Modelling stratospheric ozone variability with MOCASSIM

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Outline

• Motivation
• The MOCASSIM model
• Comparison with other SSI reconstructions
• Stratospheric chemical abundances calculations
• Conclusion and future work
O-Motivation

• Possible relation between solar activity and climate
O-Motivation

- Possible relation between solar activity and climate

Credit: P. Charbonneau
0-Motivation

• Possible relation between solar activity and climate
O-Motivation

• Possible relation between solar activity and climate
• Solar irradiance varies on many time scales
  – 11-yr cycle
Motivation

Possible relation between solar activity and climate

Solar irradiance varies on many times scales – 11-yr cycle

Deland & Cebula (2008), JGR, 113, A11103
Possible relation between solar activity and climate

Solar irradiance varies on many timescales – 11-yr cycle

Deland & Cebula (2008), JGR, 113, A11103
0-Motivation

• Possible relation between solar activity and climate
• Solar irradiance (especially in the UV) varies on many time scales
  – 11-yr cycle
O-Motivation

• Possible relation between solar activity and climate
• Solar irradiance (especially in the UV) varies on many time scales
  – 11-yr cycle
• We need models reconstruct SSI before 1978
• ...then use it in climate models
1-The MOCASSIM model

• Driven by surface flux evolution model
• Injection of observed spots (area, position on solar disk)
• Stochastic model for backside emergences
• Fragment classified as "spots" or "faculae" according to radius
1-The MOCASSIM model

- Calculation of spots and facular contrast + quiet Sun contribution + network contribution
  - Spots: ratio of flux on a synthetic spectrum @ $T_{\text{eff}}=5250\text{K}$ vs $T_{\text{eff}}=5750\text{K}$
1-The MOCASSIM model

- Calculation of spots and facular constrast + quiet Sun contribution + network contribution
  - Network: daily random contribution, weighed by wavelength-dependent factor
  - Artificial rotational modulation amplification (proportionnal to active regions total area) to account for chromospheric plages

2-Comparison with other SSI reconstructions

• Comparison between 5 SSI reconstruction models
  
  – **MOCASSIM**
  – **NRLSSI** (Lean et al. (2000) GRL, 27:2425)
  – **SATIRE** (Krivova et al. (2010) JGR, 115:A12112)
2-Comparison with other SSI reconstructions

- Comparison between 5 SSI reconstruction models

![Graph showing SSI ratio reconstructed ATLAS 1 to measured ATLAS 1](image)
3-Stratospheric chemical abundances calculations

• Motivation reminder: use SSI reconstructions in atmospheric models to determine the impact of solar variability on climate
• Main effect on the stratosphere, through ozone
3-Stratospheric chemical abundances calculations

- **Motivation reminder**: use SSI reconstructions in atmospheric models to determine the impact of solar variability on climate

\[ O_2 + hv \rightarrow O + O \]
\[ 2 \times (O_2 + O \xrightarrow{M} O_3) \]
\[ net: 3O_2 + hv \rightarrow 2O_3 \]
\[ O_3 + hv \rightarrow O_2 + O \]
\[ O_3 + O \rightarrow O_2 + O_2 \]

\( \lambda < 242 \text{ nm} \)
\( \lambda < 300 \text{ nm} \)
3-Stratospheric chemical abundances calculations

- **Simple column model**
  - At the equator
  - Evolution of 57 chemical species in pure photochemistry mode
    - No heating, no dynamics, etc.
  - 10-day simulations for different levels of solar activity (min, max of a few cycles), using different spectral reconstructions
    (Details in Muncaster et al. (2012) Atmos. Chem. Phys., 12:7707.)

- **Rationale**: isolate photochemical origins of observations
3-Stratospheric chemical abundances calculations

• Comparison between min and max of cycle 22 (September 1986, November 1989)
  – Using NRLSSI (results published in Muncaster et al. (2012))
3-Stratospheric chemical abundances calculations

- Comparison between min and max of...
3-Stratospheric chemical abundances calculations

- Comparison between min and max of cycle 22 (September 1986, November 1989)
  - Using NRLSSI (results published in Muncaster et al. (2012))
  - Using MGNM
3-Stratospheric chemical abundances calculations

- Comparison between min and max of

![Graphs showing chemical abundances at different altitudes and times]

- Using NRLSSI (results published in Muncaster et al. 2012)
- Using MGNM

![Graphs showing specific chemical abundances like O/Oh, HOx, NOx, Clx, Brx]
3-Stratospheric chemical abundances calculations

- Comparison between min and max of cycle 22 (September 1986, November 1989)
  - Using NRLSSI (results published in Muncaster et al. (2012))
  - Using MGNM
  - Using MOCASSIM
3-Stratospheric chemical abundances calculations

- Comparison between min and max of

![Diagram showing stratospheric chemical abundances](image)
3-Stratospheric chemical abundances calculations

- Comparison between min and max of cycle 22 (September 1986, November 1989)
  - Using NRLSSI (results published in Muncaster et al. (2012))
  - Using MGNM
  - Using MOCASSIM
3-Stratospheric chemical abundances calculations

• Comparison between min and max of cycle 22 (September 1986, November 1989)

– Using NRLSSI (results published in Muncaster et al. 2012)
– Using MGNM
– Using MOCASSIM

![Graph showing bands (nm) vs. R(No89:Sep86) (%) for MOCA, NRLSSI, and MGNM]
3-Stratospheric chemical abundances calculations

• **Comparison between min and max of**

![Graphs showing comparison between min and max of chemical abundances](image-url)
3-Stratospheric chemical abundances calculations

• Comparison between min and max of cycle 22 (September 1986, November 1989)

  – Using NRLSSI (results published in Muncaster et al. 2012)
  – Using MGNM
  – Using MOCASSIM
3-Stratospheric chemical abundances calculations

• Comparison between modern minimum (March 2009) and Maunder minimum (average over 1680)
  – MOCASSIM
3-Stratospheric chemical abundances calculations

- Comparison between modern minimum (March 2009) and Maunder minimum (average over 1680 – MOCASSIM 30)
3-Stratospheric chemical abundances calculations

Comparison between modern minimum (March 2009) and Maunder minimum (average over 1680) – MOCASSIM
3-Stratospheric chemical abundances calculations

Comparison between modern minimum (March 2009) and Maunder minimum (average over 1680) – MOCASSIM 32
4-Conclusion and future work

• Conclusion
  – Variation in max ozone roughly proportional to variation in solar spectrum between 180 and 240 nm (in pure photochemistry mode)

• Future work
  – More realistic representation of the network (on TSI model first)
  – More realistic/complete stratospheric model (CMAM)
  – Disentangle photochemistry from dynamics