CERES Angular Distribution Model Working Group Report

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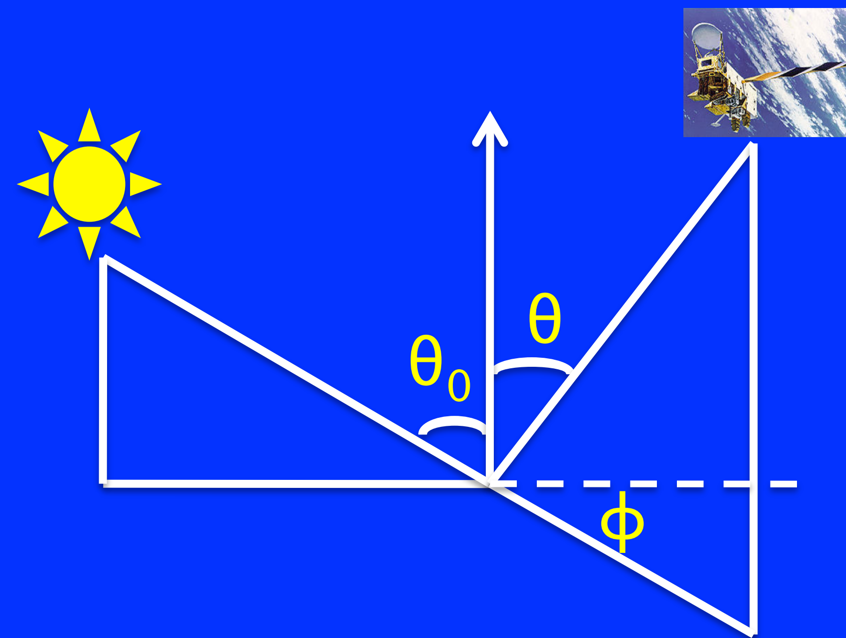
From radiance to flux: angular distribution models

- 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;



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

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

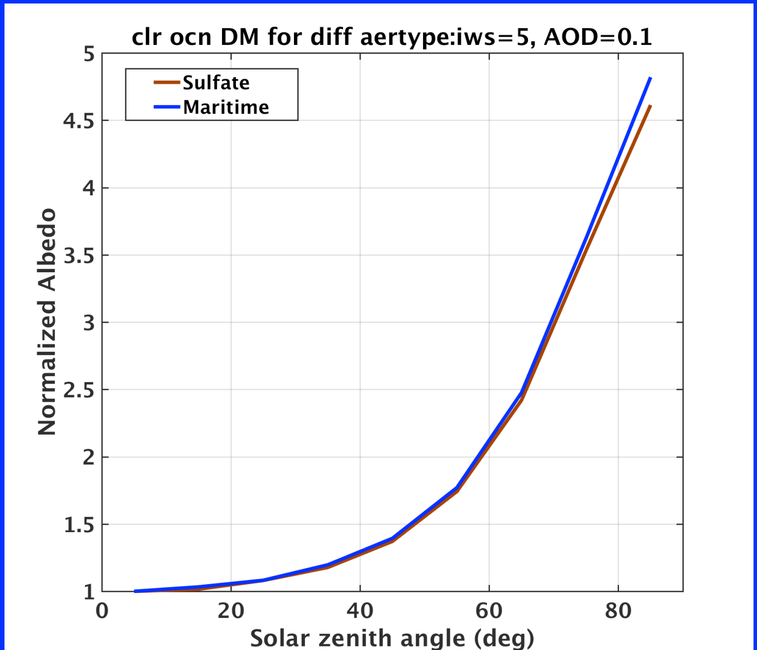
Outline

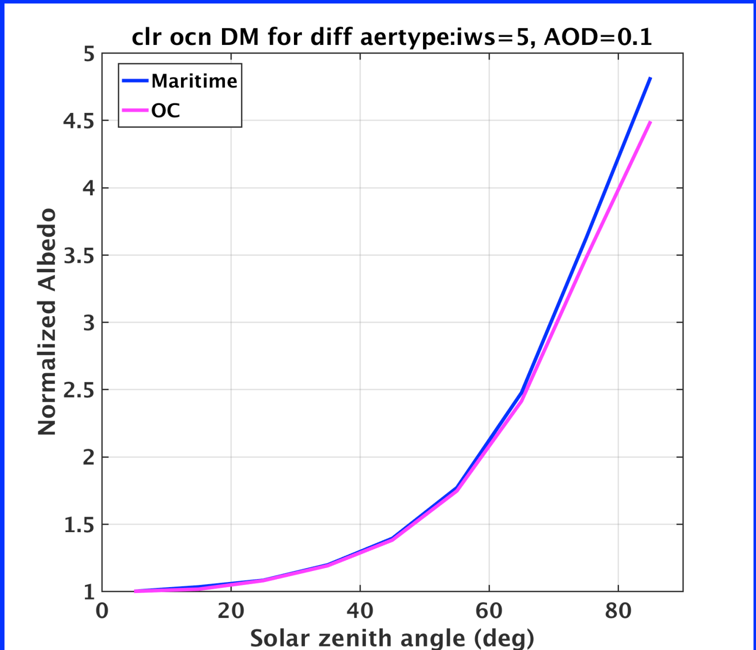
- Theoretical aerosol dependent albedo directional models over clear ocean and their effects on 24-hour averaged fluxes;
- Comparison of different sea ice fraction datasets and their impact on cloud retrievals and flux inversions;

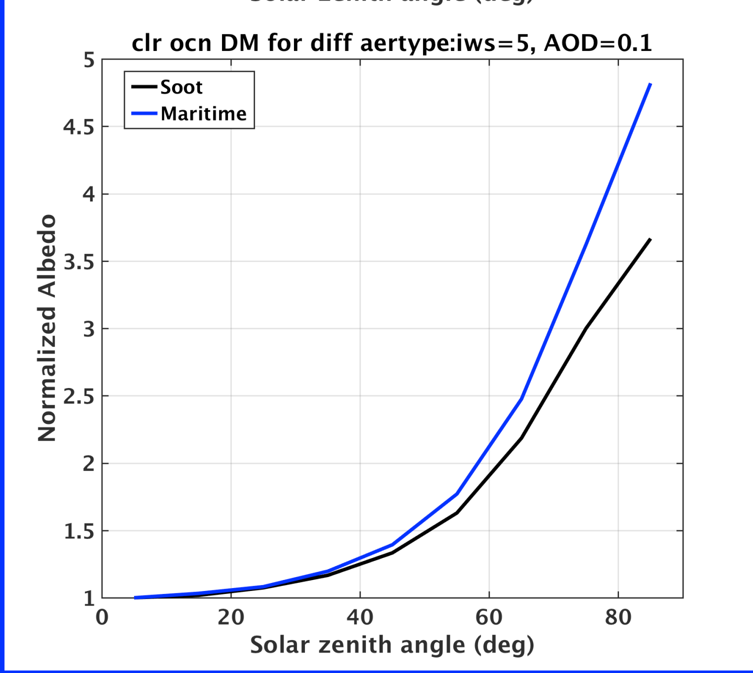
CERES directional model: albedo as a function of SZA

