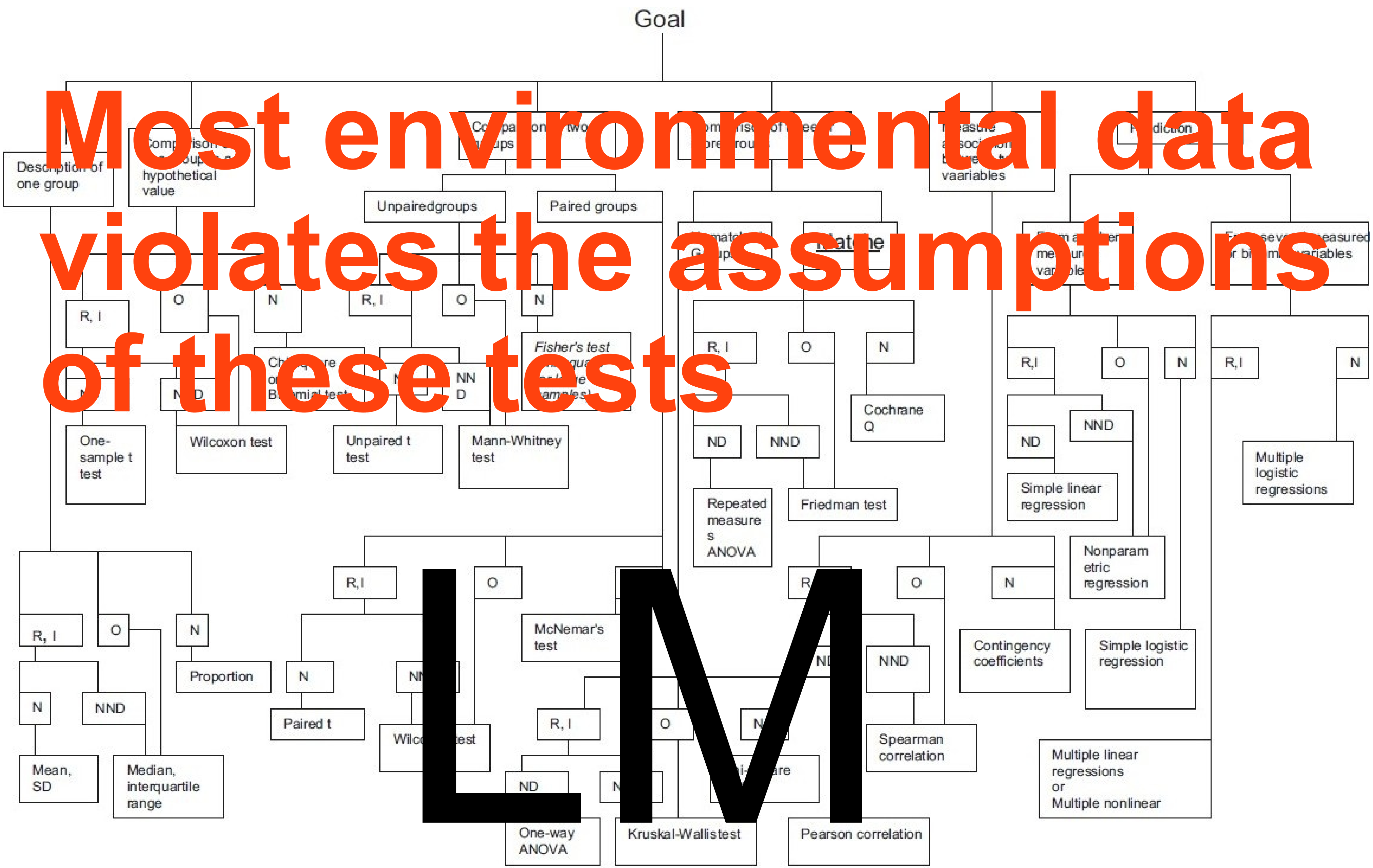
Applied Environmental Statistics

GE 509

Instructor: Prof. Michael Dietze

Introductions

Most environmental data violates the assumptions of these tests



LM

R, I = Ratio and Interval data   O= Ordinal data   N = Nominal data

N = Normal distribution   NND = Non normal distribution

What is statistical modeling?

