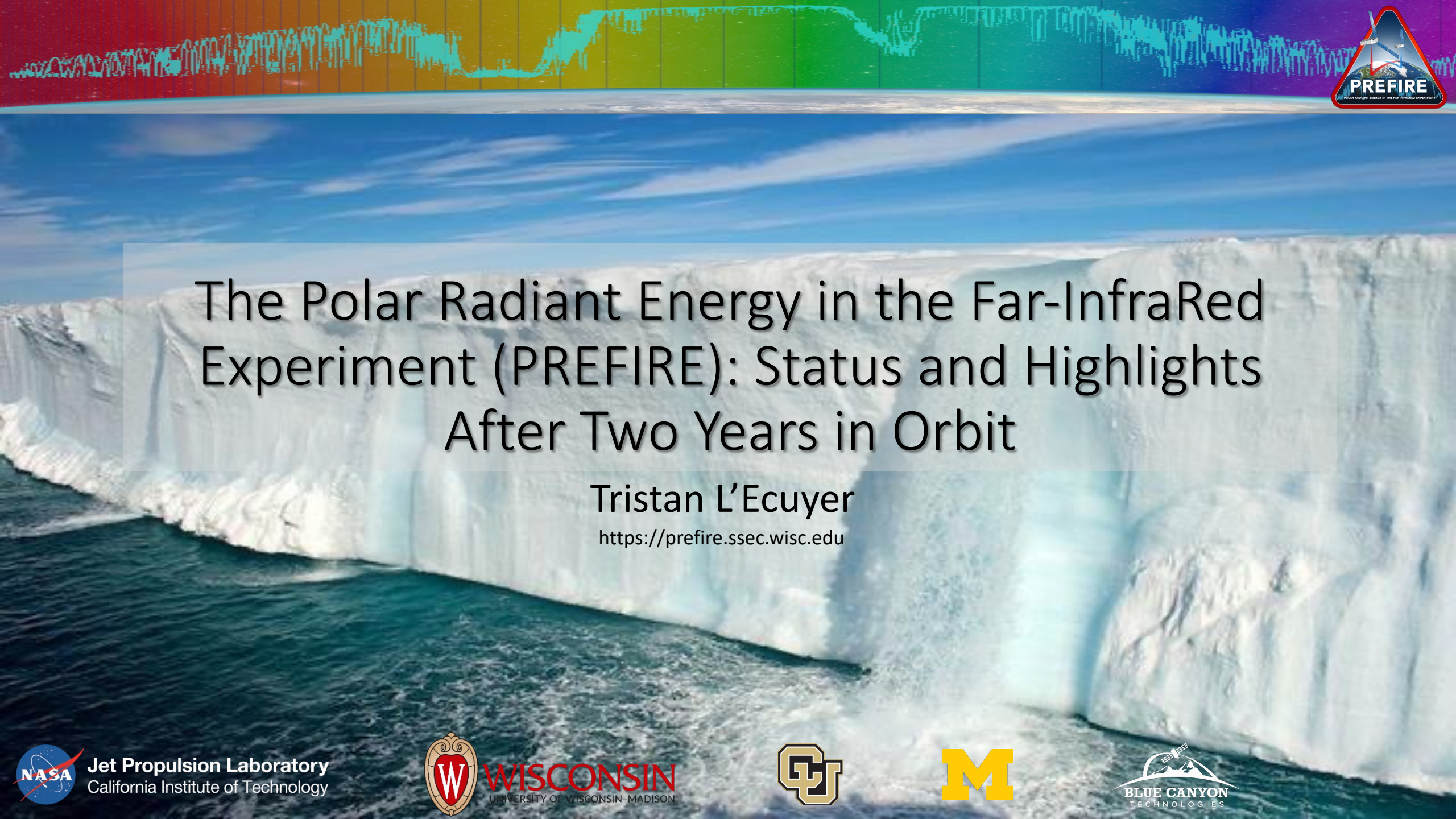


The Polar Radiant Energy in the Far-InfraRed Experiment (PREFIRE): Status and Highlights After Two Years in Orbit

Tristan L'Ecuyer

https://prefire.ssec.wisc.edu

Jet Propulsion Laboratory
California Institute of Technology

WISCONSIN
UNIVERSITY OF WISCONSIN-MADISON

BLUE CANYON
TECHNOLOGIES

The PREFIRE Team



2026 PREFIRE Science Team
Meeting Oct. 19 – 21, 2026

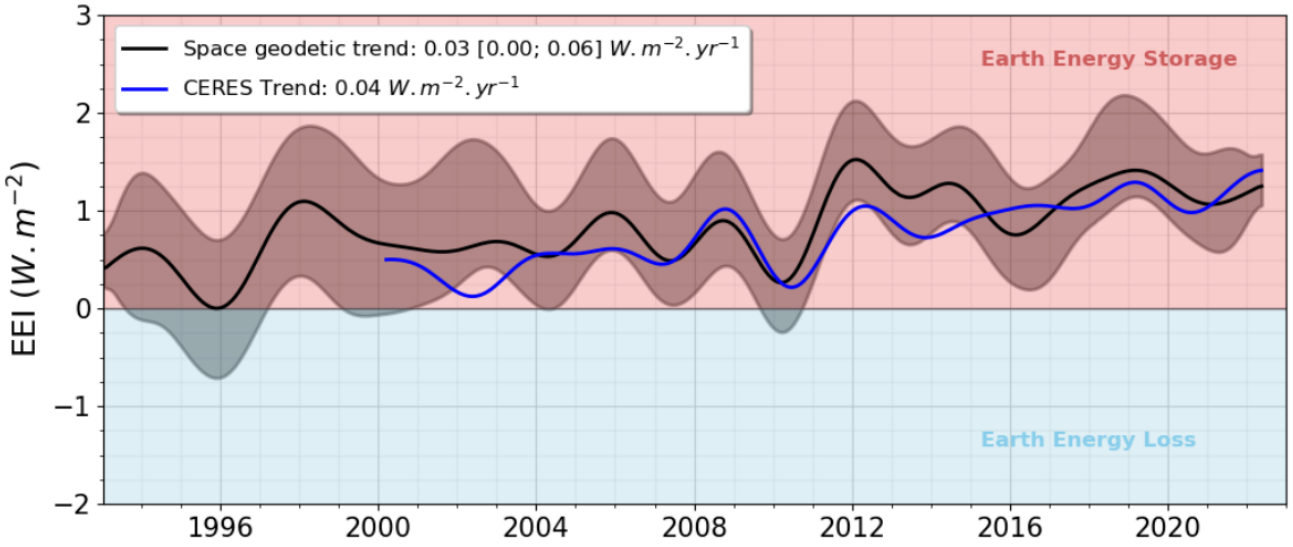


Why Are We Here?



Earth Energy Imbalance

Average: 420 Trillion Watts



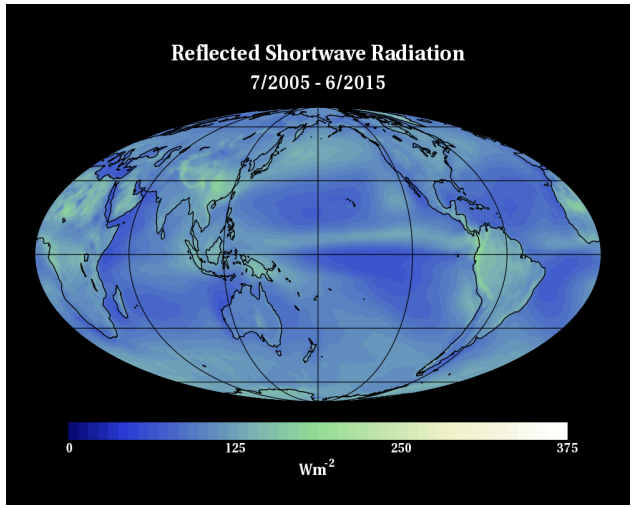
Period: 01/1993 - 05/2022
Confidence level at [5%; 95%]

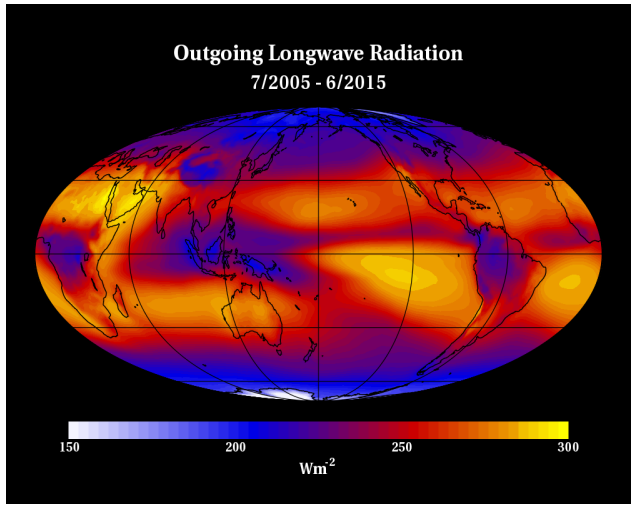
© ESA, CNES, CNRS-LEGOS, Magellium, 2023

Updated from Figure 3 of Marti et al, ESSD (2022)

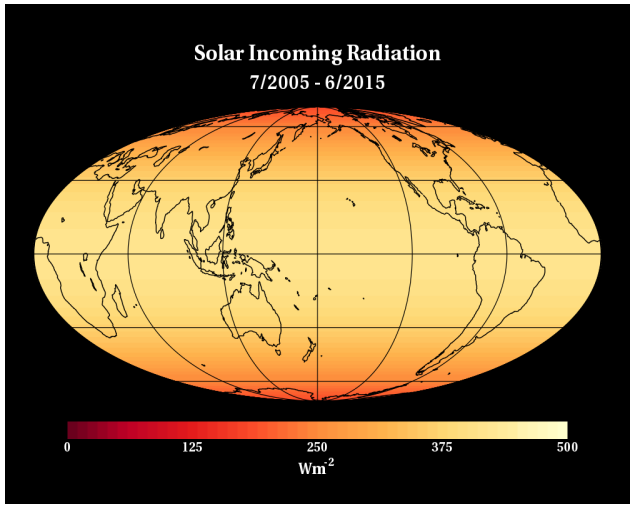
Emission Varies Spatially and Spectrally

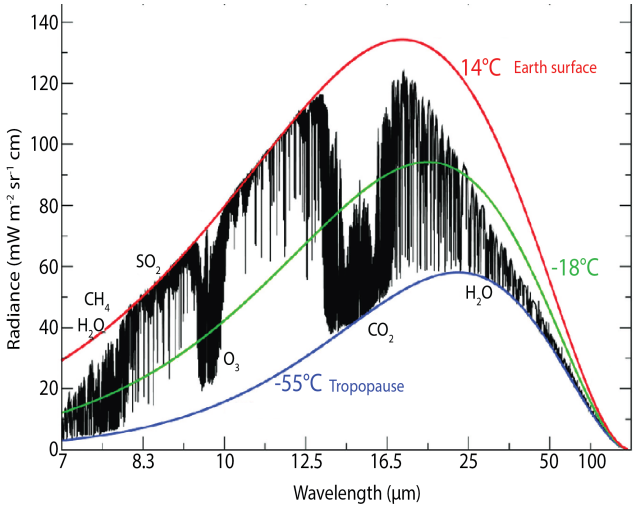
Earth's emission varies spatially, temporally, and spectrally. PREFIRE seeks to map near-complete spectra and their temporal evolution, anchored by CERES (and Libera) broadband OLR.





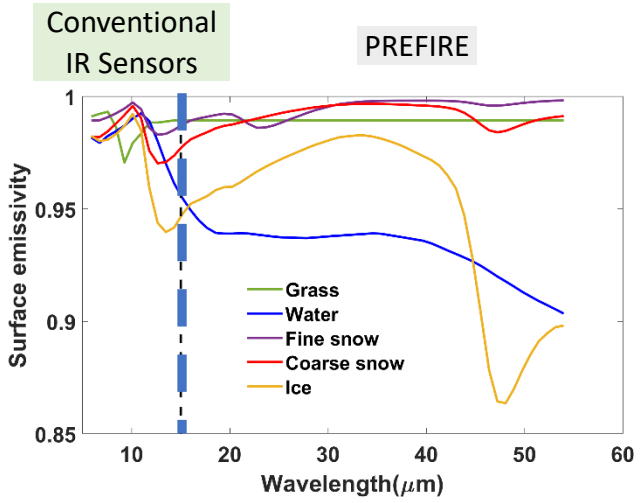




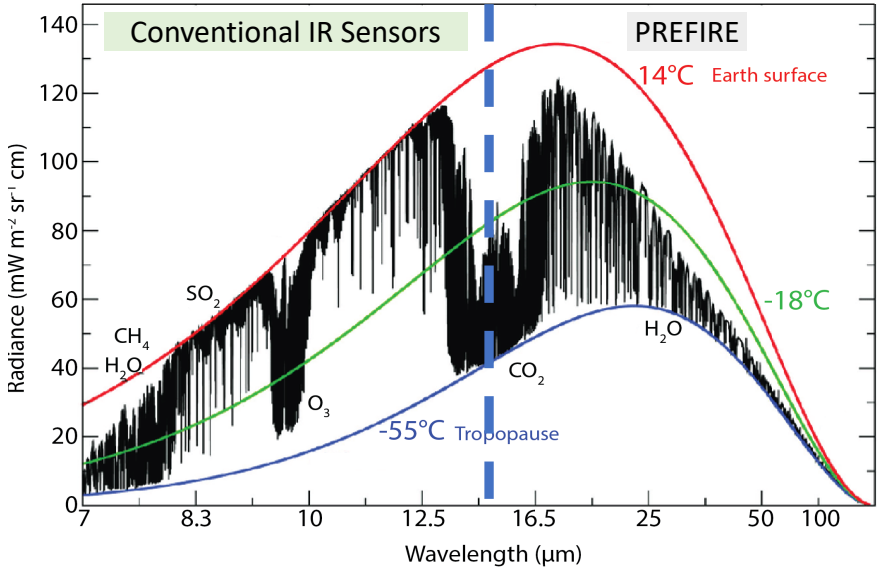


Isolating Distinct Influencing Factors

Surface

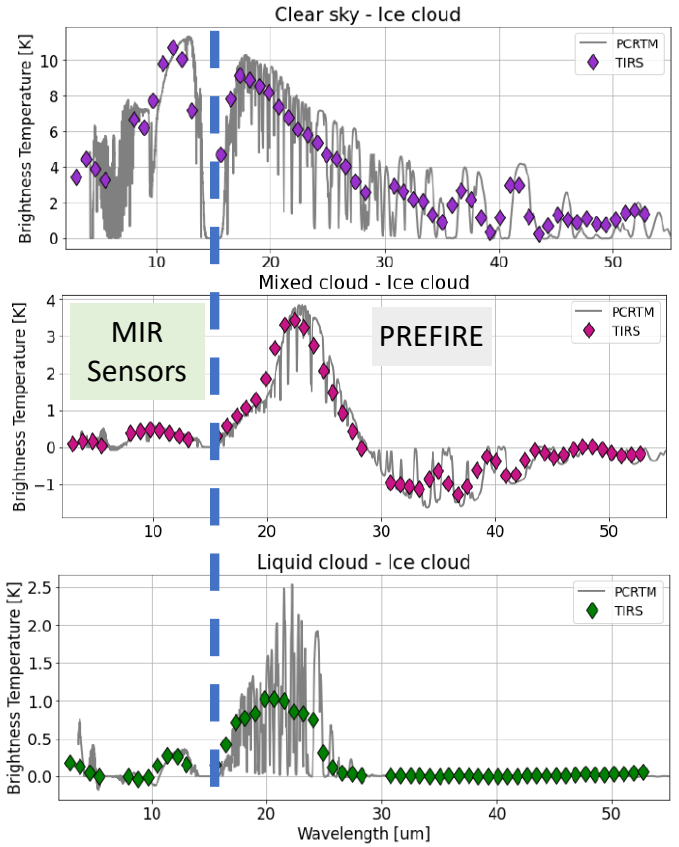


Atmosphere



Clouds

(Summit Station, Greenland, winter)



- Different surfaces, atmospheric gases, and clouds all exhibit unique spectral signatures across the full spectrum
- Far-infrared wavelengths longer than 15 μm constitute more than half of global emission but were not spectrally resolved prior to PREFIRE

PREFIRE utilizes measured spectra to isolate the factors influence Earth's emission and their space-time variations.

Polar Radiant Energy in the Far-InfraRed Experiment

PREFIRE fills the far-infrared observing gap by documenting variability in spectral fluxes from 5–53 μm on hourly to seasonal timescales.

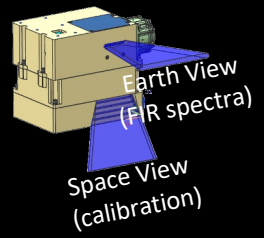
Prime Mission: July 2024–April 2025
Extended Mission: May 2025–present

Nominal Operations
Continuous global data collection
Downlink (S-band) up to 4x daily to KSAT Lite Stations at Punta Arenas and Puertollano

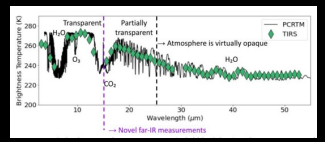
Total Lifecycle Cost through Prime Mission: $40M

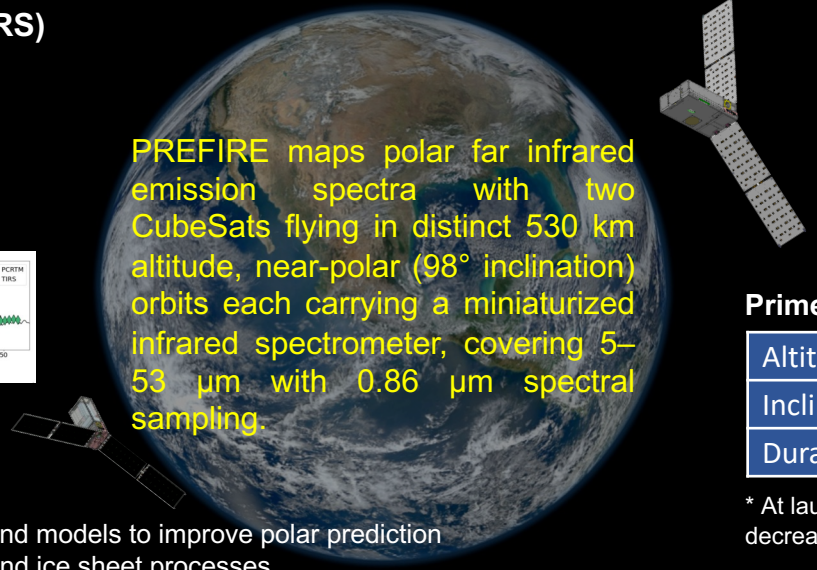
Thermal InfraRed Spectrometer (TIRS)

5 to 53 μm spectral range
0.86 μm sampling
8×64 spatial x spectral channels
Size: < 3.2U Mass: 2.7 kg Power: 4.3 W



TIRS Spectrum

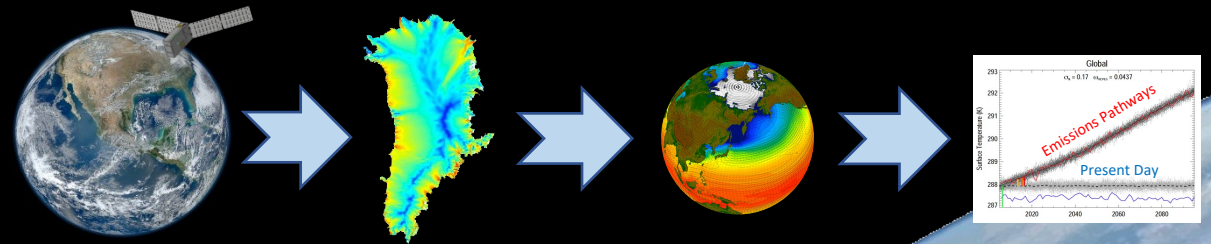




PREFIRE maps polar far infrared emission spectra with two CubeSats flying in distinct 530 km altitude, near-polar (98° inclination) orbits each carrying a miniaturized infrared spectrometer, covering 5–53 μm with 0.86 μm spectral sampling.

PREFIRE Science

PREFIRE connects observations, analyses, and models to improve polar prediction including Arctic temperatures,sea ice cover, and ice sheet processes



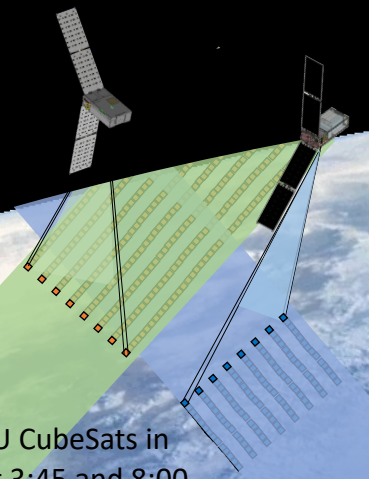
Prime Mission

Altitude*	530 km
Inclination	98°
Duration	10 months

* At launch. CubeSat altitude decreases over time.

