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All-sky Tracking of Sporadic-E Irregularities as a Novel Probe of Thermospheric Winds

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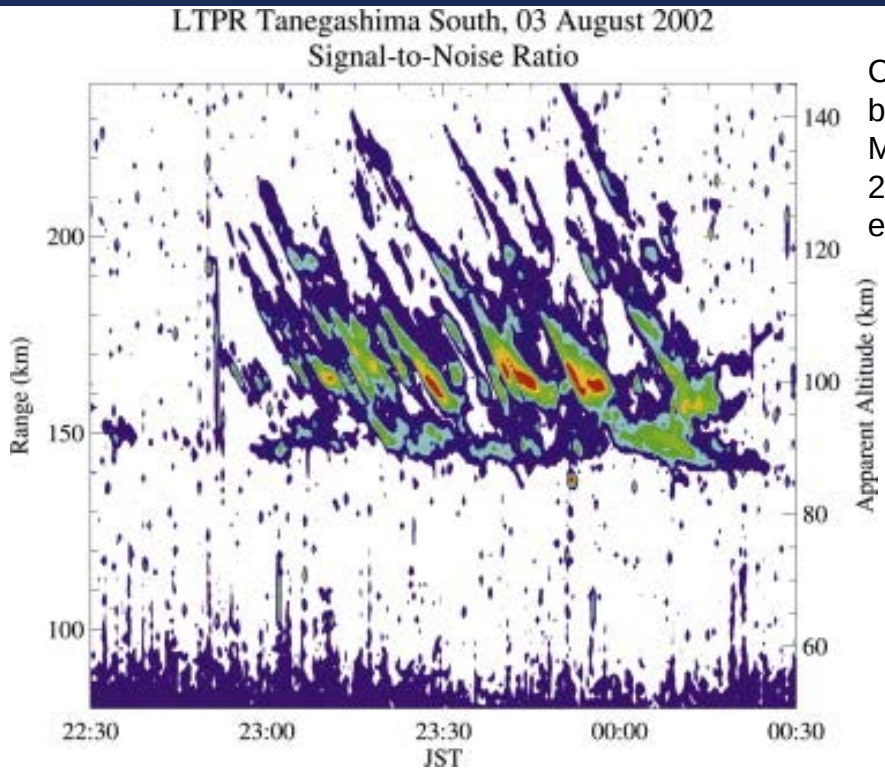
Tracking Sporadic-E

Backscatter from E_S

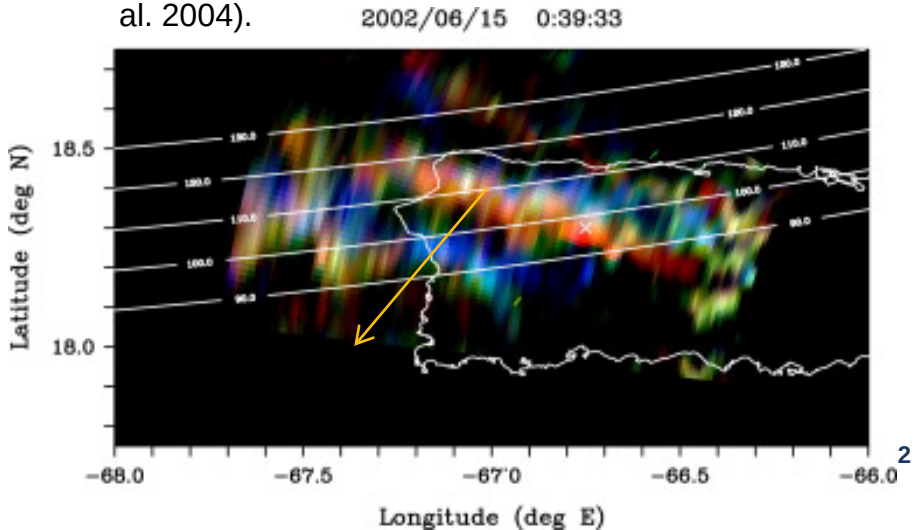
Coherent backscatter radars useful tool for studying E_S structure

- Field-aligned irregularities (FAIs) within E_S layers allow for mapping E_S structure in time and range/height.
- With interferometric receiver array, can make 2-D images as a function of time (i.e., movies).
- In E-region where layers form, dynamics chiefly wind-driven (drifts that form E_S layers relatively weak/slow).
- Tracking motion of E_S structures can provide novel probe of thermospheric winds, especially at heights not easily accessible with meteor radars or optical methods (up to ~100 km).



