Cross-comparison of upper atmospheric winds observed by two independent thermospheric optical Doppler spectrometers

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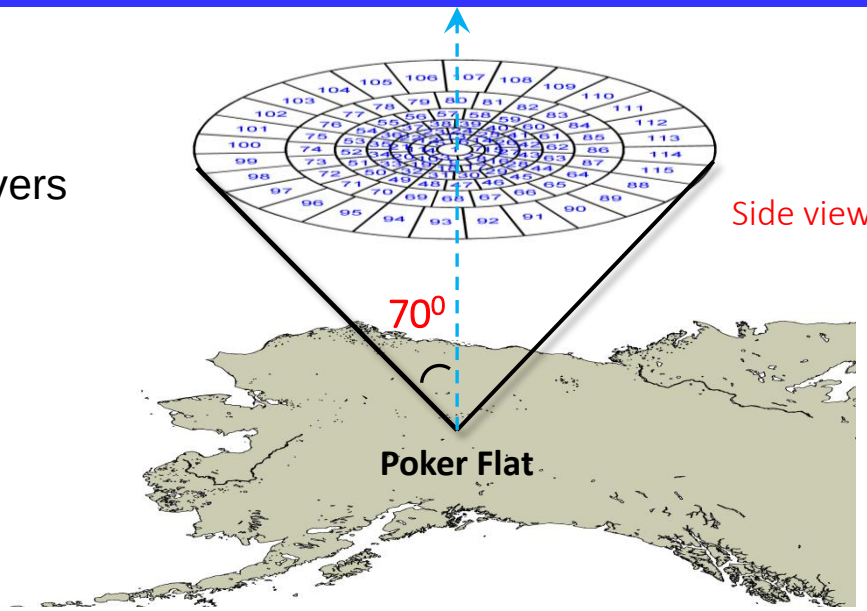
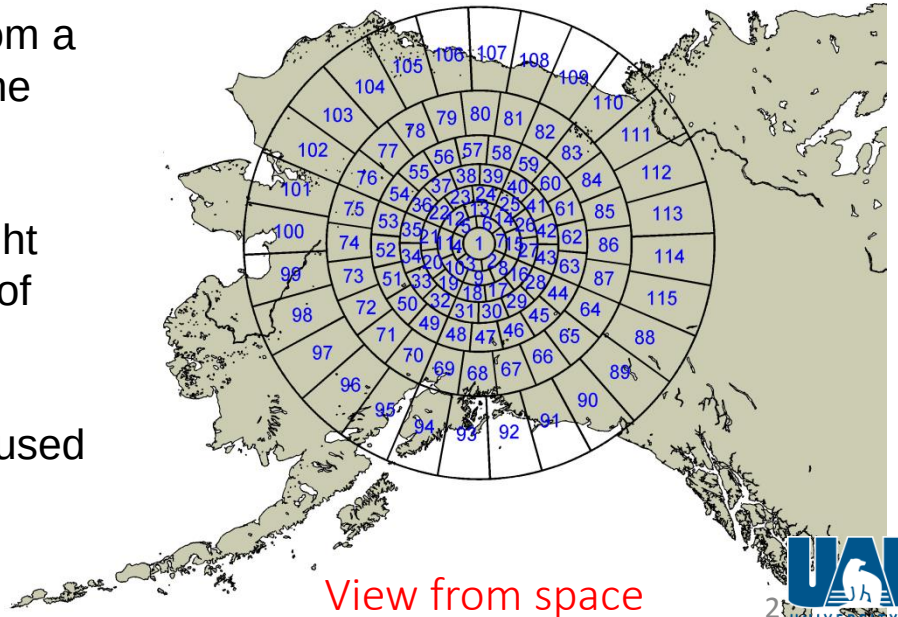
All-Sky Scanning Doppler Imager (SDI)

