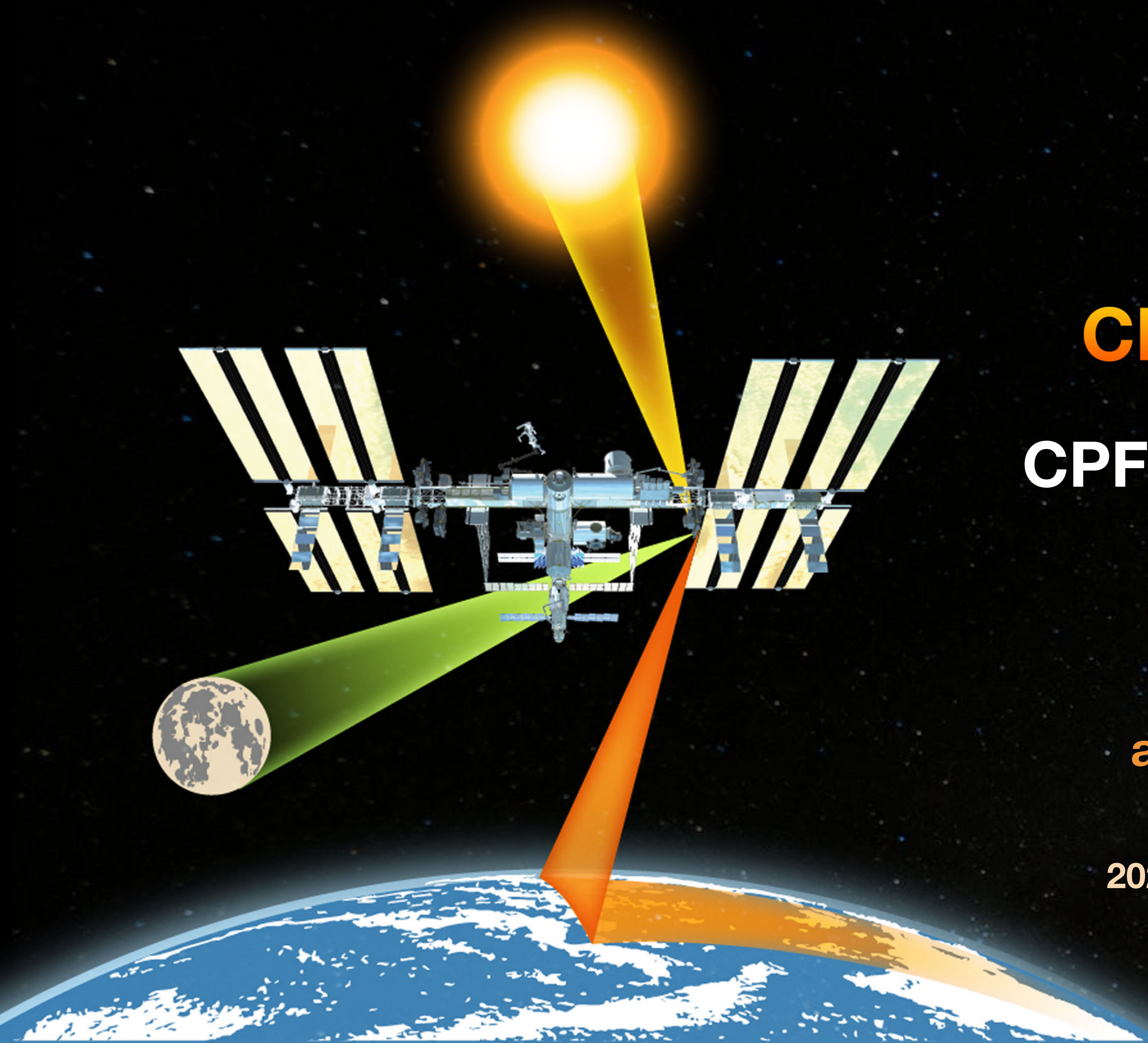
National Aeronautics and
Space Administration



