





2m of SLR in 100 years  
(Deconto and Pollard, 2016)



60-120 years later?

# The Dynamics of Coastal Adaptation to Sea Level Rise

Dylan McNamara

Department of Physics and Physical Oceanography, UNCW

# Outline

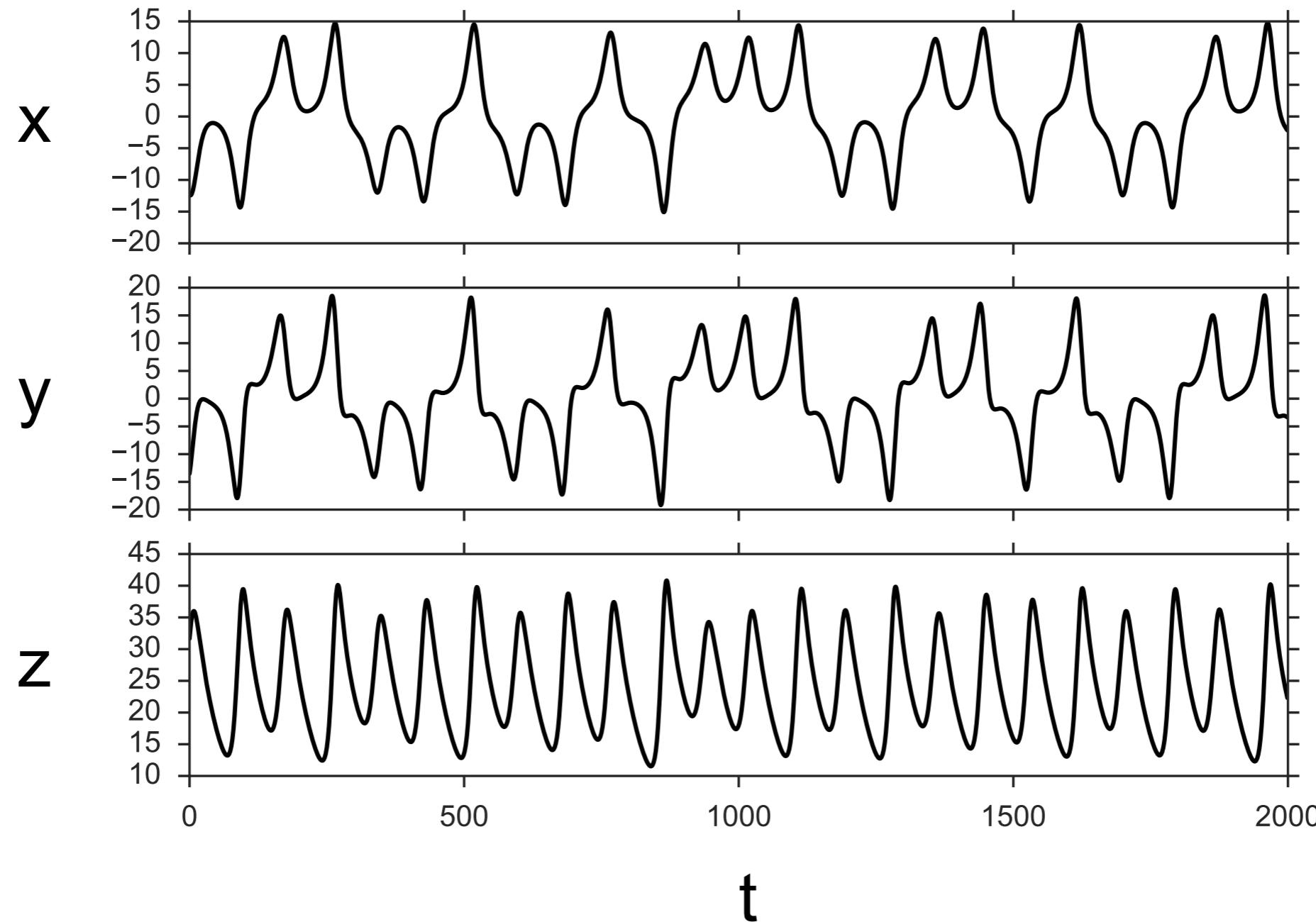
- Nonlinear Forecasting as a Tool
- Beach Nourishment
- Environmental Econophysics
- Model
- Results
- Implications

# Nonlinear Forecasting

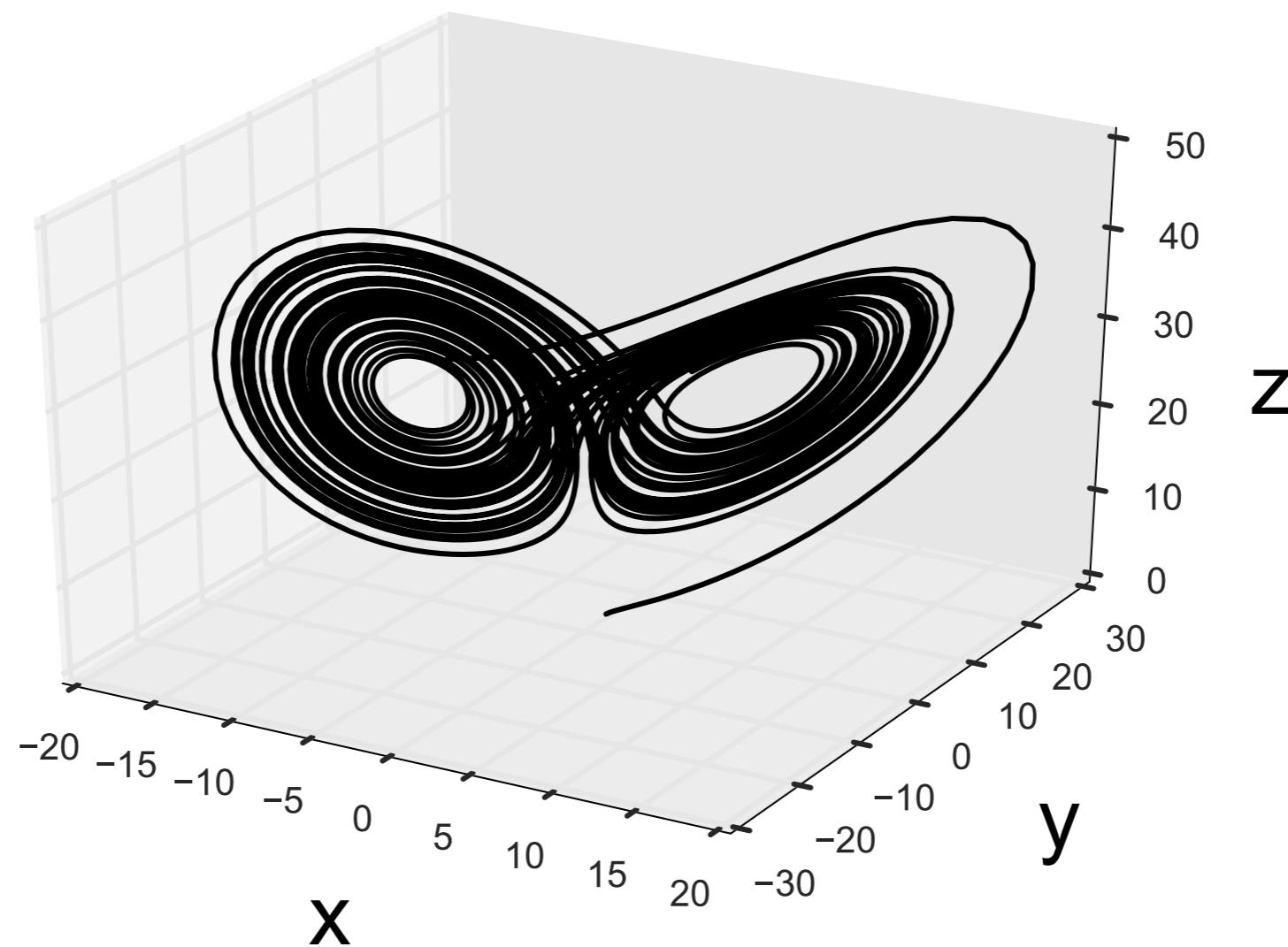
## Lorenz System

$$\begin{aligned}\frac{dx}{dt} &= -\sigma x + \sigma y \\ \frac{dy}{dt} &= -xz + rx - y \\ \frac{dz}{dt} &= xy - bz\end{aligned}$$

# Nonlinear Forecasting



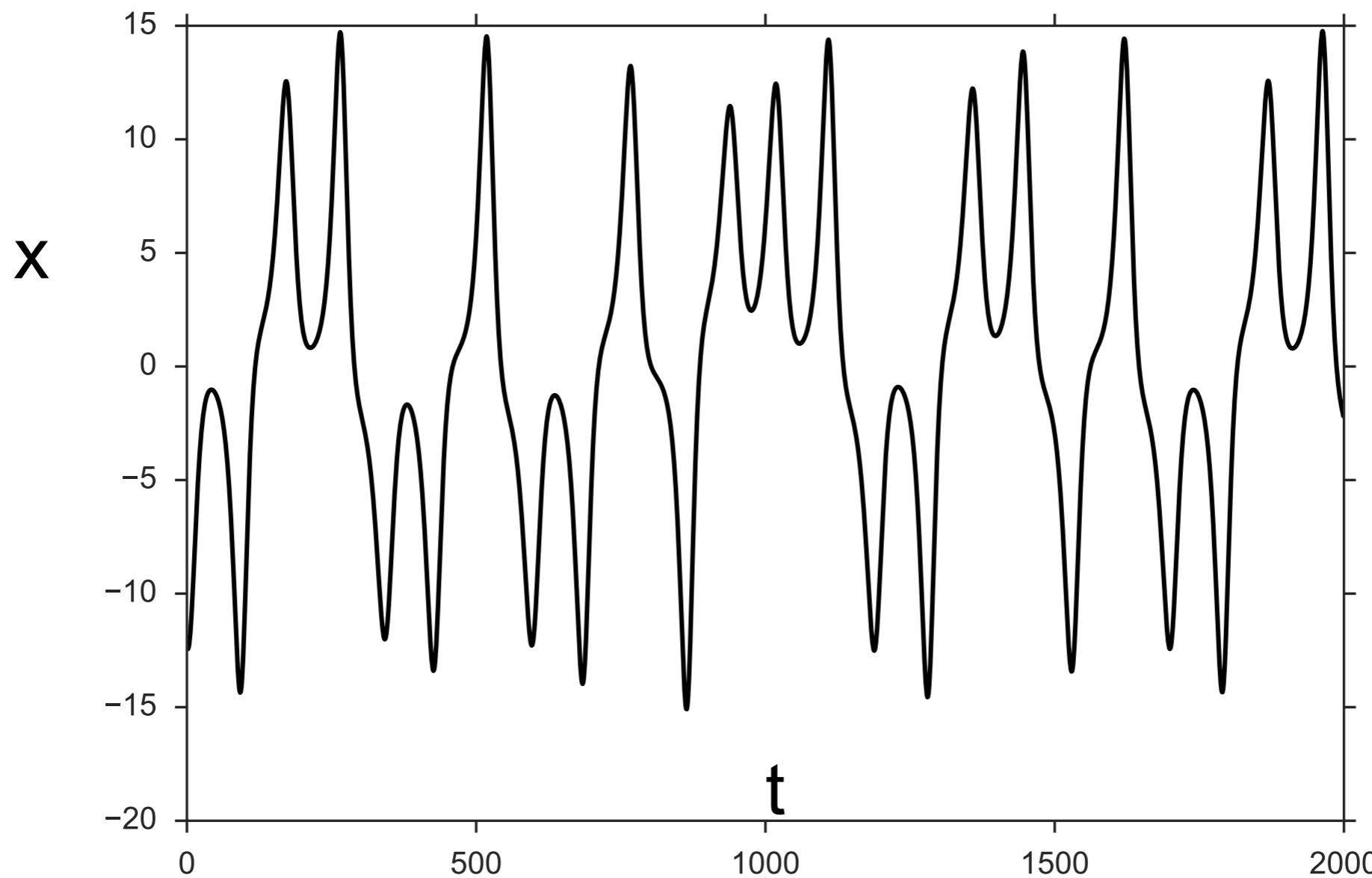
# Nonlinear Forecasting



# Nonlinear Forecasting

imagine you only measured  $x(t)$

can one verify  $x(t)$  is deterministic?



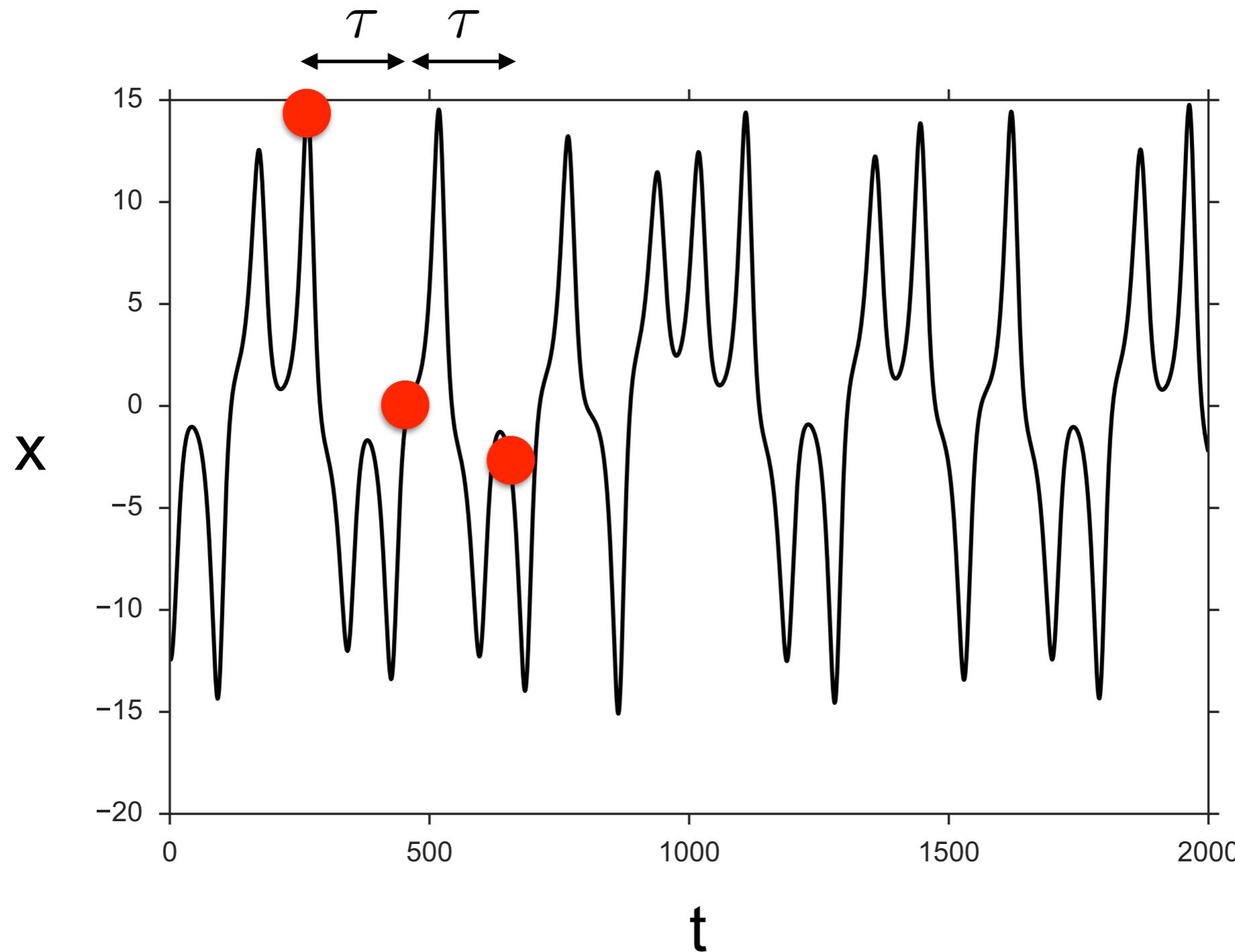
# Nonlinear Forecasting

## Taken's Theorem:

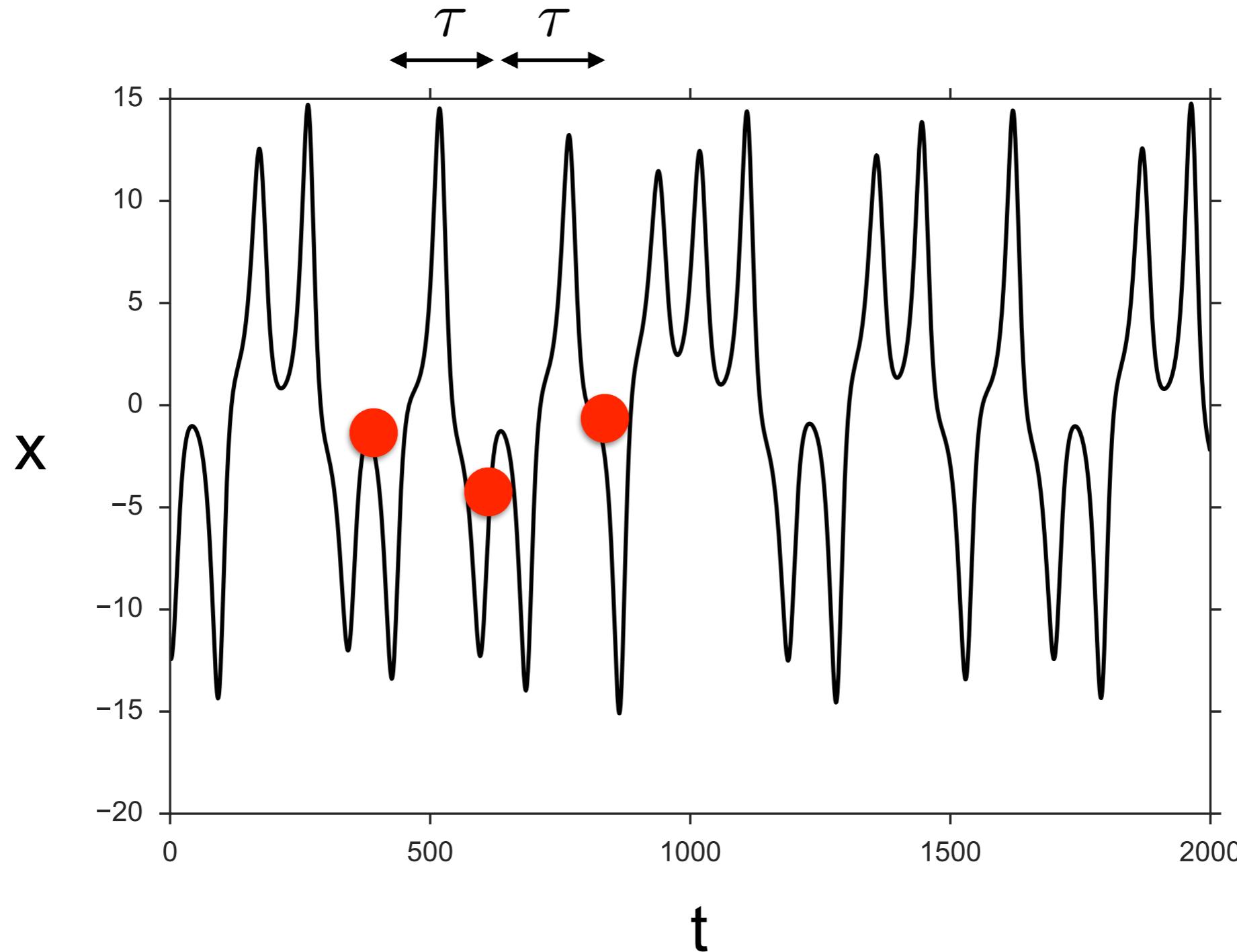
Measurements of a single dynamical variable, can be embedded in  $m$  dimensional space, revealing the structure and determinism of the full system.

