Surface Atmosphere Radiation Budget (SARB) working group update

Seiji Kato[1], Seung-Hee Ham[2] Fred G. Rose[2],

David A. Rutan[3], Thomas E. Caldwell[2]

Antonio Viudez-Mora[2], Tyler J. Thorsen[1], Emily E. Monroe[3],

Anthony C. DiNorscia[2], David Fillmore[3], and Xianglei Huang[4]

[1]NASA Langley Research Center

[2]Analytical Mechanics Associates, Inc.

[3]ADNET Systems, Inc

[4]NCAR

[5]University of Michigan

CERES Science Team Meeting
October 1-3, 2024

Outline of this presentation

- Edition 4 data products
  - CRS
  - EBAF (Edition 4.2)
  - MATCH (NOAA20 aerosol optical thickness consistent with Aqua)
- Edition 5 algorithm developments
  - Aerosol transport model
  - CERES radiative transfer model
  - Polar surface albedo

Edition 4 products

- Edition 4 CRS
  - Instantaneous surface and in atmosphere irradiances (Level 2)
  - Gridded instantaneous irradiances (SYN1deg, Level 3)
  - January 2018 through December 2022 (Terra or Aqua) were released
- Edition 4.1 SYN
  - Gridded (1 deg × 1deg) hourly, daily, and monthly mean surface and in atmosphere irradiances.
  - Produced through June 2024.
  - Edition 4B (MET-10 bug fix, 2-channel nighttime optical depth, and no twilight algorithm with TISA new interpolation) available soon.
- Edition 4.2 EBAF
  - Gridded (1 deg × 1deg) monthly mean surface irradiances
  - Produced through May 2024
  - Reprocess clouds over the NOAA20 period (April 2022 onward) with MERRA-2 .
  - Climatological adjustments to NOAA20 will be applied with Terra+Aqua using a common period from May 2018 through March 2022.
  - The revised product (Edition 4.2.1) will be released early 2025
- Edition 4 MATCH
  - Consistency of aerosol optical thickness derived from MODIS and VIIRS
  - Working with the Deep Blue team to mitigate the AOD differences
- CCCM D2 version
  - Produced with CALIPSO V4-51and CloudSat R05 data products.
  - Will be released soon.

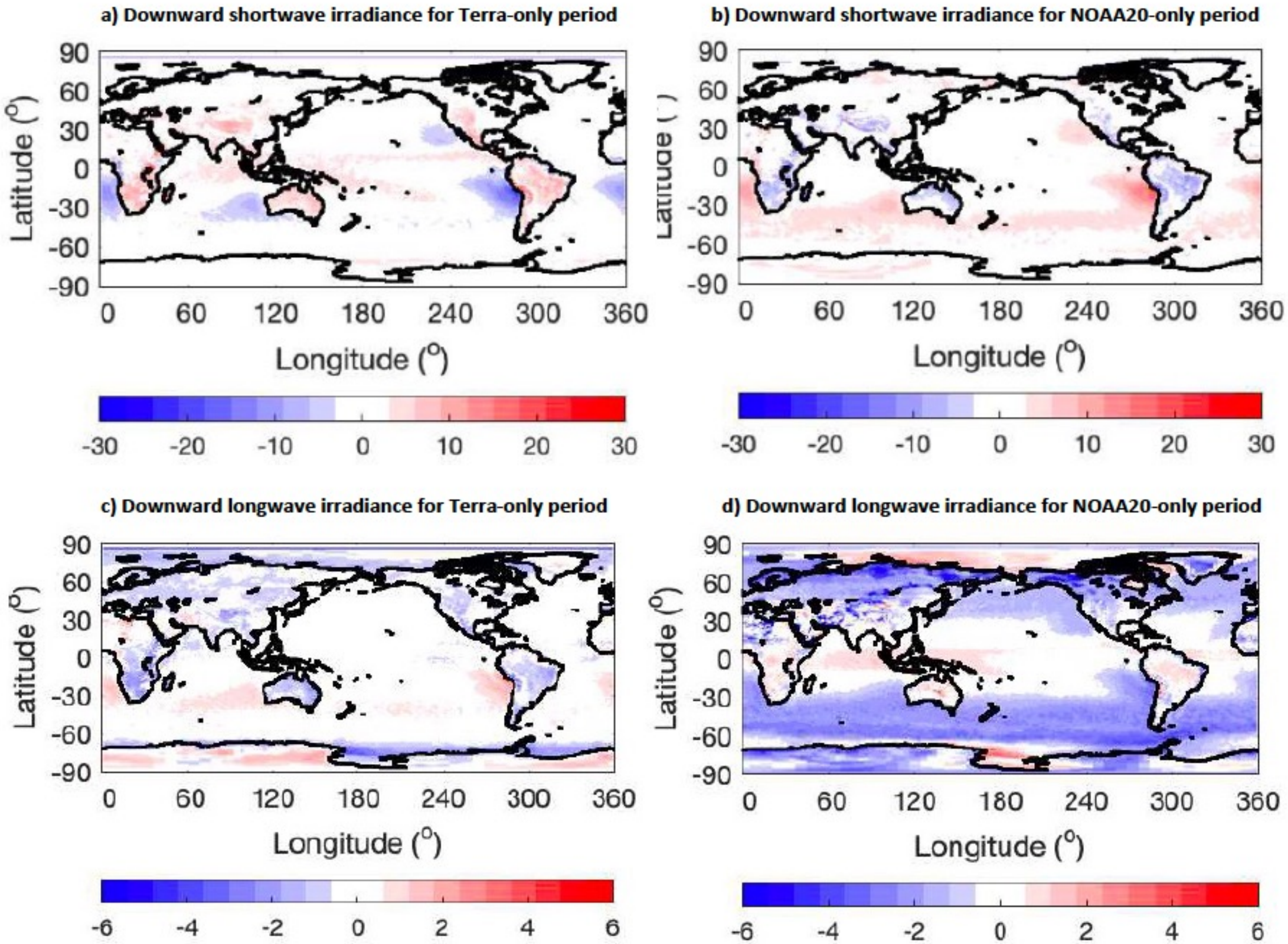
Edition 4.2 EBAF climatological adjustment in Wm^{-2}

Terra only and Terra+Aqua
Common period
from July 2002 through June 2007

NOAA20 only and Terra+Aqua
Common period
May 2018 through March 2022

Downward Shortwave adjustments

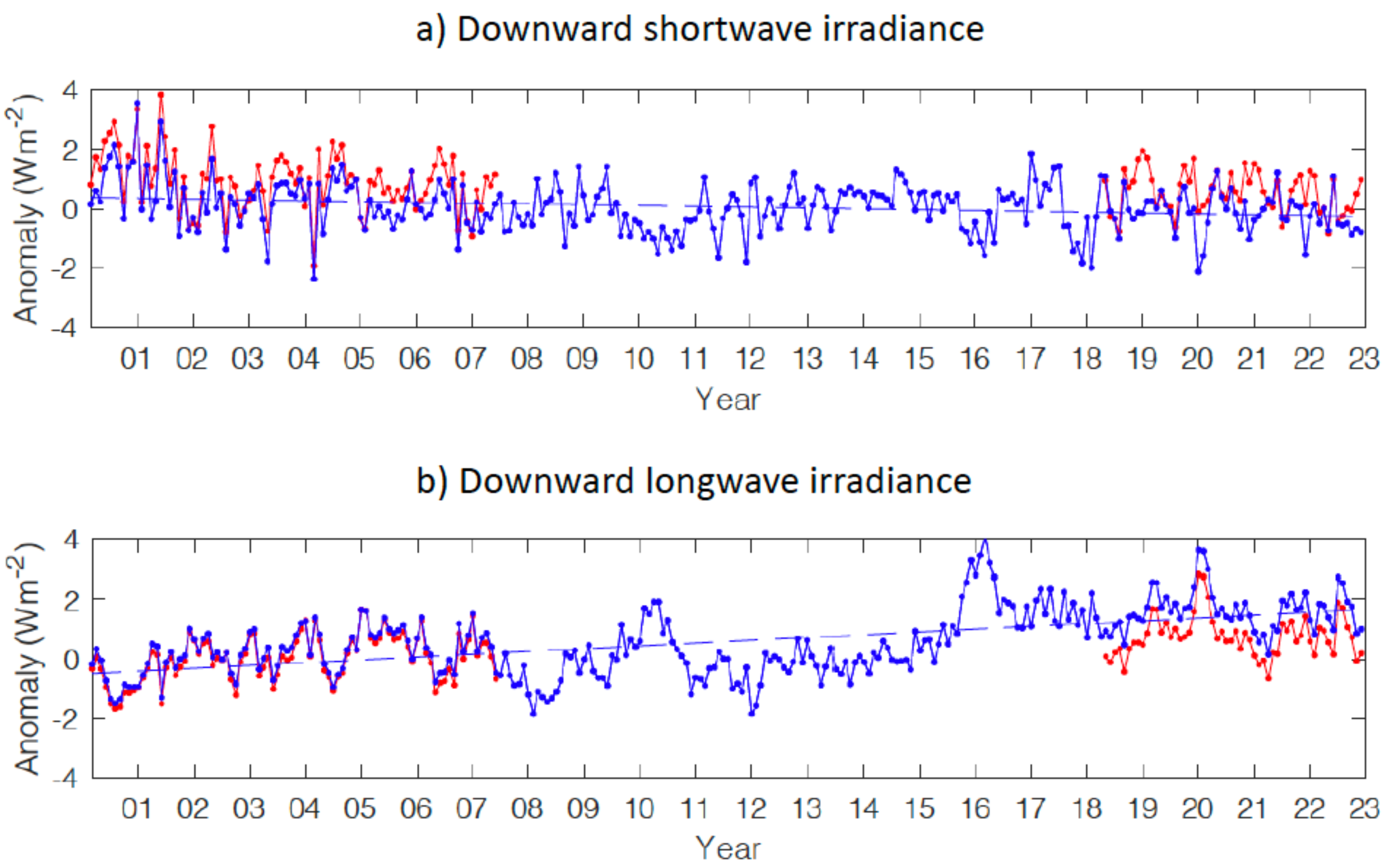
Downward Longwave adjustments



Kato et al. 2024

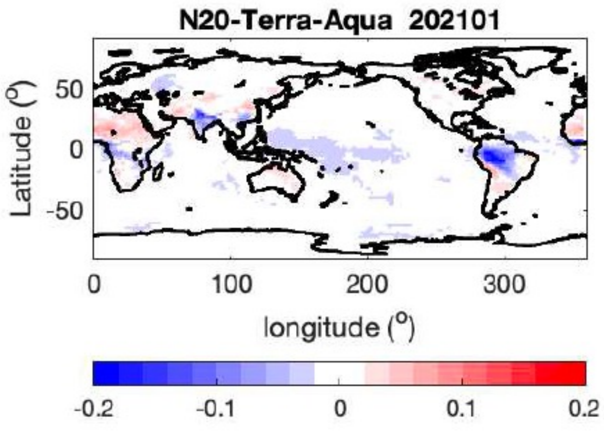
Terra, Terra+Aqua, and NOAA20 Global monthly anomaly time series

Blue: with climatological adjustments
Red: without climatological adjustment



Edition 4 aerosol (MATCH)

- Because the Deep Blue algorithm uses a newer algorithm for NOAA20 VIIRS than Terra and Aqua, there are significant discontinuity in aerosol optical thickness.
  - Jaehwa Lee provided coefficients to correct NOAA20 AOT.
- There are some discontinuities of Dark Target aerosol optical thickness over ocean and land.
  - We developed coefficients to correct NOAA20 Dark target optical thickness over land.



