ETH
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IACETH

Modeling Past and Future Solar Influences on the Terrestrial Climate

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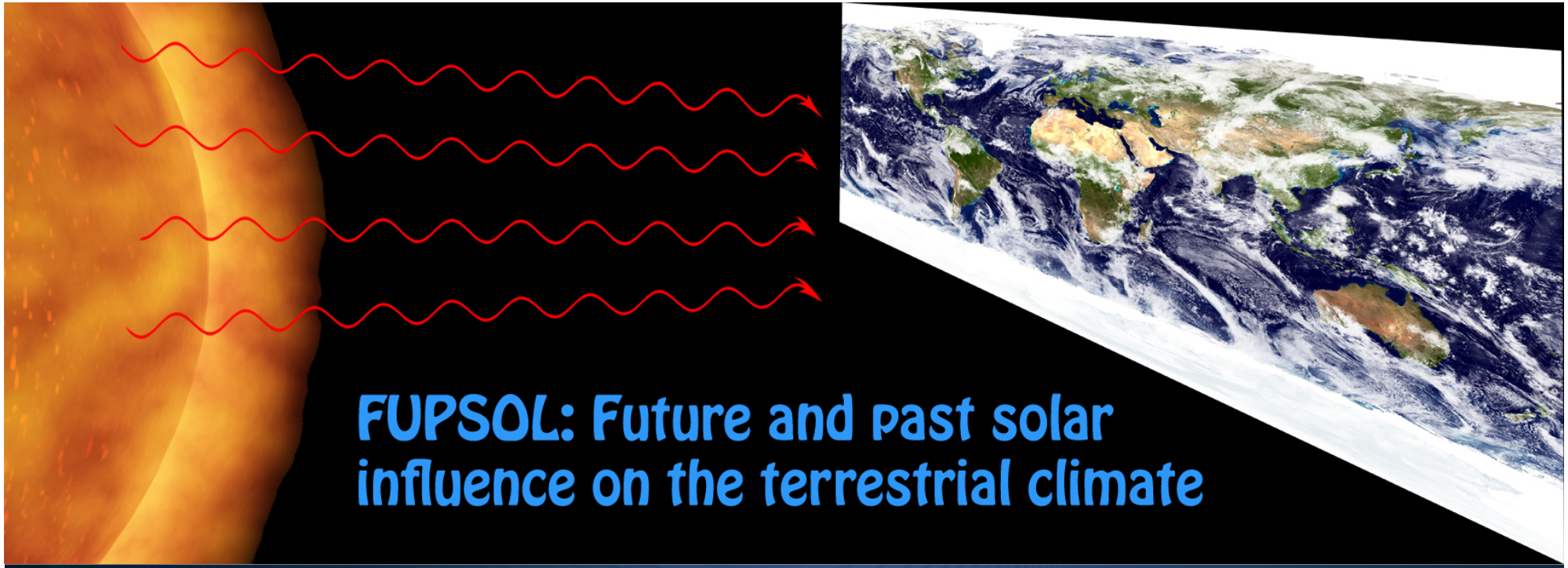
FUPSOL-PAGES, Davos



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

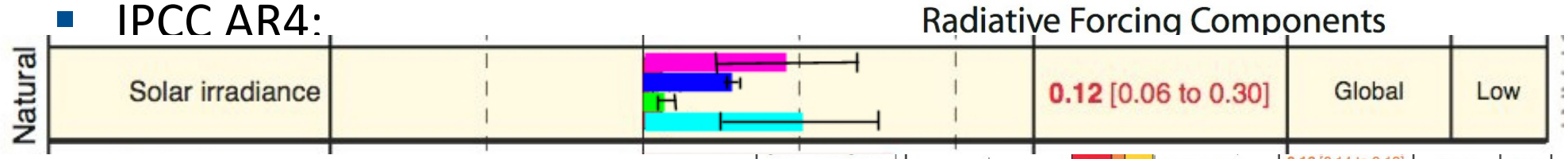
- Overall goal: Estimate **contribution of solar forcing** to the global climate during the **17th to 21st centuries**

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

- Embedded in Sinergia SNSF project called «FUPSOL»

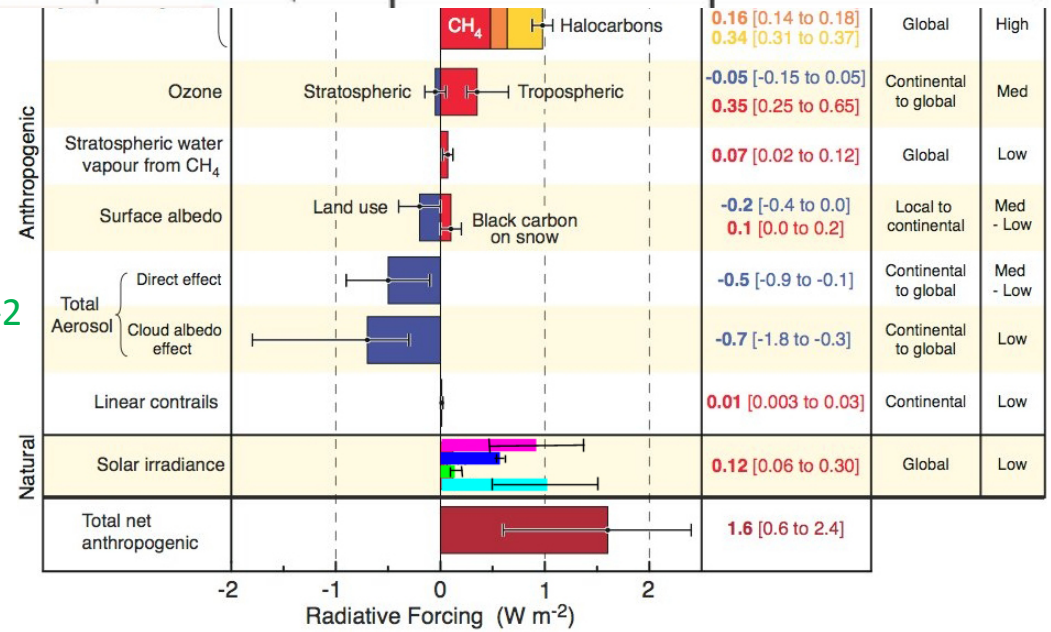
IPCC – uncertainties in solar forcing!

- IPCC AR4:



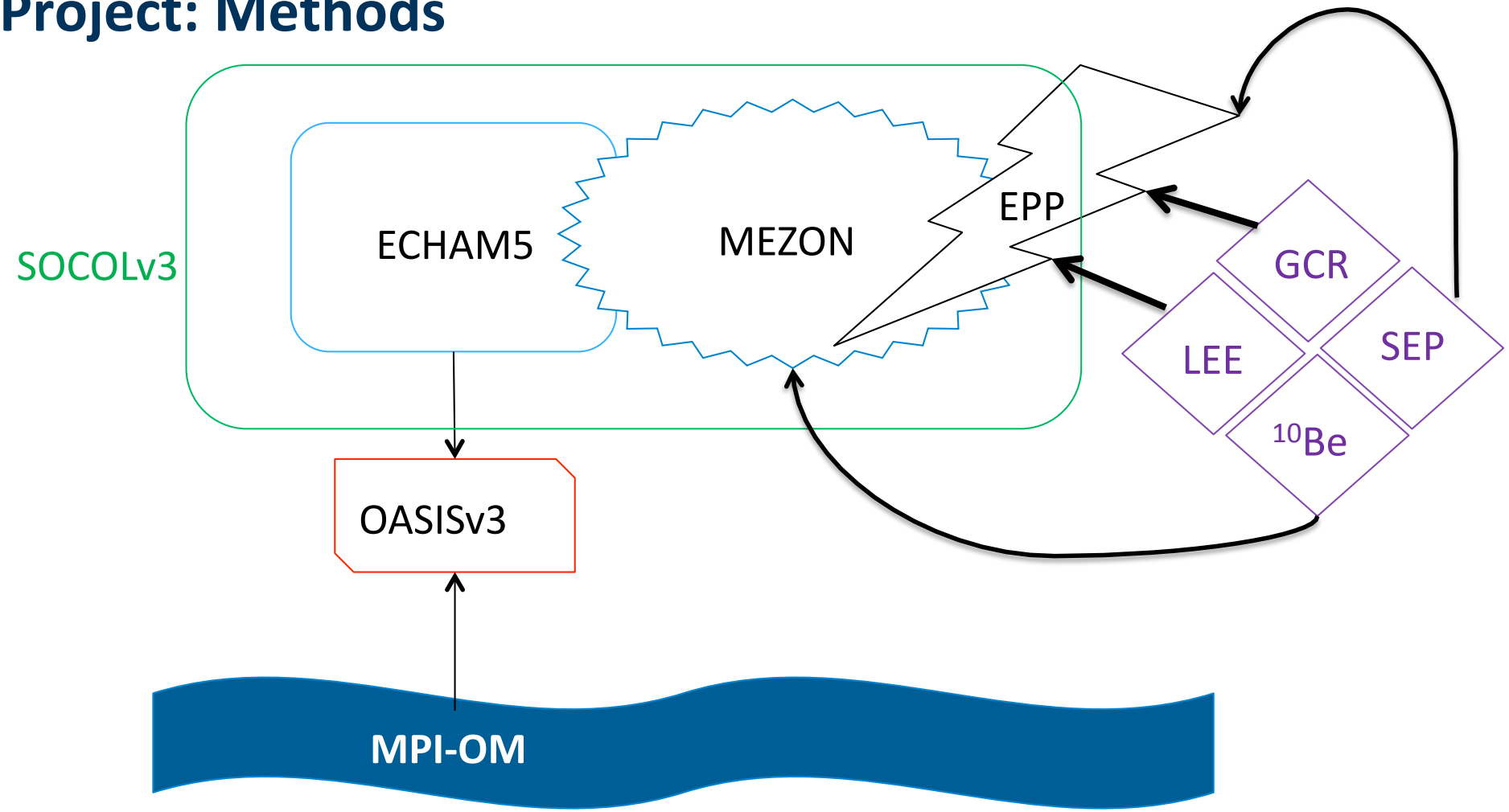
- Diff. reports ΔRF(PD-MM) :
  - Solanki 1998: 0.4-1.4 Wm^{-2}
  - Lean 2000: 0.5-0.6 Wm^{-2}
  - Steinhilber 2009: 0.1-0.2 Wm^{-2}
  - Shapiro 2011: 0.5-1.5 Wm^{-2}

- ➔ Big uncertainty!



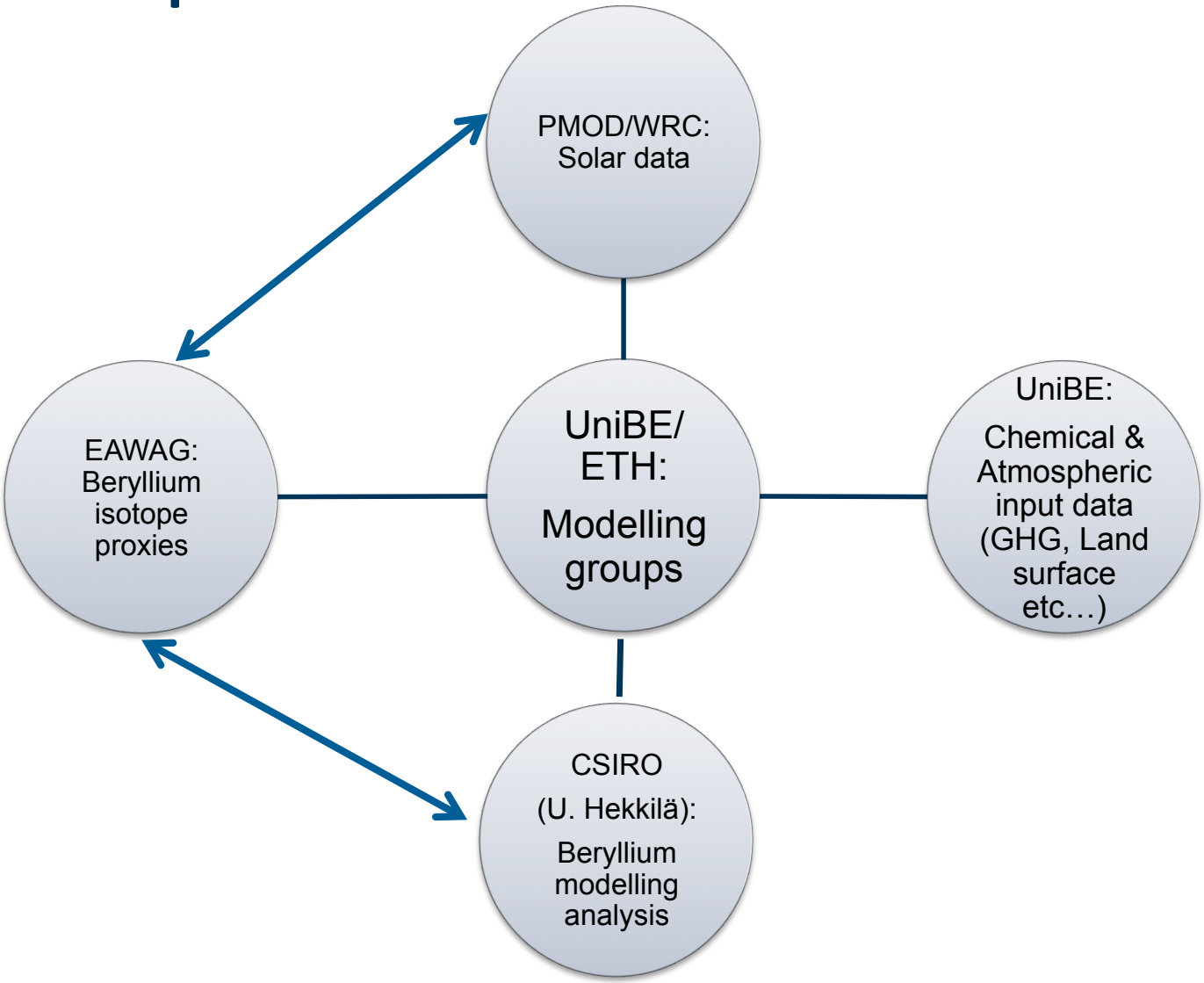
Source: IPCC (2007)

Project: Methods



No interactive Land-Surface vegetation, no interactive inland glaciers

Project: Cooperation



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 (…)

