South American Cyclogenesis

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Most atmospheric phenomena are directly related to heat-to-work conversion. In nature, all these processes are constrained by the Second Law of Thermodynamics, which has at its core the entropy concept. The idea of the atmosphere behaving as a heat engine that converts heat to work is long recognized [e.g. *Brunt*, 1926]. However, only in recent decades has this concept been extended to atmospheric vortices ranging from dust devils [*Rennó et al.*, 1998] to hurricanes [*Emanuel*, 1988]. The general idea is that the energy made available through the heat-to-work conversion is used by the system to overcome dissipation thus maintaining the system during its life cycle.

Extratropical cyclones play a central role in the maintenance of global climate and are responsible for the transport of heat and moisture through the troposphere [*Peixoto and Oort*, 1992; *Simmonds and Keay*, 2000]. The South Atlantic is one of the regions of the globe where cyclones preferably occur. According to *Frederiksen* [1985], the observed location of the primary storm track just downstream and poleward of the polar jet stream in the southern hemisphere is accounted for by linear baroclinic instability theory.

However, *James and Anderson* [1984], using one of the first years of analyzed data for the Southern Hemisphere, provided by the European Centre for Medium-range Weather Forecasts (ECMWF), found that the linear dry-baroclinic theory was unable to explain the observed storm track in the South Atlantic sector. At the same time, these authors noted the anomalous low level wind field over the South American continent, with a strong mean north-south flow east of the Andes Mountains. Such flow could imply an extra source for cyclogenesis, through moisture entrainment into the low-level westerlies at midlatitudes downstream of the source in the Amazon basin [*Mendes et al.*, 2007].

In order to investigate that relationship more closely, Dr. Mendes, from the Centro de Ciência do Sistema Terrestre/Instituto Nacional de Pesquisas Espaciais (CCST-INPE, Brazil) and Dr. Souza, from the Federal University of Campina Grande, Brazil, used NCEP/NCAR data to set up their study. They used various meteorological variables for the region of 120°W–0°, 60°S–0°S, spanning the period from 1979 through 2003. The data were used to study the thermodynamic state of the system through two variables: the equivalent potential temperature (θ_e) and the saturation equivalent potential temperature (θ^*_e). These variables can be related to entropy [*Emanuel*, 1989], and were therefore used for understanding cyclogenesis.

Figure 1 displays the JJA mean distribution of 850 hPa wind and 1000 hPa θ_e, and θ_e variance. It shows important meridional low-level flow on both sides of the Andes Mountains. The region of maximum θ_e (indicated by the contour lines) lies east of the Andes, extending southward along the northerly warm and moist flow from the Amazon basin, i.e. the low level jet [*Marengo et al.*, 2004]. The region of maximum θ_e variance (indicated by the shading) is much further to the south, centered near 25°S, 60°W, over Argentina, and coincides with a region where extratropical cyclones occur [*Gan and Rao*, 1991; *Satyamurty et al.*, 1998]. The high variance over latitudes south of 60°S marks the mean position of the circumpolar winter storm tracks [e.g., *Simmonds and Keay*, 2000]. The fact that the region of most frequent cyclogenesis is located slightly to the south of the region of maximum θ_e variance suggests a link between the build-up of anomalous θ_e in the continent and the cyclogenesis process [e.g. *Mendes et al.*, 2007].

In summary, the mid-latitude cyclones that are produced in the southern South American region are largely controlled by interactions between the mid-latitude circulation and the tropics, through north-south flow over the continent along the east slope of the Andes Mountains. The mean circulation in the region, reinforced in the days prior to cyclogenesis (not shown here), transports moist air from the Amazon basin into eastern subtropical South America, near 15°S 70°W, very close to the Andes [*Mendes et al.*, 2007].

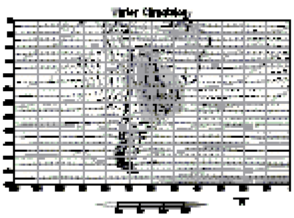

Figure 1 - Winter (JJA) climatological mean (contour lines; K) and variance (shaded; K^2) of equivalent potential temperature at 1000 hPa, computed for the 1979-2003 period. Arrows represent the mean wind vector (ms^{-1}) at 850 hPa, for the same period.

Studies such as this one are important for understanding cyclogenesis in the Southern Hemisphere. The authors investigated other issues related to this subject matter that are not shown in this article. For more information, please contact Dr. Mendes at dmendes@cptec.inpe.br.

References:

Brunt, D. (1926) Energy in the earth's atmosphere, *Philos. Mag.*, *7*, 523-532.

Emanuel, K. A., (1988), The maximum intensity of hurricanes, *J. Atmos. Sci.*, *45*, 1143-1155.

Emanuel, K. A. (1989) The finite-amplitude nature of tropical cyclogenesis, *J. Atmos. Sci.*, *46*, 3431–3456.

Frederiksen, J. S. (1985), The geographical locations of Southern Hemisphere storm tracks: linear theory, *J. Atmos. Sci.*, *42*, 710–723.

Gan, M. A. and V. B. Rao (1991) Surface cyclogenesis over South America, *Mon. Wea. Rev.*, *119*, 1293–1302.

James, I. N. and D.L.T. Anderson (1984), The seasonal mean flow and distribution of large-scale weather systems in the southern hemisphere: the effects of moisture transports, *Quart. J. R. Met. Soc*, *110*, 943–966.

Marengo, J. A., W.R. Soares, C. Saulo, and M. Nicolini (2004), Climatology of the low-level jet east of the Andes as derived from the NCEP reanalyses, *J. Climate*, *17*, 2261–2280.

Mendes, D., E.P. Souza, I.F. Trigo, and P.M.A. Miranda (2007), On Precursors of South-American Cyclogenesis, *Tellus A*, *59*,114-121.

Peixoto, J. P. and A.H. Oort (1992), *Physics of Climate*. American Institute of Physics, New York, 520 pp.

Renno, N. O., M.L. Burkett, and M.P. Larkin (1998), A simple theory for dust devils, *J. Atmos. Sci.*, *55*, 3244-3252.

Satyamurty, P., C.A. Nobre, and P.L. Silva Dias (1998), Meteorology of the tropics. South America, pp 119–139, in *Meteorology of the Southern Hemisphere*. (eds D. K. Karoly and D. G.Vincent). Meteorological Monographs, *49*, American Meteorological Society, Boston.

Simmonds, I. and K. Keay (2000), Mean southern hemisphere extratropical cyclone behavior in the 40-year NCEP-NCAR reanalysis, *J. Climate*, *13*, 873–885.