Is There a Viable Social Physics? Yes, No, and In Part

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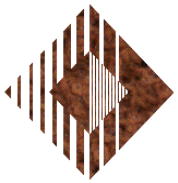
Prefatory I: The Issues Aren't New

- From an exchange at the 1958 Boulder Conference on Biophysics, as reported by Platt (*Science*, 1964):
  - "A distinguished cell biologist rose and said, `No two cells give the same properties. Biology is the science of heterogeneous systems.' ....
  - To which Cy Levinthal replied: `Well, there are two kinds of biologists, those who are looking to see if there is one thing that can be understood, and those who keep saying it is very complicated and that nothing can be understood. ... You must study the *simplest* system you think has the properties you are interested in.'"

Prefatory II: Conflict Is Not Inevitable

- **"...because we assume that humans and their social systems are part of the natural world (Carnap, 1961: 182-183), social or sociological phenomena are a part of the natural world. Hence, sociology is a natural science, or sociology does not exist. Either view is acceptable to me, but for purposes of this essay I will assume that sociology exists." - B. Mayhew, "Baseline Models of Sociological Phenomena" (*JMS*, 1984)**
- **"In their view, anyone who follows my suggestions will risk finding themselves in a field like physics, clearly a horrible fate." - B. Mayhew, "Chance and Necessity In Sociological Theory" (*JMS*, 1984)**



Outline

- Origins of social physics
- Three notions of social physics
- Some examples (pro and con)
- Programmatic issues

The Origins of Social Physics

- **August Comte**
  - French engineer and follower of Saint-Simon; coined the term "sociology" in the 1820s to refer to a new science of society which would satisfy both predictive and normative objectives; initially labeled his enterprise "social physics," to distinguish it from Saint-Simon's "social physiology"
- **Adolphe Quételet**
  - Belgian astronomer and statistician, published volume in 1835 subtitlted "*An Essay on Social Physics"* in 1835; attempted to account for crime, suicide, marriage, etc. via statistical methods (particularly least squares)
- **Vilfredo Pareto**
  - French engineer; highly influential economic and sociological theorist whose main works were in the 1890s; made extensive claims for ubiquity of power law distributions within social phenomena
- **Implication: "social physics" was a central founding ambition of sociology and social statistics (not a late add-on)**

Continuing Influences

- **Many subsequent uses**
  - **Talcott Parsons and Pitrim Sorokin's grand theories (1920s/30s)**
  - **George Zipf's *Principle of Least Effort* (1949) (loosely specified action principle)**
  - **Norbert Wiener's "cybernetics" (late 1940s-60s)**
- **Recent efforts (1990s-present)**
  - **Adrian Bejan's "constructal theory"**
  - **"Complex systems" field**
- **In addition, substantial continuous impact on individual formal theorists throughout the period**
  - **See, e.g., journals like *Behavioral Science, JMS***

Historical Upshot (One View)

- Social physics is "organic" to the social sciences (particularly sociology)
- Never completely died out, but substantial drift occurred
  - New developments in physics only slowly absorbed by social sciences
  - Most sociological usage became empty and metaphorical, with a small faction of active users
    - With some exceptions (e.g., demography), even formal modeling relatively detached from empirical and methodological research
  - Alternative formal approaches (e.g., choice theory, networks) displaced emphasis on dynamic systems in 1980s and 1990s
- Current "physics of society" initiatives should be seen as attempts to restore or reforge original connection

Three Kinds of "Social Physics"

- Direct application of physical models to social systems (aka "mere relabeling")
  - Find a model which looks facially similar, and try it
- Use of physical reasoning, techniques, and formal results
  - Includes exploitation of "parallel evolution"
- Study of physical constraints on social systems
  - Limits on human movement, technology, energy/resources