Overlapping Measurements

Co-located ground scenes separated by 1–12 hours



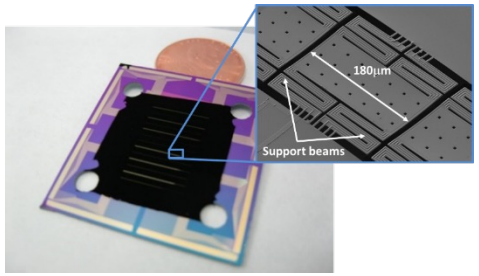
Two 6U CubeSats in orbits at 3:45 and 8:00 reveal the fingerprints of polar processes

L'Ecuyer et al., *BAMS* (2021)

https://prefire.ssec.wisc.edu

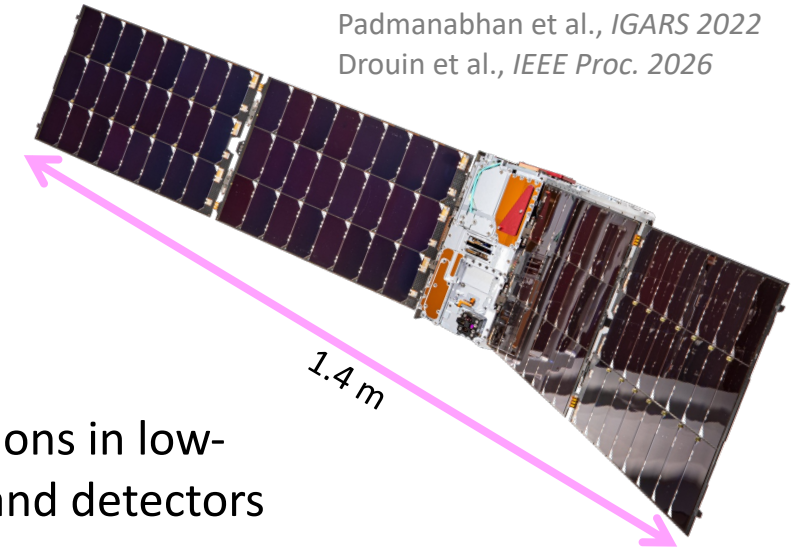
PREFIRE: Economical, Efficient, and Innovative

Drouin et al., *Earth and Space Sciences 2025*

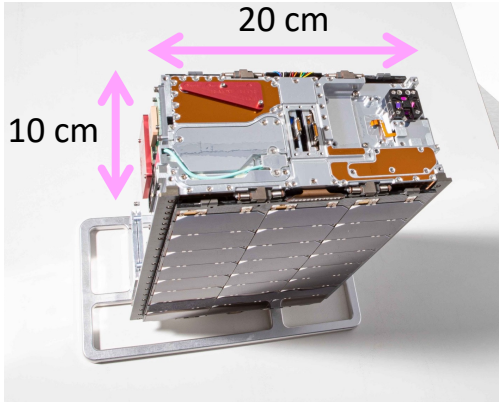




Padmanabhan et al., *IGARS 2022*
Drouin et al., *IEEE Proc. 2026*



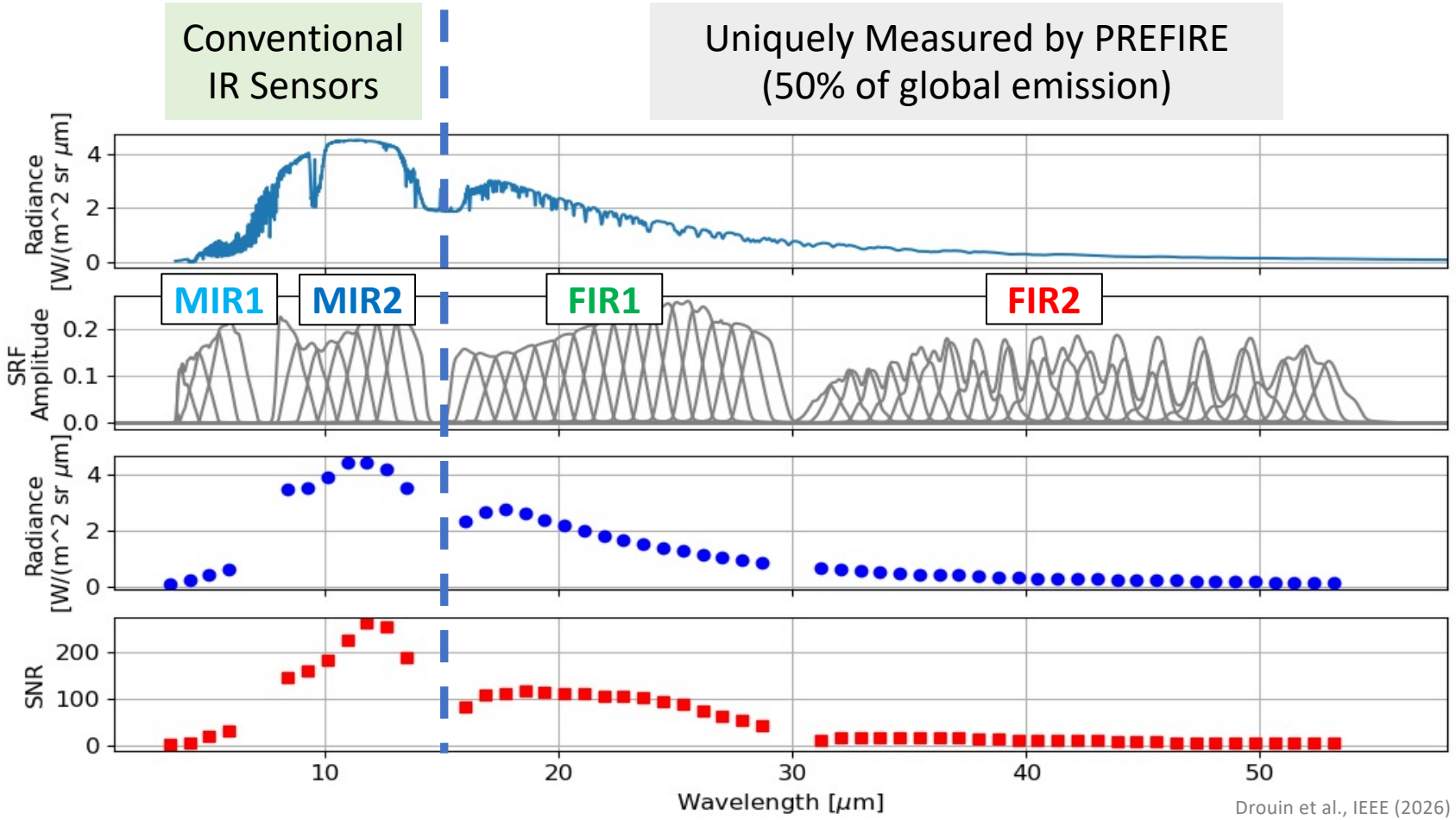
- PREFIRE stimulated technological innovations in low-power, miniaturized optical components and detectors
- PREFIRE is pioneering scientific measurements from low-cost, commercial off the shelf (CoTS) platforms
- PREFIRE has supported industry initiatives to improve CubeSat technology and demonstrate new commercial launch capabilities
- PREFIRE uses interpretable machine-learning methods to keep computational costs low and data yields high



Two 6U CubeSats
(1U = 10x10x10cm)



PREFIRE Measures Complete Emission Spectra Globally



Drouin et al., IEEE (2026)

PREFIRE's Thermal InfraRed Spectrometers (TIRS) make spectrally-resolved measurements throughout the mid- and far-infrared (5–53 μm) at 0.86 μm sampling covering >95% of Earth's emission.

PREFIRE Launches

Rocket Lab LC-1, Mahia, New Zealand



May 25, 2024 7:41 pm NZST



June 5, 2024 3:15 pm NZST

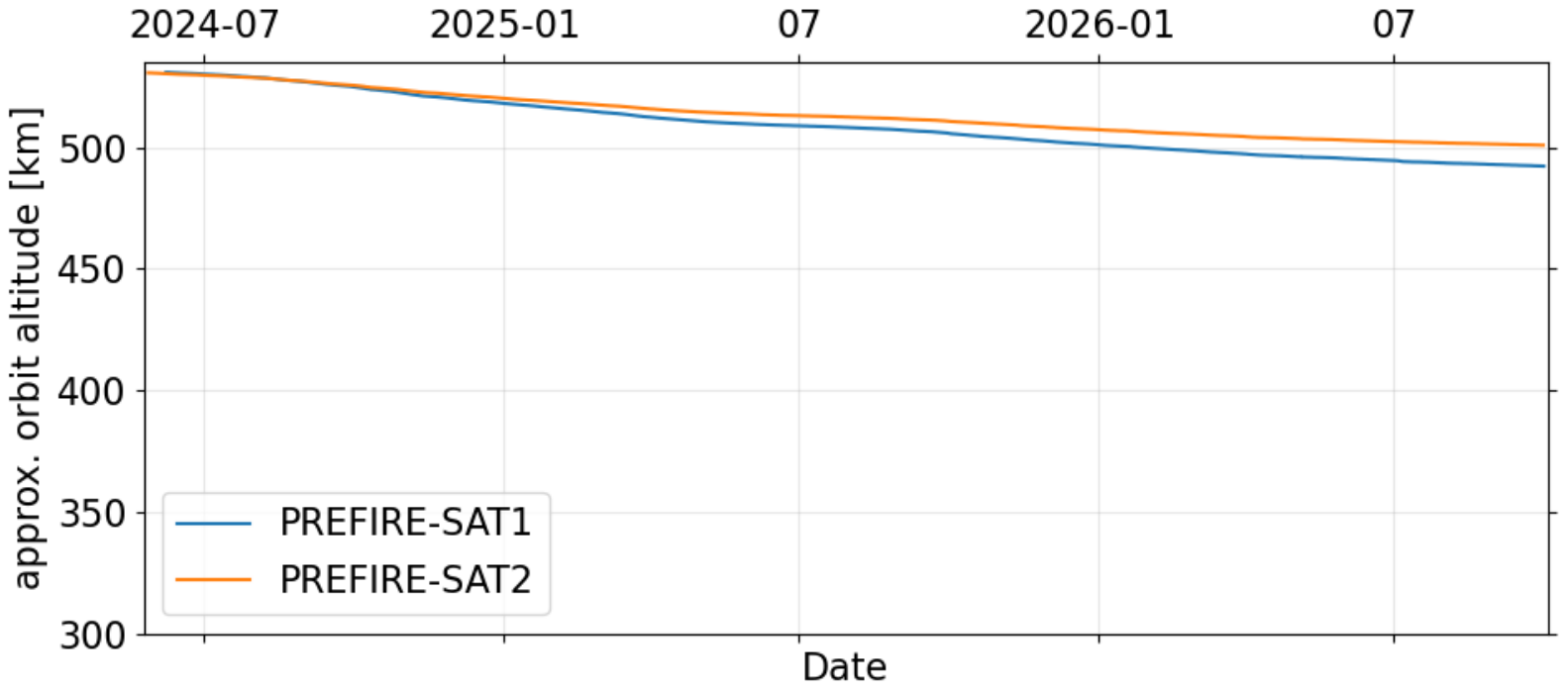


PREFIRE Orbit Evolution

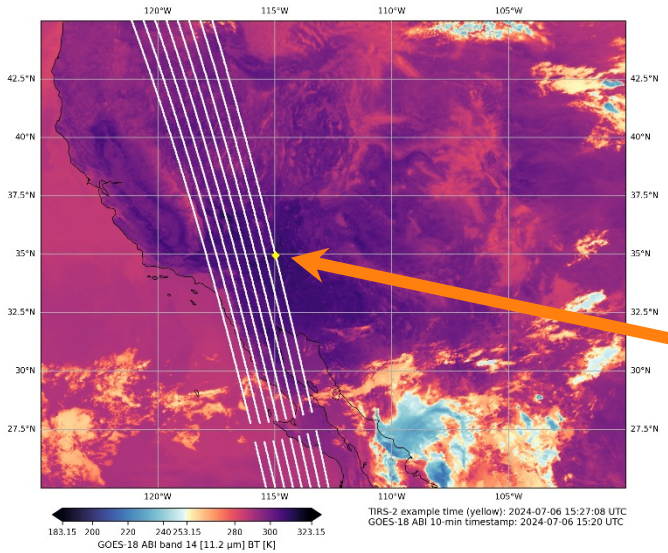
- The PREFIRE CubeSats are slowly drifting to lower altitudes due to drag
- Drag is now considerably less than after launch due to reduced solar activity
- SAT-1 is experiencing more drag than SAT-2 due to its 3:45 am/pm orbit
- Both satellites are projected to remain viable through <u>at least 2030</u>

Initial altitude ~530 km

Attitude control compromised ~350 km

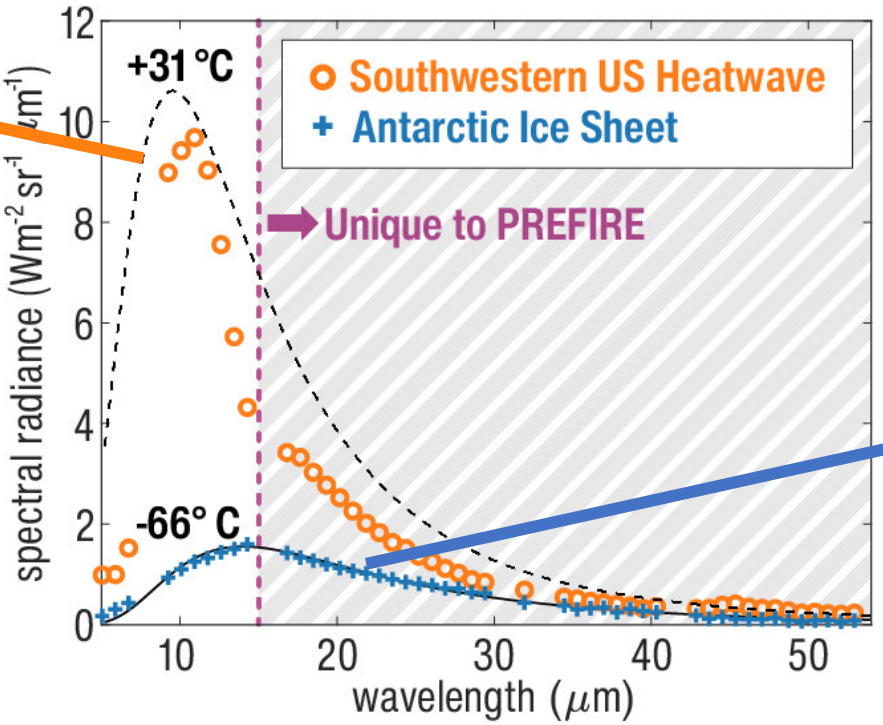


Example Emission Spectra (July 6, 2024)

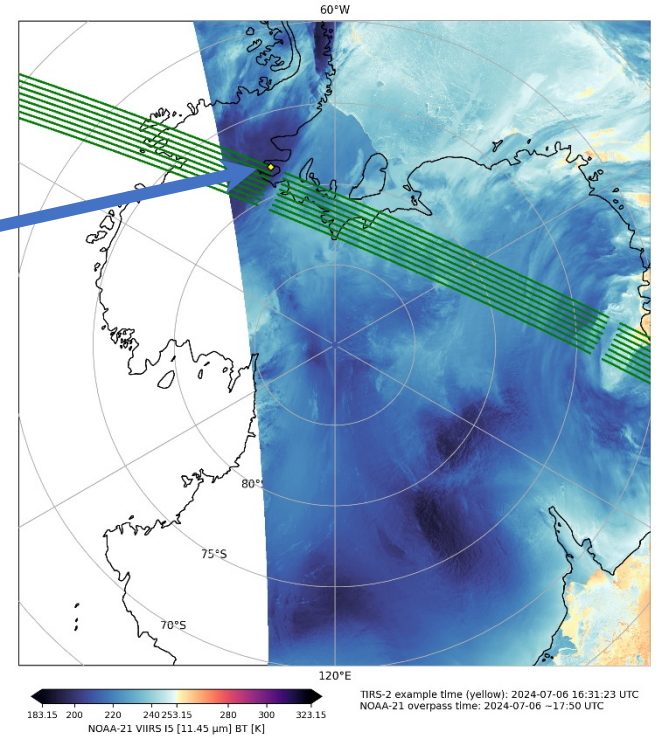


Extreme heat in the Southwestern U.S.

Emission Spectra Spanning ~100°C in One Orbit

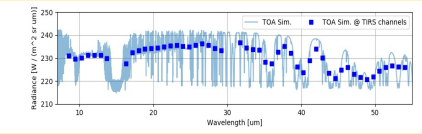
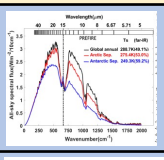
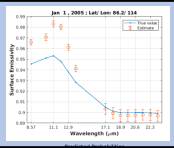
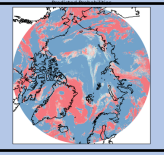
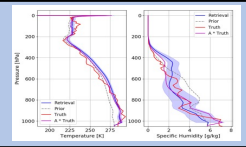
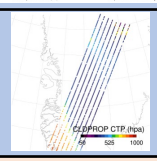
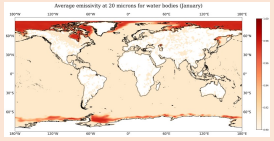


Cold Winter Temperatures in Antarctica



PREFIRE has collected > 1.4 billion spectra … and counting

What Are We Doing with the Measurements?

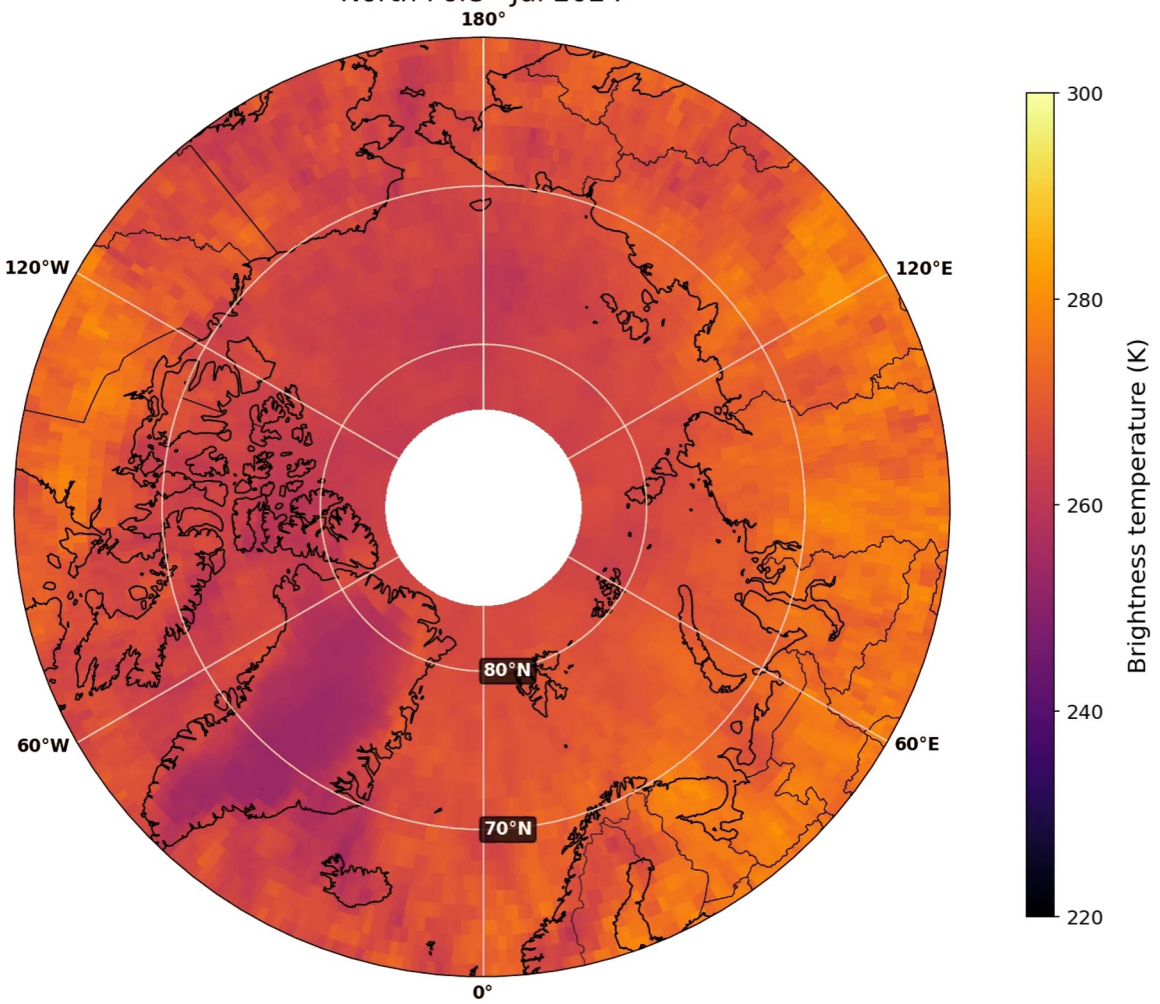
Product	Contact	Details	Examples
L0 (telemetry+ instrument)	B. Drouin	Time-stamped instrument and spacecraft data	
L1B Radiances/ Fluxes	B. Drouin	Instrument model	
L2B Flux	X. Huang	3% accuracy (8 W/m^2 for total and 4 W/m^2 for FIR)	
L2B Surface Emissivity	X. Huang	1% accuracy spectral emissivity	
L2B Cloud Mask	B. Kahn and C. Bertossa	Detect 80-90% of clear-sky occurrences; confidence flags; MODIS and AIRS heritage	
L2B Atmospheric Properties	A. Merrelli	T/q profiles; 10% accuracy for column water vapor	
L2B Cloud Properties	N. Miller	Cloud top pressure, cloud optical thickness, effective cloud fraction Cloud phase, ice particle size	
L3 Gridded Climatology	N. Vos	Daily and monthly gridded products for each CubeSat	

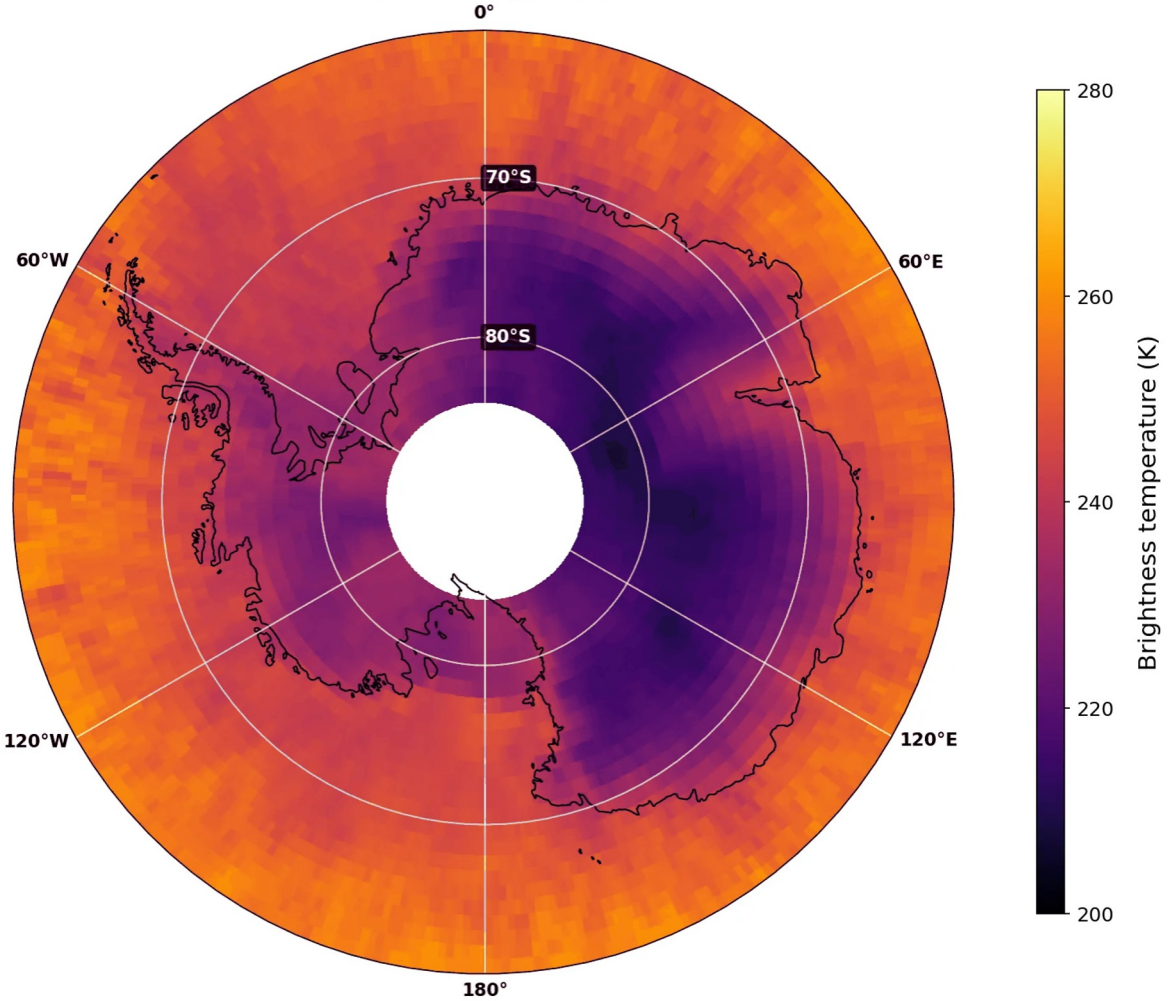

PREFIRE
Spectral Radiances
NASA
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Annual Cycles of Polar Emission (Jul ’24 – Aug ’26)

Wenyuan Du

11 µm





Two Annual Cycles of Arctic Emission (Jul ’24 – Aug ’26)

