Text S1. Event description

In this section, we provide a brief description of each of the twelve events focusing on the predominant atmospheric circulation.

Prior to E01 start (9th Jan 2018) there was anticyclonic conditions near the South and Southeast regions of Brazil. This system acted together with the SALLJ, causing moisture advection to the coastal region of SBr. The extra moisture and also the warm air from the tropics increased instability, further leading to heavy and continuous rain, especially in coastal SC. After the first day (11th Jan), the anticyclone moved away from the coastal zone of Brazil and a low pressure area developed over SBr (12th Jan), which increased the instability in the area. During those days, the rain caused major flooding and landslides in SC central and north coastal region. Close to the event end (14th Jan), there was cyclogenesis in RG2, associated with moisture convergence over SC and PR producing further precipitation. Although precipitation levels were not high, the previous conditions might have contributed for landslides and further damage in the affected cities.

In days that preceded E02 an cyclogenesis event in RG2 region bought precipitation to the SBr coastal region. In the first day of the event (01st Jun 2017) there was cyclogenesis in RG1, associated with instability in the coastal region of SC and RS states and isolated rainfall episodes. As in the previous event, the instability over the region was favored by the SALLJ moisture transport. After the EC moved eastward, there was post-frontal anticyclogenesis (03th Jun) in the coast near the southern and southeastern regions of Brazil. Three days after the event start (04th Jun) there was moisture convergence over many areas of the SBr region, resulting from the combination of northerly/northeasterly flow, related to the marine anticyclone, and with the passage of a cold front due to a cyclogenesis event in RG3. The precipitation associated with this event displaced thousands of people in the RS state and although most of the damages were reported for the northern part of the state, the coastal area was also affected, with a causality been reported. Furthermore, in the SC capital there were reports of several places with heavy flooding.

The E03 was related with heavy rain in the SC state, in contrast with RS and PR states, that were experiencing dry conditions. The position of the anticyclone lead to cold air advection from higher latitudes and favored subsidence over SBr. Then, a cold front moved from the south of RS, associated with a EC in the extreme south of Argentina, became stationary over the southernmost part of PR (06th Sep 2011). This system was favored by an increased intensity of the subtropical jet and lead to high amounts of accumulated precipitation over various localities of SC state.

Although heavy rainfall for some localities was reported during E04, the main impacts were high oceanic waves, strong winds and storm surge. The event started with a cyclogenesis over RG2 (25th may 2011), favored by the position of subtropical jet over Uruguay and Argentina, which increased instability over SBr. The EC initially moved southeastward, as most cyclones in the SAO (Hoskins & Hodges 2005), but later on (27th May) it began to move northwestward and presented hybrid features, being classified as subtropical (Candella & Souza 2013). The cyclone would retake its normal eastward and poleward track only two days later (29th May). It was reported strong winds and restless sea for all states in southern and southeastern Brazil. The maximum wave height reached 10m in some localities, the highest values registered for the buoys located in the region, while wind speeds over the ocean reached values as high as 100 km/h (Candella & Souza 2013).

The E05 resulted from the combination of various phenomena. Firstly, the CPTEC-INPE reported a SACZ condition (18th Jan 2011), with enhanced convection due to the presence of the SALLJ and middle-level cyclonic circulation over SBr, converging moisture to the area. Pinheiro (2011) highlighted the contribution of moisture advection from easterly winds in the coast of SC, which were further trapped due to the local topography. The easterly winds were related to an anticyclone located near southeastern Uruguay coastal region. The cumulative effect of those phenomena resulted in heavy precipitation for the southern and southeastern regions of Brazil. Furthermore, there was cyclogenesis over RG1 (20th Jan), associated with more episodes of heavy rainfall over the PR and SC states. After the poleward displacement of the EC there was one more event of anticyclogenesis close to the coast of southeastern Uruguay (21th Jan). Again, the easterly flow over the coast of SC triggered precipitation over the area.

The E06 was related with strong cyclogenesis north of RG1, prior to the event start, and a post-frontal anticyclone located southeast of Argentina (7th June 2010). The EC was slow moving, staying over the latitude of the SC state for more than one day (8th-9th June). This resulted in an extensive fetch over the coastal region between SC and the northeast Brazilian coast, which generated extreme high waves that propagated to this part of the Brazilian coast (Silva 2013) and caused storm surges in some localities.

