

Lidar Update

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DOE ASR PI meeting, June 10-14, North Bethesda/Rockville, MD



Pacific Northwest
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Proudly Operated by **Battelle** Since 1965

- ▶ ARM currently operates the following “advanced” lidar systems

	SGP					ENA	NSA	OLI		
	C1	E32	E37	E39	E41	C1	C1	M1	AMF1	AMF2
HSRL							✓			✓
Raman	✓					✓		✓		
Doppler	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

- ▶ ARM also operates MPLs and Ceilometers at most sites

ARM Raman Lidars

All systems developed by John Goldsmith at Sandia – Livermore

All systems operate at 355 nm



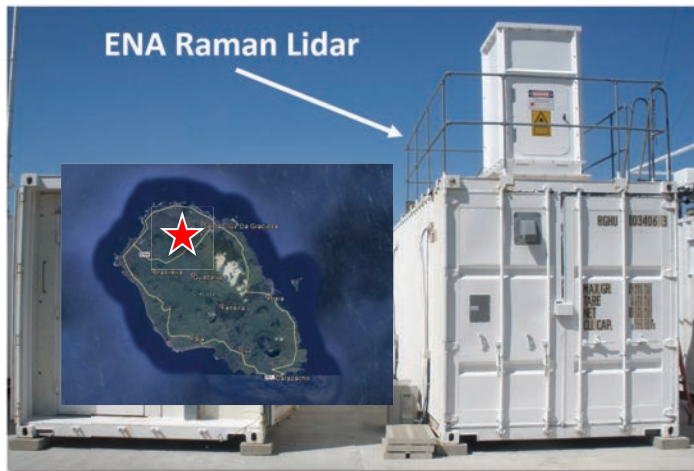
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▶ SGP C1

- In operation since 1996
- Upgraded and moved to radar cluster in Fall 2015



▶ ENA C1 (Graciosa)

- In operation since 9/2015
- Previously deployed at TWP C3 from DEC '10 to JAN '15



▶ AMF3 (Oliktok Point)

- Deployed in 10/2014
- Newest of the 3 ARM Raman lidars
- Non-operational during winter (October-May)
- There is talk of moving it to Barrow



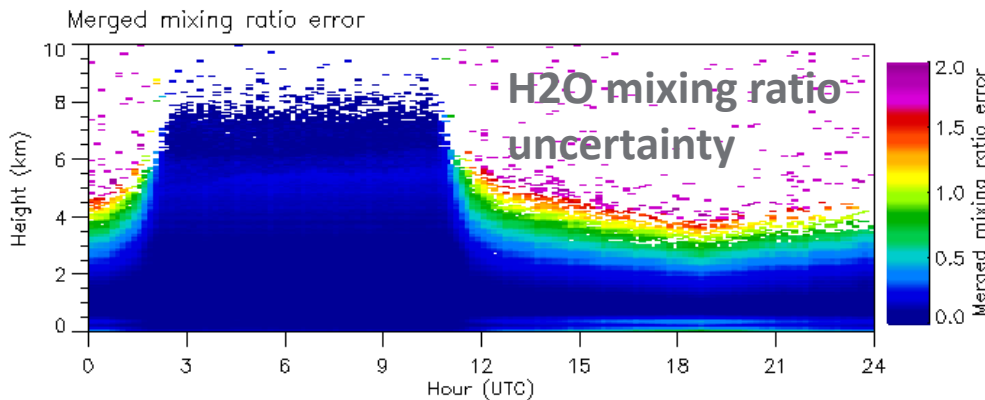
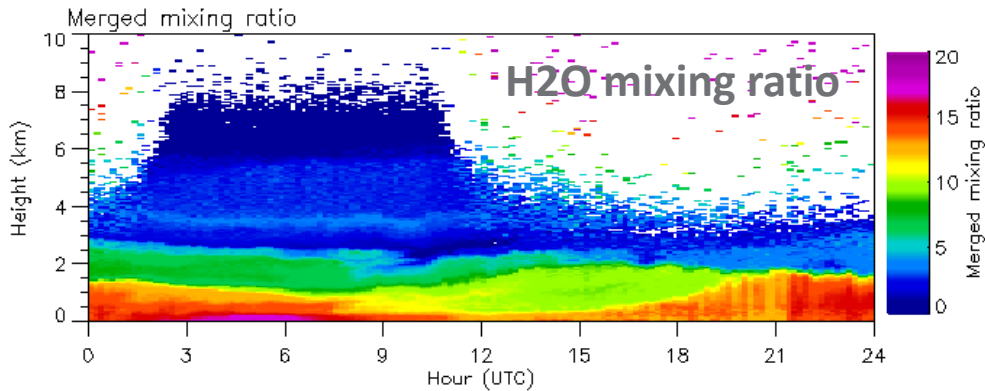
Raman Lidar Data Products

