Introduction to Agent-Based Modeling

EES 4760/5760

Agent-Based and Individual-Based Computational Modeling

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Class #1: Wednesday, August 20 2025

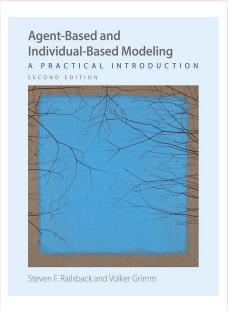
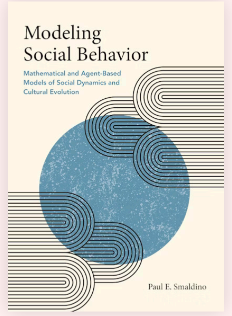
Who Are You?

Who Are You?

1. Who are you? (Name, year, major)
2. What is something that made you interested to study computational modeling?
3. Ask me a question about computational modeling
4. Something interesting about yourself

Overview of the Semester

Textbooks

	Steven F. Railsback & Volker Grimm, *Agent-Based and Individal-Based Modeling* (2nd Edition)
	Paul E. Smaldino, *Modeling Social Behavior*

Getting Started

For Monday:

- Download and install NetLogo on your computer.
  - URL in syllabus and assignment sheet

Course Web Site

- ees4760.jgilligan.org
  - Syllabus
  - All reading and homework assignments for the semester
  - Slides from class.
  - Files you will need for homework assignments.
  - Links to helpful resources.
- Slides:
  - The title slide has QR code with link to online version.
  - PDF versions are also posted to course web site (link on title slide)
  - Slides have two-dimensional navigation (in a browser, hit "?" for help)

Agent-Based Modeling

Agent-Based Modeling

- Simulate individuals:
  - Autonomous
  - Heterogeneous
  - Quasi-local
  - Bounded rationality
- Simulate environment
- Emphasize simplicity, minimal assumptions
- **Emergence:** Large-scale phenomena arise from small-scale individual interactions
  - Interesting when large-scale is not easily predicted from small-scale

Simple Experiments

- Play with economics
  - Simple agents trade with each other
  - Confirm 1st welfare theorem:

    Trading leads to Pareto equilibrium
  - Find conditions for satisfying theorem:
    - Not necessary for traders to be completely rational
      - How much rationality do you need?
    - Equilibration can be slow
    - Time-varying preferences can prevent equilibration
- Dynamics of agent-based models connect to nonlinear dynamics and chaos

