

Sensitivity of tropical stratospheric ozone to short term solar variability

Sébastien BOSSAY, Slimane BEKKI, Marion MARCHAND,
Gérard THUILLIER, Alain HAUCHECORNE, David BOLSEE,
Ralf TOUMI and Virginie POULAIN



I. Context

- a. Solar variability
- b. Solar influences on climate
- c. The Solar UV / Ozone relation

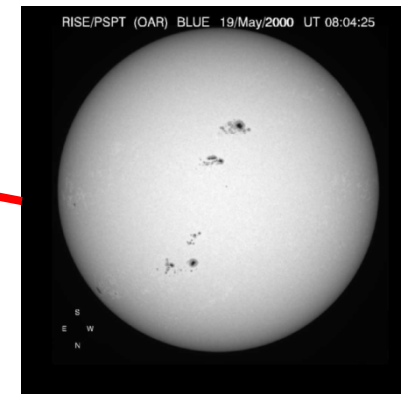
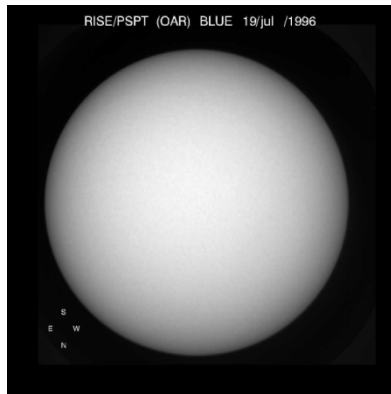
II. Objective and data

III. Results

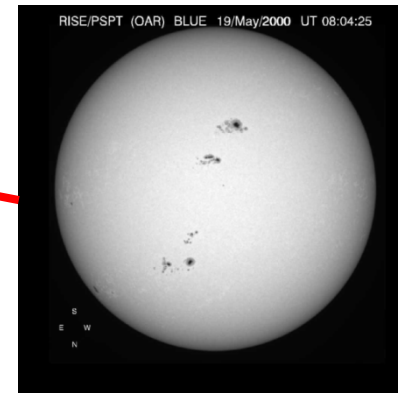
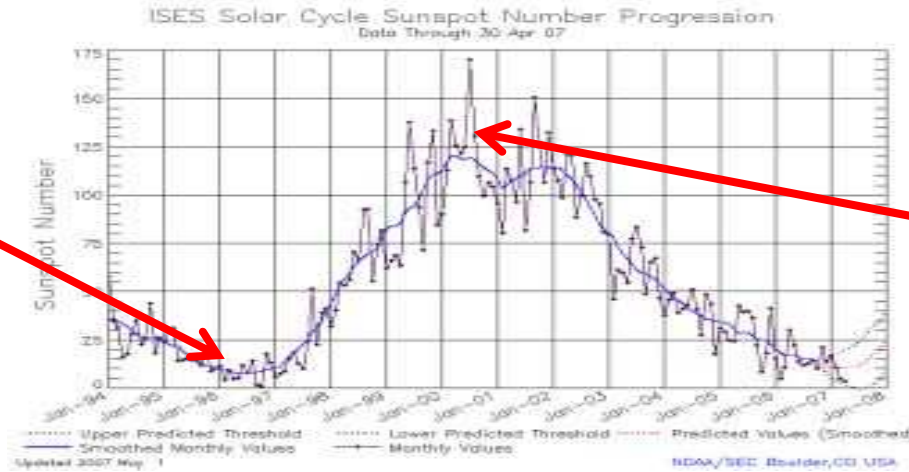
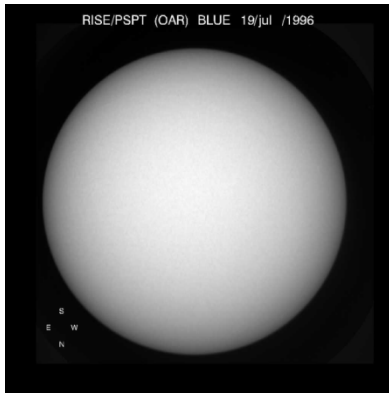
- a. Spectral analysis
 - i. 205 nm solar irradiance
 - ii. Ozone timeseries
- b. Cross-spectral analysis
 - i. Cross-correlation
 - ii. Sensitivity