	Ocean				Land			
O=yes X=no	Dark Target	Correction	Deep Blue	Correction	Dark Target	Correction	Deep Blue	Correction
Terra+Aqua	o	x	x	x	o	x	o	x
NOAA20	o	x	o	o	o	o	o	o

Edition 5 aerosol transport model

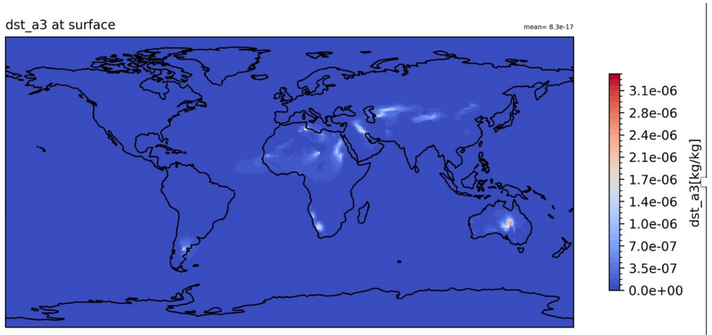
Model	Edition 4 MATCH (Model for Atmospheric Transport and Chemistry)	Edition 5 CAM6 MAM4 (Community Atmosphere Model, Modal Aerosol Module)	Edition 5 GEOS-IT
Spatial resolution of meteorological inputs	NCEP/NCAR reanalysis ~1.9×1.875, 28 levels	GEOS-IT Interpolated to 0.9375 × 1.25, 32 levels	GEOS-IT native resolution 0.5 × 0.625 72 levels
Aerosol representation	Bulk (SO4, OC, BC, Sea-salt, Dust)	Mode 1 (BC, POM, SOA, SU, DU, SS) Mode 2 (SOA, SU, DU, SS) Mode 3 (SU, DU, SS) Mode 4 (BC, POM)	Bulk (SO4, OC, BC, Sea-salt, Dust)
Aerosol mixing	External	**Internal**	External
Assimilated AOD	MODIS (Terra and Aqua) VIIRS (NOAA20) (AOD optimal interpolations)	MODIS (Terra and Aqua) VIIRS (NOAA20) (AOD nudging)	MODIS (Terra and Aqua) VIIRS (NOAA20) Aeronet
SAAB radiative transfer interface	3D spatial aerosol concentrations	4D Spatial spectral aerosol radiative properties (extinction, omega, g)	4D Spatial spectral aerosol radiative properties (extinction, omega, g)

BC: Black Carbon, POM: Primary Organic Matter, SOA: Secondary Organic Matter, SU: Sulfate, DU: Dust, SS: Sea Salt

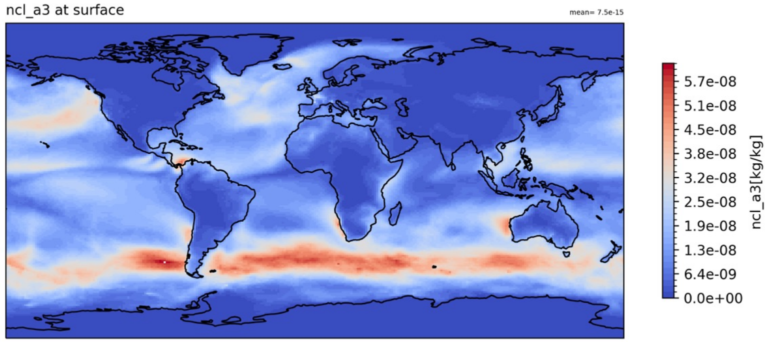
CAM6-CERES radiative transfer model interphase

3D and temporal space of mixing ratio of all aerosol types from CAM6 or GEIS-IT

Dust aerosol mixing ratio



Sea salt mixing ratio

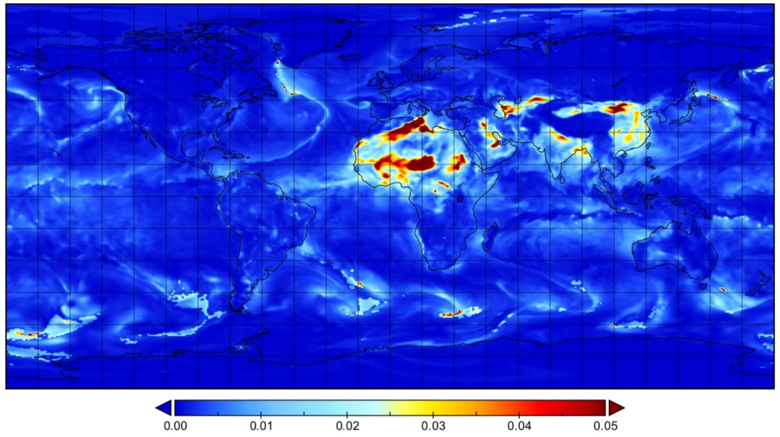


Aerosol types from CAM6 are separated by size

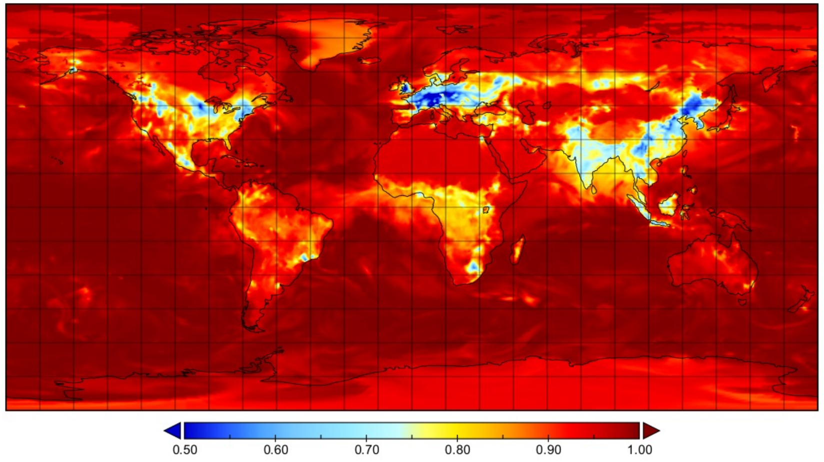
Accumulation
Aitken
Coarse
Primary Carbon

3D space of Tau, omega, and g as a function of time and wavelength

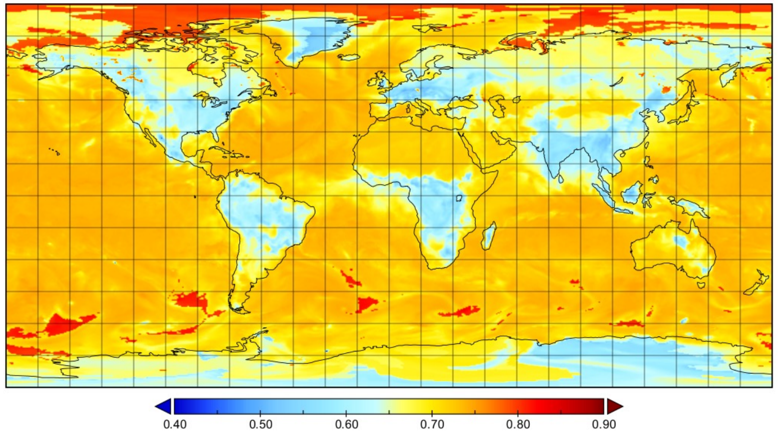
Tau (surface layer @650 nm)



Omega (surface layer @650 nm)



g (surface layer @650 nm)



CERES Cloud Radiative Swath (CRS) Update

Seung-Hee Ham[1], Seiji Kato[2], Fred Rose[1], David Rutan[3], Emily Monroe[3], Anthony C. DiNorscia[1], Tom Caldwell[1], David Fillmore[1], Antonio Viudez-Mora[1], Norman Loeb[2], David Doelling[2], Patrick Taylor[2], Pamela Mlynczak[1], Walter Miller[1], Victor Sothcott[1], and Joshua C. Wilkins[1]

[1]Analytical Mechanics Associates (AMA), Hampton, Virginia
[2]NASA Langley Research Center, Hampton, Virginia
[3]Adnet Systems, Hampton, Virginia

Collaboration with:

TISA Group: Joshua C. Wilkins, David Doelling and Pamela Mlynczak (TISA gridding for CRS1deg product)

Data Management: Walter Miller, Victor Sothcott, Joshua C. Wilkins, and Kathleen Dejwakh

ADM Group: Lusheng Liang, Wenying Su (TOA fluxes)

Cloud group: Bill Smith Jr, Sunny Sun-Mack, and Ben Scarino (Cloud and skin temperature retrievals)

FLASHFLUX group: Paul Stackhouse (Parameterized surface fluxes in FLASHFLUX)

Level 2 CRS Flux Algorithm

Inputs

Atmospheric Profiles	GMAO Reanalysis p(z), T(z), q(z), and $O_3(z)$
Surface	Surface Skin Temperature Surface Emissivity Surface Albedo
Clouds	MODIS Clouds
Aerosol	MODIS & CATM* Aerosol