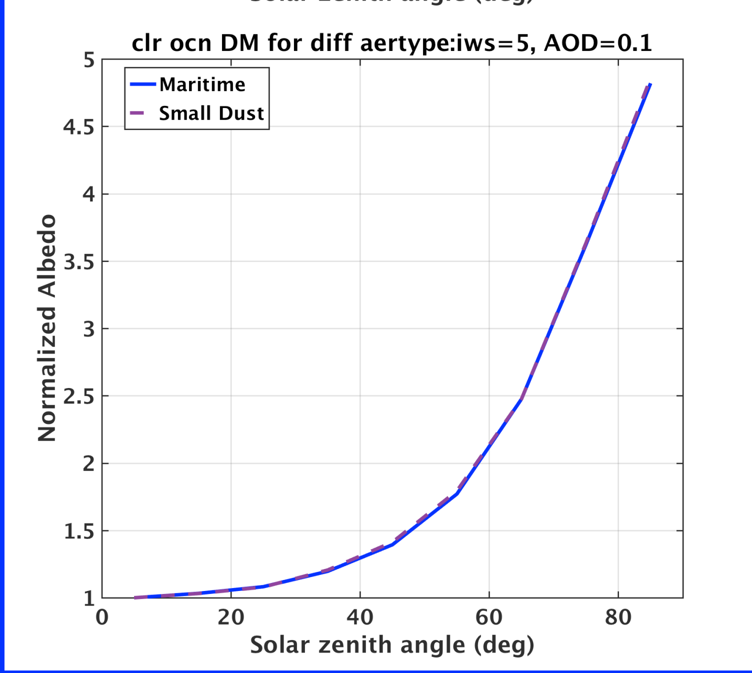
- CERES observations on TRMM were used to construct albedo directional models for different scene types;
- These directional models are used to convert instantaneous CERES shortwave fluxes to 24h-averaged fluxes;
- Over clear ocean, only one directional model was created;
- To test the sensitivity of the 24h-averaged flux to different clear-ocean directional models, a set of clear ocean directional models was generated for different wind speeds, aerosol types, and aerosol optical depths using Fu-Liou radiative transfer model;
- Surface albedo for these different cases were calculated using COART radiative transfer model;

Maritime/dust aerosols are more anisotropic than other aerosol types



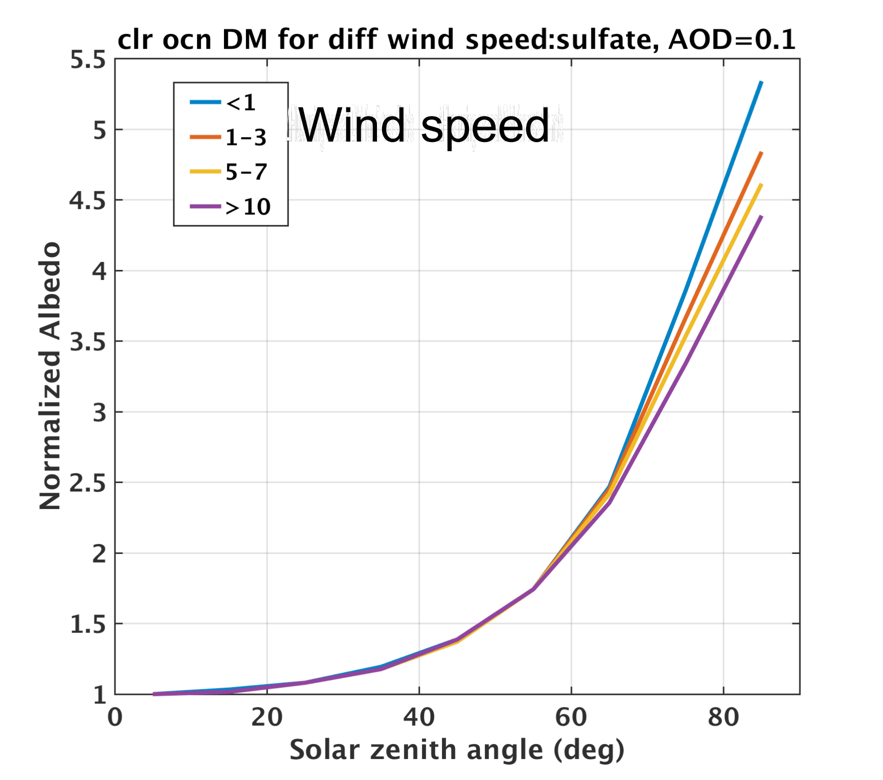


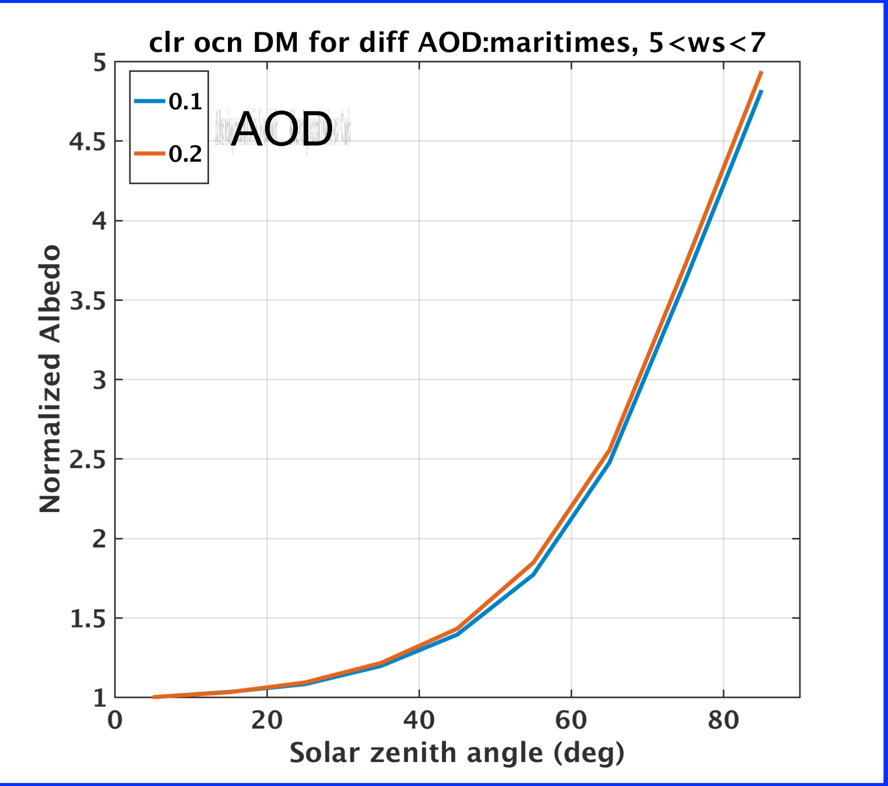




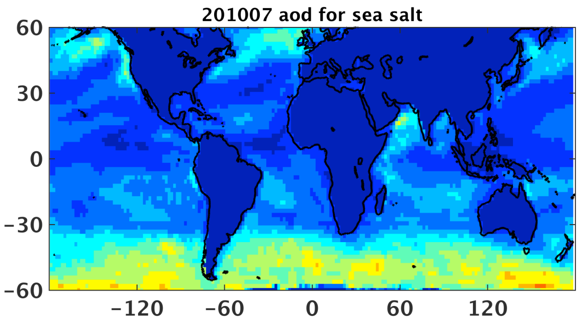
Directional models are also sensitive to wind speed and aerosol optical depth

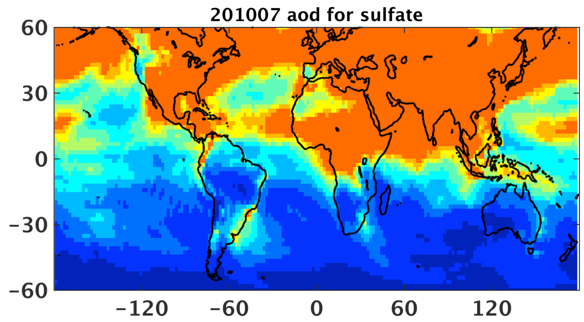
- Clear-ocean directional model is more isotropic as wind speed increases: large sensitivity to wind speed;
- Dependence of clear-ocean directional model on aerosol optical depth is relatively small.

