Connecting Stratospheric and Ionospheric Anomalies

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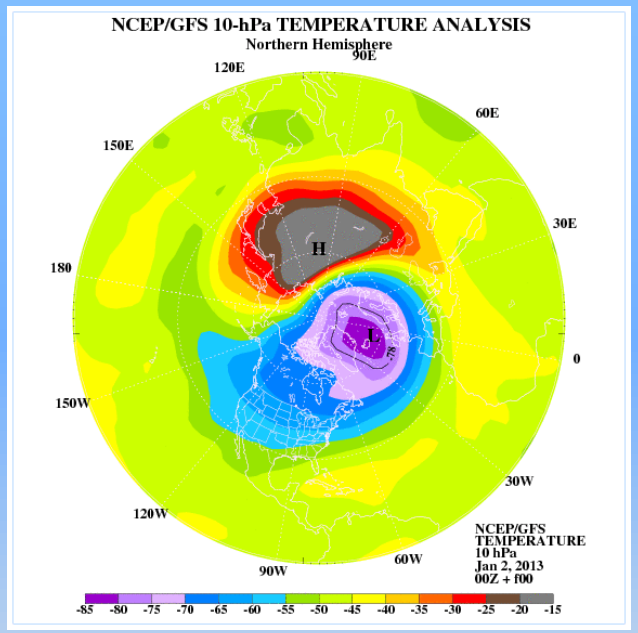
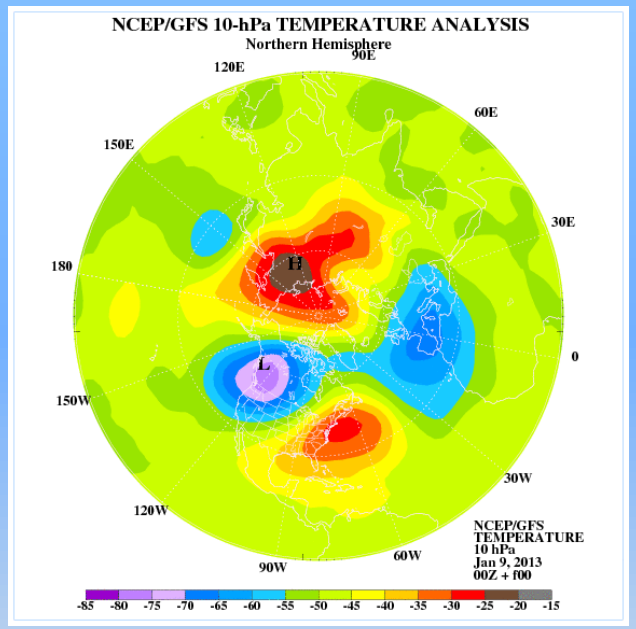
A Brief Introduction

- Sudden stratospheric warmings (SSWs) are extremely large and dramatic meteorological phenomena
  - Affects the winter Northern polar stratosphere



