
1.9m
1.2m
2m of SLR in 100 years
(Deconto and Pollard, 2016)
1.8m

60-120 years later?

The Dynamics of Coastal Adaptation to Sea Level Rise

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Outline

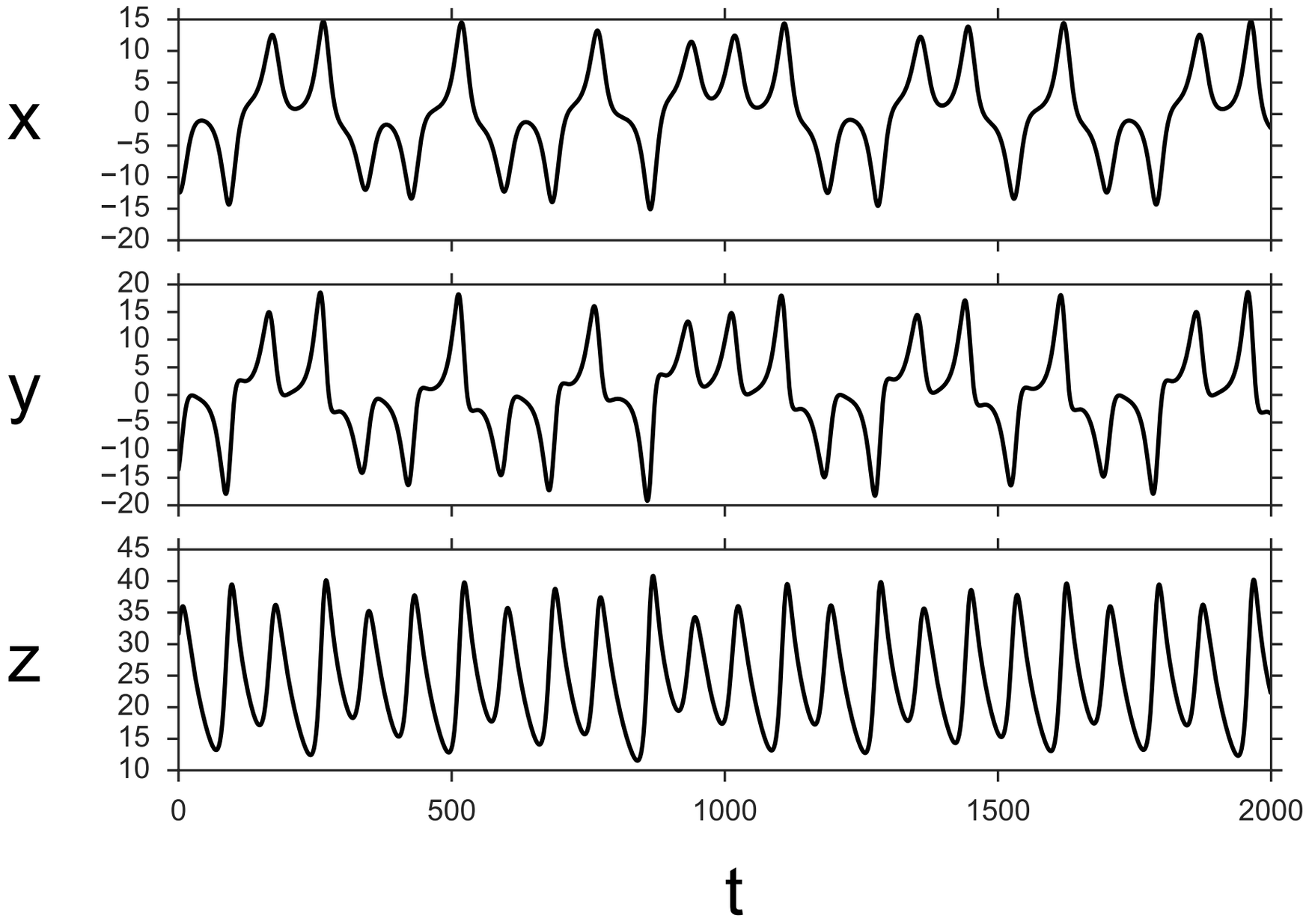
- Nonlinear Forecasting as a Tool
- Beach Nourishment
- Environmental Econophysics
- Model
- Results
- Implications

Nonlinear Forecasting

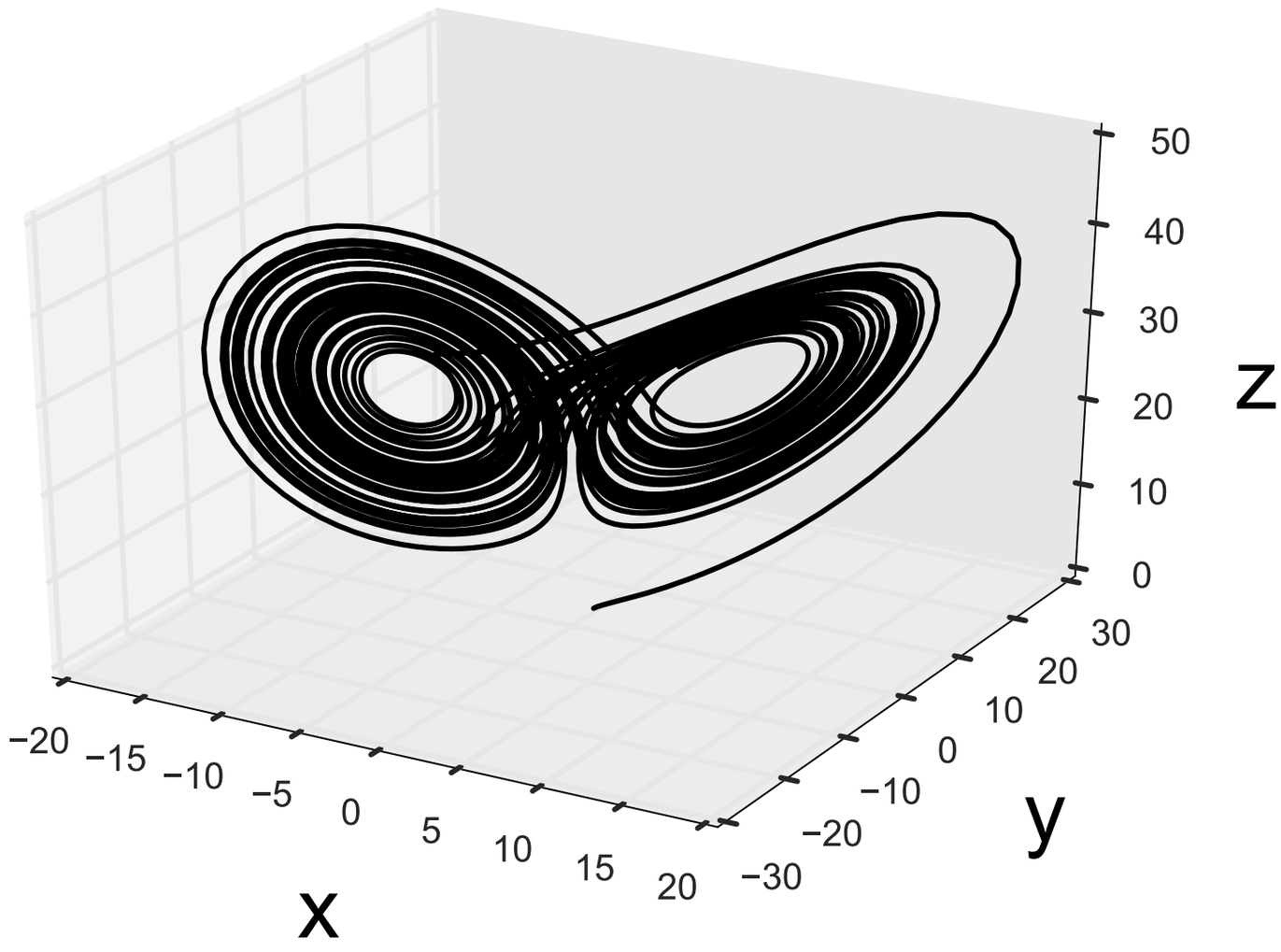
Lorenz System

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

Nonlinear Forecasting



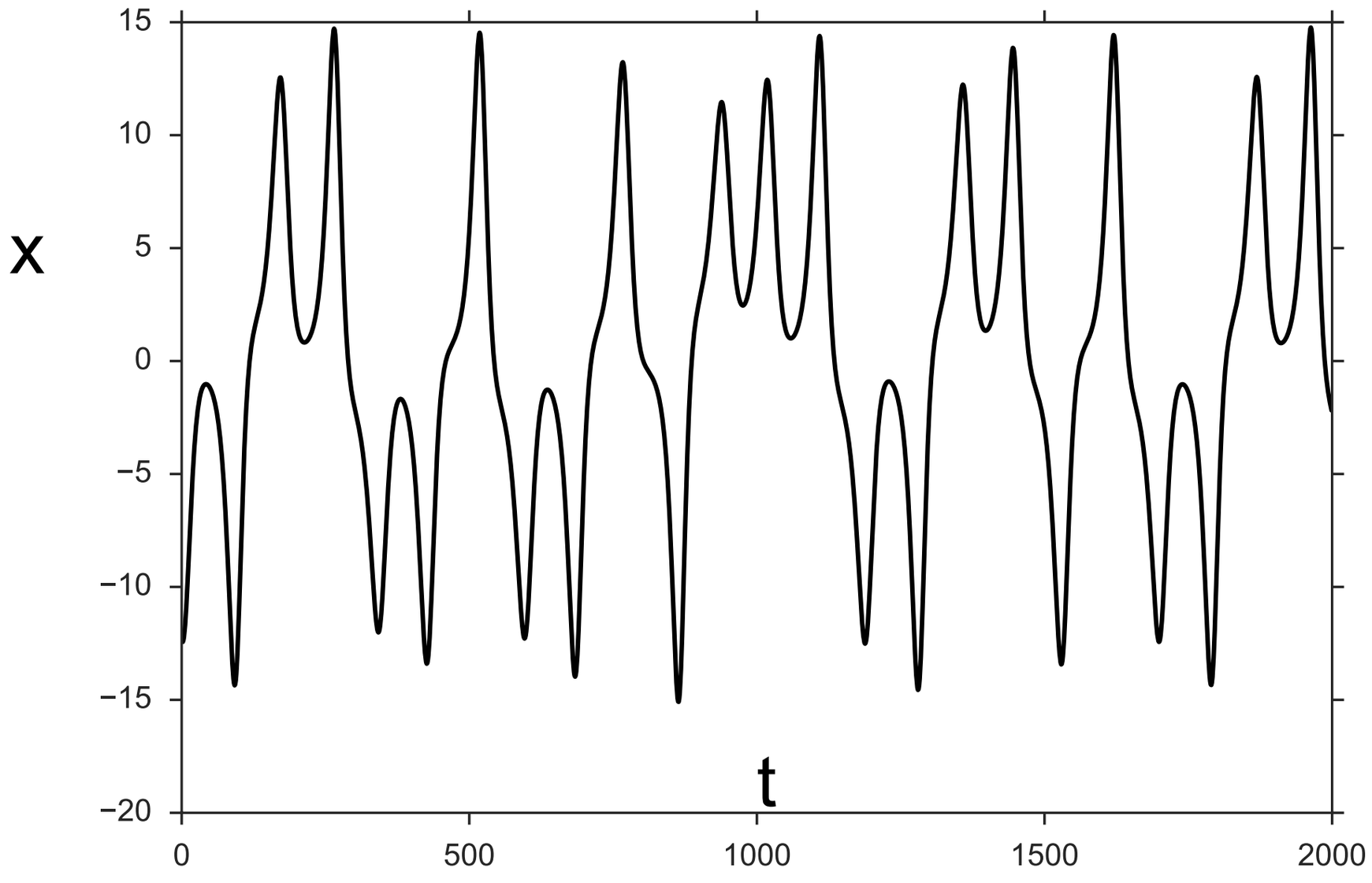
Nonlinear Forecasting



Nonlinear Forecasting

imagine you only measured x(t)

can one verify x(t) is deterministic?



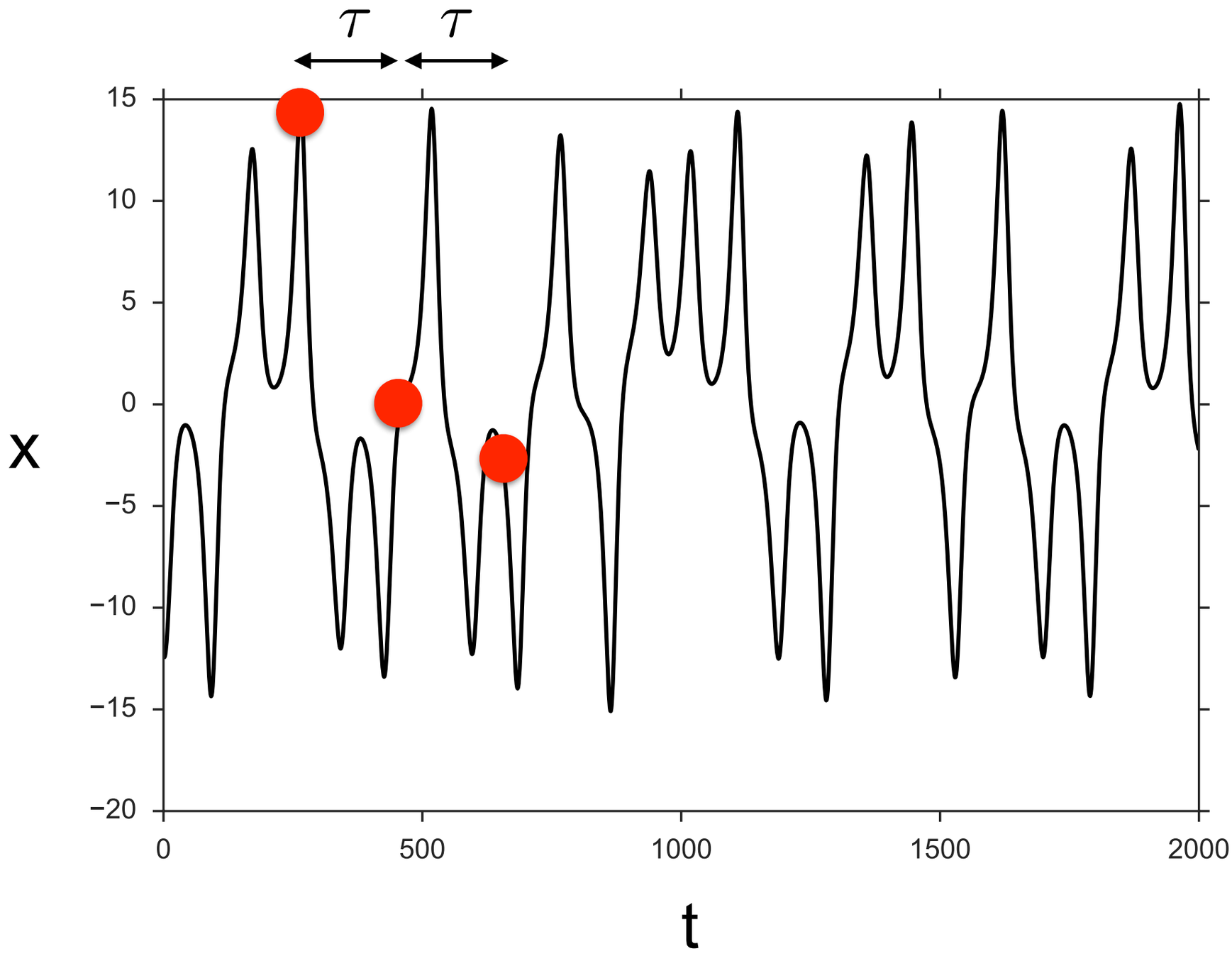
Nonlinear Forecasting

Taken's Theorem:

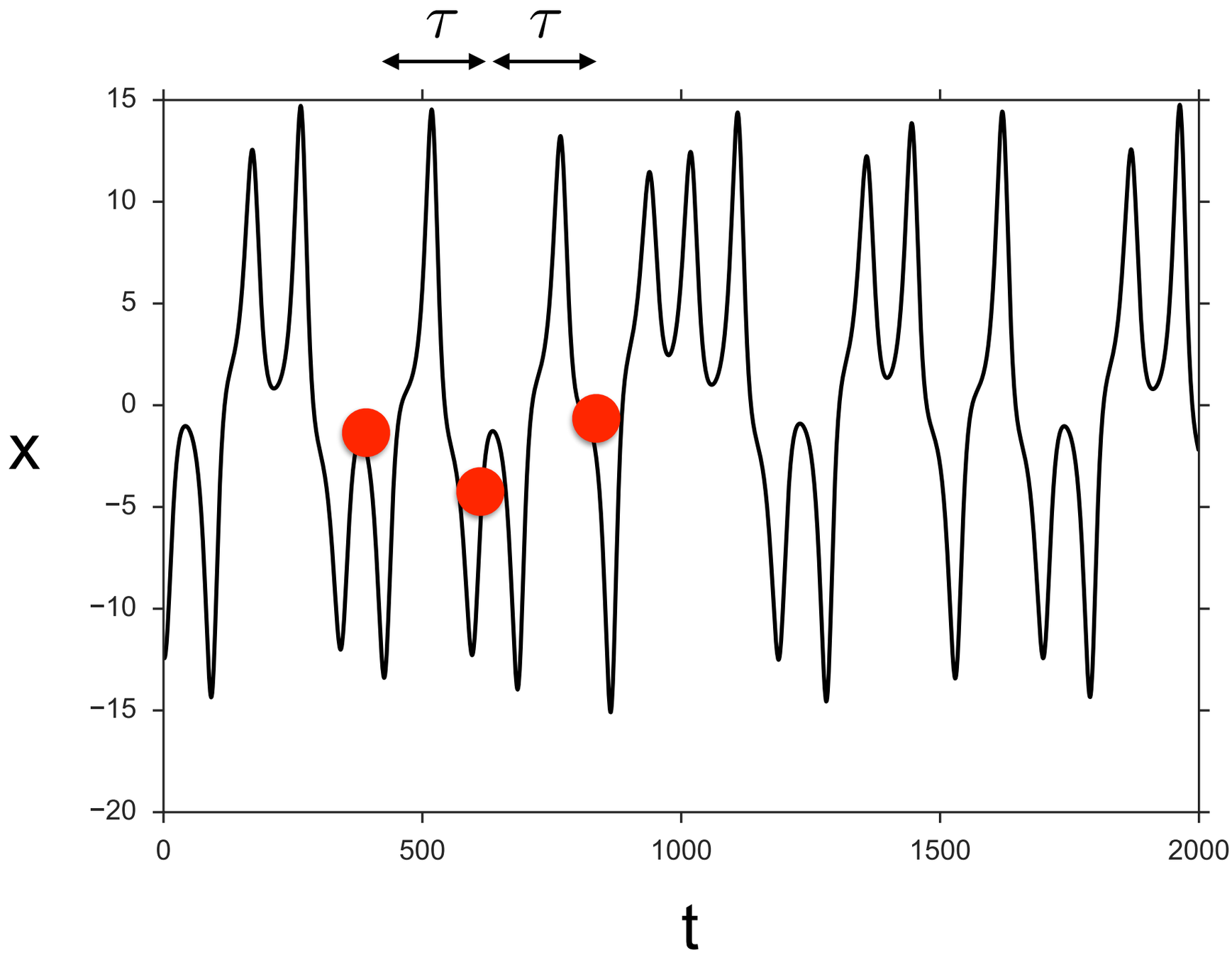
Measurements of a single dynamical variable, can be embedded in *m* dimensional space, revealing the structure and determinism of the full system.

