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A stochastic, turbulence based model of weather, macro weather and climate

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In a series of publications, we have shown that aircraft, satellite and in situ data as well as reanalyses and numerical weather models accurately follow the predictions of (stochastic) space-time multiplicative cascade models up to scales of ≈ 5000 km in space and ≈ 5 – 10 days in time. The space-time fluctuations are linked by typical advection speeds of about 1000 km/day. Assuming that the turbulent energy flux (ε) is dominant in the horizontal, and using the observed value ε ≈10**-3 W/Kg, this corresponds to advection by the largest (planetary scale) eddies (this value can be estimated quite accurately from first principles starting from solar energy inputs). The implied wide range horizontal scaling is possible because of the strong scaling anisotropy characterizing the stratification.

Overall, these empirical “weather regime” characteristics are well modeled by stochastic turbulence models developed over the last thirty years. It is therefore tempting to extend the cascades to much larger time scales. When this is done, the cascade model predicts that at scales beyond the “weather regime” scale (≈ 10 days, the lifetime of planetary scale structures) there is a “dimensional transition” due to the “quenching” of the spatial degrees of freedom. This corresponds quantitatively and qualitatively to the basic empirical observation of a drastic change in the statistics of the state variables, and includes a reasonable estimate of the (scaling) statistics in the new lower frequency “macroweather” regime. Whereas in the “weather regime” fluctuations generally grow with scale, in “macroweather”, they typically diminish with scale.

At scales beyond ≈ 30 yrs (but highly variable from one geographical location and one epoch to another), fluctuations again start to increase with scale corresponding to the beginning of the climate regime. In order to model the entire weather-macroweather-climate process, we therefore propose to include a new space-time (multiplicative cascade based) climate process dominant at low frequencies and which we propose multiplicatively modulates the weather-macroweather fluxes. We show how the resulting weather-macroweather-climate process models both spatial variability (including climate zones), as well as the temporal variability up to scales of 50 – 100 kyrs (corresponding to the glacial/interglacial transitions).