Economics of Cooperation
Game Theory

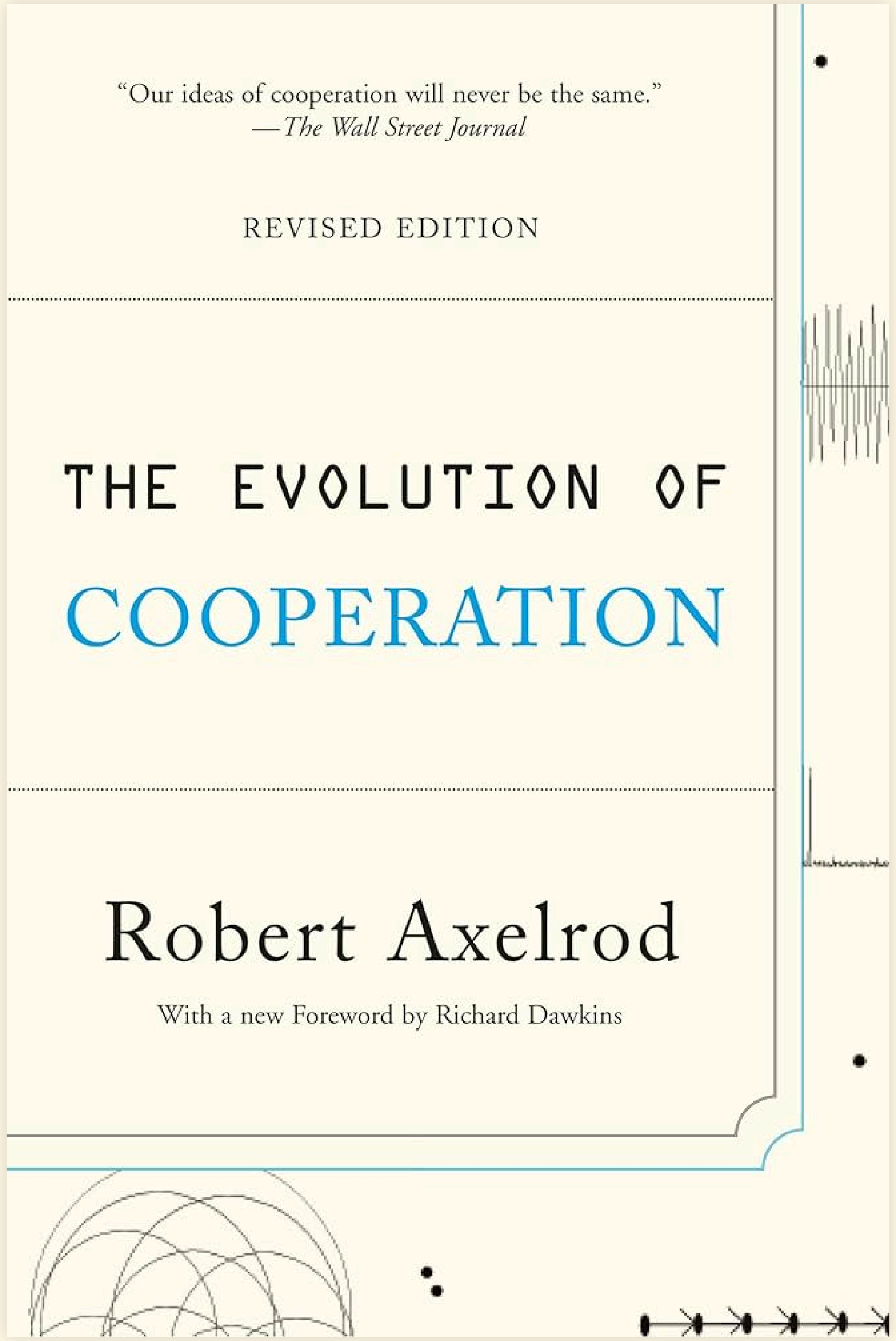
- Prisoner's Dilemma Game:

A \ B	B Cooperates	B Defects
A Cooperates	(3,3)	(0,4)
A Defects	(4,0)	(1,1)

- Nash Equilibrium:
  - No matter what player A does, player B is better off defecting
  - No matter what player B does, player A is better off defecting
  - **End result:** Both players end up worse off than if they had both cooperated.

Iterated Prisoner’s Dilemma

- R. Axelrod (1981)
  - Tournament of algorithms
- Winner: “tit-for-tat”
- Evolutionary Game Theory:
  - Basic principles of good strategies:
    - Be nice
    - Be provocable
    - Don’t be too envious
    - Don’t be too clever
- Nay & Gilligan (2015)
  - Real-world strategies involve randomness, unpredictability



Modeling Evolution and Game Theory

1. J. Shihui, W. Zhiyi, “An evolutionary game model with reputation threshold and reputation score to promote trust in the sharing economy.” *Sci Rep* **15**, 14635 (2025).
2. D. Vernon-Bido, A. Collins, “Finding Core Members of Cooperative Games Using Agent-Based Modeling.” *JASSS* **24**, 6 (2021).
3. M. Chica *et al.*, “An Evolutionary Game Model with Punishment and Protection to Promote Trust in the Sharing Economy.” *Sci Rep* **9**, 19789 (2019).
4. A. Morris *et al.*, “Evolution of flexibility and rigidity in retaliatory punishment.” *PNAS* **114**, 10396 (2017).
5. J. J. Jordan *et al.*, “Third-party punishment as a costly signal of trustworthiness.” *Nature* **530**, 473 (2016).