What is statistical modeling?

“Confronting models with data”

- Model fitting / parameter estimation
- Model comparison
- Estimation, partitioning, and propagation of uncertainties

What is statistical modeling?

"Confronting models with data"

Design the statistical analysis to fit the data rather than the data to fit the test

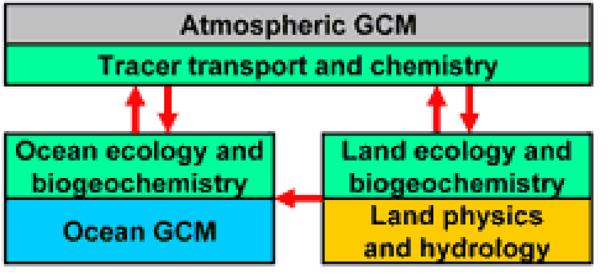
What is a model?

What is a model?

A conceptual, graphical, or mathematical representation / abstraction of some empirical process(es).

A mathematical function that formalizes our conceptual model / theory

$$f(x) = a \qquad f(x) =$$



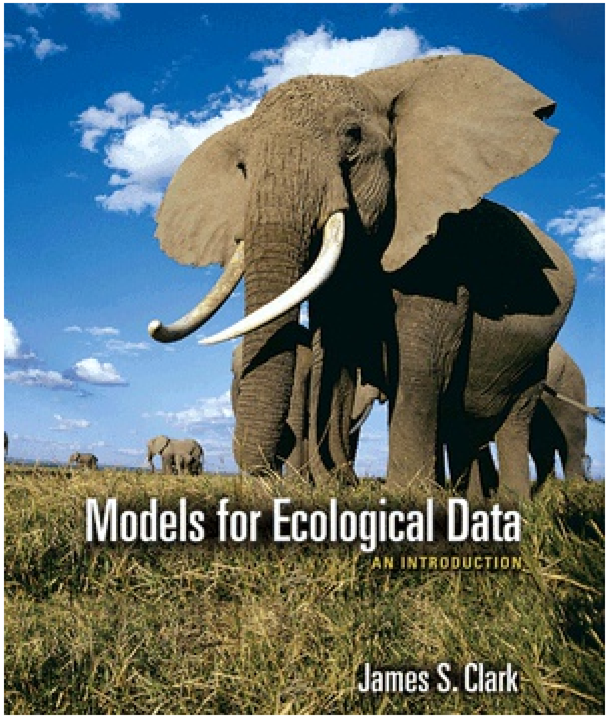
What is a model?

Models are HYPOTHESES

Syllabus

Course Materials

- Reading assignments, lecture slides, project details, etc. are all posted on the lab website
  http://people.bu.edu/dietze/Bayes2018/GE509.htm
- Primary Text:
  "Models for Ecological Data"
  Clark 2007 Princeton U Press
- Software:
  - R / RStudio
  - OpenBUGS / JAGS
  - Git / GitHub



Grading

Grading will be based on lab reports, a semester-long project, and four exams.

Lab reports/problem sets (10 points each)		= 150
Semester project (GRAD)		= 95
project proposal	2/9	(10)
model description	3/2	(15)
preliminary analysis	4/9	(20)
Final report	before exam 4	(50)
Exams (30, 25, 30, 30 points) [non-cumulative]		= 115
	Total	= 360

Labs

- **LAB IS MANDATORY**
- Labs will be posted in git repository https://github.com/mdietze/EE509
- Due FOLLOWING WEEK by the start of lab
- Must be turned in individually
- Can work together

Semester Project

- Final product:
  "Journal article" on a data analysis
  - You choose topic
  - ENCOURAGED to use your own data
  - <u>Analysis must be new</u>, use concepts from class
  - "Methods" heavy
- Four milestones
- One lab is peer critique

Lecture & Exams

- Four sections
  - Probability theory and Maximum Likelihood
  - Bayesian methods
  - Hierarchical/mixed models
    - Linear regression $\rightarrow$ nonlinear, non-gaussian
  - Advanced topics
    - Time series
    - Spatial

