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# The Earth's Climate at Deep Minima of the Solar Activity

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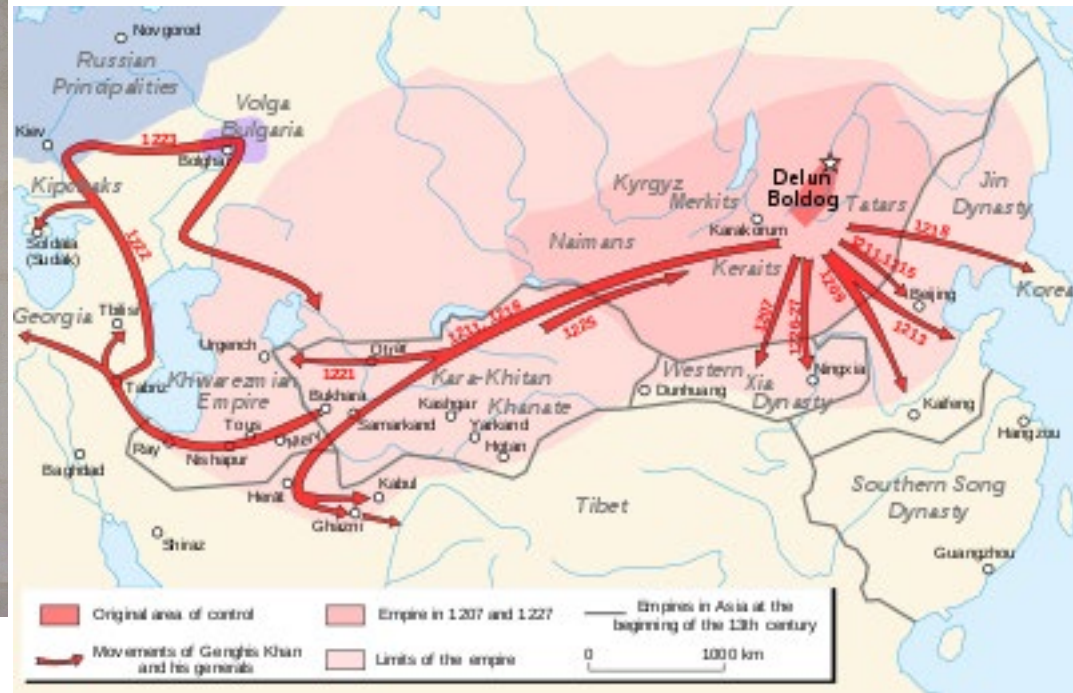
# Some Cases of the Earth's Climate Change on the Centennial Time Scale

# 8-9 century Collapse of Maya Civilization



- Series of draughts (associated with the shift of ITCZ to South)
- Loss of climate stability leads to widespread dislocation, war
- Leads to depopulation, population migration, never recovered

