Simulation of Little Ice Age Initiation on Baffin Island Using Paleoclimate Modeling Intercomparison Project (PMIP3) Models

Mira Berdahl[1,2] & Alan Robock[1]

[1]Dept. of Environmental Sciences, Rutgers University, New Brunswick, NJ

[2]Corresponding Author: mberdahl@envsci.rutgers.edu

Abstract

Recent modeling efforts have suggested that the Little Ice Age (LIA) could have been caused by four decadally-paced volcanic eruptions in the late 13th century CE. These results corroborate geological evidence collected on Baffin Island in the Canadian Arctic which shows a sudden snow line elevation change of several hundred meters in a matter of decades during the same time frame. The modeling results, however, were very sensitive to the conditions of the North Atlantic Ocean when the eruptions took place. Thus, we investigate whether any of four PMIP3 Last Millennium simulations produced enough cooling and a sudden enough change in snow line elevation to match the observations from Baffin Island. We compare the amplitude of cooling, snow cover and sea ice expansion, and circulation patterns after these eruptions and during the transition into the LIA between models.

Past Millennium Experiment

The models are run 850–1850 CE, with boundary conditions prescribed by the PMIP3. The following global climate models were available and used:

- Beijing Climate Model (BCC)
- Community Climate System Model Version 4 (CCSM4)
- Goddard Institute for Space Studies (GISS) ModelE
- Max Planck Institute (MPI)

Proxy Data

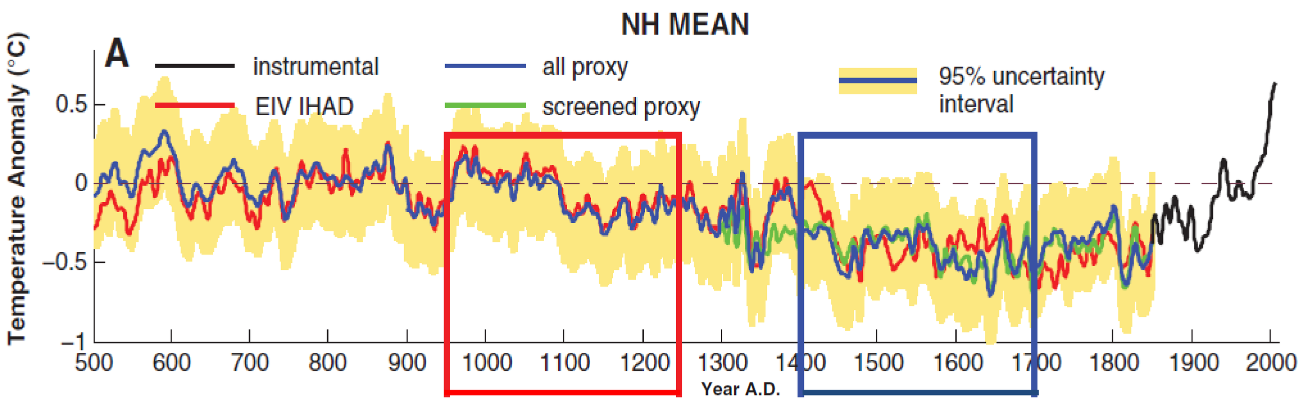

Figure 1. Decadal surface reconstructions averaged over Northern Hemisphere (NH). Red and blue boxes define the Medieval Climate Anomaly (MCA) and LIA. Anomaly with respect to 1961-1990 mean. Figure from *Mann et al.* (2009).

