Computer Assisted Agent-Based Modeling for Intelligence Purposes: The Actual, the Probable, the Plausible, and the Impossible

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Technology for the United States Navy and Marine Corps, 2000-2035 Becoming a 21st-Century Force: Volume 9: Modeling and Simulation

Product of an 18-month study requested by the Chief of Naval Operations, who in 1995 asked the National Research Council to initiate through its Naval Studies Board a thorough examination of the impact of advancing technology on the form and capability of the naval forces to the year 2035."

"Agent-based modeling and generative analysis. **Some of the most interesting new forms of modeling involve so-called "agent-based systems" in which low-level entities with relatively simple attributes and behaviors can collectively produce (or "generate") complex and realistic "emergent" system behaviors. This is potentially a powerful approach to understanding complex adaptive systems generally—in fields as diverse as ecology, economics, and military command control."**
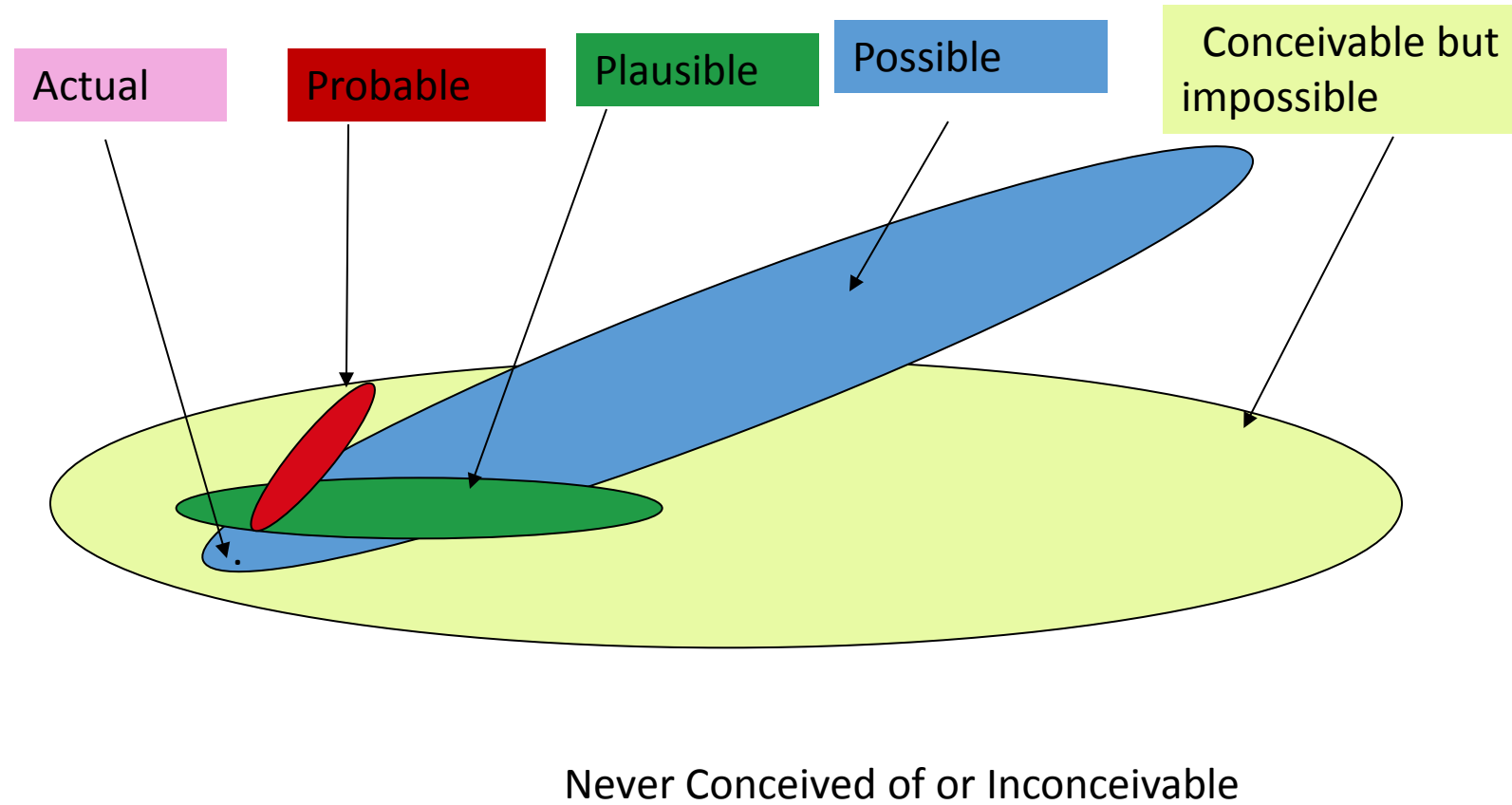
The Study's Forecasts Related to M&S

• By 2005, basic large-scale interoperability support.

• By 2010 to 2015, operationally robust support for large-scale maneuvers, including some agent-based mission-domain model checking.

• By 2015, credible simulation of combat operations before and during combat, including two-sided information warfare simulation.

• Greatly improved semi-automated forces (SAFOR).

• Speech- and natural-language interfaces to M&S.

• Agent-based mediation of input and output and of system configuration when constructing M&S for a given purpose.

• Greatly improved virtual reality systems with three dimensions and tactile and auditory stimuli. Users will enter the virtual reality and alter parameters."