Coherent backscatter at ~30 MHz during SEEK-2 campaign (Saito et al. 2005).

E_S images with the 30 MHz radar over Puerto Rico (Hysell et al. 2004).



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The Long Wavelength Array

LWA1

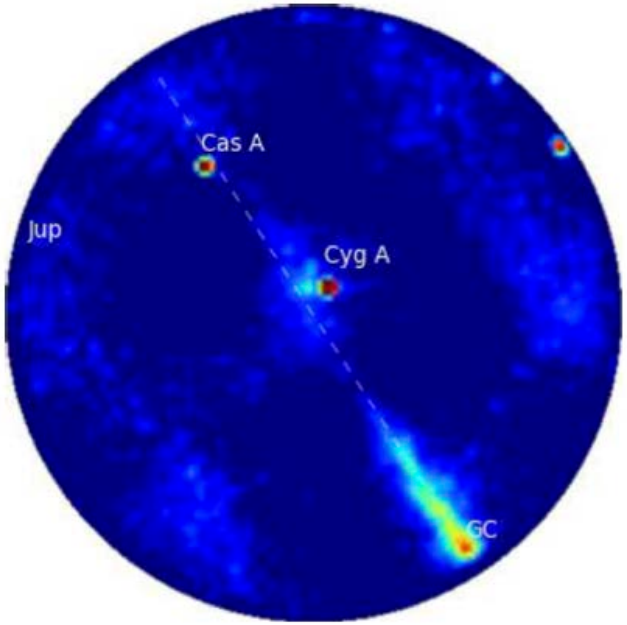
LWA1 is first of (hopefully) many

- Roughly ~100-m wide array of 256 bent dipole/bowtie antennas (NRL-patented design) in quasi-random configuration (minimizes sidelobes in station beam) located at Very Large Array site in NM.
- Can form up to 4 beams simultaneously, each with 16-MHz of bandwidth.
- Also has transient buffer (TB) mode that records I/Q data at 100 kHz sampling rate from each antenna; allows for all-sky imaging.
- Dedicated backend (PASI) makes images every second when in TB mode; can stream them in (near) real time:

http://www.phys.unm.edu/~lwa/lwatv.html

(or google “LWA TV”)

- Second station now operational ~100 km away near Sevilleta wildlife refuge.



Prototype All-Sky Imager (PASI) image at 74 MHz (Ellingson et al. 2013).

