

Using MODIS spectral information to classify sea ice scenes for CERES radiance-to-flux inversion

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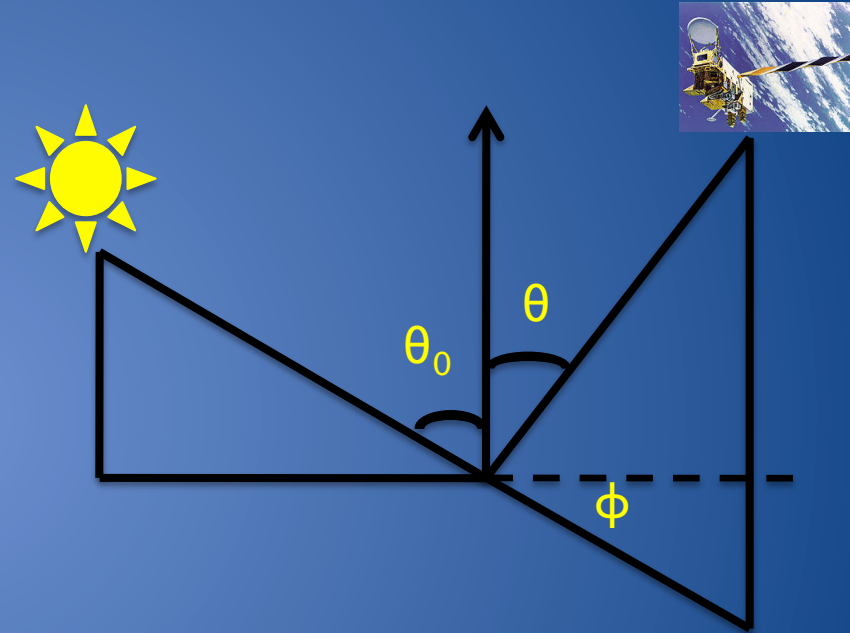
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CERES and MODIS

- Clouds and the Earth's Radiant Energy System
 - Measures shortwave, longwave and window radiances
 - Flying on Terra, Aqua and Soumi-NPP
- MODerate resolution Imaging-Spectrometer
 - Measures radiances in 36 channels
 - km level resolution
 - Flying on Terra and Aqua (VIIRs on Soumi-NPP)

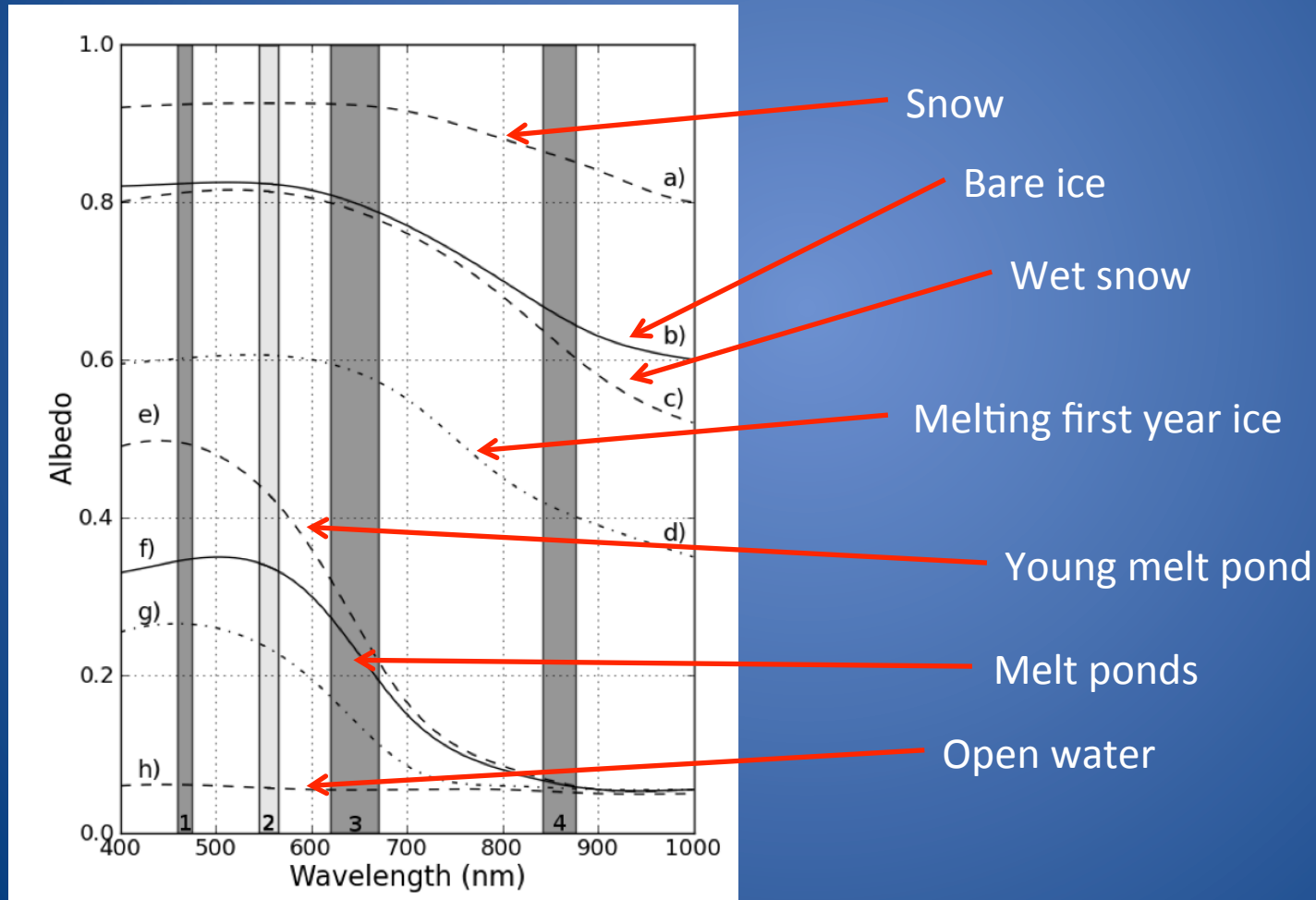
From radiance to flux: angular distribution model (ADM)

