1.2.4 Effects of polar-mid latitude interactions on ozone trends

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Abstract.

As the initial stage of the study of long termed ozone trends combined with the analysis of polar vortex behavior, the deseasoned QBO model was developed. The data of 40-years NCAR/NCEP Reanalysis Project (zonal component of equatorial winds) have been treated using harmonic analysis technique.

Keywords:

QBO (Quasi-biennial Oscillations), ozone trends, polar vortex, solar activity, NCEP Reanalysis data.

The mechanism of the ozone depletion in the Arctic polar vortex is essentially same as that in the Antarctic Ozone Hole and the ozone loss rate of it is also as large as that in the Antarctic Ozone Hole (e.g. Rex et al.,1998). Therefore, the negative trend of ozone in the northern hemisphere, which is largest in winter/spring, should be affected by the ozone depletion in the Arctic polar vortex. Taking the above effects into account, we need the following procedures for trend analysis of ozone in the northern hemisphere:

(1)to remove seasonal variation,
(2) to remove the effects of the Quasi Biennial Oscillation (QBO),
(3) to remove the effects of the variation of solar activity,
(4) to choose the data affected by the polar vortex,
(5) to apply trend analysis.

We apply a multiple regression model including seasonal variation, QBO, the solar activity. A sinusoidal model for the seasonal variation and the 10.7 cm solar flux for the solar activity can be used for the multiple regression analysis. As we also need the QBO to carry out the multiple regression analysis, in this report we will show the details of QBO modeling. As to the effects of polar vortex, we used the method developed by Ninomiya and Nakane (1998).

The interannual variability of the vertical distribution of stratospheric ozone is affected by several factors among which the seasonal variations and the Quasi-biennial oscillations are dominating. The latter phenomena is closely linked with the behavior of stratospheric tropical wind, namely its zonal component. Different approaches to QBO modeling have been applied (see SPARC (1998) and the references herein), but the problem is still far from being completely investigated. In particular, it is important to separate the seasonal and QBO influence to ozone distribution.

The author was proposed to compile the model for the clean QBO-signal using the data provided by National Center for Environmental Prediction and National Center for Atmospheric Research (Kalnay E. et al.(1996)). The most comprehensive archive contains data saved on 2.5° long.×2.5° lat. grid on 17 pressure levels (including 200, 150, 100, 70, 30, 20, and 10 hPa) with 6-hr time step for 40 years period (1958—1997). The zonal component of equatorial wind over Singapore is the subject of the following analysis.

An example of the data set under discussion is shown on Fig. 1 (total of 14579 points, only daily averaging of data applied). The straight dashed line represents the trend. On the first look on the plotted time series the Fourier analysis of these data suggests itself.

Fig. 2 shows the first 100 amplitudes of discrete Fourier spectrum for these time series after prior removal of trend component (the lower plot). The maximal signal corresponds to period of about 860 ± 30 days, or 2 years and 3--5 months, which is usually treated as the period of QBO. The second clear peak (index 40) has 364 ± 5 days period. This is annual component.

The part of the spectrum selected to build the demonstrative QBO model is marked with red dots. Having been inversely transformed, it provides the smooth sinusoid-like curve presented (also in red) on the upper plot of fig. 2. The blue curve shows the sum of reconstructed QBO signal and the seasonal (annual and semiannual) components.

Fig. 3 allows to compare the changes of spectrum with height. Height decreasing, the QBO peak becomes smaller. The annual component remains almost the same, the semiannual one becoming more clear. Neither trend removal nor different averaging procedures do not affect these signals quality and distribution.

These results agree well with other empirical approaches to QBO modeling. For example, in Randel et al. (1995), weighted average of zonal winds with the following weights is used: 10 mbar (0.24), 15 mbar (0.51), 20 mbar (0.60), 30 mbar (0.50), 40 mbar (0.26), 50 mbar (0.04), 70 mbar (-.09). The largest weight is prescribed to 20 mbar level, seen as the largest peak on figs. 2 and 3.

We have not found references for Fourier analysis application to QBO modeling. It was possibly due to the absence of long-termed equi-spaced data. Instead, the most of researches use regression technique, as in Stolarski et al. But the information contained in Fourier spectrum is useful for both regression model design and as a final representation of the signal under study.