↓

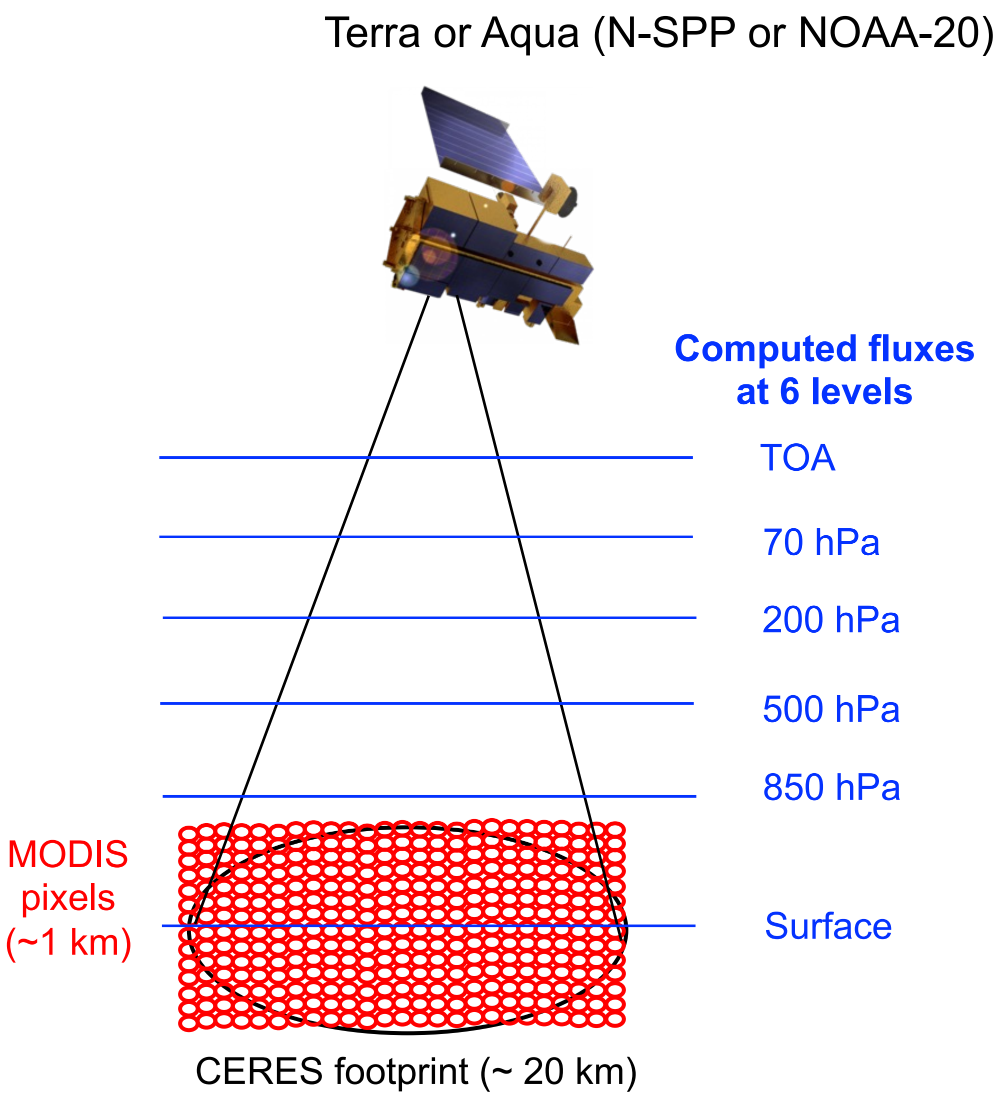
Fu-Liou Radiative Transfer Model

Four Conditions

Total Sky	(Aerosol o Clouds o)
Clear Sky	(Aerosol o Clouds x)
No Aerosol	(Aerosol x Clouds o)
Pristine	(Aerosol x Clouds x)

↓

Computed Instantaneous Fluxes at 6 vertical levels for every CERES footprint



CATM : CERES Atmospheric Transport Model produced by CERES SARB group

Changes from the Ed4 to Ed5 CRS Algorithm

	Ed4 (Released in May 2023)	Ed5 (Ongoing Development) (Beta data target release date: 2026)
$T(z)/q(z)/O_3(z)$ profiles & wind speed	MOA-GEOS-5.4.1 (1° grid)	MOA-GEOS-IT (0.5° grid)
Skin Temperature	• T_{skin} derived from the MODIS 11-μm channel • GEOS-5.4.1 T_{skin}	• T_{skin} derived from the MODIS 11-μm channel • T_{skin} derived by the Neural Network (NN) algorithm • GEOS-IT T_{skin}
Surface Albedo	▪ Parameterized albedo model from Jin's model (2004, 2008) ▪ MODIS BRDF Spectral albedo ▪ Surface albedo history (SAH) Ed4 map derived from clear-sky CERES measurements	▪ Parameterized albedo model from Jin's model (2004, 2008) ▪ MODIS BRDF Spectral albedo ▪ Surface albedo history (SAH) Ed5 map derived from clear-sky CERES measurements
Surface Emissivity	▪ CERES Emissivity for 11-12 μm bands ▪ Climatological emissivity based on IGBP	▪ ADM Group-generated merged LW emissivity maps: Derived from far IR (Huang et al. 2016) and IASI-derived LW (Zhou et al. 2013) emissivity models.
Cloud properties	MODIS clouds from Ed4 Cloud Algorithm	MODIS clouds from Ed5 Cloud Algorithm
Aerosol Properties	• Ed4 Hourly CERES Atmospheric Transport Model (CATM) (Fillmore et al., 2022) • MODIS C6 multi-channel aerosol optical depths	• Ed5 Hourly CATM: MODIS/VIIRS aerosol with CAM6 aerosol scheme MODIS C7 multi-channel aerosol optical depths
RTM	Ed4 Langley Fu-Liou model	Ed5 Langley Fu-Liou model with updated correlated k gas absorption features

Legend: Blue — Algorithm being tested; Green — Completed

Changes from the Ed4 to Ed5 CRS Algorithm

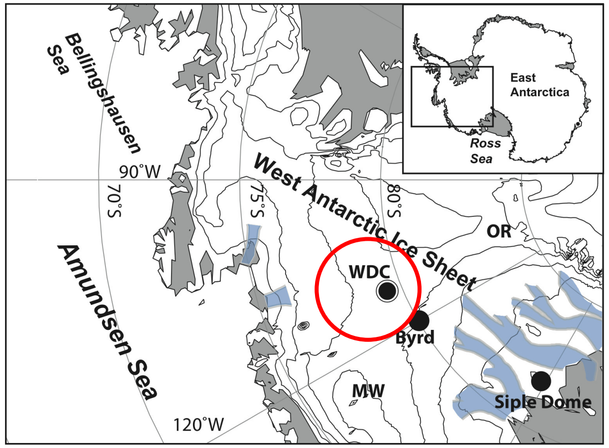
	Ed4 (Released in May 2023)	Ed5 (Ongoing Development) (Beta data target release date: 2026)
$T(z)/q(z)/O_3(z)$ profiles & wind speed	MOA-GEOS-5.4.1 (1° grid)	MOA-GEOS-IT (0.5° grid)
Skin Temperature	• T_{skin} derived from the MODIS 11-µm channel • GEOS-5.4.1 T_{skin}	• T_{skin} derived from the MODIS 11-µm channel • T_{skin} derived by the Neural Network (NN) algorithm • GEOS-IT T_{skin}
Surface Albedo	▪ Parameterized albedo model from Jin's model (2004, 2008) ▪ MODIS BRDF Spectral albedo ▪ Surface albedo history (SAH) Ed4 map derived from clear-sky CERES measurements	▪ Parameterized albedo model from Jin's model (2004, 2008) ▪ MODIS BRDF Spectral albedo ▪ Surface albedo history (SAH) Ed5 map derived from clear-sky CERES measurements
Surface Emissivity	▪ CERES Emissivity for 11-12 µm bands ▪ Climatological emissivity based on IGBP	▪ ADM Group-generated merged LW emissivity maps: Derived from far IR (Huang et al. 2016) and IASI-derived LW (Zhou et al. 2013) emissivity models.
Cloud properties	MODIS clouds from Ed4 Cloud Algorithm	MODIS clouds from Ed5 Cloud Algorithm
Aerosol Properties	• Ed4 Hourly CERES Atmospheric Transport Model (CATM) (Fillmore et al., 2022) • MODIS C6 multi-channel aerosol optical depths	• Ed5 Hourly CATM: MODIS/VIIRS aerosol with CAM6 aerosol scheme MODIS C7 multi-channel aerosol optical depths
RTM	Ed4 Langley Fu-Liou model	Ed5 Langley Fu-Liou model with updated correlated k gas absorption features

Algorithm being tested   Completed

Validation of the CRS Flux Algorithm over Polar Regions

- More frequent observations by the sun-synchronous (Aqua or Terra) satellite orbits over the polar regions, compared to other lower latitude regions (but only daytime during summer and nighttime during wintertime).
- Ability to validate the computed surface radiation budget using ground site measurements with a diurnal cycle
- The surface type is usually snow and sea ice (SIC), meaning that the assumption of high surface albedo is important in the radiative transfer.
- Uncertainties in the skin temperature of the analysis dataset are large over the polar regions, requiring further examination of the input temperature and humidity properties to the radiative transfer model.

WAIS-Divide
over the West Antarctica
(Lat 79.46°S, Lon 112.083°W, Elevation 1797 m, Dec 2015 to January 2016)



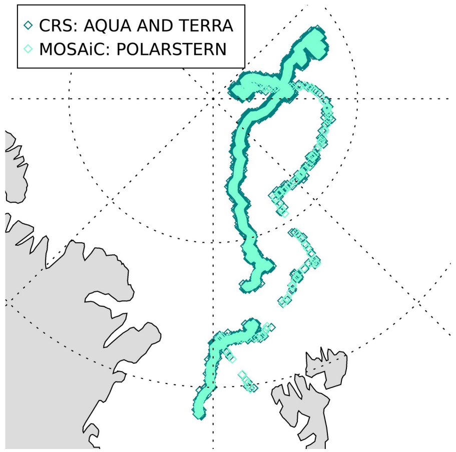
"Permanent snow"

Siple Dome
over the West Antarctica
(Lat 81.65°S, Lon 148.81°W, Elevation 720 m, Dec 2019 to January 2020)

https://www.usap-dc.org/view/dataset/601540

"Permanent snow"

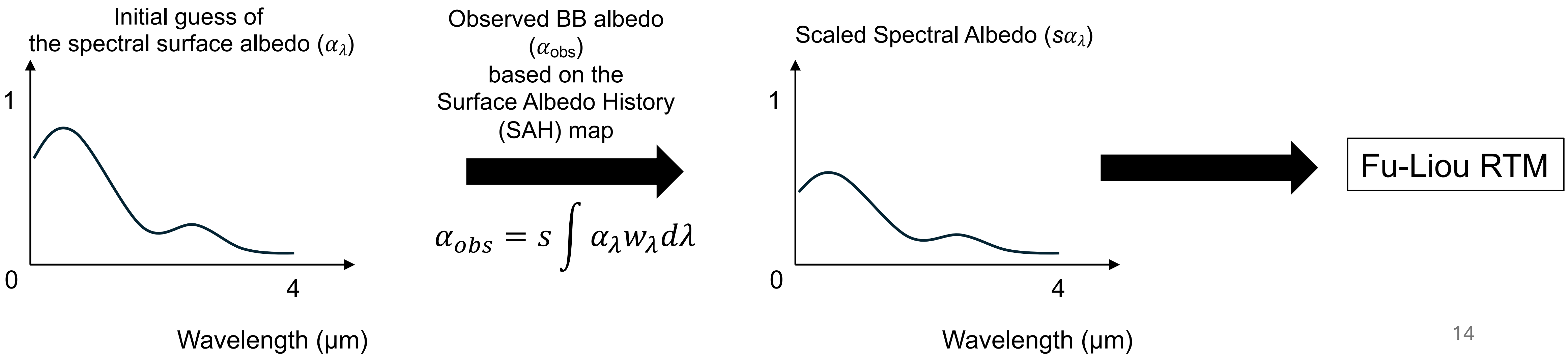
MOSAiC Ship Campaign
over the Arctic Sea
(September 2019 to October 2020)



