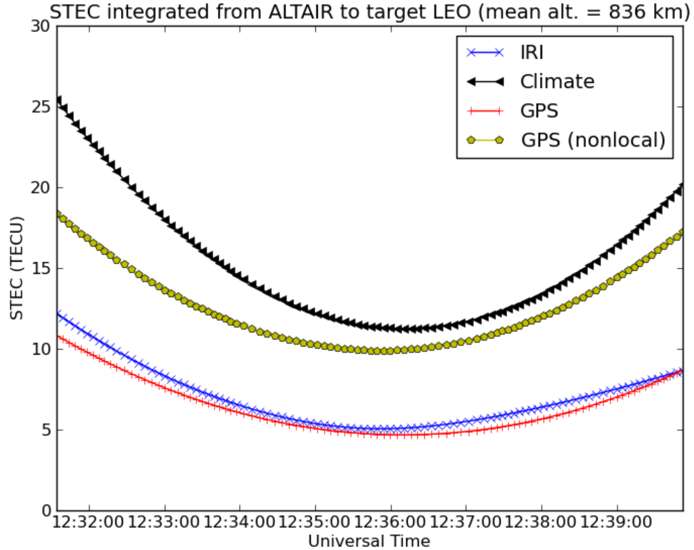
757 km
9:50 UT

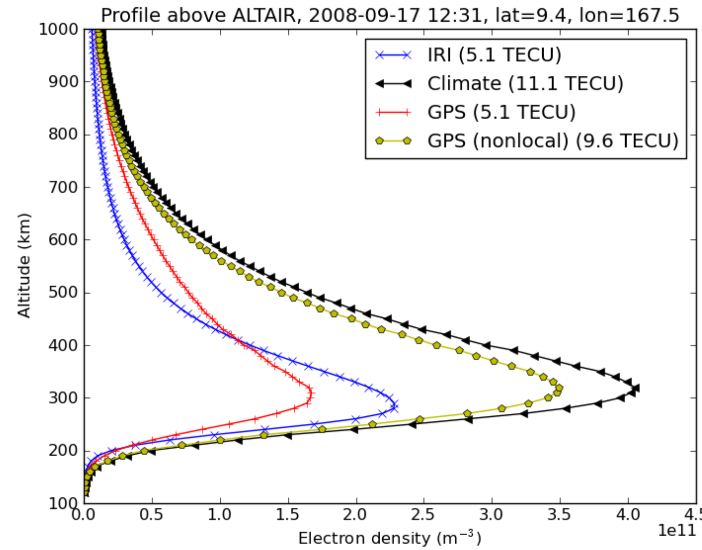


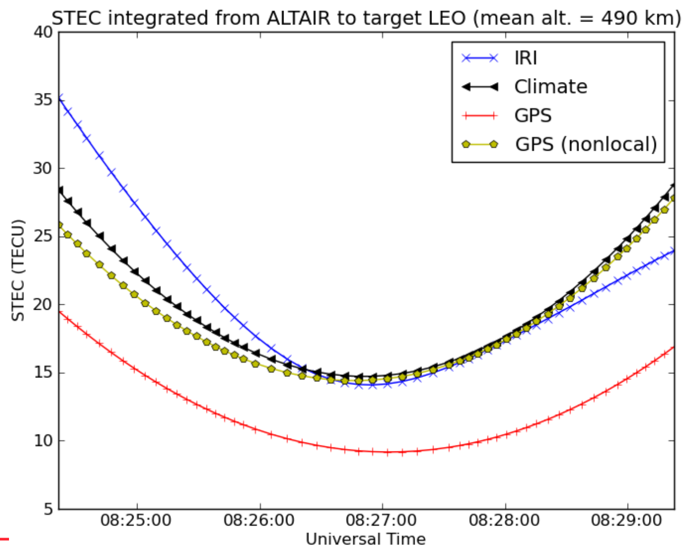
490 km
8:30 UT

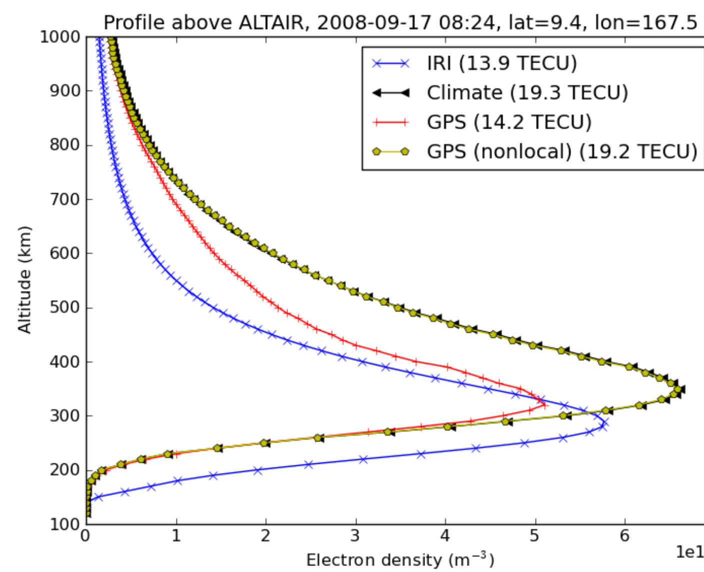


Profile Shape is Critical

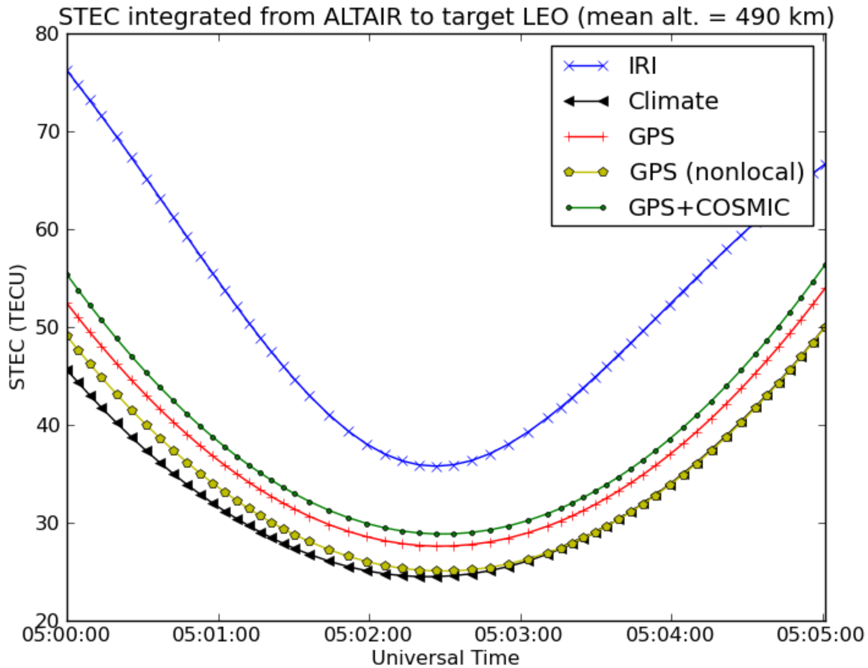


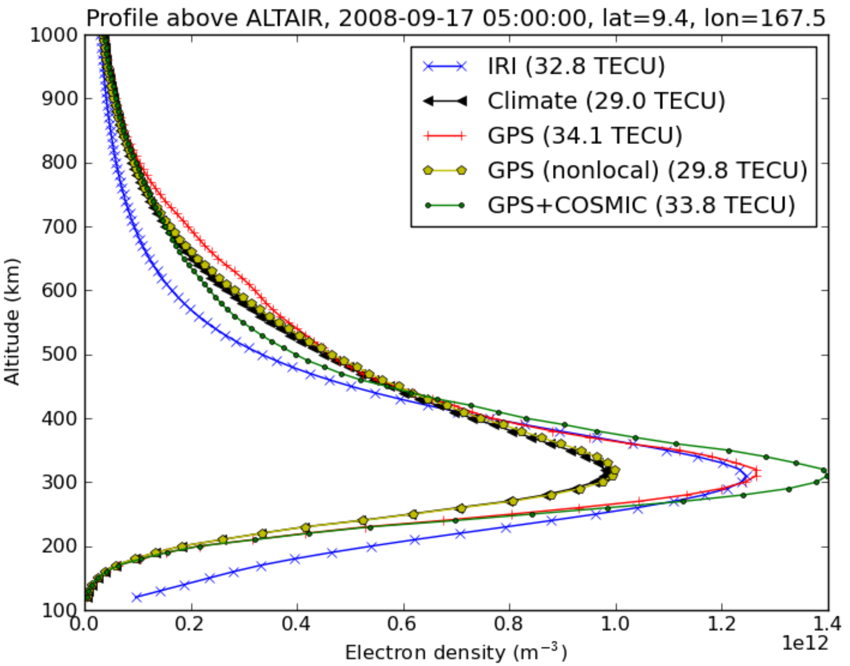