IV. Conclusions and perspectives

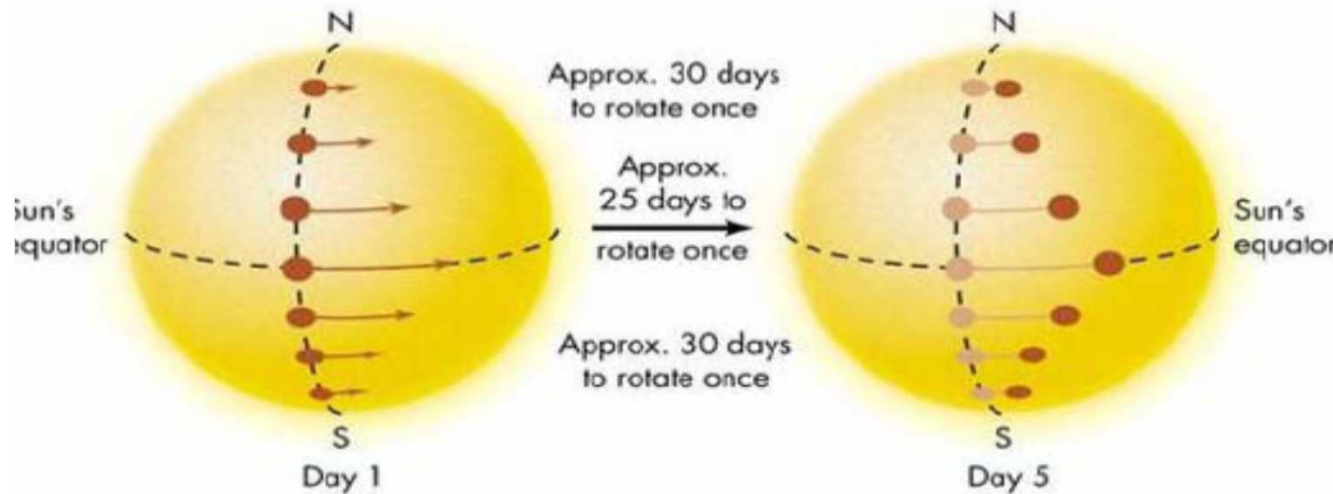
The 11-year solar cycle

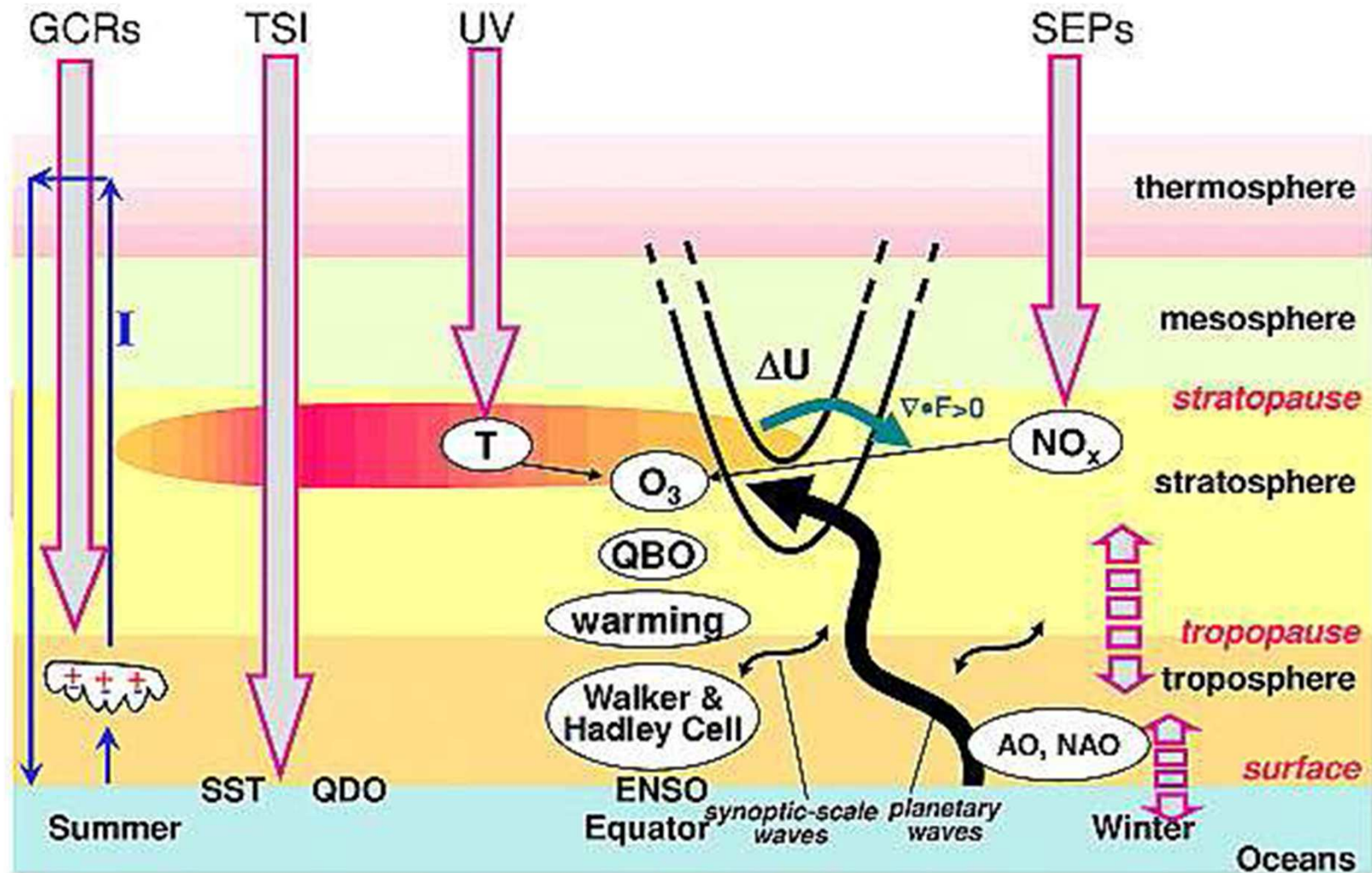


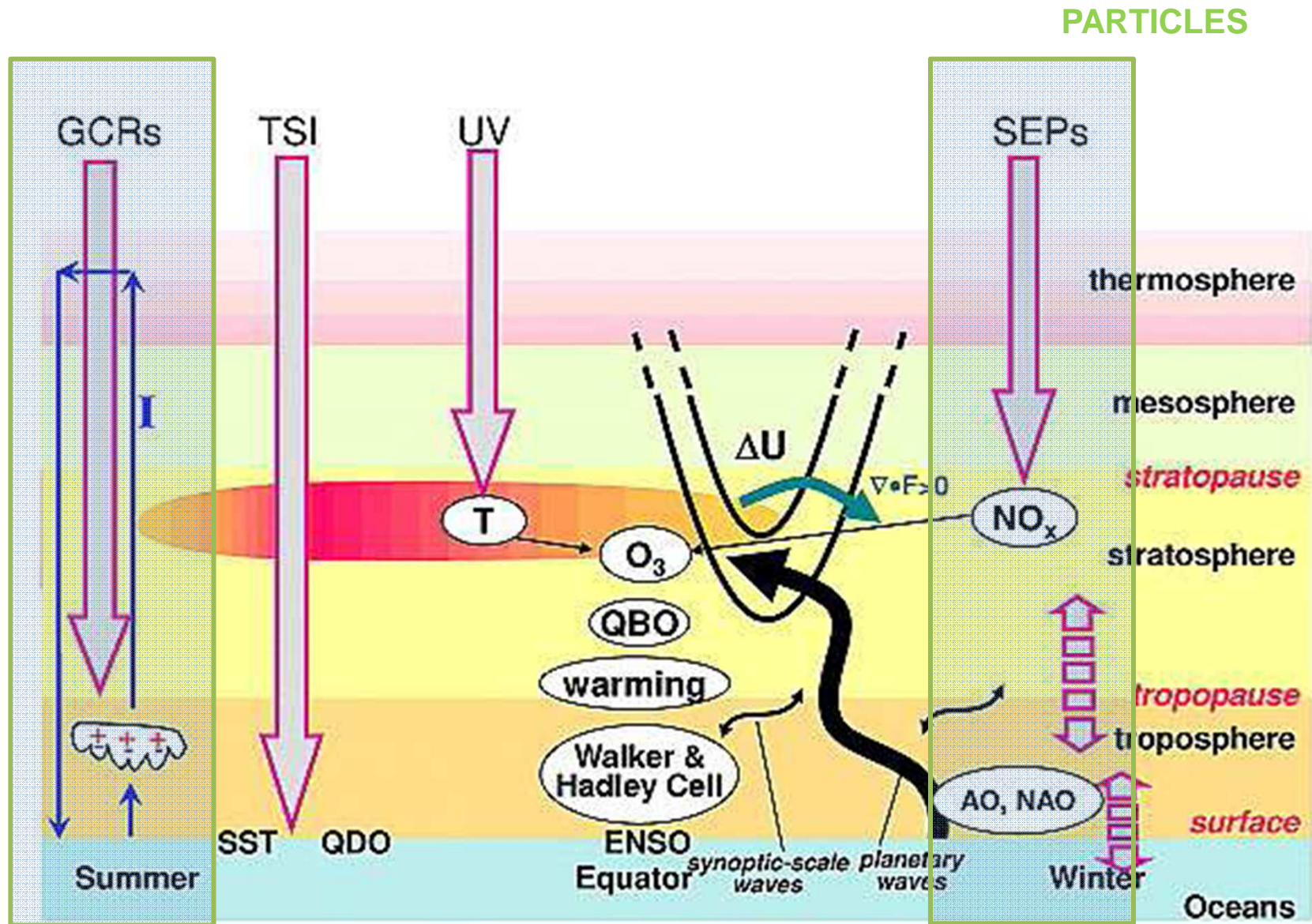
The 11-year solar cycle



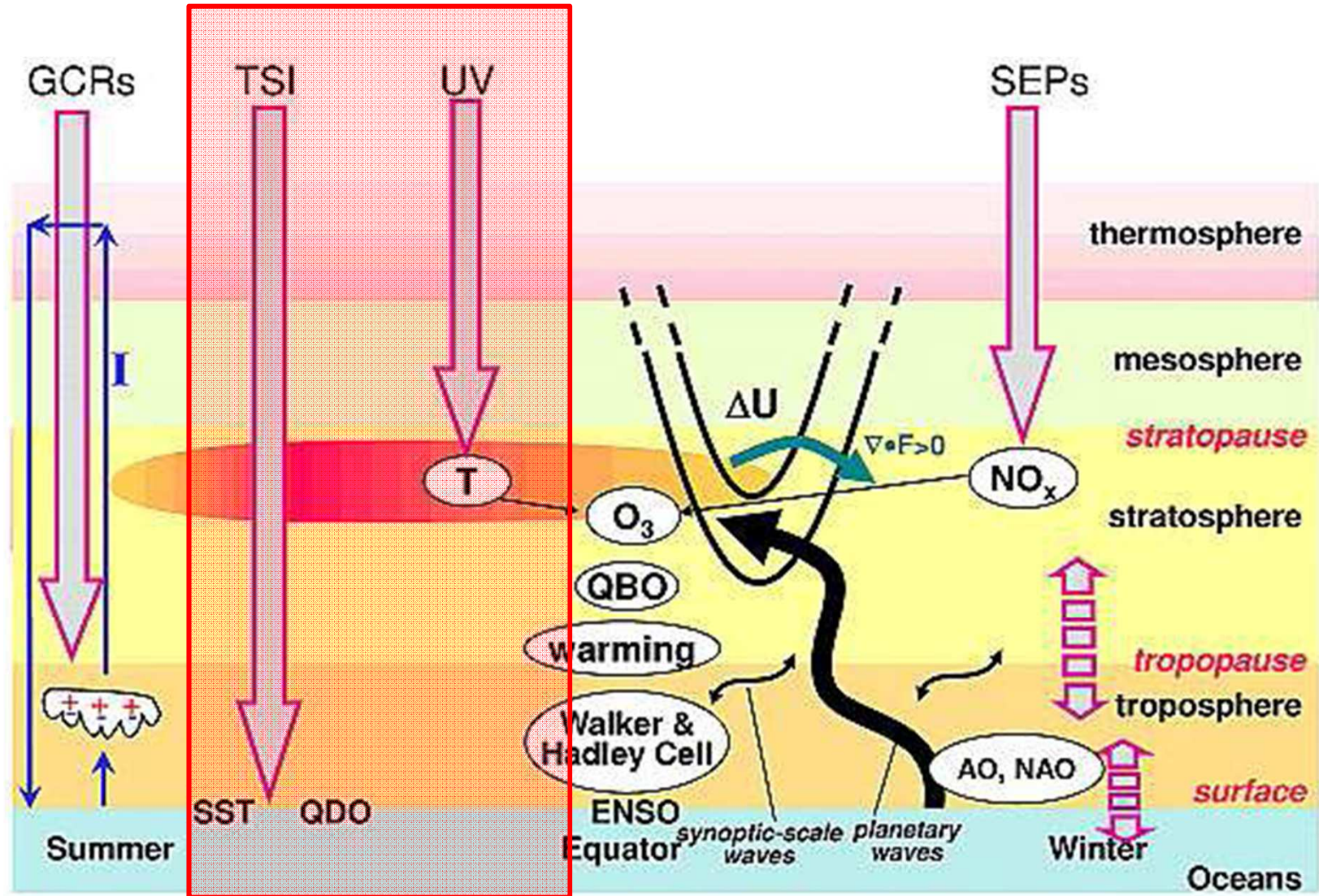
The 27-day solar cycle

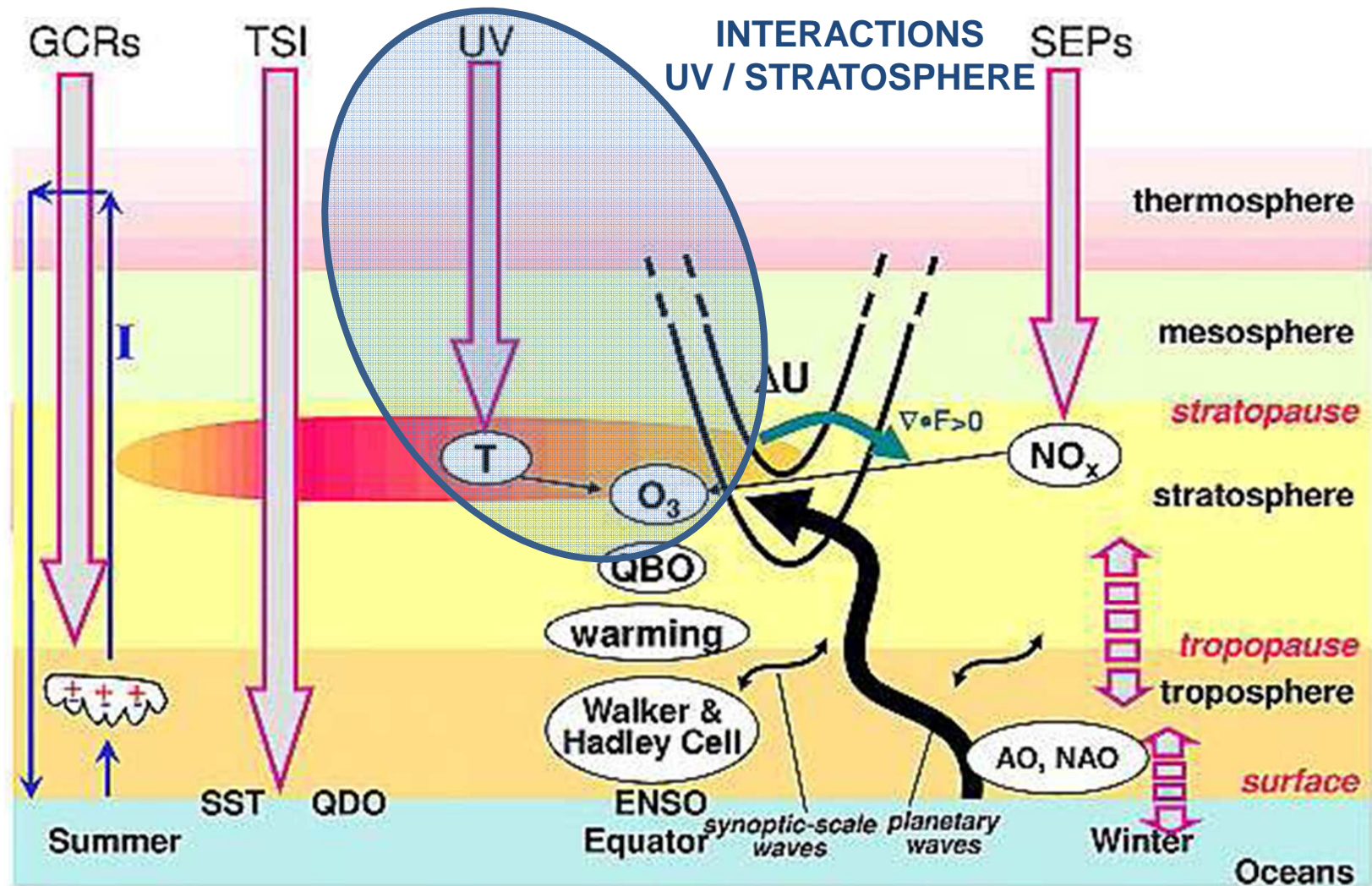






RADIATION



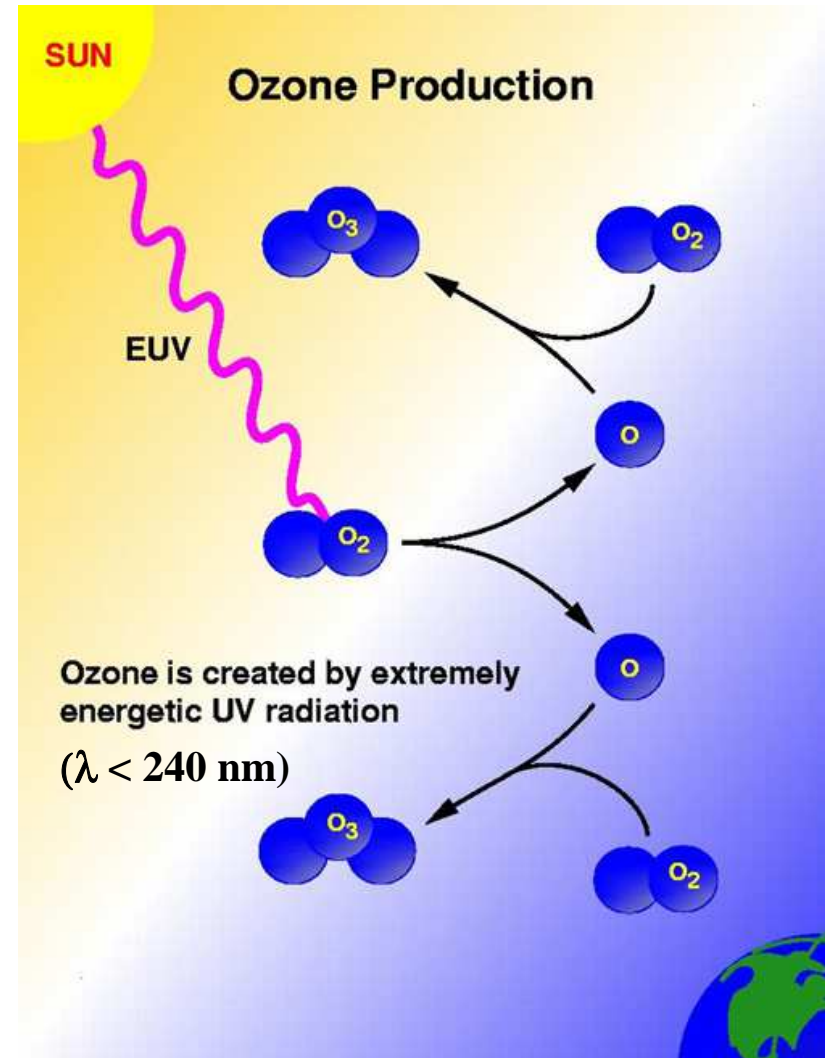


Energy arriving at the top of Earth's Atmosphere.

	UV ~5-10%
• Total Solar Irradiance	1360 W/m ²
• TSI over Solar Cycle (0.1%)	1.36 W/m ²

Solar Variability requires **AMPLIFICATION** to affect climate.

Adapted from J. Haigh et al., 2005



Adapted from C. David

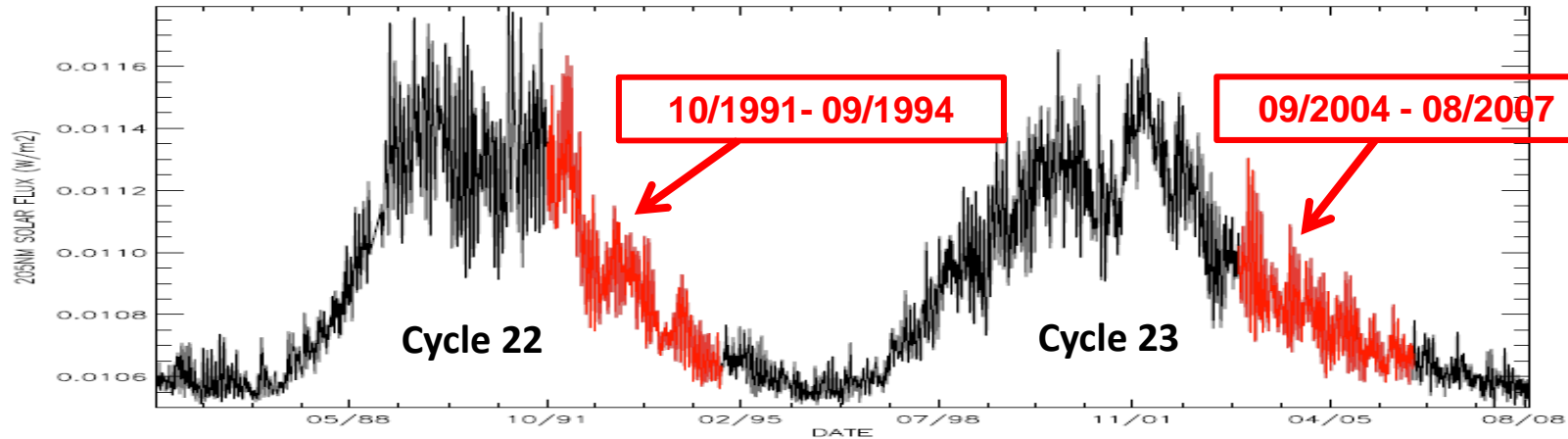
Objective :

