Comparison of Allsky-FPI inferred Thermospheric Neutral Winds with TMA Wind Profiles on March 2, 2017

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Outline of this Talk

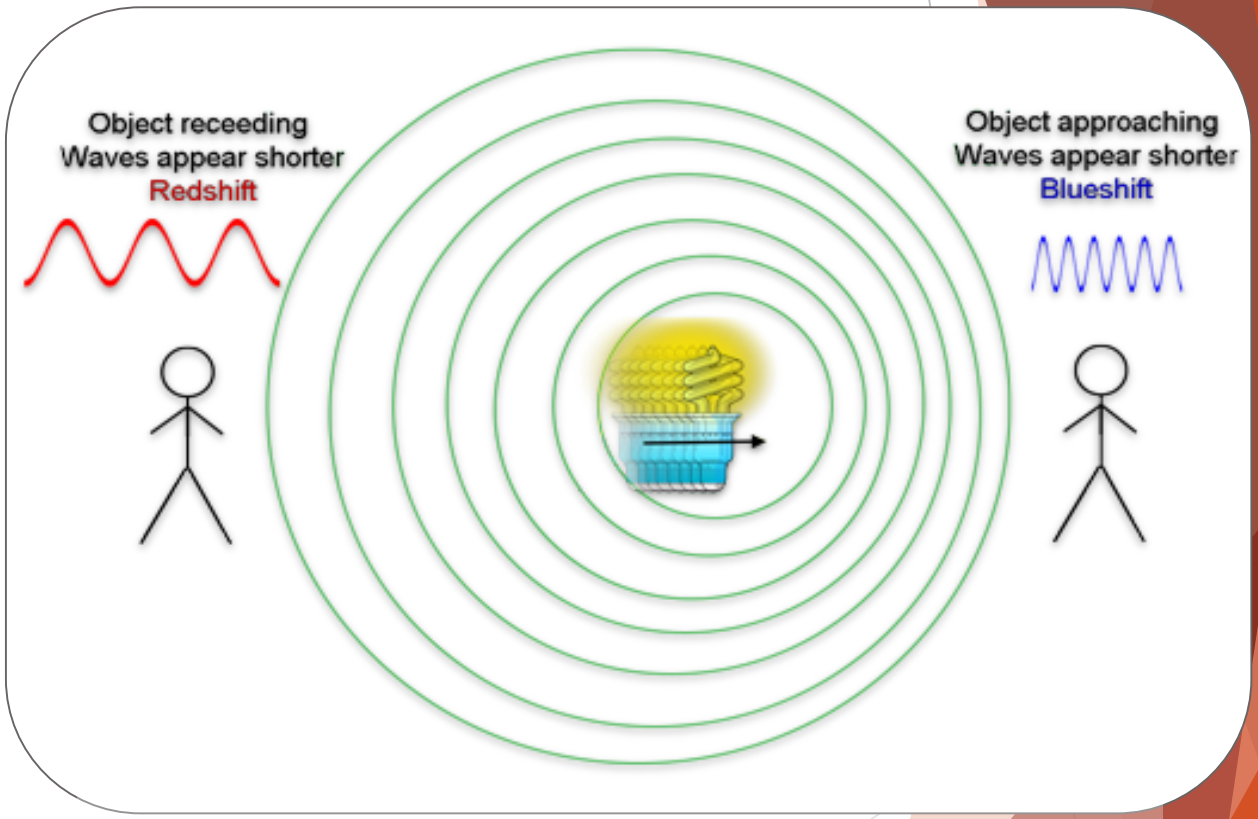
- Briefly describe a Fabry-Perot Interferometer (FPI)
  - Standard concept FPI
  - Scanning Doppler Imager (SDI)
- Describe the geophysical inverse algorithm used
- Compare inverse technique to previously validated method applied to FPI data for the same night
- Compare inverse winds to Trimethylaluminium (TMA) wind profile
- Discuss results

How An FPI Works : Doppler Shift

- [O] is sending signal at known frequency in the Thermosphere
  - The received signal has shifted peak and broader spectrum
- Light travelling away from instrument will have longer wavelengths
- Light travelling towards instrument will have shorter wavelengths
- Observed Frequency is :

$$f = \left(1 + \frac{\Delta v}{c}\right) f_0$$

- Spectral width describes random motion (total motion minus bulk flow), e.g. temperature



Credit: NASA's Imagine the Universe
https://imagine.gsfc.nasa.gov/features/yba/M31_velocity/spectrum/doppler_more.html

