





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

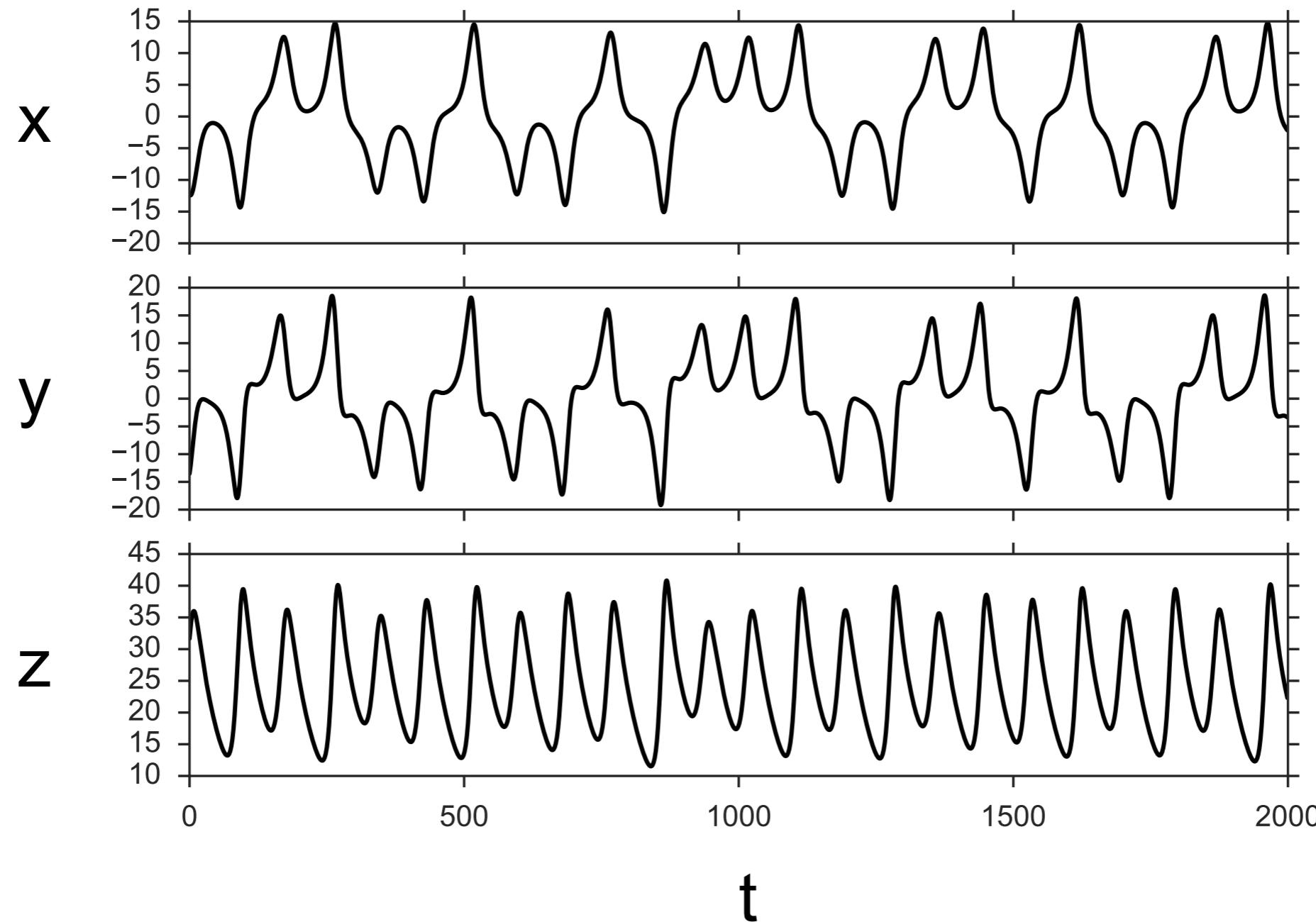
- Nonlinear Forecasting as a Tool
- Beach Nourishment
- Environmental Econophysics
- Model
- Results
- Implications

# Nonlinear Forecasting

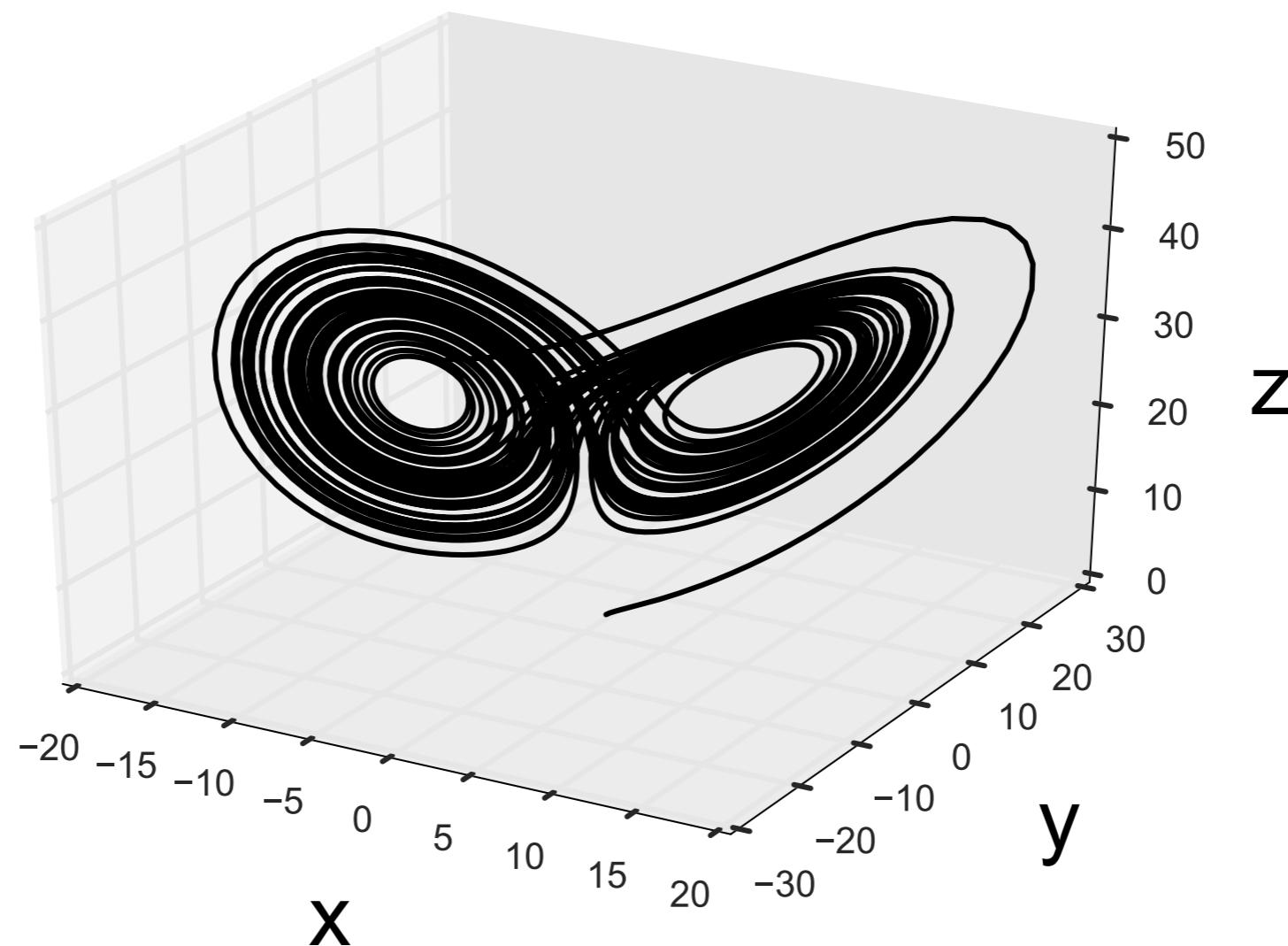
## Lorenz System

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

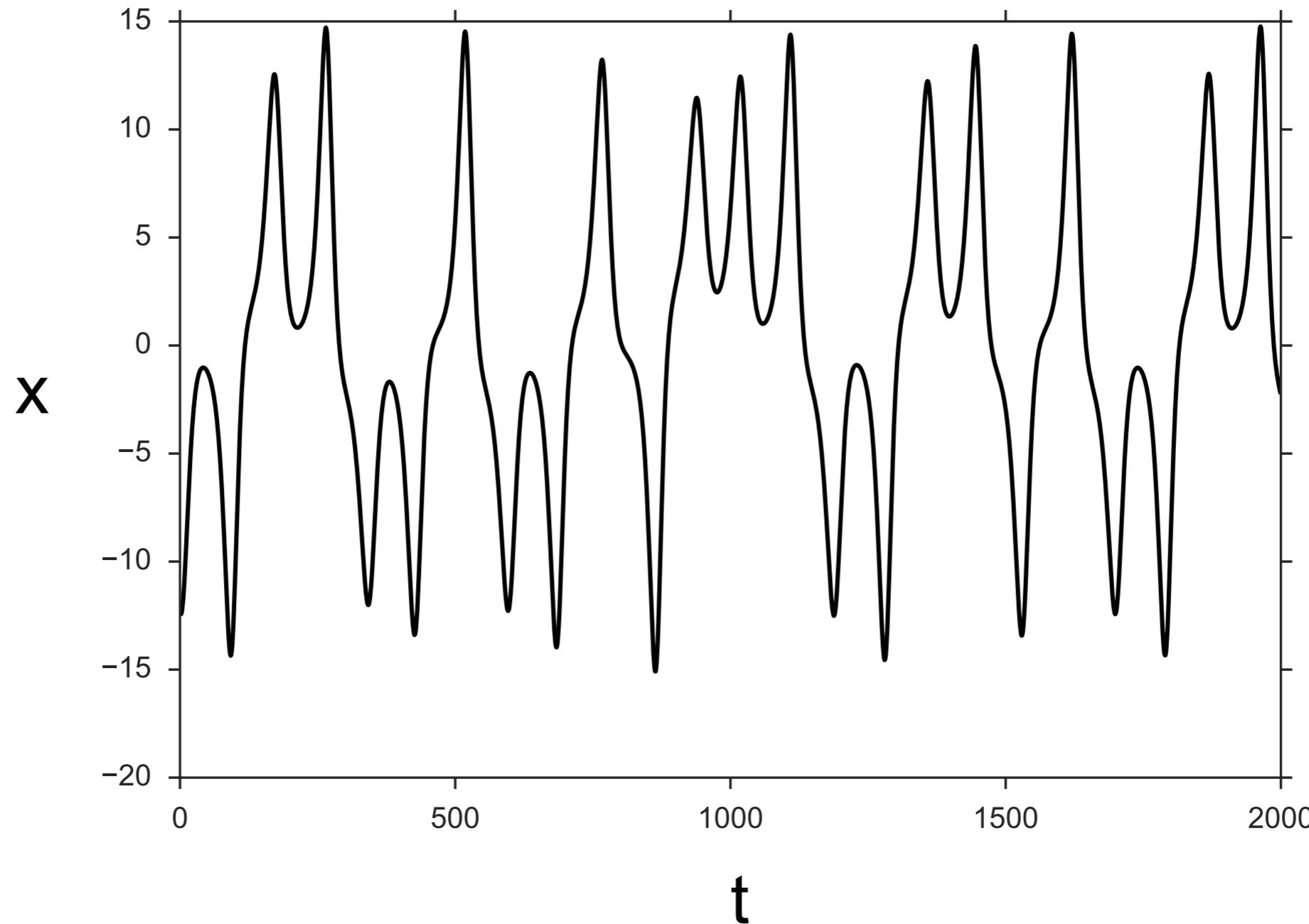
# Nonlinear Forecasting



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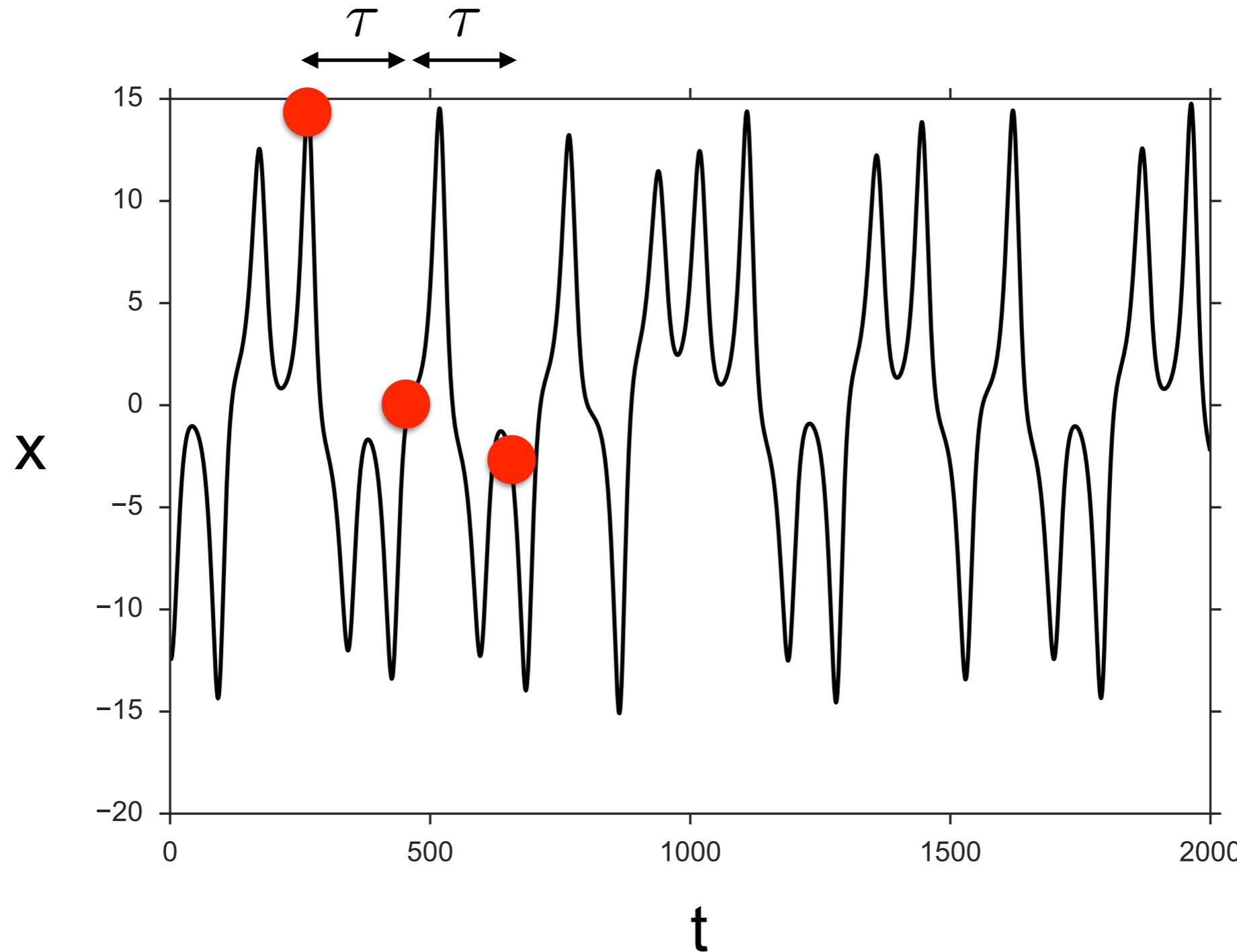
# Nonlinear Forecasting

## Taken's Theorem:

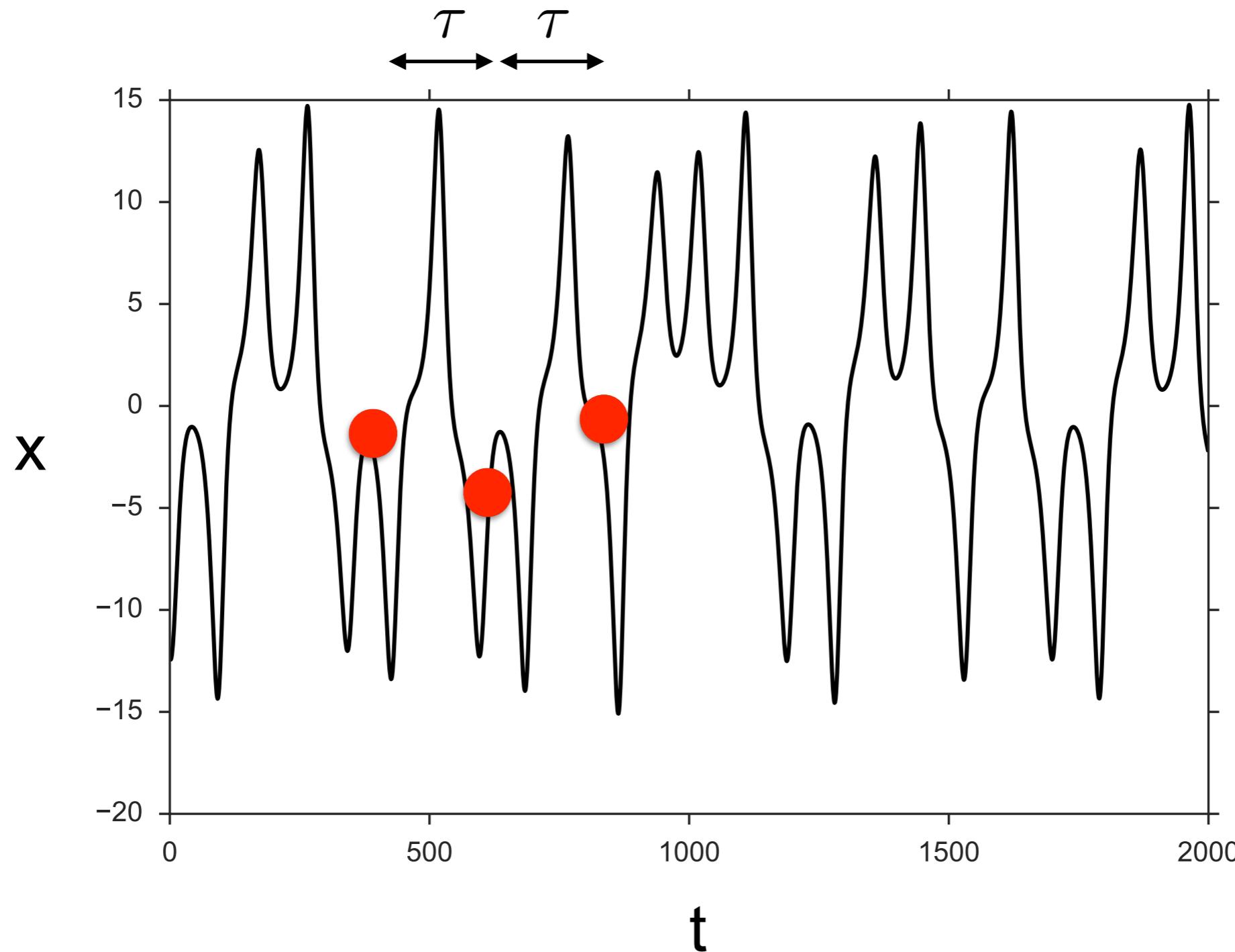
Measurements of a single dynamical variable, can be embedded in  $m$  dimensional space, revealing the structure and determinism of the full system.

