Initial Thoughts on Potential Synergies between EarthCARE and PREFIRE

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https://prefire.ssec.wisc.edu

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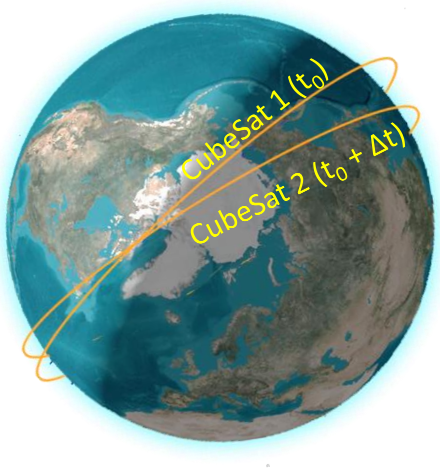
BLUE CANYON TECHNOLOGIES

Polar Radiant Energy in the Far-InfraRed Experiment

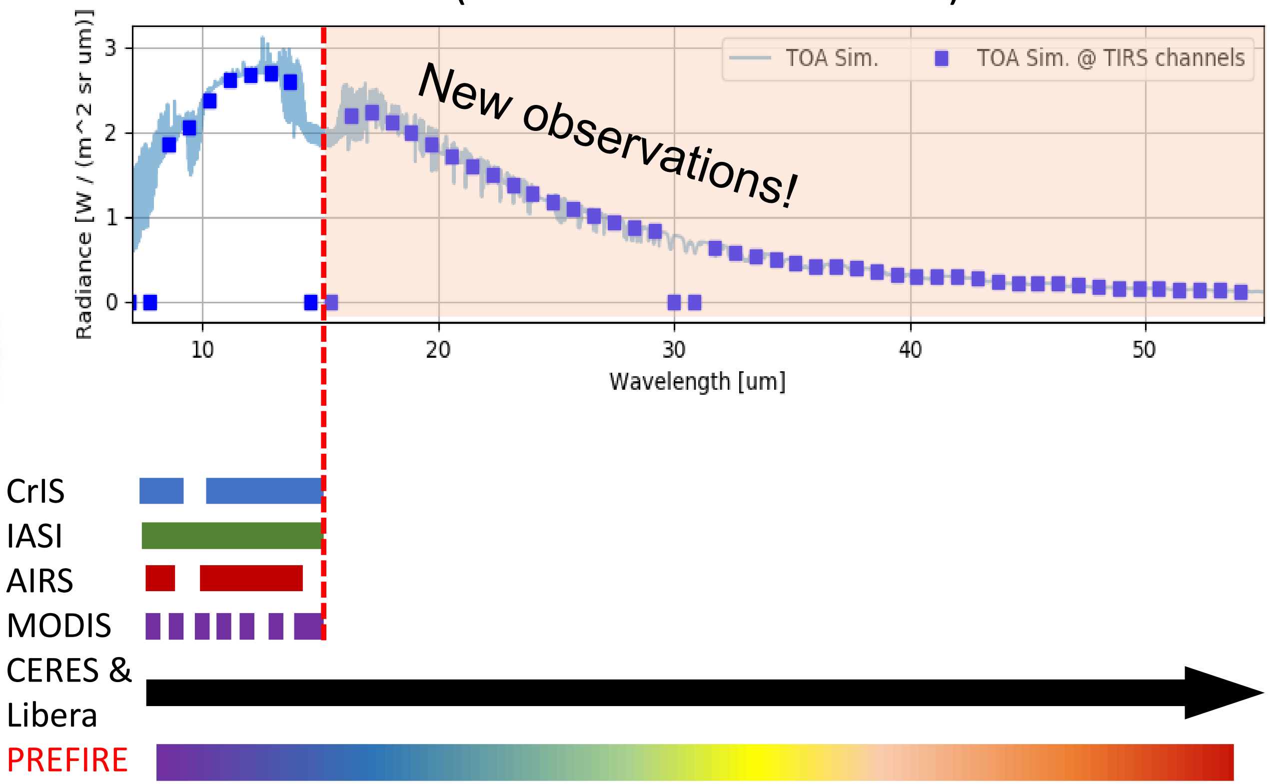
PREFIRE fills the far-infrared observing gap by documenting variability in spectral fluxes from 5 - 53 µm on hourly to seasonal timescales.

PREFIRE:

- ❑ Polar far infrared emission spectra
- ❑ Two CubeSats flying at 520 km altitude
- ❑ Near-polar (82° inclination) orbits
- ❑ Carrying miniaturized infrared spectrometer (5-53 µm) with 0.84 µm spectral sampling,
- ❑ 12×30 km footprints



Spectral channels on the PREFIRE TIRS (Thermal InfraRed Sensor)



PREFIRE Mission Concept

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

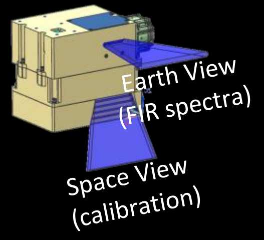
L'Ecuyer et al, *BAMS* (2021)

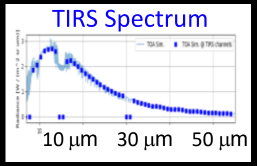
Prime Mission: 10 months
(~5-6 year projected lifetime)

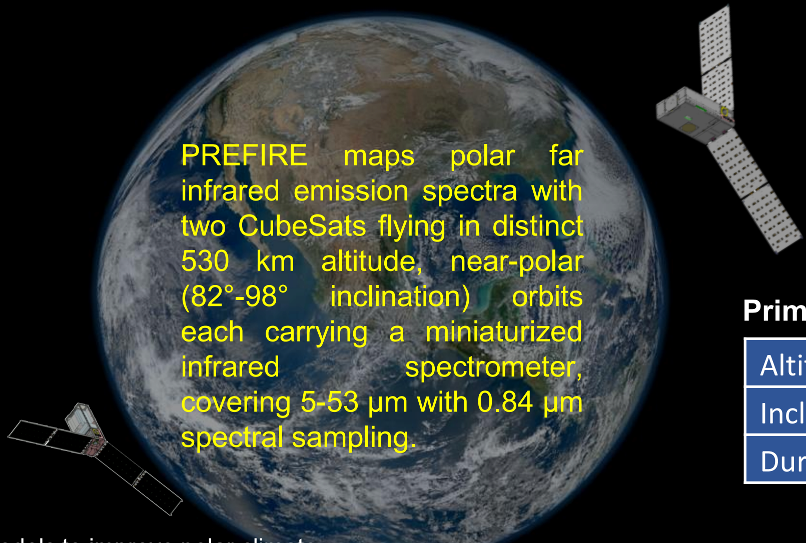
Nominal Operations
Continuous global data collection
Downlink (S-band) up to 4x daily to KSAT Lite Stations at Punta Arenas and Puertollano

Thermal InfraRed Spectrometer (TIRS)

5 to 53 μm spectral range
0.84 μm sampling
8x64 spatial x spectral channels
Size: 4U Mass: 3 kg Power: 4.5 W



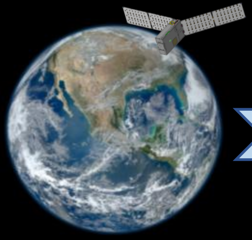




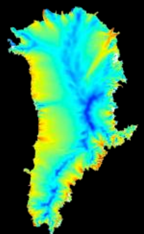
PREFIRE maps polar far infrared emission spectra with two CubeSats flying in distinct 530 km altitude, near-polar (82°-98° inclination) orbits each carrying a miniaturized infrared spectrometer, covering 5-53 μm with 0.84 μm spectral sampling.

PREFIRE Science

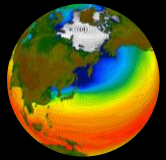
PREFIRE connects observations, analyses, and models to improve polar climate prediction including rates of Arctic warming, sea ice decline, and ice sheet melt



