High Spectral Resolution Lidar – Gen 2 (HSRL-2) Status Update

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ACTIVATE Science Team Meeting

2022 November 7th

Tucson, Az

HSRL2 Archived Data Products	Wavelengths (nm)			Product Resolutions: Horz. (km)	Product Resolutions: Vert. (m)
Extensive Properties					
Aerosol Backscatter	355	532	1064	1	30
Aerosol Extinction	355	532		6	225
Intensive Properties					
Aerosol Depolarization	355	532	1064	1	30
Extinction-to-Backscatter Ratio	355	532		6	225
Angstrom Exponent – Extinction	355/532			6	225
Angstrom Exponent – Backscatter	355/532	532/1064		1	30

CORE PRODUCTS

Additional Products	Data Product Notes
Summary Plot Images	Full flight curtain images of products
Aerosol Type (e.g., smoke, dust, marine, …)	Full flight curtain of inferred aerosol type based on optical properties
Aerosol Optical Thickness	1-D full column; 2-D range resolved curtains
Cloud Top Heights	1-D upper cloud top product
Mixed Layer Heights	Lower-most aerosol gradient boundary above threshold
f(RH) NEW	Well-mixed layer f(RH) using dropsonde/HSRL combined products
Cloud Products NEW	New products for opaque cloud tops (Slide 5)
Surface Winds NEW	New 10-m surface horizontal wind products (Slide 9)
$3\beta + 2\alpha$ Retrievals	Case-by-case basis only of aerosol microphysical retrievals (Slide 11)

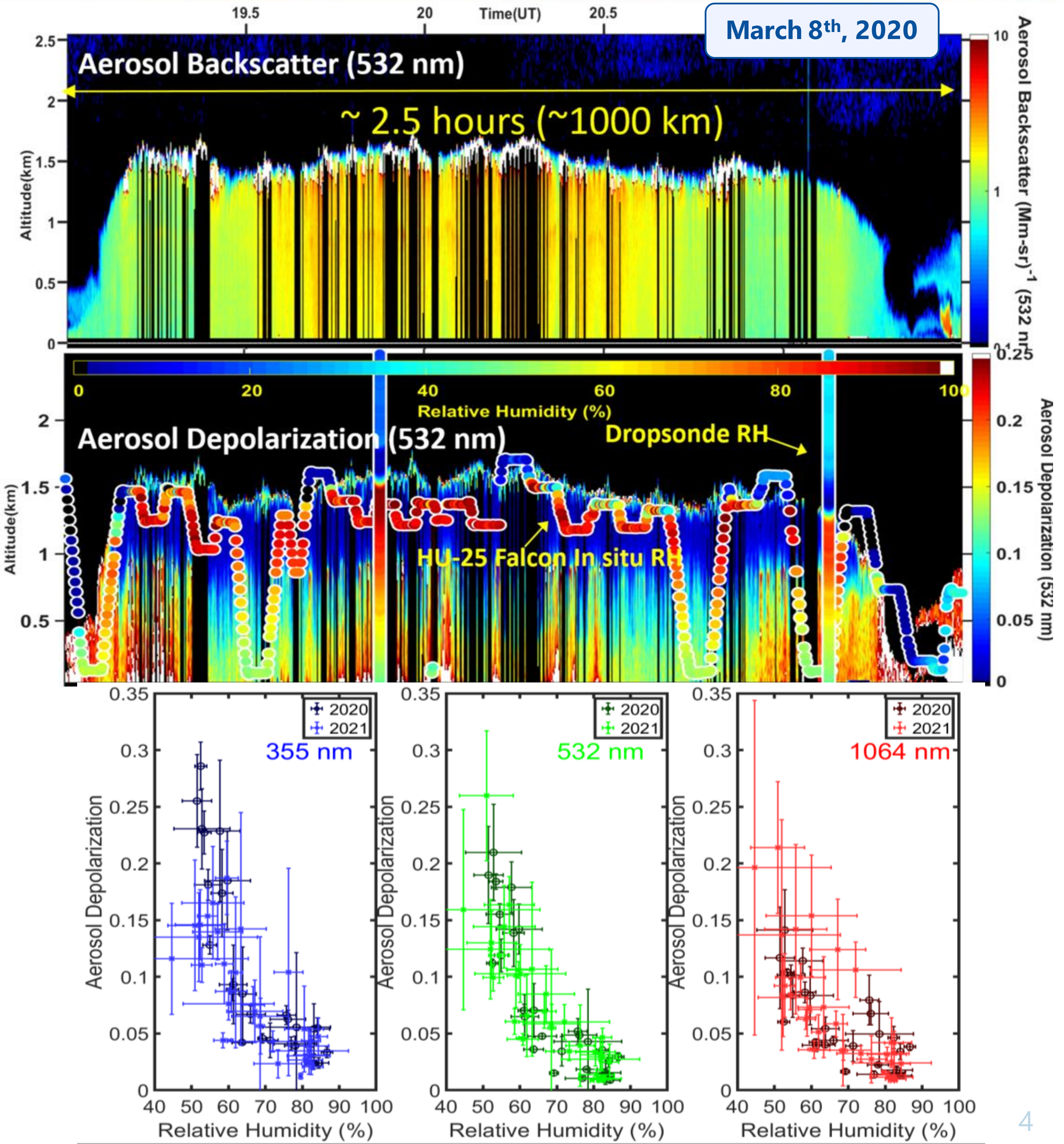
Status of HSRL2 Data Products to be Archived	Flight Years 2020	2021	2022
Extensive Properties			
Aerosol Backscatter	ARCHIVED	ARCHIVED	ARCHIVED*
Aerosol Extinction	ARCHIVED	ARCHIVED	ARCHIVED*
Intensive Properties			
Aerosol Depolarization	ARCHIVED	ARCHIVED	ARCHIVED*
Extinction-to-Backscatter Ratio	ARCHIVED	ARCHIVED	ARCHIVED*
Angstrom Exponent – Extinction	ARCHIVED	ARCHIVED	ARCHIVED*
Angstrom Exponent – Backscatter	ARCHIVED	ARCHIVED	ARCHIVED*
Additional Products			
Summary Plot Images	ARCHIVED	ARCHIVED	ARCHIVED*
Aerosol Type (e.g., smoke, dust, marine, …)	ARCHIVED	ARCHIVED	ARCHIVED*
Aerosol Optical Thickness	ARCHIVED	ARCHIVED	ARCHIVED*
Cloud Top Heights	ARCHIVED	ARCHIVED	ARCHIVED*
Mixed Layer Heights	ARCHIVED*	ARCHIVED*	Jan '23
f(RH) NEW	> Jan '23	> Jan '23	> Jan '23
Cloud Products NEW	Jan '23	Jan '23	Jan '23
Surface Winds NEW	Jan '23	Jan '23	Jan '23
$3\beta + 2\alpha$ Retrievals	TBD - Case studies may be processed if there is interest		

