Forecast

To predict the future state of a variable or system

Prediction is very difficult, especially if
it's about the future - *Niels Bohr*

Inference

- Pearson: How reliable is the evidence?
  - how reliable is the procedure?
- How reliable are algorithms (Efron & Hastie 2016)?

Different inference goals

Estimation
Infer a property of a population (e.g. mean) from a sample

Model selection
Infer the data generating process from among a set of candidate data-generating processes

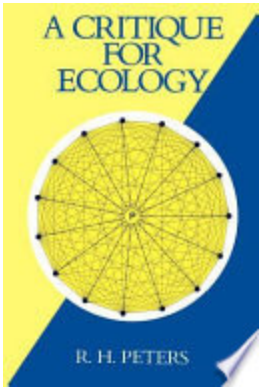
Hypothesis test (association)
Infer that y is associated with x

Causation
Infer that x causes y
Infer the size of an effect due to an experimental intervention (estimation)
Infer that an experimental intervention had an effect (H-test)

Prediction
Predict the value of a new observation or population state (extrapolation or interpolation)
Predict the population state in the future (forecast/extrapolation)

Why forecast?

- Make decisions about the future
  - Scenarios: what will happen if we ...?
  - Making ecology relevant to society
- Prediction: progress and test understanding
  - RH Peters 1991 A Critique for Ecology
  - Houlahan et al 2017
  - but counter arguments



History of ecological forecasting

- Early qualitative (e.g. climax concept)
- Population Viability Analysis
  - 1990s data science competitions
- Foot and Mouth Disease, UK 2001
  - SIR model, nearly real time forecasts
- Then: small data. Now/soon: big data
  - new satellite instruments
  - drones, cameras, audio etc
  - low orbit IoT connectivity

Cultures & algorithms

- 3 cultures of modeling with data
  - Natural process, data generative, algorithmic
- 3 algorithm classes
  - Model, training, inference

Modeling with data

Algorithm classes

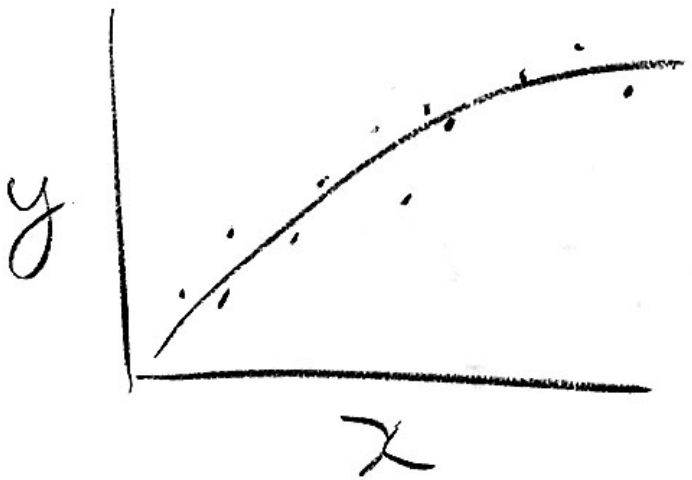
Modeling culture

	Model	Training	Inference	
Natural process "science"	HiFi process (e.g. predator -prey, C cycle)	Frequentist: Optimization (e.g. max lik)	Sampling distribution	→ Confidence intervals Prediction intervals
Data generative "statistics"	Generic functions (e.g. linear, normal)	Bayesian: Integration (e.g. MCMC)	Posterior sample	→ Credible intervals Posterior prediction intervals
		Other:	Cross-validation	→ CV, AIC, BIC etc
Algorithmic "machine learning"	Generic algorithms (map inputs to outputs)	Optimization	Cross-validation	

