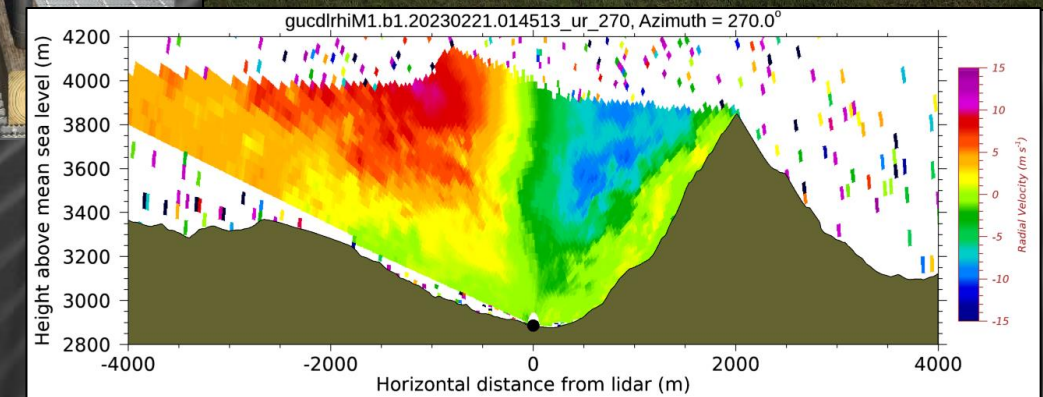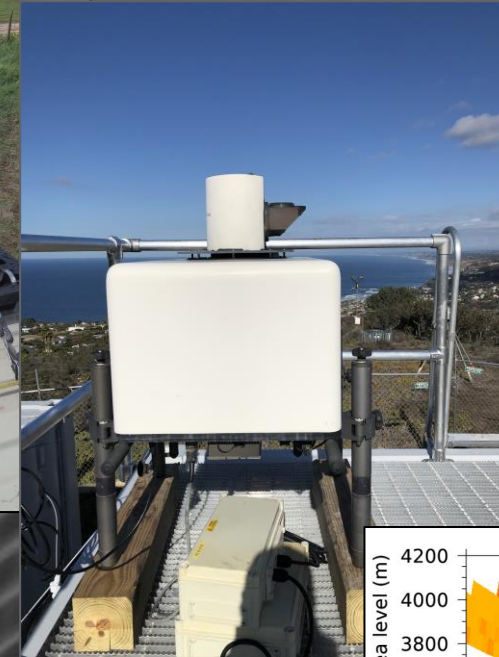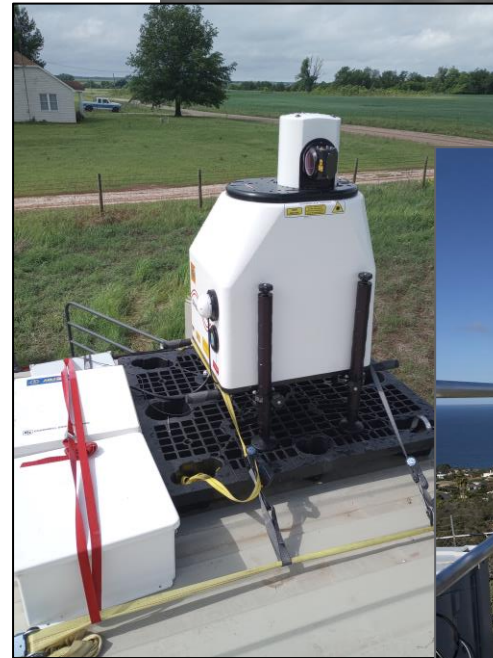# Lidar Applications Breakout

Rob Newsom,

Raghu Krishnamurthy

Damao Zhang

The goal of this session is to provide an opportunity for scientists to describe the use of ARM lidar data in their research, and to provide a forum to discuss scientific and data-related challenges associated with the use of that data. Brief instrument and VAP updates will be provided along with plans for relocating existing instrumentation, new instrument procurements, and VAP development. Our focus is primarily on the use of Raman, Doppler and HSRL data.

Agenda

1. Brief overview and update on advanced ARM lidar systems – **Rob Newsom (10 min)**
2. Upgrades and Additions to the ARM High Spectral Resolution and Raman Lidars - **Ray Bambha (10 min)**
3. Update on ARM lidar-related data products – **Damao Zhang (10 min)**

4. Assessment of vertical CCN retrieval methods against in-situ CCN measurements from SGP – **Gourihar Kulkarni (5-10 min)**
5. High-resolution lidar with a range resolution down to 10 cm - **Fan Yang (5-10min)**
6. Observations of Wind Farm Atmosphere Interactions within the American Wake Experiment (AWAKEN) - **Patrick Moriarty (5-10min)**
7. Update on AWAKEN analysis – **Raghu Krishnamurthy (5-10min)**
8. A comprehensive dataset of Boundary Layer Height using Micropulse Lidar at multiple ARM sites. **- Natalia Henao, Tianning Su, Zhanqing Li (5-10min)**

9. Discussion. Potential topics might include:
    a. Doppler lidar scan strategies
    b. Lidar Simulators
    c. Applications of edge computing
    d. Cooperative lidar/aircraft measurements
    e. Others?