- Characterize and estimate the stratospheric ozone response to the 205 nm solar irradiance at short timescales (27 days) over two consecutive 11-year solar cycles (solar cycles 22 and 23)

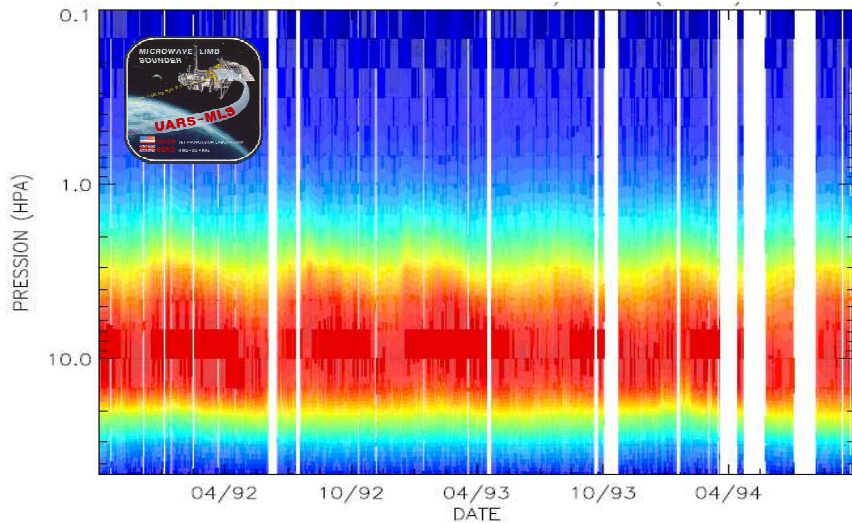
Data:

- Daily 205 nm solar irradiance reconstructed from the **NRL-SSI model** (*Lean et al., 2000*)
- Daily ozone timeseries zonally averaged on the tropical band [20°N-20°S] and measured by the **MLS** instruments on board of **UARS** satellite (*Froidevaux et al., 1994*) and **AURA** satellite (*Waters et al., 2006*)

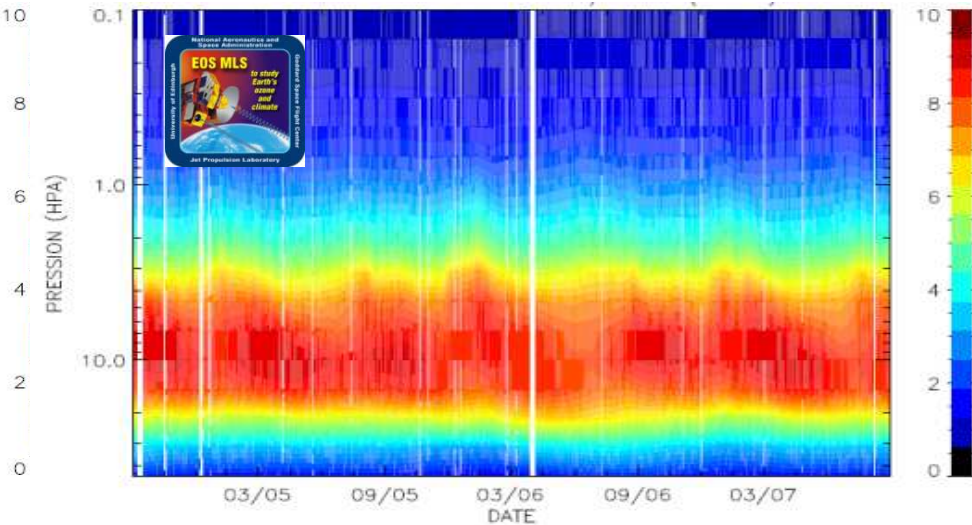
Solar irradiance at 205nm (W/m²) from the NRL-SSI model



Ozone (ppmv)



MLS/UARS ozone (solar cycle 22)

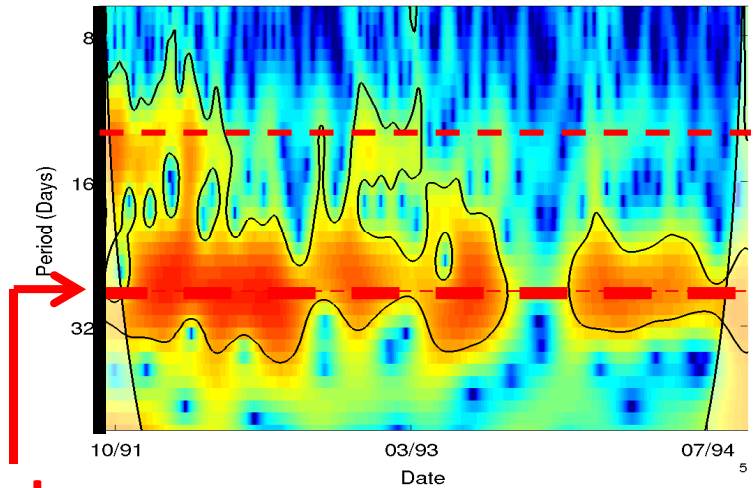
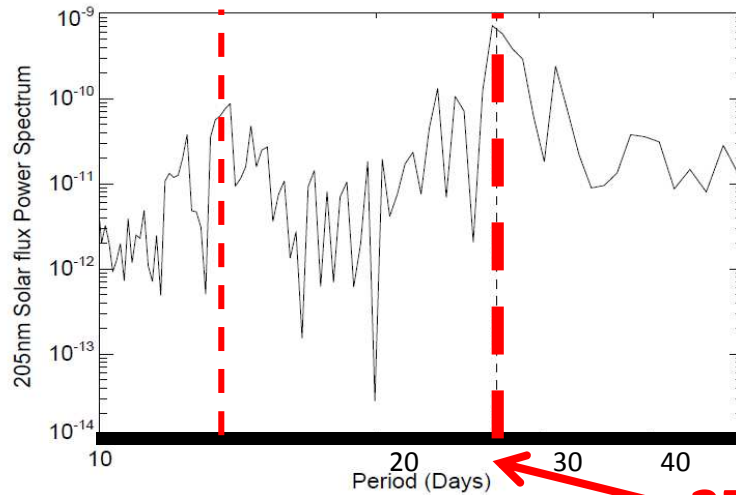


MLS/AURA ozone (solar cycle 23)

