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Guest paper

Revisiting remote drivers of 2014 drought in South East Brazil

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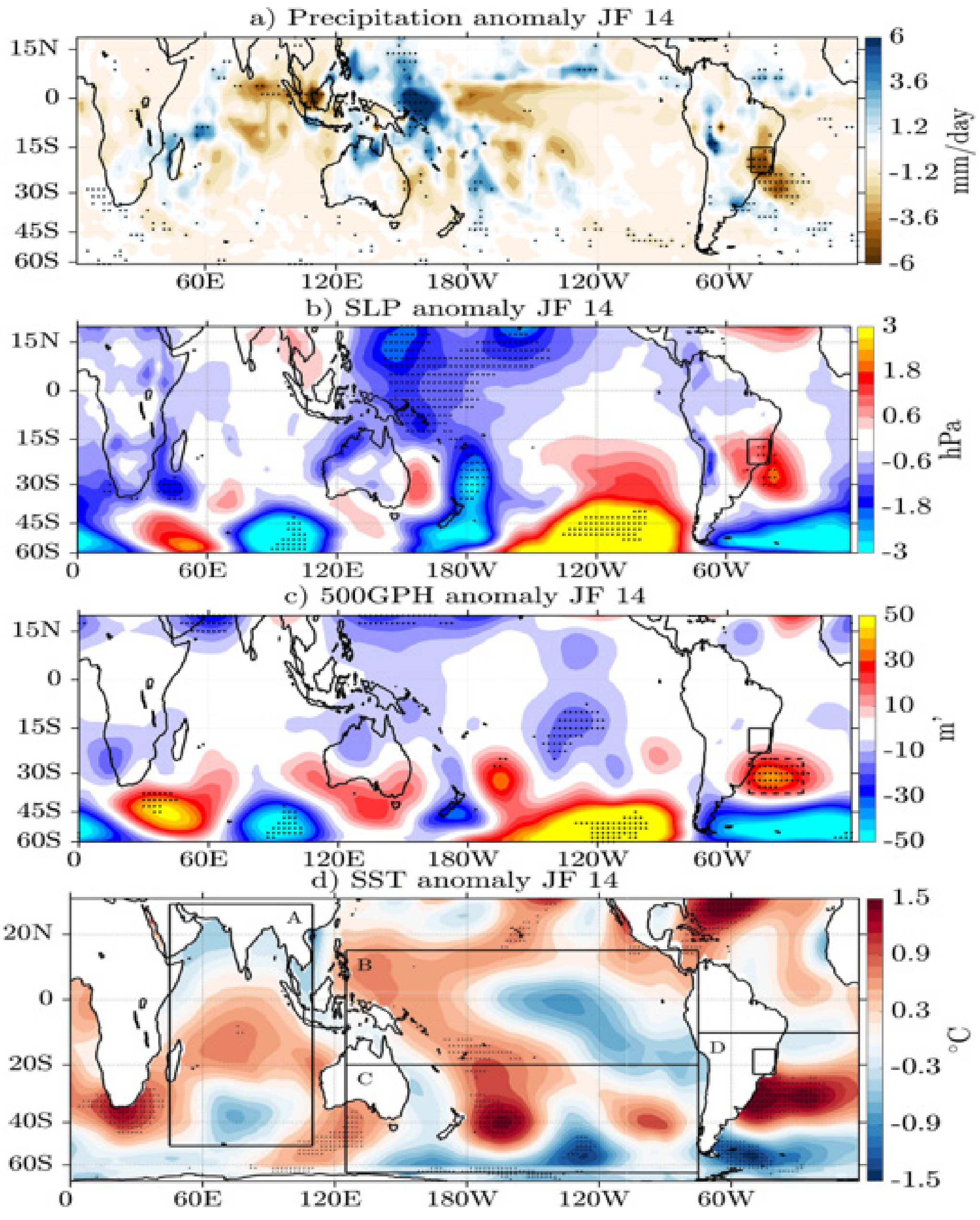
Introduction

