Quantifying the variability of Electron density in the Ionosphere during SSW events

CJ Begalke[1], Naomi Maruyama[2]
[1]Creighton University, Omaha, NE
[2]NOAA Space Weather Prediction Center

Outline

1. Brief Background
    1. Important things to know
2. Research objectives
3. Methodology
4. Tools/Models used for research
5. Data quality scan
6. Results
7. Conclusions
8. Future work

Ionosphere overview

- Ionosphere- the casing of free electrons and Ions that surround the earth
  - Ionized by solar radiation
  - Our focus is on F2 region (highest)
- Important to HF radio propagation
  - High density electrons can block radio waves
- 60km-~1000km

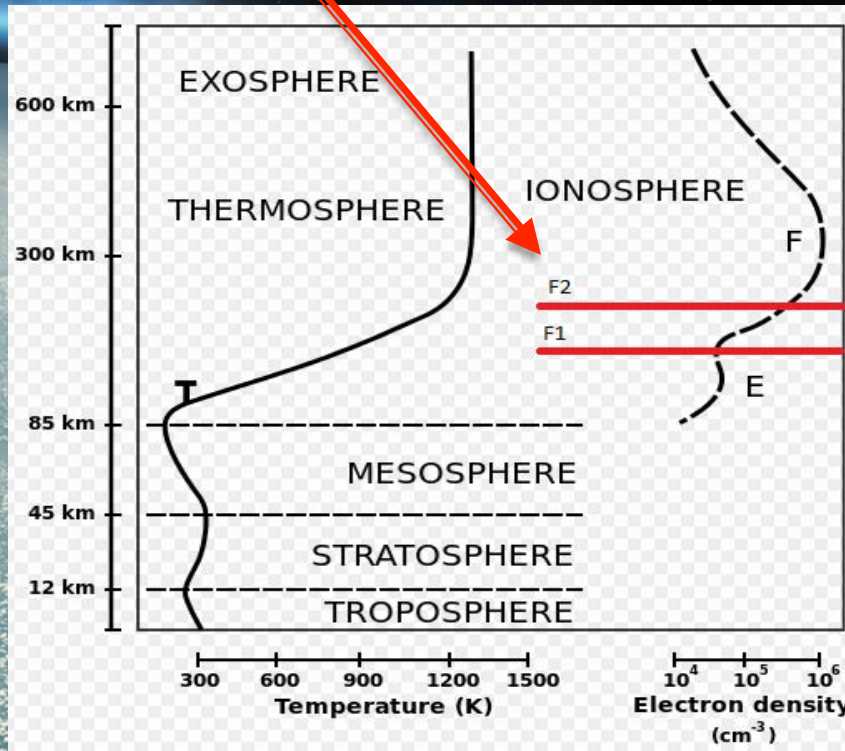


Diagram hmF2 and NmF2

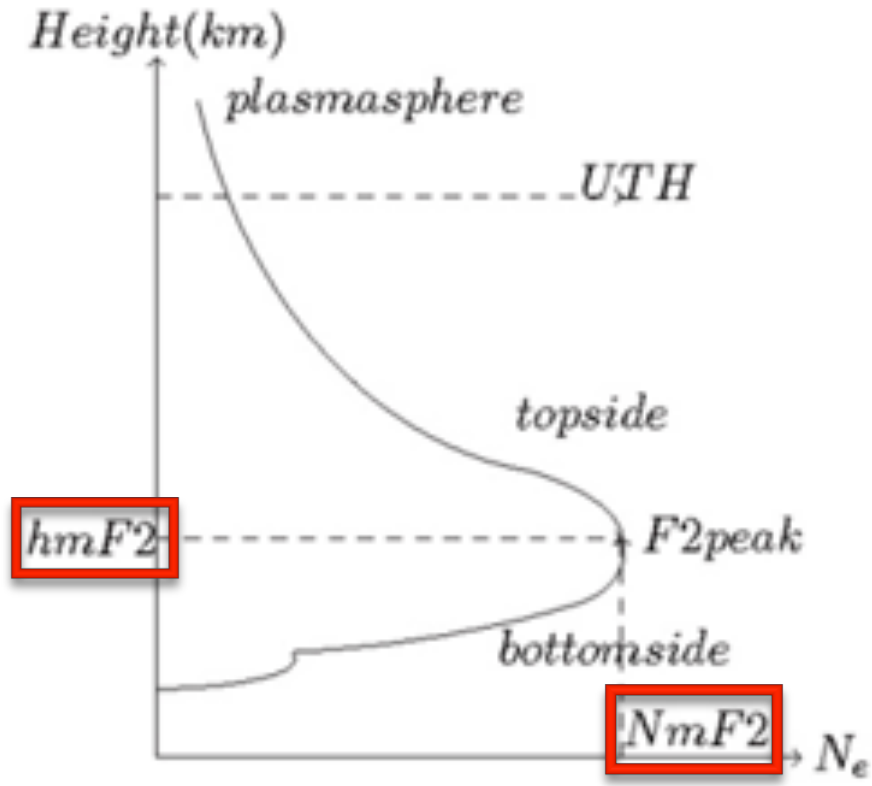


Fig. 1. An illustration of the different regions into which the ionosphere can be divided (not to scale.)

http://www.scielo.org.za/scielo.php?pid=S0038-23532009000500016&script=sci_arttext

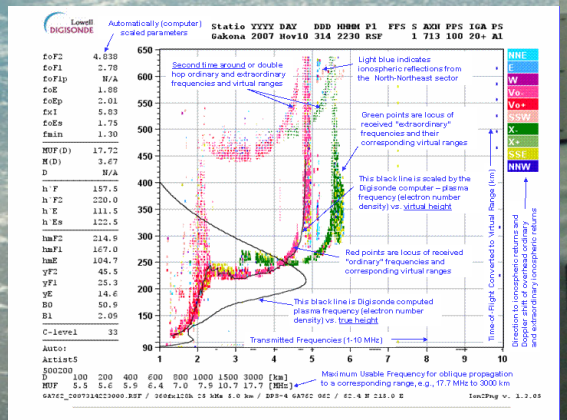
Sudden Stratospheric Warming

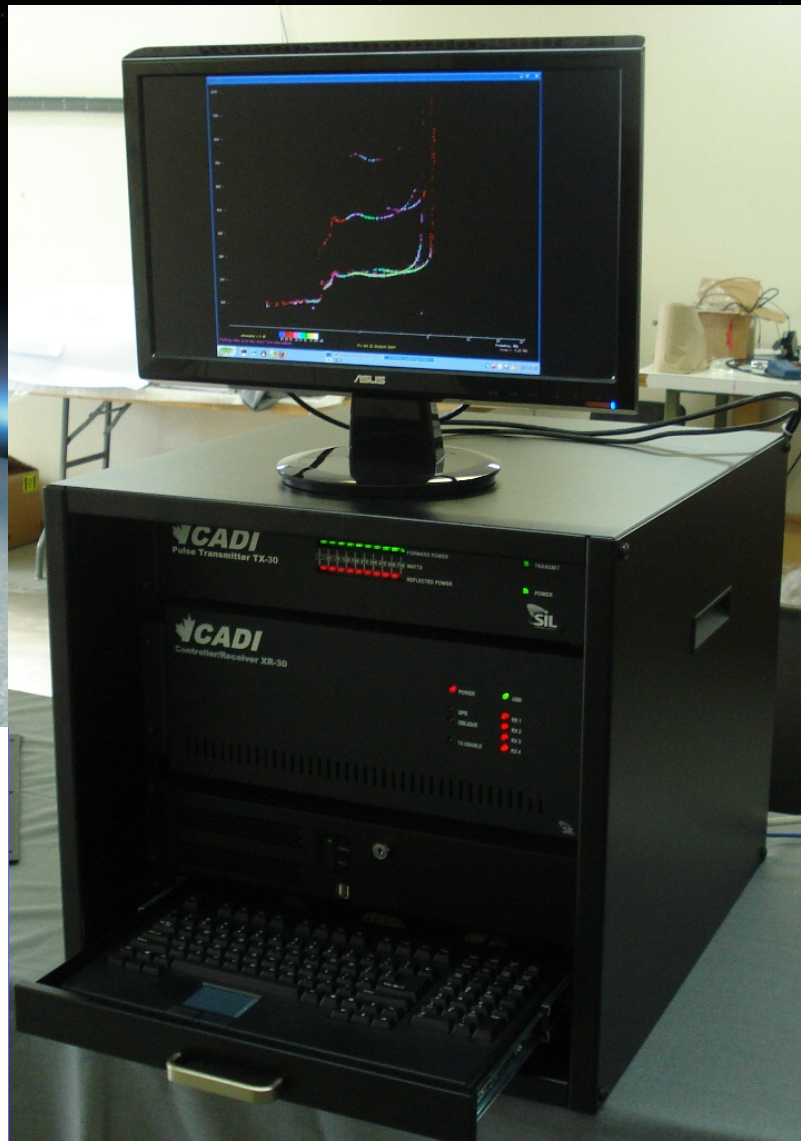
- **Sudden Stratospheric Warming (SSW)**
  - **Large, fast disruption in Northern Stratospheric westerly winds**
- Features:
  - Westerly winds may be reduced or switch direction
  - Potential break down of polar vortex
  - May cause rise in stratospheric temperatures by tens of degrees kelvin