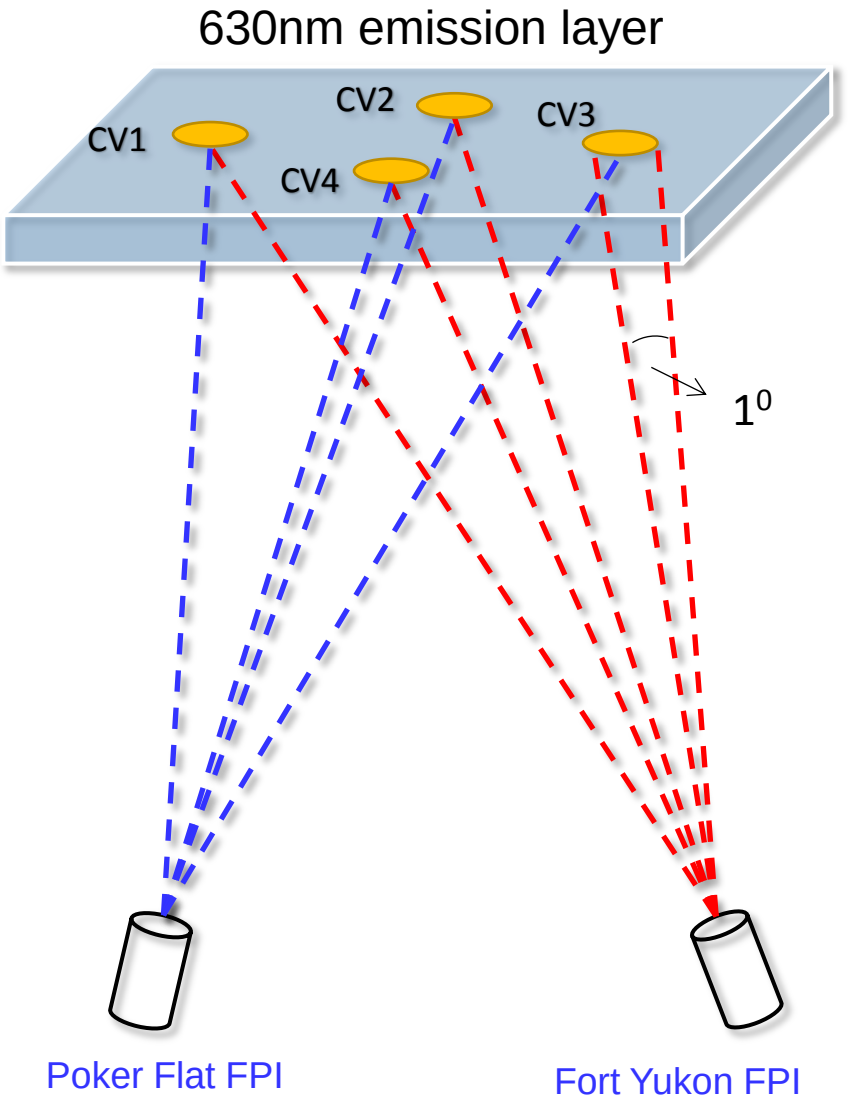
- Typical full field of view (FOV) is 140^0 which covers wide geographic region when projected at F-regions (240 km) altitude.
- Entire FOV is divided typically into 115 zones (configurable in software).
- Each zone records its own spectrum.
- 115 independent LOS wind measurements from a single SDI station for each exposure across the sky.
- ~27000 measurements across the sky per night per instrument (on a good night in the middle of winter.
- SDIs located at Poker Flat and Gakona were used in this cross-comparison



