Understanding the Space Weather and Thermospheric Wind in the Polar Region

Qian Wu, NCAR, USA
William Ward, Univ. of New Brunswick, Canada
Geonhwa Jee, Jeong-Ham Kim KORPI, Korea

Polar Technology Conference Boulder, March 10, 2020

NCAR
NATIONAL CENTER FOR ATMOSPHERIC RESEARCH

NSF

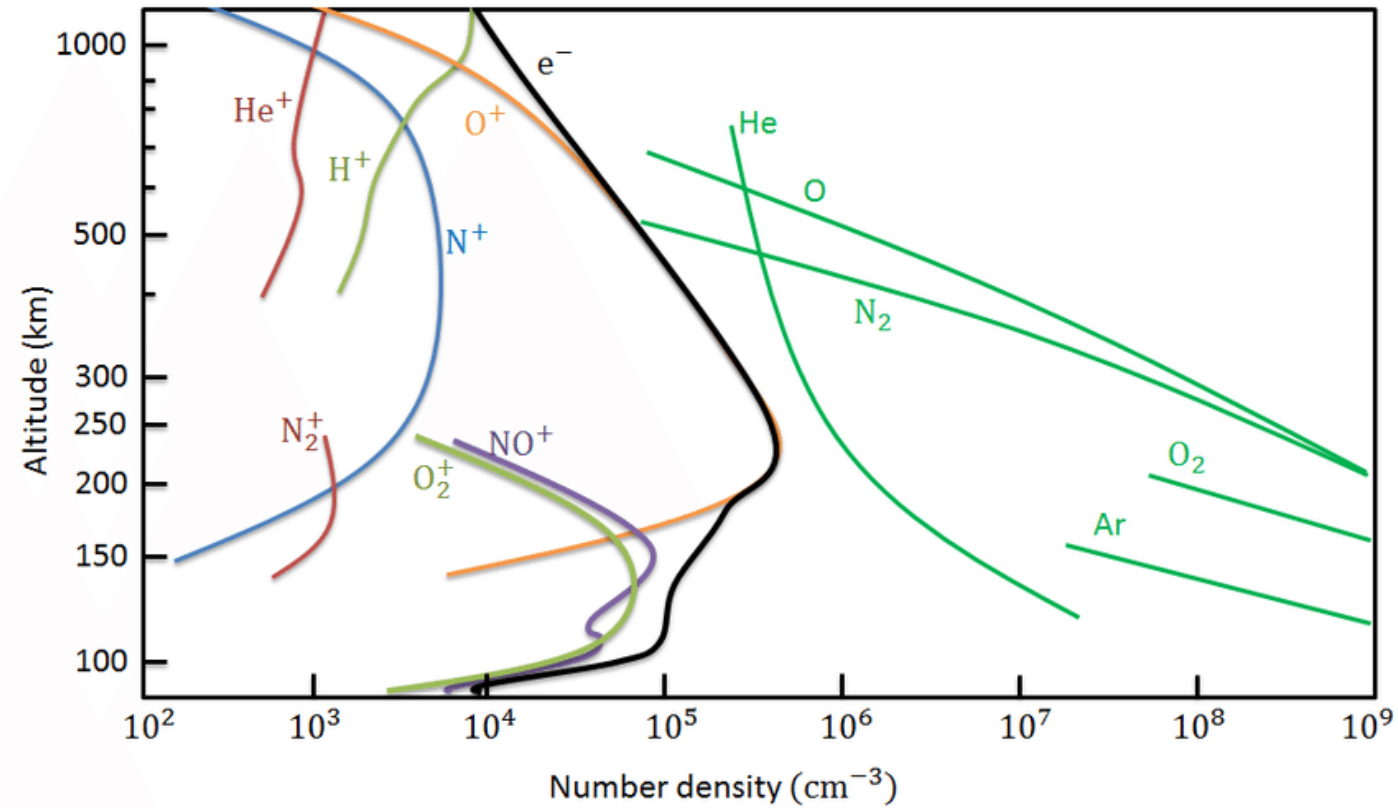
Outlines

- Why do we investigate space weather in the polar region?
- Why do we need to know thermospheric winds?
- Current status of thermospheric wind instruments in the polar regions.
- Potential future expansion plan.

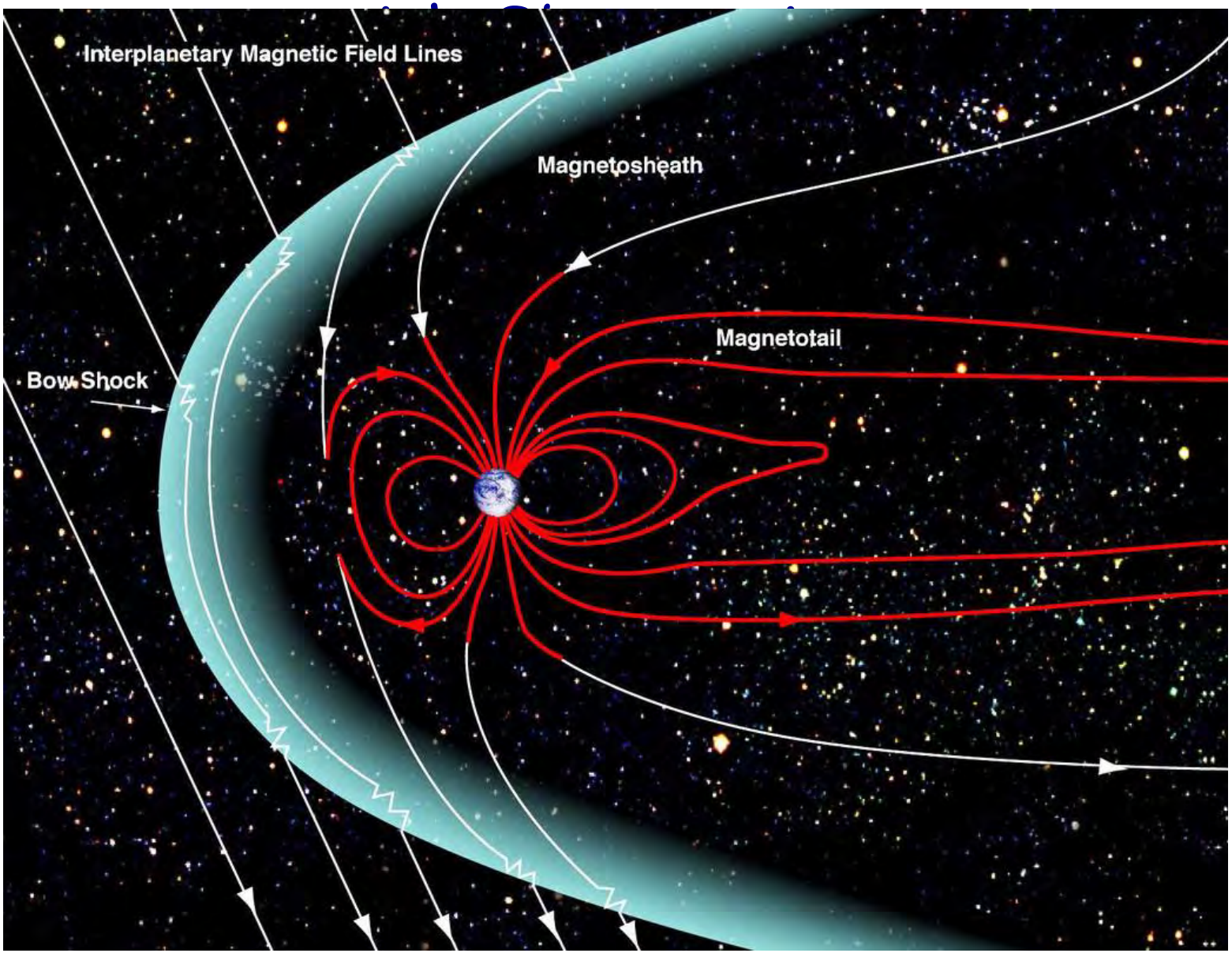
Why we need to care about space weather?

- Space weather usually starts with ionospheric disturbances in the polar region, then propagates to mid- and low-latitudes.
- Space weather can be very disruptive to navigation and communications systems. In the polar region, the GPS satellites are mostly at low elevation and more susceptible to ionospheric activities lead to signal scintillation.
- With more commercial activities in the Arctic region, space weather impact can be more significant.
- The goal of space weather research is to be able to accurately forecast ionospheric activities and predict how fast and how far the ionospheric disturbance can travel to mid and low latitudes.

