A comparison between CERES TOA Radiative Fluxes and airborne radiative flux measurements from ARISE

Patrick C. Taylor, Kyle F. Itterly, Sergio Sejas, Wenying Su, Joe Corbett

2022 Spring CERES Science Team Meeting

NASA Langley Research Center

April 27, 2022

Arctic Radiation-IceBridge Sea ice Experiment (ARISE)

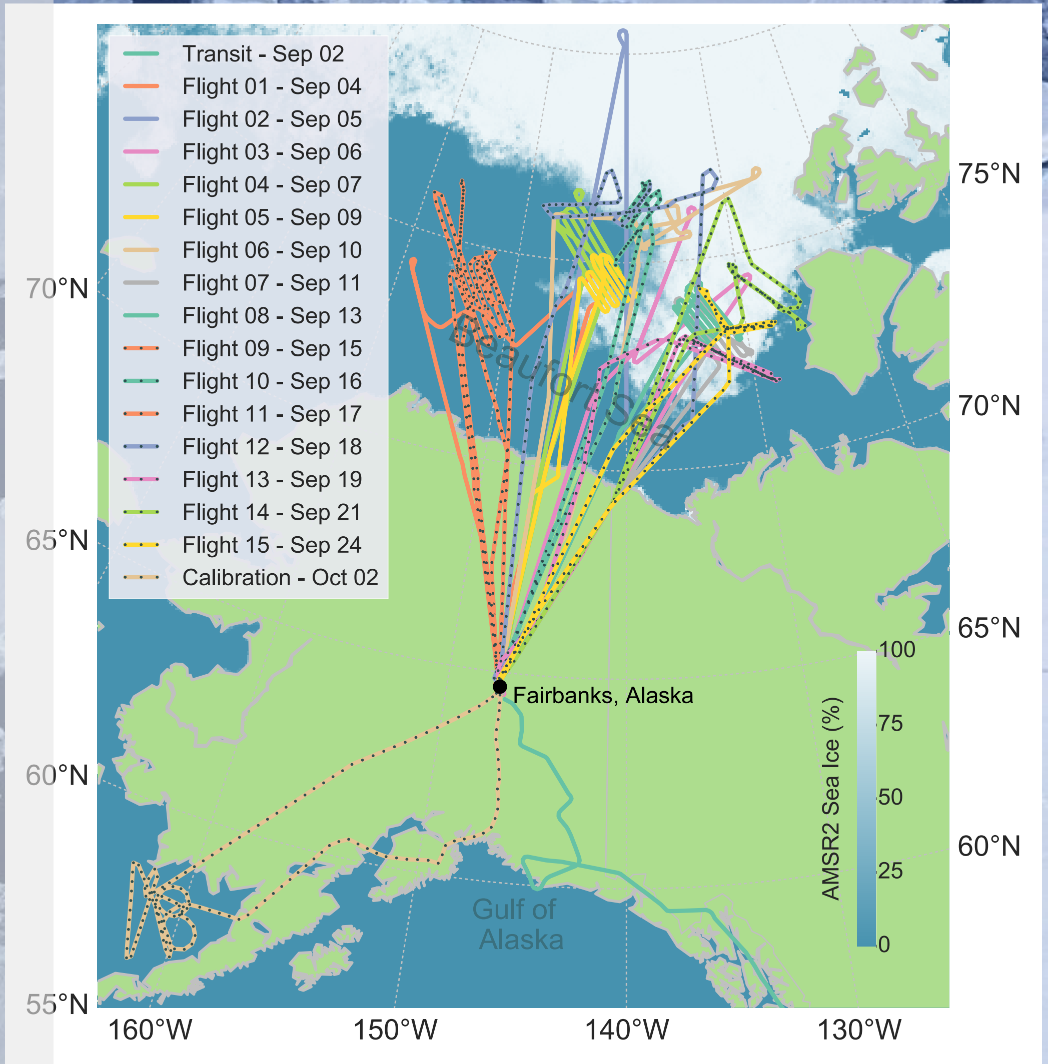
Based in Fairbanks, Alaska during September 2014

From the NASA C-130:

- Measure spectral and broadband radiative flux profiles
- Quantify surface characteristics, cloud properties, and other atmospheric state parameters under a variety of Arctic atmospheric and surface conditions
- Coincide with satellite overpasses as often as possible

Naval Research Laboratory Broadband Radiometers (BBR):