FFT periodogram

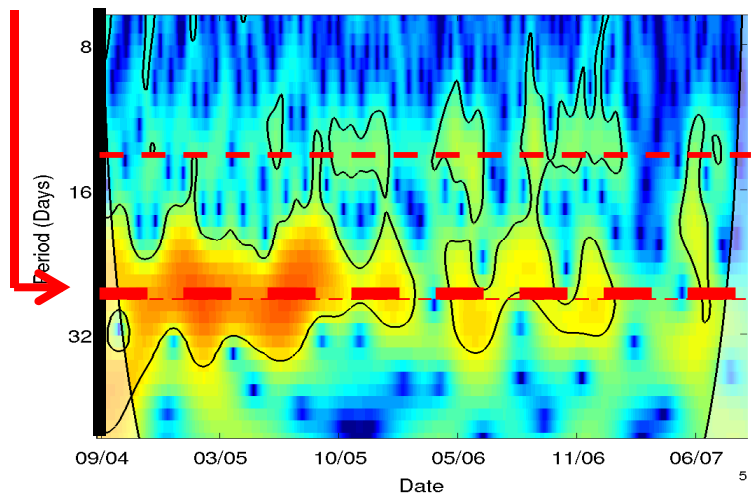
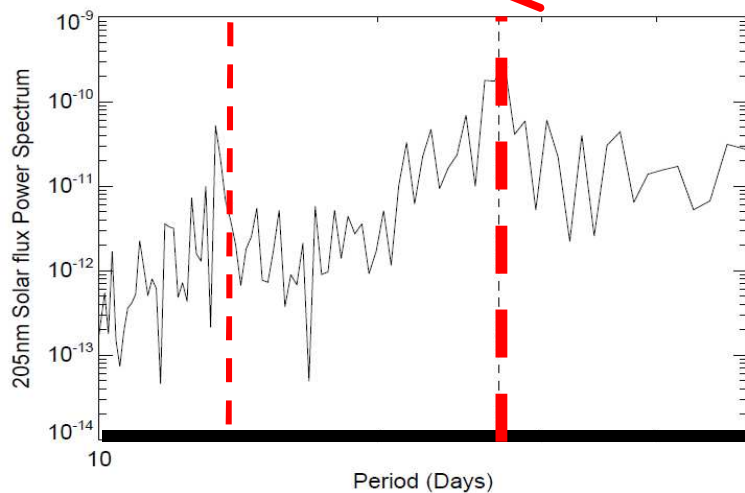
Wavelet transform (CWT)

Solar cycle 22
(10/91-09/94)



27 days

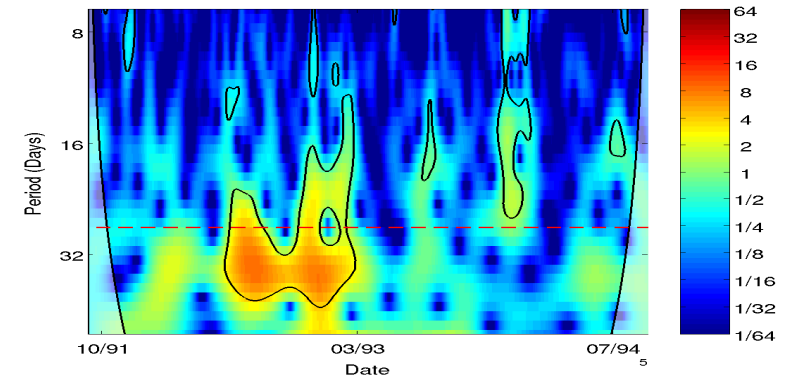
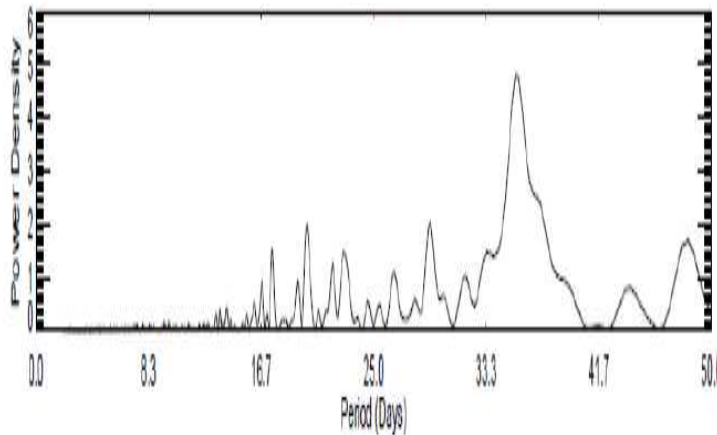
Solar cycle 23
(09/04-08/07)



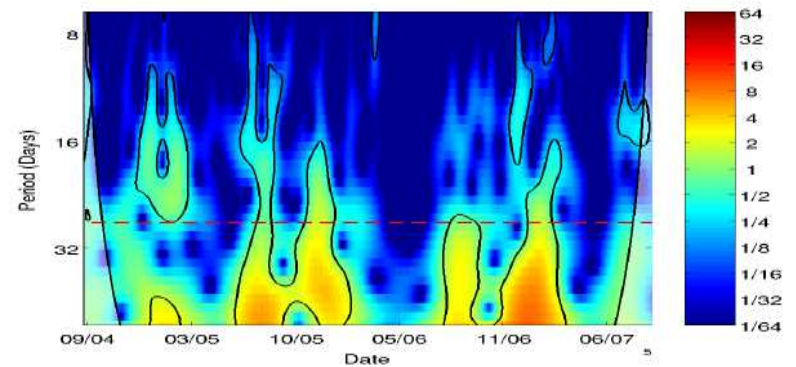
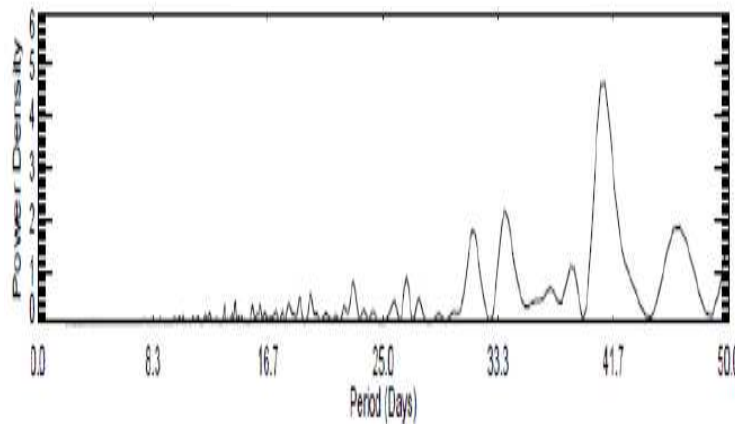
**Lomb-Scargle periodogram
of ozone at 3.2 hPa (~39 km)**

**Wavelet transform (CWT)
of ozone at 3.2 hPa (~39 km)**

**Solar cycle 22
(MLS/UARS)**



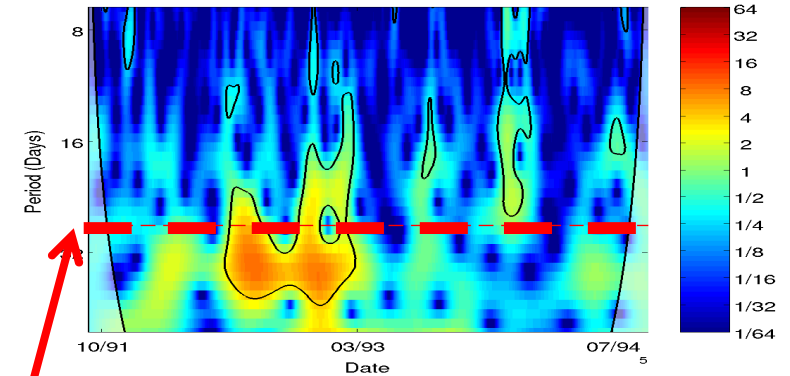
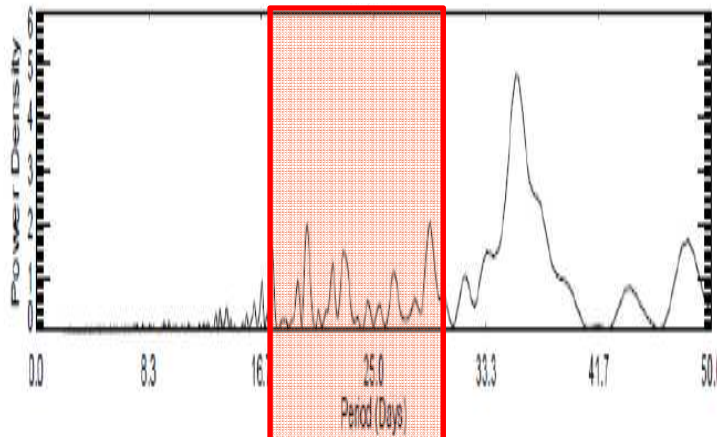
**Solar cycle 23
(MLS/AURA)**



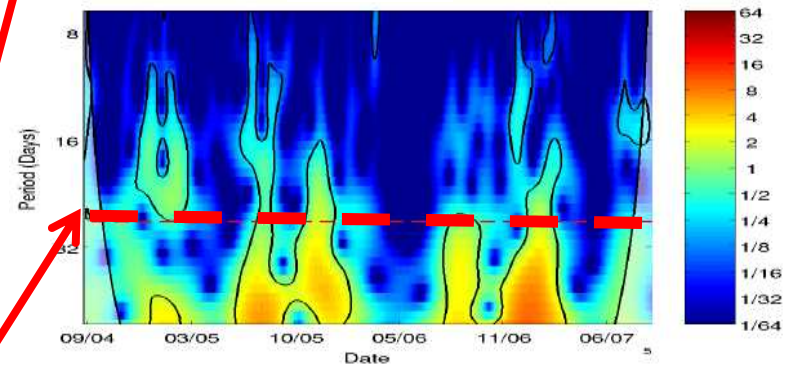
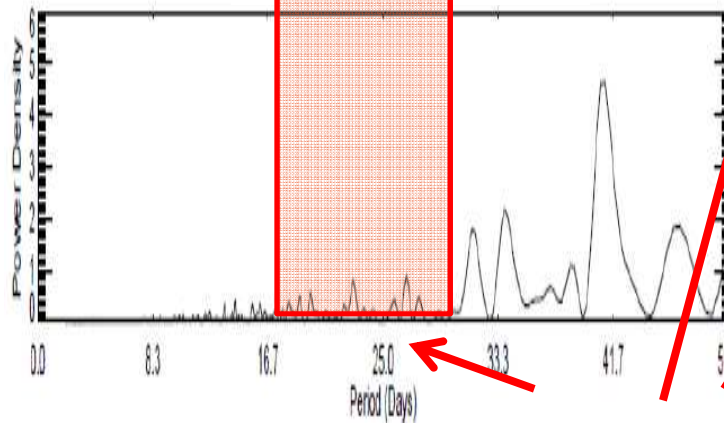
**Lomb-Scargle periodogram
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**Wavelet transform (CWT)
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**Solar cycle 22
(MLS/UARS)**