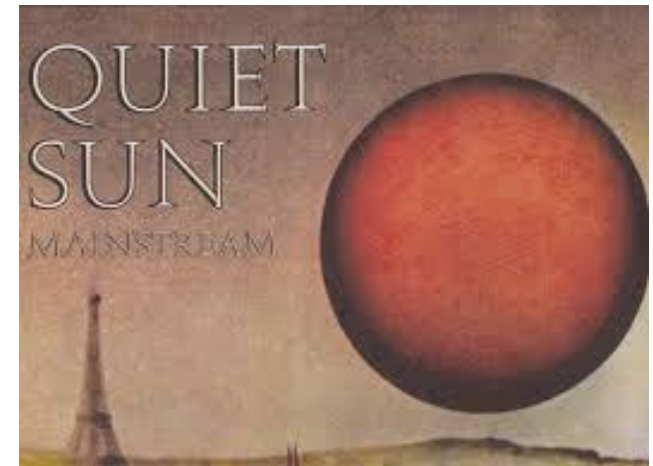
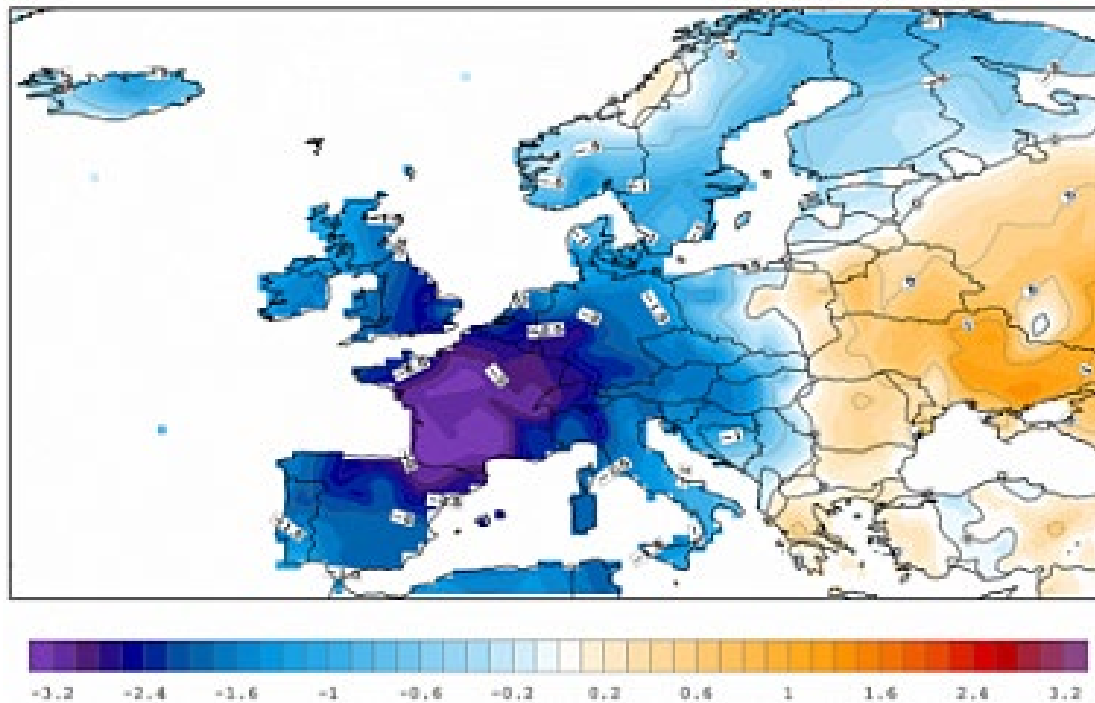
# 13 Century Success of Genghis Khan



- The tree rings record in the Khangai Mountains of Mongolia (Pederson, 2014) revealed that Central Mongolia was wettest and warmest in 1211 – 1225, the exact time of the Great Mongol empire rise of Genghis Khan.

# 19th century minimum

1816 Summer temperature anomaly



Year without summer: quiet Sun or Tambora?

Byron & Mary Shelley (Frankenstein) in Switzerland

Alexander Pushkin in Sankt Petersburg



# 20th century minimum



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

**New York American**  
EDITION FOR GREATER NEW YORK  
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."

A black and white illustration of the Titanic ship sailing on the ocean. A large iceberg is visible in the foreground, and the ship is positioned near it. The illustration shows the ship's smokestacks and the surrounding water.

April 1912, Titanic

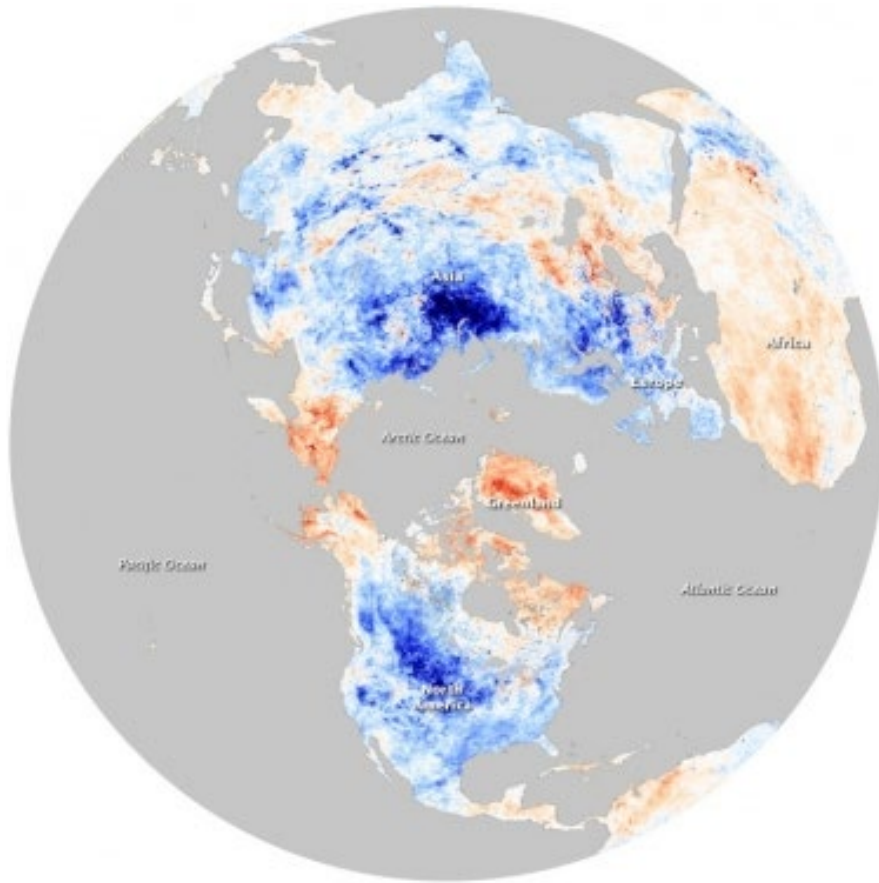
# Did sunspots kill Titanic?



