

National Aeronautics and
Space Administration



CLARREO Pathfinder

CPF-VIIRS Intercalibration Strategy and Potential Outcomes

**Raj Bhatt, Yolanda Shea,
and CPF Intercalibration Team**

2023 MODIS/VIIRS Science Team Meeting

College Park, MD

May 1-4, 2023

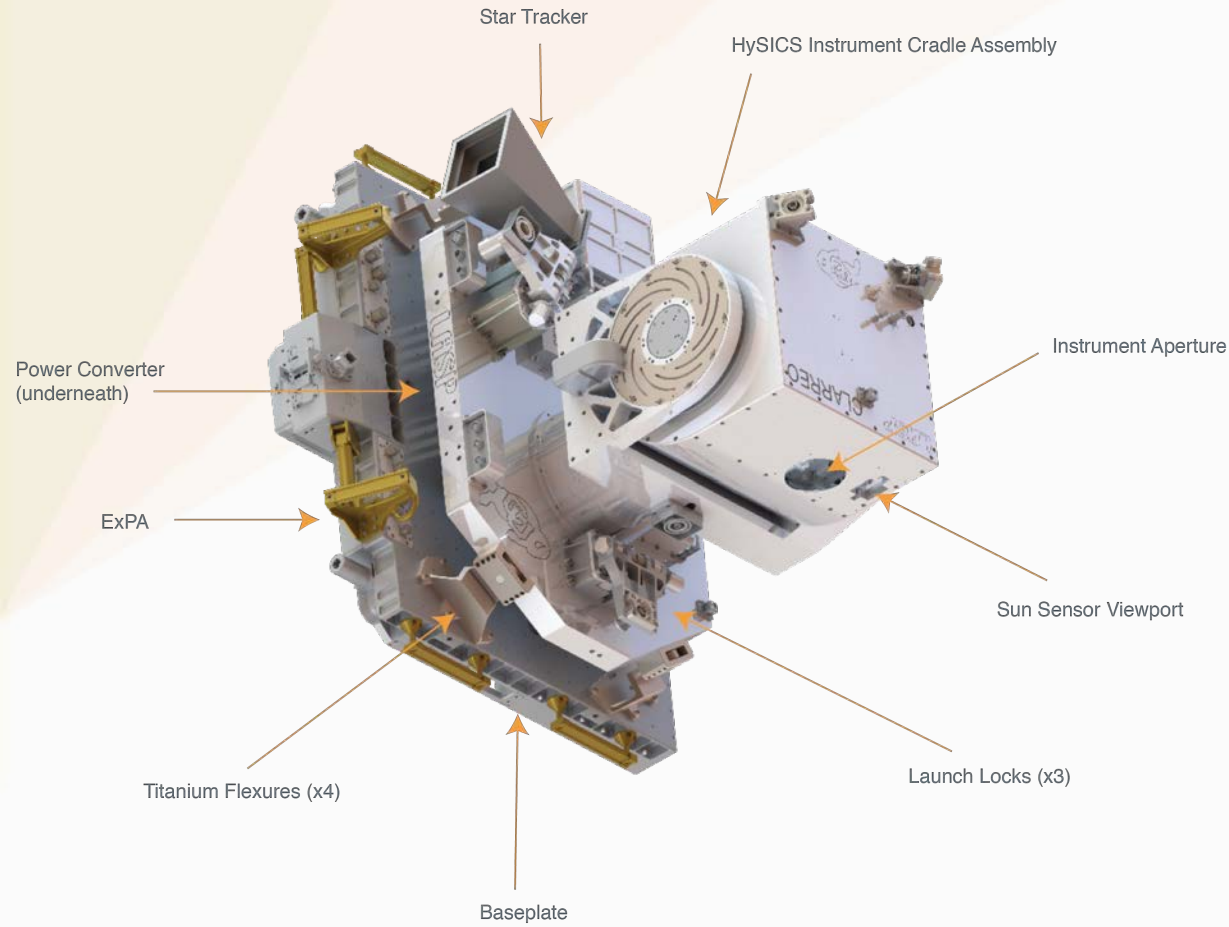




CLARREO Pathfinder Payload



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/>

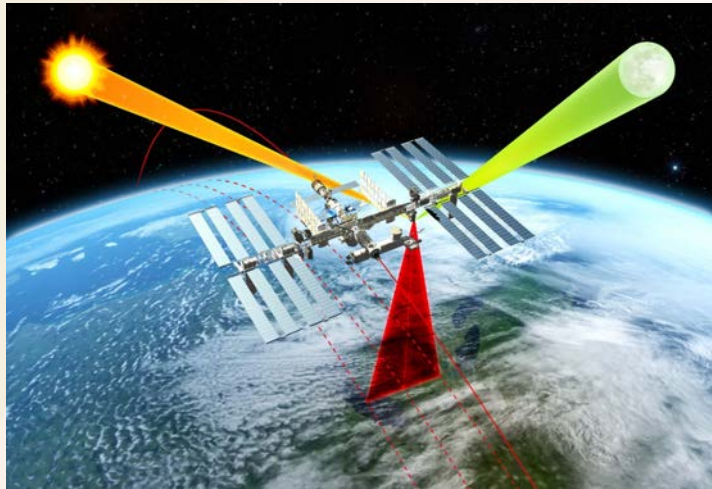




CPF Science Objectives

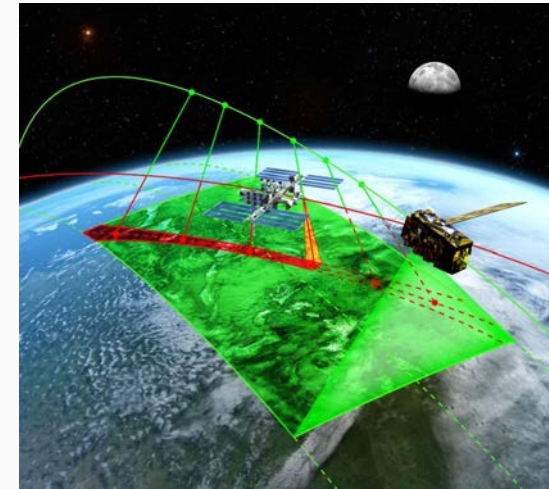


Objective #1: High Accuracy SI-Traceable Reflectance Measurements



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.