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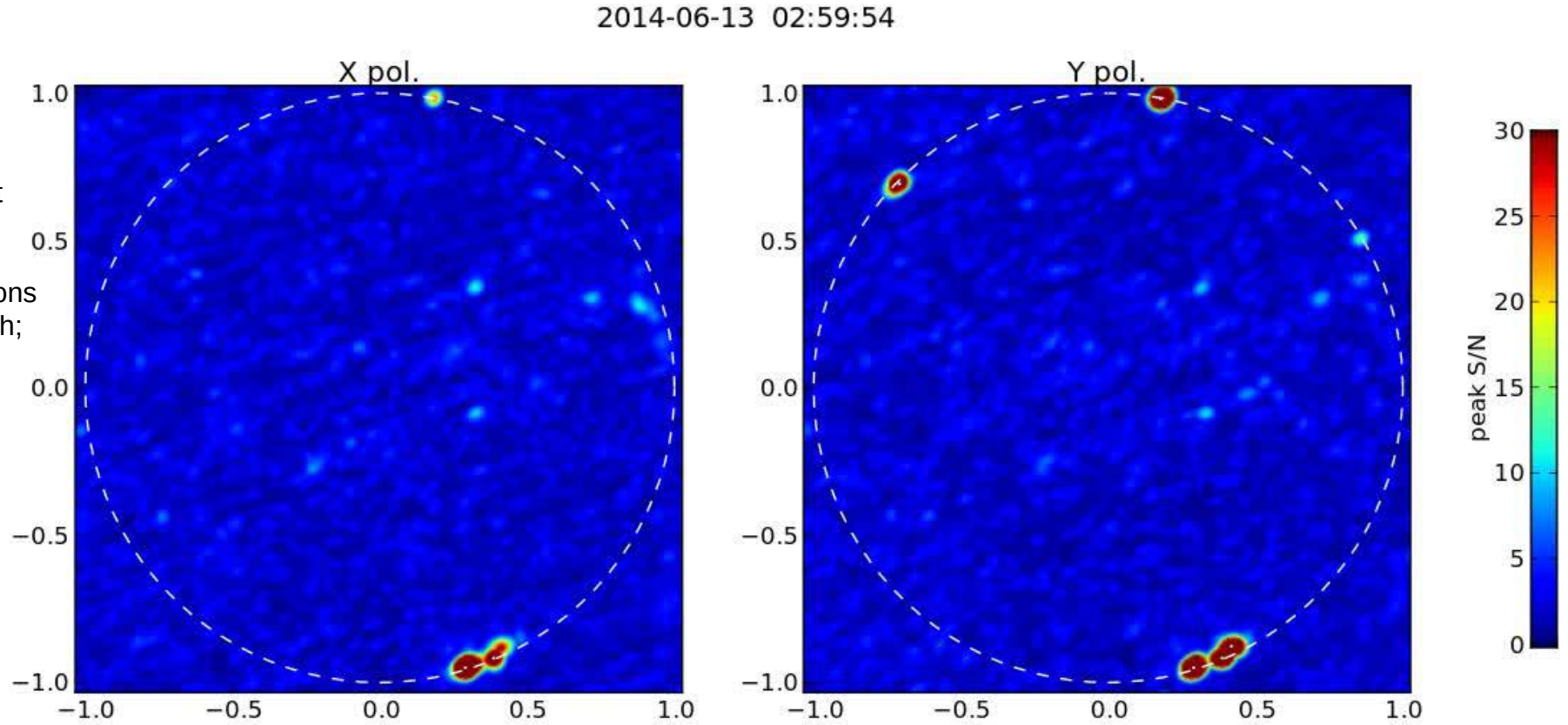
Transmitters of Opportunity

All-sky backscatter imaging

Developed imaging pipeline for use with analog TV signal

- Uses narrow-band video carrier at 55.25 MHz from Channel 2 in Ciudad Juarez, Mexico (XEPM; ~290 km away).
- Pipeline is tailored to look for backscatter from meteor trails, but also see airplanes and XEPM ground wave.
- When E_S present, get backscatter from FAIs along arcs to the north.



All-sky backscatter at 55.25 MHz in June 2014 for two polarizations (X=north-south; Y=east-west).