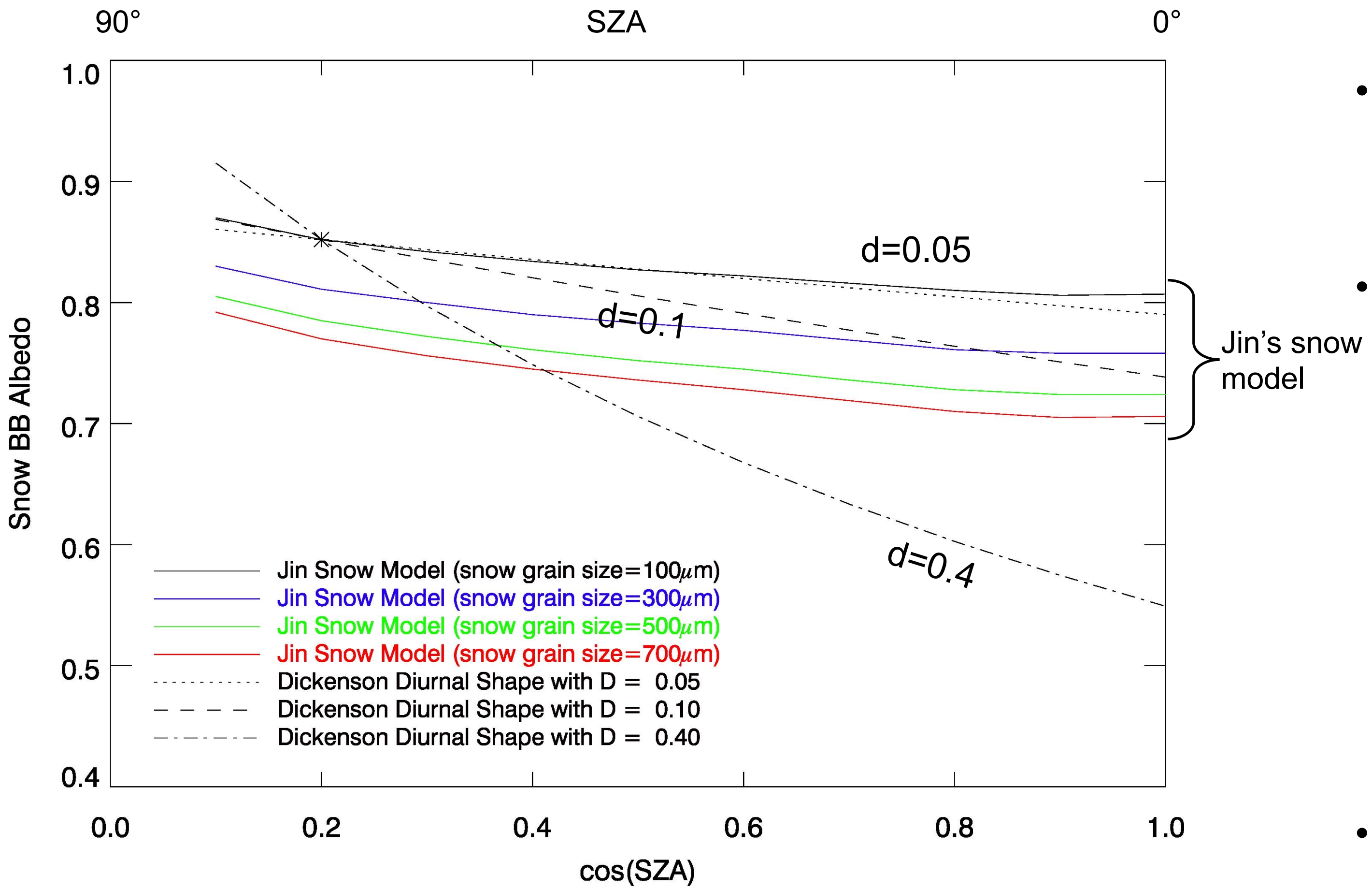
"Partly or completely Sea Ice (SIC)"

Constraining Surface Spectral Albedo Using Observed Surface BB albedo

- First guess of the spectral surface albedo is based on the following sources.
  - ✓ MODIS land surface BRDF product over land (MCD43C1)
  - ✓ Jin's ocean, snow, and sea ice (SIC) spectral albedo model (Jin et al., 2004, 2008)
- These spectral albedos are constrained by the observational-based broadband (BB) surface albedo, by deriving a scaling factor. The observed BB surface albedo is from TOA (CERES or MODIS) observations for clear sky cases, called **S**urface **A**lbedo **H**istory (SAH) Map.
- Until Ed4, the scaling factor was derived regardless of the cloudy conditions. This caused problems for cloudy skies since the observed BB albedo is only from clear skies. The cloudy-sky snow/SIC BB albedo is larger than the clear-sky albedo for snow or sea ice (SIC) surface types. In the Ed5 algorithm, we derive the scaling factor based on the clear sky assumption. Then the scaling factor is used for total, clear, no-aerosol, and pristine skies simulations.



Better Angular Correction of the Observed Snow Surface Albedo Related to the Solar Zenith Angle (SZA) Changes in the Ed5 Algorithm



The surface albedo decreases with increasing cos(SZA). As the value of *d* is larger, a larger decrease of the surface albedo over cos(SZA).

- The monthly gridded Surface Albedo History (SAH) map provides the observed surface BB albedo at a certain solar zenith angle (SZA).

- The angular correction is needed to get the surface albedo at the desired SZA. In the CRS algorithm, the angular correction model is based on Dickinson's diurnal variation model of the albedo (1983):

$$\alpha(\mu_2) = \alpha(\mu_1)\frac{(1+2d\mu_1)}{(1+2d\mu_2)}$$

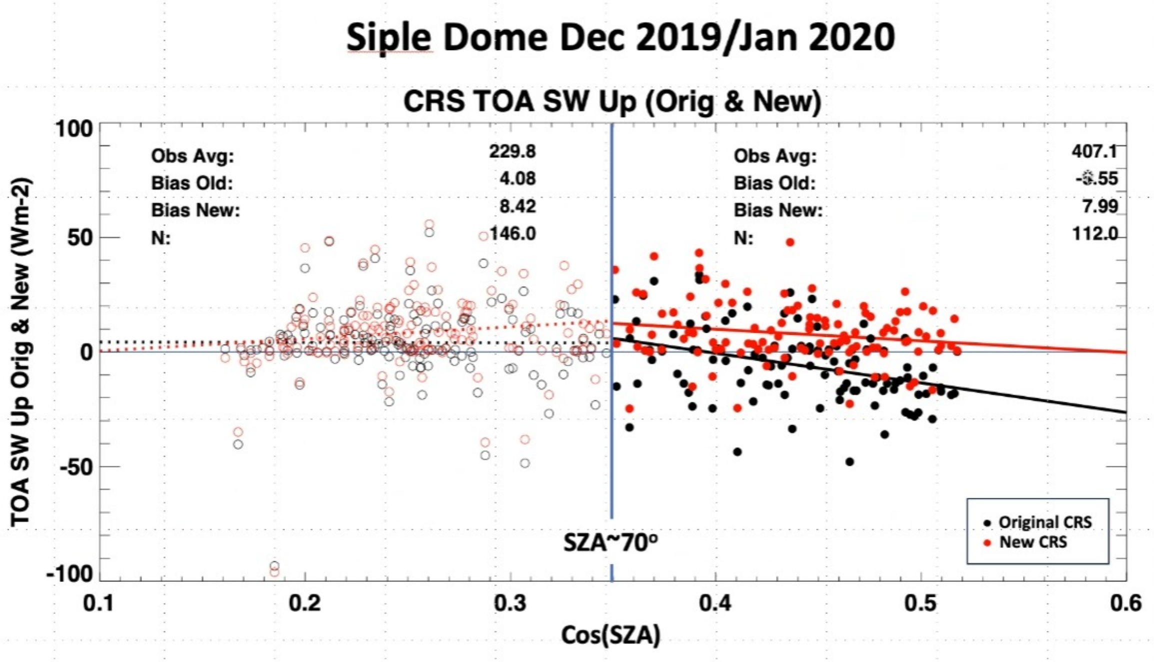
A smaller d value means a smaller variation of the albedo over the SZA.

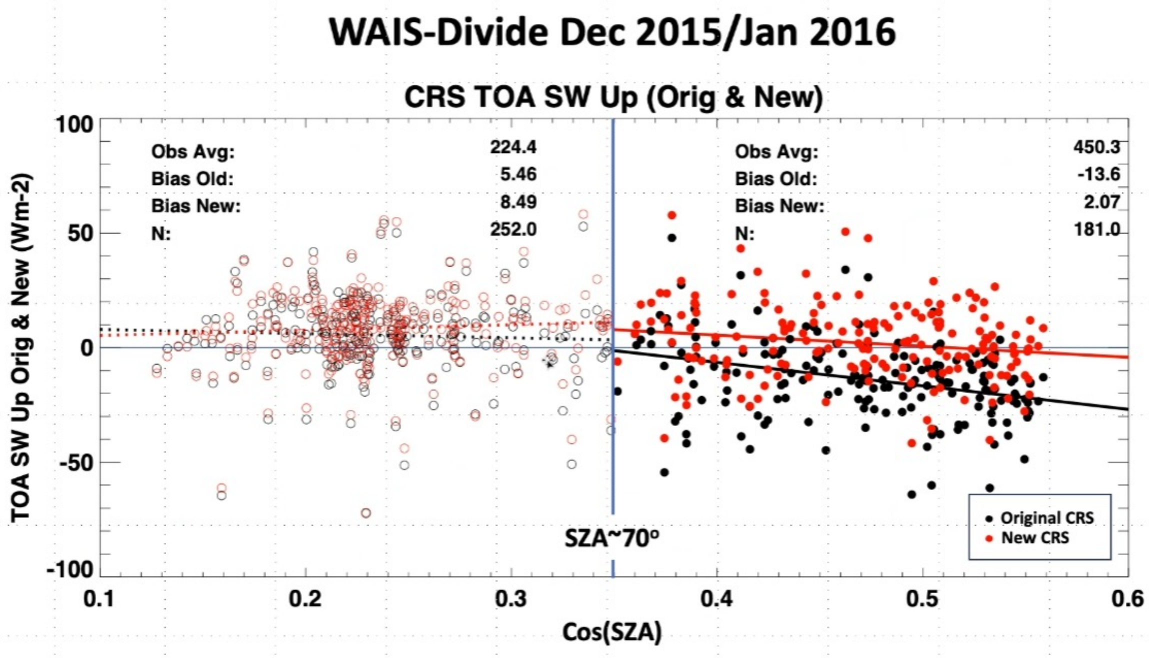
- For the snow surface type, d=0.1 was used for the Ed4 CRS algorithm. In the Ed5 algorithm, d=0.05 is used. This is more consistent with Jin's snow spectral albedo models and are also with observations (next slides).

