NCAR Earth System Laboratory

CCSM4 Last Millennium and proxy comparisons

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CCSM4 Last Millennium – data comparison

- *Background (brief!)*

Model-proxy comparisons:

- *850-2005 CE temperature record*
- *Medieval Climate Anomaly (950-1250 CE) into the Little Ice Age (1450-1750 CE)*
- *Response to Volcanoes*
- *Modes of Variability (PDO, ENSO, AMO and NAO)*

CCSM4 Last Millennium Background (brief!)

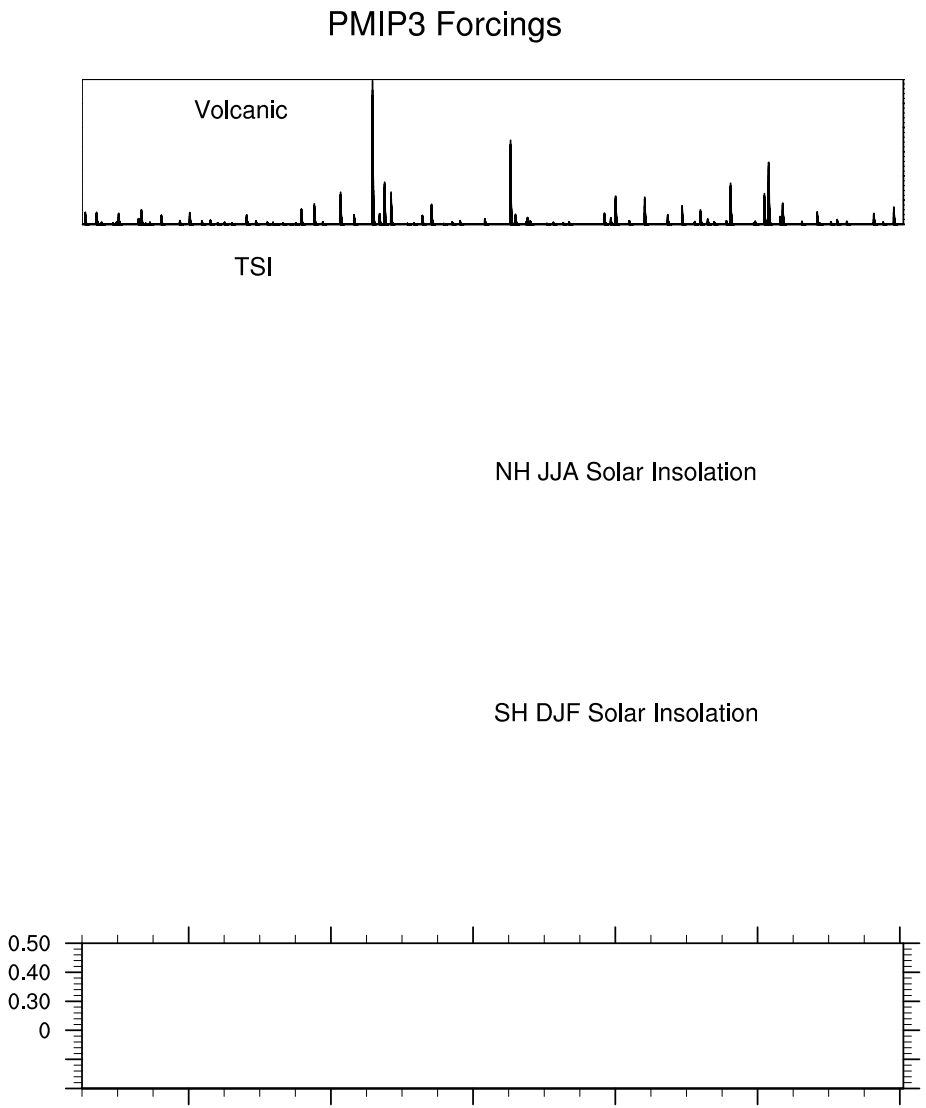
- *part of the IPCC CMIP5/PMIP3*
- *Community Climate System Model version 4 - fully coupled atmosphere, ocean, sea-ice, land model at nominal 1˚ resolution*
- *Forcings per PMIP3 protocols, and merged with those used in CCSM4 CMIP5 20th Century runs (with exception of orbital parameter)*

LM prescribed forcings

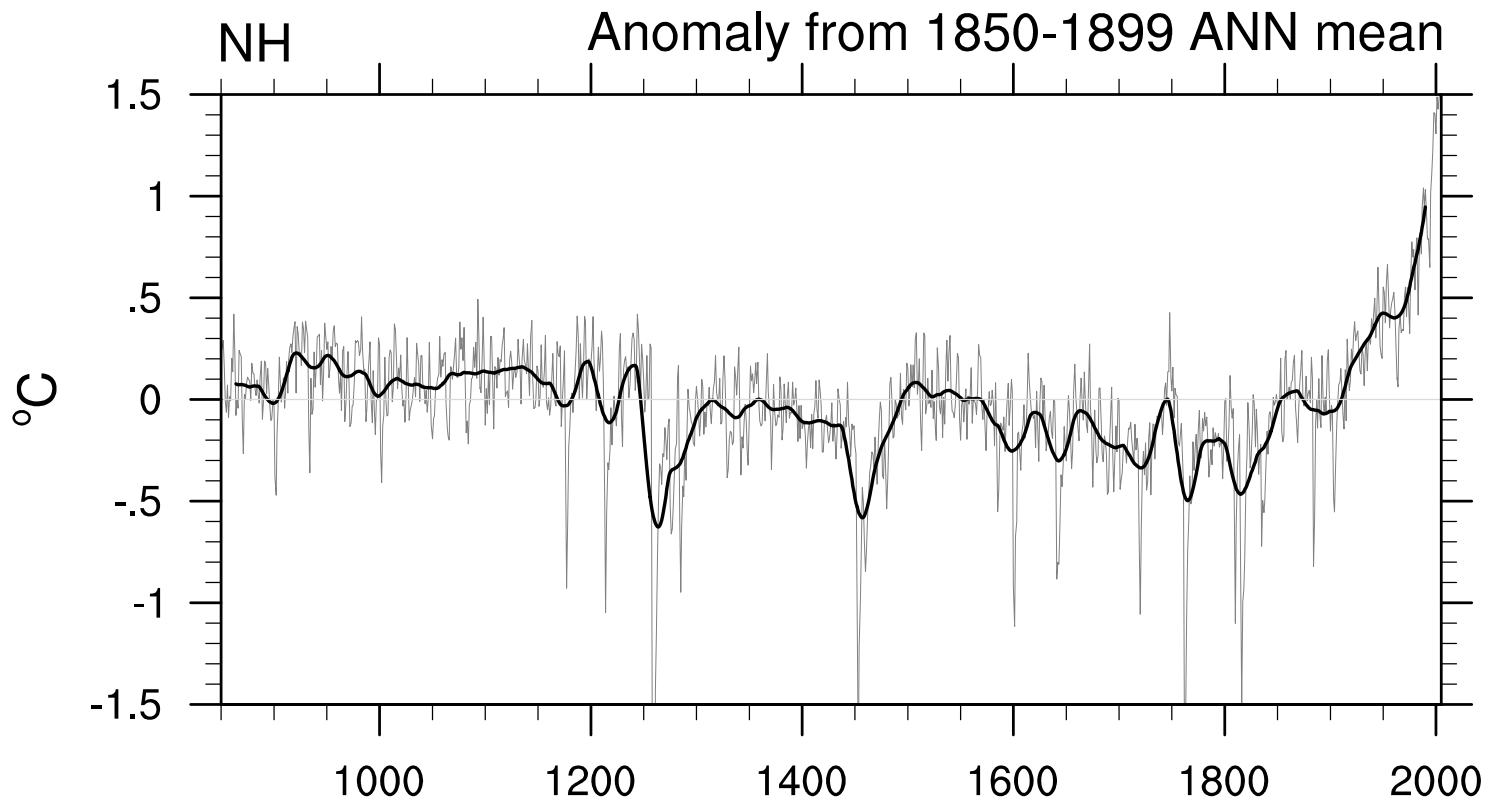
- forcings and boundary conditions follow the protocols of PMIP3 (Schmidt et al., 2011)

