Real-Time Fitted Data for the Poker Flat Incoherent Scatter Radar

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Abstract

The Poker Flat Incoherent Scatter Radar (PFISR) is an Advanced Modular Incoherent Scatter Radar (AMISR) located on the Poker Flat Research Range (PFRR) in Alaska. PFISR typically operates in multiple beam modes, taking advantage of the electronic beam steering capabilities of the AMISR architecture. The multiple beam capability produces a large amount of data that provides a significant computational challenge for real time processing. Historically, the unavailability of cheap computational resources have prevented real time fitting of PFISR data, but these challenges are no longer present with modern multi-core processors and parallel processing.

Real time fitted data products from an Incoherent Scatter Radar (ISR) are excellent tools for ionospheric scientific campaigns. Real time ISR data can provide context that may be critical to campaign decision making, such as deciding whether or not ionospheric conditions are optimal for launching a sounding rocket.

Here we present a system architecture for processing PFISR data in real time. The real time products include low-level data (signal-to-noise ratio, uncorrected electron density, and a rough estimate of the line-of-sight velocity), fitted data products in each beam produced by fitting the autocorrelation functions (corrected electron density, electron temperature, ion temperature, and line-of-sight velocity), and derived products produced by combining data from multiple beams (vector velocities and E-region neutral winds). The PFISR real-time system was initially deployed in February 2017, and real time fitted PFISR data supported the February 13, 2017 to March 3, 2017 PFRR sounding rocket campaign.

Advance Modular Incoherent Scatter Radar

Advance Modular Incoherent Scatter Radars (AMISR) are modular and mobile radar systems used for Incoherent Scatter Radar (ISR) diagnostics of the ionosphere. AMISR operates in the UHF band and with a phased antenna array design that contains up to 4096 antennas. The phased array design enables nearly instantaneous beam switching (switch time of 400 μs) providing multiple beam measurement capabilities. This allows for volumetric imaging of ionosphere. Figure 1 shows a picture of the Poker Flat ISR (PFISR) located in Poker Flat, Alaska. Two additional AMISRs (RISR-N and RISR-C) are located in Resolute Bay, Nunavut.

PFISR Specifications:

- 128 panels
- 2 MW peak power at 440 MHz
- Continuous operation since 2007
- Located in the auroral zone

RISR-N and RISR-C Specifications:

- 121 panels
- 1.89 MW peak power at 440 MHz
- RISR-N operating since 2009/RISR-C since 2015
- Located in the polar cap

AMISR radars produce estimates of the electron density, electron temperature, ion temperature, ion velocity, and ion composition. These estimates are obtained by fitting an ISR model to the autocorrelation functions (ACFs) produced from voltage samples measured by the radars. The ACFs are fitted using a model of the incoherent scatter power spectrum, ambiguity functions of transmit pulse waveform, and model of the ion composition. The Levenburg-Marquardt non-linear least-squares technique is used to produce estimates of the best fit parameters and estimates of the fitting errors. The multiple beam capabilities produces a large amount of raw data that imposes a significant computational cost to proces the data. This poses a significant challenge for processing data in real-time, but modern computation resources and software provide a simple solution.

Figure 1: A photograph of the Poker Flat Incoherent Scatter Radar (PFISR) taken November 2011.

Data Transport Network

Data Transport Network is an open-source Python-based software project that was designed to automate the collection, processing, and transfer of data collected by scientific instruments at remote sites. It was developed by Todd Valentic at SRI International. Data Transport Network provides a suite of Python classes that run on top of an InterNet News (INNs) server using the Network News Transfer Protocol (NNTP). The software is extremely versatile and can be used to do everything from running an AMISR radar to managing security camera footage with a Raspberry Pi. Typical uses include: collecting data from multiple remote sites, transferring data offsite, monitoring instrument status and health, remotely controlling and scheduling, and automating data processing. A real-time processing server currently running at PFISR operates a Data Transport Network server to automate the real-time processing tasks.