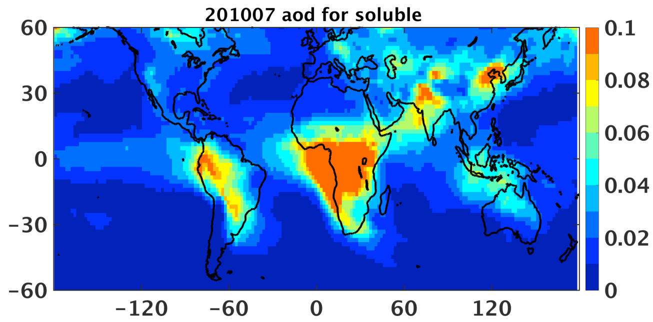


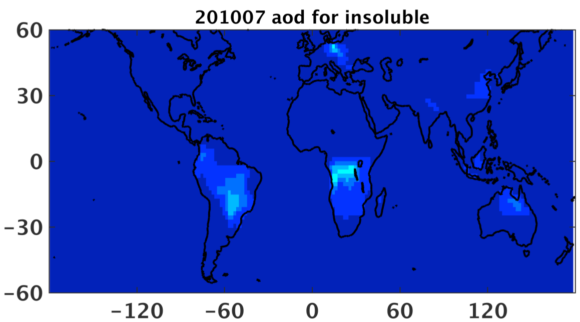


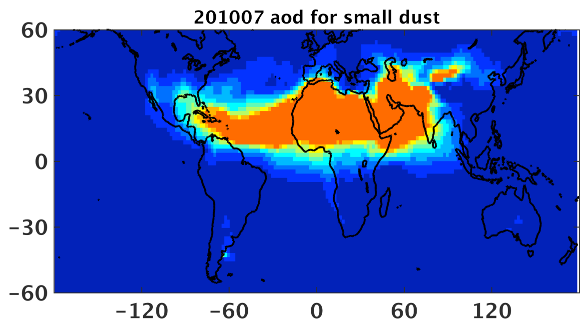
Daily gridded MATCH aerosol type and optical depth are used to determine the directional model

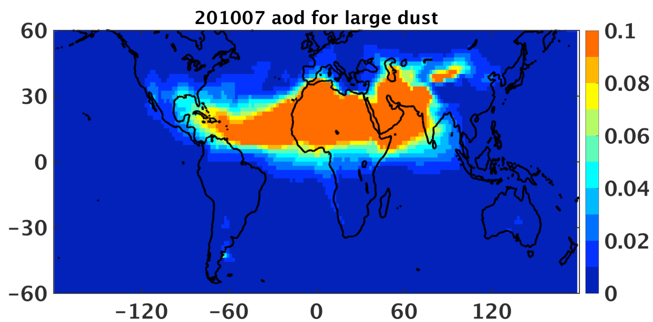


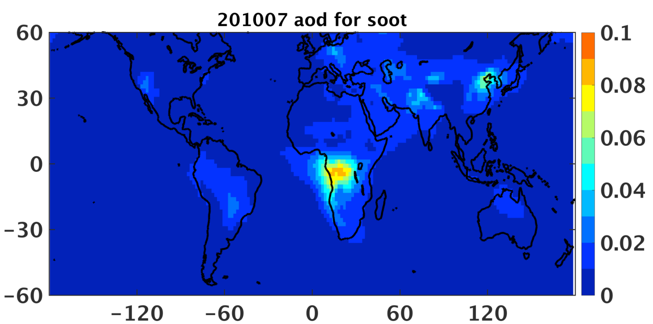












Method

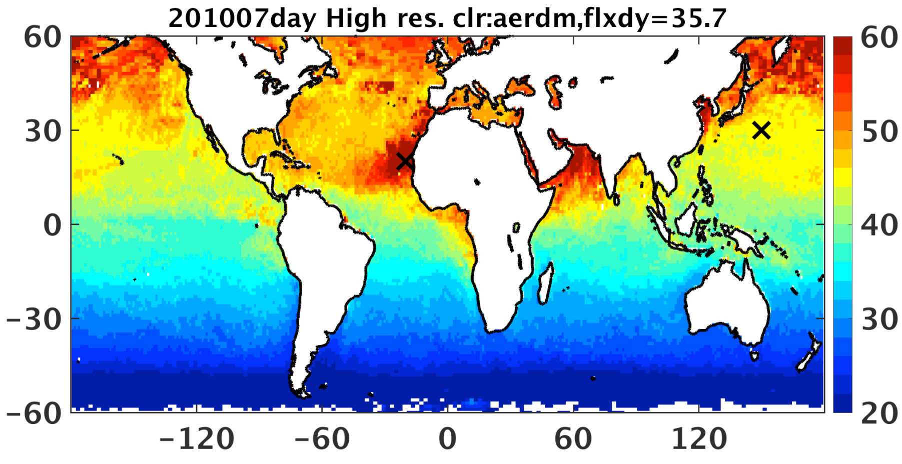
- For each grid box, the albedo directional model is determined based upon the daily MATCH aerosol composition and loading, and the wind speed:

$$\alpha = \sum_{i=1}^{7} \frac{\alpha_i(\tau_i, ws)\tau_i}{\tau_i}$$

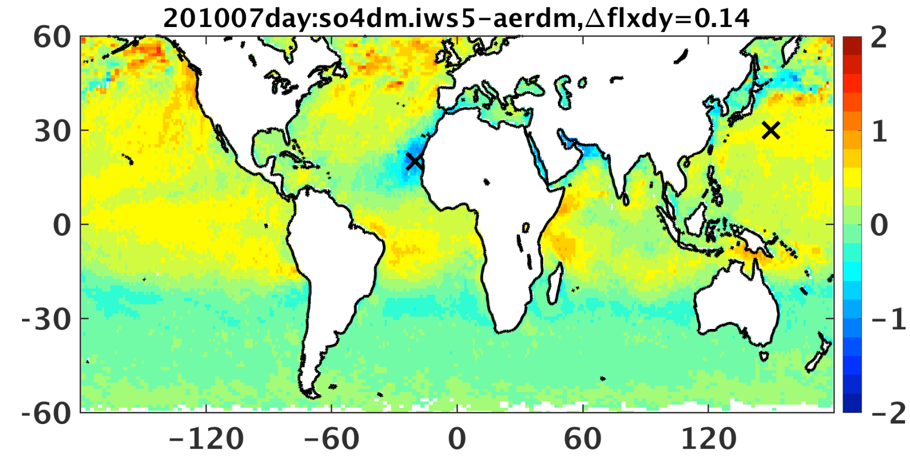
- The 24-hour averaged fluxes derived using the above aerosol and wind speed dependent directional models are compared with the 24-hour averaged fluxes derived using a single direction model:
  - Sea salt aerosols with optical depth of 0.12 for wind speed between 5 and 7 m/s;
  - Sea salt aerosols with optical depth of 0.12 for wind speed greater than 10 m/s;
  - Sulfate aerosols with optical depth of 0.12 for wind speed between 5 and 7 m/s;