CORE PRODUCTS (Extensive Properties through Cloud Top Heights)

Science Highlights – Elevated Depolarization

Work by Rich Ferrare, NASA LaRC

- During nearly a third of the ACTIVATE flights, airborne HSRL-2 measurements revealed enhanced (>15-20%) particulate linear depolarization in the lowest levels of the marine boundary layer. These observations occurred often during Cold Air Outbreaks (CAO).
- The strong correlation of elevated depolarization with low (<60%) relative humidity (RH), low (20-25 sr at 532 nm) aerosol extinction/backscatter (i.e. lidar) ratio, coincident airborne in situ size and composition measurements, and aerosol transport models indicate that the elevated depolarization is associated with crystalline sea salt, consistent with previous lidar observations.
- Examination of CALIOP measurements during several CAO episodes and SODA retrievals of column lidar ratio suggest that CALIOP operational aerosol algorithms tended to classify these aerosols as dusty marine rather than marine aerosols. Such misclassification leads to overestimates in the assumed lidar ratio and in the resulting retrievals of aerosol optical depth and aerosol extinction.
- Draft manuscript describing these observations has been completed and will be submitted after review by co-authors



Data Product Availability – Cloud Products NEW

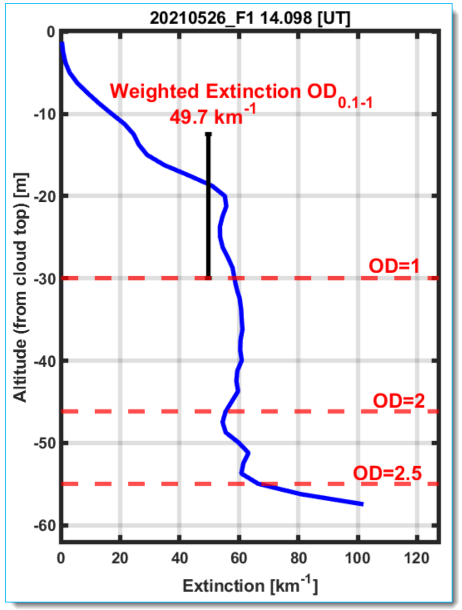
Work by John Hair, NASA LaRC

- New HSRL cloud-top products:
    - **Extinction Profile**, Integrated Attenuated Backscatter, Linear Integrated Depolarization

