Updates to the CERES SW Sea Ice ADMs

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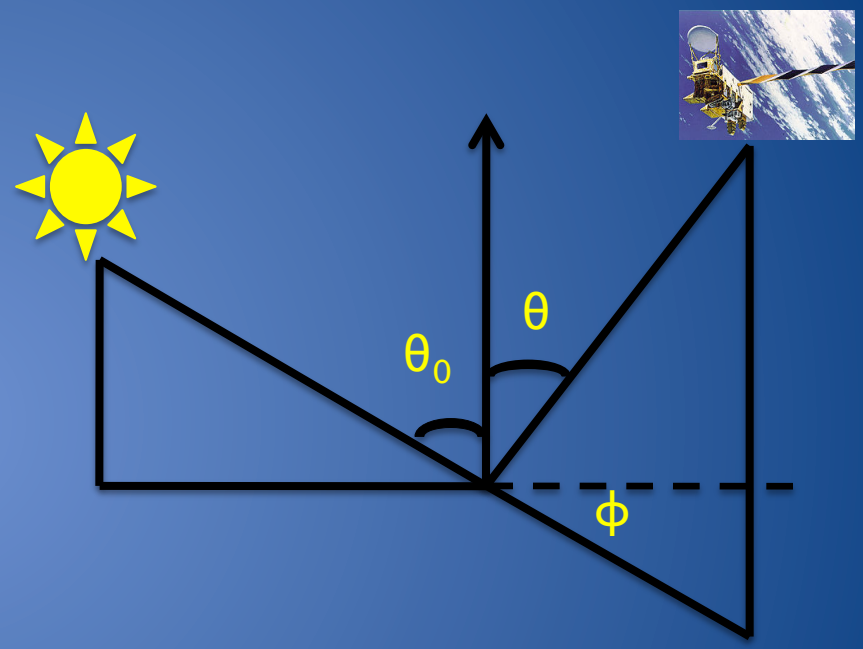
CERES STM May 2013

NASA Langley

1)SSAI, 2)NASA Langley

From radiance to flux: angular distribution model

- Sort observed radiances into angular bins over different scene types;
- Integrate radiance over all θ and φ to estimate the anisotropic factor for each scene type;
- Apply anisotropic factor to observed radiance to derive TOA flux;



$$R(\theta_0,\theta,\phi) = \frac{\pi \hat{I}(\theta_0,\theta,\phi)}{\int_0^{2\pi}\int_0^{\frac{\pi}{2}} \hat{I}(\theta_0,\theta,\phi) cos\theta sin\theta d\theta d\phi} = \frac{\pi \hat{I}(\theta_0,\theta,\phi)}{\hat{F}(\theta_0)}$$

$$F(\theta_0) = \frac{\pi I_o(\theta_0,\theta,\phi)}{R(\theta_0,\theta,\phi)}$$

Sea Ice

- Highly variable surface
  - First year ice vs multi-year ice, sea ice fraction, clouds vs sea ice
- Changes significantly during the course of a year
  - Snow covered -> melting snow -> melt ponds/bare ice -> open water
  - Large albedo changes for different types of sea ice
- High solar zenith angles
- Cloudy
- Need ADMs that can account for as much of the change as possible

Existing ADMs

- Clear sky:
  - based on sea ice fraction
  - For >99% sea ice cover: 2 ADMs based on surface brightness
  - Surface brightness for different regions specified by mean nadir MODIS 0.645µm band over 2000-2004.
  - ADM selected by matching the measured CERES radiance to the ADM radiance

- Overcast:
  - 4 ADMs based on surface brightness and cloud optical thickness (>10,<10)
  - Bright/dark ADM selected by matching the measured CERES radiance to the ADM radiance

- Fractional cloud scenes:
  - 25% cloud fraction and 25 % sea ice fraction bins

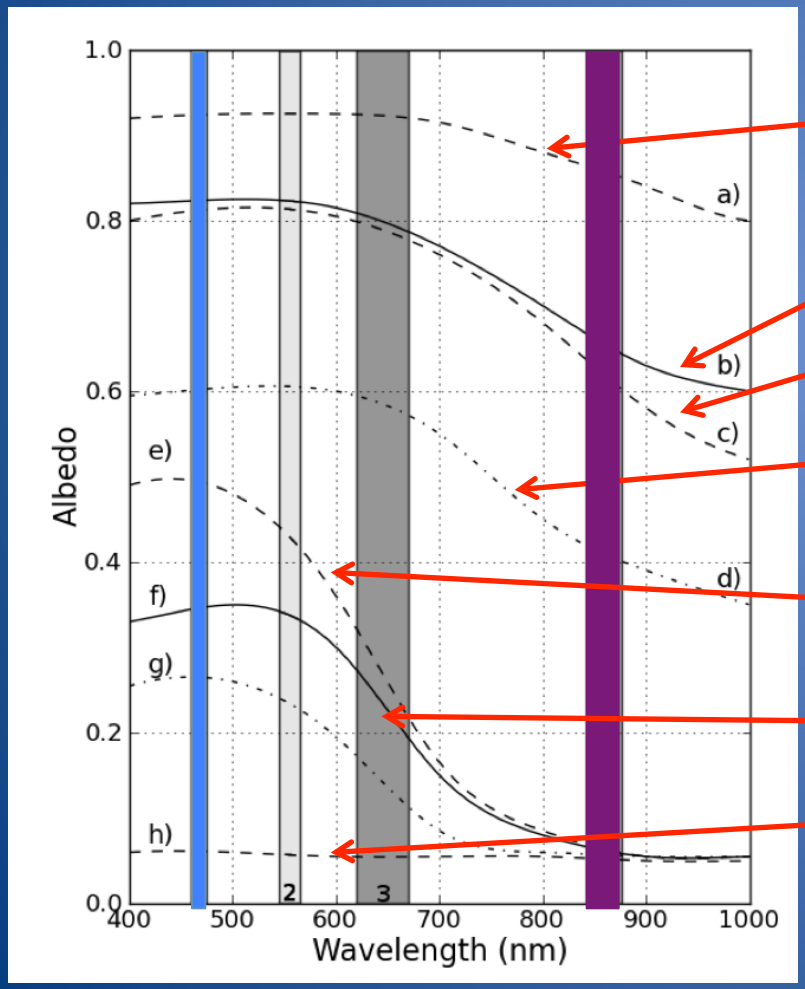
New approach

- Classify surface brightness using a band-differenced ratio that can be determined for each footprint.
- Classify scenes by surface brightness.
- For overcast scenes apply a linear fit in log (tau).

Classifying Sea Ice Surface Brightness

- Use the differenced ratio of clear-sky MODIS 0.469µm and 0.858µm bands

$$seaiceindex = 1 - \frac{\rho_{0.47} - \rho_{0.86}}{\rho_{0.47} + \rho_{0.86}}$$