Ionosondes

- High frequency (HF) radio transmitter
- Sweeps variety of frequency ranges (1-40 MHz)
  - Range is usually 1-16 MHz
- Measures heights from 100km to 600km
  - E region
  - F region

https://en.wikipedia.org/wiki/Ionosonde

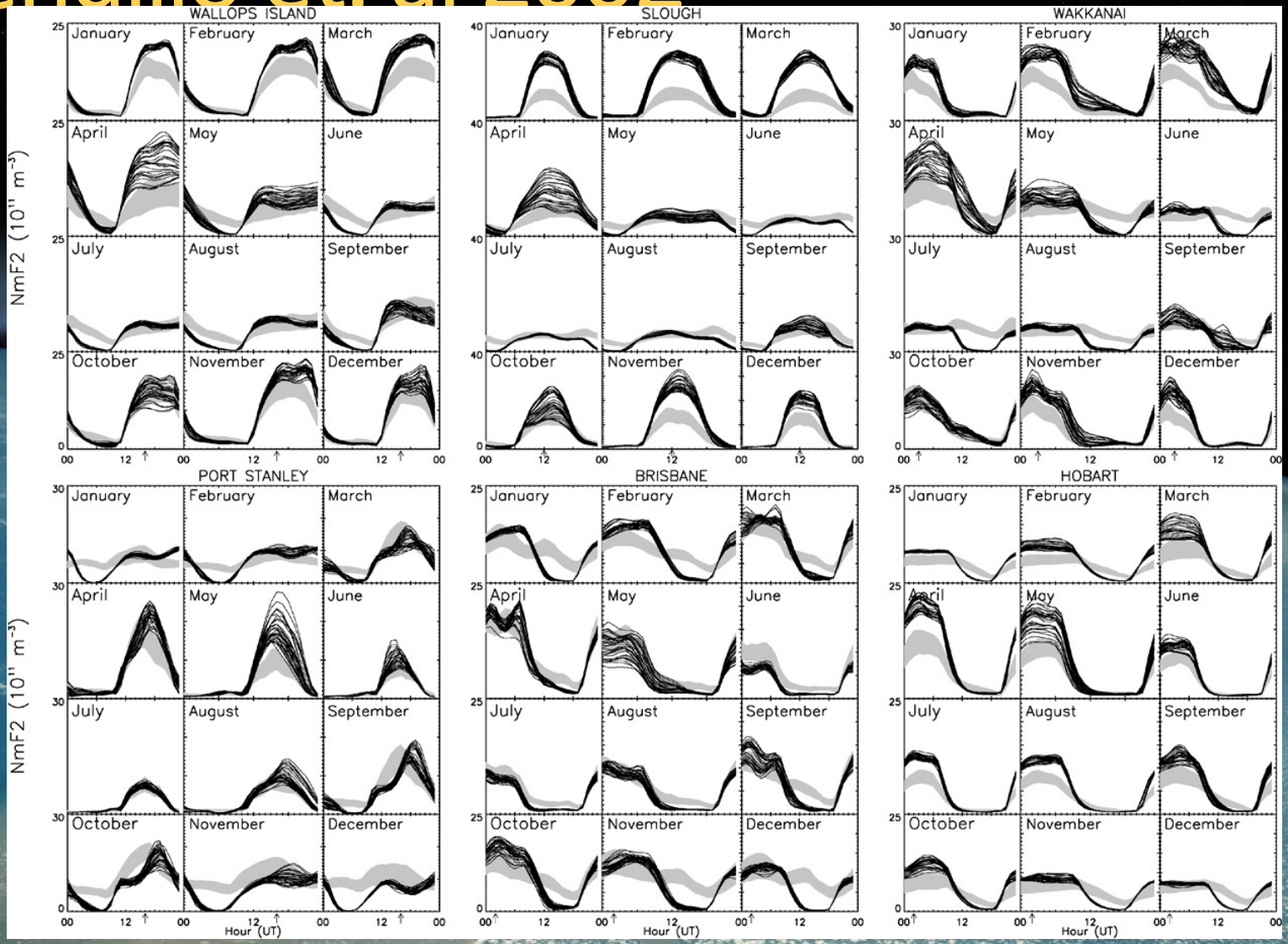




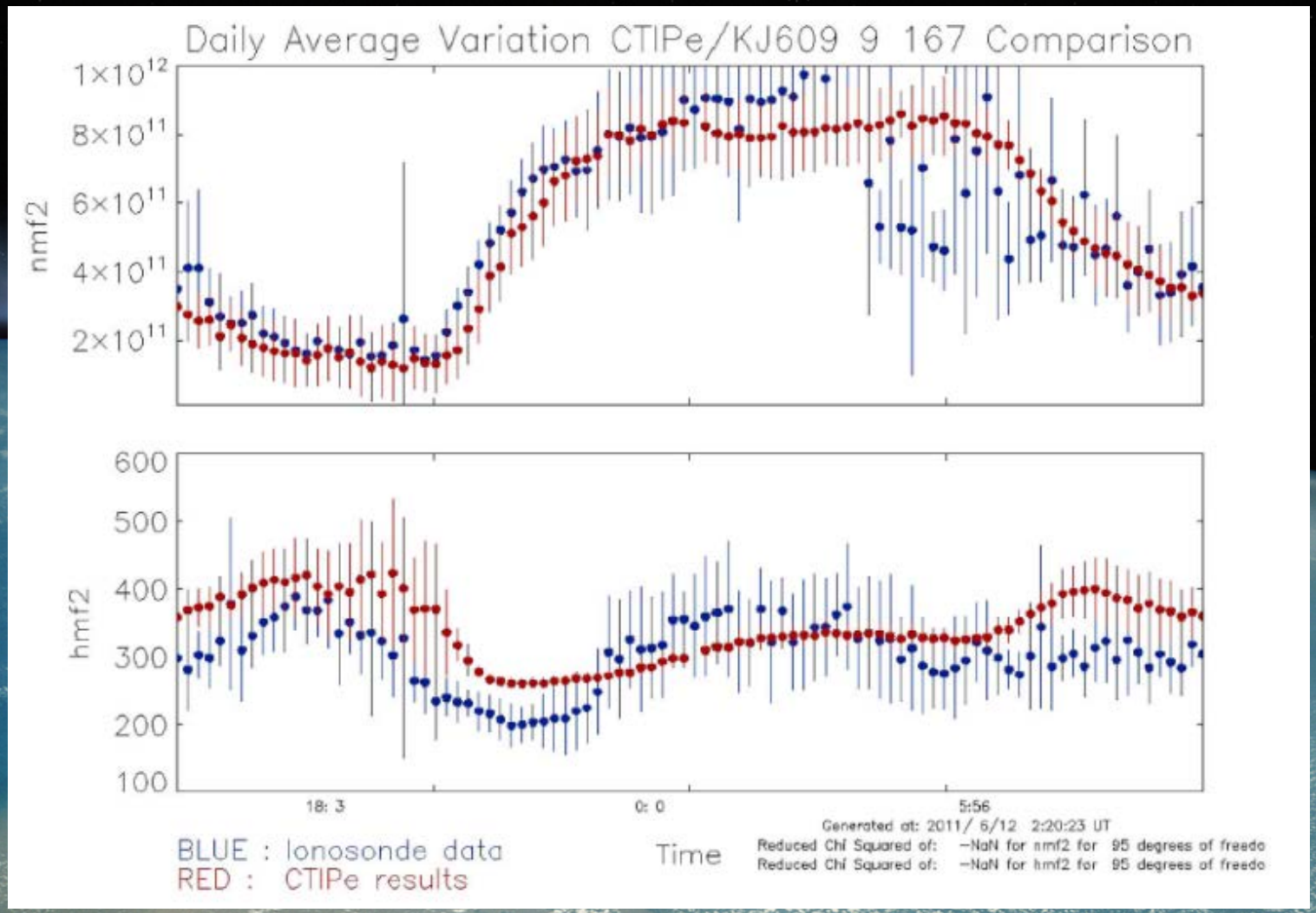
Research objectives

- **Determine possible causes of variability in electron densities**
  - **Solar cycle (minimum or maximum)**
  - **Geomagnetic activity (i.e., solar storms)**
  - ***Lower atmospheric forcing (enhanced in SSW)***
- Assess the variability of Electron Density
- Primary focus is lower atmospheric forcing
  - Specifically during SSW events
- Compare observed data with models
  - IRI model and IPE model

Day-to-day Variation as seen in Mendillo et. al 2002

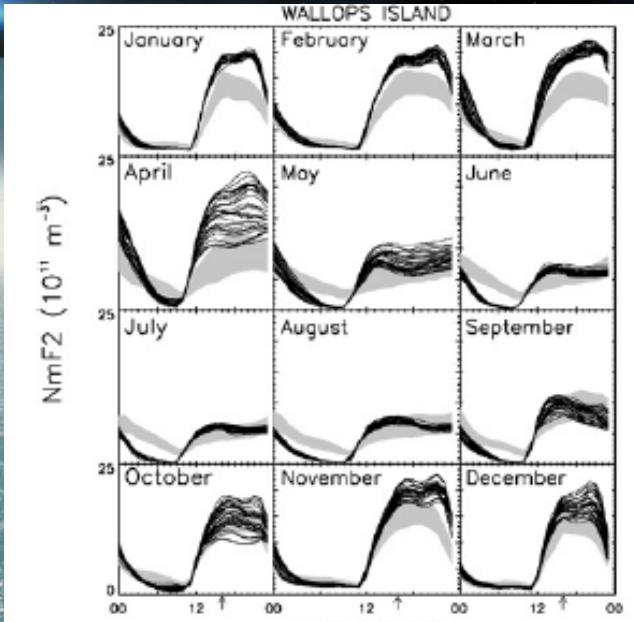


Variation seen in Codrescu et al. 2012



Methodology

- Study and analyze ionosonde data
  - Quality scan the observed data
- **Figure out what effect lower atmospheric forcing has on electron densities**
  - **Study events where electron densities are variable**
  - **Plot and analyze the variation**



