The Influence of Intraseasonal Variations on Medium- to Extended-Range Weather Forecasts over South America

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1. Introduction

The climatology of the large-scale circulation over South America shows intense convective activity during the austral summer, especially over the Amazon basin. Many previous studies have demonstrated that associated with the region of deep cumulus convection and intense precipitation, there is an upper-level anticyclone, the Bolivian high, and a downstream trough over northeast Brazil (Horel et al. 1989; Jones 1990; Lenters and Cook 1999). Another region with prominent cloudiness features, the South Atlantic Convergence Zone (SACZ), extends from southeast Brazil toward the western portion of the subtropical Atlantic Ocean (Jones and Horel 1991). The convective activity and summertime precipitation in South America vary over wide ranges of time and space scales. While convection in the Amazon basin exhibits strong diurnal and seasonal changes, intraseasonal (10–90 days) variations are more pronounced over the SACZ. At 30–60 days the Madden–Julian Oscillation (MJO; Madden and Julian 1994) shows an important modulation of the SACZ. Teleconnection studies, for instance, have indicated that the 30–60-day variability over the SACZ region can be forced by Rossby wave propagation linked to MJO events in the Pacific Ocean (Grimm and Silva Dias 1995). Furthermore, spectral analysis of outgoing longwave radiation (OLR) reveals additional intraseasonal variability (27, 16, 10, and 8 days) along the SACZ (Liebmann et al. 1999).

An important question one may ask is how the skill of numerical weather prediction is affected when one type of intraseasonal variation over the SACZ is more predominant than the remaining ones. In a recent study, Nogue’s-Paegle et al. (1998) (hereafter NPMP) examined the skill of 8-day forecasts generated from initial conditions every 5 days by the National Centers for Environmental Prediction–National Center for Atmospheric Research (NCEP–NCAR) reanalysis project (Kalnay et al. 1996). Using OLR anomalies in the 10–90-day band, NPMP identified periods of enhanced (strong SACZ) and suppressed (weak SACZ) convective activity (see NPMP for details on the methodology) and calculated the root-mean-square errors of 500-hPa geopotential height over the Pan American region (PAN) (60°S–60°N, 120°–30°W). An interesting result in NPMP is that initial forecast errors during weak SACZ are smaller than for strong events. The growth rate of the errors during weak SACZs, however, is larger than the growth rate of strong SACZ cases. Their results show that the strengthening and southward extension of the SACZ is connected to the ITCZ in the central Pacific. In contrast, the weakening of the SACZ is related to suppressed convection in the central Pacific but enhanced convective activity in the western and eastern Pacific. The different behavior in the predictability during strong versus weak SACZ events deserves additional investigation. The purpose of this note is to further motivate research on the influence of intraseasonal variations in the predictive skill over the SACZ. As is pointed out above, the SACZ exhibits a wide range of intraseasonal variability. Therefore, this study considers the errors in numerical weather forecasts in South America for two types of variations: 30–70 days and 10–30 days. The former is directly related to the MJO, while the latter is still intraseasonal but not necessarily linked to the 30–60-day oscillation.

2. Methodology

In this study we use results from the recent Dynamical Extended Range Forecast (DERF) experiment conclu-
ed with the reanalysis version of the Medium Range Forecast (MRF) model (Schemm et al. 1996; see also Jones et al. 1998). The present DERF experiment includes 50-day forecasts, initialized once a day (0000 UTC) with reanalyses fields, and covering the 5-yr period from 1 January 1985 to 31 December 1989. In the present version of the DERF forecast runs, the sea surface temperature (SST) is damped from its initial observed values to climatology using a 90-day e-folding time. The reanalysis version of the MRF model is identical to the NCEP global operational model of 1996, except the horizontal spectral resolution is reduced to T62 (equivalent to 210 km) (Kalnay et al. 1996). The NCEP–NCAR reanalysis fields at 0000 UTC are used for forecast verification and we limit our discussion to errors in 500-hPa geopotential height ($Z_{500}$) in the austral summer (1 November–31 March; 1985–86, 1986–87, 1987–88, and 1988–89). Time filtering was applied to verification and forecast fields in order to compute anomalies from the annual cycle, which was determined by averaging the 5 yr of reanalysis and computing the first two harmonics. The annual cycle constructed with the mean and first two harmonics was then subtracted from the time series of $Z_{500}$. No other filtering is applied to the forecasts and reanalysis.

