Investigating the role of soil moisture gradients on extreme precipitation over Southeastern South America

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Introduction

Soil moisture plays an important and complex role in the climate predictibility, since it forces the atmosphere in different spatial and time scales. Its interaction with the precipitation (couplings, positive/negative feedbacks) has been and remains a subject of study connected to the hydrological cycle, using observational and satellite data and climate models (e.g. Sörensson and Menéndez, 2010). The influence of the soil moisture horizontal contrasts on precipitation in different spatial scales has been suggested in some articles (e.g. Emori, 1998; Frye and Mote, 2009; Wolters et al., 2010). In a new approach, we investigate the possible connection between the soil moisture horizontal gradient and extreme precipitation, using a regional climate model over Southeastern South America (SESA, Fig.1), during the development of the South American Monsoon System 1992-93.

Model and Methodology

The Rossby Centre Atmospheric regional model RCA3-E (Samuelsson et al., 2011) was employed. This model version has a better representation of the land surface than earlier versions. The land surface scheme has two soil moisture layers, the top one being 7 cm deep and the deep one was determined by Ecoclimap (Champeaux et al., 2005) at each grid point. The model domain covers the South American continent, and is based on a rotated grid system with a horizontal resolution of 0.5º and 24 unevenly spaced sigma levels in the vertical with the five lowest levels below 900 hPa. All initial and boundary conditions are from ECMWF Re-Analysis (ERA-40, Uppala et al., 2005).
An ensemble of ten four-months continuous simulations was created, starting from different initial dates. Each member extends from November 1 1992 to March 31 1993 (neutral ENSO conditions). In order to initialize the regional model with the atmosphere–soil moisture in equilibrium, the soil moisture initial conditions are set to the soil moisture fields of corresponding initial date from a RCA3-E/ERA-40 integration initialized on September 1, 1990. The analysis is focused on the SESA region during DJF, region and period in which RCA-E has a good performance in the mean precipitation (Fig.1).
We identified at each grid point the extreme precipitation events defined as the percentile 95 of the ensemble, and we perform a composite of the "day 0" (mean precipitation of days in which rainfall equals or exceeds that percentile). We also computed time-lag composite fields of the absolute value of the top soil moisture horizontal gradient for previous days (day -1). Then we calculated fields of relative anomalies (defined as the difference between the composite and the mean value, divided by the mean value) of precipitation for "day 0" and those of soil moisture gradient for "day -1".

Results

Over the region, rainfall extremes are associated with intense convective storms (e.g. Zipser et al., 2006). We speculate that the surface soil moisture heterogeneities would favor the development of heavy precipitation events. In our experiment we find that, on the day before the extreme precipitation event, the spatial heterogeneity of soil moisture tends to be enhanced relative to that in the mean field ensemble. This is shown in Fig.3 where there are mostly positive relative anomalies of soil moisture gradient, with large surface contrasts on day -1 over parts of eastern Argentina, southern Brazil, Uruguay, and along the coasts (blue dots, values close to unity indicating that the horizontal contrast doubles the mean value). In general, these maxima are located in regions where precipitation anomalies are high (greater than 10 times the mean, Fig.2). In the "day -2" (not shown) no significant changes are seen on the gradient´s map. As expected, the relative anomalies of soil moisture gradient in the "day 0" are mostly negative, because the heavy rainfalls tend to homogenize the soil moisture field. The future work includes inquiring into the physical processes involved and carrying out additional ensembles for other years.

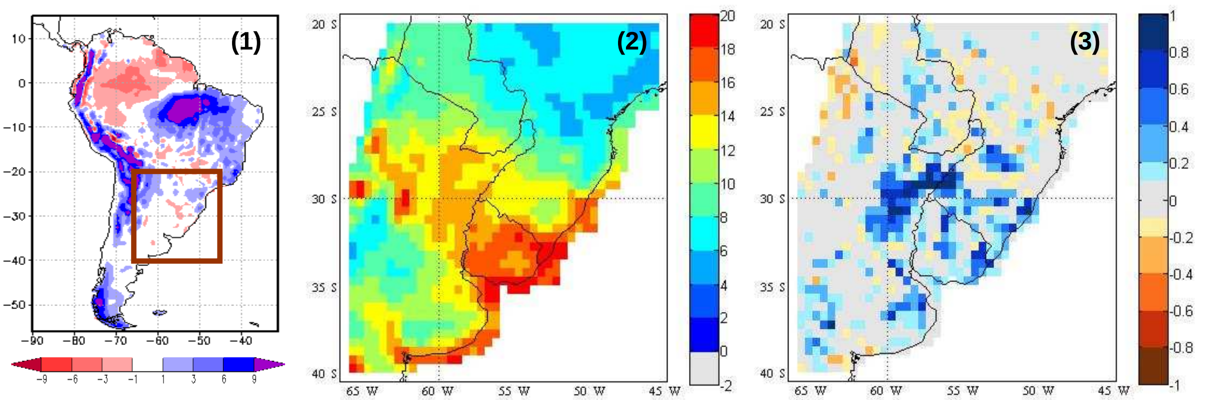

Fig (1): Mean Precipitation Bias (RCA3-E minus CRU) in DJF 1980-99 (mm/day) and studied SESA region inside box. Fig (2): Relative anomalies of precipitation, "day 0". Fig (3): Relative anomalies of absolute value of top soil moisture horizontal gradient, "day -1". Ocean and altitudes higher than 1200 m are masked.

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