



Portable Remote Imaging Spectrometer

Radiometric and spectral stray light correction for the PRISM coastal ocean sensor

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Jet Propulsion Laboratory
California Institute of Technology

Overview

PRISM instrument and field expeditions

Science data processing

Electronic panel artifact corrections

Spectral stray light correction

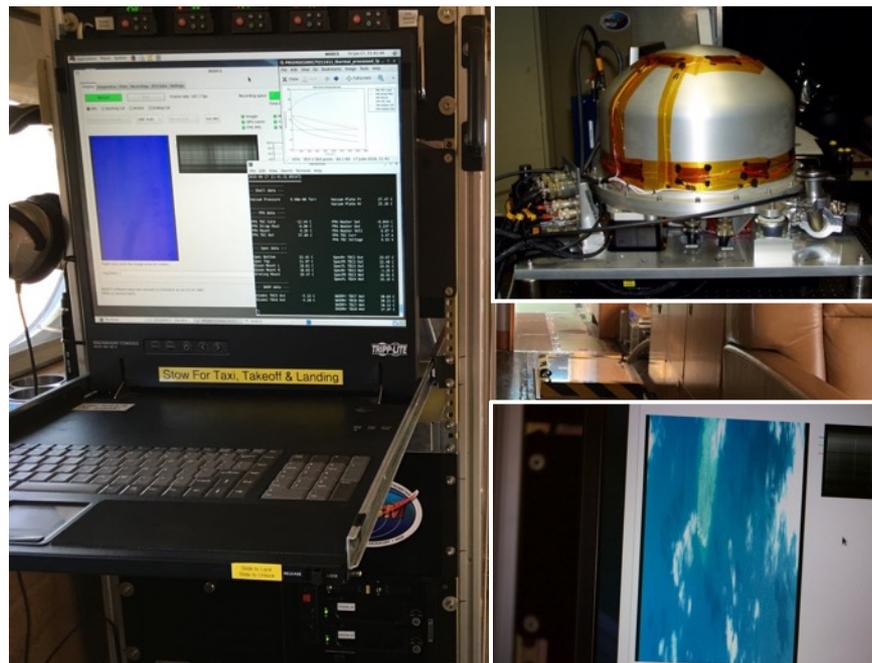
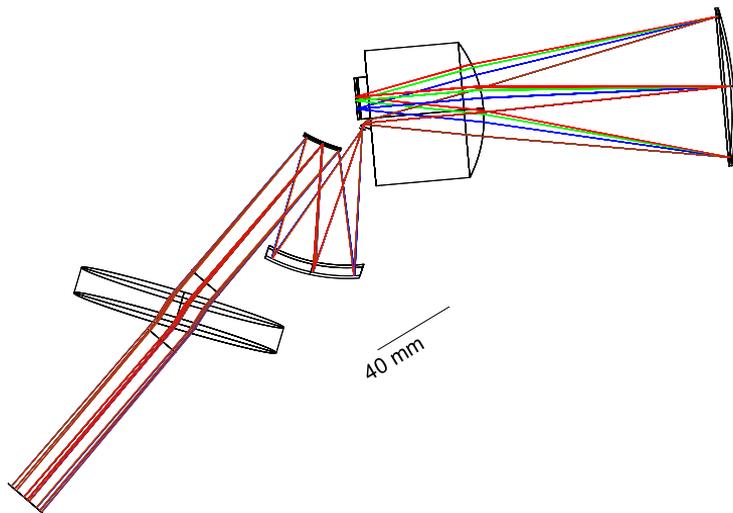
Radiance and reflectance



