Move over weatherperson: Can we actually forecast ecology?

Freshwater

Ankur Desai, Dept of Atmospheric and Oceanic Sciences
UW-Madison NTL LTER Science Mtg, 16 October 2018

Columbia Pictures

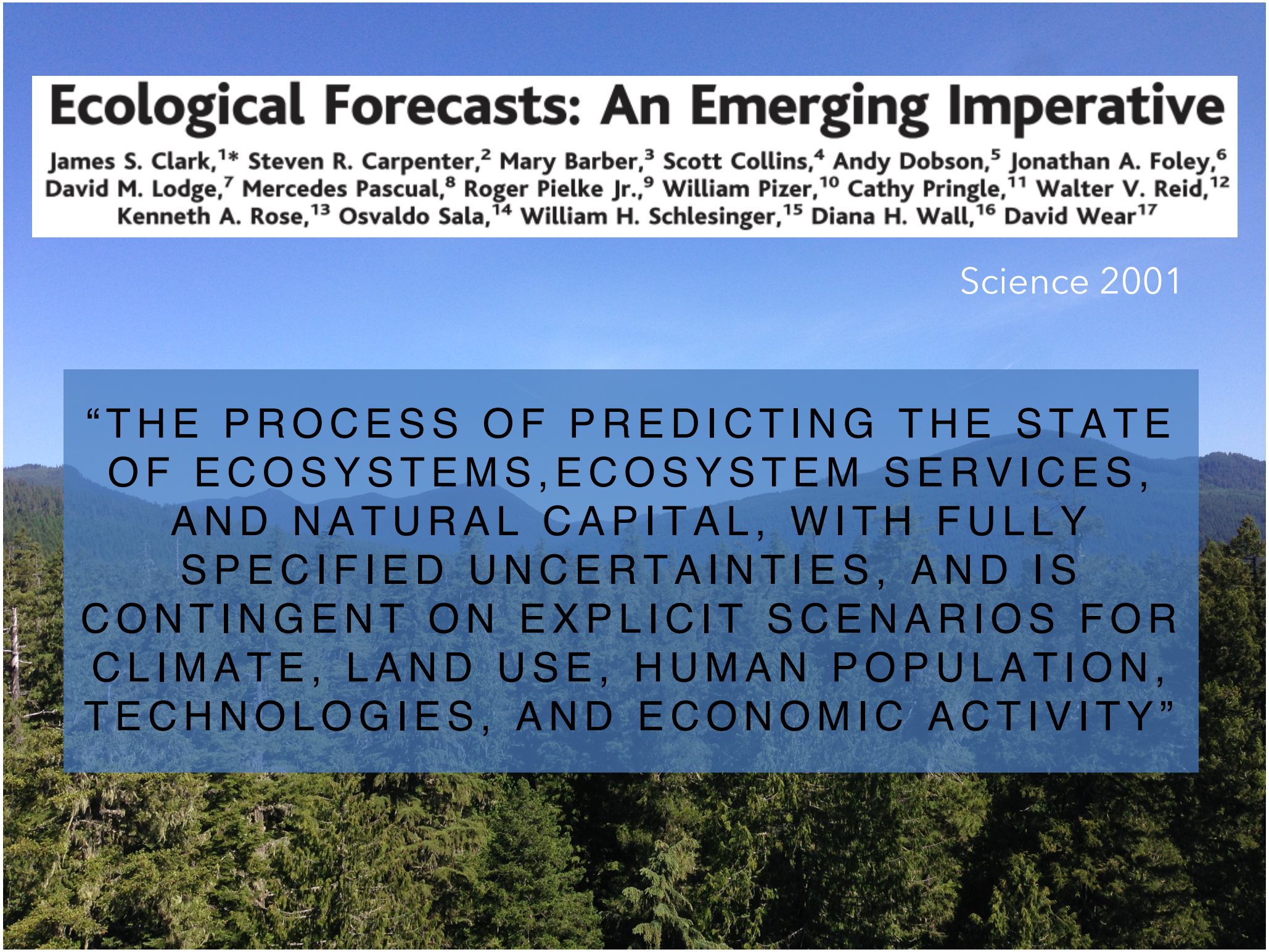
Kika Tuff (Impact Media)

http://flux.aos.wisc.edu desai@aos.wisc.edu @profdesai

Ecological Forecasts: An Emerging Imperative

James S. Clark,[1]* Steven R. Carpenter,[2] Mary Barber,[3] Scott Collins,[4] Andy Dobson,[5] Jonathan A. Foley,[6] David M. Lodge,[7] Mercedes Pascual,[8] Roger Pielke Jr.,[9] William Pizer,[10] Cathy Pringle,[11] Walter V. Reid,[12] Kenneth A. Rose,[13] Osvaldo Sala,[14] William H. Schlesinger,[15] Diana H. Wall,[16] David Wear[17]

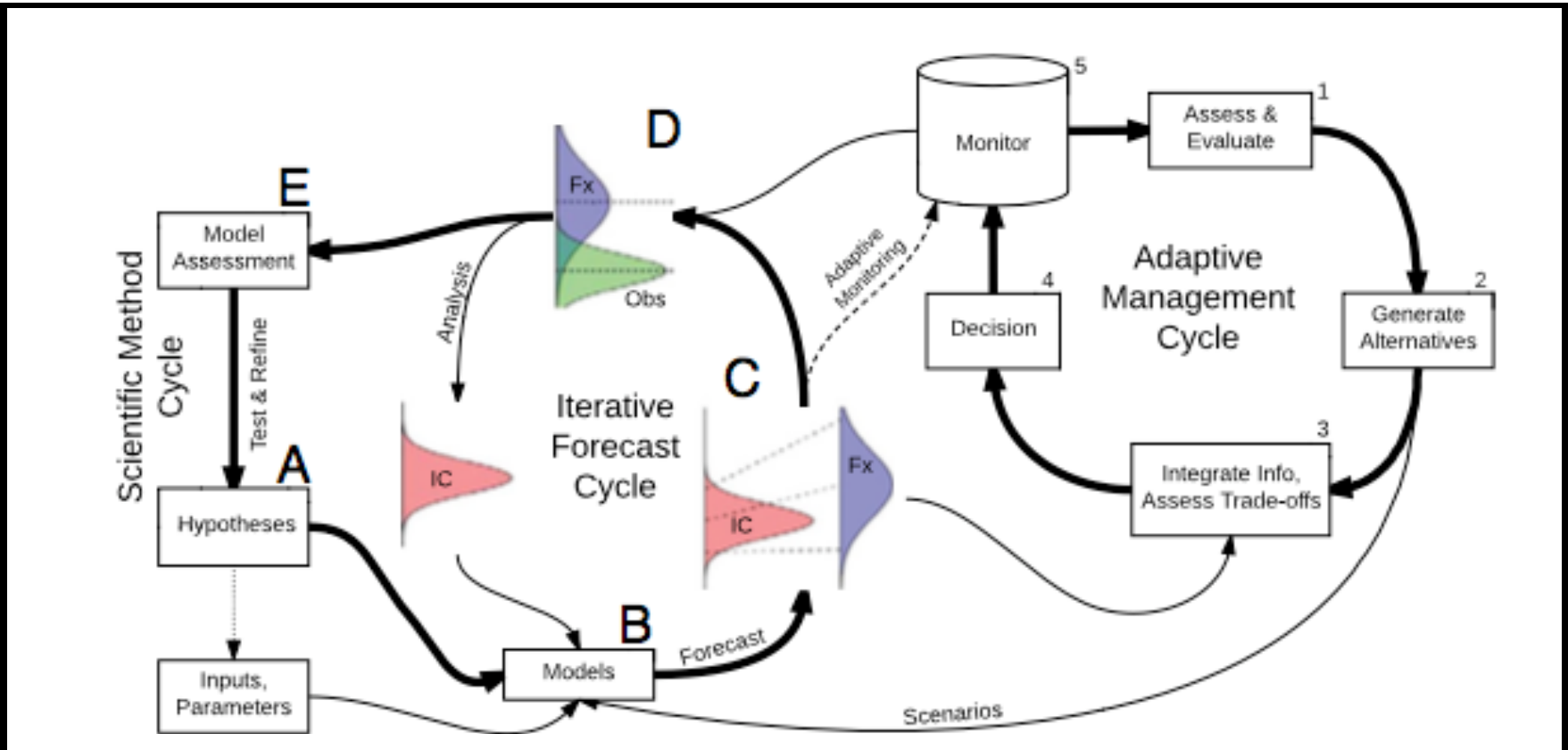
Science 2001



"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"

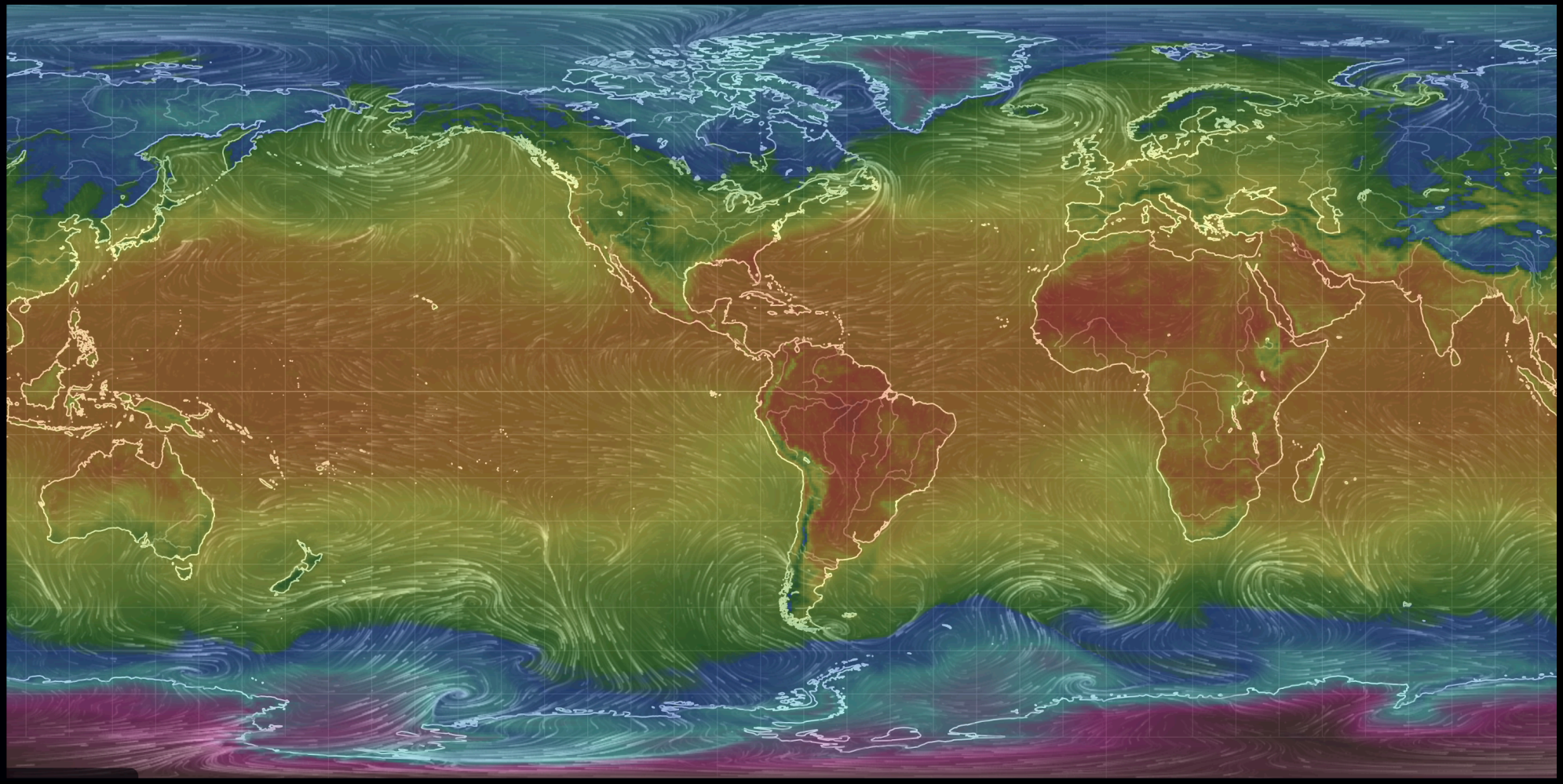
Iterative near-term ecological forecasting: Needs, opportunities, and challenges

