



SOCIAL / INSTITUTIONAL SIMULATION  
AND INNOVATION DYNAMICS

# A Simulation Model for Historical Evolution of Geopolitical Entities

Andrea Agosta

School of Industrial Engineering, LIUC - Carlo  
Cattaneo University, Castellanza, Italy  
Intelligence, Complexity and Technology Lab  
(ICT Lab), LIUC - Carlo Cattaneo University



# Modeling historical territorial dynamics is challenging

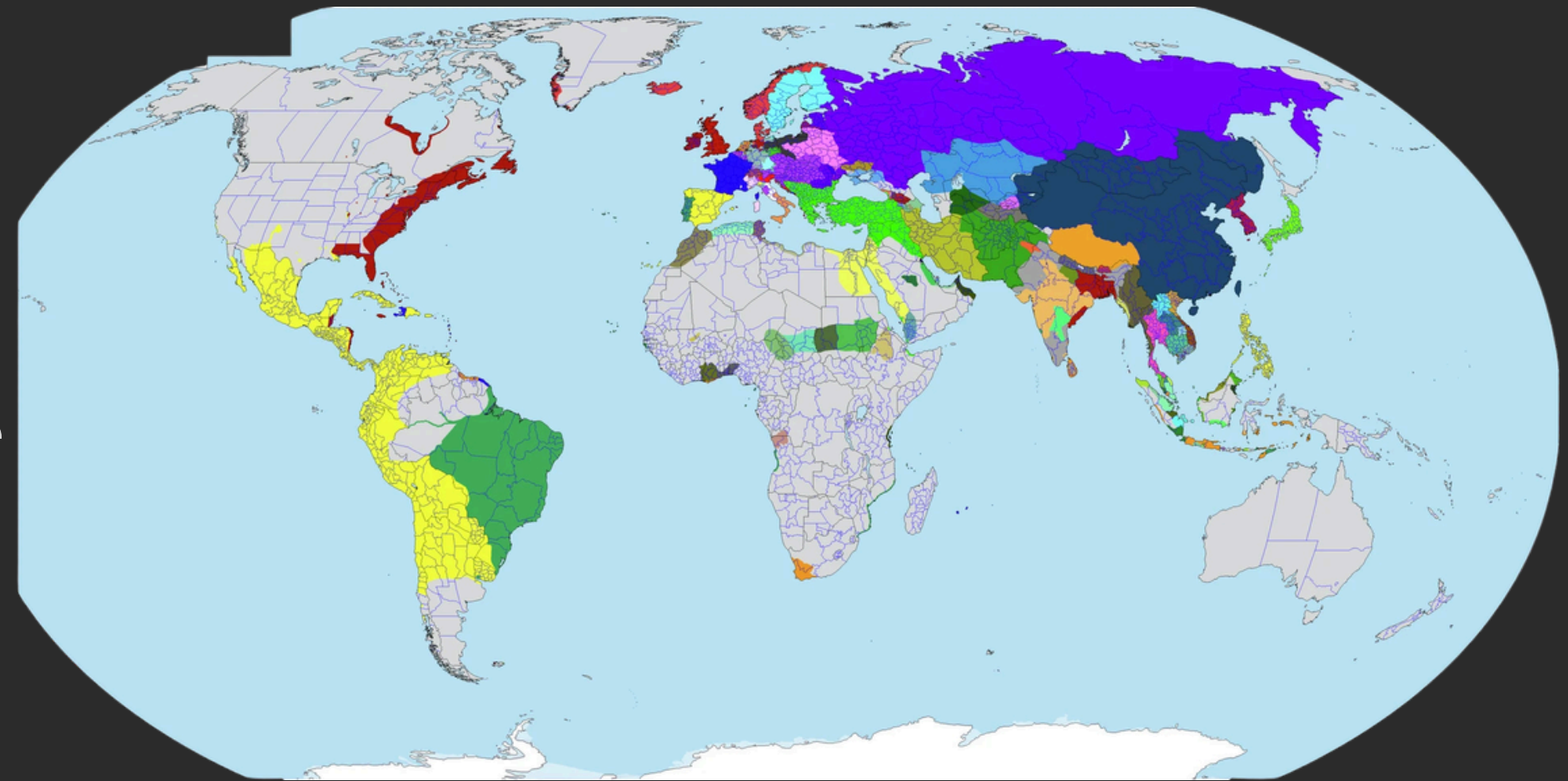
- The temporal evolution of territorial control is a key signature of long-term social dynamics
- Historical territorial series exhibit complex temporal patterns
- Until recently, systematic data were scarce
- Mechanistic explanations are often over-specified



