

# Observing the Earth's Topside Ionosphere with Multiple Atmospheric Instruments

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# Introduction

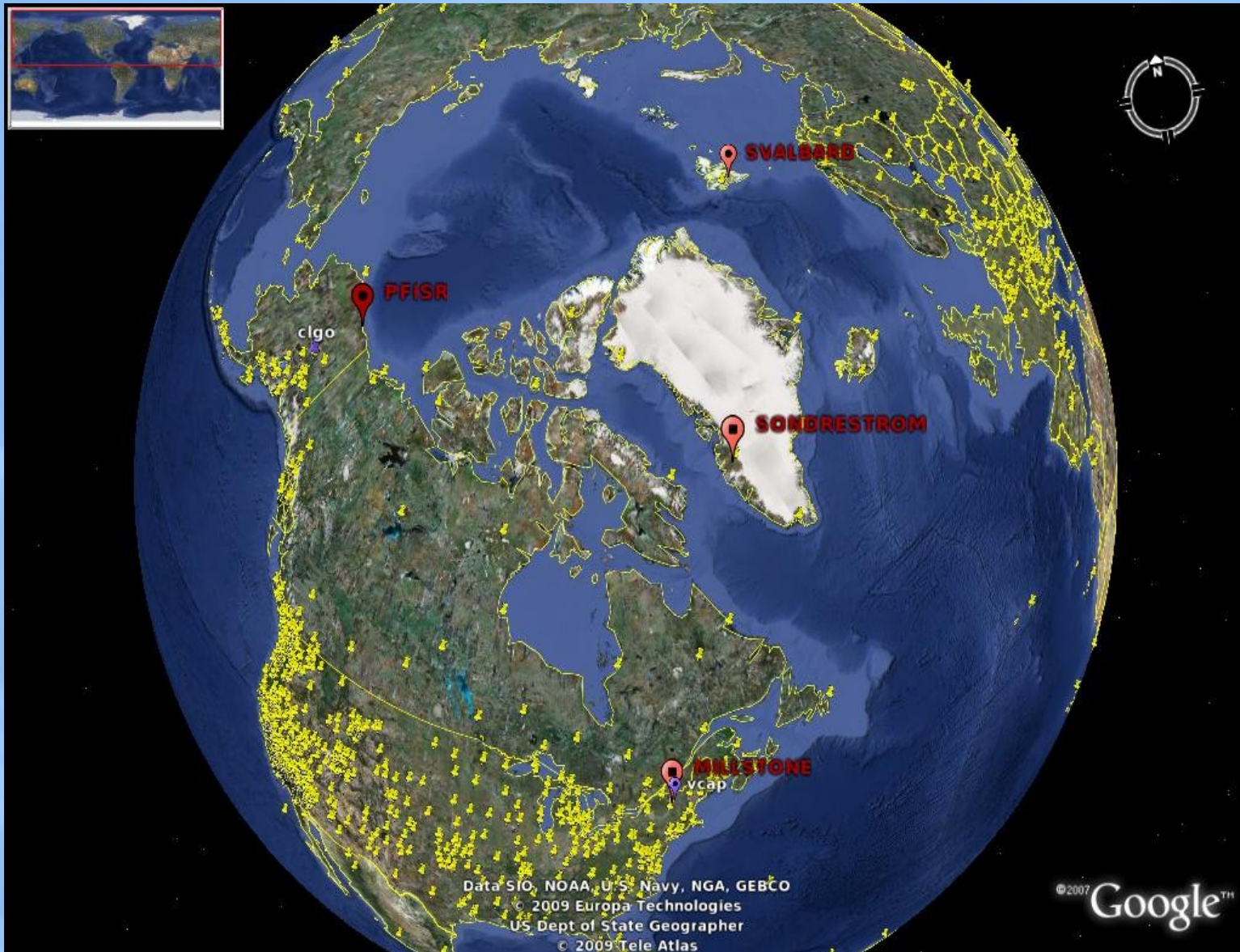
- Amount of electrons above 500 km
- Measurements taken with GPS and ISR
  - GPS: up to 20,000 km
  - ISR: up to 500 - 800 km
  - Compare to find TEC of upper ionosphere
    - TEC = total electron content
- Regions
  - Mid-latitude/Sub-auroral, Auroral, Polar/High-latitude
- Importance
  - Satellites reside in this area
  - Affects GPS calculations



