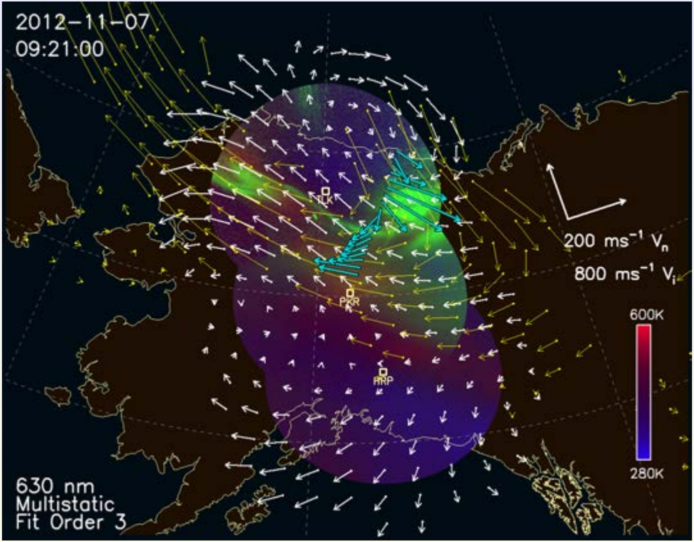
High-Resolution Mapping of Auroral Ion-Neutral Coupling



Mark Conde

With Substantial Contributions From:

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Bill Bristow

Don Hampton

Mike Nicolls

CEDAR Workshop June 2013.

Motivation and Outline

It has been known for decades that a major term in the momentum equation governing thermospheric winds is due to “ion drag” – ions responding to electrodynamic forces collide with neutrals and exchange momentum. At high latitudes ions driven by magnetospheric electric fields can be a major driver of the winds.

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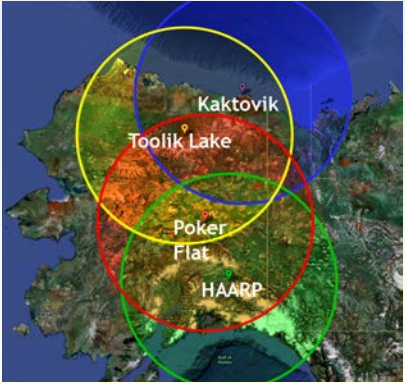

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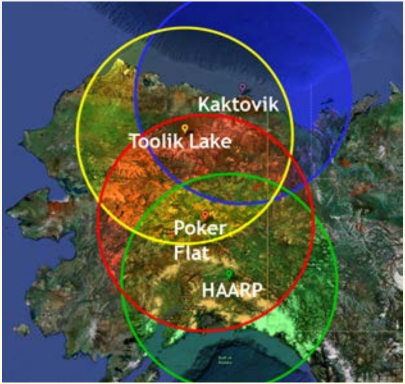

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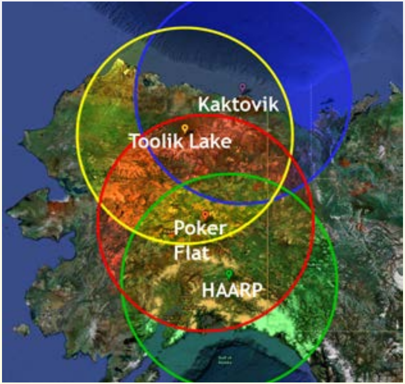