CLARREO Pathfinder

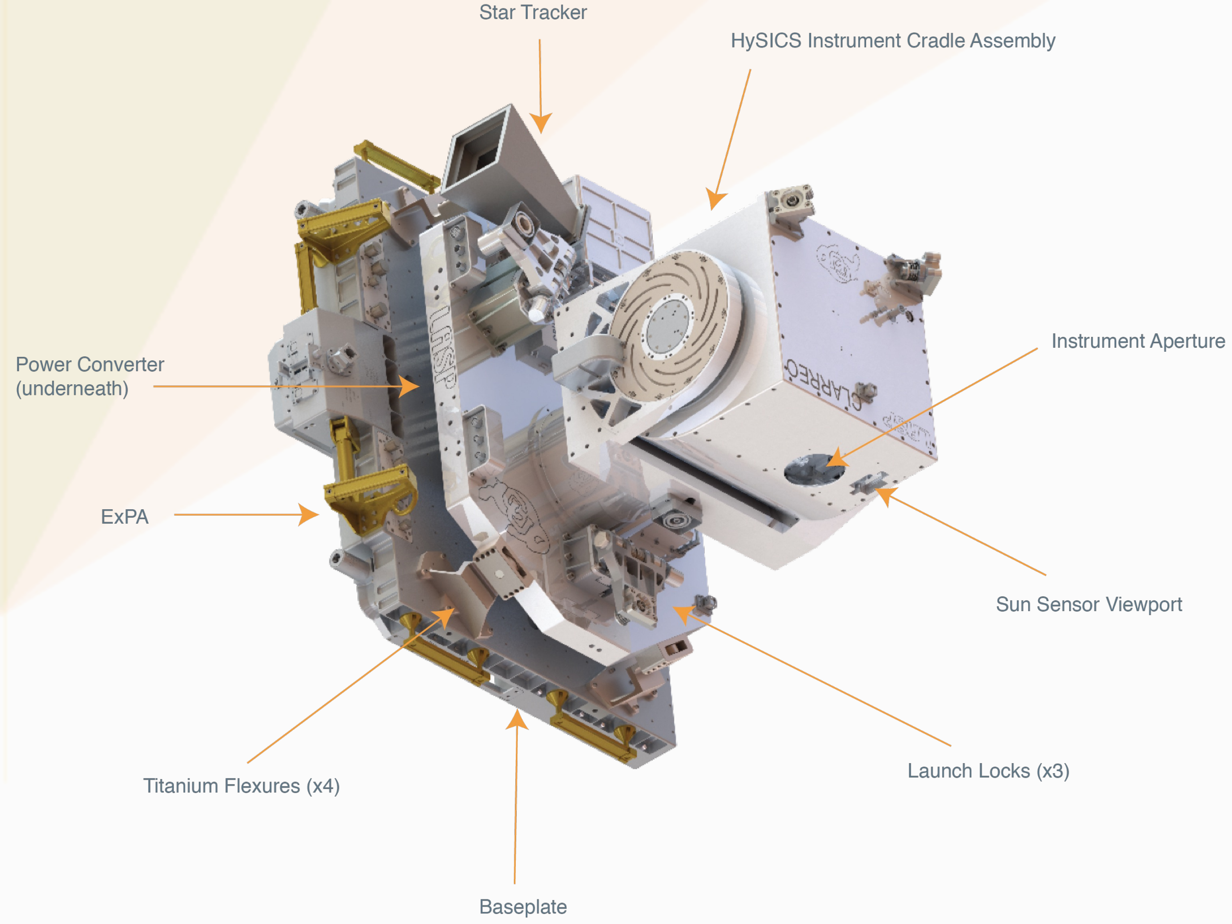
CPF-VIIRS Intercalibration Methodology

Raj Bhatt, Yolanda Shea,
and CPF Intercalibration Team

2023 MODIS/VIIRS Science Team Meeting
May 1-4, 2023

CLARREO Pathfinder Payload

HySICS: HyperSpectral Imager for Climate Science



Push-broom spectrometer

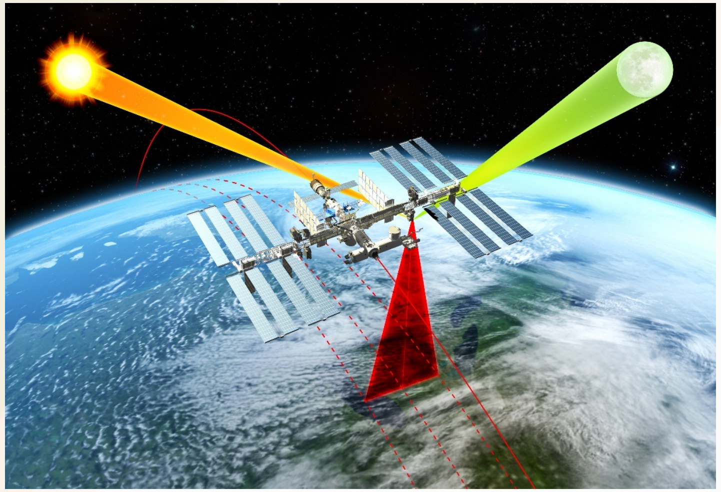
Spectral Range	350 nm – 2300 nm
Spectral Sampling	3 nm
Radiometric Uncertainty	0.3% (1-sigma)
Swath Width	10° (70 km nadir)
Spatial Sampling	0.5 km
Platform	ISS

https://clarreo-pathfinder.larc.nasa.gov/

CPF Science Objectives

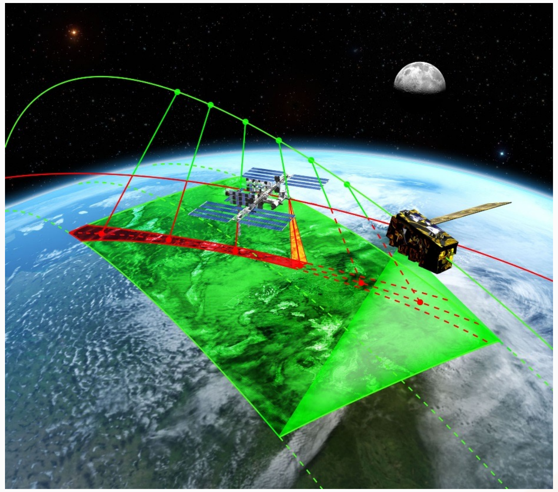
CLARREO Pathfinder

Objective #1: High Accuracy SI-Traceable Reflectance Measurements



Demonstrate on-orbit calibration ability to reduce reflectance uncertainty by a factor of ***5-10 times*** compared to the best operational sensors on orbit.

Objective #2: Inter-Calibration Capabilities



Demonstrate ability to transfer calibration to other key RS satellite sensors by inter-calibrating with CERES & VIIRS.