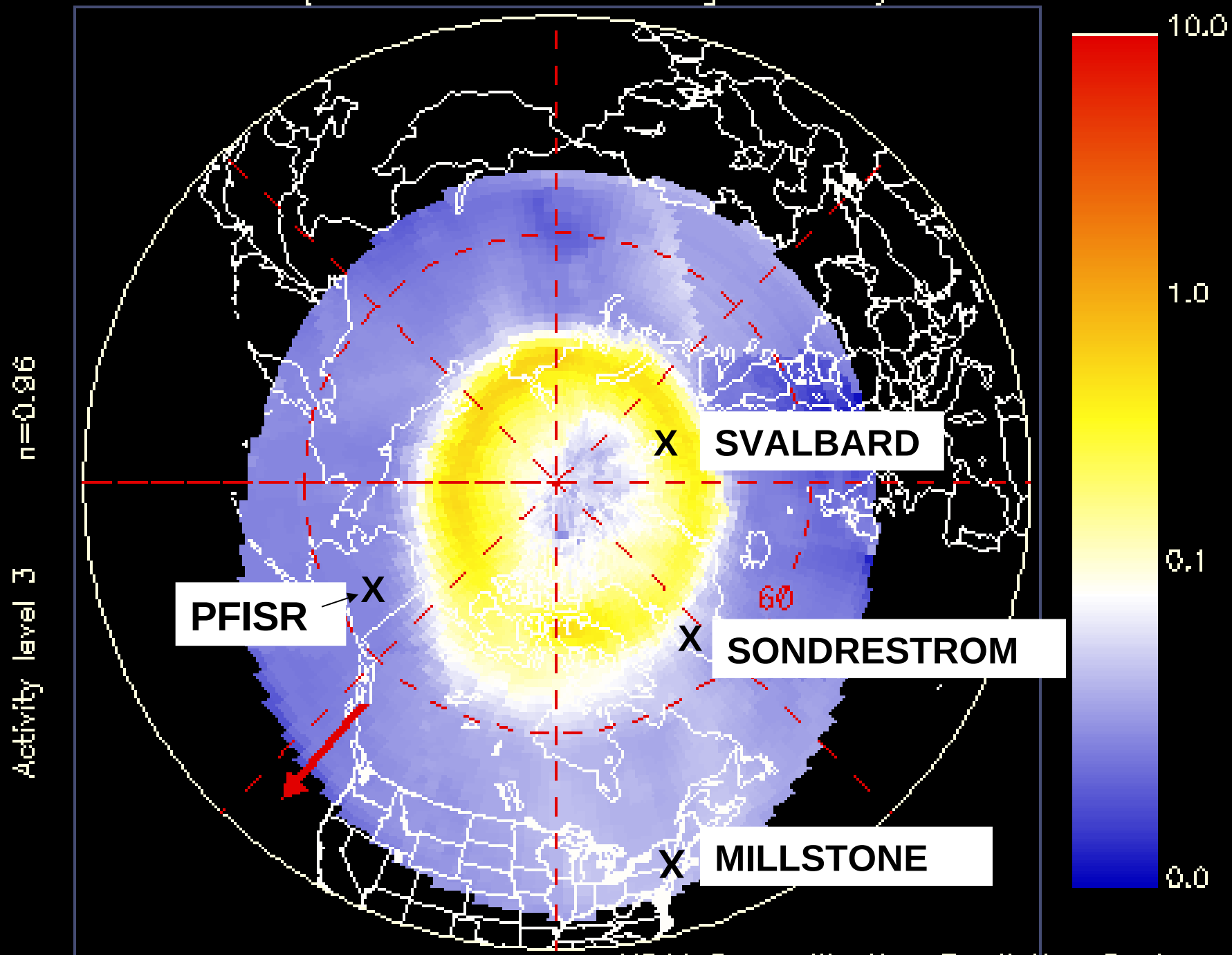
# Methods

- Total electron content measured with GPS and ISR
- Coordinated ISR observations
  - 1-6 March 2007
  - 9-13 July 2008
- Locations
  - Millstone Hill: Westford, MA
  - AMISR/PFISR (SRI): Poker Flat, AK
  - Sondrestrom (SRI): Kangerlussuaq, Greenland
  - Svalbard (EISCAT): Longyearbyen, Svalbard
- Fits made with Fourier Transforms
  - 25 terms/spectral frequencies
- Plots made in Matlab

# ISR Locations



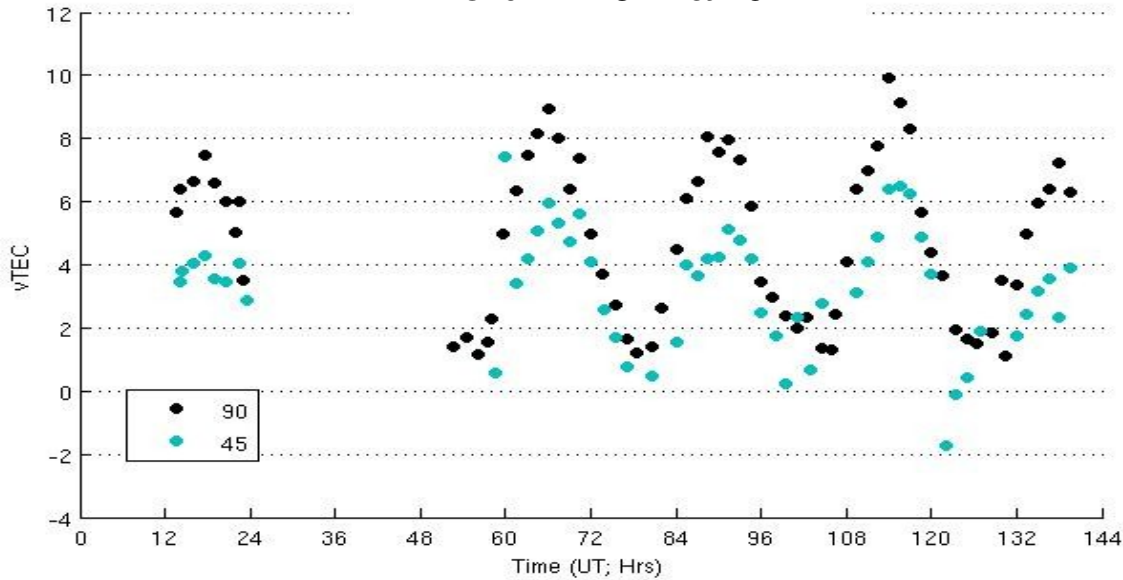
STATISTICAL AURORAL OVAL  
Extrapolated from NOAA-15  
Current time: 2009 August 05 20:43UT  
(Color bar is in units of  $\text{erg} \cdot \text{cm}^{-2} \cdot \text{s}^{-1}$ )



