Solar influence on the troposphere through dynamical processes

Kunihiko Kodera (STEL, Nagoya Univ.)

What is the solar signal on the Earth’s surface ???

Solar signal is regional:

→ solar signal is global, but has a regional structure
→ Global mean temperature is not a essential variable
Traditional point of view

- Total solar irradiance
  - Solar radiation: 1 W/m²
  - Earth radiation: +ΔT, 0.1 K
  - Global temperature
Global surface temperature

11-year solar cycle

Wolf Number & Land Air Temp. (8–25 yrs)

Nitta and Yoshimura (1993)

Correlation between surf. temp and solar activity

Georgieva et al. (2007)
11-year Solar signal in sea surface temperature

Composite difference (High – low solar period)

SST

Time coefficients

Zhou and Tung (2010)
Expected response to a TSI change

Coupled Ocean model

TSI: 0.65%

Ammann (2007)
Solar Induced Surface Temperature Anomaly

(different reconstruction, different analysis)

(i) Mid-latitude warming
(ii) Equatorial non warming (cooling in E. Pacific and Atlantic of the SH)
Solar signal in sea level pressure in boreal winter

Multiple regression

DJF (1850–2004)

Roy and Haigh (2010)

Pacific surface temperature <- circulation change in winter
Frame and Gray (2010)

ERA 40 (1978-2008)

Vertical structure of the annual solar signal

Temperature

Zonal wind

Annual mean

Vertical velocity

Cor. F10.7
Cor. F10.7

Annual mean
1979-2010

Cor. SOI

Solar signal v.s. ENSO signal

Pressure

ω

U

SST

Global
Meridional -> longitudinal

Pacific
Longitudinal -> meridional
How can we explain this complicated structure of solar signal?
Climatology: T and U in December

- Polar night jet
- Subtropical Jet
- Planetary waves

- Sun
- UV: 4-8%
- Visible: 0.1%
Difference between $S_{\text{max}}$ and $S_{\text{min}}$ in NH winter

(i) zonal –mean flow interaction

Kodera and Kuroda, (JGR, 2002)
Solar High – Low
\[ \text{div } \mathbf{F} = - (\rho_0 a \cos \phi) f \mathbf{v}^* \]

(i) zonal – mean flow interaction
(ii) Meridional circulation

(Δ: SSW – non SSW)

Kodera et al. (2011)
Possible processes producing the surface solar signal

Extratropical solar signal
- Polar front jet
- Storm track
- Subtropical Jet
- Solar induced temperature anom.

Tropical solar signal
- Tropopause stability
- Hadley circulation
- East-West circulation

Wave mean-flow interaction
Brewer-Dobson circulation

Solar UV

CMD-derived spatial pattern of the solar SST response (°C)
stratosphere - troposphere connection

A numerical experiment with coupled ocean model

i) Extratropics
   Polar Night jet Oscillation, Annular mode

ii) Tropics
    BD circulation, Monsoon, ENSO)
Stratospheric footprint experiment

Momentum Forcing
Peak: 5/sec/day

Control

Accelerate

Decelerate

Difference

Yukimoto and Kodera (2007)
Stratospheric momentum forcing experiment

F

U

EPF

T

Jul

Oct

Jan

Apr
Stratospheric momentum forcing experiment (strong - weak PNJ)
Tropical solar signal

Extratropical solar signal

Polar front jet

Storm track

Subtropical Jet

Annual mean SST

Stratospheric forcing

Tropical solar signal

Hadley circulation

East-West circulation

Solar signal (1880-2007)
Boreal summer solar signal

JJA

Cor. SST

Climatology SST

Climatology OLR v 925
Pale climate evidence of solar influence

Fleetmann et al. (2003)

Kodera (2004)

L. M. Gputa et al. (2003)

Kodera (2004)
Indian Ocean monsoon

Regression

July SST, F10.7 1979-2008

NOAA-CIRES/Climate Diagnostics Center

Strat. footprint July SST

July SST (W-E)