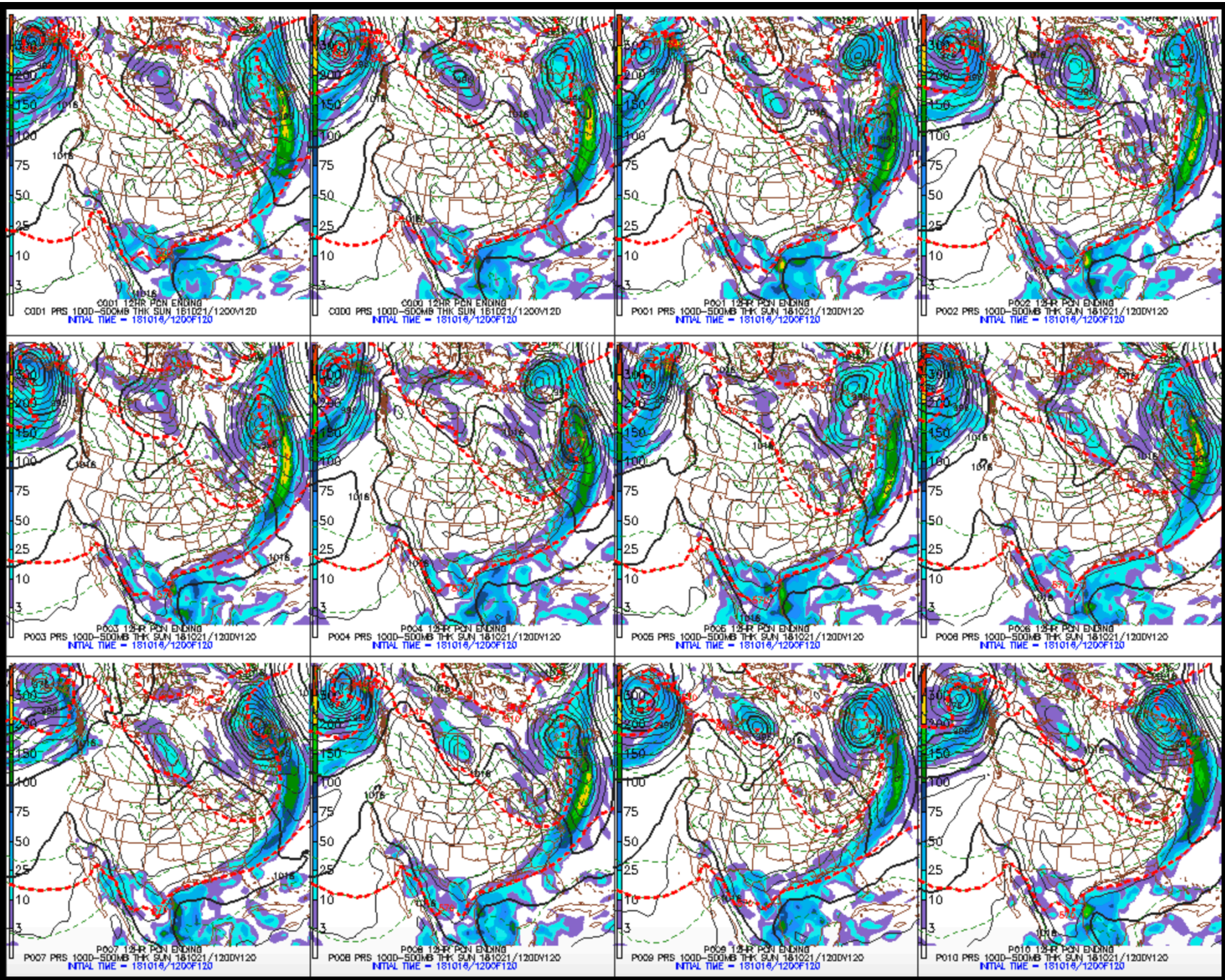
Michael C. Dietze[a,1], Andrew Fox[b], Lindsay M. Beck-Johnson[c], Julio L. Betancourt[d], Mevin B. Hooten[e,f,g], Catherine S. Jarnevich[h], Timothy H. Keitt[i], Melissa A. Kenney[j], Christine M. Laney[k], Laurel G. Larsen[l], Henry W. Loescher[k,m], Claire K. Lunch[k], Bryan C. Pijanowski[n], James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



www.pnas.org/cgi/doi/10.1073/pnas.1710231115

https://earth.nullschool.net/#current/wind/surface/level/overlay=temp/equirectangular

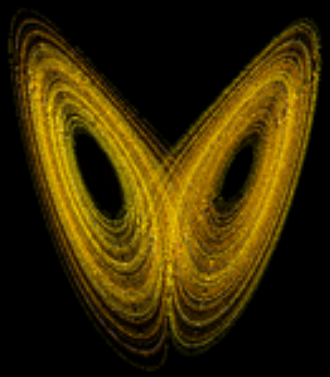


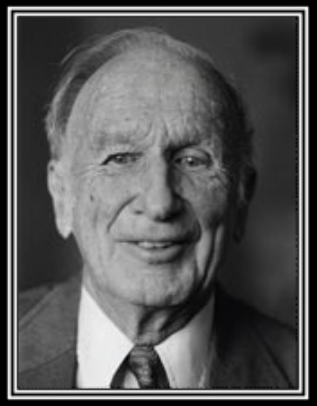


http://mp1.met.psu.edu/~fxg1/ENSPRS_12z/ensloop.html

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[1]

EDWARD N. LORENZ

Massachusetts Institute of Technology

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

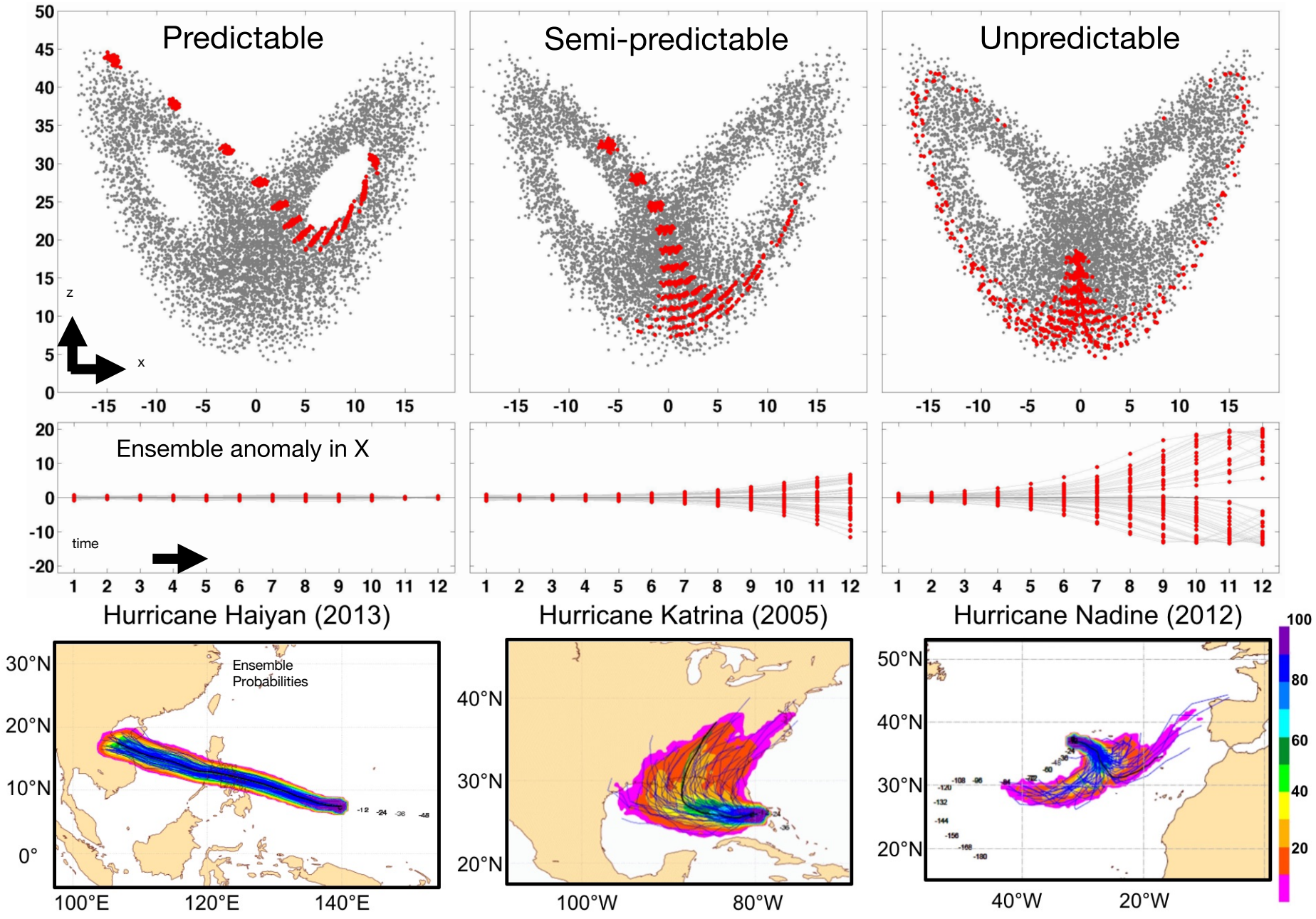
ABSTRACT

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.

