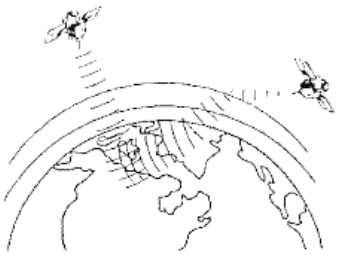
USTEC Model Analysis

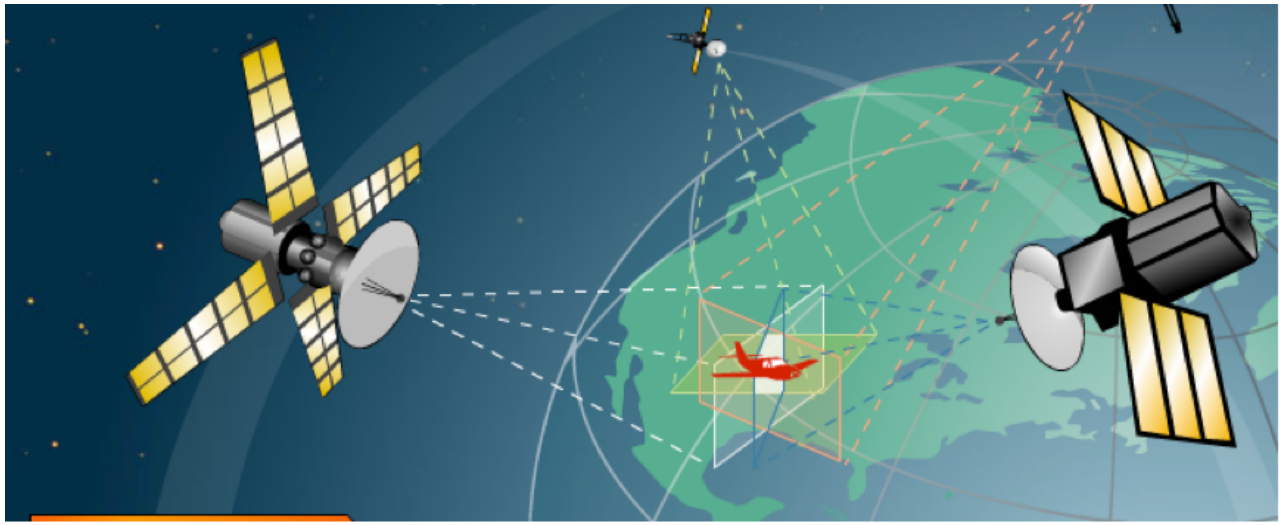
HANNA KRISTENSEN, PEPPERDINE UNIVERSITY
Advisor: Mihail Codrescu

GPS and the Ionosphere

- A signal gets broadcasted down from the satellite to the GPS receiver
- This signal passes through the Ionosphere
- The electron density of the Ionosphere changes during solar storms
- This changes the speed of the signal and causes triangulation errors
- Extra time in a given position is needed to correct for these errors
- Without a warning system GPS users do not know the precision of their measurement

GPS signals through ionosphe





Warning Systems

- We currently have alerts/warning for Geomagnetic Storms, Solar Radiation Storms, and Radio Blackouts
- The creation of a GPS Space Weather Scale

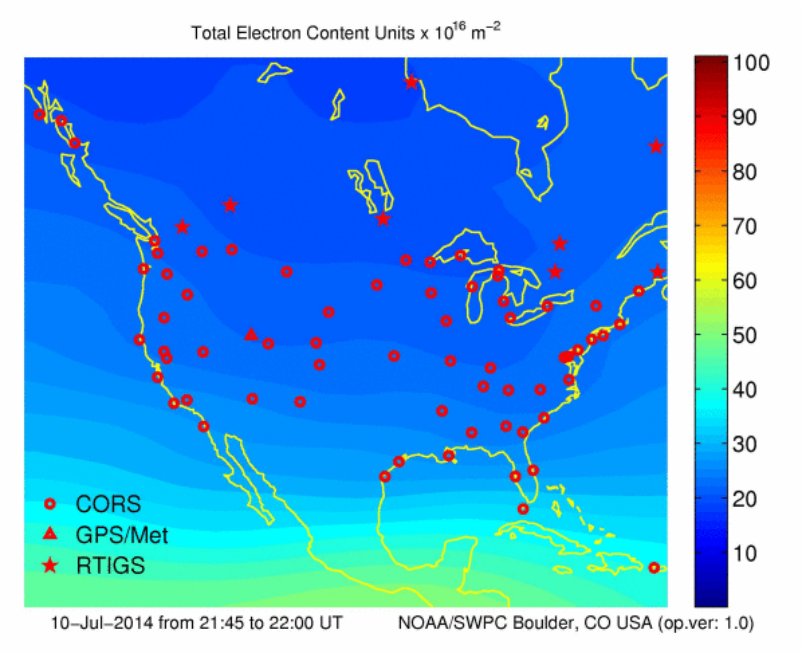
NOAA Space Weather Scales

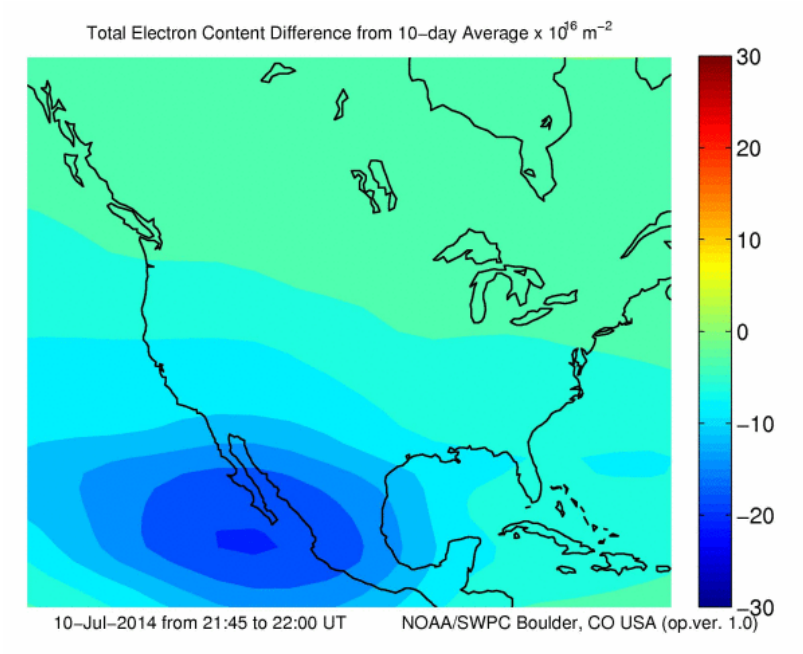
Category		Effect	Physical measure	Average Frequency (1 cycle = 11 years)
Scale	Descriptor	Duration of event will influence severity of effects		
Geomagnetic Storms			Kp values* determined every 3 hours	Number of storm events when Kp level was met; (number of storm days)
G 5	Extreme	Power systems: widespread voltage control problems and protective system problems can occur, some grid systems may experience complete collapse or blackouts. Transformers may experience damage. Spacecraft operations: may experience extensive surface charging, problems with orientation, uplink/downlink and tracking satellites. Other systems: pipeline currents can reach hundreds of amps, HF (high frequency) radio propagation may be impossible in many areas for one to two days, satellite navigation may be degraded for days, low-frequency radio navigation can be out for hours, and aurora has been seen as low as Florida and southern Texas (typically 40° geomagnetic lat.).**	Kp=9	4 per cycle (4 days per cycle)
G 4	Severe	Power systems: possible widespread voltage control problems and some protective systems will mistakenly trip out key assets from the grid. Spacecraft operations: may experience surface charging and tracking problems, corrections may be needed for orientation problems. Other systems: induced pipeline currents affect preventive measures, HF radio propagation sporadic, satellite navigation degraded for hours, low-frequency radio navigation disrupted, and aurora has been seen as low as Alabama and northern California (typically 45° geomagnetic lat.).**	Kp=8	100 per cycle (60 days per cycle)
G 3	Strong	Power systems: voltage corrections may be required, false alarms triggered on some protection devices. Spacecraft operations: surface charging may occur on satellite components, drag may increase on low-Earth-orbit satellites, and corrections may be needed for orientation problems. Other systems: intermittent satellite navigation and low-frequency radio navigation problems may occur, HF radio may be intermittent, and aurora has been seen as low as Illinois and Oregon (typically 50° geomagnetic lat.).**	Kp=7	200 per cycle (130 days per cycle)
G 2	Moderate	Power systems: high-latitude power systems may experience voltage alarms, long-duration storms may cause transformer damage. Spacecraft operations: corrective actions to orientation may be required by ground control; possible changes in drag affect orbit predictions. Other systems: HF radio propagation can fade at higher latitudes, and aurora has been seen as low as New York and Idaho (typically 55° geomagnetic lat.).**	Kp=6	600 per cycle (360 days per cycle)
G 1	Minor	Power systems: weak power grid fluctuations can occur. Spacecraft operations: minor impact on satellite operations possible. Other systems: migratory animals are affected at this and higher levels; aurora is commonly visible at high latitudes (northern Michigan and Maine).**	Kp=5	1700 per cycle (900 days per cycle)