- Sort observed CERES 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



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

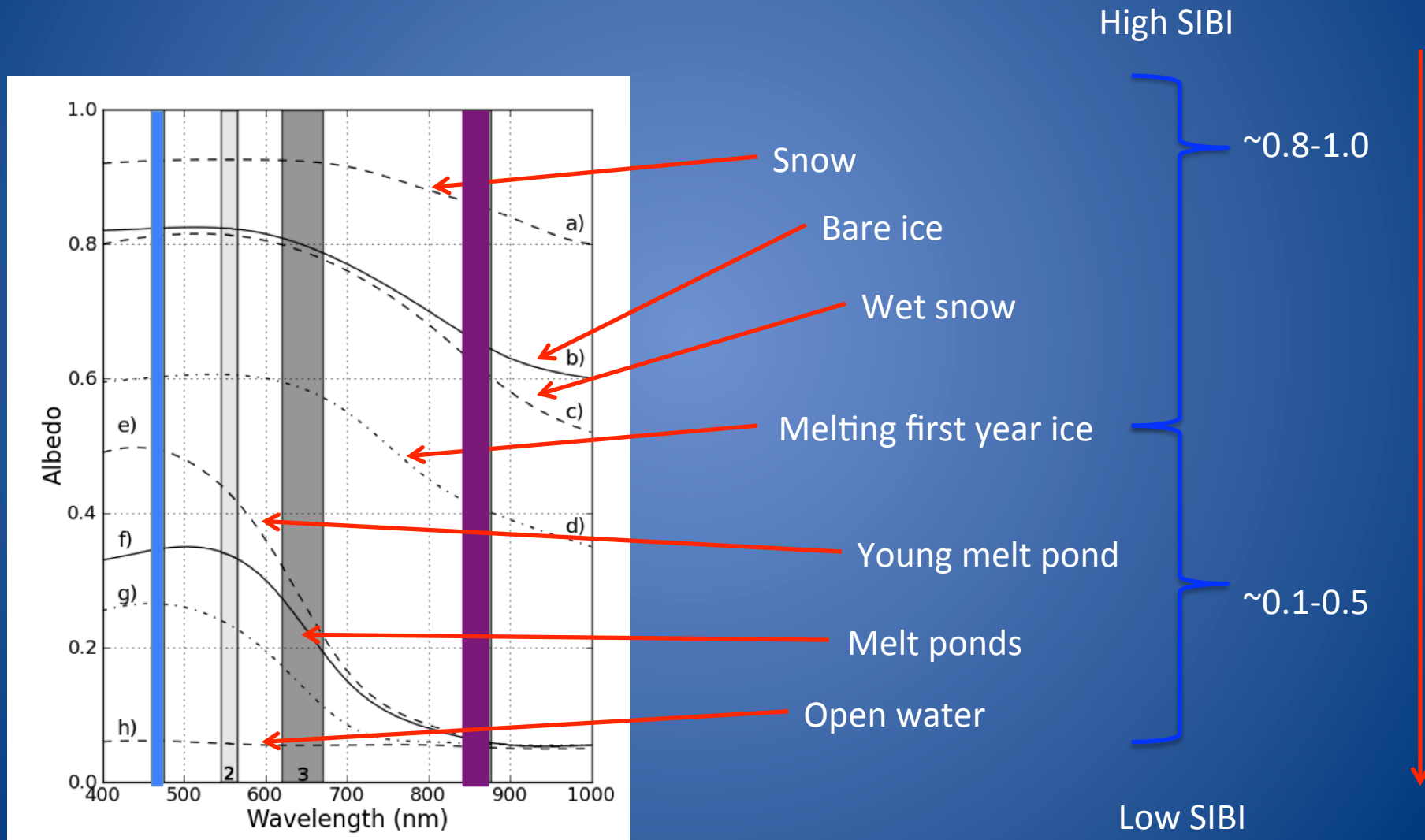
Spectral properties of different sea ice surfaces



Rosel et al 2012, surface values

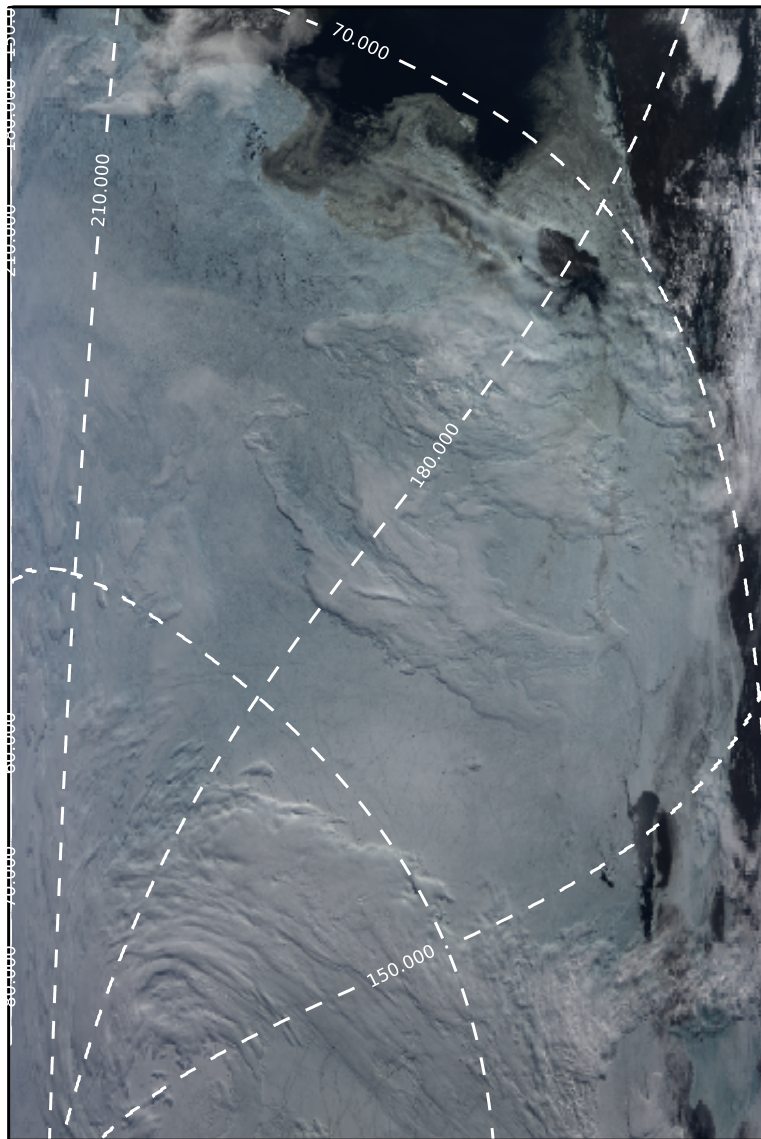
The Sea Ice Brightness Index (SIBI)

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

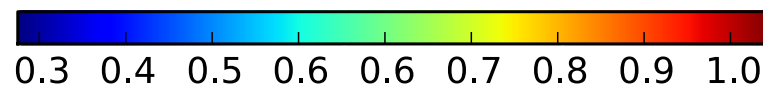
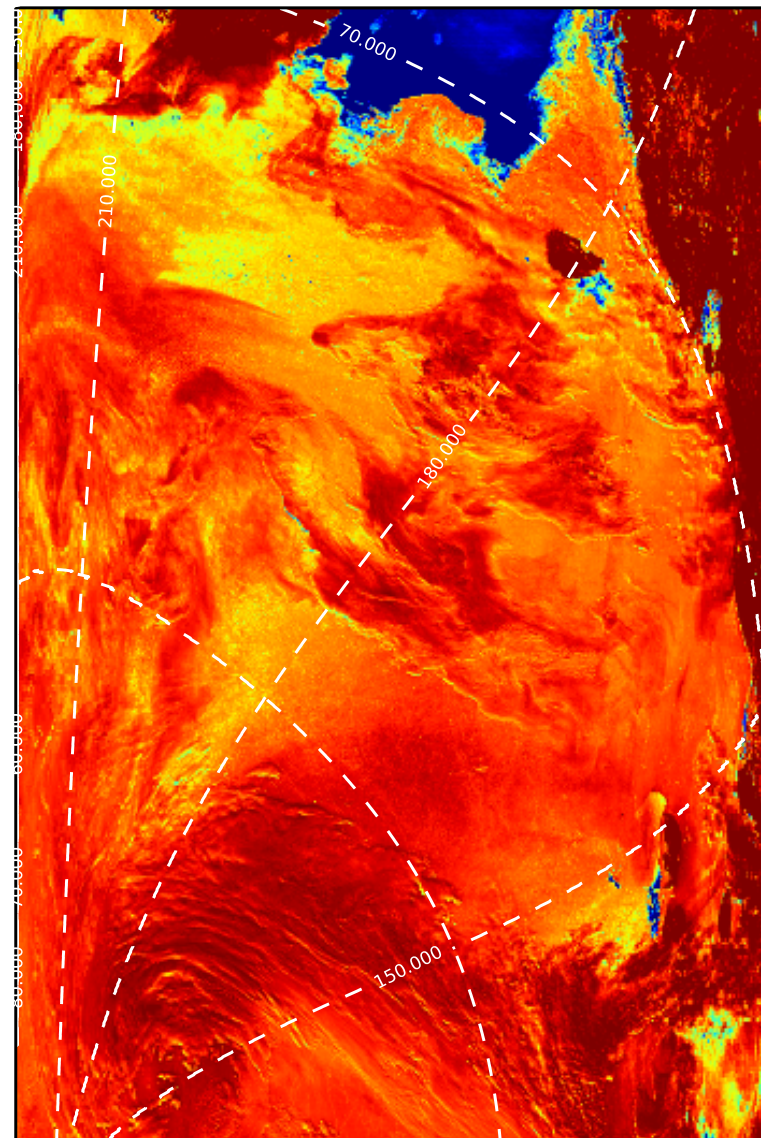


