# *Dusk Observations at Millstone Hill*

Draven Galeschuk, Kiwook Lee, Subir Mandal, Liane Tarnecki

**ISR Summer School**
**27 July 2018**

# Outline

- Experiment
  - Observations
  - Conditions
- Results
- Conclusions

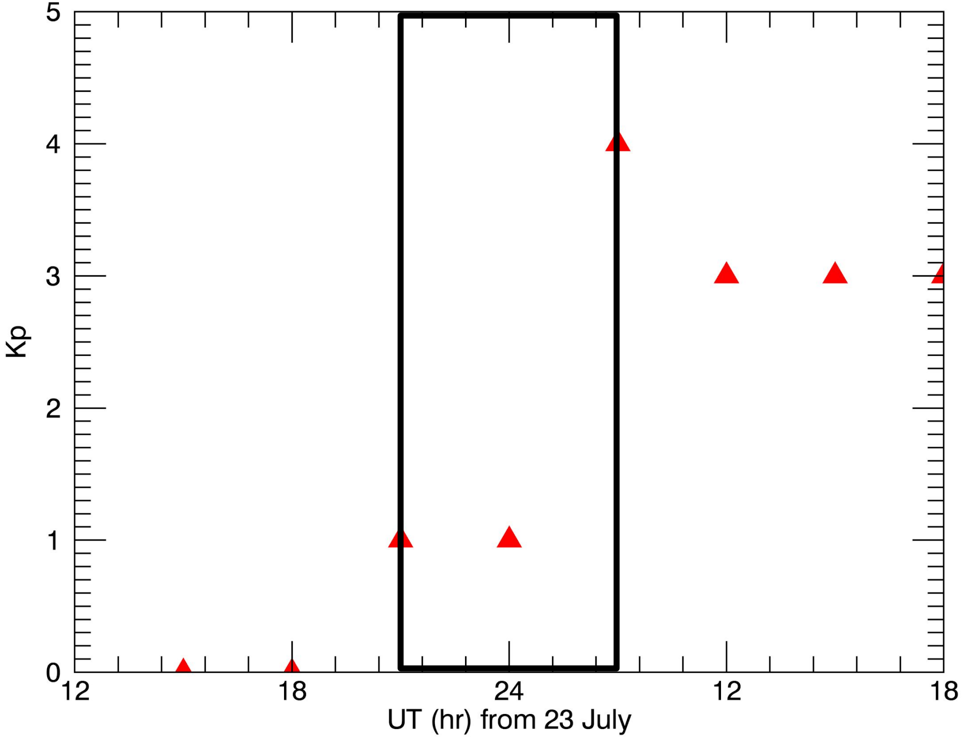
# Experiment

Mode: Wide Field Scanning

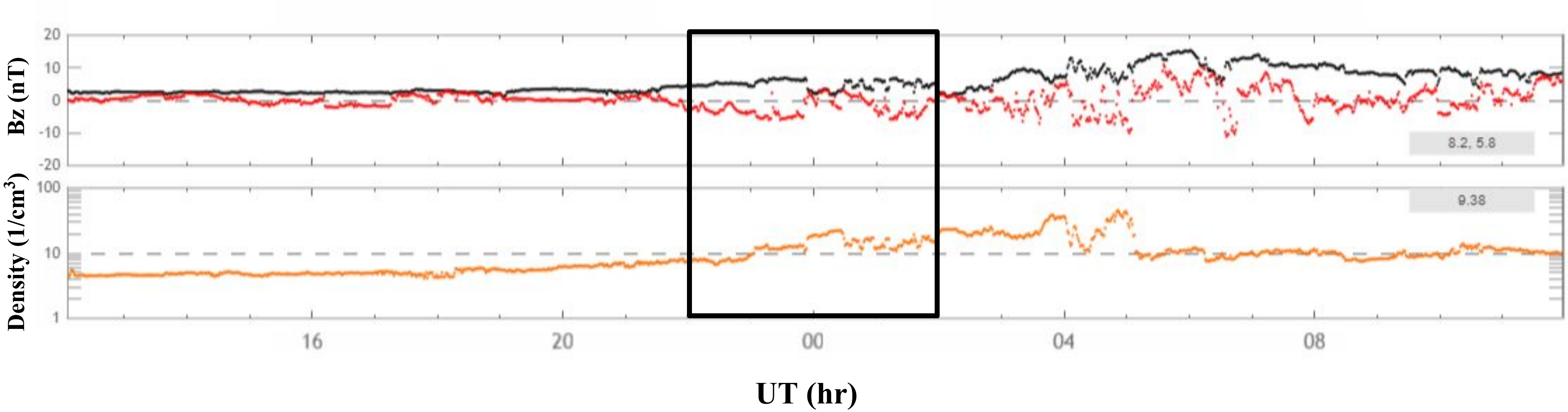
- Four 16 minute scans
- Fixed observations at zenith and either side of the meridian

Time: 19-21 LT (23-01 UT)