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

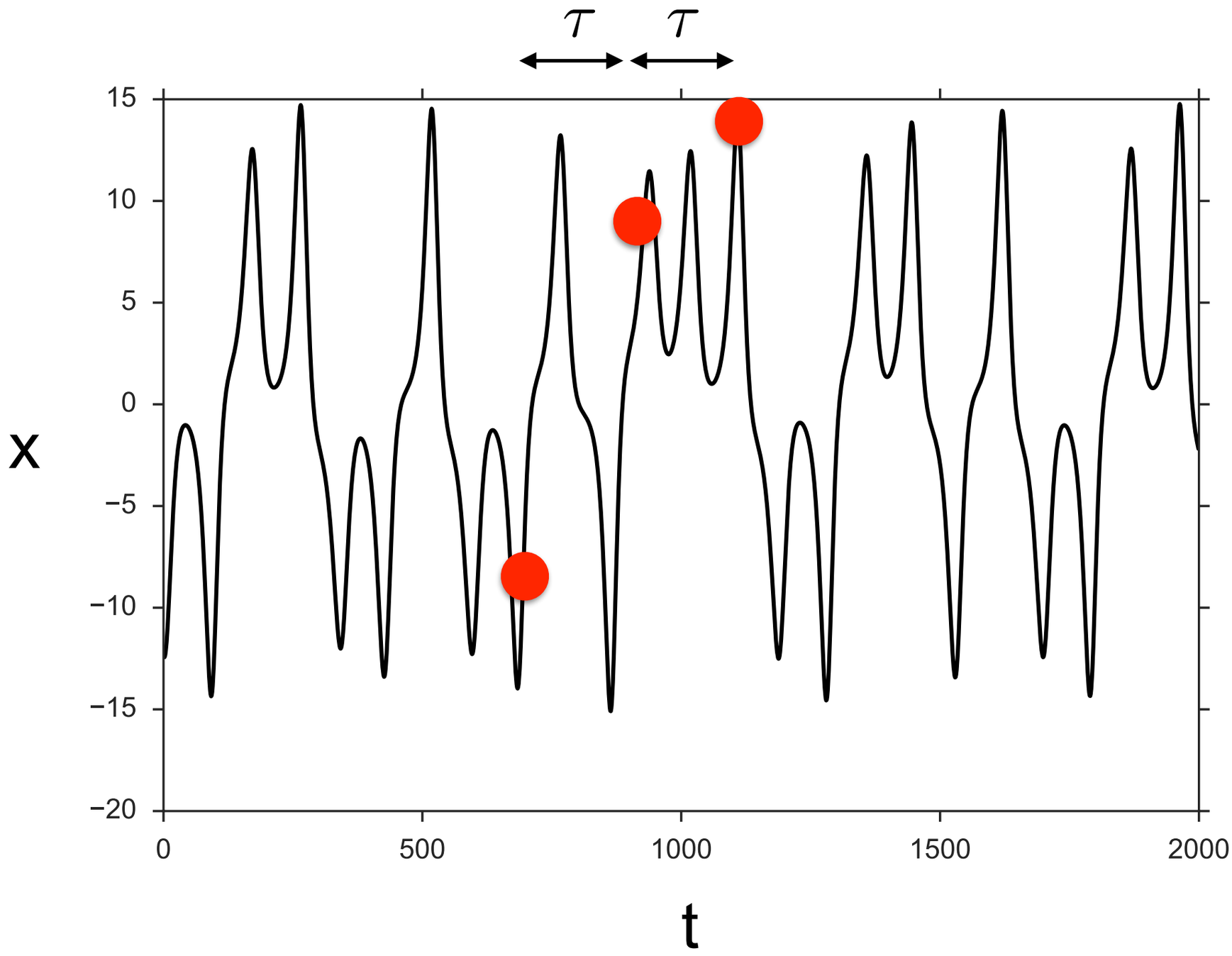
Nonlinear Forecasting



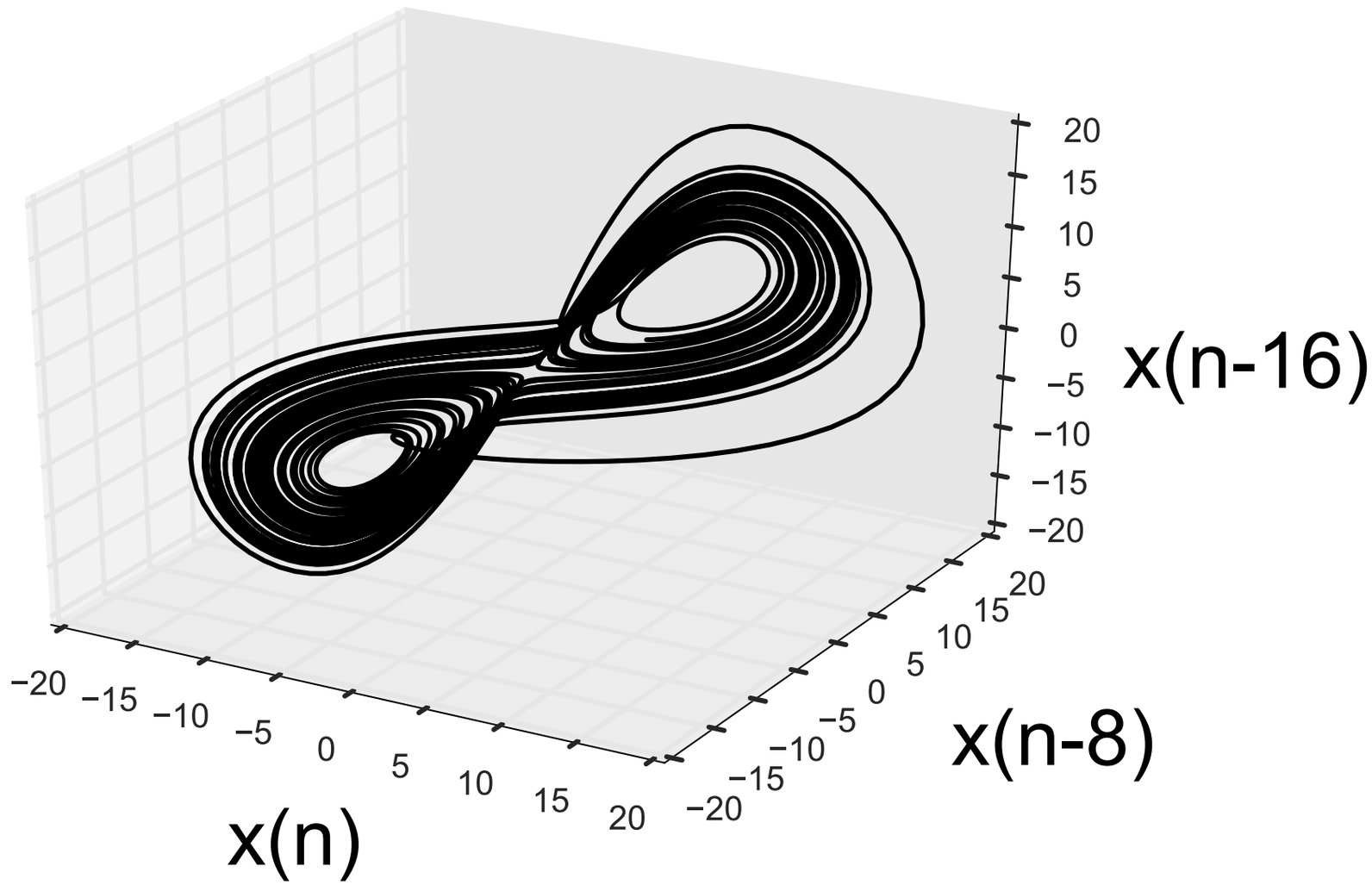
Nonlinear Forecasting



Nonlinear Forecasting

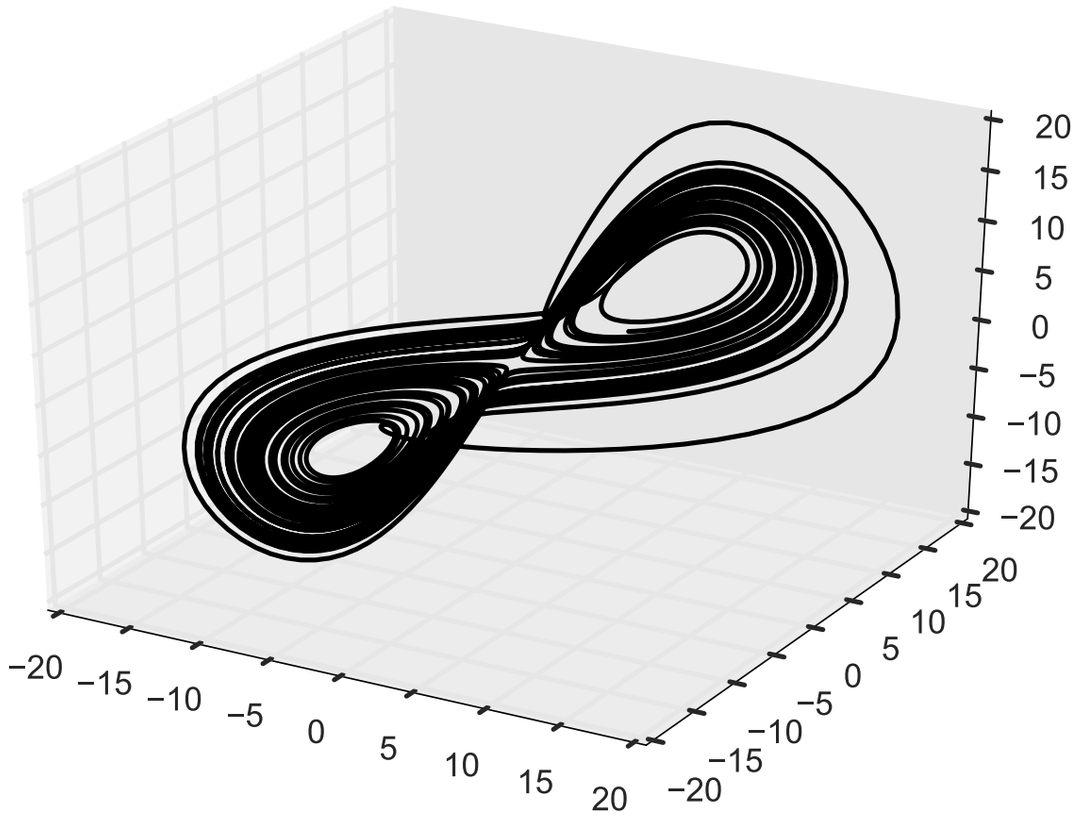


Nonlinear Forecasting

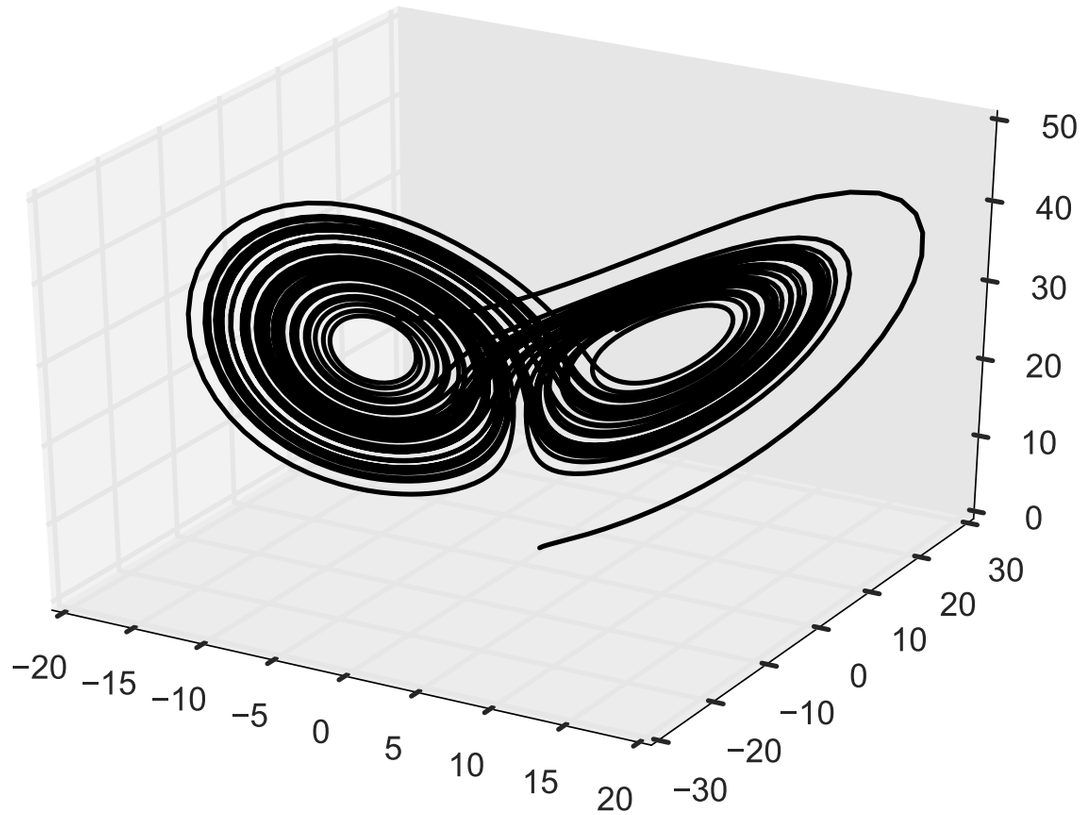


Nonlinear Forecasting

Reconstructed Attractor

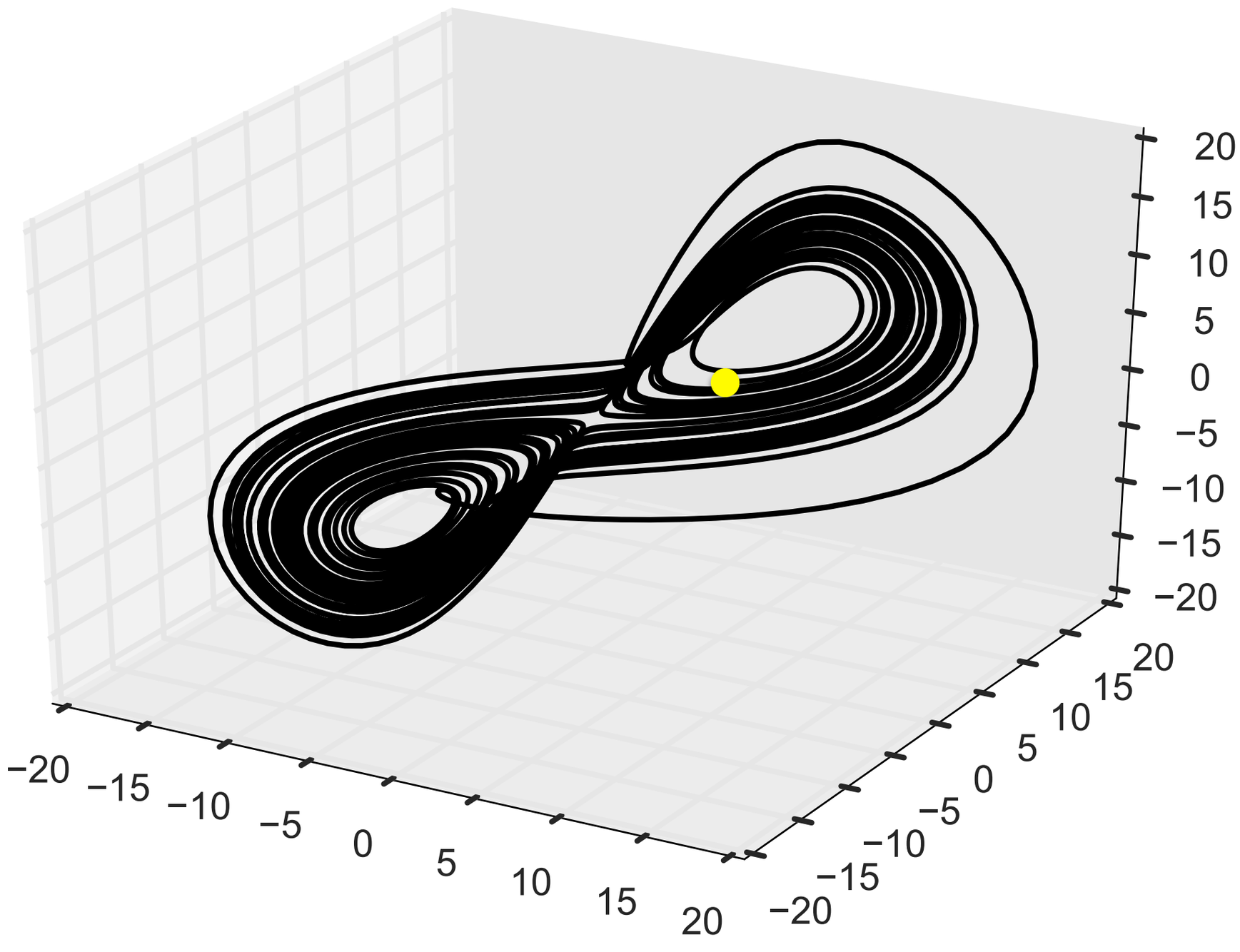


Lorenz Attractor



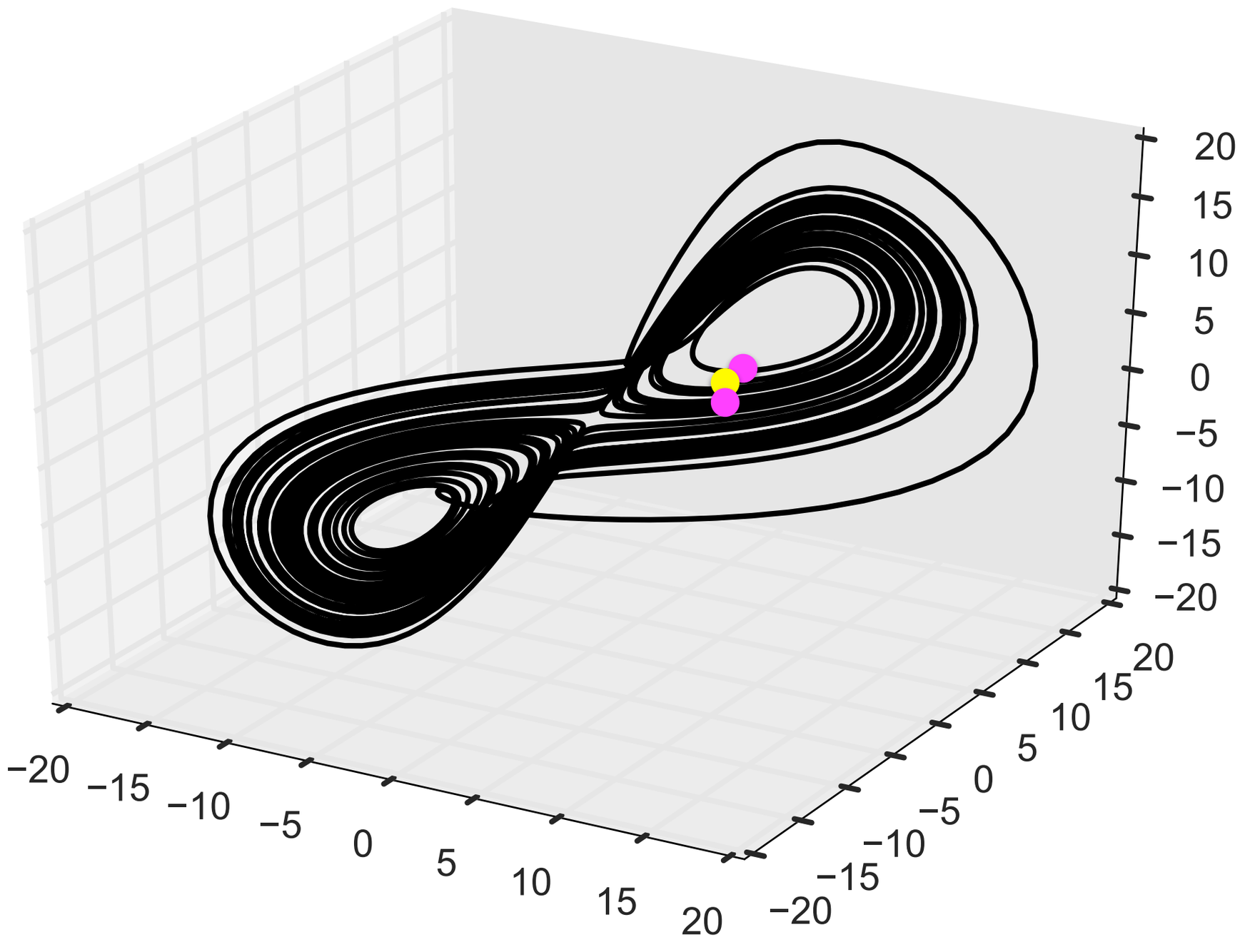
Nonlinear Forecasting

Reconstructed Attractor



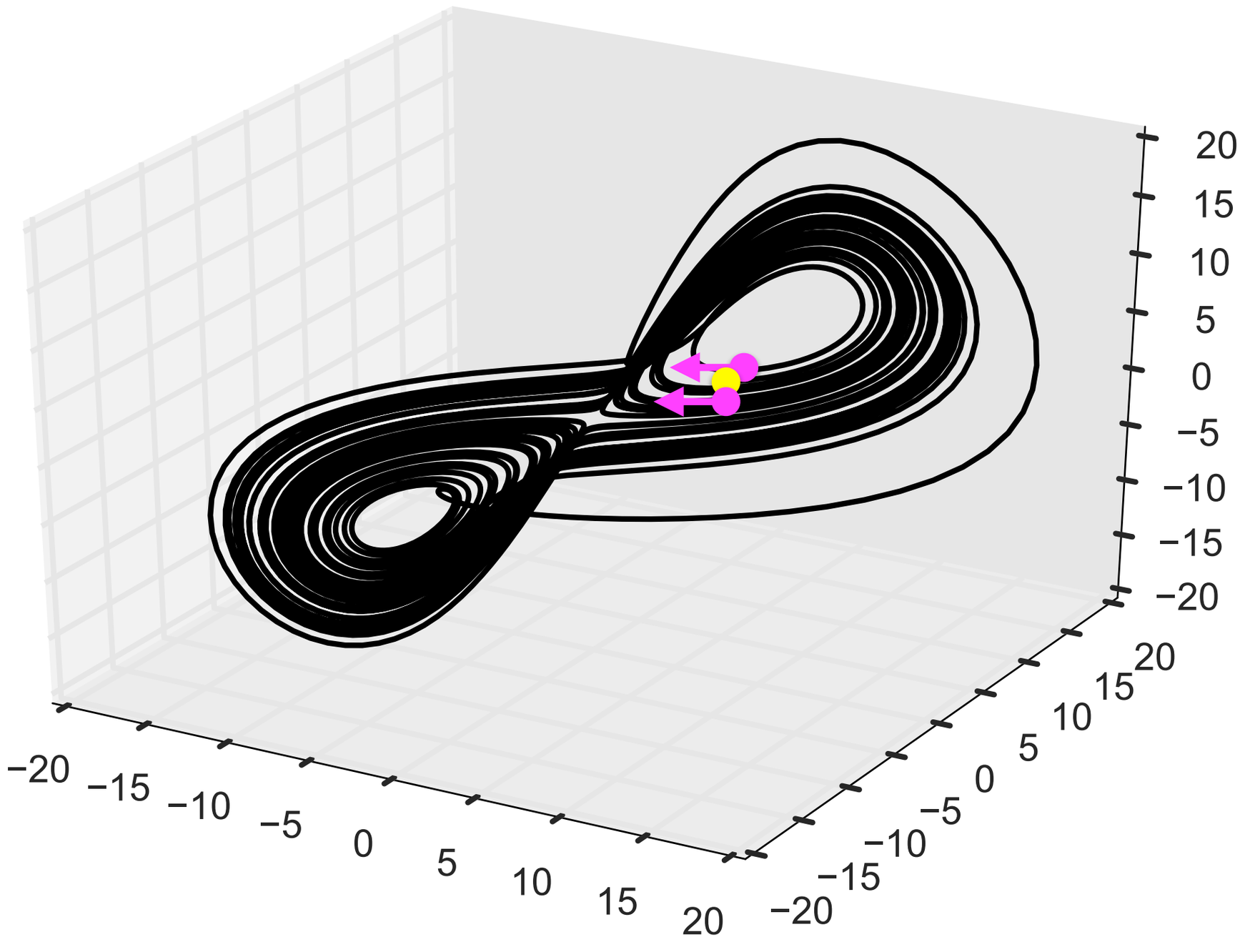
