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Arctic Cloud Radiative Forcing in Contemporary Atmospheric Reanalyses

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1. A View From TOA

The response of Arctic clouds to the evolving sea ice surface is a focus of current research. Top-of-atmosphere (TOA) radiative fluxes are directly observed by satellites. Here, we examine six reanalyses over a central Arctic Ocean domain in comparison to CERES-EBAF4.1 and ERBE data.

Table 1. Reanalyses Examined

	Resolution	Period	Reference
ASRv2	15 km	2000-2016	*Bromwich et al. 2018*
CFSR	35 km	1979-2010	*Saha et al. 2010*
ERA-I	78 km	1979-2018	*Dee et al. 2011*
ERA5	31 km	1979-2018	*Hersbach and Dee 2016*
JRA-55	63 km	1979-2013	*Kobayashi et al. 2015*
MERRA-2	69 km	1980-2018	*Gelaro et al. 2017*

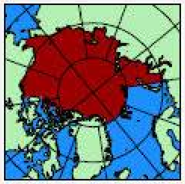

FIGURE 1. Averaging domain.

2. Sea Ice Follies

Reanalyses use different sea ice & SST boundary conditions that may change with time. Concentration differences over the domain can be large.

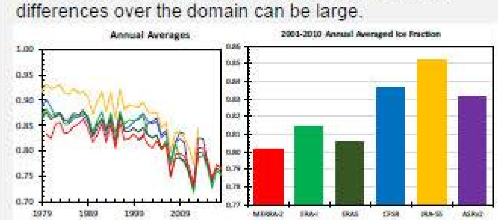

FIGURE 2. Domain-averaged reanalysis ice cover fraction. Monthly comparison is for overlapping period 2001-2010.

- JRA-55 uses threshold ice cover, has largest ice fraction.
- MERRA-2, ERA5 have lowest ice concentrations, particularly for May-August.
- ERA-I used 100 percent ice concentration poleward of 82°N for a large part of the time series.
- We may contrast reanalyses with low ice fraction (MERRA-2, ERA-I) with those that use threshold ice cover or are otherwise higher (JRA-55, CFSR).

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3. Insolation Follies

There are interesting differences in reanalyses TOA downward solar insolation. Orbital variations have largest effects at the poles and should be considered.

- ERA-I used a large solar constant (1370 W m^{-2} versus 1365 W m^{-2} for other reanalyses).
- The spring equinox undergoes a 4-yr intercalary cycle, but trends earlier with axial precession. This has largest calendar averaging effects at the poles in transitional seasons – a few W m^{-2} over 40 yr. Interestingly MERRA-2 does not model this effect (!).
- ASRv2 also has differences with CERES-EBAF.

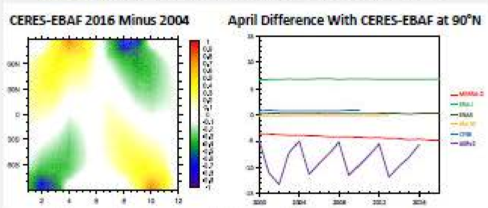

FIGURE 3. Left: CERES-EBAF TOA downwelling solar flux, 2016 minus 2004. Right: April TOA downwelling solar flux at 90°N minus CERES-EBAF [W m^{-2}].

4. 2001-2010 Comparison

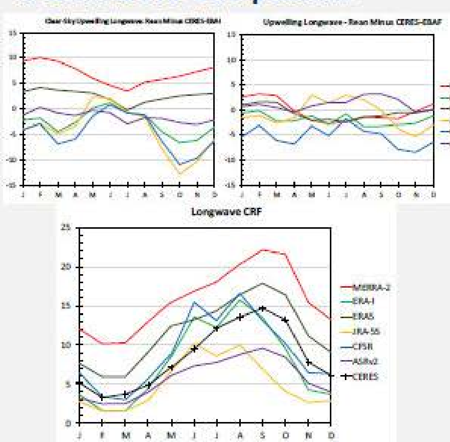

FIGURE 4. Top: Clear-sky and total upwelling shortwave flux minus CERES-EBAF. Bottom: longwave CRF [W m^{-2}].

