Lidar Breakout Session

R. K. Newsom (PNNL), R. Krishnamurthy (PNNL), V. Ghate (ANL)

11:00 am – 1:00 pm 22 June 2021

- 11:00 am - 11:30 am - **Introduction and instrument updates**
  - Raman, Doppler, Ceilometers, MPLs (Newsom)
  - New Capabilities for the ARM High Spectral Resolution Lidar (Bambha)
- 11:30 am -12:40 pm - **Short Talks on applications** (10 min each)
  - **Robert Jackson**: “ARMing The Edge: Edge Computing Demonstration Project for ARM”
  - **Damao Zhang**: “Development of the Best Estimate Planetary Boundary Layer Height Value-added Product”
  - **Raghavendra Krishnamurthy**: “Estimating PBL height from Doppler lidar observations using machine learning”
  - **Erol Cromwell**: “The Micropulse Lidar Cloud Mask Machine Learning Value-Added Product”
  - **Yufei Chu**: “PBL analysis”
  - **Hailing Xie**: “Aerosol retrievals with MPL and HSRL data at the NSA”
  - **Virendra Ghate**: “Turbulence in The Marine Boundary Layer and Air Motions Below Stratocumulus Clouds as Observed at The ARM Eastern North Atlantic Site”
- 12:40-1:00 pm - **Discussion**

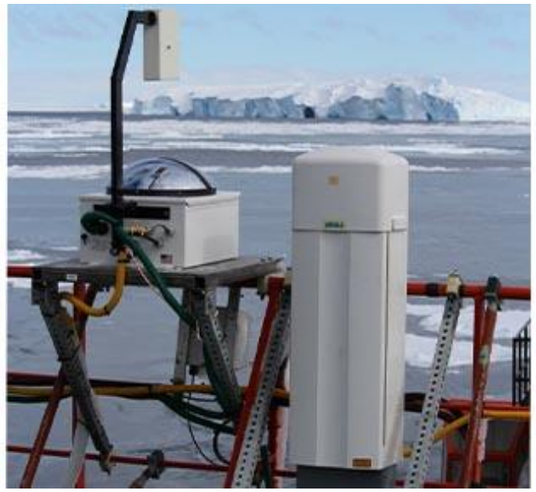
Pacific Northwest
NATIONAL LABORATORY

What's new with the ARM Ceilometers and Micropulse Lidars?

ARM Ceilometers

New PBL Height estimates

- Vaisala has upgraded their ceilometer software to include PBL height estimates in addition to the traditional cloud-base-height estimates.
- New datastream = **ceilpblht**
  - Available from all sites with ceilometers
  - Reports up to 3 candidate PBL height estimates for each profile
  - Reports up to 3 cloud-base-height measurements per profile (max height = 7.7km)
- See Vic's poster: https://asr.science.energy.gov/meetings/stm/posters/pdf/2021/P002687.pdf



The ARM MicroPulse Lidars (MPLs)

Improved overlap correction

- To improve performance in the near-field, ARM is testing a wide-field-of-view receiver (WFR) for the MPLs.
  - The WFRs are installed on top of the MPL telescope (as shown)
  - Requires careful boresighting of the WFR
  - Currently used on the AMF1 and AMF2 MPLs
- The WFRs enable estimation of the overlap correction for the narrow-field-of-view.
- The overlap corrections obtained using the WFR demonstrate a significant improvement compared to the vendor-provided corrections of the past.
- See Paytsar's poster for more details:

