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Title: Applications of the ER-2 Meteorological Measurement System

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The NASA ER-2 aircraft is used as a platform for high-altitude atmospheric missions. The Meteorological Measurement System (MMS) was developed specifically for atmospheric research to provide accurate high-resolution measurements of pressure (±0.3 mb), temperature (±0.3°C), and the 3-dimensional wind vector (±1 m s^{-1}) with a sampling rate of 5 s^{-1}. Operational since 1986, the MMS participated in three scientific expeditions: the Stratospheric-Tropospheric Exchange Project (STEP) in Australia during January and February of 1987, the Airborne Antarctic Ozone Experiment (AAOE) in Chile during August and September of 1987, and the Airborne Arctic Stratospheric Expedition (AASE) in Norway during January and February of 1989.

The MMS consists of three subsystems: (1) an air motion sensing system to measure the velocity of the air with respect to the aircraft, (2) a high-resolution inertial navigation system (INS) to measure the velocity of the aircraft with respect to the earth, and (3) a data acquisition system to sample, process and record the measured quantities. The instrumentation of the MMS was reported in detail by *Scott et al.* [1990], and the calibration of the MMS will be discussed in a companion poster paper by *Bowen et al.* [1991].

MMS data have been used extensively by ER-2 investigators in elucidating the polar ozone chemistry. In this paper applications on atmospheric dynamics are emphasized. Large-scale (polar vortex, potential vorticity, model atmosphere), mesoscale (gravity waves, mountain waves) and microscale (heat fluxes) atmospheric phenomena are investigated and discussed.

With the aircraft cruising on isentropic surfaces along a north-south path during the AASE and AAOE, features of the Arctic and Antarctic vortexes (boundary, position, strength, variance, shape) are best depicted by latitudinal variations of the horizontal wind. The 1989 Arctic vortex during the AASE is weaker (wind speed), smaller (in areal extent) and more variant (shape and jet stream fluctuations) than the 1987 Antarctic vortex during the AAOE. The 1987 Antarctic vortex in mid-winter was dominated by a strong circumpolar circulation with small meridional amplitudes and the 1989 Arctic vortex in late winter and early spring was composed of several synoptic scale waves imbedded in two planetary waves with separated low pressure centers.

The potential vorticity on isentropic surfaces is a quasi-conservative quantity and important dynamical tracer. Large-scale features of the potential vorticity distribution computed from the horizontal wind and temperature gradient (lapse rate) data agree with those of observed nitrous oxide, also a quasi-conservative tracer (*Hartmann et al.*, 1989). The aircraft data provide temporal and spatial detail that is not currently achievable with other measurement techniques. In principle, this resolution allows the study of fine structure in the potential vorticity distribution and offers added insight into the details of the mixing processes.

The ER-2 can climb and descend rapidly, and measurements during aircraft takeoff, landing, mid-flight descent and ascent provide near-vertical profiles. MMS temperature profiles are used in developing model atmospheres (*Chan et al.*, 1989; *Chan et al.*, 1990). An AAOE or AASE model atmosphere (an idealized temperature profile) is a reference atmosphere at a specific latitude for the duration of the expedition. For a specific flight, concurrent synoptic or in situ meteorological data should be used. However, for investigations requiring the mean meteorological environment as the boundary condition during the expedition, the model atmosphere (substantially different from the standard atmosphere) is needed.

Small and periodic variations in the vertical wind data ($\approx \pm 1$ m s^{-1}) are the first indications of atmospheric wave phenomena. Coherence and phase relationships of the temperature and wind data by cross-spectral analyses provide the evidence of gravity waves and their physical properties. Gravity waves, generated by Cyclone Jason in Australia (2/8/87), will be discussed and illustrated.

Large and periodic variations in the wind data ($\approx \pm$ 2-6 m s^{-1}) are the indications of waves of different origin. Mountain waves over the Palmer Peninsular of Antarctica (9/22/87) and near Iceland in the northern polar region (2/10/89) are the best examples of orographically generated waves observed by the MMS.

Small and irregular variations in the temperature and vertical wind data are analyzed and heat fluxes computed. Episodic downward heat fluxes during the STEP (1/31/87) are identified and illustrated. Evidence of turbulence is supported by the comparison of power spectra of vertical wind and temperature during quiet and disturbed periods.

Real-time wind profiling (30 s lag) capability of the ER-2 MMS via telemetry was demonstrated at Kennedy Space Center during the Space Shuttle STS-28 launch on 8 August 1989. In addition to providing the quick access to the wind profiles, the quality and high resolution of the wind shear information measured by the MMS on a controlled platform offer advantages over the "Jimsphere" balloon system currently used in the support of Space Shuttle launch operation.

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