Stray light calibration of the multi-angle spectropolarimeter SPEXone using a multi-kernel approach

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SRON

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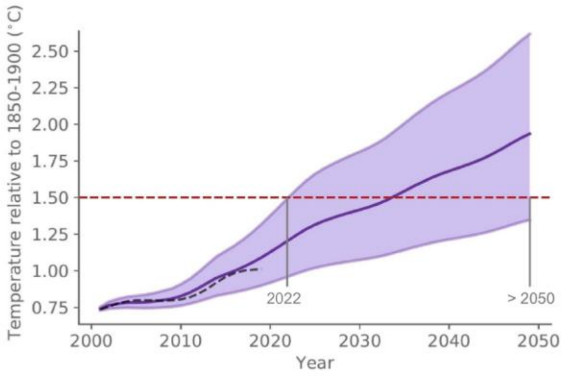
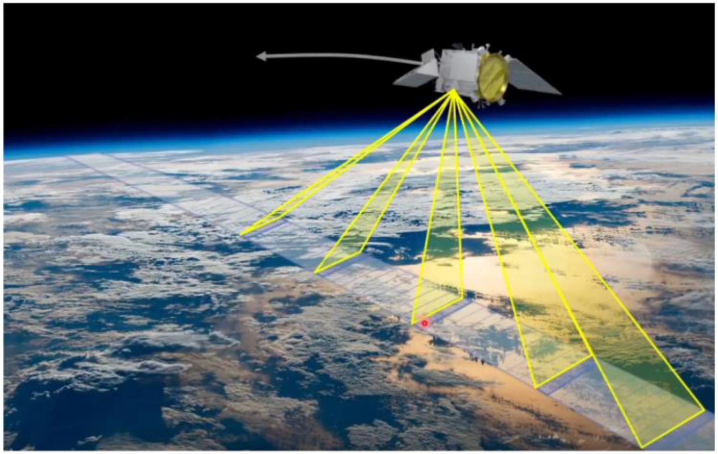
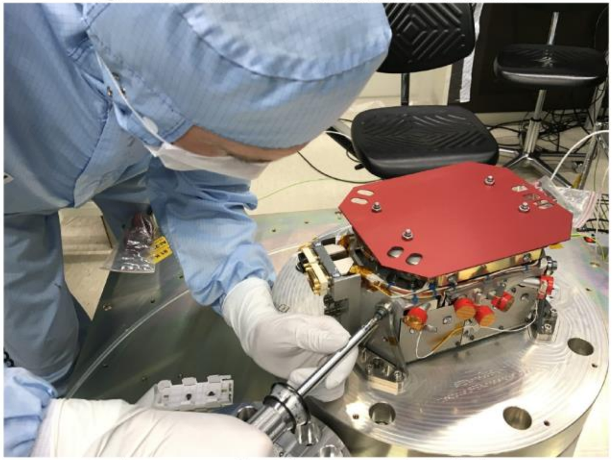
- SPEXone instrument is a multi-angle polarimeter
- Part of NASA's PACE (Plankton, Aerosol, Cloud, ocean Ecosystem) mission
- **Launched on February 8, 2024**
- Measures intensity and degree/angle of linear polarization of reflected sunlight (Stokes I, q, u) in 5 directions
- Objective to study atmospheric aerosols

Uncertainty in the 1.5°C exceedance largely due to aerosols





SPEXone instrument

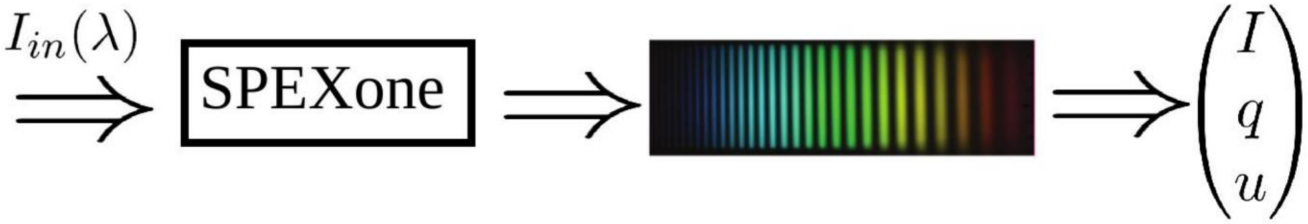


Mounted on PACE (2022 June)

Launch (2024 Feb)