ARM Raman Lidars

- Raman Lidar #1
  - Southern Great Plains
  - In operation since 1996
  - Developed by John Goldsmith @ SNL
- Raman Lidar #2
  - Darwin, AU from 12/2010 to 1/2015
  - ENA since 9/2015
  - Developed by John Goldsmith @ SNL
- Raman Lidar #3
  - AMF3, Oliktok Point from 9/2014 to 10/2019
  - Developed by John Goldsmith @ SNL
  - Currently non-operational at SGP
  - Will relocated to BNF soon.
  - Developed by John Goldsmith @ SNL

SGP Raman Lidar

ENA Raman Lidar
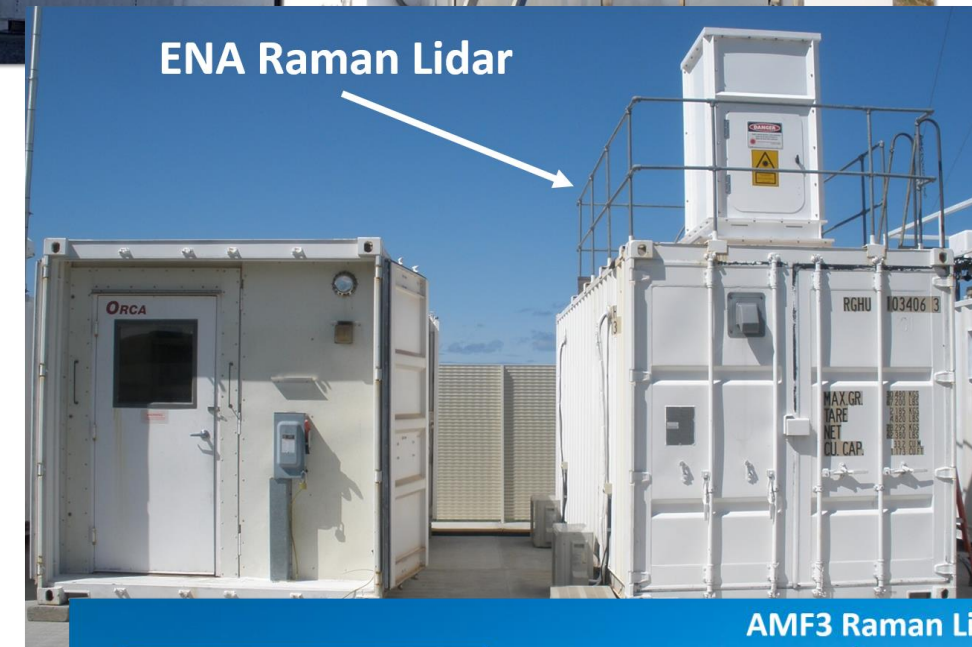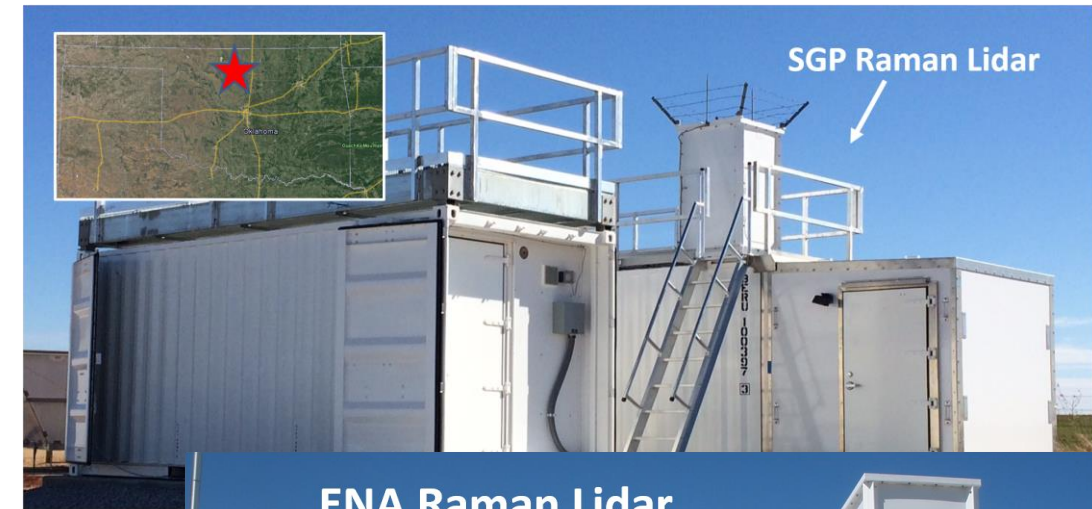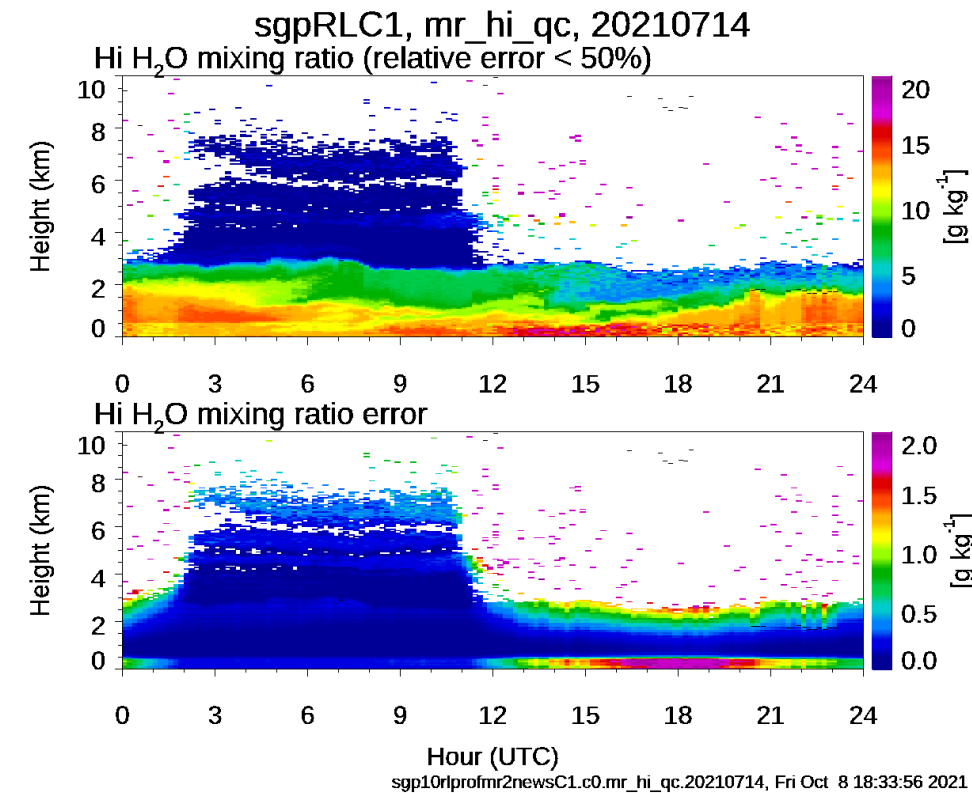
AMF3 Raman Lidar