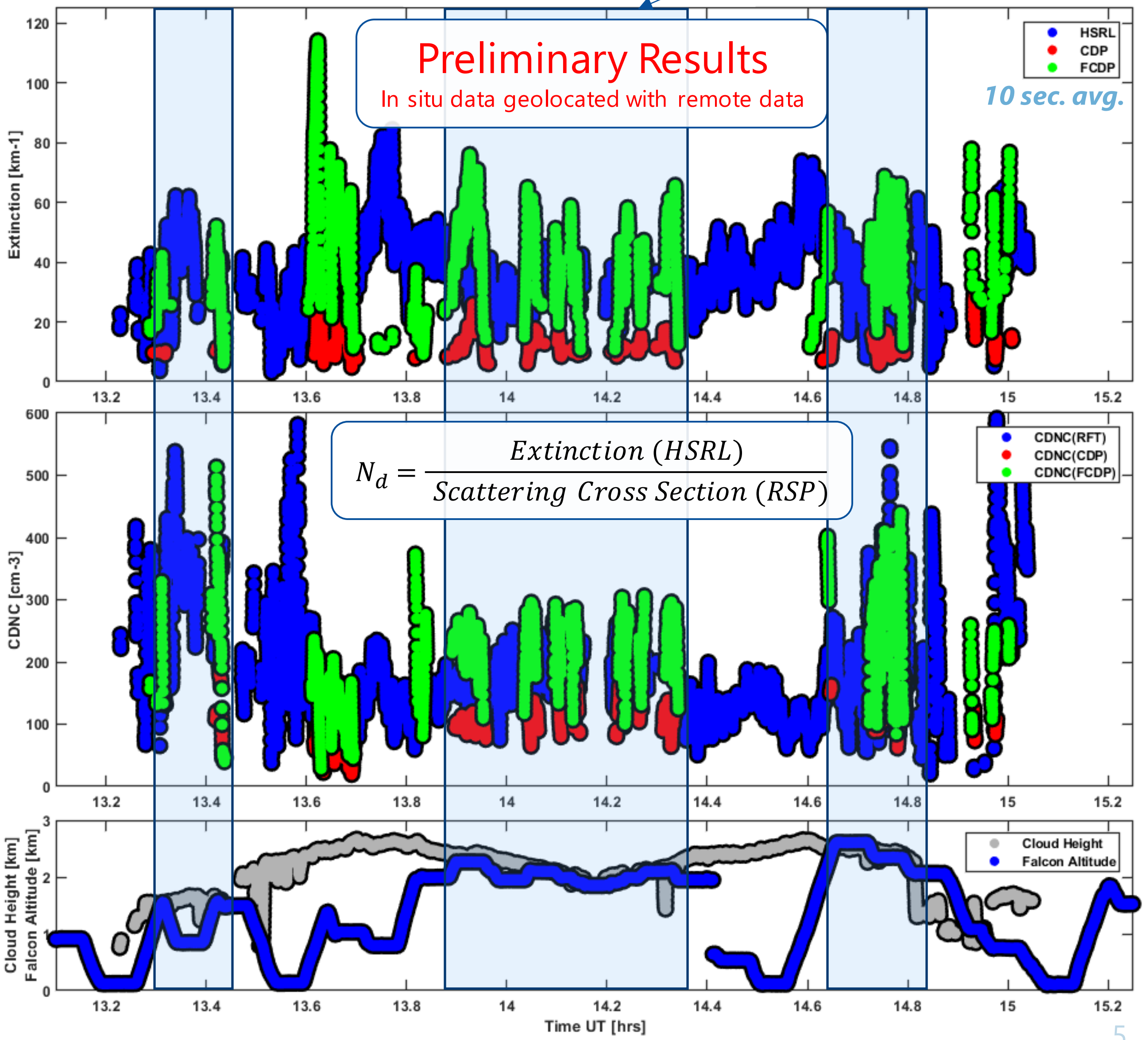
      0.5 sec temporal, 1.25 m vert. resolution
    - **Lidar Ratio, Weighted Extinction ($OD_{0.1\text{-}1}$)**
- New HSRL surface products: Transmission (from surface), Reflectance (from surface), Wind Speed (10m)
- Targeting archive: January 2023
- Publication in progress: 2023
- When combined with RSP, can calculate **cloud top N_d** and **Liquid Water Content**

  (working w/ Sinclair/Cairns)

Hu, Yongxiang et al., 2006
Alexandrov, Mikhail D., et al. 2012



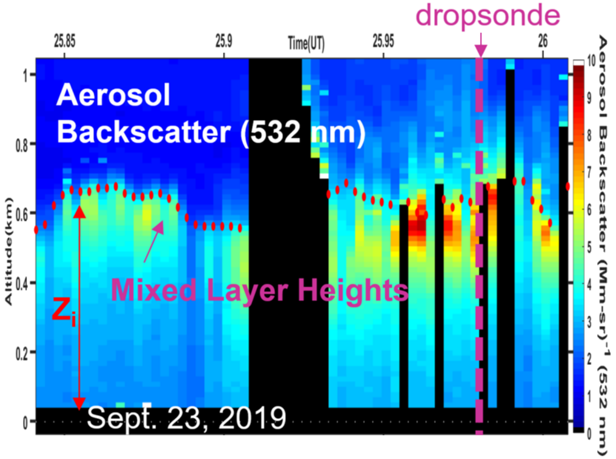
Agreement at BCT w/ FCDP, CDP lower

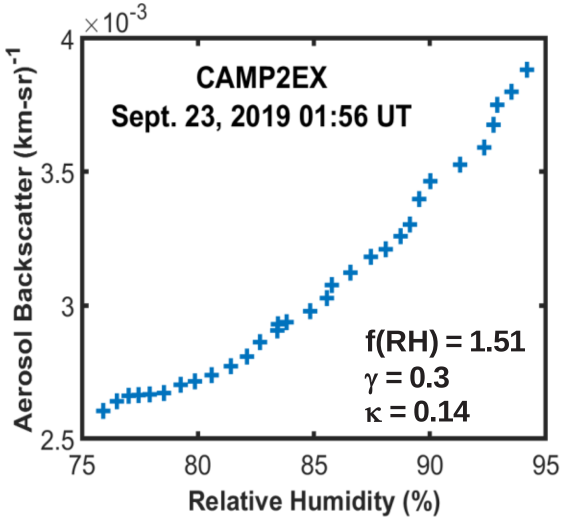


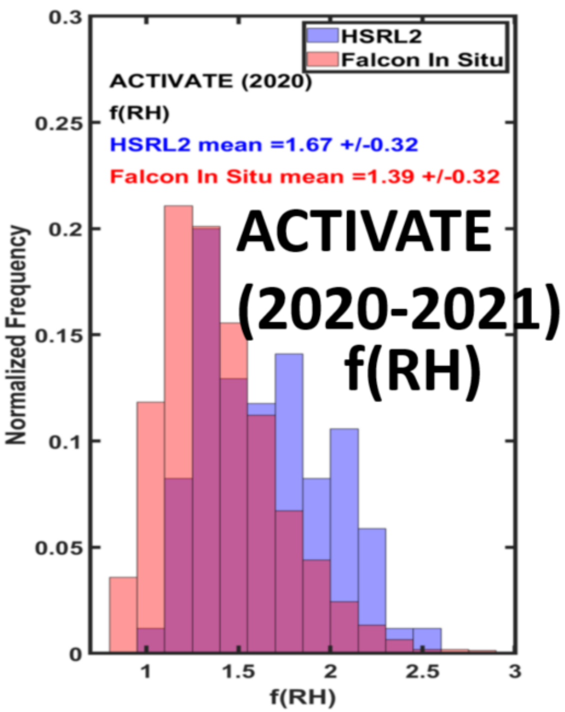
Science Highlights – Aerosol Humidification NEW