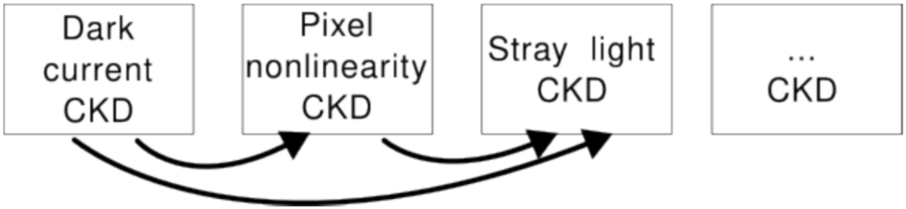
SPEXone in space

- SPEXone optics module converts reflected sunlight into modulated spectra.
- Polarization information is encoded in the modulation.
- SPEXone calibration software then extracts the Stokes I, q, u from the modulated spectra.



Calibration code architecture

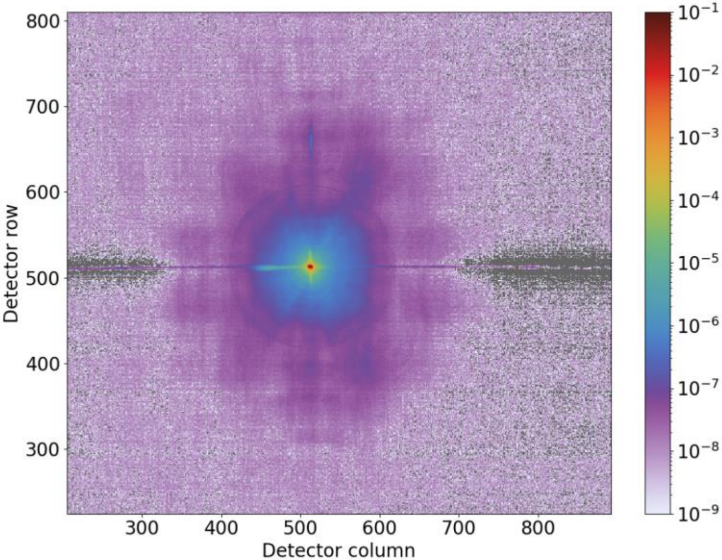
- The calibration key data (CKD), used for calibrating images, are derived by the same data processor that is used for calibrating flight images.
- The CKD is built up step by step from different sets of calibration measurements.
- Each calibration measurement is itself calibrated up to the highest level available.
- The processor is designed to be modular.



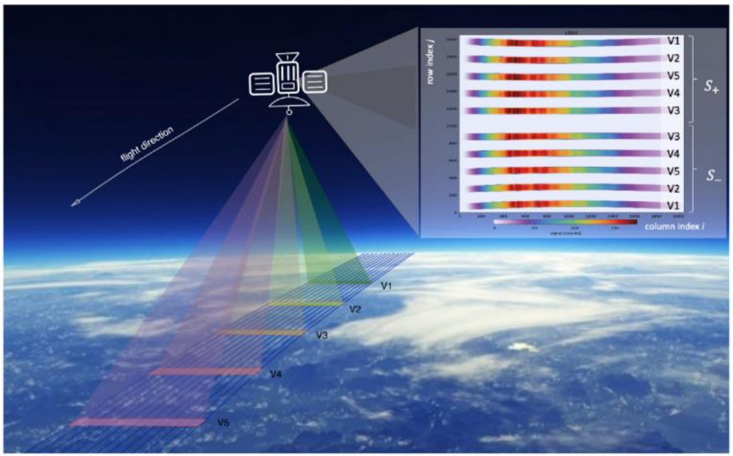
Stray light calibration measurements

- Stray light is light in an optical system which was not intended in the design.
- CKD stores stray light kernel(s) used in a deconvolution procedure for calibration of images.
- Calibration measurements use a narrow-field laser source.