Rosel et al 2012, surface values

High Sea Ice Index

Snow

Bare ice

Wet snow

Melting first year ice

Young melt pond

Melt ponds

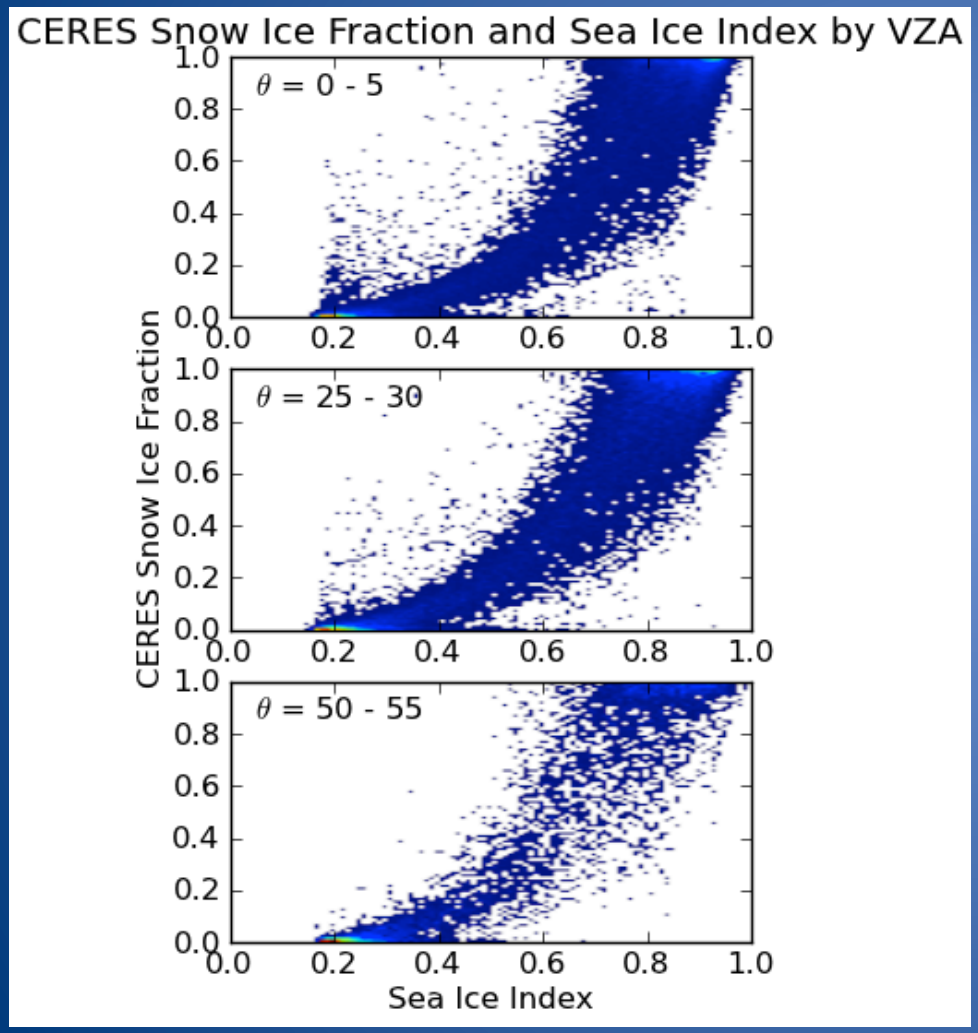
Open water

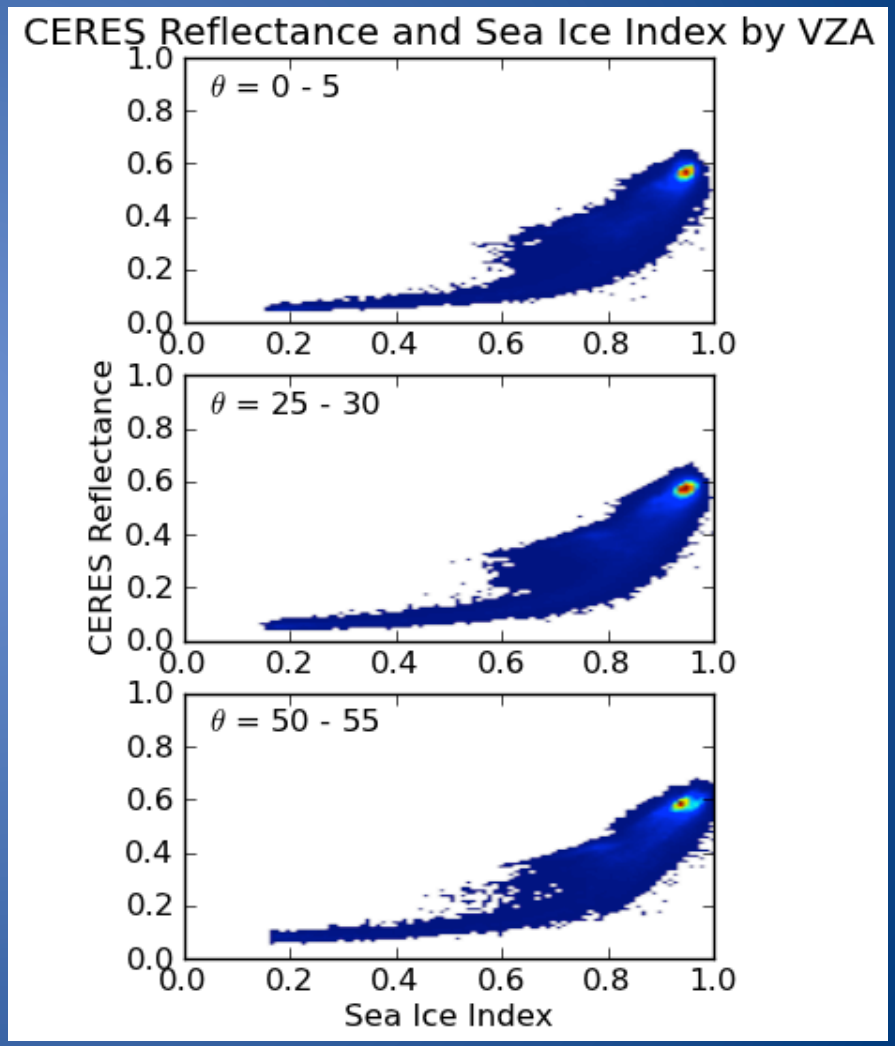
~0.8-1.0

~0.1-0.5

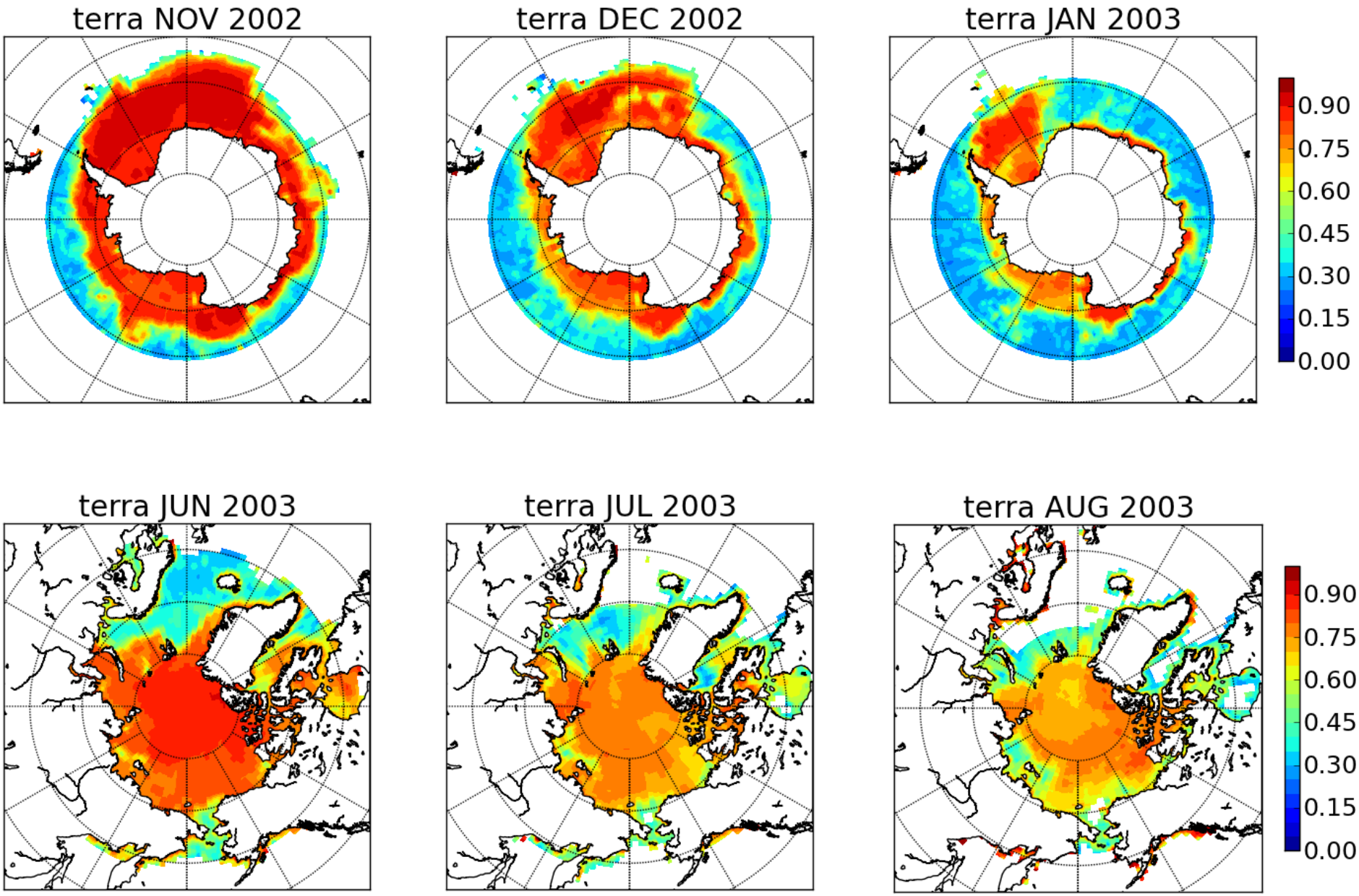
Low Sea Ice Index

Sea Ice Index, Sea Ice Fraction and Reflectance





Change in Sea Ice Index over melt season



Clear Sky

- 6 Sea ice fraction bins :
  - ≤1%, 1% - 25%,25% - 50%, 50% - 75%, 75% - 99%, ≥99%
- For scenes with sea ice fraction >99%:
  - 3 sea ice index bins: ≤0.85, 0.85 – 0.935, >0.935