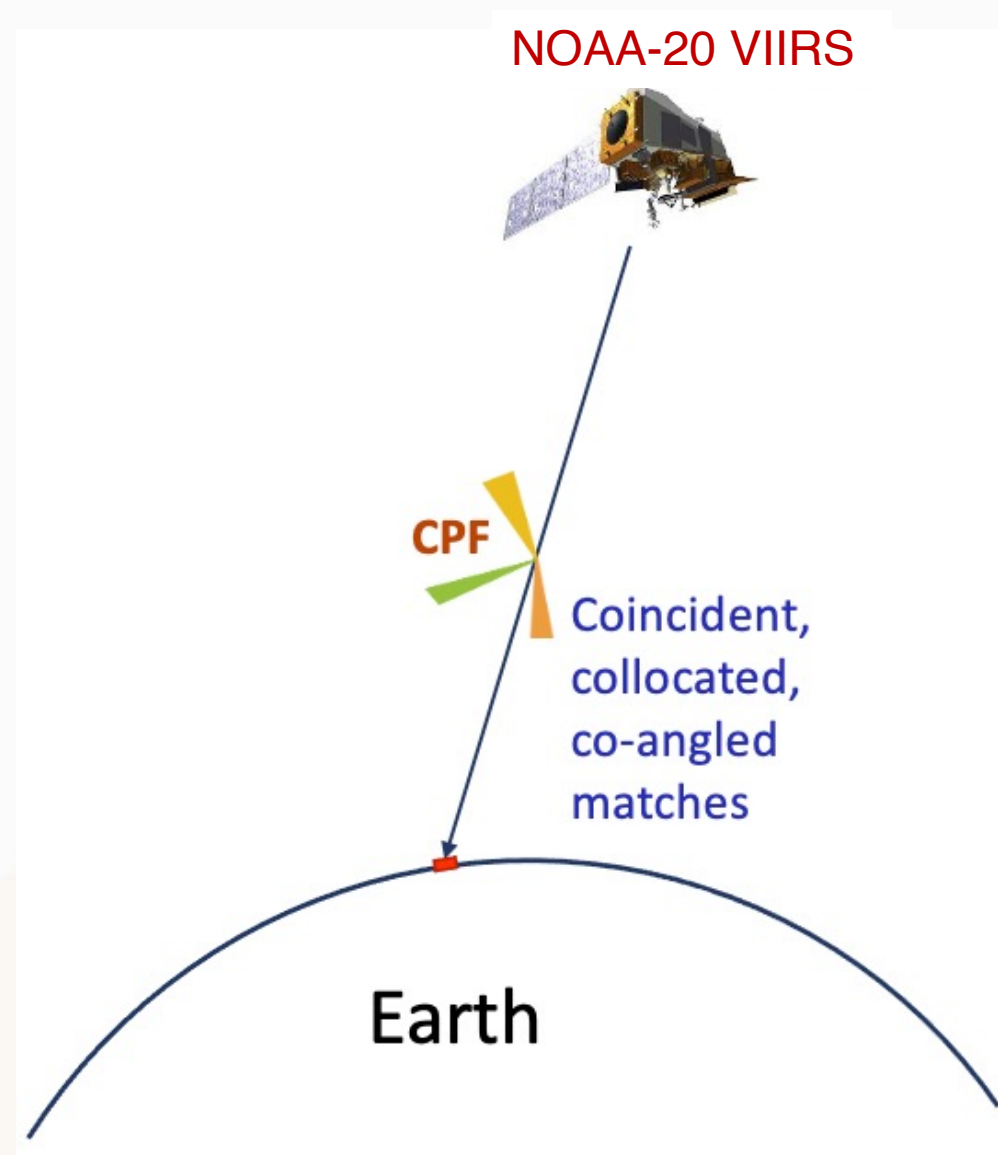
	Objective #1	Objective #2
Uncertainty	Spectrally-resolved & broadband reflectance: $\leq 0.3\%$ (1σ)	Inter-calibration methodology uncertainty: $\leq 0.3\%$ (1σ)
Data Product	Level 1A: Highest accuracy, best for inter-cal, lunar obs Level 1B: Approx. consistent spectral & spatial sampling, best for science 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