ARM Raman Lidar

- Transmitter
  - 355 nm (300 mJ, 5ns pulse @ PRF = 30)
  - Class IV inside the trailer
- Receiver consist of multiple detection channels
  - 355 nm (elastic, co- and de-polarized)
  - 387 nm (N2)
  - 408 nm (H2O)
  - 353 and 354 nm (Temperature sensitive)
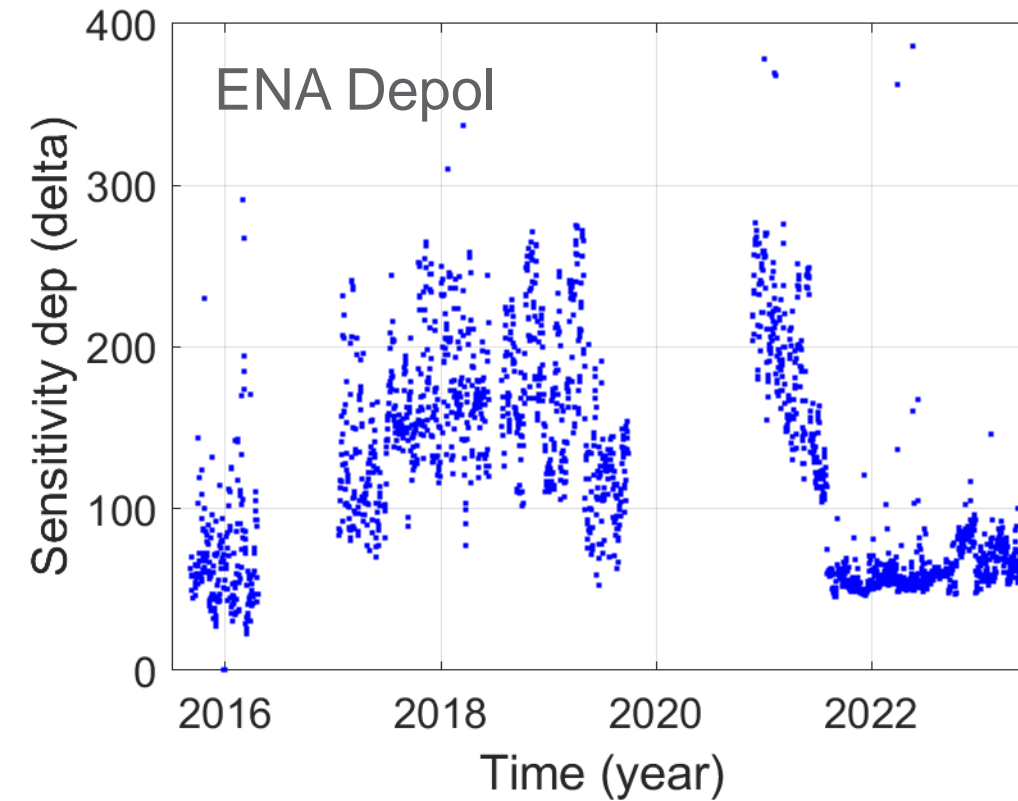- Direct Measurements consist of photon counting rates from each channel

ARM Raman Lidar Measurements

Derived Measurements

- Water Vapor Mixing Ratio (10 min, 60 m), *rlprofmr2news*.c0

- Temperature (10 min, 60 m), *rlprofmr2temp*.c0

- CBH (10 sec), *rlprofmergenews*.c0

- Aerosol/Cloud Optical Properties *rlproffexthor*.c0
    - Backscatter coefficient
    - Extinction coefficient
    - Linear depolarization ratio
    - AOD

sgpRLC1, mr_hi_qc, 20210714

Hi H_2O mixing ratio (relative error < 50%)