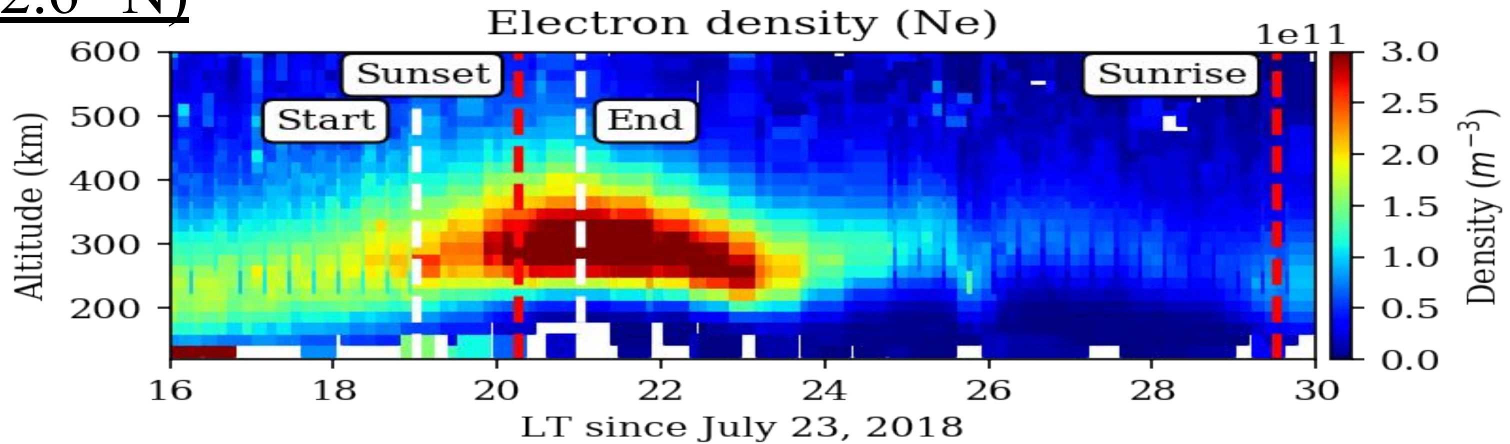
# Space Weather Conditions

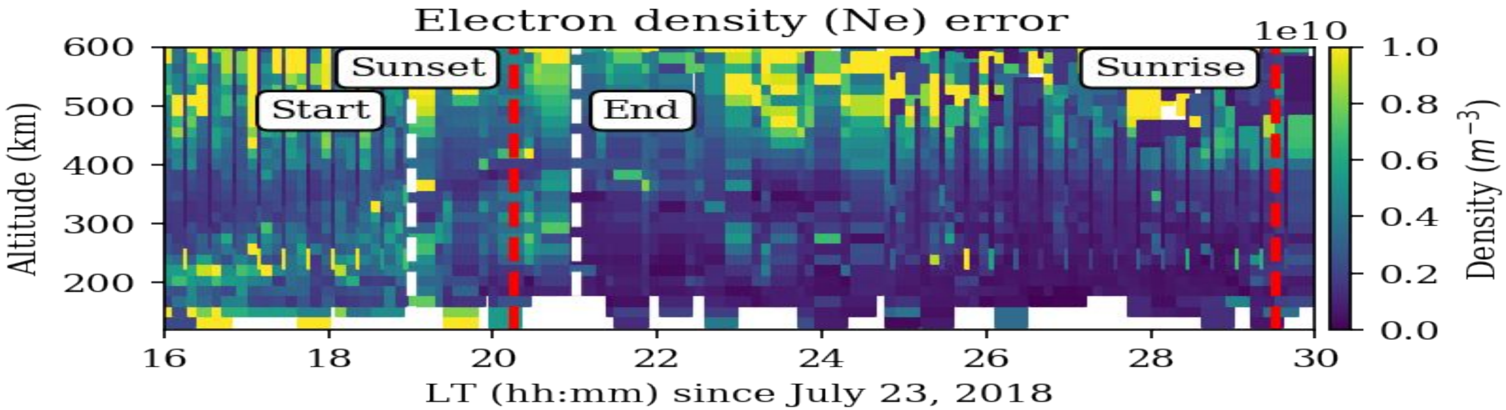


# Space Weather Conditions

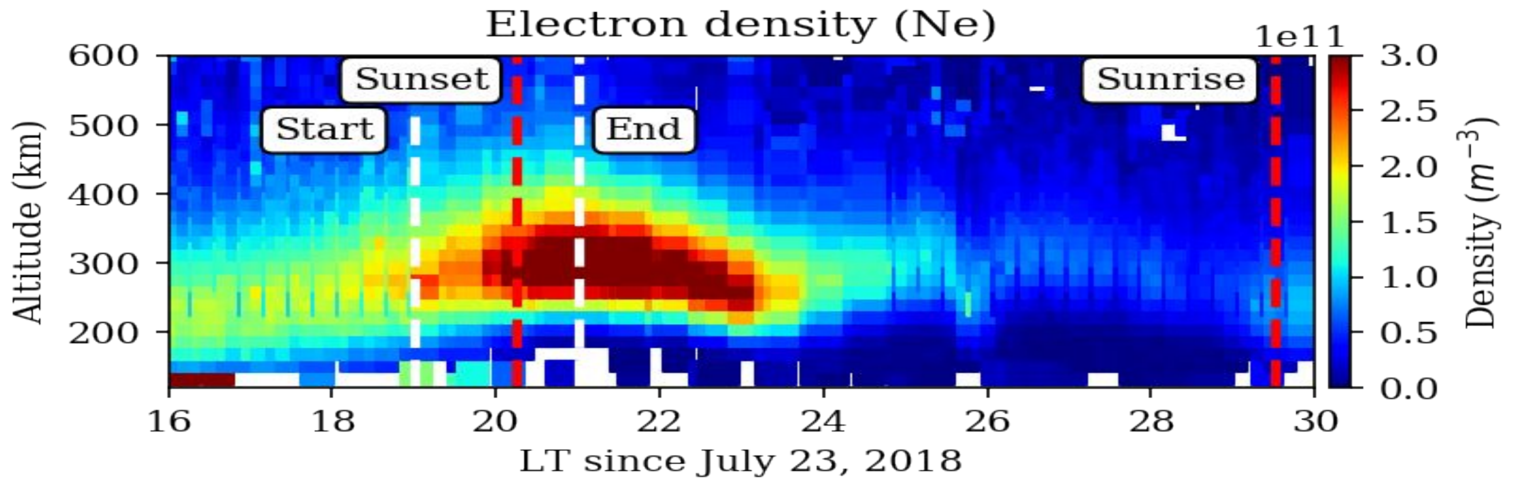


# Electron Density Variation over Millstone Hill (Long : 71.5°W, lat : 42.6° N)



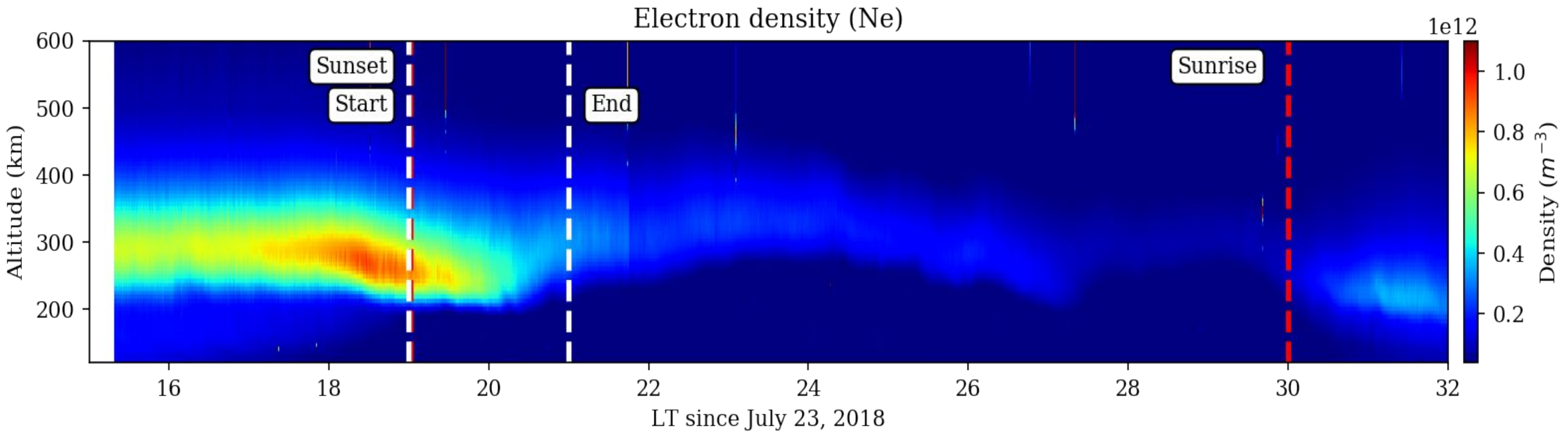



# Electron Density Variation over  Millstone Hill (Long : 71.5°W, lat : 42.6° N)



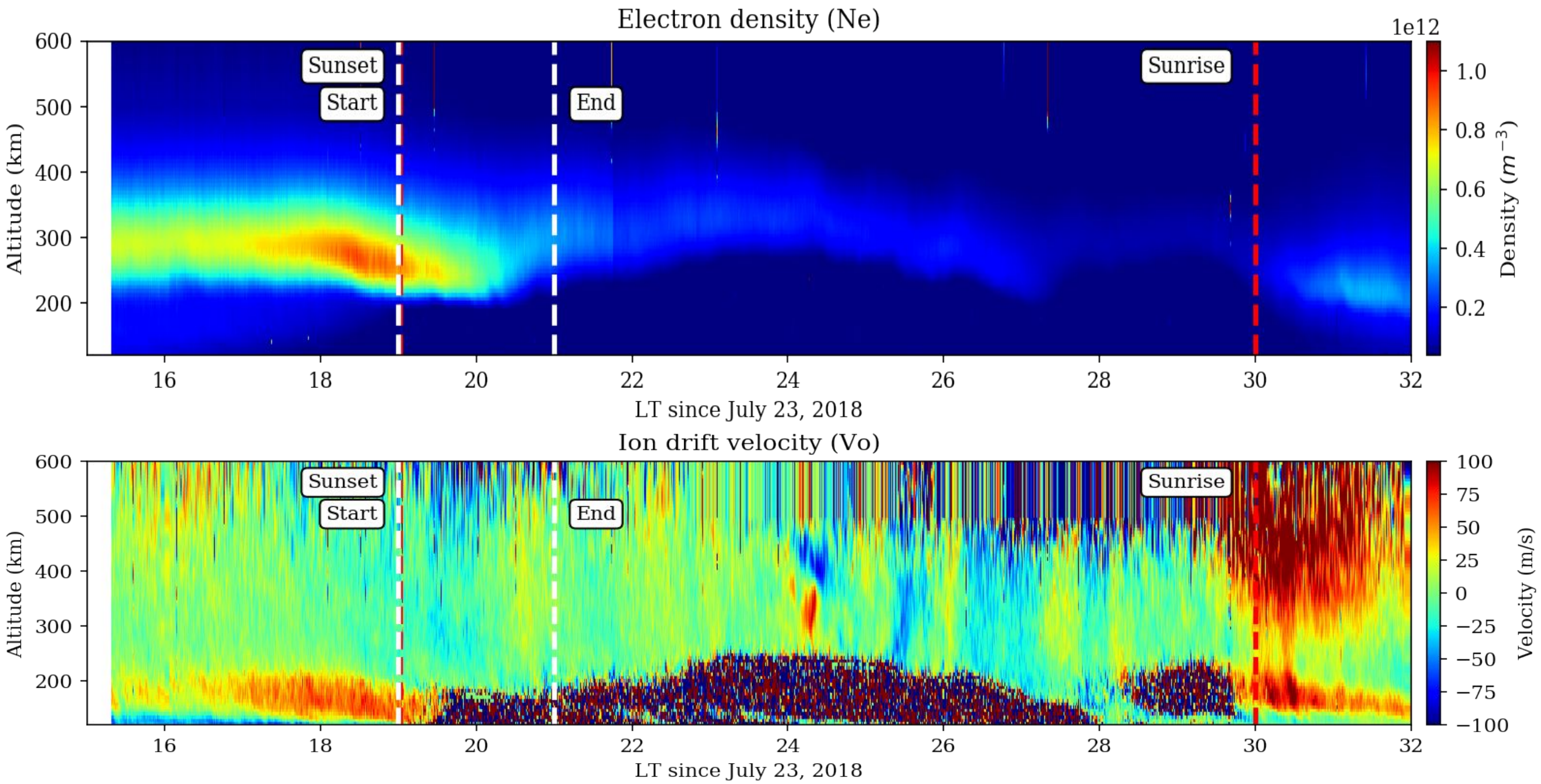

- ❖ The F-layer is moving up (Will be described by Liane)
- ❖ The electron density enhancement in post sunset hours (Will be described by Kiwook)