Reached goals

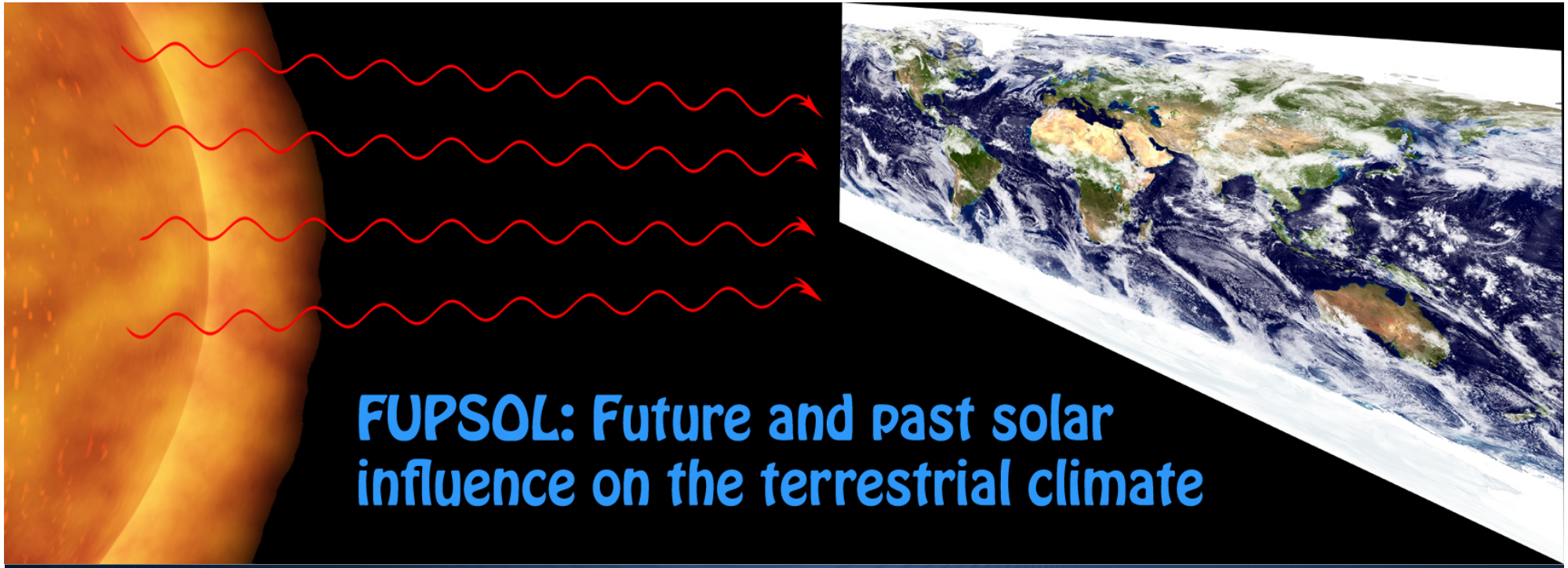
- Coupling AC-GCM SOCOLv3 to deep layer ocean model
  - -> Fully coupled AOC-GCM SOCOL-MPIOM (papers in prep.)
- Perform Dalton Minimum sensitivity runs
  - -> Reaction of chemistry / atmosphere to UV/VIS and volcanic forcing (papers in prep.)
- Transient runs soon reach year 2000
  - -> Evidence that solar forcing might be too strong for our model as temperatures do not match reconstruction

