The scale-dependency of the signal-to-noise ratio in a regional oceanic system

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The internal variability is ubiquitous in the climate system; it emerges at all locations and times, at all scales (von Storch et al., 2001, Hasselmann, 1976). Tang et al. (2019) demonstrated the existence of the internal variability in a regional oceanic system., namely the South China Sea. Here, we conceptualize the variability coming from the external forcing as "signal", and the variability coming from the internal variability as "noise".

By using an ensemble of four simulations of the flow in the South China Sea with the same ocean models exposed to the same atmospheric forcing as recorded in 2008, which differ only in the initial conditions, the scale-dependency of the signal-to-noise (S/N) ratio of the barotropic flow is studied. The barotropic velocities is stored one per day. Although these members are almost identical except the initial condition, there are significant notable differences between the.

The "signal" is measured by the ensemble mean computed as $\mu(t)=\langle X(t)\rangle$. The "noise" is measured by the standard deviation σ between the four members of the ensemble, i.e., by $\sigma(t) = \sqrt{\left(\sum_{i=1}^{4}(X_i(t) - \mu(t))^2\right)/4}$. Thus, the S/N ratio is the ratio between the standard deviation of the time series of $\mu(t)$ across 2008, and the standard deviation $\sigma(t)$ of the variations relative to $\mu(t)$ in 2008.

For studying the scale dependency of the S/N ratio, we determine first the EOFs of the daily barotropic velocity potential across all four 2008-simulations. The EOFs are ranked as usual, with an index sorted according to the percentage of explained variance. An inspection of the patterns reveals that low-indexed EOFs go with large scales, medium-indexed EOFs with medium scales and high-indexed one with small scales. Thus, principal components of these EOFs are associated with scales, which decrease with increasing indices of the EOFs.

Figure 1 shows the distribution of the S/N ratio as a function of the index of EOFs. We find that the S/N ratios decline with the increases of the EOFs-indices. This means that the variability of the large-scale components of the barotropic ocean dynamics is mainly controlled by the external forcing while the influence of internal variability is mostly negligible, in other words - the S/N ratio is high. On the other hand, the small-scale barotropic dynamics is associated with small S/N ratios, which indicates that the external forcing is weak and internal variability is dominant,

Based on the distribution of the S/N ratio, we divide the scales in three boxes, EOF 1-10, EOF 11-50 and EOF 50-1400.Then in order to get the map of the S/N ratio, we use the daily barotropic states for the range of EOFs as X at each point for computing the S/N ratio (Figure 2).

By studying the scale-dependency of the S/N ratio, this work demonstrates that the small-scale variability in the South China Sea is not only influenced by the external forcing but also by the internal variability. The significance of the externally driven component, and of the internally driven component, changes with the scale; the larger the scale, the more important the external forcing, the smaller the scale, the more the internal generated variability.

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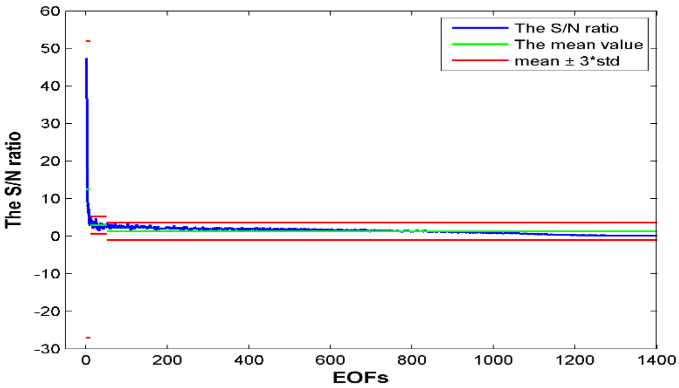

Figure 1 The S/N ratios as a function of EOF index. Small scales are situated at the right end, large-scales at the left end. Based on the distribution of the S/N ratio, the scales (EOFs) are divided into three boxes, EOF 1-10, EOF 11-50 and EOF 51-1400. The green line in each box is the mean value of the ratio values, and the red lines above and below the green line in each box are the mean value ± 3 standard deviation of the S/N ratio in the same box, respectively.

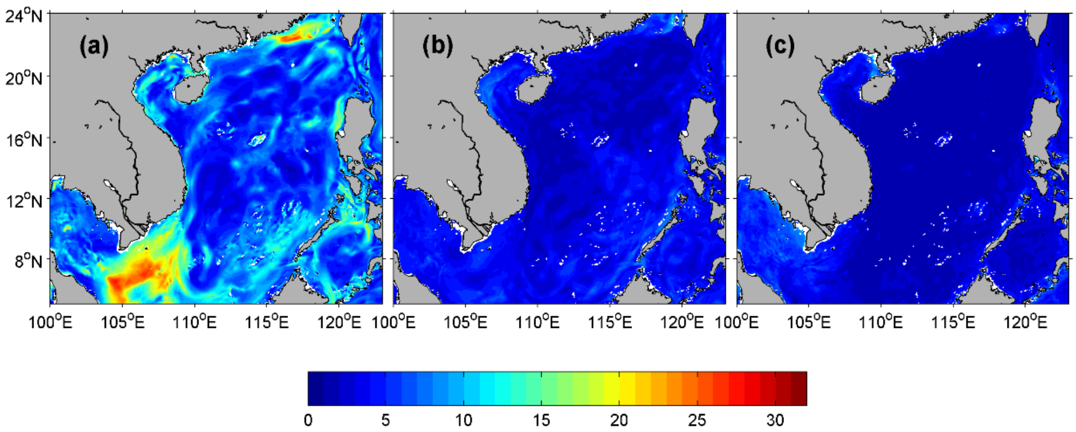

Figure 2 Maps of the S/N ratio for (a) the first box EOF 1-10, (b) the second box EOF 11-50, (c) the third box EOF 51-1400.