Solar imprint in climate reconstructions and reanalyses

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Outline

> Introduction
> Data: Proxies, reconstructions, reanalyses, assimilation
> Imprint of the 200-yr De Vries cycle in tree rings during the past 2000 yrs
> Imprint of the 11-yr solar cycle on upper-level circulation and ozone during the past 100-150 yrs
> Conclusions and outlook
Low-frequency solar variability and temperature

Solar or volcanic

(c) Overlap of reconstructed temperatures

IPCC 2007
Solar cycle imprint in 3-D fields

Haigh 2003
Mechanisms unknown

Effect via Hadley circulation

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Amplitude of Response (°C)

Phase Lag of Response Behind Forcing (months)
Data

- Proxies: Tree rings
- Reanalyes
- Upper-level reconstructions
- Ozone assimilation
Network of 2K tree ring chronologies

Breitenmoser et al. 2012
The Twentieth Century Reanalyses

Global 6-hourly 3-d data set back to 1871 based on Ensemble Kalman Filter assimilation of surface and sea-level pressure plus SST/sea ice as boundary condition (Compo et al. 2011)
Comparison with radiosonde data

> Correlation with 300 hPa GPH (Compo et al. 2011)
Upper-level reconstructions

> REC1: Statistical reconstruction (large-scale PCs), back to 1880, monthly, global, GPH/Temp, 6 levels, uses SLP, temperature, upper-air data

> REC2: Statistical reconstruction (grid columns; „cone of influence“), back to 1920s, monthly, global (with many gaps), 6 levels, Temp, GPH, wind, uses SLP, temperature and upper-air data

REC2 and 20CR are quasi-independent
Reconstructions

predictand (grid column: u, v, GPH, T)

reconstruction

predictand in calibration period (ERA-40)

24 series
(6 levels x 4 variables)

5-7 PCs

approx. 4-20 PCs

PC analysis

coefficients

linear regression

predictor (observations)

«cone of influence»

predictor (surface and upper-air observations)

gaps filled with ERA-40 plus noise

reconstruction period
month x in year y

calibration period
months (x-1, x, x+1) in all calibration years

time
Predictor data
Performance: Winter in European Arctic
Ozone assimilation

> „Off-line“ assimilation of historical total ozone data in Ensemble of Chemistry-Climate Model simulation
> Monthly, 2D (lat-alt), back to 1900 (but no observations assimilated before 1920s)
Historical observations
Ozone Assimilation
Solar data

> Sunspot number
Results

> Imprint of the 200-yr De Vires cycle in tree ring chronologies
> Imprint of the 11-yr sunspot cycle in atmospheric circulation
> Imprint of the 11-yr sunspot cycle in ozone
Spectral analysis of raw chronologies

Breitenmoser et al. 2012
Phase relations of raw chronologies

Breitenmoser et al. 2012

12. September 2012
Removal of volcanic influence

\[ T(t) = T(t-1)e^{-a \Delta t} - b \cdot \text{AOD} \]

Breitenmoser et al. 2012

12. September 2012
"Volcanic" and "residual" spectra

Breitenmoser et al. 2012
Imprint of the 11-yr cycle

- Compositing (max-min)
- Multiple linear regression
- Multiple data sets
- Multiple time periods
Jürg Luterbacher‘s SLP reconstructions

Brugnara et al. 2012
Jürg Luterbacher‘s index reconstructions

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Brugnara et al. 2012
300 hPa GPH composite

Brugnara et al. 2012
300 hPa GPH regression

Brugnara et al. 2012
300 hPa zonal wind
300 hPa meridional wind
300 hPa wind vectors
300 hPa Temperature
850 hPa Temperature

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Stucki et al. (submitted)
300 hPa GPH recent minimum

Stucki et al. (submitted)
Ozone
Conclusions

> Imprint of De Vries cycle in tree rings: Spectral signature found
> Imprint of 11-yr sunspot cycle on reconstructions + reanalyses: Changes in jets, meridional flow over Europe
> Imprint of 11-yr sunspot cycle on ozone: Global increase lower and upper stratosphere

> Longer time periods confirm what was known from shorter periods
> Mechanisms?
> Early Twentieth Century warming?