Intercalibration between CPF and VIIRS

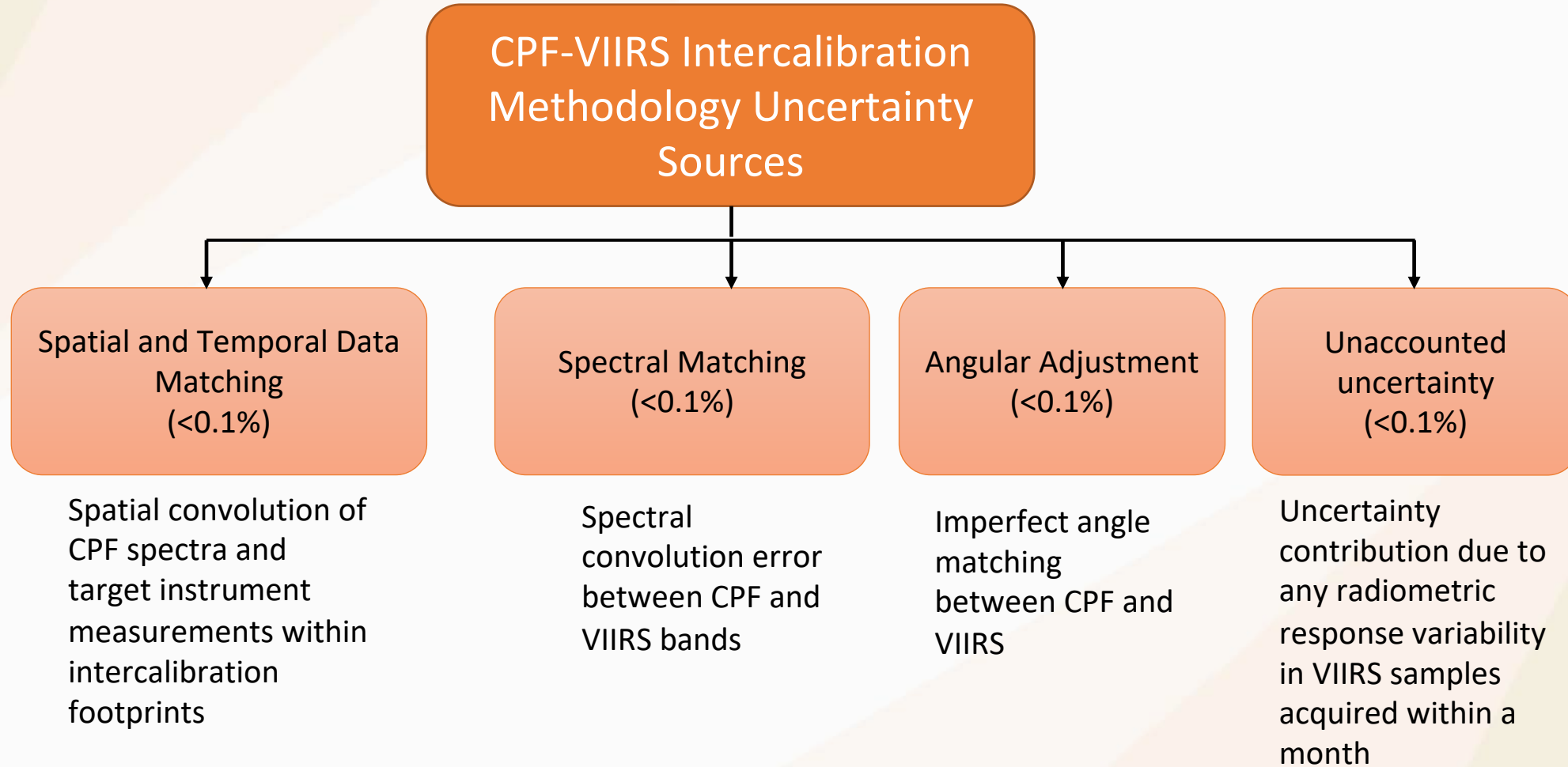


- An idealized intercalibration setup requires perfectly matched data in **time**, **space**, **angles**, and **wavelengths**
- Realistic intercalibration tolerates finite differences in sampling, thereby resulting in several sources of uncertainty
 - *Spatial mismatch*
 - *Angular differences (SZA, 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