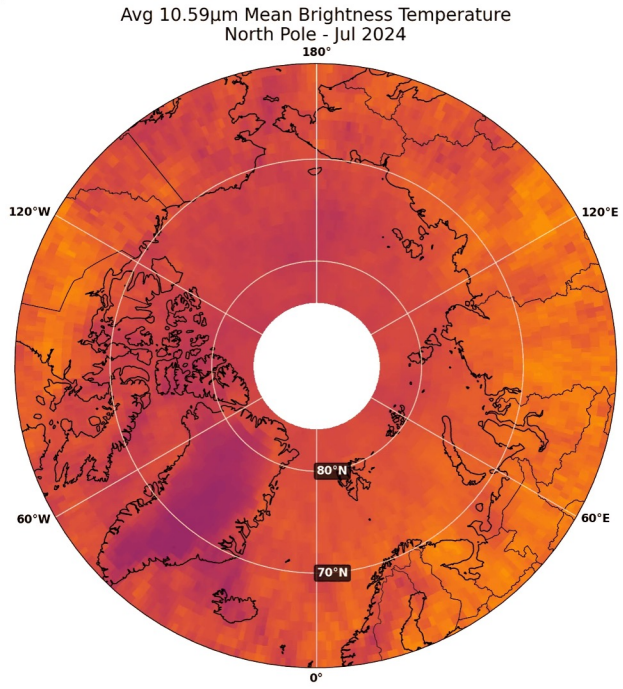
Wenyuan Du

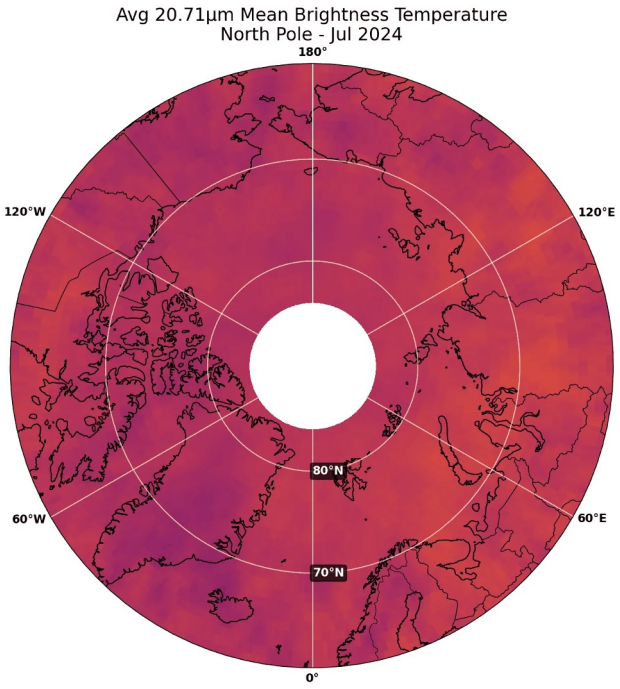
10.6 µm

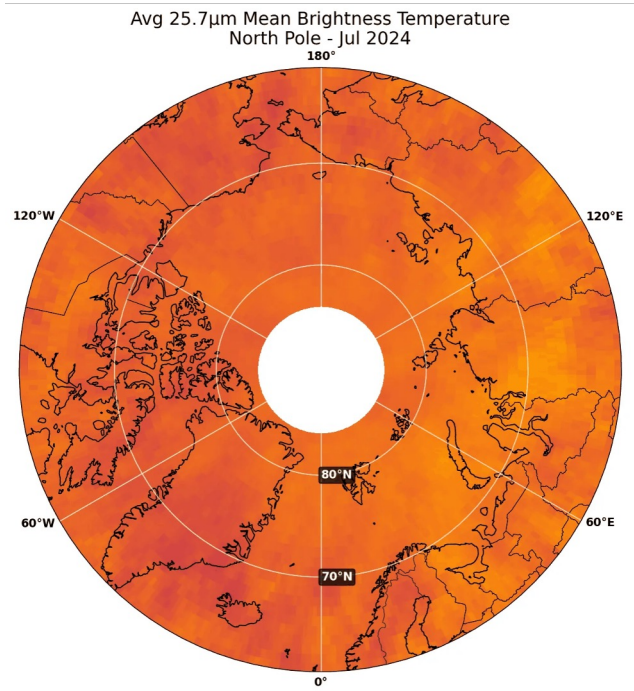
20.7 µm

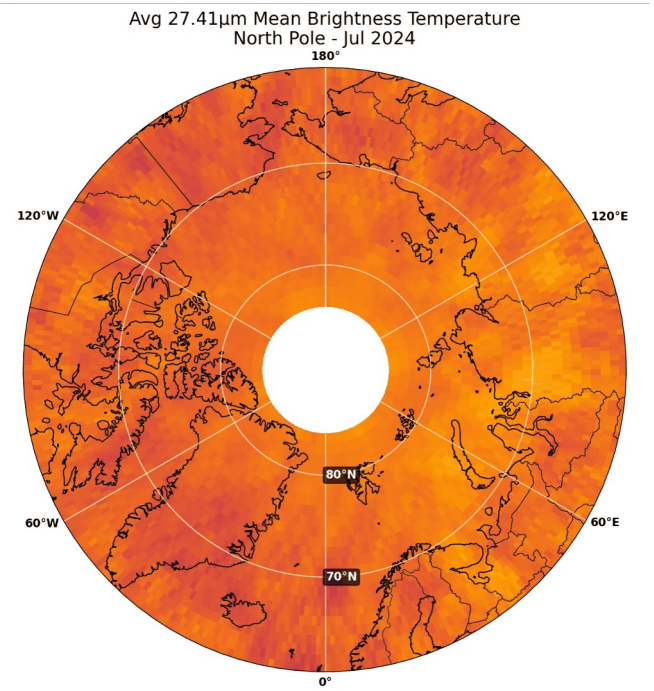
25.7 µm

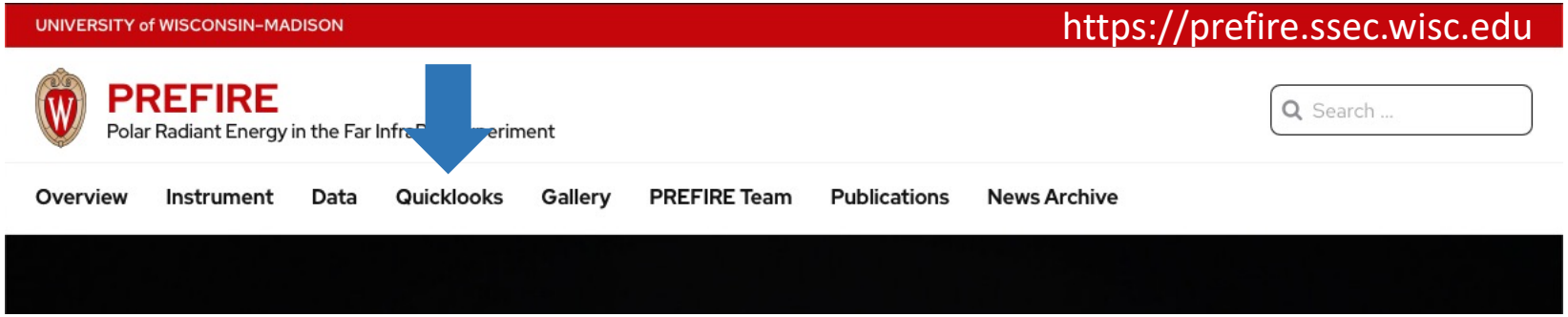
27.4 µm







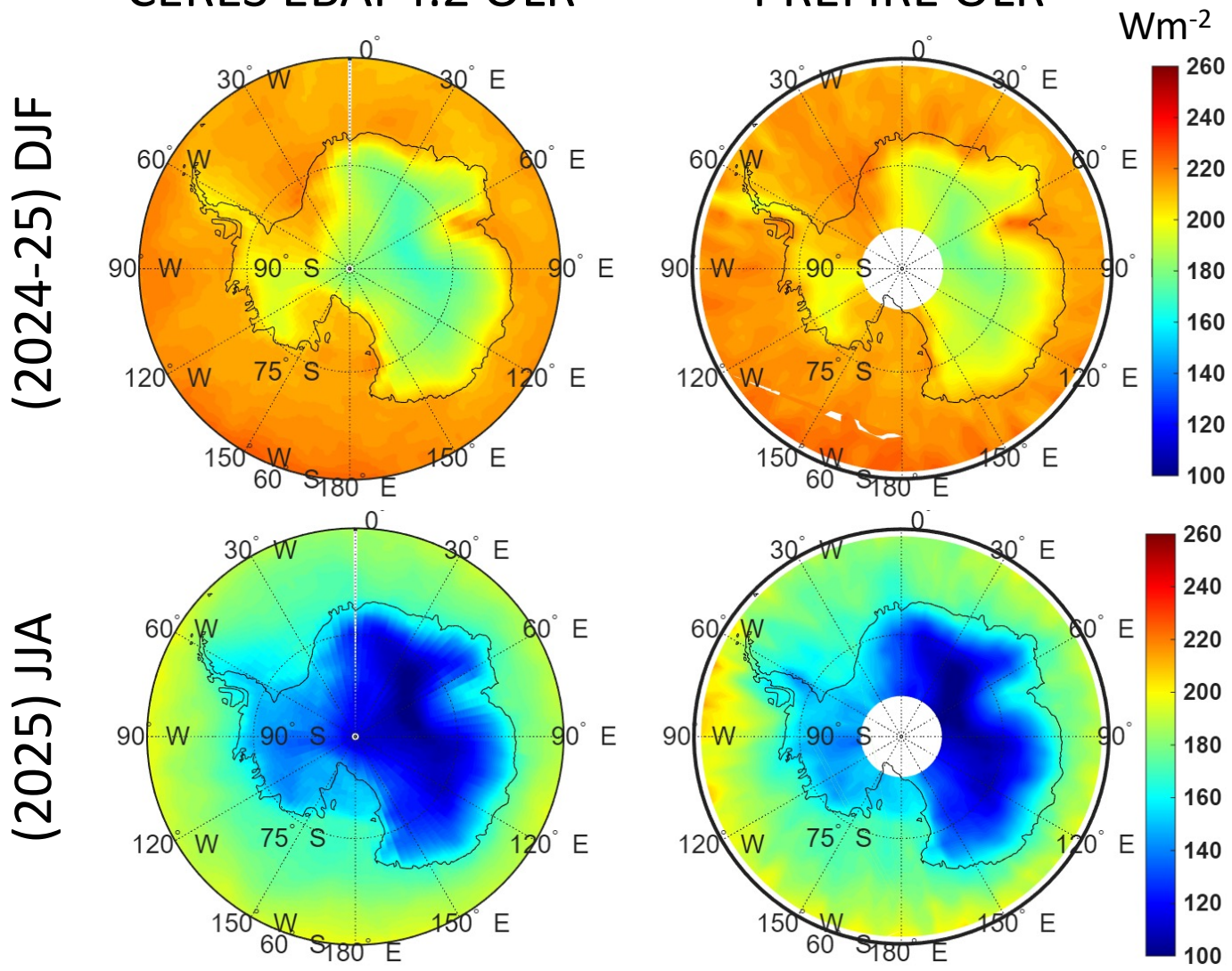




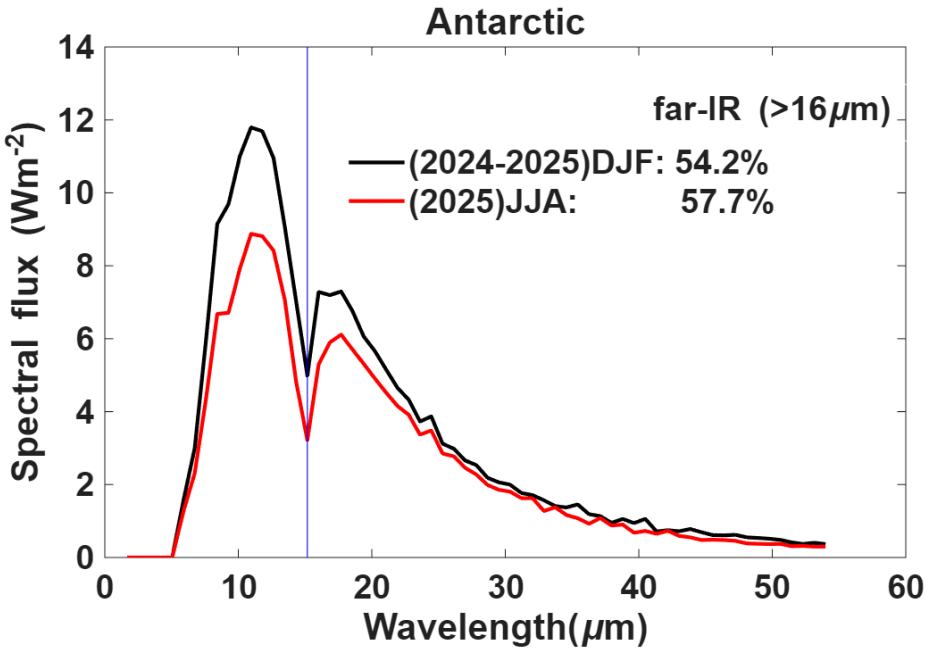

PREFIRE
Spectral Fluxes
NASA
Jet Propulsion Laboratory
California Institute of Technology
WISCONSIN
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BLUE CANYON
TECHNOLOGIES