Exams

- Multiple Choice
- Matching
- Fill in the blank
- Short Answer / Derivation
- ~15 questions

Expectations

- You have seen basic calculus at some point
  - Primarily need to <u>follow</u> derivations
- Basic familiarity with statistical concepts
  - e.g. experimental design, randomization, mean, median, variance
- Open mind
- You will work hard
- You won't 'get' Bayes the first time they see it (but will need to by the 2^{nd} exam)

Objectives

- Literacy
  - Read and evaluate advanced stats used in papers
- Proficiency
  - underlying statistical concepts
  - Software: R, JAGS
- Exposure to advanced topics
- Paradigm shift

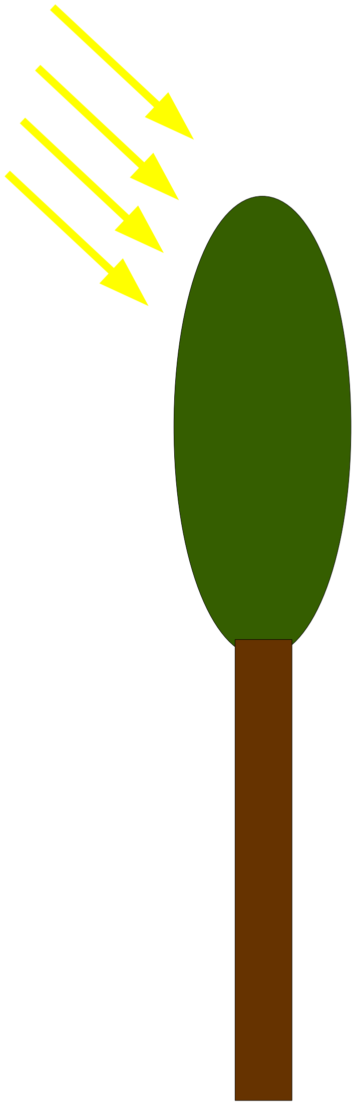
A bit more on motivation....

Data are usually complex

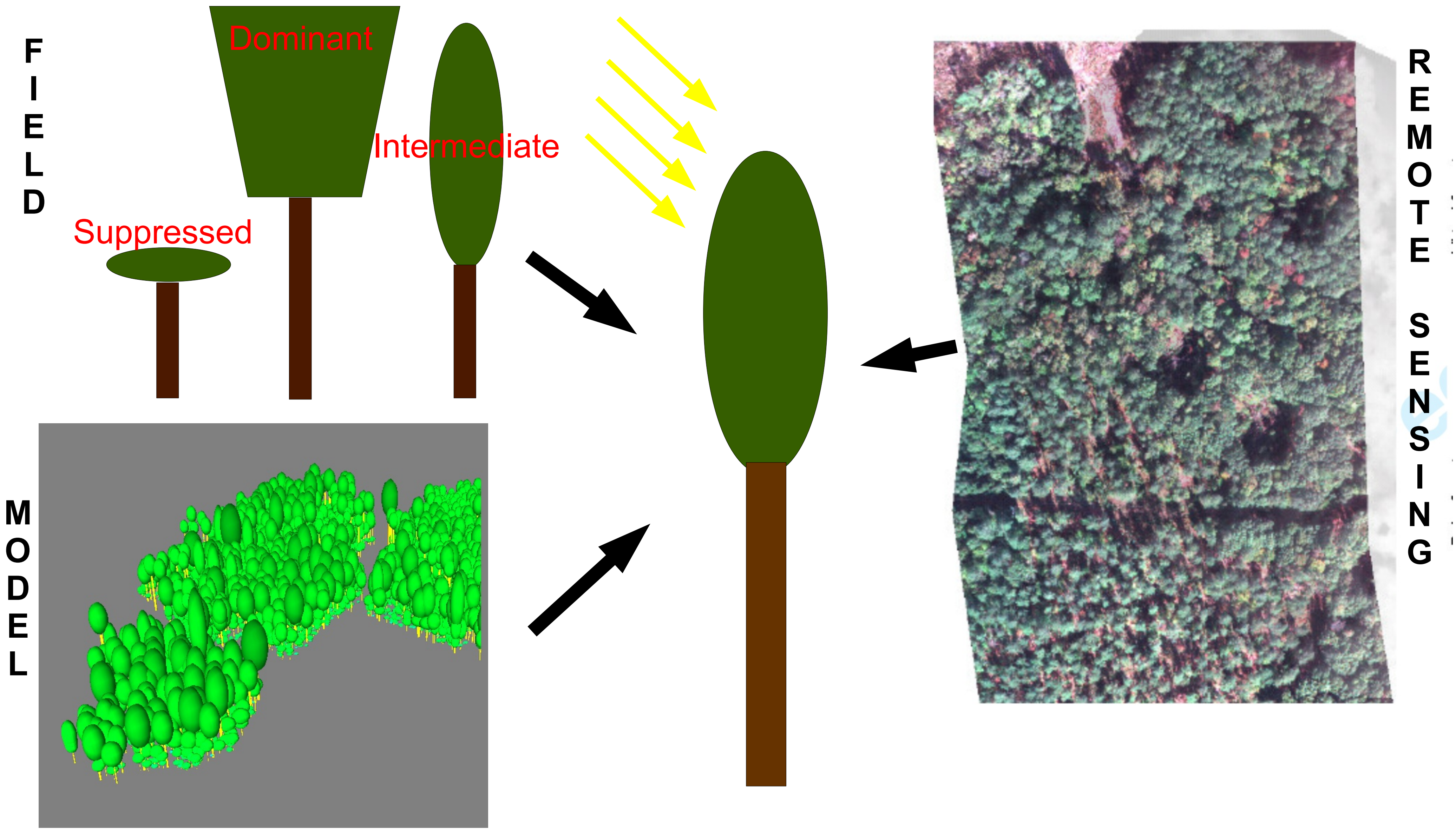
Violate the assumptions of classical tests

