The Centennial Gleissberg Cycle: a Driver of Climate Change

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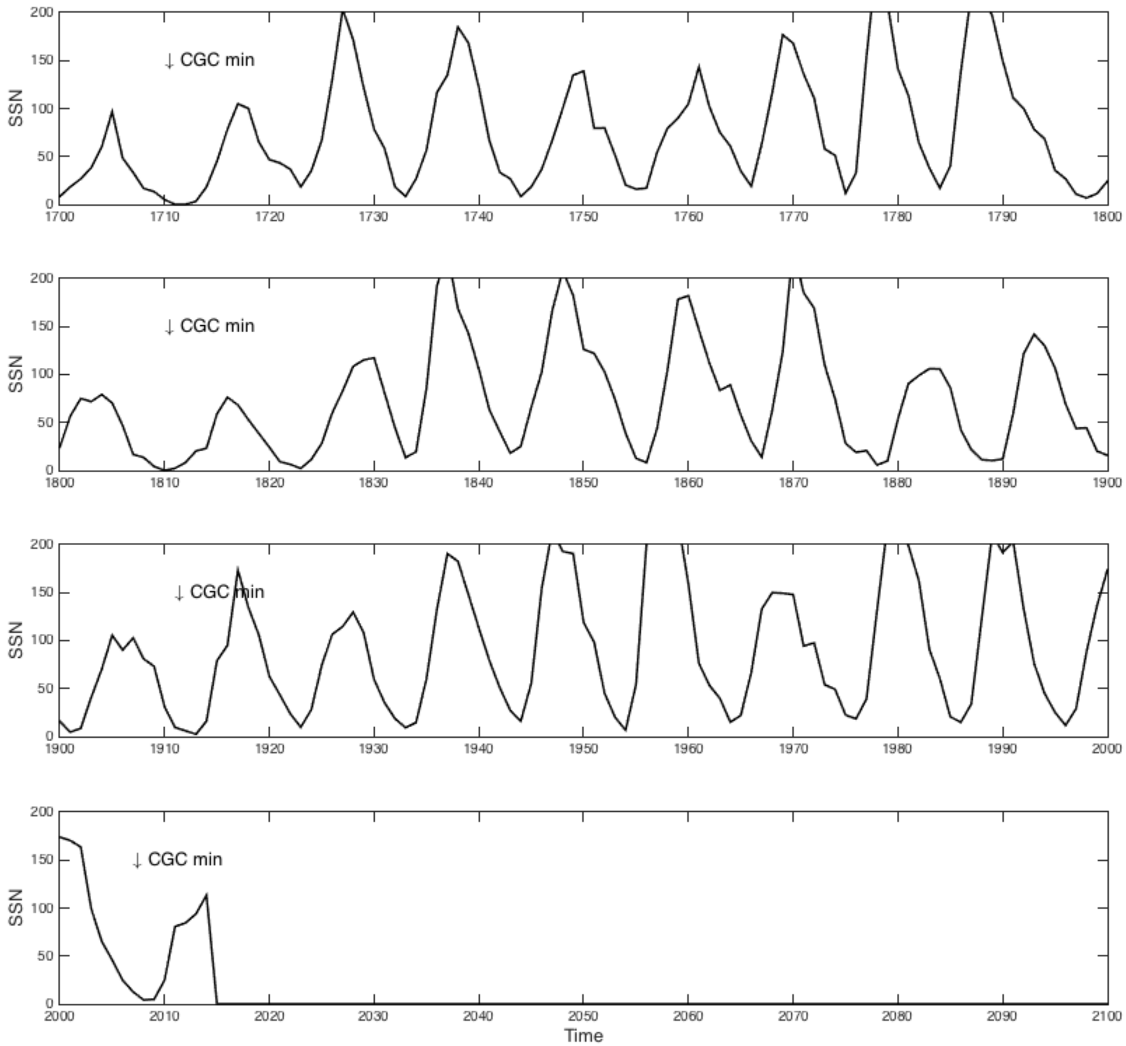
Motivation

- Solar influence on the Earth's climate on centennial time scale (CGC

- Most previous studies were focused on time variability of solar influence on climate. What is the spatial signature of solar forcing?

- The recent solar cycles and climate conditions resemble the minima and the Earth's climate at CGC minima in 18th, 19th, and 20th centuries

Centennial Gleissberg Cycle (CGC)



90-110 year quasi-periodic modulation of 11-year cycle amplitude

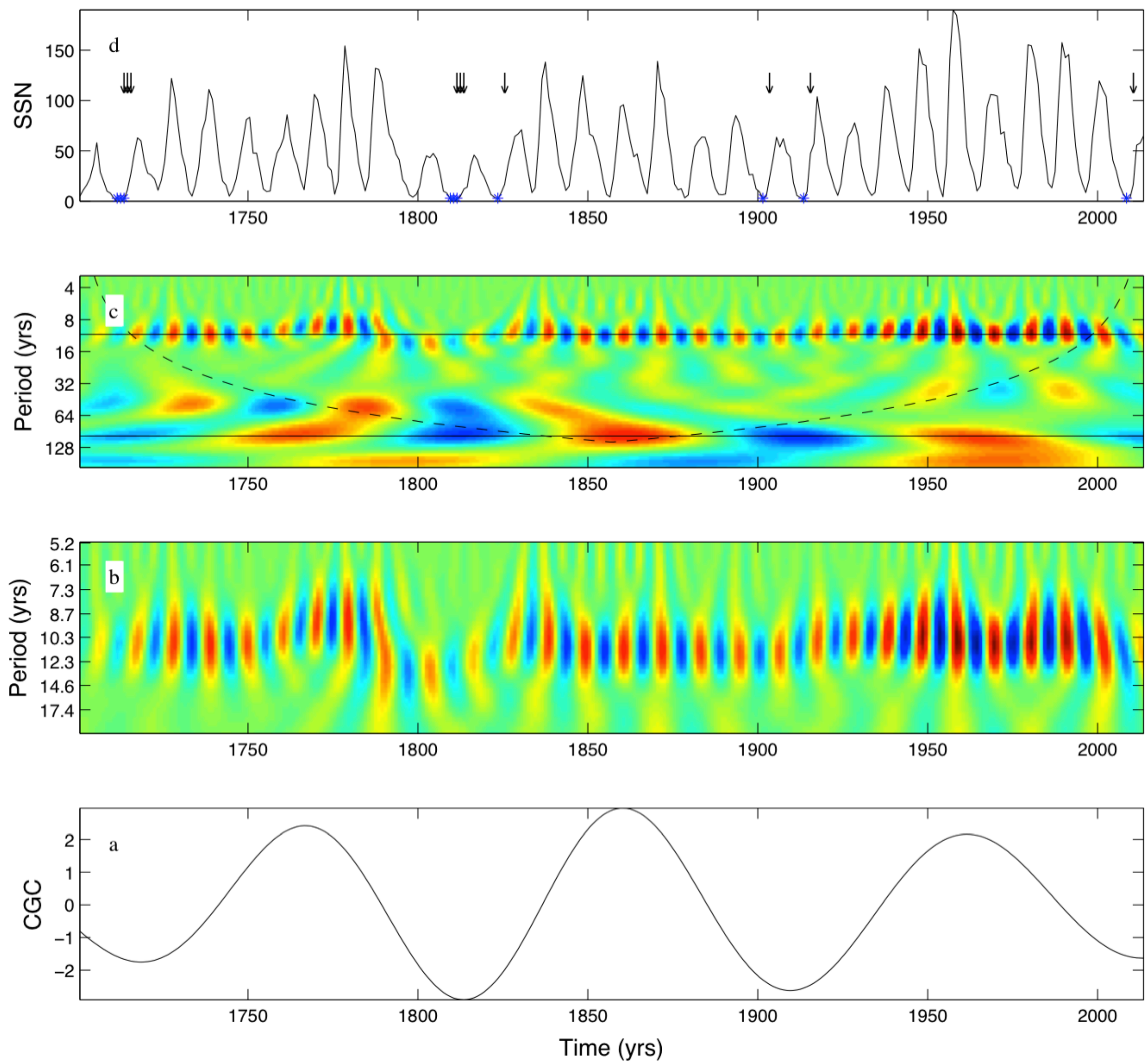
CGC recorded in 450 AD - 1450 AD (auroras)

--Feynman & Fougere (1988), Ruzmaikin et al. (2006)

CGC recorded in ^{10}Be, ^{14}C

-- Beer et al. (2007), Ogurtsov et al. (2013), Usoskin (2013), McCracken (2015)