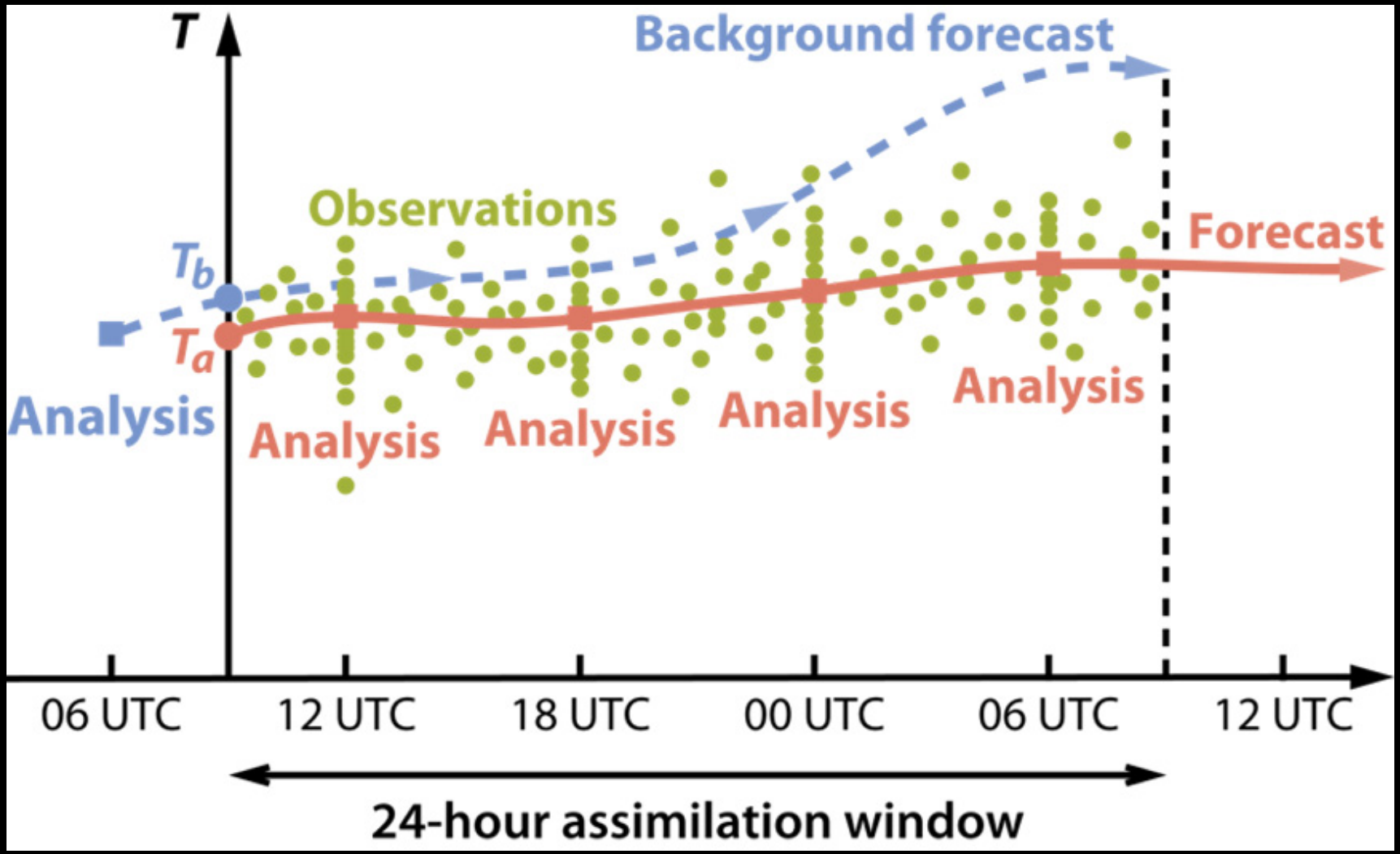
A simple system representing cellular convection is solved numerically. All of the solutions are found to be unstable, and almost all of them are nonperiodic.

The feasibility of very-long-range weather prediction is examined in the light of these results.

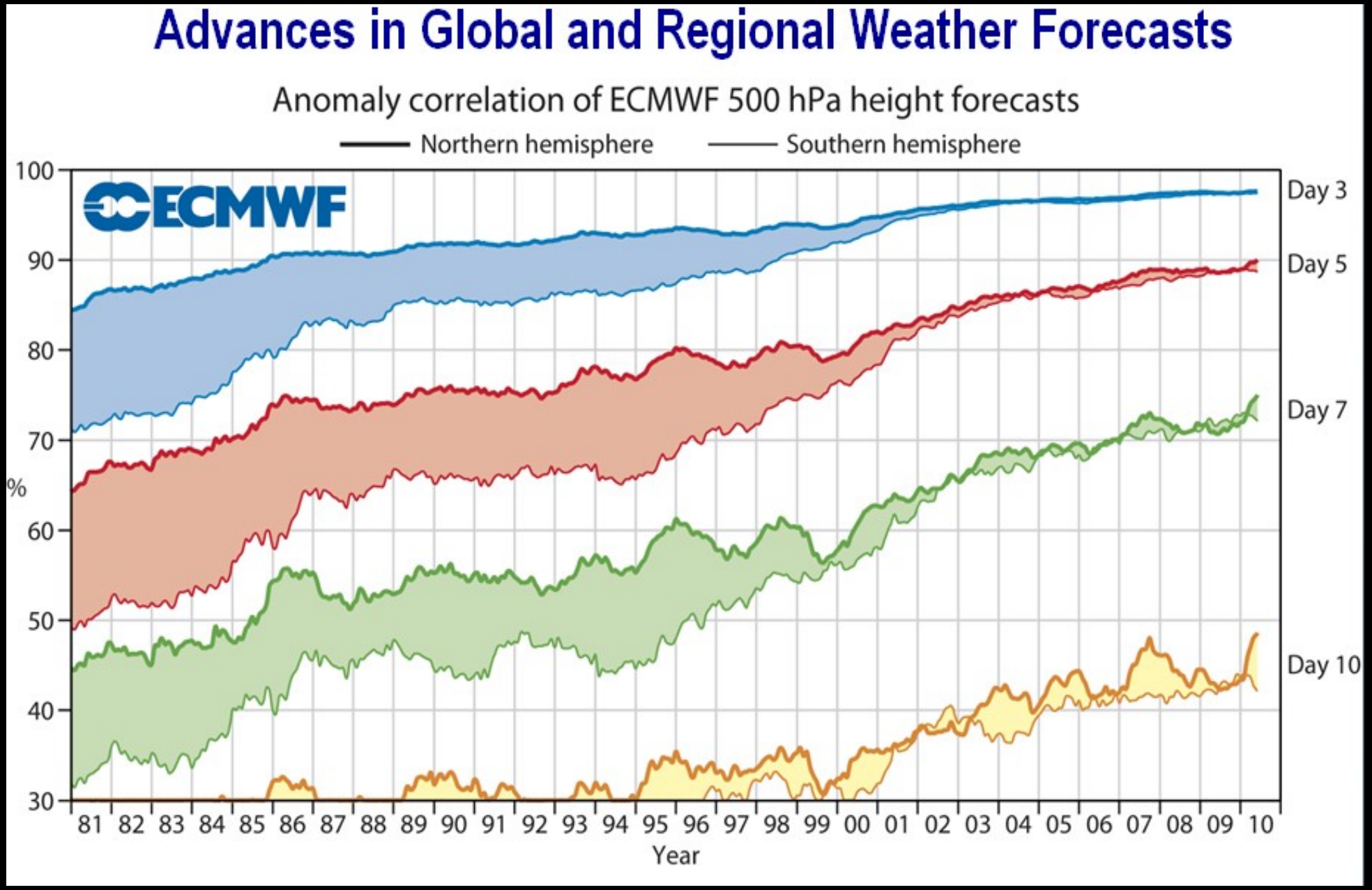
Courtesy of A. Subramanian (Scipps)

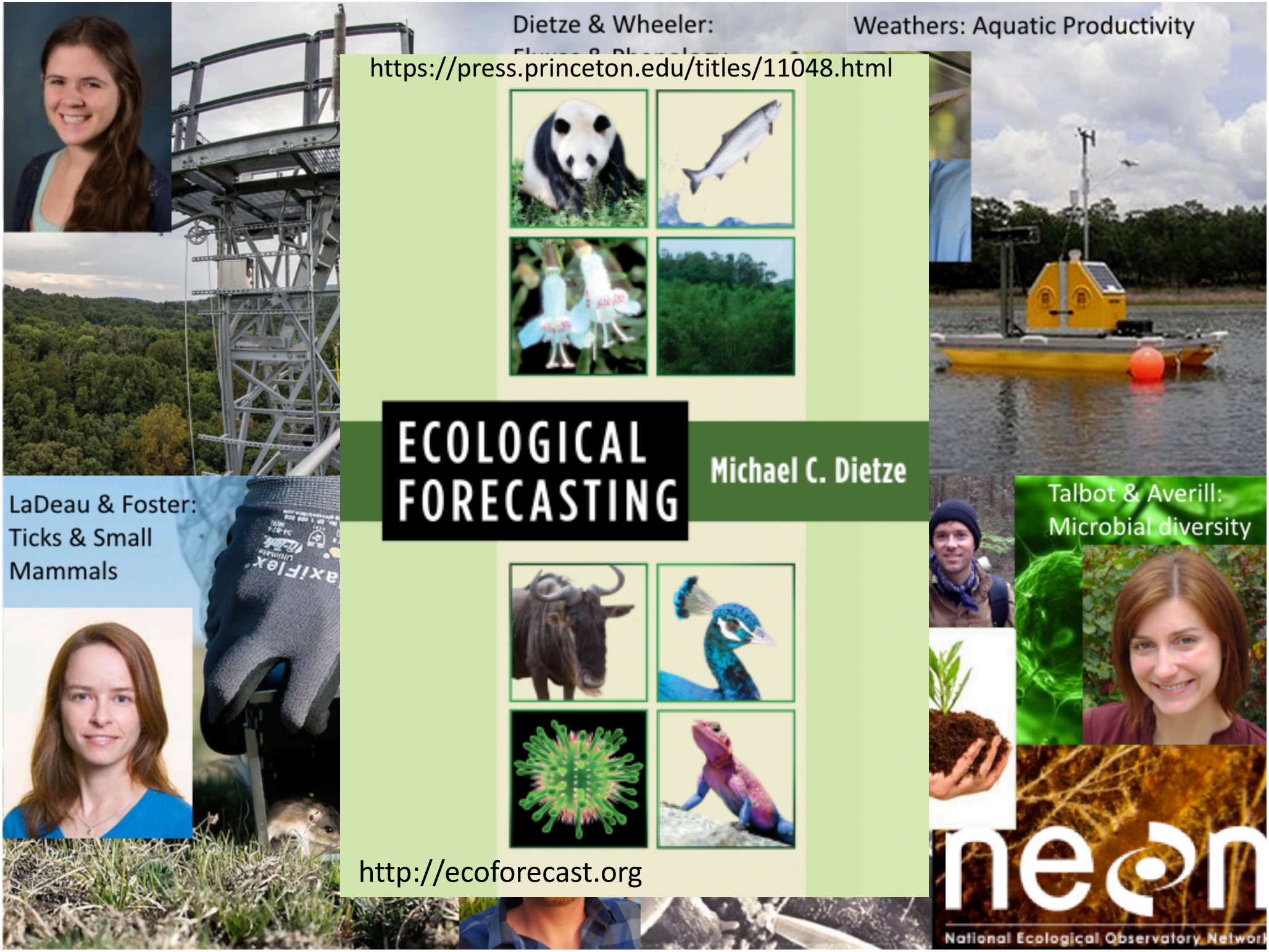

Predictable
Semi-predictable
Unpredictable
z
x
Ensemble anomaly in X
time
Hurricane Haiyan (2013)
Hurricane Katrina (2005)
Hurricane Nadine (2012)
Ensemble
Probabilities
100
80
60
40
20