Spectrally Resolving Earth's OLR

Xianglei Huang and Xiuhong Chen

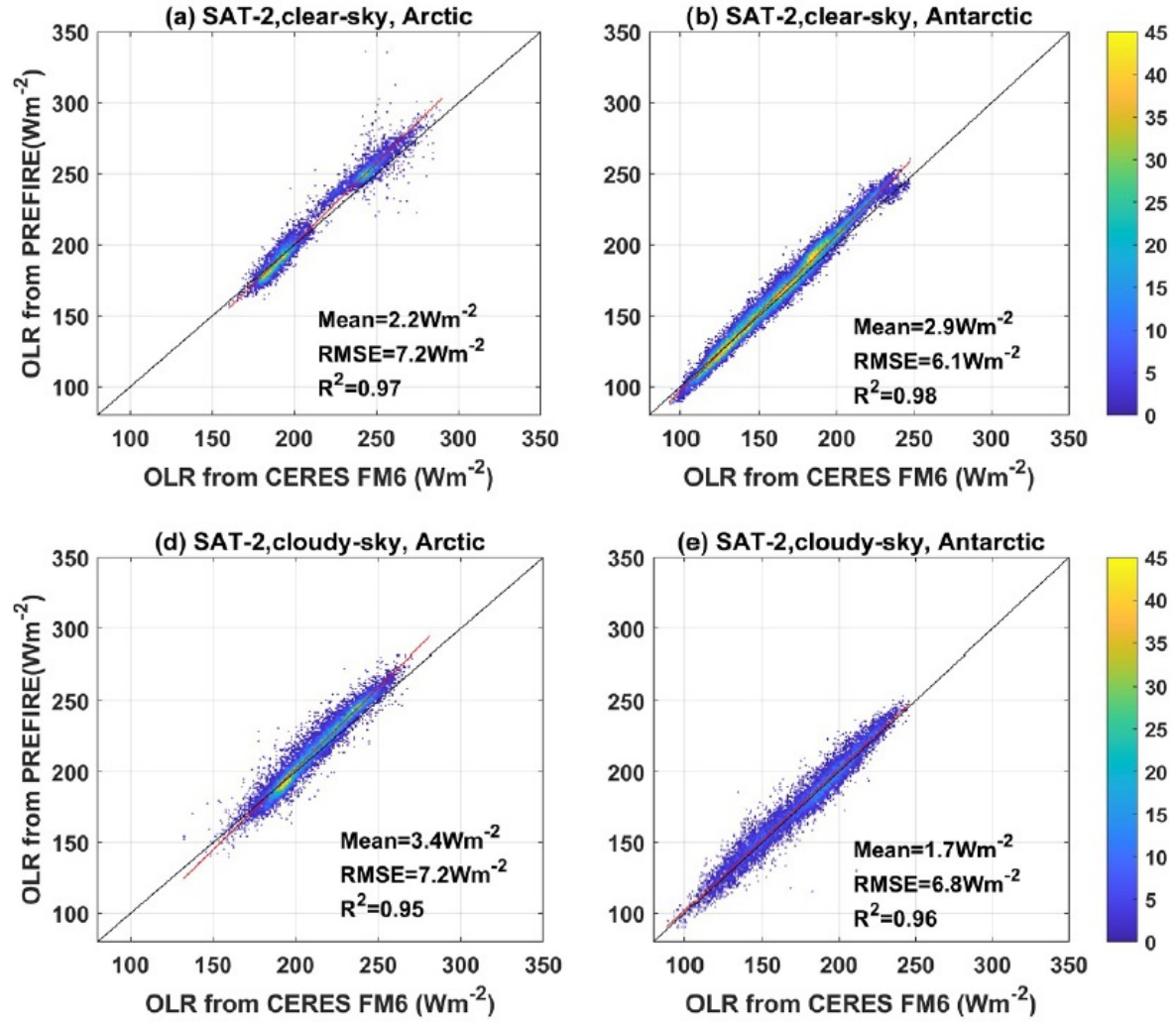


Antarctic Mean Spectral Flux

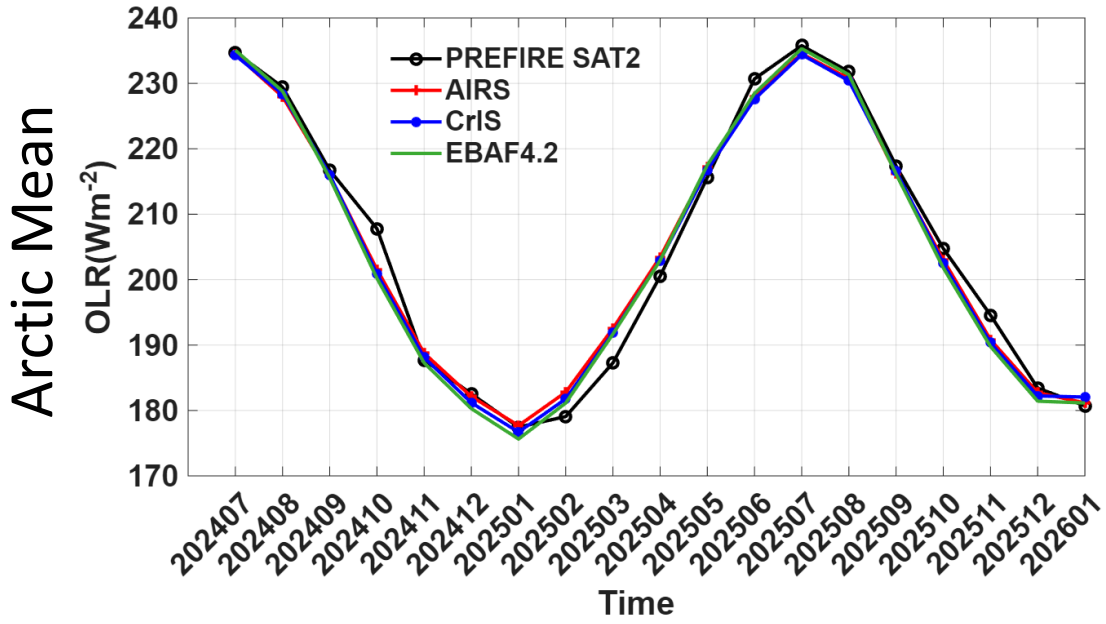


CERES Anchors PREFIRE Broadband OLR

Comparisons with Collocated CERES FM6 SSF



Temporal Monitoring Over the Arctic

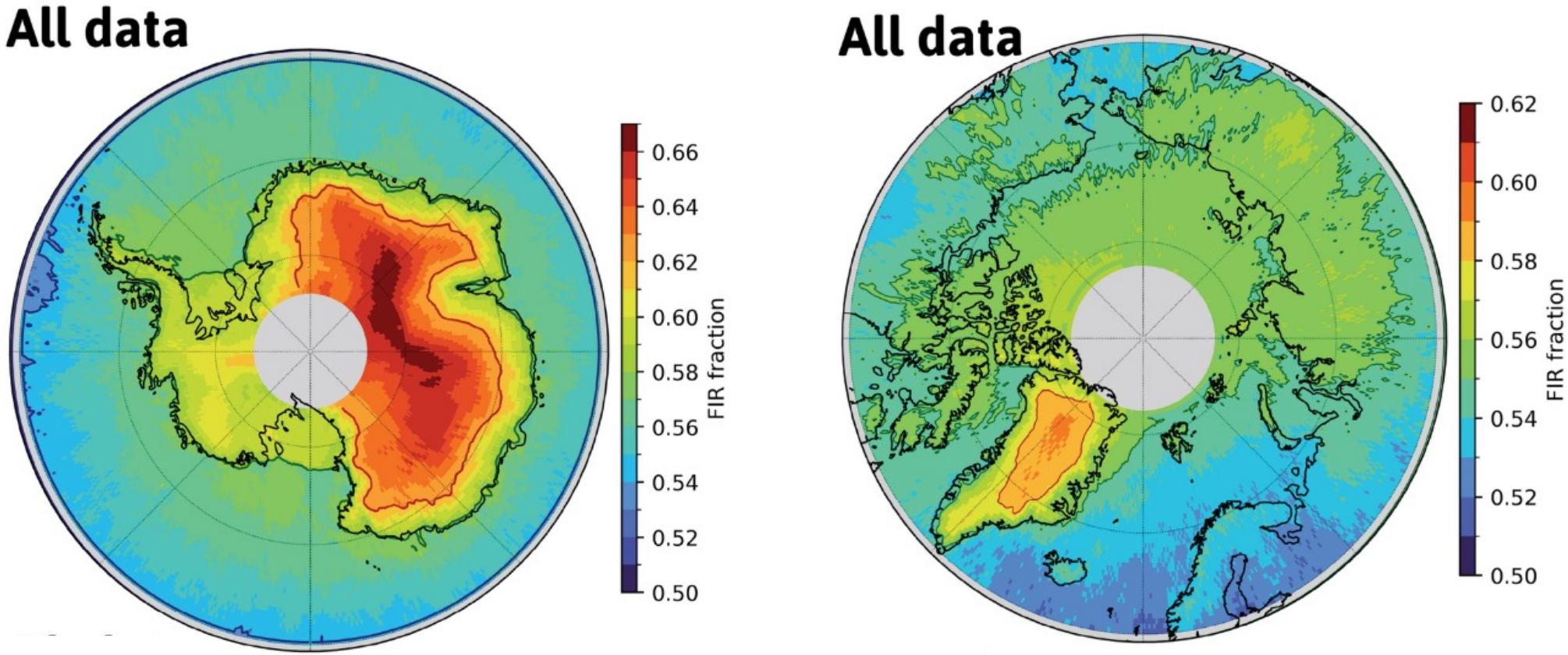


Measured Far-Infrared Contribution to OLR

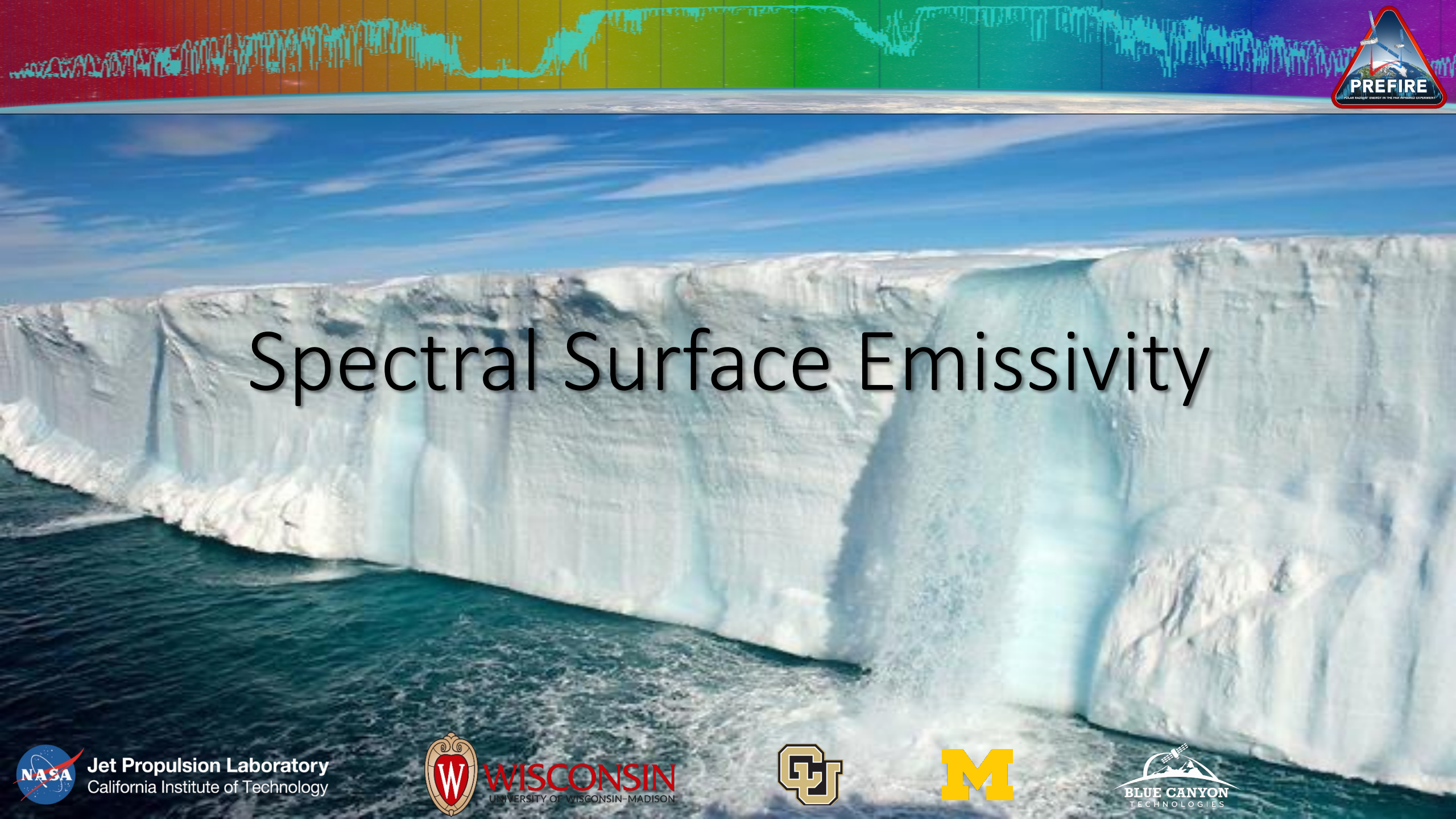
Hamish Prince

2025 Annual Mean

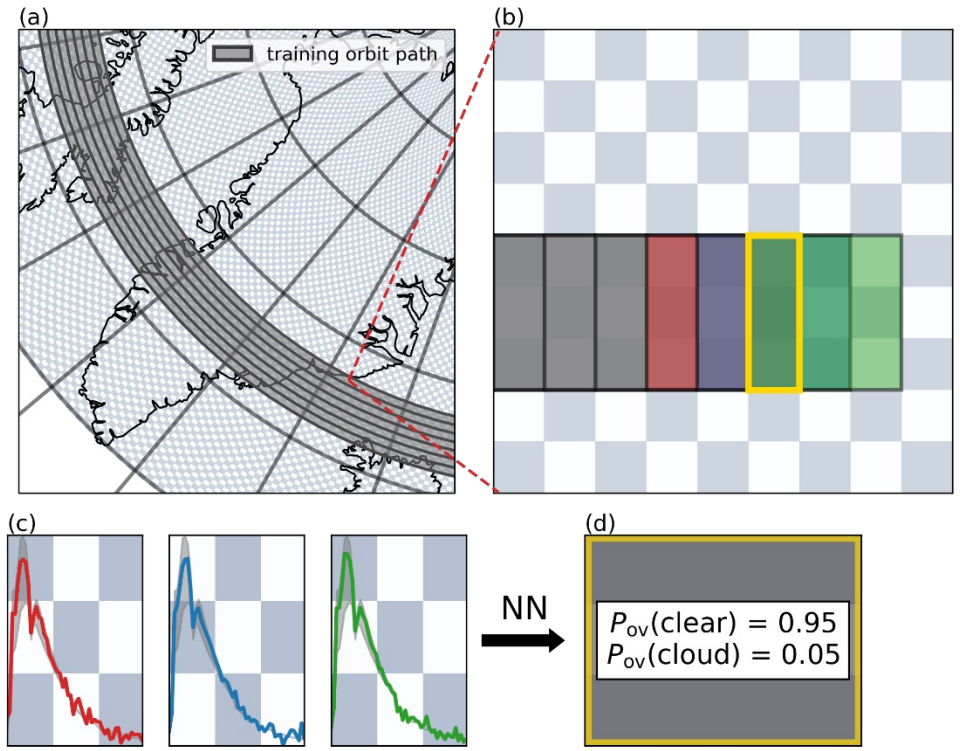
(from PREFIRE 2B-FLX)



L'Ecuyer et al., *in preparation*


PREFIRE
Spectral Surface Emissivity
NASA
Jet Propulsion Laboratory
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Step 1: Cloud Identification



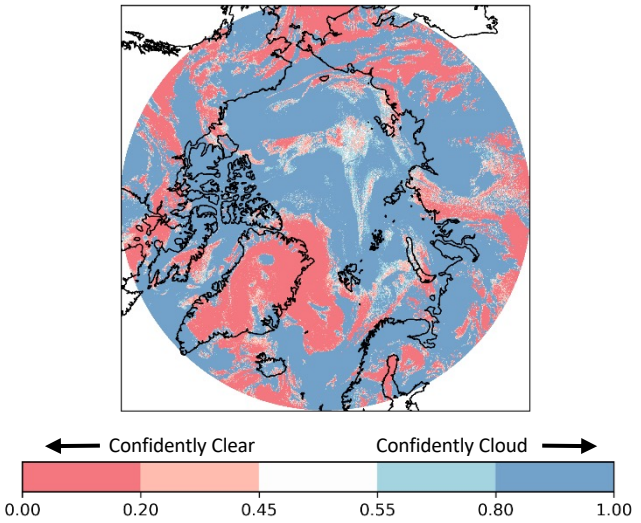
Bertossa et al., *J. Tech.* (2021)

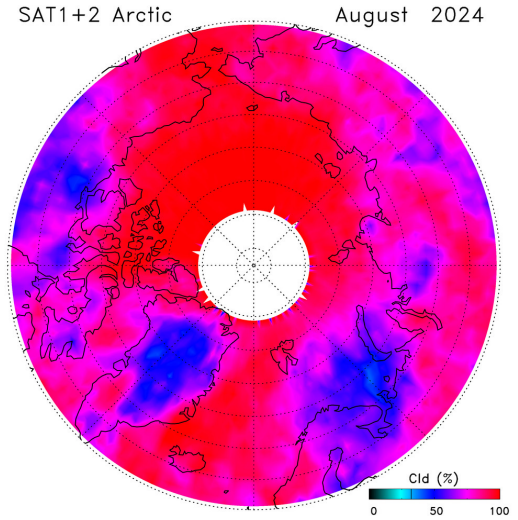
PREFIRE's cloud detection product (2B-MSK) uses machine learning trained on collocated VIIRS visible and infrared cloud retrievals

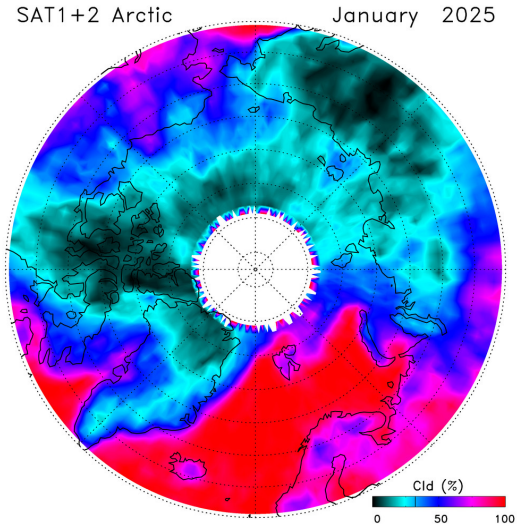
Truth (cloud = white)



Predicted Cloud Probabilities





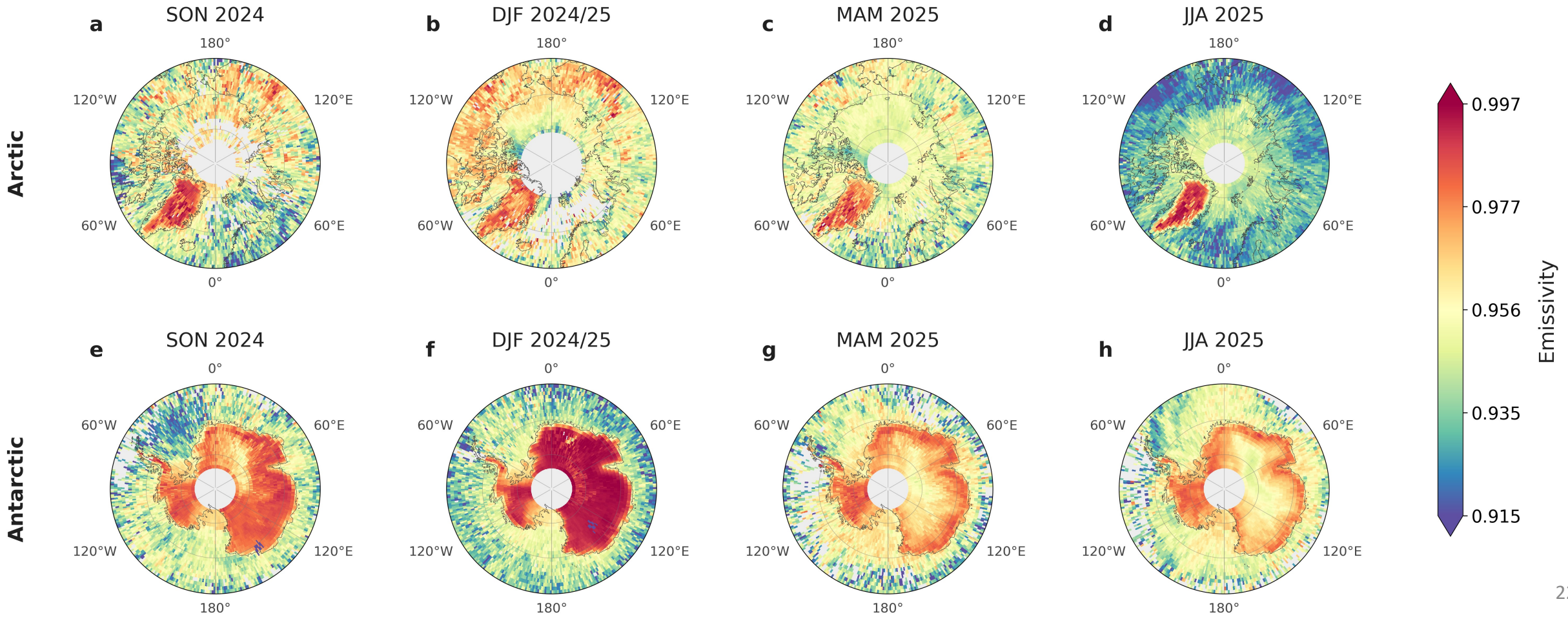


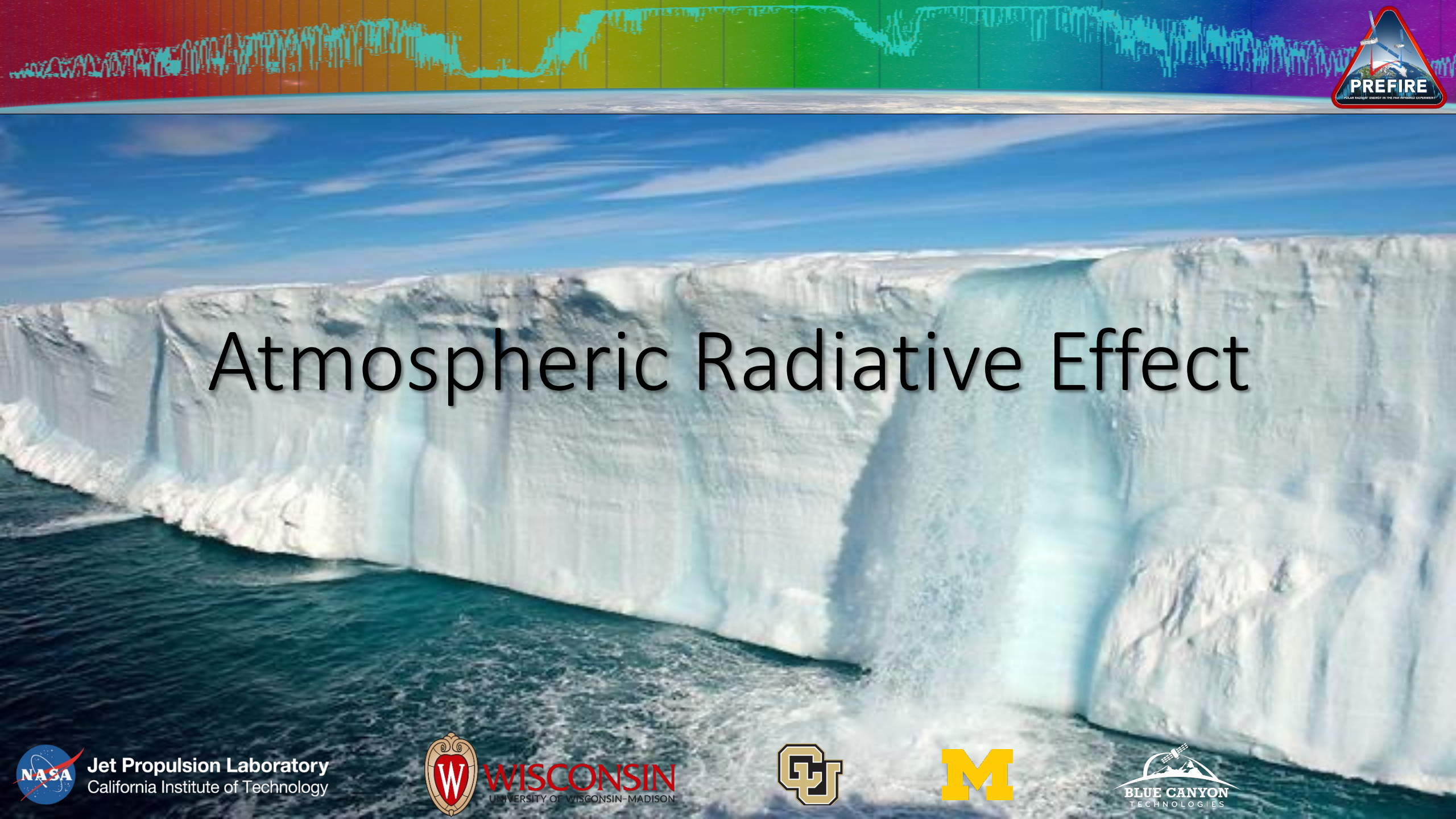
Bertossa et al., *J. Tech* (2023)

Spectral Surface Emissivity

Surface Emissivity at 22.8μm (Dec. 2024 – Nov. 2025)

Fine-tuned model (cloud probability < 0.4)

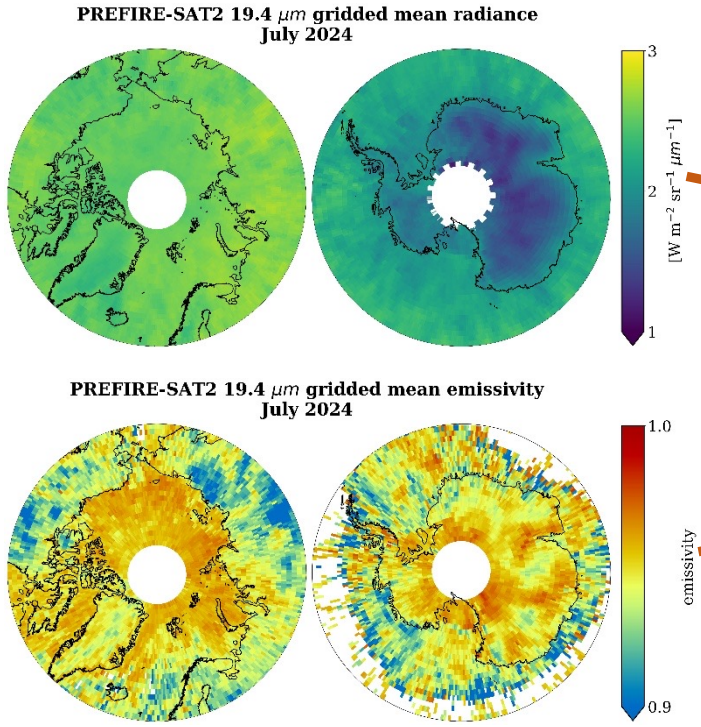


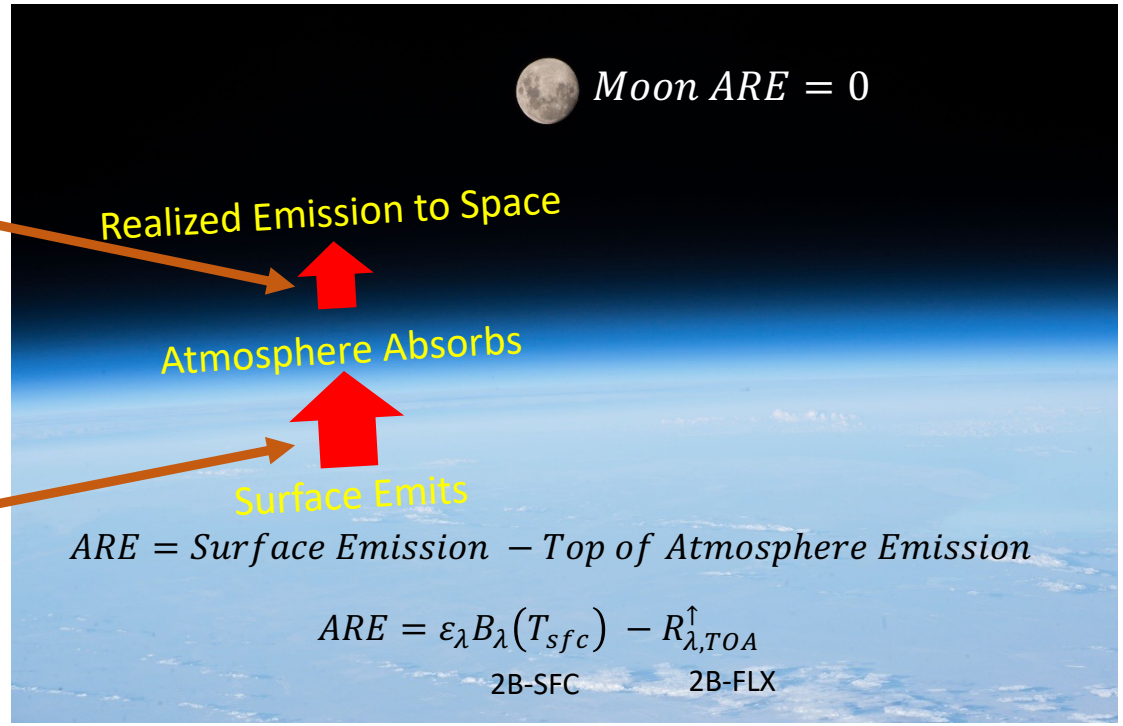

PREFIRE
Atmospheric Radiative Effect
NASA
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Spectral Atmospheric Radiative Effect (ARE)

19.4 µm Top of Atmosphere Emission

19.4 µm Surface Emissivity

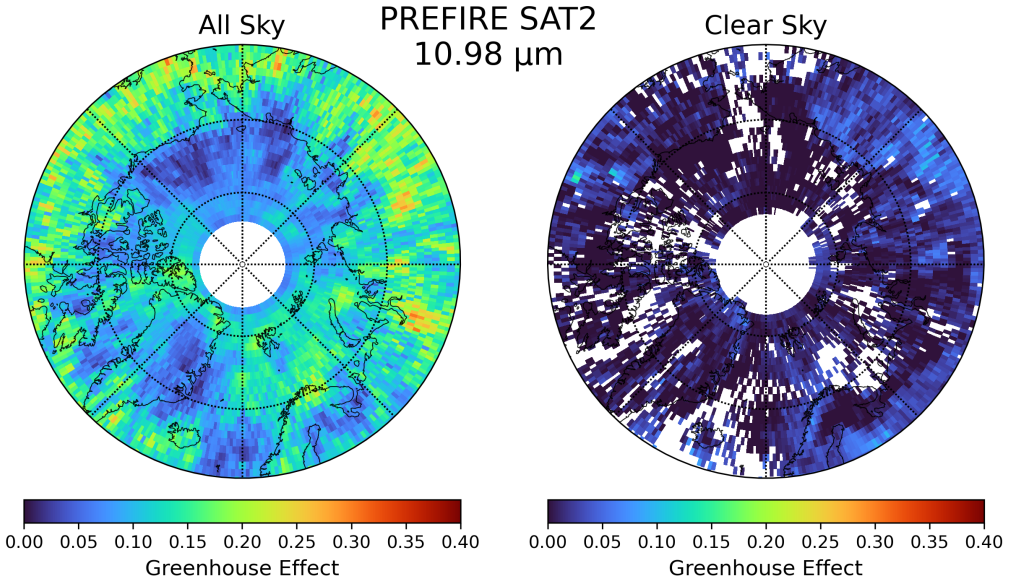




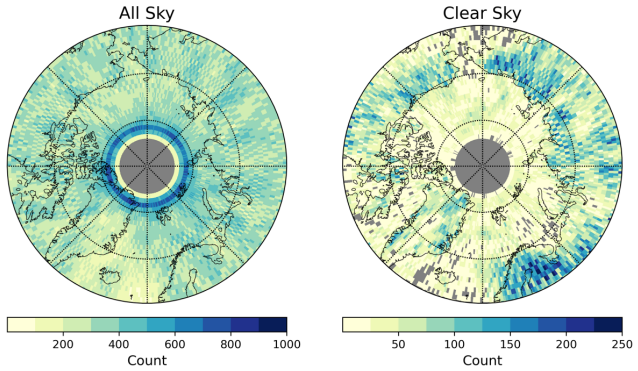
The PREFIRE products reveal how the atmosphere influences outgoing longwave radiation in all spectral bands