The Alaskan Allsky Interferometer Network

- Scanning Doppler Imagers (SDIs) are an allsky viewing implementation of a Fabry-Perot Interferometer (FPI)
- SDIs are capable of resolving hundreds of look directions simultaneously
- One SDI has ~500km viewing radius at 240km Red-line spectra
- Alaskan Network has partially spatially overlapping SDIs spread across Alaska
- SDIs autonomously operate and collect laser drift correction throughout the night
- Locations: Poker Flat, Eagle, Toolik Field Station, and Kaktovik

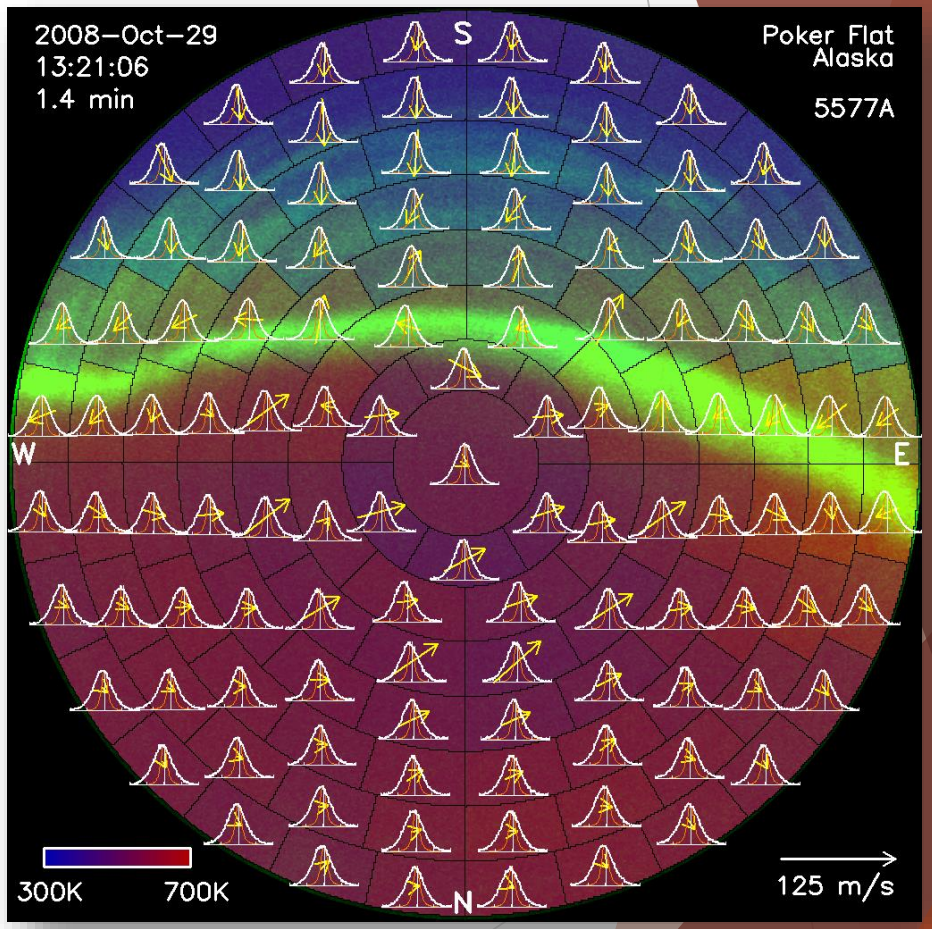
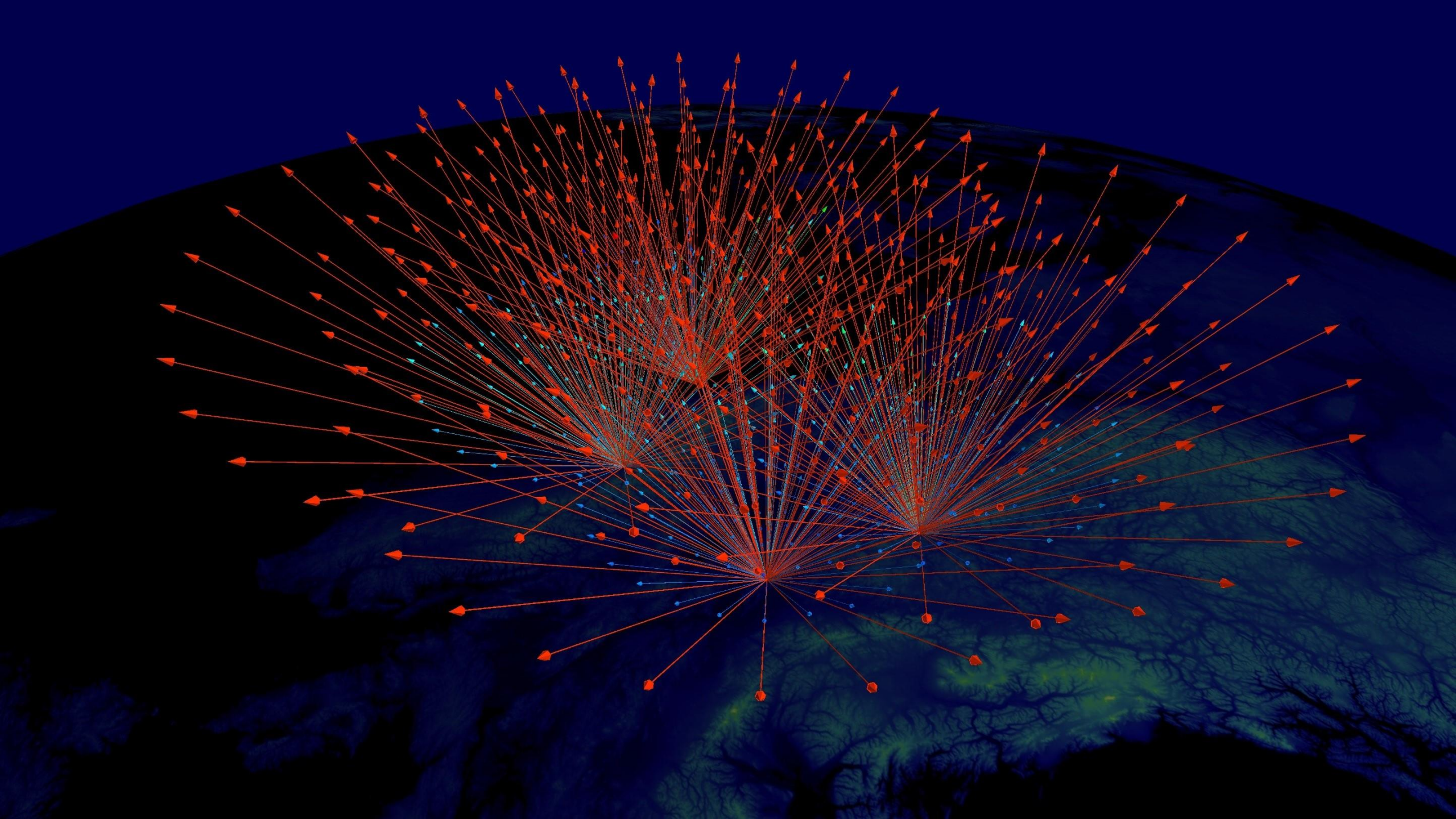