Model spread needs to be constrained by data



Advances in Global and Regional Weather Forecasts



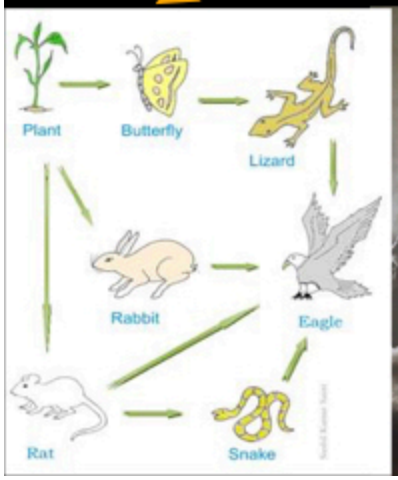

Dietze & Wheeler:
Weathers: Aquatic Productivity
https://press.princeton.edu/titles/11048.html
ECOLOGICAL FORECASTING
Michael C. Dietze
LaDeau & Foster:
Ticks & Small Mammals
Talbot & Averill:
Microbial diversity
http://ecoforecast.org
neon
National Ecological Observatory Network

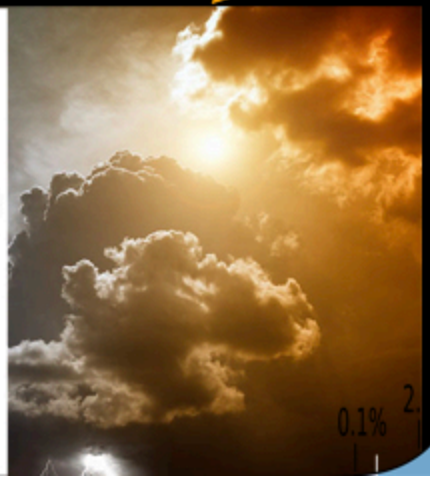
Dietze *2017 Ecological Applications*

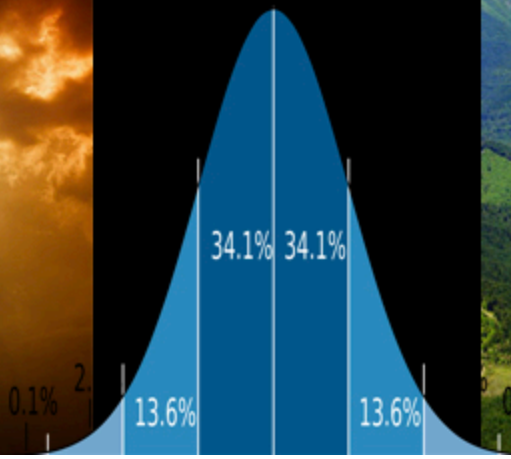
PREDICTABILITY IS KEY TO ECOLOGICAL THEORY AND PRACTICE

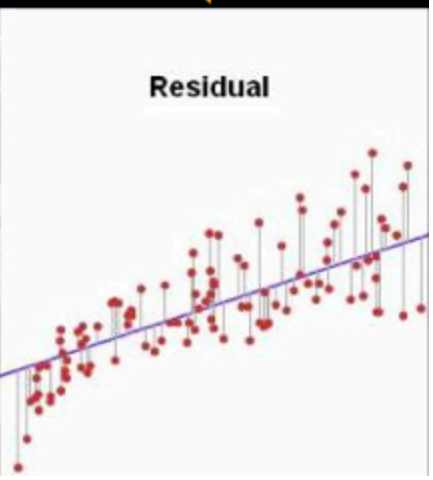
$$Var[Y_{t+1}] \approx \underbrace{\left(\frac{\partial f}{\partial Y}\right)^2}_{stability} \underbrace{Var[Y_t]}_{\substack{IC \\ uncert}} + \underbrace{\left(\frac{\partial f}{\partial X}\right)^2}_{\substack{driver \\ sens}} \underbrace{Var[X]}_{\substack{driver \\ uncert}} + \underbrace{\left(\frac{\partial f}{\partial \theta}\right)^2}_{\substack{param \\ sens}} \left(\underbrace{Var[\bar{\theta}]}_{\substack{param \\ uncert}} + \underbrace{Var[\alpha]}_{\substack{param \\ variability}} \right) + \underbrace{Var[\varepsilon]}_{\substack{process \\ error}}$$

$$= INTERNAL + EXTERNAL + PARAMETERS + \underbrace{RANDOM\ EFFECTS}_{} + \underbrace{PROCESS\ ERROR}_{}$$









Journal of Hazardous Materials 287 (2015) 356–363

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Journal of Hazardous Materials

journal homepage: www.elsevier.com/locate/jhazmat

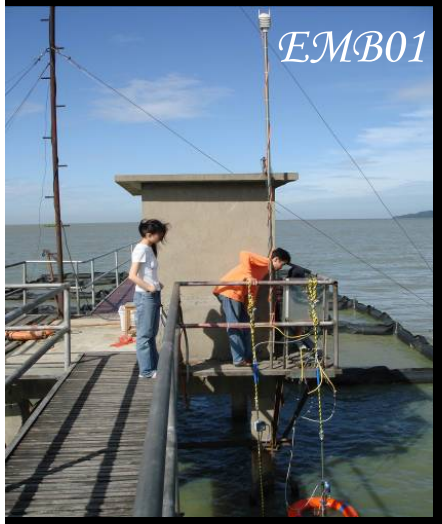
Cyanobacterial bloom management through integrated monitoring and forecasting in large shallow eutrophic Lake Taihu (China)

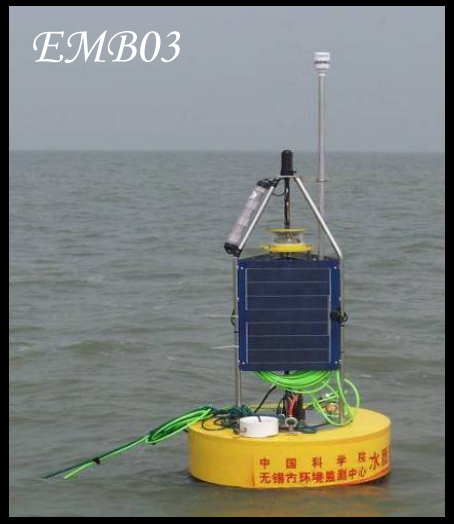
Boqiang Qin*, Wei Li, Guangwei Zhu, Yunlin Zhang, Tingfeng Wu, Guang Gao

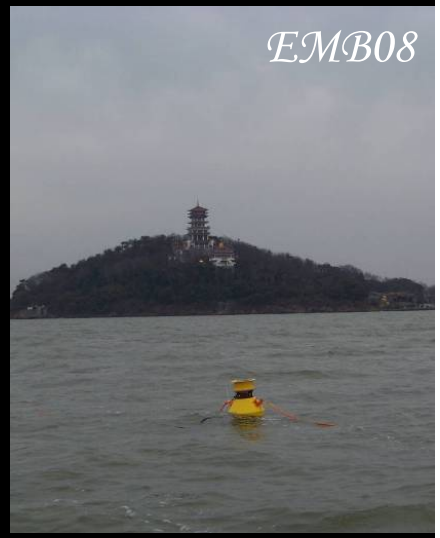
State Key Laboratory of Lake Science and Environment, Nanjing Institute of Geography and Limnology, Chinese Academic of Sciences, 73 East Beijing Road, Nanjing 210008, China

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

太湖水污染及蓝藻监测预警半周报

太湖水污染及蓝藻监测预警工作小组　　2010-07-29

中国科学院南京地理与湖泊研究所太湖蓝藻监测预警半周报

预测地点：太湖梅梁湾、贡湖湾　　日期：2010-07-29

	巡测点叶绿素 a 含量(微克/升)				三日温度（℃）			三日风向			三日气象		
	0	1	2	3	30	31	01	30	31	01	30	31	01
梅梁湾	10.5	6.3	3.3	4.1	28-35	28-36	28-36	SW	SW	SW	多云	多云	多云
贡湖湾	3.2	3.7	6.5	1.8									