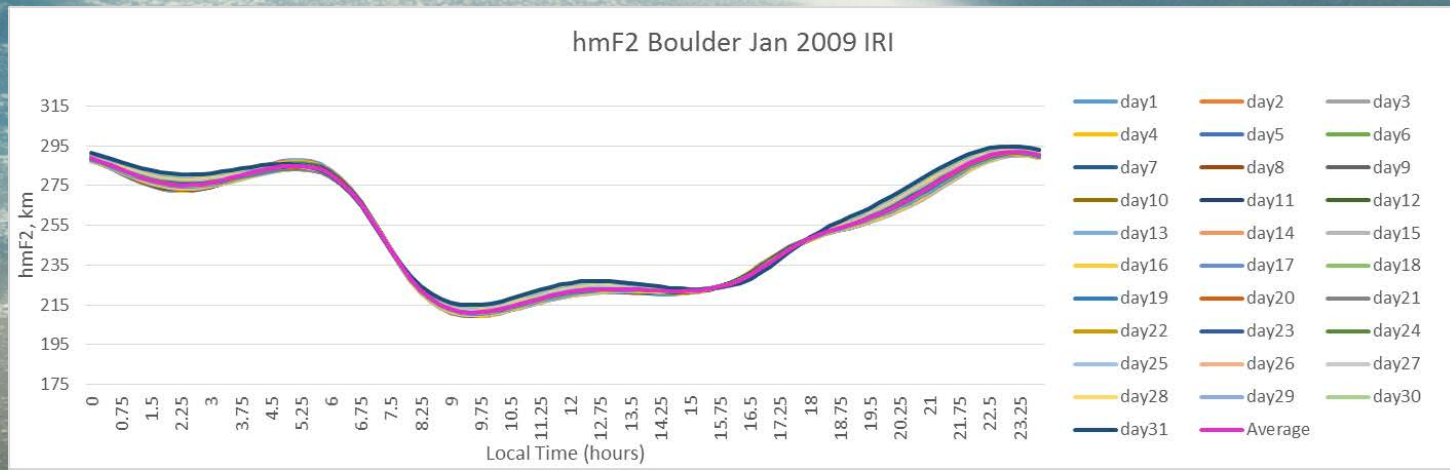
Mendillo et al. 2002

Methodology continued

- We need to focus on a specific time period
  - SSW events emphasize lower atmospheric forcing effects, chose January 2009
- Download and plot variability of observed data
- Compare the variability of observed data with models
  - Models will emphasize different parameters
- IPE focuses on lower atmospheric forcing
  - These particular IPE simulations

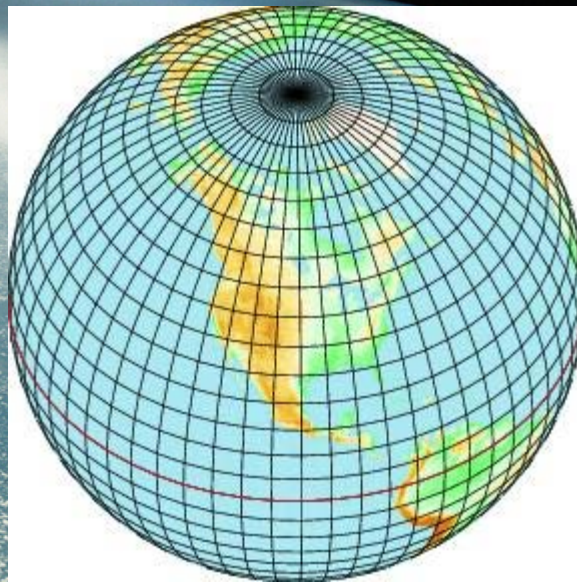
Models: International Reference Ionosphere (IRI)

- Empirical model
- Uses kp indices and solar flux as input parameters, primarily quiet time
  - These parameters offer little variation during Jan 2009
- Does not take into account lower atmospheric forcing



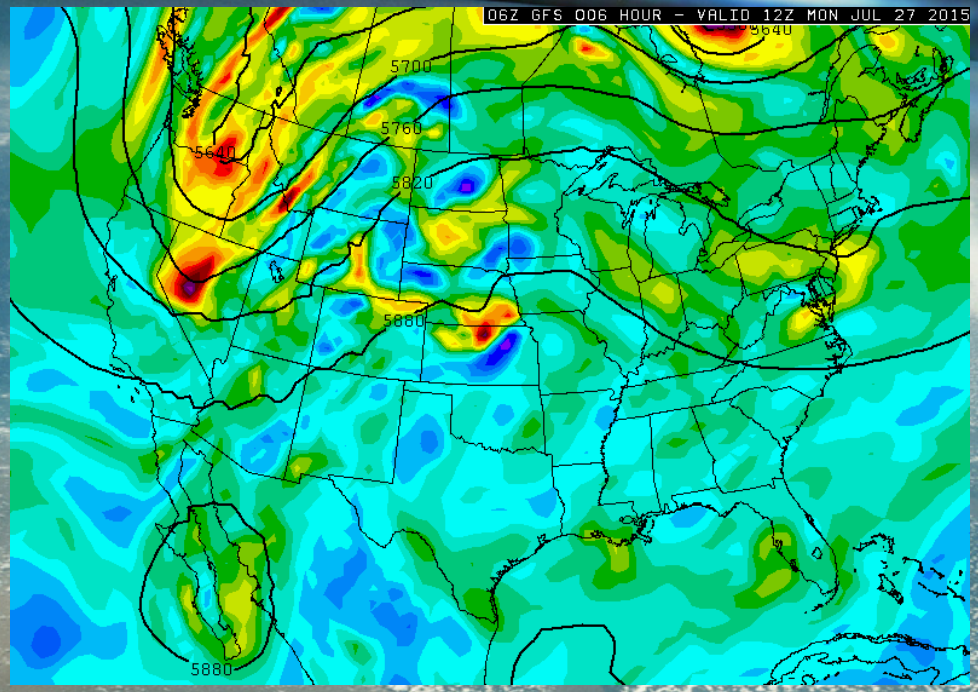
Models: Ionosphere-Plasmasphere Electrodynamics (IPE) Model

- Developed in collaboration with NOAA SWPC and GSD, CU Boulder, GMU
- Time dependent, 3D, physics based model
- Provides 3D plasma densities
  - 9 different ion species
- Uses a global grid
- Driven with WAM model
  - Includes lower atmospheric forcing
  - Neutral wind



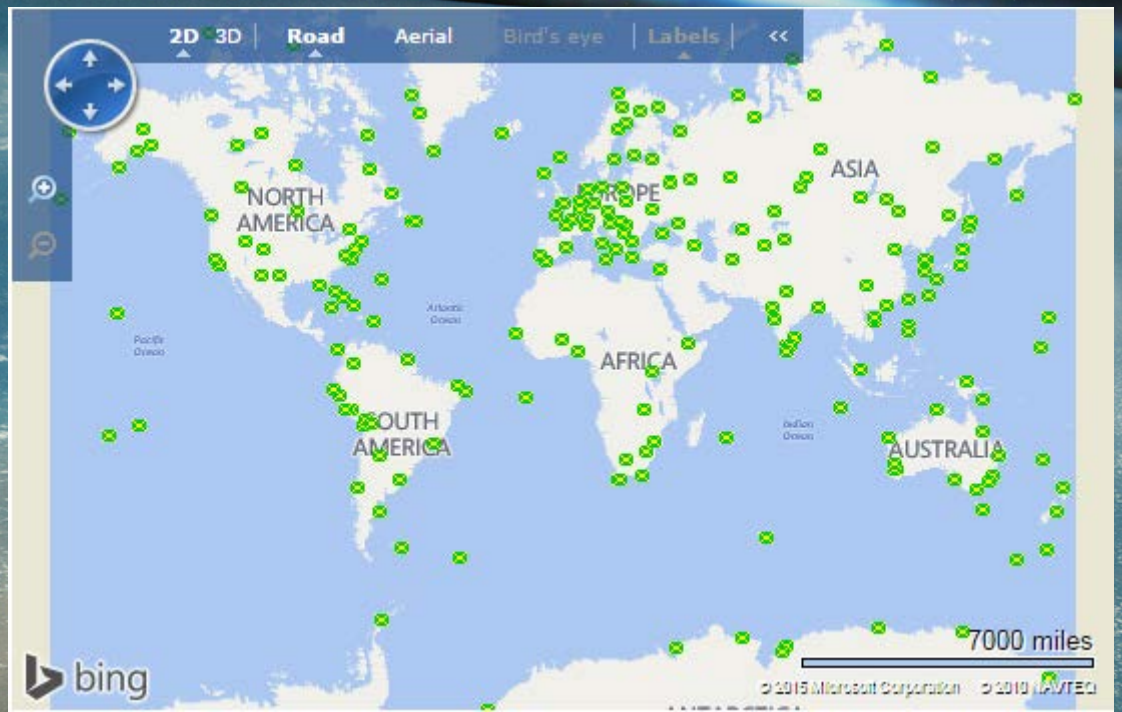
Models: Whole Atmosphere Model (WAM)

- Based on Global Forecast System (GFS)
  - Popular forecast used for terrestrial weather
- GFS only goes roughly 60km up
- WAM extends GFS to nearly 600km