Ex Cathedra Polemic On the Three Types

- **Mere relabeling *may* work, but is rarely useful**
  - **Devil is in the details – and the details (and underlying assumptions) frequently will not match**
  - **Many models have similar surface features; what's the chance that the one you grab will work**
- **Use of physical reasoning is *often* helpful, when used judiciously**
  - **Where it is clear that assumptions match, conclusions are generic (and can be imported)**
- **Study of physical constraints *requires* input from physics, and fills an important gap**
  - **Understudied, although we have seen a few good examples at this workshop!**

Where Direct Application Fails: Catastrophe Theory and Chaos in Sociology

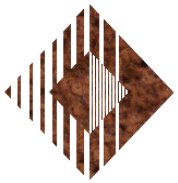
- **Substantial surges of interest in specific phenomena from nonlinear dynamics, following popular publications**
  - **Somewhat millennial predictions, with little lasting impact**
- **Why the failure?**
  - **Use motivated by loose metaphor ("catastrophic change," "chaotic behavior") rather than inadequacy of specific models**
  - **Few attempts to use these ideas to understand "native" models; by 1984, Fararo (*Beh.Sci.*) noted that no such attempt had appeared in the social science literature**
  - **From abstract of Sussman and Zahler (*Beh.Sci.*, 1978)**
    - **"...many catastrophe theory models in social science possess serious weaknesses. The catastrophes supposedly account for real-life behavior, but actually are only a restatement of the fact that discontinuities exist. No deep mathematical results are actually used. The hypotheses are ambiguous or far-fetched. ... The theory is helpful on neither the qualitative nor the quantitative level. Finally, better and simpler mathematical tools exist."**

Parallel Evolution: Statistical Mechanics of Social Systems

- General form, now widely used:

$$\Pr\left(S=s\middle|\theta,\eta,\mathbb{S}\right)=\delta_{\mathbb{S}}(s)\frac{\exp\left(\eta\left(\theta\right)^{T}t\left(s\right)\right)}{\sum_{s'\in\mathbb{S}}\exp\left(\eta\left(\theta\right)^{T}t\left(s'\right)\right)}$$

  - Stochastic system state S w/support $\mathbb{S}$; t:$\mathbb{S}\rightarrow\mathbb{R}^{p}$, $\eta(\theta)\rightarrow\mathbb{R}^{p}$
  - Model is ERG when $\mathbb{S}$ is a graph set
    - But, can choose $\mathbb{S}$ to get permutations, location models, etc.
  - Obtain a baseline model (a la Mayhew, 1984) when $\eta=0$
    - In general, model maximizes entropy over $\mathbb{S}$, given $\mathrm{E}_{\theta}t(S)$
- Approach entered social sciences through statistical literature, motivated as an inferentially tractable model for dependent systems – however, has a statistical mechanical interpretation