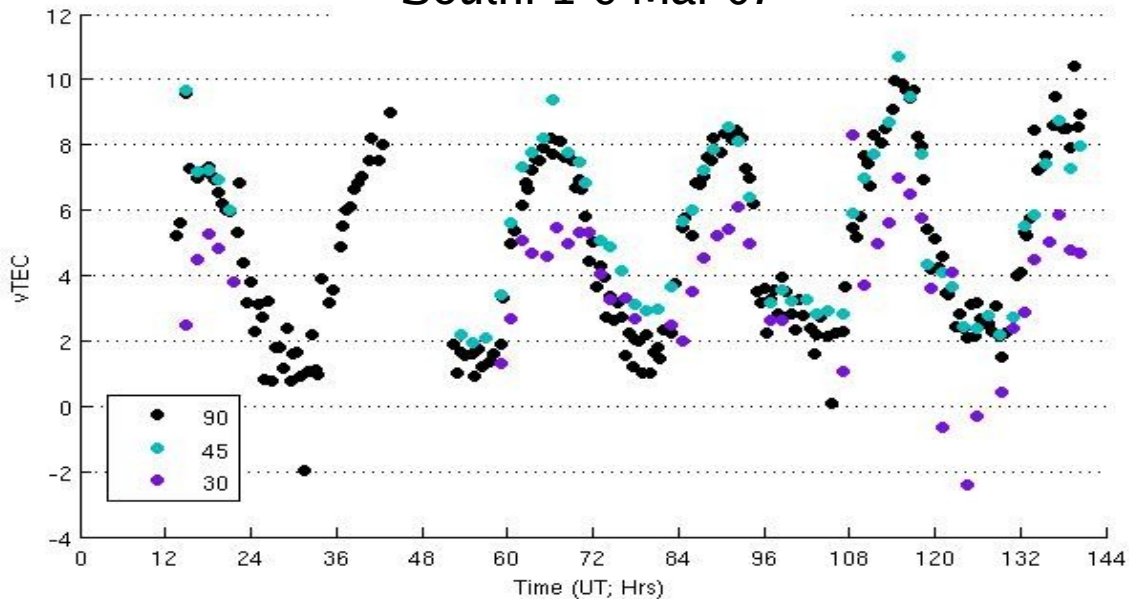
NOAA Space Weather Prediction Center

# ISR vTEC Elevation Comparison

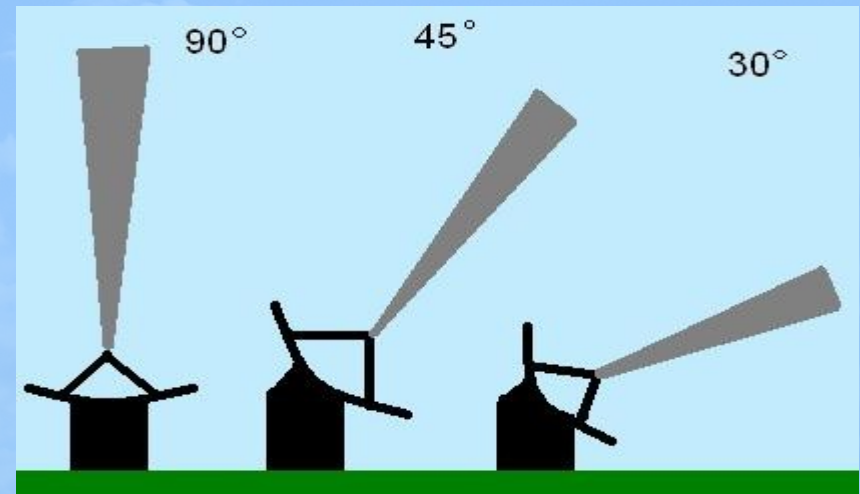
North: 1-6 Mar 07



South: 1-6 Mar 07

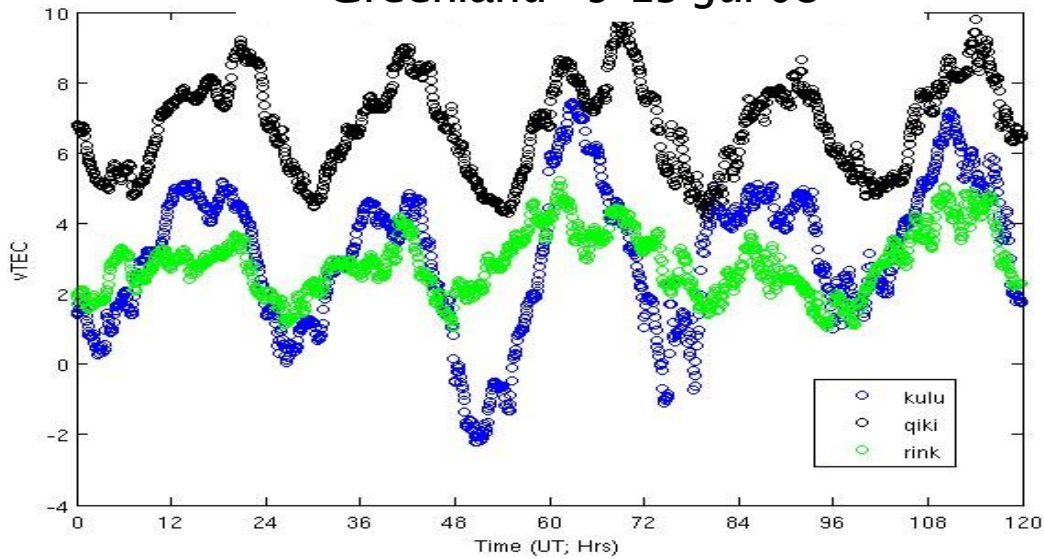


- Millstone Hill
- $vTEC = TEC \cdot \sin(\text{elevation})$ 
  - $\sin(90^\circ) = 1$
  - $\sin(45^\circ) = 0.707$
  - $\sin(30^\circ) = 0.5$
- $TEC \sim \text{line-of-sight } TEC$
- Ionospheric structure
- High elevations used hereafter