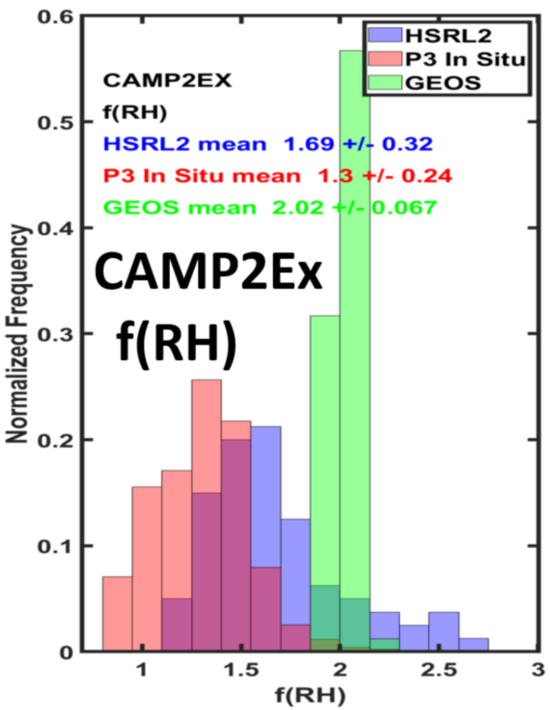
Work by Rich Ferrare, NASA LaRC

- As RH increases with height within Mixed Layer, hygroscopic particles take on water, so aerosol backscatter and extinction increase.
- To quantify this increase, we compute aerosol enhancement factor f(RH), gamma (γ), kappa (κ) within the mixed layer (i.e. Z/Zi < 1) using aerosol backscatter profiles from HSRL2 and RH profiles from dropsondes for data collected during CAMP2Ex and ACTIVATE
- Average $f\left(RH_{\frac{80\%}{20\%}}, 532\,nm\right)$ derived from HSRL-2 and dropsonde data was about 1.67 during both CAMP2Ex and ACTIVATE (2020-2021)
- f(RH) values derived from HSRL-2 & dropsonde data are higher than those from airborne in situ data most likely because lidar observes both fine and coarse (sea salt) aerosol in contrast to in situ measurements of only fine mode aerosol
- GEOS model values of f(RH) are higher and have less variability than those derived from both HSRL-2 & dropsonde and airborne in situ values. Work ongoing to continue investigating in situ and GOES humidification factors, anticipating manuscript in 2023.
- Looking to archive HSRL2/dropsonde f(RH) values (2023).





