The Cryosphere Radiative Effect in CESM

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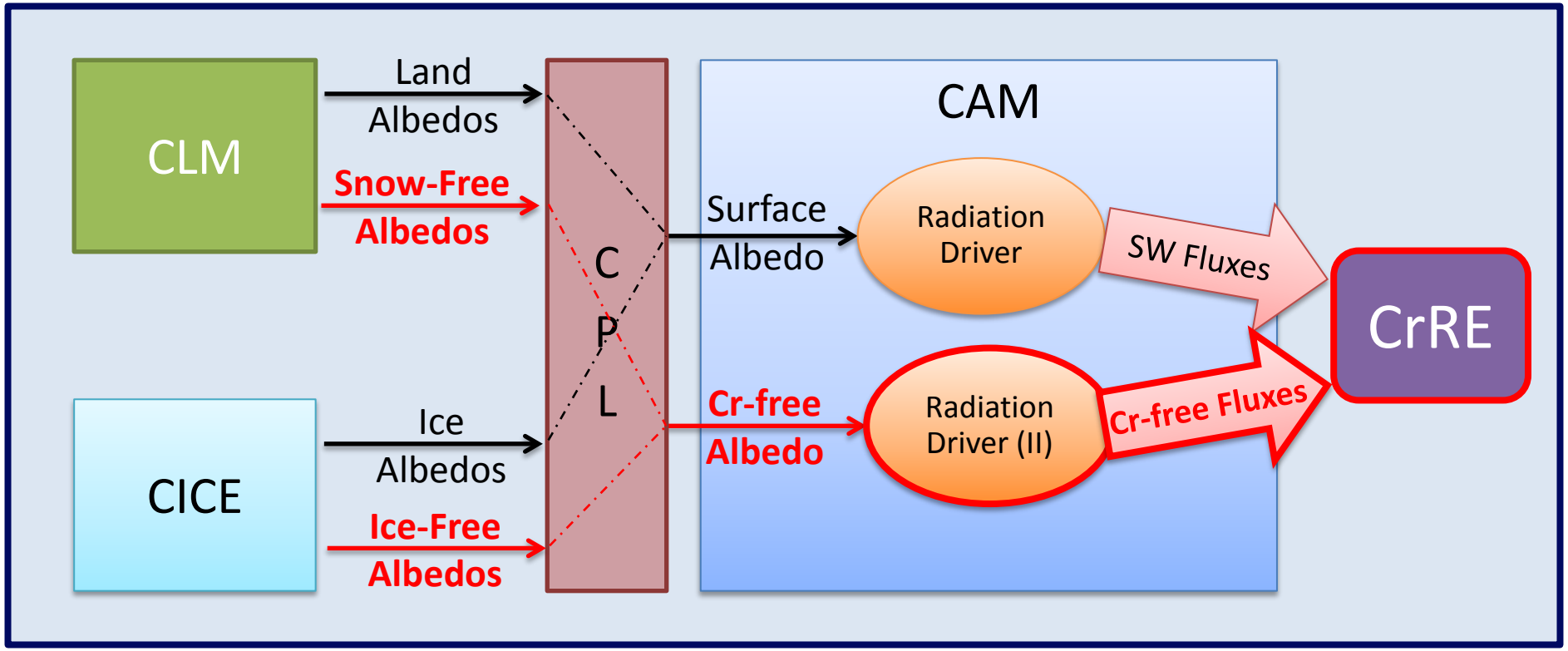
Cryosphere Radiative Effect (CrRE)

- A new diagnostic feature is available for CESM:
  - **Cryoshere Radiative Effect (CrRE):** the instantaneous influence of surface snow and ice on TOA energy budget
  - Analogous to the cloud radiative effect
  - Able to calculate snow & ice related effects on albedo & energy flux at every radiation calculation without altering climate state
- Realistic portrayal of cryospheric change is critical for accurate climate change modeling
- Snow and sea-ice cover metrics are important and often used to valuate climate models, but do not capture the cryospheric radiative influence
- CrRE incorporates influences of vegetation, ice ponding, insolation, cloud cover, and underlying albedo

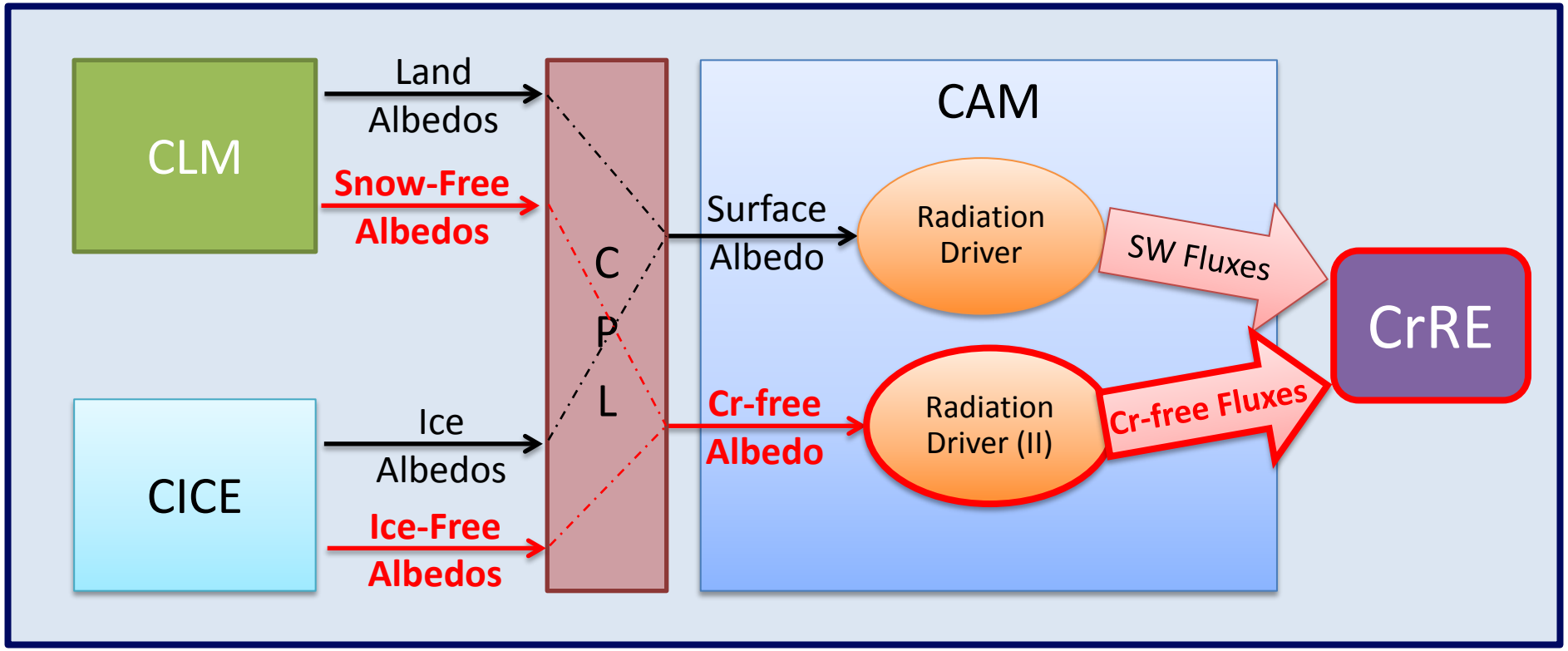
Computing Cryosphere Radiative Effect

- Extracts snow-free albedo from CLM and calculates ice-free ocean albedo in CICE
- New snow-free CLM and ice-free open ocean CICE variables merged in CPL to create cryosphere-free surface albedos, then CAM shortwave driver calculates fluxes for the cryosphere-free situation