预测概率

7 月 30 日至 8 月 1 日三天内

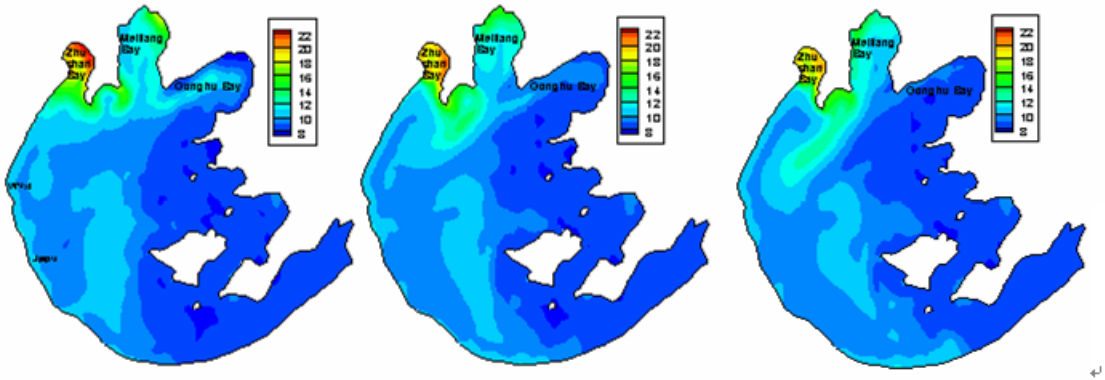
梅梁湾水面灾害性蓝藻水华发生概率　90 %

主要区域：牵龙口、东部沿岸带

贡湖湾水面灾害性蓝藻水华发生概率　90 %

主要区域：湾顶、北部沿岸带

梅梁湾、贡湖湾随后三天叶绿素 a 浓度分布



7 月 30 日　　7 月 31 日　　8 月 1 日

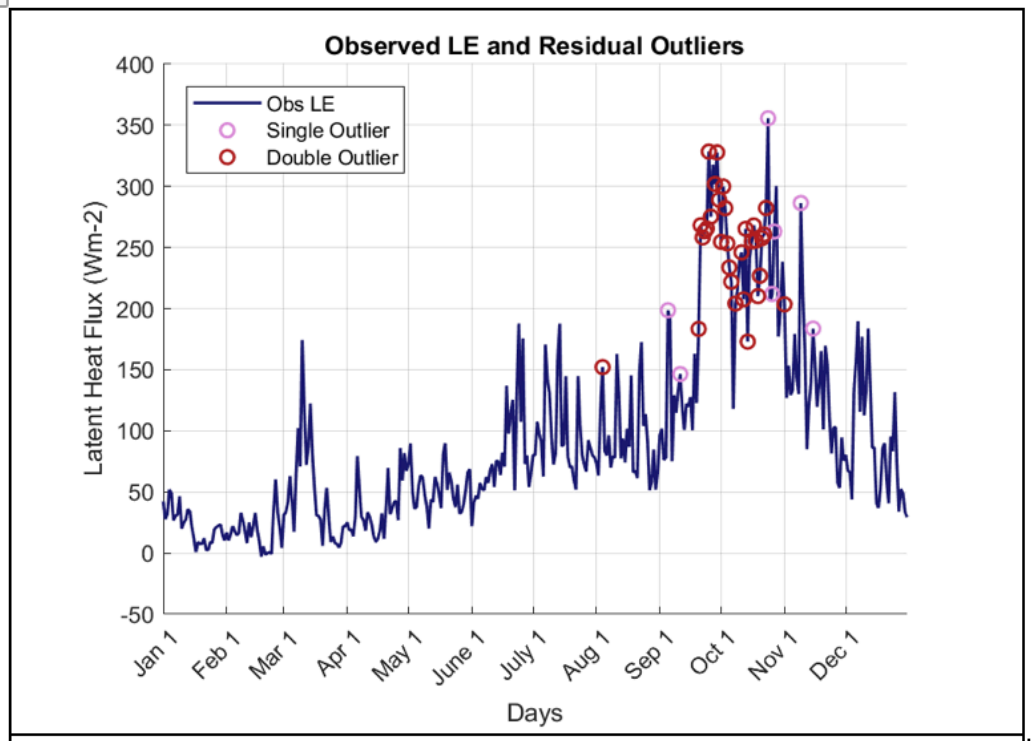
今日太湖蓝藻水华现状描述：巡测时段西南风 3－4 级，风浪偏大，乌溪港以北至竺山湾次岸带水华密度很大，覆盖整个水面生物量也很高。夹浦以东，湖心藻颗粒密度不大，生物量也较少。梅梁湾东部湾口蓝藻水华密度中等，东北牵龙口水域，西部沿岸带南段有少量水华。贡湖湾口蓝藻密度较大，湾心至锡东水厂藻密度小于湾口，北部沿岸带蓝藻生物量中等。

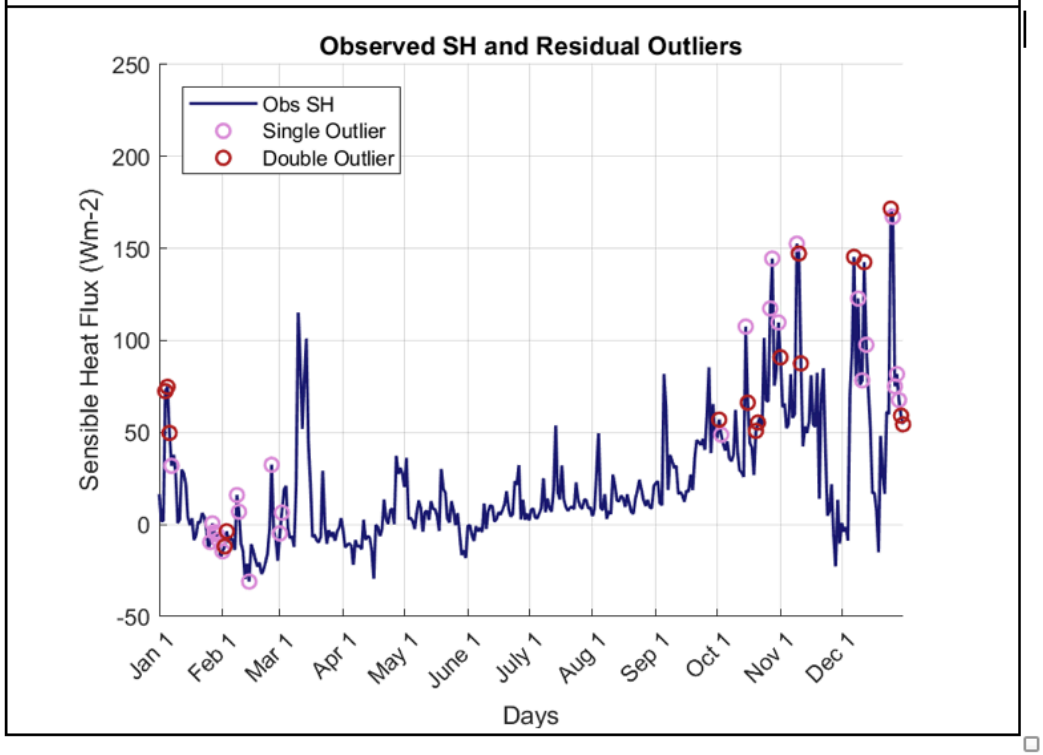
未来三天内蓝藻水华发展趋势：未来三天天气炎热，风向为西南风。在西南风的影响下，竺山湾东部将出现较多蓝藻水华，而处于上风口的西太湖沿岸带与次沿岸带的水华情况可能稍有缓解，但仍需关注其变化。蓝藻将会向处于下风口的梅梁湾牵龙口水域、湾心以东的大部水域，贡湖湾湾心以西，尤其湾顶锡东水厂一带及南泉水厂附近的北部沿岸带漂移，容易形成水华堆积，应关注这一带的变化，并加强水源地的保护。