Agriculture, particularly coffee farming, plays a prominent role in Brazil's economy. Having a climate in Brazil's south-eastern (SE) part that provides ideal growing conditions (de Camargo, 2010), the country evolved into the largest coffee exporter in the world (Varangis et al, 2003). SE Brazil experienced a devastating drought during the monsoon season in early 2014 that severely affected the state's agriculture, ultimately resulting in significant economic losses (e.g. Benfield et al, 2015). As coffee plants are sensitive to fluctuations in temperature and precipitation (de Camargo, 2010), scarce rainfall, strongly lacking soil moisture, and unusually high temperatures in January and February (JF) 2014 (Blunden and Arndt, 2015; Nobre et al, 2016; Silva et al, 2015) led to a reduction of coffee harvest by 15% to 40% (Nobre et al, 2016). An anomalous blocking anticyclone extended the South Atlantic subtropical high's western boundary over land (Seth et al, 2015). Consequently, the passage of cyclones, normally migrating from the South to the area of interest, was blocked



a) Two-monthly composite anomalies for JF 2014 for a precipitation rate (in mm/day), b) SLP (in hPa), c) 500GPH (in m'), d) SST (in ºC). The data in a) is based on CMAP, b) and c) are based on the ERA-Interim reanalysis and d) is derived from ERSSTv4. SLP, 500GPH and precipitation datasets are analyzed for the time period from 1979 to 2019 while data from 1958 to 2019 are used for SSTs. The dotted anomalies reflect significance at the 