- ▶ MERGE (rlprofmerge2news.c0)
 - Photon counting rates from 9 detection channels
 - Resolution: $\Delta z = 7.5\text{m}$, $\Delta t = 10\text{ s}$
 - Cloud base height
- ▶ Water Vapor Mixing Ratio VAP (rlprofmr2news.c0)
- ▶ Temperature VAP (rlproftemp2news.c0)
- ▶ FEX VAP (rlproffex1thor.c0)
 - Aerosol and cloud optical properties
 - Feature mask
 - Extinction coefficient
 - Aerosol Scattering Ratio
 - Volume backscatter coefficient
 - Linear Depolarization Ratio



Raman Lidar H₂O Mixing Ratio VAP

sgpRLC1, mr_merged_qc, 20180628



sgp1Orlprofmr2newsC1.c0_mr_merged_qc.20180628, Sat Jan 12 00:11:45 2019

▶ Water Vapor Mixing Ratio VAP

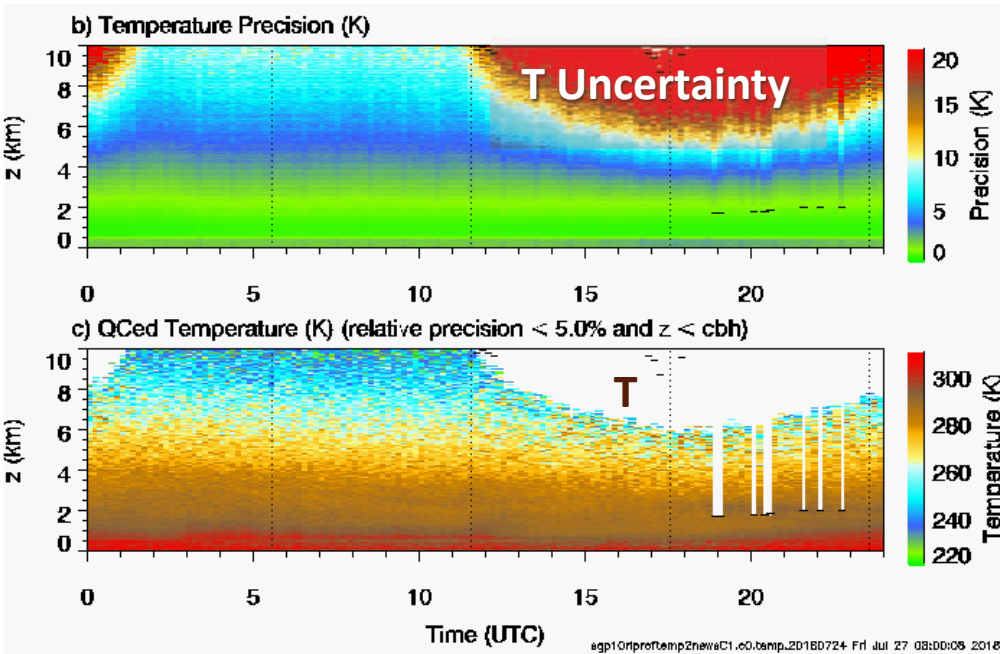
- Datastream: rlprofmr2news.c0
- Resolution is configurable
 - We currently use $\Delta z = 60\text{m}$, $\Delta t = 10\text{ min}$
 - The limit is $\Delta z = 7.5\text{m}$, $\Delta t = 10\text{ sec}$
- Calibrated using radiosondes
- Generated using a delayed processing schedule, as opposed to near realtime.
- Includes estimates of random error.
- End users need to apply QC
 - Recommend filtering based on maximum acceptable relative error
 - Plot to the left uses a threshold of 25%



Raman Lidar Temperature VAP

► Temperature VAP

- Datastream: rlproftemp2news.c0
- Resolution is configurable
 - We currently use $\Delta z = 60\text{m}$, $\Delta t = 10\text{ min}$
 - The limit is $\Delta z = 7.5\text{m}$, $\Delta t = 10\text{ sec}$
- Calibrated using radiosondes
- Generated in near realtime.
- Includes estimates of random error.
- End users need to apply QC
 - Recommend filtering based on maximum acceptable relative error
 - Plot to the left uses a threshold of 5%