Diurnally averaged clear-sky flux difference over ocean between aerosol-dependent and aerosol-independent directional models

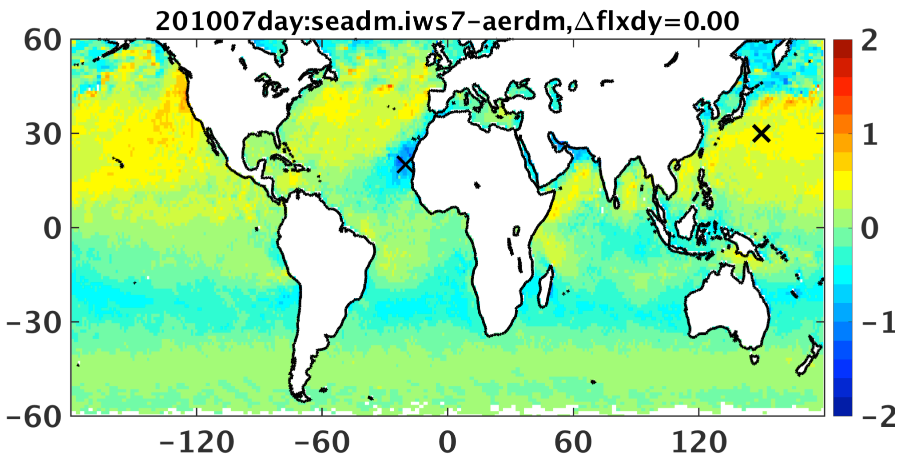
Diurnally averaged flux over clear ocean