PRISM instrument design

Airborne pushbroom imaging spectrometer

Two-mirror telescope
F/1.8 Dyson spectrometer



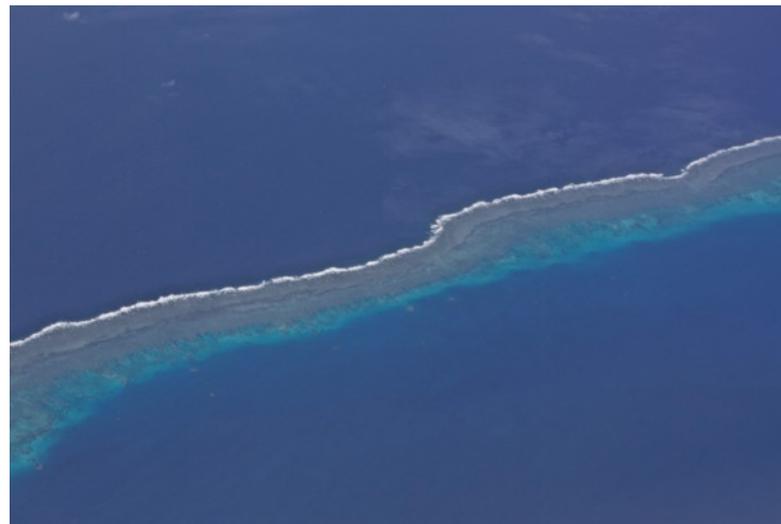
PRISM recent field expeditions

NSF ORCAS campaign to the Southern Ocean



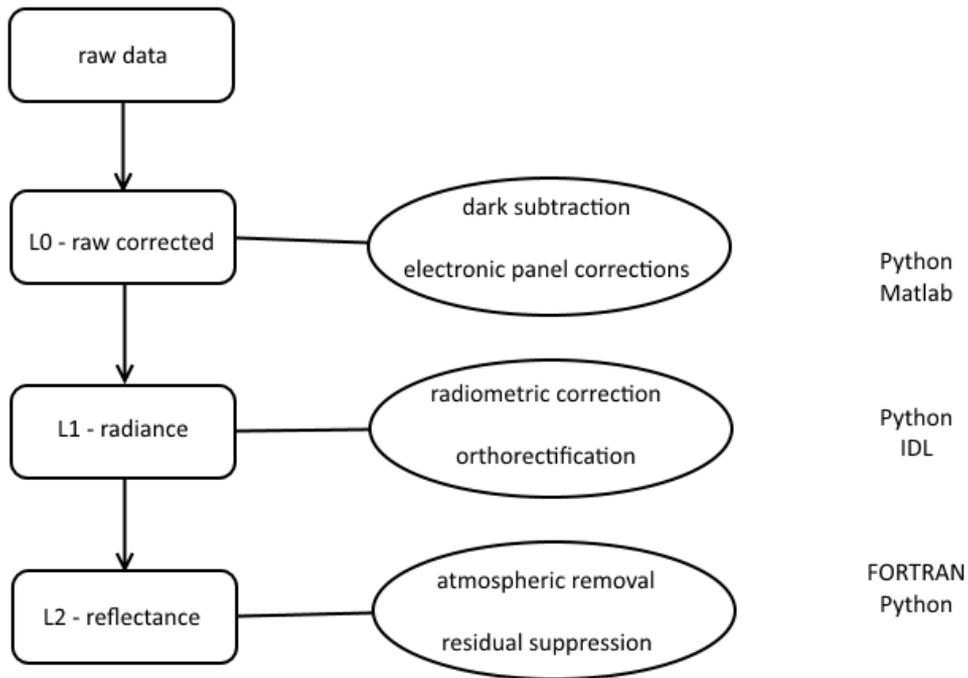
PRISM recent field expeditions

NASA CORAL mission including GBR and Hawaii



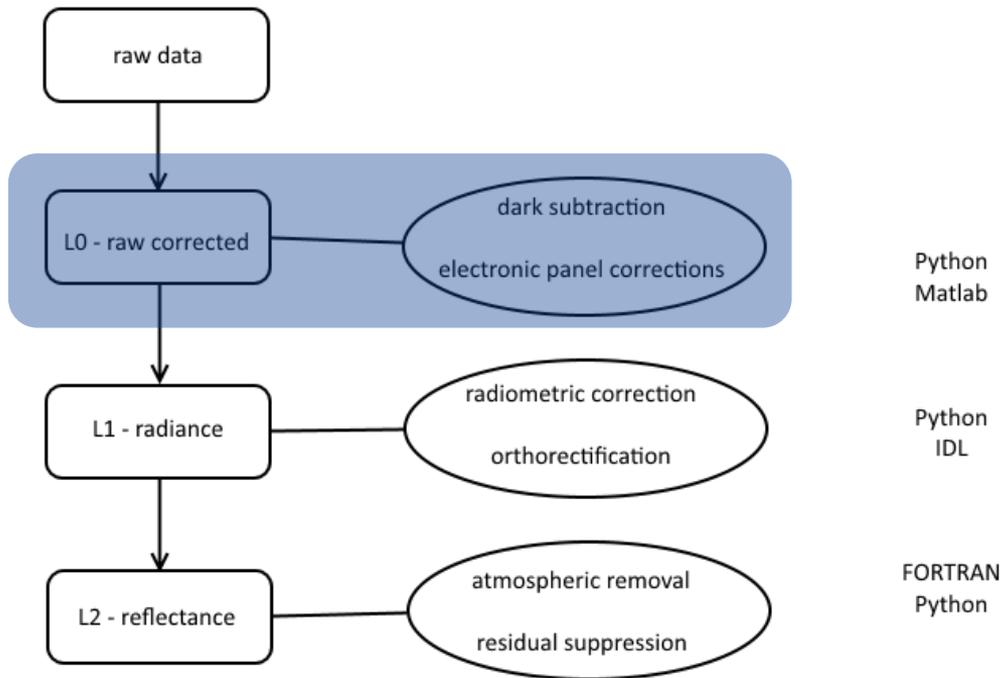
Science data processing

From raw to reflectance



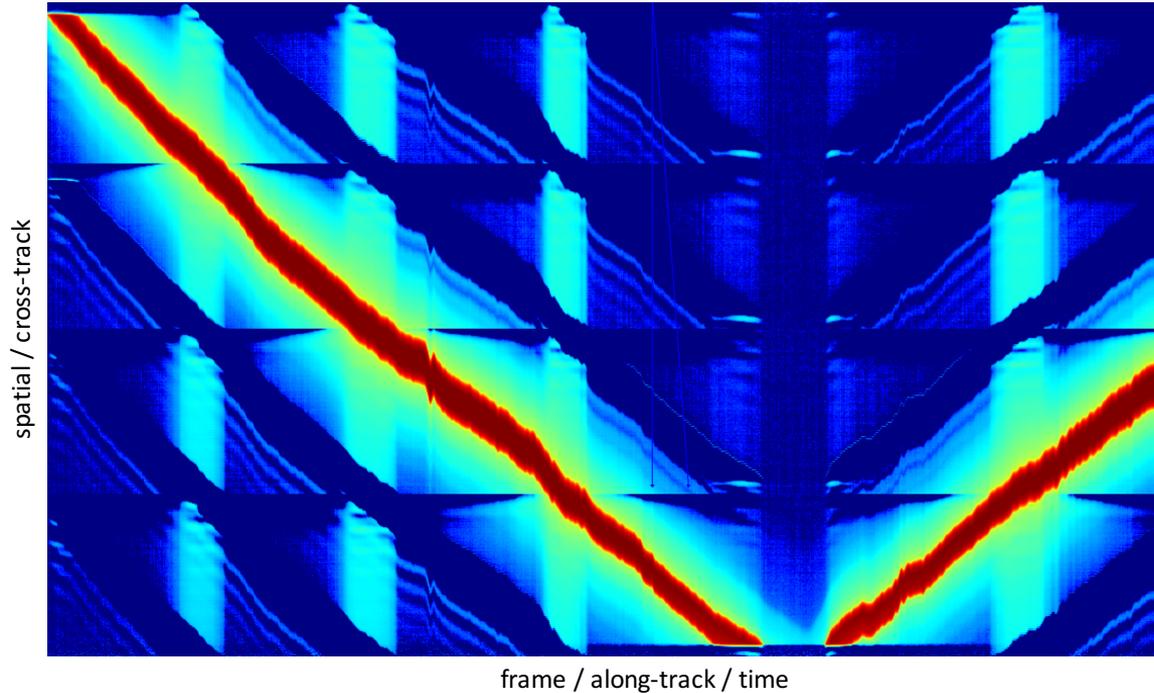
Science data processing

From raw to reflectance



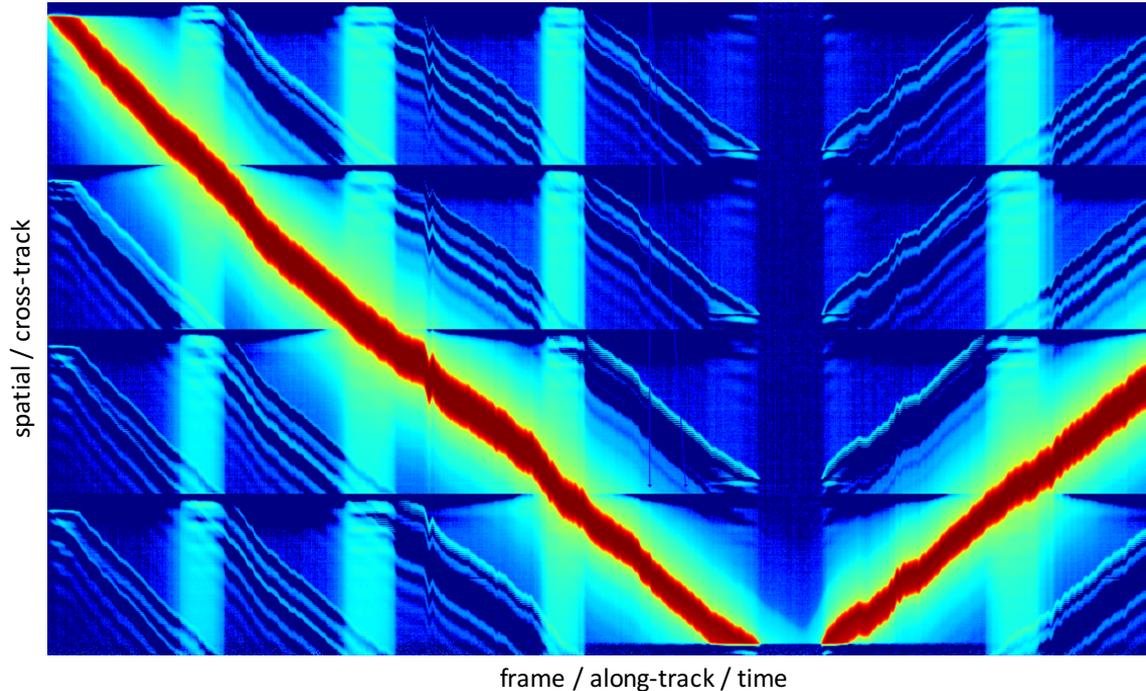
Electronic panel (EP) artifact corrections