# Electron Density Variation over Arecibo (Long : 66.6°W, lat : 18.4° N)



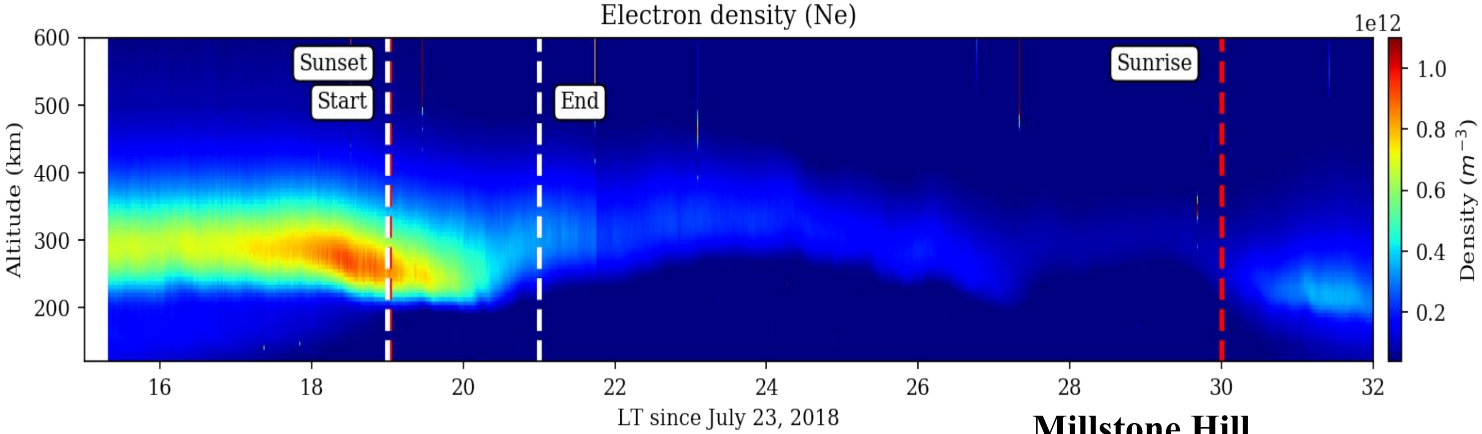

- ❖ Downward movement of F-layer
- ❖ Density decreases very fast.

# Electron Density Variation over Arecibo (Long : 66.6°W, lat : 18.4° N)

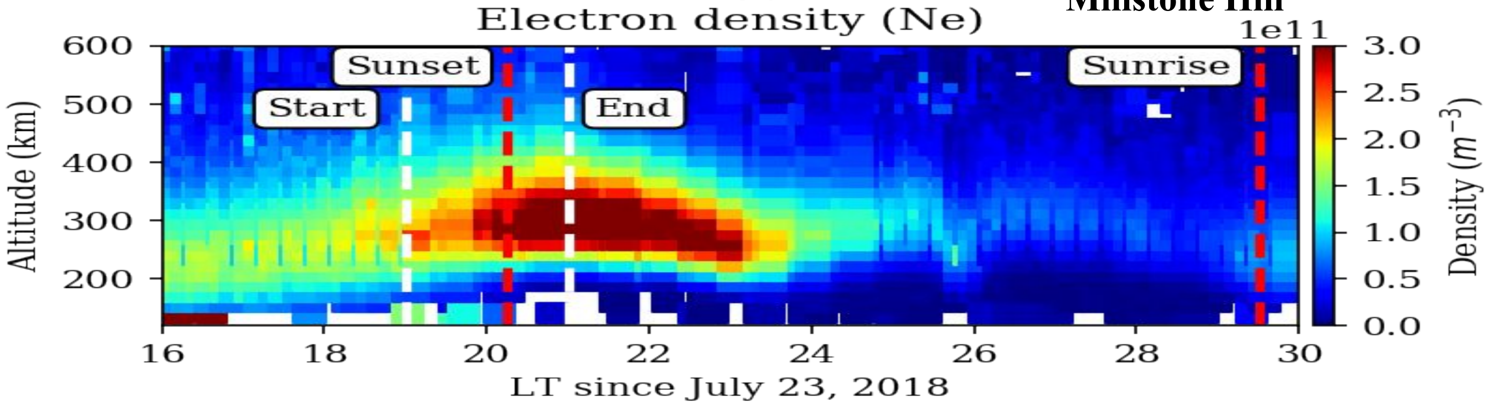


- Peak electron density values over Arecibo are an order of magnitude higher than over Millstone Hill

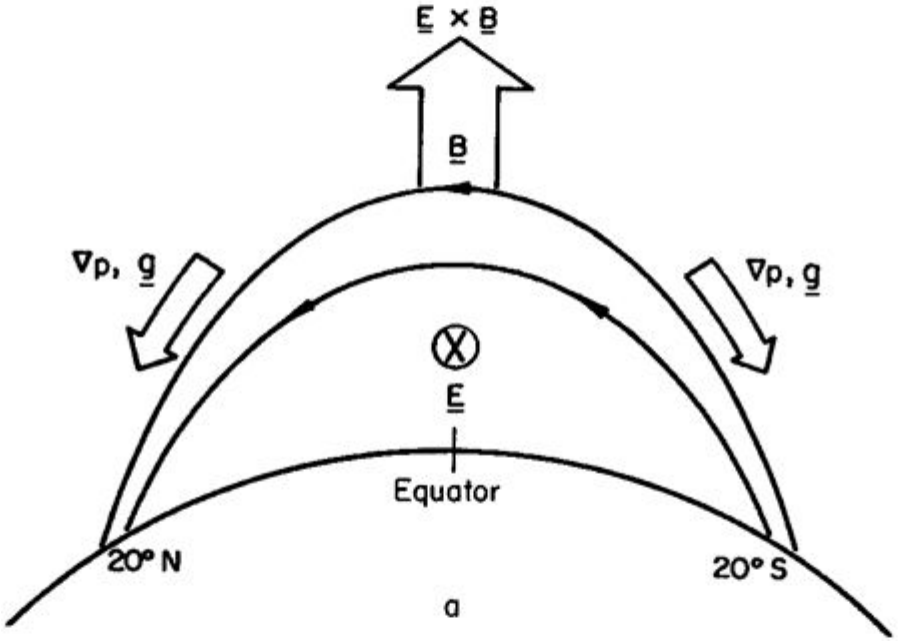
**Arecibo**




**Millstone Hill**



- Equatorial Ionization Anomaly causes enhancement in increment in electron density over low latitudes

