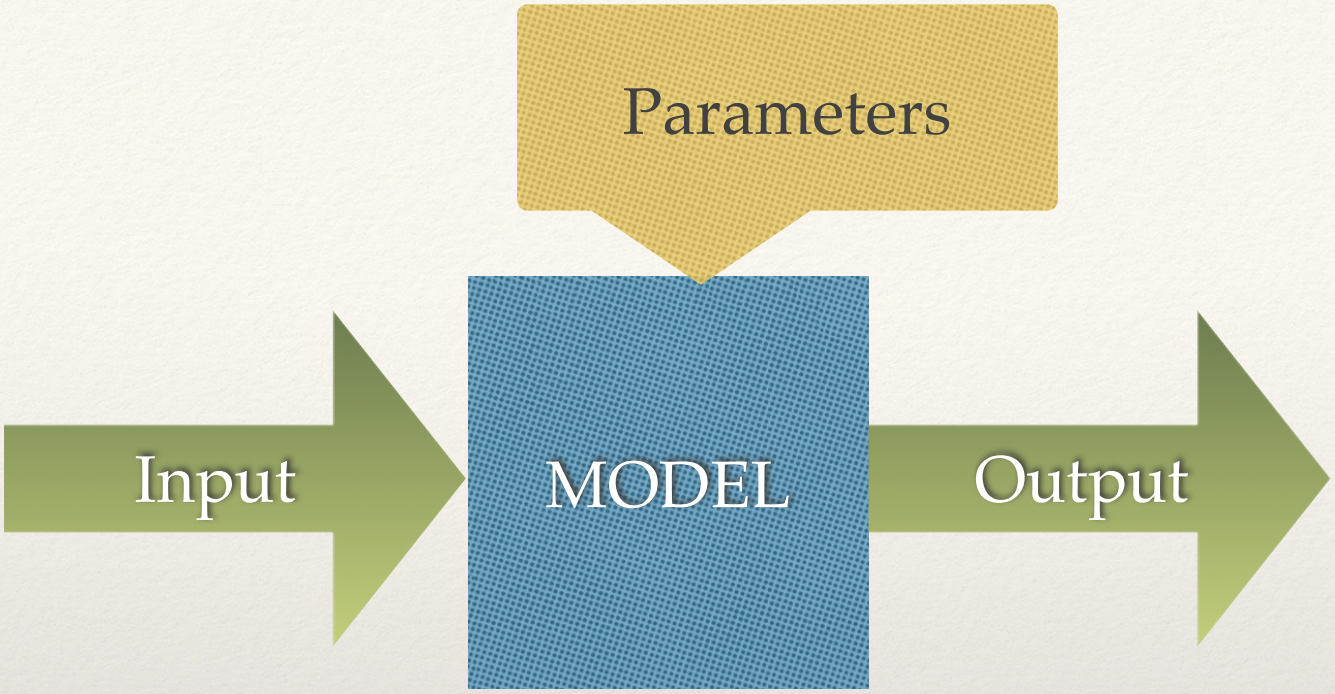
STEPS: Modeling for Problem Solving in ES

1. **Clearly define your goal (question you want to answer, hypothesis you want to test, prediction you want to make) - as precisely as possible**
2. Design or Select your model
3. Implement the model
4. Evaluate the model and quantify uncertainty
5. Apply the model to the goal
6. Communicate model results