Hi H_2O mixing ratio error

Hour (UTC)

sgp10rlprofmr2newsC1.c0.mr_hi_qc.20210714, Fri Oct 8 18:33:56 2021

Recent Raman Lidar Issues
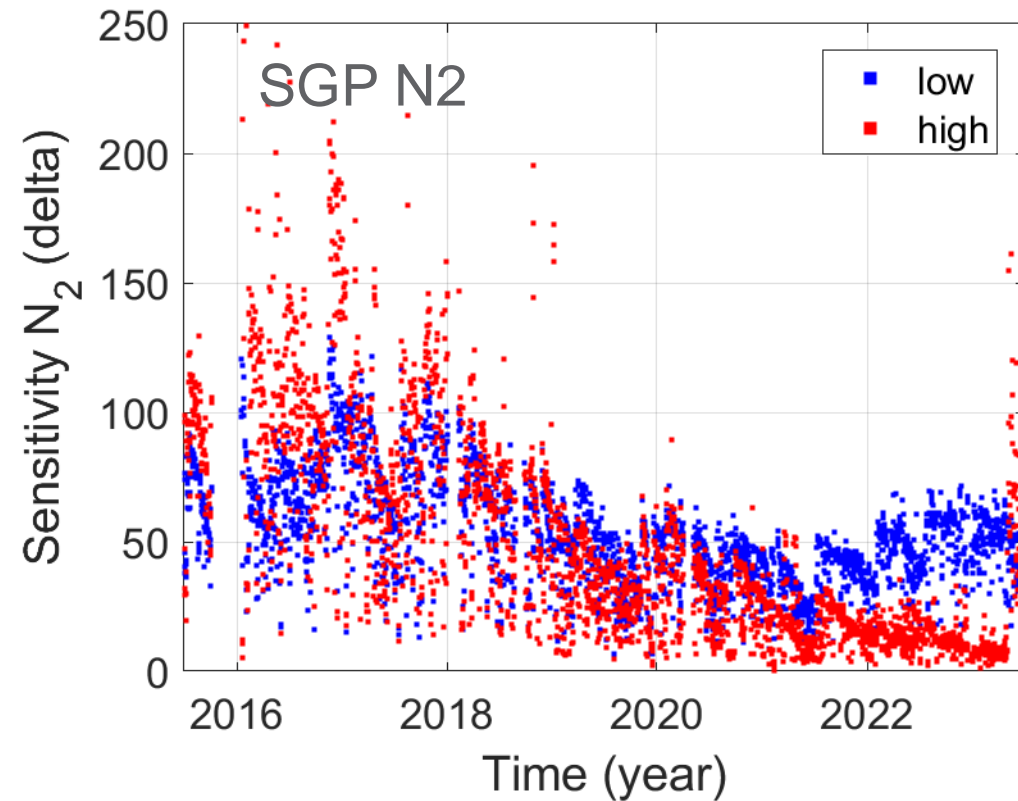
- Gradual loss of sensitivity in N2 (hi) at SGP
- More sudden loss of sensitivity in the depol channel at ENA
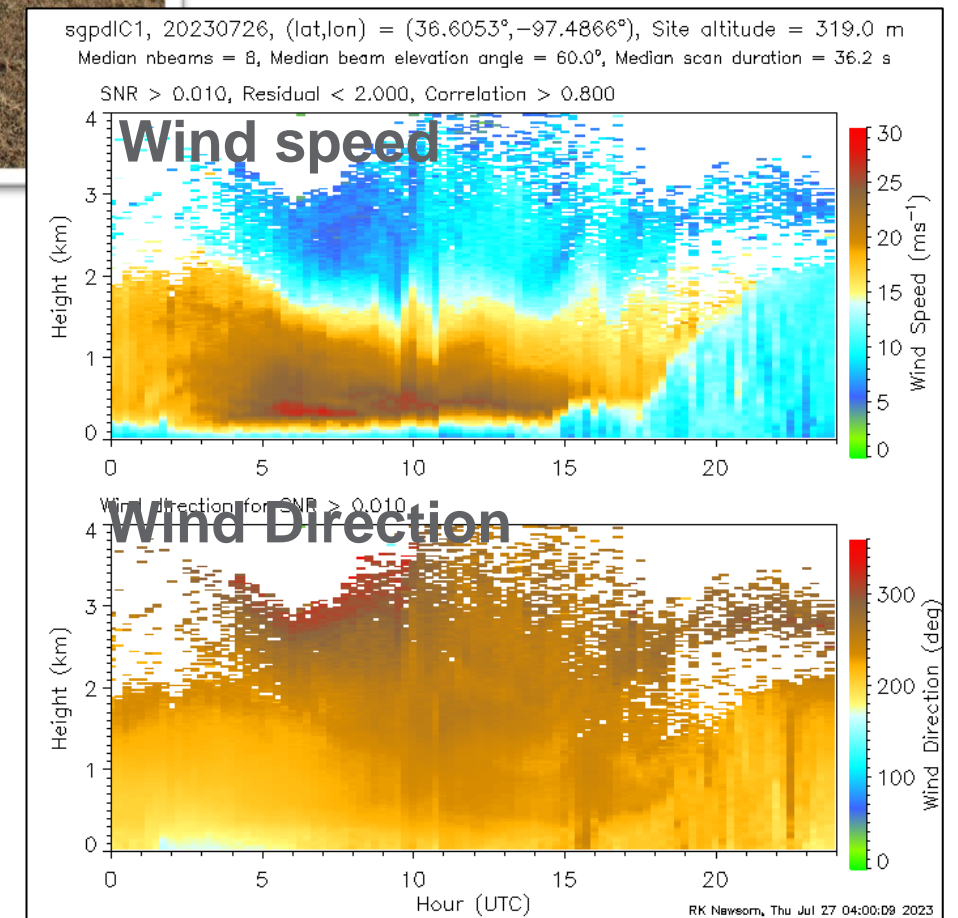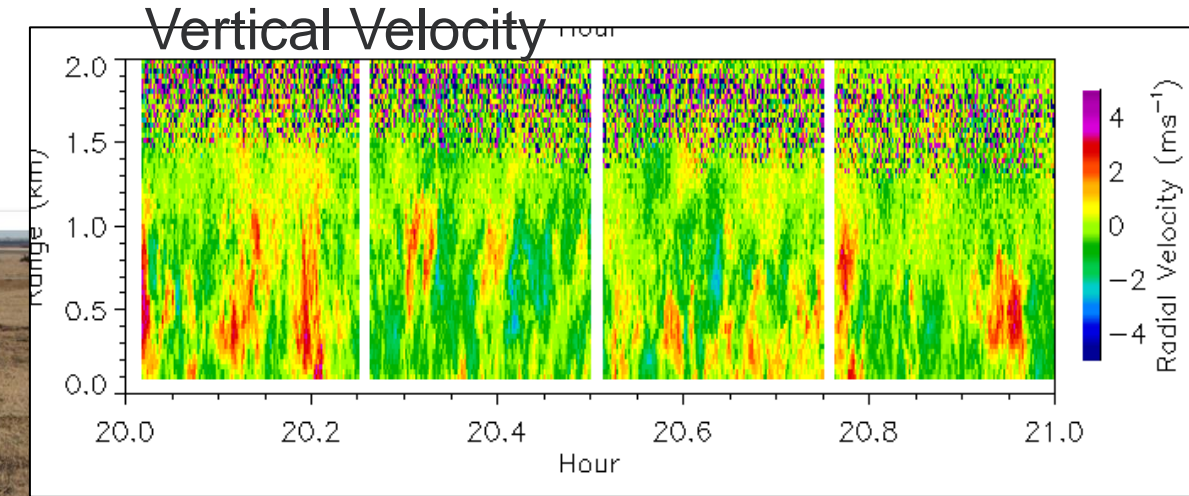
ARM Doppler Lidars