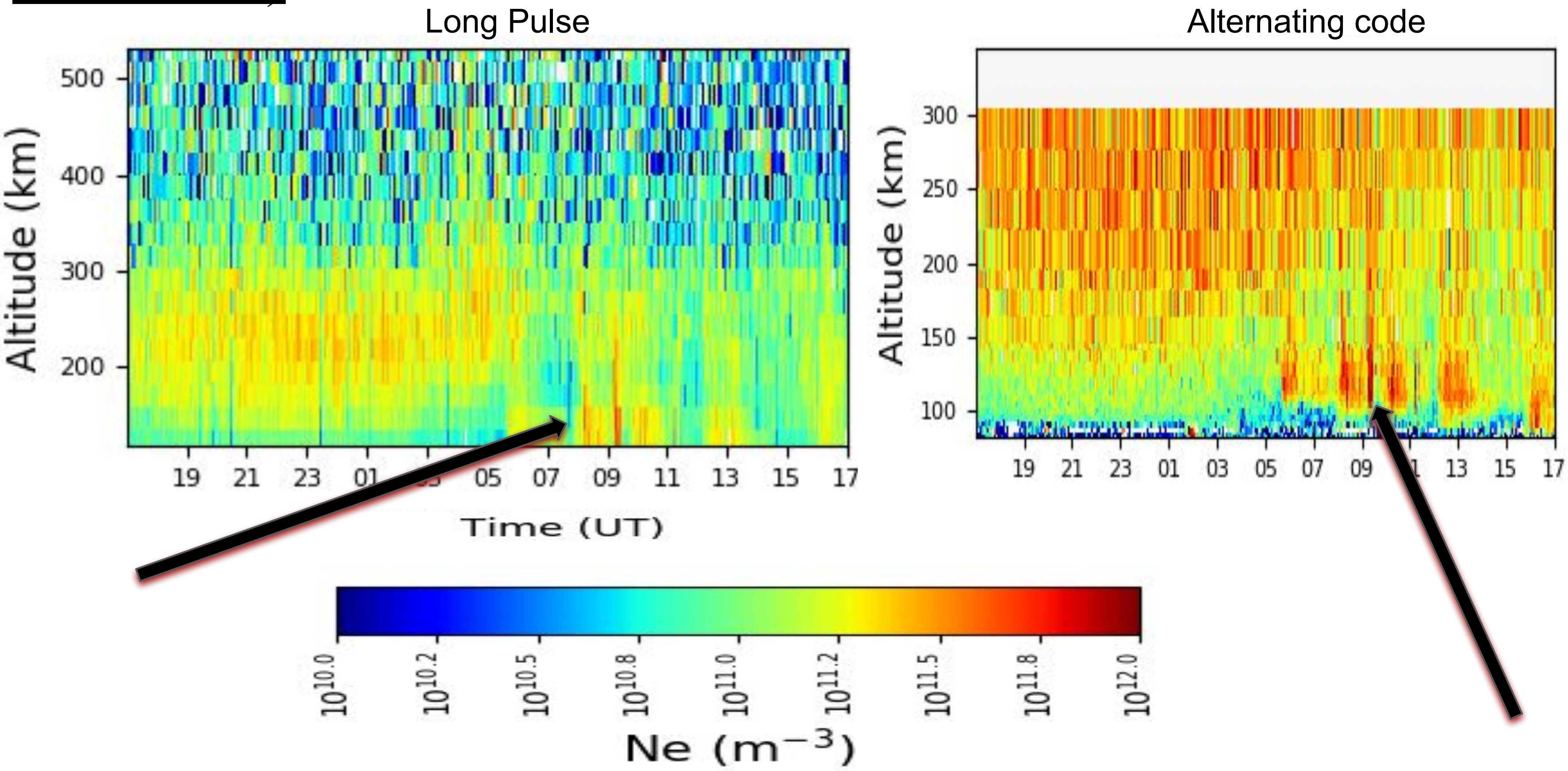


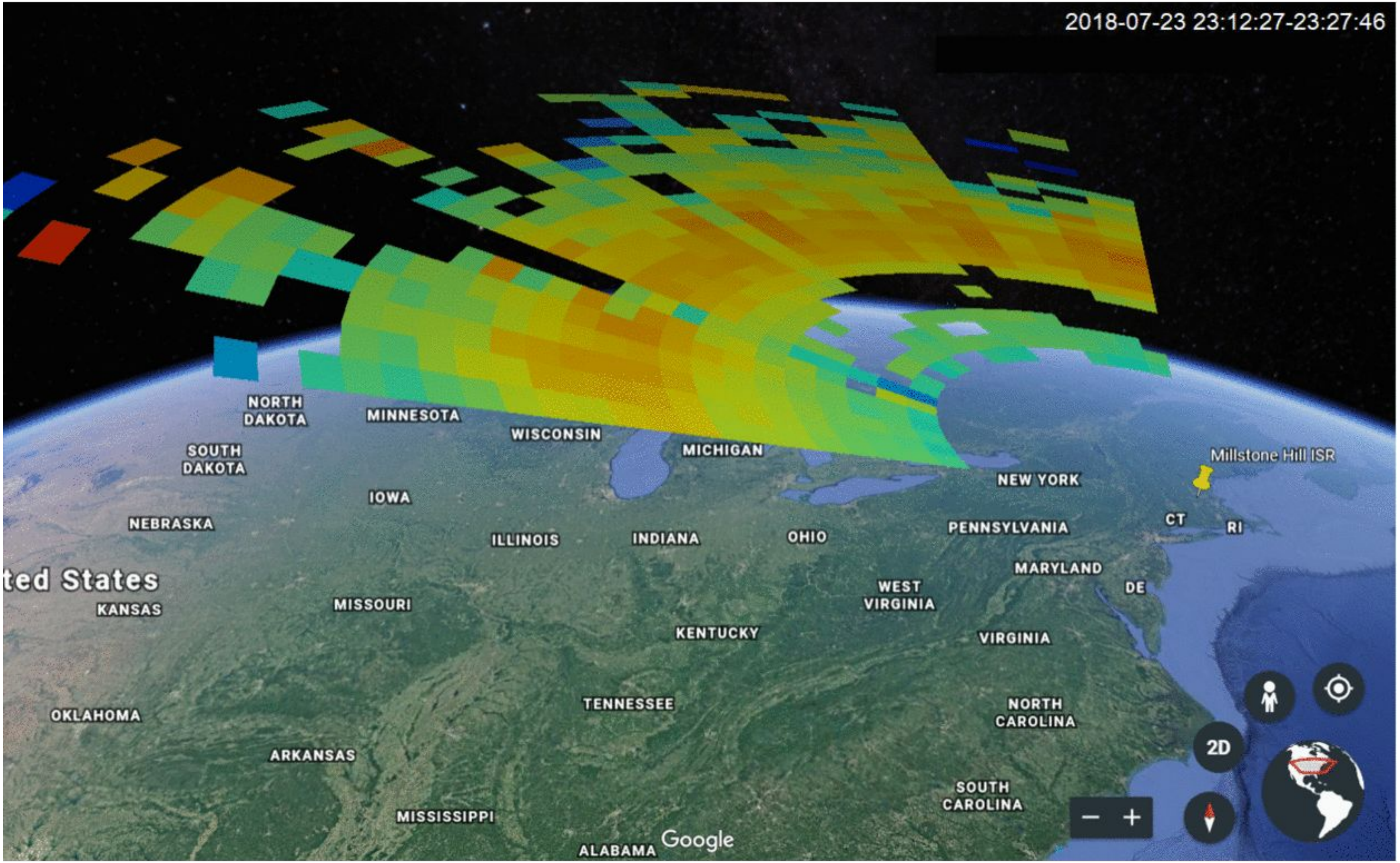

Latitudes:

Millstone Hill : 42.6° N

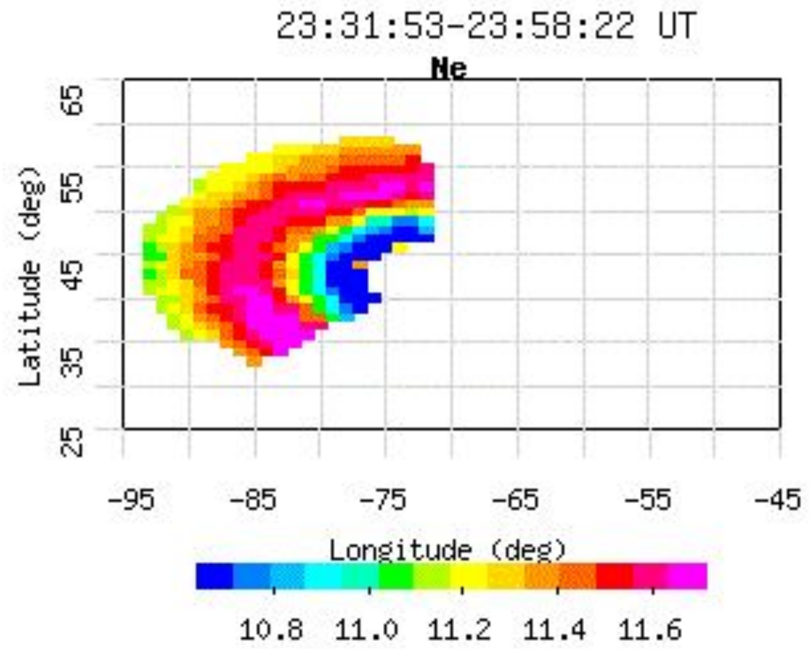
Arecibo Observatory : 18.4° N

# Electron Density Variation over PFISR over Alaska (Long : 147° W, Lat : 65° N)




2018-07-23 23:12:27-23:27:46
NORTH DAKOTA
MINNESOTA
WISCONSIN
MICHIGAN
SOUTH DAKOTA
IOWA
NEBRASKA
ILLINOIS
INDIANA
OHIO
NEW YORK
PENNSYLVANIA
Millstone Hill ISR
CT
RI
MARYLAND
DE
WEST VIRGINIA
ted States
KANSAS
MISSOURI
KENTUCKY
VIRGINIA
TENNESSEE
NORTH CAROLINA
OKLAHOMA
ARKANSAS
SOUTH CAROLINA
MISSISSIPPI
ALABAMA
Google
2D

# Electron Density - Sunset $N_e$ increase




Phil Erickson, MIT/Haystack Observatory. (1990) CEDAR Madrigal database.

