Summary of the CLARREO Pathfinder workshop meeting held Nov 2-3, 2021

Dave Doelling

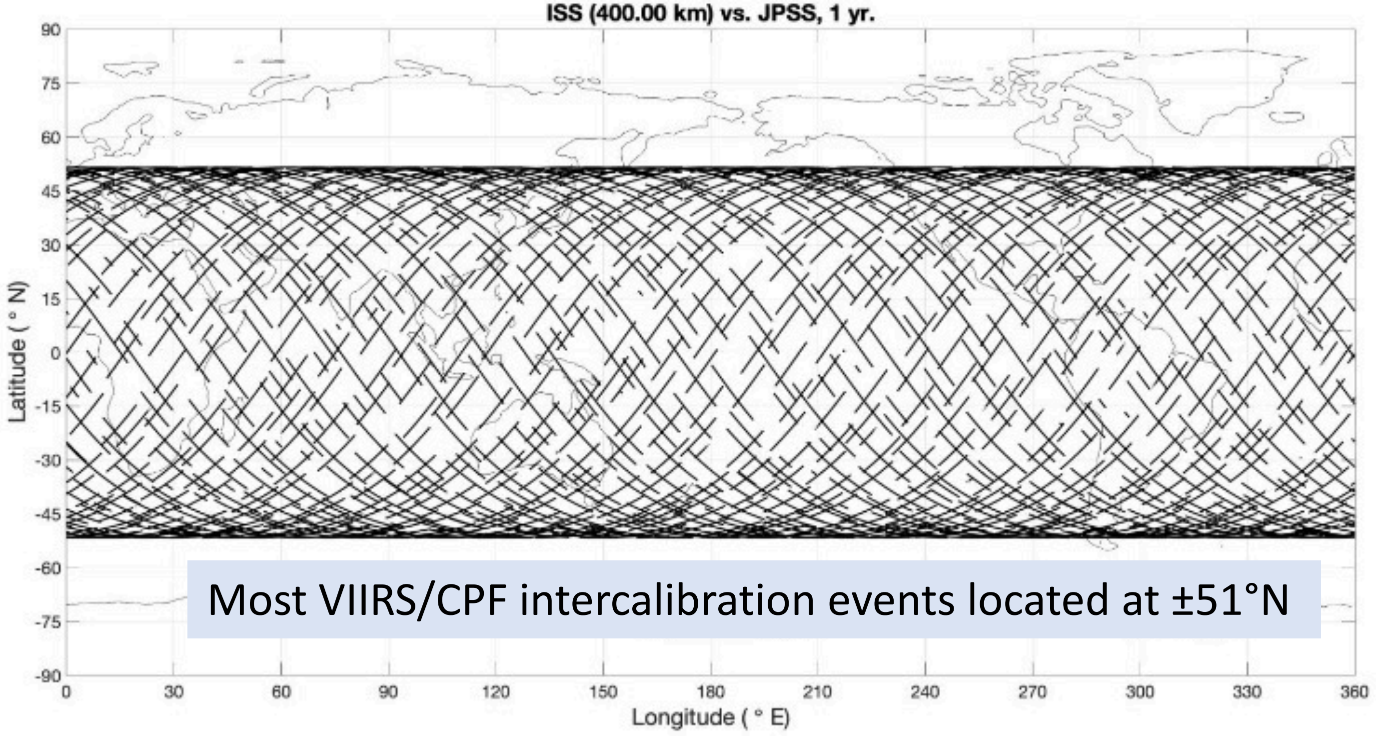
CLARREO Pathfinder objectives

Launch-Ready: Late 2023	Prime Mission Ops	Extended Mission Ops (?)
Observation Type	**1-Year Mission**	**1+ Years**
On-orbit Instrument Calibration	Demonstrate success of calibration approach over 1 year	Confirm success of calibration approach over longer period
Earth Reflectance and Radiance Nadir Spectra	Will be used to demonstrate achieved calibration, geolocation, etc requirements	• Develop partial (nearly-global) climate benchmark prototype • Potential for overlap with TRUTHS • Additional opportunities for use in science studies
LEO On-orbit Inter-calibration	• Measurements and data analysis for CERES and VIIRS Only • Potential Landsat measurements	• Additional flexibility to inter-calibrate other on-orbit LEO sensors (e.g. PACE, Sentinel, commercial sensors)
GEO On-orbit Inter-Calibration	• Demonstration measurements with 1 GEO	• Expand GEO inter-calibration measurements (e.g. TEMPO, GOES, GERB, Himawari series, GeoCarb)
Enhanced Land/DCC Pseudo-Invariant Calibration Site (PICS) Characterization	• Measurements over high priority PICS	• Additional PICS added with additional viewing opportunities
Improved characterization of the Moon	• Leveraging existing ops mode to cover libration and phase angles available	• Additional sampling within libration and phase angles to further make lunar models more robust

Raj Bhatt CPF presentation

ISS CLARREO Orbit

- CLARREO will be hosted by the International Space Station
  - Is in a precessionary orbit with an inclination of 51.6° (will not observe polar regions) with an altitude ~416km
  - It has a 63 day repeat cycle, every 63 days all local hours will observed, will sample local noon every 32 days combining ascending and descending nodes



