ARM CLIMATE RESEARCH FACILITY

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Lidar Applications Breakout Session

ROB NEWSOM, *PACIFIC NORTHWEST NATIONAL LABORATORY, RICHLAND, WA, USA*
JOHN GOLDSMITH, *SANDIA NATIONAL LABORATORY, LIVERMORE, CA, USA*
ED ELORANTA, *UNIVERSITY OF WISCONSIN, MADISON, WI, USA*

ASR PI Meeting, Vienna, VA, May 2-5, 2016

Lidar Applications Breakout Session Agenda

7:30-9pm, Wednesday May 4, Room: Vienna

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- Doppler Lidar Update - Newsom
  - Recent procurements and SGP Reconfiguration
  - VAPs
- Raman Lidar VAPs – Newsom
- Raman Lidar Update – Goldsmith
- HSRL Update – Eloranta
- Using the Raman Lidar to diagnose Rh_{crit} – Kwiten Van Weverberg
- CHARMs Update – Newsom/Thorsen/Goldsmith/Eloranta

ARM Doppler Lidars

- ARM currently operates 9 Doppler lidar systems
  - SGP, Oklahoma, USA
    - C1 - 2011 to present
    - E32 – May 3, 2016 to present
    - E37 – May 3, 2016 to present
    - E39 – April 13, 2016 to present (formerly at TWP C3)
    - E41 – May 3, 2016 to present
  - AMF1
    - Nainital, India, June 2011 to March 2012
    - Cape Cod, MA, USA, July 2012 to July 2013
    - Manacapuru, Brazil, January 2014 to September 2015
    - Ascension Island, 2016 to present
  - NSA, Barrow, Alaska, USA, 2014 to present
  - AMF3, Oliktok Point, Alaska, USA, 2014 to present
  - ENA, Graciosa Island, Azores, 2014 to present

AMF2 is the only site that does not have a Doppler lidar

ARM Doppler Lidar Specs

- Specs
  - Manufacturer: Halo Photonics (UK)
  - Wavelength: 1.5 μm
  - Pulse width: 150ns (22.5m)
  - Pulse repetition Frequency: 15 kHz
  - Velocity precision: <10cm s^{-1}
  - StreamLine has full upper hemispheric scanning capability
  - StreamLineXR - same as StreamLine + 4X pulse energy + enhanced signal processor
  - StreamLinePro – same as StreamLine but with reduced field-of-regard (±20° from zentih)


Halo Photonics StreamlineXR (at SGP)

- Direct Measurements
  - Radial Velocity
  - SNR
- Derived Measurements
  - Attenuated backscatter
  - Winds
  - Vertical velocity statistics
  - Cloud base height and cloud base vertical velocity


Halo Photonics StreamLinePro (at NSA, AMF3)


Halo Photonics Streamline (at SGP, AMF1, ENA)