Agent-Based Modeling and Highway Traffic

Phantom Traffic Jams

powered by NetLogo

jg-traffic

File: New | Revert to Original

Export: NetLogo | HTML

Mode: Interactive   Commands and Code: Bottom

model speed

ticks:

number-of-cars 20

setup

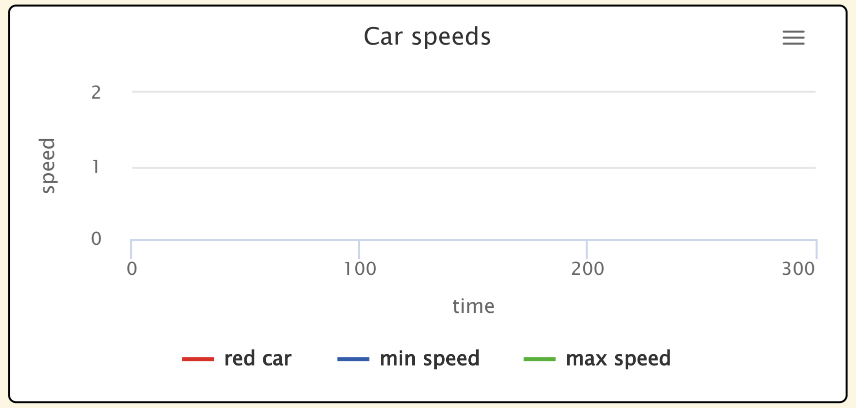
go

red car speed

0

acceleration 0.0045

deceleration 0.026



Command Center

NetLogo Code

Model Info

Real World Application

Can Self Driving Cars Revolutionize Traffic? | Quantum Potential

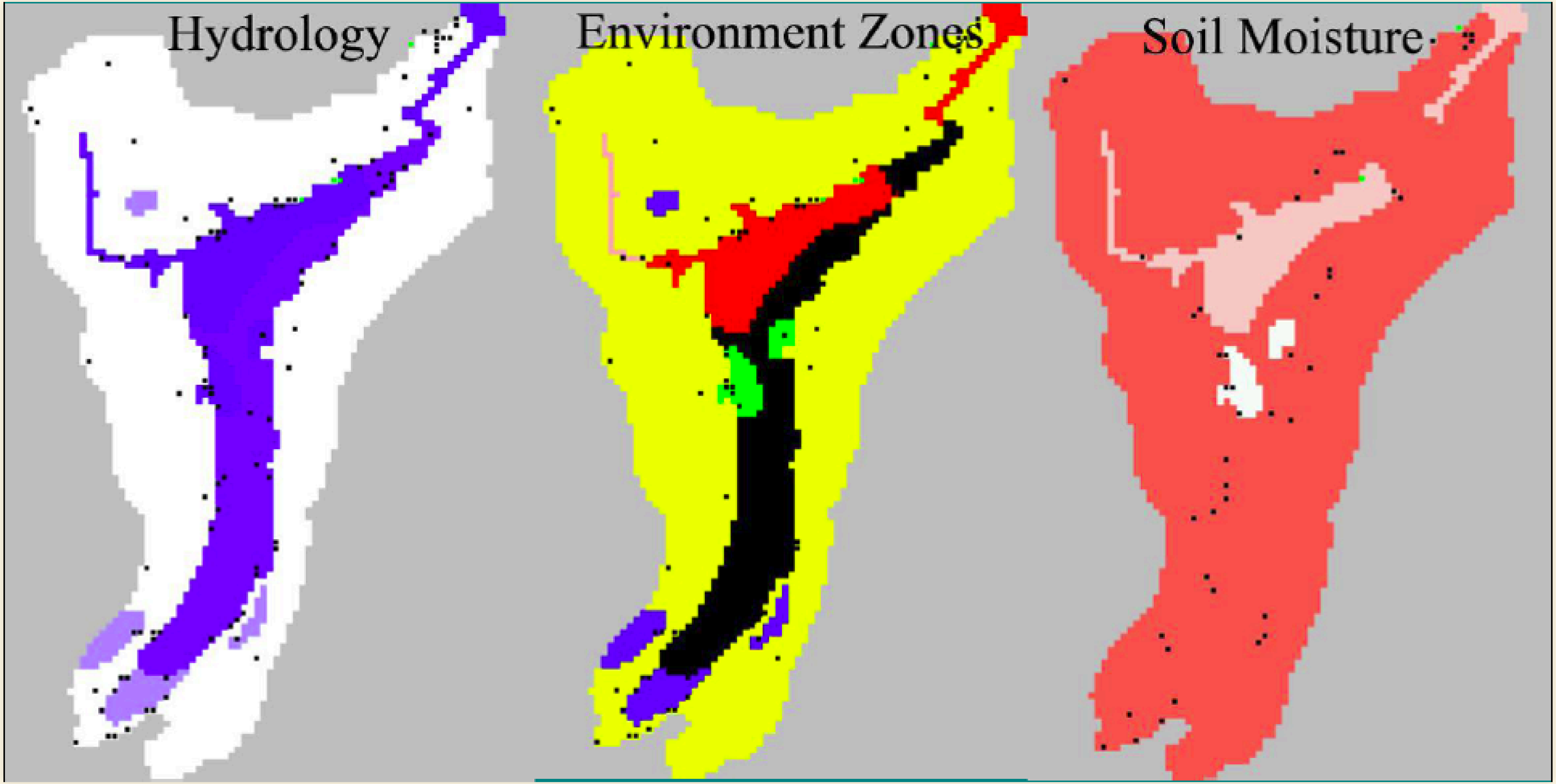
Artificial Anasazi