Intellectual Connections

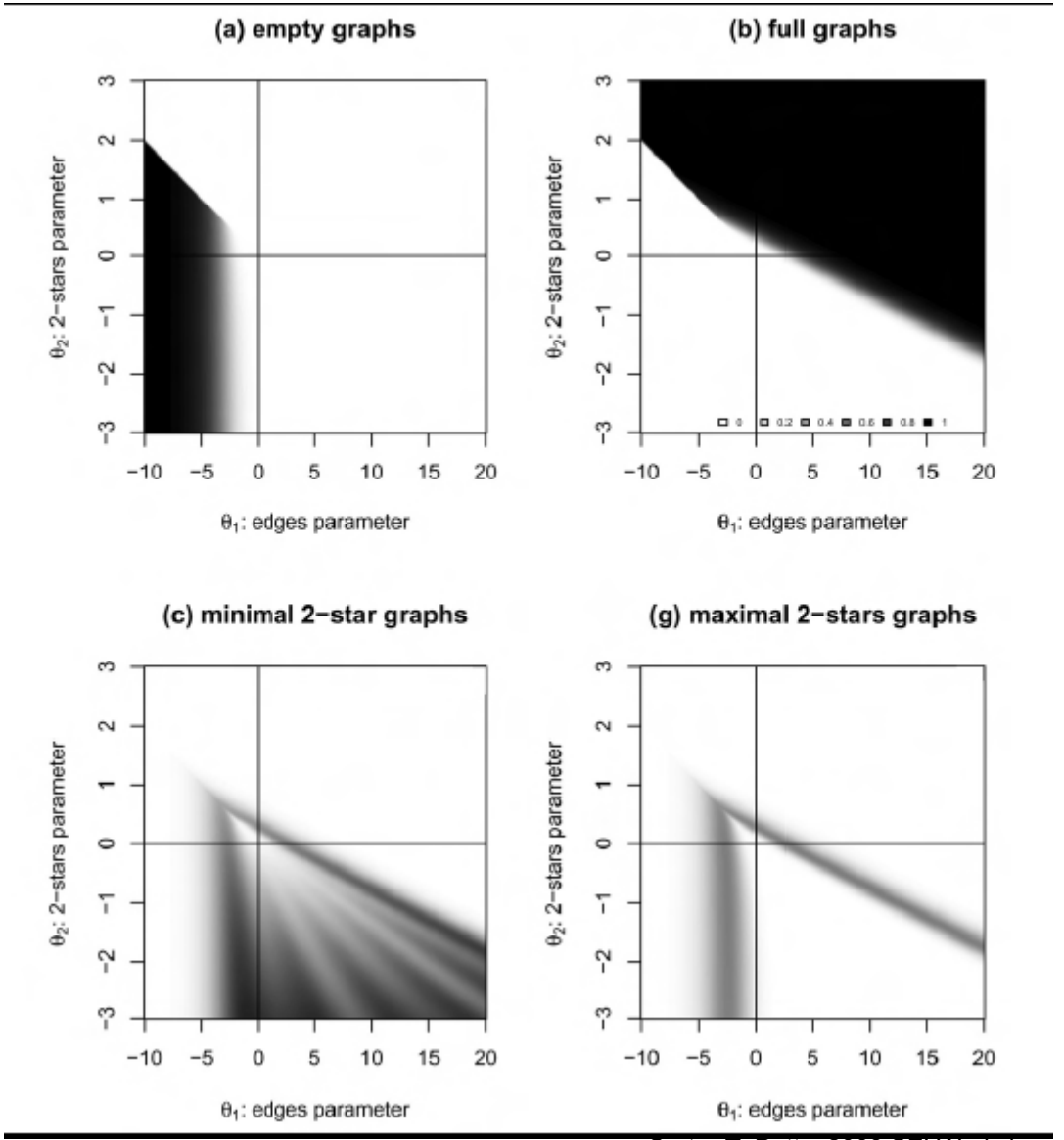
- **Large body of statistical theory**
  - **Log-linear models (Fienberg and Wasserman, 1981)**
  - **Distributional theory (Barndorff-Nielsen, 1978)**
  - **Spatial statistics (Besag, 1974; 1975)**
  - **Stochastic geometry (Stoyan et al., 1987)**
- **Strong analogy w/statistical mechanics (Strauss, 1986)**
  - $\exp(\theta^{T} t(x))$ **analogous to *Boltzmann factor***
  - $Z=\Sigma_{x'}\exp(\theta^{T} t(x'))$ **analogous to *partition function***
  - $t(x)$ **analogous to microstate energy function**
  - θ **analogous to inverse temperature (i.e.,** $\tau=1/\theta$**)**

Deductive Issues in the ERG Case

- Use of dependence graphs to obtain sufficient statistics
  - Let D be the graph formed on $E(G)$ by pairwise conditional dependence
  - Then, complete and minimal class of ERGs implementing D can be found by Hammersley-Clifford theorem
    - Sufficient statistics are cliques of D; may employ partial conditional dependence (e.g., Pattison and Robins, 2002; Butts, 2006) to find reduced classes of statistics
  - Duality between "causal" influence and essential network features
- An important gap: analytical approximations
  - Model behaviors known only through simulation
  - Few if any analytical results outside independent-dyad models
    - Will need to find local approximations; not trivial

Another Gap: Characterizing Model Behavior

- **Essential step in theoretical development: movement from point estimates to identification of regimes**
  - **General typology of model behavior**
  - **Analytical approximation of regime boundaries**
- **Ideally, want to characterize model *families*, not models!**