There have now been a number of model developments, notably
in the United States and Germany, that have advanced the state of the art in such matters. **In the decades ahead, this agent-based modeling will improve greatly—given adequate support and high enough standards**. At present, many workers are pleased when the models represent stereotyped doctrinal tactics at low levels, but, with time, the models will become increasingly adaptive and will probably have "learning capability."
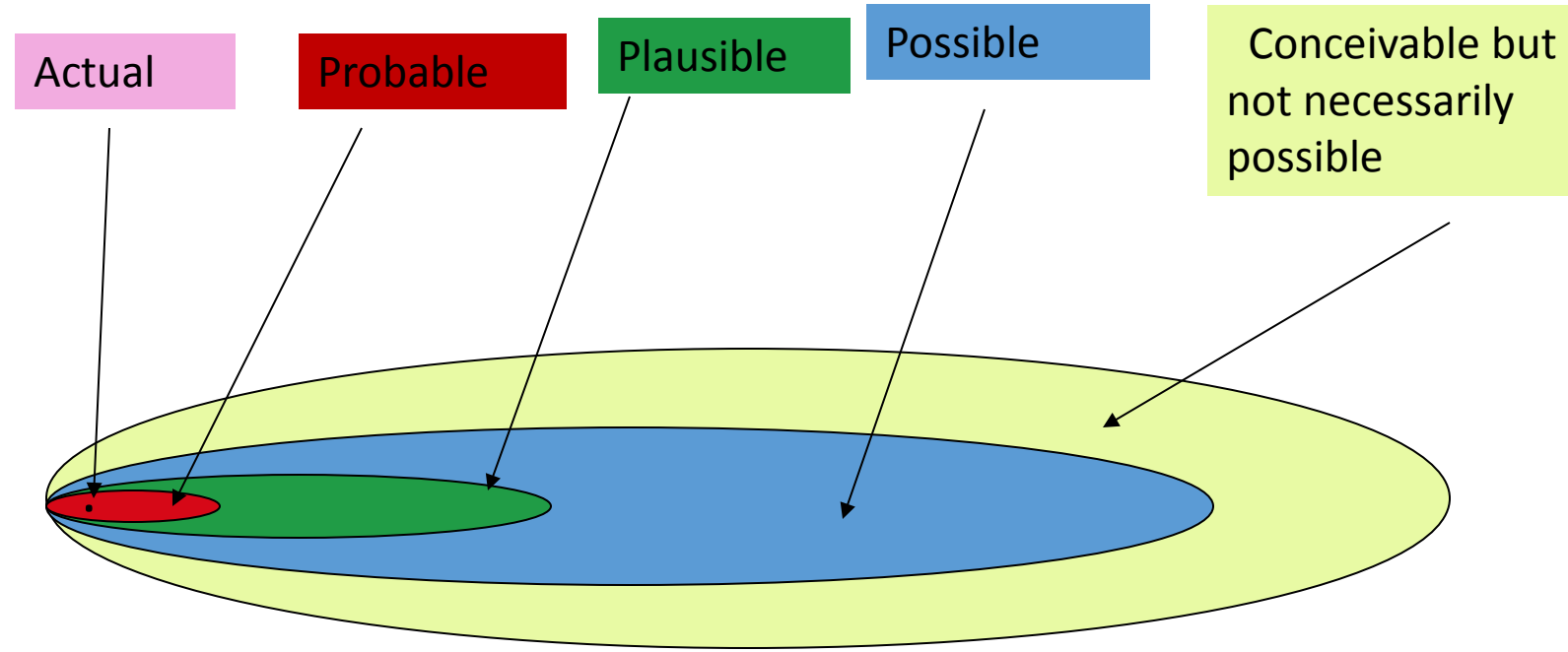
Why has ABM in the domain of the social sciences been so slow and so unsuccessful compared to its promise?

- Computer Science Legacy
  - Programming imagined to be necessary
  - Uncoupled from domain knowledge
  - Uninformed by corroborated social science theory
- KISS (Keep It Simple Stupid) Robert Axelrod
- Conservatism of the Academy
  - Stranded on local maxima
  - Misconceptions about what "formal modeling" means
- Validation challenges when the targets for forecasting are rare and interesting (a distribution of the possible), rather than convenient (point predictions of commonly occurring events)

How Accurate is Our Map of the Future?

Actual

Probable

Plausible

Possible

Conceivable but impossible

Never Conceived of or Inconceivable

A Proper Aspiration for Imagining the Future

Actual

Probable

Plausible

Possible

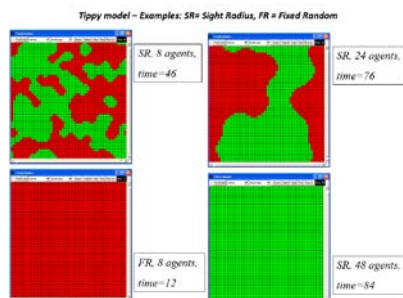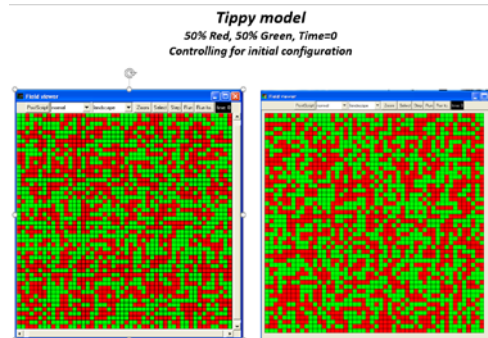Conceivable but not necessarily possible

Never Conceived of or Inconceivable

Except for the actual, all possible worlds/outcomes (past or future) are counterfactuals.

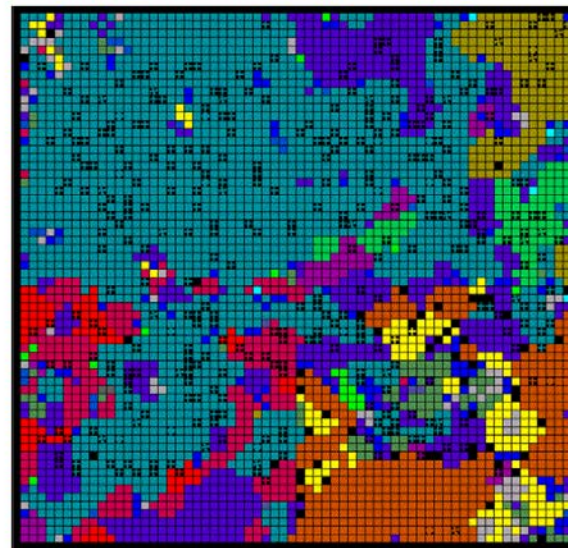# Titrating Complexity in Agent-Based Models

- Algebraic Formal Models must be simple, therefore research design is straightforward

- ABM formal models can be complex, so research design (how much complexity to include) is not straight-forward; more similar to the challenges of non-formal research

- Three kinds of studies with ABM:
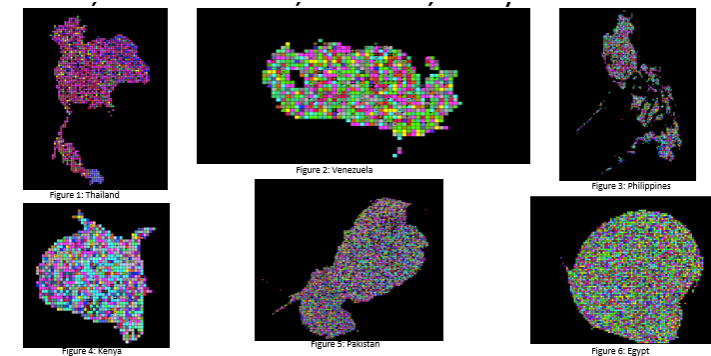
Abstractions   **Ensemble/Generic**   **Virtualization**