监测人：季江、薛静琛　　数据整理人：李未　　预报人：秦伯强、李未、孔繁翔

Courtesy of Guangwei Zhu

Z. Taebel
A. Baldocchi
D. Reed





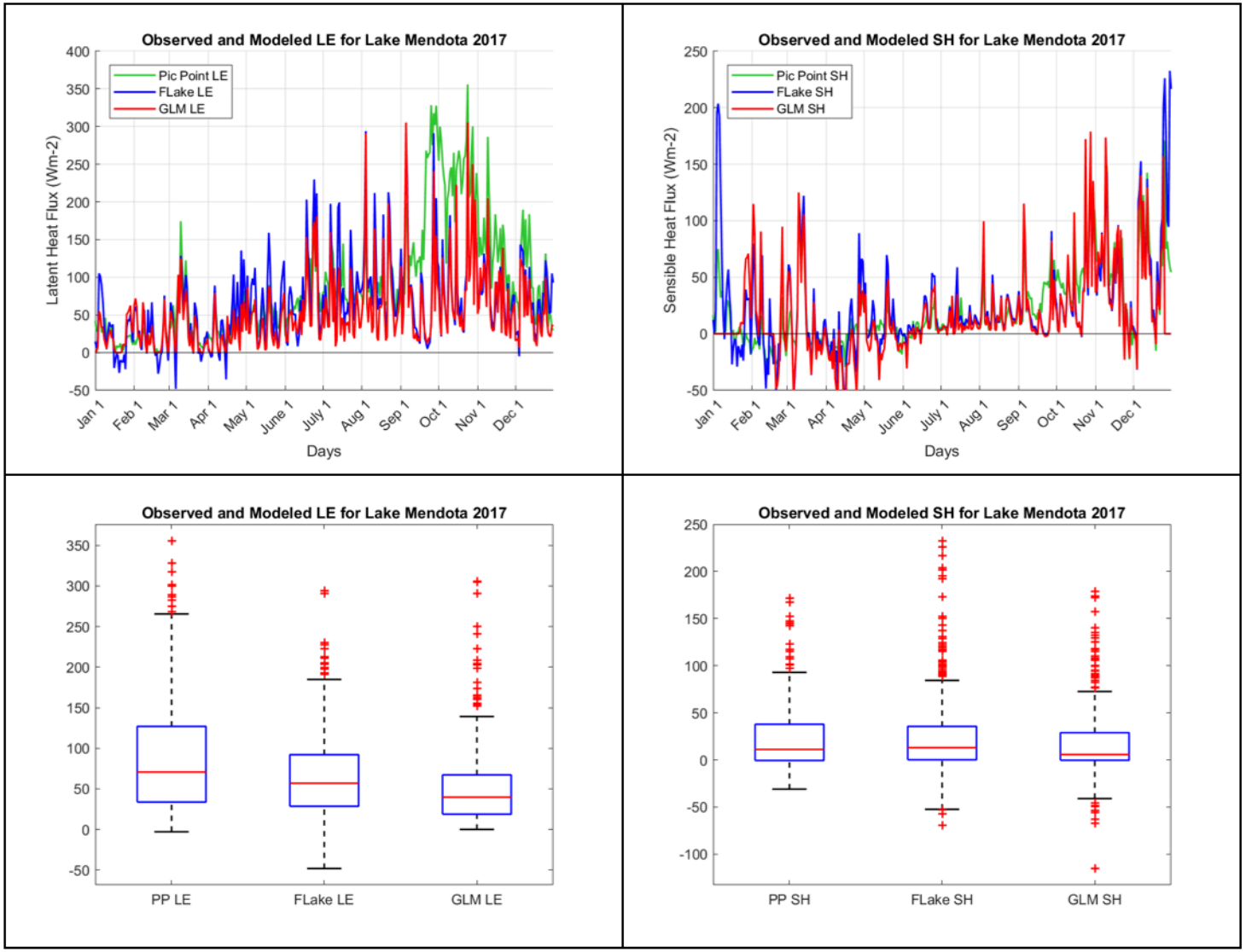
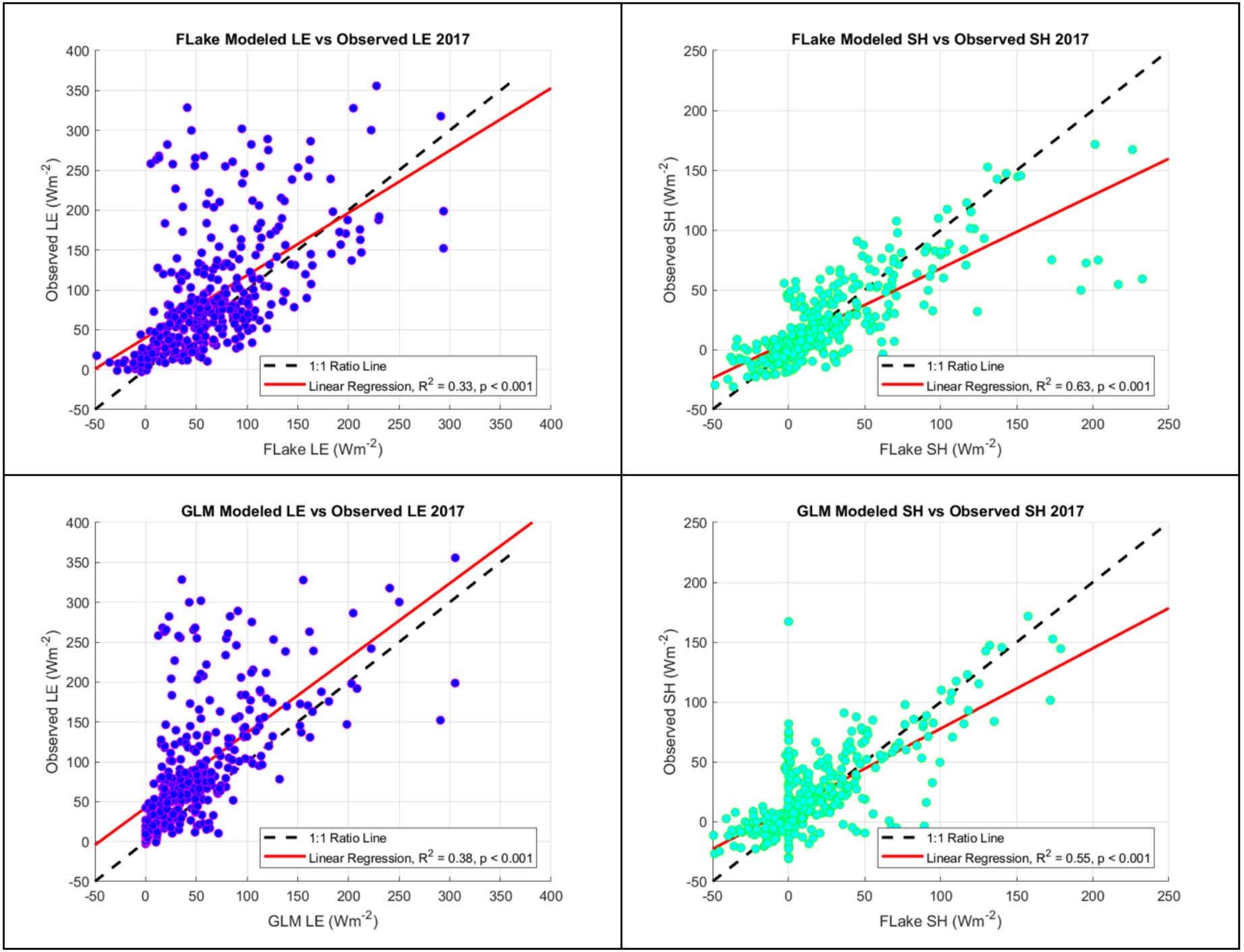
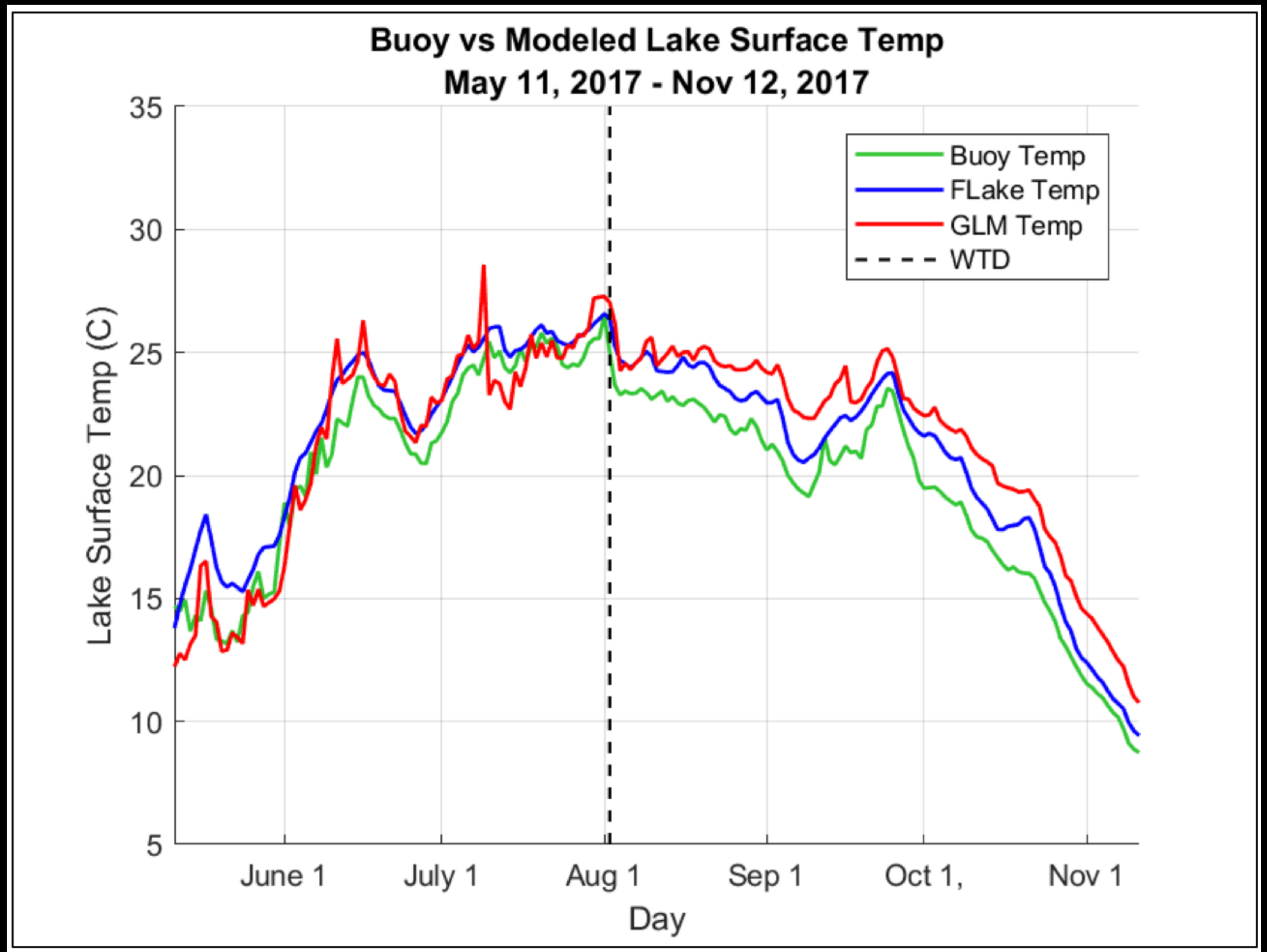
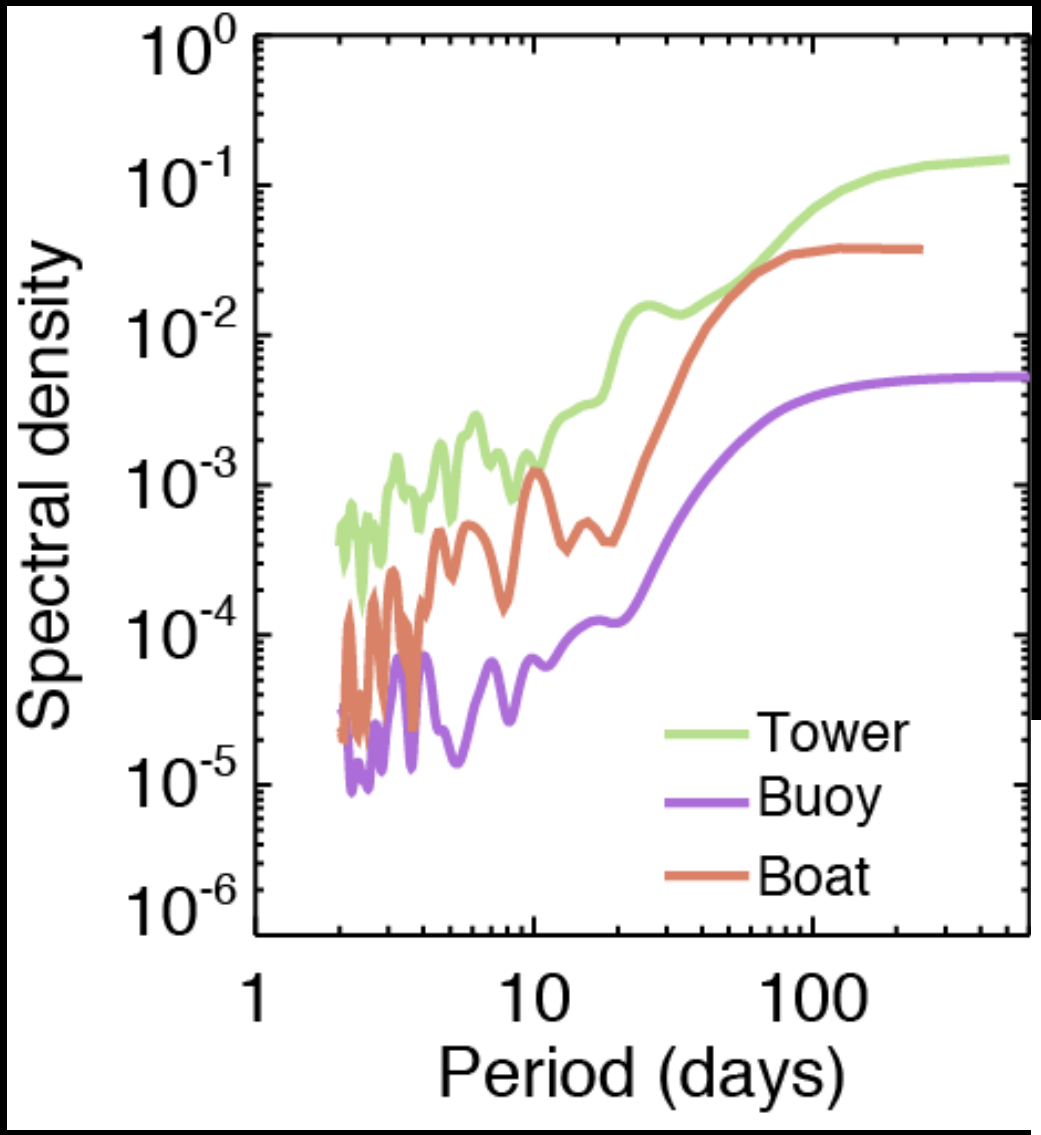


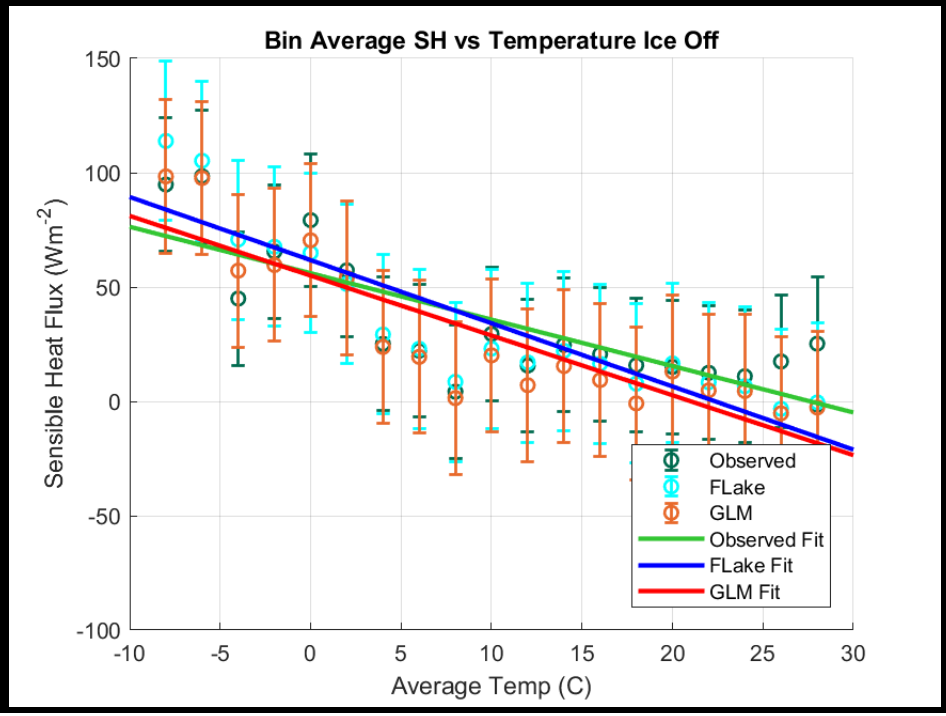
Figure 1: (clockwise from top left) Picnic Point and model latent heat fluxes for 2017; Picnic Point and model sensible heat fluxes for 2017; Boxplot of 2017 Picnic Point and modeled sensible heat fluxes; Boxplot of 2017 Picnic Point and modeled latent heat fluxes