Characteristics

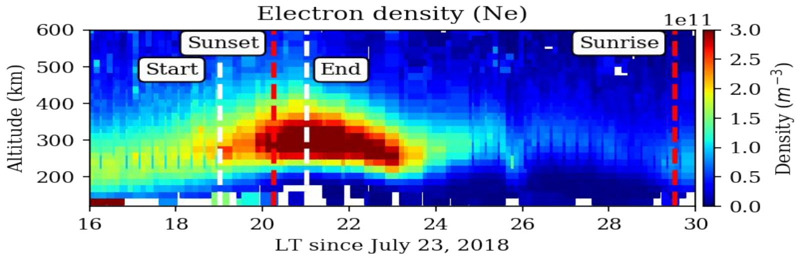
- Increased at solar minimum
- Latitudinally dependent
- Interhemispheric asymmetric

Possible Causes

- $T_e$ decrease at sunset collapses the F region
- Lifting due to equatorward winds reduces the recombination rate + long-lasting sunlight

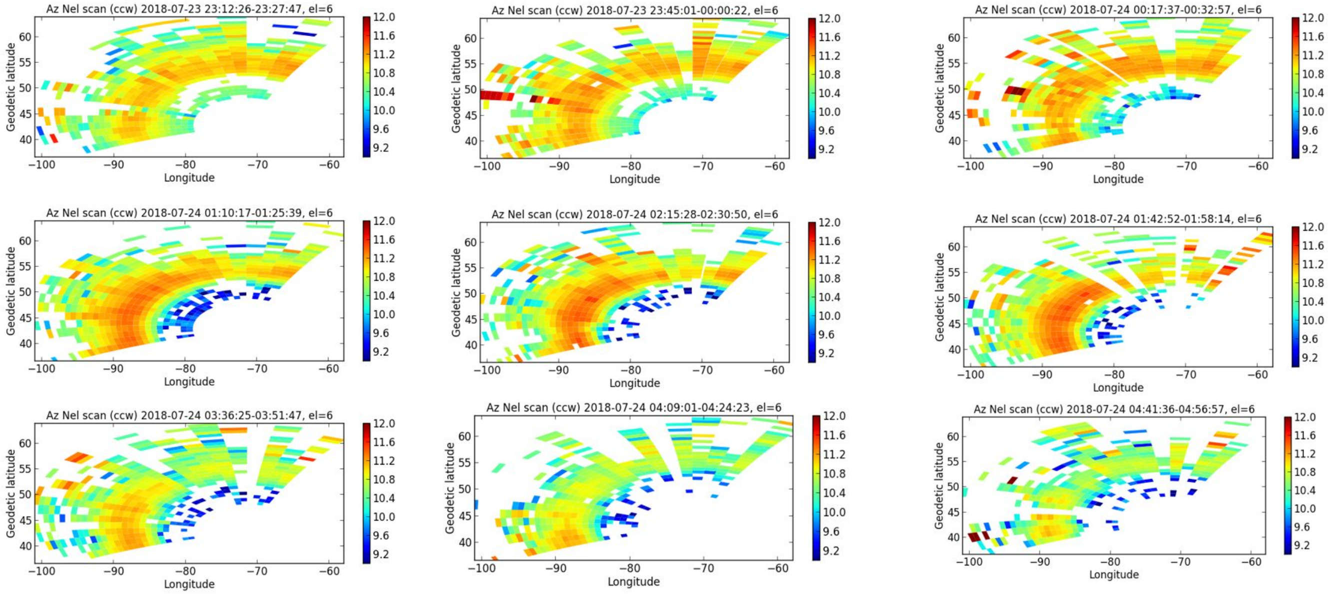
Evans, Planet. Space Sci. 1967, Lin et al. JGR 2010, Chen et al. Ann. Geo. 2015

