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High-resolution simulations of turbulence events over the North Atlantic

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Two distinct episodes of moderate and severe turbulence were reported near the tropopause on 15 Nov 2011 over the N. Atlantic. These turbulence events occurred in response to the enhancement of an upper-level jet by widespread deep convection occurring upstream along a surface cold front. The turbulence producing mechanisms supporting this turbulence outbreak are investigated using high-resolution numerical simulations. The simulated episodes are related to the presence of eastward-propagating inertia-gravity waves emanating from the anticyclonic exit region of an upper-level jet, and depend on widespread deep convection occurring upstream during the previous afternoon and early evening. The inertia-gravity waves are shown to facilitate turbulence by influencing the vertical shear and static stability beneath them in the upper troposphere, which promote regions of banded cirrus clouds, near or within which the turbulence occurs.

The simulations suggest that while both episodes are influenced by inertia-gravity waves, they arise from fundamentally different mechanisms. In the first and most severe turbulence episode, enhanced upper-tropospheric vertical shear associated with the passage of the first and strongest inertia-gravity wave supports Kelvin-Helmholtz Instability (KHI). The KHI is, itself, excited by vertically-trapped internal gravity waves originating in the middle troposphere in response to relatively small areas of shallow convection. The second episode resulted from thermal instability related to larger-scale inertia-gravity waves reducing the static stability in the upper troposphere. The gravity waves control where regions of static instability and cirrus banding occur, but cloud radiative feedbacks are crucial for the instability to develop. The KHI episode would be difficult to predict, however the second episode is dominated by larger scale effects that may be at least partially resolved with horizontal grid spacings ($\sim$ few km) typical of the current highest resolution operational limited area NWP models.