MODIS RGB

$r=0.645\mu\text{m}$, $g=0.555\mu\text{m}$, $b=0.469\mu\text{m}$

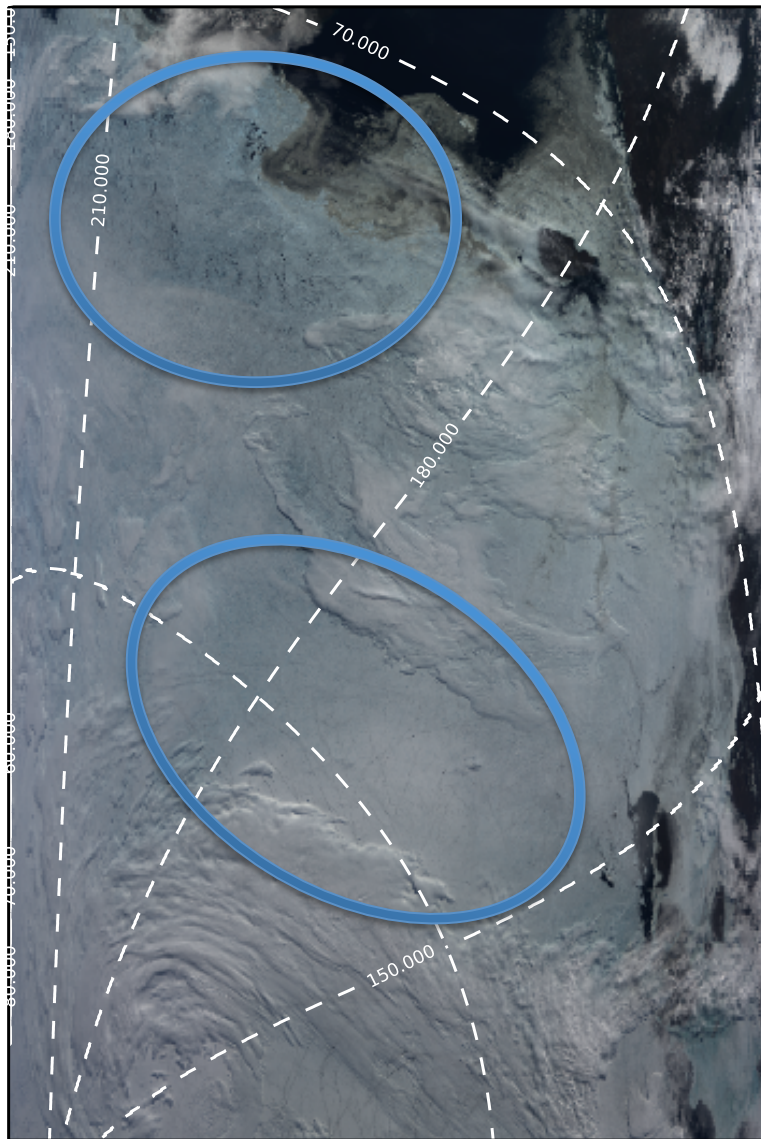


SIBI

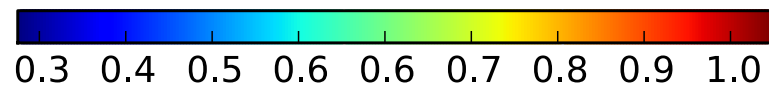
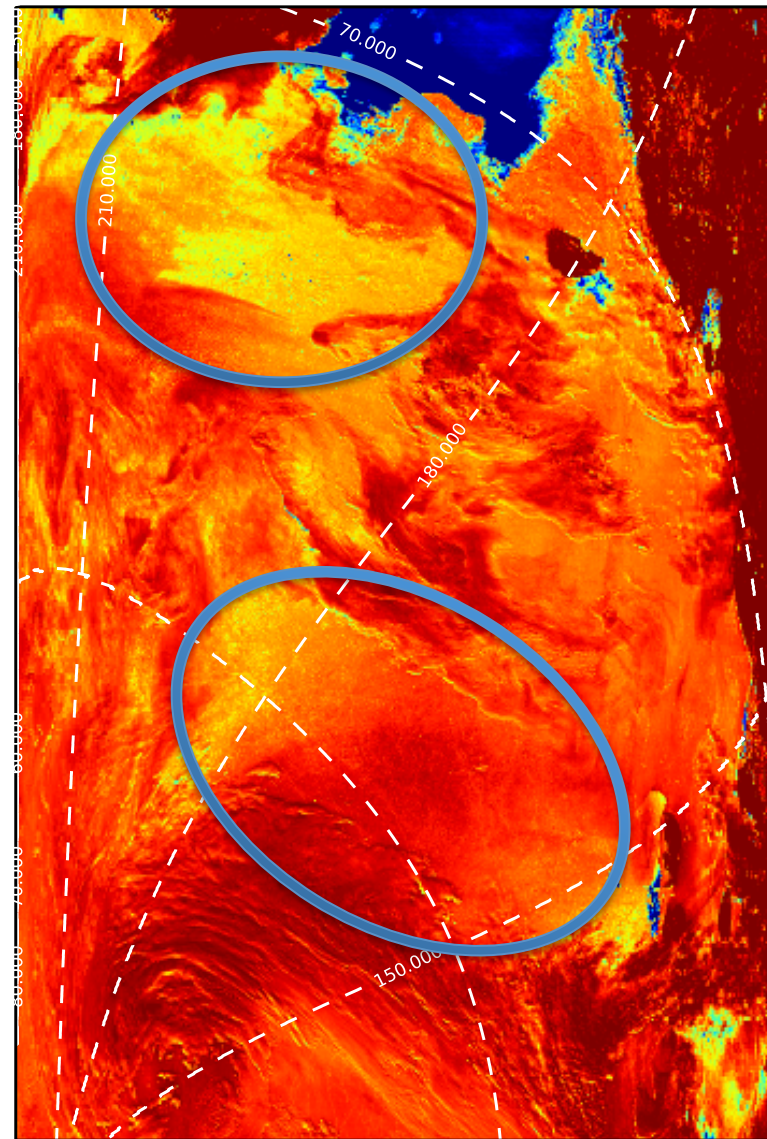


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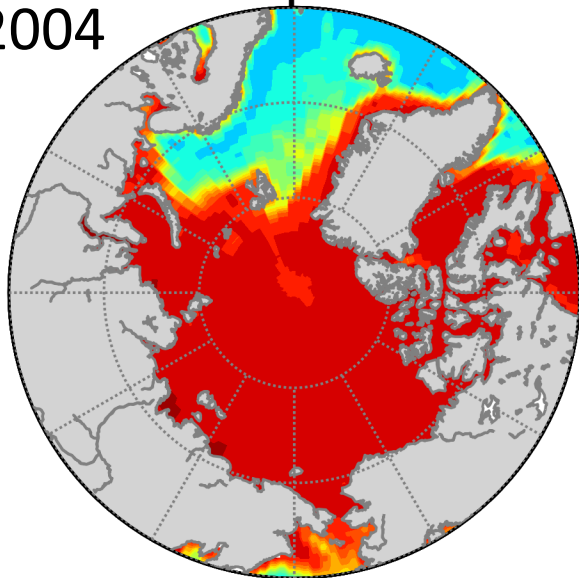