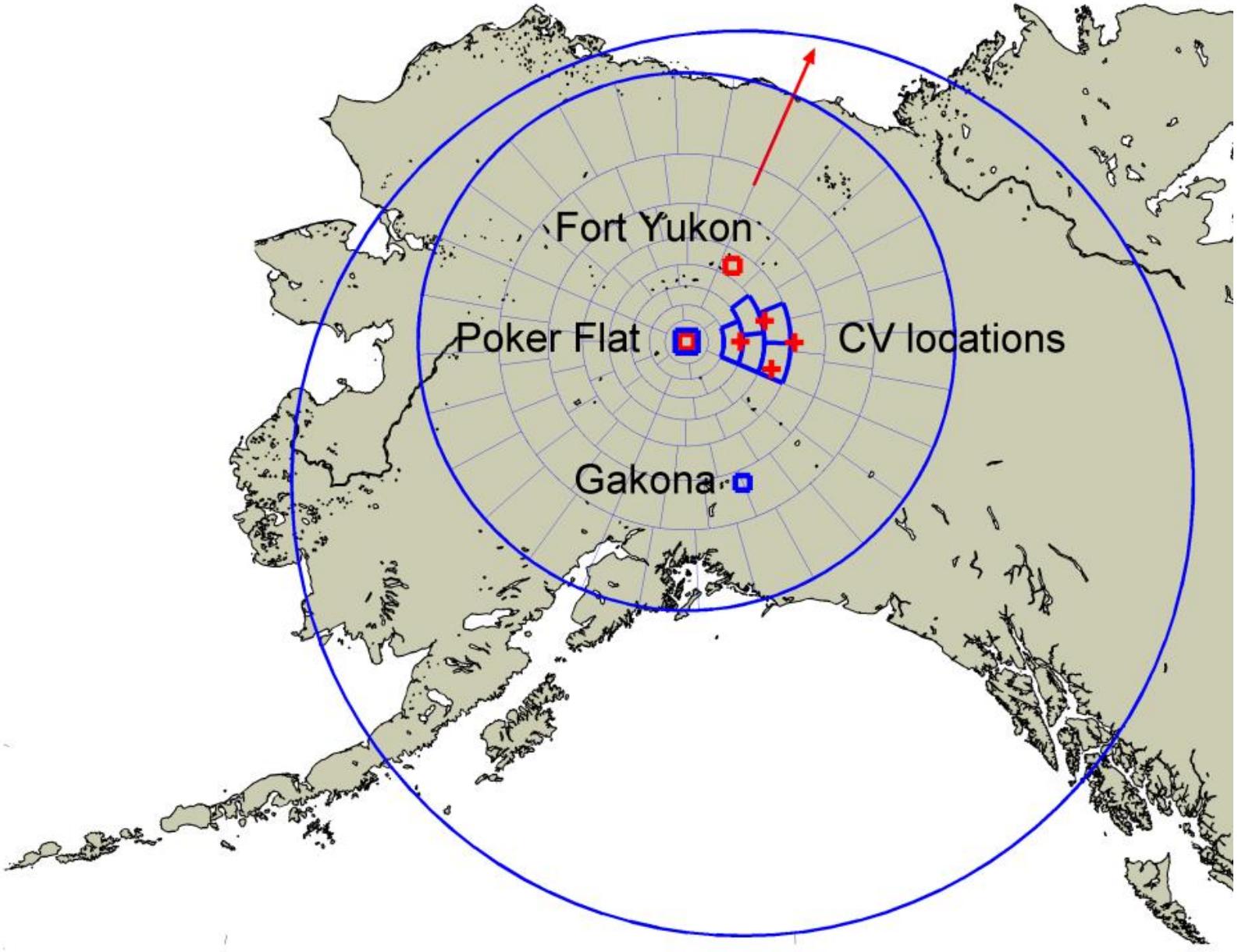


Narrow field FPI

- A narrow field FPI has a steerable double axis sky-scanner that can observe in any direction.
- Typical field of view of FPI is 1^0 with a spatial extent of ~4-5 km when projected at 240-250 km.
- FPI's located at Poker and Fort Yukon were used in cross-comparison.
- They are configured to observe in four different look directions.
- Selection of FPI look directions was achieved in such a way that the LOS by one FPI instrument intersects the LOS by another FPI instrument through the 630nm emission layer. Locations of intersections are referred to here as '"common volume (CV) locations".
- Two lines of sights were measured at each CV location for each exposure.



Geographical Setup



SDI: Monostatic wind fit

A single station can only measure single LOS wind of what is a three component wind vector. In such case, monostatic wind fit is employed to infer horizontal wind field under some substantial assumptions.

Assumptions

- Functional form of spatial wind: horizontal wind was modeled by the first order Taylor expansion about the zenith:

$$u(x,y) = u_o + \frac{\partial u}{\partial x}x + \frac{\partial u}{\partial y}y \rightarrow \text{Zonal}$$

$$v(x,y) = v_o + \frac{\partial v}{\partial x}x + \frac{\partial v}{\partial y}y \rightarrow \text{Meridional}$$

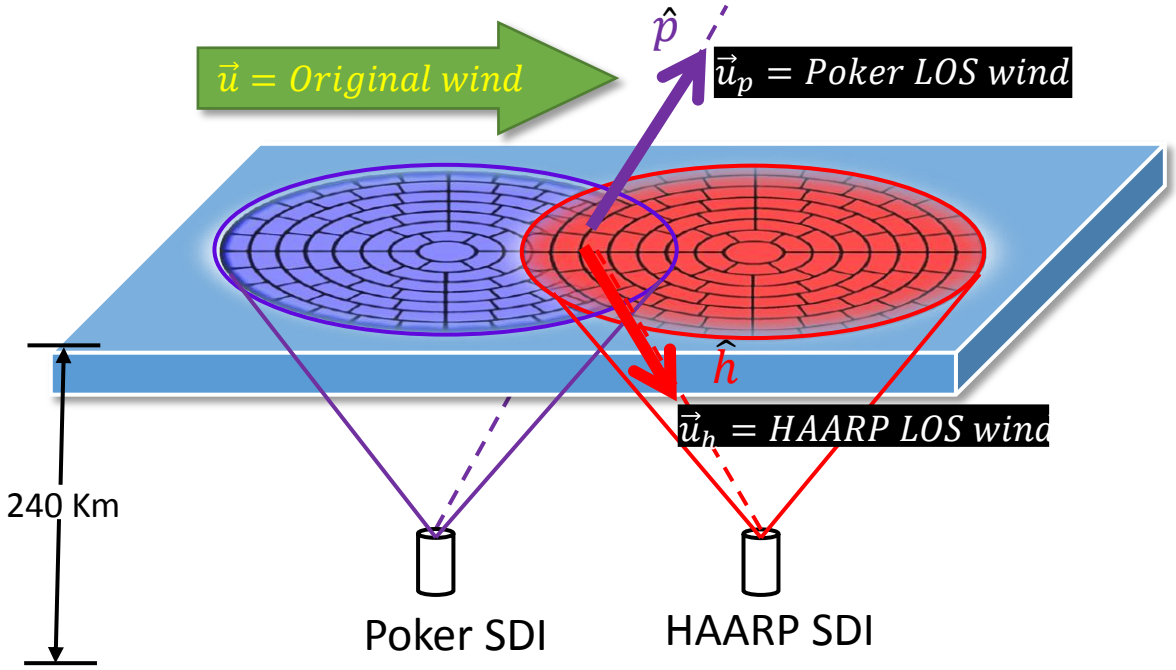
- Change in zonal gradient of meridional wind is negligible ($\frac{\partial v}{\partial x} = 0$)

- Vertical wind W = 0 m/sec (Thermosphere is very strongly convectively stable. Large energy inputs are required to drive vertical motion. That's is why only very small vertical winds are usually observed compared to horizontal wind)

SDI: Bistatic wind fit

Bistatic wind fit is implemented when two Line of Sight wind components of original winds are present. Since there was an overlap in the FOV's of SDI at Poker and HAARP, it made bistatic fit possible.