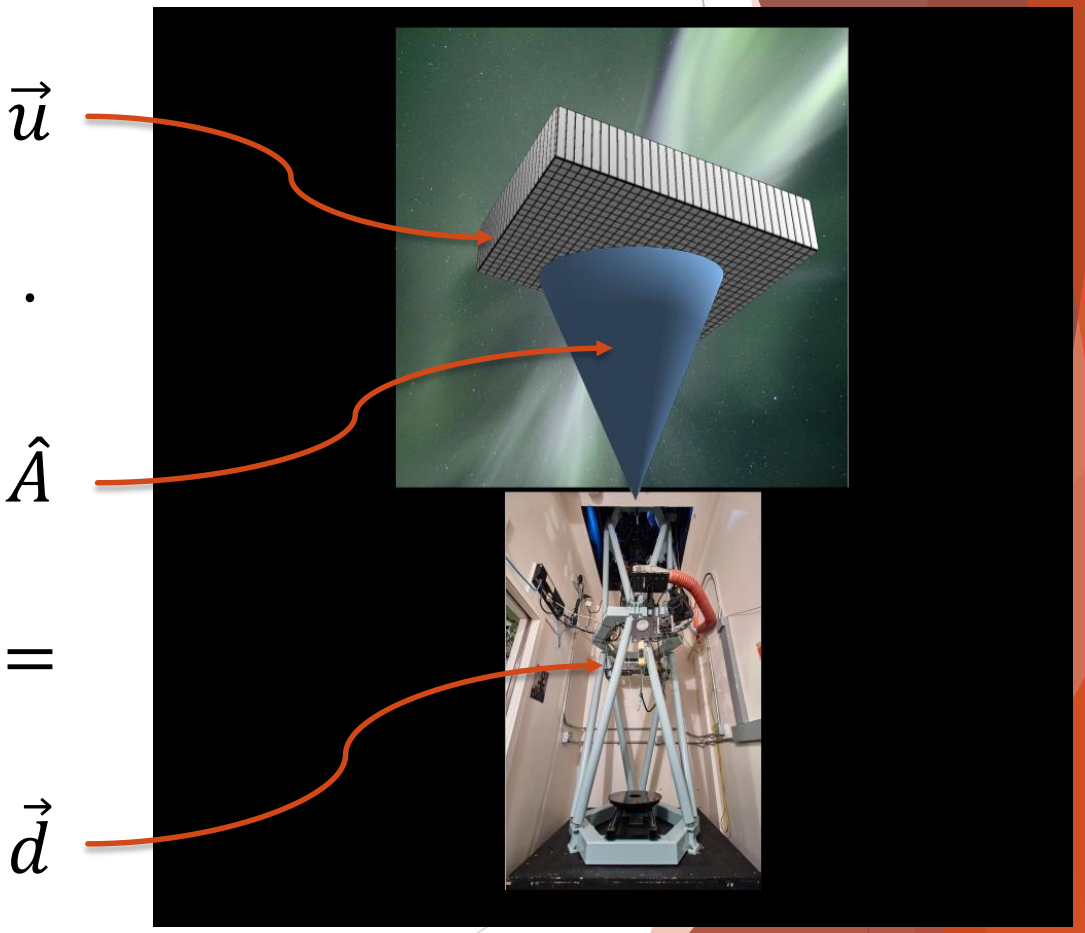
Image shows individual spectra and temperature collected by Poker Flat SDI. SDI can be used as crude imager as well, as shown. Plot courtesy of Mark Conde University of Alaska Fairbanks