Tippy model
50% Red, 50% Green, Time=0
Controlling for initial configuration

Tippy model – Examples: SR= Sight Radius, FR = Fixed Random

SR. 8 agents, time=46
SR. 24 agents, time=76

FR. 8 agents, time=12
SR. 48 agents, time=84

Beita: Coding Secession: Not Secession

No Secession

Figure 1: Thailand
Figure 2: Venezuela
Figure 3: Philippines
Figure 4: Kenya
Figure 5: Pakistan
Figure 6: Egypt
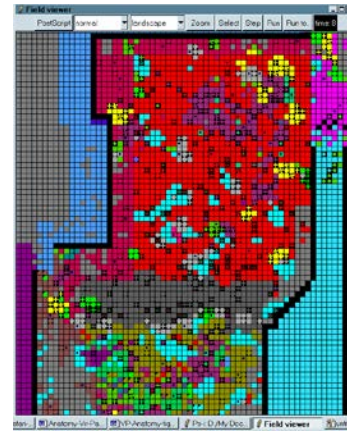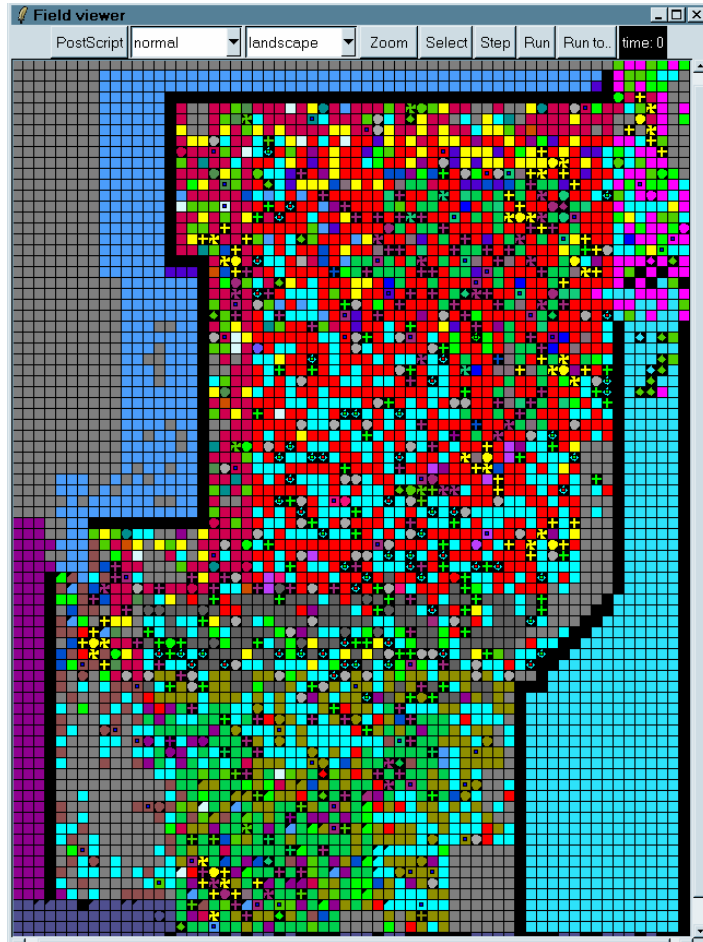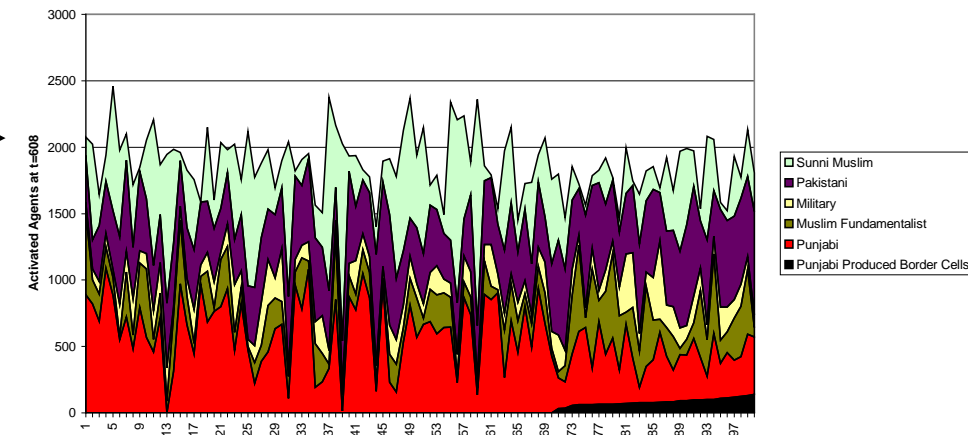
Virtual Pakistan runs forward repeatedly, perturbed randomly during trajectory in time perturbed randomly
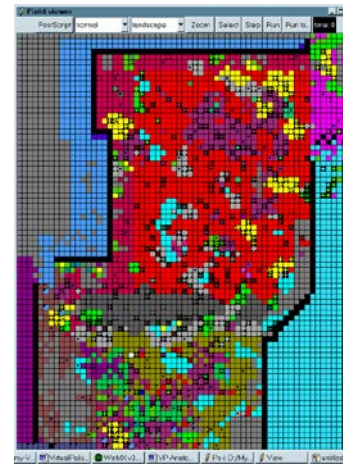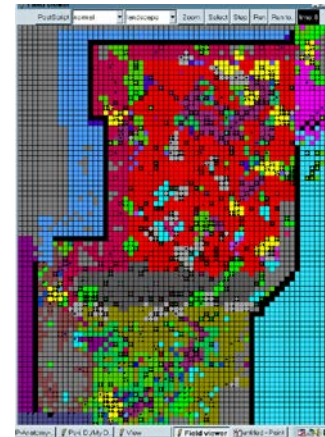
Statistical analysis on hundreds or thousands of alternative possible futures to map the space of the future and identify patterns

Prevalence of Selected Identities: Sorted by Punjabi Secessionism
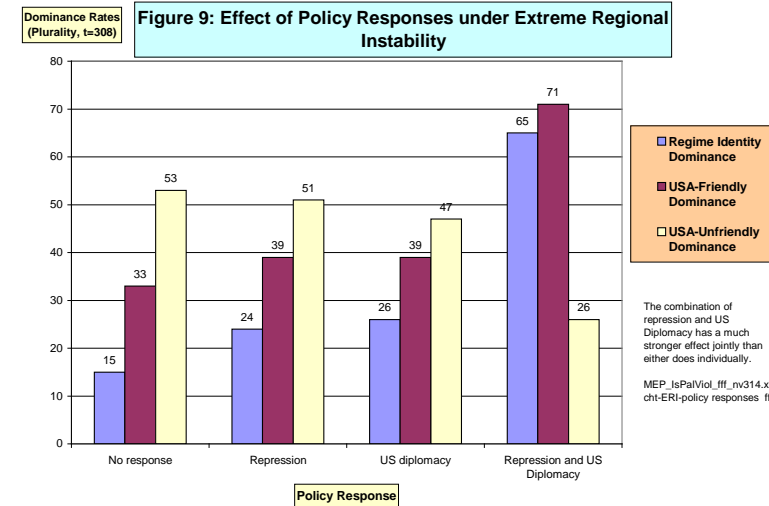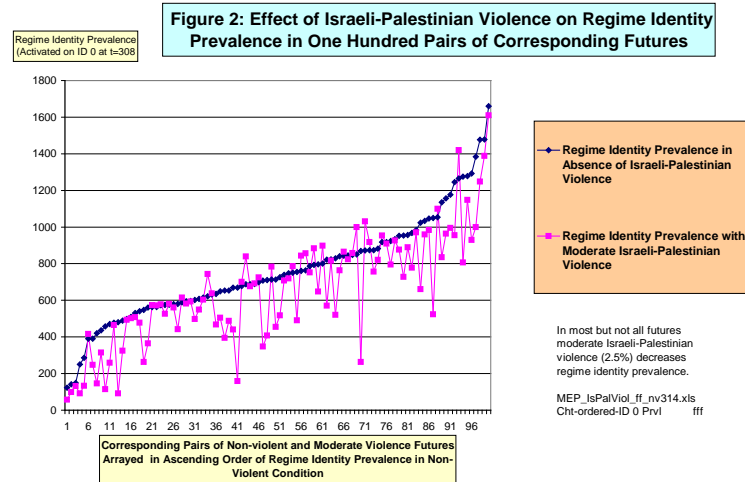
- Sunni Muslim
- Pakistani
- Military
- Muslim Fundamentalist
- Punjabi
- Punjabi Produced Border Cells

Punjabi secessionism as rare but possible and more likely when Pakistan is ruled by coalition of strong statists and Islamists

Illustrations of USG Taskings for Generic and Virtualization Models

- 2001-02: What is the relative likelihood of grossly different futures for Pakistan over the next 2-3 years? What is the likelihood of a severe breakdown in nuclear technology C and C?

