CLARREO Pathfinder Inter-calibration: Data Flow & Algorithms

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Outline:

- Inter-calibration Data Products
- Data & Algorithms flow
- Inter-calibration Planning
- Telemetry, Level-0, and Level-1 data products
- Spatial & spectral sampling: imagers
- Spectral & spectral sampling: CERES
- Polarization corrections
- Inter-calibration analysis
- Key Publications
- Expectations

Inter-Calibration Data Products

Product	Contents	Resolution	Granule
Level-1 Products for VIIRS CERES GEO (NOAA, ESA, etc.) Landsat (USGS) Surface Sites Moon	Calibrated and geo-located CPF observations.	Full spectral and spatial resolution of the CPF RS Instrument.	Each granule contains single CPF inter-calibration event.
Level-4 Products for VIIRS CERES	Collections of CPF (Level-1), VIIRS, and CERES matched data (Level-1 & Level-2).	CLARREO (Level-11) and VIIRS (Level-1 & Level-2, Clouds and Aerosols) data spatially convolved over IC sample. CLARREO Spectral re-sampling. CLARREO (Level-1) spatially convolved over CERES FOV's PSF. CLARREO conversion to broadband reflectance. Scene ID from the CERES SSF.	Data processed by the CPF inter-calibration events.
Level-4 Products for VIIRS CERES	Inter-calibration results: Constraints on effective offset, gain, non-linearity, sensitivity to polarization, and spectral degradation.	N/A	N/A

- Additional data analysis – by a separately funded science team

Data & Algorithms Flow

Rectangles: data
Circles: algorithms

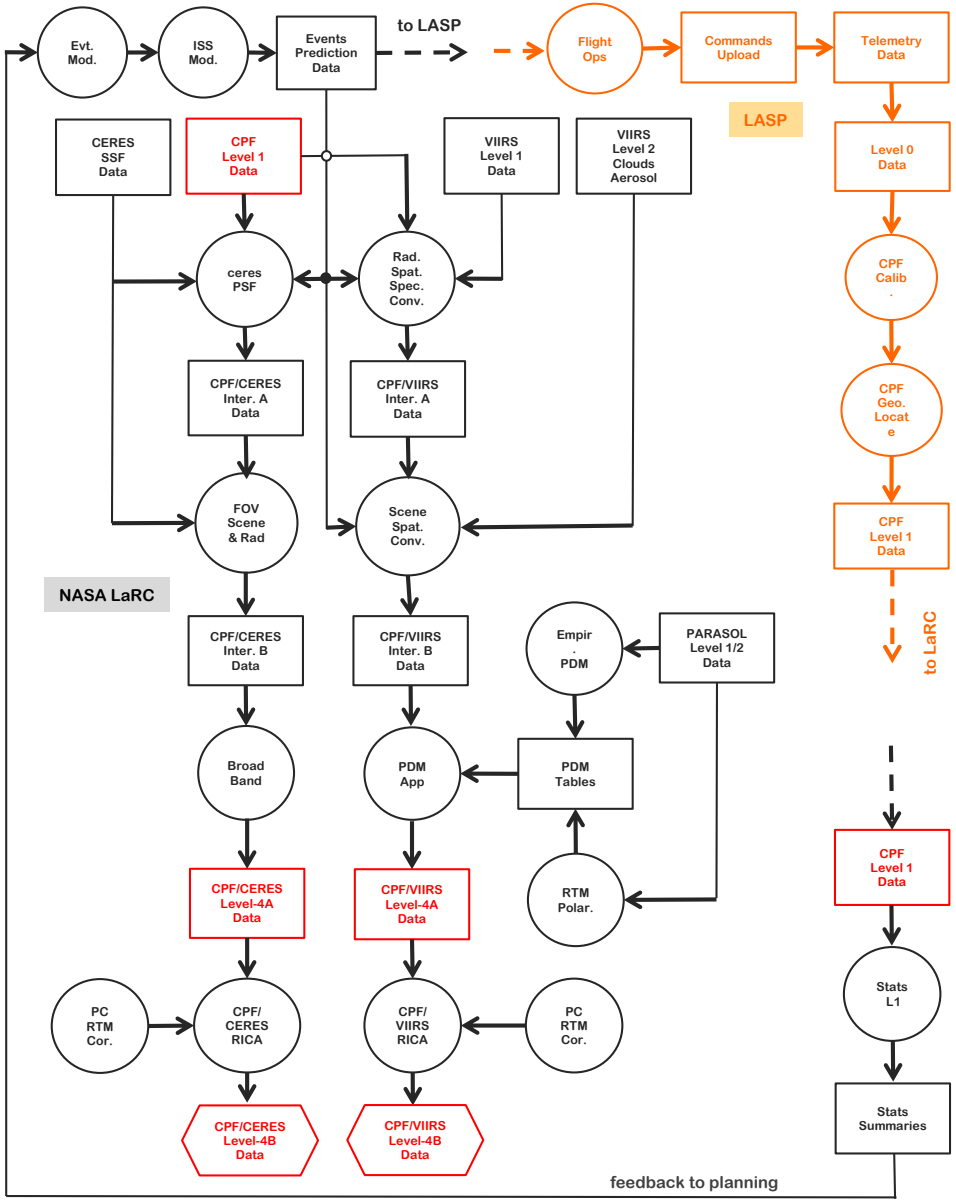
Data Inputs:

