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Challenging physics at the boundary between the Earth's atmosphere and Space

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The extended mesosphere and lower thermosphere (MLT-X) region, spanning altitudes between 60 and 200 km, constitutes the interface where Earth's atmosphere transitions into space. Situated beyond the reach of traditional in situ measurements via satellites or balloons, exploration of the MLT-X has primarily relied on remote sensing techniques employed by ground-based instruments such as radars, lidars, and imagers, complemented by satellite observations and occasional sounding rockets missions. This region plays a pivotal role in bridging our understanding of meteorological weather with space weather phenomena. Addressing scientific inquiries within the MLT-X demands a multidisciplinary approach, integrating principles from hydrodynamics, thermodynamics, electrodynamics, and other pertinent physical disciplines. Among the remarkable phenomena observed in this altitudinal region is the polar summer mesopause, where temperatures reach as low as 120 K, exhibiting deviations from radiative equilibrium exceeding 100 degrees.

In this presentation, we elucidate the fundamental characteristics of the MLT-X region and underscore its significance in the context of global climate change studies, space weather forecasting, and applications pertinent to sub-orbital or very-low orbital space environments (e.g., commercial sub-orbital flights, satellite re-entry). Subsequently, we focus on a specific observational anomaly that challenges prevailing theoretical frameworks governing processes within the MLT-X. Specifically, we scrutinize the occurrence of extreme vertical drafts in the mesosphere (~80-90 km altitude), which exhibit magnitudes surpassing five times their standard deviation (e.g., Chau et al., 2021, Hartisch et al., 2024). This phenomenon points to the intricate interplay between gravity waves and turbulence motions, elucidating the nonlinear dynamics governing this atmospheric region.

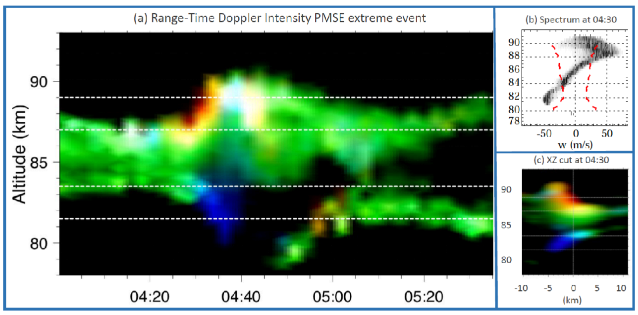

Figure 1. Observations of a varicose event with extreme vertical velocities with a power radar in northern Norway: (a) brightness of the echoes, (b) doppler spectrogram, and (c) 2D cut around the time of maximum vertical velocity.

Keywords: atmospheric waves; extreme events; mesosphere and lower thermosphere; nonlinear dynamics; vertical velocities

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