Better Angular Correction for the Snow Surface Albedo Related to the Solar Zenith Angle (SZA) Changes

Biases of the CRS SW TOA fluxes with d=0.1 over snow
Biases of the CRS SW TOA fluxes with d=0.05 over snow

Two Antarctic Ground Sites

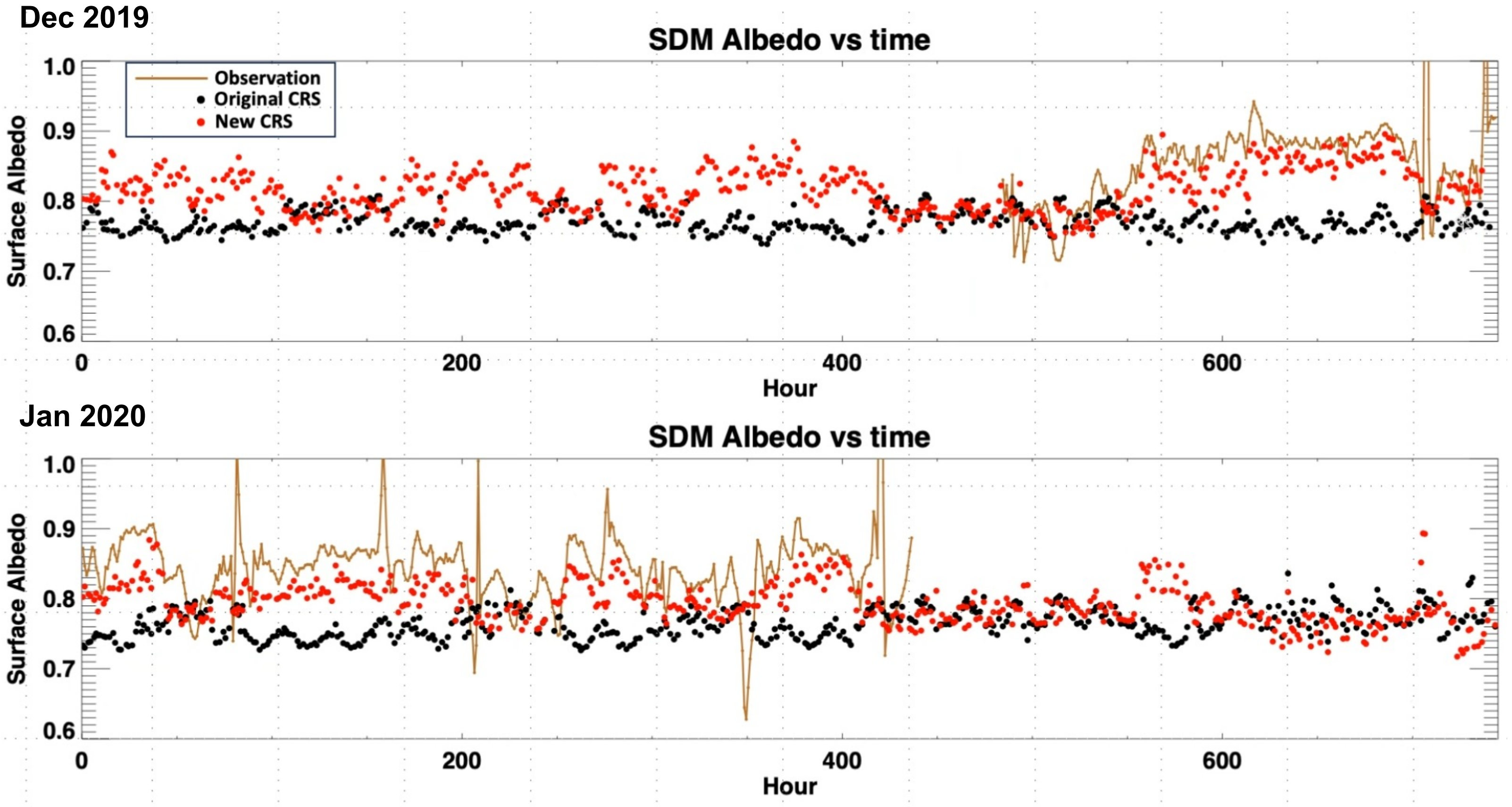




- CERES-derived observed TOA fluxes are compared with CRS computed TOA fluxes, as a function of cos(SZA) over the two Antarctic ground sites.
- The new angular correction of the surface albedo (red dots) gives better agreements of the TOA fluxes with the CERES observations, and the TOA biases are less dependent on the SZA, compared to the old angular correction method (black dots).

Improving Biases in the Snow Albedo for Cloudy Skies

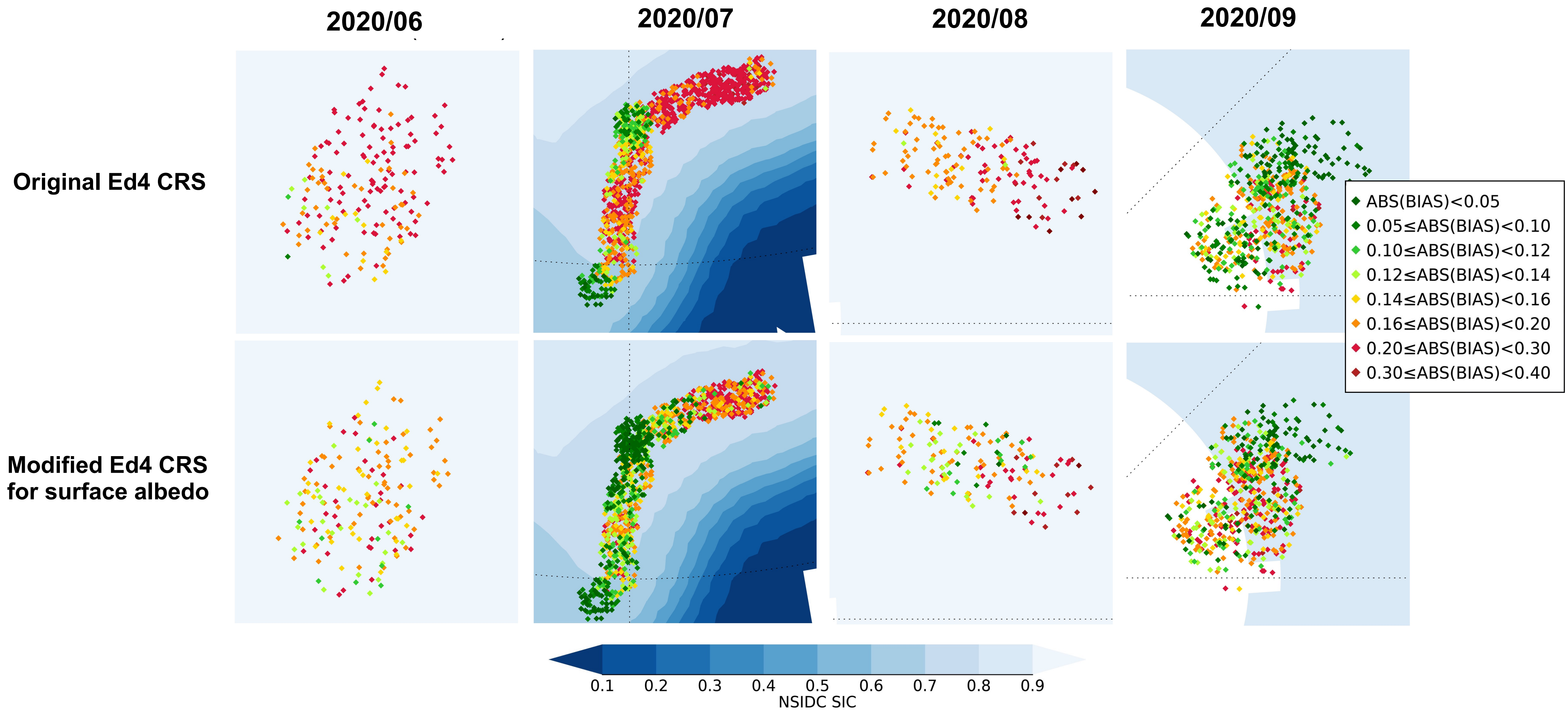
Comparison of Surface Albedo over the Siple Dome Ground Site



- One of issues in the Ed4 algorithm was the underestimation of the snow surface albedo for cloudy skies.
- The underestimation was related to the scaling factor derived regardless of the cloud conditions.
- The new albedo scaling factor is derived in the Ed5 algorithm based on the clear-sky assumption, reducing the underestimation issues.

Ground Observation
Original Ed4 CRS snow albedo algorithm (scaling factor was derived regardless of cloudy conditions)
Modified Ed4 CRS snow albedo algorithm (scaling factor is based on the clear-sky assumption)

Improving Biases in the Sea Ice (SIC) Surface Albedo for Cloudy Skies



- Larger uncertainties in the assumption of surface albedo over the Arctic Ocean compared to the Antarctic ground sites due to the uncertainties in the surface type assumption (SIC coverage changes, snow accumulation over the ice layer).
- Still the broadband albedo is improved by using the new observational constraining method over the Arctic.

The Ed5 Fu-Liou Model

- ❑ Main radiative solver (4-stream for SW and 2-stream for LW) remains the same as in the Ed4 Fu-Liou model
- ❑ More flexibility in changing the Fu-Liou band structure
- ❑ Updating the line-by-line (LBL) dataset (especially water vapor continuum) (Hogan et al. 2020, 2022) and including more gas species in generating CKD table
- ❑ CO_2 and CH_4 are variables for both SW and LW calculations.
- ❑ Aerosol interface to use CAM6 output is under development.

SW Band Structure

Ed4

Band	Wavelength (μm)		Gas Species
1	0.18	0.22	O_3
2	0.22	0.24	O_3
3	0.24	0.29	O_3
4	0.29	0.30	O_3
5	0.30	0.32	O_3
6	0.32	0.36	O_3
7	0.36	0.44	O_3
8	0.44	0.50	O_3, H_2O
9	0.50	0.60	O_3 and H_2O
10	0.60	0.69	O_3 and H_2O
11	0.69	0.79	H_2O, O_3 and O_2
12	0.79	0.89	H_2O
13	0.89	1.04	H_2O
14	1.04	1.41	H_2O
15	1.41	1.90	H_2O, CO_2
16	1.90	2.50	H_2O, CO_2, CH_4
17	2.50	3.51	H_2O, CO_2, O_3 and CH_4
18	3.51	4	H_2O, CO_2 CH_4

In the Ed5 model, nine gas species (O_3, O_2, N_2O, N_2, CO_2, H_2O, CH_4, CFC11, and CFC12) are considered for all Fu-Liou bands.

