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Intraseasonal Variability of the Rainfall in South-central Chile (30-50°S)

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Introduction

South-central Chile (30ºS – 50ºS), located along the west coast of southern South America, is year round in the path of mid-latitude disturbances moving from the South Pacific, producing a relatively flat annual cycle in rainfall with a weak peak during austral winter. Frontal rainfall is enhanced as the moist-laden air masses are uplifted over the Andes cordillera (1000-2000 m high in this range of latitude) producing mean annual precipitation between 800 and 1800 mm. The large annual precipitation in this region feeds some of the country's major rivers, several of them intensively used for power generation and agriculture.

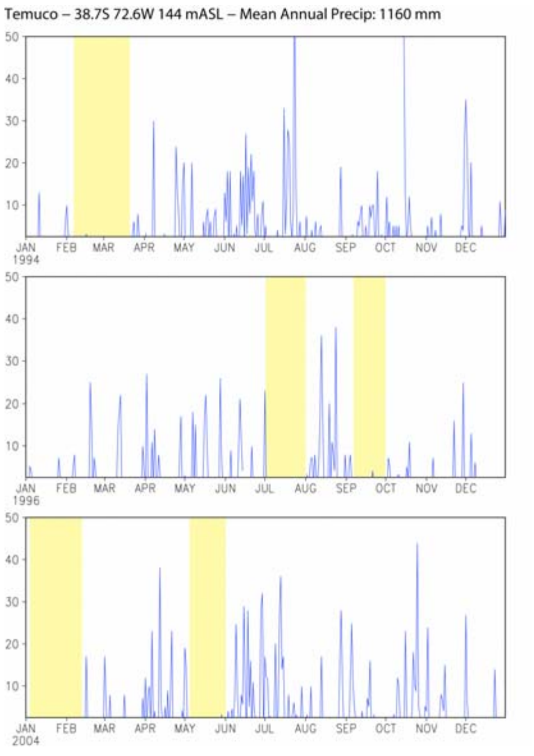

Figure 1. Daily rainfall records at Temuco (38°S-71°W) for three years. Filled areas indicate extended dry periods.

While rainfall variability in south-central Chile is dominated by synoptic-scale fluctuations (3-14 days), longer period variations are clearly present and highly relevant. Considerable attention has been directed to interannual variations, which are largely modulated by the ENSO cycle in a complex pattern that changes with latitude. Much less is known about the intraseasonal variability (IS, 20-60 days) and its potential predictability. Nevertheless, a quick look of rainfall records reveals several weeks characterized by "normal" synoptic activity, with alternance of dry and rainy days, interrupted by similarly extended periods of dry conditions, as shown in Fig. 1. Similar picture emerge from examining temperature time series.

Data and Methods

Our basic variable to quantify the synoptic activity, and its intraseasoanal variability, is the daily average of the meridional wind speed at 300 hPa (V_{300}), obtained from the NCEP-NCAR reanalysis for the period January 1990 to December 2004. At any given point, V300 exhibits large day-to-day fluctuations (± 20 m/s) associated with the passage of baroclinic waves, and thus is a helpful indicator of synoptic activity. Furthermore, we use a high pass filtered version of V_{300} (Butterworth filter with cutoff period of 14 days) to ensure that only synoptic variability was retained. Then, at each grid point, we calculate the variance of V_{300} (hereafter σ^2) on a 30-day time window. The window was moved forward at increments of 1-day and the value was assigned to the central day of the window. Thus, we obtained time series of σ^2 with daily resolution, indicative of intraseasonal periods of intense or suppressed synoptic activity at each grid point.

Before we explore the intraseasonal variability of the synoptic activity, it is worthwhile to explore some climatological information contained in σ^2. For each month we calculate the monthly mean value of σ^2. The climatological storm track (subtropical and subpolar), that is the preferred path of the individual storms, can be readily detectable on the maps of the long-term monthly means of σ^2 (Fig. 1), and agree fairly well with previously published climatologies (e.g. Nakamura and Shimp 2004).