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

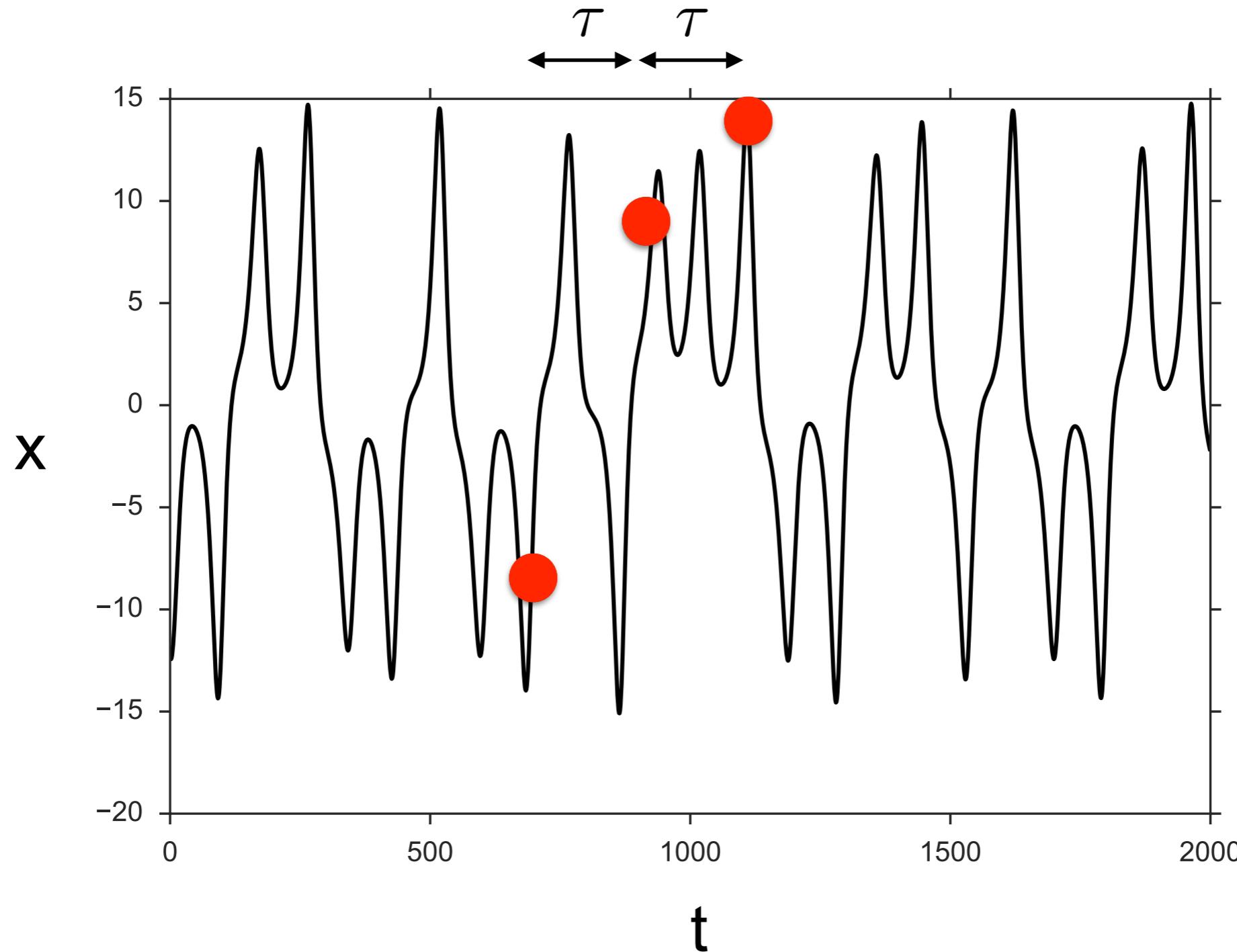
# Nonlinear Forecasting



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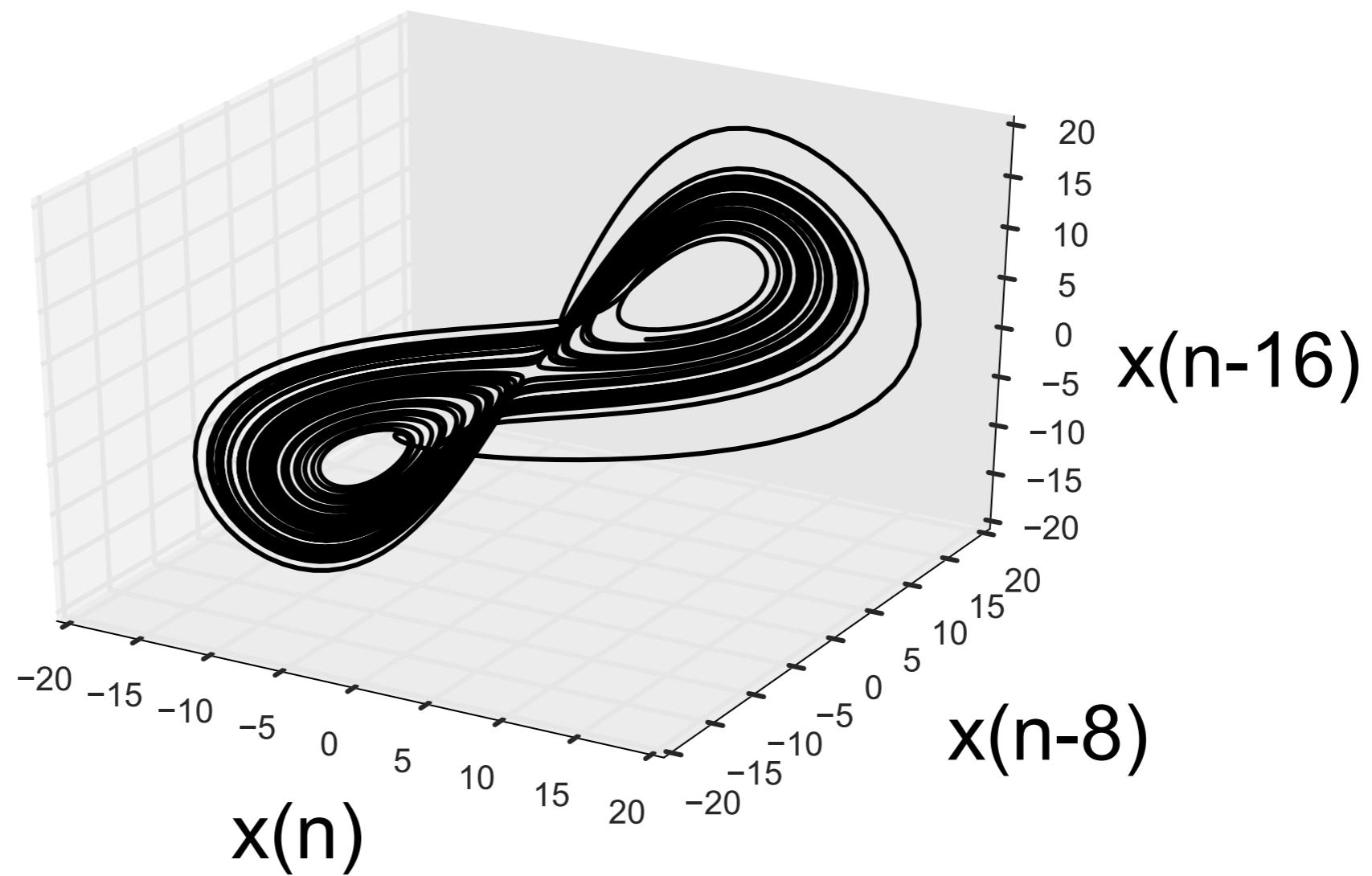