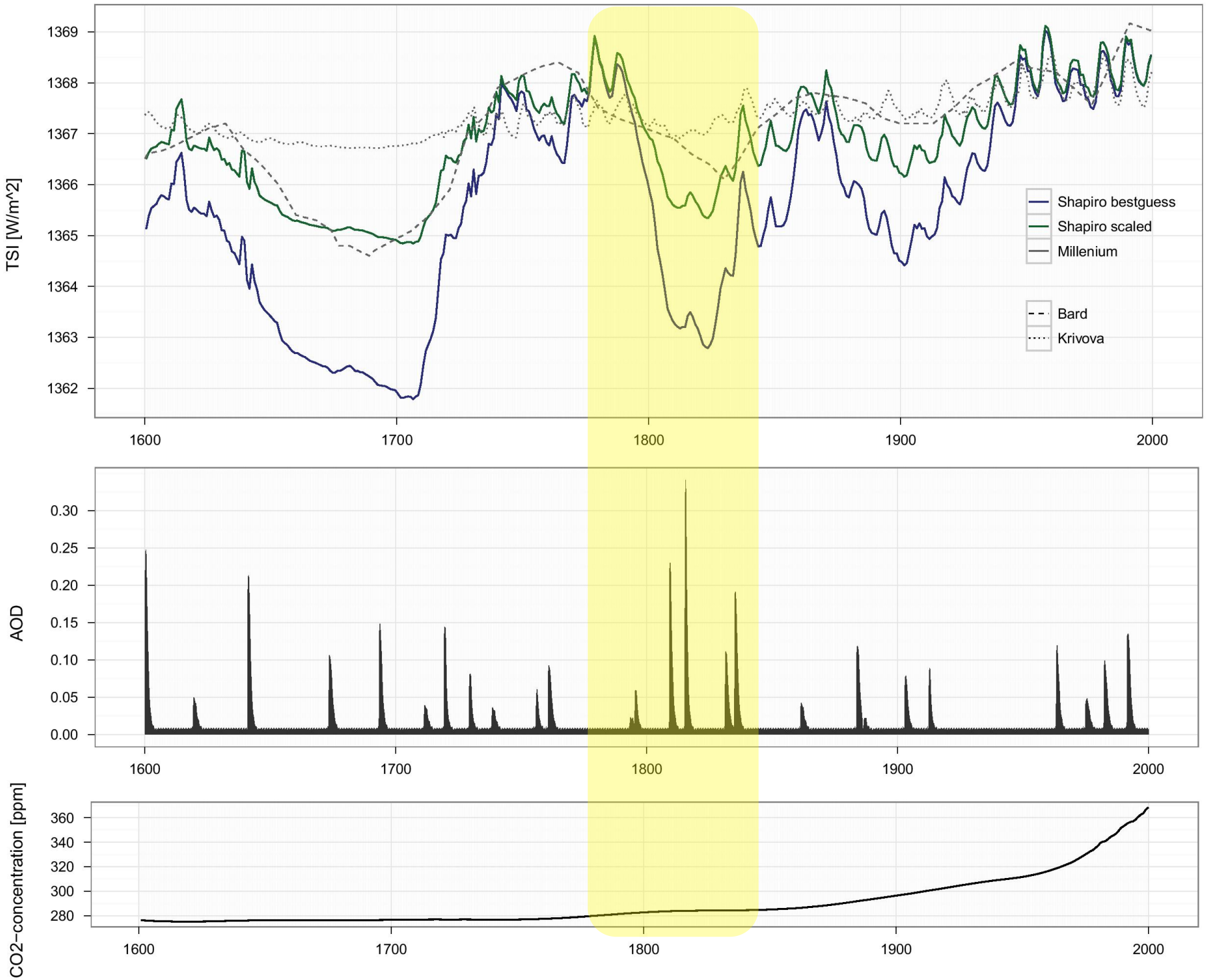
Open question up to now / To do

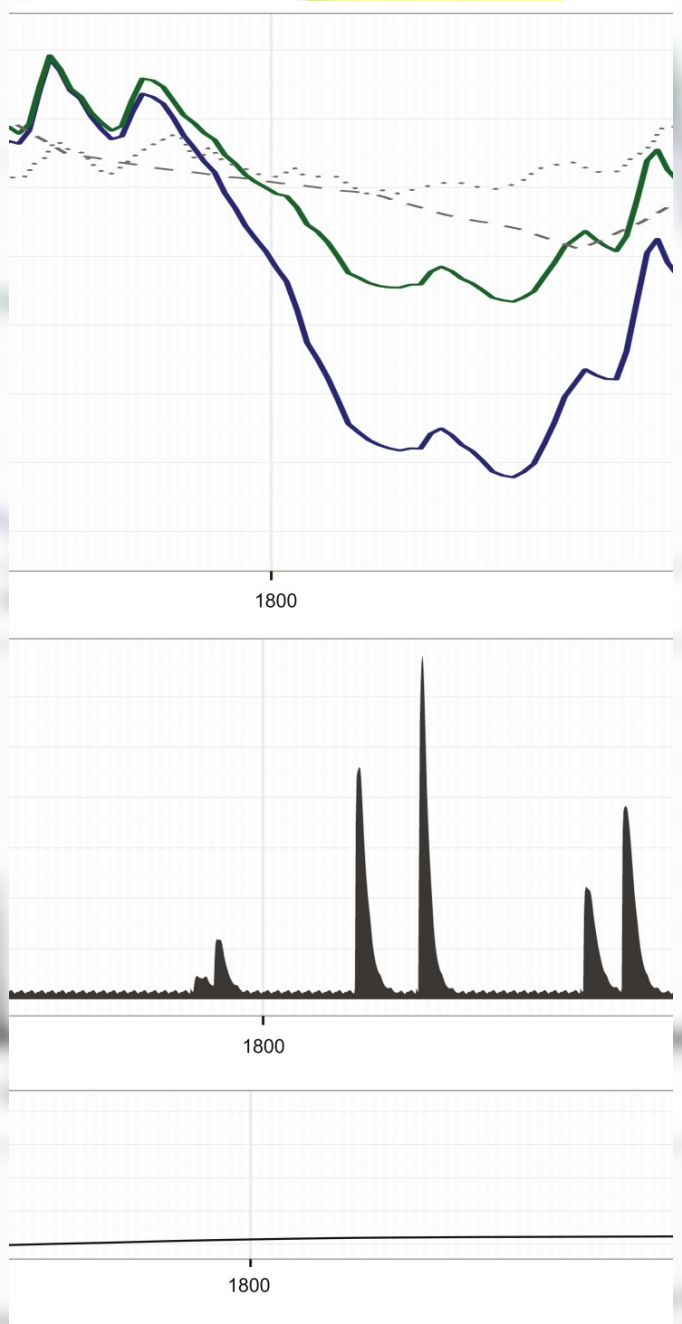
- Continue the run until year 2100?
- Effect of volcanic eruptions and reduction of UV/VIS on global circulation (in terms of BD-circulation; Clear footprint needed)
- What is the effect of a reduction in UV, a stronger ionization by GCRs and a strong volcanic eruption on a future atmosphere?

Dalton Minimum: Sensitivity studies

FUPSOL-PAGES, Davos

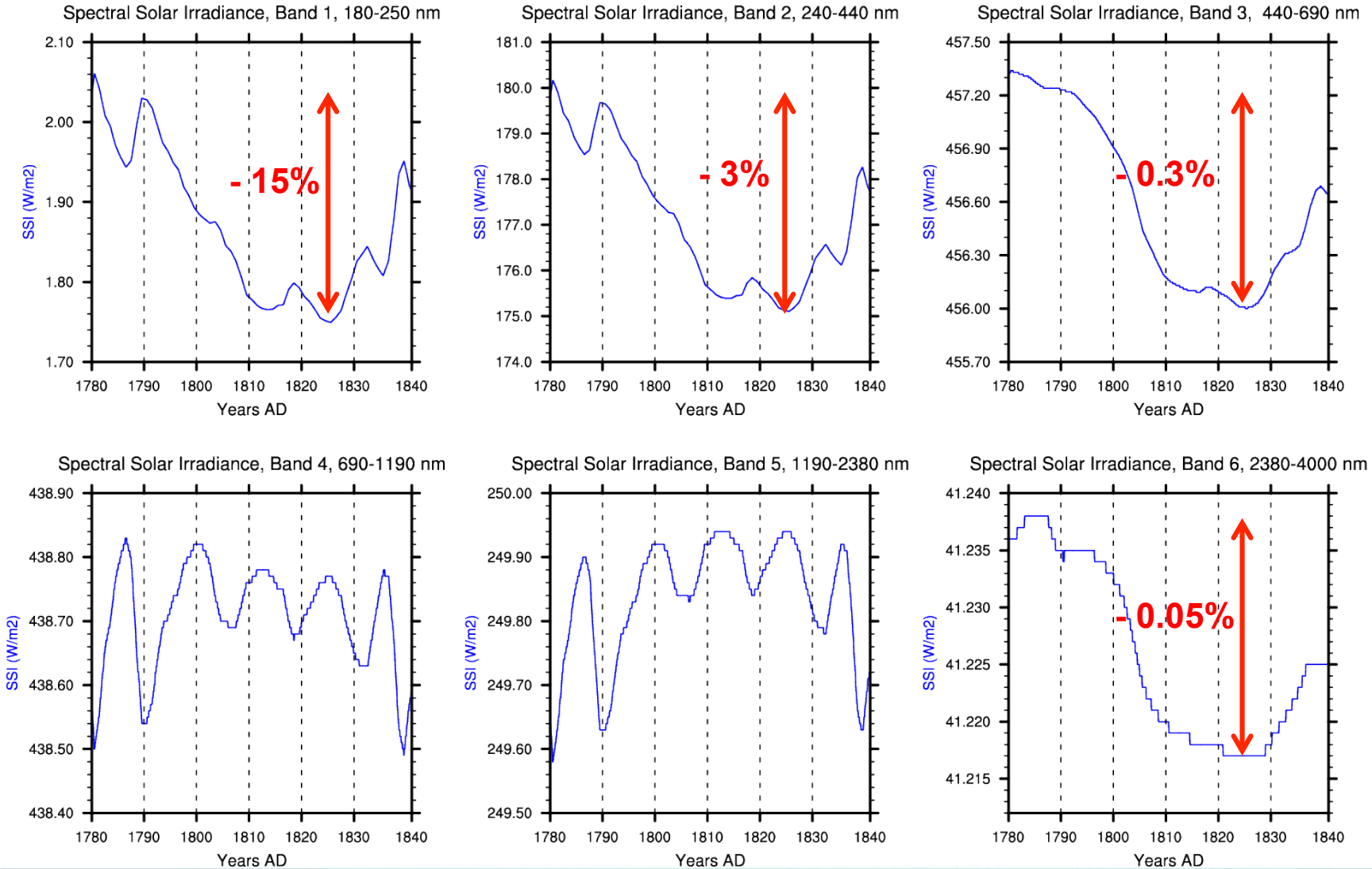



TSI [W/m^2]
1369
1368
1367
1366
1365
1364
1363
1362
1600
1700
1800
1900
2000
Shapiro bestguess
Shapiro scaled
Millenium
Bard
Krivova
AOD
0.30
0.25
0.20
0.15
0.10
0.05
0.00
CO2−concentration [ppm]
360
340
320
300
280