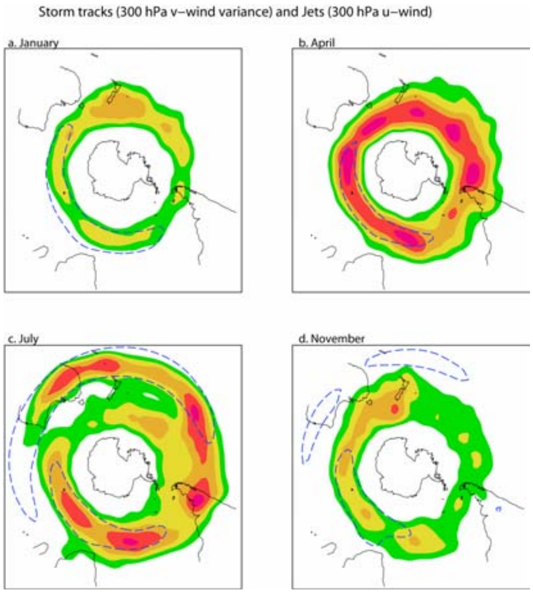

Figure 1: Climatological monthly mean fields of σ^2 (colors, beginning at 100 m^2/s^2 and with increments of 20 m^2/s^2) and 300 hPa zonal wind (dashed lines indicate values in excess of 30 m/s)

In particular, the climatological behavior of the storm track over the eastern Pacific / western South America region can be described using σ^2 averaged between 260°-290°W (Fig. 2). In this region, the synoptic activity is maximum in fall and winter. During MAM the storm track is centered at 50°S near the southern tip of the continent under the subpolar jet stream (identified by the maximum of U300). In JJA the storm tack moves equatorward to reach 37-40°S, just poleward of the subtropical jet. At the seasonal time scale, the displacement of the storm track is followed closely by the maximum in rainfall.

Latitude-time sections of daily σ^2 averaged between 260°-290°W for each individual year also are useful to identify intraseasonal periods of reduced synoptic activity (see examples on Figure 3). Here we focus on extended periods of time (more than 20 days) in which σ^2 is significantly reduced with respect to the long-term mean over a latitudinal range of at least 5°.

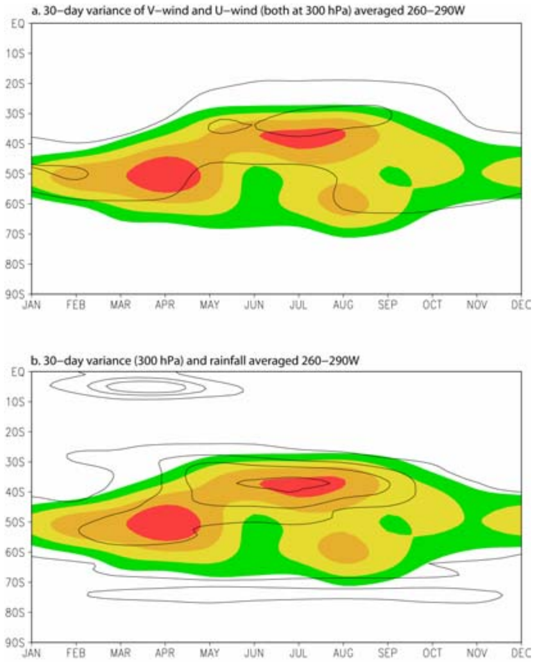

Figure 2. (a) Climatological annual cycle of σ^2 (colors, beginning at 100 m^2/s^2 and with increments of 20 m^2/s^2) averaged between 260-290°W superimposed with 300 hPa zonal wind (dashed lines indicate values in excess of 15 and 30 m/s). (b) As (a) but for rainfall.

