# 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

# 0-Motivation

- Possible relation between solar activity and climate

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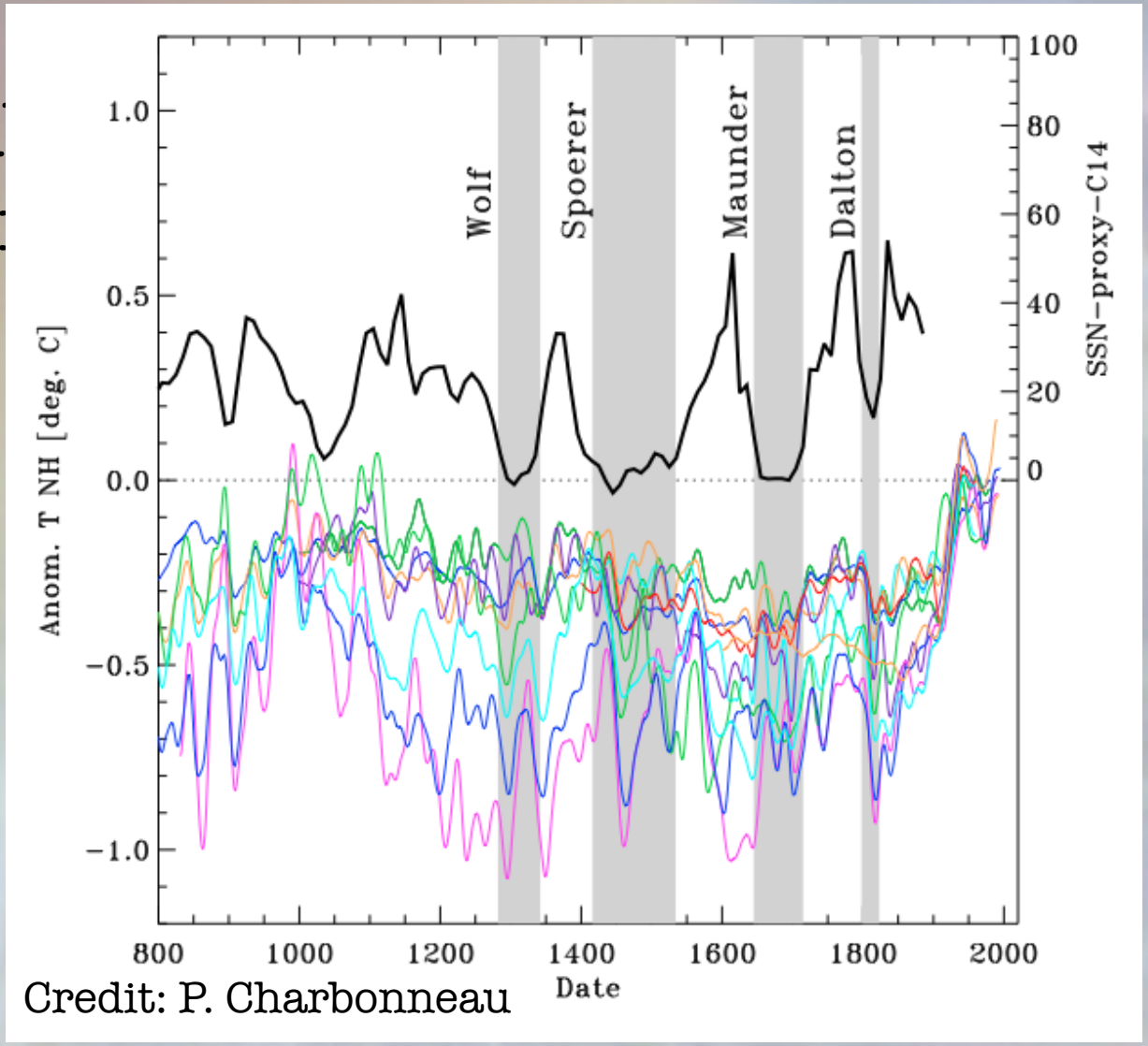


Credit: P. Charbonneau

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- Possible relation between solar activity and climate