- Direct measurements
    - Radial Velocity
    - Attenuated Backscatter
    - Spectral Width
    - Signal-to-noise ratio
- Derived Measurements
    - Wind speed and direction (10-15 min, 30 m): *dlprofwind2news*.c1
    - Vertical velocity statistics (30 min, 30 m): *dlprofwstats2news*.c1
        - ✓ Variance, skewness, kurtosis
        - ✓ CBH and cloud base vertical velocity
    - Boundary-layer height VAP
    - Other possible derived measurements
        - ✓ TKE, momentum flux, eddy dissipation rate, raindrop terminal fall speeds and drop sizes, …

Vertical Velocity

Wind speed

Wind Direction

ARM Doppler Lidars Specs

- Halo Photonics (now Lumibird)
- StreamLine (SL)
  - Full Scanning
  - PRF = 15 kHz
  - <100 mJ per pulse
  - Range resolution: 18 – 60 m
  - Beams rate > 10 Hz
  - Velocity Precision < 10 cm sec^{-1}
  - Deadzone: ~ 90m
- XR+
  - Same as SL except…
  - PRF = 15kHz
  - Stronger pulse and enhanced signal processor
  - Longer range
- PRO (profiling)
  - Same as SL except…
  - Scan only to within +/-20 deg of zenith
  - Deadzone: ~ 50m for the PRO

XR+

PRO (profiling)

SL

Currently Deployed

- ARM Currently has ~~15~~ 14 operational Doppler lidars

Site	Facility	Serial Number	Model	Year acquired
EPC	S2	007	SL	2010
SGP	S5	008	SL	2010
NSA	C1	082	PRO	2014
SGP	C1	083	SL	2014
ENA	C1	084	SL	2014
SGP	C1	107	XR+	2016
SGP	E37	108	SL	2016
EPC	M1	109	PRO	2016
SGP	E39	160	PRO	2019
SGP	S4	215	XR+	2021
SGP	S6	216	XR+	2021

