Searching Chaotic Attractors and Coherent Structures in Atmospheric Time Series

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Amazonia is one of the last great tropical forest domains, the largest hydrological system in the planet, and plays an important role in the function of regional and global climates. A subject of great relevance for understanding how the Amazon terrestrial biosphere interact with the atmosphere is the correct modeling of the turbulent exchange of heat, humidity, greenhouse gases, and other scalars at the vegetation-air interface. However, this issue, as many other aspects of this fragile and highly complex system, remains unclear for the scientific community. This is partly due, on one hand, to the lack of high-frequency, detailed *in situ* measurements, and, on the other hand, to the fact that turbulence has been a notoriously difficult problem to grasp.

In the last decades, several studies have handled the problem of turbulence - and of atmospheric turbulence, in particular - with the tools of chaos theory. Perhaps the most paradigmatic example of this approach is the work of E. N. Lorenz (Lorenz (1963)), based on a simplified model of the dynamics of a convective fluid layer. Soon after this landmark paper, it was conjectured that the atmosphere might also be governed by a low-dimensional chaotic attractor (Weber *et al.* (1995)). Since then, various works reported the existence of low-dimensional chaotic attractors based on the analysis of climatic or weather time series (Nicolis & Nicolis (1984); Fraedrich (1986); Fraedrich & Leslie (1989); Göber *et al.* (1992); Poveda-Jaramillo & Puente (1993); Fraedrich (1986); Xin *et al.* (2001); Gallego *et al.* (2001)). However, in spite of the growing empirical evidence, the subject remains controversial. Grassberger (1986) objected to the validity of some early findings because of the small number of data points used in the analyses. Later, Weber *et. al* (Weber *et. al* (1995)) found no evidence of a low-dimensional attractor on wind velocity turbulent time series with several million data points long. Lorenz himself found unlikely that weather or climate systems possess low-dimensional attractors because of their intrinsic complexity (Lorenz (1991)). In his opinion, however, positive claims were not meaningless but resulted from the fact that the atmosphere “might be viewed as a loosely coupled set of lower-dimensional subsystems”. In other words, as speculated by Ruelle and Takens (1971), although the phase spaces of many dynamical systems in nature are infinite-dimensional, the dynamical invariant sets responsible for many observable phenomena of physical interest may lie in some low-dimensional manifold (Lai *et al.*, (2003)).

Within the context above we set two objectives to this work. First, investigate the existence (or not) of a low-dimensional chaotic attractor in the atmospheric turbulence above a densely forested area in the Amazon region. Second, examine the role played by coherent structures (or eddies) - here viewed as the lower-dimensional subsystems conjectured by Lorenz (1991) - in the predictability properties of the atmosphere. Turbulent flows in canopies are dominated by such coherent structures of whole canopy scale (Finnigan (2000)), which might be responsible for up to 75% of the turbulent fluxes in the atmospheric surface layer (Krushe & Oliveira (2002)). Under convective conditions, coherent structures are recognized in time series of temperature and other scalars by the presence of ramp-like patterns, i.e. a gradual rise in the signal, followed by a sudden fall (Antonia *et al.* (1979)). To attain our goals, we used fast-response experimental data obtained during a field campaign of the large-scale biosphere-atmosphere experiment in Amazonia (known as the LBA project), carried out during the wet season (January-March), in the southwestern part of the Brazilian Amazonia.

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