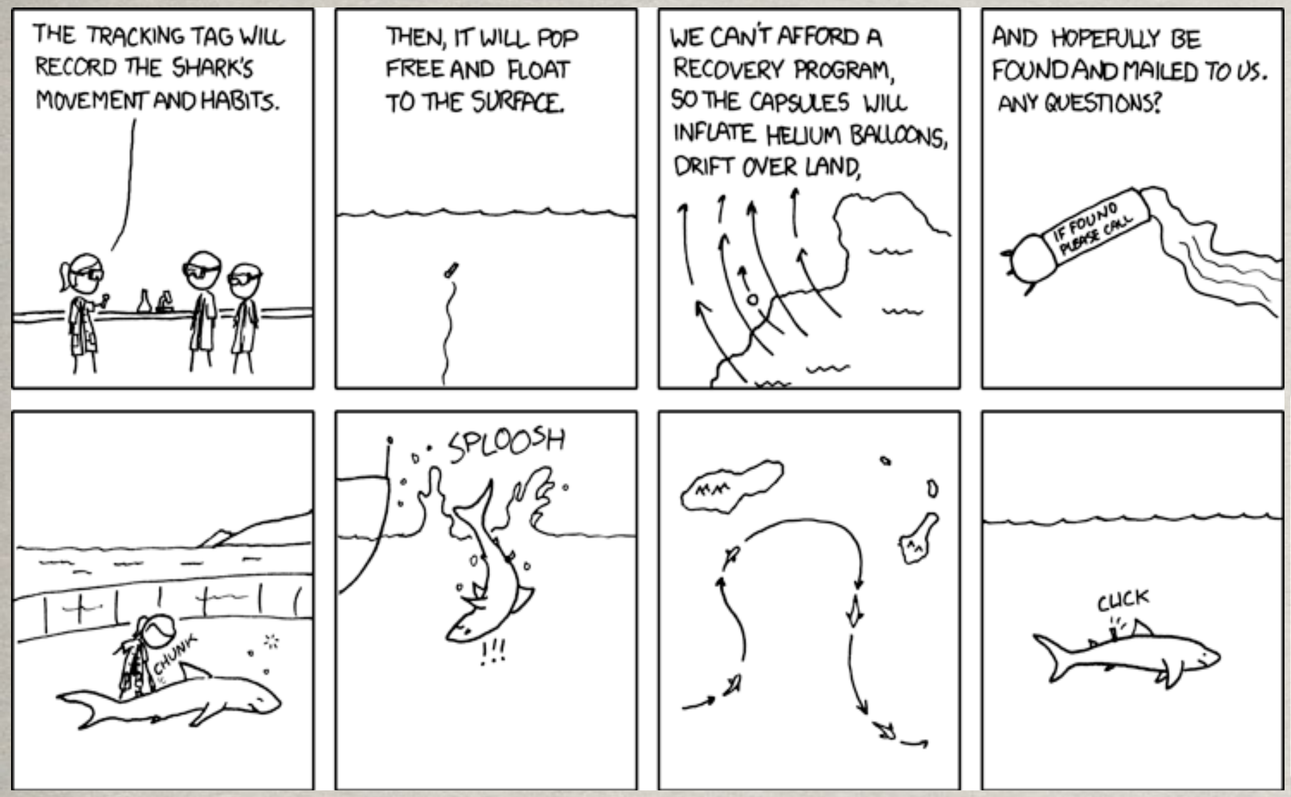
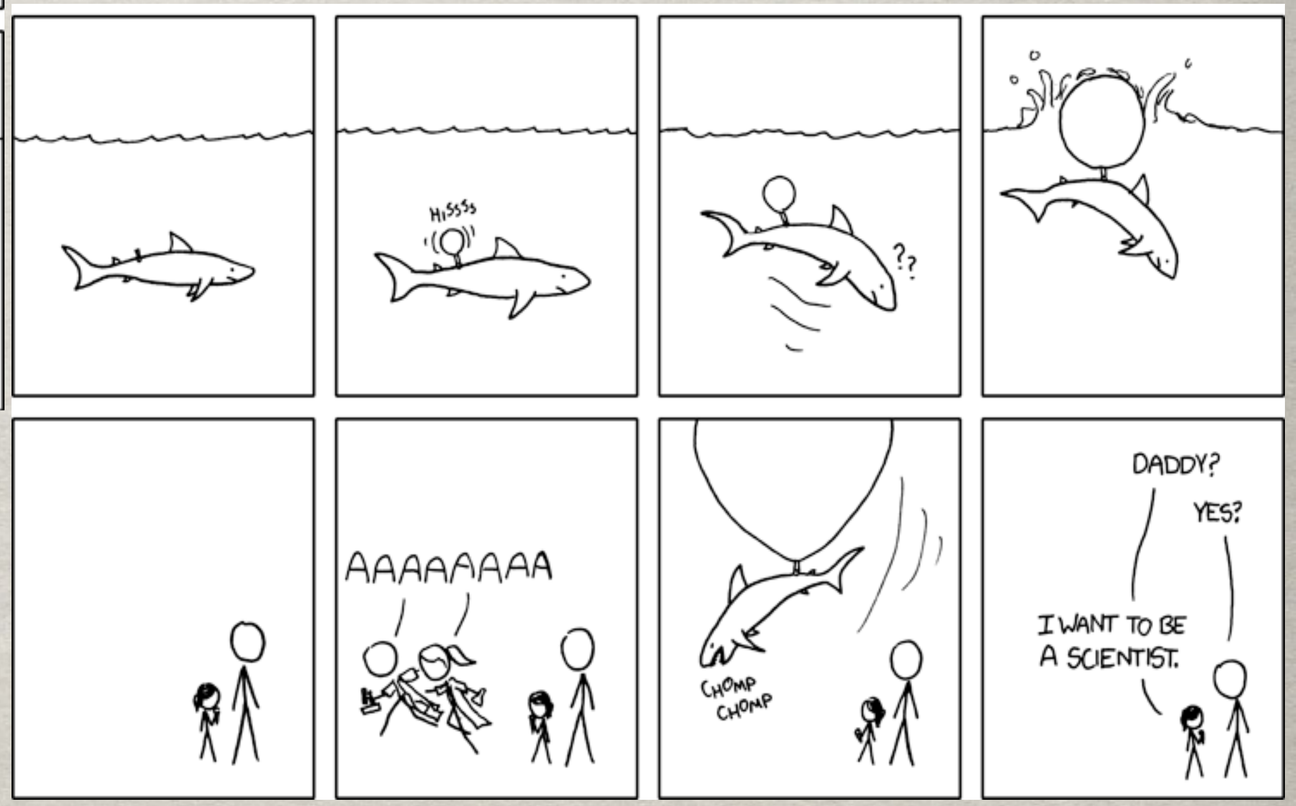

THE TRACKING TAG WILL RECORD THE SHARK'S MOVEMENT AND HABITS.
THEN, IT WILL POP FREE AND FLOAT TO THE SURFACE.
WE CAN'T AFFORD A RECOVERY PROGRAM, SO THE CAPSULES WILL INFLATE HELIUM BALLOONS, DRIFT OVER LAND,
AND HOPEFULLY BE FOUND AND MAILED TO US. ANY QUESTIONS?
IF FOUND PLEASE CALL
CHUNK
SPLOOSH
!!!
CLICK


HISSSS
??
AAAAAAAA
CHOMP CHOMP
DADDY?
YES?
I WANT TO BE A SCIENTIST.

xkcd.com/585

Ecological Forecasts: An Emerging Imperative

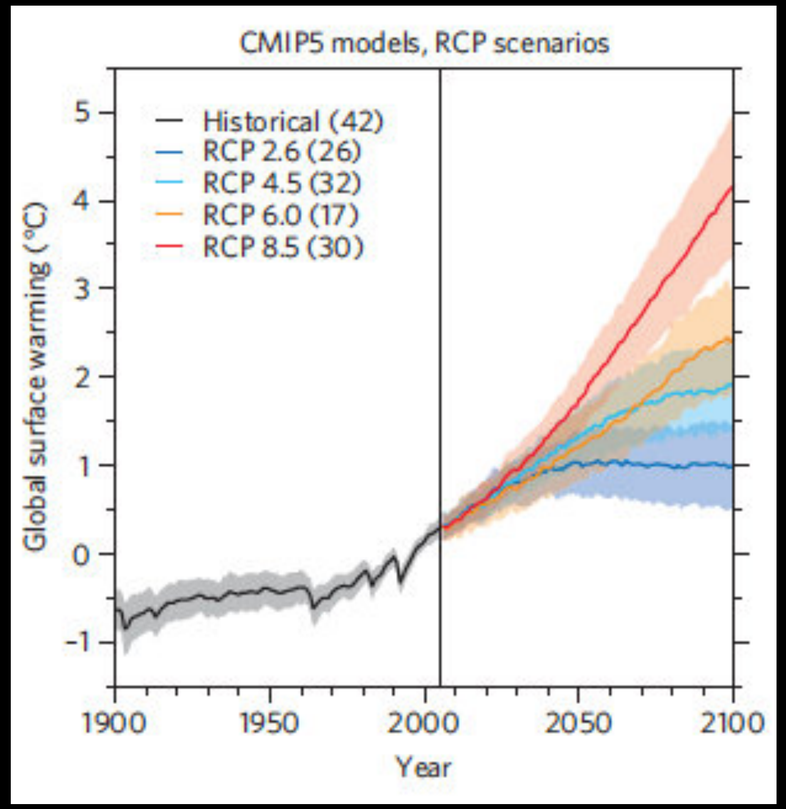
James S. Clark,[1]* Steven R. Carpenter,[2] Mary Barber,[3] Scott Collins,[4] Andy Dobson,[5] Jonathan A. Foley,[6] David M. Lodge,[7] Mercedes Pascual,[8] Roger Pielke Jr.,[9] William Pizer,[10] Cathy Pringle,[11] Walter V. Reid,[12] Kenneth A. Rose,[13] Osvaldo Sala,[14] William H. Schlesinger,[15]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

PROJECTION

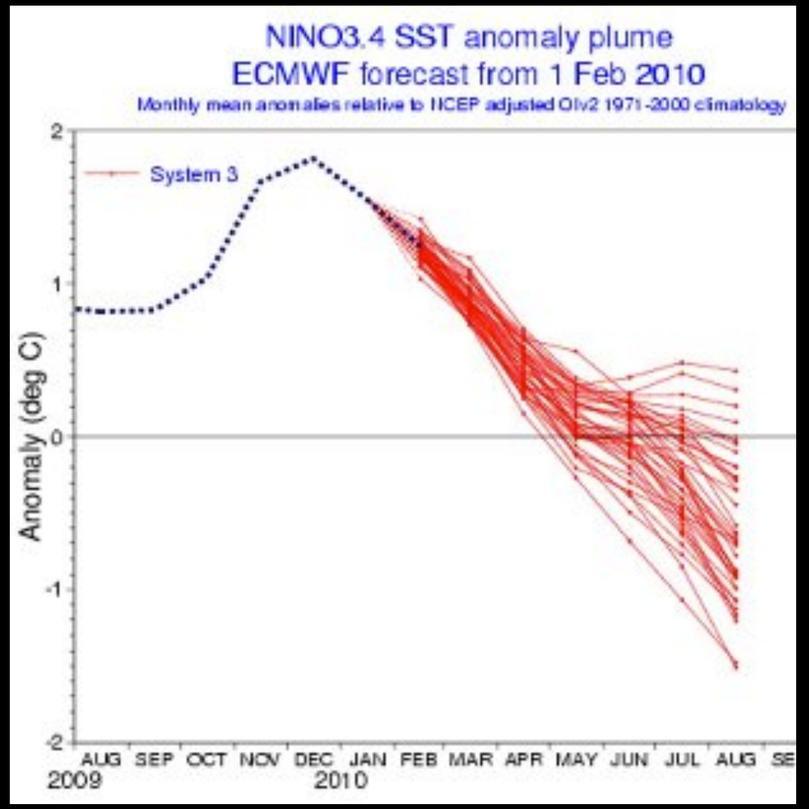
"PROBABILISTIC STATEMENT THAT IT IS POSSIBLE THAT SOMETHING WILL HAPPEN IN THE FUTURE" GIVEN BOUNDARY CONDITION SCENARIOS



MacCracken 2001

PREDICTION

"PROBABILISTIC STATEMENT THAT SOMETHING WILL HAPPEN IN THE FUTURE BASED ON WHAT IS KNOWN TODAY"



WHY FORECAST?

