CEDAR-GEM 2016
Ionosphere-Thermosphere Interactions:
Modeling and Observations

Global and Regional Total Electron Content

Anthony Mannucci, Xing Meng,
Panagiotis Vergados, Attila Komjathy
JPL/Caltech

Collaborators: Sarah E. McDonald, John Emmert
NRL

Outline

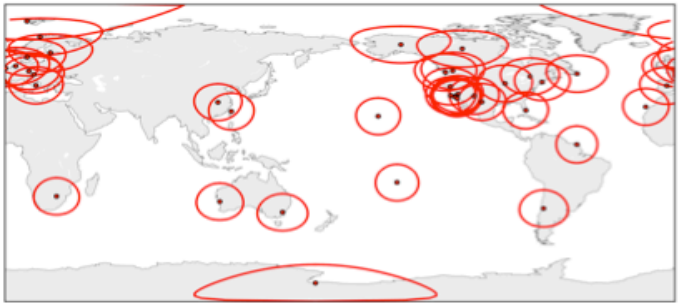
- Key points from John's presentation
- Regional test
- Global ionosphere maps (GIM) and thermosphere-ionosphere science

Using GIM For Decade-Scale Investigations

- Changing station distribution
- Consistent processing
- Systematic error

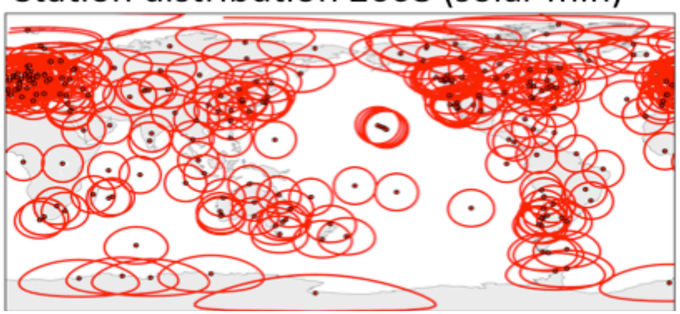
Station Distribution

Station distribution 1993



Station distribution 1996 (solar min)

Station distribution 2008 (solar min)



Generate a 23-year product 1993-2016

Generate a 20-year product 1996-2016

Generate an 8-year product 2008-2016

Inter-compare these TEC map iterations

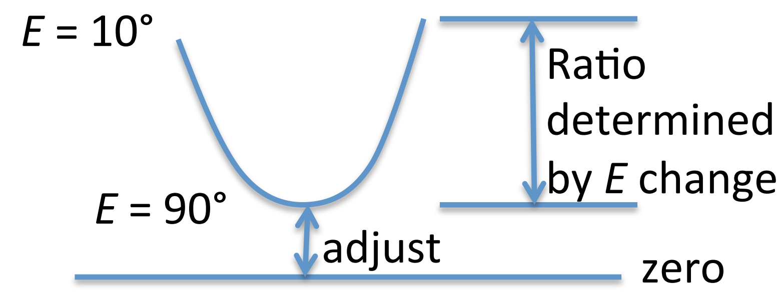
- ✓ Determine bias between these runs
- ✓ Bias observed but acceptable for the science

Consistent Processing

- Reprocessed 35, 50 and 100 station distributions for 20-year period, each
  - "Fiducial" or "anchor" station approach to selecting station distribution
  - Station distribution could vary a little over time
  - Algorithm to select broad station spread was used
- Local time reference frame and temporal smoothing bridges spatial gaps effectively
- Daily GPS receiver and satellite bias estimation

Global Mapping Algorithm

- Biases co-estimated with TEC daily
- One bias fixed for well-posedness
- Some solar cycle dependence to be expected



