

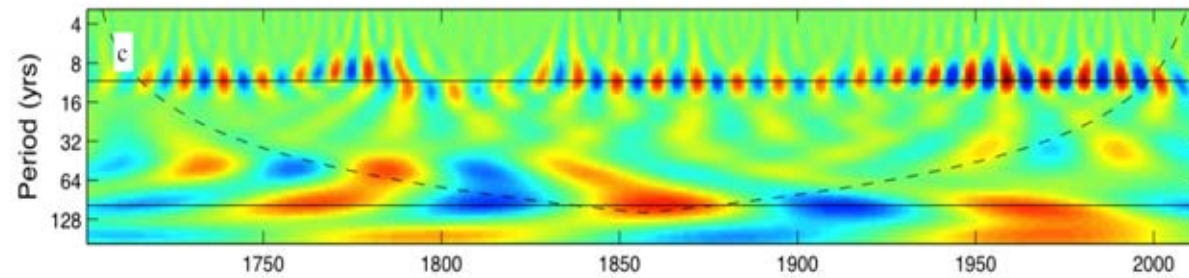
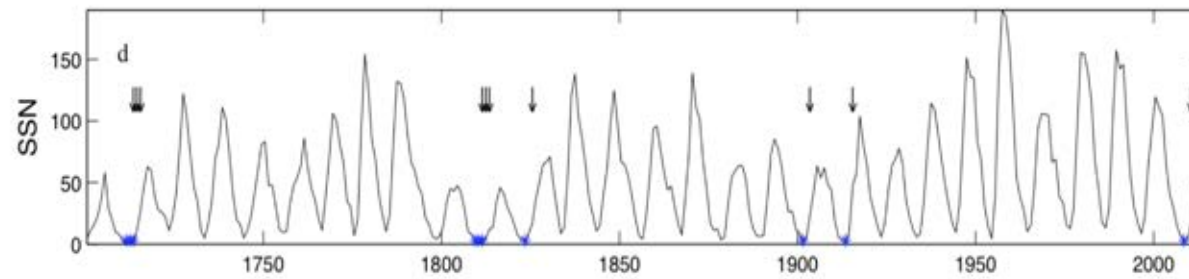


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Solar Influence on the Earth's Climate on the Centennial Time Scale

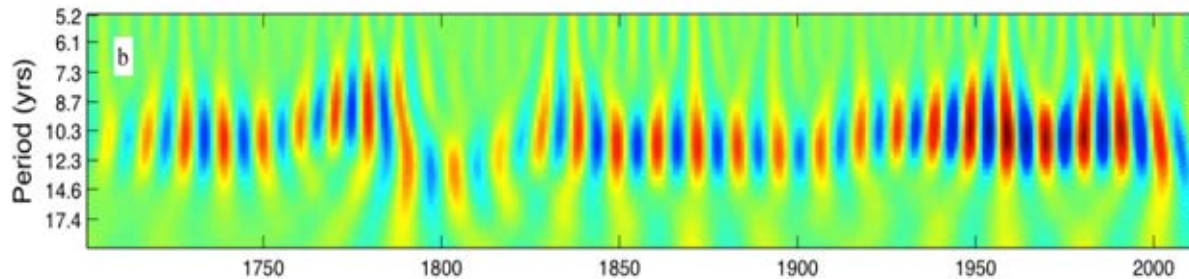
Alexander Ruzmaikin,
Joan Feynman
JPL, California Institute of Technology
and
Judith Lean, NRL

Centennial Variability in SSN Wavelet

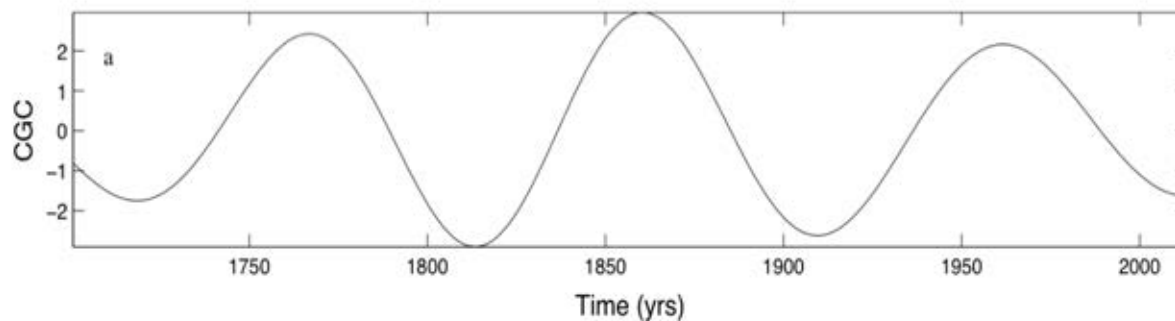


11-year mode

100 year mode

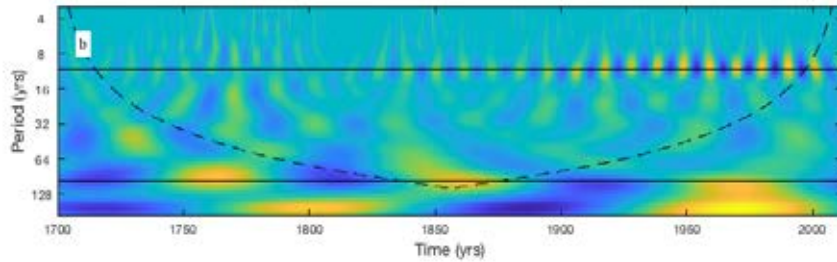
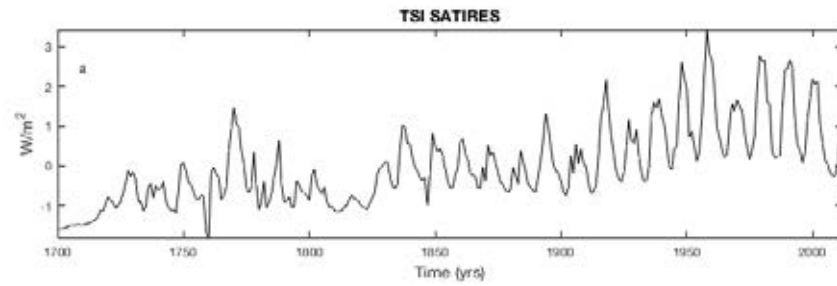


frequency modulation
of the 11-year cycle (?)

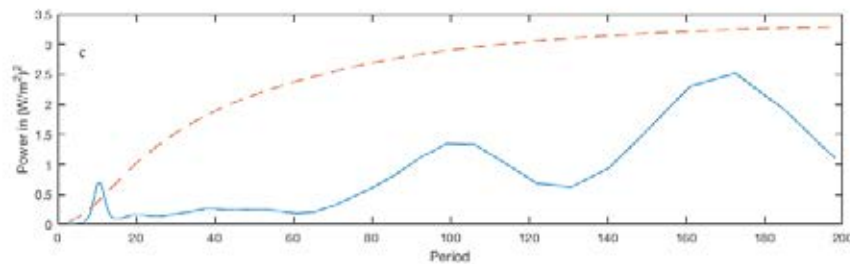


CGC Mode (80-110
yrs)

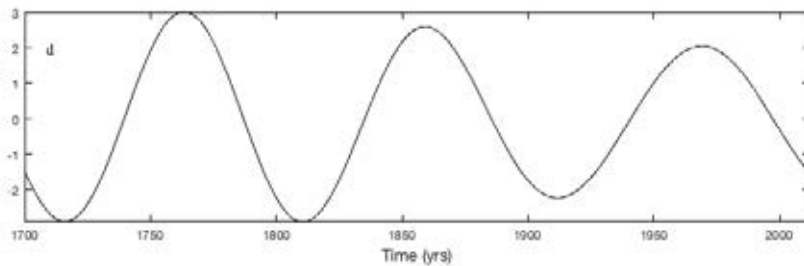
Wavelet of Centennial Variability using SATIRES TSI



