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Turbulence parameter space, budgets, scaling laws, and structure parameter models in stably stratified shear flows from aircraft measurements.

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During the period 1998 to 2006 eight turbulent measurement campaigns were made with Airborne Research Australia's GROB 520T EGRETT instrumented aircraft in an attempt to capture the structure of severe turbulence events that could impact the performance of high energy laser systems or could lead to loss or damage to high altitude manned and unmanned surveillance aircraft. Measurements were confined to the winter subtropical jet stream with one campaign in Japan in February 1999 and with the remainder in the vicinity of Adelaide, Australia in August/September. An early goal was to characterize severe turbulence events by measured values of turbulent Reynolds number, turbulent Prandtl number, turbulent Froude number, and bulk gradient Richardson number. There are multiple forms of the turbulent Reynolds and Froude numbers that arise in the budget equations for the three turbulent kinetic energy components, the temperature variance, the three components of Reynolds stress, and the three components of heat flux. In addition these budget equations can be used to define multiple turbulent length scales that arise in structure parameter models for steady state turbulence where the net production (shear and/or stratification) at integral scales can be used to model the structure parameters which are representative of the turbulent dissipation. These structure function models are comprised of correlation functions, length scales and temperature and velocity scales.

A long-term goal of these aircraft turbulence measurements was to contribute to the development and validation of structure function parameter models for velocity components and refraction (temperature) for stably stratified free shear flow where turbulence scaling laws need to be established. The magnitude of the length scales and length scale ratios that are used to model the structure function parameters can be evaluated from the aircraft measurements or from direct numerical simulation (DNS) model studies (Joseph et al., JAS, 2004) but cannot be predicted with current mesoscale numerical weather prediction models. More comparisons of DNS studies and aircraft measurements to evaluate the impact of the turbulent Reynolds number difference. The DNS model studies are limited to turbulent Reynolds numbers of about $10^{4;}$ aircraft measurements are in the $10^7$to 10^8 range. A further difficulty evident in the aircraft measurements is the anisotropy in the inertial subrange of the vertical velocity spectra even at these high turbulent Reynolds numbers.

One form of severe turbulence event of interest to both laser propagation and flight safety are the cliff - ramp structures found at scales larger than inertial sub-range scales in the shear layer below and above the peak in the jet stream winds. Progress in understanding these structures has come from preliminary comparison of aircraft measurements of cliff-ramps with their structure and time evolution captured in DNS studies.