The Geophysical Inversion Algorithm

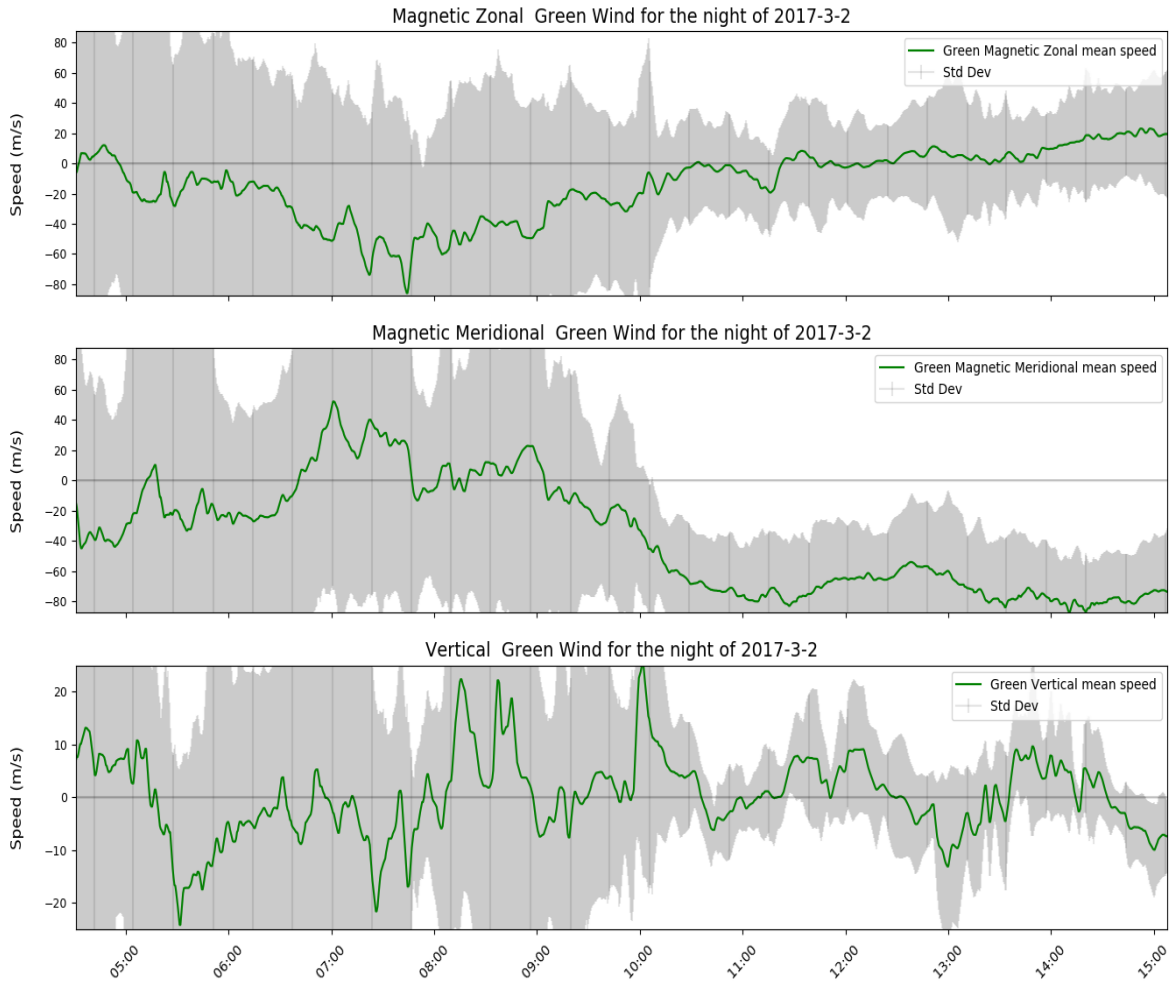
- Tikhonov Regularized method
  - Forward Model : $\vec{d} = \hat{A} \cdot \vec{u}$
  - $Loss\ Function$: $\left\|\hat{A} \cdot \vec{u} - \vec{d}\right\|_2^2 + \left|\left|\hat{\Gamma} \cdot \vec{u}\right|\right|_2^2$
  - $Analytic\ Soln$: $\vec{u}^* = \left(\hat{A}^T \hat{A} + \hat{\Gamma}^T \hat{\Gamma}\right)^{-1} \hat{A}^T\ \vec{d}$
  - $Tikhonov\ Matrix$: $\hat{\Gamma} = \alpha \cdot \hat{\mathrm{I}}$
- Instrument Transform $\hat{A}$ is geometric
- α is condition optimized using SVD
- Multiple SDI datasets are incorporated
- Fully automated, self optimizing
- Red : 25km x 25km grid element resolution