$$\vec{z}_n = (x_n, x_{n-\tau}, x_{n-2\tau}, \dots, x_{n-(m-1)\tau})$$

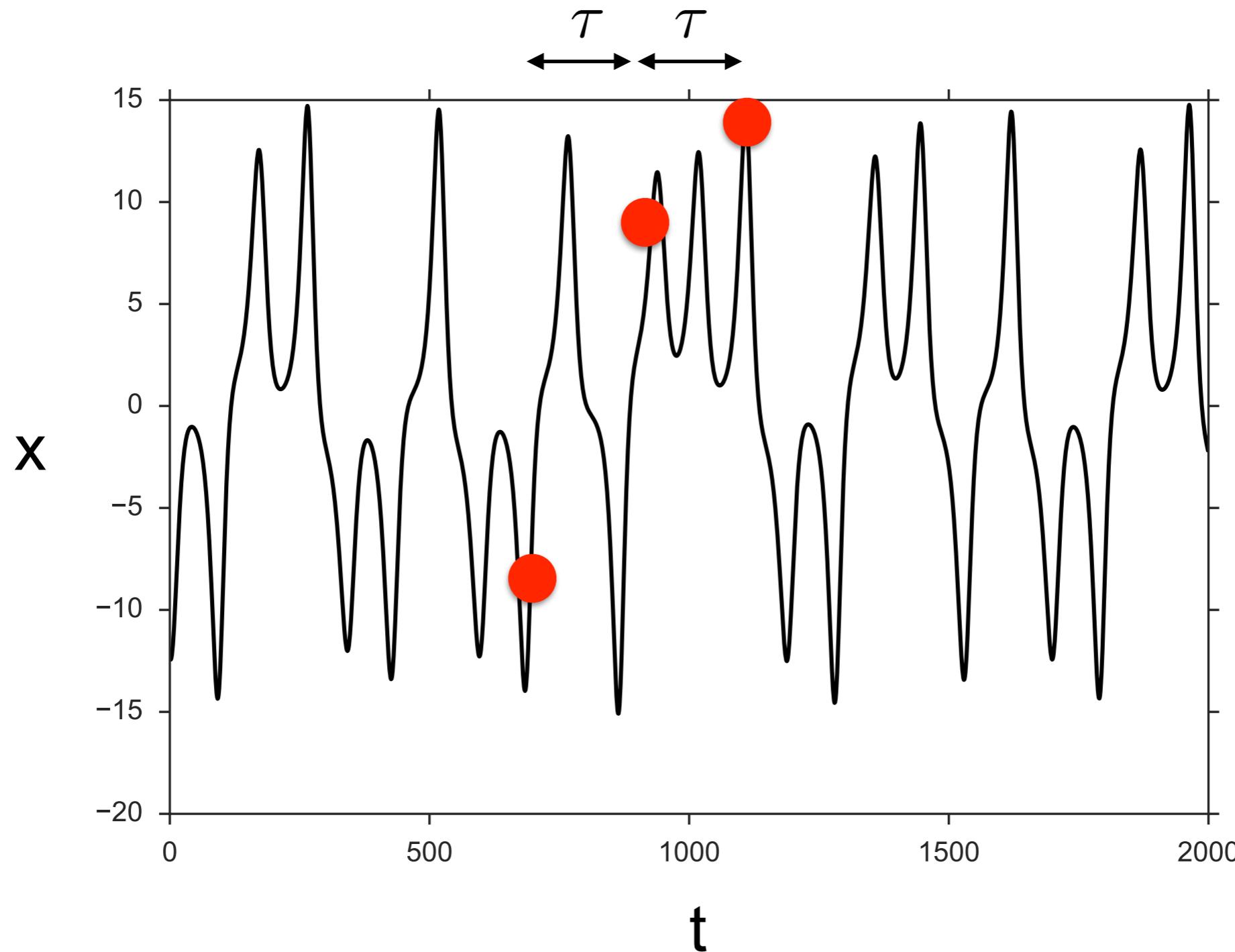
# Nonlinear Forecasting



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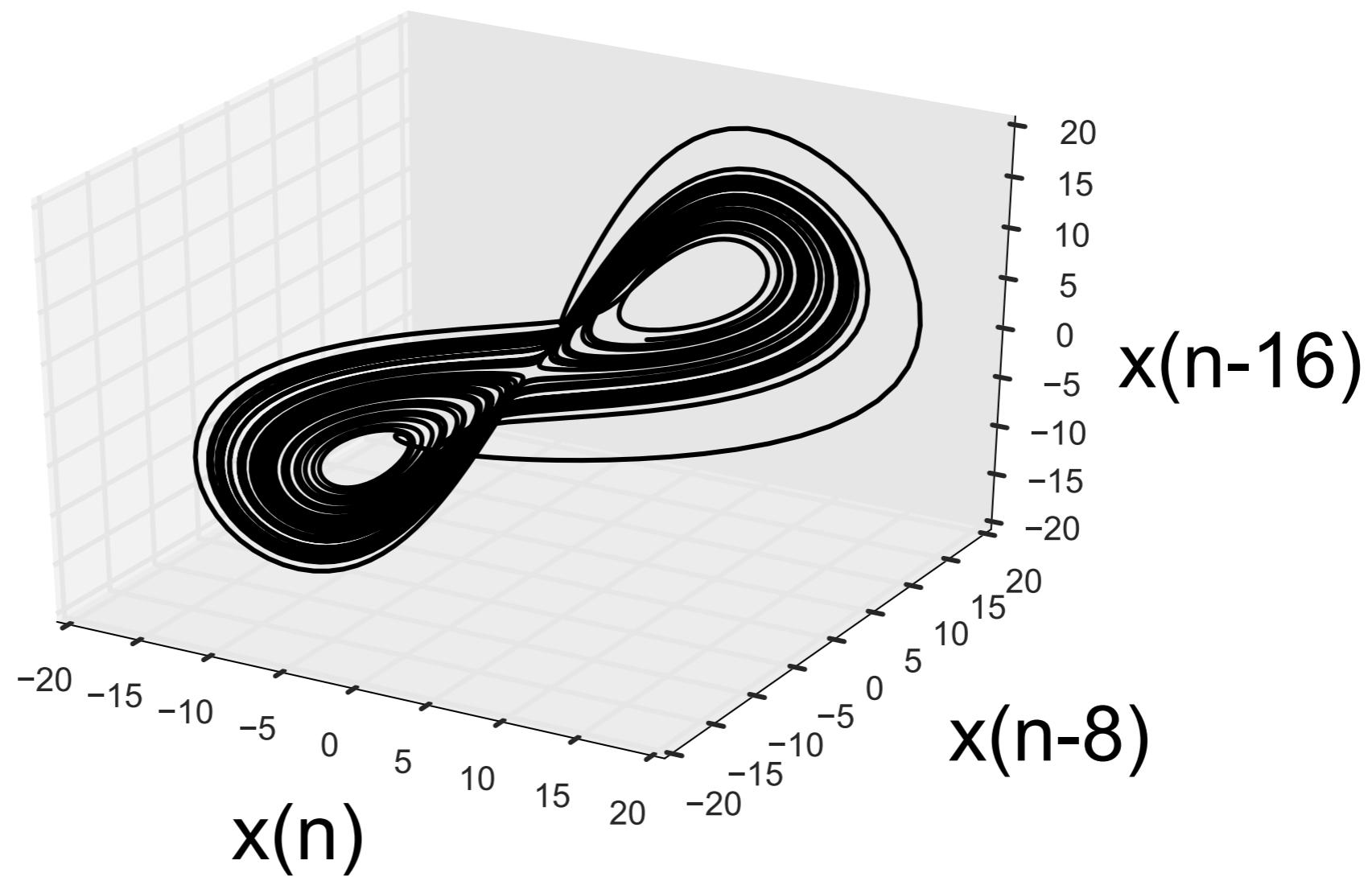