[https://pmip3.lsce.ipsl.fr/wiki/doku.php/pmip3:design:lm:final]

- Two LM extensions to 2005: both adopt the same time-dependent datasets as the CCSM4 20th century simulations; one includes variations in incoming solar radiation due to orbital variations, (not standard CMIP5).



850-2005 NH Temperature record



- Annual values in light grey; 30-year Gaussian smoothed in heavy black
- Cooling ~0.5˚ C 850-1800
- Steep warming ~1.5˚ C, 1850-2005 (~1.4˚ C in 20th C)
- Strong cooling with large volcanic events

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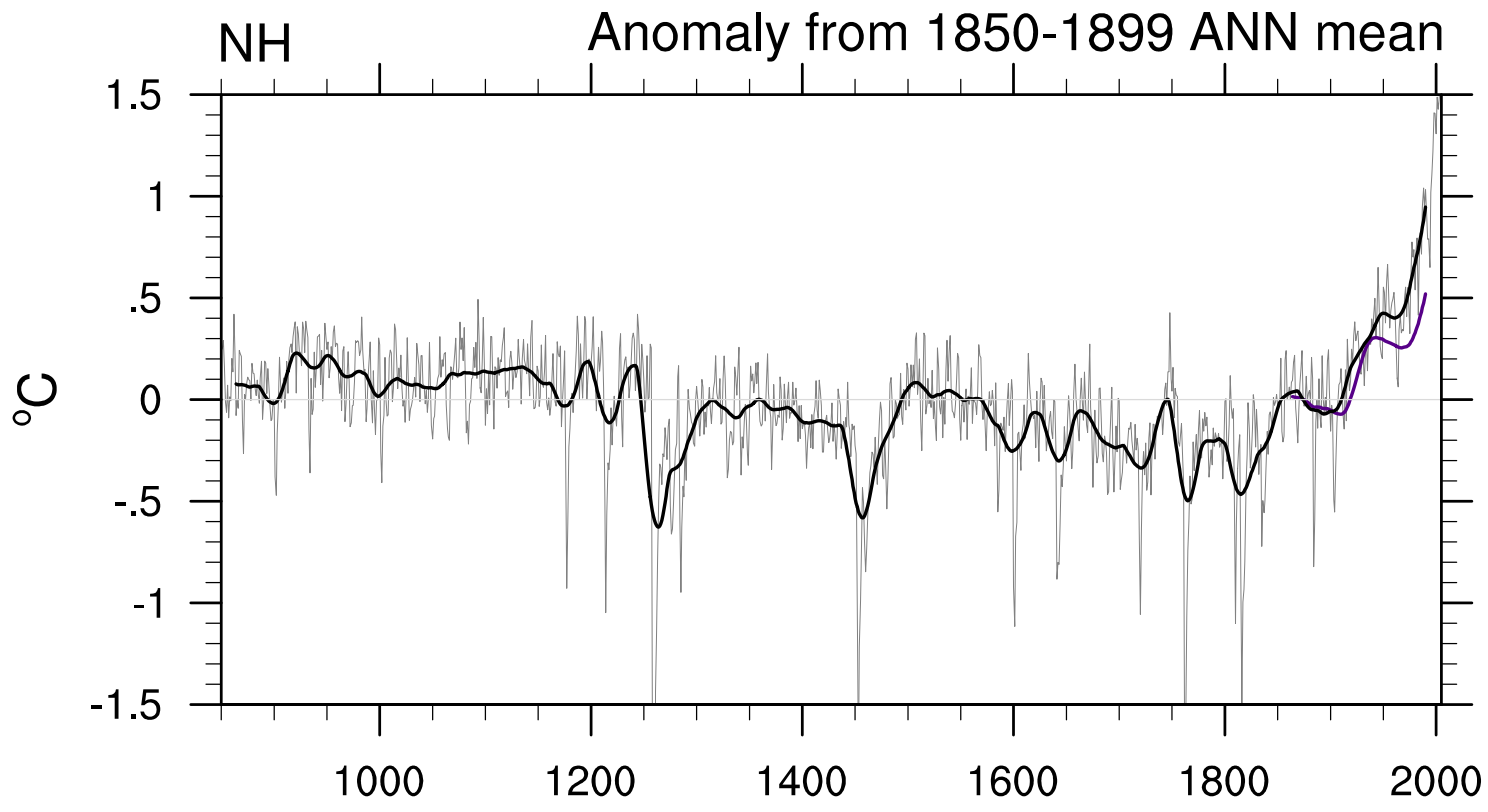

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- 20thC warming exceeds instrumental record