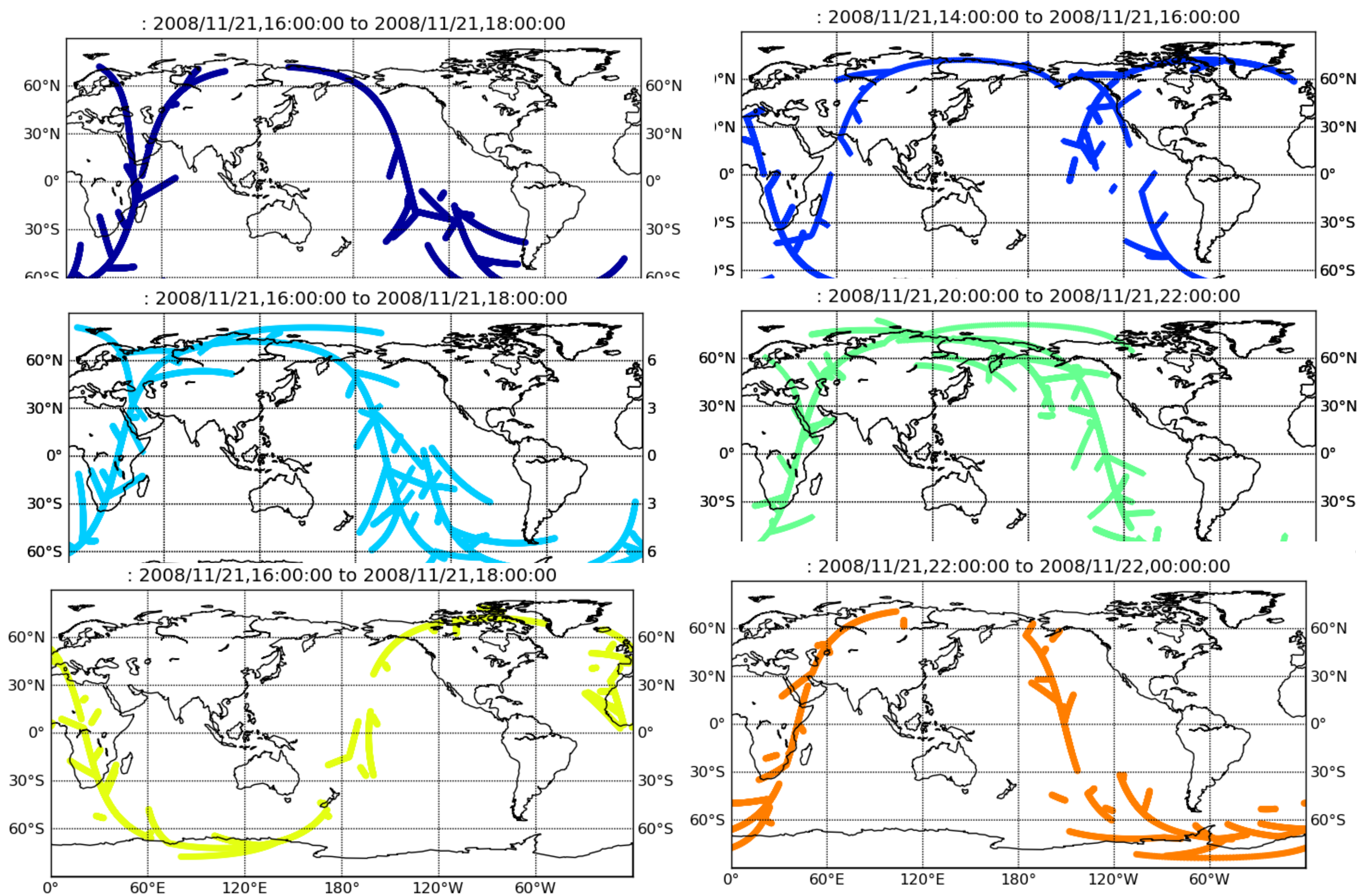
Improvement from COSMIC



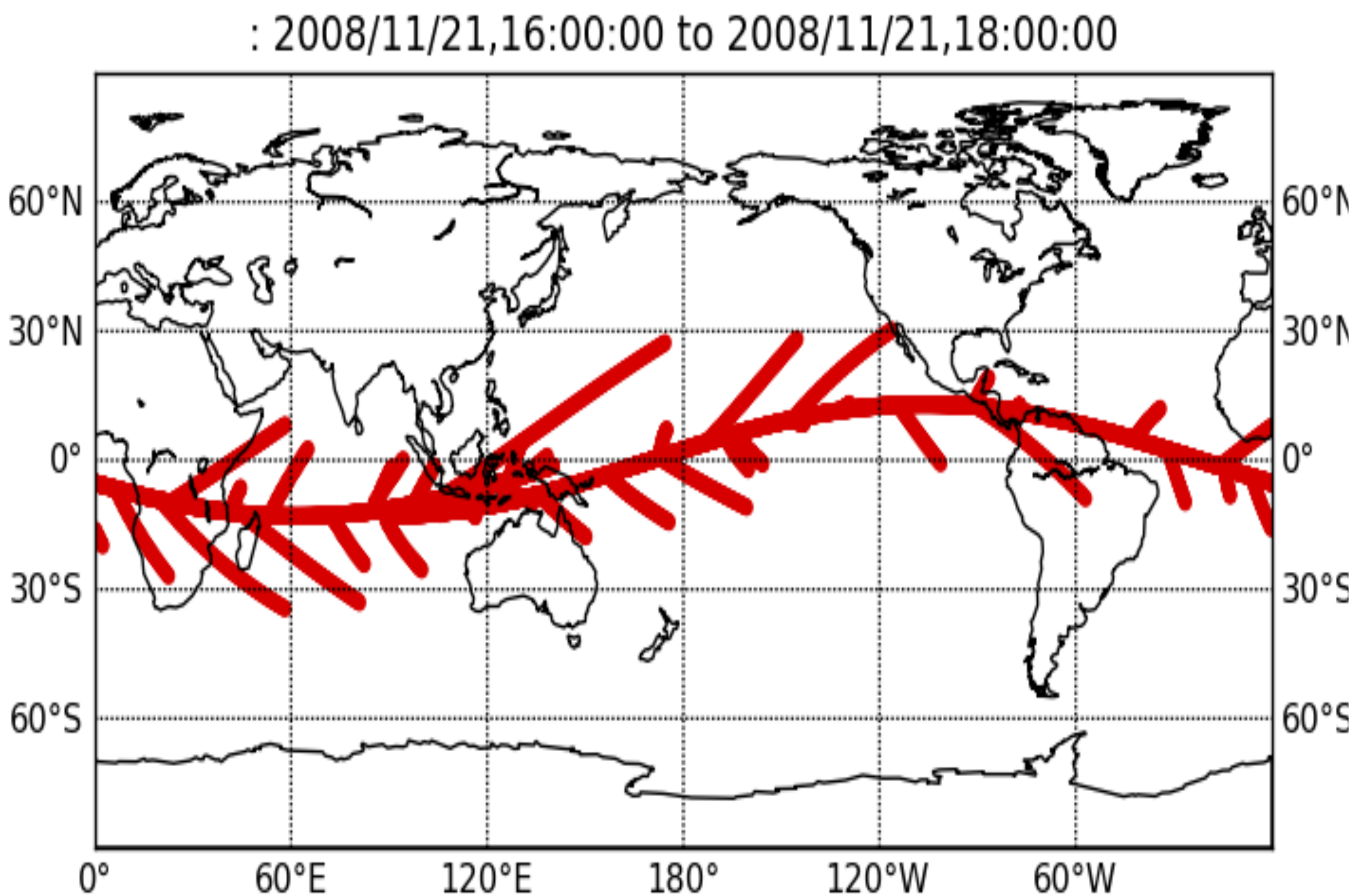


- Time of ALTAIR track has been shifted to 5:00 UT to coincide with COSMIC pass
- Top-side has improved (to the detriment of NmF2) and the bottom-side remains unchanged
- GPS+COSMIC is the closest to the ground truth