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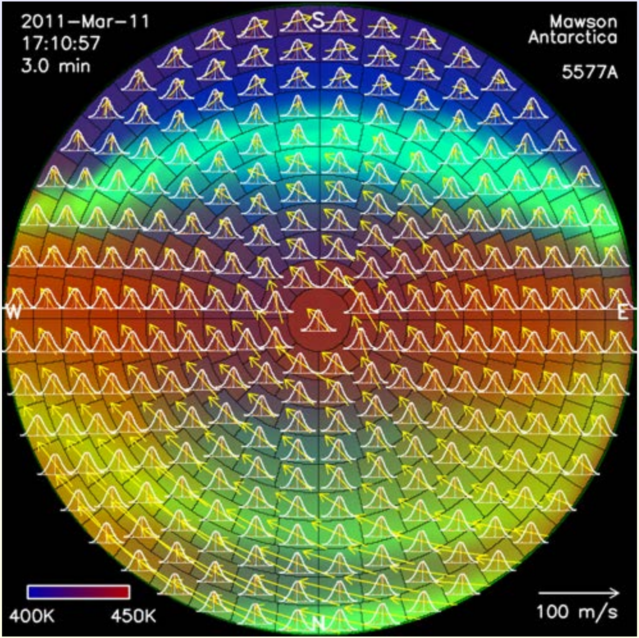
- *A major theme of the FPI work presented this year's meeting has been to combine multipe instruments to form multistatic arrays.* Today I will report specifically on an array of three all-sky FPIs that has been operating in Alaska since October 2012.
- *The PINOT initiative* is combining these and other instruments and analyses into an "integrative aeronomy" study of ion-neutral coupling.

The Scanning Doppler Imager (SDI)



- The SDI records monochromatic images of the sky, modulated by a Fabry-Perot interference pattern. Scanning the etalon gap produces spectra spanning $\sim 10\,\mathrm{pm}$ in wavelength.
- This image shows $\lambda 558\,\mathrm{nm}$ spectra from 261 "zones" across the sky.
- Green hues show $558\,\mathrm{nm}$ brightness, blue through red hues show Doppler temperature, and yellow arrows show the fitted horizontal wind field.

The New SDI at Toolik Lake

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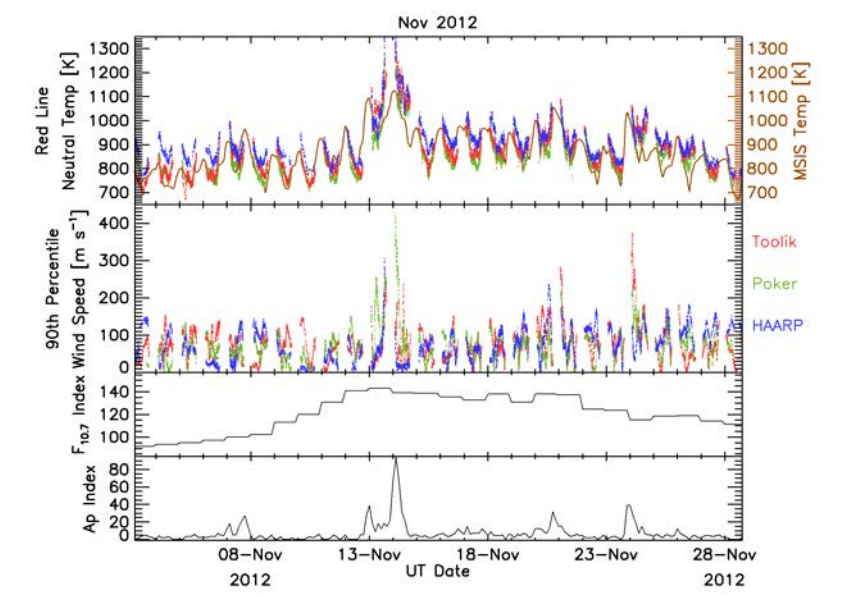
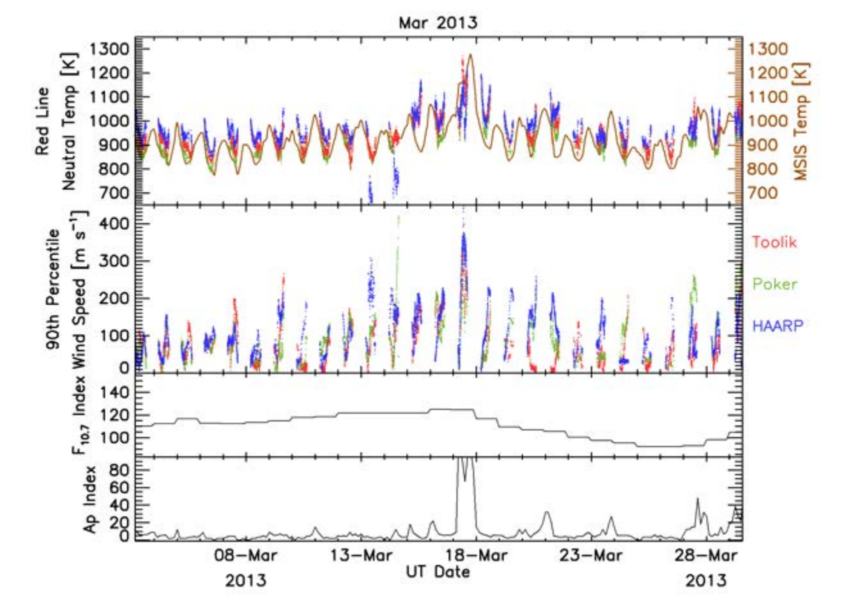
November 2012 PINOT Campaign Period

