Cryosphere Radiative Forcing: An Indicator of Climate Feedback and Environmental Change

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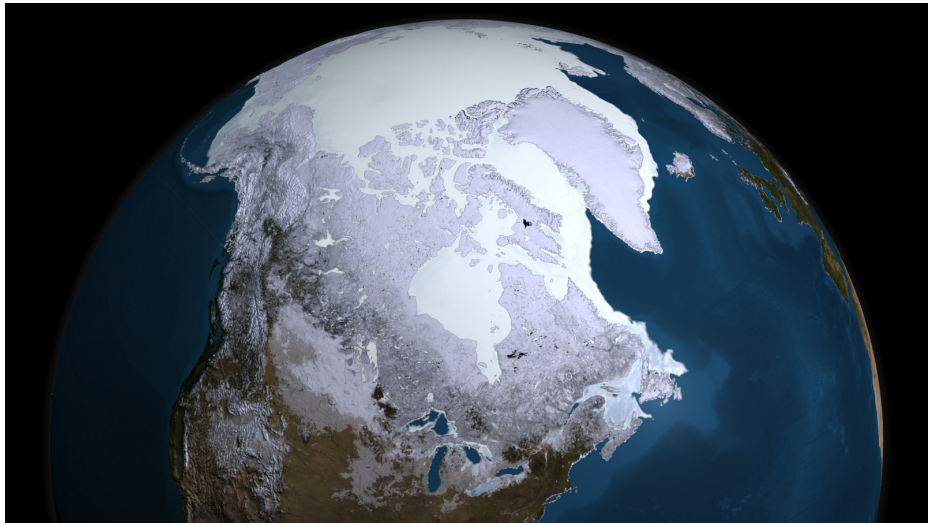
University of Michigan

April 9, 2014
NASA National Climate Assessment and Indicators Team Meeting

Motivation and goal



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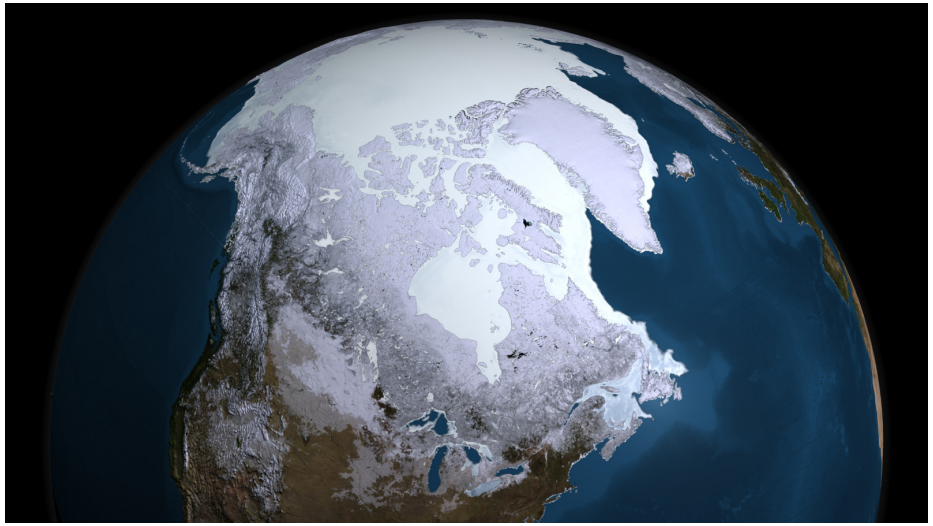

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- A 1% reduction in Earth's planetary albedo exerts a "forcing" of $3.4\,\mathrm{W\,m^{-2}}$, almost as large as a doubling of CO_2. Large capacity for albedo change and positive feedback on climate from the cryosphere

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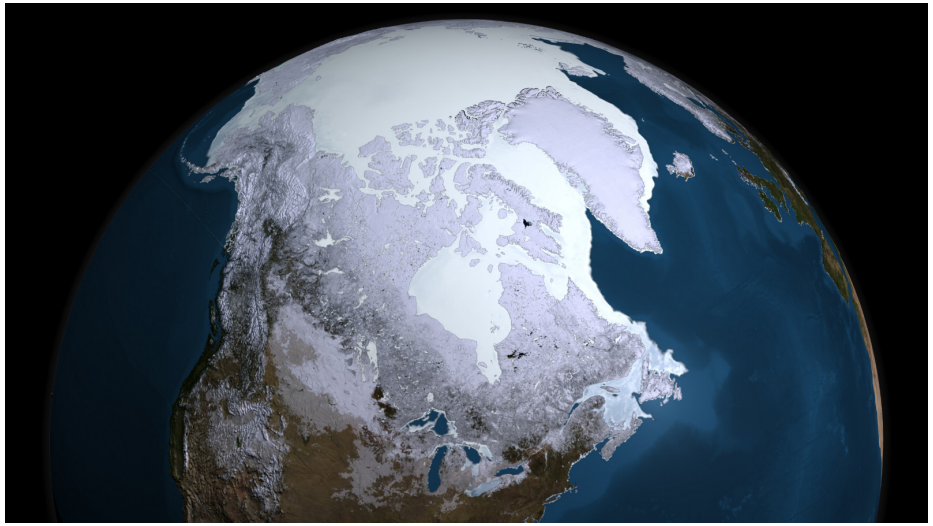

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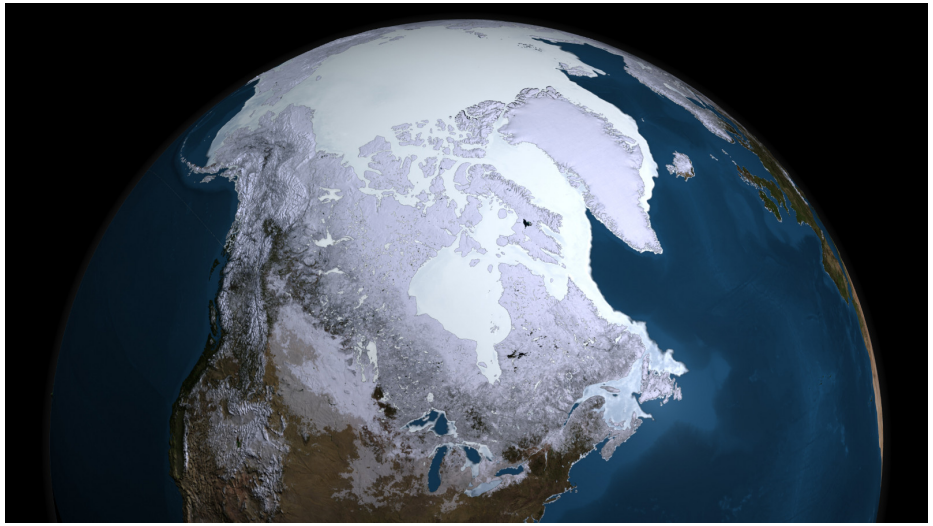

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- **Goal**: Provide a continuously updated, near real-time product of the global *cryosphere radiative effect*

