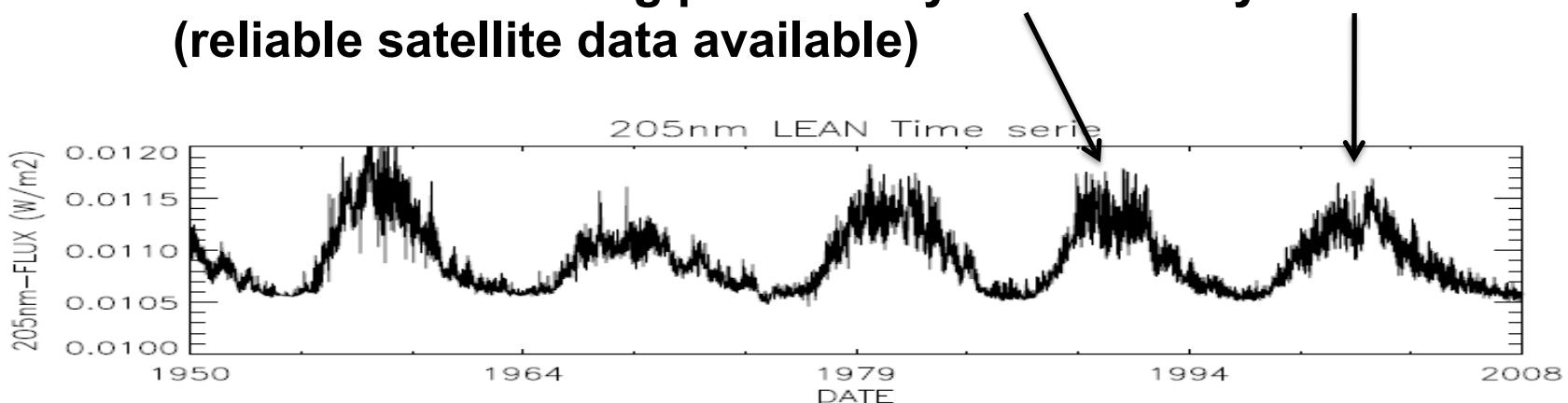


Impact of short-term solar variability on middle atmospheric ozone

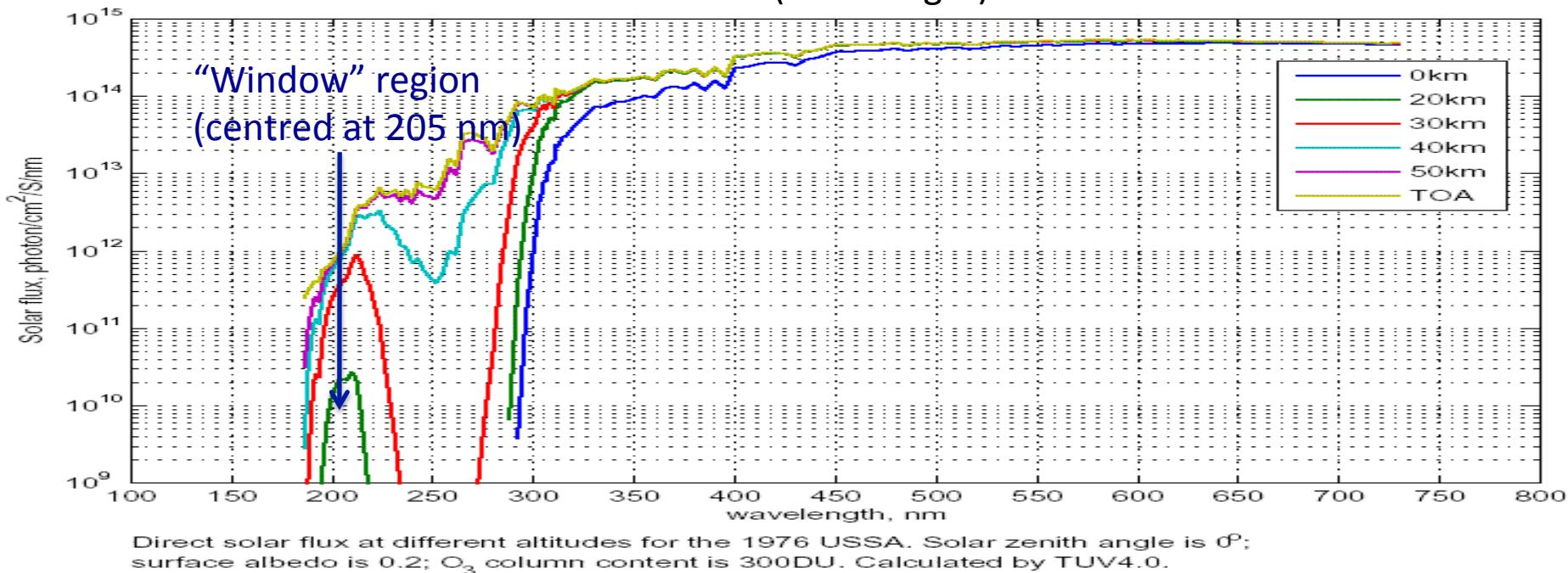
S. Bossay, M. Marchand, G. Thuillier,
A. Hauchecorne, P. Keckhut, C. Claud & S. Bekki

- Short term variability: 27 day cycle (clearest periodicity within satellite data time series)
- Middle atmospheric ozone: tropical ozone (photochemistry driven, simple relationship)
- Periods: descending phase of cycle 22 and cycle 23 (reliable satellite data available)



Solar UV data

Solar flux=f(wavelength)



Cycle 22: Reconstructed solar spectra irradiance from NRL-SSI model (Naval Research Laboratory Spectral Solar Irradiance, called thereafter LEAN) & from MG-SSI model (MaGnesium and Neutral Monitor, called thereafter THUILLIER). Measurements SOLSTICE/UARS.

Cycle 23: Reconstructed NRL-SSI, MG-SSI, measurements SIM/ SORCE

Ozone data

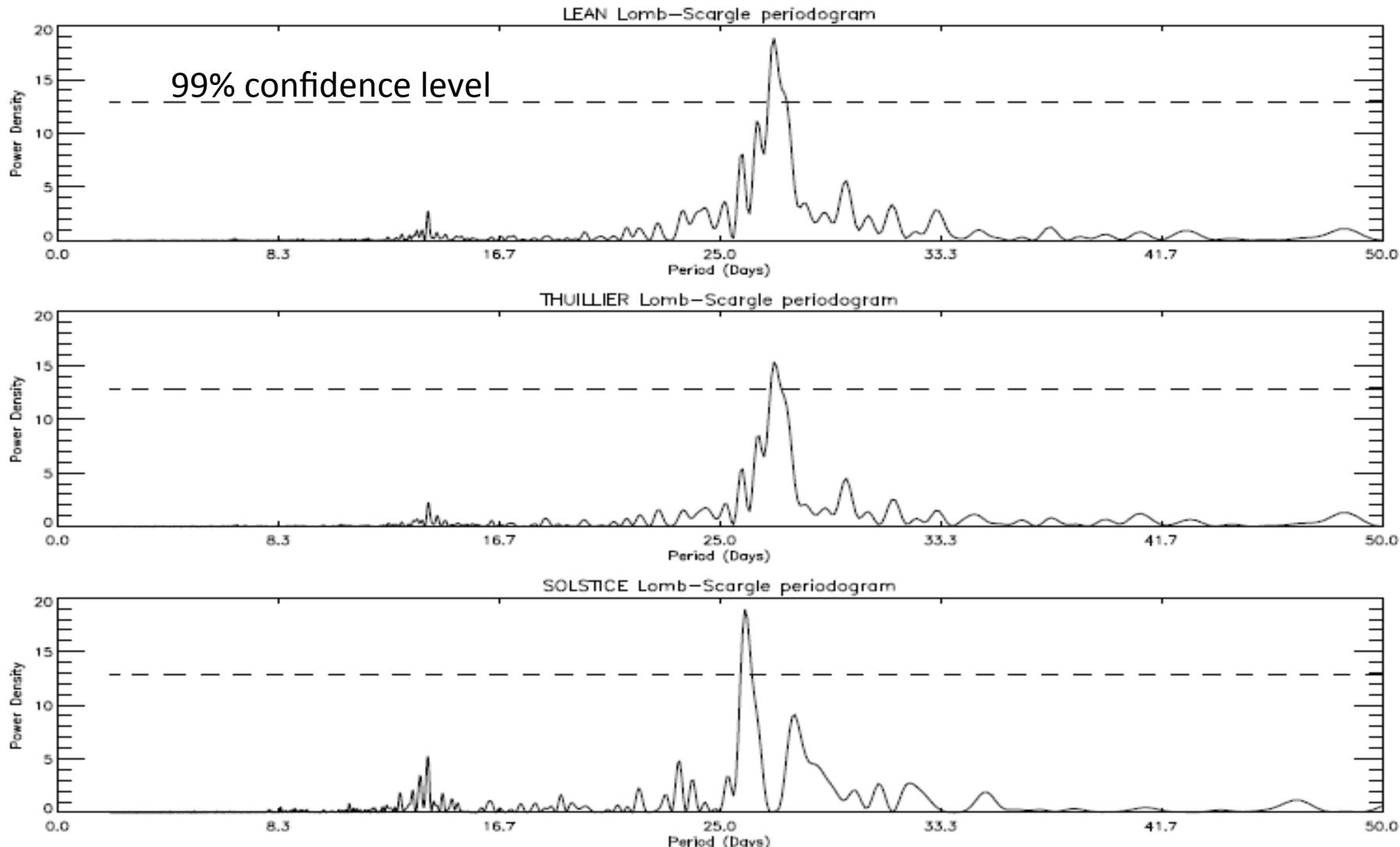
Cycle 22: MLS/UARS

Cycle 23: MLS/AURA, GOMOS/ENVISAT

Statistical analysis

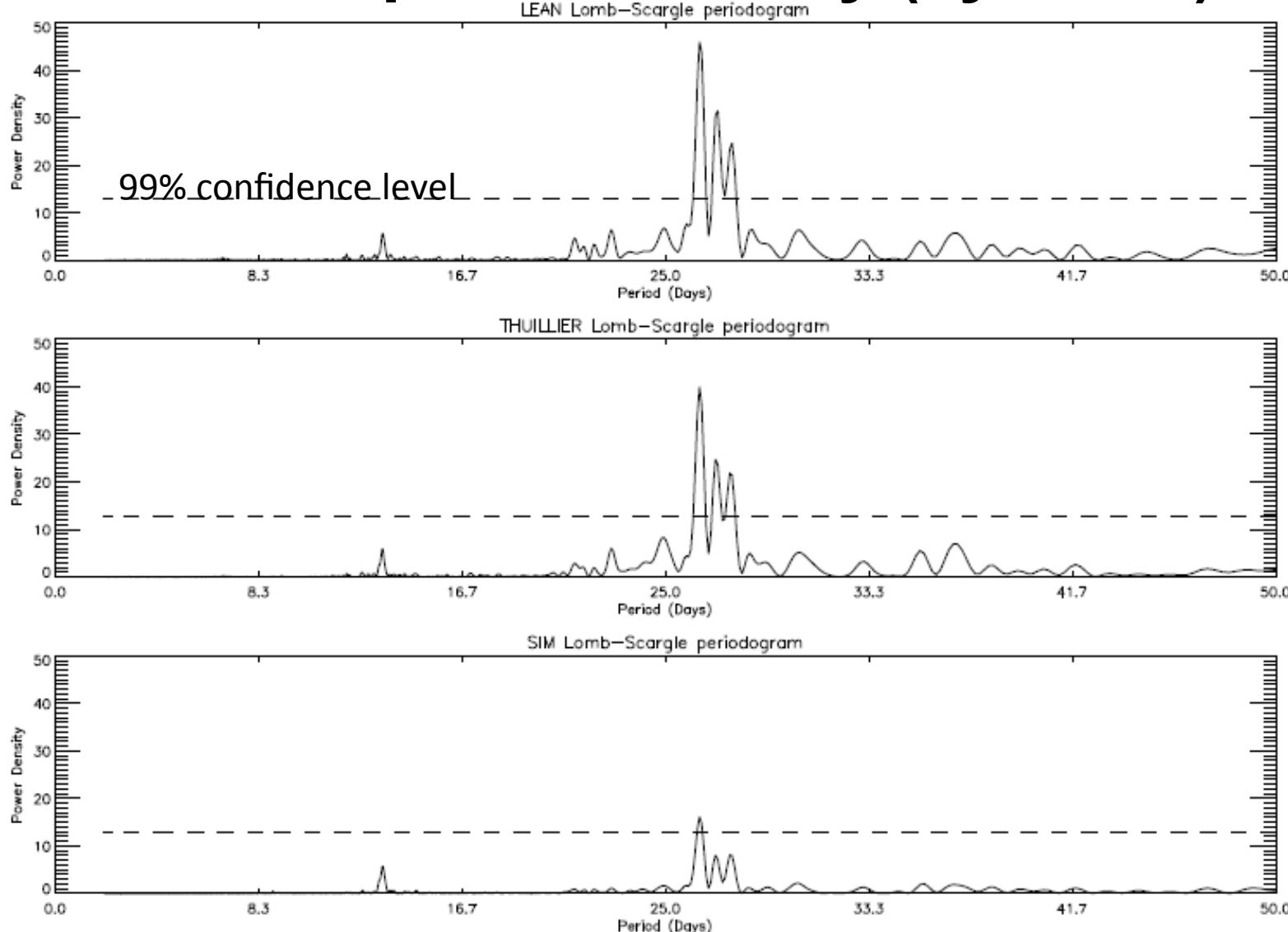
- **Spectral analysis**
 - Lomb Scargle periodogram: spectral density (contribution of a period to the variance of a signal), deals better than Fourier with gaps in series
 - Wavelet transform: time-frequency analysis
- **Filtering method**
 - Digital filter
 - Fourier filter
- **Cross-correlation and sensitivity**

UV flux spectral density (cycle 22)



Lomb-Scargle periodograms of 205 nm solar flux (top: from NRLSSI model, middle: from MGSSI model, bottom: from UARS/SOLSTICE instrument) during the descending phase of solar cycle 22 (1992-1996).
The dotted line represents the 99% confidence level