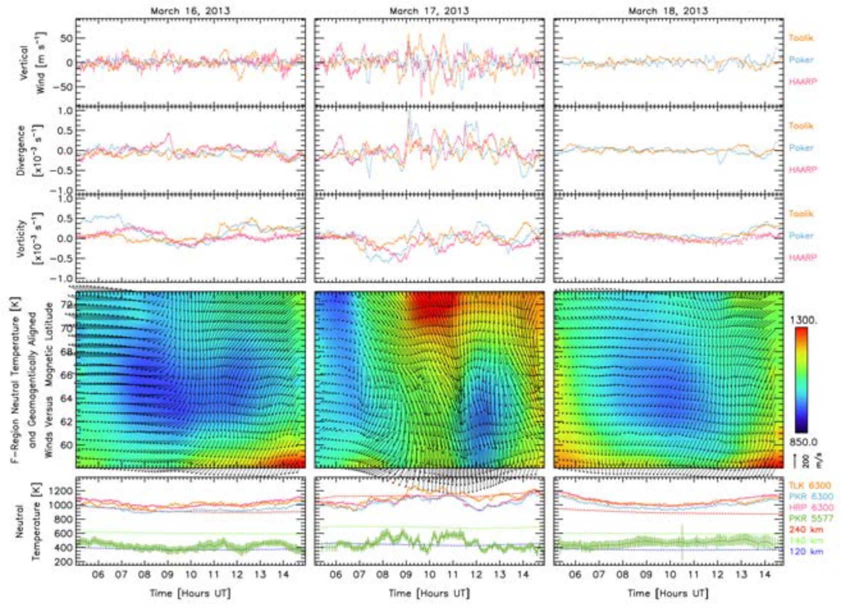


March 2013 PINOT Campaign Period



PINOT: Integrative Aeronomy in Action

Monostatic Storm Studies



Penrose's First Law of Observational Science

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Never measure the same quantity more than once....