CGC in SSN Wavelet



11-year mode

100 year mode

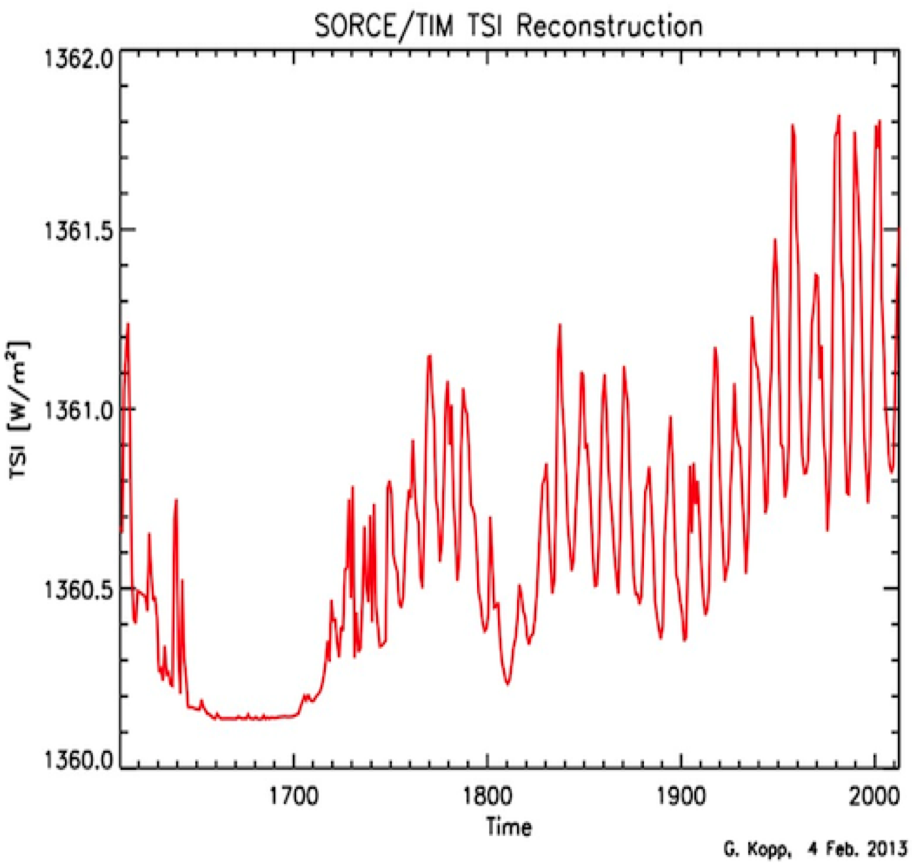
frequency modulation of the 11-year cycle (?)

CGC Mode (80-110 yrs)

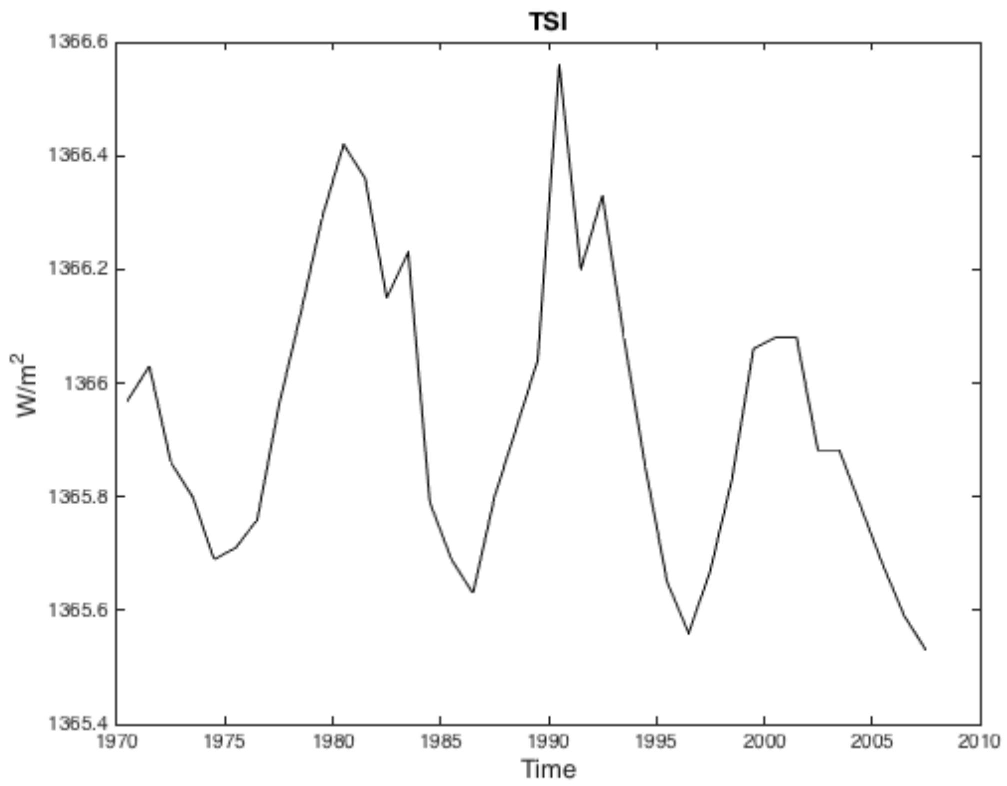
CGC Minima

- ✓ Auroral Minima (450 - 1450)
- ✓ Beginning of 18^{th} century (1710 - 1720 end of MM)
- ✓ Beginning of 19^{th} century (1800 - 1820, Dalton min)
- ✓ Beginning of 20^{th} century (1900 - 1920, Gleissberg min)
- ✓ Beginning of 21^{th} century (2006 - ? , predicted by S. Silverman)

CGC variation in Solar Irradiance

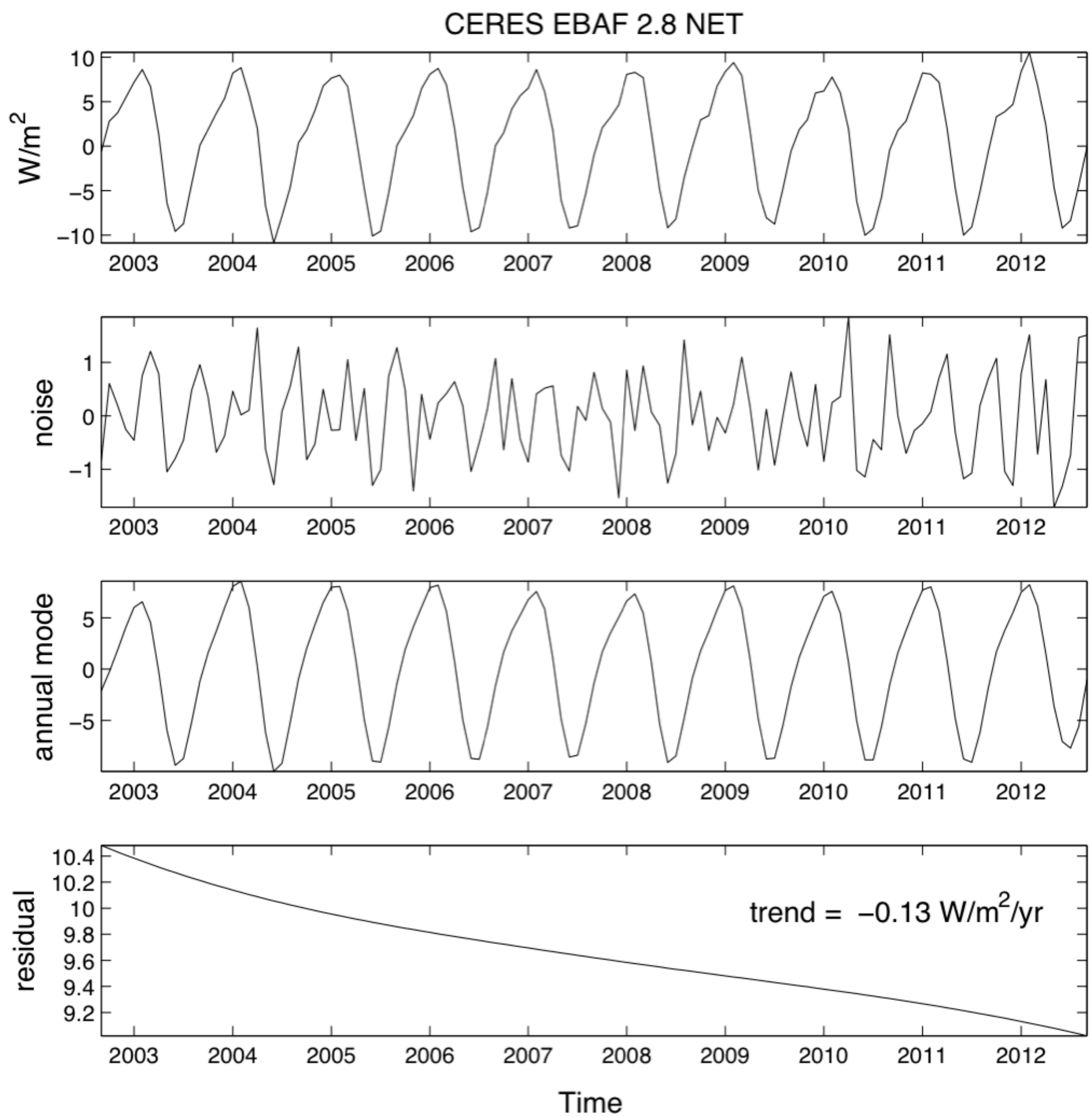


TSI reconstructions (Wang, Lean, Schelley. 2005; Krivova et al. 2010; Kopp, 2013)



