J12.12 LIFE SPAN OF SUBSEASONAL LOCALLY COUPLED ANOMALIES

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1. INTRODUCTION

The life span of atmospheric anomalies is an issue of scientific and practical value. Much effort has been dedicated to understand the mechanisms that control the duration of anomalies, particularly for events when anomalies last unusually long. It is commonly observed that these long-lasting atmospheric anomalies tend to coincide with long periods of anomalies in surface variables such as SST over the ocean or surface temperature over land. The direct relationship of the atmosphere with other components of the climate system is clear from observational studies since the weekly and monthly average data of atmospheric anomalies are well correlated with surface variables (e.g., Wallace and Jiang, 1987; Deser and Timlin, 1997, Peña et al, 2003). Whether surface anomalous conditions are involved in the duration of atmospheric anomalies has been proposed in the past (e.g., Namias, 1974), but a mechanistic understanding has only being feasible until recently with the use of more realistic GCMs (e.g., Hong and Kalnay, 2002).

The life span of anomalies is also related with predictability. In the synoptic timescales, it has been shown by Tracton et al (1989) that the skill of numerical weather predictions tend to be higher when the anomalies are persistent. For longer timescales, it has been suggested that the coupling of the atmosphere with the surface conditions damps the decaying rate of the anomaly, thus, persisting the anomaly (Barsugli, 1995), and has also been considered an opportunity to produce skillful predictions beyond the intrinsic limit of atmospheric predictability (e.g., Shukla, et al 2000). For example, since the SST anomalies decay much more slowly than the atmospheric anomalies, they may be able to produce a persistent forcing, and therefore, prolong the lifespan of the atmospheric anomalies. Fully coupled GCMs, aimed at capitalizing on the long memory of the ocean, ice and land climate variables, are still under development and require more understanding on the nature of coupling between climate systems. The complexity of these models has led to a simpler approach to perform dynamical extended range predictions: One-way interaction approach. This is the so-called two-tier approach that consists on prescribing forecasted SST anomalies to atmospheric GCMs. The scheme allows for the ocean to influence the atmosphere but not the other way around. This assumption that the ocean *always* forces the atmosphere is incorrect, particularly in the extratropics. An assessment of whether ignoring the atmospheric feedback has an impact on the duration and the skill of extended predictions is clearly needed.

We here attempt to answer the following question: whether long-lasting atmospheric anomalies have a preferential local phase relationship with locally coupled anomalies in the surface boundary. As described in Mo and Kalnay (1991), the local phase relationship between low-level circulation and SST may indicate the predominant forcing direction in locally coupled anomalies.

2. DATA AND METHOD

This study is an extension to the study by Peña et al. (2003) where details on the data and procedure to diagnose the forcing direction of anomalies over the ocean can be found. Here we analyze the effect of SST anomalies (over the ocean) and the skin temperature (ST, over land) on locally coincident 850 hPa relative vorticity anomalies in the 5-days average data from both the NCEP/NCAR reanalysis (Kalnay et al 1996) and an NCEP AMIP run for the period 1980-1998 (see Gates et al., 1999 for a description of AMIP). The annual cycle, represented by the first two annual harmonics, was subtracted from the time series of each grid point of both fields. We considered only anomalies whose departure from the annual cycle continuously exceeded one standard deviation for at least 15 days in the 5-day average data. We refer to these high-amplitude long-lasting anomalies as *locally coupled* when they occur simultaneously in both the SST and the relative vorticity fields. We have deliberately reversed the sign of the relative vorticity field in the Southern Hemisphere. Thus positive vorticity anomalies are cyclonic, and negative anomalies anticyclonic in both hemispheres.

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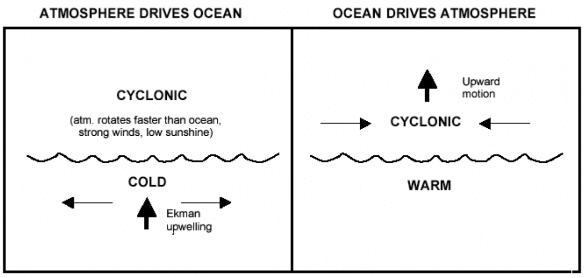

Fig. 1 Schematic of the local phase relationship between SST and the low-level atmospheric vorticity depending on whether the atmosphere drives the ocean (left) or the ocean drives the atmosphere (right).