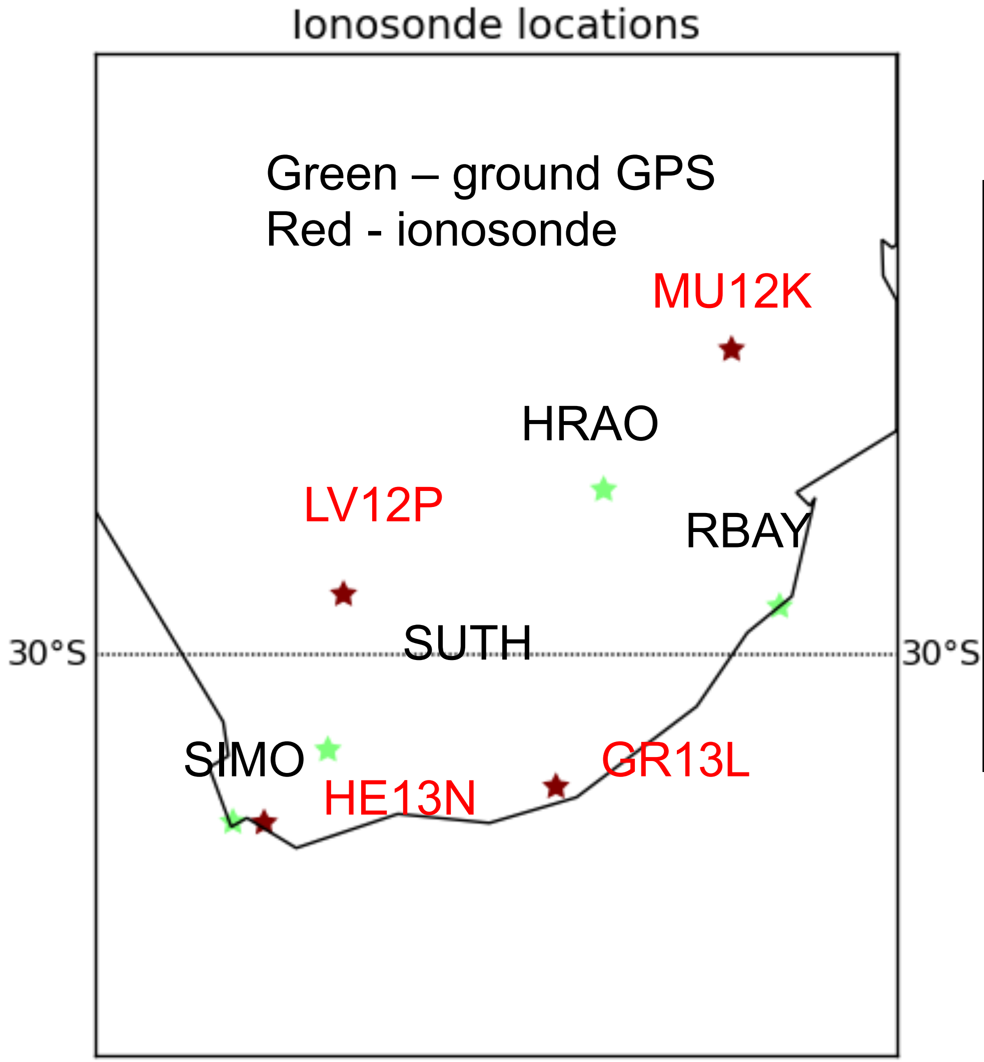
COSMIC Coverage on Nov 21, 2008

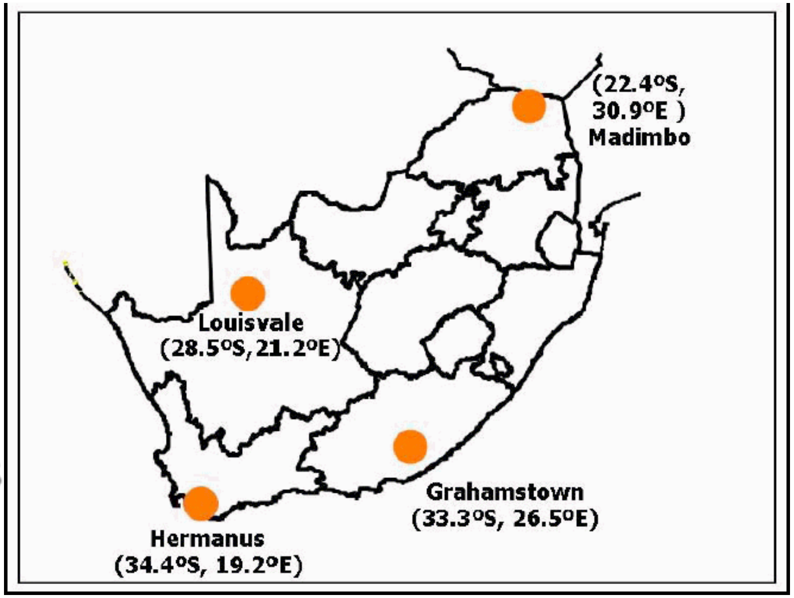


CNOFS Coverage on Nov 21, 2008



Ionosonde Locations in RSA

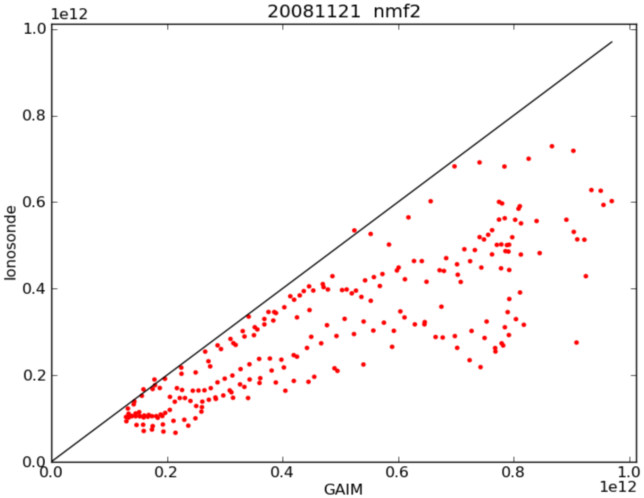




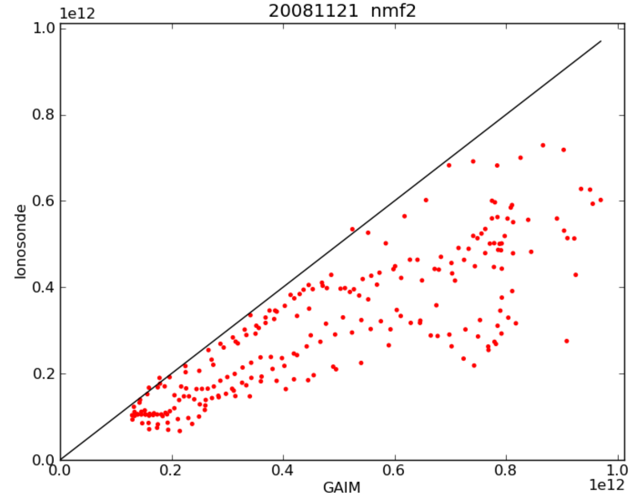
Courtesy of L. McNamara

Nmf2 (e/m^3) Statistics for Nov 21, 2011

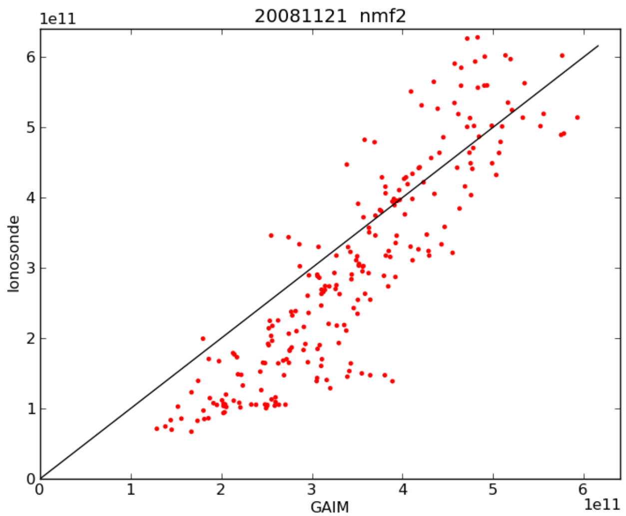