- 2002: What would the effect be on USA-Friendly Middle Eastern regimes of different levels of Israel-Palestinian violence or regional violence?

- 2007-2013: How are probabilities changing for high impact instability events distributed across the future of countries such as Pakistan, Bangladesh, Venezuela, Thailand, Indonesia, Philippines?

- 2011: What effect will be associated with the death of the King of Thailand under different general circumstances in Thailand?

- 2011: What effects on ISAF success would accompany arming the tribes in Kunduz and Kandahar?

- 2013: What effects will the death of Chavez have on Venezuelan politics?

- 2013: What policies will be more likely to foster stability and democracy in Bangladesh re holding elections under the auspices of a caretaker government, or under an Awami League government?

- 2015: How do combinations and sequences of tactics and circumstances affect the number and success of insurgent IED attacks?

- 2015-16: What difference does it make if ISIS is understood as an authentic Jihadi movement as opposed to a Stasi-like gang?

Varieties of Visualized Model Output for Users

Figure 2: Effect of Israeli-Palestinian Violence on Regime Identity Prevalence in One Hundred Pairs of Corresponding Futures

Regime Identity Prevalence (Activated on ID 0 at t=308)

- Regime Identity Prevalence in Absence of Israeli-Palestinian Violence
- Regime Identity Prevalence with Moderate Israeli-Palestinian Violence

In most but not all futures moderate Israeli-Palestinian violence (2.5%) decreases regime identity prevalence.

MEP_IsPalViol_ff_nv314.xls
Cht-ordered-ID 0 PrvI   fff

Corresponding Pairs of Non-violent and Moderate Violence Futures Arrayed in Ascending Order of Regime Identity Prevalence in Non-Violent Condition

Figure 9: Effect of Policy Responses under Extreme Regional Instability

Dominance Rates (Plurality, t=308)

- Regime Identity Dominance
- USA-Friendly Dominance
- USA-Unfriendly Dominance

The combination of repression and US Diplomacy has a much stronger effect jointly than either does individually.

MEP_IsPalViol_fff_nv314.xls
cht-ERI-policy responses fff

Policy Response

Moderate levels of Israeli-Palestinian Violence tend to destabilize USA-Friendly, Semi-Authoritarian Muslim regimes in the region, but not under all conditions.

The combination of US diplomacy on the Arab-Israeli issue plus Arab state repression has a more potent and positive effect than either strategy applied separately.
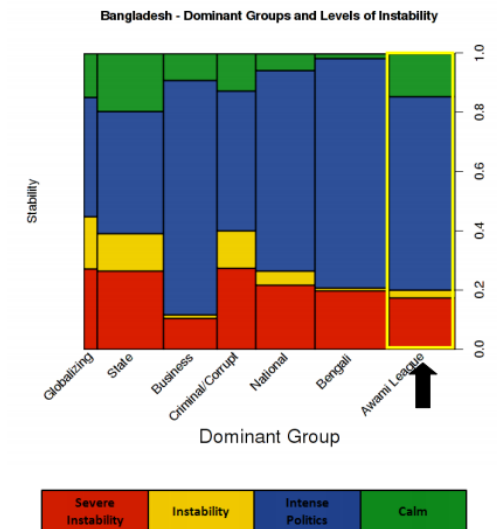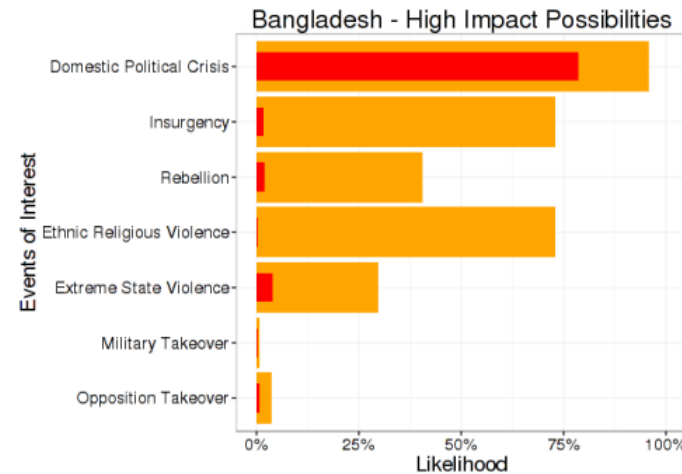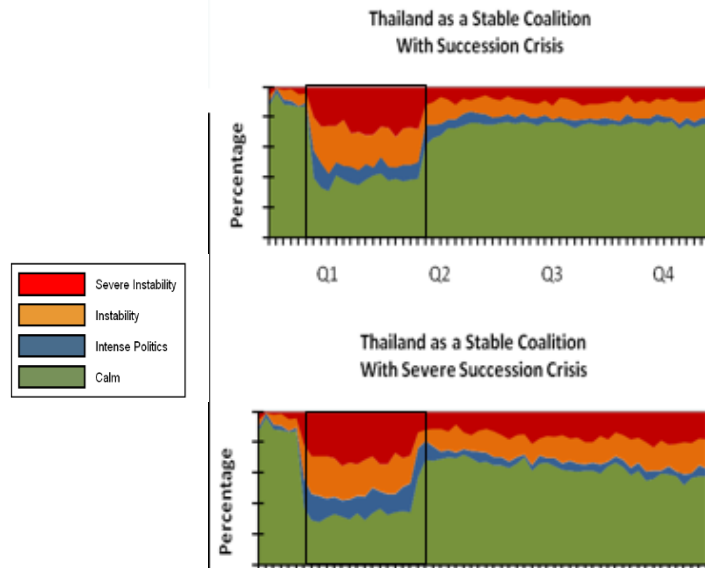