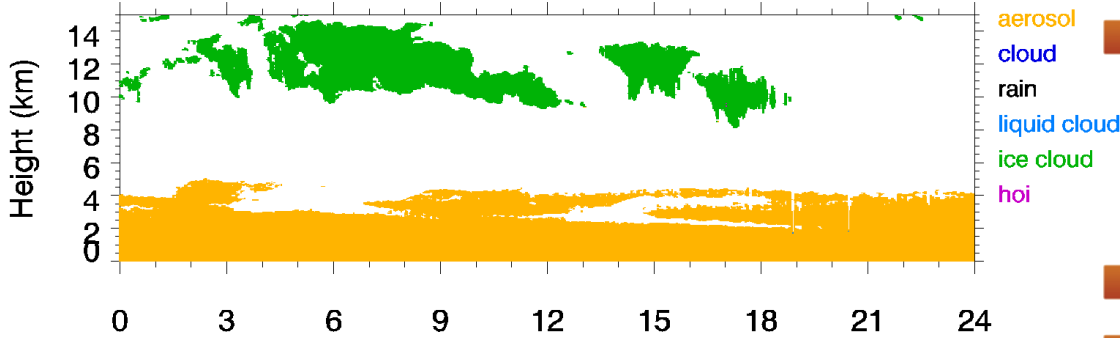


Raman Aerosol VAP

► Feature detection and EXtinction (FEX) VAP

sgprlproffex1thorC1.c0.mask.20180724

a) Feature Mask



■ Datastream: rlproffex1thor.c0

■ Resolution is configurable

● We currently use $\Delta z = 30\text{m}$, $\Delta t = 2\text{min}$

● The limit is $\Delta z = 7.5\text{m}$, $\Delta t = 10\text{sec}$

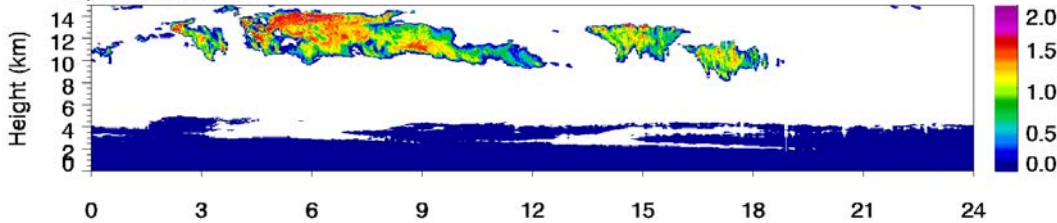
■ Generated in near realtime.

■ Includes estimates of random and systematic uncertainty.

■ End users need to apply QC using the feature mask that is supplied in the output

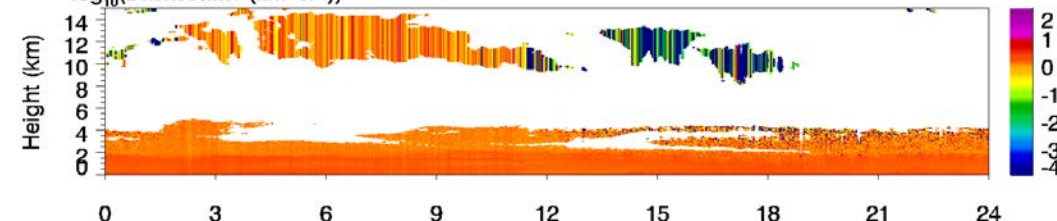
sgprlproffex1thorC1.c0.dep.20180724

Depolarization Ratio



sgprlproffex1thorC1.c0.bscat.20180724

$\log_{10}(\text{Backscatter (km}^{-1}\text{sr}^{-1}))$



ARM Doppler Lidars

► Specs

- Manufacturer: Halo Photonics (UK)
- Wavelength: 1.5 μm
- Pulse width: 150ns (22.5m)
- Pulse repetition Frequency: 15 kHz
- Velocity precision: $<10\text{cm s}^{-1}$
- 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 ($\pm 20^\circ$ from zenith)



► Direct Measurements

- Radial Velocity
- SNR

► Derived Measurements

- Attenuated backscatter
- Winds
- Vertical velocity statistics
- Cloud base height and cloud base vertical velocity





Doppler Lidar Network at SGP

- ▶ Network of 5 Scanning Doppler lidars
- ▶ SGP C1 installed April 2011
- ▶ SGP E32, E37, E39, and E41 installed May 2016, (almost) in time for Hiscale



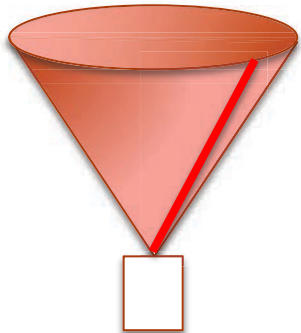


Doppler lidar data products



▶ Staring data

- datastream: dlftp.b1
- Usually vertical staring but could be slant path. End users should always check the “elevation” variable.
- Used to derive vertical velocity statistics and cloud base height