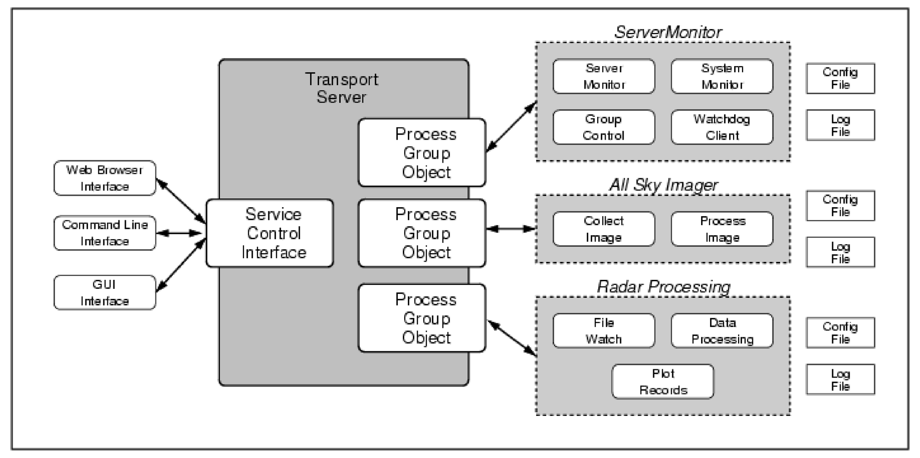

Figure 2: A system block diagram of a basic Data Transport Server.