CLIMATE CHANGE

Stationarity Is Dead: Whither ~~Water~~ Environmental Management?

P. C. D. Milly,[1]* Julio Betancourt,[2] Malin Falkenmark,[3] Robert M. Hirsch,[4] Zbigniew W. Kundzewicz,[5] Dennis P. Lettenmaier,[6] Ronald J. Stouffer[7]

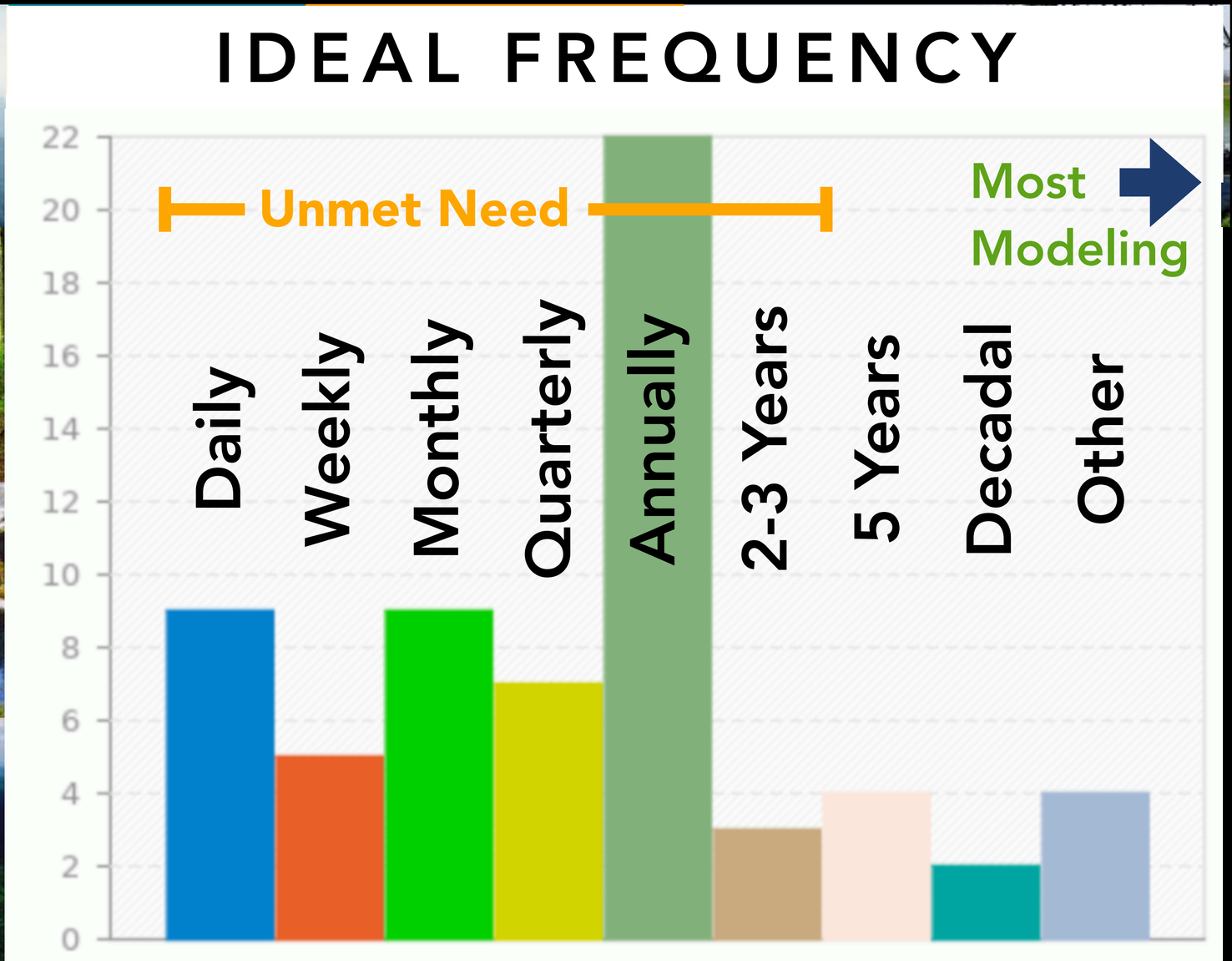
Climate change undermines a basic assumption that historically has facilitated management of water supplies, demands, and risks.

Science 2008

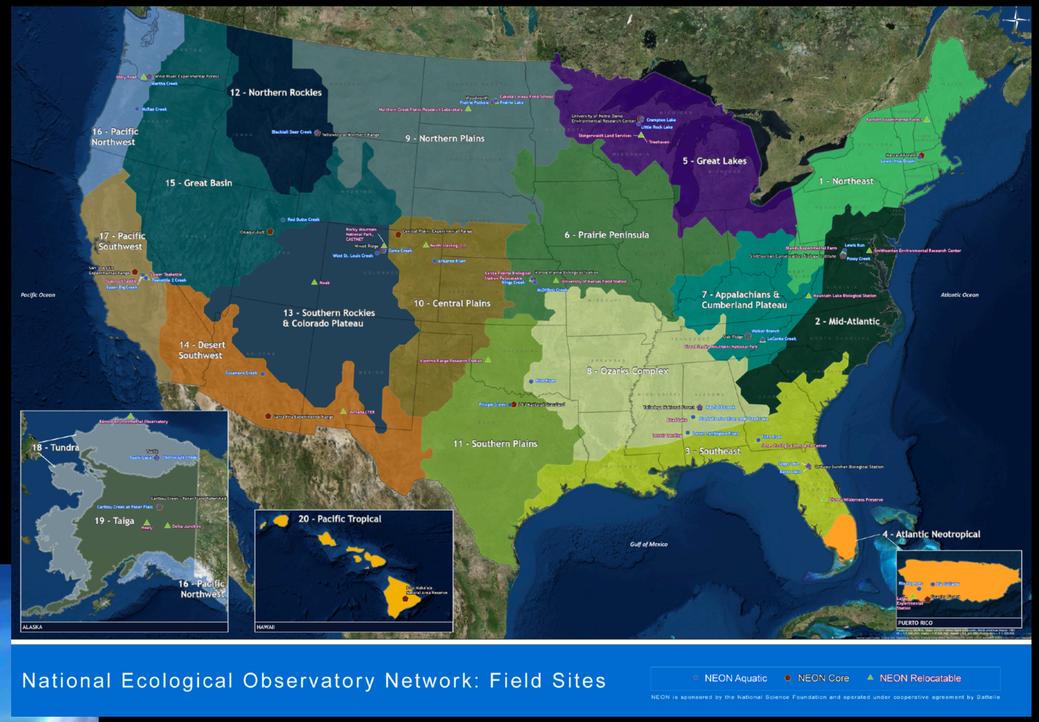
DECISIONS ARE ABOUT THE FUTURE

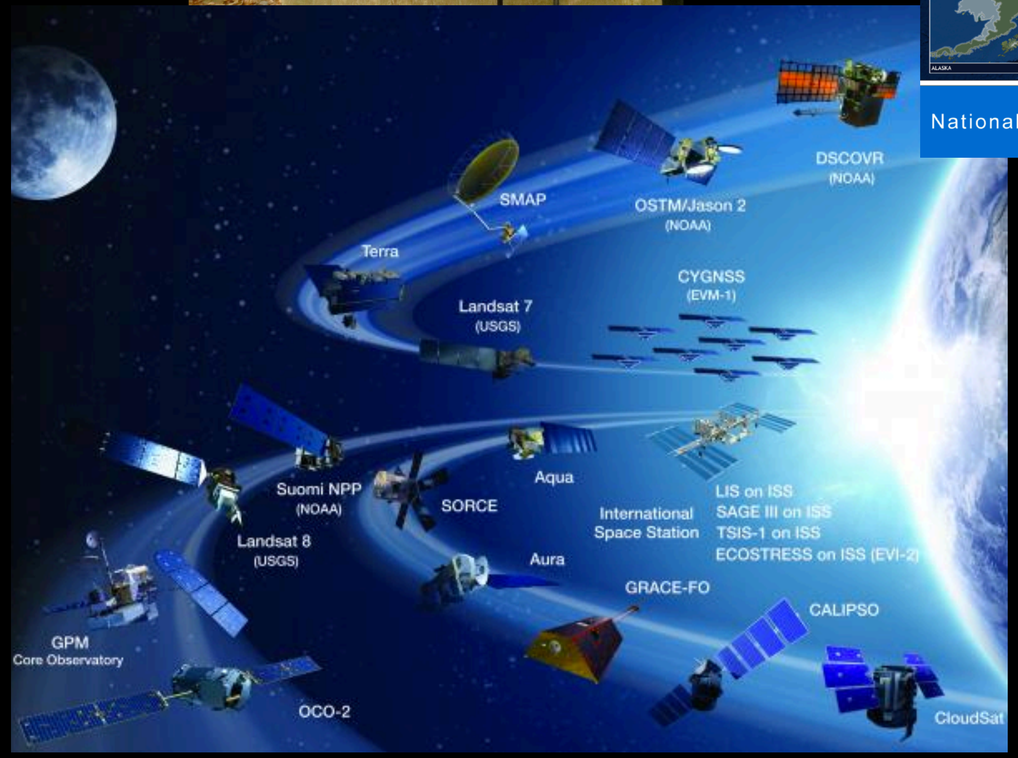
NASA Carbon Monitoring **Stakeholder** Survey

data courtesy Edil Sepulveda Carlo



REAL TIME SCIENCE





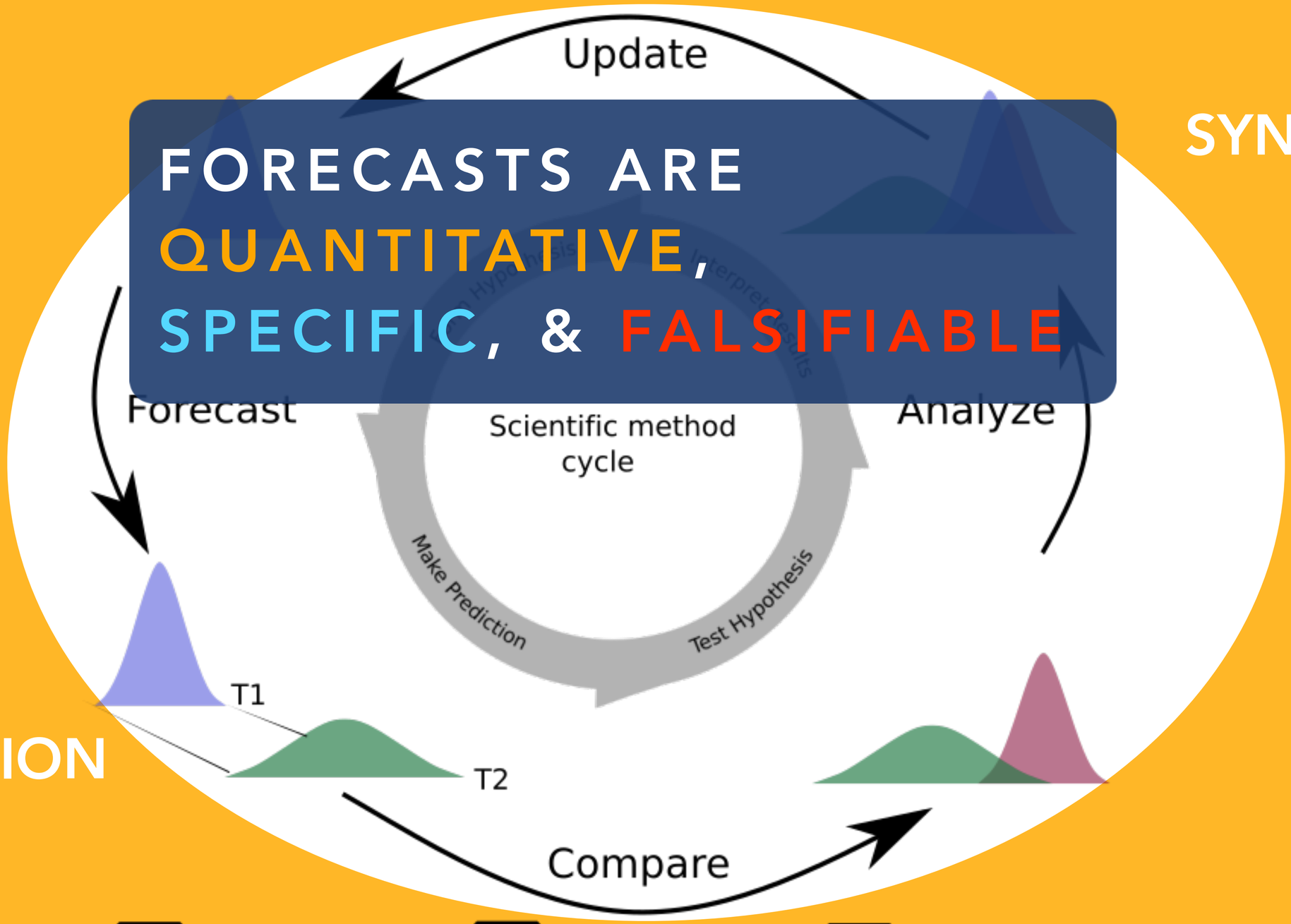
USA npn National Phenology Network
Taking the Pulse of Our Planet