Measured TSI decreased in three successive recent minima

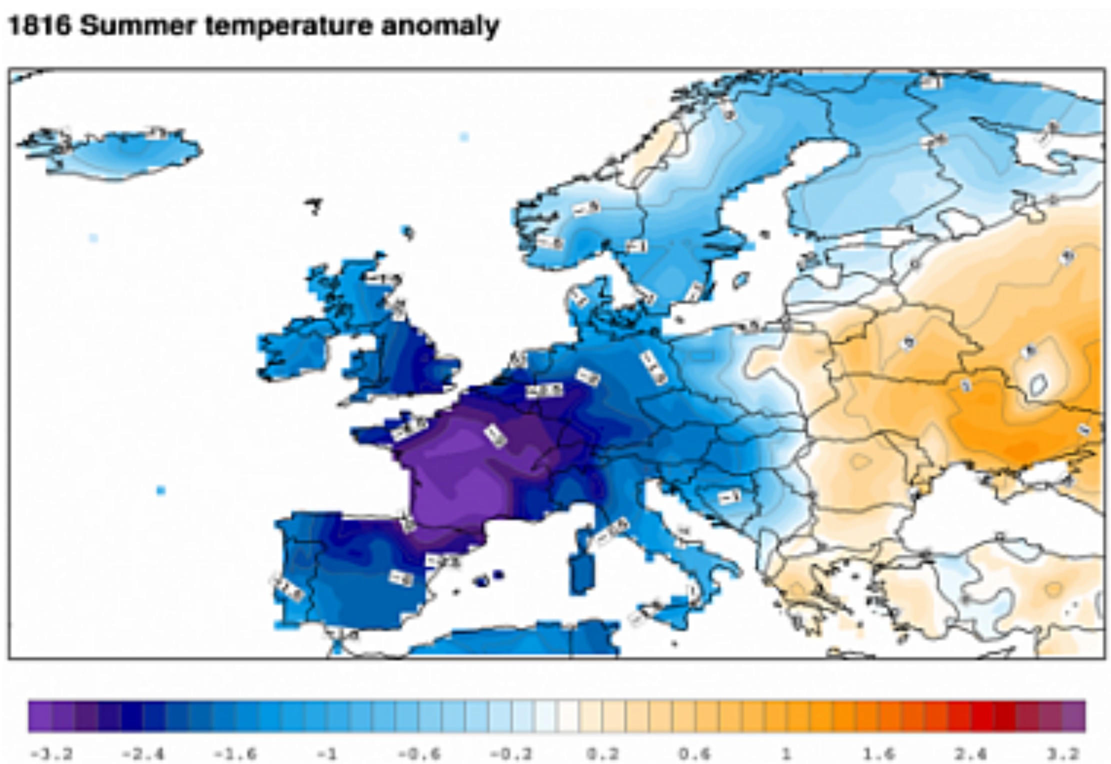
The Earth Cooling measured by satellites



Forcing the Earth's Climate on the Centennial Time Scale

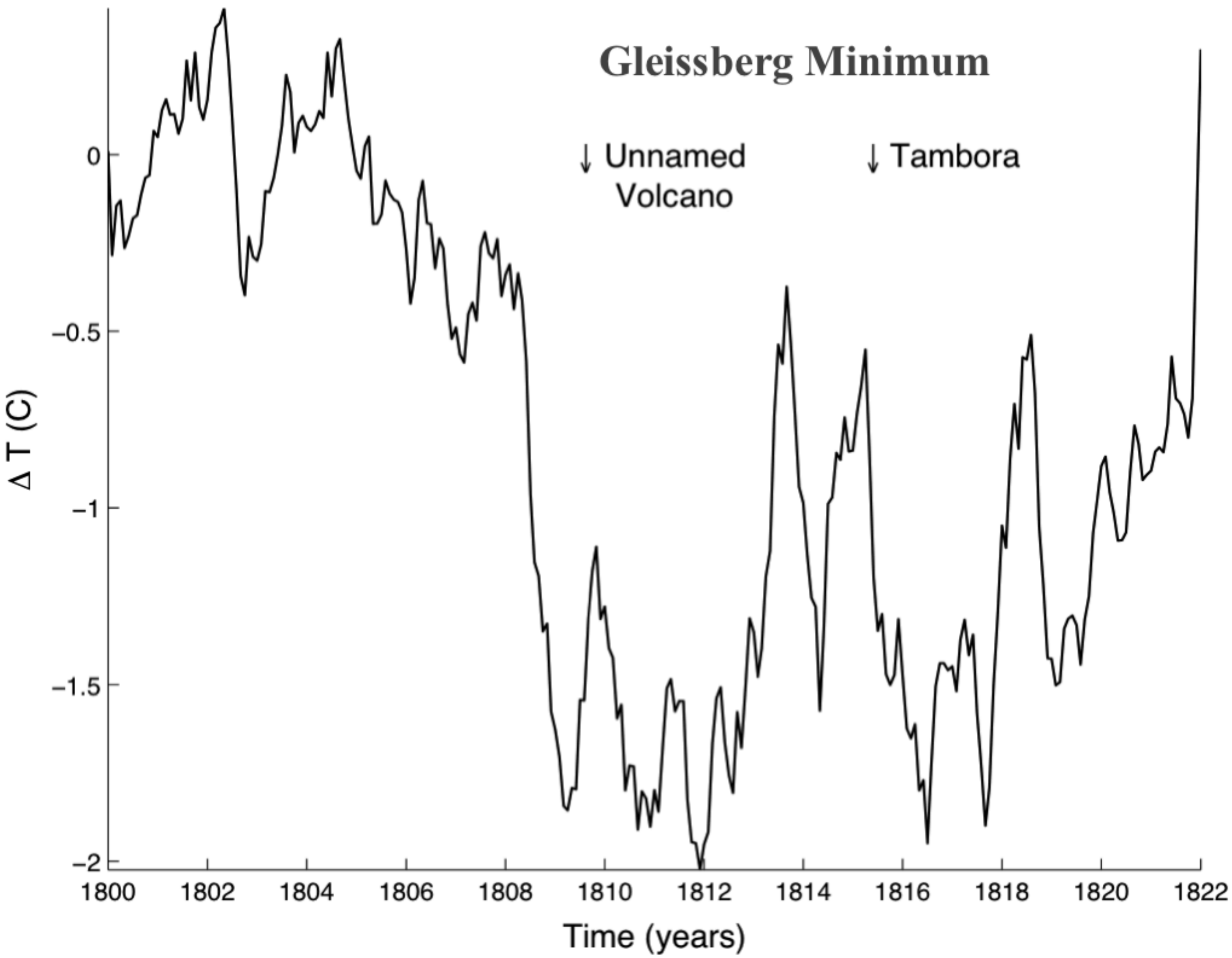
Anecdotal Evidence

19th century CGC minimum



Year without summer: solar and/or Tambora?

19th century CGC minimum in T Land



Data from Berkley Earth Project, Rohde et al. (2013)

20th century CGC minimum

Scott Expedition, 1910-13,
the coldest winter in Antarctica (-77F)

New York American

EDITION FOR GREATER NEW YORK.

BUSINESS PROPERTY

No. 10,499. TUESDAY, APRIL 16, 1912. 16 PAGES PRICE ONE CENT

J. J. ASTOR LOST ON TITANIC

1,500 TO 1,800 DEAD

John Jacob Astor was among the passengers who went down with the ship, according to a wireless dispatch received by Bradstreets last night from the liner Olympic. Mrs. Astor was saved and is being brought to shore by the Carpathia.

The Wireless Operator at Cape Race, Newfoundland, Flashes: "Eighteen Hundred Lives Have Been Lost in the Wreck of the Titanic."