Normalize predicted and observed radiance

Observed radiance:

$$I_j^o, \quad j = 1, \cdots, n$$

Predicted radiance:

$$\hat{I}_j, \quad j = 1, \cdots, n$$

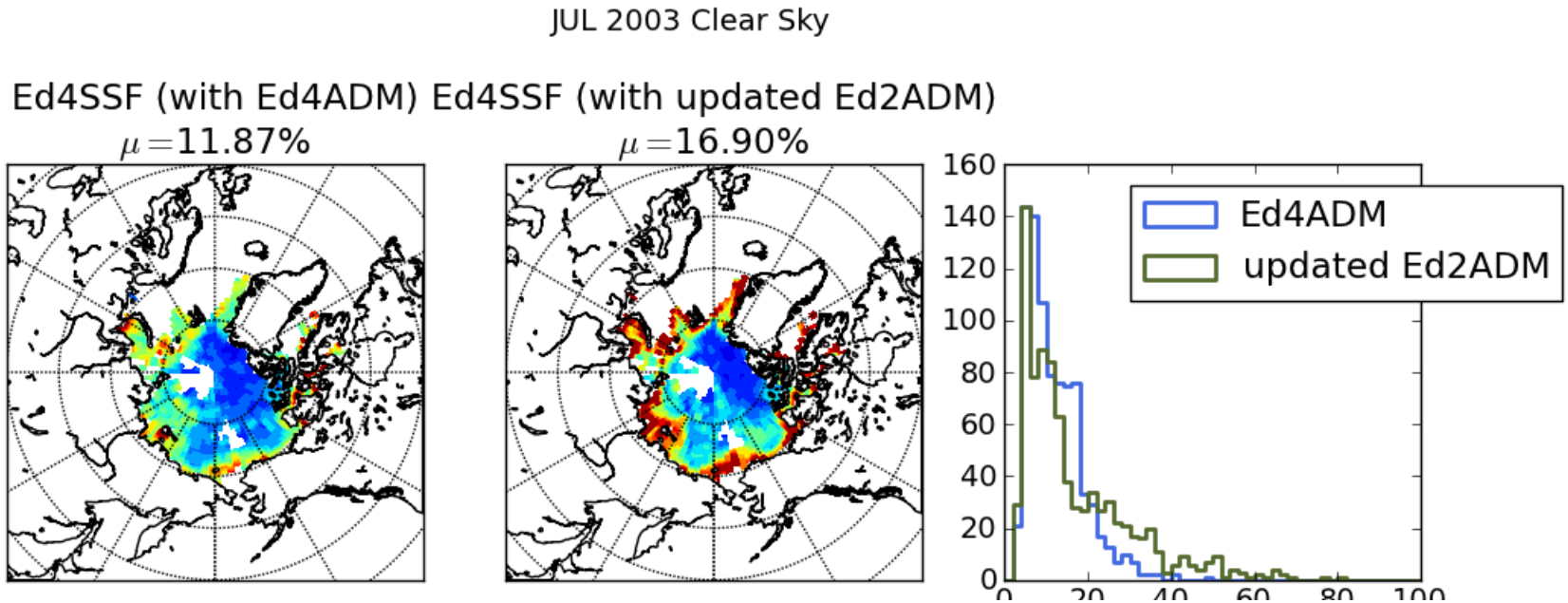
1°

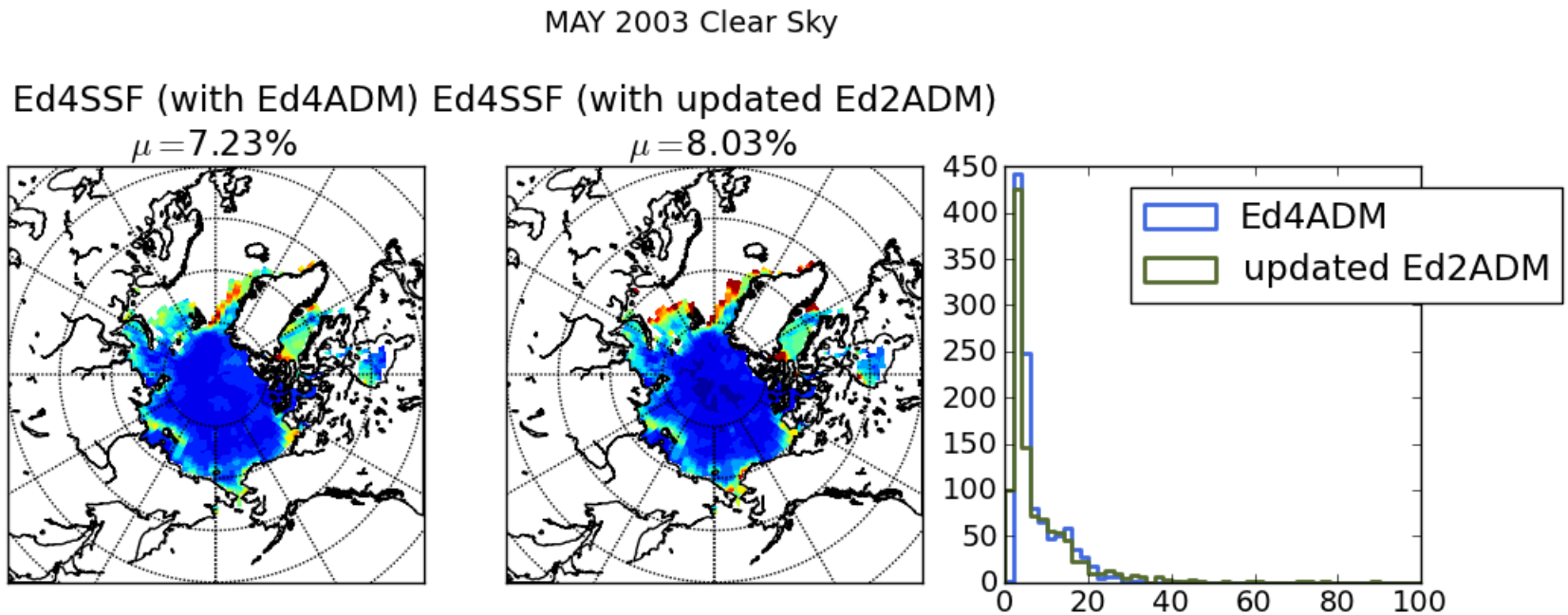
1°

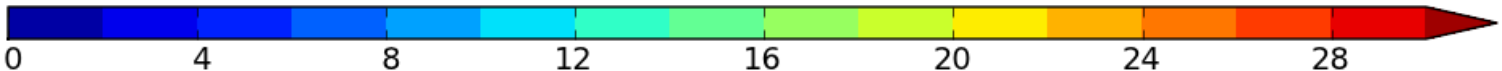
$$\overline{I^o} = \frac{1}{n}\sum_{j=1}^{n} I_j^o \qquad \overline{\hat{I}} = \frac{1}{n}\sum_{j=1}^{n} \hat{I}_j$$

$$RMS = \sqrt{\frac{1}{n}\sum_{j=1}^{n}\left(\frac{\hat{I}_j}{\overline{\hat{I}}} - \frac{I_j^o}{\overline{I^o}}\right)^2}$$

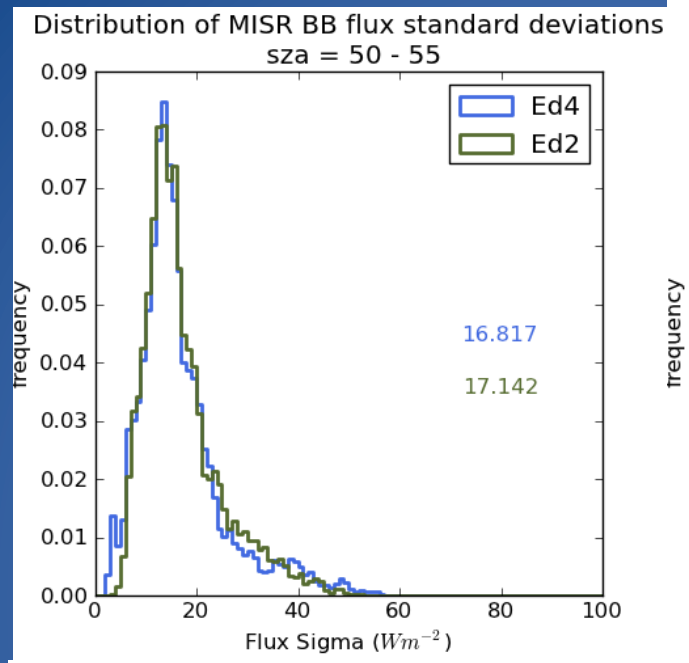
- RMS error between normalized predicted radiance and normalized observed radiance is closely related to the ADM error