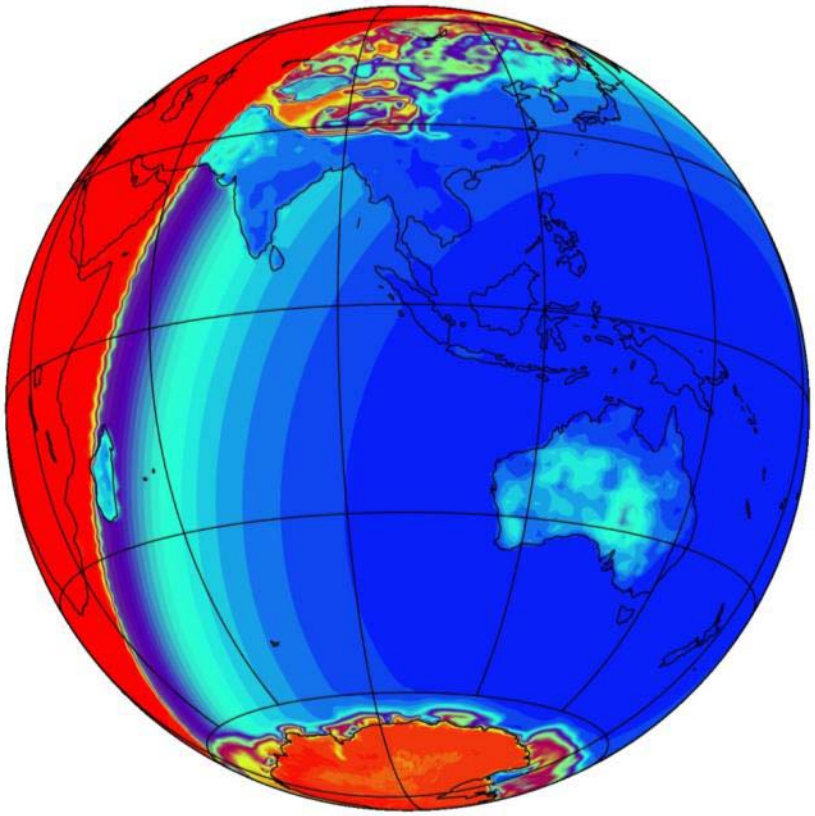
Computing Cryosphere Radiative Effect

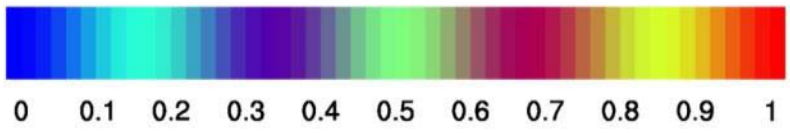
- The original model albedos remain unmodified by code
- < 20% increase to computation time in B RCP compset
- Implemented in CESM 1.0.3 & 1.1.1