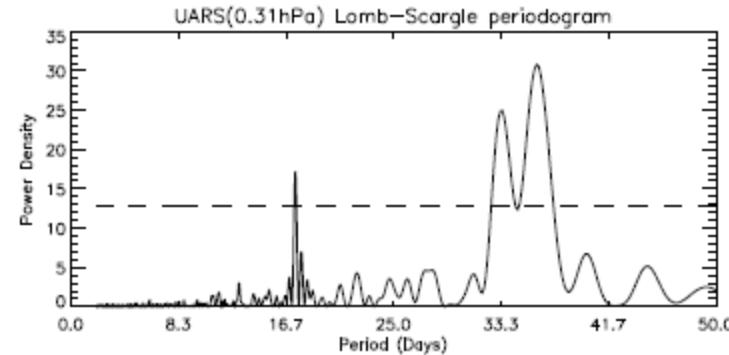
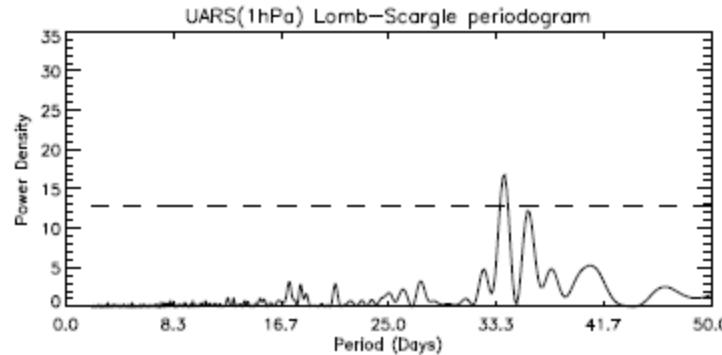
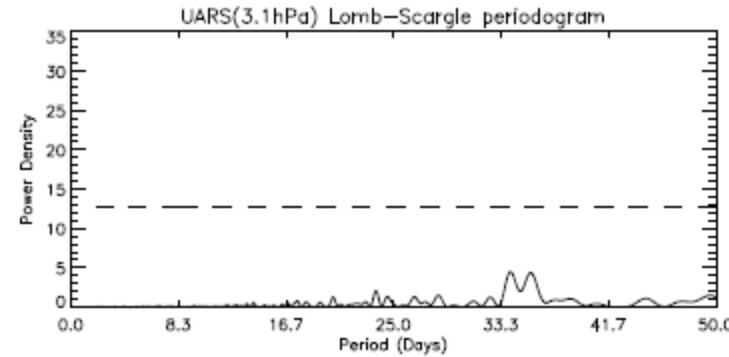
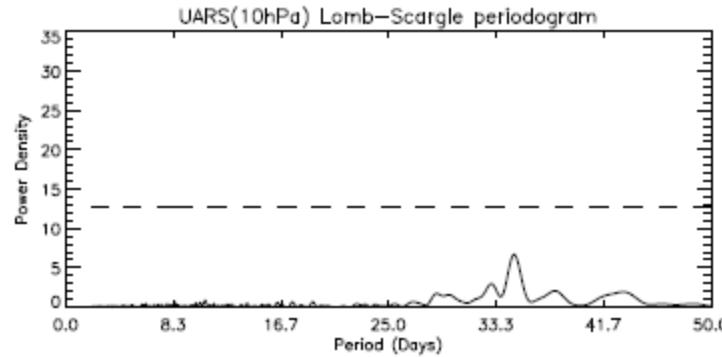
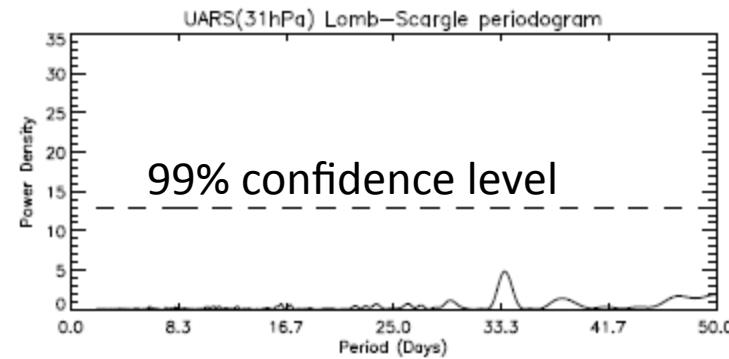
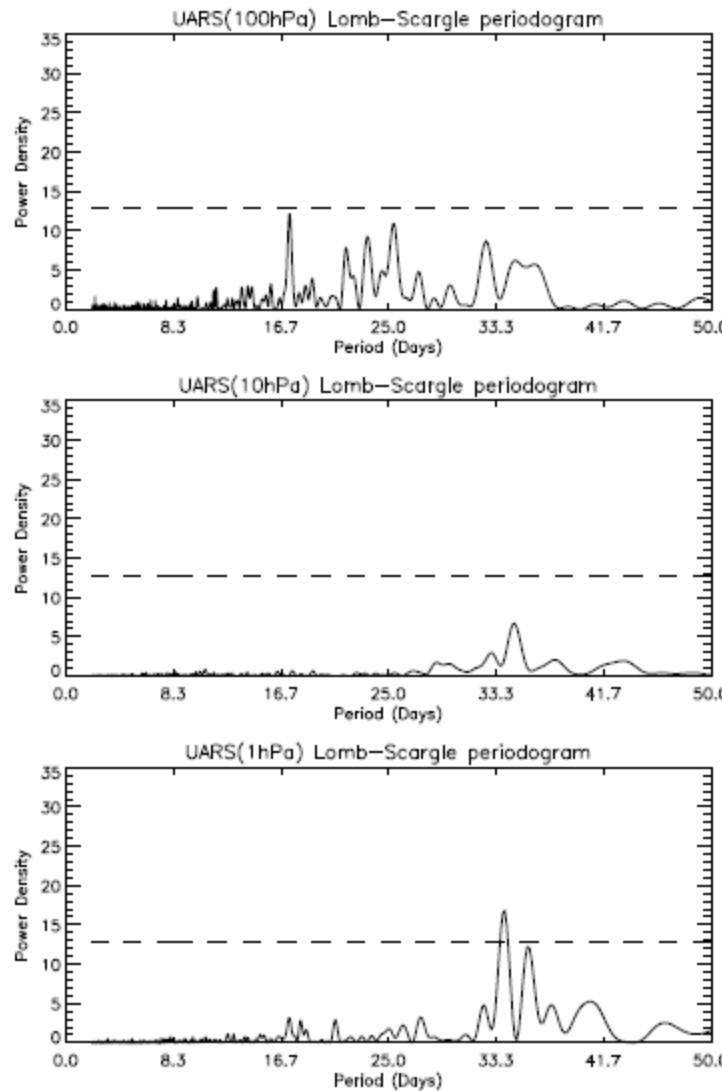
UV flux spectral density (cycle 23)



Lomb-Scargle periodograms of 205 nm solar flux (top: from NRLSSI model, middle: from MGSSI model, bottom: from SORCE/SIM instrument) during the descending phase of solar cycle 23 (2004-2008).

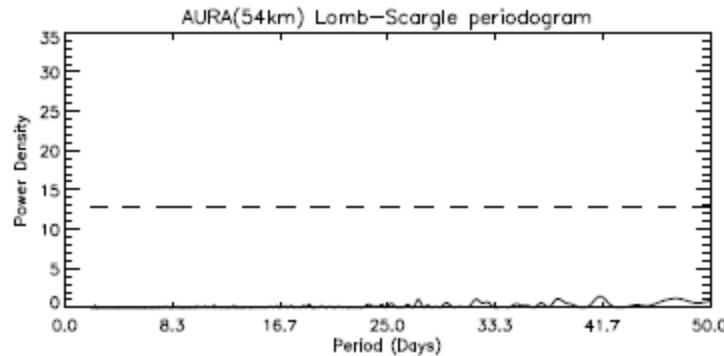
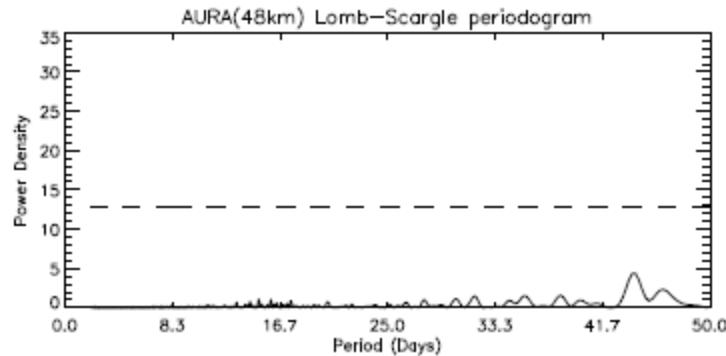
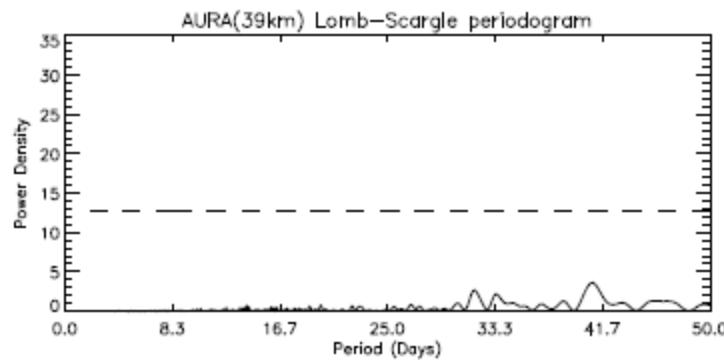
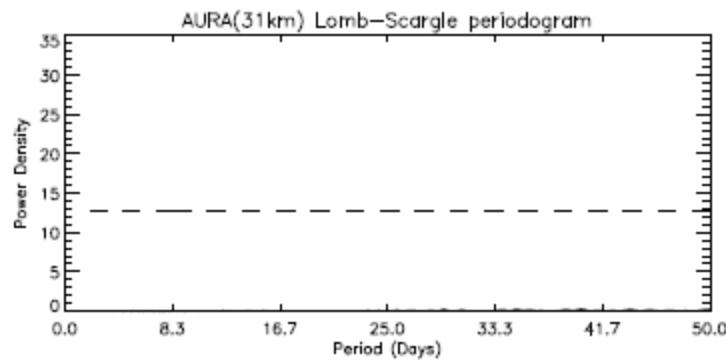
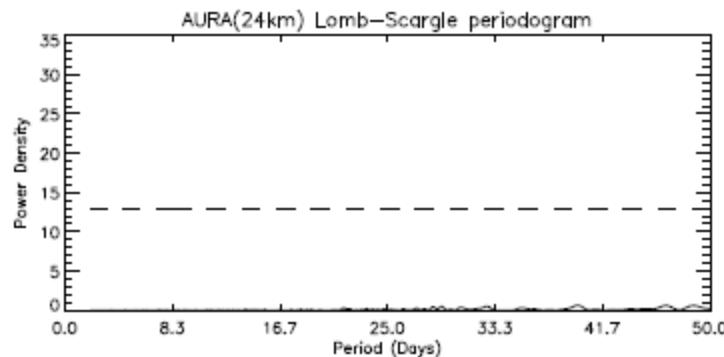
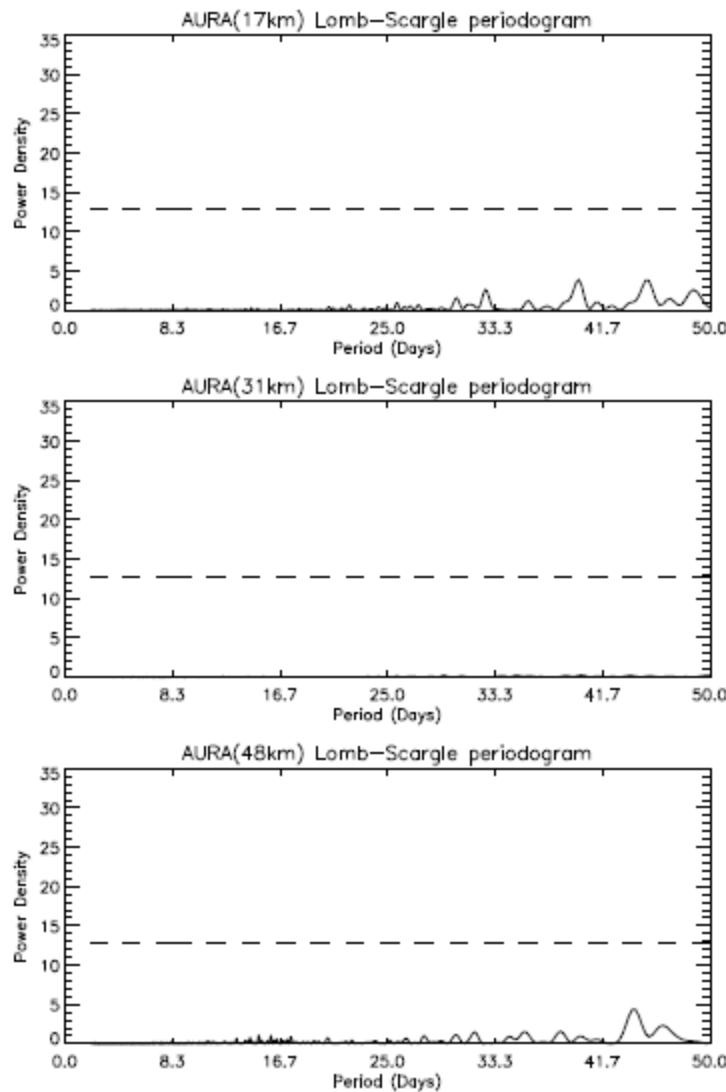
The dotted line represents the 99% confidence level

ozone spectral density (cycle 22)