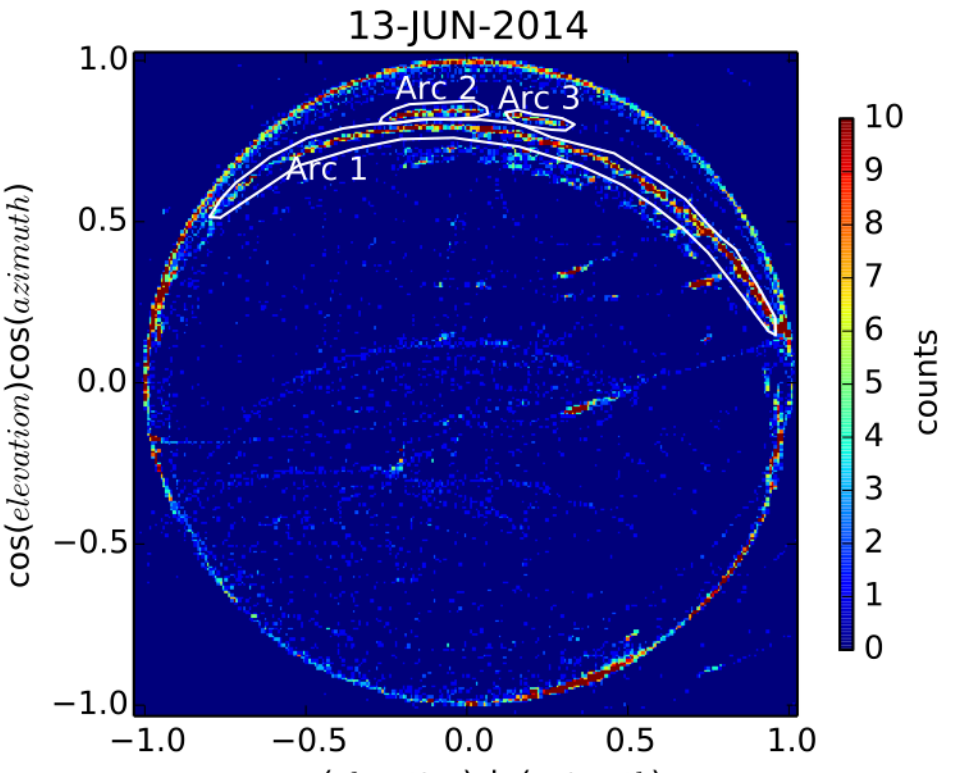
Identifying E_S Clouds

2014 Observing campaign

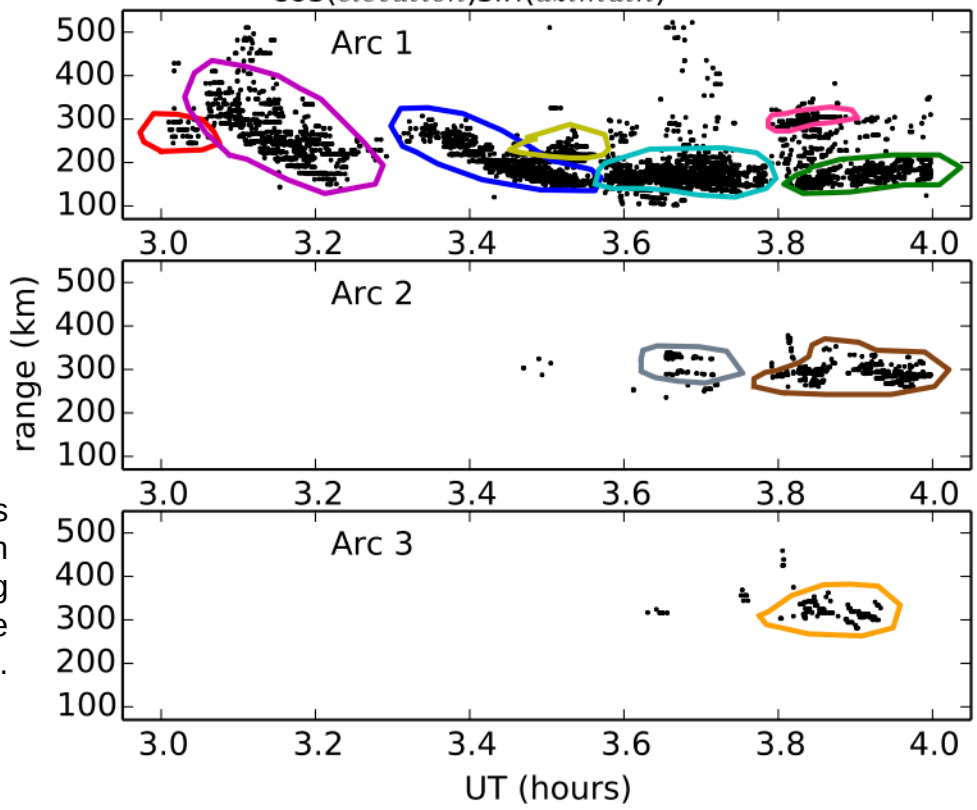
Looking for meteor streams, finding FAIs

- 2014 observing campaign: Did 1-hour collection once every 40 hours, 03—04 UT (pre-midnight), 11—12 UT (post-midnight), and 19—20 UT (midday).
- Found northern arcs associated with E_S FAIs (mostly) during summer nighttime; interference from airplanes too high during midday.
- Identified individual arcs by eye with polygons; convert sky positions to Cartesian coordinates using known XEPM and LWA1 locations with dipole field model.
- Within each arc, identify groups/clouds moving together using range vs. time plots.

Source counts from one-hour 55.25 MHz collection; three arcs identified and shown with polygon boundaries.



Find clouds within each arc using range time series.