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  1. Seasonal snow cover
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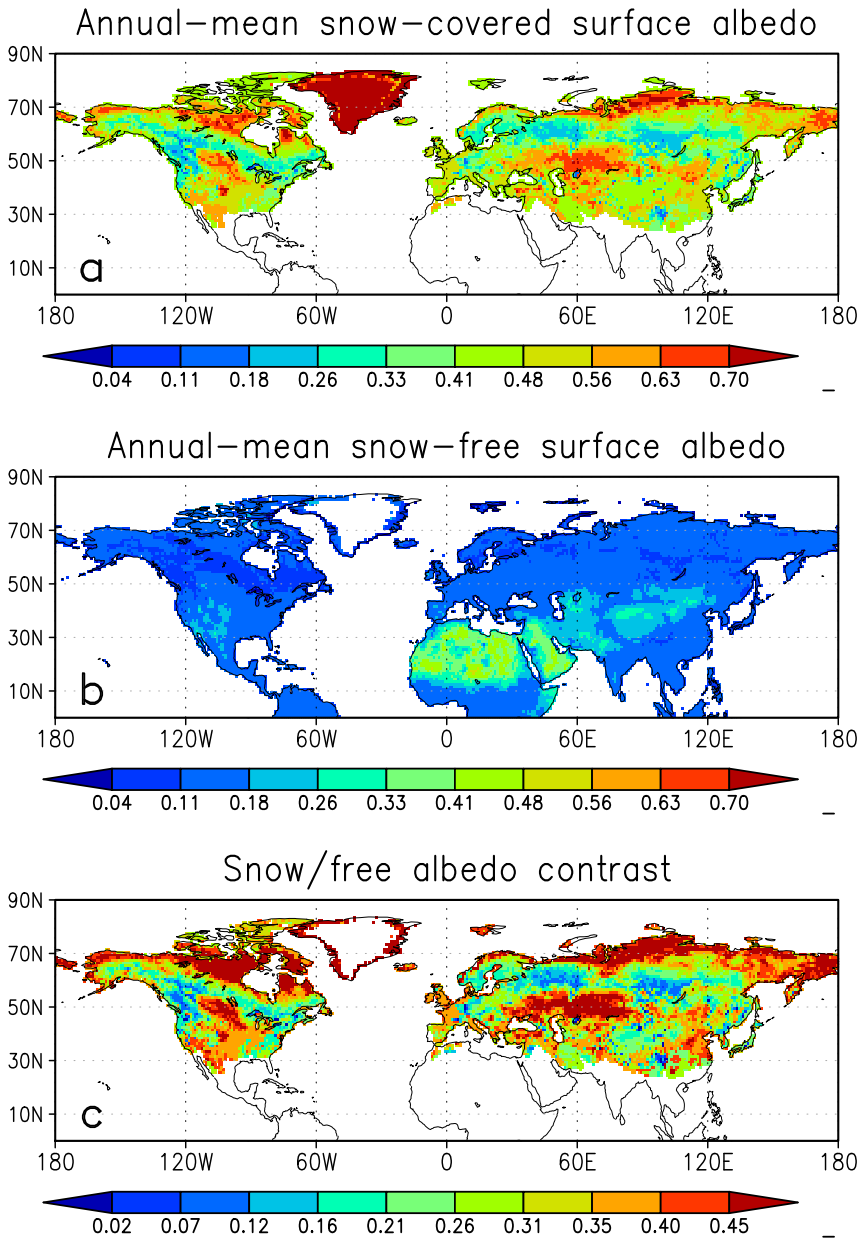
- CrRE influences:
  1. Albedo of the snow or ice
  2. Albedo of the underlying substrate (contrast induced by cryospheric presence)
  3. Insolation
  4. Cloud masking

Snow-covered / snow-free albedo contrast



- Reduced snow albedo impact over mature forests

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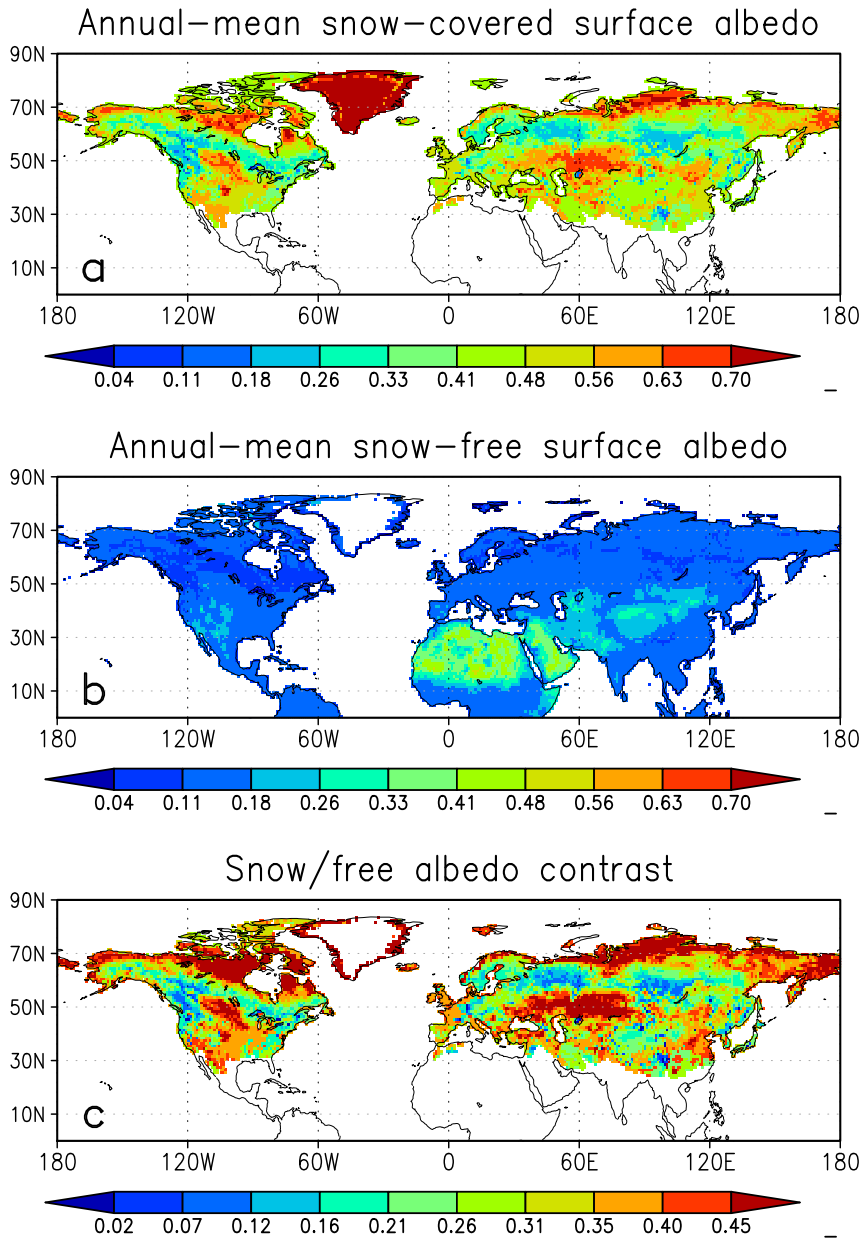

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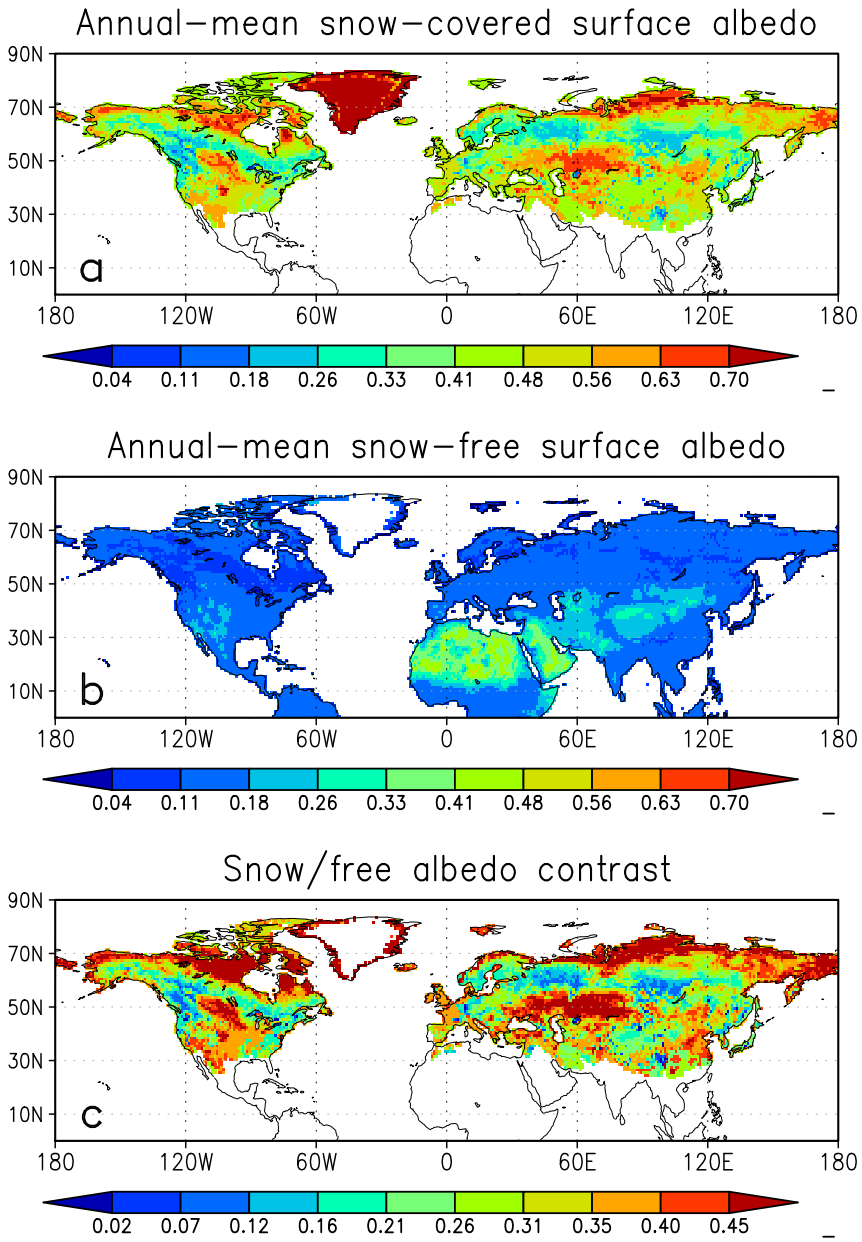