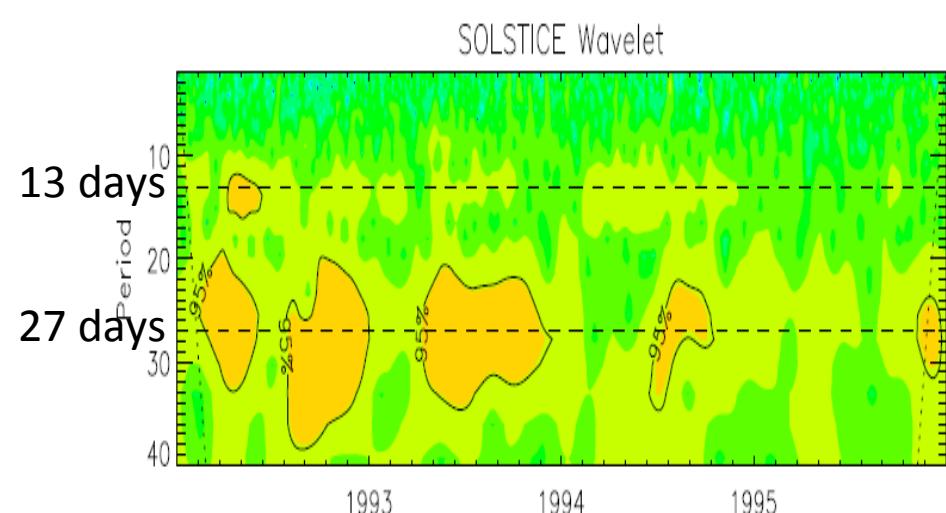
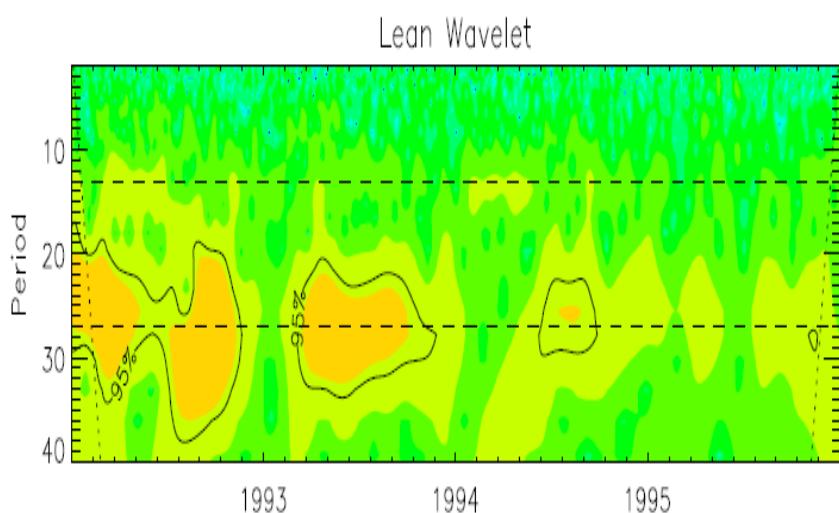
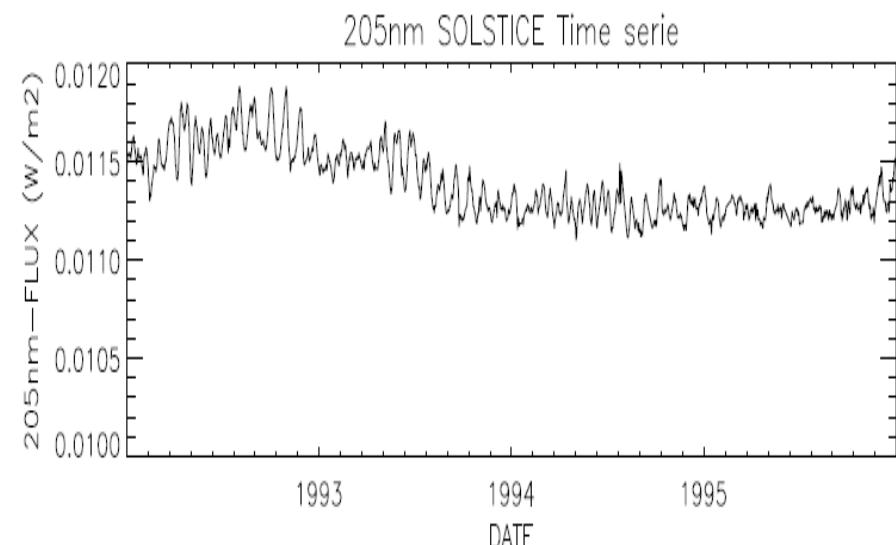
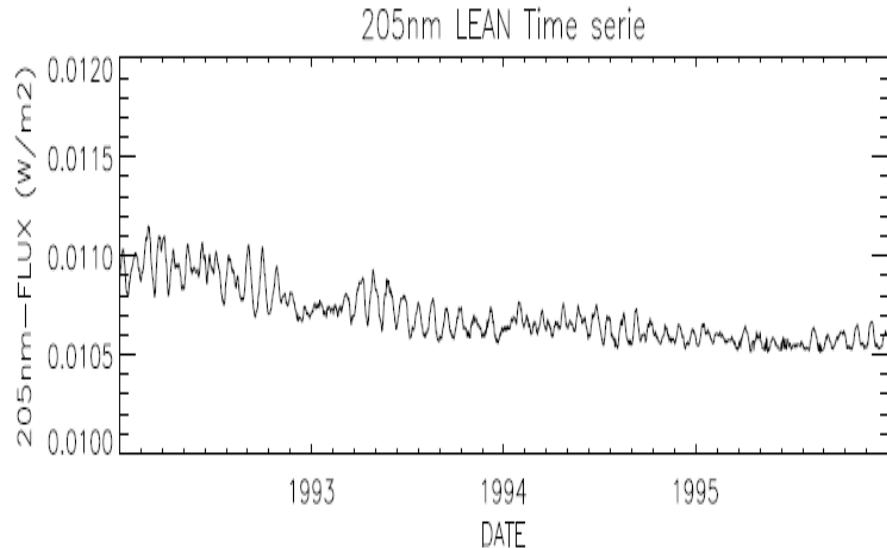
Lomb-Scargle periodograms of MLS/UARS ozone at six different levels during the descending phase of solar cycle 22 (1992-1996). The dotted line represents the 99% confidence level

MLS/AURA Ozone spectral density (cycle 23)



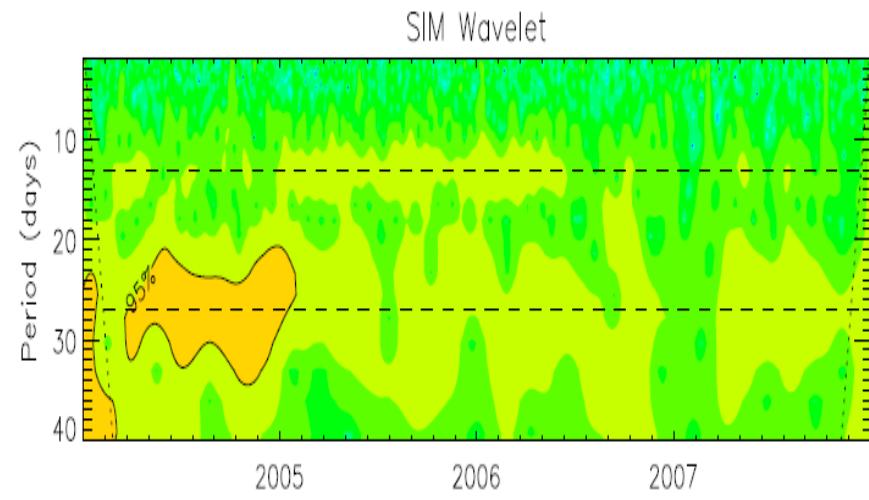
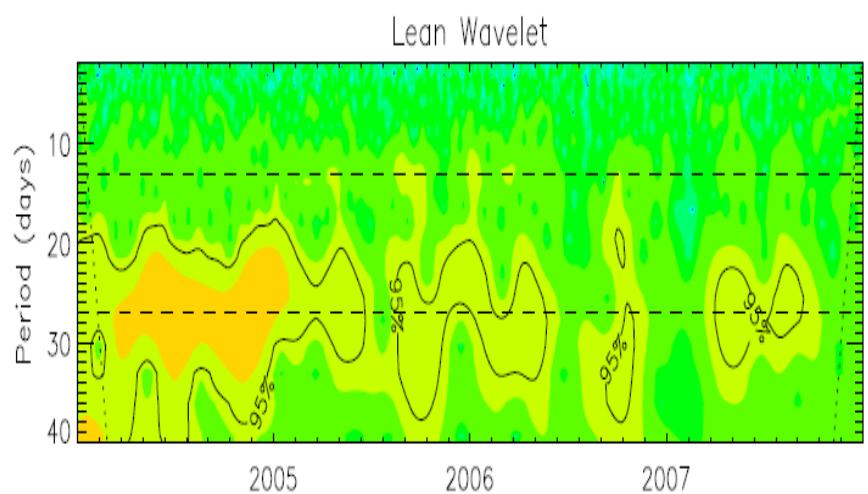
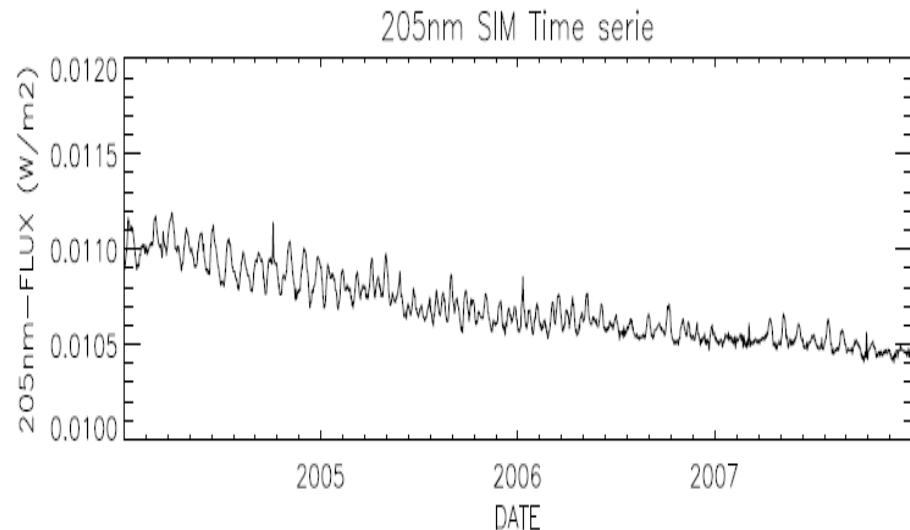
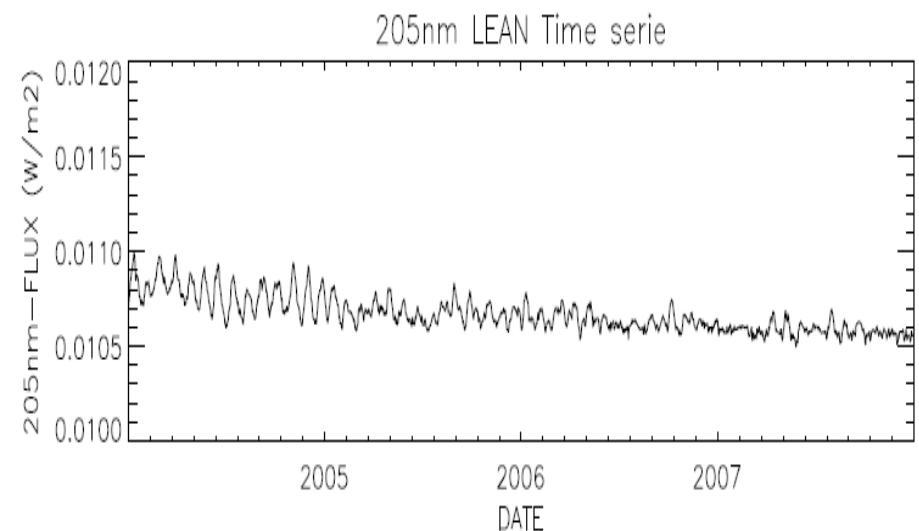
Lomb–Scargle periodograms of MLS/AURA ozone at six different levels during the descending phase of solar cycle 23 (2004–2008). The dotted line represents the 99% confidence level

UV wavelet analysis (cycle 22)



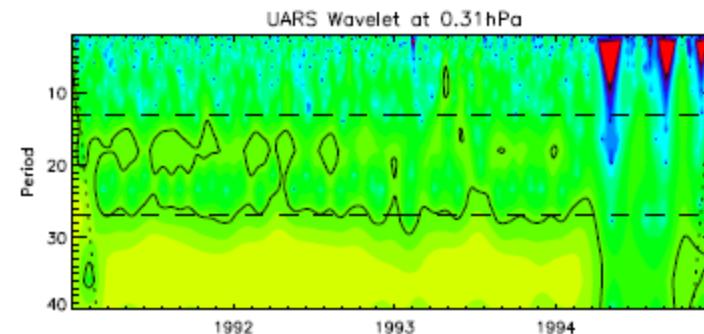
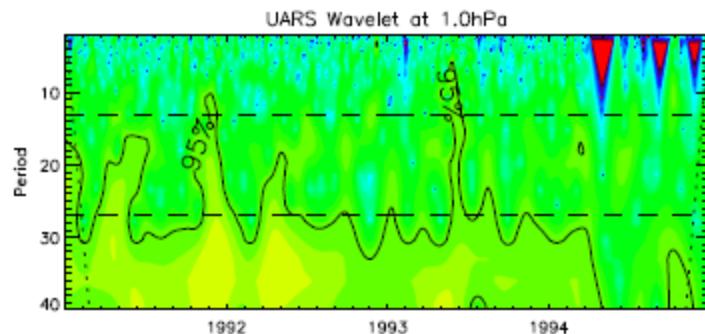
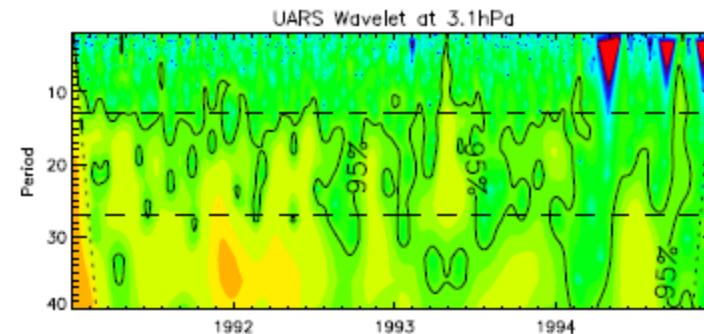
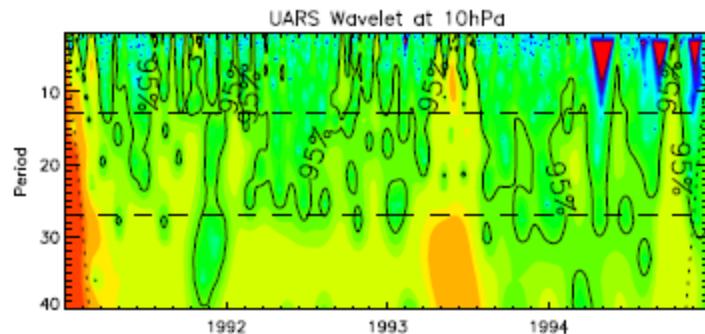
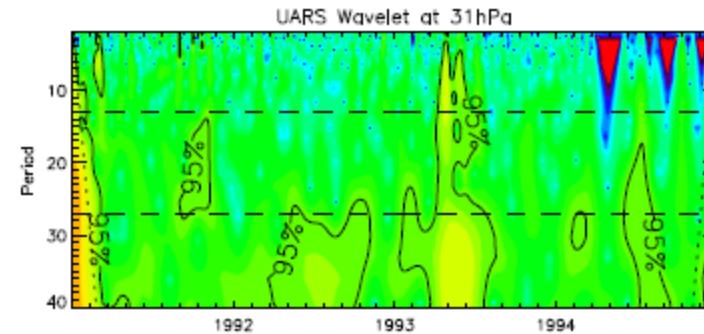
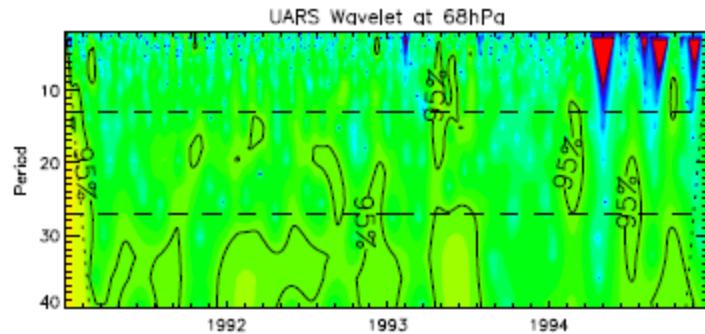
Wavelet transtform of solar timeseries (left: NRLSSI flux, right: UARS/SOLSTICE flux) during descending phase of solar cycle 22 (1992-1996)