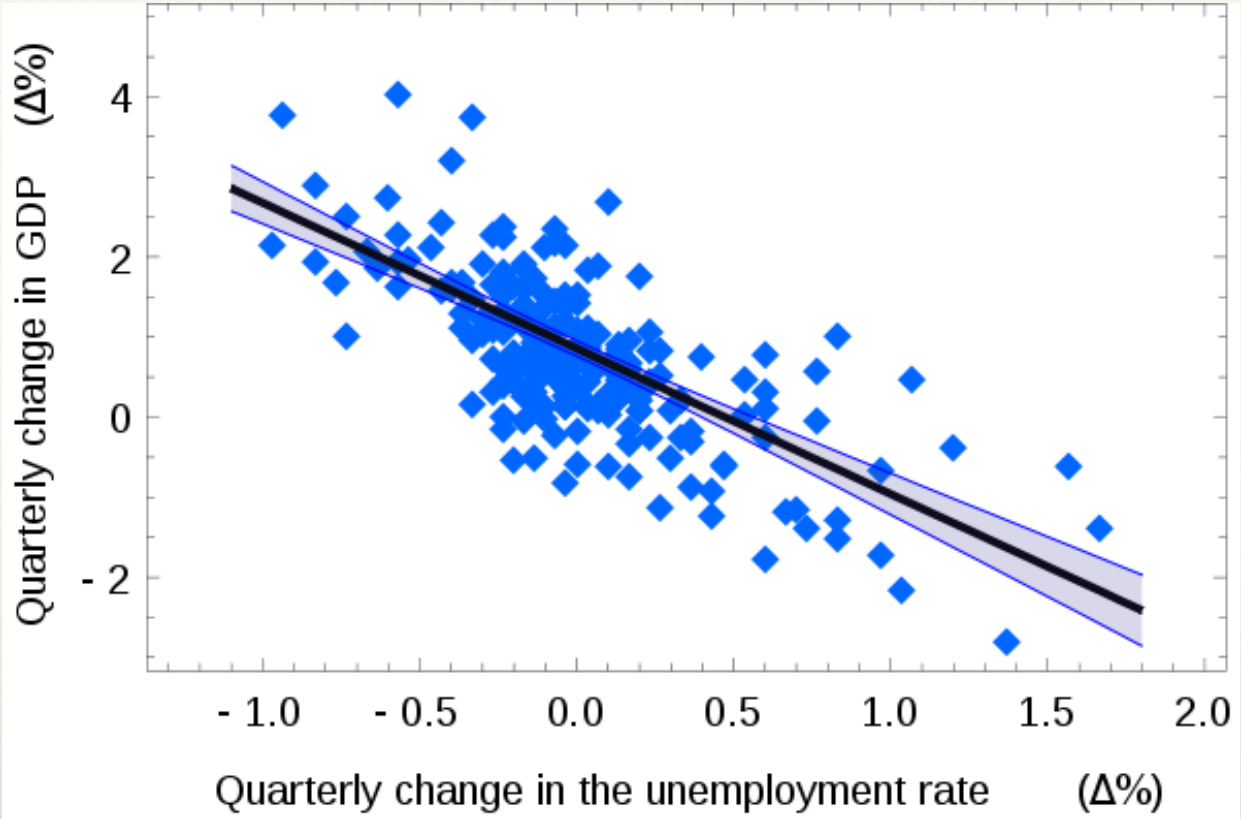
Design/Selecting Models

- What are your inputs-outputs
- What's in the box (the model itself) that gives you a relationship between outputs and inputs
  - Transfer function
- Parameters, values that influences how the model relationships work



Basic components of models

Inputs: Varying; think x of a x vs y regression
Parameters: single values that influence relationships in the model
Outputs: what you want to estimate



The US "changes in unemployment – GDP growth" regression with the 95% confidence bands.