- There was an overlap between the FOV of SDI's at Poker Flat and HAARP
- In overlapping region two independent LOS's of a same wind vector were measured.
- Assuming negligible vertical wind (W =0), the zonal and meridional components of horizontal wind were computed.



$$\vec{u} = u_x\hat{x} + u_y\hat{y}$$

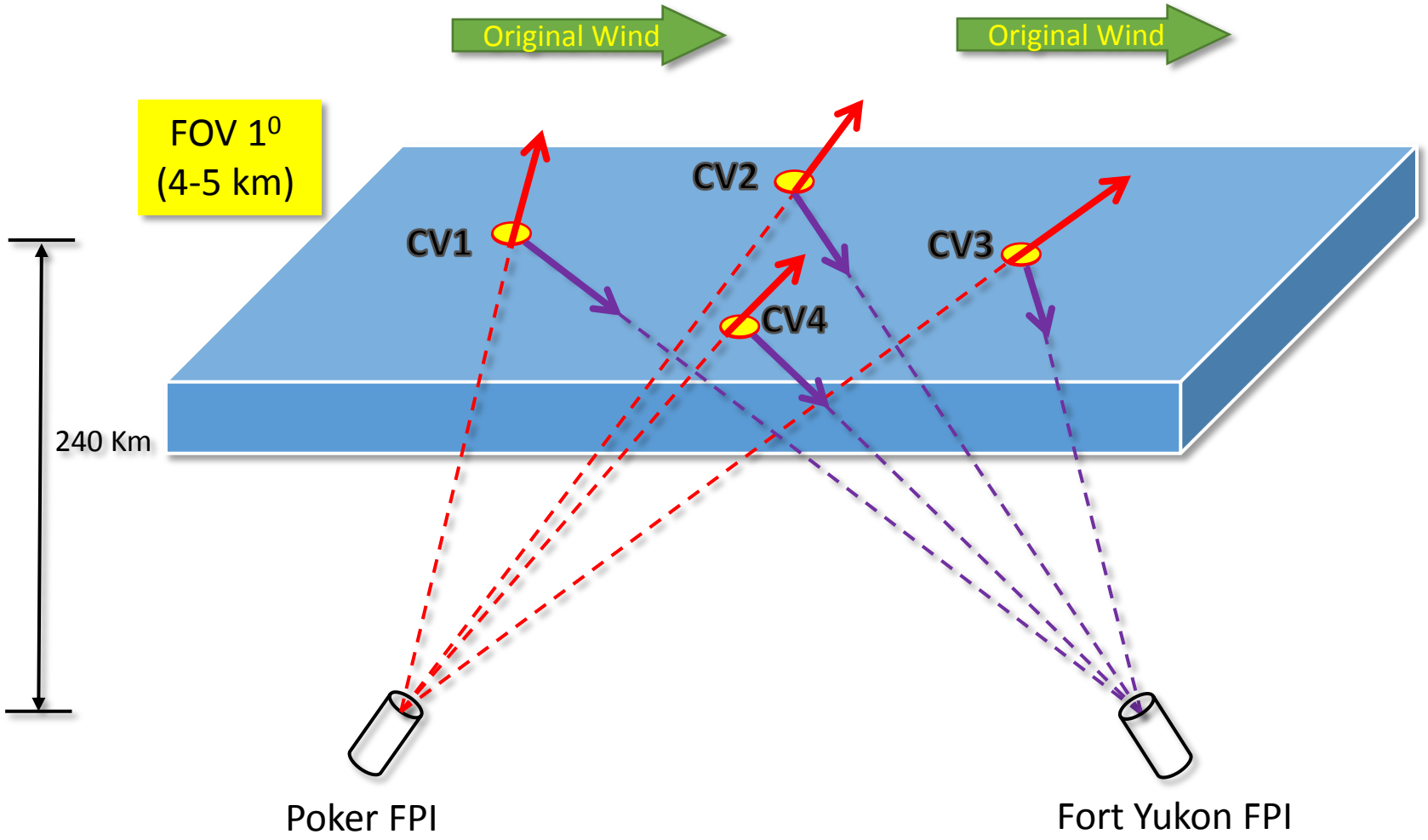
$$u_p = \hat{p}.\vec{u}$$
$$u_h = \hat{h}.\vec{u}$$