[Figure from Handcock (2005)]

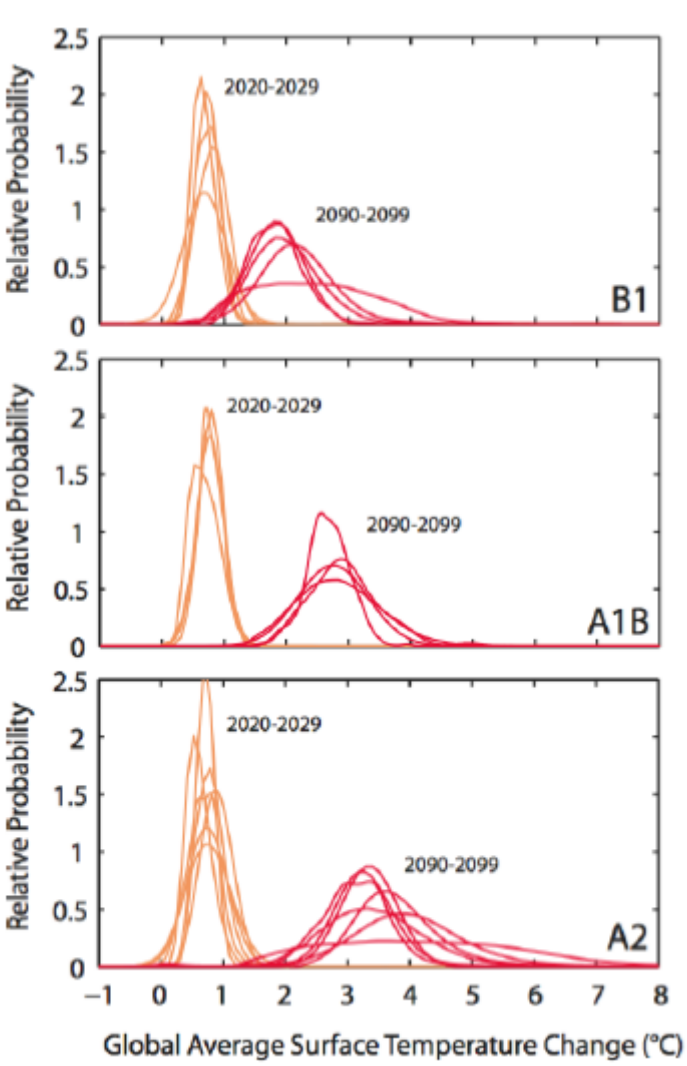
Micro-process Side Note: Exponential Families and Potential Games