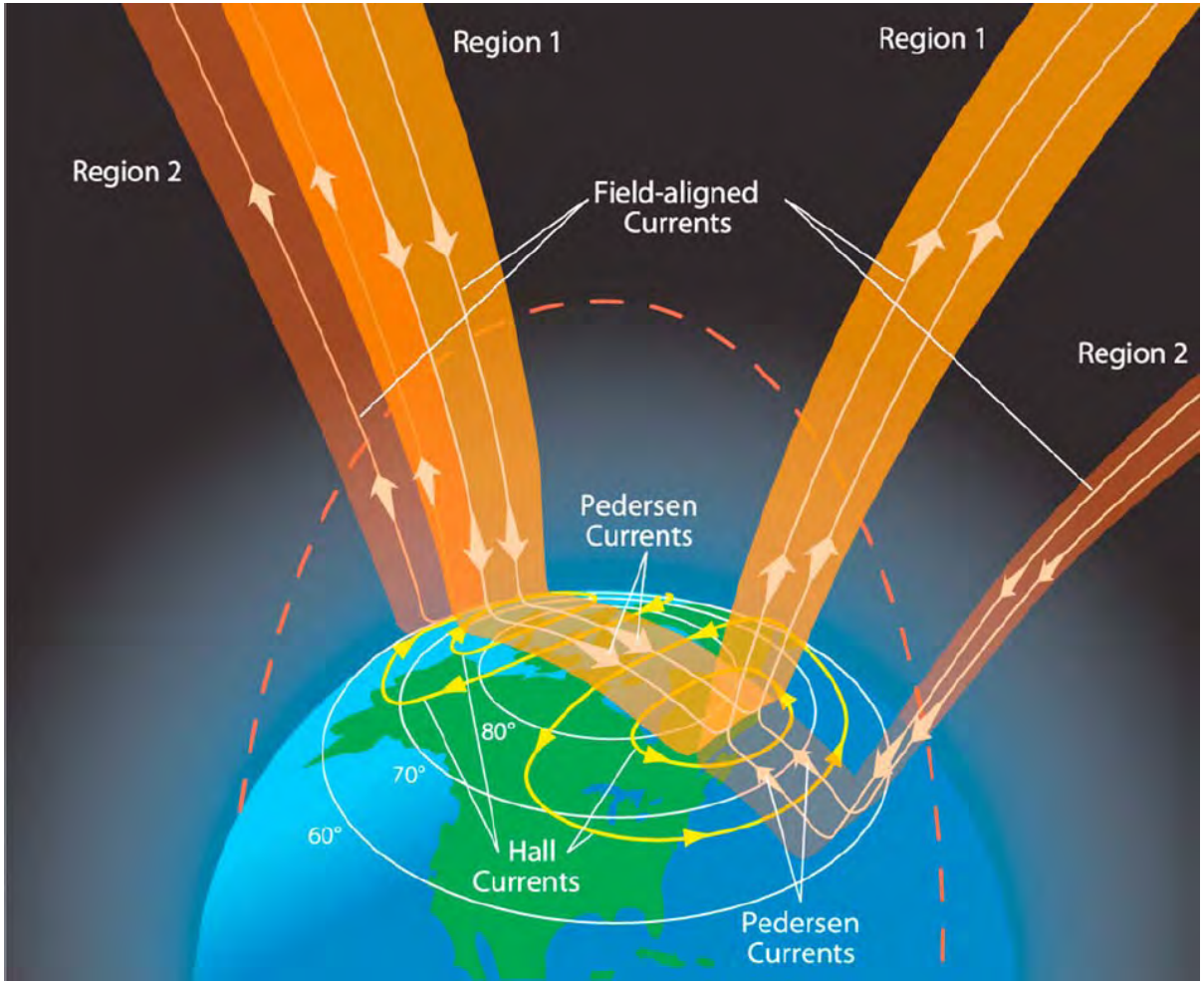
Ionosphere Density Profile



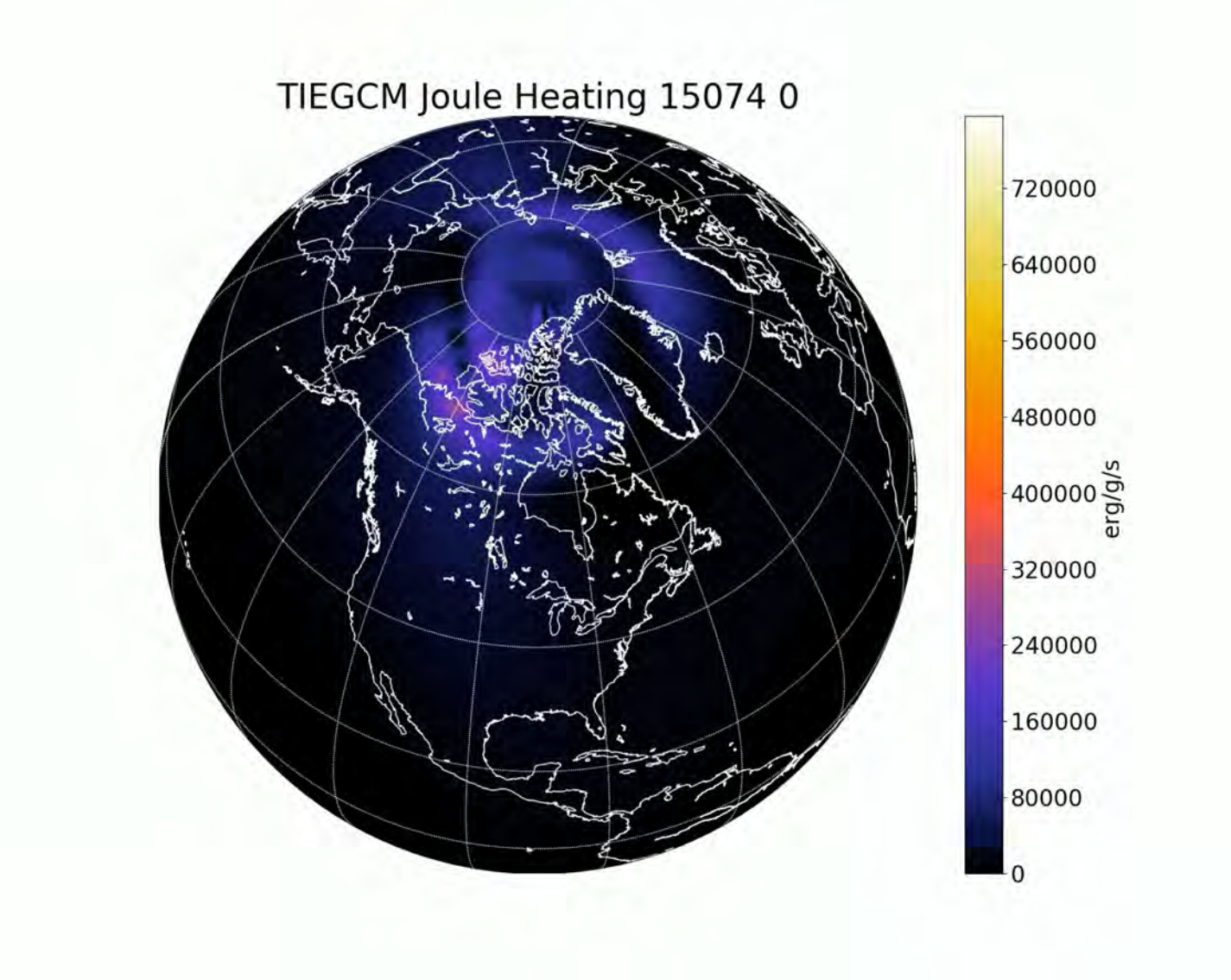
TIEGCM Thermospheric Wind Comparison



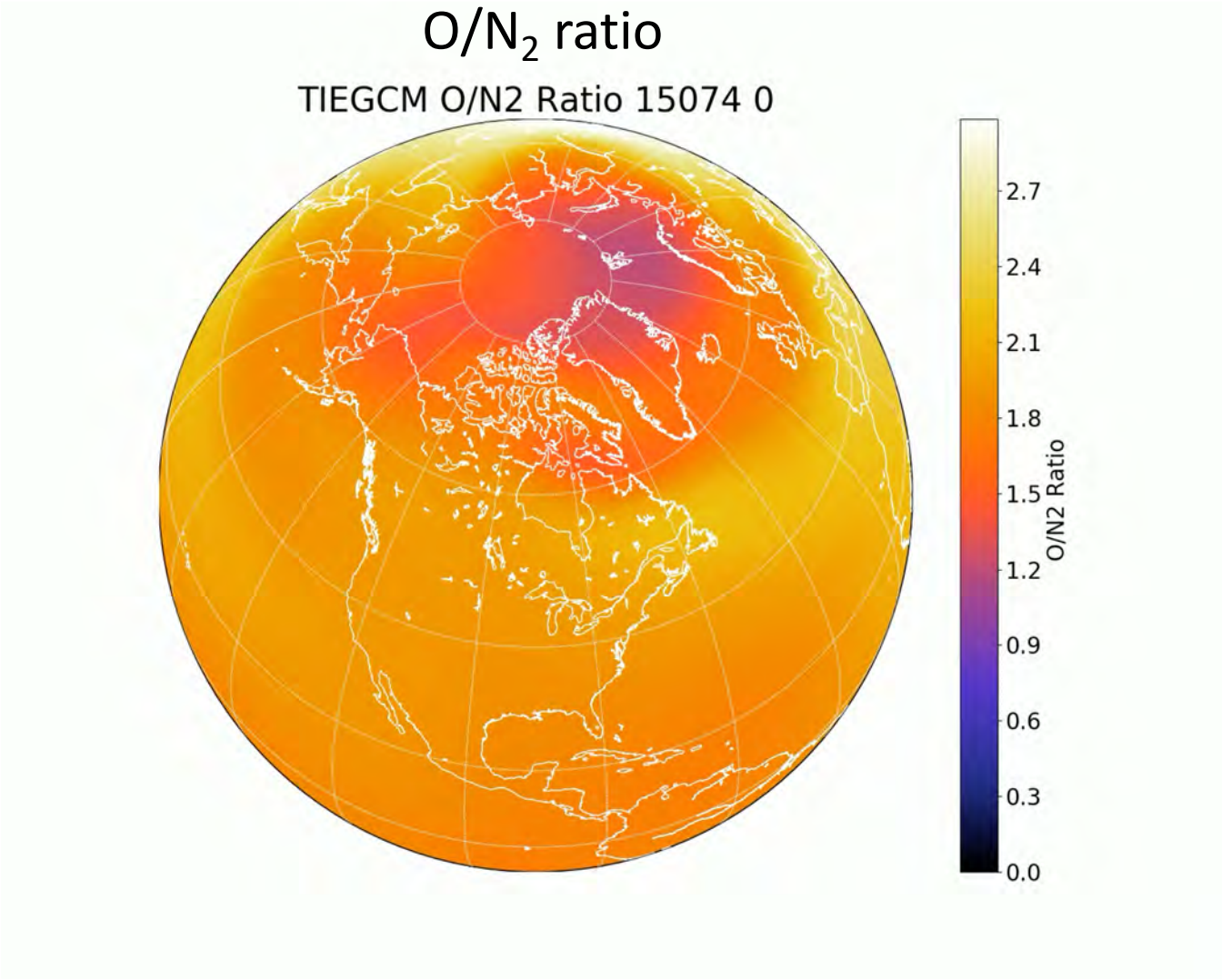
Electrodynamics Over the Polar Cap



2015 St. Patrick's Day Mar 17-18 (Day 76-77) TIEGCM 2.0 Simulation 2.5 x 2.5 deg Res.



TIEGCM O/N_2 Ratio



Assessment of Model Simulations

- Simulations show complex structure inside the polar cap.
- Joule heating is directly link to the ion drift and thermospheric winds