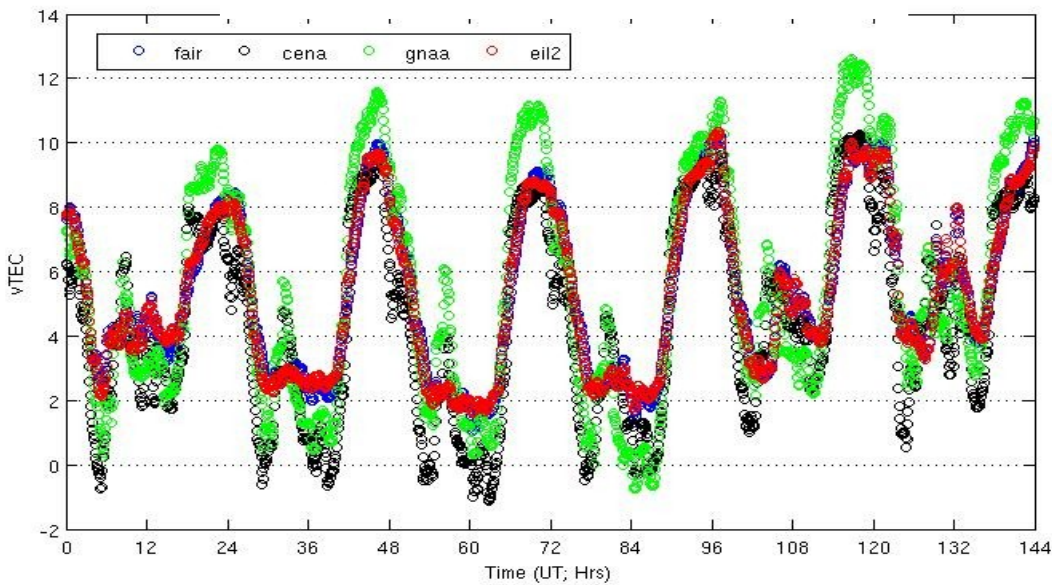
# GPS Data Problems

Greenland -9-13 Jul 08



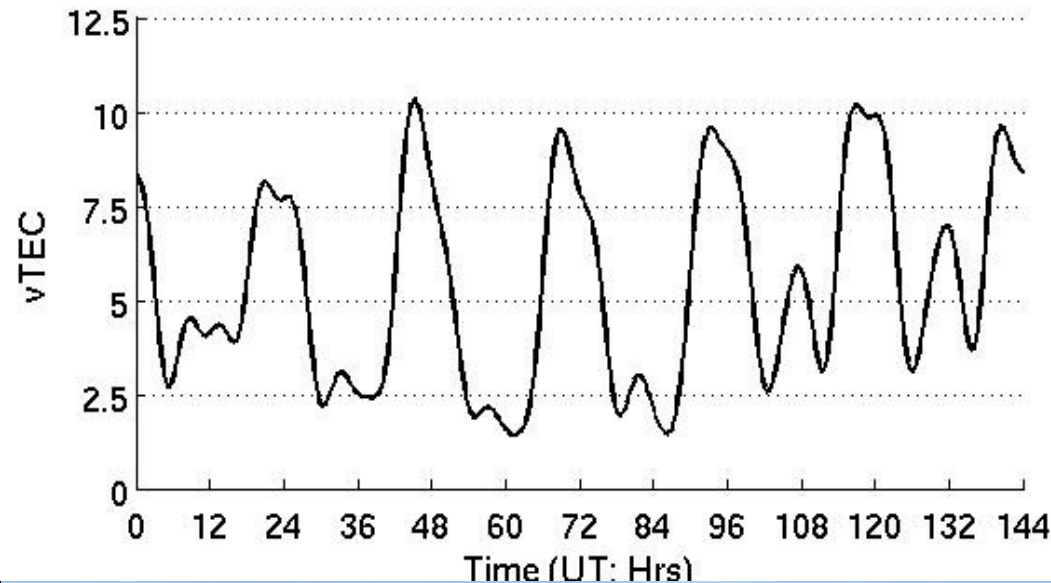
- Geophysics – ionospheric structure
- Receiver bias