Uptime for the ARM Doppler Lidars

1 Jan 2015 through 1 Mar 2016

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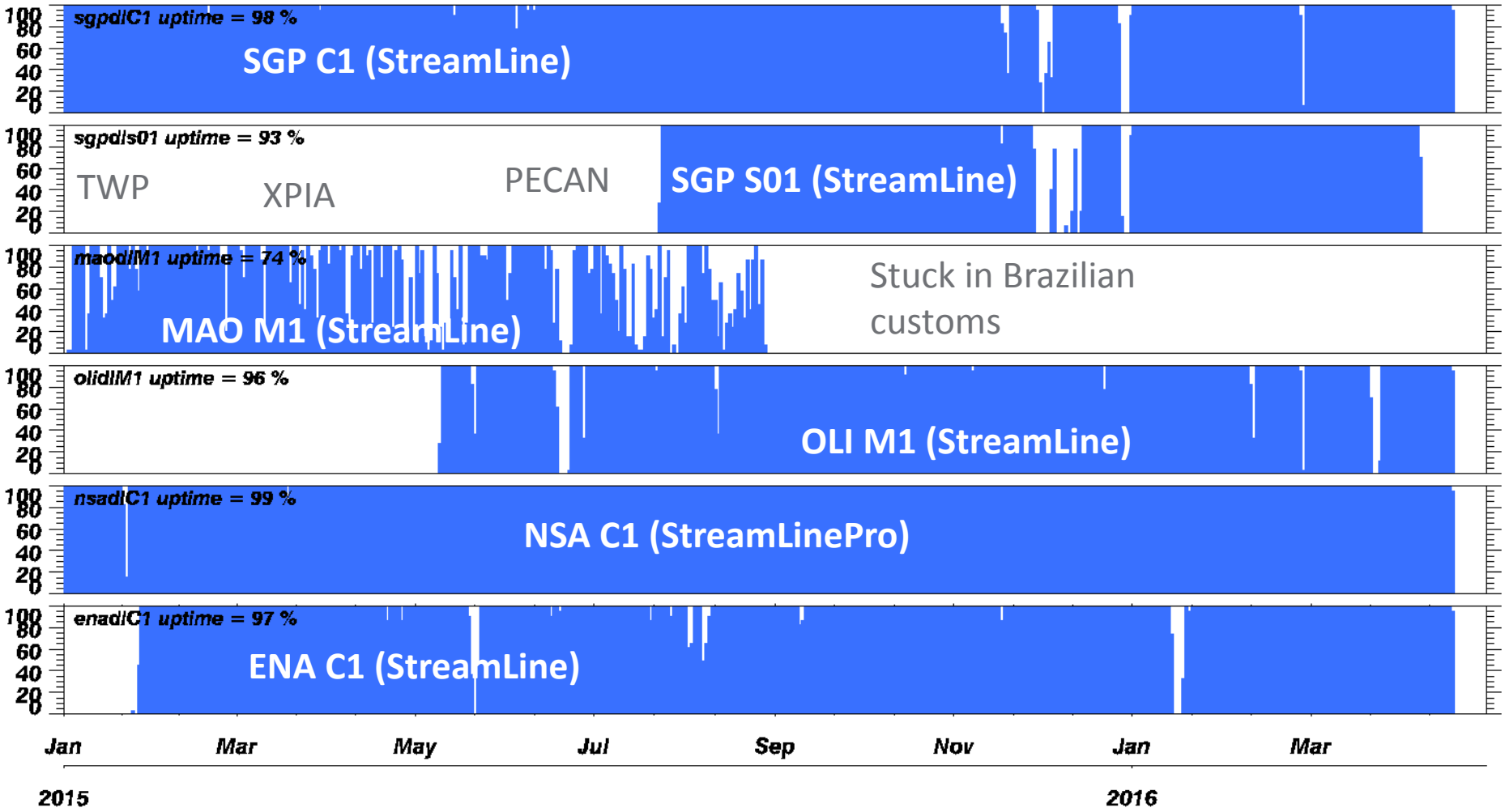