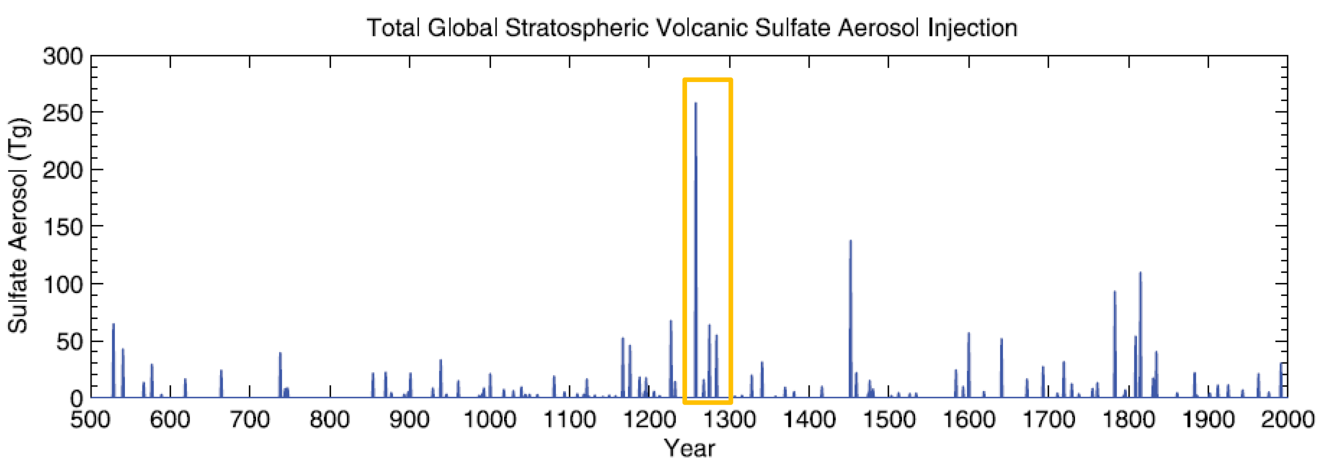

Figure 2. Annual global stratospheric volcanic sulfate aerosol injection derived from 54 Arctic and Antarctic ice cores. Highlighted eruptions in orange show the 1258/Rinjani super eruption followed by 3 successive decadally-paced eruptions. Figure from *Gao et al.* (2008).

Time Series Results

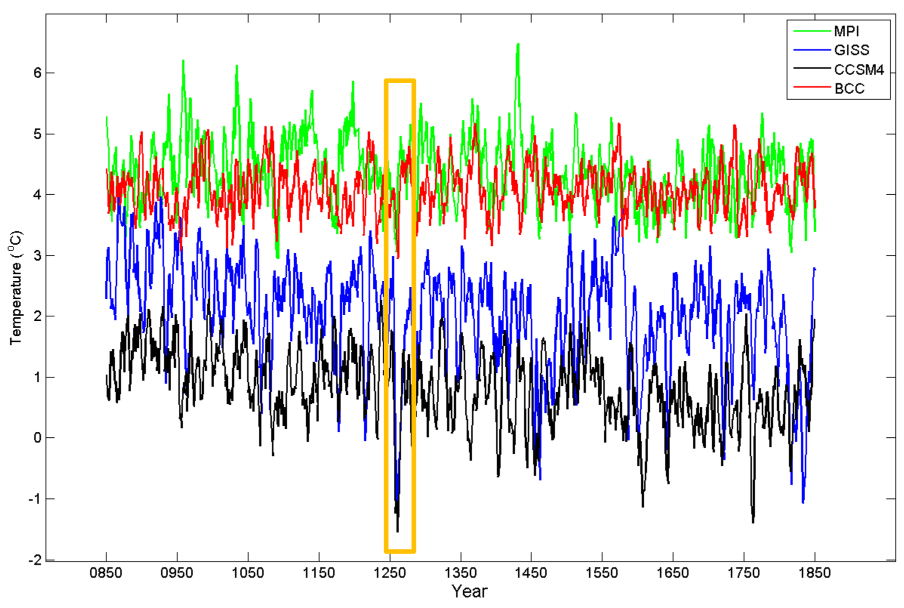

Figure 3. Five year running mean of June-July-August (JJA) Baffin Island temperature on land only. Large model biases are evident. Only GISS and CCSM4 show significant effects below freezing after Rinjani (1258) eruption.

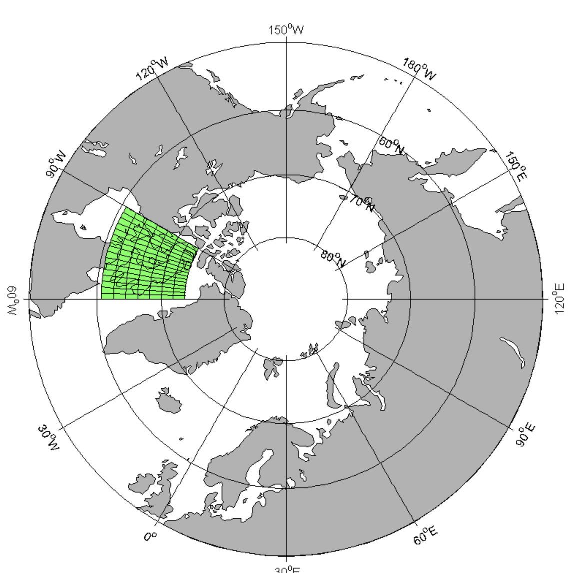

Figure 4. Domain extracted over Baffin Island shown in green.