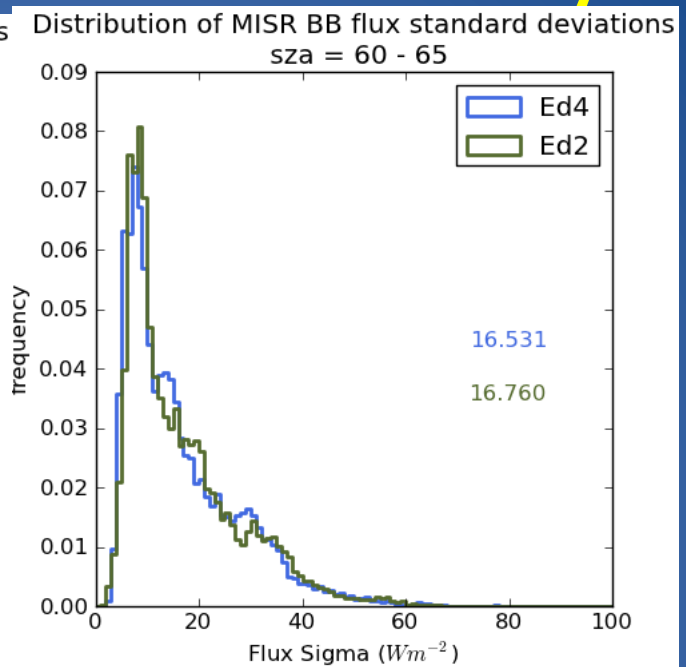

JUL 2003 Clear Sky
Ed4SSF (with Ed4ADM)
Ed4SSF (with updated Ed2ADM)
μ =11.87%
μ =16.90%
Ed4ADM
updated Ed2ADM
0
20
40
60
80
100
120
140
160

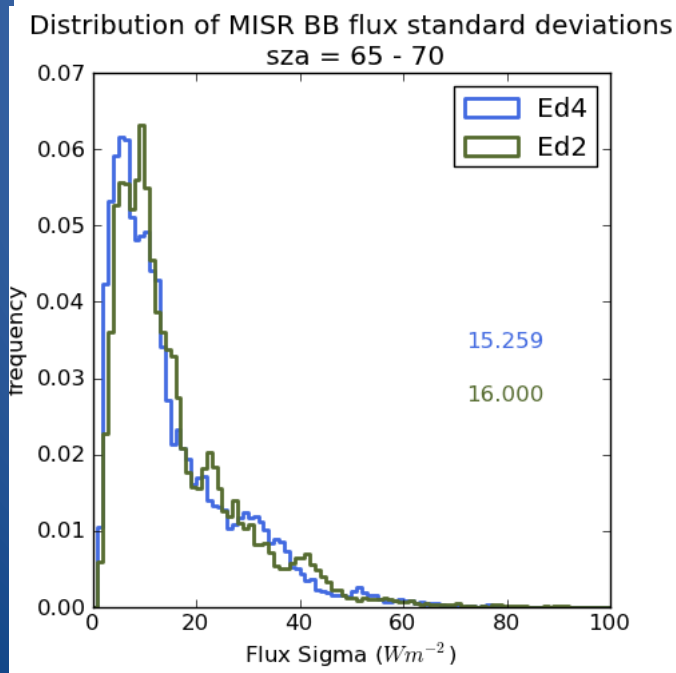

MAY 2003 Clear Sky
Ed4SSF (with Ed4ADM)
Ed4SSF (with updated Ed2ADM)
μ =7.23%
μ =8.03%
Ed4ADM
updated Ed2ADM
0
50
100
150
200
250
300
350
400
450
0
20
40
60
80
100