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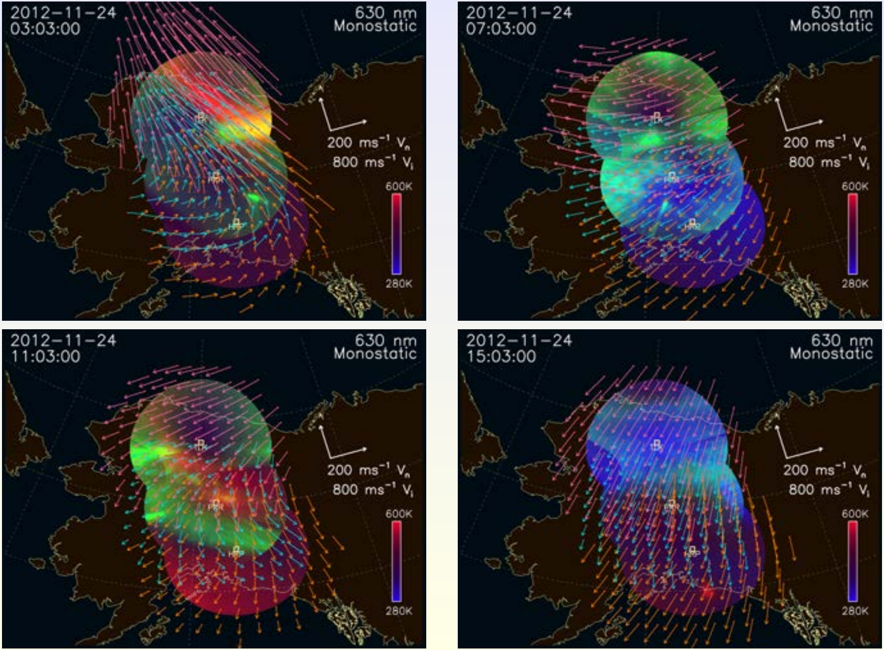
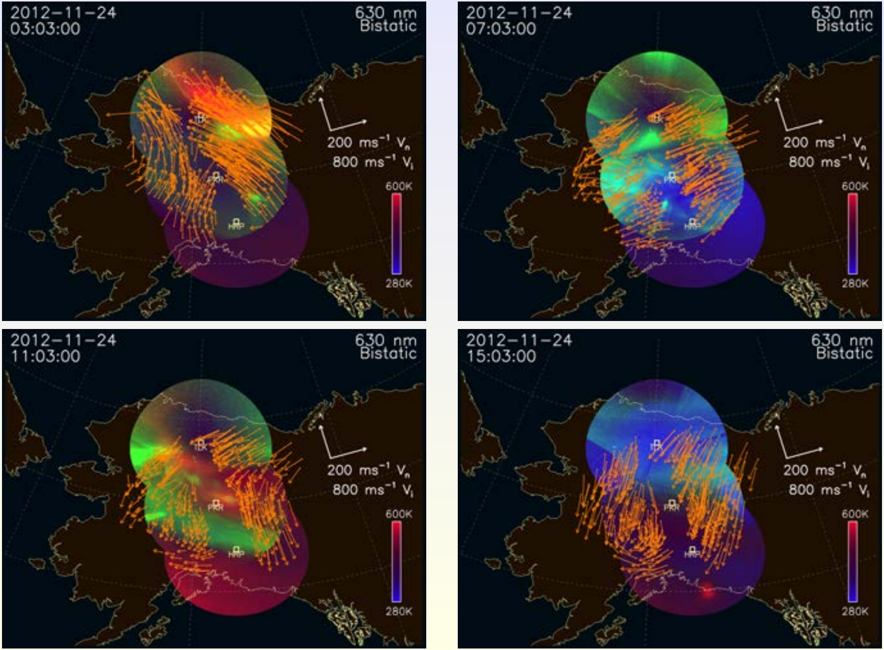
You'll end up spending all your time explaining why you got different answers!

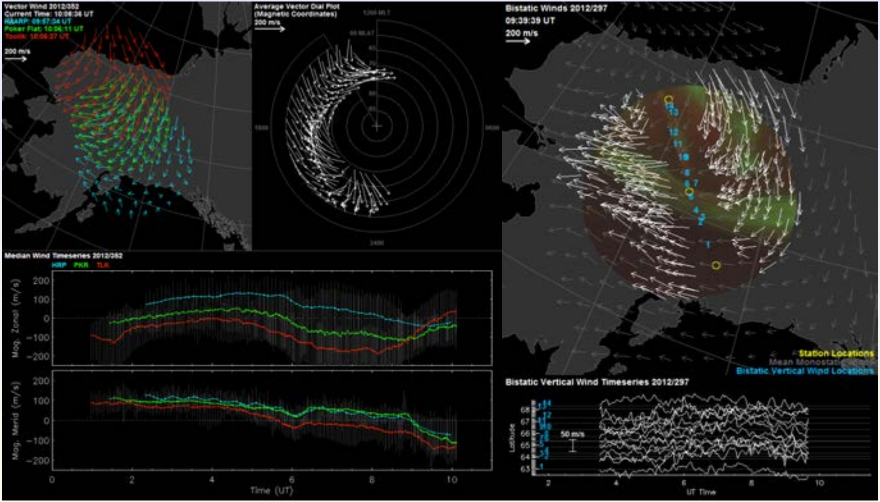
Monostatic Winds Show Good Agreement



Bistatic Winds



Real-Time Wind Data from HAARP, Poker, and Toolik Lake



- This is an example *real-time data products*. The left panel shows instantaneous monostatic wind fields from HAARP, Poker, and Toolik Lake, along with time histories of wind components and assimilated vector data for the whole night so far.