$$Q_j = N_e m_i (v - u)^2,$$

where, N_e electron density,

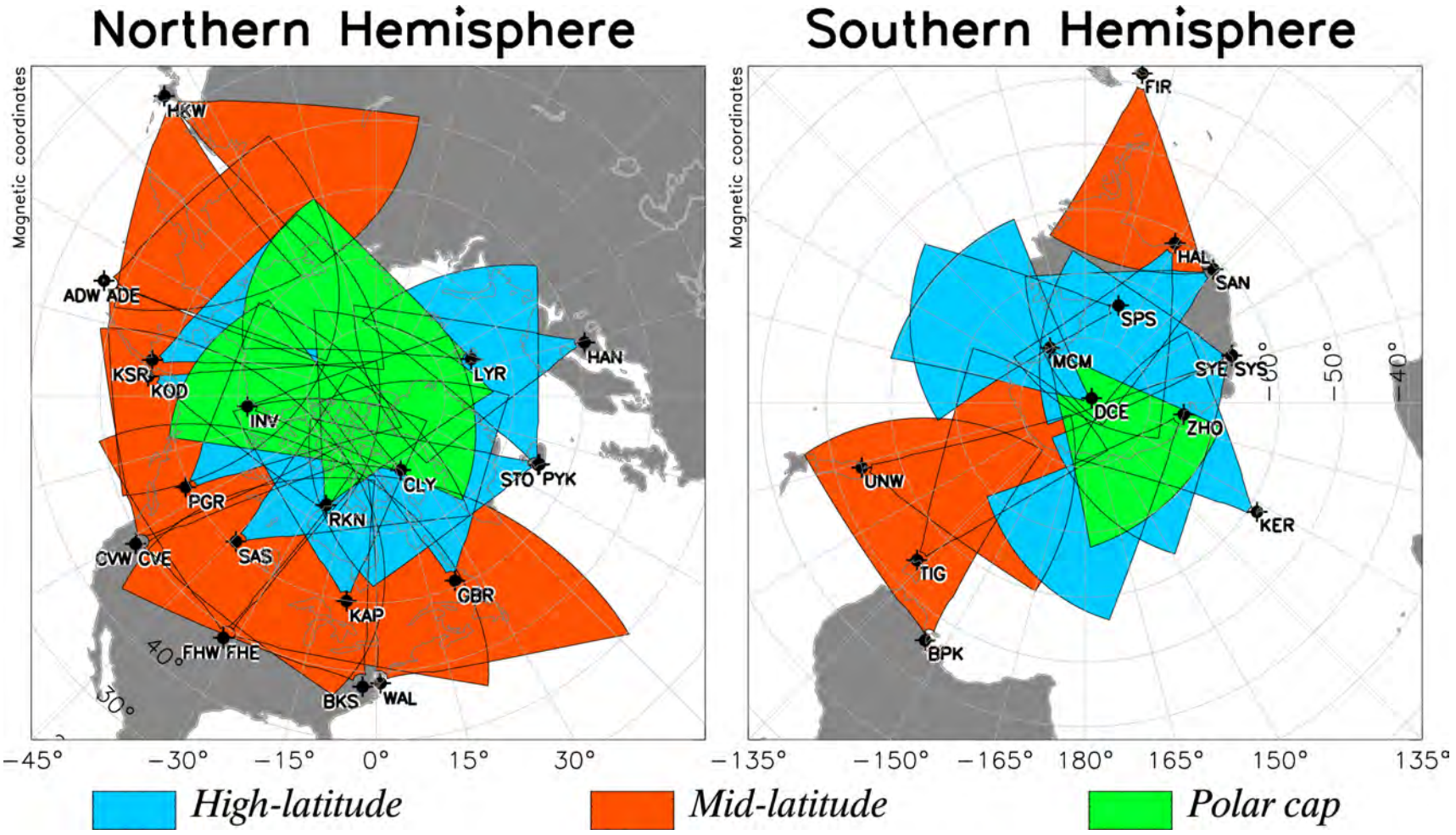
m_i average ion mass,

v ion drift,

u thermospheric neutral wind

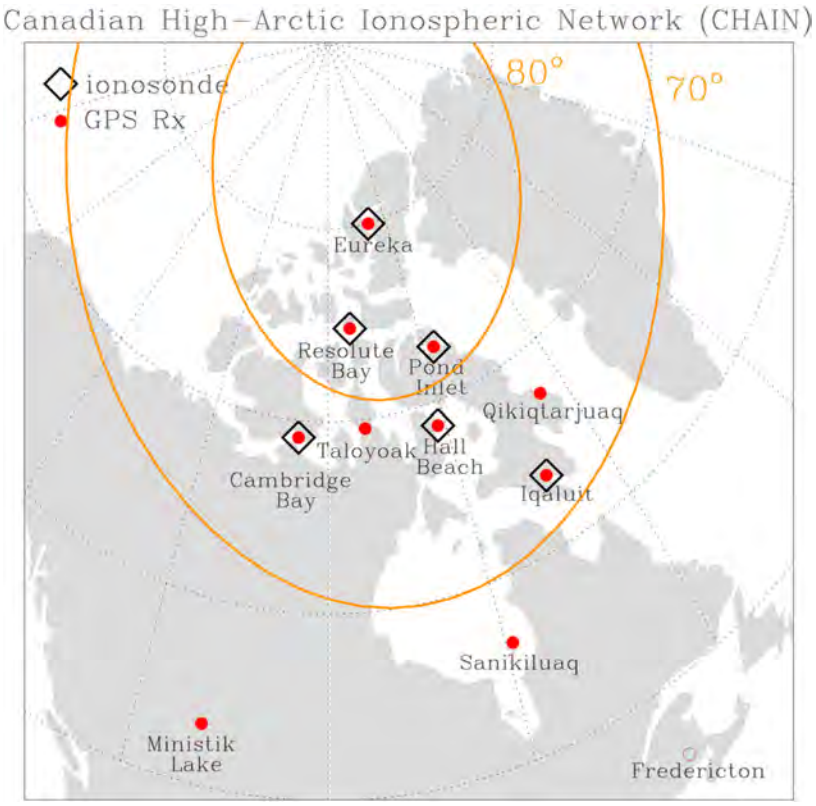
- We need observations of N_e, v, and u to validate the model simulations.

SuperDARN Coverage Map for Ion Drift Observations



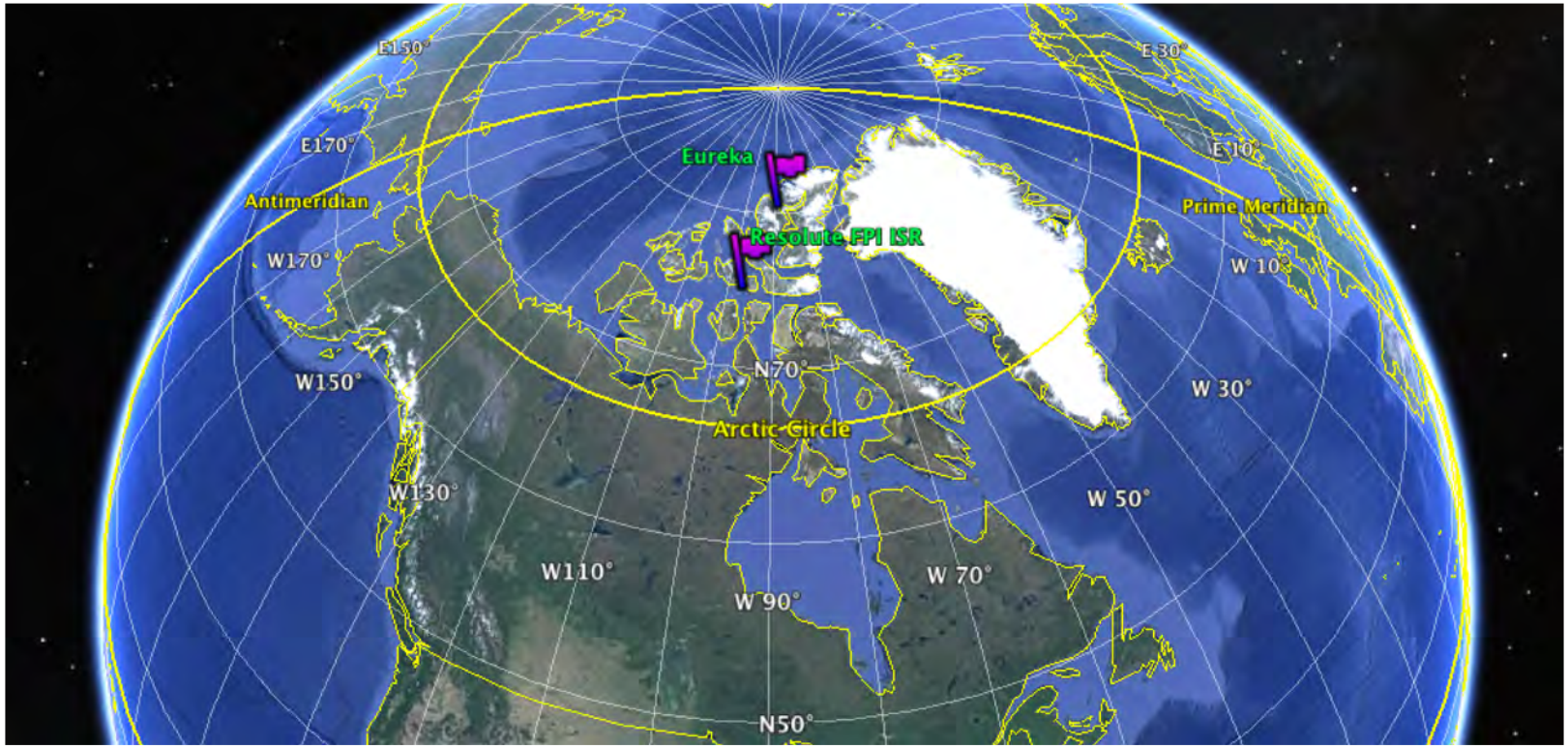
Resolute Incoherent Scatter Radar (RISR) & Ionosonde Network for Ionospheric Density Observations