`http://datatransport.org`

Real Time Data Processing System

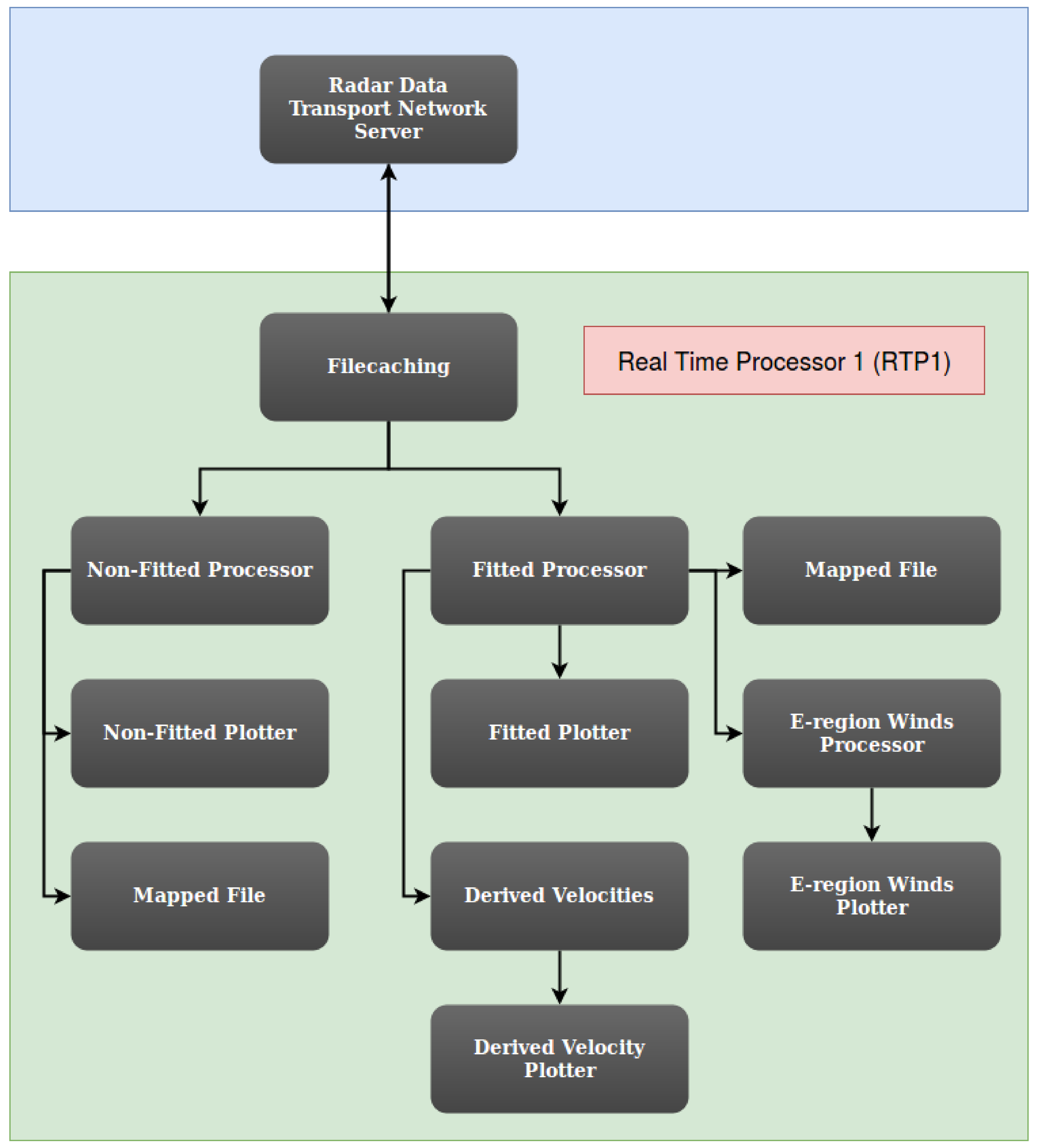

Figure 3: A system block diagram of the Data Transport processes.

Server Hardware and Software Specifications:

- CentOS 7 with Python, AMISR Fitting Software, Data Transport Network, NGINX, and Django
- Silicon Mechanics Server: 2x Intel Xeon E5-2620v4 8-core CPUs, 64 GB RAM, 240 GB SSD, and 6 TB spinning HDD
- Software is mode agnostic; data is processed using all information provided in raw files
- AMISR fitting software modified to use multiprocessing

Processing Delay:

- Filecaching: 1 to 3 seconds
- Nonfitted: 1 to 4 seconds
- Fitted: up to 45 seconds for 23 beams
- Vector Velocities: 1 to 3 seconds
- Plotting: 30 seconds to 2.5 minutes (depending on beams, times, and data type)
- Total delay during 2017 Rocket Campaign: 1.5 minutes