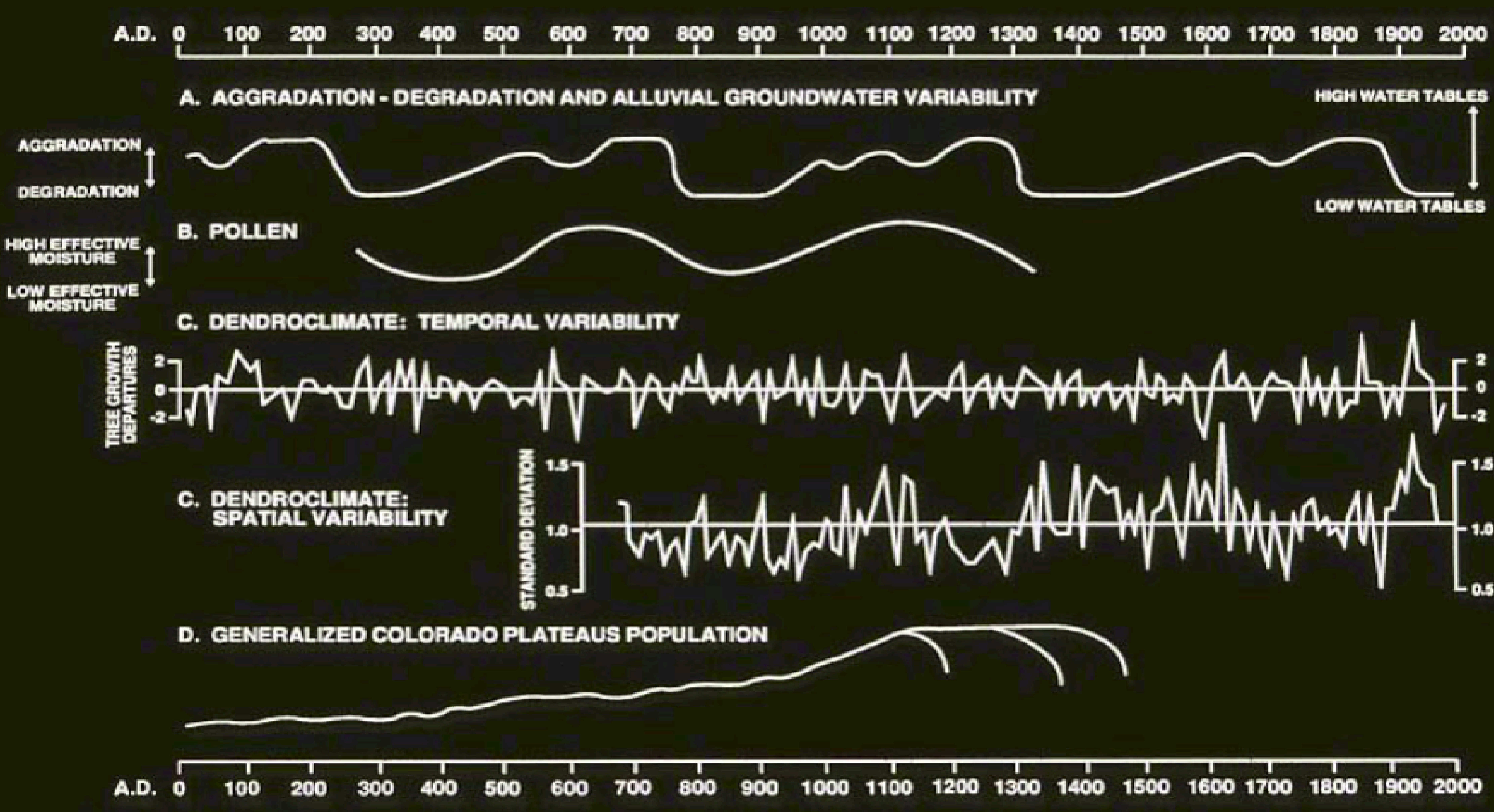
Example: Artificial Anasazi

Axtell, Dean, Epstein, *et al.*

Long House Valley (flourished ca. 1800 BCE–1300 CE)

Modeling Environment




A.D. 0 100 200 300 400 500 600 700 800 900 1000 1100 1200 1300 1400 1500 1600 1700 1800 1900 2000
A. AGGRADATION - DEGRADATION AND ALLUVIAL GROUNDWATER VARIABILITY
HIGH WATER TABLES
AGGRADATION
DEGRADATION
LOW WATER TABLES
B. POLLEN
HIGH EFFECTIVE MOISTURE
LOW EFFECTIVE MOISTURE
C. DENDROCLIMATE: TEMPORAL VARIABILITY
TREE GROWTH DEPARTURES
2
0
-2
C. DENDROCLIMATE: SPATIAL VARIABILITY
STANDARD DEVIATION
1.5
1.0
0.5
D. GENERALIZED COLORADO PLATEAUS POPULATION
A.D. 0 100 200 300 400 500 600 700 800 900 1000 1100 1200 1300 1400 1500 1600 1700 1800 1900 2000

Constructing model

- Paleoclimate:
  - Assess different kinds of soil
  - Assess tree rings, pollen, etc.
  - Reconstruct drought severity index
- Society:
  - Archaeology gives #, location of households
- Make assumptions about:
  - # people per household,
  - Agriculture,
  - …
- Devise rules for behavior:
  - Marriage, reproduction, migration, …
- Simulate years 800–1300