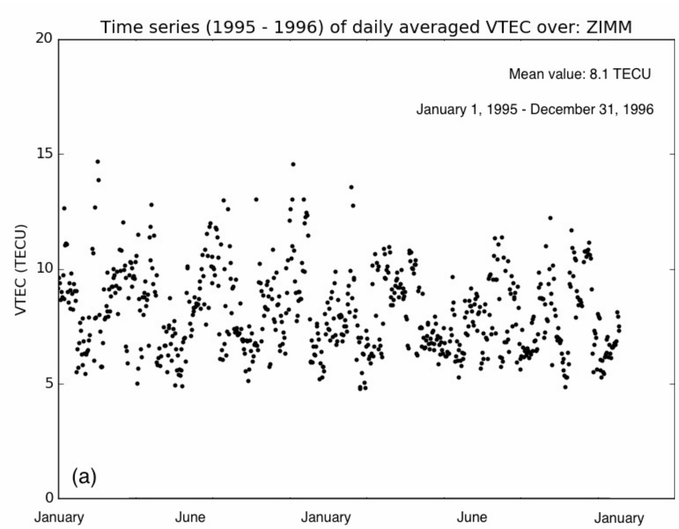
Single shell model used

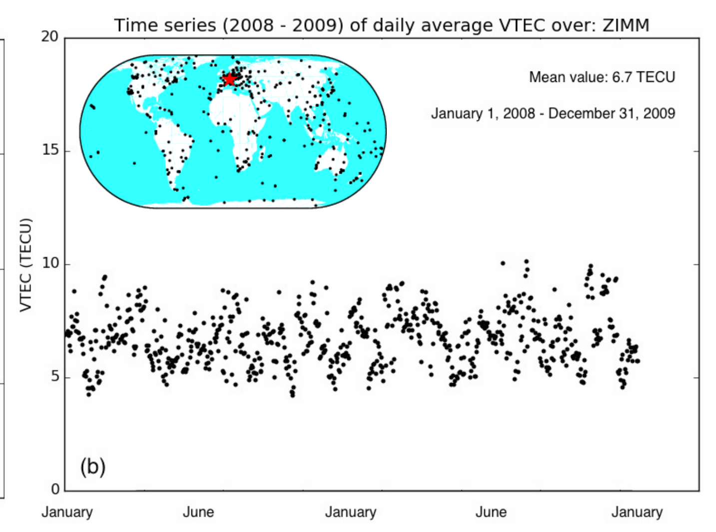
$$TEC = M(h,E)\sum_i C_i B_i(lat, lon) + b_r + b_s$$

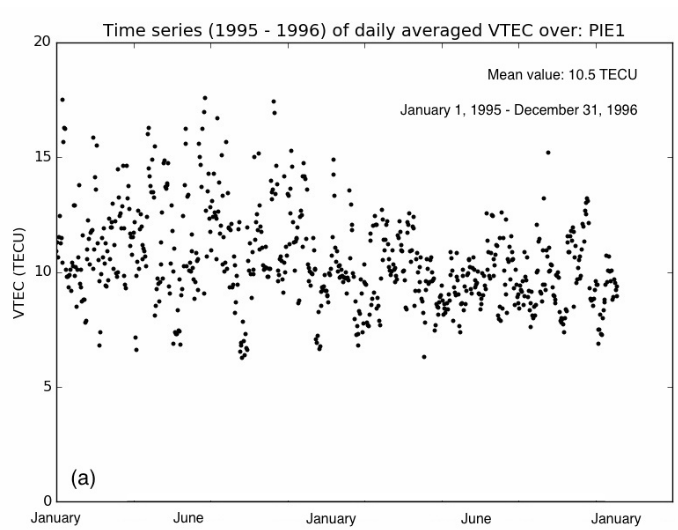
where

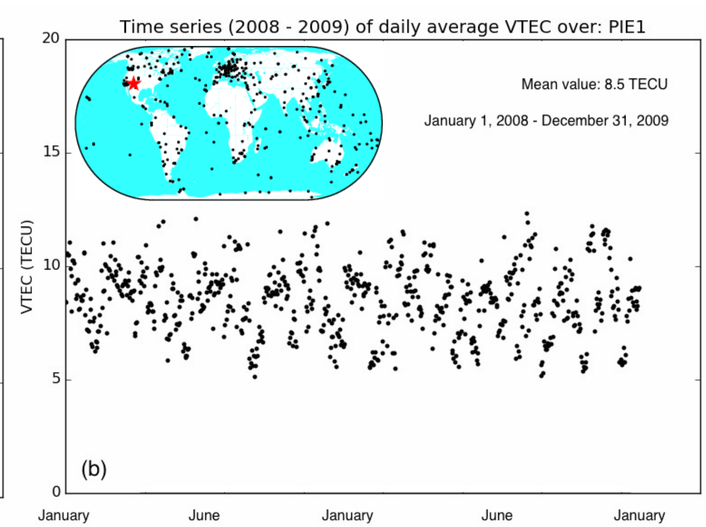
TEC	is the measured biased slant TEC; (differential simulated measurements added for regularization)
$M(h_1, E)$	is the elevation scaling function, elevation *E*, iono height *h*
$B_i(lat, lon)$	is the horizontal basis function (C^2 local support, covers sphere uniformly); (lat, lon) is latitude and solar local time
C_{1i}	are the basis function coefficients solved for in the Kalman filter (stochastic parameter model), indexed by horizontal (i) indices;
b_r, b_s	are the satellite and receiver instrumental biases.