Fitted Data Products

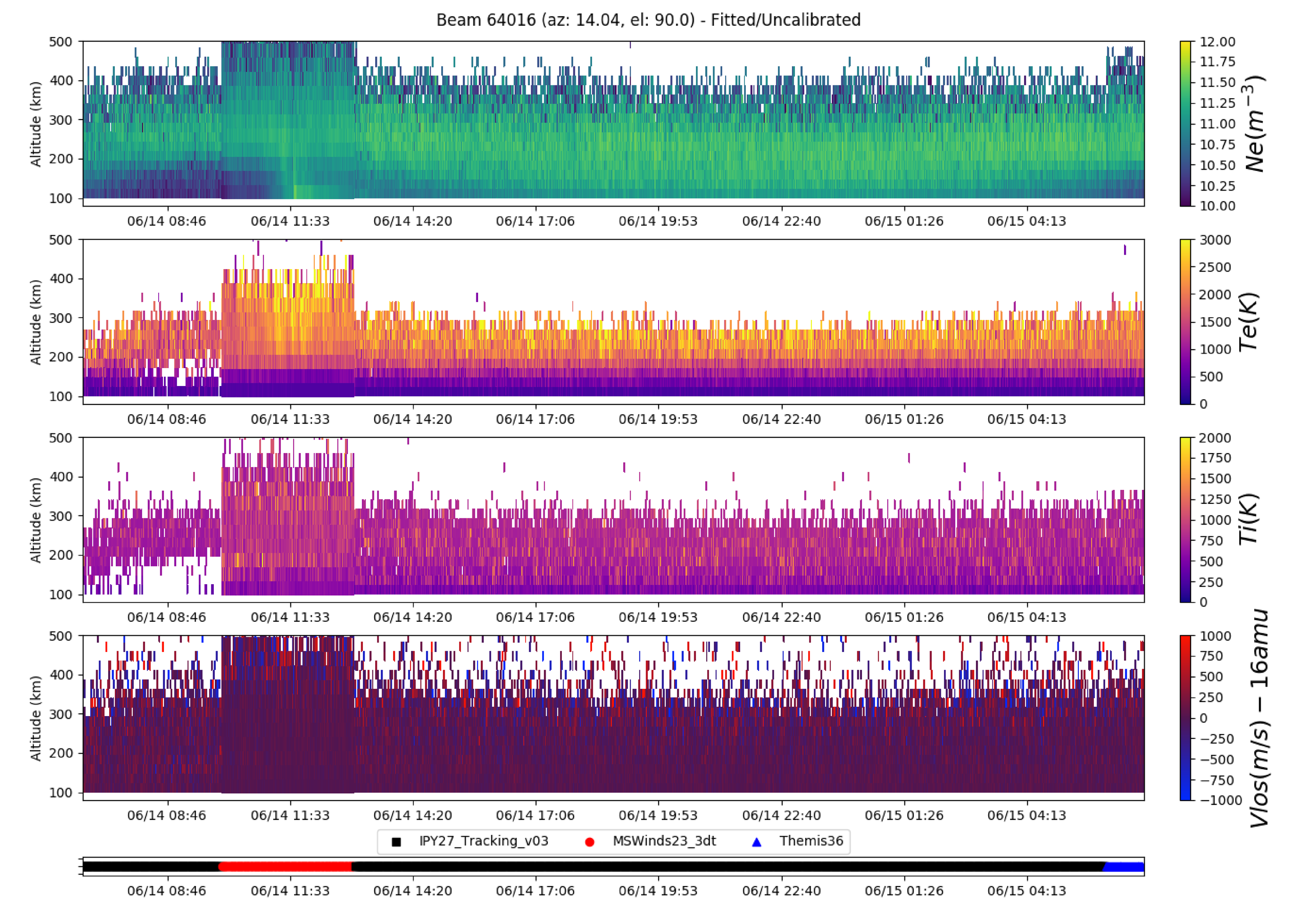

Figure 4: Fitted data products: electron density, electron temperature, ion temperature, and fitted LOS velocity.

