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A relation between frequency shift and the changes in activity indices

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Abstract. We present a linear relation between the shift in p-mode frequencies and variation in two solar activity indices, namely the sunspot number and 10.7 cm radio flux. From this relation, an empirical model is constructed to estimate the mean frequency shifts with respect to activity index. We also compare the observed and estimated shifts for solar cycle 22 and comment on the systematic errors in different helioseismic data sets.

Key words : Solar oscillation, helioseismology, Solar activity

It is well established that the p-mode frequency shifts are correlated with different activity indices (e.g. Jimenéz-Reyes et al. 1998, Bhatnagar et al. 1999 and references therein). Here we derive empirical relations between the variation in mean frequency and change in activity index by showing that there exists a linear correlation between these two parameters. For this study, we use the available p-mode frequencies from BBSO (1986, 88, 89, 90), South Pole (1987, 89, 91), LOWL (1994-95) and GONG (1995-1998) stations covering the solar cycle 22 and beginning of cycle 23.

To derive the empirical relations, we have calculated the mean frequency shifts ($\delta\nu$) from 27 GONG data sets (June 1995 to October 1998) by taking the first data set as the reference. To be consistent in our analysis, we have considered only those modes which are common in all the four stations. This yielded 292 common modes in the frequency range of 1500-3500 μHz and intermediate degree l from 5 to 99. A linear least square fit has been performed between $\delta\nu$ and the change in solar activity indices (δi); the International sunspot number (R_I) and 10.7 cm radio flux (F_{10}), where the change in activity indices are computed for the same epoch as that of frequency shifts. We find that a good correlation exists between $\delta\nu$ and δi and are described by the following relations :

$$\delta\nu(nHz) = (2.284 \pm 0.008)\delta R_I - (6.637 \pm 0.215) \quad (1)$$

$$\delta\nu(nHz) = (2.925 \pm 0.001)\delta F_{10} - (3.911 \pm 0.201) \quad (2)$$

where F_{10} is in sfu.

The relation (1) is used to estimate the mean frequency shifts for the solar cycle 22 and ascending phase of cycle 23. This is shown by dotted line in Figure 1 whereas the observed shifts calculated from BBSO, South Pole, LOWL and GONG frequencies are shown by symbols. It is clear that the derived frequency shifts from the relation (1) follow the trend of observed shifts and demonstrate that the relations are independent of activity cycles or epochs. However, we notice that the South Pole frequencies are systematically higher than other stations. A similar conclusion was arrived by Duvall et al. (1988) by comparing frequencies between South Pole and BBSO data sets. Our analysis for the period 1986-1996 also suggests that the difference may be due to the different data reduction technique between South Pole and other stations or the presence of unidentified systematic error.

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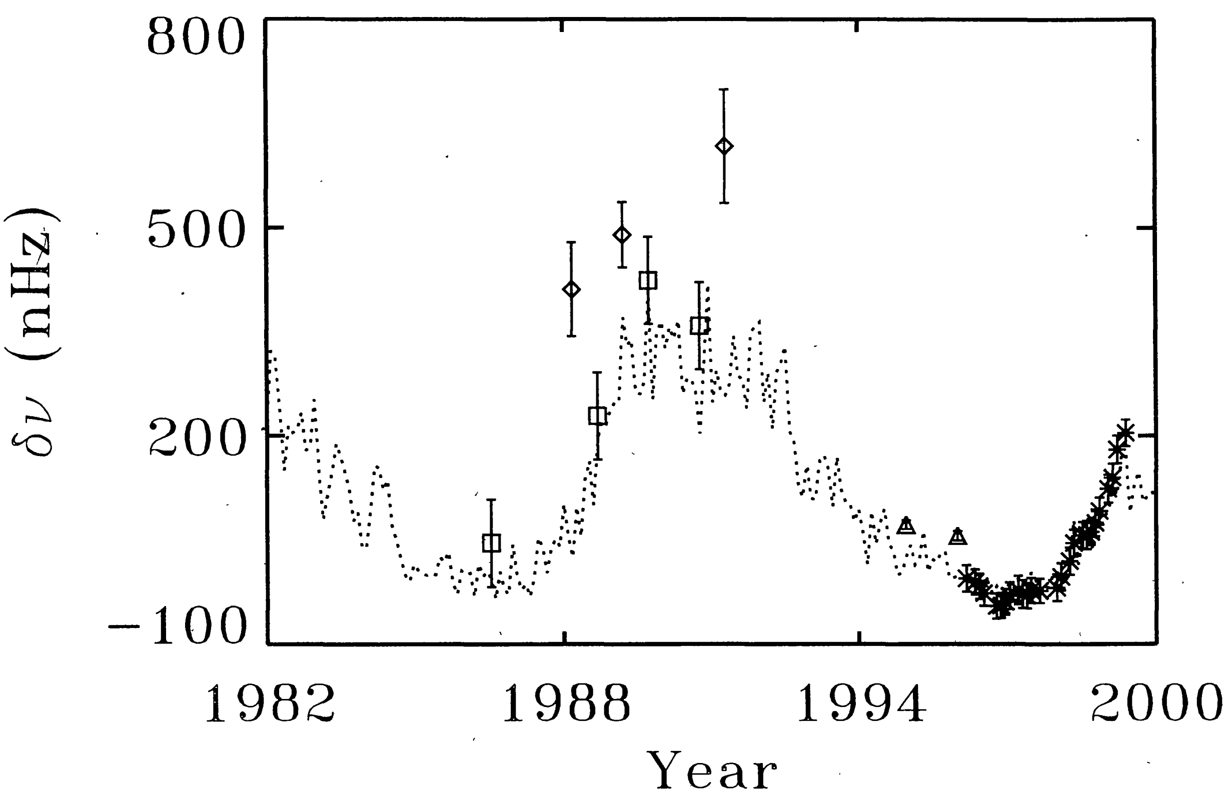

Figure 1. The observed p-mode frequency shifts for the solar cycle 22 and ascending phase of cycle 23. The symbols denote frequencies from BBSO (squares), South Pole (diamonds), LOWL (triangles) and GONG (star) stations. The dotted line shows the frequency shifts estimated from relation (1) using sunspot numbers taken from Solar Geophysical Data.