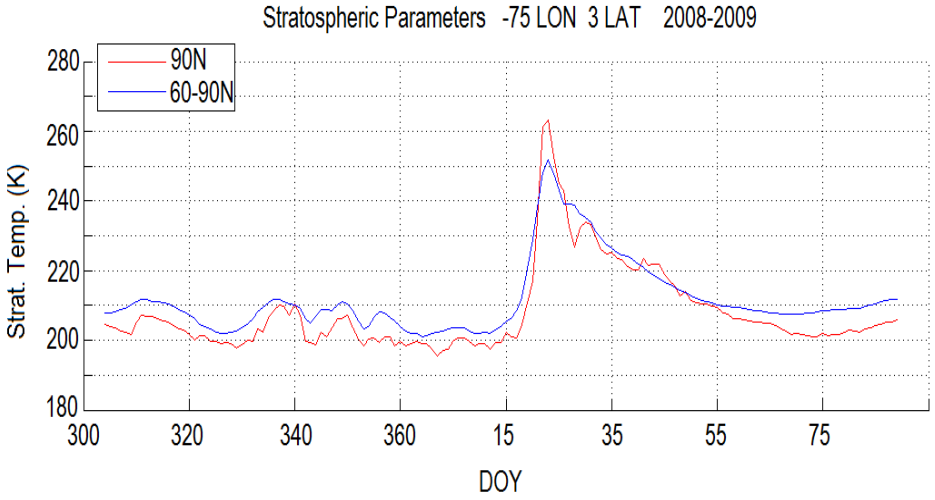
Jan. 2, 2013 vortex shift

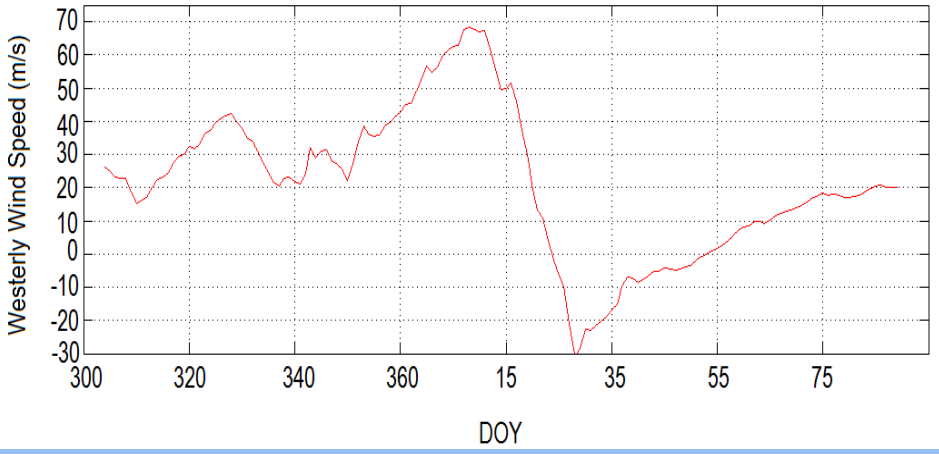
Polar stratosphere temperature maps for 10hPa

