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Fluctuations and Response in Geophysical Fluid Dynamics

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The climate is a complex, chaotic, non-equilibrium system featuring a limited horizon of predictability, variability on a vast range of temporal and spatial scales, instabilities resulting into energy transformations, and mixing and dissipative processes resulting into entropy production. Despite great progresses, we still do not have a complete theory of climate dynamics able to account for instabilities, equilibration processes, response to changing parameters of the system, and multiscale effects. We will outline some possible applications of the response theory developed by Ruelle for non-equilibrium statistical mechanical systems, showing how it allows for setting on firm ground and on a coherent framework concepts like climate sensitivity, climate response, and climate tipping points, and to construct parametrizations for unresolved processes. We will show results for comprehensive global climate models. The results are promising in terms of suggesting new ways for approaching the problem of climate change prediction and for using more efficiently the enormous amounts of data produced by modeling groups around the world. Ref: V. Lucarini, R. Blender, C. Herbert, F. Ragone, S. Pascale, J. Wouters, *Mathematical and Physical Ideas for Climate Science, Reviews of Geophysics* 52, 809-859 (2014)