High-Resolution Mapping of Auroral Ion-Neutral Coupling

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Motivation and Outline

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- 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 ~10pm in wavelength.
- This image shows λ558nm spectra from 261 “zones” across the sky.
- Green hues show 558nm 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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Monostatic Winds Show Good Agreement
Bistatic Winds
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

\[ u = u_0 + \frac{\partial u}{\partial x}x + \frac{\partial u}{\partial y}y + \frac{\partial^2 u}{\partial x^2}x^2 + \frac{\partial^2 u}{\partial x \partial y}xy + \frac{\partial^2 u}{\partial y^2}y^2 + \ldots \]

\[ v = v_0 + \frac{\partial v}{\partial x}x + \frac{\partial v}{\partial y}y + \frac{\partial^2 v}{\partial x^2}x^2 + \frac{\partial^2 v}{\partial x \partial y}xy + \frac{\partial^2 v}{\partial y^2}y^2 + \ldots \]

\[ w = w_0 + \frac{\partial w}{\partial x}x + \frac{\partial w}{\partial y}y + \frac{\partial^2 w}{\partial x^2}x^2 + \frac{\partial^2 w}{\partial x \partial y}xy + \frac{\partial^2 w}{\partial y^2}y^2 + \ldots \]

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 \( \left( \frac{\partial u}{\partial x}, \frac{\partial u}{\partial y}, \frac{\partial v}{\partial x}, \text{ and } \frac{\partial v}{\partial y} \right) \) 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

The following video contains images that some computer modelers may find frightening. (Viewer discretion is advised.)
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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.
Note that the strongly negative vorticity everywhere – *this flow easily satisfies the condition for inertial instability.*
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.
Green hues in the vorticity map denote regions that satisfy the criterion for inertial instability, which is simply that the sum of horizontal vorticity $\zeta$ plus the Coriolis parameter is negative: $\zeta + 2\Omega \sin(\text{lat}) < 0$. 
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...