Multistatic Analysis

- To address the limited geographic coverage of direct bistatic analysis, we fit the line-of-sight winds from all observing stations simultaneously with *low-order Taylor series expansions* of the zonal, meridional, and vertical components.

- That is

$$
\begin{aligned}
u &= u_0 + \frac{\partial u}{\partial x}x + \frac{\partial u}{\partial y}y + \frac{\partial^2 u}{\partial x^2}x^2 + \frac{\partial^2 u}{\partial x \partial y}xy + \frac{\partial^2 u}{\partial y^2}y^2 + \ldots \\
v &= v_0 + \frac{\partial v}{\partial x}x + \frac{\partial v}{\partial y}y + \frac{\partial^2 v}{\partial x^2}x^2 + \frac{\partial^2 v}{\partial x \partial y}xy + \frac{\partial^2 v}{\partial y^2}y^2 + \ldots \\
w &= w_0 + \frac{\partial w}{\partial x}x + \frac{\partial w}{\partial y}y + \frac{\partial^2 w}{\partial x^2}x^2 + \frac{\partial^2 w}{\partial x \partial y}xy + \frac{\partial^2 w}{\partial y^2}y^2 + \ldots
\end{aligned}
$$

  where x and y are distances east and north from our reference location. Currently we fit horizontal winds to 3rd order.

- By using a distance weighting scheme, the fits can be (somewhat) localized spatially. This allows us to produce (crude) maps showing how the fit coefficients vary spatially. Since the fit coefficients include all four first-order gradients ($\frac{\partial u}{\partial x}$, $\frac{\partial u}{\partial y}$, $\frac{\partial v}{\partial x}$, and $\frac{\partial v}{\partial y}$) *we are now able to make crude maps of how divergence and vorticity of the thermospheric wind varies across Alaska*.

- This localization will be critical for obtaining reasonable inversions once our arrays grow to cover synoptic scales and above.

Viewer Advice

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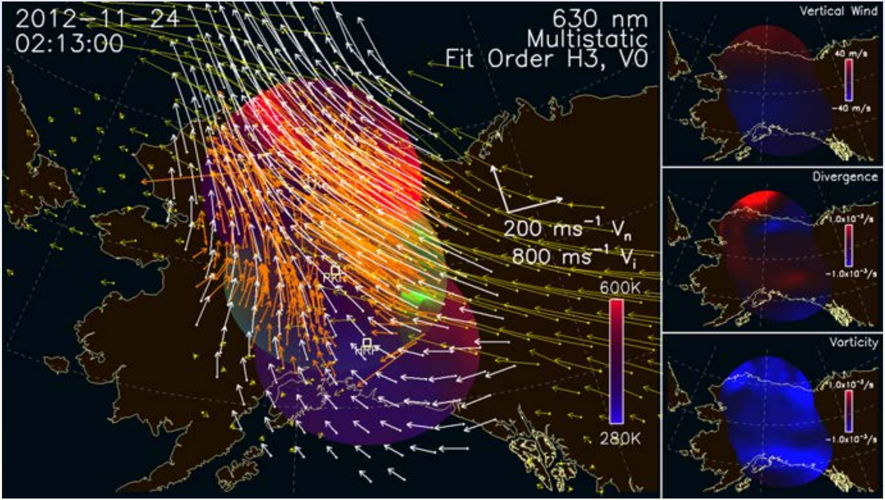
The following video contains images that some computer modelers may find frightening....

(Viewer discretion is advised.)