- CLARREO Pathfinder Level-1 data
- CERES Level-1/2 (SSF)
- VIIRS Level-1 (SDR) and Level-2 (EDR)
- Polarization Distribution Models

Algorithms:

- Event Prediction and ISS obscuration
- Spatial convolution/resampling
- Spectral convolution/resampling
- RT broadband modeling (CERES SW)
- Scene ID resampling (clouds, aerosols)
- RT polarization modeling (PDMs)
- PCRTM Corrections (angular)
- Inter-calibration analysis for effective offset, gain, non-linearity, and sensitivity to polarization.

Distributed & Archived Products (red)
NASA DAAC is TBD



Event Predictions and ISS

Predictors:

- LEO – LEO Sensors (CERES and VIIRS, Landsat, Sensinel-2A/B)
- LEO – GEO Sensors (GOES-16 ABI, others TBD)
- Earth Surface Sites (Libyan deserts, others TBD)
- Moon

ISS trajectory, attitude, and obscuration:

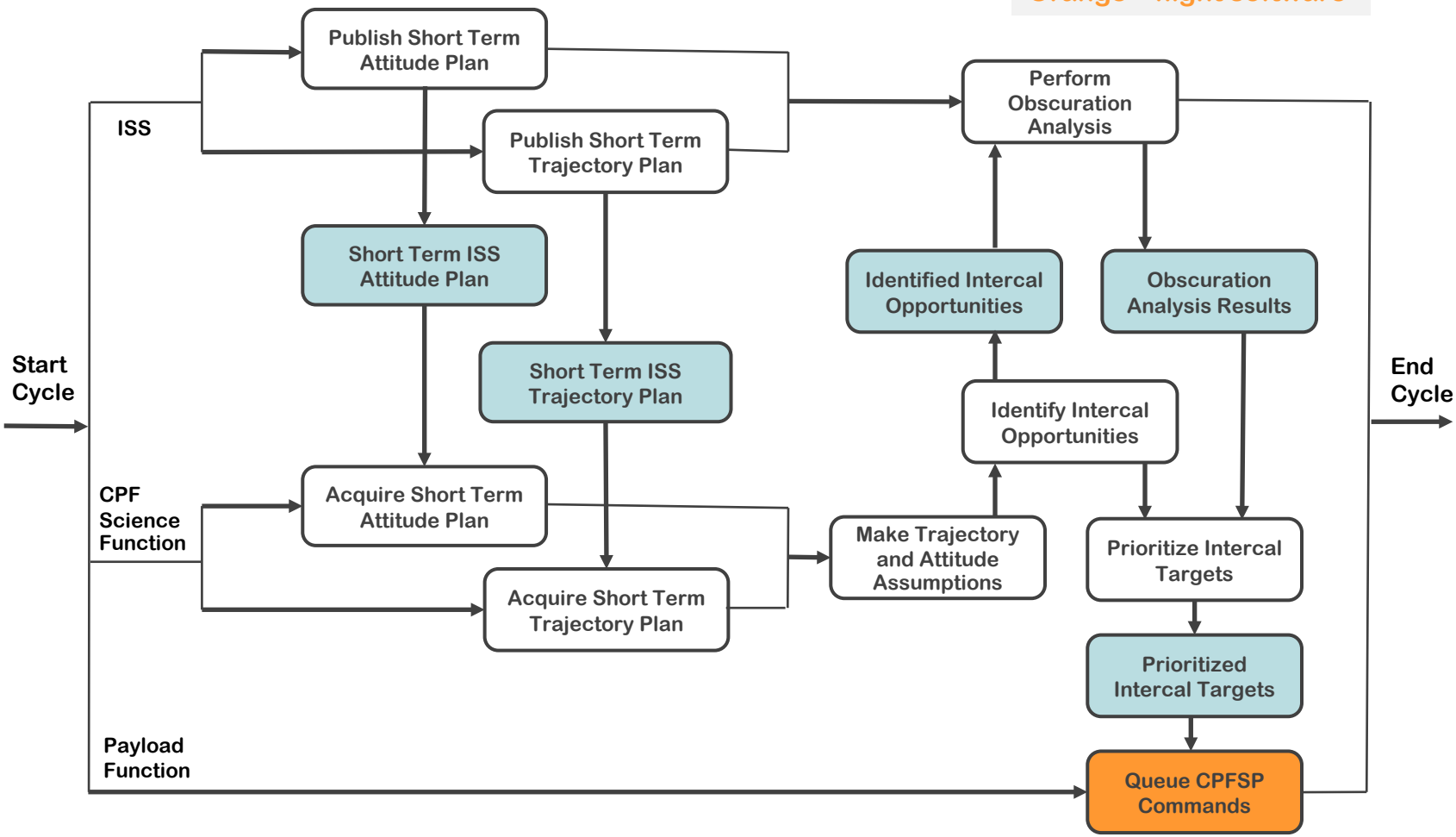
- Short-term operations, cycle from 3 to 10 days (TBD)
- Static obscuration – info from ISS
- Dynamic obscurations (solar panels) – info from ISS
- ISS trajectory and attitude accurate prediction – Challenge ?

Interface between Science and Payload team is critical !

Inter-Calibration Cycle: Planning Effort

Current outline from C. Hutchinson & J. Chrone

Blue – data files
White – tasks / software
Orange – flight software



Telemetry, Level-0, and Level-1 Data

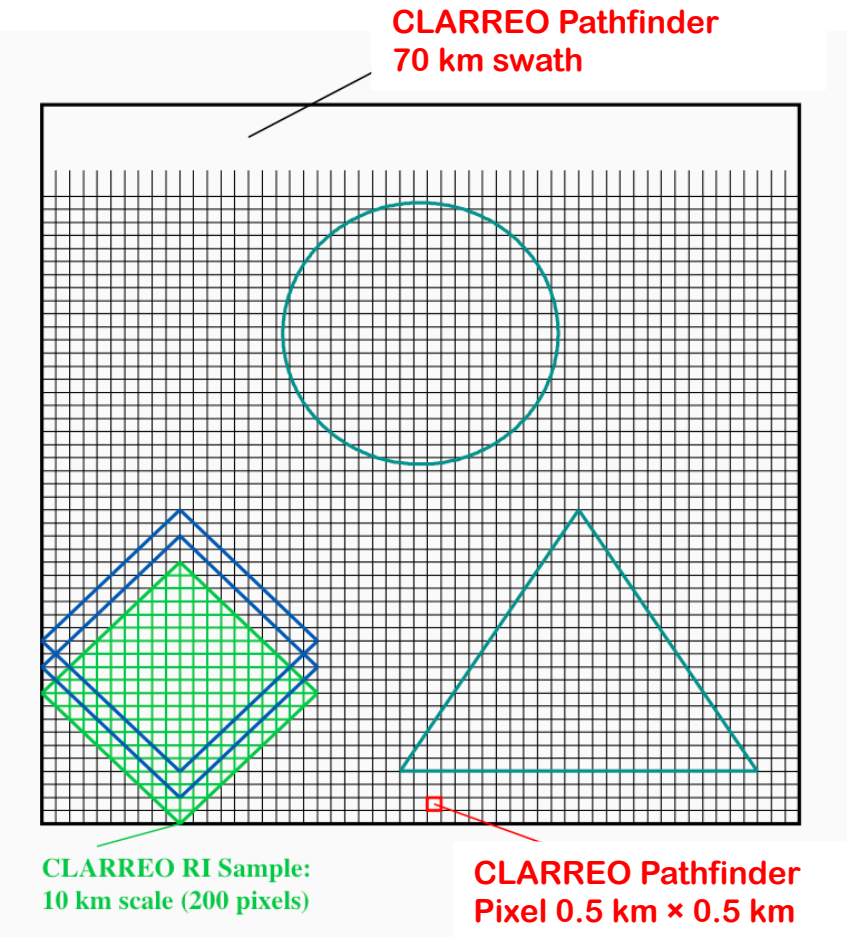
- Telemetry: data received from the payload.
- Level-0 data product: organized telemetry.
- Level-1 data product (TBD):