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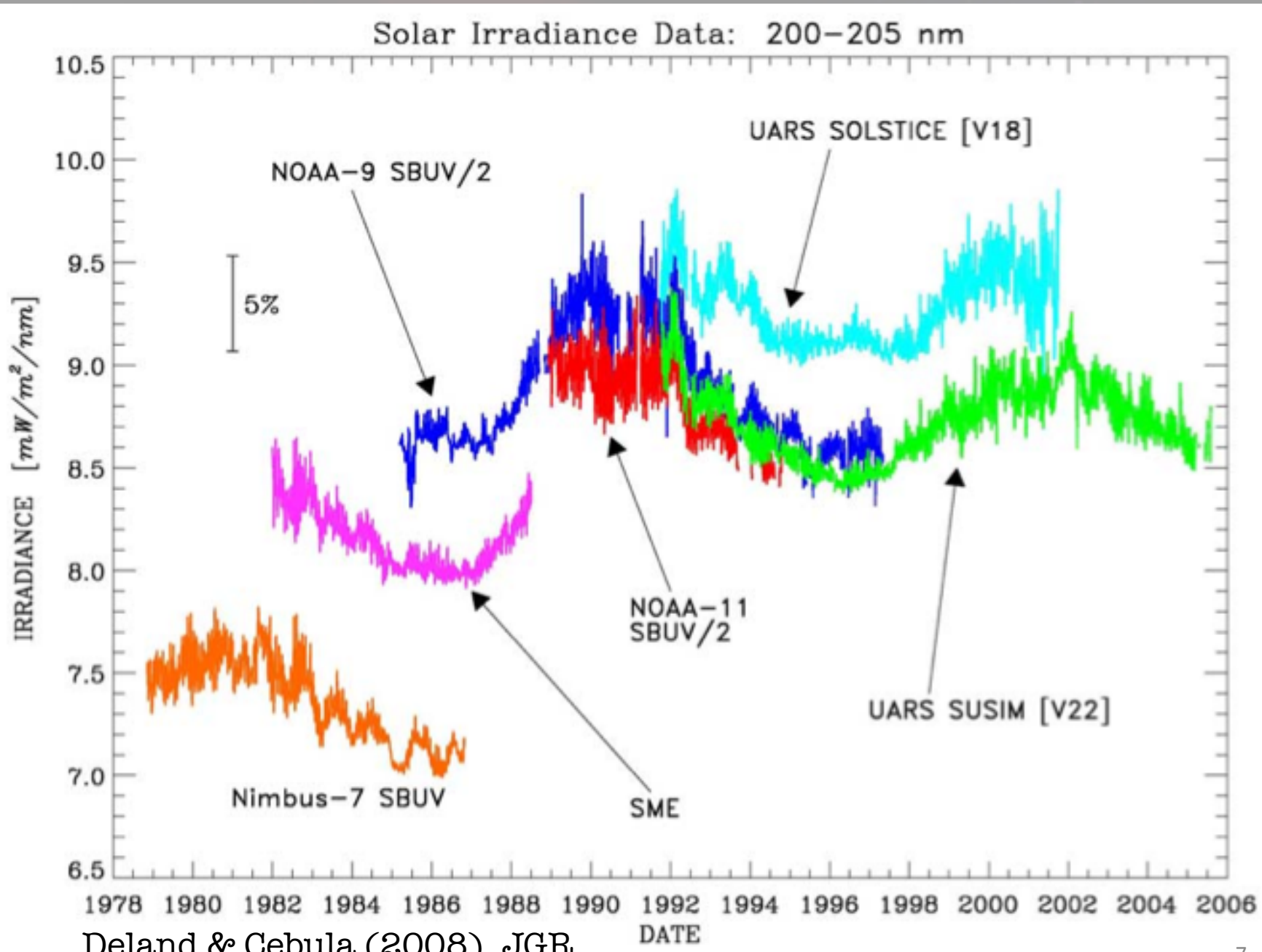
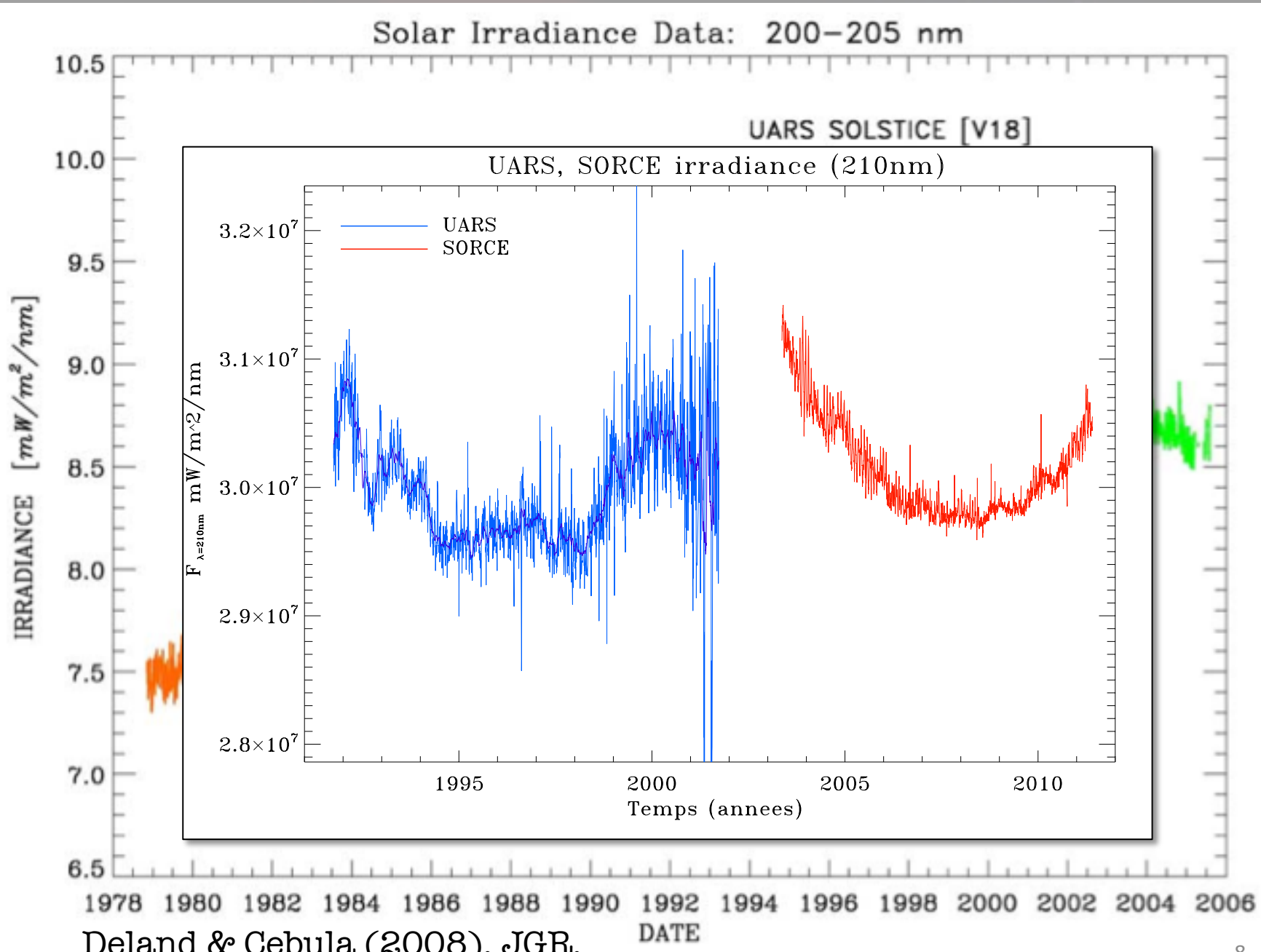
- Solar irradiance varies on many time scales
  - 11-yr cycle




Deland & Cebula (2008), JGR, 113, A11103

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- Possible relation between solar activity and climate
- Solar irradiance (especially in the UV) varies on many time scales
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- 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
- Simulation of sunspot evolution (fragmentation and erosion) according to Crouch et al. (2008) ApJ 677:723.
- Fragment classified as "spots" or "faculae" according to radius

# 1-The MOCASSIM model

- Calculation of spots and facular constrast + quiet Sun contribution + network contribution
  - Spots: ratio of flux on a synthetic spectrum @ $T_{eff}$=5250K vs $T_{eff}$=5750K
  - Facular contrast: Black body inversion procedure (see Solanki and Unruh (1998) A&A 329:247)
  - Quiet Sun: from Atlas 3 (Thuillier et al. (2003) Sol. Phys. 214:1) modulated by a temperature correction derived from the TSI reconstruction from Tapping et al. (2007) Sol. Phys. 246:309.

# 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

    Details in: Bolduc et al (2012) Sol. Phys. 279:383, Bolduc et al (2014) Accepted in Sol. Phys.

# 2-Comparison with other SSI reconstructions

- Comparison between 5 SSI reconstruction models

  (Thuillier et al. (2014) Sol. Phys. 289:1115.)