RISR at Resolute



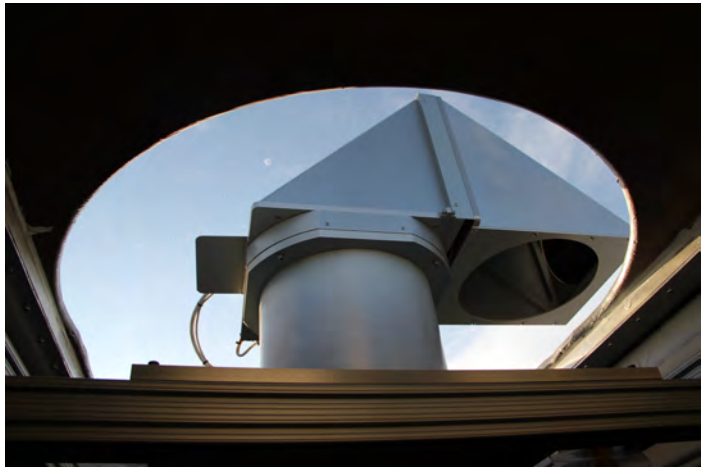
Ionosonde Network

Thermospheric Wind Instrument Station Locations

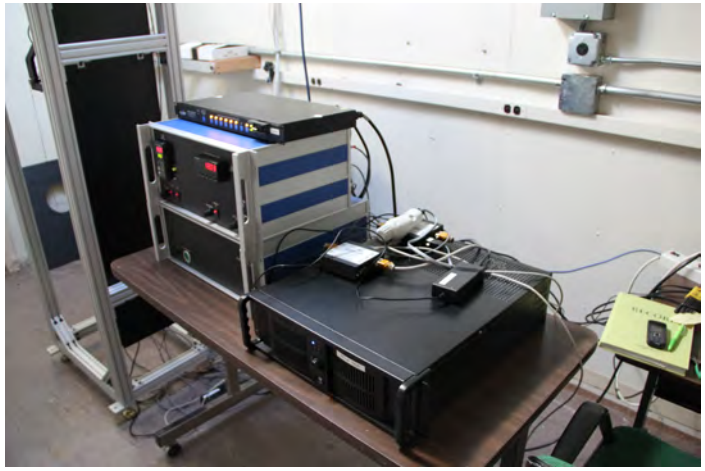


Locations of Eureka and Resolute in the northern polar region. Eureka (80N, 86W), Resolute (75N, 95W)