# Nonlinear Forecasting



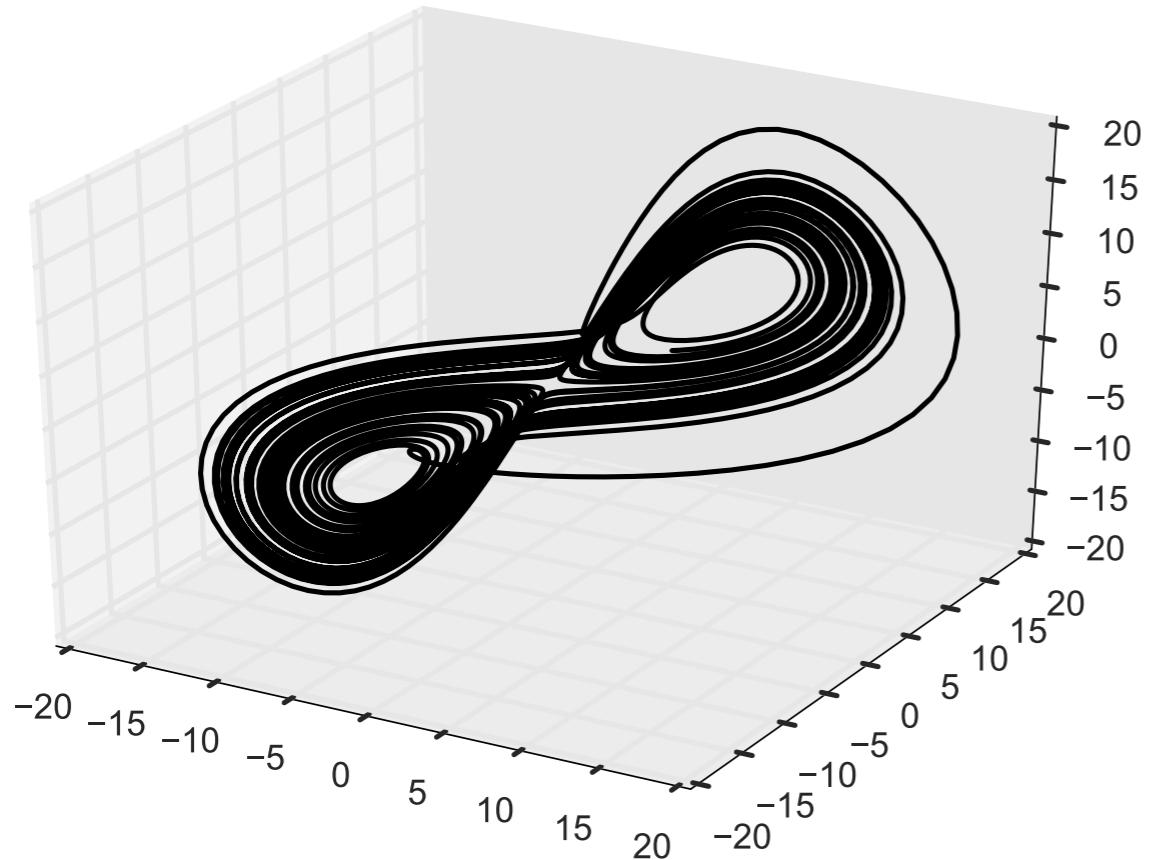
# Nonlinear Forecasting

## Reconstructed Attractor

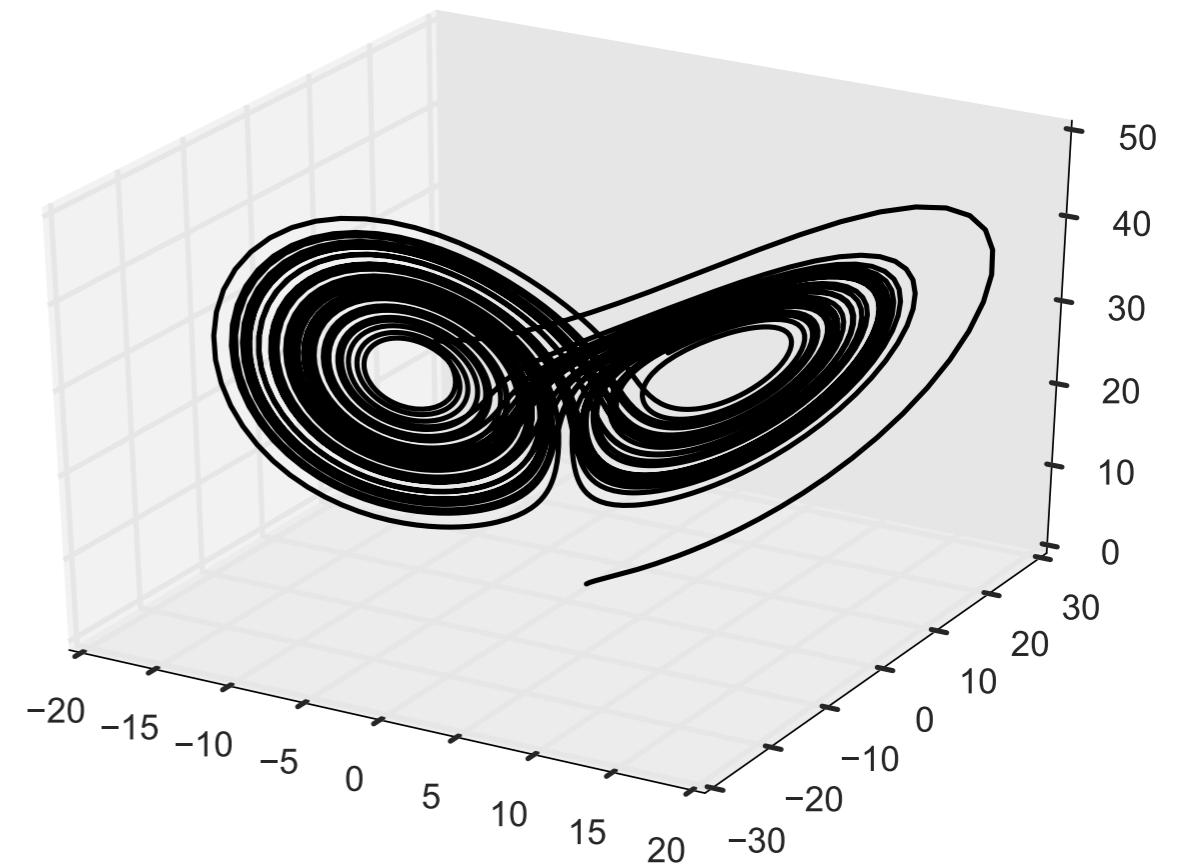


# Nonlinear Forecasting

## Reconstructed Attractor

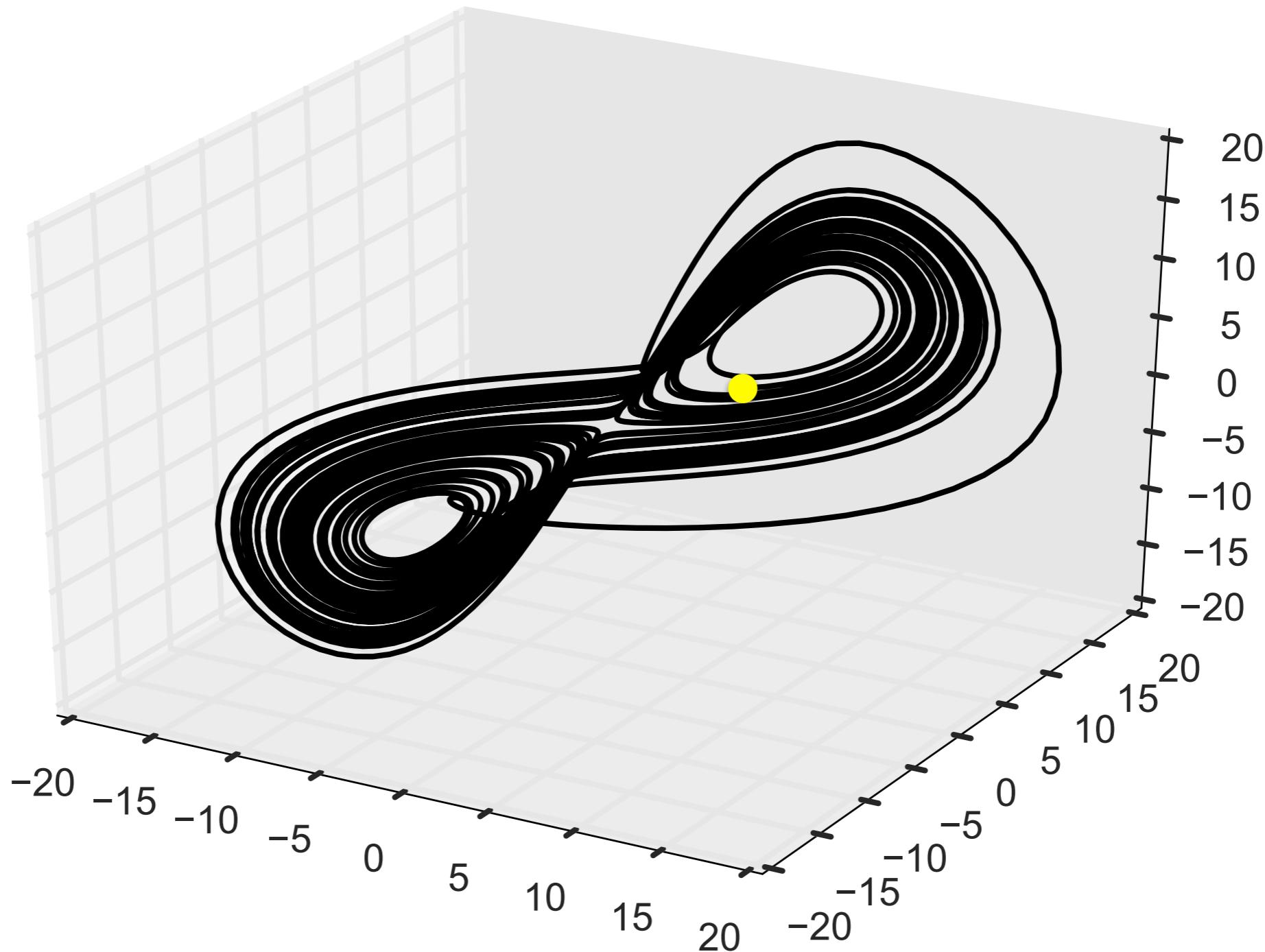


**Lorenz Attractor**



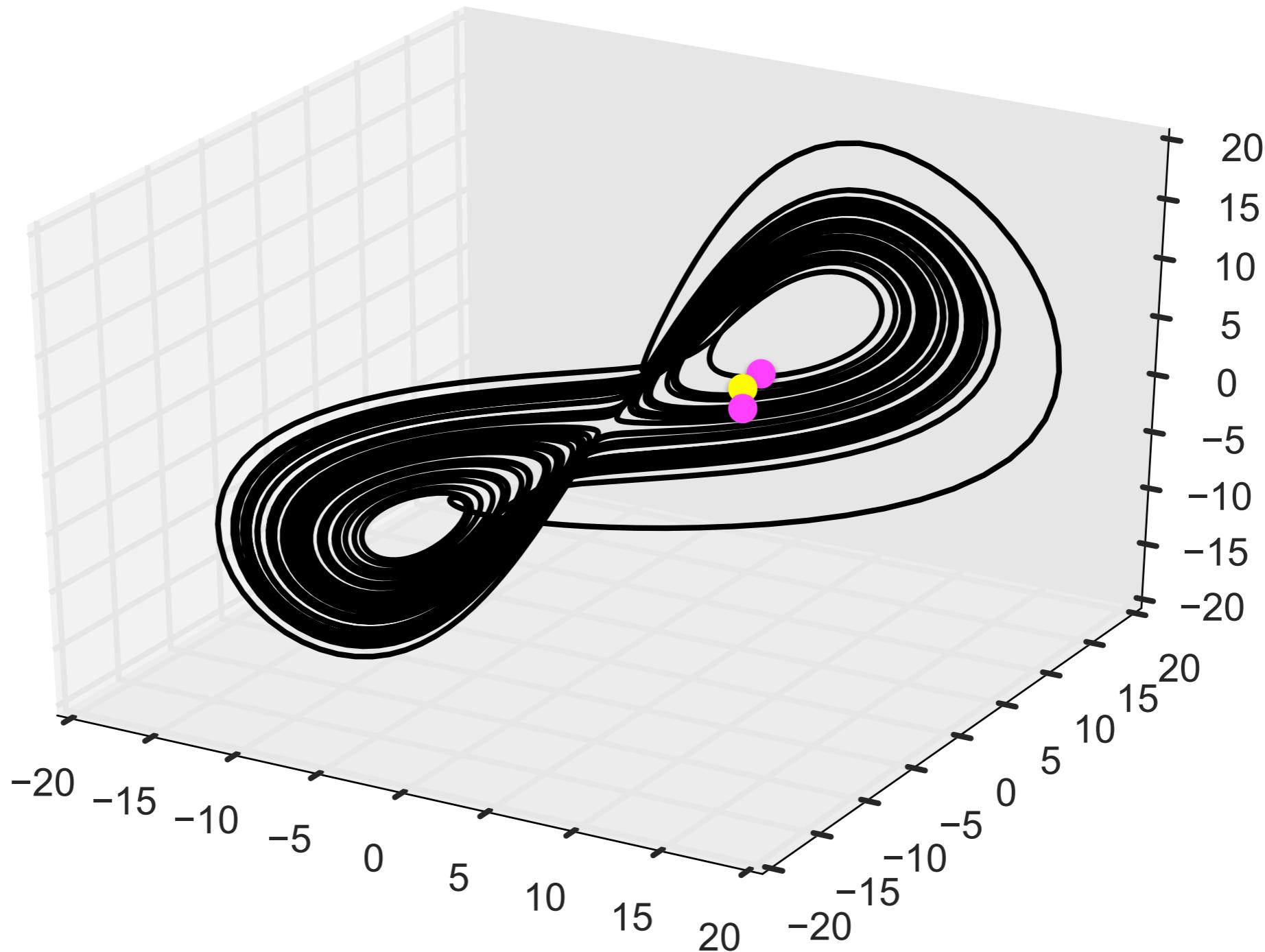
# Nonlinear Forecasting

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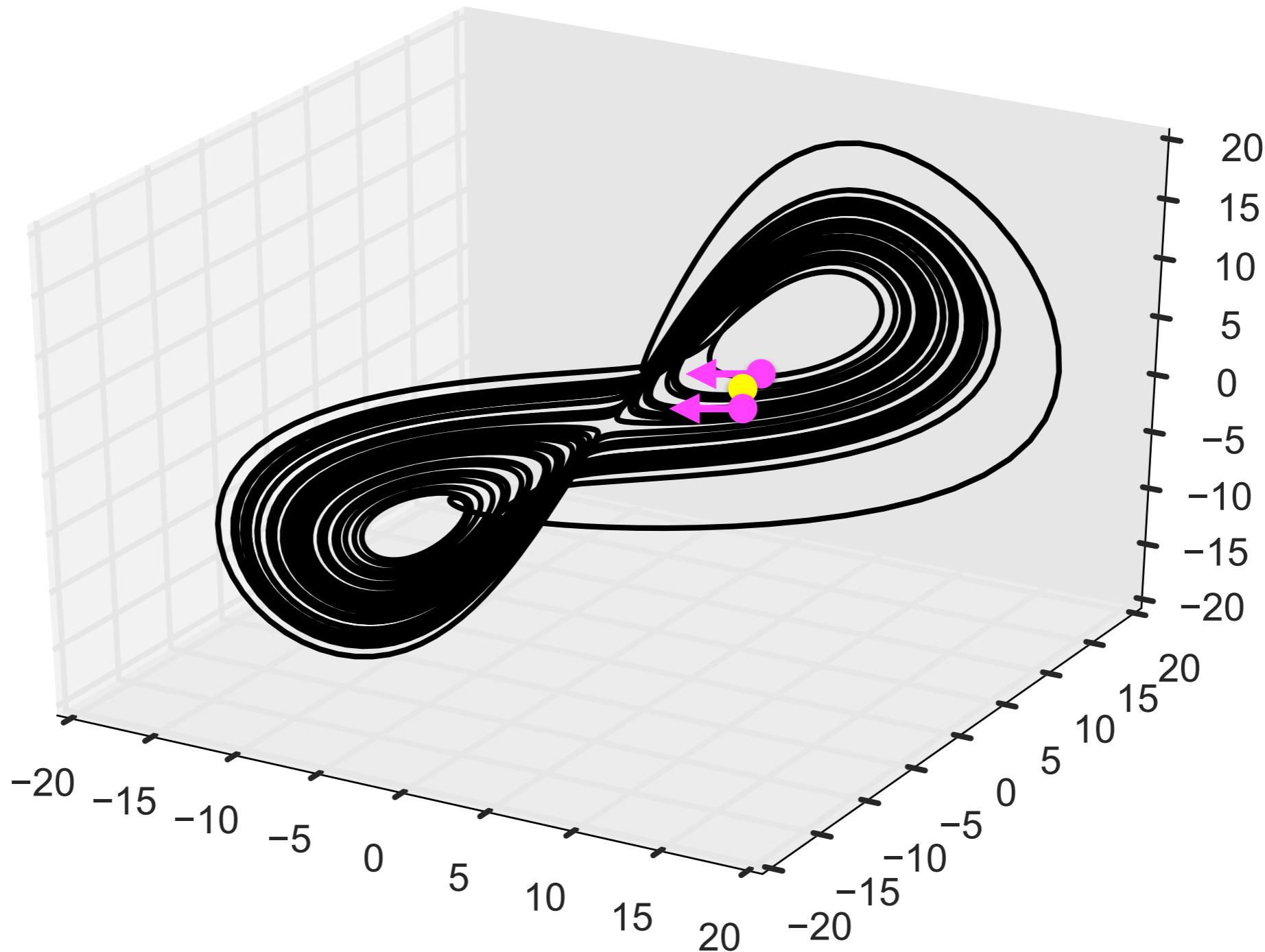
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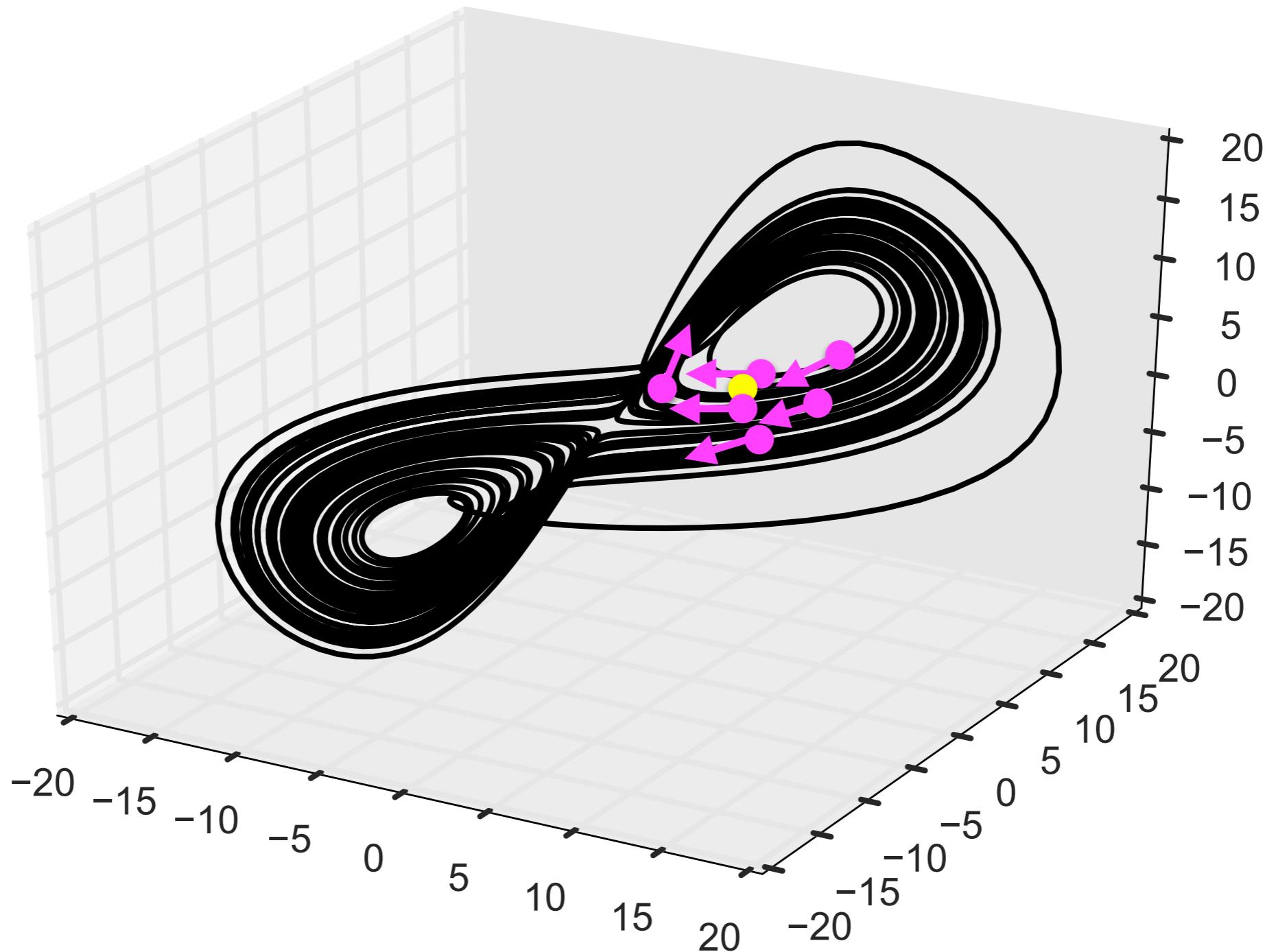
# Nonlinear Forecasting

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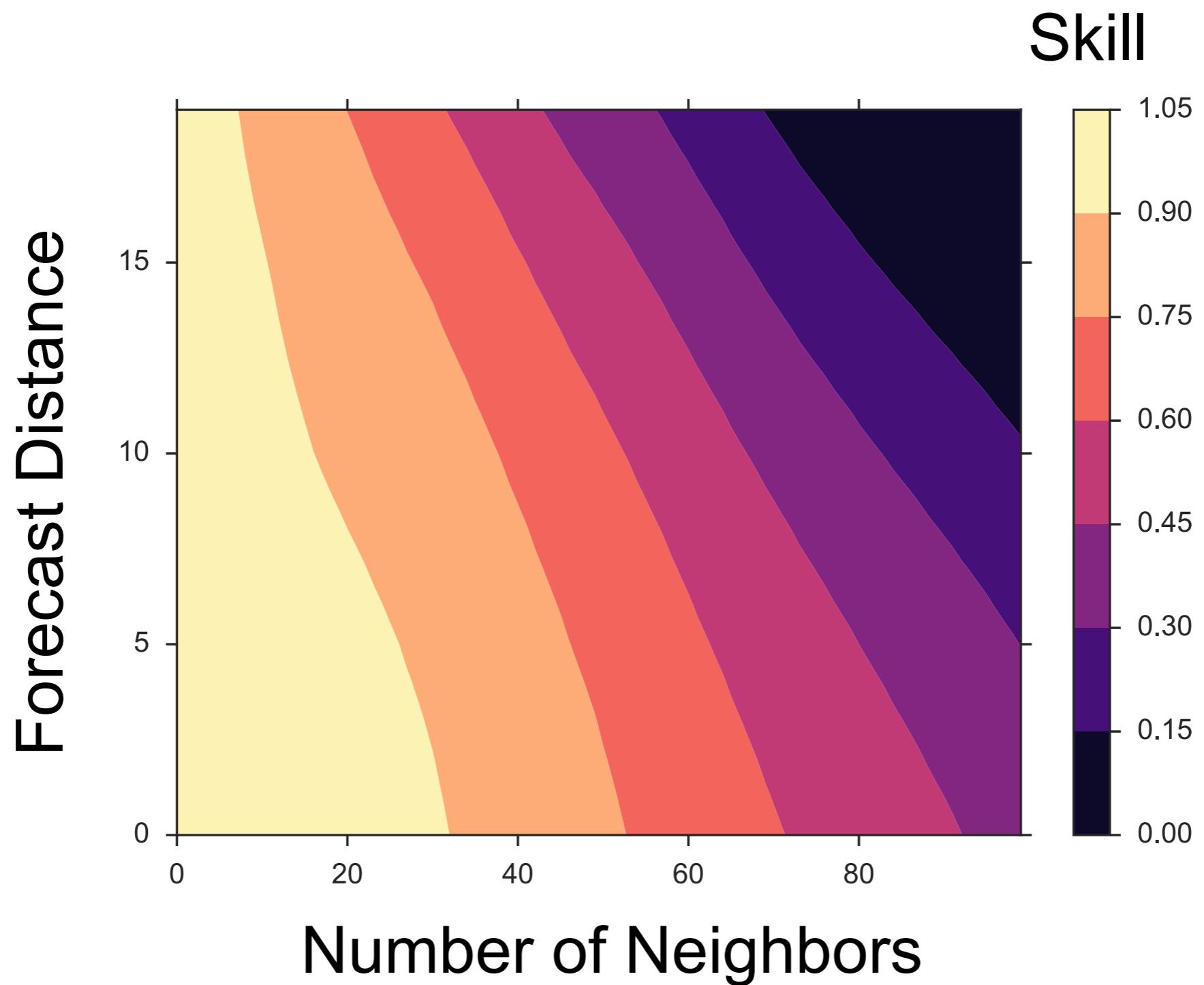