5% level. The black box over South America indicates the study area in SE Brazil. The dashed black box over the South Atlantic in c) indicates the area associated with the blocking anticyclone. Boxes A–D in d) indicate the areas of the 2013/2014 SST anomalies in the Indian Ocean, the tropical and South Pacific as well as the Atlantic that are used as forcing in the model experiments.

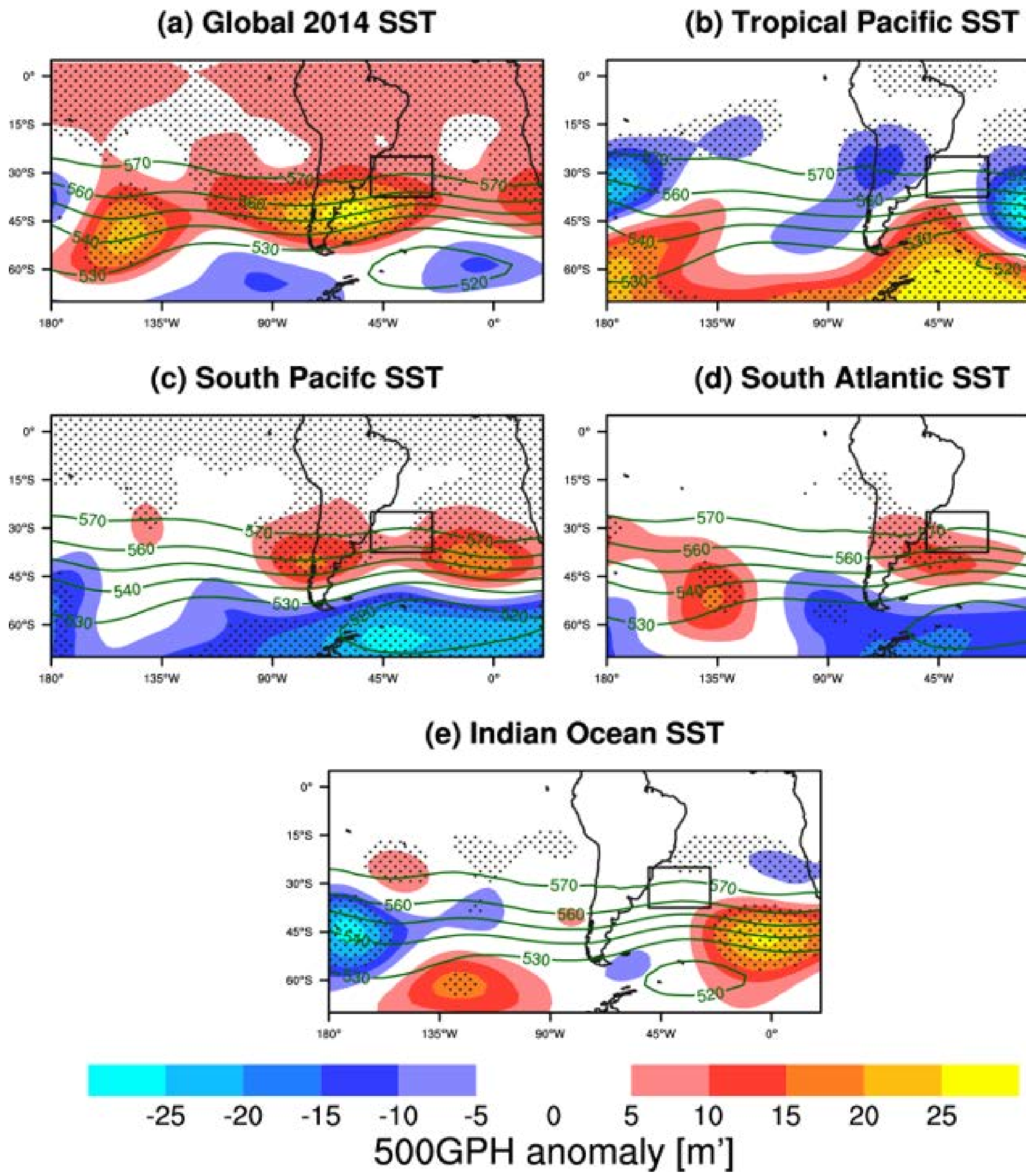
(Seth et al, 2015; Silva et al, 2015; Coelho et al, 2016; Nobre et al, 2016). Additionally, moist air from the Amazon Basin, usually transported towards SE Brazil by the South American low-level jet was redirected (Silva et al, 2015; Nobre et al, 2016) and convective activity due to descending air over SE Brazil was inhibited. All three of these processes contributed to the absence of precipitation in early 2014 (Silva et al, 2015; Coelho et al, 2016; Nobre et al, 2016). As the country's economy is dependent on the coffee crop's productive yield, a number of studies have investigated local and remote processes that might have been involved in producing the South Atlantic blocking and thus, fuelling the drought conditions. Western tropical Pacific sea surface temperatures (SSTs) (Seth et al, 2015) and concurrent unusual convective heating (Seth et al, 2015; Coelho et al, 2016) have been suggested to have induced an atmospheric tropical-extratropical teleconnection toward the South Pacific that influenced the circulation anomalies propagating toward South America (Coelho et al, 2016).