# Cliopatra Dataset



- The Cliopatra dataset provides time-indexed territorial data
- Polygon geometries allow surface reconstruction
- We can now build large historical time series
- Enables testing minimal generative hypotheses



# Can simple dynamics explain historical territorial change?

## Creation



Two-regime stochastic generative model specified

## Calibration



Model parameters automatically tuned via genetic algorithm

## Validation

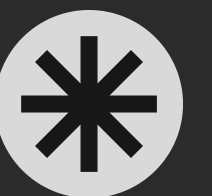


Simulated and empirical patterns compared at multiple scales

## Results

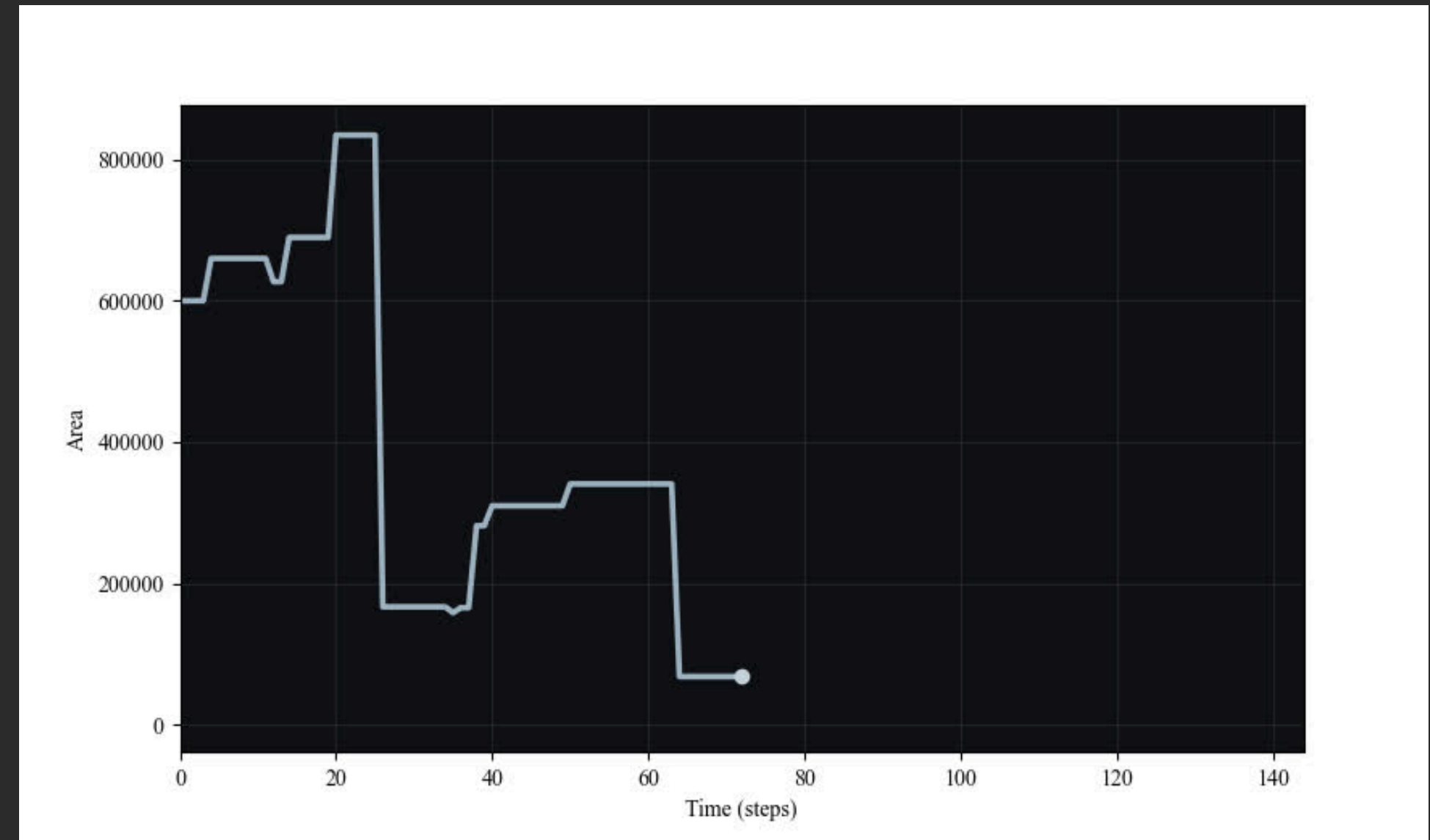


Minimal stochastic dynamics reproduce the observed macro-patterns



# Generative Model

- Territorial time series may exhibit both small and large deviations
- These occur with different probabilities during both expansion and contraction phases