SIBI

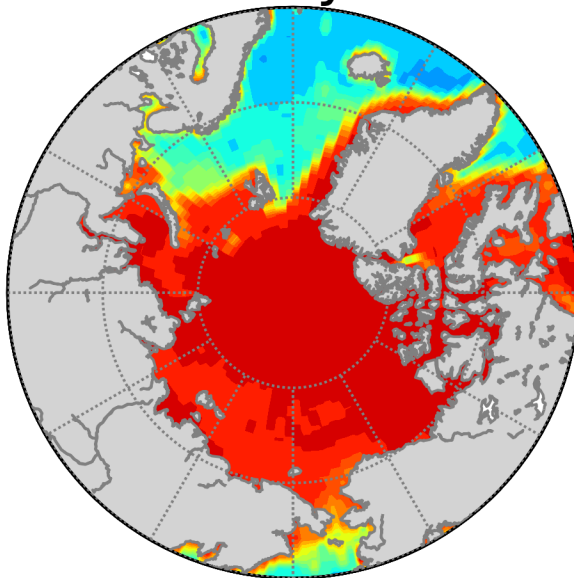


SIBI
2004

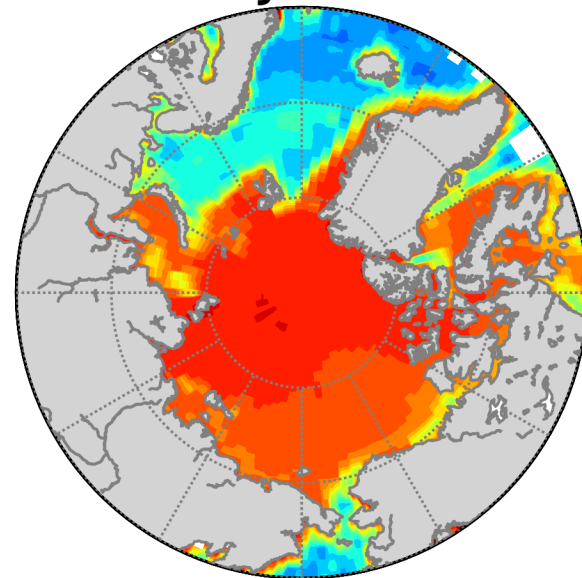
Apr



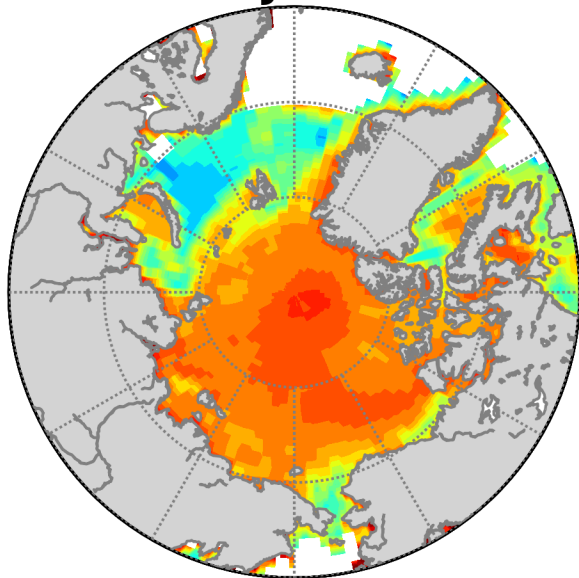
May



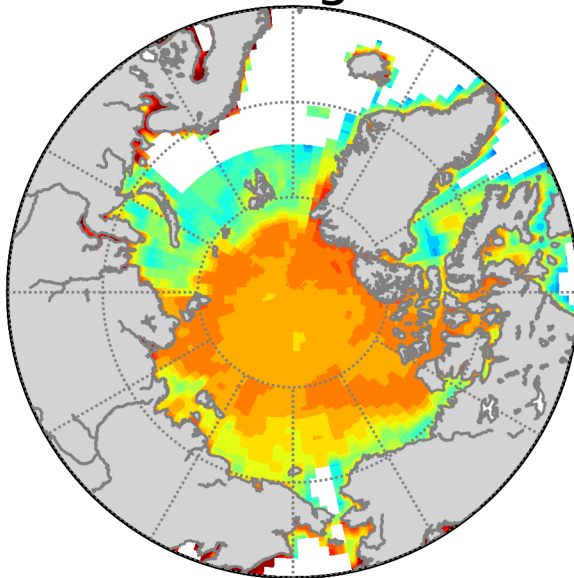
Jun



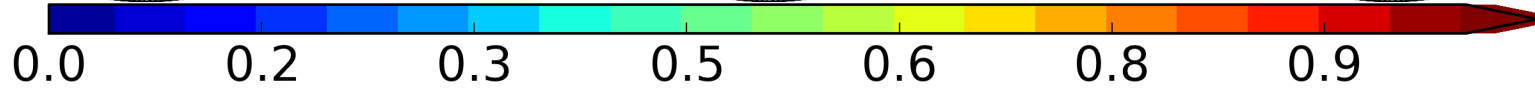
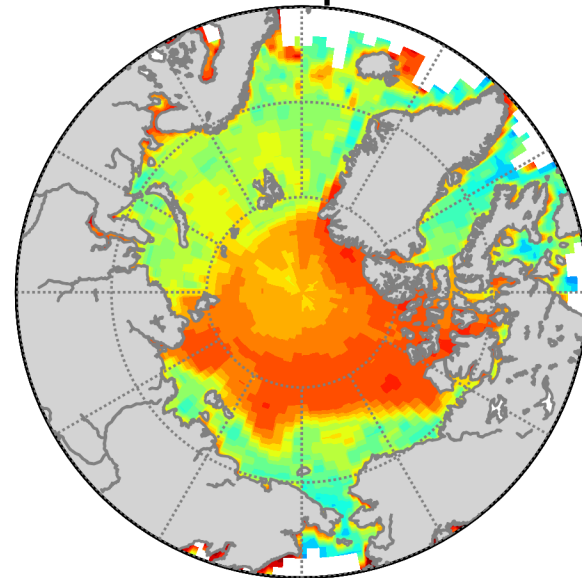
Jul