Regional Case Study: Daily Average









Line of sight vertical TEC averaged using biases determined by GIM

Stn	Years	TEC
ZIMM	‘95-’96	8.1
ZIMM	’08-’09	6.7
PIE1	’95-’96	10.5
PIE1	’08-’09	8.5

Recent solar min period lower by 17%-19%

Why A Global Map Product?

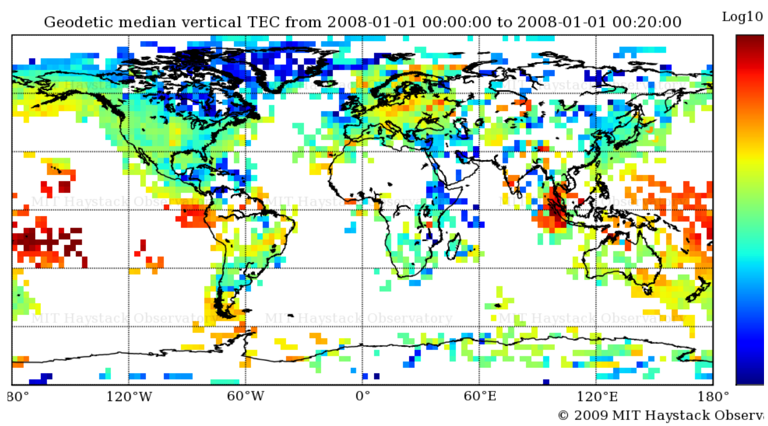
E.g. widely available TEC data product from Madrigal (MIT Haystack Observatory)

Advantages of GIM

- **Global averaging is more consistent**
- **Strongly data-driven, minimal dependence on climatology**
- **Consistent bias processing**