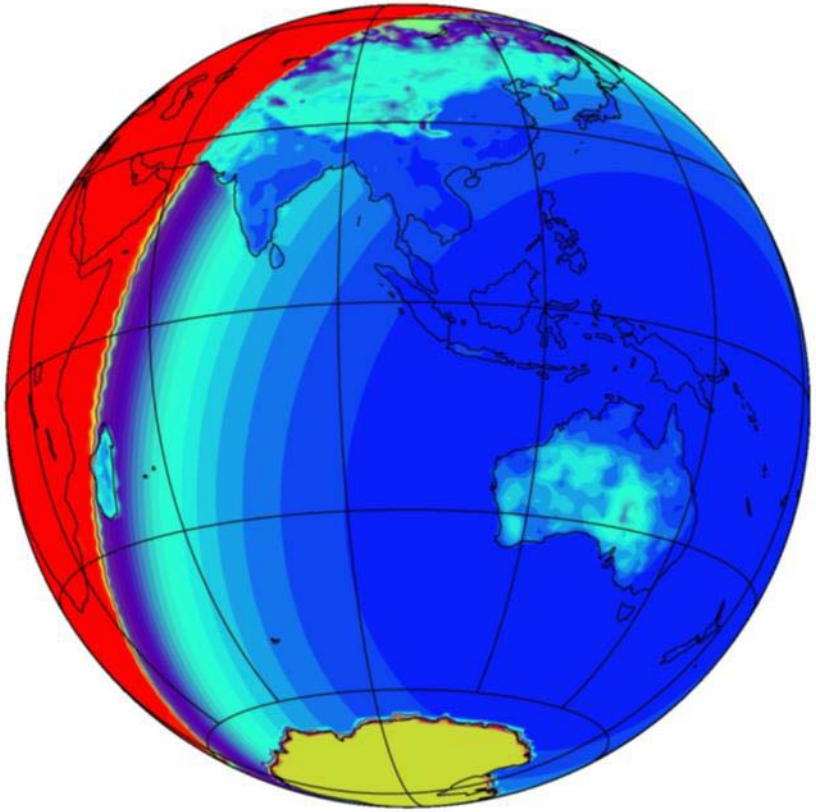
Visible Direct Albedo

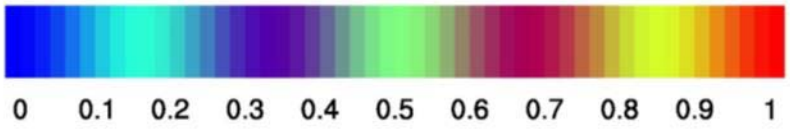
Unaltered



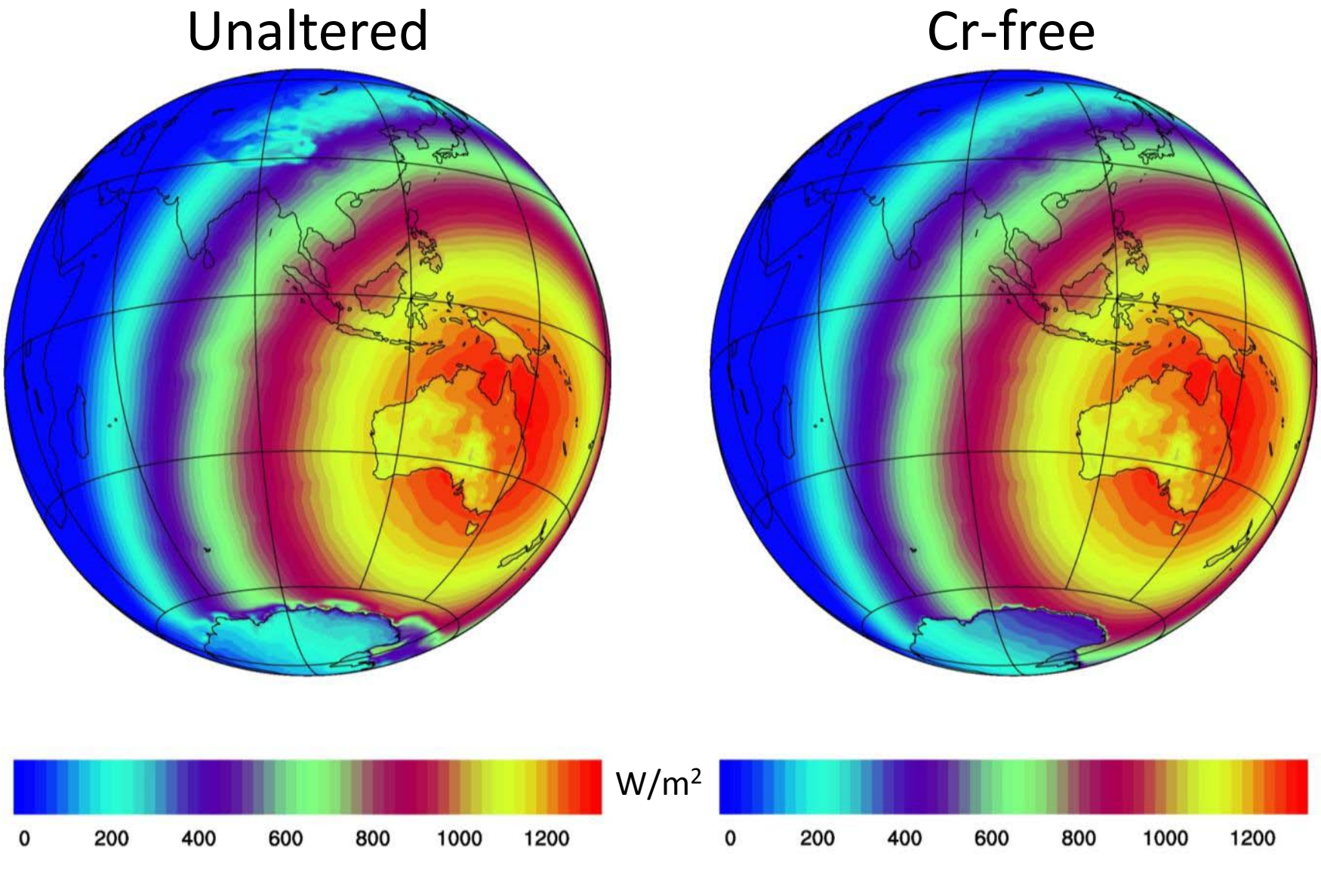


Cr-free



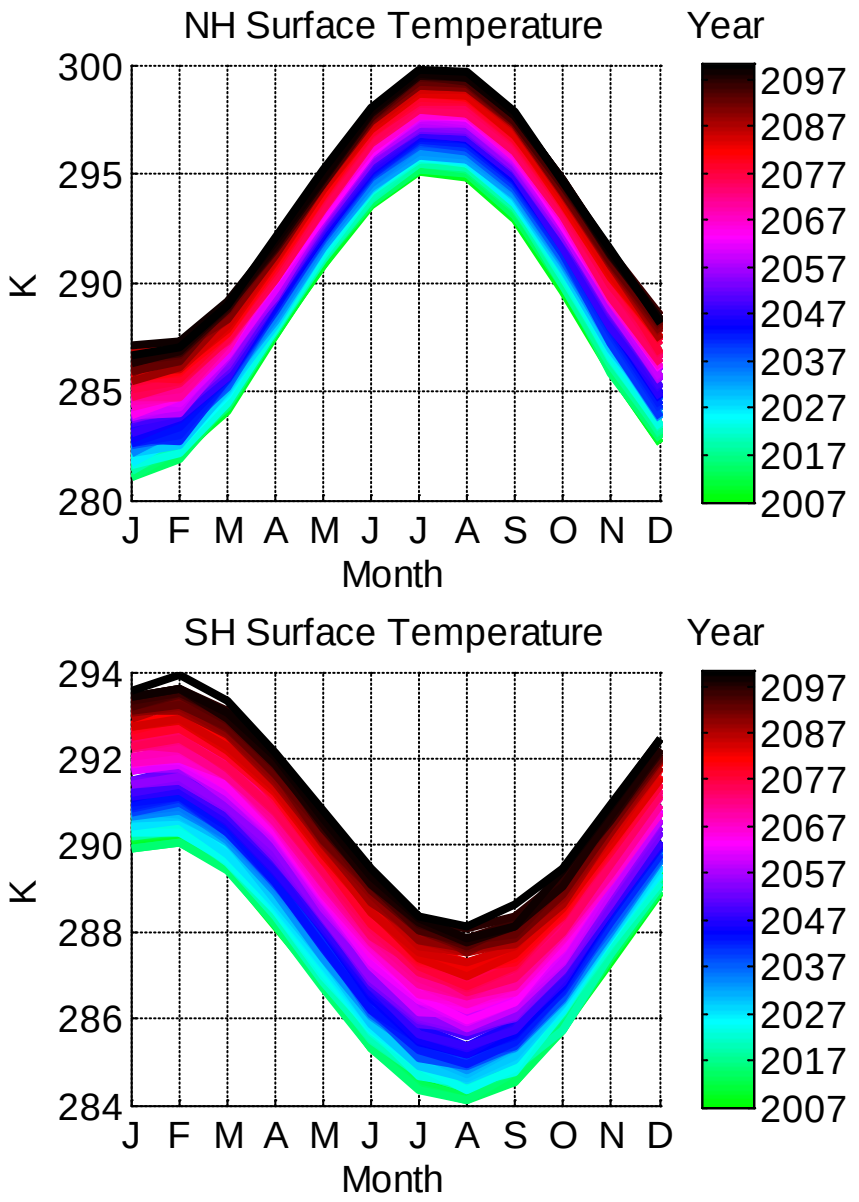


Clearsky FSNT at TOA



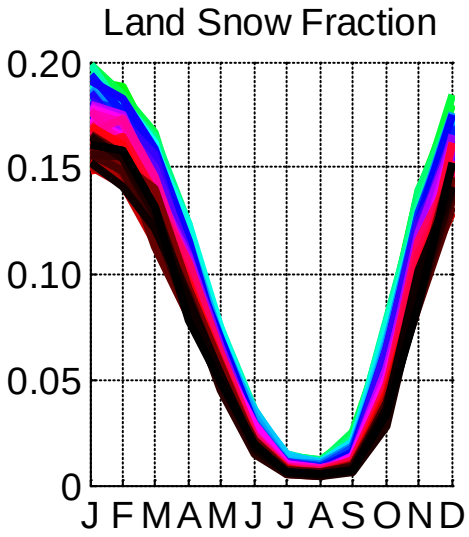
RCP 8.5 Scenario Run

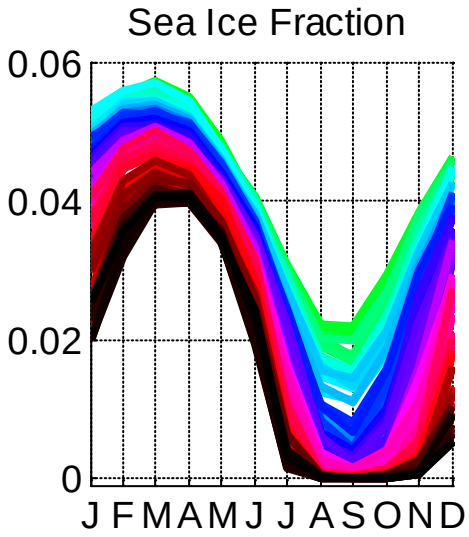
- CESM 1.1.1, B_RCP8.5_CAM5_CN
- 1° resolution
- 21st simulation to investigation evolution of cryosphere influence
- Resources from PCWG