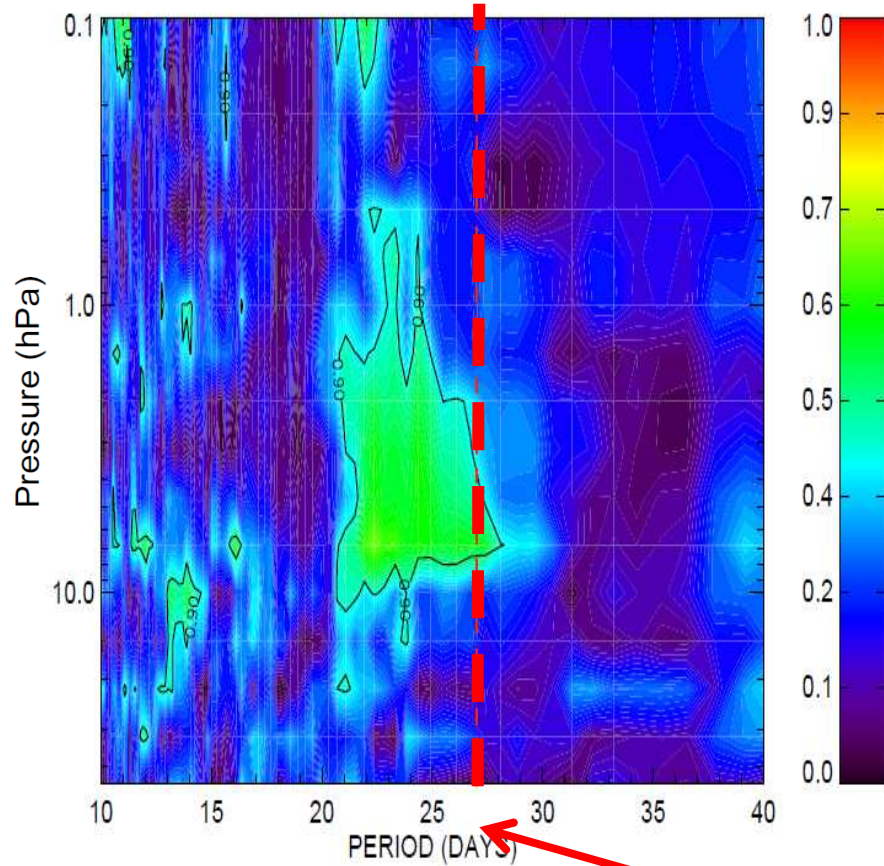
**Solar cycle 23
(MLS/AURA)**



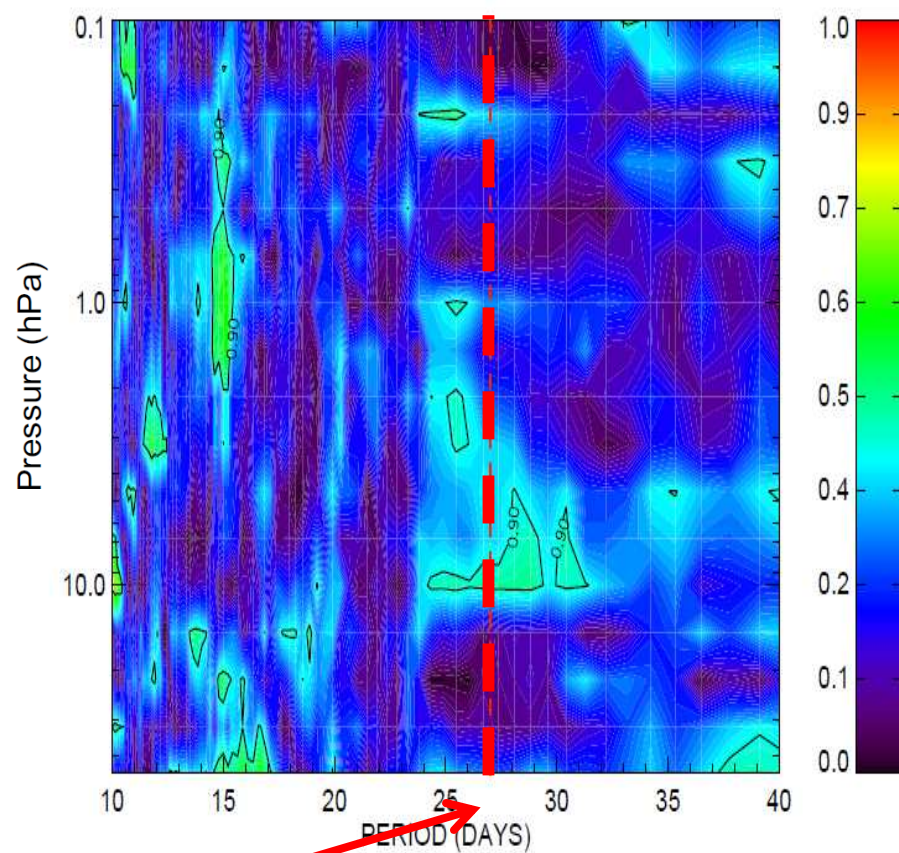
27 days

Coherence between solar irradiance (205 nm) and ozone

Solar cycle 22 (MLS/UARS)



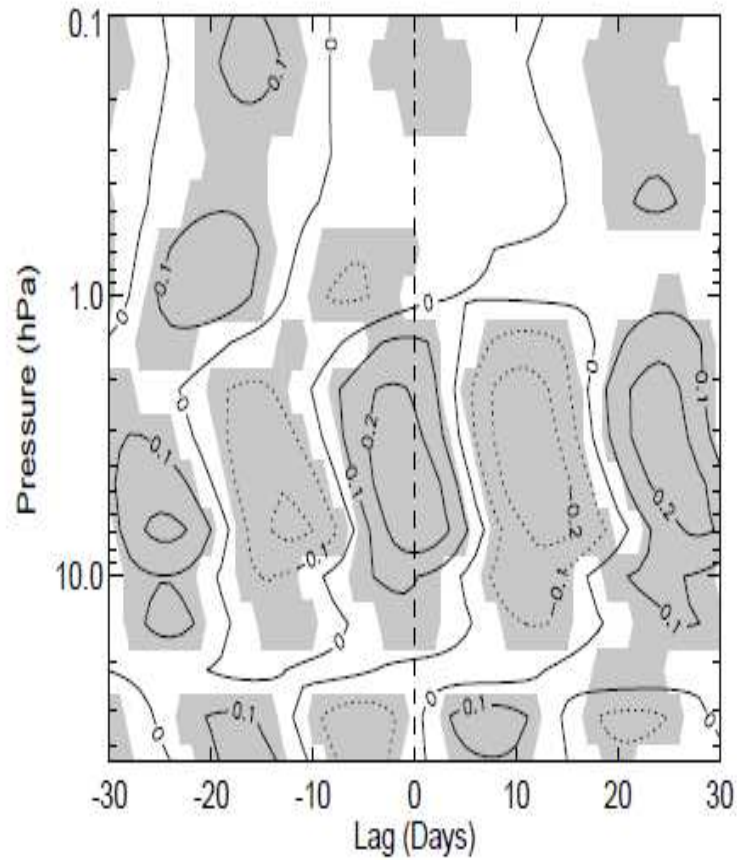
Solar cycle 23 (MLS/AURA)



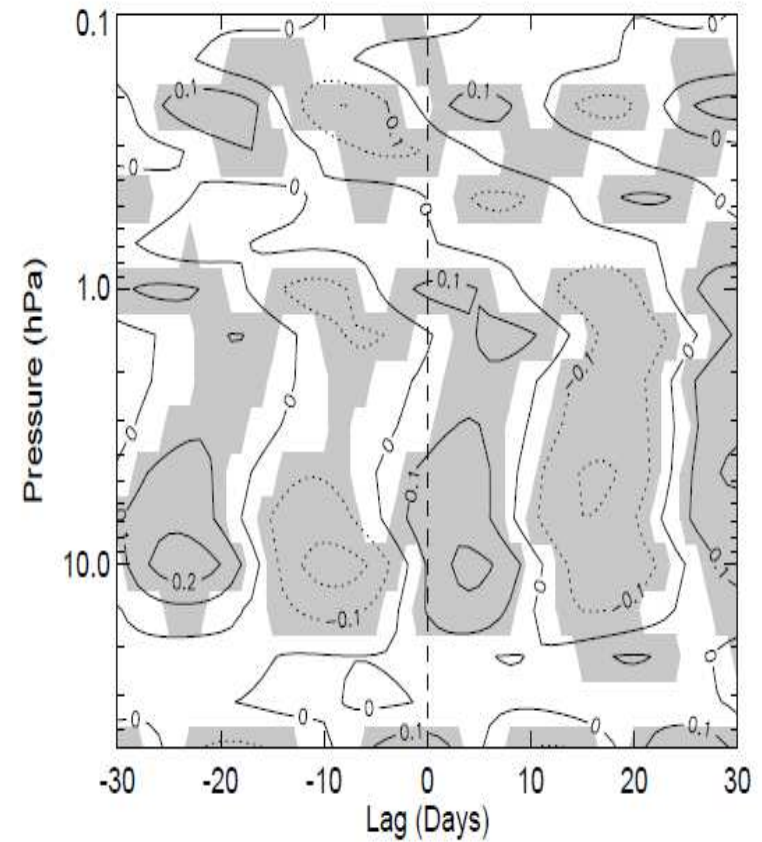
27 days

Cross-correlation between solar irradiance (205 nm) and ozone

Solar cycle 22 (MLS/UARS)

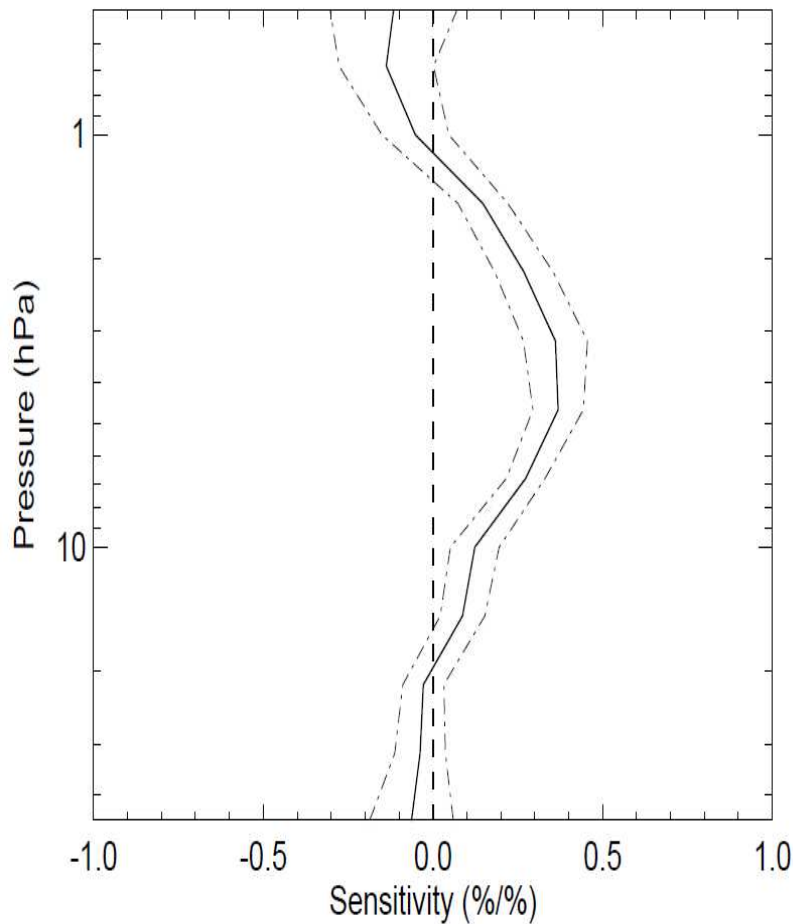


Solar cycle 23 (MLS/AURA)