A similar classification is made for the locally coupled anomalies over land. Because of the rapid adjustment of the ST over land to atmospheric anomalies, there is not an immediate interpretation for the forcing direction as there is over the ocean. We denote **coupled anomalies as having the "same sign"** when they are cyclonic over warm or anti-cyclonic over cold, and **coupled with "opposite sign"** when they are cyclonic over cold or anti-cyclonic over warm.

3. DISTRIBUTION OF LONG LASTING ANOMALIES

For each grid point we computed the number of atmospheric anomalies, the number of atmospheric anomalies locally coupled with SST and ST over the ocean and land, respectively, and the number of cases of coupled with "same sign" and "opposite sign". The percentage of long-lasting coupled atmospheric anomalies with "opposite sign" is shown in Fig.2.

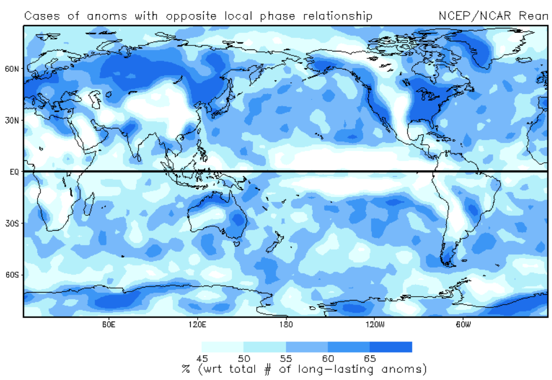

Fig. 2 Percentage of the number of cases of locally coupled anomalies with "opposite sign" (land and ocean).

The figure indicates a tendency of more "opposite sign" anomalies over the extratropical ocean, which according to the dynamical rule (Fig. 1) implies more atmosphere-driving anomalies. In contrast, in the tropics more than 50% of the cases have "same sign" or "ocean-driving anomalies". These results are in agreement with past studies that suggest the atmosphere tends to force the ocean in the extratropics and the ocean tends to force the atmosphere in the tropics (e.g., Kushnir, et al 2002, for a review). They are also consistent with lag/lead cross-correlation statistics. The distribution is almost identical to Fig. 2 if we use instead of the NCEP/NCAR reanalysis the ECMWF-15 reanalysis data. While in the extratropical oceans the distribution is uniform, over the tropics, there is a clear difference between the central and eastern Pacific and the rest of the tropical oceans. This suggests that an additional diagnostic rule might be necessary for guidance on the forcing direction in coupled anomalies depending on the background flow.

Another important conclusion that can be drawn from the figure is the well-marked regional differences over land. The regions of "opposite" sign" tend to occur in the regions of high availability of moisture (not shown), such as the Eastern U.S., and in some arid zones. Whether this can help detect possible mechanisms involved in the duration of anomalies will require analysis of other variables. A closer look at the local phase relationship between skin temperature and low-level circulation anomalies, for example, over the U.S., reveals three distinct regions, which are shown in Fig. 3 using cross-correlation statistics for the warm season: regions with predominant "opposite sign" (or negative correlation), transitional zone (nearly zero correlation) and regions with predominant "same sign" (or positive correlation).

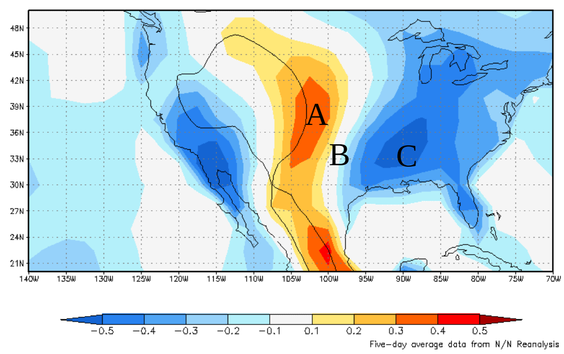

Fig. 3. Cross-correlation of 850hPa and Skin temperature (SST over the ocean) over the conterminous U.S. for the JJA months. The 1.5 km height is plotted as a black contour. A, B and C

correspond to “same sign”, “transition” and “opposite sign” regions. See text for details.