1800
1800
1800

Spectral solar forcing to the model, Dalton Minimum

Shapiro et al. 2011

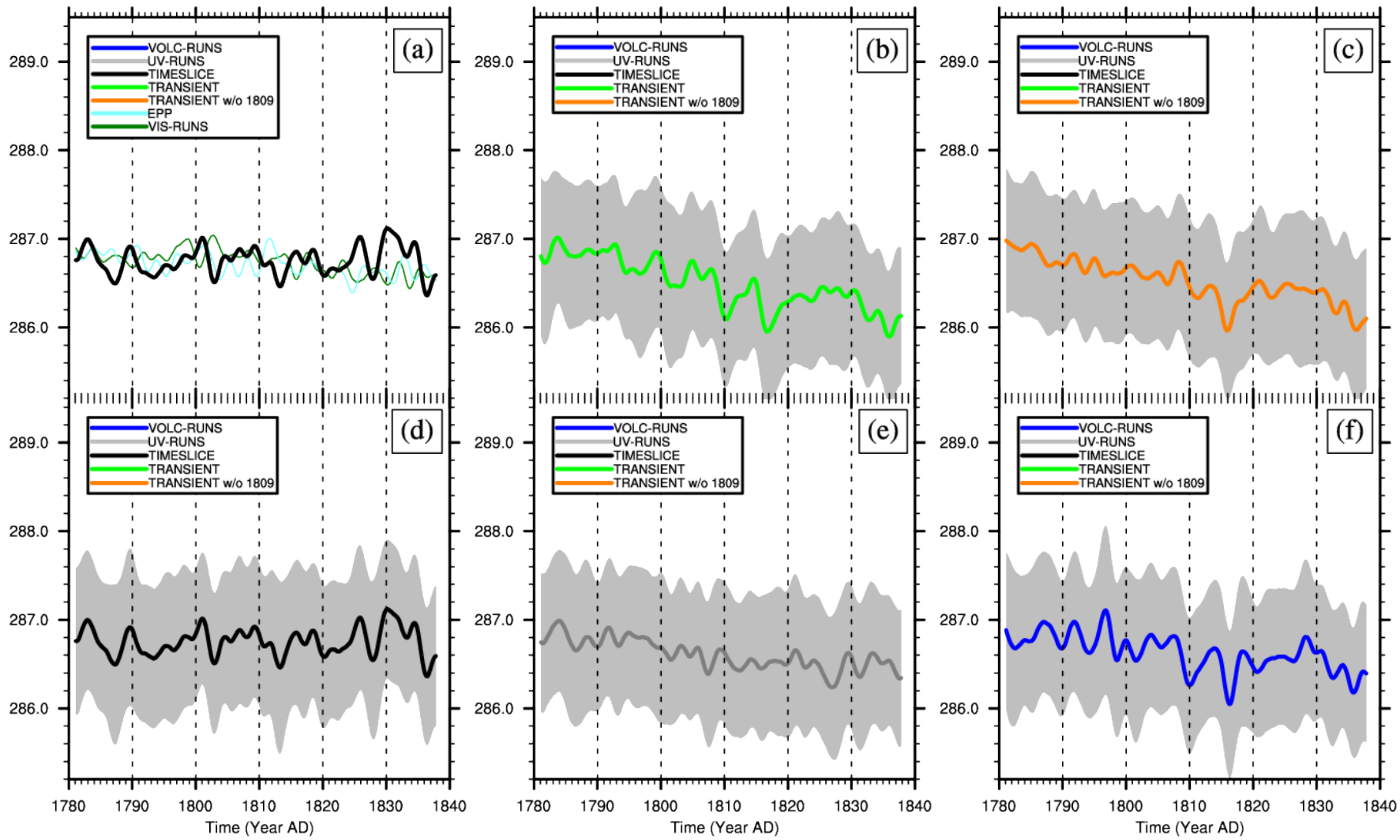


Experiments performed

- Started from transient run in year 1780

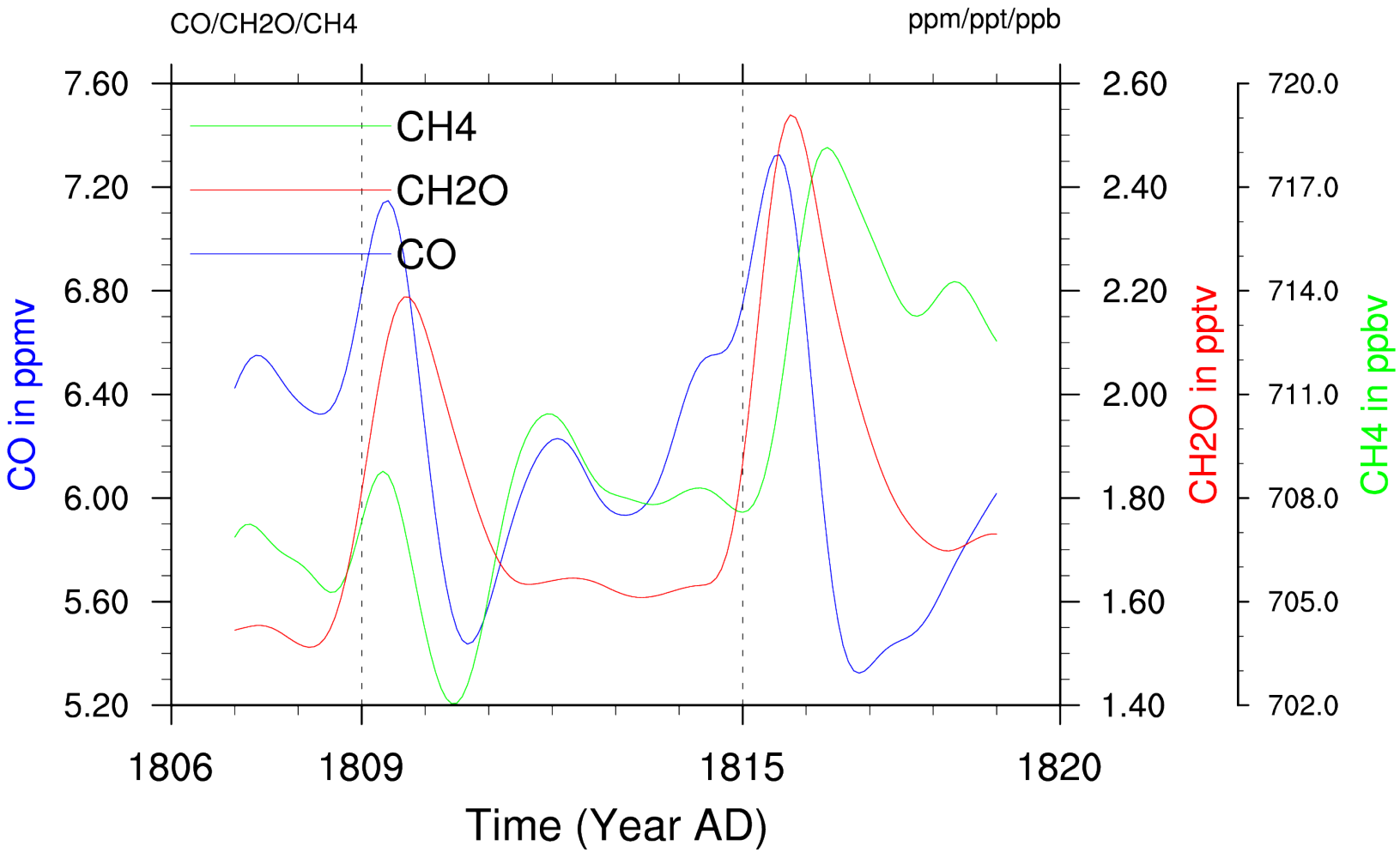
- 3 ensemble members per experiment ("mini-ensemble")
- TRANSIENT: Reference run, everything transient
- VOLC: Solar forcing constant (1780), EPP off, Volc on
- VIS: UV forcing constant (1780), VIS transient, EPP & Volc off
- UV: VIS forcing constant (1780), UV transient, EPP & Volc off
- TIMESLICE: 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