Results

Once we identified extended periods of suppressed synoptic activity along the western coast of South America, we perform a visual inspection of the overall structure of the storm track on those periods. As an example, Fig. 4 shows monthly averages of σ^2 (along with anomalies) for 3 months in which the synoptic activity was particularly weak in southern part of the continent.

In all those cases, low values of σ^2 are not confined to the area of selection, but they extend meridionally to encompass most of the Southern Pacific, and part of the Southern Atlantic. In contrast, σ^2 is larger over the subtropical Pacific, suggesting a general weakening of the subpolar storm track and an intensification of the subtropical storm track over the Pacific Ocean.

To further describe the spatial structure of the σ^2 field associated with anomalies in western South America, we regressed σ^2 upon the same field averaged between 260-290°W at different ranges of latitude (Fig. 5).

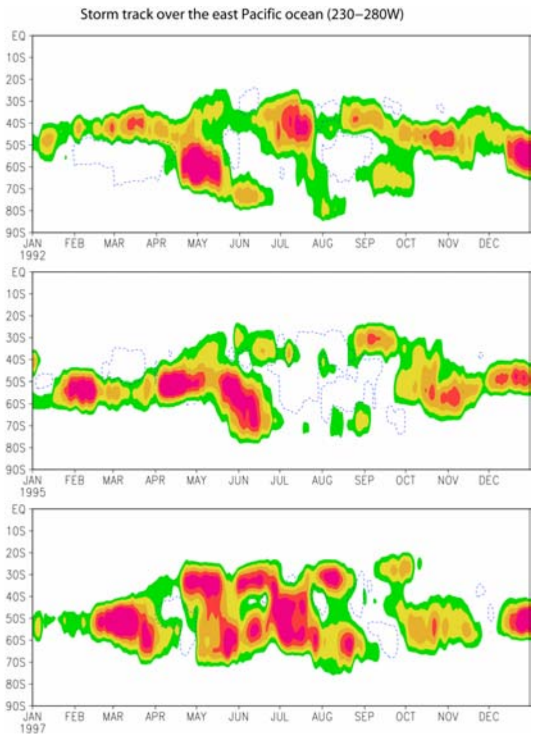

Figure 3: Storm track (along the Chilean coast) for several individual years. σ^2 (colors, beginning at 100 m^2/s^2 and with increments of 20 m^2/s^2) averaged between 260-290°W. Dashed lines indicate negative anomalies wrt to the long-term mean.

The changes in the storm track / storm activity are likely the results of slow changes in the large-scale zonal circulation, as the later controls the Eady growth rate. At least two phenomena can in turn modulate the mean circulation in the Pacific in the frequency range of interest: (a) the tropical Madden-Julian Oscillation and its associated teleconextions, and (b) the high-latitude Southern Hemisphere (SH) annular mode (or Antarctic oscillation).

To investigate these plausible relationships we regressed the monthly mean fields of 500 hPa geopotencial height upon σ^2 averaged between 260-290°W at different ranges of latitude (Fig. 6). Enhanced synoptic activity at the subtropics seems associated with a warming of the tropical troposphere at a global scale and the presence of a blocking high at multitudes just to the west of the Antarctic Peninsula. Enhanced synoptic activity at higher latitudes seems associated with a stronger than normal meridional pressure gradient in that region due an elongated dipole between midlatitudes and the subpolar regions. In both subtropical and extratropical cases the regional enhancement of the synoptic activity is consistent with stronger than normal westerly flow.

