Geophysical Research Abstracts,
Vol. 10, EGU2008-A-05003, 2008
SRef-ID: 1607-7962/gra/EGU2008-A-05003
EGU General Assembly 2008

Mechanisms of stochastic resonance in a North Pacific wind-driven ocean model

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The low-frequency variability of the large-scale wind-driven ocean circulation has been extensively analyzed in the last two decades by means of process studies based on the so-called double-gyre model. In the typical approach a constant-in-time wind forcing is considered, so that the variability produced by intrinsic nonlinear mechanisms is better evidenced; however, in order to describe more realistic scenarios the effect of a variable component of the wind should also be considered. In this communication we show that a double-gyre model of the North Pacific ocean, known to produce a fairly realistic Kuroshio Extension (KE) decadal relaxation oscillation, exhibits mechanisms of coherence resonance (a case of stochastic resonance) if a noise is superimposed on the mean wind stress forcing. Coherence resonance occurs in excitable systems, i.e. in dynamical systems that have a stable state and a threshold to an excited state, which tends to decay over a time scale much larger than that of small perturbations about the stable state itself: in such a case an appropriate noise can excite the system, which will then relax spontaneously. In our model this kind of behavior is found to occur in a parameter range for which the system has not yet undergone the homoclinic bifurcation that generates the relaxation oscillation, but is close to it. In this case, with only a constant wind, unrealistically small amplitude periodic or chaotic oscillations of a contracted KE jet are present. If, however, a low-frequency noise is added, then the orbit is often able to leave the basin of attraction of the contracted state and spans a large region of phase space, in so reproducing a KE decadal cycle. Sensitivity numerical experiments show that the spectral content of the wind noise time-series is more critical than its amplitude, and that interannual variations are

necessary to excite the system. Finally, a fairly realistic seasonal wind forcing is added to the mean wind (in the absence of noise) to check if it is able to induce an analogous coherence resonance phenomenon. Not surprisingly (in view of the preceding result), the answer is negative: with this relatively high frequency forcing such mechanism cannot occur. In conclusion, these results provide insight into the role played by wind variations (from the seasonal to the interannual time-scale) on the decadal variability of the KE.