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On finite-size Lyapunov exponents in multiscale systems

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We study the effect of regime switches on finite size Lyapunov exponents (FSLEs) in determining the error growth rates and predictability of multiscale systems. We consider a dynamical system involving slow and fast regimes and switches between them. The surprising result is that due to the presence of regimes the error growth rate can be a non-monotonic function of the initial error amplitude. In particular, the signature of slow regimes in FSLE spectra is shown to be troughs at the large scales, whereas fast regimes are shown to cause large peaks of the FSLEs with associated error growth rates far exceeding those estimated from the maximal Lyapunov exponent. We present analytical results explaining these signatures and corroborate them with numerical simulations. We show further that in stochastic parametrizations of the fast chaotic processes these peaks disappear, and the associated FSLE spectra reveal that the large scale predictability properties of the full deterministic model are well approximated whereas the small scale features are, as expected, not properly resolved.