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

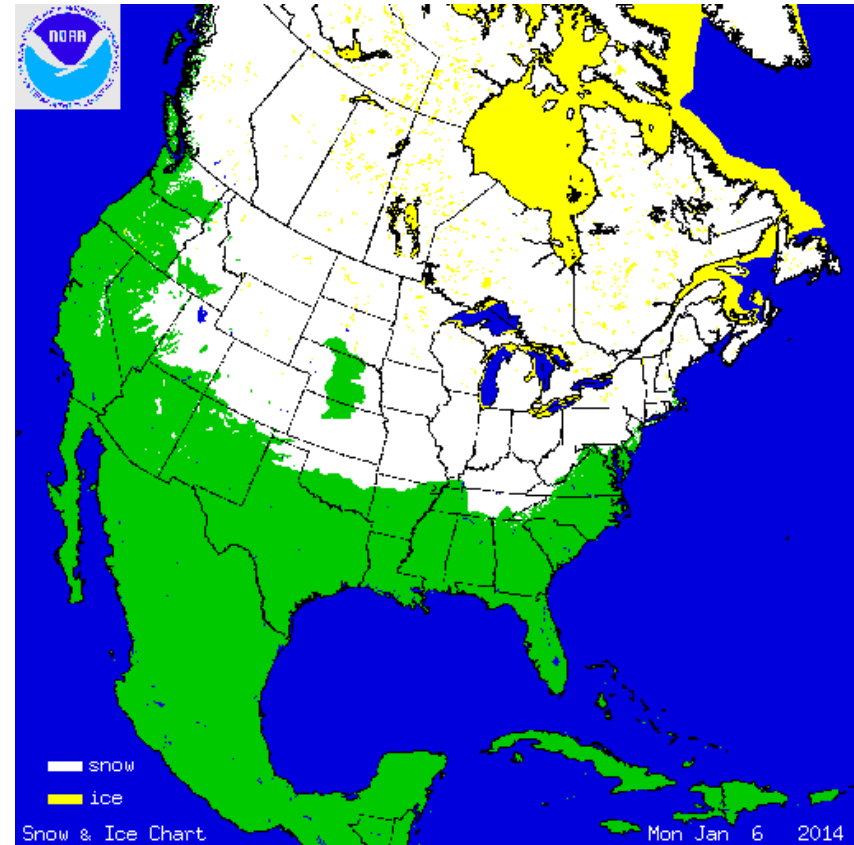


# 21st century minimum



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

No snow in S. Petersburg this winter 2019-2020



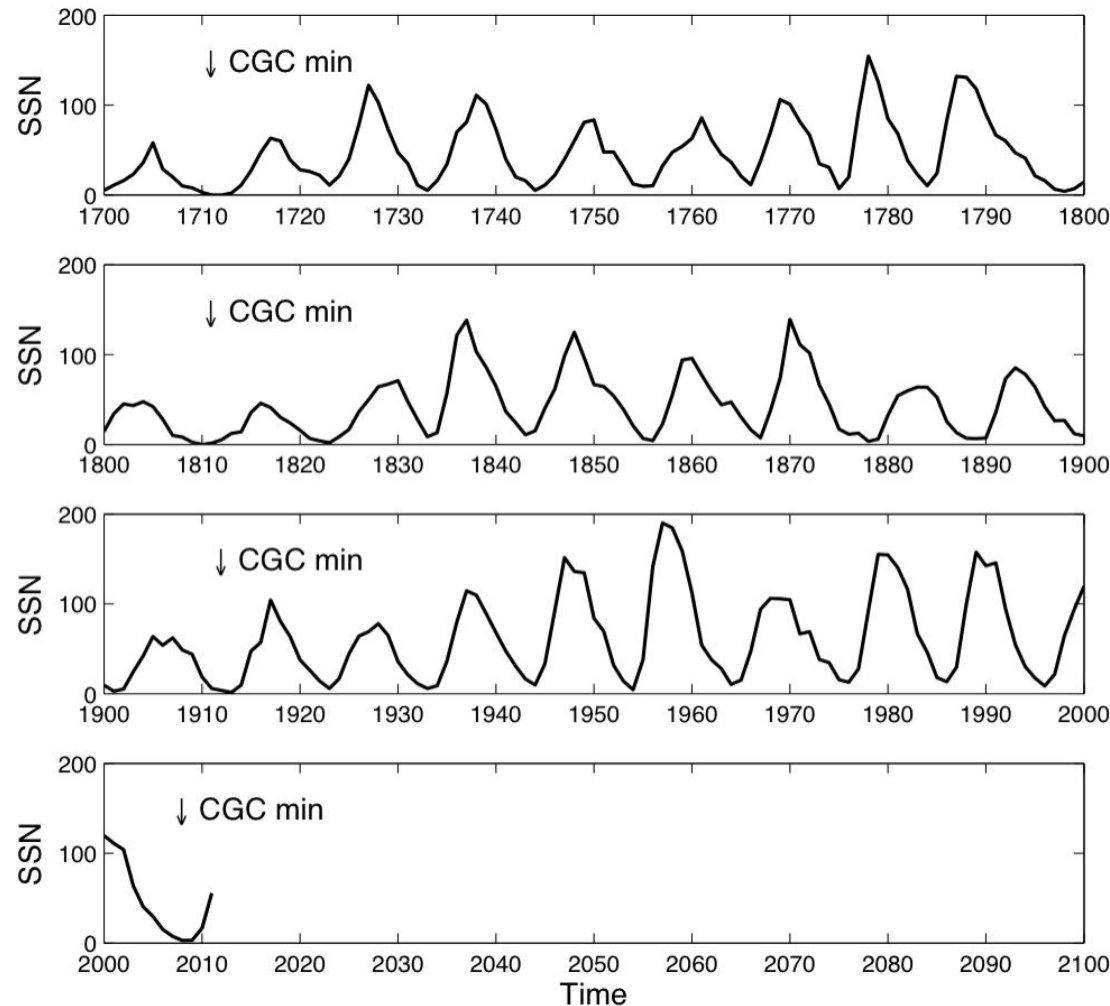
2014 N. America cold wave



Solar Cause of these and others  
Climate Changes ?