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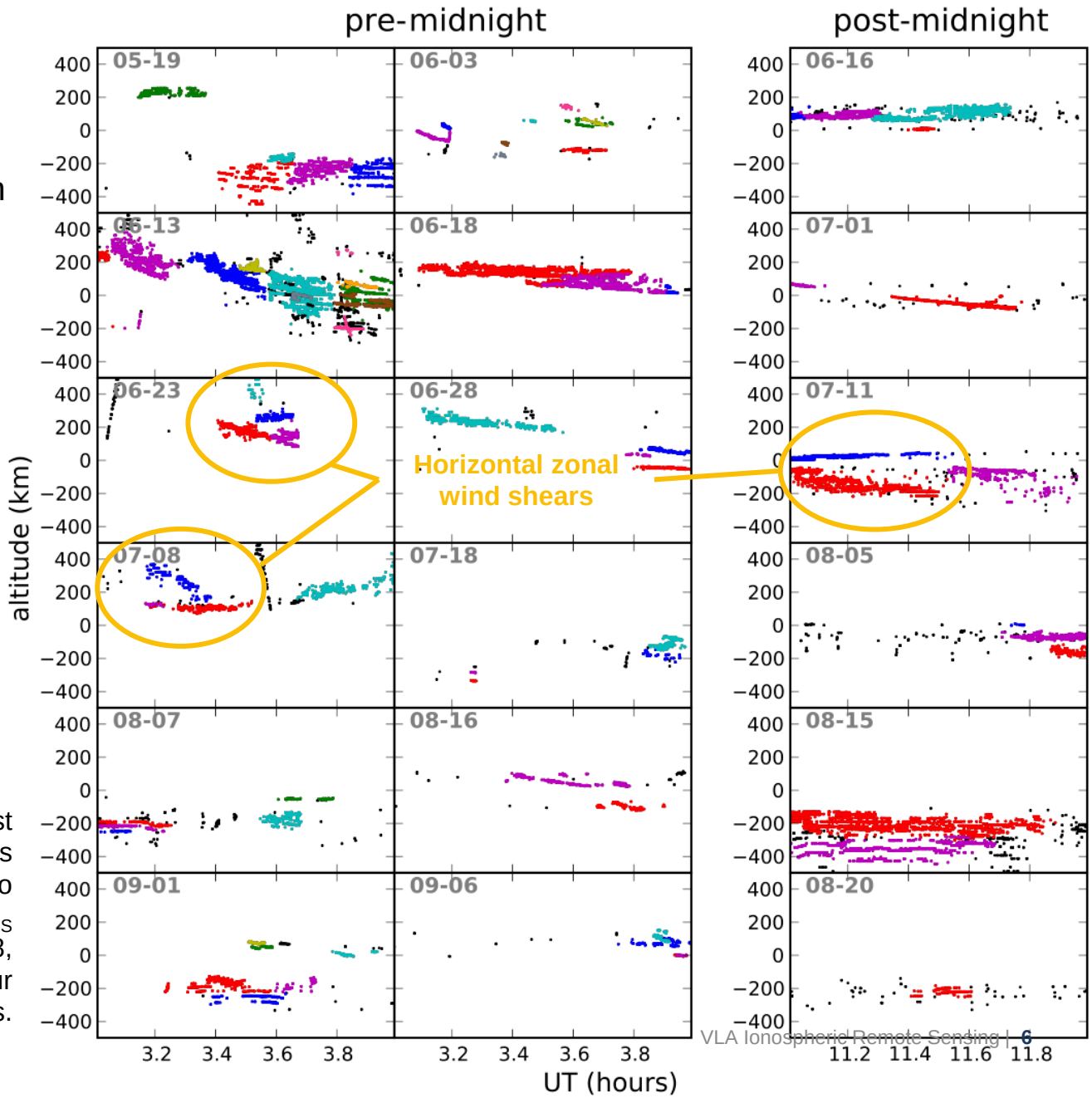
Tracking E_S Clouds

2014 Observing campaign

Used cloud motions and wind tracers

- For each group of sources/cloud, used linear fit of estimated Cartesian positions vs. time to get horizontal velocity vector per cloud.
- Used distribution of heights to estimate cloud thickness (range from few km to ~30 km).
- Groups observed simultaneously generally move in same direction; did find 3 instances of apparent horizontal zonal wind shear (magnitudes ~1 m s^{-1} km^{-1}).



East-west positions (relative to LWA1) of E_S clouds for 18, one-hour collections.