Nonlinear Forecasting

Reconstructed Attractor



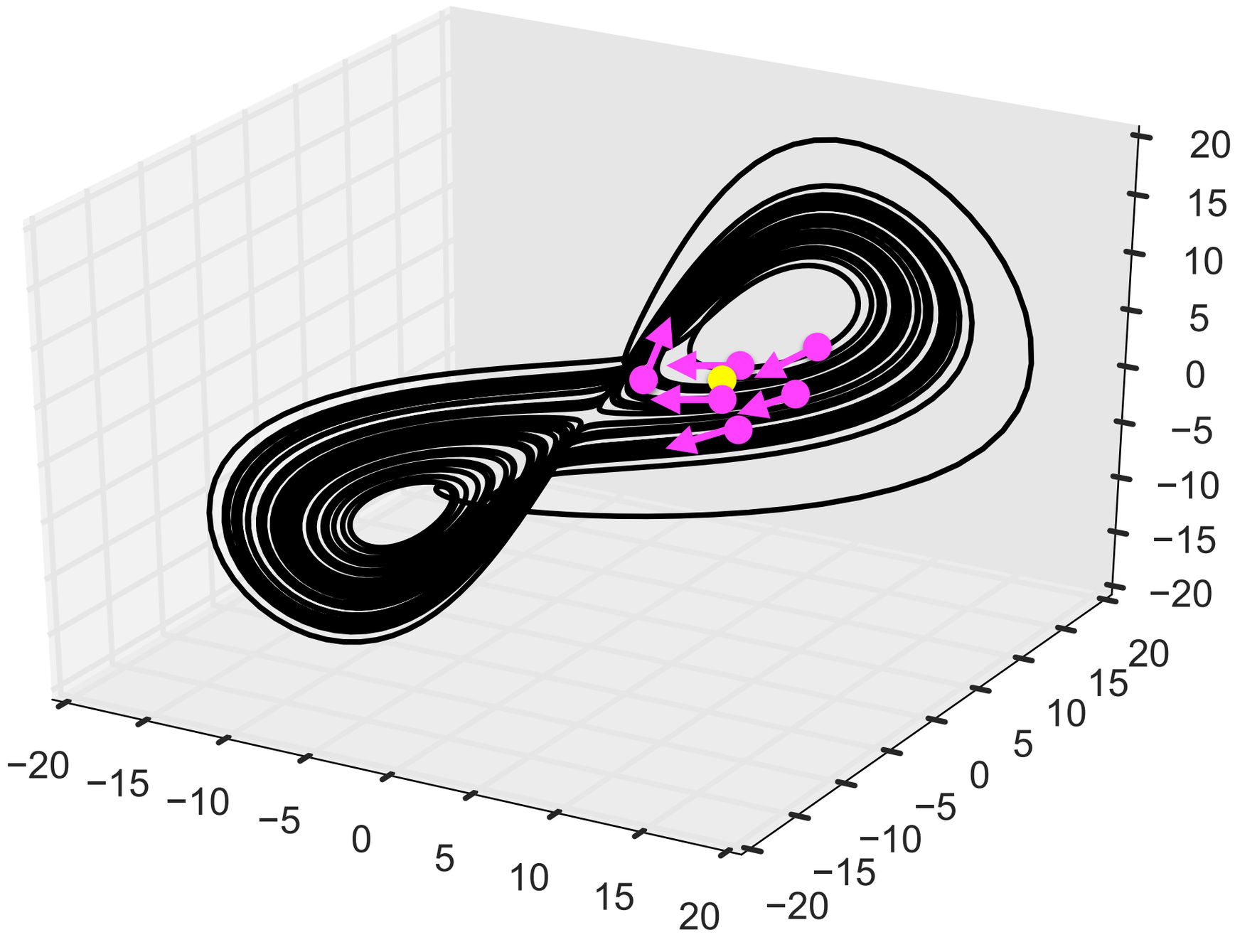
Nonlinear Forecasting

Reconstructed Attractor

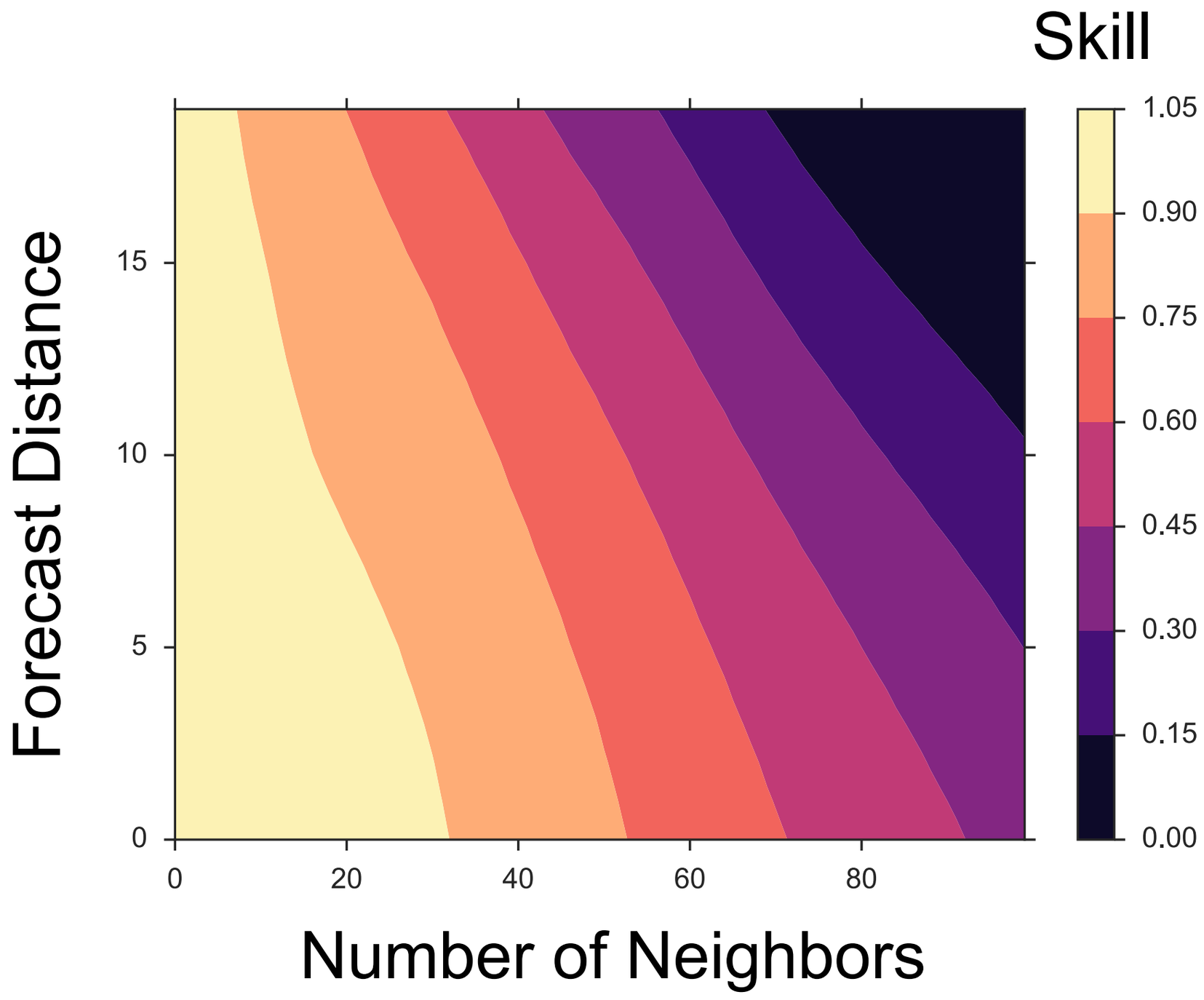


Nonlinear Forecasting

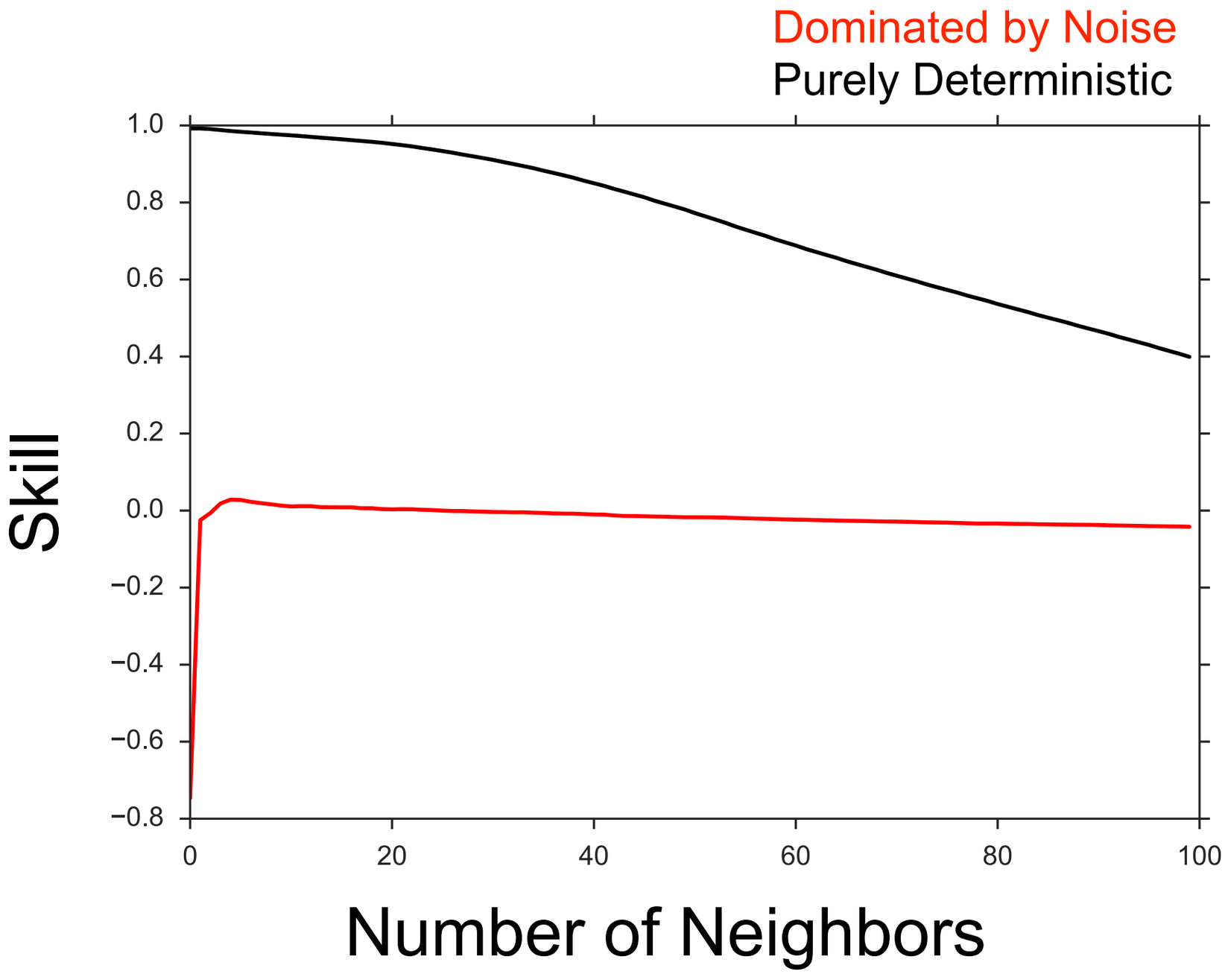
Reconstructed Attractor



Nonlinear Forecasting



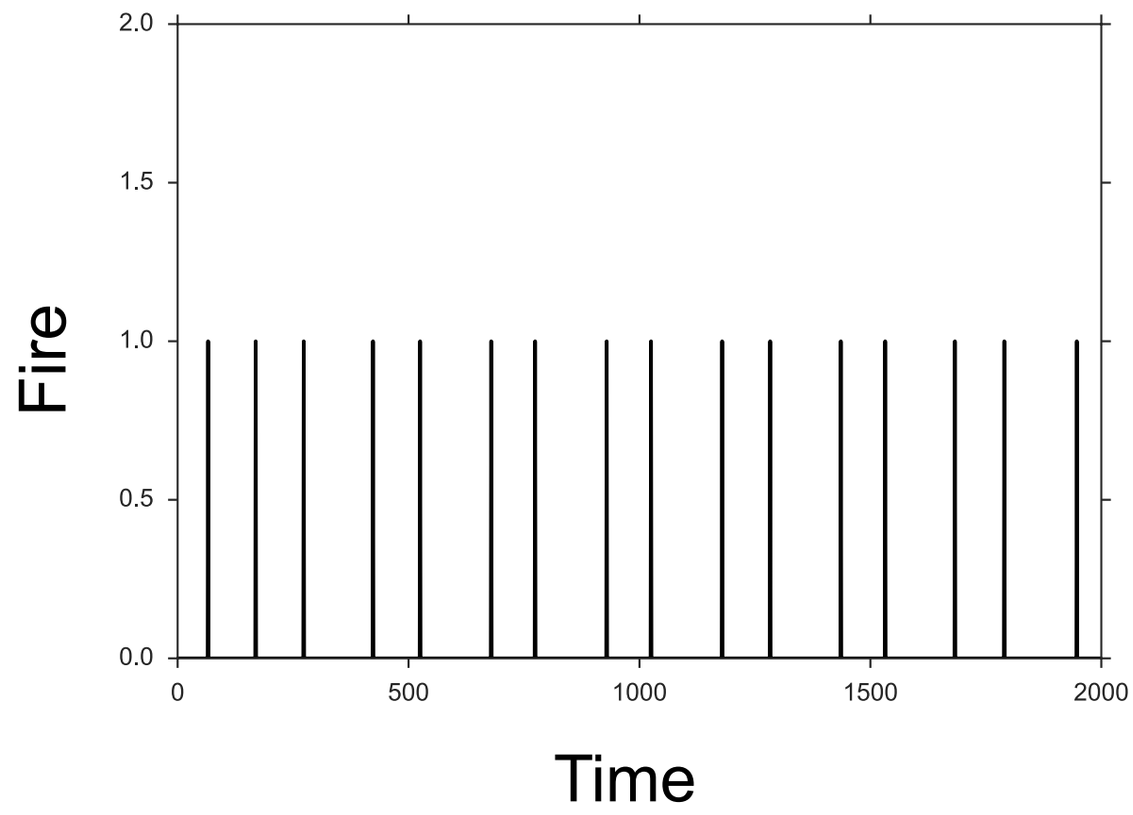
Nonlinear Forecasting



Nonlinear Forecasting

Integrate and Fire

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



Nonlinear Forecasting

Integrate and Fire

