

## **'Energy box diagram' investigation of South Atlantic hurricane Catarina**

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The unusual cyclone Catarina (2004) in Brazil has earned a place in history as the first observed South Atlantic hurricane during the satellite era. It originated as a baroclinic (frontal) cyclone, undergoing Tropical Transition (TT) and achieving hurricane status while still keeping a hybrid structure (Pezza and Simmonds, 2005). The partition into zonal and eddy components of both the atmospheric Available Potential Energy (AZ and AE, respectively) and Kinetic Energy (KZ and KE, respectively) as proposed by Lorenz (1967) is here adopted to study the energetics associated with the transition of this very rare event. As far as we are aware this is the first time that such technique is used to study a TT case in the Southern Hemisphere. The cycle is completed by the conversion between the various energy forms given by CA (from AZ to AE), CE (from AE to KE), CK (from KE to KZ), and CZ (from AZ to KZ). Here the Lorenz diagram is presented so that the conversion terms are always positive and the arrows indicate the direction of the fluxes (figure 1a). For more details on the methodology the reader is referred to Wahab et al. (2002) and references therein.

Figure 1b shows the day of greater baroclinic conversion (March 21, 12 UTC) when Catarina was still driven by the westerlies and clearly frontal. For that particular time the term CE was dominant, meaning that the eddy kinetic energy KE was growing at the expense of the available energy in a highly baroclinic way. The conversion term CA indicates that the energy flow discussed above was originating from the zonal available potential energy AZ, and the barotropic conversion term CK shows only a small contribution towards increasing the zonal kinetic energy. The sudden transition of Catarina is seen in figure 1c for March 22<sup>nd</sup> at 06UTC. The diagram for that particular time shows a significant change in the energy cycle with the

baroclinic conversion terms CE and CA becoming very small and the barotropic conversion CK becoming the major driver. The time series of the baroclinic conversion terms CE and CA (figure 1d) indicated a sharp maximum on the 21<sup>st</sup> followed by an increase in CK (negative) on the following day, with the other terms presenting less pronounced changes. A likely mechanism for the reduction in the baroclinicity was the formation of the blocking system over the domain, cutting Catarina off from the westerlies.

Lorenz, E. N., (1967), *The Nature and Theory of the General Circulation of the Atmosphere*. World Meteorological Organization, 161 pp.

Pezza, A.B., and Simmonds, I, 2005: The first South Atlantic hurricane: Unprecedented blocking, low shear and climate change. *Geophysical Res. Letters*, **32**, doi:10.1029/2005GL023390.

Wahab M. A., Basset, H. A. and Lasheen A. M. (2002), On the mechanism of winter cyclogenesis in relation to vertical axis tilt. *Meteorol. Atmos. Phys.*, **81**, 103-127.

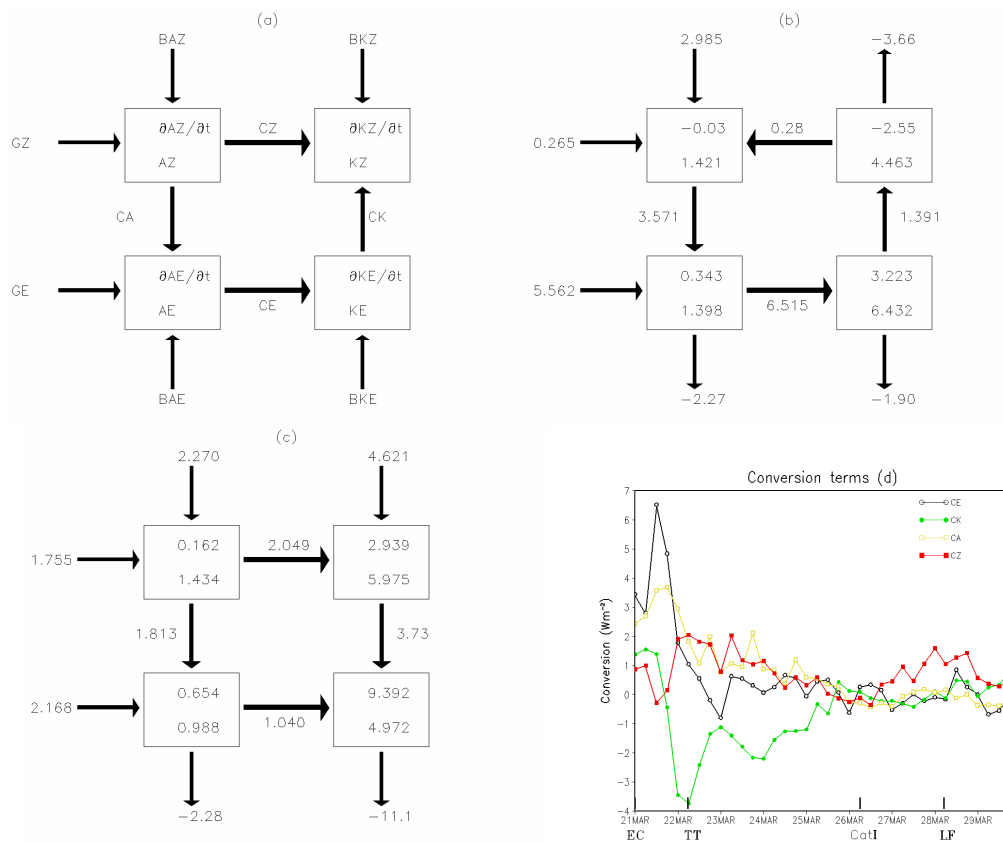


Figure 1: Volume integrated energy terms for (b) 2112 UTC and (c) 2206 UTC. Panel (d) shows the time series of vertically integrated conversion terms (CA, CE, CK and CZ) for the period 21-29 March 2004. The relevant periods during Catarina's lifecycle are indicated in panel (d). Panel (a) shows the energy cycle here adopted as a reference guide. Units are in  $10^5 \text{ J/m}^2$  and  $\text{W/m}^2$ , respectively, for energy and conversion terms. See text for further details.