Climate



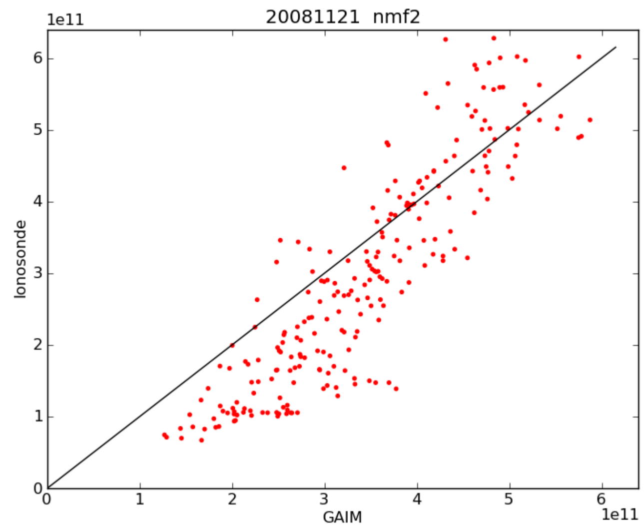
Ground



Ground + Cosmic

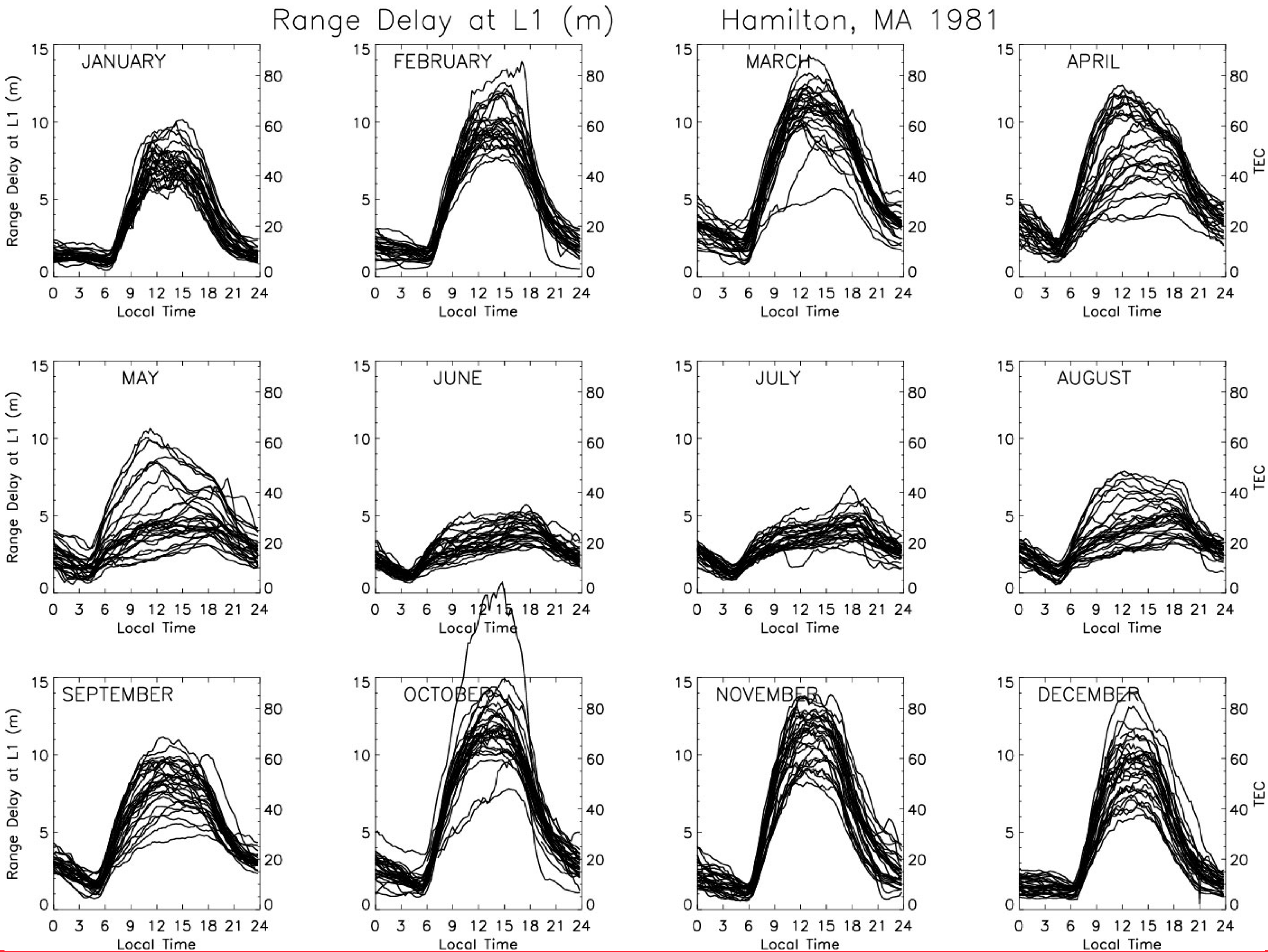


Ground+Cosmic+CNOFS

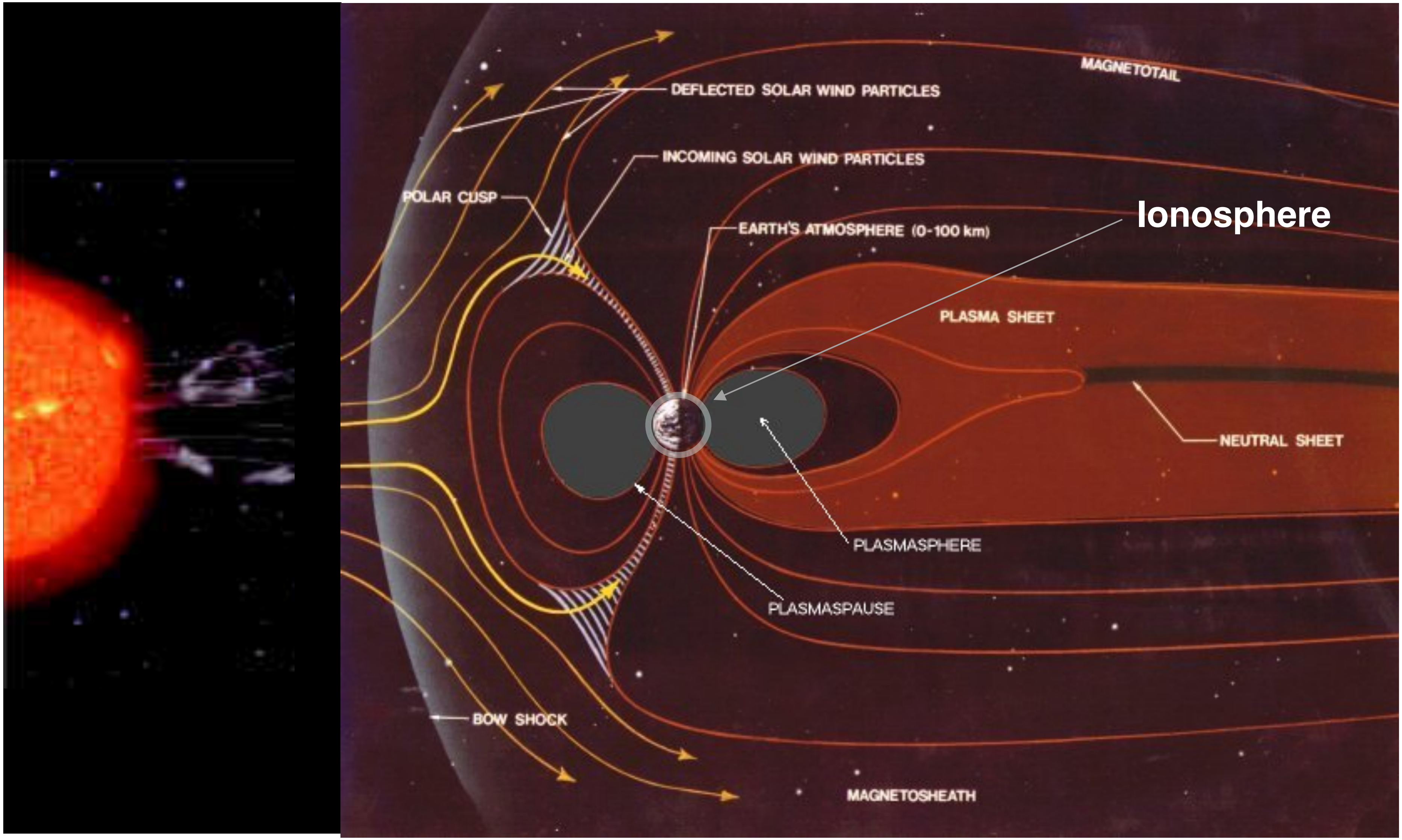


Slopes:
Climate: 0.565
Ground: 1.387
G+C: 1.352
G+C2: 1.349

Day-To-Day Ionospheric Variability

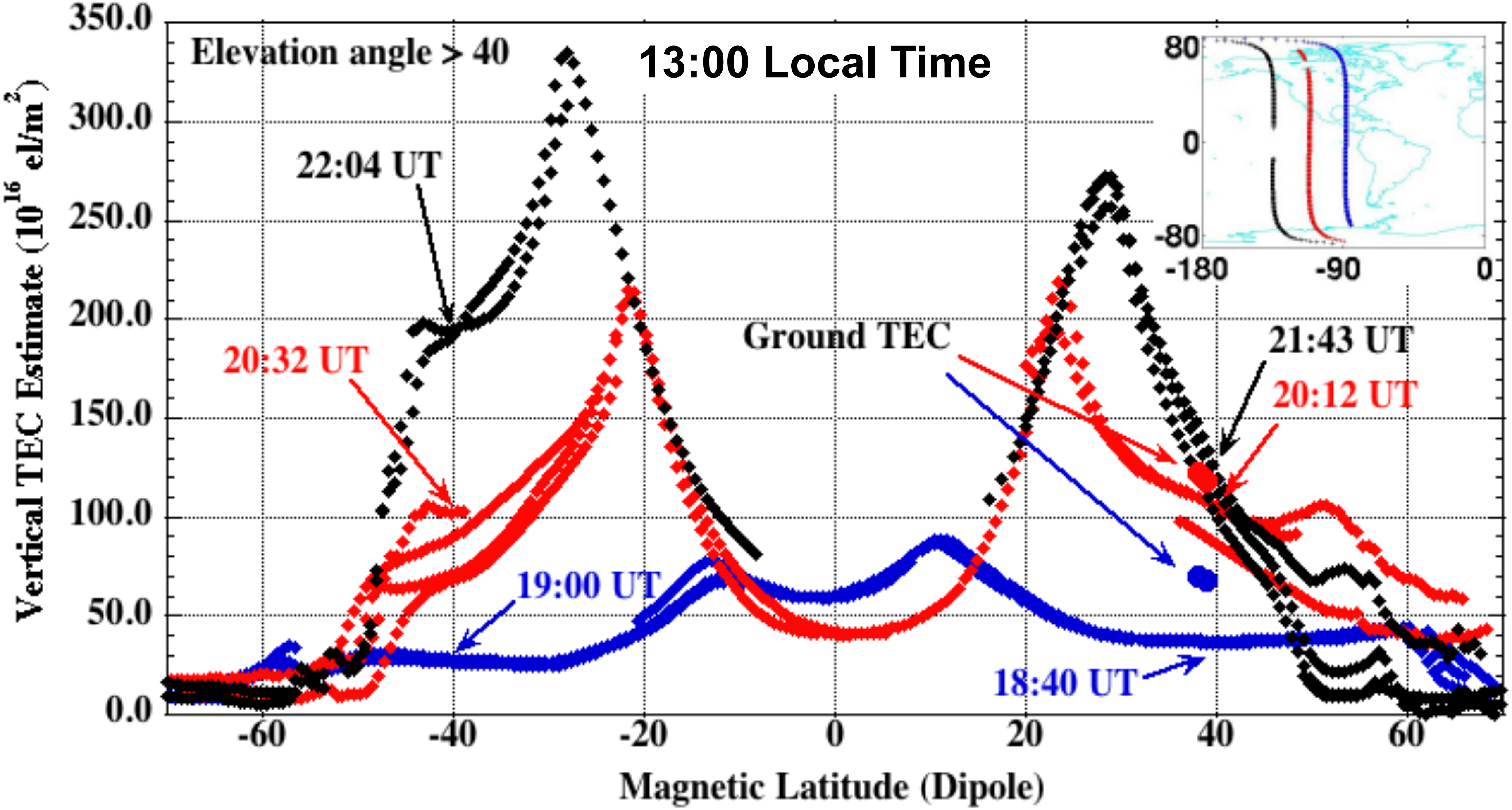