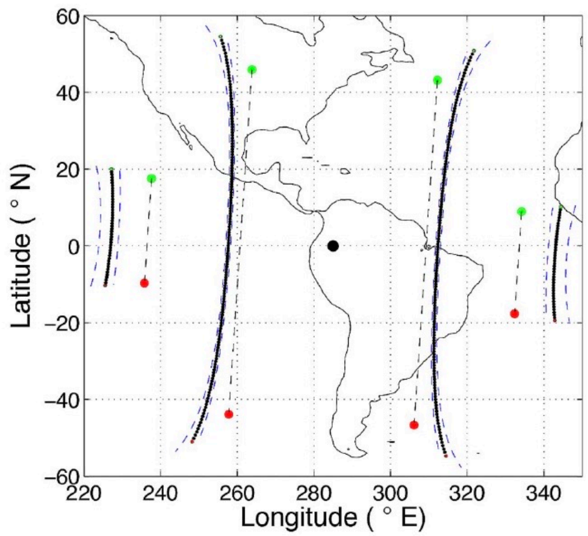


Fig. 7. CLARREO and GEO-based imager matched data for one day period: CLARREO (solid black curves) boresight ground tracks and (dashed blue lines) swath edges. Solid black circle indicates GEO subsatellite point, and black dashed lines show CLARREO ground track during intercalibration event.

Every ISS overpass will have inter-calibration opportunities with GEO

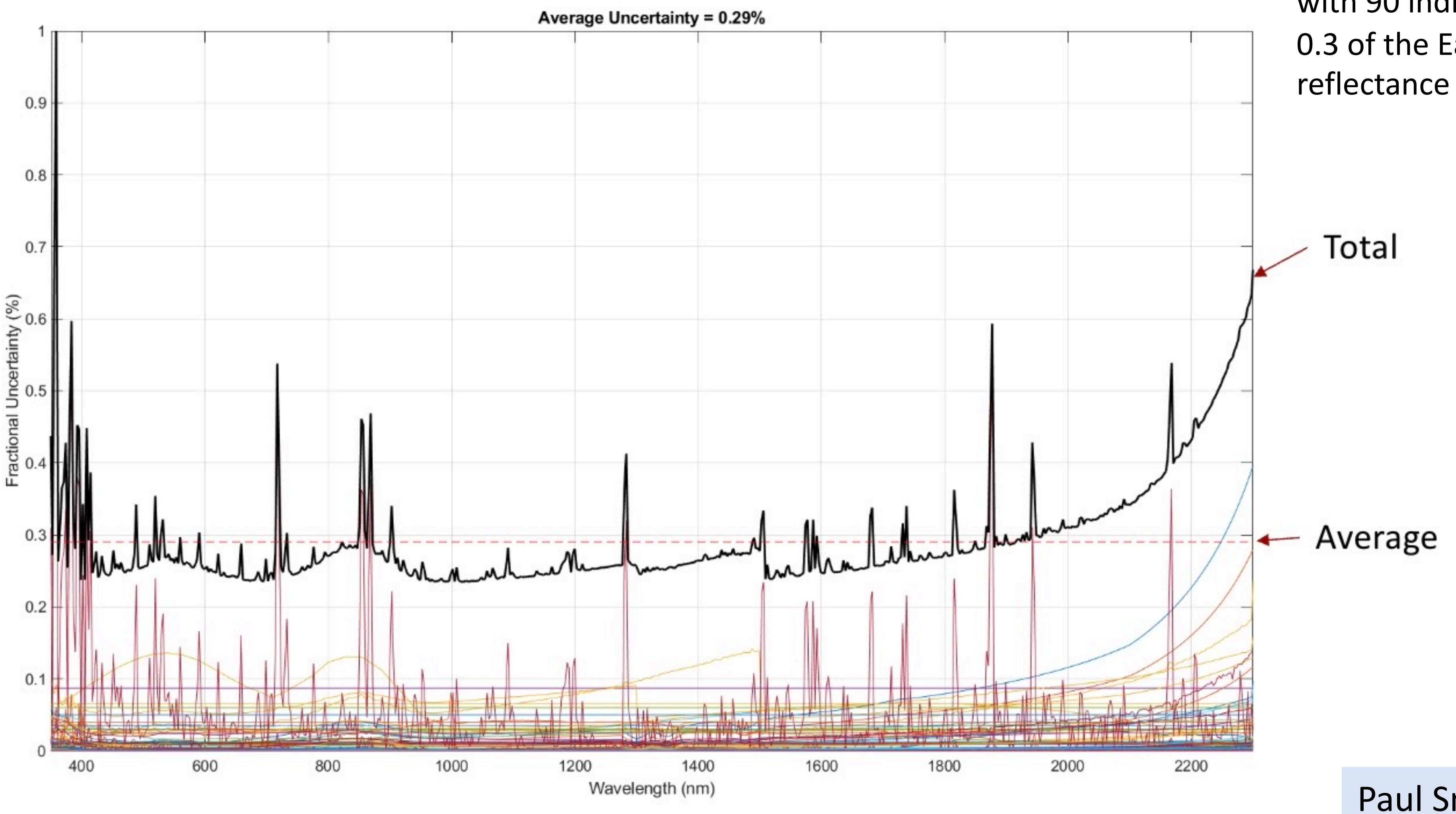
Paul Smith CPF presentation

CLARREO HySICS specifications

- Spectral range
  - 350 –2300 nm
- Spectral sampling
  - 6.28 nm resolution (3.14 nm sampling)
- Spatial sampling
  - Cross track and along track: 0.5 km at nadir
  - Swath width: 70 km at nadir (10° VZA)
  - Radiometric accuracy of reflectance measurement
  - Spectrally resolved: 0.3% Uncertainty
  - Spectrally integrated: 0.3% Uncertainty
- Polarization Sensitivity
  - Less than 1% (350-1800 nm), less than 2% (1800-2300 nm)