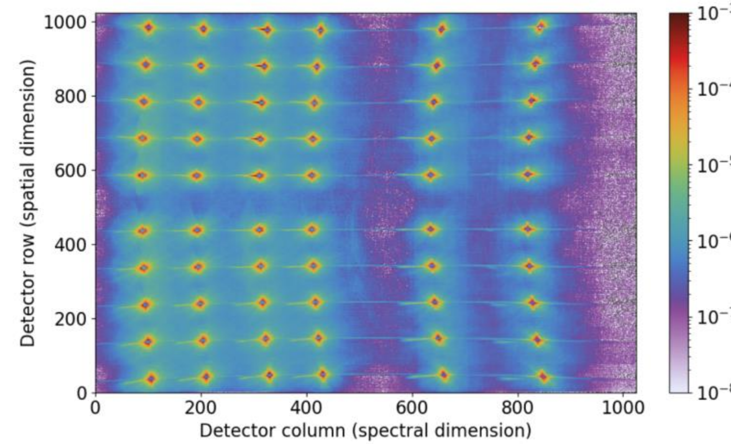
- **Each calibration measurement is corrected for dark offset, current, pixel nonlinearity, and PRNU.**
- **Next set of calibration measurements will additionally be corrected for stray light.**



- Signal from 5 viewports, split into two spectra each, all recorded on a single detector.
- Stray light kernels corresponding to 10 detector bands and 6 laser wavelengths were measured.

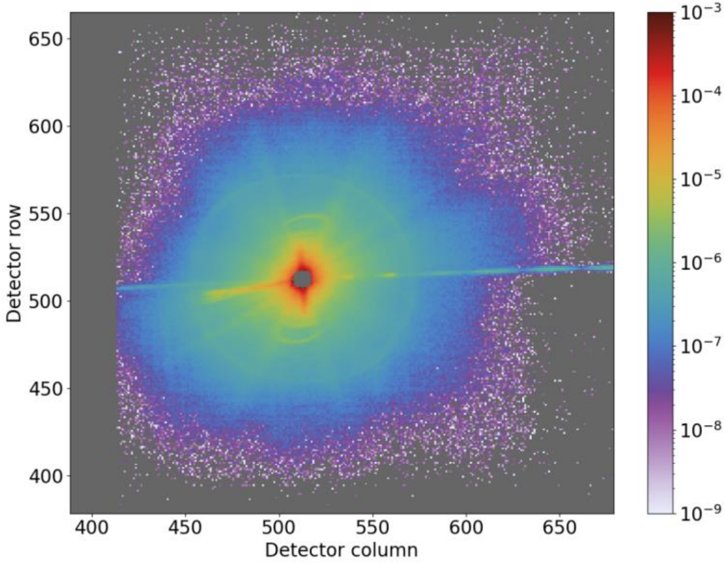


All kernels visualized on the detector

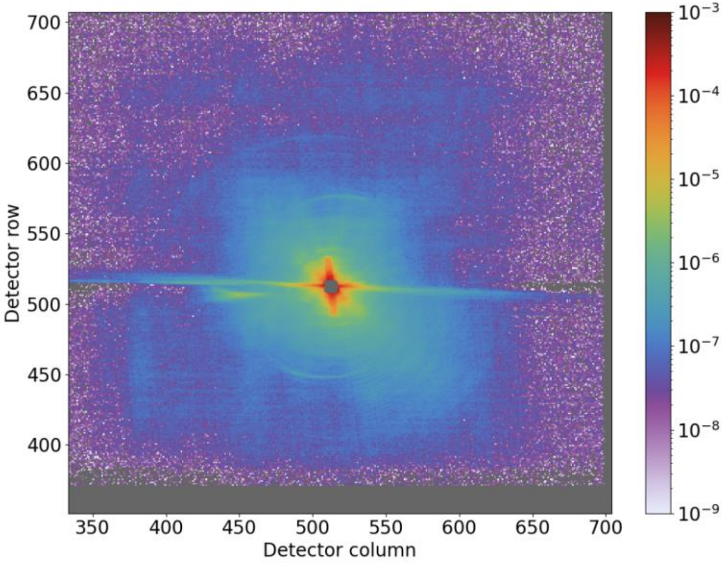


- Kernels corresponding to different locations on the detector have difference shapes and magnitudes.
- Signal spills over to neighboring ground pixels (across detector rows) and wavelengths (across detector columns).