Regions In Geospace: Ionosphere is Near-Earth Space



Variability During Geomagnetic Storms October 30, 2003

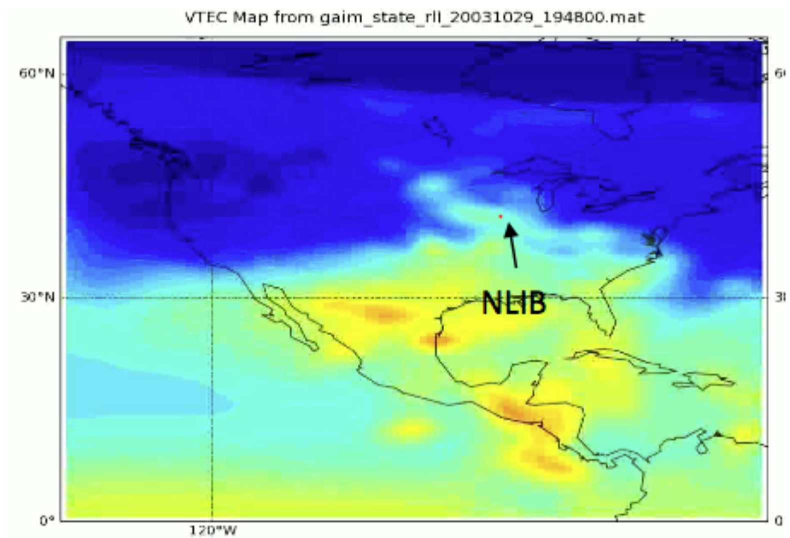
Electron content above 400 km altitude

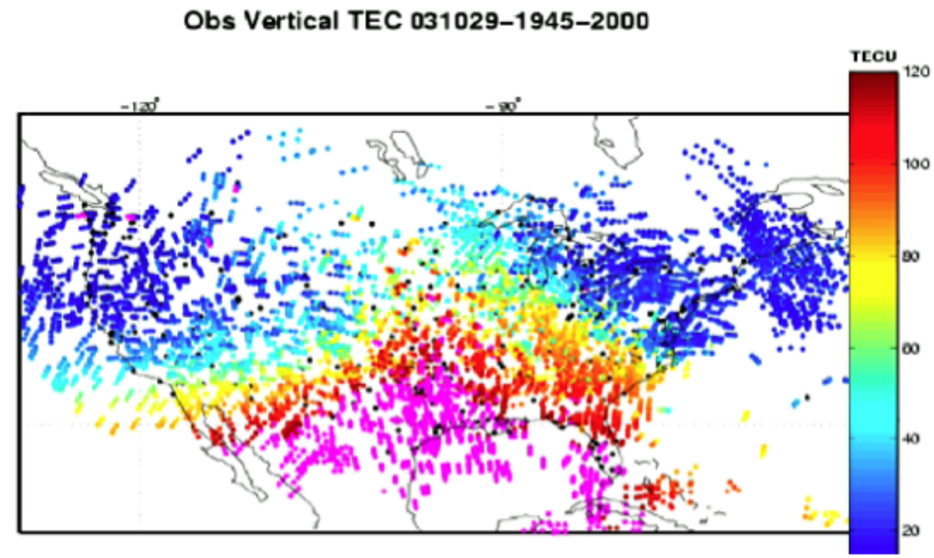


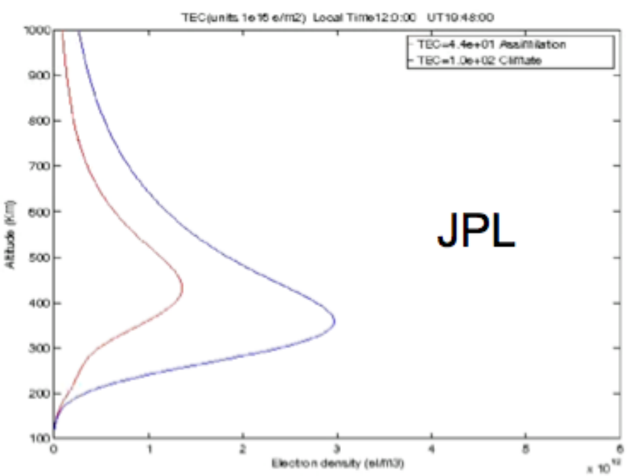
Mannucci et al., *GRL* 2005

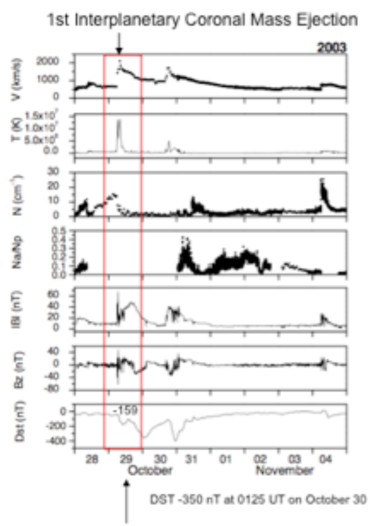
"Global Ionospheric Storm"