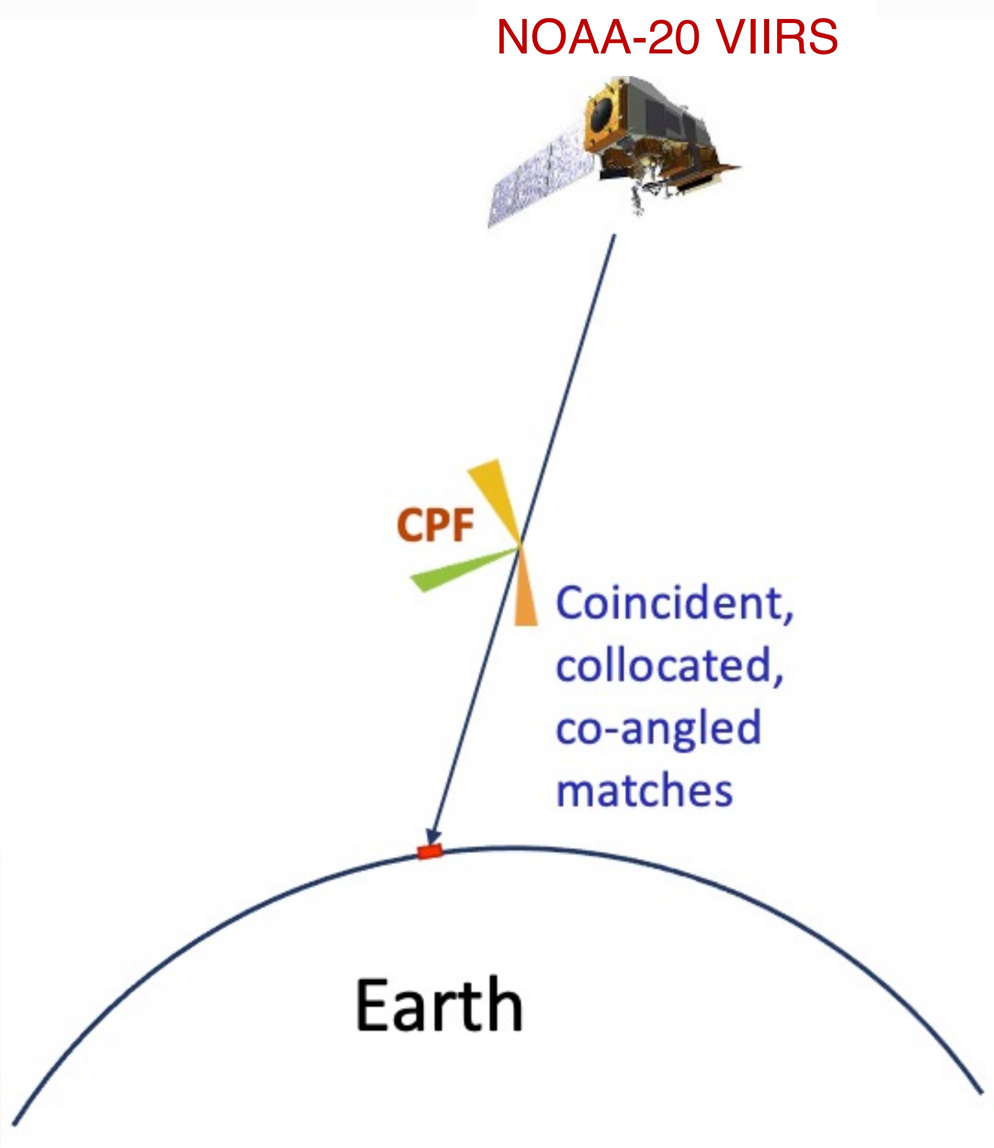
	Objective #1	Objective #2
Uncertainty	Spectrally-resolved & broadband reflectance: ≤0.3% (1σ)	Inter-calibration **methodology** uncertainty: ≤0.3% (1σ)
Data Product	Level 1A: Highest accuracy, best for inter-cal, lunar obs Level 1B: Approx. consistent spectral & spatial sampling, best for science studies using nadir spectra	Level 4: One each for CPF-VIIRS & CPF-CERES inter-cal. Merged data products including all required info for inter-cal analysis

https://clarreo-pathfinder.larc.nasa.gov/

LASP

Intercalibration between CPF and VIIRS

- An idealized intercalibration setup requires perfectly matched data in **time**, **space**, **angles**, and **wavelengths**
- Realistic intercalibration tolerates finite differences in sampling, thereby resulting in several sources of uncertainty
  - *Spatial mismatch*
  - *Angular differences (SZA, VZA, and RAA)*
  - *Spectral band differences*
- CPF will demonstrate a state-of-the-art intercalibration methodology that mitigates the uncertainties from imperfect data matching
  - *2-axis pointing capability*
  - *Mitigates impacts from spatial, angular, and spectral mismatches*



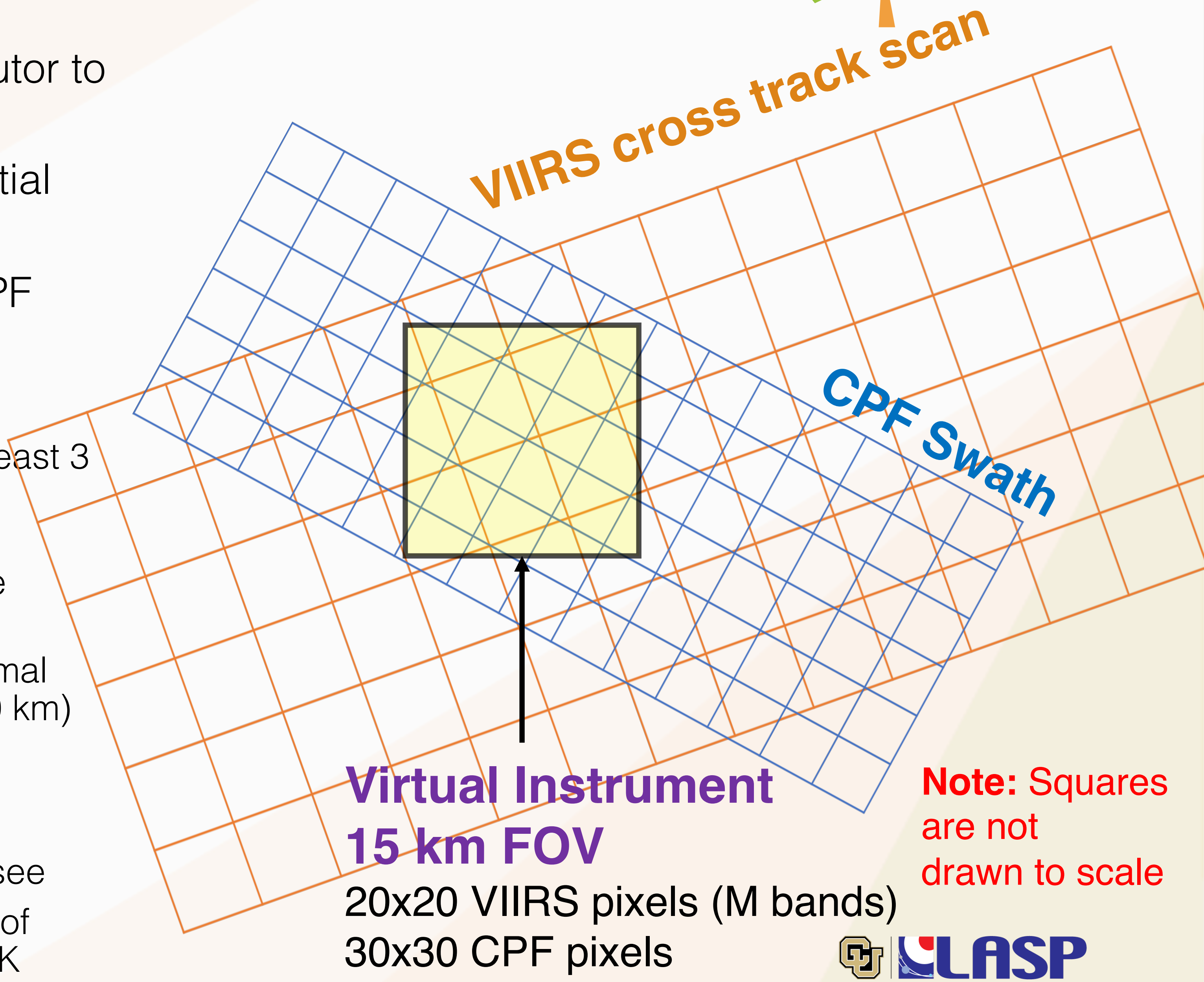
CPF-VIIRS Intercalibration Uncertainty Budget