  - Calibrated measurements (Earth, Sun, Moon);
  - Geo-location (elliptical and elevation adjusted Earth models);
  - Full spectral sampling;
  - Spatial sampling at about 0.5 km;
  - Payload predicted attitude/pointing;
  - Payload actual attitude/pointing;
  - All relevant uncertainties;
  - Payload auxiliary (temperatures, health, etc.);
  - Etc.

- Level-0 and Level-1 data products to be archived at a NASA DAAC: tentative LaRC ASDC.

Reference Inter-Calibration Samples: Imagers

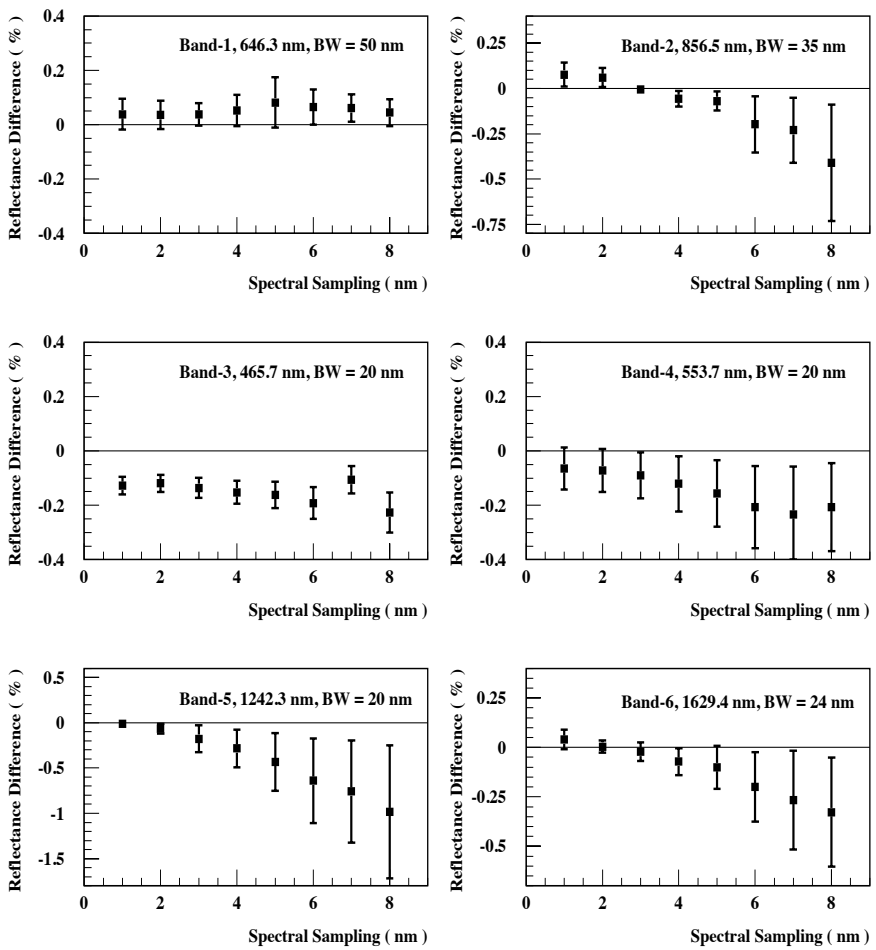
Conceptual Spatial Sampling for Imagers

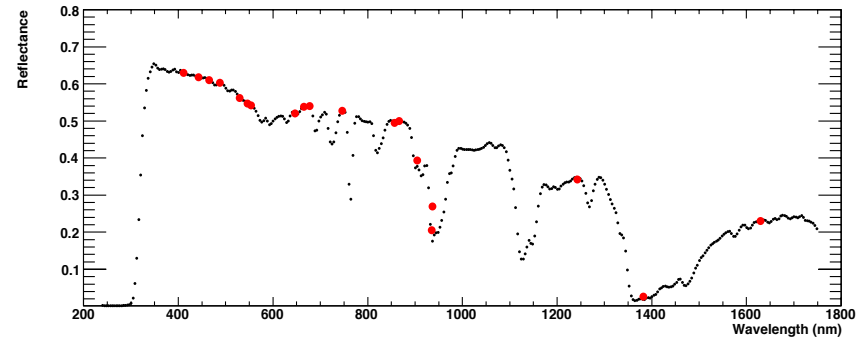


- CLARREO Pathfinder Inter-Calibration Event: on-orbit time/angle/space matched data.
- CLARREO Pathfinder Swath: 70 km
- CLARREO Pathfinder Inter-Calibration: sample area of 10 - 20 km scale (reduction of spatial matching noise to 1 – 2%). *(Wielicki et al., IGARSS, 2008)*