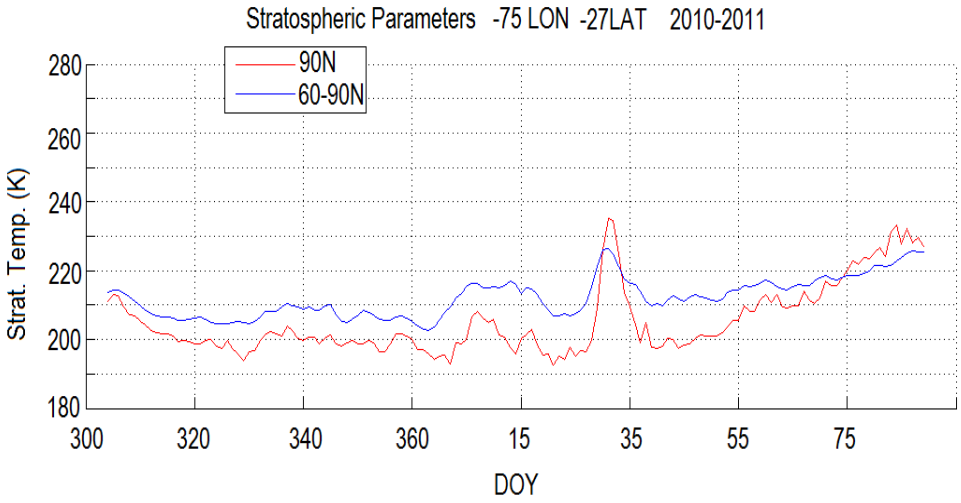


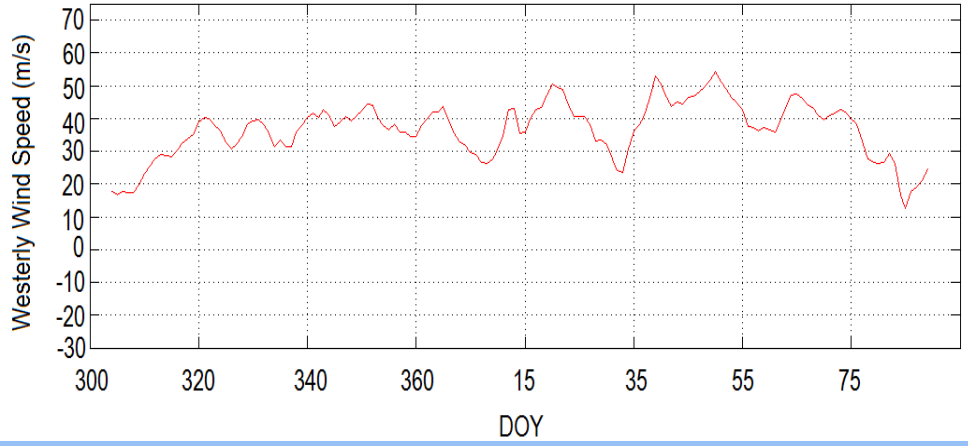
Jan. 9, 2013 vortex split

Major vs. Minor Events