* Based on this measure, but other physical measures are also considered.

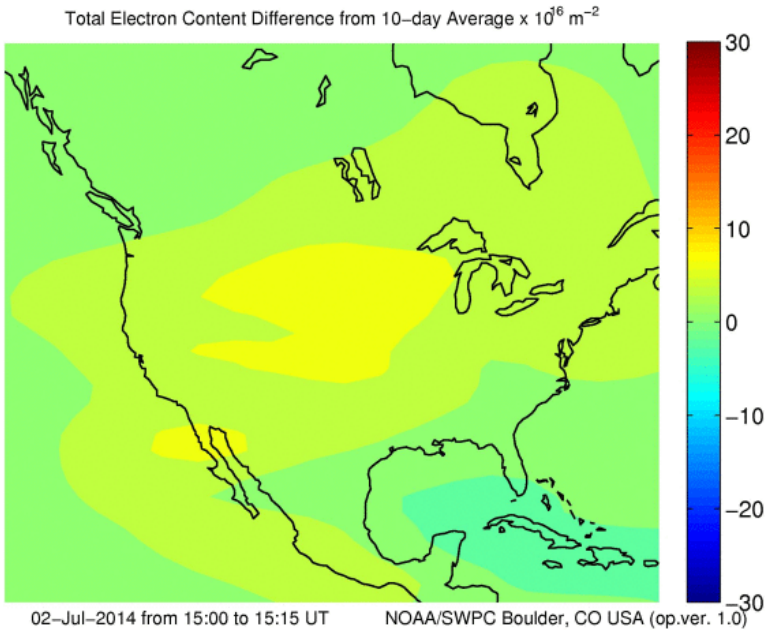
** For specific locations around the globe, use geomagnetic latitude to determine likely sightings (see www.swpc.noaa.gov/Aurora)

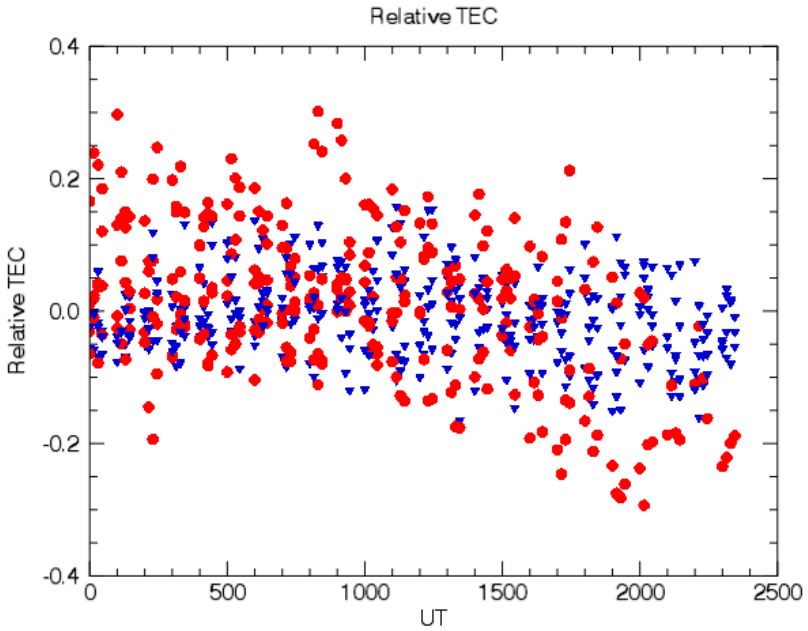
Current Model: Monitoring the Ionosphere