https://www.orau.gov/support_files/2021ARMASR/posters/P002714.pdf

Pacific Northwest
NATIONAL LABORATORY

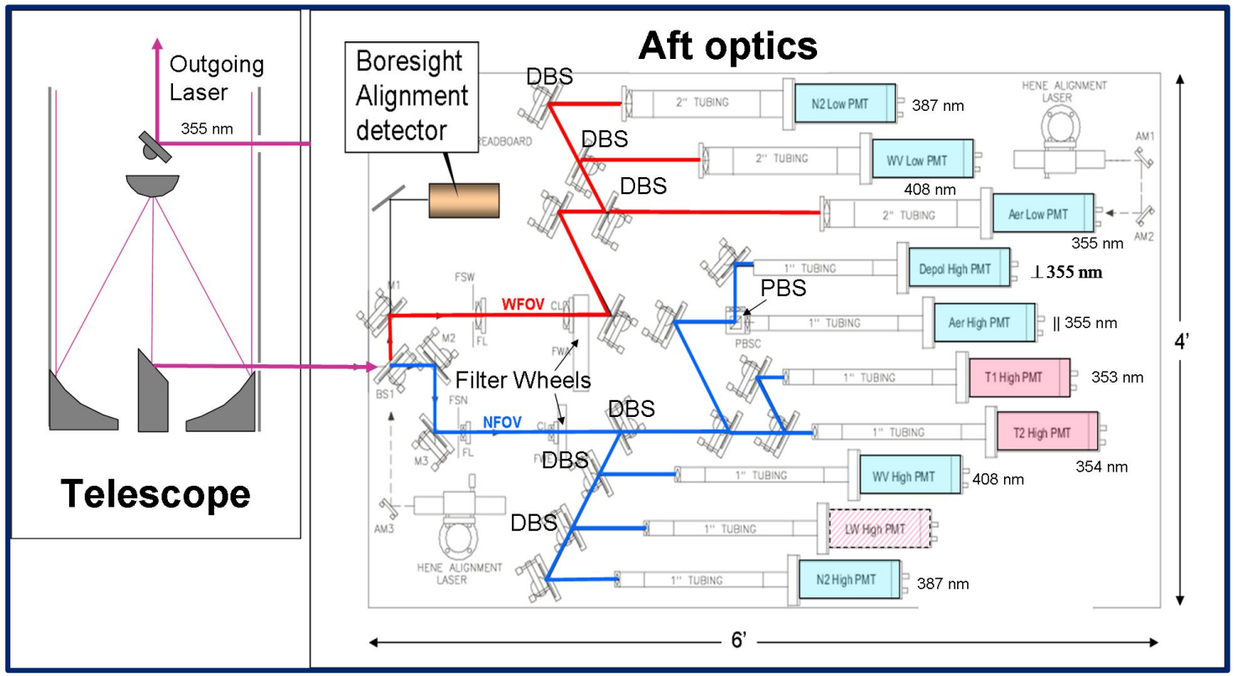
What's new with the ARM Raman Lidars?

ARM Raman Lidars

- ARM currently operates 3 Raman Lidar Systems
  - SGP C1 – since 1996
  - ENA C1
    - Since 2015
    - Previously deployed at TWP C3 from December 2010 to January 2015
  - AMF3 (Oliktok)
    - Since 2014
    - To be redeployed to SEUS in FY21/22
- All systems were built by Sandia, and all use similar design
- Measurements of:
  - water vapor mixing ratio
  - temperature
  - aerosol and cloud properties (extinction, backscatter, depolarization ratio, etc…)