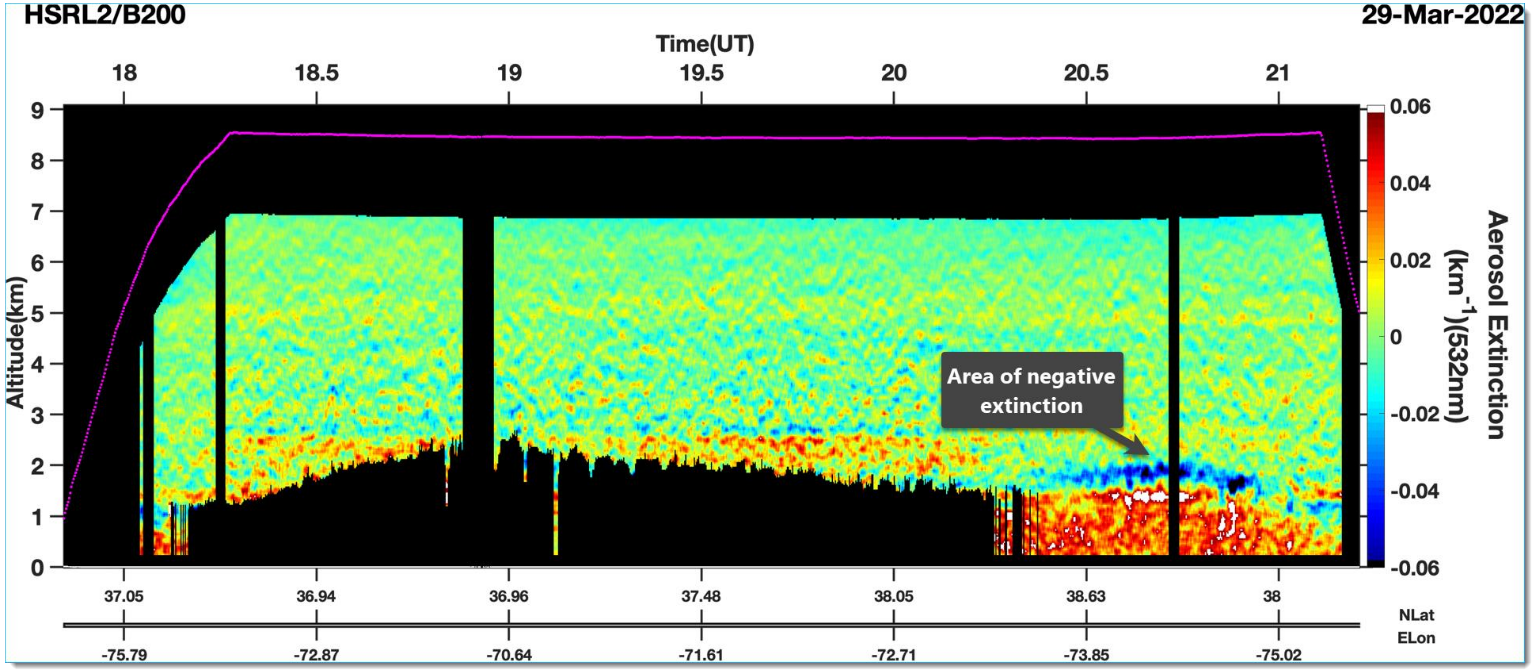




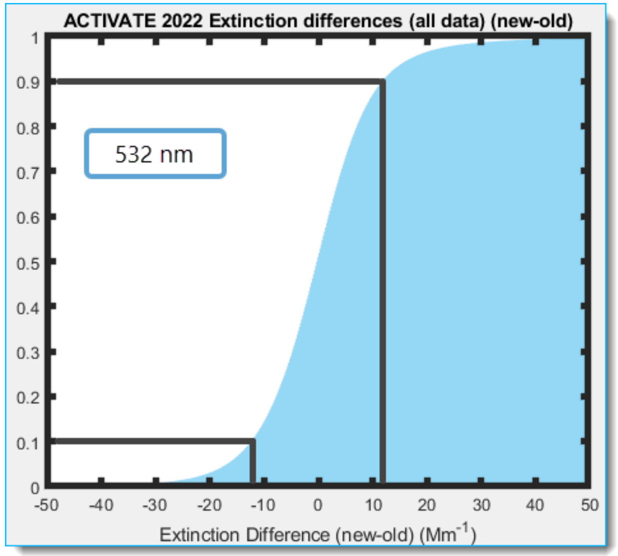
Data Product Comment – Extinction

Work by Rich Ferrare and Marta Fenn, NASA LaRC

- **Problem**: Areas of lower-than-expected extinction. This was highlighted by areas of negative extinction.
- The likely cause of this is due to regions of turbulence creating a change in refractive index (e.g., an optical lensing effect). These are *typically* found near the top of the boundary layer and have been associated with strong wind shear.



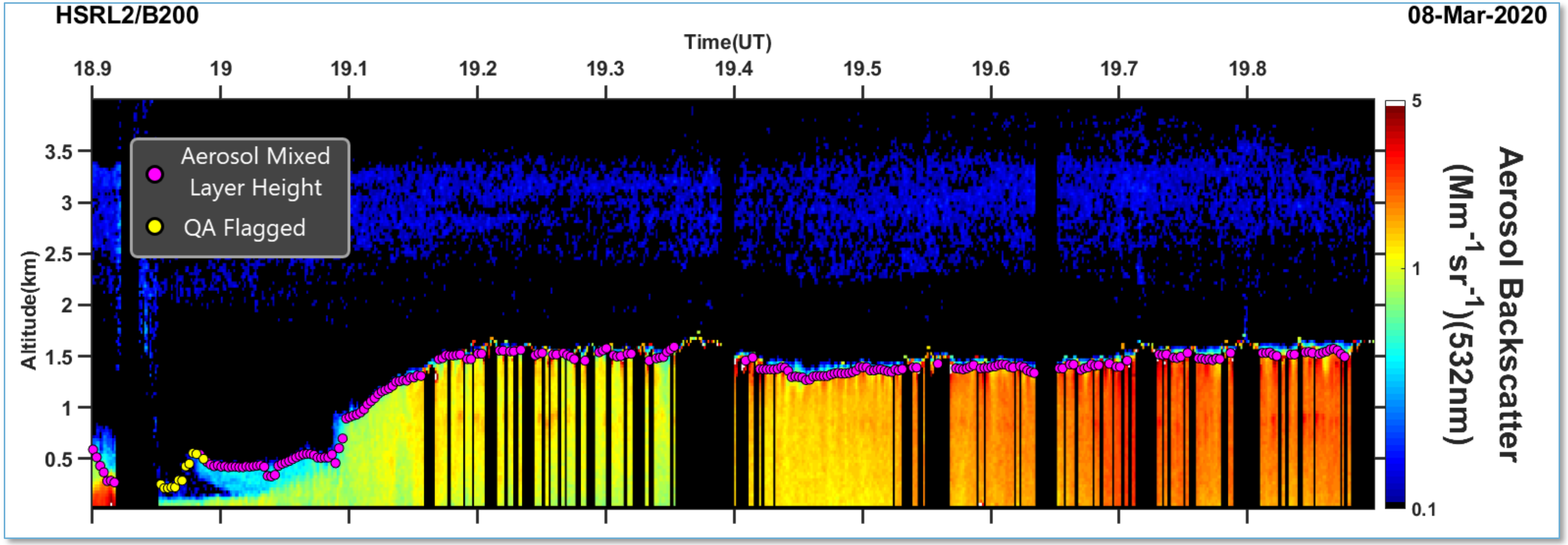
- **Solution**: Applied a second extinction calculation method that is not susceptible to the same problem. Both methods available in the archive along with their resulting column AOD calculations.
- **Impact**: As many as 1/3rd of the flights may have seen this issue; however, in comparing the difference in the values of the extinction calculated with the revised method vs the original method, about 80% of the 532 nm data lies within +/- 12 Mm^{-1}. This issue does **not** impact the backscatter measurements.
- If there are specific questions on a case study, please contact us if you would like guidance on which extinction calculation approach is best to use.