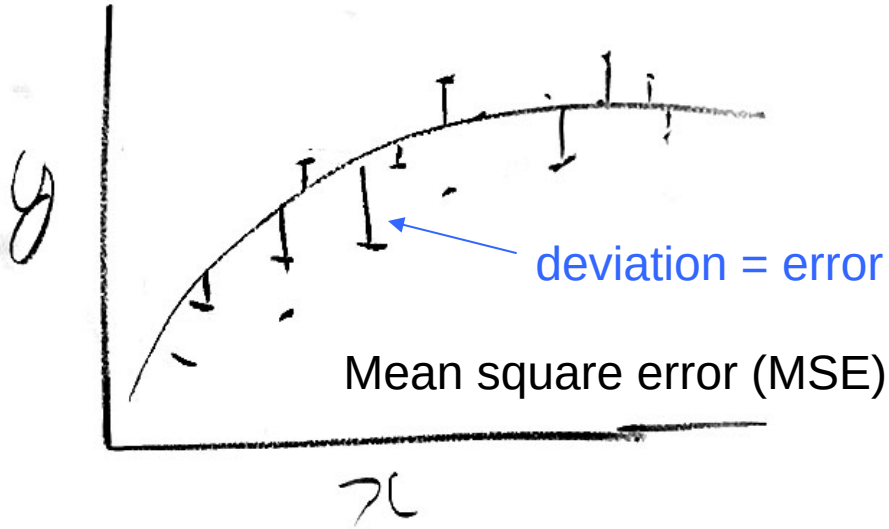
Predictive performance

Basic idea: out-of-sample validation

Fit model to training dataset

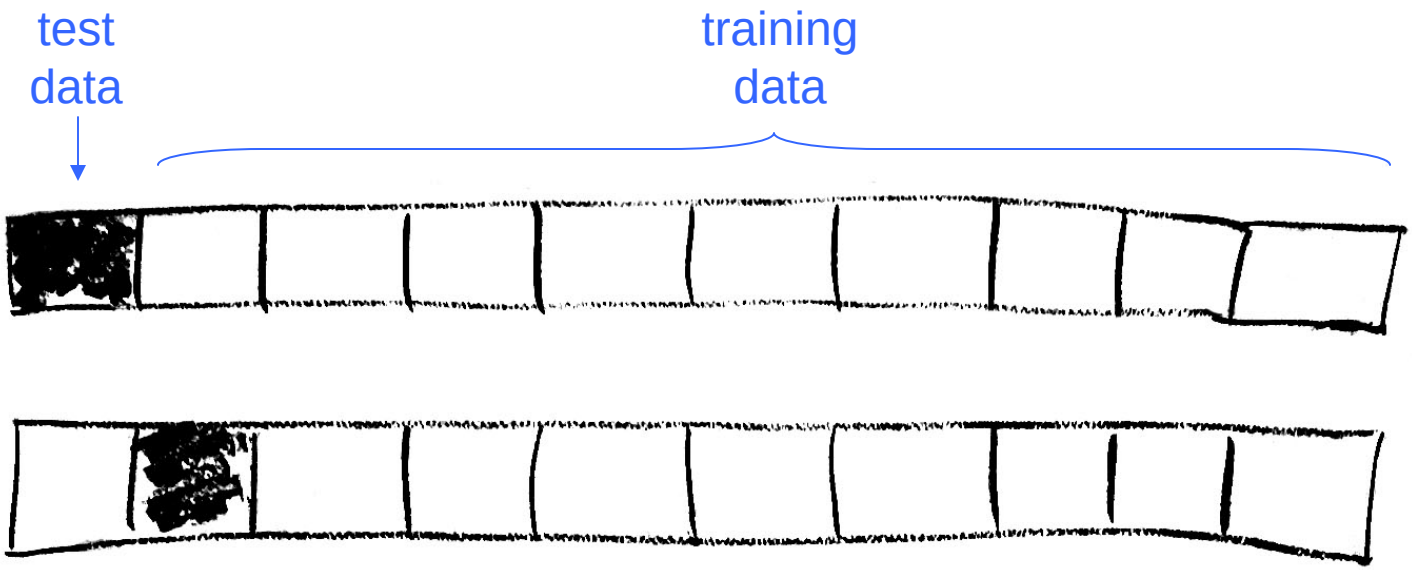


Test model on validation dataset



k-fold cross validation (CV)

Divide dataset into k parts (preferably randomly)



... repeat with each test subset

Leave-one-out cross validation

- LOOCV
- This is k-fold CV for k = n
- Information criteria
  - AIC - frequentist LOOCV asymptotically
  - AICc - frequentist LOOCV, finite sample
  - WAIC - Bayesian LOOCV asymptotically
  - LOOIC - Bayesian LOOCV, finite sample

