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

- Mean boreal winter (DJF) and summer (JJA) surface temperature change: $T_{S_{MCA}} - T_{S_{LIA}}$
- 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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- Amplified polar response, particularly in winter hemisphere
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- Reduced sea ice ($S_{E_{MCA}} - S_{E_{LIA}}$ in %)
MCA- LIA Temperature records: models and reconstructions

CCSM4 1° and CSM1.4 Last Millennium runs: ANN TREFHT
MCA (950-1250) - LIA (1400-1700)

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 yr 3, although no mid-continental cooling.
- LM simulations show discrepancies in yr 2 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

• 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)
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 (11th-12th 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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LM modes of variability

- **AMO**: Atlantic Multidecadal Oscillation (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)
Modes of Variability: control run vs transient forcing

- ENSO: slight increase in variance in LM (1.20 ° C²) from control run (1.10 ° C²)
- PDO: similar power spectrum LM and 1850 control
- AMO: increased variance in LM (0.161 ° C²) compared to 1850 control run (0.121 ° C²)
- NAO and SAM: generally white spectrum, little change b/w control run and LM