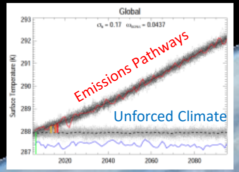
OBSERVE



ANALYZE



MODEL

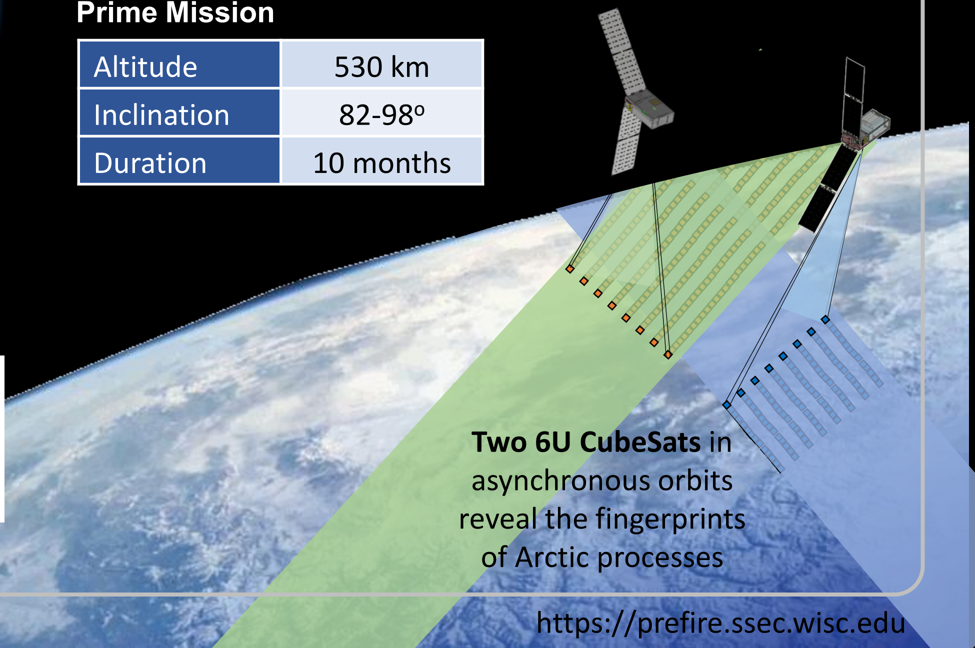


PREDICT

Prime Mission

Altitude	530 km
Inclination	82-98°
Duration	10 months

Overlapping Measurements
Co-located ground scenes separated by 1-12 hours



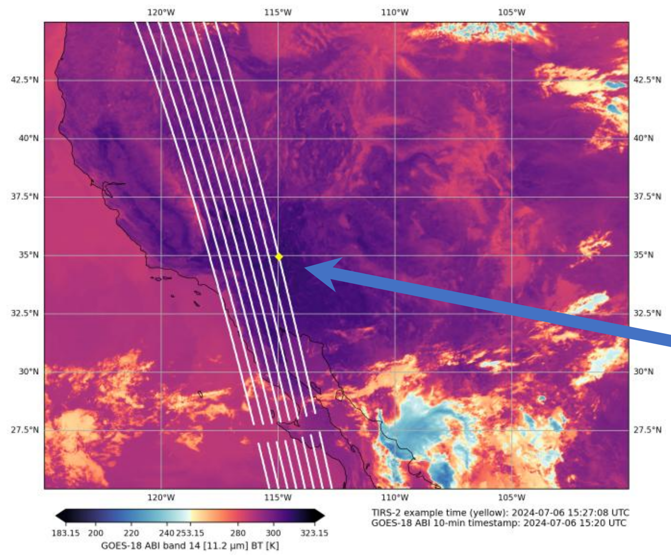
Two 6U CubeSats in asynchronous orbits reveal the fingerprints of Arctic processes

https://prefire.ssec.wisc.edu

Hot and Cold Emission Spectra

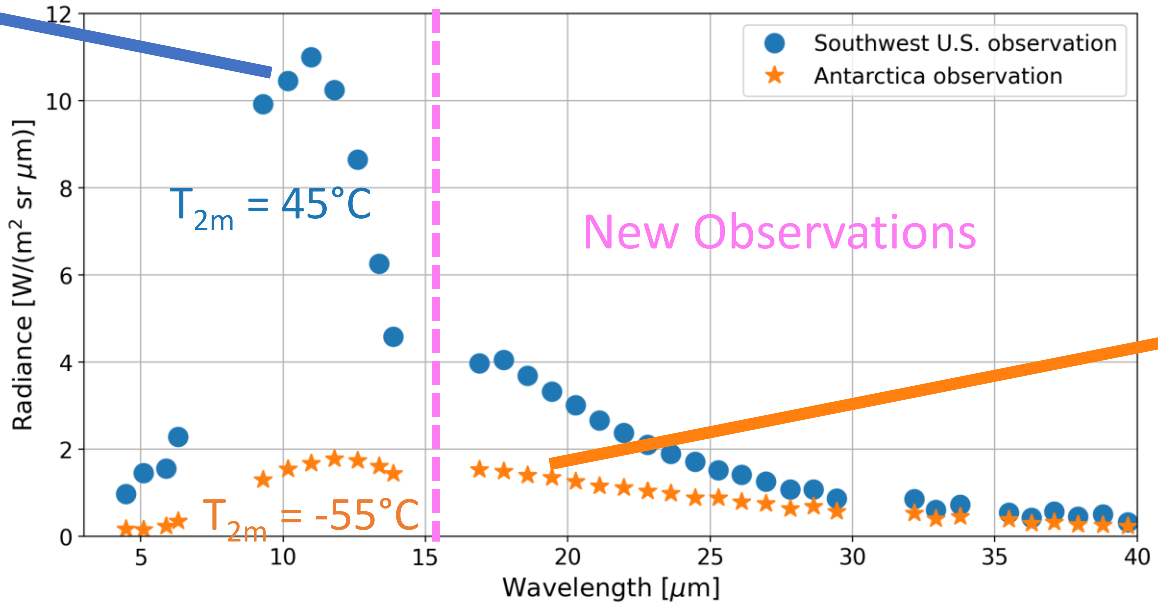
Nate Miller and Kyle Mattingly, UW-Madison

PREFIRE measures near-complete spectra including wavelengths longer than 15 µm that are responsible for half of Earth's emission.

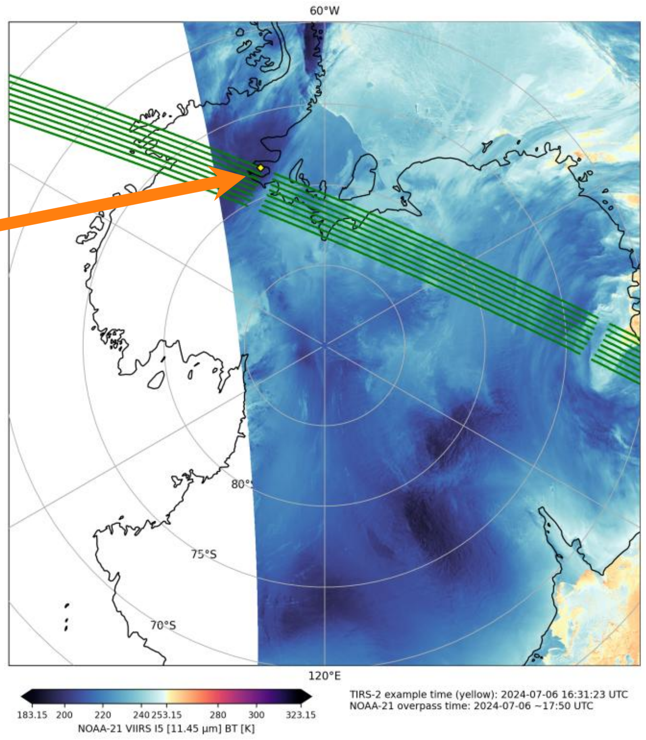


Extreme heat in the Southwestern U.S.