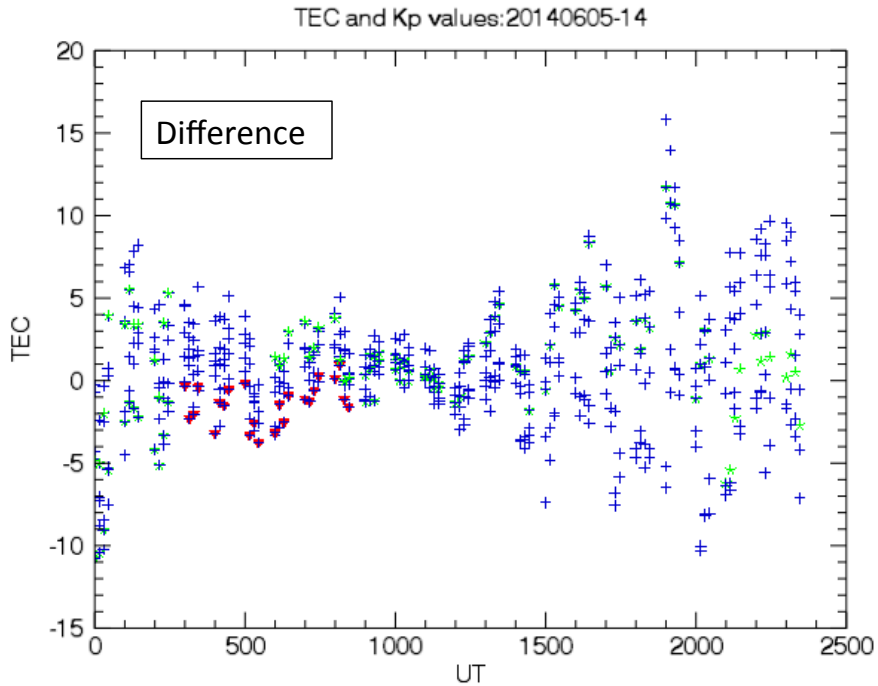


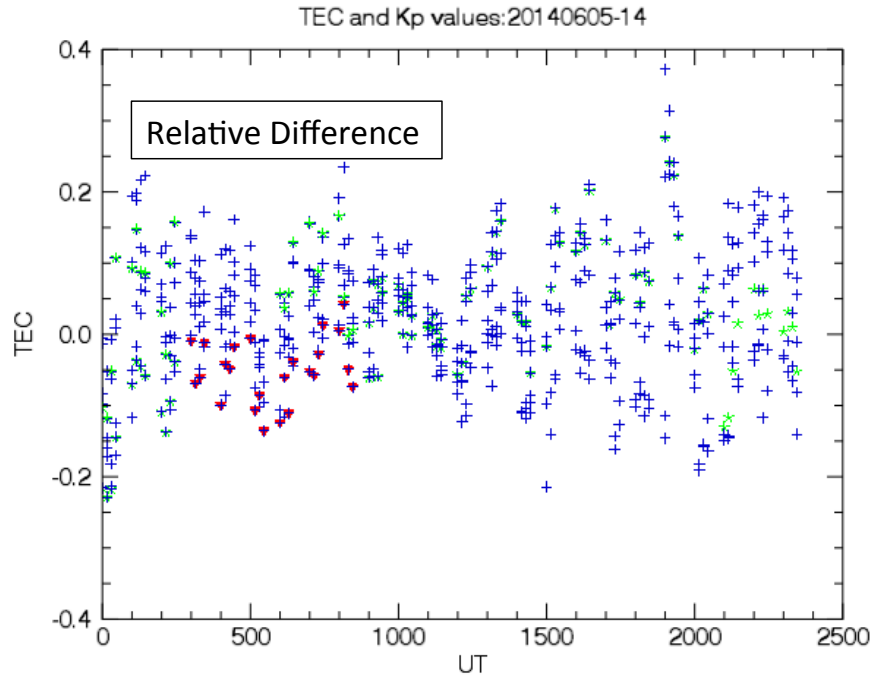
Creating a scale

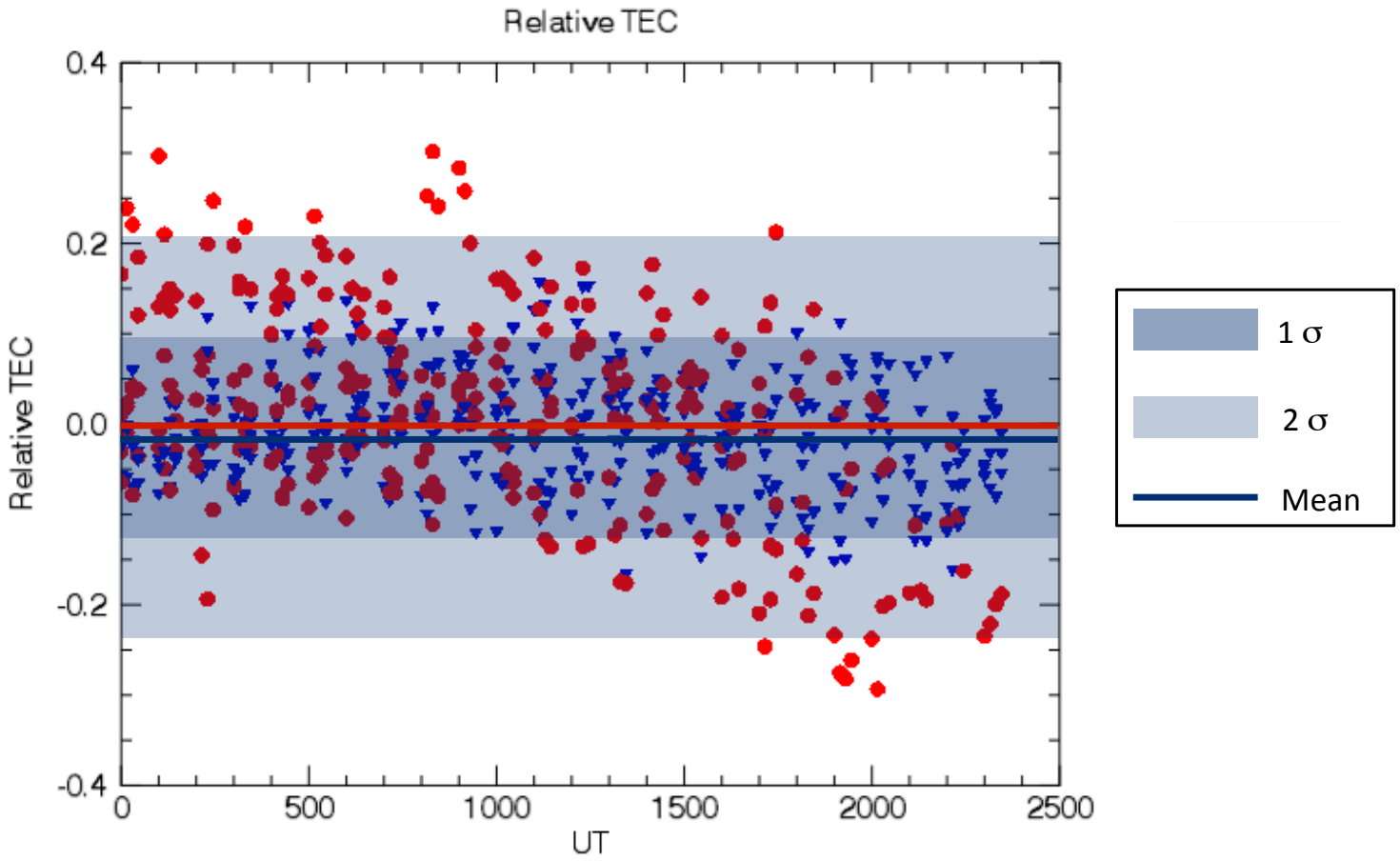


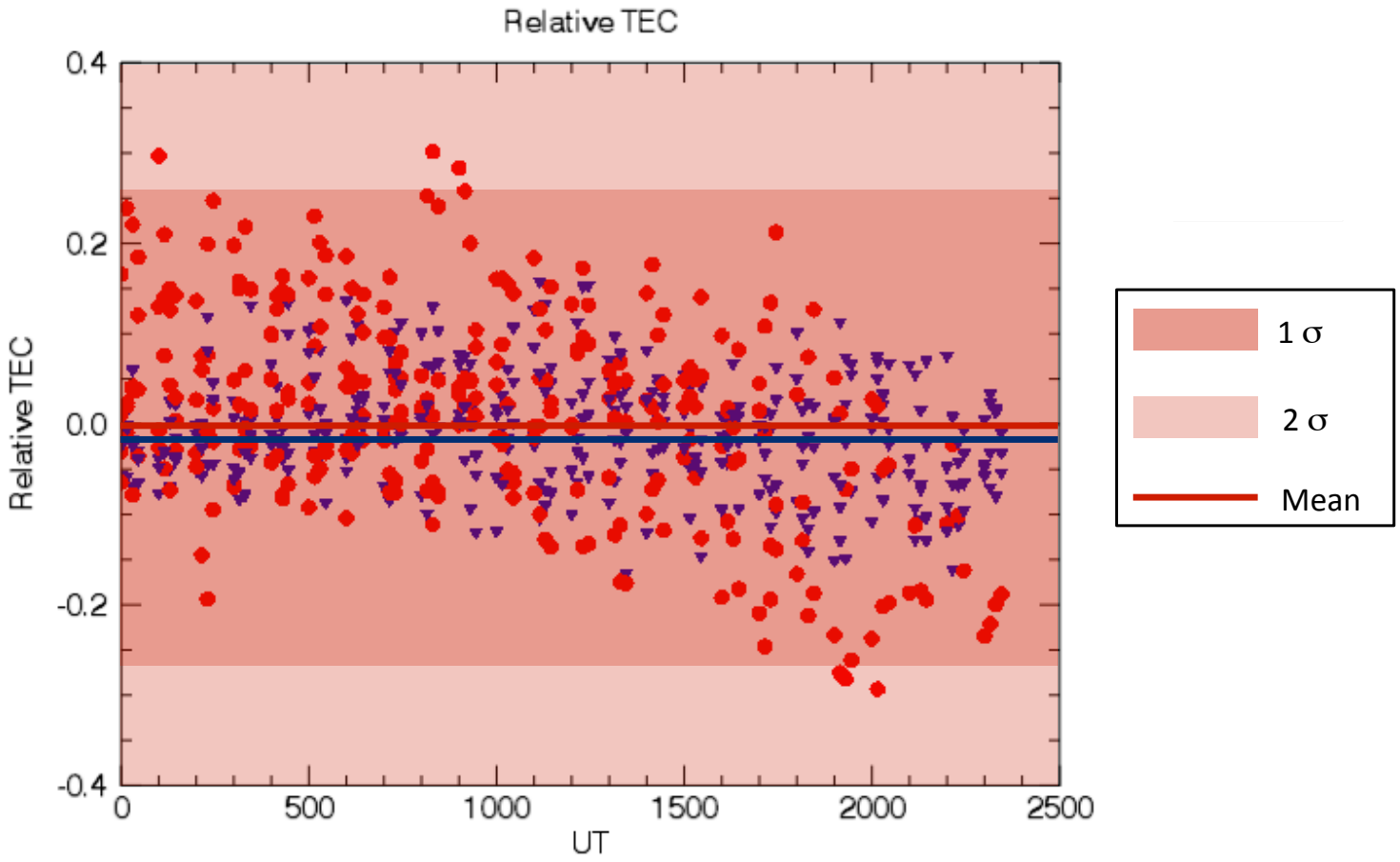


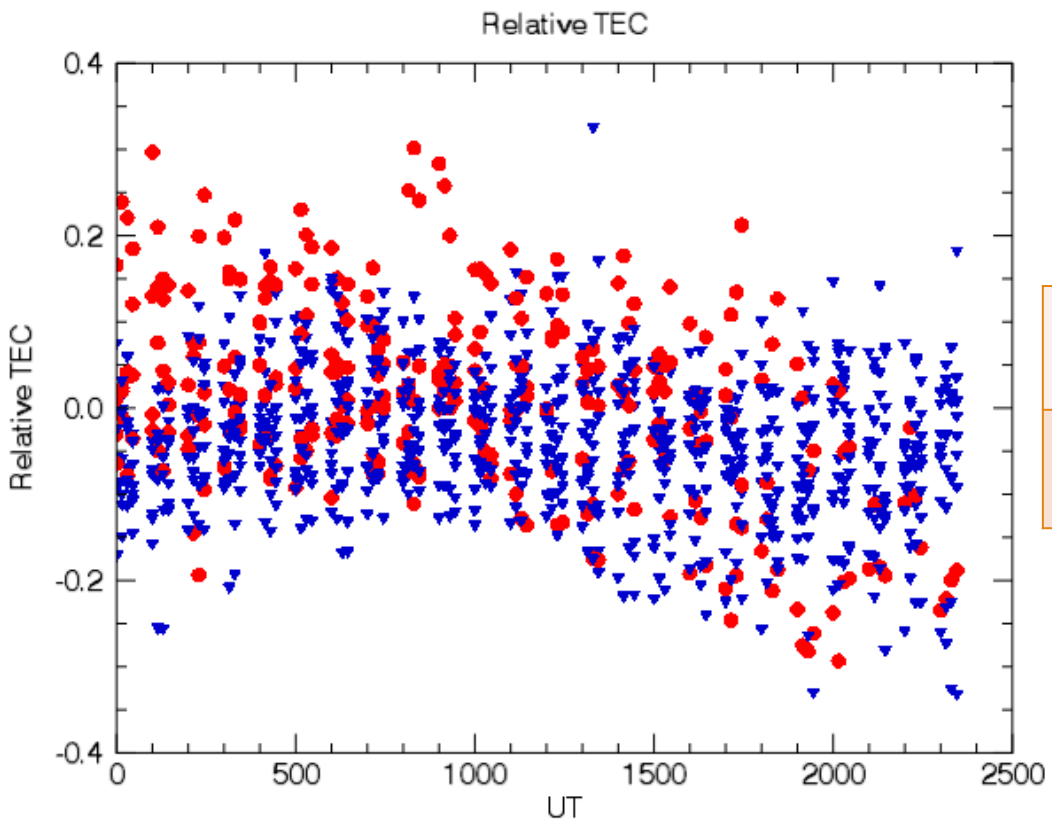
Differentiating days



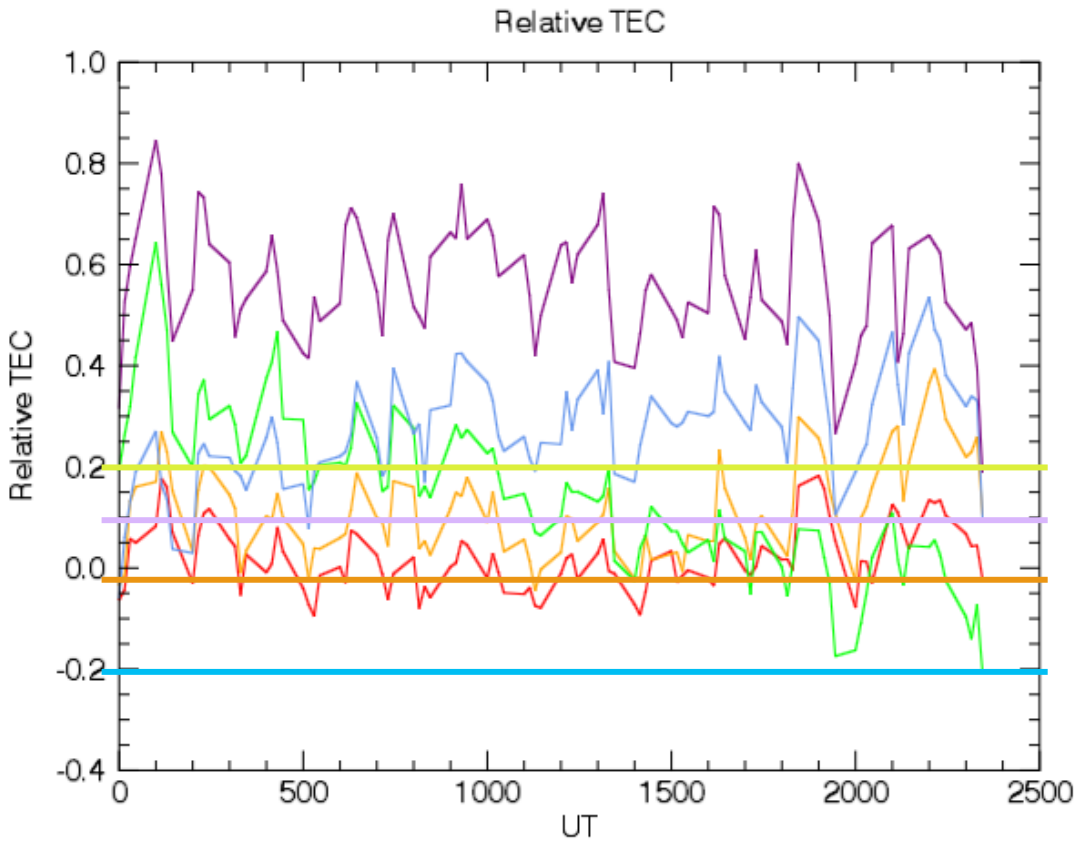


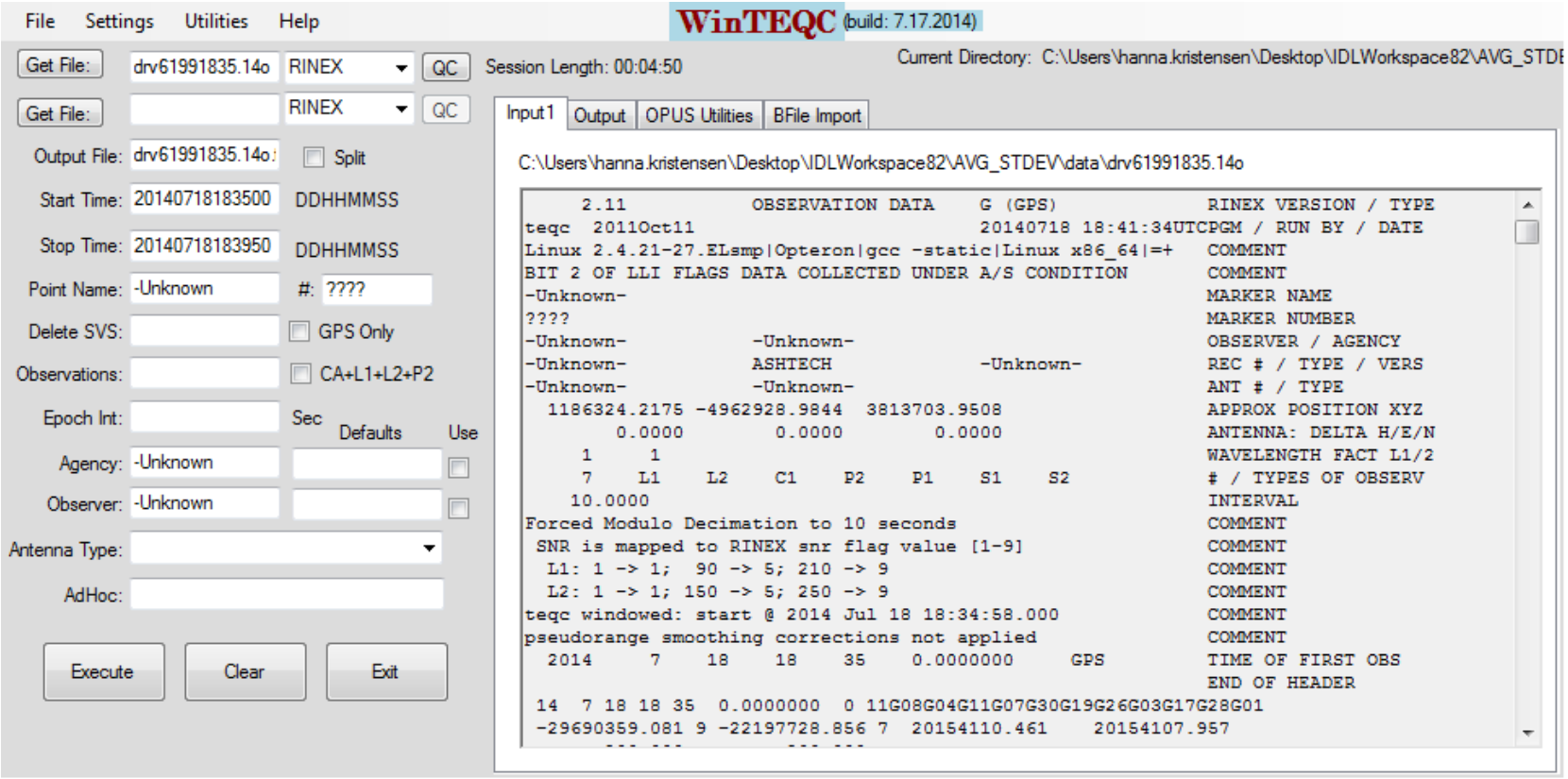

Relative TEC
0.4
0.2
0.0
-0.2
-0.4
Relative TEC
0
500
1000
1500
2000
2500
UT
1 σ
2 σ
Mean


Relative TEC
0.4
0.2
0.0
-0.2
-0.4
Relative TEC
0
500
1000
1500
2000
2500
UT
1 σ
2 σ
Mean



Quiet Average	Quiet STDEV	Disturbed Average	Disturbed STDEV
-0.0310038	7.21839	-0.0363879	13.9891


Relative TEC
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
Relative TEC
0
500
1000
1500
2000
2500
UT


File
Settings
Utilities
Help
WinTEQC (build: 7.17.2014)
Get File:
drv61991835.14o
RINEX
QC
Session Length: 00:04:50