PRISM data scan after Pedestal Shift (PdS) correction



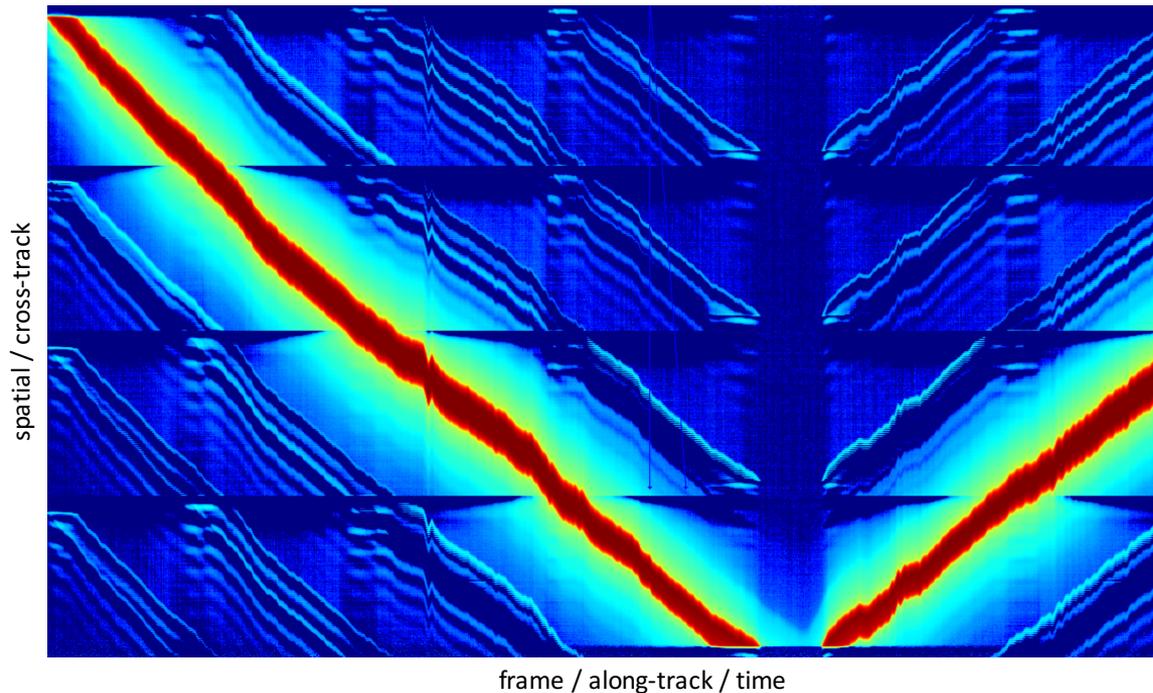
Electronic panel (EP) artifact corrections

PRISM data scan after PdS and EP Ghost (EPG) corrections



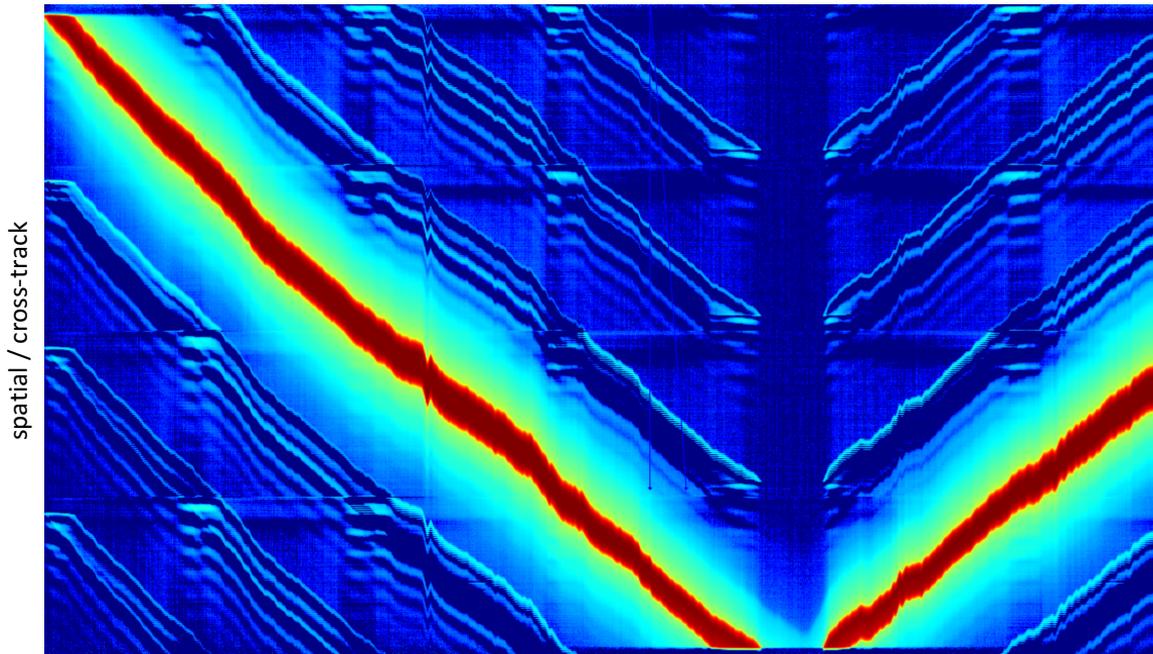
Electronic panel (EP) artifact corrections