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- Mean contrast varies with definition of "snow-covered"

1979–2008 change in boreal CrRE

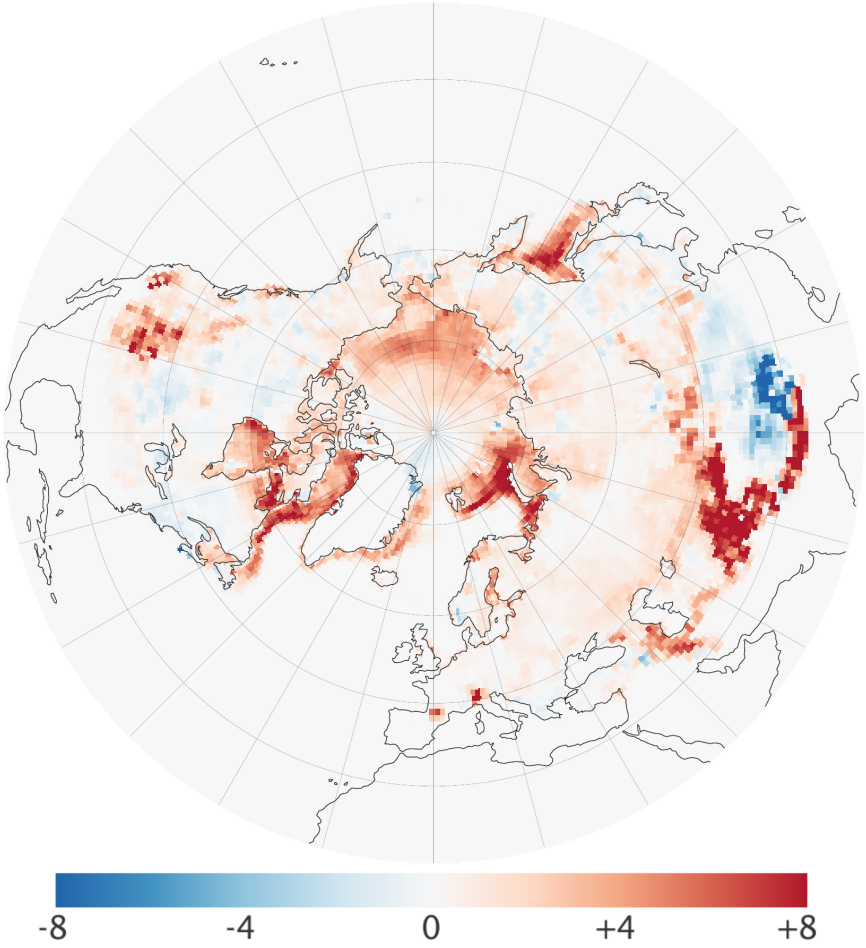

Figure: Flanner et al, 2011

- Long-term record derived from AVHRR snow cover data, microwave sea-ice data

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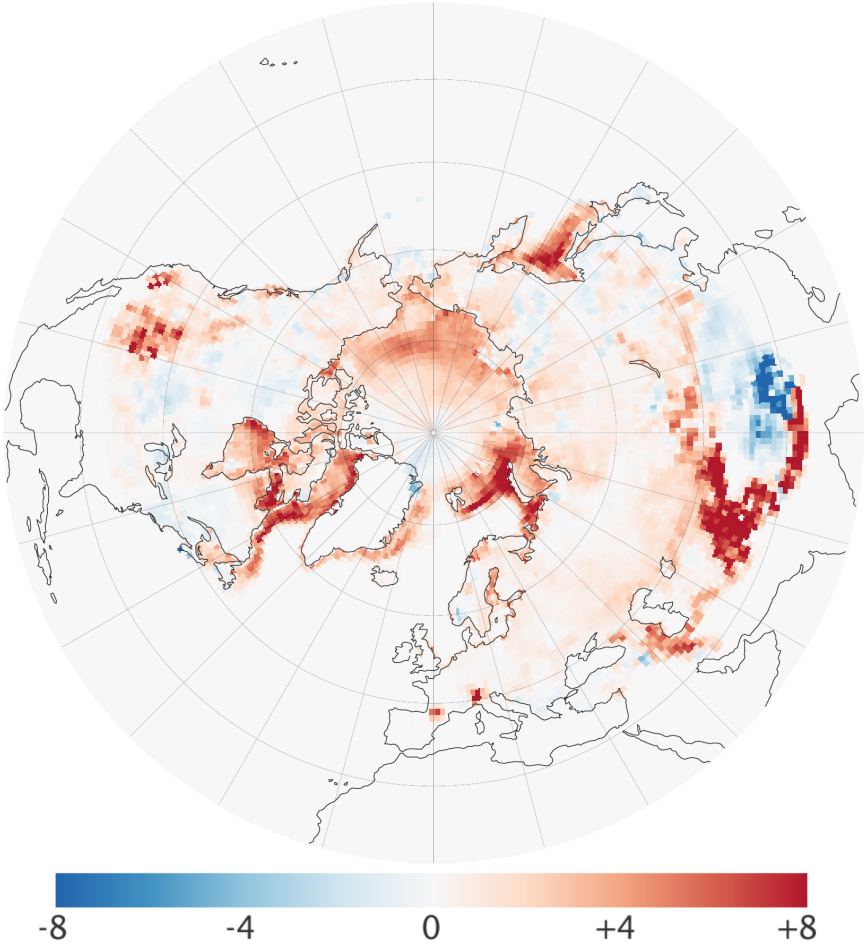

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- Long-term record derived from AVHRR snow cover data, microwave sea-ice data
- 30-year change in NH land CrRE: $+0.22\ (0.11 - 0.41)\,\mathrm{W\,m^{-2}}$
- 30-year change in sea-ice CrRE: $+0.22\ (0.15 - 0.32)\,\mathrm{W\,m^{-2}}$

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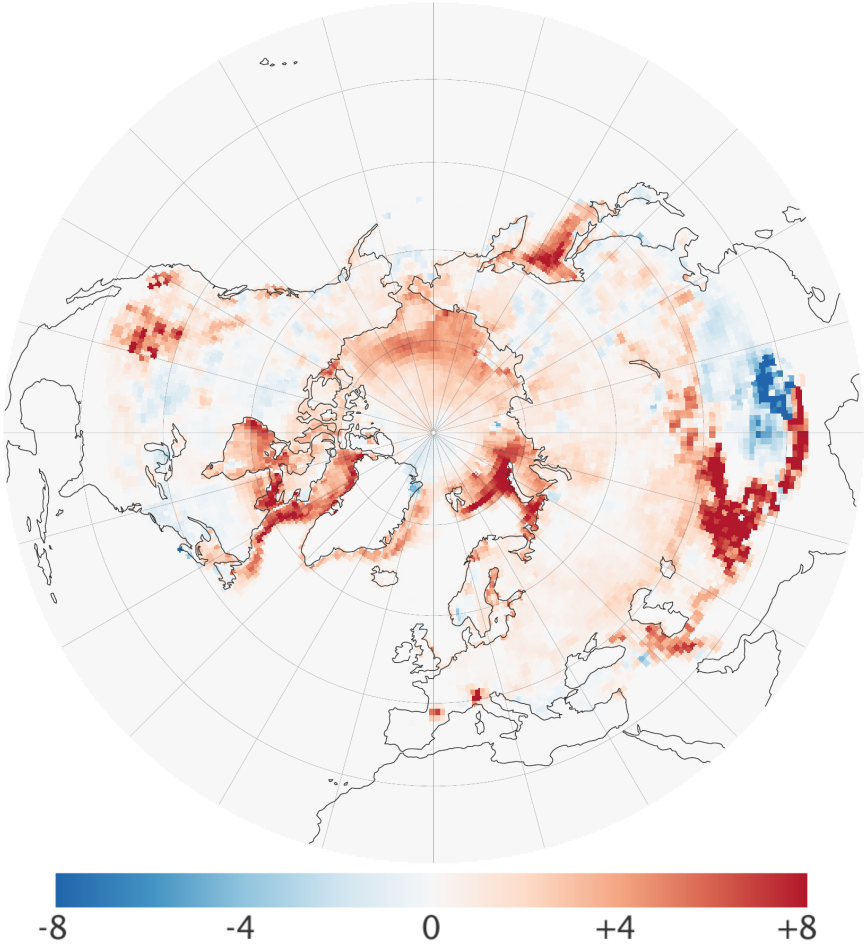

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- 30-year change in sea-ice CrRE: $+0.22\ (0.15 - 0.32)\,\mathrm{W\,m^{-2}}$
- Combined global effect was $\sim 30\%$ as large as the change in CO_2 forcing over the same time period

