Move over weatherperson: Can we actually forecast ecology?

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UW-Madison NTL LTER Science Mtg, 16 October 2018

Columbia Pictures
Kika Tuff (Impact Media)

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Ecological Forecasts: An Emerging Imperative

James S. Clark, Steven R. Carpenter, Mary Barber, Scott Collins, Andy Dobson, Jonathan A. Foley, David M. Lodge, Mercedes Pascual, Roger Pielke Jr., William Pizer, Cathy Pringle, Walter V. Reid, Kenneth A. Rose, Osvaldo Sala, William H. Schlesinger, Diana H. Wall, David Wear

“THE PROCESS OF PREDICTING THE STATE OF ECOSYSTEMS, ECOSYSTEM SERVICES, AND NATURAL CAPITAL, WITH FULLY SPECIFIED UNCERTAINTIES, AND IS CONTINGENT ON EXPLICIT SCENARIOS FOR CLIMATE, LAND USE, HUMAN POPULATION, TECHNOLOGIES, AND ECONOMIC ACTIVITY”
Iterative near-term ecological forecasting: Needs, opportunities, and challenges

Michael C. Dietze\textsuperscript{a,1}, Andrew Fox\textsuperscript{b}, Lindsay M. Beck-Johnson\textsuperscript{c}, Julio L. Betancourt\textsuperscript{d}, Mevin B. Hooten\textsuperscript{e,f,g}, Catherine S. Jarnevich\textsuperscript{h}, Timothy H. Keitt\textsuperscript{i}, Melissa A. Kenney\textsuperscript{j}, Christine M. Laney\textsuperscript{k}, Laurel G. Larsen\textsuperscript{l}, Henry W. Loescher\textsuperscript{k,m}, Claire K. Lunch\textsuperscript{k}, Bryan C. Pijanowski\textsuperscript{n}, James T. Randerson\textsuperscript{o}, Emily K. Read\textsuperscript{p}, Andrew T. Tredennick\textsuperscript{q,r}, Rodrigo Vargas\textsuperscript{s}, Kathleen C. Weathers\textsuperscript{t}, and Ethan P. White\textsuperscript{u,v,w}

www.pnas.org/cgi/doi/10.1073/pnas.1710231115
https://earth.nullschool.net/#current/wind/surface/level/overlay=temp/equirectangular
Predictability in a deterministic nonperiodic flow

“Does the flap of a butterfly’s wings in Brazil set off a tornado in Texas?”
-(Lorenz 1972)

Deterministic Nonperiodic Flow

Edward N. Lorenz
Massachusetts Institute of Technology

(Manuscript received 18 November 1962, in revised form 7 January 1963)

Abstract

Finite systems of deterministic ordinary nonlinear differential equations may be designed to represent forced dissipative hydrodynamic flow. Solutions of these equations can be identified with trajectories in phase space. For those systems with bounded solutions, it is found that nonperiodic solutions are ordinarily unstable with respect to small modifications, so that slightly differing initial states can evolve into considerably different states. Systems with bounded solutions are shown to possess bounded numerical solutions. A simple system representing cellular convection is solved numerically. All of the solutions are found to be unstable, and almost all of them are nonperiodic.

The feasibility of very-long-range weather prediction is examined in the light of these results.
Model spread needs to be constrained by data.
Advances in Global and Regional Weather Forecasts

Anomaly correlation of ECMWF 500 hPa height forecasts

- Northern hemisphere
- Southern hemisphere

ECMWF

Year

%
Dietze & Wheeler: 
Ecoforecast: 
https://press.princeton.edu/titles/11048.html

Weathers: Aquatic Productivity

LaDeau & Foster: 
Ticks & Small Mammals

Talbot & Averill: 
Microbial diversity

http://ecoforecast.org
Predictability is key to ecological theory and practice.

\[
\text{Var}[Y_{t+1}] \approx \left( \frac{\partial f}{\partial Y} \right)^2 \text{Var}[Y_t] + \left( \frac{\partial f}{\partial X} \right)^2 \text{Var}[X_{\text{IC}}] + \left( \frac{\partial f}{\partial \theta} \right)^2 \left( \text{Var}[\tilde{\theta}] + \text{Var}[\alpha_{\text{param variability}}] \right) + \text{Var}[\varepsilon_{\text{process error}}]
\]

= INTERNAL + EXTERNAL + PARAMETERS + RANDOM EFFECTS + PROCESS ERROR
Cyanobacterial bloom management through integrated monitoring and forecasting in large shallow eutrophic Lake Taihu (China)

Boqiang Qin*, Wei Li, Guangwei Zhu, Yunlin Zhang, Tingfeng Wu, Guang Gao

State Key Laboratory of Lake Science and Environment, Nanjing Institute of Geography and Limnology, Chinese Academy of Sciences, 73 East Beijing Road, Nanjing 210008, China

Algal Bloom in Taihu, 12 Jul, 2007, Guangwei Zhu

Slides courtesy of K.C. Weathers, Cary Institute and GLEON
Early-warning the harmful algal bloom

13 High frequency monitoring systems were built for basic data of the model (Guangwei Zhu)
The 3-days forecasting and early-warning report of harmful algal to public.

Courtesy of Guangwei Zhu
**Figure 1:** (clockwise from top left) Picnic Point and model latent heat fluxes for 2017; Picnic Point and model sensible heat fluxes for 2017; Boxplot of 2017 Picnic Point and modeled sensible heat fluxes; Boxplot of 2017 Picnic Point and modeled latent heat fluxes.
C Flux power spectra
Thoughts for discussion?

• What are bottlenecks to modeling and forecasting lake physical, biogeochemical, exchange processes?

• How can we extend work by PRAGMA, GRAPLER, etc.. beyond GLM?
Enter
Predictive Ecosystem Analyzer (PEcAn)

HTTP://PECANPROJECT.GITHUB.IO/

DEVELOP AND PROMOTE ACCESSIBLE TOOLS FOR REPRODUCIBLE ECOSYSTEM MODELING AND FORECASTING
Standardized inputs and outputs
Provenance: Transparent & Repeatable
Accessible interface
Reusable tools for execution, analysis, visualization
INFORMATICS MODULES

Cowdery et al. in prep
Characterize

Reduce

Propagate

Analyze
Thoughts for discussion?

• What are bottlenecks to modeling and forecasting lake physical, biogeochemical, exchange processes?
  – Data diversity, model informatics, compute resources, unmeasurables

• How can we extend work by PRAGMA, GRAPLEr, etc.. beyond GLM?
  – A role for PEcAn or similar tools? Learning from weather->terrestrial ecology->freshwater science?