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Influence of Short-Term Solar UV Variability on the Determination of Solar Cycle Minimum

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Determining the precise date for solar activity minimum on solar cycle time scales requires an understanding of potential sources of variability on shorter time scales. Direct use of daily measurements is subject to the effects of both observational noise and rotational modulation. Uncertainties of 0.5% or less are significant when evaluating a solar cycle dynamic range of 8-9% – that observed for the 205 nm irradiance and the Mg II index. Simple smoothing functions such as running averages are commonly used to minimize or remove the effects of short-term variations. Statistical analysis shows that the Mg II index's nominal 27-day rotational modulation period varied between 26 and 29 days during Cycle 22.

Solar variability on intermediate time scales (*e.g.* 50-250 days), which has been observed previously in sunspot numbers, could also influence the identification of solar minimum. We used periodogram analysis to examine the NOAA-11 SBUV/2, UARS SUSIM (V19), and UARS SOLSTICE (V09) spectral irradiance and Mg II data sets, and found no evidence of intermediate-term periodicities related to solar activity. Occasional instances of statistically significant periodogram power were not repeatable between instruments in either period or spectral location, suggesting that they may represent artifacts.

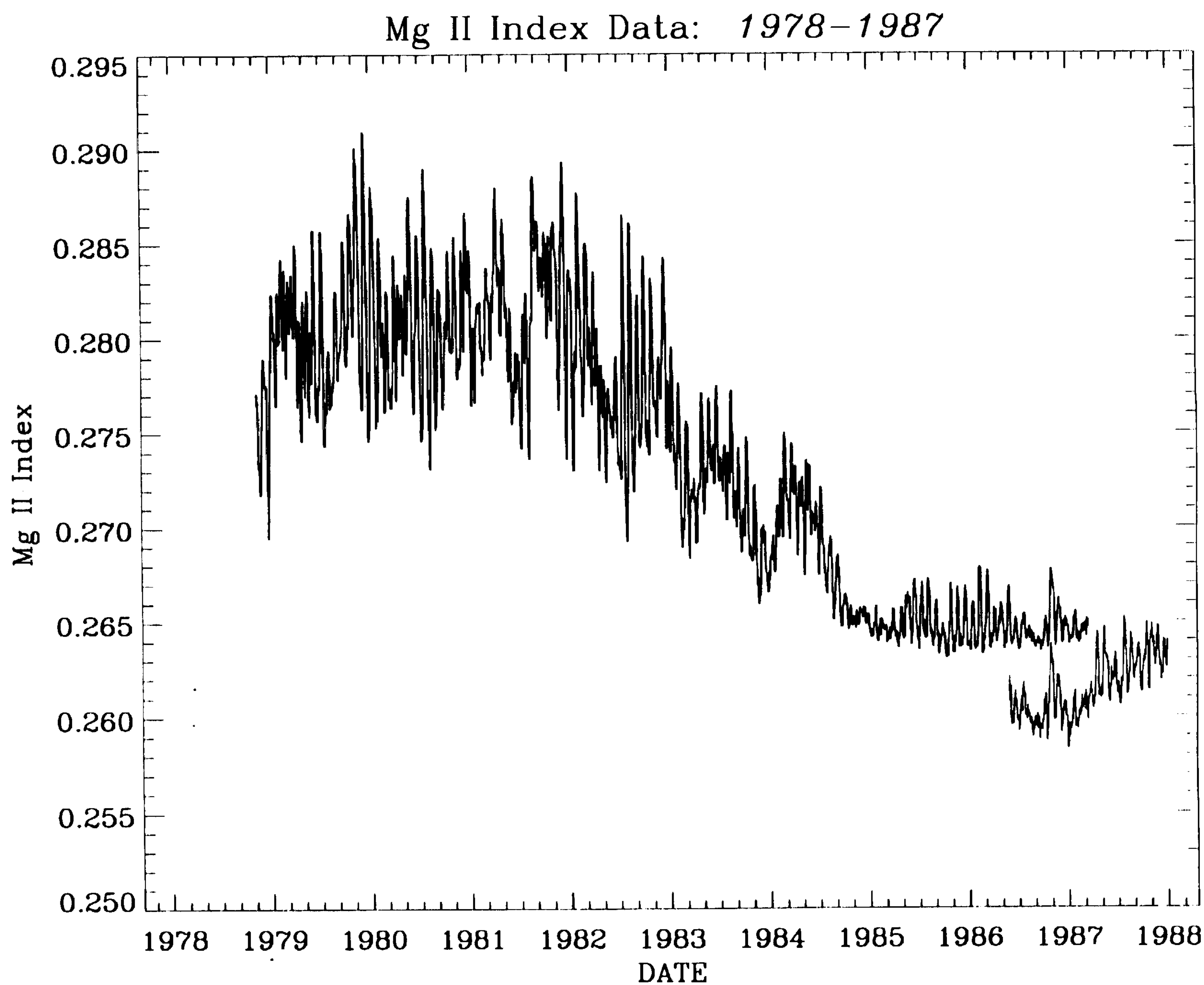
Our results suggest that the use of daily unsmoothed values to identify solar cycle extrema in date and magnitude is problematic because of the impact of rotational modulation and measurement noise. Running averages which smooth the data on rotational time scales provide significant improvement.