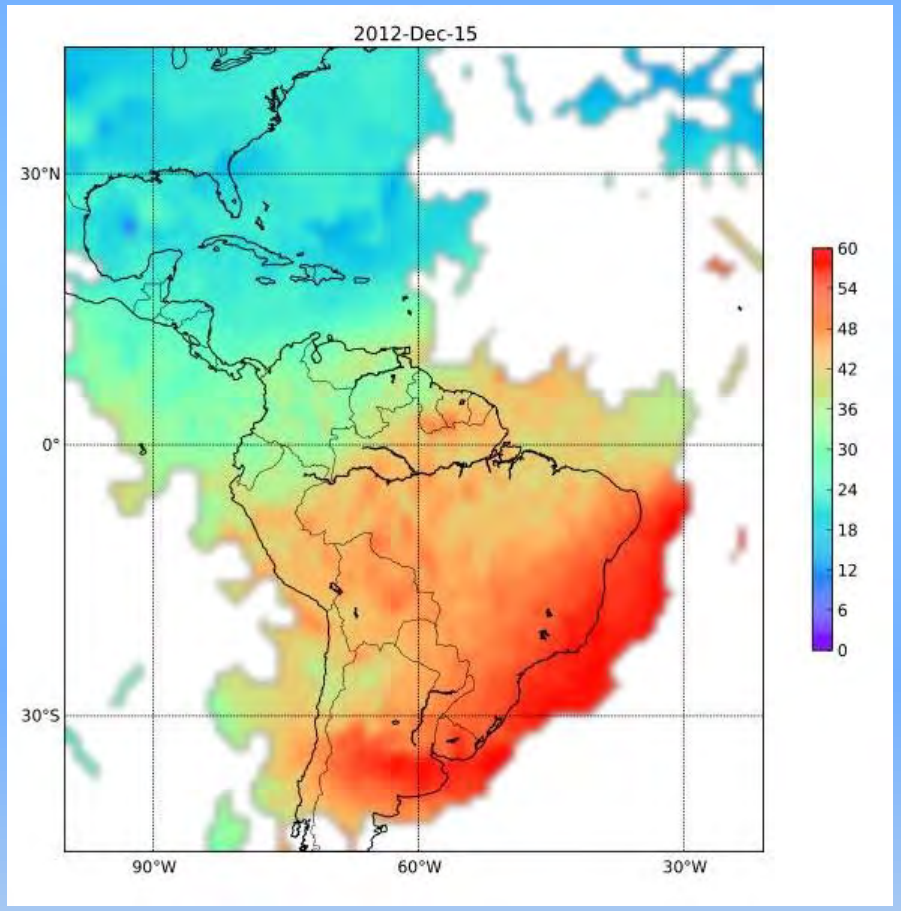


January 2009 (largest recorded SSW)

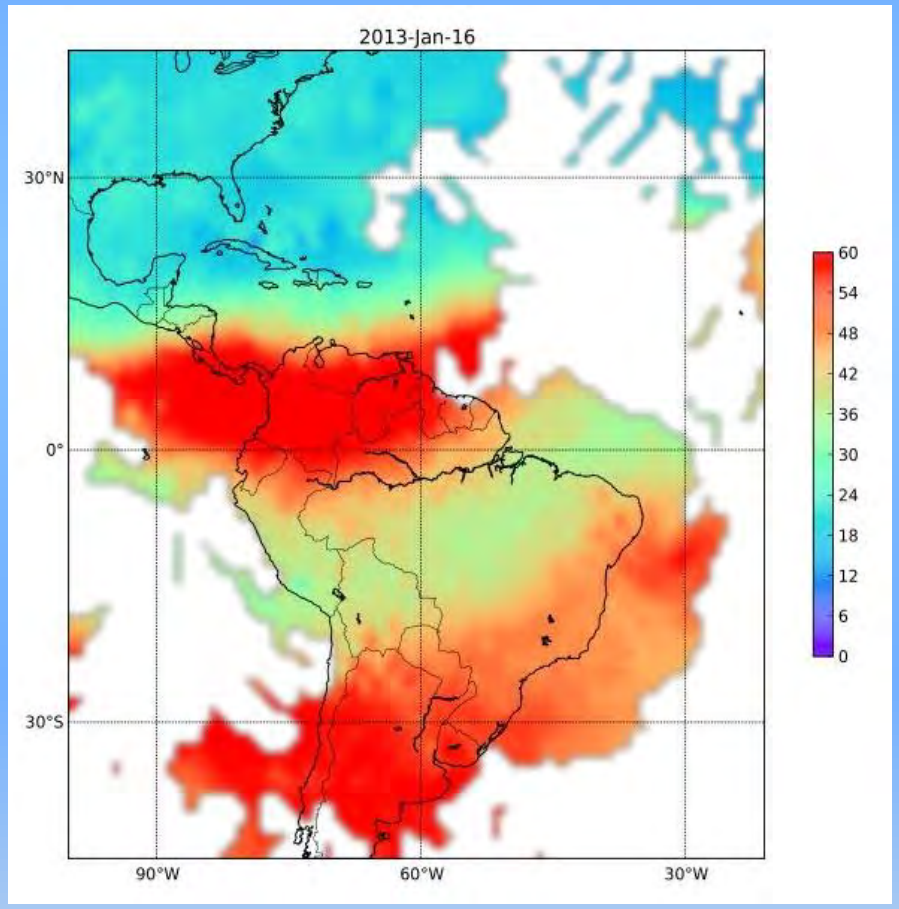
January 2011 (very minor event)