# Centennial Gleissberg Cycle (CGC)

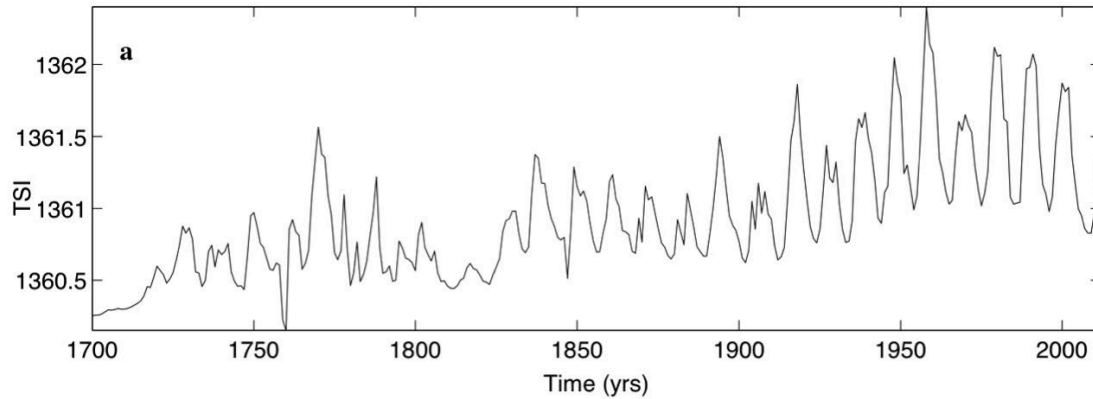


90-110 year quasi-periodic modulation of 11-year cycle of sunspots

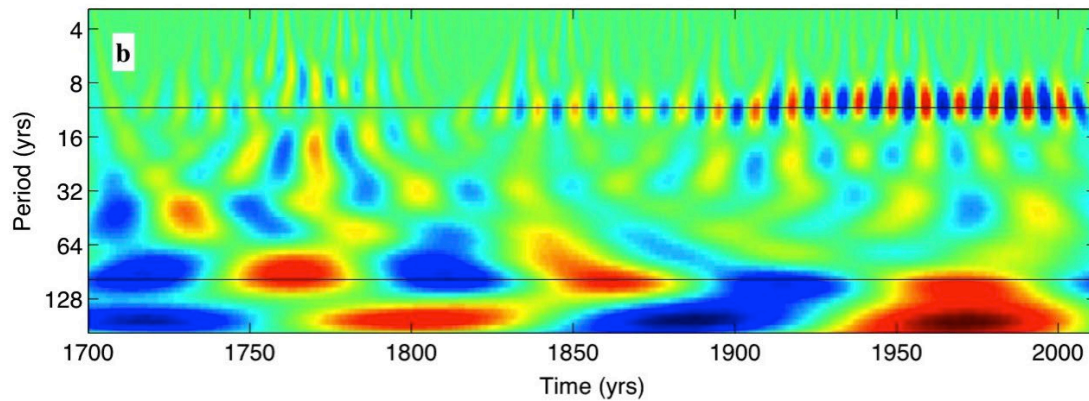
CGC recorded in 450 AD - 1450 AD (auroras)--Feynman & Fougere (1988), Ruzmaikin et al. (2006)

CGC recorded in  $^{10}\text{Be}$ ,  $^{14}\text{C}$  -- Beer et al. (2007), Ogurtsov et al. (2013), Usoskin (2013)

# CGC in TSI Wavelet

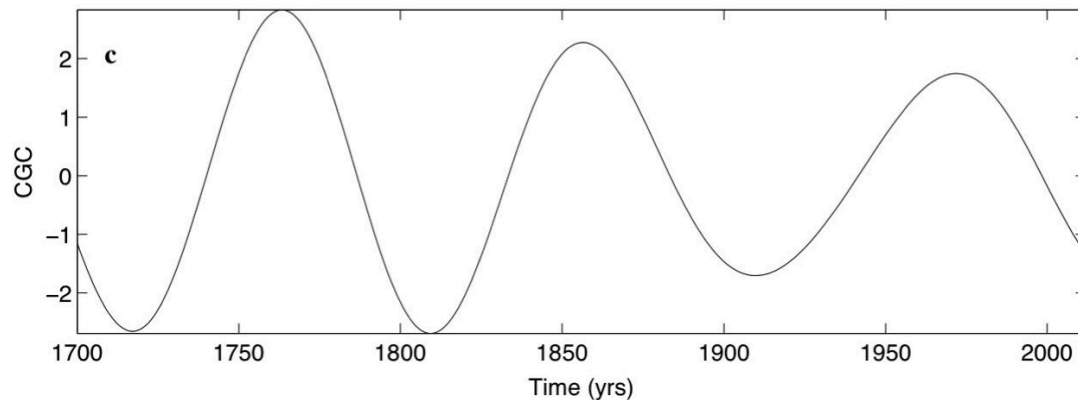


TSI from [www.lasp/sorce](http://www.lasp/sorce)



11-year cycle scale

centennial scale



CGC Mode (80-110 yrs)



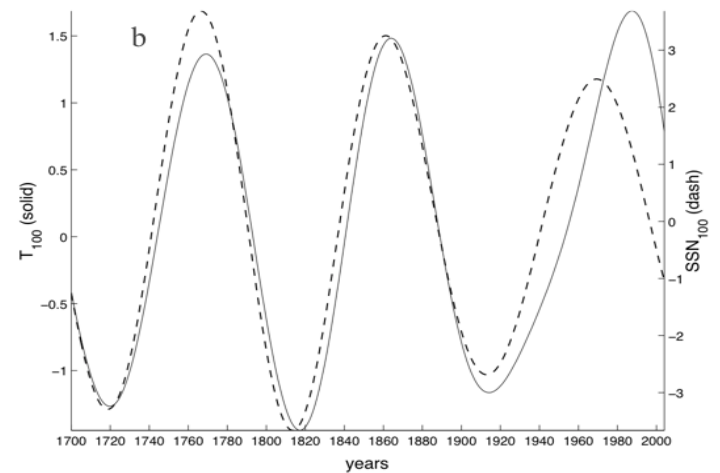
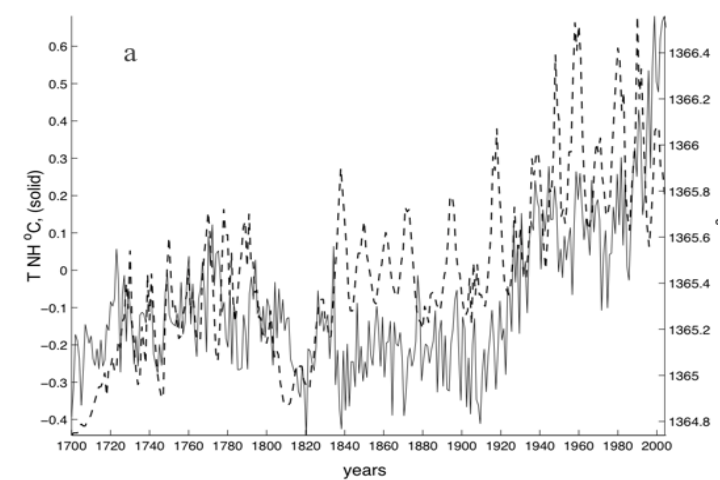
# CGC Minima

