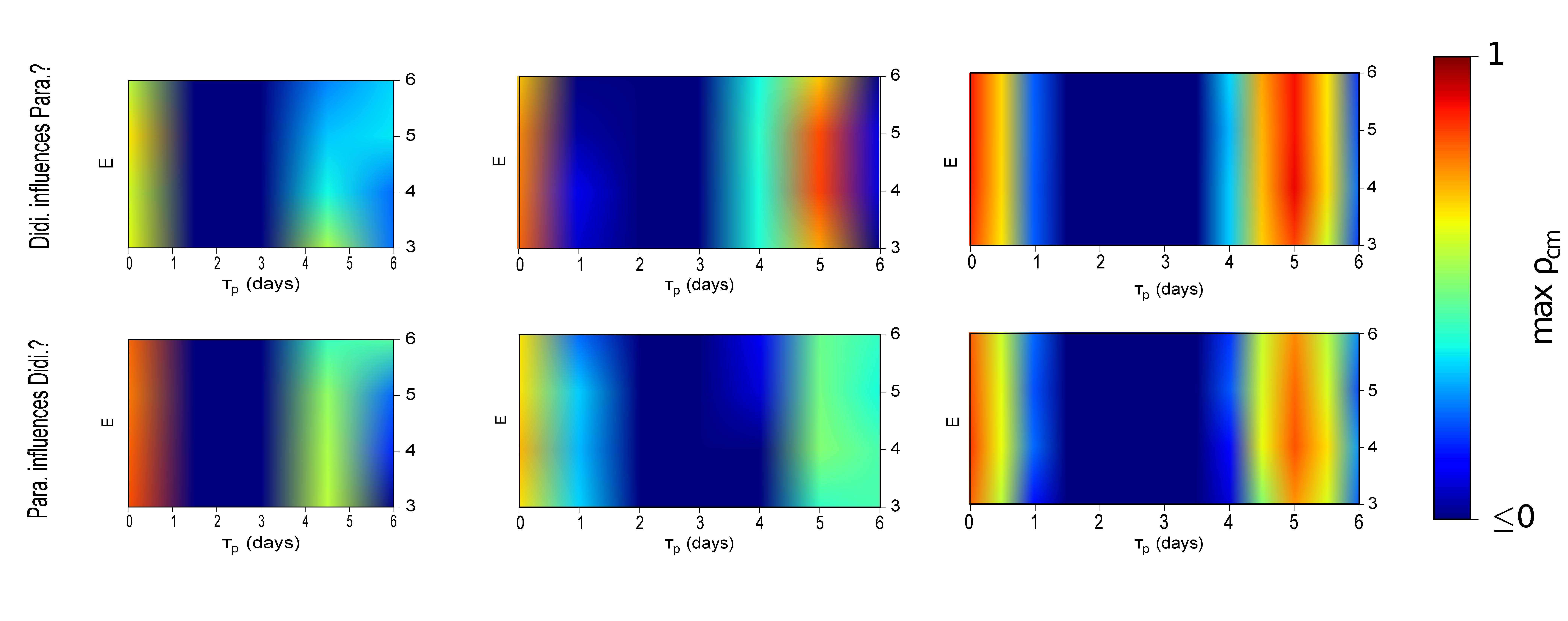
# Convergent cross mapping algorithm

Consider time series of hypothetical variables *X* and *Y.* Convergent cross-mapping (CCM) employs state space reconstruction (SSR), thereby using time-lagged coordinates of each of these variables to produce shadow versions of their respective source manifolds. We will refer to these projection manifolds as *Mx* and *My*. To test whether *X* causes *Y*, CCM applies the following logic: Because manifold reconstruction preserves the Lyapunov exponents of the original system [18], if *X* causes *Y*, then time points that are close in *My* should also be close in *Mx*. Since *Mx* is constructed from lags of the observations of *X*,the points that are close in *Mx* will also have similar values in the corresponding time series*.* Therefore, if *X* causes *Y*, then *My* can tell us which observations of *X* should best predict a given point from *X.* Furthermore, predictability should increase with the number of manifold points that are considered.

To test whether *X* causes *Y*, *My* is used to infer the points in *X* that will best predict a given held-out point from X*.* We measure this performance using predictive skill, quantified by ρccm. Intuitively, this procedure works as follows: A point is held out from *X*. We then use *My*to infer the points in *Mx* that will be closest to that point of interest*.* Using exponential weights derived from the relative pairwise distances of corresponding points in *My,* we predict the held-out point using other observations from *X.* Finally, ρccm is calculated as the Pearson correlation between observed and predicted points, and so is a cross-validated measure. To examine whether the signal converges as expected for a causal relationship, these steps are repeated using increasing time series length (*L*).

# Paramecium-Didinium system

Didinium is a free-living unicellular carnivore. Paramecium is its prey. More information about this system, as well as interactive graphs of time series and manifold constructions, can be found at: <http://cyrusmaher.github.io/CauseMap.jl/ParaDidiExample.html#paramecium-and-didinium>



One-third thinned

One-half thinned

Full dataset

**Figure S1. The maximal predictive skill as a function of E, tau p, and the number of included points.**

# Fourier transform analysis

We calculated the characteristic frequencies of the paramecium and didinium time series by performing fourier transform analysis using the rfft function in the python module scipy.