iNaturalist
Explore Learn Record

eBird

GLOBAL SOUNDSCAPES

FORECASTS ARE
QUANTITATIVE,
SPECIFIC, & FALSIFIABLE

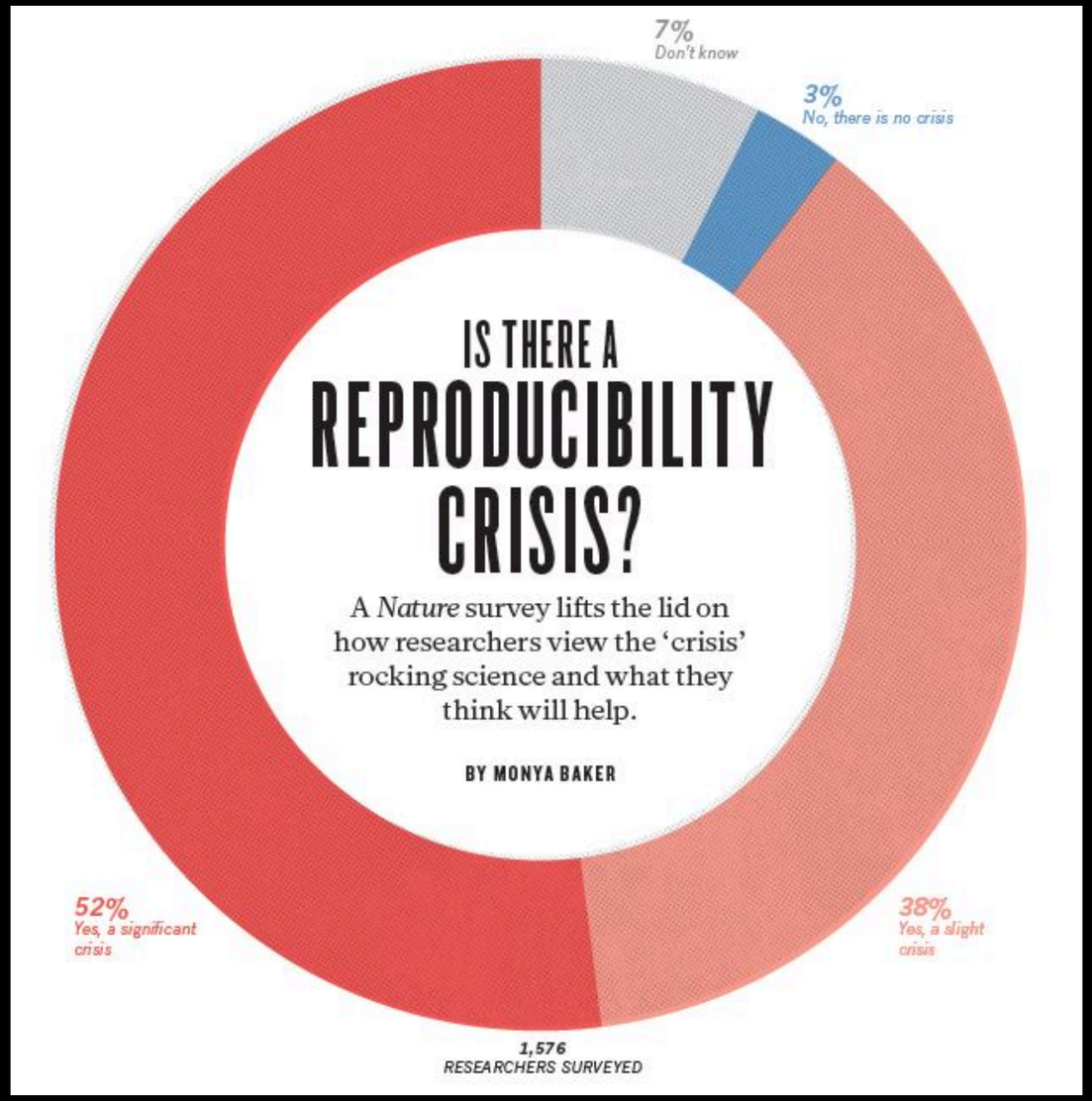


SYNTHESIS

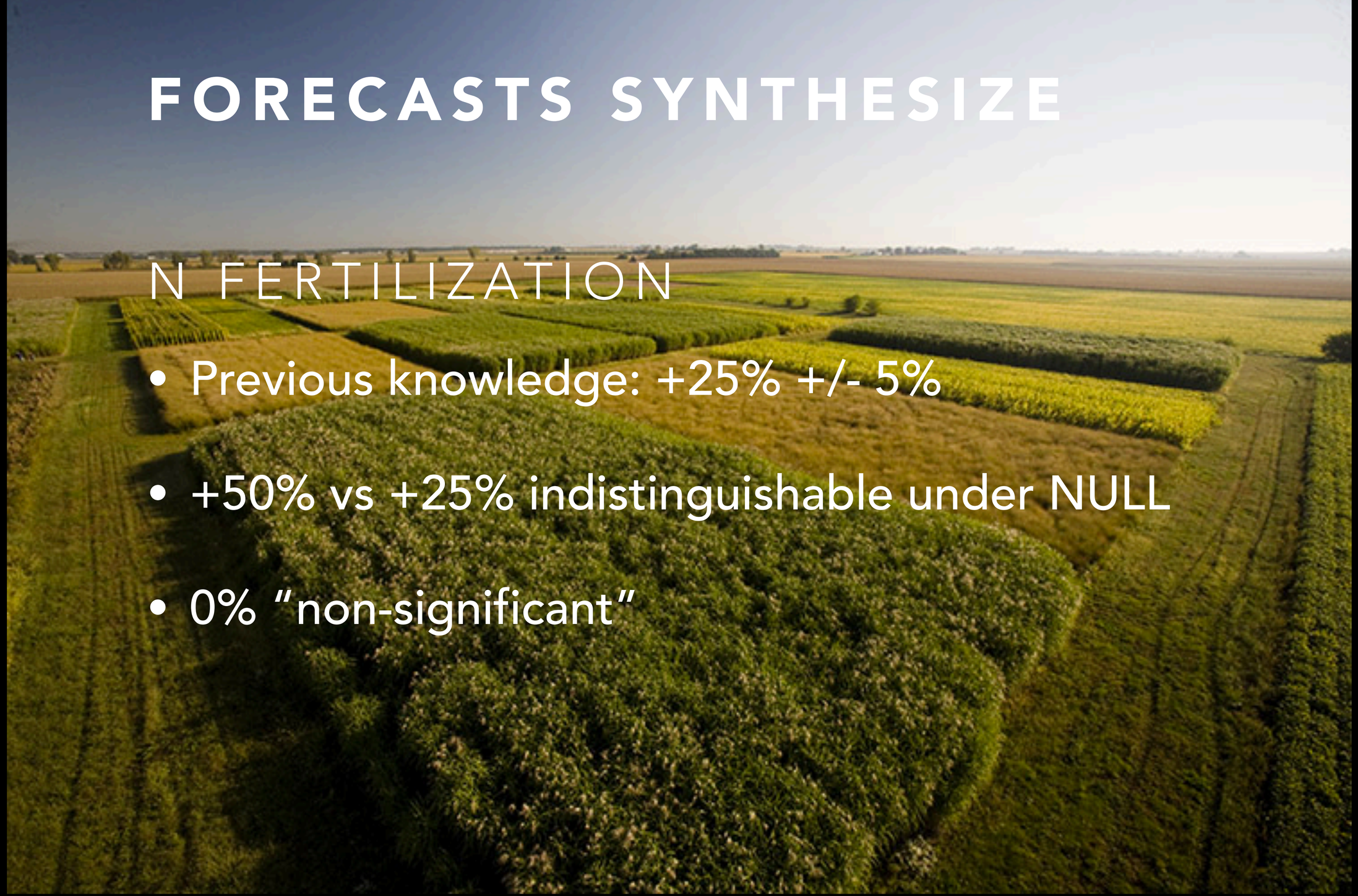
PREDICTION

Figure: T. McCabe
Dietze et al 2018 PNAS

Forecasts are a priori



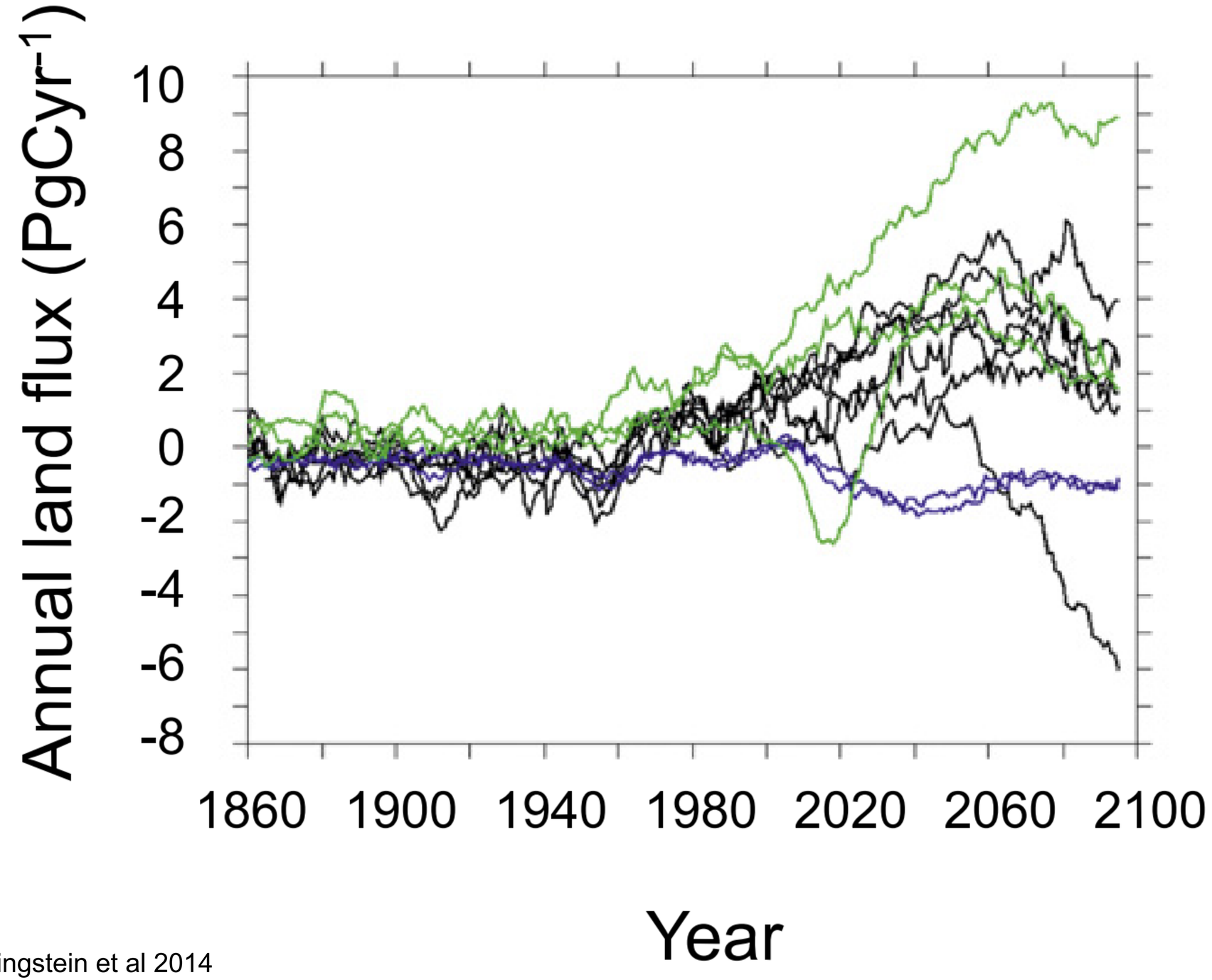
and out-of-sample



FORECASTS SYNTHESIZE

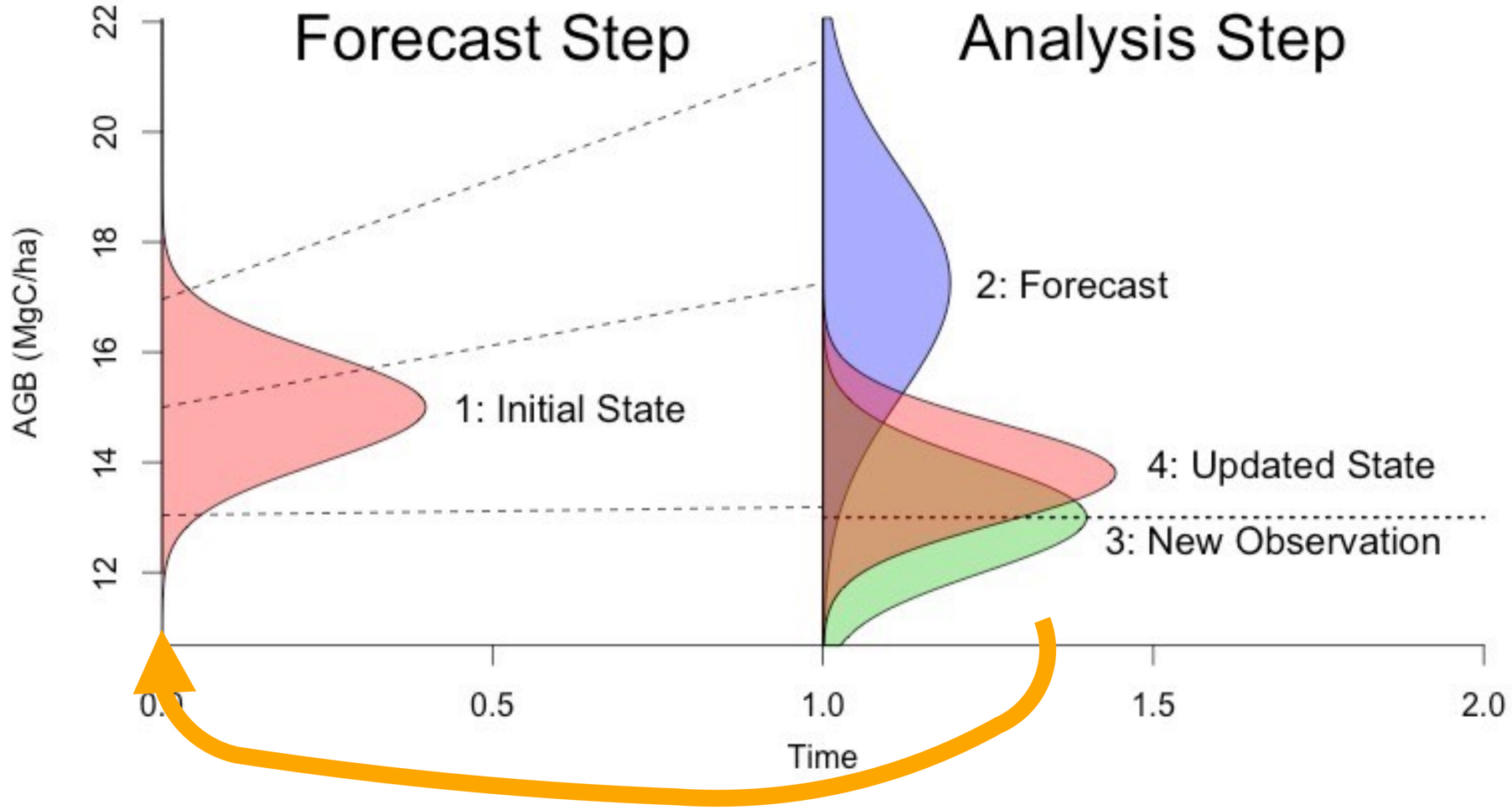
N FERTILIZATION

- Previous knowledge: +25% +/- 5%
- +50% vs +25% indistinguishable under NULL
- 0% “non-significant”