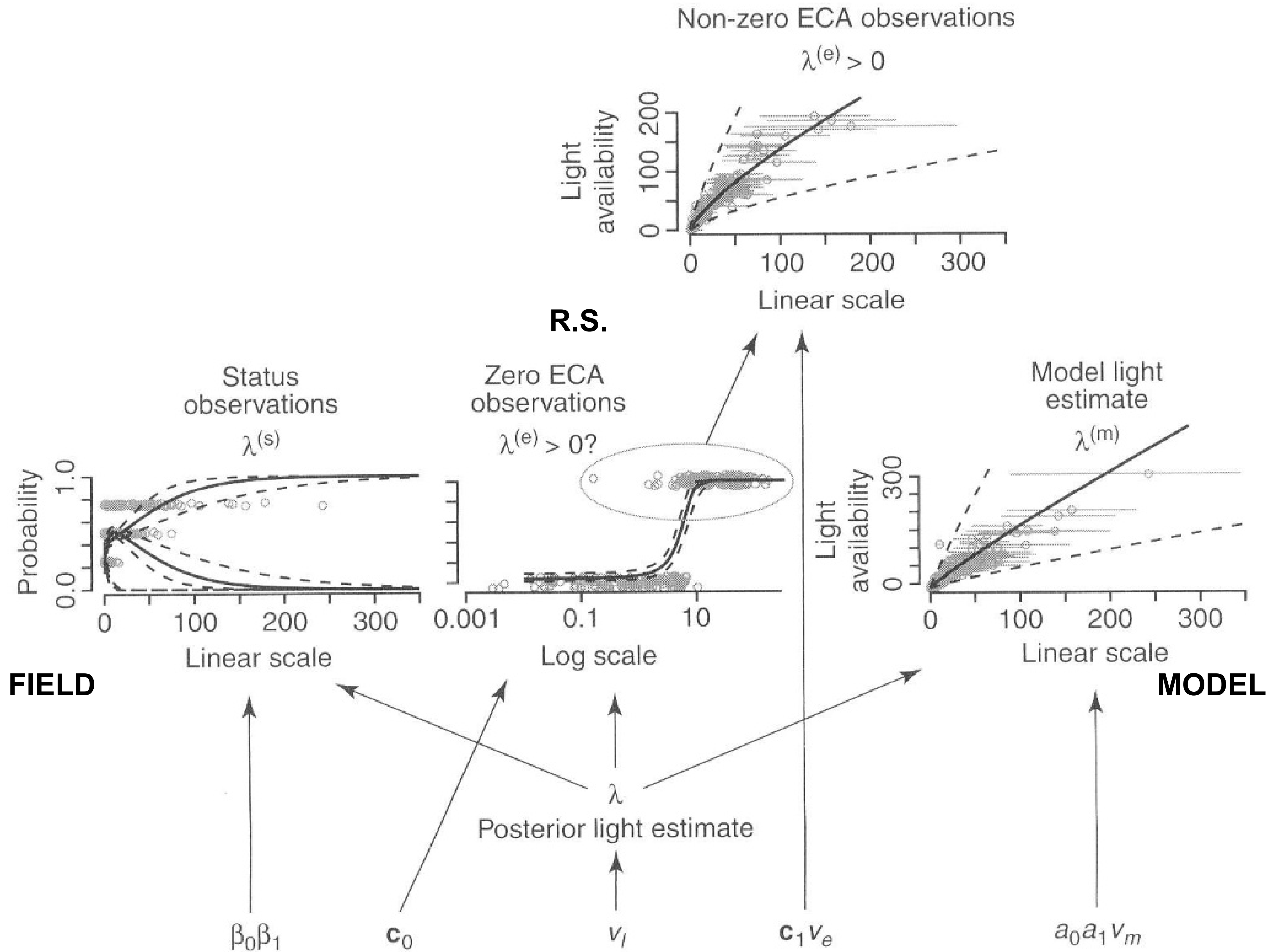
This complexity can be addressed with modern techniques