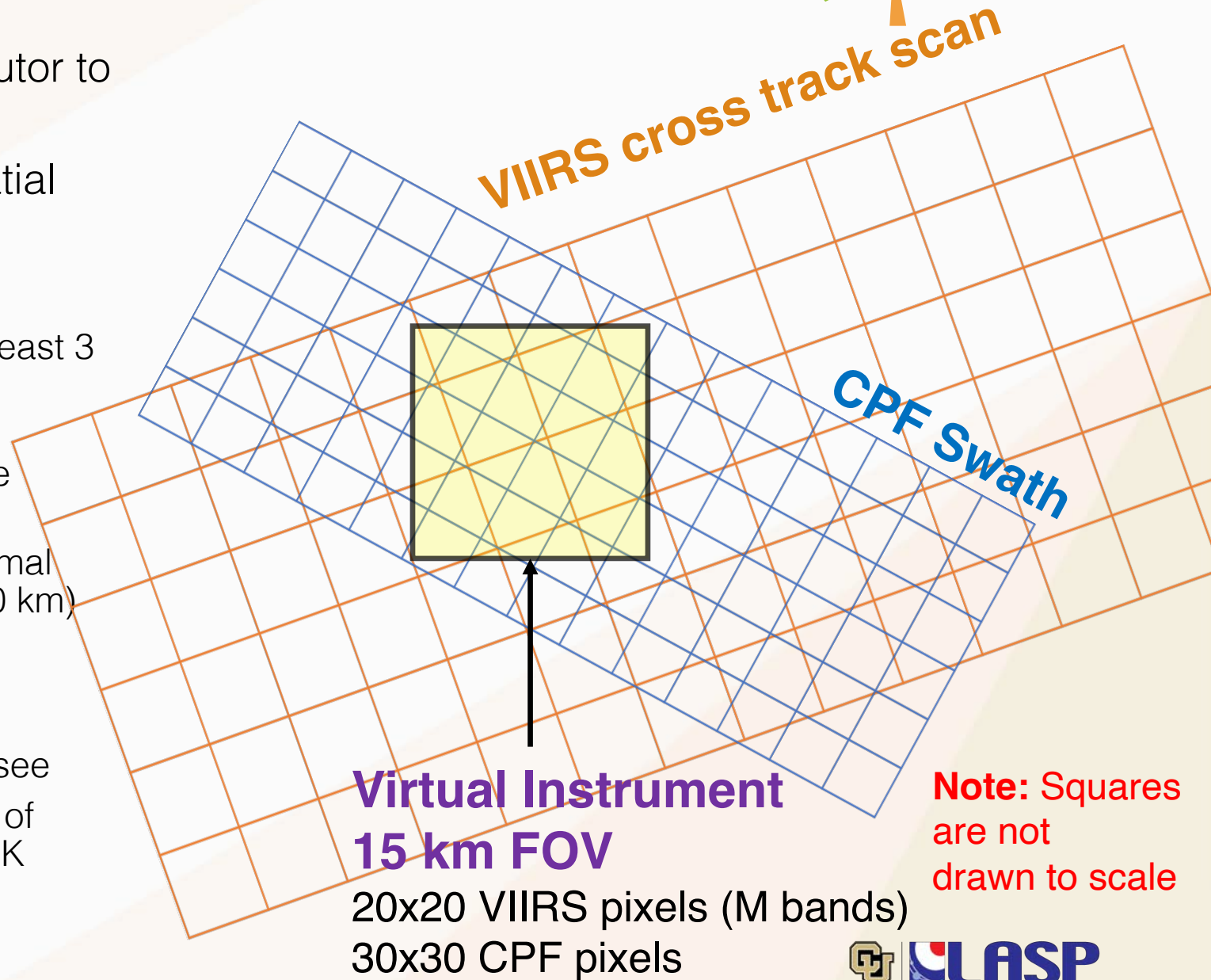




Temporal and Spatial matching noise



- Spatial mismatching is a prime contributor to uncertainty budget
- For VIIRS, 15 km (at nadir) FOV for 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

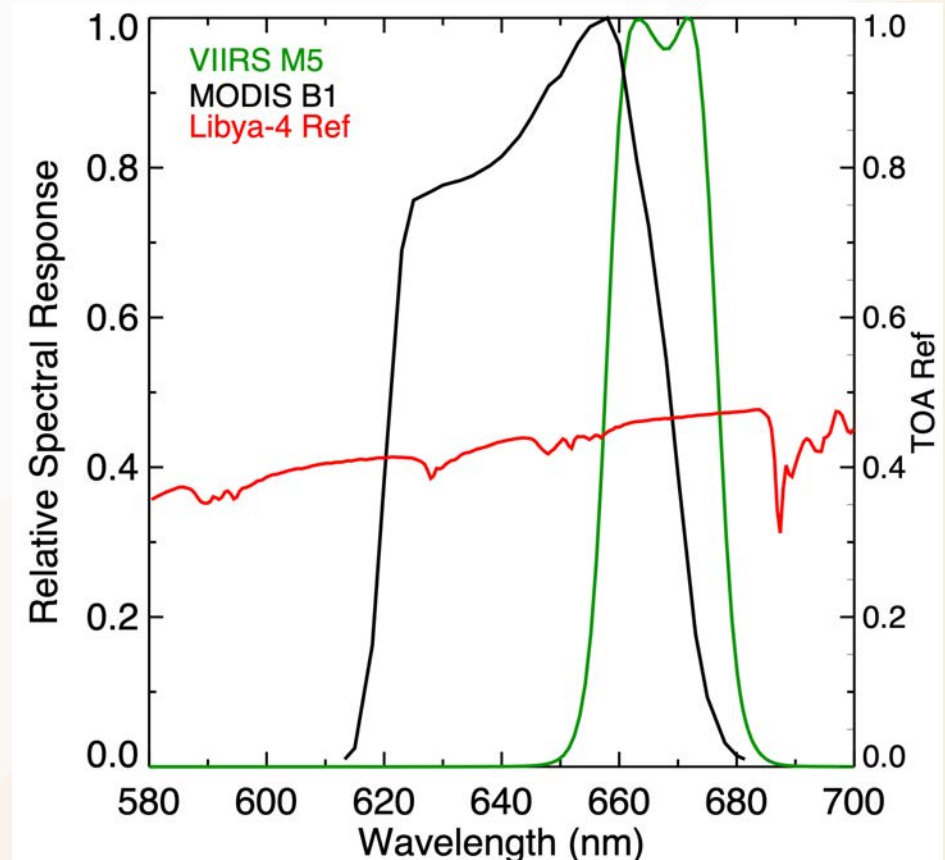
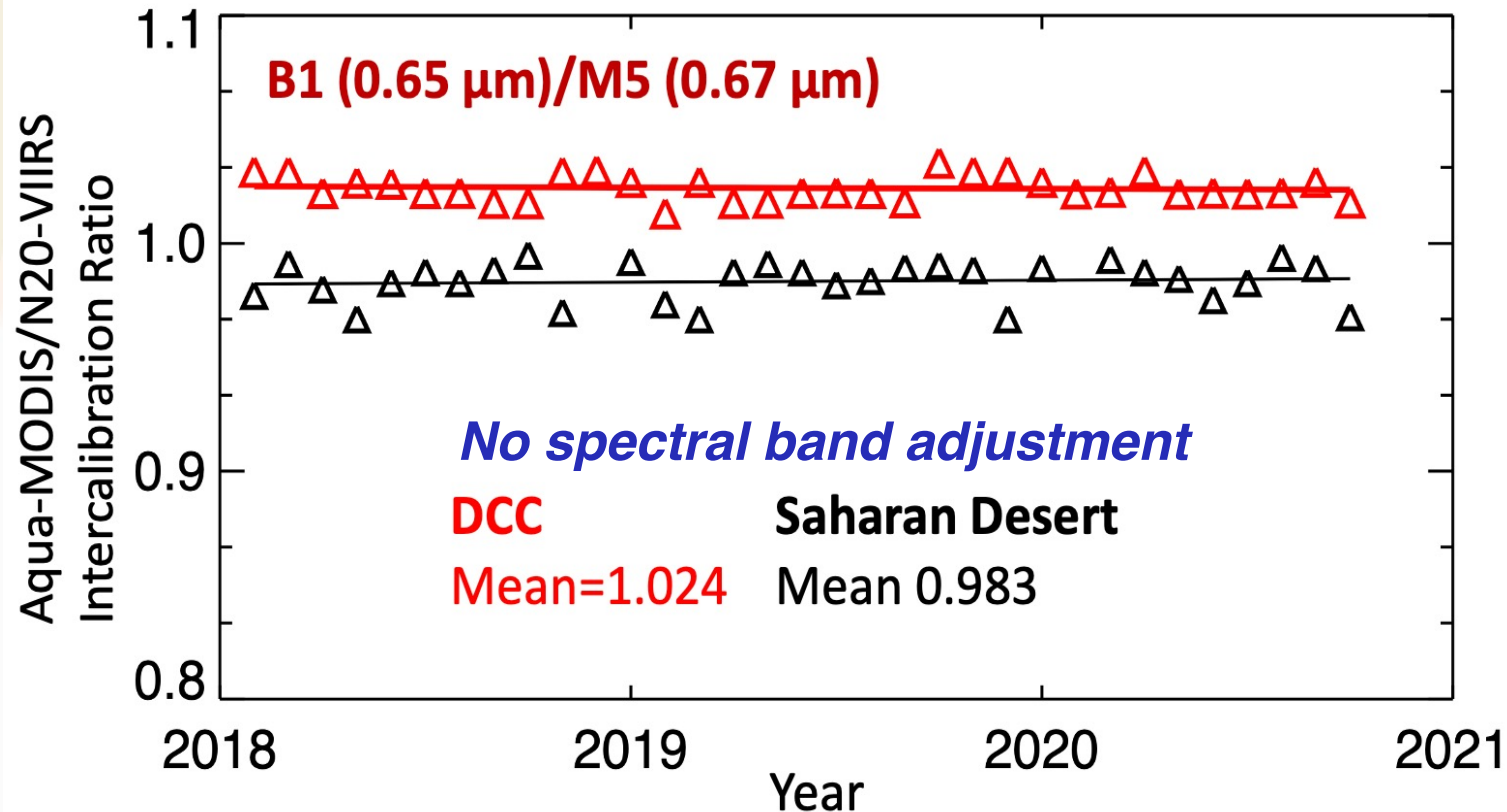




