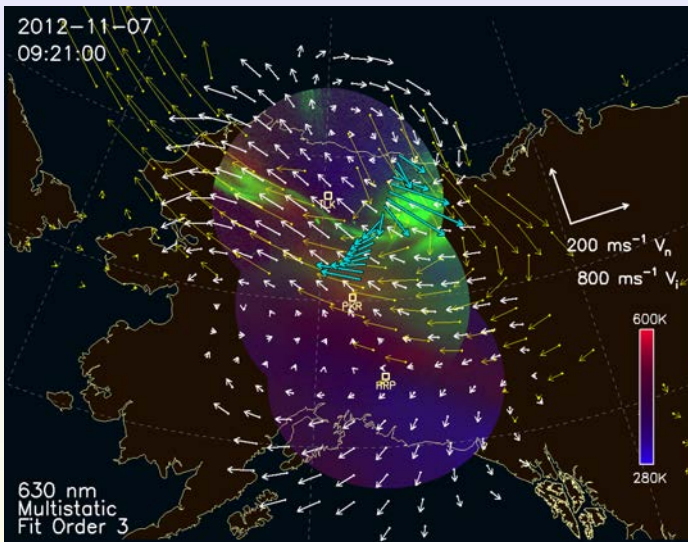


High-Resolution Mapping of Auroral Ion-Neutral Coupling



Mark Conde

With Substantial
Contributions
From:

Callum
Anderson

Bill Bristow

Don Hampton

Mike Nicolls

CEDAR
Workshop
June 2013.

Motivation and Outline

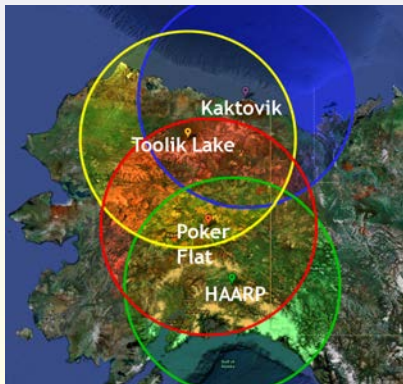
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The purpose of today's talk is to report on two recent developments that are addressing this:



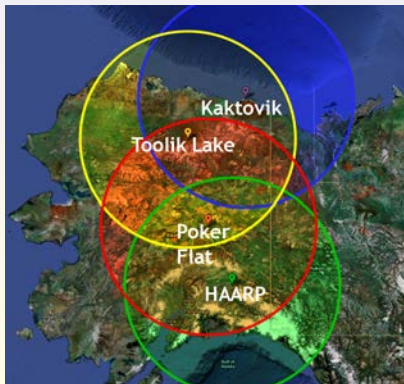
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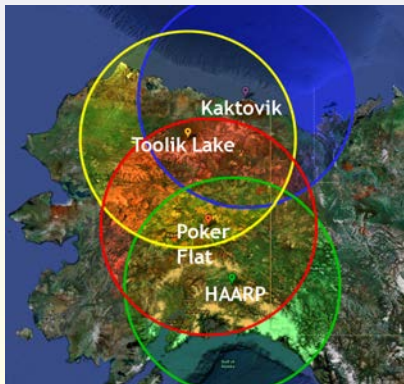
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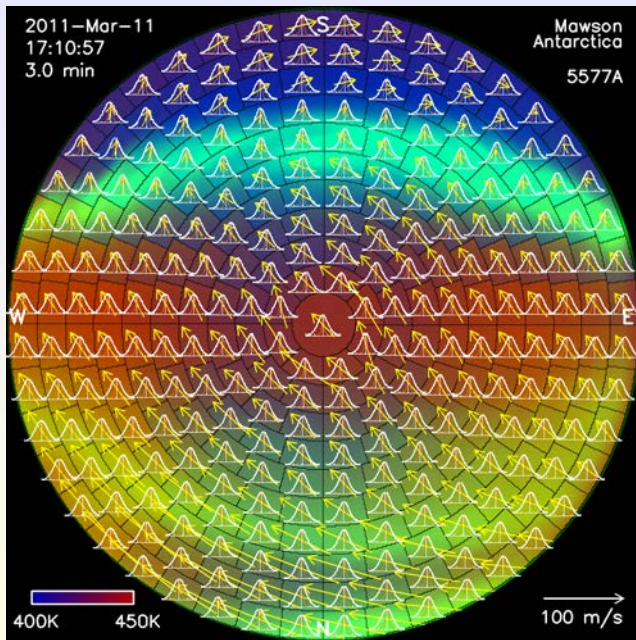
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- *A major theme of the FPI work presented this year's meeting has been to combine multiple instruments to form multistatic arrays.* Today I will report specifically on an array of three all-sky FPIs that has been operating in Alaska since October 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 $\sim 10\text{pm}$ in wavelength.
- This image shows $\lambda 558\text{nm}$ 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.