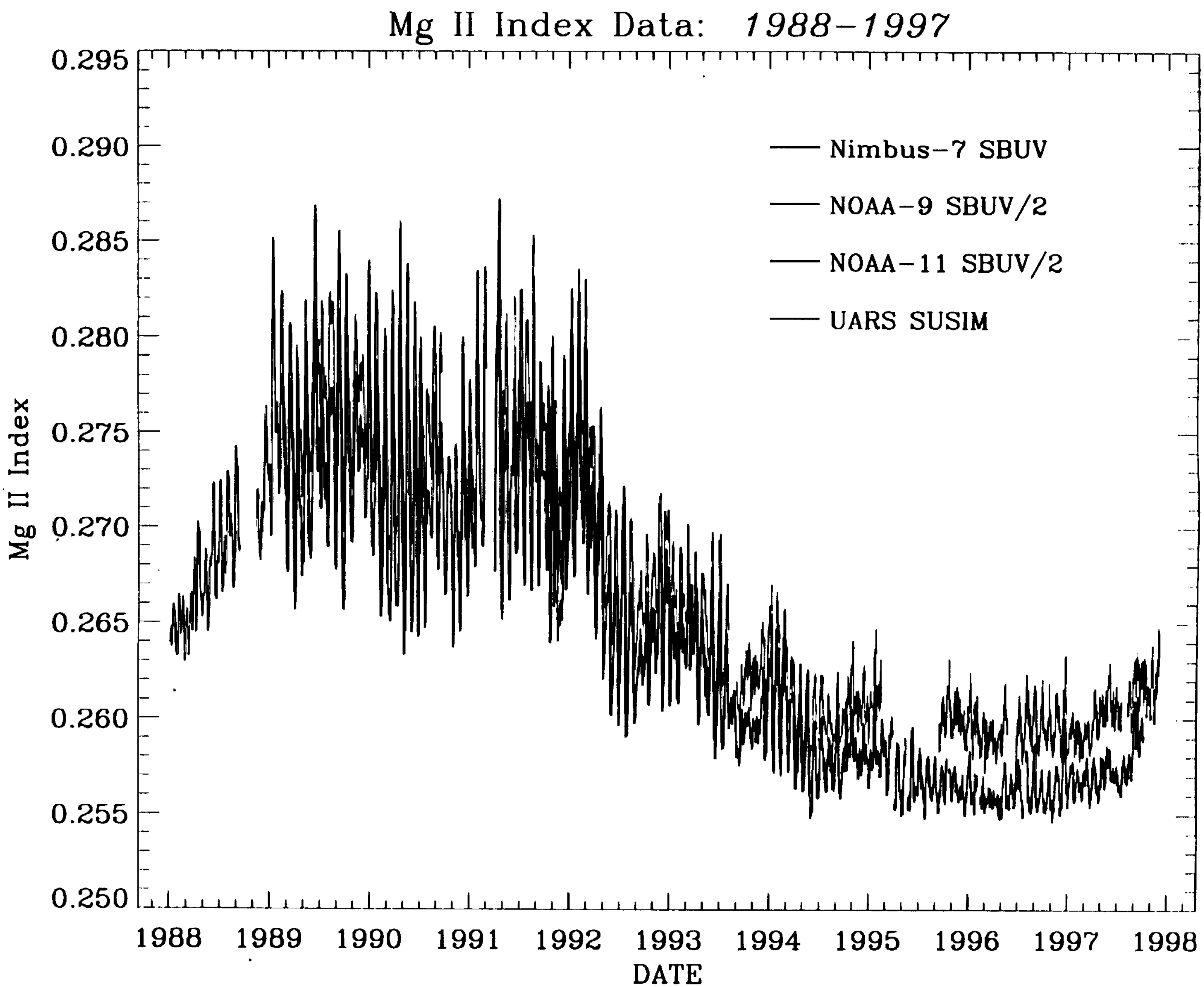
Solar UV Activity Timescales

- **Solar Cycle** (*~11 years*)
  - Controlled by strength of magnetic field.
  - Length of period can vary ±1 year or more.

- **Intermediate** (*< 1 year, > 1 month*)
  - Reflects lifetime of active regions.
  - Visibility in full-disk data varies.
  - No persistent periodicity identified for Cycle 22 in UV data.

- **Short-term** (*~27 days*)
  - Caused by rotation of active regions.
  - Nominal 27-day period can vary, evolve.
  - 13-14 day periodicity (two regions on opposing hemispheres) can appear at any part of cycle.


Mg II Index Data: 1978–1987
Mg II Index
0.295
0.290
0.285
0.280
0.275
0.270
0.265
0.260
0.255
0.250
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
DATE


Mg II Index Data: 1988-1997
Nimbus-7 SBUV
NOAA-9 SBUV/2
NOAA-11 SBUV/2
UARS SUSIM
Mg II Index
0.250
0.255
0.260
0.265
0.270
0.275
0.280
0.285
0.290
0.295
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
DATE

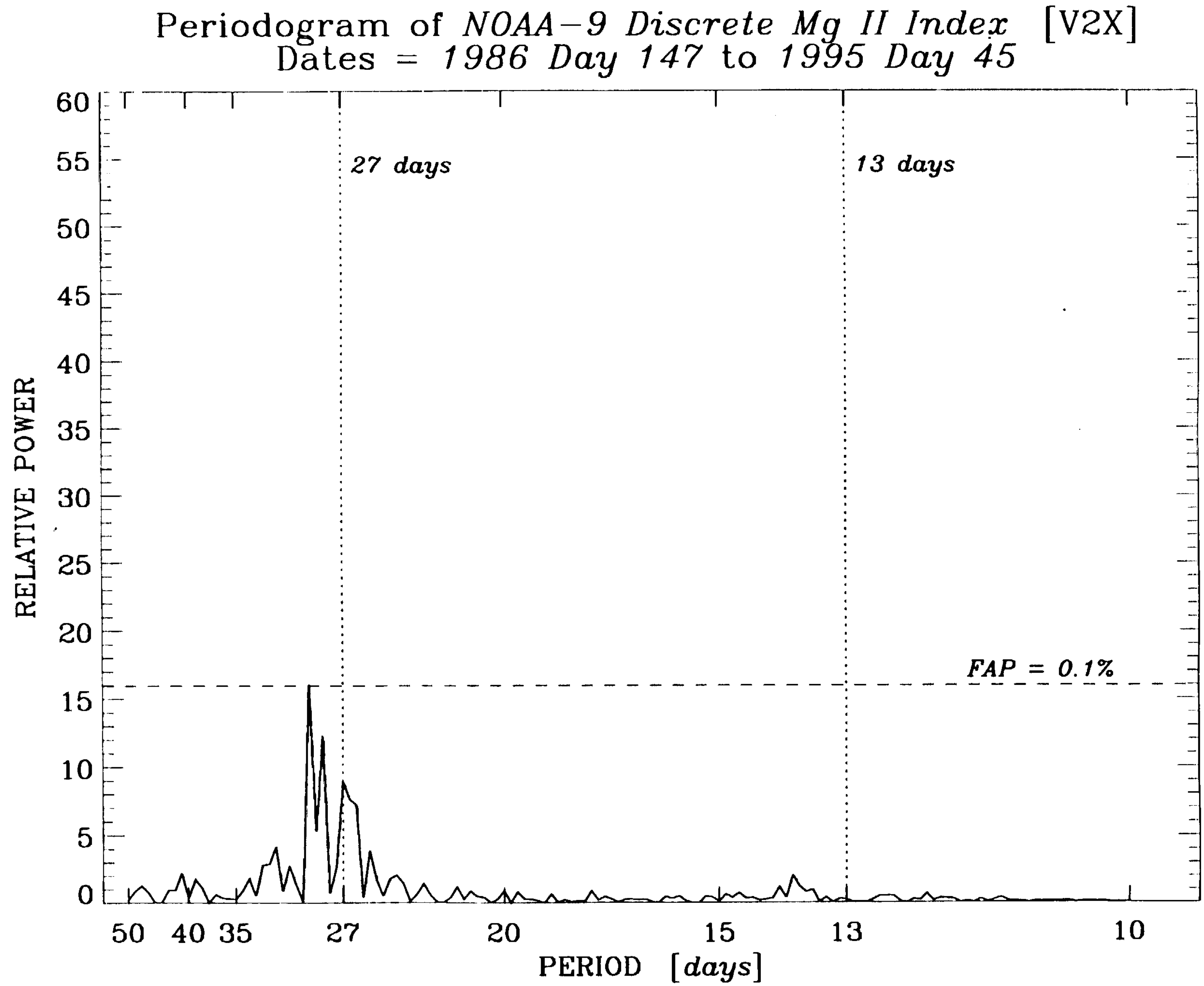
Short-term Activity

- Periodogram of full NOAA-9 Mg II index has power at multiple frequencies near nominal rotational period. No single frequency persists for entire cycle → reduced power levels.