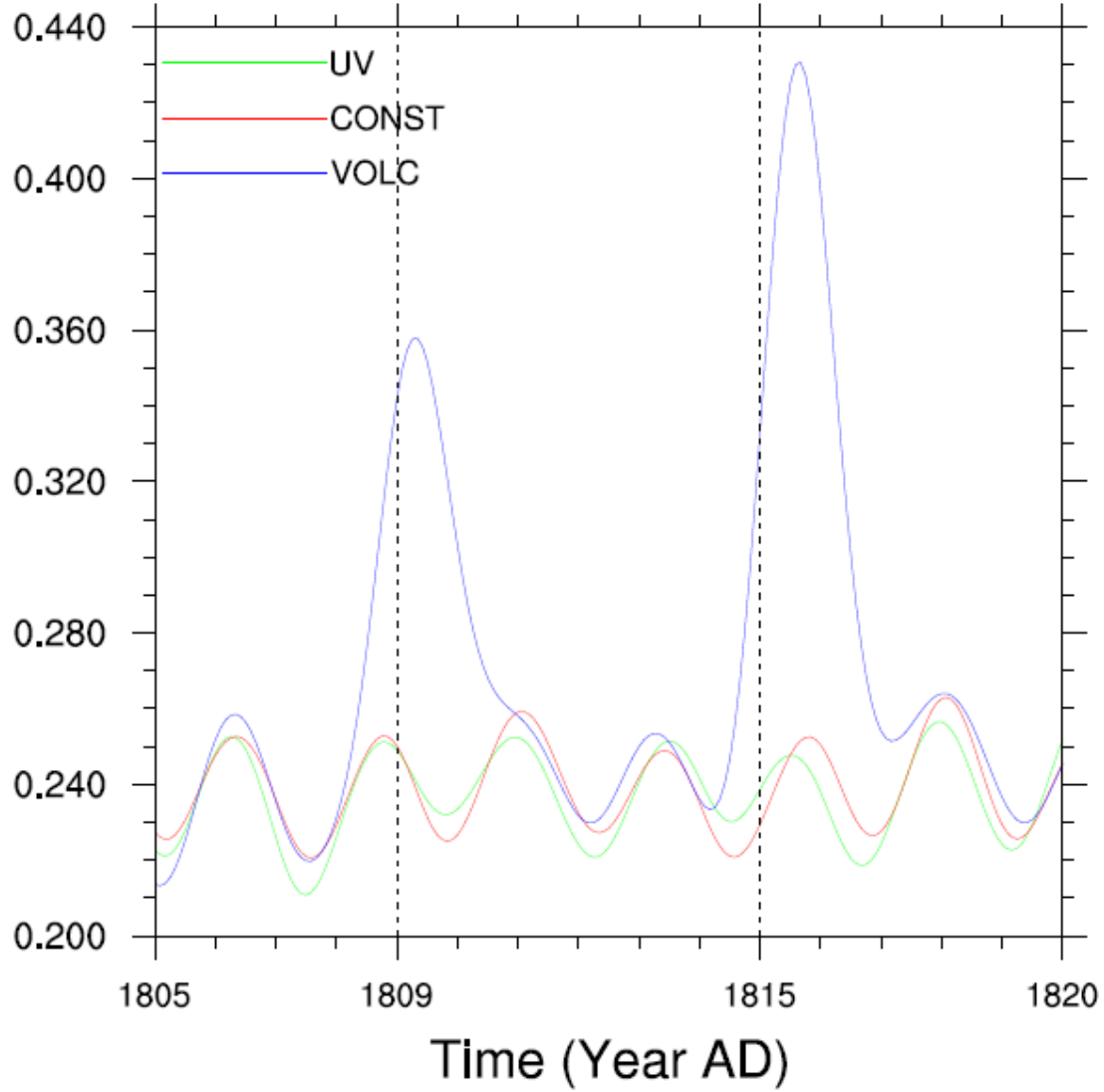


48 month low-pass filtered, grey shaded = 2 σ

VOCs at 50 hPa, Equator

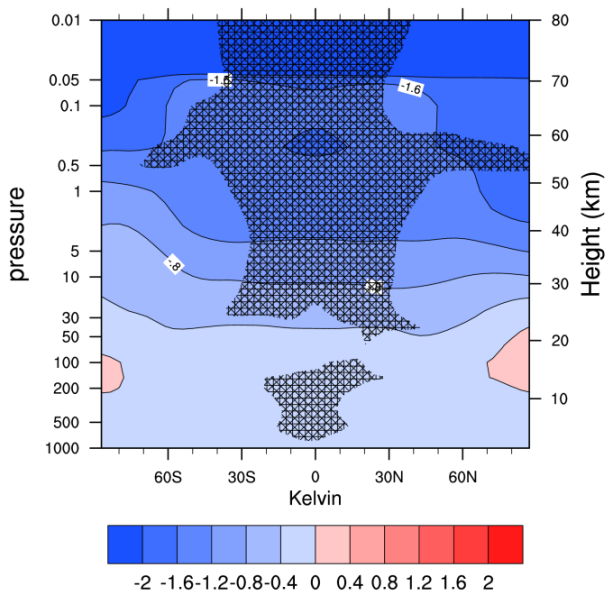


Vertical residual circulation (mm/s) at 50 hPa, Equator



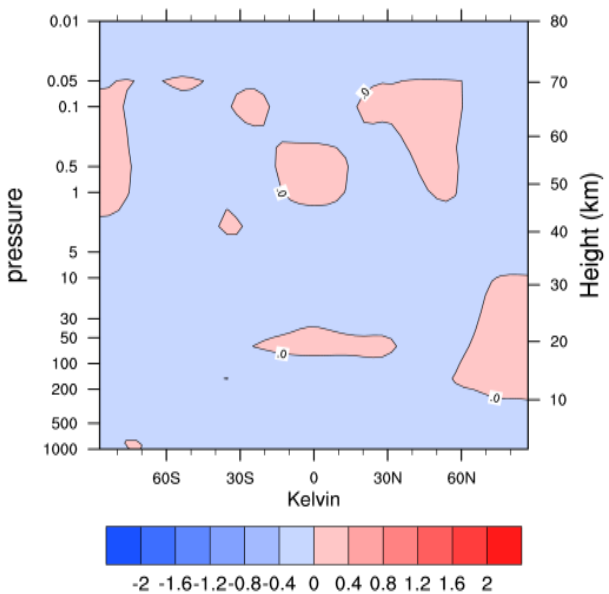
Temperature differences relative to constant forcing run