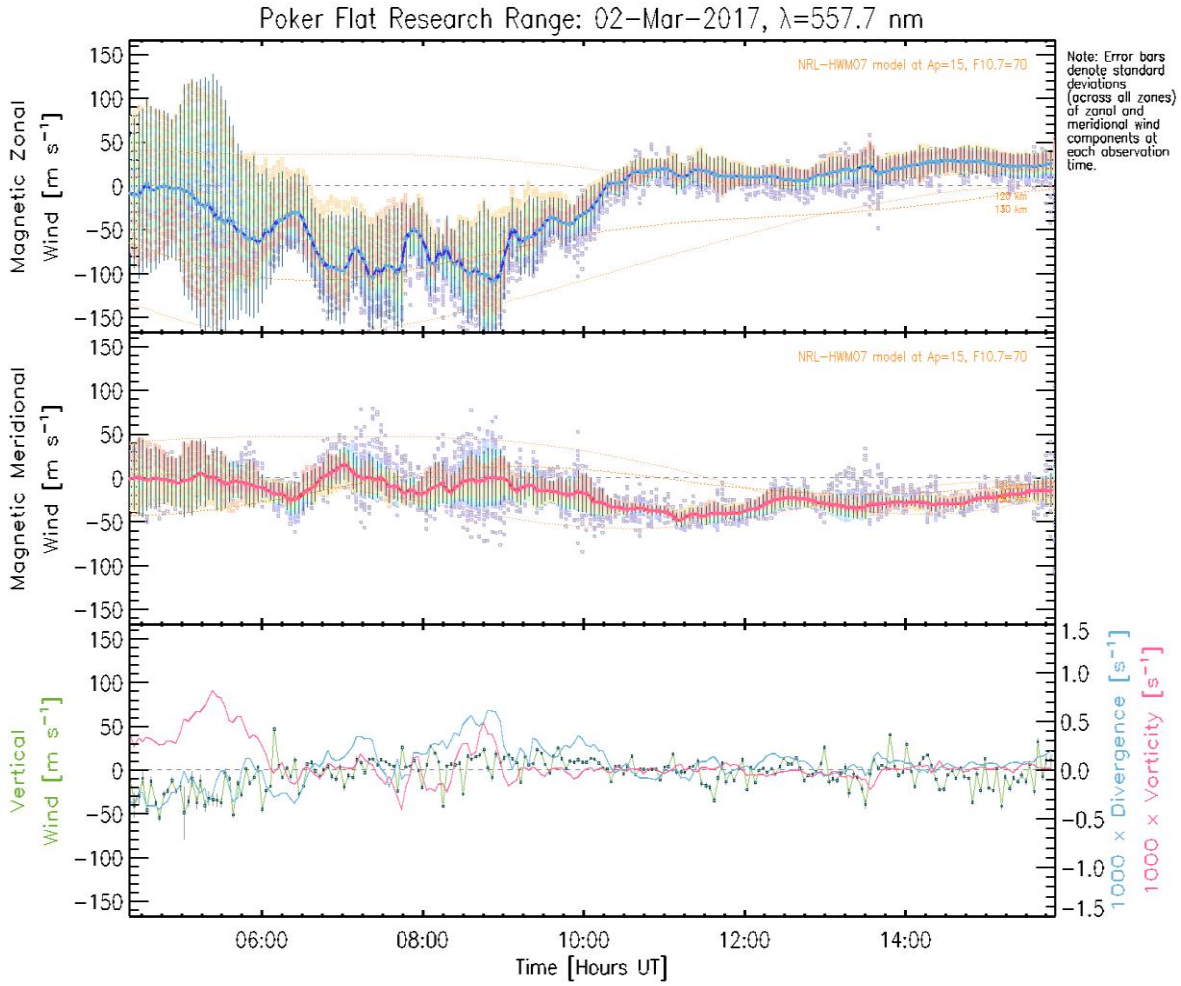
  Green : 20km x 20km grid element resolution