# Nonlinear Forecasting



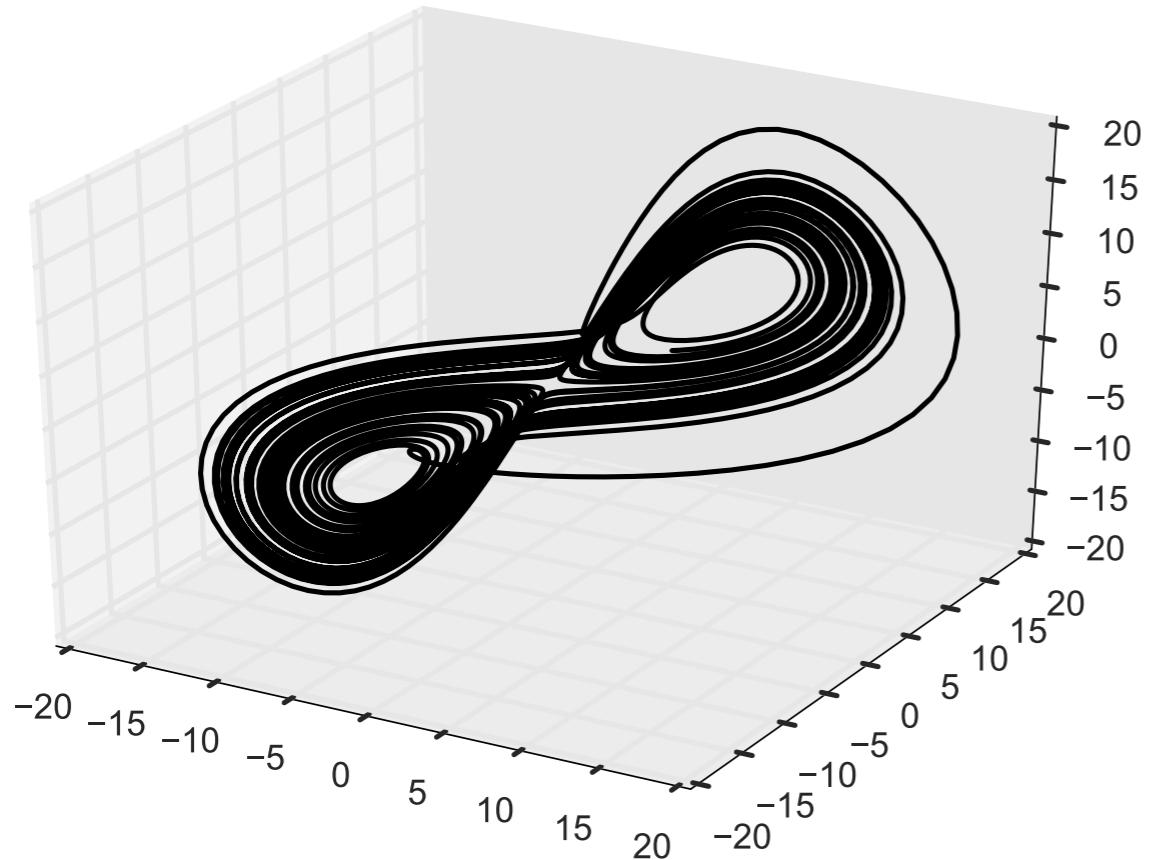
# Nonlinear Forecasting

## Reconstructed Attractor

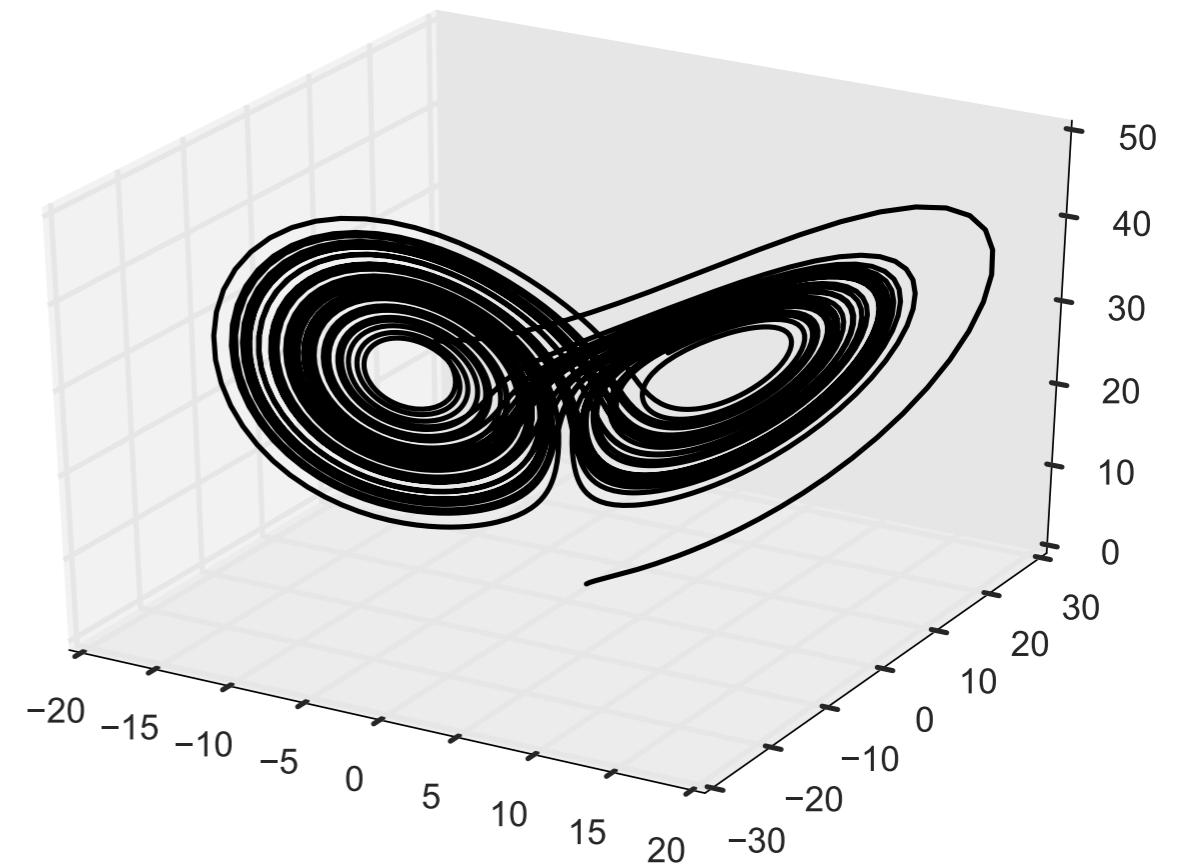


# Nonlinear Forecasting

## Reconstructed Attractor

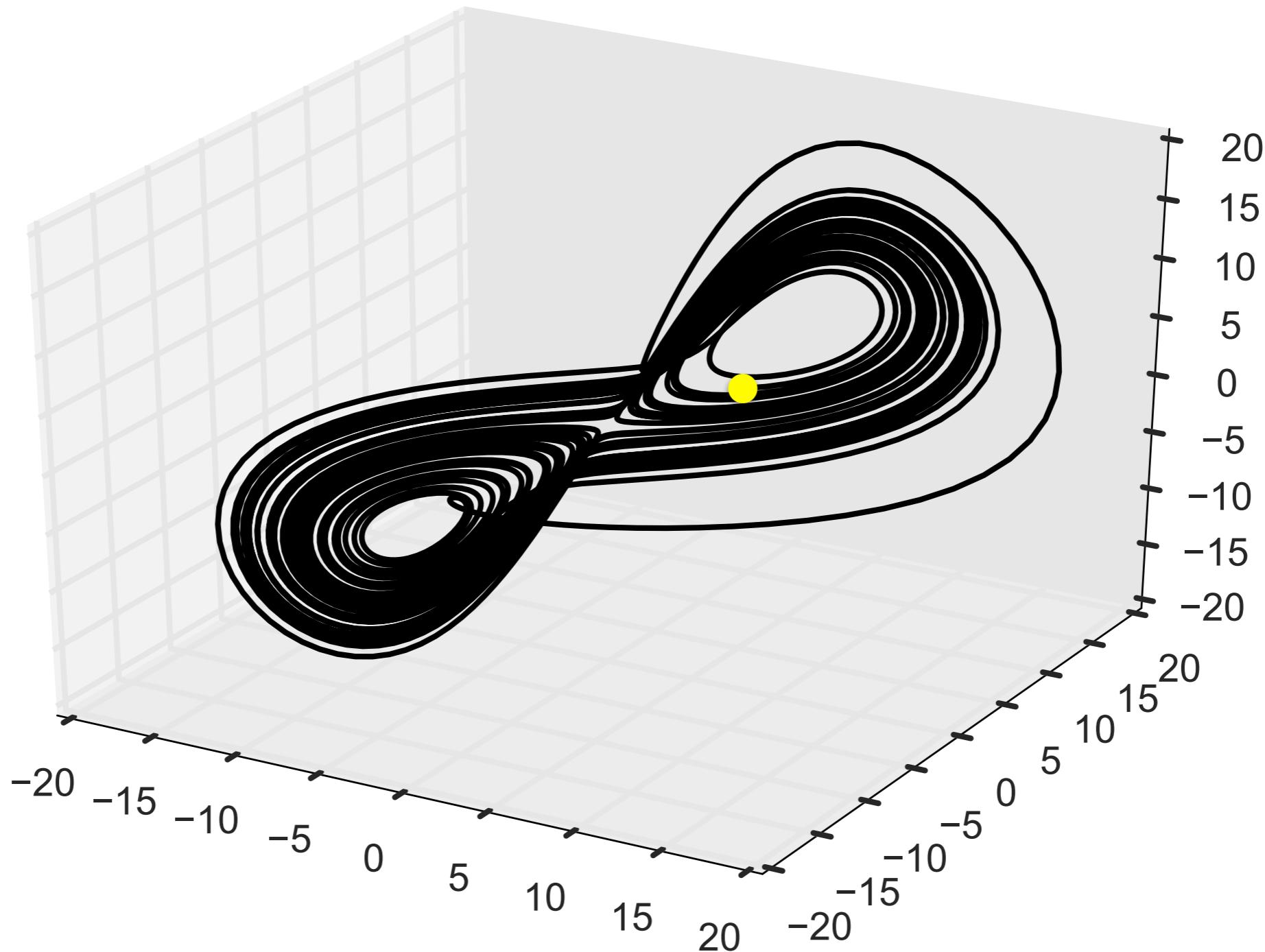


Lorenz Attractor



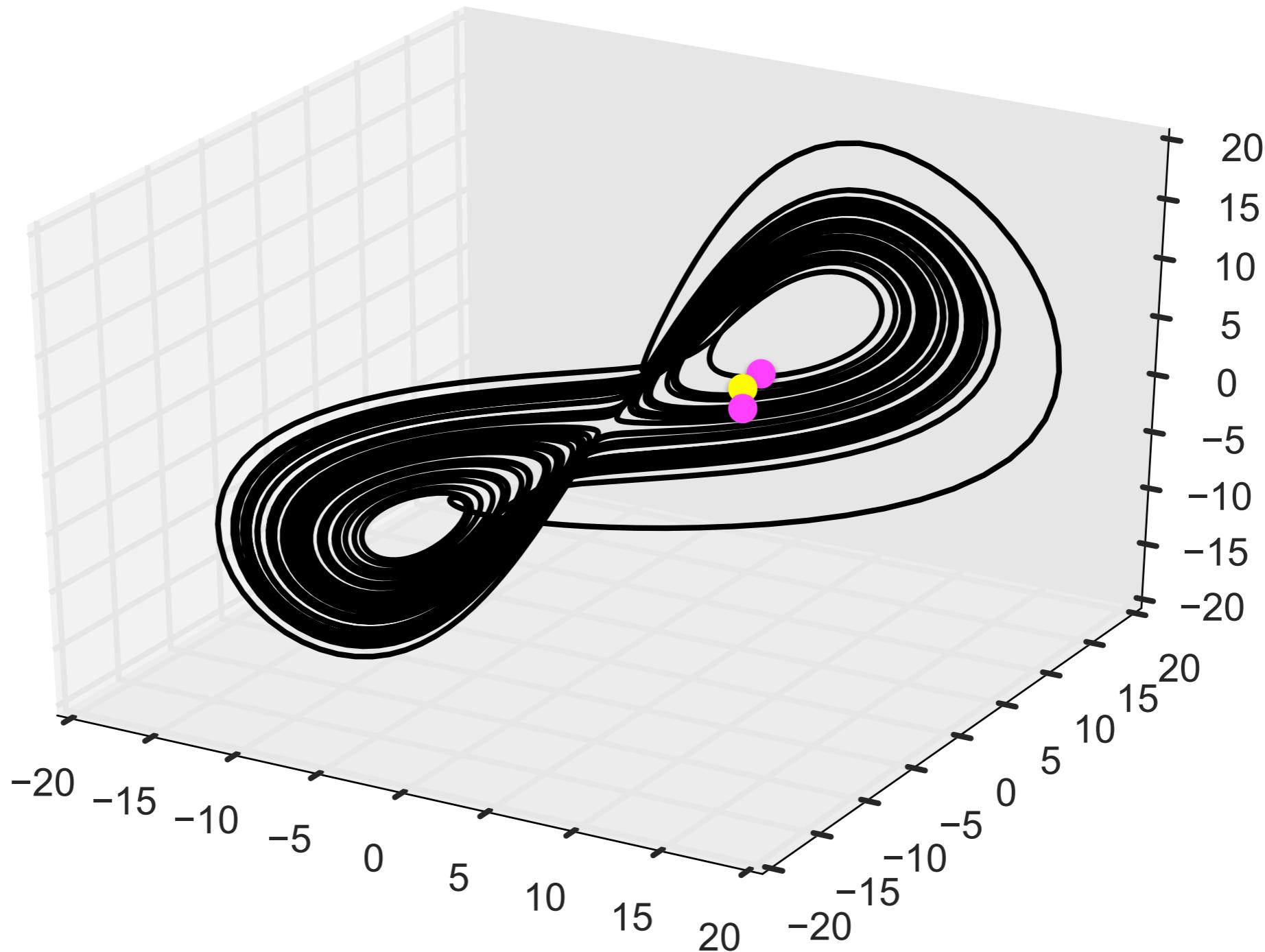
# Nonlinear Forecasting

## Reconstructed Attractor



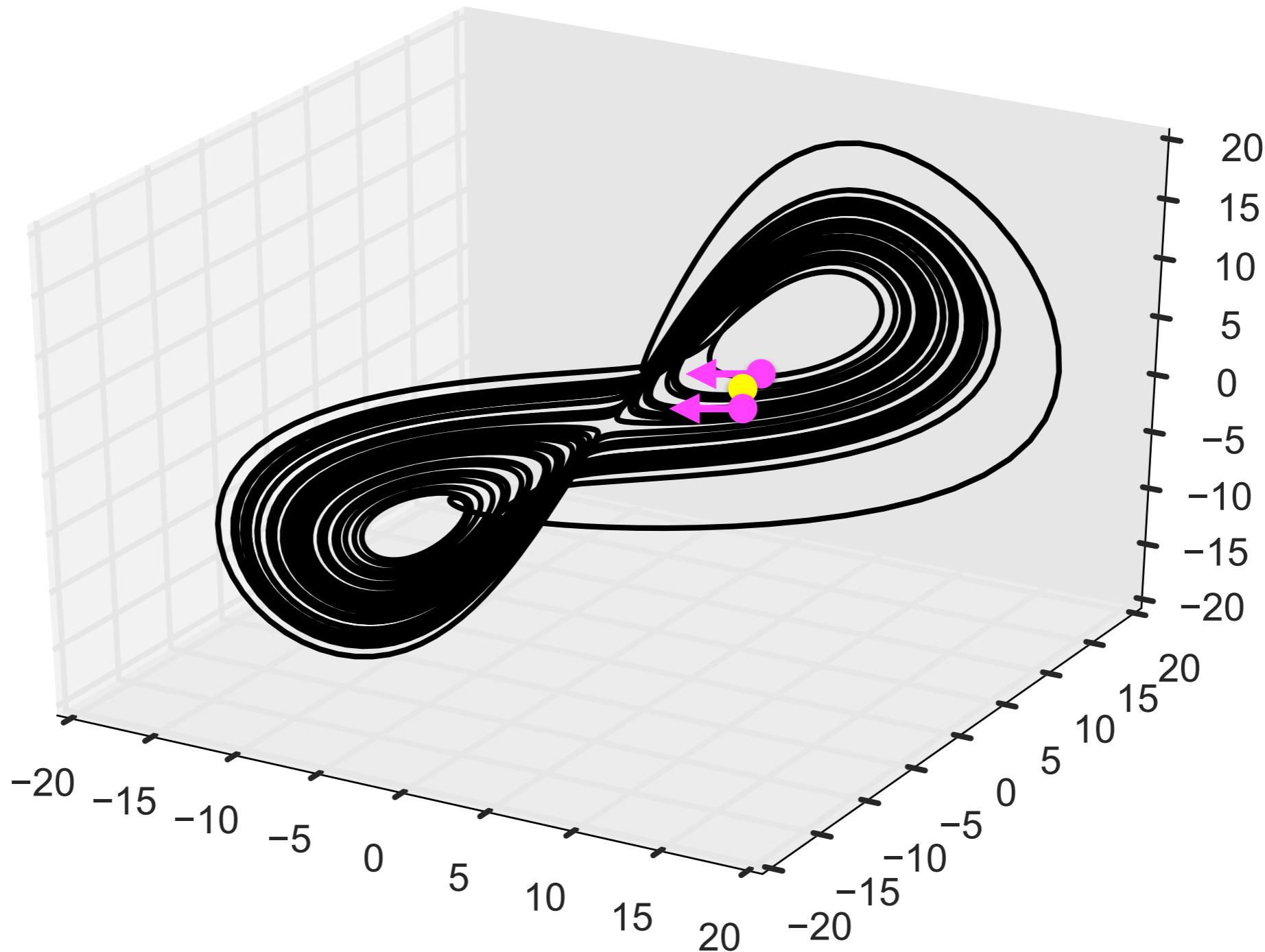
# Nonlinear Forecasting

## Reconstructed Attractor



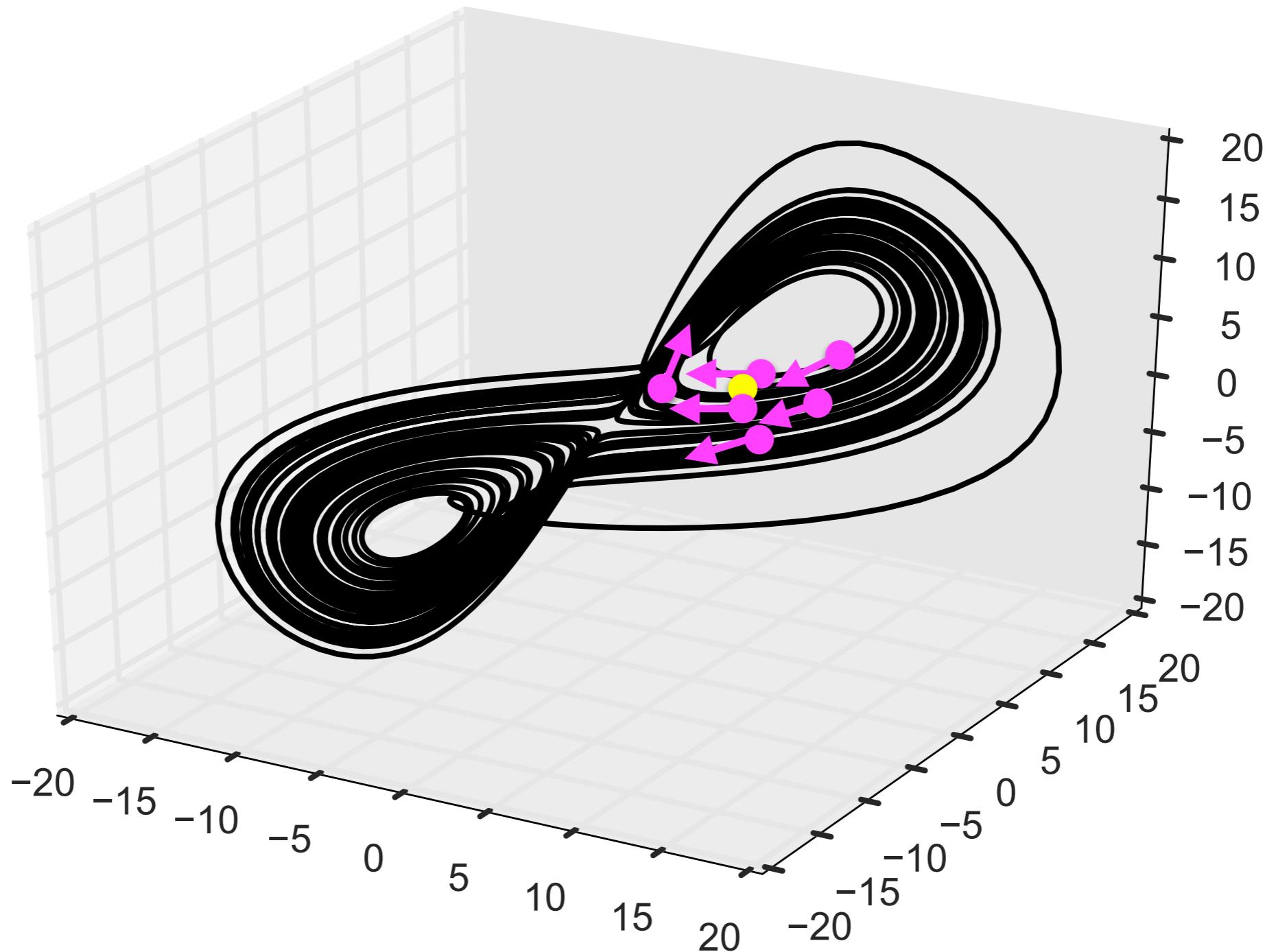
# Nonlinear Forecasting

## Reconstructed Attractor

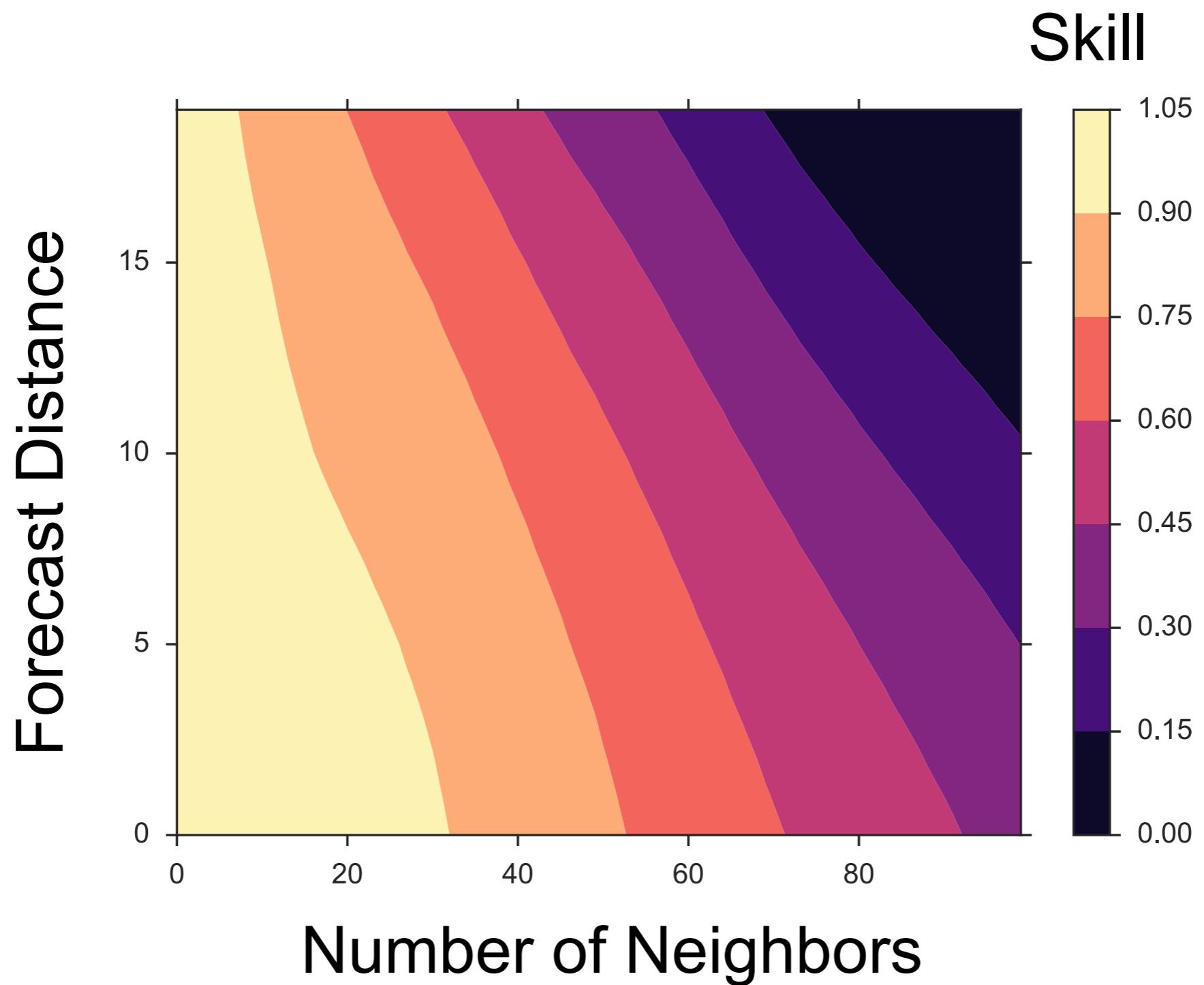


# Nonlinear Forecasting

## Reconstructed Attractor



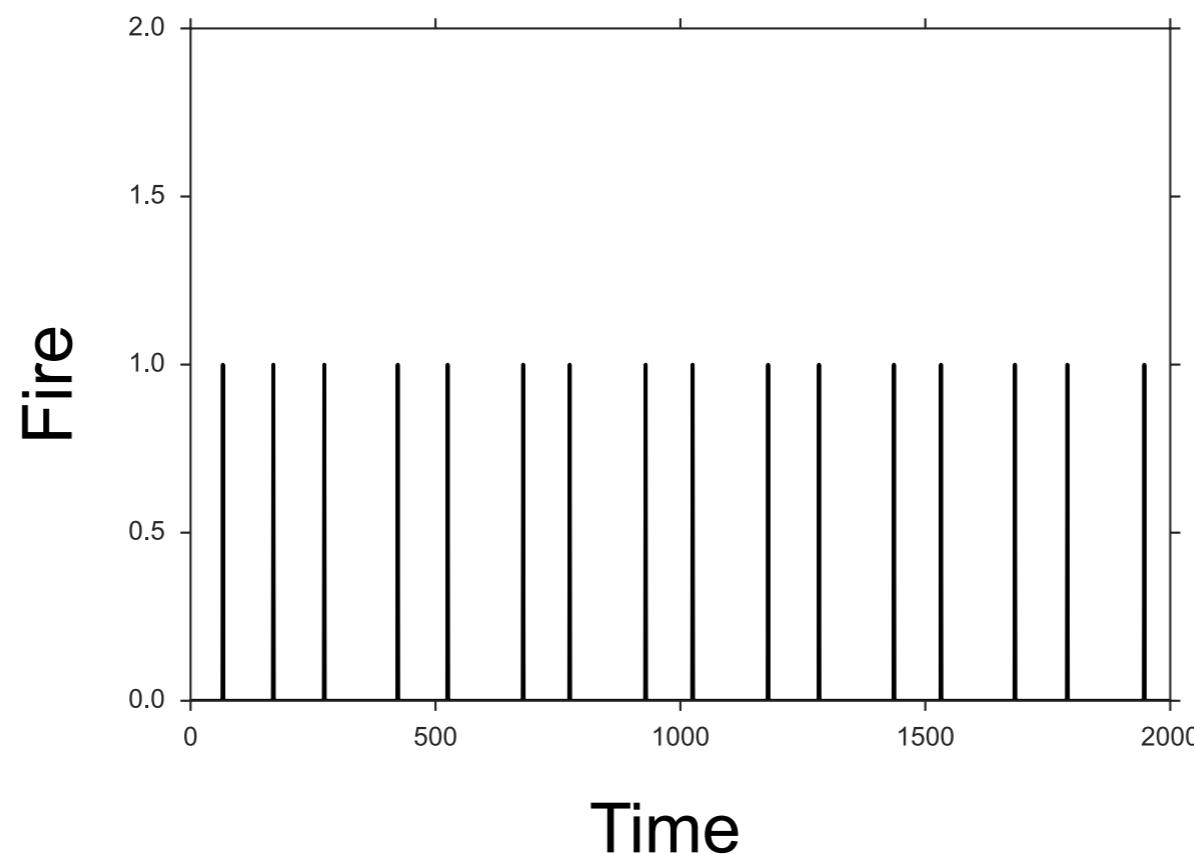
# Nonlinear Forecasting



# Nonlinear Forecasting

## Integrate and Fire

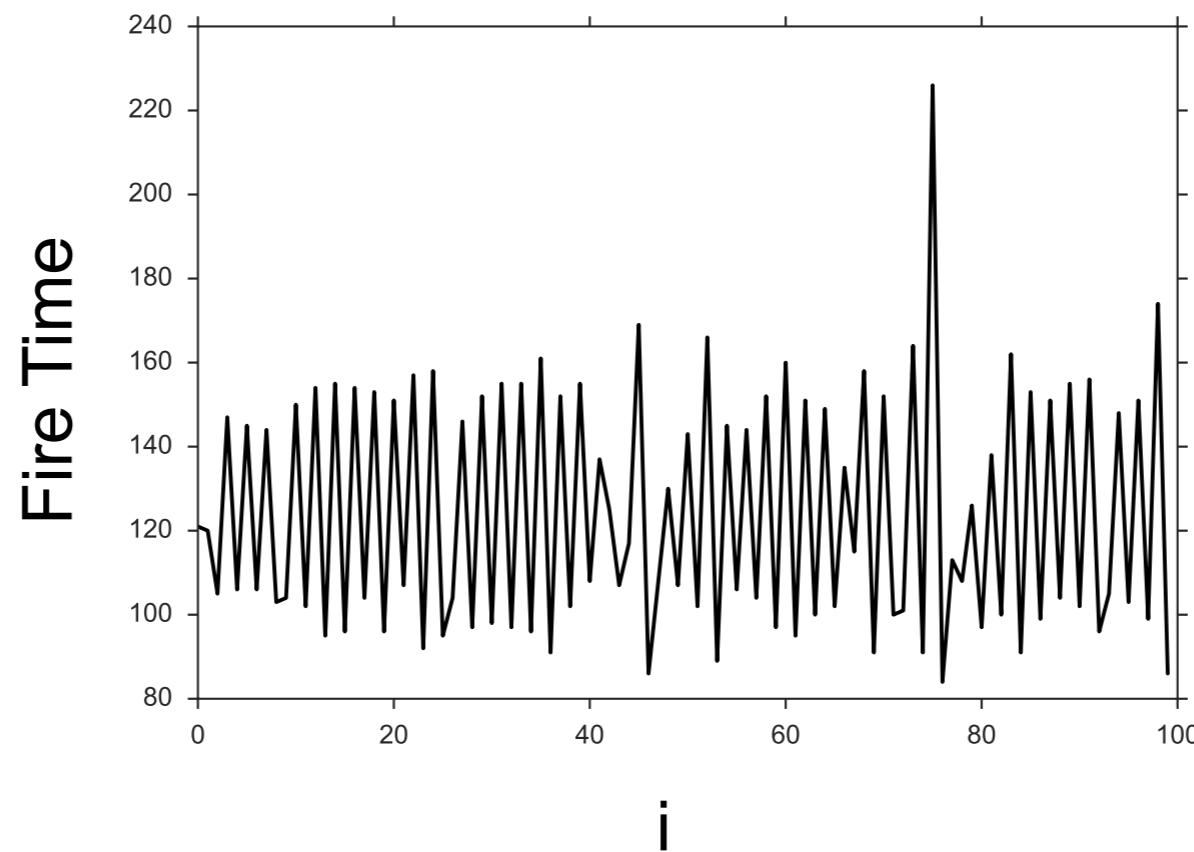
$$\int_{T_i}^{T_{i+1}} x(t)^2 dt = \theta$$