HySICS Uncertainty Budget (15 km averaged)

The SI traceable reflectance uncertainty was computed with 90 individual terms at 0.3 of the Earth observed reflectance



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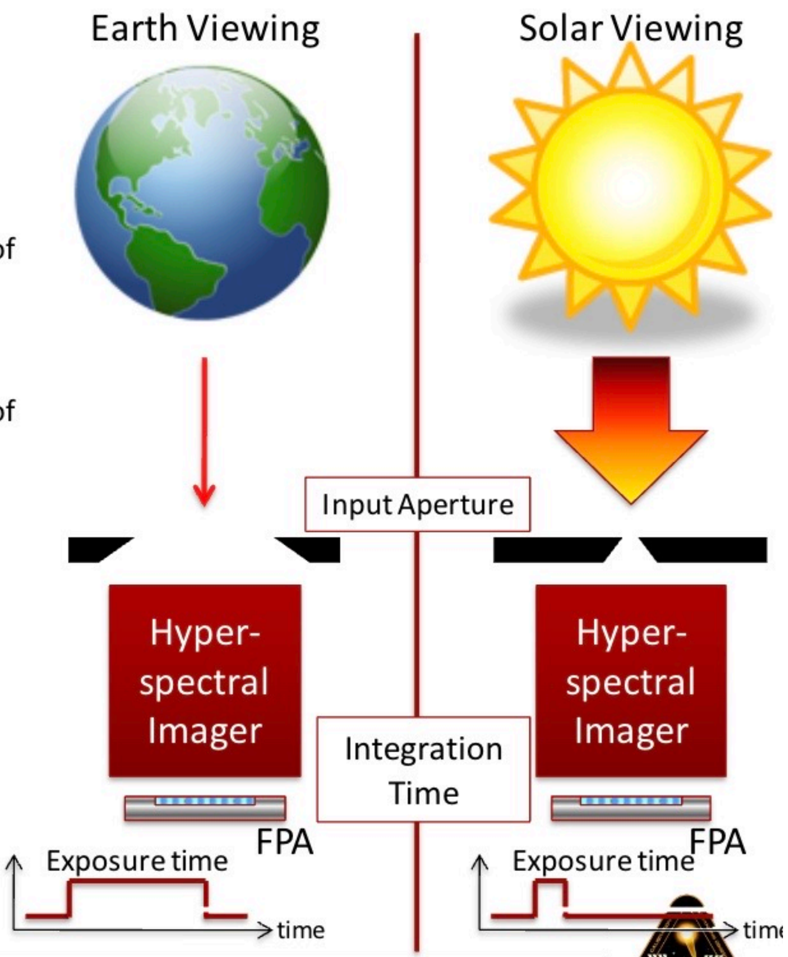
Relative Measurement Concept (SI traceable reflectance measurement

- **How are we accomplishing solar vs. Earth viewing?**
  - Reduction of input aperture area (aperture attenuation)
    - Can achieve over 3 orders of magnitude of attenuation (20 mm to 0.5 mm)
  - Reduction of detector integration time (integration time attenuation)
    - Can achieve over 2 orders of magnitude of attenuation (66 ms to 122 μs)
- **Why are we going to look at the Sun?**
  - The solar irradiance is known to 0.2% via other *absolute-calibration* instruments, such as TSIS SIM
  - The Sun is the most stable on-orbit light source
  - All attenuation methods are *relative measurements*. No direct measurement of solar or Earth irradiances is made.



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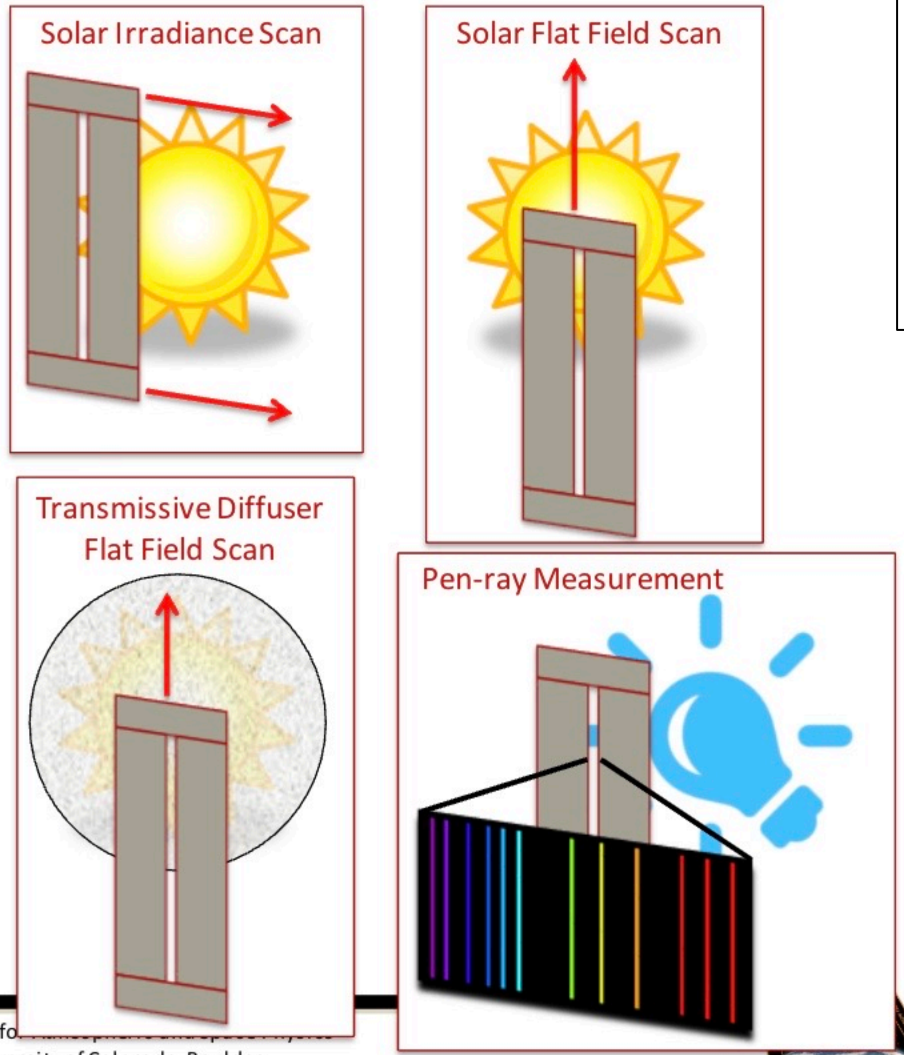
On Orbit calibration

