18-22 July 1994, Portland, Oregon, USA

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UNIVERSAL SPECTRUM FOR BOUNDARY LAYER FLUXES OF SENSIBLE HEAT AND MOMENTUM

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1. INTRODUCTION

The symbiotic existence of fluctuations of all scales ranging in size-duration from millimetre-second (turbulence) to thousands of kilometres-days (planetary scale) contribute to the vertical fluxes of sensible heat and momentum in the atmospheric boundary layer (ABL) and result in the formation of weather systems of all scales. The temporal fluctuations of meteorological parameters exhibit selfsimilarity, i.e., the power spectra follow the inverse power law of form $1/f^{B}$ where f is the frequency and B, the exponent. Inverse power law indicates scaling or selfsimilarity. The values of B, the scaling factor is found to be different for different length scales. Fritts and Van Zandt (1993) have summarised numerous studies over the last three decades, of the remarkably uniform spectral shape of fluctuations which are signatures of atmospheric gravity (buoyancy) waves. The spectral shape, namely, the inverse power law form is universal and independent of time, location and altitude of observation. Lovejoy and Schertzer (1985, 1986) and Tesser et al (1993) have also documented and discussed the universal nature of the inverse power law spectra of temporal fluctuations in atmospheric flows. Such self-similar scaling behaviour in geophysical parameters also has been documented (Agnew, 1992). Inverse power law form for power spectra indicate long-range temporal correlations. Atmospheric flows exhibit long-range spatial correlations also as manifested in the selfsimilar fractal geometry to the global cloud cover pattern documented by Lovejoy and Schertzer (1986). Such selfsimilar fractal pattern evolution by selfsimilar fluctuations on all time scales is generic to all dynamical systems in nature and is recently identified as signature of self-organized criticality (Bak, Tang and Wiesenfeld 1988). Self-organized criticality implies long-range spatiotemporal correlations, i.e., sensitive dependence on initial conditions in real world extended dynamical system such as atmospheric flows. Finite precision computer realizations of nonlinear mathematical models of atmospheric flows also exhibit such sensitive dependence on initial conditions identified as deterministic chaos, an area of intensive research in all branches of science. The physics of deterministic chaos or self-organized criticality in real world and model dynamical systems is not yet identified. Deterministic chaos in computed model dynamical systems precludes long-term predictability. Traditional deterministic models of atmospheric flows cannot explain satisfactorily the observed selfsimilarity in atmospheric flows (Tesser et al 1993). Recently (since 1980) developed concepts in nonlinear dynamical systems theory may help identify the observed fractal

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amplitude therefore represents probability of occurrence. Such a concept that additive amplitudes of eddies, when squared, represent probability densities is observed in subatomic dynamics of quantum systems. Atmospheric flows therefore follow quantum-like mechanics with inherent long-range spatiotemporal correlation, i.e., self-organized criticality, since, by concept, the power spectrum of temporal fluctuations follow the universal inverse power law form of statistical normal distribution. Atmospheric eddy energy spectrum has unique structure independent of details of dynamics.

3. DATA AND ANALYSIS

Continuous periodogram spectral analysis (Jenkinson, 1977) was done for TOGA (Tropical Ocean Global Atmosphere) global 1000 mb 00 GMT temperature data for the 92-day period June to August 1988. THe latitudinal mean power spectra are plotted in Figure 1 as the cumulative percentage contribution to total variance versus the normalised standard deviation t equal to $(\log L/\log T_{50})-1$ where L is the period in days and T_{50} the period upto which the cumulative percentage contribution to total variance is equal to 50. The power spectra are found to closely follow the statistical normal distribution consistent with model predictions.

4. CONCLUSION

Universal structure for atmospheric eddy energy spectrum presented in this paper is independent of details of dynamics and does not require arbitrary assumptions and approximations for modelling atmospheric flows such as in traditional NWP models. Energy input into any one scale propagates to all scales so as to conform to the universal spectrum.

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LATITUDINAL MEAN POWER SPECTRA
TOGA 1000MB 00GMT DAILY TEMPERATURE JUNE–AUGUST 1988
SOUTHERN HEMISPHERE 0 TO 50 DEG LAT 2.5 DEG GRID