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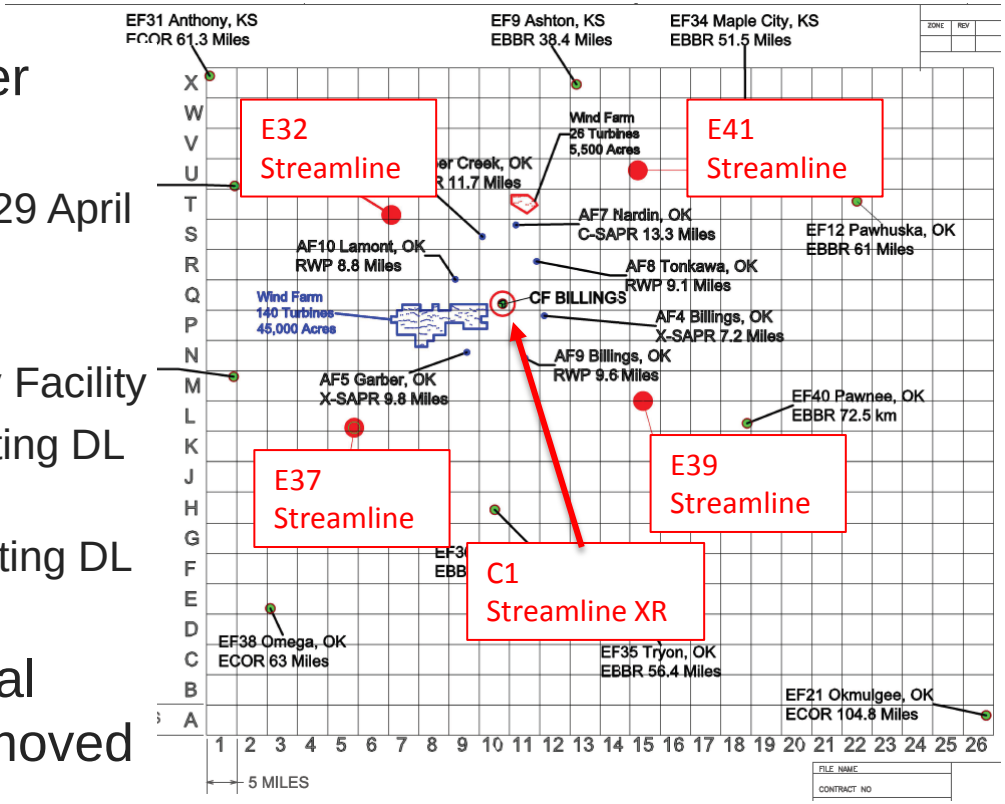
Doppler lidar procurements and SGP reconfiguration

- Procurement of 3 new Doppler lidars was started in 2015
  - Delivered to SGP for testing on 29 April 2016
  - Vendor: Halo Photonics
  - 1 StreamLine for SGP Boundary Facility
  - 1 StreamLineXR to replace existing DL at the SGP Central Facility.
  - 1 StreamLinePro to replace existing DL at Oliktok
- Existing DL at the SGP Central Facility (StreamLine) will be moved to Boundary Facility
- Existing DL at Oliktok (StreamLine) will be moved to SGP Boundary Facility