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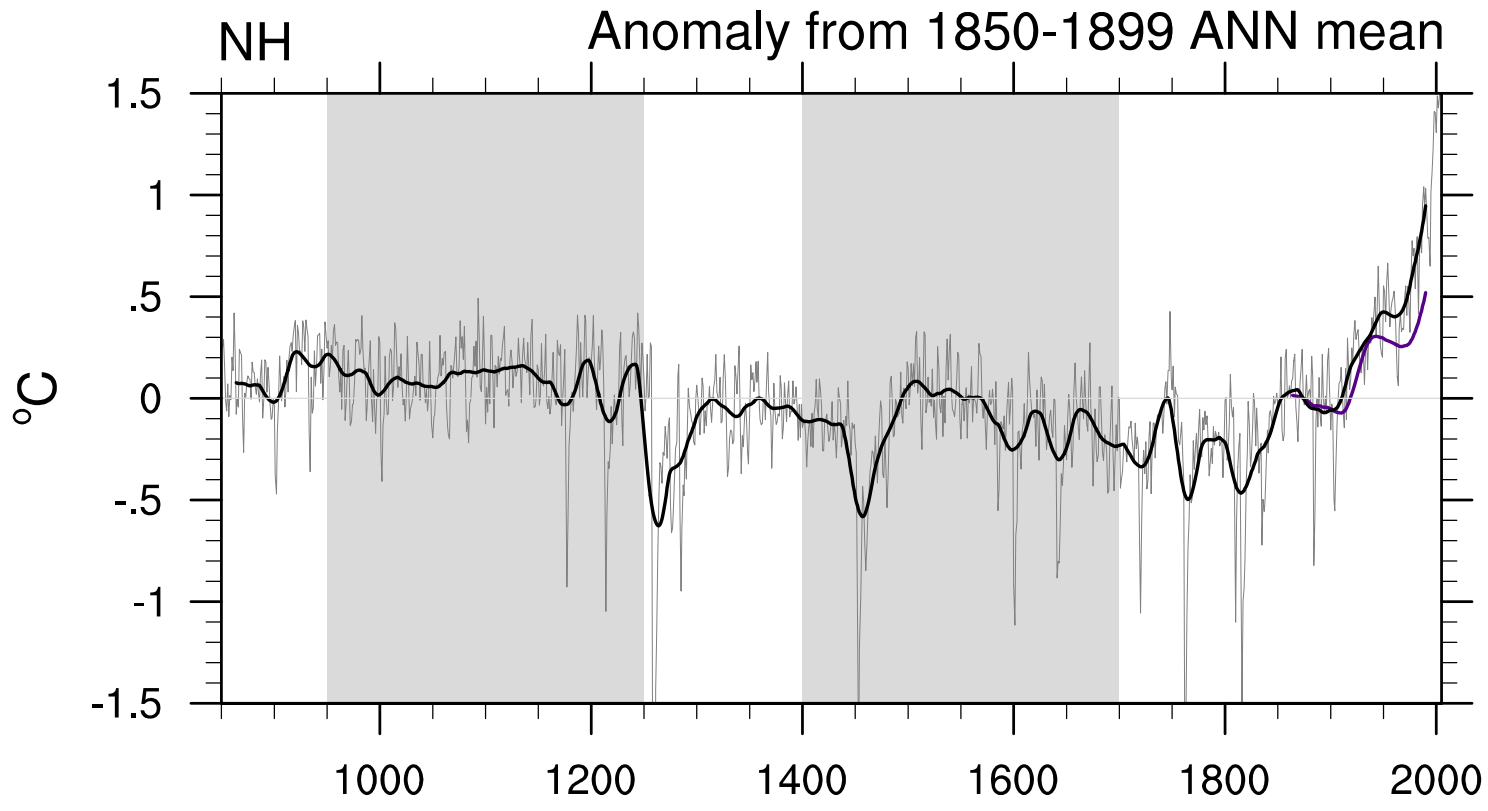

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- LM warmer during MCA (950-1250 CE) than LIA (1450-1750 CE)

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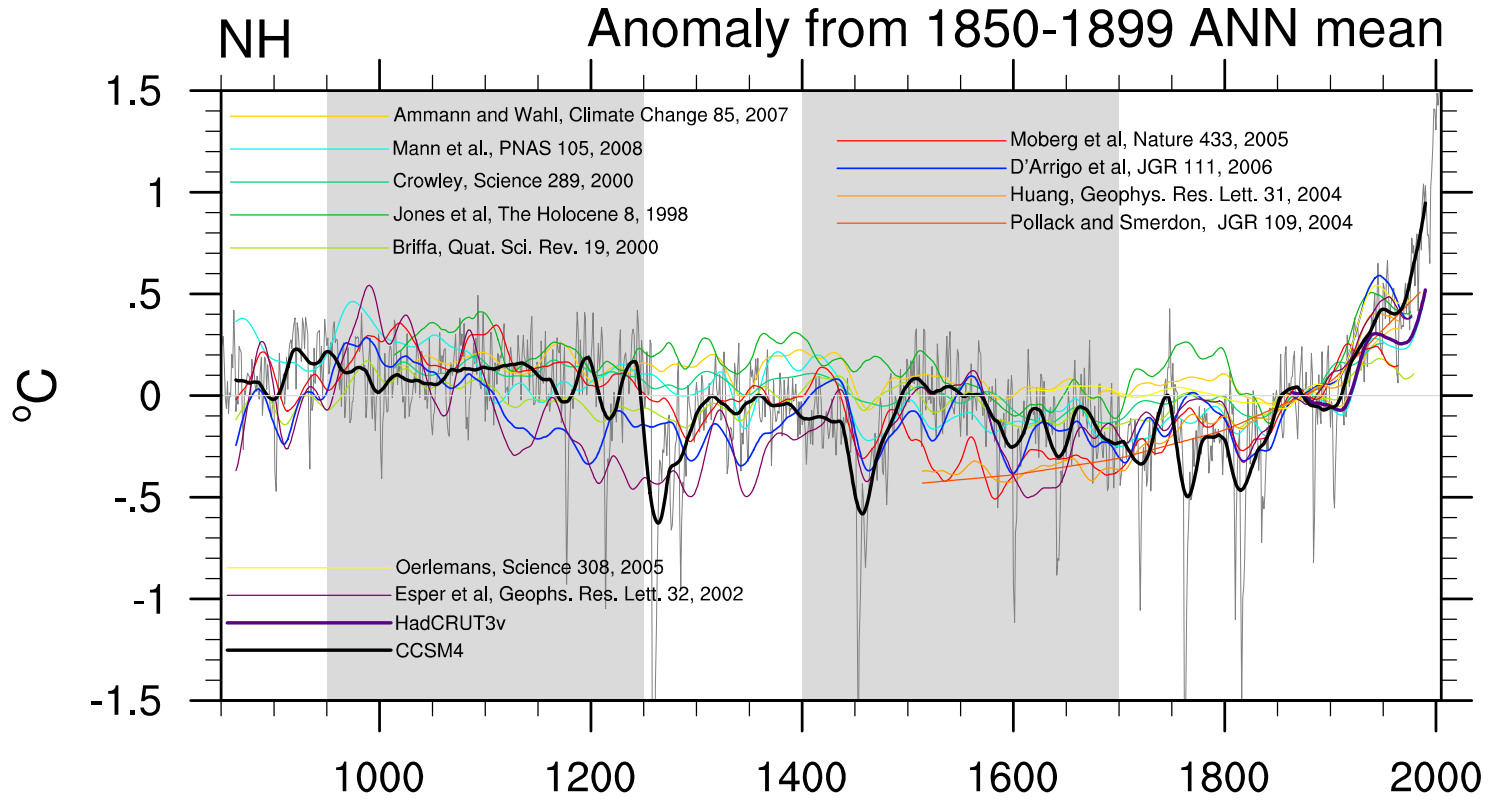