- **Solar Irradiance Scan**
  - Cross-slit scan of the Sun, attempting to collect all of the power incident at the input aperture
  - Directly used as denominator in reflectance measurement
- **Solar Flat Field Scan**
  - Relative gain measurement of each "pixel" in the instrument with the solar-viewing aperture (0.5 mm diameter)
- **Transmissive Diffuser Flat Field Scan**
  - Relative gain measurement of each "pixel" in the instrument with the Earth-viewing aperture (20 mm diameter)
- **Pen-ray Measurement**
  - Absolute measurement of atomic spectrum from a Hg-Ar light source for wavelength location on camera



Calibration Data
- Solar Spectral Irradiance (daily)
- Flat Fields (2 types)
- Pen-ray Measurements
- Dark Images (~5 minutes)
- Miscellaneous measurements

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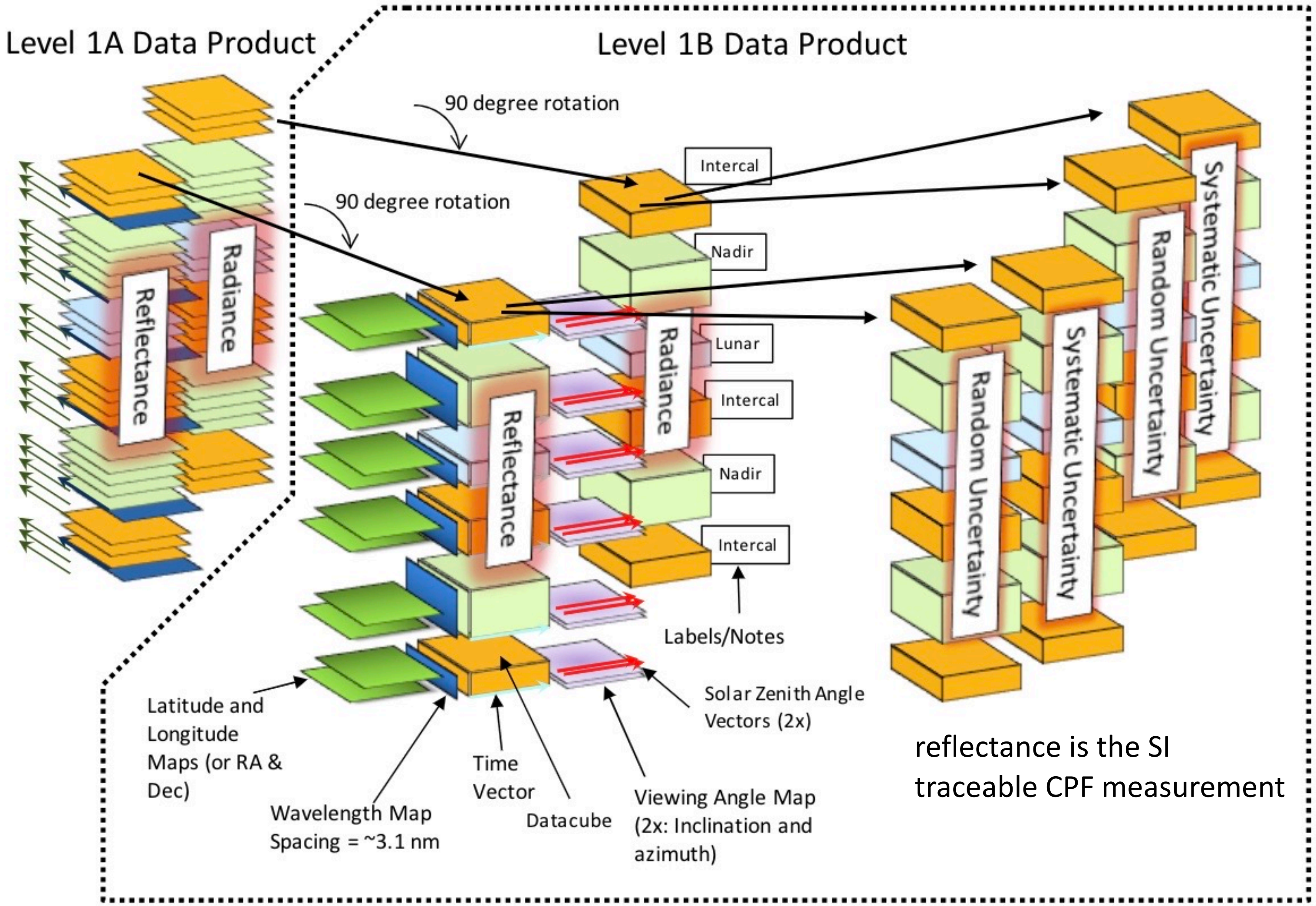
Level 1B Data Product