Testing the New Doppler Lidars

SGP C1 30 April to 2 May 2016

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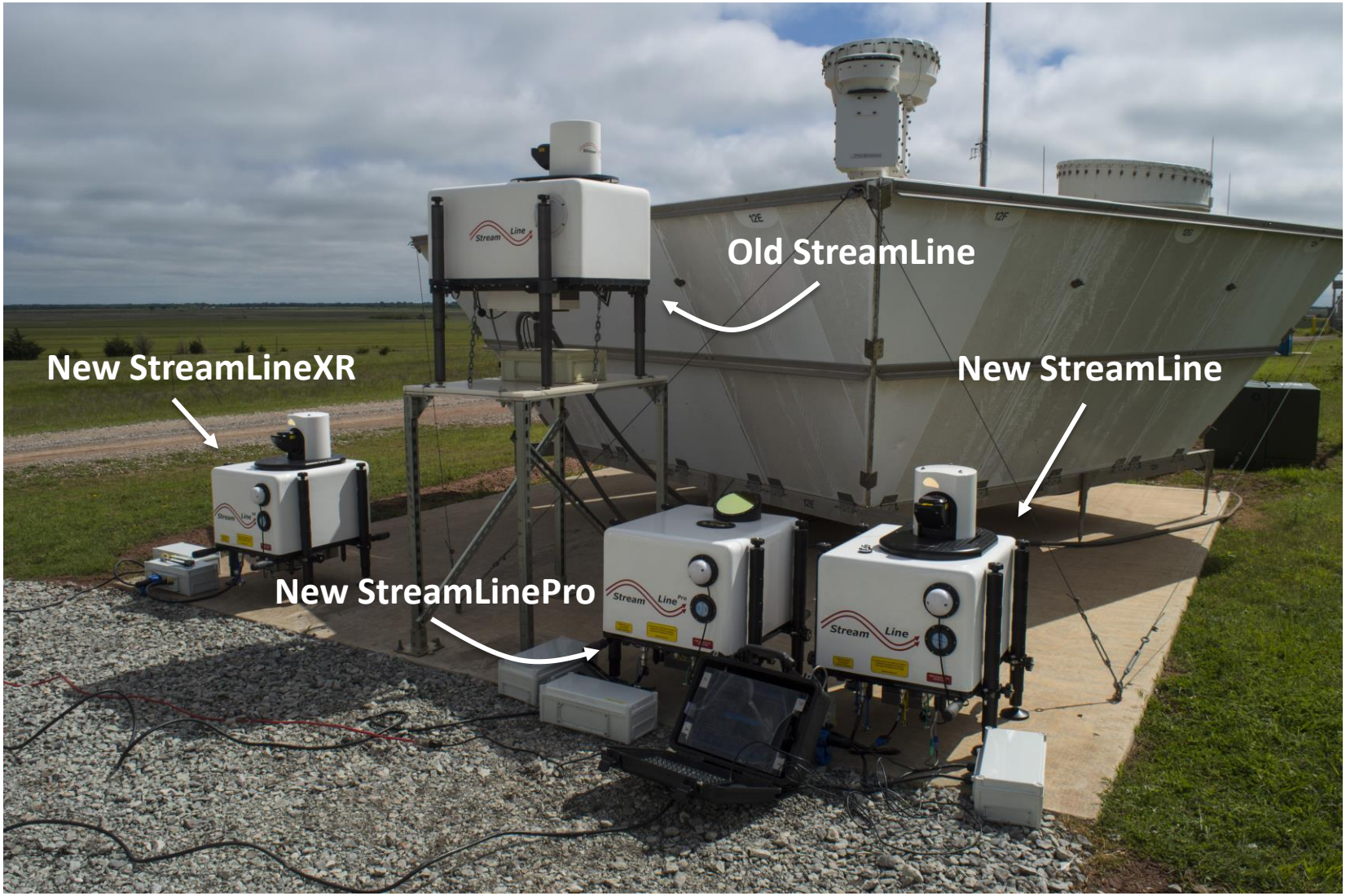