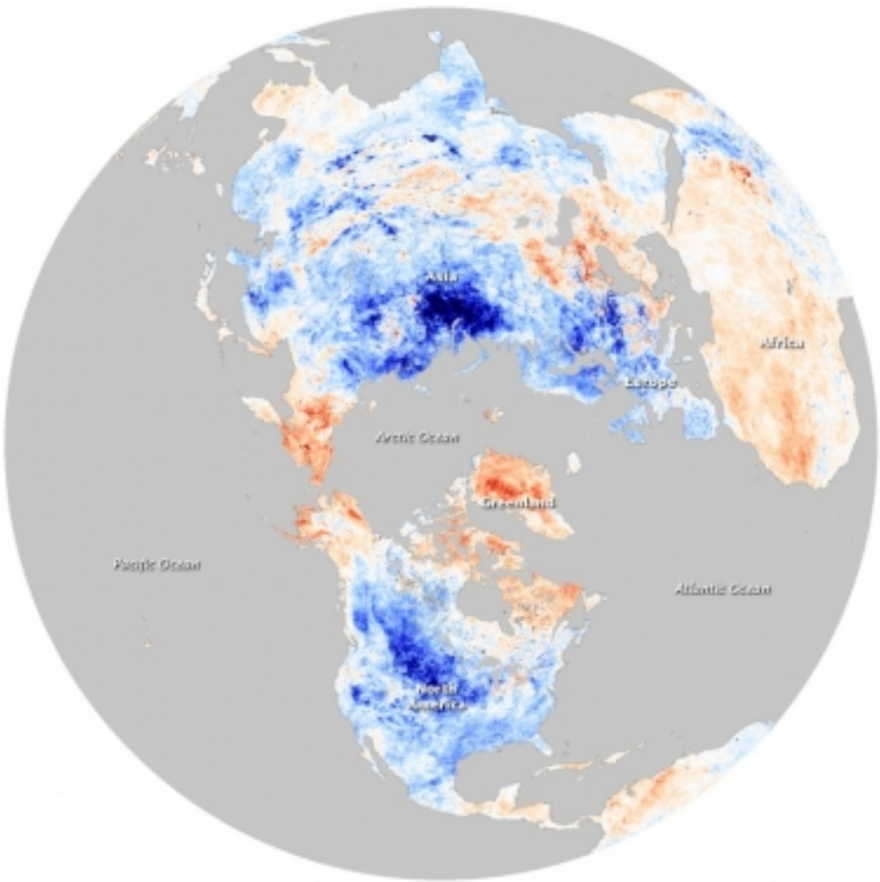
April 1912, Titanic

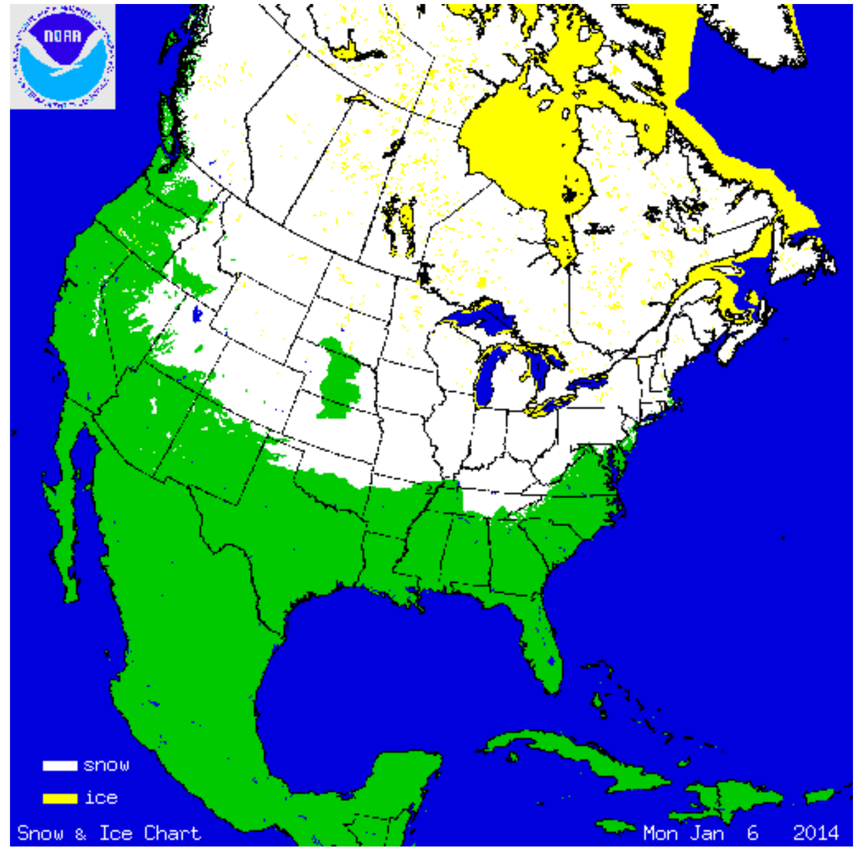
Did sunspots kill Titanic?

45°

"extreme and prolonged low sunspot-number regime reversed the dearth of southern icebergs in the North Atlantic" (E. N. Lawrence, Weather, 2000)

21st century CGC minimum

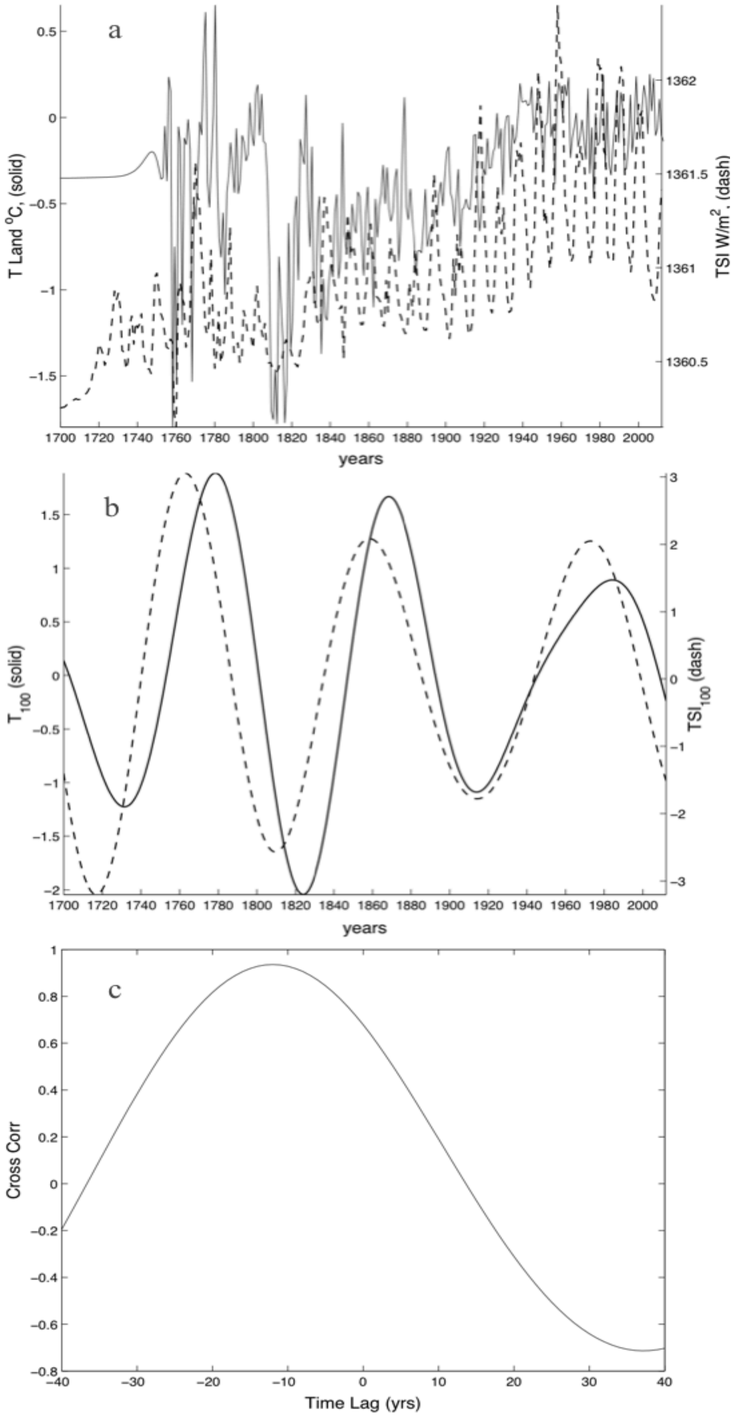




Winters in Europe and Asia were cooler than normal:
deep chill Jan 2006, Jan 2008, Dec 2010, Feb 2012