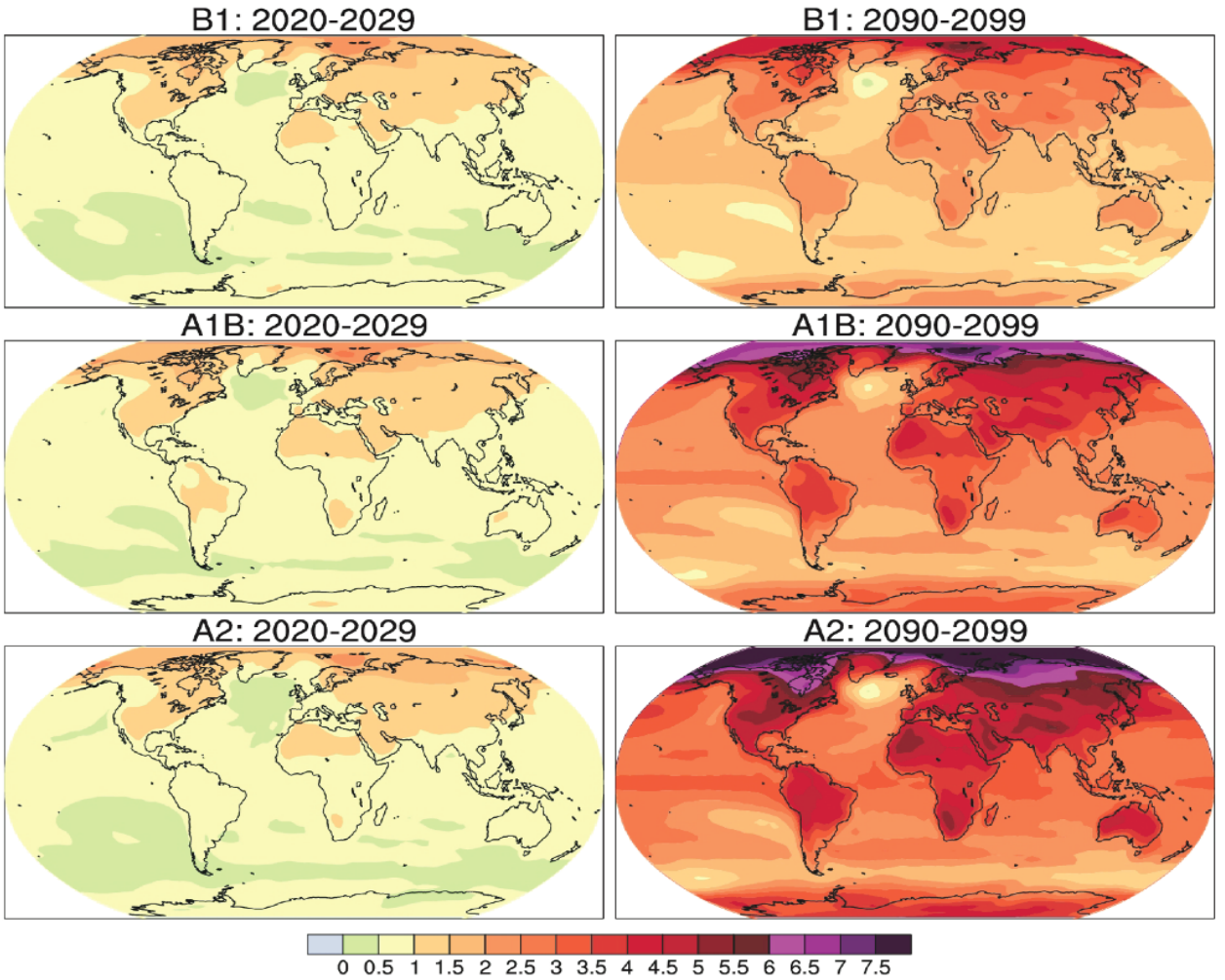
- **Stochastic choice and potential games**
  - Let G be an n-player game with utility function vector u, and let $\mathbf{X}$ be a vector of strategy choices
    - G is a potential game if $\exists \rho: u_i(\mathbf{X}_i,\mathbf{X}_{-i})-u_i(\mathbf{X}'_i,\mathbf{X}_{-i})=\rho(\mathbf{X}_i,\mathbf{X}_{-i})-\rho(\mathbf{X}'_i,\mathbf{X}_{-i})=\rho'(\mathbf{X})-\rho'(\mathbf{X}') \; \forall \mathbf{X},i$
  - Under stochastic choice assumption, $\Pr(\mathbf{X}) \propto \exp(\rho'(\mathbf{X}))$ (Young, 1998)
  - Thus, if u can be written as $\eta(\theta)^{\mathrm{T}} s(\mathbf{X})$, can use exponential family theory to estimate u from $\mathbf{X}$ (see, e.g., Butts, 2007)
    - Can also simulate, etc. (e.g., Zhang, 2004)
    - Can find Nash equilibria in certain cases as limits of $\Pr(\mathbf{X}|\beta\rho')$ as $\beta \to \infty$ (Young, 1998)
- **Example of a "macro-micro link"**
  - Model statistics are macro-features, but model has choice-based interpretation