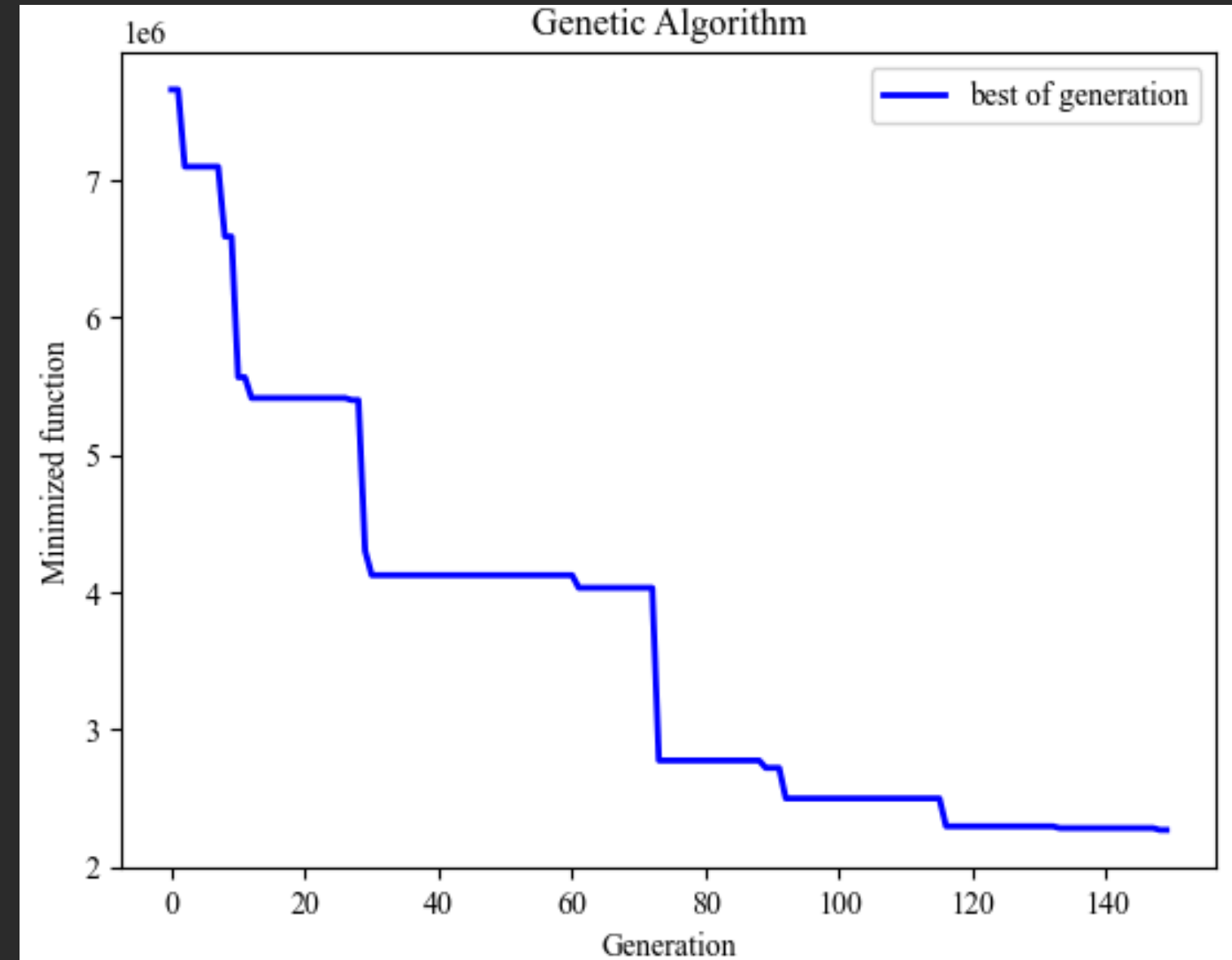


A two-regime stochastic process is assumed



# Model calibration

- Model parameters were calibrated to empirical data
- Calibration performed via genetic algorithm optimization
- Objective was to identify parameter sets reproducing observed statistical patterns