- ✓ Auroral Minima in (450 - 1450) record
- ✓ Beginning of 18<sup>th</sup> century (1710 - 1720 end of MM)
- ✓ Beginning of 19<sup>th</sup> century (1800 - 1820, Dalton min)
- ✓ Beginning of 20<sup>th</sup> century (1900 - 1920, Gleissberg, Feynman-Crooker min)
- ✓ Beginning of 21<sup>th</sup> century (2006 - ? , Silverman min)

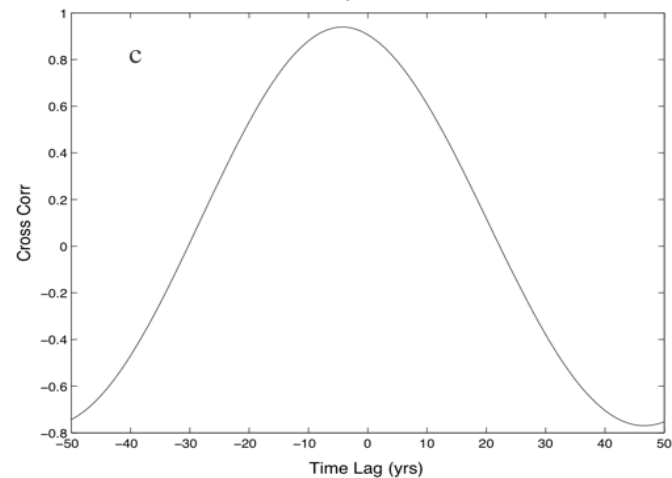
# North Hemisphere Temperature & TSI

Data: TSI Krivova et al. (2007)