4. ZONAL MEAN NUMBER OF ANOMALIES OVER OCEAN

We computed the mean number of atmospheric anomalies over the ocean as a function of latitude and classified them according to their duration. These statistics help distinguish the impact of both the coupling with the underlying SST and the forcing direction on the duration of the anomaly. Our results (Fig. 4) indicate that the longest lasting anomalies occur more often in the deep tropics than in the extratropics and, more importantly, that almost all the long-lasting anomalies are locally coupled with SST anomalies.

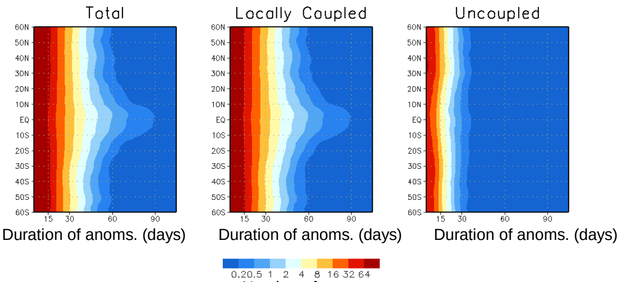

Fig. 4 Zonally averaged number of 850 hPa Relative Vorticity (RV) anomalies over the ocean versus duration of anomalies (a) total over 19 years, (b) locally coupled with SST anomalies, and (c) locally uncoupled.

We apply the dynamical rule (Fig. 1) to diagnose the forcing direction of the locally coupled anomalies and obtain two distributions one for the “ocean-driving” and another for the “atmosphere-driving” cases. Fig. 5 shows the difference of these two distributions. In the deep tropics, “ocean-driving” anomalies tend to last longer than “atmosphere-driving” whereas in the extratropics it is the reverse. It also shows that “atmosphere-driving” anomalies do exist in the tropics and “ocean-driving” do exist in the extratropics but they tend to decay much faster.

Fig. 5 also shows differences between the northern and the southern hemisphere. Particularly interesting is the larger number of “ocean-driving” in the S.H. extratropics than in the N.H. extratropics. This difference arises from the existence of the Southern Hemisphere Convergence Zones in both the Atlantic and Pacific.

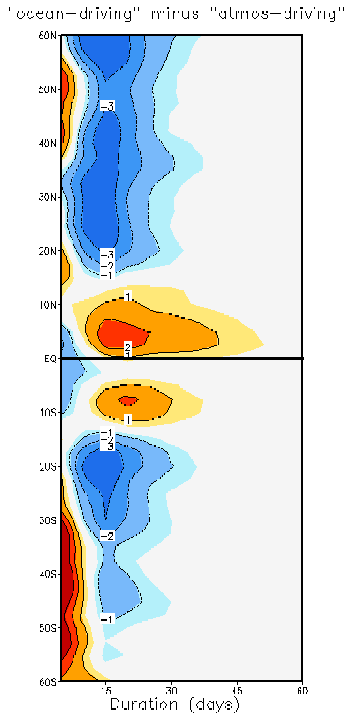

Fig. 5 Difference between the distribution of zonal mean of “ocean-driving” and the distribution of “atmosphere-driving” cases.

5. TWO-WAY VERSUS OCEAN-DRIVING (AMIP) SCENARIO

The impact of neglecting the feedback of the atmosphere upon the ocean can be quantified by comparing the statistics generated in data that contains the two-way ocean-atmosphere interactions, such as the Reanalysis, with model data with prescribed SST, where the ocean always forces the atmosphere. We computed the zonal mean distribution of duration of atmospheric anomalies using both datasets. The difference between these two distributions, given in Fig. 6, indicates that the ocean-driving scenario tends to produce more longer-lasting anomalies in the tropics and more shorter-living anomalies in the extratropics than observed in the Reanalysis. Since the ocean has a longer memory and thus provides a longer lasting forcing to the atmosphere one might expect that simulated anomalies would be more persistent than observed anomalies. However, this only happens in the tropics, where the dominance of the ocean-driving scenario in the AMIP run is correct. In extratropics, the artificially longer lasting forcing from the prescribed SST actually damps out the atmospheric anomalies much faster than in the real system.