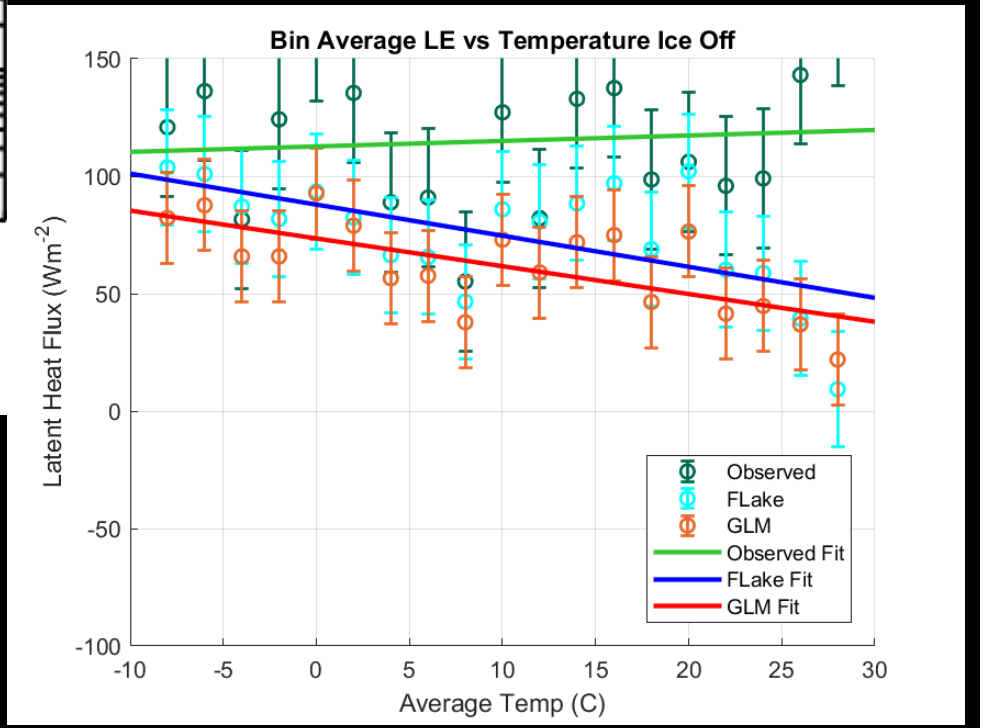

FLake Modeled LE vs Observed LE 2017
Observed LE (Wm-2)
FLake LE (Wm-2)
1:1 Ratio Line
Linear Regression, R2 = 0.33, p < 0.001
FLake Modeled SH vs Observed SH 2017
Observed SH (Wm-2)
FLake SH (Wm-2)
1:1 Ratio Line
Linear Regression, R2 = 0.63, p < 0.001
GLM Modeled LE vs Observed LE 2017
Observed LE (Wm-2)
GLM LE (Wm-2)
1:1 Ratio Line
Linear Regression, R2 = 0.38, p < 0.001
GLM Modeled SH vs Observed SH 2017
Observed SH (Wm-2)
FLake SH (Wm-2)
1:1 Ratio Line
Linear Regression, R2 = 0.55, p < 0.001


Buoy vs Modeled Lake Surface Temp
May 11, 2017 - Nov 12, 2017
Buoy Temp
FLake Temp
GLM Temp
WTD
Lake Surface Temp (C)
35
30
25
20
15
10
5
June 1
July 1
Aug 1
Sep 1
Oct 1,
Nov 1
Day



C Flux power spectra





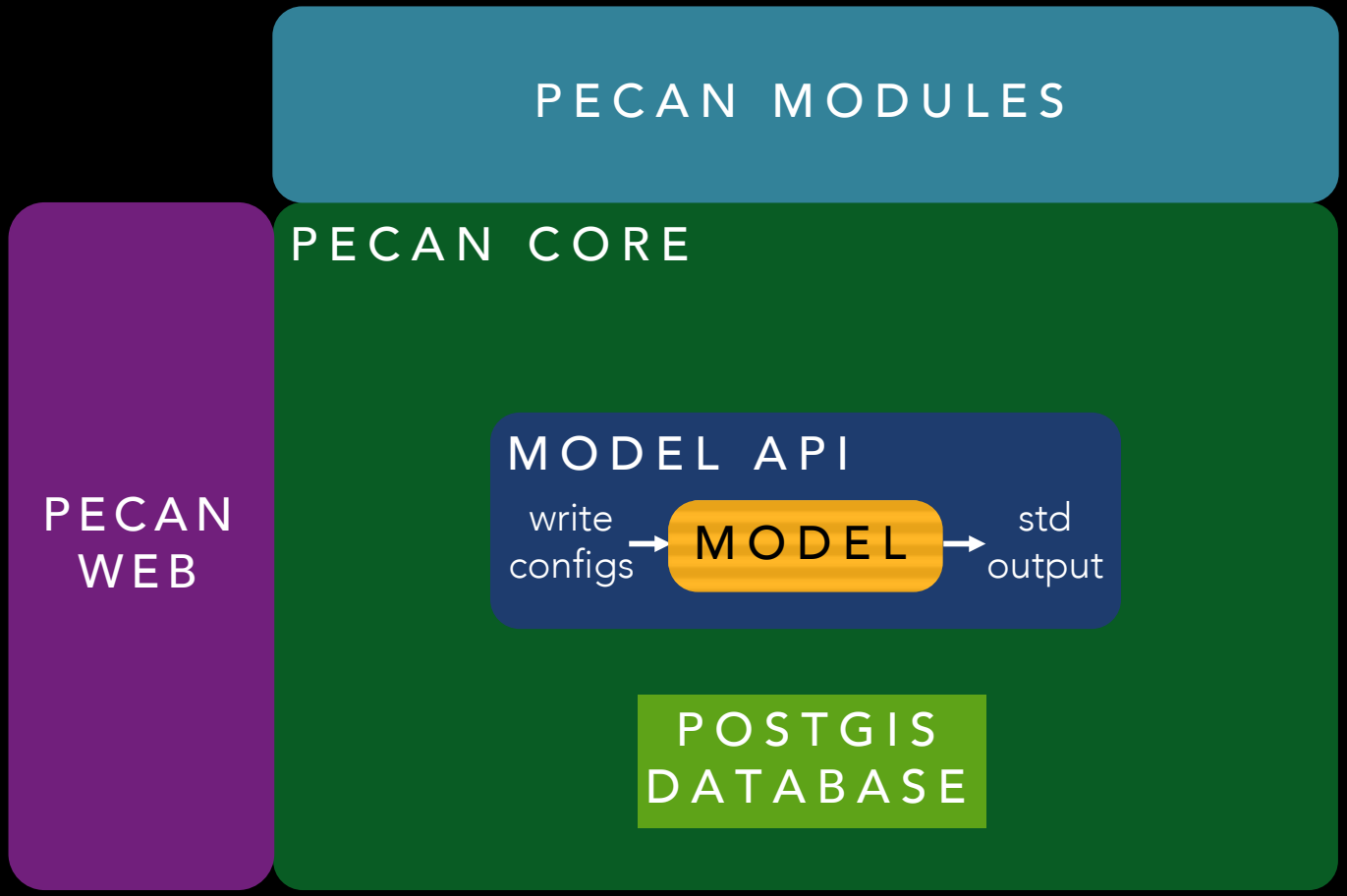
Thoughts for discussion?