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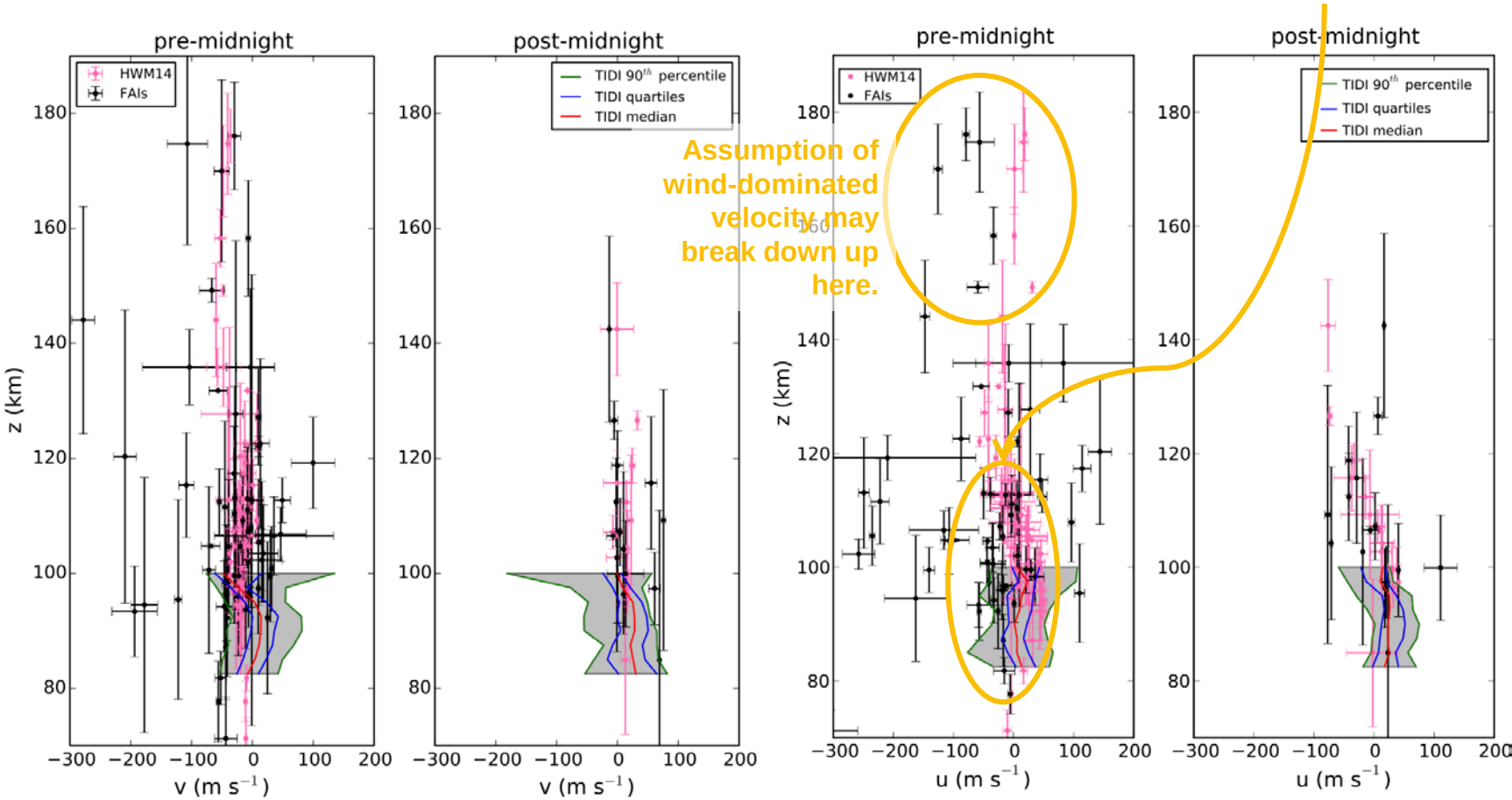
E_s-derived Winds

Compare with TIDI and HWM14

Full campaign gives composite vertical profiles

- Agreement with mid-latitude TIDI profiles (25°—45° latitude; 20—04 UT) fairly good in region of overlap except pre-midnight zonal winds.
- Agreement with updated Horizontal Wind Model (HWM14) also quite good, especially post-midnight. Strong gusts of ~100—200 m s^{-1} seen pre-midnight; not possible for climatological HWM14 to capture these; consistent with chemical release experiments (e.g., Larsen 2002). Pre-midnight zonal winds show westerly offset.