# Post sunset enhancement in Ne

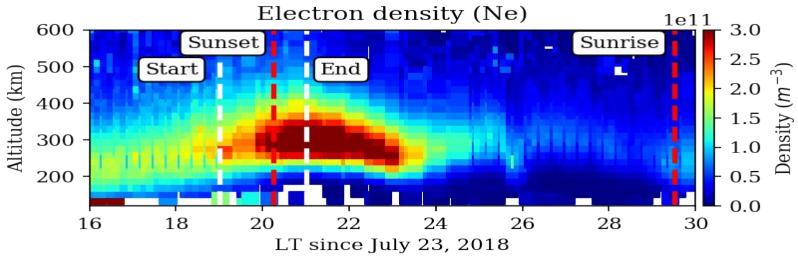



Start

End

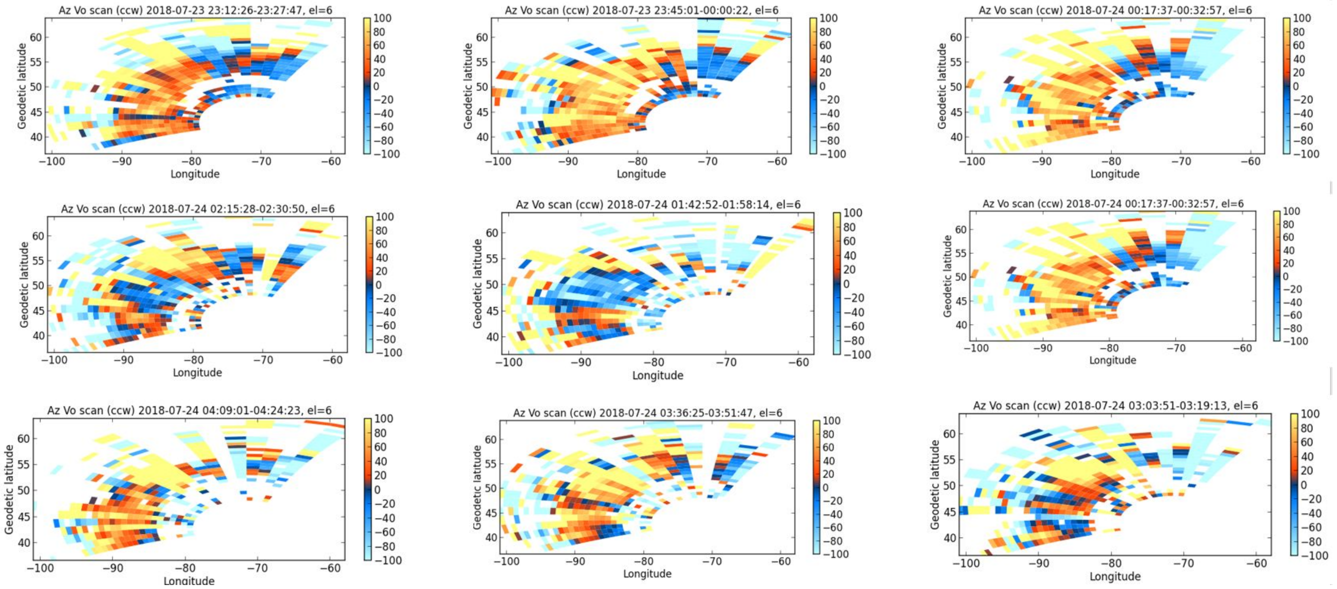


# Post sunset enhancement in Ne

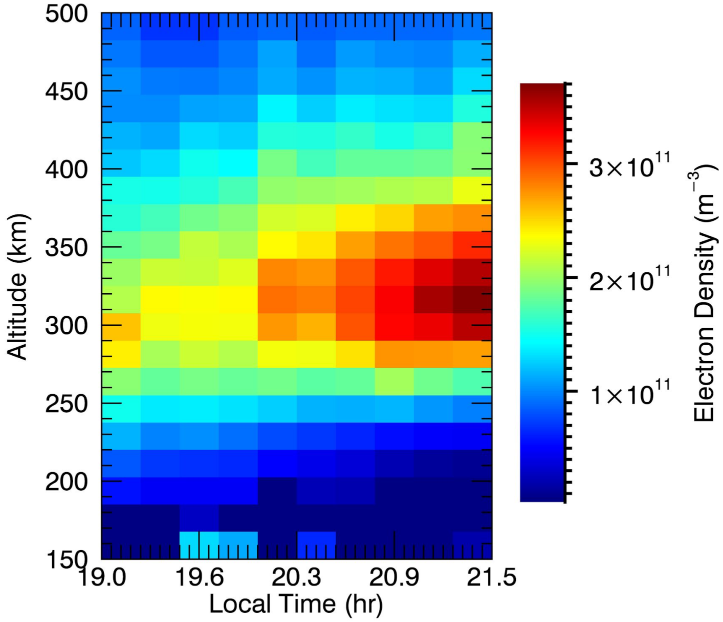


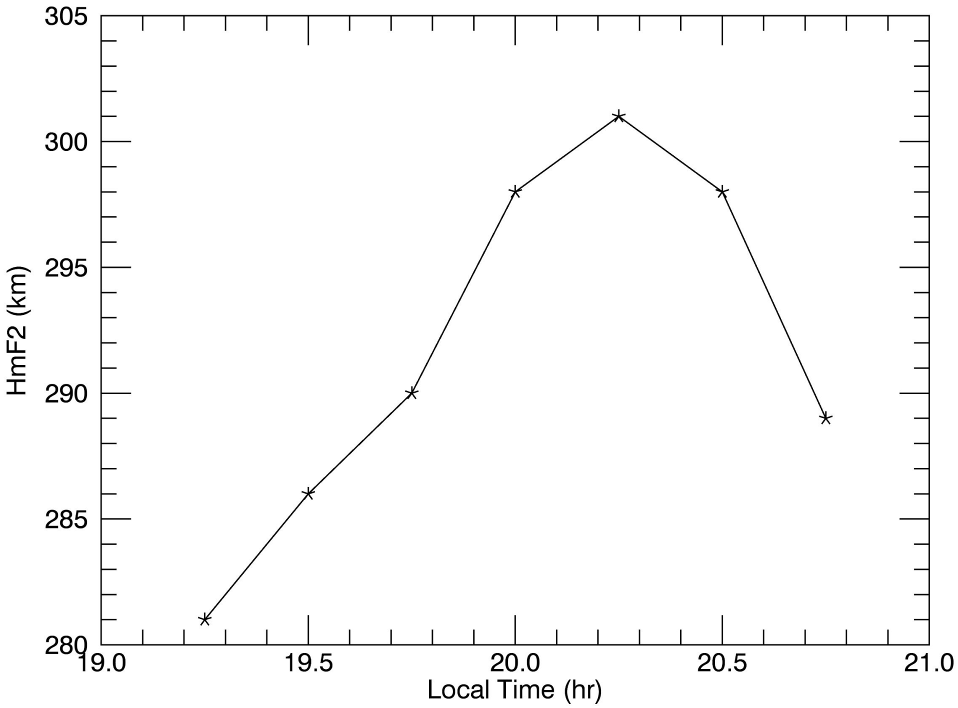

Start

End

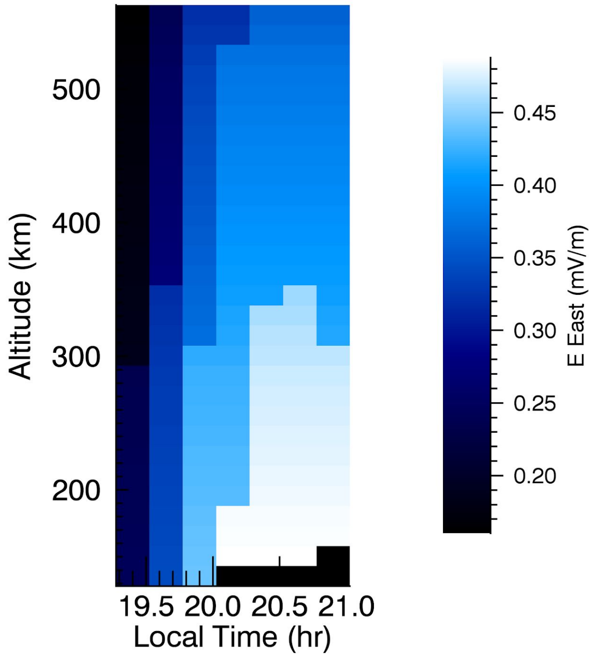


# Electron Density - HmF2 Variation

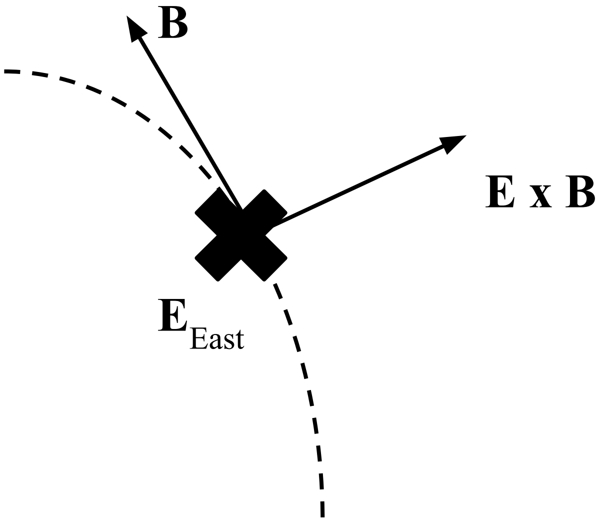