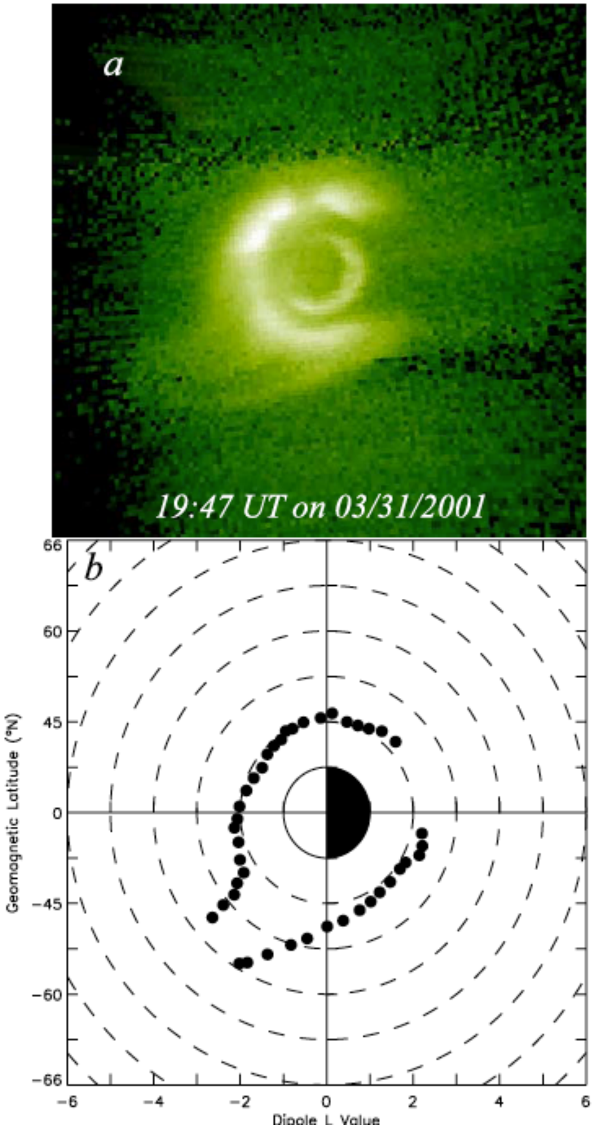
Disadvantages of GIM

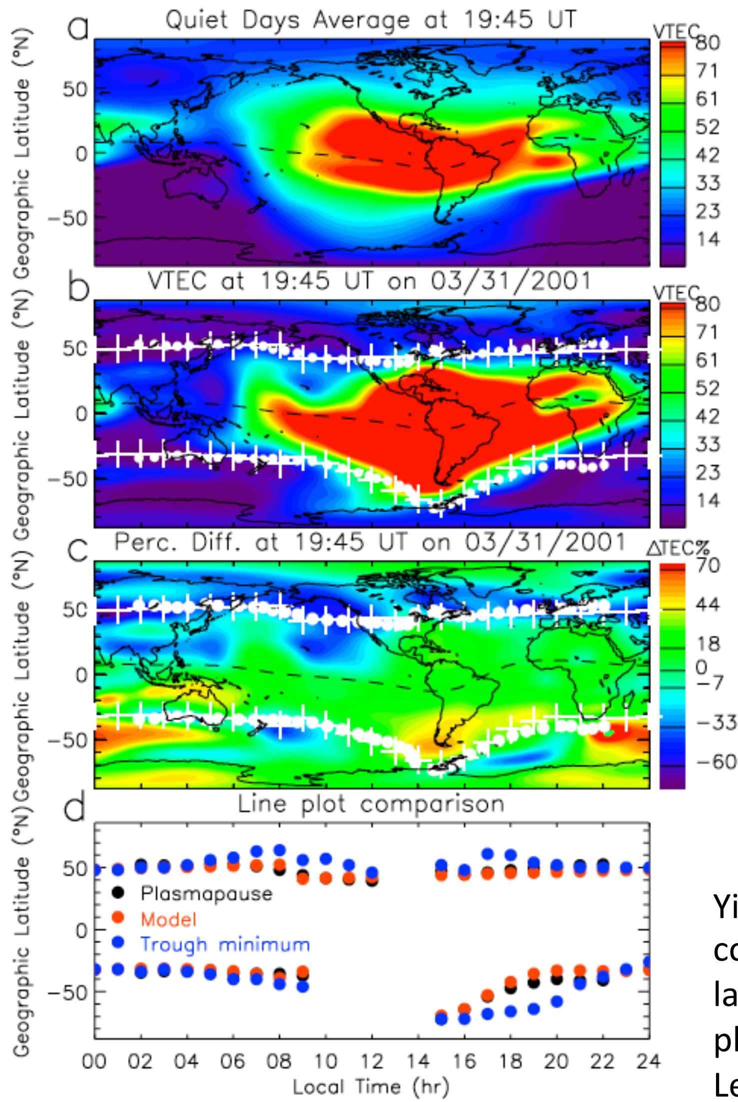
- **No physical model**
- **Cannot be used for forecast**