References

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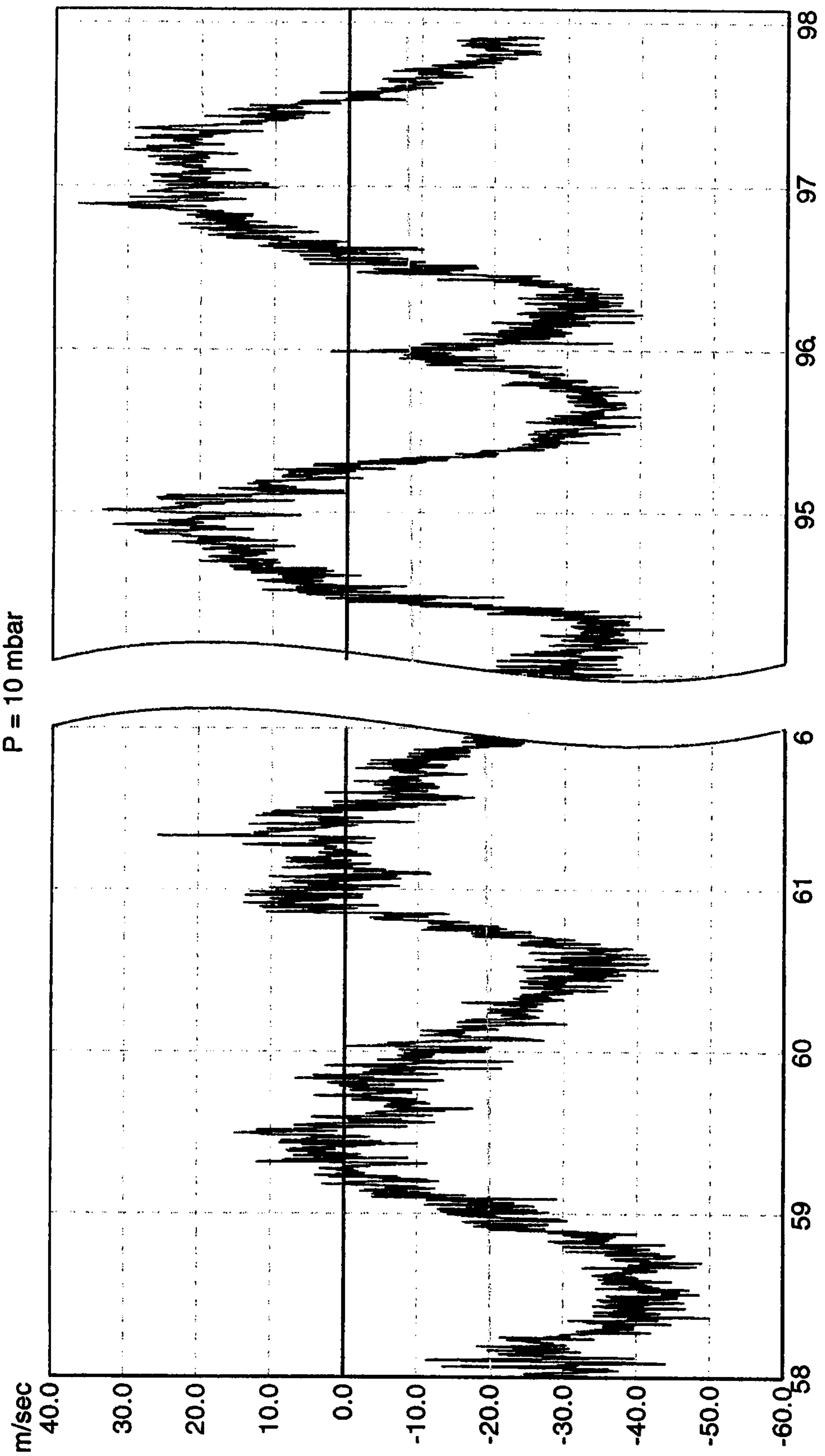
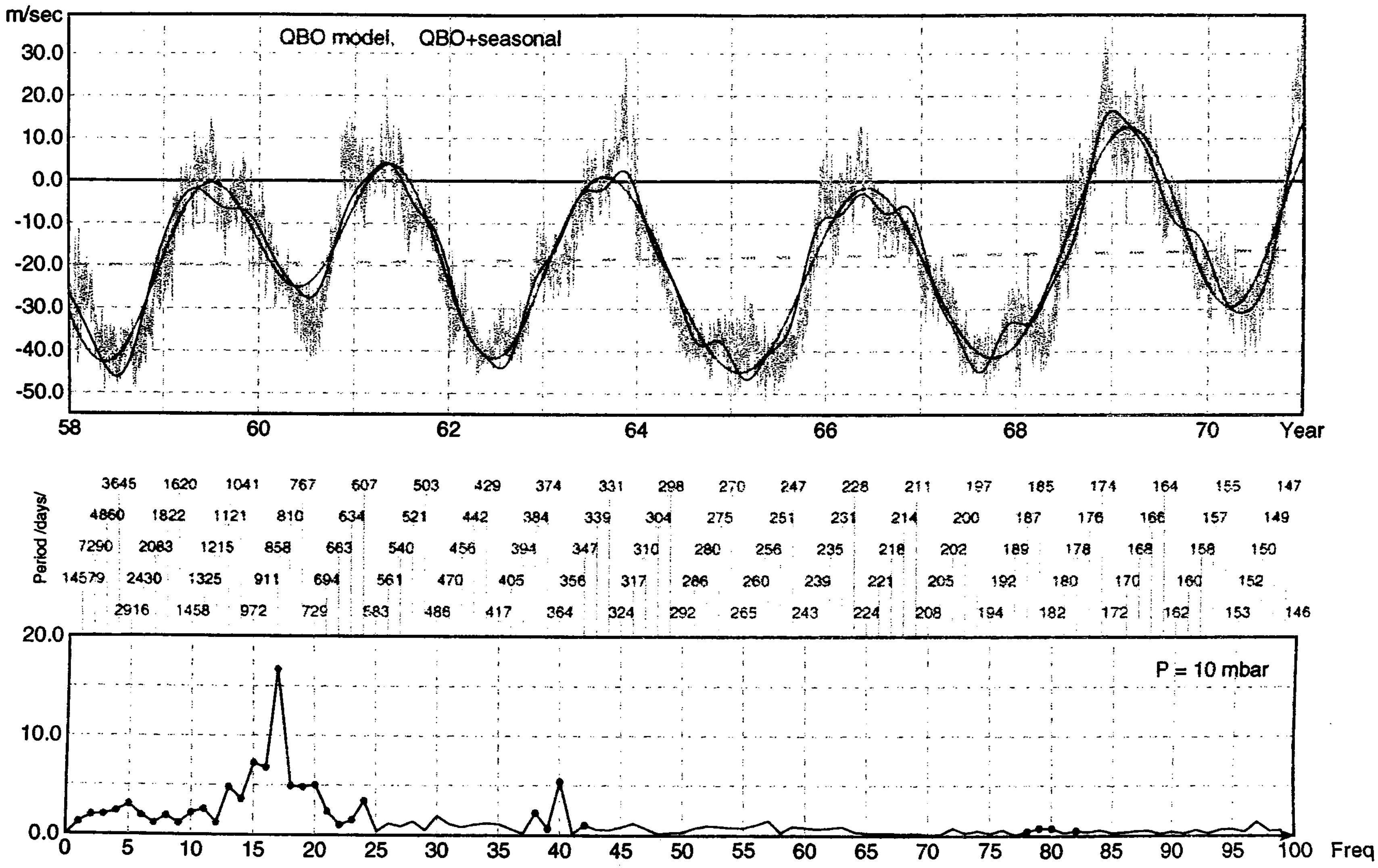