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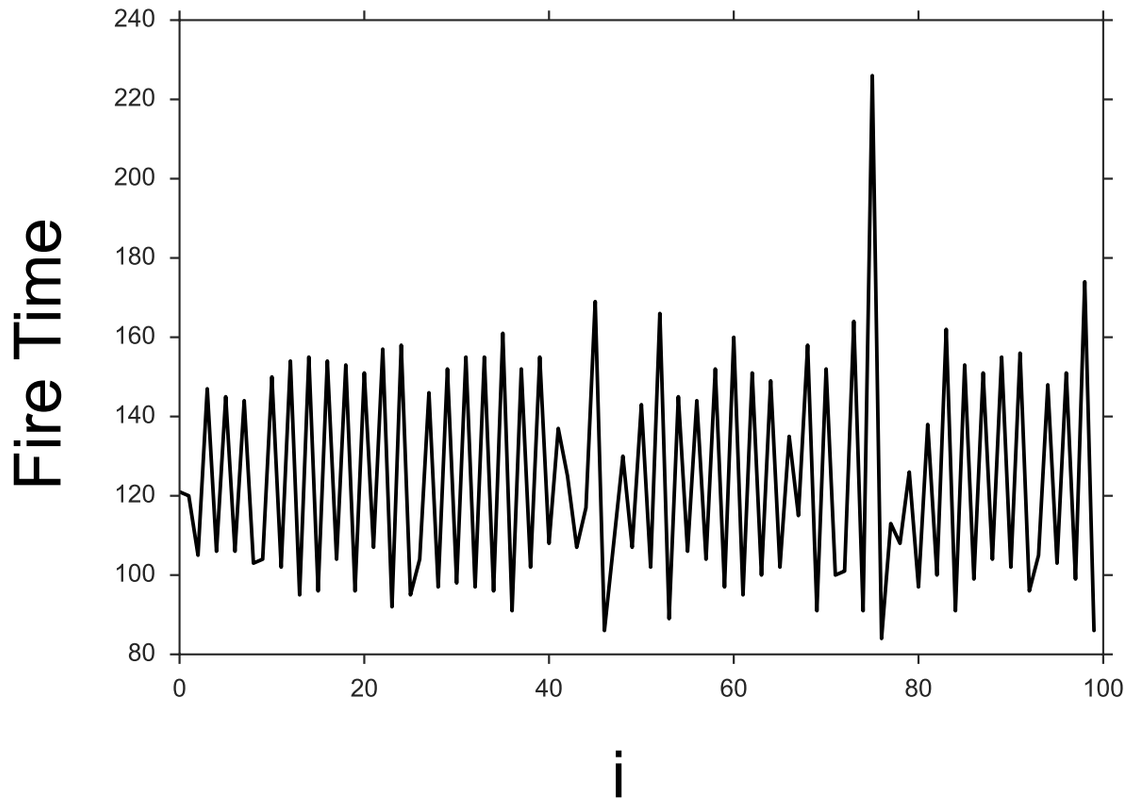
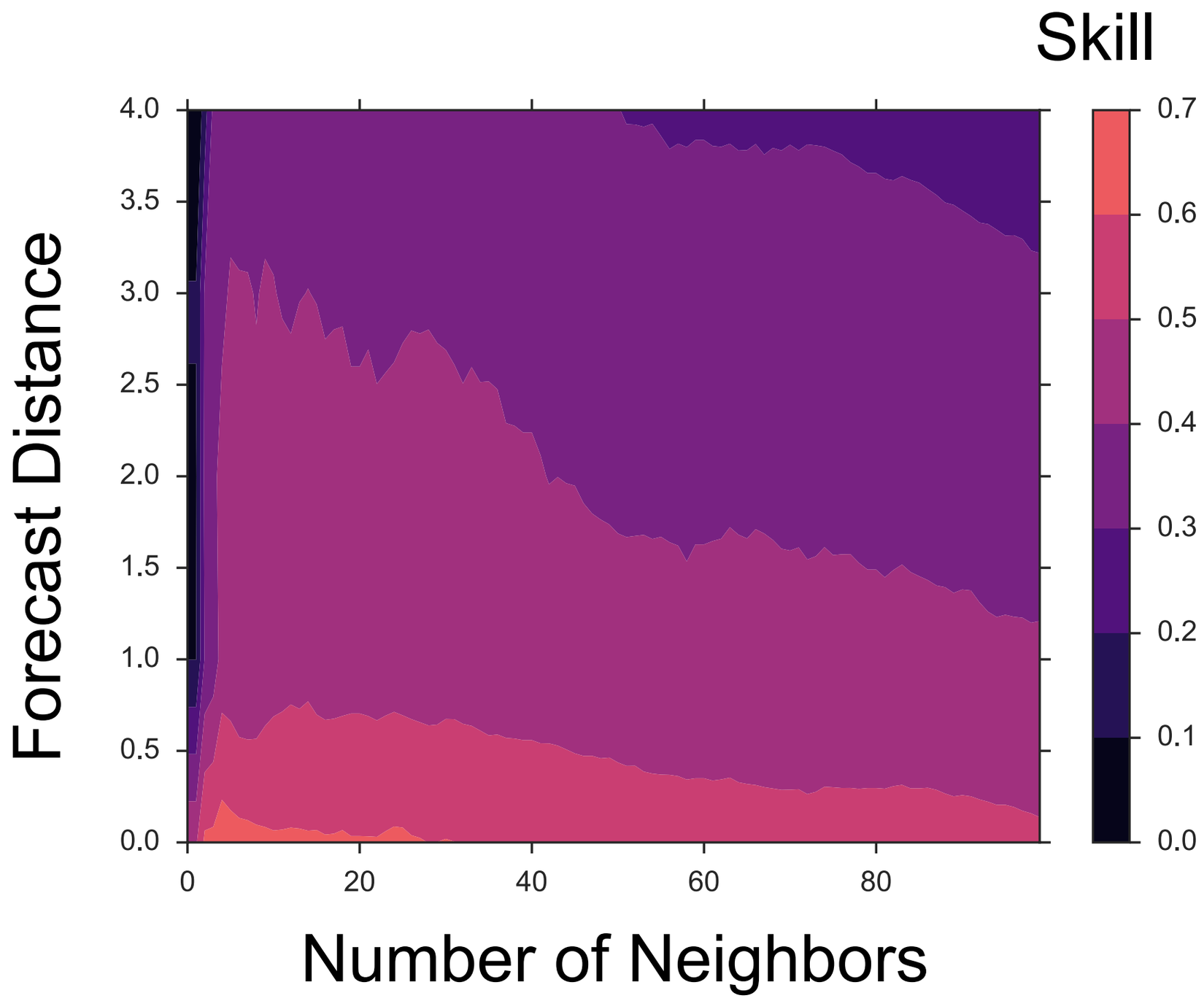
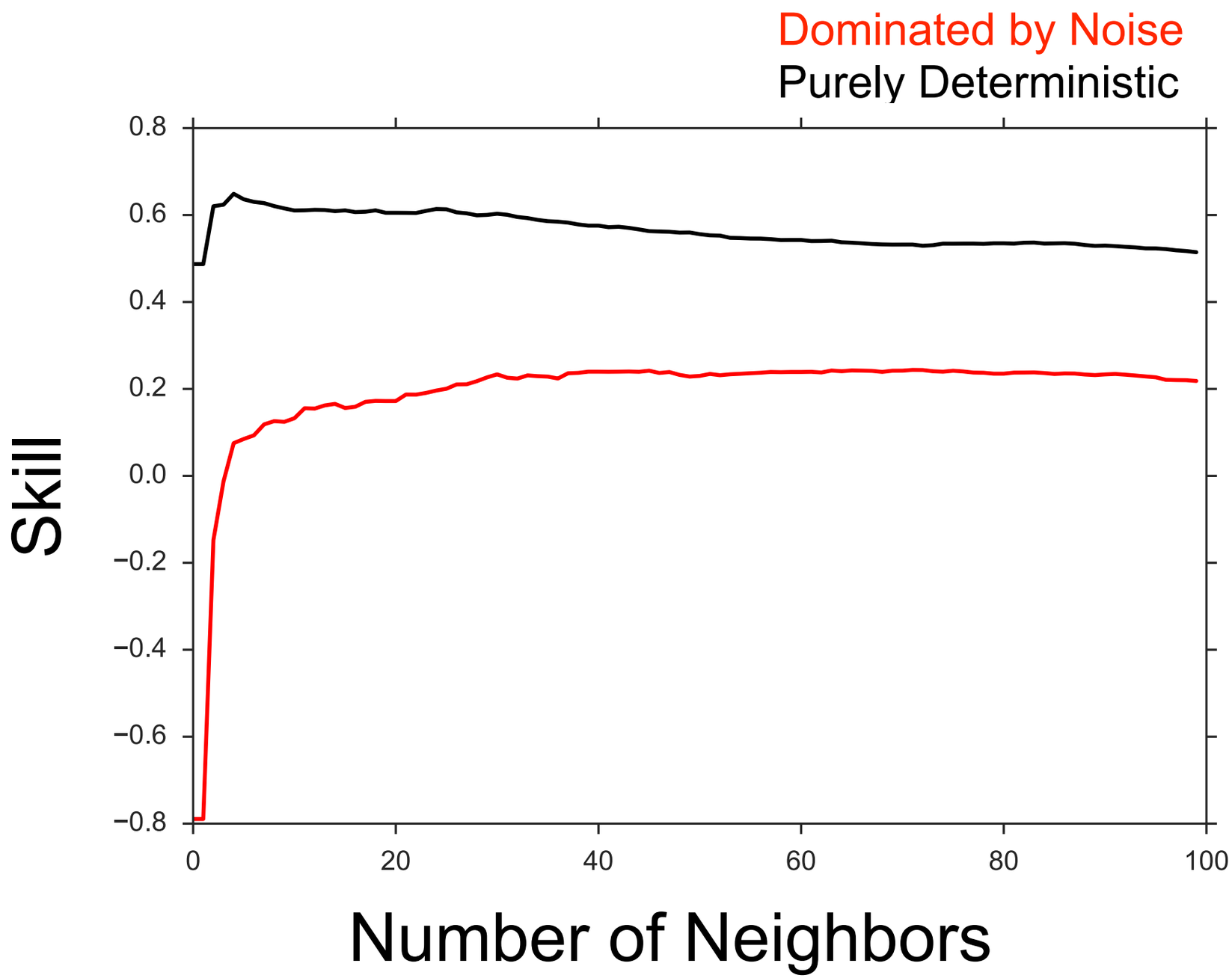


Nonlinear Forecasting



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

Maximize,

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

Benefits *Costs*

subject to,

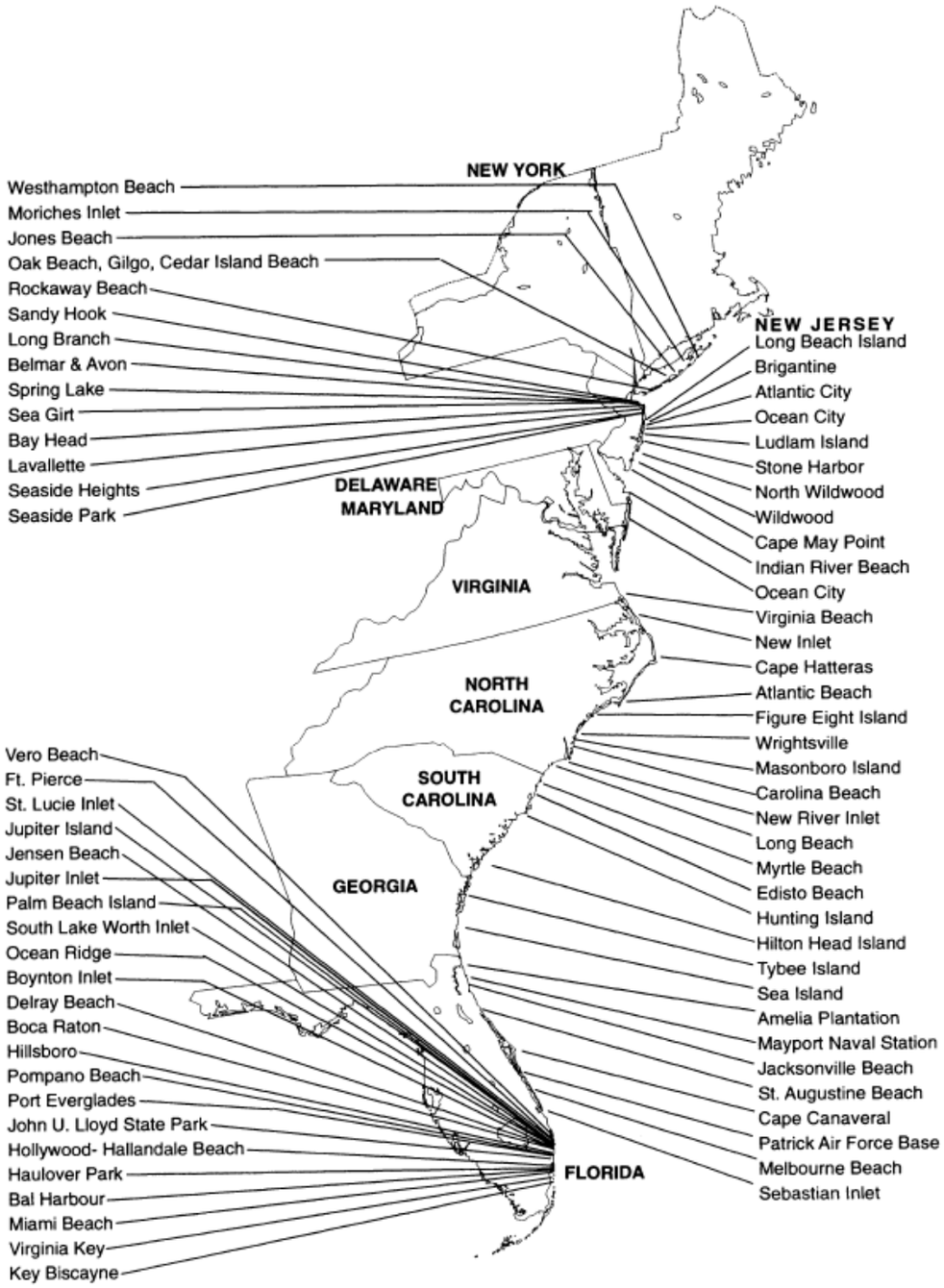
$$\frac{dx}{dt} = f(x, \lambda_x, \lambda_E)$$

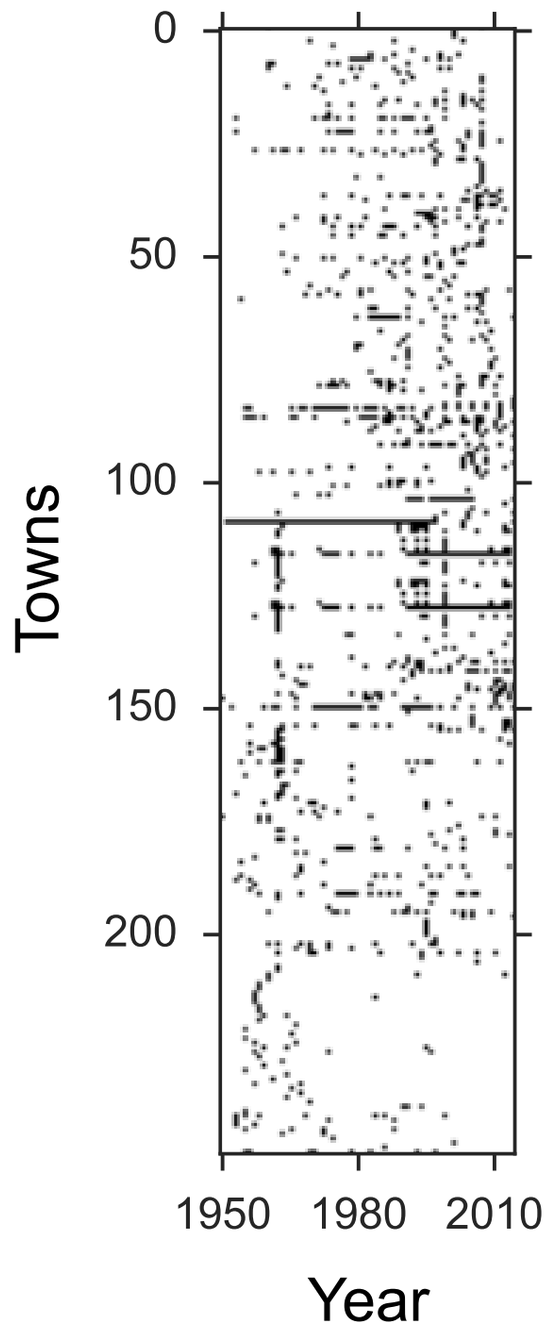
where

$x(t)$ beach width

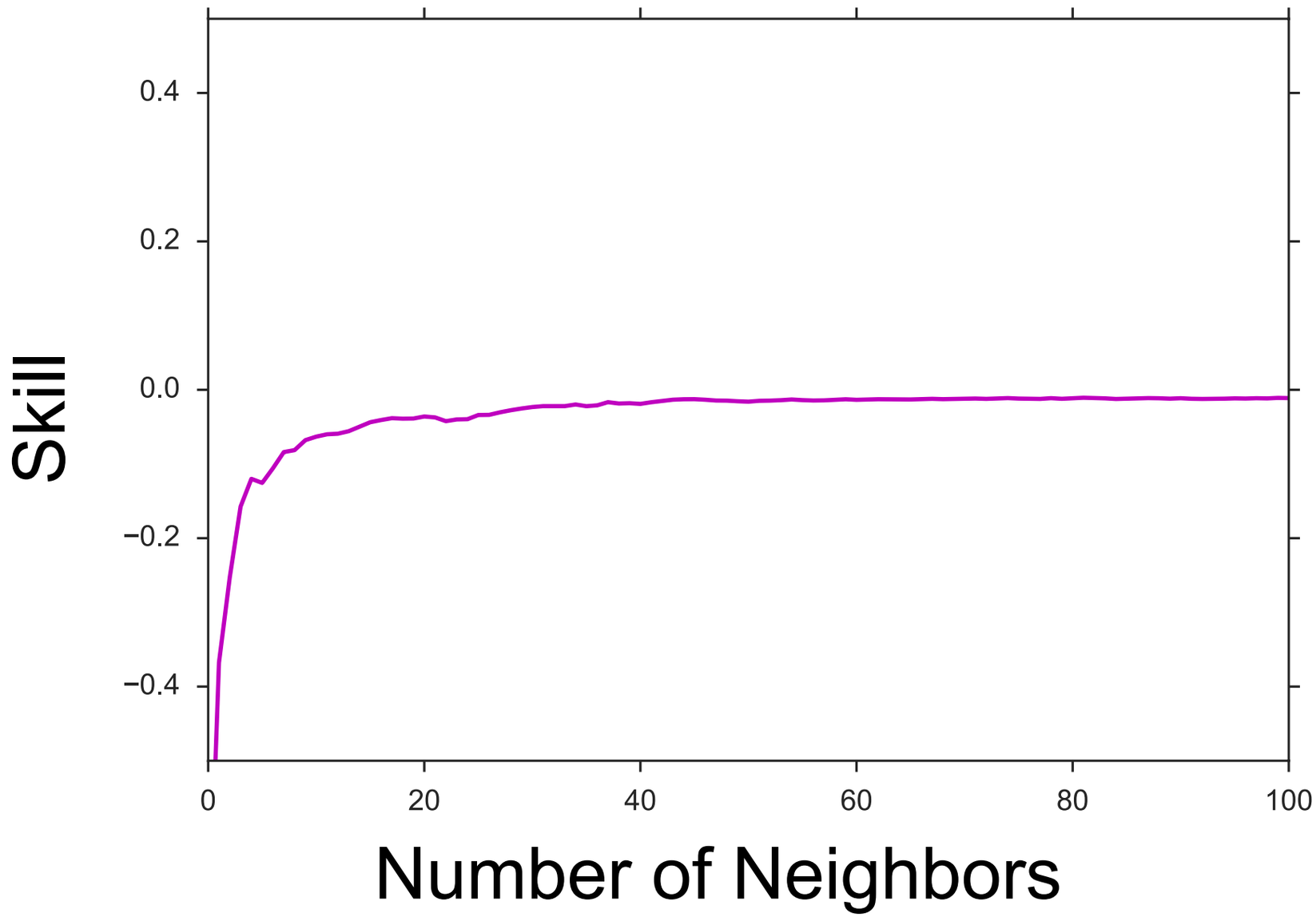
IS THIS SYSTEM DETERMINISTIC?