2014 N. America cold wave

Global Land Temperature & TSI

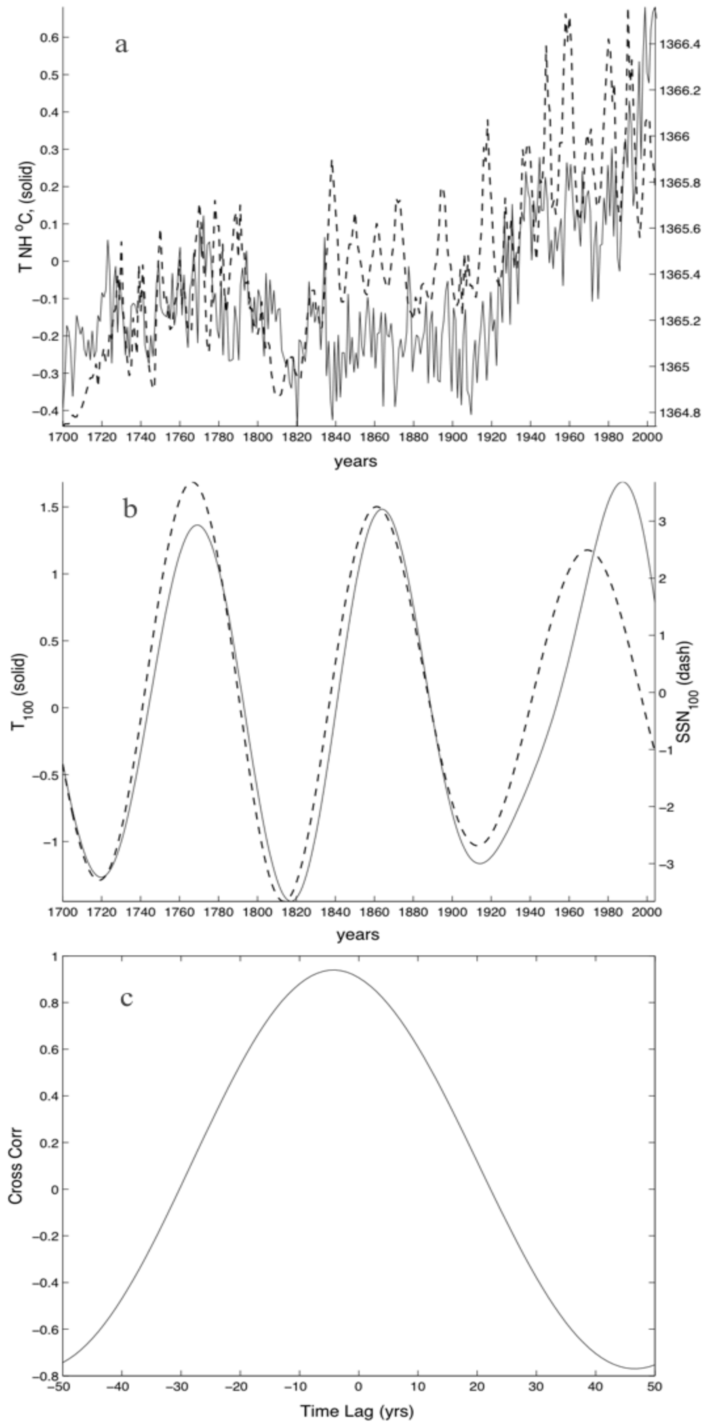


Centennial mode

Cross Correlation

Data extended: TSI Krivova et al. (2007)
T Land Rohde et al. (2013)

North Hemisphere Temperature & TSI



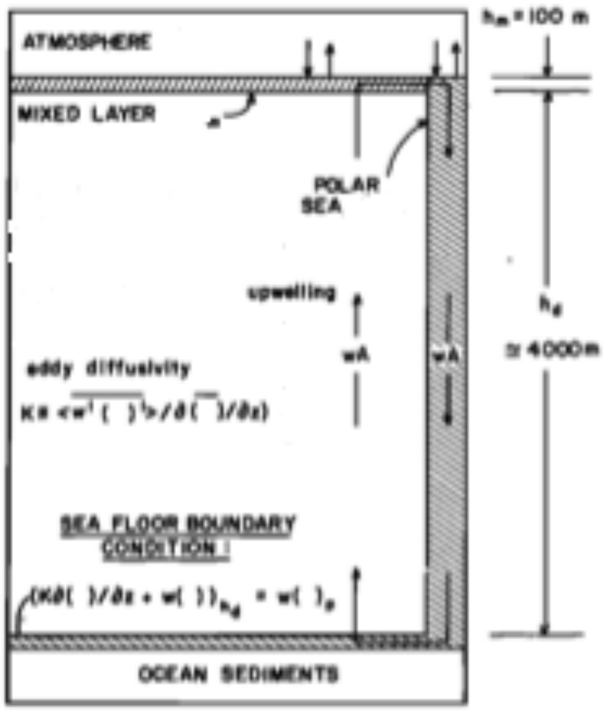
Centennial mode

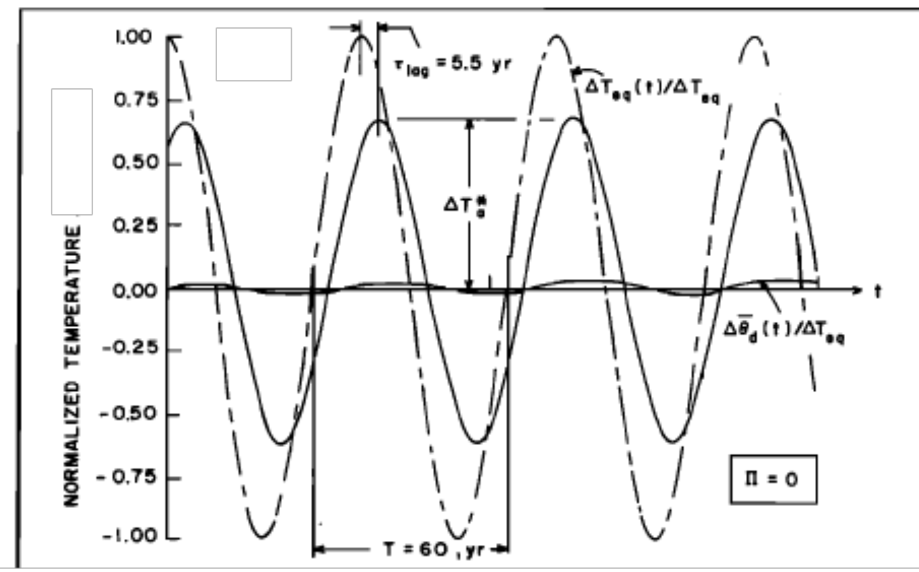
Cross Correlation

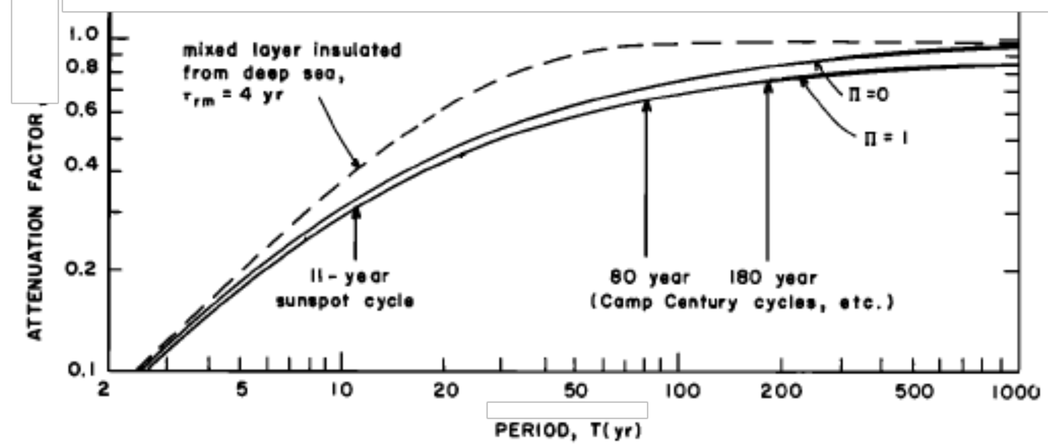
Data extended: TSI Krivova et al. (2007)
T NH Mann et al. (1999) detrended for CO_2 rise

A 1D Model of Ocean Response

Hoffert et al, 1980





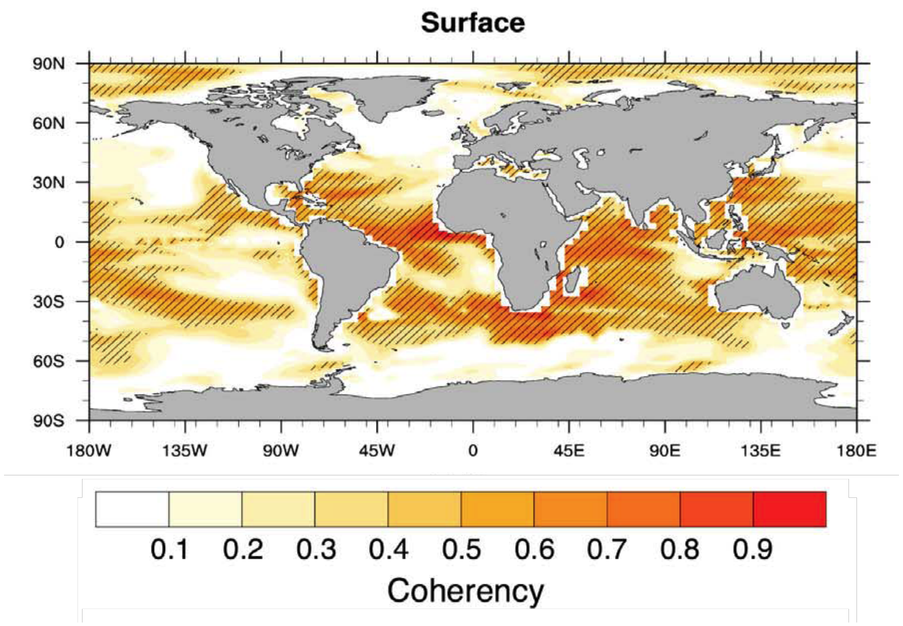


Model predicts a phase shifted periodic Tem response to a periodic forcing

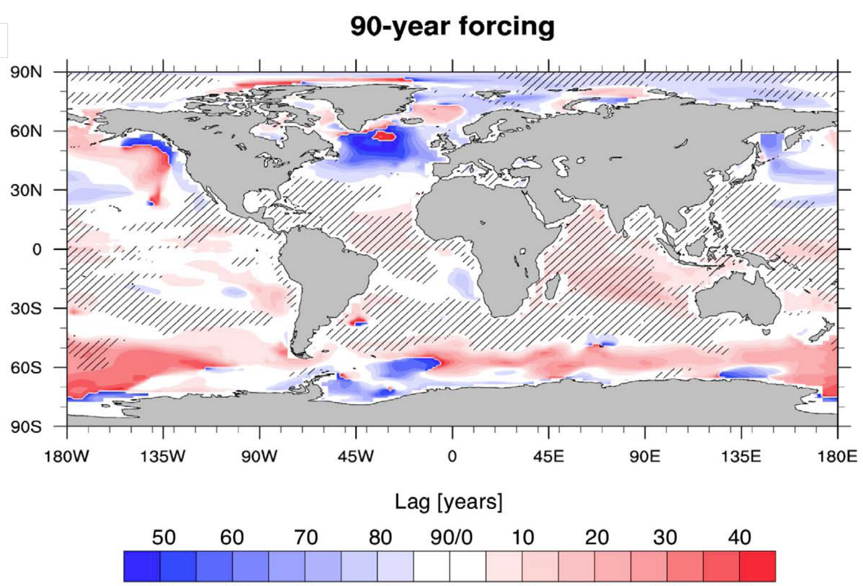
Only mixed layer involved on 11-year scale. Phase shift 3-4 years

Deep ocean engaged on centennial time scale. Phase shift (time lag) increases.