Considered to be the most extreme weather event for the SC up to this date, during the E07 record amounts of precipitation were registered for the northern and central regions of coastal SC. November 2008 was the wettest month ever recorded for the coastal northern region of SC while the 22nd/23th presented the highest amounts of accumulated precipitation for a single day (Minuzzi & Rodrigues 2008). The event was caused by a persistent blocking condition over the western SAO and therefore easterly winds, associated with moisture transport from the ocean. There were already high values of accumulated precipitation for the three months prior to the event therefore there were already high levels of ground water. In the 21st a cold core high-level cyclonic vortex was positioned above SC and established dynamical and thermo-dynamical conditions that increased precipitation rates (Silva-Dias, 2008). Due to the excessive and continuous rain, flooding and landslides had occurred over large areas, affecting over 1.5 million people in 63 cities and causing over 100 fatalities (Fraga 2009).

The E08 was associated with a EC with an abnormal track, considered one of the stronger systems recorded for the study area (Guimarães et al. 2014). The cyclogenesis occurred in RG2 (2nd May 2008) but due to the presence of a blocking pattern, the cyclone remained very close to the coast for two days. There were reported high southerly wind speeds and severe storms in the RS and SC coastal regions (Sausen et al. 2009) and numerical models indicated high waves, up to approximately 8m in the oceanic region near the RS northern coast (Guimarães et al. 2014).

The E09 was also one of the strongest EC recorded for the study area (Guimarães et al., 2014). However, in this case cyclogenesis occurred in the south at RG03 prior to the event date (26th July 2007). After genesis, the system had a slightly northward track, approaching the SBr coastal zone (until the 28th July). Although the system produced light precipitation, numerical models estimated that the swell generated waves of more than 8m high in the oceanic region near the RS southern coast (Guimarães et al., 2014) and the sea level rise contributed to major erosion episodes along the RS and SC coast.

The E10 presented similar characteristics to both E08 and E09, also being one of the extreme events reported by Guimarães et al. (2014). It was related to strong cyclogenesis in RG2 (2nd September 2006) that followed a southeastward trajectory and caused major erosion over the RS coast (Parise et al., 2009a) and high southerly wind speeds over all coastal SBr. This EC is estimated to have generated waves of approximately 8m high in the oceanic region near the RS coast (Guimarães et al. 2014). There was also cold air incursions over most central-southern parts of Brazil, causing snowfall in some southern cities, a uncommon event in Brazil.

Prior to E11 there was cyclogenesis in RG2 with the EC having a southeasterly trajectory (5th August 2005). After this, there was anticyclogenesis over southern Argentina (7th August), and further cyclogenesis in RG2 (10th August). This combination of both EC and anticyclone resulted in an extensive south-southeast fetch in the western SAO. The resulting swell had the highest wave heights recorded for the for the buoy in the oceanic area close to the SC coast (7.2m), for the period ranging from years 2002 to 2005 (Melo Filho et al. 2006). The high windspeed caused by this system and the sea level rise caused coastal flooding and landslides in some cities.

The E12 is the Catarina Hurricane, the first hurricane ever reported in the SAO (McTaggart-Cowan et al. 2006), which caused losses of half billion US dollars for the Brazilian government and 11 deaths. The damage was caused by high wind speeds, of 150 km h^{-1} at the landfall location, high precipitation rates and storm surge. As a result, many cities were flooded and urban infrastructure was compromised displacing thousands of people. The hurricane began as a subtropical cyclone with genesis north of RG2 (20th March 2004) and an eastward trajectory. It undergone tropical transition three days later (23th March) and developed a westward track, making landfall in the 28th March (Pezza & Simmonds 2005). Normally, the oceanic and atmospheric conditions over SAO would suppress the development of tropical cyclones, however, the Catarina encountered an environment of low wind-shear and strong blocking conditions that were unprecedent in this region (Pezza & Simmonds 2005). As the hurricane moved westward, air-sea fluxes counterbalanced the relatively cool SST conditions and further favored the system intensification (Pereira Filho et al. 2010).