Spectral wavelength matching



- 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)



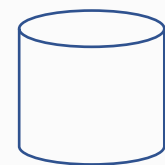


CPF-VIRS Angular Adjustment



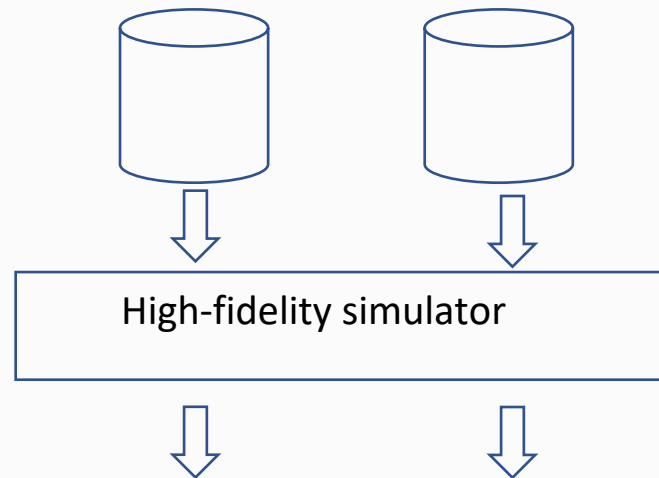
- CPF IC team has developed a PCRTM-based algorithm for angular adjustment
- Angular correction LUTs generated based on thousands of simulated CPF-like radiance spectra (randomly chosen) at different angular conditions
- Significant reduction of bias and noise after angular correction