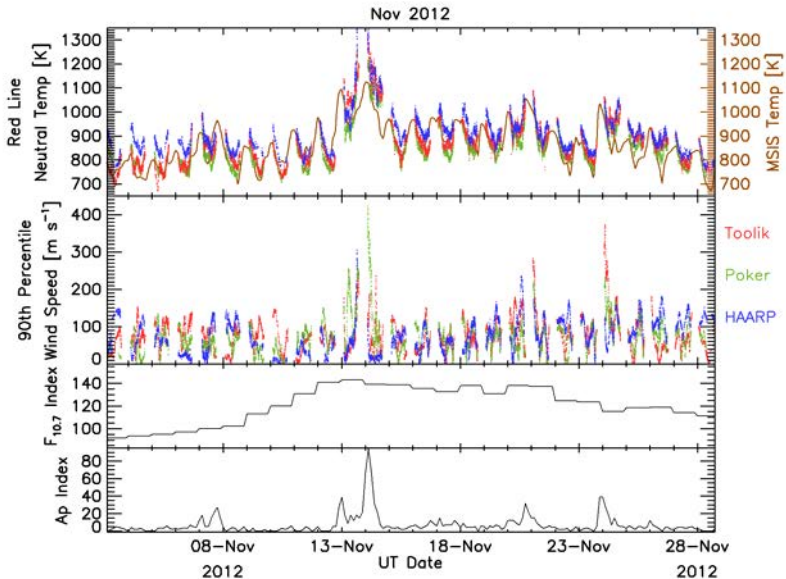
The New SDI at Toolik Lake



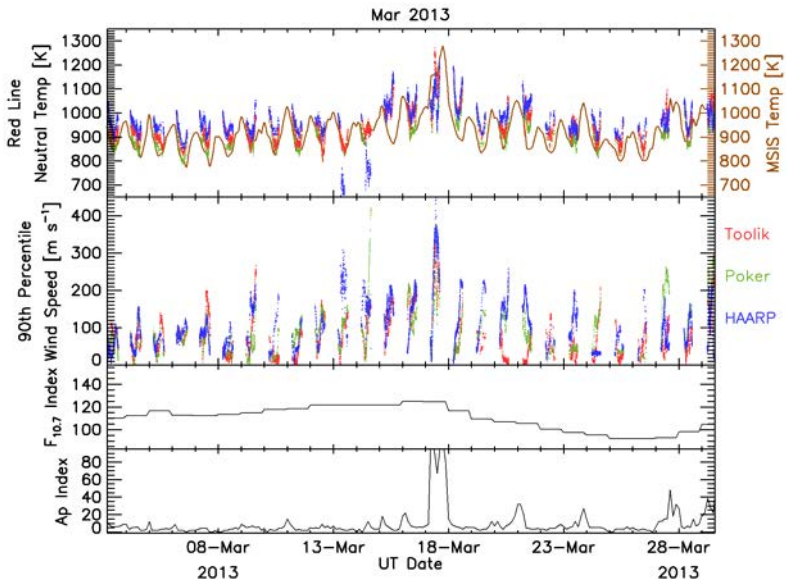
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November 2012 PINOT Campaign Period