Graphical representation of forward model

Mean Winds over the State of Alaska for the Night of March 2nd, 2017





Left : Green-line winds inferred over Alaska by geophysical inverse technique. Right : Monostatic green-line wind fit over Poker Flat provided online by Mark Conde

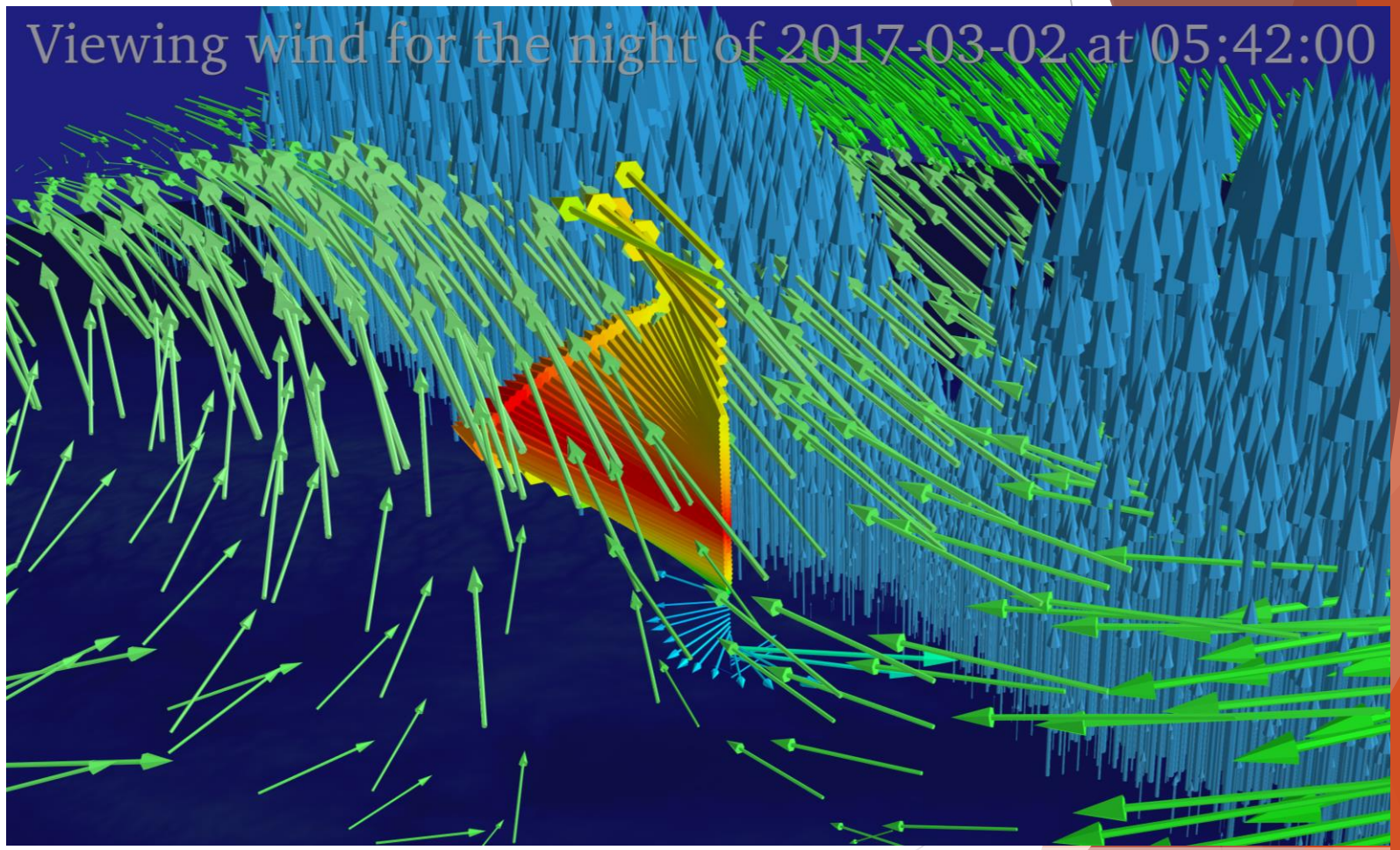
JETS Launch on the night of March 2nd, 2017

- Twin rockets Launched 90 seconds apart
- Both rockets released TMA
- TMA profile constructed from ~95km to 180km altitude
- Horizontal wind profiles developed by Miguel Larsen, Clemson
- Mission is looking for Neutral Jets in Auroral Arcs (JETS)

Image of the second JETS rocket launching. Smoke plume from the first launch present left of the imaged launch.