Total uncertainty is calculated by data consumer

- *For each pixel,* Total uncertainty is the quadrature sum of random and systematic uncertainties
- *For a radiance integration using multiple pixels (50x50 pixels)*
  - Total uncertainty is quadrature sum of uncertainty of each pixel
  - The average random uncertainty is decreased by the square root of the number of pixels in the calculation

All laboratory-measured factors contributing to uncertainties will be included in the Calibration Level 1A data set

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Level 1A Data Product Definition

- Contains all ground and lunar scan data converted to reflectance (1/sr) and radiance units (W/(m2·sr·nm))
- Primary data: All calibrated scans of the ground and Moon
  - Groups of images from each contiguous ground scan (intercaland nadir)
  - Groups of images from each Lunar irradiance scan
  - Images are time-tagged
  - Images are instrument location-tagged (GPS)
  - All radiometric corrections have been applied
    - Pointers to correction data sets are provided (Many of the calibration data sets will have pointers to their correction data sets as well)
    - SSI scan (will include TSIS SIM data set)
    - Flat field
    - Dark Images/Blank aperture correction
    - Pen-ray measurement
    - Lab data set
  - Include contemporaneous TSIS SIM SSI Scan (for solar temporal variations)
- Uncertainty information is given for every pixel
  - Systematic and random fractional uncertainties will be separated
- Provided with each scan:
  - Wavelength scale information provided with each scan
  - Field angle scale provided with each scan
  - May change from scan to scan
- Geolocation data will be provided for each image row
  - Will enable customized gridding and averaging of data
- Labels provided with each scan

Level 1B Data Product Definition

- Like the Level 1A data product, contains all ground and lunar scan data in units of reflectance (1/sr) and radiance (W/(m2·sr·nm))
- Axes will be rotated so that HDF5 files can easily output spatial-spatial composite images and re-gridded along spatial or spectral axes
  - These HDF5 files are considered the “datacube”
    - Latitude/longitude coordinates provided for the center of each pixel in ground scans
    - RA/dec coordinates provided for lunar scans
    - Wavelength maps provided
    - UTC times of each image provided
    - Viewing angle maps for each pixel in composite image (possibly inclination and azimuth)
    - Solar zenith angle for each image (requires 2 angles to completely define)
- Metadata
  - Labels to enable searching (scan type)
  - Nadir scan, Inter-calibration, Lunar scan
  - Possibly notes on data quality, look direction, (QA), etc.
- Unlike the Level 1A data product, there will be no calibration data in the Level 1B data set
  - Calibration data can only be accessed by viewing the Level 1A product
- Manik suggested for CLARREO to provide a sample of the expected L1B data file to the calibration community, Greg Kopp thought this was a good idea
  - The possibility exists for a pre-launch for a L1A or L1B format to be provided
- Fred Wu and others wanted to know if the uncertainty values will be available
  - YES, uncertainty will be given, along with the radiances, geolocation, and time/pointing parameters

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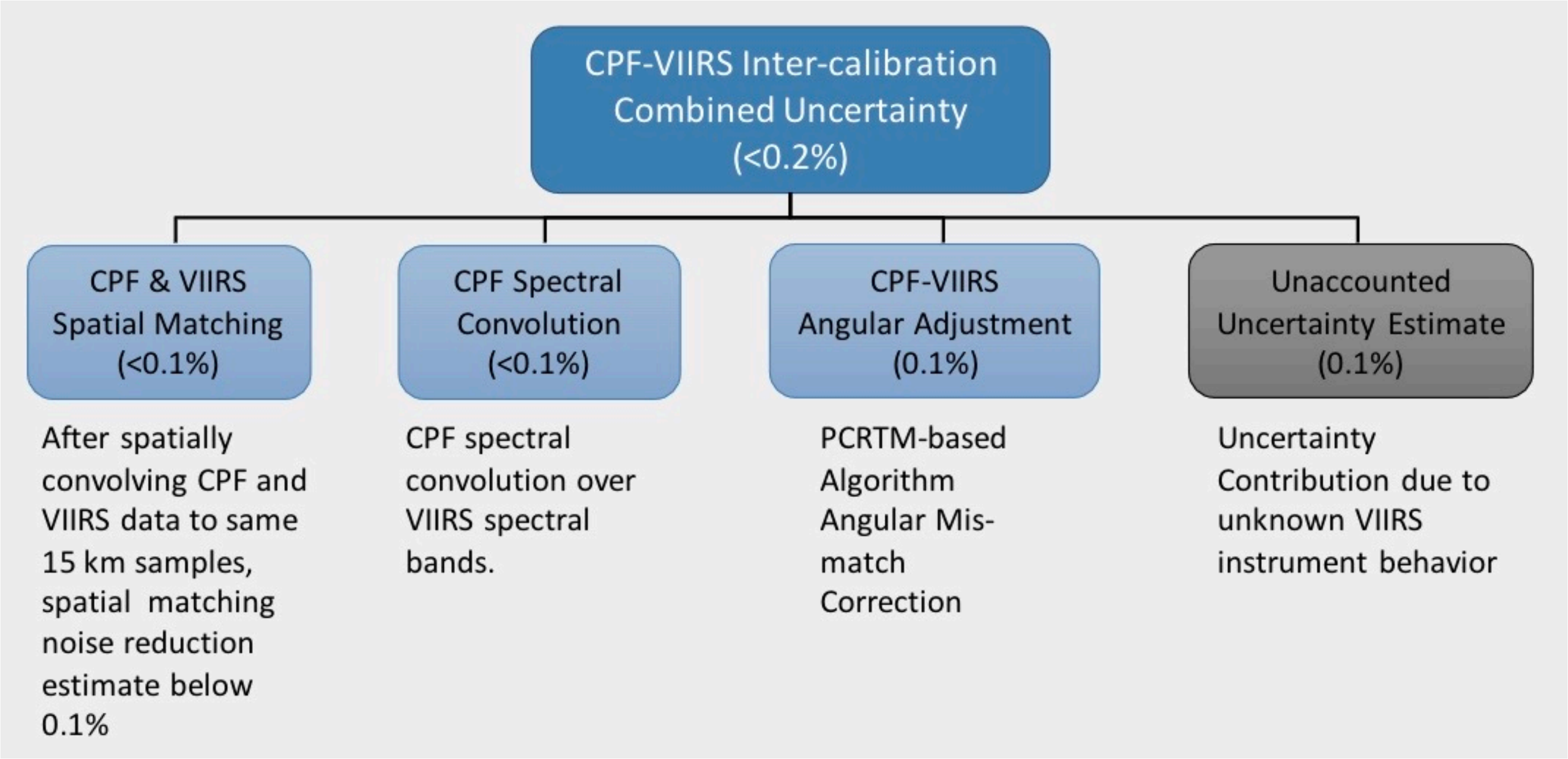
VIIRS/CLARREO intercalibration and VIIRS as a transfer radiometer