# Nonlinear Forecasting

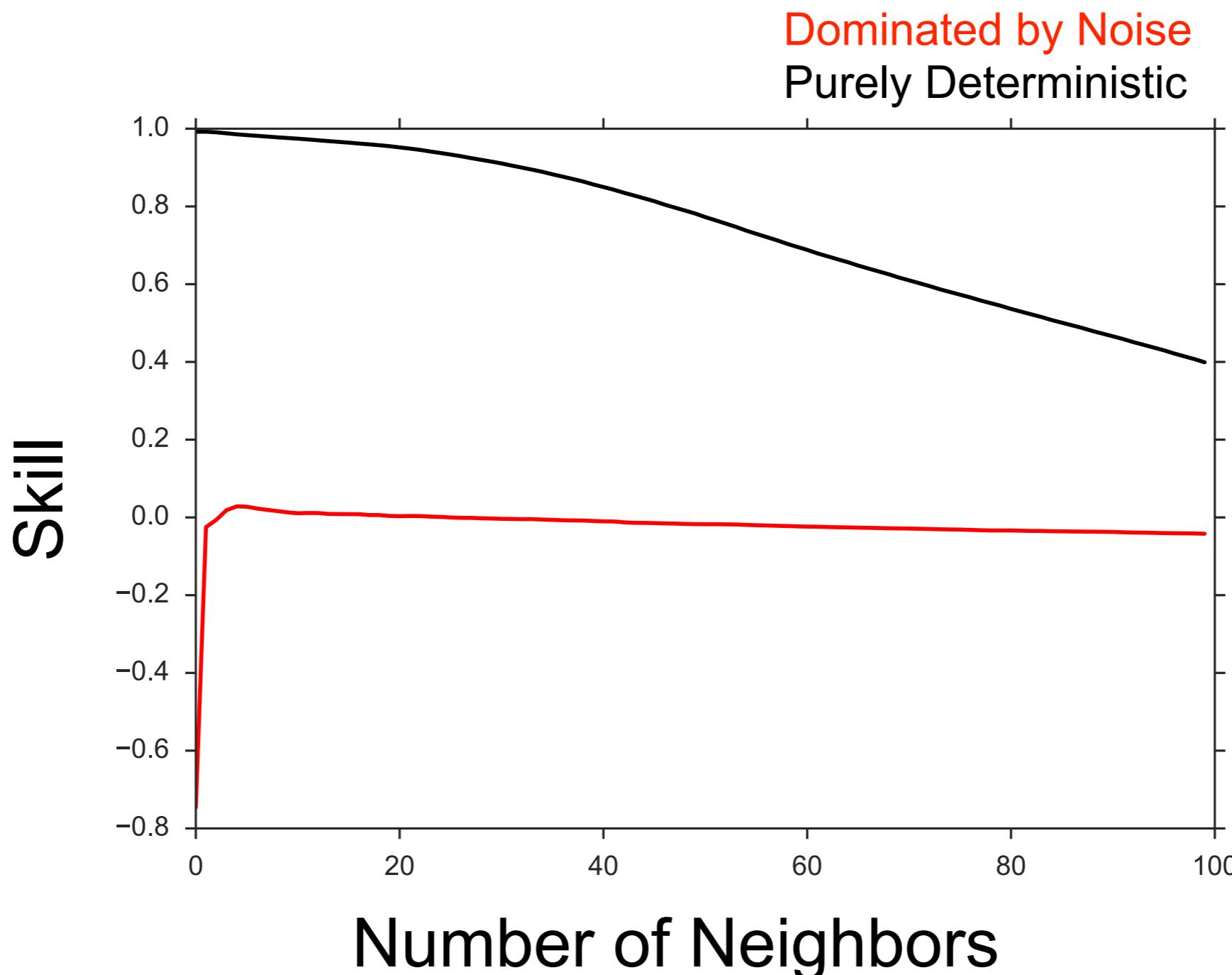
## Reconstructed Attractor



# Nonlinear Forecasting



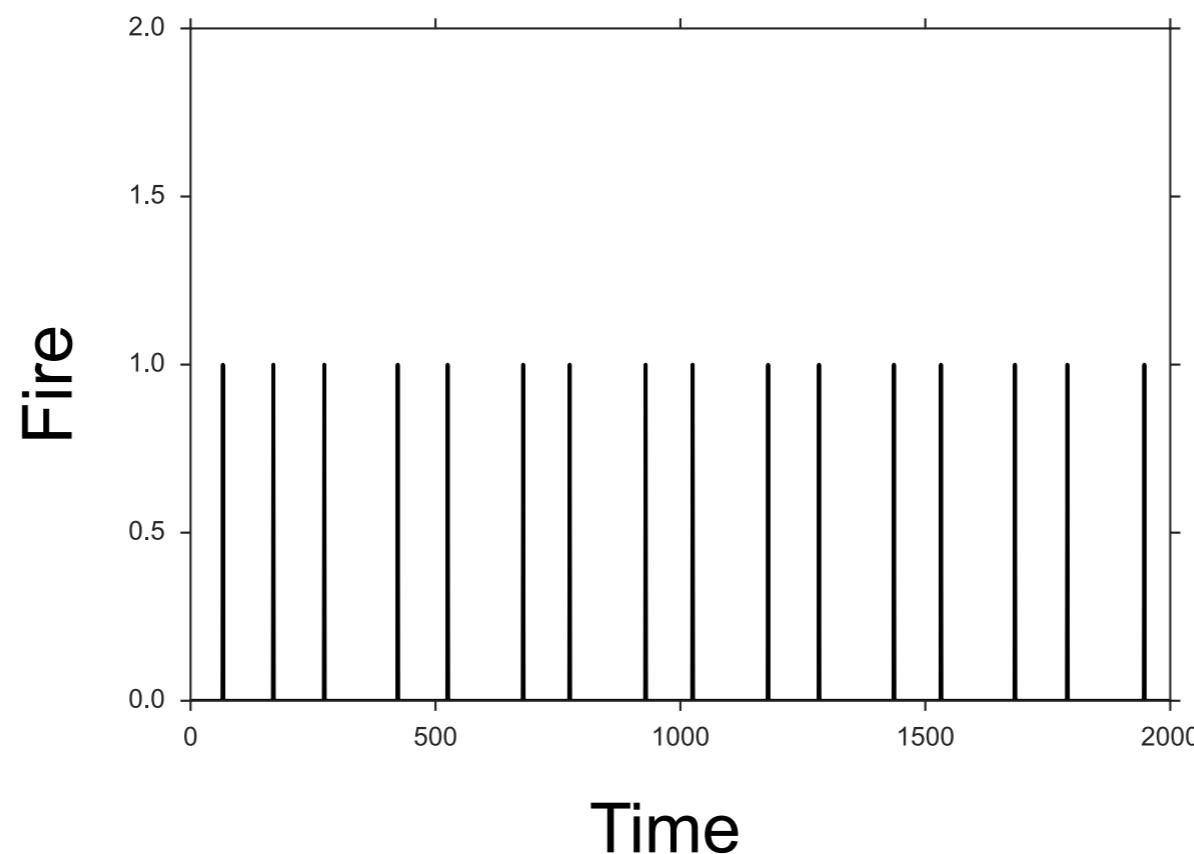
# Nonlinear Forecasting



# Nonlinear Forecasting

## Integrate and Fire

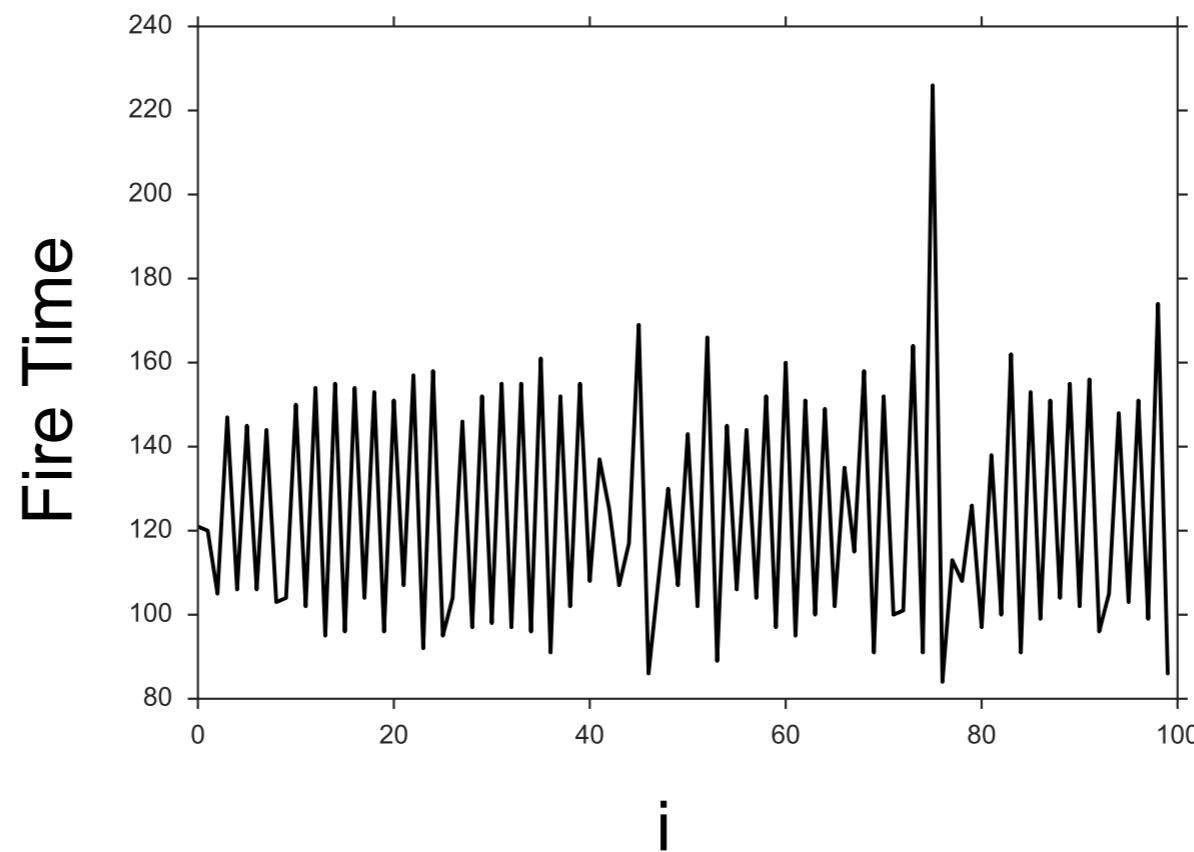
$$\int_{T_i}^{T_{i+1}} x(t)^2 dt = \theta$$



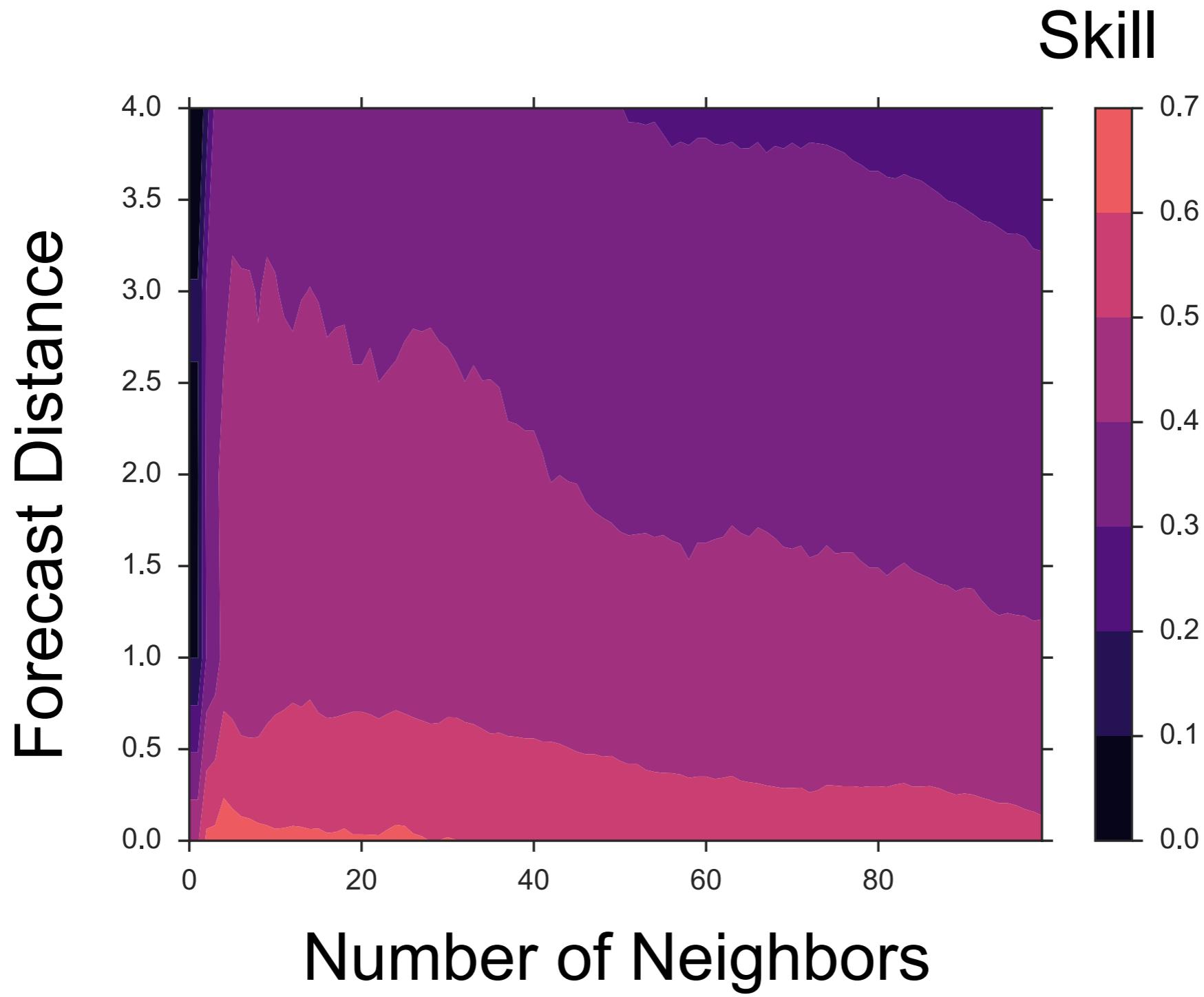
# Nonlinear Forecasting

**Integrate and Fire**

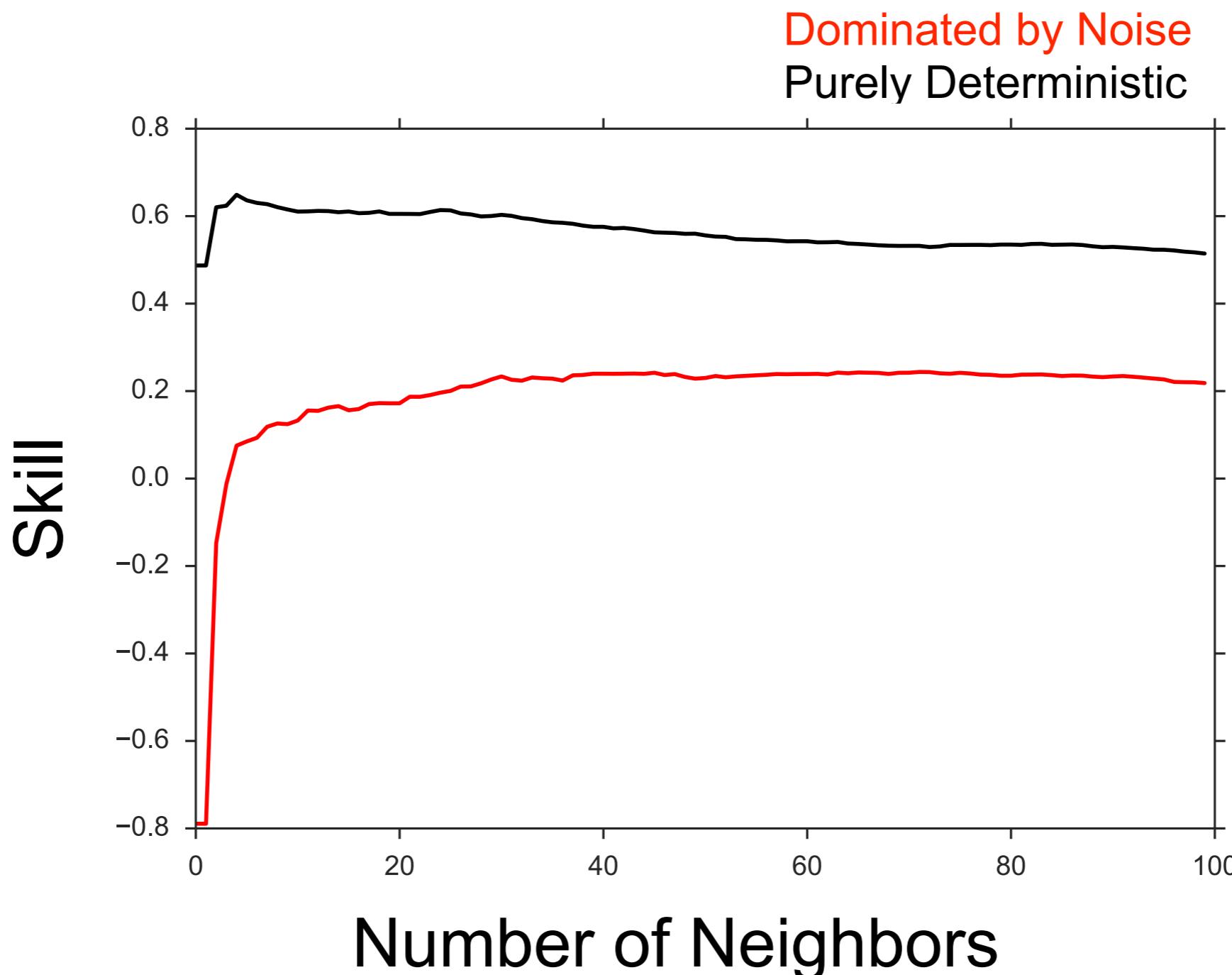
$$\int_{T_i}^{T_{i+1}} x(t)^2 dt = \theta$$



# Nonlinear Forecasting



# Nonlinear Forecasting



# Beach Nourishment

## **Vernon Smith, 2004 Nobel Speech:**

“Within economics there is essentially only one model to be adapted to every application: optimization subject to constraints...The economics literature is not the best place to find new inspiration beyond these traditional technical methods of modeling”

# Beach Nourishment

Maximize,

$$\int_{T_i}^{T_{i+1}} [B(x(t), \lambda_b) - C(x(t), \lambda_c)] dt$$

*Benefits*                                   *Costs*

subject to,

$$\frac{dx}{dt} = f(x, \lambda_x, \lambda_E)$$

where

$x(t)$  beach width

# Beach Nourishment

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$$\int_{T_i}^{T_{i+1}} [B(x(t), \lambda_b) - C(x(t), \lambda_c)] dt$$

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subject to,

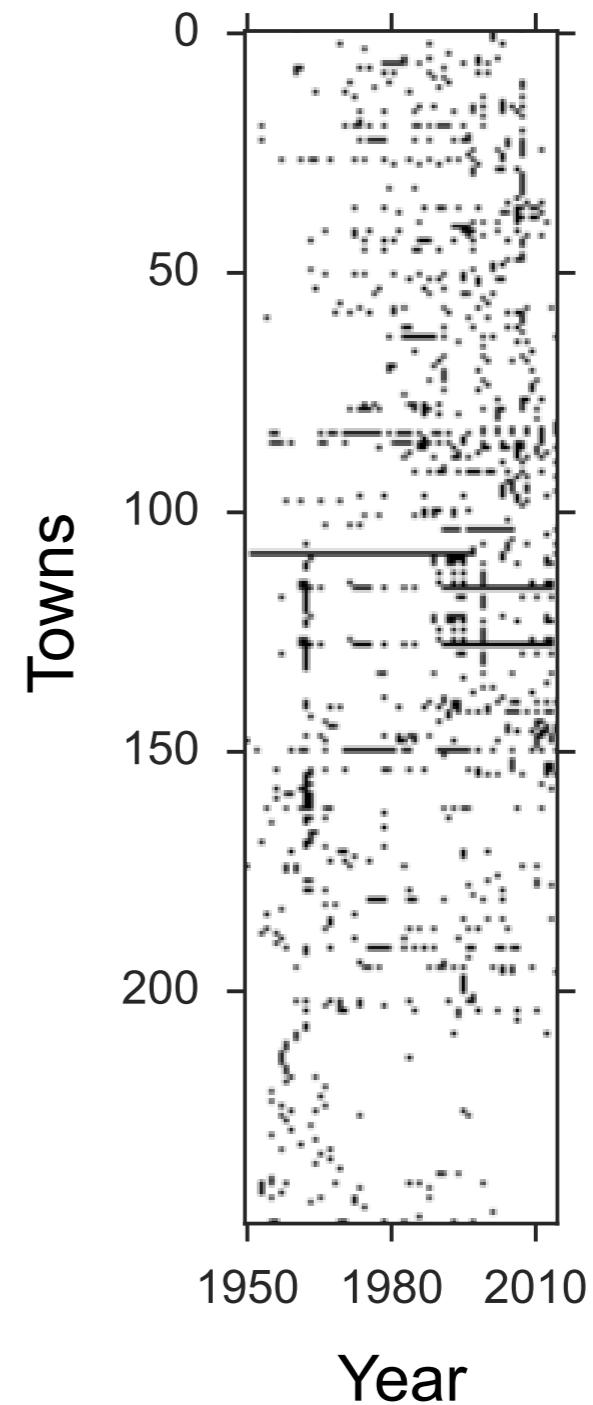
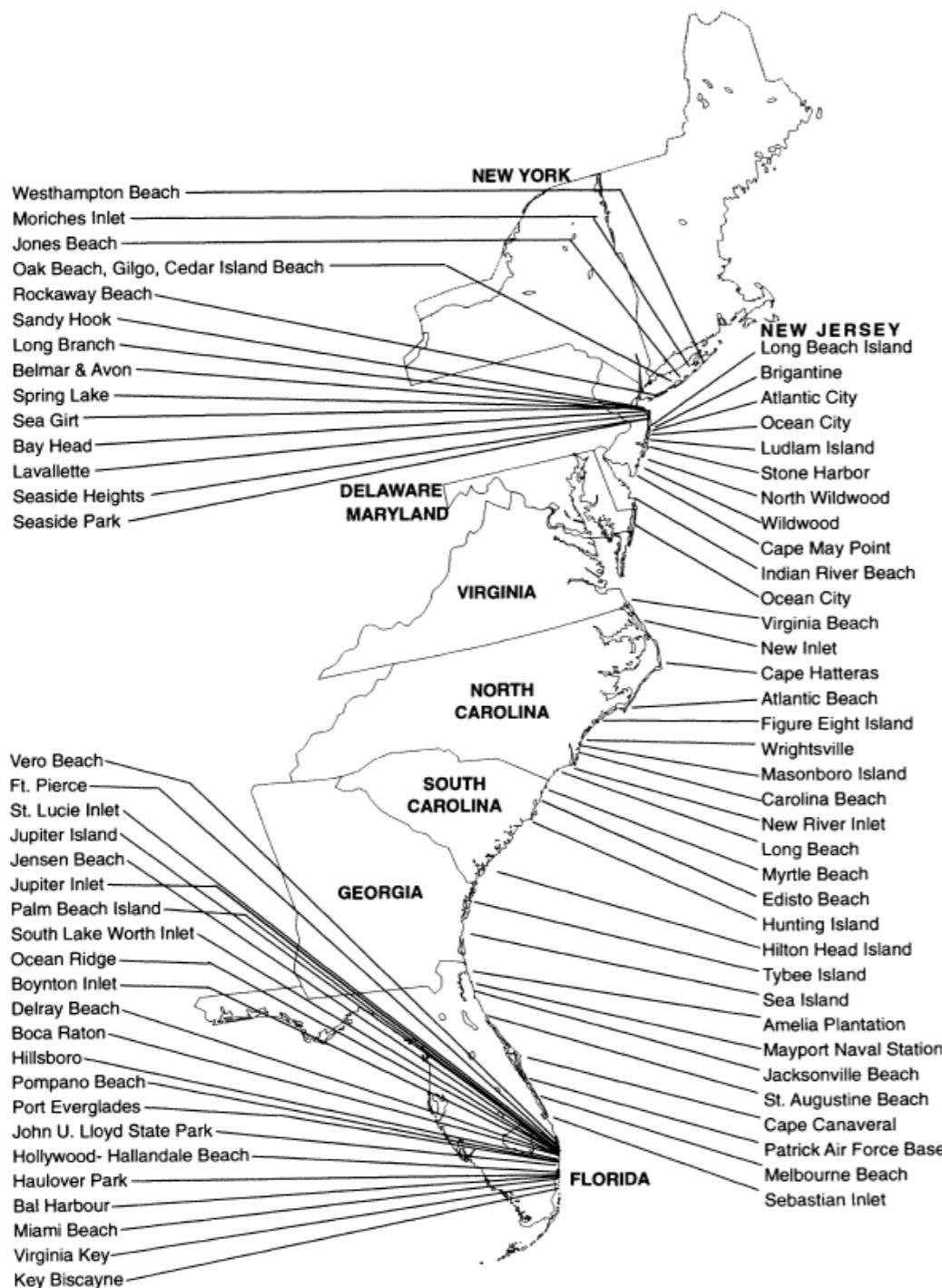
$$\frac{dx}{dt} = f(x, \lambda_x, \lambda_E)$$