Emission Spectra Spanning 100°C in One Orbit



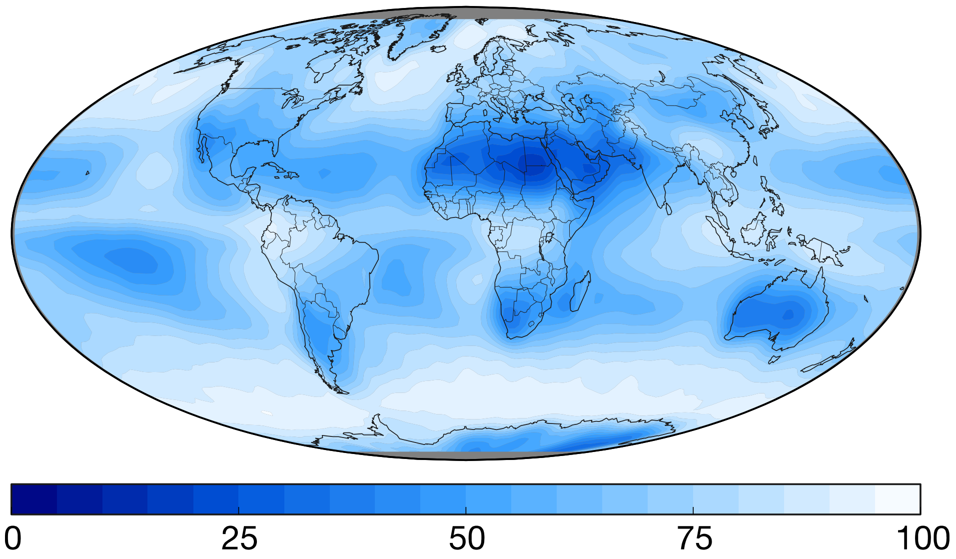
Cold Winter Temperatures in Antarctica



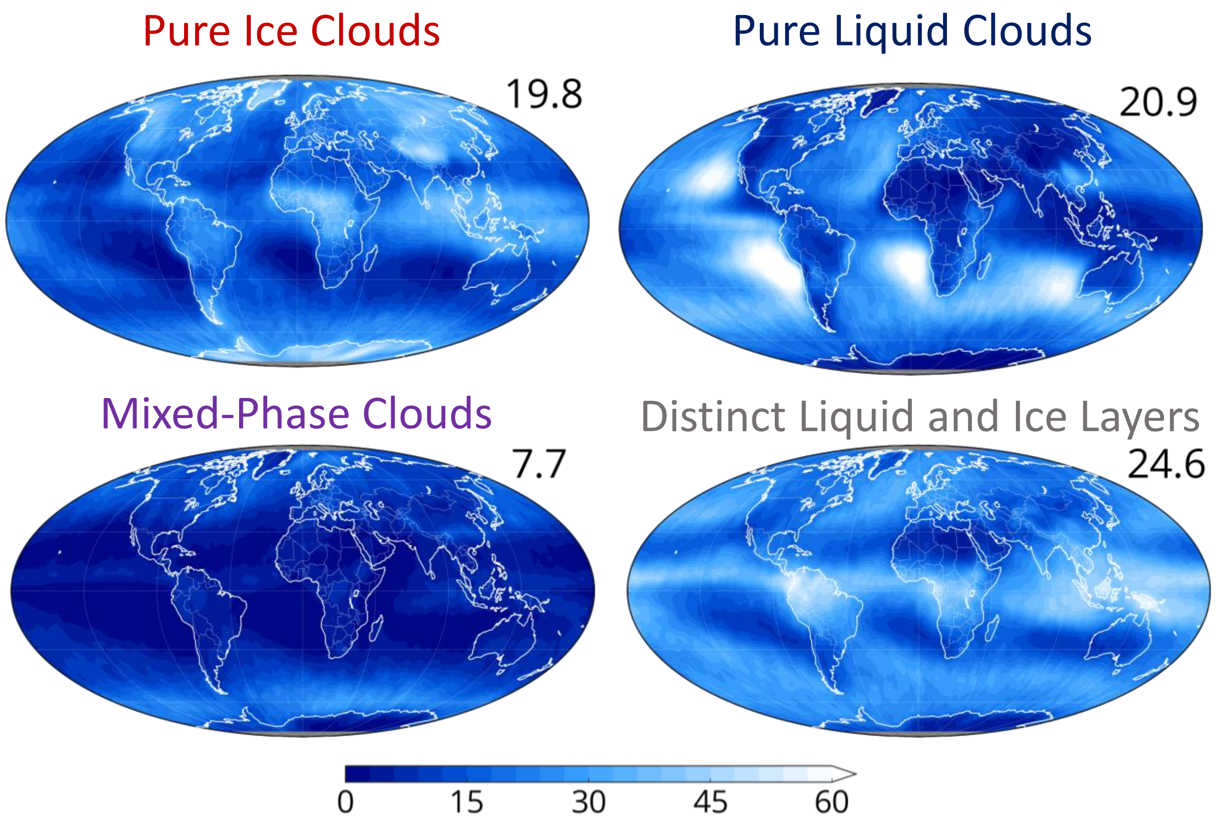
Potential Synergy with Active Sensors

Prior Results from CloudSat and CALIPSO

Total Cloud Fraction

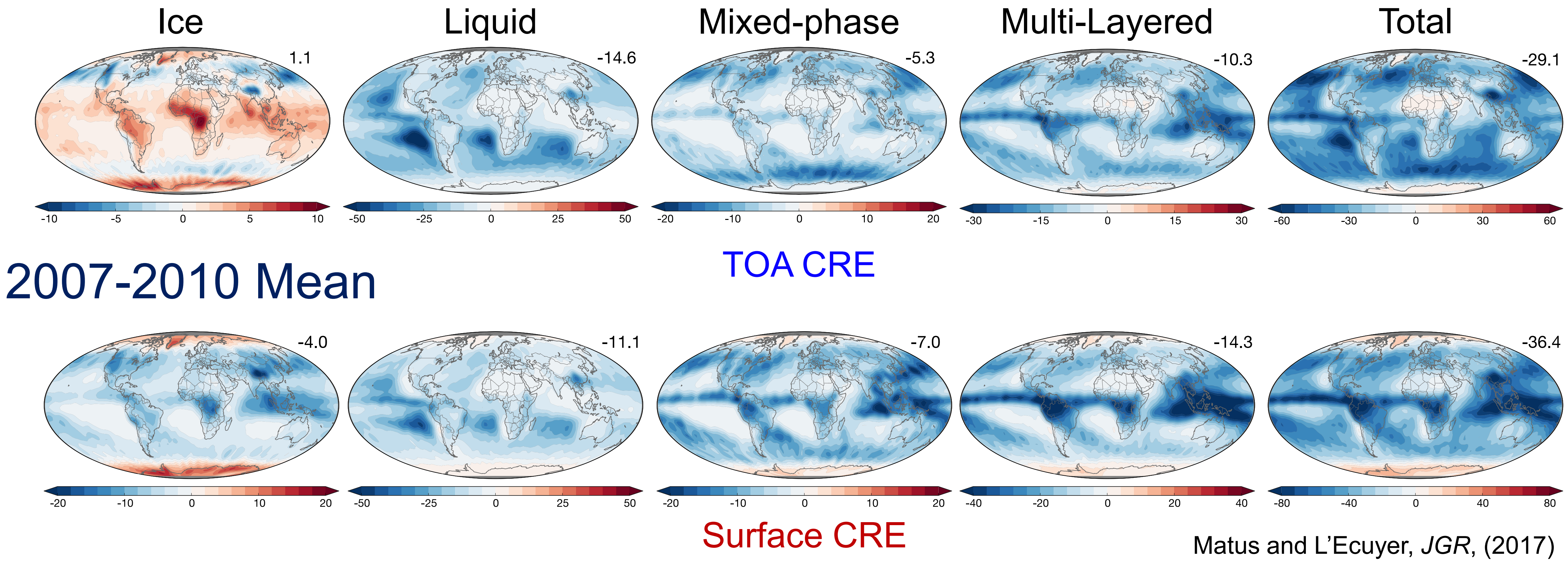


Matus and L'Ecuyer, *J. Geophys. Res.*, (2017)



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

Cloud Phase Impact on Radiative Effects

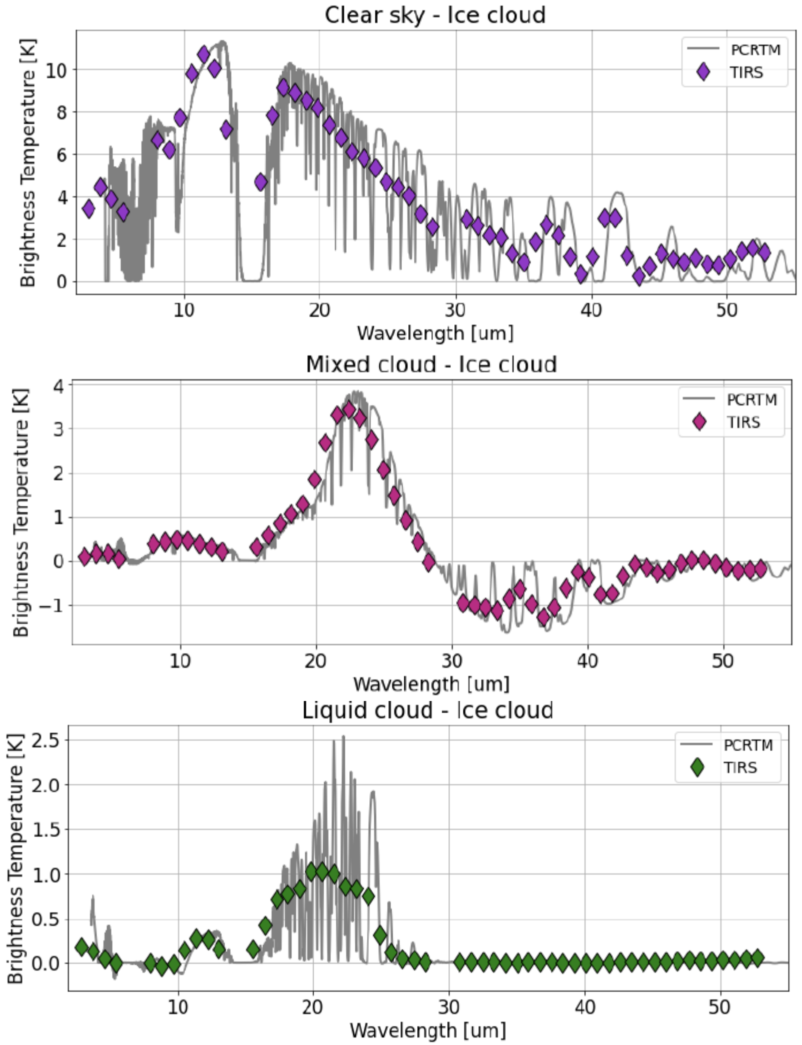


Matus and L'Ecuyer, *JGR*, (2017)

Despite making up only **8%** of total cloud cover, mixed-phase clouds contribute about **20%** of the NET CRE at both TOA and surface

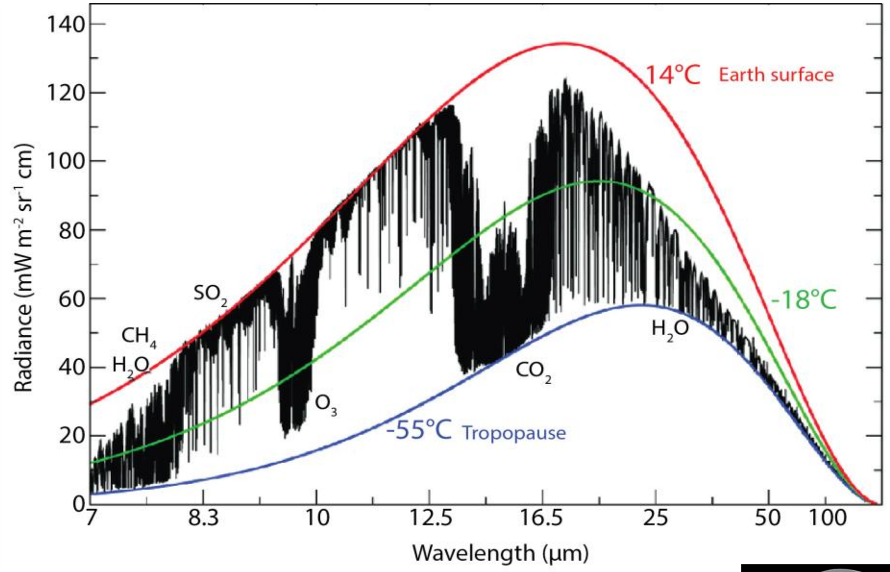
Adding a Spectral Dimension

Simulated Cloud Spectra
(Summit Station, Greenland, winter)

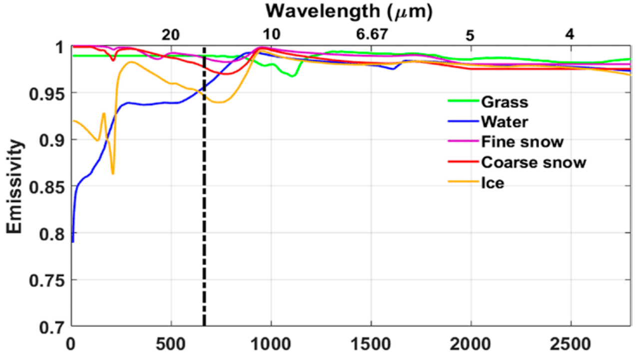


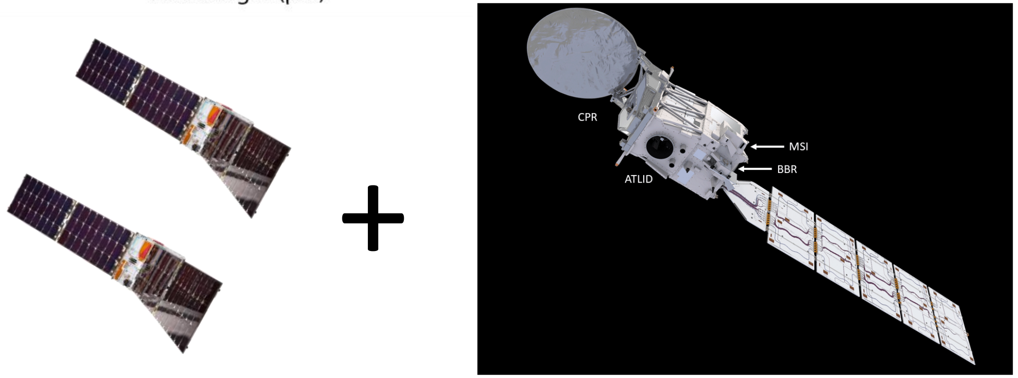
Cassidy Johnson (M.S. Thesis)

Atmosphere



Surface





Radar

Lidar

BBR

MSI

Collocated PREFIRE and EarthCARE observations should reveal the spectral signature of distinct cloud regimes and distinguish them for various clear sky and surface signals.