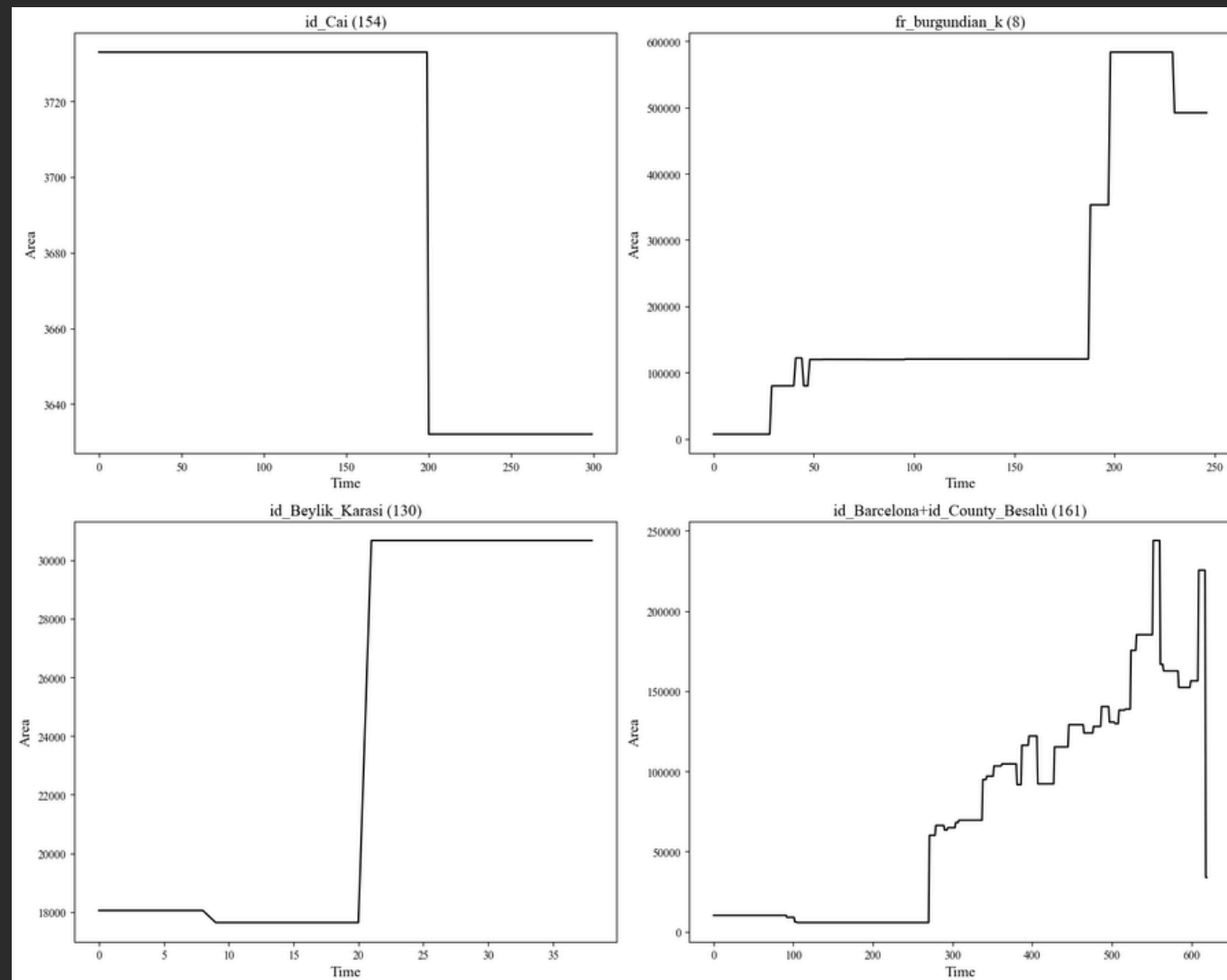
# Model Validation

- Empirical distributions of key territorial statistics were computed
- The generative model was used to simulate large ensembles of synthetic series
- Validation assesses whether the model reproduces the relevant empirical patterns
- The goal is not to match individual histories but to reproduce the correct statistical regularities