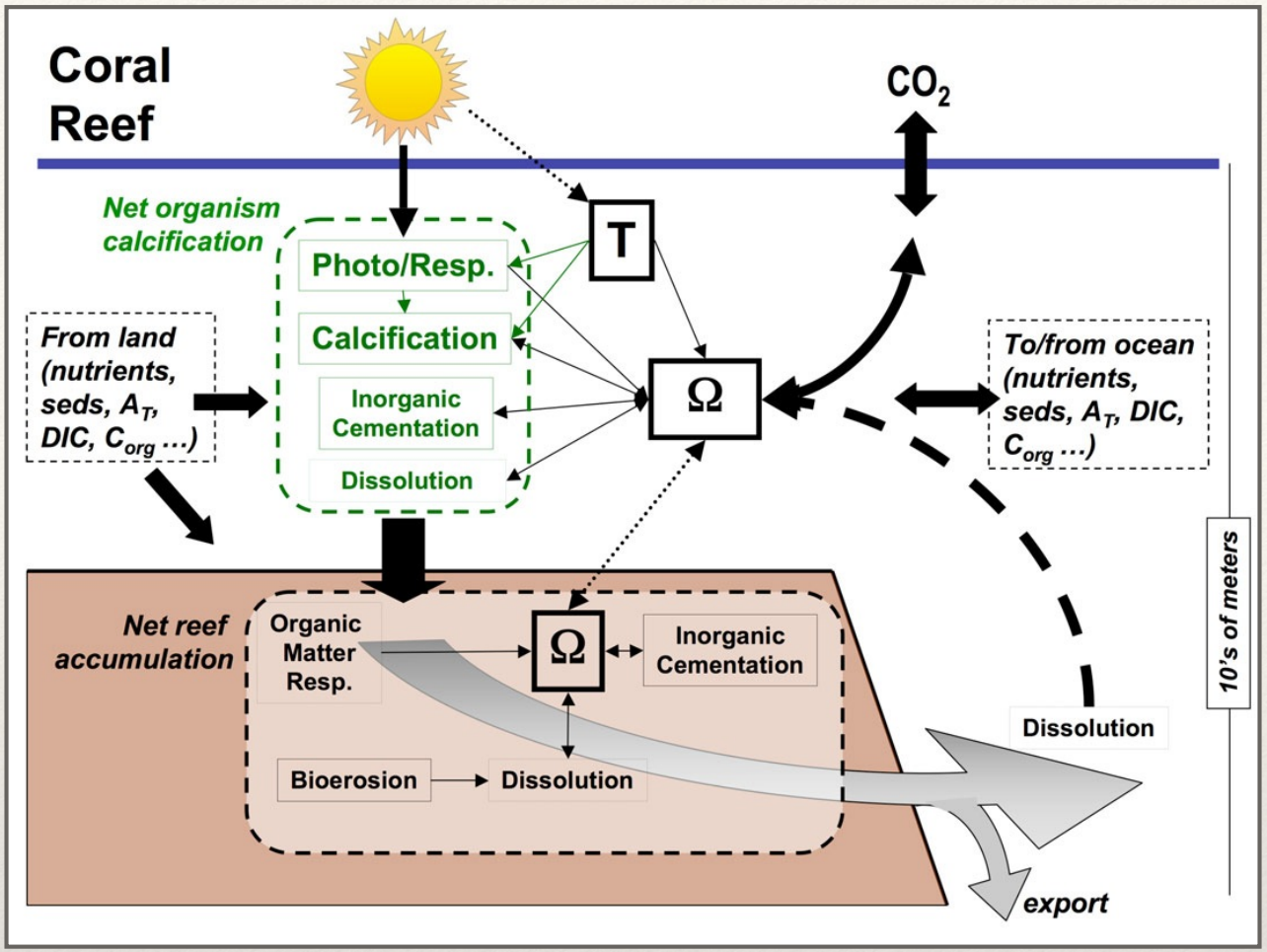
Lorem Ipsum Dolor

Simple model

Input: Change in unemployment rate
Output: Change in GDP
Parameters: Slope and intercept of the line

What's in the box

- Often more complicated than a simple regression…
- So we need to think through what the relationships are; the processes are that we want to take in to account
- Here's where we decide: whats included and what isn't!
- Conceptual models are a good place to start



Modeling changes both the changes in seawater chemistry in coral reef waters, as well as the responses of reef organisms.

