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Chaos and Slow Earthquakes Predictability

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Slow Slip Events (SSEs) are episodic slip events that play a significant role in the moment budget along subduction megathrust. They share many similarities with regular earthquakes, and have been observed in major subduction regions like, for example, Cascadia, Japan, Mexico, New Zealand. They show striking regularity, suggesting that it might be possible to forecast their size and timing, but the prediction of their extension and exact timing is still yet to come. They certainly are a great natural system to study how friction works at scale of the order of hundreds or thousands of km, and their recurrence time being much shorter than that of regular earthquakes, they give us the possibility to study multiple cycles and test their predictability. Here we focus on the Cascadia region, where SSEs recur every about 1 or 2 years, depending on the latitude. We use a catalog containing dozens of SSEs derived from the study of GPS position time series during the time span ranging from 2007 to 2017. The data show a clear segmentation with a few major patches interacting with one another, a behavior that recalls that of a discrete body system. We use both classical embedding theory and Extreme Value Theory applied to the study of dynamical systems to show that, where the Signal to Noise Ratio is sufficiently high, a low-dimensional (< 5) non-linear chaotic system is more appropriate to describe the dynamics than a stochastic system. We calculate major properties of the strange attractor like its correlation and instantaneous dimension, its instantaneous extremal index and a possible range for the metric entropy of the system. This knowledge is important for the determination of the predictability of the system, since it is related to the rate at which two trajectories in the phase space diverge. We further validate our results with a fuzzy inference system model to check the predictability of the slip and slip rate. In conclusion, SSEs in Cascadia can be described as a deterministic, albeit chaotic, system rather than as a random process. As SSEs might be regarded as earthquakes in slow motion, regular earthquakes might be similarly chaotic and predictable.