  – **MOCASSIM**

  – **MGNM** (Thuillier et al. (2012) Sol. Phys. 277:245)

  – **NRLSSI** (Lean et al. (2000) GRL, 27:2425)

  – **SATIRE** (Krivova et al. (2010) JGR, 115:A12112)

  – **SEA** (Shapiro et al. (2011) A&A, 529:A67; JASTP, 73:348)

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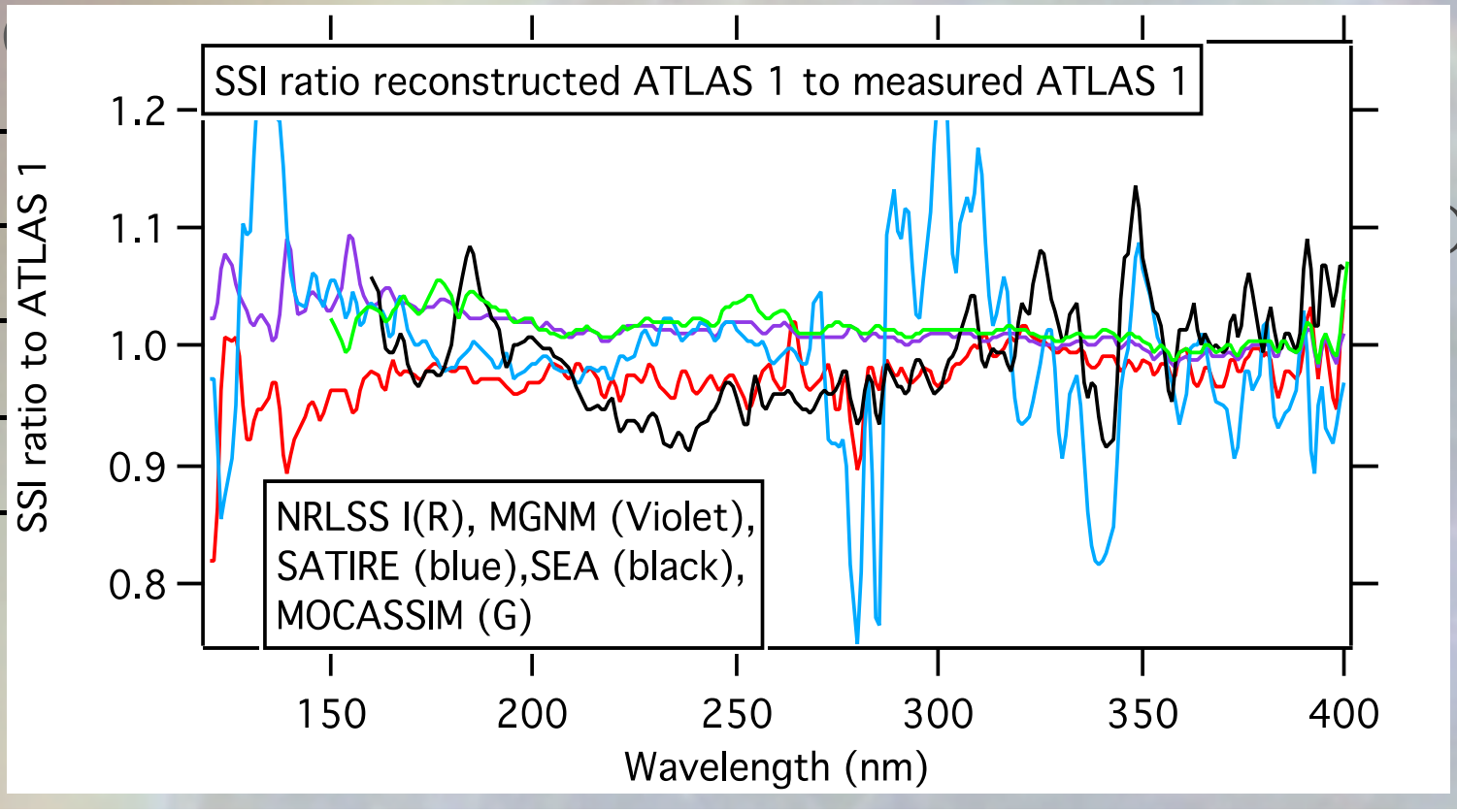

# 3-Stratospheric chemical abundances calculations

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

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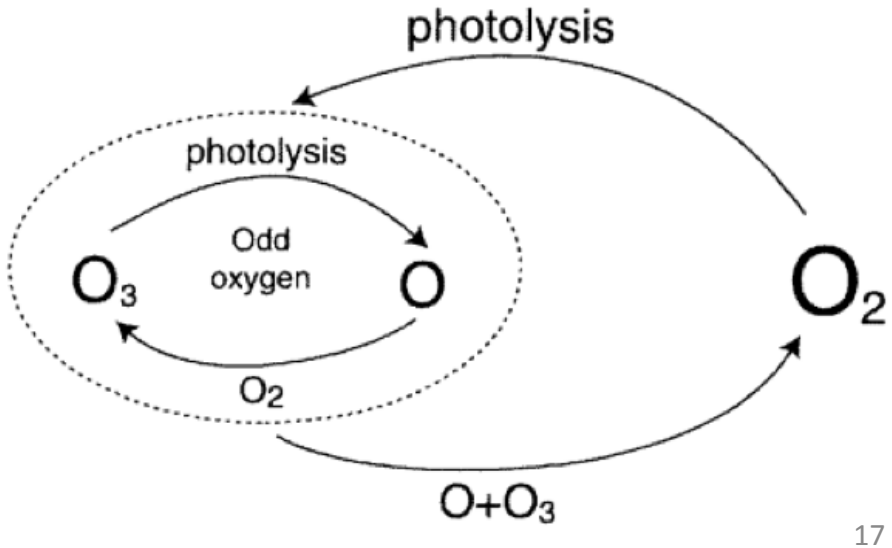
$$O_2 + h\nu \rightarrow O + O \qquad \lambda < 242 \text{ nm}$$