UV wavelet analysis (cycle 23)



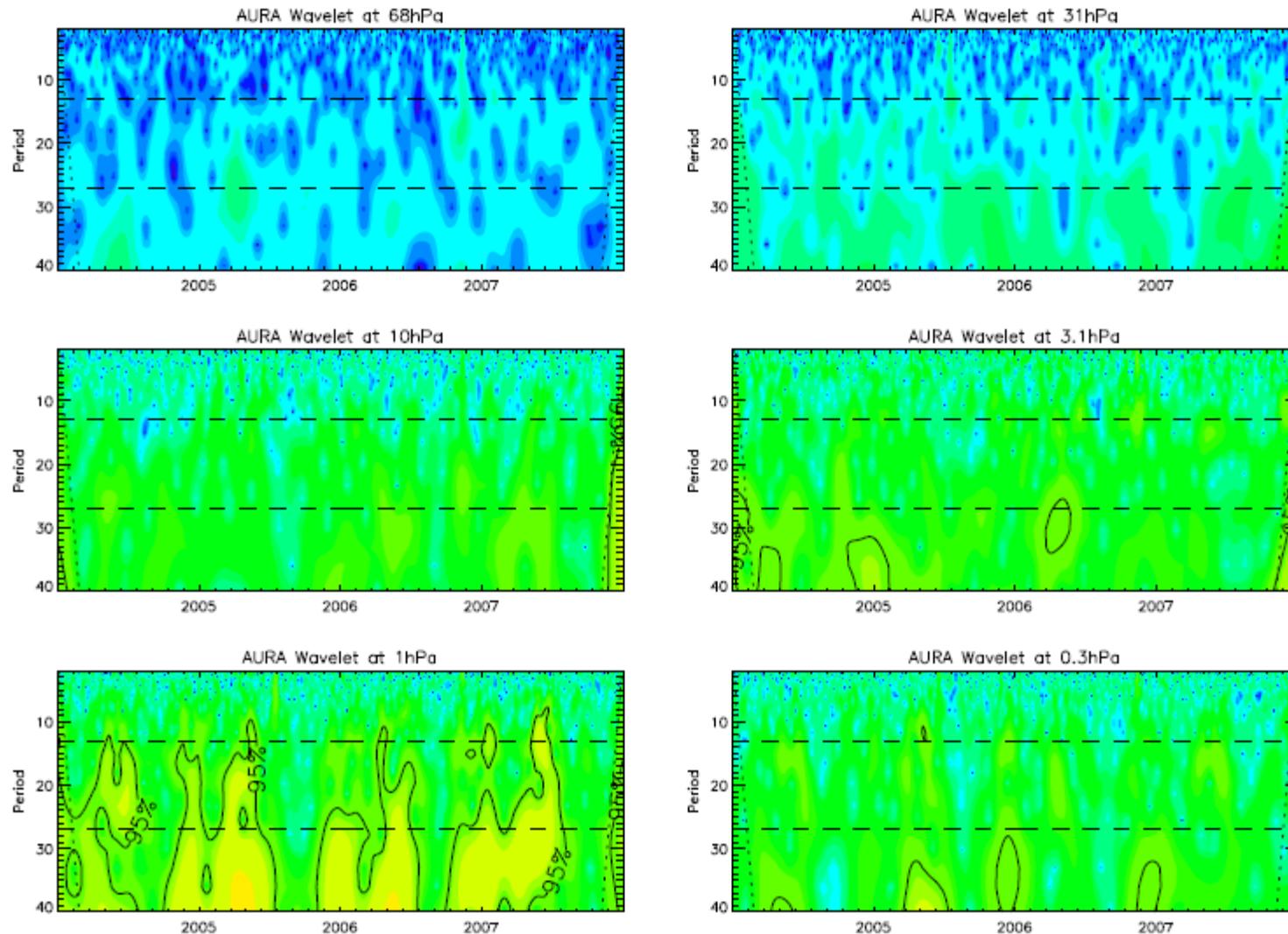
Wavelet transform of solar timeseries (left: NRLSSI flux, right: SORCE/SIM flux) during descending phase of solar cycle 23 (2004-2008)

MLS/UARS Ozone wavelet analysis (cycle 22)



UARS/MLS wavelet transforms at six different levels during the descending phase of solar cycle 22

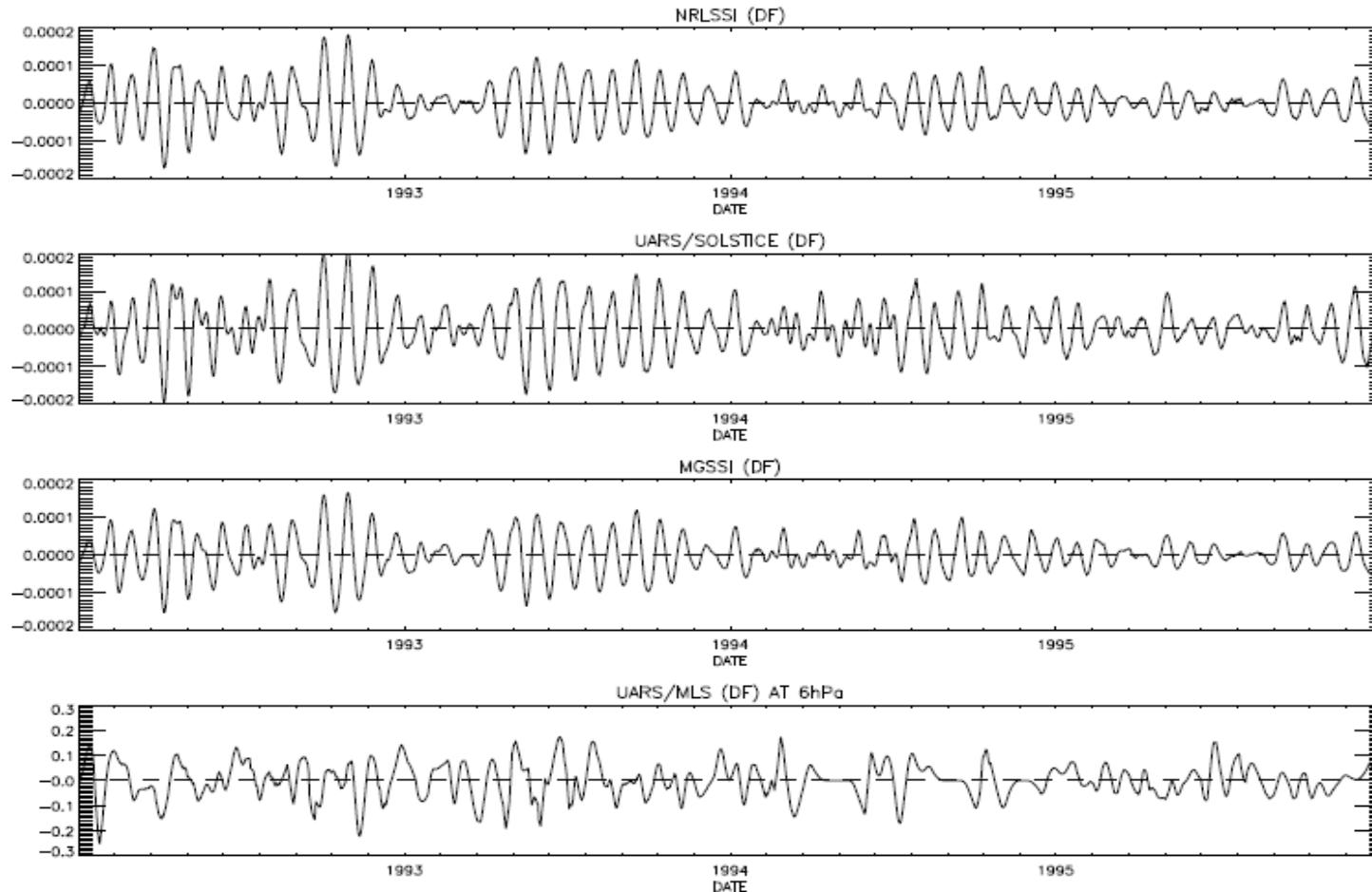
MLS/AURA Ozone wavelet analysis (cycle 23)



AURA/MLS wavelet transform at six different levels during the descending phase of solar cycle 23

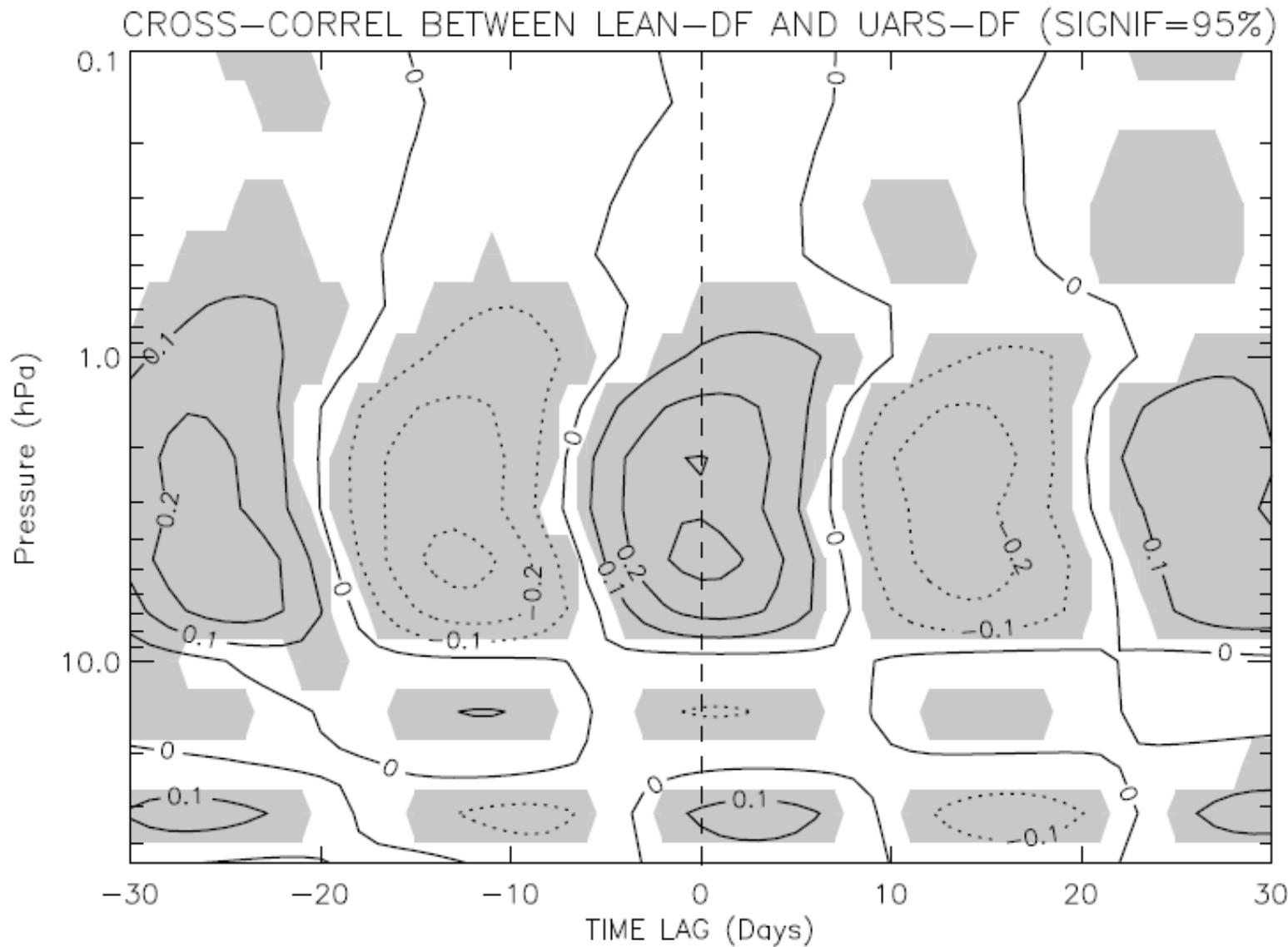
Data digital filtering

Remove short-term (by a 7-day running mean) and long-term (by subtracting a 35-day running mean) fluctuations from UV and O₃ time series