Results

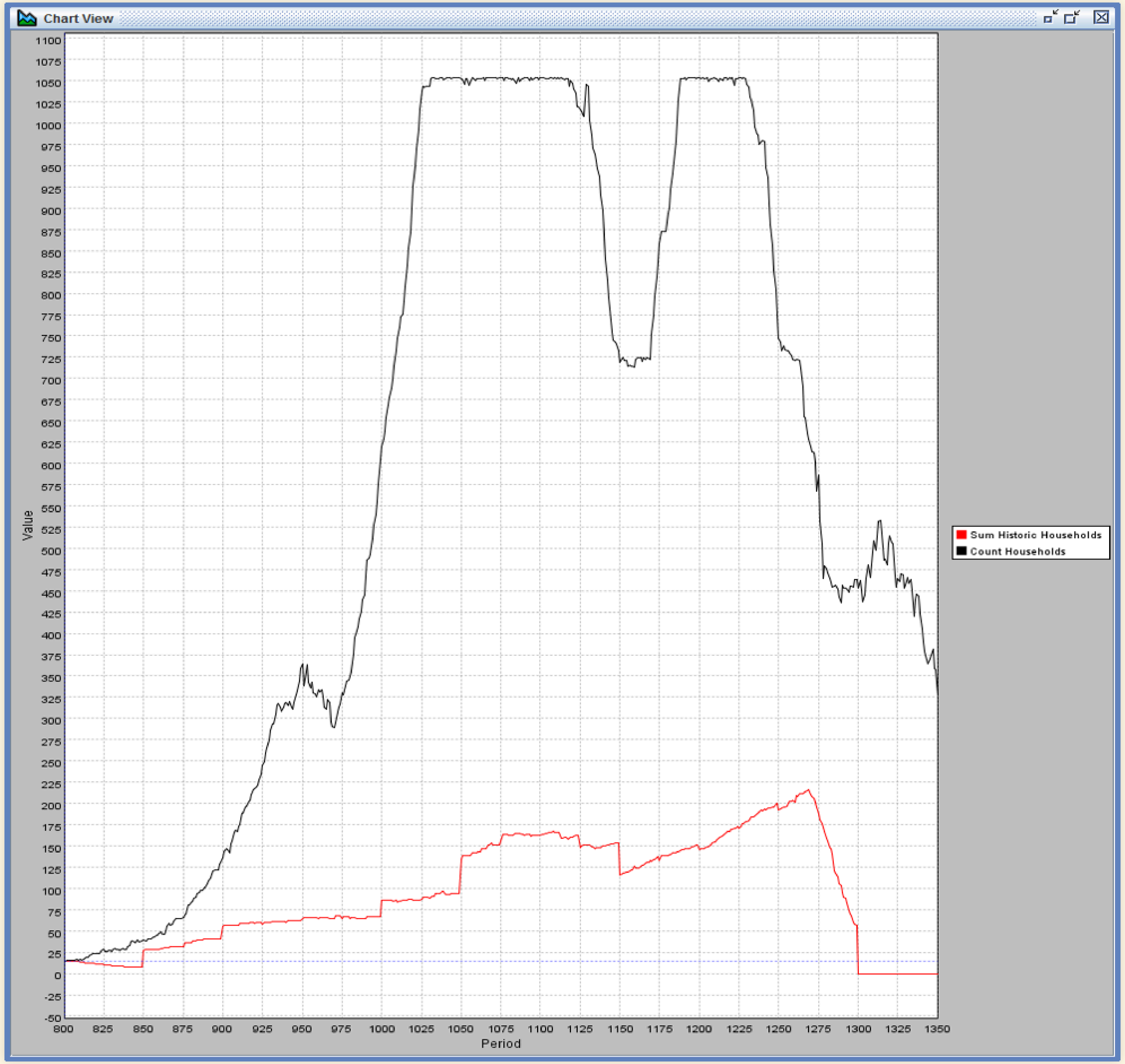