CCSM3 Modeling of Ocean Response



Positive SST & TSI correlation consistent with a direct, thermal forcing of the sea surface.



SST response to 90-year sin (TSI) forcing lags by about 20 years.

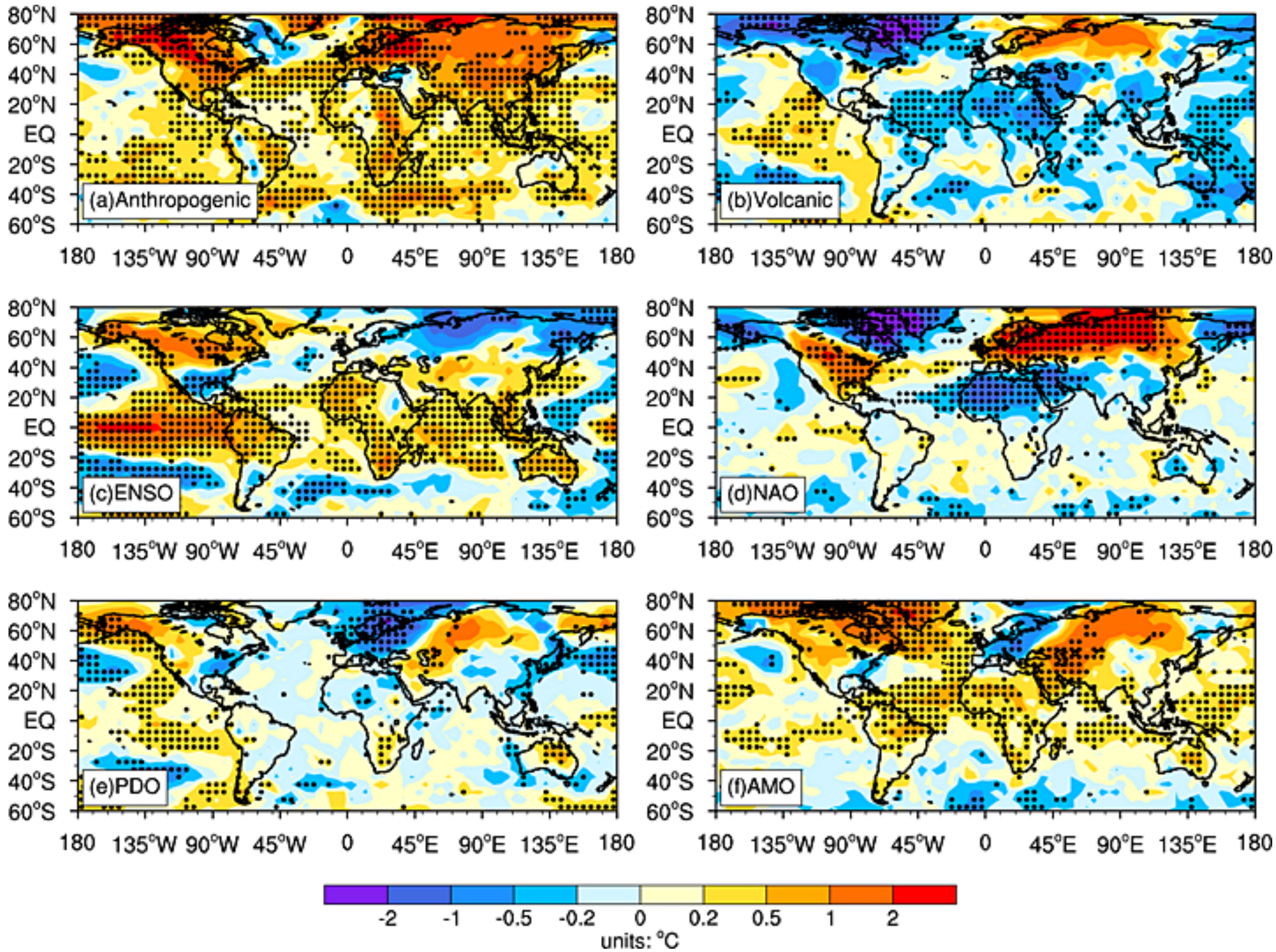
Seidenglanz et al. 2012

Spatial signatures of climate forcings

Natural deviations from Global Mean

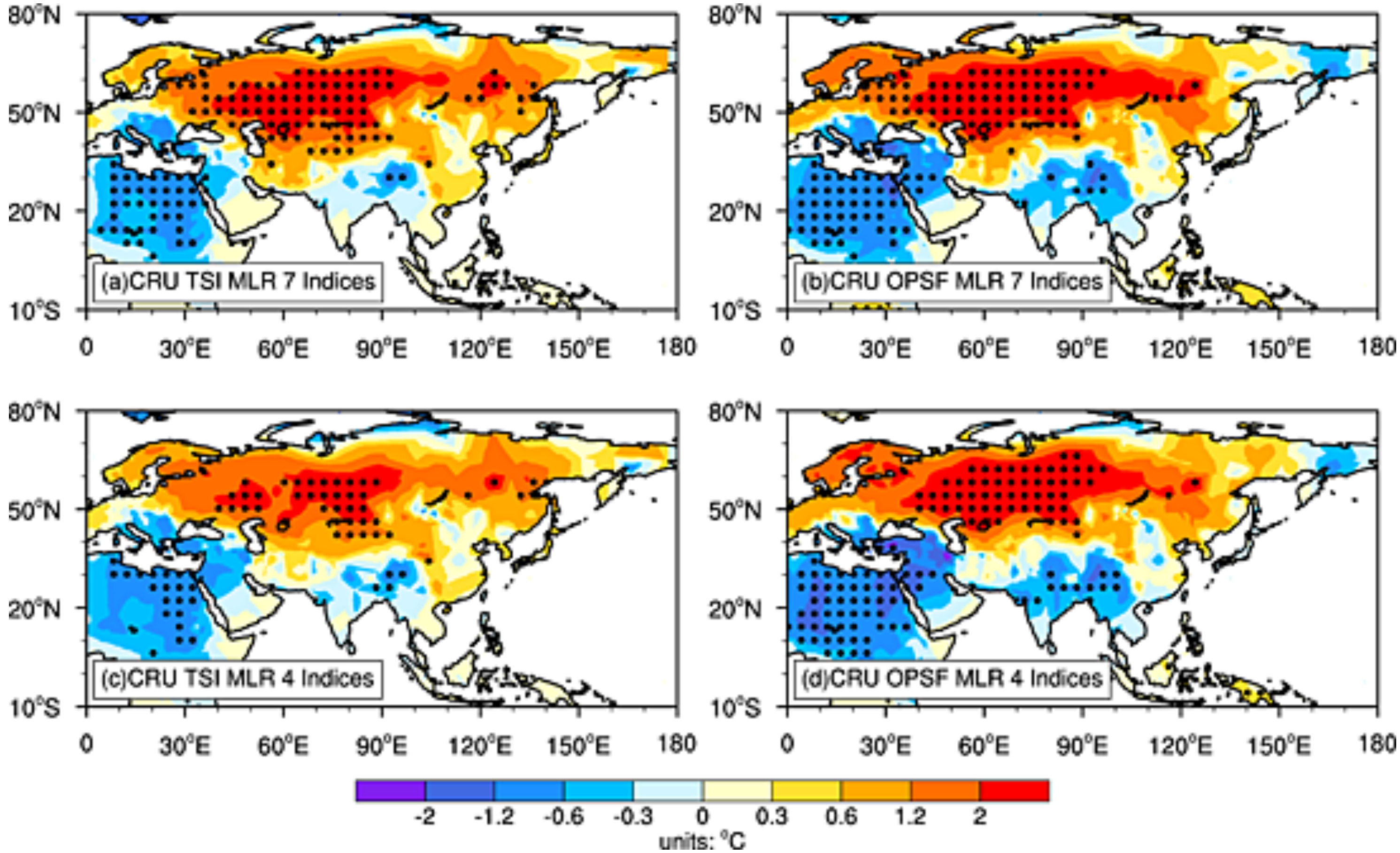
-- appear as **spatial patterns** of preserved shape but changing magnitude; naturally generated by non-linear, noisy atmosphere-ocean system