Spectral Greenhouse Effect (19.4 µm)

Hamish Prince, UW-Madison

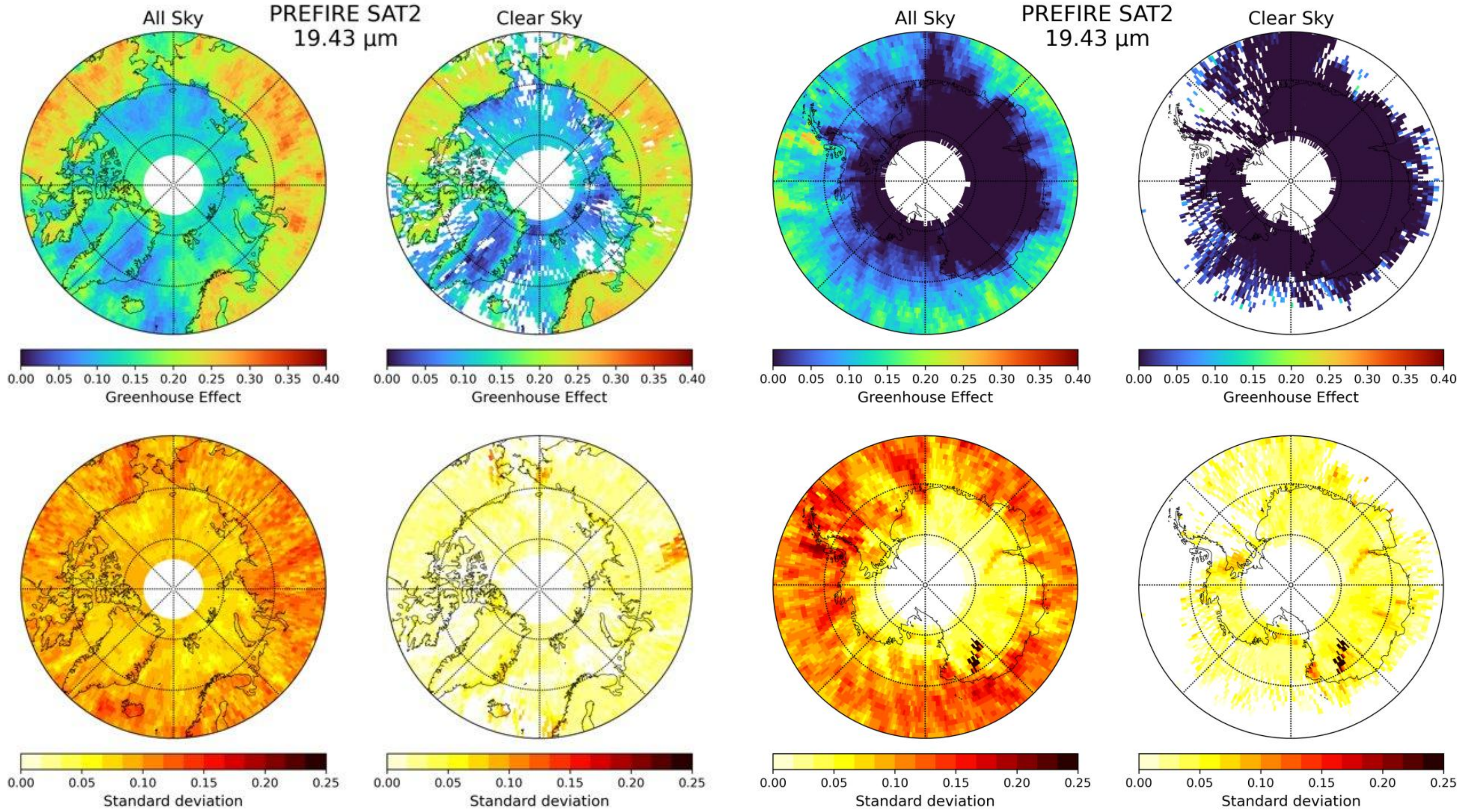
$$G_\lambda = 1 - \frac{OLR_\lambda}{SFC\ Emitted_\lambda}$$