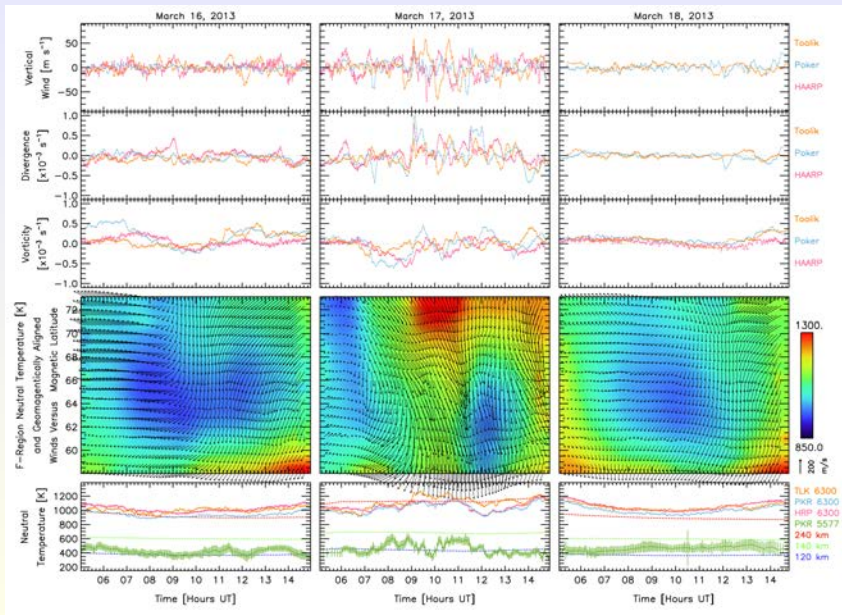


March 2013 PINOT Campaign Period



PINOT: Integrative Aeronomy in Action

Monostatic Storm Studies



Penrose's First Law of Observational Science

Penrose's First Law of Observational Science

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

Penrose's First Law of Observational Science

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

⇒ Because if you do ...

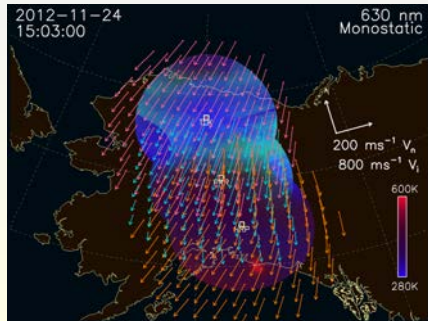
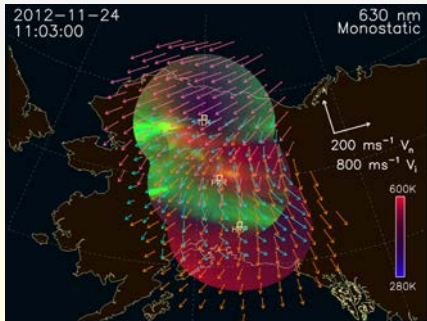
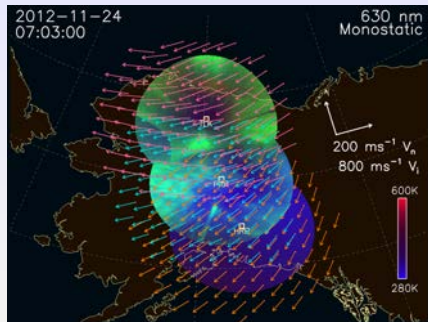
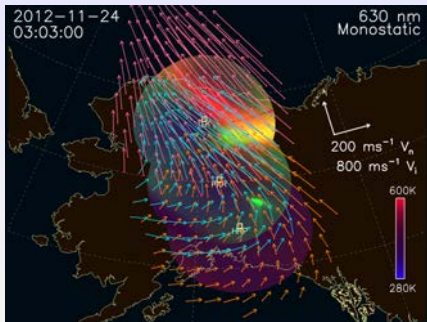
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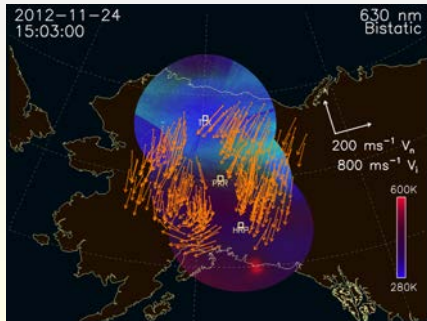
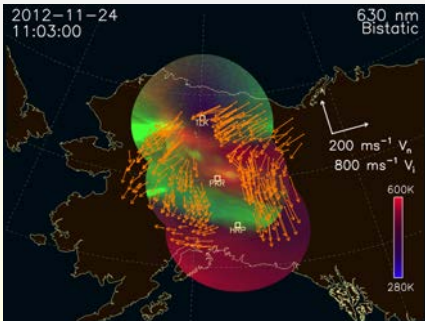
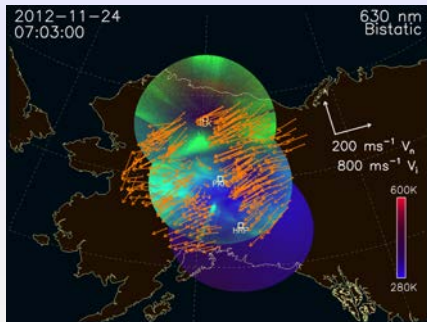
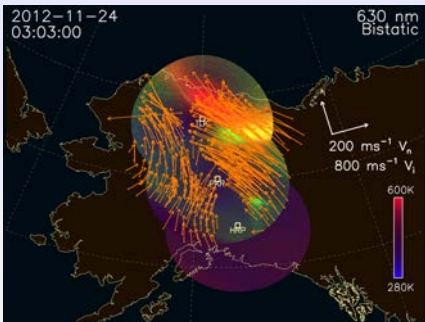
⇒ Because if you do ...