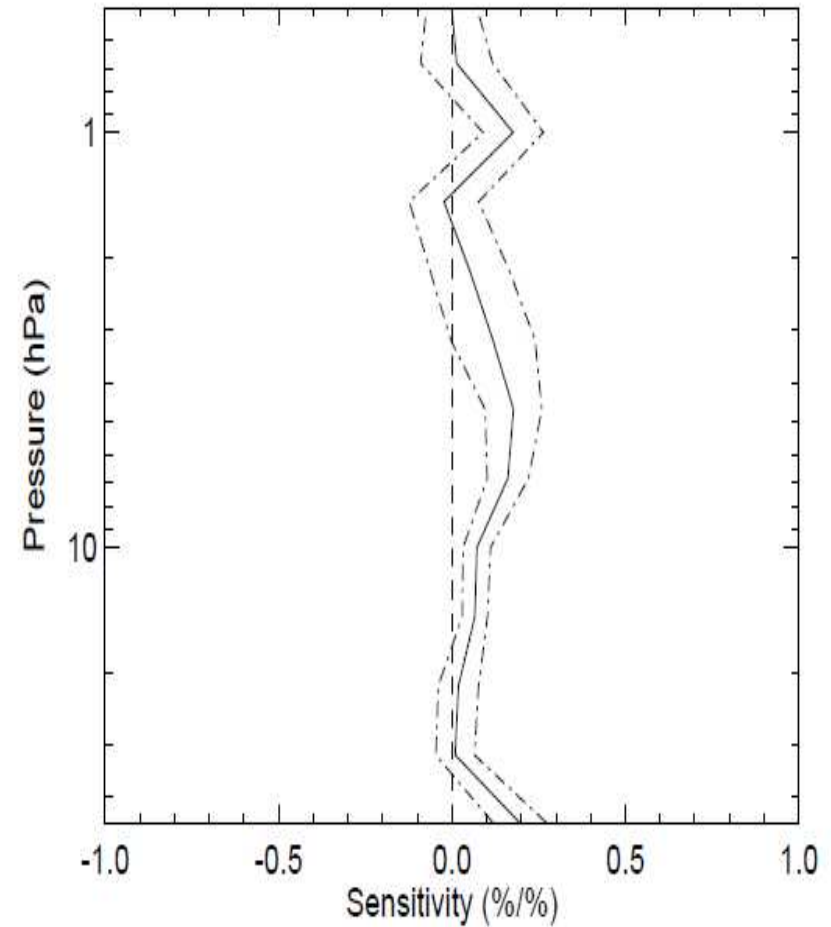


Sensitivity ($\% \Delta(\text{O}_3) / 1\% \Delta(\text{F}205\text{nm})$)

Solar cycle 22 (MLS/UARS)

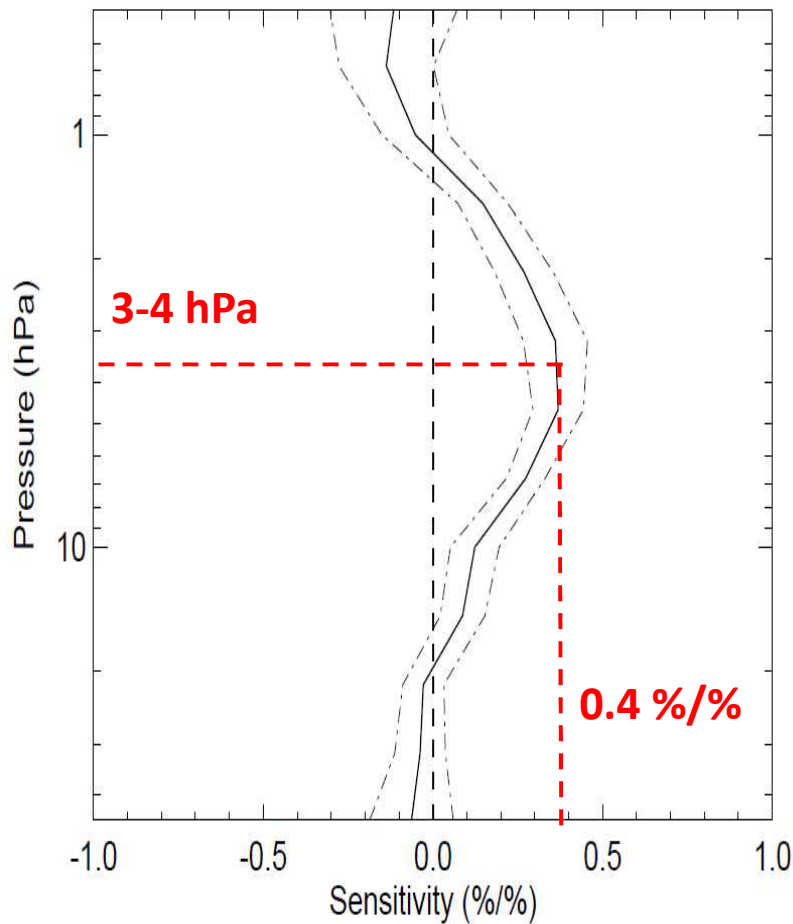


Solar cycle 23 (MLS/AURA)

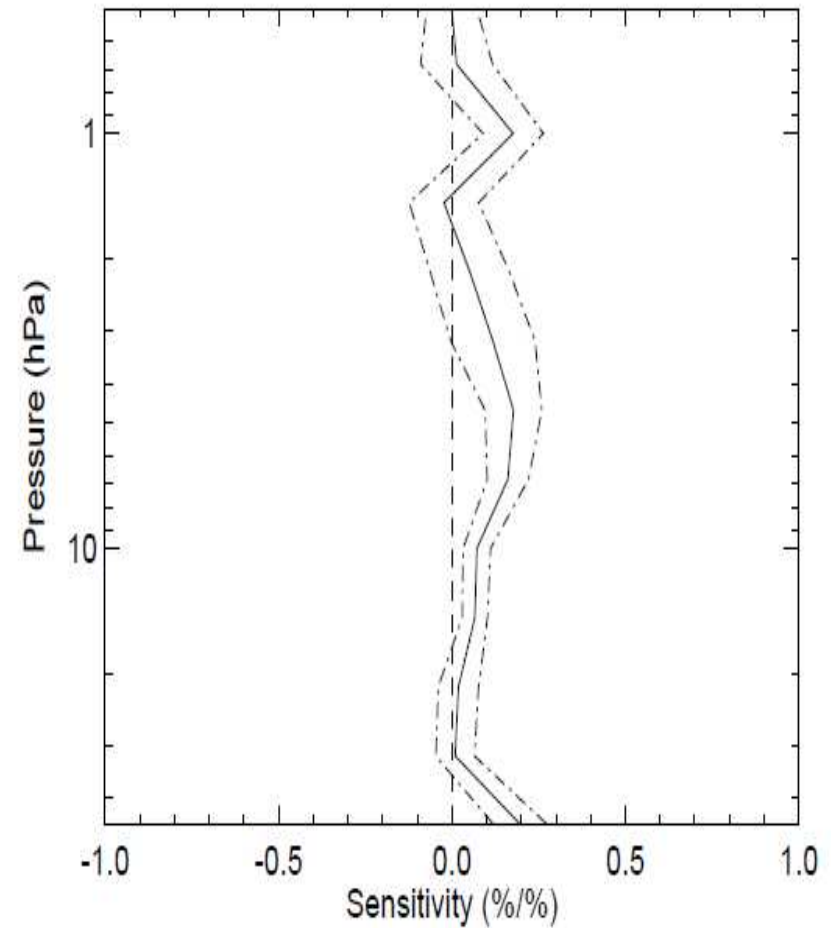


Sensitivity ($\% \Delta(\text{O}_3) / 1\% \Delta(\text{F}205\text{nm})$)

Solar cycle 22 (MLS/UARS)

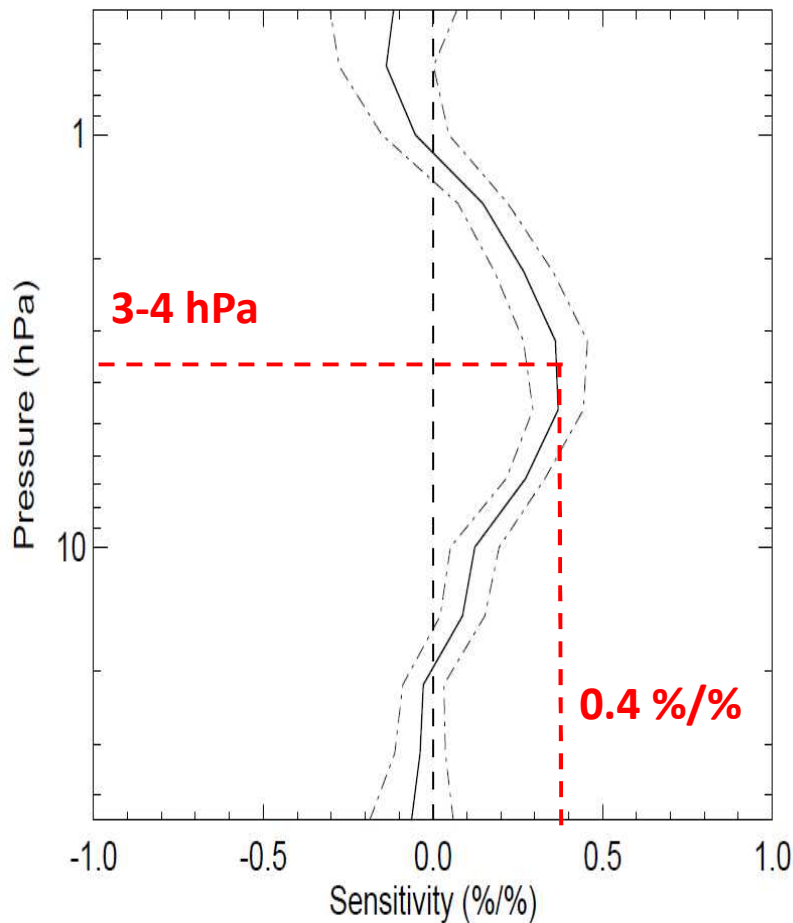


Solar cycle 23 (MLS/AURA)