Observation Data

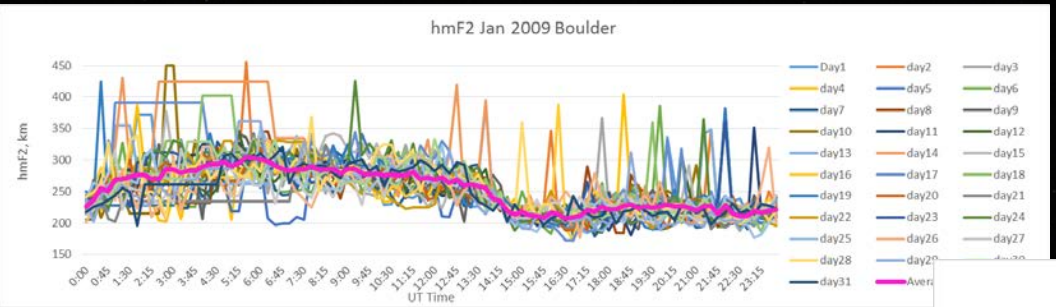
- Space Physics Interactive Data Resource (SPIDR)
- Archived Ionosonde data across globe
- Ionograms from NGDC, now called NCEI
- Measures in FoF2, simple conversion to NmF2

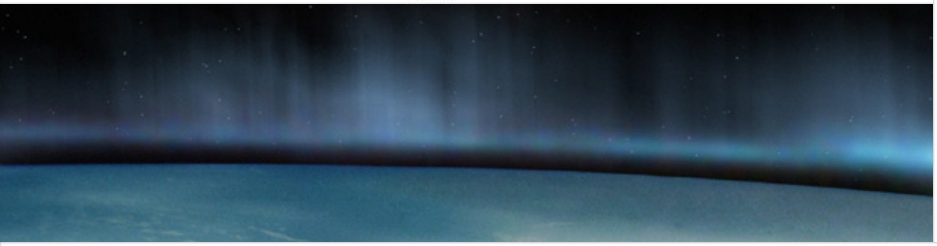


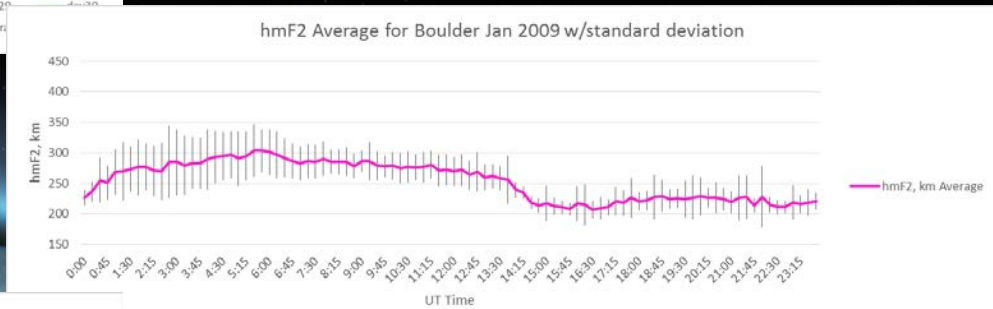
Quality scan

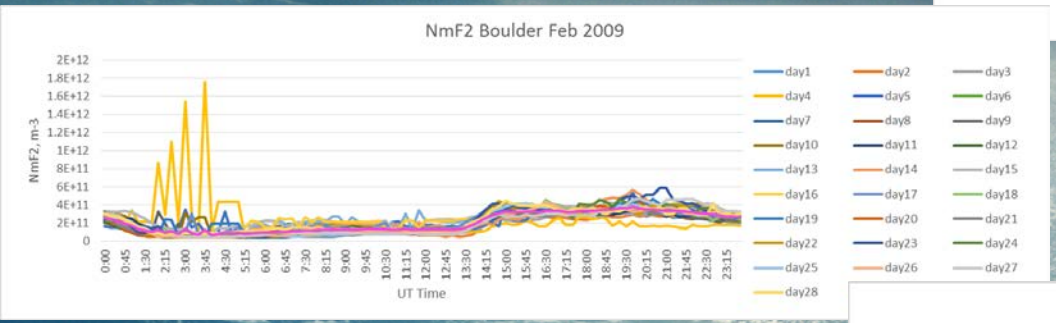
- Most datasets have a quality scan function
  - Used to take out anomalous points
- Our ionosonde observed data, did not have a quality scan set up
- To make sense of data, we had to quality scan the data manually
  - Challenging without using a program or code
  - Can be fairly subjective
- Very tedious, consider it "necessary evil"

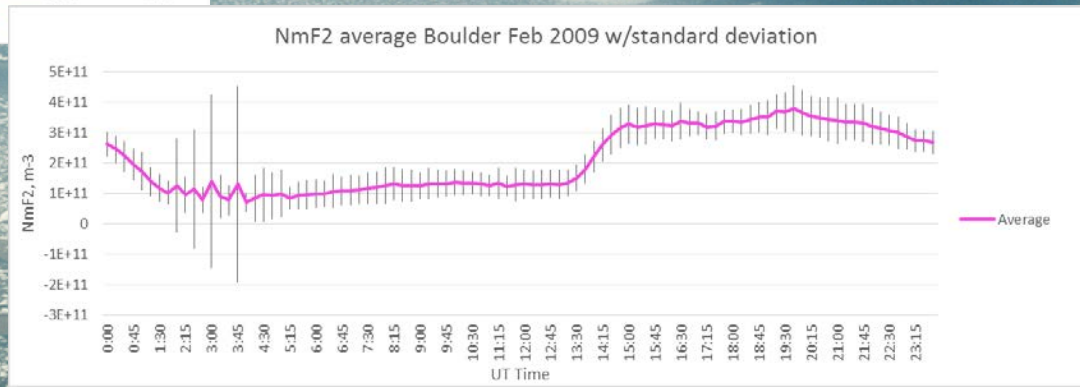
Anomalous points in plots





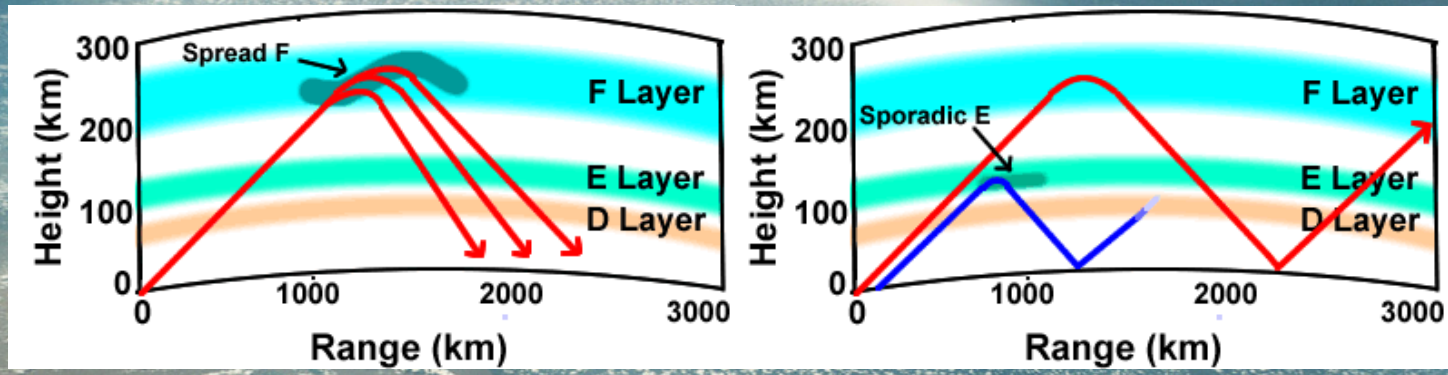






Explain possible errors in Ionogram

- Sporadic E[region]
  - Concentrated region of electrons, acts as a scattered cloud
  - Potentially blocks the ionosonde, refracts it
- Spread F
  - Causes frequency to deviate at different levels
- Need for ionogram to show F/E region
- Impossible increase/decrease of 100+km in hmF2 in 15 min