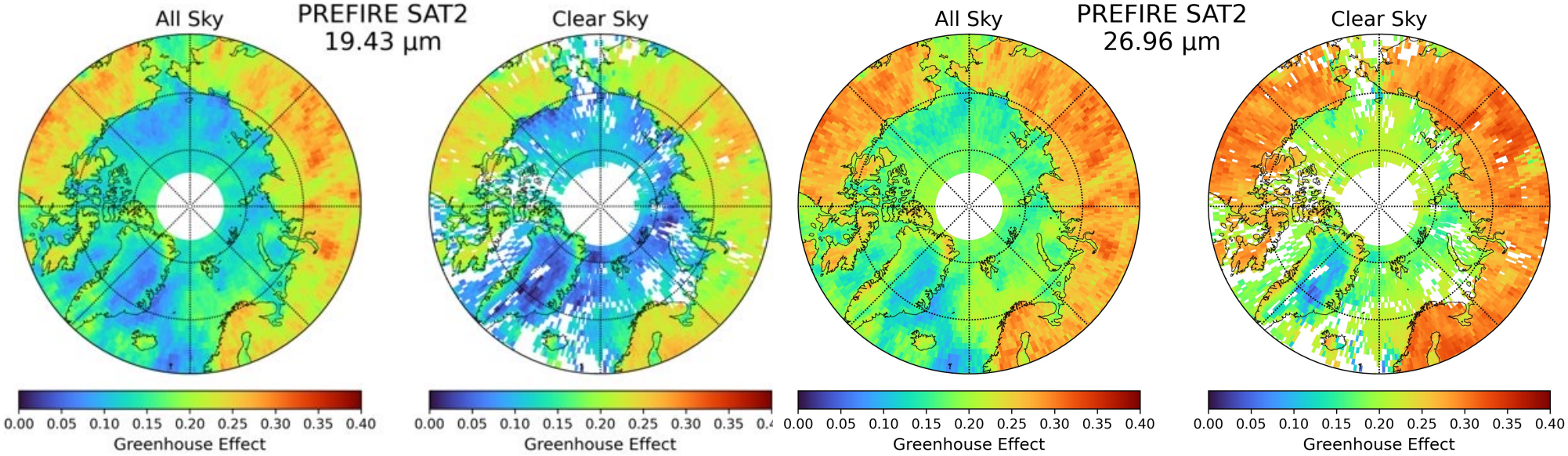
First Estimates of ARE (July 2024)

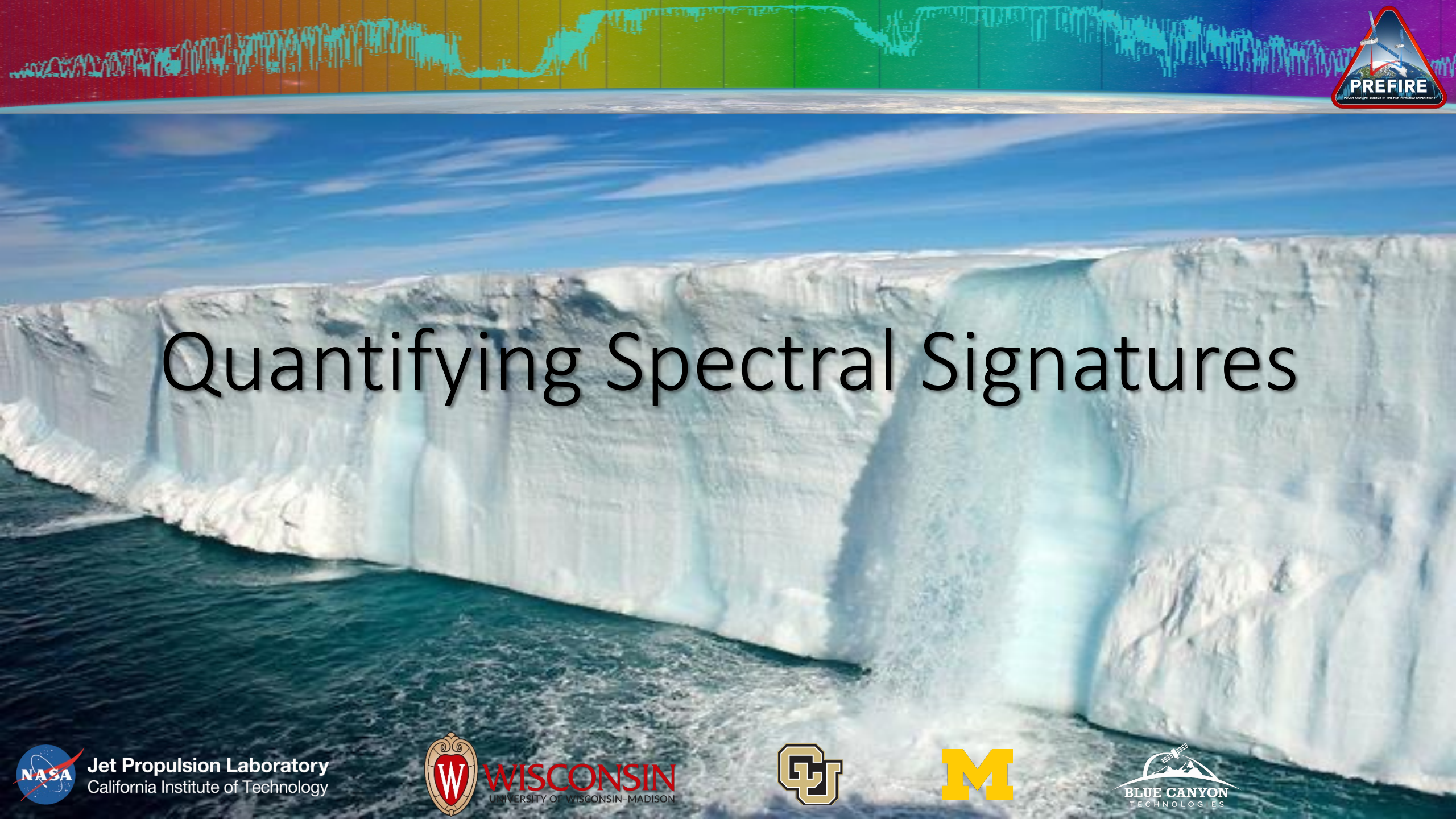
Hamish Prince



Sampling



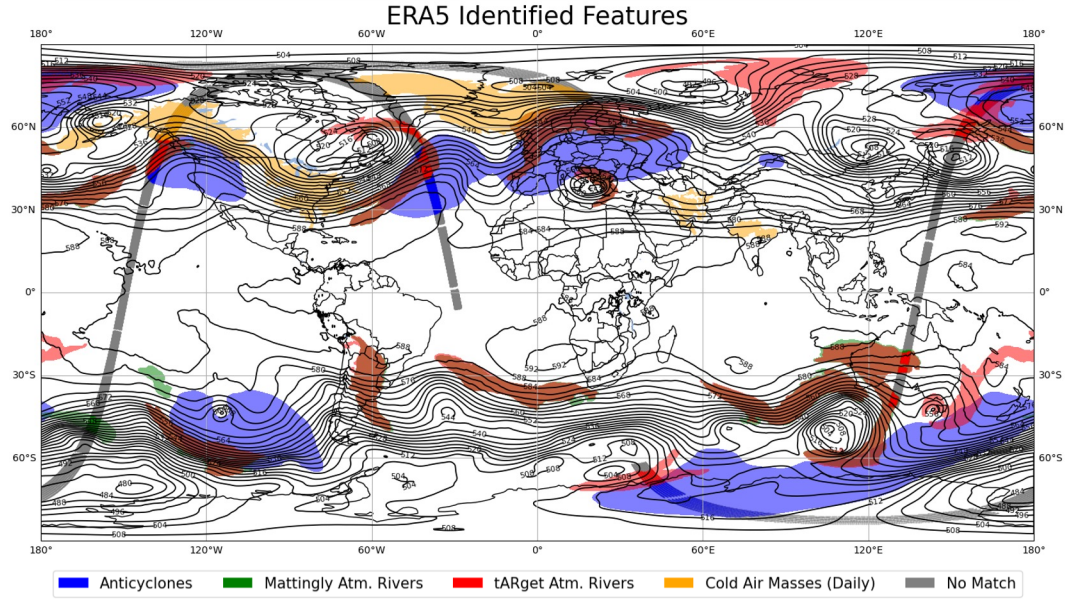



PREFIRE
Quantifying Spectral Signatures
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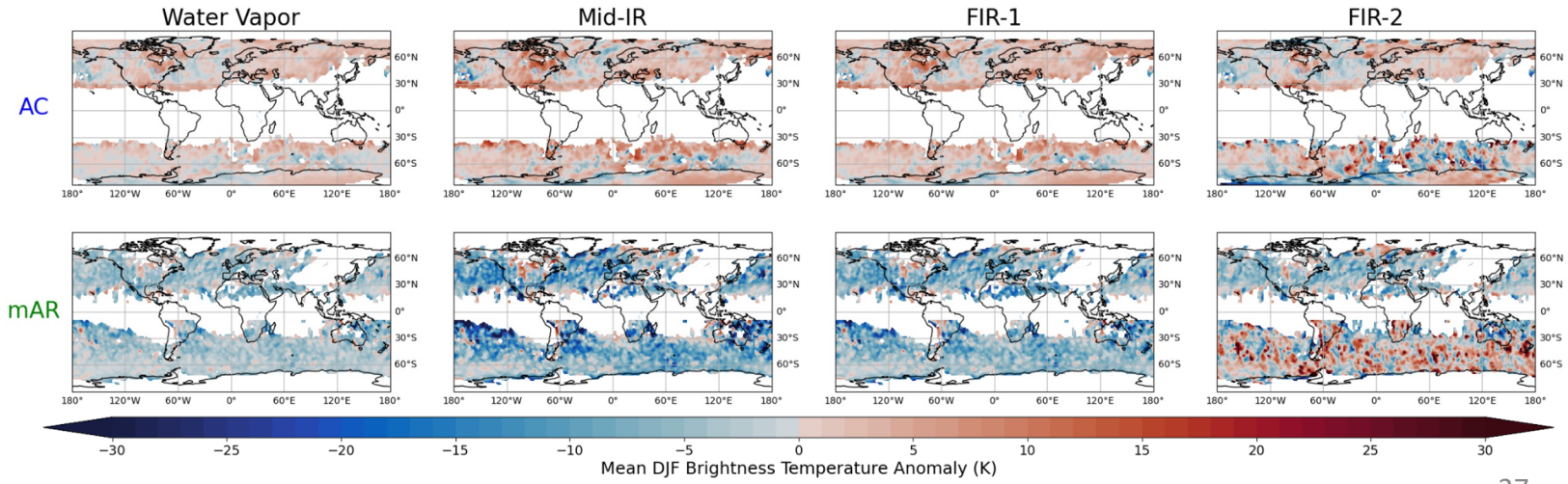
Reanalysis Feature Matching

Caden Schmear and Kyle Mattingly

- Uses MERRA-2 and ERA5 reanalysis inputs to identify and match synoptic-scale features to PREFIRE orbits
  - Anticyclones
    - Zonal 500hPa geopotential height anomalies, Loikith et al. 2022
  - Atmospheric rivers
    - Mattingly et al. 2018
    - tARget, v4
  - Cold Air Masses
    - Developed from He et al. 2023 and Lillo et al. 2021



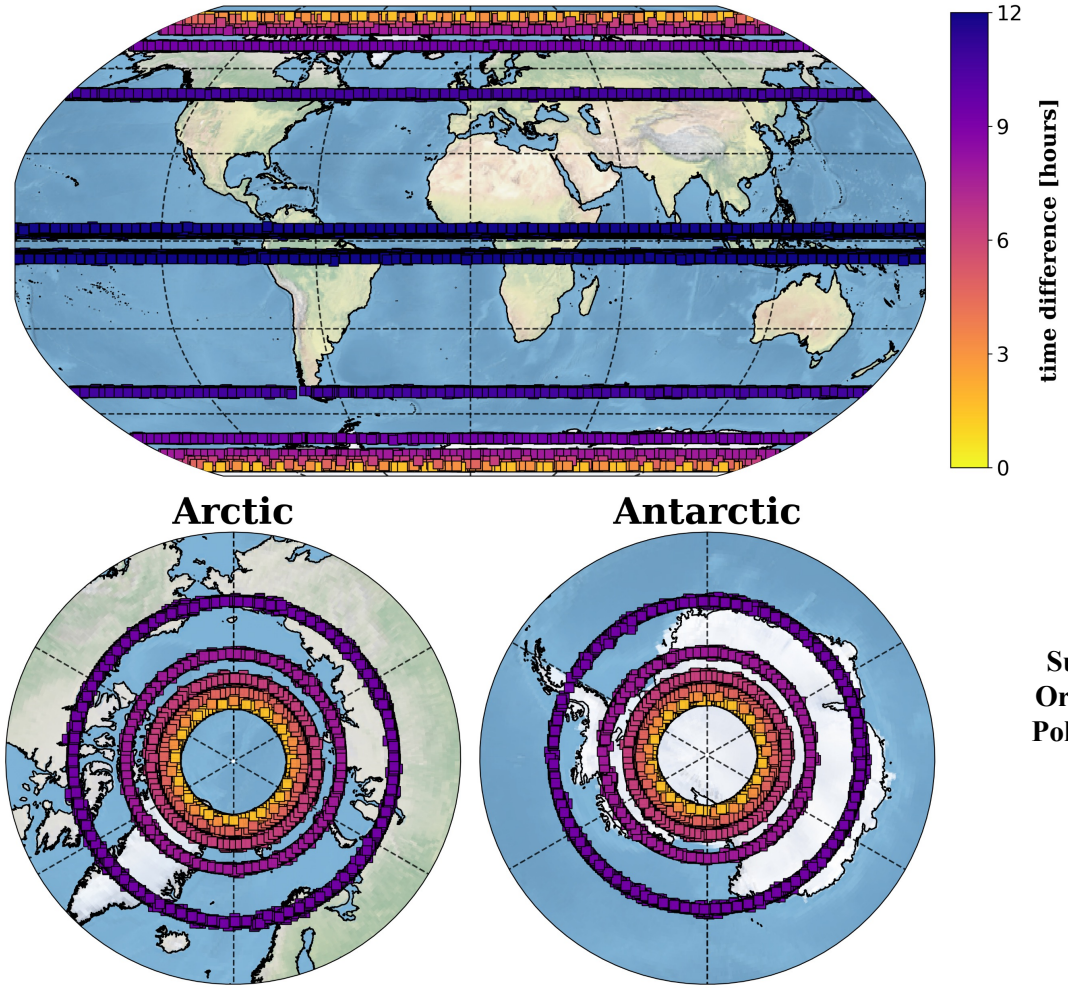
- Demonstrates spatial variation of spectral signatures associated with synoptic features
  - Land/sea differences
  - Consistent across spectral bands
  - Decrease in anomaly strength towards the poles



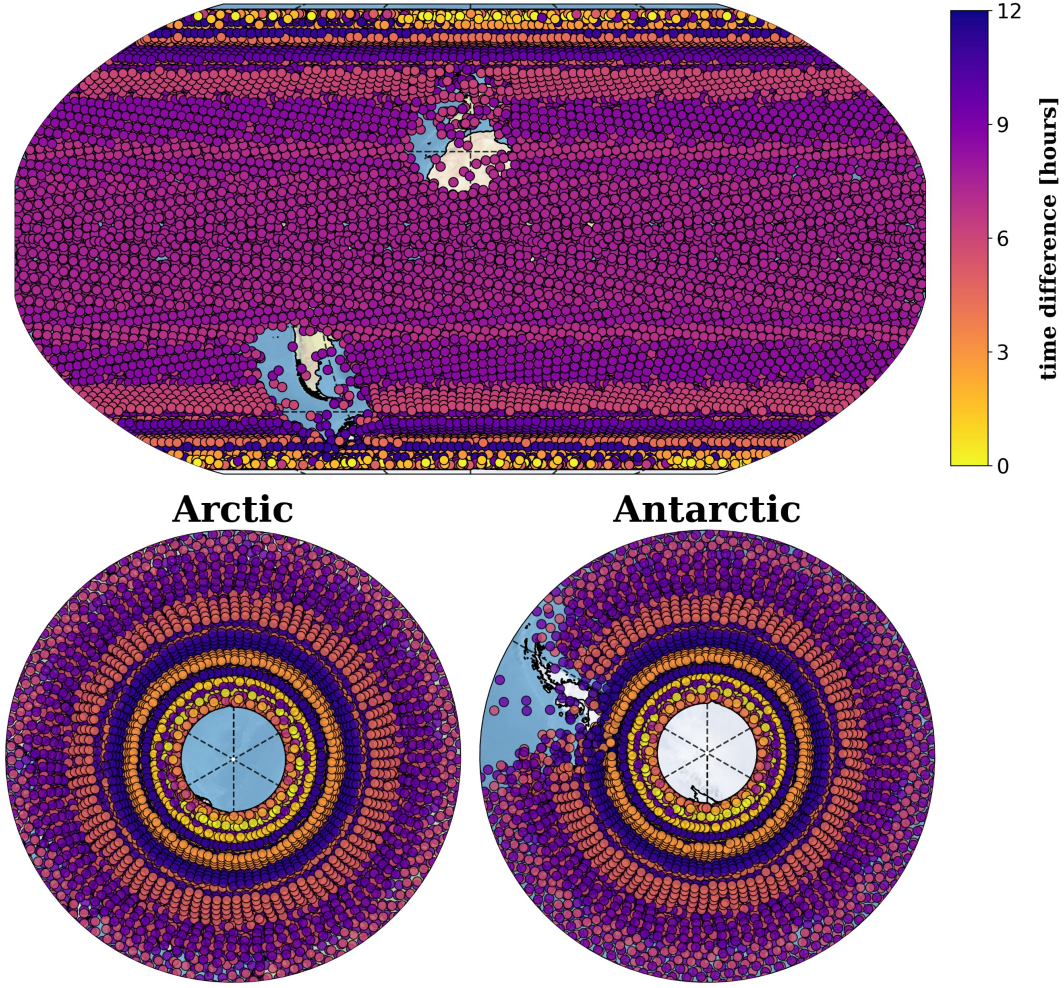
Schmear et al., *in preparation*

PREFIRE Satellite Intersections (Prime Mission)

Self-intersections over Prime Mission



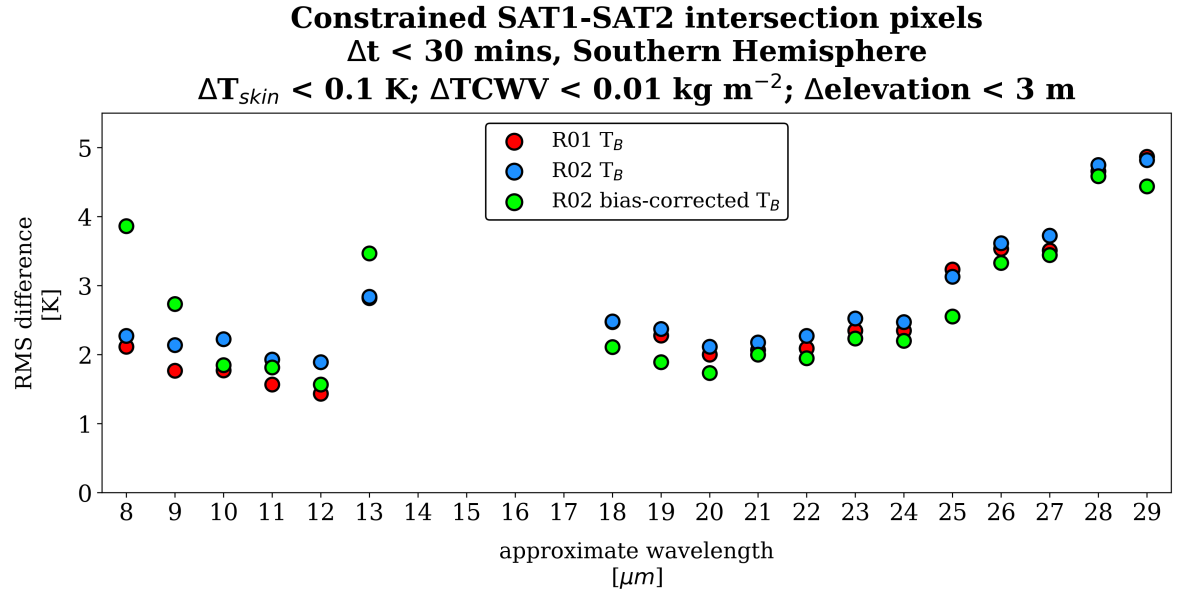
SAT1-SAT2 intersections over Prime Mission

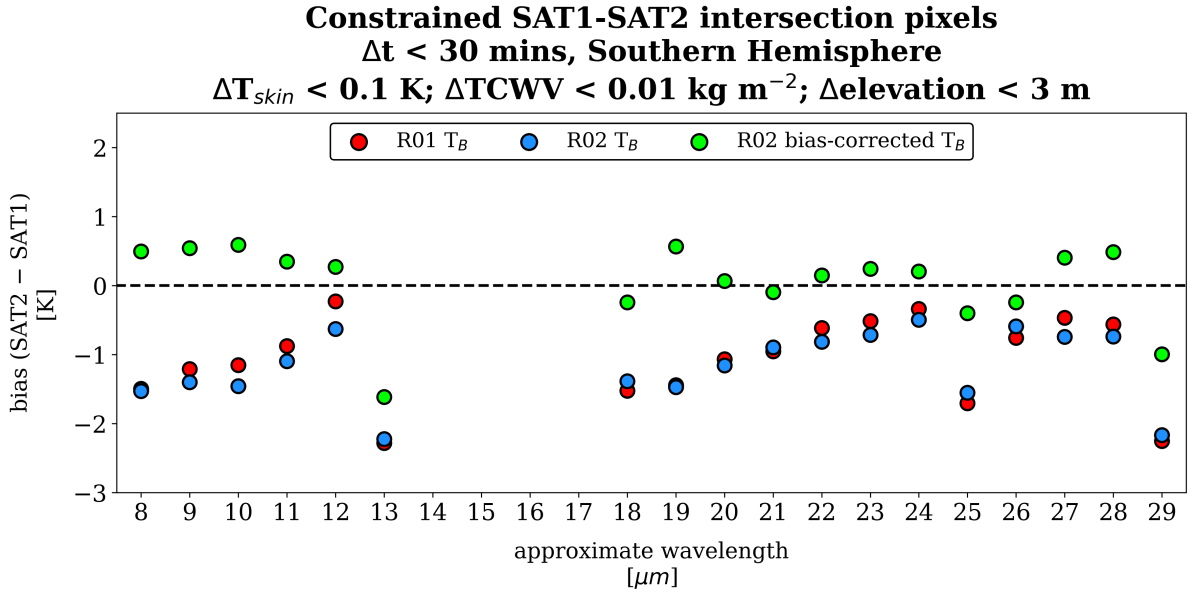


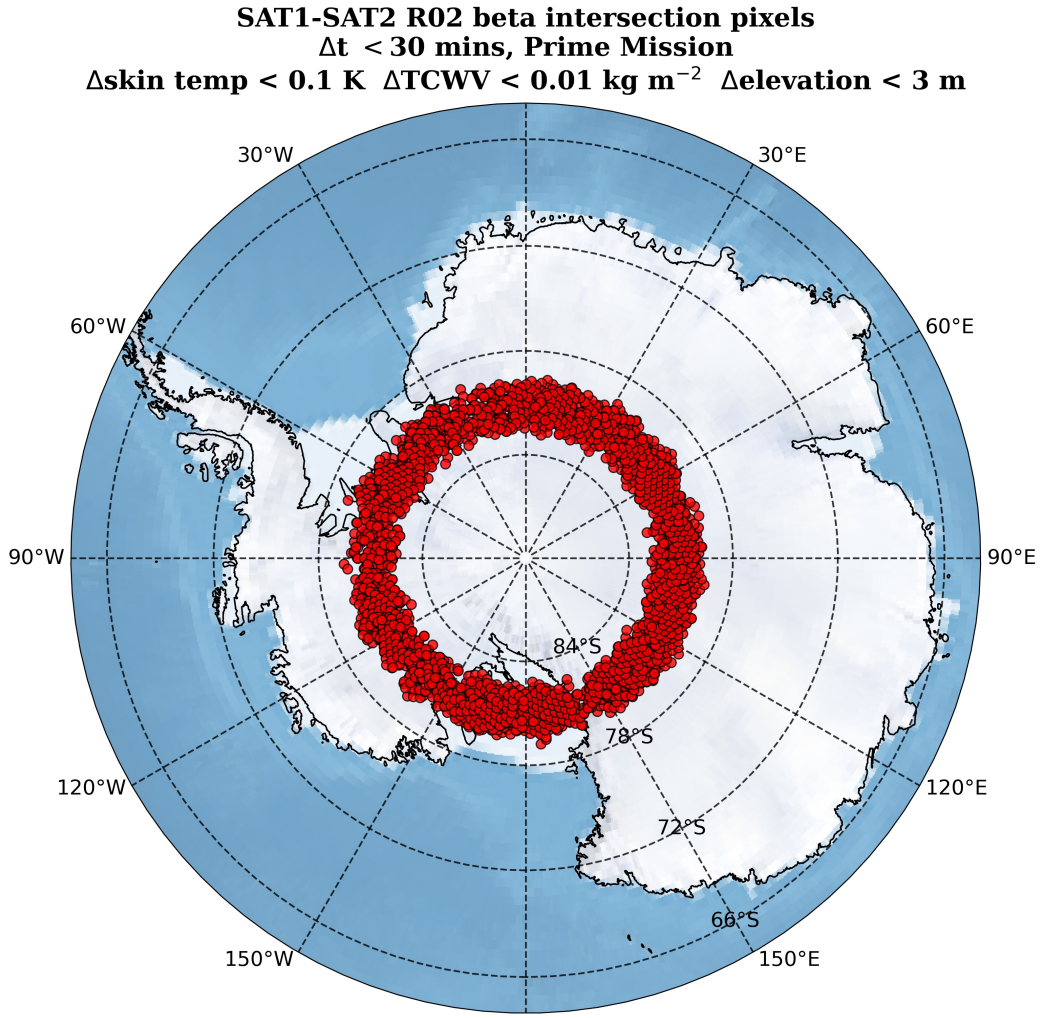
Subdaily PREFIRE Orbit Resampling for Polar Process Science, Vos et al. 2026

Intersections between two satellites offer much better geographic coverage than a single satellite.