ARM Raman Lidars

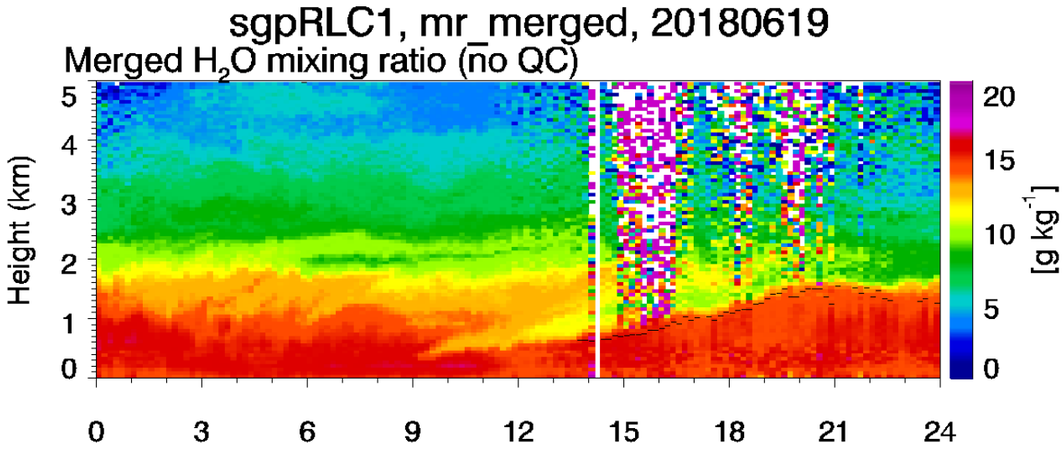
Specifications

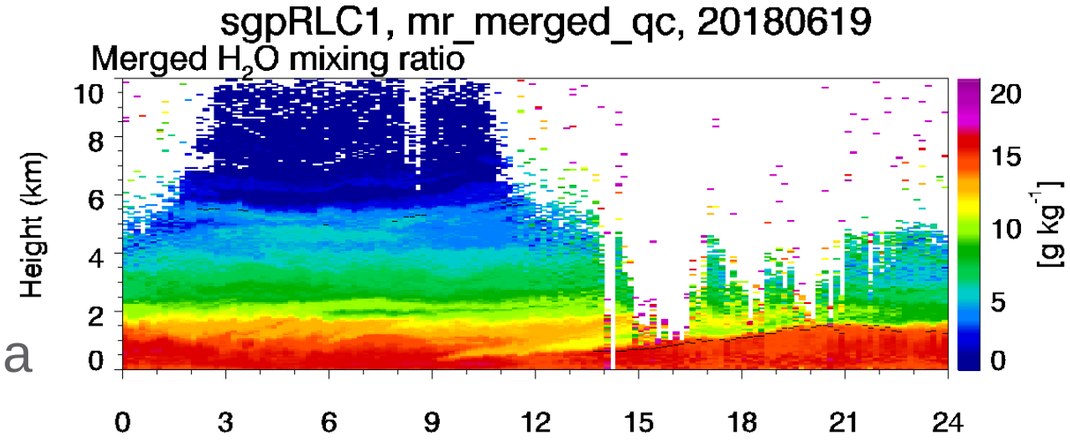


- Transmitter
  - wavelength = 355 nm
  - pulse rate = 30 Hz
  - pulse energy = 300 mJ
- Receiver:
  - Nine Detection channels
    - Wide field of view
      - H_2O at 408 nm
      - N_2 at 387 nm
      - Elastic at 355 nm
    - Narrow-field-of-view
      - H_2O at 408 nm
      - N_2 at 387 nm
      - Copol at 355 nm
      - Depol at 355 nm
      - “high J” rotational near 353 nm
      - “low J” rotational near 354nm

Raman Lidar water vapor mixing ratio VAP

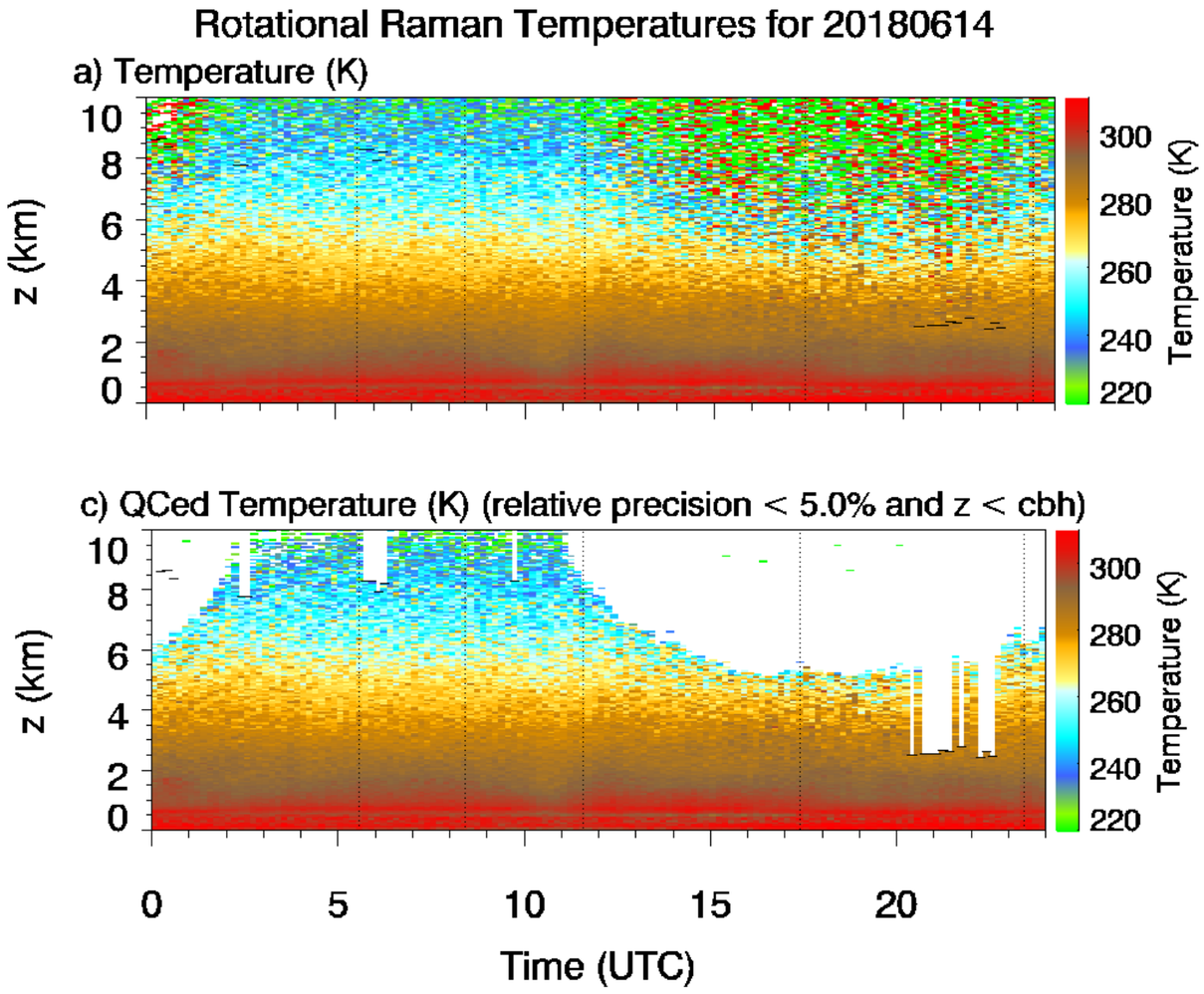
- Datastream: rlprofmr2news10m
  - Profiles of water vapor mixing ratio
  - Calibrated using radiosondes
  - Runs at SGP, ENA and OLI
  - Relevant variable names:
    - ✓ mr_merged
    - ✓ mr_merged_err (estimated random error)
- Users should perform QC
  - Relative error = mr_merged_err/mr_merged
  - Reject values that exceed a prescribed relative error threshold
  - Plots on the right illustrate the effect of using a threshold of 50%
  - One can also screen values above the cloud base height