Aug

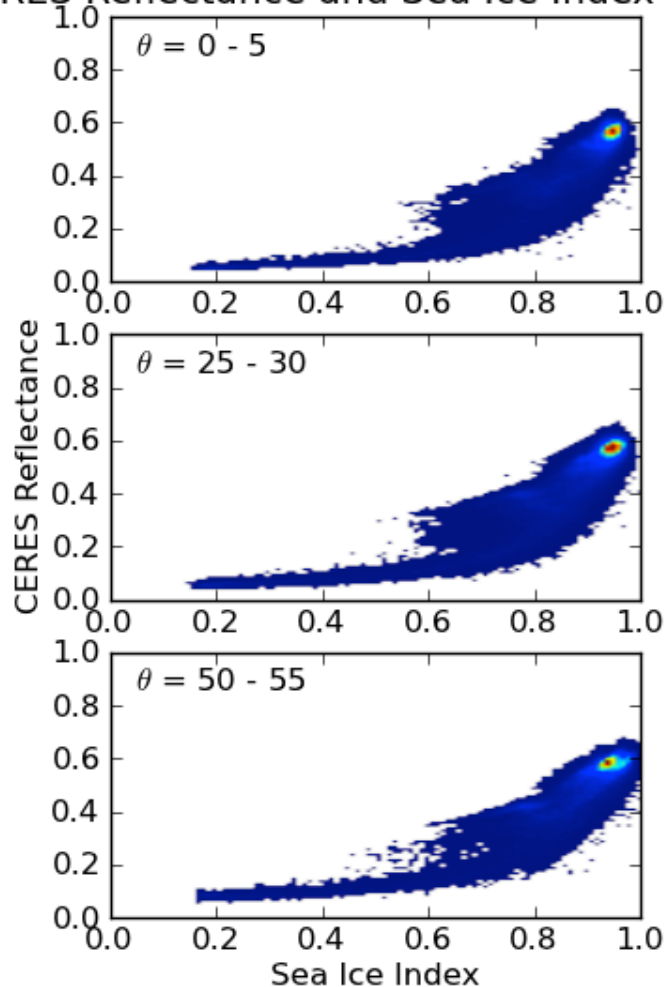


Sep

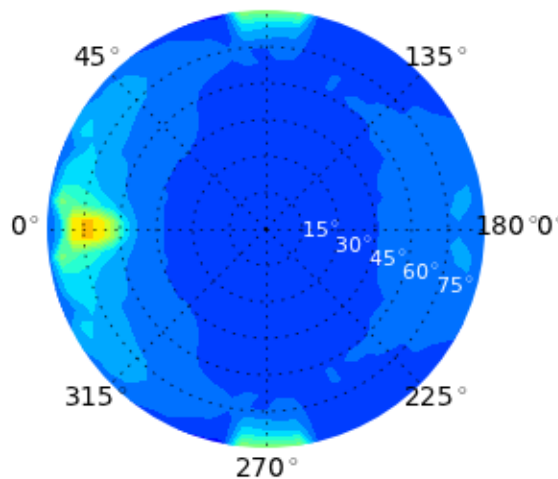


SIBI, Sea Ice Fraction and Reflectance

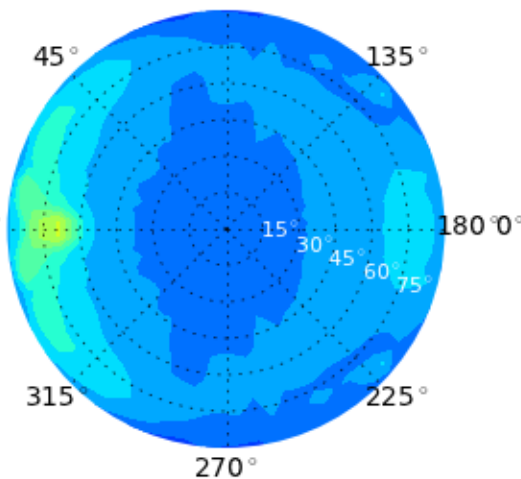
CERES Reflectance and Sea Ice Index by VZA



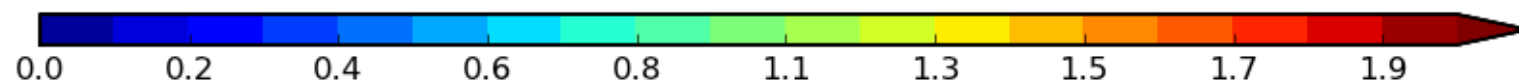
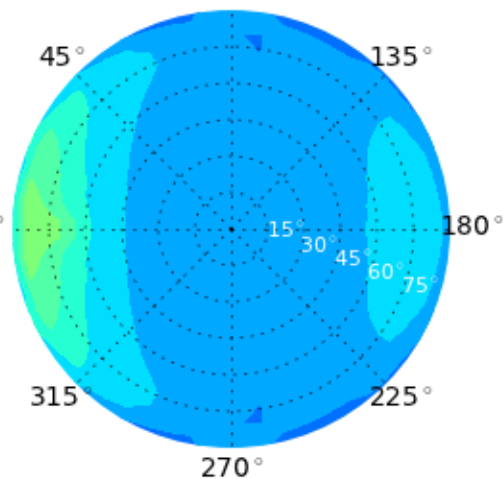
SIBI < 0.85
albedo = 0.42