Power of Centennial variations

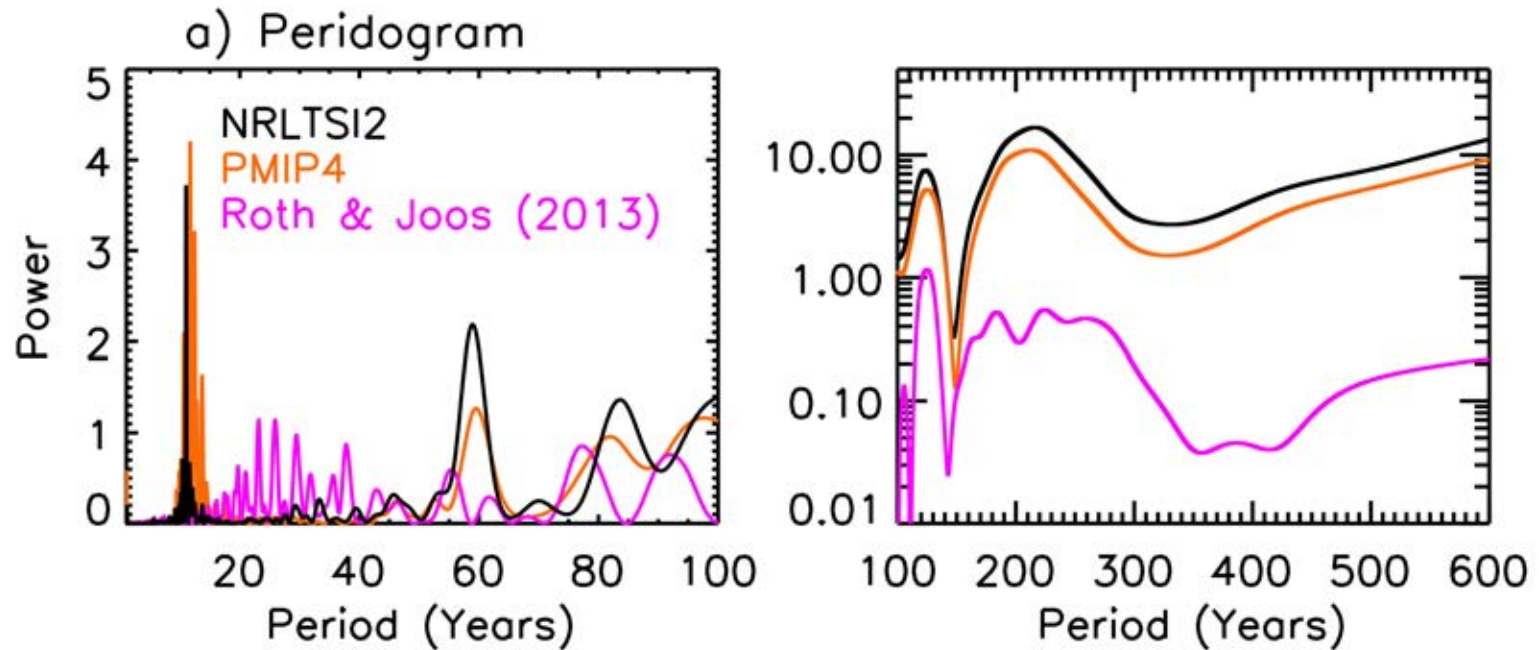


Integral Wavelet Spectrum

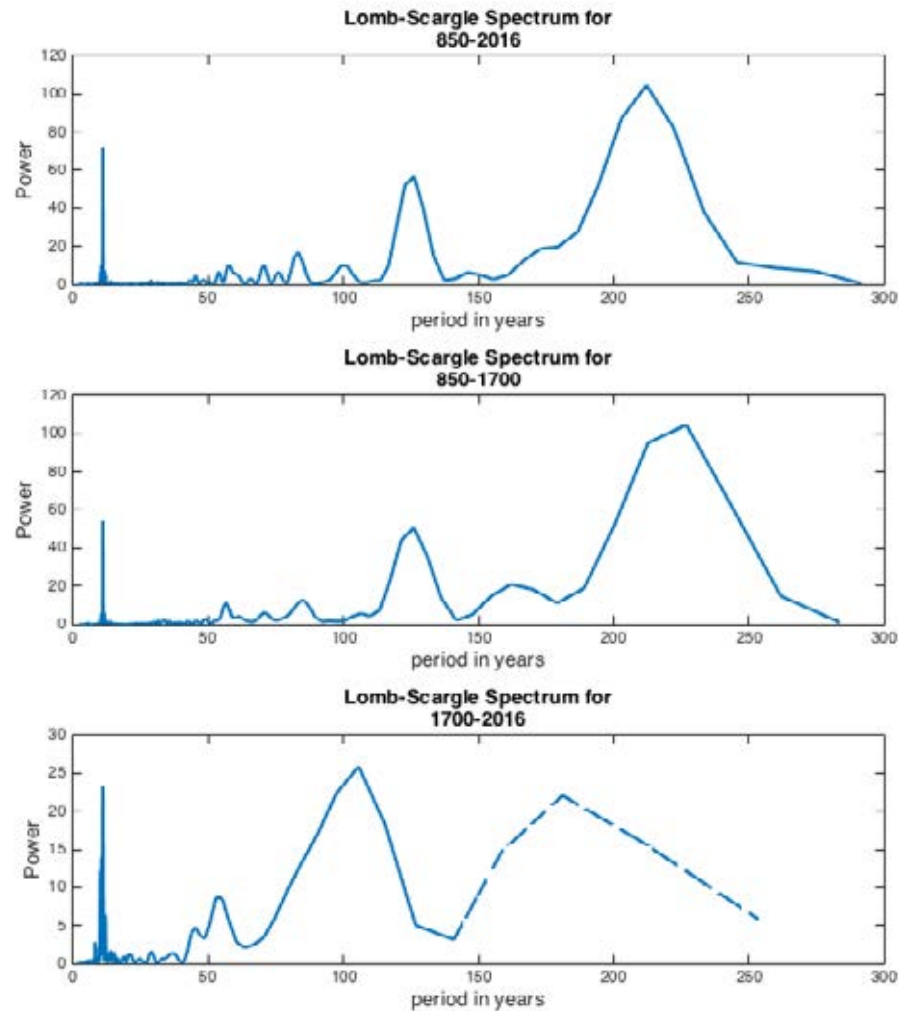


Centennial Mode
(100 yrs) in time

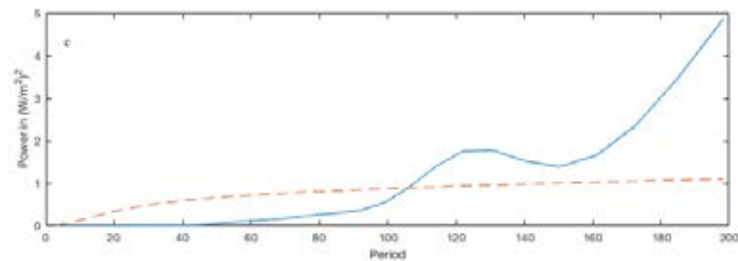
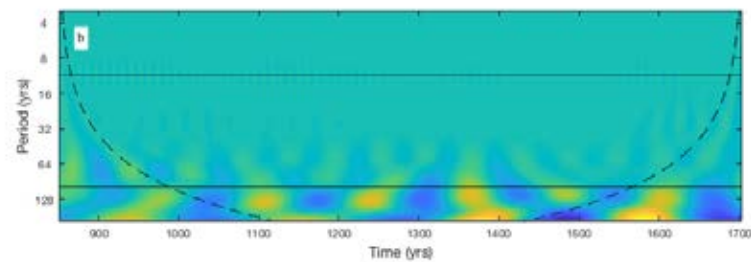
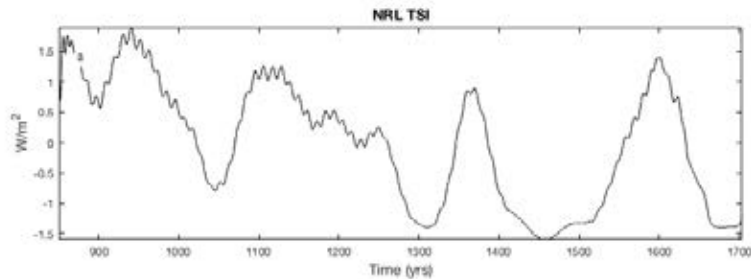
Lomb Spectra NRL TSI 850 to 2016 (Lean, 2018)



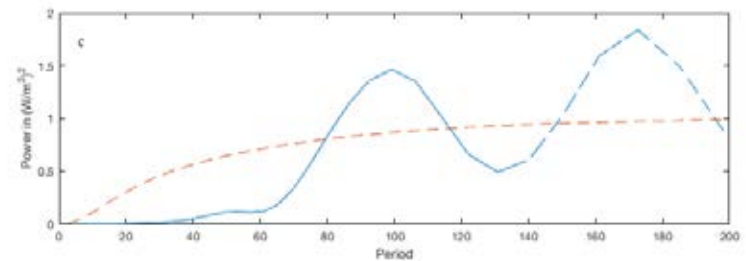
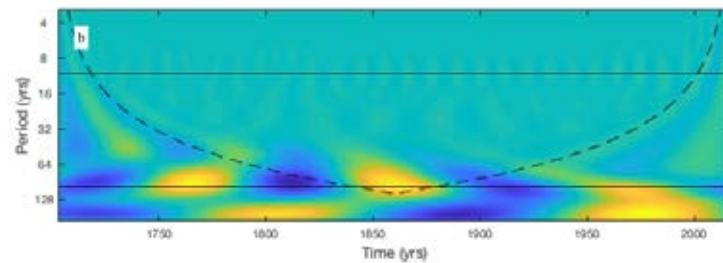
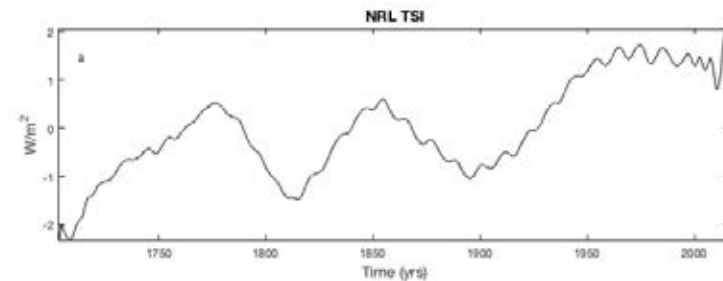
Lomb Spectra NRL TSI 850 to 2016 Split in Time