Friedlingstein et al 2014

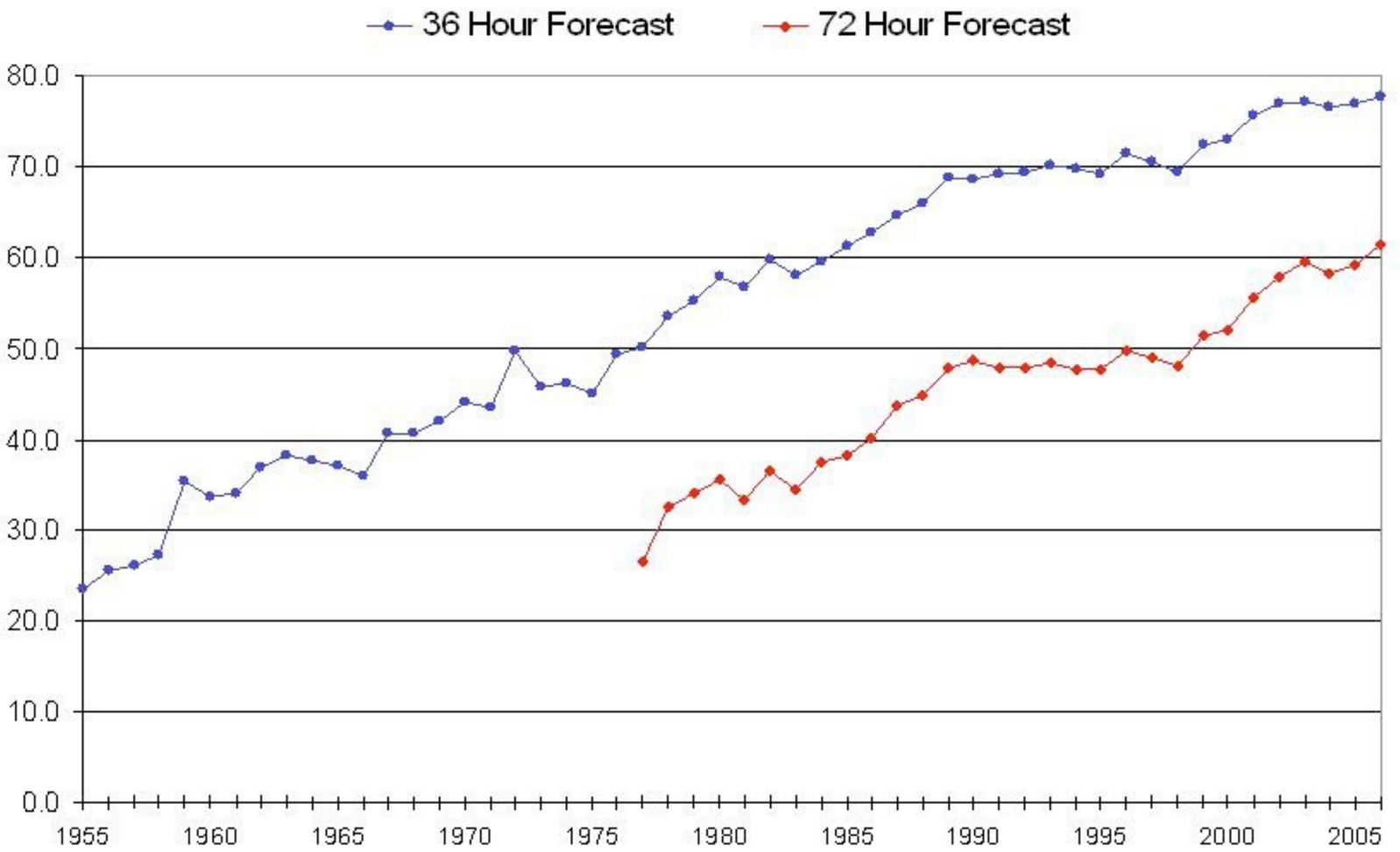
Improvement requires feedback



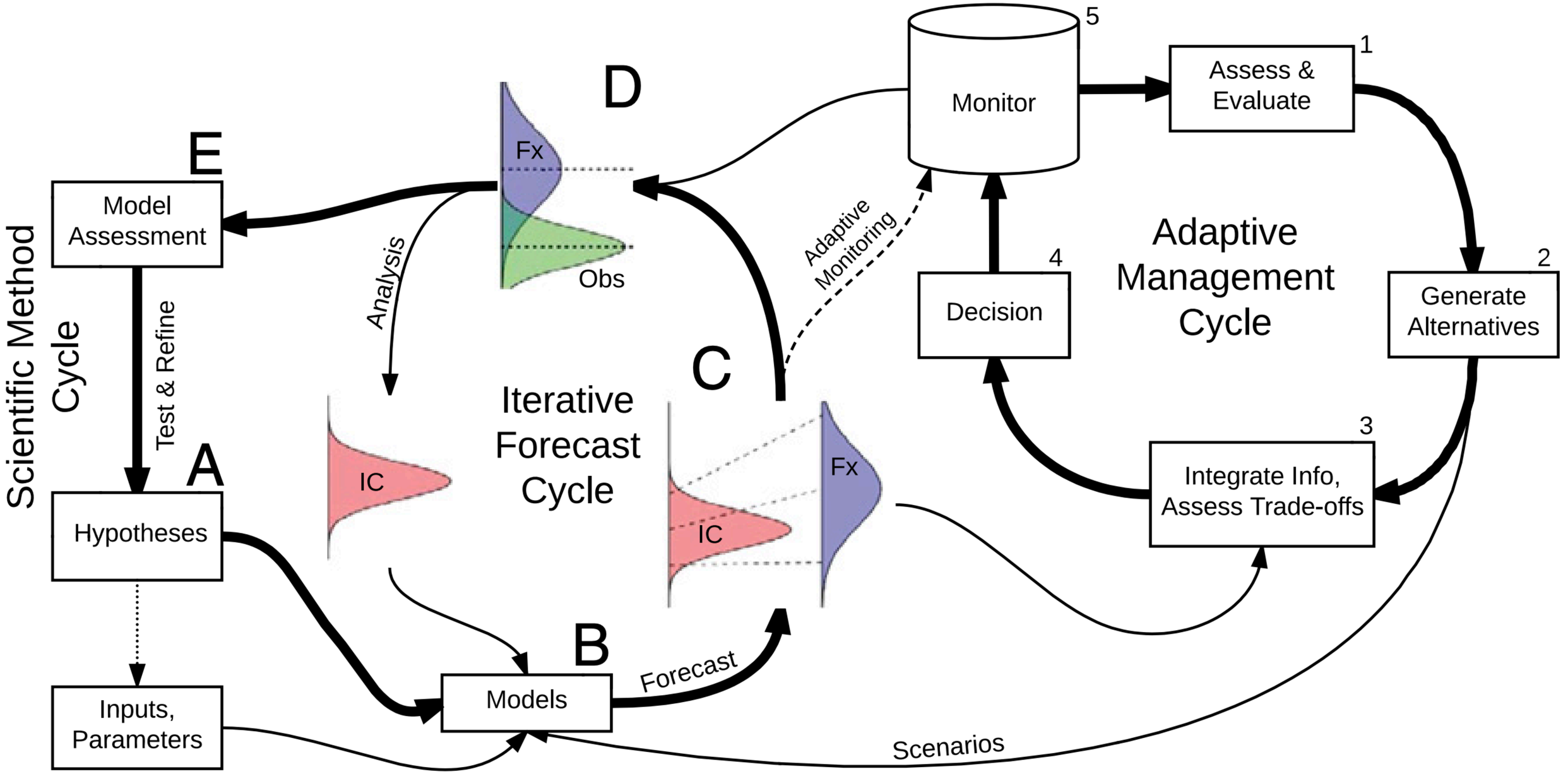
NCEP Operational Forecast Skill

36 and 72 Hour Forecasts @ 500 MB over North America

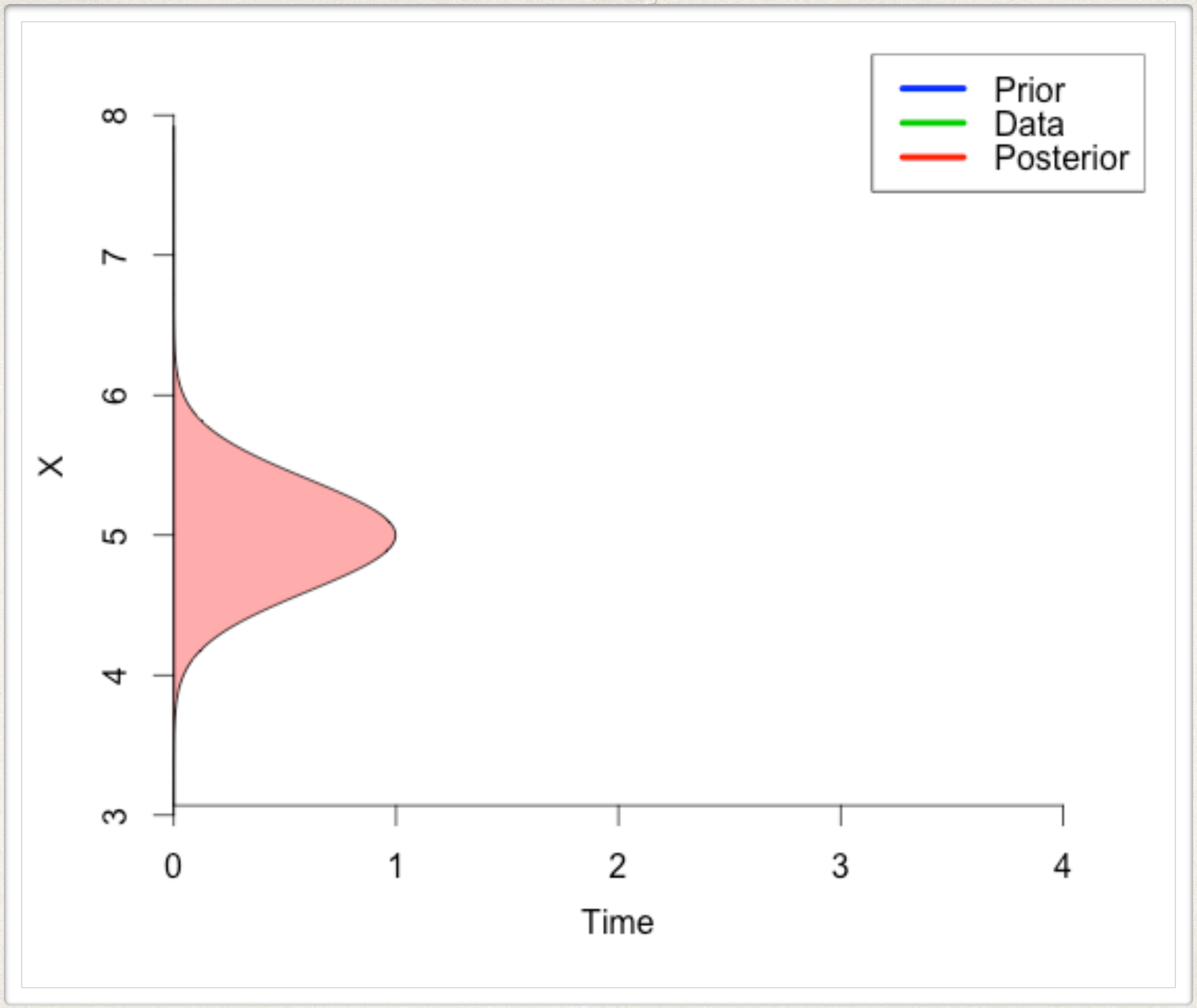
[100 * (1-S1/70) Method]