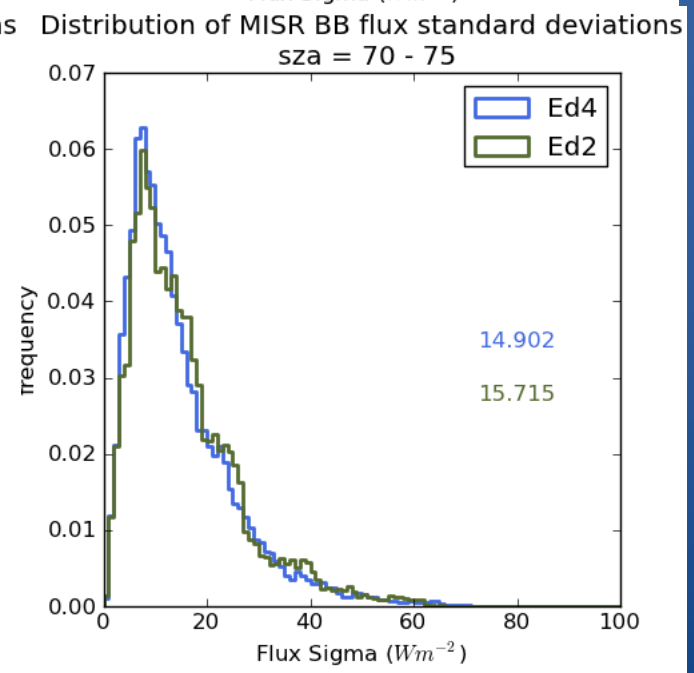

0
4
8
12
16
20
24
28

MISR BB flux consistency



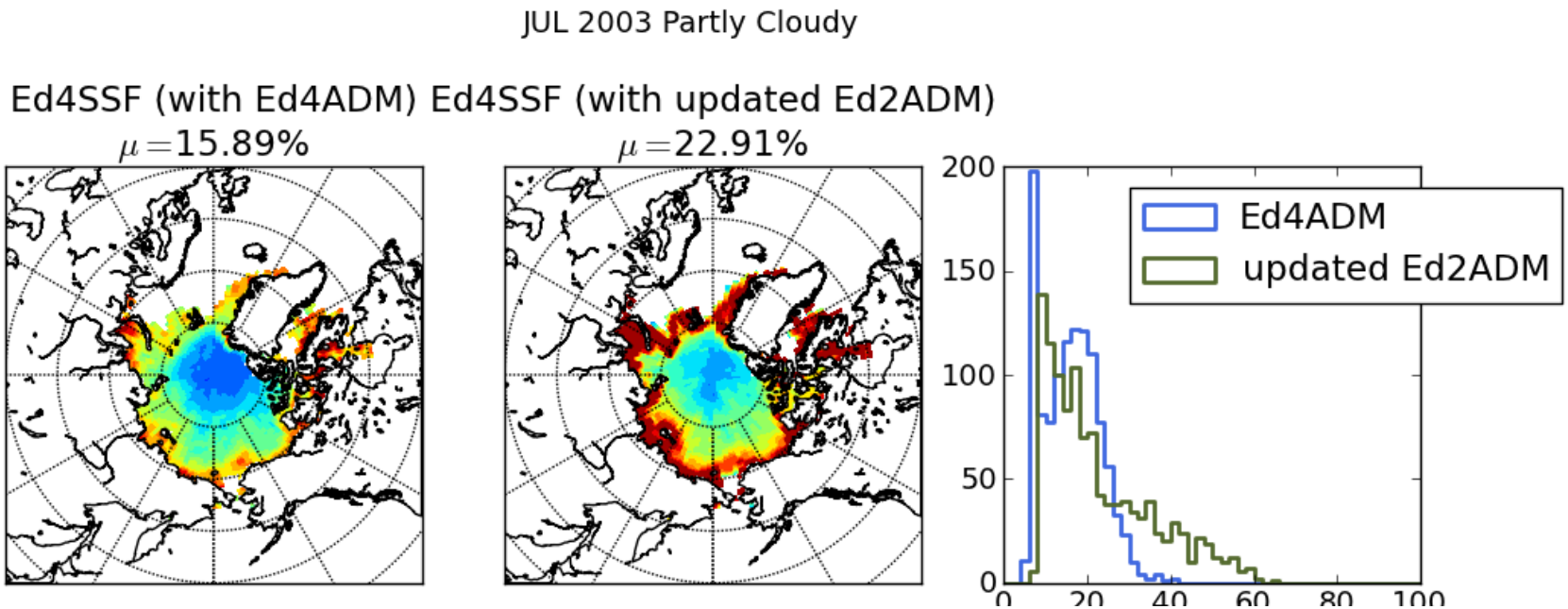


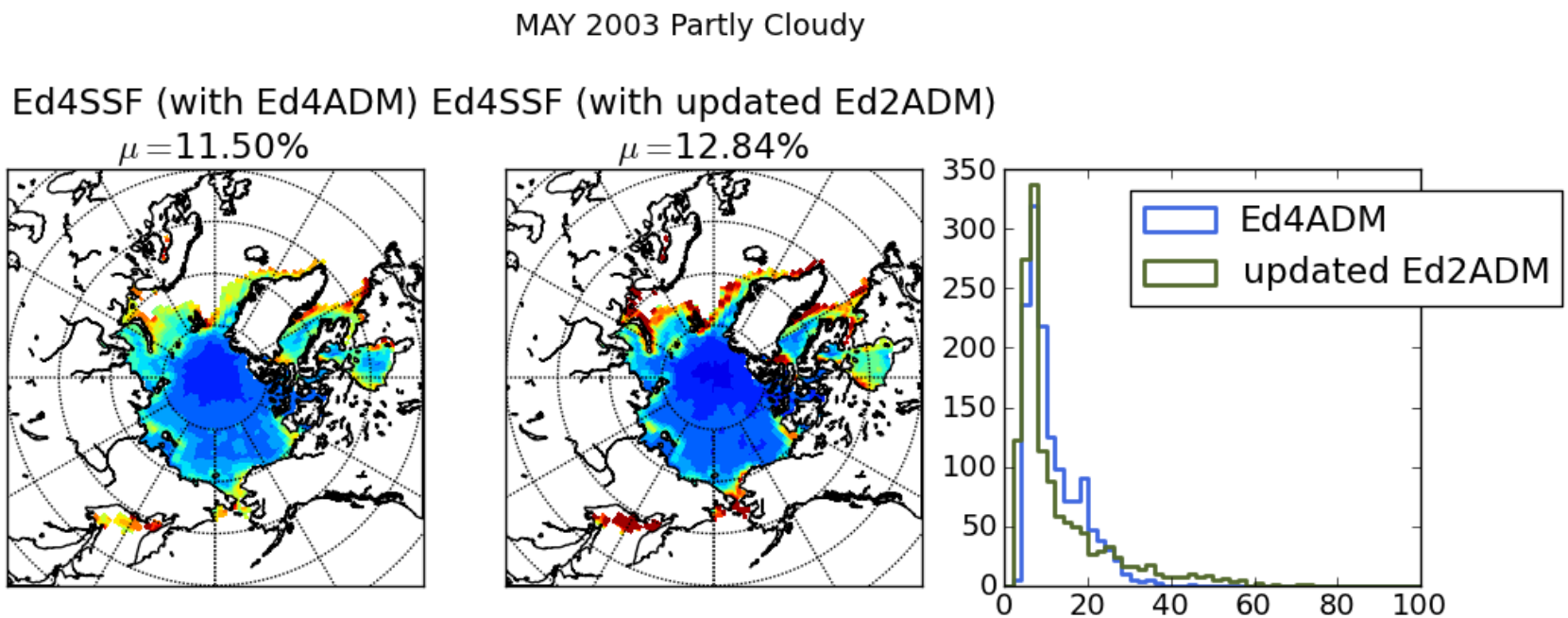


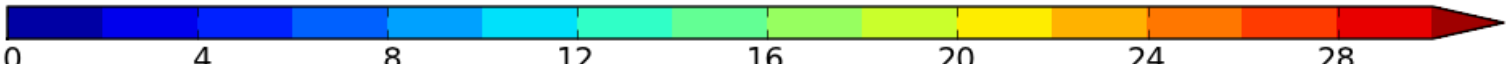


Partly Cloudy Scenes

- 4 cloud fraction bins:
  - 1% - 25%,25% - 50%, 50% - 75%, 75% - 99%
- 2 log(tau) bins:
  - ≥1,<1
- 6 Sea ice fraction bins :
  - Sea ice fraction is calculated by assuming the footprint sea ice fraction is the same as the sea ice fraction in the clear portion.
  - ≤1%, 1% - 25%, 25% - 50%, 50% - 75%, 75% - 99%, ≥99%
- For scenes with sea ice fraction ≥99%:
  - 3 sea ice index bins: ≤0.85, 0.85 – 0.935, >0.935


JUL 2003 Partly Cloudy
Ed4SSF (with Ed4ADM)
Ed4SSF (with updated Ed2ADM)
μ =15.89%
μ =22.91%
Ed4ADM
updated Ed2ADM
0
50
100
150
200
0
20
40
60
80
100


MAY 2003 Partly Cloudy
Ed4SSF (with Ed4ADM)
Ed4SSF (with updated Ed2ADM)
μ =11.50%
μ =12.84%
Ed4ADM
updated Ed2ADM
0
50
100
150
200
250
300
350
0
20
40
60
80
100


0
4
8
12
16
20
24
28

Overcast Scenes

Perform a linear fit between the mean reflectance in log tau bins of width 1 and log tau bin midpoint.

- separate fits for:
  - water phase and ice phase clouds
  - 5 clear-sky sea ice index ranges (using a monthly map)