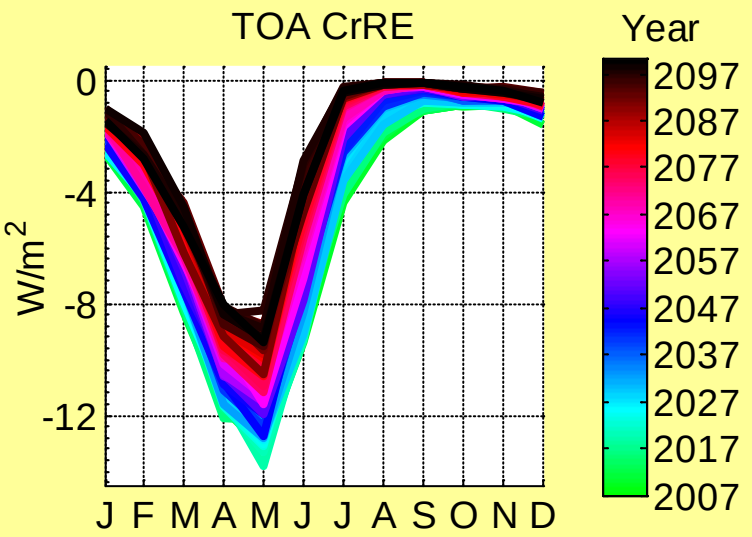


RCP 8.5 Scenario Run, Hemisphere Means

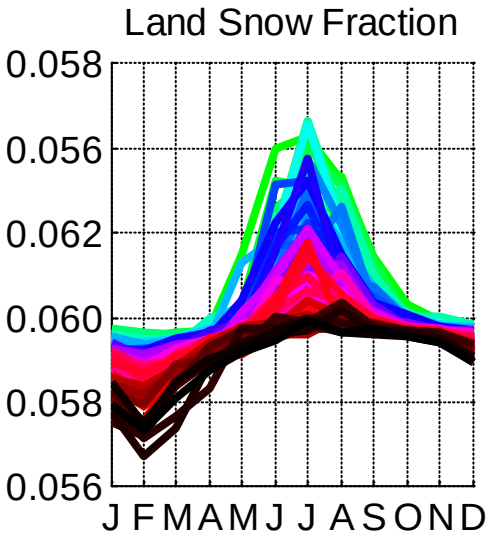
NH

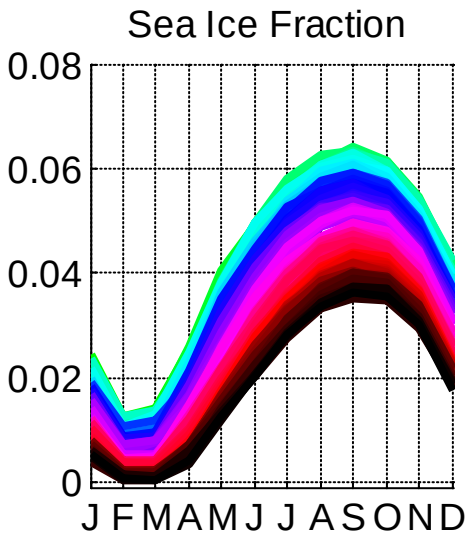


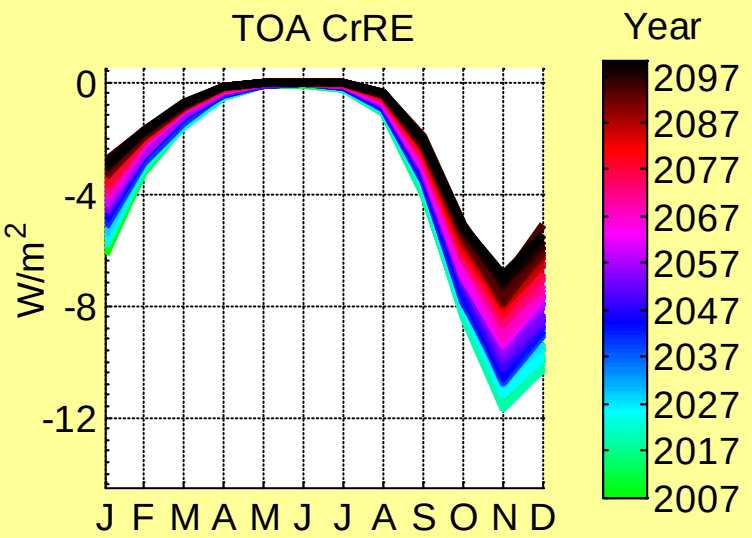