Data Product Availability – Mixed Layer Heights

Work by Amy Jo Scarino, NASA LaRC

- Aerosol mixed layer heights identified using a modified Haar wavelet approach (Scarino et al., 2014)
- ACTIVATE proved to be a challenging environment for this analysis: shallow MBL, residual aerosol, layers aloft, etc.
- Available in ICARTT format as a 10 second 1 dimensional product, QA confidence flag available as well.
- Campaign years 2020 and 2021 archived, 2022 to be archived soon.

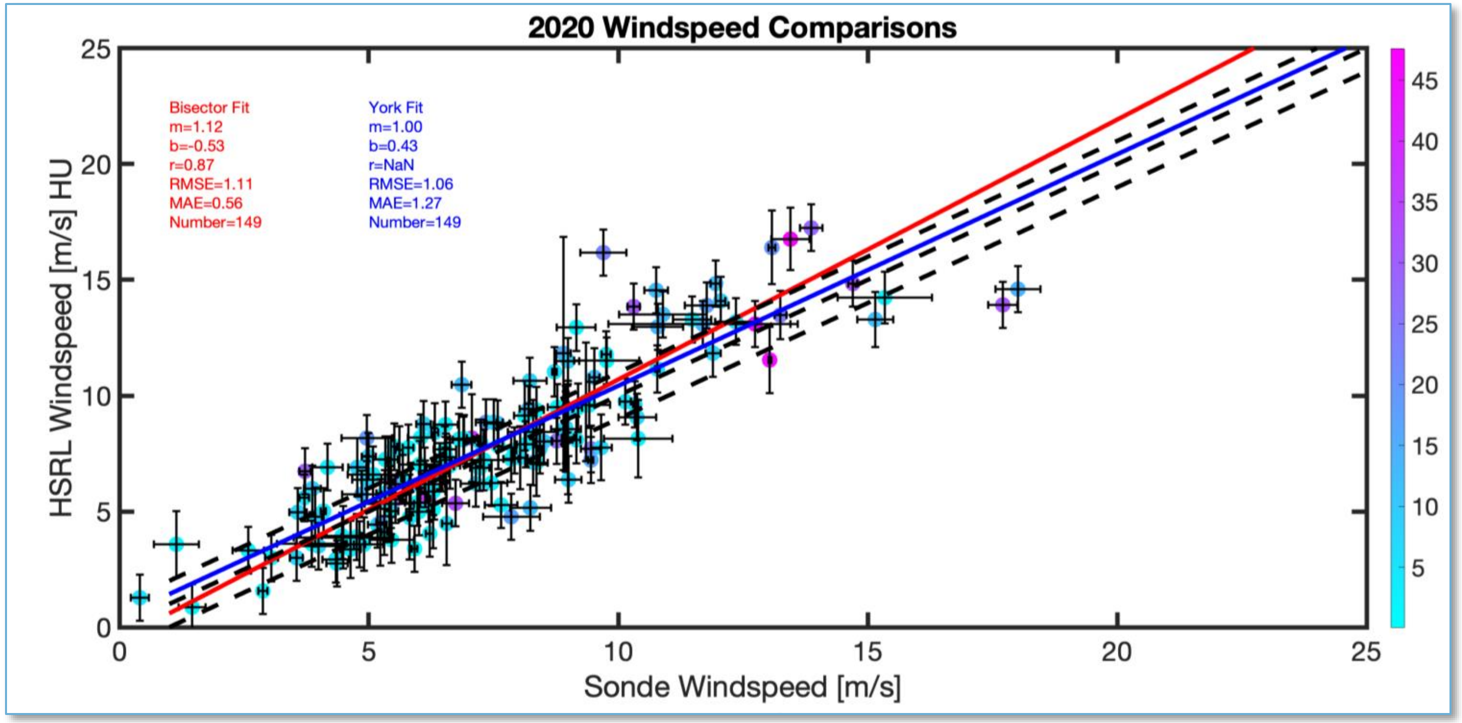


Science Highlights – Surface Winds NEW

Work by John Hair, NASA LaRC and Sanja Dmitrovic, U of A

- Surface wind speeds derived from HSRL surface measurements are a new product from the LaRC team
- Surface wind speed measurements were enabled by a recent instrument upgrade (1.25 m vertical sampling) and the HSRL technique allowing for correction of the attenuation down to the ocean surface.
- HSRL-2 ocean surface return used to derive the wave slope variance, which can be related to 10 m wind speed.
- Sanja is comparing ACTIVATE HSRL-2 derived surface wind speeds to AVAPS dropsonde 10 m wind speeds and TAMMS (Falcon in-situ air motion measurements)
- Sanja has a publication in progress, where the surface wind speeds methods will be included.
- ACTIVATE Surface wind speed products added to the archive for all three years.