Step 1: Intercalibration

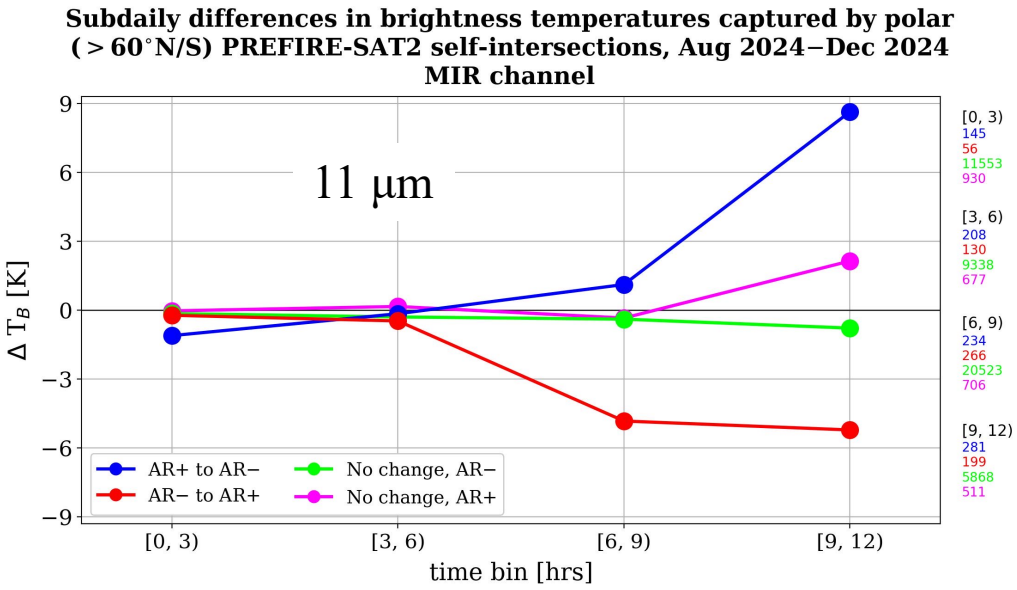


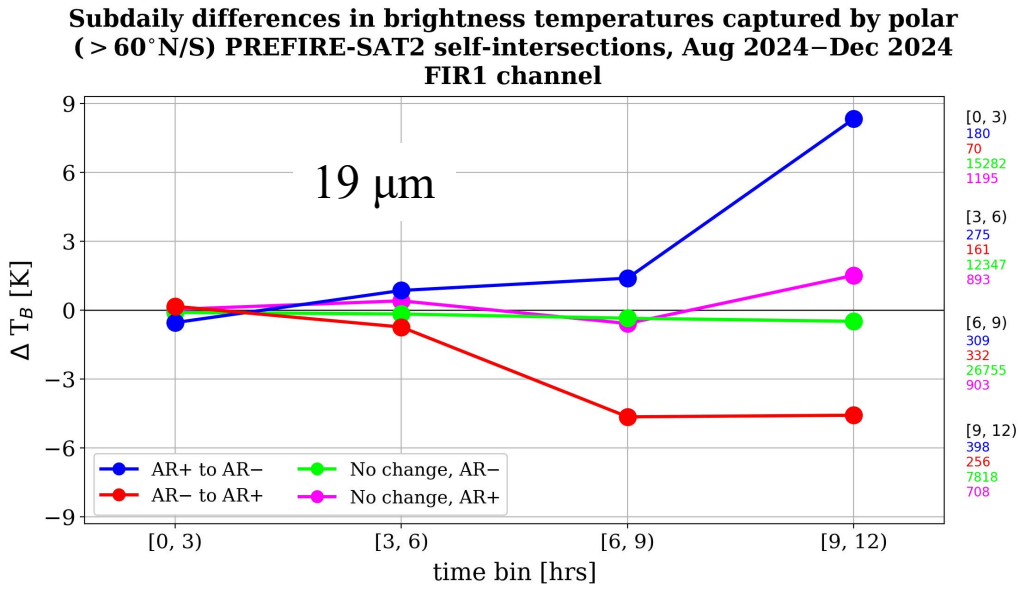




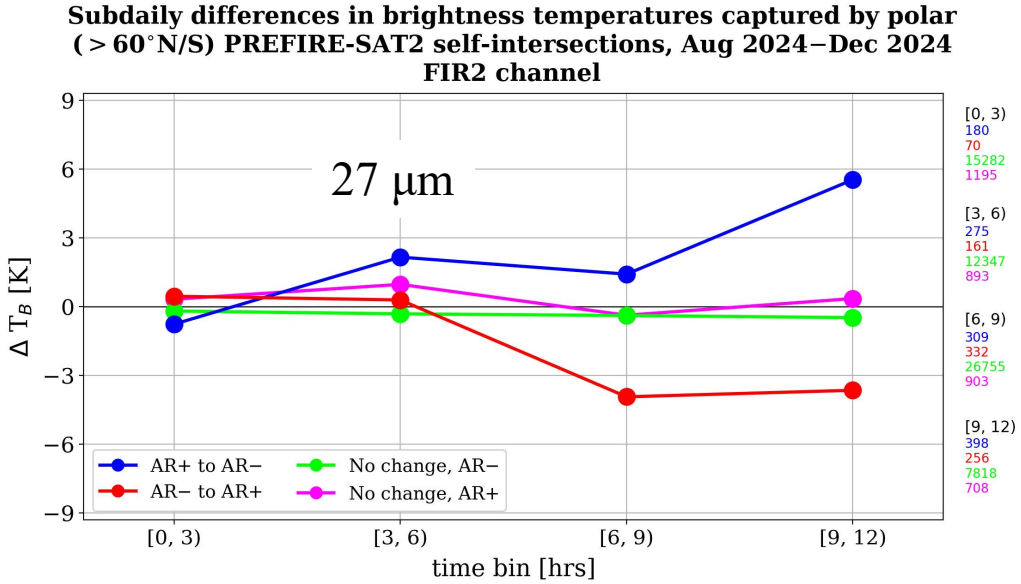
Goal 2: Quantify Process Signatures

Natasha Vos





Preliminary analyses of intersections where AR reanalysis feature mask indicates change in AR presence



AR+ to AR−
AR− to AR+
No change, AR−
No change, AR+

Both scenarios where AR presence changes suggest ARs reduce emission (especially in window channels) likely due to increased cloud cover/depth



Global Expansion

Approved as a result of 2026 ESD Senior Review

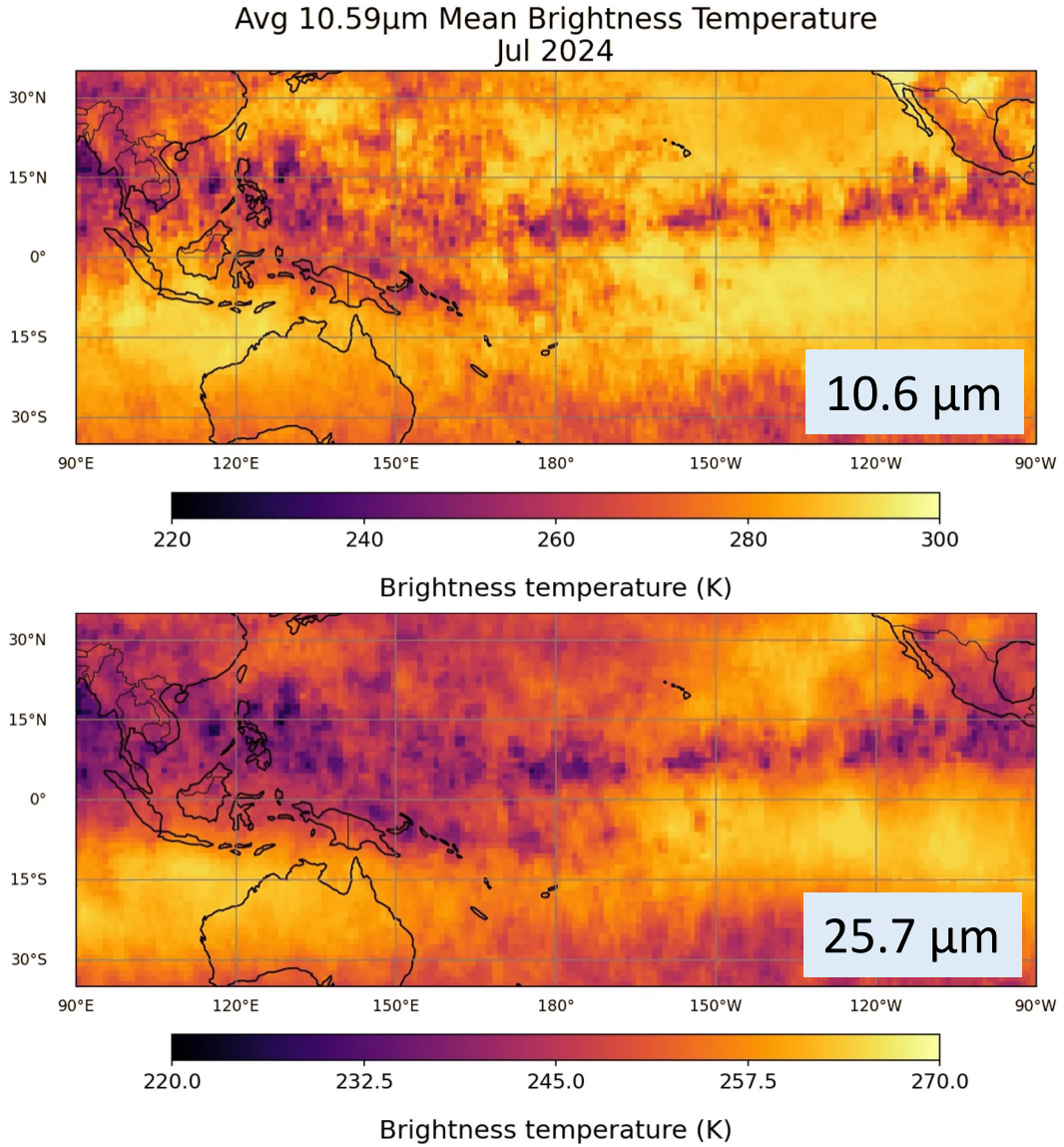
Jet Propulsion Laboratory
California Institute of Technology

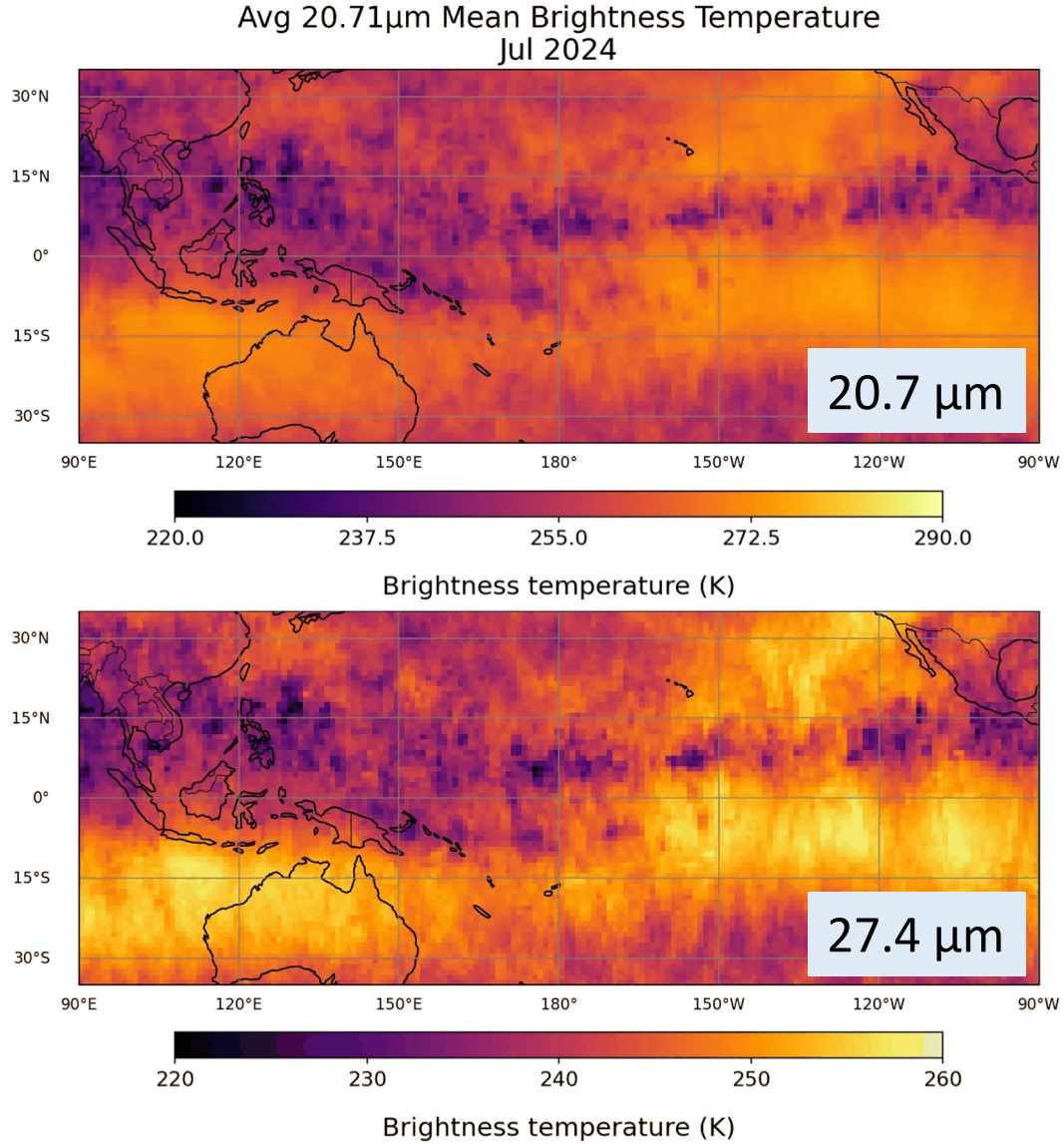
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El Niño Onset in the Pacific

Wenyuan Du



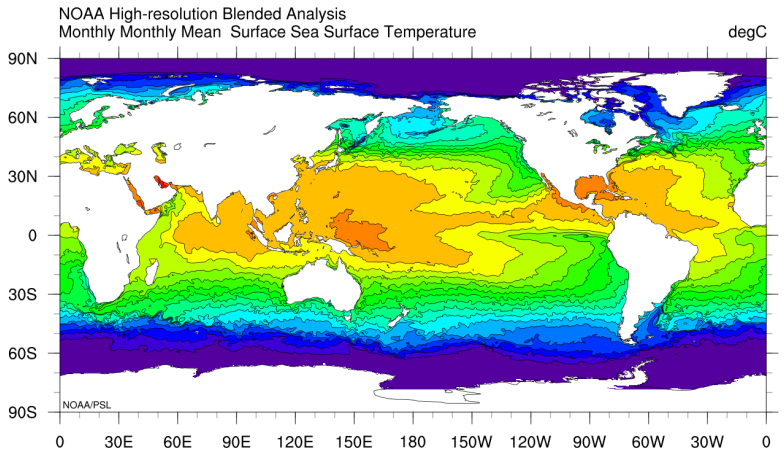


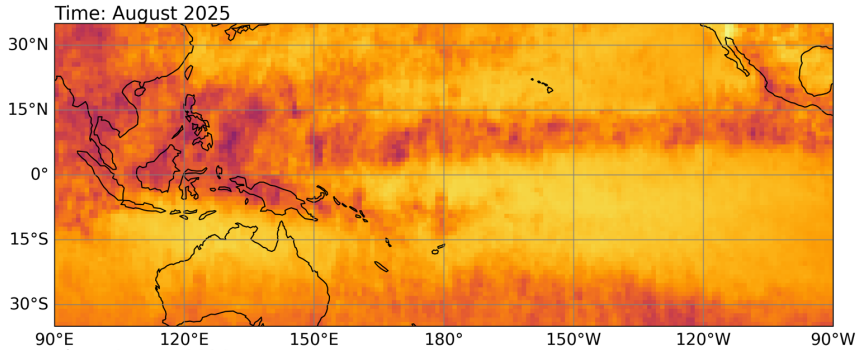
El Niño's Spectral Fingerprints Are Already Emerging