1979–2008 change in CrRE: Seasonal cycle

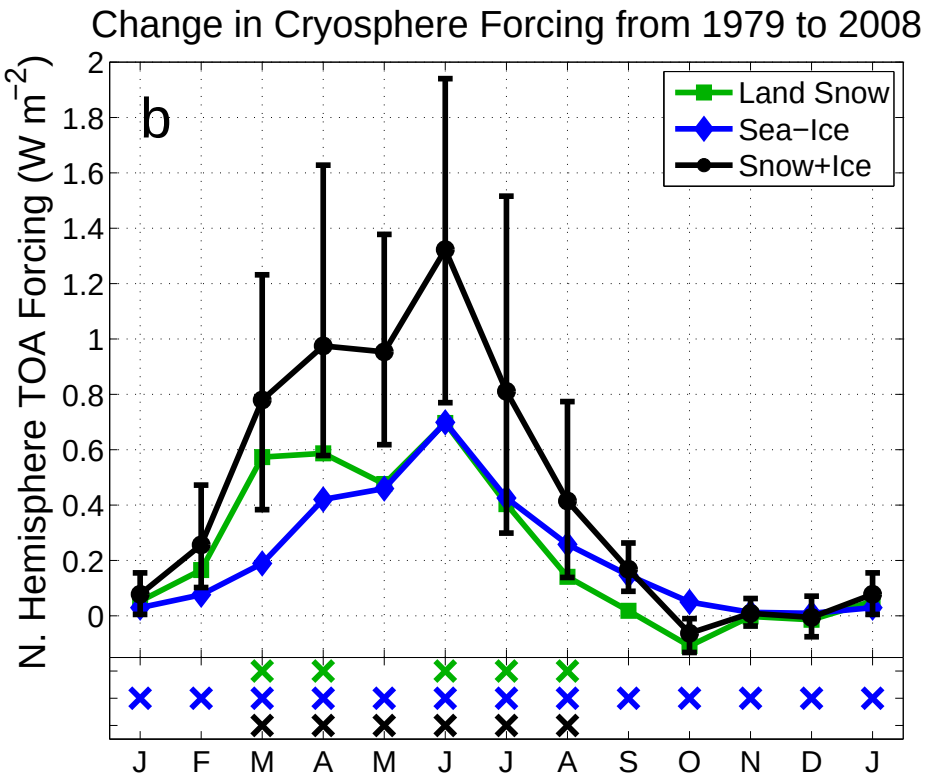

Figure: 'X' indicates month of statistically-significant change ($p = 0.01$). Flanner et al. (2011)

- Peak sea-ice change occurs in **June**

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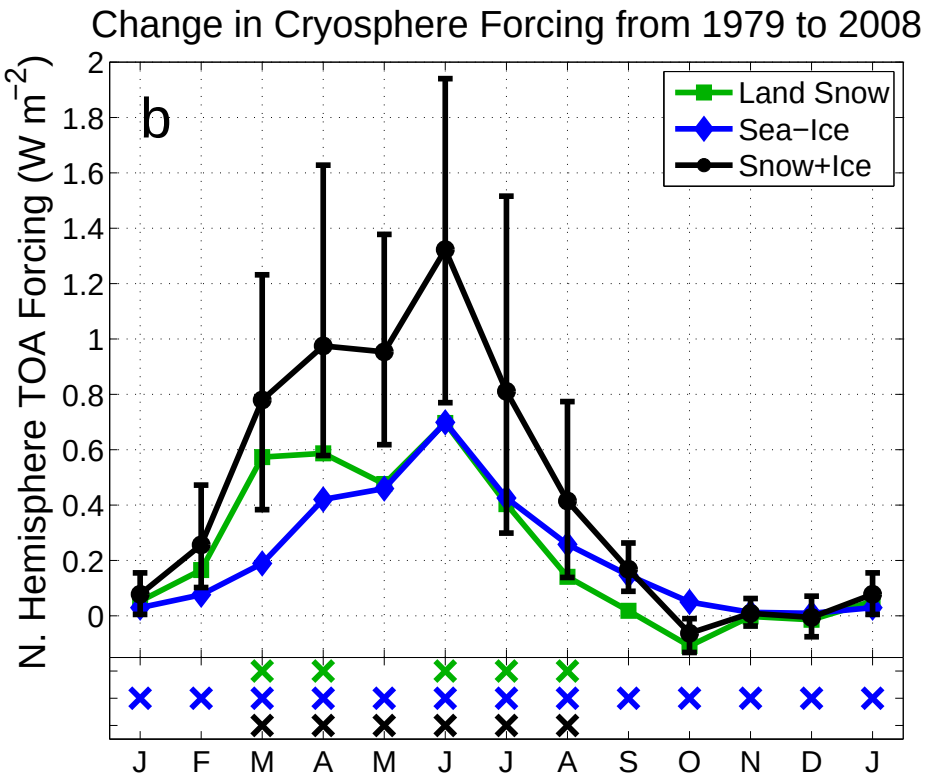

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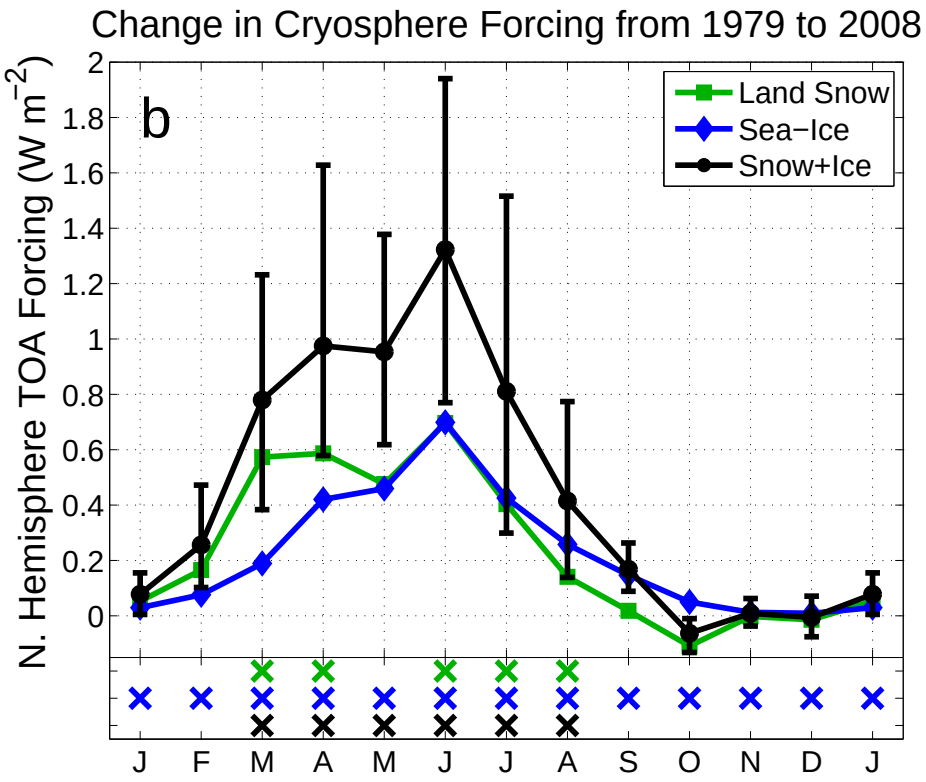

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- Land-snow CrRE changes are significant during March–August
- June peak in land snow change is sensitive to mountain snow cover estimates (Himalaya, Tien Shan)

1979–2011 CrRE change from Arctic sea-ice

- Recently, *Pistone et al.*, (2014, PNAS) derived a larger estimate ($0.43\,\mathrm{W\,m^{-2}}$) of the NH-averaged 1979–2011 change in CrRE due to Arctic sea-ice loss.