Ed5

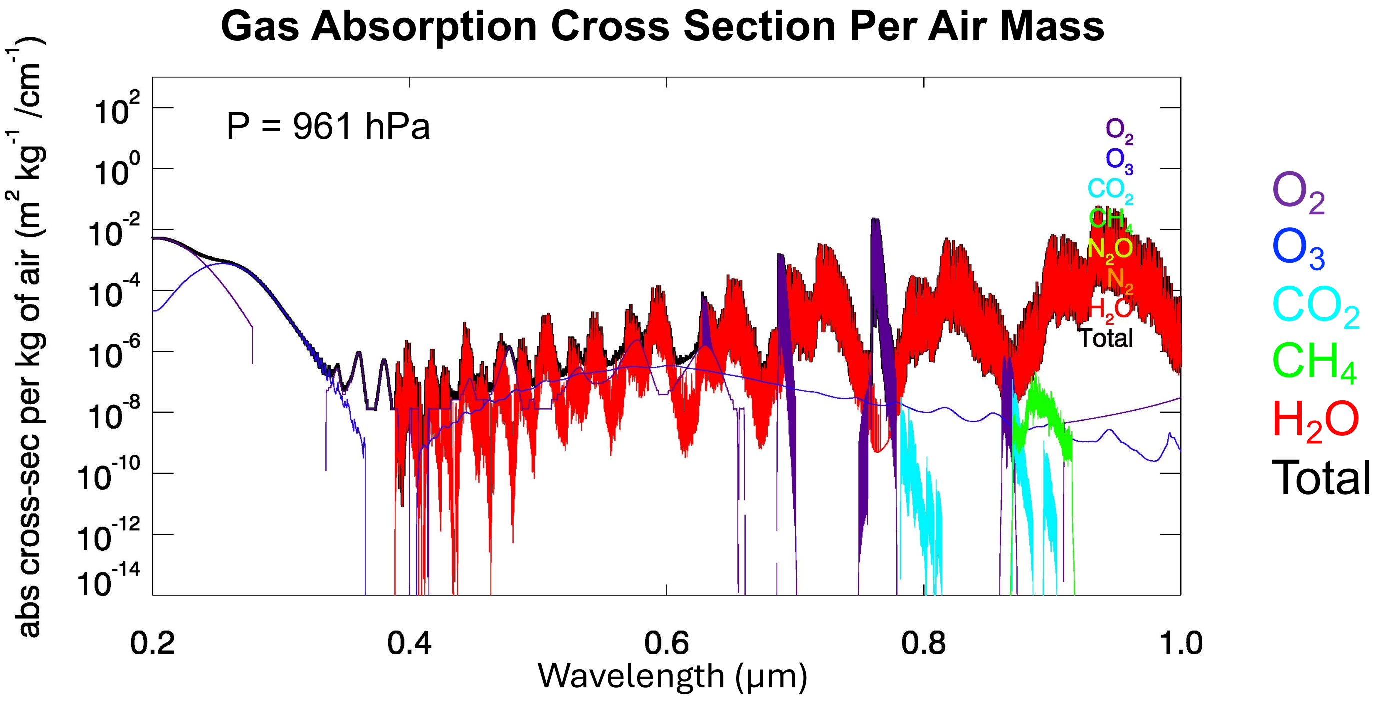
Band	Wavelength (μm)	
1	0.18	0.22
2	0.22	0.24
3	0.24	0.28
4	0.28	0.32
5	0.32	0.4
6	0.40	0.44
7	0.44	0.50
8	0.50	0.56
9	0.56	0.60
10	0.60	0.63
11	0.63	0.68
12	0.68	0.70
13	0.70	0.74
14	0.74	0.79
15	0.79	0.89
16	0.89	1.04
17	1.04	1.41
18	1.41	1.90
19	1.90	1.94
20	1.94	1.99
21	1.99	2.03
22	2.03	2.08
23	2.08	2.13
24	2.13	2.28
25	2.28	2.50
26	2.50	3.51
27	3.51	4.0
28	4.0	5.0
29	5.0	12.5

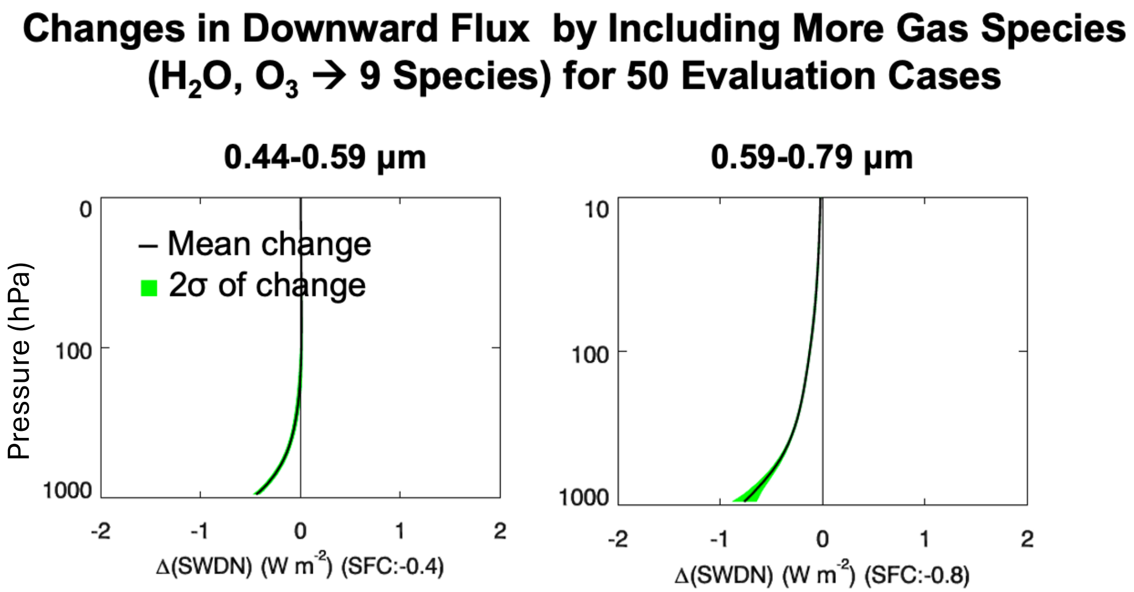
- ❑ Changes in the SW band structures (18 to 29 bands):
  - ✓ To reduce errors due to the correlated-k distribution (CKD) assumptions
  - ✓ To have band boundaries at 400 and 700 nm for the Libera study (visible & split SW bands)
  - ✓ Better optimization method in assigning optimal k terms (still progress)

LW Band Structure (Ed4 & Ed5)

- Ed5 LW band structure remains the same as in the Ed5. However, more gas species are included.
- Red fonts are gas species considered in the Ed4.
- Ed5 considers 9 gas species for all bands.

Band	Wavelength (μm)		Gas Species
1	3.50	4.00	O_3, O_2, N_2O, N_2, CO_2, H_2O, CH_4, CFC11, and CFC12
2	4.00	4.54	O_3, O_2, N_2O, N_2, CO_2, H_2O, CH_4, CFC11, and CFC12
3	4.54	5.26	O_3, O_2, N_2O, N_2, CO_2, H_2O, CH_4, CFC11, and CFC12
4	5.26	5.88	O_3, O_2, N_2O, N_2, CO_2, H_2O, CH_4, CFC11, and CFC12
5	5.88	7.14	O_3, O_2, N_2O, N_2, CO_2, H_2O, CH_4, CFC11, and CFC12
6	7.14	8.00	O_3, O_2, N_2O, N_2, CO_2, H_2O, CH_4, CFC11, and CFC12
7	8.00	9.09	O_3, O_2, N_2O, N_2, CO_2, H_2O, CH_4, CFC11, and CFC12
8	9.09	10.2	O_3, O_2, N_2O, N_2, CO_2, H_2O, CH_4, CFC11, and CFC12
9	10.2	12.5	O_3, O_2, N_2O, N_2, CO_2, H_2O, CH_4, CFC11, and CFC12
10	12.5	14.9	O_3, O_2, N_2O, N_2, CO_2, H_2O, CH_4, CFC11, and CFC12
11	14.9	18.5	O_3, O_2, N_2O, N_2, CO_2, H_2O, CH_4, CFC11, and CFC12
12	18.5	25.0	O_3, O_2, N_2O, N_2, CO_2, H_2O, CH_4, CFC11, and CFC12
13	25.0	35.7	O_3, O_2, N_2O, N_2, CO_2, H_2O, CH_4, CFC11, and CFC12
14	35.7	200	O_3, O_2, N_2O, N_2, CO_2, H_2O, CH_4, CFC11, and CFC12





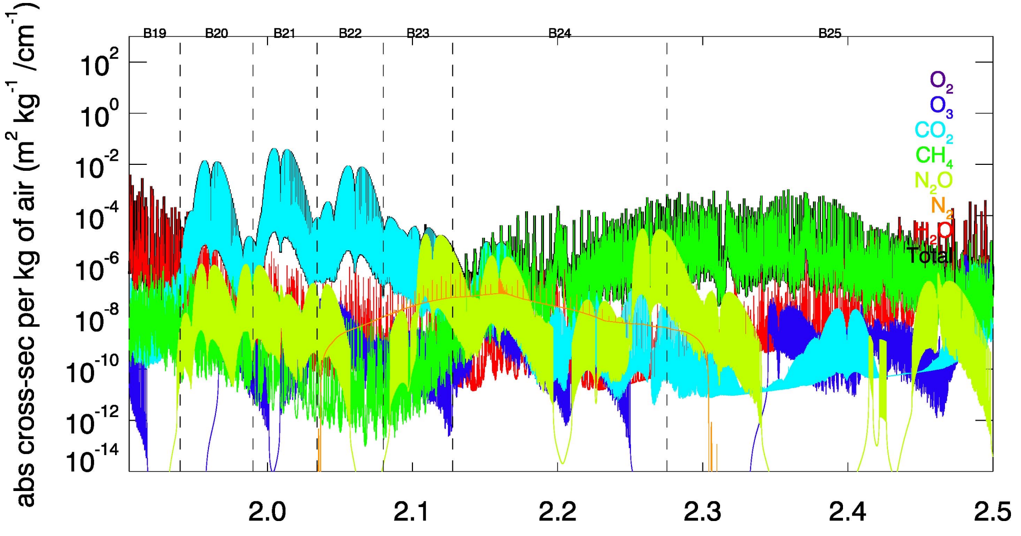
Impact of Inclusion of More Gas Species on the SW Fluxes

- In Ed4, O_2 absorption was not included in most SW Fu-Liou bands. However, O_2 absorption can be comparable to O_3 and H_2O absorption in some bands.
- For UV bands, the impact of ignoring O_2 is small since the solar radiation is mostly absorbed in the stratosphere (not shown).
- The impact of ignoring O_2 is noticeable near surface in the visible bands (0.59 – 0.79 µm). The difference in surface downward fluxes can change by 1 W m^{-2}.

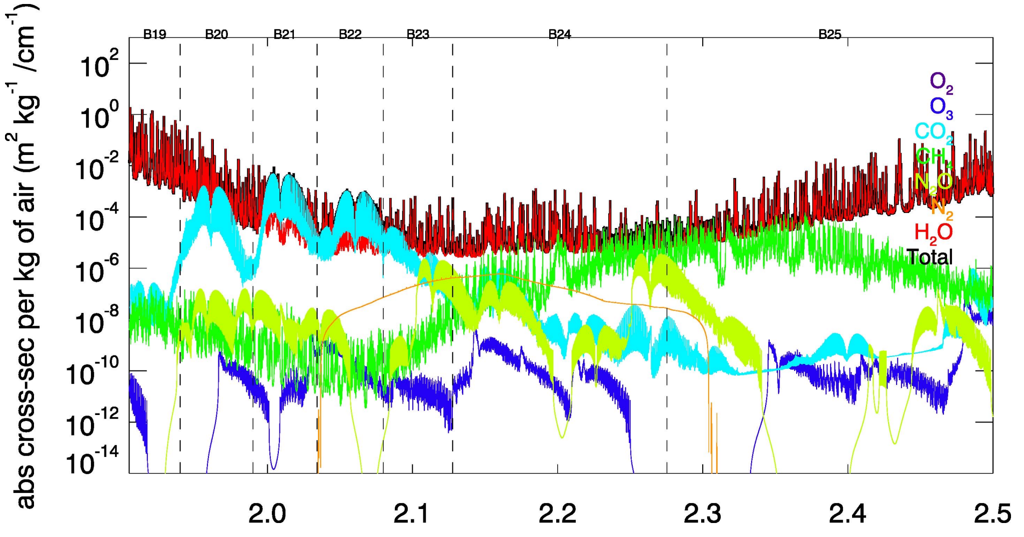
Splitting Near-Infrared (NIR) Bands to Make "Correlated-k Assumption" Work Better

Median gas amounts in CKDMIP data

100 hPa



961 hPa



- Gas absorption for the 1.9-2.5 μm spectral region in the Ed4 model was underestimated by 1 W m^{-2}, consisting of 50% of SW broadband error.