http://cedar.openmadrigal.org/

GIM Application: Mid-Latitude Trough

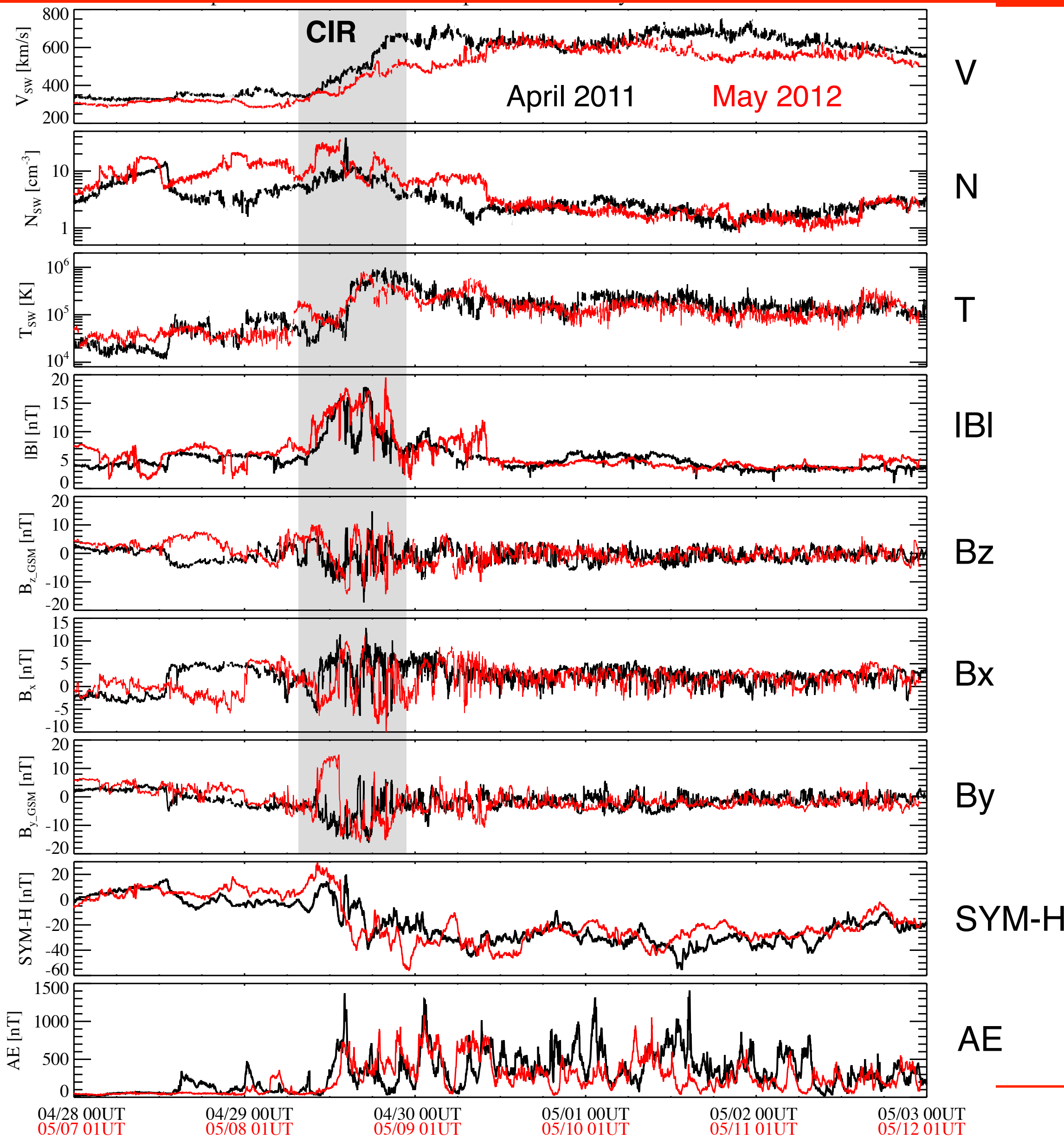




Global Ionospheric Maps (GIM), generated using ground based GPS receivers, are used to detect the globally extended mid-latitude trough; while global IMAGE EUV pictures are used to estimate the plasmapause position… The two independent observations (mid-latitude trough and plasmapause positions) and an empirical model have been compared on a global scale and found to be in excellent agreement.

Yizengaw, E., et al., " The correlation between mid-latitude trough and the plasmapause, Geophys. Res. Lett., 2005.