Change of Spectra of Centennial Variability with New NRL TSI

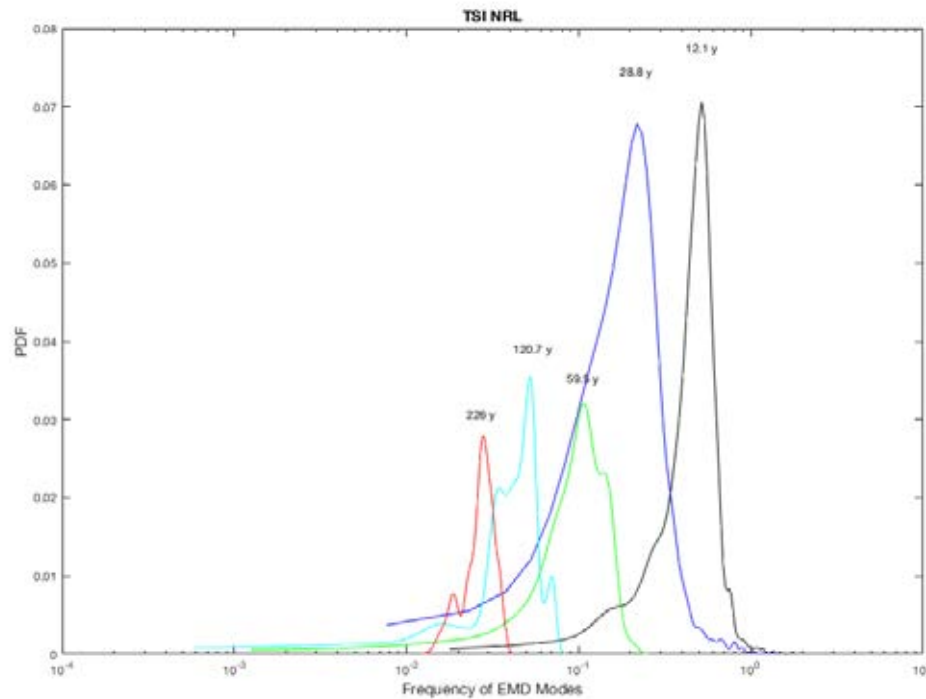


850-1700



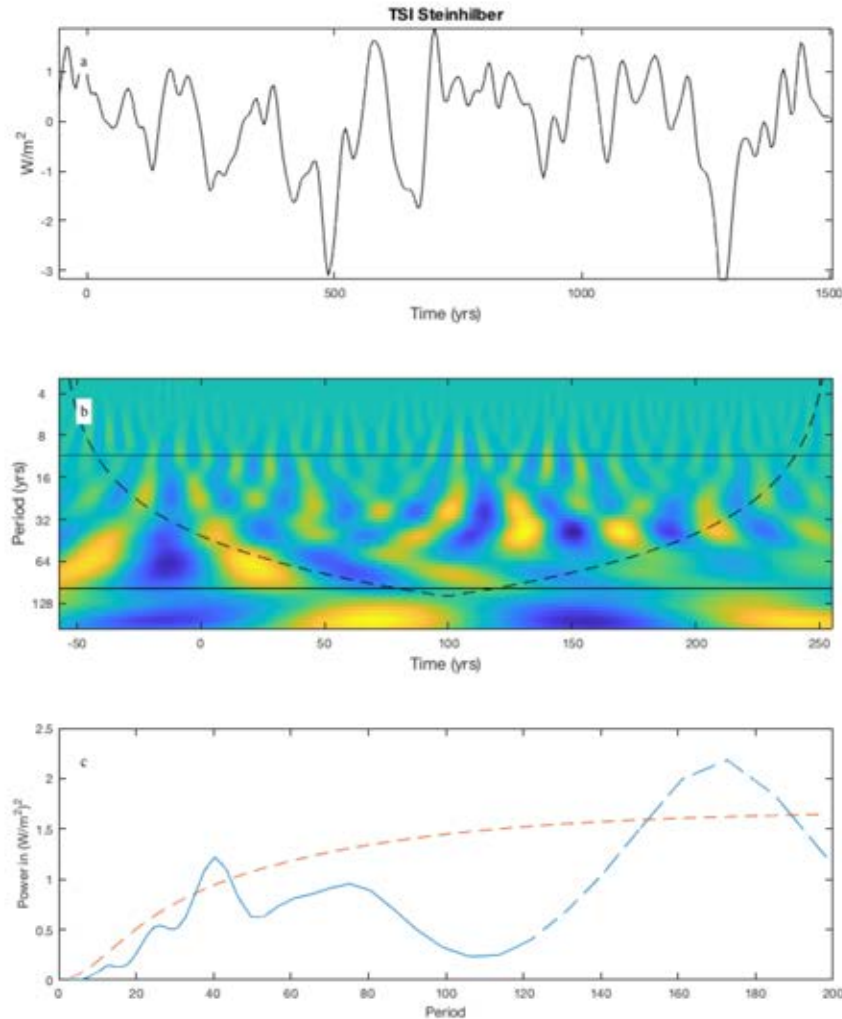
1700- 2016

Frequency Distributions by EMD using the New NRL Data



Centennial Mode
at about 120 yrs

Wavelet Spectra using SWISS TSI from 1700 to 2009 (Steinhilber et al , 2009)



Aurora Spectra from 450 -1450 AD (Feynman and Fougere, 1984)

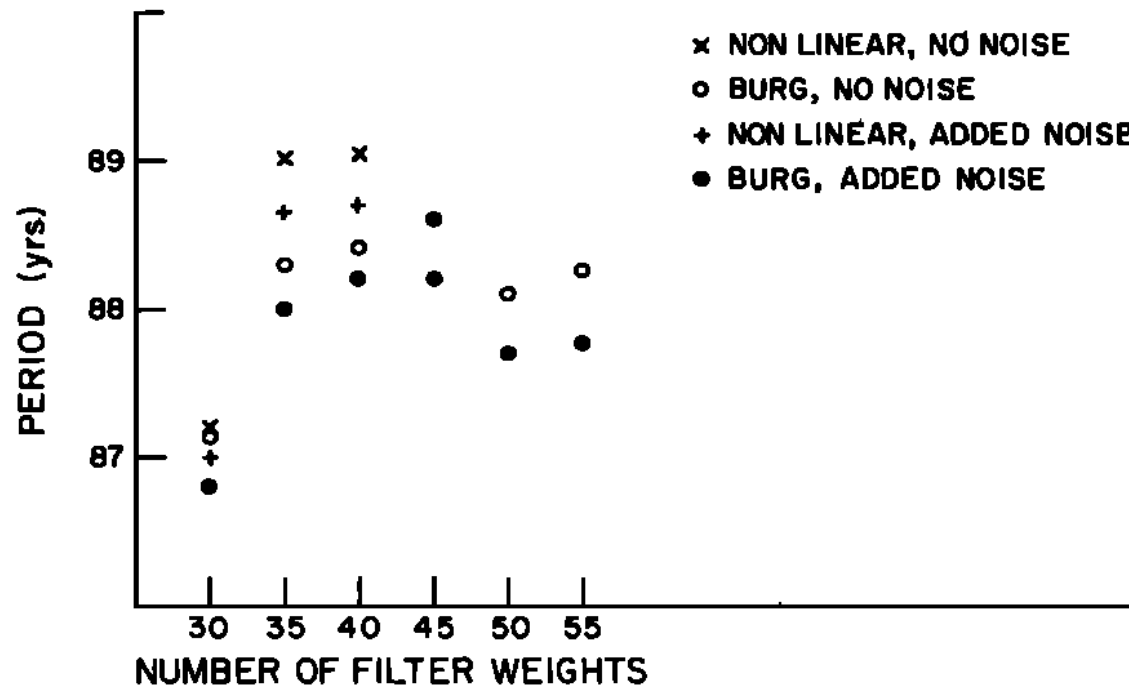
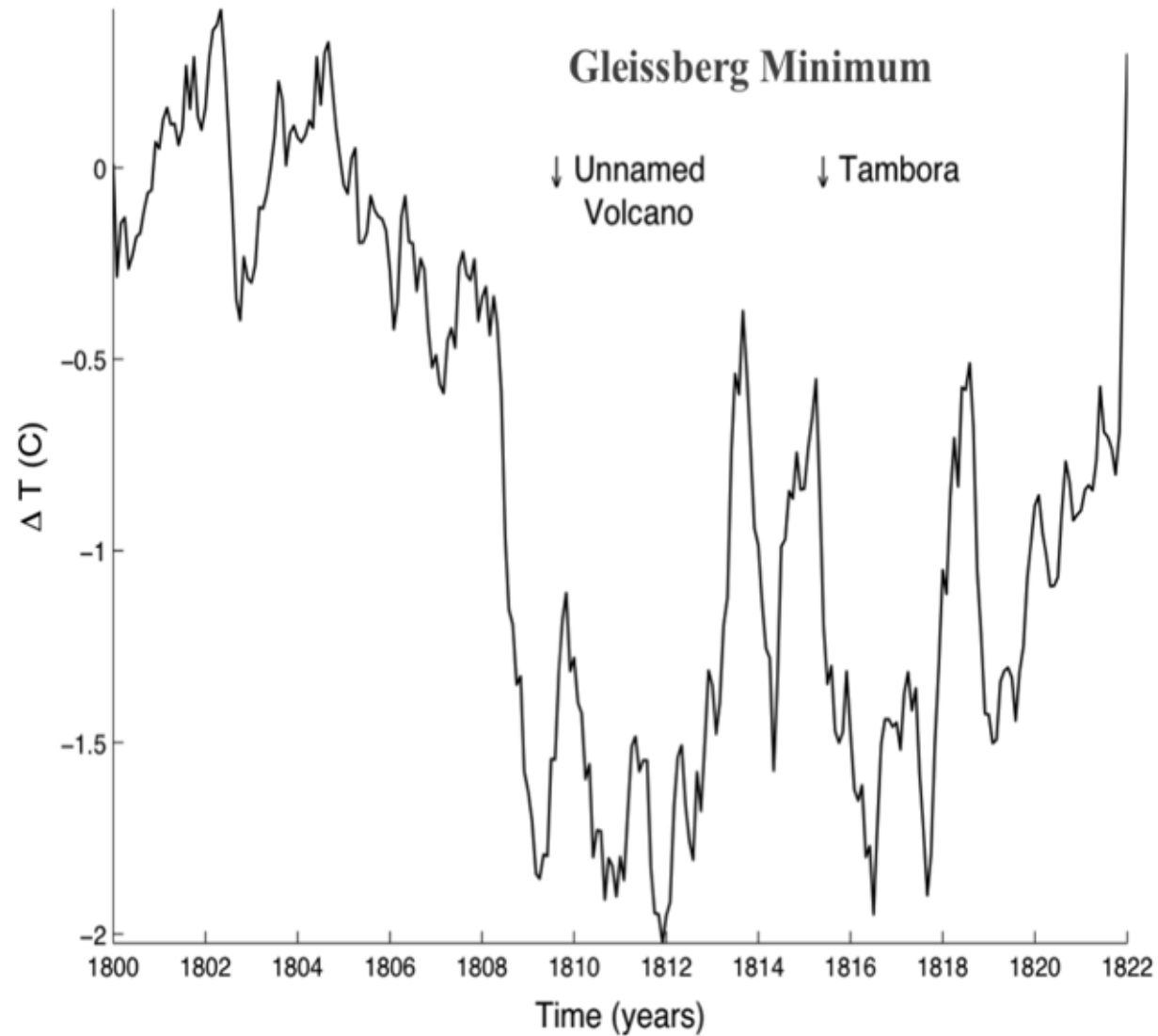