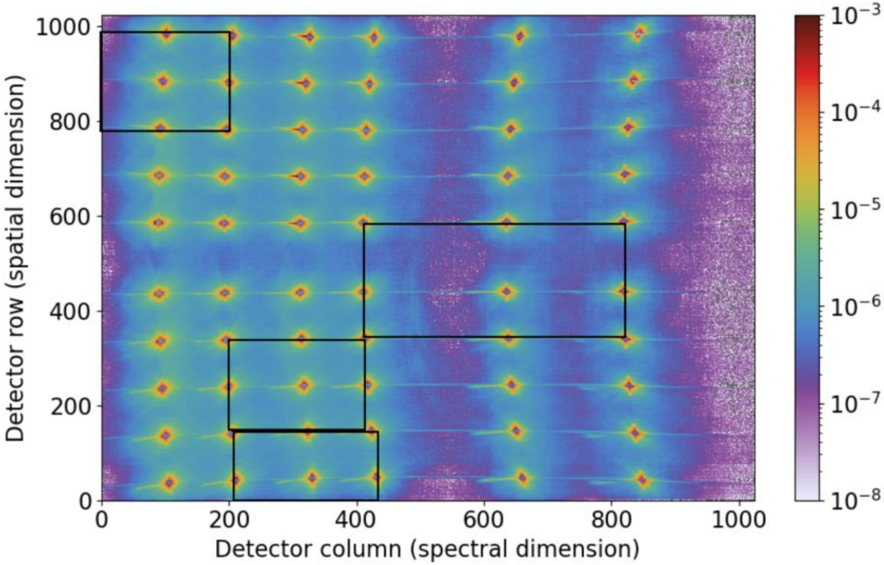
Stray light kernel at viewport -20 deg, 457 nm



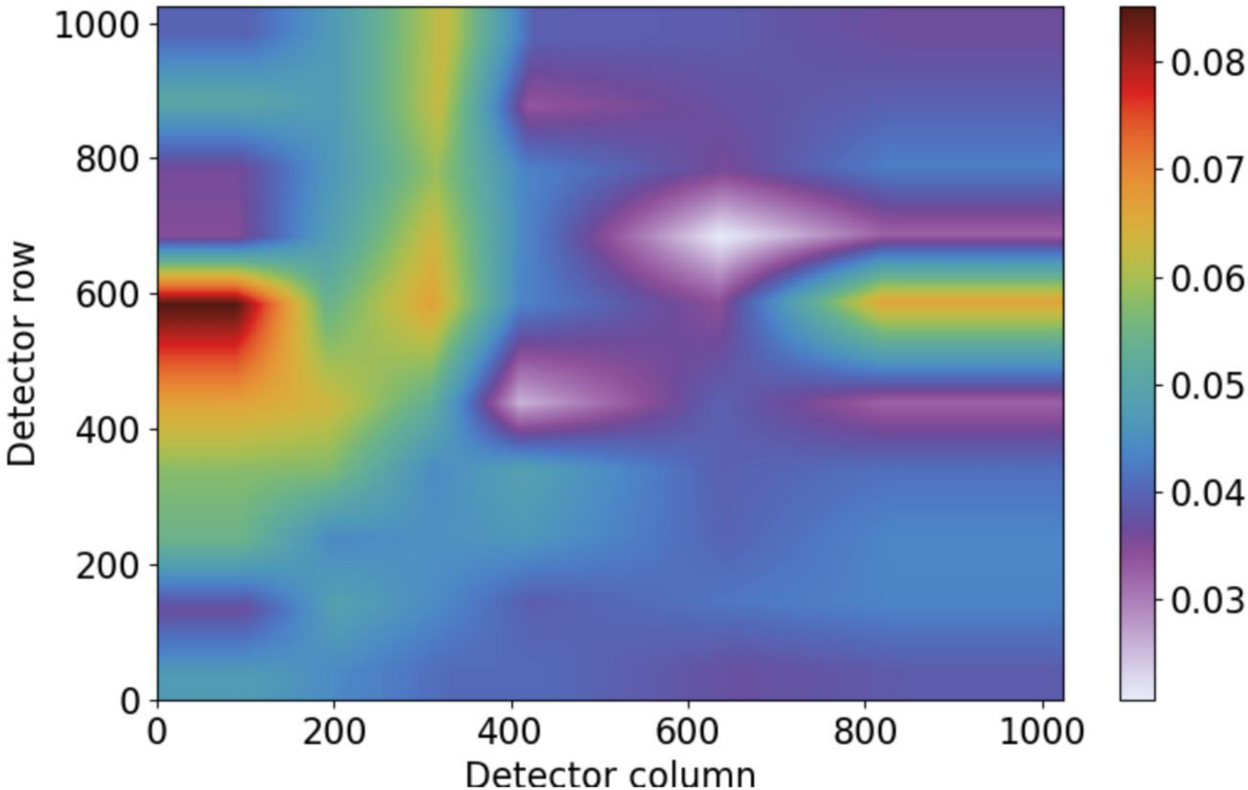
Stray light kernel at viewport -20 deg, 732 nm



- Divide the detector into domains of influence for each stray light kernel.
- Use an interpolating kernel algorithm to deconvolve detector images with stray light kernels.
- Deconvolution algorithm based on the iterative Van Cittert algorithm.