Beach Nourishment

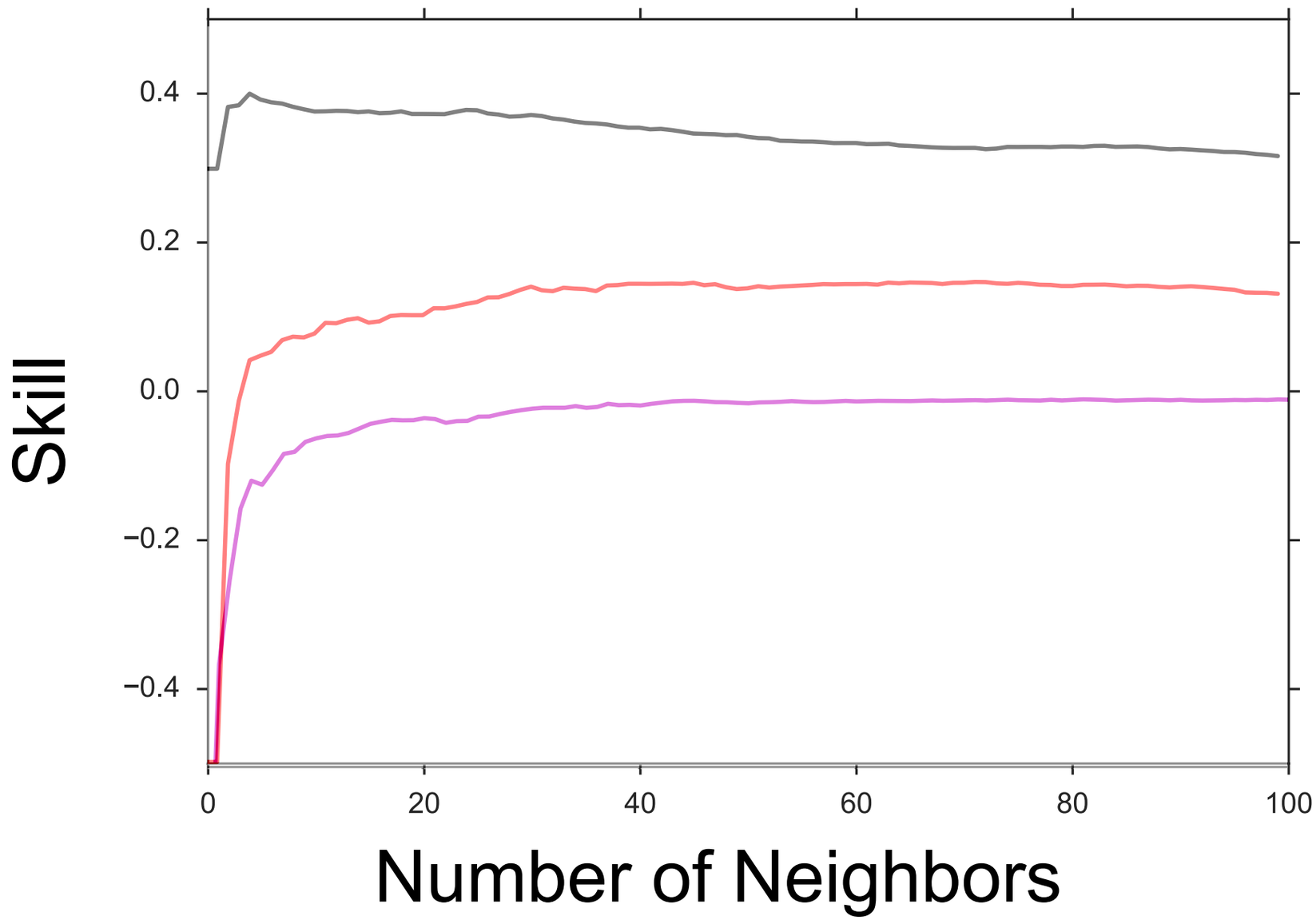




Beach Nourishment



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

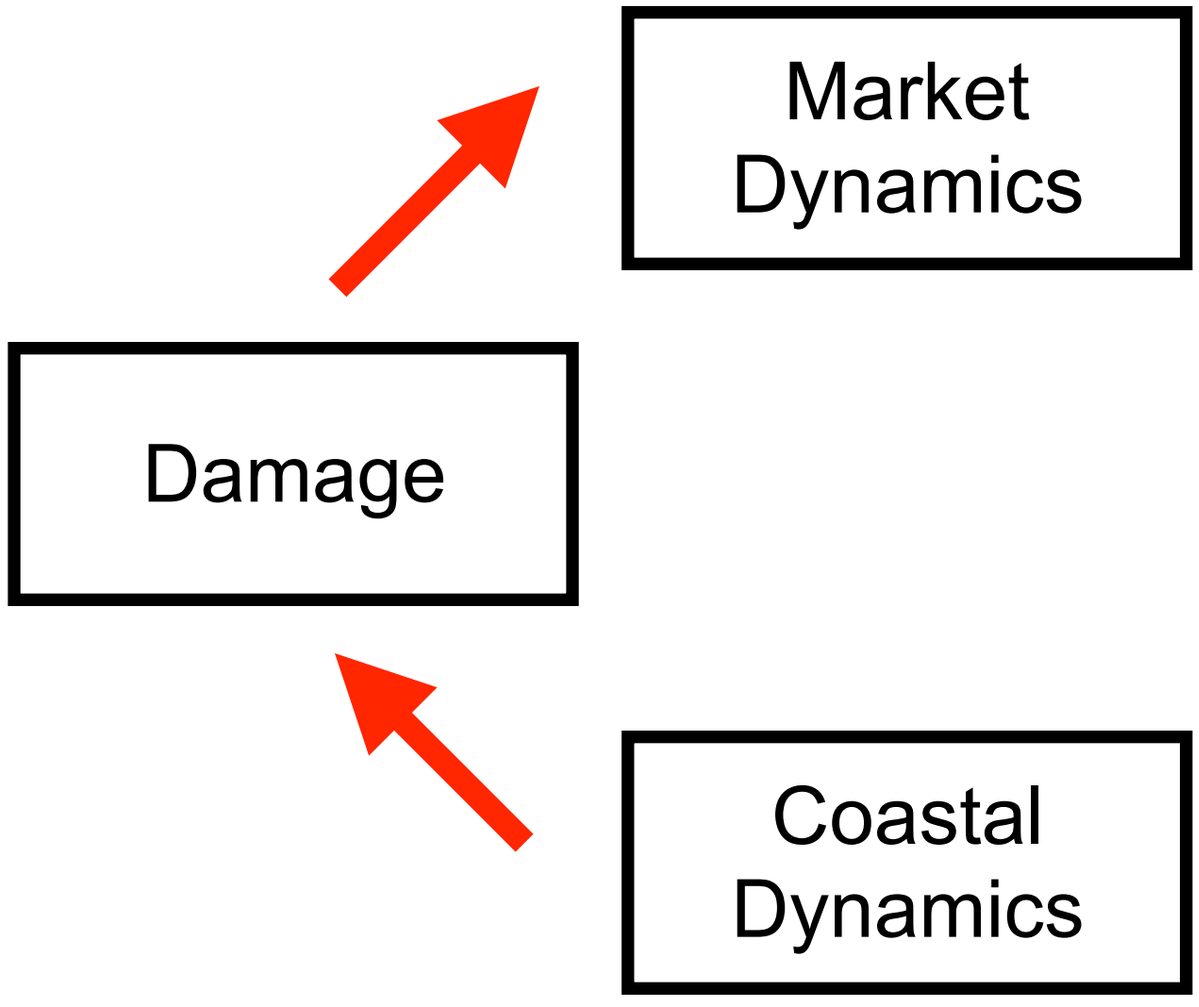
Environmental Econophysics

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

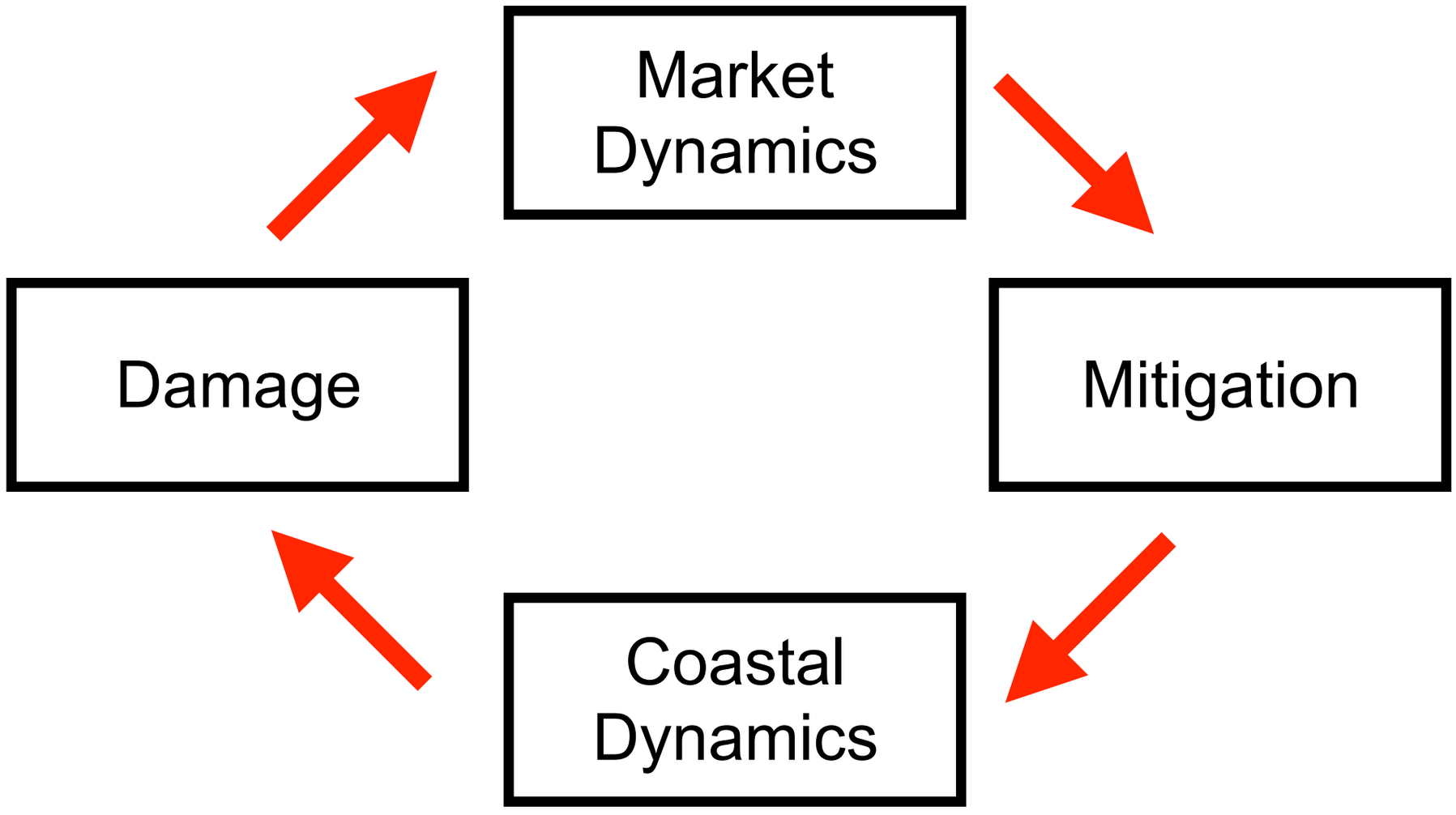
Model

Market
Dynamics

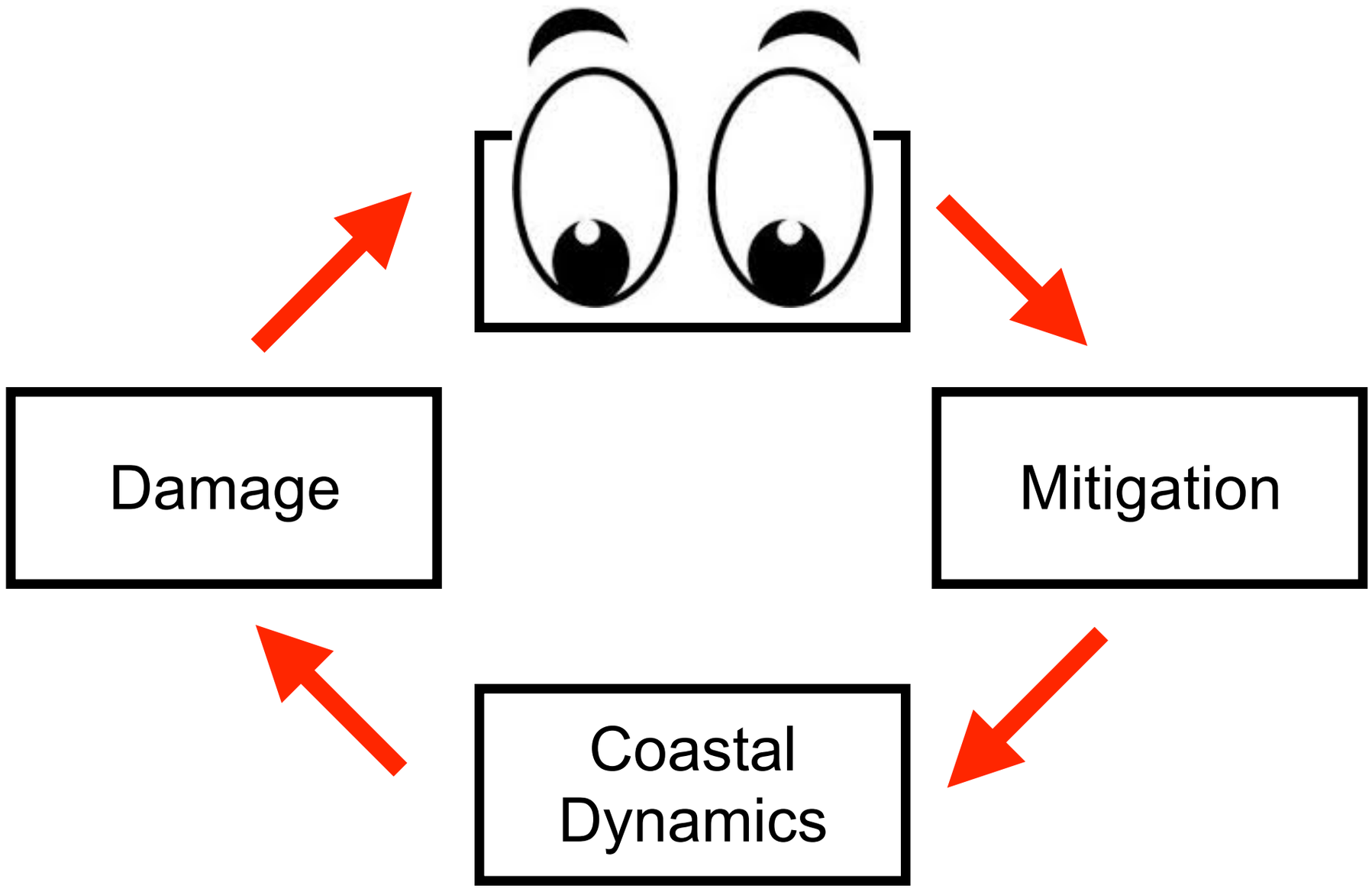
Model



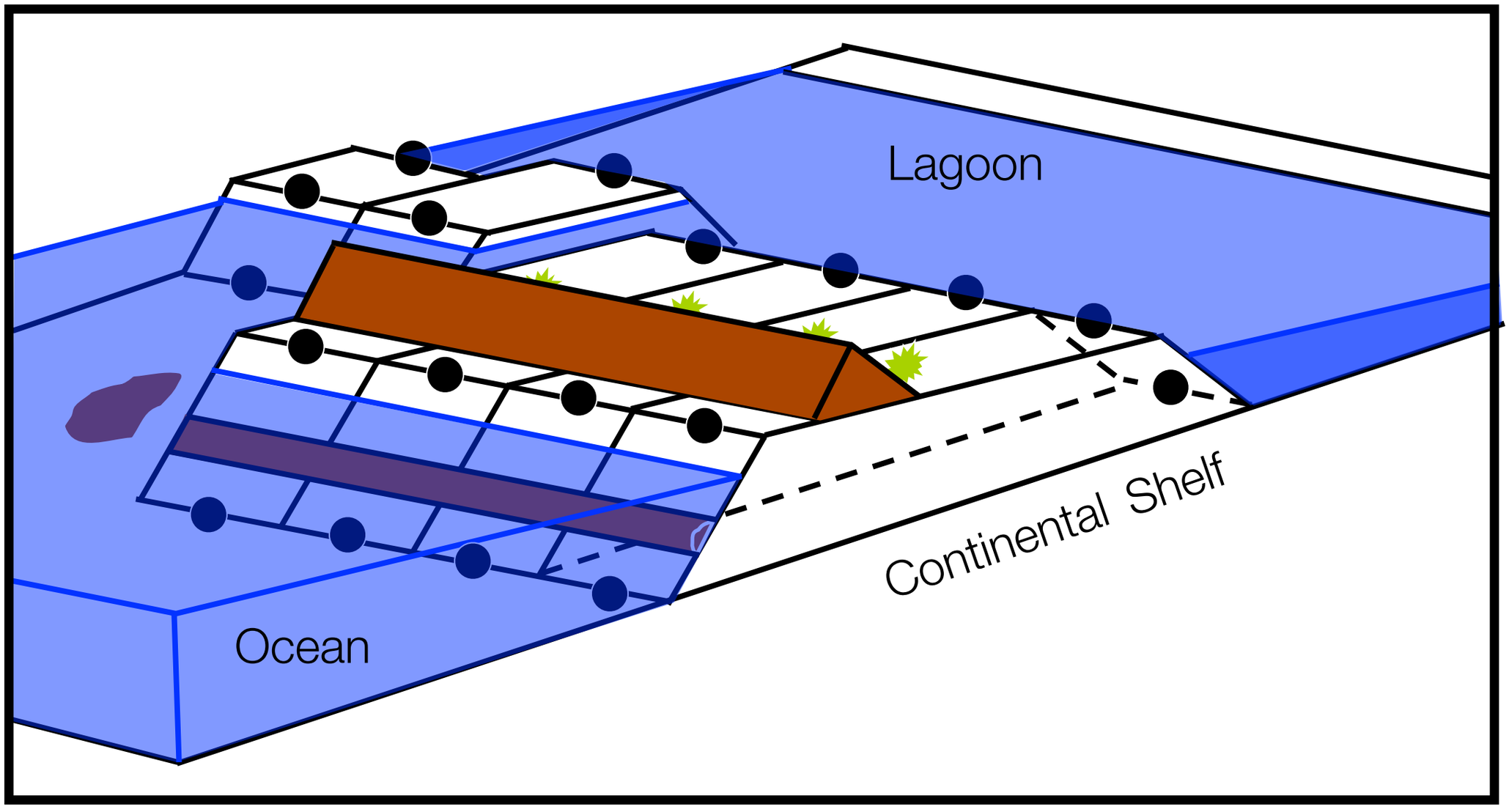
Model



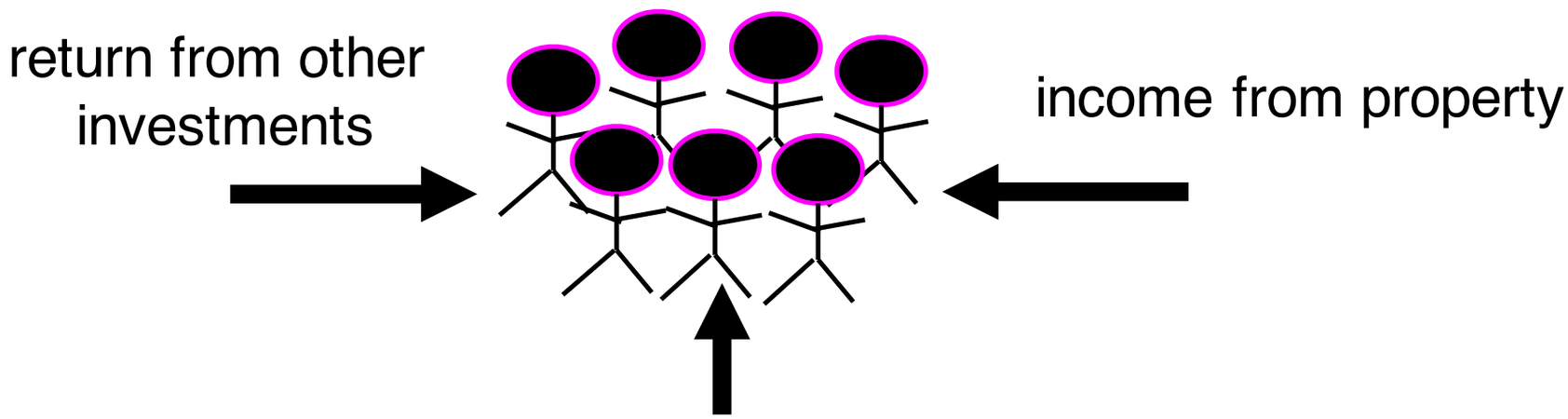
Model



Coastal Dynamics

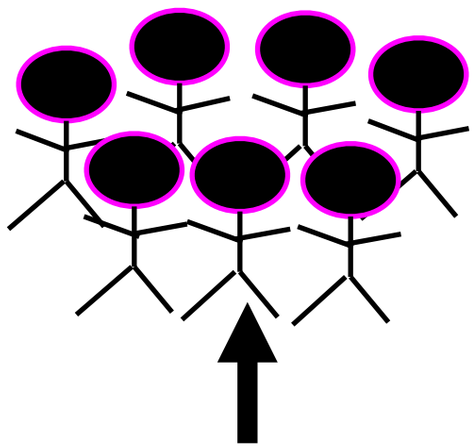