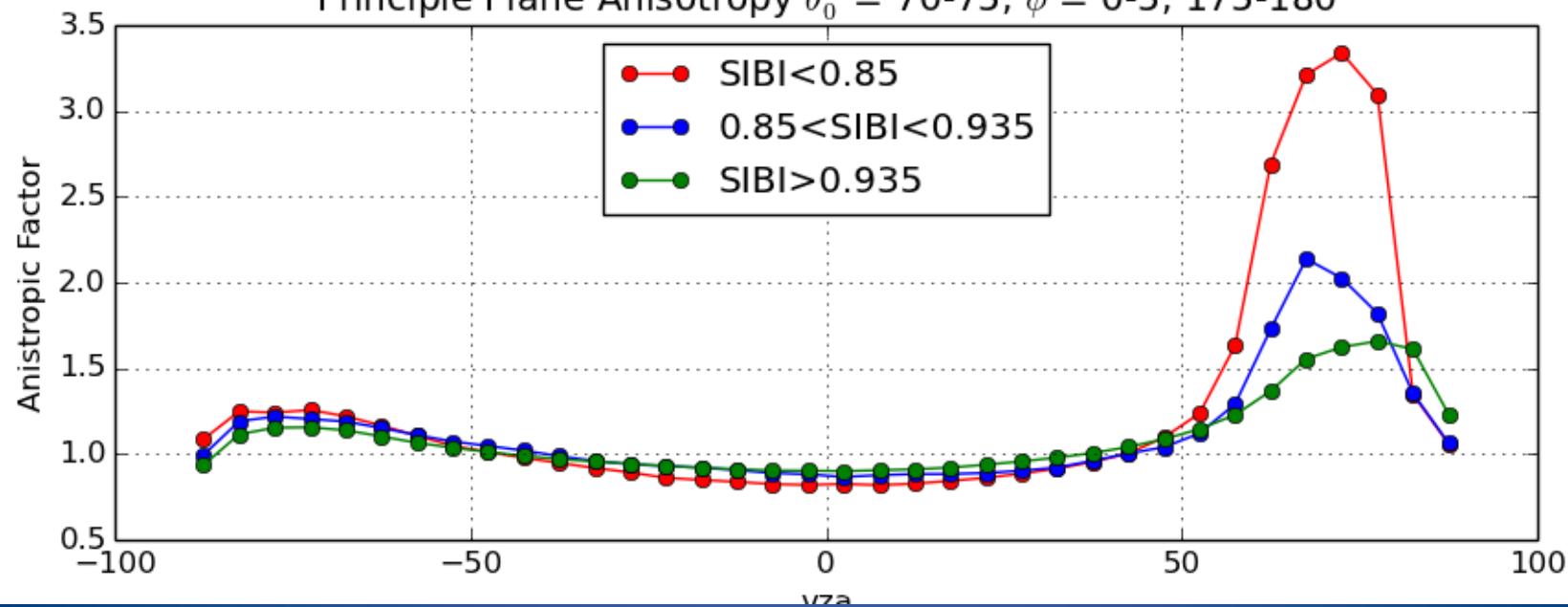
0.85 < SIBI < 0.935
albedo = 0.54



SIBI > 0.935
albedo = 0.60



Principle Plane Anisotropy $\theta_0 = 70-75$, $\phi = 0-5$, $175-180$



Apr - Δ RMS = -1.95

May - Δ RMS = -2.82

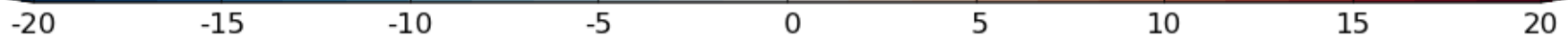
Jun - Δ RMS = -6.49

Comparing RMS error

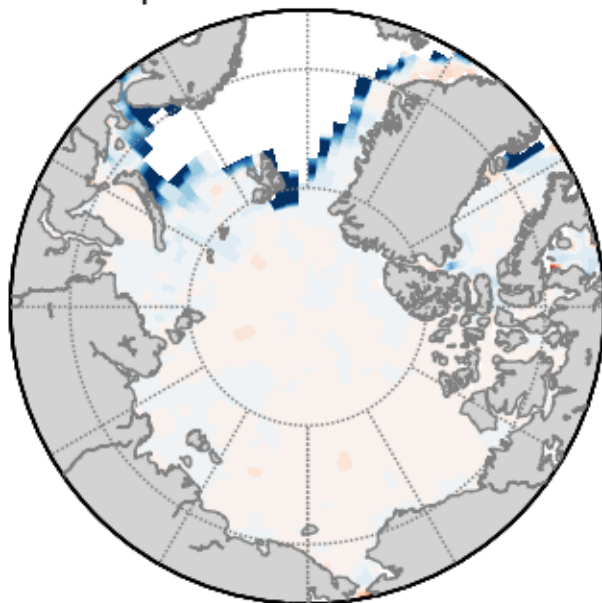
- ADMs can provide us with a predicted radiance
- For each grid-box calculate the RMS between the measured and predicted radiances, normalised by their respective grid-box means.

Provides an indication of how well the shape of the ADM radiances agrees with the shape of the measured radiances.

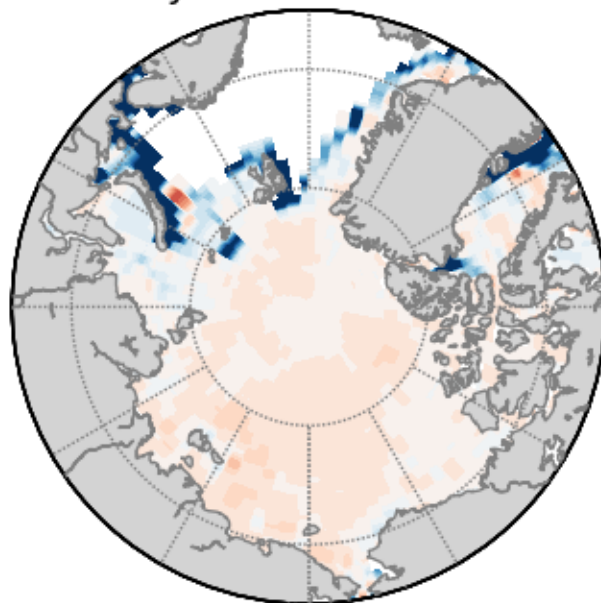
By comparing the ed2 results with the SIBI based ADMs we can see if we have improved.



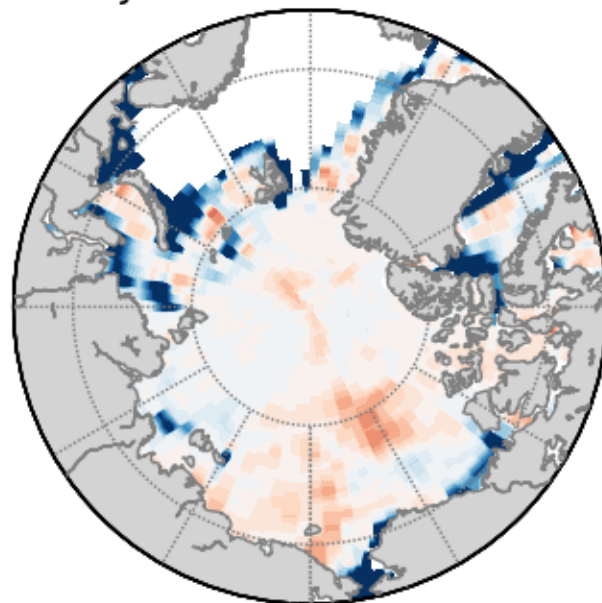
Apr - $\Delta \text{RMS} = -1.95$



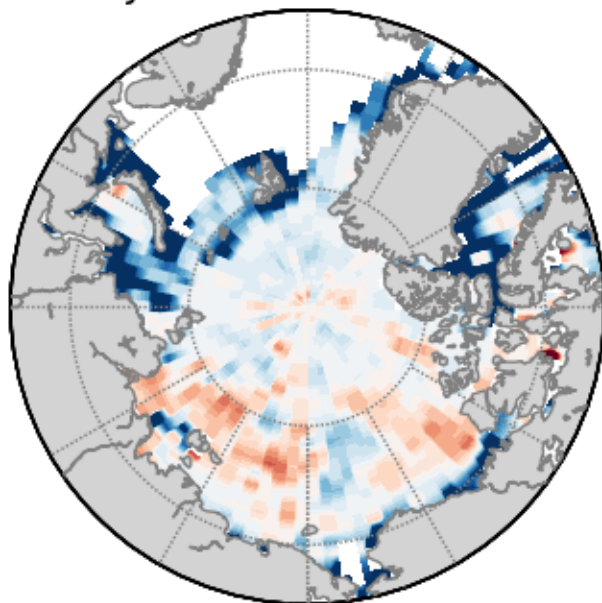
May - $\Delta \text{RMS} = -2.82$



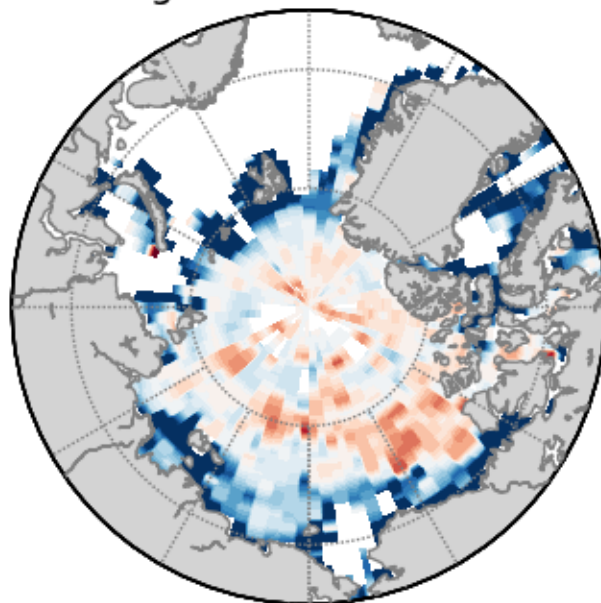
Jun - $\Delta \text{RMS} = -6.49$



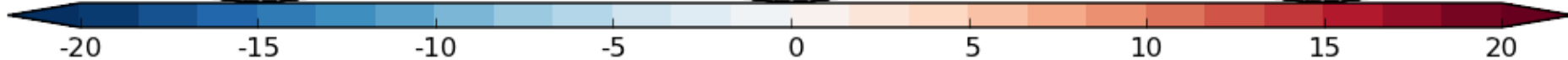
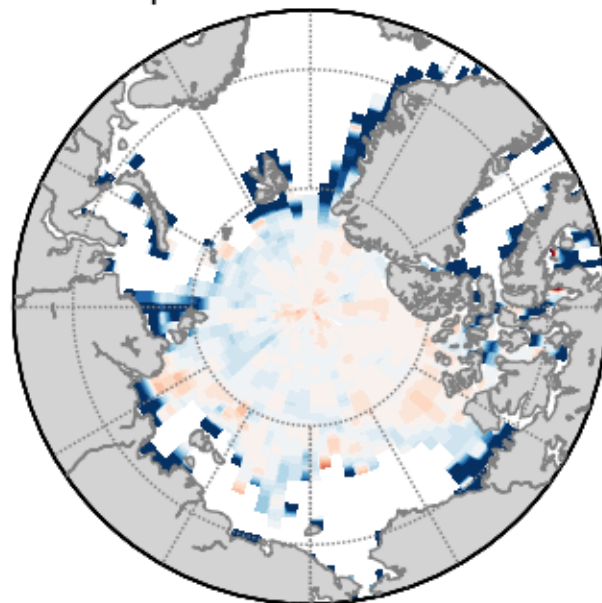
Jul - $\Delta \text{RMS} = -9.75$