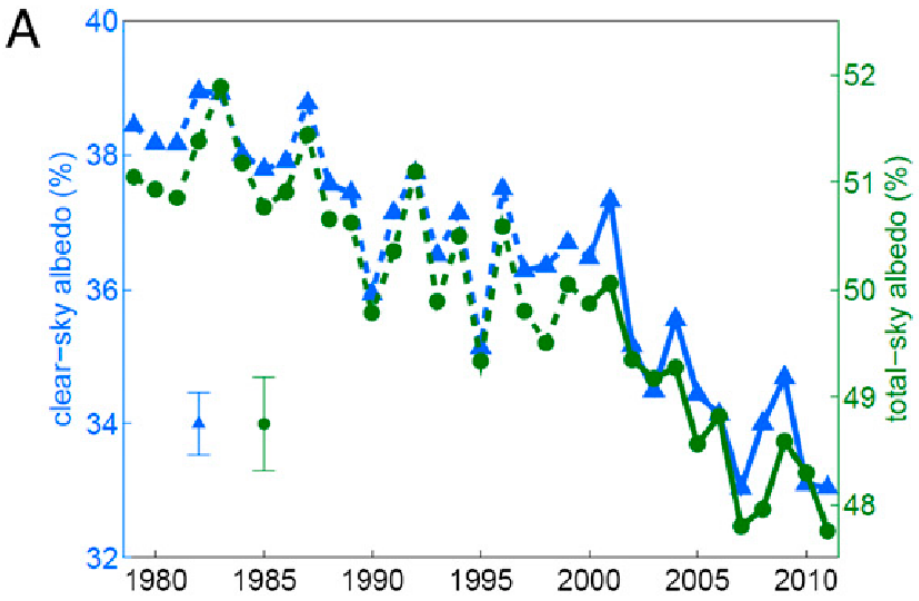


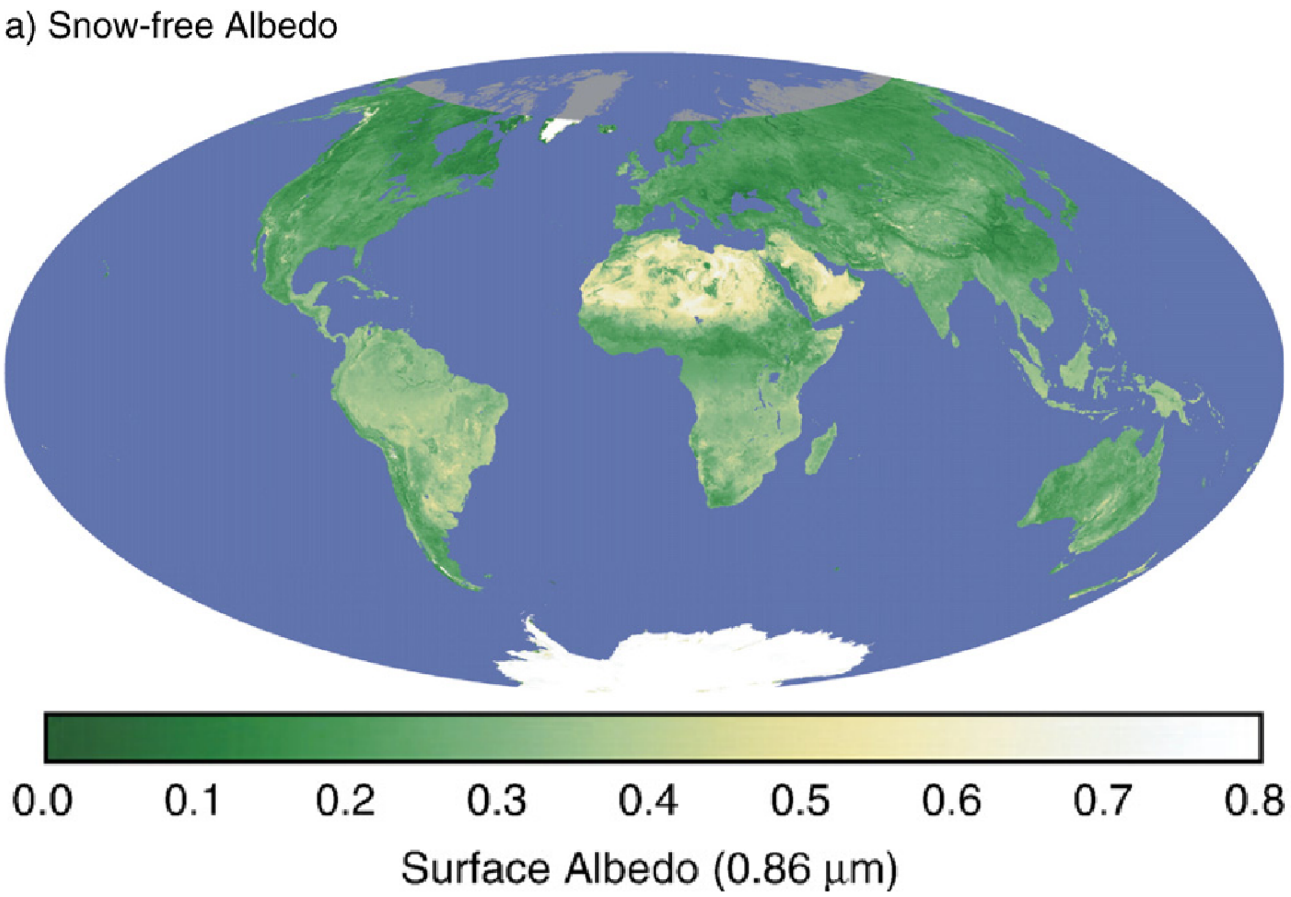
Figure: Pistone et al. (2014)

Work in progress

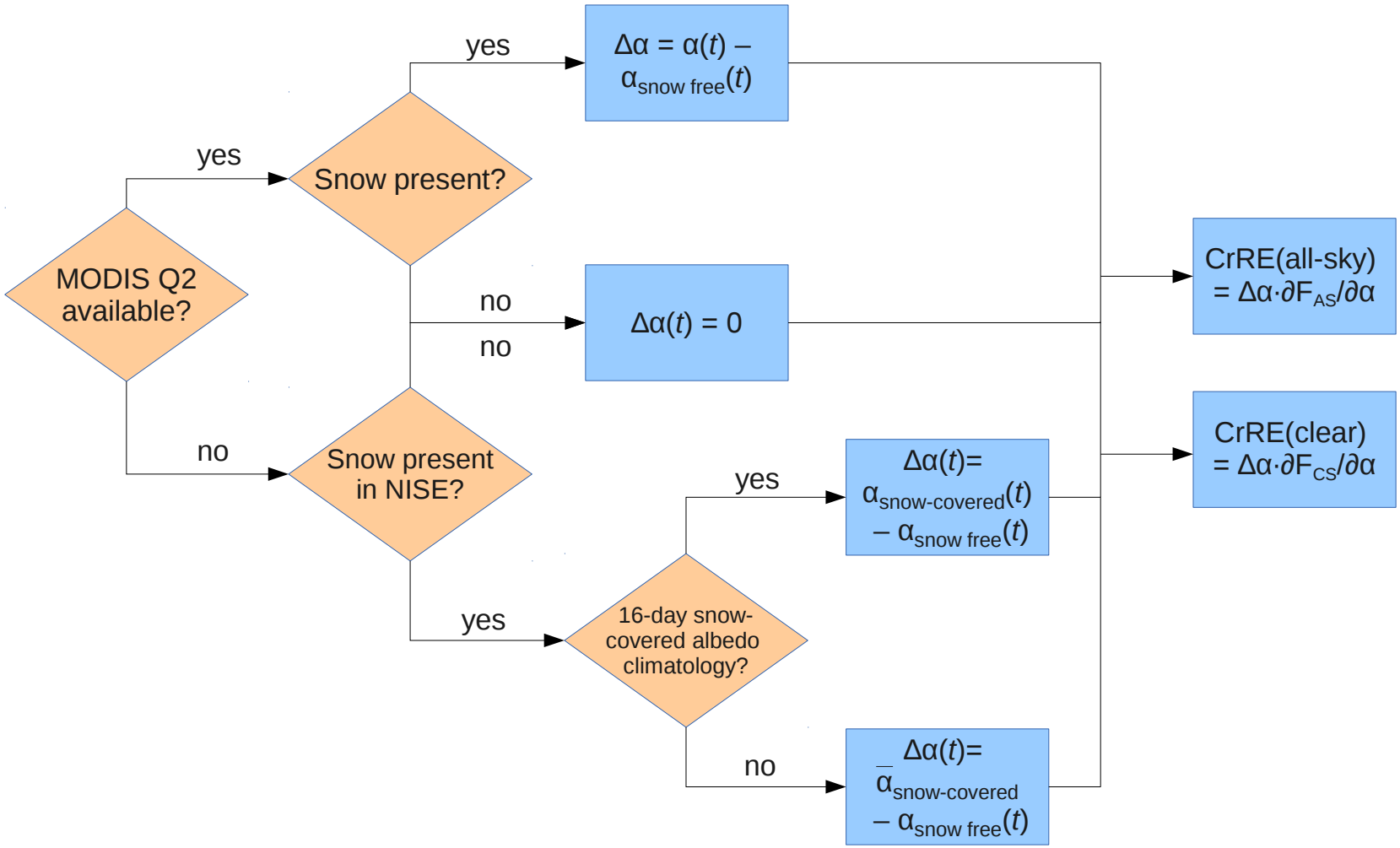
- Phase 1a: Develop 2001–2013 spatially-continuous land-based CrRE from MODIS, NISE, and model-generated radiative kernels
- Phase 1b: Adapt algorithm to accommodate VIIRS data
- Phase 2: Develop algorithm for sea-ice CrRE that accommodates frequent updates