Intraseasonal convective activity over the SACZ is selected according to the magnitude of OLR anomalies. Pentads of OLR were obtained from NCEP from 1–5 January 1979 through 27–31 December 1996. To obtain intraseasonal anomalies, two Lanczos band-pass filters with 49 weights were applied to the OLR pentads [see Jones et al. (2000) for details on time filtering]. Figure 1 shows the frequency responses of the two band-pass filters: 30–70 days and 10–30 days. The first band is denoted here as intraseasonal type 1 (IS1), while the second is intraseasonal type 2 (IS2).

3. Results

Before examining the skill of the MRF model over the SACZ region for each band of intraseasonal variations, it is instructive to discuss the mean summertime $Z_{500}$ and the standard deviation fields (Fig. 2). The mean $Z_{500}$ (top) indicates a midtroposphere maximum associated with the Bolivian high and strong horizontal gradients in subtropical and middle latitudes of South America. The total standard deviation in $Z_{500}$ (bottom) shows, as expected, small magnitudes near the equatorial region and increasing variability toward the mid-latitudes of the Southern Hemisphere. Anomaly correlations between $Z_{500}$ forecasts and verification fields for all days during the four summer seasons were computed for 1–20 days lead time (Fig. 3). The MRF model shows higher skill (correlations greater than 0.7 for 1 day lead time) in a narrow band over subtropical South America. Note that near the equatorial region the skill is less and progressively breaks down toward higher latitudes as the lead time increases. These results can be compared to the errors in the forecasts for each IS1 and IS2 band discussed next.

Figure 4a displays the mean OLR during the austral summer and Fig. 4b shows the total standard deviation (i.e., variations greater than two pentads and shorter than the seasonal average). Although the lowest values of OLR, indicative of strong tropical convection, are observed over the Amazon basin, the largest variability is...
found over eastern South America. The standard deviations of OLR anomalies (OLRA) in the 30–70 days and 10–30 days are shown in Figs. 4c,d respectively, and indicate that intraseasonal variations account for a large part of the total variance (Liebmann et al. 1999). Based on the spatial pattern of the OLRA variability, we defined a base region (solid lines) in which the magnitudes of the OLRA were used to characterize periods of weak (strong) SACZ. The extent of the base region is chosen to represent the mean position of the SACZ. A time series of 30–70-day OLRA spatially averaged in the base region was constructed and periods above (below) 0.8 (−0.8) standard deviation during the austral summer were selected. The weak events are denoted IS1 positive (IS1 pos), while the strong are IS1 negative (IS1 neg). In addition, periods of very inactive SACZ were selected when the magnitudes of the 30–70-day OLRA values in the base region were between ±0.3 standard deviation (IS1 null). Likewise, a time series of 10–30-day OLRA was constructed over the base region. Periods of weak IS2 variability were selected when OLRA are above 0.8 standard deviation (IS2 pos); strong when OLRA are below −0.8 standard deviation (IS2 neg); and null events when OLRA are between ±0.3 standard deviation (IS2 null). The frequency distributions of the selected IS1 and IS2 events per season are plotted in Fig. 5. For the IS1 type (top) there are a total of 27 (IS1 pos), 29 (IS1 neg), and 32 (IS1 null) pentads, which represent 11, 11, and 20 independent events, respectively. Similarly, for IS2 type there are 23 (IS2 pos), 23 (IS2 neg), and 34 (IS2 null) pentads, so that 20, 19, and 22 are independent events. We consider independent events nonconsecutive pentads.

The skill of the MRF model in forecasting Z500 was examined for each sample of intraseasonal variability defined above (IS1 and IS2). Two skill measures, anomaly correlation and root-mean-square (rms) error, were computed for samples IS1 pos, IS1 neg, IS1 null, IS2 pos, IS2 neg, and IS2 null. The statistics were then averaged over the SACZ base region indicated in Fig. 4 (solid lines) and over the South America region defined by (40°S–20°N; 90°–20°W). Figure 6 shows the anomaly correlation averaged over the SACZ domain (top) and over the South American domain (bottom). The anomaly correlation during IS1 averaged over the SACZ domain (top left) indicates that the correlations start at about the same values (0.65) for IS1 pos, IS1 neg, and IS1 null for 1-day lead time. Note that these values are averaged over the SACZ domain and the MRF model shows higher skill farther south (see Fig. 3). However, as forecast time progresses, the anomaly correlations for IS1 null are systematically smaller than IS1 pos and IS1 neg. Correlations of 0.3 persist up to 10 days lead time for IS1 pos and IS1 neg. The anomaly correlations during IS2 averaged over the SACZ (top right) show similar magnitude (0.65) for 1 day lead time. In contrast, as lead time increases, the anomaly correlations for IS2 pos and IS2 neg are smaller than for IS2.
FIG. 3. Anomaly correlation between Z500 forecasts and verification fields. Skill is computed considering all days from the four austral summers during the DERF period. Skill is shown for 1, 4, 6, 8, and 11 days lead time. Correlations greater than 0.50 are indicated by dark shading.
Austral Summer 1979-96