$$2 \times (O_2 + O \xrightarrow{M} O_3)$$

$$net: 3O_2 + h\nu \rightarrow 2O_3$$

$$O_3 + h\nu \rightarrow O_2 + O \qquad \lambda < 300 \text{ nm}$$

$$O_3 + O \rightarrow O_2 + O_2$$



# 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))

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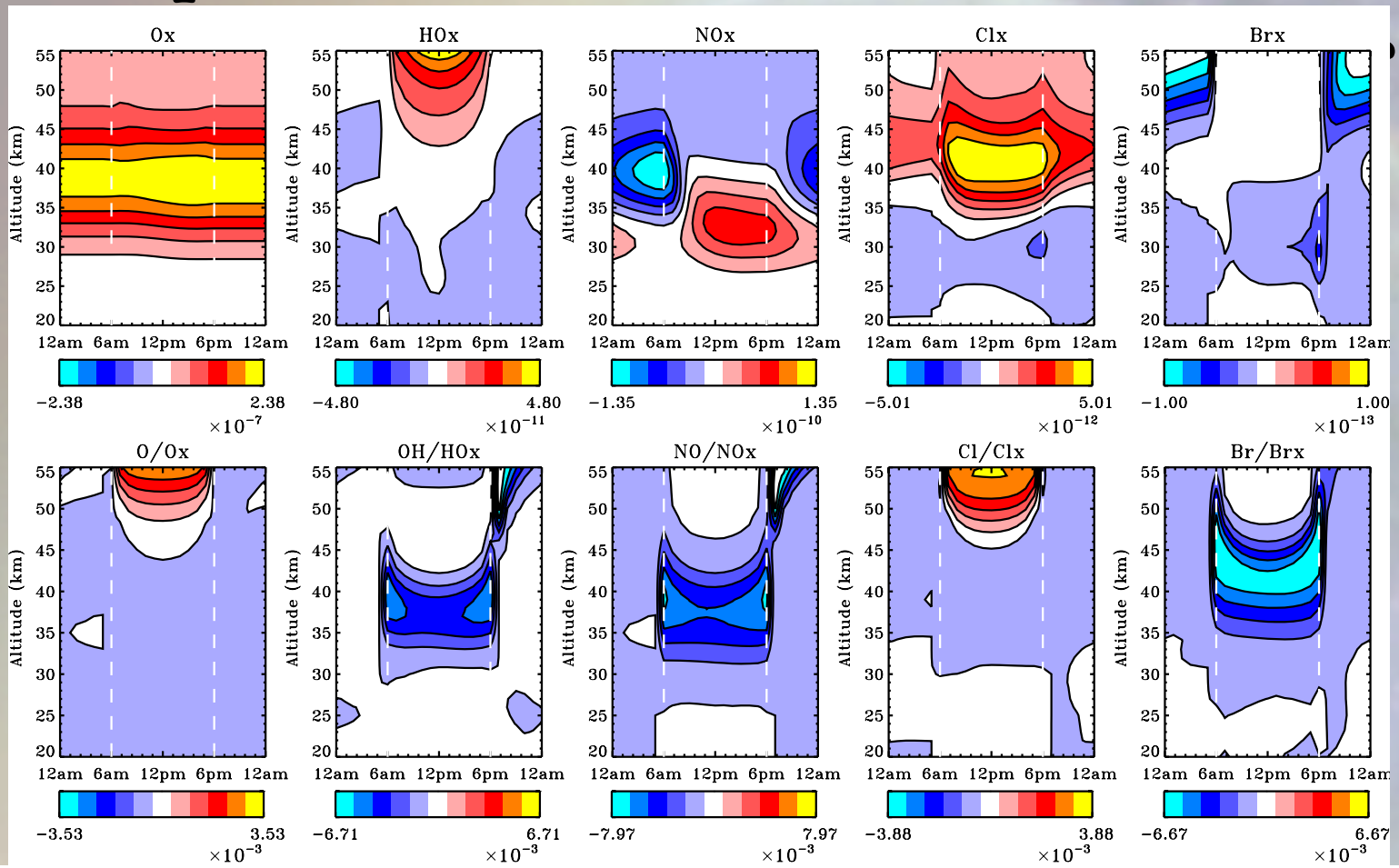

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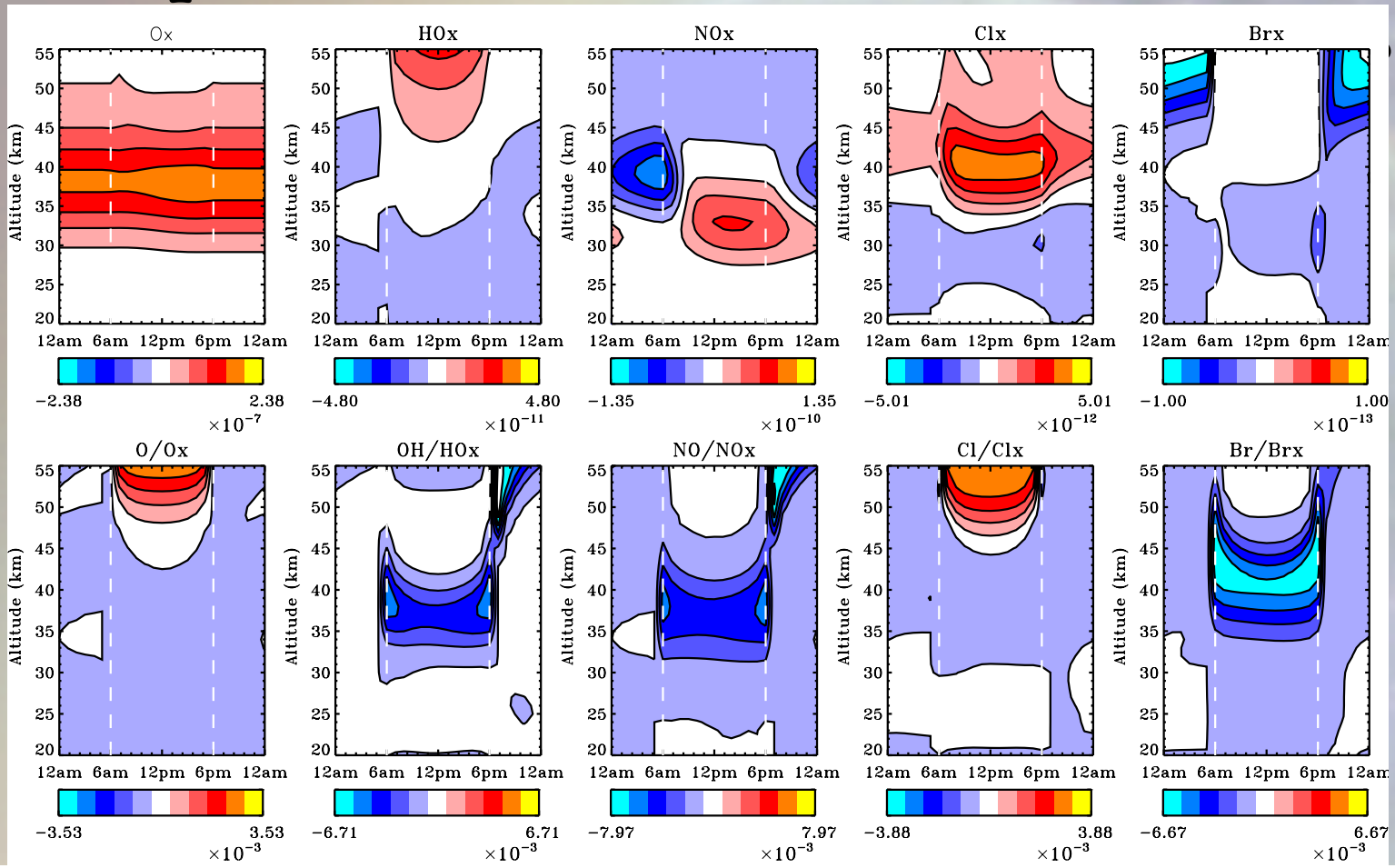