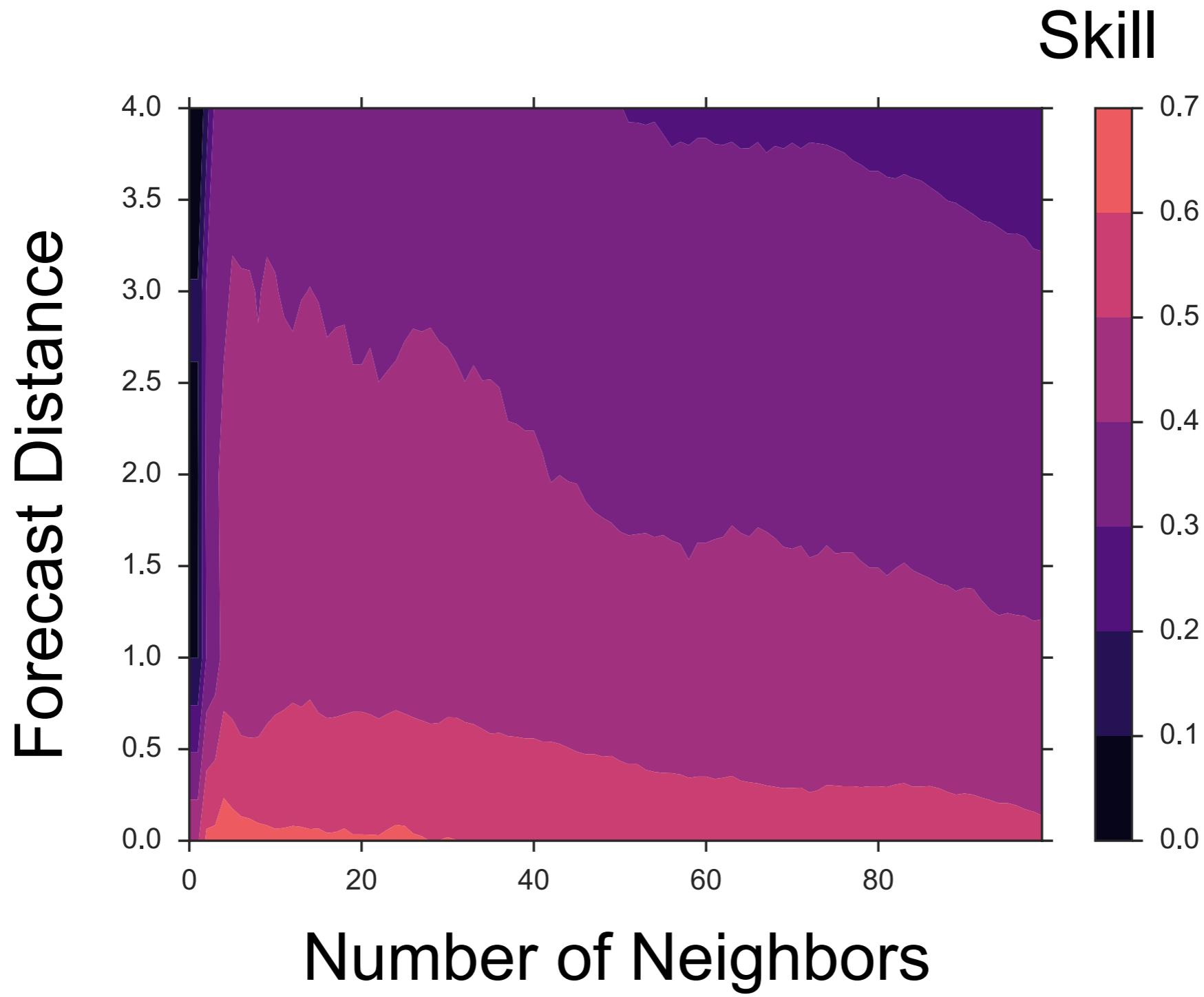
# Nonlinear Forecasting

**Integrate and Fire**

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



# Nonlinear Forecasting

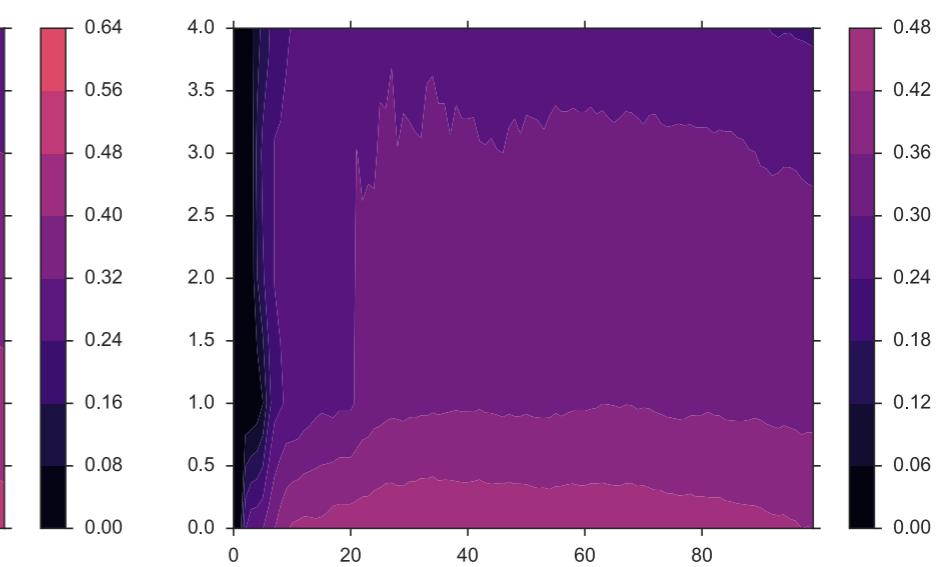
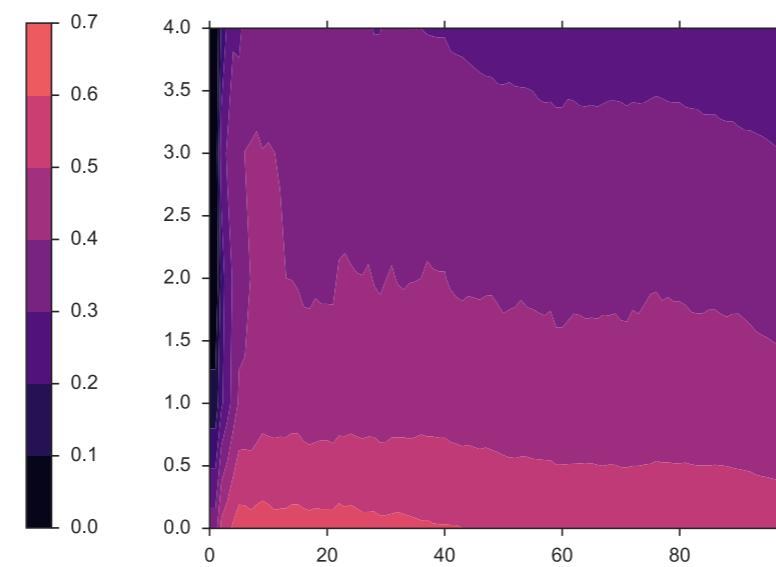
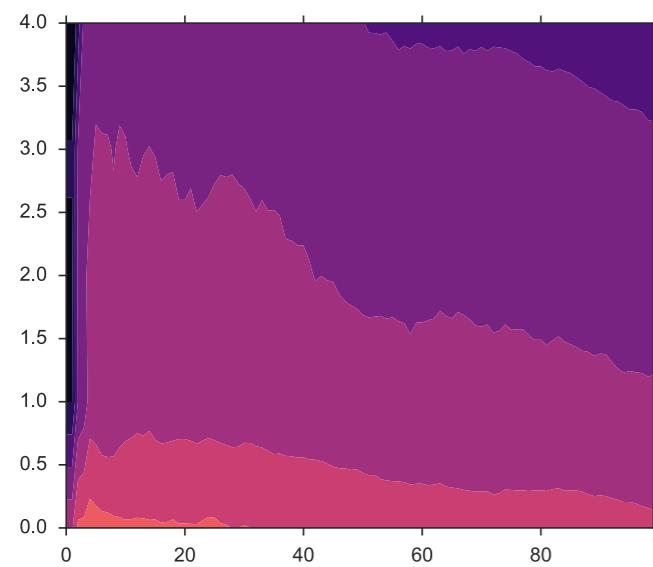


# Nonlinear Forecasting

Increasing Noise



Forecast Distance



Number of Neighbors

# 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,

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

Subject to,

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

# Beach Nourishment

Maximize,

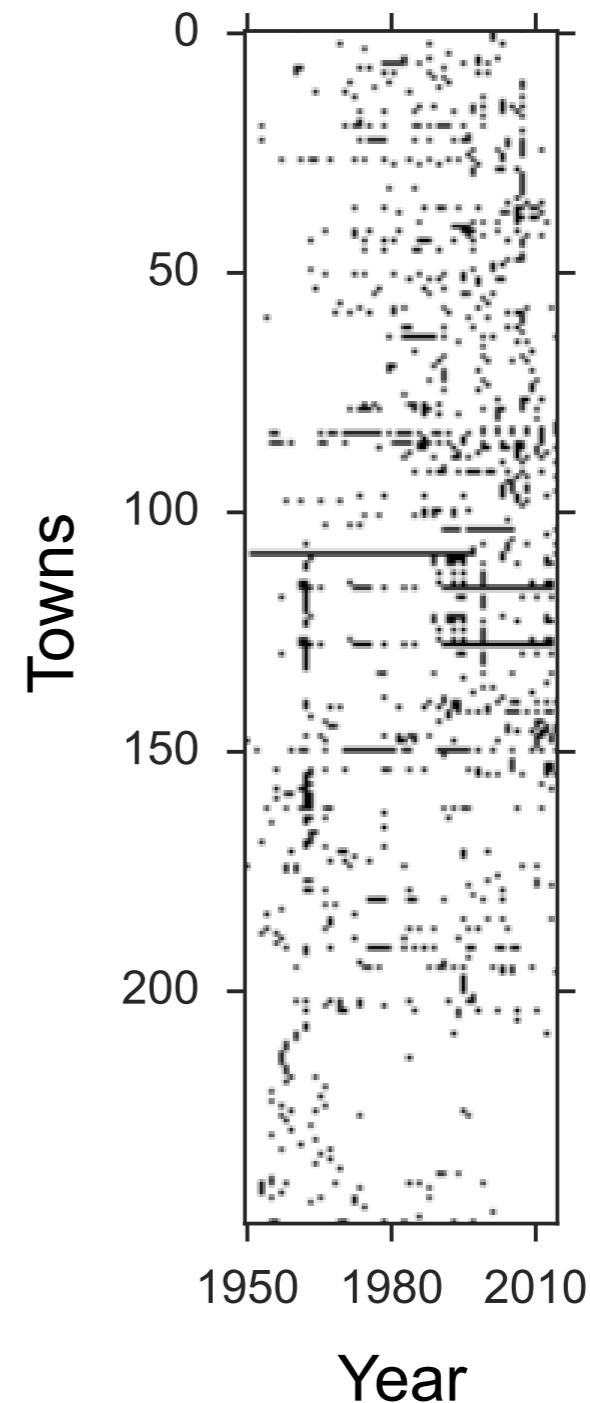
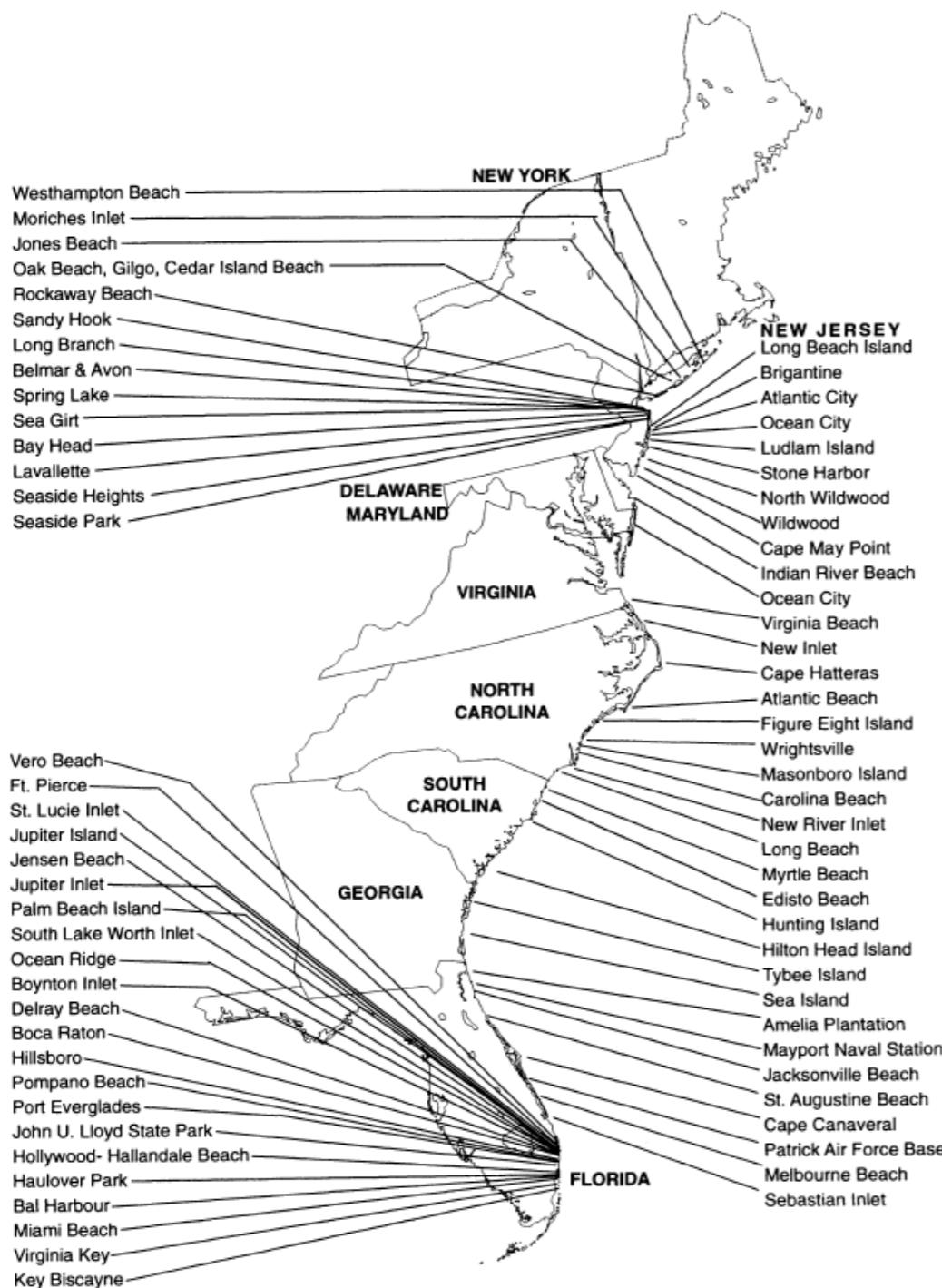
$$\int_{T_i}^{T_{i+1}} [B(x(t), \lambda_b) - C(x(t), \lambda_c)] dt$$

Subject to,

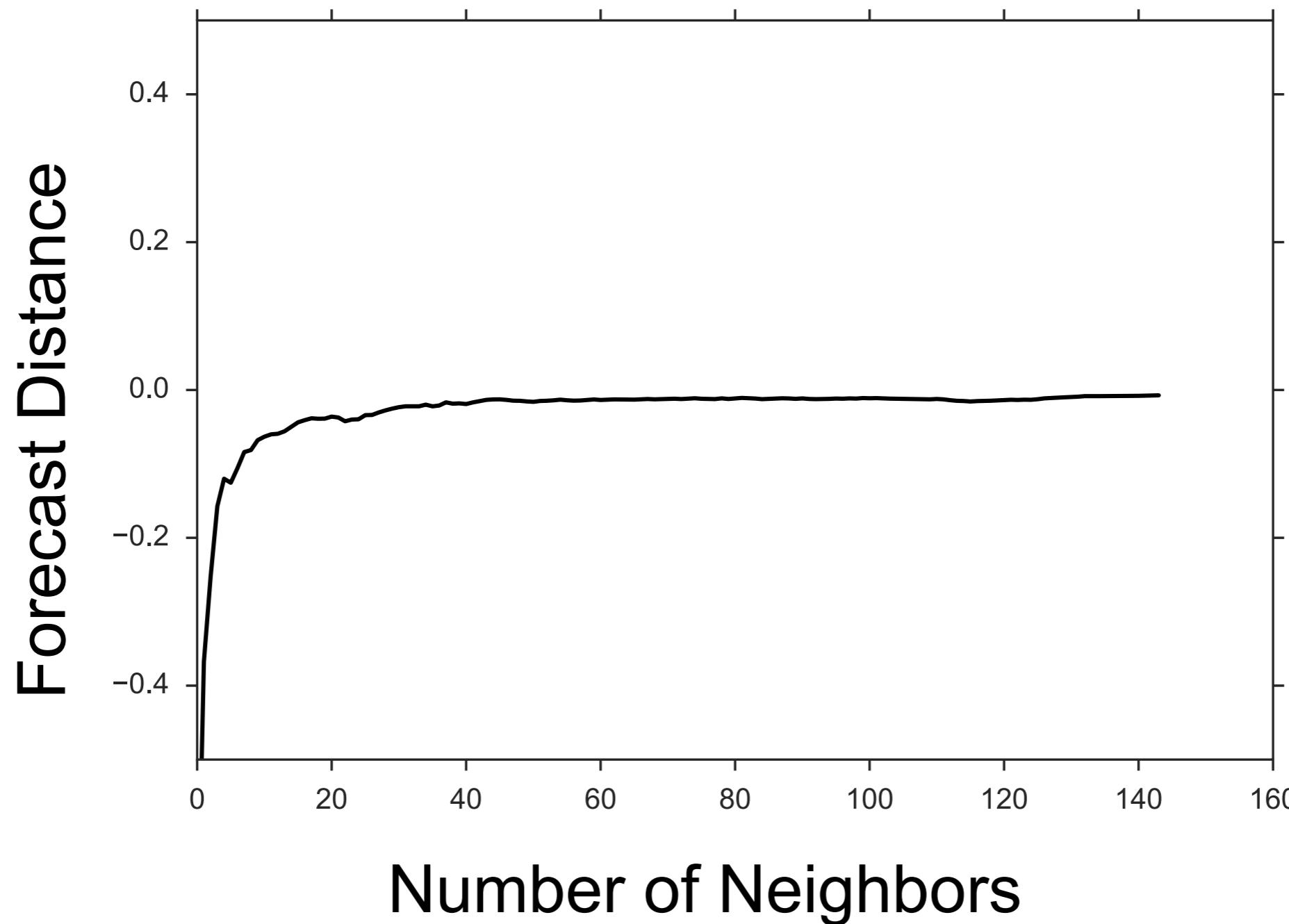
$$\frac{dx}{dt} = f(x, \lambda_x, \lambda_E)$$