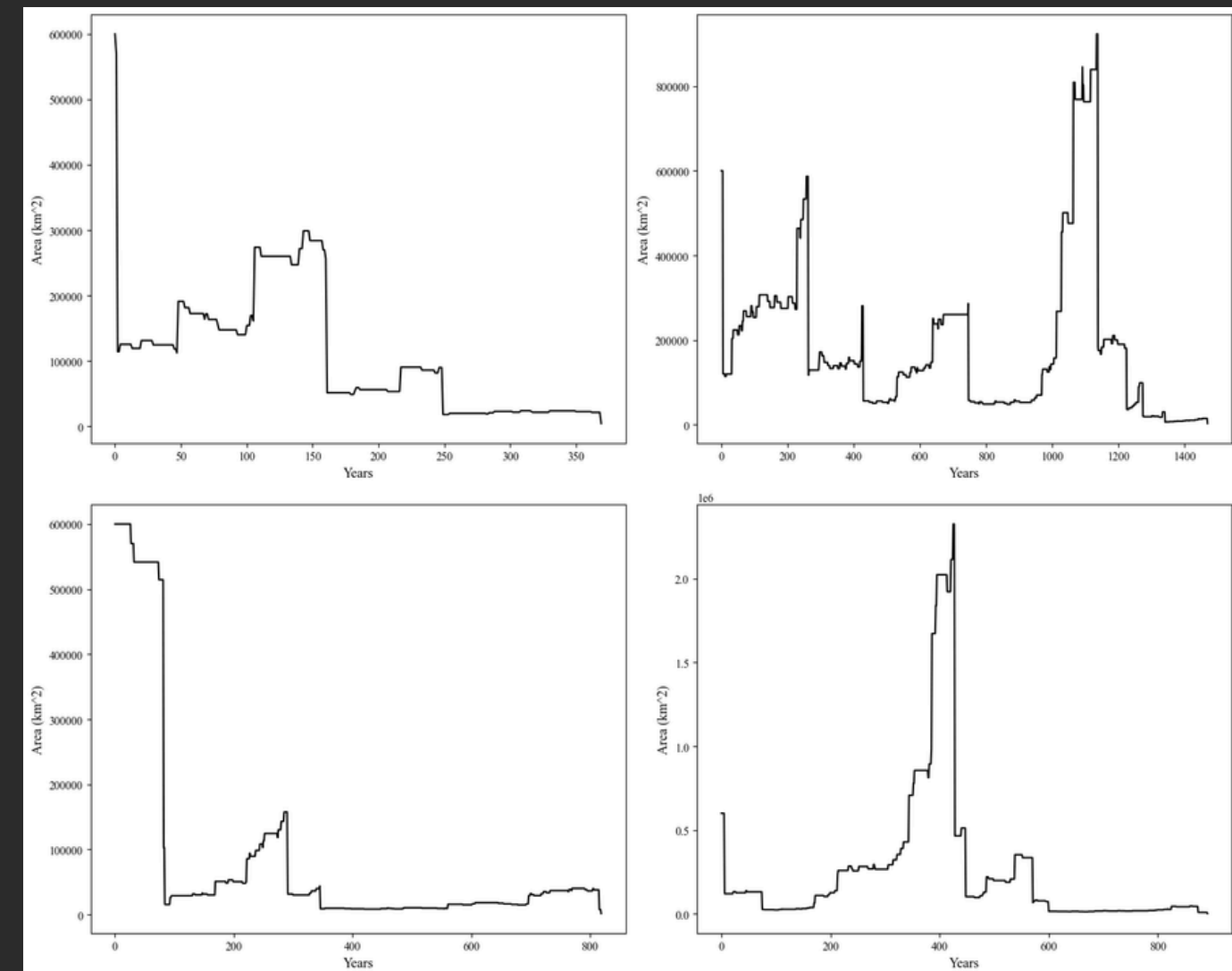
# Trajectory-level comparison

- Compare simulated and empirical time series
- Assess similarity in overall temporal behavior
- Focus on qualitative pattern reproduction