StreamLine XR Deployment Location at SGP C1

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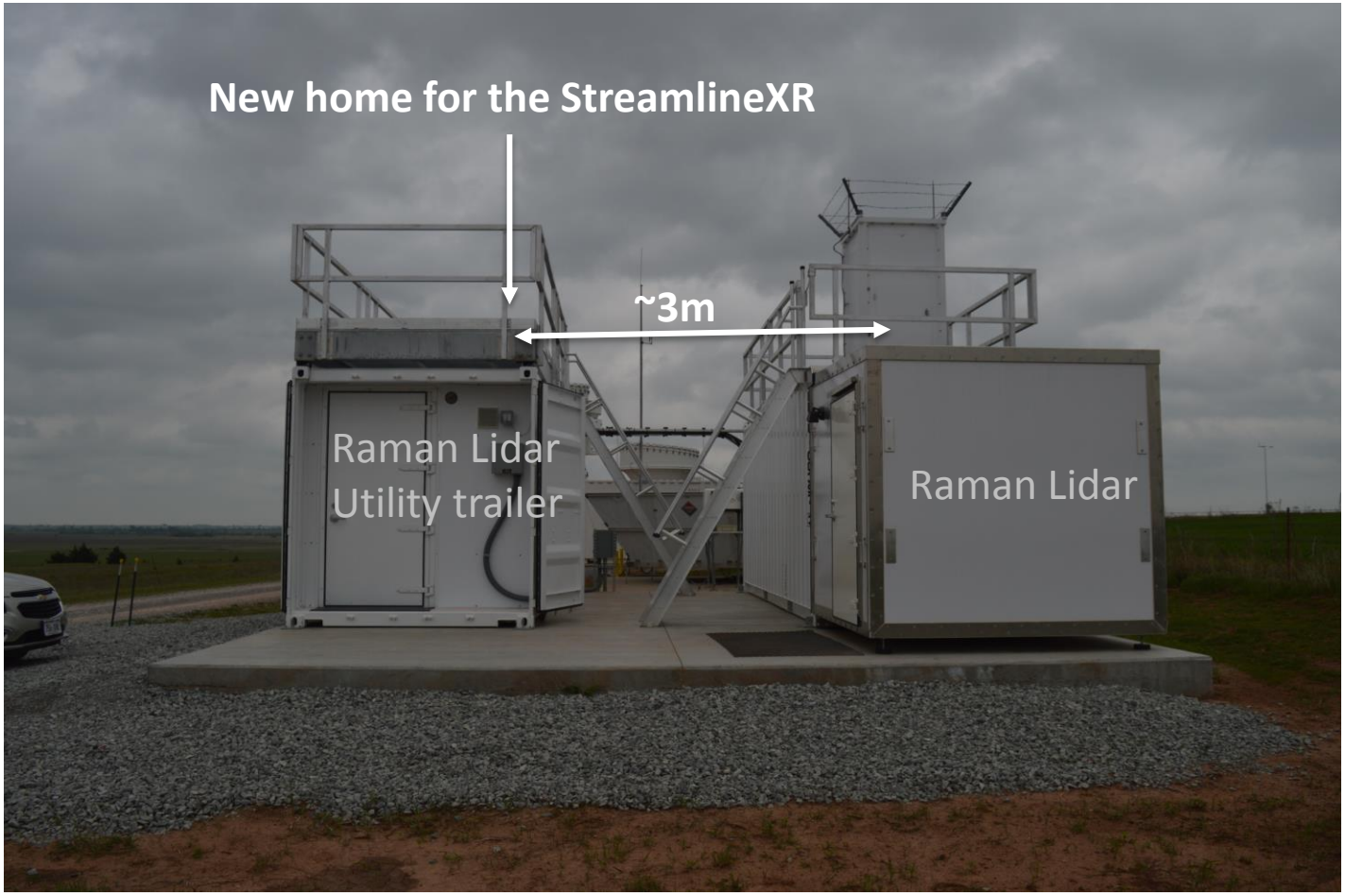
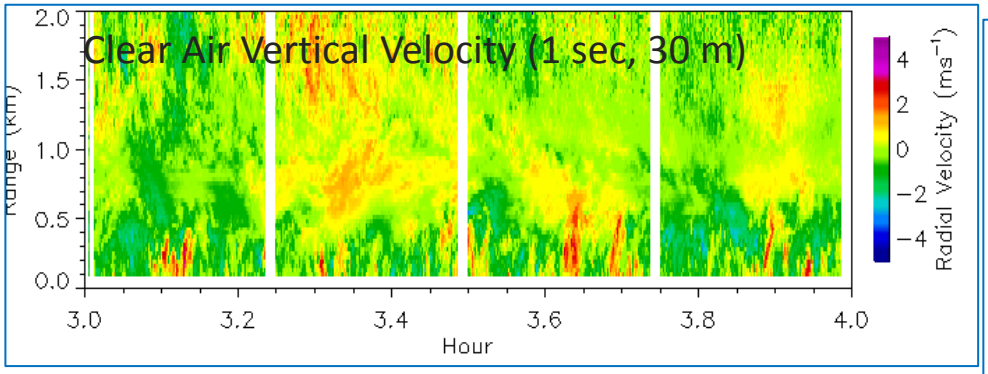
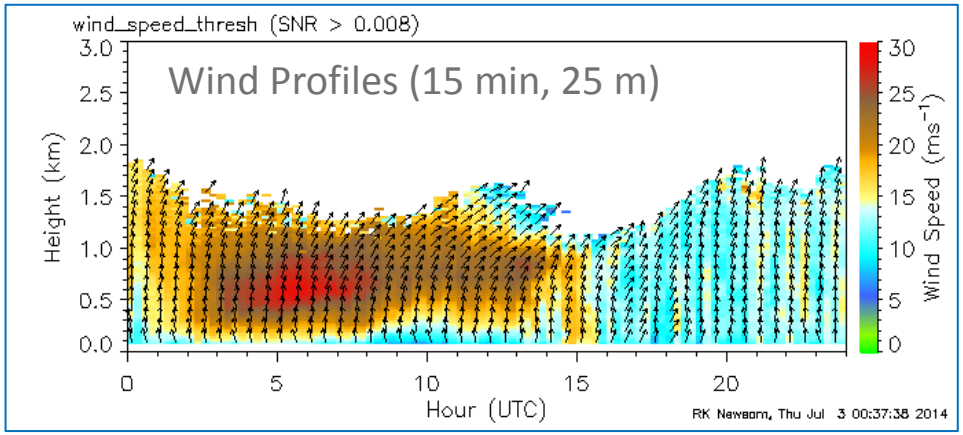