Tem. NH Mann et al. (1999) detrended for CO<sub>2</sub> rise

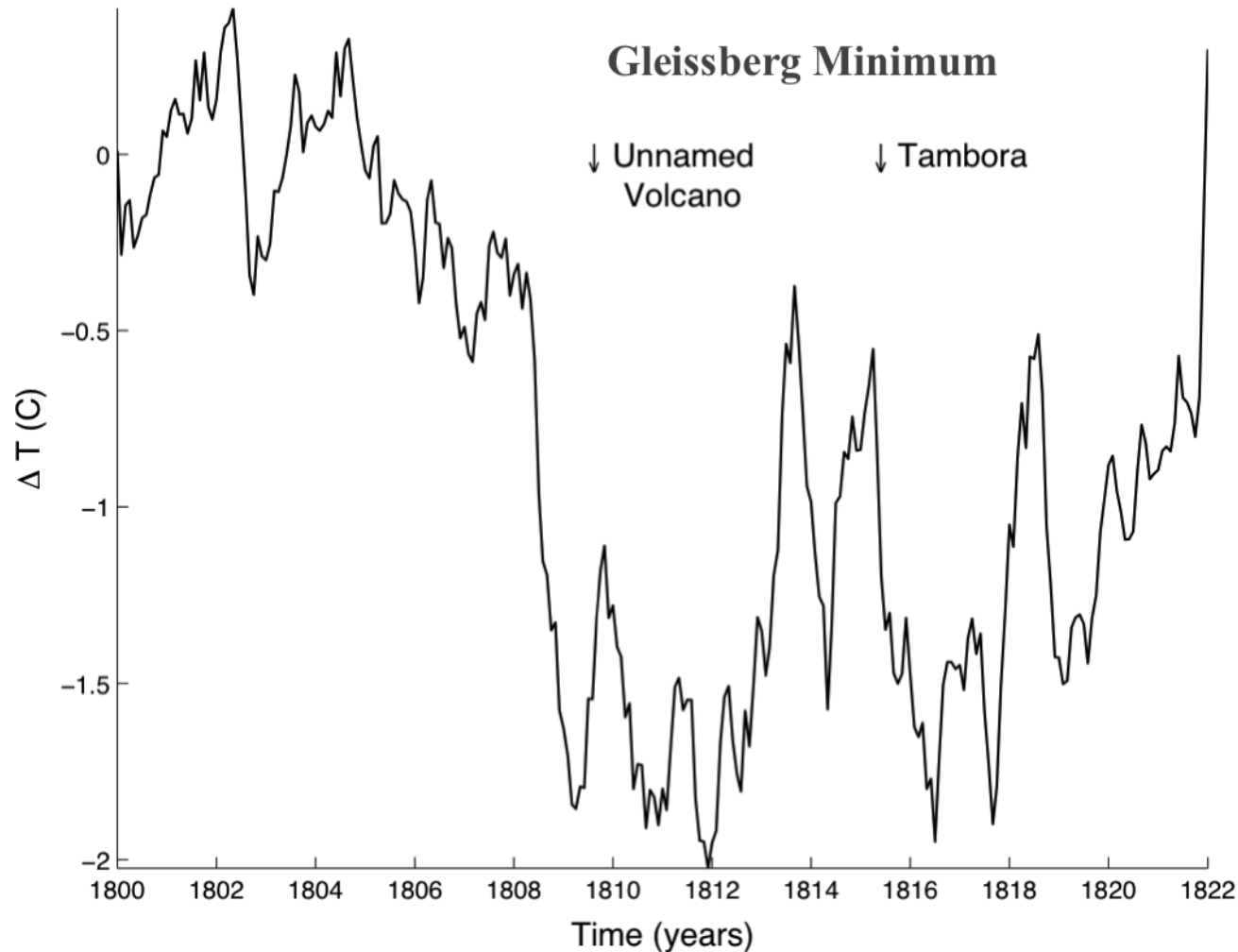


Centennial modes



Cross Correlation of TSI and the Earth's Temperature

# 19th century CGC minimum in T Land



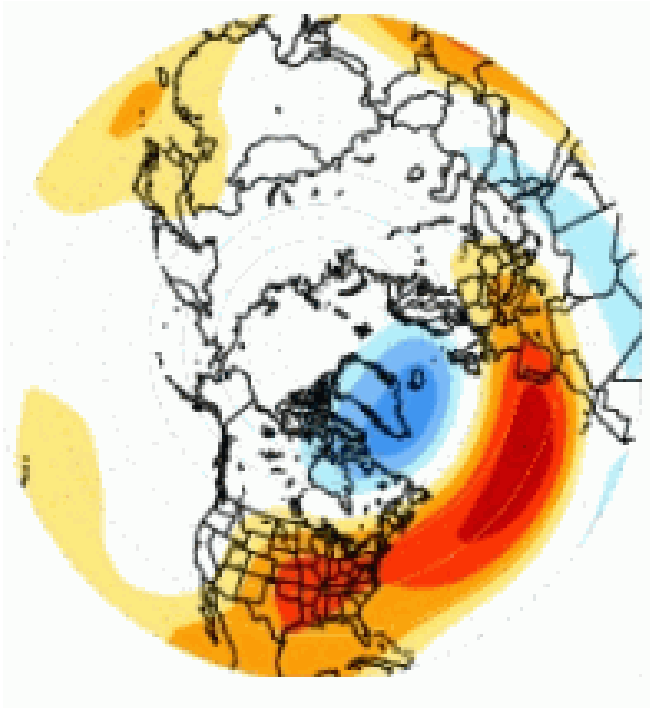
Temperature data from Berkley Earth Project, Rohde et al. (2013)