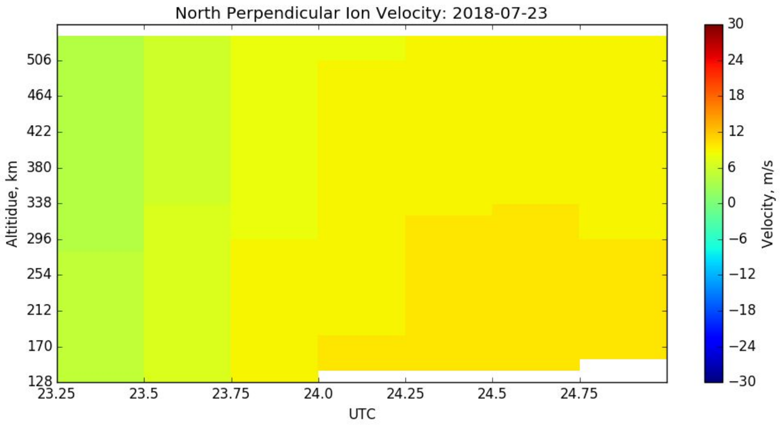
# Electron Density - F2 Variation

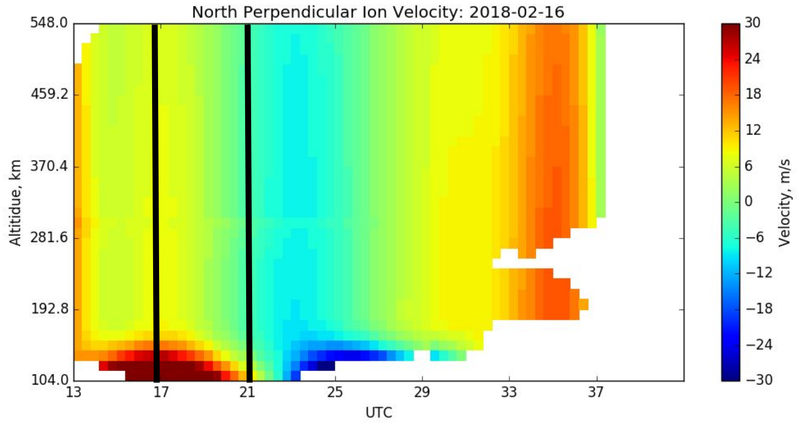


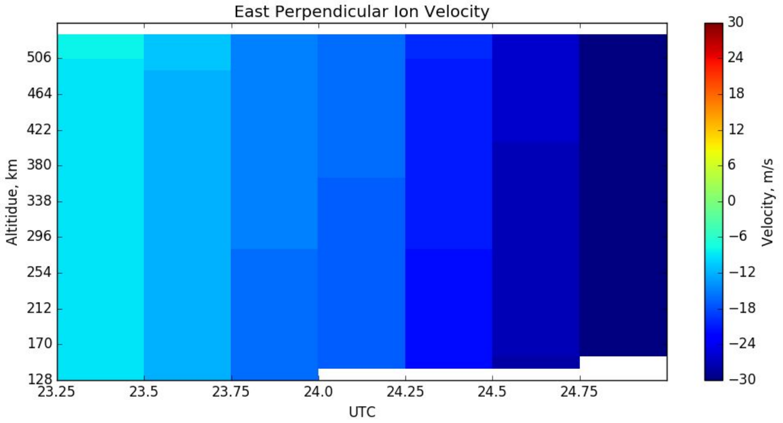

- Eastward electric fields cause vertical/northward **E**x**B** drifts

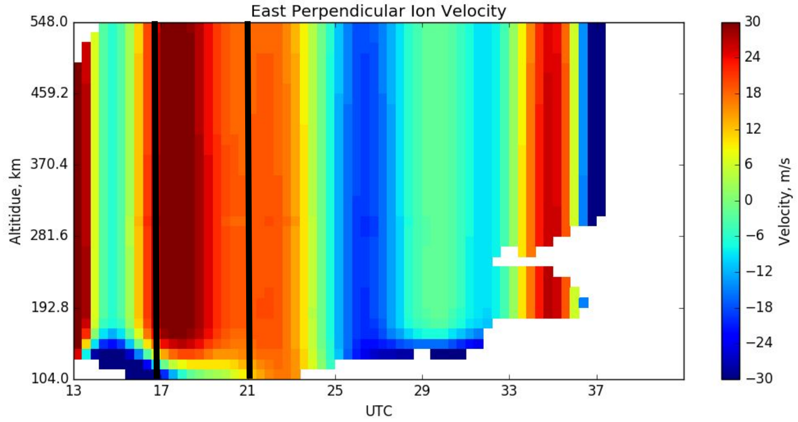


# Ion Velocity

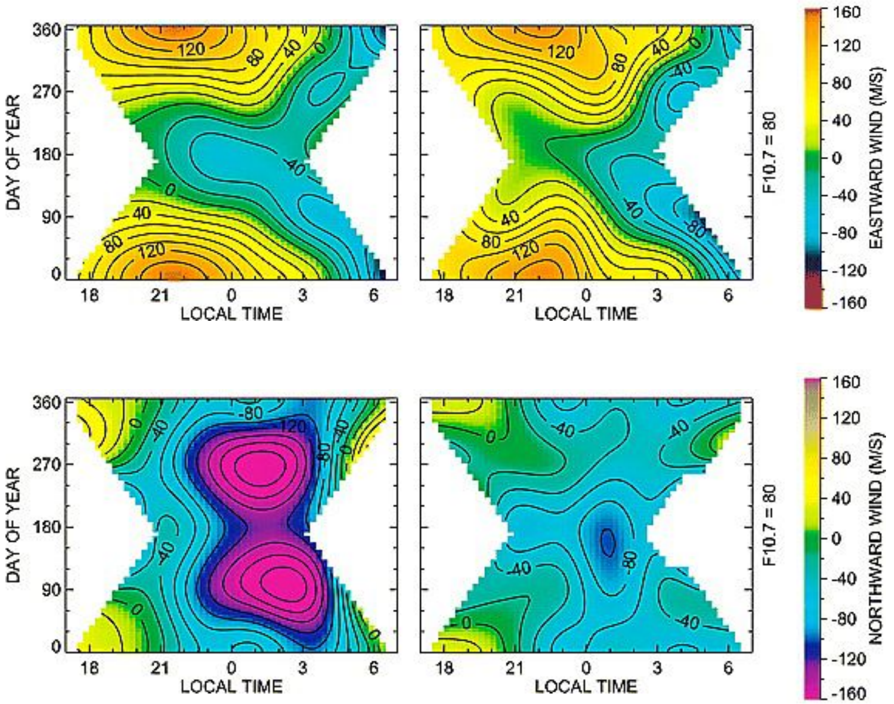


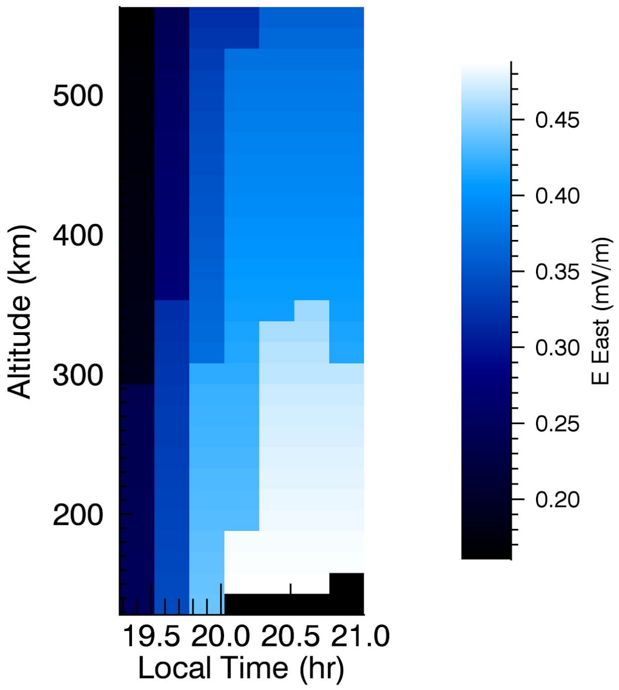
# Neutral Wind Model Over Millstone Hill

