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Suppression of chaos at slow variables by rapidly mixing fast dynamics

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Chaotic multiscale dynamical systems are common in many areas of science, one of the examples being the interaction of the slow climate dynamics with the fast turbulent weather dynamics. One of the key questions about chaotic multiscale systems is how the fast dynamics affects chaos at the slow variables, and, therefore, impacts uncertainty and predictability of the slow dynamics. Here we demonstrate that the linear slow-fast coupling with the total energy conservation property promotes the suppression of chaos at the slow variables through the rapid mixing at the fast variables, both theoretically and through numerical simulations. A suitable mathematical framework is developed, connecting the slow dynamics on the tangent subspaces to the infinite-time linear response of the mean state to a constant external forcing at the fast variables. Additionally, it is shown that the uncoupled dynamics for the slow variables may remain chaotic while the complete multiscale system loses chaos and becomes completely predictable at the slow variables through increasing chaos and turbulence at the fast variables. This result contradicts the common sense intuition, where, naturally, one would think that coupling a slow weakly chaotic system with another much faster and much stronger chaotic system would result in general increase of chaos at the slow variables. This, in turn, raises more questions not thought of before. In particular, could the global climate be less chaotic and more predictable, than we presently tend to think ?

For reference article, see `http://arxiv.org/pdf/1105.3164`.

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