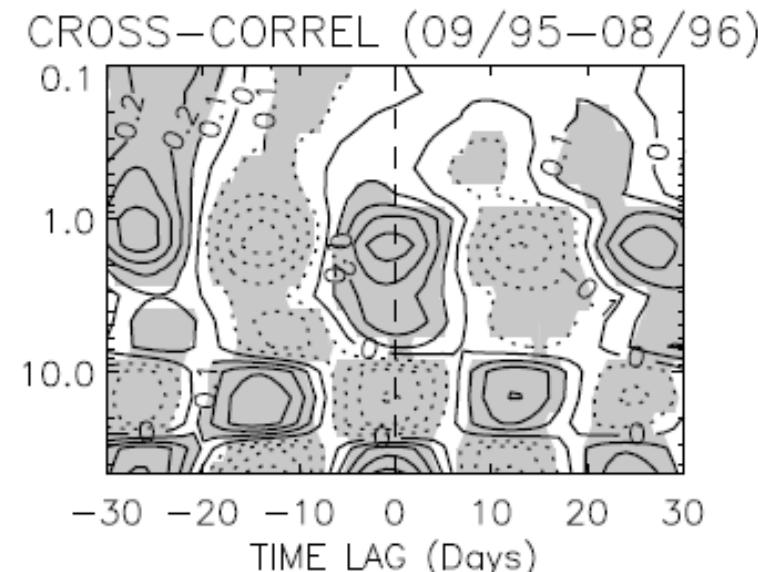
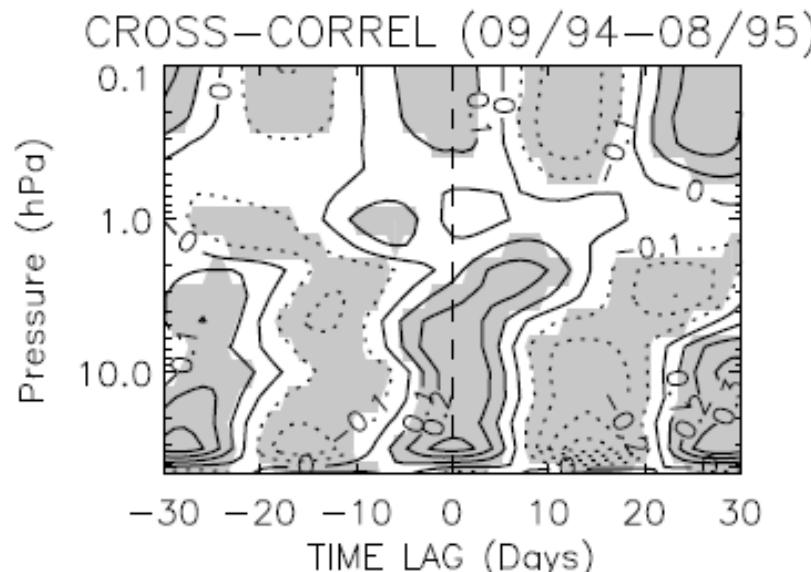
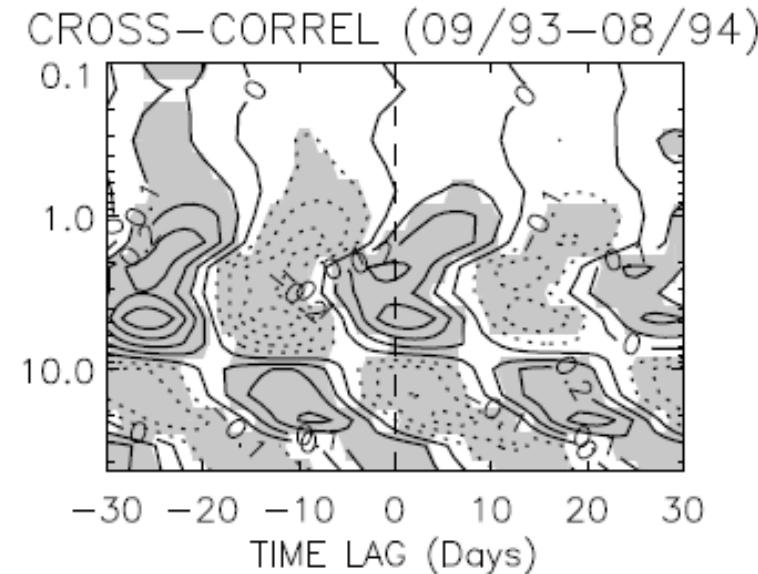
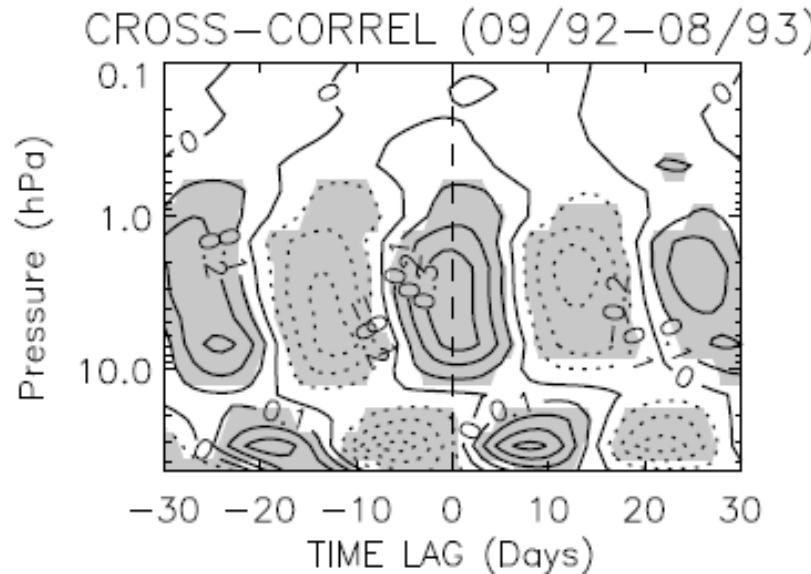
Time series filtered by « digital filter » used in previous studies (Hood, 1986).
The first three are 205 nm solar time series and the last one is from MLS/UARS
one level (6 hPa) time series

Correlation analysis (cycle 22)



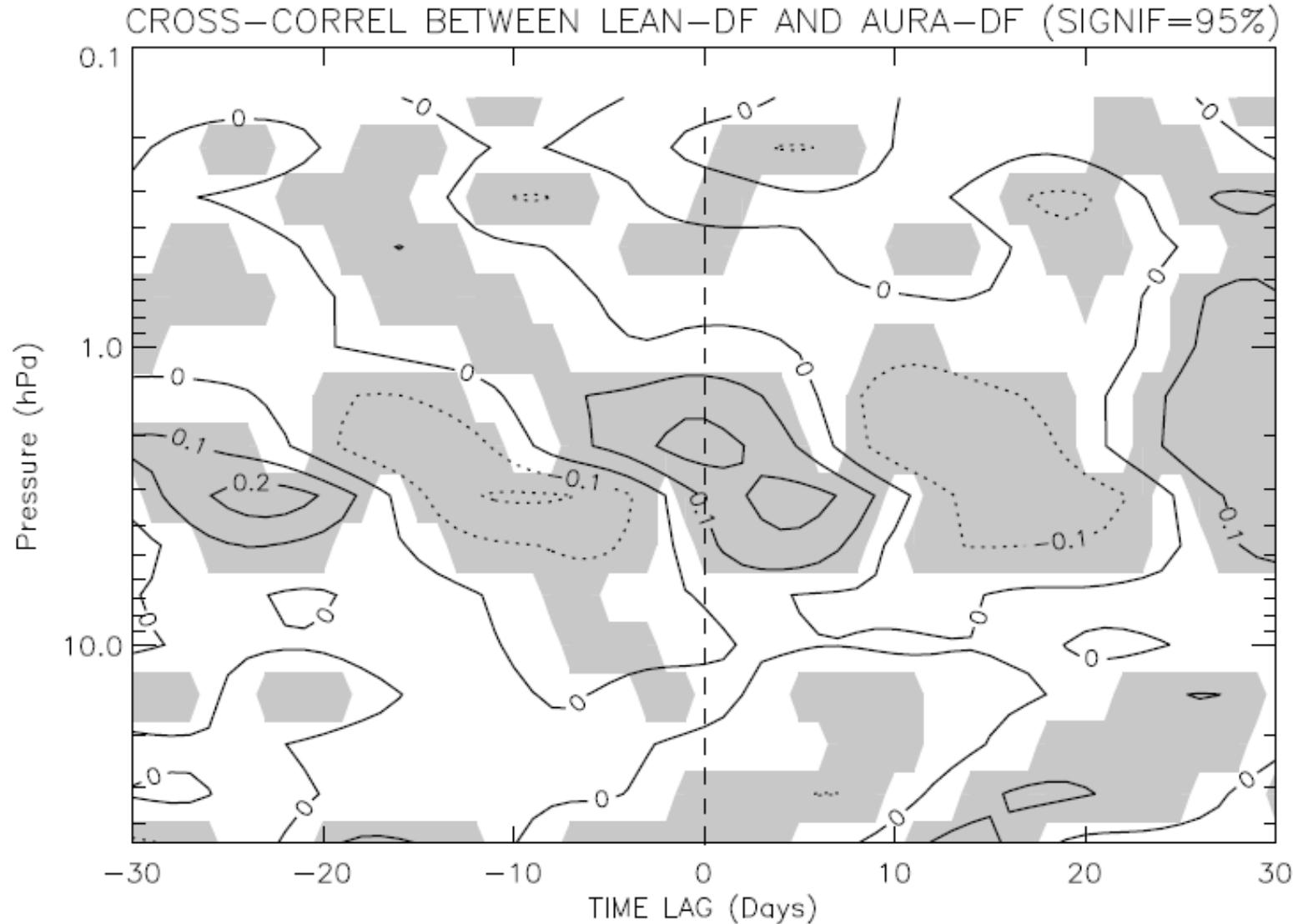
Cross correlation coefficients of the 27-day variations for NRLSSI solar flux (205 nm) and MLS/UARS tropical ozone (20°N - 20°S) between 1992 and 1996 (filtered (DF) time series)

Correlation analysis (cycle 22): different periods



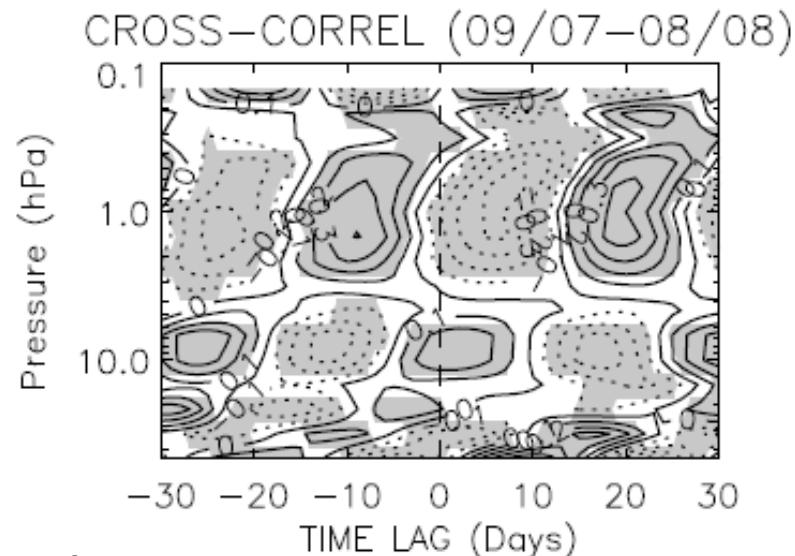
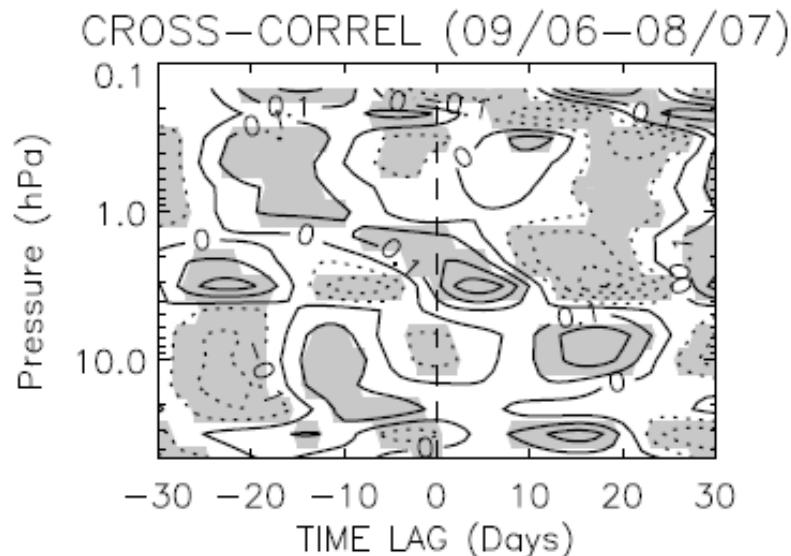
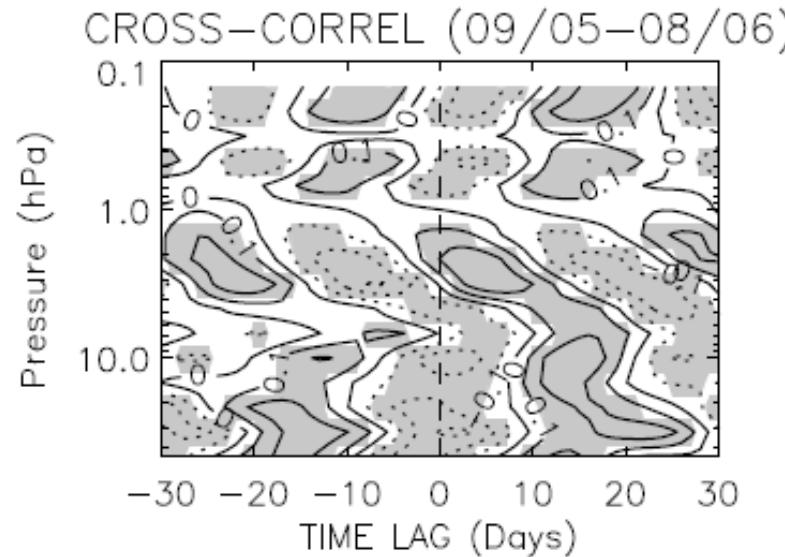
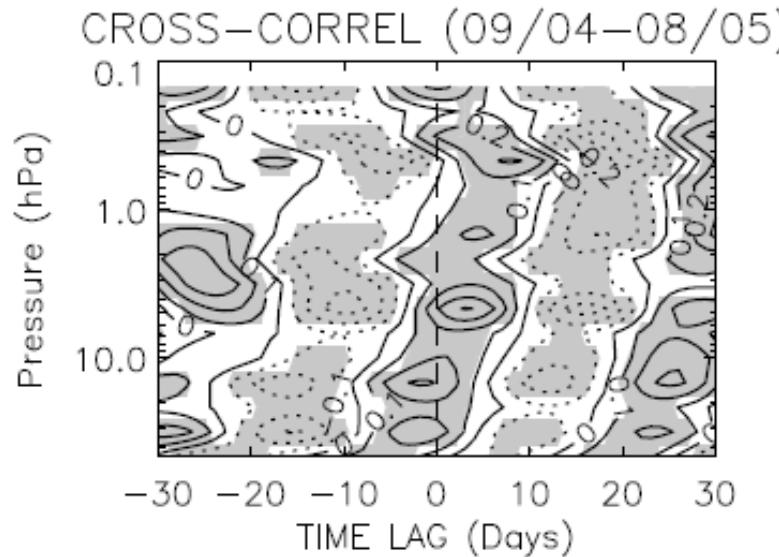
**Cross-correlation between UARS/MLS ozone (DF) and NRLSSI
205NM FLUX (DF) for the four 1 year periods**

AURA Correlation analysis (cycle 23)



Cross correlation coefficients of the 27-day variations for NRLSSI solar flux (205 nm) and MLS/AURA tropical ozone (20°N - 20°S) between 2004 and 2008