- The underestimation happened since the "correlated k assumption" did not work well for the broad spectral region, where the relative impacts of CO_2, CH_4, and H_2O absorptions vary by pressure. This problem is more serious for the pre-mix approach used in Ed5.

- Remedies
  - ➢ Split the NIR spectral region into more bands to hold the correlated k assumptions
  - ➢ Increase the total k terms for the NIR spectral region

Impact of the Splitting Near-Infrared (NIR) (1.9–2.5 μm) Bands on Flux Calculations

Case1: Two bands with 8 k terms

Band 19 (1.90-2.28 μm)	nk=5
Band 20 (2.28-2.50 μm)	nk=3

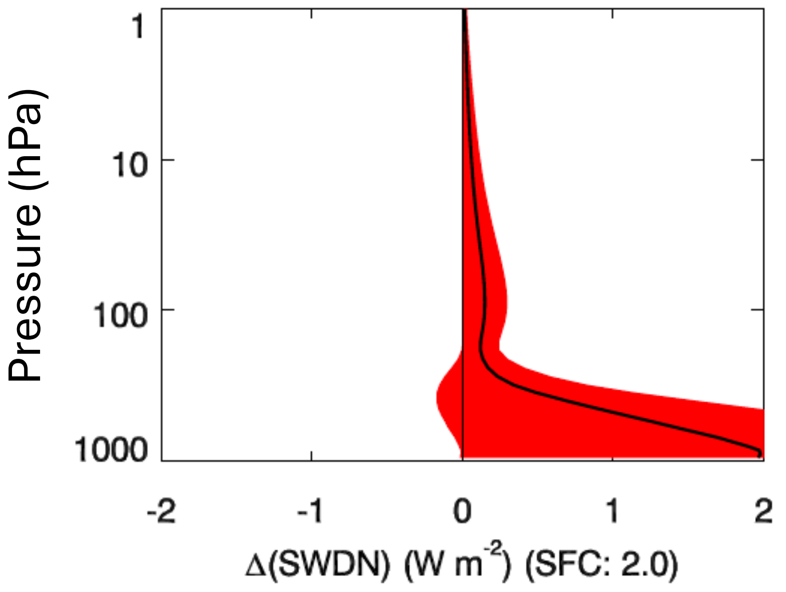
# of bands: 2, Total nk = 8

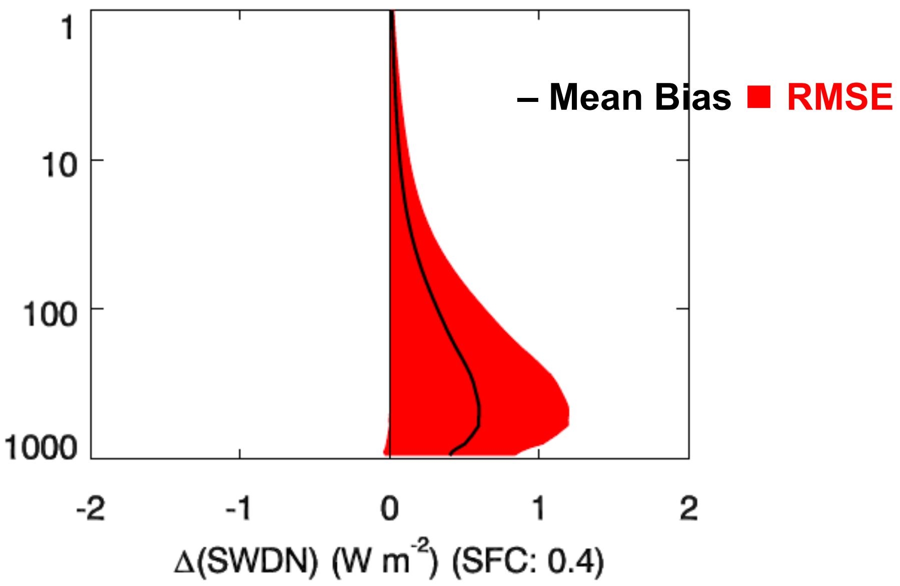
Case2: Seven bands with 14 k terms

Band 19 (1.90 -1.94 μm)	nk=2
Band 20 (1.94 -1.99 μm)	nk=2
Band 21 (1.99 - 2.03 μm)	nk=2
Band 22 (2.03 - 2.08 μm)	nk=2
Band 23 (2.08 - 2.13 μm)	nk=2
Band 24 (2.13 - 2.28 μm)	nk=1
Band 25 (2.28 - 2.50 μm)	nk=3

# of bands: 7, Total nk = 14

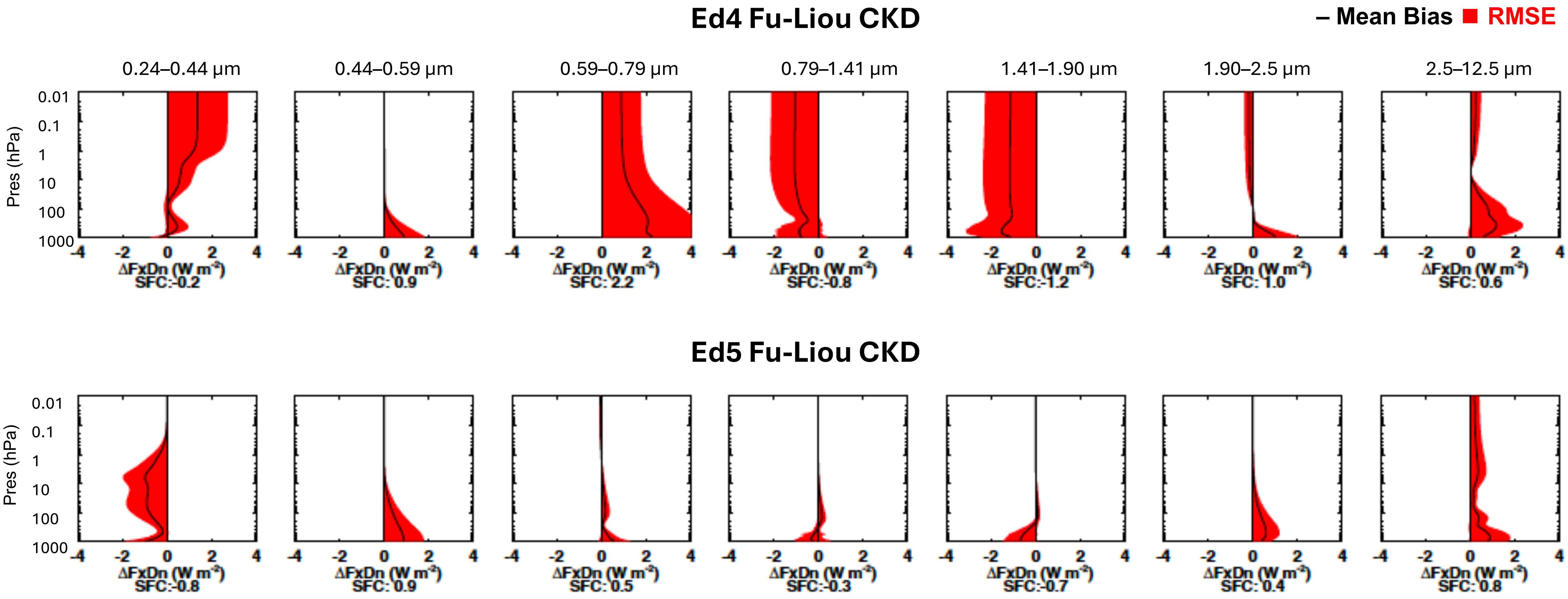
Bias of SW Downward NIR (1.9-2.5 μm) Flux Profile from the CKD method, compared to LBL flux





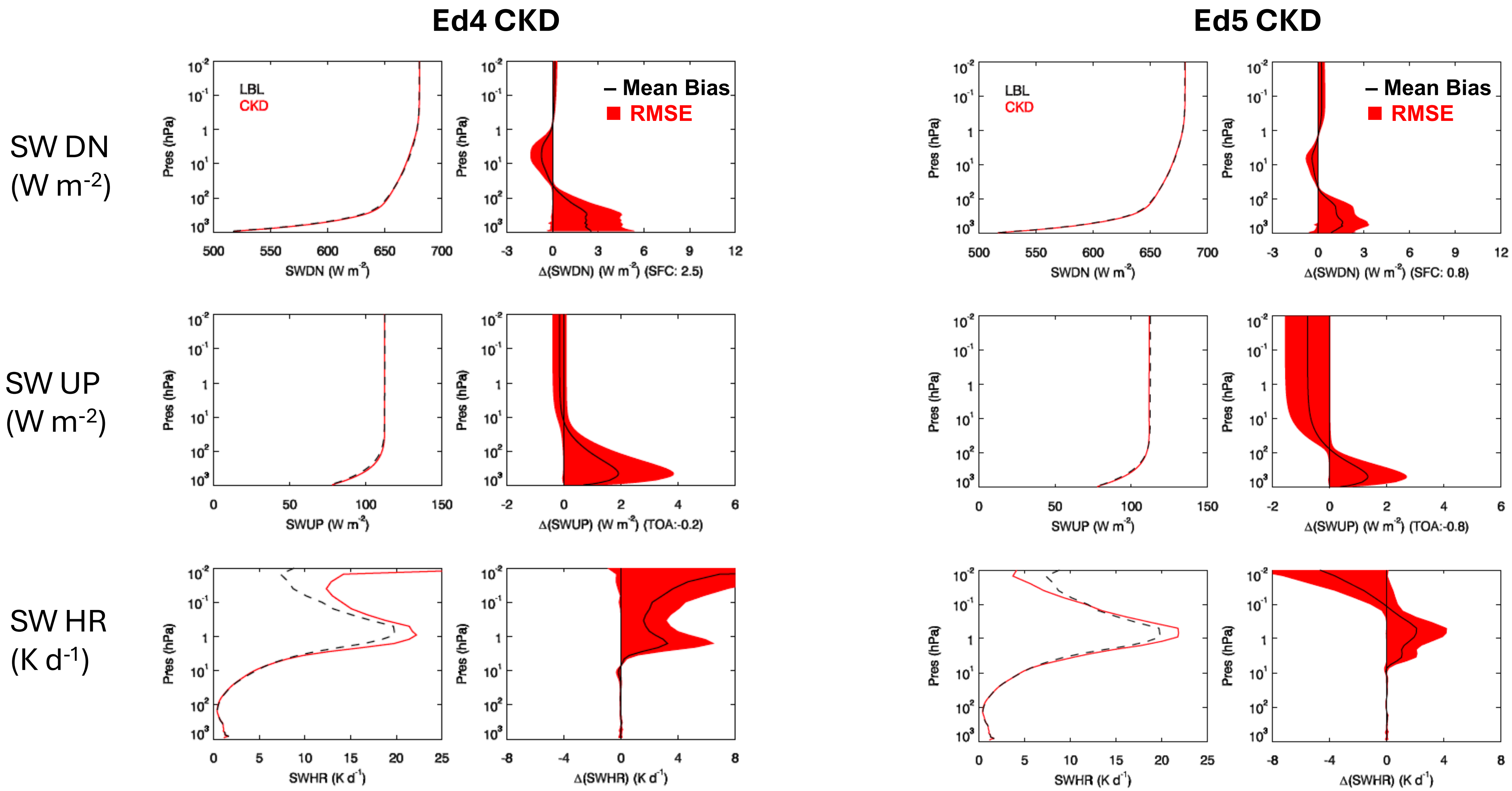
Biases in SW downward fluxes from the CKD method to the LBL results