Alaska -1-6 Mar 07

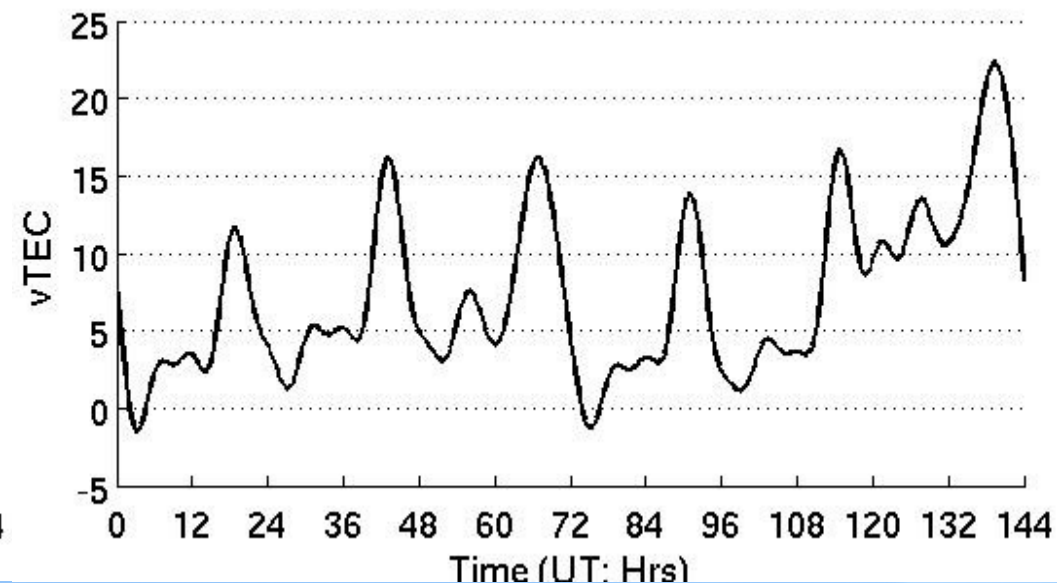


# GPS and kp Comparison: March 2007

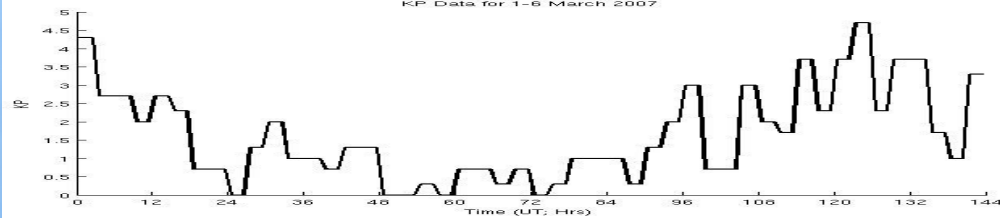
AMISR - GPS



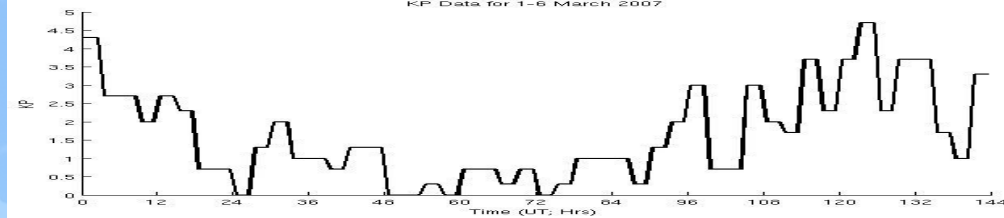
Millstone Hill - GPS



KP Data for 1-6 March 2007



KP Data for 1-6 March 2007

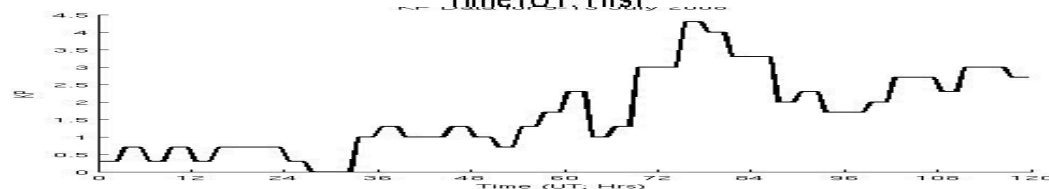
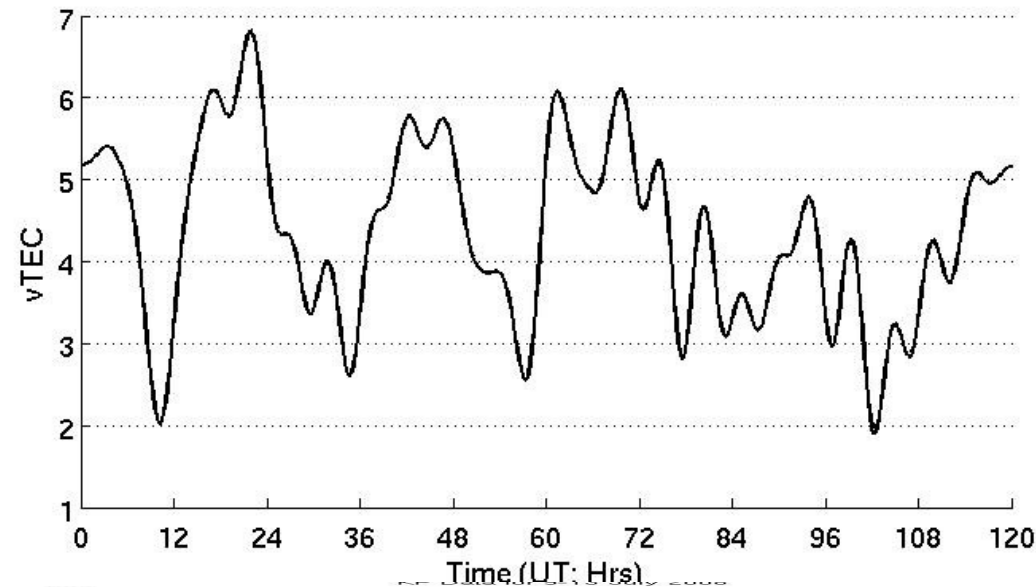


- Increased magnetic activity -> increased TEC

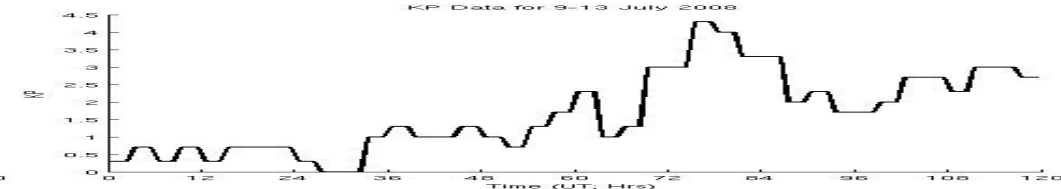
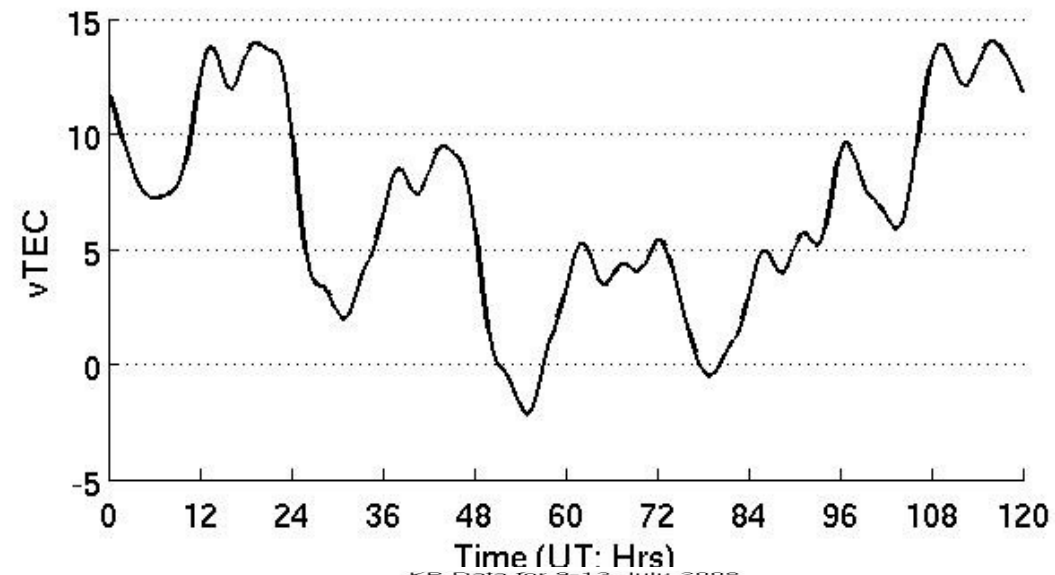