Two equations
Two unknown

u_p and u_h *measured by SDI*
$\hat{p}$ *and* $\hat{h}$ *known by geometry*

FPI: Bistatic wind

Similarly, two LOS wind components were measured at each CV location



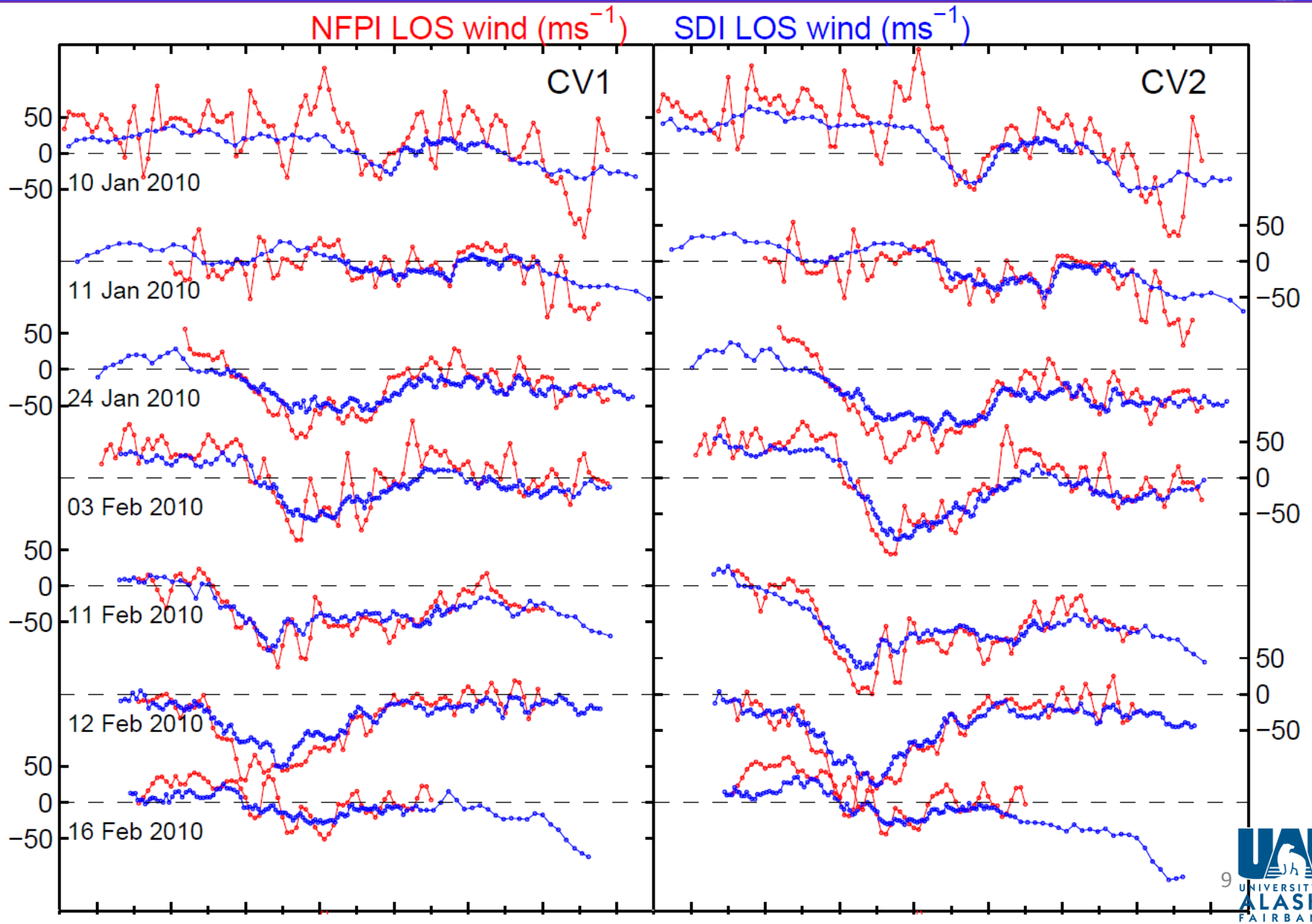
Observational data

- Comparisons were carried out for total seven nights using 630nm observations.
  - 10 January 2010
  - 11 January 2010
  - 24 January 2010
  - 03 February 2010
  - 11 February 2010
  - 12 February 2010
  - 16 February 2010

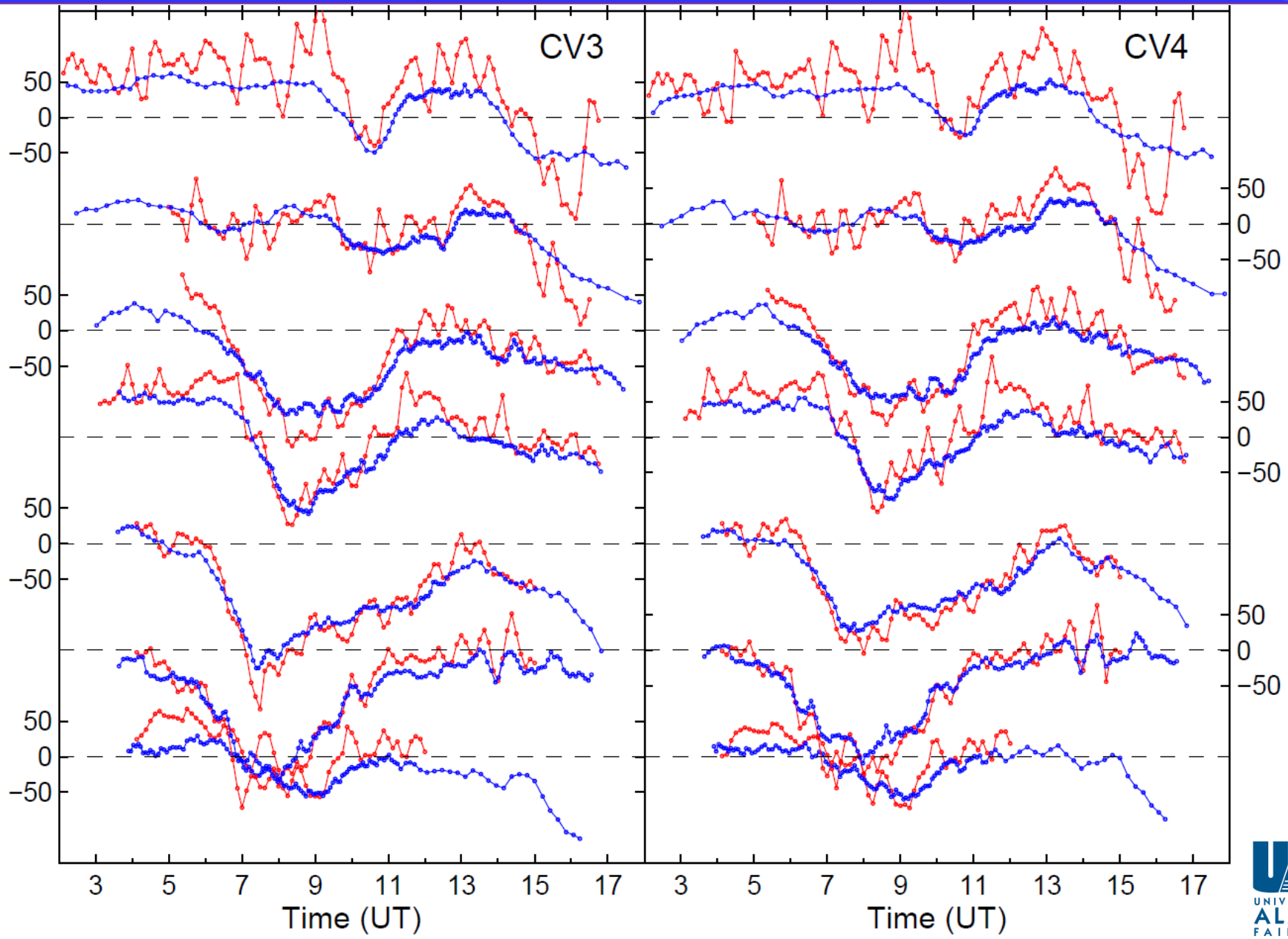
- Wind fits included in cross-comparison:

  Monostatic SDI (from Poker Flat)
  Bistatic SDI (from Poker Flat and Gakona)
  Bistatic FPI (from Poker Flat and Fort Yukon + with and without vertical wind included)

SDI and FPI LOS wind comparison (Poker Flat)

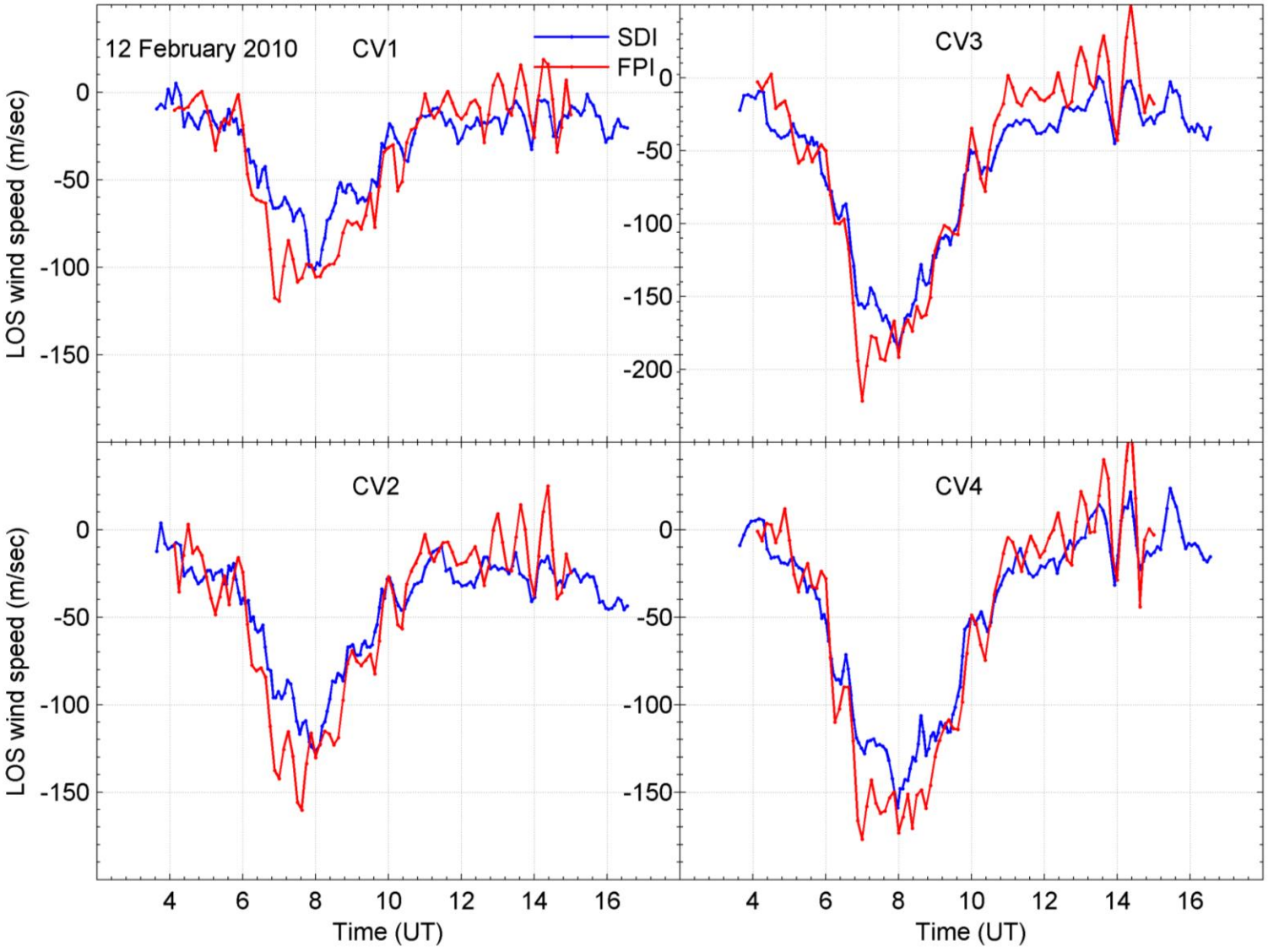


SDI and FPI LOS wind comparison (Poker Flat)



LOS wind comparison (Poker Flat)

12 Feb 2010 (zoomed-in version)



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Correlation between SDI and FPI LOS wind

Day	R_1	R_2	R_3	R_4
10 Jan 2010	0.6703	0.7710	0.8142	0.7543