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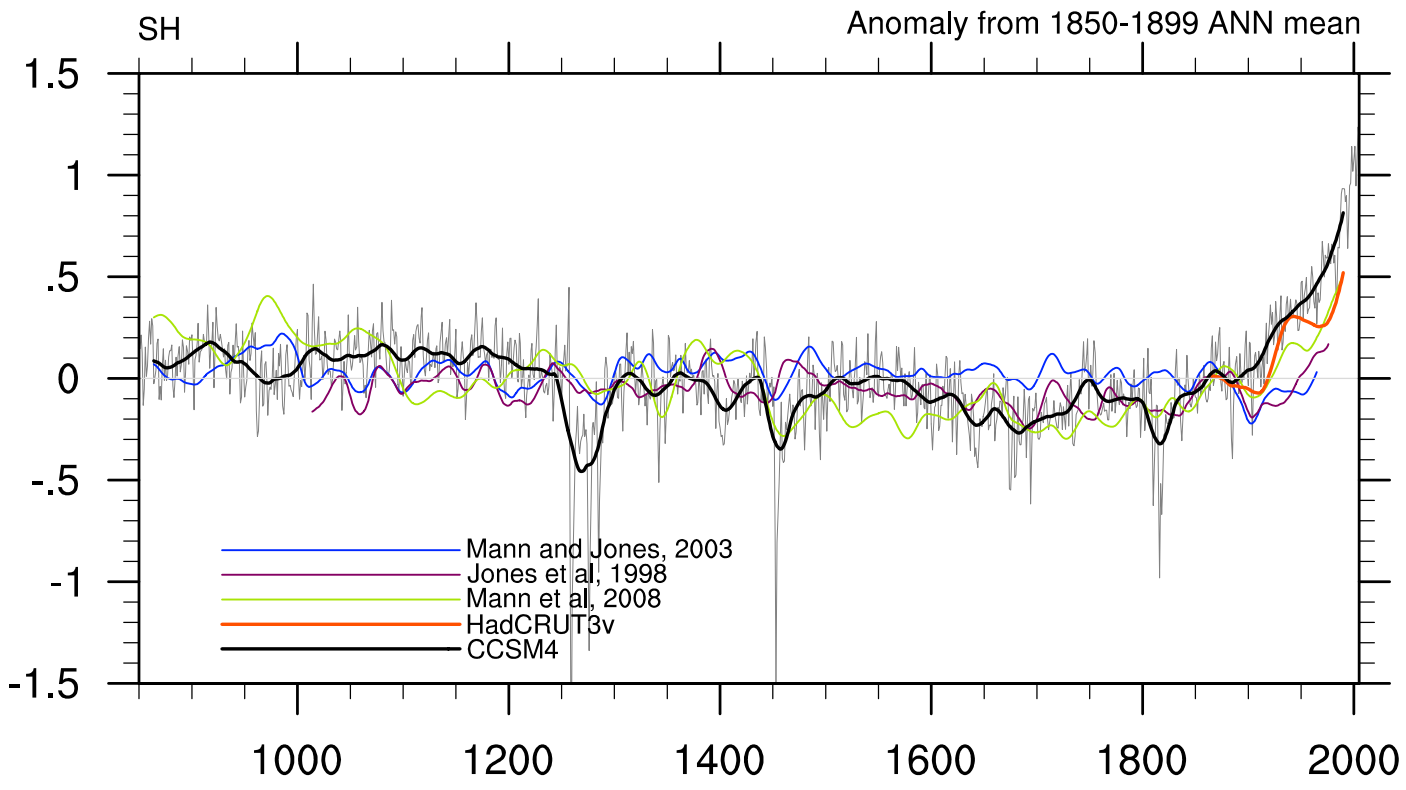
- 20thC warming exceeds instrumental record
- Strong cooling with large volcanic events
- LM warmer during MCA (950-1250 CE) than LIA (1450-1750 CE)
- Large range in proxy records, particularly 1200-1450 CE

SH Temperature records



- Less cooling (~0.3˚ C 850-1800) than NH
- Steep warming ~1.2˚ C, 1850-2005, which exceeds instrumental record
- Cooling response to large volcanic events smaller than in NH
- Reasonable agreement with smaller # of proxy records

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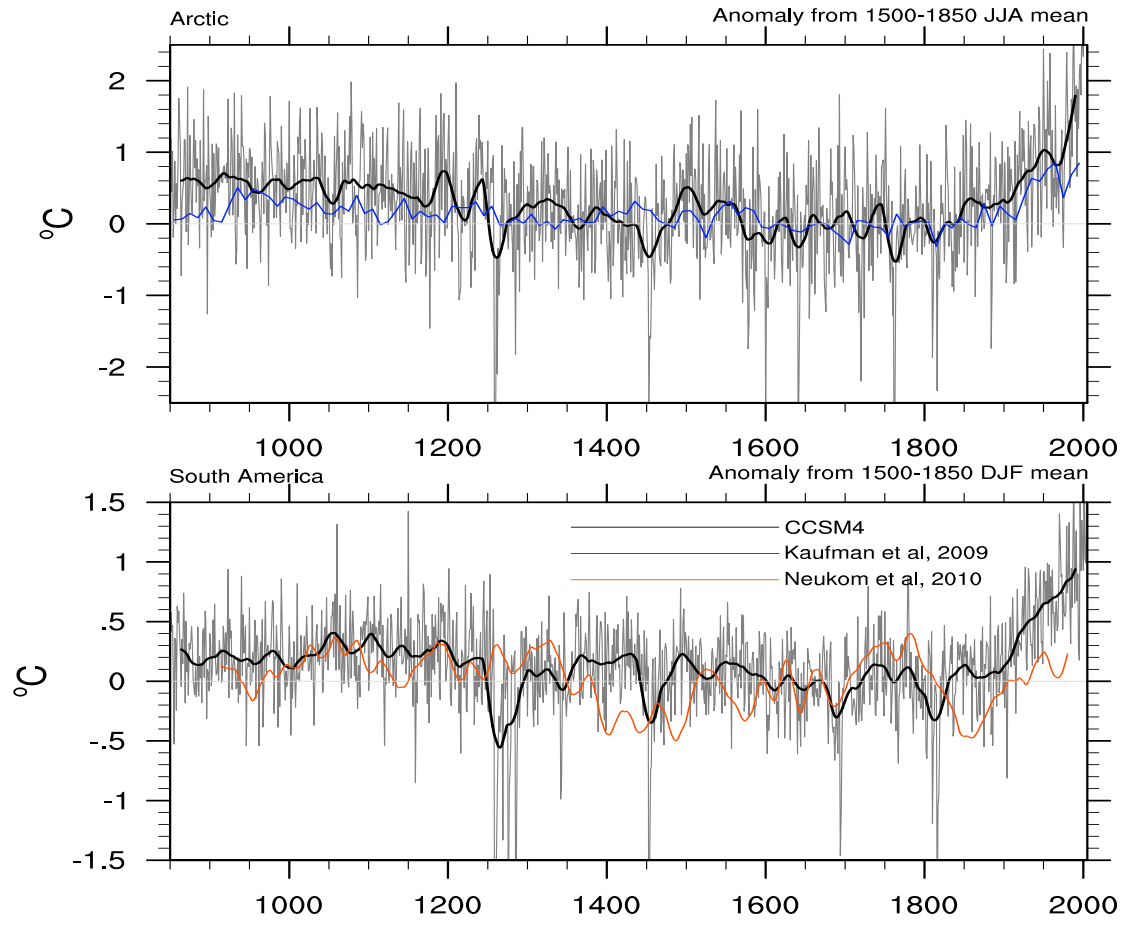
Land Temperature records: Arctic and South America