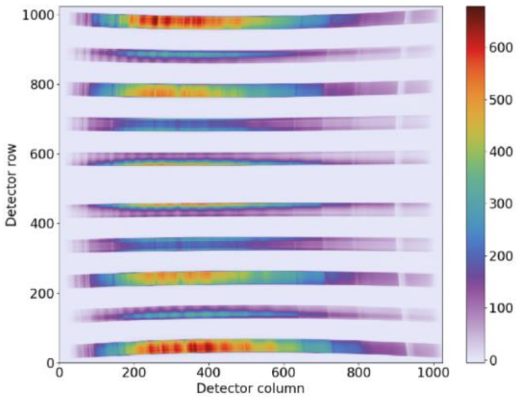
Amount of stray light per pixel ranges from 4% to 8%



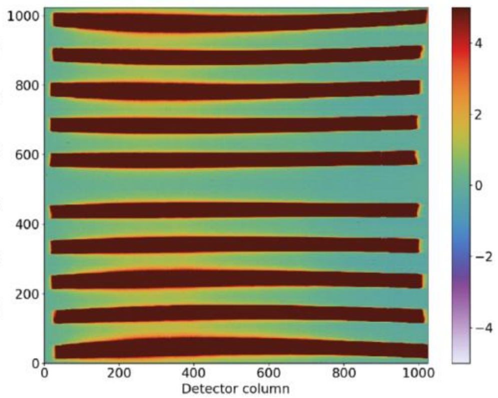
Stray light effect on real measurements

- Stray light correction applied to a detector image from March 29 2024.
- After correction, the regions between viewports have close to 0 counts.