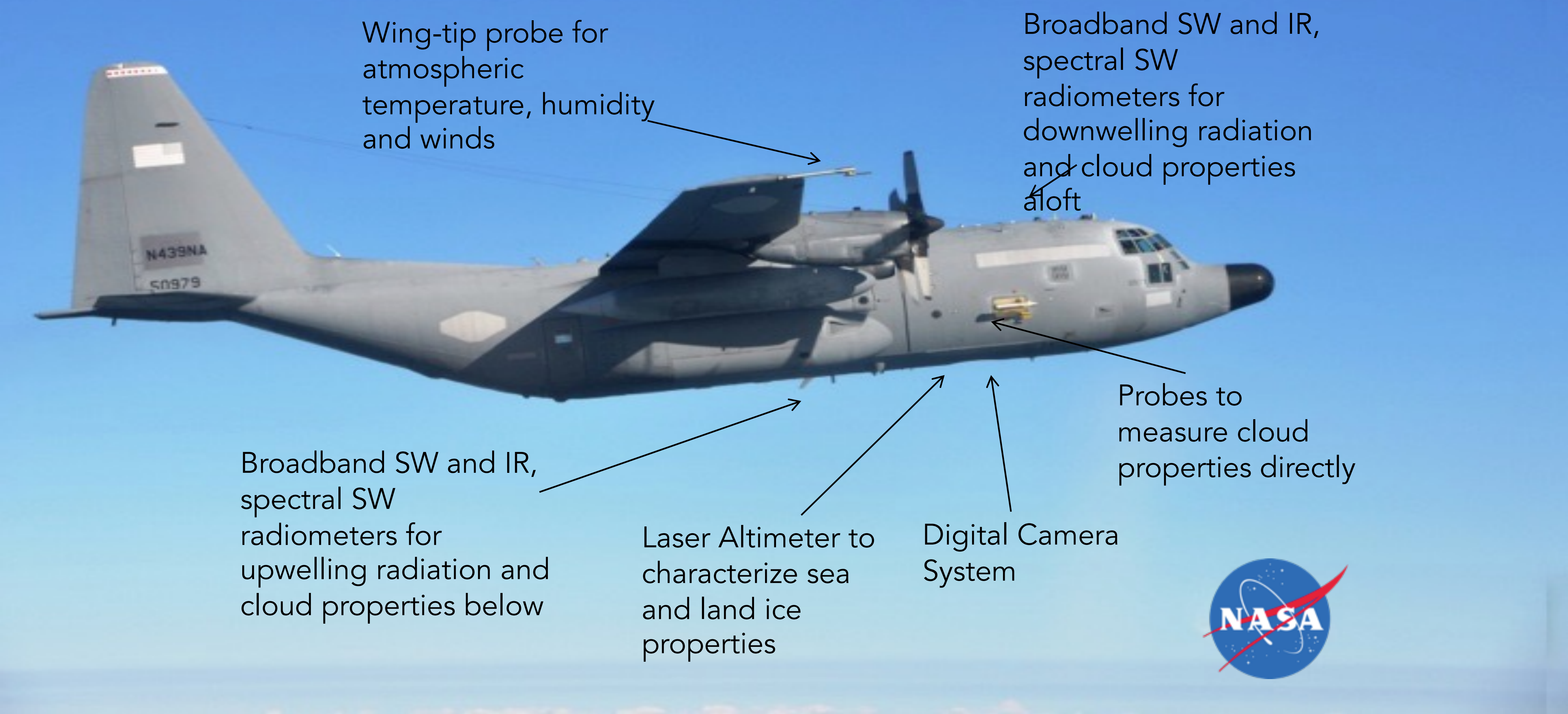
- SW up and down – modified Kipp and Zonen CM-22 pyranometers
- LW up and down – modified Kipp and Zonen CG-4 pyrgeometers
- estimated uncertainty ~ 3-5%