http://www.nar.ucar.edu/2008/RAL/images/1.2_ocean_08_lg.jpg

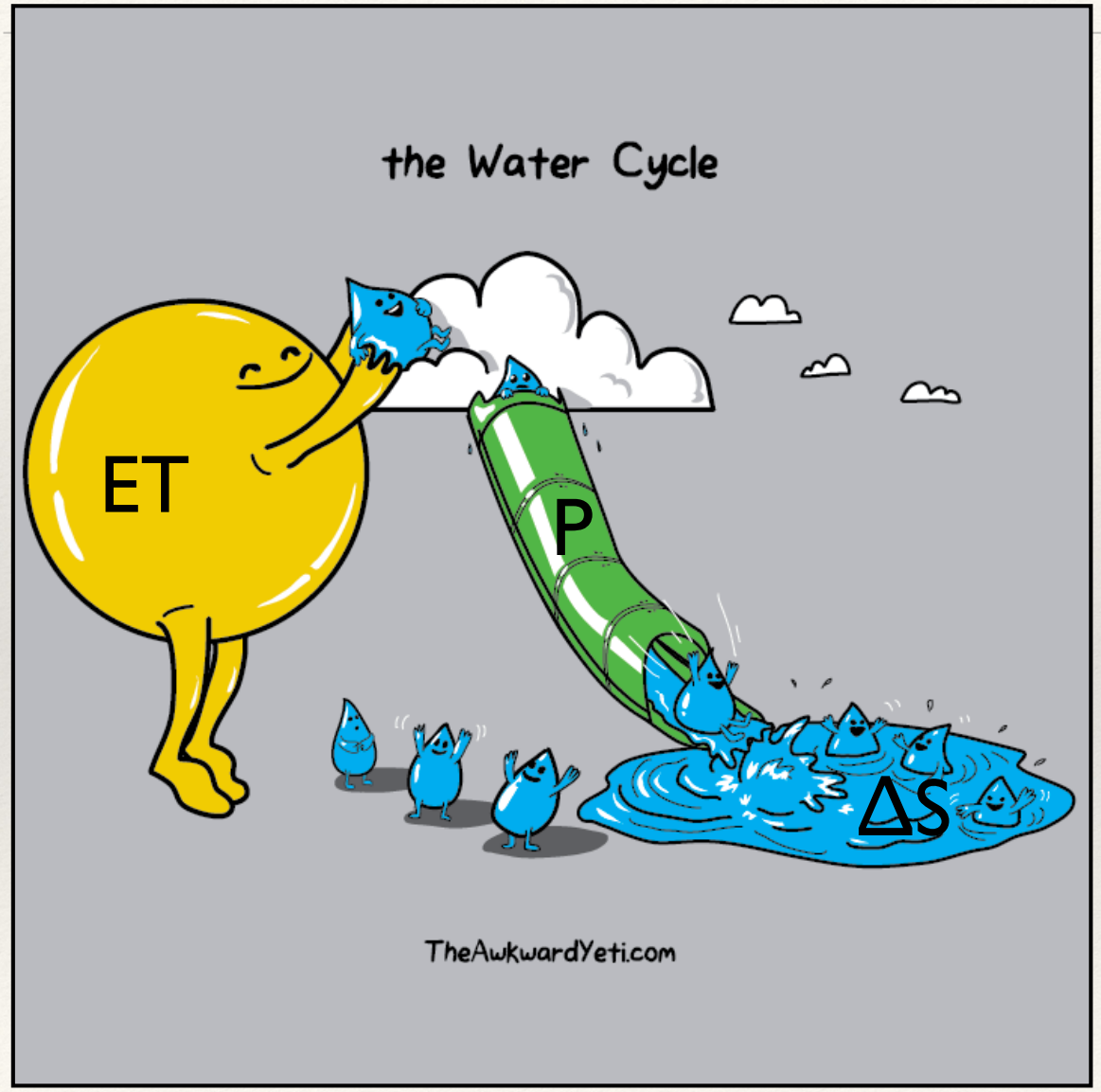
Complex model

Input: Solar energy and atmospheric CO2, land DIC,
Output: Reef Dissolution7, DOC/DIC export
Parameters: Many parameters that control rates of photo synthesis, calcification etc

Conceptual models

- Tells you what is included in translating inputs to output
- Because models are ALWAYs simplifications of reality this step is really important
  - For model development
    - What will you need to know to design or select
  - For communicating to users
    - How can they interpret results - what is accounted for what is not