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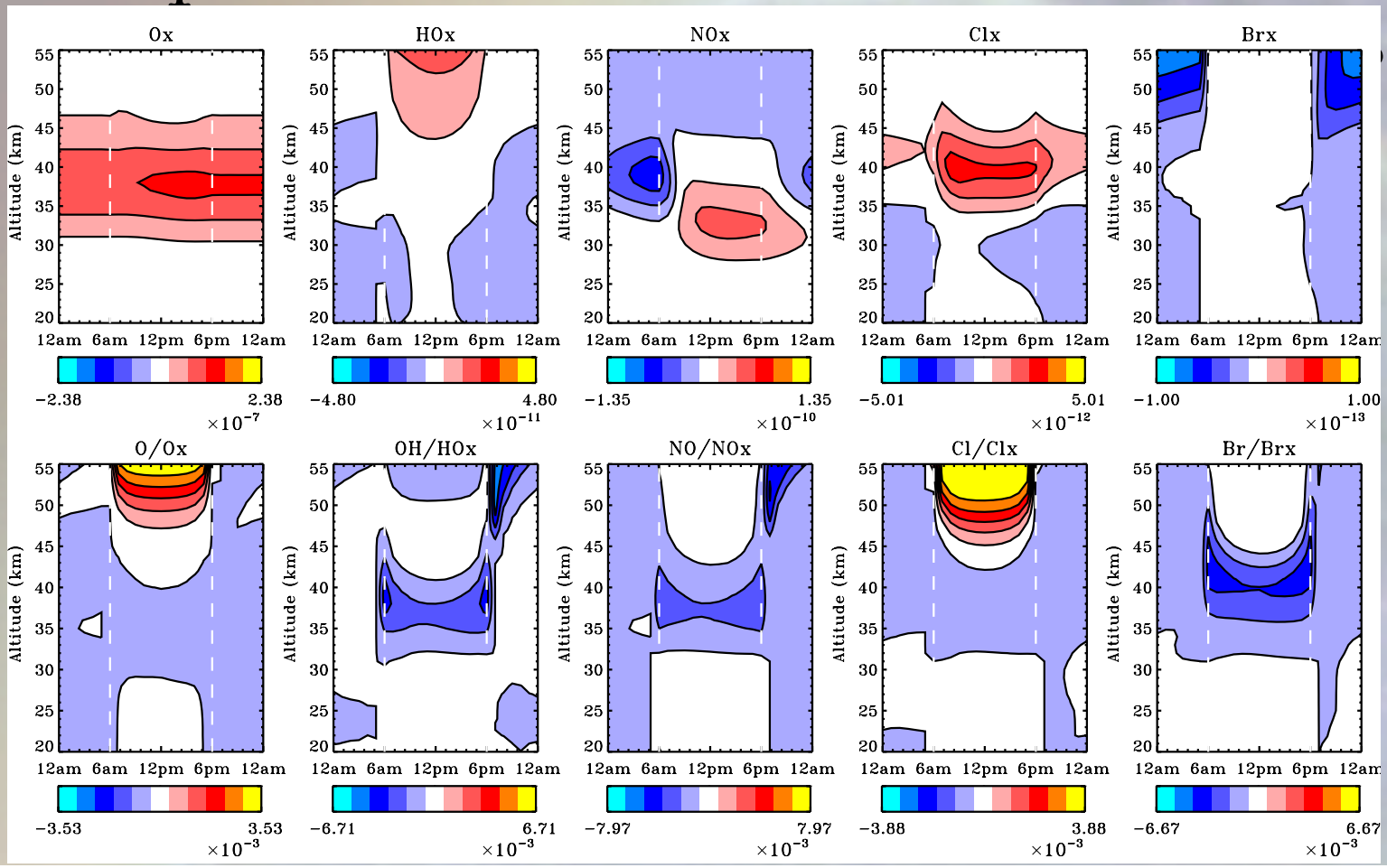

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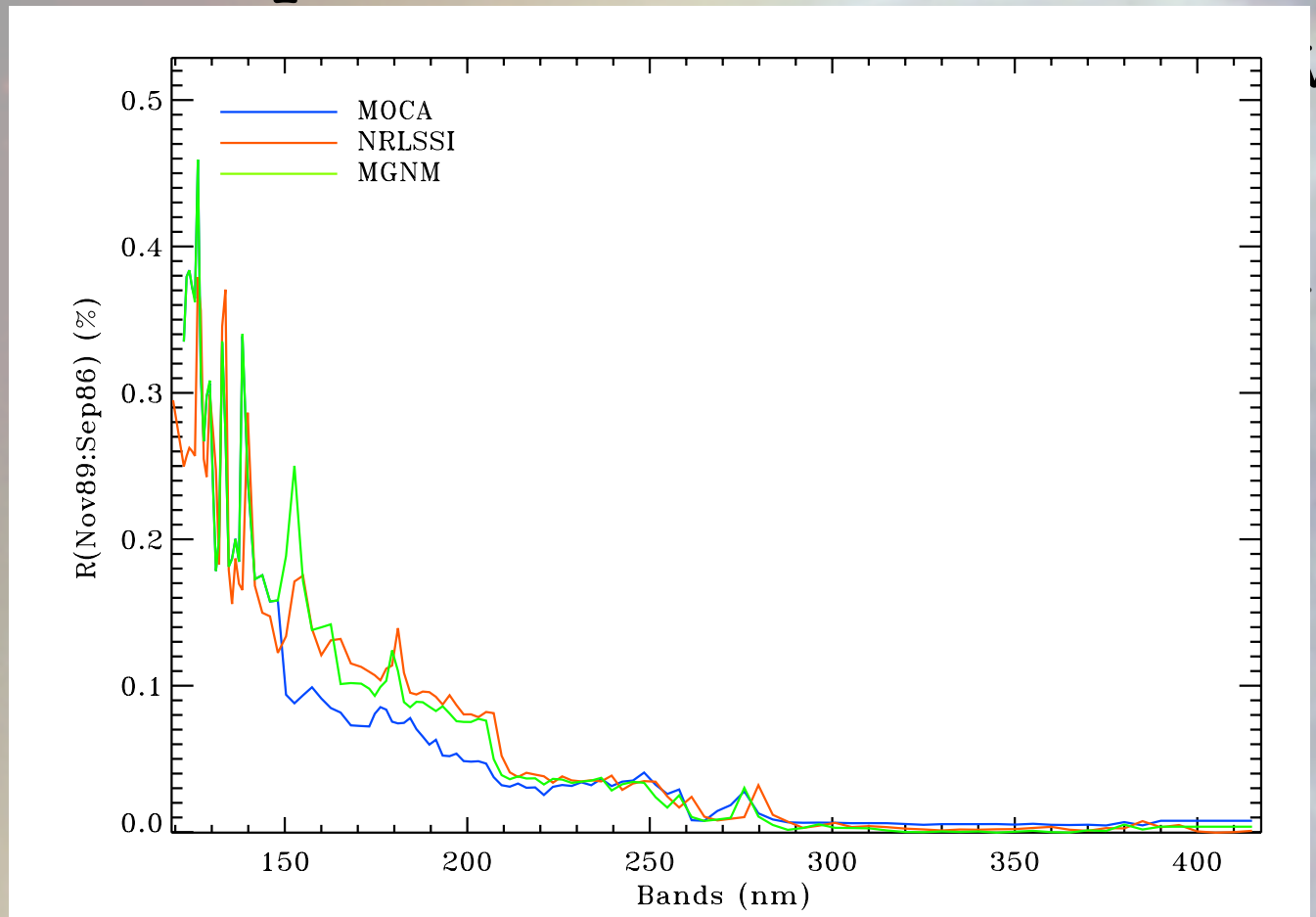