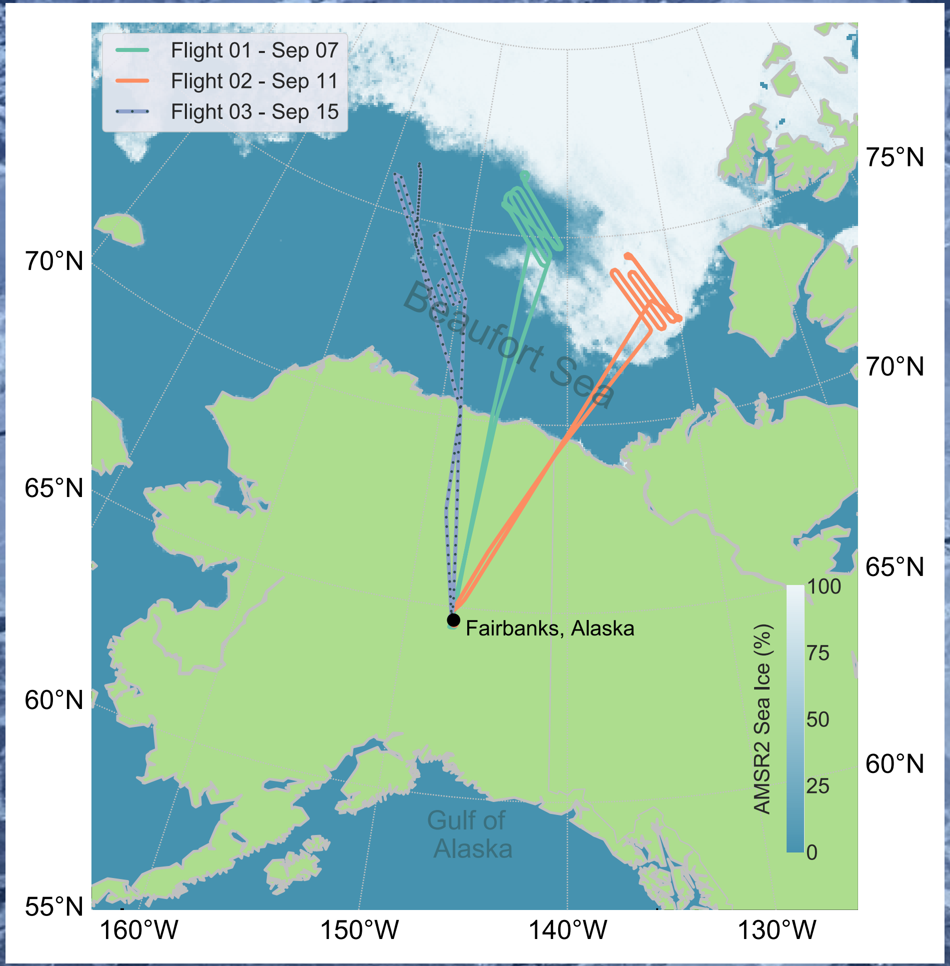
NASA C-130 PAYLOAD

Instruments	Measurement	Characteristics	Products
Broadband Radiometers (BBR) A. Bucholtz, NRL	SW and LW fluxes (↑, ↓) SW total, direct & diffuse (↓)	SW: modified K&Z CM-22 (0.2-3.6 μm) LW: modified K&Z CG-4 (4.5-45 μm) TDDR: Delta-Devices SPN-1 (0.4-2.7 μm)	Net SW, LW Irradiance, direct/diffuse SW partitioning, absorption, heating rates Surface albedo, cloud albedo
Spectral Solar Flux Radiometer (SSFR) S. Schmidt, U. of Colo.	Spectral SW fluxes (↑, ↓)	370-2170 nm, Resolution: 8-12 nm	Spectral fluxes, albedo Cloud properties
Spectral Sun-photometer 4STAR J. Redemann, NASA ARC	Spectral radiances (↓) Modes: direct beam, sky scanning, zenith	380-1700 nm	aerosols, gases, cloud properties above aircraft
Heitronics KT-19 D. Van Gilst, NSERC/UND A. Bucholtz, NRL	IR window radiance (↑, ↓)	9.6-11.5 μm	Skin temperature, sky and cloud temperature
Land, Vegetation, and Ice Sensor (LVIS) B. Blair, M. Hofton, GSFC	Geo-located waveform vector	1064 nm Scanning: 20-minute footprint, 2 km swath from 10 km, Full waveform recorded	Surface elevation, Sea-ice freeboard, Melt-pond distribution Cloud top height

NASA C-130: An airborne radiometer (thermometer) with in-situ probes and a laser altimeter to characterize the surface, atmosphere and radiative effects of sea-ice and clouds



ARISE TOA gridbox experiments:



Three flight days focus on CERES TOA gridbox experiments:

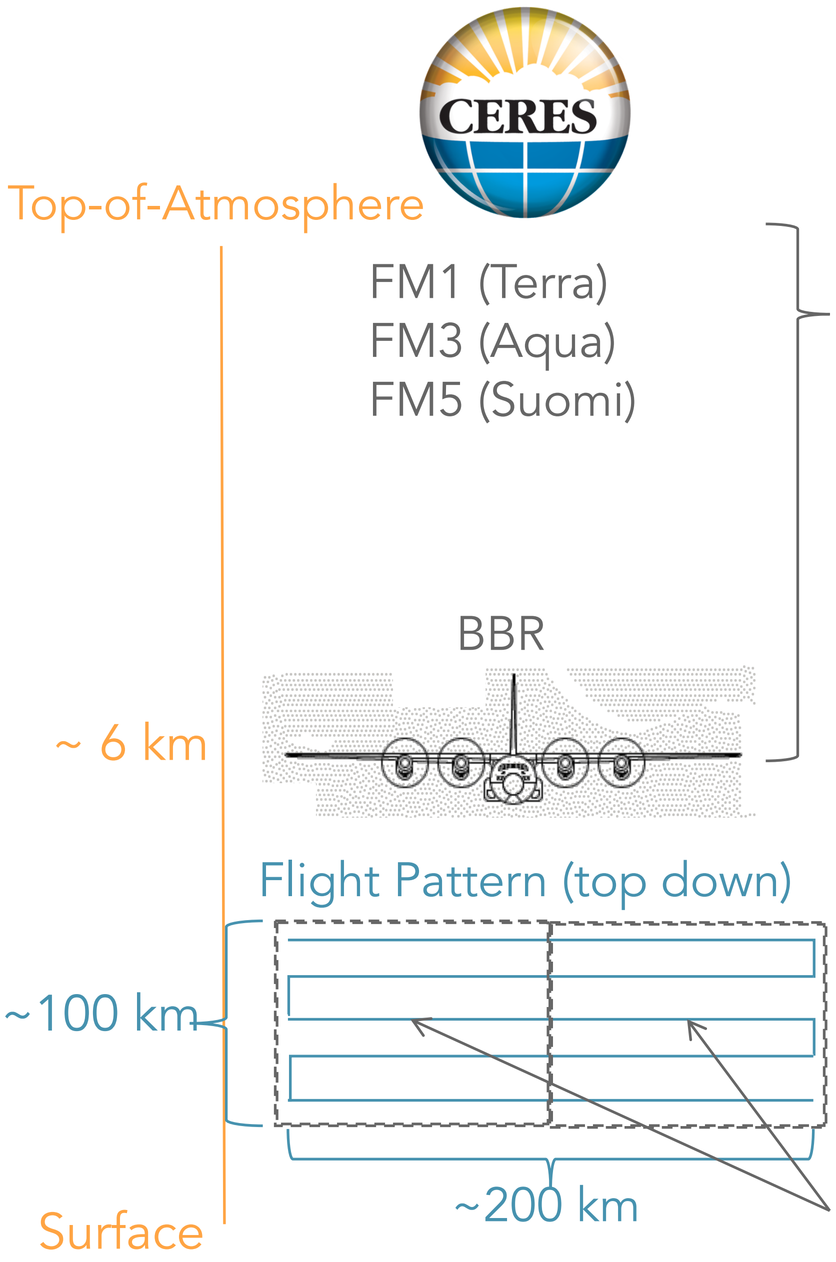
September 7, 2014: Marginal ice zone (two boxes)

September 11, 2014: High sea ice concentration (two boxes)

September 15, 2014: open ocean (one box)

A key ARISE objective was to evaluate CERES TOA and Surface data products.