The Equatorial Ionization Anomalies

Dec. 15, 2012 (before SSW)



Jan. 16, 2013 (after SSW)



During SSW, EIA shows up as bands of intense TEC at ~15^{o} north and south from magnetic equator (at N and S)

Not So Simple Effects

- Coupling between atmospheric layers during SSW is an active research topic
- Well established that SSWs in polar stratosphere are coupled with tropical ionosphere
  - But mechanisms are still uncertain
  - Planetary waves are thought to play important role
  - Existing research is mostly limited to single-event studies

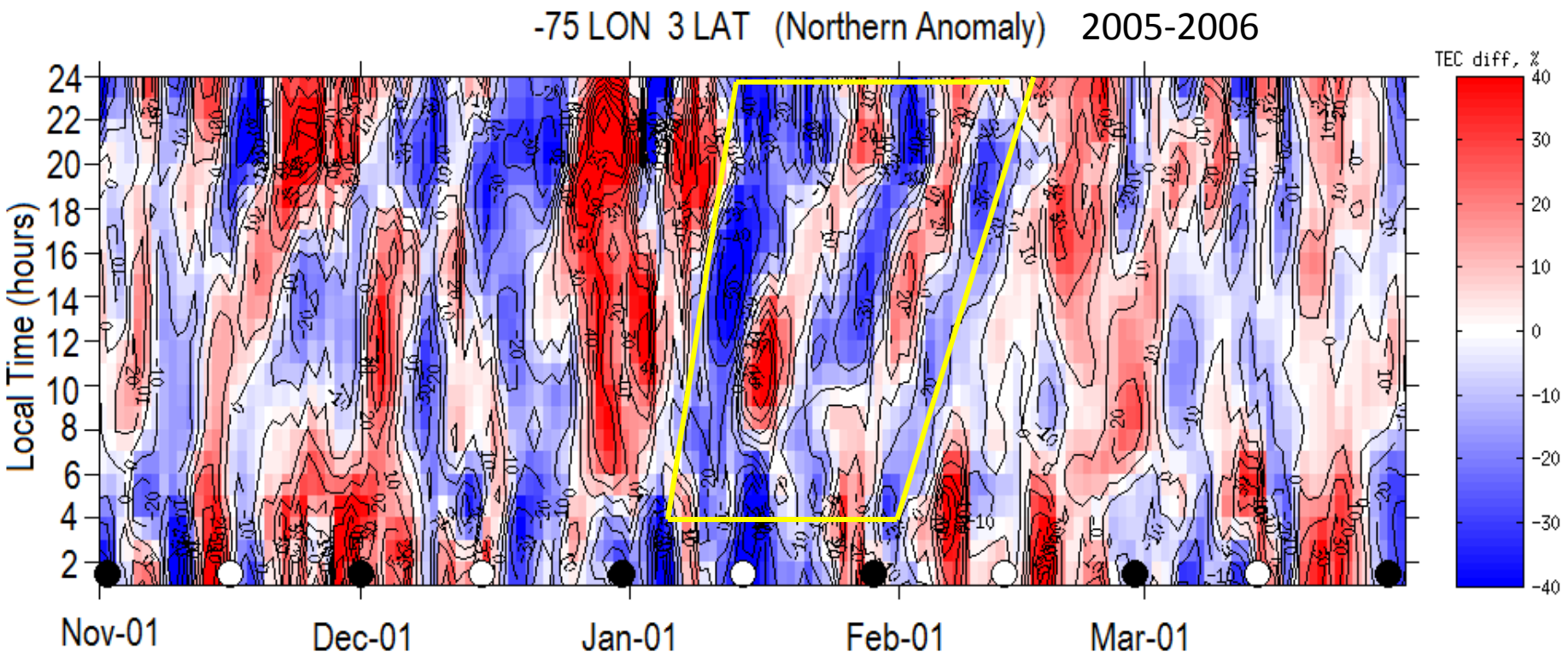
The Focus of Our Investigation

- It is known that lunar gravitational effects give rise to atmospheric tides in the mesosphere lower thermosphere
  - Are planetary waves affected by these? And do they in turn affect ionosphere features?
- I was curious as to how analogous the lunar tides on the ocean are to those on the atmosphere