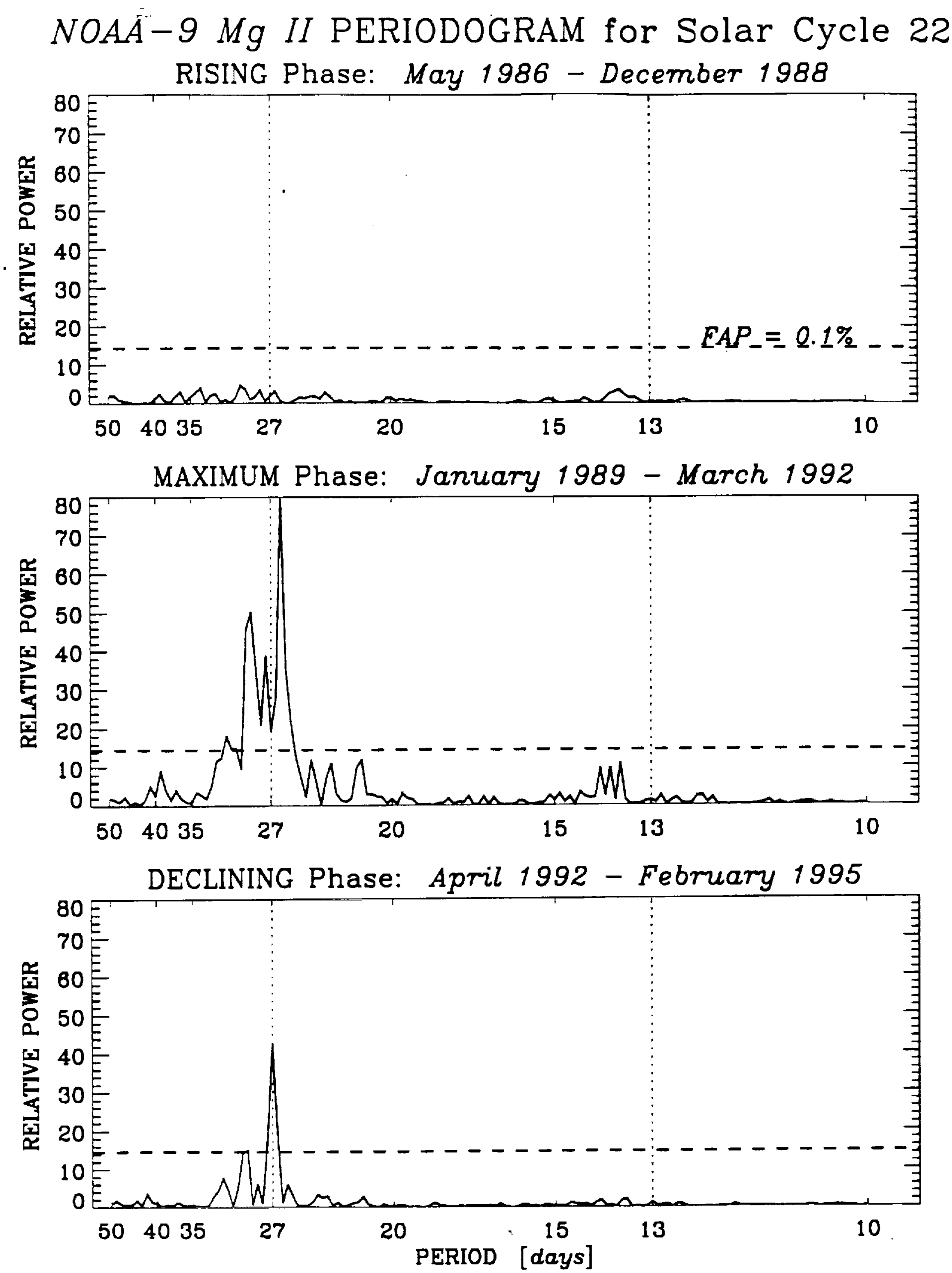
- Separating data by phase of cycle shows most power at maximum activity, multiple frequencies with significant power.

- Stepping periodogram window through data set ("dynamic power spectrum") shows evolution of periodicity during cycle.

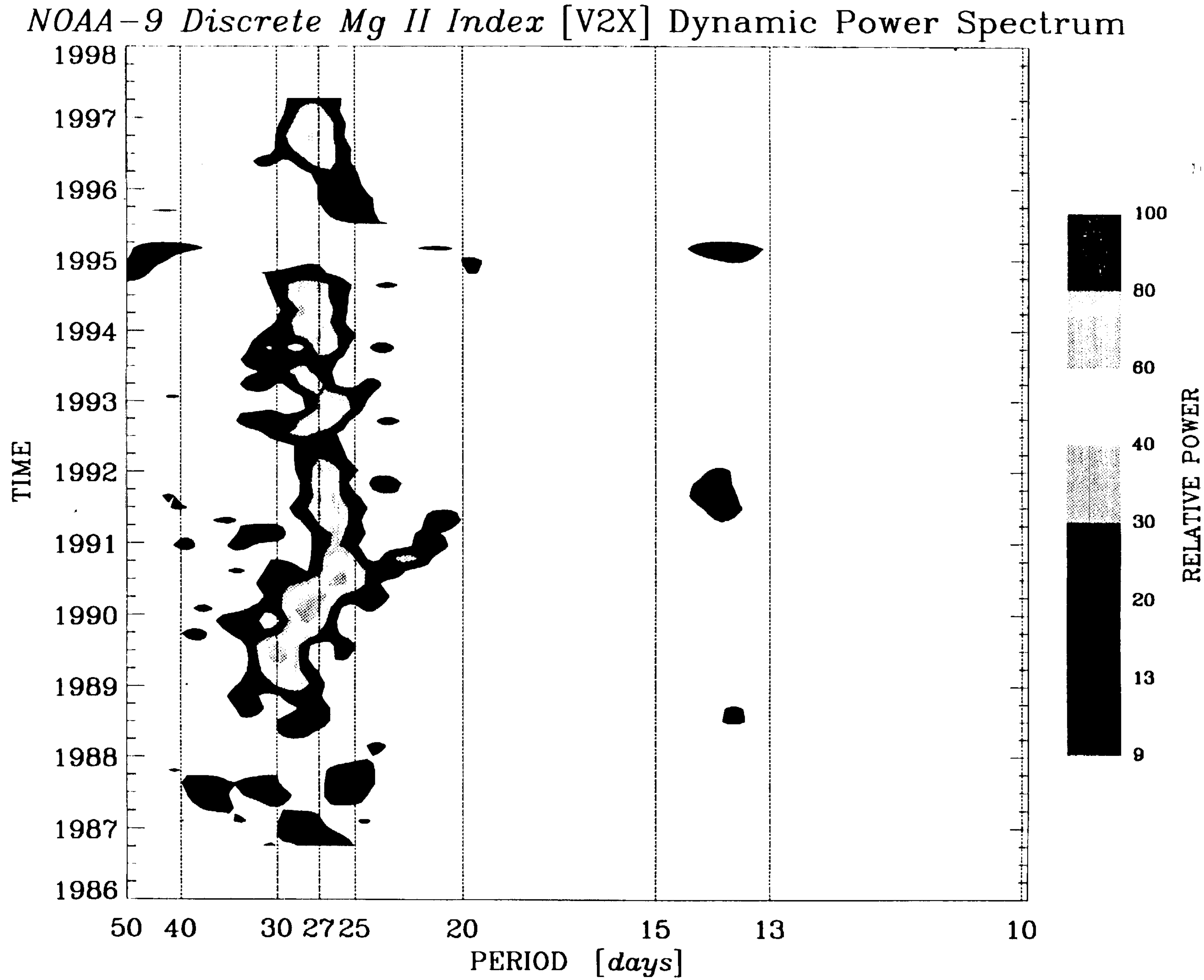
- 27-day running average of Mg II index removes power at rotational period. 35-day running average leaves time series signal, residual power at 27-day period.