Market Dynamics



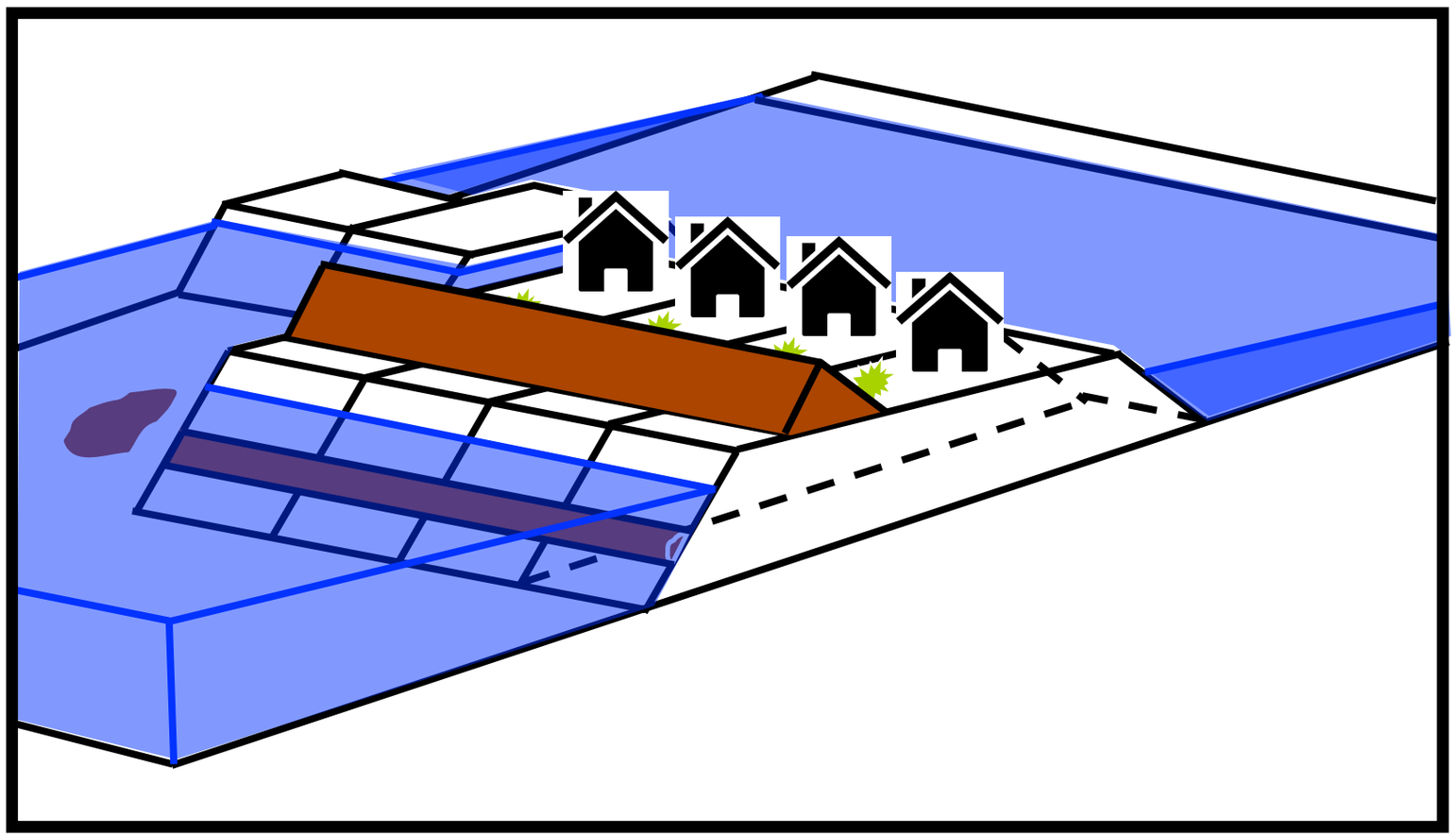
Market
Dynamics

return from other
investments



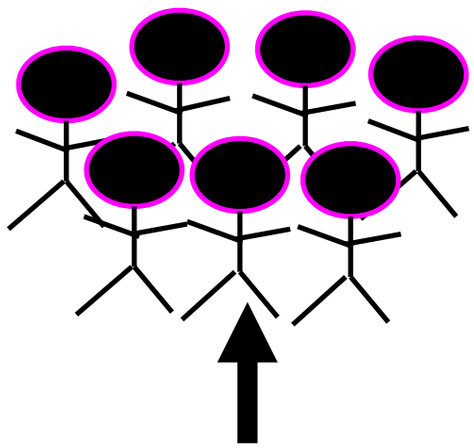
income from property

expected damage and mitigation costs



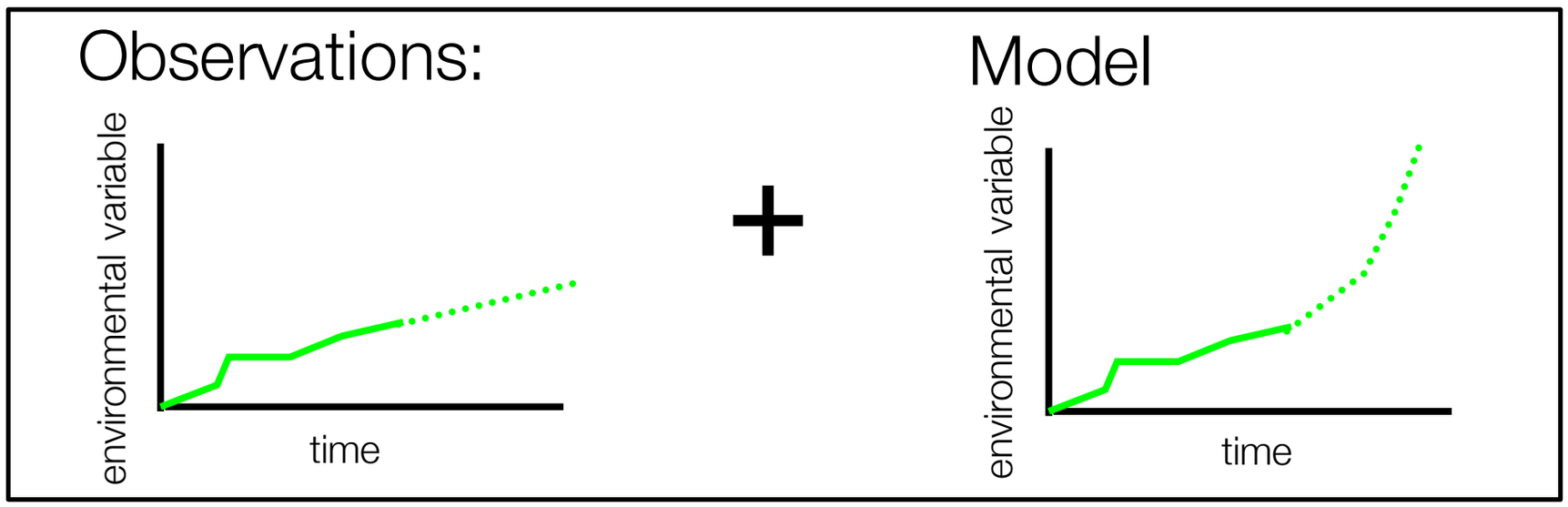
Market Dynamics

return from other investments



income from property

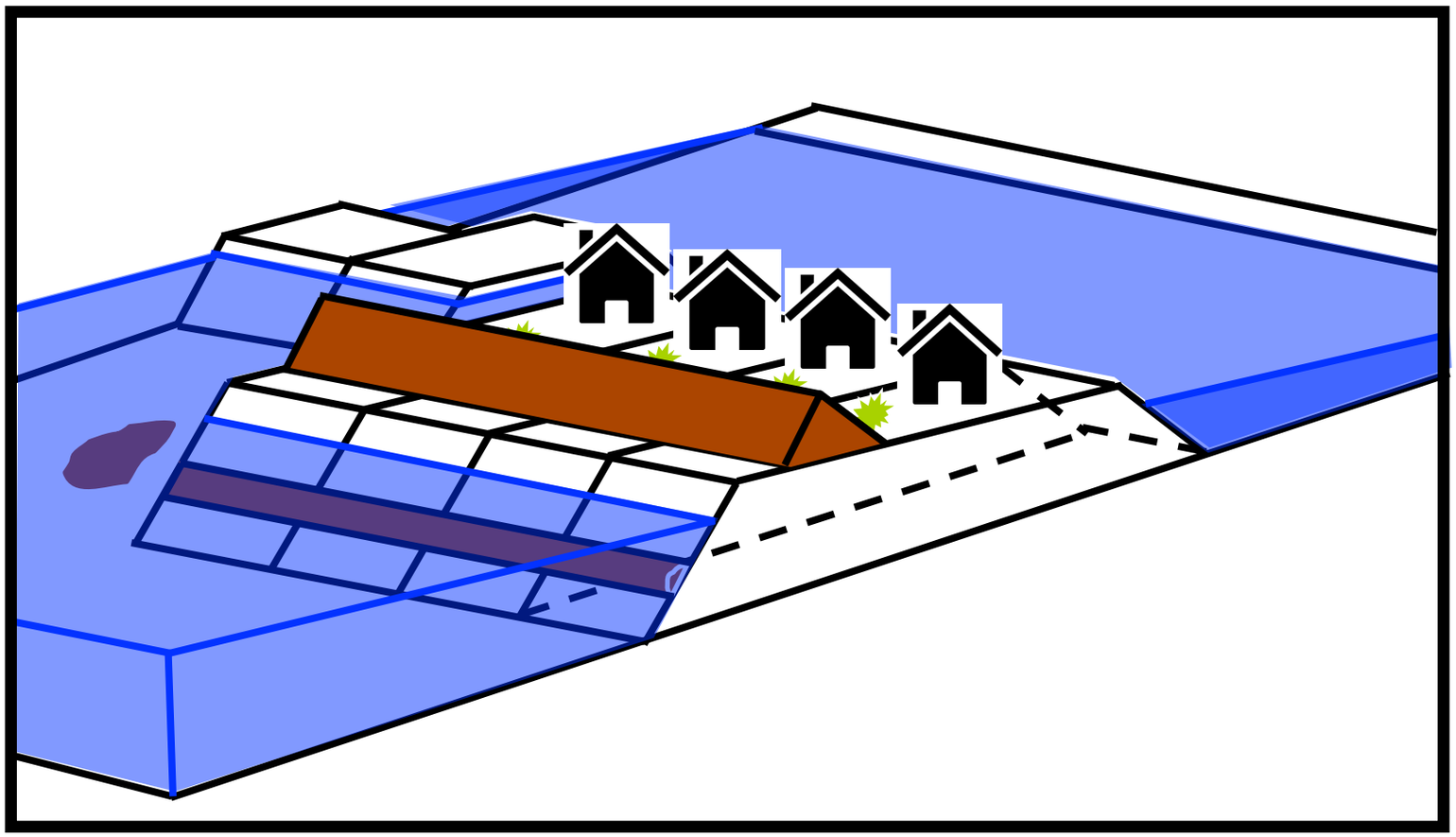
expected damage and mitigation costs



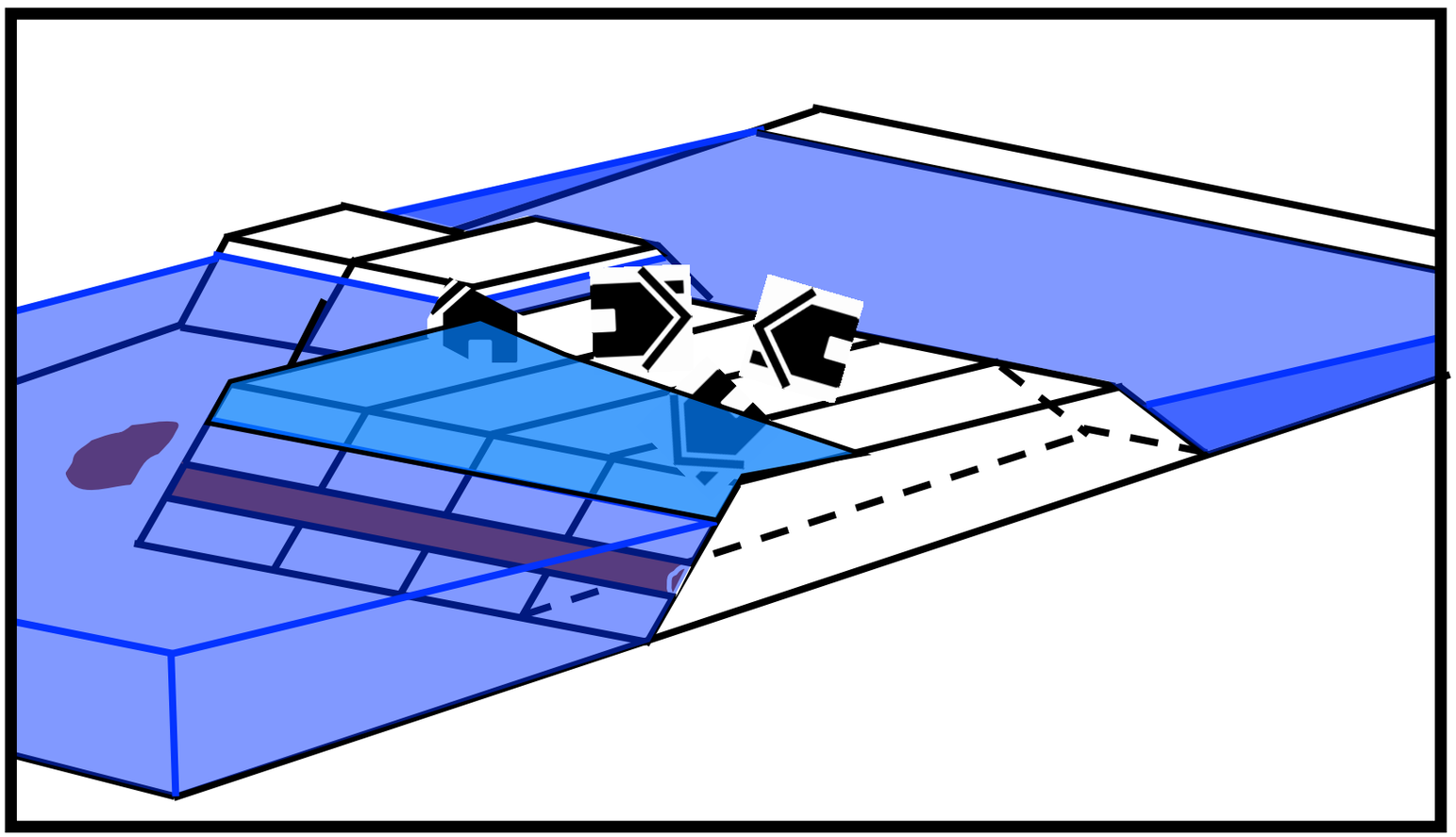
$$E_i[j(t)] = \alpha_i M[j(t)] + (1-\alpha_i) O_i[j(t)]$$