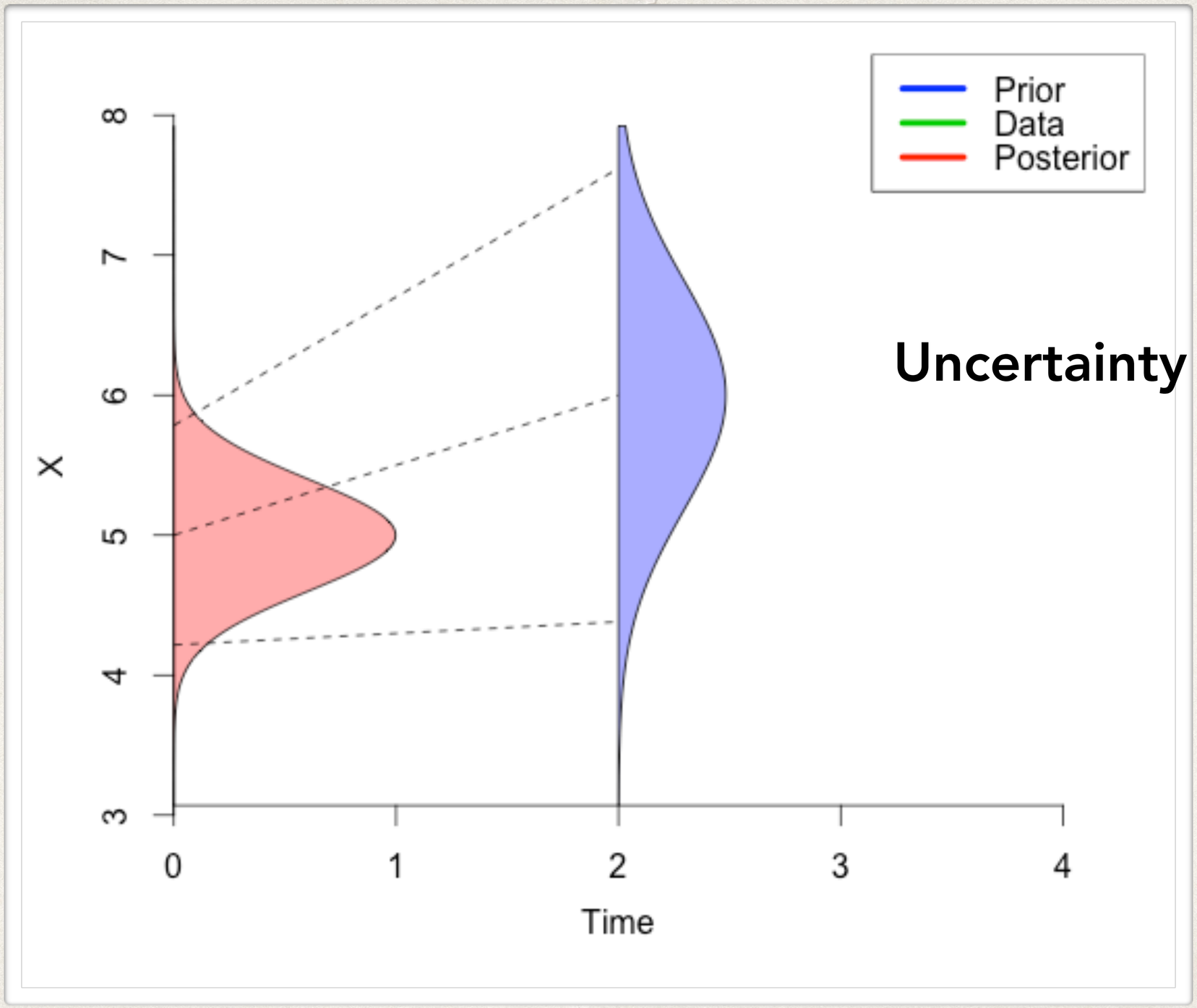


NCEP Central Operations January 2007

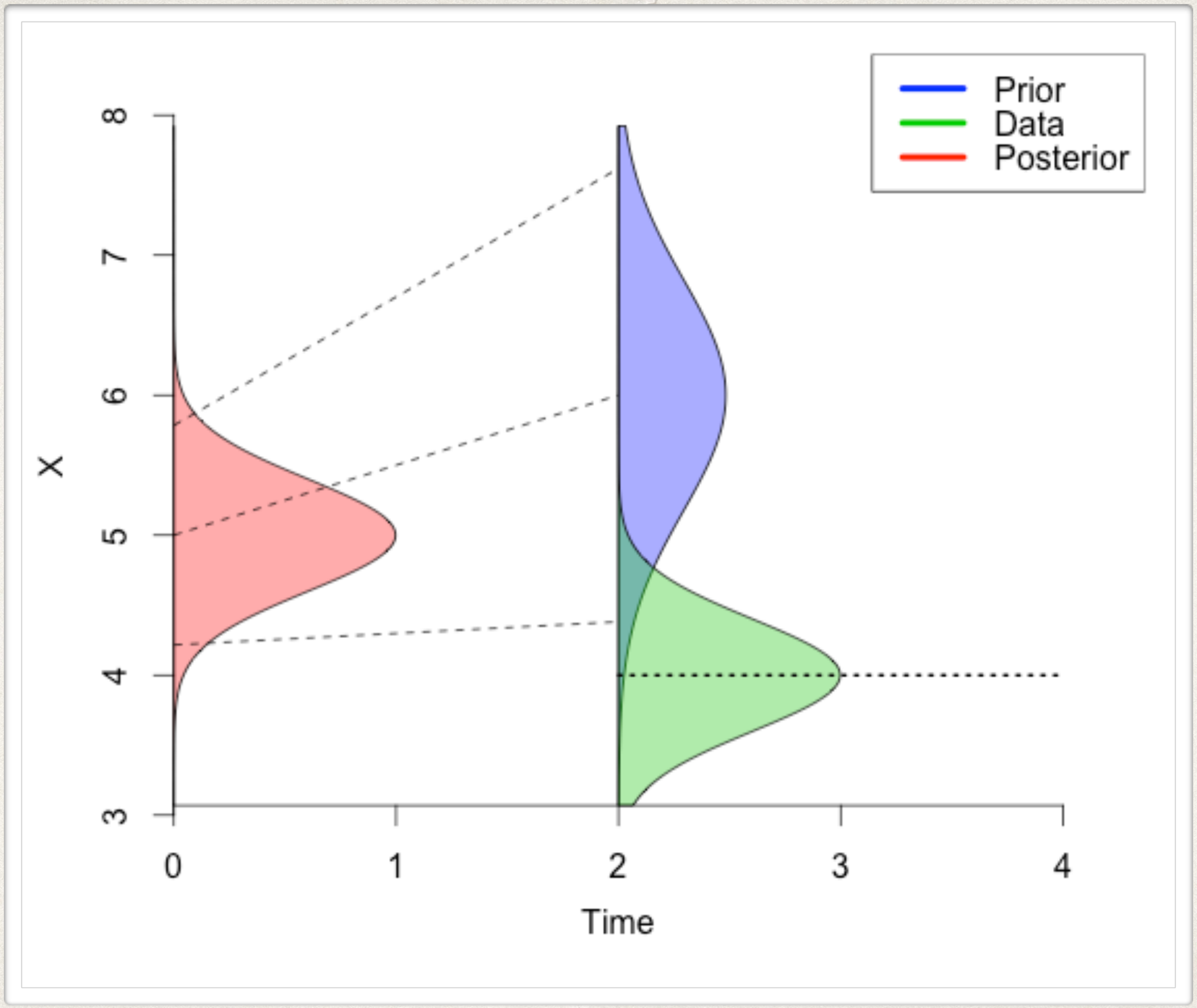


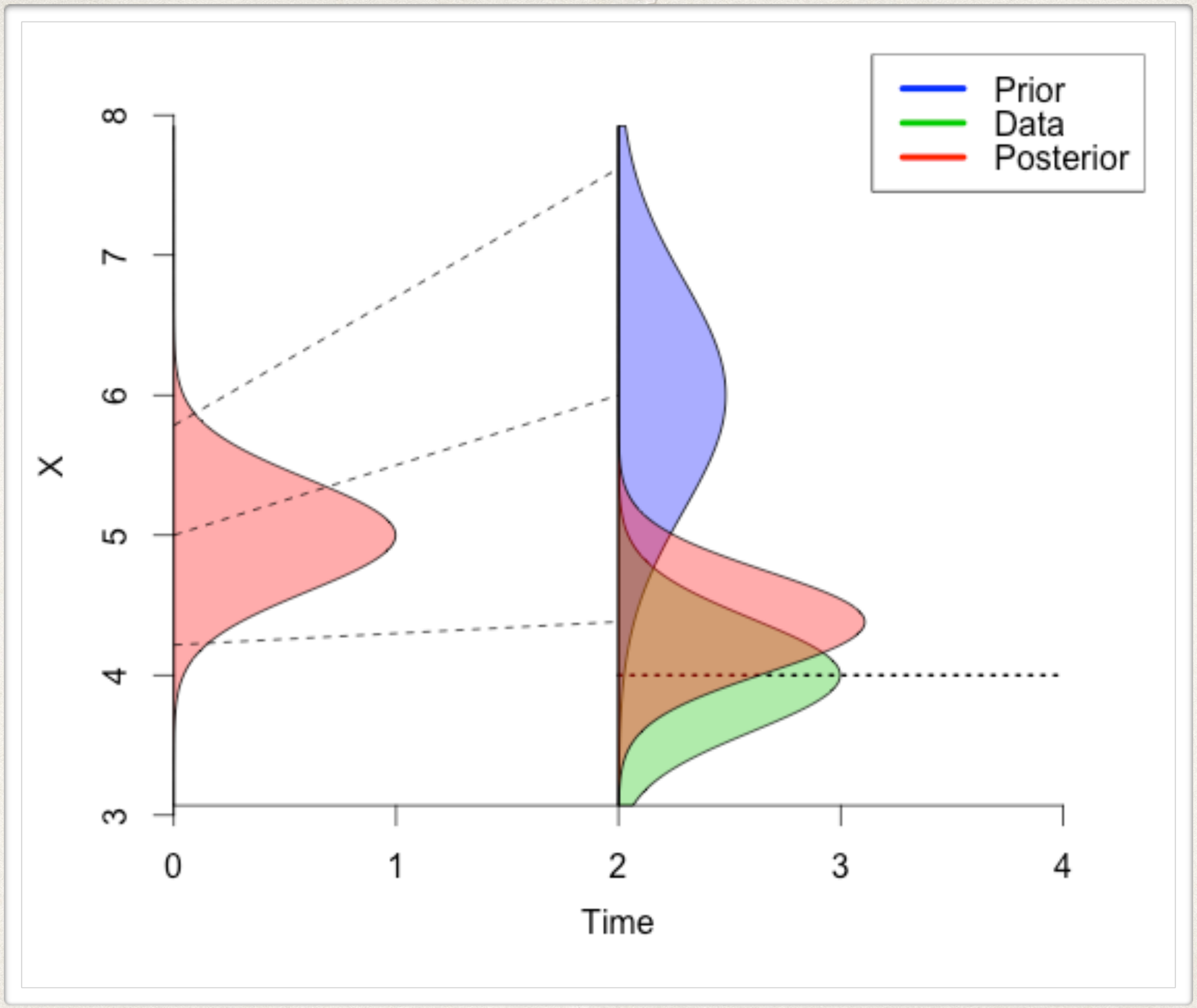
Dietze et al 2018 PNAS https://doi.org/10.1073/pnas.1710231115


Prior
Data
Posterior
X
8
7
6
5
4
3
0
1
2
3
4
Time



Uncertainty Propagation

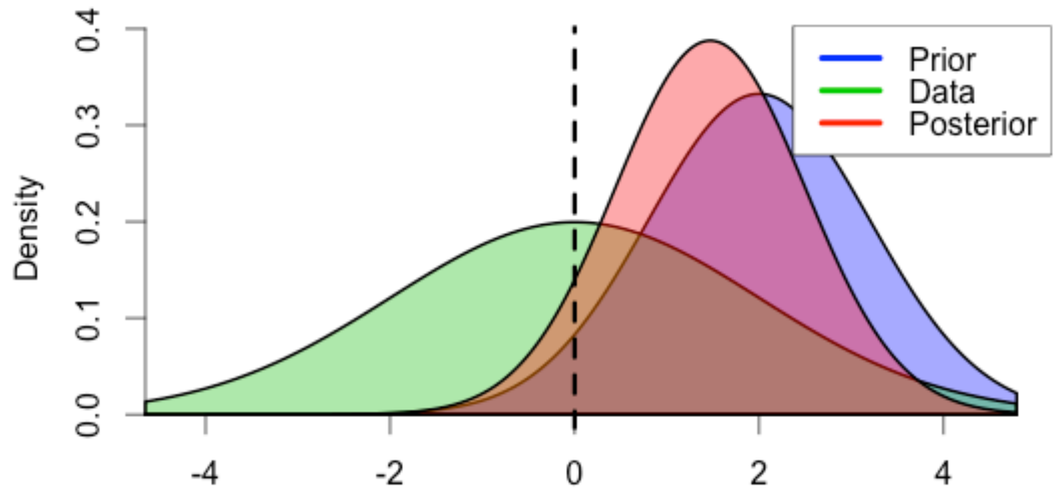

Prior
Data
Posterior
X
8
7
6
5
4
3
0
1
2
3
4
Time

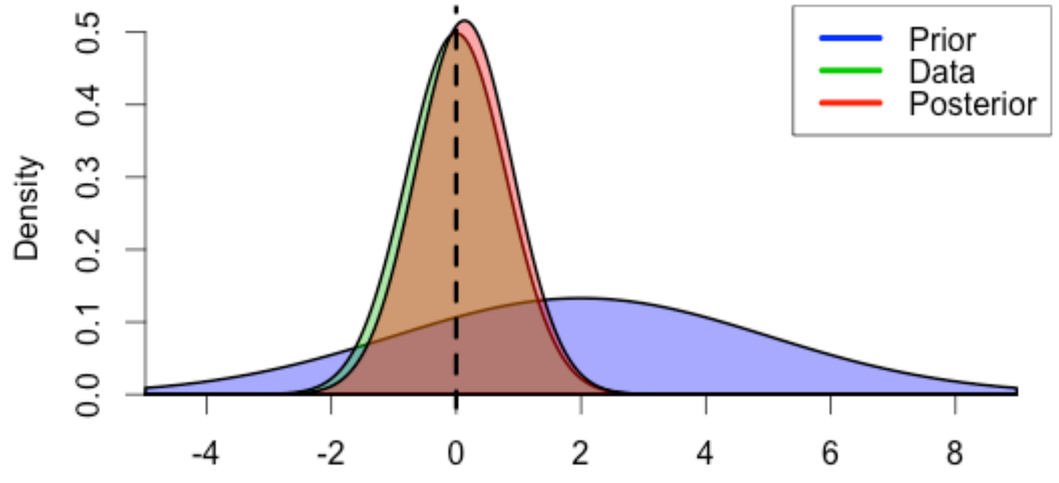