But Before We Could Begin the Analysis

- We needed clean data
  - Most of my time was spent making dataset (all longitudes and latitudes)
    - World-wide GPS Receiver Network
    - Covers 151 day winters starting in 2001 and ending in 2014, with focus on 75° W (North American sector)
- Treated with a series of Python and MATLAB scripts
  - 9 scripts total, estimate on the low side of 115 hours to run (assuming everything works)

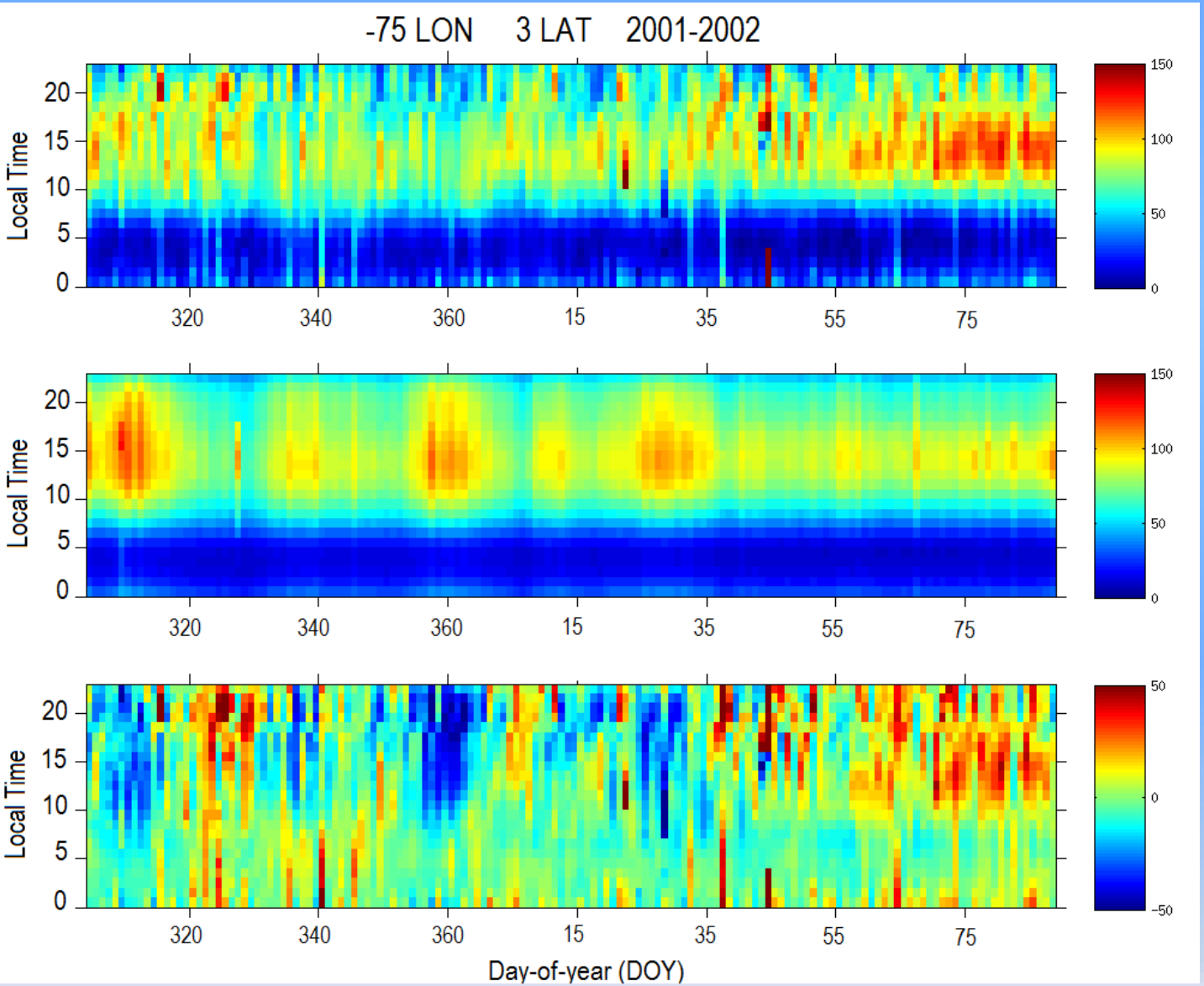
Initial Results



- Only had seasonal variation removed
- Showed TEC features attributed to solar flux and geomagnetic activity
- Looking for specific pattern (boxed)