PRISM data scan after PdS, EPG, and EP Shift (EPS) corrections



Electronic panel (EP) artifact corrections

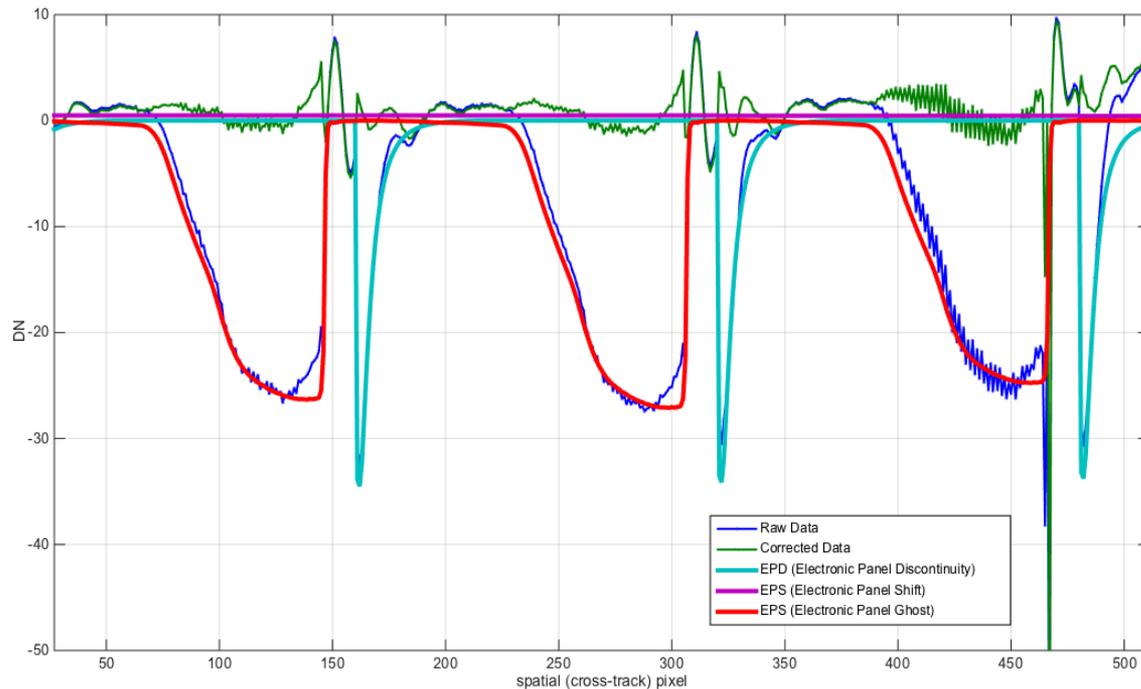
PRISM data scan after PdS, EPG, EPS, and EP Discontinuity (EPD) corrections



frame / along-track / time

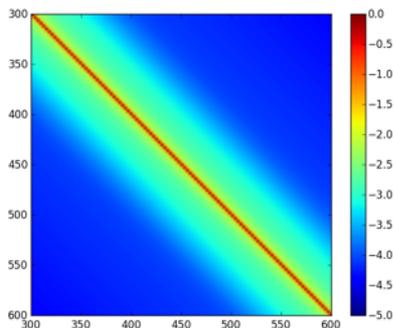
Electronic panel (EP) artifact corrections