Prior
Data
Posterior
X
8
7
6
5
4
3
0
1
2
3
4
Time

BAYES THEOREM

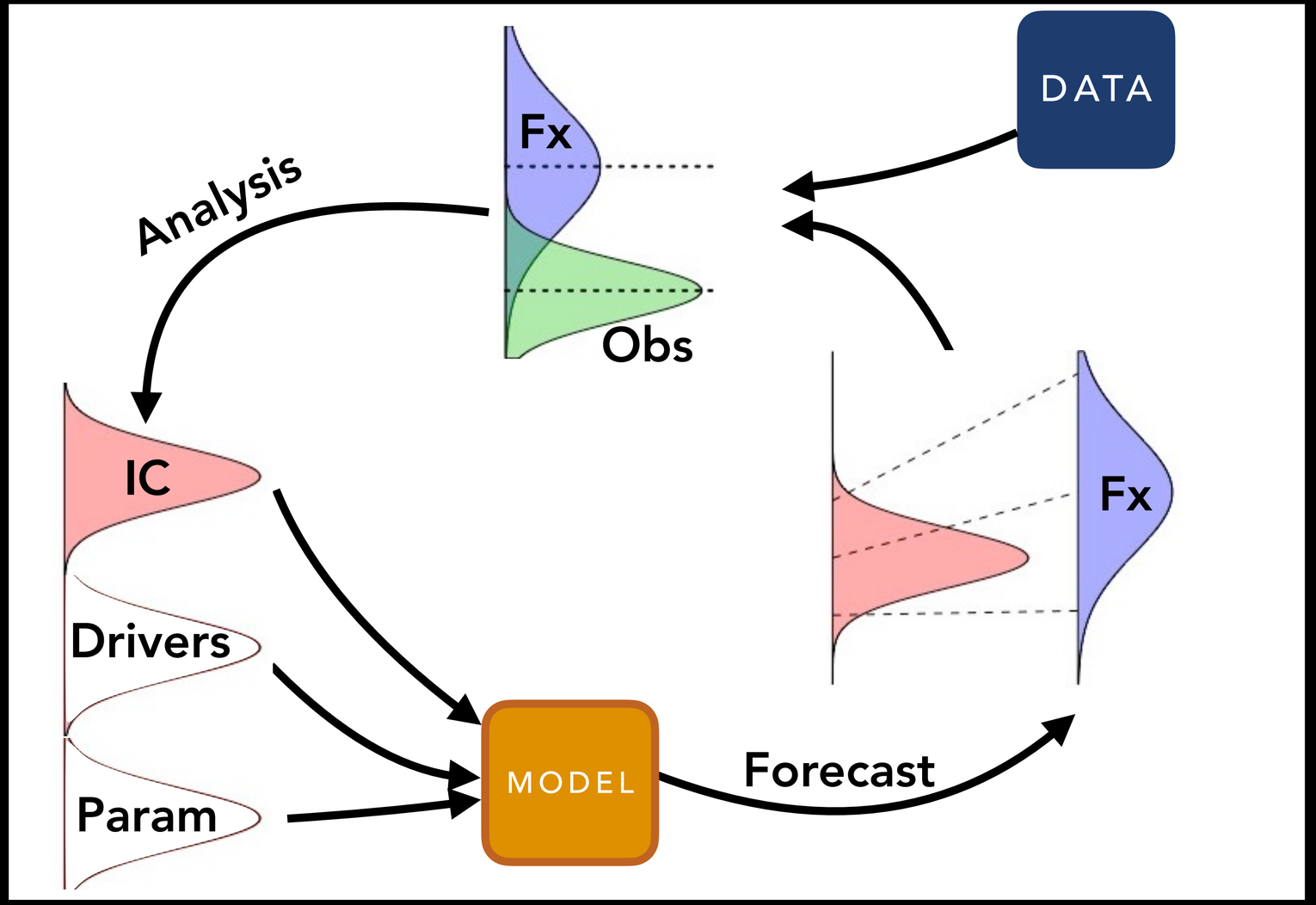
Posterior Likelihood Prior

$$P(\theta|y) = \frac{P(y|\theta)P(\theta)}{\int_{-\infty}^{\infty} P(y|\theta)P(\theta)d\theta}$$





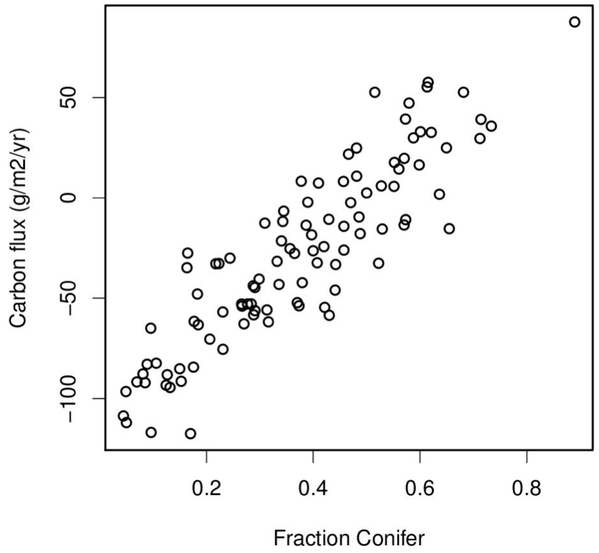
- Returns full probability distribution (uncertainty)
- Inherently iterative
- Handle's complexity of the real world
- Capture's prior knowledge