Current Directory: C:\Users\hanna.kristensen\Desktop\IDLWorkspace82\AVG_STDE
Get File:
RINEX
QC
Input1
Output
OPUS Utilities
BFile Import
Output File:
drv61991835.14o
Split
Start Time:
20140718183500
DDHHMMSS
Stop Time:
20140718183950
DDHHMMSS
Point Name:
-Unknown
#:
????
Delete SVS:
GPS Only
Observations:
CA+L1+L2+P2
Epoch Int:
Sec
Defaults
Use
Agency:
-Unknown
Observer:
-Unknown
Antenna Type:
AdHoc:
Execute
Clear
Exit
C:\Users\hanna.kristensen\Desktop\IDLWorkspace82\AVG_STDEV\data\drv61991835.14o
2.11 OBSERVATION DATA G (GPS) RINEX VERSION / TYPE
teqc 2011Oct11 20140718 18:41:34UTCPGM / RUN BY / DATE
Linux 2.4.21-27.ELsmp|Opteron|gcc -static|Linux x86_64|=+ COMMENT
BIT 2 OF LLI FLAGS DATA COLLECTED UNDER A/S CONDITION COMMENT
-Unknown- MARKER NAME
???? MARKER NUMBER
-Unknown- -Unknown- OBSERVER / AGENCY
-Unknown- ASHTECH -Unknown- REC # / TYPE / VERS
-Unknown- -Unknown- ANT # / TYPE
1186324.2175 -4962928.9844 3813703.9508 APPROX POSITION XYZ
0.0000 0.0000 0.0000 ANTENNA: DELTA H/E/N
1 1 WAVELENGTH FACT L1/2
7 L1 L2 C1 P2 P1 S1 S2 # / TYPES OF OBSERV
10.0000 INTERVAL
Forced Modulo Decimation to 10 seconds COMMENT
SNR is mapped to RINEX snr flag value [1-9] COMMENT
L1: 1 -> 1; 90 -> 5; 210 -> 9 COMMENT
L2: 1 -> 1; 150 -> 5; 250 -> 9 COMMENT
teqc windowed: start @ 2014 Jul 18 18:34:58.000 COMMENT
pseudorange smoothing corrections not applied COMMENT
2014 7 18 18 35 0.0000000 GPS TIME OF FIRST OBS
END OF HEADER
14 7 18 18 35 0.0000000 0 11G08G04G11G07G30G19G26G03G17G28G01
-29690359.081 9 -22197728.856 7 20154110.461 20154107.957

TEQC:GPS signal results

GPS carries signals with different frequencies, the receiver counts the number of times the signal goes through zero