Thailand as a Stable Coalition With Succession Crisis

Thailand as a Stable Coalition With Severe Succession Crisis

- Severe Instability
- Instability
- Intense Politics
- Calm

Bangladesh - High Impact Possibilities

Bangladesh - Dominant Groups and Levels of Instability

- Severe Instability
- Instability
- Intense Politics
- Calm

Figure 3: Baseline results, with Awami League government subset highlighted.
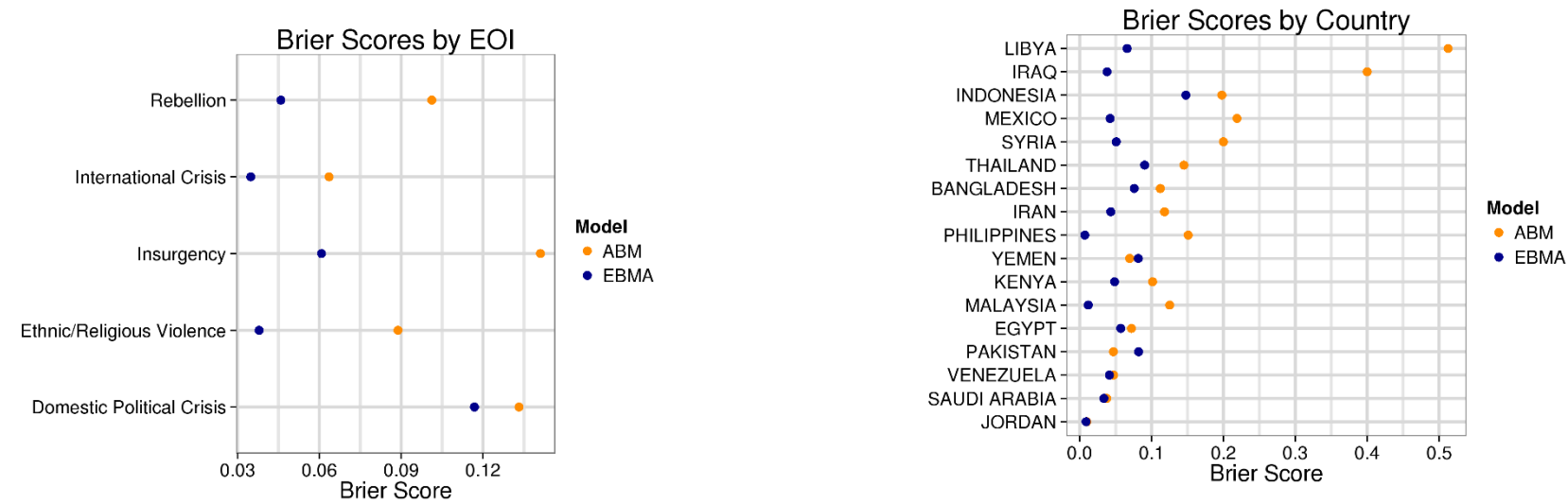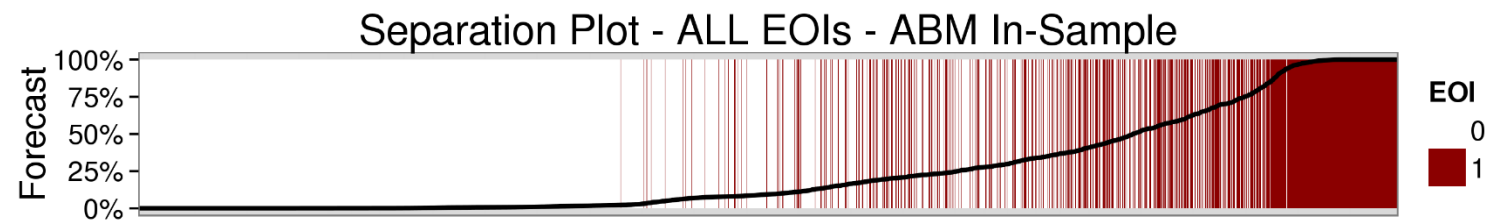
Validation via Distributions

Brier Scores by EOI

Brier Scores by Country

Figure 10: Brier scores by EOI and Country, broken down by the ABM and EBMA results

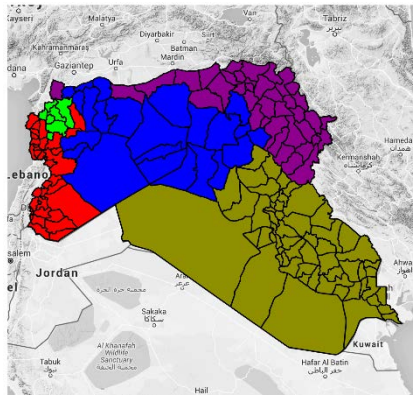Separation Plot - ALL EOIs - ABM In-Sample

In the separation plots above, each rectangular unit represents one country-month forecast. The forecasts are sorted from left to right based on the forecasted probability of an event occurring. The black line indicates the probability of event occurrence for each country-month forecast. The rectangular units are colored based on whether an event actually occurred in that month in that country (red) or did not occur (white).

EOI's:
- Domestic Political Crisis
- Insurgency
- Rebellion
- Ethno-Religious Violence

A Computational Model of ISIS (or Anything) Requires

- Identifying, mobilizing, and harnessing scientific knowledge about the **kind of thing** we are interested in:
  - Stability and group dynamics in a weakly organized and inter-penetrated political space
- About the kind of **processes** most powerfully at work:
  - federated theories operationalized within the V-SAFT model modules
    - generic political model
    - dynamic political hierarchy
- Acquiring and inputting real **data**
  - geospatial, demographic, cultural, political, military, leadership.
- Providing a realistic and appropriately articulated dynamic **context** for the specific target problem: Syraq
- **Payoffs**
  - Recognition/familiarity
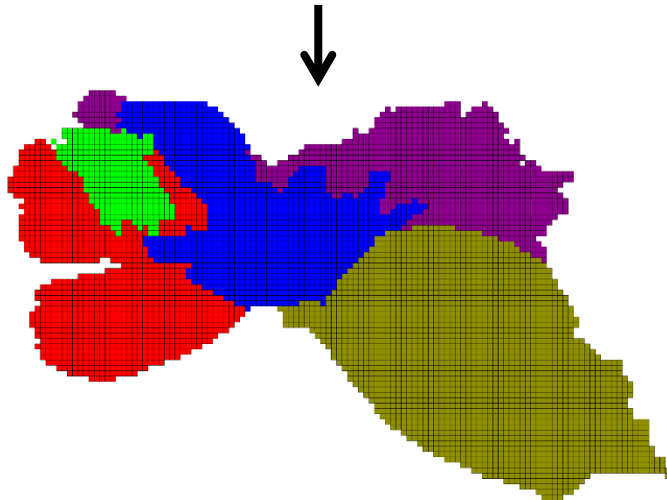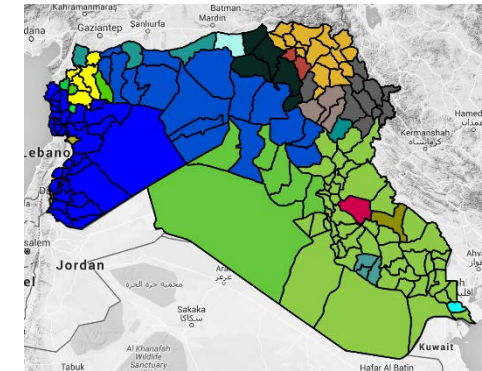 - Surprise/insight