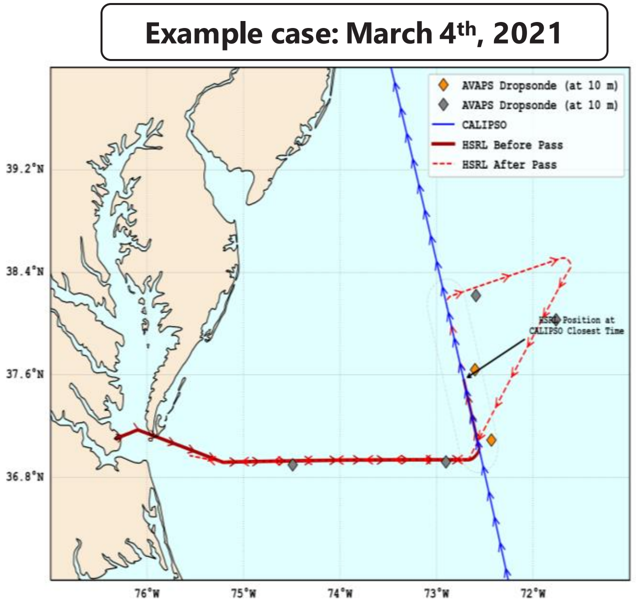
Comparison using HSRL-2 surface winds (using Hu's wind driven wave slope variance to wind speed relationship; Hu, 2008, ACP)

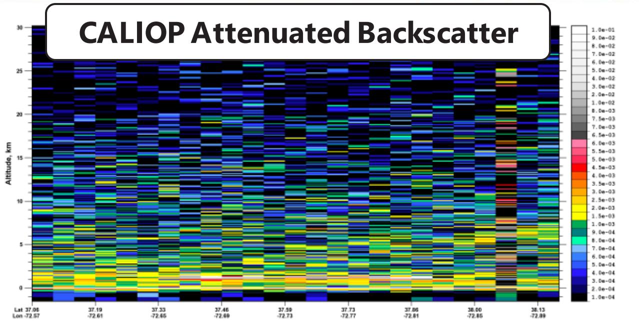


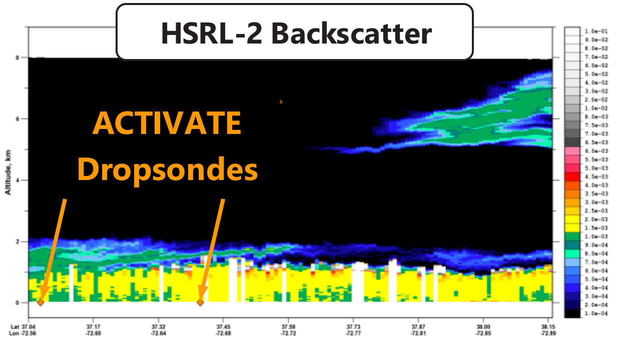
Science Highlights – CALIOP/ODCOD Validation

Work by Rob Ryan, Marian Clayton, and Rich Ferrare, NASA LaRC

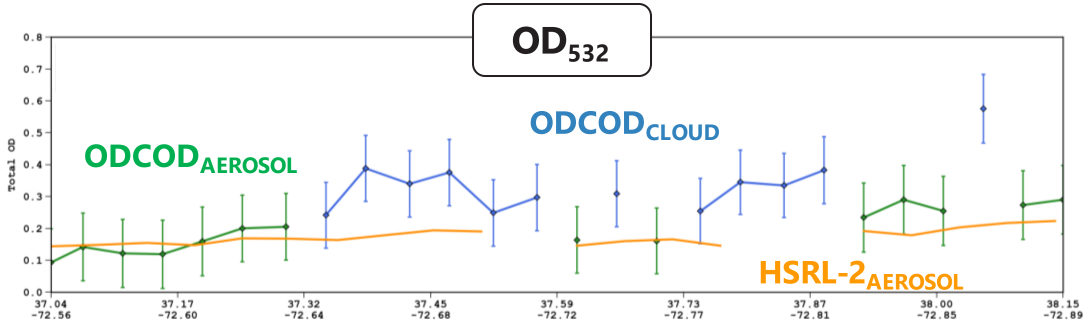
- 11 CALIPSO under-flights during ACTIVATE
- Retrievals of AOD by CALIOP rely on specifying lidar ratios to aerosol layers. **Problem:** aerosol direct radiative effects can be underestimated by as much as 30-50% due to undetected background aerosols or misassigned aerosol types (incorrect lidar ratio applied).
- **Solution:** ODCOD – uses ocean surface return and modeled surface winds to derive attenuation by clouds/aerosols.