Arctic

Antarctica

Mean

Variability

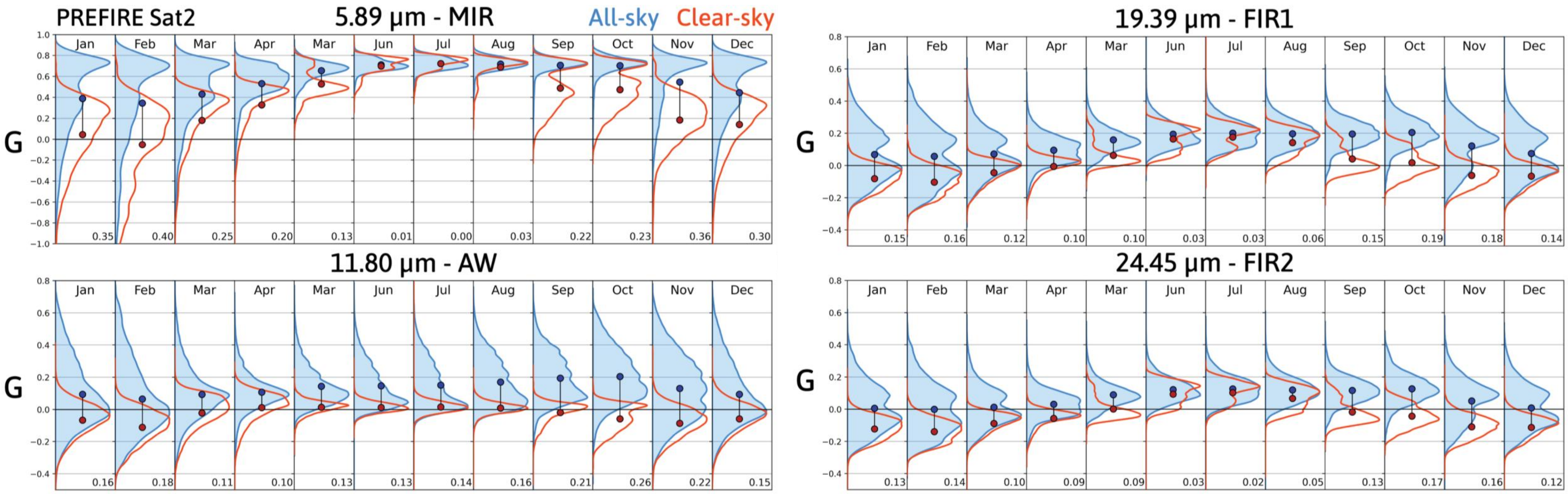


Seasonality of Spectral Greenhouse Effect

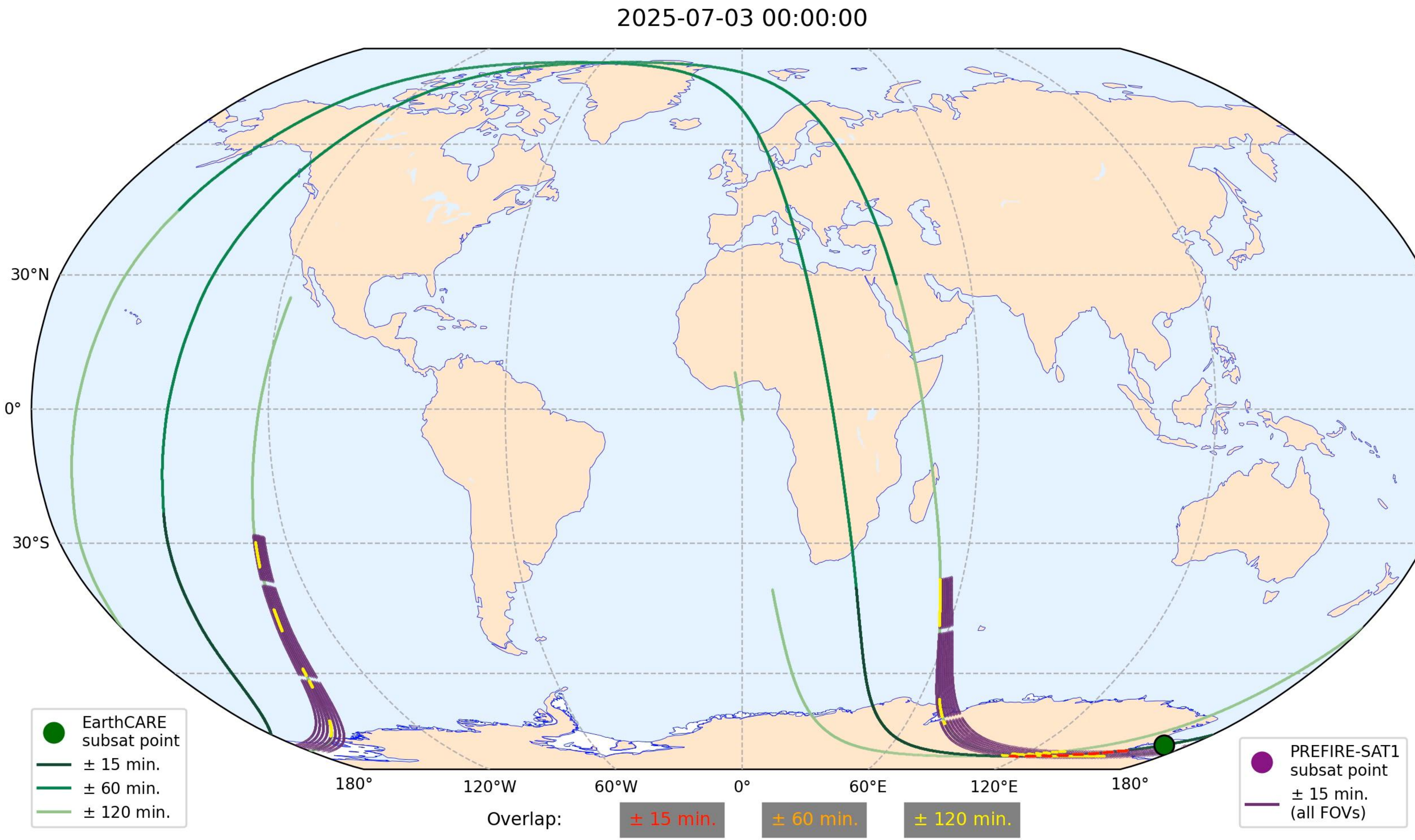
Hamish Prince, UW-Madison

$$G_\lambda = 1 - \frac{OLR_\lambda}{SFC\ Emitted_\lambda}$$

Clouds impact different spectral regions than water vapor, surface temperature, lapse rate, CO_2, etc. and different cloud types impact distinct spectral regions.

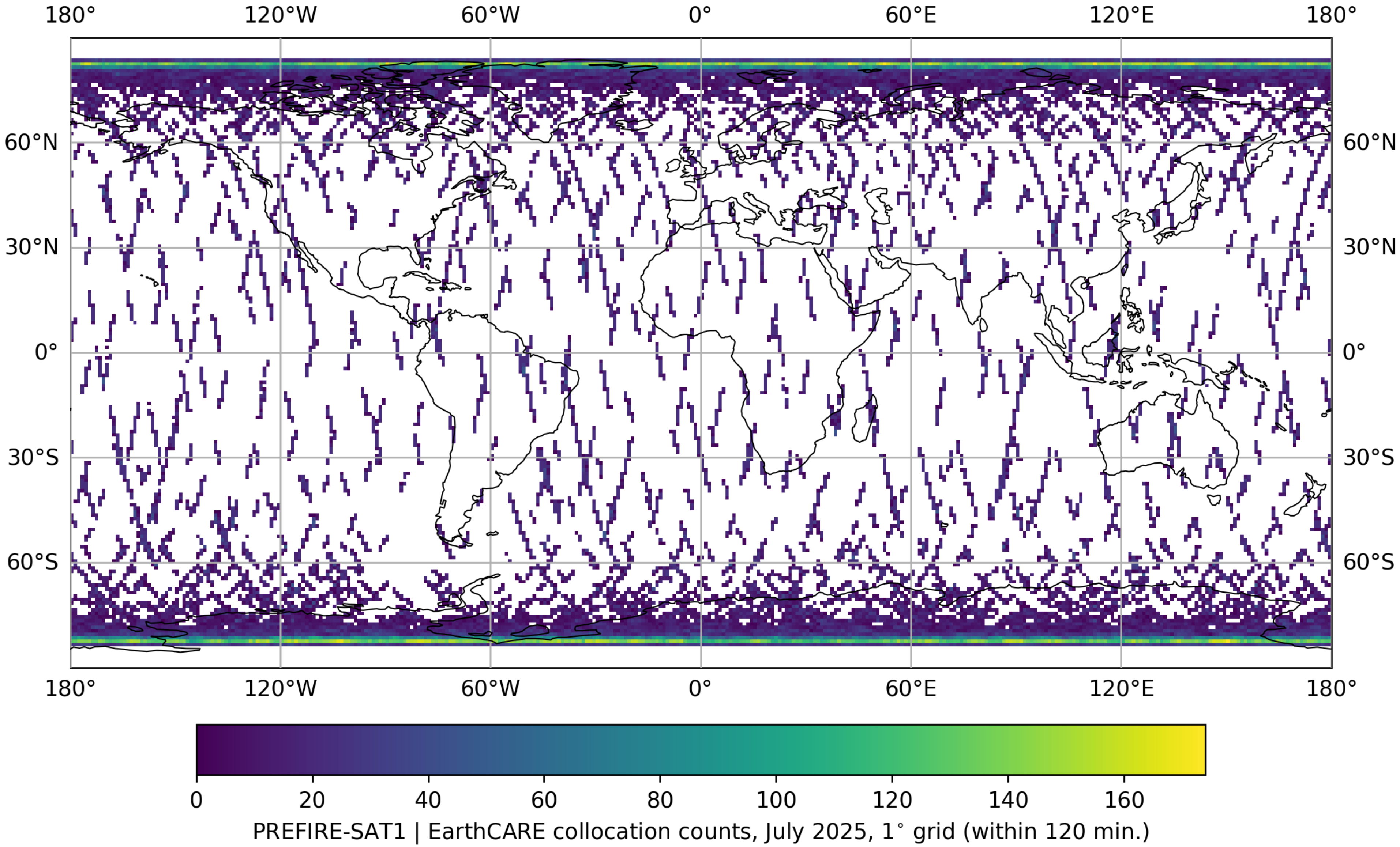


PREFIRE-SAT1 : EarthCARE Matchups



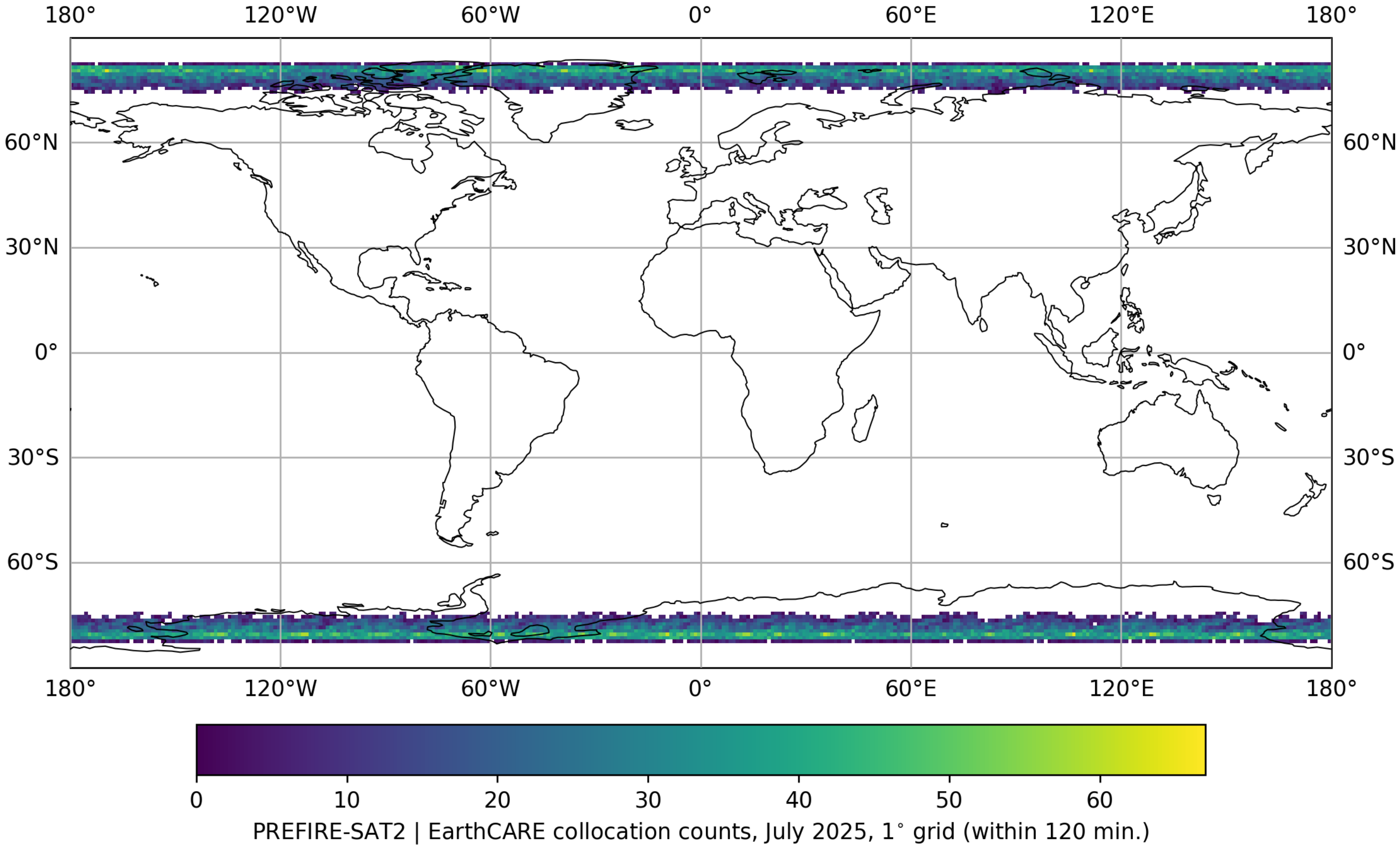
July 2025 PREFIRE SAT 1 Overlaps Within 120 Minutes

Kyle Mattingly, UW-Madison



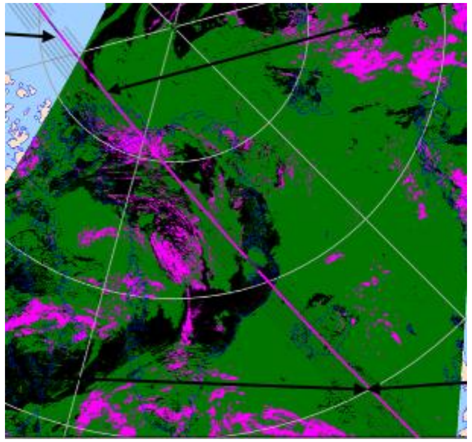
July 2025 PREFIRE-SAT2 Overlaps Within 120 Minutes