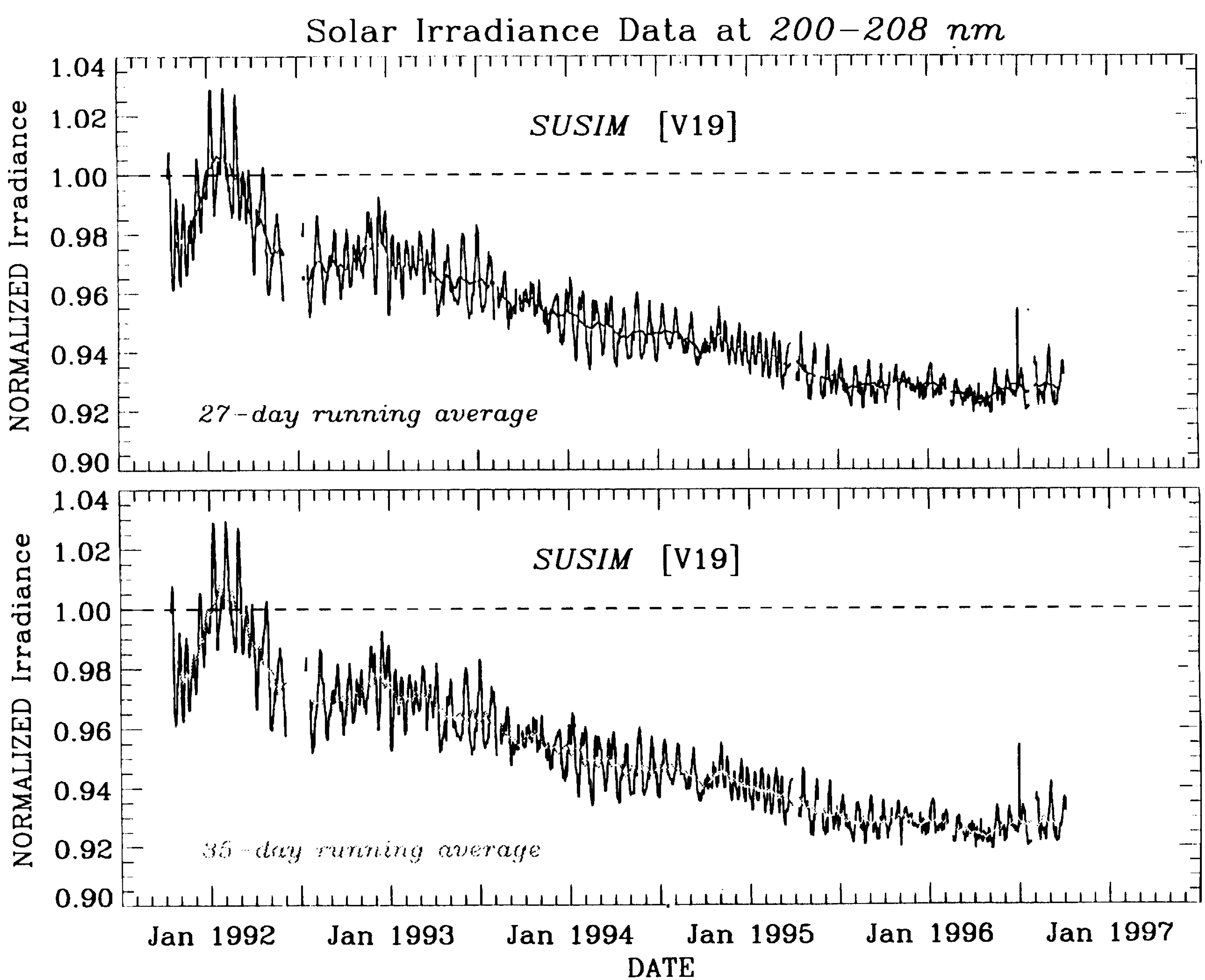


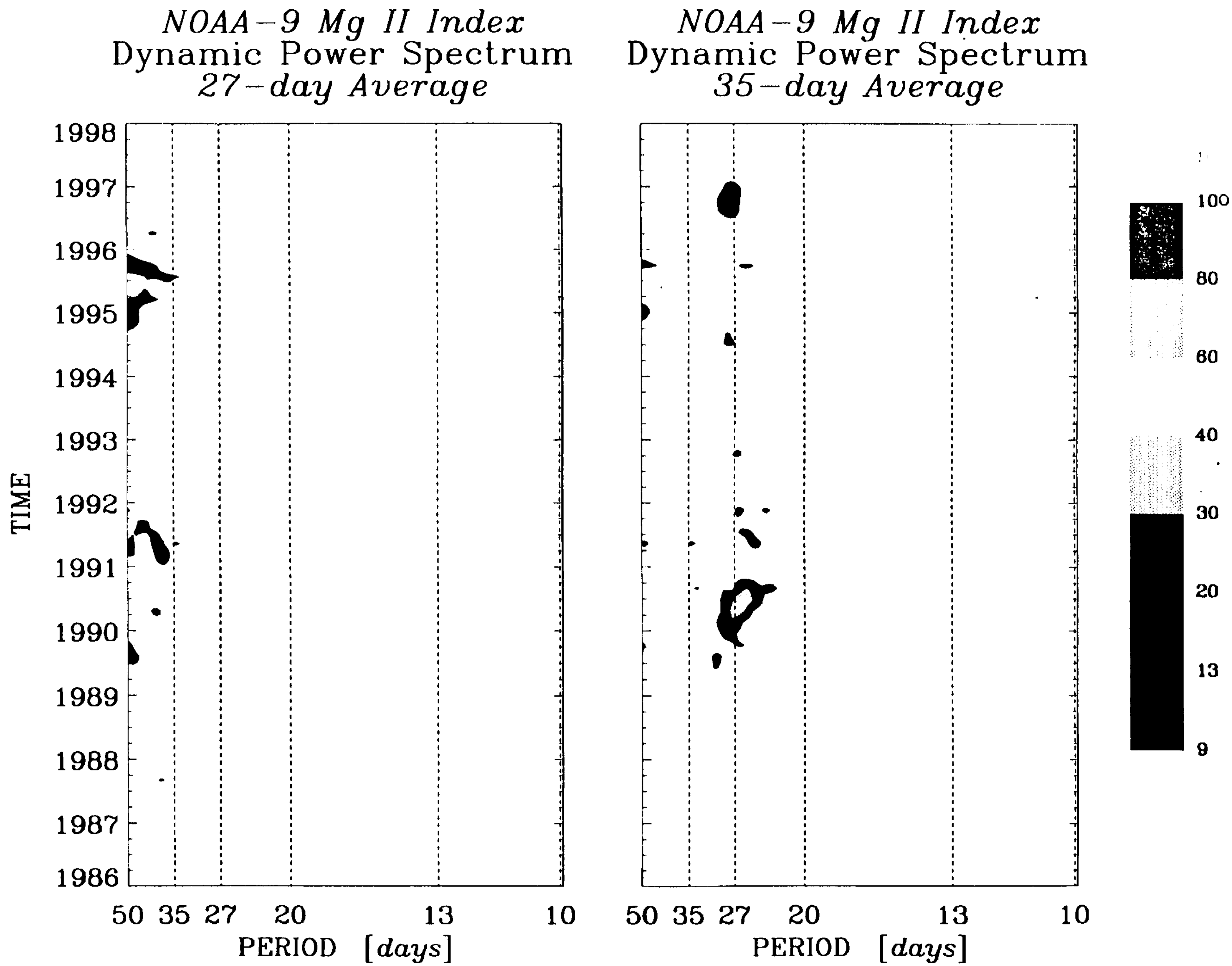
Periodogram of NOAA−9 Discrete Mg II Index [V2X]
Dates = 1986 Day 147 to 1995 Day 45
27 days
13 days
FAP = 0.1%
RELATIVE POWER
0
5
10
15
20
25
30
35
40
45
50
55
60
50
40
35
27
20
15
13
10
PERIOD [days]



NOAA−9 Mg II PERIODOGRAM for Solar Cycle 22
RISING Phase: May 1986 − December 1988
MAXIMUM Phase: January 1989 − March 1992
DECLINING Phase: April 1992 − February 1995
RELATIVE POWER
FAP = 0.1%
0 10 20 30 40 50 60 70 80
50 40 35 27 20 15 13 10
PERIOD [days]


NOAA−9 Discrete Mg II Index [V2X] Dynamic Power Spectrum
TIME
1998
1997
1996
1995
1994
1993
1992
1991
1990
1989
1988
1987
1986
50
40
30
27
25
20
15
13
10
PERIOD [days]
100
80
60
40
30
20
13
9
RELATIVE POWER