UV reduction only



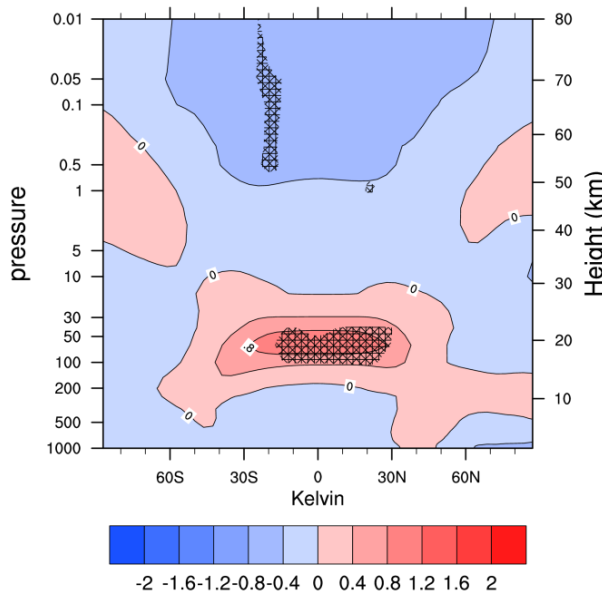
ΔT in ‰

VIS reduction only



ΔT in ‰

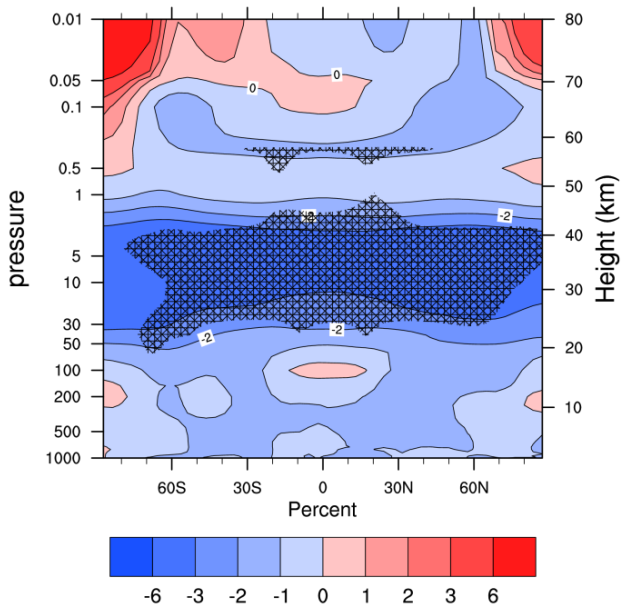
VOLC forcing only



ΔT in ‰

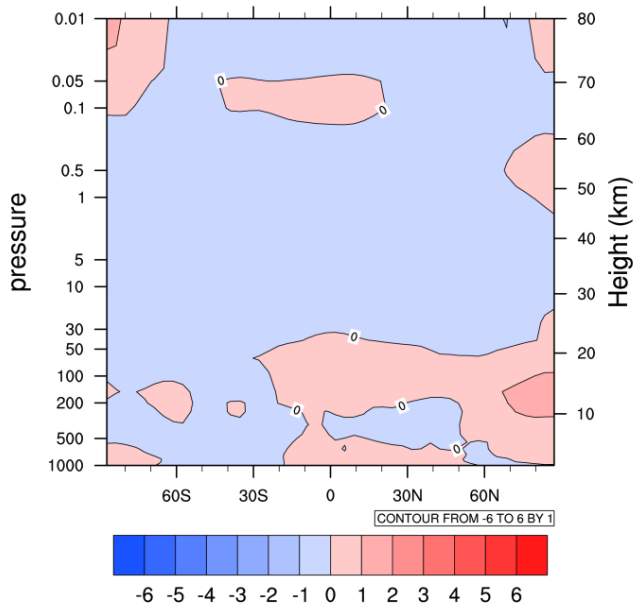
O_3 differences relative to constant forcing run

UV reduction only



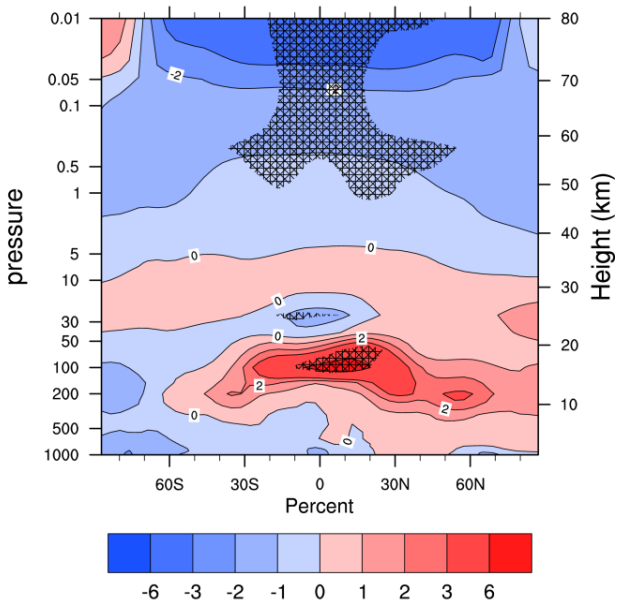
O_3 in %

VIS reduction only



O_3 in %

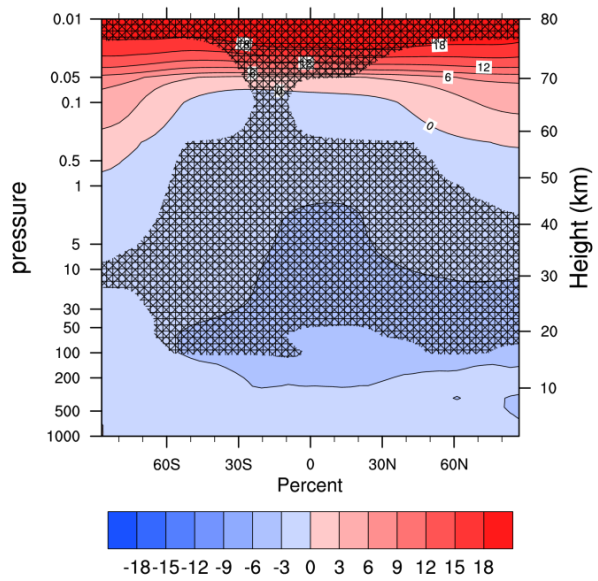
VOLC forcing only



O_3 in %

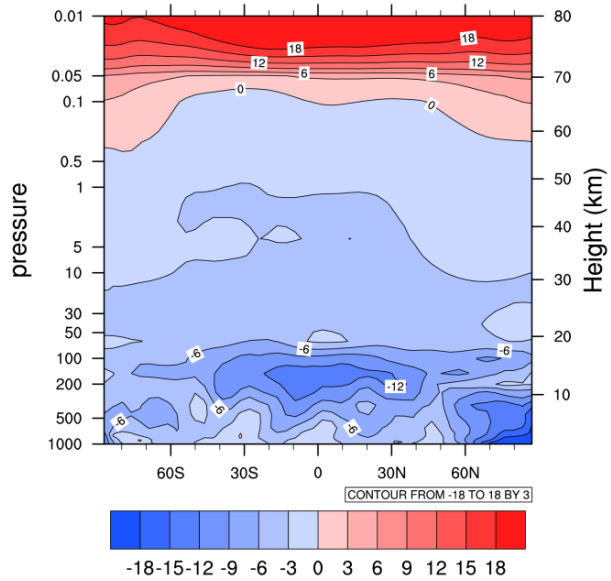
H_2O differences relative to constant forcing run