Fig. 3. Estimates of the period of the long cycle from 16 spectrums of the data in Figure 1. Our best estimate of the period is 88.4 ± 0.7 years.

CGC Minima

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

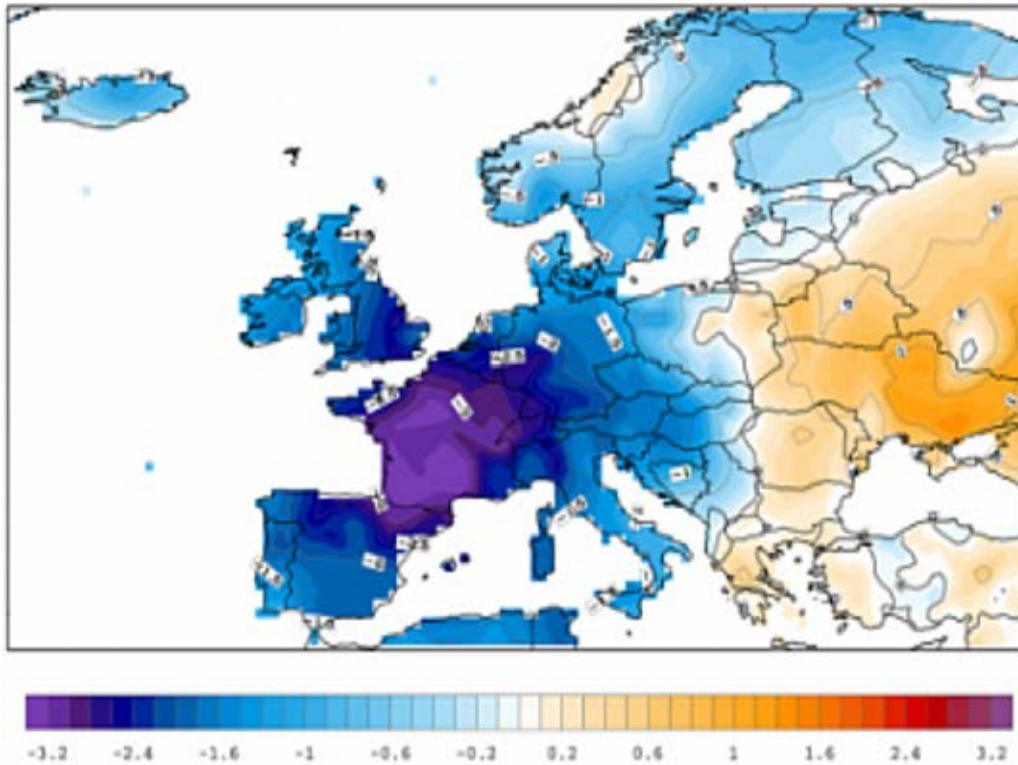
19th century CGC minimum in T Land



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

19th century CGC minimum

1816 Summer temperature anomaly



Year without summer: solar and/or
Tambora?



20th century CGC minimum



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



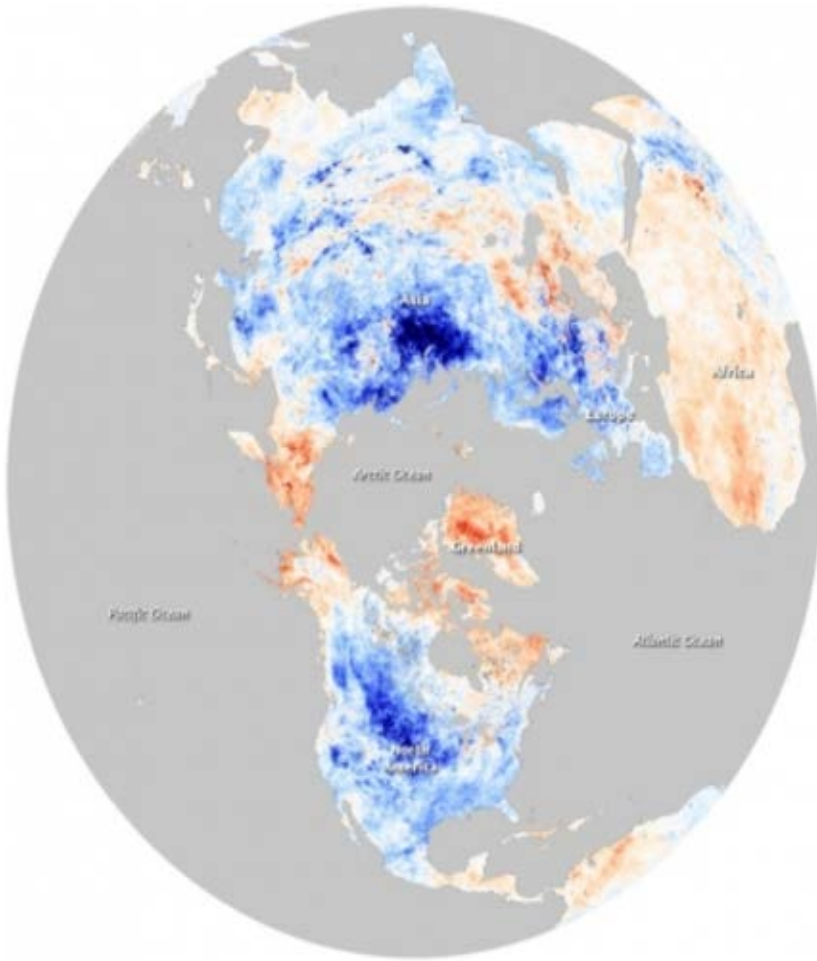
April 1912, Titanic

Did sunspots kill Titanic?