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

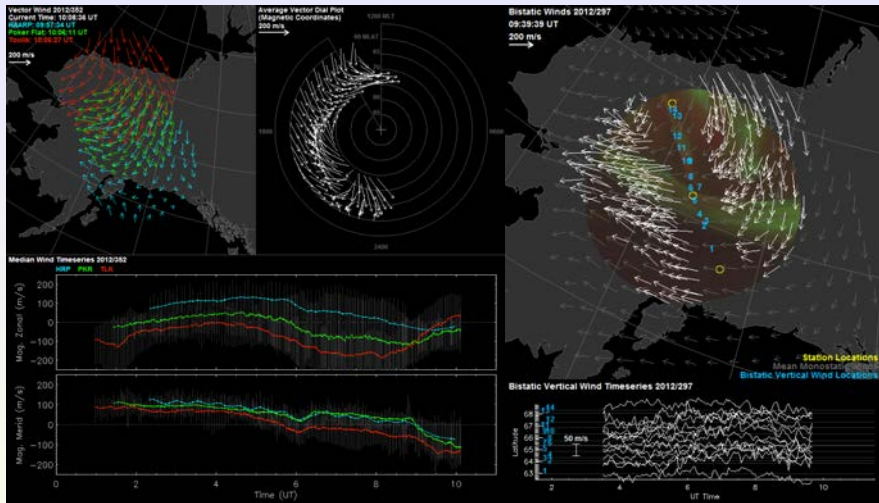
Monostatic Winds Show Good Agreement



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

$$u = u_0 + \frac{\partial u}{\partial x}x + \frac{\partial u}{\partial y}y + \frac{\partial^2 u}{\partial x^2}x^2 + \frac{\partial^2 u}{\partial x \partial y}xy + \frac{\partial^2 u}{\partial y^2}y^2 + \dots$$

$$v = v_0 + \frac{\partial v}{\partial x}x + \frac{\partial v}{\partial y}y + \frac{\partial^2 v}{\partial x^2}x^2 + \frac{\partial^2 v}{\partial x \partial y}xy + \frac{\partial^2 v}{\partial y^2}y^2 + \dots$$

$$w = w_0 + \frac{\partial w}{\partial x}x + \frac{\partial w}{\partial y}y + \frac{\partial^2 w}{\partial x^2}x^2 + \frac{\partial^2 w}{\partial x \partial y}xy + \frac{\partial^2 w}{\partial y^2}y^2 + \dots$$

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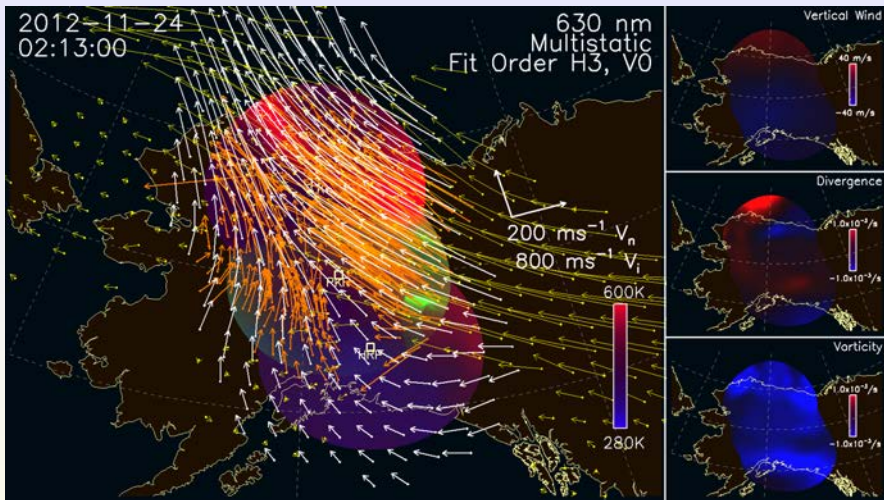
The following video contains images that some computer modelers may find frightening....