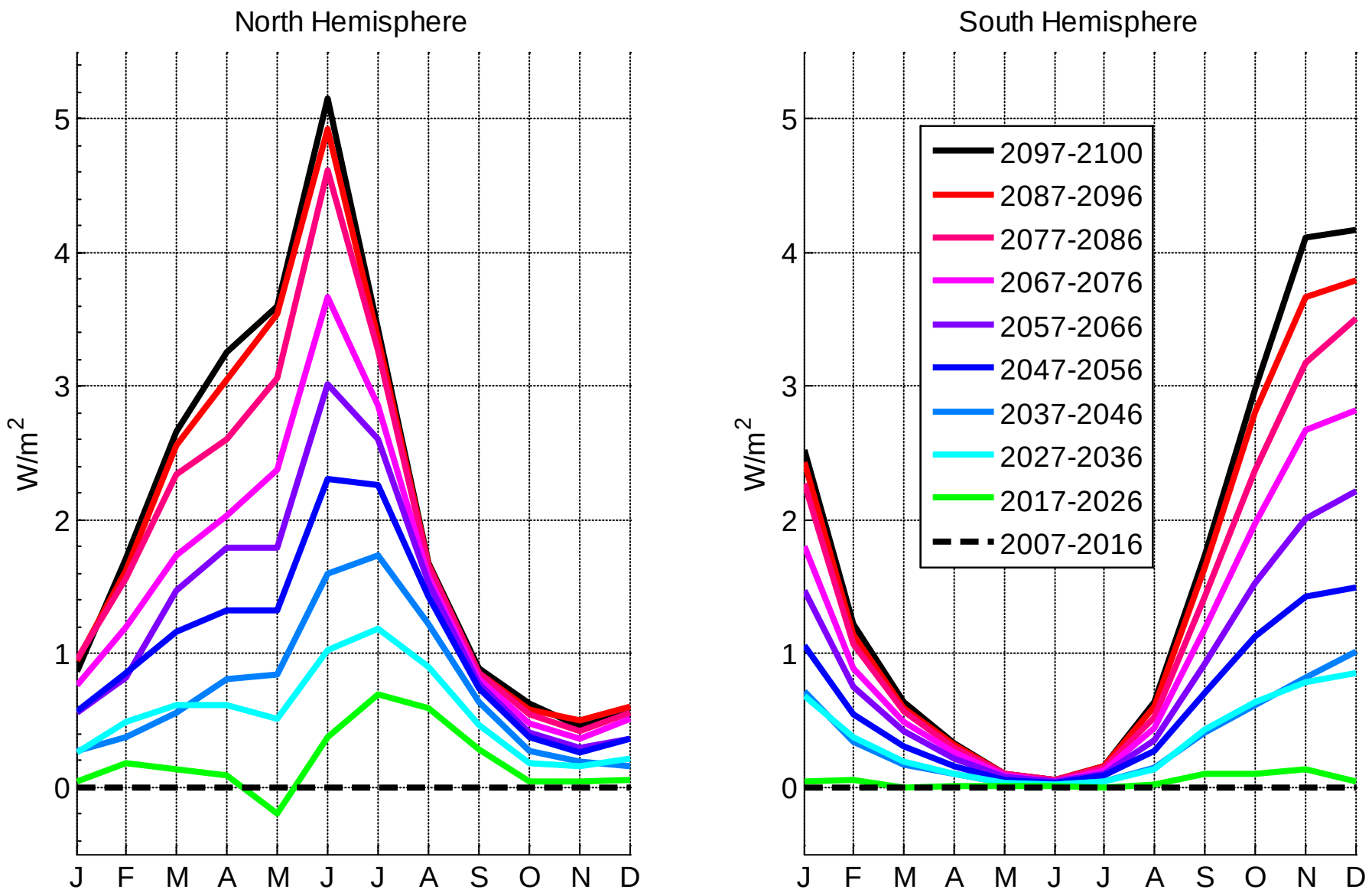
SH



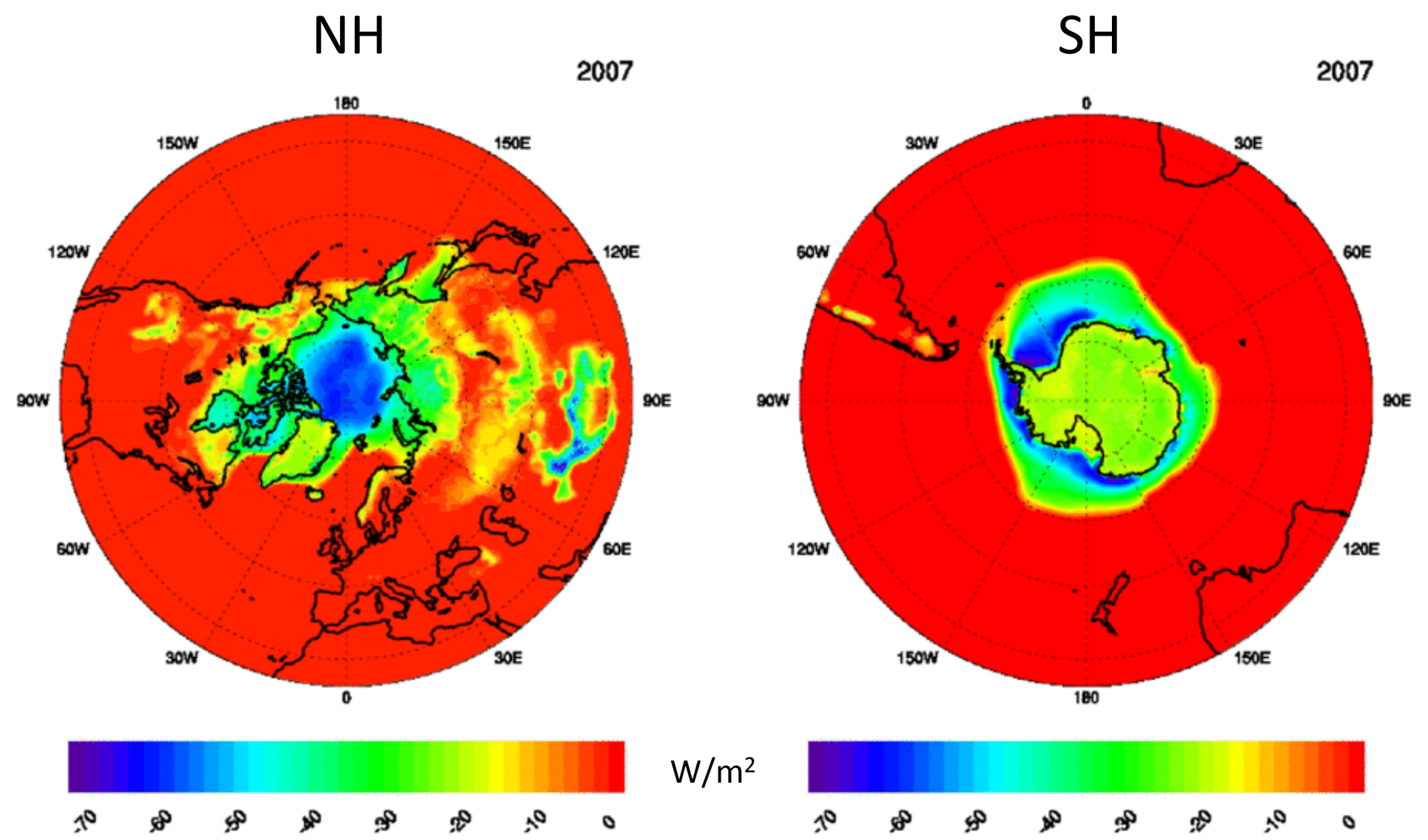




Decadal Change in CrRE from 2007-2016



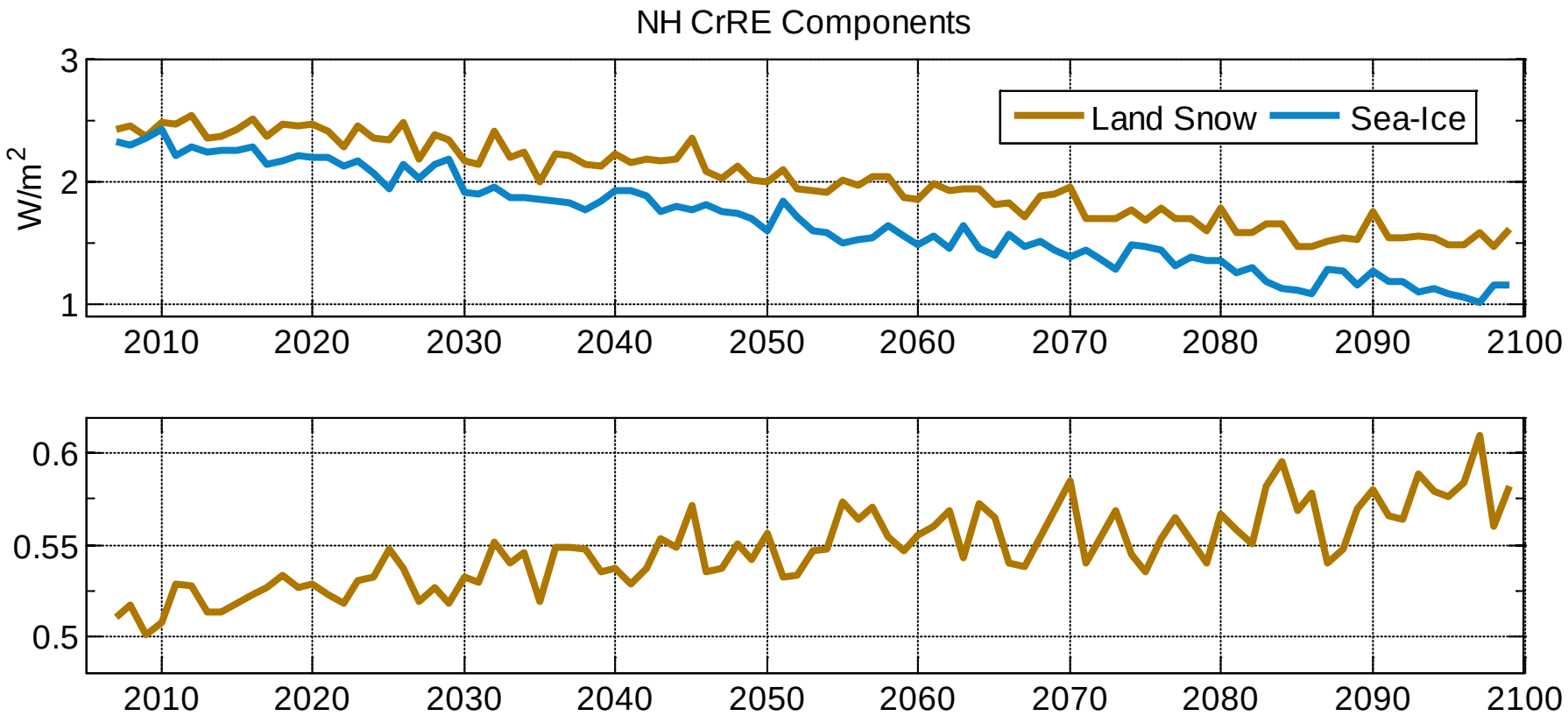
Decadal CrRE, 2007-2100