Fabry Perot Interferometer



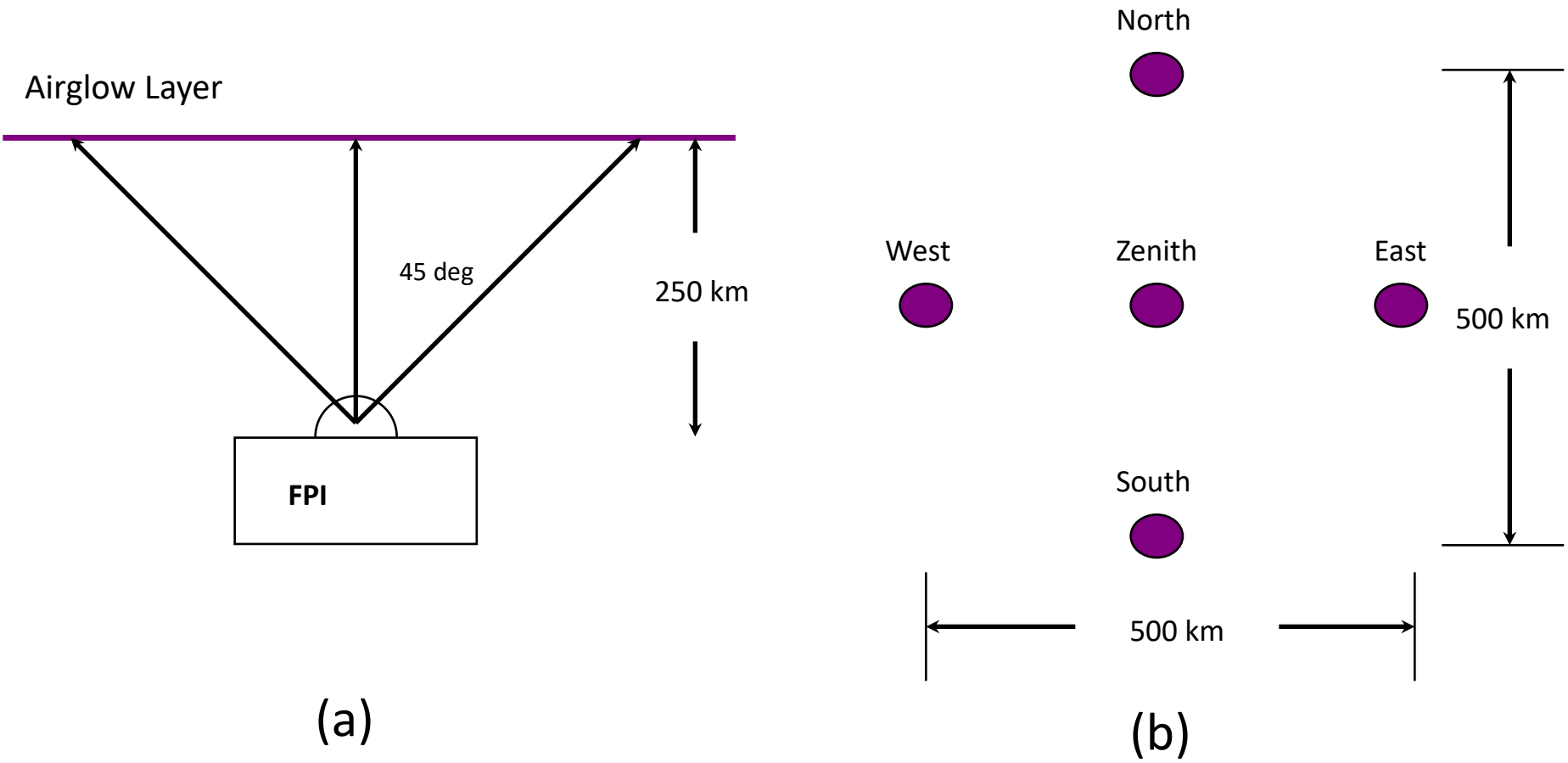
Sky scanner



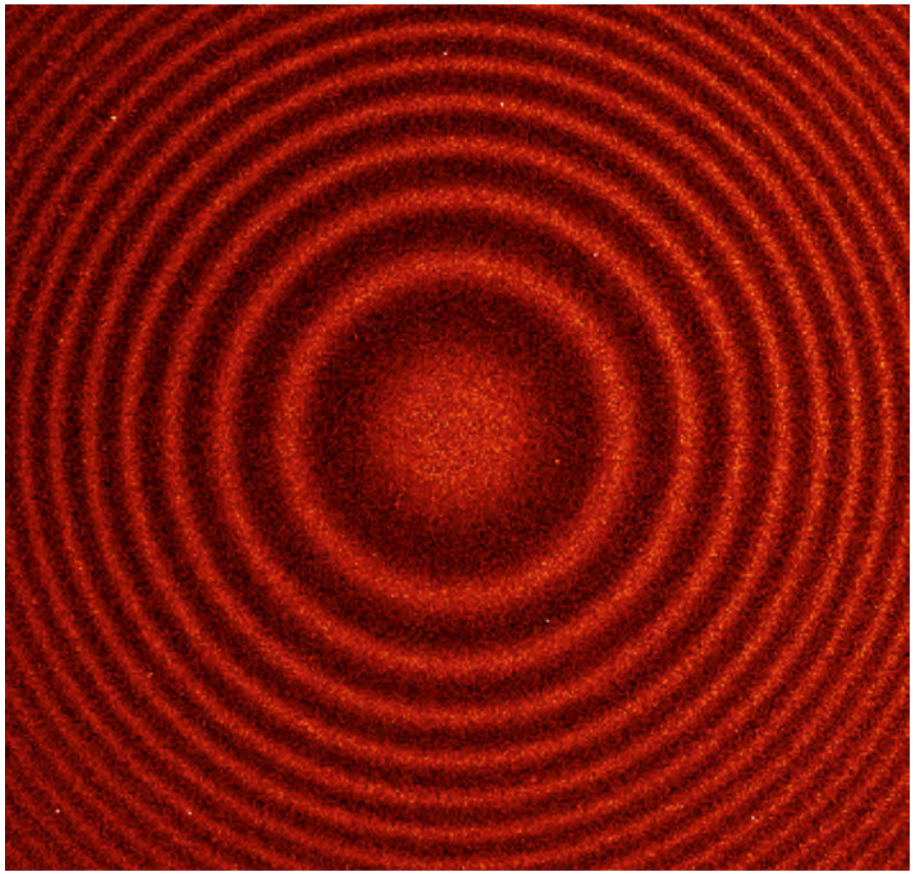
Control electronics

Instrument

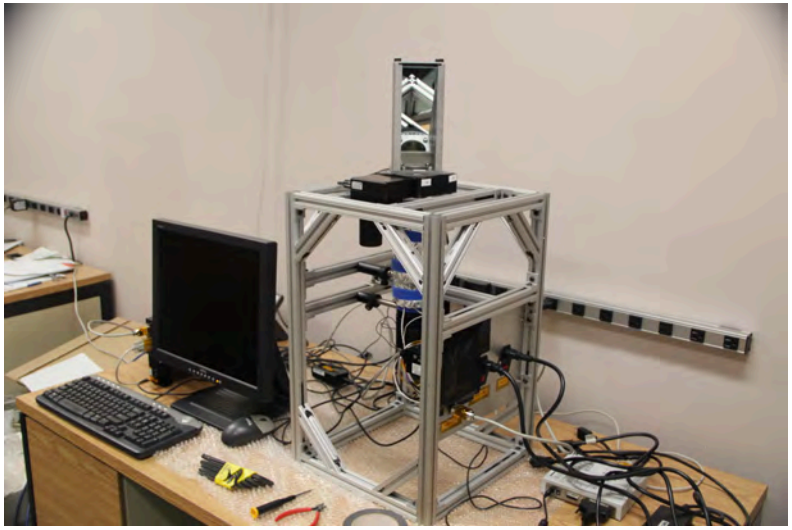
Instrument Operation



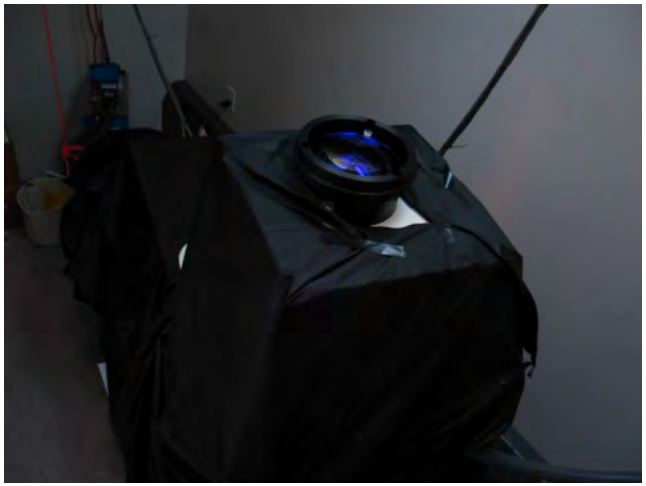
Fabry Perot Interferometer Interferogram



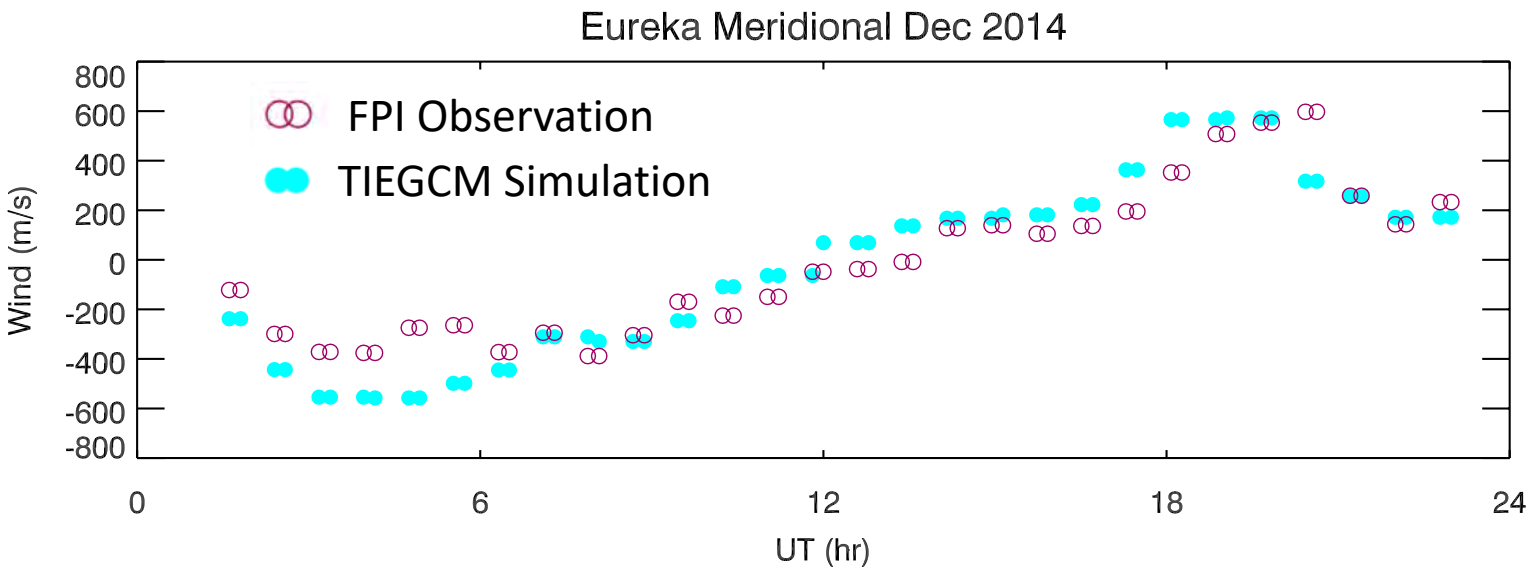
Install Instrument in Eureka

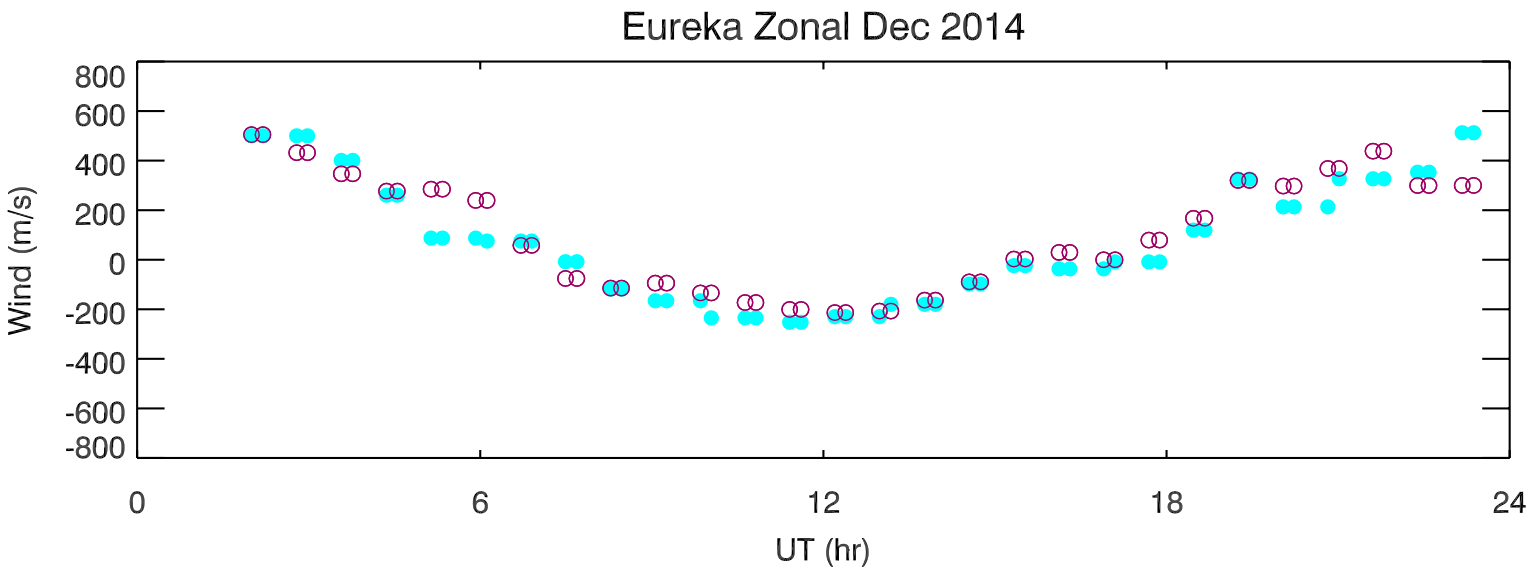


Resolute FPI (75N,94.4W)