Physical Constraints on Social Systems: The Case of Global Climate Change

- Social systems are part of the physical world – and are subject to its constraints
  - Pedestrian motion, limits to group size from hearing/talk time, resource constraints
- Currently obvious example: global climate change
  - Climate forcing results from human activity
  - Human activity changes due to climate forcing
  - Events occur on same time scale – thus, a joint sociophysical model is needed

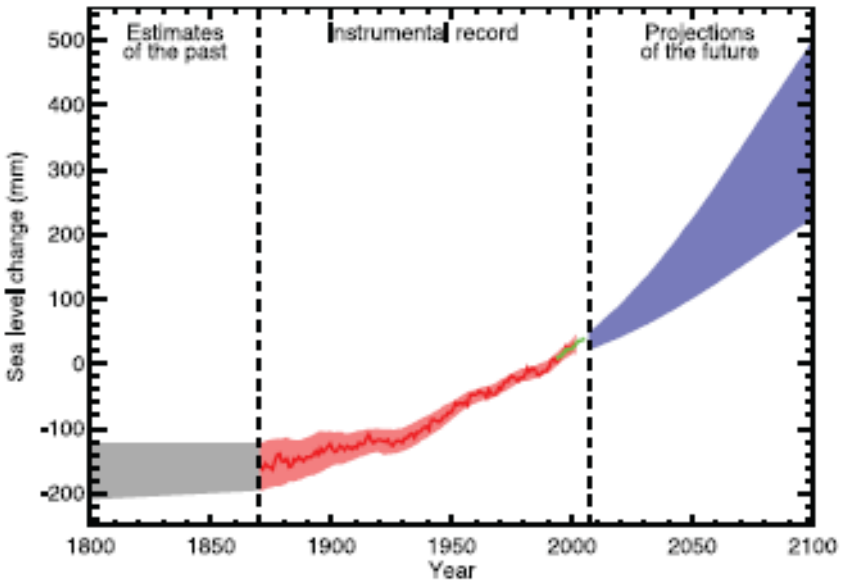
Environmental Forcing: Global Temperature Change