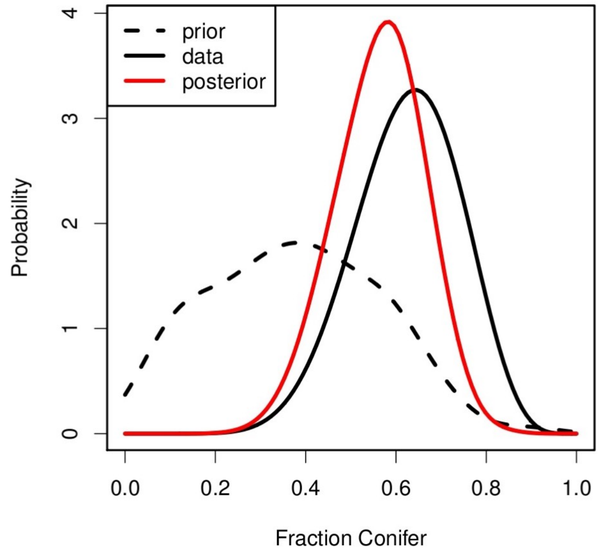


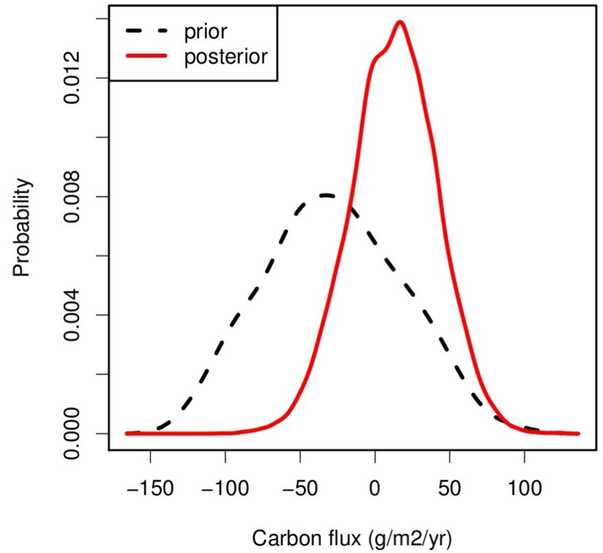
Forecasts should be updated when new data becomes available

$$P(\theta|y) \propto P(y|\theta)\,P(\theta)$$

State-Variable Data Assimilation

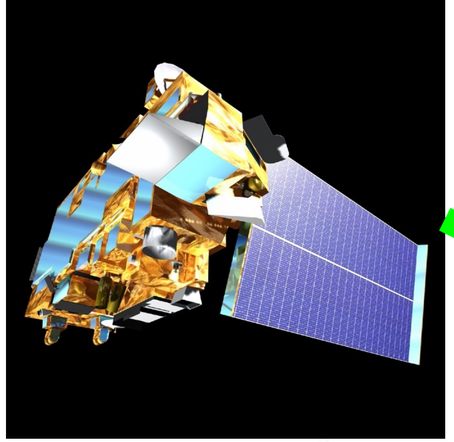


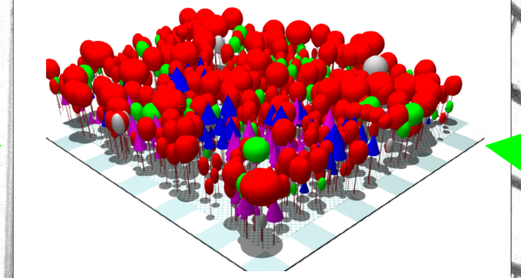




$$P(\theta|y) \propto P(y|\theta)\,P(\theta)$$

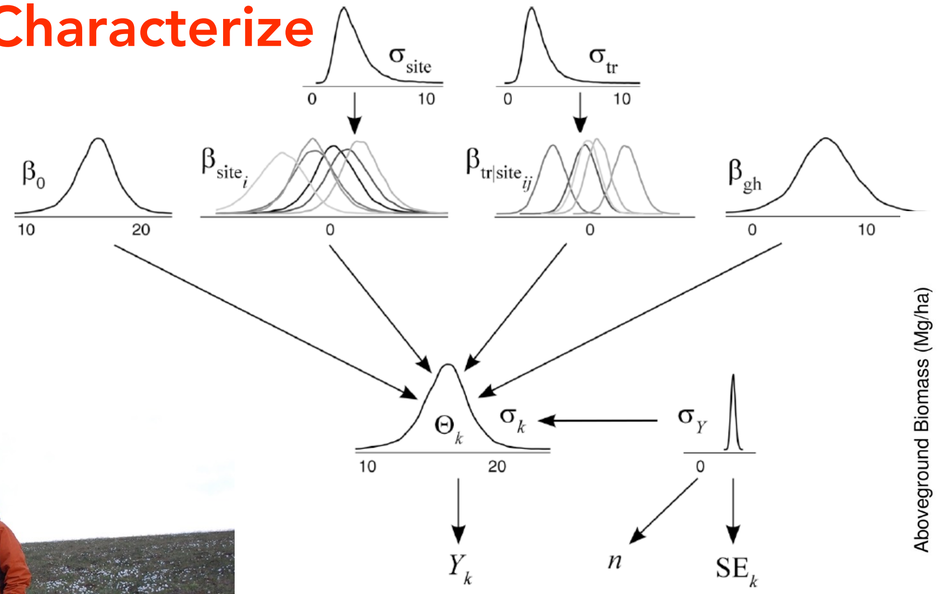
Updated State **Data** **Model**



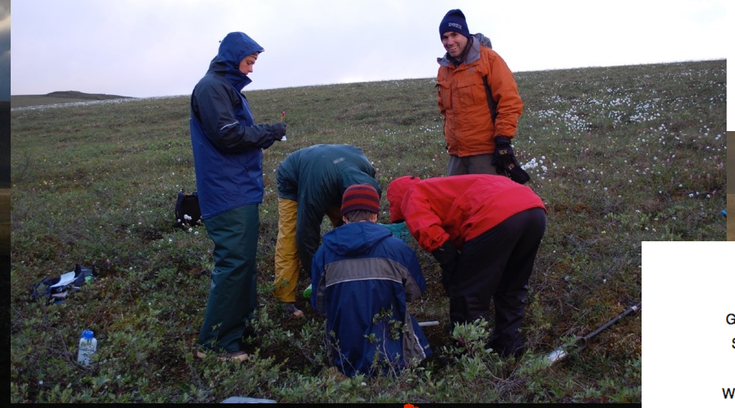

early hardwoods
late evergreens
mid hardwoods
northern pines
late hardwoods


©2007 Jeffrey Pippen

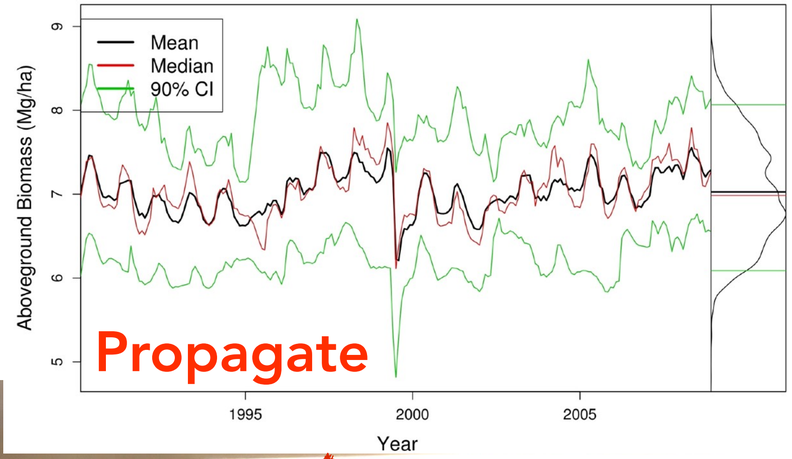
Characterize



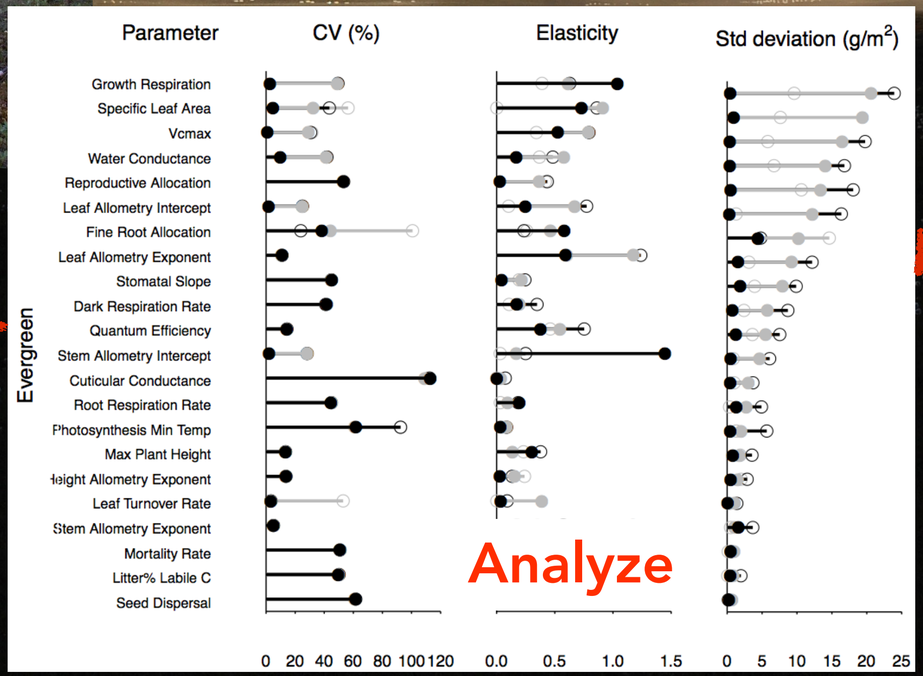
Reduce



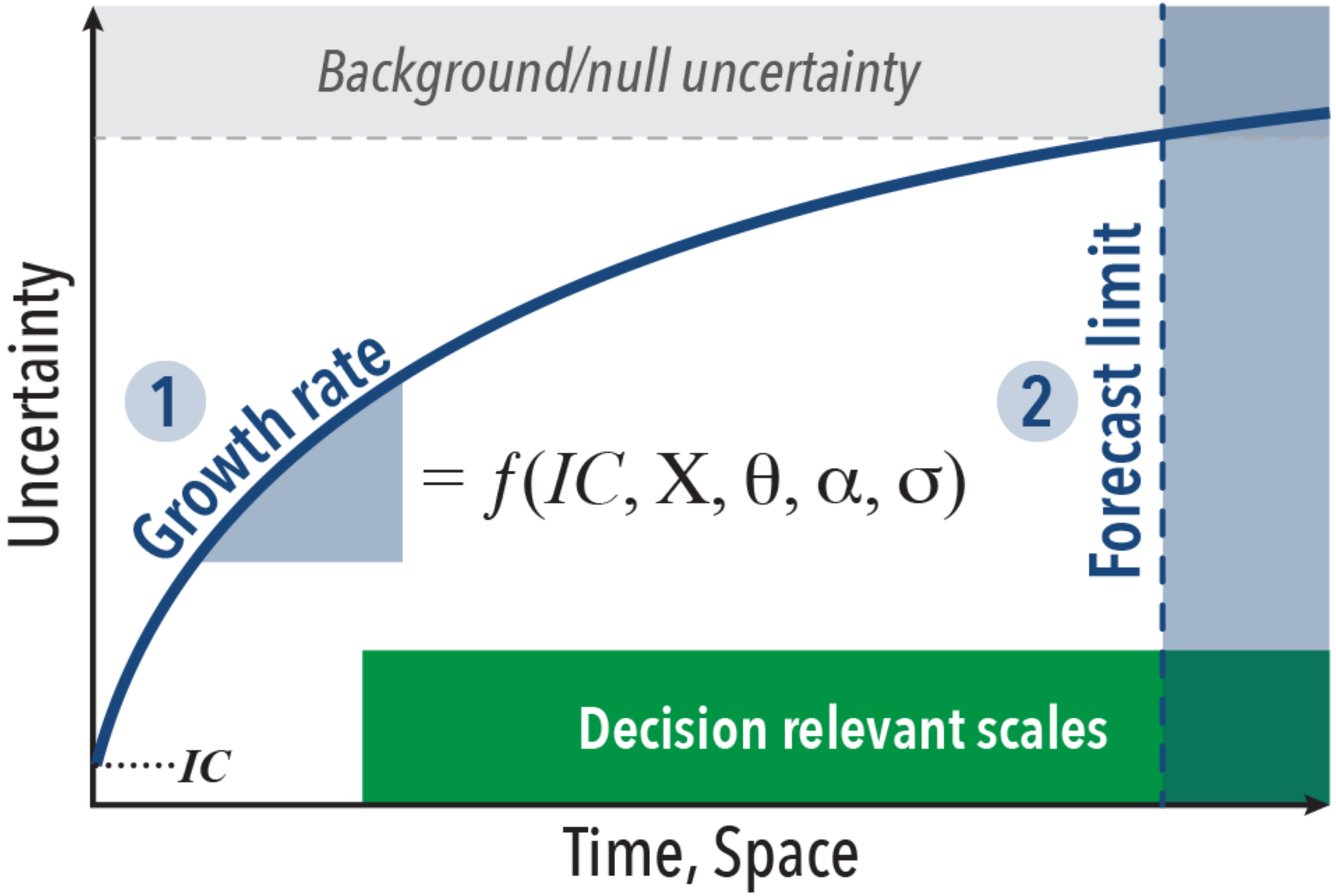
Propagate



Analyze



HOW DO WE MEASURE PREDICTABILITY?