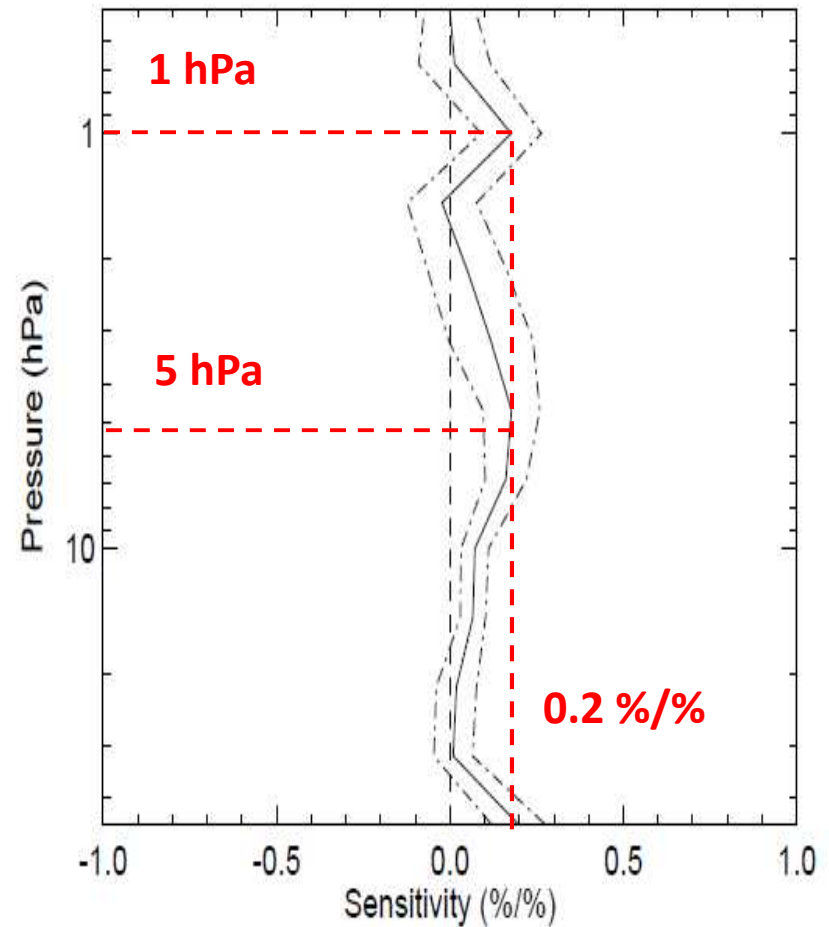


Sensitivity ($\% \Delta(\text{O}_3) / 1\% \Delta(\text{F}205\text{nm})$)

Solar cycle 22 (MLS/UARS)



Solar cycle 23 (MLS/AURA)



Spectral analysis:

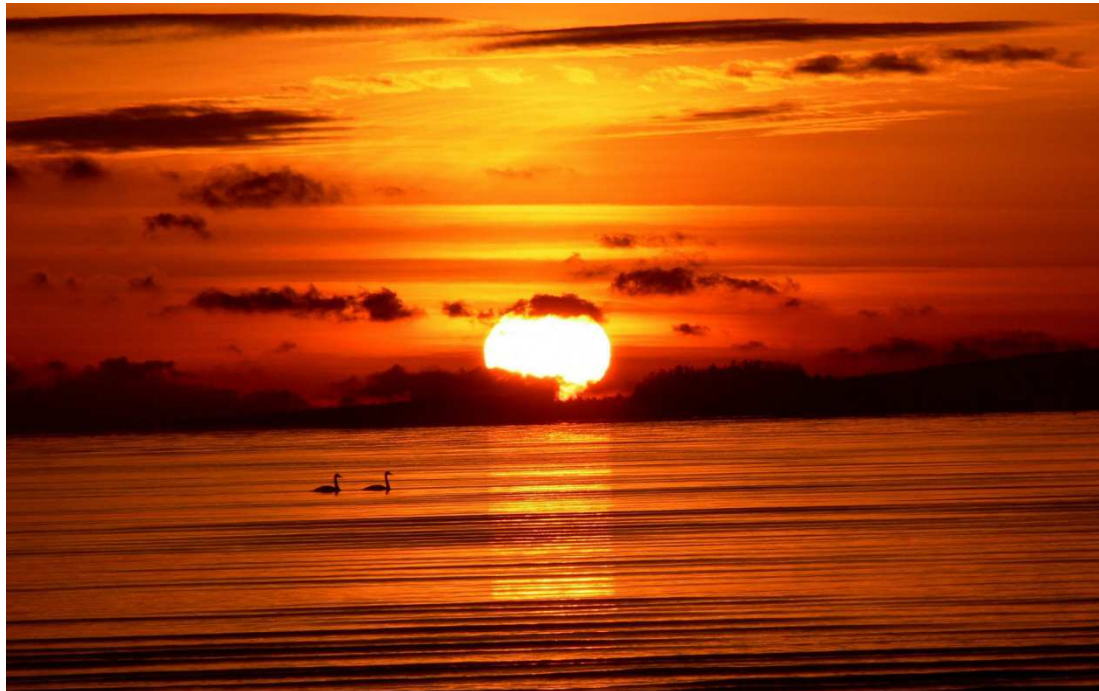
- **Broad peak centered around 27 days for both solar time series (cycles 22 and 23); the amplitude is larger for solar cycle 22**
- **Great temporal intermittence of the 27-day solar cycle in 205 nm solar time series**
- **Difficulties to retrieve a clear 27-day solar signal from ozone time series**

Cross-spectral analysis:

- **Correlation/sensitivity results vary also strongly with time and altitude, large interannual variability in cross-spectral results**
- **Sensitivity peaks at 0.4%/‰ around 3-4 hPa (~35 km) for cycle 22; while sensitivity is peaking at 0.2%/‰ at 5 and 1 hPa for cycle 23**

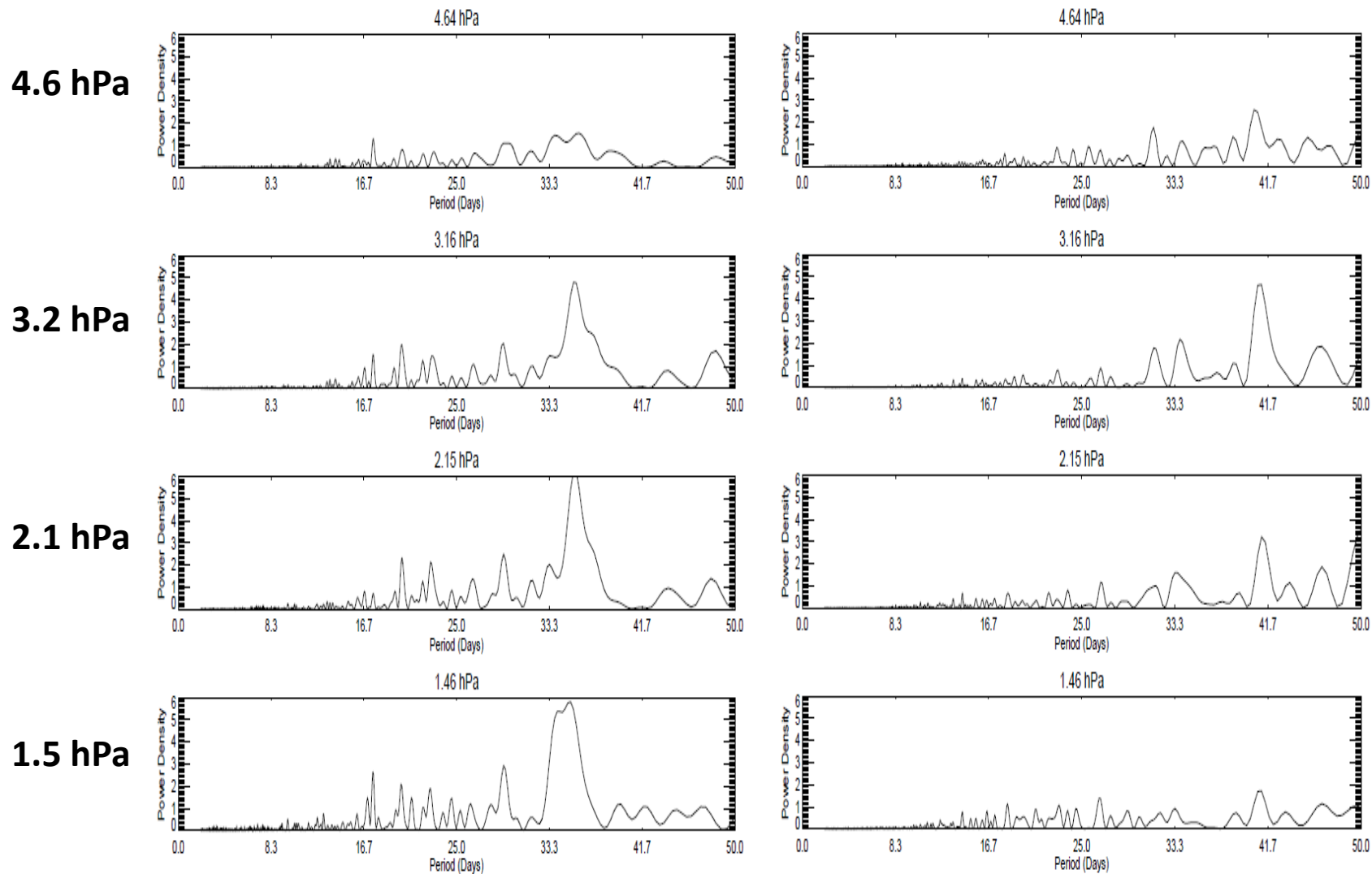
- **Study of the ozone sensitivity to solar UV variations during the 11-year solar cycle 24 which is more anomalous than solar cycle 23**
- **Use of the Chemistry Climate Model (CCM) (LMDz-REPROBUS) to carry out the same comparison study of sensitivity over the same periods (cycles 22 and 23) in order to test the model physics and chemistry**