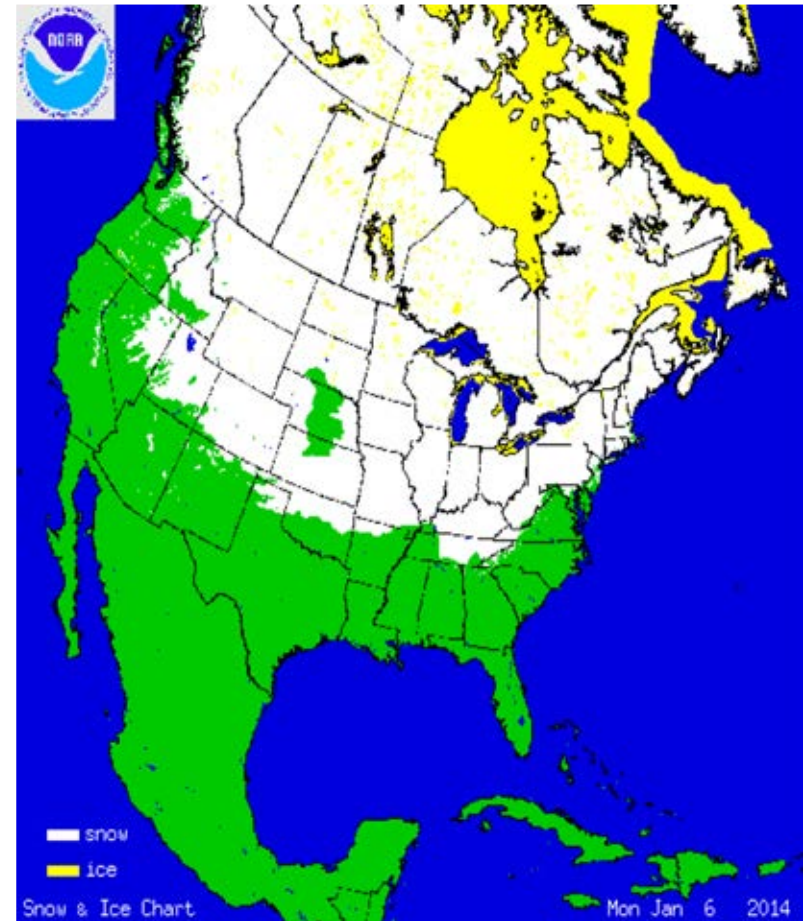


“extreme and prolonged low sunspot-number regime reversed the dearth of southern icebergs in the North Atlantic” (E. N. Lawrence, Weather, 2000)

21st century CGC minimum

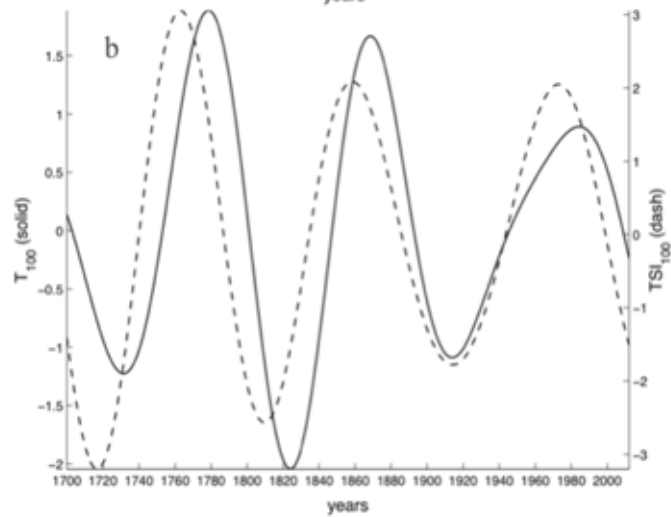
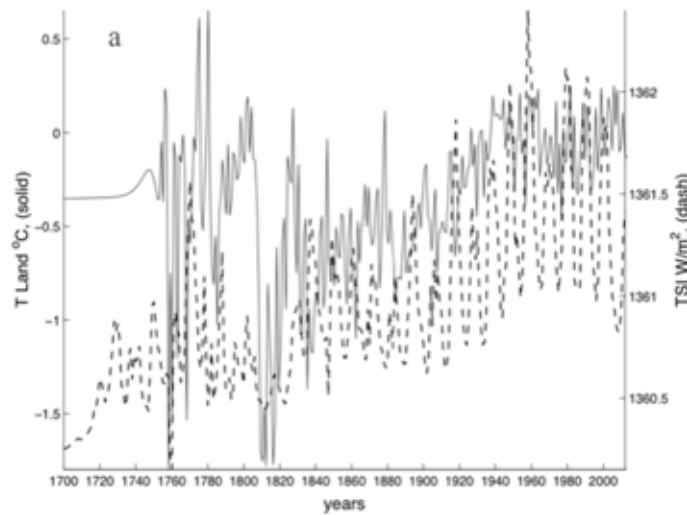


Winters in Europe and Asia were cooler than normal:
deep chill Jan 2006, Jan 2008, Dec 2010, Feb 2012

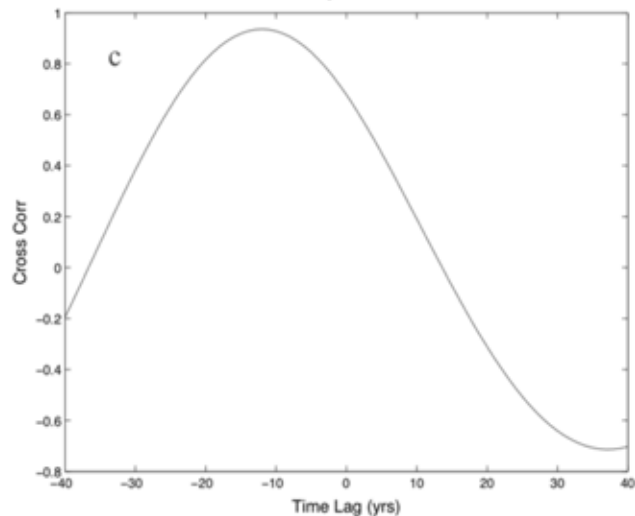


2014 N. America cold wave

Global Land Temperature & TSI



Centennial mode

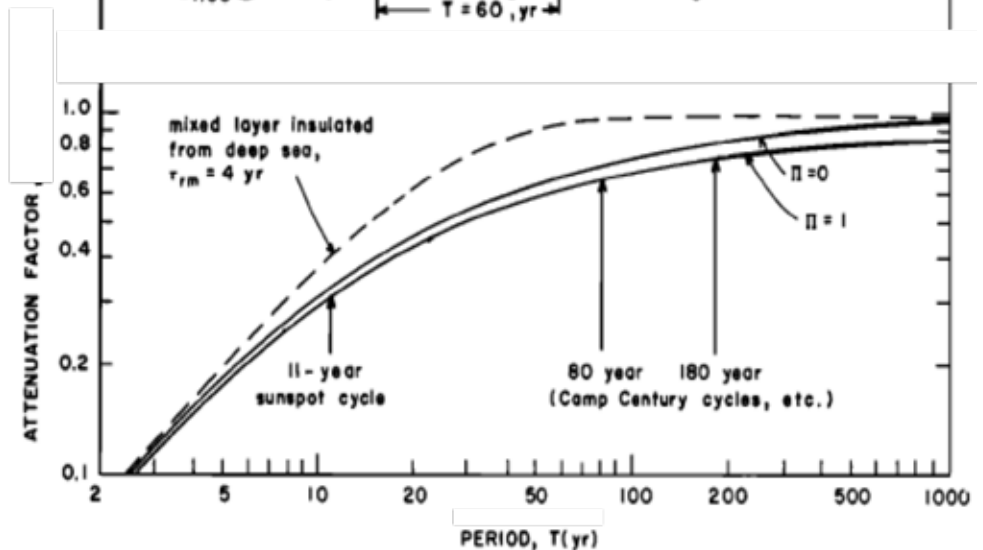
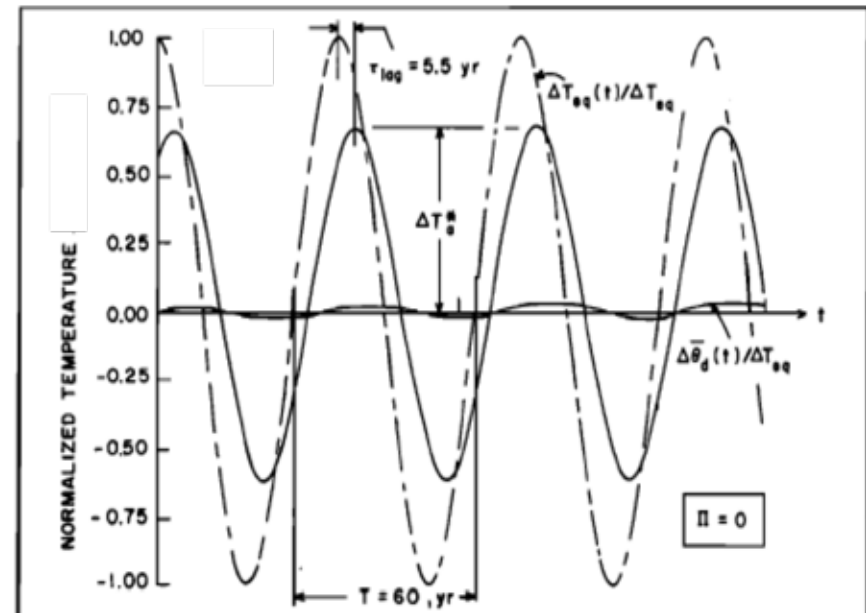
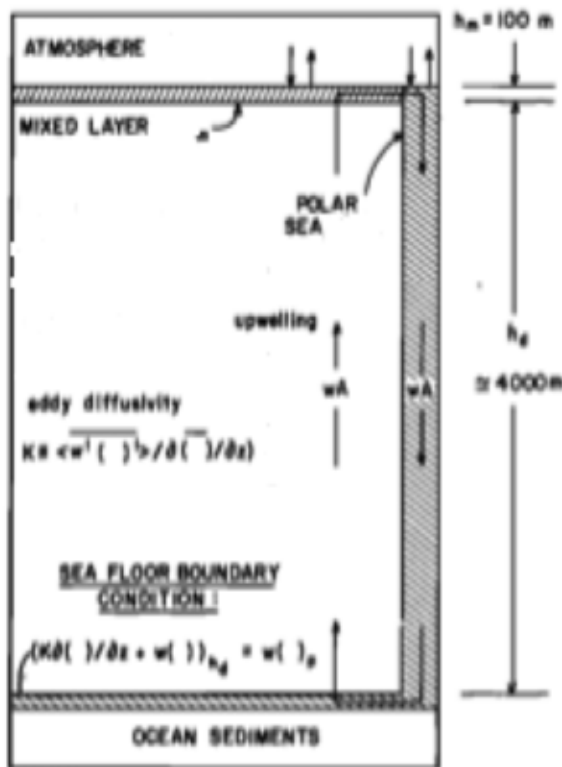