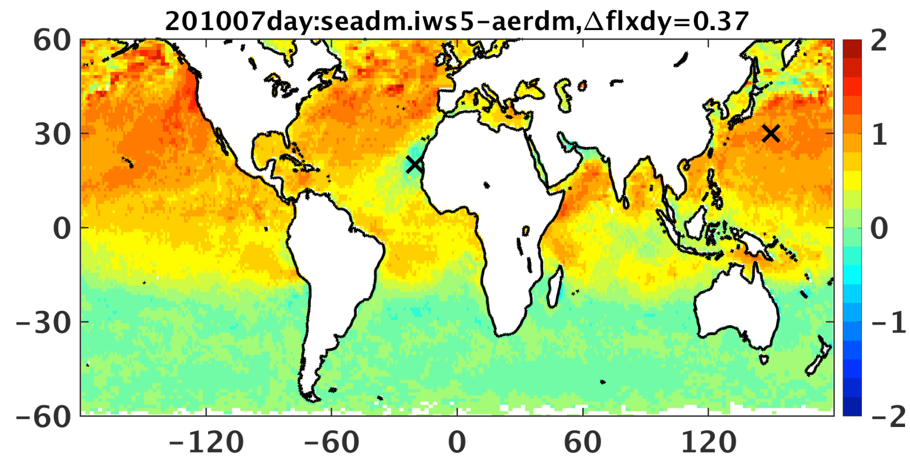
ΔFlux using sulfate DM for 5<ws<7



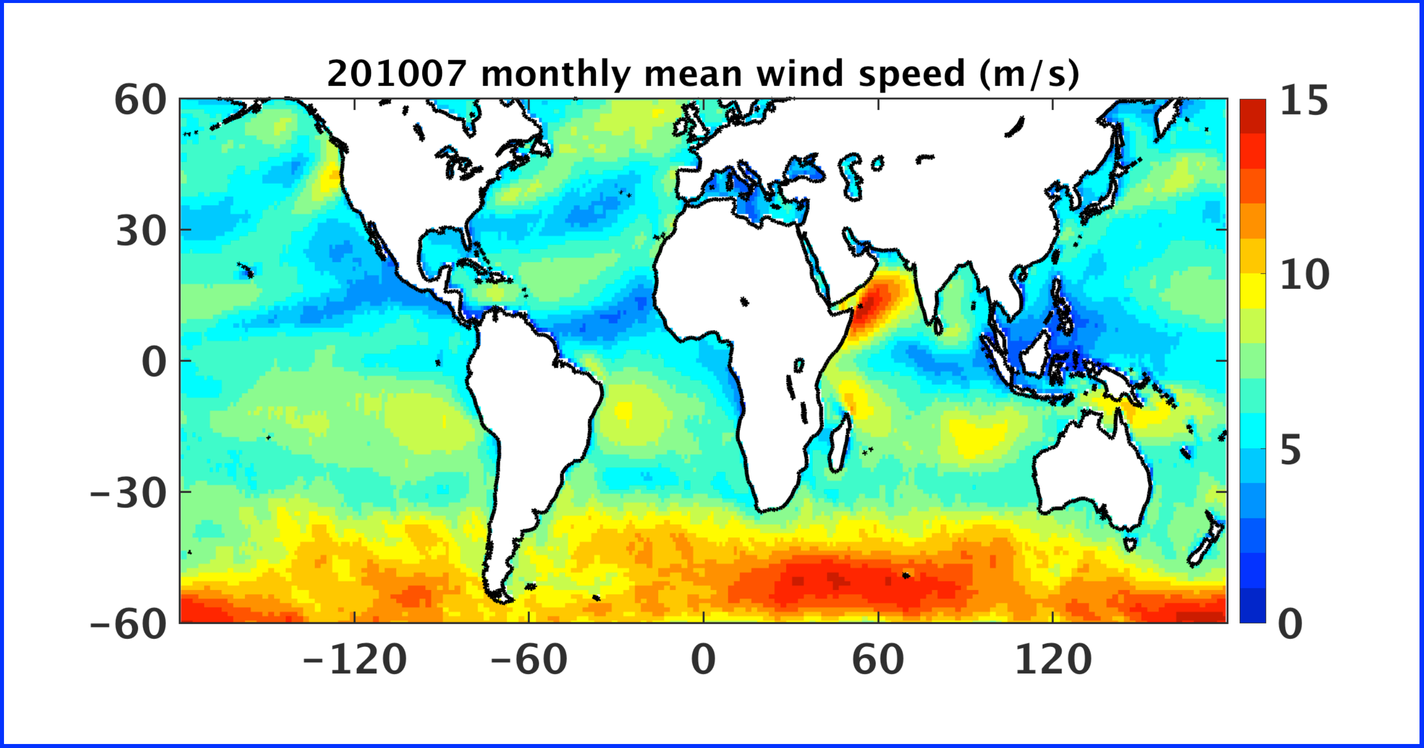
ΔFlux using seasalt DM for ws>10m/s



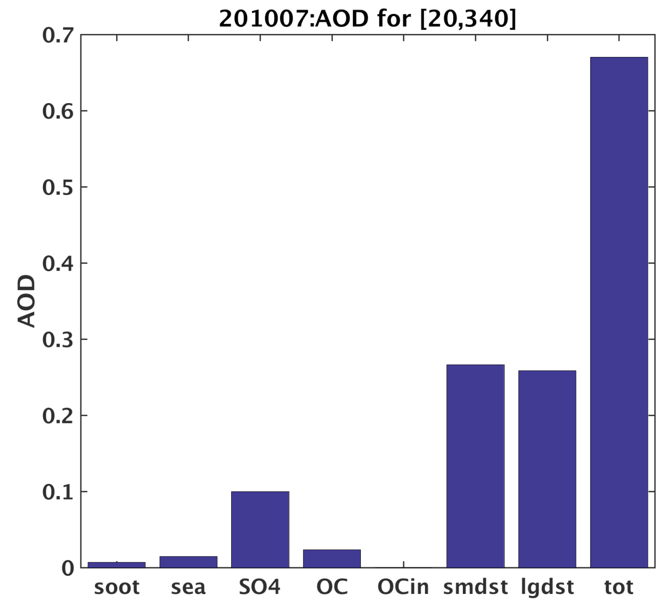
ΔFlux using seasalt DM for 5<ws<7m/s

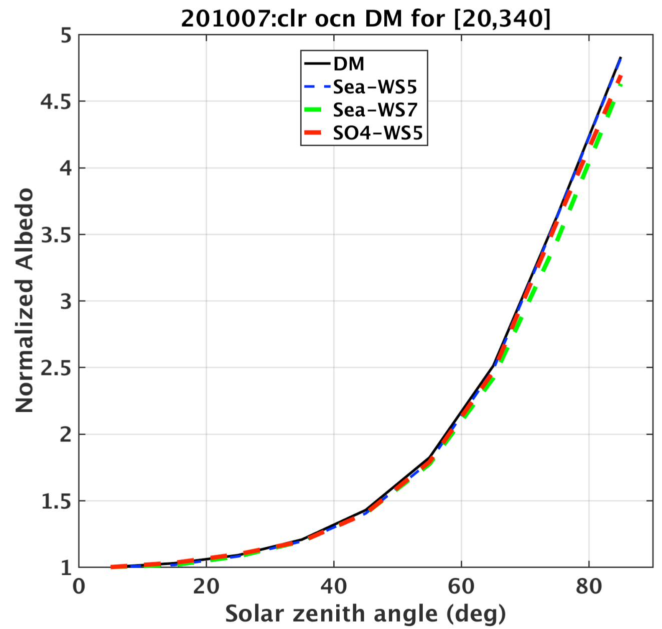


Wind speed distribution for July 2010

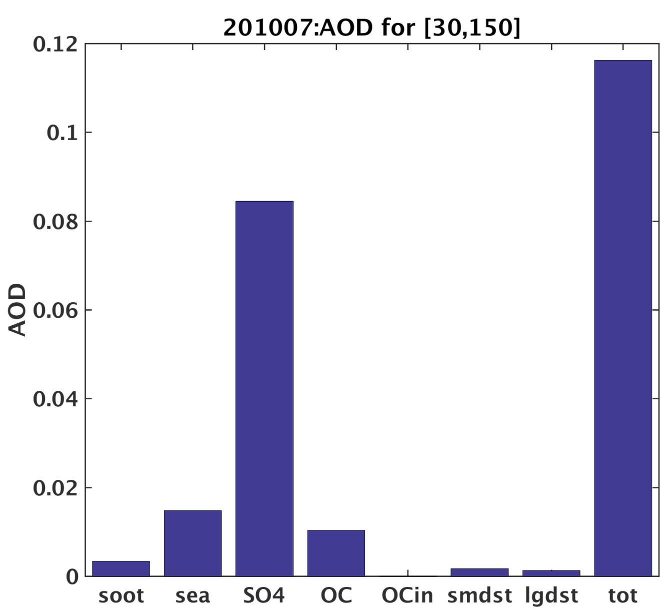


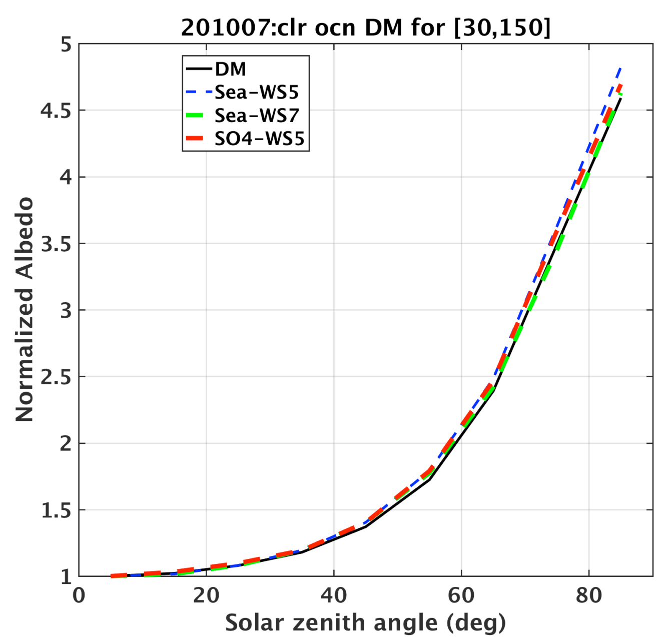
Comparison of directional models for two cases





