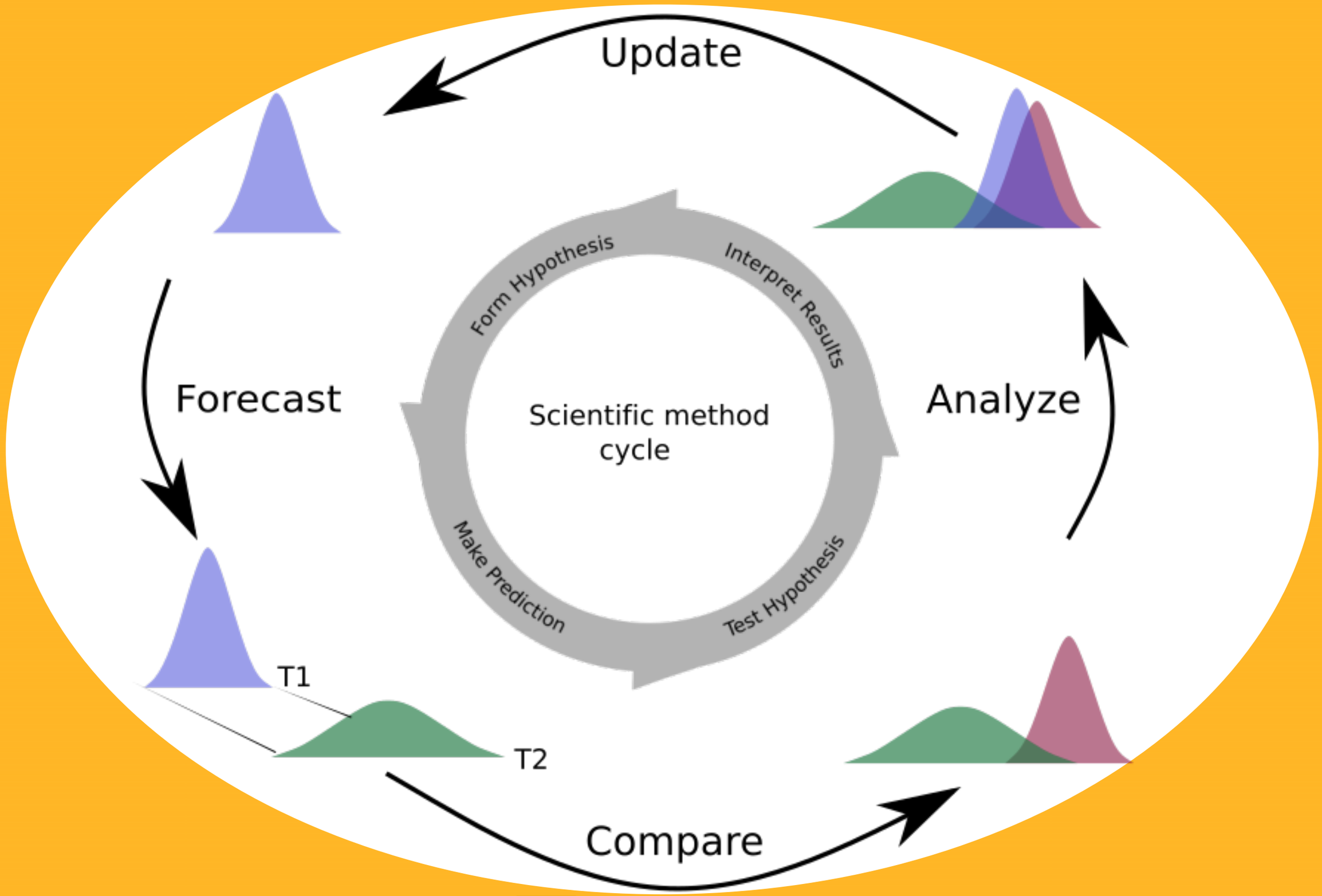
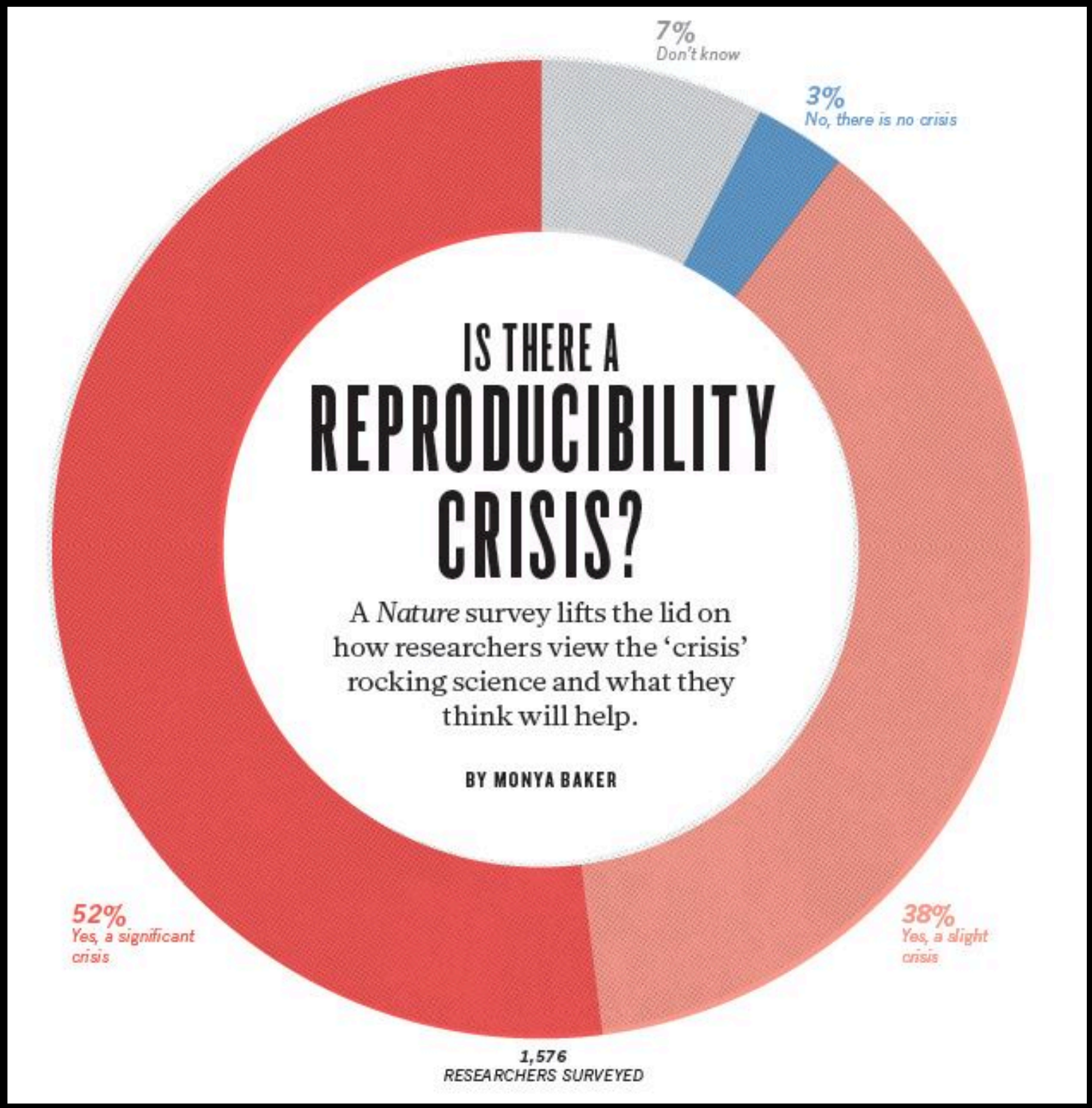
Ecological Forecasting