- Kaufman inferred long-term cooling in NH to 19th C due to insolation (orbital: decreased boreal summer insolation) – supported by LM simulation
- LM warmer in 20th C in both Arctic and S. American regions than proxies
- Less coherence in S. American regional record than overall SH between LM and proxy record
- South American record (Neukom et al., 2010) – spatially limited 20° -55° S; 30° -80° W

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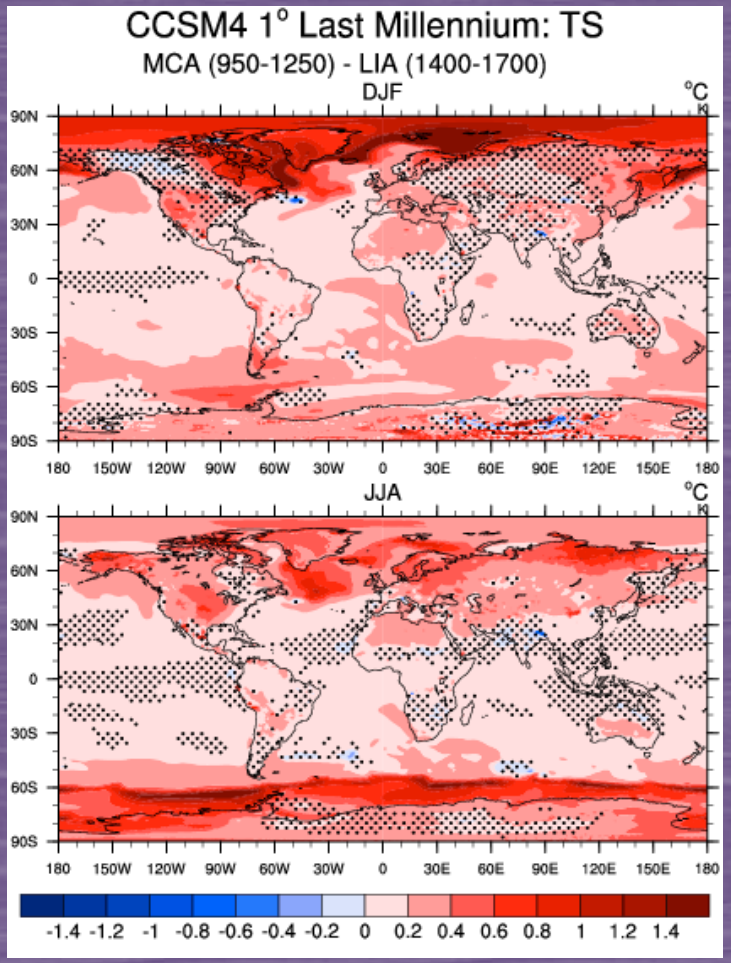
Medieval Climate Anomaly (950-1250 CE) into the Little Ice Age (1450-1750 CE)

- Mean boreal winter (DJF) and summer (JJA) surface temperature change: $TS_{MCA} - TS_{LIA}$
- Amplified polar response, particularly in winter hemisphere
- Reduced seasonal contrast in Polar latitudes (persistence of Greenland settlements in MCA – McGovern, 1991)



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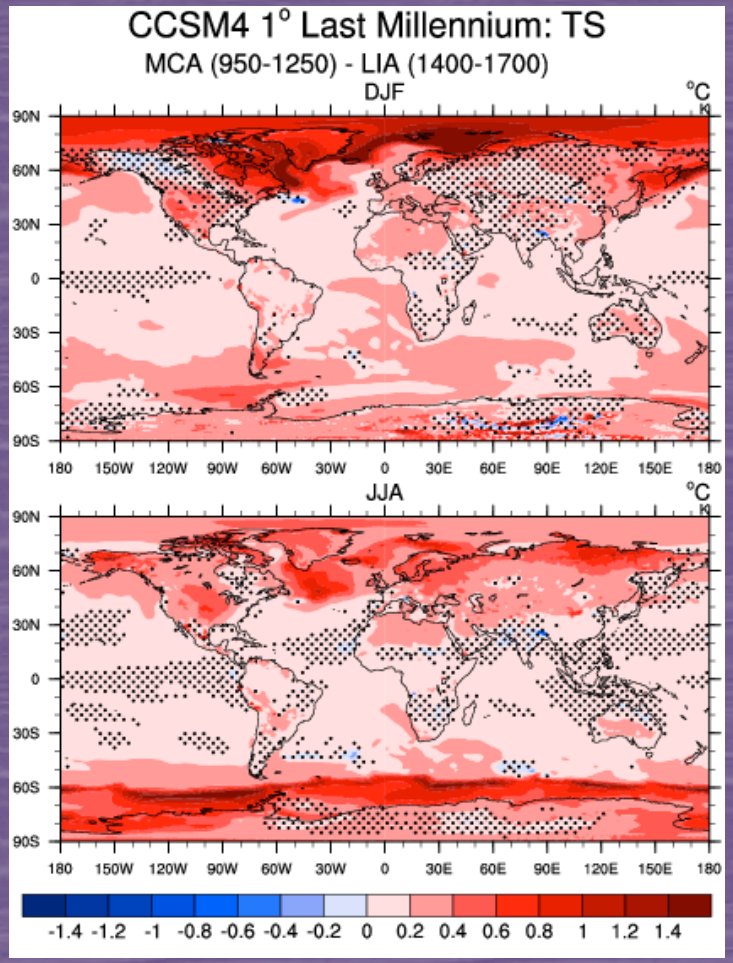
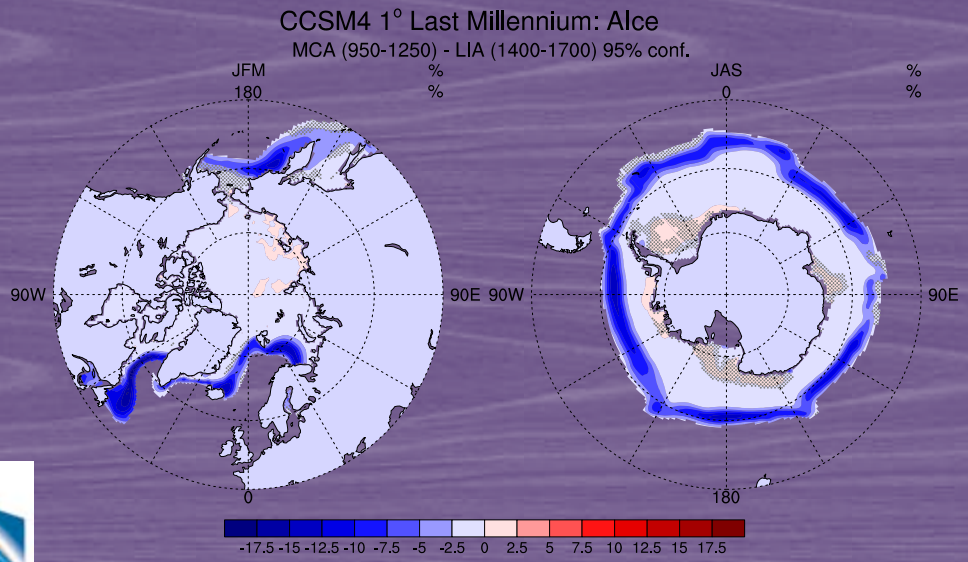
- Reduced sea ice ($SIE_{MCA} - SIE_{LIA}$ in %)