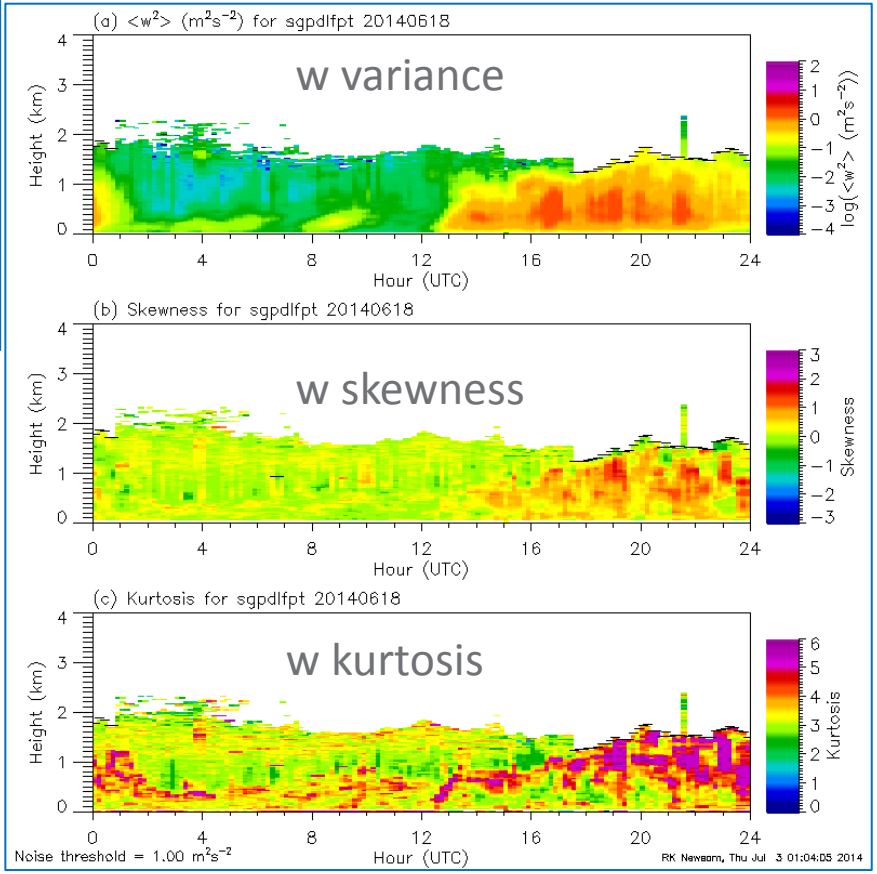
DL Deployments at the SGP Boundary Facilities