CPF-VIIRS Intercalibration Methodology Uncertainty Sources

- **Spatial and Temporal Data Matching (<0.1%)**
  Spatial convolution of CPF spectra and target instrument measurements within intercalibration footprints
- **Spectral Matching (<0.1%)**
  Spectral convolution error between CPF and VIIRS bands
- **Angular Adjustment (<0.1%)**
  Imperfect angle matching between CPF and VIIRS
- **Unaccounted uncertainty (<0.1%)**
  Uncertainty contribution due to any radiometric response variability in VIIRS samples acquired within a month

Temporal and Spatial matching noise

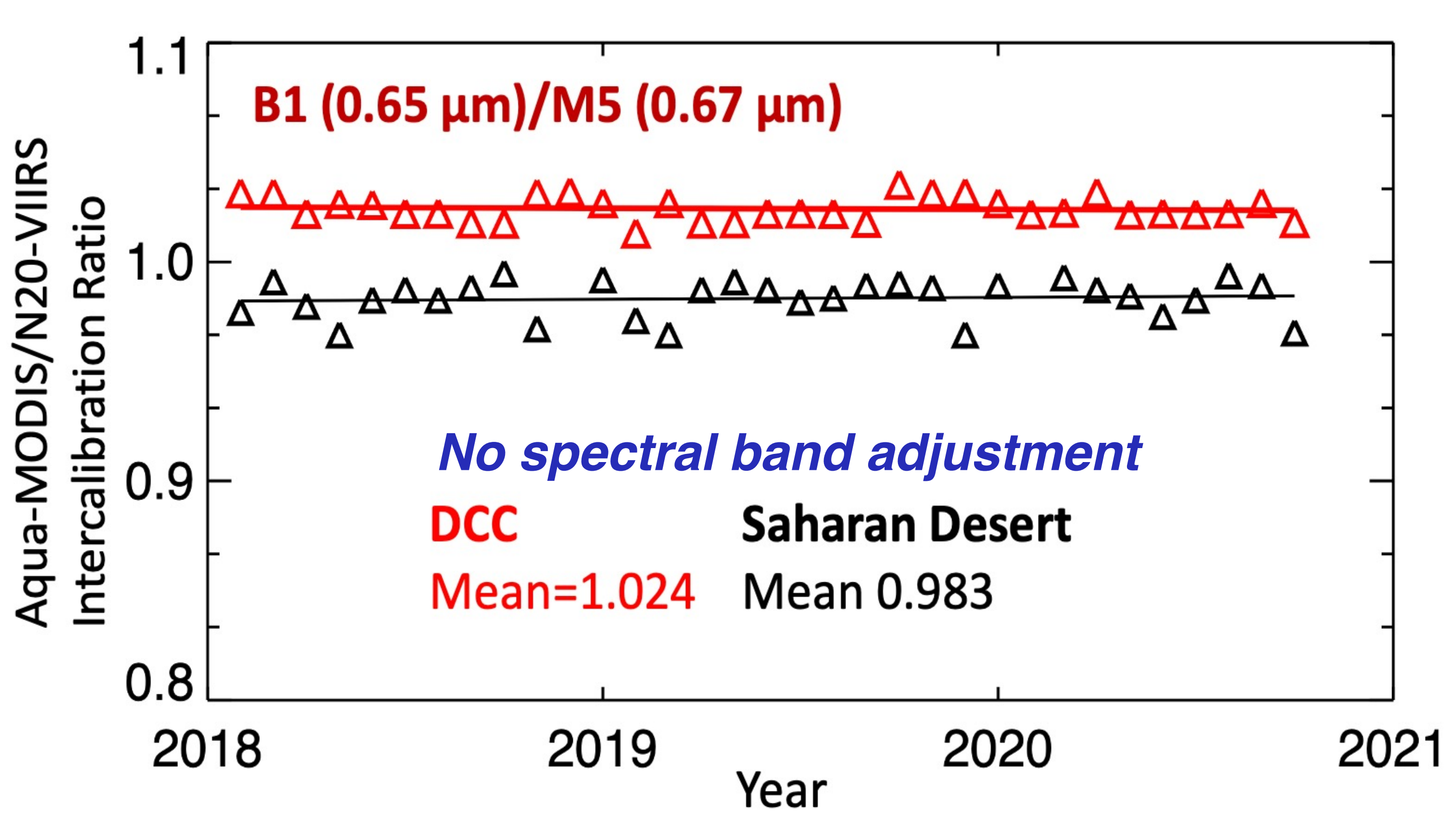
- Spatial mismatching is a prime contributor to uncertainty budget
- For VIIRS, 15 km (at nadir) FOV for spatial convolution
- For CERES, prelaunch PSF used for CPF spatial convolution
- Based on Wielicki et al. (2008)
  - Large intercalibration FOV preferred (at least 3 to 10 times the native spatial resolution)
  - For ≥15 km FOV, ~5000 intercalibration samples would be needed to mitigate the spatial matching noise below 0.1%
  - Dependence on time simultaneity is minimal below 6 minutes for larger FOV (e.g., 100 km)
  - Summarized in CPF-SER-022
- Revisiting the sampling study
  - Emulating scene variability that CPF will see
  - Estimated single sample matching noise of 10% -> Increases samples needed to 10K