http://www.met.nps.edu/~psguest/EMEO_online/module3/module_3_3.htm

How to read Ionograms

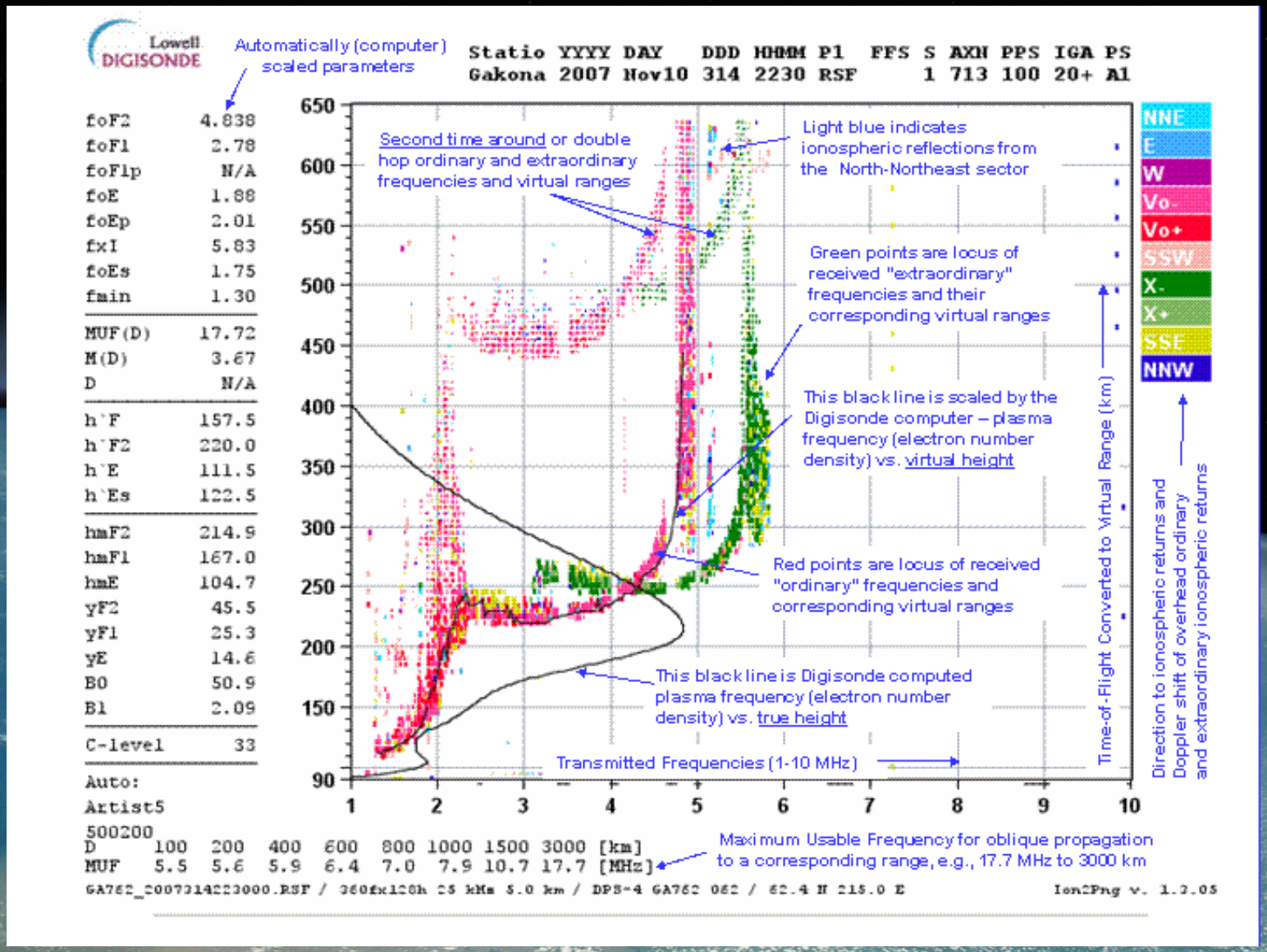
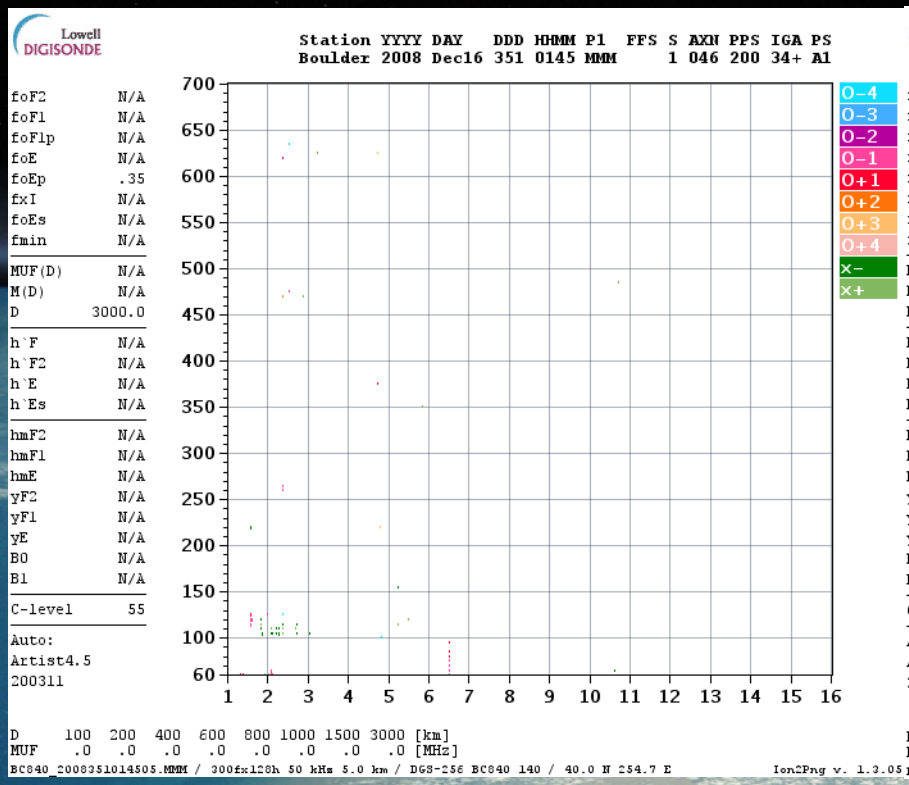
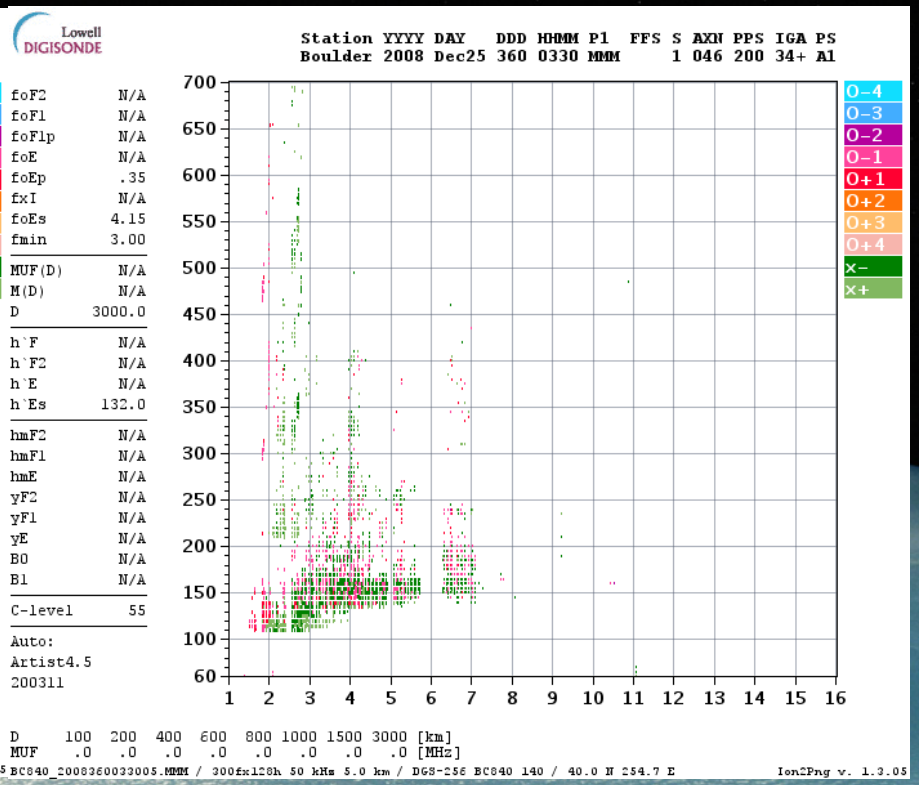
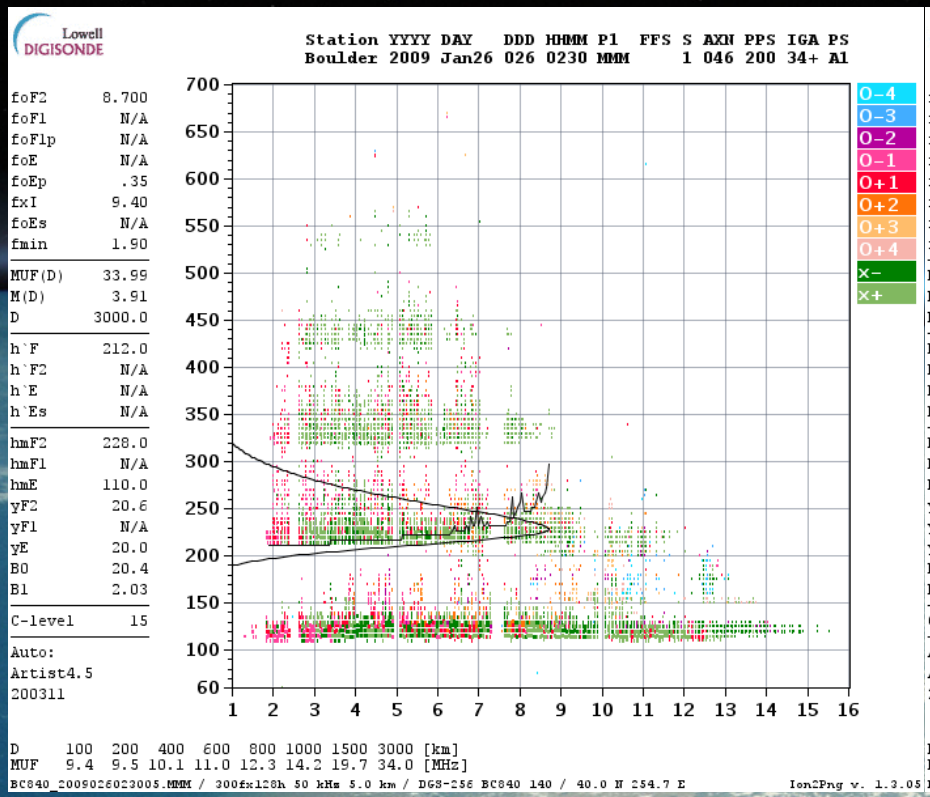