Example:
How much light is a tree getting?

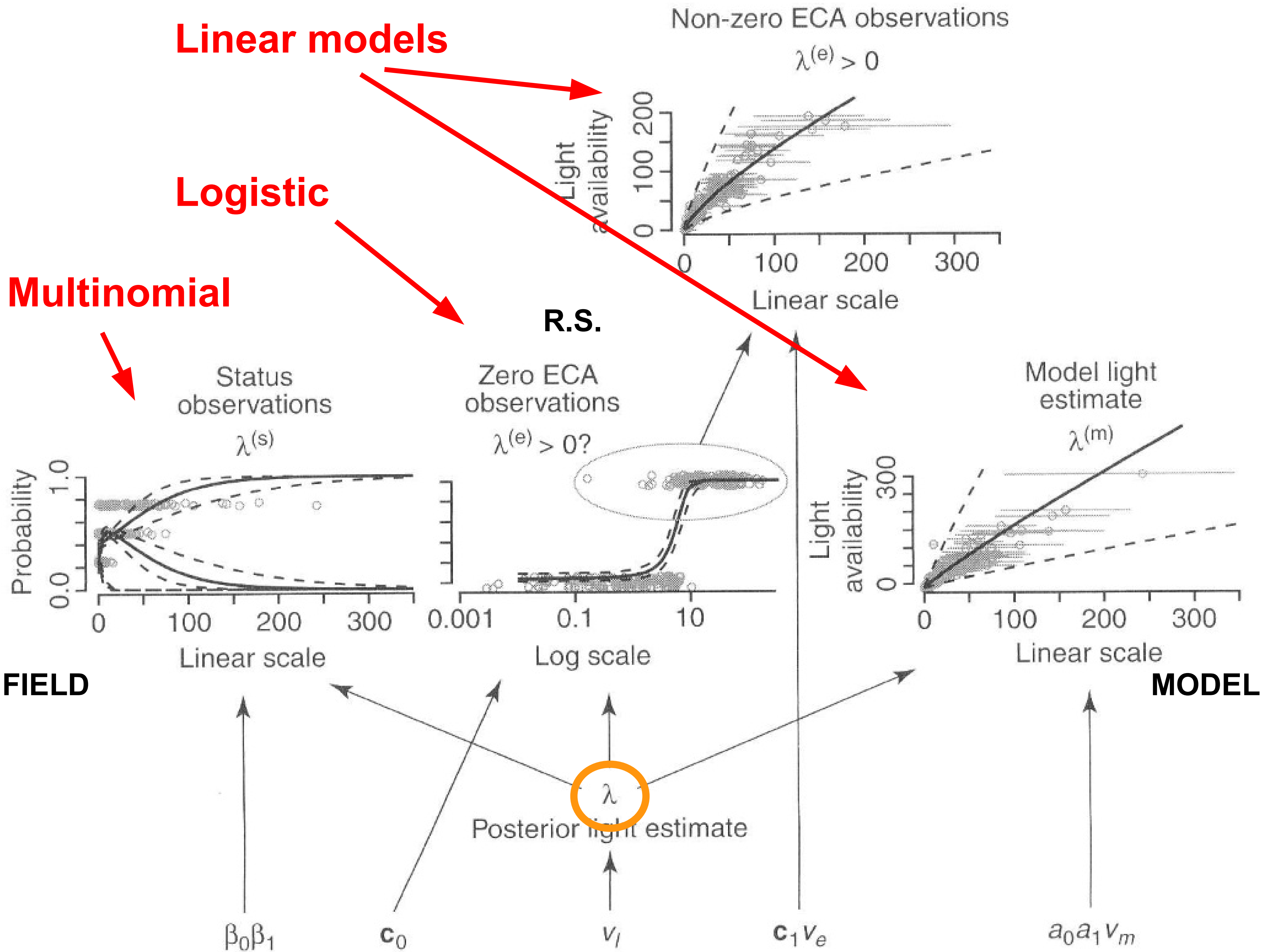


Example:
How much light is a tree getting?





Non-zero ECA observations
$\lambda^{(e)} > 0$
Light availability
0
100
200
0
100
200
300
Linear scale
R.S.
Status observations
$\lambda^{(s)}$
Probability
0.0
1.0
0
100
200
300
Linear scale
Zero ECA observations
$\lambda^{(e)} > 0?$
0.001
0.1
10
Log scale
Model light estimate
$\lambda^{(m)}$
Light availability
0
300
0
100
200
300
Linear scale
FIELD
MODEL
λ
Posterior light estimate
$\beta_0\beta_1$
$\mathbf{c}_0$
v_l
$\mathbf{c}_1 v_e$
$a_0 a_1 v_m$



Linear models
Logistic
Multinomial
Non-zero ECA observations
λ(e) > 0
Light availability
0 100 200
0 100 200 300
Linear scale
R.S.
Status observations
λ(s)
Probability
0.0 1.0
0 100 200 300
Linear scale
Zero ECA observations
λ(e) > 0?
0.001 0.1 10
Log scale
Model light estimate
λ(m)
Light availability
0 300
0 100 200 300
Linear scale
FIELD
MODEL
λ
Posterior light estimate
β0β1
c0
vl
c1ve
a0a1vm

Problem Characteristics

- Multiple data constraints
- Non-linear relationships
- Non-Normal residuals
- Non-constant variance
- Latent variables (response variable not being observed directly)
- Distinction between observation error and process variability
- Missing data

Statistical Paradigms

- Classical (e.g. sum of squares)
- Maximum Likelihood
- Bayesian

Statistical Paradigms

	Statistical Estimator	Method of Estimation	Output	Data Complexity	Prior Info
Classical	Cost Function	Analytical Solution	Point Estimate	Simple	No
Maximum Likelihood	Probability Theory	Numerical Optimization	Point Estimate	Intermediate	No
Bayesian	Probability Theory	Sampling	Probability Distribution	Complex	Yes

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The unifying principal for this course is statistical estimation based on **probability**

Next lecture

- Will cover basics of probability theory
- Read
  - Clark 2007 - Chapter 1
  - **Hilborn and Mangel p39-62** (course website)
- Optional
  - Clark 2007 – Appendix D (Probability)
  - Otto and Day – Appendix 1 (Math) and 2 (Calculus) (course website)