(Viewer discretion is advised.)

Assimilated Data From HAARP, Poker, & Toolik Lake

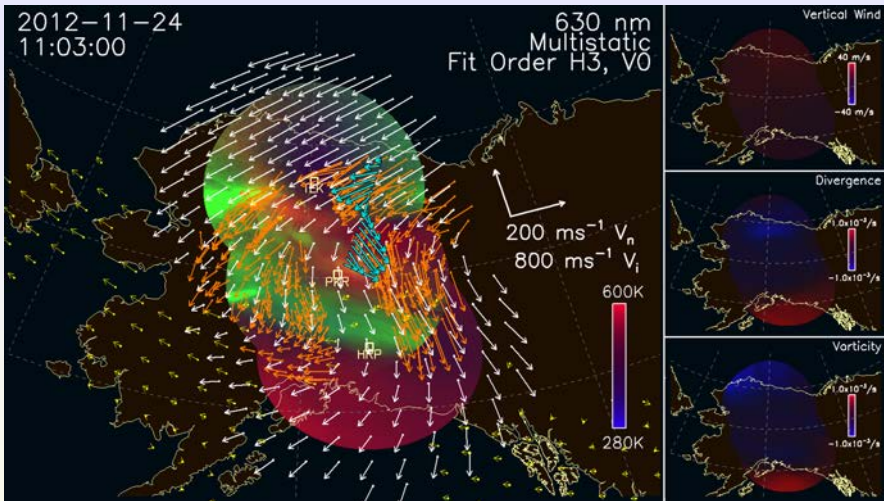
- White: SDI, Yellow: SuperDARN, Blue: PFISR, Orange: Direct bistatic.
- Green hues denote auroral brightness at 558 nm, whereas blue through red hues denote temperature derived from 558 nm SDI spectra.

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 ζ plus the Coriolis parameter is negative: $\zeta + 2\Omega \sin(\text{lat}) < 0$.

Data Availability

Scanning Doppler Imager - Monthly Data Browser

Months: [Log Summaries Tightly](#) [Print Table ASCII Page](#)
 Year: [List of Existing Log Entries](#)
 Site: [Log Summaries Tightly](#)
 Wavelength:

Date & DOY	Wind Dir	Vector Wind	Wind Summary	Sky Map Summary	Sky Map LOS Wind	Sky Map Temp	ECM Sky Map	Temp vs Time	Estimate vs Time	Temp vs SWR	Vs vs Dir	Cloud Open	ASCI Data	All Temp	All Wind Dir	Magnitudes	Log Page
10 - 060	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir
10 - 061	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir
10 - 062	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir
10 - 063	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir
10 - 064	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir
10 - 065	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir
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10 - 070	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir
10 - 071	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir
10 - 072	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir
10 - 073	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir
10 - 074	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir
10 - 075	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir
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10 - 079	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir
10 - 080	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir
10 - 081	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir
10 - 082	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir
10 - 083	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir
10 - 084	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir
10 - 085	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir
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10 - 088	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir
10 - 089	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir
10 - 090	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir	Dir

Note: Colors in the "Date & DOY" column indicate data quality. They are derived from logbook entries for the SDI experiment (when available). The color key is: **green**, **blue**, **post**, **overcast**, **unknown**. Asterisks (*) surrounding a date indicate that SDI data for this day have been flagged as **very interesting**, i.e. worthy of special study.

[Here is a single SDI routine](#) that should allow you to easily read ASCII data files downloaded from the table above, using the IDL programming language. An example call is shown below. In this case "result" is the returned SDI data, and IDL's "dialog_pickfile" routine has been called to allow the user to interactively select the ASCII data file that will be read. The returned result is an IDL data structure, with a number of fields that contain the various data items read from the ASCII file.

```
result = sdi_ascii_reader(dialog_pickfile())
```

Warning:

These plots have been automatically generated. There is **no quality control** applied when making the plots themselves. These data include (cloudy observing periods, periods of poor astronomical performance, periods with significant moonlight contamination, times when the viewing dome was under command, etc etc). The fraction of "good" data may be as low as 20 to 30 percent. Information on observing conditions and astronomical performance for certain days may be found by clicking the links in the "Logbook Pages" column. Please contact the P.I., Mark Condit, for more information regarding the quality of any of these data - especially for data on days without a logbook page.

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...