Data Infusion and Model Building

- We then combine our data matrix output, population estimates, thickness scores, elite network linkages, and Wikipedia territory control maps into an agent-based model with about 5,200 agents, five DPH zones, and 53 identities.
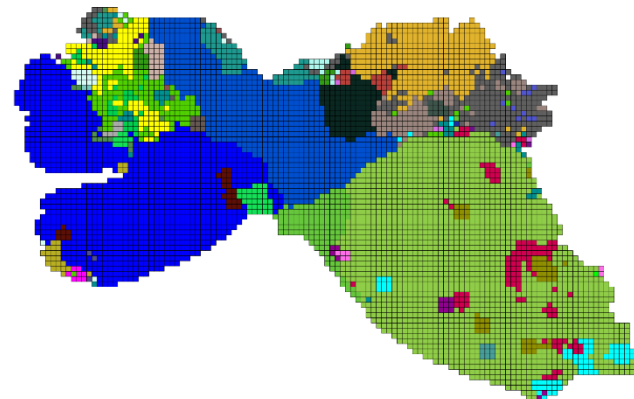

Most-common DPH Zones

Most Common Activation

Modal Activation

| Iraq_National | Citizens_Alliance |
Syria_State	Sadrist_Movement
Iraq_State	Mattahidoon
Iraq_Military	Iraqia
Arab	KDP
Kurd	PUK
Turkmen	Movement_for_Change
Druze	Shammar
Alawite	Ougaidat
Shia	Baggara
Sunni	Nuim
IS	Bani_Khaled
Islamic_Front	Hadidyn
Free_Syrian_Army	Ubayd
Southern_Front	Sharabia
Business	Dulaym
Globalizing	YPG
Corruption	Peshmerga
Labor	Al_Nusra_Front
Refugee	Hezbollah
State_of_Law	

Recognition/Familiarity: Pillars and Aprons - Cross-zone Attacks
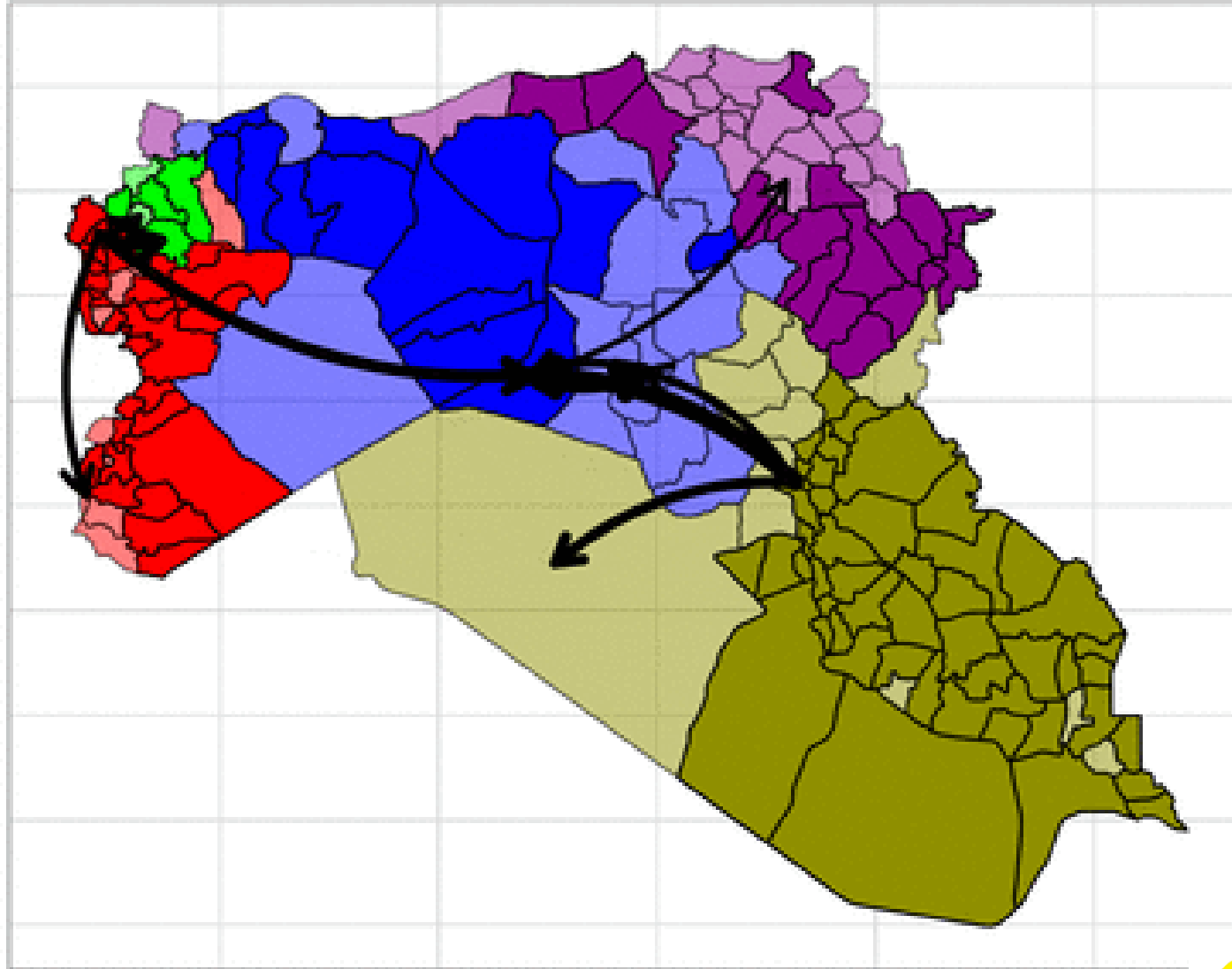
- This chart shows the average number of attacks carried out by each zone's pillar and apron. Light shades represent that zone's apron, and darker shades represent that zone's pillar.
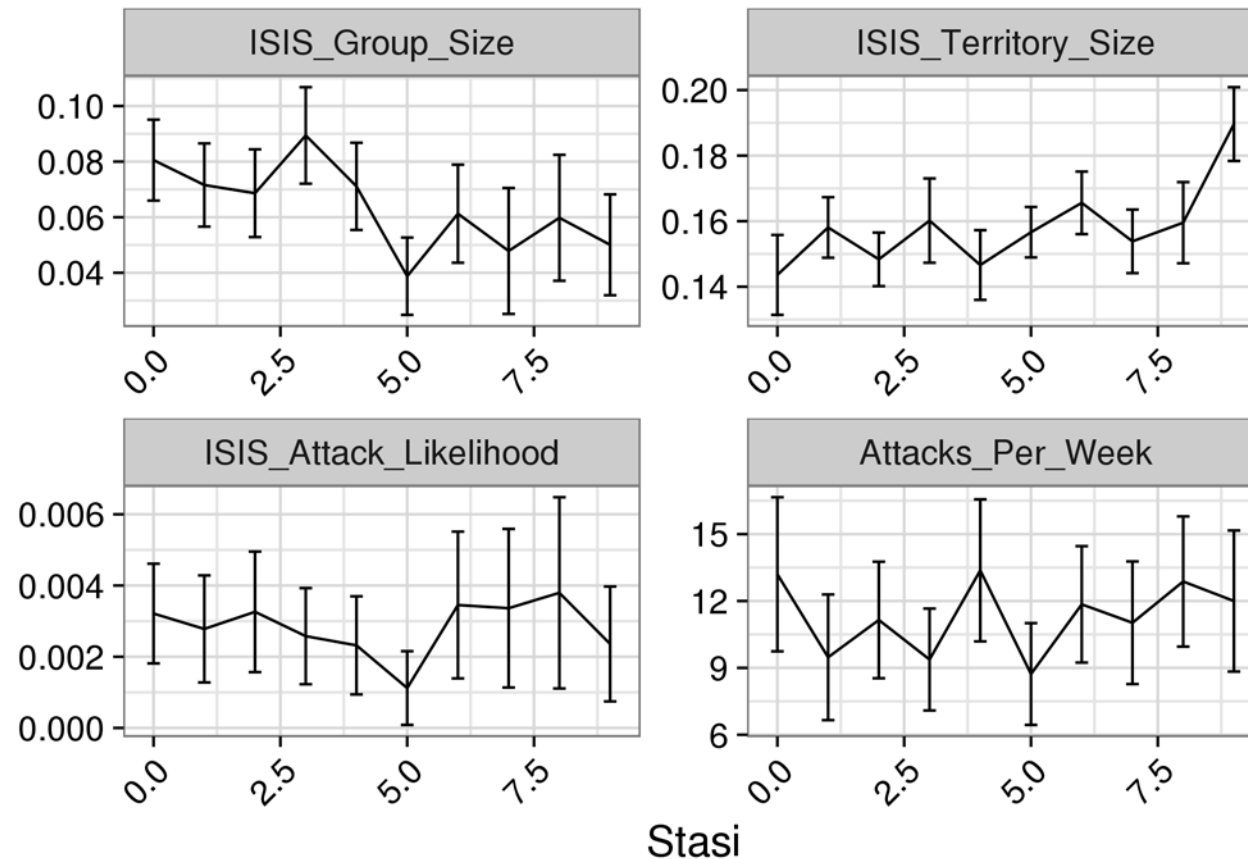- Thicker lines represent a higher average level of violence.