Solar Irradiance Data at 200–208 nm
SUSIM [V19]
27-day running average
35-day running average
NORMALIZED Irradiance
1.04
1.02
1.00
0.98
0.96
0.94
0.92
0.90
Jan 1992
Jan 1993
Jan 1994
Jan 1995
Jan 1996
Jan 1997
DATE


NOAA−9 Mg II Index
Dynamic Power Spectrum
27−day Average
NOAA−9 Mg II Index
Dynamic Power Spectrum
35−day Average
TIME
1998
1997
1996
1995
1994
1993
1992
1991
1990
1989
1988
1987
1986
50 35 27 20 13 10
PERIOD [days]
100
80
60
40
30
20
13
9

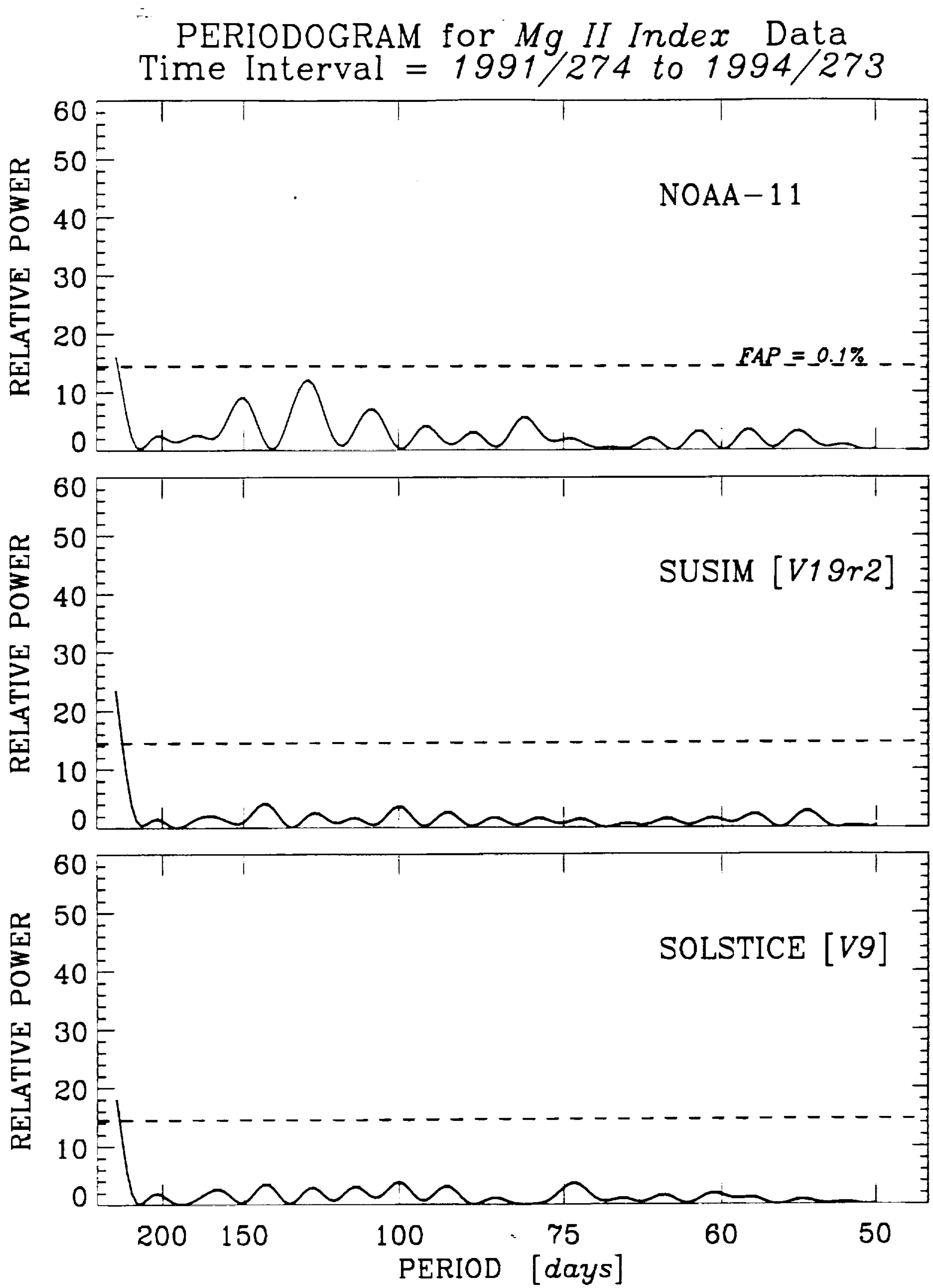
Intermediate-term Activity

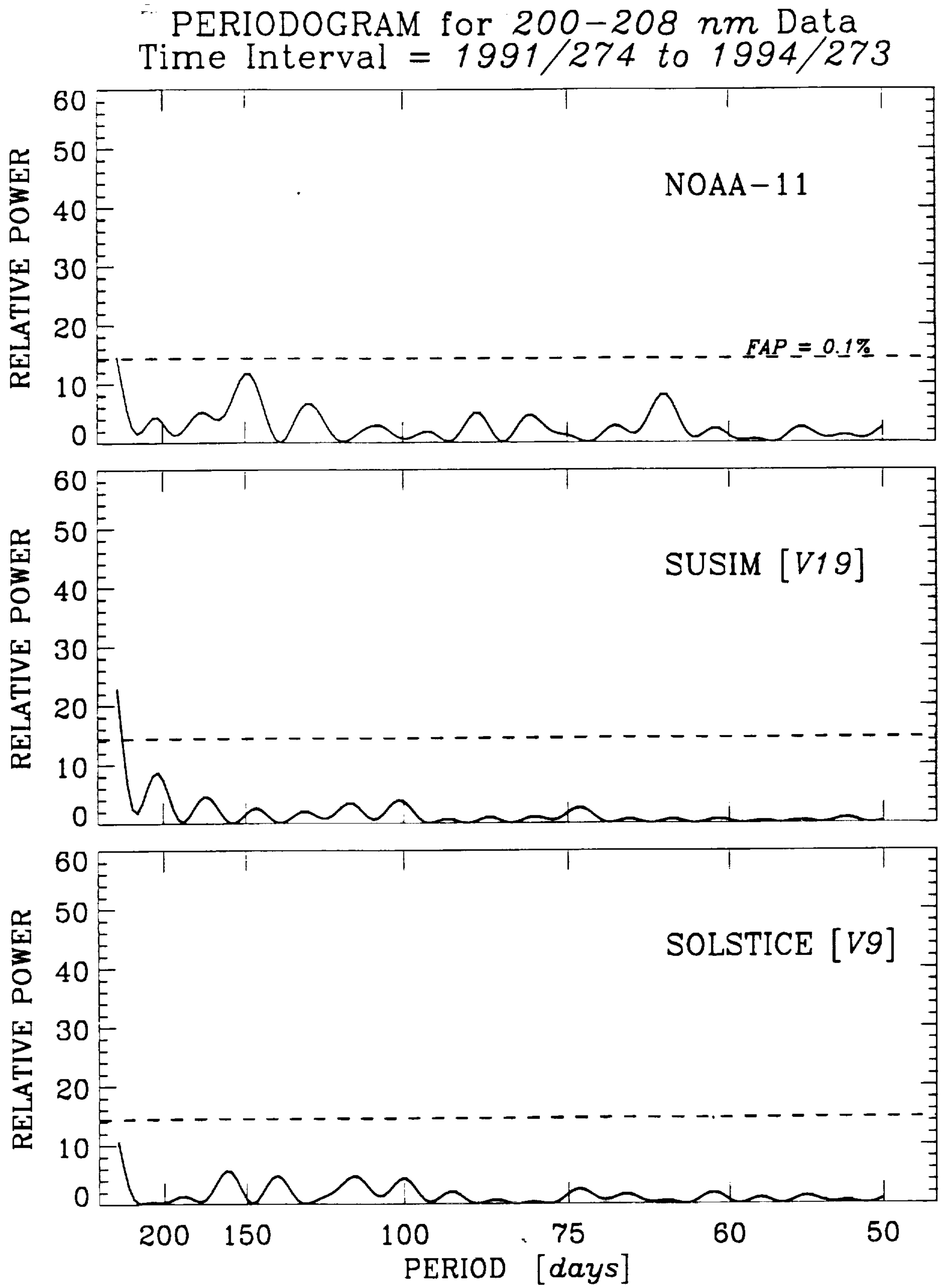
- Previous studies found examples (~155 days) in sunspot number, total irradiance. Recent paper (*Zhou et al.* [1997]) claims 60-80 day periodicity in UARS SOLSTICE V8 solar UV data, UARS MLS stratospheric ozone data during Cycle 22.