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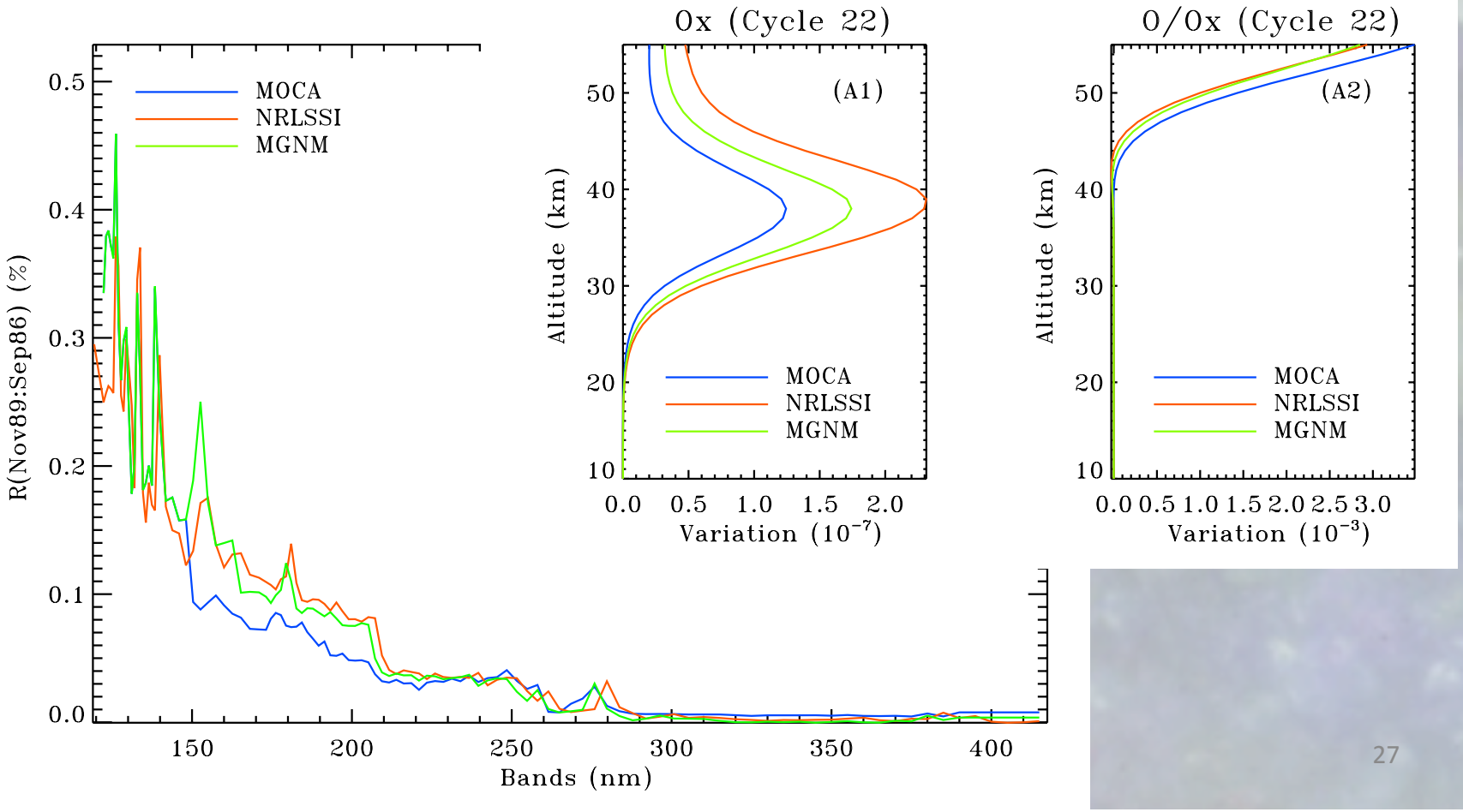

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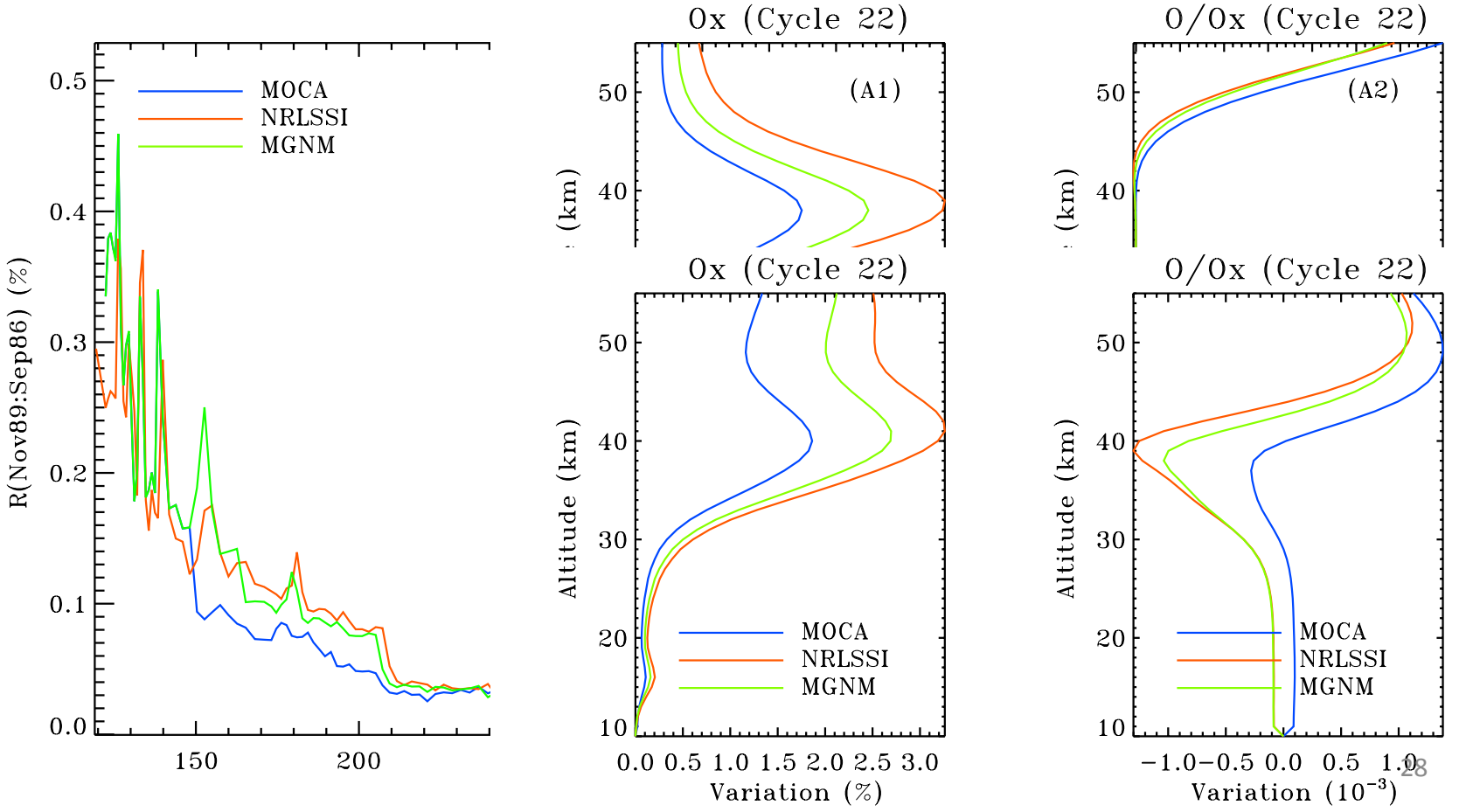

