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Atmospheric waves and fractional order wave equations: waves as emergent high Reynolds number phenomena

Shaun Lovejoy (1), Julien Pinel (1), and Daniel Schertzer (2)

(1) McGill University, Department of Physics, Montreal, Canada (lovejoy@physics.mcgill.ca, +1-(0)514-3988434), (2) Université Paris-Est, ENPC/CEREVE, 77455 Marne-la-Vallee Cedex 2, France

The atmosphere is a strongly nonlinear, high Reynolds number system displaying both turbulent and wavelike behaviours. The Reynolds numbers (Re) are so high (typically Re $\approx$ 10**12) that the atmosphere is fully turbulent; a fact routinely confirmed through the evidence of spectra and other scaling statistics. At the same time, almost all of our theories of atmospheric waves are based on linear techniques including low Reynolds number linearizations such as the Taylor-Goldstein equations.

The application of low Re theories to high Re fluids is paradoxical; to understand it we must realize that it is only the dispersion relations that are empirically tested (other "polarization" relations are used purely diagnostically). Indeed, we show directly from pairs of high resolution drop-sondes that the linearizations themselves are not at all empirically valid. However the dispersion relations are essentially just scaling relations between frequencies and wavevectors and hence it is sufficient that - just as with the classical laws of turbulence - the dynamics respect space-time scaling symmetries. The waves and their dispersion laws thus emerge at high Re.

In this talk we present a Wheeler-Kiladis type analysis of geostationary thermal IR satellite data to show that while these radiances obey a classical dispersion relation, that they are compatible with wave equations of order Hw with Hw $\approx$ 0.15 i.e. they are of fractional rather than integer order. While this anomalous result effectively rules out explanations based on linearized equations, it may nevertheless be readily understood as an "emergent" consequence of scaling symmetries and high Re.