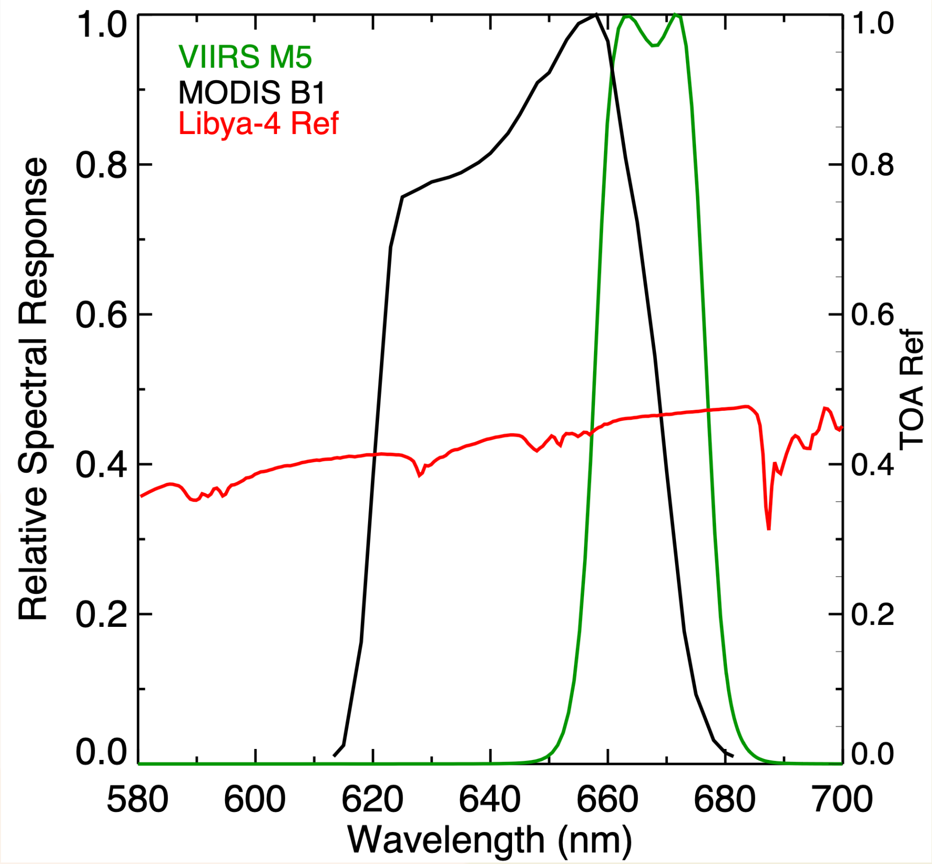


Note: Squares are not drawn to scale

Spectral wavelength matching

- Spectral mismatch between reference and target sensors results in scene-dependent intercalibration results (e.g., MODIS and VIIRS)
- Hyperspectral measurements from reference sensor substantially mitigates the spectral difference issue
- At 4 nm spectral sampling, the impact is within 0.1% for MODIS bands (Wu et. al. 2015)