where

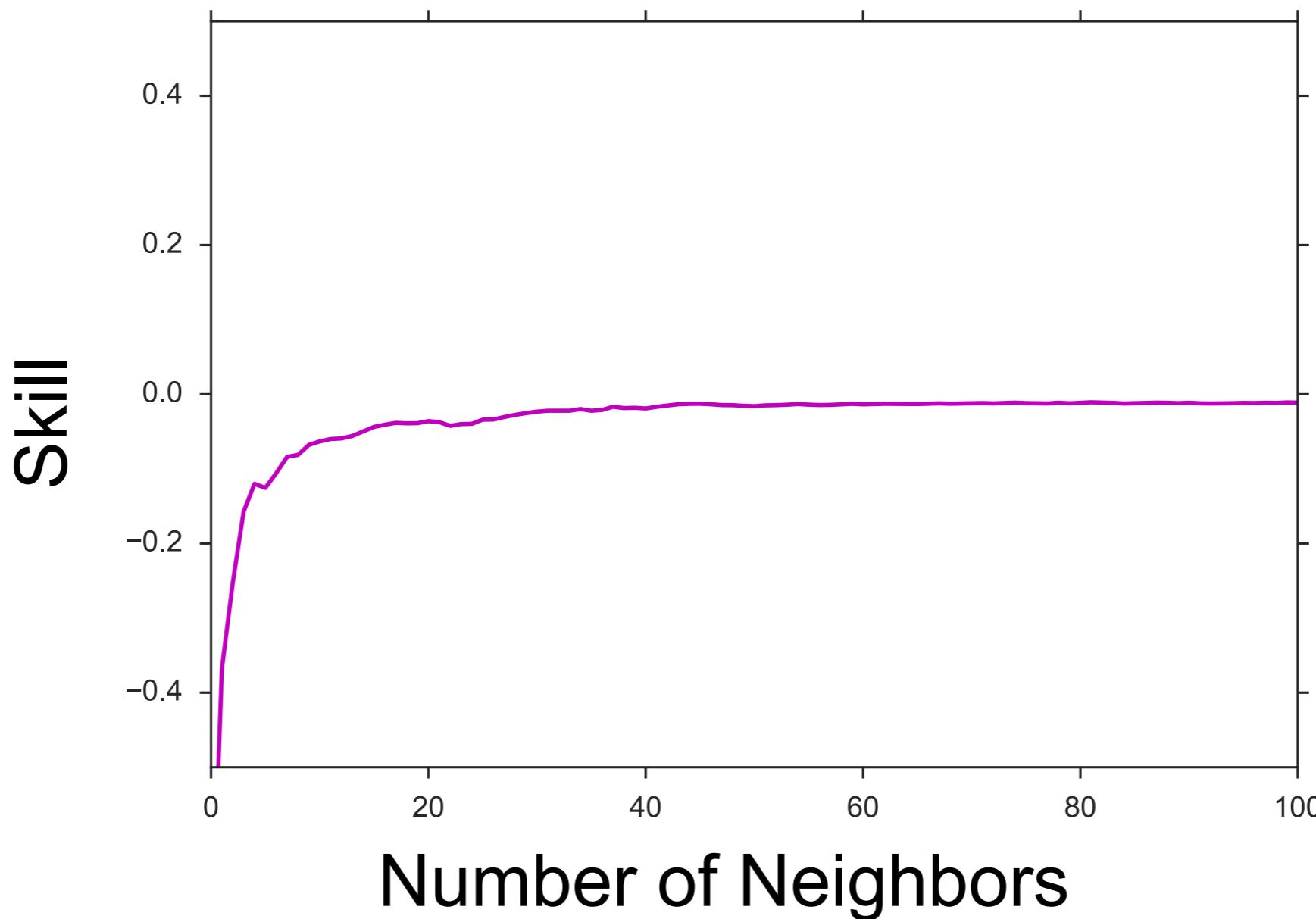
$x(t)$  beach width

**IS THIS SYSTEM DETERMINISTIC?**

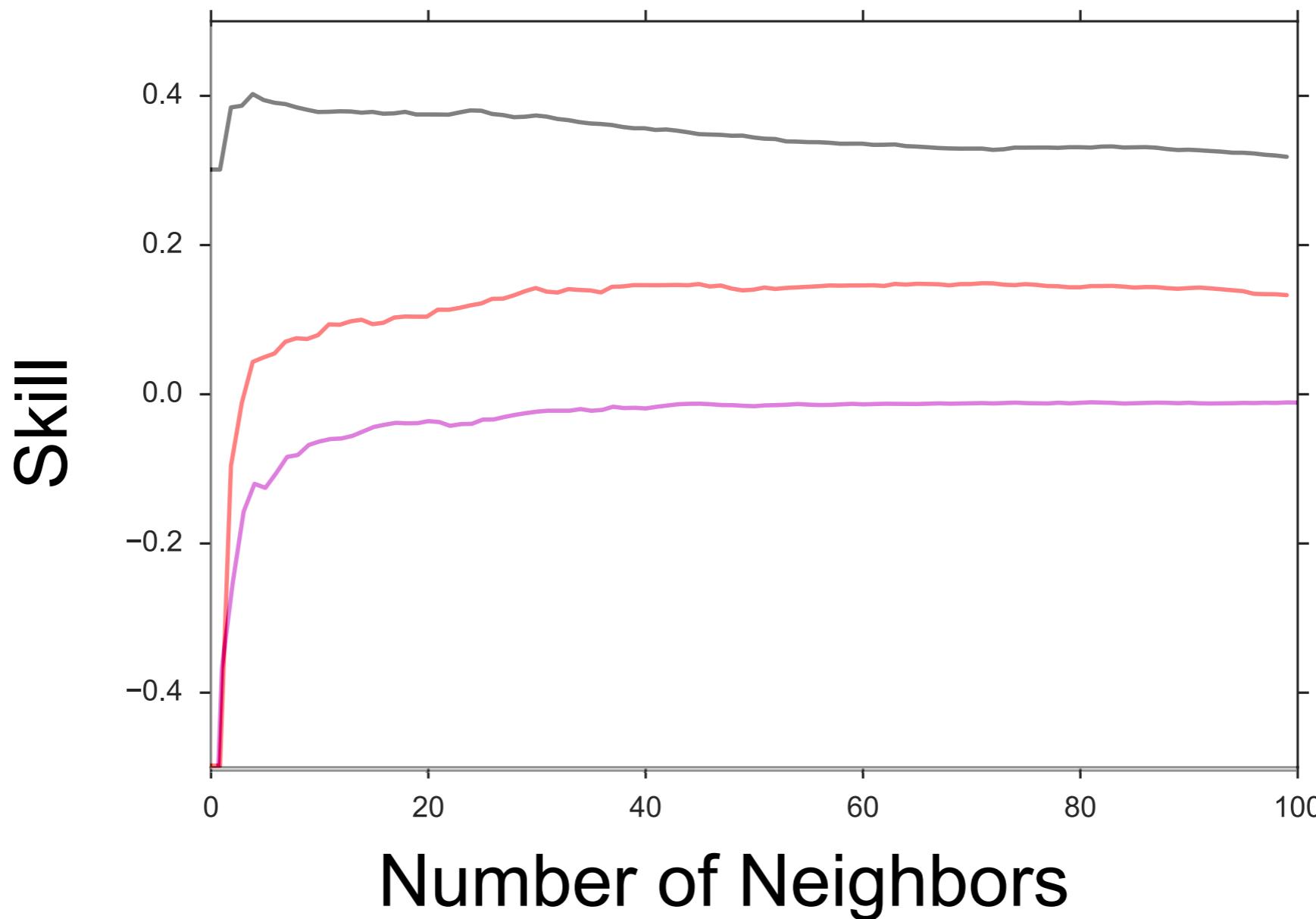
# Beach Nourishment



# Beach Nourishment



# Beach Nourishment



# New Way

- Optimization framework is of limited utility
- 2008 crash - efficient market hypothesis (hoax)
- Birth of “econophysics” - social atoms
- Time for environmental econophysics...

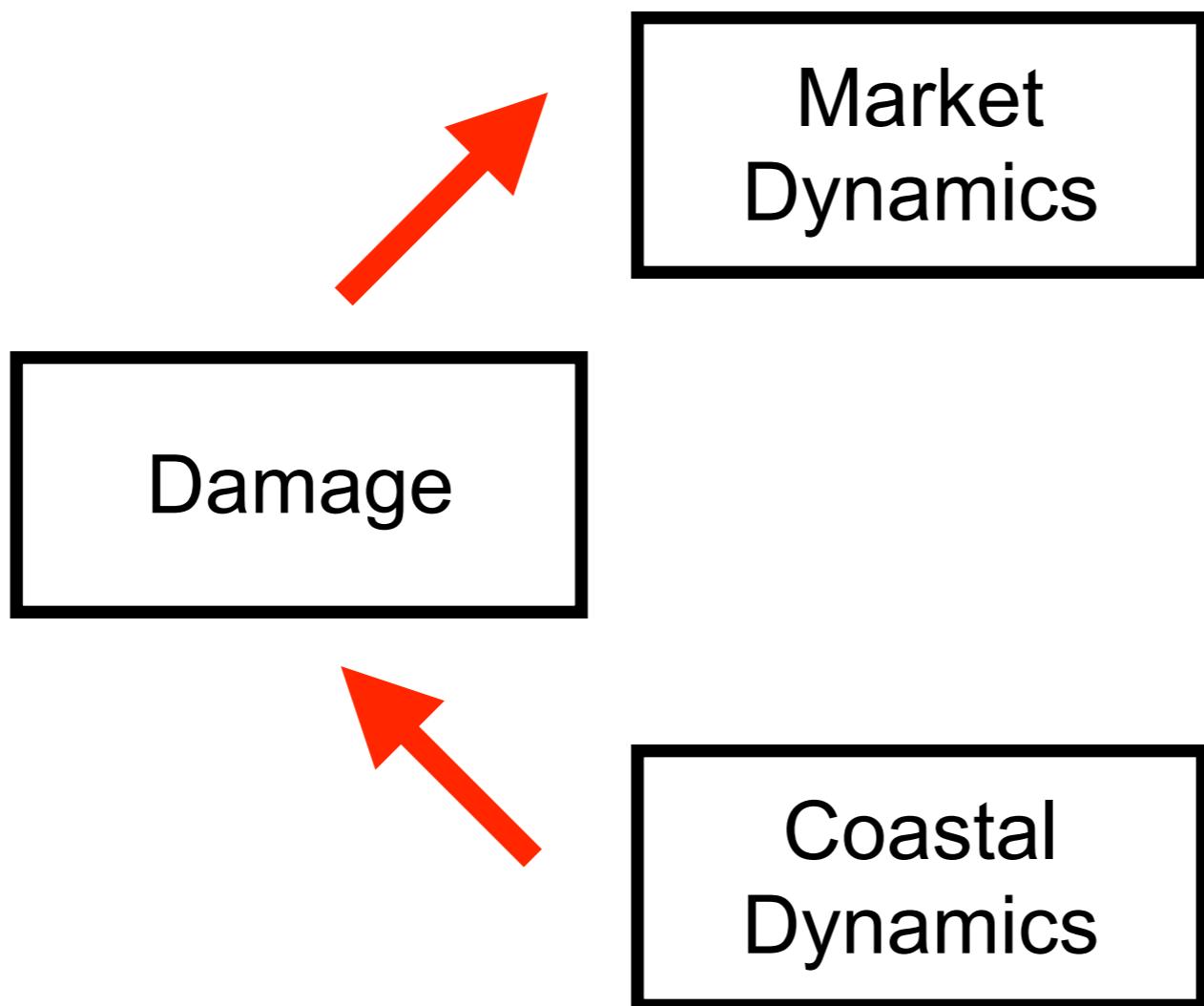
# Environmental Econophysics

- Complex dynamical system
  - natural, economic, social, dynamics
  - strong coupling
- Social atoms at the Beach:
  - simple market rules
  - natural dynamics
  - inductive