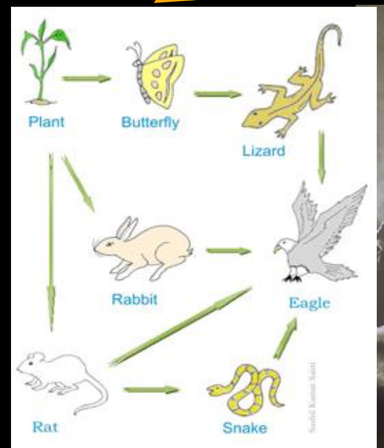


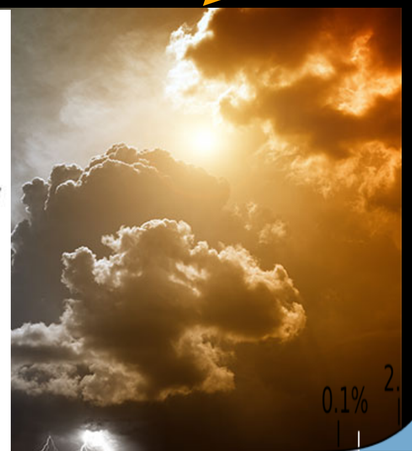
Dietze *2017 Ecological Applications*

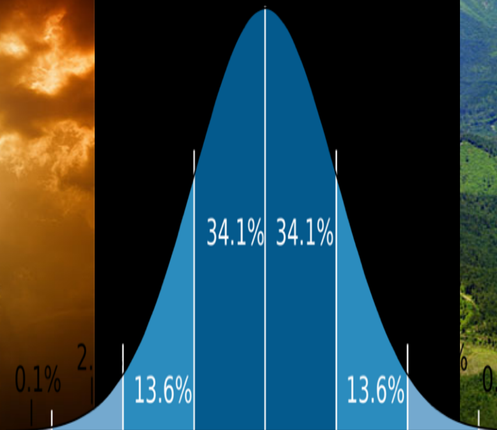
WHAT CAUSES VAR TO INCREASE WITH TIME?

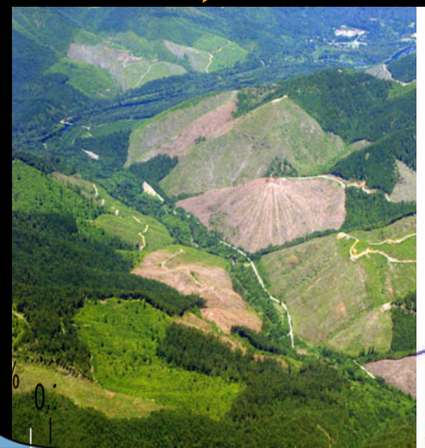
$$Var[Y_{t+1}] \approx \underbrace{\left(\frac{\partial f}{\partial Y}\right)^2}_{stability} \underbrace{Var[Y_t]}_{\substack{IC \\ uncert}} + \underbrace{\left(\frac{\partial f}{\partial X}\right)^2}_{\substack{driver \\ sens}} \underbrace{Var[X]}_{\substack{driver \\ uncert}} + \underbrace{\left(\frac{\partial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

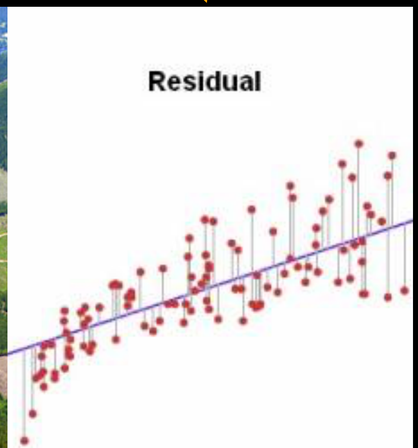
$$= INTERNAL + EXTERNAL + PARAMETERS + \frac{RANDOM}{EFFECTS} + \frac{PROCESS}{ERROR}$$





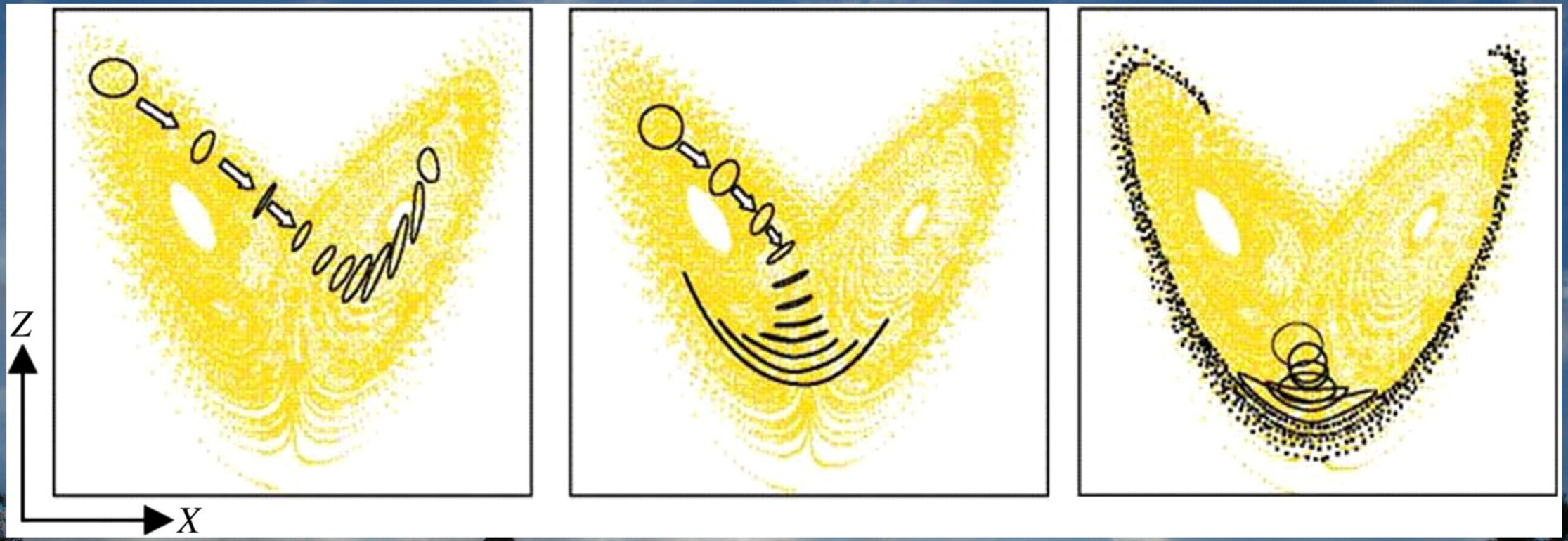






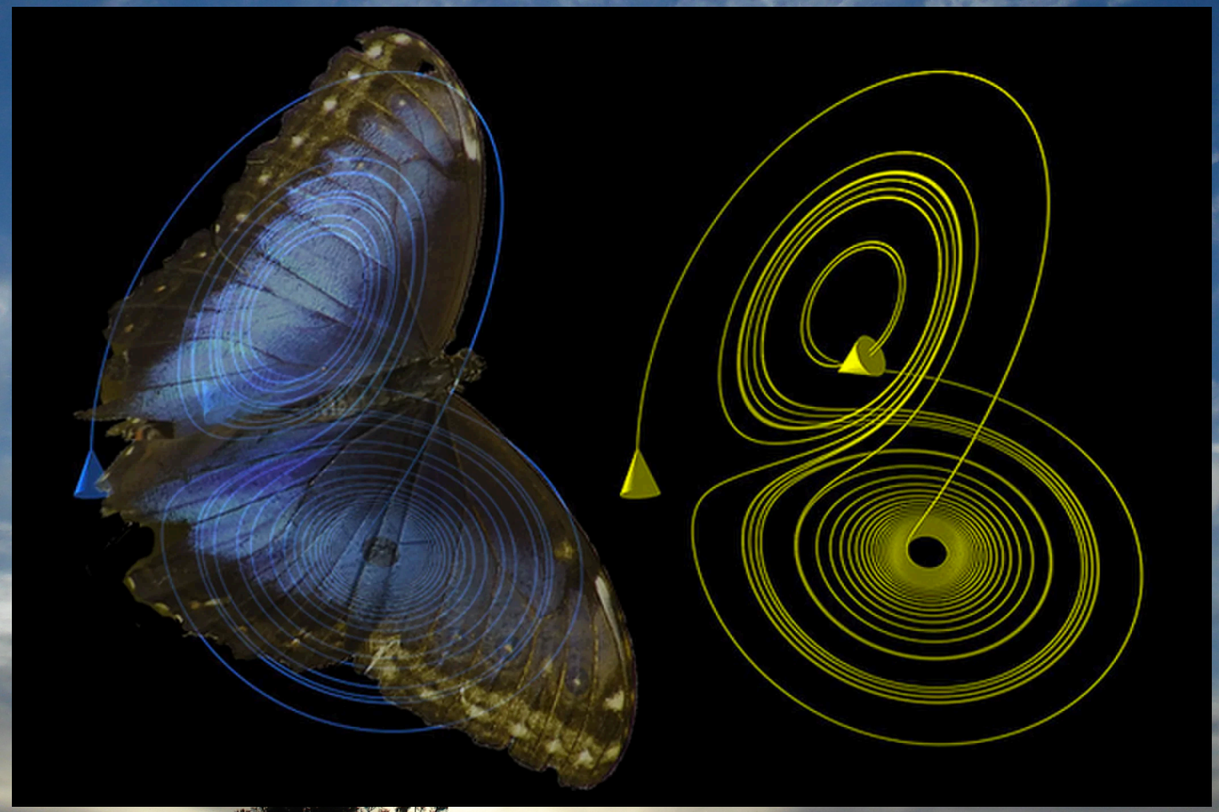
WEATHER FORECASTING:
AN INITIAL CONDITIONS PROBLEM

$$Var[Y_{t+1}] \approx \underbrace{\left(\frac{\partial f}{\partial Y}\right)^2}_{stability} \underbrace{Var[Y_t]}_{\substack{IC \\ uncert}} +$$



Slingo & Palmer. 2011. Phil. Trans. R. Soc. A

WEATHER FORECASTING:
AN INITIAL CONDITIONS PROBLEM



State Space ⟶ Kalman Filter

DISCOVER WHETHER NATURE IS PREDICTABLE

ECOLOGICAL FORECASTING

- Is more than forward simulation
- Requires a fusion of models and data
- Must address multiple sources of uncertainty and variability
- Think Probabilistically!!
- Needs advances in theory and methods