Polar Region Thermospheric Wind Observations

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(1) Introduction

Polar cap is the source region of the space weather disturbances, which expand to mid and low latitudes. Large southward IMF Bz leads to strong cross polar cap potential generating intense Joule heating from ion neutral collisions. To understand how much Joule heating is generated, one must know the thermospheric winds. Joule heating affects the global circulation of thermosphere and ionosphere configurations.

Over the years, National Center for Atmospheric Research (NCAR) has been operating ground based Fabry Perot interferometers (FPI) monitoring the thermospheric winds in the Canadian Arctic region by Doppler remote sensing the O 630 nm airglow emission. The ground based FPI however can only operate during the winter season.

NCAR also operates FPI on stratosphere balloon (HIWIND), which can observe thermospheric winds during the day and night. We had three HIWIND flights in the past. Two of them were in the Arctic region.

NCAR is currently building a CubeSat called WindCube, which will provide more affordable satellite wind observations in the polar region during all seasons to support space weather research. This report will give an overview of thermospheric wind observation activities at NCAR to support space weather research.

(2) CubeSat FPI (WindCube)

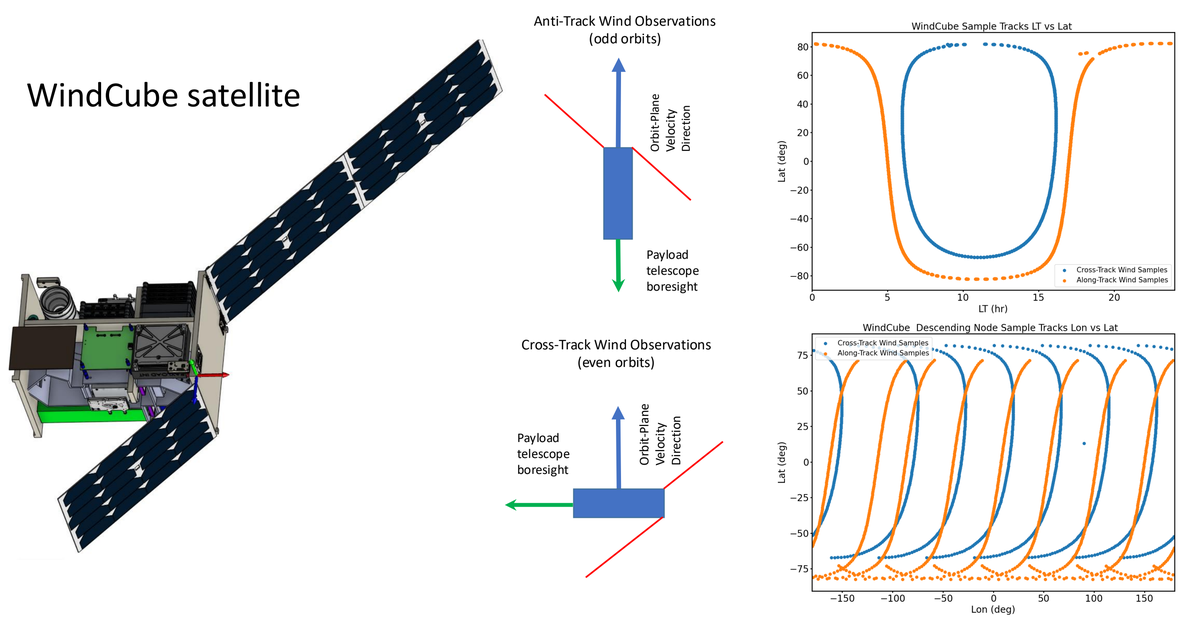


Figure 1: WindCube is a NASA funded 16U CubeSat with an FPI for measuring thermospheric winds using Doppler remote sensing of the O 630 nm emission (left). It is under construction and scheduled to be launched in 2026. It will have a dawn-dusk sun-synch orbit . It will view anti-track (upper middle) and cross-track (lower middle) on alternating orbits to sample meridional and zonal winds. In a high inclination orbit, WindCube will be able observe polar region in the southern hemisphere. In the past, space-borne FPI required large satellite mission with high cost. WindCube offer is an inexpensive way to observe thermospheric winds. Currently, there is no wind measuring satellite in space. The observation will have cover dawn and dusk local times (upper right), with continuous data samples from high to low latitudes over all longitudes (lower right). The instrument will provide wind observations with error about 5 m/s.