# GPS and kp Comparison: July 2008

AMISR GPS



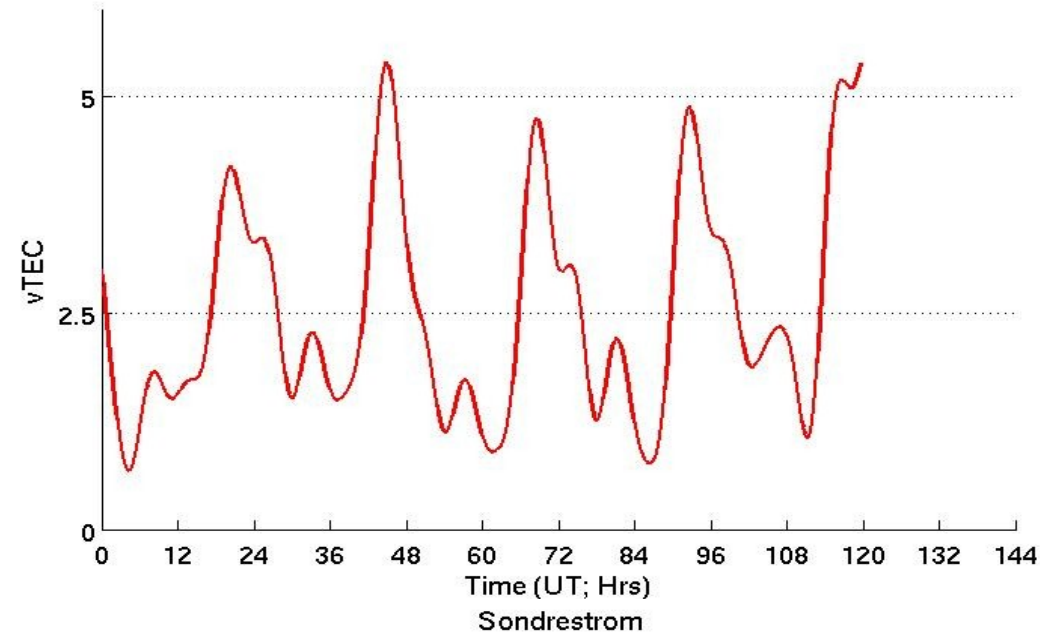
Millstone Hill - GPS



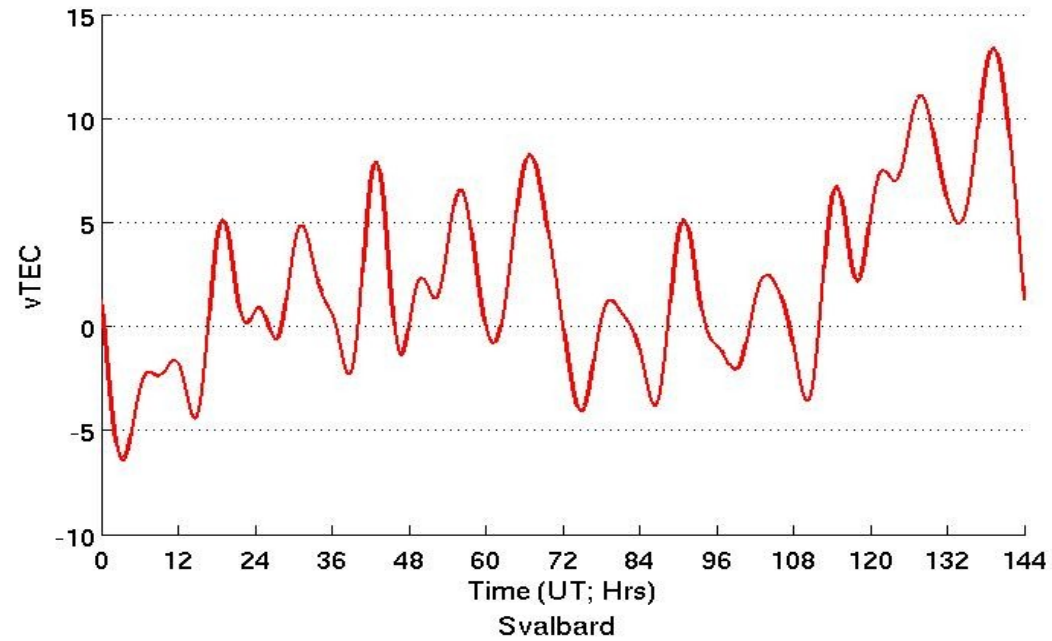
- Increased magnetic activity -> increased TEC
- Increased magnetic activity -> more TEC activity