Snow-free albedo

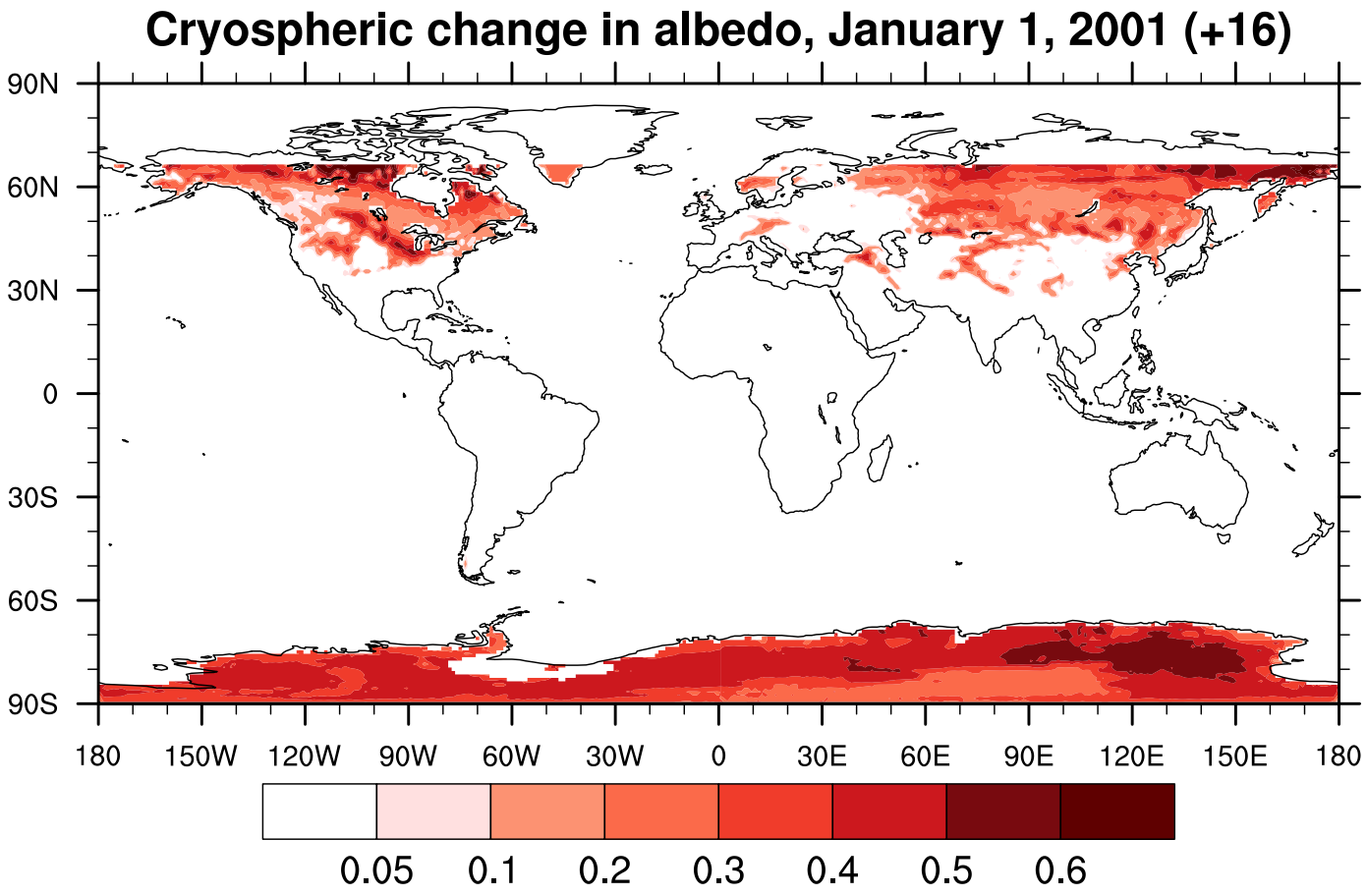
- 16-day snow-free albedo climatologies from *Moody et al.* (2007) serve as baseline (MODIS product MOD43B3).



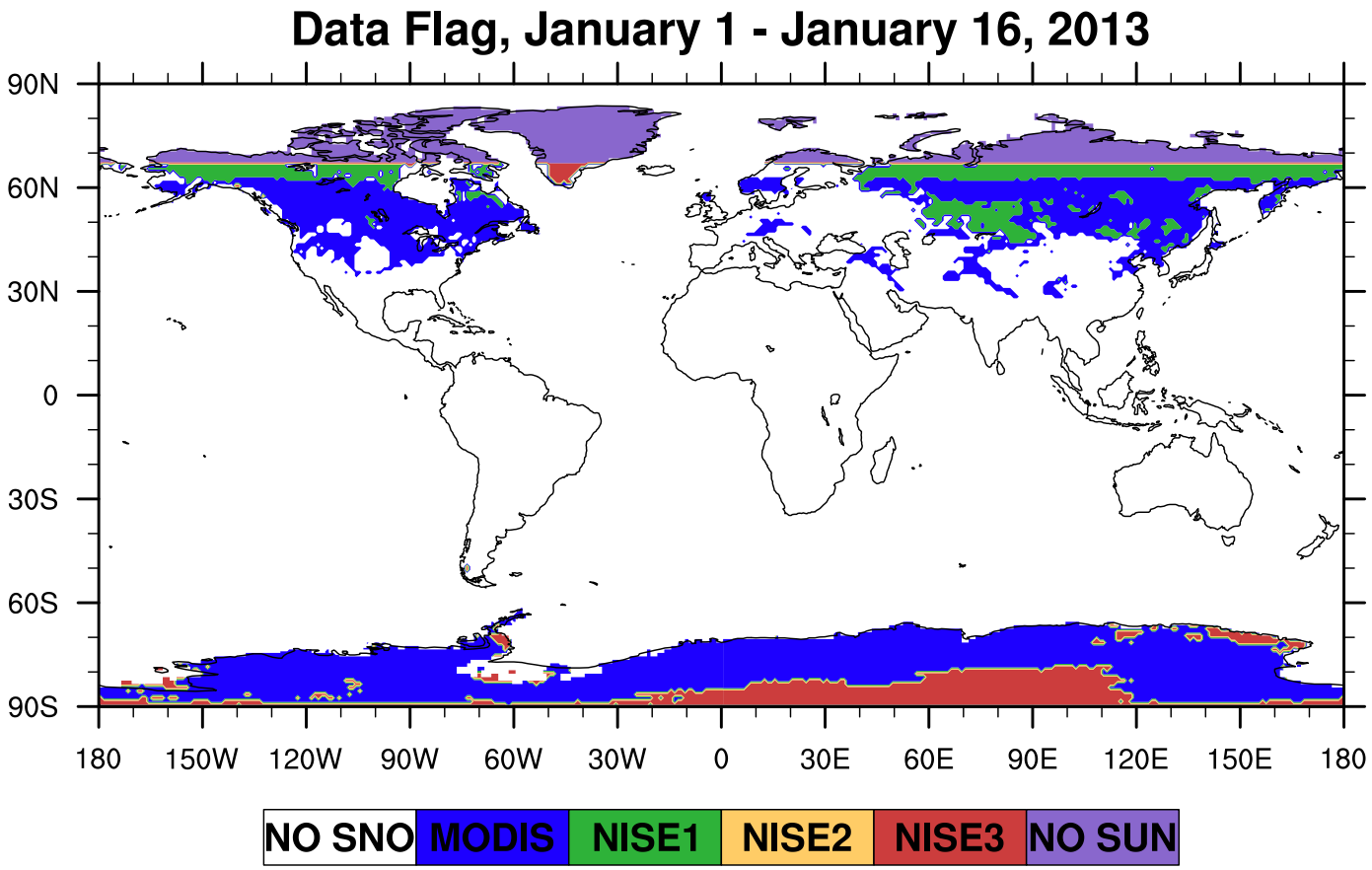
Phase 1a: Algorithm



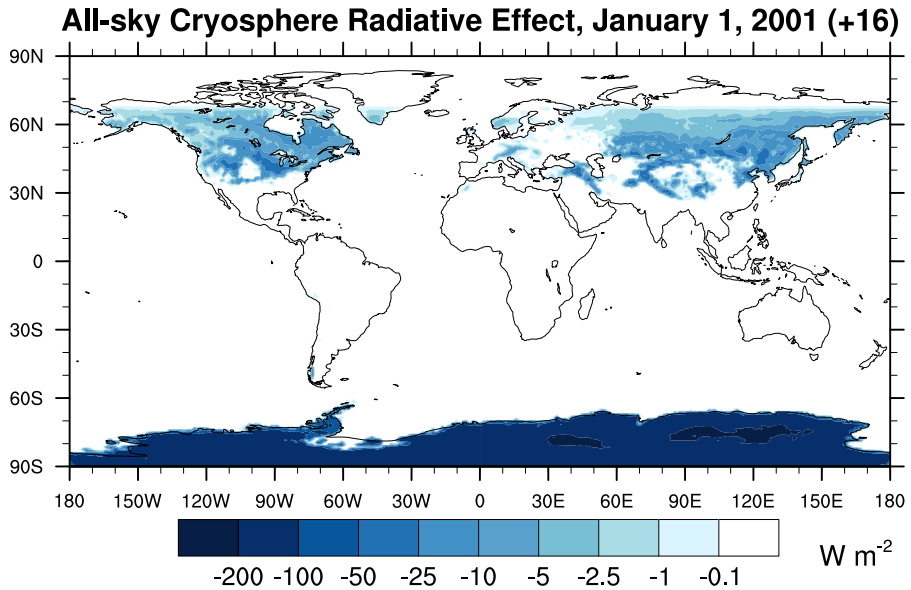
Example: Cryosphere-induced Change in Albedo