Time Evolution of NH Cr Radiative Effect

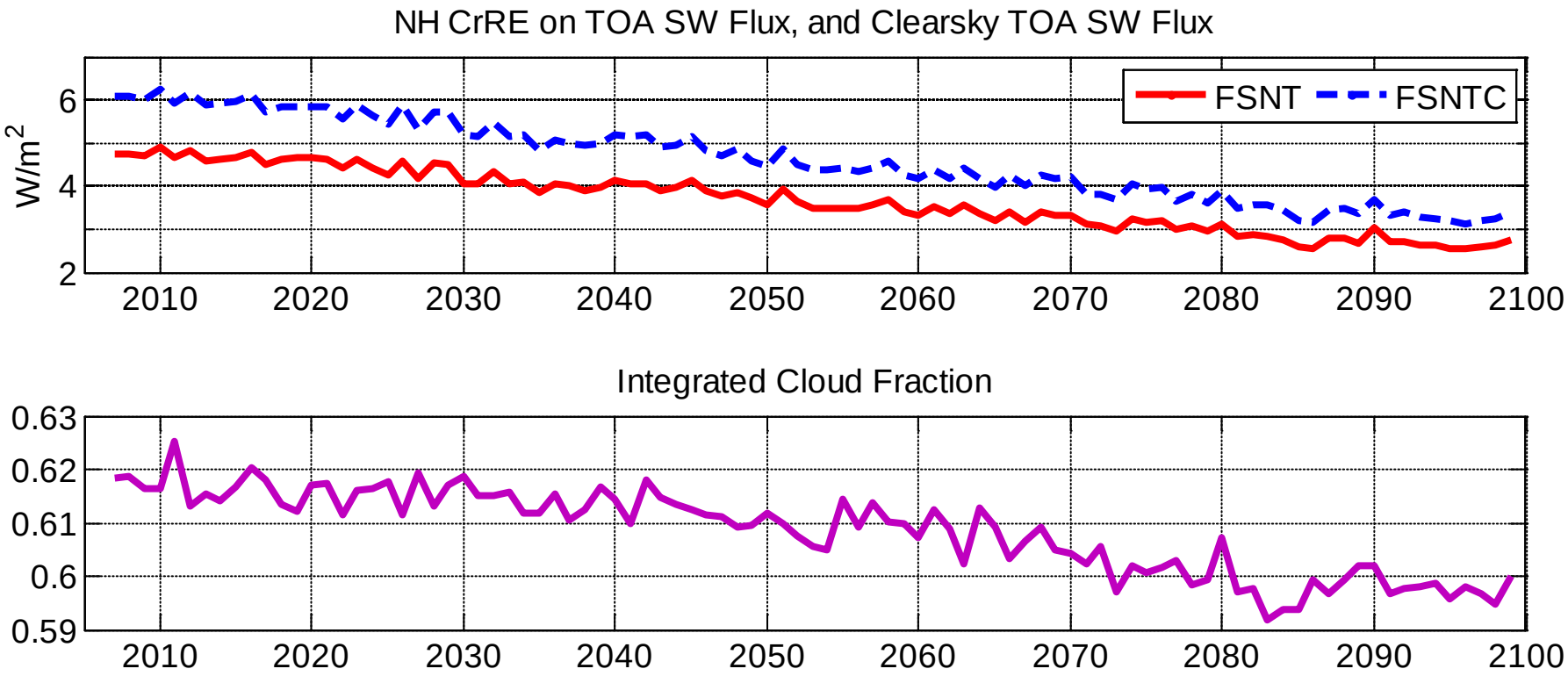
- North Hemisphere absorbs additional ~2.0 W/m^2 by 2100 from reduced cryosphere extent
- Greater decrease in sea-ice radiative influence than land

