7.7 Extratropical Intra-Seasonal Variability in a Minimal Model

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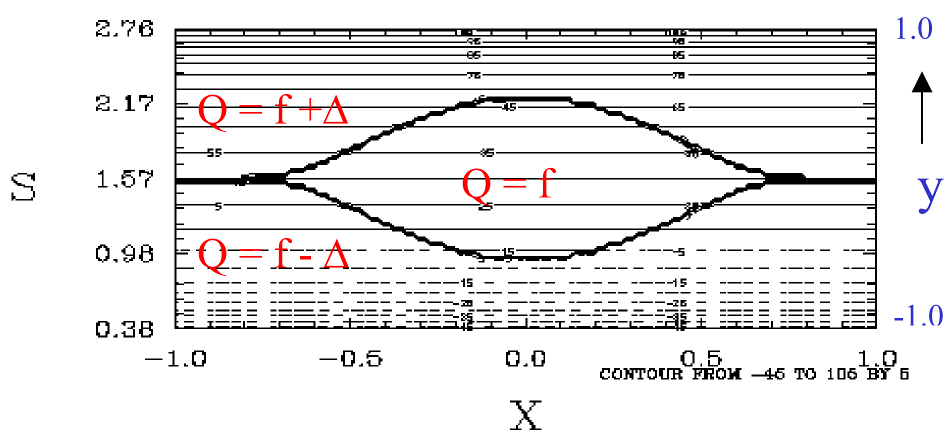
Excitation of extratropical intra-seasonal variability is investigated with a nonlinear quasi-geostrophic divergent barotropic model on a beta-plane. The forcing is introduced through an externally driven background potential vorticity (PV) field with temporal/spatial variations. It is an idealized version of the observed winter background PV at an upper isentropic level. The corresponding winter background flow has a time dependent localized jet with strong diffluence/confluence in an extensive downstream region bounded by two wave-guides. This temporally/spatially varying background winter flow can be linearly unstable with respect to synoptic-scale disturbances. The equilibrated disturbances interacting with the temporally varying background flow give rise to pronounced intra-seasonal variability of larger scale in winter. The model response is diagnosed in terms of empirical orthogonal functions of the disturbance field, the spectra of the leading principal components, the local energetics of the disturbance field as well as the potential vorticity dynamics. Most of the variance in the flow is associated with large zonally elongated disturbances, which have an intra-seasonal time scale. The results highlight the importance of seasonally varying forcing and non-linear dynamics in the excitation of intra-seasonal variability. The possible importance of additional stochastic forcing on intra-seasonal variability is also explored.

Model & results

Intra-seasonal variability is associated with large-scale disturbances that have intra-seasonal time scale, an equivalent barotropic structure and are mostly prevalent in winter. It would be relevant to investigate their dynamics in the context of a forced dissipative QG divergent barotropic channel model. The observed background PV field suggests that it would be relevant to consider an idealized annually varying background PV field, $P = Q(x,y)H(t_* - t)\sin(\omega t)$ for a relaxation forcing in the model with $H(t)$ a step-function, ω frequency of a year and $Q(x,y)$ shown below.

Fig.1 Background non-dimensional model PV field in mid-winter when $H(t_* - t)\sin(\omega t) = 1$



$S(y)$ is a meridionally stretched coordinate so that the resolution is highest in middle of the domain and progressively decreases away from it. The corresponding background flow $\Psi(x,y,t)$ can be linearly unstable. The evolution of the disturbance field is numerically integrated for a period of one year, $105 \geq t \geq 0$. The disturbance field is most intense in the winter season. The fluctuations are diagnosed in terms of the empirical orthogonal functions and their principal components of the disturbance streamfunction field.

