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Rossby Waves, Fronts and Wildfires in Southern Australia

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Severe fire weather conditions in southern Australia are invariably associated with strong anticyclones, which direct very dry northerlies or northwesterlies on their western flanks from the interior of the continent across the region. These hot, dry airstreams precede the passage of strong cold fronts and are followed by strong southerlies or southwesterlies. Using the ERA Interim dataset, it is shown that this characteristic pattern of severe fire weather is associated with propagating Rossby waves, which grow to large amplitude and eventually irreversibly overturn. Moreover, all very strong, summertime fronts (the key ingredient to severe fire weather) and all major wildfires in southeastern Australia are associated with Rossby wave breaking and this characteristic weather pattern.

As Rossby waves break, they stir the atmosphere, redistributing the potential vorticity (among other things) on almost two-dimensional isentropic surfaces (geostrophic turbulence). In the present work, such stirring is characterized by the local instantaneous Lyapunov exponent, which is closely connected to the potential vorticity frontogenesis function. It is shown that, over southern Australia, such stirring is most vigorous in summer, at which time the Rossby wave breaking in the region is overwhelmingly anticyclonic. Rossby wave breaking in the region produces an upper-level cyclonic potential vorticity anomaly to the north (towards the equator) with an upper-level anticyclonic potential vorticity anomaly to the south (towards the pole). Moreover, severe fire weather conditions in the south of the continent are commonly accompanied by heavy rainfall in the north. From a potential vorticity perspective, the severe fire weather is associated with the anticyclonic anomaly while the rainfall is connected to the cyclonic anomaly.

The south Atlantic or South America appears to be the origin of these Rossby waves. These waves propagate along the large potential vorticity gradients co-located with the jet. During summer, the principal jet stream in the Southern Hemisphere is directed from the Atlantic to south of Australia. As Rossby wave breaking is connected to the existence of critical levels (regions where the phase speed of a wave equals the background wind speed), the northward (equatorward) side of the jet and the jet exit south of Australia are preferred regions for breaking and, hence, stirring. The local instantaneous Lyapunov exponent is larger in this region than anywhere else in the Southern Hemisphere in summer.