- No periodicity in 50-250 day range observed for Mg II index, 200-208 nm irradiance data from NOAA-11 SBUV/2, UARS SUSIM [V19], UARS SOLSTICE [V9] during overlap period (October 1991 – September 1994).

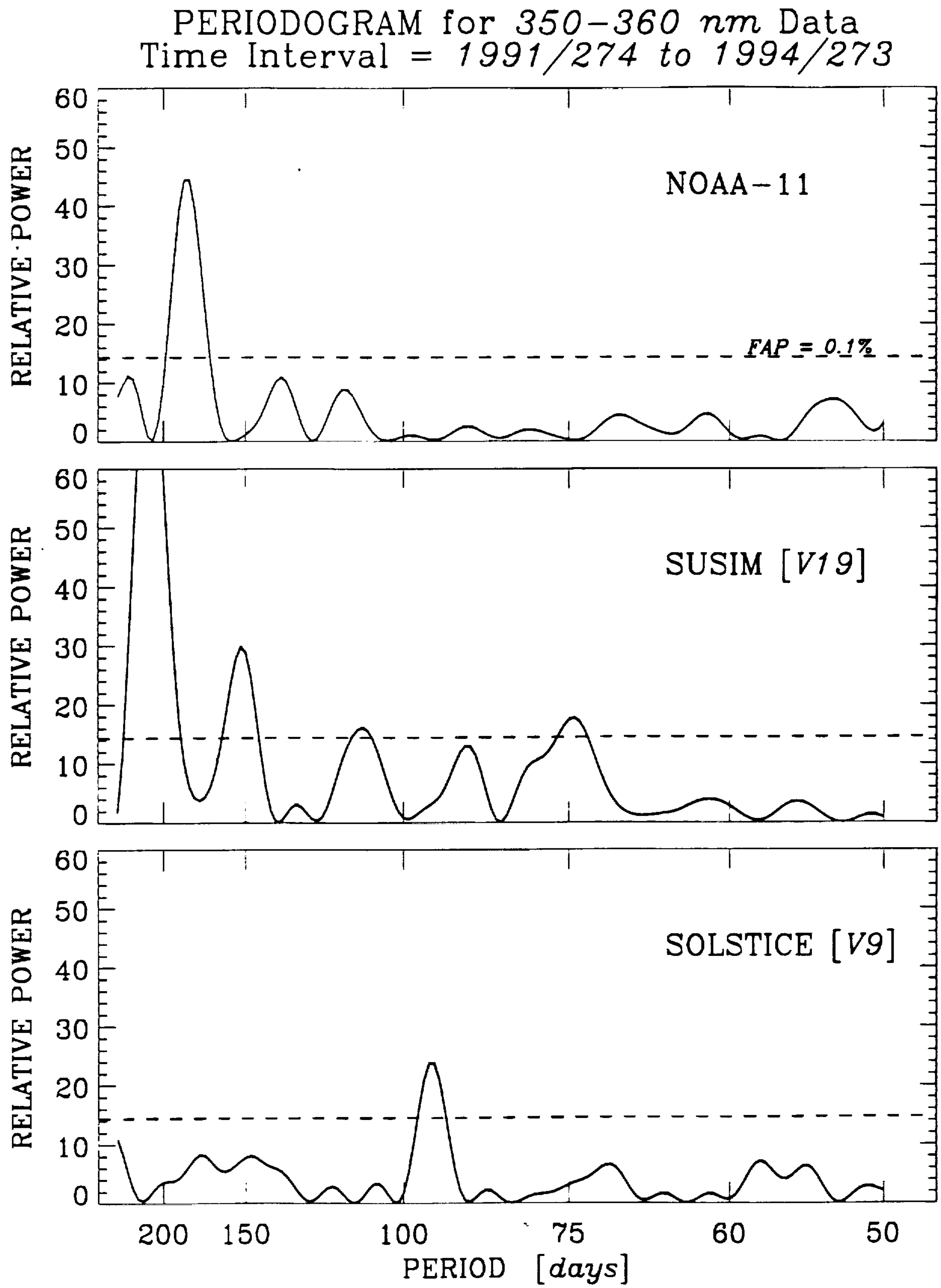
- Some peaks observed at long wavelengths, but not consistent in temporal or spectral location between instruments.

- Significant periodicity observed in SOLSTICE V8 irradiance data at ~72 days (2*x* UARS yaw period) has been removed in V9 irradiance data.