**IS THIS SYSTEM DETERMINISTIC?**

# Beach Nourishment



# Beach Nourishment



# New Way

- Optimization framework is of limited utility
- A dynamical attractor for human occupied coastal system does exist - **and it will change**
- Dynamics are complex - natural, economic, social
- 2008 stock market crash - birth of “econophysics”
- Social Atoms

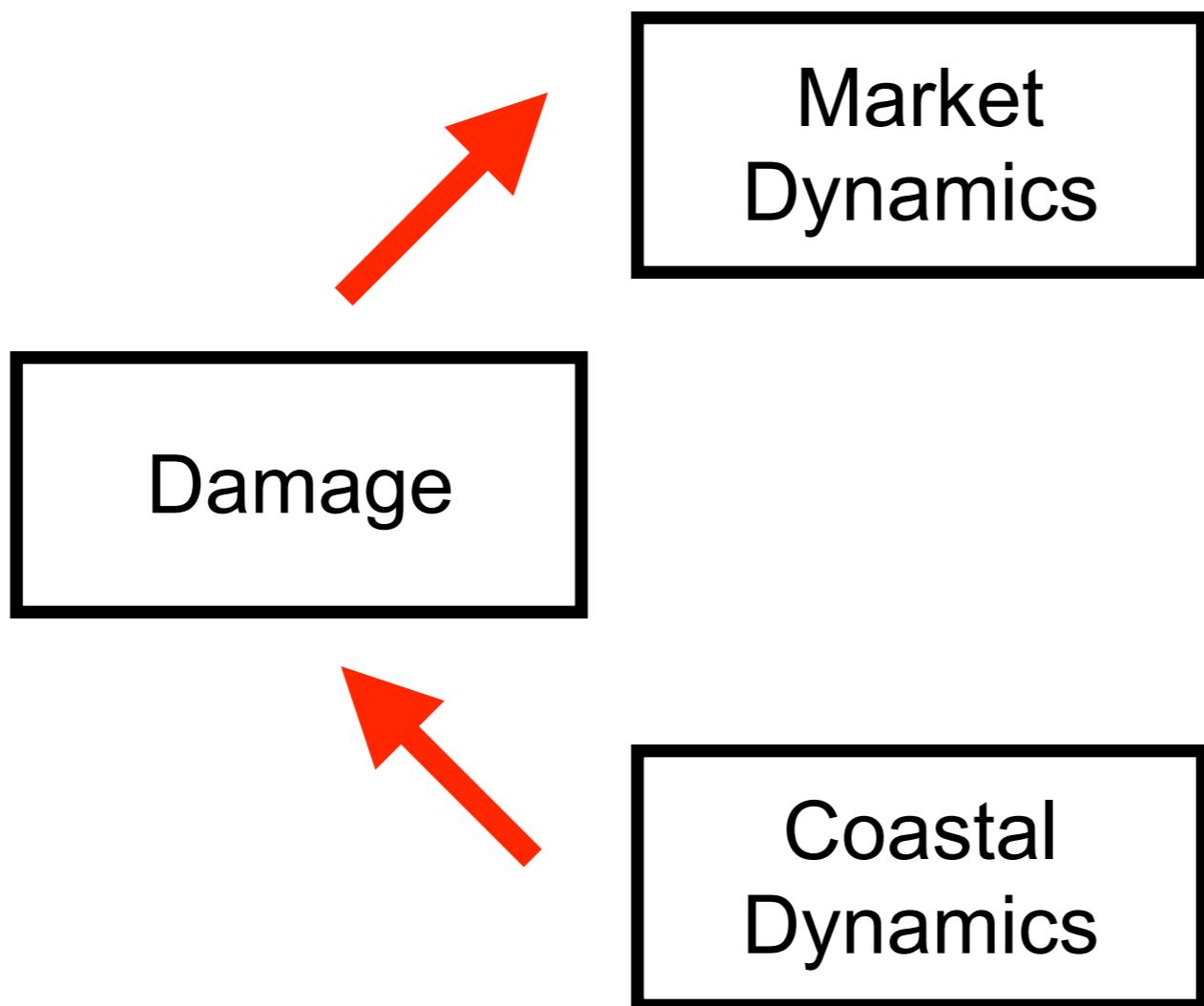
# Environmental Econophysics

- Social Atoms at the Beach:
  - Buy property as investment
  - Protect investment with mitigation
  - Develop risk perceptions
    - Complicated natural signal