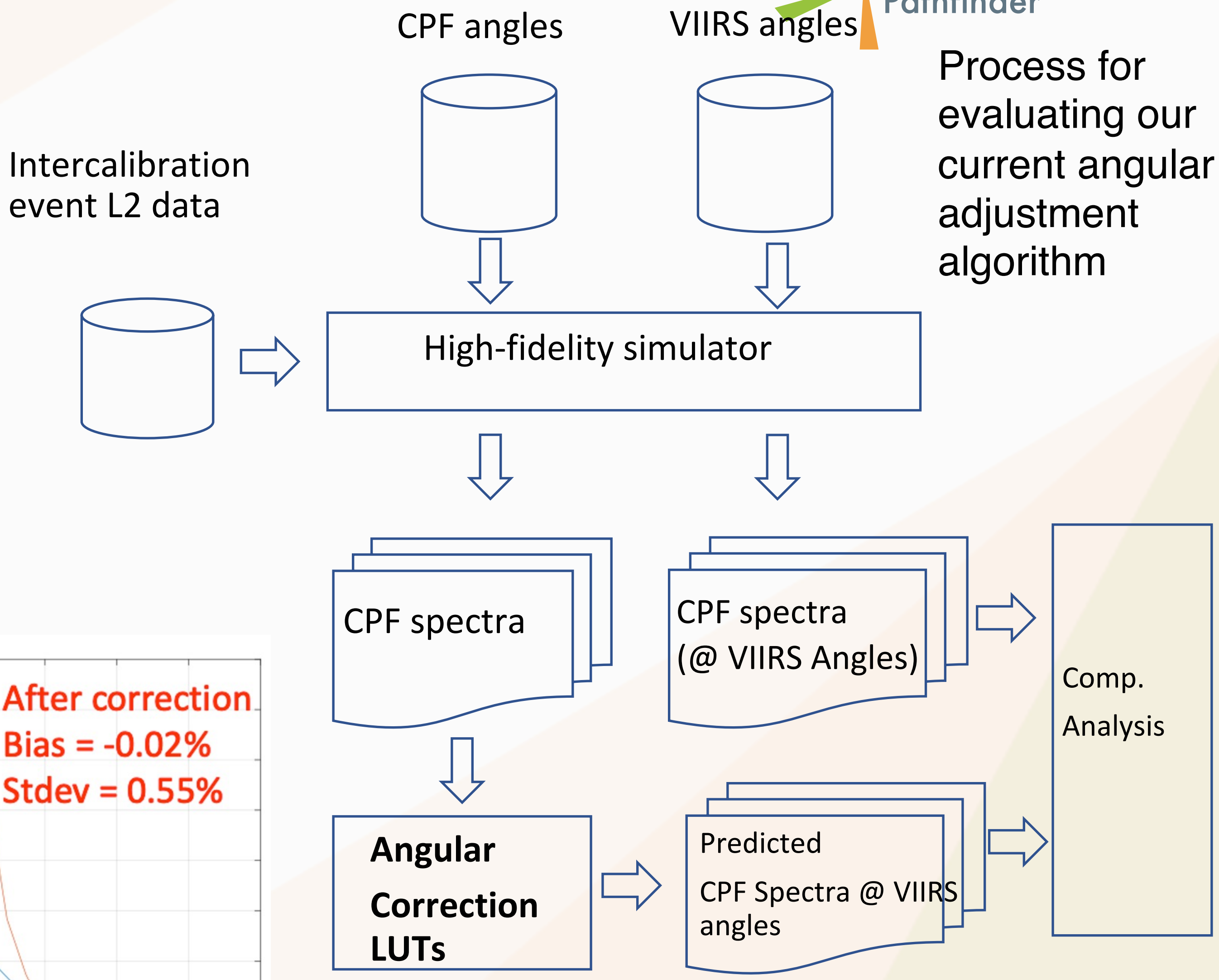


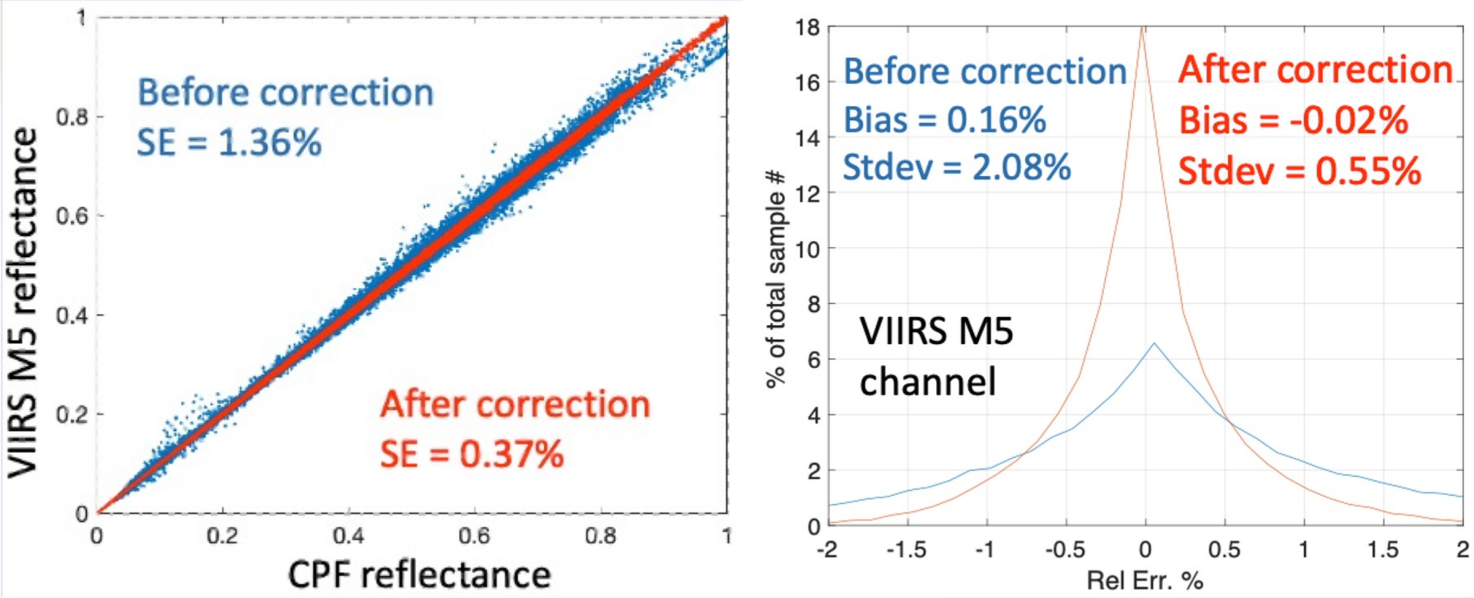


CPF-VIRS Angular Adjustment

- CPF IC team has developed a PCRTM-based algorithm for angular adjustment
- Angular correction LUTs generated based on thousands of simulated CPF-like radiance spectra (randomly chosen) at different angular conditions
- Significant reduction of bias and noise after angular correction

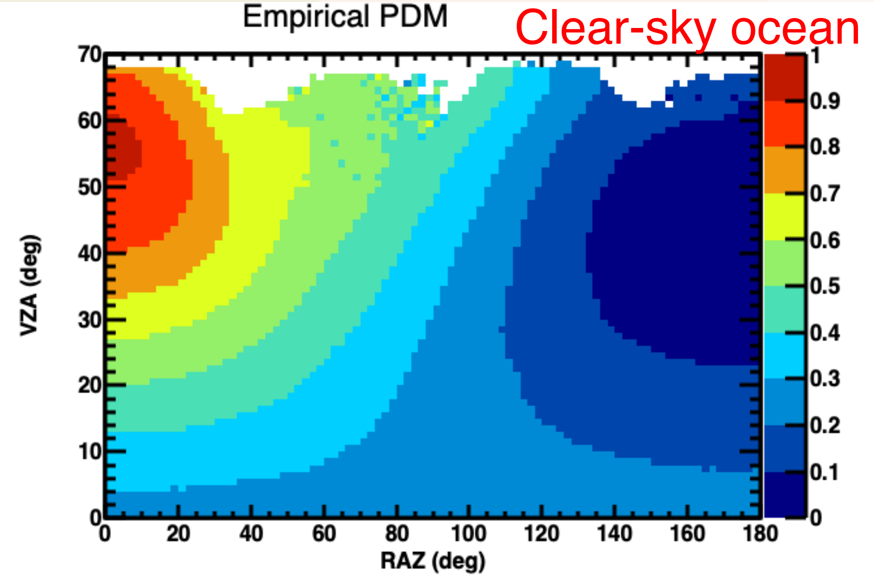
Process for evaluating our current angular adjustment algorithm