PRISM data scan profile showing all EP corrections

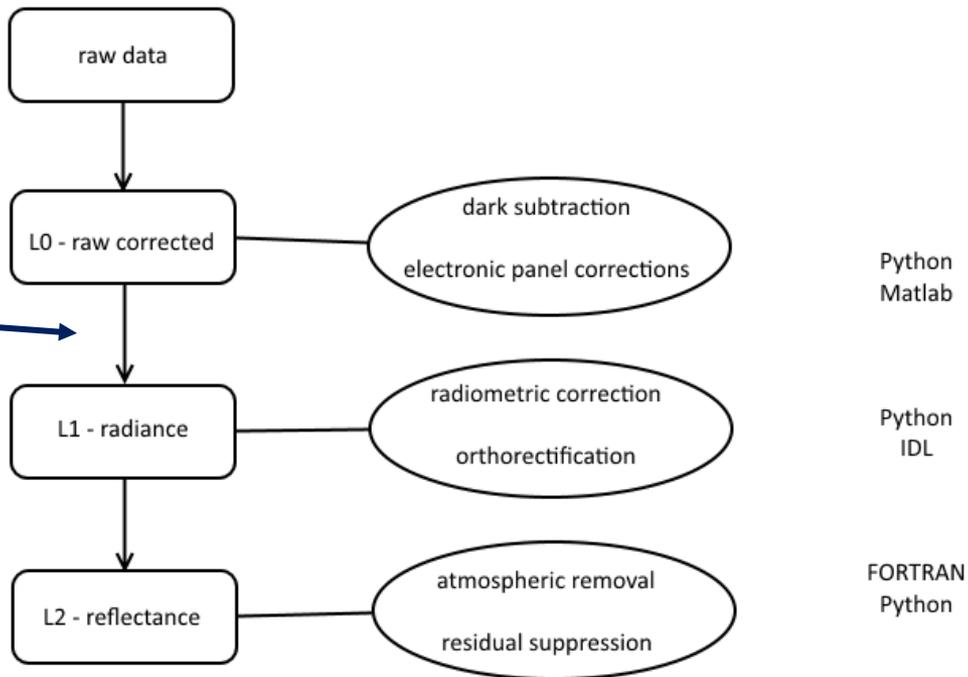


Science data processing

From raw to reflectance

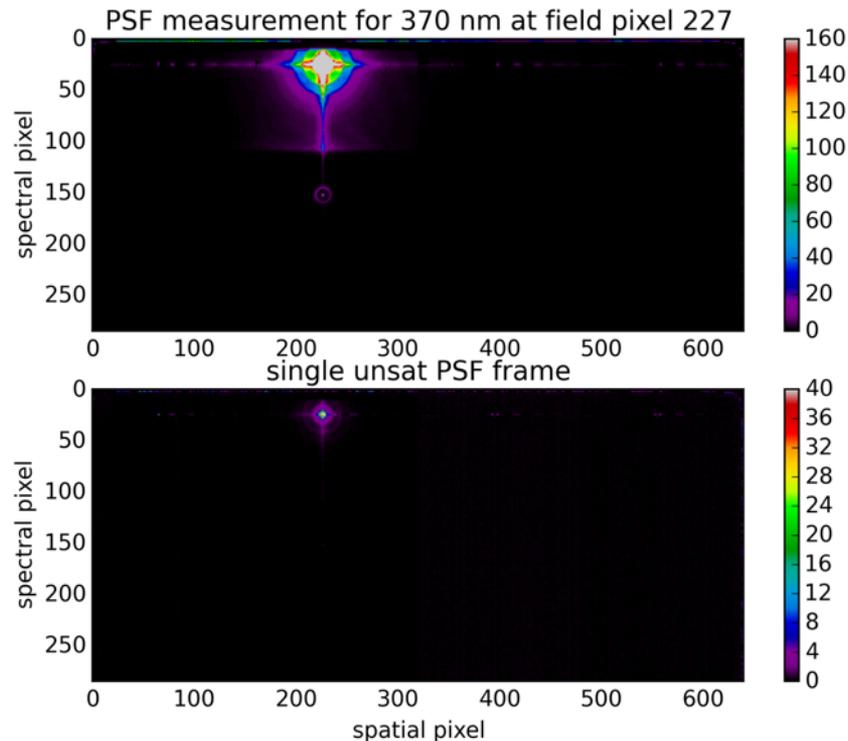
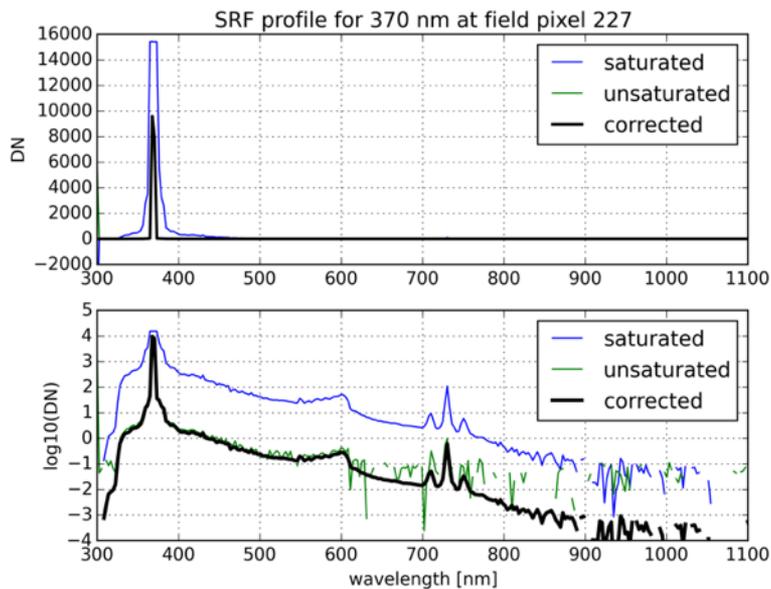


Add stray light correction



Point spread function (PSF) measurements

Tunable laser through monochromator
subpixel stimulus



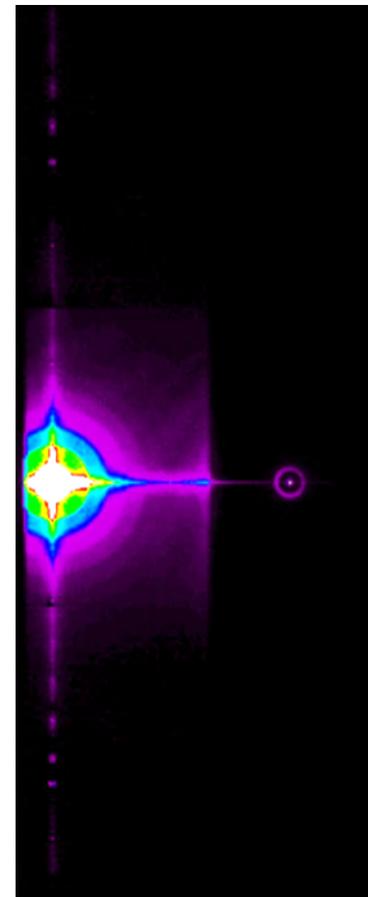
Spectral response data extraction

Full 2D correction required for general application

Initial correction will use spatially integrated PSF to obtain spectral line spread function (SLSF).

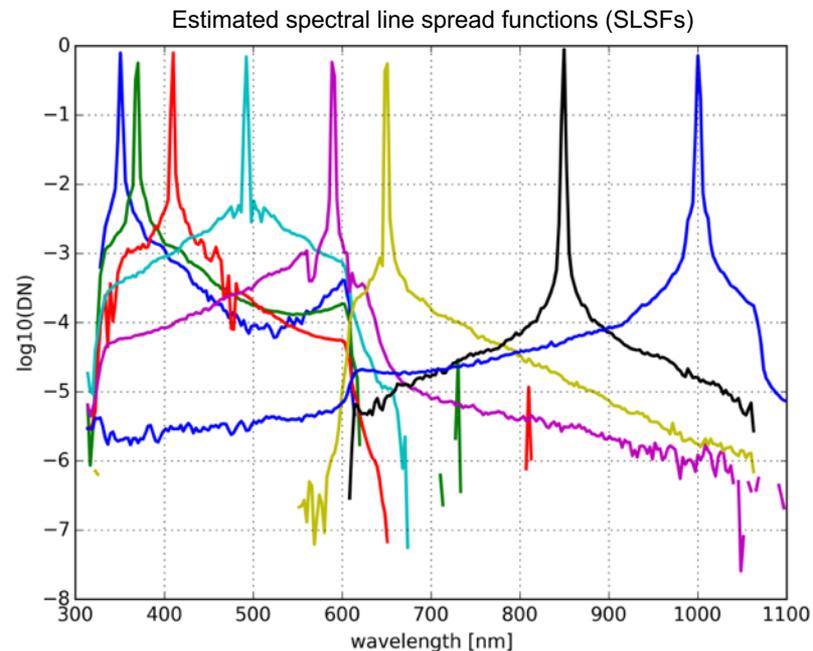
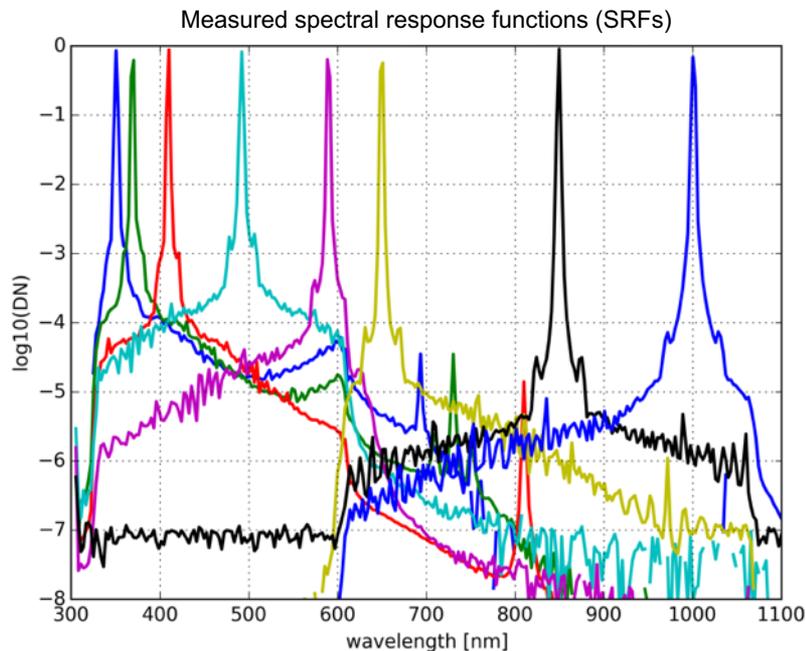
Most significant error is in radiometric correction step, where spatially averaged DNs are currently used.