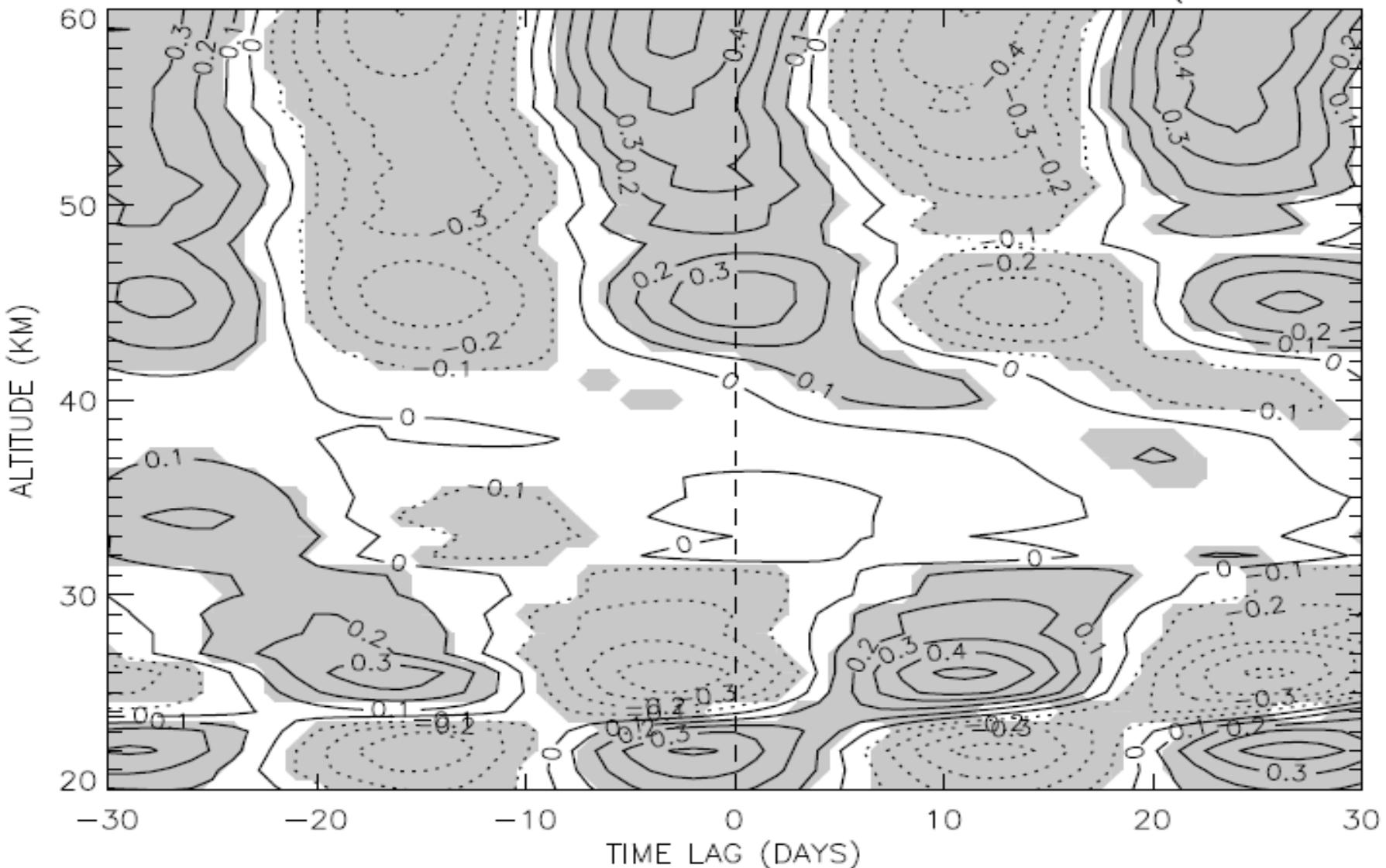
AURA correlation analysis (cycle 23): diff. periods



**Cross-correlation between AURA/MLS ozone (DF) and NRLSSI
205NM FLUX (DF) over four one-year ranges**

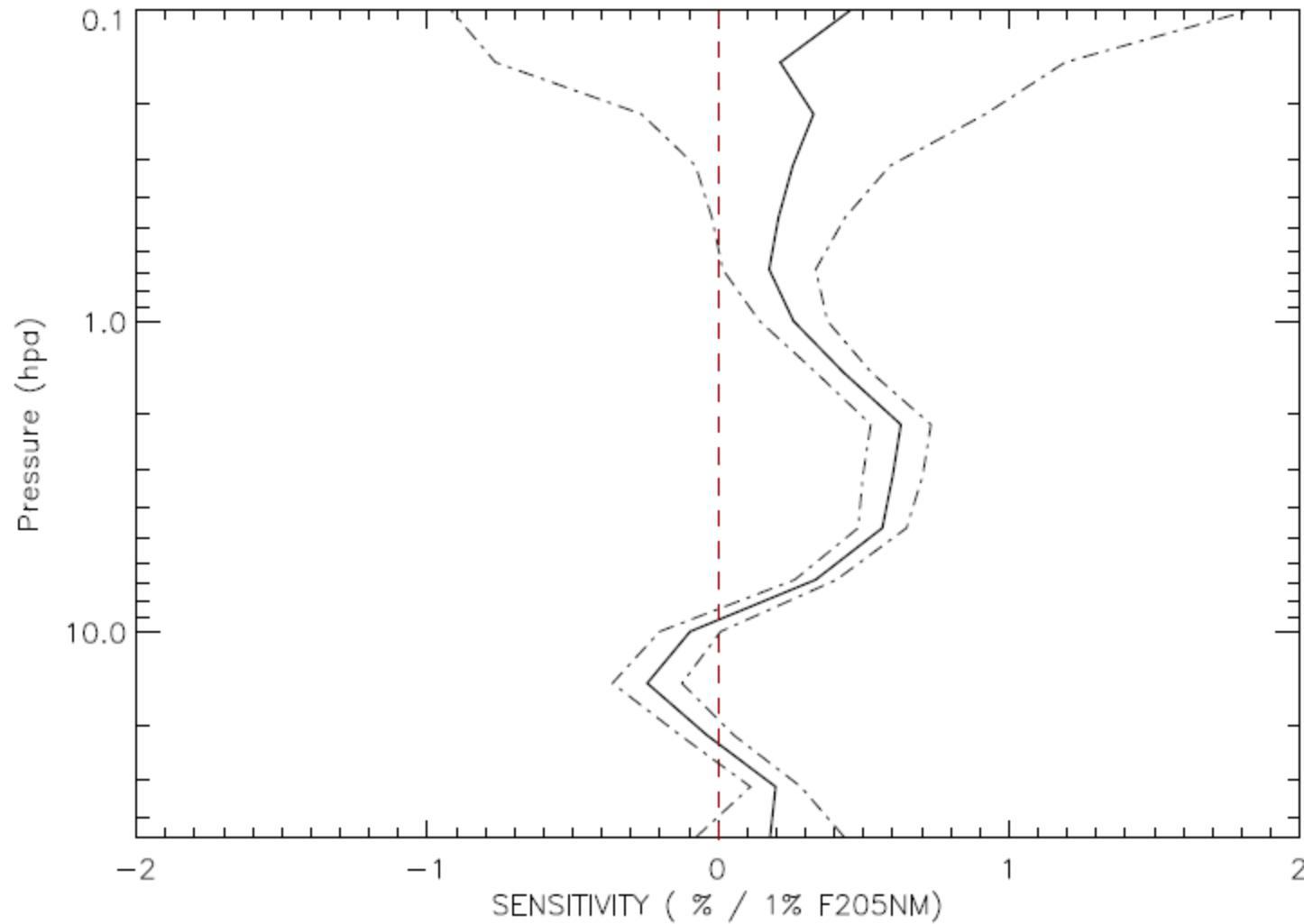
GOMOS correlation analysis (cycle 23): first period

CROSS-CORREL BETWEEN THUILLIER-DF AND GOMOS-DF (SIGNIF=95%)



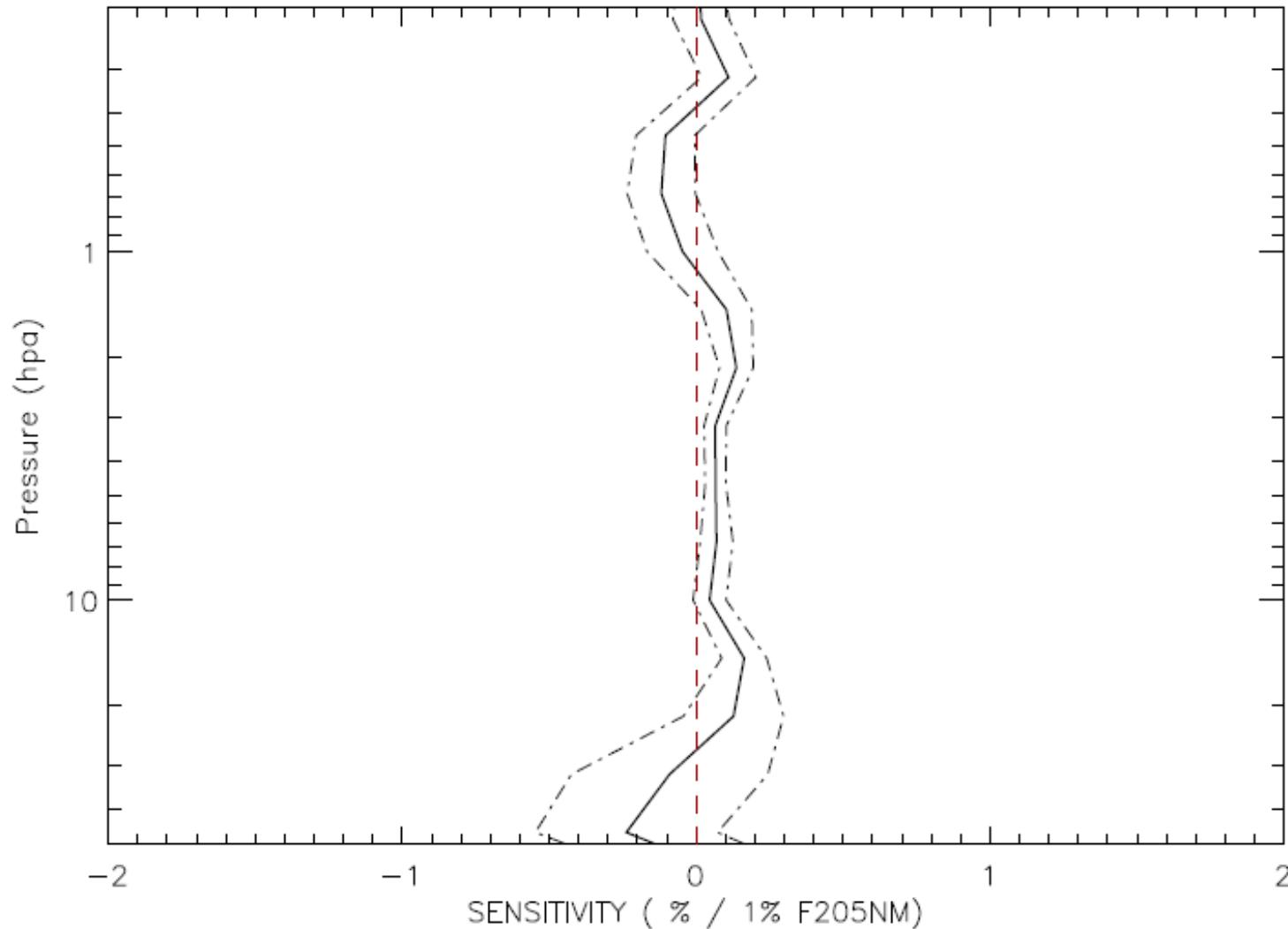
Cross-correlation between 205NM FLUX (DF) from MGSSI and
Ozone (GOMOS) (DF) (27/09/2003-24/01/2005)

O₃ sensitivity to UV 27-day variations (cycle 22)



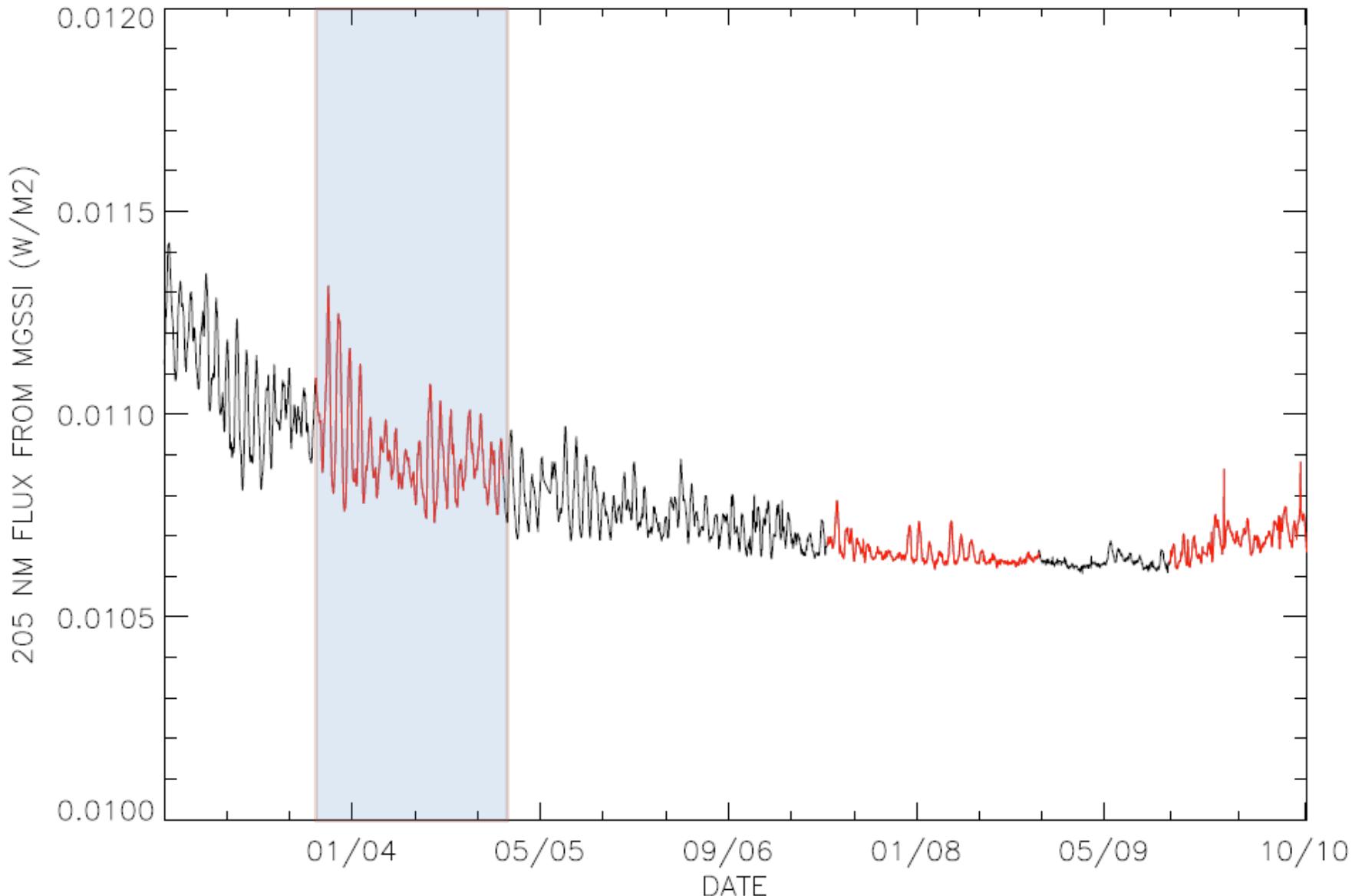
MLS/UARS ozone sensitivity to 205 nm NRLSSI solar flux as % change in O₃ for a 1% change in 205nm flux and is calculated by regressing linearly the O₃ time series against the 205 nm flux time series during solar cycle 22

O₃ sensitivity to UV 27-day variations (cycle 23)



MLS/AURA ozone sensitivity to 205 nm NRLSSI solar flux as % change in O₃ for a 1% change in 205nm flux and is calculated by regressing linearly the O₃ time series against the 205 nm flux time series during solar cycle 23