ARM Doppler Lidar Data Products





Vertical Velocity Variance, Skewness and Kurtosis



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ARM Doppler Lidar Data Products

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- <site>dlfpt<facility>.b1
  - Staring data
  - 1-sec pulse integration time
  - 30-m range gate (18m at NSA and Oliktok)
- <site>dlppi<facility>.b1
  - PPI scan data
  - 2-sec pulse integration time
  - 8 beams around the compass
  - 60^{o} elevation angle
  - ~40 second for complete scan
  - Repeat rate = 15 min
- <site>dlprofwind4news<facility>.c1
  - Horizontal wind profiles derived from PPI scan data
- <site>dlprofwstat4news<facility>.c1
  - Vertical velocity variance, skewness, kurtosis, CBH, cloud base vertical velocity, …, derived from vertical staring data.

Doppler Lidar Artifacts

Periodic modulation in mean variance profiles

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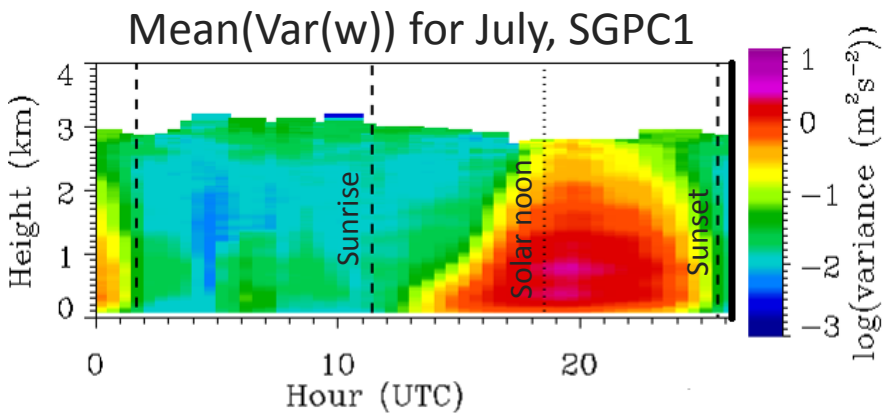
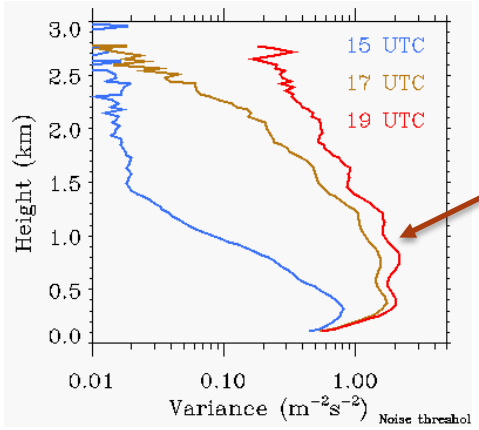
- Climatological analysis shows the presence of a sinusoidal modulation in the mean variance profiles from the Doppler lidar
  - Possibly due to temperature-dependent alignment issue
  - Occurs during hot summer afternoons when the internal temperature approaches 40C
  - The artifact only becomes obvious after sufficient averaging
  - Effects the following systems
    - SGPDLC1 from October 2010 through July 2014 (prior to refurbishment in Sept/Oct 2014)
    - TWPDLC3 from October 2010 through June 2014 (prior to refurbishment in Aug/Sept 2014)
    - AMF1 DL (PGHDLM1, PVCDLM1) from October 2010 through June 2013 (prior to refurbishment in Fall 2013)
  - DQR D160229.3





