DYNAMICAL MECHANISMS OF SOLAR CLIMATE FORCING IN PAST CENTURIES

Michael E. Mann

Department of Environmental Sciences, University of Virginia, Charlottesville, VA

Collaborators: B. Adams, C. Ammann, R. Bradley; J. Brigham-Grette; M. Cane; A. Clement, T. Delworth; M.K. Hughes; T. Osborn; P. Jones, T. Rittenour, S. Rutherford; G. Schmidt; D. Shindell; S. Zebiak, Z. Zhang

SORCE Meeting on Decadal Variability in the Sun and Climate Meredith, NH
Oct 28, 2004
DYNAMICAL MECHANISMS OF SOLAR CLIMATE FORCING IN PAST CENTURIES

• Evidence for Solar Periodicities
  – The Instrumental Record
  – Long-term proxy data and proxy-based reconstructions

• Model/data comparisons
Bidecadal Variability in North American Atmospheric Circulation and Drought During the 20th century?

Bidecadal Variability in North American Atmospheric Circulation and Drought During the 20th century?

Bidecadal Variability in North American Atmospheric Circulation and Drought Prior to the 20th century?
The existence of a bi-decadal (~20 years) drought rhythm in the western USA has been documented in instrumental drought records covering the past 100+ years, and its longer-term existence has been demonstrated as well in long tree-ring reconstructions of past drought extending back to AD 1700. This mode of variability is strongly related to forcing by the 22-yr Hale solar magnetic cycle and the 18.6-yr lunar nodal tidal cycle (Cook et al., 1997), an interaction that modulates the overall bi-decadal drought rhythm at centennial timescales. A new drought area reconstruction for the western USA now extends back to AD 800. This development has provided an opportunity for a much longer evaluation of solar and lunar tidal forcing to be made than was previously possible. In so doing, the results strongly show that solar and lunar tidal forcing have jointly influenced bi-decadal drought formation in the western USA for the past 1200 years and probably much farther back in time. In addition, the long tree-ring-based drought area reconstruction provides evidence for multi-centennial drought variability that might indicate longer-term solar forcing as well. This new information is described and compared to indicators of long-term solar variability in 14C and 10Be records. Overall, the results of this study provide compelling long-term statistical evidence for solar forcing of drought in the western USA. The challenge now is to understand the physics behind such forcing so that it can be properly modeled.
Bidecadal Variability in North American *Prior to 20*th century*

New England Glacial Varves

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**A**

*Raw Varve Thickness*

**B**

*Transformed Varve Thickness*

**C**

*Processed (filtered and standardized) Varve Thickness*

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Bidecadal Variability in North American Prior to 20th century?
New England Glacial Varves

CLIMATE FORCINGS

CLIMATE FORCINGS

Anthropogenic

Proxy-based Temperature Reconstructions in Past Centuries

Sensitivity in 10-25 year band
European Winter Cooling During the *Little Ice Age*

**Empirical**

LIA winter cooling in Europe associated with an NAO trend due to solar irradiance changes, interacting with stratospheric atmospheric dynamics and chemistry.

**NASA/GISS Model**

Annual average late 17th vs late 18th Century Temperature change

Proxy based reconstruction

GCM Solar + Volcanic patterns

Solar Forcing of El Nino?

Decadally-smoothed Mann et al NINO3 (x-1)

Jones et al, Science, 2001

The rise and fall of Lake Naivasha

Theoretical mechanism for natural radiative forcing of El Nino

Fig. 1. Annual mean SST anomaly (in degrees Celsius) generated by the Lamont intermediate coupled ocean-atmosphere model (12) when forced by an imposed uniform heating. [Adapted from (7)]

Theoretical mechanism for natural radiative forcing of El Nino

Response to Volcanic Forcing

Composite Nino3 (100 realizations of CZ model)


Tropical Volcanic radiative forcing (0.1 x W/m²)
Theoretical mechanism for natural radiative forcing of El Nino


Superposed Epoch Analysis AD 1649-1868
all (7) tropical events exceeding -2 W/m2

Superposed Epoch Analysis AD 1000-1999
All (7) tropical events exceeding -4 W/m2
Theoretical mechanism for natural radiative forcing of El Nino

Combined response to Solar + Volcanic Forcing

Ensemble mean Nino3 (100 realizations of CZ model)

Palmyra coral isotopes (standardized to have same mean and standard deviation as Nino3 composite series)

Theoretical mechanism for natural radiative forcing of El Nino
Theoretical mechanism for natural radiative forcing of El Nino

Graph showing the relationship between drought area indices and El Nino/La Nina events over time. The graph includes two lines: red for DAI<1 and blue for CZ model. The years are marked from 1000 to 2000, with key events of MORE DROUGHT, LESS DROUGHT, LA NINA, and EL NINO indicated. The graph is courtesy of E. Cook.
CONCLUSIONS

• Evidence exists for decadal timescale periodicities in instrumental and proxy climate records that may be related to solar forcing.

• Decadal timescale signals suggest both thermodynamic and dynamical responses of the climate to solar radiative forcing.

• Proxy-based climate reconstructions suggest persistent decadal and multidecadal relationships with solar forcing over centuries and millennia.

• Forced changes in large-scale atmospheric circulation such as the NAO, and internal dynamics related to El Nino, may play an important role in explaining regional patterns of response to solar forcing.
Proxy-based Temperature Reconstructions in Past Centuries

Proxy-based Temperature Reconstructions in Past Centuries

Estimating Sensitivity from Model/Data comparisons

Proxy-based Temperature Reconstructions in Past Centuries

Sensitivity on timescales > 40 year

Decadal Variability in the Great Salt Lake Level During the 20th Century

Quasi-Decadal Variability in North American Atmospheric Circulation During the 20th Century

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Bidecadal Variability in North American Atmospheric Circulation and Drought During the 20th century?