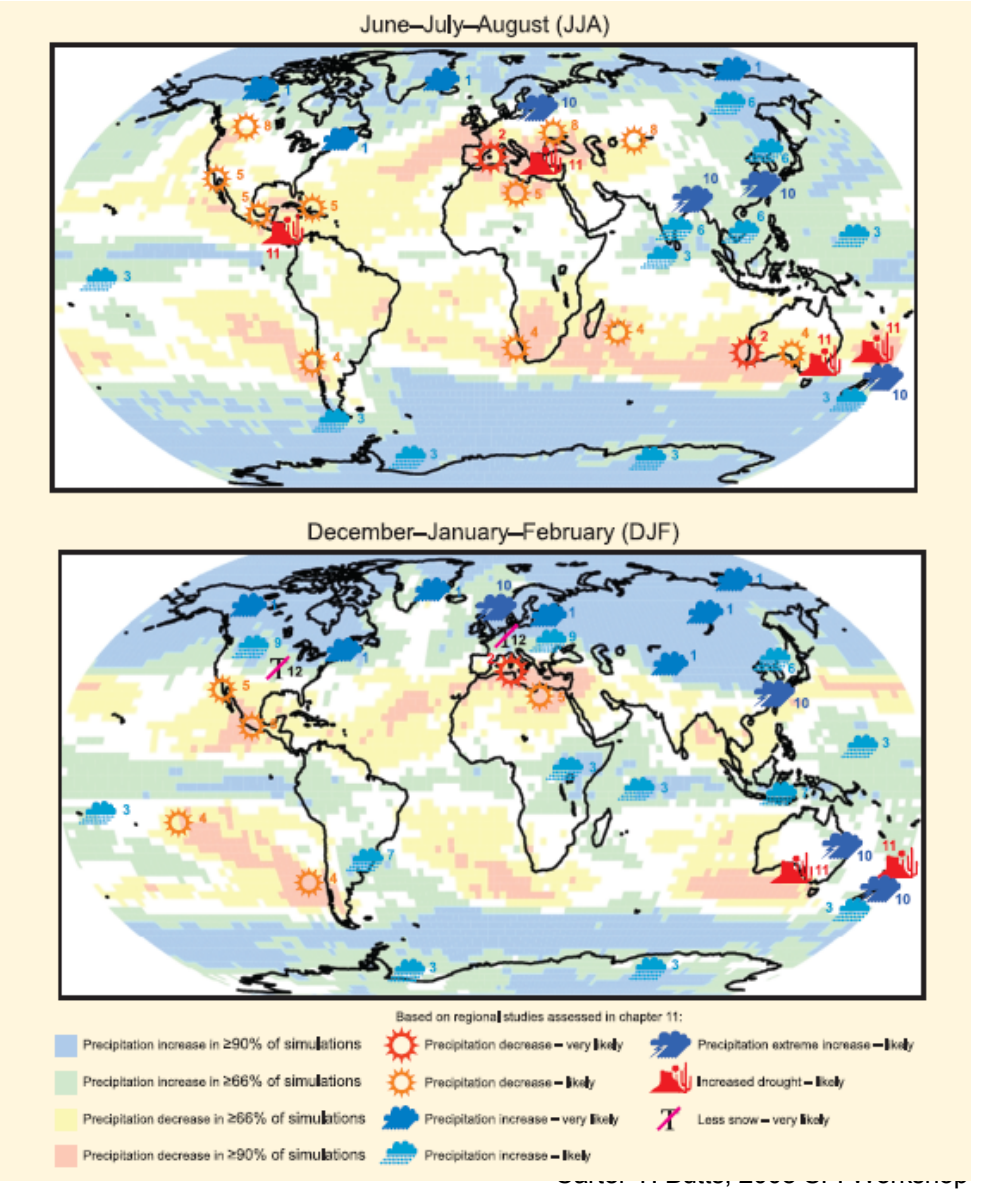




[Figures from IPCC AR4, WG1 (2007)]