Non-Fitted and Velocities

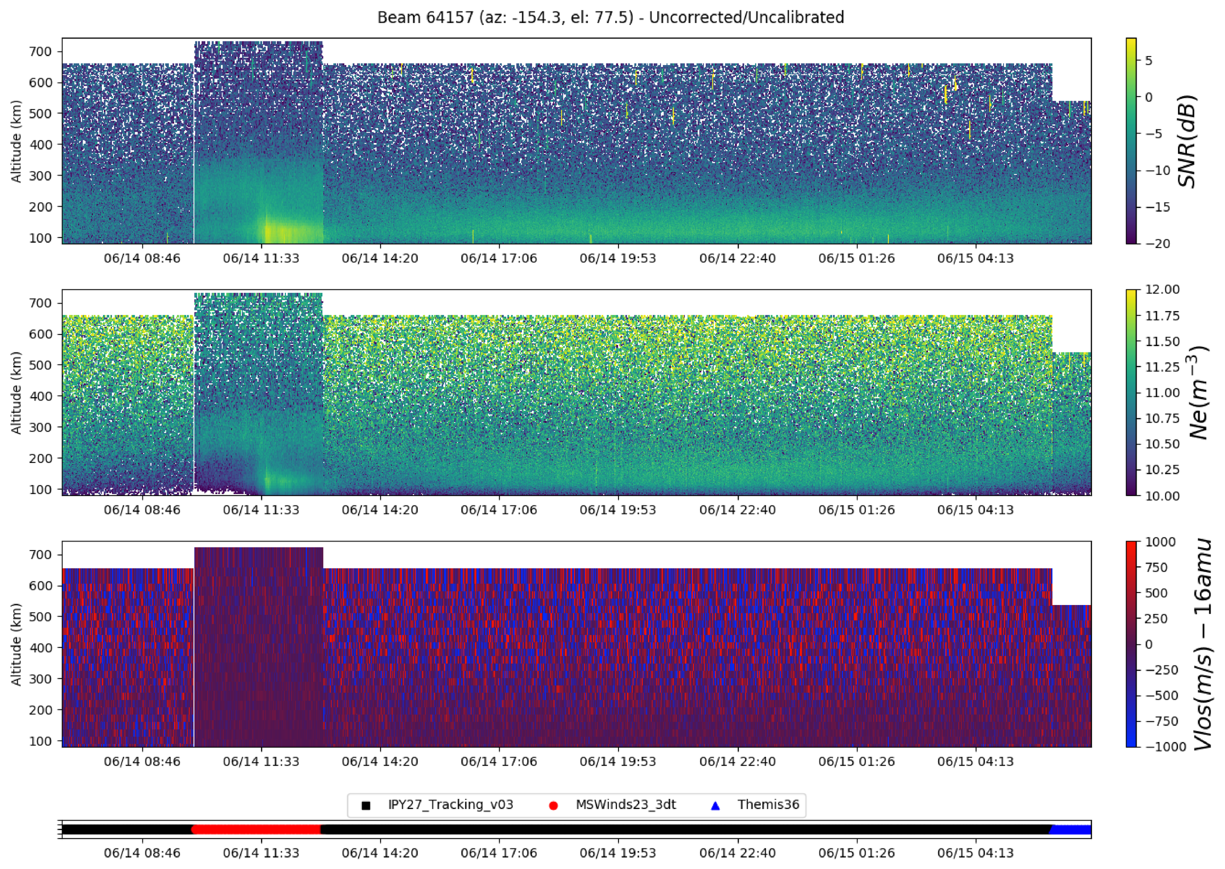

Figure 5: Non-fitted data products: Signal-to-noise ratio (SNR), Uncorrected and uncalibrated electron density, and Line-of-sight (LOS) velocity.