Create BRDFs for a range of log tau values and integrate to get albedo

Perform a linear fit between albedo and log tau to get the albedo dependence

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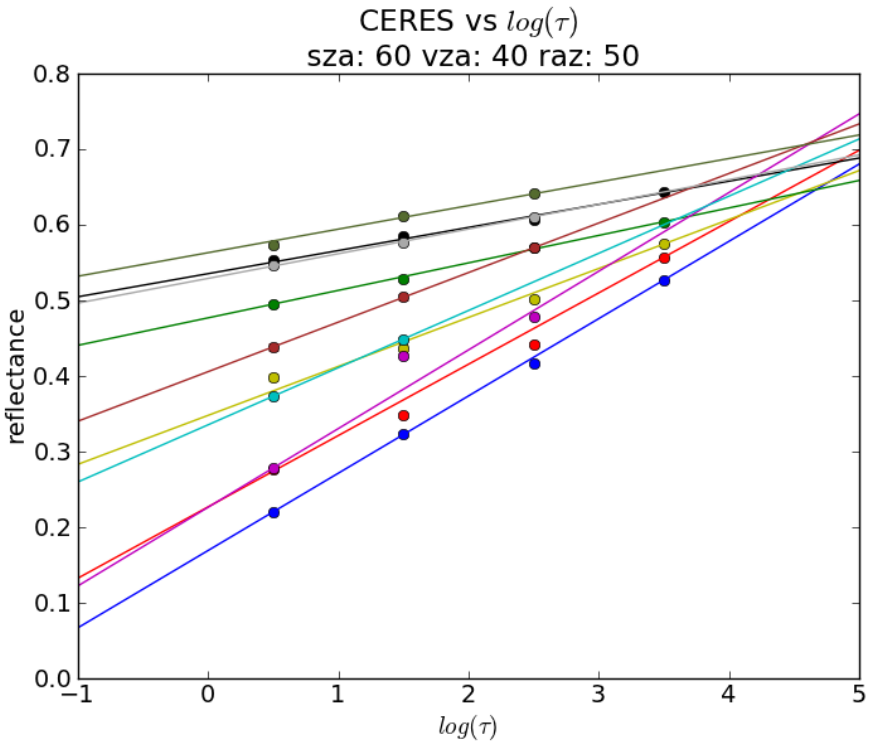
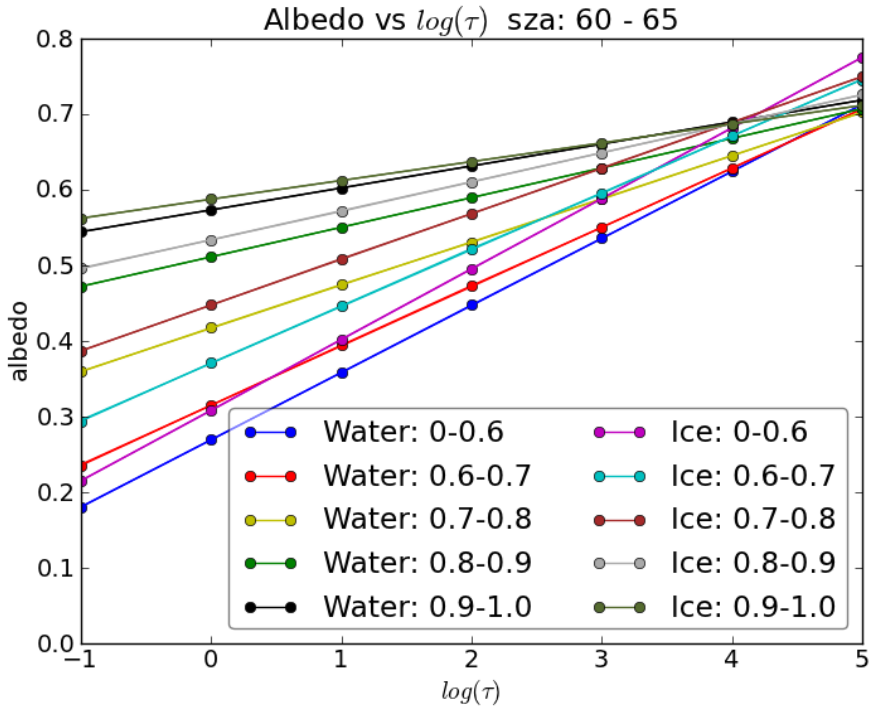
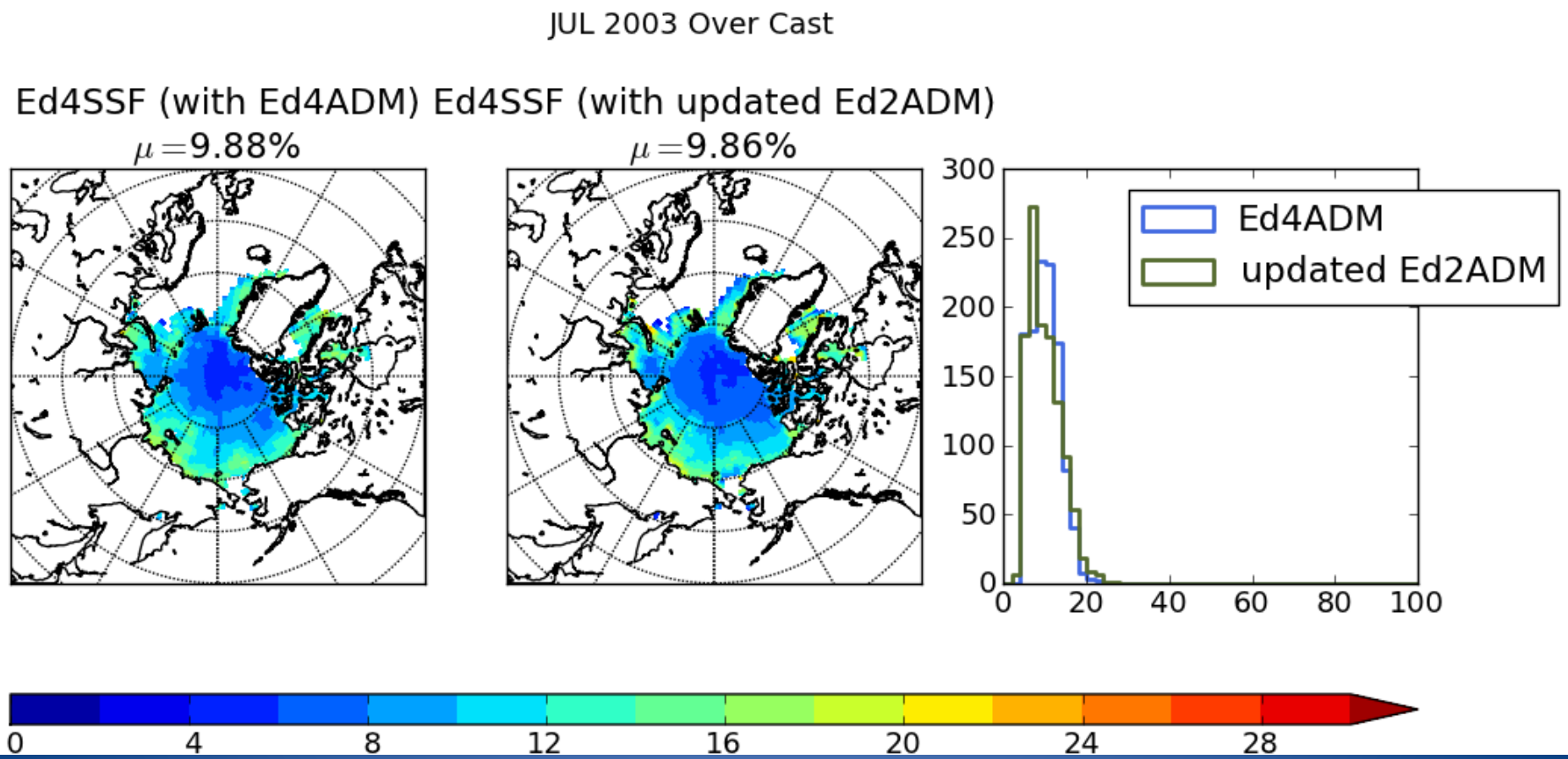
Perform a linear fit between albedo and log tau to get the albedo dependence





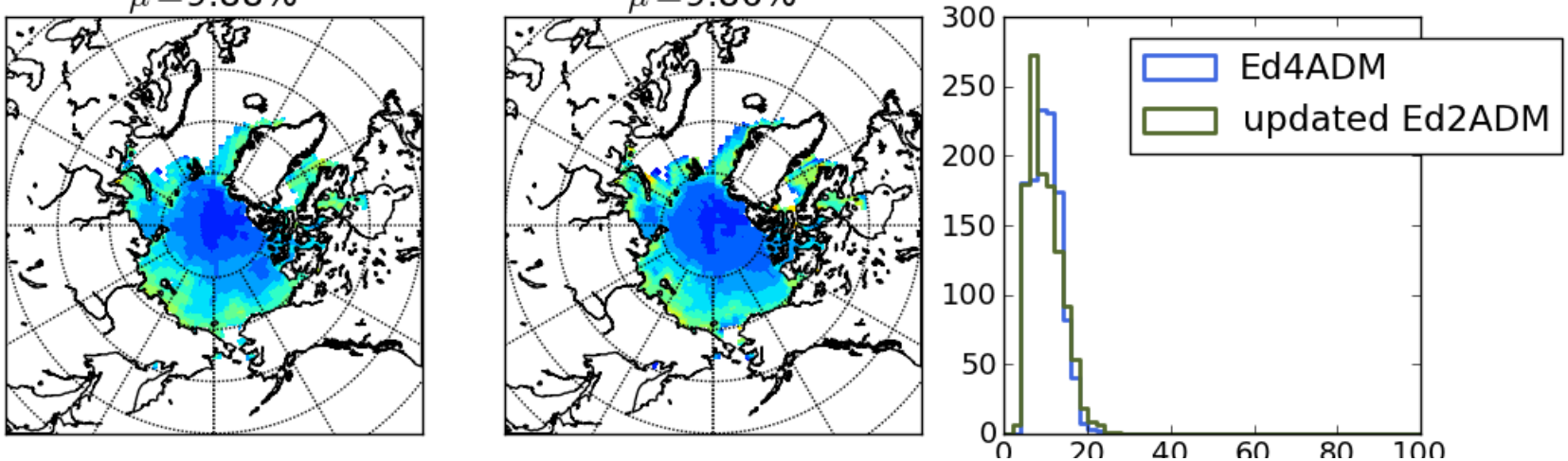
Results – normalized radiance differences



JUL 2003 Over Cast

Ed4SSF (with Ed4ADM) Ed4SSF (with updated Ed2ADM)