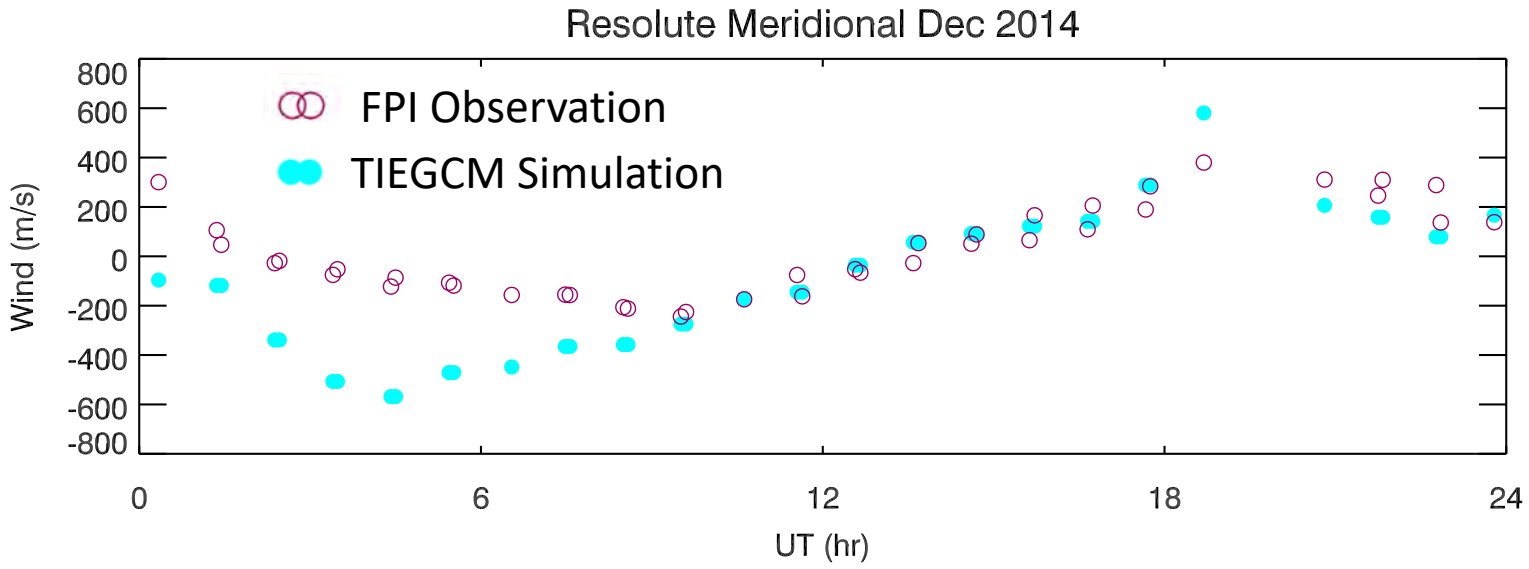


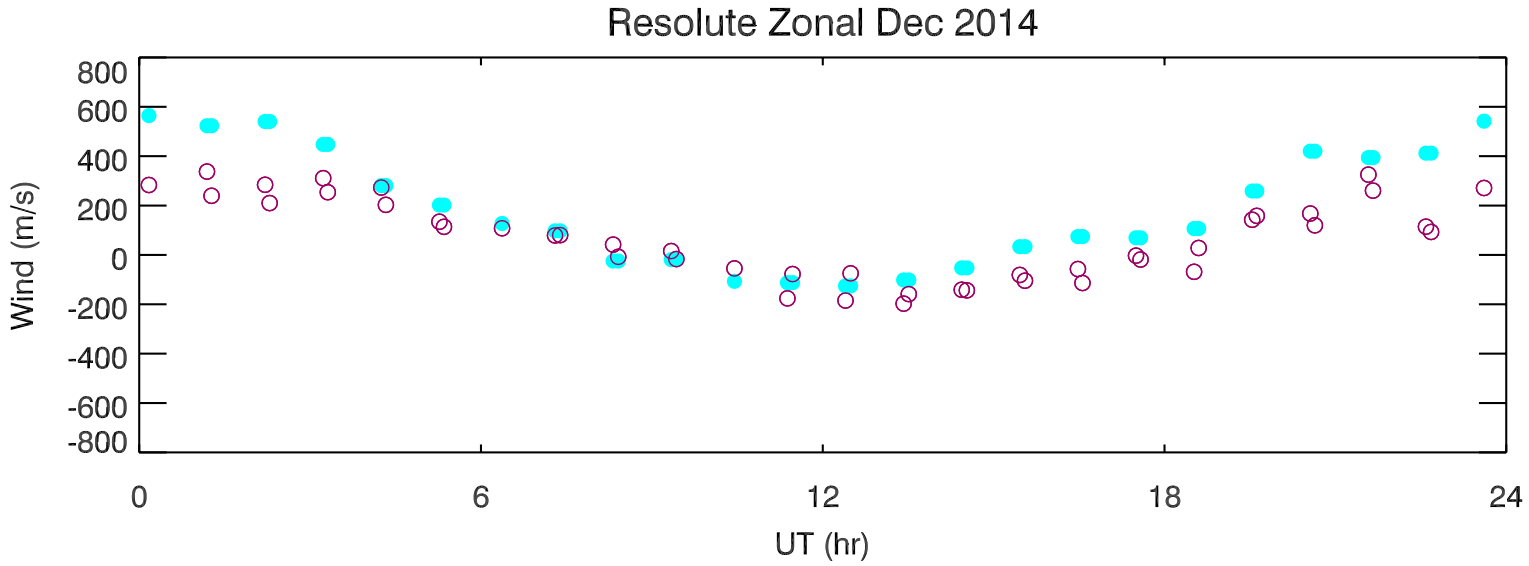
Eureka FPI data 14360



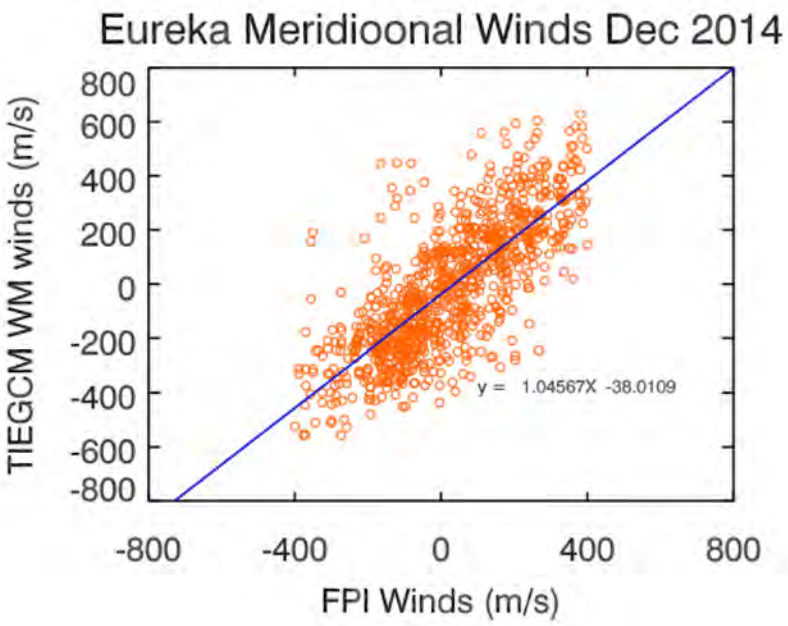


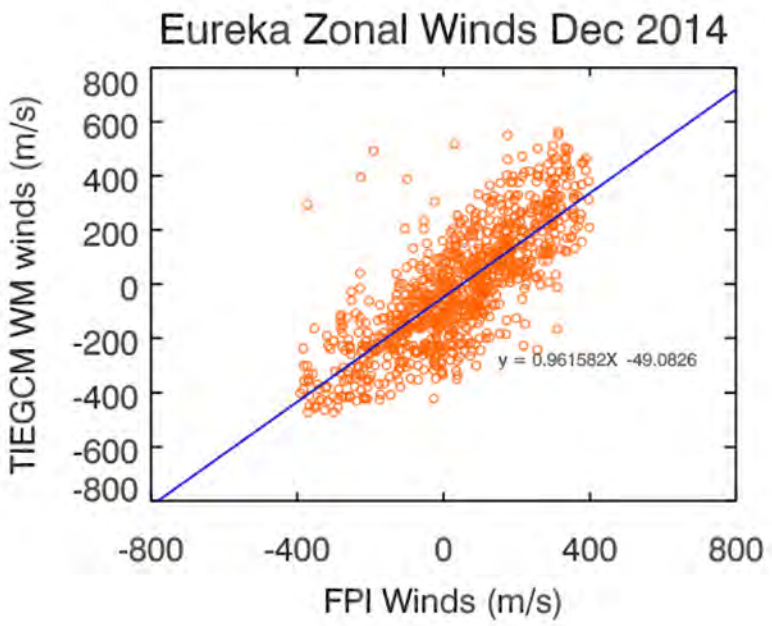
Resolute FPI data 14360



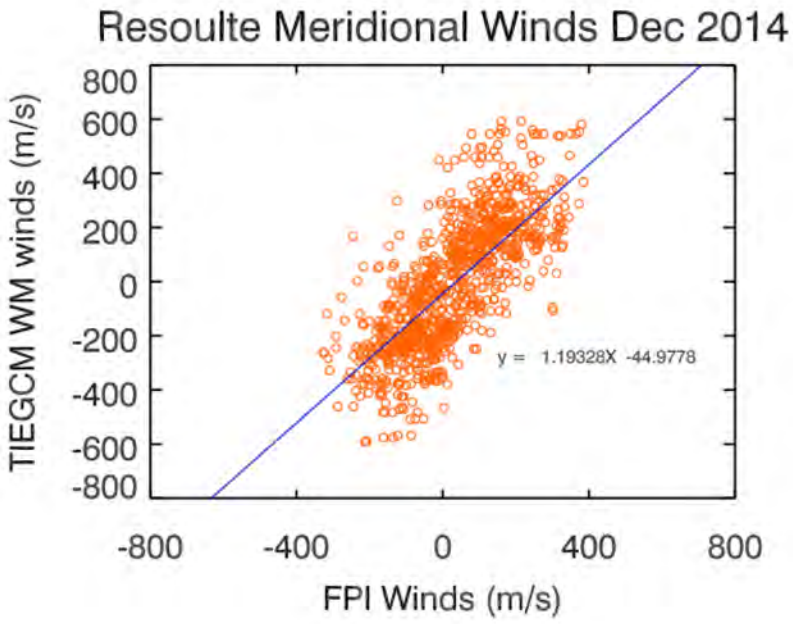


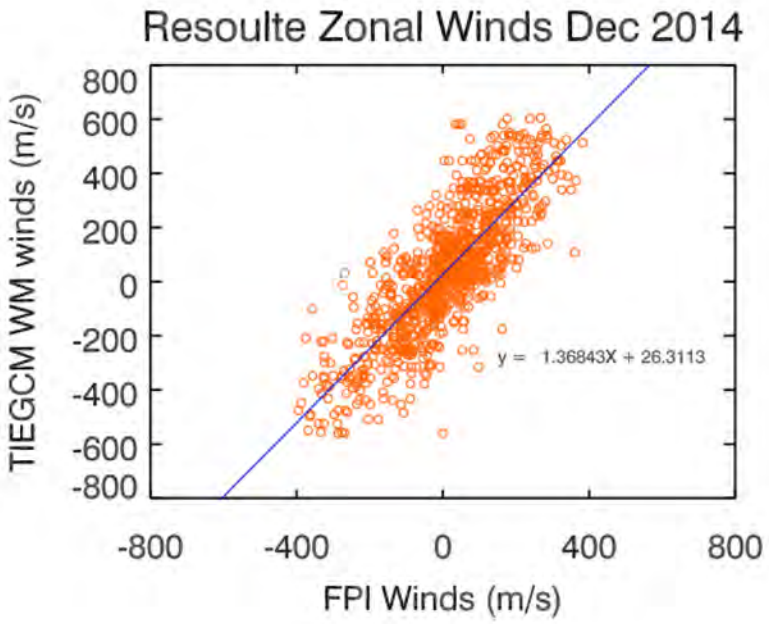
Eureka FPI and TIEGCM Comparison



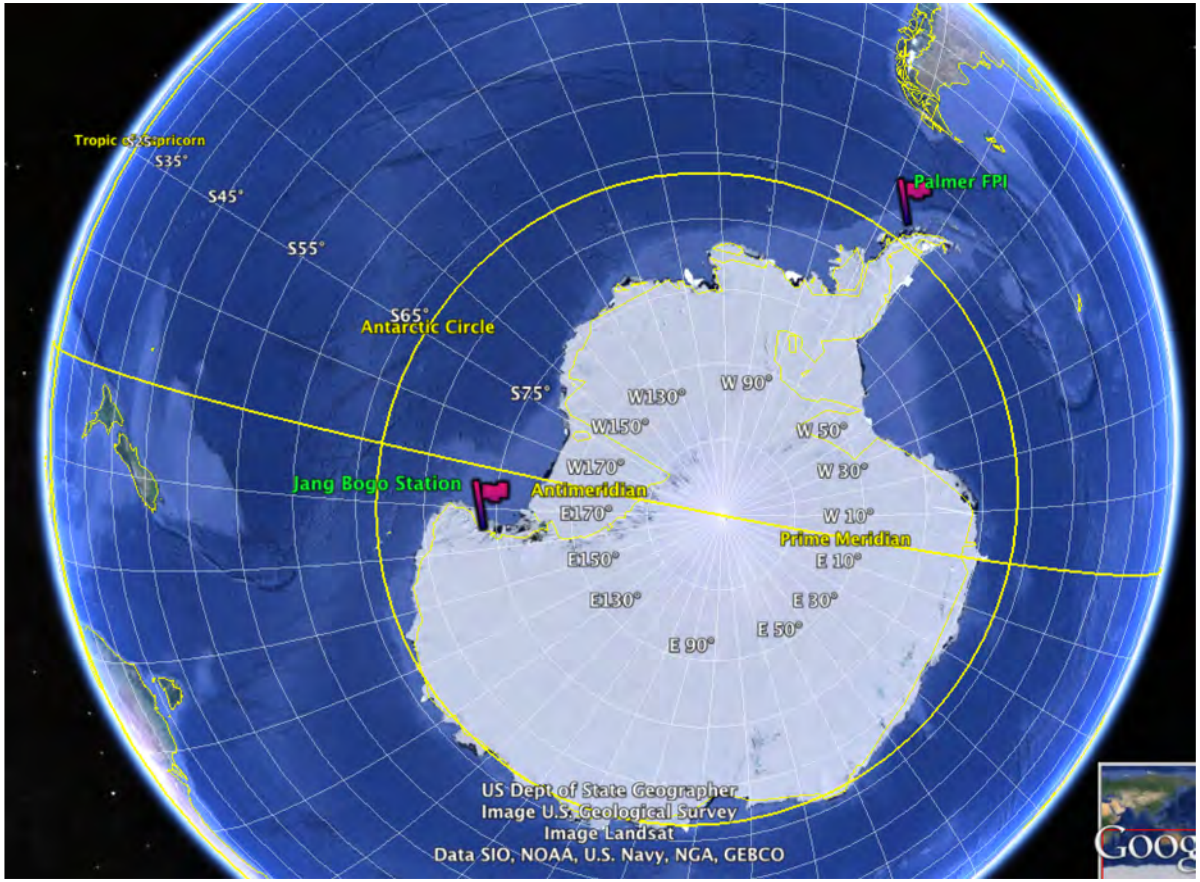


Resolute FPI and TIEGCM Comparison

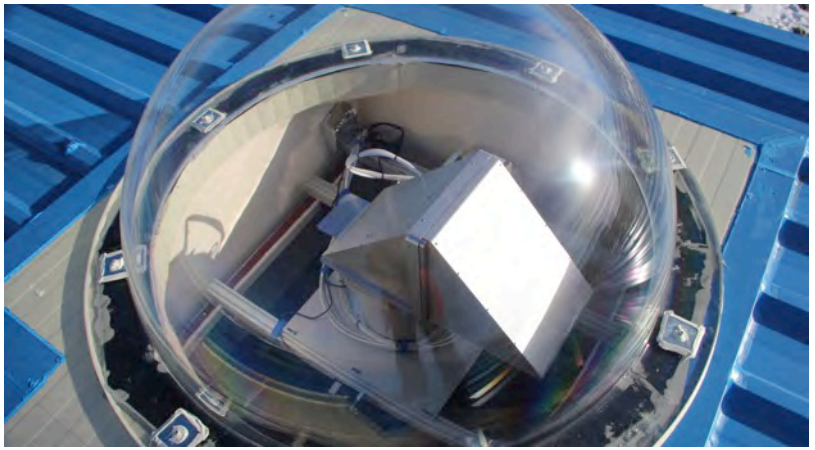


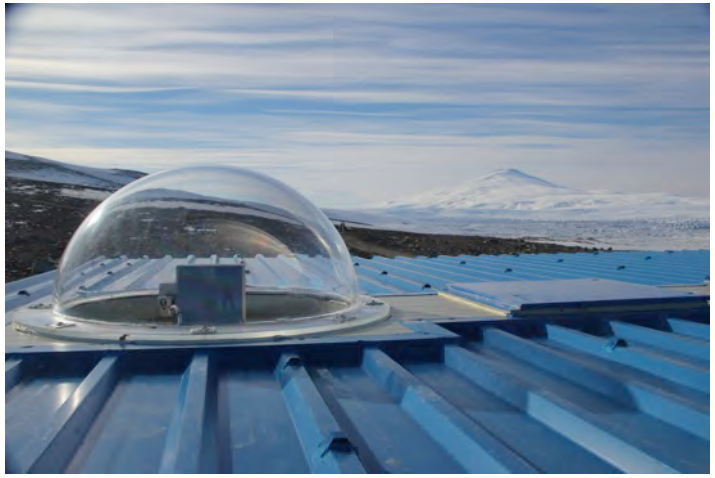


Antarctica Jang Bogo Station

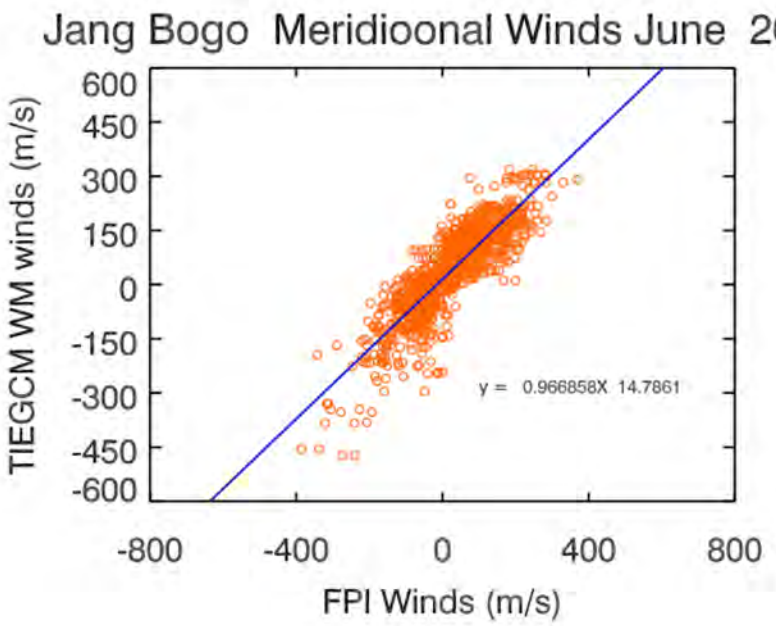


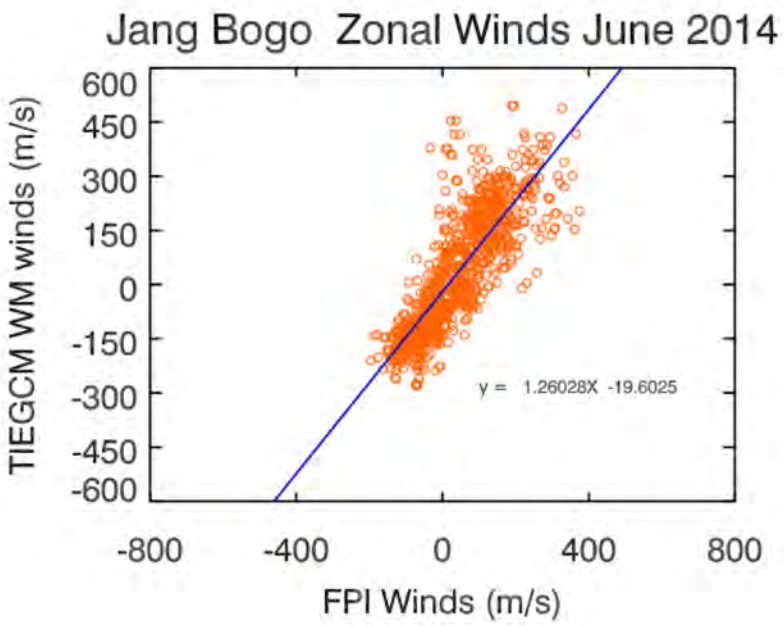
Jang Bogo FPI (74.6S,164.2E ML 77)





Jang Bogo FPI and TIEGCM Comparison





Jang Bogo FPI and TIEGCM meridional and zonal wind point to point comparison. The TIEGCM zonal winds are about 30% larger than the observed values, while the meridional winds are comparable.