CERES-Aircraft Comparison Methodology:



Need to access for:

LW - absorption

SW - scattering/absorption

Langley Fu-Liou Radiative transfer model:

- Atmospheric state information from GEOS 5.4.1
- Cloud property information from MODIS (CERES cloud group)
- Surface information from the AMSR2 ASI 3.5km sea ice concentration dataset (Uni. Hamburg)

To convert BBR from 6 km to TOA:

$$\text{BBR TOA} = (F(TOA)_{model}/F(6km)_{model}) \times \text{BBR}$$

Compare mean BBR TOA and mean CERES fluxes for each grid box

ARISE TOA gridbox experiments :

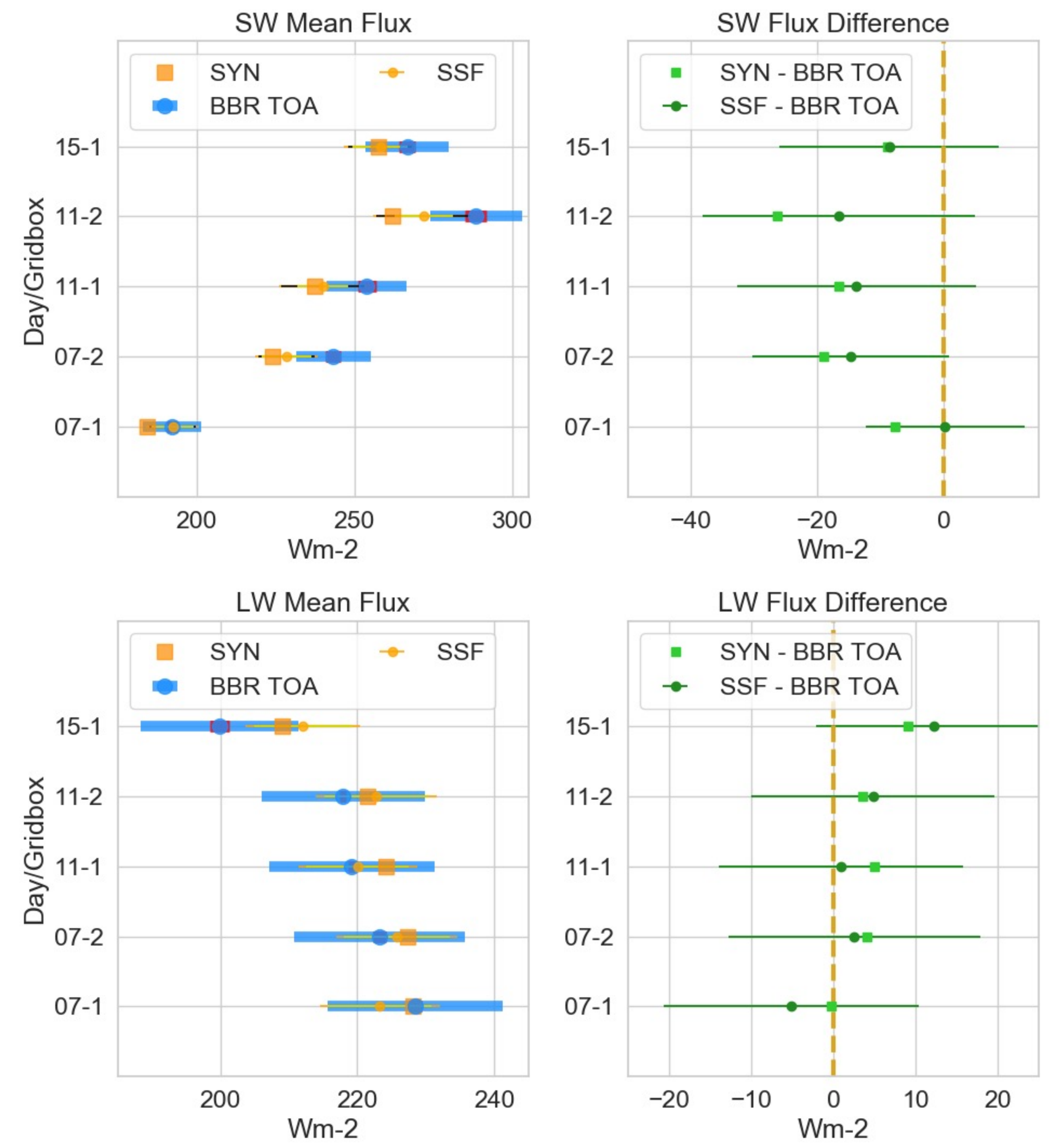
Overcast ocean

Partly cloudy sea ice

Overcast sea ice

Overcast MIZ

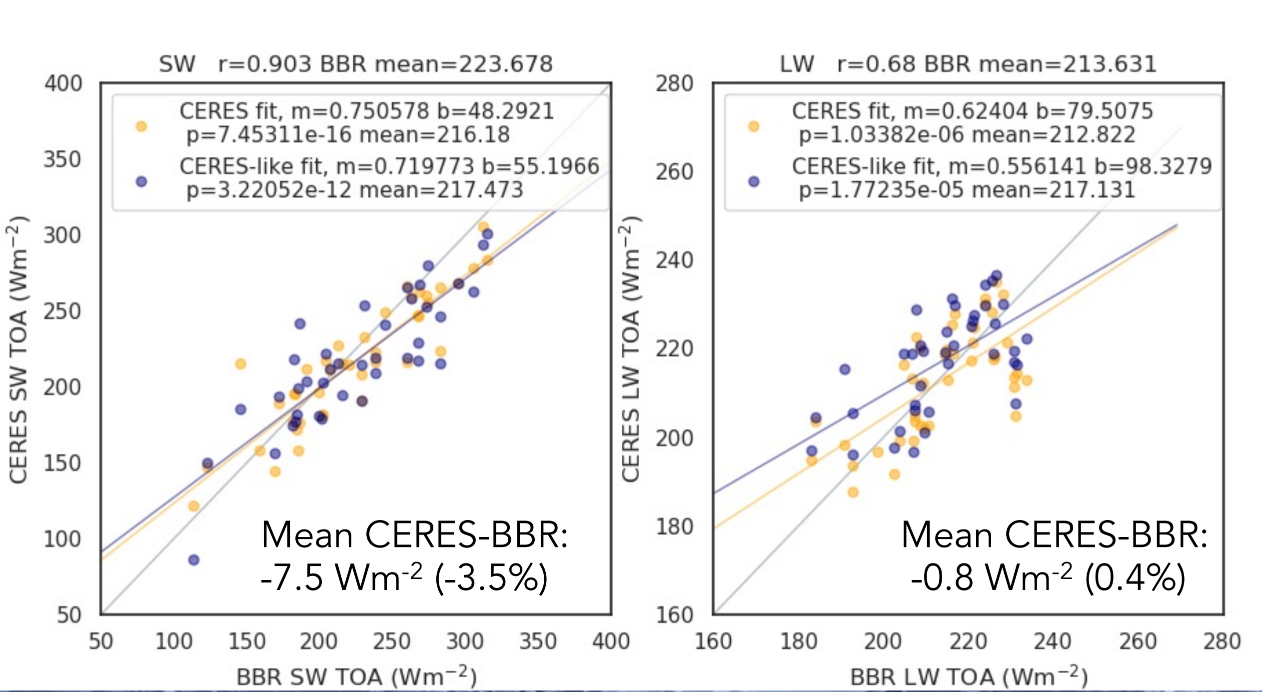
Overcast MIZ

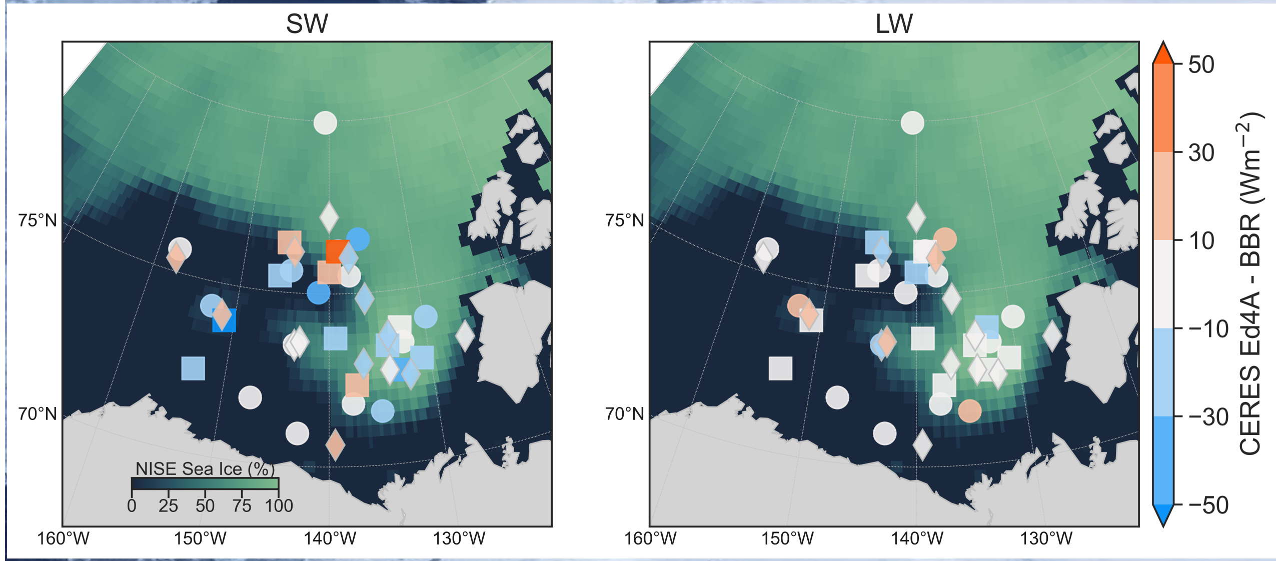


- LW shows good agreement for all grid-boxes (< +/- 2 Wm^{-2})
- SW shows agreement within uncertainty for 4/5 grid-boxes
- Cause of the negative biases?
    - Calibration
    - ADMs
    - Sampling

Instantaneous comparisons: 38 matched FOVs