Difference in CrRE 2099-2007			
(W/m^2)	Total	Snow	Sea Ice
Global	1.8	0.5	1.3
NH	2.0	0.8	1.2
SH	1.6	0.1	1.5



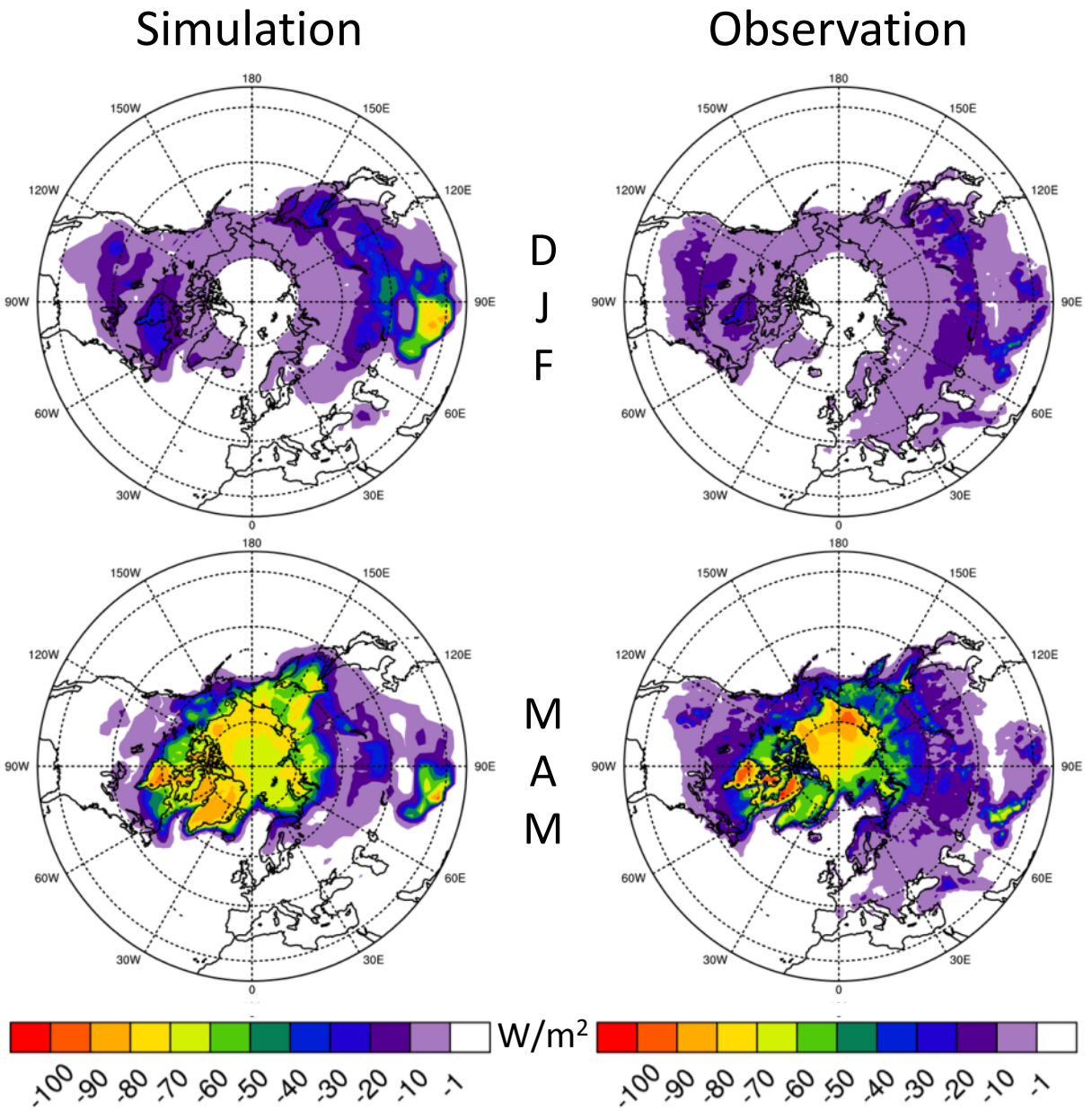
Time Evolution of NH Cr Radiative Effect

- Effect of normal TOA CrRE not linear with clear-sky TOA CrRE
- Evolution is influenced by changes in atmospheric conditions, among other factors



Initial Comparison with Observation

- Now have 1979-2008 observational record of CrRE derived from remote sensing measurements (Flanner et al, 2011)
- Compared with 2° res CESM 1.0.3 CAM4 E_2000 run