Concluding thoughts...

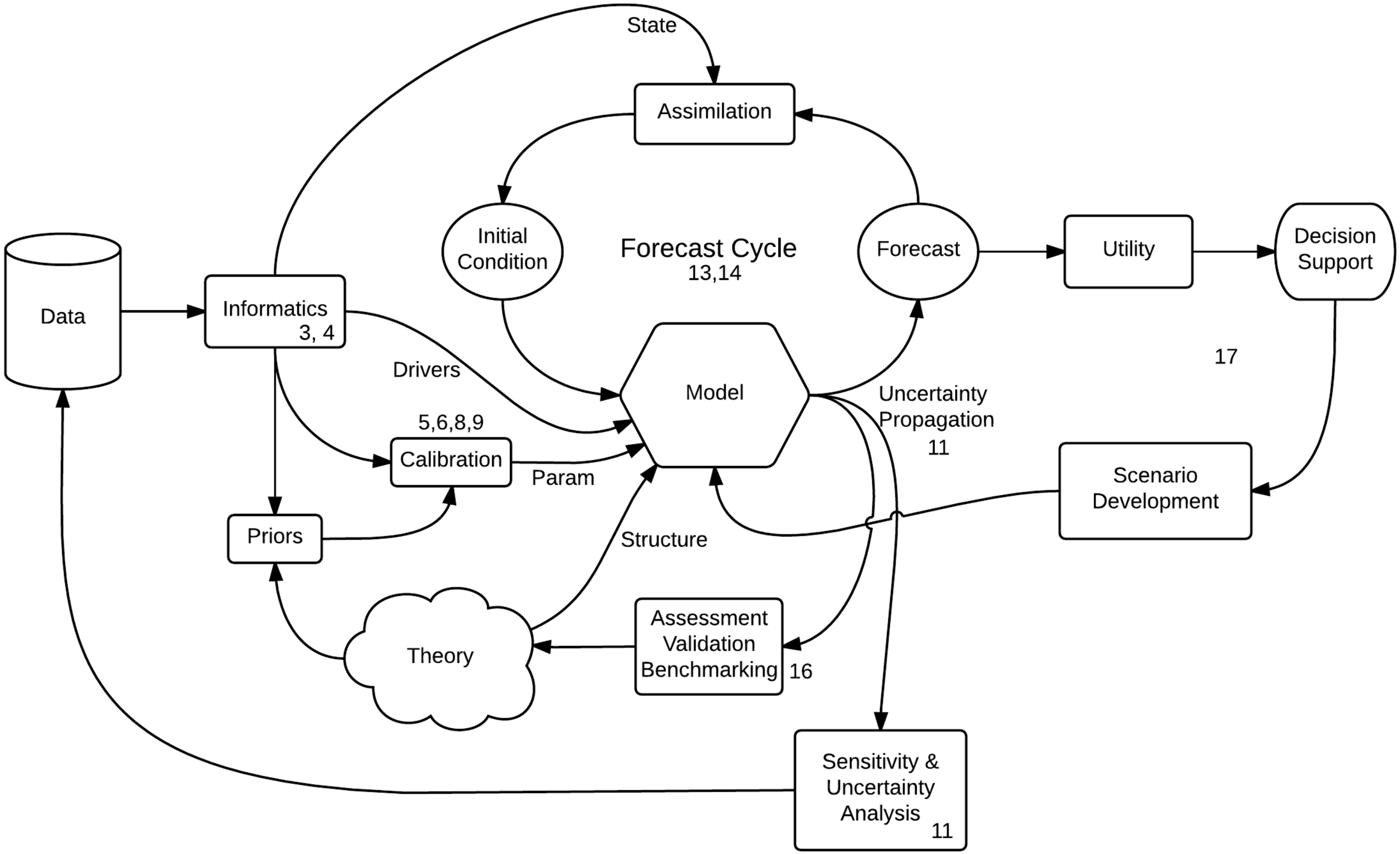
FORECASTS ARE QUANTITATIVE, SPECIFIC, & FALSIFIABLE



Forecasts are <u>a priori</u>



and out-of-sample


State
Assimilation
Initial Condition
Forecast Cycle
13,14
Forecast
Utility
Decision Support
Data
Informatics
3, 4
Drivers
5,6,8,9
Calibration
Param
Model
Uncertainty
Propagation
11
17
Scenario Development
Priors
Structure
Theory
Assessment
Validation
Benchmarking
16
Sensitivity &
Uncertainty
Analysis
11

Data

- Importance of observation error
- Improving Standards for transparency, accountability, reproducibility
- Management and use of big data is a rapidly evolving field
- Real time monitoring!

Model-Data Integration

- Think Probabilistically!
- Bayes' Theorem
- Characterize scales and sources of uncertainty
  - Random Effects, EIV, State-space

Fusing Data

- Multiple likelihoods
- Avoid ad hoc weighting
- Systematic errors !!
- Non-independence in space & time
- Change of support

Uncertainty & Predictability

$$Y_{t+1} = f(Y_t, X_t | \bar{\theta} + \alpha) + \varepsilon$$

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

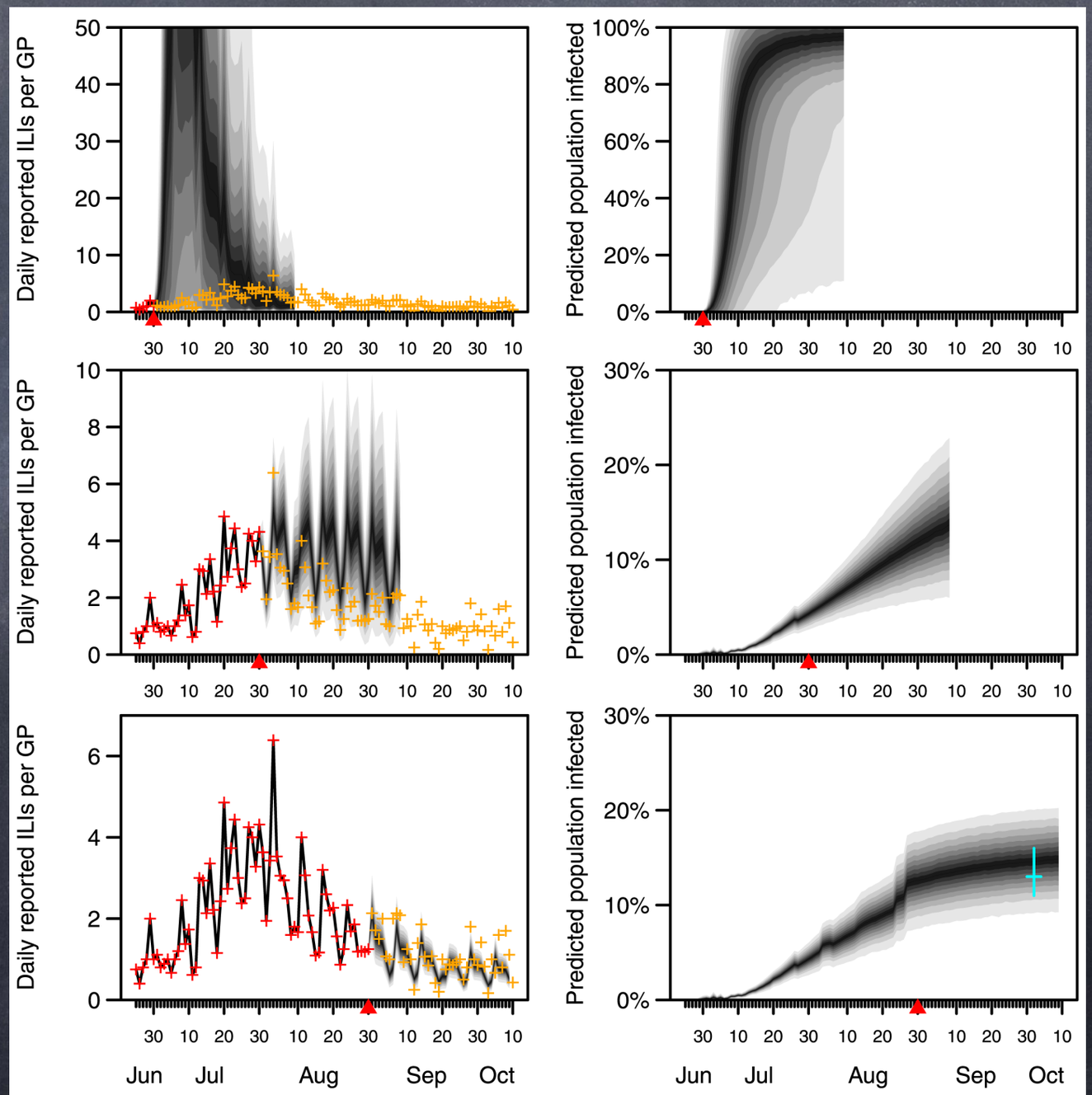
UNCERTAINTY PROPAGATION
APPLIED IN THE FORECAST STEP

Approach		Output: Distribution	Output: Moments	
	Analytic	Variable Transform	Analytical Moments	KF
			Taylor Series	EKF
	Numeric	Monte Carlo	Ensemble	EnKF
		PF		

