Modeling Past and Future Solar Influences on the Terrestrial Climate


FUPSOL-PAGES, Davos
Outline

- Basics about FUPSOL
- Reached points & Open questions
- Validation of the AOC-GCM SOCOL-MPIOM
- Response to external forcing
- Results from DM sensitivity experiments
Motivation

- Overall goal: Estimate **contribution of solar forcing** to the global climate during the 17th to 21st centuries

- Further goals:
  - Climate response during Dalton Minima -> Sensitivity studies
  - “Past is the key to the future” -> Solar weakening in 21st century: Effects?

- Embedded in Sinergia SNSF project called «FUPSOL»
IPCC – uncertainties in solar forcing!

- **IPCC AR4:**
  - **Radiative Forcing Components**
  - **Global**
  - **Low**

- **Diff. reports ΔRF(PD-MM):**
  - **Solanki 1998:** 0.4-1.4 Wm\(^{-2}\)
  - **Lean 2000:** 0.5-0.6 Wm\(^{-2}\)
  - **Steinhilber 2009:** 0.1-0.2 Wm\(^{-2}\)
  - **Shapiro 2011:** 0.5-1.5 Wm\(^{-2}\)

- ➔ Big uncertainty!

Source: IPCC (2007)
No interactive Land-Surface vegetation, no interactive inland glaciers
Project: Cooperation

PMOD/WRC: Solar data

UniBE/ETH: Modelling groups

UniBE: Chemical & Atmospheric input data (GHG, Land surface etc...)

CSIRO (U. Hekkilä): Beryllium modelling analysis

EAWAG: Beryllium isotope proxies
Novelties

- Fully coupled Atmosphere-Deep Layer Ocean-Chemistry-GCM used for a 500 year long climate simulation
- AOC-GCM not only driven by TSI, but by SSI
- Shapiro et al. 2011 reconstruction never been used in a AOC-GCM before
- Energetic particle precipitation rarely included in long-term simulations of the climate
- Chance to have a transient simulation from recent past to future century (...)

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Reached goals

- Coupling AC-GCM SOCOLv3 to deep layer ocean model
  - -> Fully coupled AOC-GCM SOCOL-MPIOM (papers in prep.)

- Perform Dalton Minimum sensitivity runs
  - -> Reaction of chemistry / atmosphere to UV/VIS and volcanic forcing (papers in prep.)

- Transient runs soon reach year 2000
  - -> Evidence that solar forcing might be too strong for our model as temperatures do not match reconstruction
Open question up to now / To do

- Continue the run until year 2100?

- Effect of volcanic eruptions and reduction of UV/VIS on global circulation (in terms of BD-circulation; Clear footprint needed)

- What is the effect of a reduction in UV, a stronger ionization by GCRs and a strong volcanic eruption on a future atmosphere?
Dalton Minimum: Sensitivity studies

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Future and past solar influence on the terrestrial climate
Spectral solar forcing to the model, Dalton Minimum

Shapiro et al. 2011

Spectral Solar Irradiance, Band 1, 180-250 nm

Spectral Solar Irradiance, Band 2, 240-440 nm

Spectral Solar Irradiance, Band 3, 440-690 nm

Spectral Solar Irradiance, Band 4, 690-1190 nm

Spectral Solar Irradiance, Band 5, 1190-2380 nm

Spectral Solar Irradiance, Band 6, 2380-4000 nm

-15%

-3%

-0.3%

-0.05%
Experiments performed

- Started from transient run in year 1780
- 3 ensemble members per experiment (“mini-ensemble”)
- TRANSIENT: Reference run, everything transient
- VOLC: Solar forcing constant (1780), EPP off, Volc on
- VIS: UV forcing constant (1780), VIS transient, EPP & Volc off
- UV: VIS forcing constant (1780), UV transient, EPP & Volc off
- TIMESLICE: Everything 1780 constant
- TRANSIENT w/o 1809: Like DMREF, but without the 1809 volcano
- EPP: Like CONST, but with EPP enabled
NH 2m temperatures, compared

48 month low-pass filtered, grey shaded = $2\sigma$
VOCs at 50 hPa, Equator

CO/CH2O/CH4

Time (Year AD)

ppm/ppt/ppb

CO in ppm

CH4

CH2O

CO

1806 1809 1815 1820

7.60

7.20

7.00

6.80

6.40

6.00

5.60

5.20

2.60

2.40

2.20

2.00

1.80

1.60

1.40

720.0

717.0

714.0

711.0

708.0

705.0

702.0
Vertical residual circulation (mm/s) at 50 hPa, Equator

Time (Year AD)
Temperature differences relative to constant forcing run

- UV reduction only
- VIS reduction only
- VOLC forcing only

ΔT in °C
O₃ differences relative to constant forcing run

UV reduction only

VIS reduction only

VOLC forcing only

O₃ in %

O₃ in %

O₃ in %
H₂O differences relative to constant forcing run

UV reduction only

VIS reduction only

VOLC forcing only

H₂O in %

H₂O in %

H₂O in %
HO\textsubscript{x} differences relative to constant forcing run

**UV reduction only**

- HO\textsubscript{x} in %
- Pressure
- Height (km)

**VOLC forcing only**

- HO\textsubscript{x} in %
- Pressure
- Height (km)

Contour from -10 to 10 by 2
Conclusions

- **Post-Tambora cold period:**
  - Would most probably not have happened in active sun conditions or without «unknown 1809» eruption

- **Effects of reduction in solar irradiance vs. volcanic forcing:**
  - Reduction of visible radiation results in very small effects
  - Temp: Effects of UV reduction greater than volcanoes
  - Ozone: Decrease with UV reduction, increase with volcanic forcing
  - Hox: Decrease with UV reduction, increase with volcanic forcing
  - Surface temperature: UV / VOLC approx. in same range of temperature decrease

- **Effects of volcanic eruption:**
  - Using CH4 as long-lived species -> W* is increasing
    -> Vertical circulation changes after a major eruption
Thank you!

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