Expectation of environmental variable j for agent i

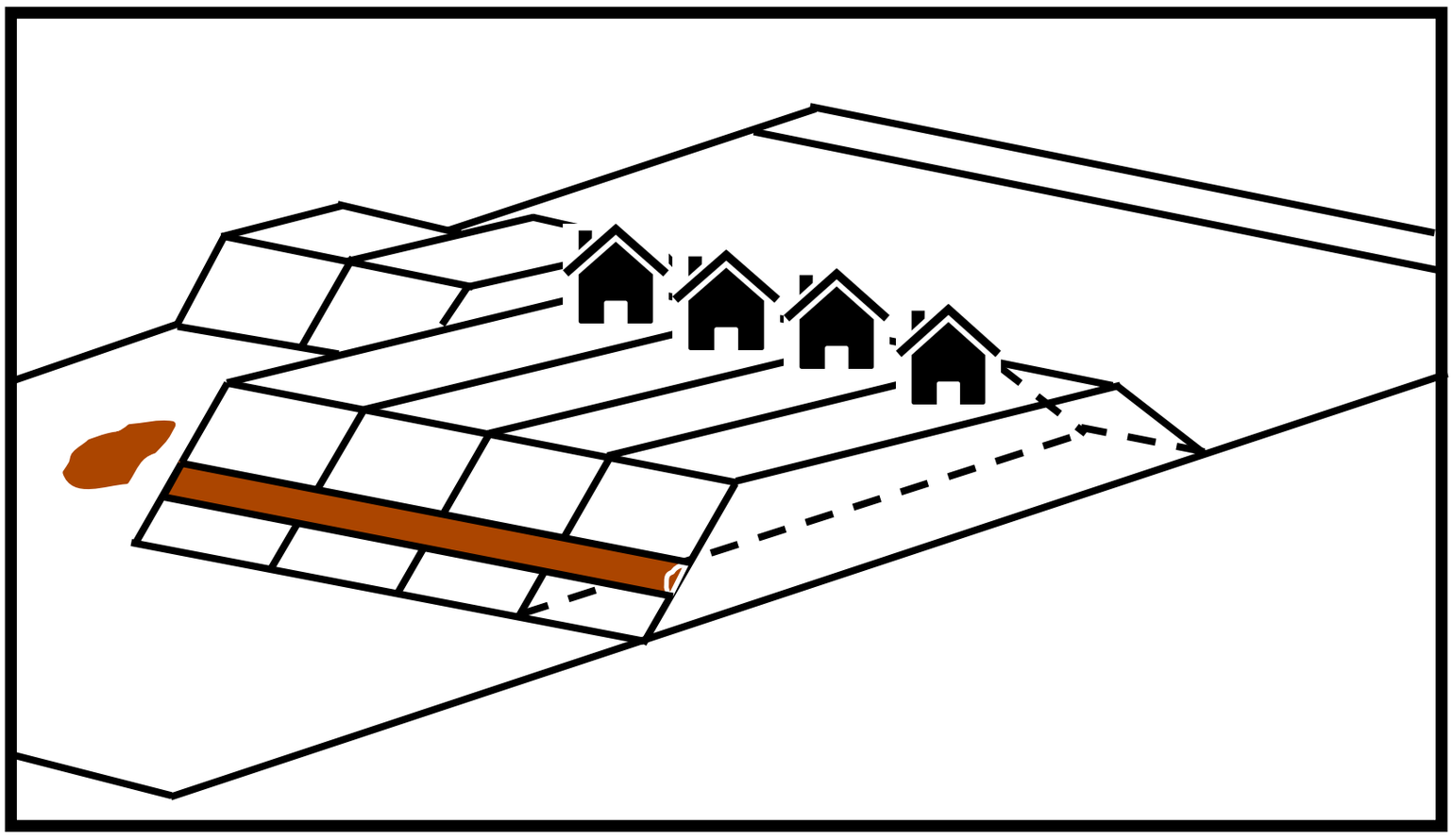
Damage



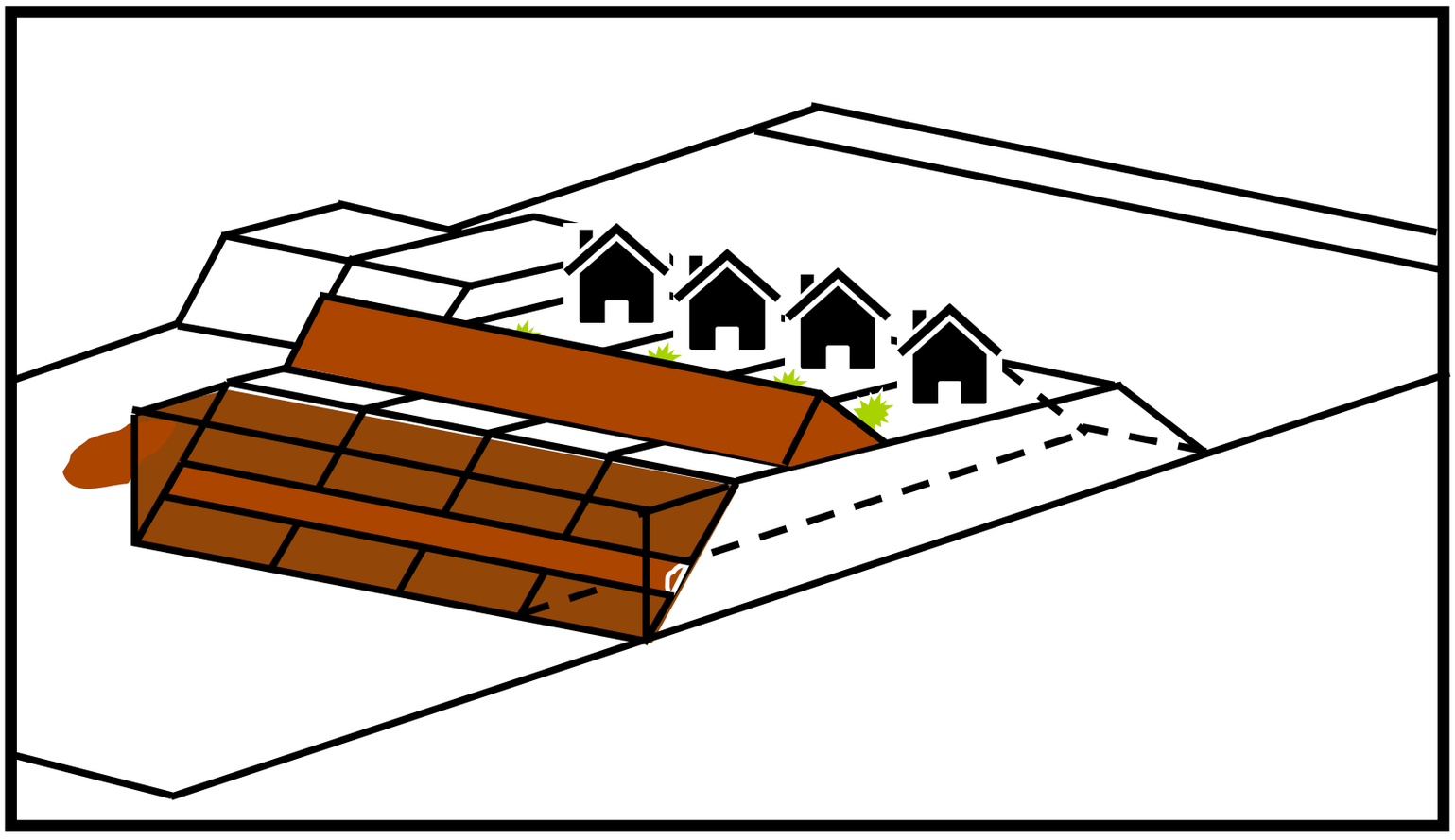
Damage



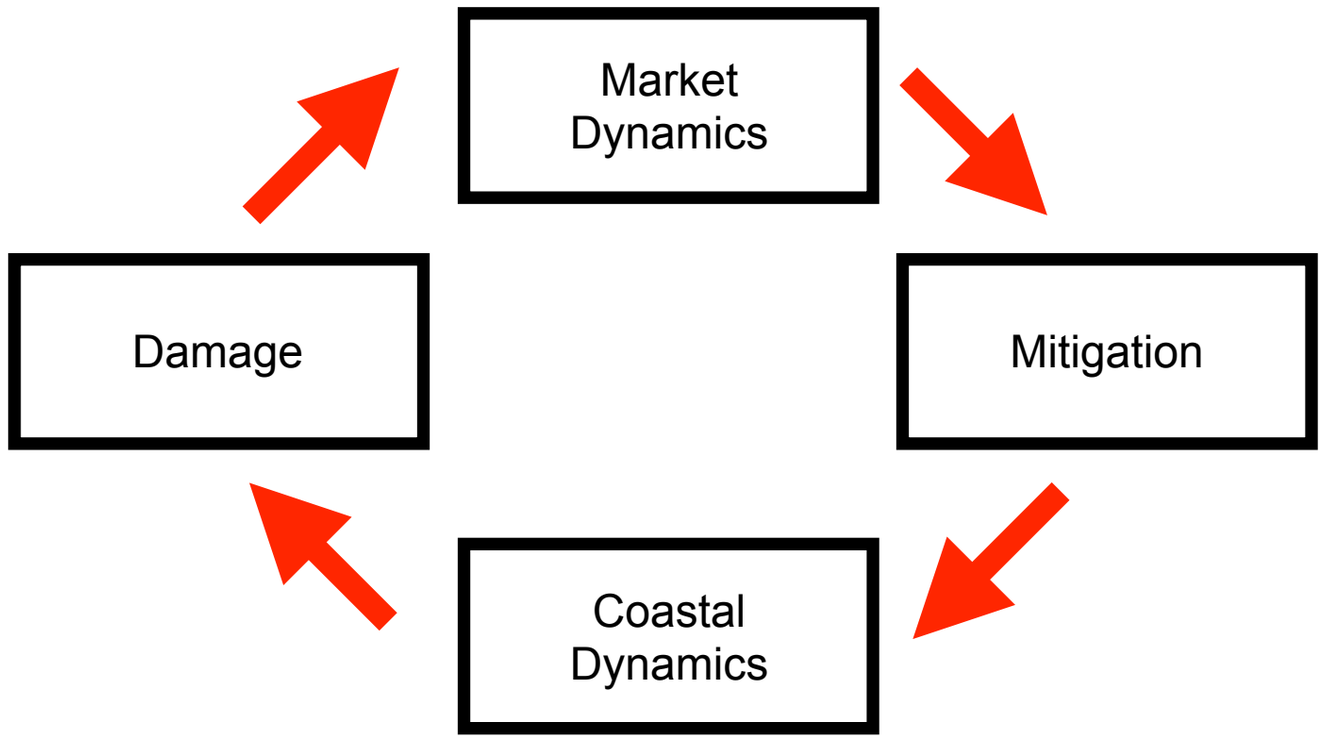
Mitigation



Mitigation

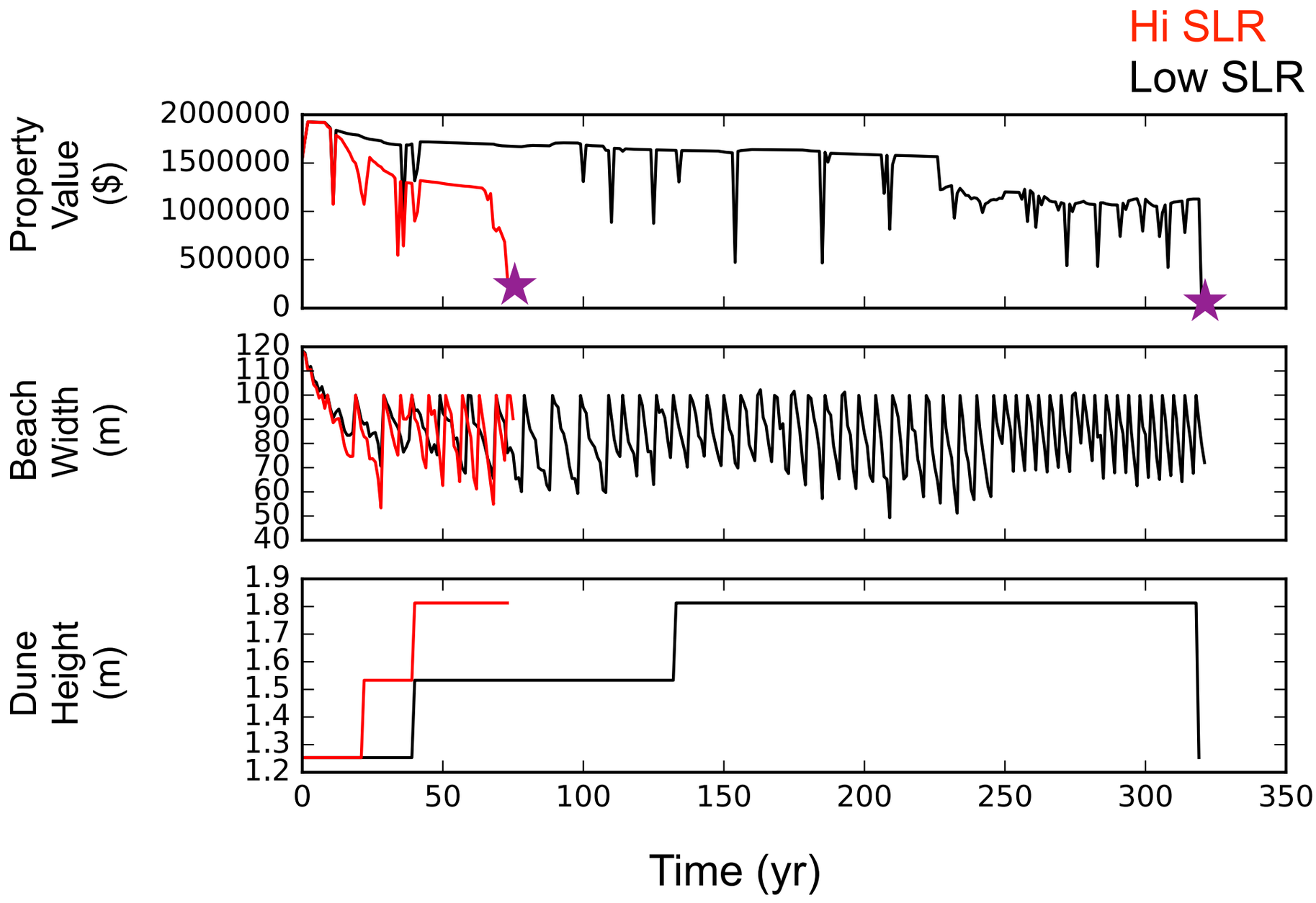


Model

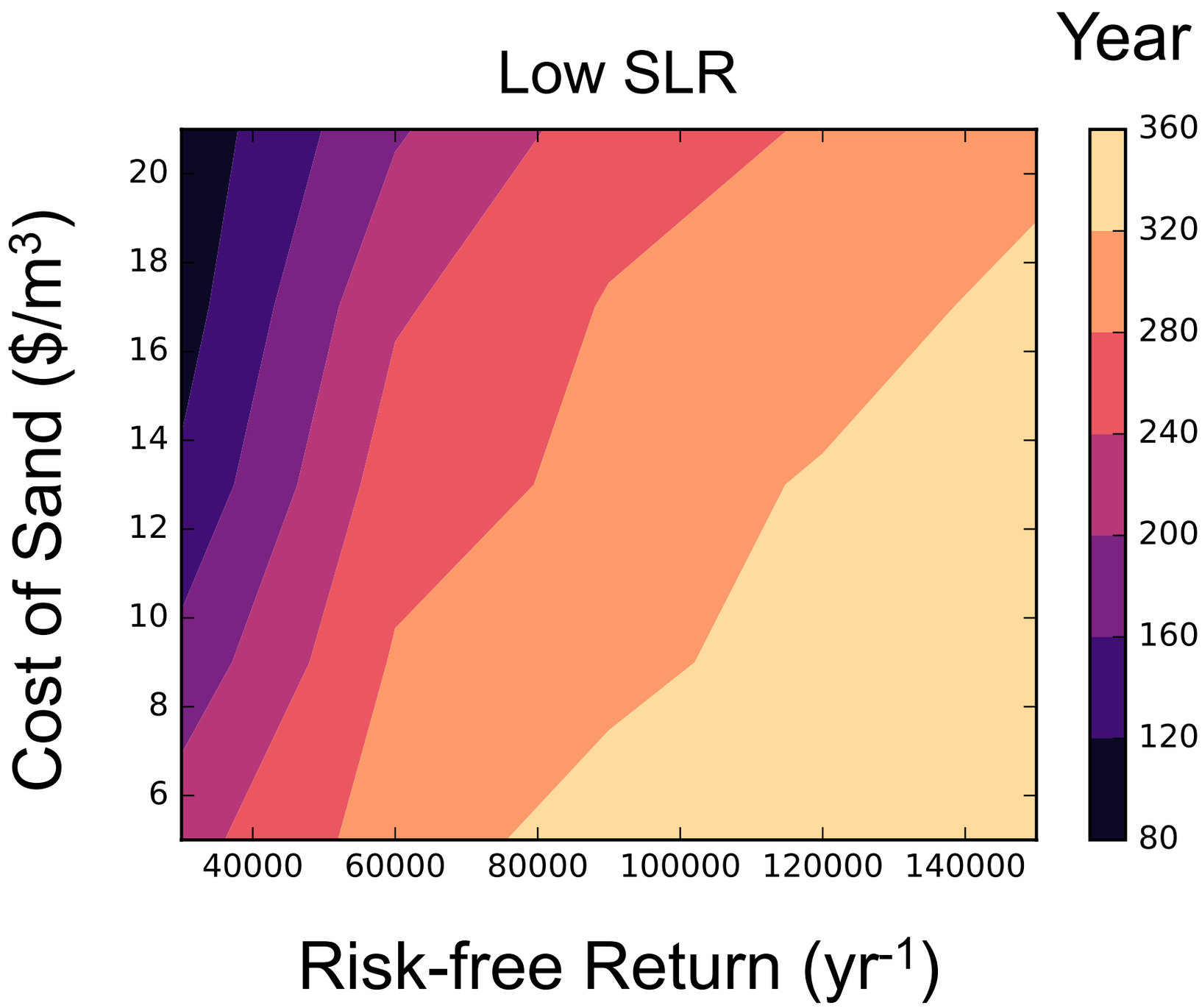


- Does the model reproduce current attractor?
- Does this attractor go away with SLR?
- How does change depend on natural, economic, social, factors?