- An alternative to the gridbox experiments is to compare only the instantaneous matches between aircraft and CERES FOVs
- Time match: within 15 minutes
- Despite the small number of samples, the overall results matches the gridbox experiments.





SW BBR and CERES mean difference: -7.5Wm^{-2} (-3.5%)
LW BBR and CERES mean difference: -0.8 Wm^{-2} (0.4%)

Instantaneous comparisons: 38 matched FOVs

- An alternative to the gridbox experiments is to compare only the instantaneous matches between aircraft and CERES FOVs
- Time match: within 15 minutes
- Despite the small number of samples, the overall results matches the gridbox experiments.

ADM GROUP	N (count)	CERES Ed4a SW Mean Difference (W m^{-2})	STDEV (W m^{-2})	SW NISE as imager Mean Difference (W m^{-2})	STDEV (W m^{-2})	CERES Ed4a LW Mean Difference (W m^{-2})	STDEV (W m^{-2})
Ocean Cloudy	17	-1.0	16.6	-2.5 (14)	16.8	-2.2	11.2
Sea Ice Clear	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Sea Ice Partly Cloudy	9	-17.1	13.6	+9.2 (12)	17.1	1.9	7.4
Sea Ice Overcast	15	-9.1	29.3	-9.1 (15)	29.3	-0.9	11.0