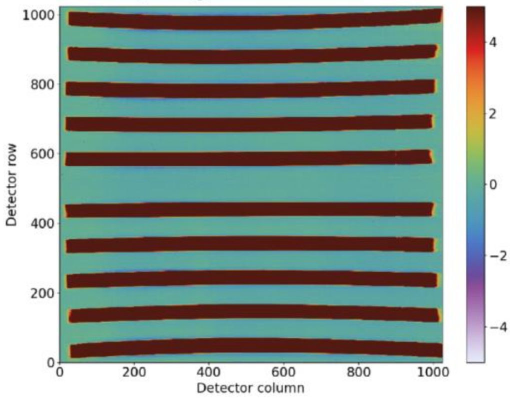
Detector image



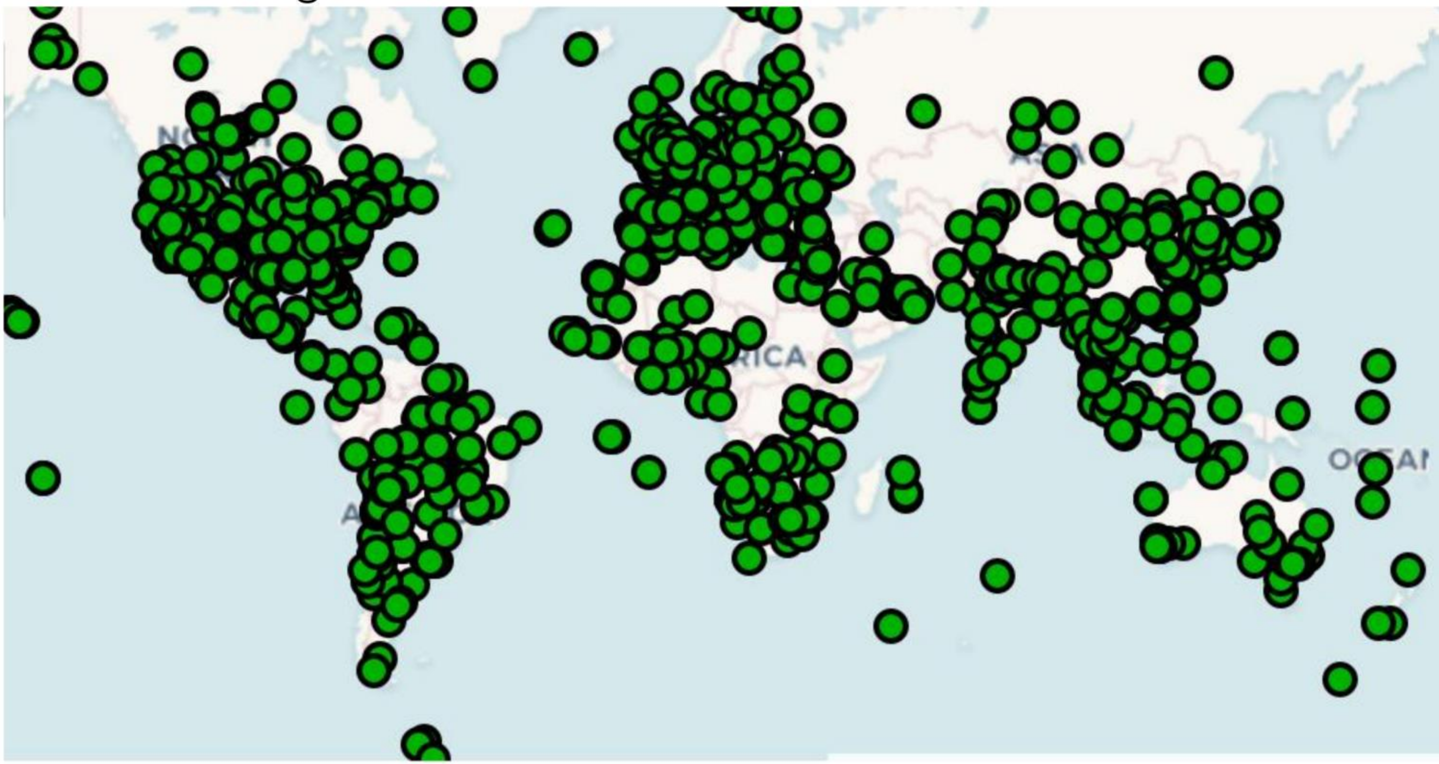
Detector image (zoomed scale)