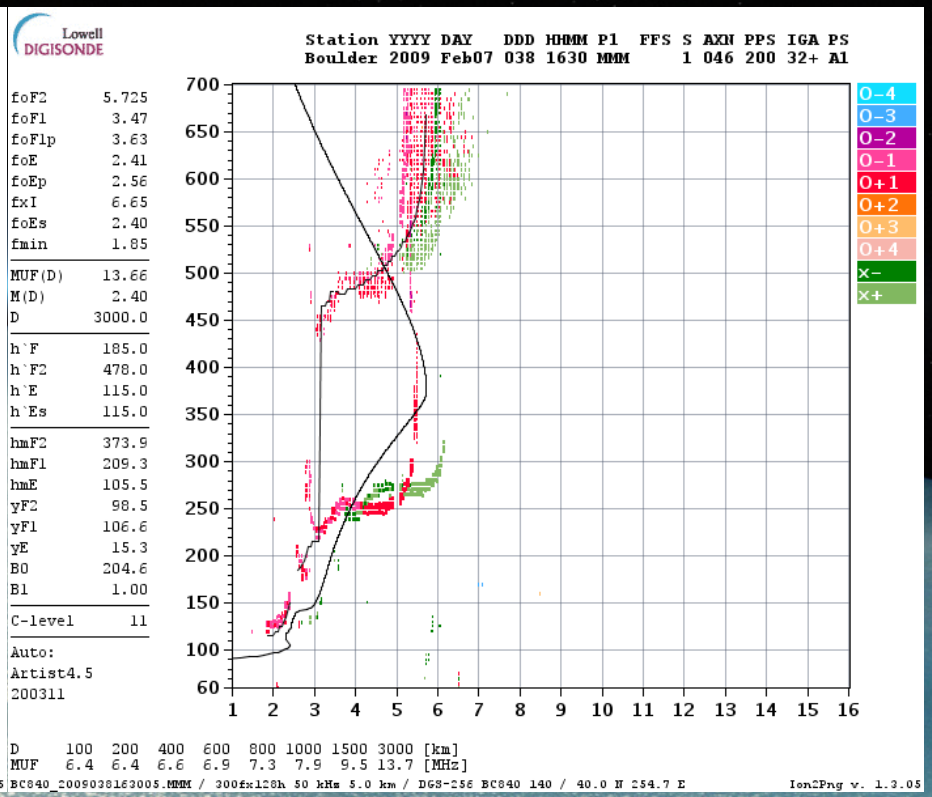
Image examples of anomalous



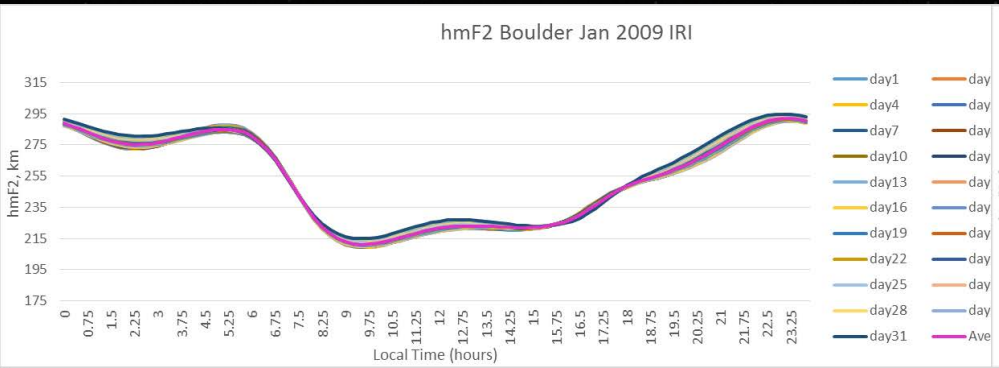


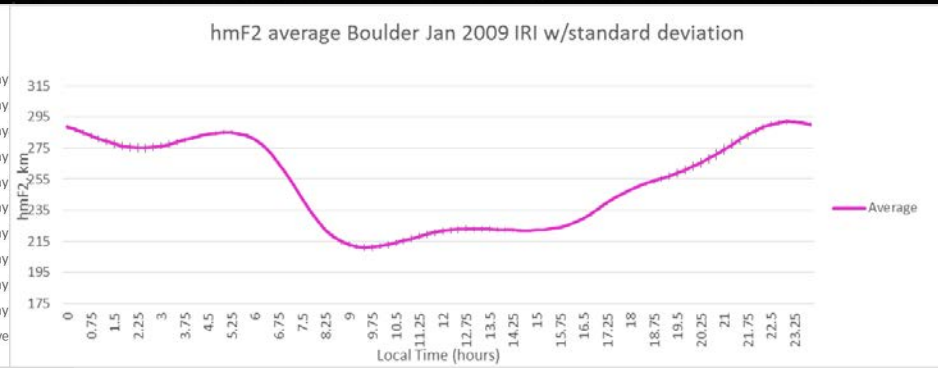
Anomalous Ionograms

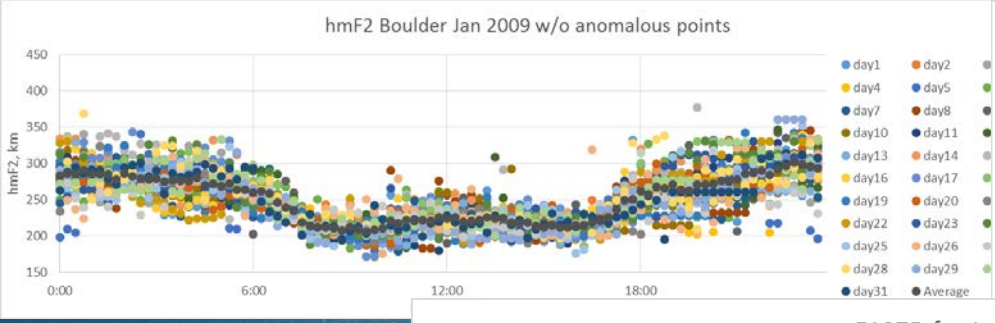


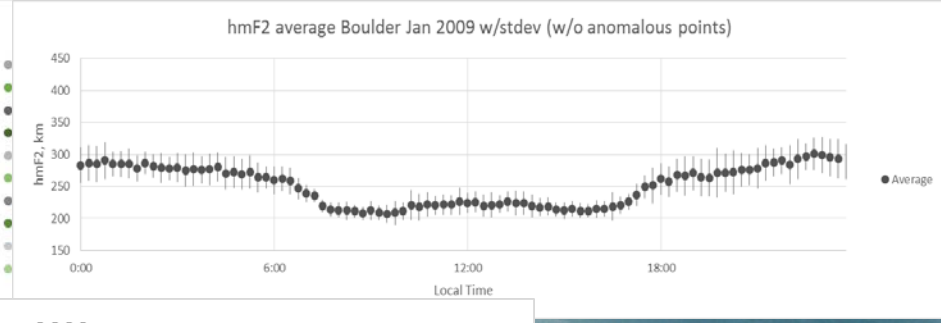


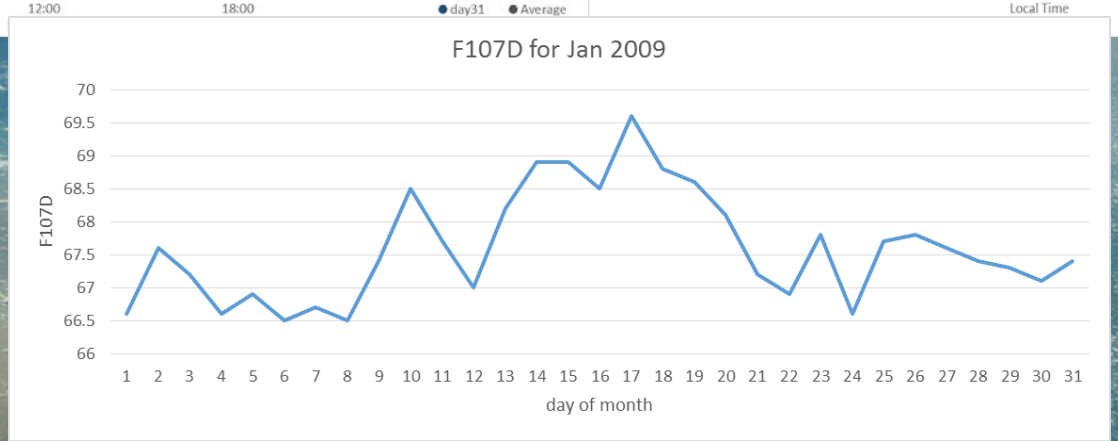
Results: IRI vs. Ionosonde Data



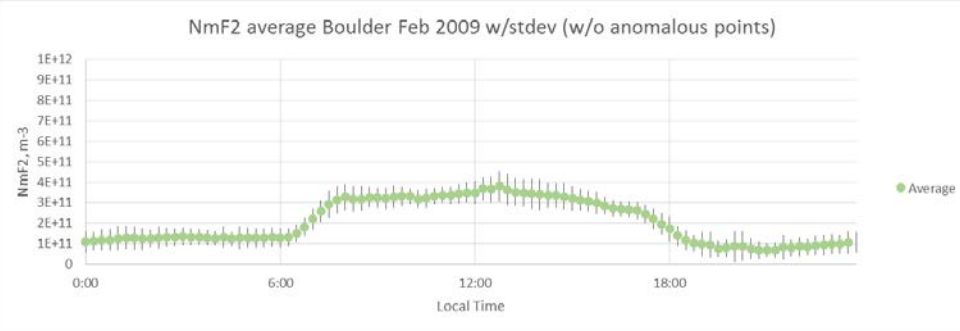


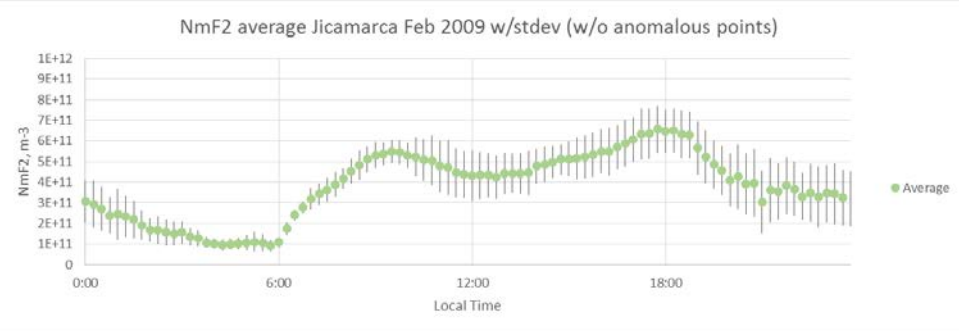


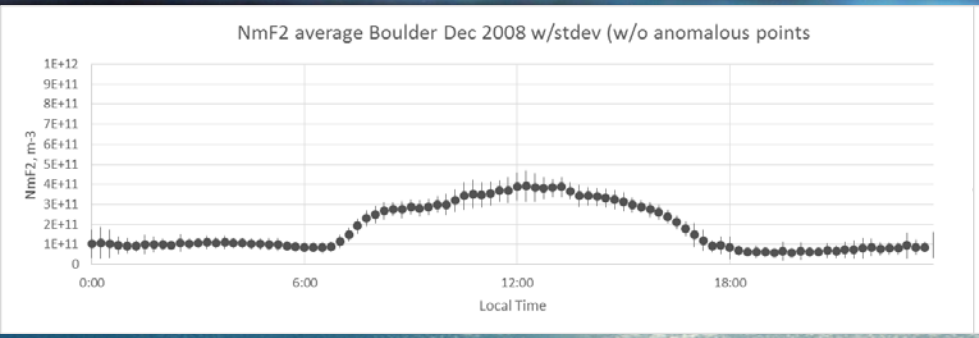


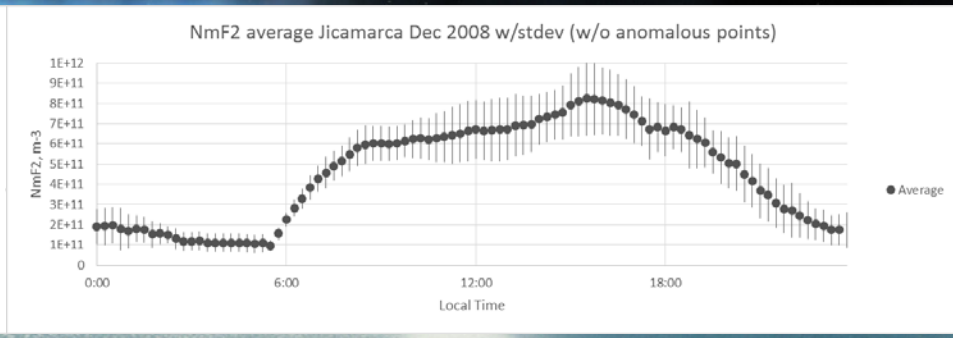


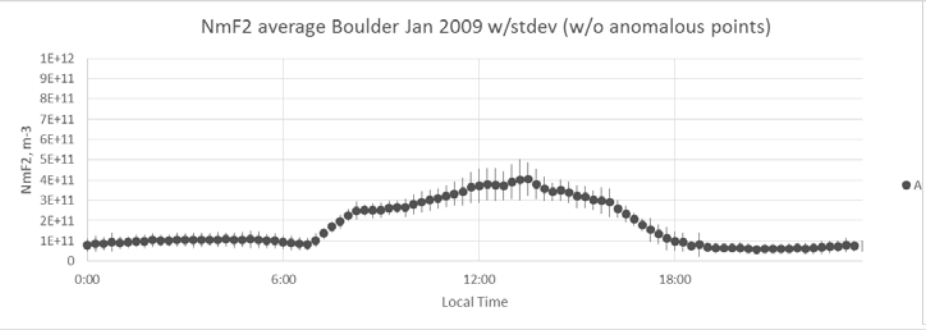
Results: Boulder vs. Jicamarca

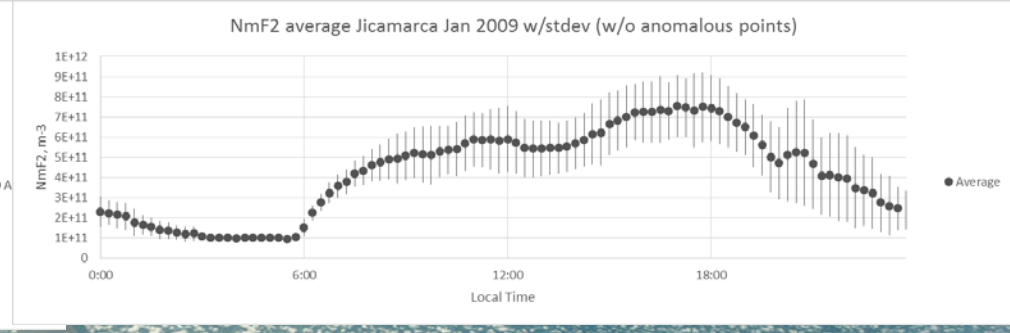




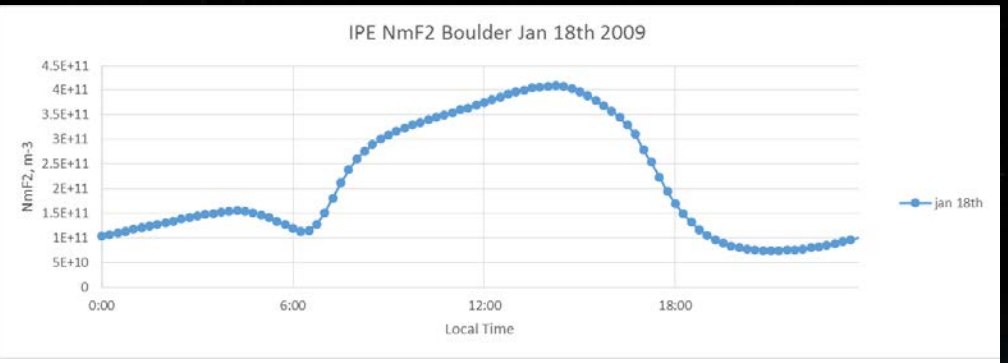