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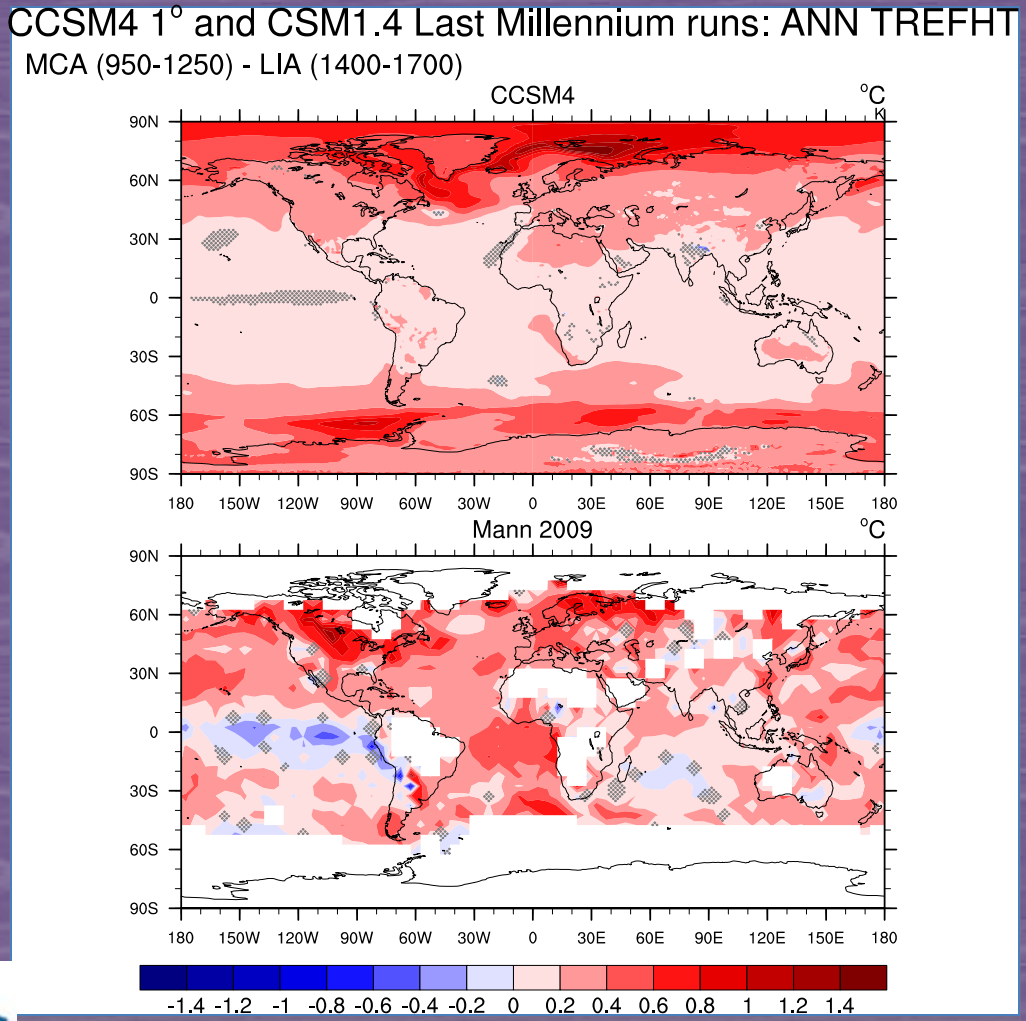
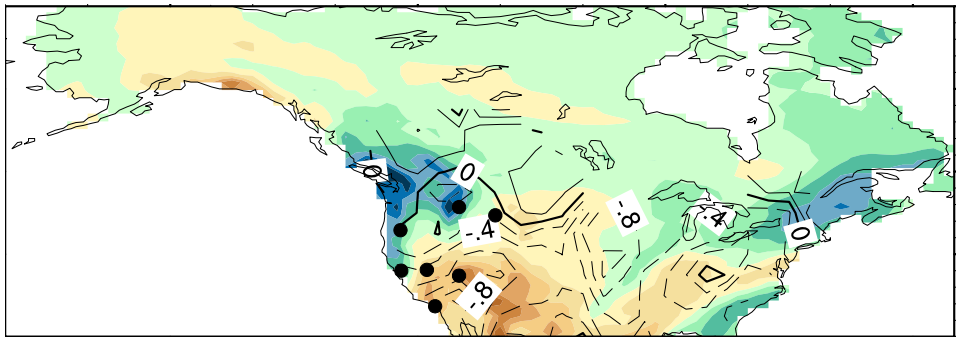
MCA- LIA Temperature records: models and reconstructions



CCSM4 (upper) and Multi-proxy reconstruction of Mann et al, 2009 (lower)

- Higher spatial variability in proxy reconstruction
- LM simulations do not show cooler equatorial Pacific

MCA- LIA hydroclimate



- Few regions show robust precipitation changes in LM simulation
- North America – regions of >90% conf. level changes in precipitation-evaporation
- Excellent regional proxy records (North American Drought Atlas, Cook et al, 2004; Cook, 2008)
- LM simulations general agreement with proxies – SW US dry Medieval (winter) and dry NE US (summer)
- LM simulation shows dry SW US but does NOT simulation La Nina type conditions in equatorial Pacific

CCSM4 Last Millennium: Response to Volcanic events

- Compare model response to proxy-based reconstruction response for:

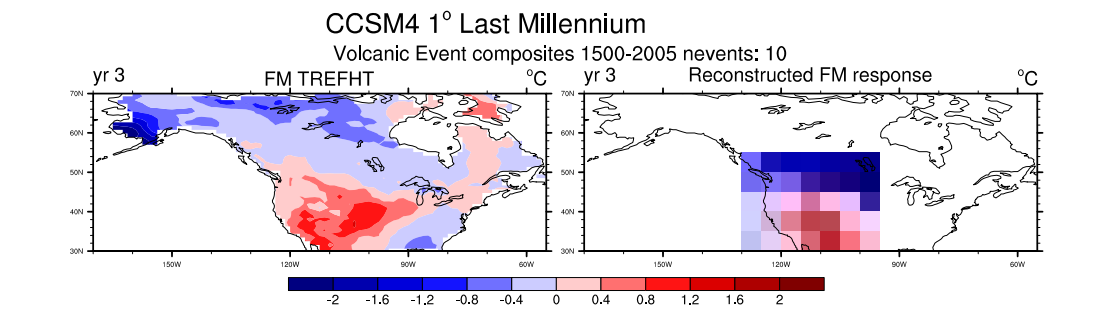
  North America (Wahl and Amman, 2010)