Storm Study Using GIM and the Global Thermosphere Ionosphere Model (GITM)

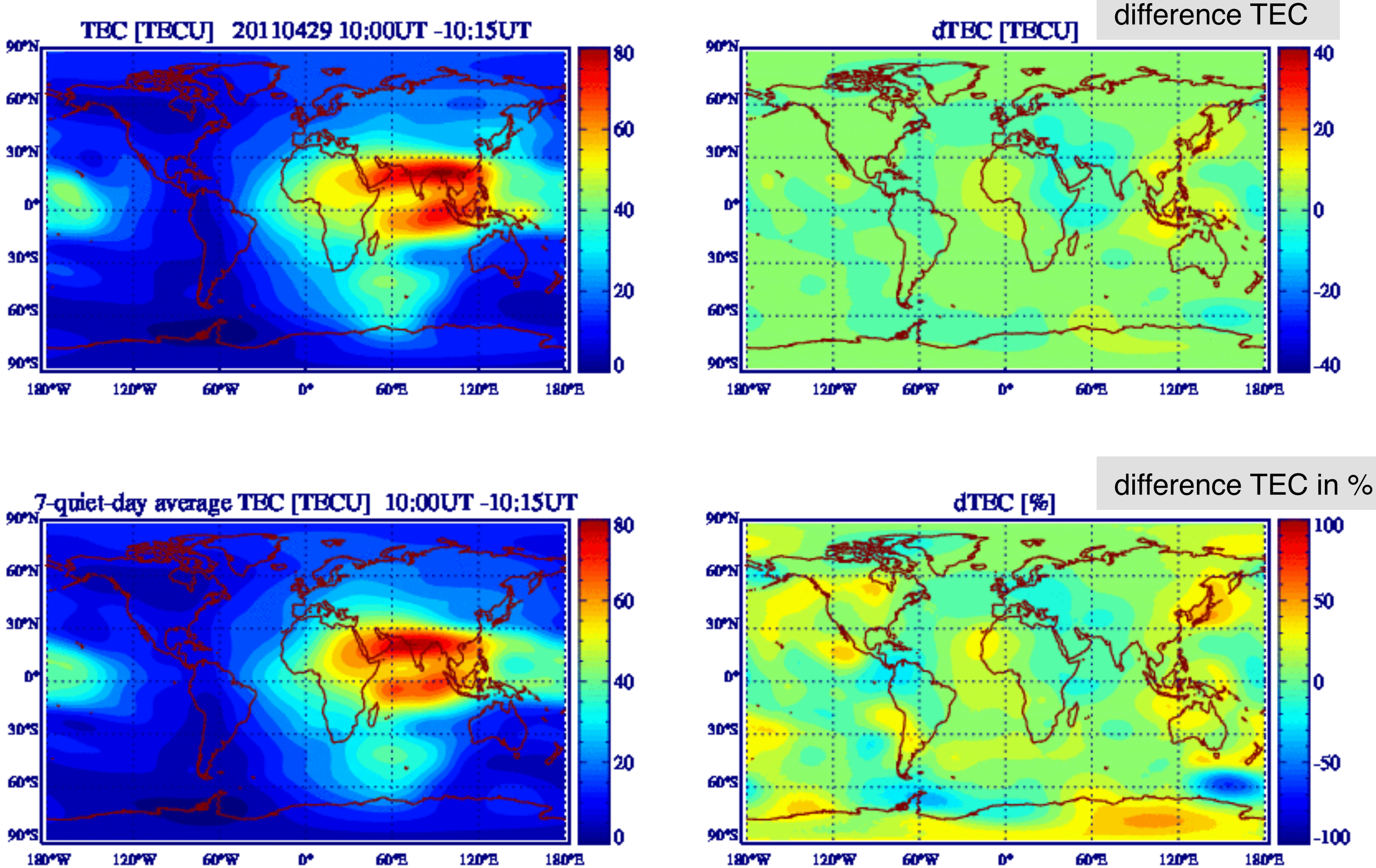


OMNI data shows similar solar wind conditions for the two events: 1 hour shift

GITM: Ridley et al., 2006

Differential TEC Maps

GIM TEC map example – April 2011

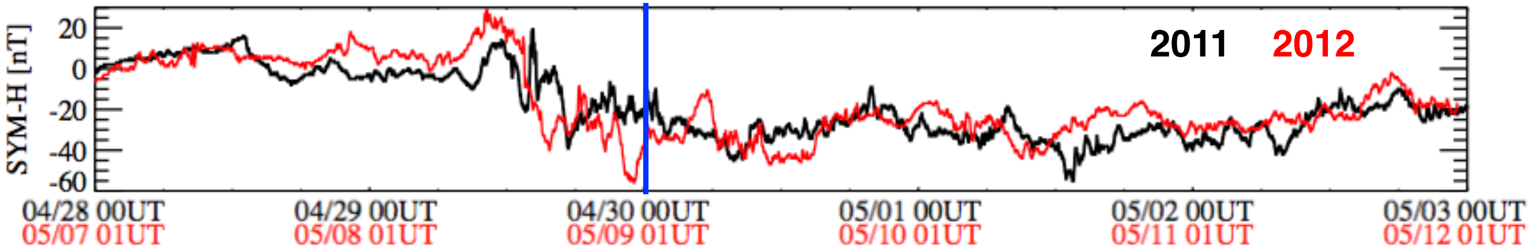


difference TEC

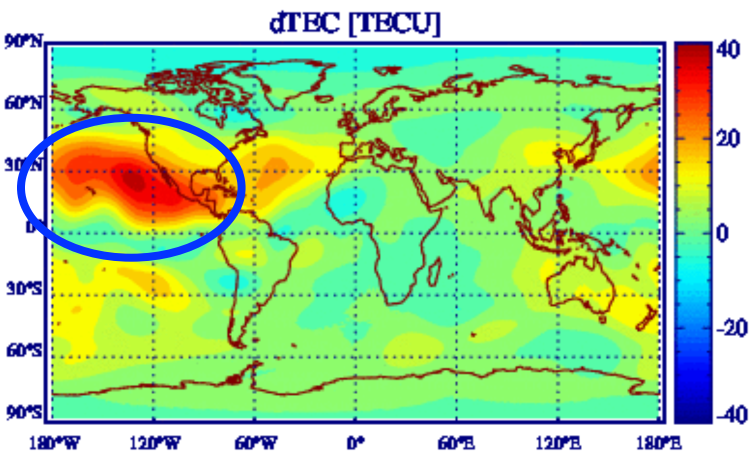
difference TEC in %

7 quiet days before the event with daily Ap < 7

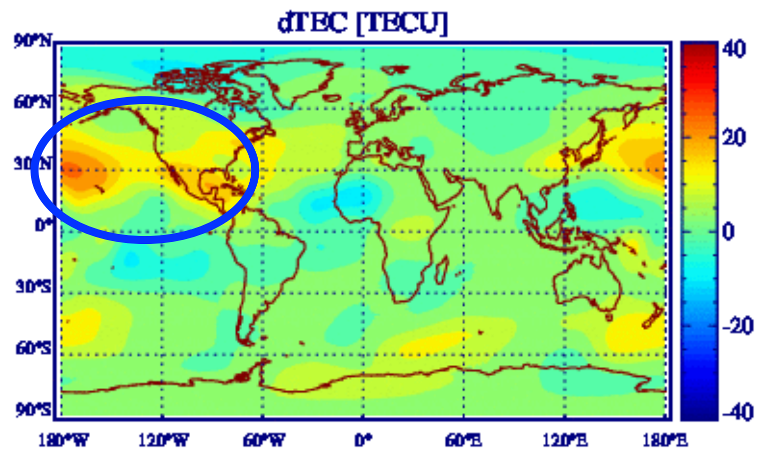
GIM TEC Response



00UT 30 April 2011



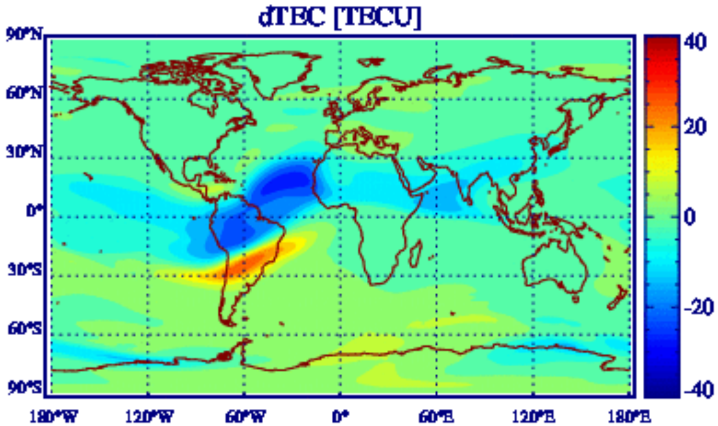
01UT 9 May 2012



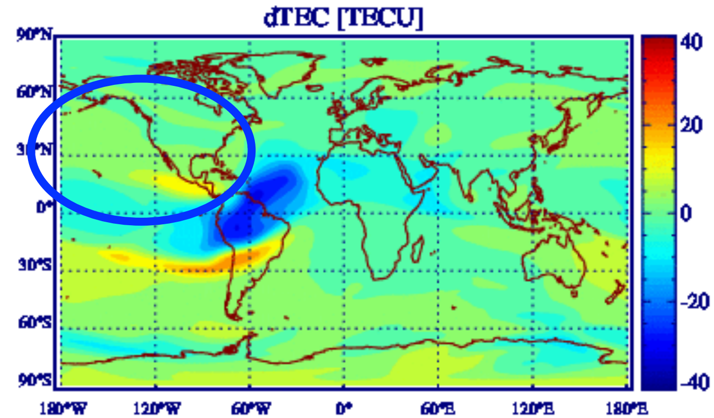