- CLARREO Pathfinder Pixel: 0.5 km × 0.5 km observed area (65% of signal).
- Scene information (cloud mask, cloud and aerosol parameters): Combination of spatial convolution and interpolation.
- Rely on detector-to-detector flat-fielding

Inter-Calibration Spectral Resampling: Imagers

Expected reflectance aliasing at six MODIS bands as function of spectral sampling frequency. All-sky July 2004 SCIAMACHY instantaneous data. The error bars show standard deviation of the difference (k=1).





Spectral sampling with 4 nm frequency and 8 nm Gaussian FWHM bandpass (black), recommended for CLARREO RS Spectrometer, and re-sampled MODIS bands (red circle). The results are based on all-sky SCIAMACHY instantaneous data from July 2004.

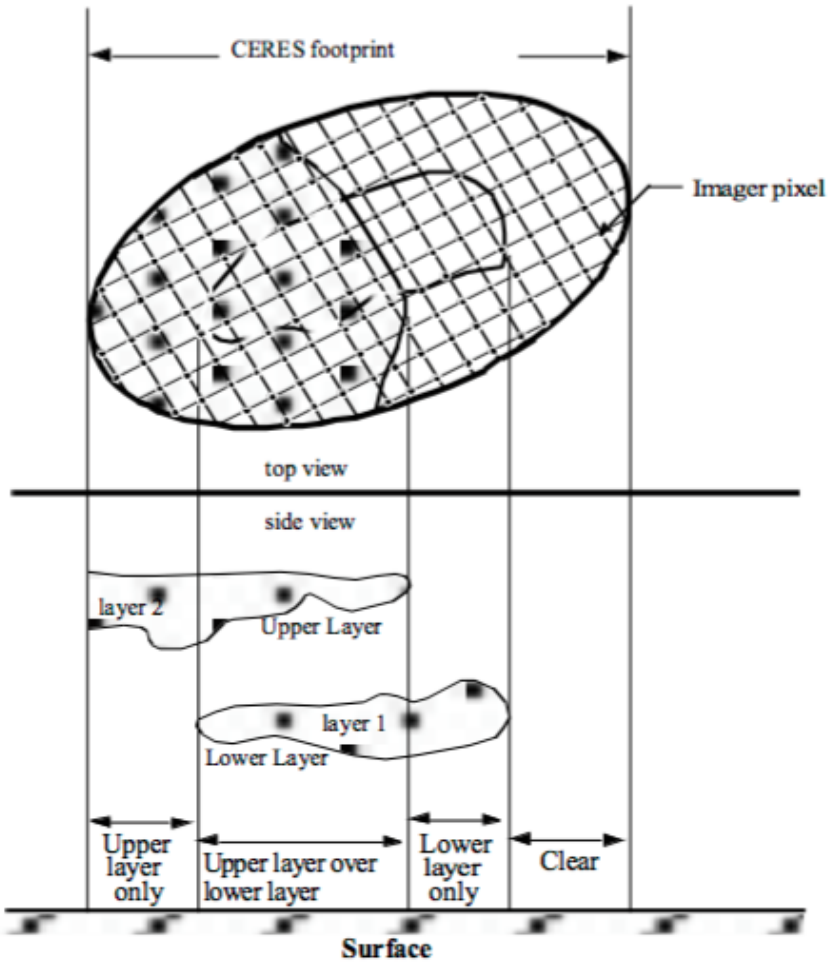
Aisheng Wu et al., IEEE Geoscience and Remote Sensing, 2015.