Cross Correlation

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

A 1D Model of Ocean Response

Hoffert et al, 1980



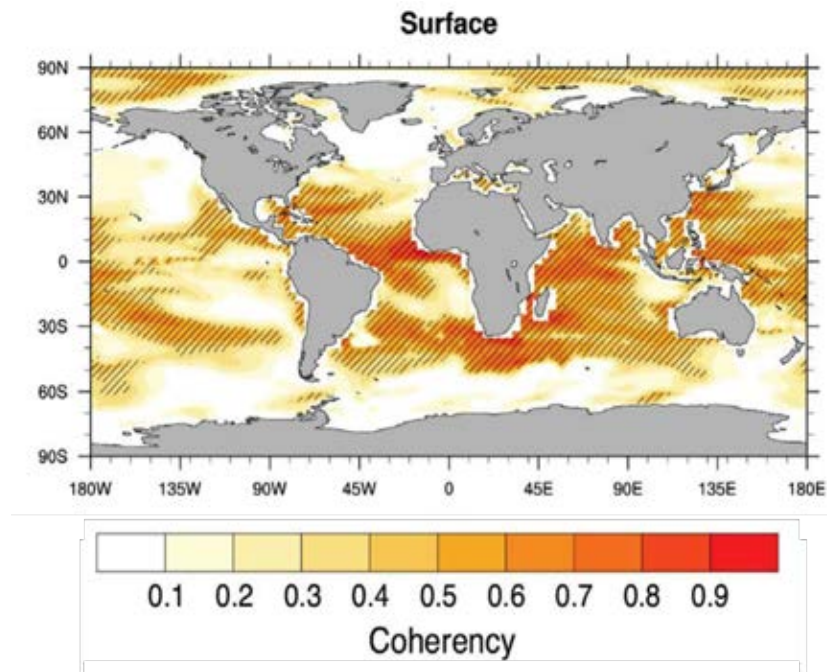
Model predicts a phase shifted periodic Tem response to a periodic forcing

Only mixed layer involved on 11-year scale.

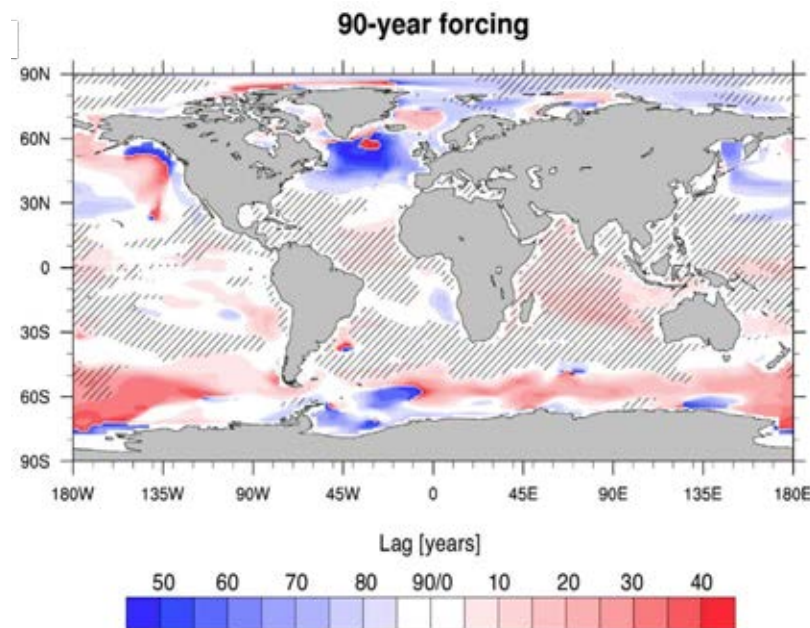
Phase shift 3-4 years

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

CCSM3 Modeling of Ocean Response

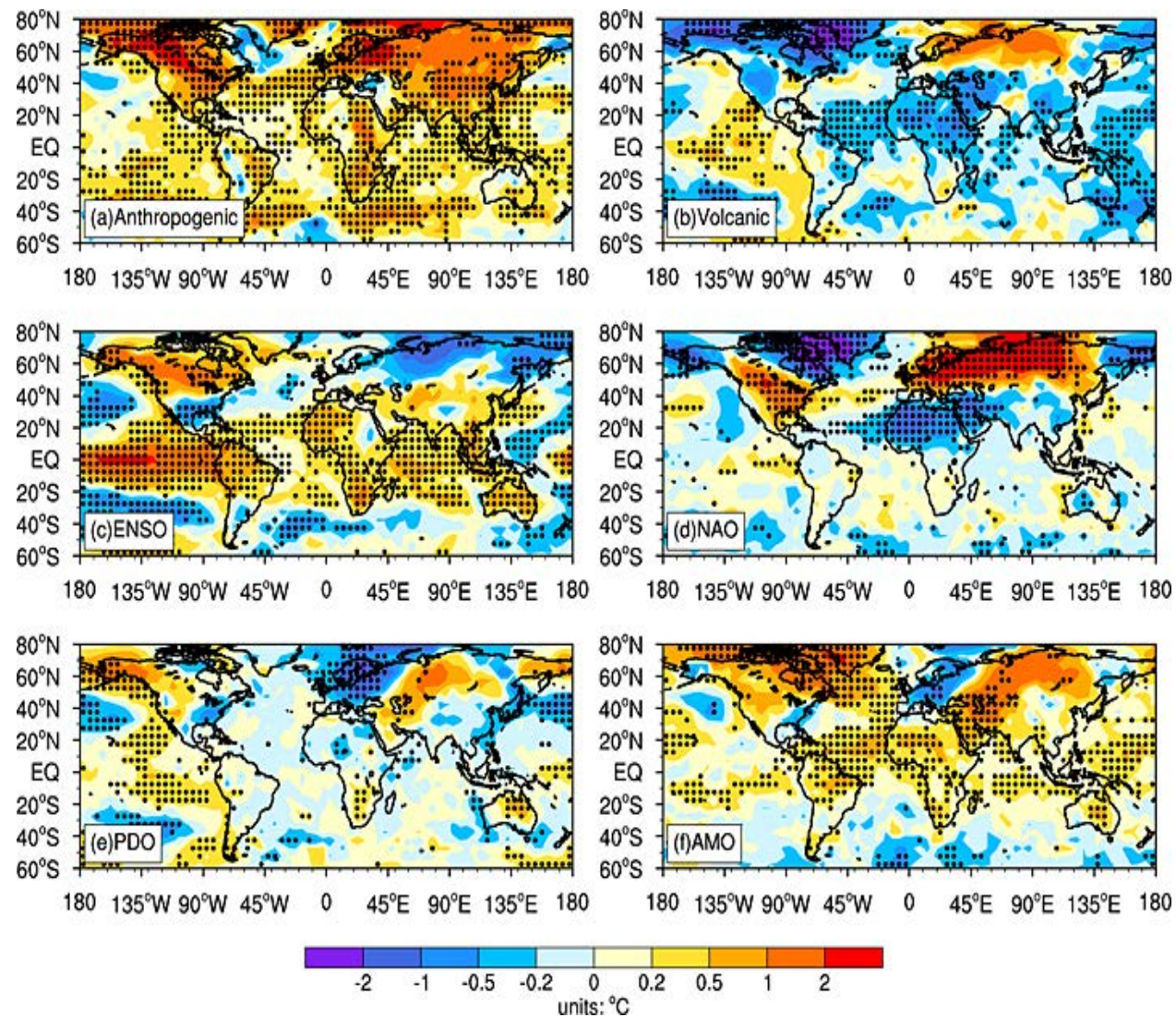


Positive SST & TSI correlation consistent with a direct, thermal forcing of the sea surface.