# GPS and ISR Differences: March 2007

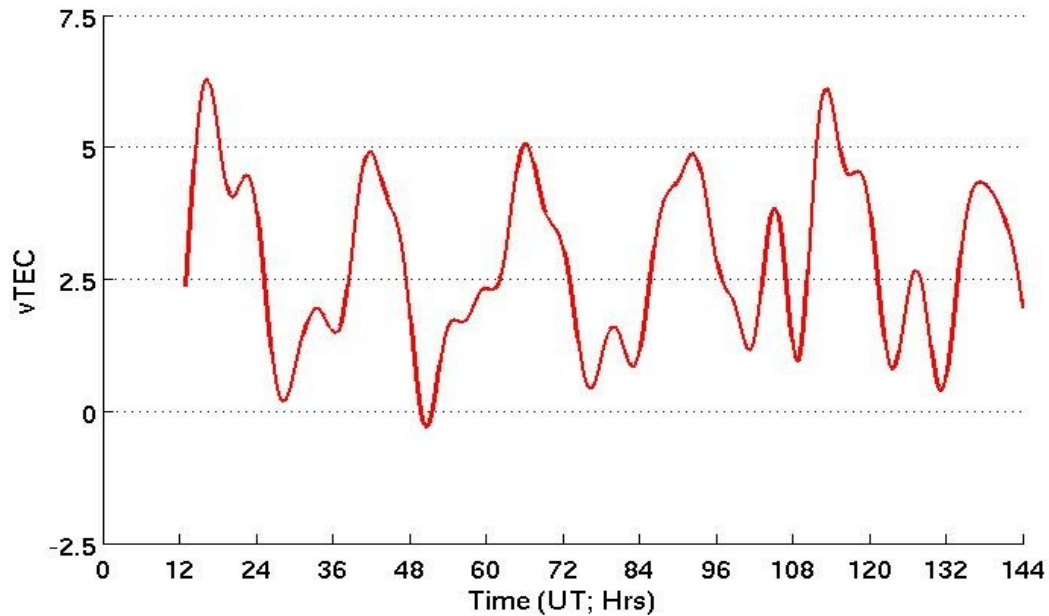
AMISR



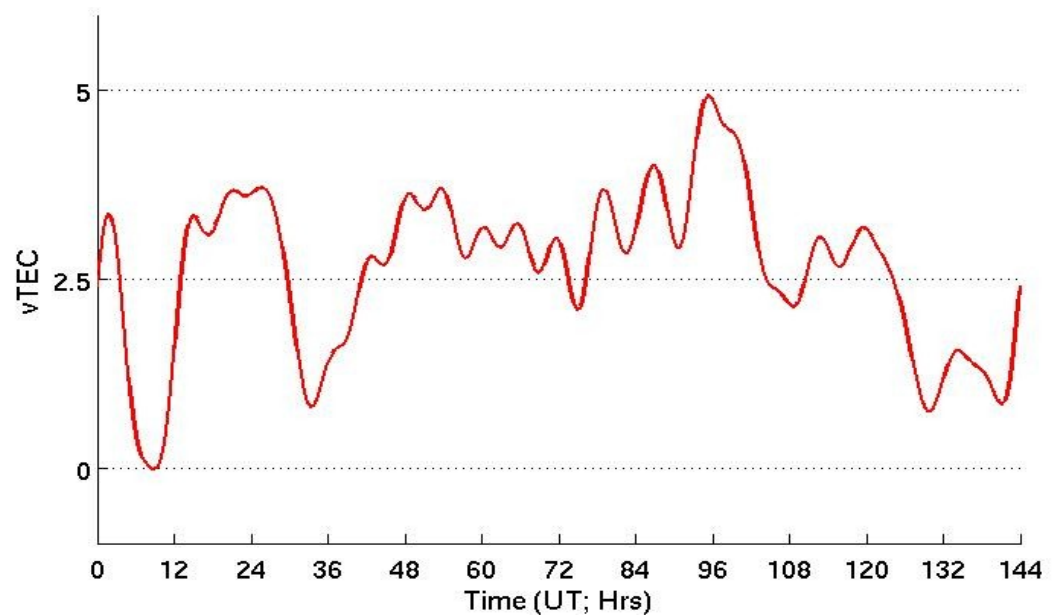
Millstone Hill



Sondrestrom

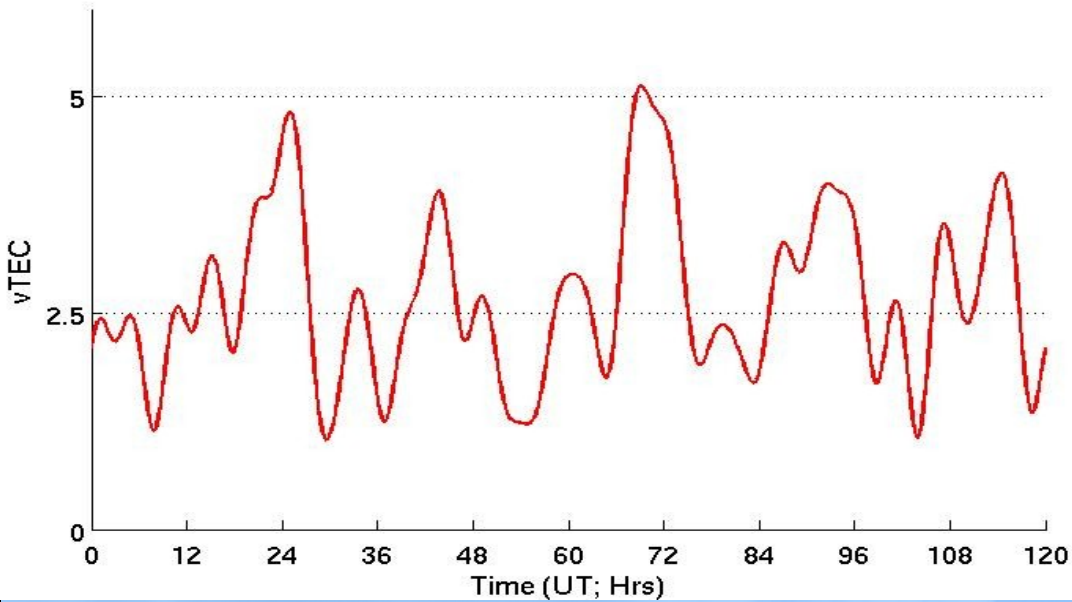


Svalbard

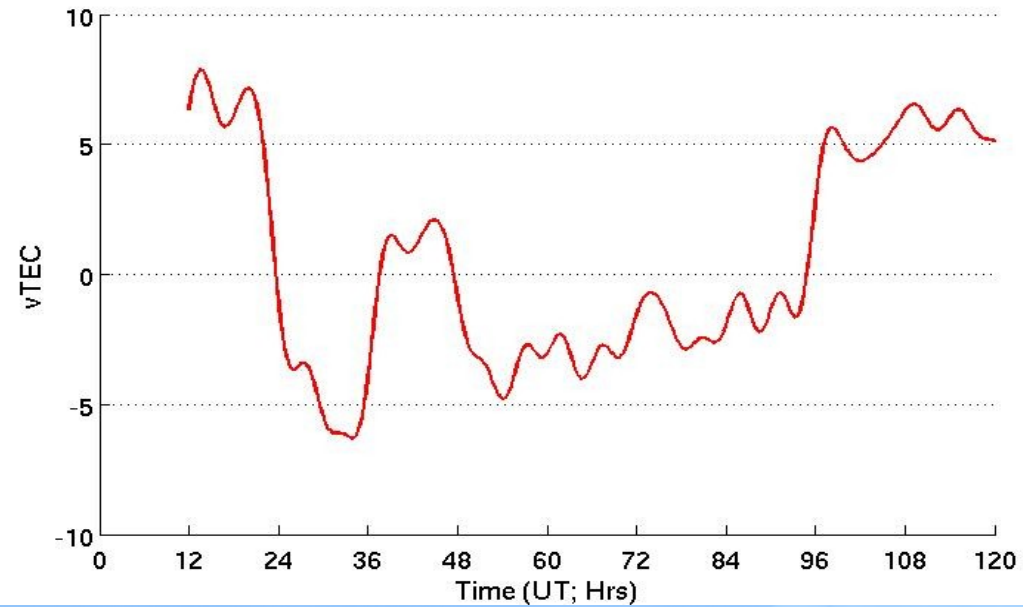


# GPS and ISR Comparison: July 2008

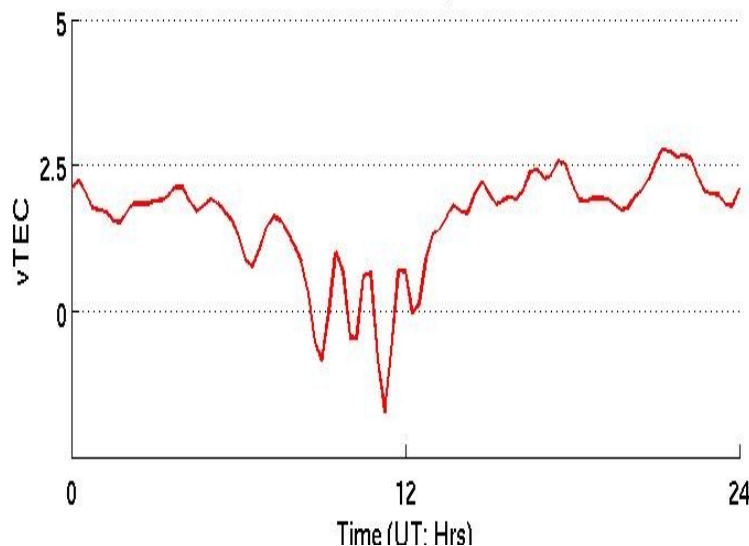
Sondrestrom



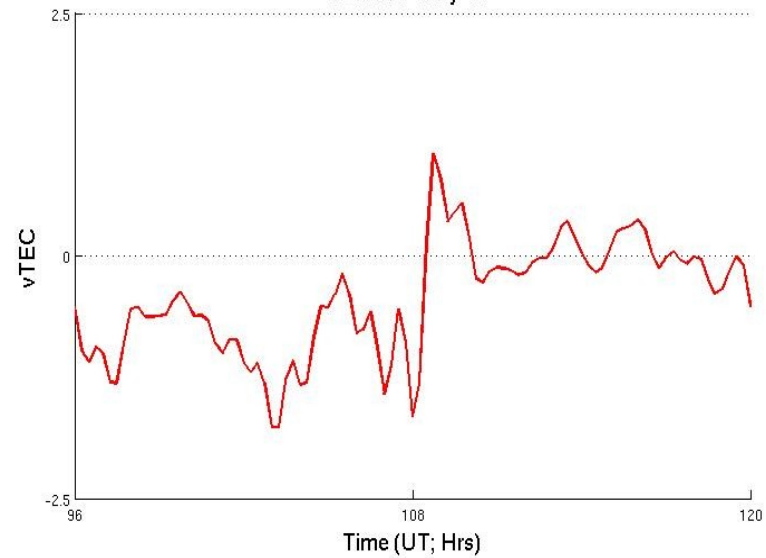
Millstone Hill



AMISR - July 9



AMISR - July 13



# Summary of TEC Difference Results

	1-5 March 2007	9-13 July 2008
AMISR	2.47	0.55/0.83**
Millstone Hill	0.81/1.74	0.63/2.08
Sondrestrom	2.56	2.65
Svalbard	3.52	N/A

- Average of TEC difference Fourier fit
- \* For num1/num2: num1 = uncorrected, num2 = all neg num -> 0
- \* All units in TECu
- \*\* Only for July 9 & 13

# Conclusions

- Ionospheric structure
  - ISR elevation differences facing North
  - GPS data anomalies
- Difficulties with GPS receiver biases
- Increased TEC and activity with increased magnetic activity
  - March 2007: increased TEC &  $k_p$  at approx. same time
  - July 2008: increased TEC and/or increased activity followed increased  $k_p$
- Average TEC difference is approx. equal across all latitude
  - Fourier fit values are generally between 0-5 TEC units
  - Mean TEC values
    - March 2007: ~2.3/2.6 TECu
    - July 2008: ~1.3/1.9 TECu

# Acknowledgements

- Thanks to my mentors for the guidance this summer
  - Anthea Coster & Shunrong Zhang
- Thanks to the following for providing the ISR data
  - Millstone Hill
  - SRI: AMISR/PFISR & Sondrestrom
  - EISCAT: Svalbard
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- Thanks to the REU program directors and everyone at Haystack who helped with the program this summer
  - Vincent Fish, K.T. Paul, & Phil Erickson