Possibility: not to use the Relative Spectral Response (RSR) from sensors to avoid uncertainty.

Reference Inter-Calibration Samples: CERES sampling

Spatial Convolution for CERES:

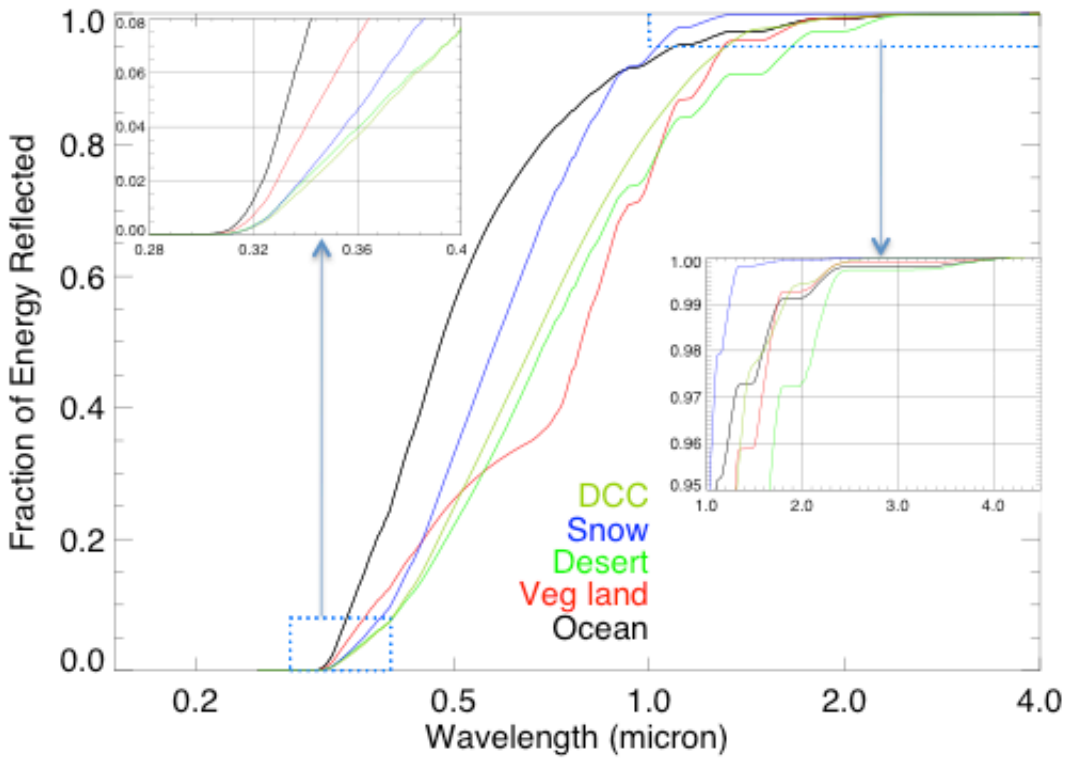
- CERES Point Spread Function (PSF)
  Uncertainty ?
  Uniform scenes only (clear, clouds) ?
- Large spatial averages:
  Reduced sampling ?
- Take all of the above !
- Scene information to be obtained from the CERES SSF Edition-1CV data (clouds, aerosols, etc.)
- CERES PSF code to be adapted from the CERES project.