(Tested with 50 evaluation cases of the CKDMIP study (Hogan et al. 2020))

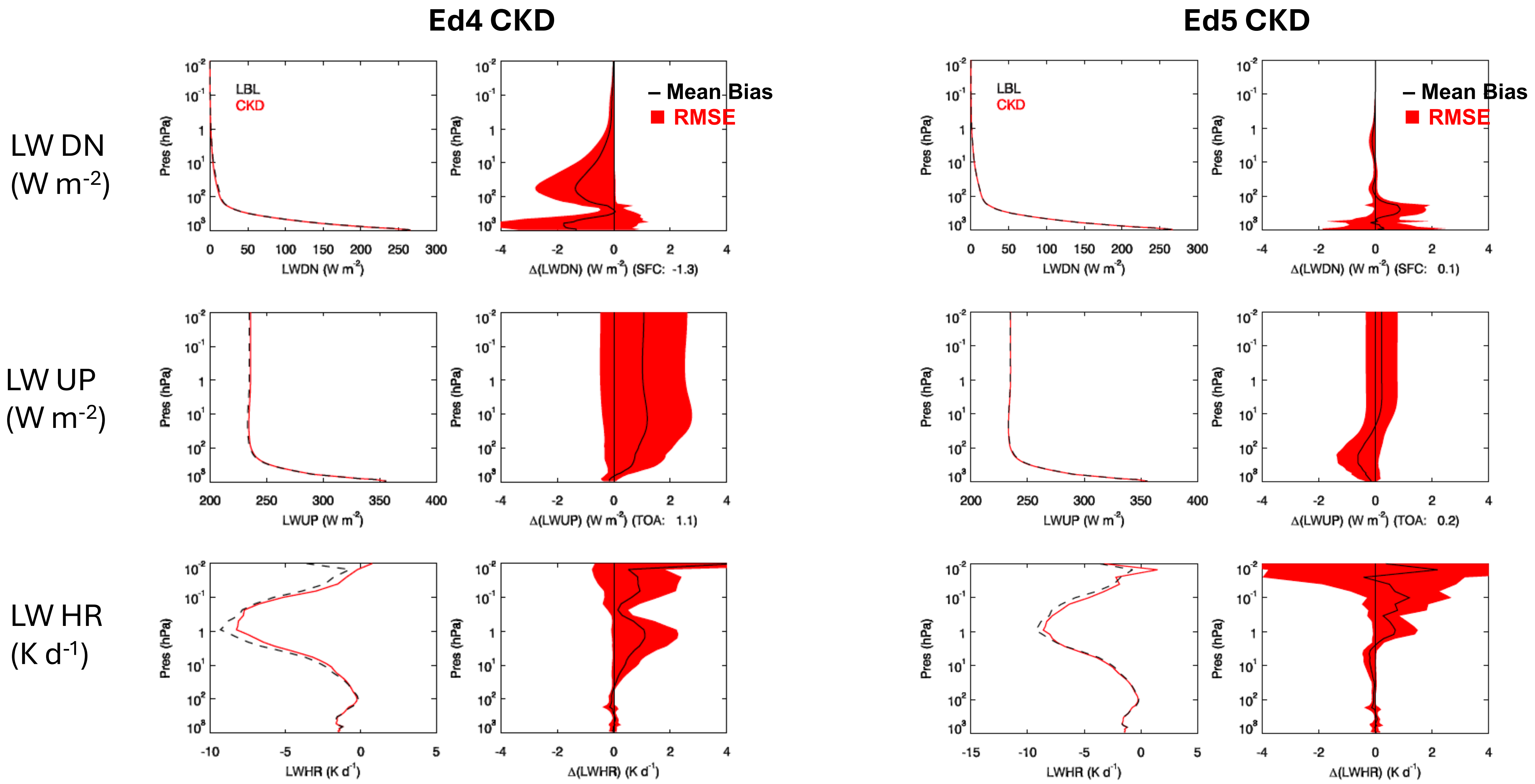


- Biases in the downward fluxes for the separated bands are larger in the Ed4 results compared to the Ed5 results, but these are largely cancelled out in the broadband flux biases.

SW Broadband Biases by the CKD Methods Compared to the LBL Results

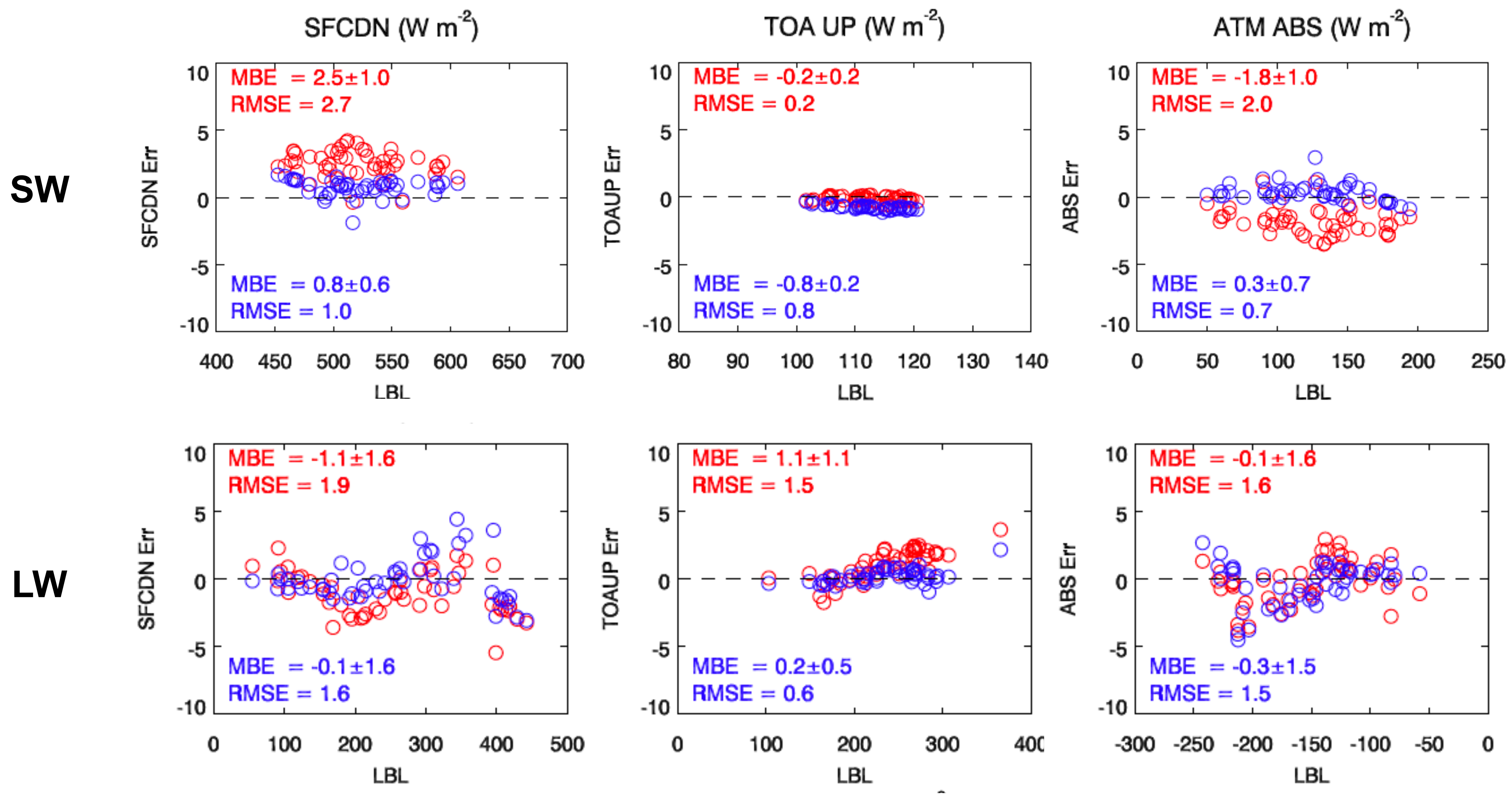


LW Broadband Biases by the CKD Methods Compared to the LBL Results



Broadband Flux Biases to LBL (50 Evaluation Cases by Hogan et al.)

Ed4
Ed5



Summary

- VIIRS Deep Blue correction was developed by the deep blue team (Jaehwa Lee) and Dark target correction was also developed to be used in Ed4 process.
- Edition 4.2 EBAF-Surface from April 2022 will be reprocessed and released in early 2025 (Edition 4.2.1).
- Edition 5 aerosol transport model and interphase to radiation transfer model continues.
- The snow or sea ice (SIC) albedo was improved by using the scaling factor based on the clear-sky assumption. By using the new approach, underestimation of the surface albedo issue was largely removed, showing a better agreement with ground observations.
- The Ed5 Fu-Liou model is under development. This include:
  - ✓ More flexible interface in case we need changes in the SW or LW band structures, cloud scattering parameter databases, and aerosol scattering databases.
  - ✓ Updated correlated-k distribution table based on more recent version of line-by-line gas database and more inclusion of gas species
- Preliminary results for the clear-sky conditions show that
  - ✓ SW and LW BB fluxes for Ed4 and Ed5 are not very different, < 2 W m^{-2} differences.
  - ✓ When the fluxes are compared for narrow bands, the Ed4 and Ed5 are quite different. When comparing with the line-by-line results, Ed5 results show better performance than the Ed4 model.

Publications

- Ham, S.-H., N. G. Loeb, S. Kato, T. J. Thorsen, A. Voigt, W. L. Smith Jr., and D. Winker, 2023: Zonal cloud trends observed by passive MODIS and active CALIPO and CPR sensors, Submitted to *J. Climate*.
- Kato, S., N. G. Loeb, F. G. Rose, S.-H. Ham, T. J. Thorsen, D. A. Rutan, W. F. Miller, T. E. Caldwell, D. R. Doelling, S. Sun-Mack, 2023: Seamless continuity in CERES Energy balanced and Filled (EBAF) surface radiation budget across multiple satellites, submitted *to J. Climate*.
- Riihimaki, L. D., M. F. Cronin, ... D. Rutan,..... 2024: Ocean surface radiation measurement best practice, *Front. Mar. Sci. 11:1359149. doi: 10.3389/fmars.2024.1359149*
- Loeb, N. G., D. R. Doelling, S. Kato, W. Su, P. E. Mlynczak, and J. C. Wilkins, 2024: Continuity in top-of-atmosphere earth radiation budget observations, *J. Climate*, Accepted

Thank you for your attention!

31