Thermospheric Dynamics: Past informs present

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Best Source on the FPI

• Proud to have been Gonzalo’s mentee
• This tome is the ultimate deep dive into the FPI
• He was “the perfectionist’s perfectionist”
Selective History of Auroral FPI measurements

• 1955: Dave Wark used a FPI brought to College by C.T. Elvey to measure the width of the 15,867 cm\(^{-1}\) (630 nm) line in twilight and aurora
  
  • He obtained a temperature of 710±50 K in twilight, 730±80 K in aurora.
  
  • Wark concluded the emission layer height was ~210 km.
  
  • First imaging work

• 1961: Nilson and Shepard obtained temperatures in auroral structures using the 17,924 cm\(^{-1}\) (557.7 nm)
  
  • Gordon Shepard has made many innovative instruments during his 50+ year career, including the first “digital array” FPI for auroral measurements
History

1972: Hays, Meriwether, and Roble bring a FPI to Ester Dome and measure winds using the red line.

The Height Problem

- Passive remote sensing has poor vertical resolution
- Red line emission is broad and variable
- This was used to argue temperature wasn’t useful
  - What about wind shear? (viscosity)
  - Temperature is hard, not useless

Constant SNR scanning

- Auroral variability is fast
- We take for granted now videos which show the OI emissions lagging behind the precipitation.
- First colour cameras to show this were a big deal
- We compensated by using the time to achieve a constant SNR as opposed to a constant sampling interval.

Average Horizontal Winds

- 10 - Low, 25 - Moderate, 9 - High activity nights

Average Vertical Winds

- Note on systematics. We used a single frequency HeNe laser measured against the 18,857 cm⁻¹ (530 nm) neon line; over many hours the “wind” was always less than 20 m/s.

- We lumped the systematic into the random for a total uncertainty in all plots.
Normal Means Substorms

- Substorms define the steady state in the auroral zone, much like thunderstorms define the ITZ (intertropical convergence zone).

![Meridional Wind, December 20, 1982 UT](image1)

Fig. 1. Wind measurements on December 20, 1982, UT, (a) meridional, (b) zonal, and (c) zenith. The coordinate system employed has northward, eastward, and upward positive. The zonal measurements are shifted in magnetic local time (MLT) to the time at the point of observation for an assumed 225 km emission layer. The solid line is the high geomagnetic activity wind average from paper 1. The uncertainty of the line is about ±30 m/s.

Temperature Response to Precipitation

Fig. 4. The ratio of 15867 K to 23368 K emission rates in the College magnetic zenith calculated from intensity measurements obtained with a tilting-filter meridian-scanning photometer on December 20, 1982, UT.
“Disturbed” Conditions

- Here disturbed means no substorm.
- “Wave” in vertical winds until...
- A substorm comes along and smooths out the flow.
Interesting Variations with $B_y$

Fig. 2. Individual components of the wind and temperature averages for $B_y$ positive and negative for cases 1 and 2. The measurements were obtained in the magnetic dipole north, south, east, and west. The bar through the conditioned is the root mean-square deviation of the average is height. The predictions of the NCAR F12CM at a height of about 225 km are also shown for the grid point nearest College.

Ion Energy Balance

- The impetus behind CEDAR was GBOA
- Initially poor synergy between optical and radar techniques
- Fortunately that is in the distance past (scientifically)
- I believe there have been quite a few significantly better studies like this since.

OEM for profiles?

• Everything about the optimal estimation method in 15 s

• Data
  • FPI intensity scan
  • Red line intensity

• Forward model:
  • Volume emission profile
  • Instrument function

• Retrieve
  • Volume emission profile
  • Weighted temperature
Summary

• Auroral substorms define the steady state for the auroral zone
• Relaxation from the steady state “stagnates” the flow
• Neutral atmosphere responds rapidly to the magnetosphere: so focus on the relation to morphology.
• Temperature measurements are useful, and their interpretation improved, possibly using inverse modelling.
• Don’t forget the green line.
• Use an alkali metal lidar in the upper mesosphere & lower thermosphere. With the green line could validate the inverse model.