Comparing TMA Winds on Up-Leg

- TMA up-leg TMA profile
  - Time : 0542
  - Lat : 65.12 Degrees
  - Lon : -147.43 Degrees
- Green-line MSIS-estimated altitude is 135 km
- TMA windspeed at 134.6km
  - u = -227.6 ms^{-1}
  - v = 274.7 ms^{-1}
  - Φ = 129.6 Degrees
  - Speed : 356.7 ms^{-1}
- Inverse windspeed at 135km
  - u = -109.5 ms^{-1}
  - v = 147.7 ms^{-1}
  - Φ = 126.5 Degrees
  - Speed : 191 ms^{-1}



Scene is viewed approximately 100 miles southeast of Poker Flat bearing 305 degrees at 150km altitude. Blue vertical vector are log-intensity of Poker Flat allsky imager provided online by Don Hampton. Green arrows are geophysical inverse inferred green-line winds. Jet color-mapped vectors are TMA upleg wind profiles.

Understanding the Differences

- TMA is considered ground truth
- Resolutions of both techniques are quite different
  - TMA resolves to a volume of about 1km x 1km x 1km
  - Allsky-FPI at green-line altitude can best-case resolve about 25km x 25km area
- Altitude of observation is absolute with TMA, relative and averaged with FPI
- Wind angle difference is 3.1 degrees
  - Not statistically significant
  - Considered in good agreement
- Geophysical inversion under-reports winds by half
  - Inverse algorithm applies smoothing that tends toward zero
  - FPIs are averaging over much larger areas, tending toward lower wind speed

Observing Neutral Jets in Auroral Arcs (The JETS Mission)