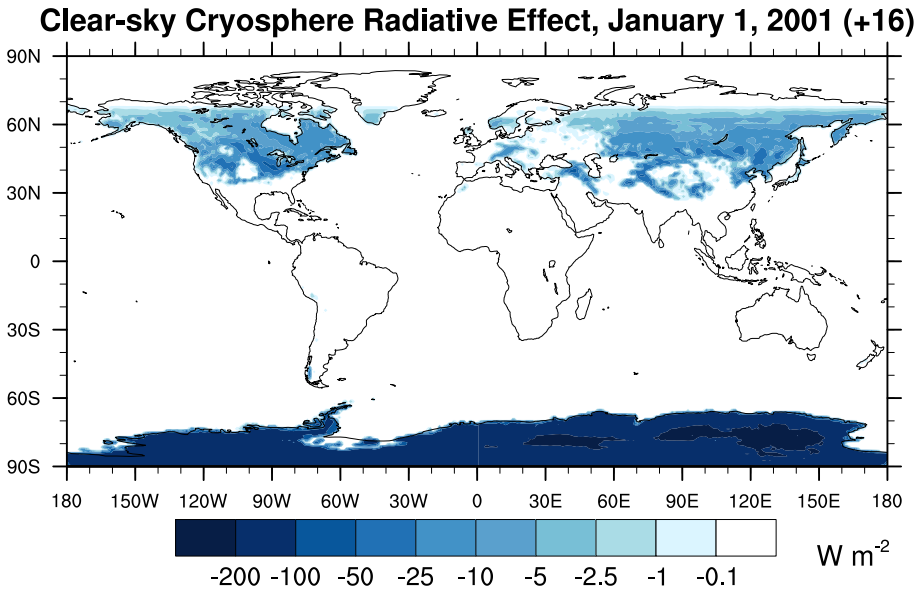


Example: Method used to determine $\Delta\alpha$



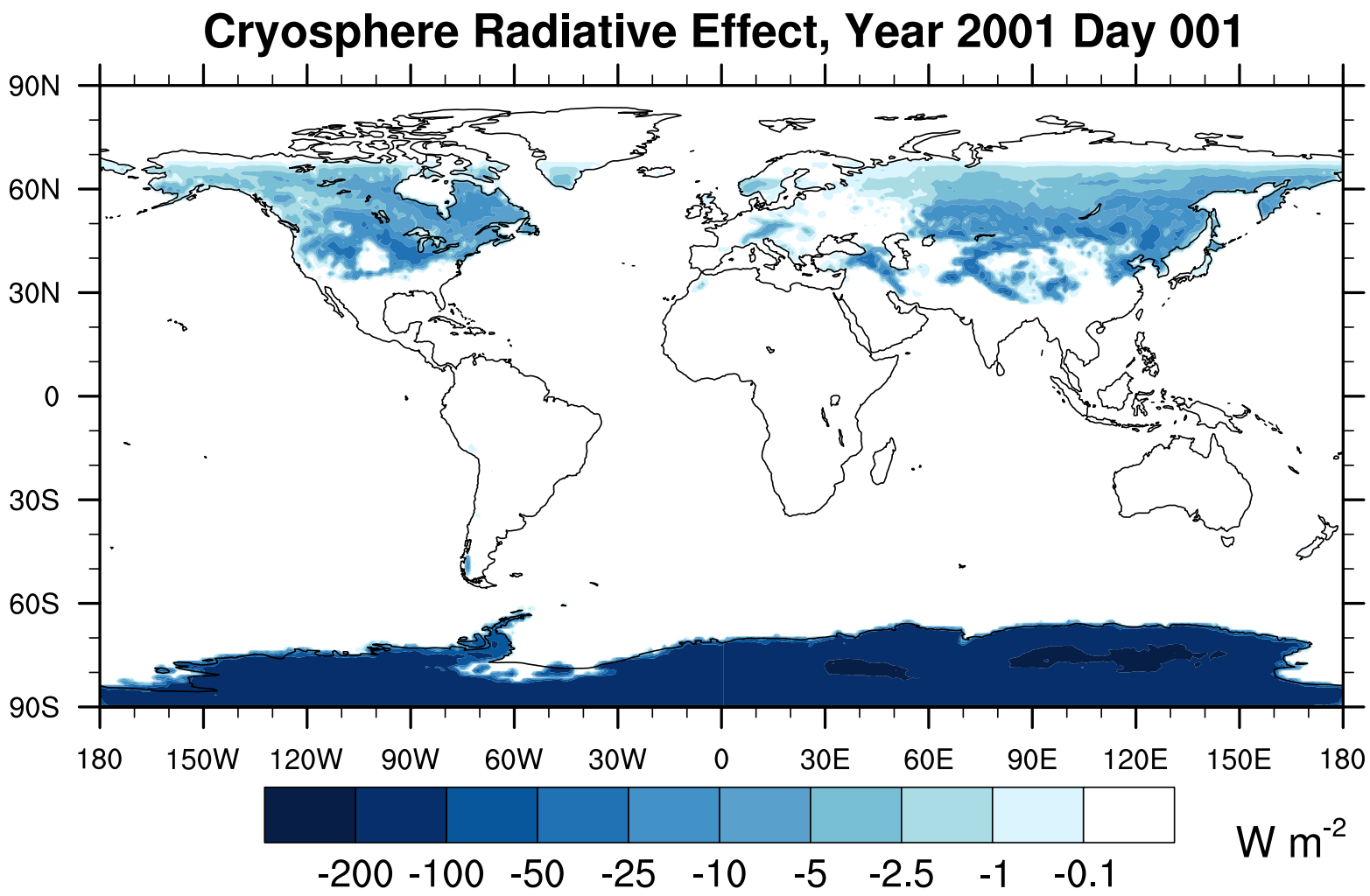
Example: All-sky and clear-sky CrRE



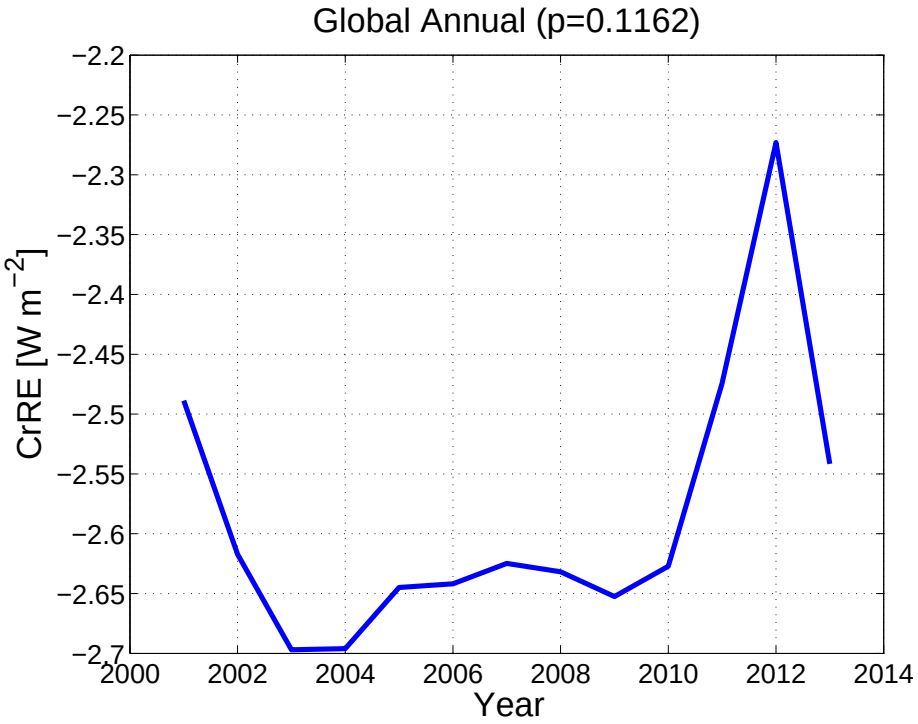


Global-mean: $-4.3\,\mathrm{W\,m^{-2}}$ $-4.7\,\mathrm{W\,m^{-2}}$

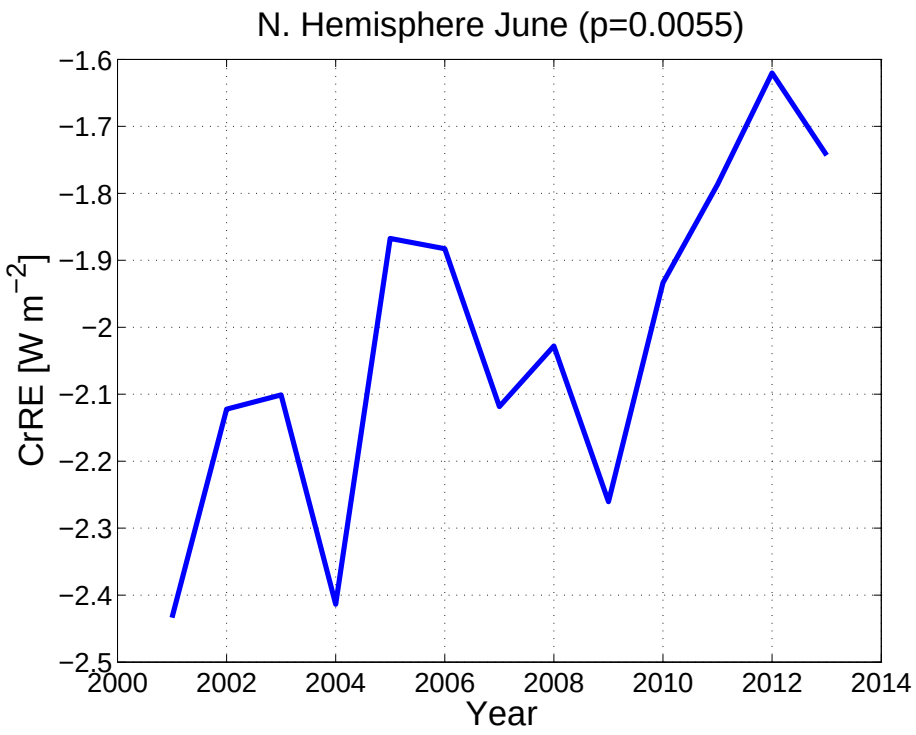
Example: Animated Timeseries of All-sky CrRE