# 3-Stratospheric chemical abundances calculations

- Comparison between modern minimum (March 2009) and Maunder minimum (average over 1680)
  - MOCASSIM

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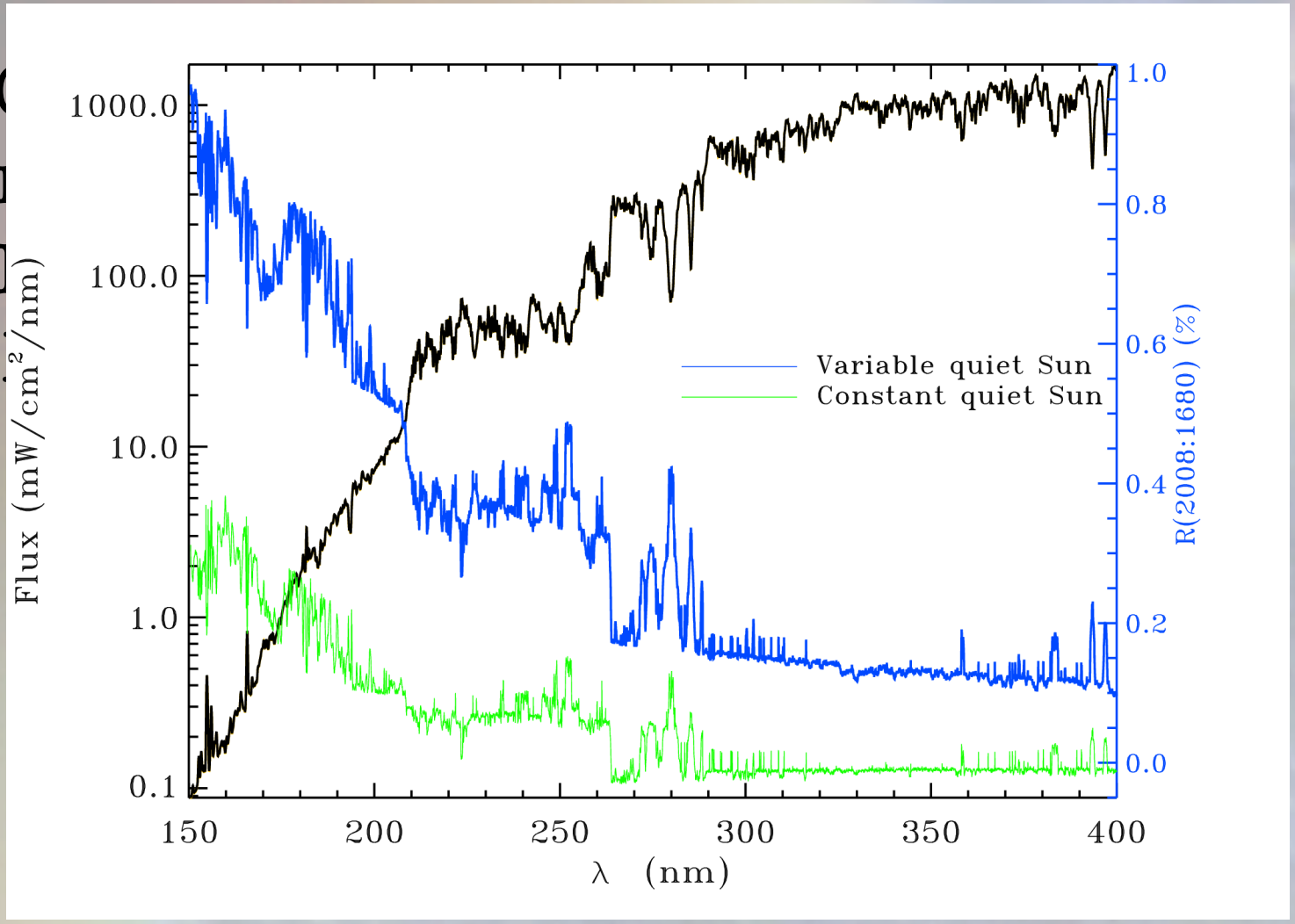