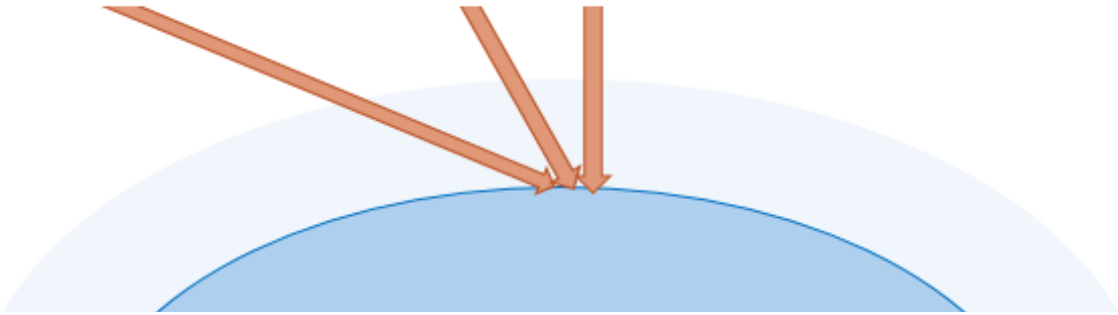
L1: 1575.42 MHz

L2: 1227.6 MHz

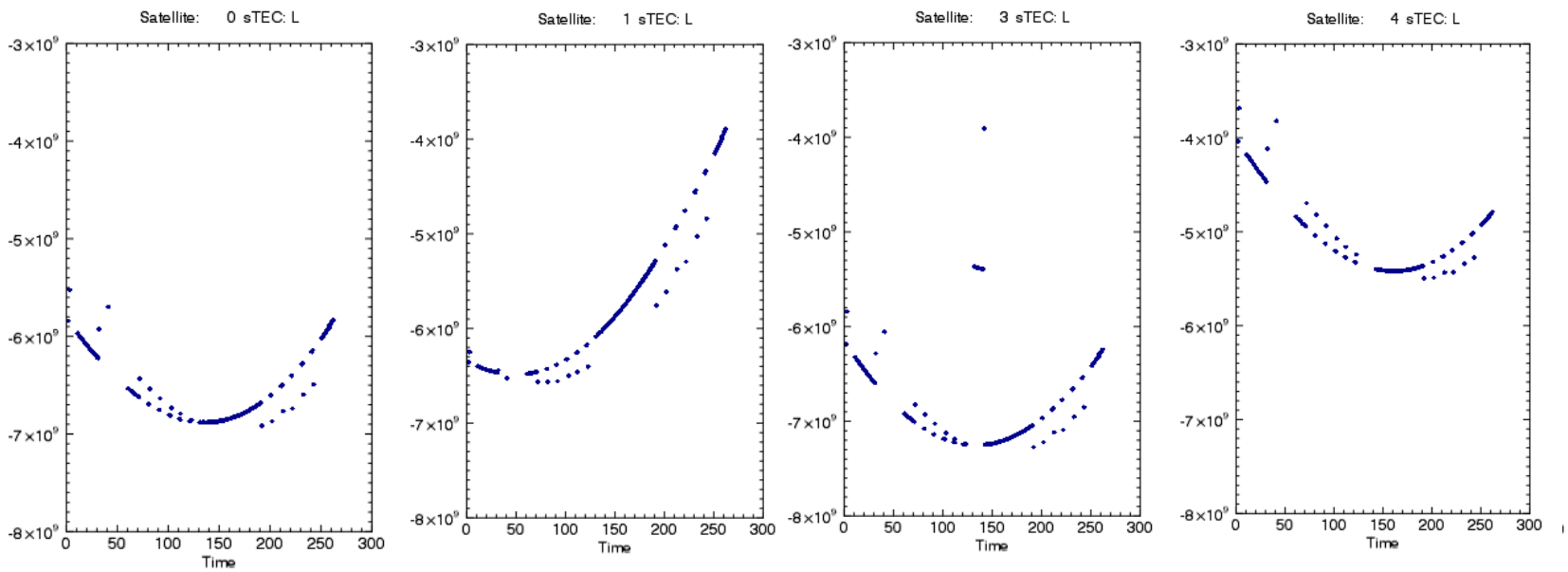
Disturbance Index

$$sTEC=9.52(L1-L2)$$

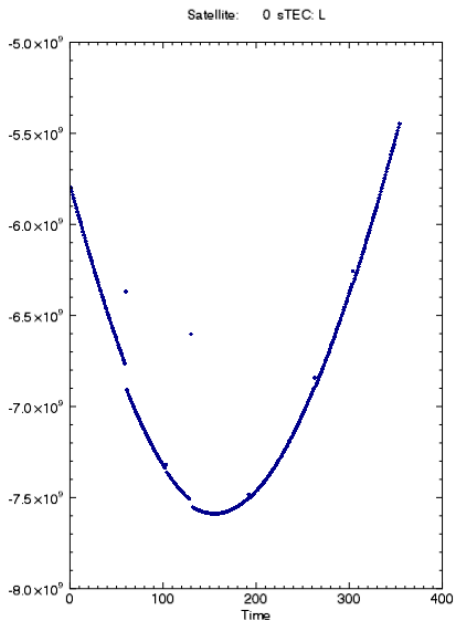
$$\Delta TEC=sTEC_0-sTEC_f$$

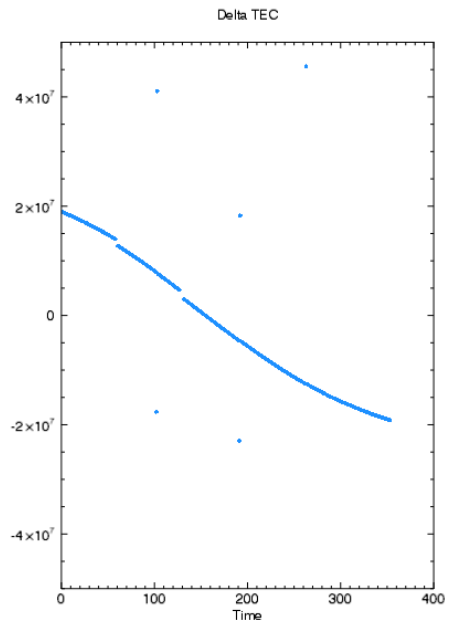


Slant TEC

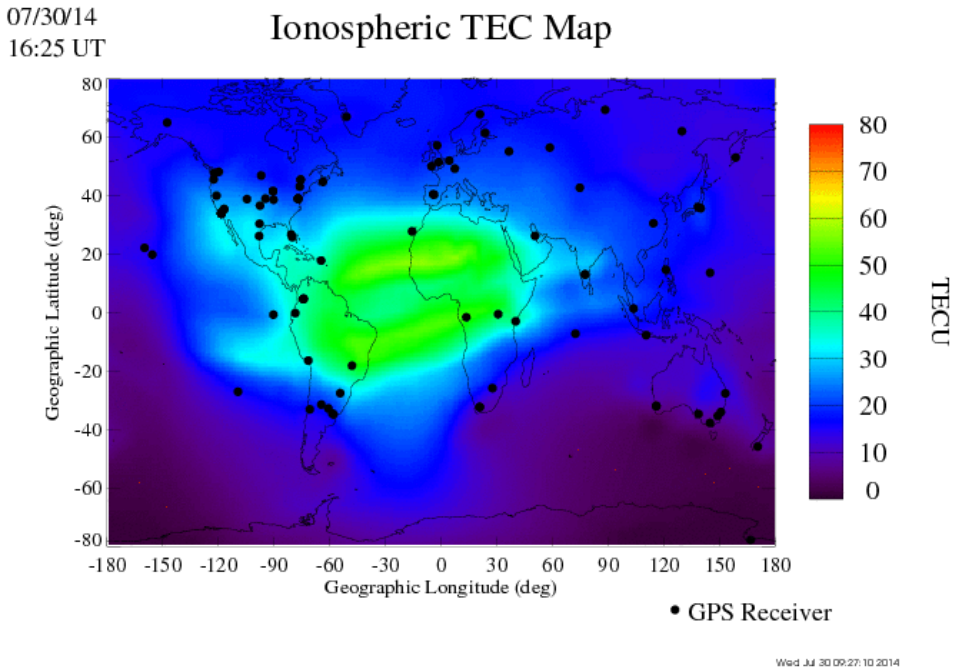

Satellite: 0 sTEC: L
Satellite: 1 sTEC: L
Satellite: 3 sTEC: L
Satellite: 4 sTEC: L
-3×10^9
-4×10^9
-5×10^9
-6×10^9
-7×10^9
-8×10^9
0 50 100 150 200 250 300
Time