Mean wind profiles for the pre- and post-midnight sectors; distributions for TIDI mid-latitudes are shown as grey shaded regions; HWM14 predictions are in pink.



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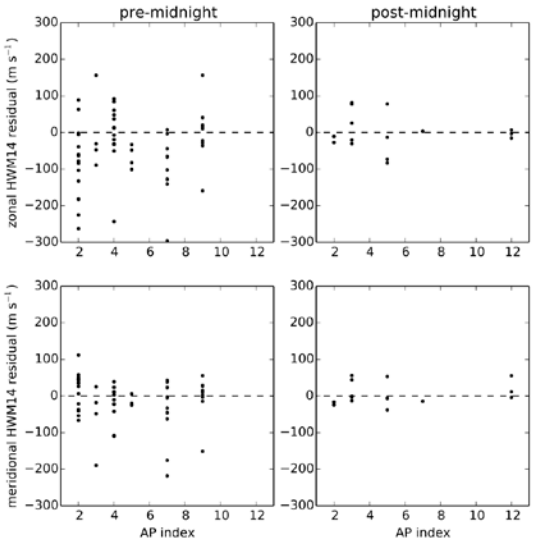
Gravity Waves?

Cause of pre-midnight westerly offset not clear

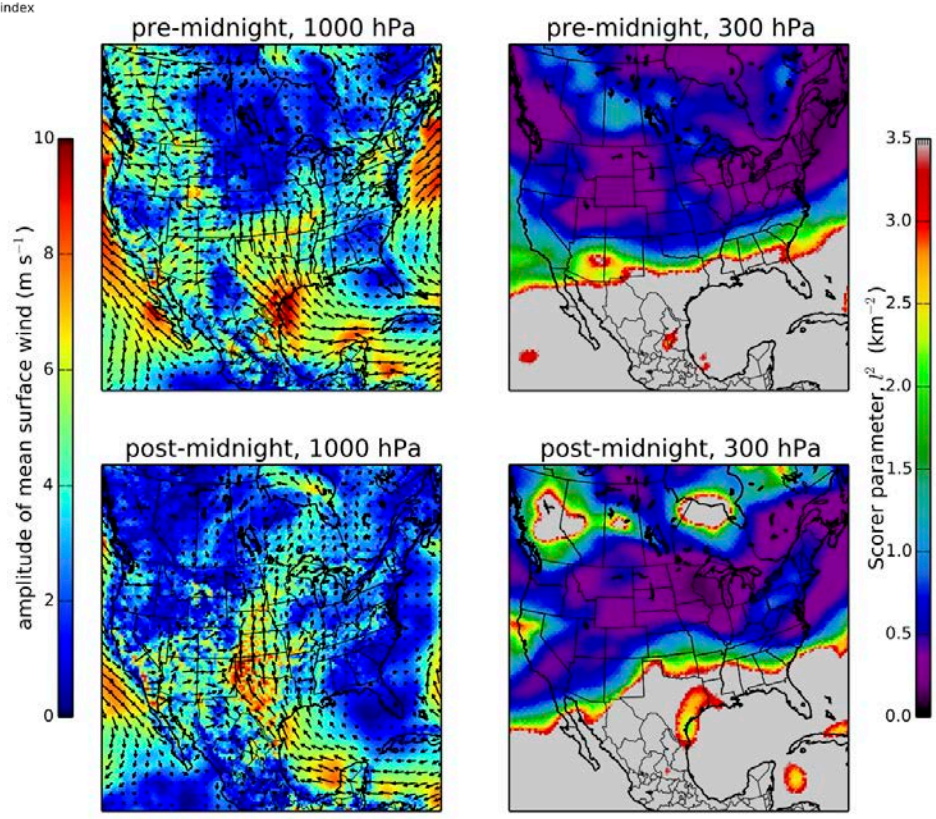
Could be unaccounted-for drift, localized distortion in tides, solar/geomagnetic activity . . .

- No apparent trend with AP index.
- Semi-diurnal tides that drive wind profile shape possibly modified by gravity waves.
- But, they would have to be local to the region near LWA1, or TIDI/HWM14 would be affected, too.
- Southwestern CONUS is very mountainous, but mountain waves usually can't leave troposphere during summer.
- Some indication from wind data (NARR) that pre-midnight collections at times when conditions favorable to mountain waves escaping troposphere over Arizona.