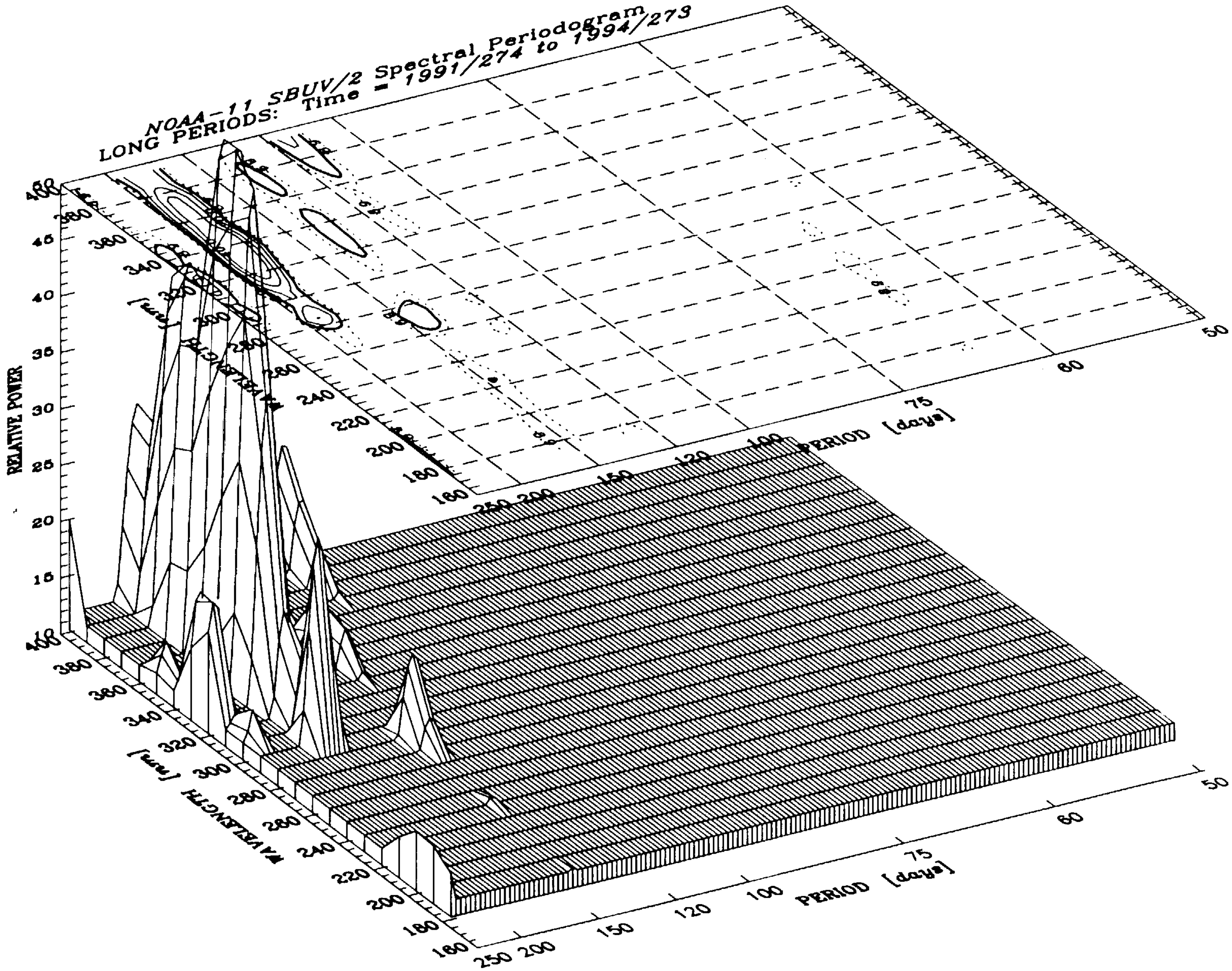

PERIODOGRAM for Mg II Index Data
Time Interval = 1991/274 to 1994/273
RELATIVE POWER
NOAA-11
FAP = 0.1%
SUSIM [V19r2]
SOLSTICE [V9]
0
10
20
30
40
50
60
200
150
100
75
60
50
PERIOD [days]

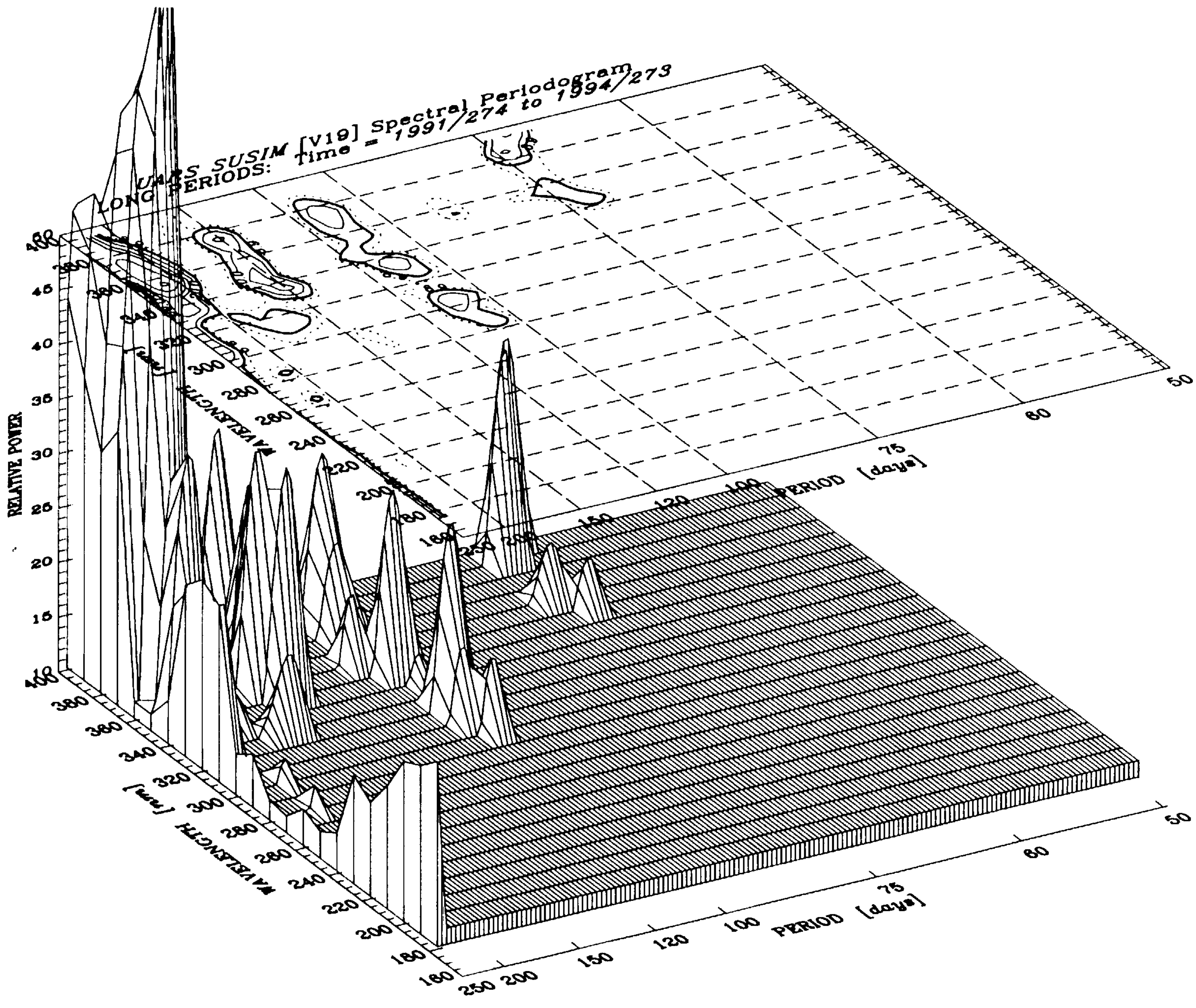


PERIODOGRAM for 200−208 nm Data
Time Interval = 1991/274 to 1994/273
RELATIVE POWER
NOAA−11
FAP = 0.1%
SUSIM [V19]
SOLSTICE [V9]
0
10
20
30
40
50
60
200
150
100
75
60
50
PERIOD [days]