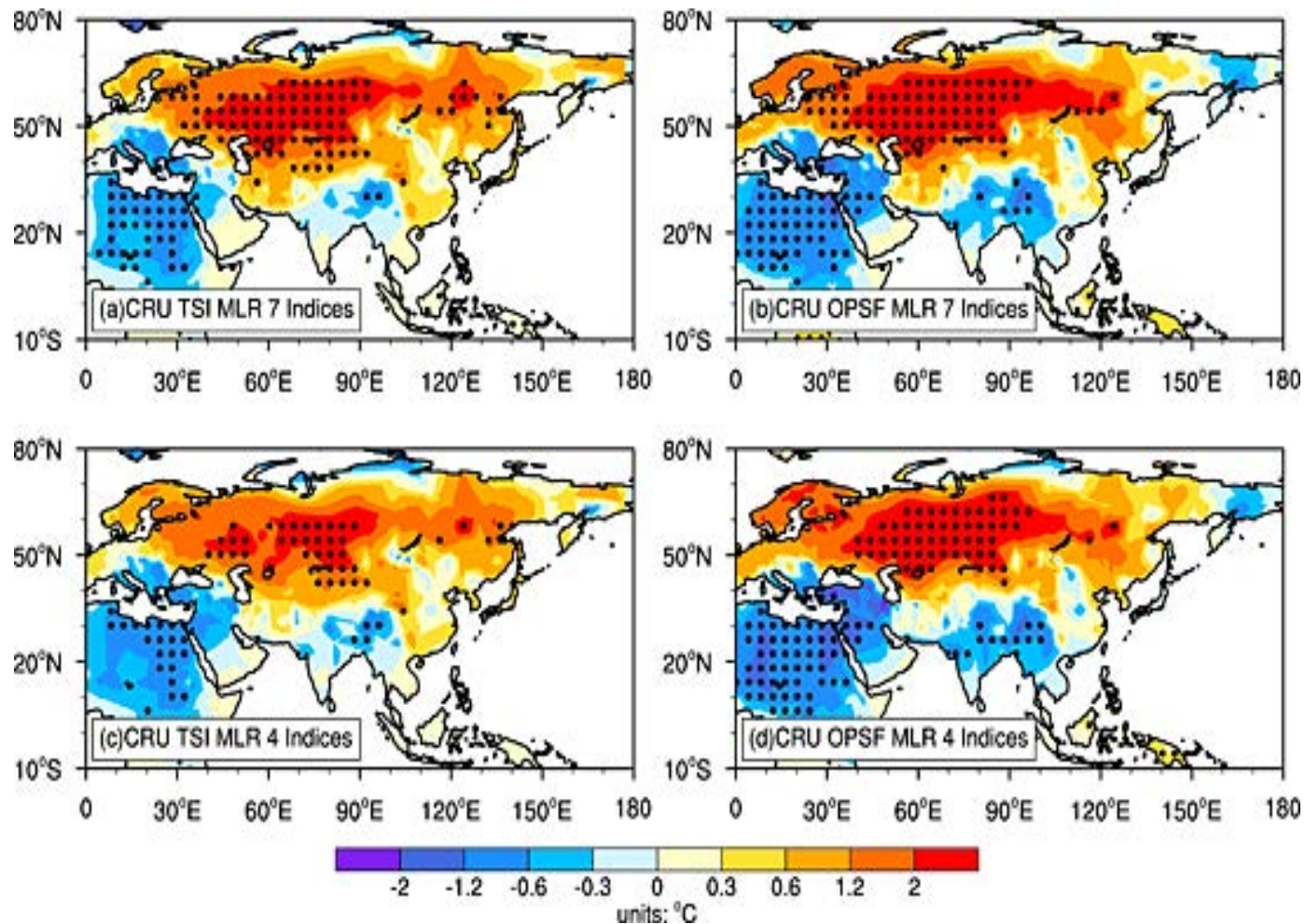


SST response to 90-year sin (TSI) forcing lags by about 20 years.

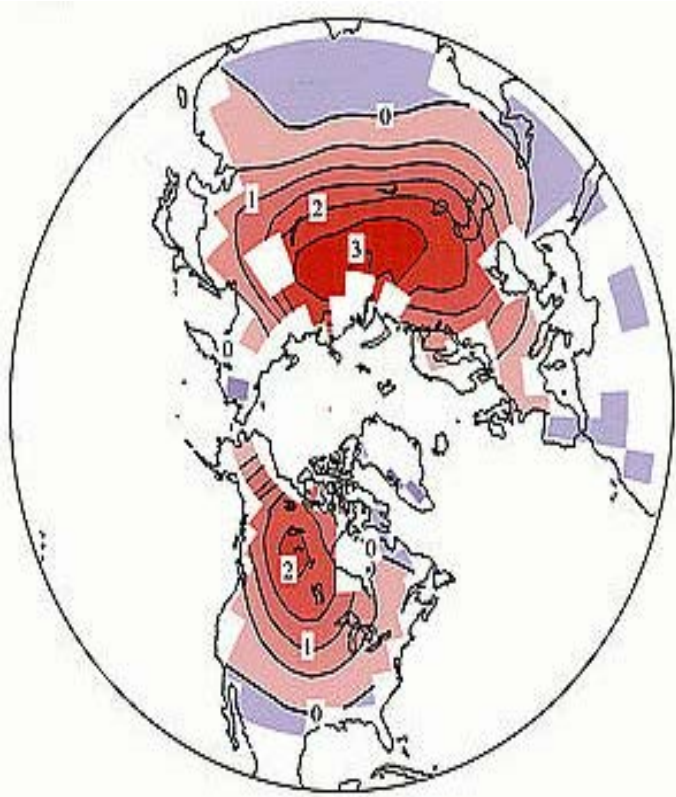
Pattern of non-solar forcings on 11-year time scale



Pattern of solar forcing on 11-year time scale



COWL pattern



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

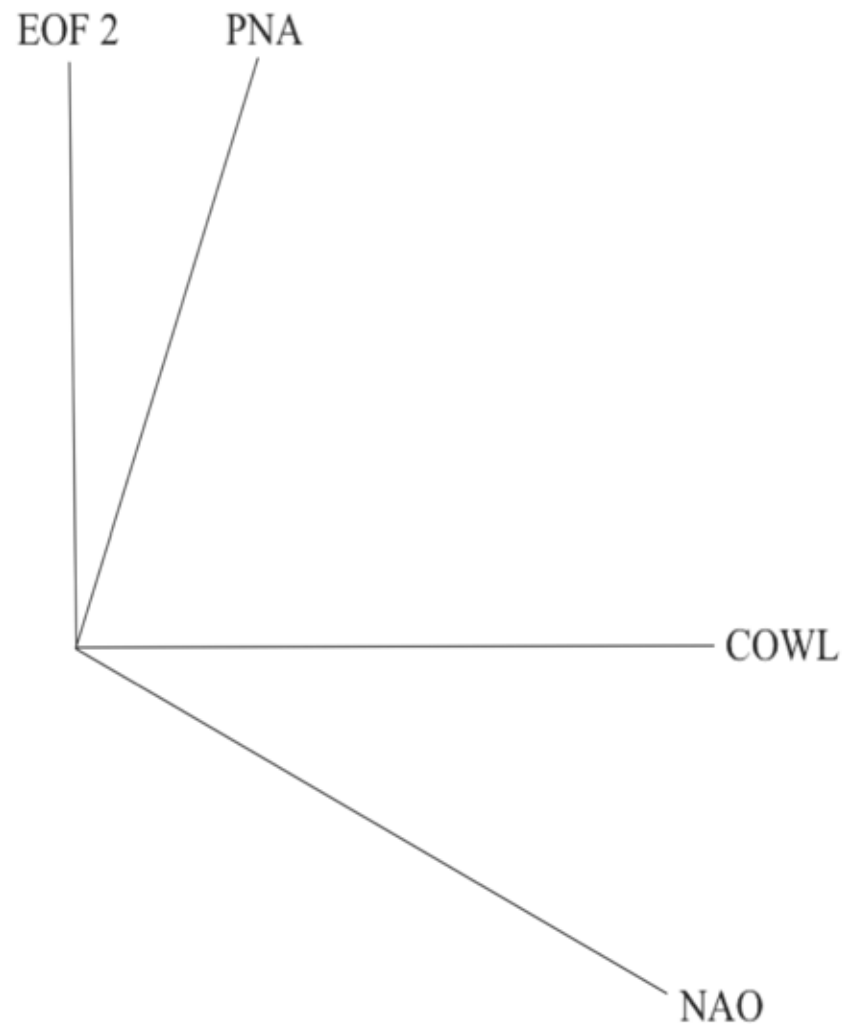
$$T_{\text{land}} = T_{\text{COWL}} + T_{\text{res}}$$