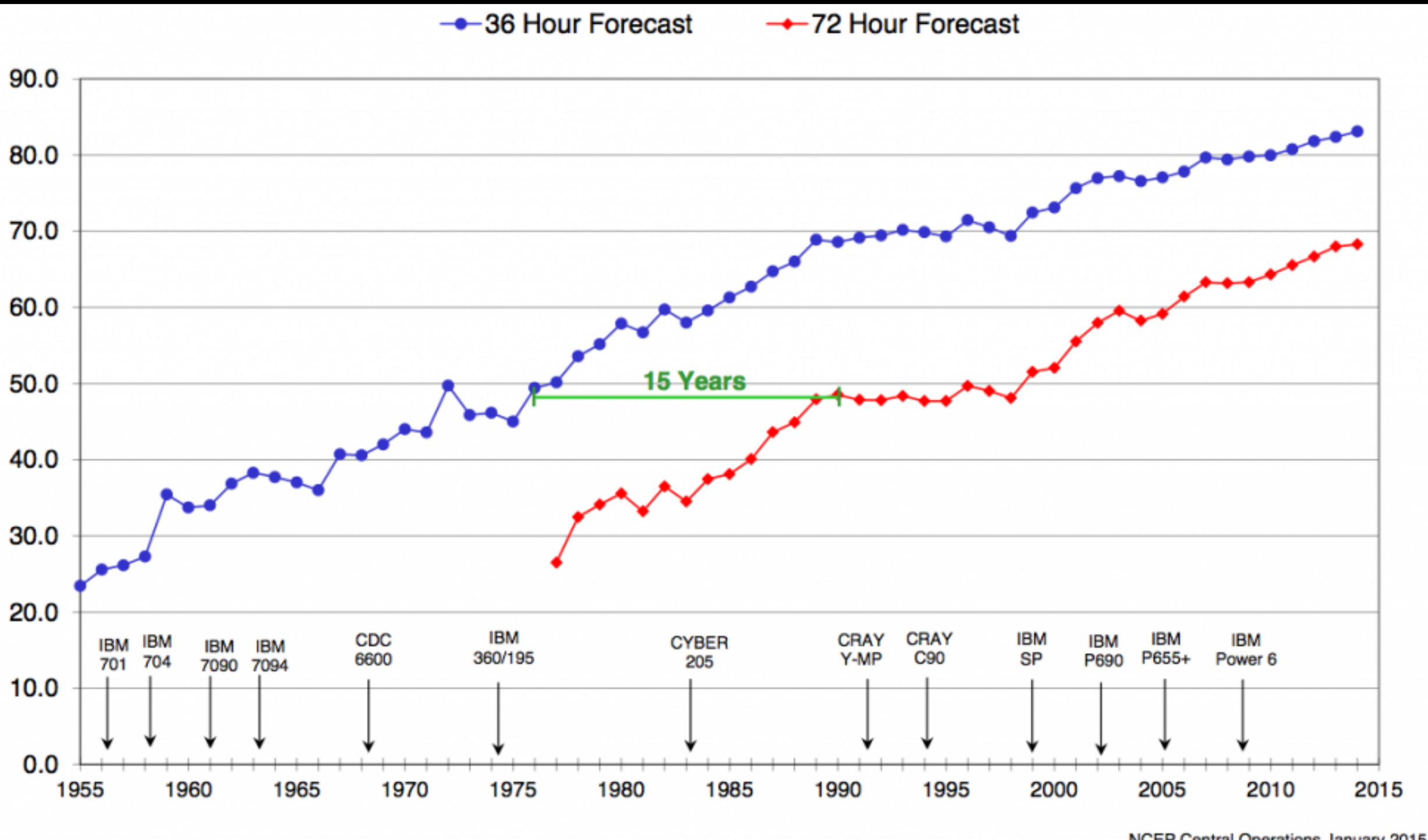
Need for new DA ideas that fit the nature of the Ecological Forecasting problem. Not just KF

Iterative Forecasting

- Few ecological examples, but growing
- An experiment every day!
- Monitoring & Decision Support



Learn by doing!



Ecological Forecasting Initiative

Forecasts to understand, manage, and conserve ecosystems

ecoforecast.org

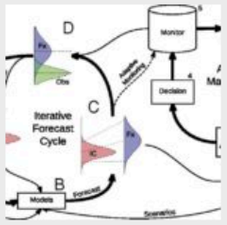
@eco4cast

- Build a community of practice
- Advance theory, tools, cyberinfrastructure, decision sci.
- Build bridges to public, agencies, industry, stakeholders

Forecasting Project Profiles

If you have an iterative ecological forecast project that you'd like added to this list, you can create a profile for the project using this form.

PROJECT	DESCRIPTION



Near-term Ecological Forecasting

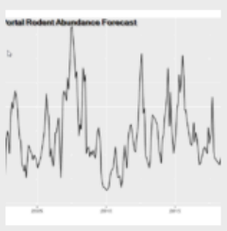
Researchers at Boston University and the Cary Institute are working to develop an iterative cycle between making forecasts, performing analyses, and updating predictions in light of new evidence.

Phenology Forecasts

Researchers at the University of Florida are forecasting leaf out, flowering, and onset of fall colors for dozens of plant species across the United States. Forecasts are updated weekly to incorporate the most recent data and forecasts for temperature.