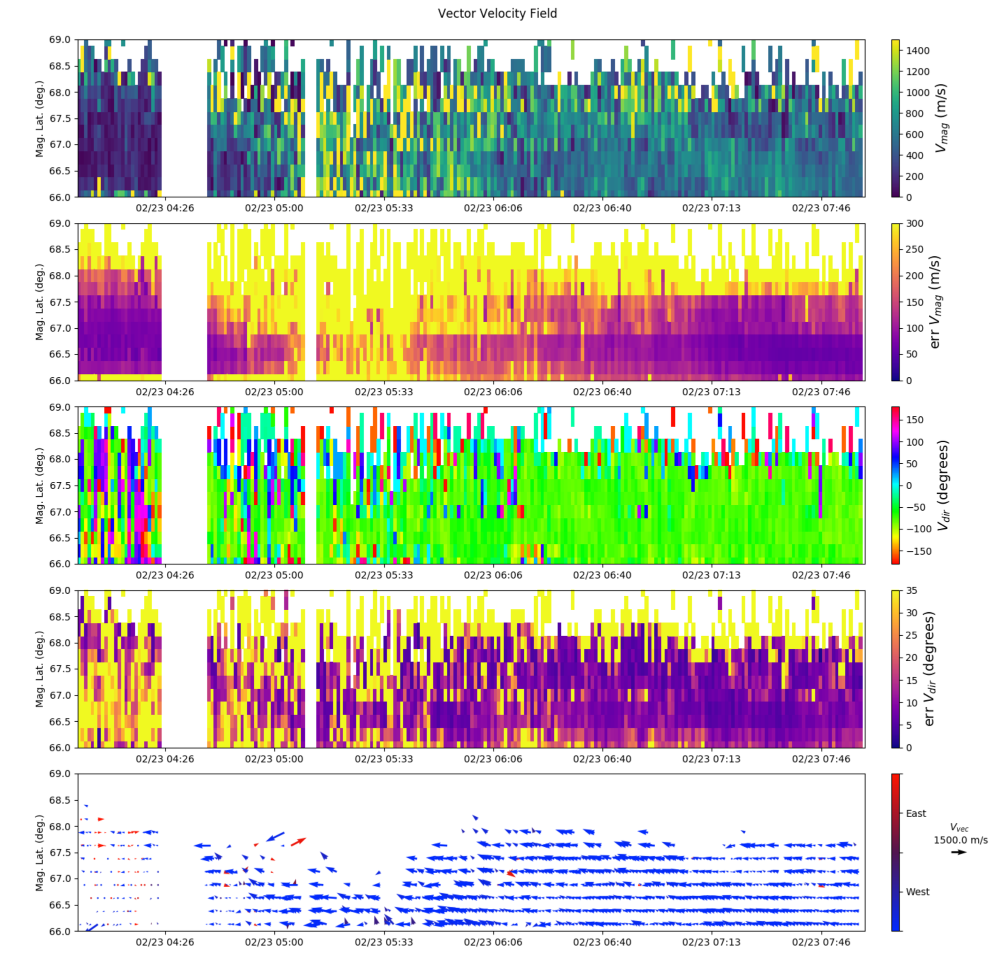

Figure 6: 2D F-region velocities derived from fitted LOS velocities.

Future Work

- Improve plotting code and optimize fitting code to handle 50 beam modes
- Implement multiple-frequency fitted data processing
- Provide public access to plots and data files
- Implement E-region neutral winds for AC and LP modes
- Real-time profile plots, ACFs, and Spectra

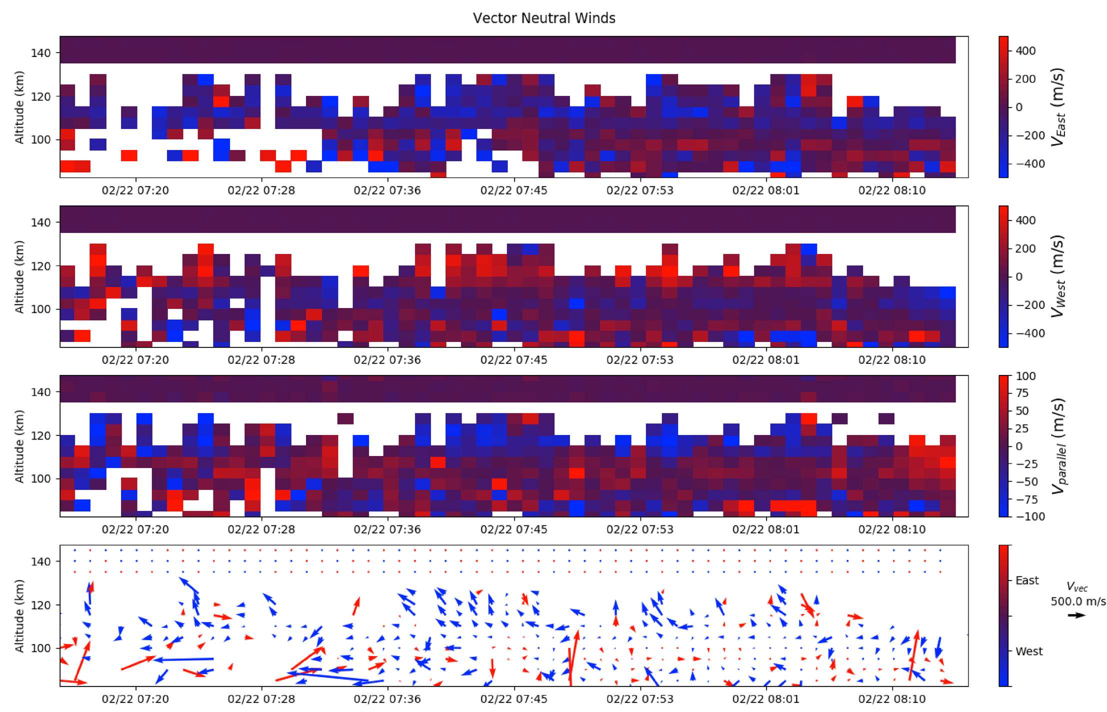

Figure 7: A rough attempt at deriving E-region neutral wind vectors using PFISR alternating code data and long pulse data.

