

PACE-PAX HSRL-2 ReadMe

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Organization: NASA Langley Research Center

Instrument Name: NASA HSRL-2

Mission: PACE-PAX (Plankton, Aerosol, Cloud, ocean Ecosystem – Postlaunch Airborne eXperiment)

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Platform: NASA AFRC ER-2

Location: GPS Lat, Lon, and Alt included in the Nav_Data records

Associated Data: Additional folders provide information used to process and locate the HSRL-2 data products

/State: parameters interpolated to HSRL-2 curtains from MERRA2 (see <http://gmao.gsfc.nasa.gov/>)

Temperature, K, atmospheric temperature

Pressure, atm, atmospheric pressure

Number_Density, per cubic meter, molecular number density

/Nav_Data: other navigational data is also included besides what is listed below

gps_time, time of the data products from 0 UT on the flight day

gps_alt, m, aircraft altitude from GPS

gps_lat, degrees, latitude N from GPS

gps_lon, degrees, longitude E from GPS

Data Info: 10 second profiles. All data products have been interpolated to the same uniform altitude grid above sea level (DataProducts/Altitude) and horizontally averaged or interpolated to the GPS times (Nav_Data/gps_time). Horizontal and vertical resolutions of the data products are found in the attributes of each scientific data set.

DOI: 10.5067/ASDC/SUBORBITAL/PACE-PAX/DATA001/ER2/AircraftRemoteSensing/HSRL2_1

Instrument Info: Multiwavelength High Spectral Resolution Lidar (HSRL-2) aerosol/cloud measurements with ocean measurement capability, see <https://science-data.larc.nasa.gov/lidar/instruments.html> For more information, see Hair, J.W., et al. (2008) and Collister, B., et al. (2024).

Uncertainty: Atmospheric Data Product Uncertainty values are included in this release.

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Project Info: <https://espo.nasa.gov/pace-pax>, <https://pace.oceansciences.org/pace-pax.htm>

Stipulations on Use: Although not required for publicly archived data, users are STRONGLY ENCOURAGED to contact the HSRL team before using the data, for advice specific to the desired application. Please use DOI for citation

Revision: R2, Final Data – Atmospheric aerosol/cloud files (R1) and Ocean file (R0)

In this revision, extinction and AOT datasets that were generated from backscatter profiles (532_ext_from_backscatter, 355_ext_from_backscatter, 532_AOT_from_bsc, and 355_AOT_from_bsc) are generated using a Machine Learning method further described in Comments on Data, Revision: R1.

Similar information from this readme file can be found within the Global Attributes of the respective HDF5 files.

Standard Atmospheric Data Products Files

Comments on Data Files: `pacepax-HSRL2_ER2_202409dd_R1.h5`

Revision: R1:

For this campaign we recommend using the extinction profile and aerosol optical thickness (AOT) calculated from the backscatter profiles for most applications (i.e. 532_ext_from_backscatter, 355_ext_from_backscatter, 532_AOT_from_bsc, 532_AOT_from_bsc_col, 355_AOT_from_bsc_col, and 355_AOT_from_bsc) rather than the standard products (532_ext, 355_ext, 532_AOT_hi, 355_AOT_hi, 532_AOT_hi_col, and 355_AOT_hi_col) calculated using the HSRL technique.

Reasoning for this recommendation:

During the PACE-PAX campaign, HSRL-2 sometimes measured anomalously low aerosol extinction values (355 and 532 nm) which are related to atmospheric turbulence associated with strong wind shear over the mountains and over the ocean that enhances the lidar backscatter signal. The effect has been denoted in the literature as enhanced backscattering or amplification of backscatter in a turbulent atmosphere. This effect impacted the ability to use the 532

nm and 355 nm molecular channels to derive aerosol extinction and the Aerosol Optical Thicknesses (AOT-hi) in these regions using the standard method as discussed by Hair et al (2008) and impacts the lidar ratio (extinction-to-backscatter ratio). This enhancement, when present, produces a low bias in the AOT and in the aerosol extinction; this AOT bias was typically less than 0.05 at 532nm. To ameliorate this issue, an additional method is implemented to compute aerosol extinction and AOT products which are provided in this archive for both wavelengths. This method uses cloud screened aerosol backscatter profiles (532_bsc_cloud_screened, 355_bsc_cloud_screened, 1064_bsc_cloud_screened) and aerosol depolarization profiles (355_aer_dep_cloud_screened, 355_aer_dep_cloud_screened, 1064_aer_dep_cloud_screened) to generate color ratio and depolarization ratio profiles. Since the HSRL method derives the aerosol backscatter and depolarization as a ratio of two channels, it is not affected by this enhanced scattering. These profiles are input to a machine learning model that estimates the extinction-to-backscatter ratio (i.e., lidar ratio) (532_Sa and 355_Sa) mean and standard deviation. Training HSRL-2 datasets were used from selected past campaigns that covered a range of aerosol types both over the ocean and land using the extinction and lidar ratios calculated from the standard HSRL technique. These data were selected to reduce the impact of the turbulence effect but may not be entirely eliminated (i.e. limited to flights that did not show indication of the turbulence enhancement in the backscatter). From these, it is a direct calculation of extinction profiles (532_ext_from_backscatter and 355_ext_from_backscatter) and AOT (532_AOT_from_bsc and 355_AOT_from_bsc). It should be noted that no other external data is used to determine these products. Uncertainties for these variables are also reported based on the standard deviations of the Sa products returned by the model. These additional extinction from backscatter products were generated from the 10 second resolution cloud screened data profiles at finer resolution than the standard products. The data variables 532_AOT_from_bsc_alts and 355_AOT_from_bsc_alts provide the altitude range over which the AOT from backscatter products are calculated and can be different from the standard product.