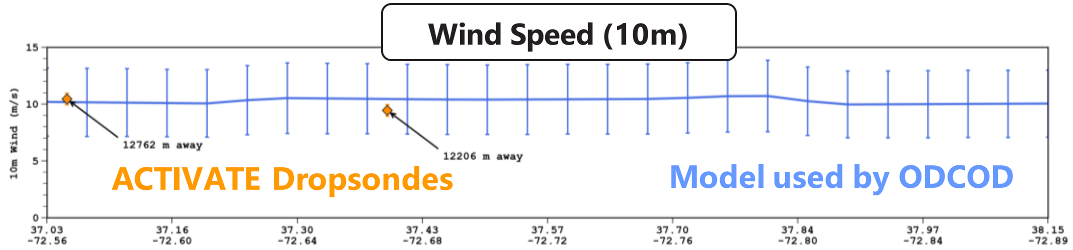


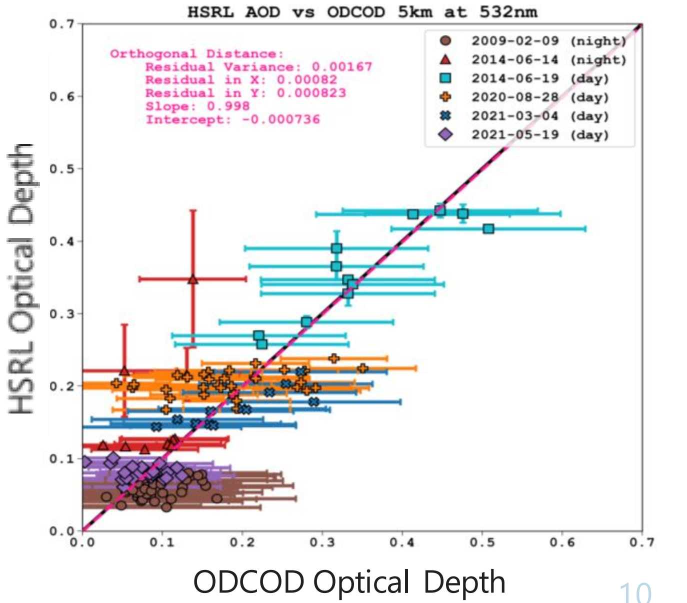




- Using ACTIVATE HSRL-2 data to validate ODCOD AOD
- Using ACTIVATE dropsondes to evaluate modeled wind speeds
- ODCOD AOD retrievals will be released in V4.5 CALIOP data
- Anticipating a publication describing ODCOD retrievals (Rob Ryan)



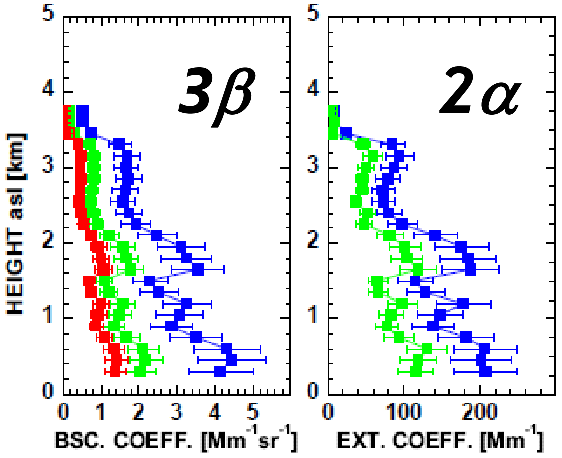




Data Product Availability – 3β + 2α Retrievals

Work by Snorre Stamnes, Ed Chemyakin, and Michael Jones, NASA LaRC

- Retrievals of aerosol microphysical properties using multiwavelength HSRL products. Backscatter at 3 wavelengths with extinction at 2 wavelengths is considered to be the minimum information content necessary for microphysical retrievals (Bockmann et al, 2005).
- The technique used for previous missions over land (DISCOVER-AQ) and for biomass burning smoke (ORACLES) is inappropriate for shallow marine layers. Snorre and team are exploring an optimal estimation approach for microphysical retrievals for the ACTIVATE domain.
- There are no plans for archival of 3β + 2α aerosol retrievals for the full set of ACTIVATE flights; however, if anyone is working on a case study and would benefit from these products, please contact us and we would be happy to work with you on these cases.



355 nm
532 nm
1064 nm
+
355 nm
532 nm

Lidar measurements

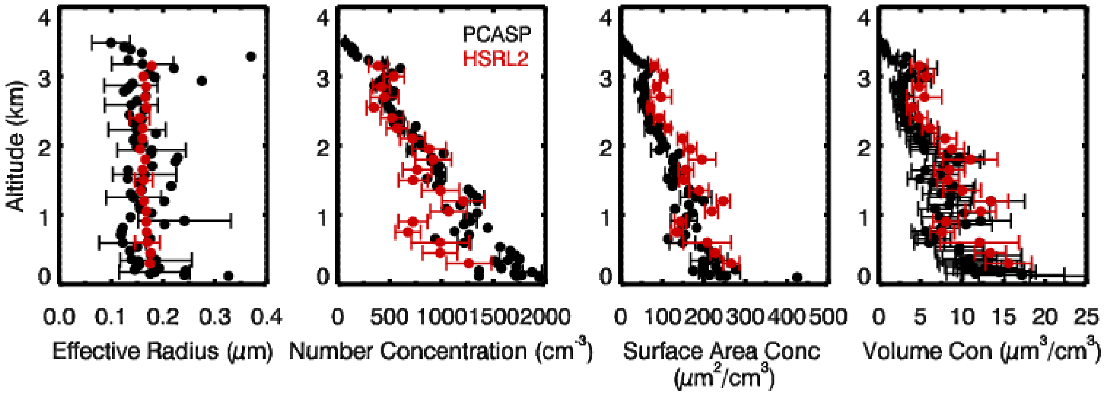
Particle Size Distribution

INVERSION

$$\beta(\lambda) = \int K_\beta(r, m, \lambda) v(r) dr$$

$$\alpha(\lambda) = \int K_\alpha(r, m, \lambda) v(r) dr$$

Size, Refractive Index, Wavelength



References: Müller et al., 2014, AMT; Sawamura et al., 2017, ACP
Müller et al., 1999, Applied Optics; Veselovskii et al., 2002, Applied Optics

Thank you