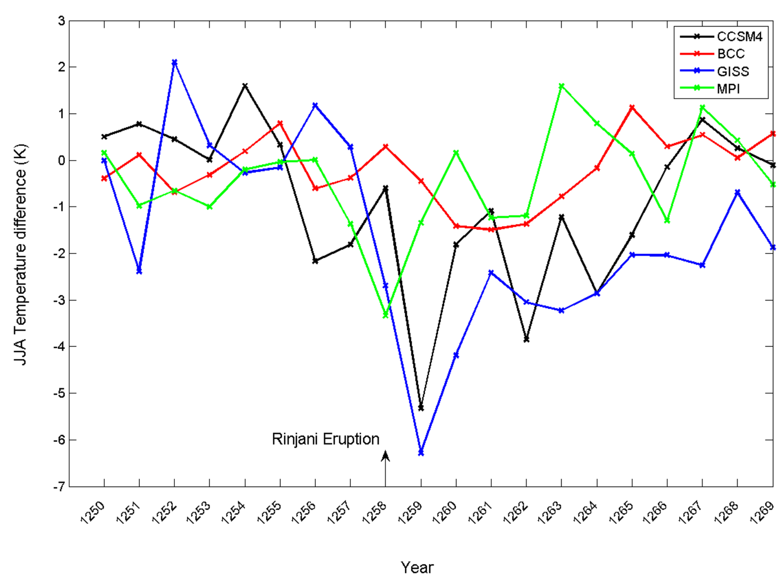

Figure 5. JJA Baffin Island land temperature after Rinjani (1258) eruption with respect to MCA mean. GISS and CCSM4 show the strongest response.

Hemispheric Results

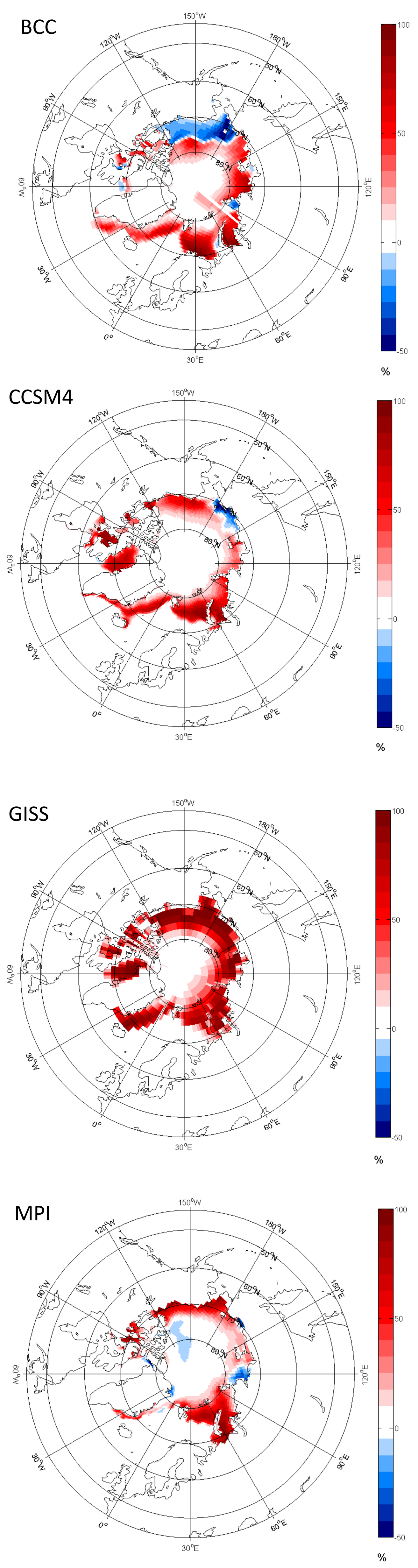

Figure 6. Sea ice concentration change between the maximum September extent after Rinjani and MCA September (minimum) average.