Raman Lidar temperature VAP

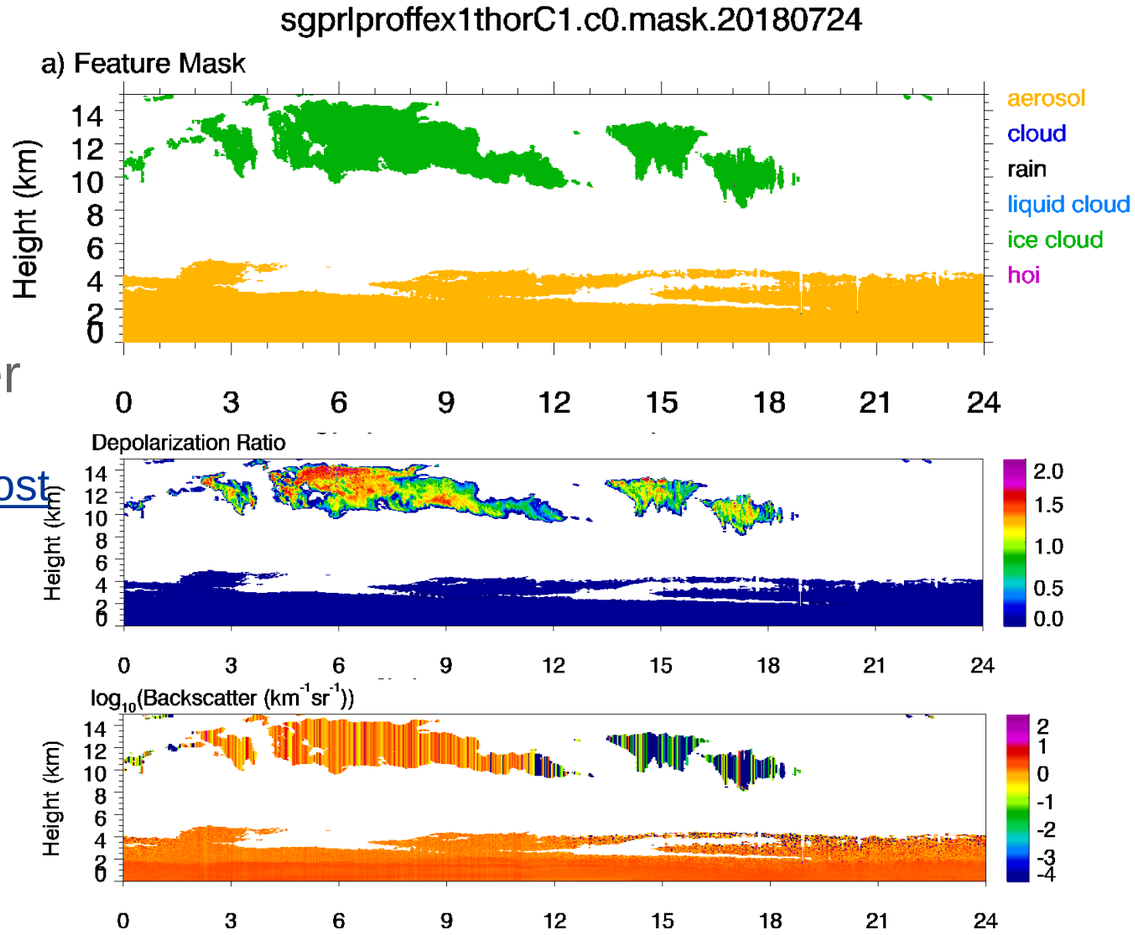
- Datastream: rlproftemp2news10m
  - Profiles of temperature
  - Calibrated using radiosondes
  - Runs at SGP, ENA and OLI
  - Relevant variable names:
    - ✓ temperature
    - ✓ temperature_err (estimated random error)
- Users should perform QC
  - Relative error = temperature_err/ temperature
  - Reject values that exceed a prescribed relative error threshold
  - Plots on the right illustrate the effect of using a threshold of 5%
  - One can also screen values above the cloud base height