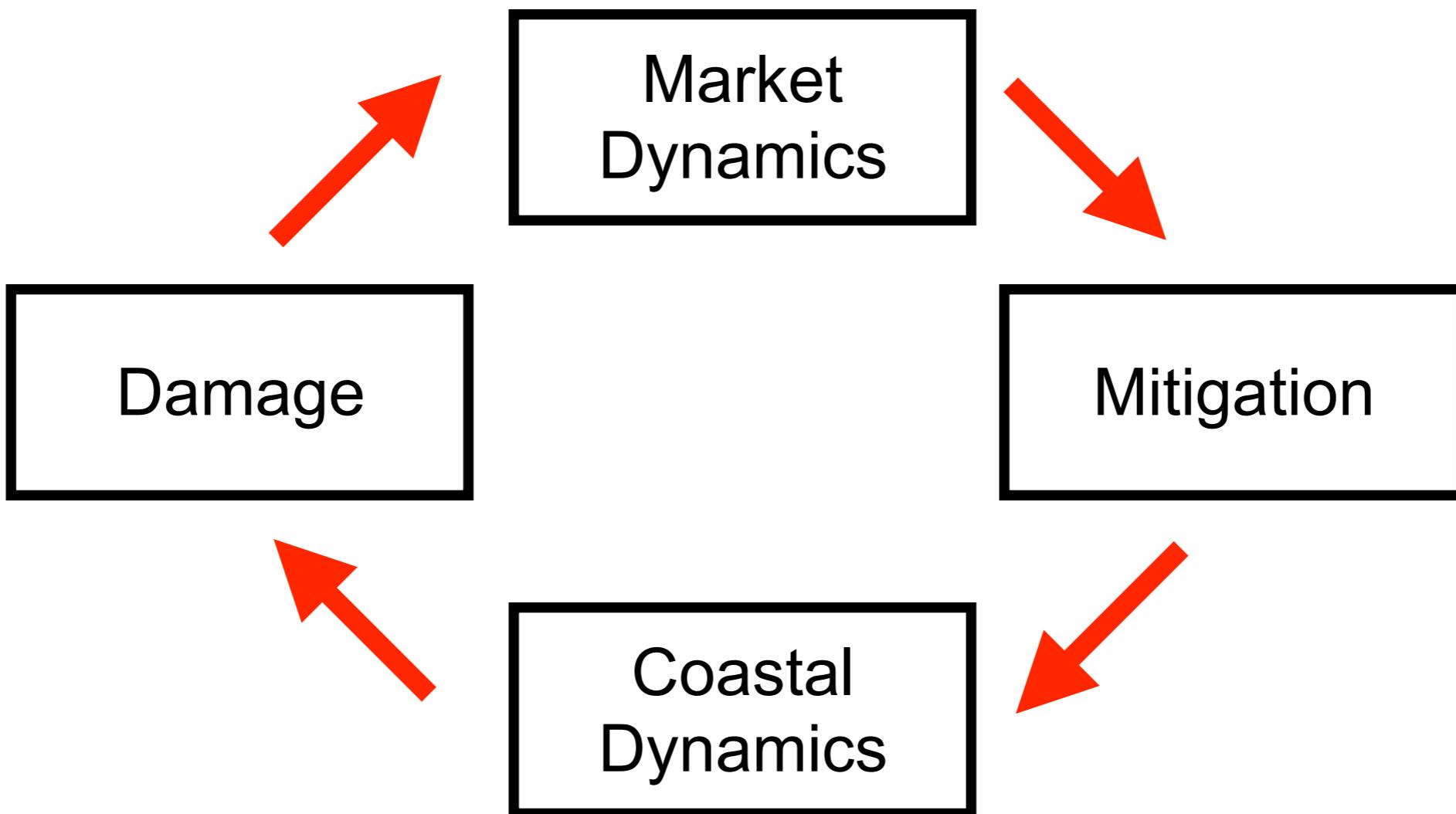
# Model

Market  
Dynamics

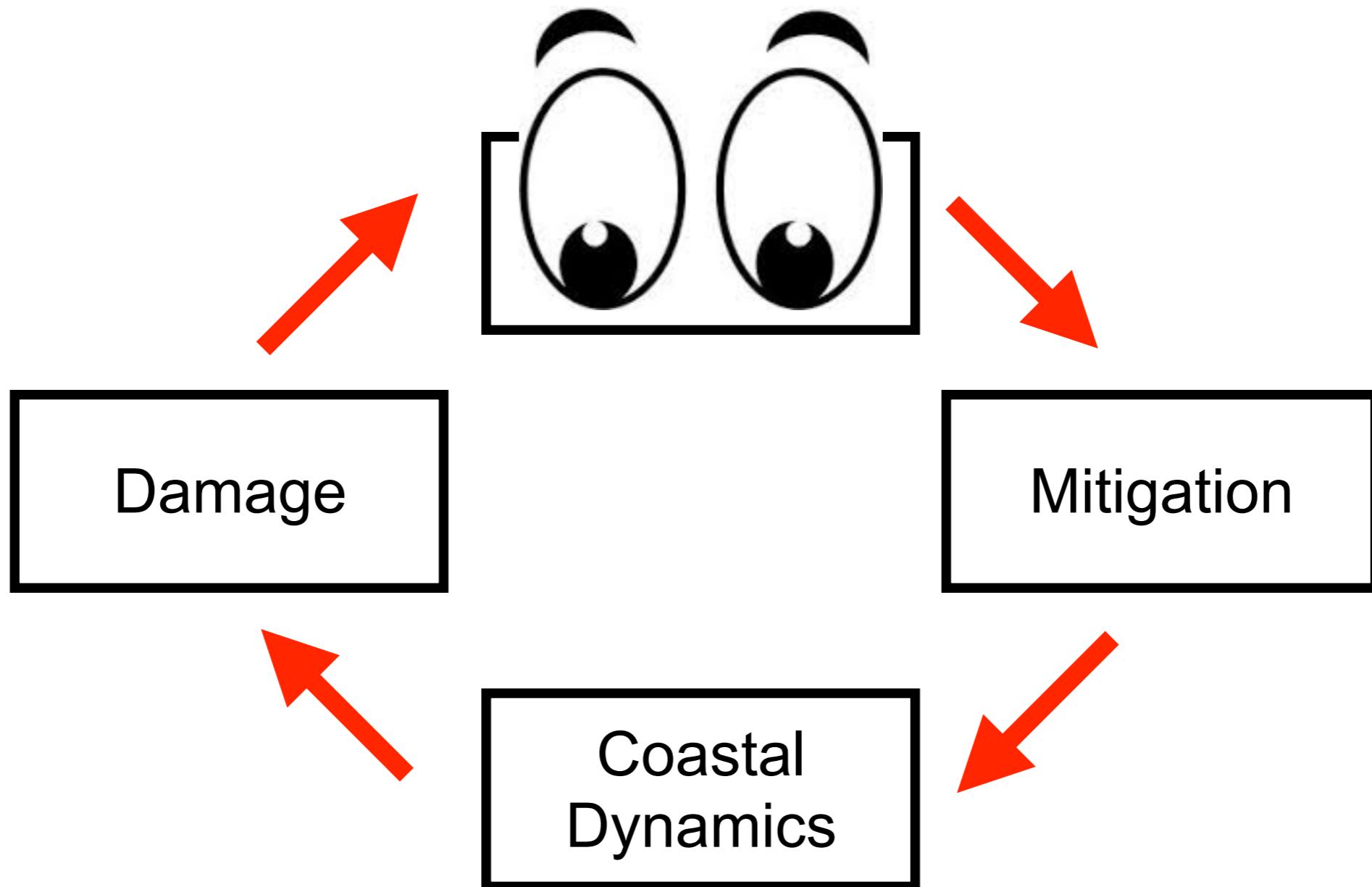
# Model



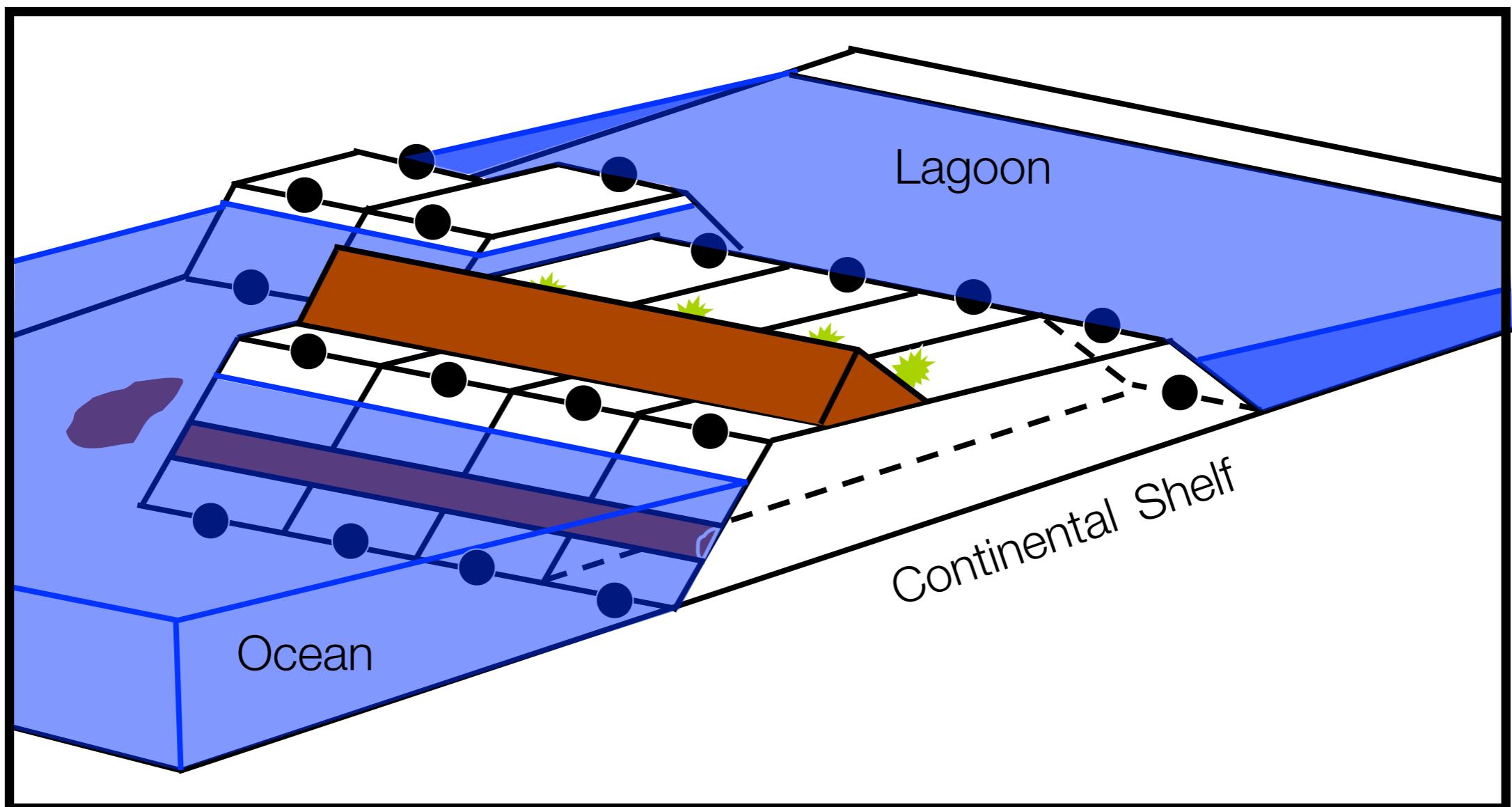
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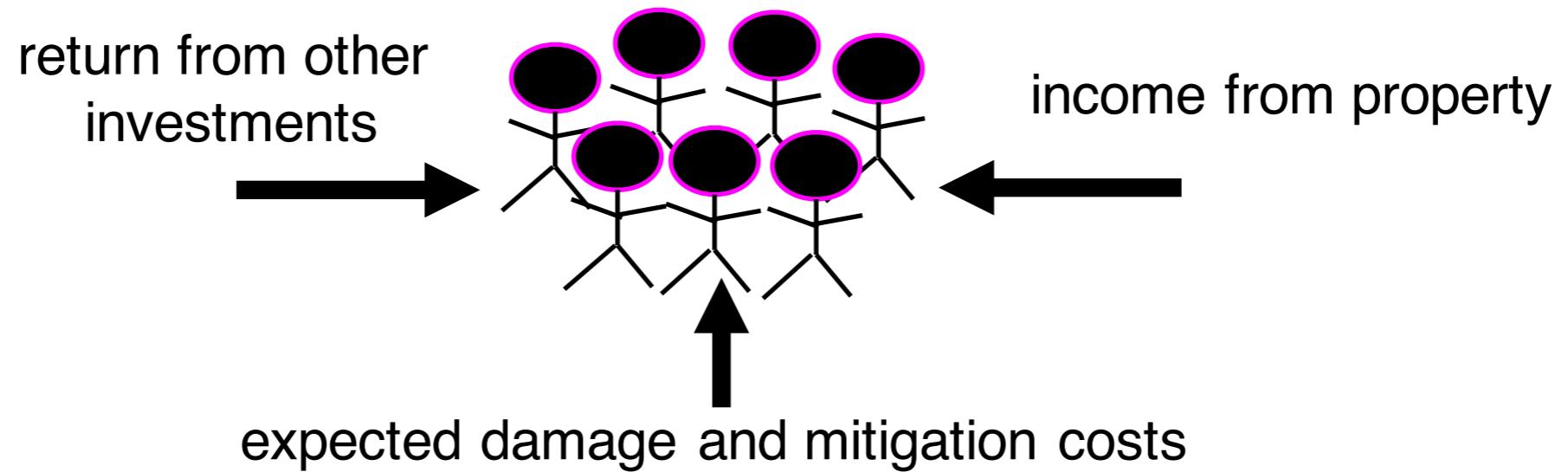
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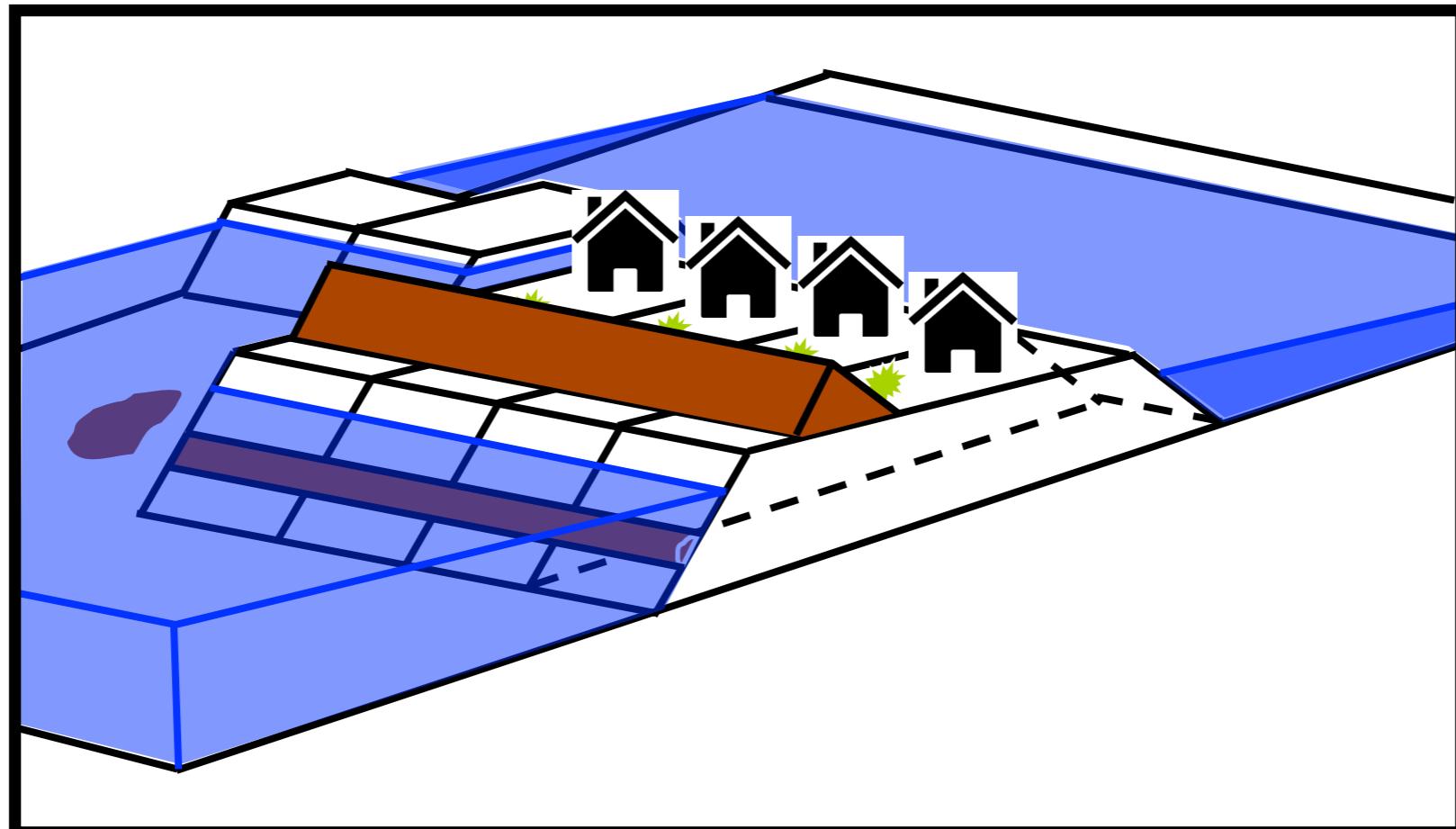
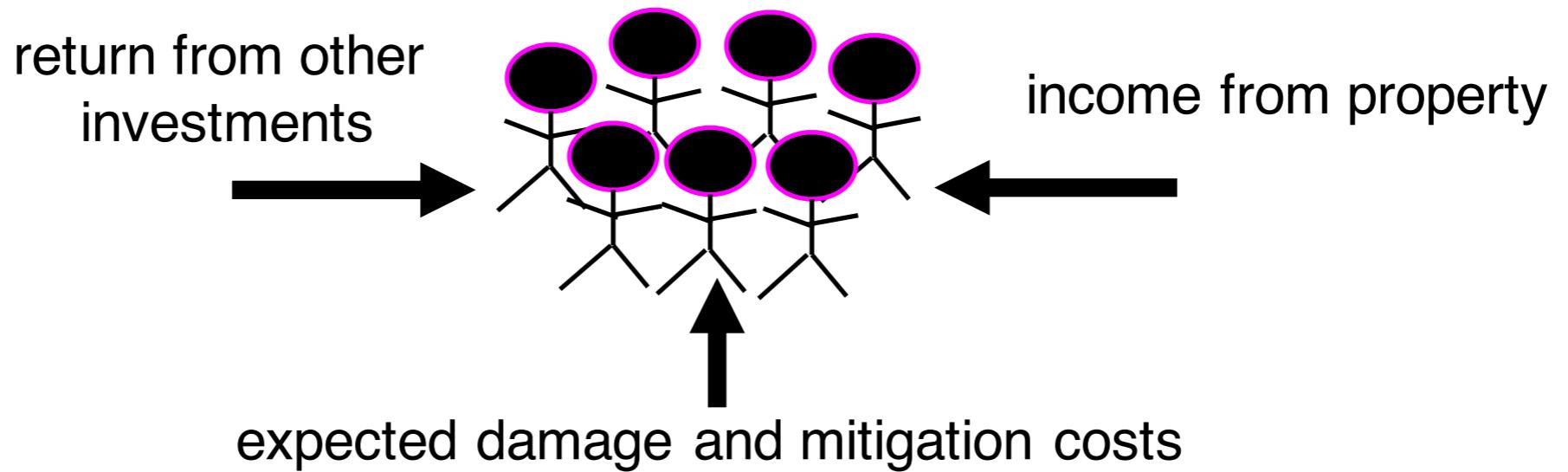
# Coastal Dynamics



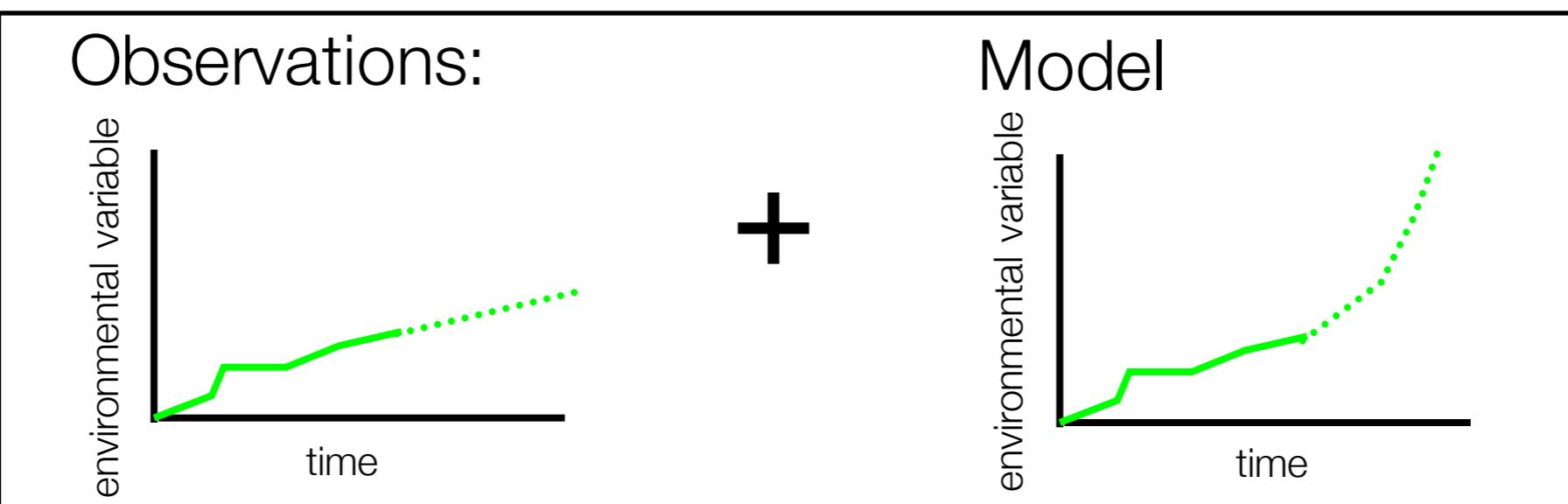
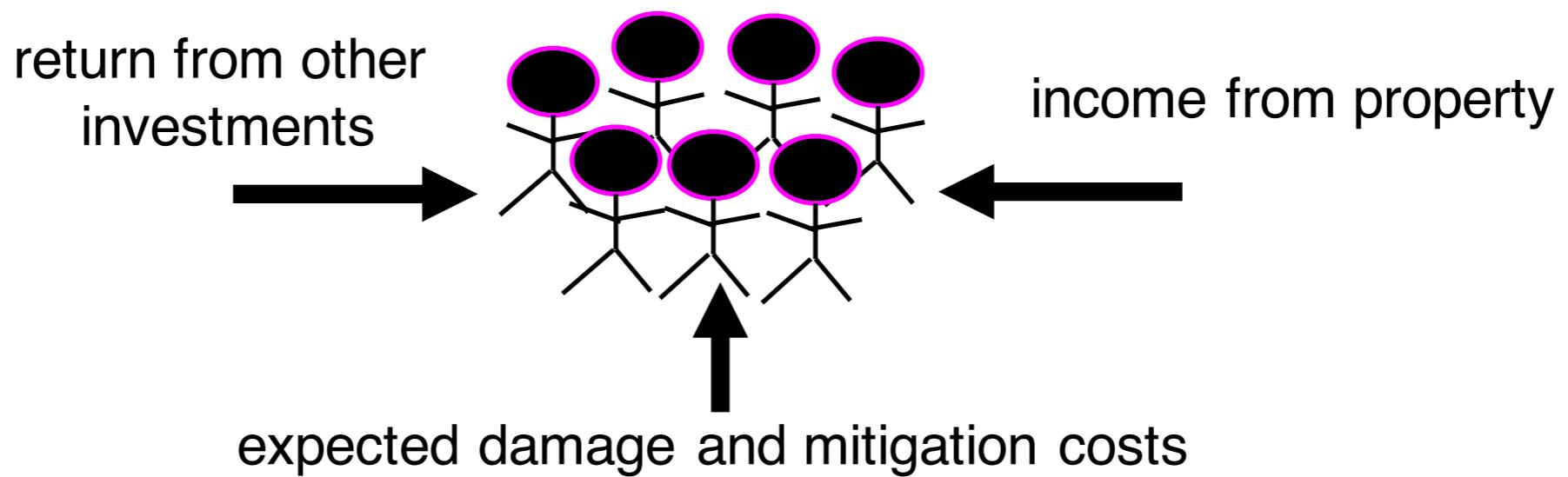
## Market Dynamics



## Market Dynamics



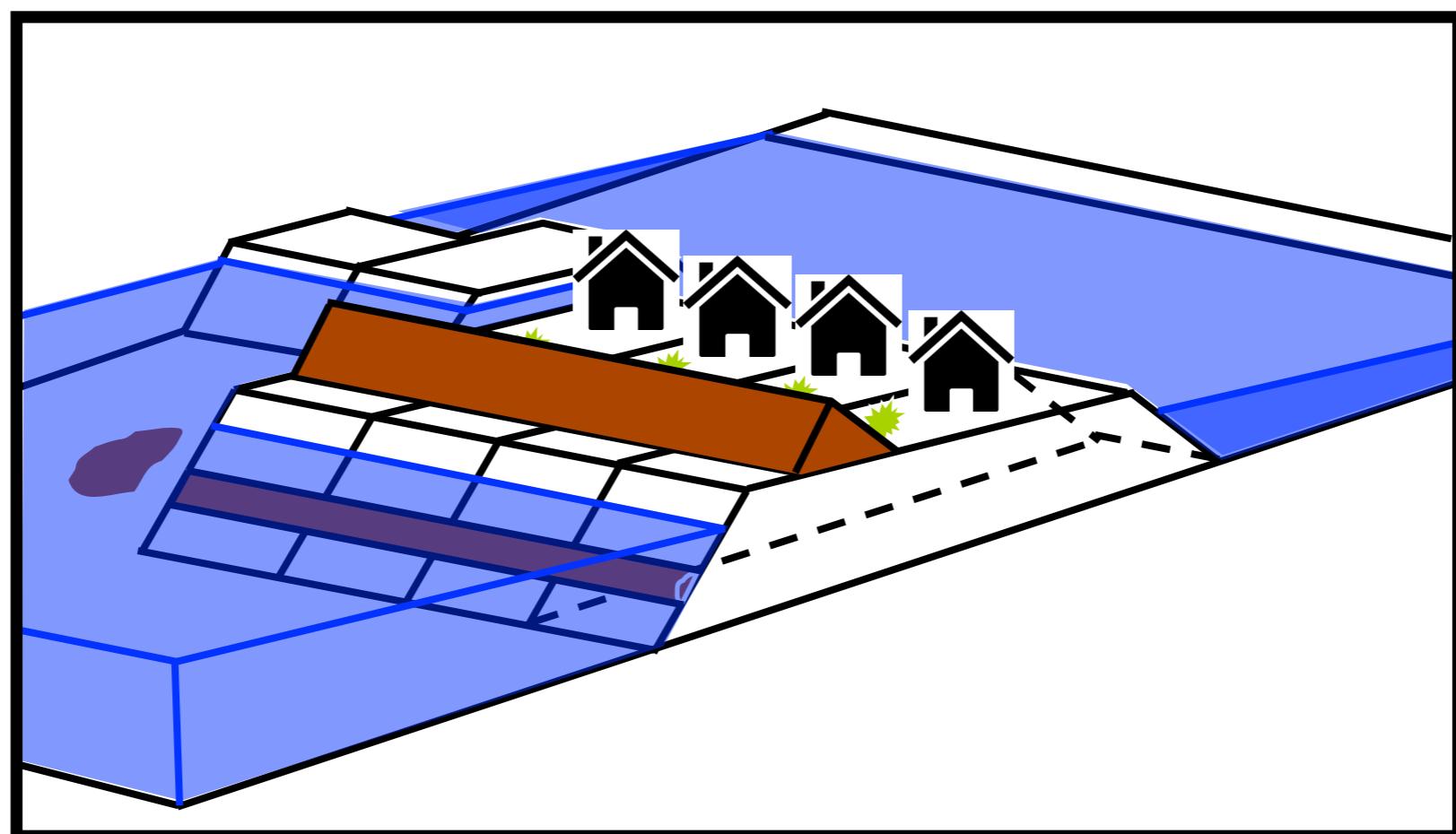
## Market Dynamics



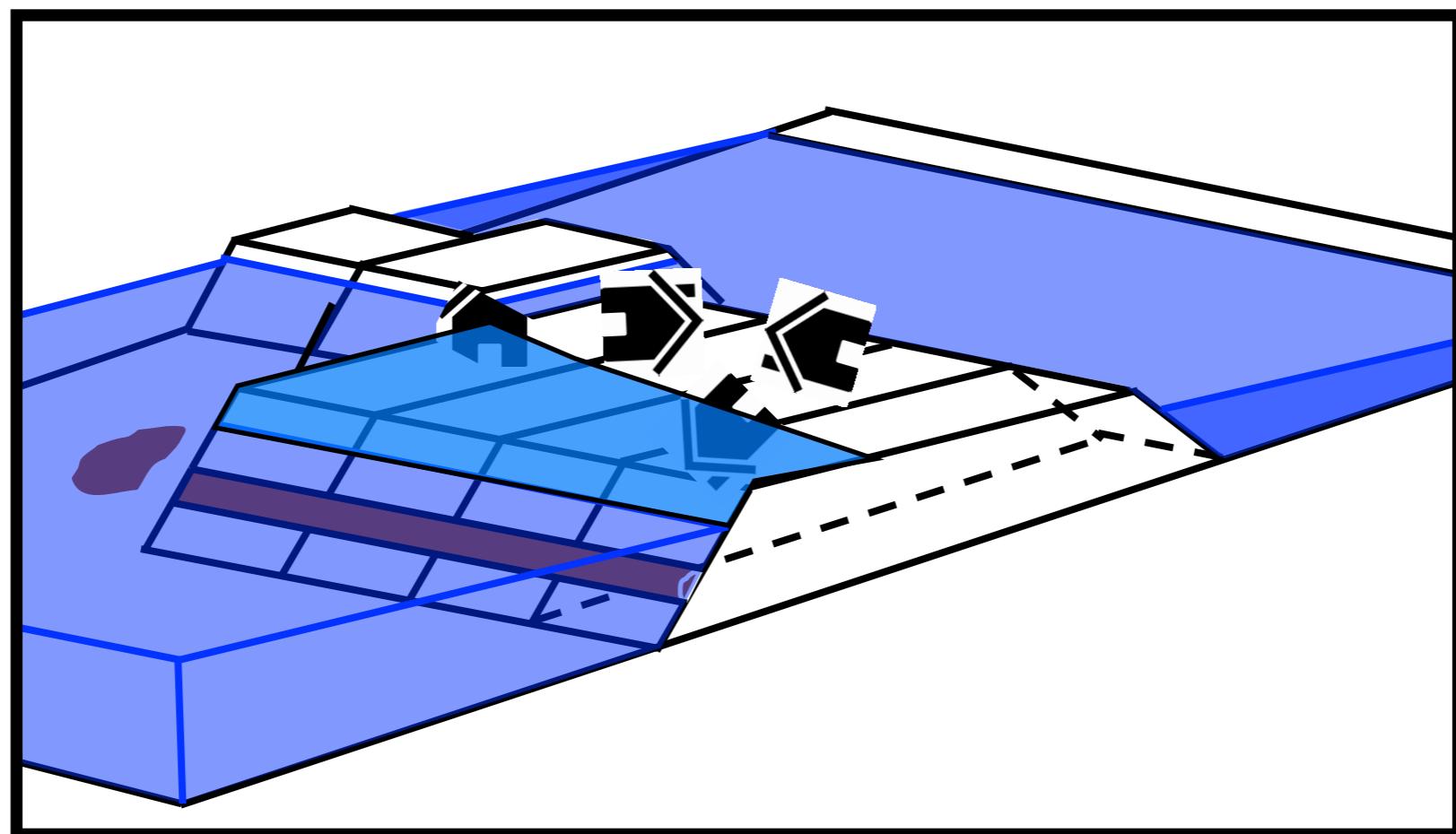
$$E_i[j(t)] = \alpha_i M[j(t)] + (1 - \alpha_i) O_i[j(t)]$$