Algorithm Development: *Wan Wu & Xu Liu*

Polarization Distribution Model (PDM) Look-up Tables



Empirical PDM Conditions: Constructed from PARASOL/POLDER Data

- SZA = [40º,50º]
- Band = 670 nm
- AOD = [0.05, 0.1]
- Wind Sp. = [2 m/s,10 m/s]

Developed by: *Daniel Goldin & Costy Lukashin*

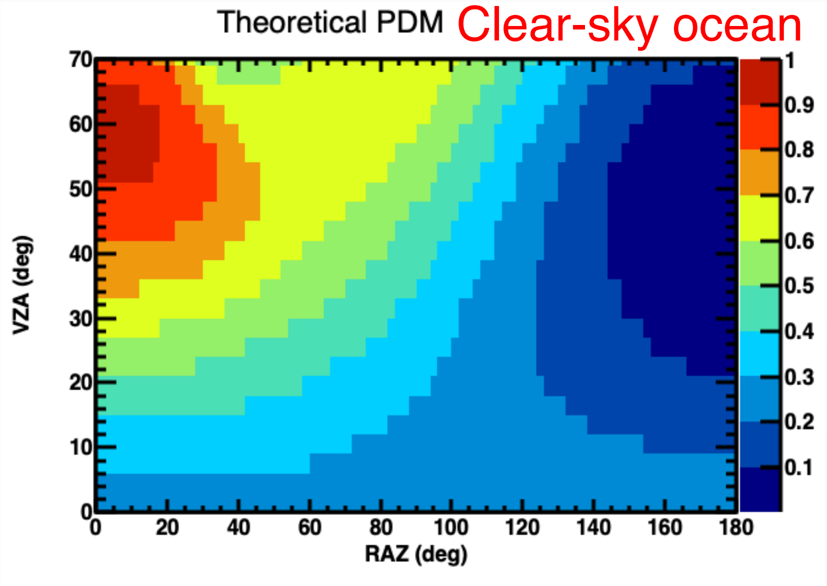
PDM Application Module: Using VIIRS scene characterization info from L2 files, identifies correct LUT DOP/AOLP estimates from ePDMs & tPDMs

PDMs will be used to identify low-polarized radiances.

Development Lead: *Daniel Goldin*

ePDM
- Based on Polder measurements
- 3 wavelengths: 490, 670, and 865 nm
- Wavelength interpolation

tPDM
- ADRTM simulation
- All wavelengths



Theoretical PDMs: Simulated using Adding-Doubling Radiative Transfer Model

- SZA = 45º
- Band = 672 nm
- AOD = 0.076
- Wind Sp. = 7.5 m/s

Simulated by: *Wenbo Sun*

Intercalibration Sampling Estimates from low-fidelity simulation data

CLARREO Pathfinder

Jan

DOP Range	< 0.01	< 0.05	< 0.1
Samples	1856	21248	49463

Feb

DOP Range	< 0.01	< 0.05	< 0.1
Samples	2786	21248	49463

Mar

DOP Range	< 0.01	< 0.05	< 0.1
Samples	625	31451	58163

Apr

DOP Range	< 0.01	< 0.05	< 0.1
Samples	2051	51388	76230

May

DOP Range	< 0.01	< 0.05	< 0.1
Samples	1261	13280	30678

June

DOP Range	< 0.01	< 0.05	< 0.1
Samples	3091	59992	83136

July

DOP Range	< 0.01	< 0.05	< 0.1
Samples	292	14212	37537

Aug

DOP Range	< 0.01	< 0.05	< 0.1
Samples	1393	39657	65429

Sep

DOP Range	< 0.01	< 0.05	< 0.1
Samples	2656	29429	60853

Oct

DOP Range	< 0.01	< 0.05	< 0.1
Samples	2520	28386	60733

Nov

DOP Range	< 0.01	< 0.05	< 0.1
Samples	3088	53488	88983

Dec

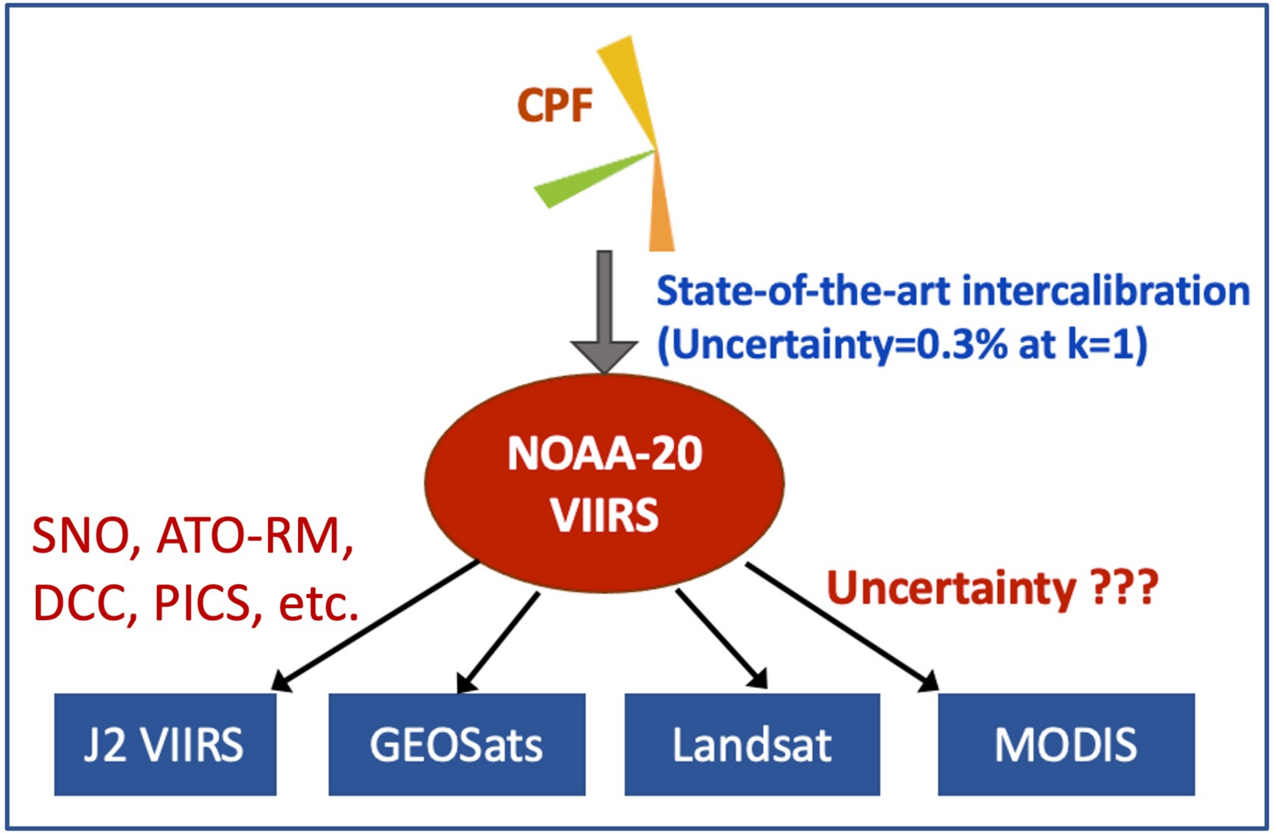
DOP Range	< 0.01	< 0.05	< 0.1
Samples	1434	12625	37164