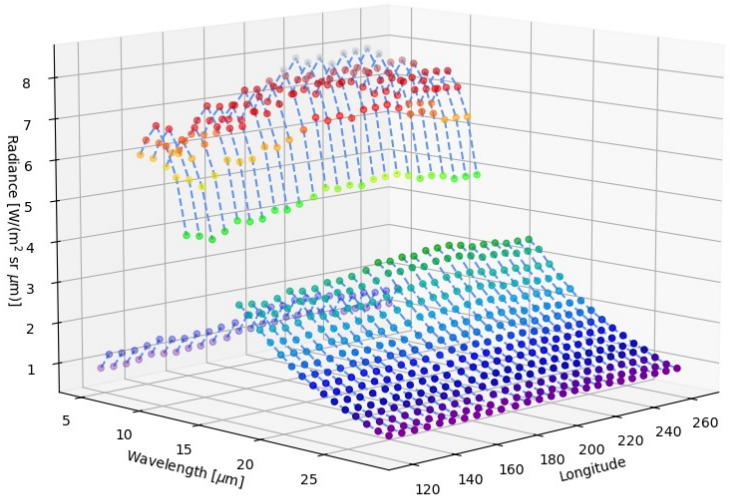
Carolyn Bean and Tim Michaels

11 µm Brightness Temperature

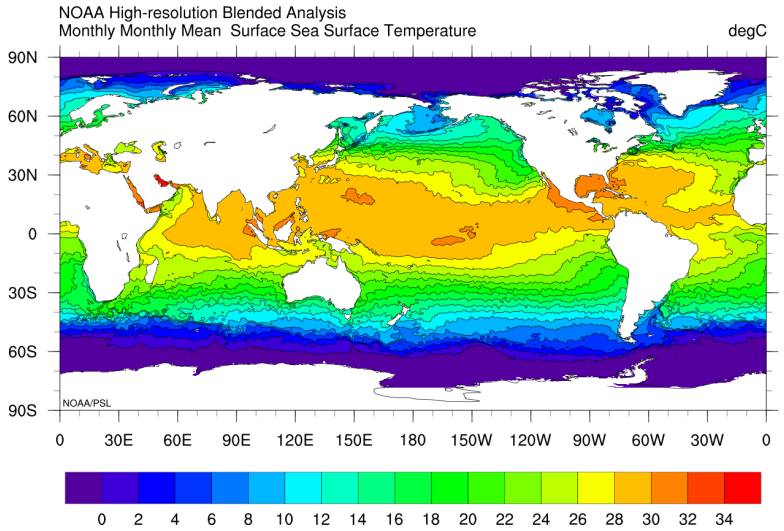
AUG 2025

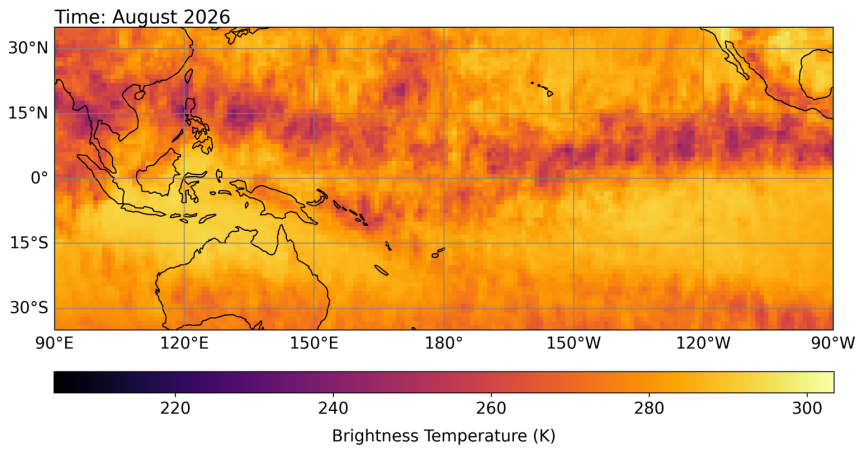


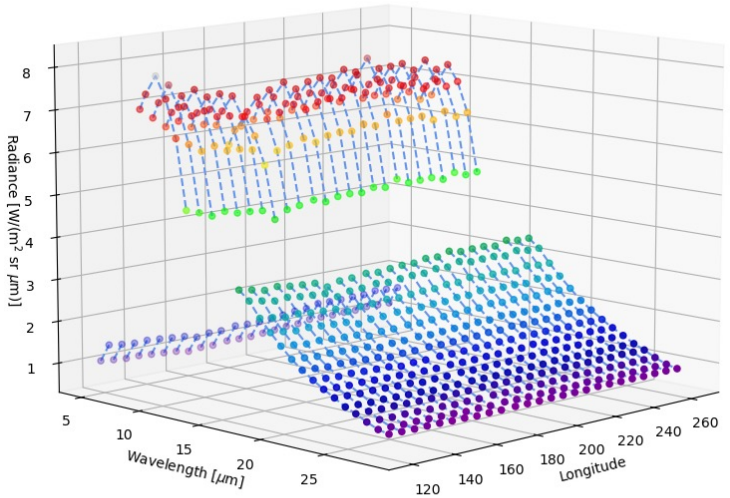




AUG 2026

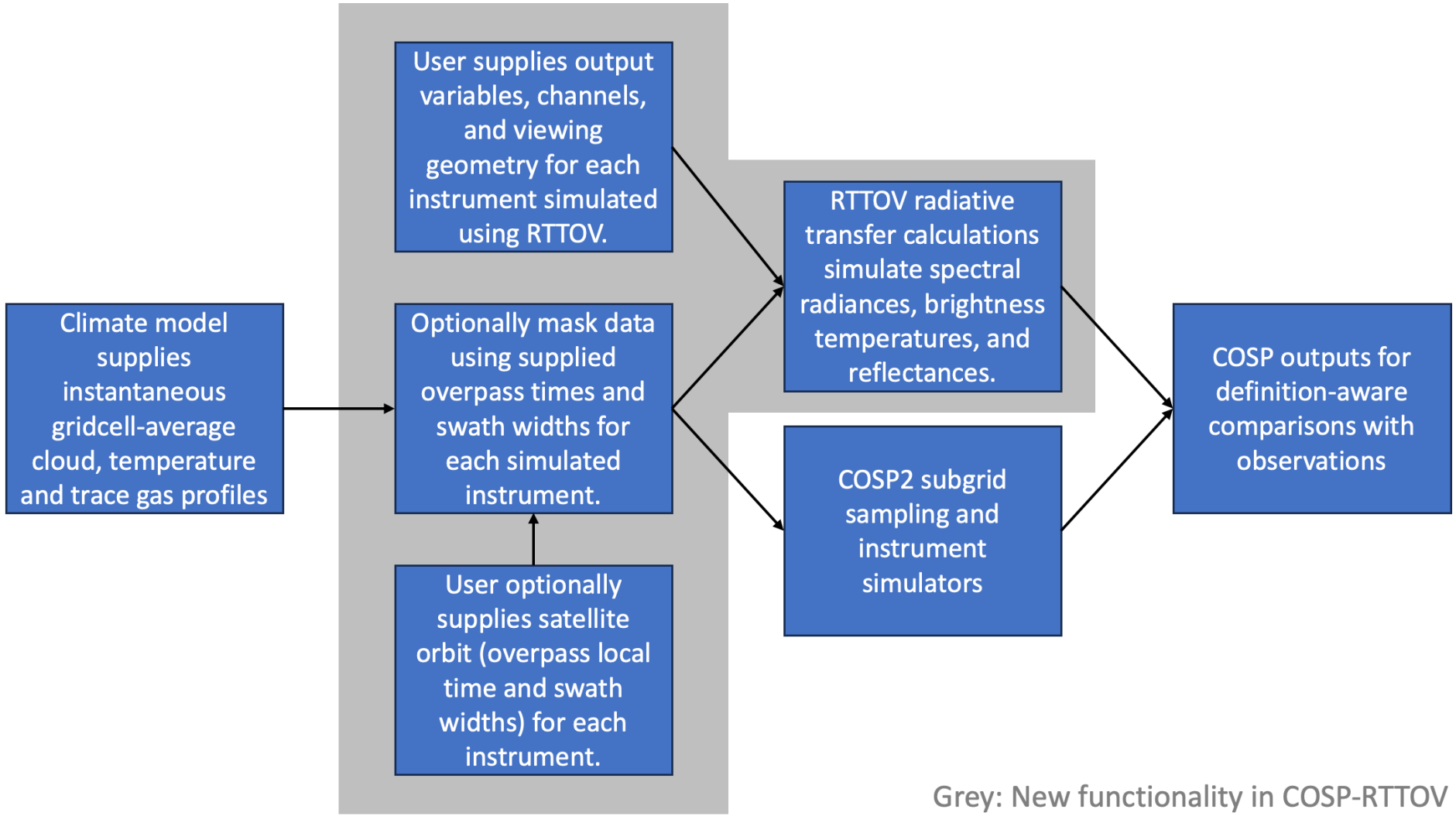






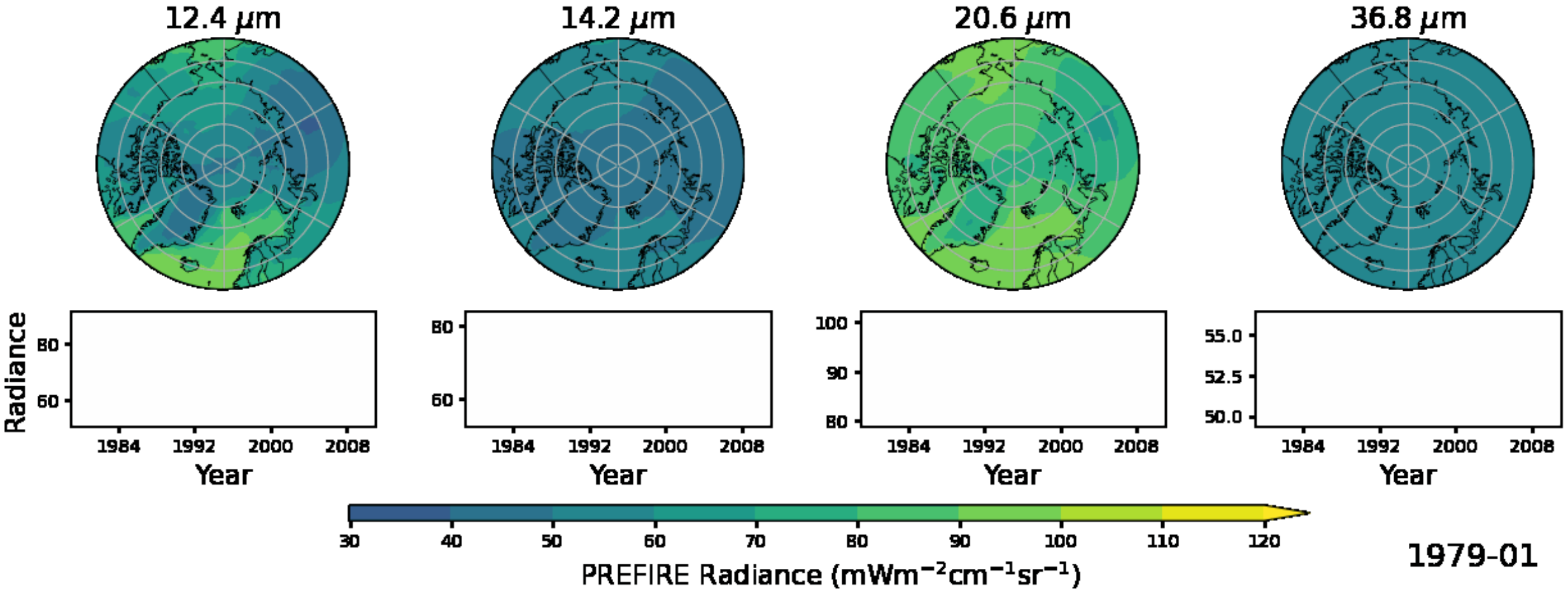
Evaluating Models: COSP-RTTOV TIRS Simulator

Jonah Shaw



Grey: New functionality in COSP-RTTOV

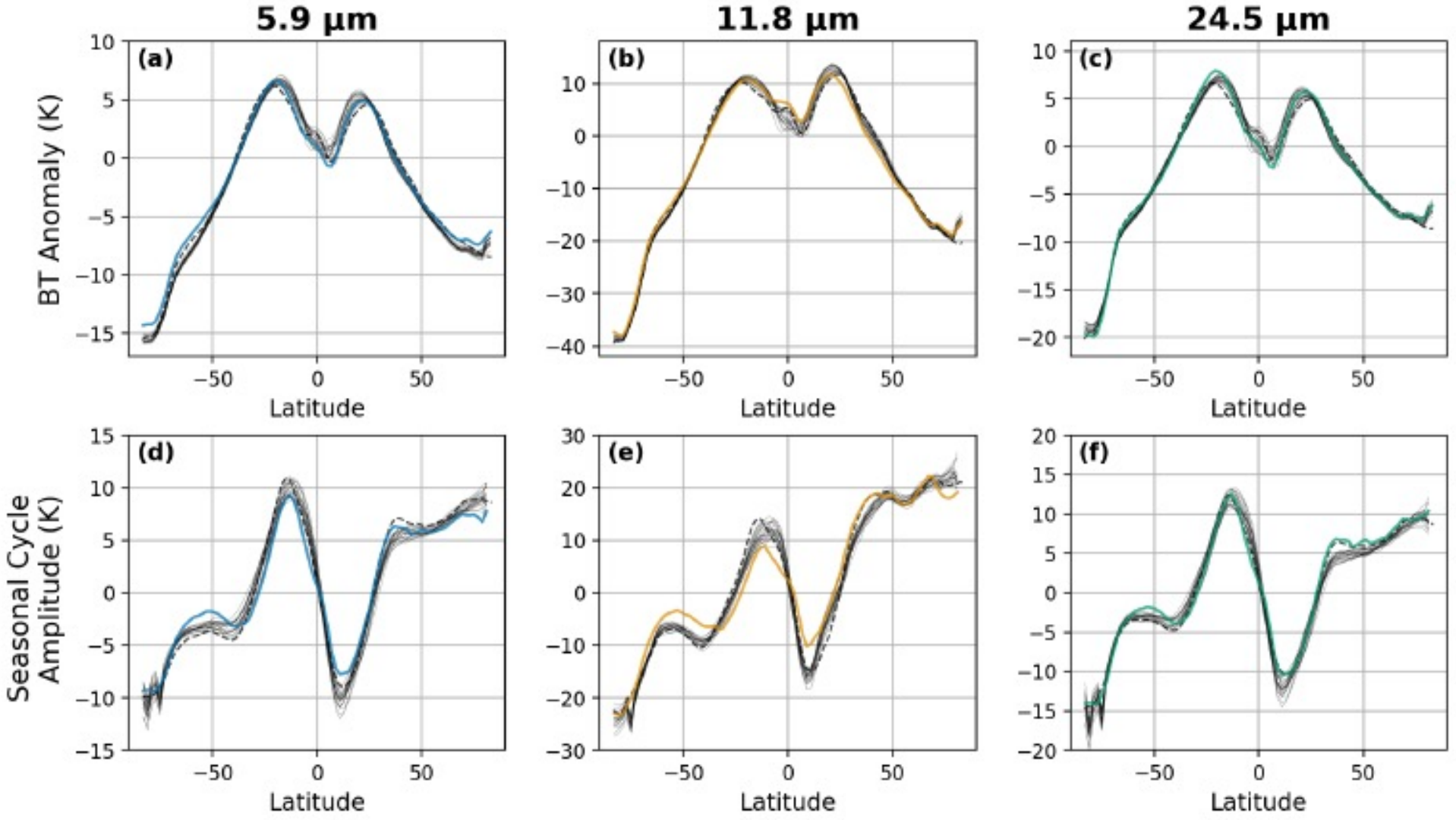
Output: "PREFIRE-like" spectra 1979 to present



PREFIRE interfaces with models through a COSP-compatible RTTOV simulator

Evaluating a Wind-Nudged CESM2 Simulation

Jonah Shaw

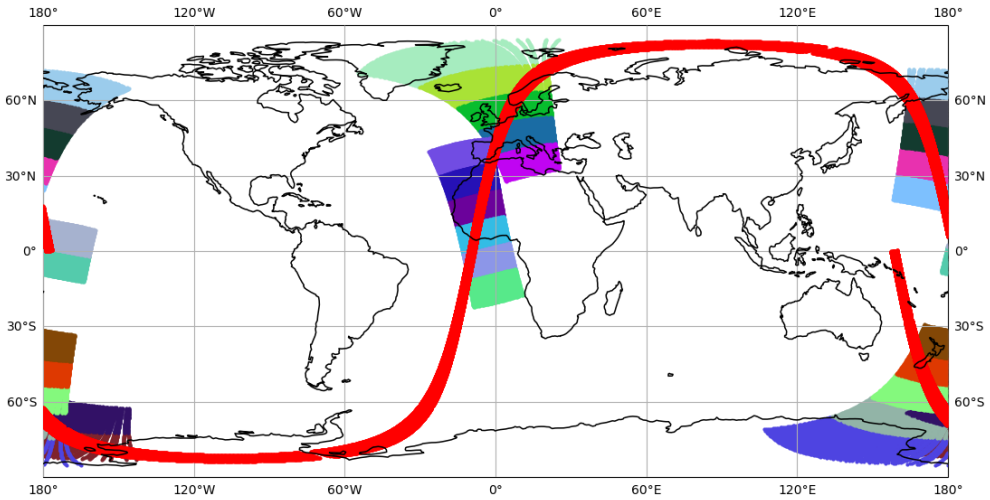


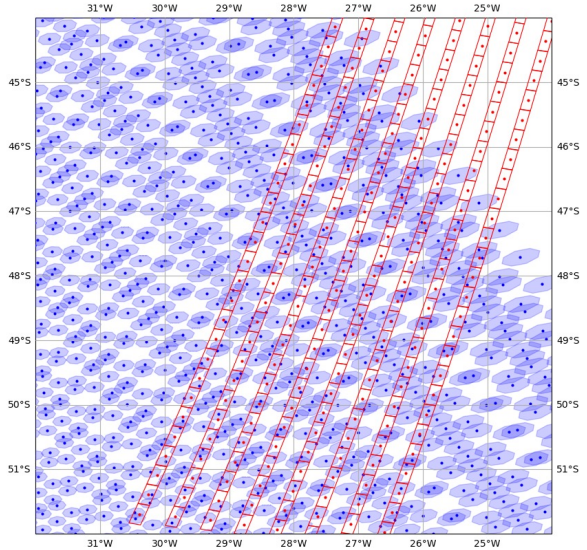


Synergy with Other Satellites

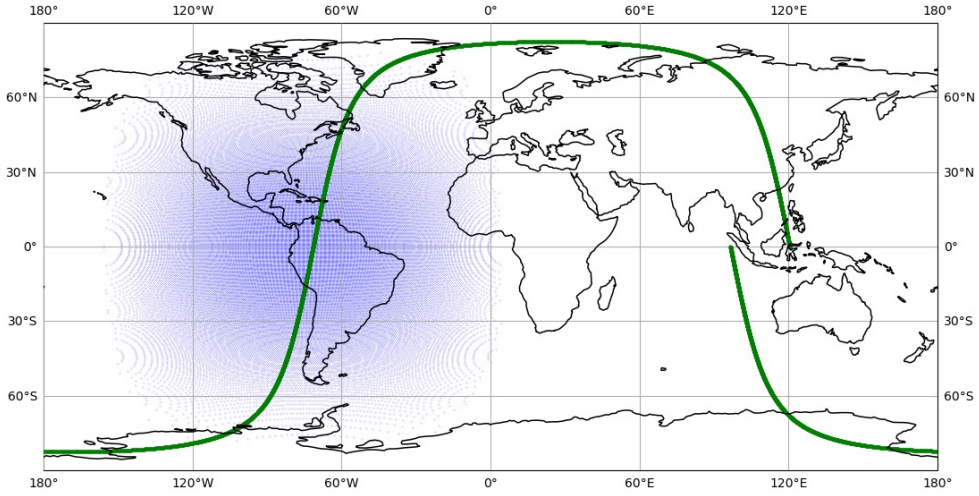
NASA
Jet Propulsion Laboratory
California Institute of Technology
WISCONSIN
UNIVERSITY OF WISCONSIN-MADISON
BLUE CANYON
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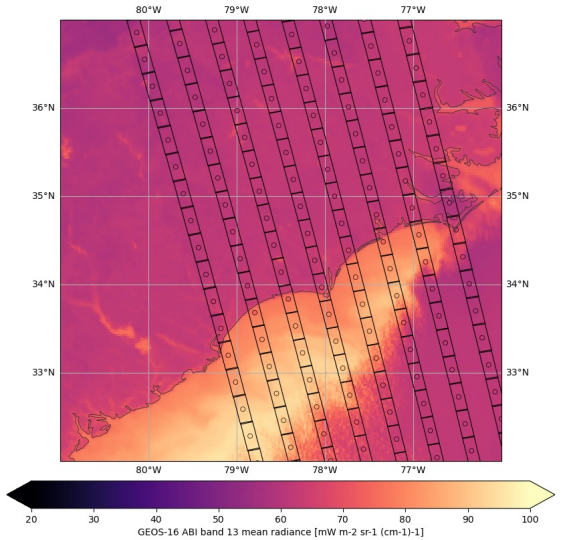
LEO and GEO Examples

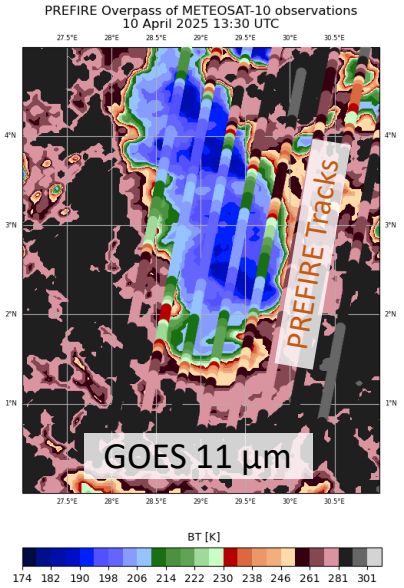




JPSS CrIS / Metop-C IASI / Aqua AIRS







GOES, MeteoSat, HIMAWARI

Implemented products

LEO

- JPSS VIIRS, CrIS, ATMS, CERES
- Aqua AIRS, CERES
- EarthCARE ATLID, CPR, BBR
- GPM IMERG

GEO

- GOES-16/18/19 ABI
- Himawari-9 AHI
- MSG SEVERI

Future Wish List

- MTG IRS
- Aqua/Terra MODIS
- EarthCARE MSI
- Libera
- INCUS
- PolSIR
- CLARREO-Pathfinder