CERES SSF Collection Guide, 2013

Reference Inter-Calibration: CERES SW Broadband

The cumulative wavelength distribution of the Earth's reflected solar energy at the nadir view for the four surface types (ocean, vegetation land, desert and snow) under clear skies and for the deep convective cloud (DCC) with optical depth of 200. The y-axis shows the cumulative fraction of the reflected solar radiation. The standard mid-latitude atmosphere is used in the calculations with solar zenith angle as 45 degree.



Aisheng Wu et al., IEEE Geoscience and Remote Sensing, 2015.

Assumption will be made about RSR degradation.

Polarization Parameters & Corrections: Scene Dependent !

$$P = \frac{L_p}{L} = \frac{\sqrt{Q^2 + U^2}}{L} = \frac{\rho_p}{\rho}.$$

Degree of linear polarization

$$\chi = \begin{cases} tan^{-1}(U/Q)/2 \\ tan^{-1}(U/Q)/2 + \pi/2 & \text{if } Q < 0. \end{cases}$$

Polarization angle, defined relative to viewing plane

Relative radiometric uncertainty:

C. Lukashin et al., IEEE Geoscience and Remote Sensing, 2013.

$$\frac{\sigma^{sensor}}{\rho^{sensor}} = \sqrt{\left(\frac{\sigma_0}{\rho_0}\right)^2 + \frac{P^2\sigma_m^2 + m^2\sigma_p^2}{(1+mP)^2}}$$

First term is uncertainty for non polarized reflectance. Second term is from Polarization effects.

$$\frac{\sigma_0}{\rho_0} = \sqrt{\left(\frac{\sigma^{clarreo}}{\rho_0}\right)^2 + \left(\frac{\sigma_{intercal}}{\rho_0}\right)^2 + \left(\frac{\sigma^{sensor}}{\rho_0}\right)^2}$$

The first term is combined accuracy of CLARREO, RI random error, and remaining Imager uncertainty (e.g. month-to-month stability).

Imager Inter-Calibration: Resulting Uncertainty

Numerical Estimates

C. Lukashin et al., IEEE Geoscience and Remote Sensing, 2013.

Inputs for calculation:

m = 3% (k=1)

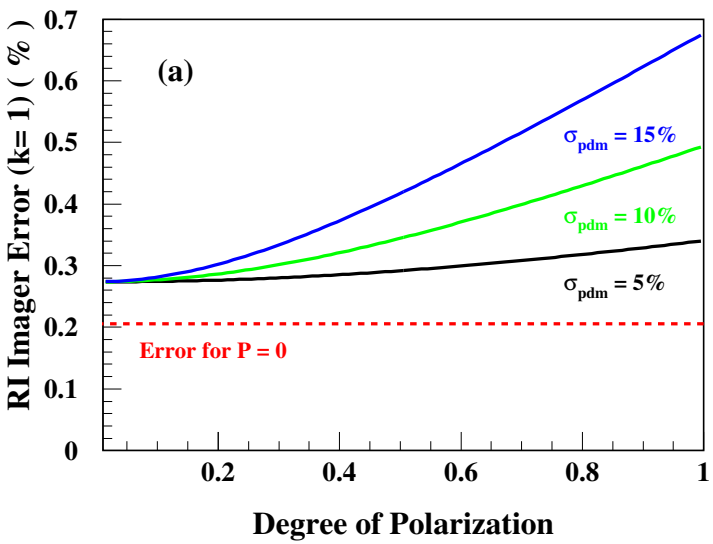
σ_{pdm} = 5%, 10%, 15% (k=1) ← Uncertainty in Polarization Distribution Models