  Europe (Fischer et al, 2007)

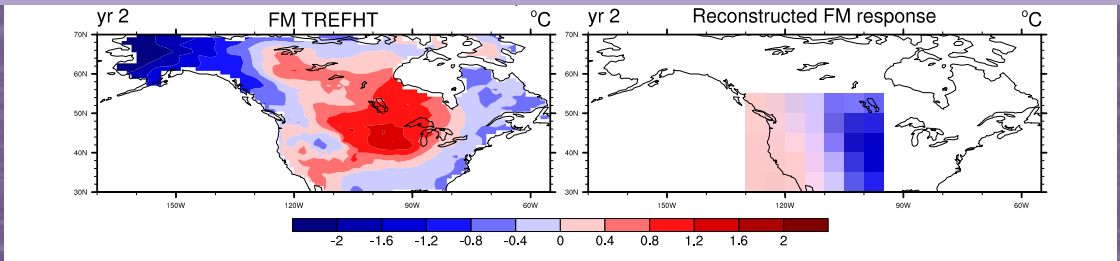
  Asia (Anchukaitis et al, 2010)

- Superposed Epoch Analysis (SEA; see Adams et al., 2003)
- Mean response to 10 events (1500-1850 – as in proxy reconstructions) as a deviation from 10 year mean state before an event
- yr0 = event year; yr1 = 1 year post event, etc.

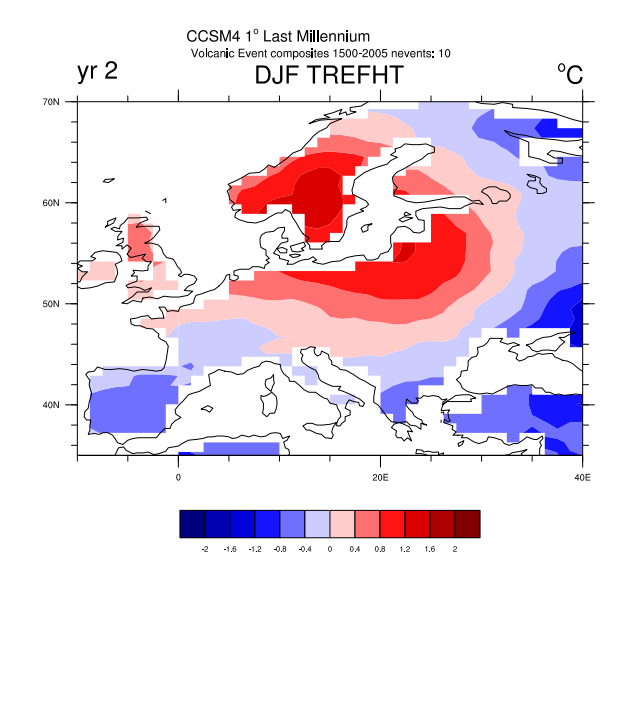
N. America Temperature response to Volcanoes

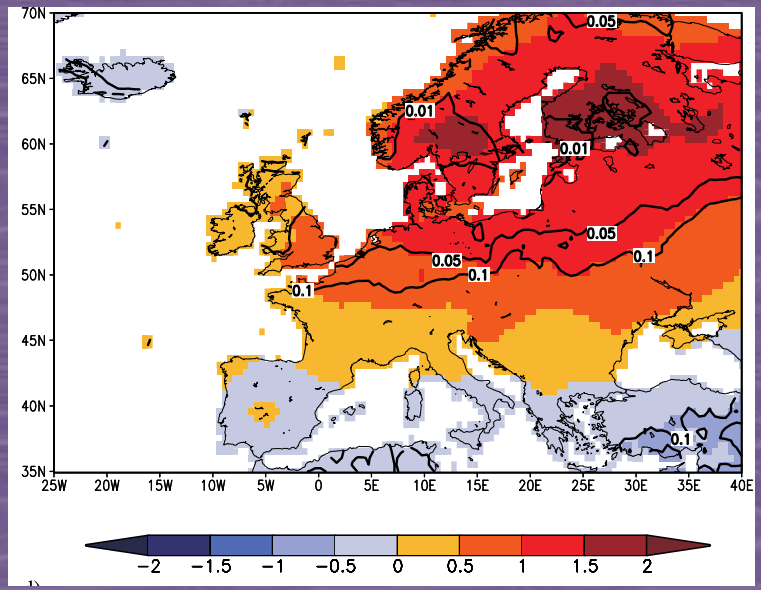


- FM response, post-event year 3
- Proxy-reconstruction: “La Nina” type pattern with SW US warming and cooling to the North and mid-continent
- LM simulation shows general agreement in yr3, although no mid-continental cooling.
- LM simulations show discrepancies in yr2 compared with proxy-based reconstructions



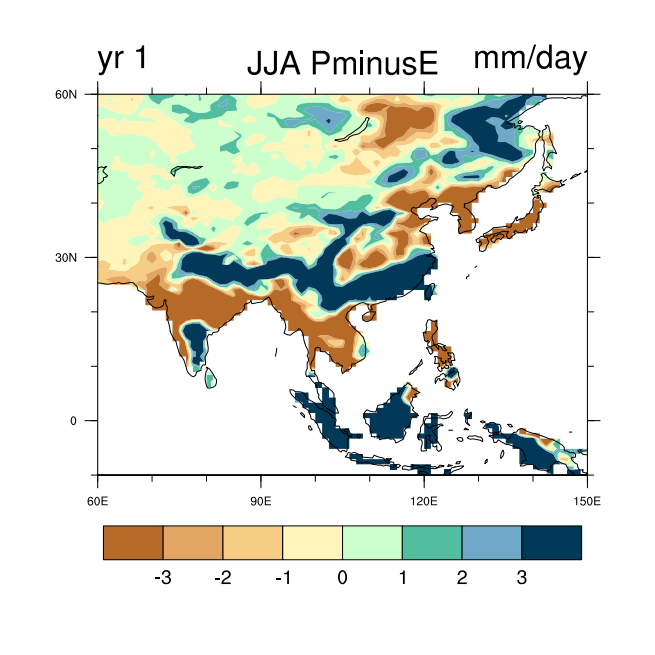
Temperature response to Volcanoes: Europe

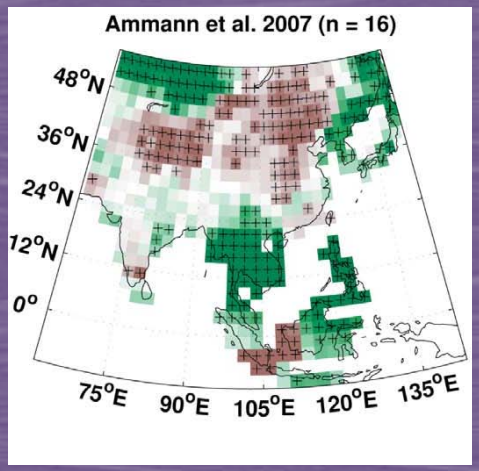




- DJF response, post-event year 2 from CCSM4 LM simulation (left) and Fischer (2007) post-event year 1 (right)
- Similar patterns; timing is off (yr2 in CCSM4, yr1 in reconstructions)

Precipitation response to Volcanoes: Asia





- JJA response, yr1, from CCSM4 LM P-E (left) and response of PDSI of the Monsoon Asian Drought Atlas (Cook et al., 2010; figure from Anchukaitis et al., 2010)
- CCSM response similar to observed anomalies of precipitation, runoff and PDSI after Pinatubo (not shown) after adjusting for 1992 El Nino (Trenberth and Dai, 2001)
- Very little resemblance to pattern made from proxy reconstructions in Anchukaitis et al (2010).

