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Three- to two-dimensional turbulence transition in the hurricane boundary layer

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The energy dynamics of a turbulent flow is governed by its dimensionality, that is, whether it is 2D or 3D. In 3D, energy flows downscale from larger to smaller scales, whereas in 2D, it flows upscale, from smaller to larger scales. It has long been thought that large scale flows in the atmosphere and oceans can be described (to first order) as two dimensional due to their large aspect ratios. However, the picture is complicated when the underlying small-scale turbulence is also considered, whose aspect ratio is small and therefore should be 3D in nature. It is not clear how these large-scale structures interact with the underlying 3D motions. Here we present two important results from manned flight measurements into tropical cyclones: The first measurement of a 2D inverse energy cascade in an atmospheric flow and also the 3D to 2D turbulence transition as a function of height. The proposed mechanism for the transition is a combination of shear, which limits the size of 3D eddies and the comparative size of the horizontal eddies. We propose that this phenomenon is not limited to tropical cyclones, where these measurements were made, but is applicable to many other large-scale atmospheric and oceanic flows.