Regarding cloud top height determination, the archive file (e.g. pacepax-HSRL2_ER2_20240906_R0.h5) reports a cloud height that is a subset from the fundamental sampling of 0.5 second for cloud heights to match the time intervals reported. Since additional cloud height information is available and users have requested a cloud height product at a higher frequency, we are providing cloud top heights at 0.5 second intervals in a separate archive file (e.g. pacepax-HSRL2-Cloud_ER2_20240906_R0.h5) under the data product name '/DataProducts/cloud_height_LBW'. LBW or 'Low Bandwidth' denotes a lower vertical resolution sampling interval of 15m from the highest sampling intervals recorded in the raw data. This is usually sufficient from most applications using retrieved cloud heights. This cloud height is determined from the 532nm backscatter ratio calculated at 0.5 second profiles using the vertical gradient calculated over 75m range interval. The threshold in the gradient to identify a cloud is determined by finding a local minimum in the distribution of backscatter ratio gradients for each flight. This threshold is then used for each profile in that flight to identify a cloud and to calculate the cloud top height. Only one height is identified for each profile for the top most value.

In addition to the product from the low bandwidth data, a refined cloud height product is provided with higher vertical resolution of 1.25m under the name '/DataProducts/cloud_height' in the same cloud archive file using the high bandwidth data. This cloud top height is determined by starting with the identified low bandwidth cloud height and is refined by the higher vertical resolution data at 1.25 m. Additional constraints are applied to ensure a cloud has been detected (i.e. the higher bandwidth cloud heights include additional conditions compared to the low bandwidth cloud height product). For this product, the 532nm backscatter ratio >50 in addition to the threshold in the gradient determined previously. Note aerosol backscatter values are in general less than this value unless in a very strong and localized plume such as near wildfires or near a dust storm. The cloud height is determined within the profile at an altitude where the 532nm backscatter ratio transitions to less than 10. Further verification requires that the profile contain valid values of 532nm backscatter ratios >10 for at least half of the 20 vertical samples below the cloud top which screens for false detections due in low signal conditions. Questions about these procedures and datasets can be directed to John Hair.

References:

Hair, J. W. et al.: Airborne High Spectral Resolution Lidar for profiling aerosol optical properties. Appl. Opt. 47, 6734-6752, doi:10.1364/AO.47.006734, 2008.

Ocean Data Products Files

Comments on Data Files: pacepax-HSRL2-Ocean_ER2_20240929_R1.h5, pacepax-HSRL2-Ocean_ER2_20240930_R1.h5

Revision: R0: First submission of final ocean data products

Ocean data products are produced separately from the atmospheric products using dedicated fast-gated detectors to avoid detecting the strong impulse from the sea surface. Ocean data product files are archived for two flights, September 29, 2024, and September 30, 2024, where gate timing was optimized and where cloud-free data were collected over ocean. In addition to screening records for clouds, low SNR, and instrument calibration time periods, ocean data are screened for successful surface detection and gating. Screened records are set to NaN before implementing a running 10s horizontal average where >50% of records in the averaging window are required to be finite or else the average is also set to NaN. Curtain plots of the ocean data products are available in 'pacepax-HSRL2-OceanImages_ER2_202409dd_R0.zip.

References:

Collister, B., et al.: Assessing the utility of high spectral resolution lidar for measuring particulate backscatter in the ocean and evaluating satellite ocean color retrievals. *Remote Sens. Environ.* 300, 113898, doi:10.1016/j.rse.2023.113898, 2024.

Hair, J., et al.: Combined atmospheric and ocean profiling from an airborne high spectral resolution lidar. *EPJ Web of Conferences*. Vol. 119. EDP Sciences, 2016. <https://doi.org/10.1051/epjconf/201611922001>