CLARREO to provide VIIRS calibration coefficients

Effective Offset	Monthly
Effective Gain	
Non-linearity	Bi-annually
Spectral Response	
Sensitivity to Polarization	

- not for a single inter-calibration event, but for the monthly aggregate

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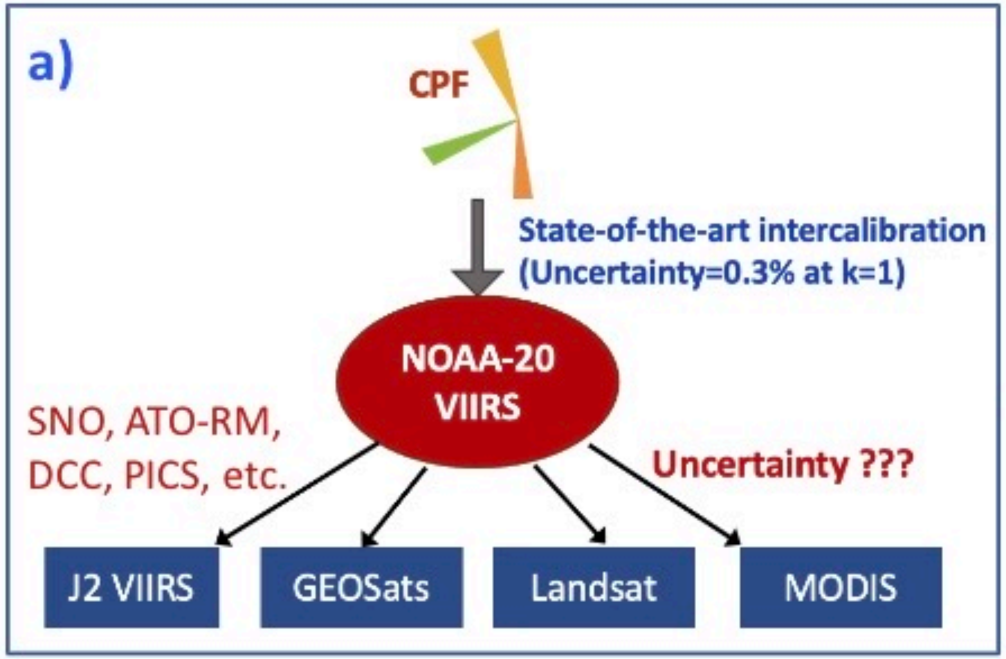
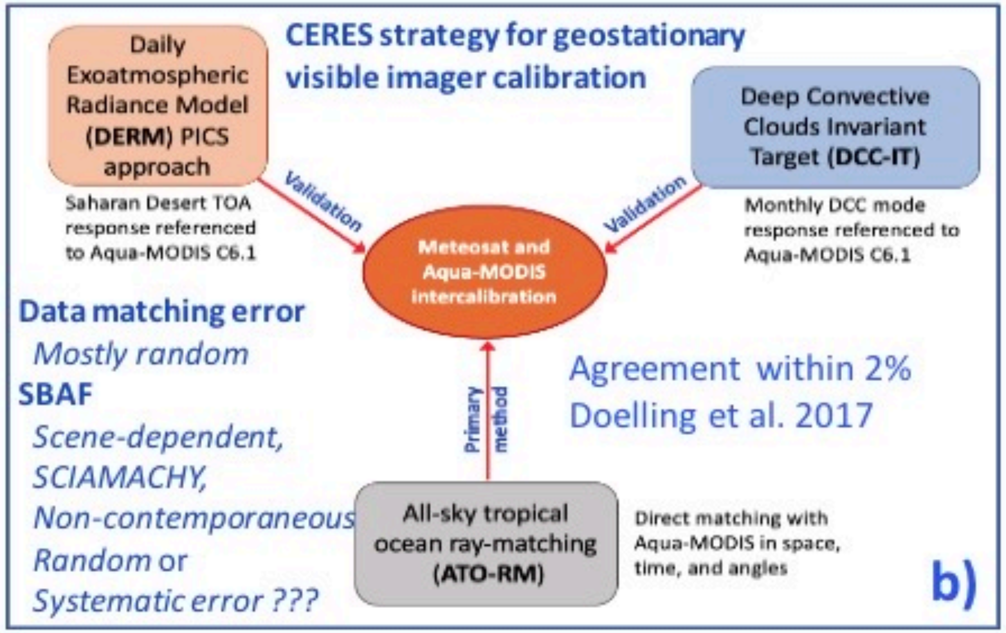
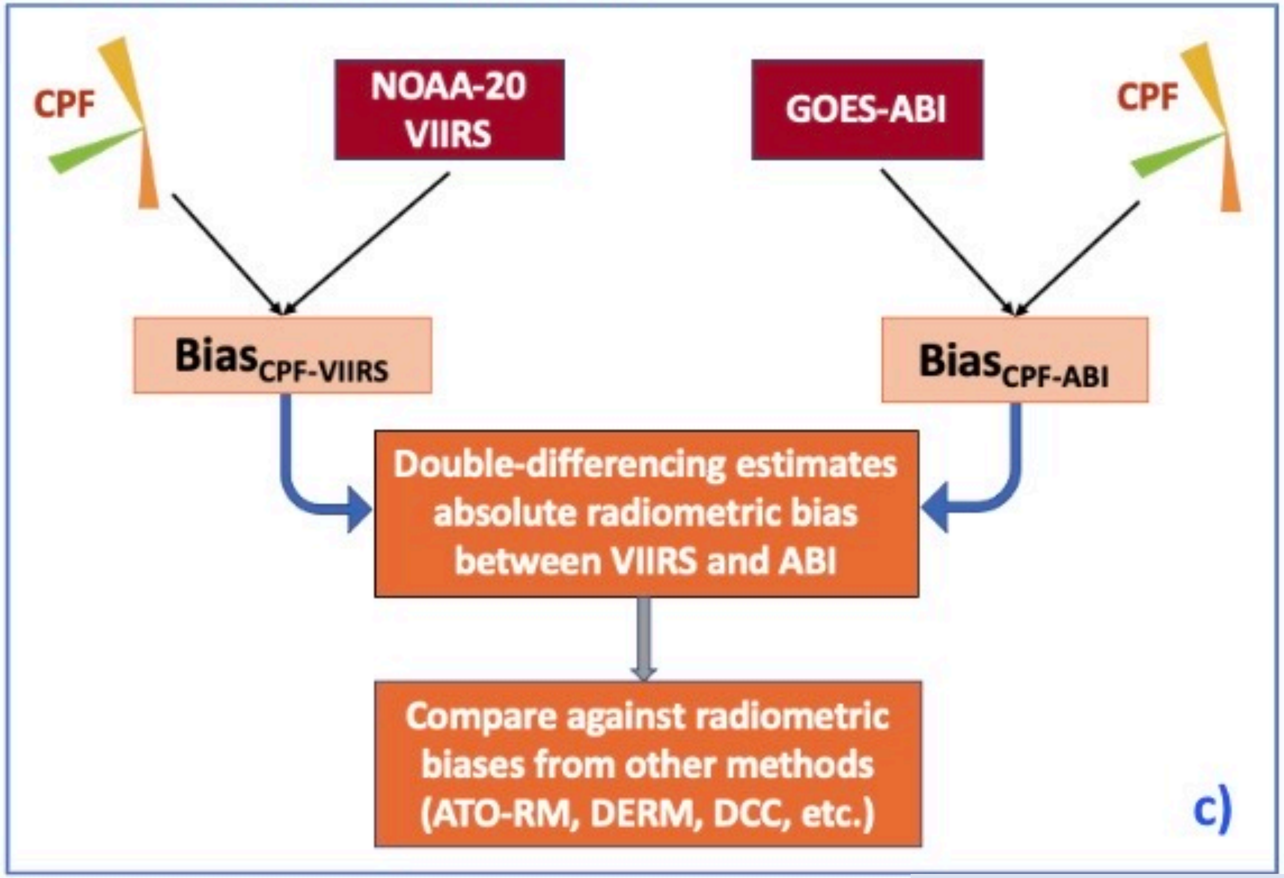
Lightning Round of utilizing CLARREO

Validation of Methods

- *Intercalibration methodologies can be validated by concurrently (same month) calibrating two instruments against CPF*
- *Help split uncertainty sources and identify the most optimal intercalibration method for a given wavelength*
- *Ultimately, these methods can be used to transfer CPF reference to future as well as past instruments*