SLSF method should be compatible with laser line measurements, which are simpler to collect in laboratory and field using integrating sphere.



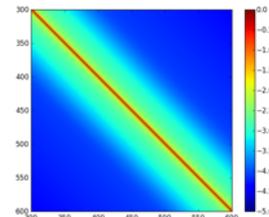
Spectral response data comparison

Difference between spectral profiles and spatial integration

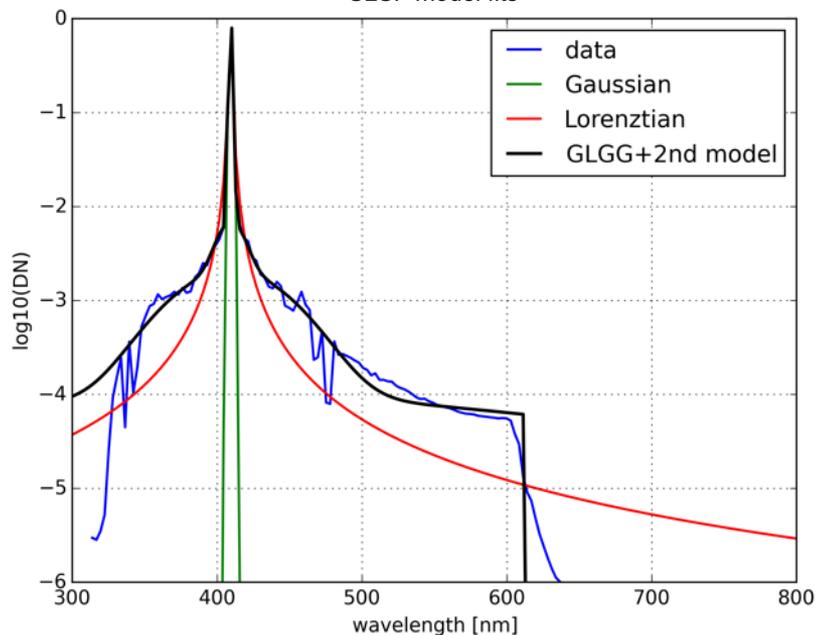


Data-derived SLSF models

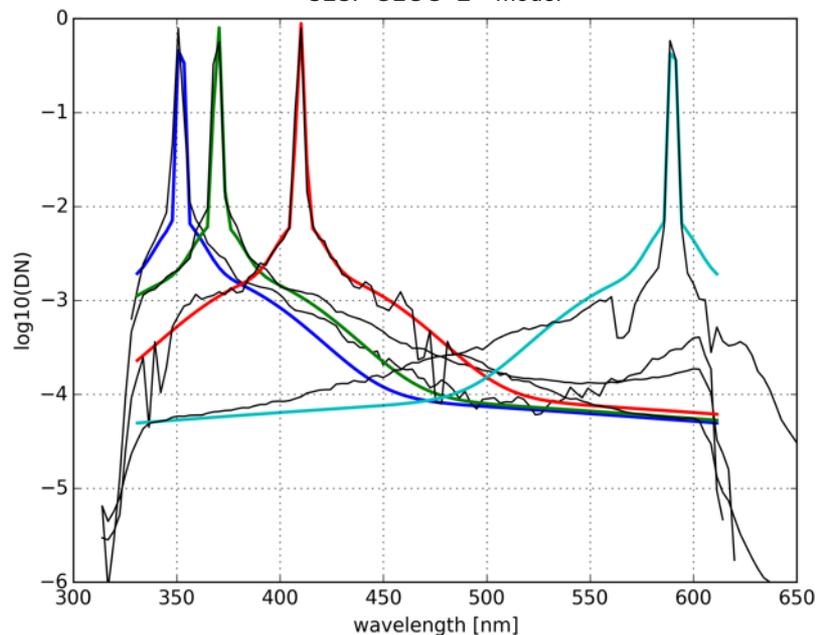
Assume single SLSF form valid for all wavelengths



SLSF model fits



SLSF GLGG+2nd model



Stray light response correction

Assume 2D PSF separable into spatial and spectral dimensions

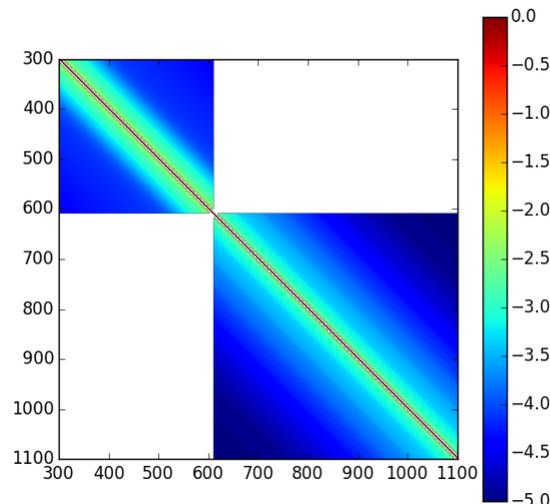
$$\mathbf{L}_{\text{meas}} = \left(\left(\mathbf{L}_{\text{actual}} \quad \mathbf{C} \right)^T \mathbf{S} \right)^T$$

$[d \times n]$
 $[d \times n]$
 $[n \times n]$
 $[d \times d]$

$$\mathbf{L}_{\text{corr}} = \left(\left(\mathbf{C}^T \right)^+ \left(\left(\mathbf{S}^T \right)^+ \mathbf{L}_{\text{meas}} \right)^T \right)^T$$

