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Does the Representation of Flow Structure and Turbulence at a Cold Front Converge on Multi-scale Observations with Model Resolution?

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In situ aircraft observations are used to interrogate the ability of a numerical weather prediction model to represent flow structure and turbulence at an intense cold front. Simulations are performed at a range of nested resolutions from grid spacings of 12 km down to 100 m and the convergence with resolution is investigated. The observations include the novel feature of a low-altitude circuit around the front that is closed in the frame of reference of the front, thus allowing the direct evaluation of area-average vorticity and divergence values from circuit integrals. As such, the observational strategy enables a comparison of flow structures over a broad range of spatial scales, from the size of the circuit itself ($\sim$100 km) to small-scale turbulent fluxes ($\sim$3 m). It is found that many aspects of the resolved flow converge successfully towards the observations with resolution if sampling uncertainty is allowed for, including the area-average vorticity and divergence measures and the narrowest observed cross-frontal width. In addition, there is a gradual handover from parametrised to resolved turbulent fluxes of moisture and momentum as cold-sector boundary-layer convective motions behind the front become partially-resolved in the highest resolution simulations. In contrast, the structure of frontal rainbands associated with shear instability along the front does not appear to converge with resolution, indicating that the mechanism of the frontal instability may not be well represented in the simulations. The parametrised turbulent fluxes associated with subgrid-scale shear-driven turbulence ahead of the front also do not converge on the observations.