Smart Reservoir

The "Smart & Connected Water Systems" project is developing a smart water system that integrates novel high-frequency sensors, cyberinfrastructure, and ecosystem forecasting techniques to improve the management of drinking water supply lakes and reservoirs



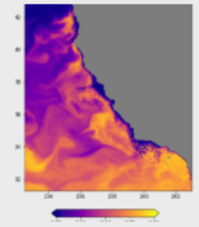
Portal Rodent Forecasts

Ecologists at the University of Florida are forecasting ecological systems from time series, specifically rodent abundances from The Portal project located in the Chihuahuan desert of southern Arizona. Iterative near-term forecasts of rodent abundances are developed then tested as new data is collected on an approximate monthly time-scale.

MAPPPD

Mapping Application for Penguin Populations and Projected Dynamics

MAPPPD (Mapping Application for Penguin Populations and Projected Dynamics) is an open access decision support tool designed for managers, scientists and the general public. This integrates advanced modeling techniques to detect and count penguin colonies from remote sensing data. MAPPPD also calculates occupancy probabilities and presents graphical output which projects how penguin populations will change in the future. The MAPPPD team recently ran a forecasting data science competition; more details HERE.



California Harmful Algae Risk Mapping (C-HARM) System

The CA HAB Bulletin, developed by the Southern California Ocean Observing System (SCCOOS), provides monthly to bi-monthly context for the C-HARM model output relative to harmful algal bloom observations and available marine mammal stranding data. C-HARM creates daily nowcasts and 3-day forecasts of harmful algal bloom (*Pseudo-nitzschia spp.*) and phycotoxin (domoic acid) risk for coastal California (domain out to 1000 km)

PalEON

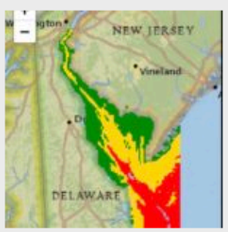
PalEON: Paleo-Ecological Observatory Network

The PalEON project improves long-term forecasts of terrestrial ecosystem response to changing climate, land-use, and natural disturbance by assimilating information from historical and paleoecological data into a suite of models.

EcoCast

EcoCast

EcoCast is a fisheries sustainability tool that helps fishers and managers evaluate how to allocate fishing effort to optimize the sustainable harvest of target fish while minimizing bycatch of protected or threatened animals.



Atlantic Sturgeon Risk of Encounter

The Atlantic Sturgeon Risk of Encounter forecast is developed for mature Atlantic Sturgeon using historic telemetry observations matched to date, bathymetry, and sea surface temperature and ocean color from NASA's MODIS AQUA satellite.

A Scalable and Secure Cyberinfrastructure for the Repeatability of Ecological Research

Boston University's Abraham Matta and Mike Dietze are building a hybrid elastic edge-cloud infrastructure to support repeatable ecological research. The webpage is under construction and will be available soon.

ecocaster

The ecocaster provides ecosystem forecasts for ticks, jellyfish, moose-car crashes, etc., based on citizen reports.

PROGNOS

PROGNOS is developing an integrated approach that couples high frequency (HF) lake monitoring data to dynamic water quality models to forecast short-term changes in water quality (e.g. DOM pulses and algal blooms).