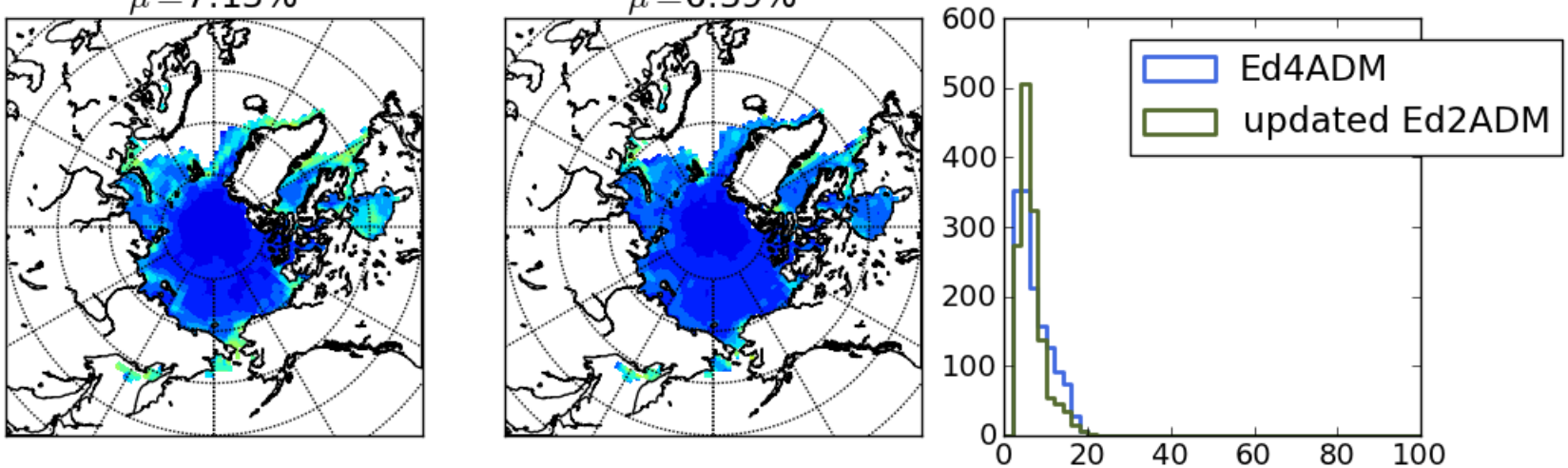
μ=9.88% μ=9.86%

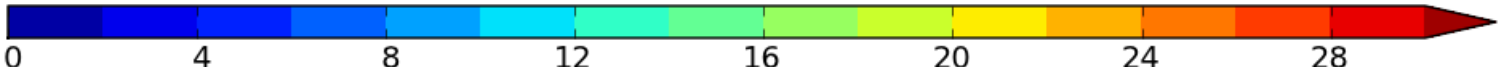


MAY 2003 Over Cast

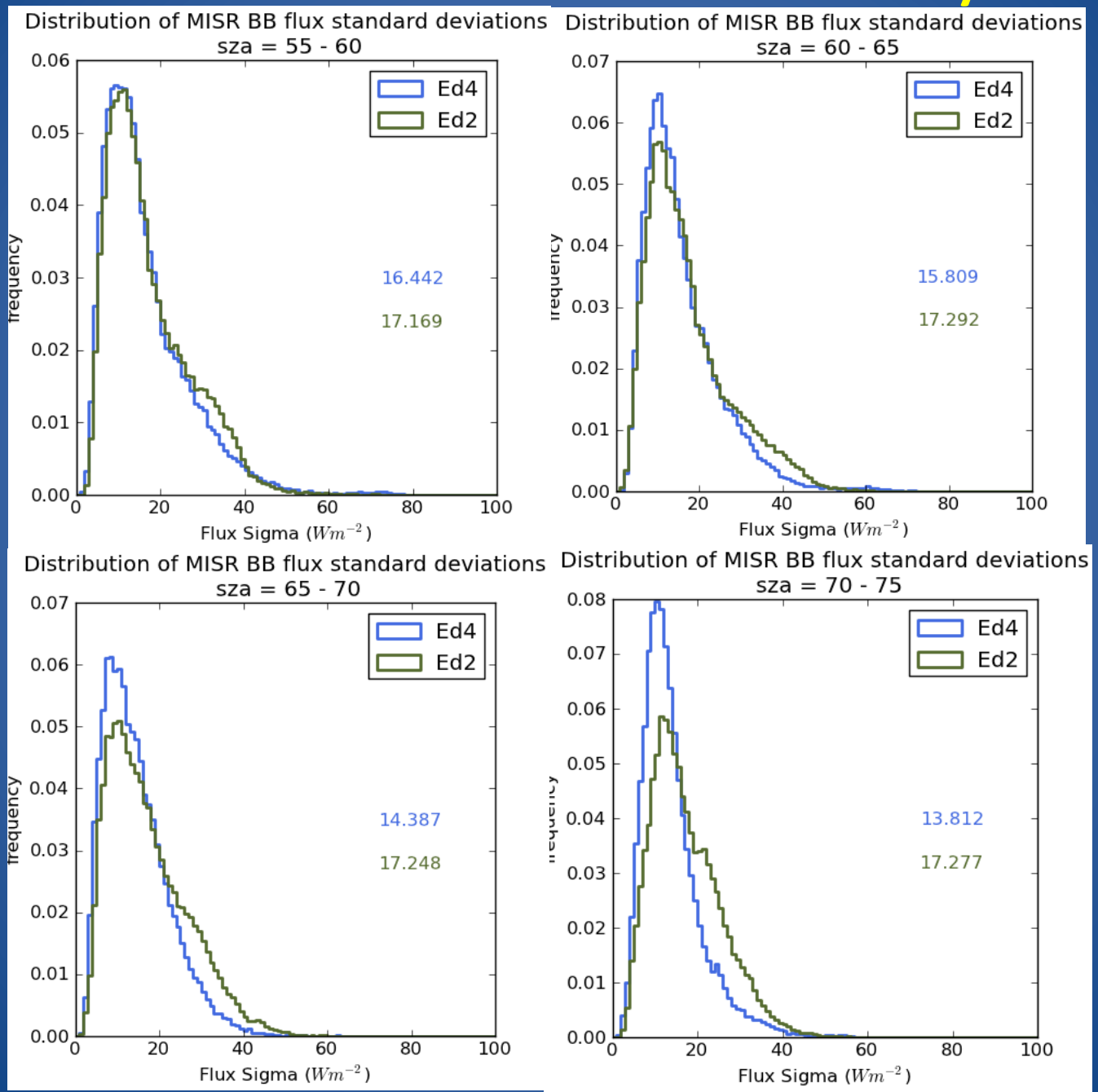
Ed4SSF (with Ed4ADM) Ed4SSF (with updated Ed2ADM)