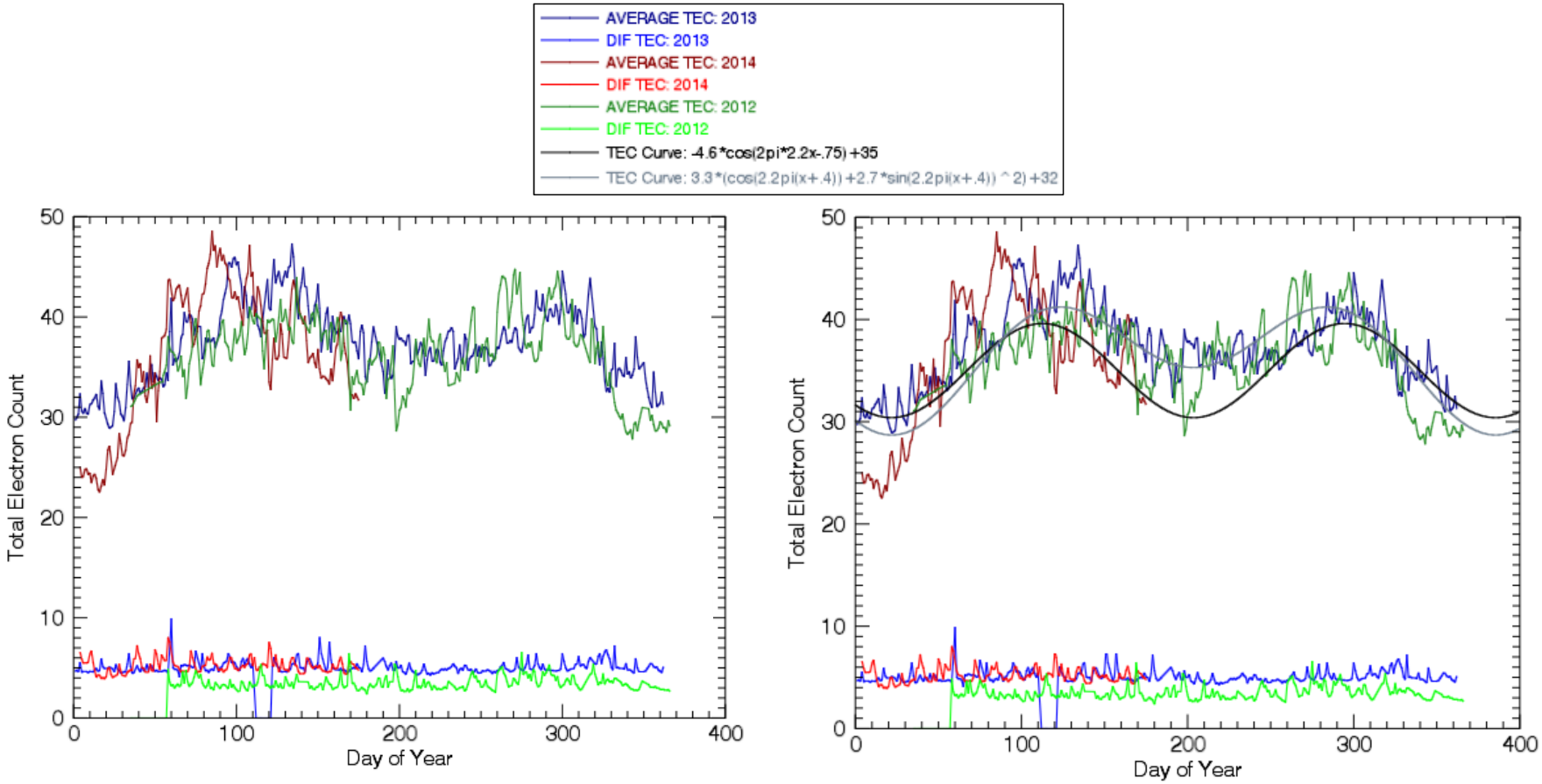
2014 7 25 17 25:890517.5740 -4568459.6989 4346302.7918





Predictive Model: Forecasting conditions



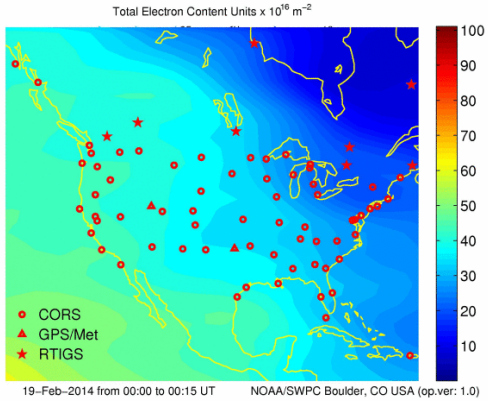

AVERAGE TEC: 2013
DIF TEC: 2013
AVERAGE TEC: 2014
DIF TEC: 2014
AVERAGE TEC: 2012
DIF TEC: 2012
TEC Curve: -4.6*cos(2pi*2.2x-.75)+35
TEC Curve: 3.3*(cos(2.2pi(x+.4))+2.7*sin(2.2pi(x+.4)) ^ 2)+32
Total Electron Count
Day of Year
0
10
20
30
40
50
100
200
300
400

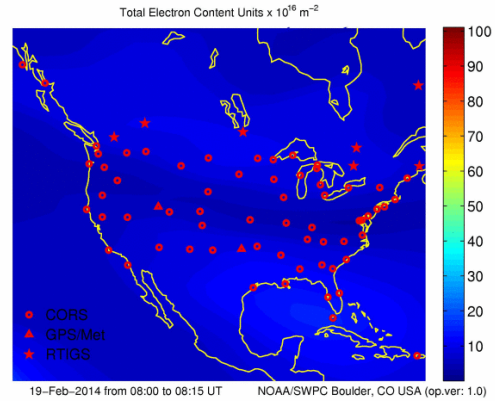
Conclusions

We found no useful correlation between CONUS vertical TEC averages or CONUS trend averages, and Kp.

This points to the need for a position dependent index, i.e. a map of GPS errors as a function of time, instead of a global number.

This makes sense as the TEC varies based on USTEC plots based on position.