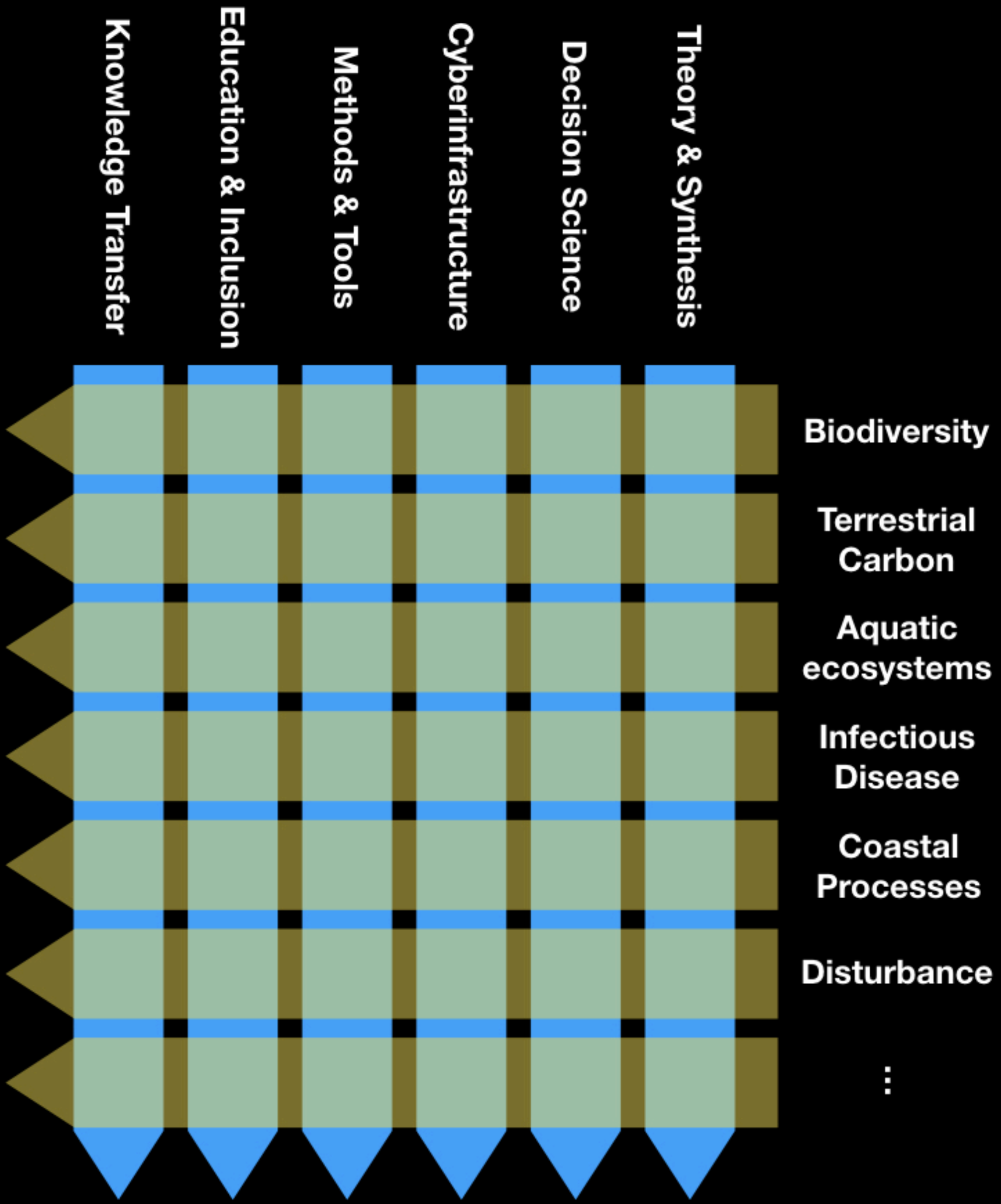
WATExR

Climate seasonal prediction for adapting water resources to extreme events

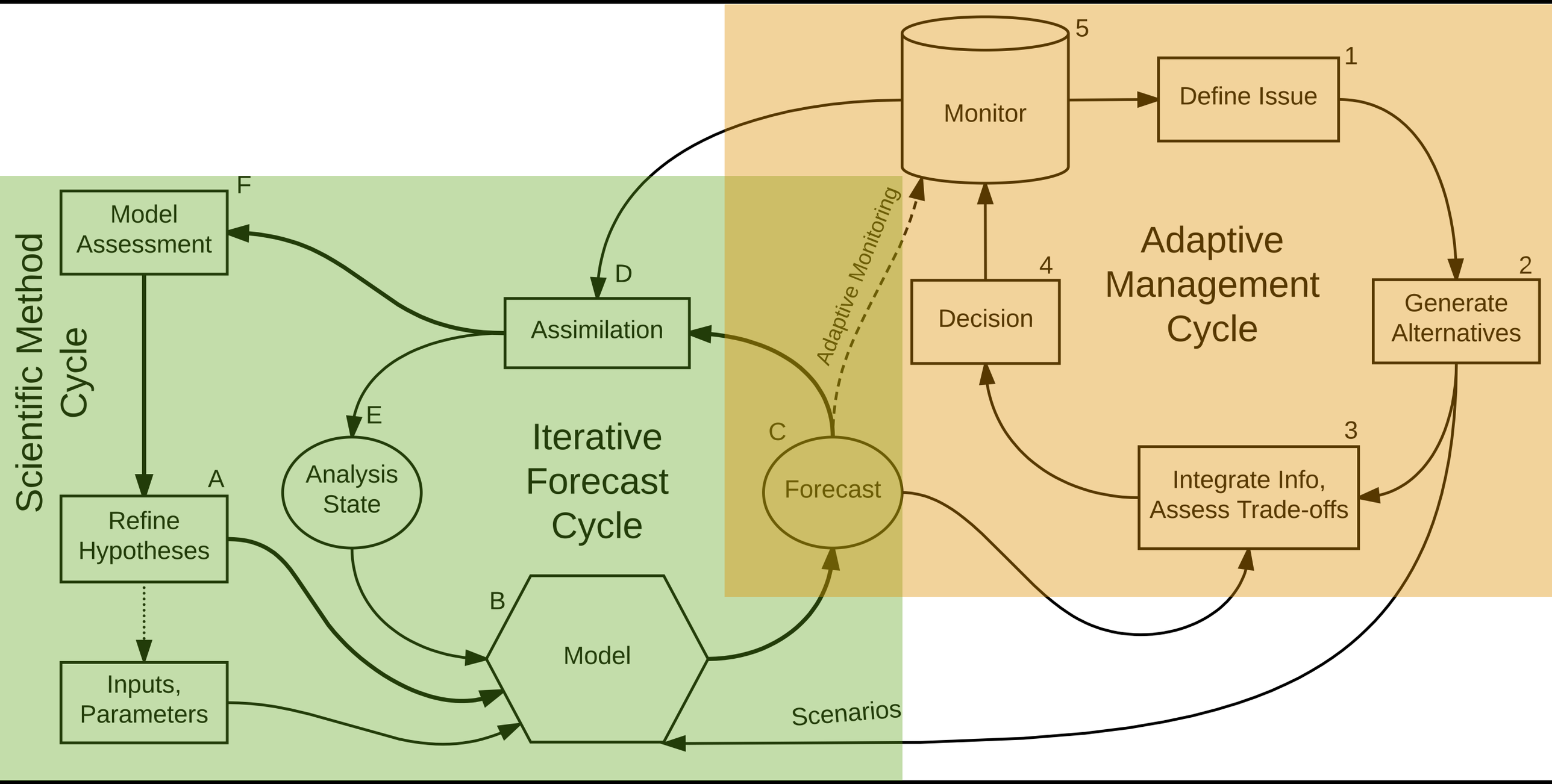
WATExR

WATExR aims to integrate state-of-the-art climate seasonal prediction and water quality simulation in a QGIS-based advanced solution to ensure efficient decision making and adaptation of water resources management to an increased frequency of climate extreme events

CROSS CUTTING THEMES



DECISIONS



- **Normative**: How to use EF to improve env decision making
- **Descriptive**: How are EF being understood and used? Communication of uncertainty?