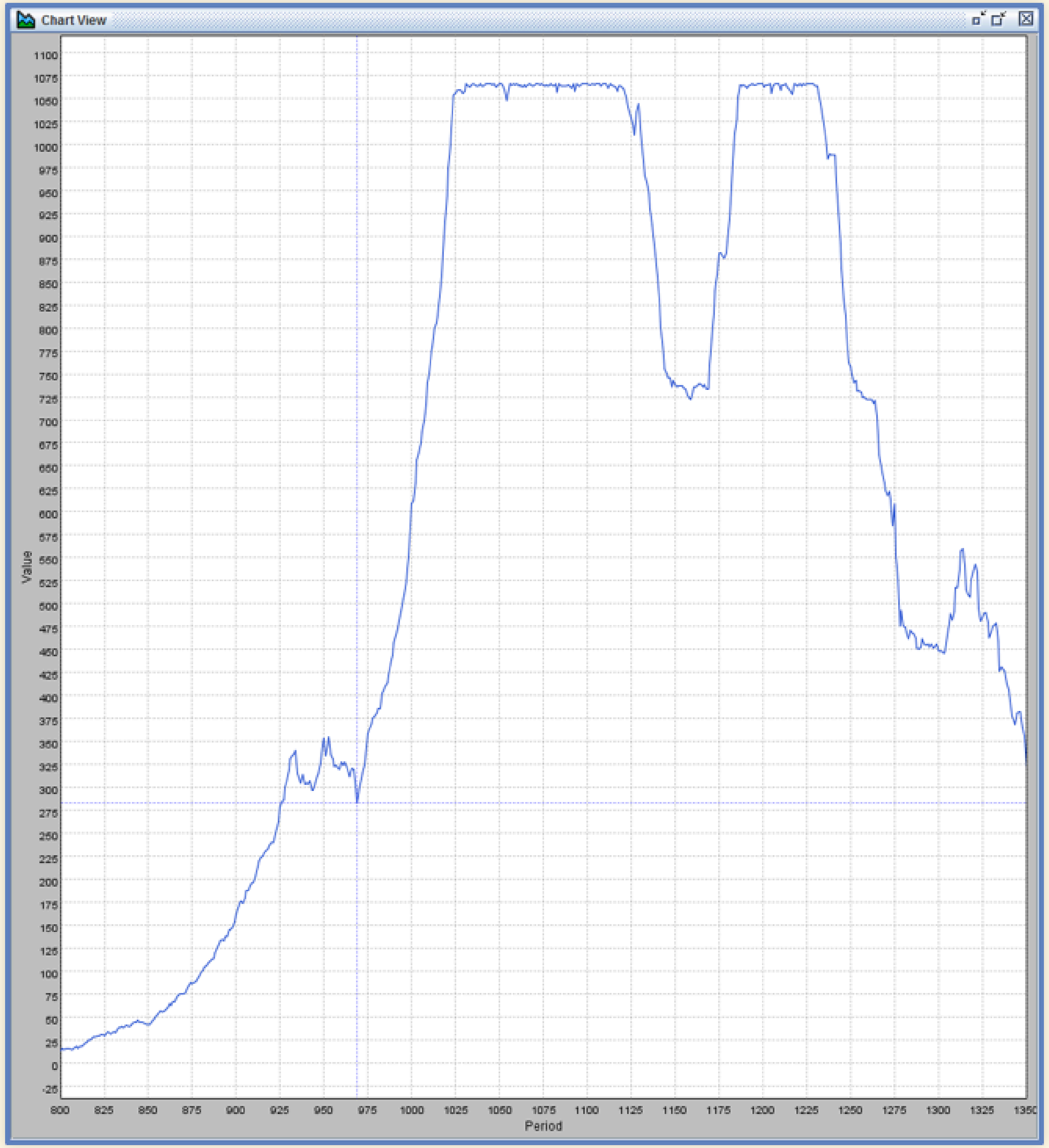