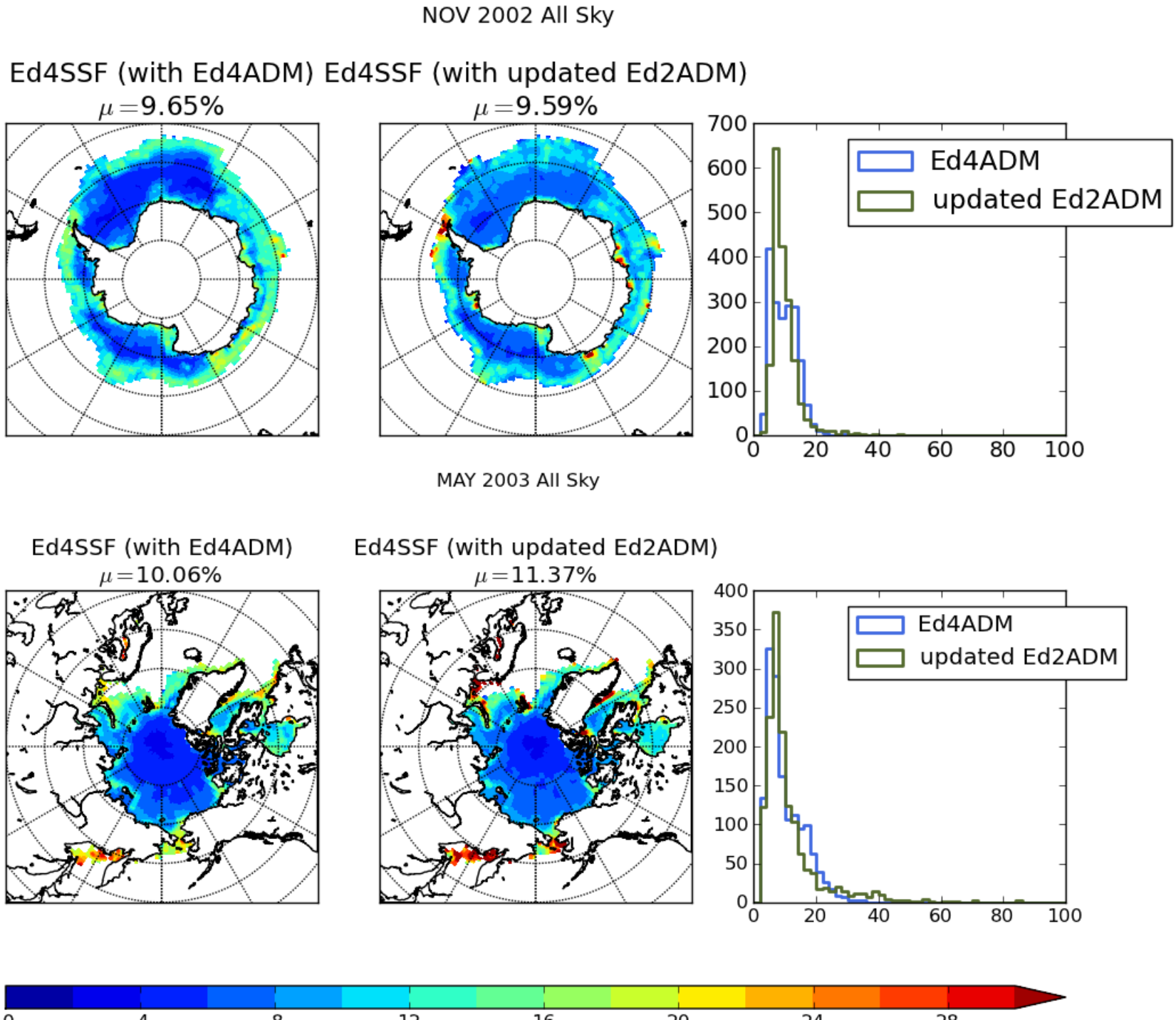
μ=7.13% μ=6.39%

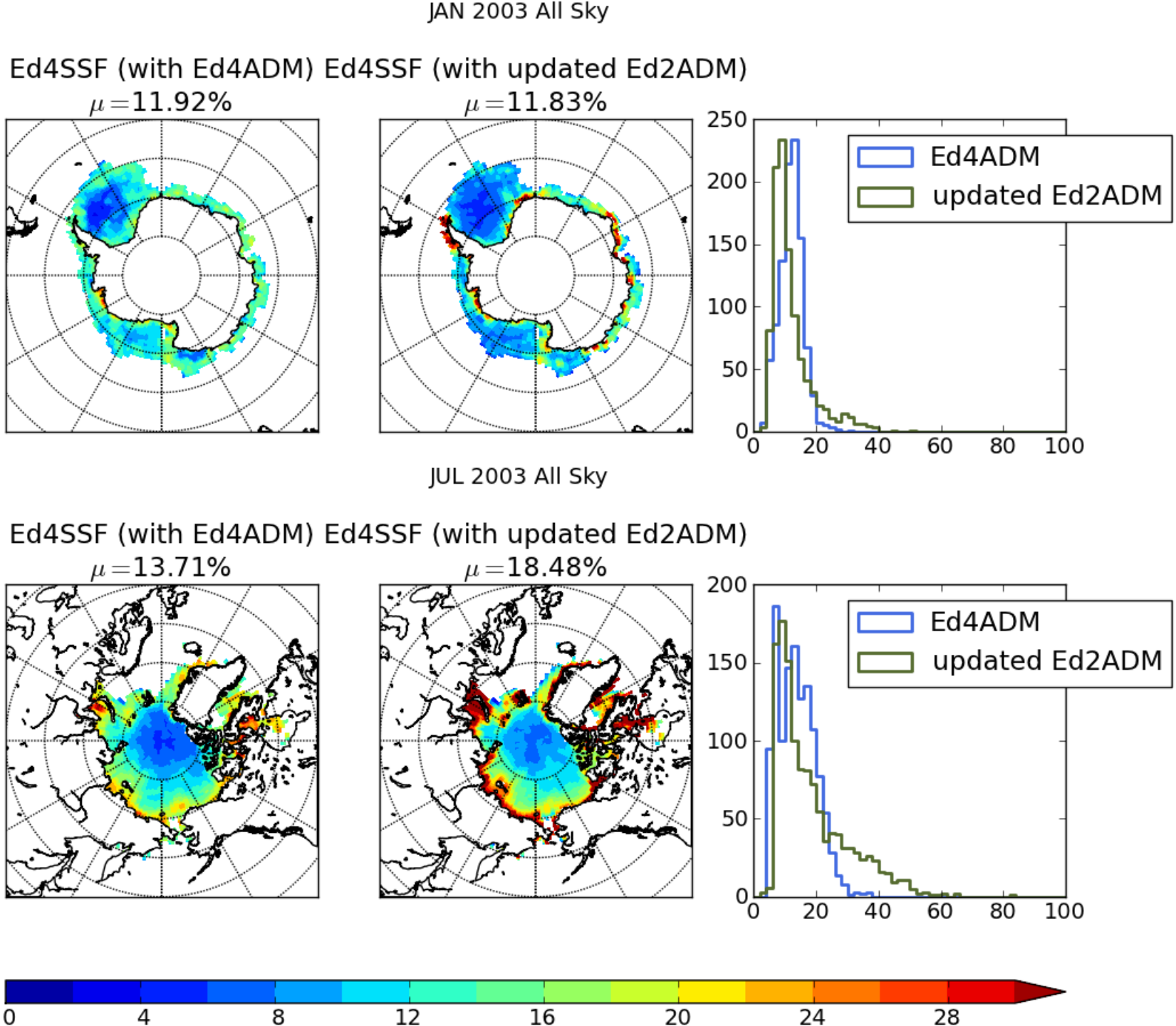




MISR BB flux consistency



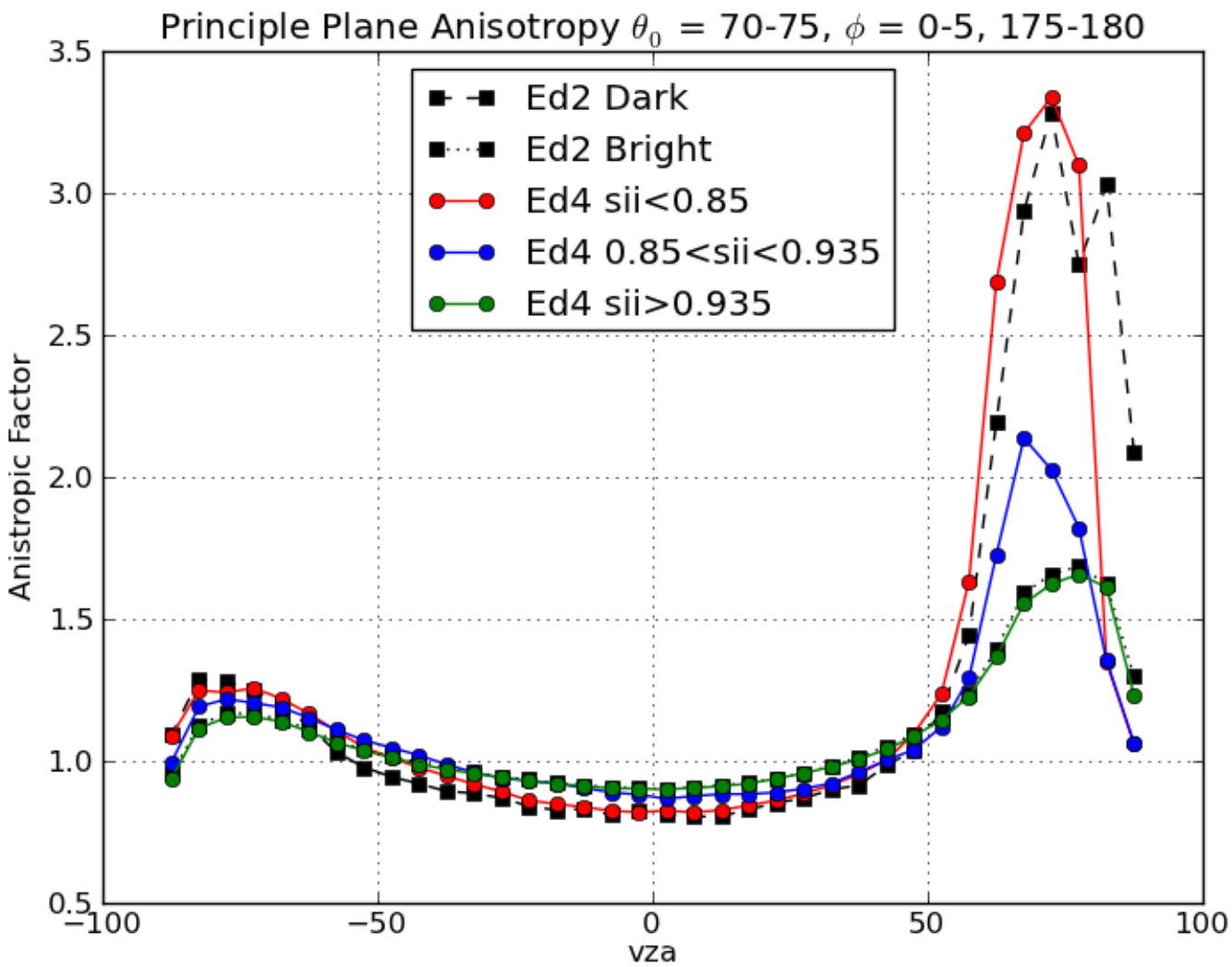

NOV 2002 All Sky
Ed4SSF (with Ed4ADM)
μ =9.65%
Ed4SSF (with updated Ed2ADM)
μ =9.59%
Ed4ADM
updated Ed2ADM
MAY 2003 All Sky
Ed4SSF (with Ed4ADM)
μ =10.06%
Ed4SSF (with updated Ed2ADM)
μ =11.37%
Ed4ADM
updated Ed2ADM


JAN 2003 All Sky
Ed4SSF (with Ed4ADM)
Ed4SSF (with updated Ed2ADM)
μ =11.92%
μ =11.83%
Ed4ADM
updated Ed2ADM
0
50
100
150
200
250
0
20
40
60
80
100
JUL 2003 All Sky
Ed4SSF (with Ed4ADM)
Ed4SSF (with updated Ed2ADM)
μ =13.71%
μ =18.48%
Ed4ADM
updated Ed2ADM
0
50
100
150
200
0
20
40
60
80
100
0
4
8
12
16
20
24
28

Summary

- New ADMs have been developed for sea ice scenes.
- Main change is the use of a normalised band difference to quantify surface brightness
- Use of a linear fit between reflectance and log (tau) is for overcast scenes.
- Results generally show an improvement over the existing ADMs

Clear Sky ADMs



Flux Changes: Ed4ADMs – Ed2ADMs