Raman Lidar Aerosol and Cloud Properties VAP

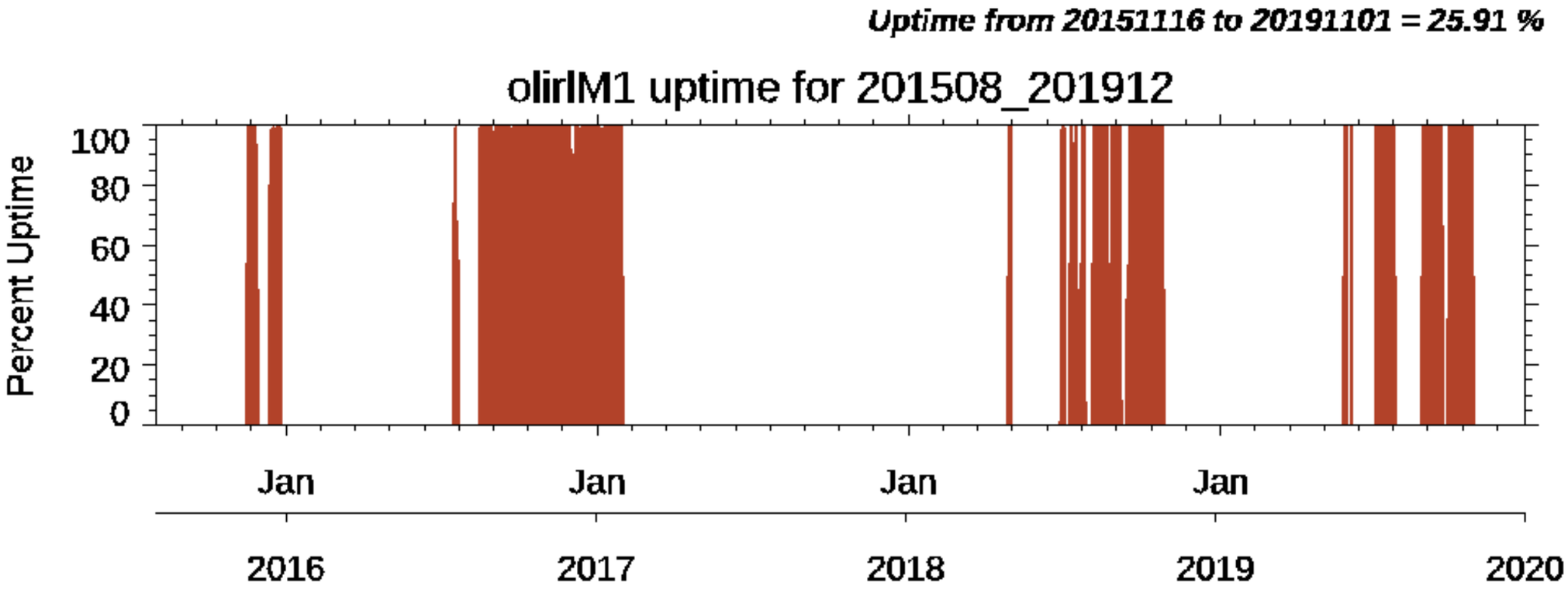
Feature detection and EXtinction (FEX)