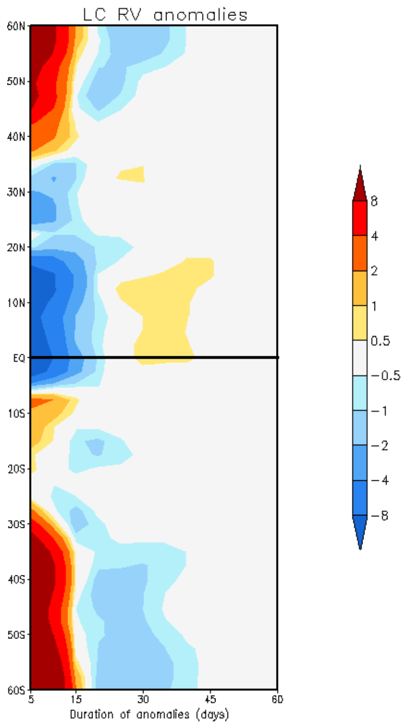

Fig. 6 Difference between the distributions of zonal mean number of cases of coupled anomalies in the reanalysis and in the AMIP run.

6. DISCUSSION

The procedure and statistics presented here, although simple, give new insight on the nature of the coupling of atmospheric anomalies with anomalies in the surface boundary conditions. Particularly interesting is the finding that the long-lasting atmospheric anomalies in the 5-days average data tend to have a particular phase relationship with the local surface temperature anomalies. For the anomalies over the ocean, each particular local phase relationship between low-level circulation and SST has been interpreted as indicative of a predominant forcing direction. Over land, the forcing direction may be more difficult to distinguish because the adjustment of land is more rapid. We are encouraged by the fact that the regions "same-sign", "neutral", and "opposite-sign" (Fig. 3) are more or less similar to the regions found using in GCM studies (Koster and Suarez, 2003).

Although it is difficult to know with certainty what causes the extratropical "atmosphere-driving" anomalies last longer than "ocean-driving" anomalies, one may be able to obtain a qualitative guidance for extended range prediction using a result as that given in Fig. 5. For example, suppose that the northern Pacific is dominated by a low-level circulation atmospheric anomaly that is in negative relationship with an underlying SST anomaly. That is, we diagnose an "atmosphere-driving" anomaly. We would then expect to have more skill using persistence than when the anomaly is "ocean-driving". On the other hand, if we were to have a model with an "ocean-driving" scheme we would expect to have a lower skill in "atmosphere-driving" situations than otherwise. We have analyzed the skill of the 25-day forecasts from the Reanalysis carried out by CDC (Whitaker, pers. comm.). The results confirm this hypothesis (Fig. 7).

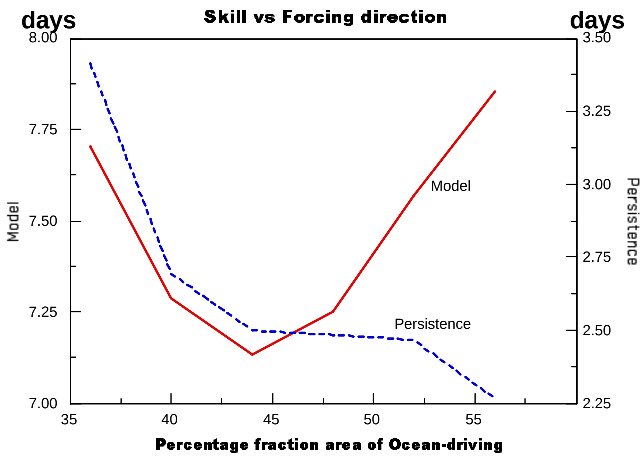

Fig. 7 Number of days with Forecast Anomaly Correlation > 0.5 using persistence (dotted blue) and using the GFS model (red), as a function of the fraction area of "ocean-driving" anomalies for the Northern Pacific region.

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