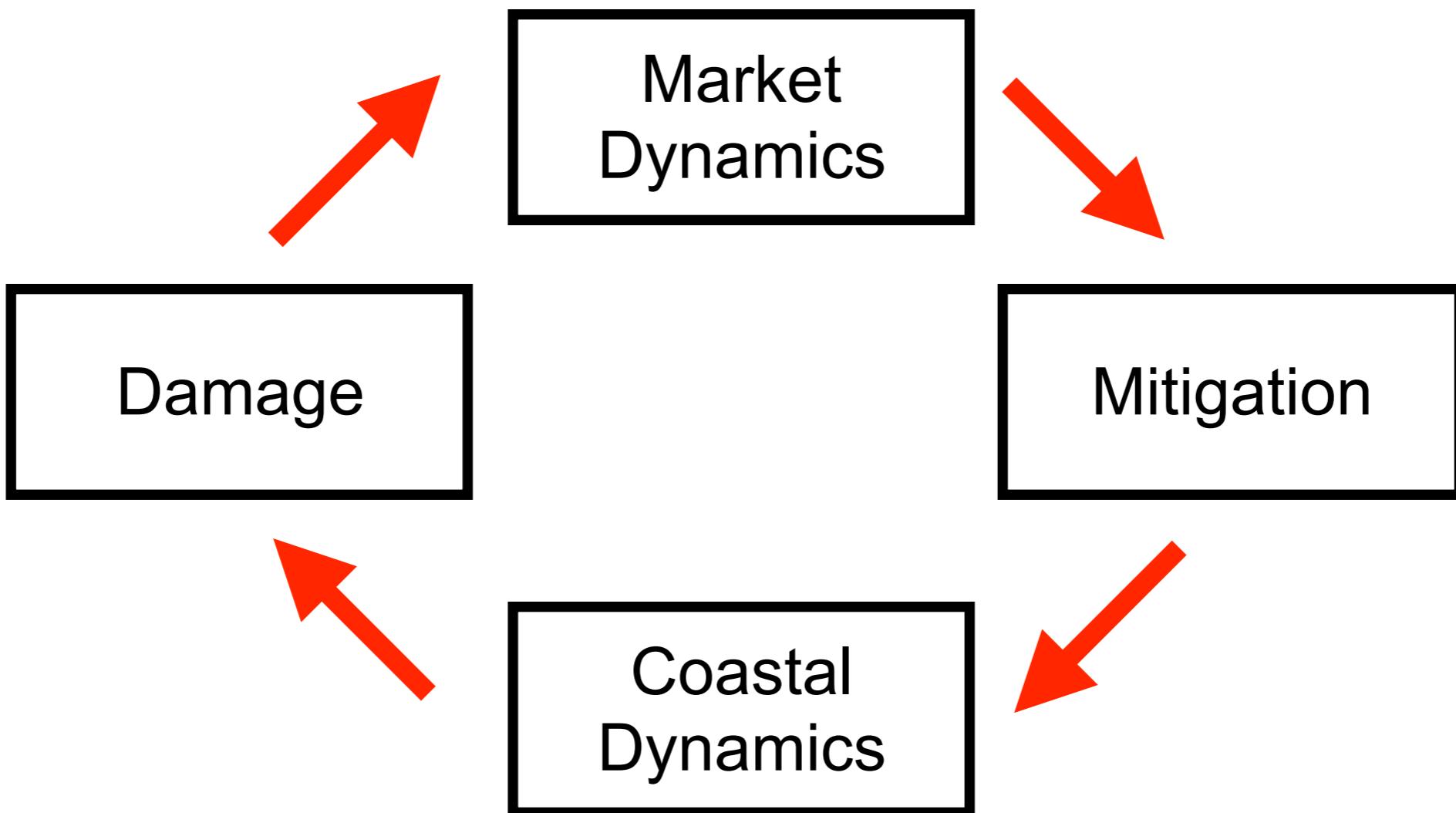
# Model

Market  
Dynamics

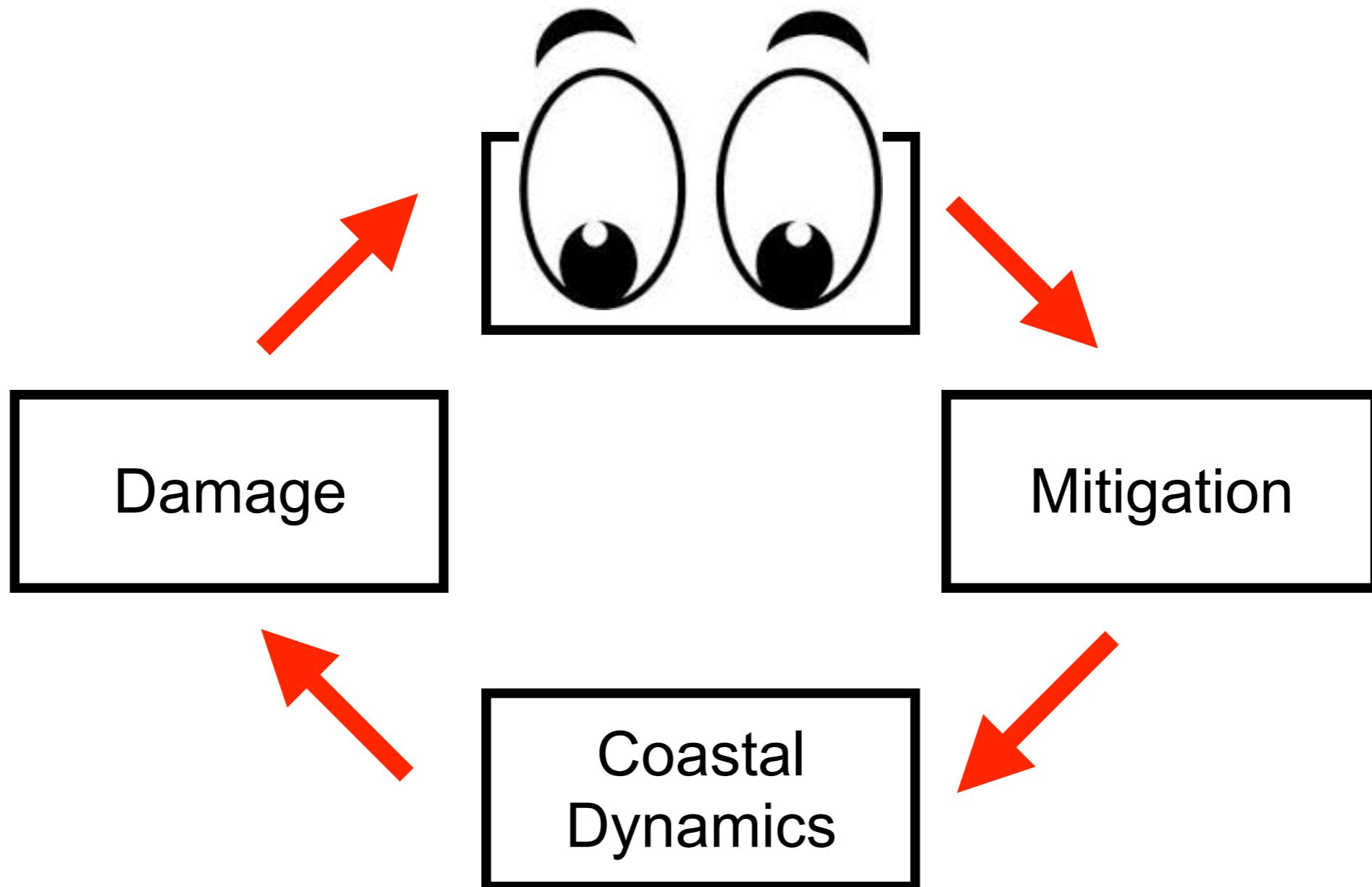
# Model



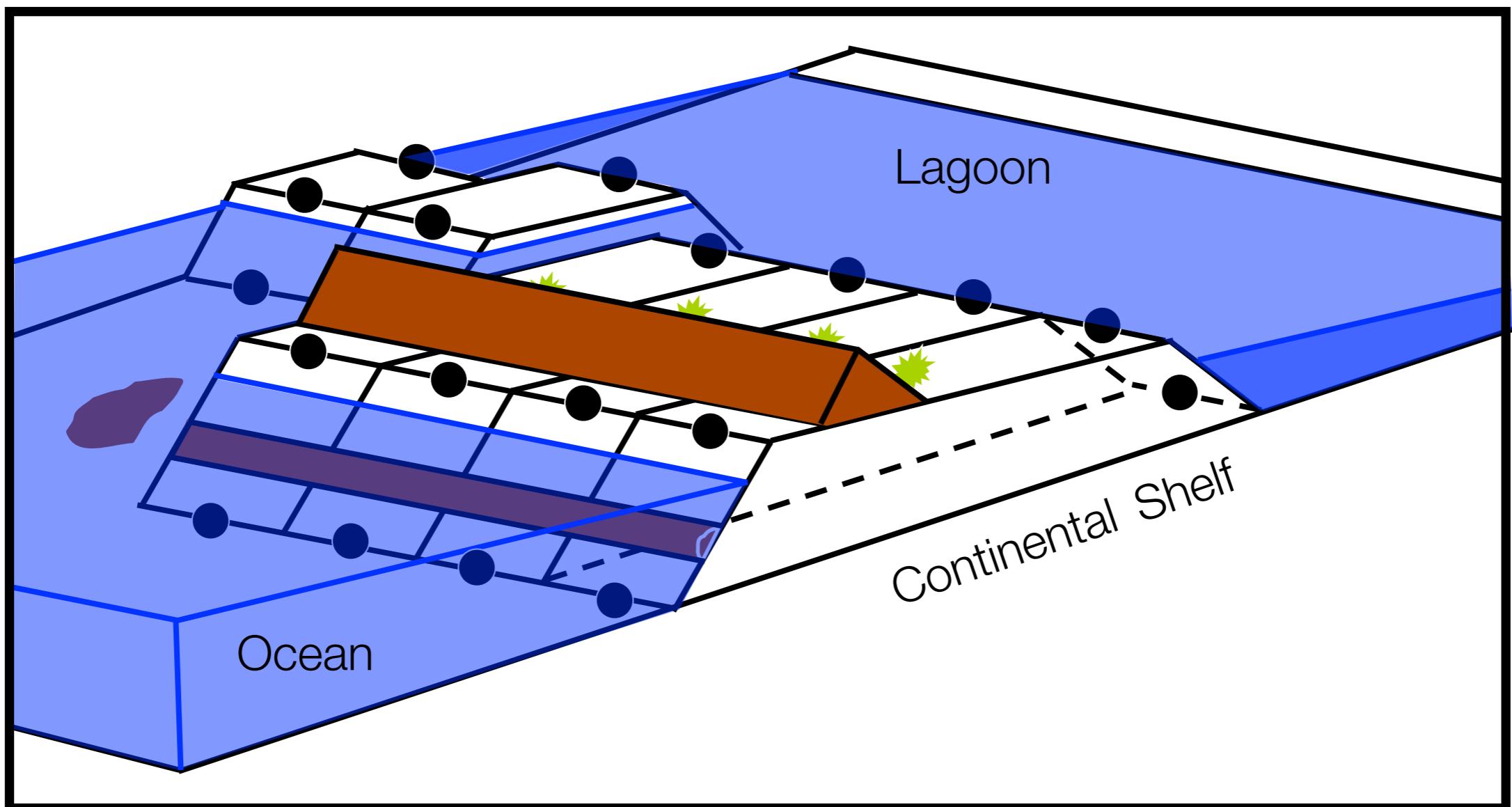
# Model



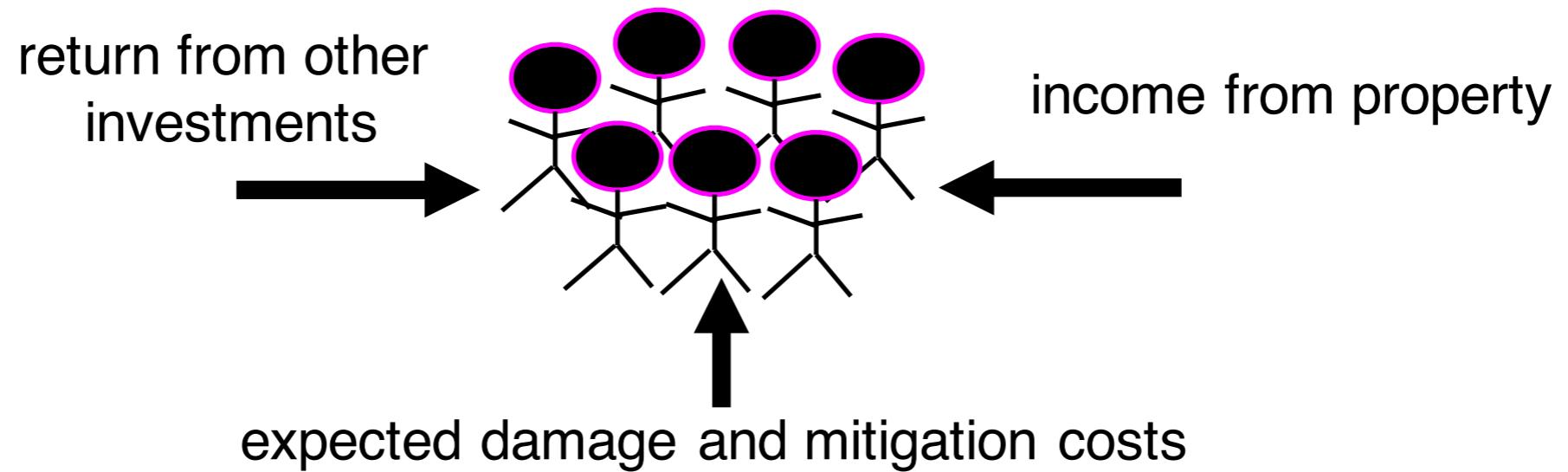
# Model



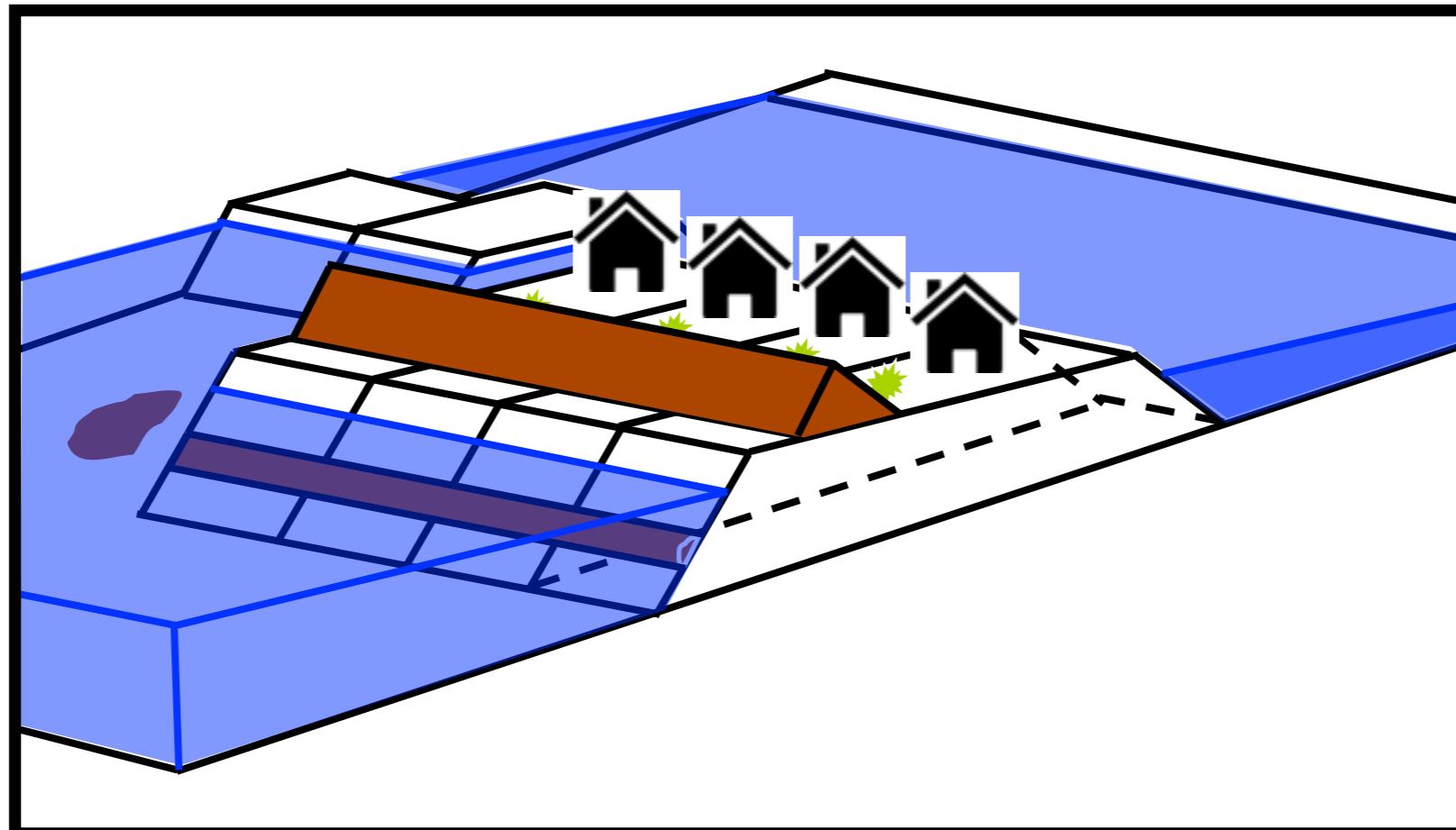
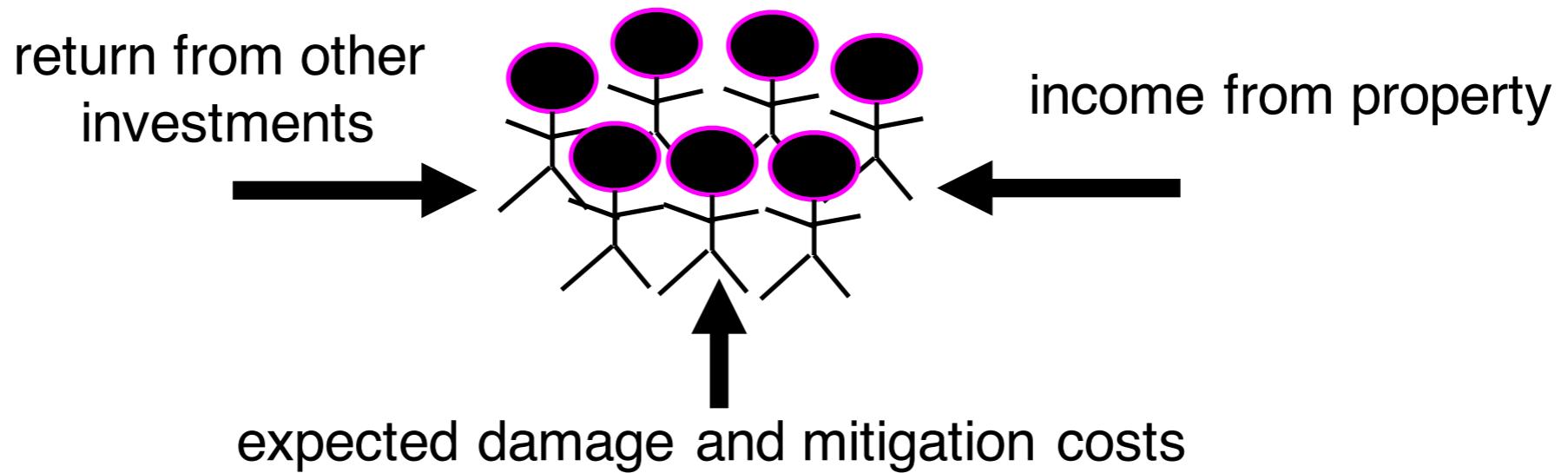
# Coastal Dynamics



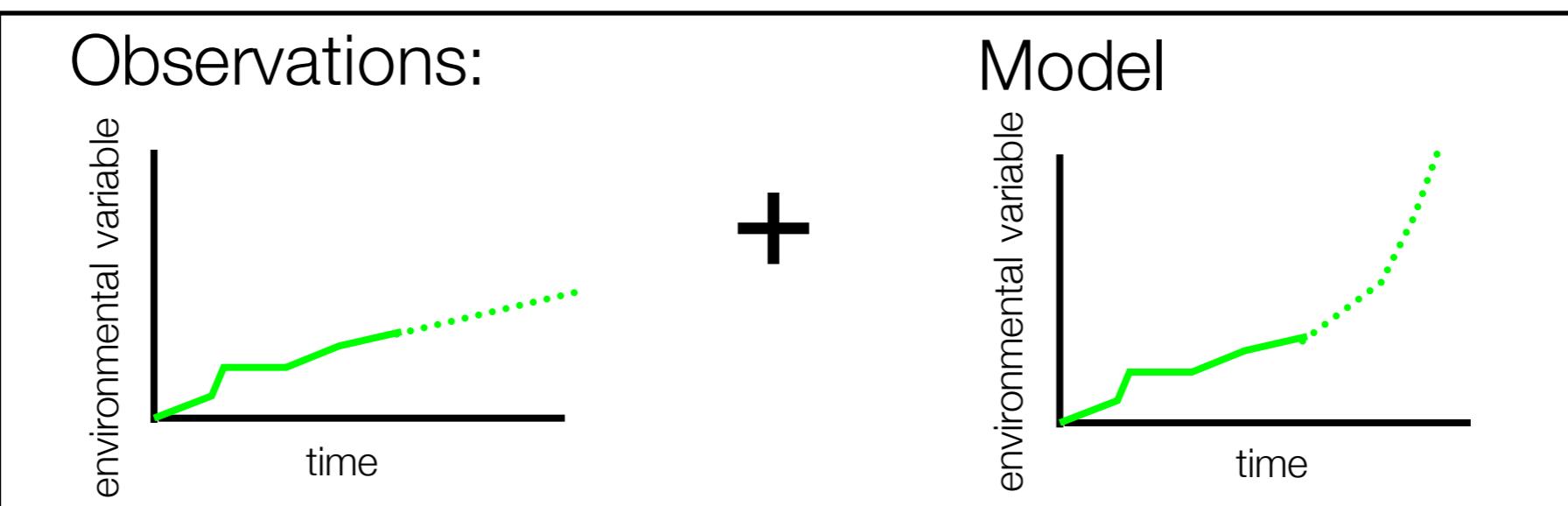
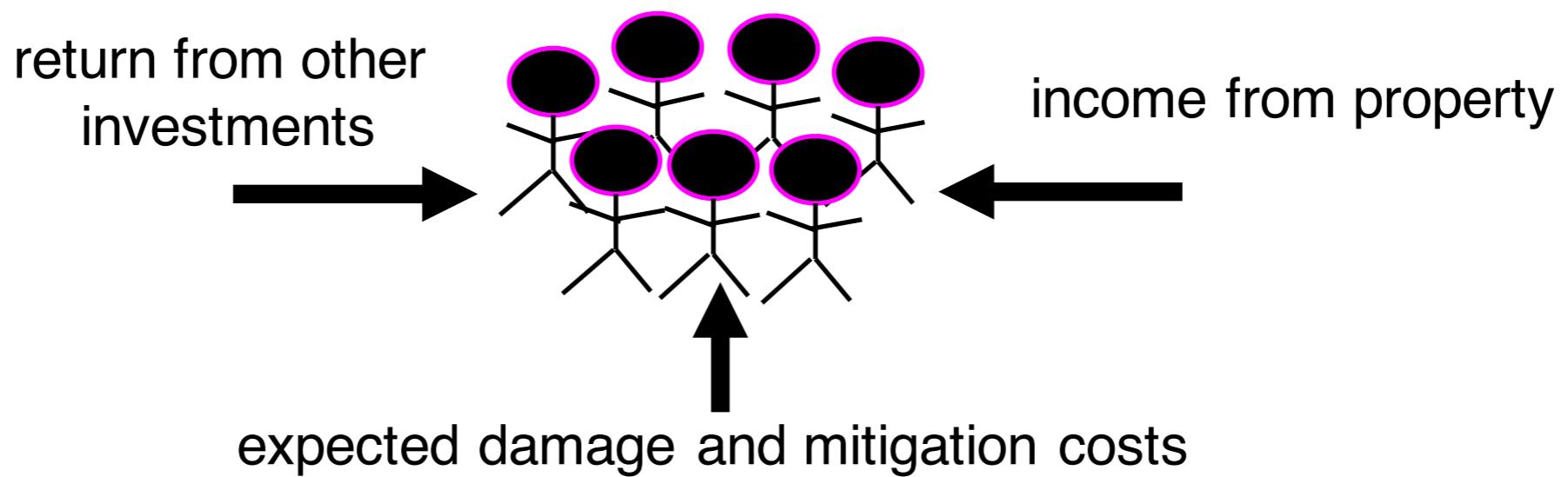
## Market Dynamics



## Market Dynamics



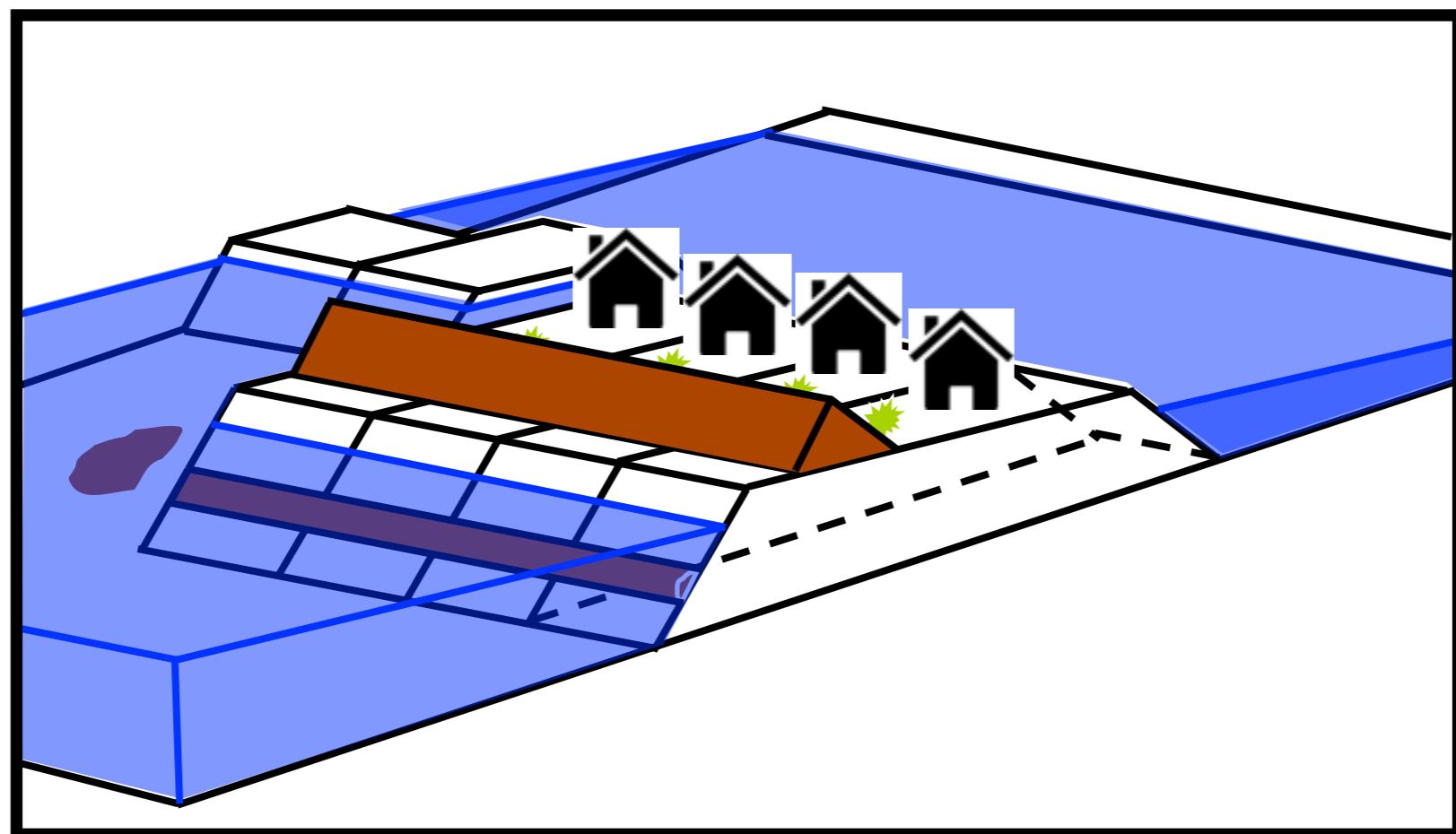
## Market Dynamics



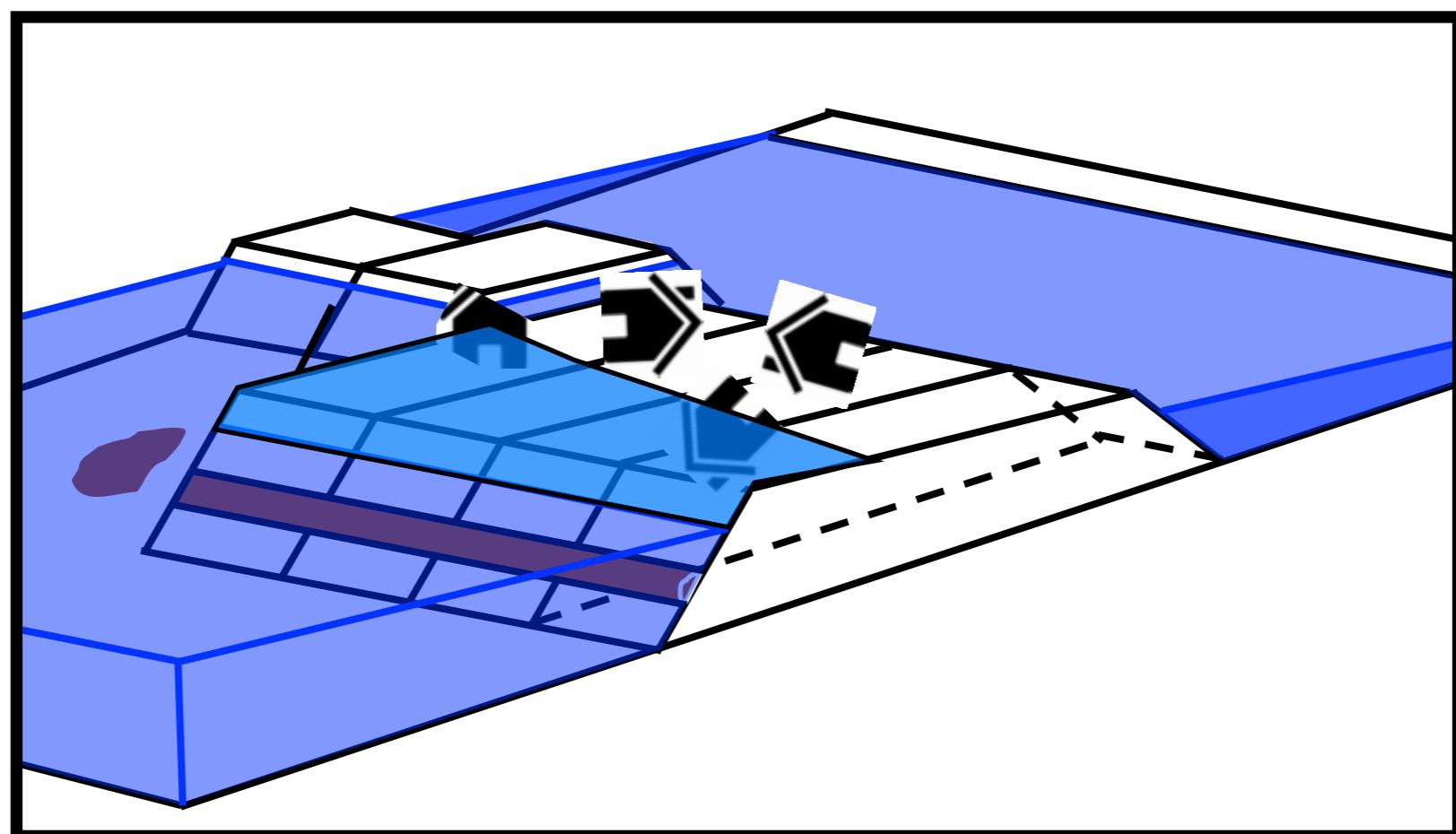
$$E_i[j(t)] = \alpha_i M[j(t)] + (1 - \alpha_i) O_i[j(t)]$$