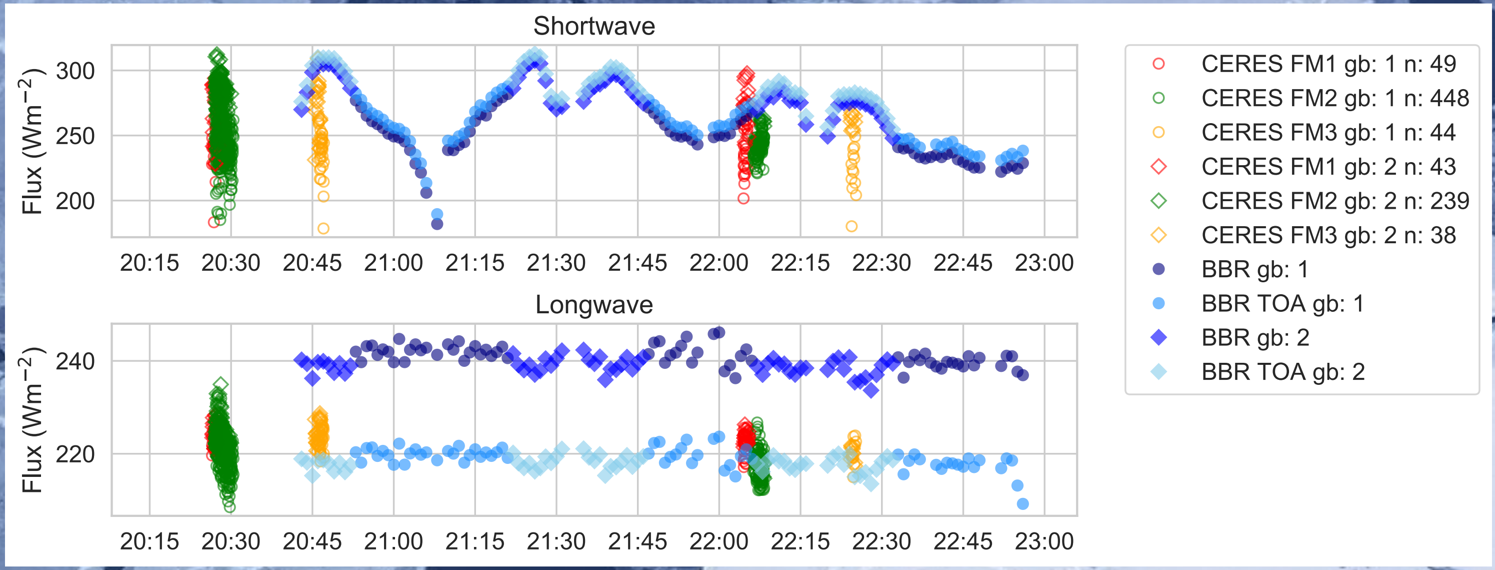
SW BBR and CERES mean difference: -7.5Wm^{-2} (-3.5%)
LW BBR and CERES mean difference: -0.8 Wm^{-2} (0.4%)

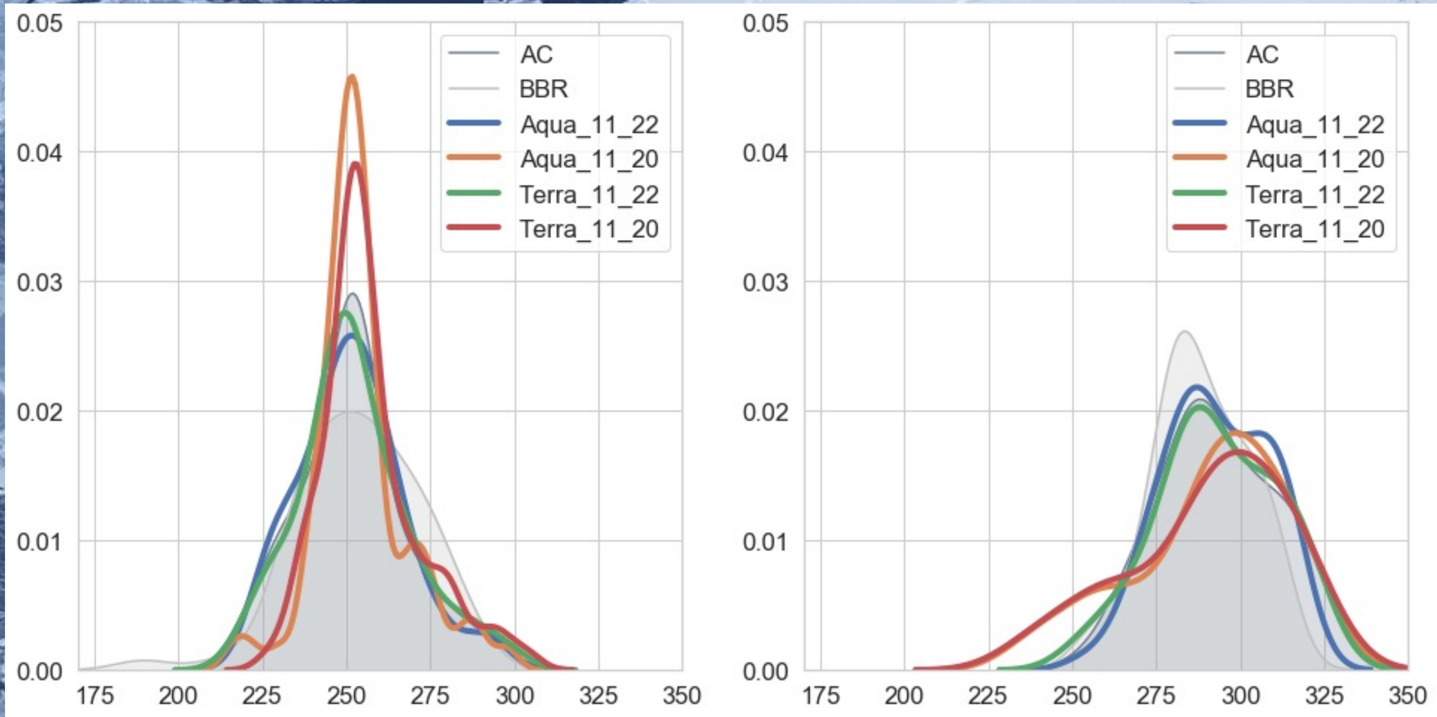
Sampling Uncertainty

Satellite sampling: grid box averages are computed from 3-4 near-instantaneous snapshots

Aircraft sampling: grid box average are computed from 2-hour continuous sampling of the grid box.