Expectation of environmental variable  $j$  for agent  $i$

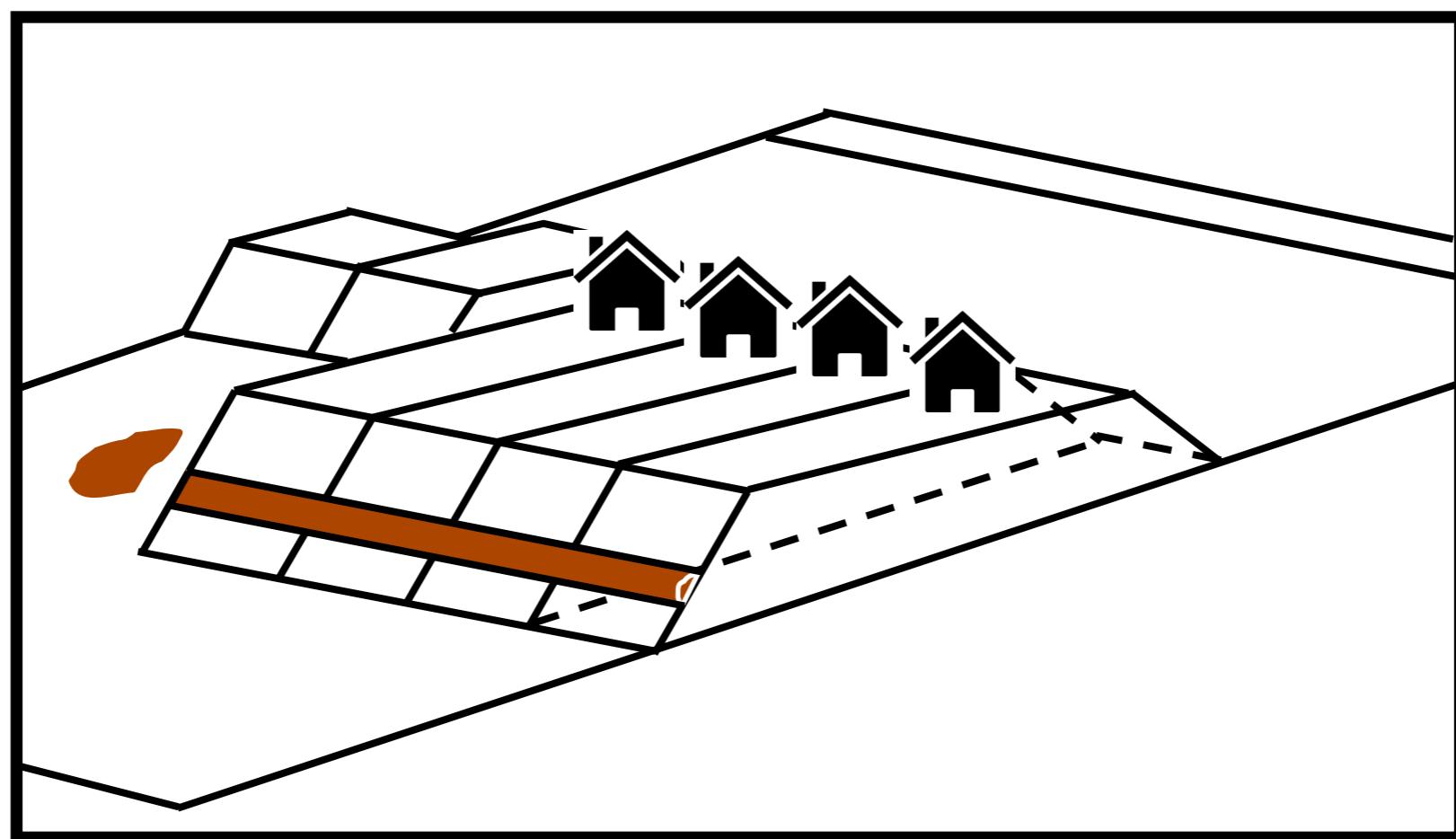
Damage



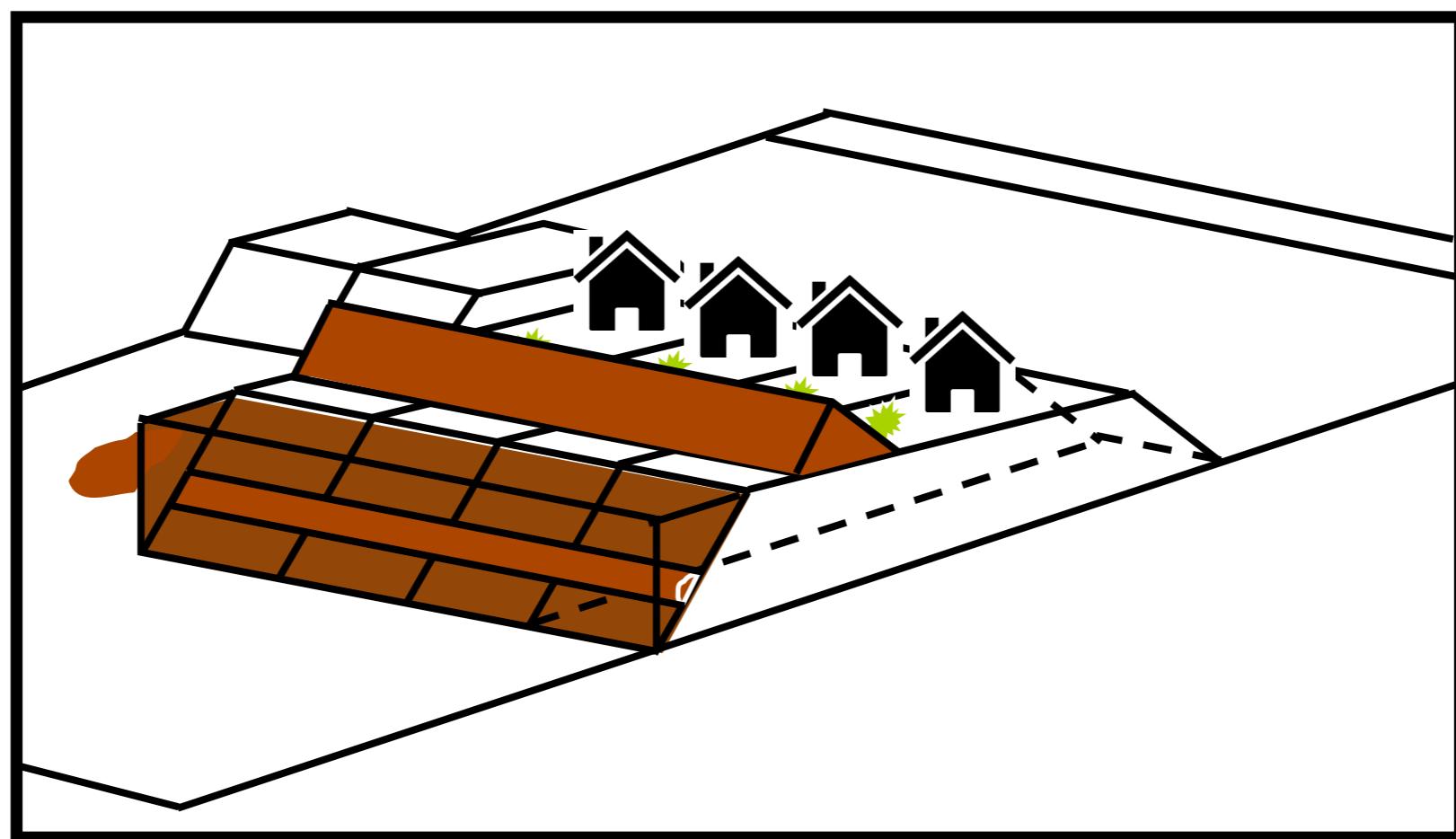
Damage



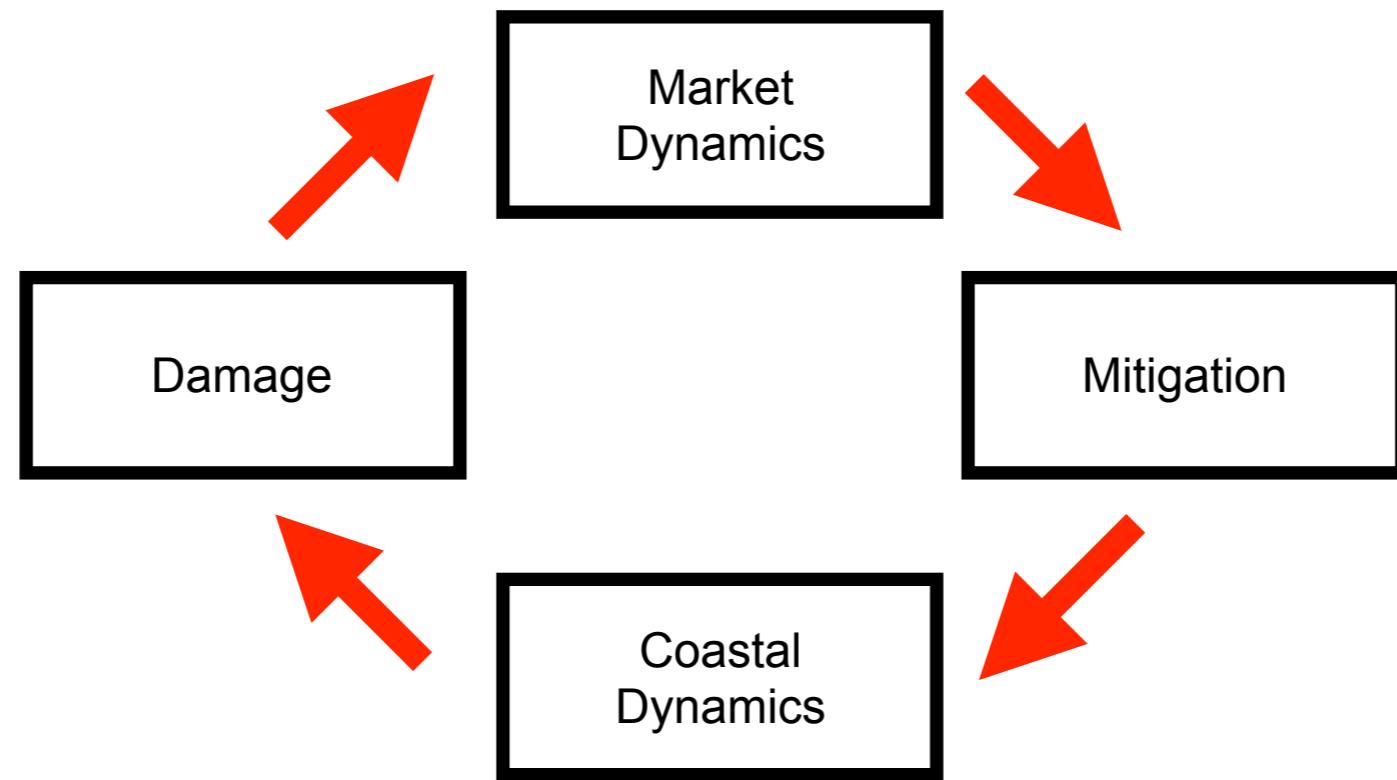
# Mitigation



# Mitigation

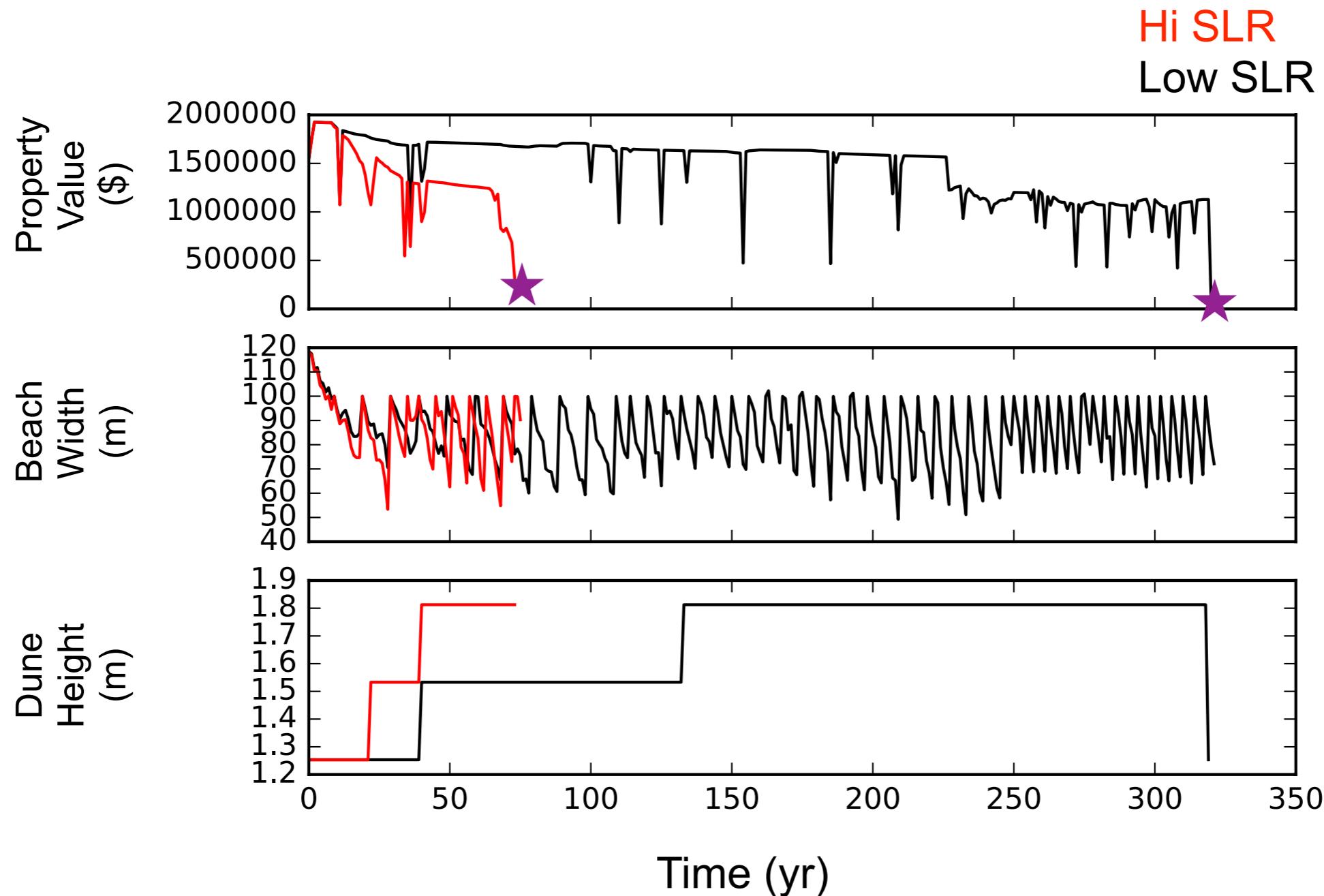


# Model

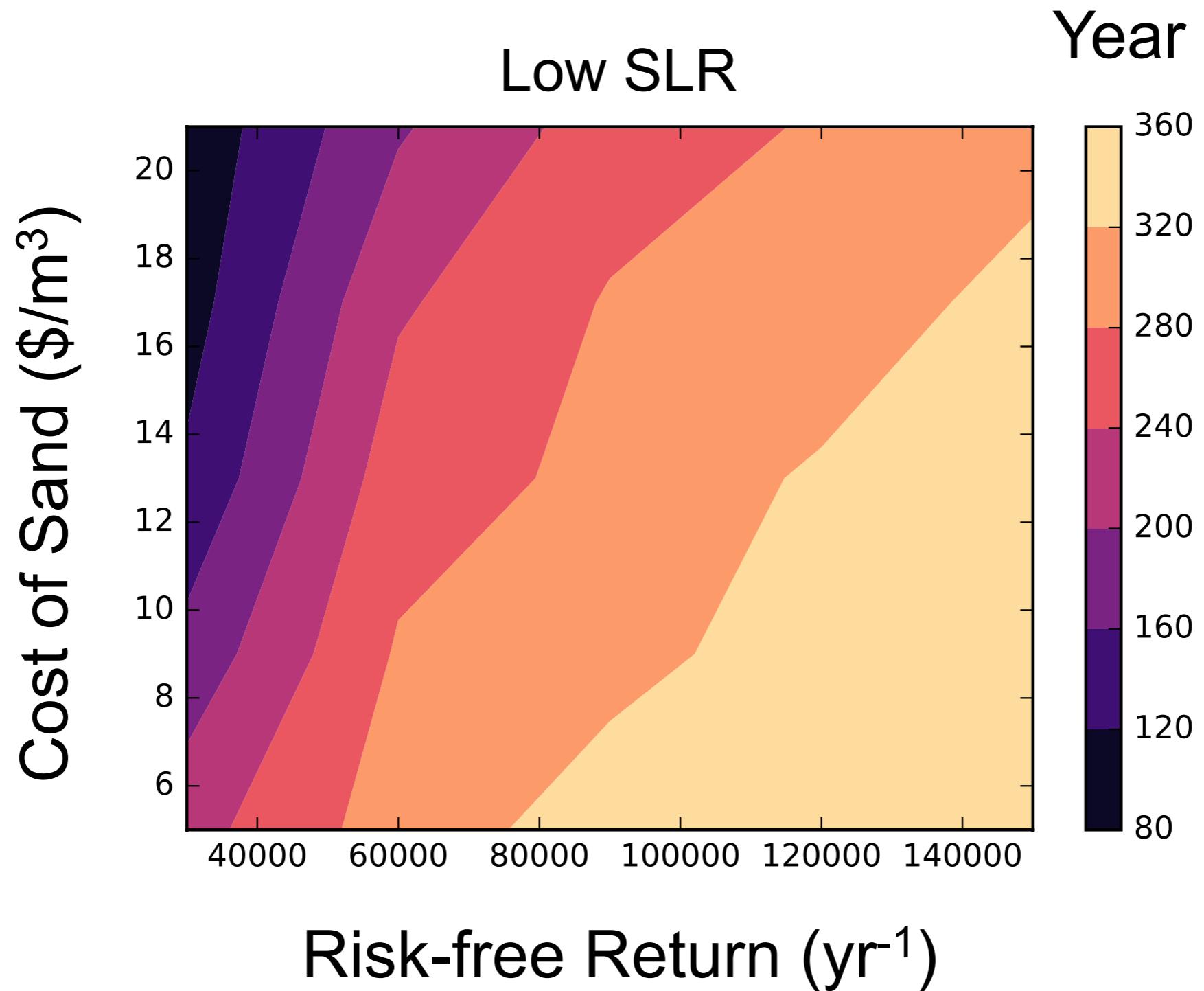


- Does the model reproduce current attractor?
- Does this attractor go away with SLR?
- How does change depend on natural, economic, social, factors?