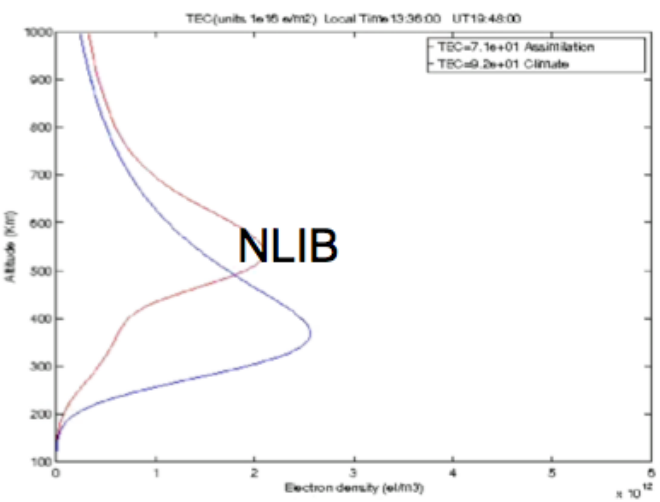
Storm Day: Oct 29, 2003, NGAIM and Truth Storm Features at NLIB



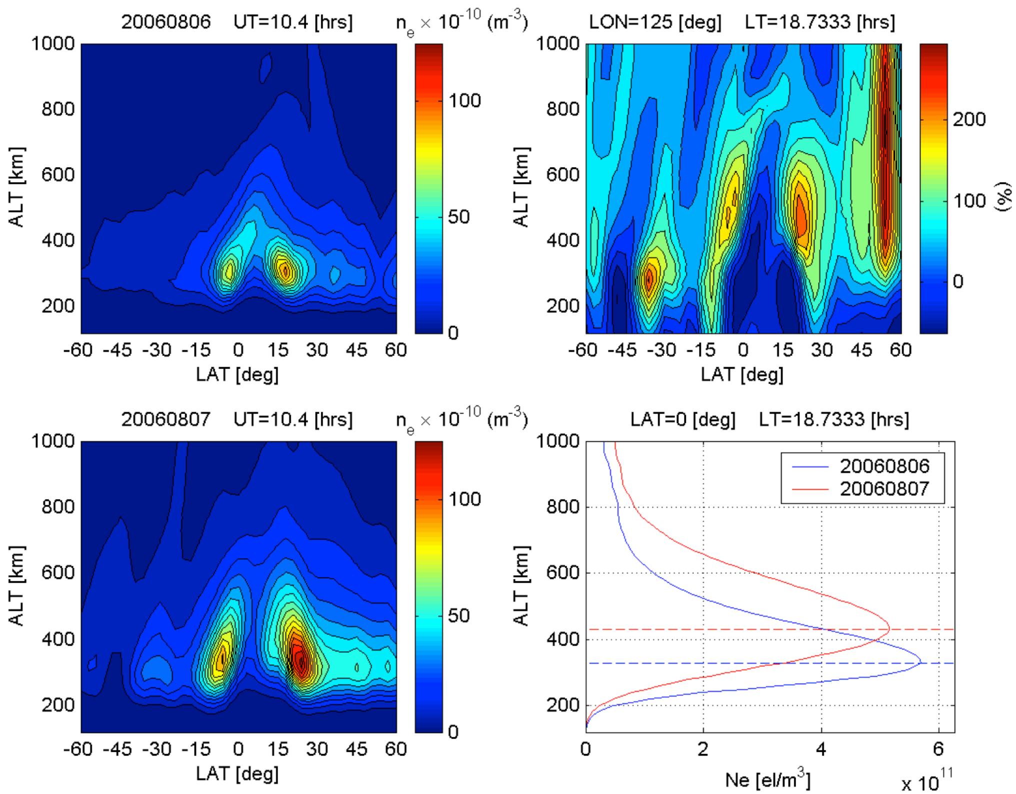








Ionospheric Electron Density Storm-Time Perturbations

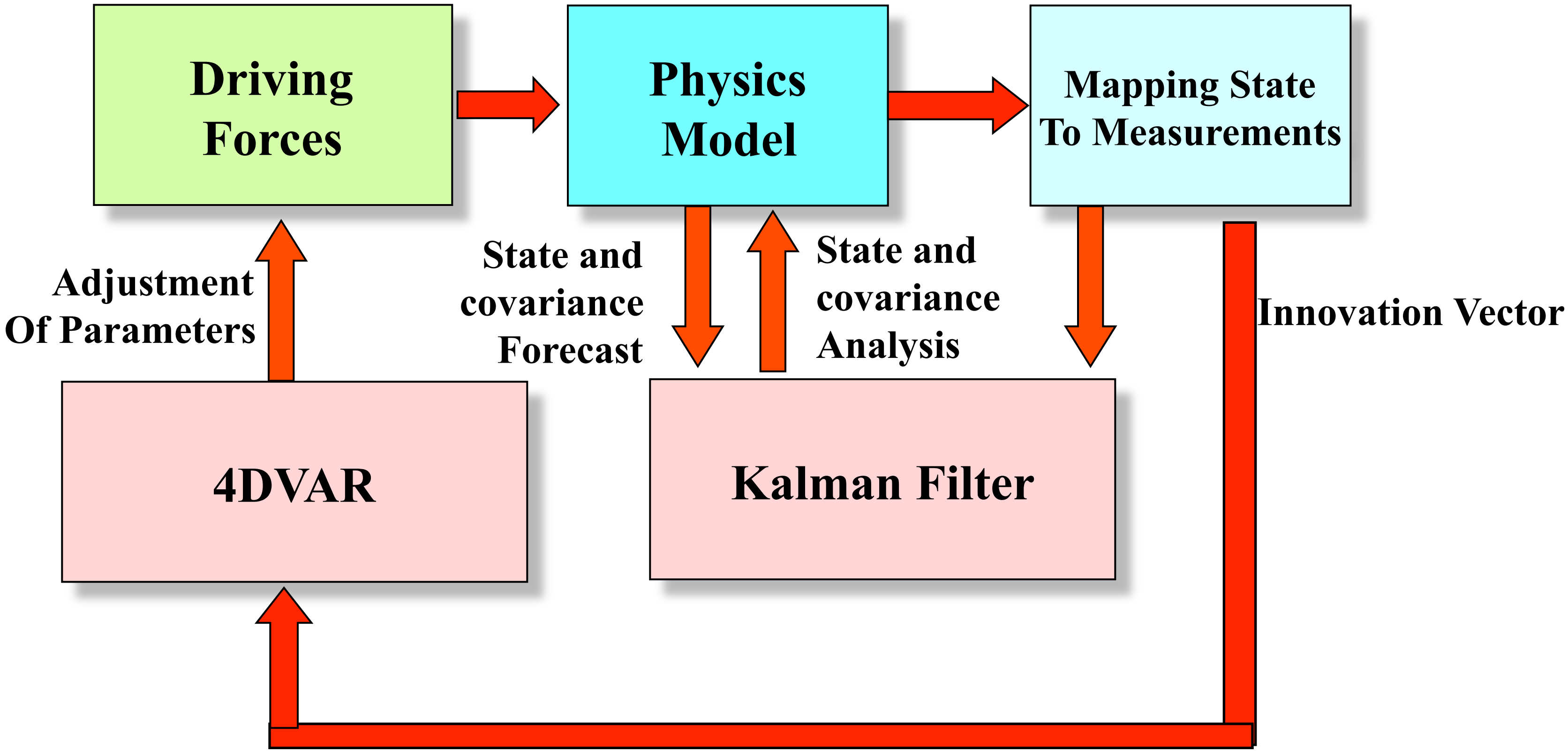


Storm-time data assimilation August 6-7 2006

Electron density contours showing the assimilative modeling results in altitude vs. latitude dimensions at 125° longitude, for the quiet day (August 6, 2006; upper left), storm day (August 7, 2006; lower left), and percentage difference between the disturbed and quiet state (upper right). A comparison of sample electron density profiles at the equator is also provided in the lower-right panel. The corresponding local time is 1844 for this longitude. The storm-time disturbance shows clear features of equatorial anomaly enhancement that must be driven by an enhancement of eastward electric field at low latitudes.