- Datastream: rlproffex1thor.c0
  - Profiles of aerosol backscatter, extinction, depolarization ratio, lidar ratio, etc… @ 355nm
  - Operational at SGP, ENA
  - Now operational at Oliktok, see Duli's poster (session 1): https://www.orau.gov/support_files/2021ARMASR/posters/P002828.pdf
- Use the feature mask
  - Bit-packed field that identifies a region as either
    - ✓ Aerosol
    - ✓ Liquid cloud
    - ✓ Ice cloud
    - ✓ Horizontally oriented ice



AMF3 Raman Lidar (olirlM1) Uptime

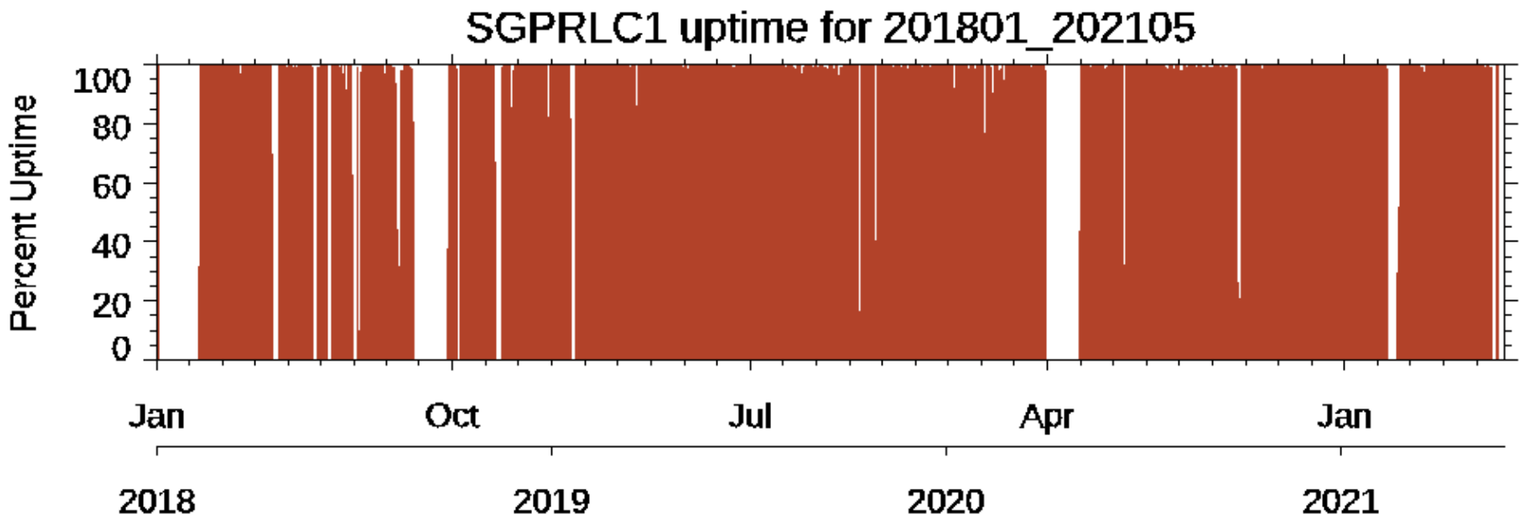
October 2015 to November 2019, the final numbers