Aug - $\Delta \text{RMS} = -15.31$



Sep - $\Delta \text{RMS} = -15.93$



Ed2 ADMs Direct Integration Flux Differences (Wm^2)
2003 Apr

Ed4 ADMs

Direct integration for SW flux

Use observed and ADM- predicted radiances to construct two sets of regional ($10^\circ \times 10^\circ$) all-sky ADMs for each season.

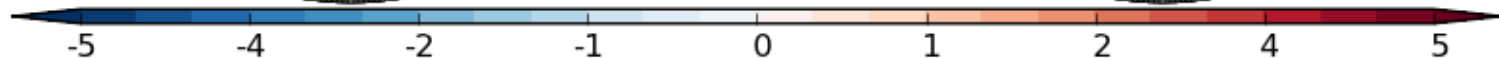
Both sets of regional all-sky ADMs have the same sampling

Compute fluxes using the two sets of ADMs

Ed2 ADMs Direct Integration Flux Differences (Wm^2)
2003 Jul

Ed4 ADMs

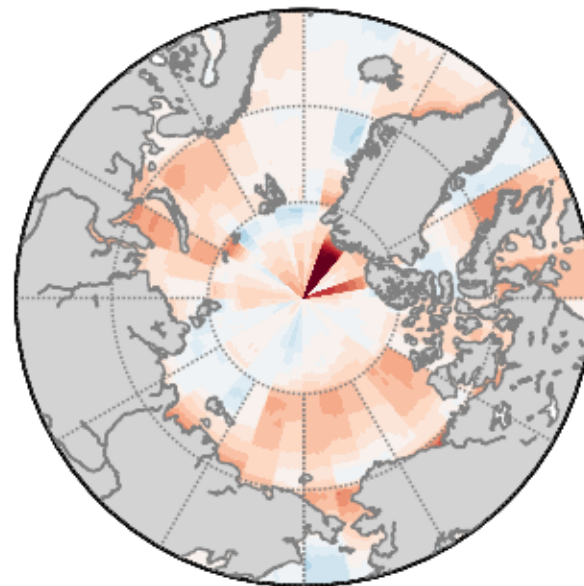
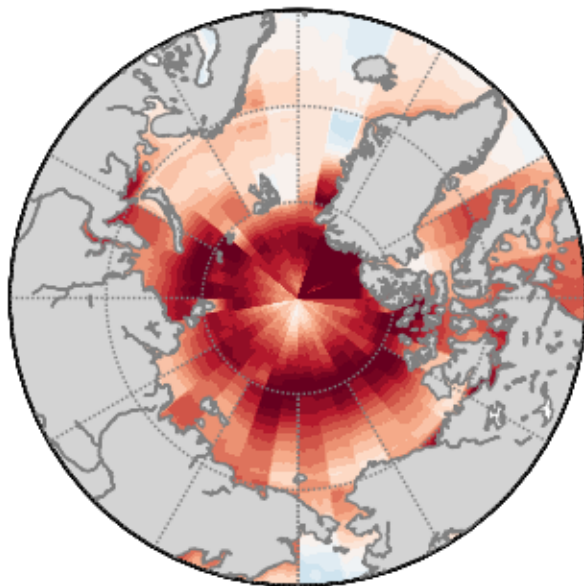
Compare fluxes derived from the ADMs for each $1^\circ \times 1^\circ$ grid box



Ed2 ADMs

Direct Integration Flux Differences (Wm^2)
2003 Apr

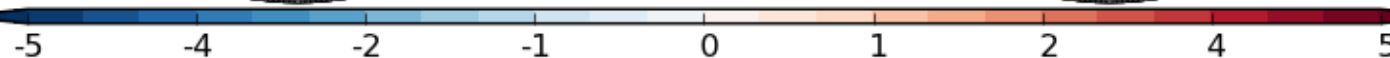
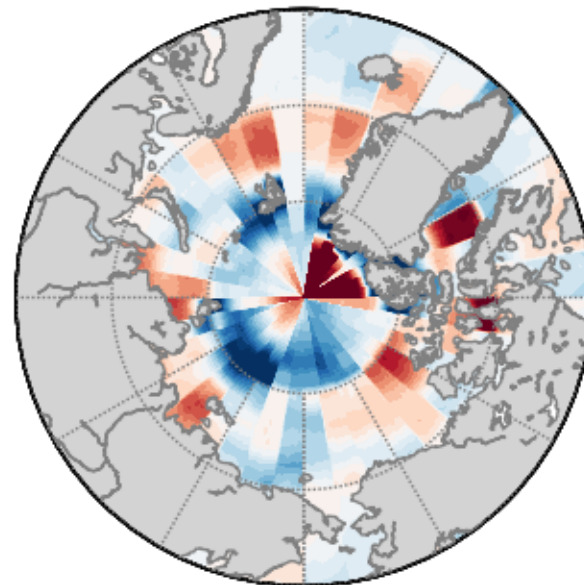
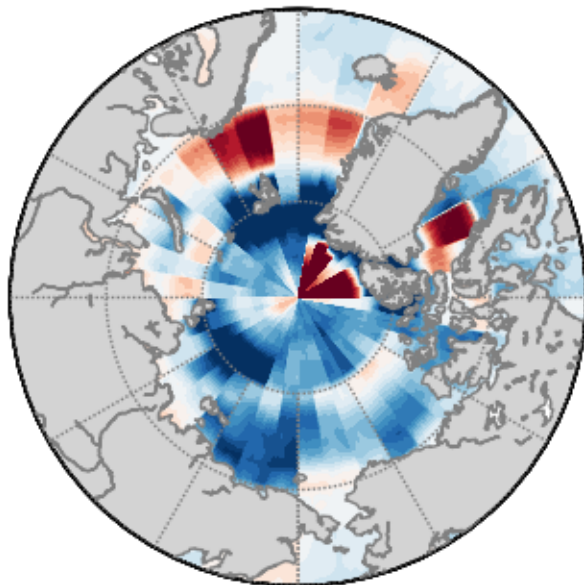
Ed4 ADMs