More recently, deep convection over the eastern Indian Ocean, associated with the Madden-Julian Oscillation (MJO), has been linked with blocking episodes over the South Atlantic (Rodrigues and Woollings, 2017), such as those observed in 2014 (Rodrigues et al, 2019) and 2017 (Manta et al, 2018). To further investigate the origins of the signal that potentially initiated the anticyclonic anomaly over the South Atlantic we analyze the sensitivity of 500hPa geopotential height (500GPH) anomalies to an observed 2013/2014 SST forcing in various ocean basins using idealized numerical experiments.

Results and Discussion

During the monsoon season in JF 2014, the study area in SE Brazil (Fig. 1a; black box) experienced extremely low precipitation rates with values almost 2 standard deviations below the long-term mean. The anomalous distributions of precipitation, sea level pressure (SLP), 500GPH and SST during JF 2014 are shown in Figure 1. Reflected by significant negative anomalies, the persistent absence of rainfall can be observed across the entire study area including the highly populated states of Minas Gerais, Espírito Santo, Rio de Janeiro and part of São Paulo (Fig. 1a). The significant positive South Atlantic SLP (Fig. 1b) and 500GPH (Fig. 1c) anomalies off the east coast of South America (Fig. 1c; dashed box) indicate a barotropic structure throughout the lower troposphere. This vertical configuration thereby disrupted the moisture supply for SE Brazil by blocking the path of cyclones and their corresponding fronts from the South as well as the inflow of moist air from the Amazon Basin towards the study region. The role of SSTs in forming this 2014 South Atlantic anticyclone is examined by performing idealized sensitivity experiments using the Isca model (Vallis et al, 2018). In the climatological run, SSTs are prescribed following the 1958-2016 climatological monthly mean seasonal cycle SSTs. In the sensitivity experiments, SSTs follow the 2013-2014 austral summer evolution, i.e., 2013 anomalies are imposed from August 2013 to April 2014, while May to July 2014 SSTs follow the climatology. In the experiments, the SST anomalies are imposed globally and in the Indian Ocean (Fig.1d; Box A), the tropical Pacific (Fig.1d; Box B), the extratropical South Pacific (Fig.1d; Box C), and the South Atlantic (Fig.1d; Box D), respectively. The atmospheric 500GPH response is computed as the difference between the climatological run and the respective 2013/14 SST anomaly run. Our study consists of an evaluation of the JF ensemble mean 500GPH (Fig. 2), the vertical structure as well as the occurrence frequency of exceptionally high 500GPHs averaged over the South Atlantic study area for each experiment. Forcing the model with the global distribution of 2013/2014 SSTs, positive anomalies develop over the South Atlantic (Fig. 2a), indicating an increased probability of enhanced 500GPHs over the study area. The decisive contribution of global SSTs is additionally reflected by a positively skewed distribution of the area averaged 500GPHs of which exceptionally strong 500GPHs have the highest occurrence frequency across the experiments. Forcing the model with anomalous South Pacific SSTs (Fig. 2c) and local South Atlantic (Fig. 2d) we similarly find an increased probability of elevated 500GPHs in the study area. The two centers of positive anomalies in the vicinities of South America that have been found in reanalysis data, is particularly well represented by the South Pacific experiment. This is consistent with findings of Coelho et al, (2016) who show that the South Pacific contributed to establishing the extratropical component of the wave train to the South American region. Across all experiments, the vertical barotropic configuration of the 2014 blocking, seems best represented by the South Atlantic experiment despite a shift in location. Hence, local SST anomalies generated by the South Atlantic atmospheric circulation in the first place (Rodrigues et al, 2019) might have been involved in arranging the vertical structure of the blocking event. On the other hand, no significant positive South Atlantic 500GPH anomalies develop in the ensemble mean response to a forcing with either tropical Pacific (Fig. 2b) or Indian Ocean (Fig. 2e) SSTs. The occurrence frequency of extremely elevated heights for the Indian Ocean simulation is even lower than the one with a climatological SST forcing. Note that the MJO, related to convection in the Indian Ocean, is generally uncoupled from underlying SSTs and can therefore not be ruled out as a remote source of the blocking event.

Further, our experiments might reveal a potential synergy between the Indian Ocean and the tropical Pacific as signals from both regions might have modified the South Pacific SSTs with which the model is forced. Finally, we find that internal variability plays a vital role in mid-tropospheric South Atlantic dynamics as the area averaged distribution of 500GPHs for the climatological simulation shows a high degree of variability.



a) JF ensemble mean 500GPH model response to the a globally prescribed 2013–2014 SST seasonal cycle, b) only the tropical Pacific, c) the South Pacific, d) the South Atlantic, and e) the Indian Ocean. See Fig. 1d for the SST forcing areas. Anomalies are computed with respect to the climatological run. Contours denote the total field (in dam) for each of the SST forced simulations. Significant geopotential height anomalies with respect to the climatological run at the 5% level are dotted.

Conclusion

While the global 2013/14 SSTs likely contributed to the South Atlantic blocking that fuelled the drought in SE Brazil, neither tropical Pacific nor Indian Ocean SSTs and the corresponding teleconnections alone can account for the observed circulation anomaly. Instead, South Pacific SSTs, as well as local feedbacks with South Atlantic SSTs were likely vitally involved in the blocking event. The present study reconciles the preceding literature on the 2014 drought in the sense that the MJO could have been the initial trigger of the Rossby wave train (Rodrigues and Woollings 2017, Rodrigues et al, 2019, Barreiro et al, 2019) that was reinforced over the South Pacific to reach South America (Coelho et al, 2016), while local South Atlantic SSTs (Zou et al, 2018, Barreiro et al, 2019) might have helped to prolong the drought during the summer season. Thus, our results emphasize the complex nature of the observed drought in SE Brazil and suggest a combination of several influences and their potential nonlinear interactions together with internal atmospheric variability as an explanation for the occurrence of such a significant and persistent event.

For further details and references please go to the original article: Finke, K., Jiménez-Esteve, B., Taschetto, A.S. et al. Revisiting remote drivers of the 2014 drought in South Eastern Brazil. Clim Dyn 55, 3197–3211 (2020). Click on link.

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