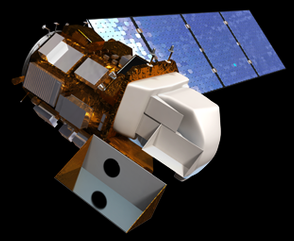
CYBERINFRASTRUCTURE

Unstructured Community Data

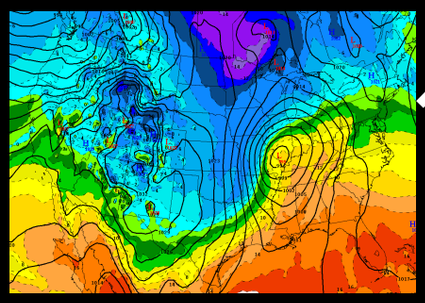
Research Infrastructure

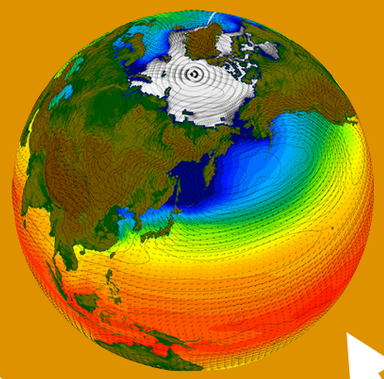
- Facilities
- Networks
- Experiments
- Sensors