Environmental Forcing: Sea Level Rise and Precipitation Change

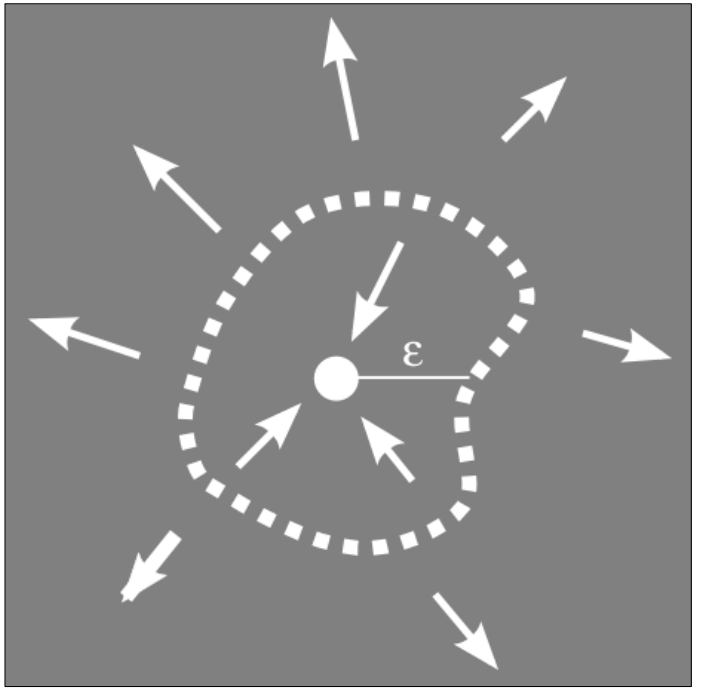


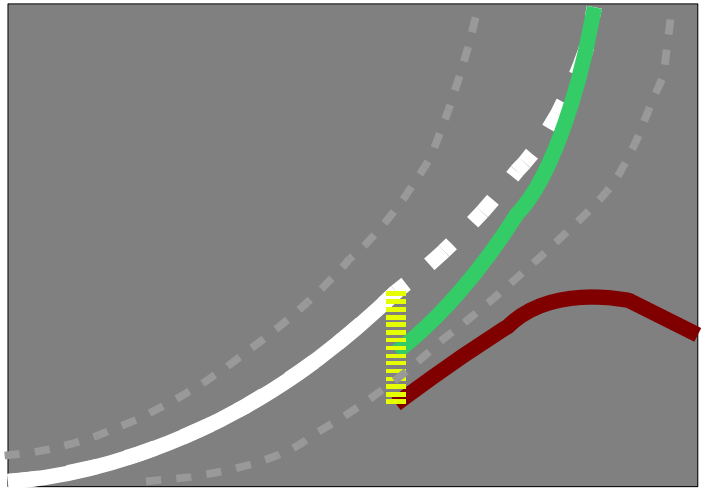


[Figures from IPCC AR4, WG1 (2007)]

Elephant In the Room: Effects of Perturbations on Human Systems

- **Many human systems seem to exhibit static or dynamic metastability**
  - **Trajectories within a given region confined with high probability...**
  - **...but trajectories outside the region depart**
- **Old, unresolved issue: homeostasis in human systems**
  - **Raised by functionalists and systems theorists (among others)**
  - **Some formal results in demography, epidemiology, but no satisfactory general treatment**





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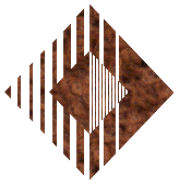
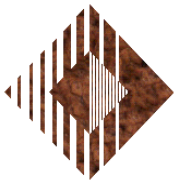
So You Say You Want a (Renewed) Social Physics?

- Easy to say, but not easy to achieve
  - Large leap from a few projects to a substantial enterprise with lasting impact
  - Can probably be done, but will require long-term dedication of time, energy, and resources
- We've been here before – perhaps we should leverage past experience?
  - Key obstacles not always substantive (nor even intellectual)
  - Opportunities for profitable exchange not always obvious to would-be participants
- A few points summarized here; hopefully, this will spur productive discussion



How Can Physicists Help?

- **Leveraging problem-relevant technical results from the physics literature**
  - **Partition functions and exponential families; spatio-temporal processes**
- **Identifying physical constraints on social phenomena**
  - **Movement and communication; technology and resource consumption; environmental perturbations**
  - **A new Rashevsky program?**
- **Promoting "cultural" and human capital exchange**
  - **Students and post-docs, conference attendance, reading literature**
- **Supplying interesting problems**
  - **New ideas of what might be studied; possible applications of social science tools/concepts to physical systems (a "society of physics?")**



How Can Social Scientists Help?

- **Leveraging results and expertise regarding inference and data analysis**
  - **Sampling theory; experience with complex, noisy data sources; inference for systems with complex error/dependence properties**
- **Deploying and sharing domain knowledge**
  - **"Physical intuition" and tacit knowledge; knowledge of empirical literature**
- **Experience with modeling social systems**
  - **ABM; ERG models; game theory; multinomial processing trees**
- **Planning and aiding with data collection**
  - **Survey/field/experimental methods; measurement techniques; study design**
- **Supplying interesting problems**

Institutional Challenges and Other Tedious (and Tendentious!) Things

- **Incentives and credit**
  - Selling the work to "traditionalists" on both sides
  - Navigating differences in citation norms
  - Avoiding "theoretical feudalism"
- **Publication and dissemination**
  - Synchronizing paper types/time scales
  - Not enough to publish – must also <u>read</u> and <u>be read</u>!
    - Getting work into the right literatures for long-term benefit
    - Helping researchers to find important papers across fields
- **Integration into academic institutions**
  - Training and academic reproduction
  - Jobs, recruitment, etc.
  - Formation/maintenance of supportive institutions

Conclusion

- Is there a physics of society? Certainly, for some definition thereof
  - Longer, more substantial tradition that is sometimes recognized
  - Some notions (perhaps) more viable than others
- How can we best move forward?
  - Find points of contact where principled exchange is possible
  - Create institutional context for long-term collaboration
  - Work hard, be correct