Fig. 4. (a) Mean outgoing longwave radiation (OLR) during austral summer (1 November–31 March). Contour interval is 5 W m$^{-2}$ and shading indicates OLR is less than 220 W m$^{-2}$. (b) Total OLR standard deviation during austral summer. Contour interval is 2.5 W m$^{-2}$ and shading indicates standard deviation greater than 20 W m$^{-2}$. (c) Standard deviation of OLR anomalies for the IS1 type (30–70 days). Contour interval is 1.0 W m$^{-2}$ and shading indicates standard deviation greater than 10 W m$^{-2}$. (d) Standard deviation of OLR anomalies for the IS2 type (10–30 days). Contour interval is 1.0 W m$^{-2}$ and shading indicates standard deviation greater than 15 W m$^{-2}$. Region indicated with thick solid lines is used to characterize periods of strong (weak) convective activity over the South Atlantic Convergence Zone (SACZ).
FIG. 5. Distribution of events (in pentads) selected according to the type of intraseasonal variability: 30–70 days (IS1; top) and 10–30 days (IS2; bottom). Events are selected when the magnitudes of the OLR anomalies averaged over the SACZ domain are less than 0.8 standard deviation (IS1 neg; IS2 neg), greater than 0.8 standard deviation (IS1 pos; IS2 pos) and between ±0.3 standard deviation (IS1 null; IS2 null). Numbers of events are displayed for each austral summer (S 85–86; S 86–87; S 87–88; S 88–89). Total number of pentads for each type of intraseasonal variability is indicated in parenthesis.
Fig. 6. Anomaly correlation between forecasts of Z500 and reanalysis averaged over the SACZ (top) and South American region (40°S–20°N; 90°–20°W) (bottom). Plots on the left are for IS1 type, while plots on the right are for IS2 type. Dashed, dotted, and solid lines indicate positive, negative, and null cases, respectively. Horizontal axis indicates lead time in days.
Fig. 7. Root-mean-square (rms) errors between forecasts of Z500 and reanalysis averaged over the SACZ (top) and South American region (40°S–20°N; 90°–20°W) (bottom). Plots on the left are for IS1 type, while plots on the right are for IS2 type. Dashed, dotted, and solid lines indicate positive, negative, and null cases, respectively. Horizontal axis indicates lead time in days.
null. In particular, during periods of strong convective activity on 10–30 days (IS2 neg) forecasts are less skillful. The different behavior of the MRF forecasts during IS1 and IS2 periods are still noticeable in the averages over the South American domain (bottom right and left), although the differences in the magnitudes of the anomaly correlations among positive, negative, and null cases are significantly smaller. However, the differences in the magnitudes of the correlation coefficients do not pass the 95% significance level.

The rms errors for the IS1 type averaged over the SACZ region (Fig. 7; top left) show that the MRF model has more skill in predicting Z500 during periods of strong convective activity (IS1 pos) as opposed to periods of suppressed (IS1 neg) activity. In addition, the growth rate of rms errors during IS1 pos is larger than in other periods. These results are consistent with the results of NPMP. In contrast, the rms errors for the IS2 type seem to exhibit a different behavior (Fig. 7; top right). The MRF model has less skill in forecasting Z500 during periods of strong (IS2 neg) and suppressed (IS2 pos) convection than in periods of weak (IS2 null) activity. In particular, the growth rate of rms error during IS2 pos is larger than for IS1 neg. A somewhat similar behavior is observed when the rms errors for IS1 and IS2 are averaged over the South American domain (Fig. 7; bottom left and right, respectively).

4. Concluding remarks

The summer season in South America exhibits strong convective activity over the Amazon basin and SACZ, with significant intraseasonal variability found in the eastern part of the continent. The recent study of NPMP showed that intraseasonal variations in the 10–90 days band impact the skill of numerical weather forecasts over the PAN region. In particular, their results pointed out that initial forecast errors during periods of weak convective activity over the SACZ are smaller than for strong events. As is discussed in previous studies, intraseasonal variability over the SACZ is modulated by the MJO as well as by shorter period variations (10–30 days). The preliminary results discussed here indicate that the MRF model has more skill (i.e., in terms of rms errors) during periods of strong convective activity associated with the MJO as opposed to periods of suppressed or weak activity. In contrast, the MRF model has less skill during periods of strong or suppressed convection associated with 10–30 days variations. Additional investigation in this research area should be useful to understand how remotely forced intraseasonal variability over the SACZ can impact local forecasts. This is especially important since the climatological position of the SACZ coincides with the densest demographic region in South America.

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