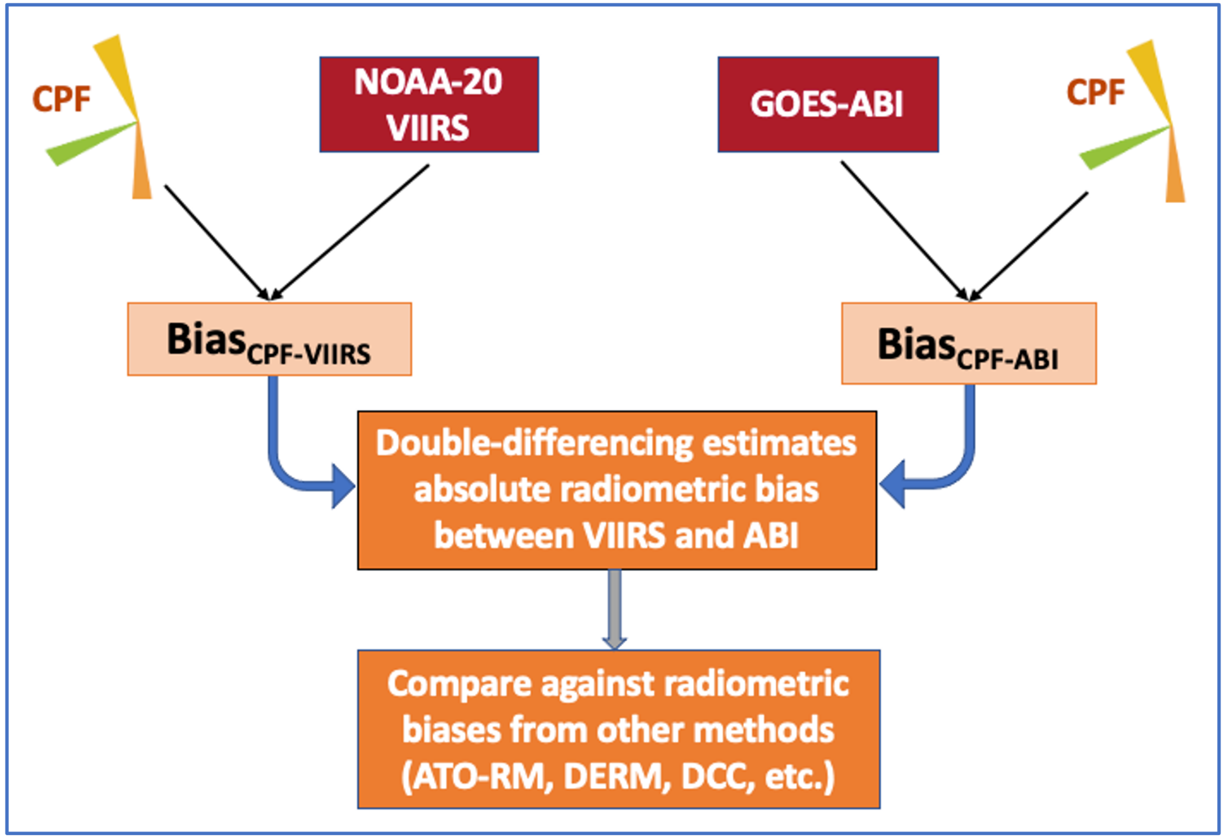
DOP: Degree of Polarization

LASP

CPF benefits to Intercalibration Community

- Improved reference instrument for satellite intercalibration
- Lunar reflectance characterization
- PICS and DCC characterization at hyperspectral level
- Augmenting existing intercalibration approaches





CPF Timeframe Update

- CPF launch delayed (previous launch date was Dec 2023)
- Payload delivery date: No earlier than Spring 2024
- ISS Schedule : Launch Date (TBD)

Conclusions

- CPF will demonstrate a state-of-the-art intercalibration capability (0.3% uncertainty at k=1) by calibrating VIIRS against high-accuracy CPF measurements
  - Extensive # of intercalibration footprints
  - CPF pointing capability
  - PDMs
  - PCRTM-based angular adjustments

Community Benefits

- Scheduled nadir scans of CPF can be used to intercalibrate other RS imagers in GEO and LEO orbits
- CPF measurements will assist validating existing intercalibration methodologies (SNO, PICS, DCC, SBAF etc.)
- Leverage angular correction algorithm and PDM LUTs