Kyle Mattingly, UW-Madison

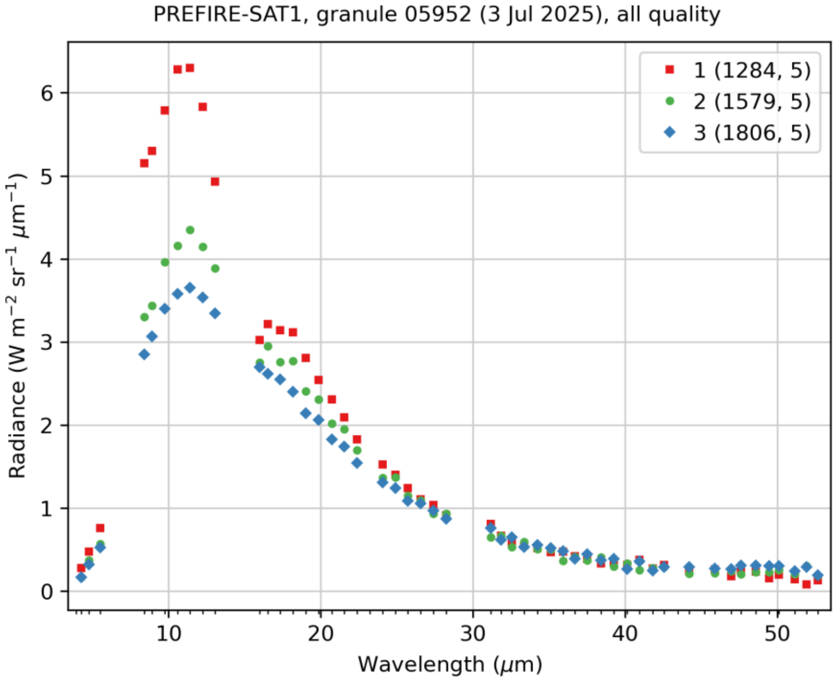


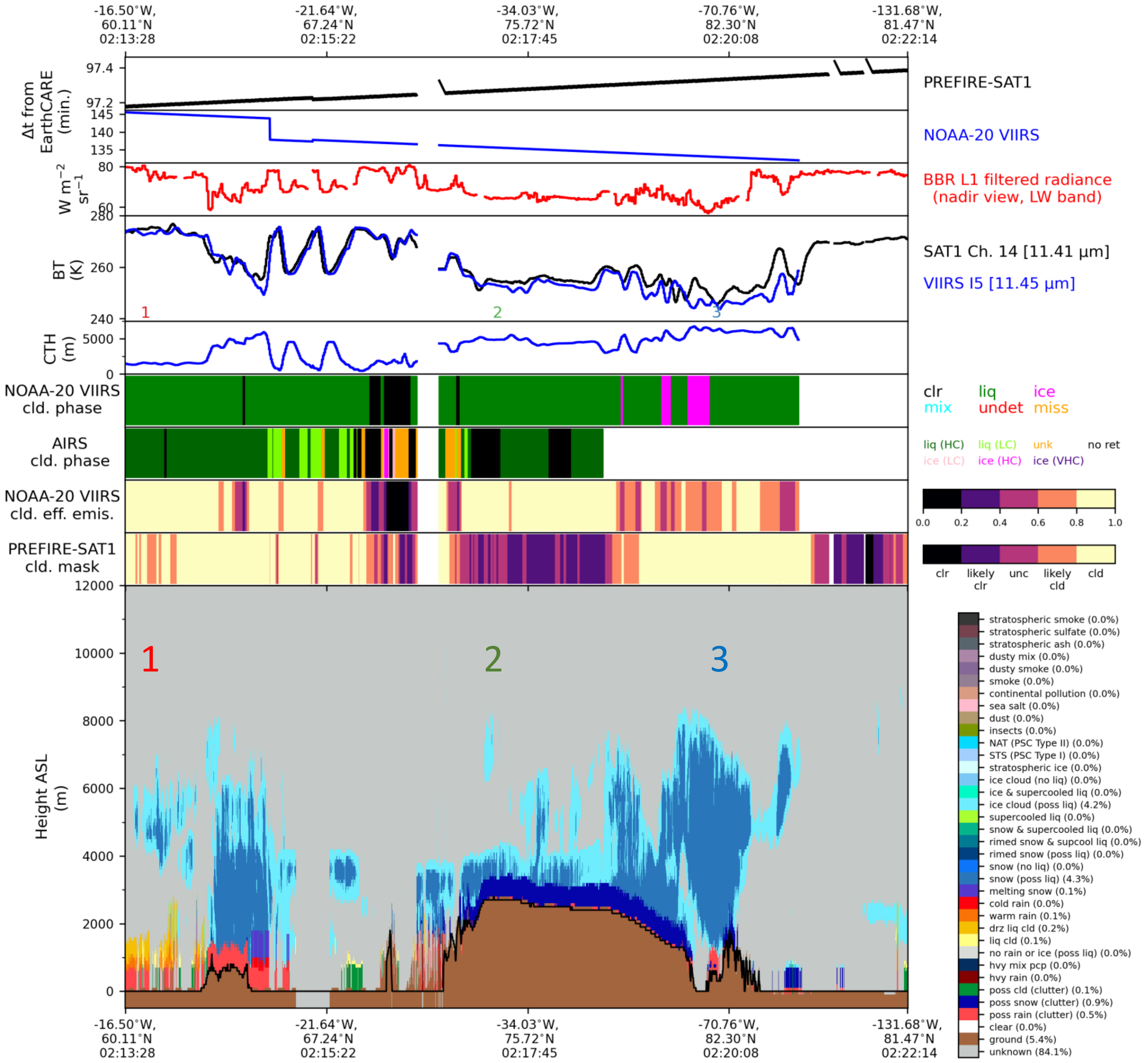
PREFIRE-SAT-1, NOAA-20, EarthCARE Matchup (July 3, '24)

TIRS-1 and EarthCARE segment



NOAA-20 VIIRS segment





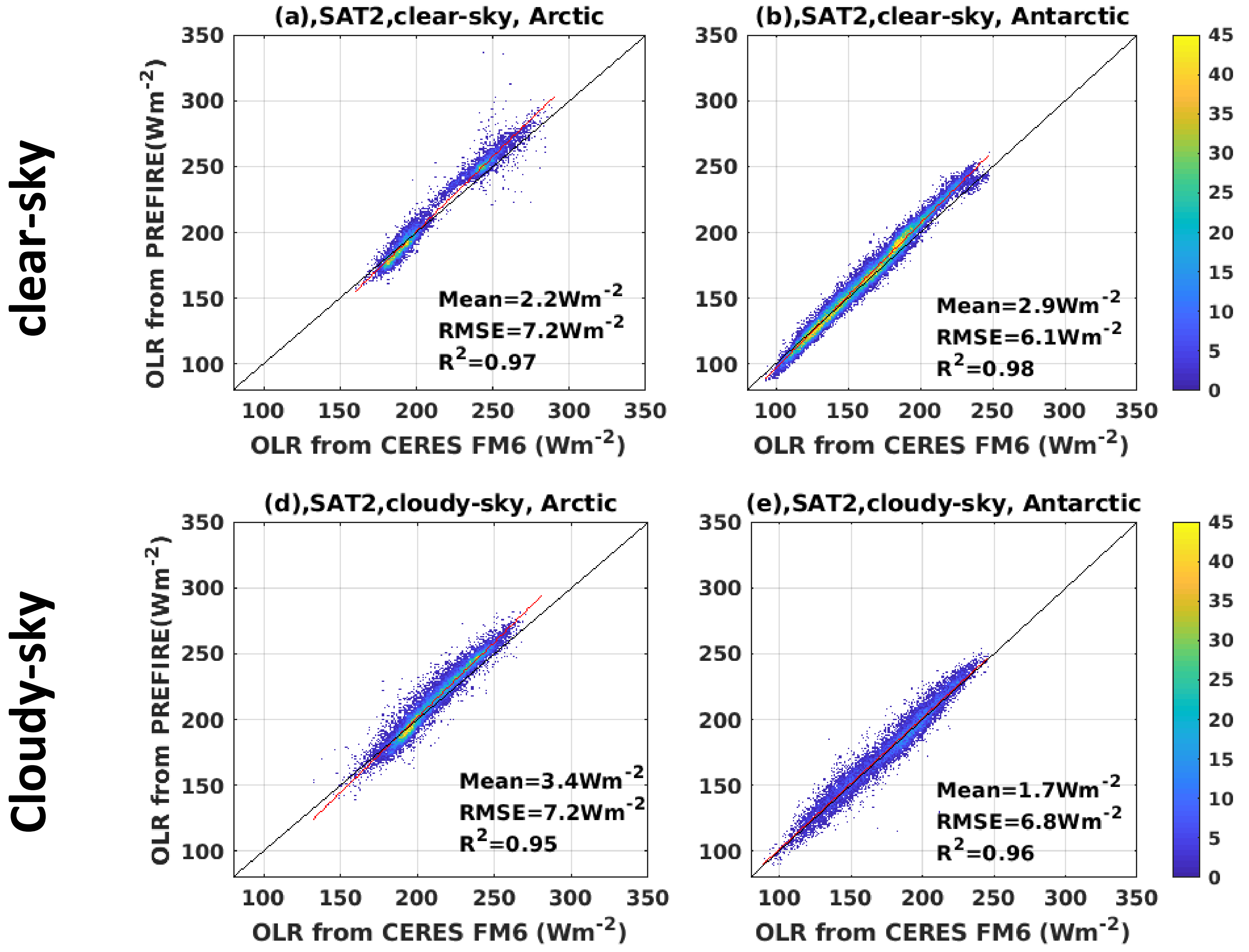
Summary

- The PREFIRE CubeSats launched on May 25 and June 5, 2024 with the goal of reducing uncertainty in polar infrared fluxes, the processes that modulate them, and the implications of polar climate predictions.
- Identical TIRS on two 6U CubeSats are measuring far-infrared spectra from 5-53 µm at 0.84 µm resolution (globally) in 3:45 and 8 am/pm orbits.
- Observed radiances across the mid- and far-infrared are being used to derive surface properties, water vapor, temperature, and cloud properties.
- Synergies with the BBR, MSI, and active sensors aboard EarthCARE offers an opportunity to add a spectral dimension to climate feedback analyses.
- While PREFIRE has already completed it’s 10 month Prime Mission, orbit predictions and instrument health suggest it may collect <u>global</u> spectral radiances through at least 2030.