Intercalibration event L2 data

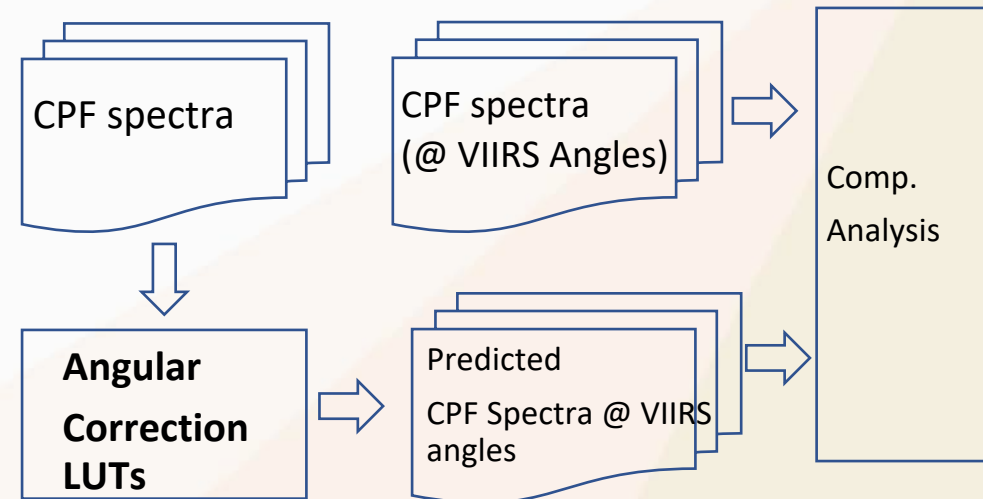


CPF angles

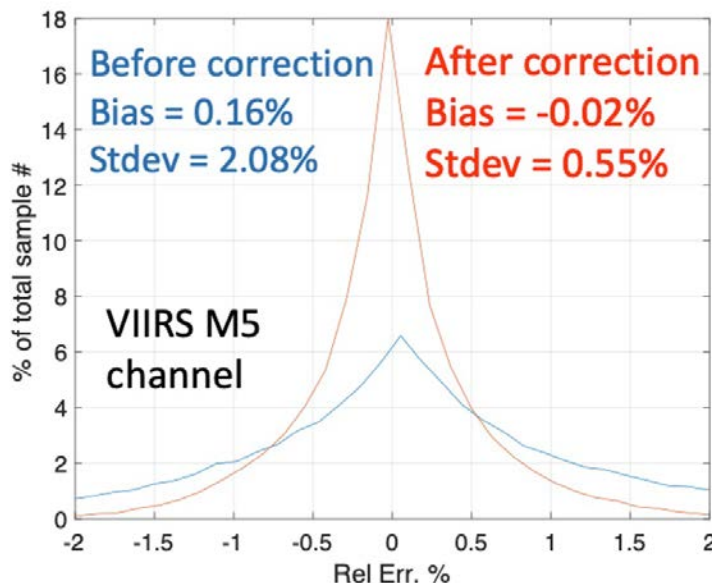
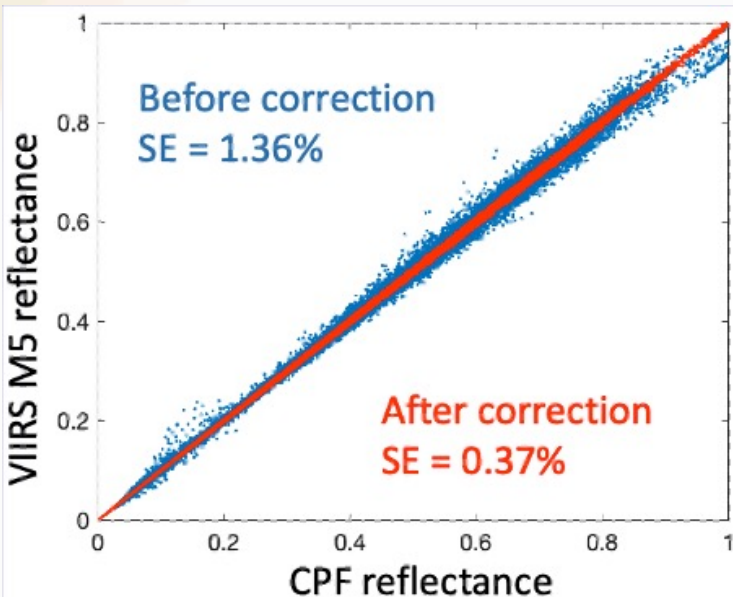
VIIRS angles



Process for evaluating our current angular adjustment algorithm

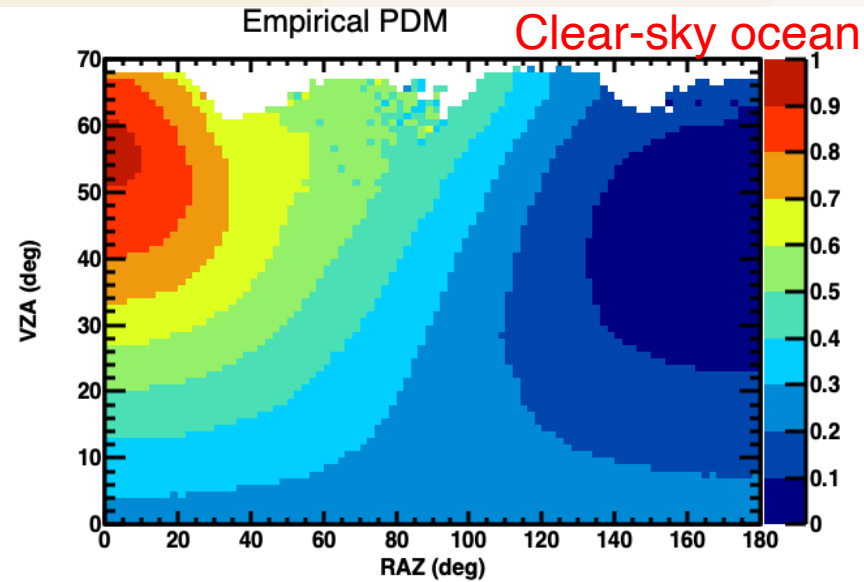


Algorithm Development: *Wan Wu & Xu Liu*





Polarization Distribution Models (PDMs)



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.

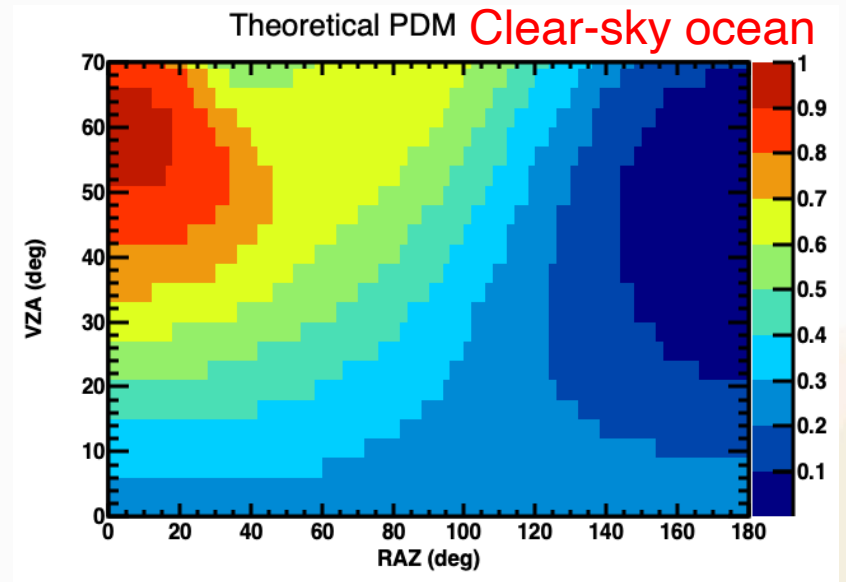
Development Lead: *Daniel Goldin*

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

Simulated by: *Wenbo Sun*

Empirical PDM Conditions:
Constructed from PARASOL/POLDER Data

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

Developed by: *Daniel Goldin & Costy Lukashin*





Intercalibration Sampling Estimates from low-fidelity simulation data



Month	Number of Samples		
	DOP<0.01	DOP<0.05	DOP<0.1
Jan	1856	21248	49463
Feb	2786	21248	49463
Mar	625	31451	58163
Apr	2051	51388	76230
May	1261	13280	30678
Jun	3091	59992	83136
Jul	292	14212	37537
Aug	1393	39657	65429
Sep	2656	29429	60853
Oct	2520	28386	60733
Nov	3088	53488	88983
Dec	1434	12625	37164