P = 10 mbar
m/sec
40.0
30.0
20.0
10.0
0.0
-10.0
-20.0
-30.0
-40.0
-50.0
-60.0
58
59
60
61
6
95
96
97
98

Fig. 1



m/sec
QBO model, QBO+seasonal
30.0
20.0
10.0
0.0
-10.0
-20.0
-30.0
-40.0
-50.0
58
60
62
64
66
68
70
Year
Period /days/
3645 1620 1041 767 607 503 429 374 331 298 270 247 228 211 197 185 174 164 155 147
4860 1822 1121 810 634 521 442 384 339 304 275 251 231 214 200 187 176 166 157 149
7290 2083 1215 858 663 540 456 394 347 310 280 256 235 218 202 189 178 168 158 150
14579 2430 1325 911 694 561 470 405 356 317 286 260 239 221 205 192 180 170 160 152
2916 1458 972 729 583 486 417 364 324 292 265 243 224 208 194 182 172 162 153 146
20.0
10.0
0.0
P = 10 mbar
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
Freq

Fig. 2

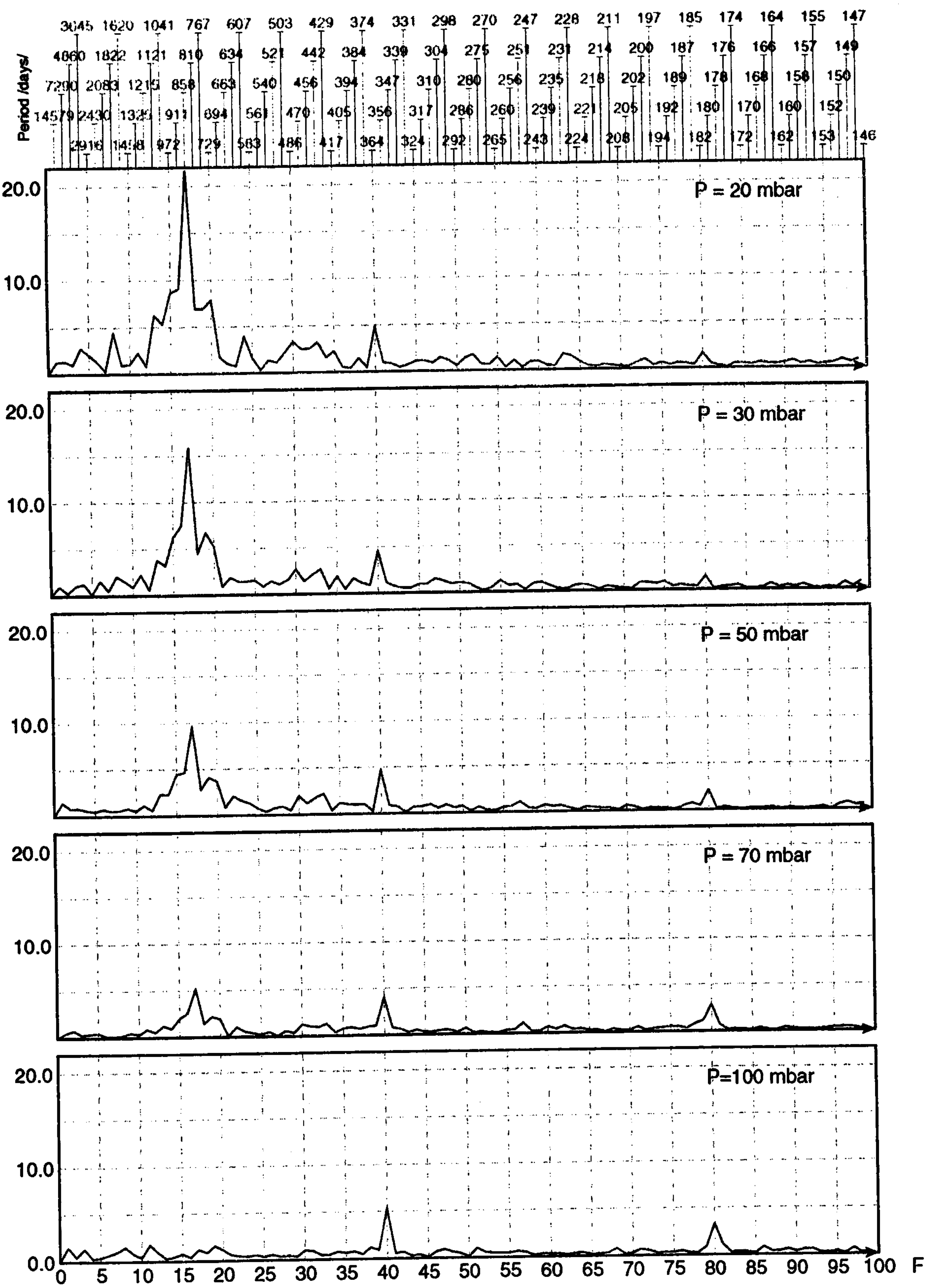

Period /days/
P = 20 mbar
P = 30 mbar
P = 50 mbar
P = 70 mbar
P=100 mbar
20.0
10.0
0.0
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100 F

Fig. 3