Earth's temperature patterns under non-solar forcings on 11-year time scale



Chen et al., 2016, JGR

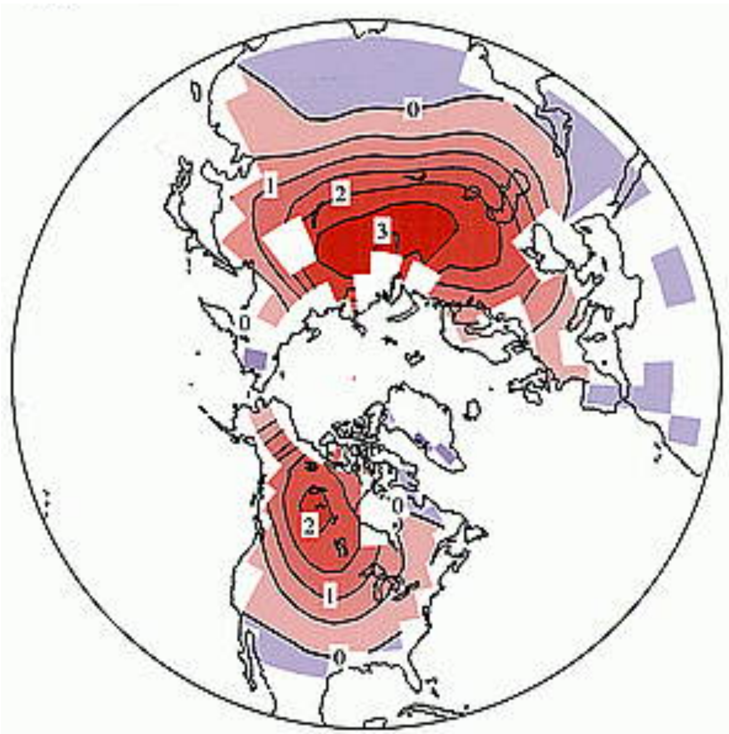
Pattern of solar forcing on 11-year time scale



Chen et al., 2016, JGR

Search for climate pattern associated with CGC

COWL pattern



COWL pattern has the highest pdf reflecting dynamics of atmosphere (Corti et al., 1999)

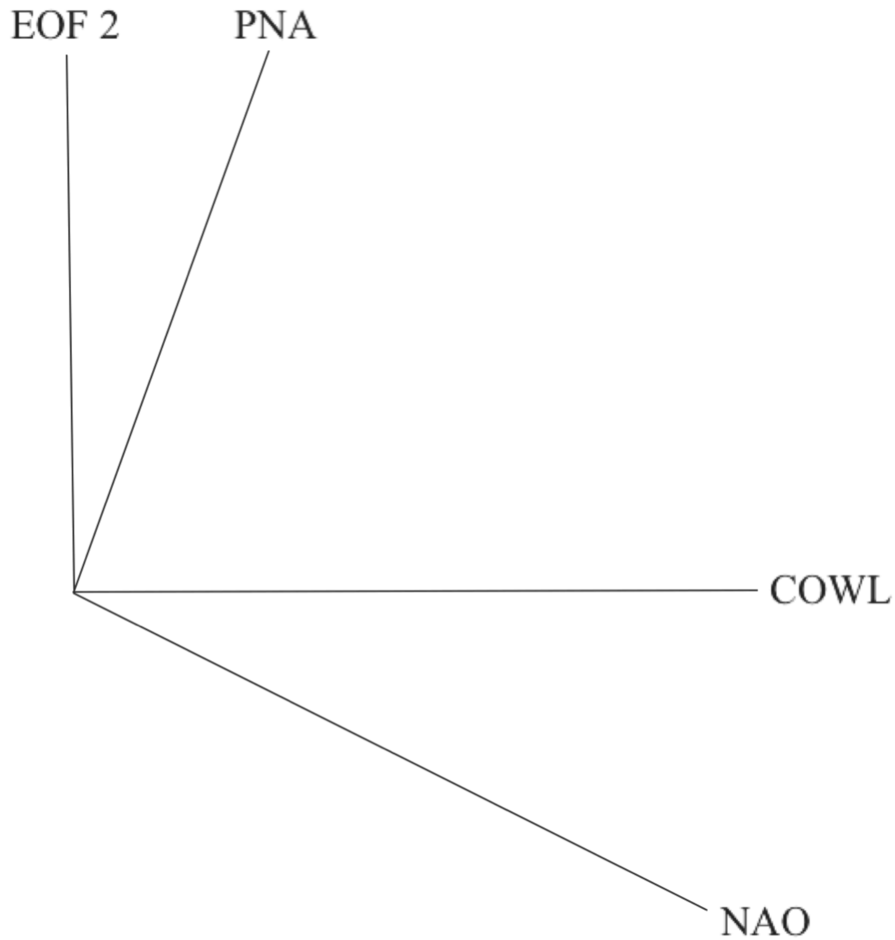
$$T_{land} = T_{COWL} + T_{res}$$

T_{COWL} is dynamically tied to atmosphere

T_{res} is radiatively driven

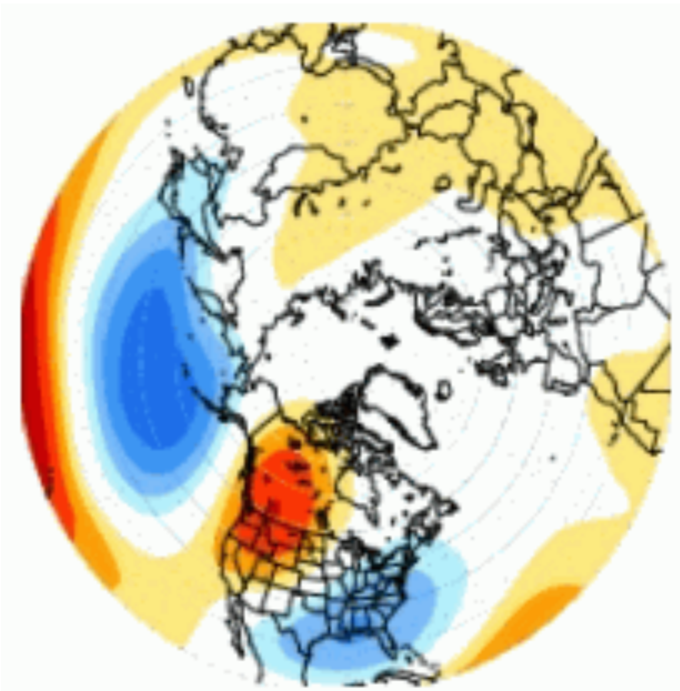
(Wallace et al., 1995)