**Thank you for your
attention**

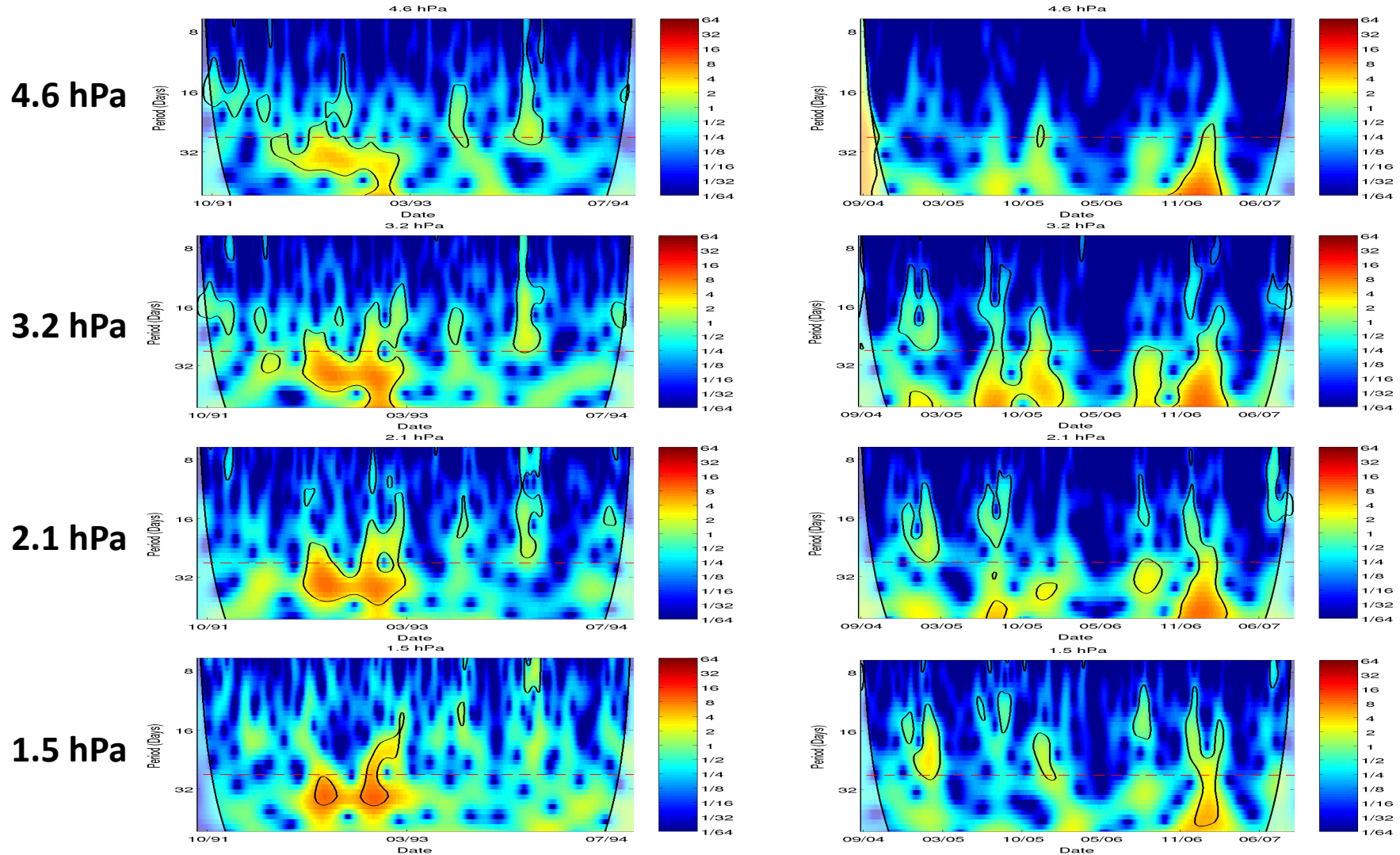


Extra slides

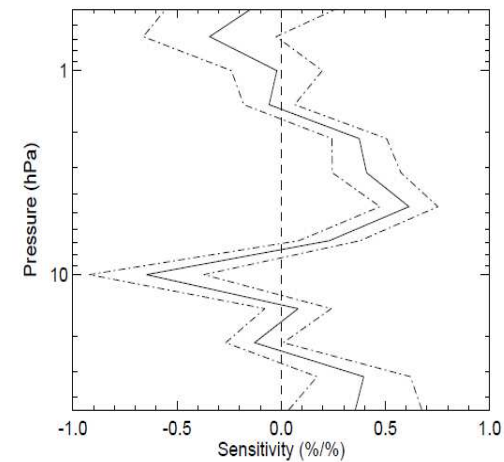
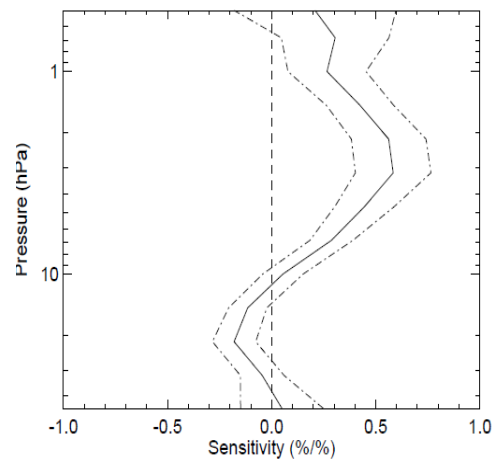
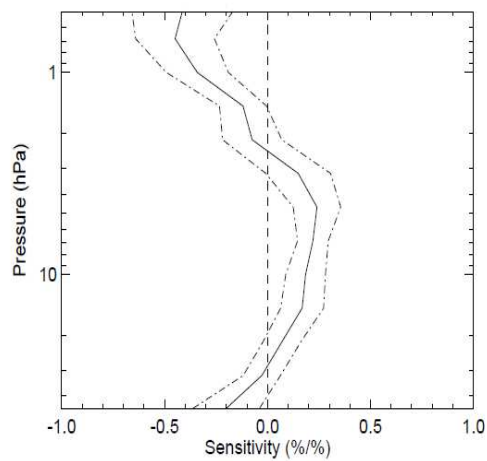
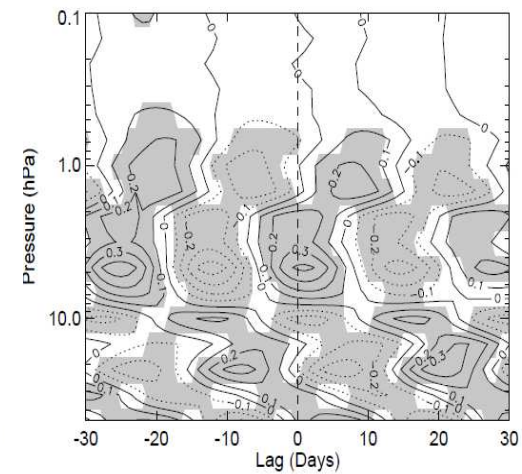
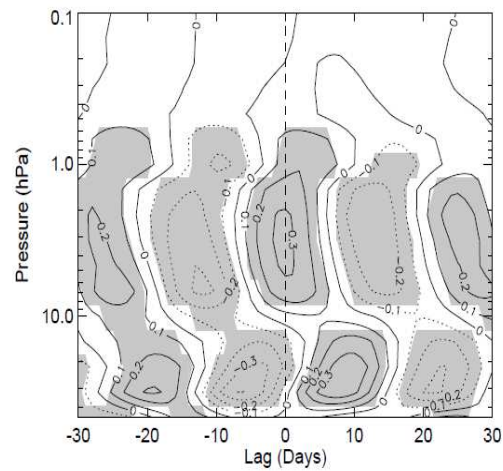
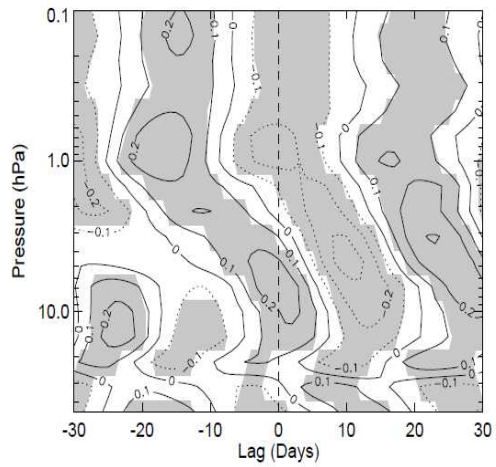
Lomb-Scargle periodograms of ozone at 4 different pressure levels



Wavelet transforms of ozone at 4 different pressure levels



Cross-correlation and sensitivity over three one-year periods During solar cycle 22

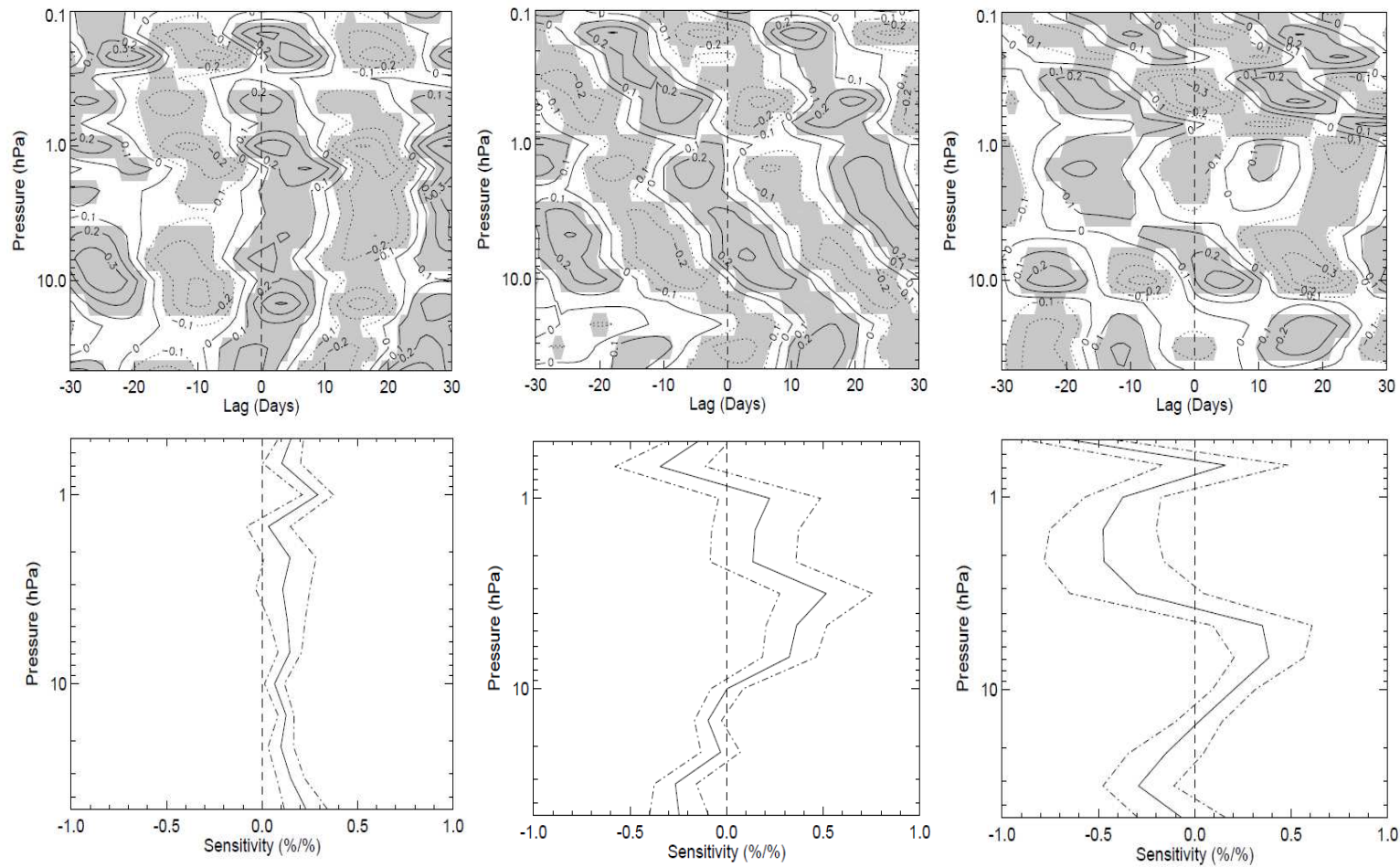


10/1991 - 09/1992

10/1992 - 09/1993

10/1993 - 09/1994

Cross-correlation and sensitivity over three one-year periods During solar cycle 23



09/2004 - 08/2005

09/2005 - 08/2006

09/2006 - 08/2007