Remote Sensing



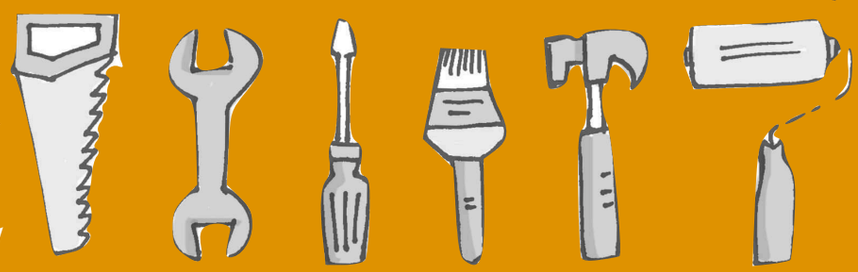
Geospatial





Models

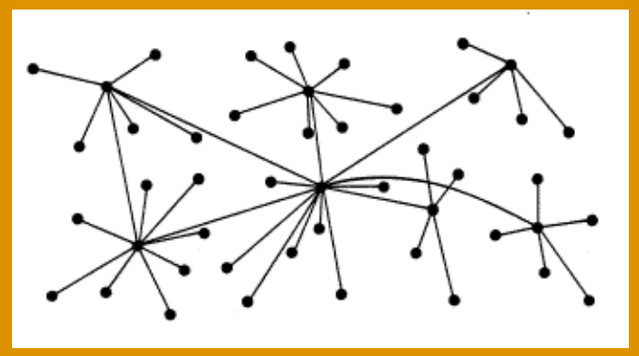
Compute



Tools

Databases

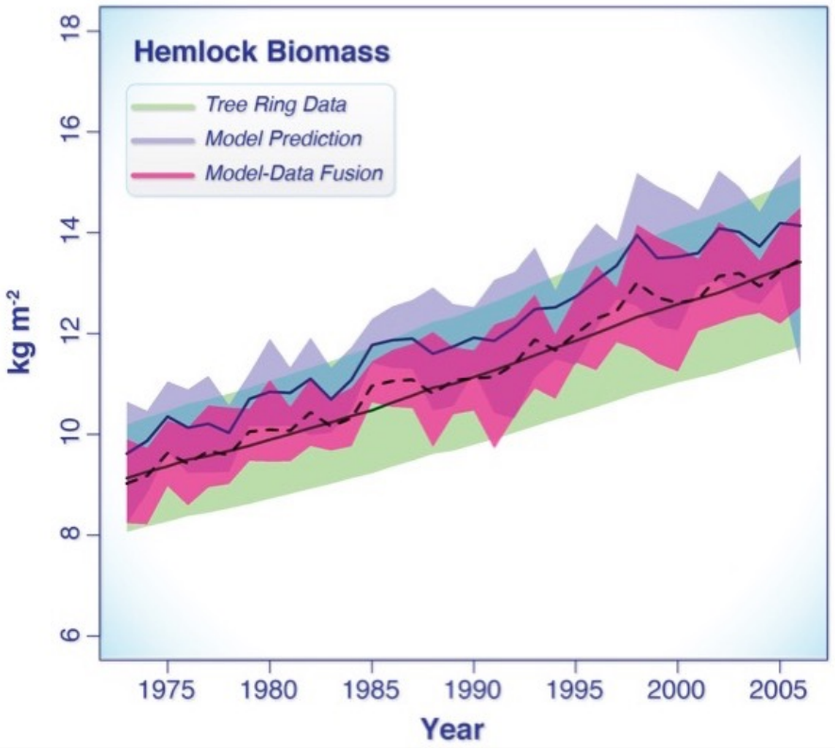
Network

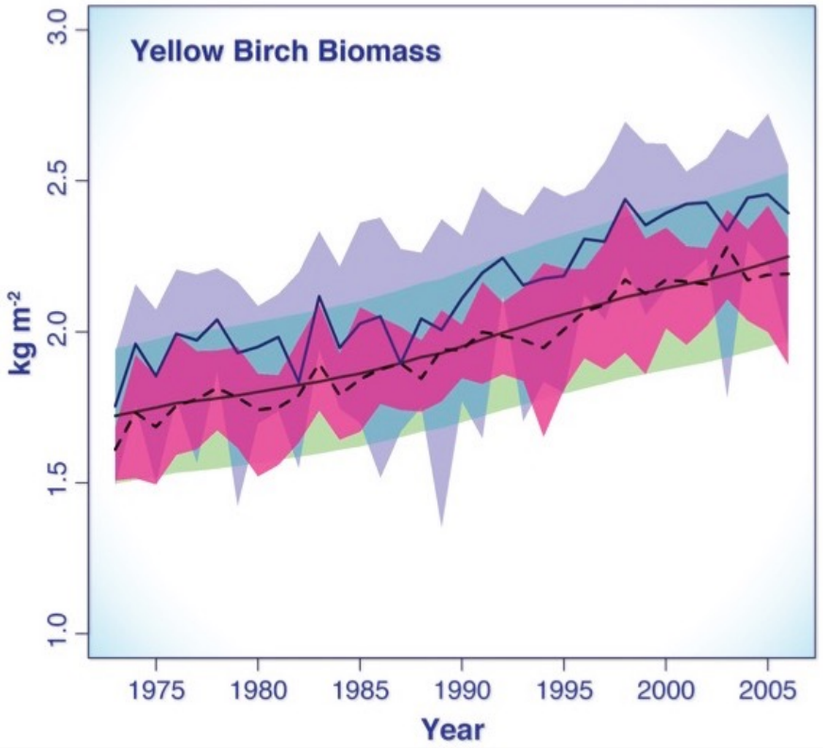


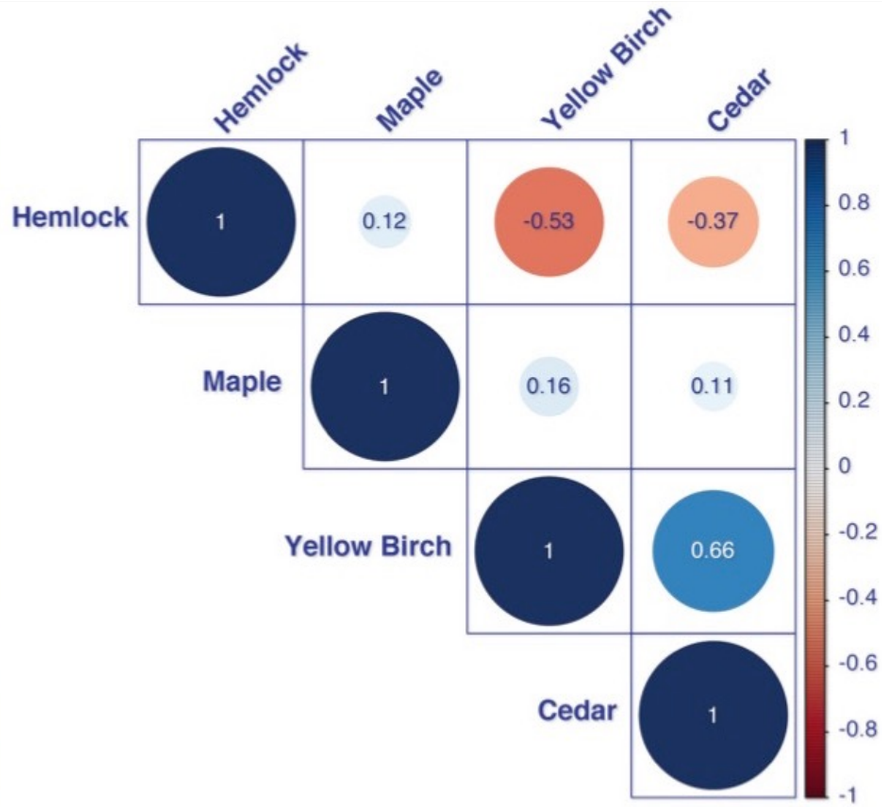
- Ingest
- Process
- Analyze
- Benchmark
- Calibrate
- Assimilate
- Visualize
- Record
- Share

PECANPROJECT.ORG

METHODS & TOOLS







Raiho et al *in prep*

- Bottlenecks?
- Relax DA assumptions
- Forecast standards (archiving)

Educational Resources

Publications

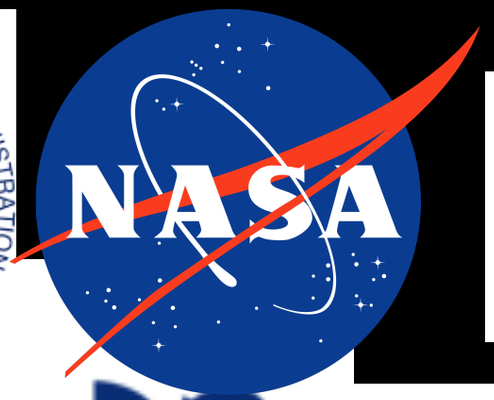
Book

Educational Resources

Multimedia Resources

COURSE	INSTRUCTORS	AFFILIATION
Ecological Dynamics and Forecasting	Morgan Ernest & Ethan White	University of Florida
Ecological Forecasting and Informatics	Michael Dietze	Boston University
Ecological Forecasting	Jason McLachlan	University of Notre Dame
Ecological Dynamics & Forecasting	Peter Adler	Utah State University
Near-Term Ecological Forecasting Initiative Summer Course	NEFI team, Melissa Kenney, Barbara Han	BU, Cary, UMd
Topics In Ecological Forecasting	Cayelan Carey, Quinn Thomas	Virginia Tech

PARTNERSHIPS



- Build bridges to public, agencies, industry, stakeholders, citizen science. Coproduction
- Bottleneck: Research to Operations

DISCOVER WHETHER NATURE IS PREDICTABLE

JOINING EFI

- ecoforecast.org
  - Member's Listing
  - Email newsletter
- Twitter: @eco4cast

DISCUSSION BOARD

- Extra Credit
  - Questions posted in advance of #EFI2019
  - Non-trivial post before 5/7
- Opportunity to continue dialog

Ecological Forecasting Initiative

UNDERSTAND · MANAGE · CONSERVE