First 2 EOFs account for half of variance

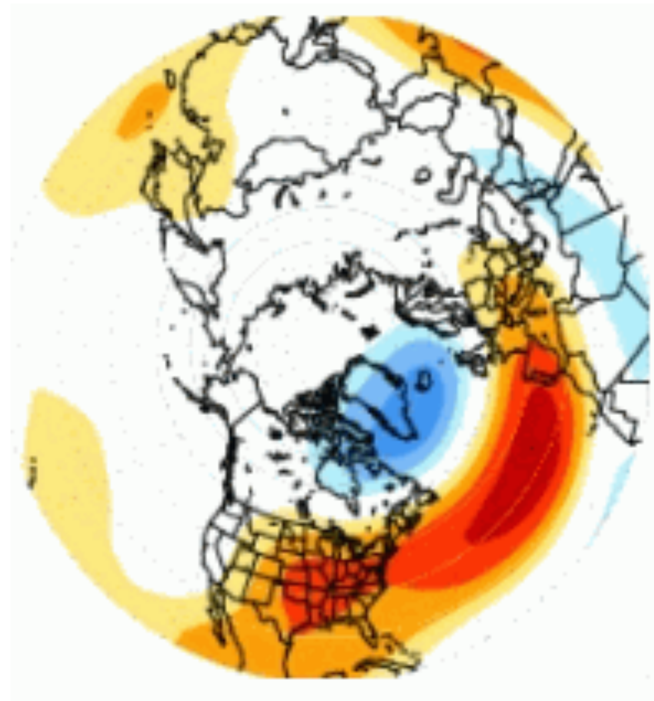


Quadrelli & Wallace, 2004

Climate Patterns associated with CGC

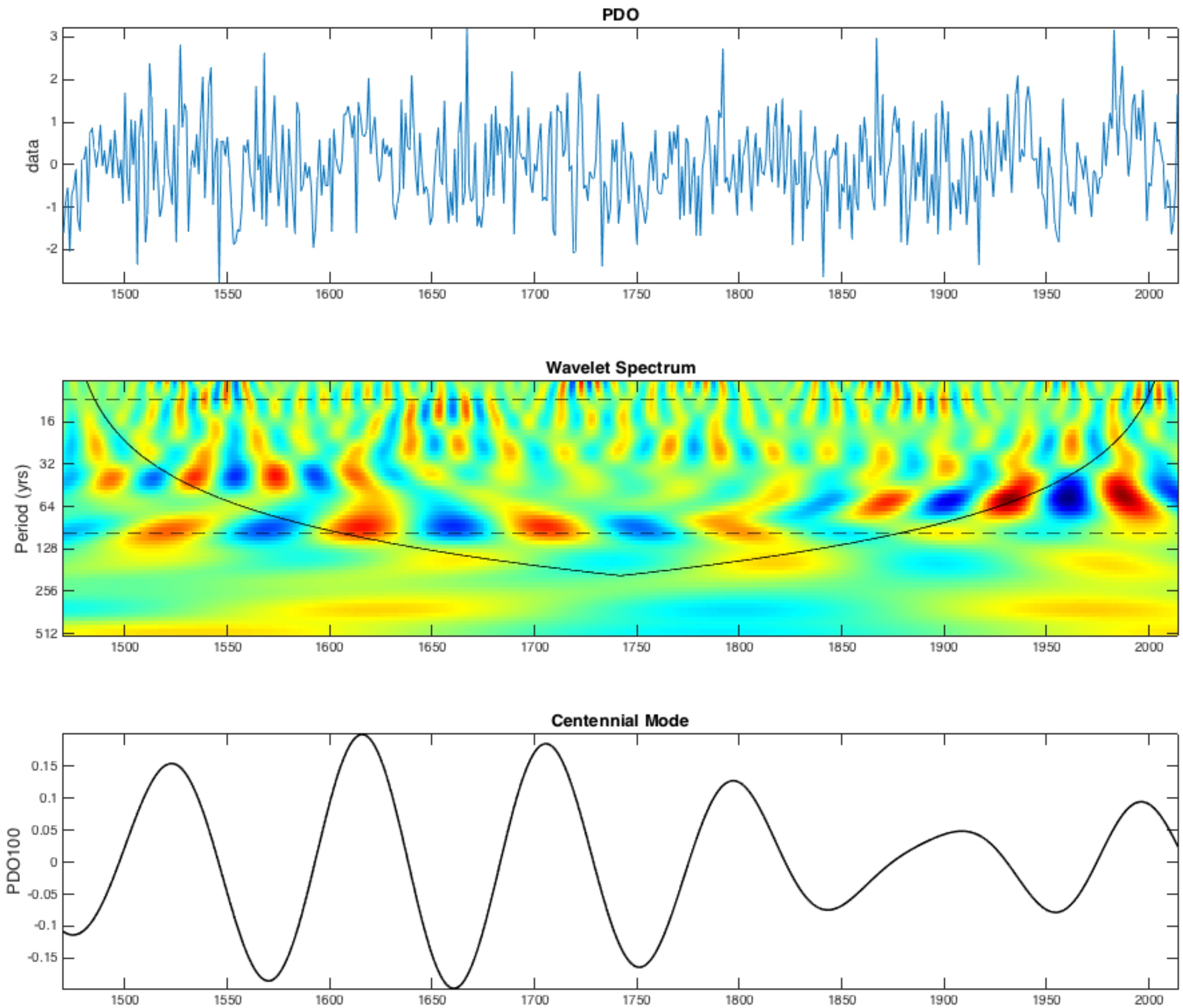


Pacific North American
(PNA)



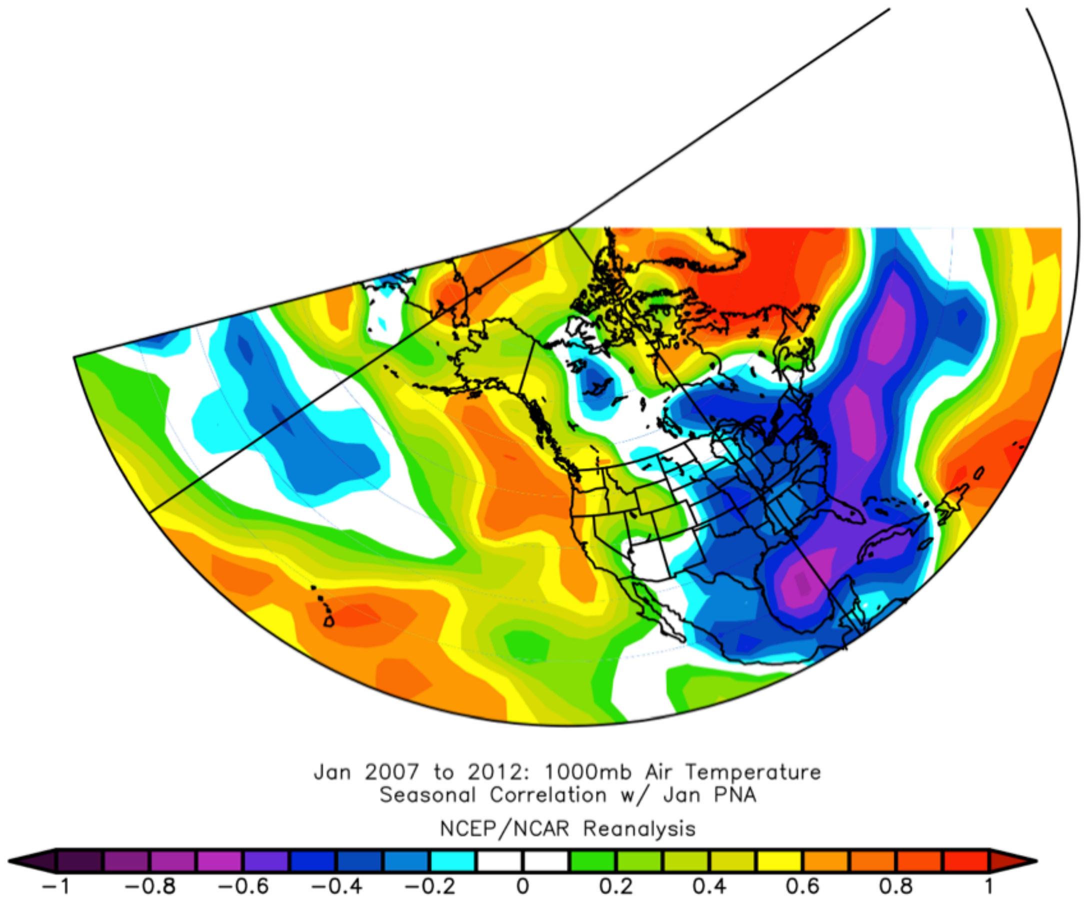
North Atlantic Oscillation
(NAO), related to NAM

PDO &CGC

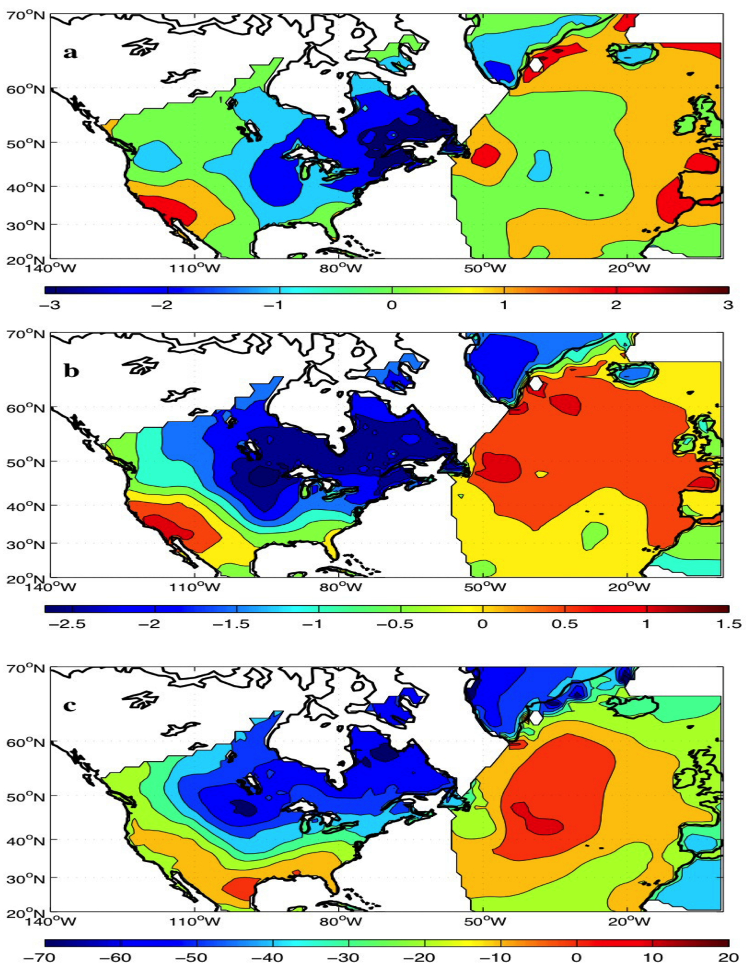


Currently (2016) PNA/PDO in its negative phase weaken El Nino

Surface Temperature, 2007-2012 Regressed on PNA



Surface Temperature, 1850-1999 Regressed on PNA



Projected on TSI

Projected on centennial mode of T

Projected on PNA index

Conclusions

- ✧ CGC influences the Earth's climate via radiative forcing. Response to CGC forcing engages the deep ocean
- ✧ The temperature response to CGC is phase delayed by about 10-20 yrs
- ✧ PNA (PDO) is a major climate pattern associated with CGC
- ✧ CGC forcing may contributed to slowdown of global warming (hiatus) and recent effect of El Niño.

The End