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TAMDAR aircraft data, anisotropic scaling and spurious scale breaks in wind statistics

J. Pinel (1), S. Lovejoy (1), and D. Schertzer (2)
(1) McGill, Physics, Montreal, Canada, (2) LEESU, Université Paris-Est, France

A fundamental issue in atmospheric dynamics is to understand how the statistics of fluctuations of various fields vary with their space-time scale. The classical - and still "standard" model - dates back to Kraichnan and Charney's work on 2-D and geostrophic (quasi 2-D) turbulence at the end of the 1960's and early 1970's. It postulates an isotropic 2-D turbulent regime at large scales and an isotropic 3-D regime at small scales separated by a "dimensional transition" (once called a "mesoscale gap") near the pressure scale height of $\approx$10 km. By the early 1980's a quite different model emerged, the 23/9-D scaling model in which the dynamics were postulated to be dominated (over wide scale ranges) by a strongly anisotropic scale invariant cascade mechanism with structures becoming flatter and flatter at larger and larger scales in a scaling manner : the isotropy assumptions were discarded but the scaling and cascade assumptions retained.

Today, thanks to the revolution in geodata and atmospheric models - both in quality and quantity – the 23/9-D model can explain the observed horizontal cascade structures in remotely sensed radiances, in meteorological "reanalyses", in meteorological models, in high resolution drop sonde vertical analyses, of lidar vertical sections, etc. All of these analyses directly contradict the standard model which predicts drastic "dimensional transitions" for scalar quantities. Indeed, until recently the only unexplained feature was a scale break in aircraft spectra of the (vector) horizontal wind. This was cut when careful analysis of scientific aircraft data allowed the 23/9-D model to explain the scaling break as an artefact of the aircraft following a sloping trajectory (roughly, isobaric levels): at large enough scales, the spectrum is simply dominated by vertical rather than horizontal fluctuations, which have the required scaling exponent.

However, objections remain: at large enough scales do isobaric and isoheight spectra really have different exponents? In this presentation we attempted to study this issue in more detail than before by analysing data measured by commercial aircraft through the Tropospheric Airborne Meteorological Data Reporting (TAMDAR) system over CONUS during year 2009. The TAMDAR system allows us to calculate the statistical properties of the wind field not only on constant pressure but also (thanks to GPS) on constant altitude levels (to within 3m) and hence to distinguish between isoheight and isobaric statistical properties (avoiding to spuriously conflating the two). We argue that the 23/9-D model is in agreement with data and can explain observed transition in scaling exponent of wind fluctuations in the horizontal for the isobaric case, (transition not seen when statistics are calculated on constant altitude levels).