Role of models

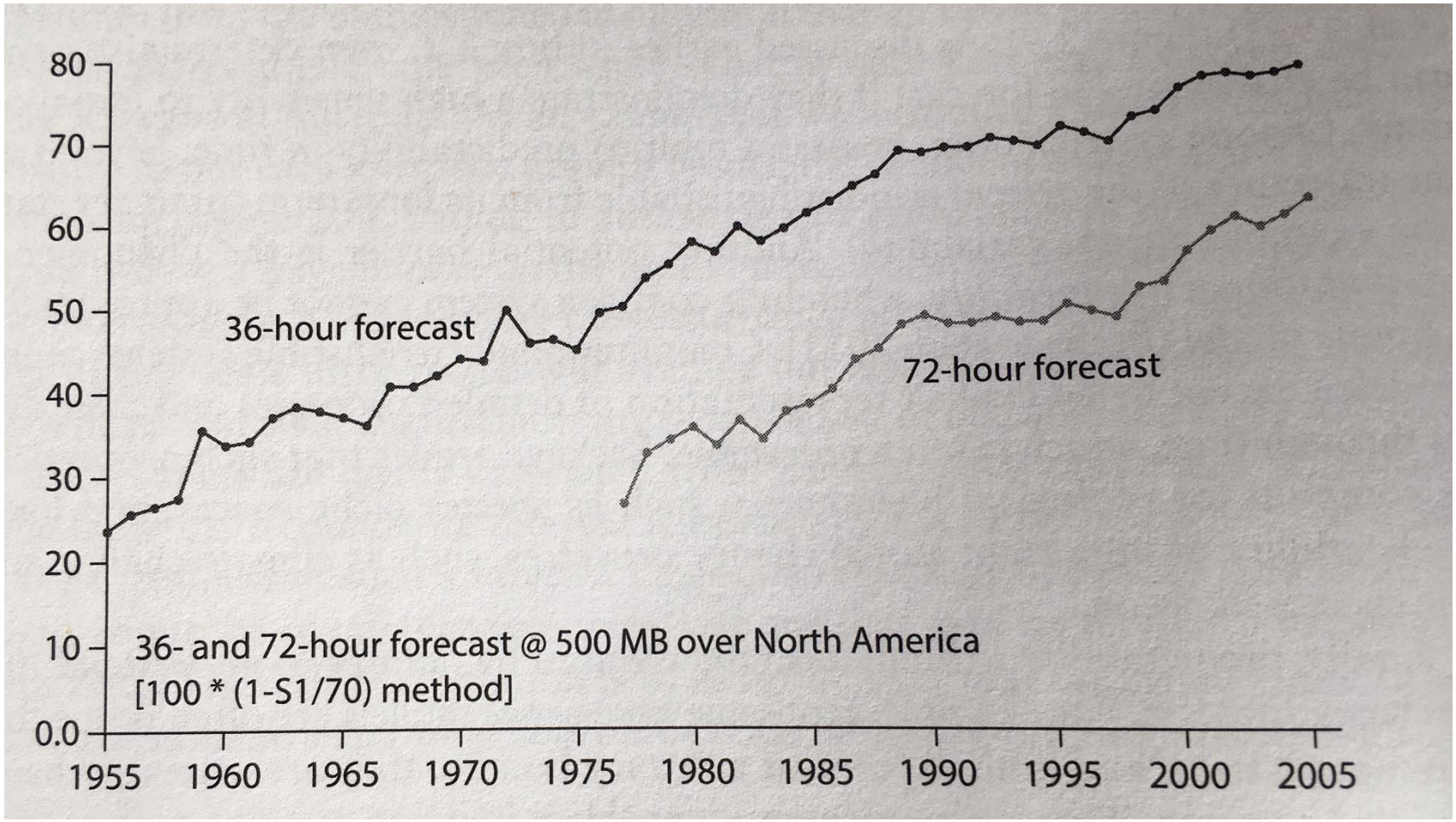
- Scaffold for knowledge - synthesis
- Uncertainty accounting (critical)
- Estimation engine (via calibration/training)
- Prediction engine

Lots of our focus will be on models

Challenges

- Informatics
  - need lots of data
  - how to work with big data!
  - quality (garbage in -> garbage out)
- What is forecastable?
  - irreducible uncertainty
  - stochasticity, nonlinearity, high dimensionality (extreme e.g. chaos)
  - weather forecasts improved

Improvements to weather forecasts



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Goals

- Just do it
- Culture & community
- Work as a team to produce a forecast using current best practices