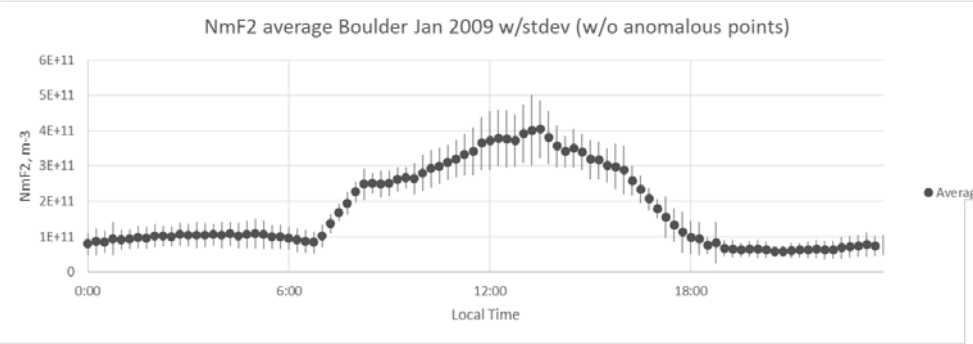


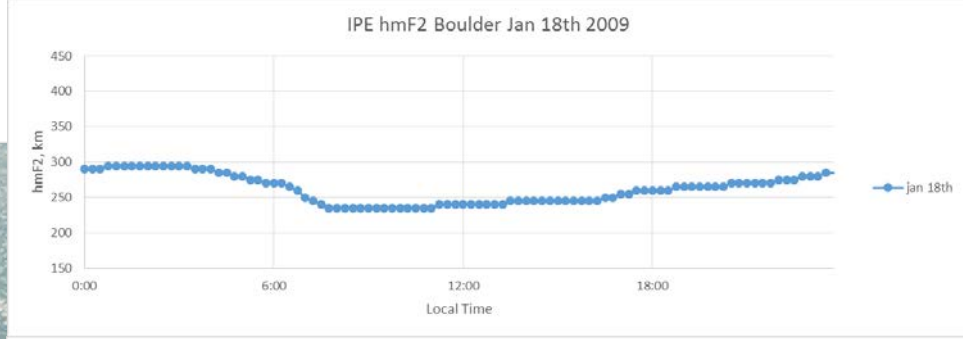


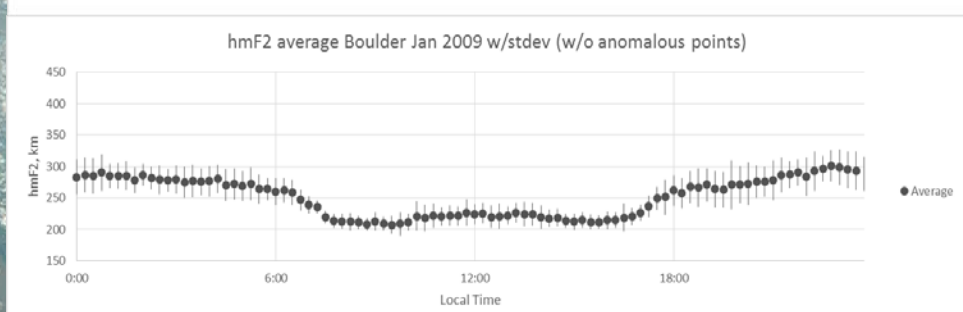


Results: IPE vs. observed data

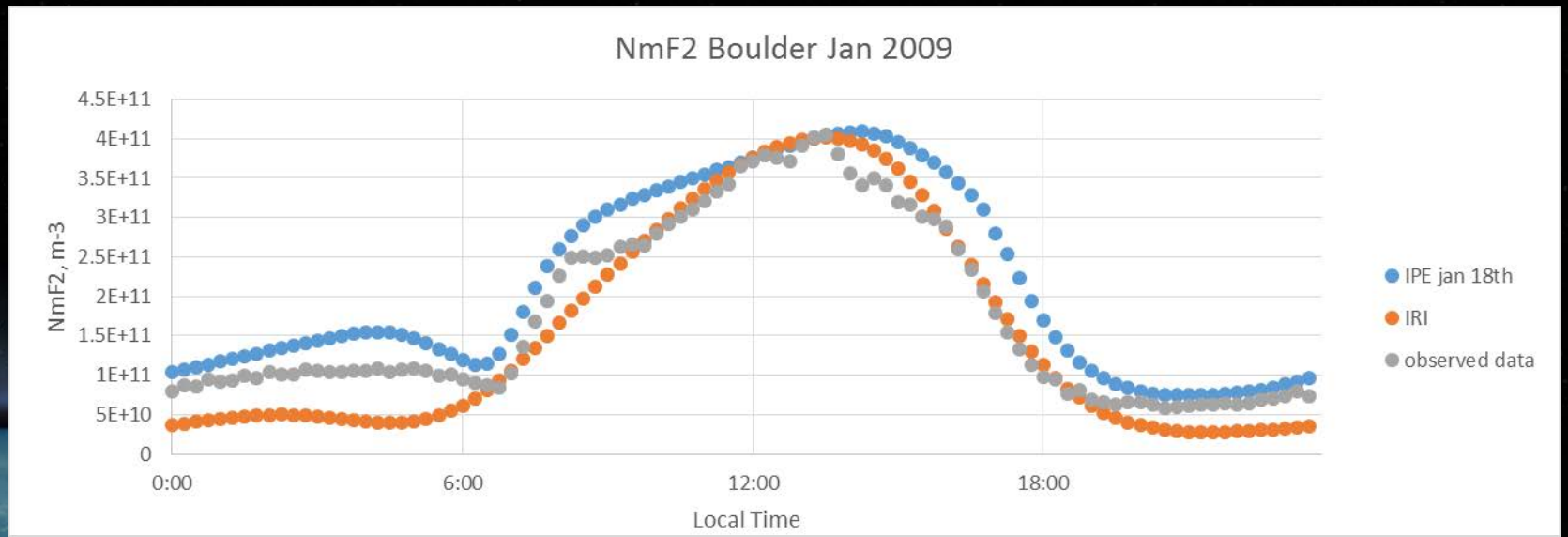


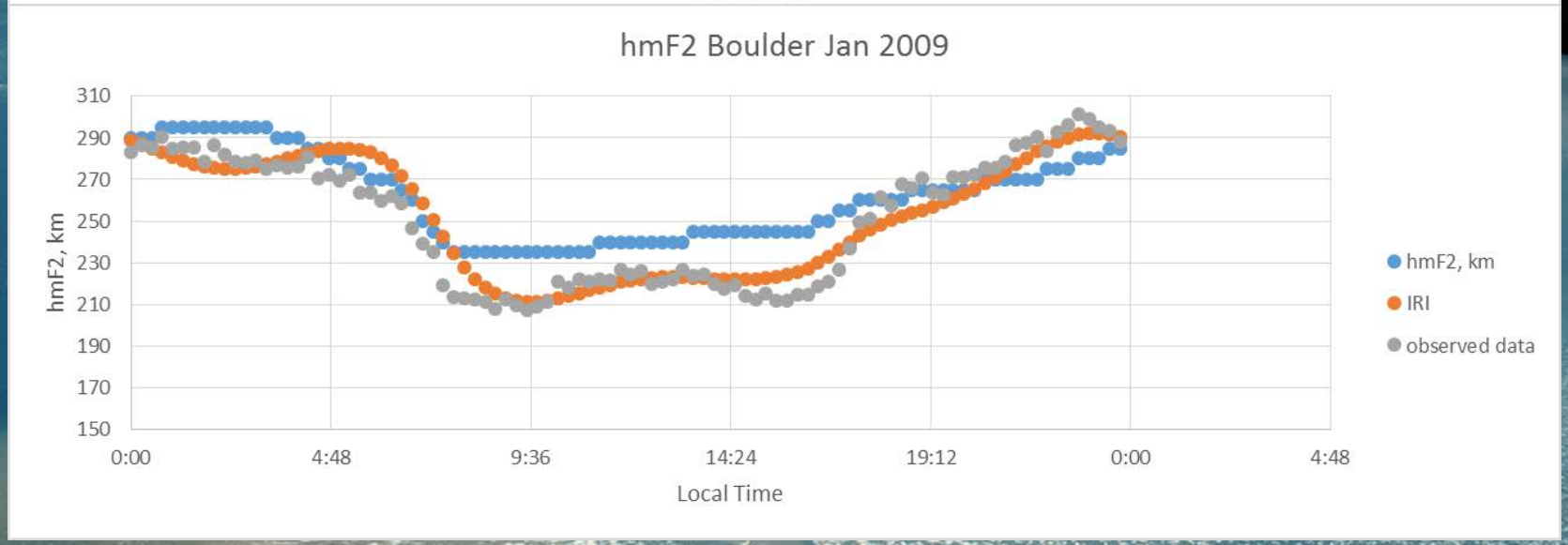






Results: Combined





Conclusions

- Before looking at any dataset, it must be quality checked
  - Avoid anomalous points
- Confirmed that lower latitudes have higher NmF2 values, Jicamarca>Boulder
  - Due to smaller zenith angle at Jicamarca
- IPE can recreate past ionospheric events with low variability, similar to IRI model

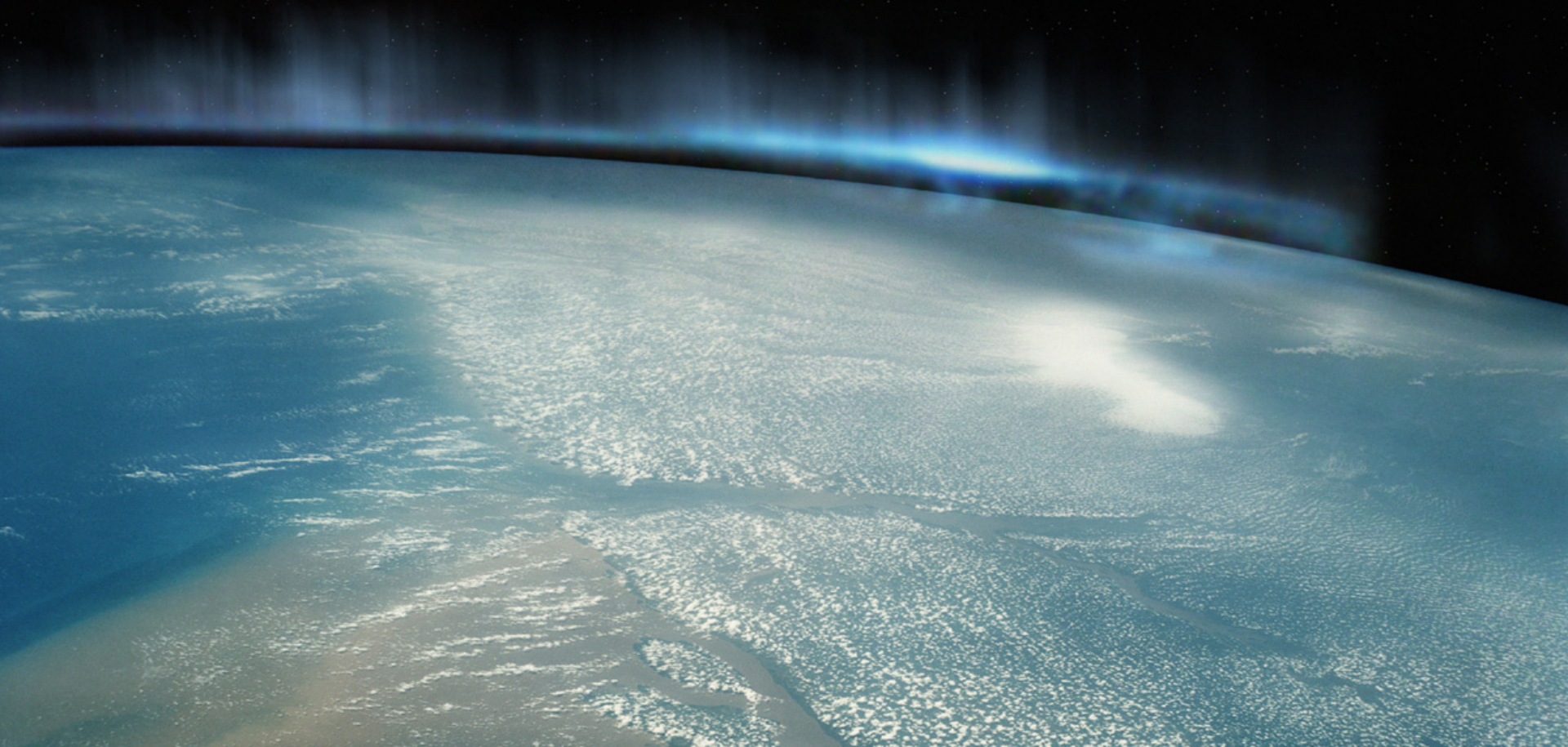
Future Work

- First, write a code to quality scan the ionosonde data
  - This will significantly improve efficiency and remove subjectivity
- Run IPE model for multiple days and locations
  - Calculate and compare variation
- Quantify variation due to lower atmospheric forcing
  - Attempt to assign weights to lower atmospheric forcing to improve model forecast capabilities

Special Thanks to:

- LASP Erin Wood and Marty Snow
- Justin Mabie, Catalin Negrea, and Mariangel Fedrizzi at NOAA for ionosonde data guidance
- National Geophysical Data Center (NGDC) for ionosonde data
- International Reference Ionosphere (IRI) for model data

Questions?



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