Climate pattern  
associated with CGC

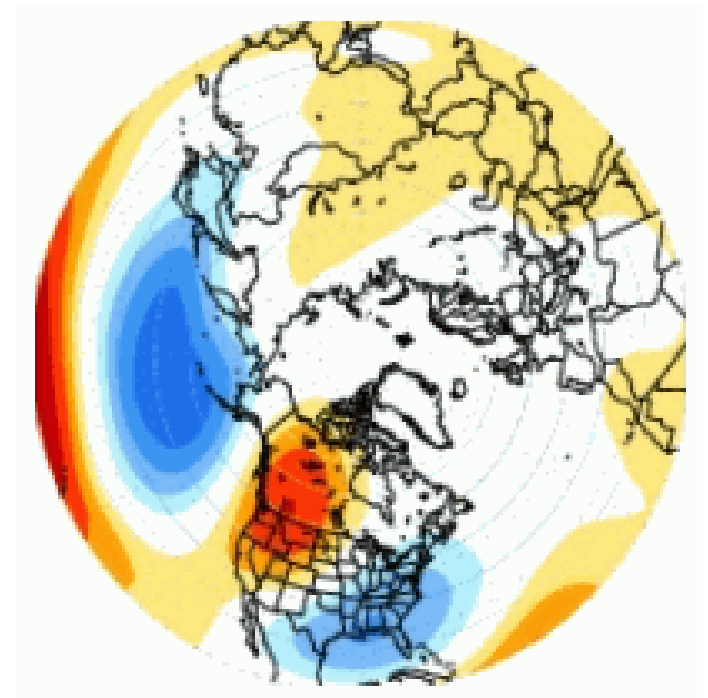
# Climate Patterns associated with solar variability

11-year cycle



North Atlantic Oscillation  
(NAO), related to NAM

CGC

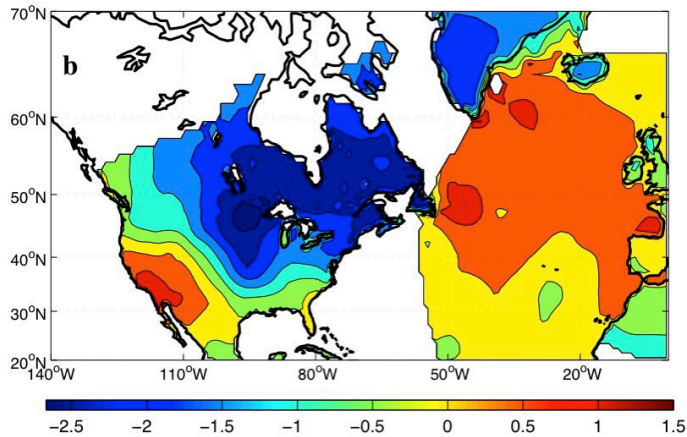
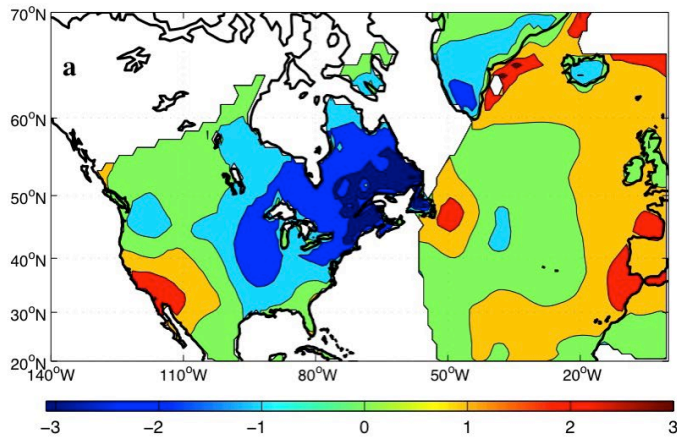


Pacific North American  
(PNA)

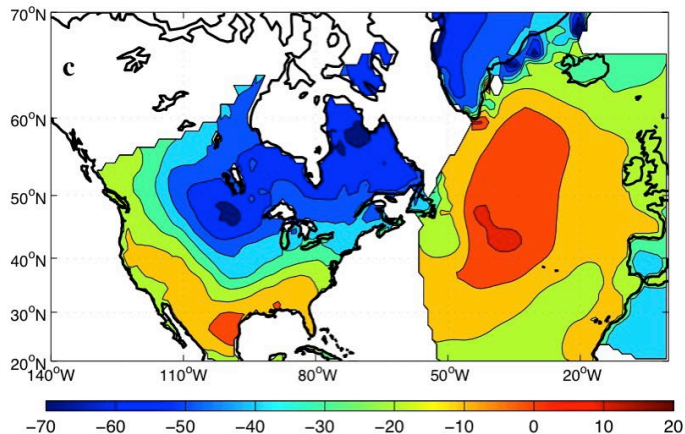
# Maps for 1850-1999:

- (a) TSI,
- (b) Tcentennial mode
- (c) PNA index

TSI



Temperature, centennial mode



PNA index

Reconstructed by Trouet  
and Taylor(2010)



# Conclusions

- ✧ CGC minima influenced the Earth's climate.
- ✧ The temperature response to CGC is phase delayed by about 10-20 yrs
- ✧ PNA is a major climate pattern associated with CGC
- ✧ The quiet Sun strongly influences the Earth's climate on long time scales.