$$\mathbf{A}^+ = (\mathbf{A}^T \mathbf{A})^{-1} \mathbf{A}^T$$

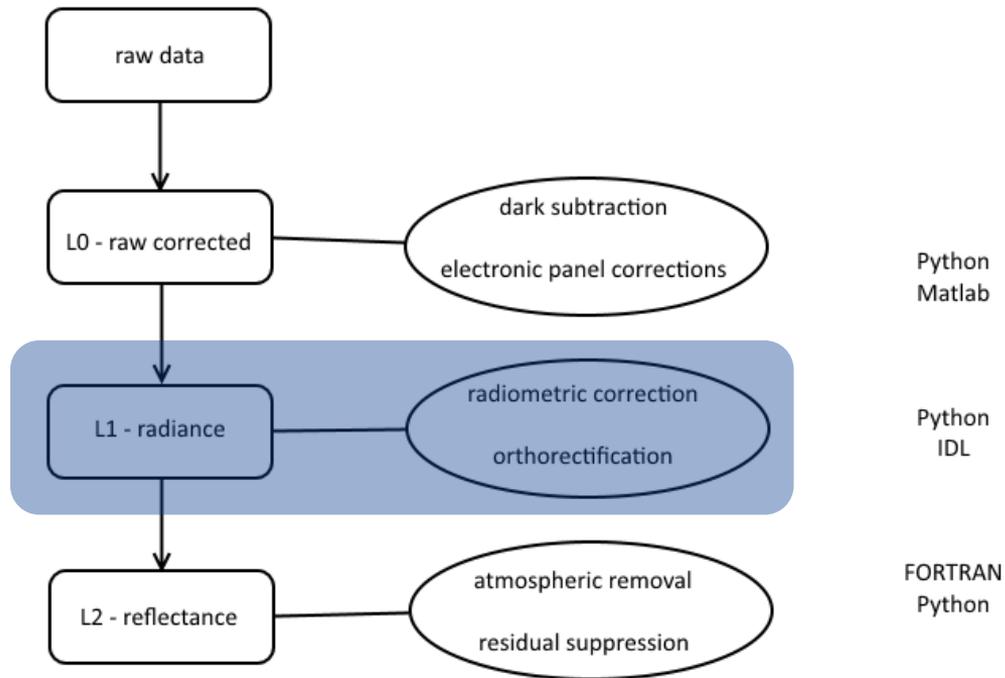
$$\mathbf{A}^+ \mathbf{A} = \mathbf{I}$$



$$\mathbf{S} = \mathbf{S}_1 + \mathbf{S}_2$$

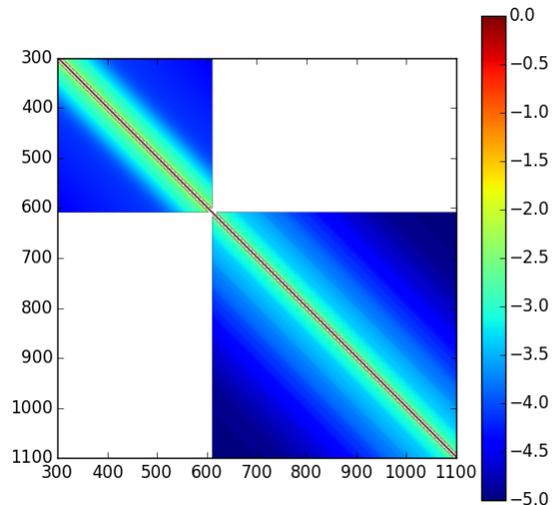
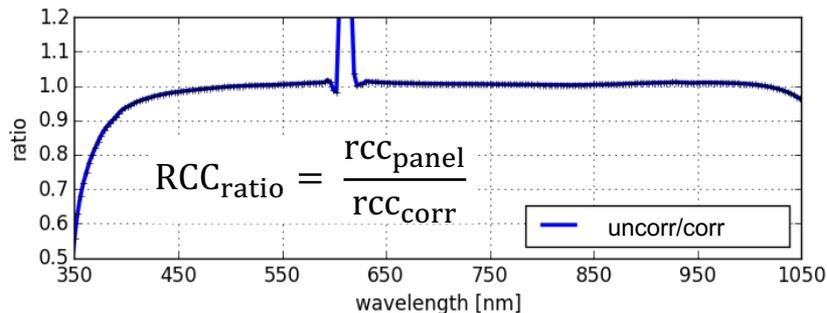
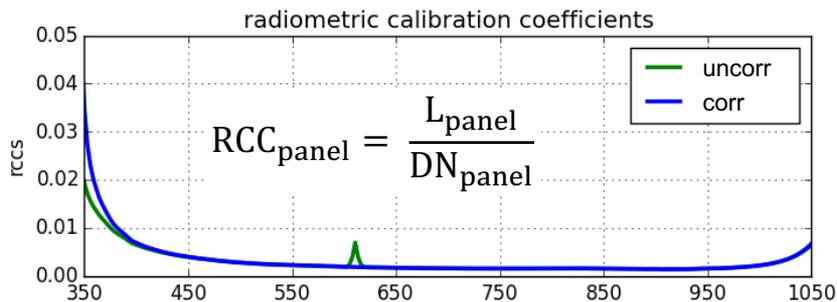
Science data processing

From raw to reflectance



Radiometric calibration

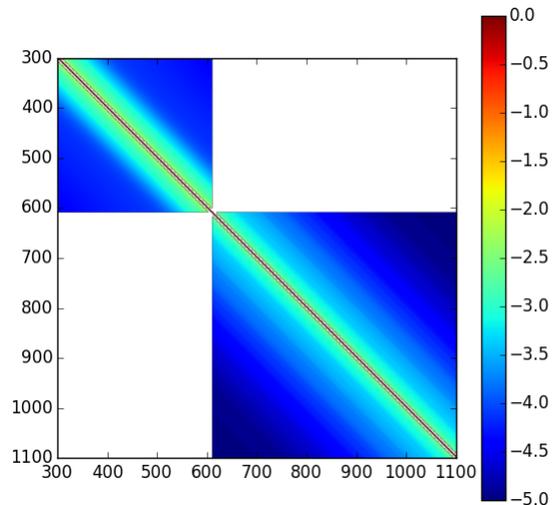
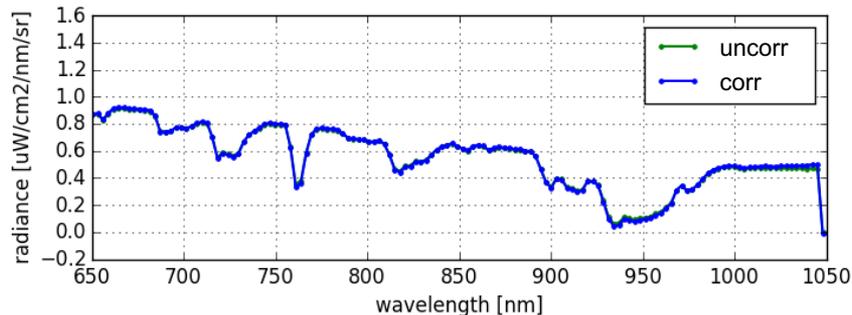
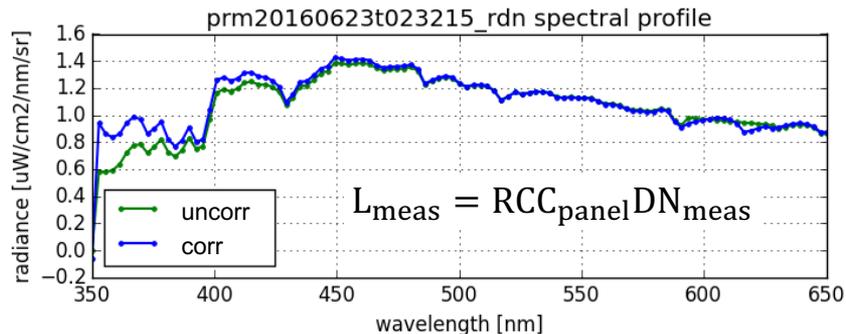
Apply SLSF correction and calculate radiometric calibration coefficients