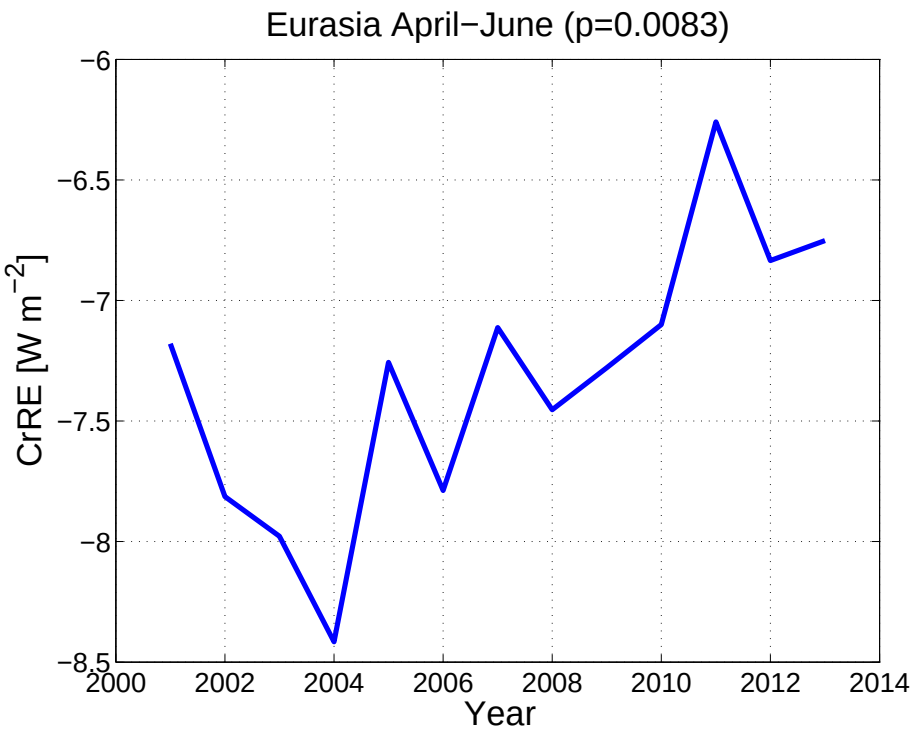


Example: Global annual-mean timeseries



Example: Continental seasonal timeseries





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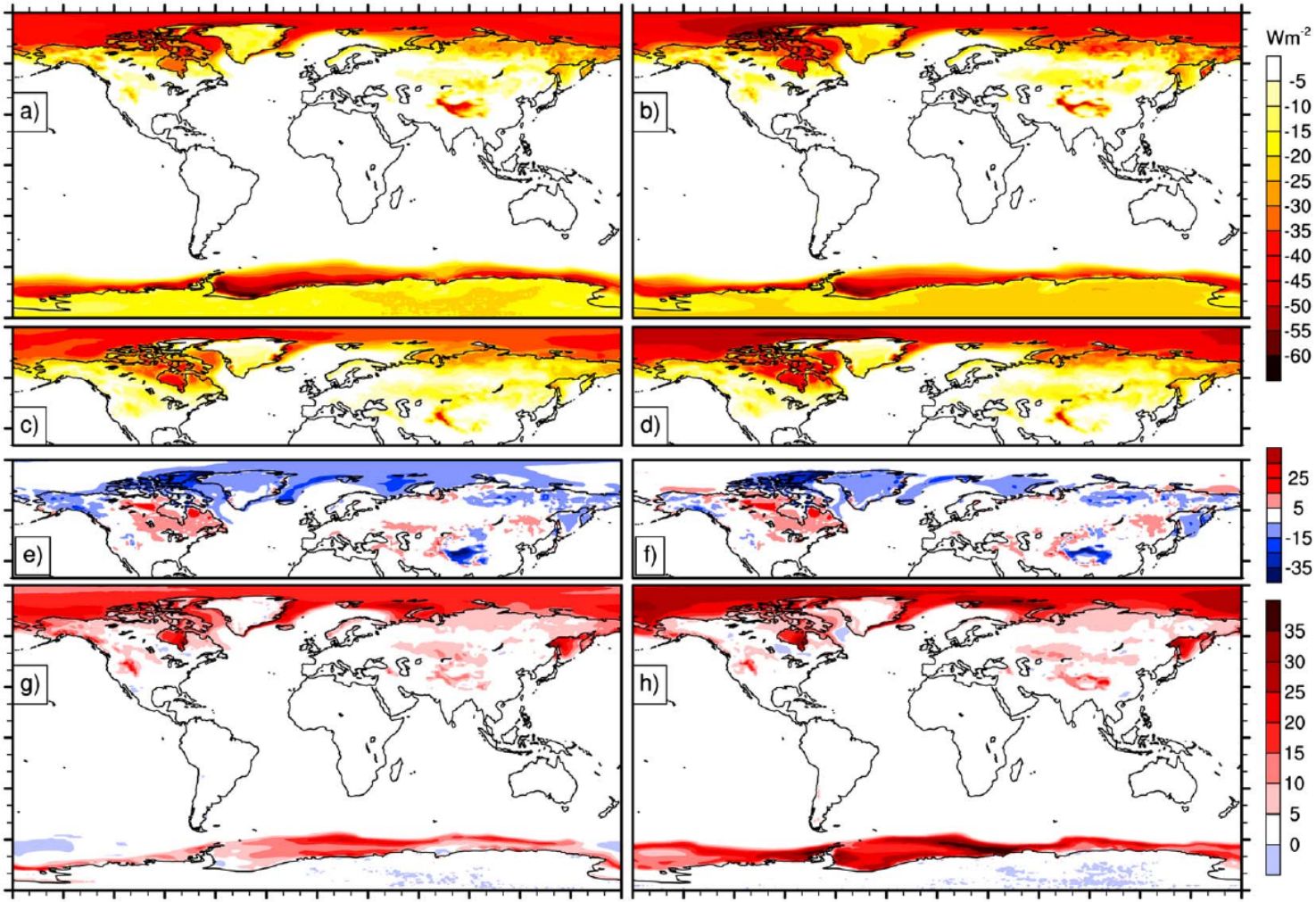
- Produce spatially-averaged timeseries for key regions of interest

Application of observational CrRE



- Evaluation of CrRE in the CESM [*Perket et al*, 2014]