DM	Flux
Aero	64.9
Sea-WS5	64.6
Sea-WS7	63.9
SO4-WS5	63.9



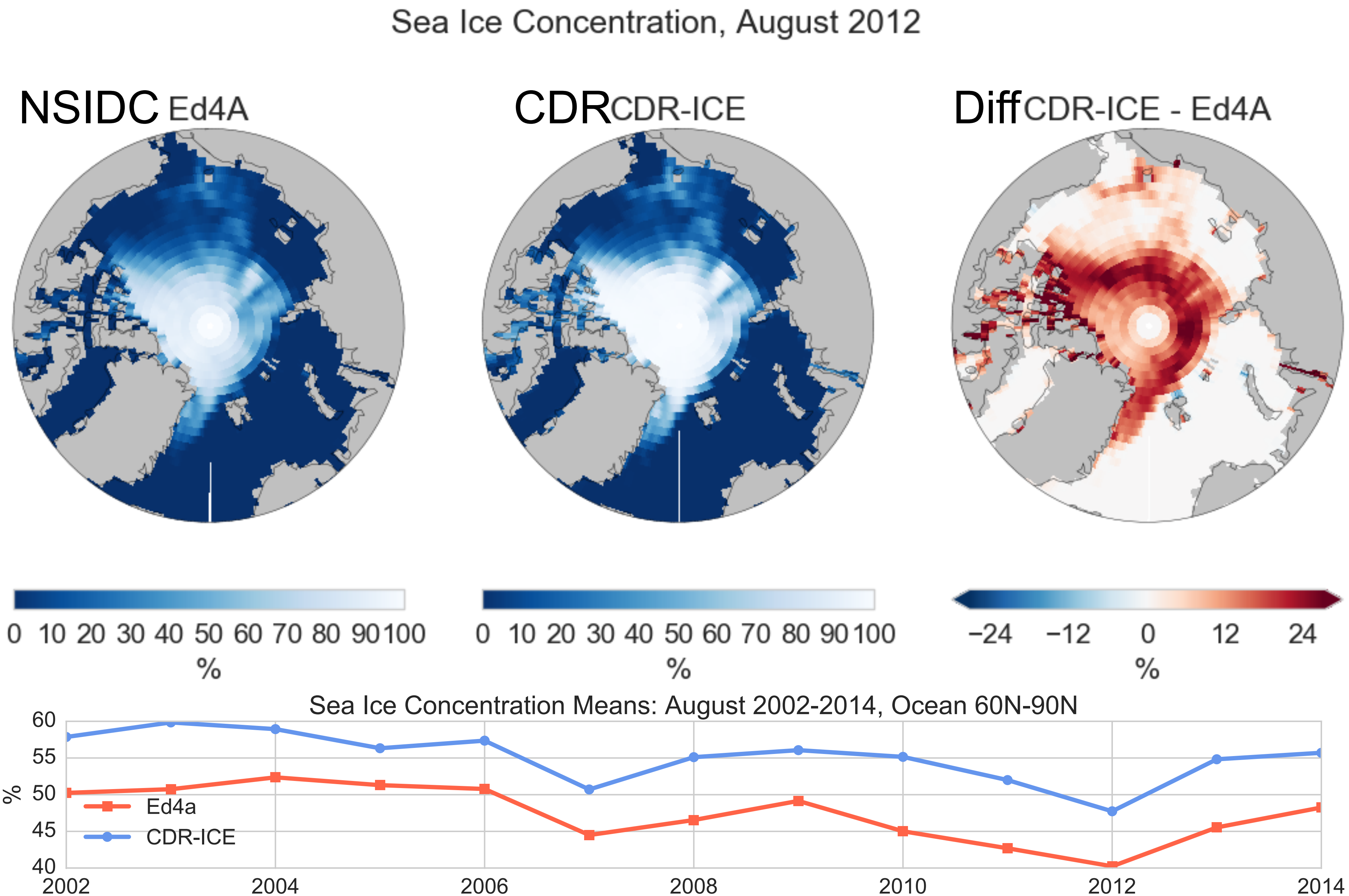


DM	Flux
Aero	44.1
Sea-WS5	45.2
Sea-WS7	44.6
SO4-WS5	44.7

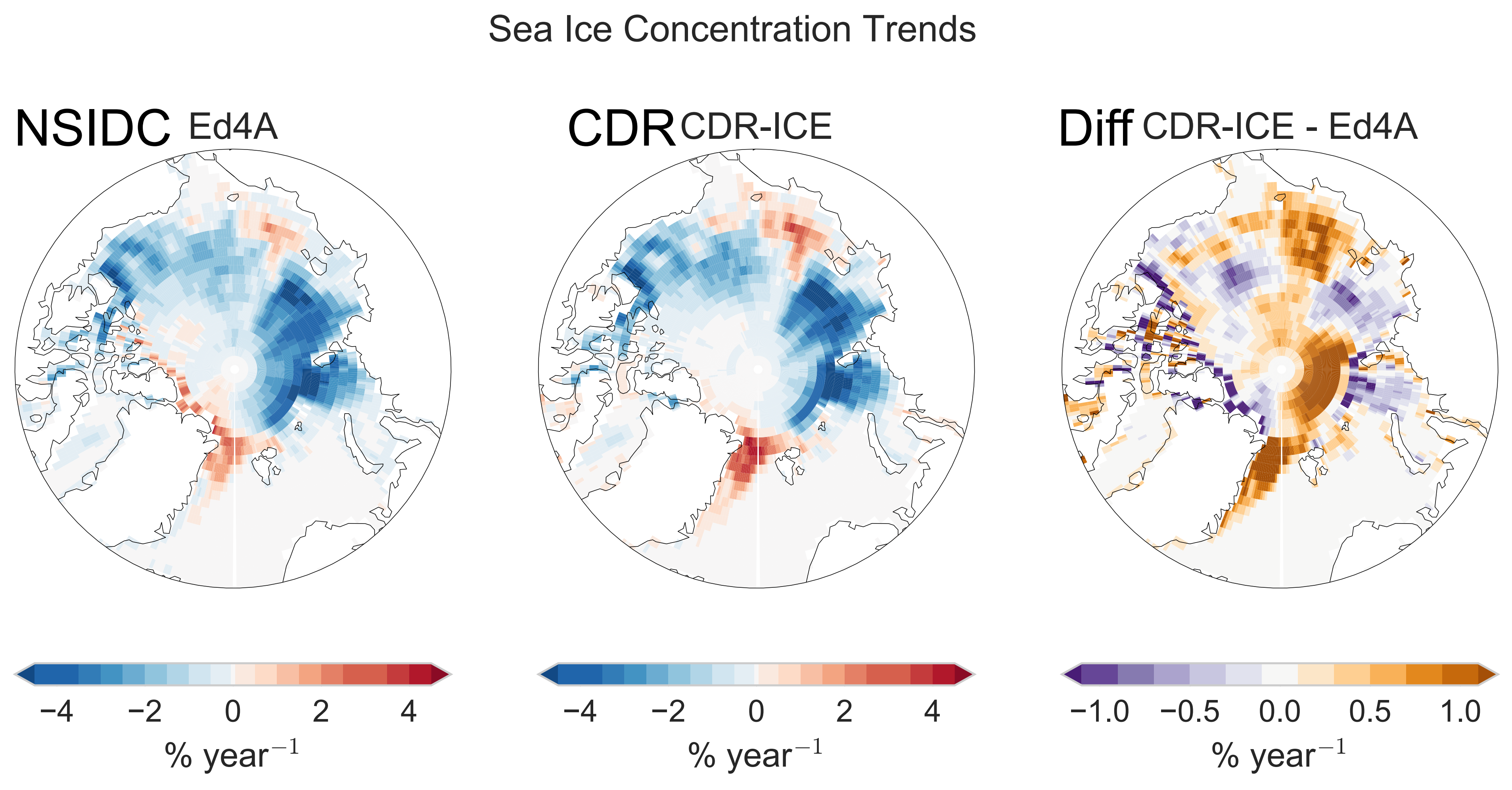
Sea ice datasets

	NSIDC Near-Real time Snow and Ice Extent (NISE): used in Ed4	NSIDC/NOAA Climate Data Record of Passive Microwave Sea Ice Concentration (CDR)	Cloud Working Group Imager Clear sky snow/ice concentration
Instrument/ Radiances	SSMI, SSMIS on DMSP F13 and F17 19.4, 37.0 GHz Tb - NESDIS	SSMI, SSMIS on DMSP F13 and F17 19.4, 37.0 GHz Tb - RSS	MODIS/VIIRS 0.6µm, 2.1µm (or 1.6µm), 11µm and 12µm
Algorithm	GSFC NASA Team	Combination of GSFC NASA Team and GSFC Bootstrap	Combination of thresholds
Resolution	25 Km	25 Km	CERES footprint – clear sky portion only
Temporal Coverage	05/1994 – 10/2016	07/1987 - 12/2014	Coincident with CERES measurements
Quality Control	Low Forward processing only	High Consistent algorithm over time series	High Consistent over time, possibly subject to MODIS drifts