- During the April 2011 event, the maximum TEC disturbance (positive) occurs at 0 UT 04/30 over north pacific/US west coast region. Strong positive TEC disturbances > 50% lasts for about 4 hours
- For the May 2012 event, the maximum TEC disturbance (positive) occurs 1 hour later in a similar region, yet much weaker than in the April 2011 event.

TEC Response GITM

00UT 30 April 2011



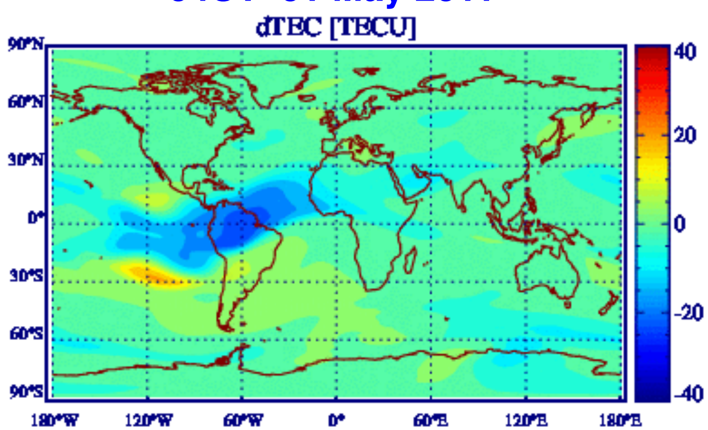
01UT 9 May 2012



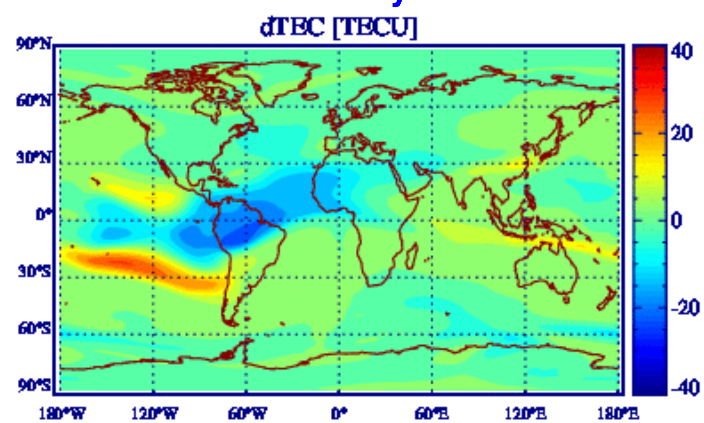
No positive storm over north pacific

- GITM simulations of the two events share more similarities than in the GIM data
- Persistent equatorial negative TEC disturbances during most time in both events

04UT 01 May 2011



05UT 10 May 2012



Conclusions

- A 20-year GIM "reanalysis" has been developed as part of a project to understand long-term upper atmosphere change
- A carefully developed algorithm has unique advantages for a number of investigations
- Nevertheless, the possibility of systematic error must be rigorously addressed
- The GIM database will be made available as part of NASA-funded effort
- We are also using the maps as a tool in a study to understand TEC forecasting using the Global Ionosphere Thermosphere Model (GITM)