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

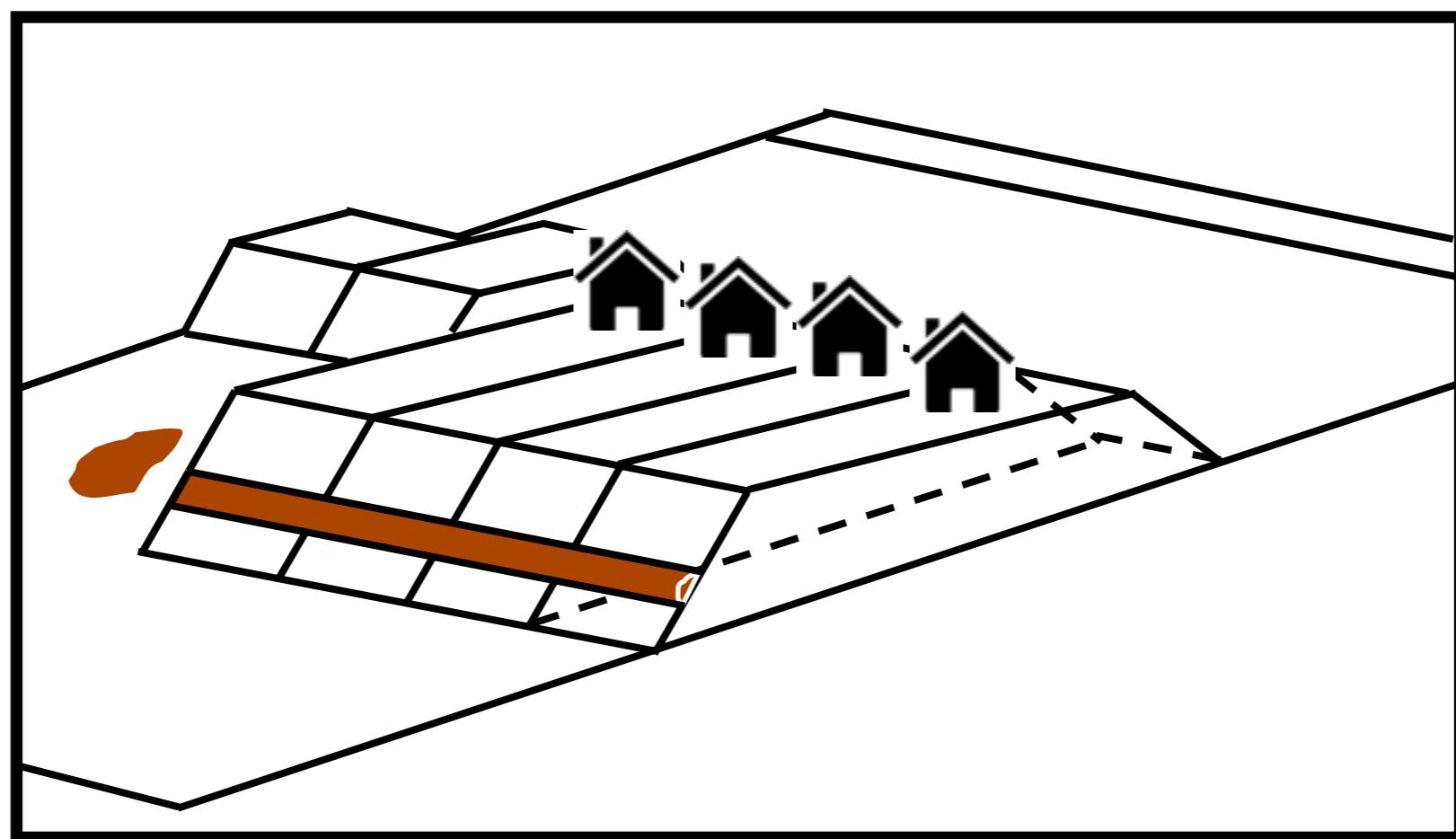
Damage



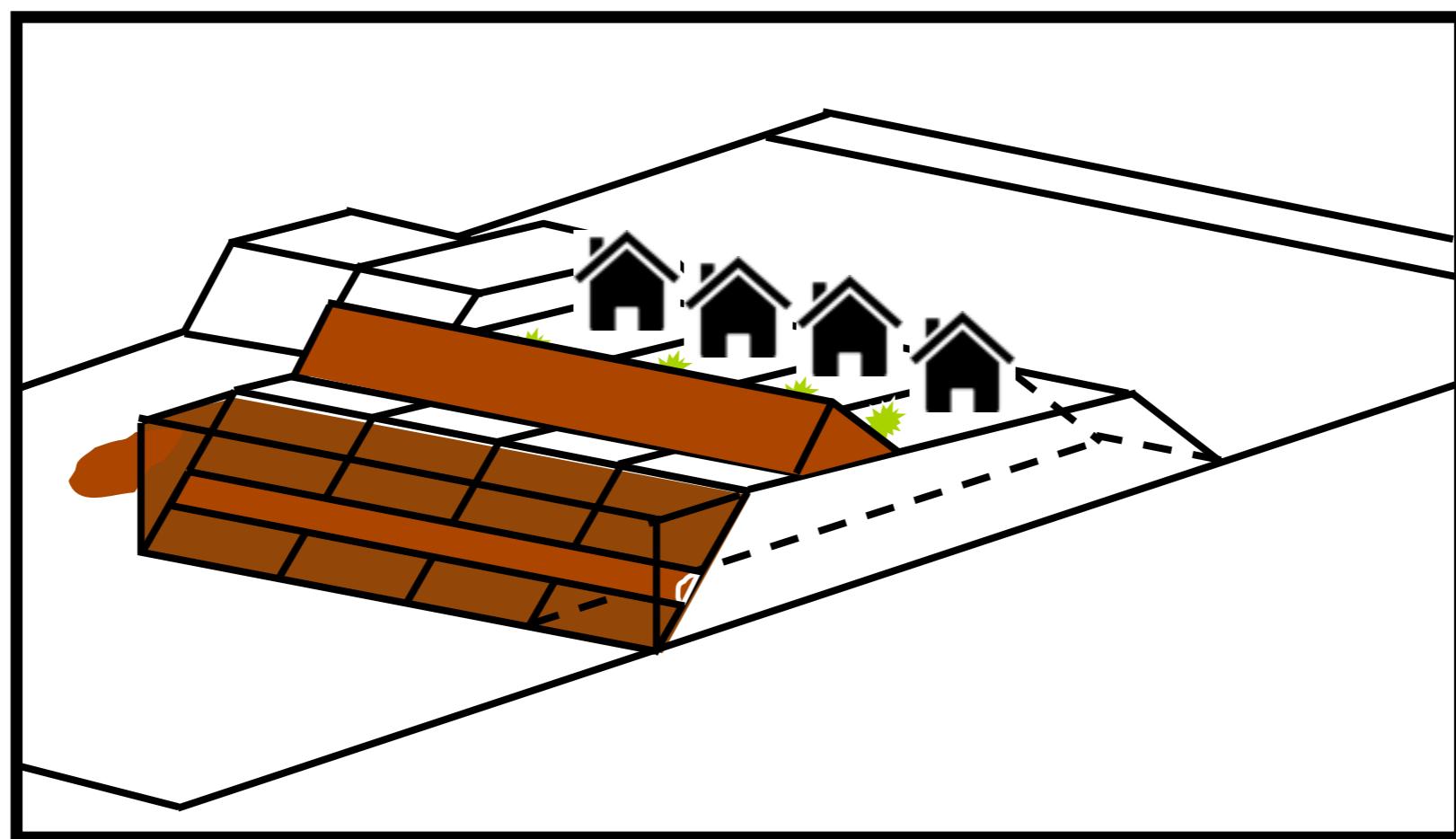
Damage



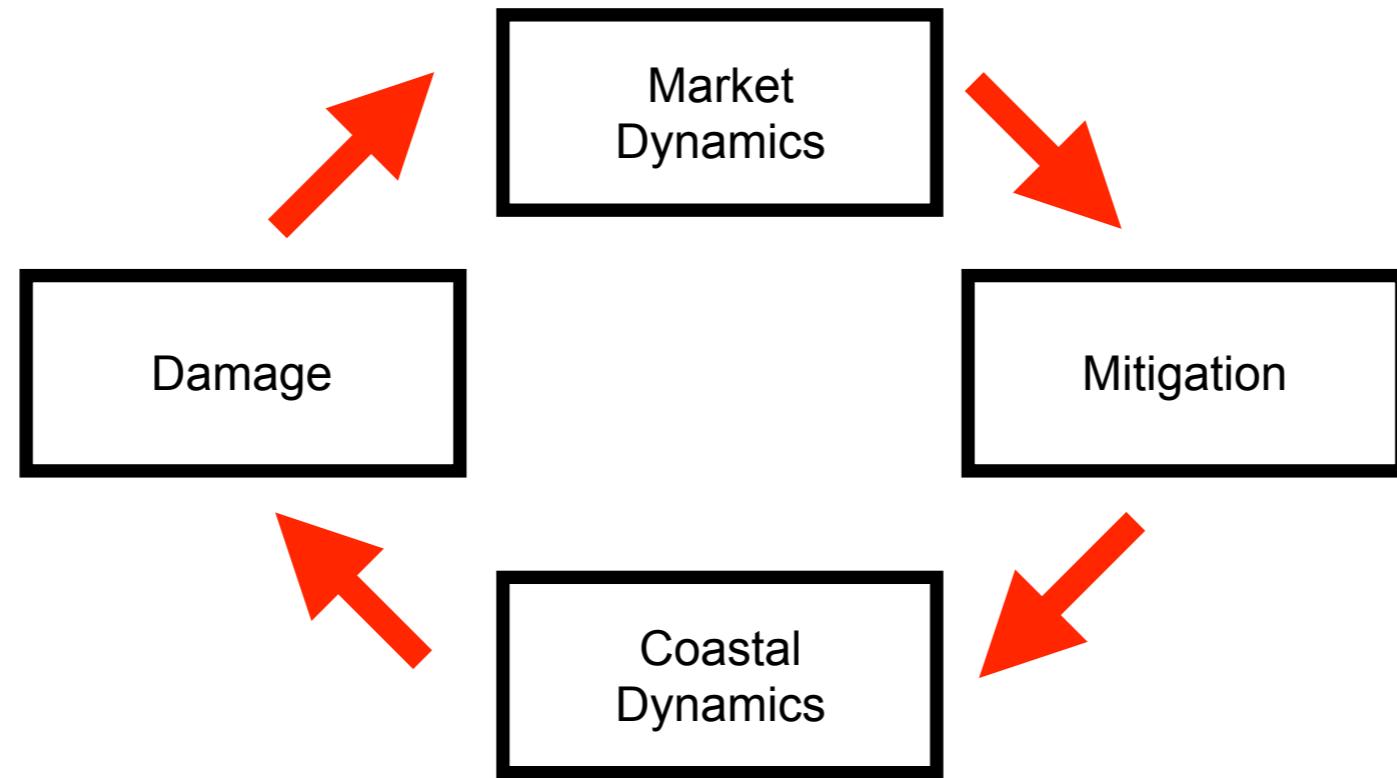
# Mitigation



# Mitigation

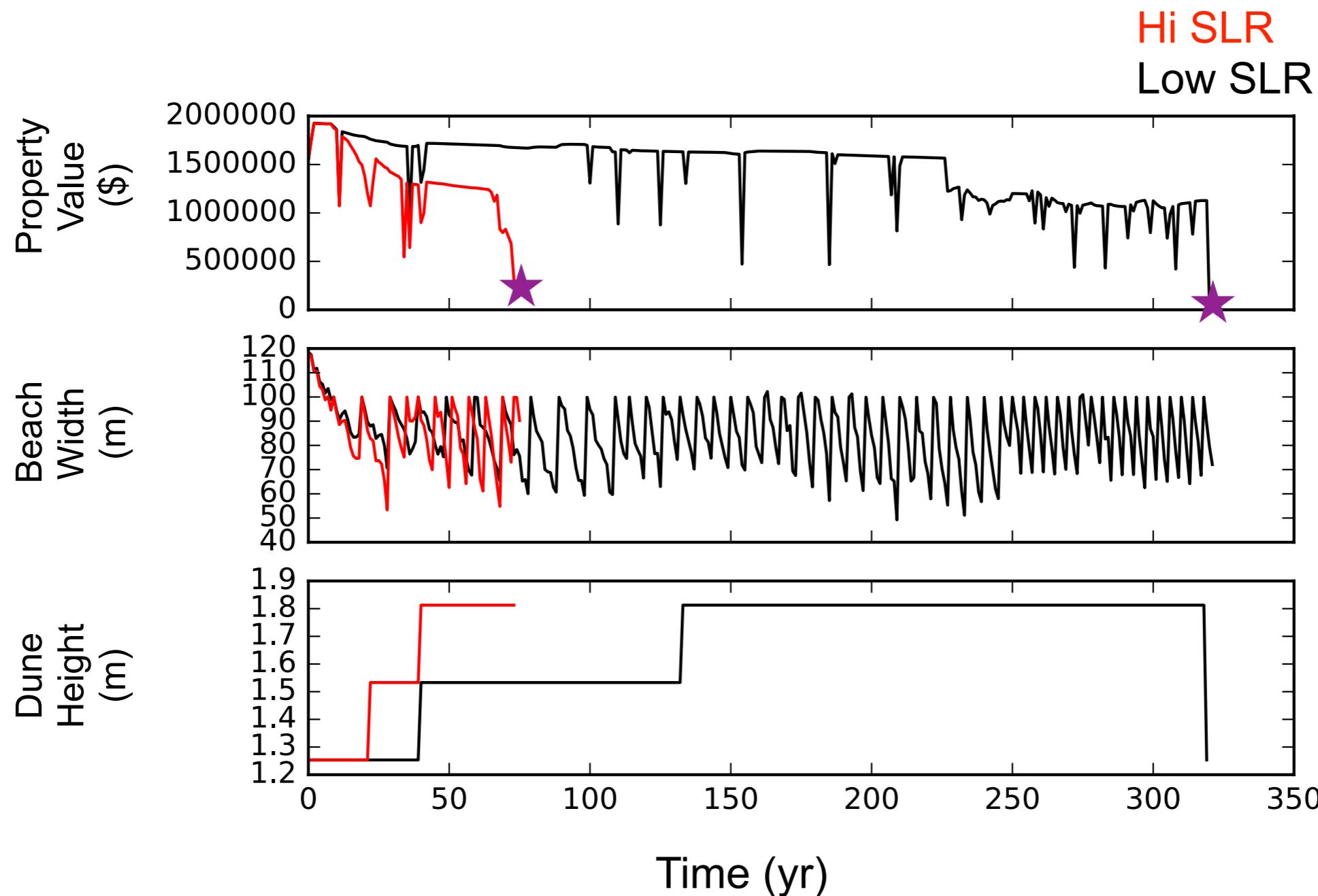


# Model

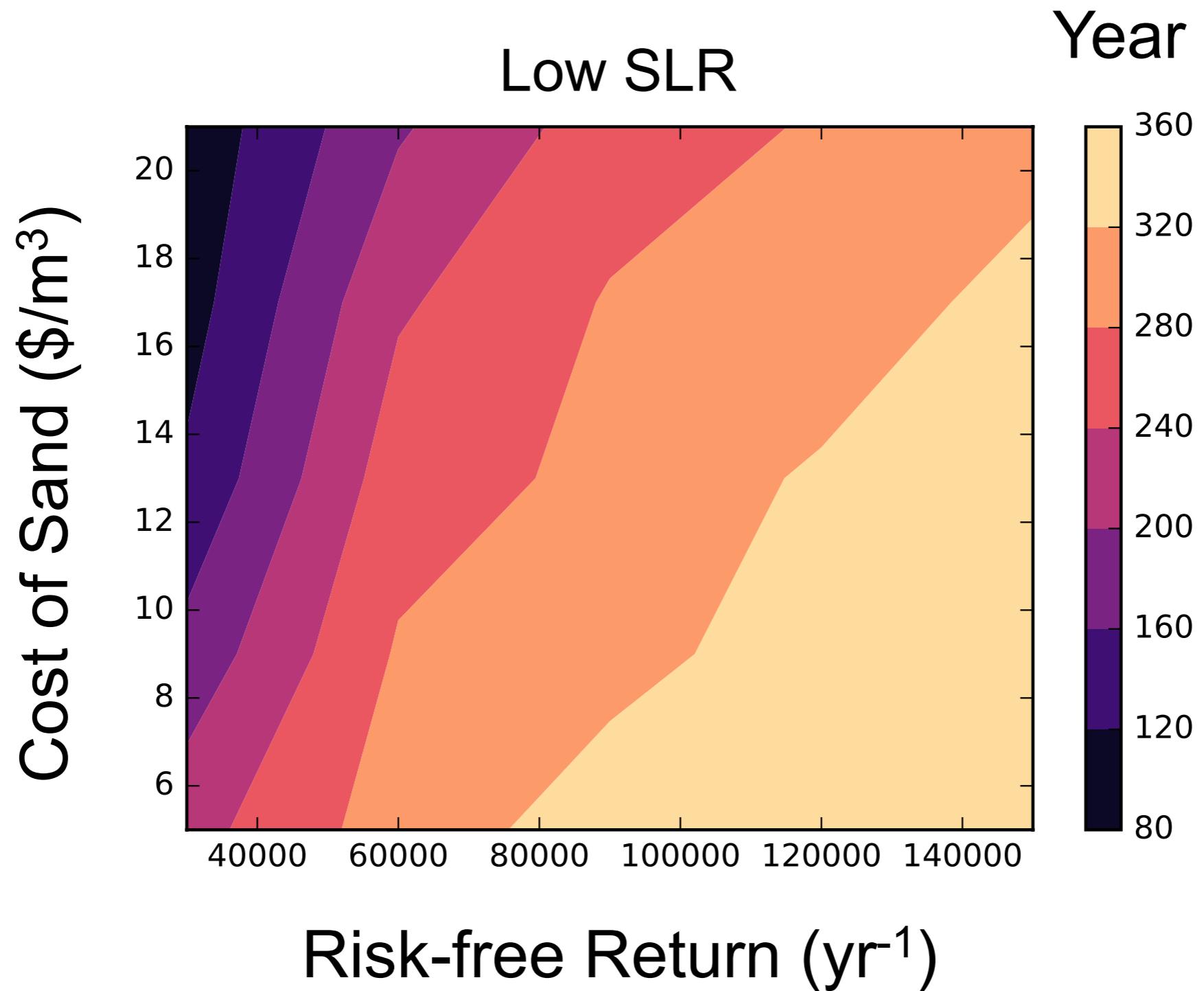


- Does the model reproduce current attractor?
- Does this attractor go away with SLR?
- How does change depend on natural, economic, social, factors?