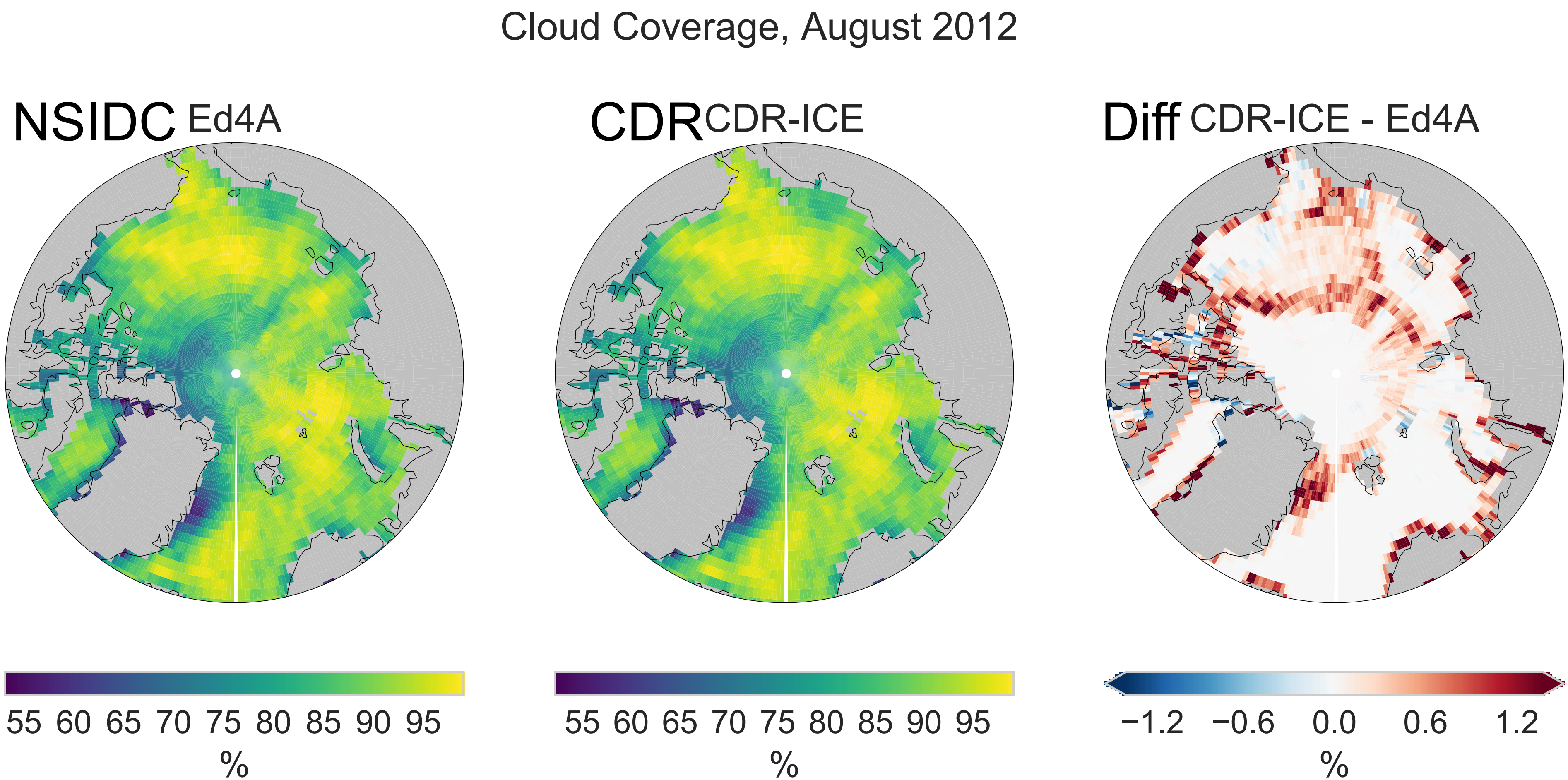
CDR product has higher sea ice concentration than NSIDC

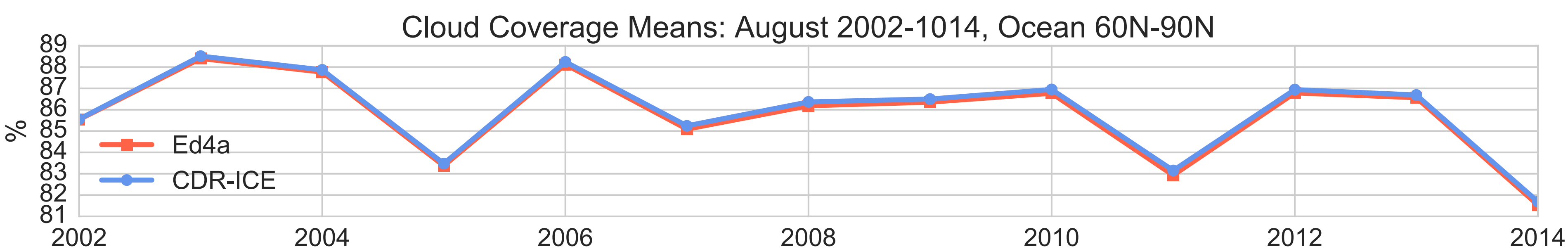


Trends in August sea ice concentration show some difference



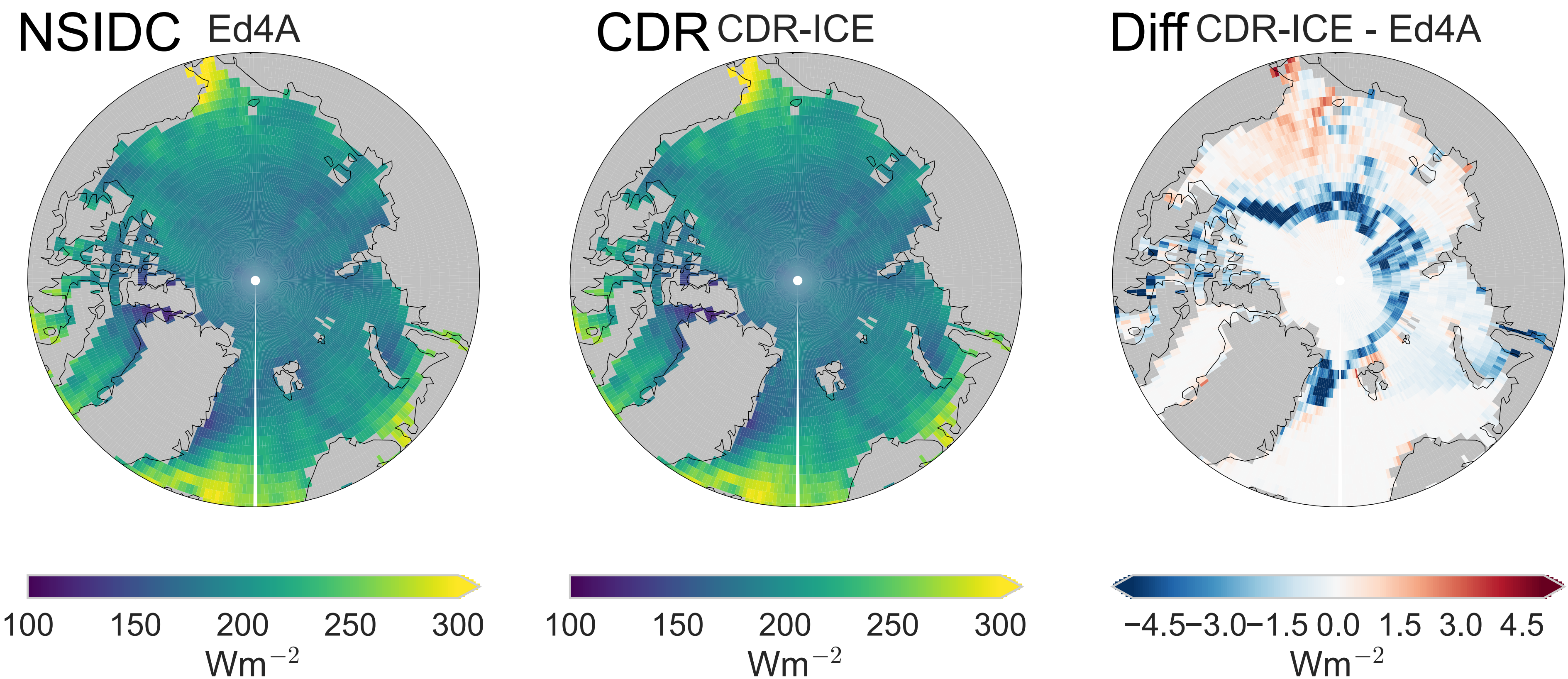
Different sea ice data sets have very little impact on cloud fraction