Residuals with HWM14 as functions of AP index.

Surface winds (left) and Scorer parameter near the tropopause (right) from NOAA North American Regional Reanalysis (NARR) for pre- and post-midnight collections.



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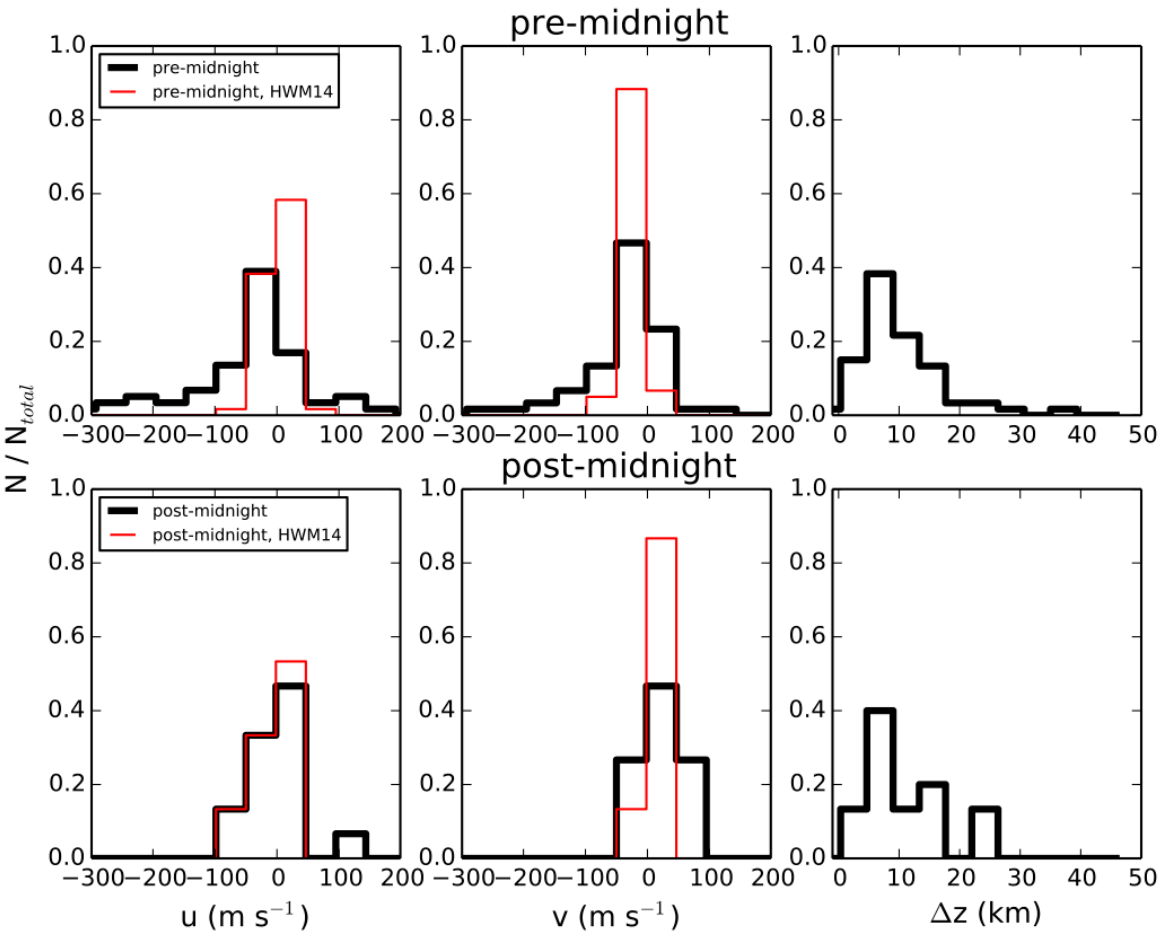
Summary

All-sky tracking E_S clouds is novel probe of winds

Unique attributes

- Can monitor the wind in several locations spread out over a large area; led to identification of three instances of horizontal zonal wind shear.
- Can reach relatively high (approaching ~150 km or higher) compared to other methods.
- Measure wind in extremely localized way; found many cases of large gusts in excess of 100 m s^{-1}.



Wind and vertical thickness distributions for the 2014 campaign; HWM14-predicted wind distributions are also plotted (in red).