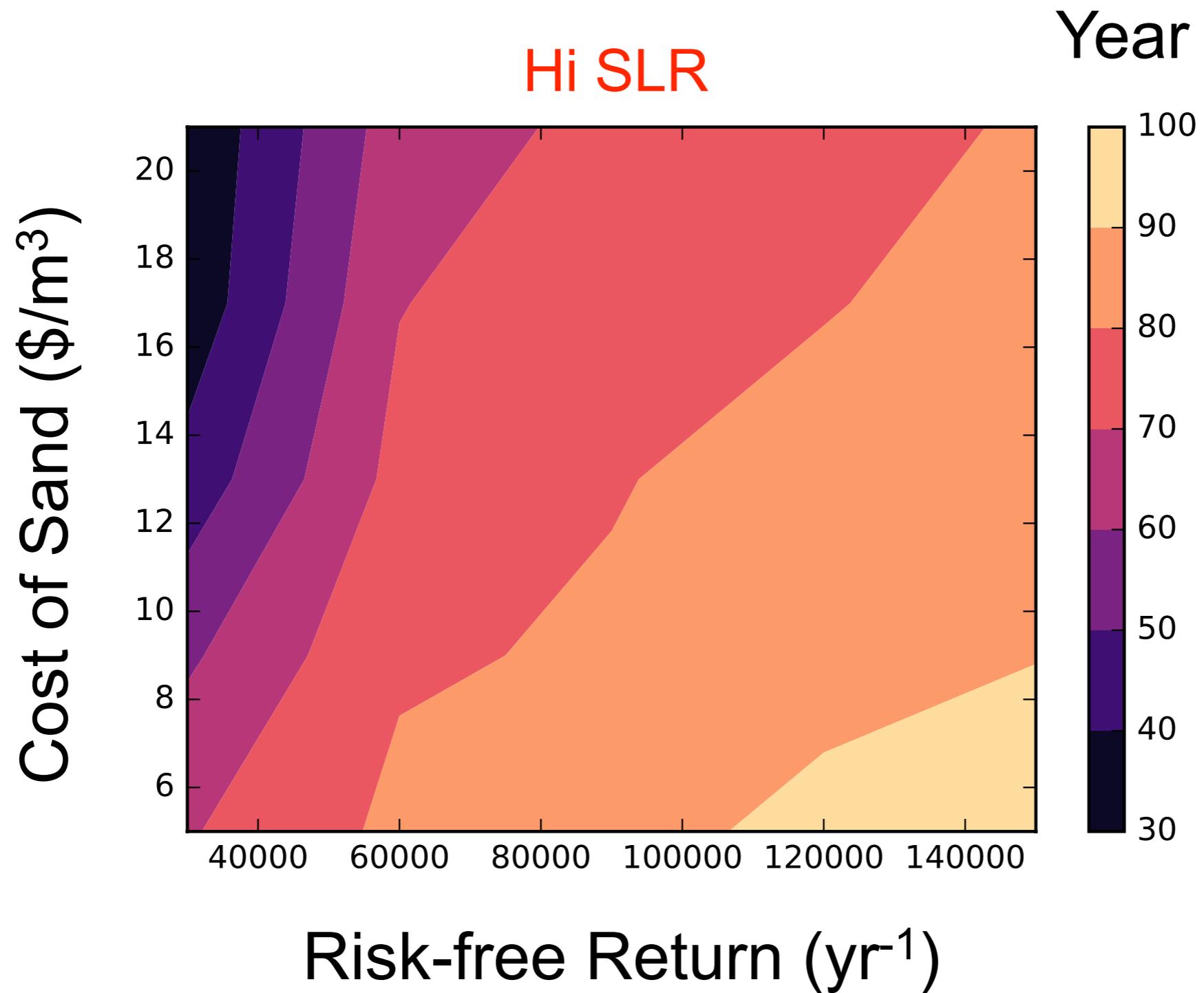
# Results



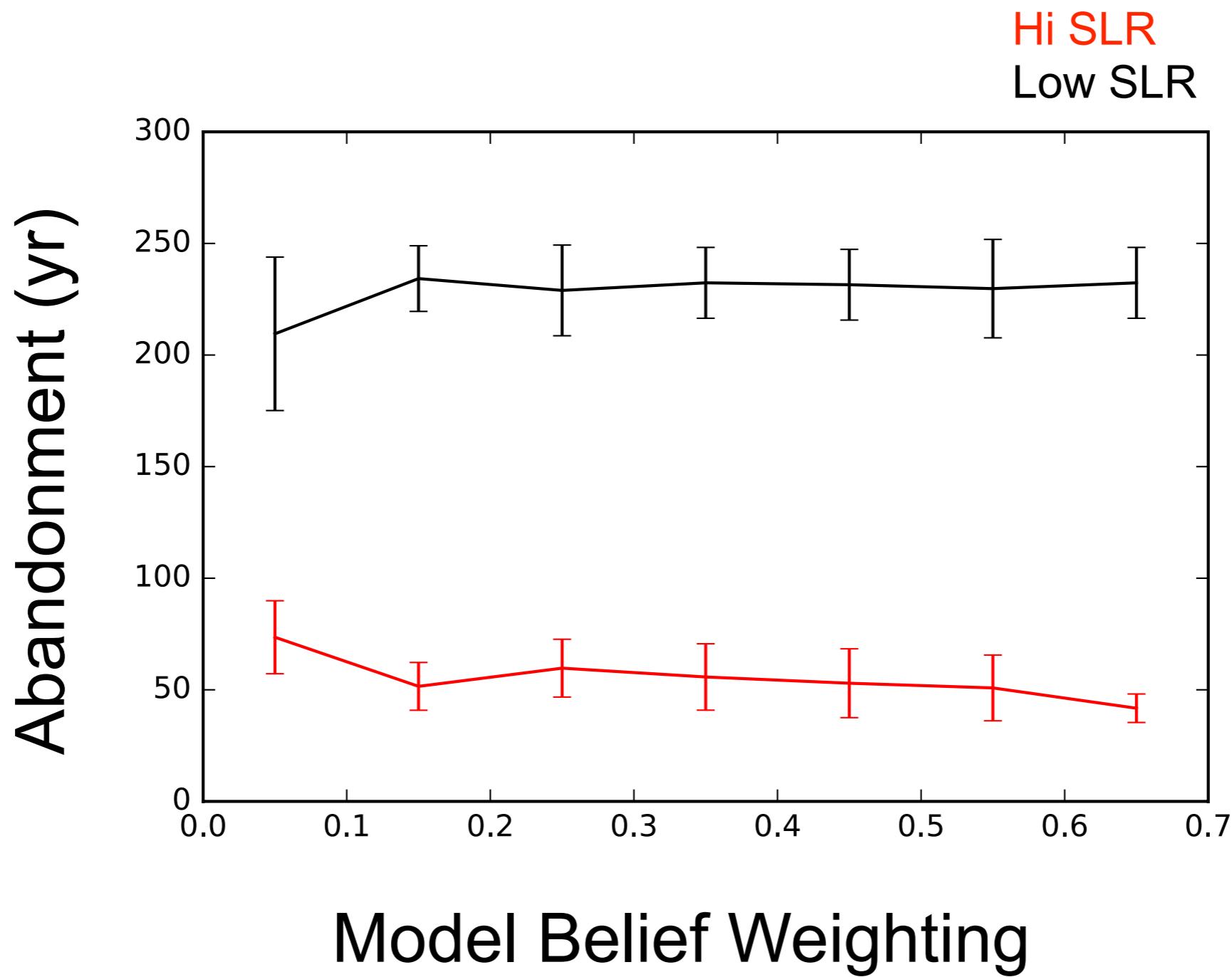
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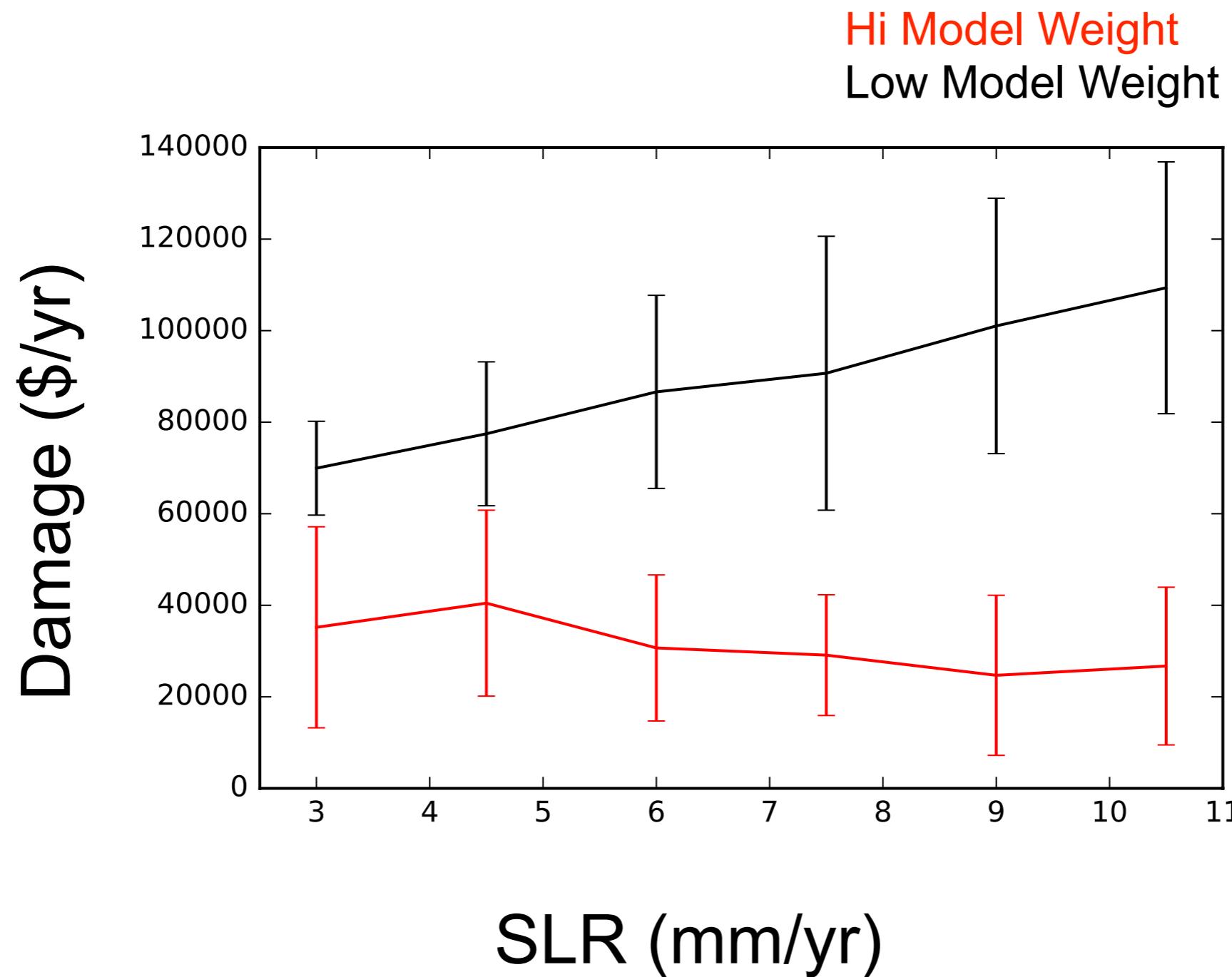
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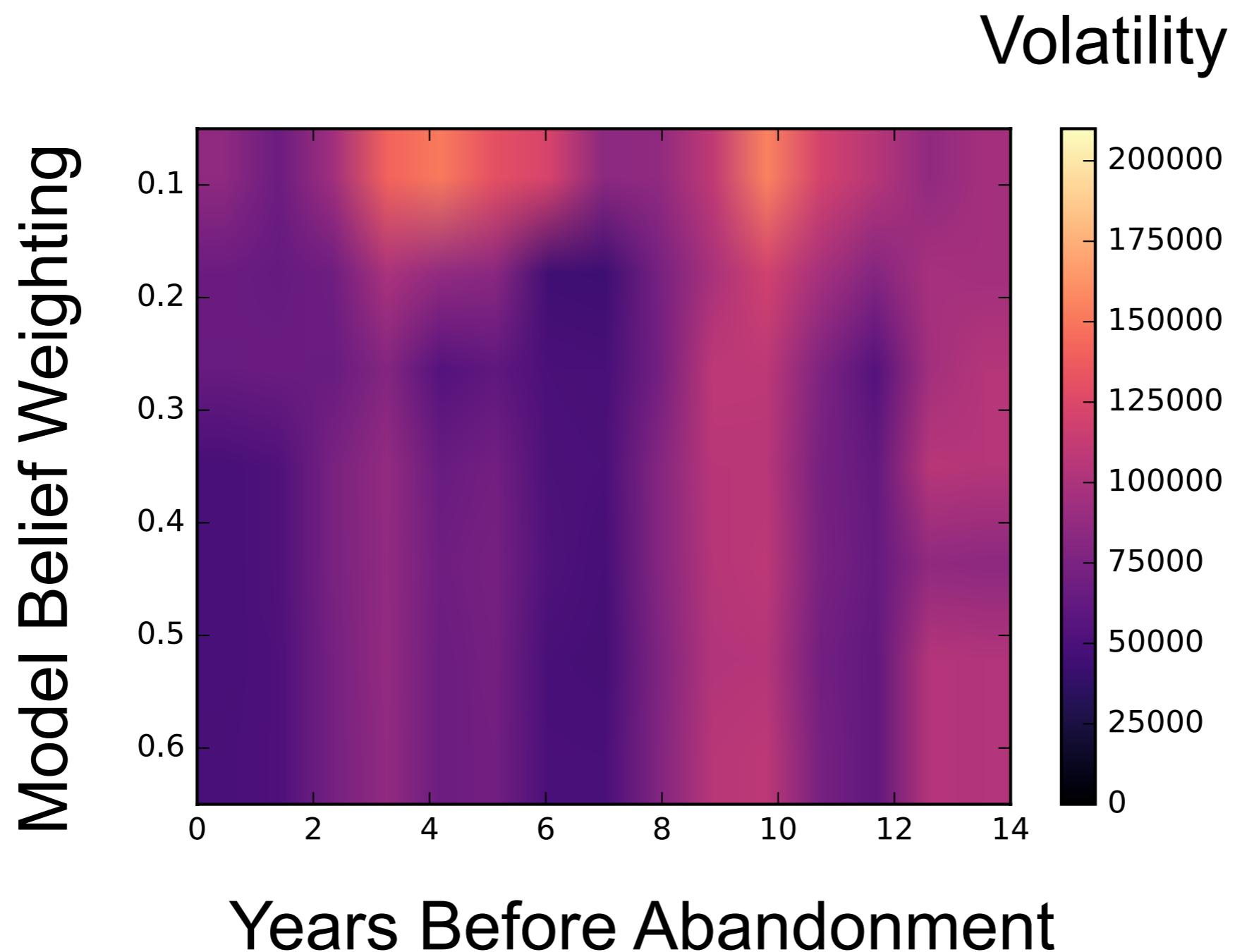
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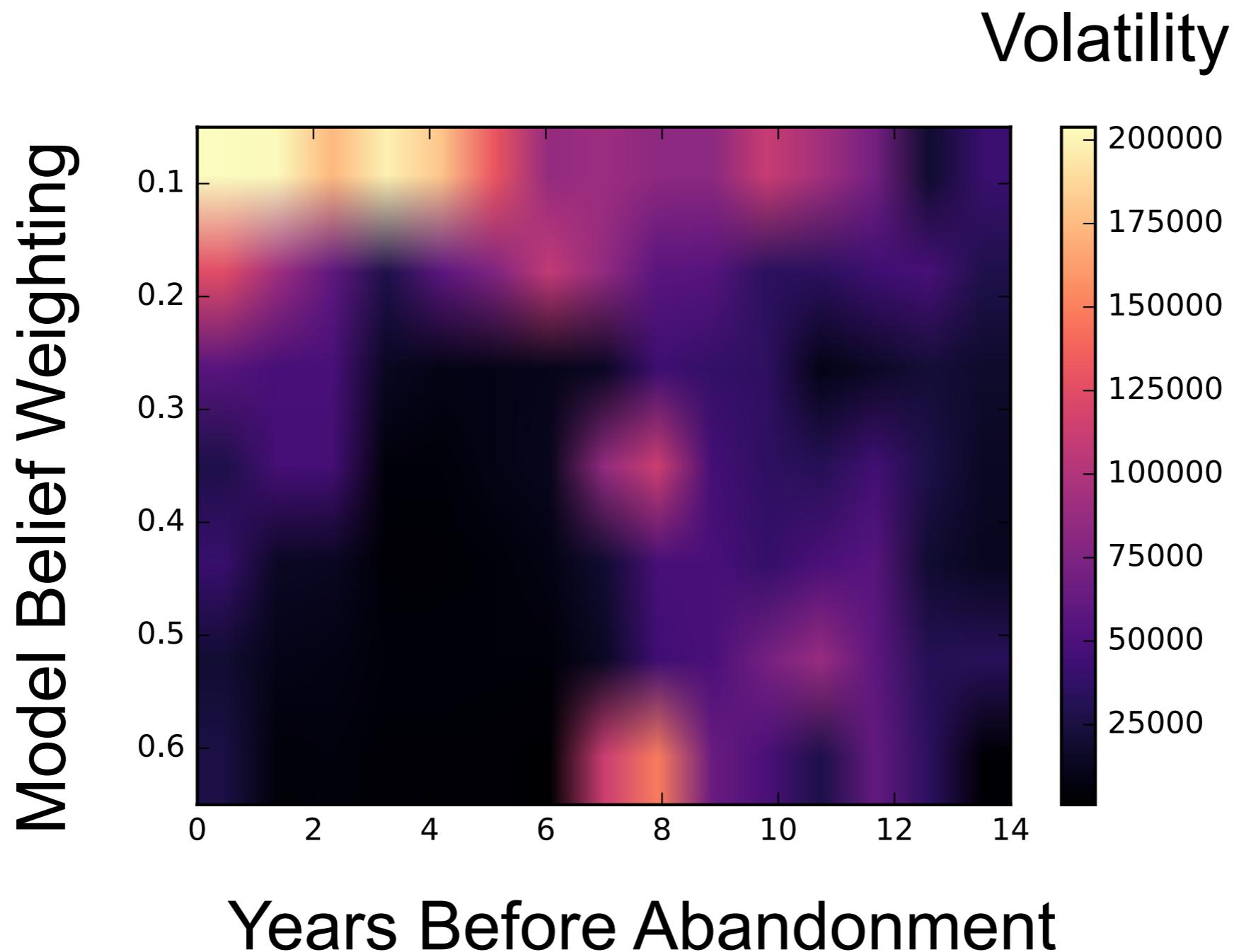
# Results



# 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