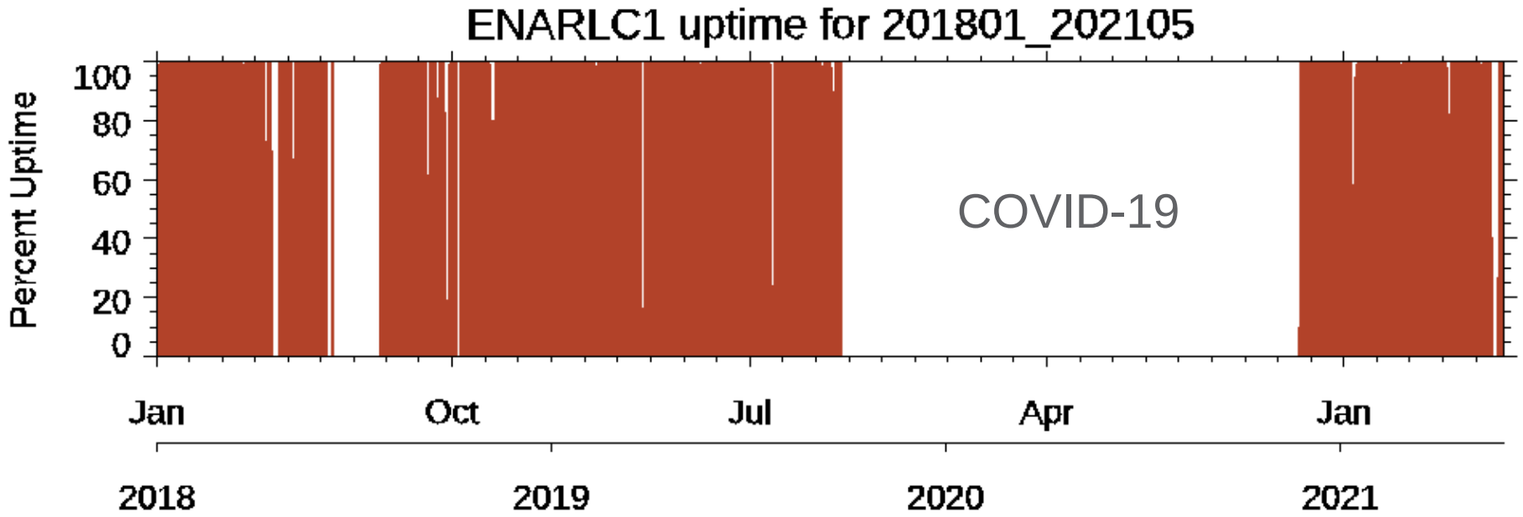
Uptime for the SGP and ENA Raman Lidars

since 1 Jan 2018

Uptime from 20180101 to 20210525 = 83.99 %

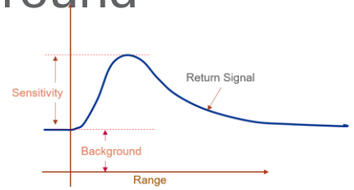


Uptime from 20180101 to 20210531 = 58.75 %

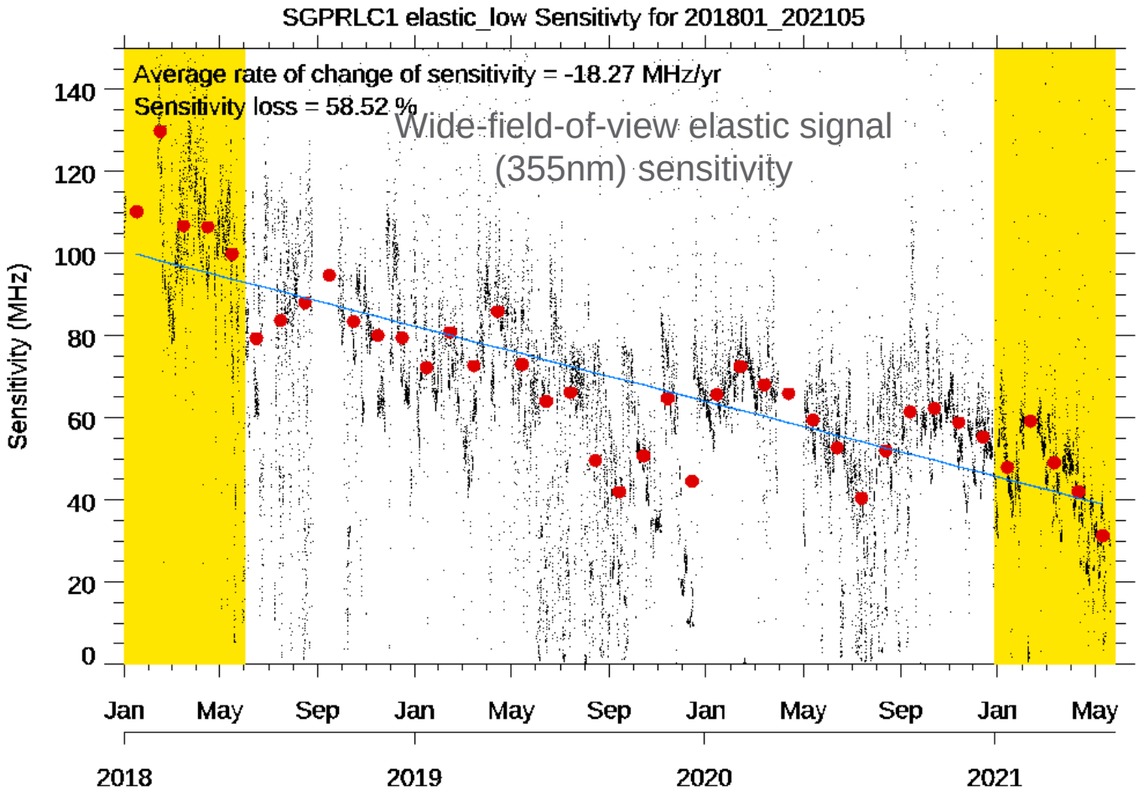


Raman Lidar Issues

- Both the ENA and SGP RLs are showing a gradual degradation in sensitivity
  - Sensitivity = peak-background
    - ✓ Pulse energy
    - ✓ Receiver characteristics
    - ✓ Atmosphere



- The sensitivity loss is larger at SGP
  - Apparent in the last 3+ years of data
  - Seen in all channels
- Time for a tune-up
  - Refurbish telescope?
  - Replace degraded optical components in the receiver
  - Realignment



Other News Concerning the ARM RLs

- VAPs that are currently under development (using RL data)
  - New PBL height VAPs
    - ✓ Stick around for Damao's talk later in this session
  - New Cloud phase VAP

- Examining methods for improving calibration of WVMR and temperature using machine learning
    - ✓ Stick around for Raghu's talk later in this session

Pacific Northwest
NATIONAL LABORATORY

What's new with the ARM Doppler Lidars?

ARM Doppler Lidars

- Doppler lidars (DL) are operated at all fixed and mobile sites, including a network of five systems at SGP.
- The DLs provide time- and range-resolved measurements of:
  - Radial (line-of-sight) velocity
  - Attenuated aerosol backscatter
  - Wideband signal-to-noise ratio
  - Spectral width ***new!***
- Current mode of operation is pretty simple
  - PPI scans every 10-15 minutes
  - Vertical stare otherwise

ARM Doppler Lidars

- All Systems
  - Manufactured by Halo Photonics
  - 1548 nm
  - Class 1M
  - Nyquist velocity = ±19.4 m s^{-1}
- Four different models: Pro, SL, XR, and XR+

Doppler Lidar Instrument Status

- SGP Network
  - C1 (XR), E32(SL), E37(SL), E39(SL) and E41(SL)
  - Frequent failures have resulted in significant downtime at some facilities