▶ Conical Scan or plan position indicator (PPI)

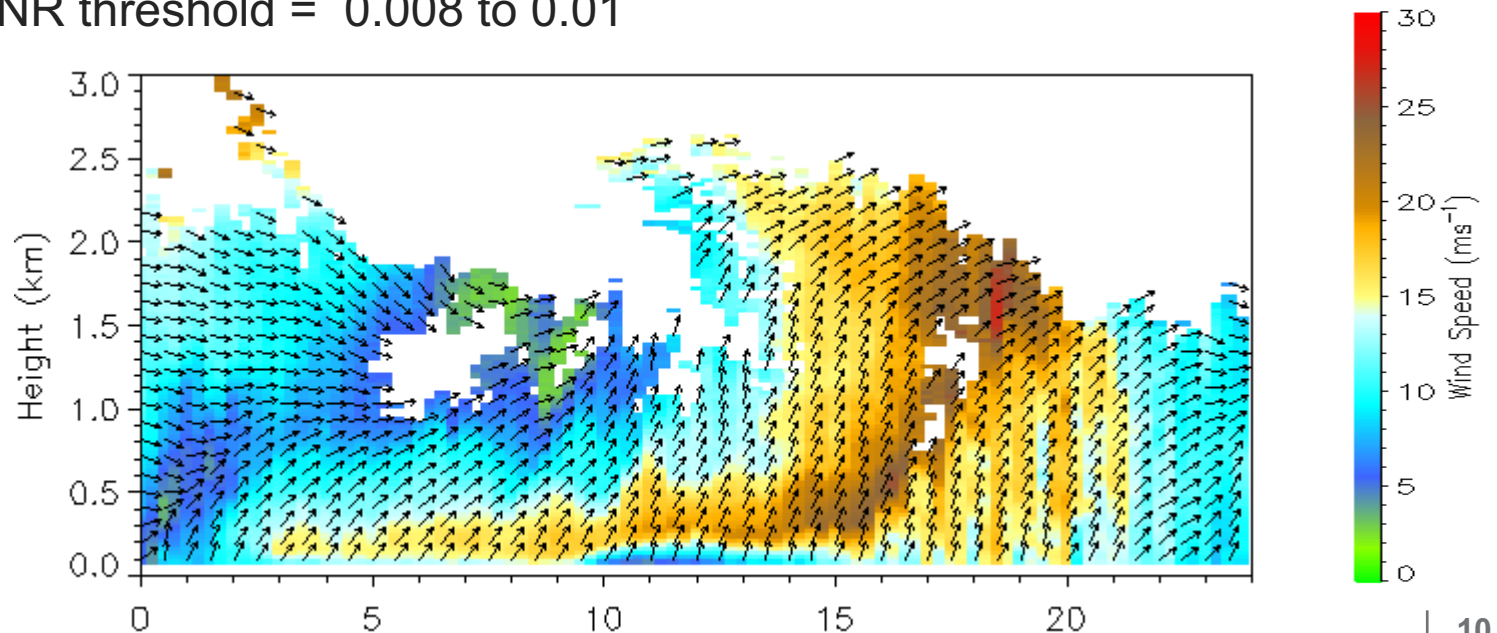
- datastream: dlppi.b1
- 8 beams at elevation=60°
- Once every 10 to 15 min,
- Typically takes about 40 s to execute
- used to derive winds



Doppler lidar Wind VAP



- ▶ Datastream: dlprof4windsnews.c1
- ▶ 40 s “snap shot” every 10 to 15 min, with $\Delta z=26$ m.
- ▶ Vertical coverage is typically <3 km
- ▶ Includes MET data for sanity check
- ▶ End users should apply QC by rejecting wind estimates corresponding to low SNR
 - Typical SNR threshold = 0.008 to 0.01





Doppler Lidar Vertical Velocity Statistics VAP

- ▶ Datastream: dlprof4wstatsnews.c1
- ▶ Vertical velocity variance, skewness, kurtosis, cloud base height, cloud base vertical velocity, cloud frequency
- ▶ Resolution: $\Delta t=30$ min and $\Delta z=30$ m.
- ▶ Vertical coverage is typically <3 km
- ▶ Includes ECOR data for sanity check
- ▶ End users should apply QC by rejecting wind estimates corresponding to low SNR
 - Typical SNR threshold = 0.008 to 0.01