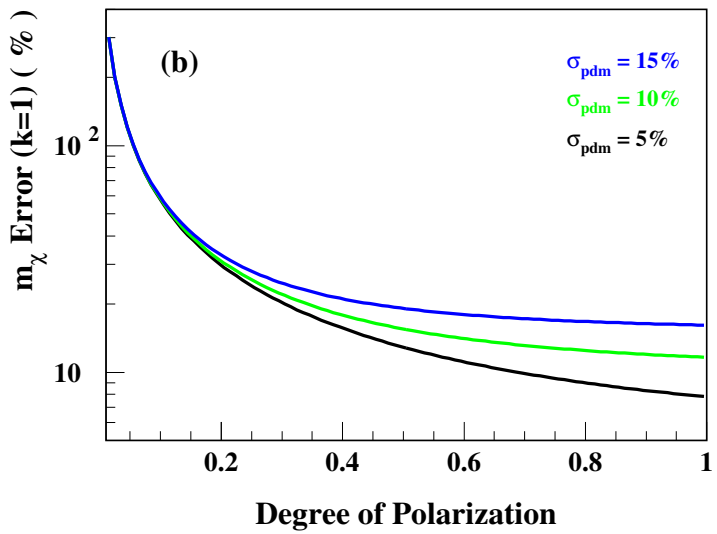
σ_{g0} = 0.10% (k=1)

σ_{gp} = 0.15% (k=1)

$\sigma_{clarreo}$ = 0.15% (k=1)

$\sigma_{residue}$ = 0.10% (k=1)





PCRTM Corrections & Inter-calibration Analysis

- PCRTM radiometric corrections for difference in angular data matching to reduce sampling noise (not presented today).
- PCRTM development: X. Liu and W. Wu
  Tested within "Climate Hyperspectral Information Content" project (PI: Yolanda Shea).
- Inter-calibration analysis: effective offset, gain, non-linearity, relative spectral response, sensitivity to polarization.
- Level-4 data product to include original Level-1 data and all intermediate results.
- Level-4 data product to be archived at a NASA DAAC and distributed to public.

Key Publications

Roithmayr, C.M., and P.W. Speth, 2012: "Analysis of opportunities for intercalibration between two spacecraft," Advances in Engineering Research Vol. 1, Chapter 13, Edited: V.M. Petrova, *Nova Science Publishers*, Hauppauge, NY, pp. 409 - 436.

Lukashin, C., B. A. Wielicki, D. F. Young, K. Thome, Z. Jin, and W. Sun, 2013: "Uncertainty estimates for imager reference inter-calibration with CLARREO reflected solar spectrometer," *IEEE Trans. on Geo. and Rem. Sensing, special issue on Intercalibration of satellite instruments*, 51, n. 3, pp. 1425 – 1436.

Roithmayr, C. M., C. Lukashin, P. W. Speth, G. Kopp, K. Thome, B. A. Wielicki, and D.F. Young, 2014a: "CLARREO Approach for Reference Inter-Calibration of Reflected Solar Sensors: On-Orbit Data Matching and Sampling," *IEEE TGRS*, v. 52, 10, pp. 6762 - 6774.

Roithmayr, C. M., C. Lukashin, P. W. Speth, D.F. Young, B.A. Wielicki, K. J. Thome, and G. Kopp, 2014b, "Opportunities to Intercalibrate Radiometric Sensors from International Space Station," *J. of Atm. and Oce. Tech.,* DOI: 10.1175/JTECH-D-13-00163.1.

Wu, A., X. Xiong, Z. Jin, C. Lukashin, B.N. Wenny, J.J. Butler, 2015: "Sensitivity of Intercalibration Uncertainty of the CLARREO Reflected Solar Spectrometer Features," IEEE TGRS, v. 53, 4741 - 4751, 10.1109/TGRS.2015.2409030

Sun W., C. Lukashin, and D. Goldin, 2015: "Modeling polarized solar radiation for CLARREO inter-calibration applications: Validation with PARASOL data," *J. Quant. Spectrosc. Radiat.*, v. 150, pp. 121 - 133.

Sun, W., R.R. Baize, C. Lukashin, and Y. Hu, 2015: "Deriving polarization properties of desert-reflected solar spectra with PARASOL data," *Atmos. Chem. Phys.*, 15, 7725 - 7734, doi: 10.5194/acp-15-7725-2015.

CLARREO Pathfinder: ATBD Expectations

- ATBD is a critical mission document
- ATBD is to be a live and public document
- ATBD effort: input from entire team (science, payload, DMT)
- ATBD feedback from the inter-calibration community
- ATBD formal start: KDP-A

- Certainty: the algorithms will be changing !