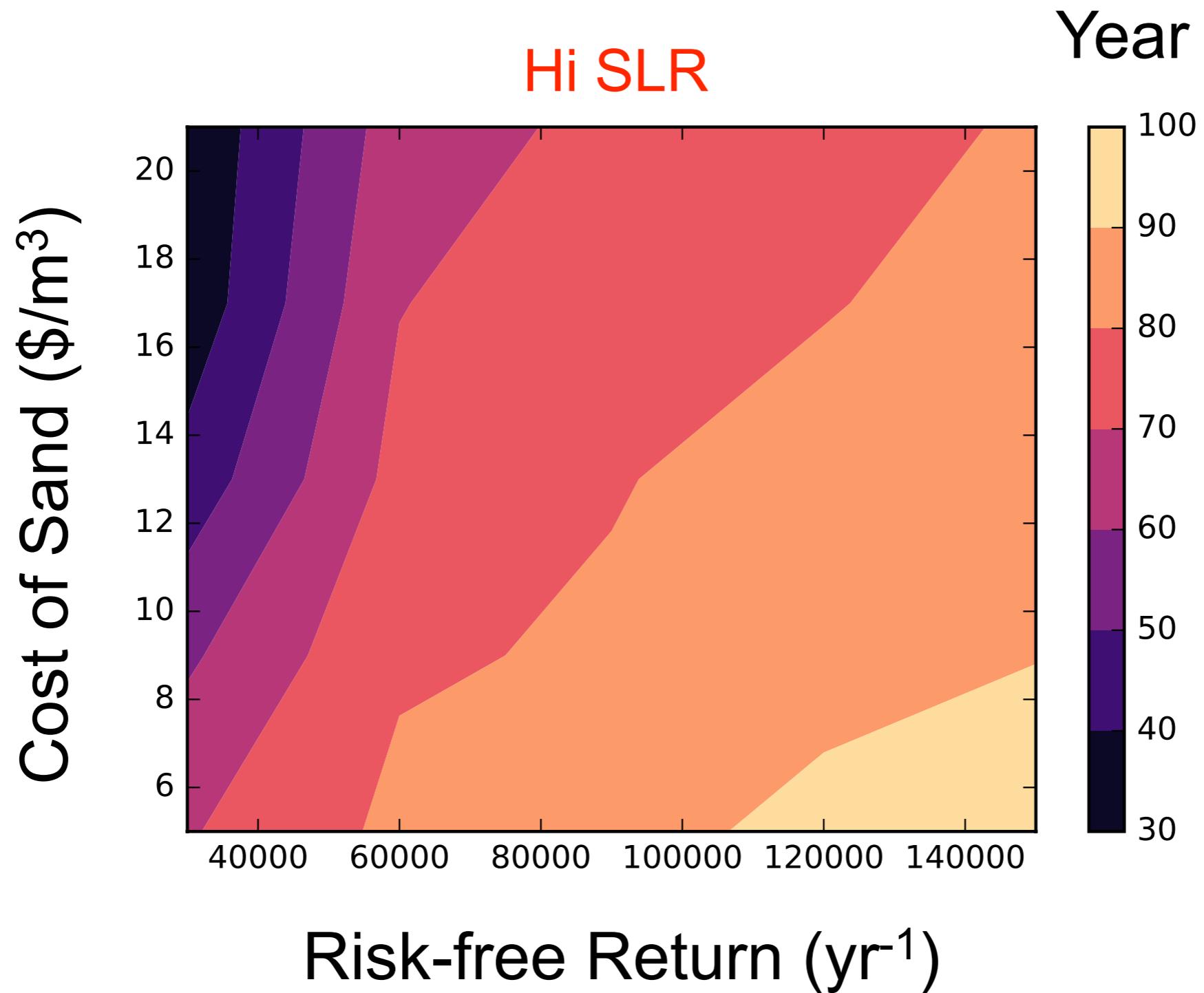
# Results



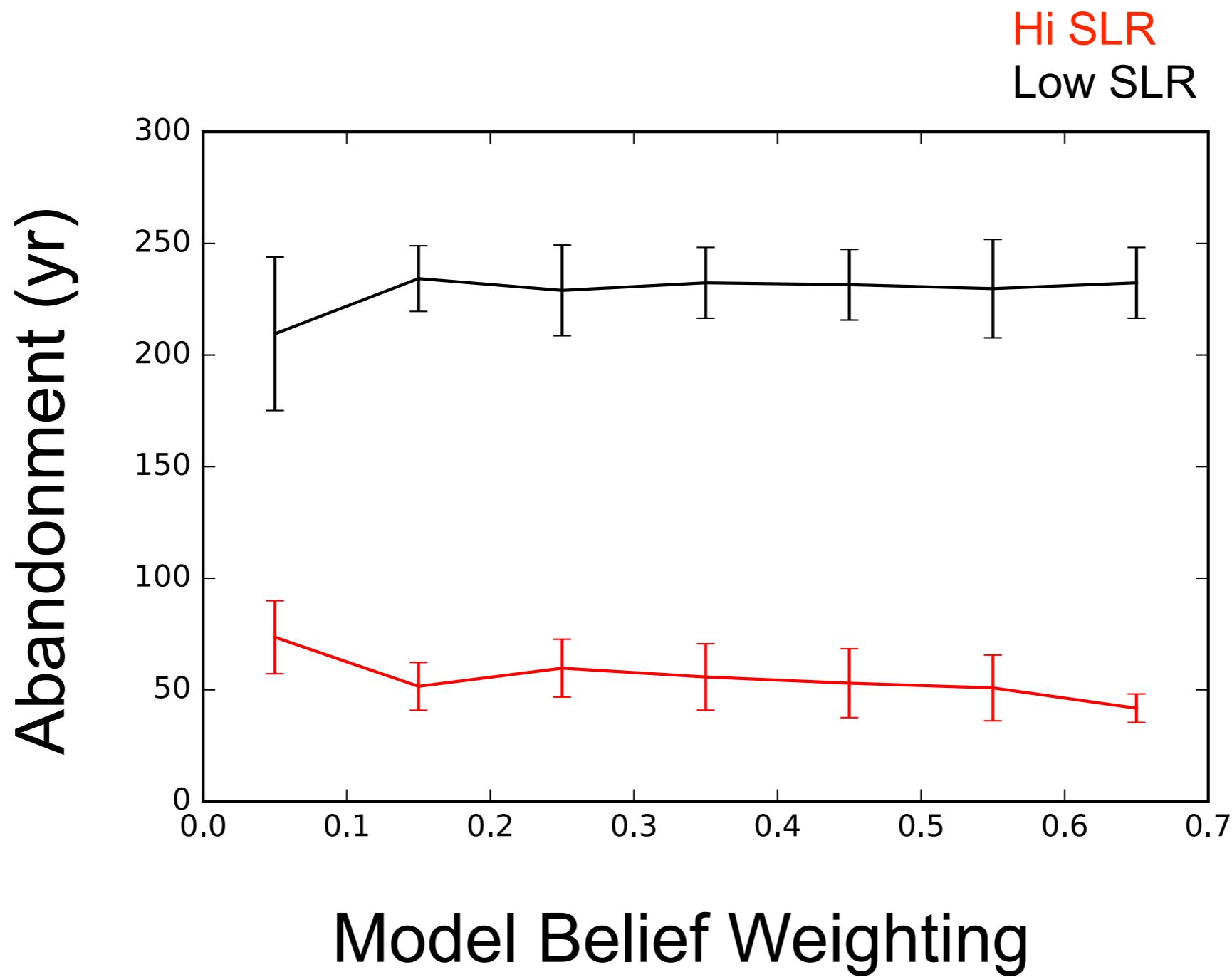
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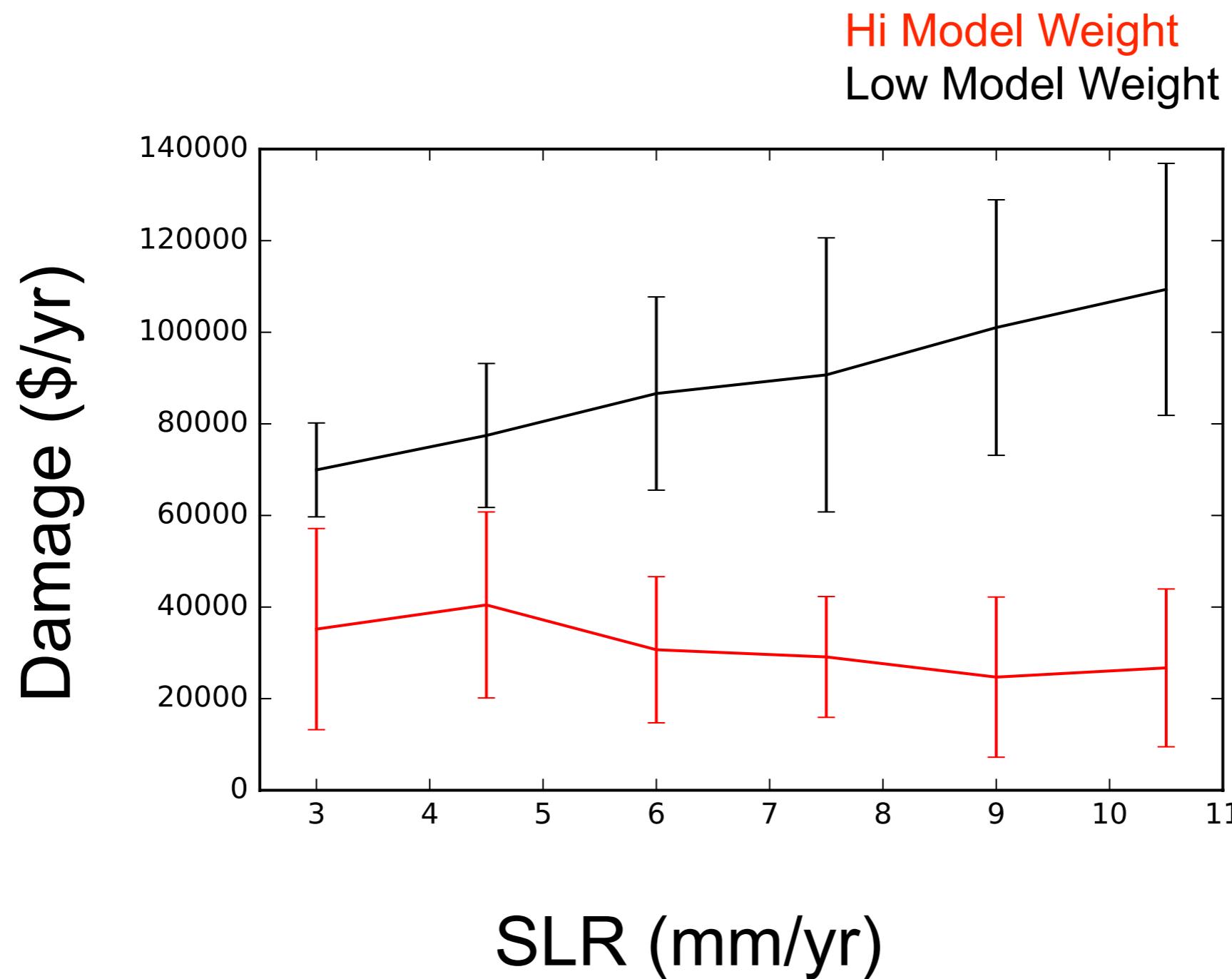
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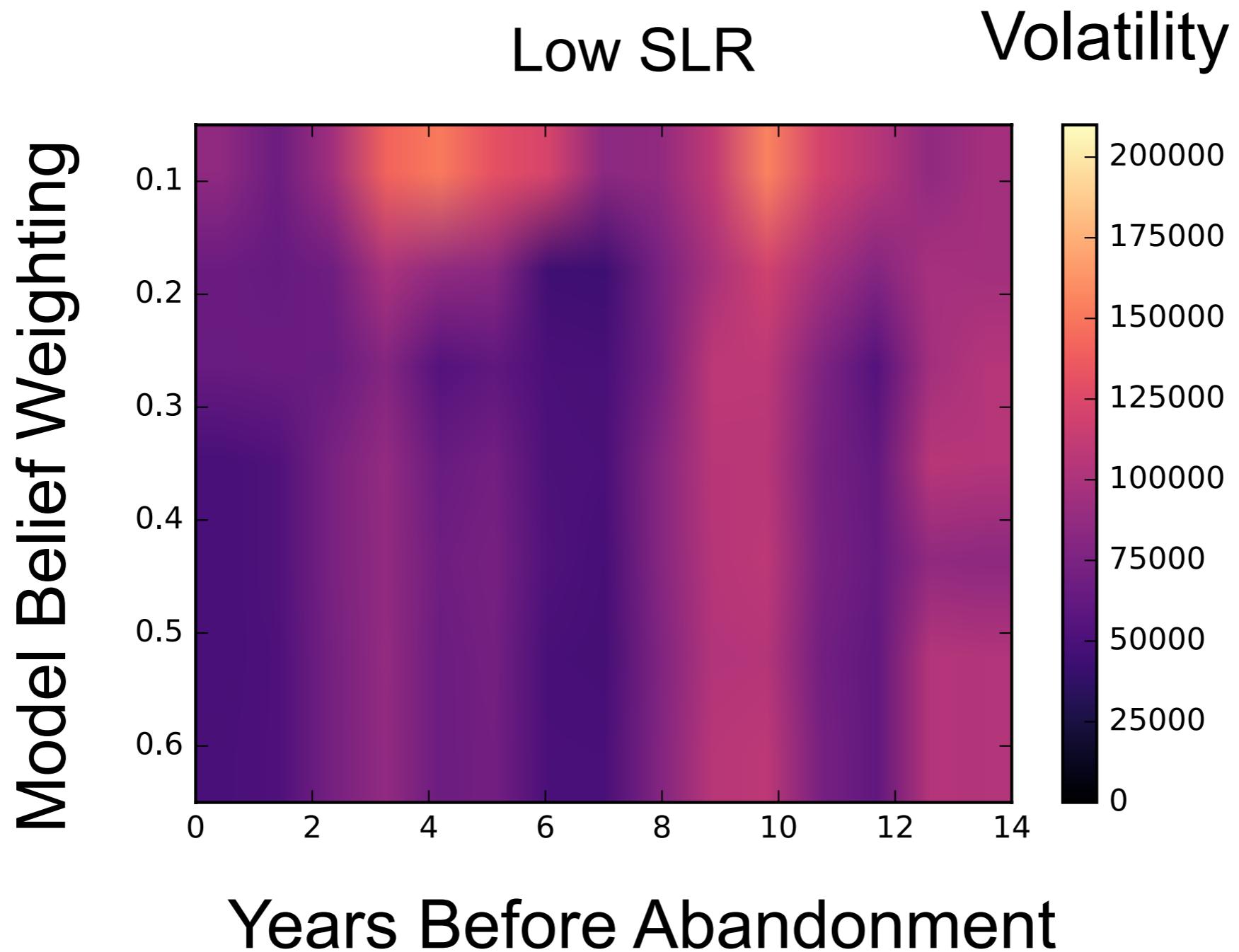
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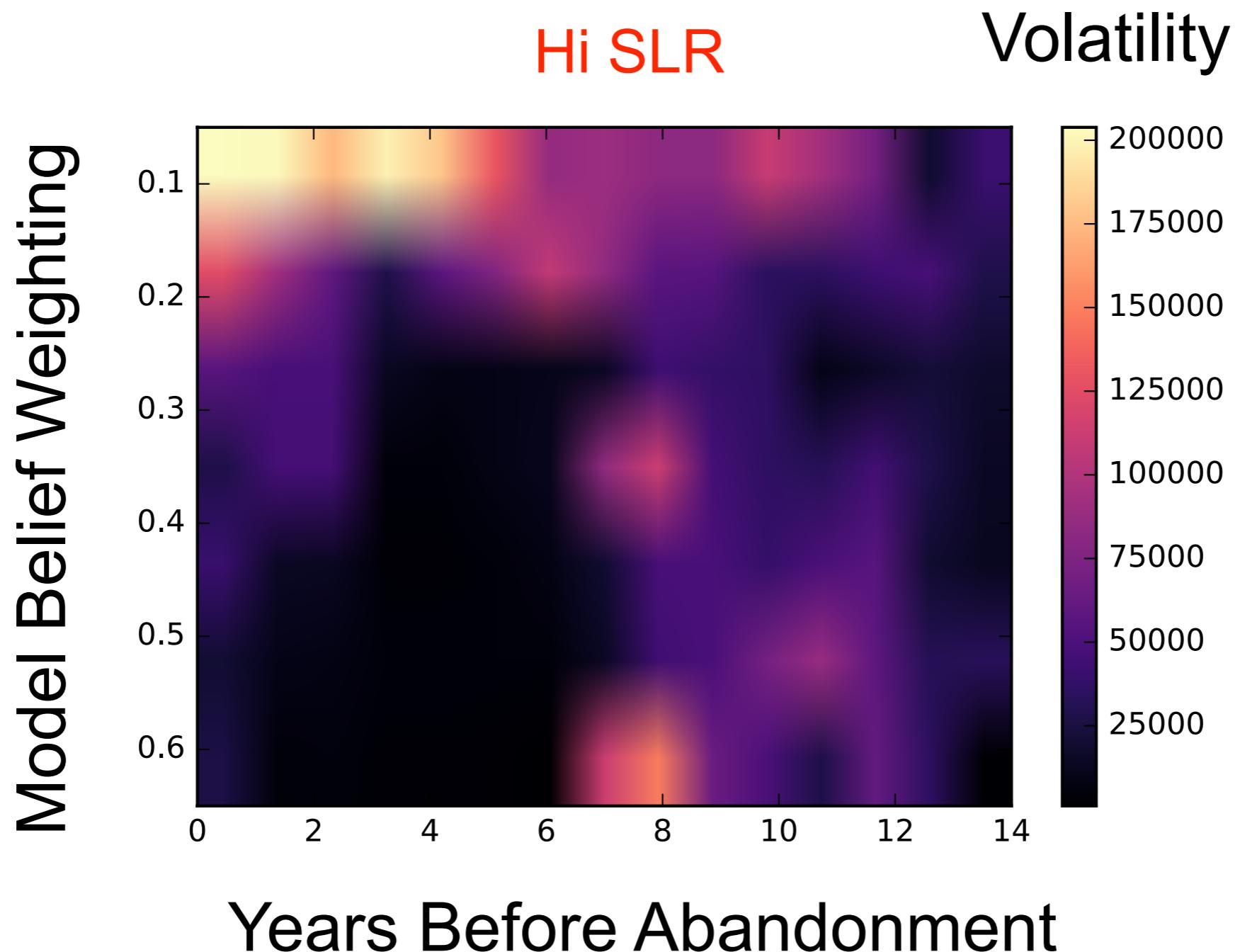
# Results



# Results



# Results



# Implications

- Environmental econophysics in exploratory phase
- Empirical grounding needed
- Subjective expectations of risk critical factor
- Disaster assistance equity issues
- Markets integrate information - provide signals

Thank You