(3) HIWIND Balloon Borne FPI

One of the missing pieces of the high latitude thermospheric wind data is summer coverage. The ground based observations of thermospheric winds are for winter season during polar night. Balloon borne FPI at 40 km height can overcome daytime solar scattering problem and make high quality daytime thermospheric wind observations. The NCAR HIWIND (High altitude Interferometer WIND experiment) have made two high latitude flights. In the 2018 flight, HIWIND northern high latitude data were combined with Antarctica ground based FPI to study the high latitude conjugacy.

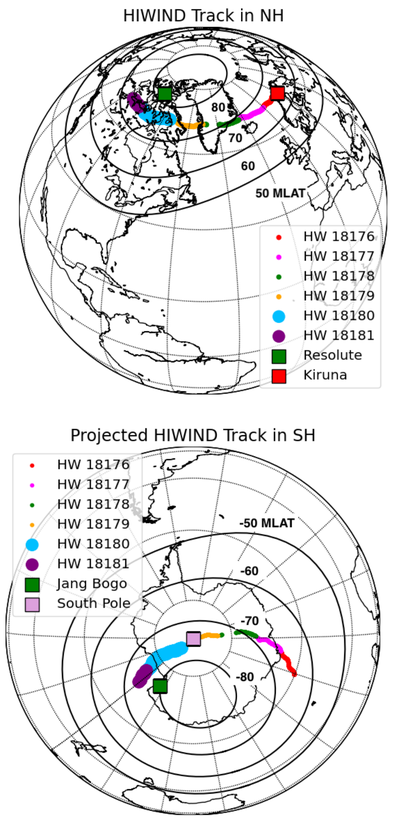
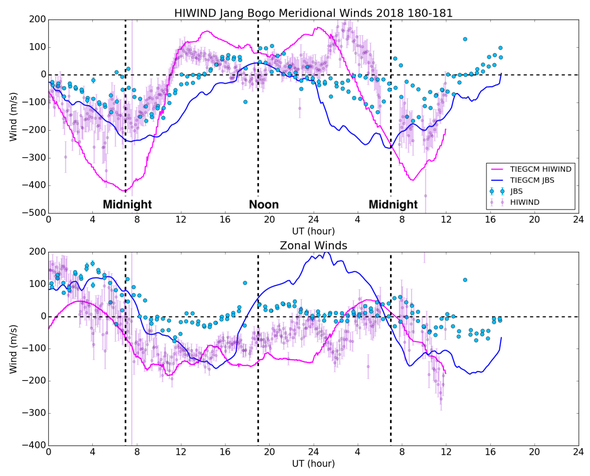


Figure 2: HIWIND on launch vehicle ready to be launched (above). The HIWIND flight path in June 2018 flight from Kiruna (upper left). The different colors are for different days. The HIWIND path projected to the southern hemisphere. During the last two days, the HIWIND projected path in the SH passed the Jang Bogo station (JBS) of KORPI where a ground based FPI. By combining the summer HIWIND NH and winter SH JBS observations, we can examine the high latitude thermospheric wind conjugacy for the first time.

(4) High Latitude Conjugate Wind Observations



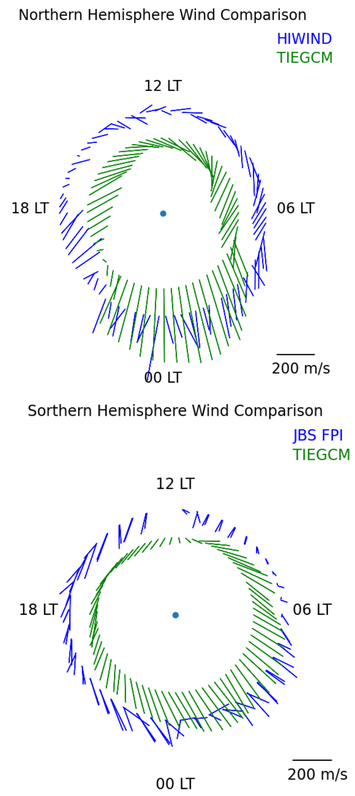


Figure 3: The meridional (upper panel) and zonal winds (lower panel) from NH (magenta) and SH (blue) are plotted. The observations (dots) are compared with TIEGCM model simulations (lines) . During the NH summer time, the HIWIND observed a double-hump feature in the meridional winds, the TIEGCM reproduced this feature whereas in the SH winter time, only a single hump was observed. We believe that is due to strong heating in the cusp and polar cap during the summer time blocking the poleward meridional flow. HIWIND observation was able to verify the simulation results from the TIEGCM. HIWIND observation also show that the TIEGCM overestimate the winds during the nighttime in both NH and SH (right upper and lower).