11 Jan 2010	0.5673	0.7323	0.8188	0.8356
24 Jan 2010	0.8542	0.8815	0.9608	0.9522
03 Feb 2010	0.8045	0.8986	0.9340	0.9028
11 Feb 2010	0.8540	0.9144	0.9723	0.9657
12 Feb 2010	0.9304	0.9366	0.9740	0.9746
16 Feb 2010	0.7863	0.8158	0.8664	0.8445

R_i = Correlation between LOS wind measured by SDI and FPI at CV_i

- High correlation means both are seeing the same events occurring in the region of their overlapping field of view.

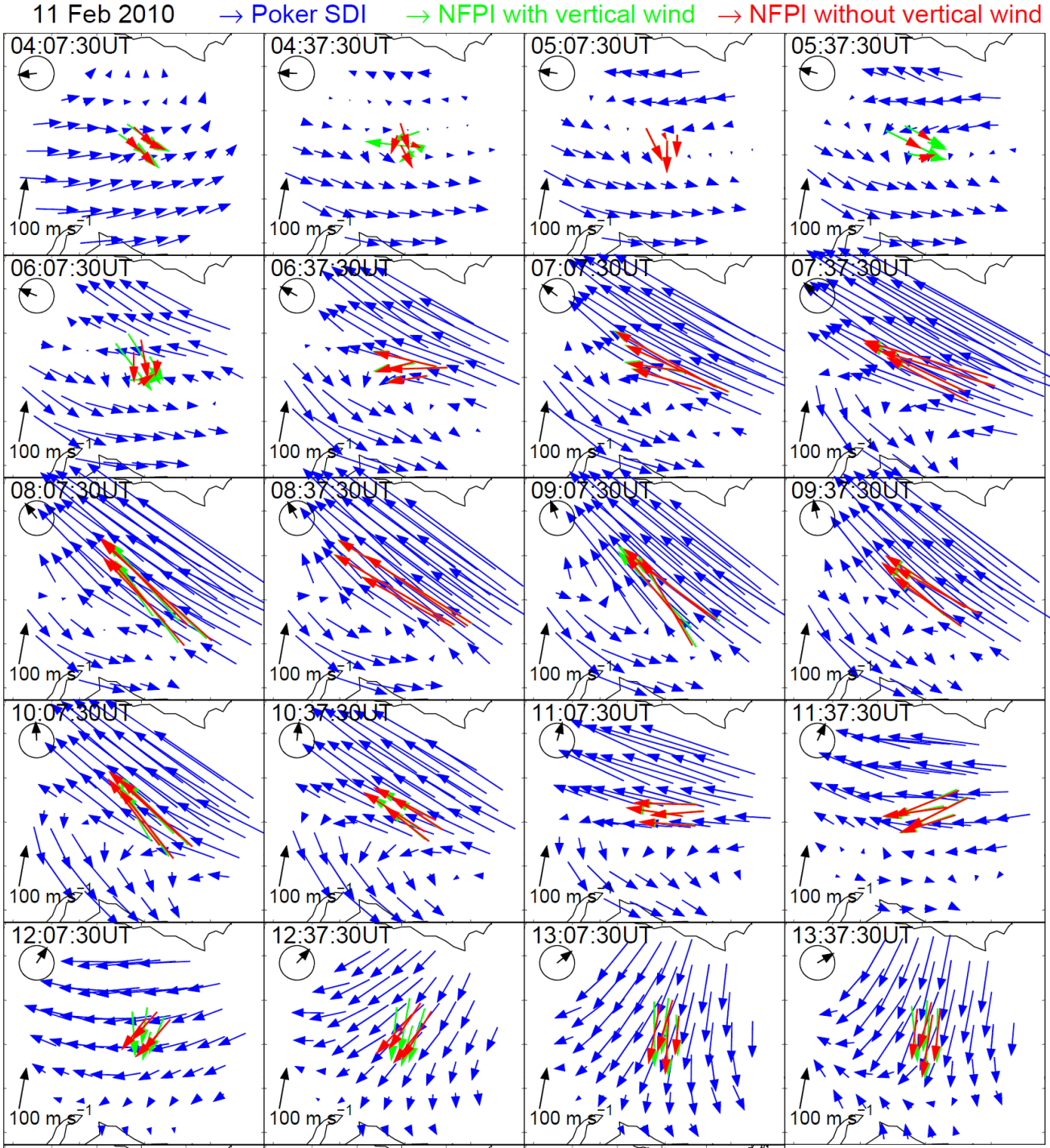
Low temporal resolution single night mapped vector wind field (Feb 11, 2010)