- These sampling differences could influence the CERES-BBR differences since the scenes are not static.

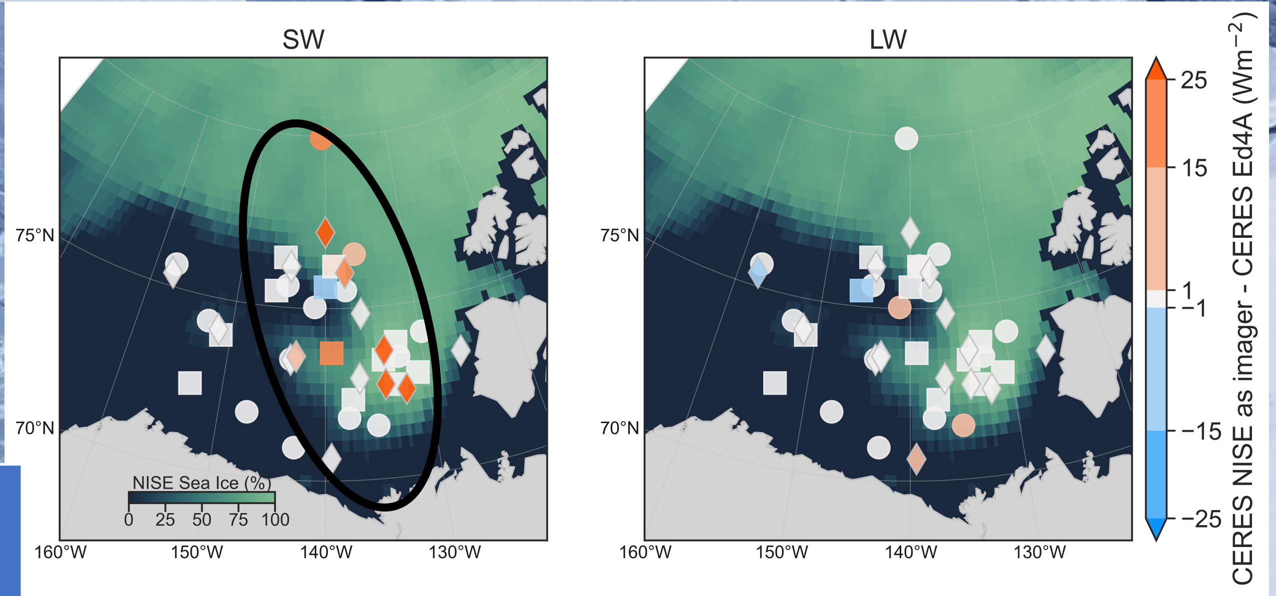




Results indicate a 1.8% and 1.7% sampling uncertainty for SW and LW, respectively.

Influence of sea ice data set: Ed4a vs. NISE

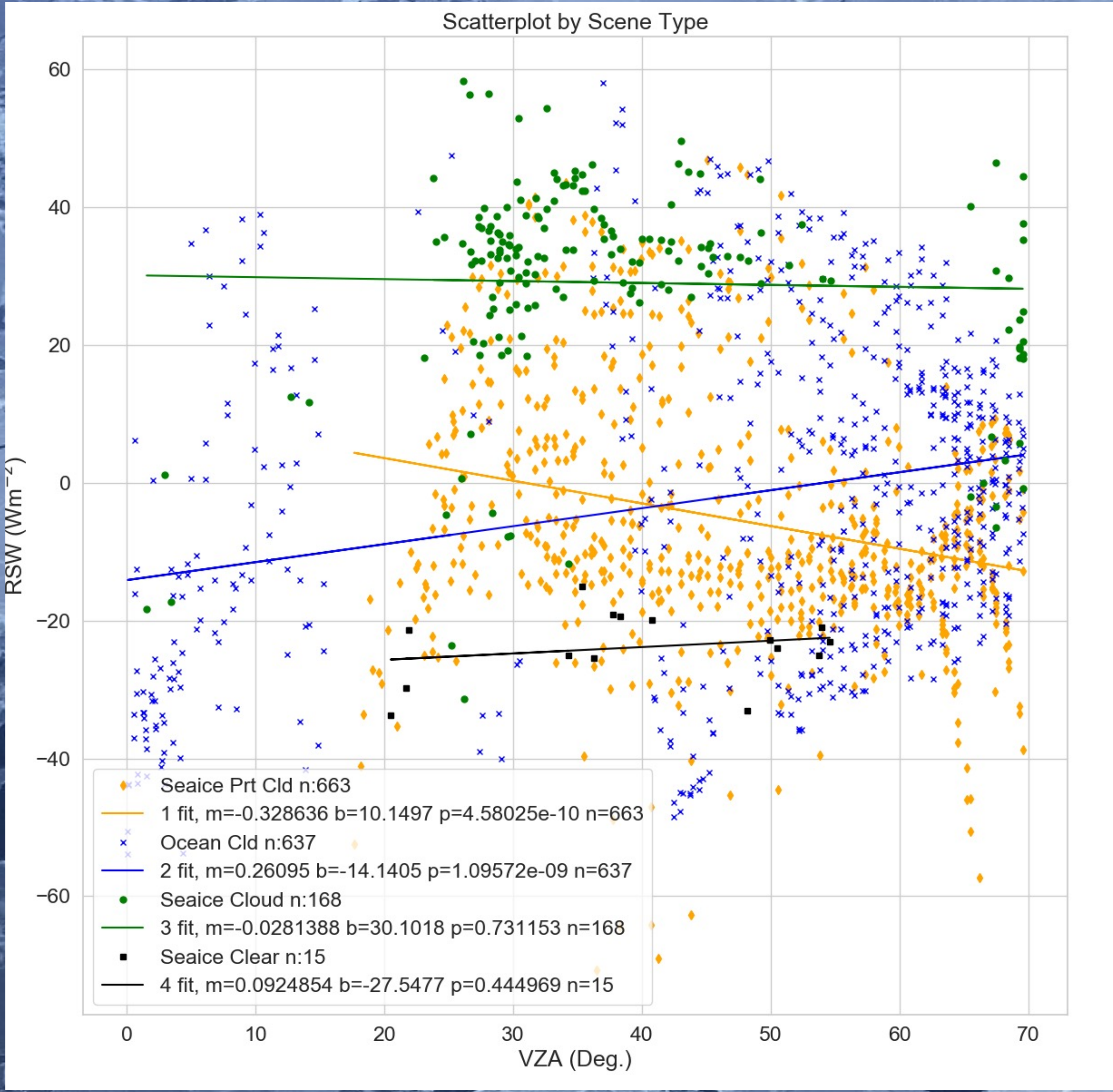
Changing the sea ice data set influenced the mean flux of 2 GBs by -3 and +10 Wm^{-2}.