Average Attack Levels Between Zones
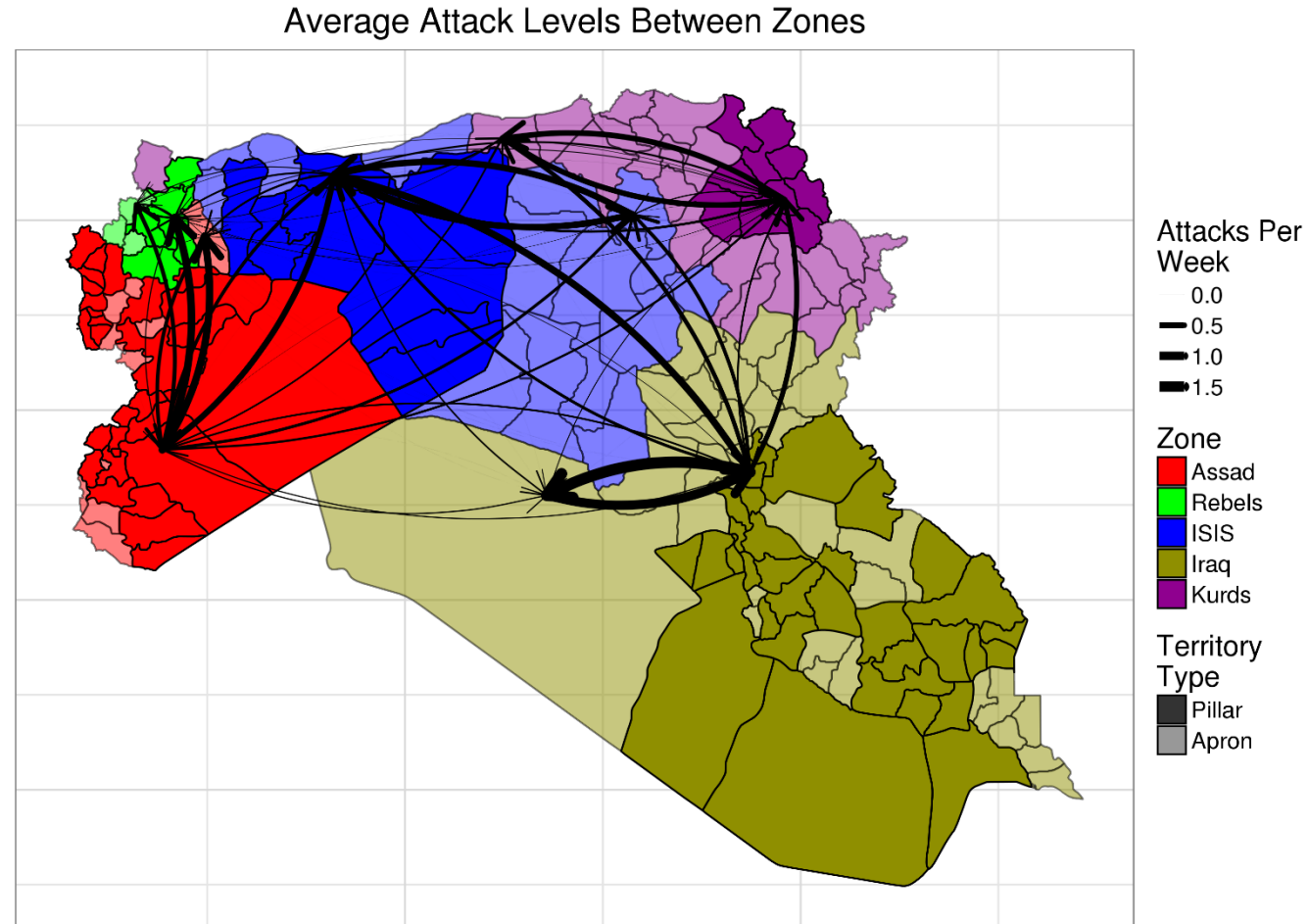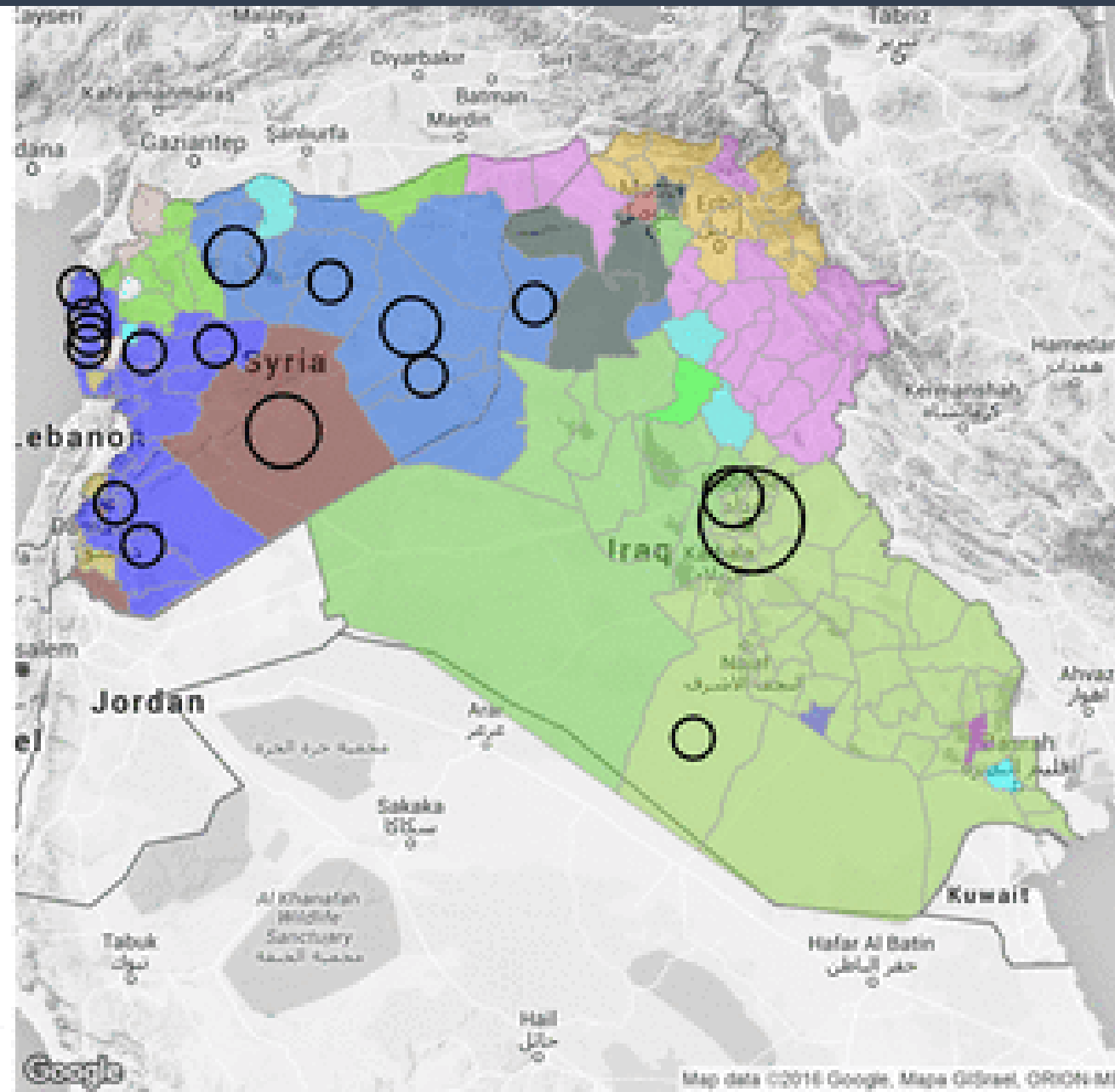
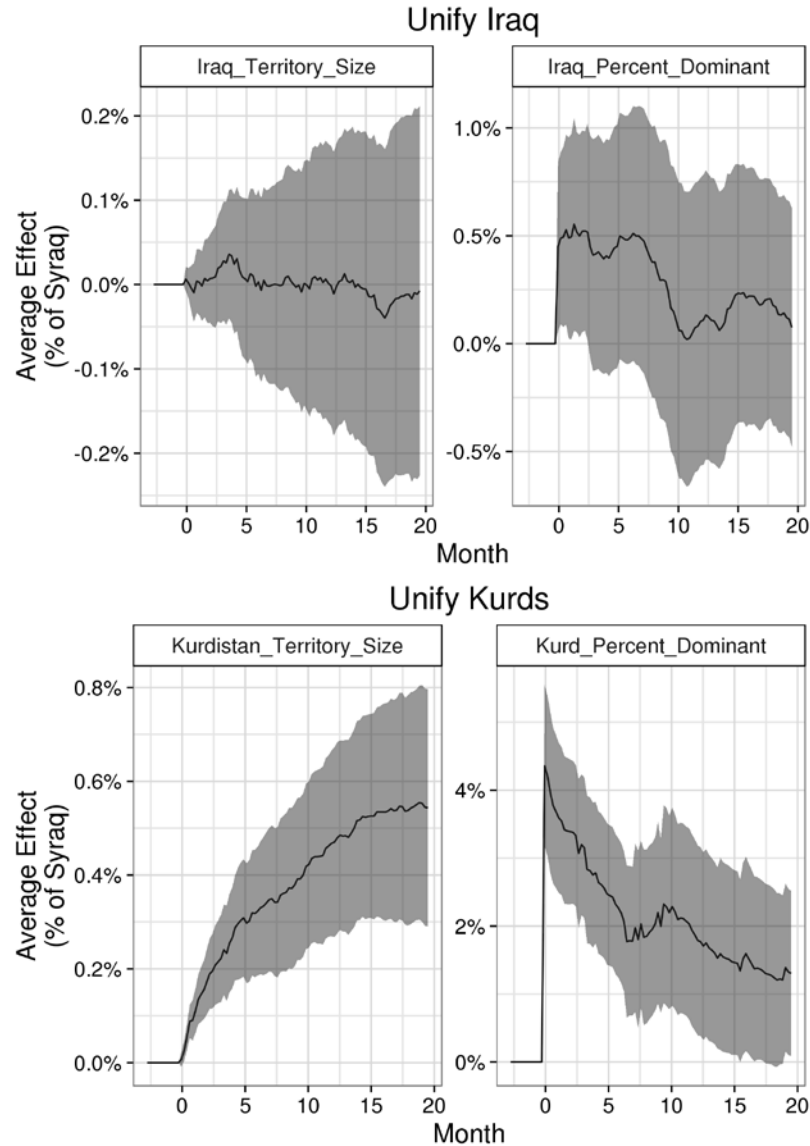# Surprise/Insight: Movement vs. Stasi Results