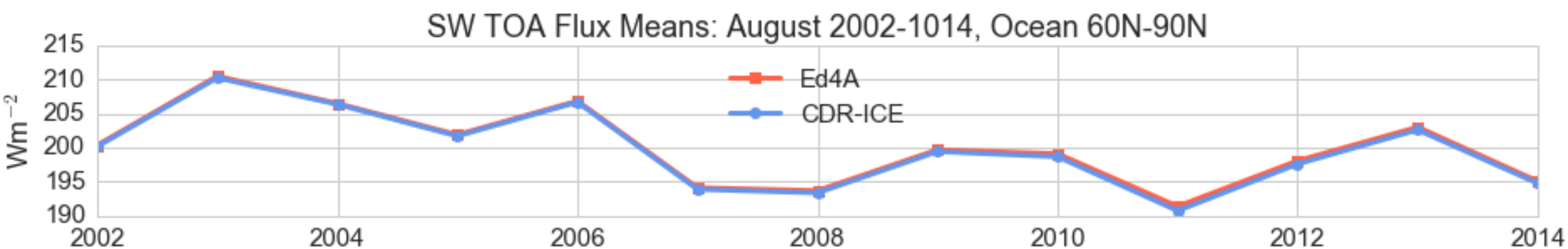


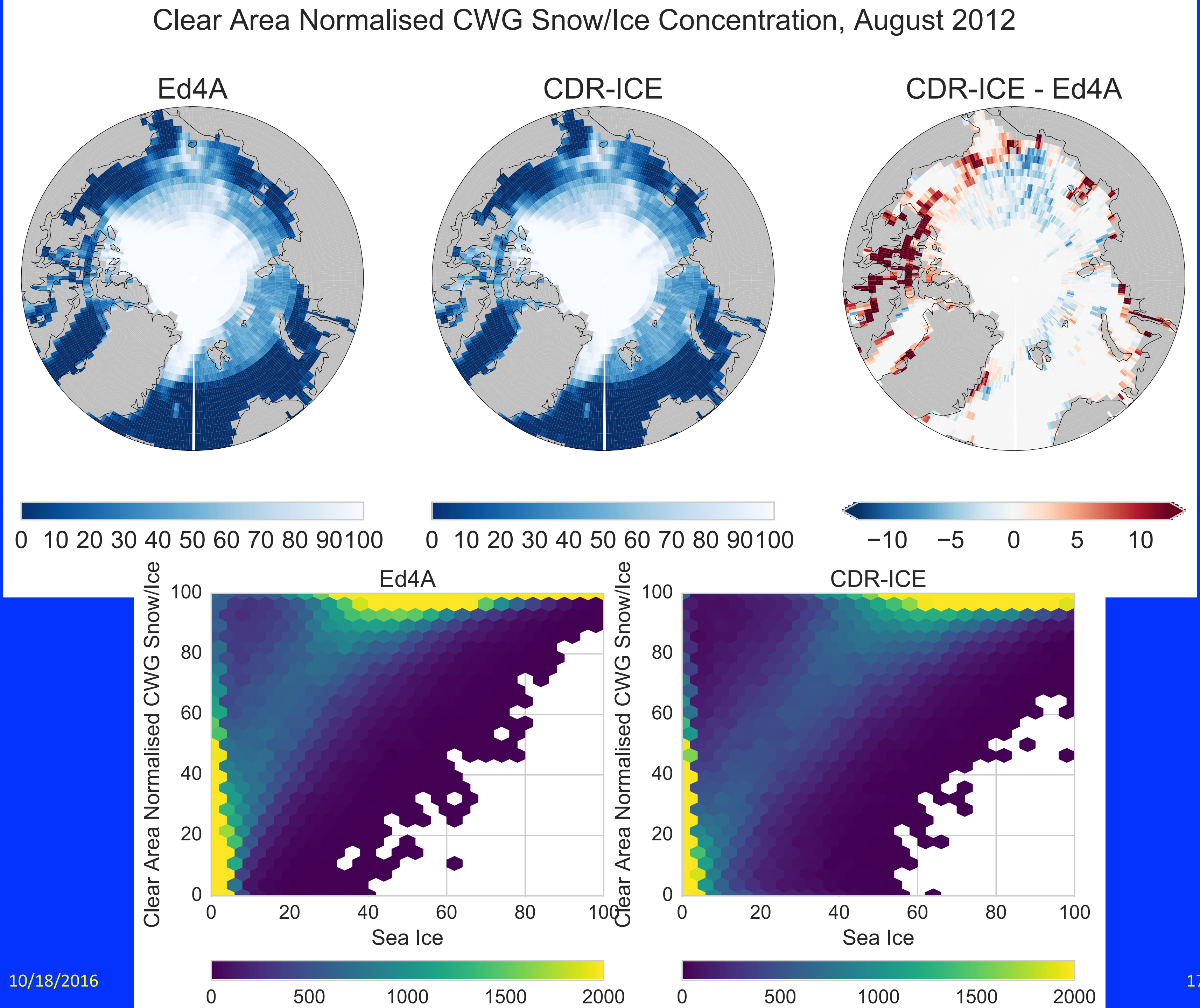


Effects on SW flux are also very small

SW TOA Flux, August 2012






Clear Area Normalised CWG Snow/Ice Concentration, August 2012
Ed4A
CDR-ICE
CDR-ICE - Ed4A
0 10 20 30 40 50 60 70 80 90 100
0 10 20 30 40 50 60 70 80 90 100
−10 −5 0 5 10
Ed4A
CDR-ICE
Clear Area Normalised CWG Snow/Ice
Sea Ice
0 20 40 60 80 100
0 500 1000 1500 2000

Summary

- Theoretical clear-ocean albedo directional models were calculated for different wind speed, aerosol types, and aerosol optical depths:
  - Monthly 24-hour averaged SW fluxes were calculated using the directional models selected based upon MATCH aerosol types and optical depths, and the GEOS wind speed;
  - Ignore the directional model's sensitivity to aerosol type/optical depth and wind speed, can lead to errors in monthly 24-hour averaged SW fluxes (60S-60N) up to 0.4 Wm^{-2}.
- Investigated the effects of different sea ice data sets on cloud retrieval and flux inversion:
  - Although the CDR has higher ice concentration than the NSIDC ice data used in CERES data production, replacing NSIDC with CDR ice concentration has minimum effects on cloud and flux;
  - The imager based sea ice fraction agrees better with the CDR data.