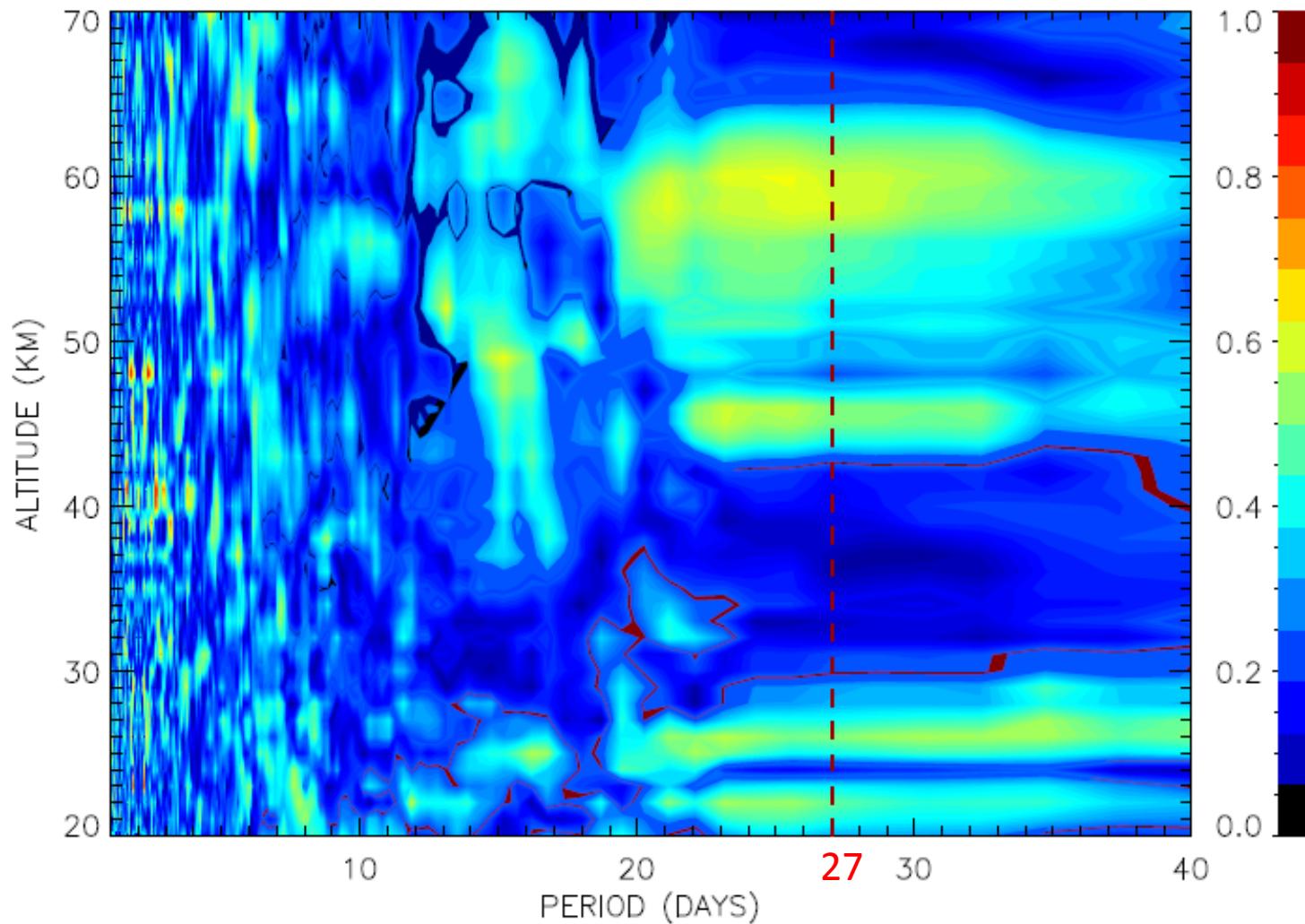
DESCENDING PHASE OF SOLAR CYCLE 23



First period (27/09/2003 – 24/01/2005)

GOMOS coherence analysis (cycle 23: first period)

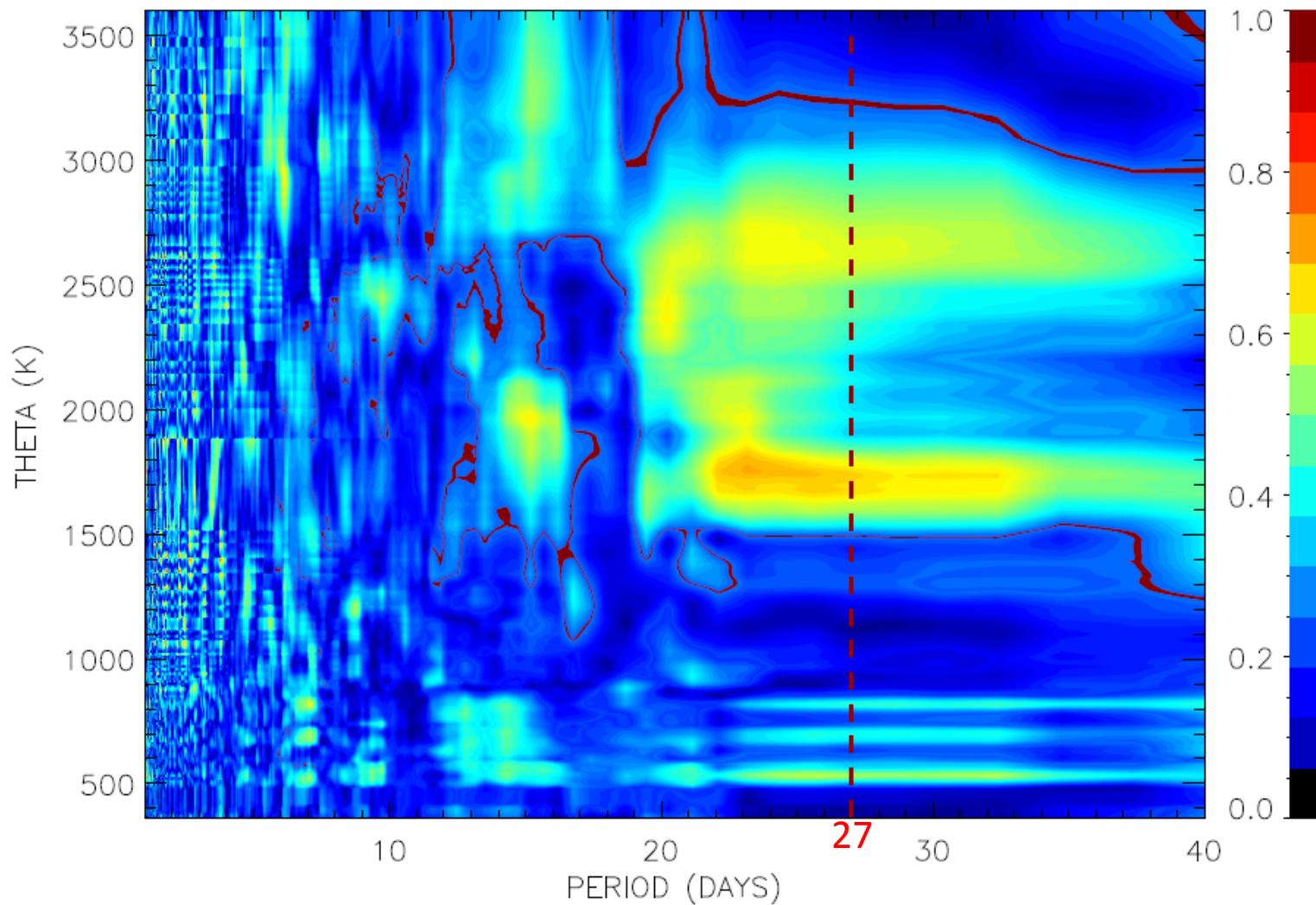
Vertical coordinate: Altitude



Cross-spectrum (coherency: correlation= $f(\text{period})$) between ENVISAT/GOMOS ozone and MGNM 205nm-solar flux as a function of period (days) and altitude (km) for first period

GOMOS coherence analysis (cycle 23: first period)

Vertical coordinate: Potential temperature

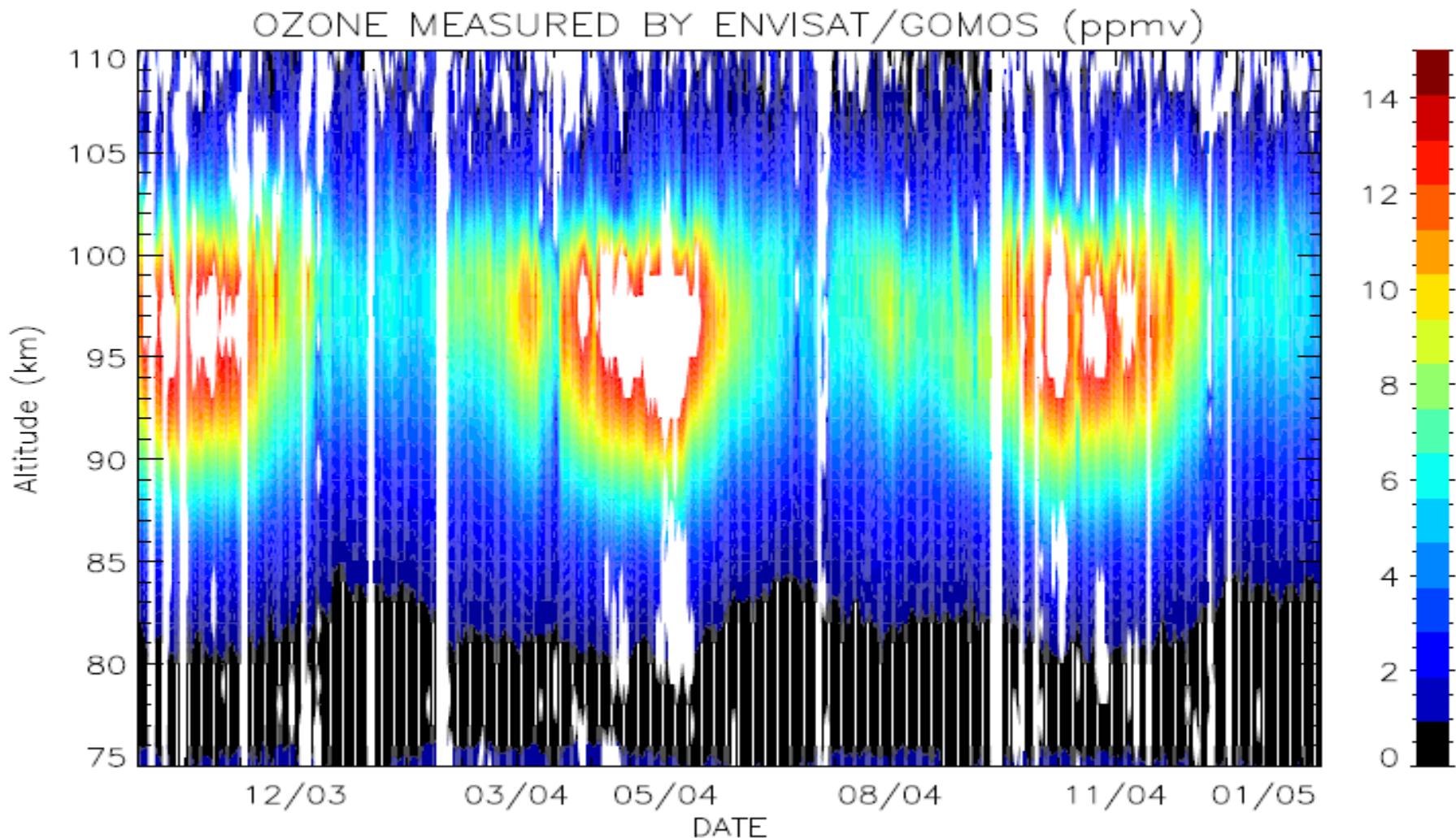


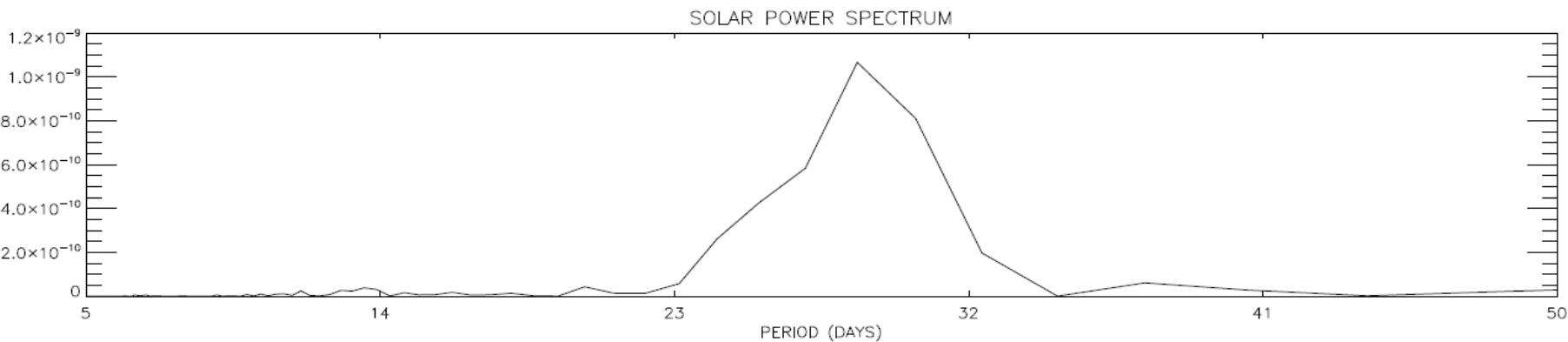
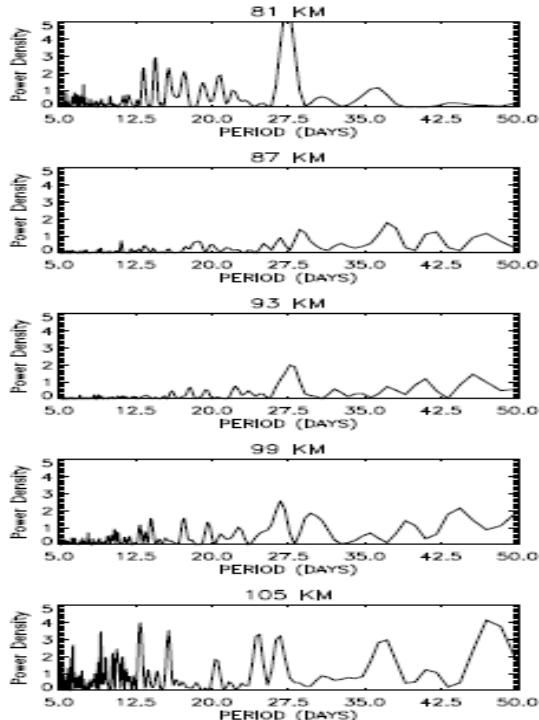
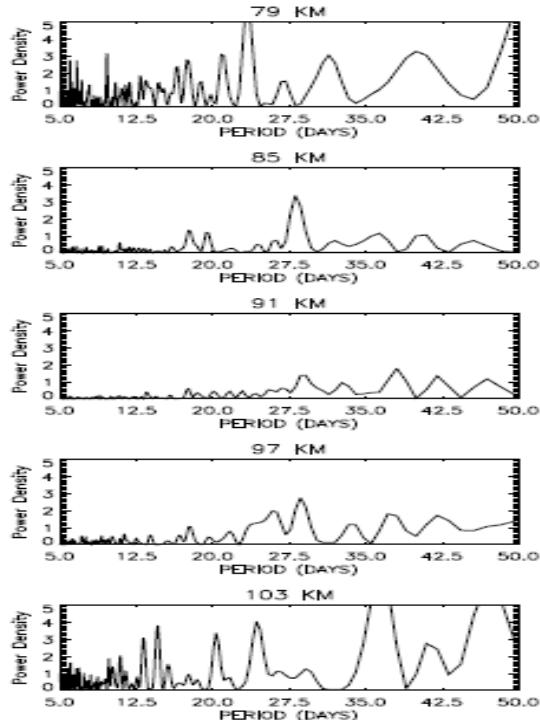
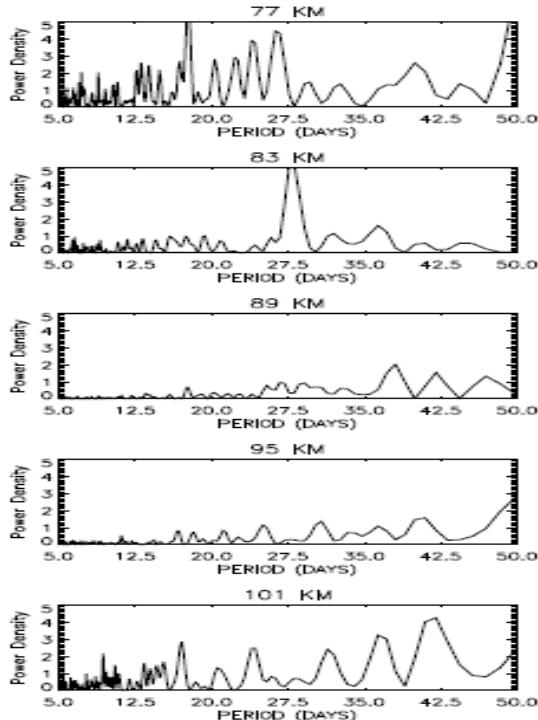
Cross-coherency between ENVISAT/GOMOS ozone and MGNM 205nm-solar flux as a function of period (days) and potential temperature (K) for first period