(5) Past, Current, and Future NH Polar GB FPI

One of the great advantage of the polar ground based FPI is it can last for a long time. Much longer than satellite and balloon observations. The limitation is winter season only. Over the years, multi-generation investigators have deployed FPIs in the NH polar stations such as Thule, Eureka, and Resolute. Long string of the observations have accumulated over decades. It is challenge to maintain the observations. We list the three most high latitude station FPI observations.

- ❖ Thule (76N, 67W, MLAT 86) FPI (1986- 1990)
  Operated by University of Michigan.
- ❖ Eureka (80N, 86W, MLAT 89) FPI (1994- 1999)
  Operated by University of Saskatchewan
- ❖ Resolute (75N, 95W, MLAT 84N) FPI (2004 – 2022)
  Operated by NCAR. The instrument was lost during a fire. We are rebuilding the instrument to be redeployed.

We have analyzed the data from the three stations [Wu et al., 2008]. In most of the time, only one of the FPI is operating. We all know that polar cap neutral convection pattern is more complex and more stations are needed. We have proposed to deploy FPIs at all three stations in the future. We hope to have FPIs at all three stations eventually.

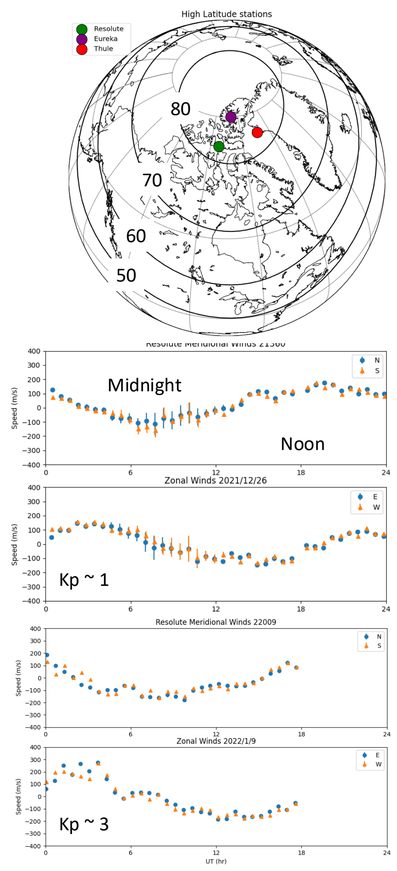


Figure 4: Locations of three stations (upper right). The magnetic latitudes from 80 to 50 are also plotted. All three stations have magnetic latitudes higher than 80. Examples of the Resolute FPI observation of meridional and zonal winds. In this quiet condition (middle right), the meridional and zonal wind has diurnal amplitude of 100 m/s. During magnetic active time (lower right), the amplitude can double or higher depending on the ion drift from the cross polar cap potential.

(6) Summary

We give an overview of polar region thermospheric wind observations based on ground based, balloon borne, and spaceborne FPIs. They each have their strengths and weakness. They complement each others.

- ❖ Ground based FPI
  - Good local time coverage during night.
  - Fixed location
  - Long term observations (over decades)
- ❖ Balloon borne FPI
  - Good local time coverage during day and night
  - Slow moving (~ 10 m/s)
  - Short campaigns
- ❖ Satellite Borne FPI
  - Limited local time
  - Fast moving global coverage
  - Multi-season and possibly multi-year

NCAR offers or will offer data from these different platforms to resolve geospace questions from decadal scale to day-to-day short term scale; from regional scale to global scale; from nighttime only to both day and night time. Each of the platform can offer unique perspective to address specific questions. Thermosphere is affected by long term solar cycle as well as short term solar storms, these different platforms can help tackle different time scales to understand the solar UV input effect and geomagnetic storm effects. Thermosphere is also influenced by small scale gravity waves and global scale tidal waves. Different platforms that can address regional and global scale issues are needed. It is important to maintain the ground based instrument at same time fly more balloon borne and spaceborne instruments.

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