- 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

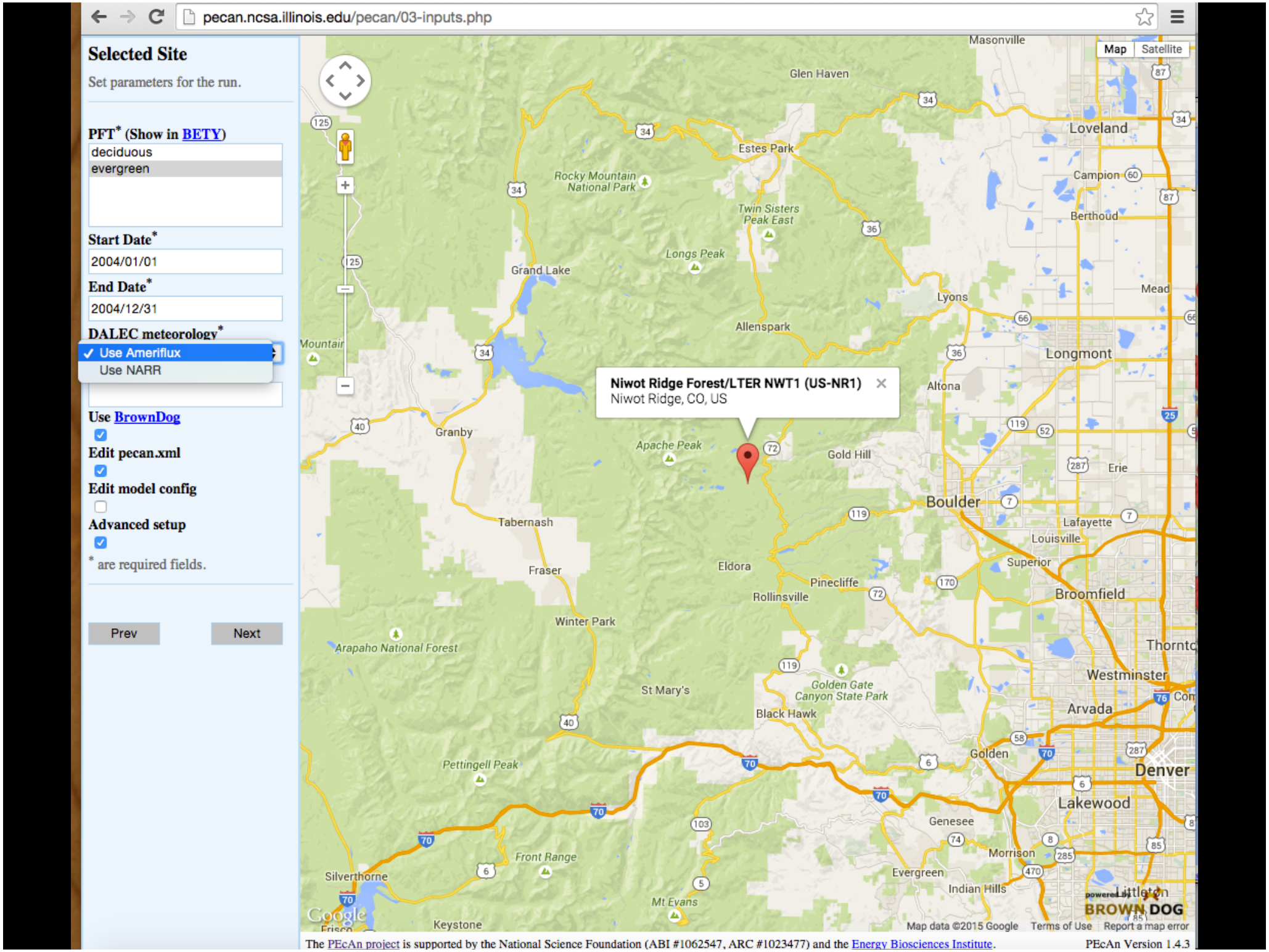


Standardized inputs and outputs

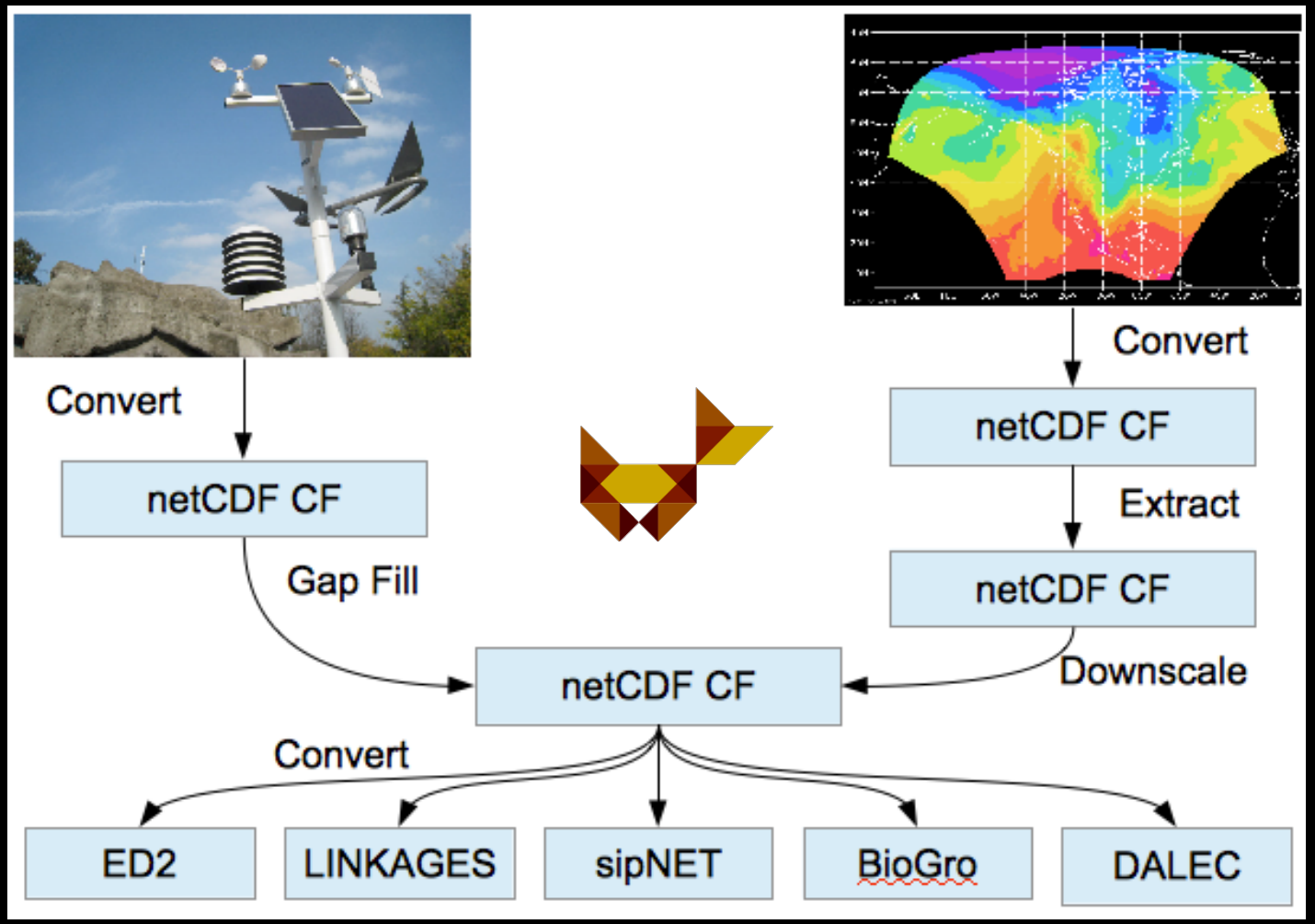
Provenance: Transparent & Repeatable

Accessible interface

Reusable tools for execution, analysis, visualization

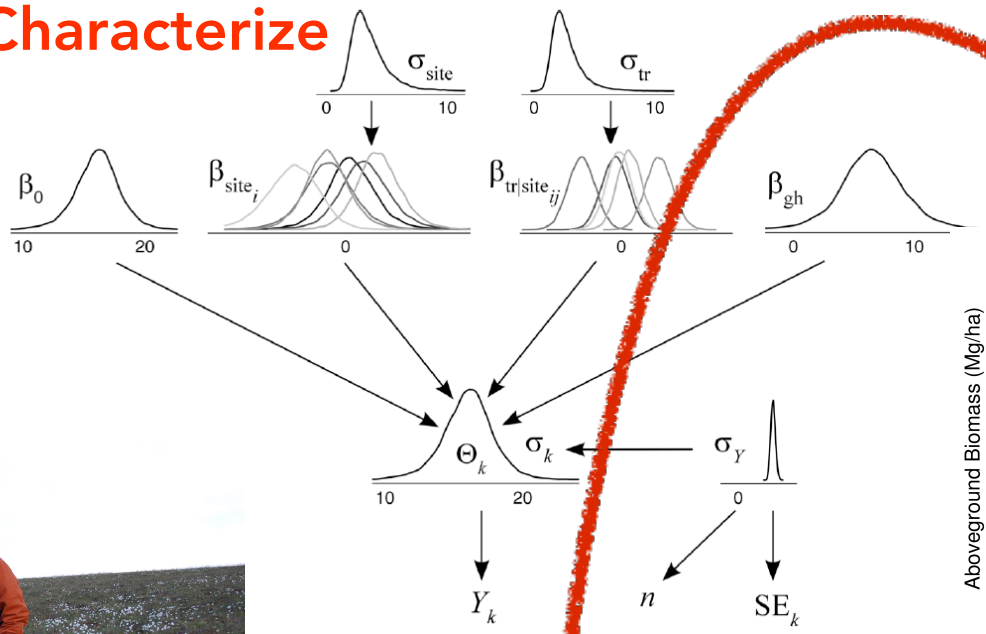

pecan.ncsa.illinois.edu/pecan/03-inputs.php
Selected Site
Set parameters for the run.
PFT* (Show in BETY)
deciduous
evergreen
Start Date*
2004/01/01
End Date*
2004/12/31
DALEC meteorology*
Use Ameriflux
Use NARR
Use BrownDog
Edit pecan.xml
Edit model config
Advanced setup
* are required fields.
Prev
Next
Map
Satellite
Niwot Ridge Forest/LTER NWT1 (US-NR1)
Niwot Ridge, CO, US
Masonville
Glen Haven
Loveland
Estes Park
Rocky Mountain National Park
Twin Sisters Peak East
Longs Peak
Grand Lake
Campion
Berthoud
Mead
Lyons
Allenspark
Longmont
Altona
Granby
Apache Peak
Gold Hill
Erie
Boulder
Lafayette
Louisville
Superior
Tabernash
Fraser
Eldora
Pinecliffe
Rollinsville
Broomfield
Winter Park
Arapaho National Forest
Golden Gate Canyon State Park
St Mary's
Black Hawk
Westminster
Arvada
Golden
Denver
Lakewood
Pettingell Peak
Genesee
Front Range
Morrison
Evergreen
Indian Hills
Silverthorne
Mt Evans
Keystone
Google
Map data ©2015 Google
Terms of Use
Report a map error
BROWN DOG
The PEcAn project is supported by the National Science Foundation (ABI #1062547, ARC #1023477) and the Energy Biosciences Institute.
PEcAn Version 1.4.3

INFORMATICS MODULES

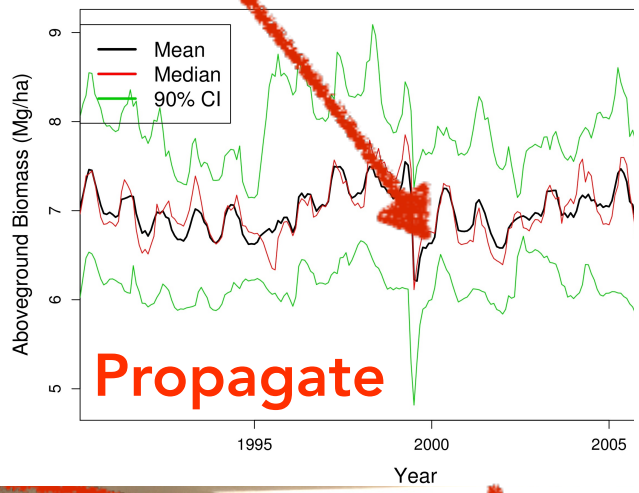


Cowdery et al in prep

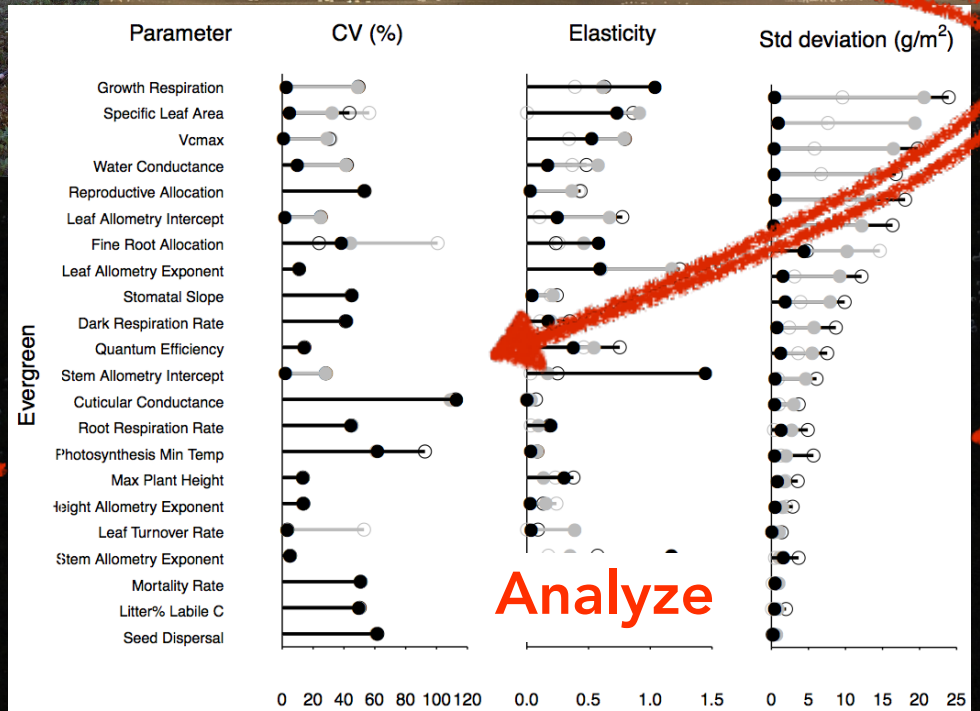
Characterize



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?