Mesospheric Ozone

- First period: 27/09/2003 – 24/01/2005
- Second period: 15/05/2007 – 10/11/2008
- Third period: 06/10/2009 – 05/10/2010

Period 1

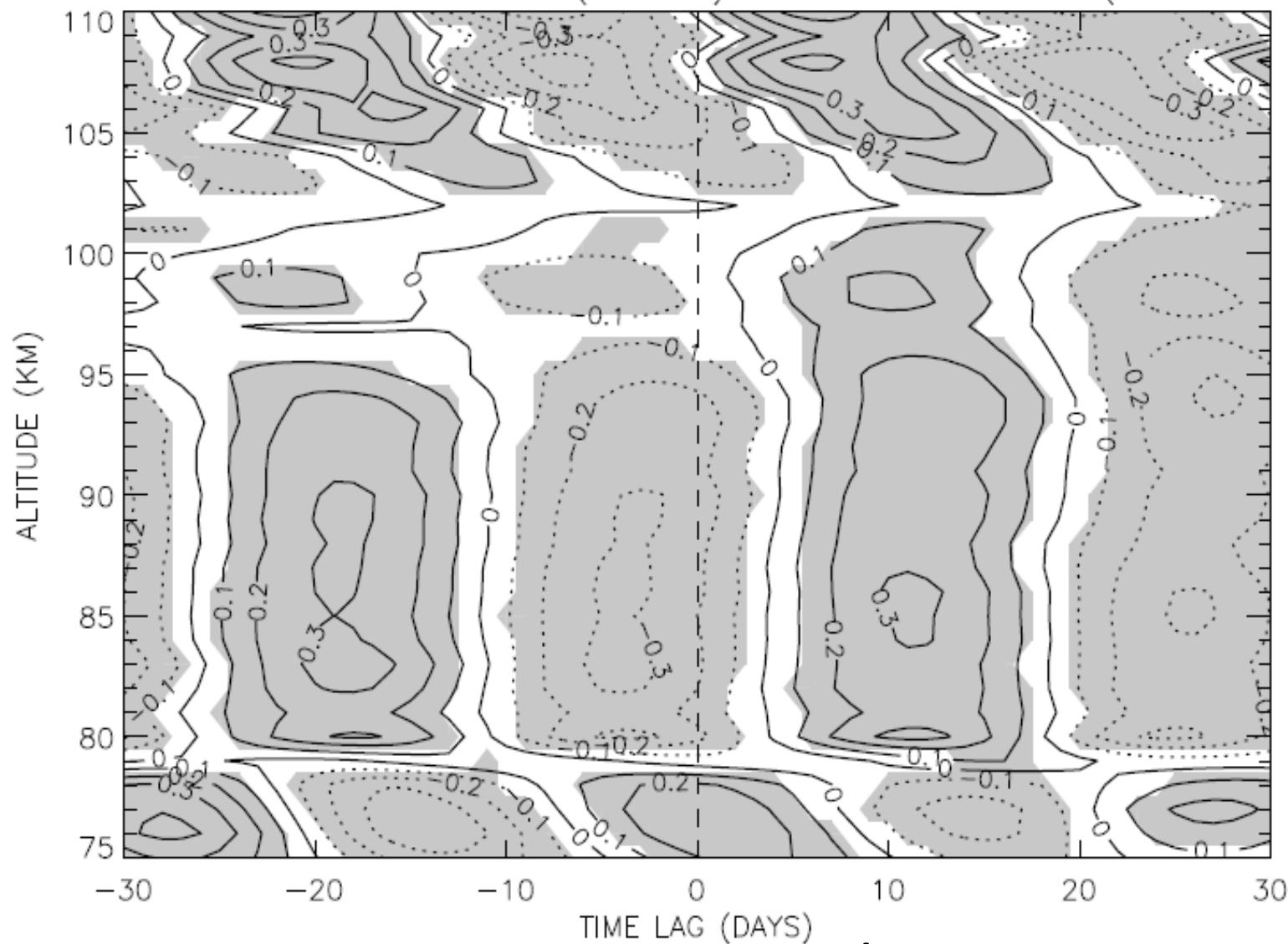




**GOMOS/ENVISAT Lomb-Scargle periodograms at different altitudes
and MGNM 205nm-solar FFT power spectrum over the first period**

GOMOS correlation analysis (cycle 23): first period

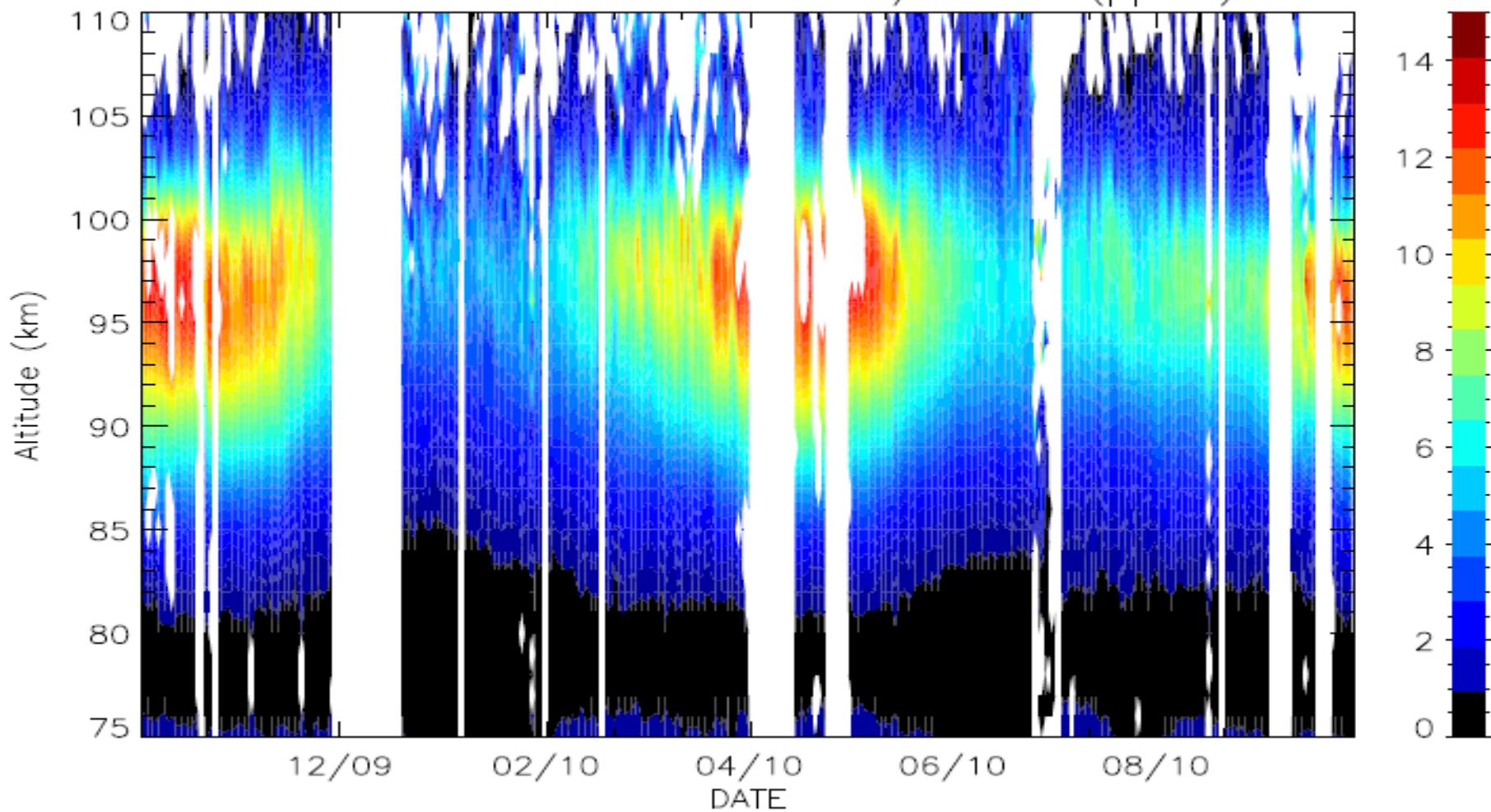
CROSS-CORREL BETWEEN O₃(GOMOS)-DF AND MGSSI-DF (SIGNIF=95%)

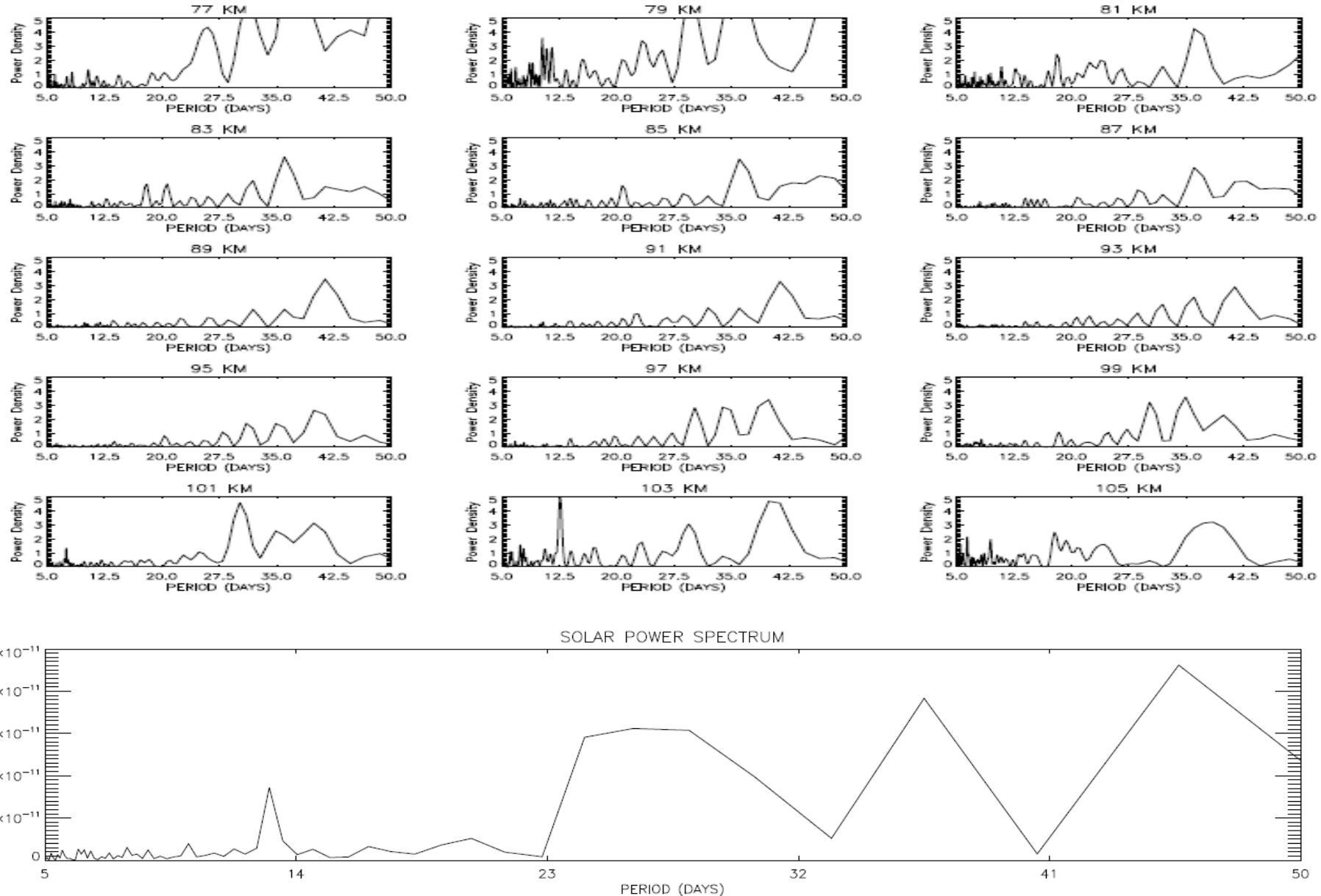


Cross-correlation between Ozone (GOMOS/ENVISAT) (DF) and 205
nm solar flux from MGNM (DF) (**first period**)

Period 3

OZONE MEASURED BY ENVISAT/GOMOS (ppmv)





**GOMOS/ENVISAT Lomb-Scargle periodograms at different altitudes
and MGNM solar FFT power spectrum over the **third** period**

Summary

- Difficult to extract the 27-day solar signal: data filtering, data sampling, data gaps, vertical coordinate, considered altitude ranges, considered periods,...: difficult to compare different studies
- Clear 27-day solar signal in the upper mesosphere (80-95 km): influence UV (O₃ production) levels reaching the stratosphere?