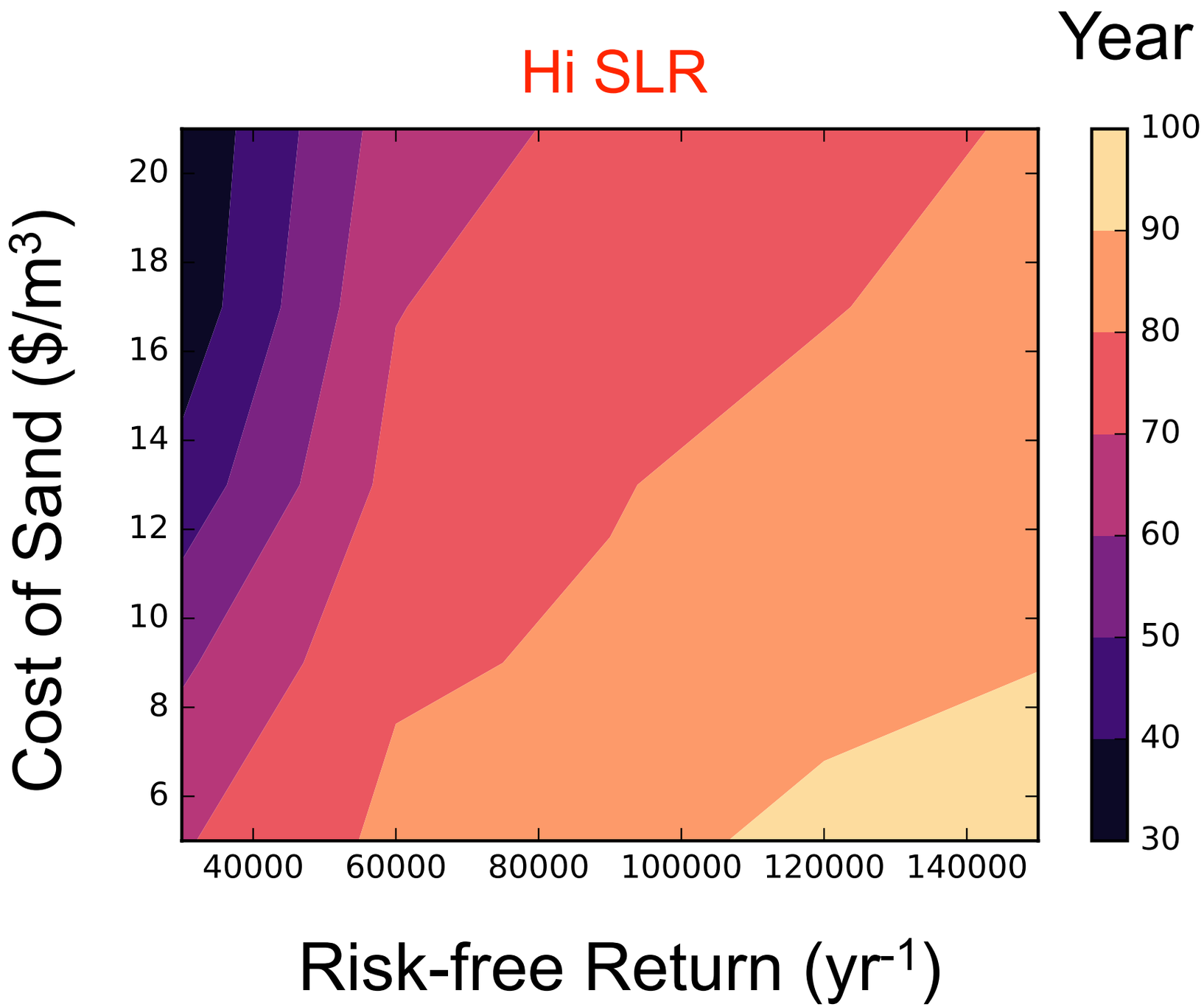
Results


Hi SLR
Low SLR
Property Value ($)
2000000
1500000
1000000
500000
0
Beach Width (m)
120
110
100
90
80
70
60
50
40
Dune Height (m)
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
0
50
100
150
200
250
300
350
Time (yr)

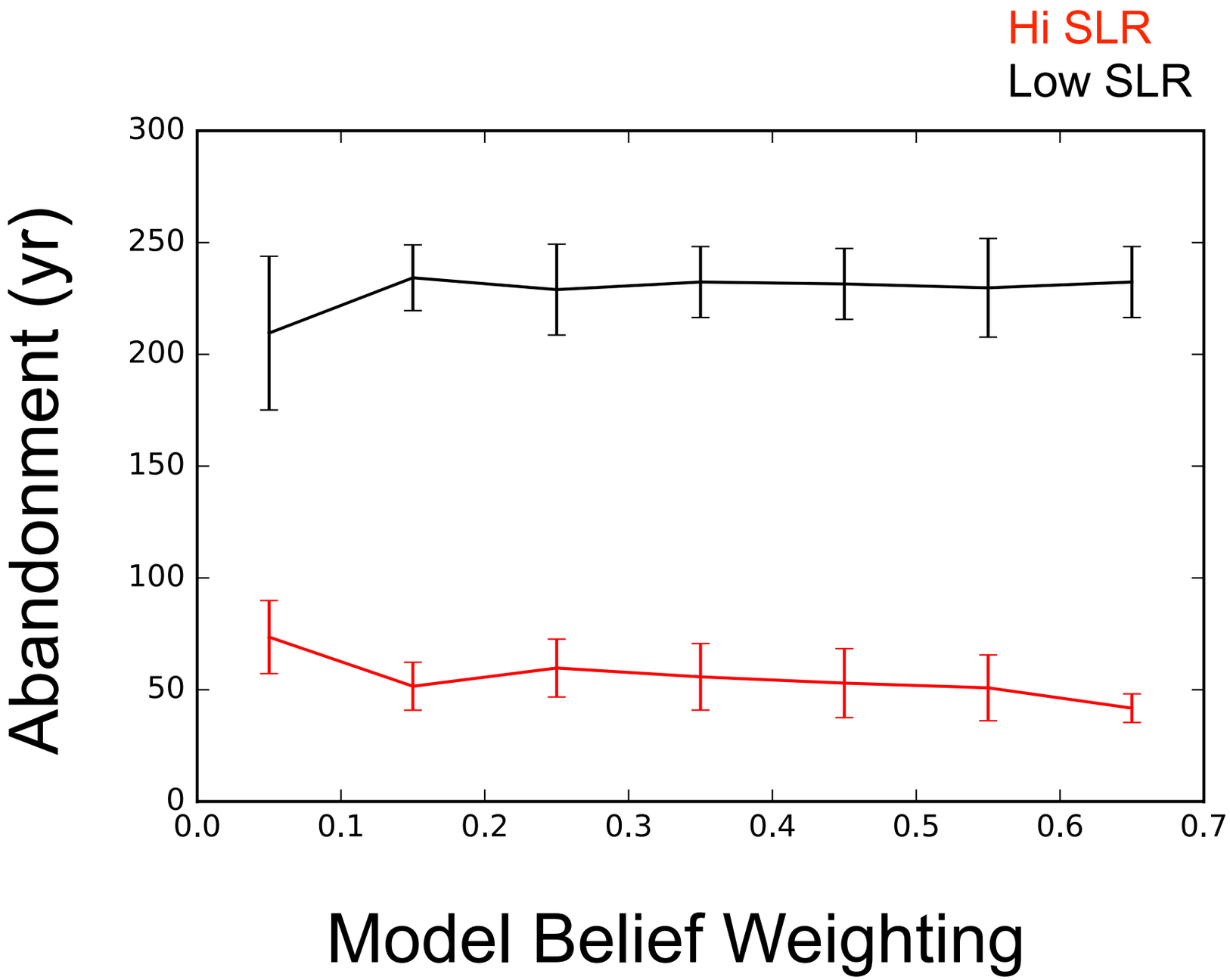
Results


Low SLR
Year
Cost of Sand ($/m³)
Risk-free Return (yr⁻¹)
20
18
16
14
12
10
8
6
40000
60000
80000
100000
120000
140000
360
320
280
240
200
160
120
80

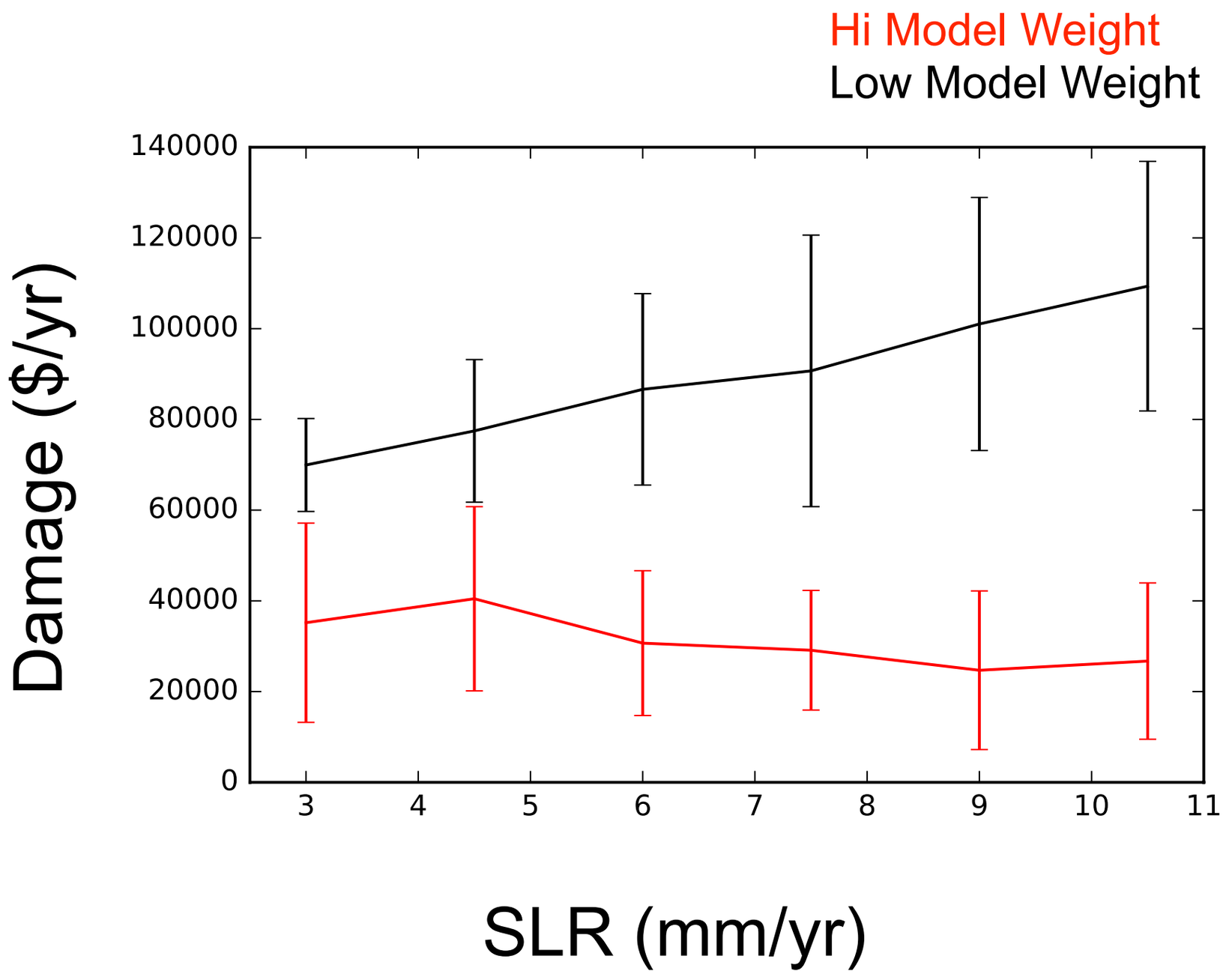
Results


Hi SLR
Year
100
90
80
70
60
50
40
30
Cost of Sand ($/m³)
20
18
16
14
12
10
8
6
40000
60000
80000
100000
120000
140000
Risk-free Return (yr⁻¹)

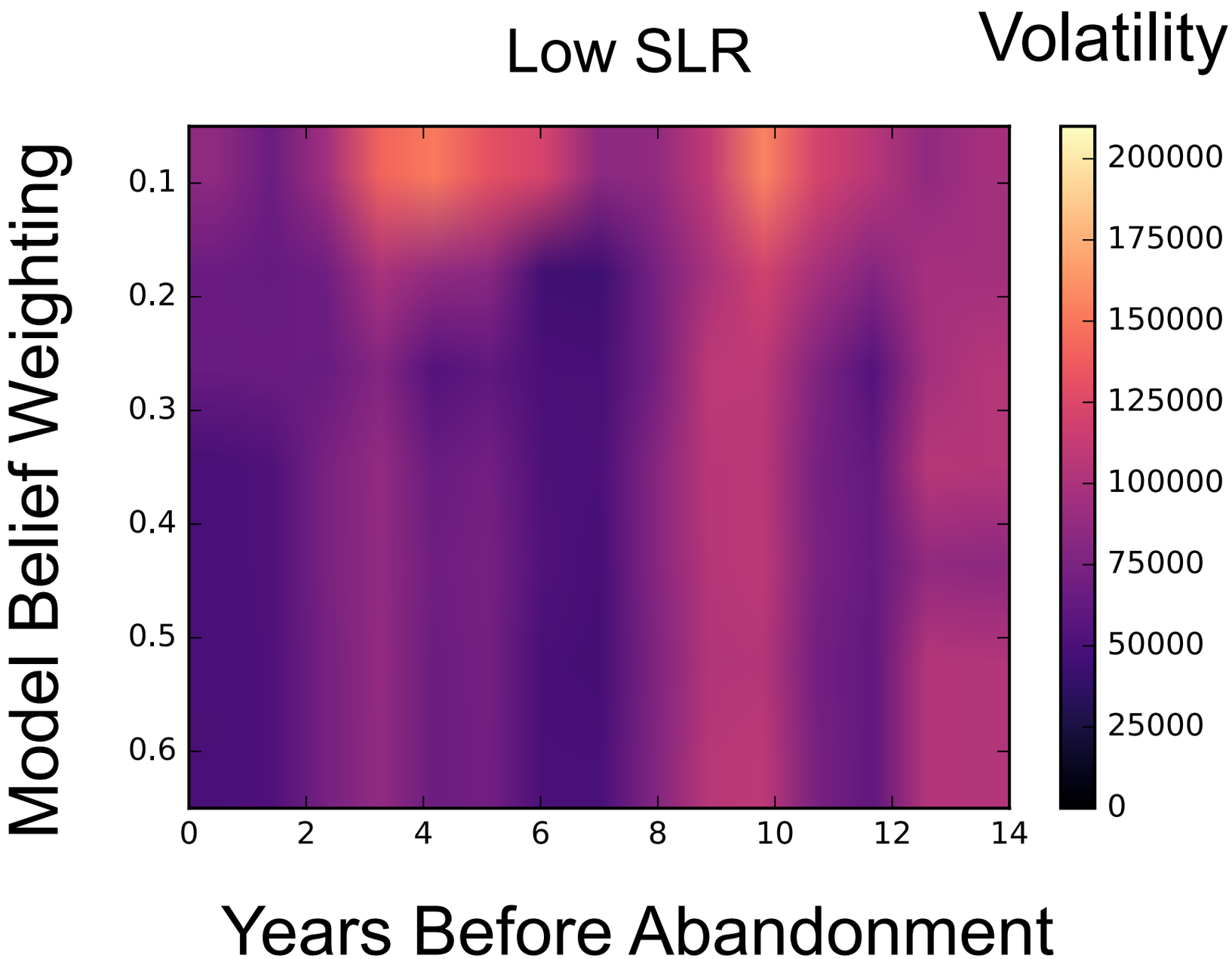
Results


Hi SLR
Low SLR
Abandonment (yr)
300
250
200
150
100
50
0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Model Belief Weighting

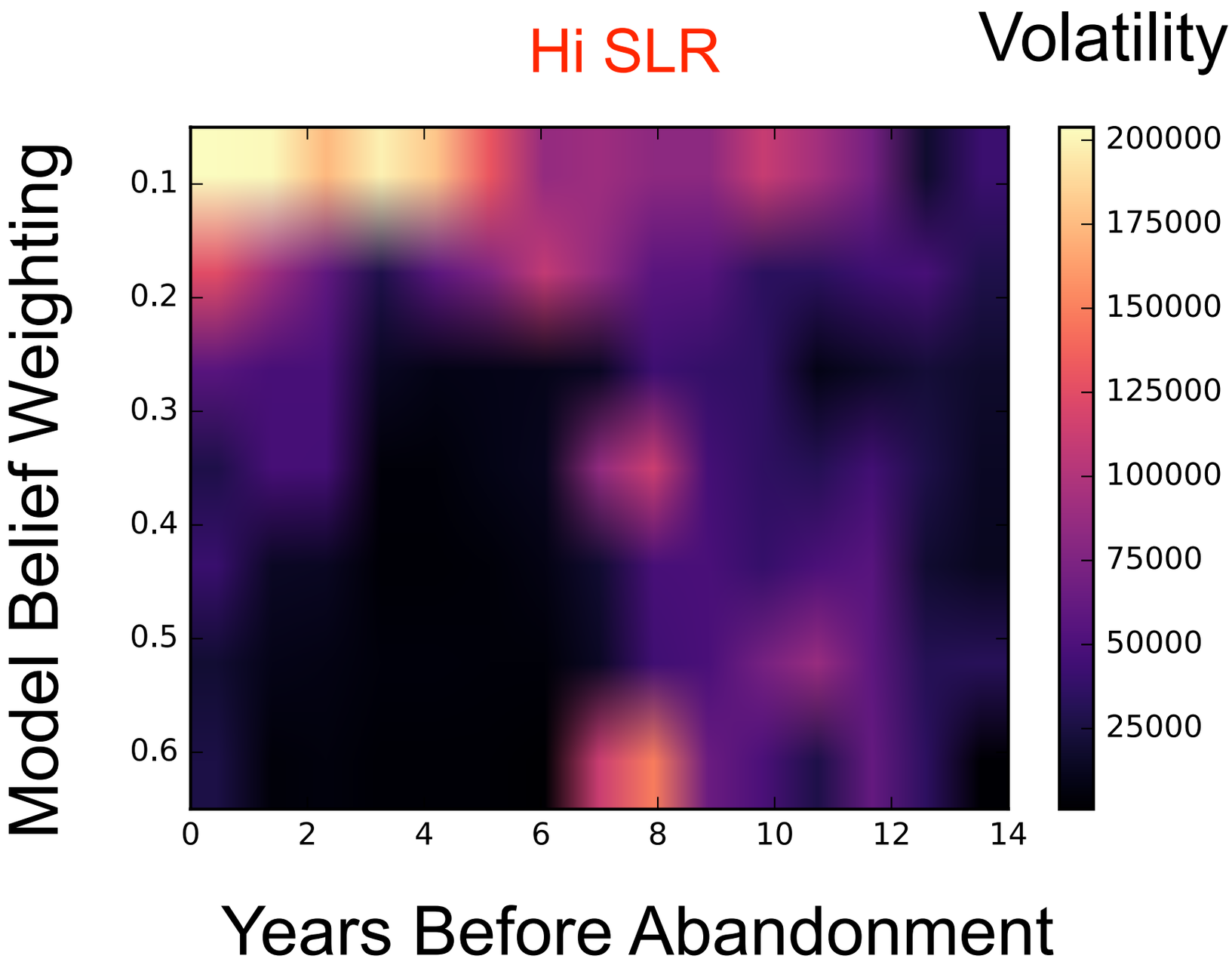
Results


Hi Model Weight
Low Model Weight
Damage ($/yr)
140000
120000
100000
80000
60000
40000
20000
0
3
4
5
6
7
8
9
10
11
SLR (mm/yr)

Results


Low SLR
Volatility
Model Belief Weighting
0.1
0.2
0.3
0.4
0.5
0.6
0
2
4
6
8
10
12
14
200000
175000
150000
125000
100000
75000
50000
25000
0
Years Before Abandonment

Results


Hi SLR
Volatility
Model Belief Weighting
0.1
0.2
0.3
0.4
0.5
0.6
0
2
4
6
8
10
12
14
200000
175000
150000
125000
100000
75000
50000
25000
Years Before Abandonment

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