Model Attempt No. 1

(Northern Anomaly)



Data

Model

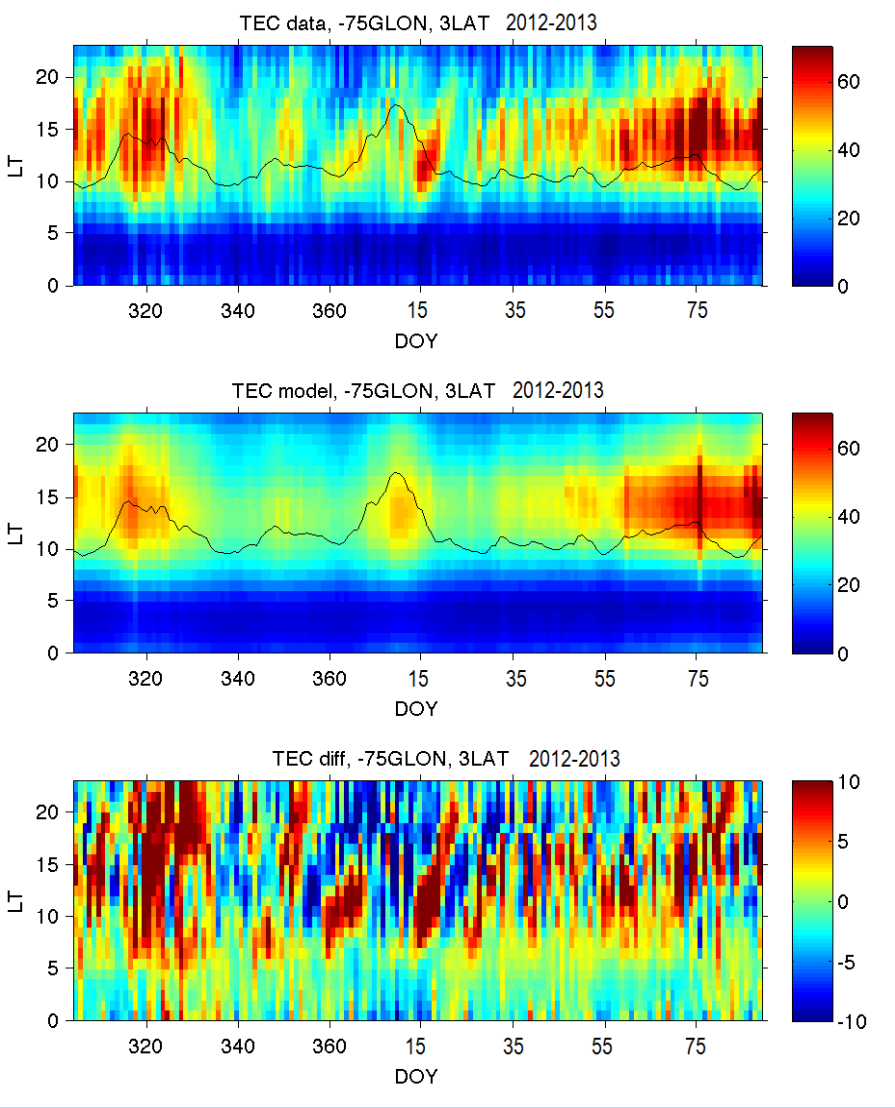
Difference

The Empirical TEC Model

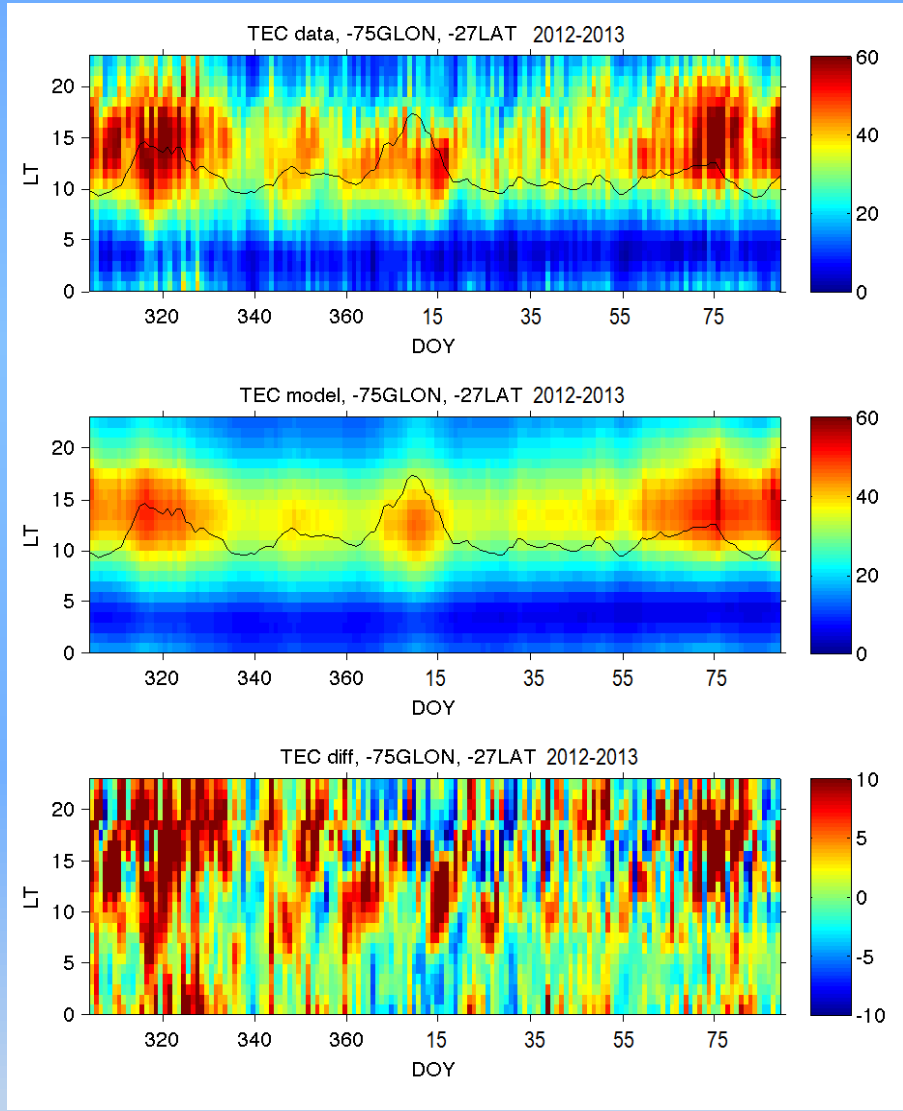
- Factors included in model:
  - Linear relationships with solar flux (PF10.7) and geomagnetic activity (Ap3)
  - Third degree polynomial for day-of-year (DOY) dependence
  - Coefficients and constant determined with least squares fit to 13 years of data
- $TEC_m = TEC_o + b_1*PF107 + b_2*Ap_3 + b_3* DOY + b_4*DOY^2 + b_5*DOY^3 + b_6*PF107*DOY + b_7*PF107*DOY^2 + b_8*PF107*DOY^3$