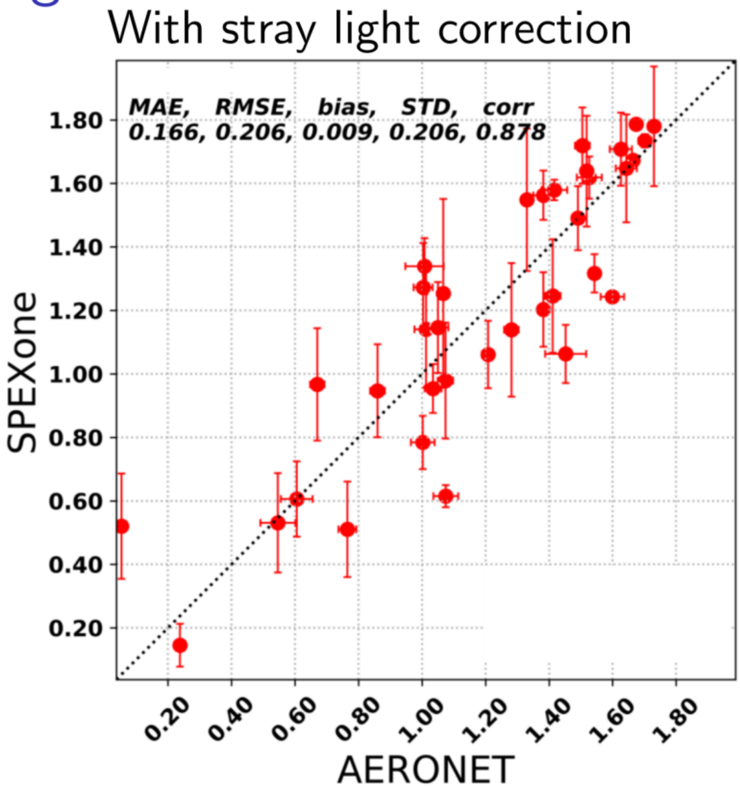
Detector image stray light corrected

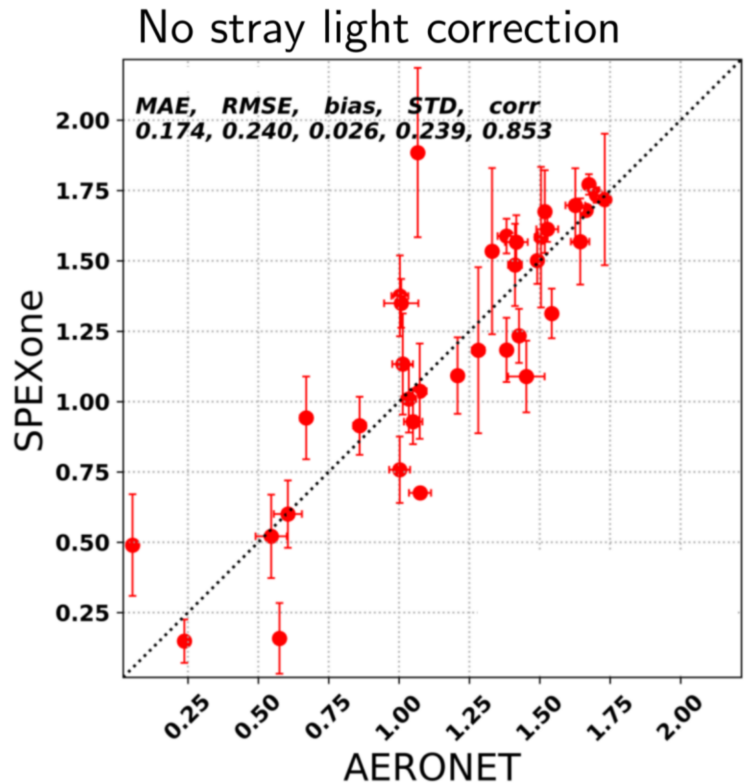


For level 2 validation, compare SPEXone measured aerosol optical thickness (AOT) and Ångström exponent (AE) with those from AERONET ground stations.



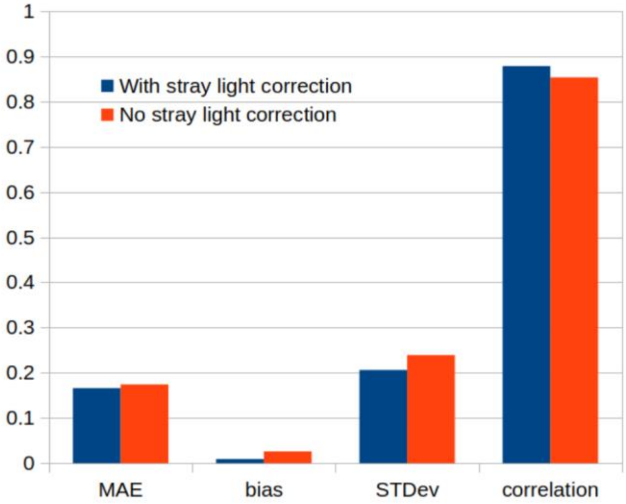
Ångström exponent (AE) over land, with and without stray light correction



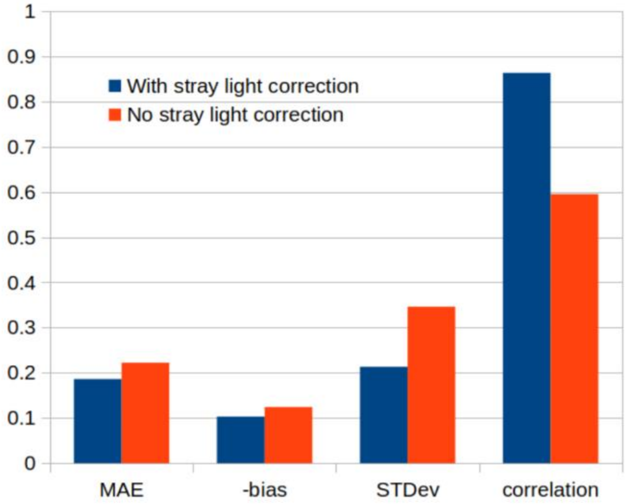


- Correlation between AERONET and SPEXone AE values is stronger with stray light correction than without over both land and ocean.
- MAE (mean absolute error), bias, and STDev (standard deviation) are lower with stray light correction.

Over land



Over ocean



- A multi-kernel stray light correction has been developed for the SPEXone instrument. Motivated by the varying nature of stray light across detector during on-ground calibration campaign.
- Based on limited data, aerosol properties over land and ocean improve with the stray light correction.
- This is our first attempt to validate level 2 data.
- Future validation will test the benefit of the multi-kernel approach.