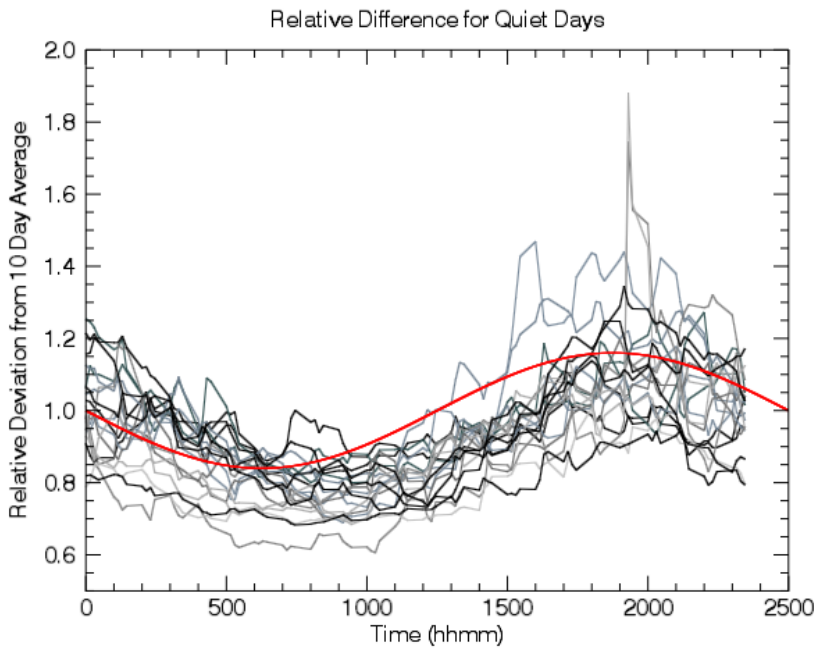


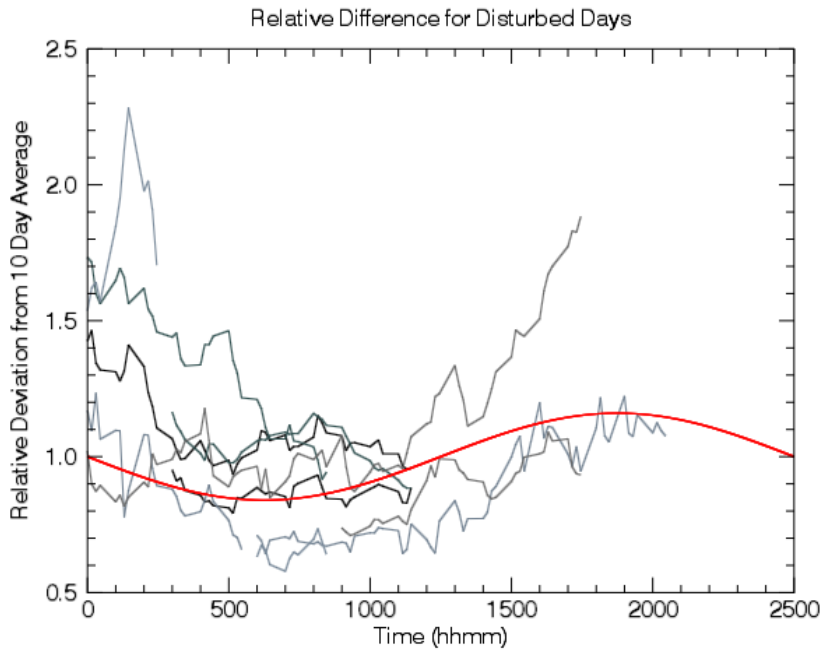
Acknowledgements

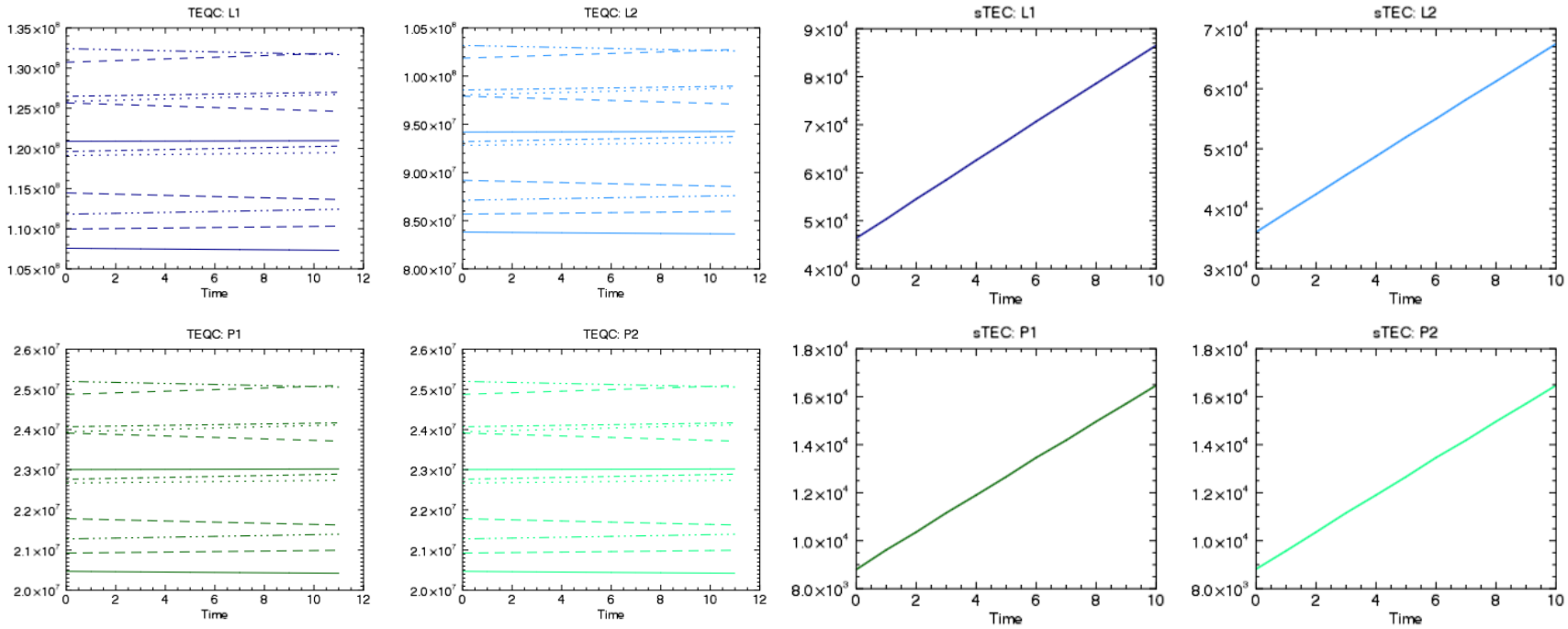
- Dr. Mihail Codrescu
- NSF
- NOAA, SWPC
- Drs. Rodney Viereck and Marty Snow
- Solar and Space Physics REU students

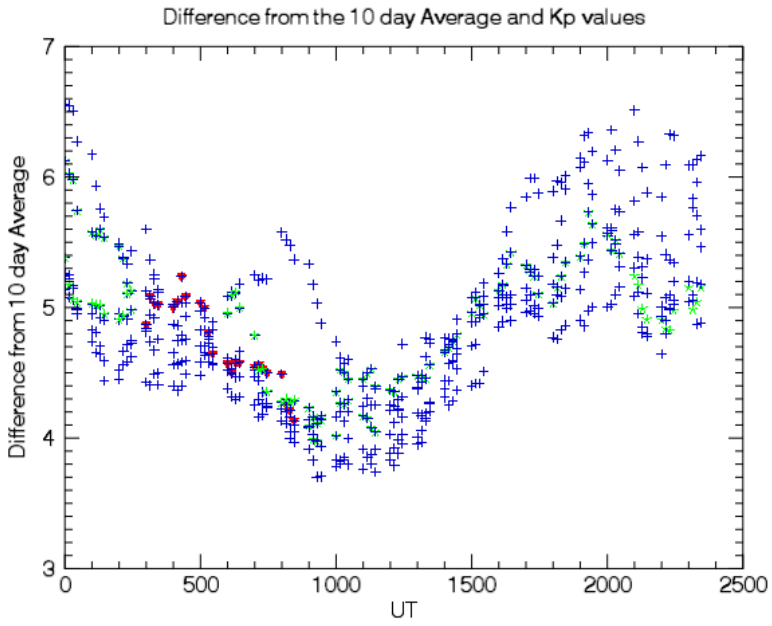
Questions

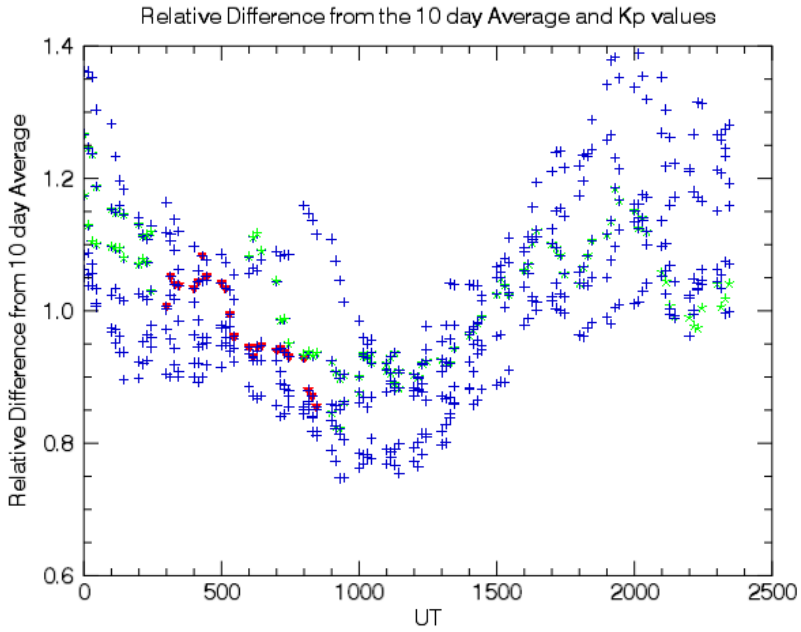
Differentiating days






TEQC: L1
TEQC: L2
sTEC: L1
sTEC: L2
TEQC: P1
TEQC: P2
sTEC: P1
sTEC: P2
Time


Difference from the 10 day Average and Kp values
Difference from 10 day Average
UT
7
6
5
4
3
0
500
1000
1500
2000
2500


Relative Difference from the 10 day Average and Kp values
Relative Difference from 10 day Average
UT
1.4
1.2
1.0
0.8
0.6
0
500
1000
1500
2000
2500