Xiaoqing Pi, Anthony J. Mannucci, Byron A. Iijima, Brian D. Wilson, Attila Komjathy, Thomas F. Runge, and Vardan Akopian (2008), "Assimilative Modeling of Ionospheric Disturbances with FORMOSAT-3/COSMIC and Ground-Based GPS Measurements," Journal Of Terrestrial, Atmospheric and Oceanic Sciences, 2008

Global Assimilative Ionospheric Model Data Assimilation Process



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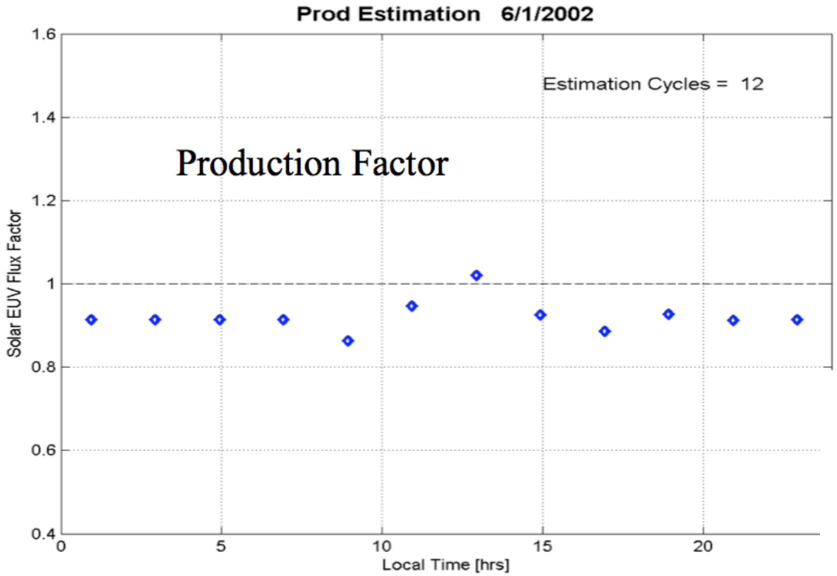
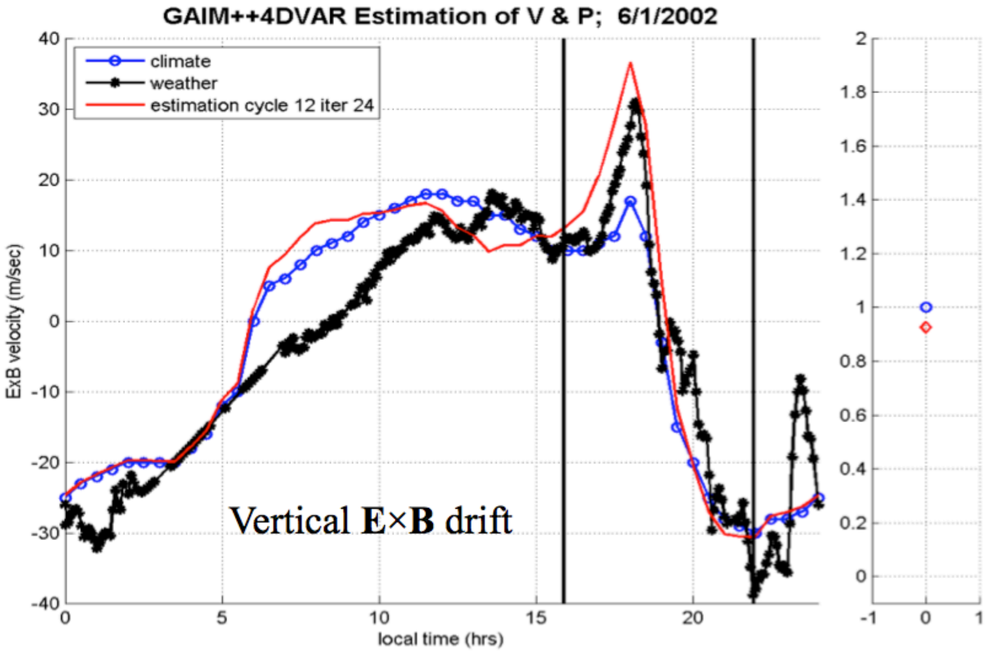
  - Covariance estimation and state correction