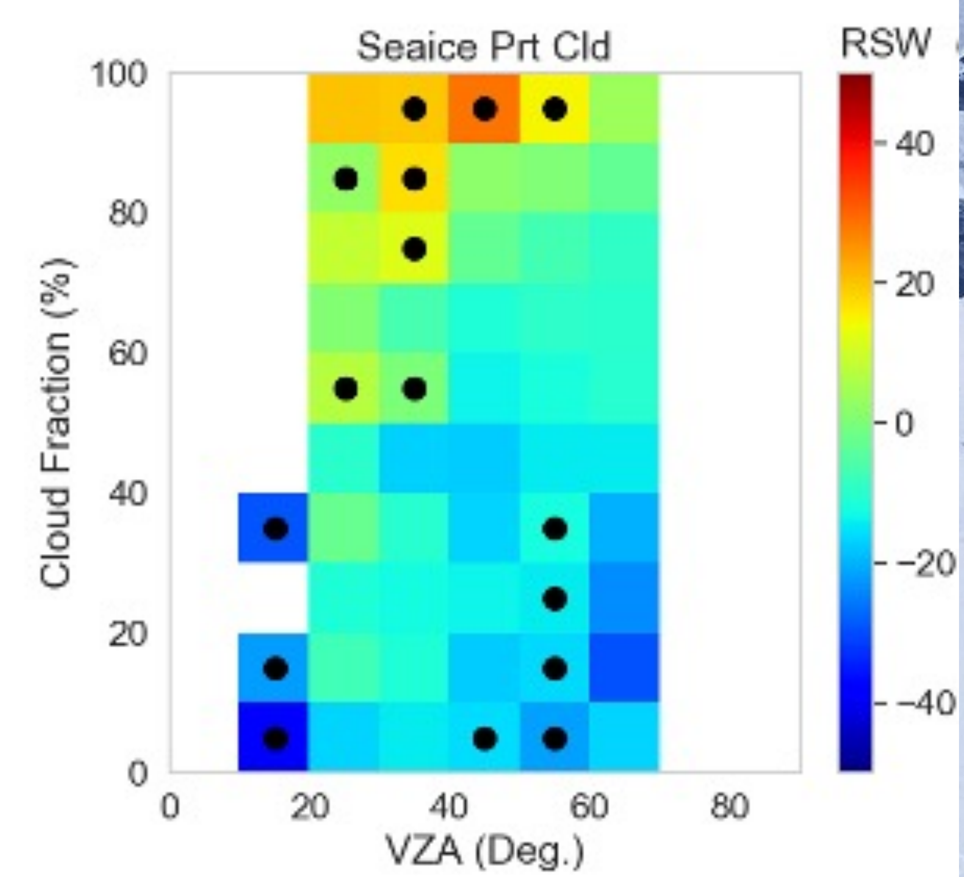


GB	SIC (%)	Imager SIC (%)	CERES Ed4a SW (Wm^{-2})	Ed4a minus NISE as SIC (Wm^{-2})	FM1: Ed4a NISE as SIC (Wm^{-2})	FM2: Ed4a NISE SIC (Wm^{-2})
07-01	10.1	0.0	195.1	0.0	0.0	0.0.
07-02	17.0	0.4	227.0	-0.3	-0.4	-0.2
11-01	86.2	56.7	240.2	0.1	-30.6	+6.2
11-02	77.3	16.5	274.3	-12.3	-19.7	-10.9
15-01	0.3	0.1	257.3	0.0	0.0	n/a

The sea ice data set changed the SW fluxes for 10 of the instant match footprints, making all but one of them more positive (ranging from -2.1 to 44.0 Wm^{-2}).

CERES Flux Inversion: VZA Dependence





Sea ice partly cloudy scenes exhibit a VZA dependence of the inverted SW flux

Summary

- The gridbox sampling/validation approach proved successful during ARISE
  - LW TOA shows good agreement – all differences within the uncertainty.
  - SW TOA not quite as good – 4/5 within the uncertainty.
  - Consistent negative CERES SW difference relative to Aircraft Observations.
- Instantaneous CERES FOV and Aircraft comparison provide similar results.
- Why the negative SW bias?
  - Sampling differences do not explain it (< 5 Wm^{-2}).
  - Scene ID (Joe didn't think so based upon observer reports)
  - ADMs…it appears that the anisotropy of sea ice partly cloud scenes could be contributing
  - Calibration…
- Five data points is not really enough to make strong claims about any biases – more experiments needed (in the future, leverage MOSAiC)
- Sampling is a key consideration for these complex scenes (mixtures of ocean and sea ice).