

Review of seasonal forecasting techniques and their applicability to Southern Africa

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Abstract

The development of a seasonal rainfall forecasting capability has recently become a priority of many research organisations in Southern Africa, but the methodologies used are still at an early stage of development. In other areas, high forecast skills are generally associated with tropical atmospheric variability, largely because of a thermally direct response of the tropical atmosphere to oceanic heat anomalies. Over South Africa, most current forecast skill relates to rainfall variability attributable to the tropical atmospheric circulation, including El Niño-Southern Oscillation (ENSO)-related anomalies. Consequently, highest forecastability exists in the summer rainfall region during the peak rainfall months, December to February, and is particularly high in areas that are strongly affected by ENSO activity. The extratropical atmosphere has an important influence on the rainfall of the region during the first half of the summer season, when forecast skill is relatively low. Occasionally, the extratropical atmosphere also remains dominant during the peak summer months, resulting in a poor forecast for that season. Consequently, an improved understanding of the response of the temperate atmosphere to tropical anomalies and internal blocking should result in considerably improved skill for seasonal forecasts throughout the summer season.

Introduction

The development of skilful extended-range weather prediction and seasonal forecasting capabilities has direct economic benefits (Madden, 1977; Preisendorfer and Mobley, 1984; Gilman, 1985; Namias, 1985; Brown et al., 1986; Sonka et al., 1986; Livezey and Barnston, 1988; Preisendorfer et al., 1988; Barnston and Livezey, 1989; Livezey, 1990a; Livezey et al., 1990, 1994; Palmer and Anderson, 1994). To illustrate, for the United States potential savings over ten years to the agricultural sector from seasonal forecasts, with only 60 per cent accuracy, are estimated to be between \$0.5 and \$1.1 bn. (O'Brien, 1992). In sub-Saharan Africa, seasonal rainfall forecasting capabilities could contribute substantially to food security and natural resource management (Hulme et al., 1992a; Mjelde et al., 1993), and benefit industry substantially (Greis, 1982; Weiss, 1982; Sonka et al., 1987; Livezey, 1990a; Harrison et al., 1991). Equally, Southern Africa should benefit considerably from skilful forecasts of rainfall and temperature. The development of such a facility has accordingly become a high priority of several research organisations within South Africa and neighbouring countries.

Techniques for predicting the future behaviour of the atmosphere are determined to a large extent by the required lead-time of the forecast (Namias, 1985). Forecast lead-times range from a few hours or days, for highly skilful numerical weather prediction, to decades, in the case of climate prediction (Fig. 1) (Lawson et al., 1984). The development of numerical weather prediction models over the last two decades has seen a remarkable improvement in the ability to predict weather conditions several days in advance (Palmer and Anderson, 1994). Several meteorological organisations make use of such models (e.g. National Meteorological Centre, NMC, and European Centre for Medium-range Weather Forecasting, ECMWF) as operational

forecasting tools. These models provide short-term (up to 3 d) deterministic predictions of global weather with considerable skill.

There is, however, a theoretical limit to deterministic weather prediction of about 15 d owing to the internal chaotic variability of the atmosphere, which tends to exaggerate any initial errors in measurements and model inaccuracies (Thompson, 1957; Lorenz, 1963, 1984, 1990; Shukla, 1981; Somerville, 1987; Brankovic et al., 1990; Palmer et al., 1990; Palmer and Anderson, 1993, 1994). Beyond this theoretical limit to deterministic forecasts, extended range weather predictions of up to 30 d are based on the probability of a change in the current weather regime, within the forecast period (Legras and Ghil, 1985; Reinhold, 1987). An ensemble of forecasts is used to define the probability of a change and the nature of any subsequent regime (Mureau et al., 1993).

On the seasonal time-scale, a number of different weather regimes are likely to occur and interact. Although it is impossible to forecast this variability because of the inherent chaotic behaviour of the atmosphere, it may be possible to identify which regimes will be most probable (Legras and Ghil, 1985; Palmer and Anderson, 1994). The probability of specific weather regimes is affected by underlying boundary conditions such as sea-surface temperatures, ice cover and land-surface characteristics. The boundary conditions generally evolve relatively slowly, and so can be used to provide a forecast of different weather regime probabilities (Shukla, 1981; Legras and Ghil, 1985; Palmer and Anderson, 1994).

In this paper, a review of seasonal forecasting techniques is presented. Firstly, a review of seasonal forecasting skill for different regions of the world is presented. Secondly, an assessment of the prospects for improving forecast skill and lead times for Southern Africa is presented.

Approaches to seasonal forecasting

Predictions of the seasonal behaviour of the atmosphere are made using both empirically- and physically-based models. Physical models attempt to forecast the time-averaged future atmospheric

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Received 23 January 1995; accepted in revised form 15 April 1996.