Potential Synergy with Active Sensors

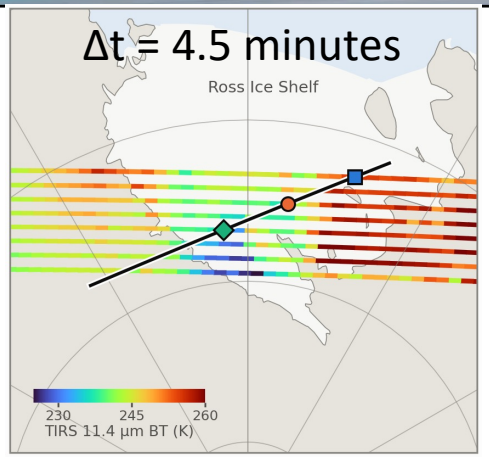




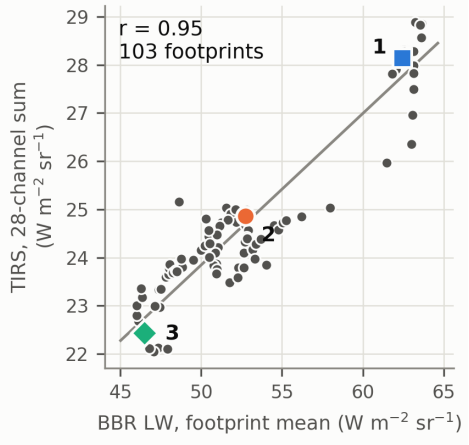


Nov. 22, 2024

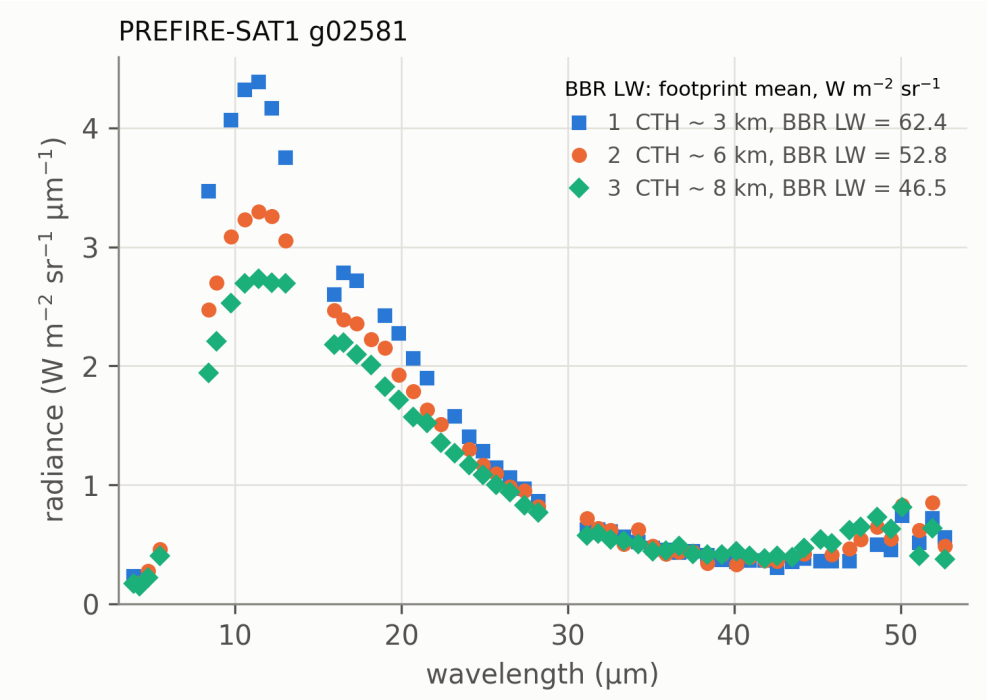
Brian Kahn

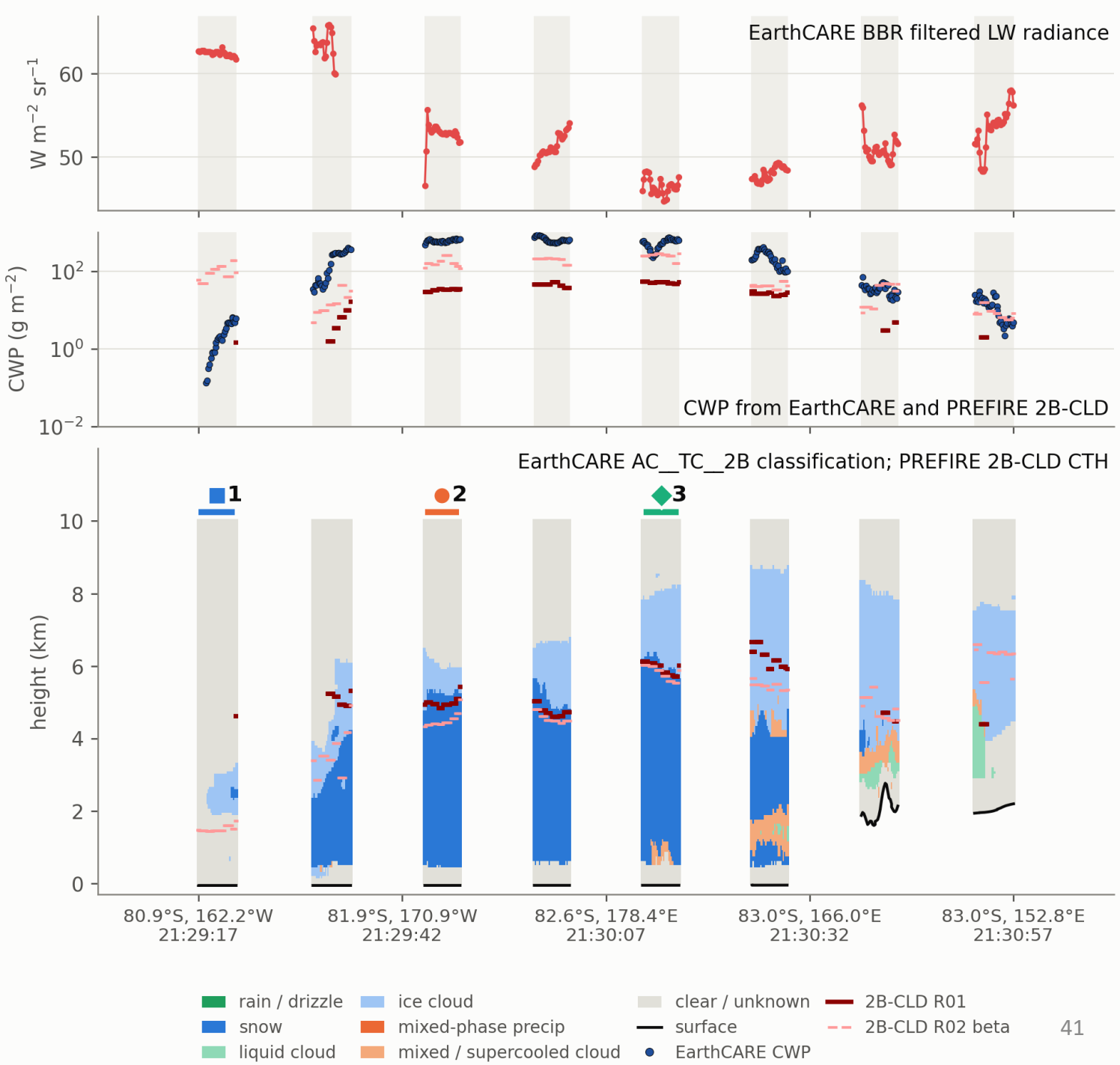


TIRS-1 and EarthCARE segment

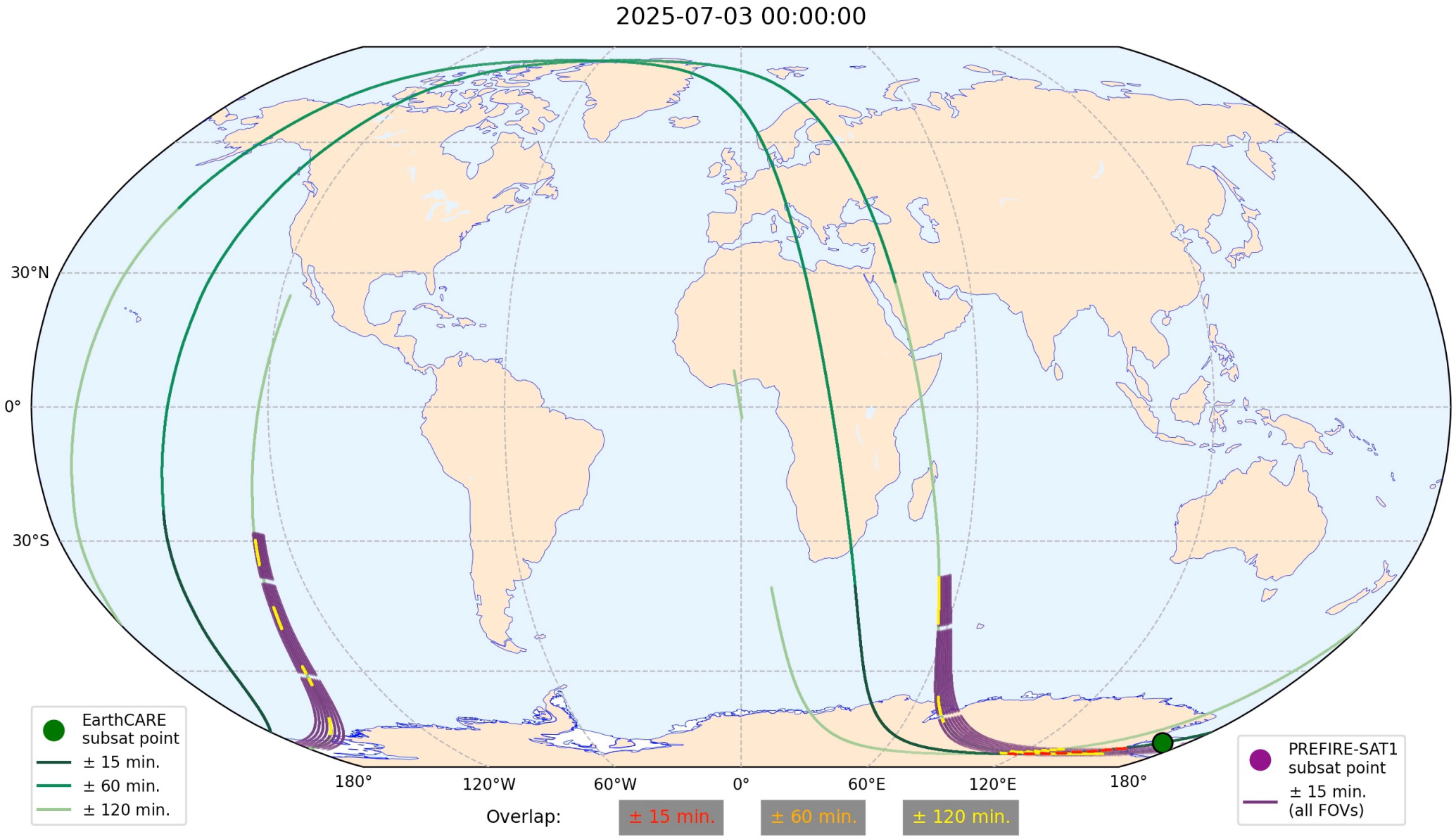


BBR vs. TIRS, same 103 footprints





PREFIRE-SAT1 : EarthCARE Matchups

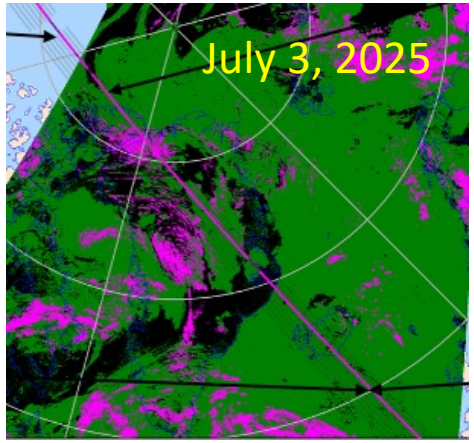


Spectral and Vertical Dimensions with PREFIRE and EarthCARE

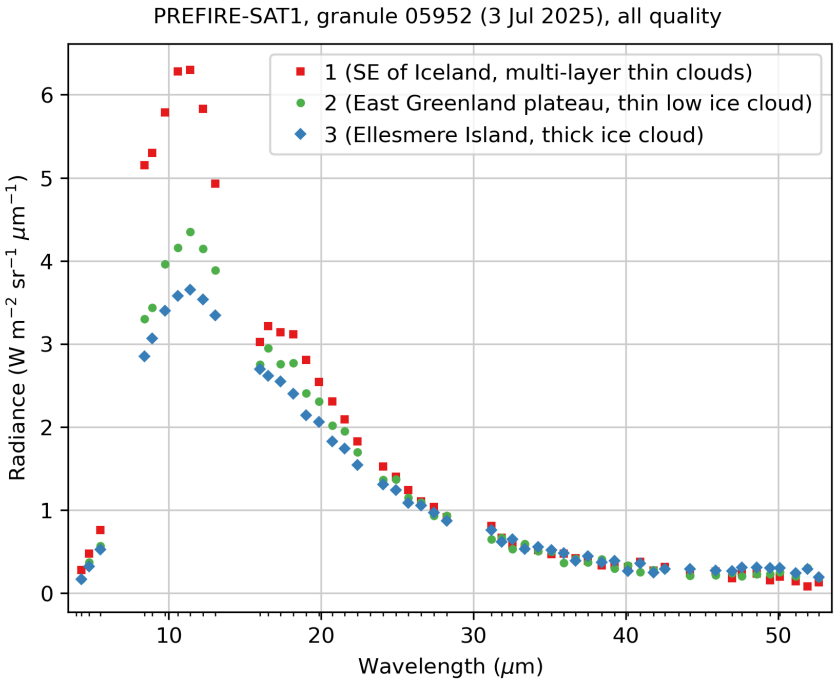
Kyle Mattingly

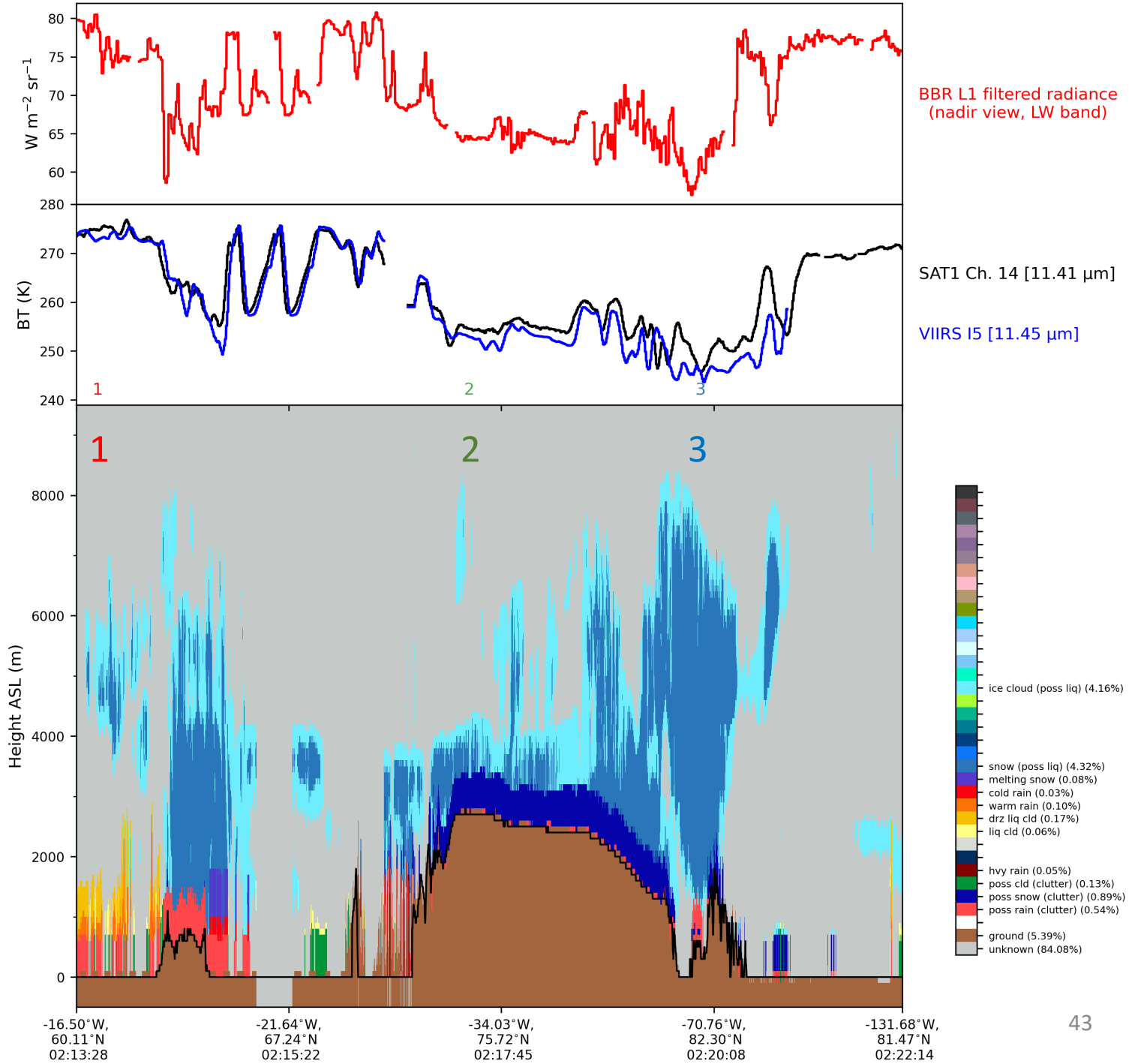


TIRS-1 and EarthCARE segment



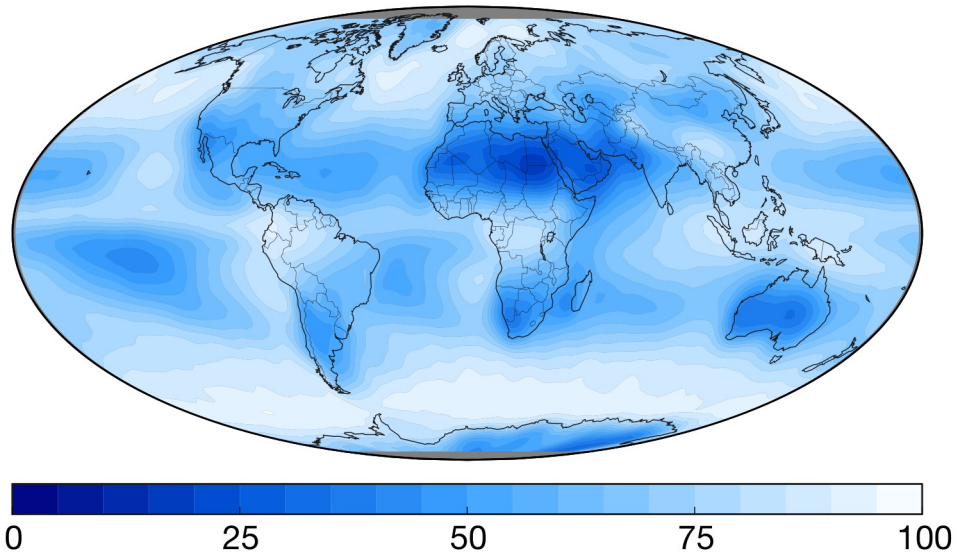
NOAA-20 VIIRS segment



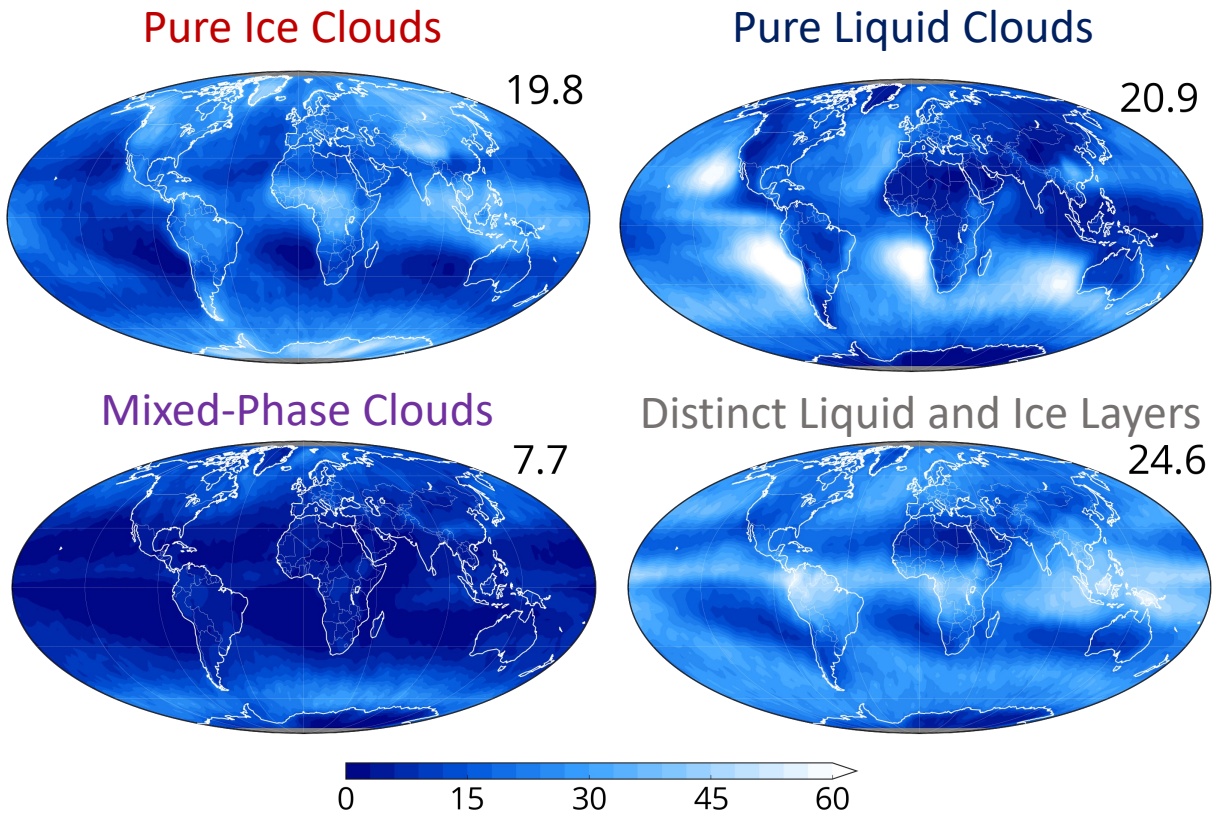


Prior Results from CloudSat and CALIPSO

Total Cloud Fraction

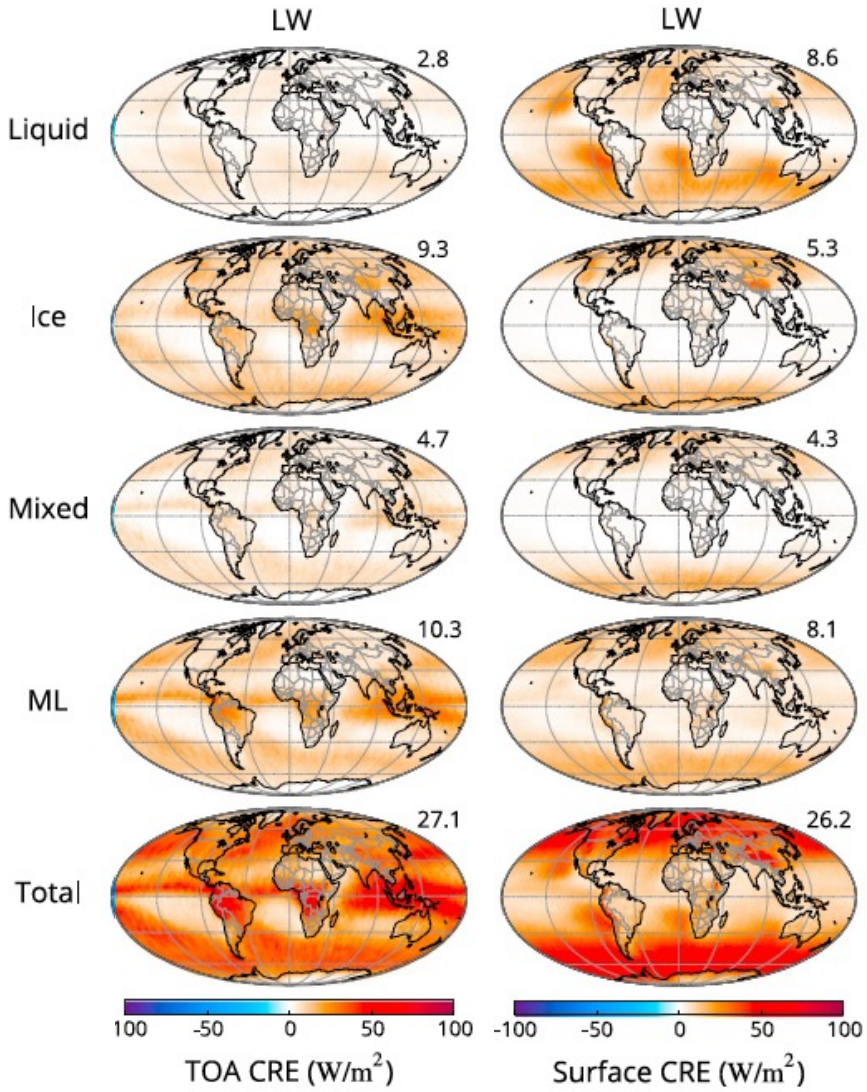


Matus and L'Ecuyer, *J. Geophys. Res.*, (2017)



Matus and L'Ecuyer, *JGR*, (2017)

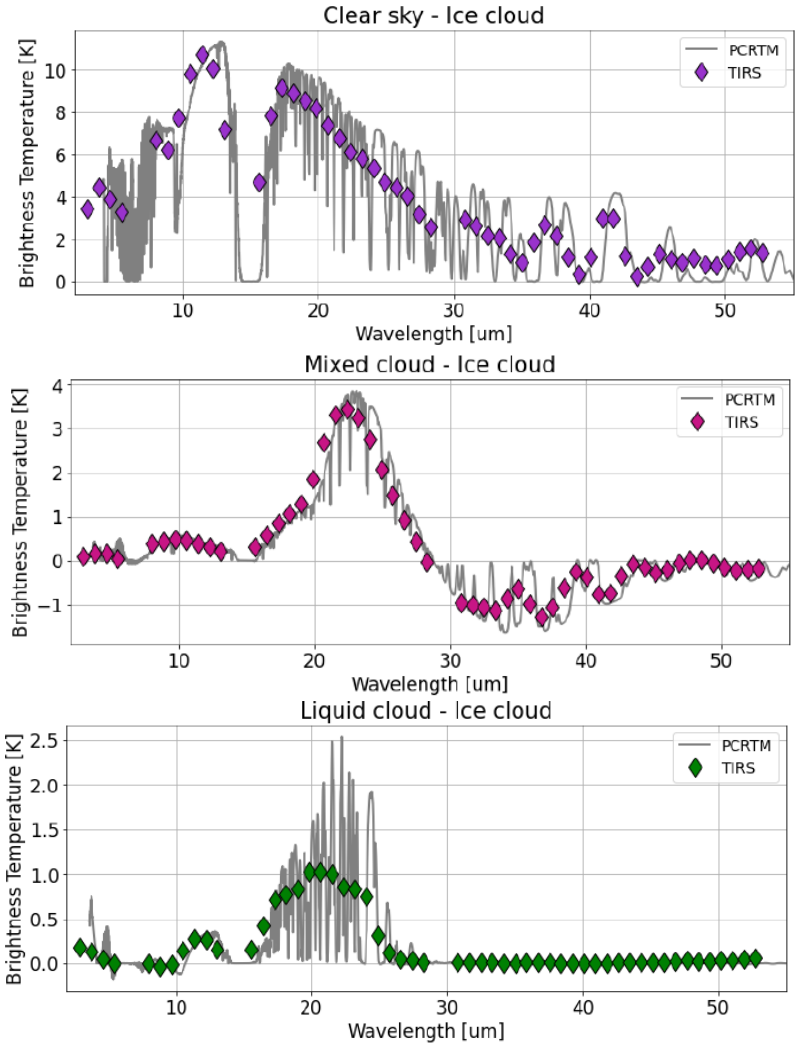
Toward Diagnosing the Spectral Dimension of LW CRE



Matus and L'Ecuyer, *JGR*, (2017)

Simulated Cloud Spectra

(Summit Station, Greenland, winter)



Cassidy Johnson (M.S. Thesis)



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