SNPP and NOAA20 VIIRS RSB comparison* (SNPP – N20) (%)

Method	VIS/NIR (μm)								SWIR (μm)		
	M1 0.41	M2 0.45	M3 0.49	M4 0.56	M5 0.67	M7 0.87	I1 0.64	I2 0.87	M8 1.24	M10 1.61	I3 1.61
SNO	6.2 ±1.7	5.9 ±1.6	4.9 ±1.9	5.0 ±1.6	4.7 ±2.3	2.9 ±1.8	3.1 ±1.6	2.8 ±1.8	2.7 ±1.4	2.6 ±3.1	3.7 ±3.2
Libya 4	7.1 ±1.0	6.1 ±1.1	4.3 ±1.2	3.5 ±1.0	4.8 ±0.7	2.7 ±0.8	3.5 ±0.9	2.9 ±0.8	2.3 ±1.2	1.9 ±0.8	3.1 ±0.8
Dome C	6.9 ±1.1	6.1 ±1.1	4.5 ±1.2	4.3 ±3.0	4.5 ±2.0	1.7 ±2.5	3.0 ±2.8	2.1 ±2.6	2.6 ±8.9	NA	NA
DCC	5.5 ±0.5	4.6 ±0.6	5.0 ±0.6	6.0 ±0.7	4.6 ±0.6	4.4 ±0.3	4.6 ±0.6	5.4 ±0.4	1.8 ±0.5	0.2 ±1.3	2.5 ±1.1
Moon	3.7	4.5	2.6	3.0	3.3	1.7	1.4	1.6	3.8	2.1	2.8

The biases from the vicarious approaches are much larger than the data uncertainty. It is expected that high-accuracy CPF would provide critical reference to evaluate our SNPP and NOAA20 inter-comparison.

