Nonlinear interaction between Sverdrup flow and basin modes in the quasi-geostrophic wind driven circulation

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ABSTRACT

The linear solution of the barotropic and baroclinic quasi-geostrophic wind driven circulation are decomposed in a weakly forced solution and a time dependent component. The steady wind forced solution consists in a classical Sverdrup flow dissipated in the western boundary layer where the viscosity is active while the homogeneous time dependent solution is a sum of oscillatory modes with arbitrary amplitudes.

The effect of the nonlinear terms is handled through a weakly nonlinear analysis providing a set of evolution equations for the modes amplitudes. We treat here the barotropic case. It can be proved that mode stability is related to the wind stress symmetry. Pure basin modes interactions yields tracts with cycling energy and sub-harmonic instabilities.

1. INTRODUCTION

From numerous time series of climate variability, it is now clear that there is significant variability on interannual to interdecadal time scales. Several paradigms apply to this low frequency variability of the climate system: from external forcing variability (solar cycles, volcanic eruption, atmospheric composition), to integration of atmospheric white noise by the ocean into a red spectrum framework given climatic model. To intrinsic modes of variability of the atmospheric jet-stream-ocean-inter-annual oceanic, or coupled systems. To the extent that the ocean intrinsic modes play an important role, the coupled ocean atmosphere will be more effective on climate variability.

2. ONE LAYER QUASI-GEOSTROPHIC CASE

One layer quasi-geostrophic dynamics

The non-dimensional one layer quasi-geostrophic evolution equations reads

\[ \frac{\partial \Psi}{\partial t} + \alpha \beta \frac{\partial \Psi}{\partial x} = -f \frac{\partial \Phi}{\partial y}, \]

\[ \frac{\partial \Phi}{\partial t} + \frac{\partial \Psi}{\partial x} = 0, \]

where \( f \) is the Coriolis parameter and \( \beta \) is the Coriolis parameter. The non-dimensional parameters are the Burger number and the sub-harmonic instabilities. The Burger number is defined as

\[ \frac{\epsilon}{\Omega^2} = \frac{\beta}{\Omega^2}, \]

where \( \epsilon \) is the wind forcing and \( \Omega \) is the critical frequency of the Rossby wave. The Burger number is a measure of the strength of the wind forcing compared to the critical frequency of the Rossby wave.

Weakly nonlinear expansion: Amplitude equations

The first order solution is then

\[ \psi_1 = \psi_0 + \epsilon \psi_1, \]

where \( \psi_0 \) is the solution of the steady flow and \( \psi_1 \) is the perturbation solution.

The steady state solution is obtained by setting \( \epsilon = 0 \) in the amplitude equations.

\[ \psi_0 = \psi_0(x), \]

where \( \psi_0 \) is the solution of the steady flow.

The nonlinear terms are handled through a weakly nonlinear analysis providing a set of evolution equations for the modes amplitudes. We treat here the barotropic case. It can be proved that mode stability is related to the wind stress symmetry. Pure basin modes interactions yields tracts with cycling energy and sub-harmonic instabilities.

3. TWO-LAYER QUASI-GEOSTROPHIC CASE

Two layers quasi-geostrophic dynamics

We decompose the flow in its barotropic and baroclinic components

\[ \psi = \psi_0 + \epsilon \psi_1, \]

where \( \psi_0 \) is the solution of the steady flow and \( \psi_1 \) is the perturbation solution.

The nonlinear terms are handled through a weakly nonlinear analysis providing a set of evolution equations for the modes amplitudes. We treat here the barotropic case. It can be proved that mode stability is related to the wind stress symmetry. Pure basin modes interactions yields tracts with cycling energy and sub-harmonic instabilities.

References