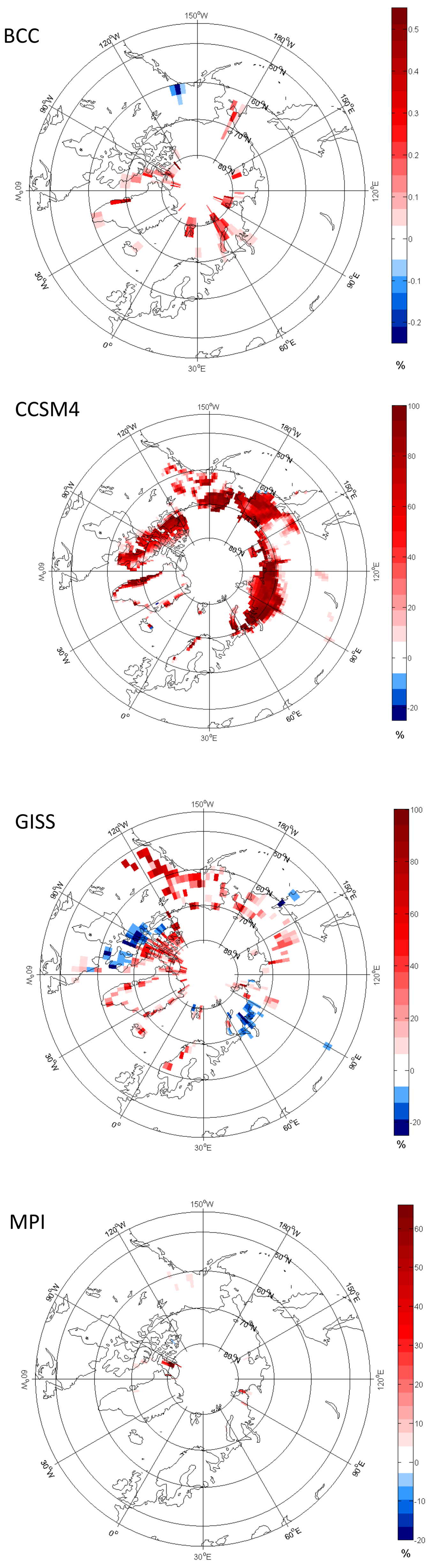

Figure 7. Snow cover concentration change between the maximum September extent after Rinjani and MCA July (minimum) average.

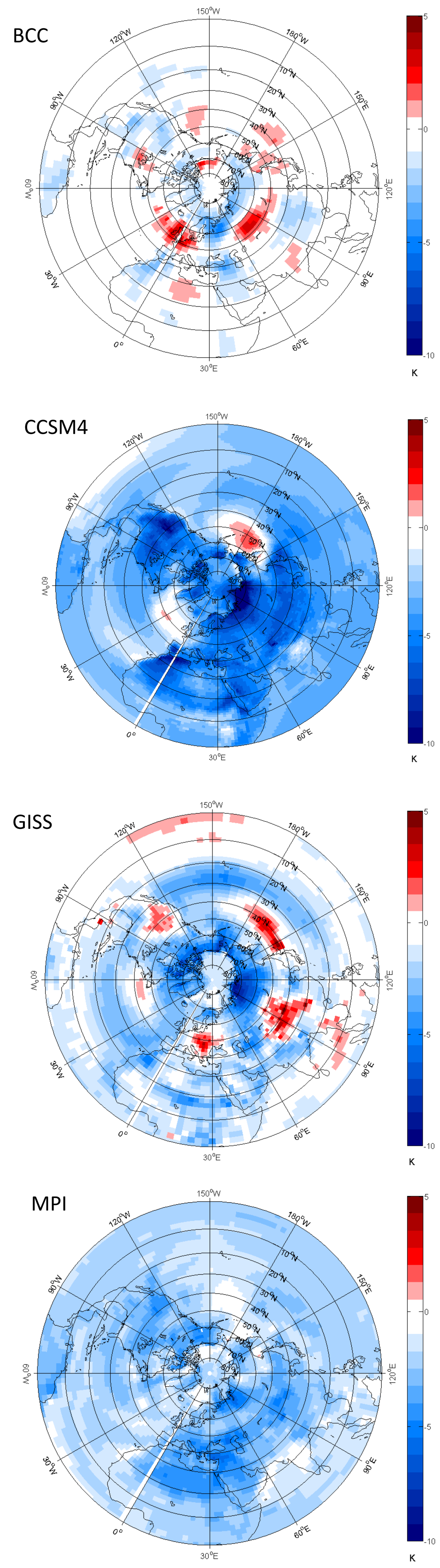

Figure 8. JJA Temperature difference between MCA average and the maximum cooling achieved after Rinjani eruption. Negative values show cooling after the eruption.

Conclusions

- The PMIP3 models available for the past millennium simulation do not produce obvious MCA or LIA periods similar to that seen in the *Mann et al.* proxy reconstructions.
- The JJA temperature change on Baffin Island after Rinjani ranges from about -6 K to -1 K, depending on the model.
- GISS and CCSM4 models show the greatest cooling, largest sea ice expansion in the Baffin area and greatest increase in minimum snow cover on Baffin Island following the Rinjani eruption.

References

Gao, C., A. Robock, and C. Ammann (2008), Volcanic forcing of climate over the past 1500 years: An improved ice core-based index for climate models, *JGR, 113,* D23111, doi: 10.1029/2008JD010239.

Mann, M., et al. (2009), Global signatures and dynamical origins of the Little Ice Age and Medieval Climate Anomaly, *Science*, vol. 326, 1256-1260, doi: 10.1126/science.1177303.