DOP: Degree of Polarization

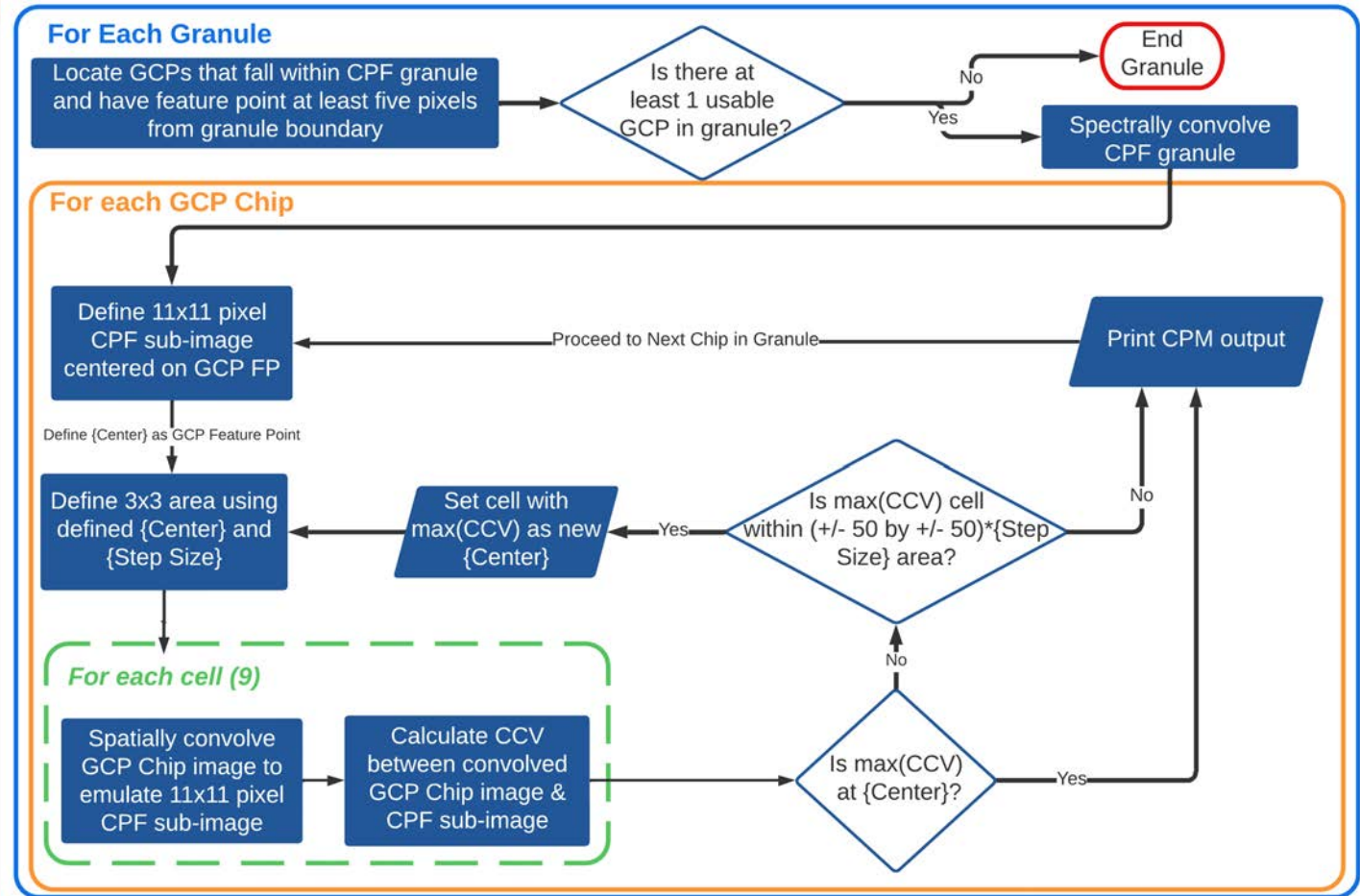




CPF Geolocation Validation - In work



- CPF Geolocation Uncertainty Requirement: 250 m ($k=1$)
 - Large uncertainties would propagate into intercalibration uncertainties -> increasing spatial matching uncertainty
- CPF Team has been working with VCST for guidance on implementing PGE560 (MODIS/VIIRS control point matching algorithm) for CPF
- Forward geolocation & validation algorithms – LASP Implementation