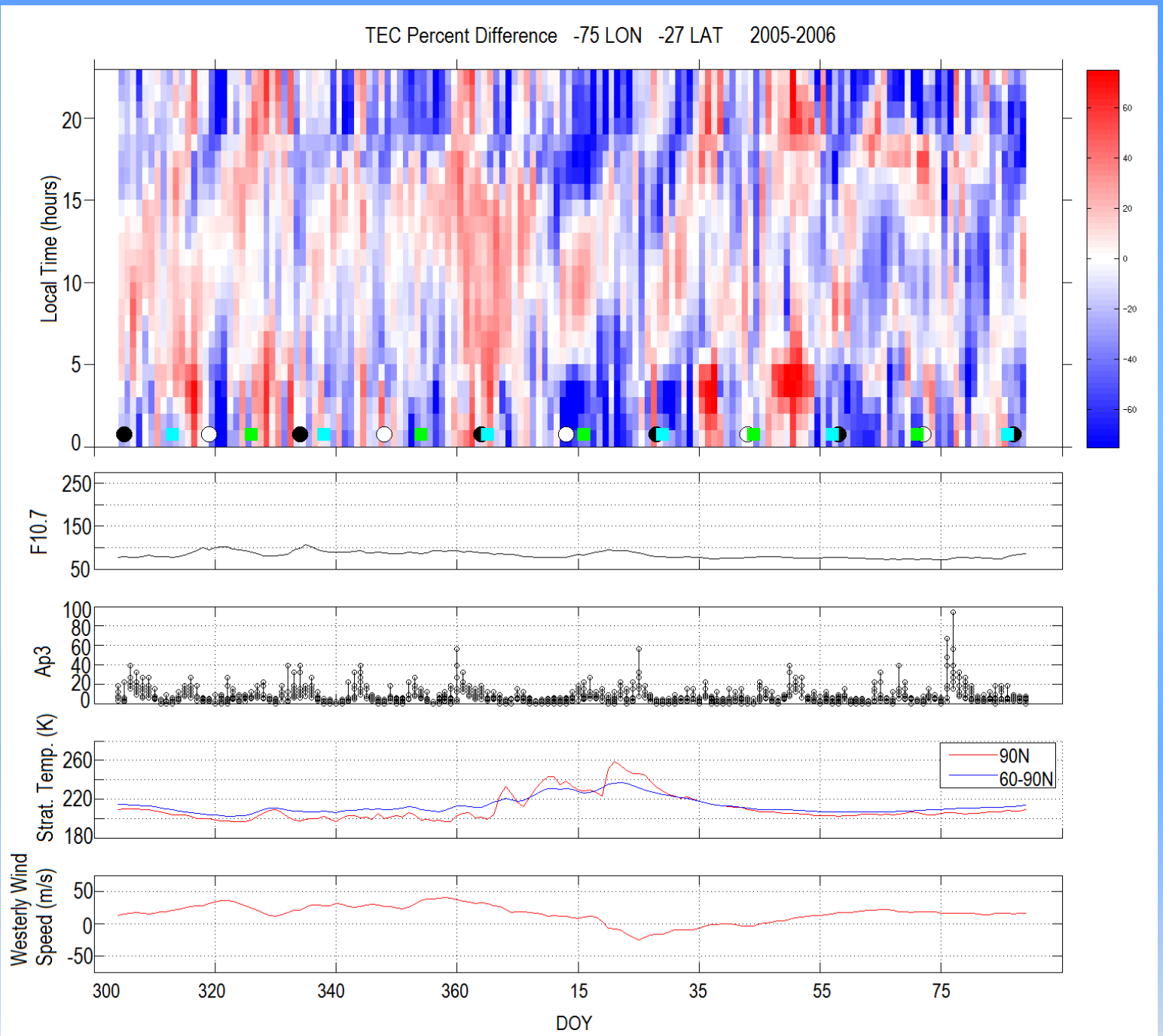
Refined Model Results

Northern Anomaly



Southern Anomaly




TEC Percent Difference -75 LON -27 LAT 2005-2006
Local Time (hours)
0
5
10
15
20
60
40
20
0
-20
-40
-60
F10.7
250
150
50
Ap3
100
80
60
40
20
0
Strat. Temp. (K)
260
220
180
90N
60-90N
Westerly Wind Speed (m/s)
50
0
-50
300
320
340
360
15
35
55
75
DOY

Winter	Type of SSW	Lat. 3° N (TEC % difference, concurrency)	Lat. 27° S (TEC % difference, concurrency)
2001-2002	Minor	20% , full moon at perigee	Not enough data
2002-2003	Major	Not clear	35%, new moon at perigee
2003-2004	Major	40%, new moon at perigee	40%, new moon at perigee
2004-2005	Major	Not clear	Not clear
2005-2006	Major	50%, new moon at perigee	35%, new moon at perigee
2006-2007	Minor	20%, full moon only	10%, full moon only
2007-2008	Major	35%, full moon at perigee	35%, full moon at perigee
2008-2009	Major	60%, new moon at apogee	45%, new moon at apogee
2009-2010	Major	20%, full moon at perigee	40%, full moon at perigee
2010-2011	Minor	No discernible features	No discernible features
2011-2012	Minor	45%, new moon only	30%, new moon only
2012-2013	Major	55%, new moon at perigee	40%, new moon at perigee
2013-2014	Minor	No discernible features	No discernible features?

Conclusions

- Ionization anomalies that occur during SSWs seem to be amplified during full or new moons,
  - Features seem to be weaker in Southern Anomaly
    - Consistent with other works
- Lunar phase has no effect on planetary wave amplitude
  - So any enhancement mechanism should not be planetary wave related
- Refining method of determining concurrency could be done in the future

Acknowledgements

- Larisa Goncharenko – for being my mentor and putting up with me

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- Shunrong Zhang – advice on the model
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