Reduction of Sectarianism in Iraq

- In order to reduce sectarianism in Iraq and Kurdistan, a portion of alienated agents in Iraq and Kurdistan were given the Iraq State and Kurdish identities, respectively.
- The visuals on the left show the effect of the punctuation on territory size and percentage of dominant agents in each zone.
- We can see that even though the operationalizations were very similar, the broadening of government in Iraq had little impact while in Kurdistan we see a large increase in both territory size and dominance.

The Present and Future of ABM for the IC

- **Actual:** Potential of ABM for intelligence purposes largely untapped. High ratio of unusable to usable modeling and difficulty discriminating among ABM models are retarding progress and uptake.

- **Probable:** Continued stasis based on time pressures, tight analytic horizons, non-social science/non-modeling culture, scanty investment in ambitious ABM computer modeling, and lack of ABM modeling sophistication within the government for evaluating, exploiting, and maintaining appropriate platforms.

- **Plausible:** New DARPA and IARPA programs evince awareness of need to take social science seriously and use ABM to domesticate and discipline the seductive and powerful theories of complexity and evolution.

- **Possible:** Standardized interfaces permitting analysts who are not programmers to directly, and in real time, query and experiment with the implications of different assumptions or policy interventions for distributions of kinds of outcomes for most of the vast array of countries, regions, and domains that fall within the IC's AOR. Simulation tools achieving the status of statistical tools.

- **Impossible:** Developing simulation tools to provide discrete answers to specific questions about "actual" outcomes.