Remove spectral stray response
Gaussian response remains

Estimate scene radiance L from raw data

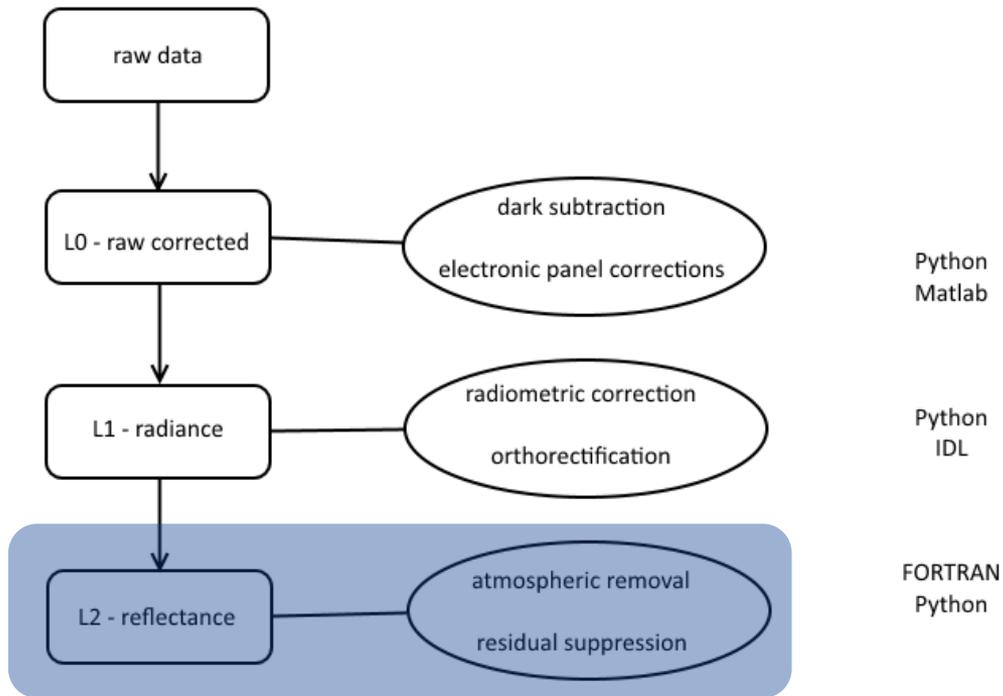
PdS and EP artifact corrections, radiometric calibration with SLSF correction



Remove spectral stray response
Gaussian response remains

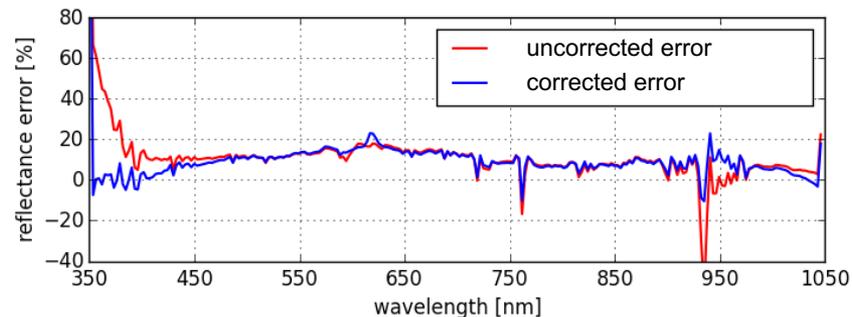
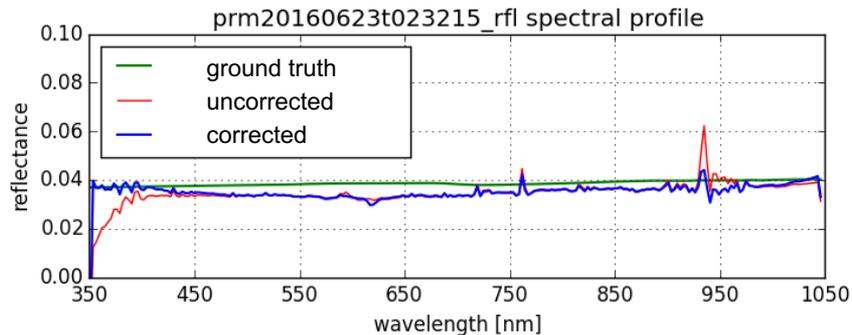
Science data processing

From raw to reflectance



Estimate remote sensing reflectance R_{RS} from L

Orthorectification, solar irradiance and atmospheric removal



Conclusions and Future Work

- SLSF method promising for RCC correction
 - Accounts for significant amount of observed near-UV error
 - Add wavelength dependence (initial efforts described in paper)
- Construct physically-based 2D PSF model
 - Simulate data frames and compare to laboratory measurements, e.g. filter transmission data and doped Spectralon targets
 - Apply full frame pixel-by-pixel correction
- Validate corrections against diverse data sets, including those with spectrally flat and sharp, bright and dark, and highly spectrally and spatially variable content.
- Introduce full 2D PSF correction in science data system
 - May need to consider lookup table or similar methods
 - Parallel data product to preserve downstream compatibility
- Investigate scene-based corrections, e.g. Thompson et al. (2017).

References

1. Mouroulis, P., Van Gorp, B., Green, R.O., Dierssen, H., Wilson, D.W., Eastwood, M., Boardman, J., Gao, B.C., Cohen, D., Franklin, B. and Loya, F., 2014. Portable Remote Imaging Spectrometer coastal ocean sensor: design, characteristics, and first flight results. *Applied Optics*, 53(7), pp.1363-1380.
2. Stephens, B., Long, M., Keeling, R., Kort, E., Sweeney, C. et al., 2017. The O₂/N₂ ratio and CO₂ airborne Southern Ocean (ORCAS) study. *Bulletin of the American Meteorological Society*. *Accepted*.
3. Kohler, D.D., Bissett, W.P., Steward, R.G. and Davis, C.O., 2004. New approach for the radiometric calibration of spectral imaging systems. *Optics Express*, 12(11), pp.2463-2477.
4. Zong, Y., Brown, S.W., Johnson, B.C., Lykke, K.R. and Ohno, Y., 2006. Simple spectral stray light correction method for array spectroradiometers. *Applied Optics*, 45(6), pp.1111-1119.
5. Green, R.O., 1998. Spectral calibration requirement for Earth-looking imaging spectrometers in the solar-reflected spectrum. *Applied Optics*, 37(4), pp.683-690.
6. Thompson, D.R., Boardman, J.W., Eastwood, M., Green, R.O., Haag, J.M., Mouroulis P., and Van Gorp, B.E., 2017. Imaging spectrometer stray spectral response: In-flight characterization, correction, and validation. *Submitted*.



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