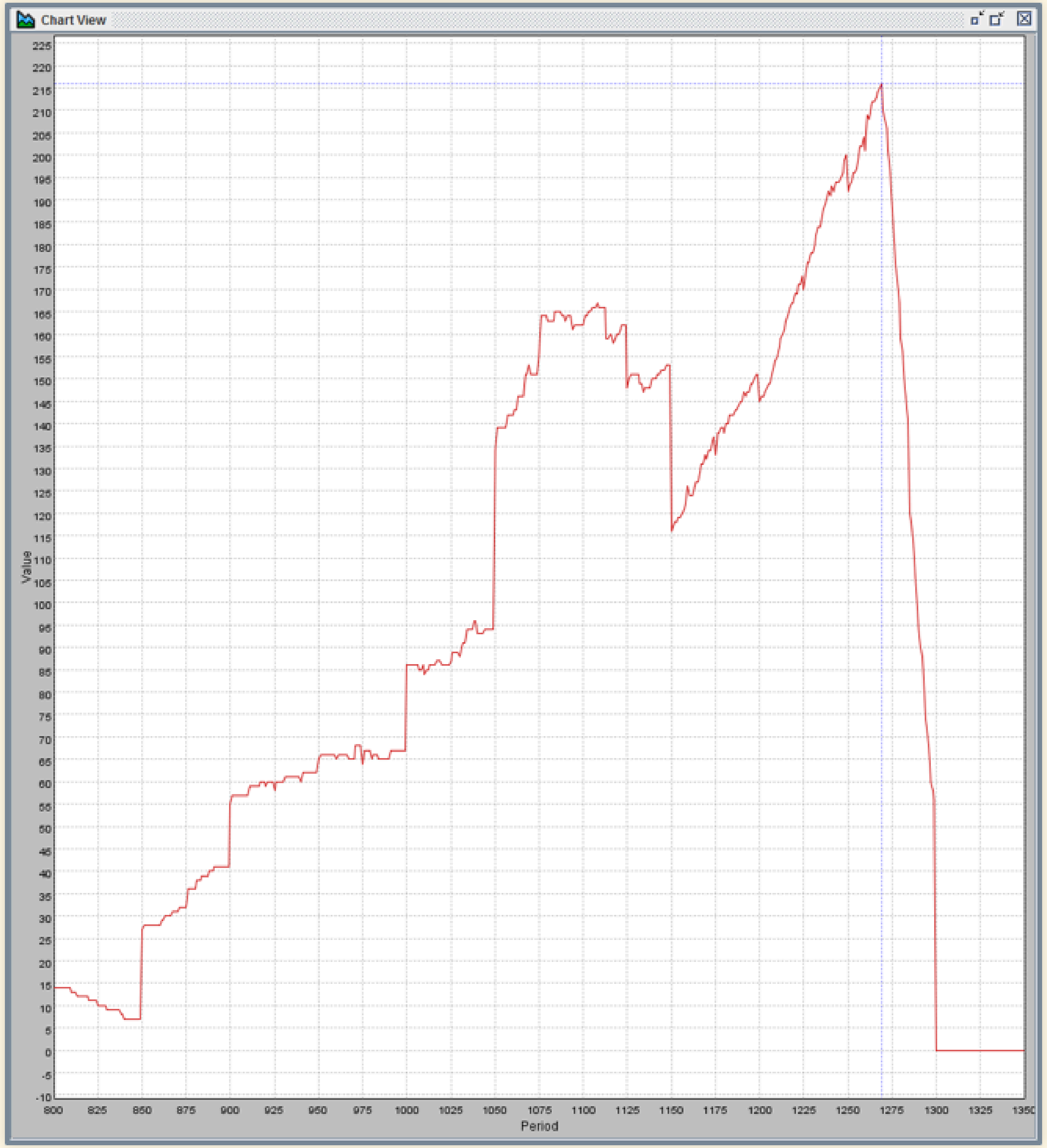
Chart View
Value
Period
Sum Historic Households
Count Households

Comparison

Simulated



Historical



Improvements

- Make agents heterogeneous
- Fit parameters to historical data

Results

Chart View
Value
Period
Sum Historic Households
Count Households