real time series



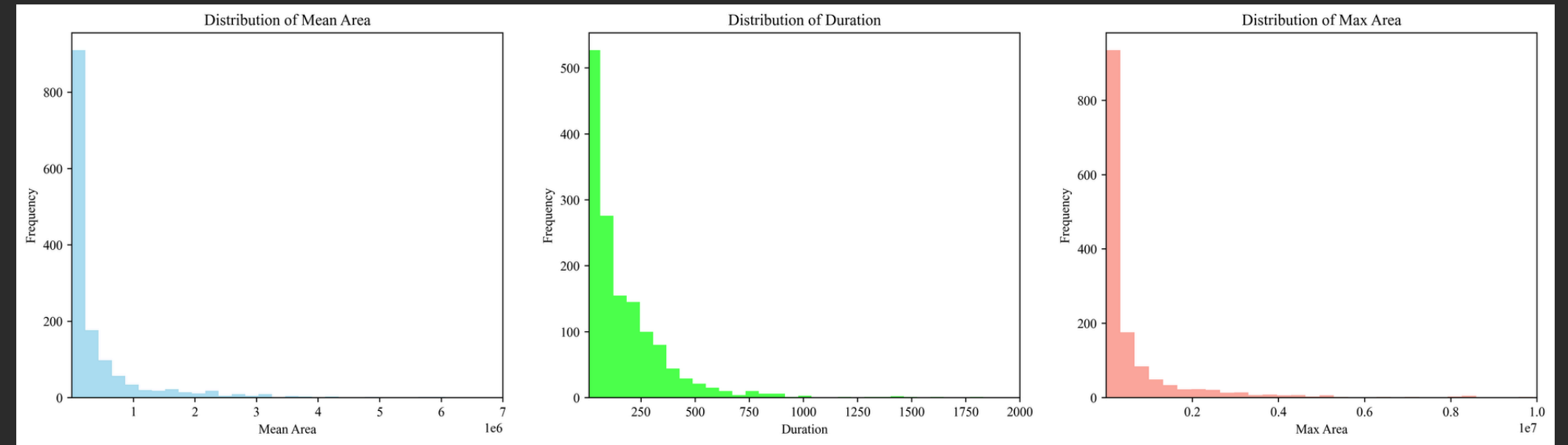
simulated time series



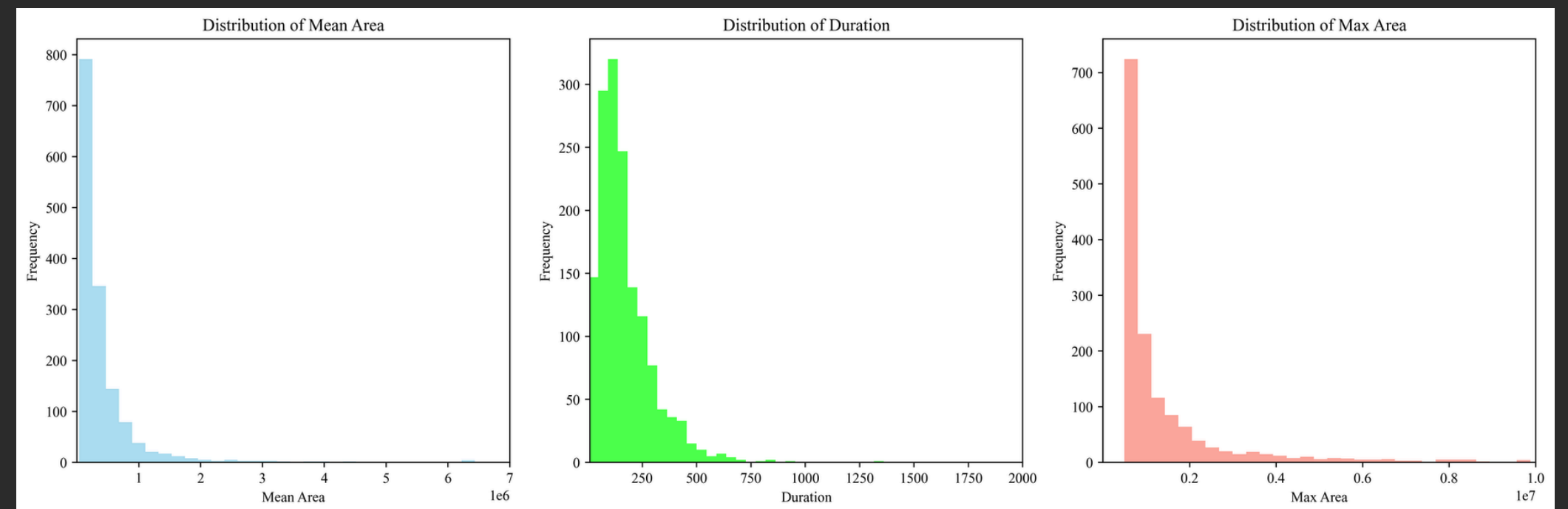
# Distributional validation

- Compute key statistics from historical series
- Compare empirical vs simulated statistical distributions
- Evaluate consistency at the aggregate level

Distribution time series real



Distribution time series simulated



# Key Findings

## 01 **Qualitative trajectory match**

Simulated trajectories reproduce the qualitative behavior of historical series

## 02 **Aggregate distribution alignment**

The model captures the empirical distributions of mean area, duration, and maximum extent

## 03 **Minimal mechanism sufficiency**

A minimal two-regime stochastic process is sufficient to reproduce the observed patterns

## 04 **Emergent distributional structure**

Negative exponential distributions emerge endogenously

# Limitations

- The model does not identify the real causal mechanisms behind territorial change
- The framework is not intended for forecasting growth or decline
- The model captures patterns through simplified stochastic dynamics
- Territorial change is reduced to frequent small variations and rare large shocks

# Implications and Future works

- Complex macro-patterns may arise from simple micro-variations
- The model provides an explanatory baseline rather than a predictive tool
- Results support an emergent interpretation of territorial dynamic

For the future...

- Match individual historical series with closest simulated counterparts
- Quantify distance between real and simulated trajectories



# Any Questions?

THANK YOU!

Andrea Agosta, Federico Carucci, Sabin Roman, Francesco Bertolotti

Affiliation: School of Industrial Engineering, LIUC - Carlo Cattaneo University,  
Castellanza, Italy Intelligence, Complexity and Technology Lab (ICT Lab), LIUC - Carlo  
Cattaneo University, Castellanza, Italy