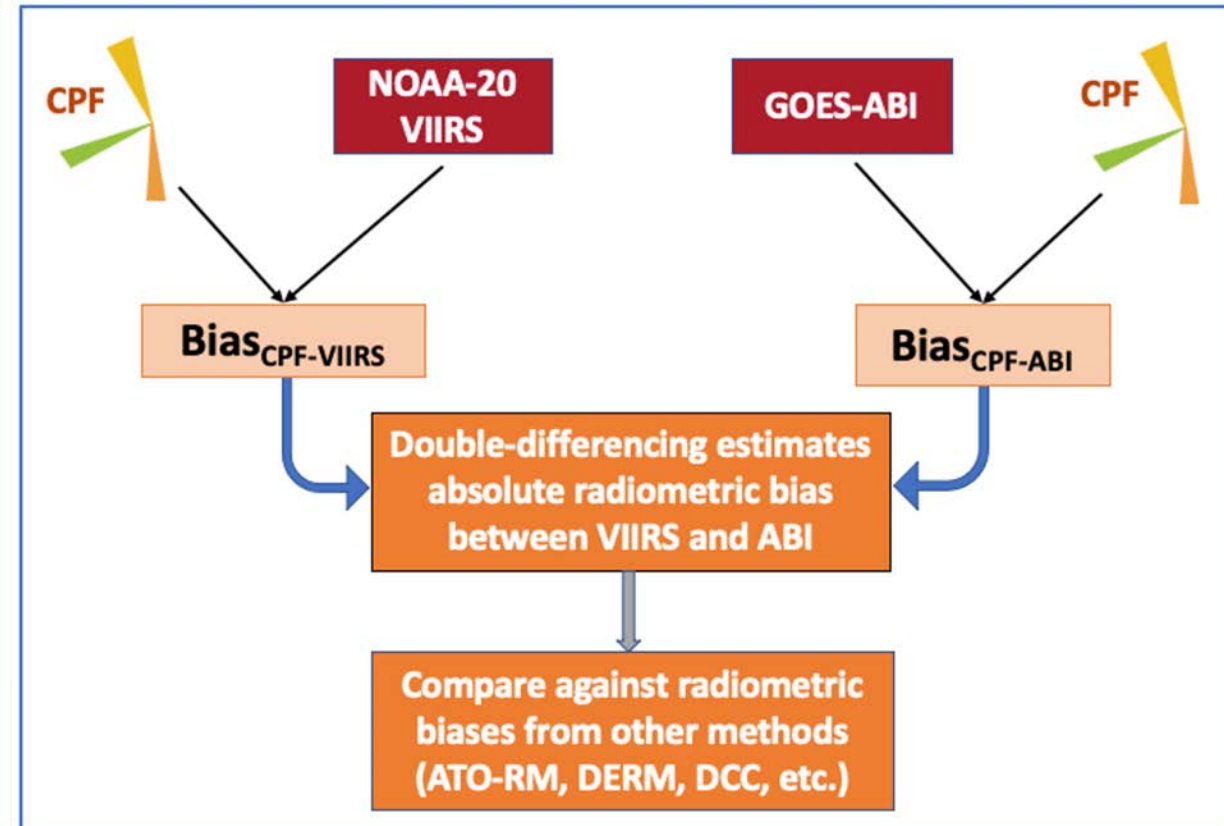
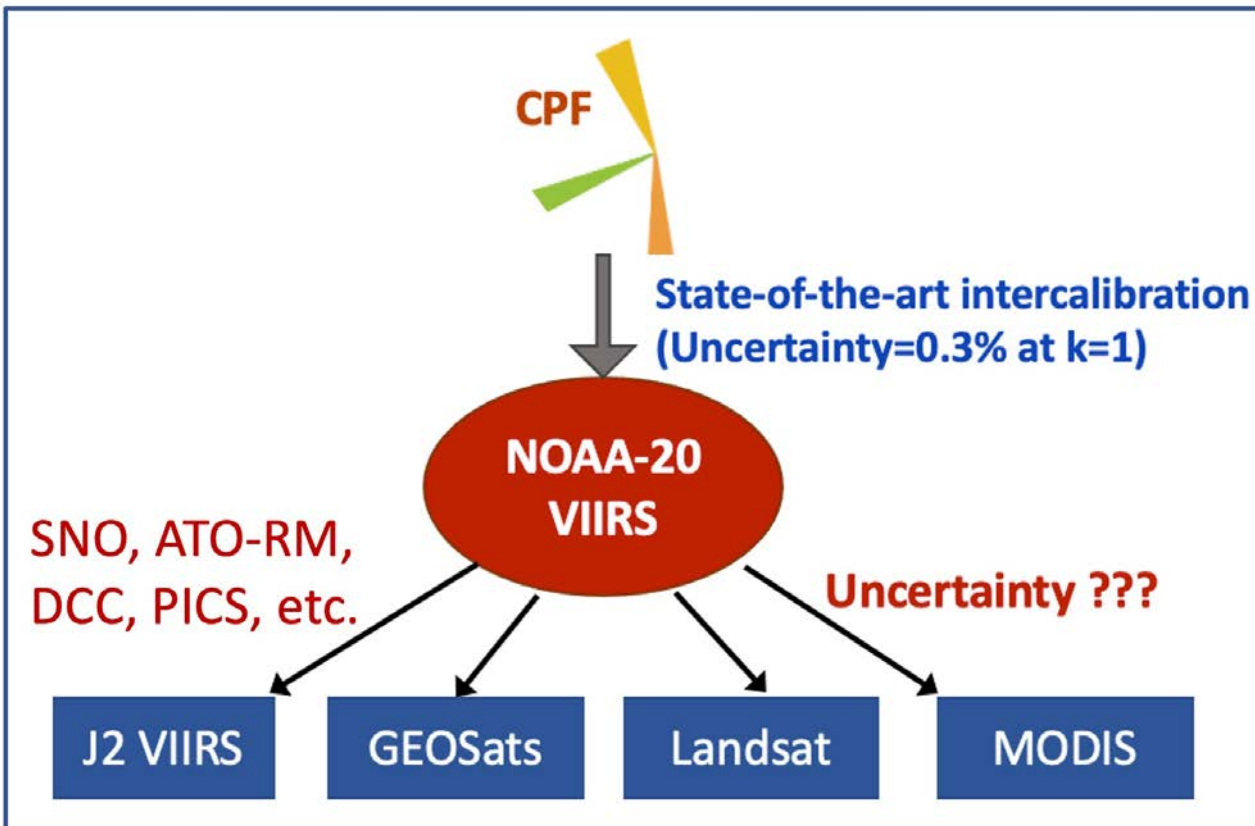




CPF benefits to Intercalibration Community



- 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 hyperspectral 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