Assimilated Data From HAARP, Poker, & Toolik Lake

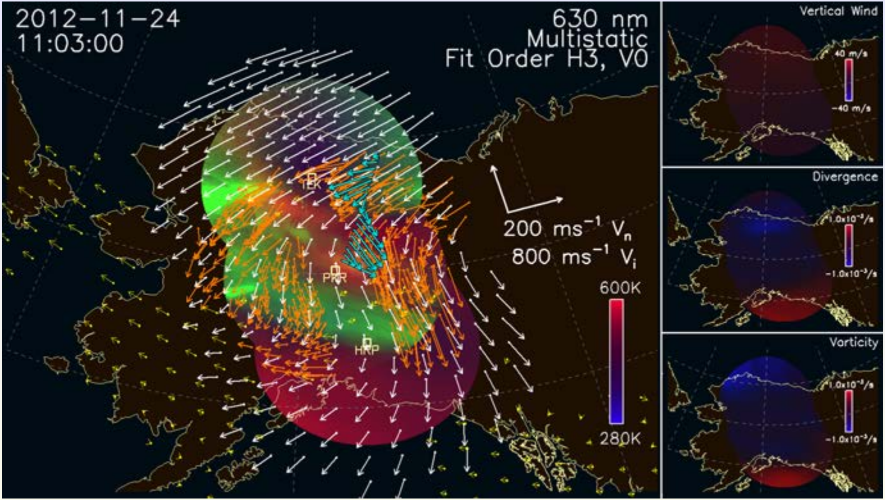
- White: SDI, Yellow: SuperDARN, Blue: PFISR, Orange: Direct bistatic.
- Green hues denote auroral brightness at 558 nm, whereas blue through red hues denote temperature derived from 558 nm SDI spectra.

Movie Frame at 02:13:00 UT



- Note that the strongly negative vorticity everywhere – *this flow easily satisfies the condition for inertial instability.*

Movie Frame at 11:03:00 UT

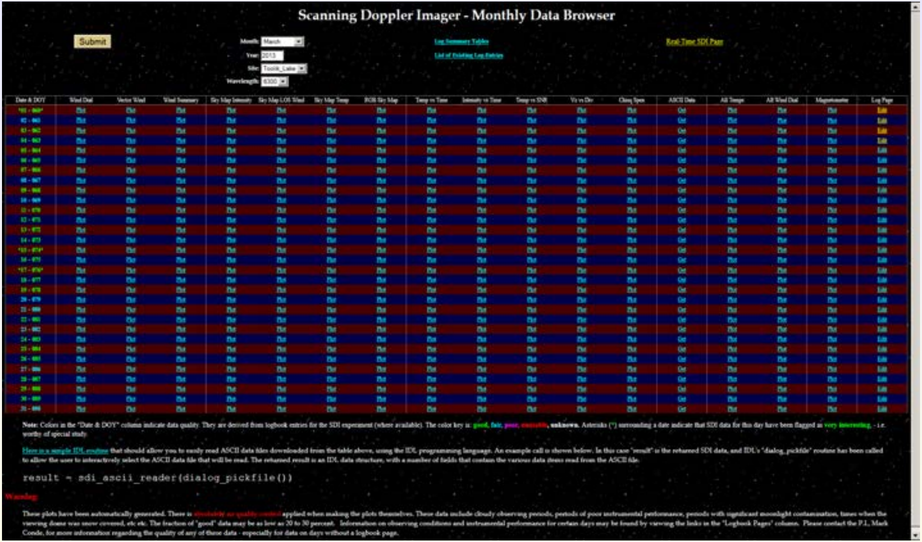


- The three-site array used here is clearly the minimum number required to make this work; significant artifacts appear in fitting the gradient terms near the extreme north and south ends of our array, where the geometry is worst.
- With more sites and better geometry, these would be fantastic products.

Mapping Inertial Instability

- Green hues in the vorticity map denote regions that satisfy the criterion for inertial instability, which is simply that the sum of horizontal vorticity ς plus the Coriolis parameter is negative: $\varsigma + 2\Omega \sin(\text{lat}) < 0$.

Data Availability



Any web user can download near real-time data plots along with post-processed plots and *ascii data* at http://sdi_server.gi.alaska.edu/sdiweb/index.asp

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Take-Home Resolution: Go home, get on the phone, and start at least one new collaboration...