  - In FY20 an XR+ system was procured for SGP as a spare unit
    - ✓ Swapped with the AMF2 DL (Pro) for the SAIL campaign because Dan wants to scan
    - ✓ This will enable scanning during SAIL.
    - ✓ The AMF2 DL (Pro) is now operating at SGP E39.
- NSA C1 DL (Pro) – Very stable and continues to perform well
- ENA C1 DL (SL) – Very stable and continues to perform well
- AMF1 DL (SL) – Functioning well. Will be deployed for TRACER

Doppler Lidar Instrument Status

- AMF2 DL
  - Halo Pro (profiling lidar)
  - Procured in FY19
  - MOSAIC was the first deployment
  - Developed and implemented motion-correction algorithm
  - See Rob's poster on Doppler lidar measurements during MOSAIC: https://www.orau.gov/support_files/2021ARMASR/posters/P002785.pdf
  - The AMF2 DL (Pro) is now operating at SGP E39
- AMF3 DL
  - This system has not been working well. Will be shipped to PNNL for evaluation
  - To be redeployed to either SEUS or SGP.
- Current and Planned Procurements
  - FY21 (in progress): 2 XR+ systems for SGP and/or SEUS
  - FY22 (planned): 2 XR+ systems for SGP and/or SEUS

Other News Concerning the ARM DL and RLs

- Development of a new PBL height VAP (ENG0000893)
  - Stick around for Damao's talk later in this session
  - Estimating PBL height from Doppler lidar data using machine learning, "On the estimation of boundary layer heights: A machine learning approach" by R. Krishnamurthy et al., Atmos. Meas. Techniques, June 2021.
- ECREASTUDY campaign at SGP C1
  - Fall of 2020
  - Collocated measurements from
    - ✓ Two Doppler lidars (C1 + Spare)
      - High-temporal-resolution wind and vertical velocities
      - Enables retrieval of TKE flux profiles
      - See Raghu's poster: https://asr.science.energy.gov/meetings/stm/posters/pdf/2021/P002757.pdf
    - ✓ Raman lidar + Upgraded NSA HSRL
      - Enables retrieval of aerosol microphysics