Systems Not Currently Deployed

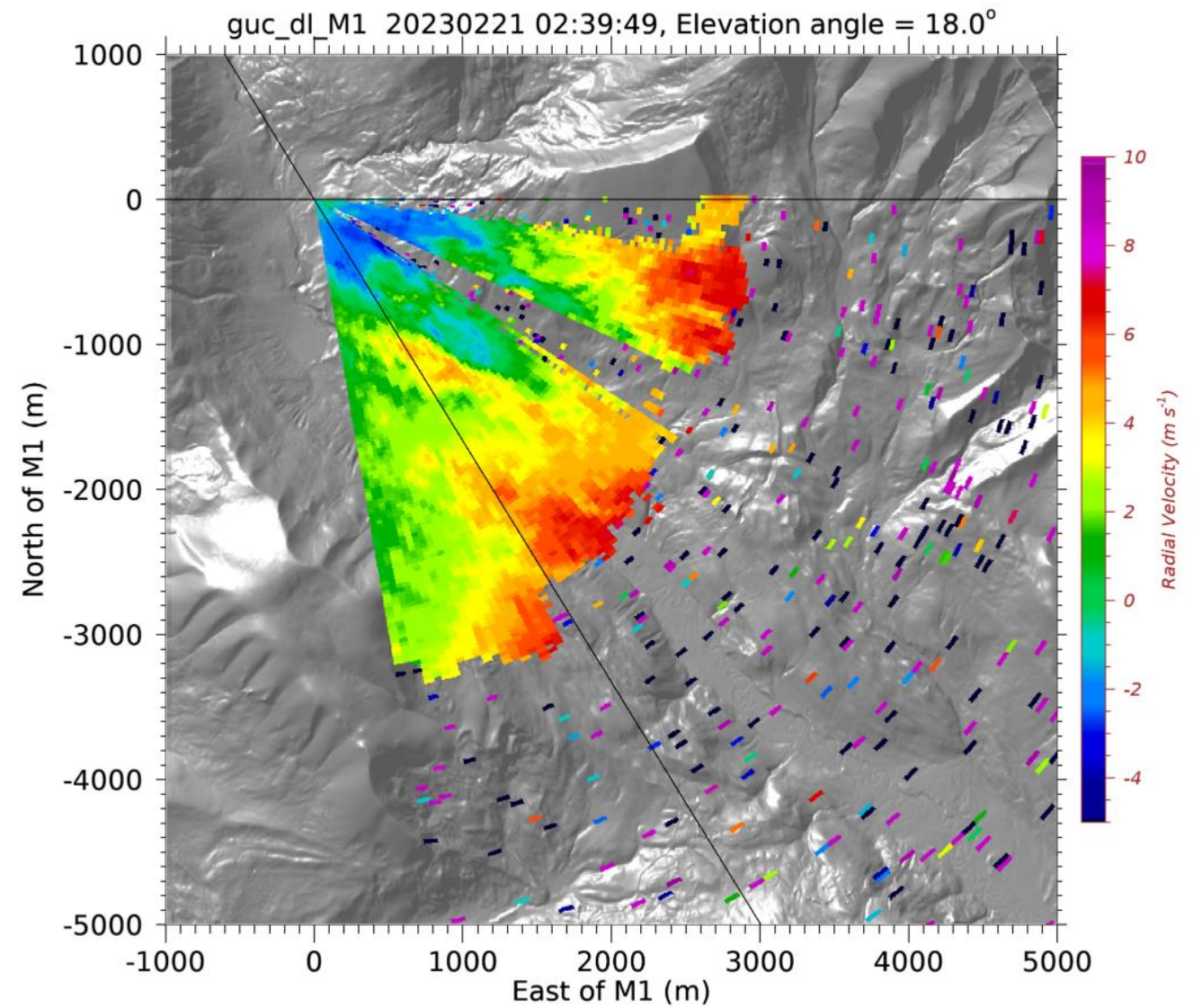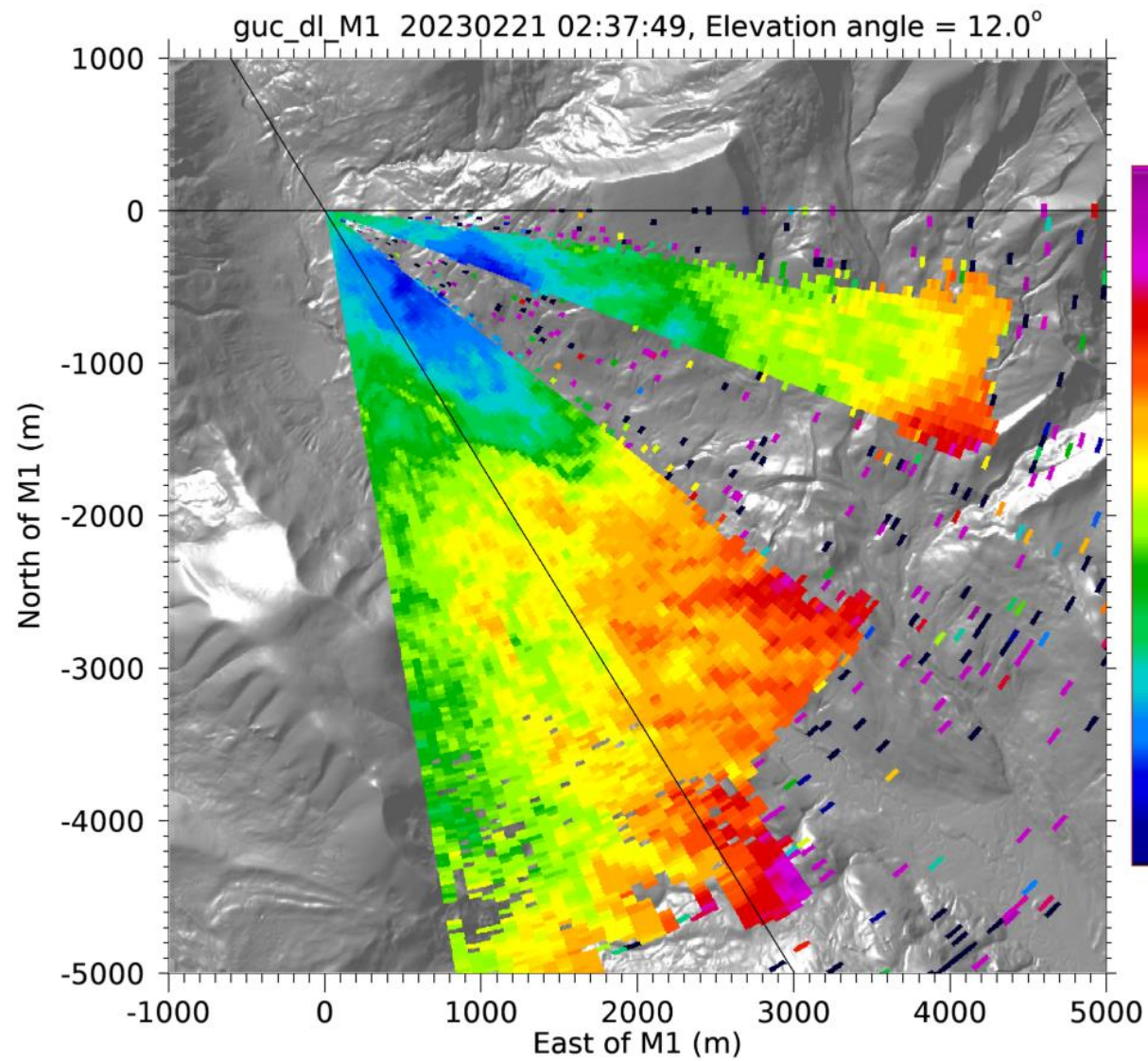| Serial Number	Model	Current Location	Comment
193	XR+	LANL	• Last deployed during SAIL. • Will replace the 07 system at EPCAPE
009	SL	SGP Warehouse	• Last deployed during TRACER • Currently not working • The first retirement of an ARM Doppler lidar!
236	XR+	SGP Warehouse	• Last deployed during AWAKEN • Will be deployed at SGP E39 • The current E39 lidar will go back to LANL for CAPE-K
237	XR+	SGP Warehouse	Last deployed during AWAKEN