https://prefire.ssec.wisc.edu

L’Ecuyer et al, *BAMS* (2021)

PREFIRE-SAT2 OLR vs. CERES FM6 SSF OLR



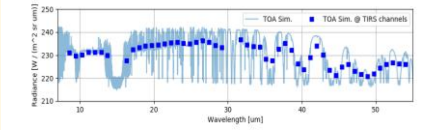
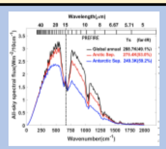
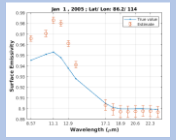
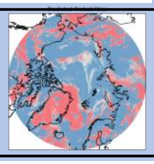
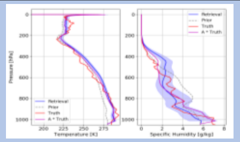
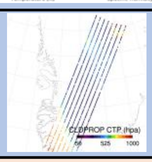
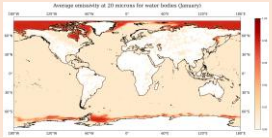
Collocation criteria:

Distance <3km

Time difference <10 minutes

Four months (123 days) examined (July, October 2024 and January, April 2025)

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	

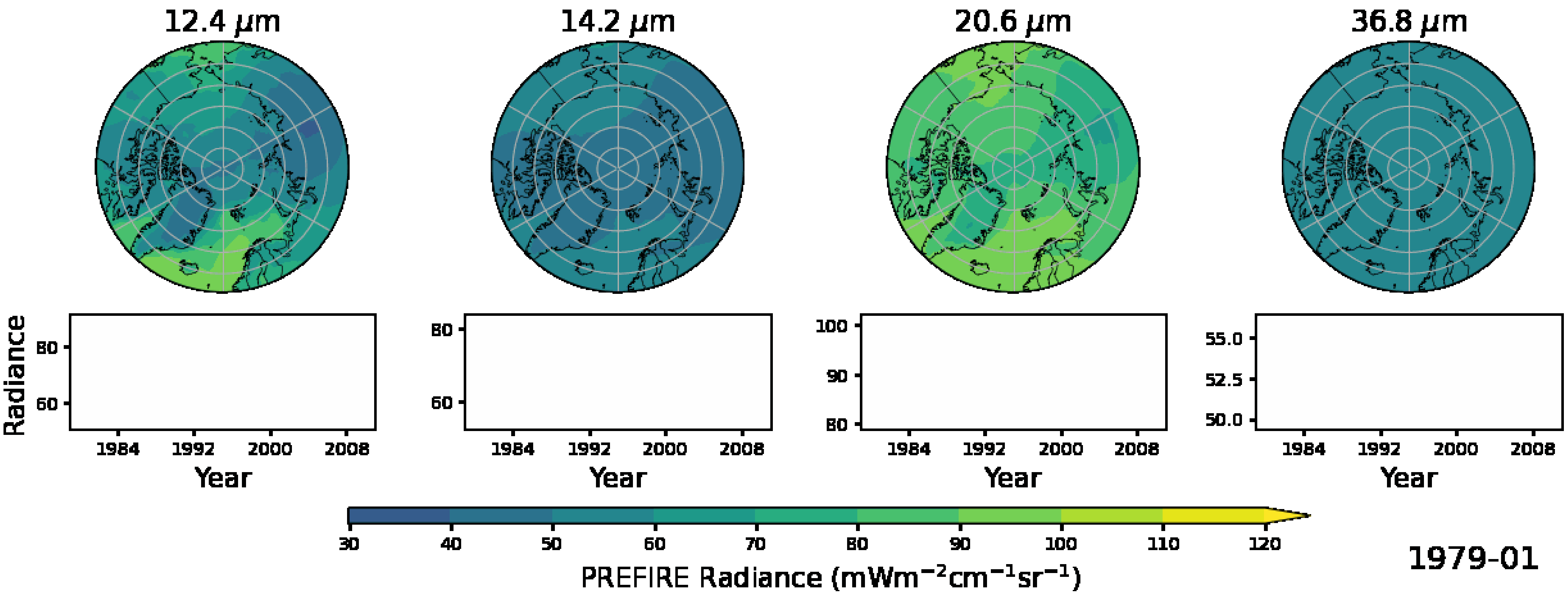
Available now at ASDC!