**RSR correction applied*

Xiong et al., Remote Sens, 2020

SNPP and NOAA20 VIIRS RSB comparison (SNPP – N20) (%)

Method	M1*		M4	
	No corr for RSR diff	With RSR correction	No corr for RSR diff	With RSR correction
SNO	4.9	6.2	5.8	5.0
Libya-4	7.0	7.1	1.6	3.5
Dome C	5.8	6.9	5.8	4.3
DCC**	5.6	5.5	5.7	6.0

** M1: largest OOB impact*
M4: largest central wavelength shift between SNPP and NOAA20
*** based on the NASA-LaRC SCIAMACHY-based SBAF Tool*

Our RSR correction is based on historic SCIAMACHY hyperspectral measurements. It is expected that correction derived using high-accuracy and real-time matched CPF data would significantly improve the biases caused by band spectral differences.

SBAF tool updates

Aisheng Wu CPF presentation

Benefiting VIIRS Absolute Calibration Accuracy from the CLARREO Mission

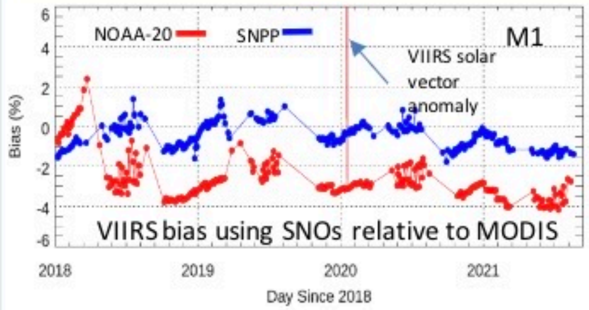
Changyong Cao with contributions from NOAA VIIRS SDR Team

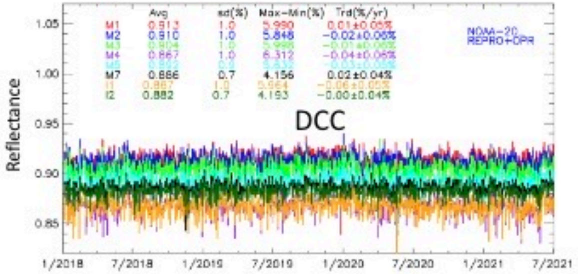
- Background
  - Solar diffuser based onboard calibration (for VIIRS solar bands) can only achieve ~2% absolute radiometric accuracy
  - Uncertainties are due to lack of on-orbit calibration standard, prelaunch cal., and possible changes in sensor characteristics after launch
  - Vicarious calibration and intercalibration do help, but with larger uncertainty
  - Radiometric stability relies on Lunar cal. combined with DCC, PICS, SNOs

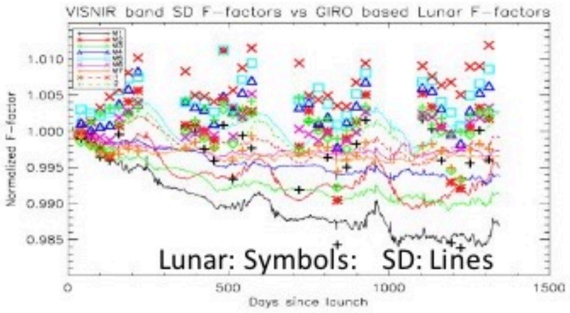
- VIIRS absolute calibration challenges
  - SNPP VIIRS shows ~2% overestimation in absolute calibration for M5, M7.
    - based on Intercomparison with MODIS, Landsat OLI, Inter-channel consistency (band ratioing) study
    - Feedback from EDR teams (NOAA and NASA Cloud and aerosol teams)
    - Reprocessed VIIRS data at NOAA/STAR has applied the correction
  - NOAA-20 VIIRS biased low than that of SNPP VIIRS on the order of 2-4% consistently for all RSBs.
    - Root cause study: points to SNPP SD BRF uncertainty prelaunch
    - However, due to absence of prelaunch witness samples of SD for SNPP VIIRS, the study was limited and still inconclusive

- CLARREO can help:
  - Understand VIIRS absolute calibration accuracy
  - Ensure consistency of all VIIRS measurements for decades (SNPP, N20, J2-J4) for climate studies, with a common radiometric scale
  - Could provide better understanding on on-orbit polarization impacts and uncertainties in calibration

- *We will gain a better understanding of the ISS platform from several related missions such as STP-H8, in preparation for CLARREO*







Chanyang Cao CPF presentation

Can we prioritize and coordinate GSICS agency objectives

- Like to prioritize sensor, PICS amongst the GSICS agencies for pointing after the first of year operations
- Coordinating with the CLARREO project to host the 2025 GSICS annual meeting
    - After first year of data analysis. Launch late 2023.

BACKUP SLIDES