T_{COWL} is dynamically tied to atmosphere

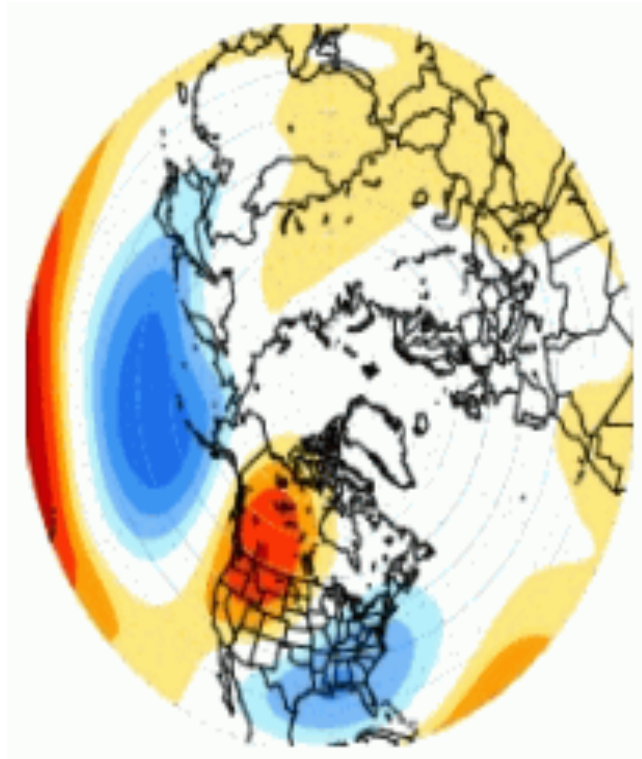
T_{res} is radiatively driven

(Wallace et al., 1995)

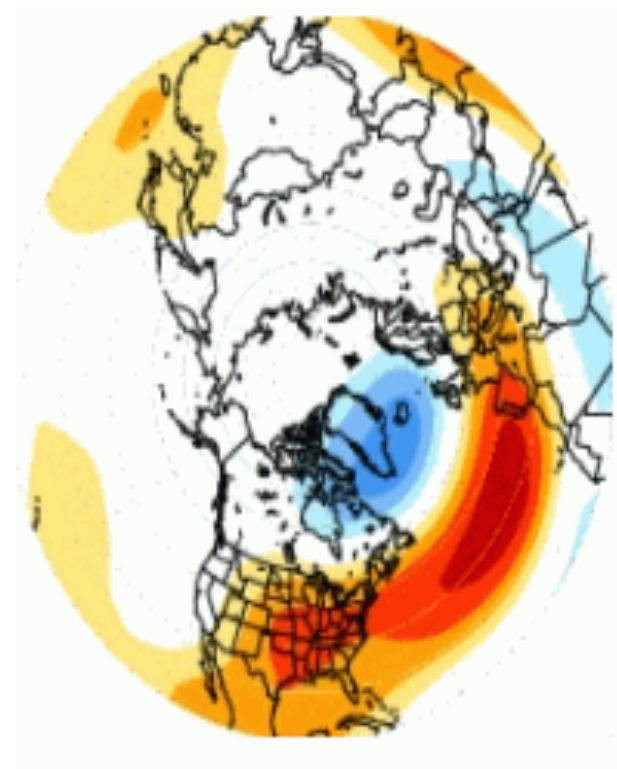
First 2 EOFs account for half of variance



Climate Patterns associated with CGC

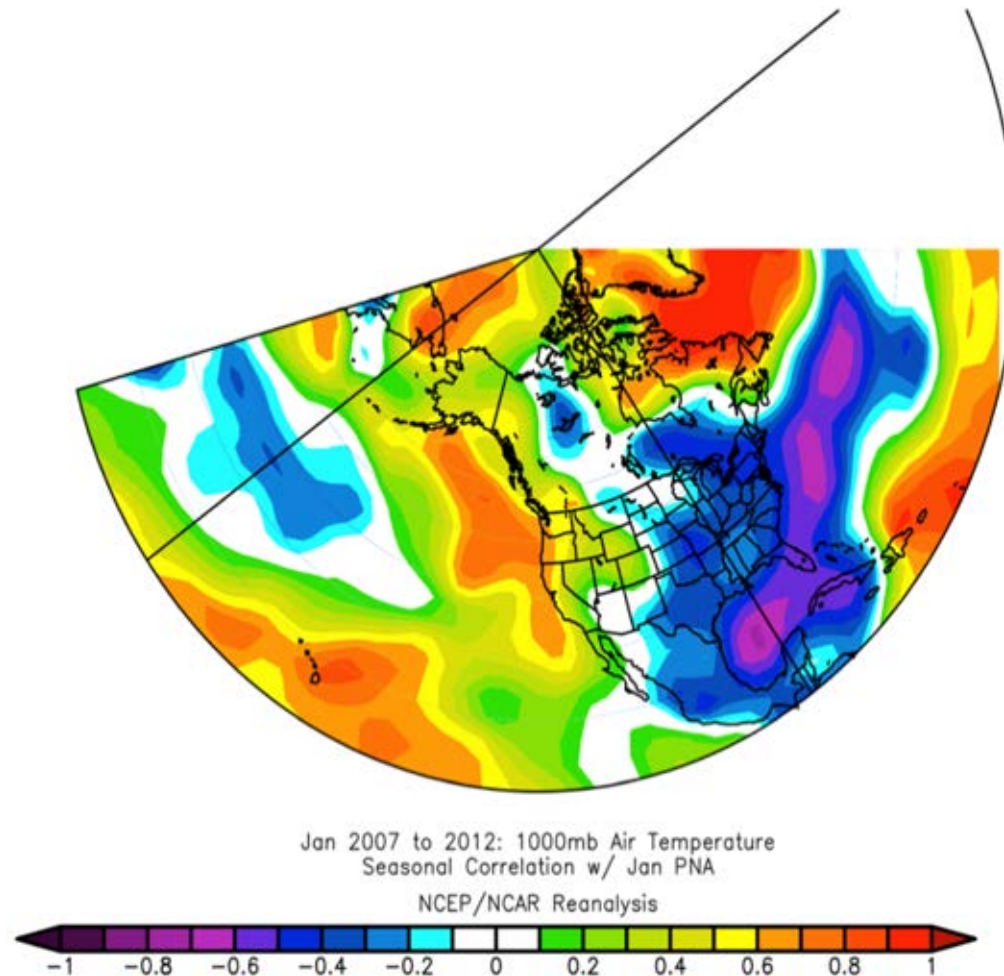


Pacific North
American
(PNA)



North Atlantic Oscillation
(NAO), related to NAM

Surface Temperature, 2007-2012 Regressed on PNA



Conclusions

- ✧ Centennial spectra are different for the sunspot record period (from 1700 to present) and for a longer time period reconstructed with cosmogenic isotopes and SW magnetic field. Thus CGC is weak in long-term time series reconstructed using ^{10}Be and open solar magnetic field
- ✧ TSI on Centennial time scale influences the Earth's climate. Response to this forcing engages the deep ocean
- ✧ The temperature response to TSI on Centennial time scale affects a climate pattern, and its phase delayed by about 10-20 yrs
- ✧ PNA (PDO) is a major climate pattern associated with CGC

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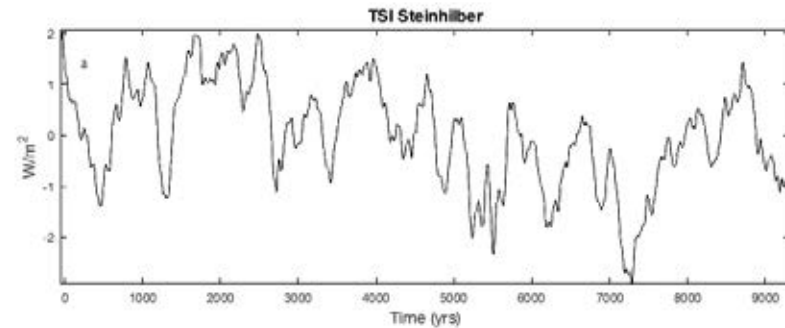
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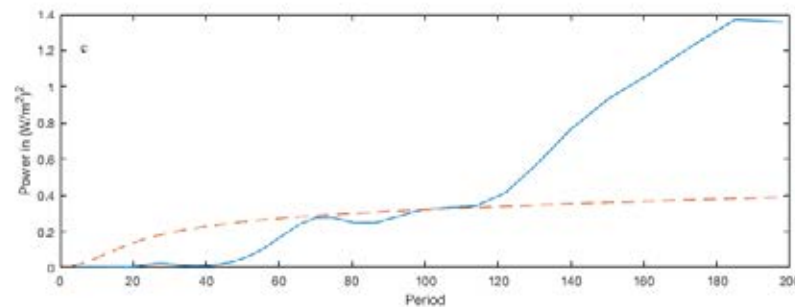
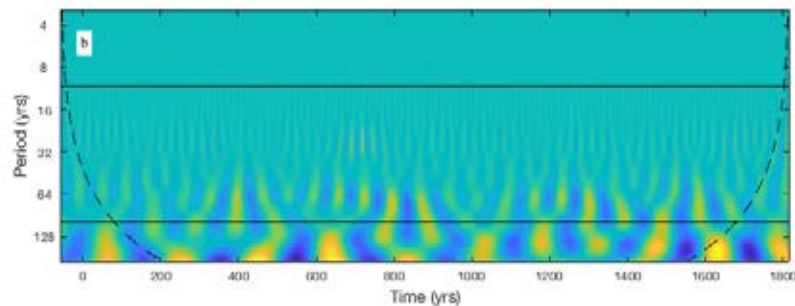
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Wavelet Spectra using TSI from -7300 to 2009 (Steinhilber et al , 2009)



40yr averaged



9300 years-long time series