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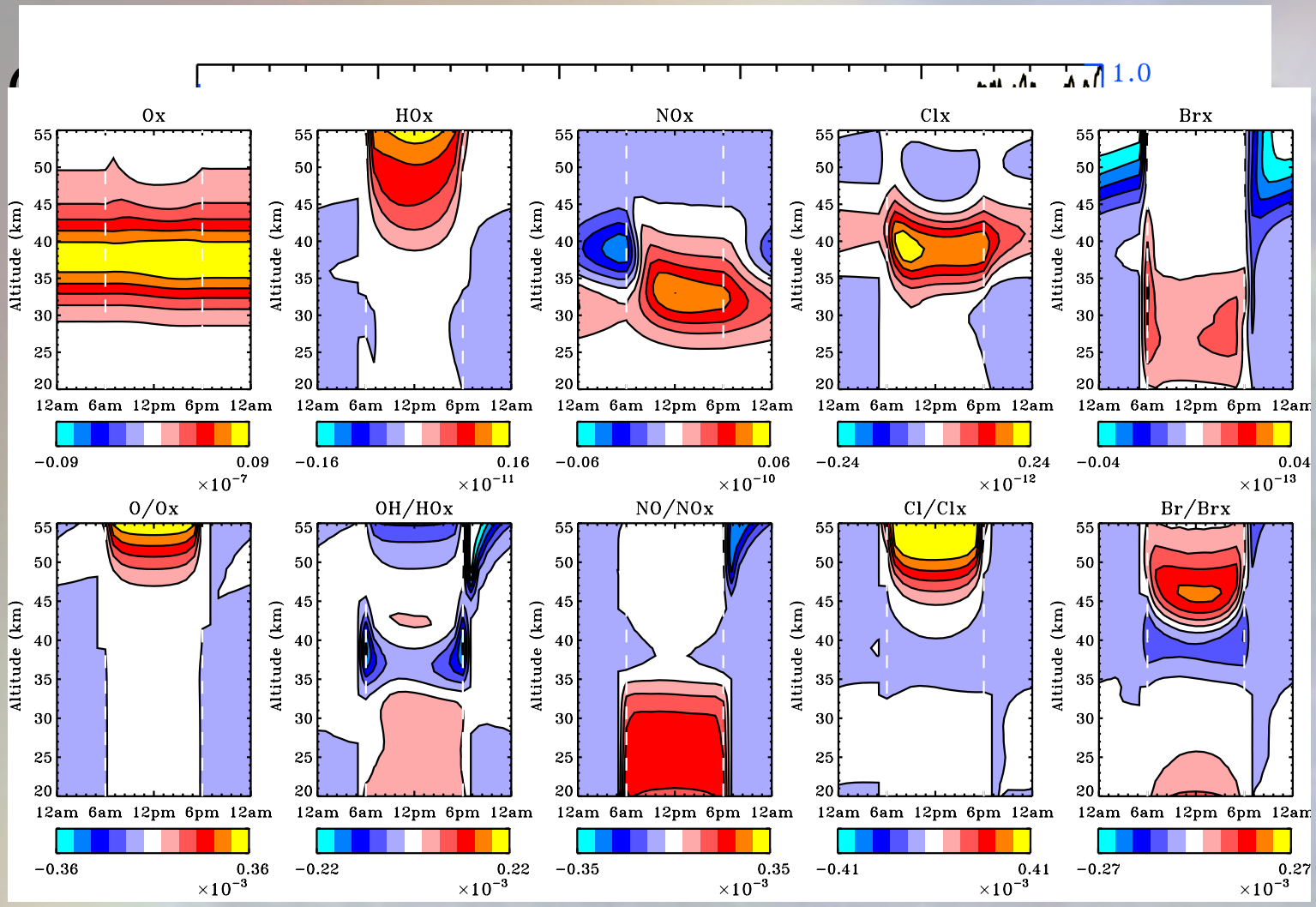

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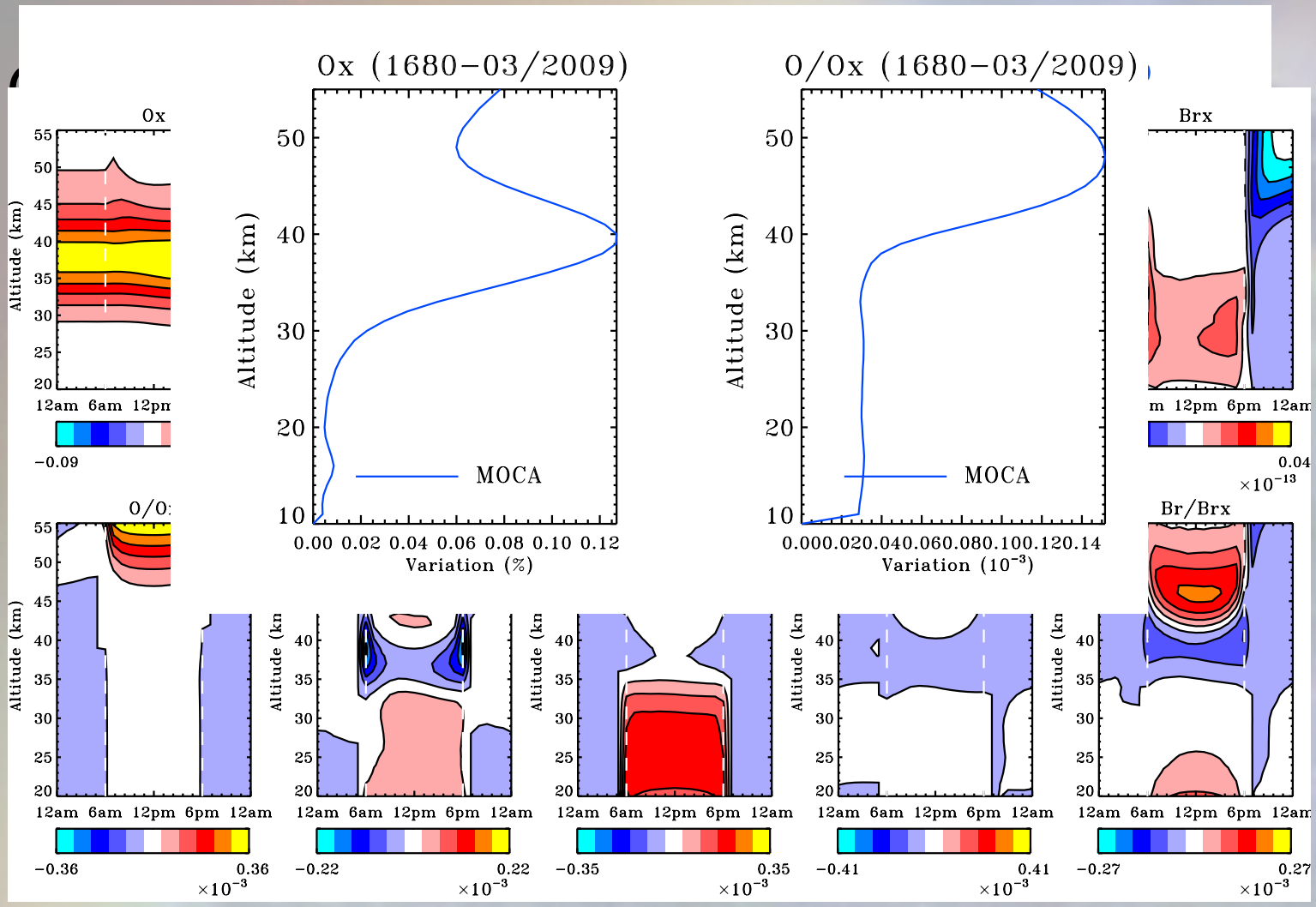

# 4-Conclusion and future work

- 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