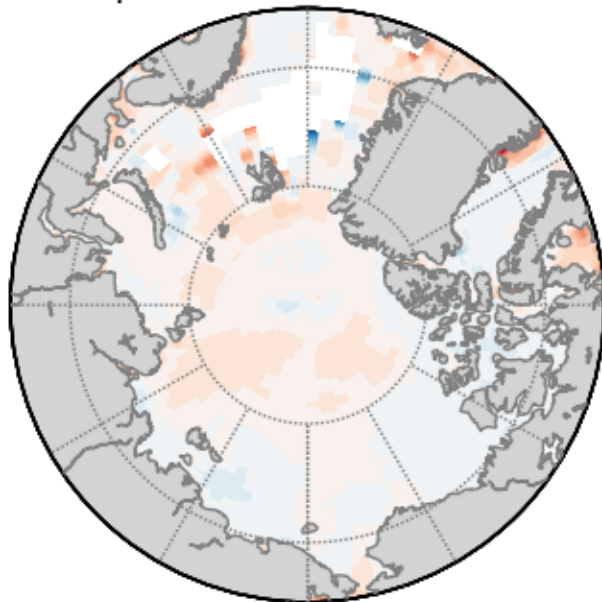
Ed2 ADMs

Direct Integration Flux Differences (Wm^2)
2003 Jul

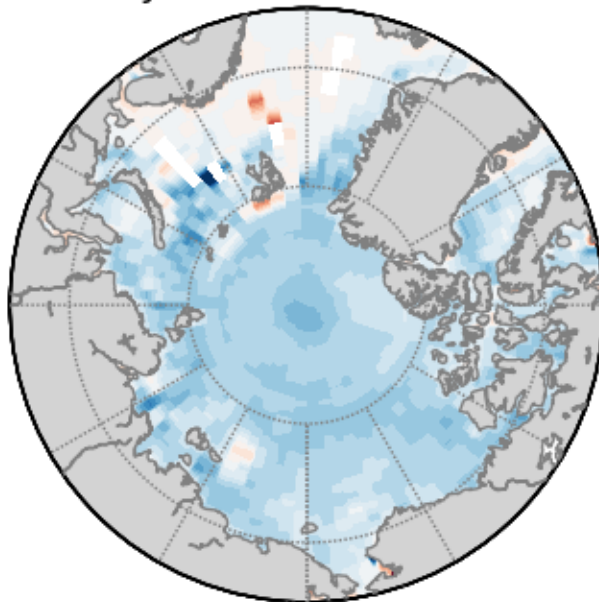
Ed4 ADMs



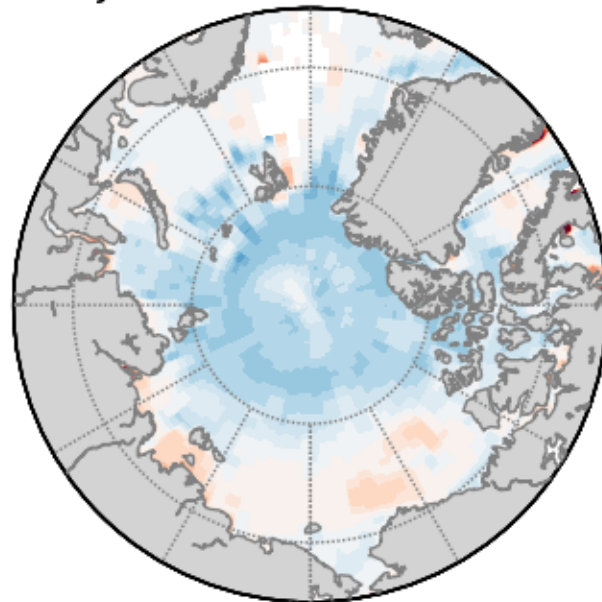
Apr - Δ Albedo = -0.00



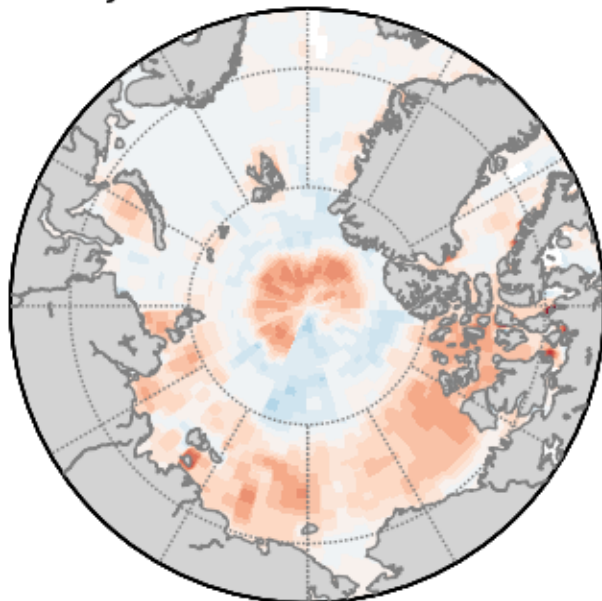
May - Δ Albedo = -0.01



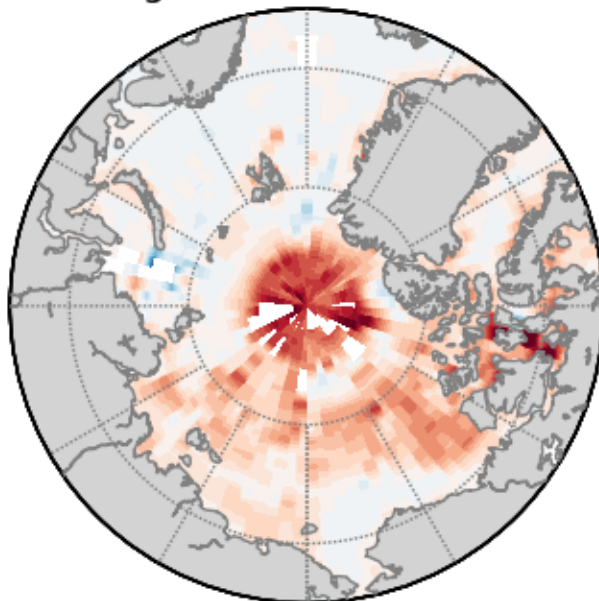
Jun - Δ Albedo = -0.01



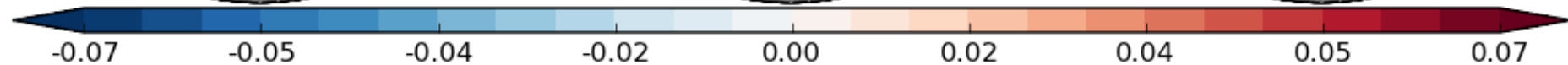
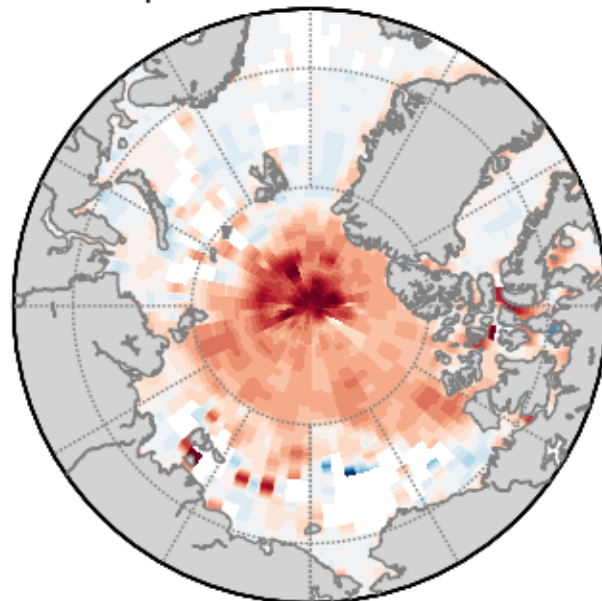
Jul - Δ Albedo = 0.00



Aug - Δ Albedo = 0.01



Sep - Δ Albedo = 0.01



Summary

- Using the 0.47 micron and 0.86 micron bands from MODIS we developed an index, the SIBI, that is related to the anisotropy of sea ice.
- The SIBI was used to develop ADMs for use with the CERES radiances.
- The SIBI based ADMs show improved performance compared to the existing ADMs.