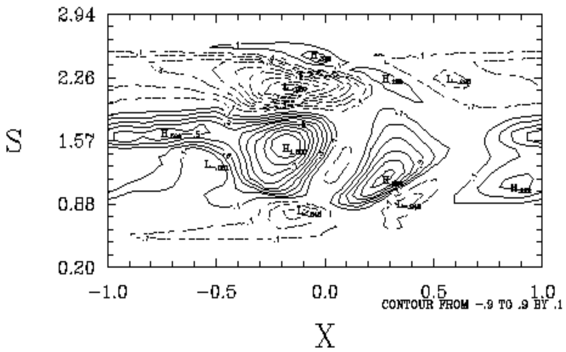


Fig.2 Structure of 1st EOF (33.3%)

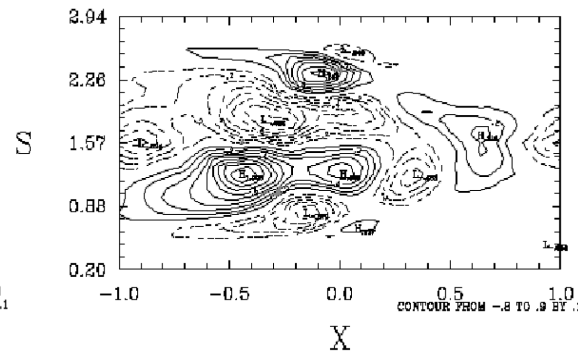


Fig.3 Structure of 2nd EOF (14.5%)

The structure of the 1st and 2nd EOF of the disturbance streamfunction are shown in Figs.2 & 3. Together they account for ~ 50% of the variance. They primarily consist of zonally elongated eddies compatible with observation. The maximum intensity is in the diffluent region downstream of the background jet. The 1st and 2nd PC have largest values in winter (Fig. 4). Most of the power in their spectra is of intra-seasonal scale (Fig.5; frequency = 0.01 corresponds to a period of ~35 days).

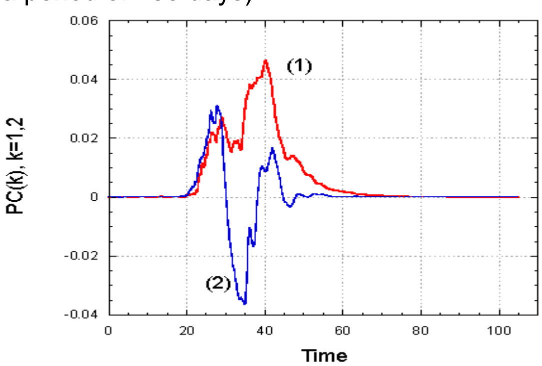


Fig.4 1st and 2nd principal components over one year

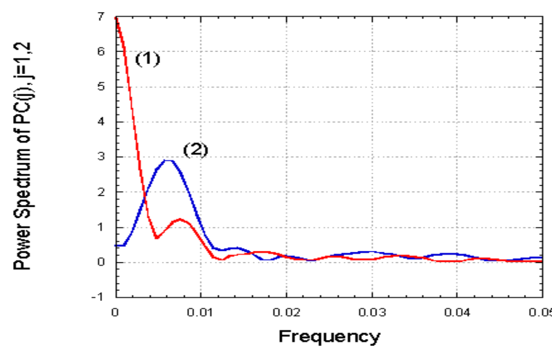


Fig.5 Power spectra of PC-1 and PC2

Other aspects of the model intra-seasonal variability will be discussed. In particular, Fig.6 shows that most of the development of the disturbance field occurs in the winter season.

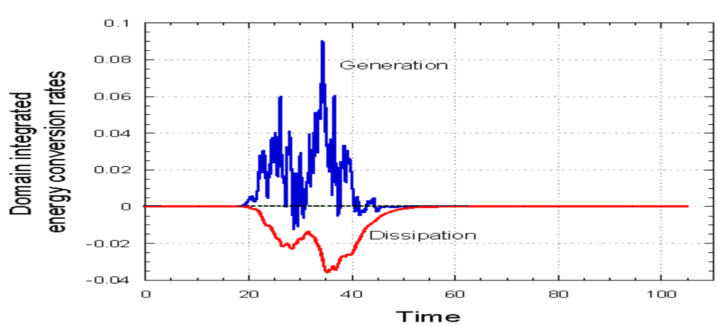


Fig.6 Variation of the instantaneous energy generation rate and dissipation rate over one year, $105 \geq t \geq 0$.