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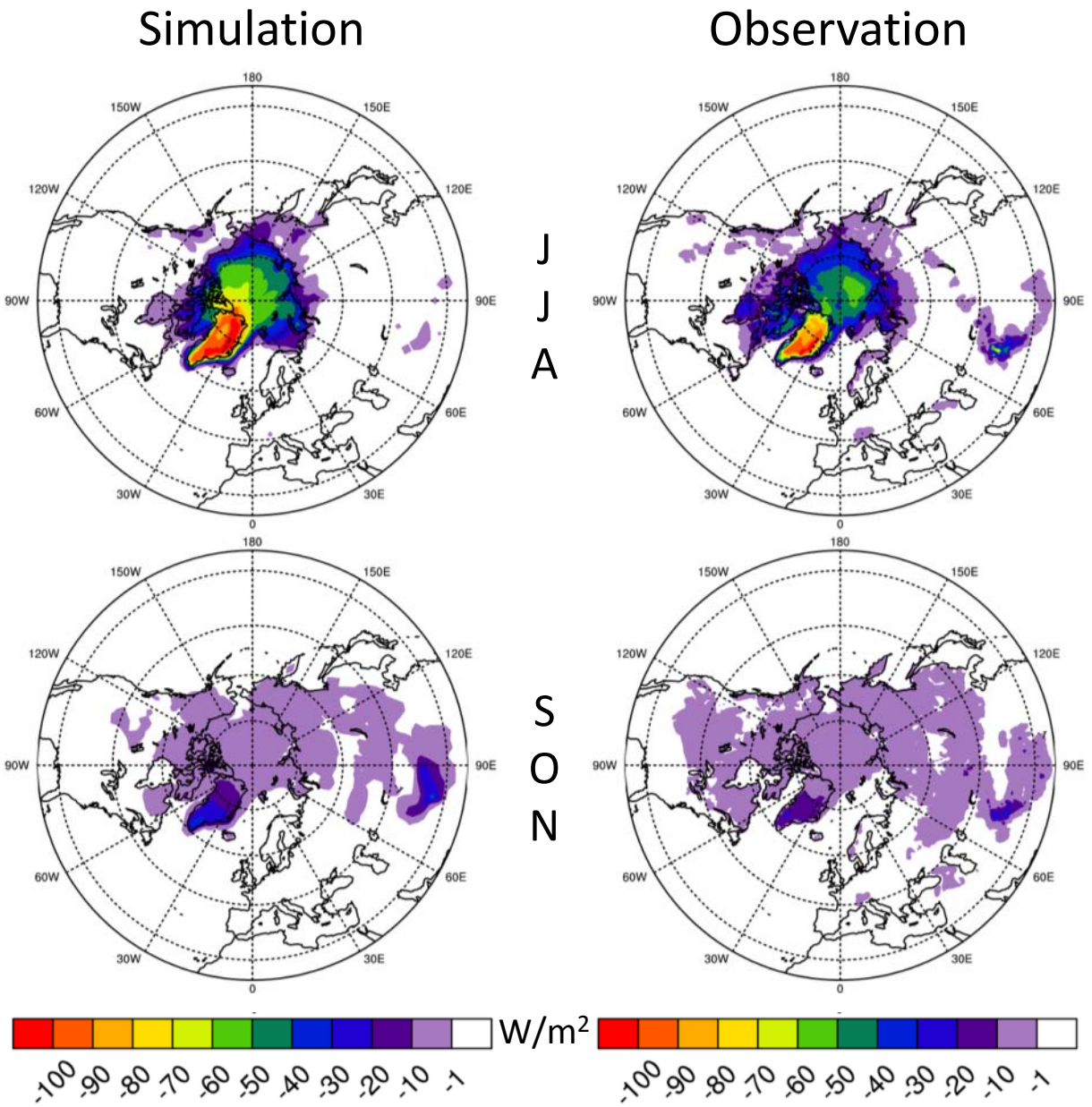
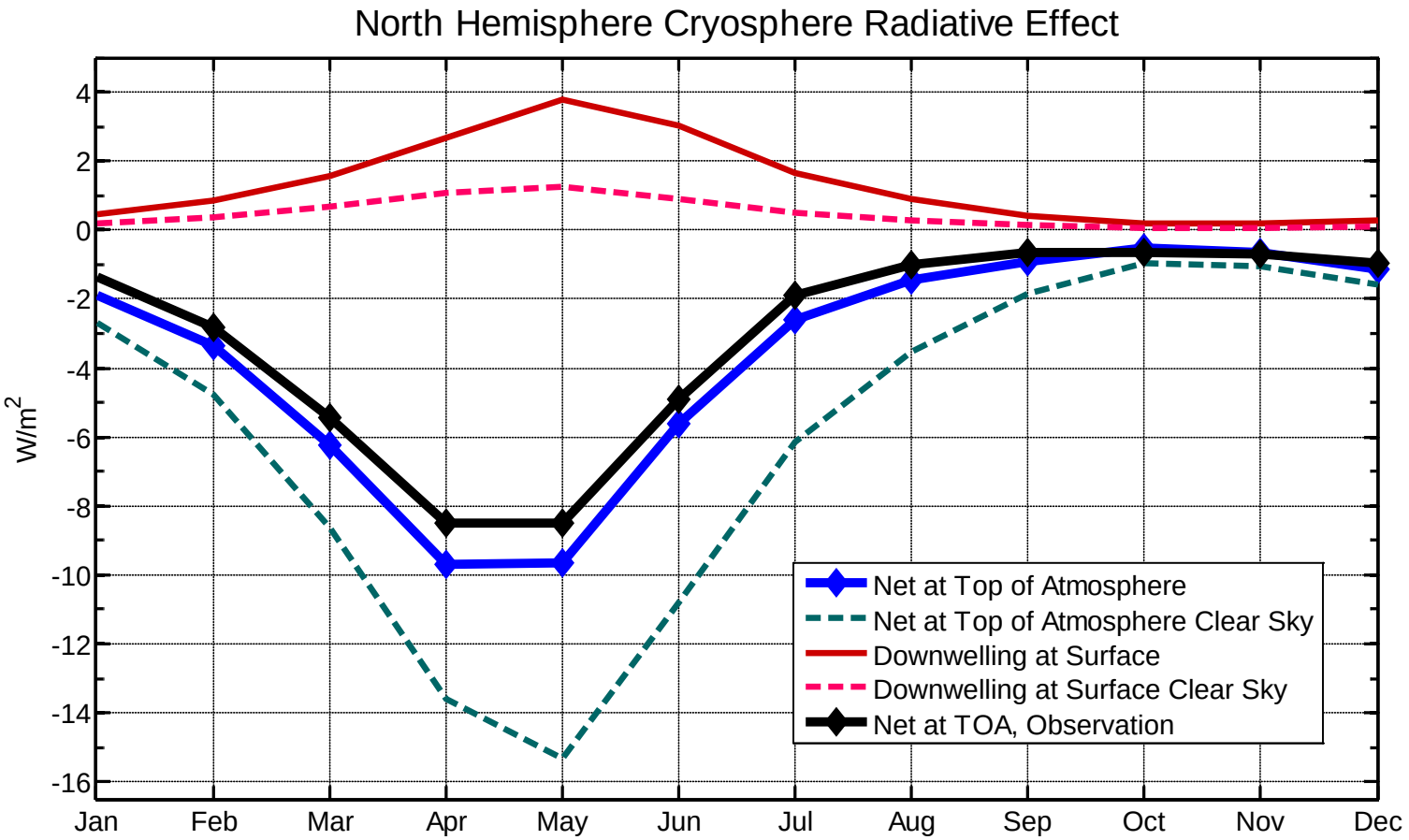


Comparison with Observation

- Agreement between model and observation-based TOA CrRE
- Demonstrates *increase* in surface downwelling from surface/cloud multiple scattering



Summary

- Cryosphere Radiative Effect (CrRE) diagnostic in CESM gives exact, instantaneous influence of snow and ice on shortwave radiation including atmosphere effects
- Initial present-day NH observation assessment favorable, but some regional discrepancies in seasonal cycle
- Globe absorbs ~0.46 W/m^2 more from snow loss, ~1.3 W/m^2 from ice loss by 2100 in CESM1.1 RCP8.5
- Potential incorporation in trunk
- Future research: Explore influences on CrRE & its evolution, including cloud conditions, ponding, and snow/ice aging