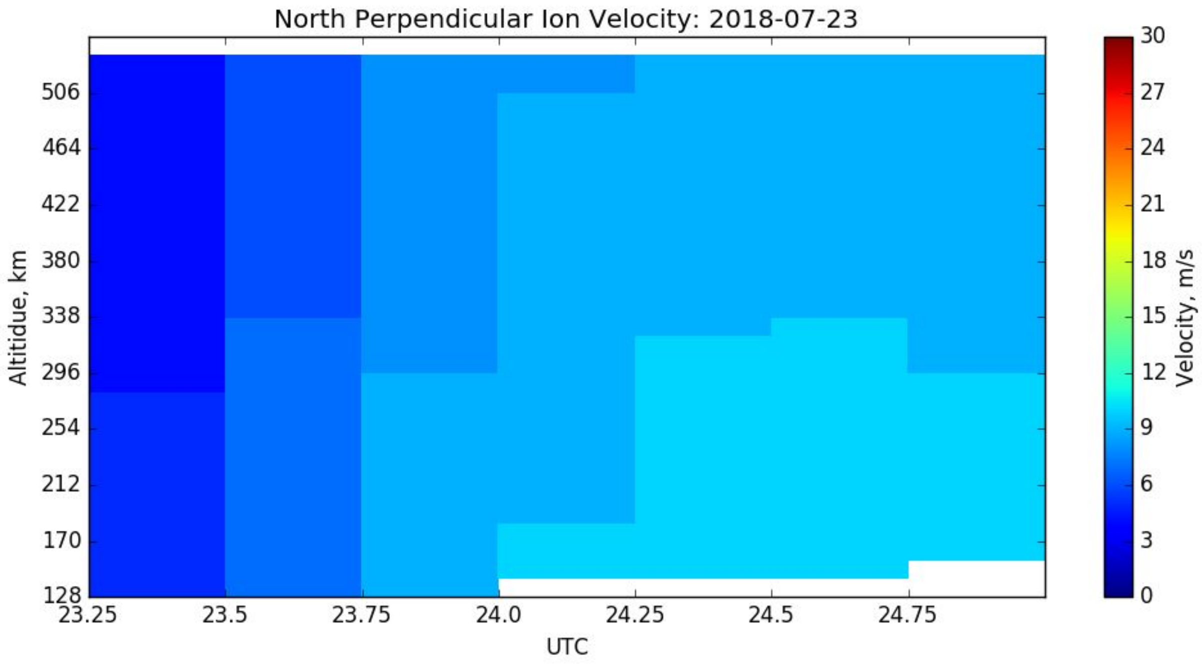



J.T. Emmert, 2003, *Journal of Geophysical Research: Space Physics*

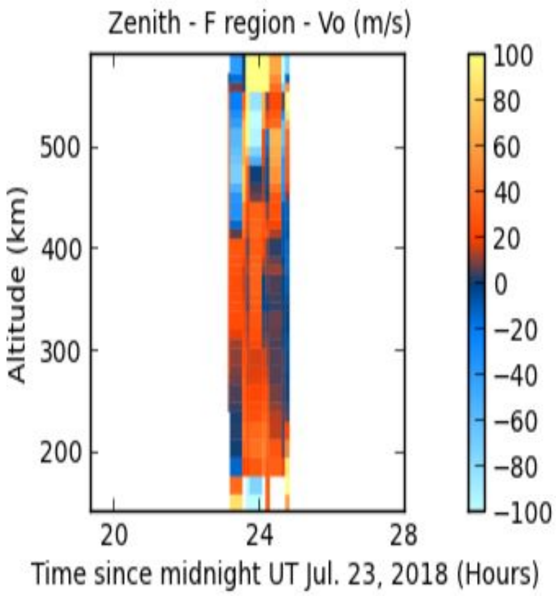
- J.T. Emmert et al. (2003) analyzed Millstone Hill Fabry-Perot neutral wind data at quiet times and developed an empirical model of eastward and northward neutral winds
- June 23 ~ 203rd day of the year
- February 16 ~ 47th day of the year
- Attempted to model neutral winds with HWM model, however model predicted flow in a direction opposite to observations

# Eastward Electric Field vs Northward Ion Velocity

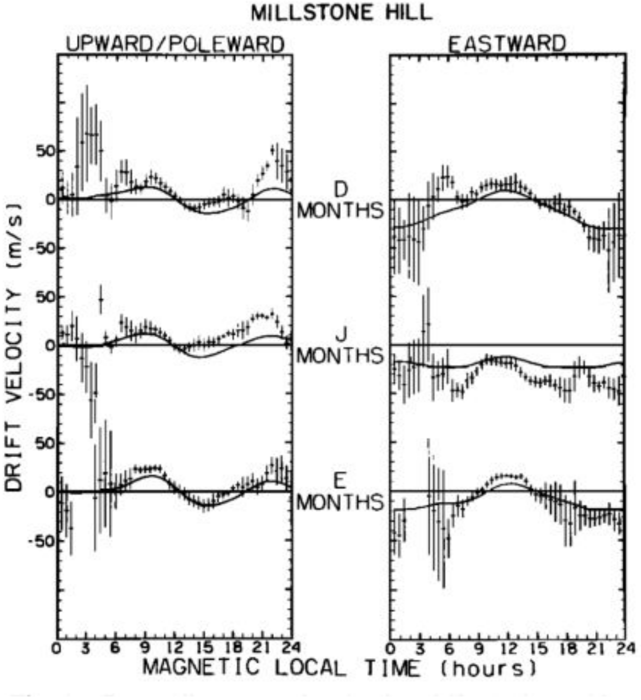


# Observed Zenith Ion Velocity



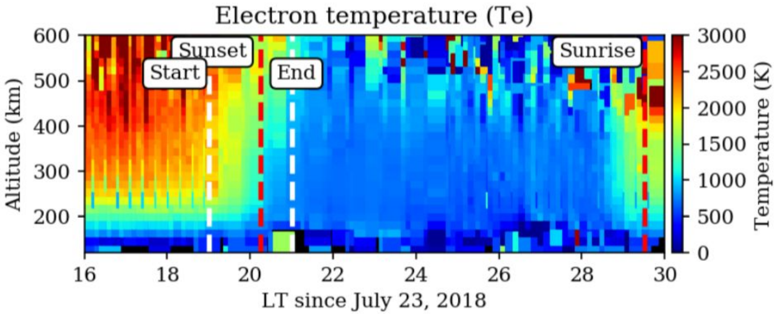

Phil Erickson, 2018, Mit/Haystack Observatory

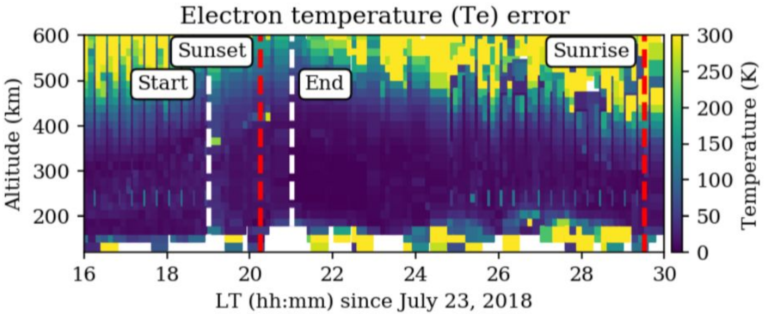



A.D. Richmond, 1980, Journal of Geophysical Research

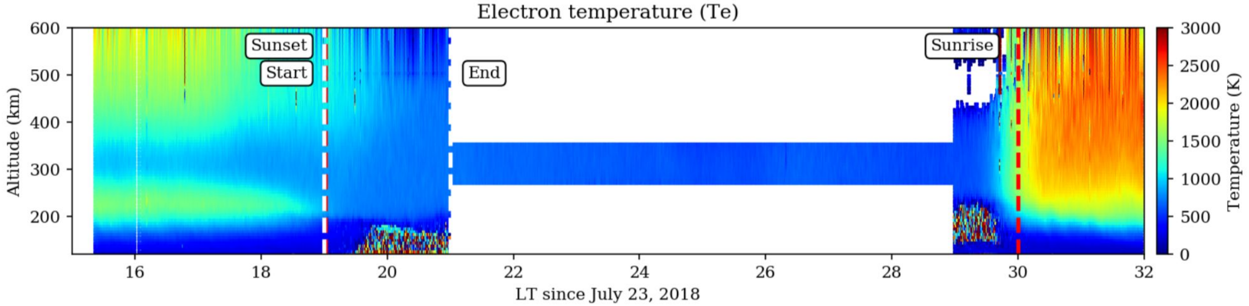
- Observe increased upward velocity at local sunset time
- Follows empirical model prediction by Richard (1980)
- Possible cause - enhanced eastward E field
- Related to increase in F-peak altitude

# Electron Temperature - Te



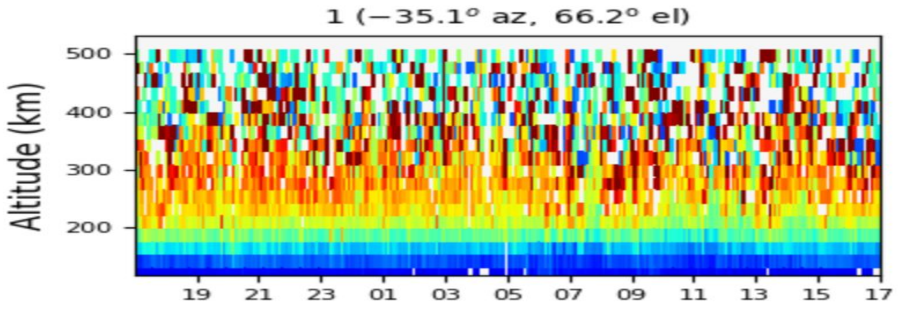




Millstone Hill (lon: 71°W, lat: 42.6°N) magnetic field: 67.2097° downward (WMM)

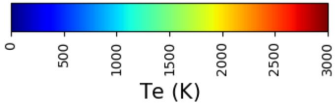



Arecibo (lon: 66.6°W, lat: 18.4°N) magnetic field: 43.1342° downward (WMM)

# Electron Temperature - Te




UT (hour)




Poker Flat: (lon: 147.45°W, lat: 65.14°N) magnetic field: 63.1404° downward

- Heat conduction causes changes in temperature gradients in different latitudes.
- Arecibo bulge (300~400 km) is created by different electron density in altitudes and low heat conduction.

# Conclusions

- Low latitude electron density is higher than mid latitude during post sunset hours due to the equatorial ionization anomaly.
- Post-sunset density enhancements are common in the summer hemisphere at solar minimum, possibly caused by neutral wind transport or collapse of the F layer
- HmF2 increases after sunset due to **E**x**B** drifts from eastward electric fields
- Northward perpendicular ion velocity increases with the eastward electric field
- Vertical ion velocity increases for a short time before post-sunset density enhancement
- Due to dip angle difference, temperature gradients vary in different latitudes.