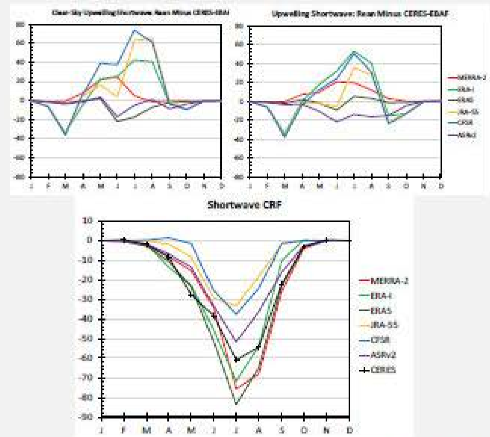

FIGURE 5. Top: Clear-sky and total upwelling shortwave flux minus CERES-EBAF. Bottom: shortwave CRF [W m^{-2}].

- There are large differences among reanalyses in clear-sky longwave fluxes in transitional seasons. Those with low ice concentration (MERRA-2, ERA5) are more similar to each other and to CERES-EBAF, with MERRA-2 significantly warmer (surface) in all seasons.
- Low ice concentration reanalyses show max longwave CRF in autumn months, while others show max in summer months.
- For shortwave fluxes, high ice concentration reanalyses (JRA-55, CFSR) over-estimate the summertime clear-sky upwelling flux by as much as 75 W m^{-2}.
- High ice concentration reanalyses have a much smaller shortwave CRF than for low ice concentration.

5. Interannual Variability

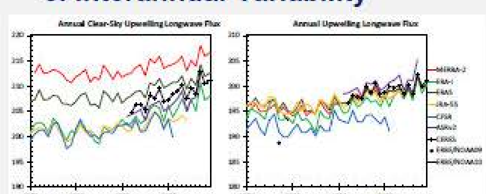

FIGURE 6. Annual clear-sky and total upwelling longwave fluxes [W m^{-2}].

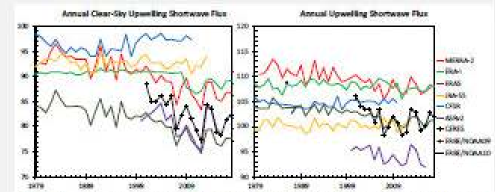

FIGURE 7. Annual clear-sky and total upwelling shortwave fluxes [W m^{-2}].

There is some agreement in year-to-year variations in flux values, but trends can differ substantially. There is general agreement with an increase in all-sky longwave flux since 1990 of ~5 W m^{-2}.

The clear-sky shortwave fluxes indicate large discrepancies associated with variations in the prescribed sea ice. ERA5, ASRv2, and MERRA-2 indicate a downward trend over the CERES period, while others show no change. A long-term downward trend in MERRA-2 is evident.

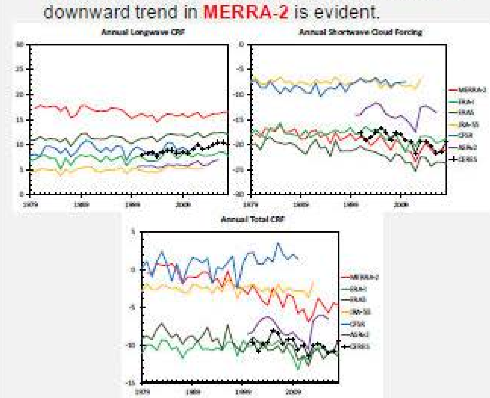

FIGURE 8. Longwave, shortwave, and total CF [W m^{-2}].

- A slight downward trend in LWCF (2 W m^{-2} over 40yr) combines with SWCF trend to give intriguing negative total CF trend for MERRA-2.
- Others show less significant trends

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