    Optimal interpolation

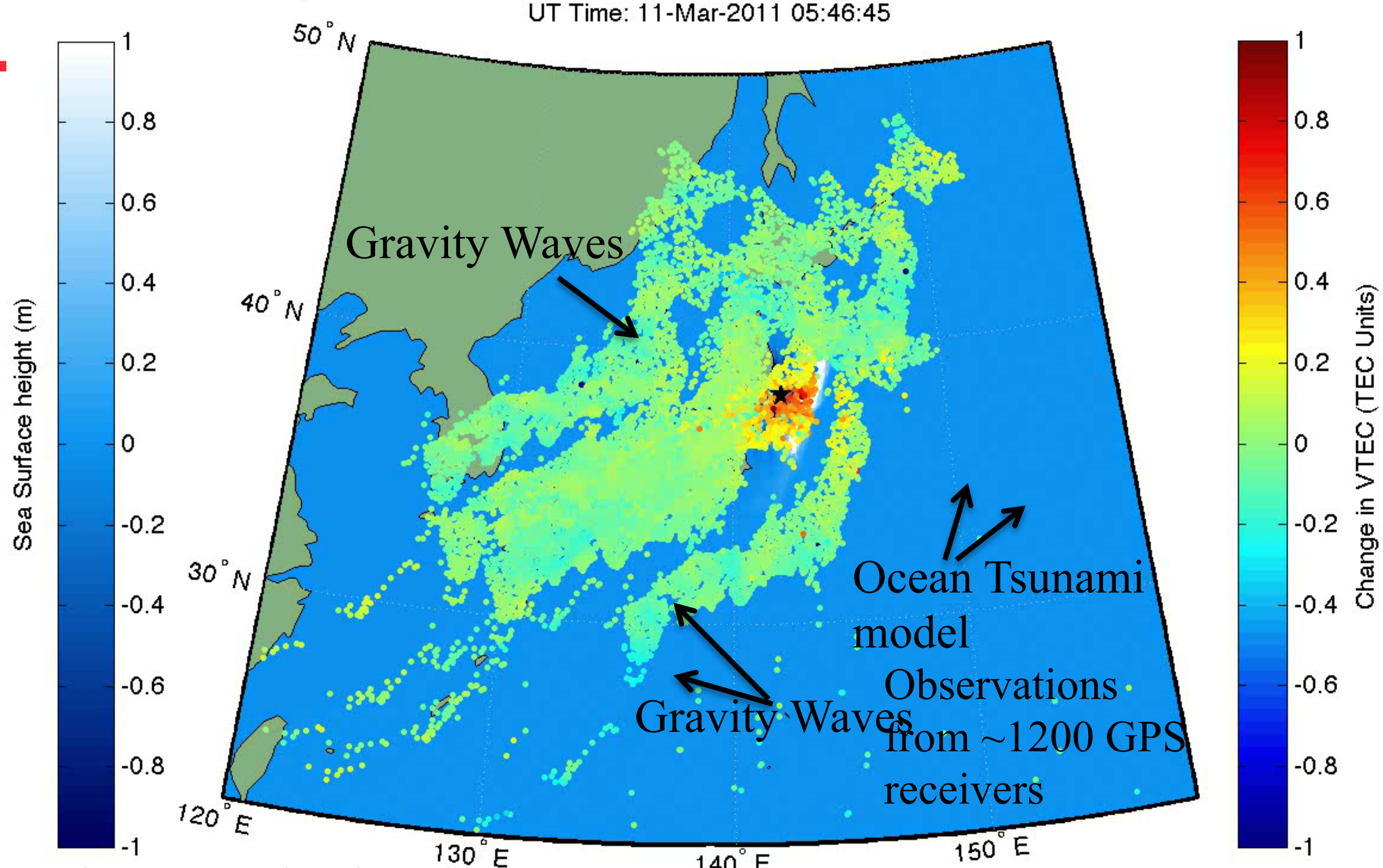
    Band-Limited Kalman filter

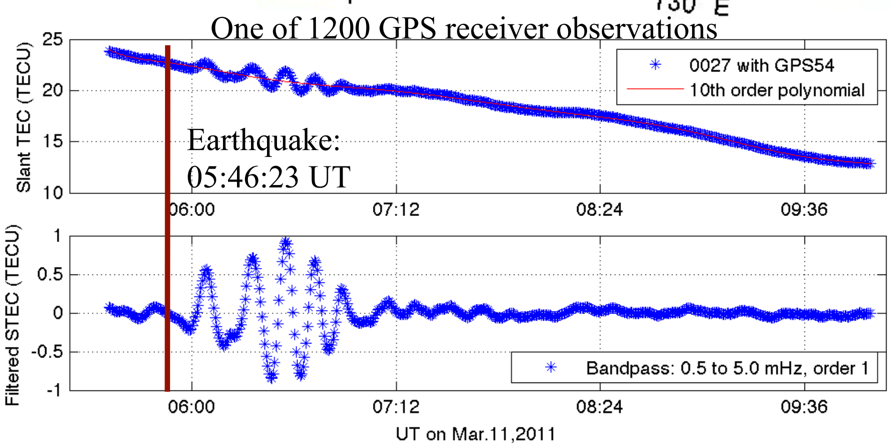
Driver Estimation Using 4DVAR





Tohoku Tsunami Seen in Ionosphere Using GPS Compared with JPL's Song Tsunami Model



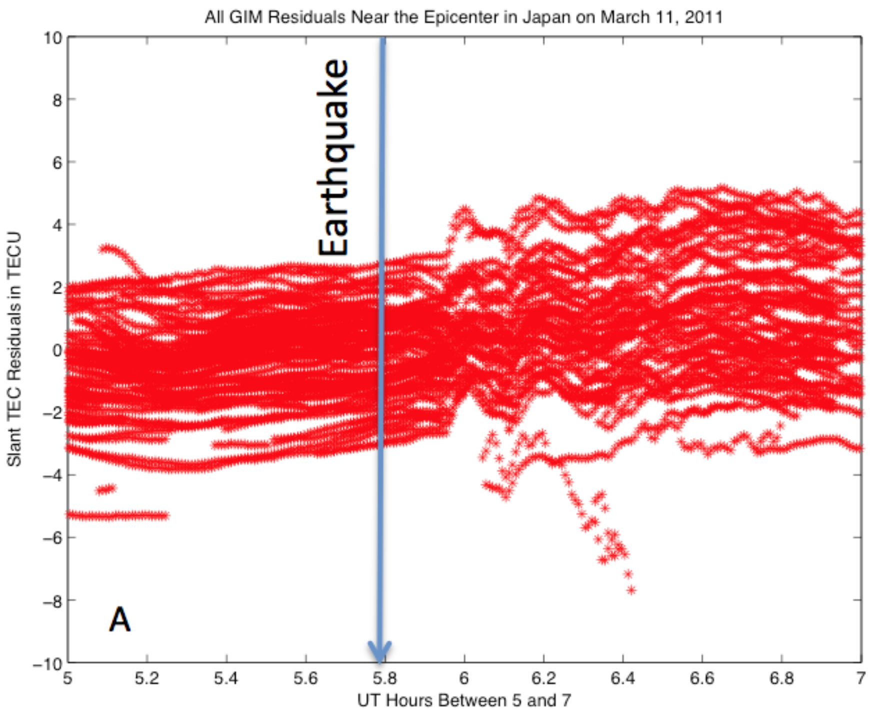


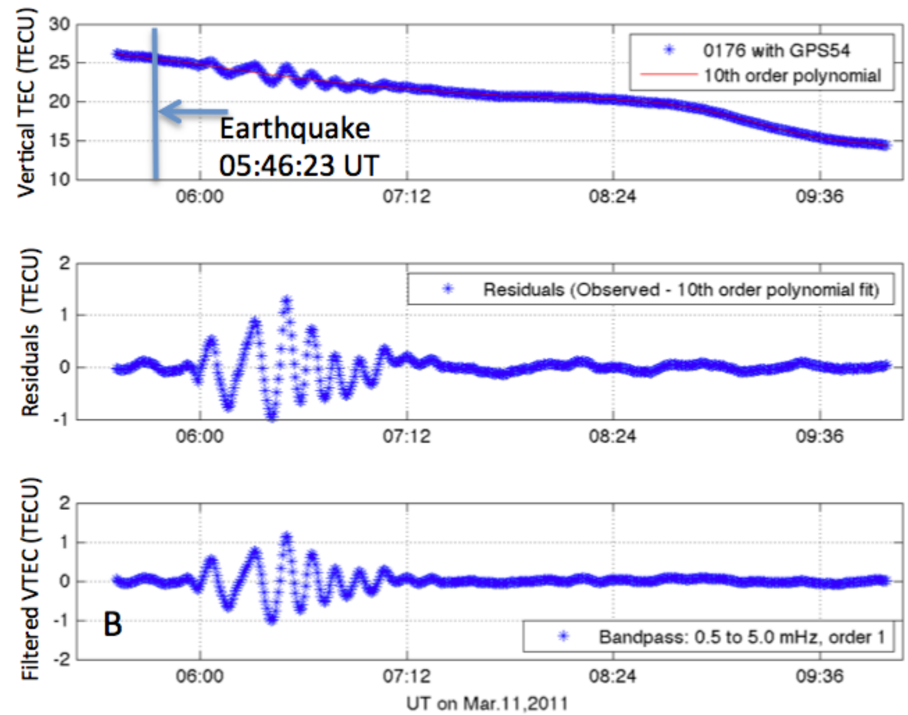
- Tsunami generates atmospheric gravity waves that propagate to ionosphere.
- Allows imaging of tsunami using GPS Total Electron Content.

Potential application:
- Real-time tsunami monitoring and early warning

Attila Komjathy (335G), David Galvan (335G), Y. Tony Song (3244), Tony Mannucci (335G)

JPL Tools for Detecting Natural Hazards: GAIM

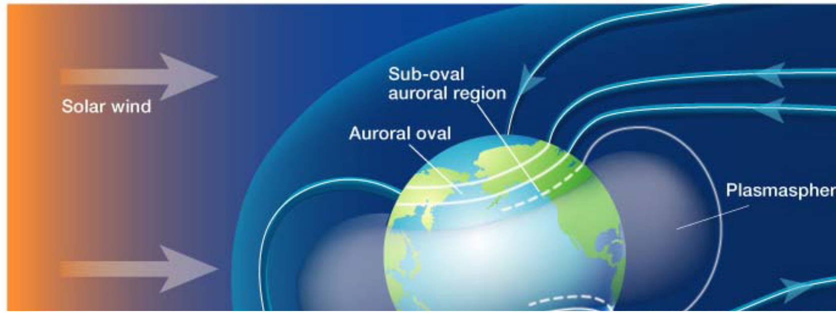




Galvan et al, 2011, submitted to JGR

Summary & Conclusions

1. The radio occultation data set
2. Survey of results
    1. Value of radio occultation to ionospheric space weather: profile shape
    2. Benefit of COSMIC-2: more profiles, and filling in major gaps
    3. Driver estimation (“holy grail”)
3. Summary and conclusions



Earth-Sun System Exploration 5

January 13-19, 2013
Kona, Hawai'i

"Earth Sun System Disturbances: Weak, Moderate, and Extreme"

Convenors: Patrick T. Newell and Bruce Tsurutani
Program Committee
(Sun through ionosphere)
Kazunari Shibata, Kyoto University, Japan
Roberto Bruno, Instiuto Fisica Spazio Interplanetario, Italy
Larry Lyons, University of California, Los Angeles, USA
Tony Lui, JHU/Applied Physics Laboratory, USA
Jesper Gjerloev, University of Bergen, Norway

E-layer science session