Periodic modulation in mean variance profile

Doppler Lidar Winds

Quantifying Uncertainty

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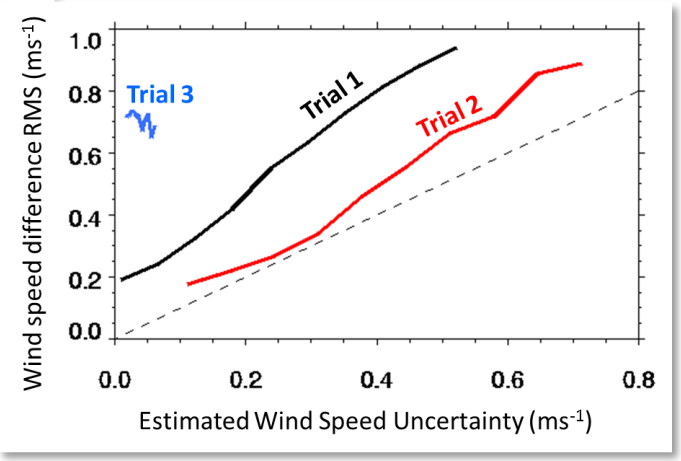
- In March and April of 2015 the ARM Doppler lidar that was formerly operated at the TWP-Darwin was deployed to the BAO for XPIA.
- The 300-m tower at the BAO site was instrumented with sonic anemometers at six levels.
- The accuracy of the Doppler lidar wind measurements and uncertainty estimates were assessed by comparison against the tower
- Three trials were performed using three different methods for estimating the uncertainty in the retrieved winds.

Trial	1	2	3
Mean wind speed difference (lidar-tower) (ms^{-1})	-0.02	-0.01	0.07
Wind Speed Difference Standard Deviation (ms^{-1})	0.43	0.52	0.75



- Trial 1 represents the method that is currently used to estimate uncertainty in the dlprofwind4news VAP.
- Trail 2 produced better uncertainty estimates
- Trail 3 ignores the contribution of turbulence to the uncertainty in the radial velocity measurements. Only the instrument noise is considered. This resulted in uncertainty estimates that were “out to lunch”.

ARM Raman Lidar Data Products

- Raw Data (<site>rl<facility>.a0)
  - Resolution: 7.5 m, 10 sec
  - Simultaneous PMT Analog voltage and photon counts
- Semi-Raw Data (<site>rlprofmerge1news<facility>.c0)
  - Photon counting rates from merging analog and photon counts
  - CBH
- Derived Data Products
  - Water Vapor Mixing Ratio
  - Temperature
  - Aerosol
    - Extinction coefficient
    - Aerosol Scattering Ratio
    - Volume backscatter coefficient
    - Linear Depolarization Ratio

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Raman Lidar VAPs and ADI

- The ARM Data Integrator (ADI) is a suite of software tools for simplifying the algorithm development process
- Using ADI to develop an algorithm …
  - Enforces ARM standards, thereby enabling easy search and discovery of products and on-the-fly data integration
  - Documents dependencies, metrics, status, and logs
  - Automates reprocessing
  - Significantly decreases the amount of resources needed to implement an algorithm
  - Produces more robust processes through the use of heavily used and well tested libraries and functions.
- The Raman lidar VAPs currently do not run under ADI. We need to fix this.

Raman Lidar VAPs and ADI

- Integrating revised RL VAP codes into ADI.
  - First step is to integrate the new MERGE VAP into ADI
    - Submitted ENG0001275 (Implementation of new Merge VAP for the RLs).
    - Chitra Sivaraman will tackle the problem pending approval of ENG0001275
  - Next step is to integrate the revised water vapor and temperature VAPs into ADI

- Implementation of Tyler Thorsen's cloud & aerosol Matlab code
  - Aerosol backscatter, extinction and depolarization
  - Will replace existing RL aerosol VAPs (i.e. ASR, EXT and DEP)
  - FY17 mentor budget request includes money to support this effort. Don't know yet if approved.
  - Initially we will not attempt integration with ADI because ADI does not currently support Matlab.