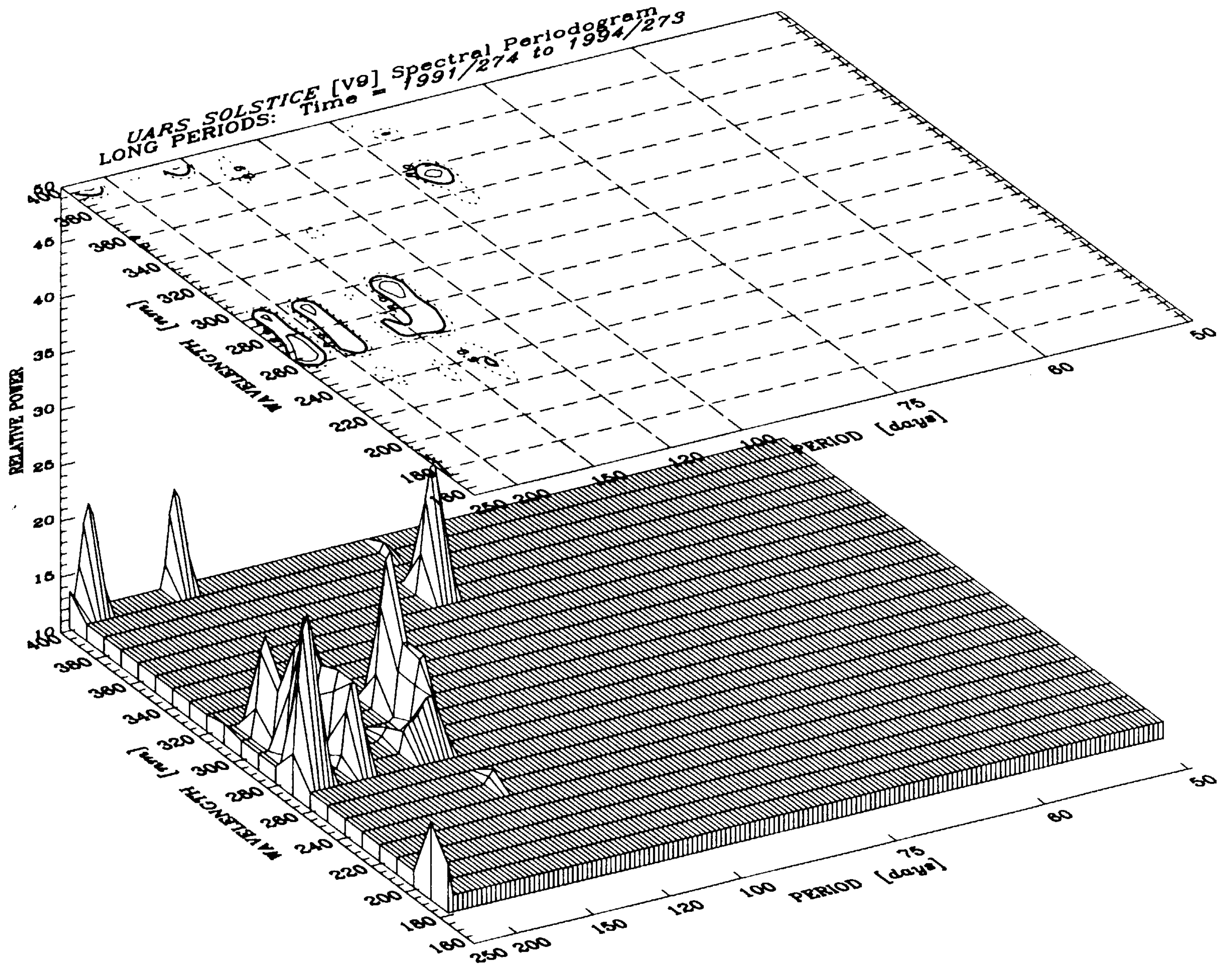


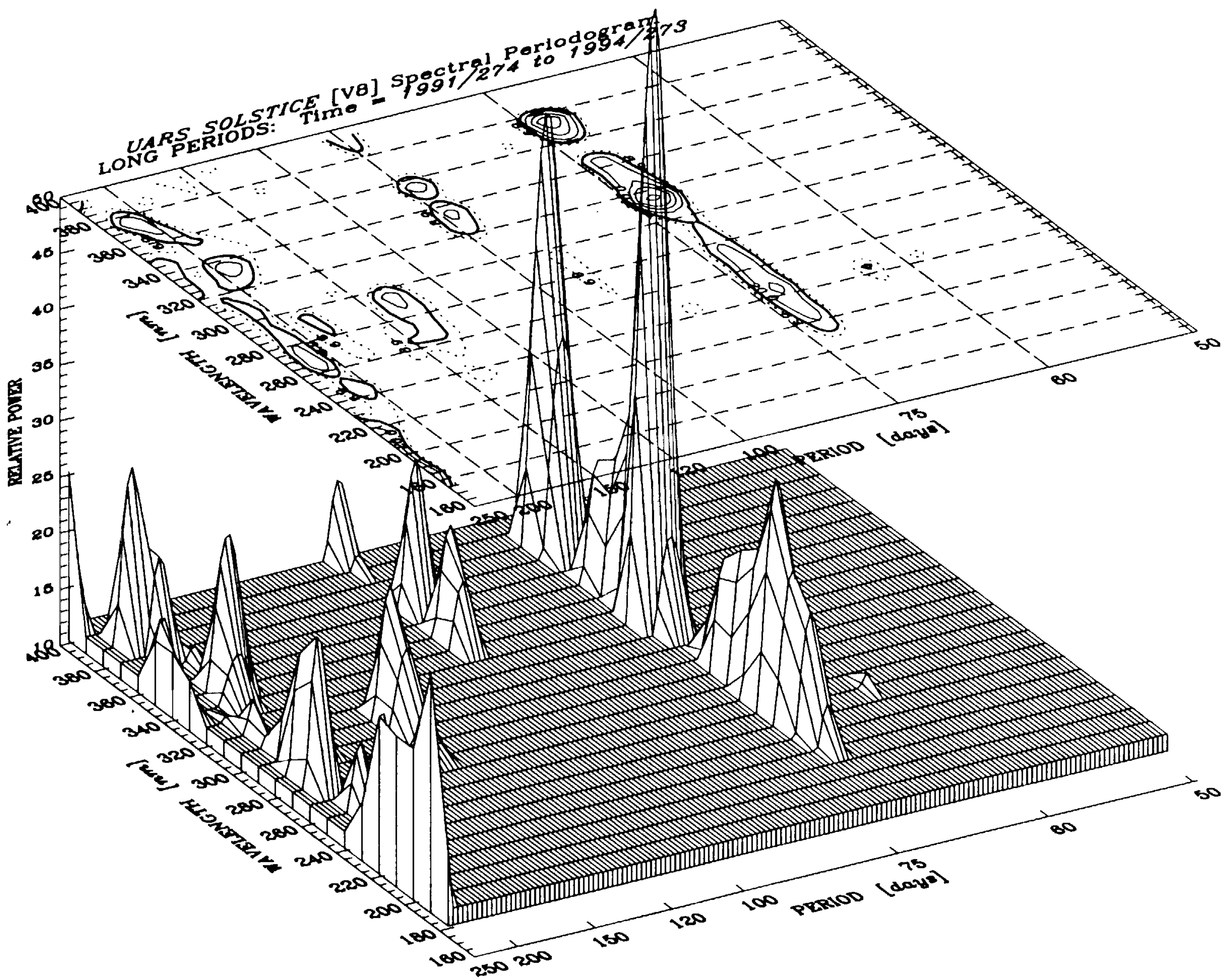
PERIODOGRAM for 350-360 nm Data
Time Interval = 1991/274 to 1994/273
RELATIVE POWER
NOAA-11
FAP = 0.1%
SUSIM [V19]
SOLSTICE [V9]
0
10
20
30
40
50
60
200
150
100
75
60
50
PERIOD [days]


NOAA-11 SBUV/2 Spectral Periodogram
LONG PERIODS: Time = 1991/274 to 1994/273
RELATIVE POWER
WAVELENGTH [nm]
PERIOD [days]



UARS SUSIM [V19] Spectral Periodogram
LONG PERIODS: Time = 1991/274 to 1994/273
RELATIVE POWER
WAVELENGTH [nm]
PERIOD [days]


UARS SOLSTICE [V9] Spectral Periodogram
LONG PERIODS: Time = 1991/274 to 1994/273
RELATIVE POWER
WAVELENGTH [nm]
PERIOD [days]


UARS SOLSTICE [V8] Spectral Periodogram
LONG PERIODS: Time = 1991/274 to 1994/273
RELATIVE POWER
WAVELENGTH [nm]
PERIOD [days]

Conclusions

- Smoothing solar UV data on rotational timescale (~27 days) improves identification of solar minimum.

- Smoothing intervals which are not multiples of rotational period (*e.g.* 35 days) can leave measurable residual signal.

- No evidence found for periodic behavior on intermediate (50-250 days) time scales during Cycle 22, based on data from three solar UV instruments.