Anticipated in early April

Anticipated in early June

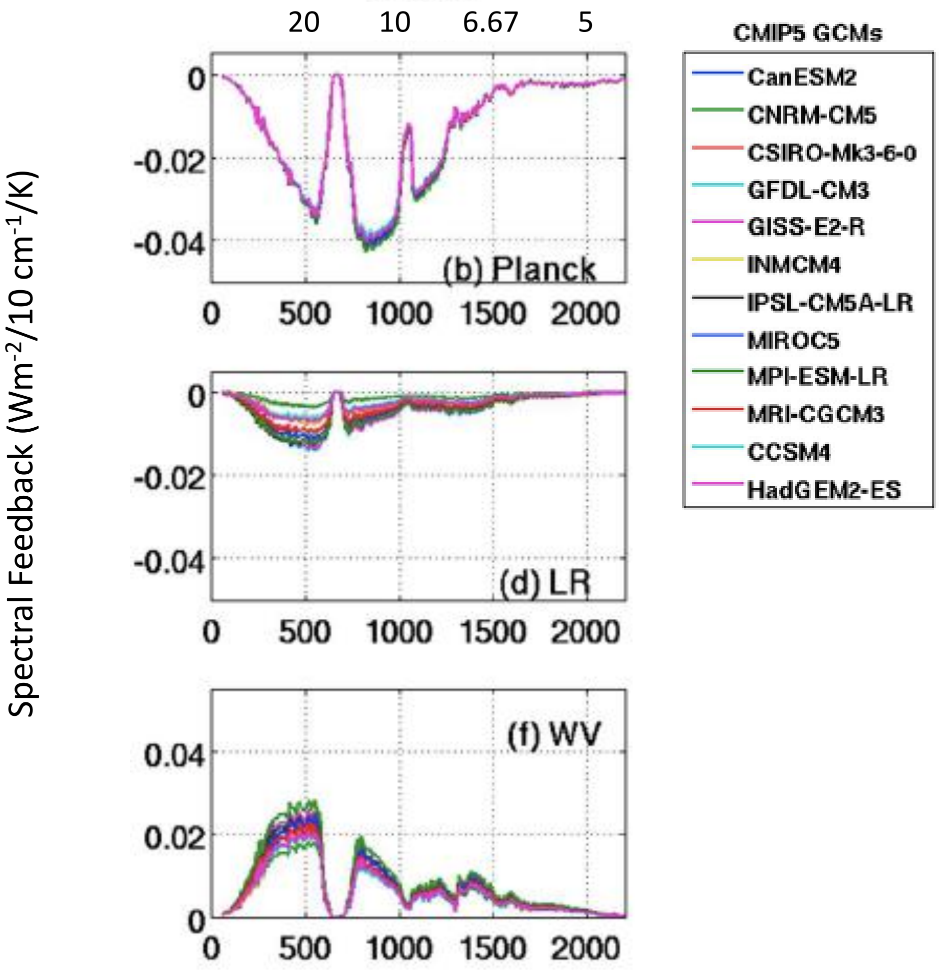
Interfacing with Models

Jonah Shaw and Jen Kay



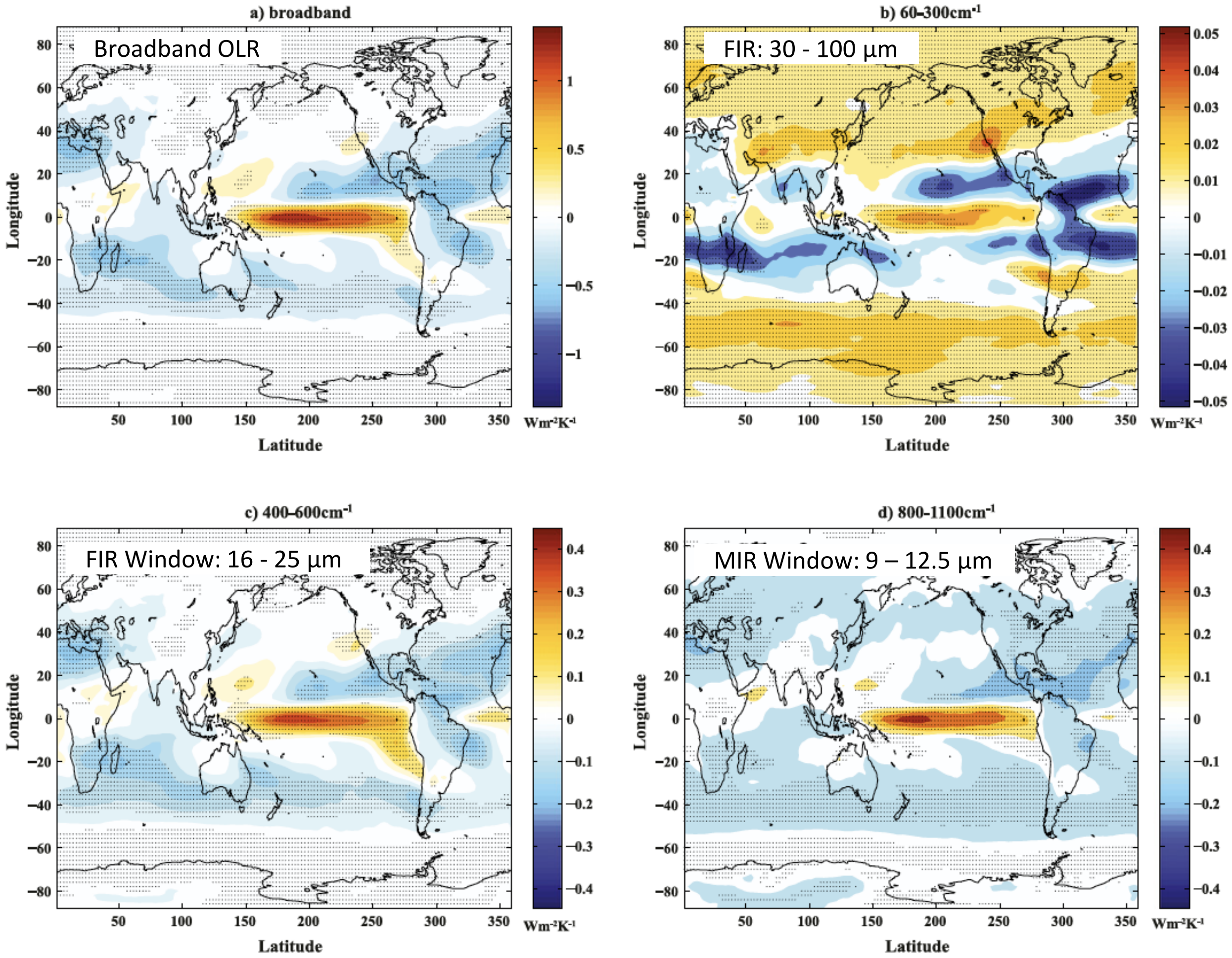
PREFIRE interfaces with models through new surface emissivity models and a COSP-compatible simulator.

Spectral Signature of RH Feedback



Huang et al, Geophys. Res. Letters (2014)

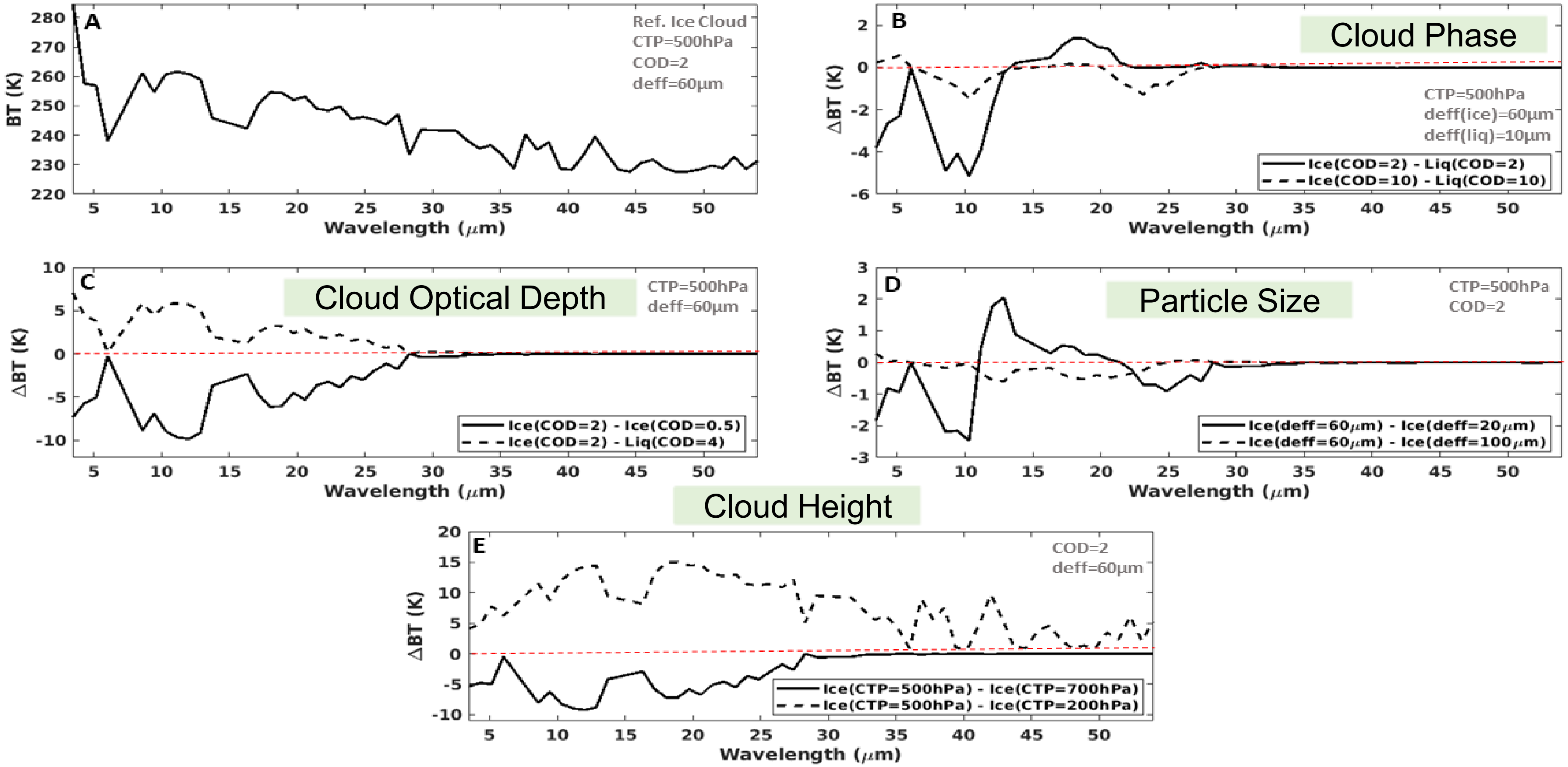
RH Feedback in CMIP5



Pan and Huang, J. Climate (2018)

Measuring complete emission spectra distinguishes the fingerprints of several important feedback processes.

Spectral Radiative Effects



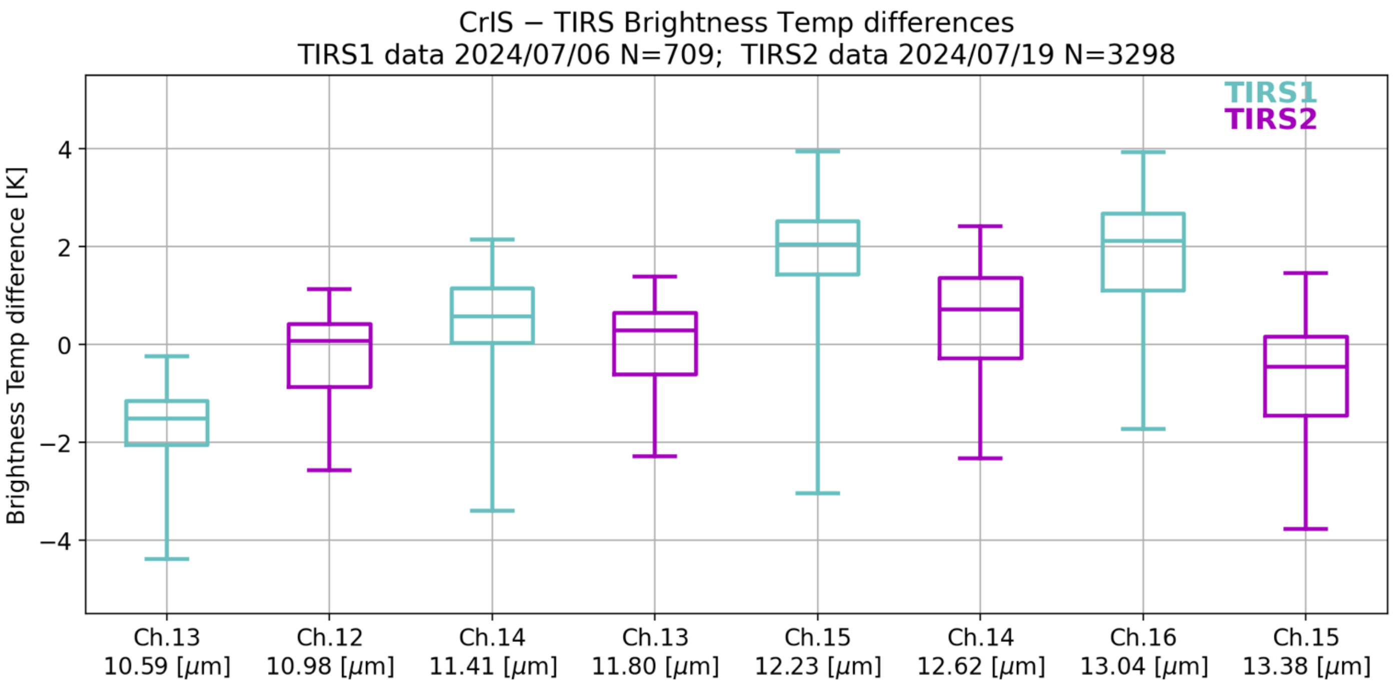
In cloudy scenes, TIRS radiances carry the spectral signatures of cloud phase and ice particle size

Preliminary Calibration Assessment

Aronne Merrelli, Nate Miller, and Brian Drouin

- ❑ Noise and sensor gain similar to pre-launch estimates.
- ❑ Calibration system (mirror and calibrator) performing as expected.
- ❑ Good radiometric accuracy in mid-infrared window channels (confirmed via matchups with operational sounders, right).
- ❑ Far-infrared channels (15 – 30 µm) consistent with modeling (no independent verification available).

TIRS1 and TIRS2 Collocations with CrIS*



- Results produced by integrating high-spectral resolution measurements from CrIS on the operational JPSS satellite over the corresponding TIRS spectral response functions.
- TIRS1 data not yet corrected for mirror pointing offsets.