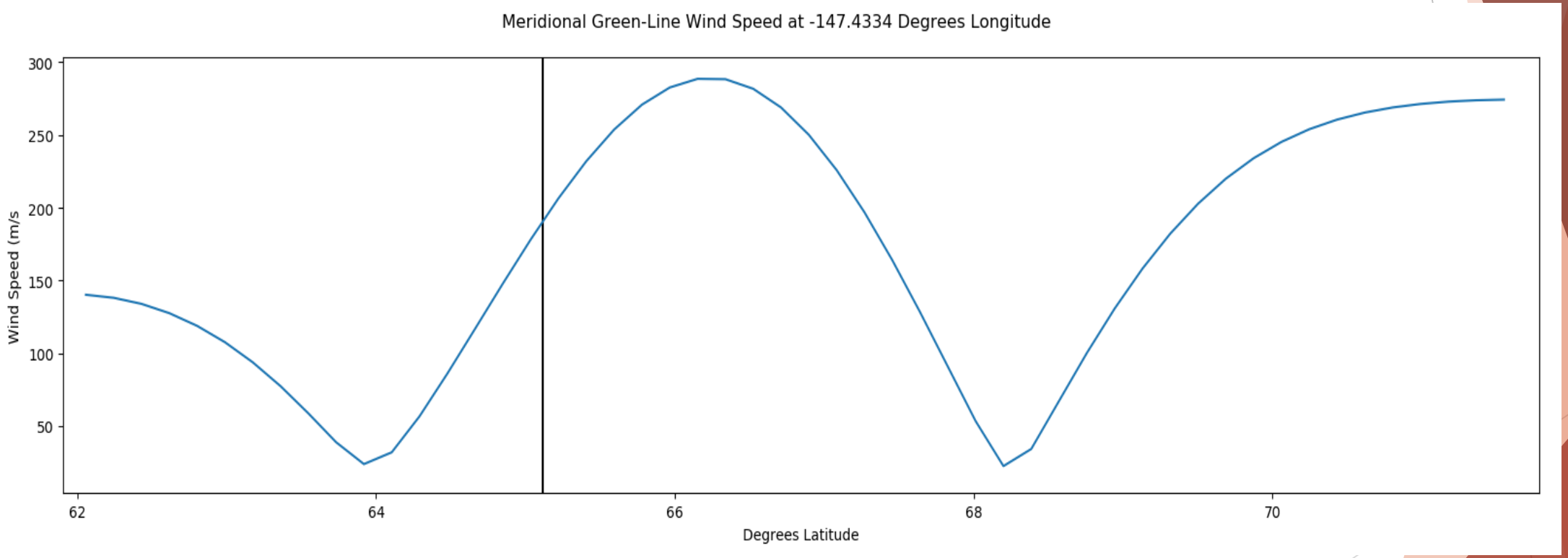
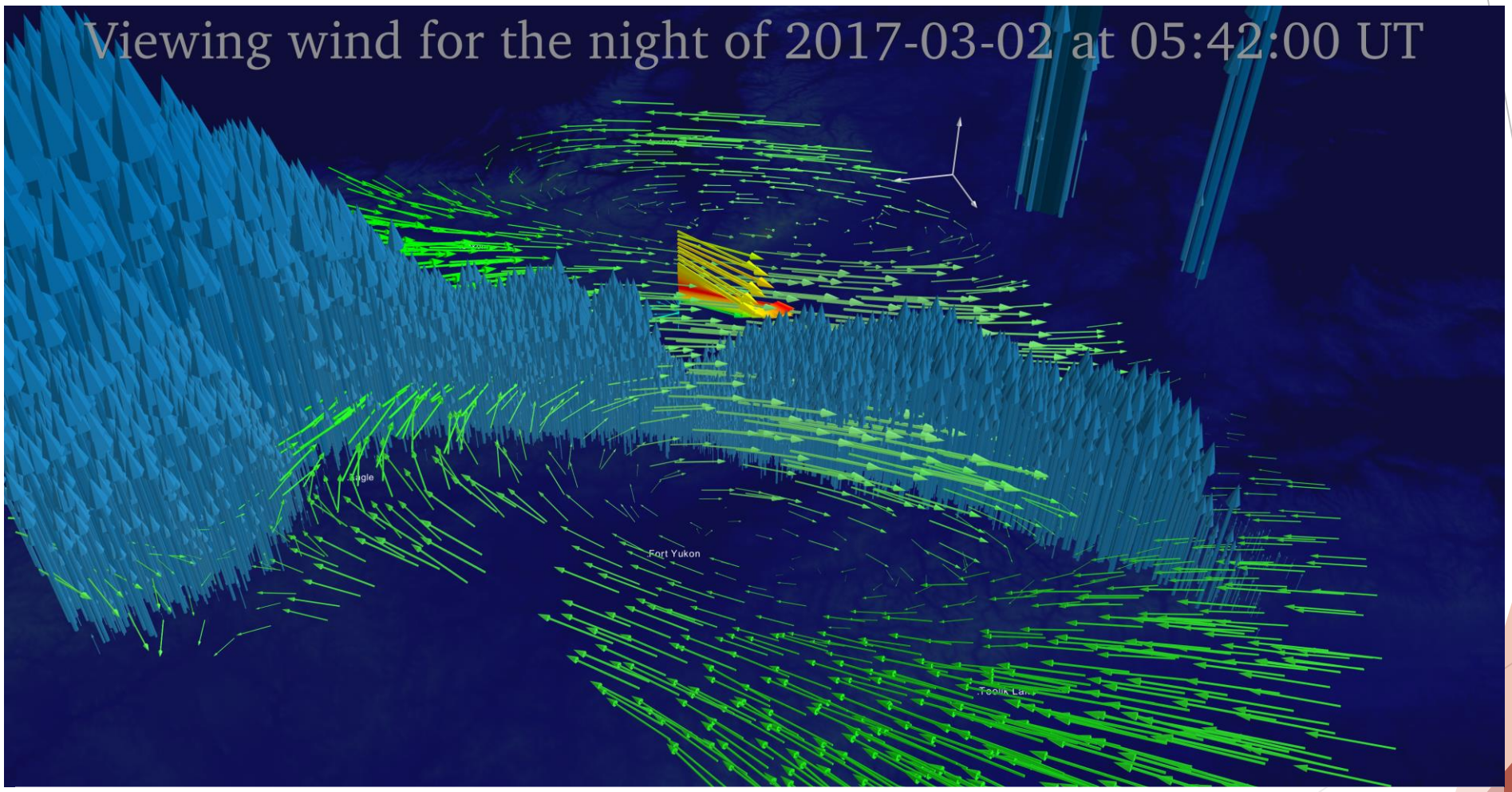


Photo Supplementing Live Demonstration



Scene is viewed from northern boundary of Canada/Alaska at 150km altitude looking approximately geomagnetically south with a focus about the TMA launch location. Intent of photo is to show neutral jet in auroral arc and small scale dynamic winds.