Blue – SDI monostatic wind fit
Green – FPI bistatic fit with vertical wind correction
Red - FPI bistatic fit without vertical wind correction

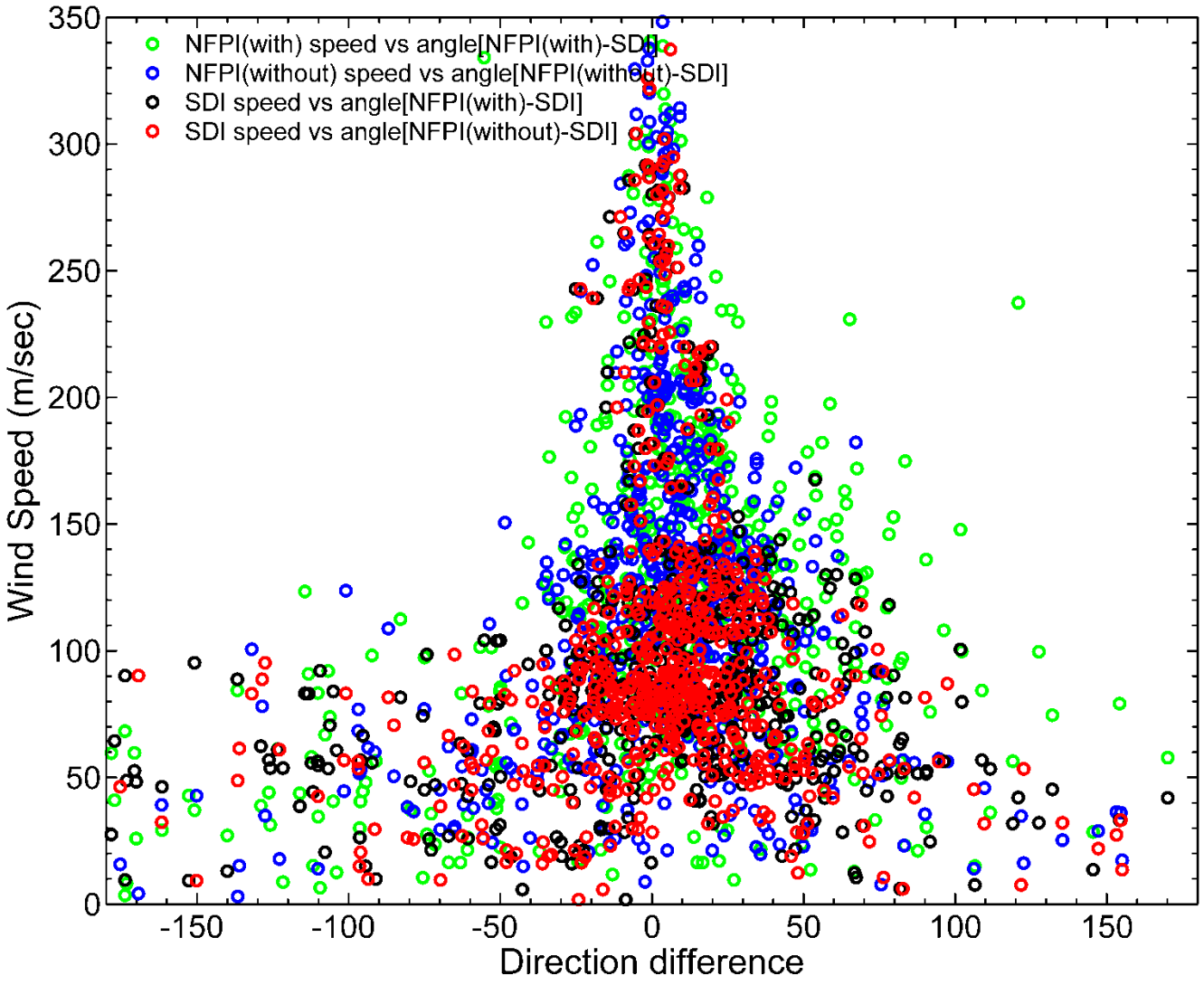
Time is indicated in universal time

Figure is produced at nominal resolution of 30 min

Arrow in circle represents the azimuthal location of sun at Poker Flat



Wind speed vs wind direction difference



Summary

- ✓ Both instruments work independently on different techniques. Modes of operation are different. Methods of analysis are utterly different. Operating software is different. But overall agreement between SDI and FPI observations was good.

- ✓ Observations of similar oscillations by two independent instruments at same time in LOS wind suggest that these high frequency oscillations have thermospheric origin.

- ✓ Since smallest zone of SDI involved in this comparison analysis spans ~40 km in radial direction and the structure in observed SDI wind seems to be suppressed, this suggests the presence of small scale structures with scale size smaller than the size of SDI zone (~40km).

- ✓ Thermospheric winds may be more complex than previously thought.

Thank you !!