UV reduction only



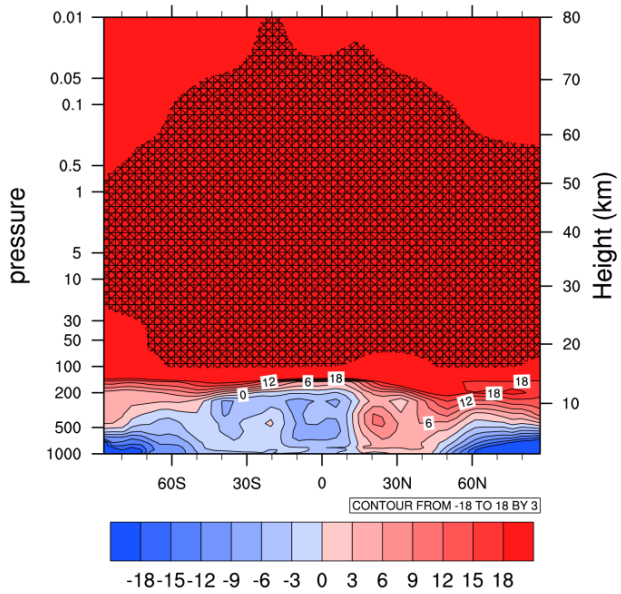
H_2O in %

VIS reduction only



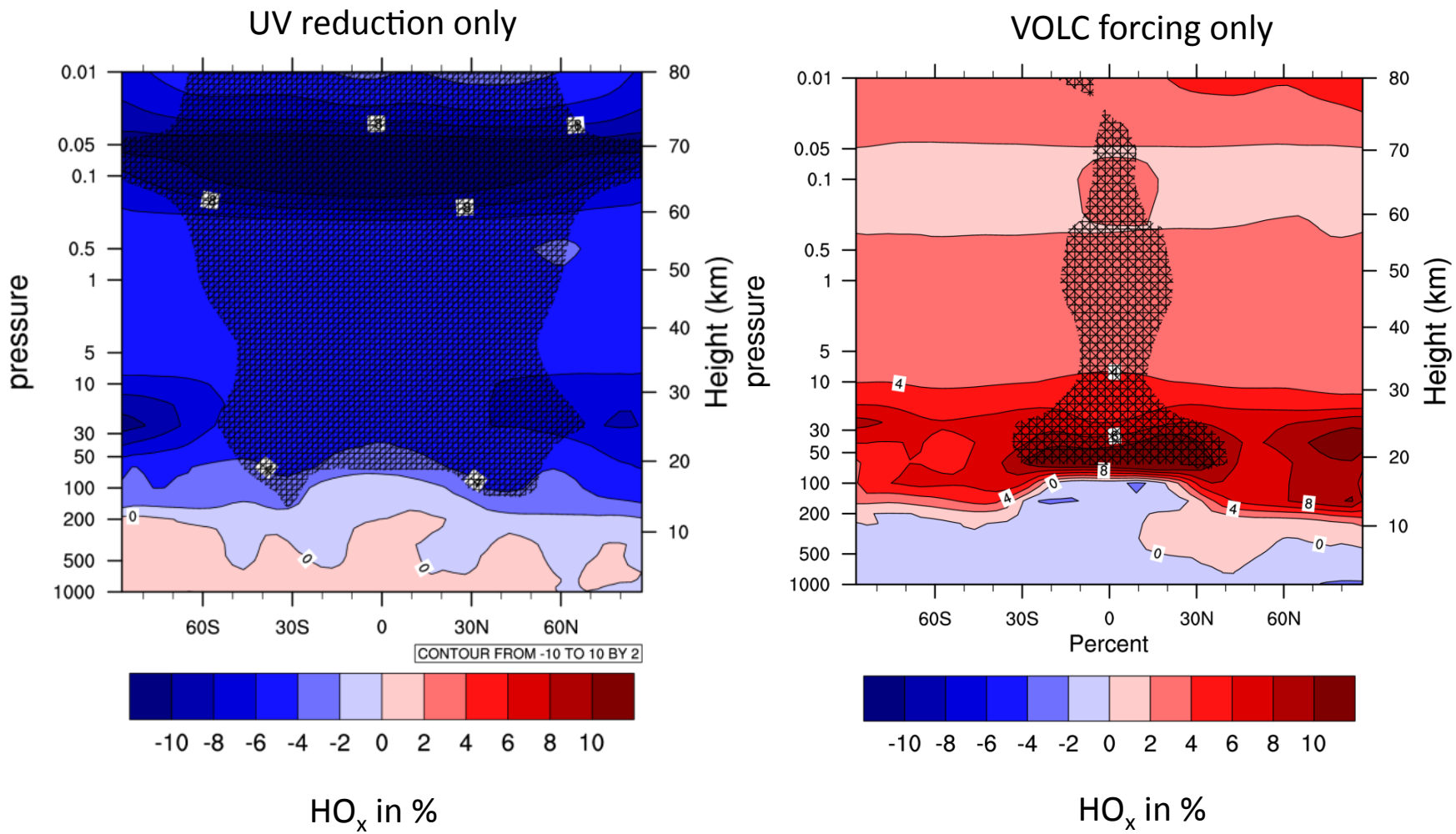
H_2O in %

VOLC forcing only



H_2O in %

HO_x differences relative to constant forcing run

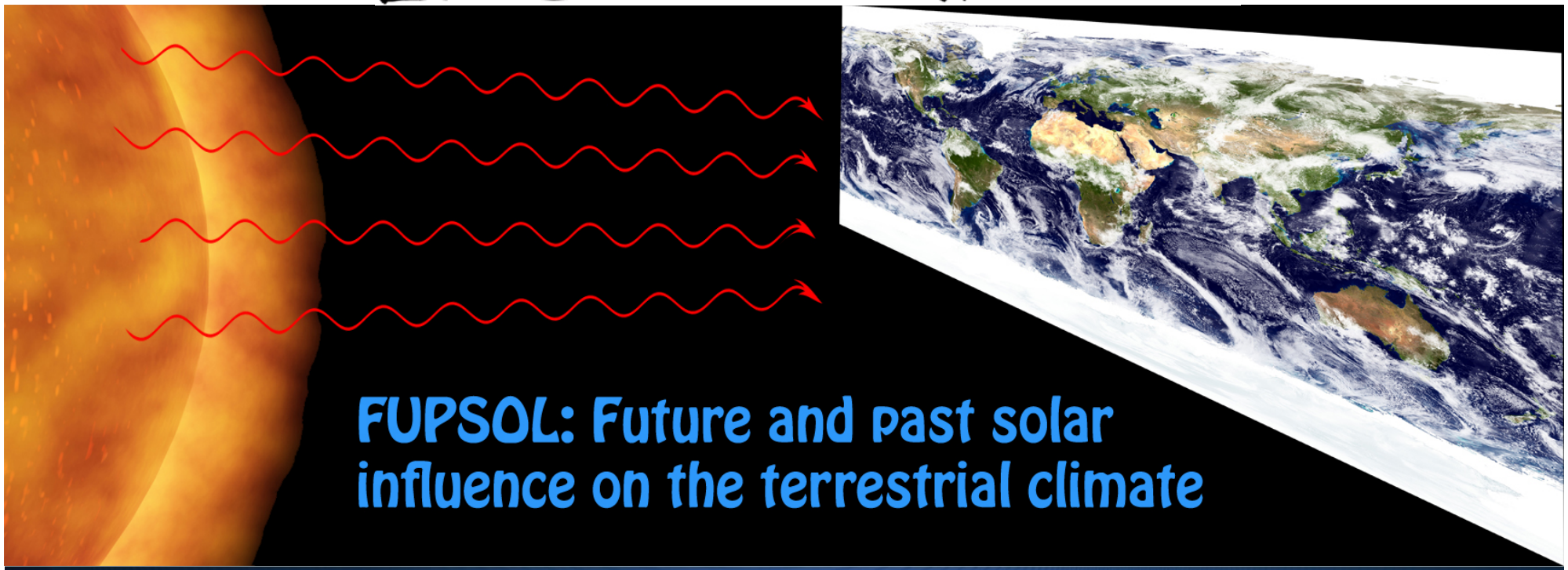


Conclusions

- 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!


calamitiesofnature.com
My future is so bright, I gotta wear shades
Actually, you'll exhaust all your fuel in 5 billion years, becoming a dim ember of your former self.


FUPSOL: Future and past solar influence on the terrestrial climate