Observing Space Weather in the Earth's Atmosphere

Qian Wu
HAO NCAR

In Collaboration with
And HAO IG, S. Sewell, G. Card, A. Lecinski
Outlines

- Introduction & Motivation
- Overview of the observation method.
- High Latitude Observations and Simulations
  - Recent deployments and upgrades have resulted in three FPIs operating in the northern and southern polar caps at Eureka (80N), Resolute (75N), and Jang Bogo (75S).
  - Comparison with NCAR TIEGCM and CMIT models
- Future Balloon FPI Observations in Antarctica
Introduction

- One of the major scientific objectives of HAO is to study the solar effect on the Earth environment and social and economical impact, which includes space weather.
- The ionosphere related space weather effect can impact communication, GPS, and possibly power grid, which is a main topic for HAO modeling and observational efforts.
- Part of the HAO observational effort is to measure the thermospheric winds.
Ion Density Profile

The graph illustrates the ion density profile as a function of altitude (km) and number density (cm$^{-3}$). Different ions and molecules are represented, including He$^+$, H$^+$, O$^+$, N$^+$, N$_2^+$, NO$^+$, O$_2^+$, O$_2^+$, and Ar. The x-axis represents the number density, while the y-axis represents the altitude.
Motivation

- Thermospheric winds are one of the most important parameters for understanding the ionosphere and thermosphere interaction.
- At high latitudes, thermospheric winds are directly related to the Joule heating and determine how energy transfer from the solar wind to the ionosphere and thermosphere system.
- At mid-latitudes, thermospheric winds can move the ionosphere upward and downward along the magnetic field lines and changing the chemical environment of ions reducing and increasing the ionosphere density.
Aurora and Nightglow
Doppler Shift in Wavelength
Thermosphere Nightglow Volume Emission Rates

![Graph showing altitude vs. volume emission rate](image-url)
Airglow Emission Sources

O 6300 Å red line

Electron impact

\[ O + e \rightarrow O(^{1}D) + e \]

Photodissociation of O2

\[ O_2 + h\nu \rightarrow O + O(^{1}D) \]

Dissociative recombination

\[ O_2^+ + e \rightarrow O + O(^{1}D) \]
Fabry-Perot Interferometer
Charles Fabry and Alfred Pérot

From Mulligan, 1998
Etalon

Incoming Light

Optical Axis

Fabry-Perot Interferometer

Imaging Lens

Image Plane
Fabry-Perot Fringe Pattern
Sky Scanner
Instrument Operation

(a) Airglow Layer

(b) North

45 deg

250 km

FPI

East

South

Zenith

West

500 km

500 km
Northern Polar Cap Observations
Eureka (80N, 86W, MLAT 88)
Resolute FPI (75N,94.4W)
Thermospheric wind from Eureka FPI on day 14360 (purple) and TIEGCM simulation (light blue). The model and observations agree very well. There is small difference before 6 UT (local midnight). The local noon is at 18 UT.
Thermospheric wind from Resolute FPI on day 14360 in comparison with the TIEGCM simulation. The TIEGCM overestimate the meridional winds on the nightside (The local midnight is at 6 UT).
Polar Region Thermospheric Wind Pattern

Day night Pressure gradient

noon
dusk
dawn
midnight
Southern Hemisphere Polar Cap Station Jang Bogo (74.6S, 164.2E)
Jang Bogo FPI (74.6S,164.2E)
Jang Bogo O 6300 Data 2014

Meridional Winds Jang Bogo O 6300 2014

Zonal Winds Jang Bogo O 6300 2014
Jang Bogo FPI and TIEGCM Comparison

Jang Bogo Meridional June 2014

Jang Bogo Zonal June 2014
Coupled Magnetosphere Ionosphere Thermosphere model (CMIT)
Resolute CMIT & Weimer (TIEGCM)
King Sejong Station FPI (62S, 58W)
Boulder FPI (40N, 105W ML 48)
Abuja FPI (9.1N, 7.4E)
HIWIND Balloon FPI June 14, 2011
HIWIND Liftoff
Balloon Size

Balloon at Launch
- 25.2 m (83 ft)
- 171.6 m (563 ft)
- 261 m (856 ft)

Furled Parachute
- 61 m (200 ft)
- 3 m (10 ft)

Washington Monument
- 169.3 m tall (555.4 ft)
- 204.5 m (671 ft)

Ladder
- 3 m (10 ft)

Payload
- 64 m (210 ft)

Balloon Characteristics:
- Balloon Volume: $1.12 \times 10^6$ m$^3$
- Balloon Surface Area: $89.50 \times 10^6$ m$^2$
- Skin Thickness: 20.32 microns
- Length of Seams: 32.20 km
- Nominal Altitude: 40.20 km
- Max. Payload Weight: 3,175 kg
- Balloon Surface Area: 39.57 \times 10^6$ ft$^2$
- Balloon Volume: 22.19 acres
- Skin Thickness: 0.8 mil
- Length of Seams: 21.6 miles
- Nominal Altitude: 132,000 feet
- Max. Payload Weight: 8,000 pounds
HIWIND Flight Path June 14-17, 2011
New TIEGCM Simulations

HIWIND 2011165  Meridional Winds

Speed (m/s)

UT (hr) LT = UT+1
New Comparison with CMIT Simulations

a) MERIDIONAL NEUTRAL WINDS

![Graph showing meridional neutral winds comparison]

- HIWIND
- TIEGCM+Heelis
- TIEGCM+Weimer
- TIEGCM+LFM

RMS-Deviation:
- HIWIND: 91.3 m/s
- TIEGCM+Heelis: 73.8 m/s
- TIEGCM+LFM: 37.9 m/s

From Zhang et al. 2016
HIWIND Landed in Canada
HIWIND team
NASA Columbia Scientific Balloon Facility Crew
Future Plan for Antarctica Flight
Summary

- HAO is expanding its thermospheric wind observation from high- to low-latitude around the world to serve the community in study of the space weather and upper atmosphere dynamics.
- Thermospheric wind observations are very important for validating ionosphere and thermosphere models from NCAR and other institutes.
- HAO observational efforts all have strong international collaborations, which are essential for the advance of the space weather research.
- HAO observational projects also received strong support from other NCAR Labs (e.g., EOL) and UCAR programs (e.g., COSMIC). We are looking forward to more collaboration within NCAR and with other international partners.