Assessment of the TIEGCM at High Latitudes

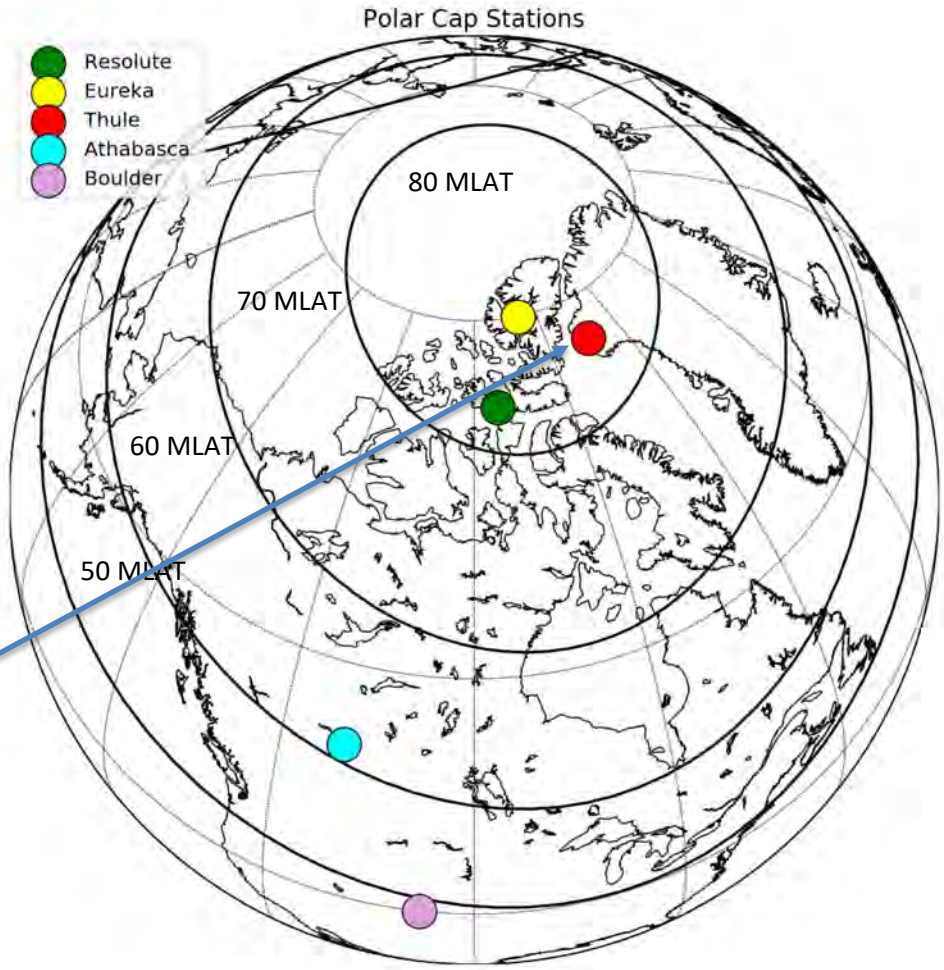
- At very high magnetic latitude, the simulation seems to do a better job.
- At ~80 MLAT, the discrepancy can be as large as ~40%, which will lead to large discrepancy in Joule heating calculations.
- Discrepancy in Joule heating can lead to more errors in thermospheric wind simulation.

Current and future thermospheric wind instruments

Existing Instruments
- Resolute (NSF)
- Eureka (UNB & NCAR)
- Boulder (NCAR)

Future Expansion
- Thule
- Athabasca

Thule Atmospheric Observatory



Current and Future Instruments in Antarctica

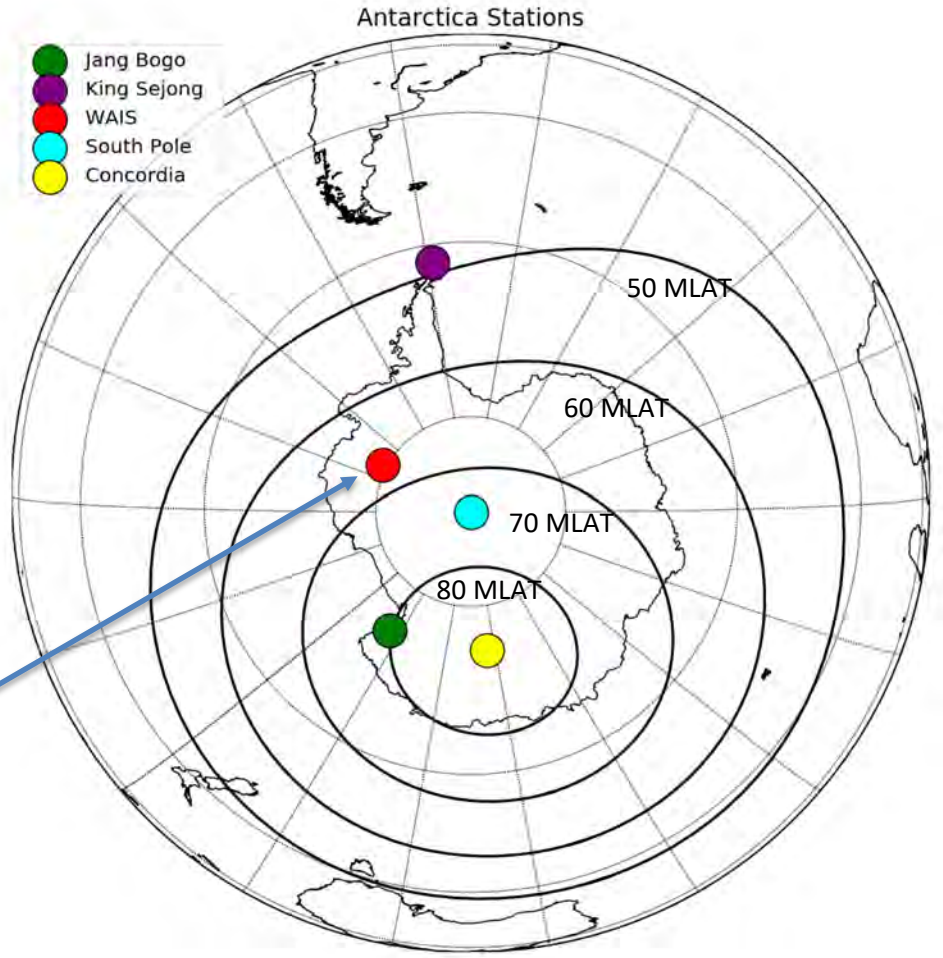
Existing Instruments

- Jang Bogo (KOPRI)
- South Pole (NSF)
- McMurdo (NSF, near Jang Bogo)
- King Sejong Station (KOPRI & NCAR)

Future Expansion

- WAIS (high geographic latitude longer winter time observations)
- Concordia

C130 at WAIS



Upgrade to Automatic Geophysical Observatory (AGO)

- More general purpose
- Higher data link speed
- More power (100s to 1000 W)
- There is a group of scientists interested in deploying instruments at WAIS, where can be a site for a new AGO.

Summary

- We need more thermospheric wind instruments in the polar regions to improve space weather forecast.
- In Arctic region, we would like to add a new instrument at the Thule Air Force Base.
- In Antarctica, we would like to deploy an instrument at WAIS.
- Like to see an upgraded version of Automatic geophysical observatory, which can house more diversified instruments.