ARM Doppler Lidar News

- Support for AWAKEN
  - Wind energy field experiment that is currently underway just south of SGP C1.
  - Couple of posters and a of couple of talks
  - Implemented more complex scan strategy than we typically use in ARM

- SAIL
  - Just rapped up
  - Deployed an XR+ model
  - Implemented more complex scan strategy than we typically use in ARM

- EPCAPE
  - 2 Doppler lidars are currently operating
    - ✓ PRO at WHOI Pier (M1)
    - ✓ SL on Mount Soledad (S2) (would like to replace with XR+)
  - Implemented more complex scan strategy than we typically use in ARM

SAIL Scan Strategies

- Worked with Prof. Jessica Lunquist at UW to implement a scanning strategy

- Half-hourly cycle with
    - Down-valley PPI scans
    - Down and cross-valley RHIs
    - "Normal" PPI scans
    - Vertical staring the rest of the time

003000	rhi_149_10	10	C	7
003330	rhi_149_10	10	C	7
003700	ppi2_012_10	10	C	7
003900	ppi2_018_10	10	C	7
004400	ppi_070	2	S	7
004500	rhi_270_10	10	C	7
004830	rhi_270_10	10	C	7
005900	ppi_070	2	S	7

Down-Valley PPI Scans

guc_dl_M1 20230221 02:37:49, Elevation angle = 12.0°

guc_dl_M1 20230221 02:39:49, Elevation angle = 18.0°

SAIL RHI Scans

- Worked with Prof. Jessica Lunquist at UW to implement a scanning strategy

- Half-hourly cycle
  - Down-valley PPI scans
  - Down and cross-valley RHIs
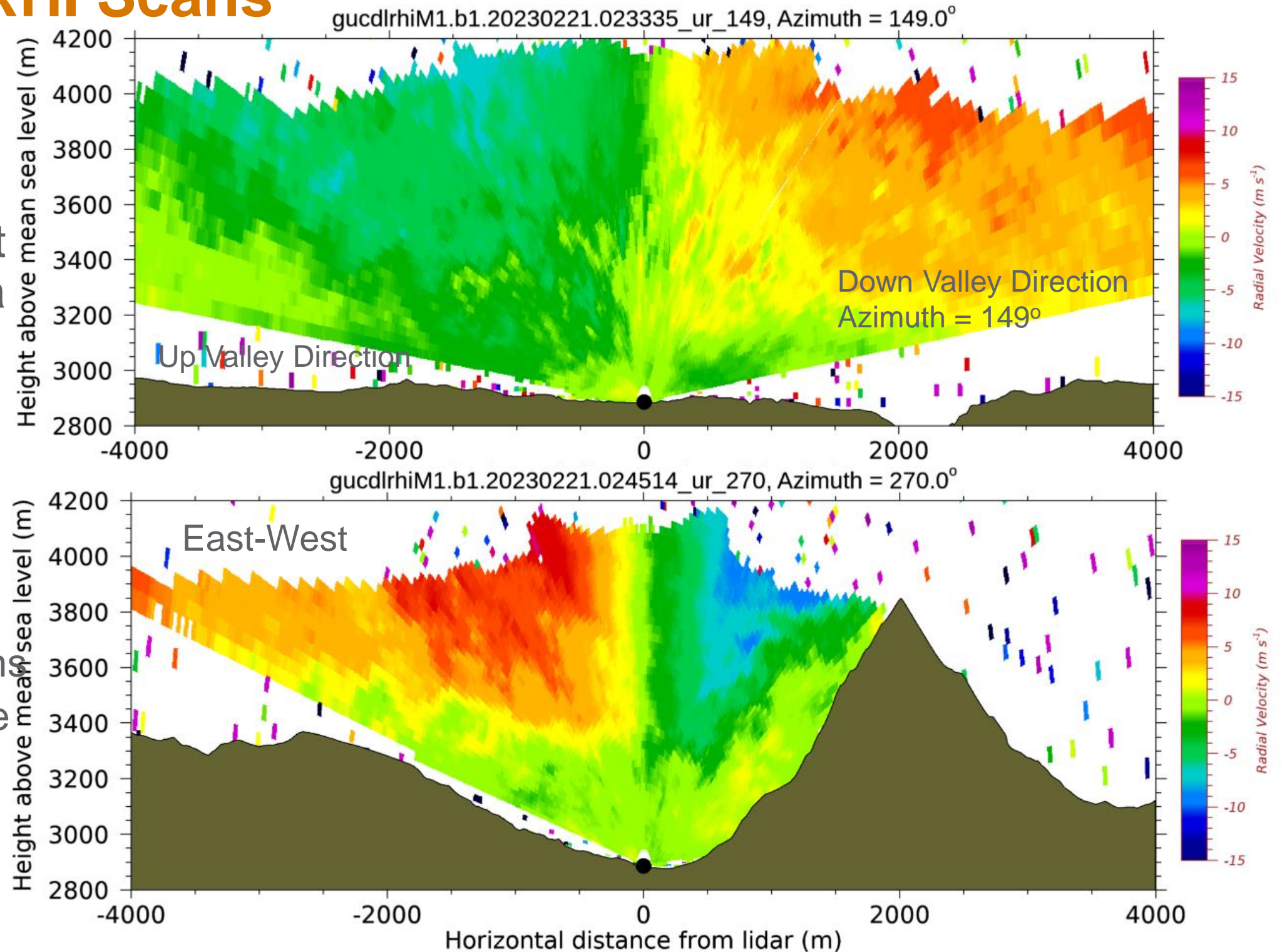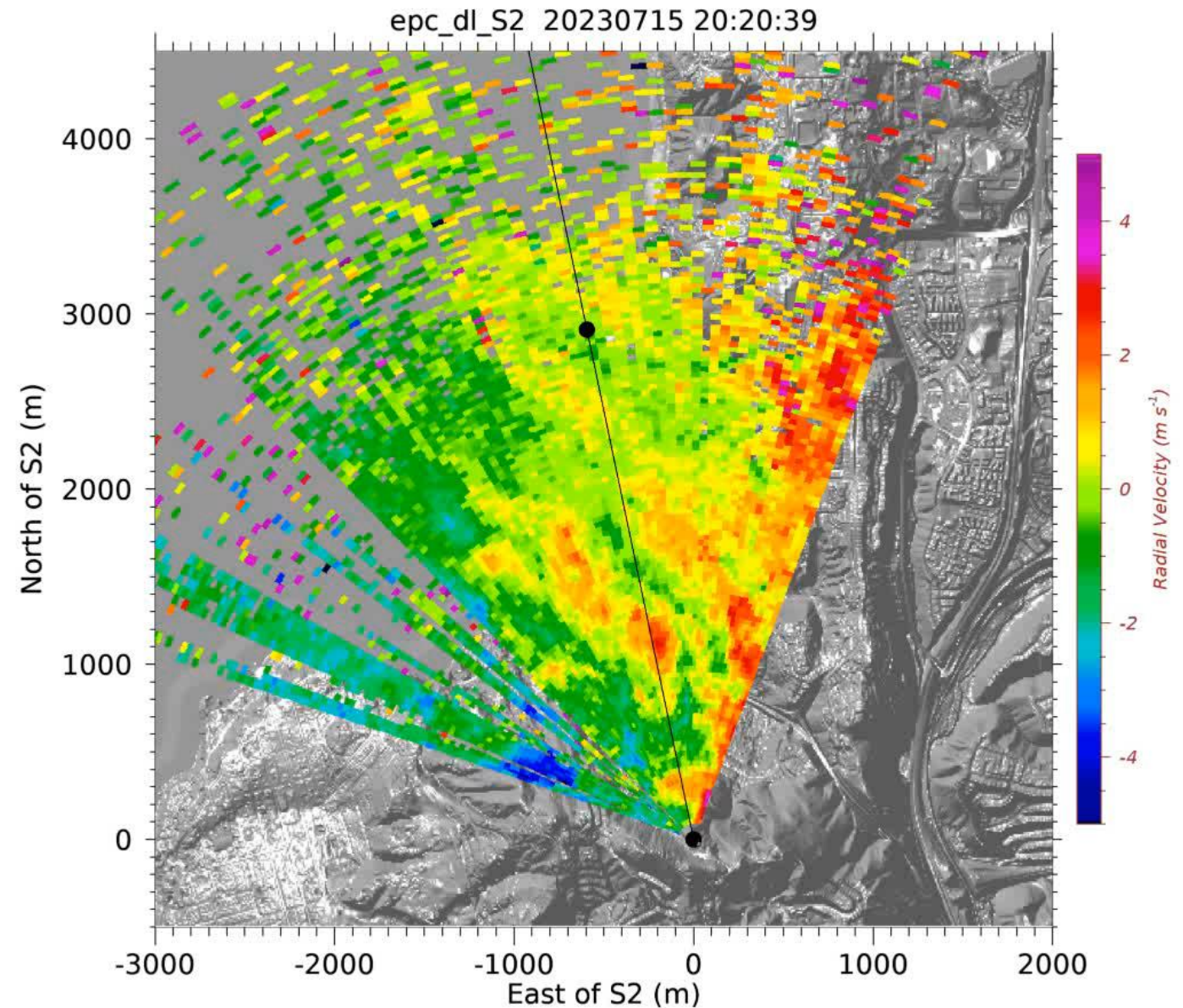 - "Normal" PPI scans
  - Vertical staring the rest of the time

EPCAPE PPI Scans

- M1: PRO system measures winds and vertical velocity.

- S2: SL system
  - Hourly Scan Schedule:
    - ✓ Sequence of sector PPI scans (NW-N sector)
    - ✓ RHI scan toward M1

epc_dl_S2 20230715 20:20:39

EPCAPE RHI Scans

epcdlrhiS2.b1.20230715.202707, 20230715 20:27:07 to 20:27:45 UTC, Azimuth = 348.0°