CCSM4 Last Millennium and data comparisons: Modes of Variability

- Modes of variability influence regional climate on seasonal to multi-decadal timescales
- Does the short instrumental record represent full range of variability in these modes?
- Do these internal modes show changes with external forcing?
- How does the LM simulation compare to "reconstructions" of these modes based on proxy-records of climate and modal-teleconnections and indices calibrated using the relatively short instrumental record?

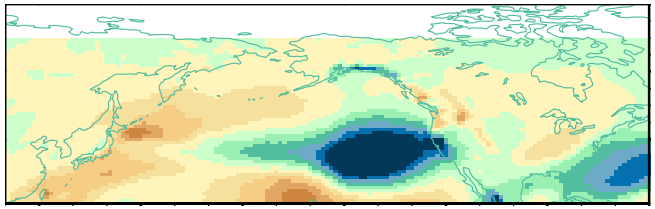
PDO and ENSO

PDO

- Proxies calibrated with 20thC obs: consistent in 20thC but not coherent before that
- Decadal variations – internal dyn.
- Model and proxies – prolonged periods of -/+ PDO

Nino3.4

- Increased variability 20thC (proxy) and 1250-1500 (CCSM4 – wavelet analysis, not shown)



2005)

CCSM4

global (Mann et al 2009)

NAO and AMO

NAO

- Influences location of jet stream and storm tracks: +NAO wetter and warmer N. Europe, drier and colder S. Europe/N. Africa
- Not + during MCA in model (as suggested by Trouet recon.)
- Lack of coherence in proxy-recon.

AMO

- SST based multi-decadal mode
- Regressions of precip and temp show some similarity to regressions on NAO
- Lack of coherence in proxy recon
- LM simulation – +AMO tendency MCA; - LIA

Summary

- CCSM4 LM simulation shows a “hockey-stick”-like pattern of surface temperatures: ~0.5(0.3)/° C cooling to the early 1800’s for the NH(SH) followed by warming to present.
- 20th century temperatures are much warmer than MCA temperatures
- The relative warmth exhibited by proxy reconstructions during the MCA (11^{th}-12^{th} centuries) is somewhat damped in the LM simulation
- Strong global cooling associated with large volcanic events
- LM captures some of the European and North American response to volcanic events, but timing and regional details are dissimilar
- LM shows overall warming with polar amplification in MCA relative to LIA
- LM does not reproduce a La Nina type response in equatorial Pacific during MCA
- Overall lack of coherence between CCSM4 modes of variability and proxy-based indices, as well as between different proxy based modes over LM prior to instrumental record
- LM does not show a persistent positive NAO or negative PDO during MCA as suggested by proxy reconstructions

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To provide facility support to the wider community; and,
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LM modes of variability

- **AMO**: Atlantic Multidecadal Osc illation (area weighted, detrended North Atlantic SST)
- **NAO:** North Atlantic Oscillation (leading order EOF of DJFM North Atlantic SLP)
- **PDO**: Pacific Decadal Oscillation (leading order EOF of North Pacific SSTs with global trends removed)
- **Nino3.4** index (area-weighted monthly SST from 5° S-5° N and 120-170° W, long-term monthly means removed)
- **OCT SAM**: Southern Annular Mode (leading order EOF of October Southern Hemisphere SLP)

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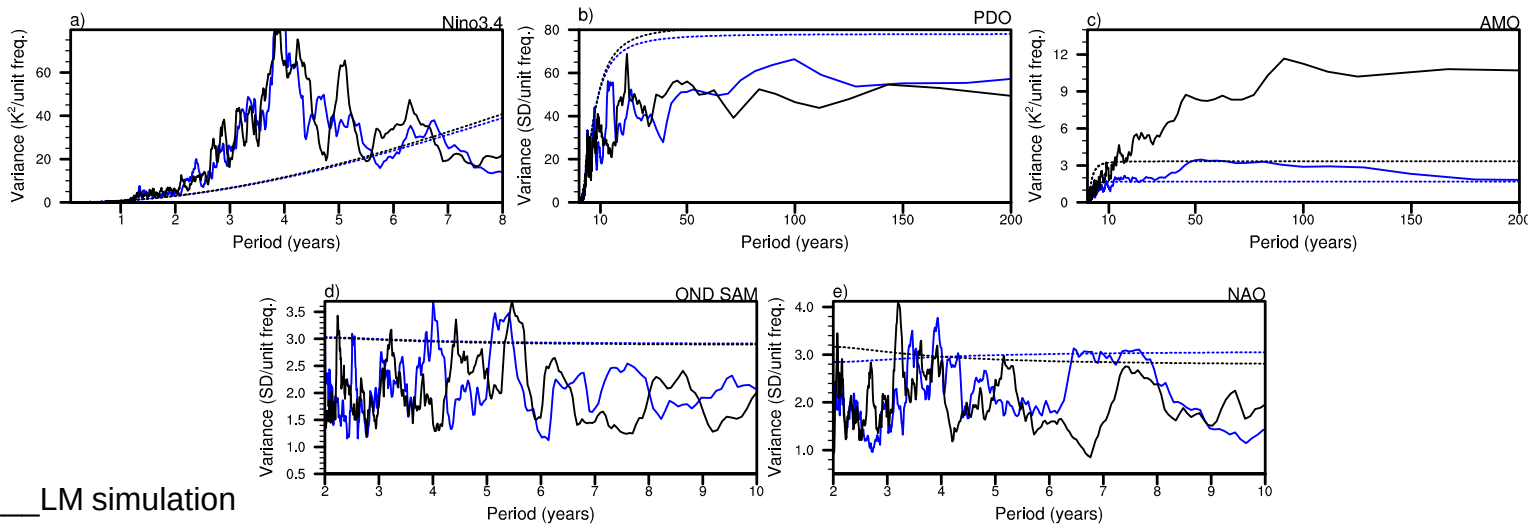
Modes of Variability: control run vs transient forcing



____LM simulation

_____1850 control run

- ENSO: slight increase in variance in LM (1.20 ° C^2) from control run (1.10 ° C^2)
- PDO: similar power spectrum LM and 1850 control
- AMO: increased variance in LM (0.161 ° C^2) compared to 1850 control run (0.121 ° C^2)
- NAO and SAM: generally white spectrum, little change b/w control run and LM