11.2 MONSOON PREDICTABILITY OF ECMWF ENSEMBLE SEASONAL SIMULATIONS

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1. INTRODUCTION

It is commonly accepted that the atmosphere behaves as a chaotic system (e.g. Lorenz, 1993; Palmer, 1993), and as a consequence, deterministic predictability is limited. However, it is also well know that at many locations, predictability of seasonal weather statistics is also possible (Palmer and Anderson, 1994). This arises from what may be termed "external" factors that alter the likelihood of residence in atmospheric attractors (cf. Palmer, 1993), enabling probalistic forecasts to be made of the seasonal mean state, on the condition that the external forcing is itself predictable. The primary source of such external forcing at seasonal timescales arises from anomalous sea surface temperature (SST) patterns (Barnston et al., 1994). It is clearly important to be able to access where on the global atmospheric variations are sufficiently affected by oceanic forcing to enable practical seasonal prediction. This requires measurements of atmospheric potential predictability. Recently, potential predictability has been measured using an ensemble of climate simulations, where all are forced by the same observed interannually varying SSTs but started from different initial atmospheric conditions (Kumar and Hoerling, 1995; Rowell, 1998; Brankovic and Palmer, 2000). For predictability study, the sensitivity to initial atmospheric conditions can be used to quantify the random component of interannual variability, where as the relative similarity (or lack of it) between ensemble members can be used to quantify the potentially predictable component of variance. The standard statistical tool for this kind of problem is "analysis of variance" (ANOVA). A particular advantage of the ensemble approach is that it is more powerful at detecting weak influences of SST (Rowell, 1998), but it has the disadvantage of relying primarily on a model's climate skill.

This this study, a set of ensemble seasonal integrations made with the European Centre for Medium-Range Weather Forecasts (ECMWF) model and ANOVA are used together to provide a global and regional assessment of potential seasonal predictability. Since the summer monsoon is one of the main climate feature over Asia, several summer monsoon indices (Wang and Fan, 1999) are also chosen for the assessment of their seasonal predictability.

2. SEASONAL ENSEMBLE EXPERIMENTS AND STATISTICAL ANALYSIS

The model version used for the integrations was ECMWF cycle 13R4 with semi-Lagrangian dynamics at T63L31 resolution. Nine-member ensembles were run over all seasons for the ERA-15 period, 1979-1993. The experimental set consists of ensembles of 14 northern winter and 15 northern spring, summer, and autumn seasons. The experiments were initiated from consecutive 1200 UTC ERA-15 analyses, from 1 to 9 days preceding the season of interest. The length of integration was 4 months. The model was run with observed prescribed SSTs taken from ERA-15 and updated daily in the integrations.

The prime statistical tool employed in this study is ANOVA. It is used with data from an ensemble of climate simulations to separate the total atmospheric variance (σ^2_{TOT}) of some time-averaged quantity into two component, one due to oceanic (SST) forcing (σ^2_{SST}), and the other component due to random internal variability (σ^2_{INT}). Potential predictability is then measured as the ratio of ocean-forced variance to total variance ($\sigma^2_{SST}/\sigma^2_{TOT}$), having an intuitive scale of 0%-100%. The main advantage of ANOVA is that having been used extensively in other scientific applications (Rowell, 1998).

3. POTENTIAL PREDICTABILITY ASSESSMENT

3.1 *Mean Sea Level Pressure and Precipitation*

Fig. 1 shows the seasonal potential predictability for northern summer. Not surprisingly, it exhibits a strong impact of SSTs in the Tropics (cf. Charney and Shukla, 1981; Palmer and Anderson, 1994) and conversely much greater chaotic variability in the extratropics. Consider the predictability of precipitation over tropical oceans, which is important because of the impact that deep convective heating has on predictability in teleconnected regions. Over the equatorial Pacific, the variance ratio pattern seems linked to the typical evolution of SST anomalies during ENSO events, perhaps because larger anomalies can have a greater impact on local convection relative to random internal variability. Over the Indian Ocean, the potential predictability is somewhat lower.

It is over land that predictability of seasonal precipitation is of greatest societal importance. Over the Indonesian archipelago, the model reflects the work of Ropelweski and Halpert (1987). The low predictability for the wet season of India and Southeast Asia is consistent with the work and ideas

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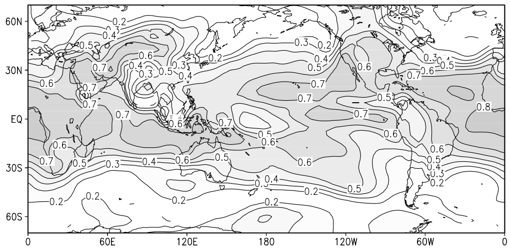
of Goswami (1994), and Brankovic and Palmer (1997). For MSLP, the spatial and seasonal pattern of variance ratio have many interesting differences from those for precipitation. Most striking is the larger latitudinal range of high MSLP predictability, presumably reflecting the larger spatial coherence of MSLP and the impact of random isolated showers on rainfall totals in the arid subtropics.

3.2 *Summer Monsoon Index*

Charney and Shukla (1981) show that anomalies in SST and in ground albedo are capable of producing large variances. Since these anomalies are usually of long duration, the possibility arises that mean monthly conditions at low latitudes, such as monsoon rainfall, maybe predictable with some accuracy. They suggest that the synoptic-scale flow instability which limit prediction so drastically at midlatitudes have less influence at low latitudes and therefore leave room for longer-period and more predictable signals. Their results show a rather high signal to noise ratio over the Indian monsoon region (Table 6.1 in Charney and Shukla, 1981).

In this section we use the summer monsoon indices chosen by the study of Wang and Fan (1999). The includes the first convective index, CI1 (mean OLR over 10N-25N, 70E-100E region), the second convective index, CI2 (mean OLR over 10N-20N, 115E-140E region), The first monsoon circulation index, MCI1 (mean zonal wind shear between 850 and 200 hPa, U850-U200, over 5N-20N, 40E-80E region), and second monsoon circulation index, MCI2 (mean differences in 850 hPa zonal wind between 5N-15N, 90E-130E region and 22.5N-32.5N, 110E-140E region)

(a) MSLP SigmaSST^2/SigmaTOT^2



(b) TOT PRECIP SigmaSST^2/SigmaTOT^2

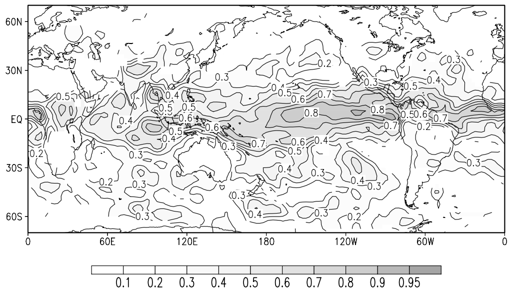


Fig.1 Variance ratio ($\sigma^2_{SST}/\sigma^2_{TOT}$) of summer mean (a) MSLP, and (b) Precipitation, computed from the ensemble of nine 1979-93 runs.

The same variance analysis is applied to the four summer monsoon indices to evaluation their potential predictability and shown in Table 1.

Table1. Comparison of the variance ratio, $\sigma^2_{SST}/\sigma^2_{TOT}$, of the four summer monsoon indices

	CI1	CI2	MCI1	MCI2
$\sigma^2_{SST}/\sigma^2_{TOT}$	0.36	0.58	0.41	0.62

It is somewhat surprised to see that both the convective and circulation indices for the East Asia summer monsoon actually have greater potential predictability than the similar indices for the India summer monsoon. It is also somewhat contradictory to the Charney and Shukla's result mentioned earlier.

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