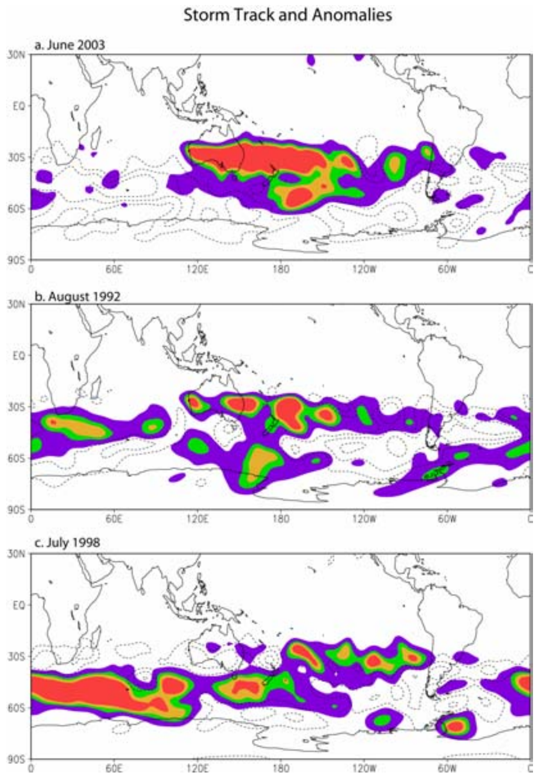

Figure 4: Storm Track (σ^2 :colors, beginning at 100 m^2/s^2 and with increments of 20 m^2/s^2) for selected months. Dashed lines indicate negative anomalies wrt to the long-term mean.

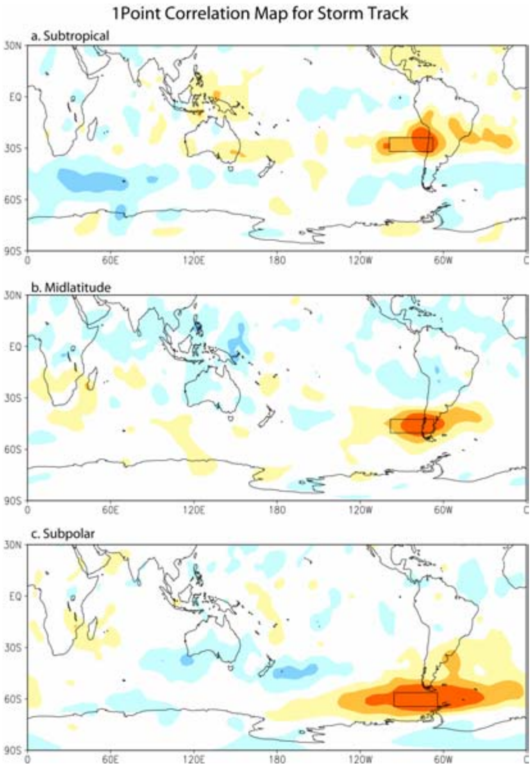

Figure 5: One-point correlation map between storm track (i.e., σ^2) averaged in each rectangle and storm track (σ^2) elsewhere.

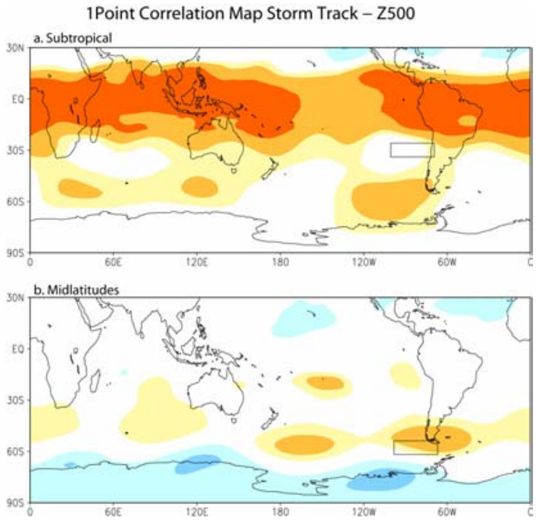

Figure 6: Storm track (i.e., σ^2) in selected areas regressed (outlined by rectangles) upon Z500 elsewhere.

Future work.

The need to investigate the actual relationship between storm-track changes and intraseasonal rainfall variability in our study area. Extended dry periods will be identified using rainfall data (surface observations / satellite) in south central Chile. Examination of atmospheric fields averaged during those periods, including σ^2 , will be followed by composting analysis.

Acknowledgements

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