Conceptual models of the hydrologic cycle



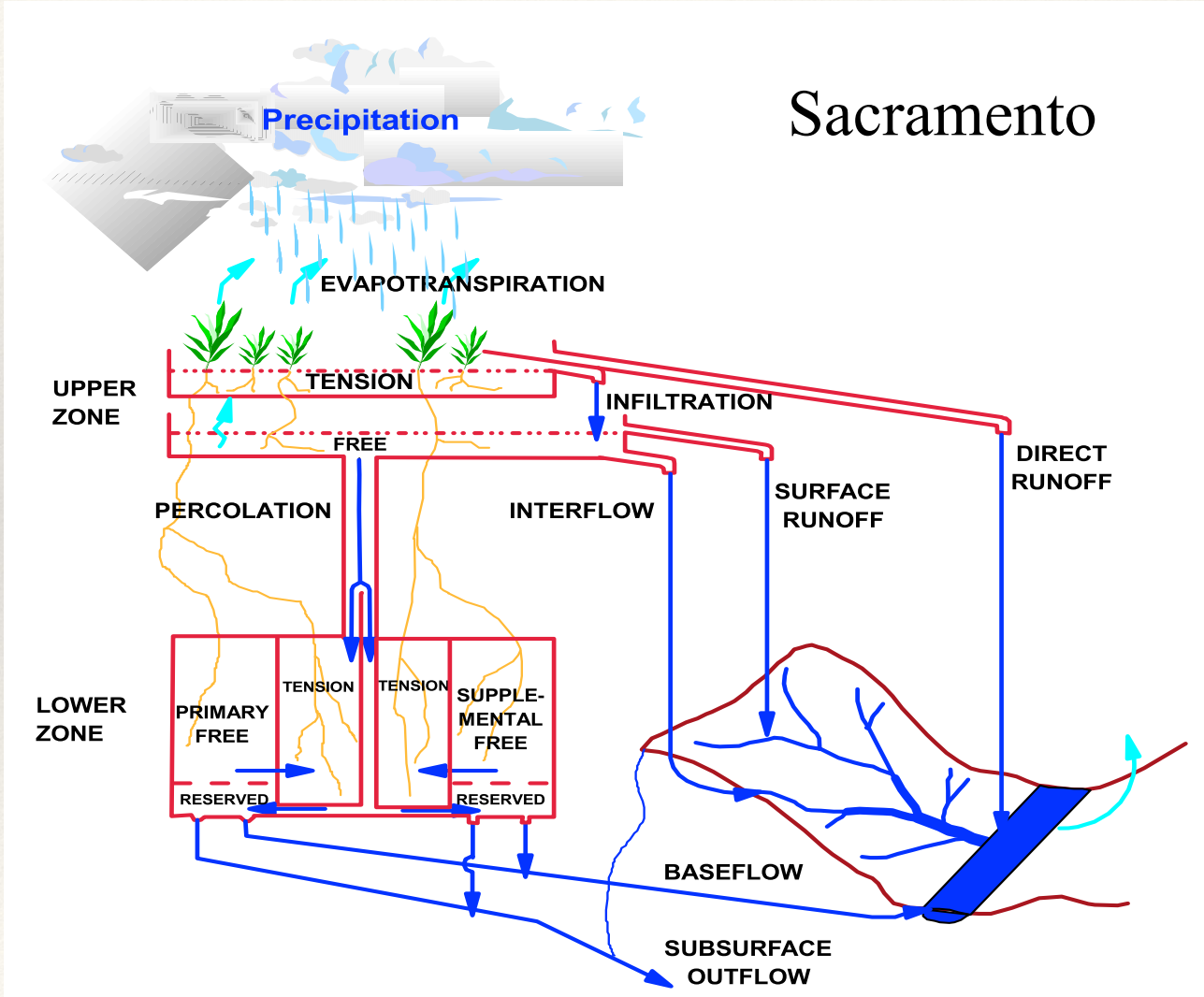
Precipitation = Evapotranspiration + Change in Storage

$P = ET + \Delta S$

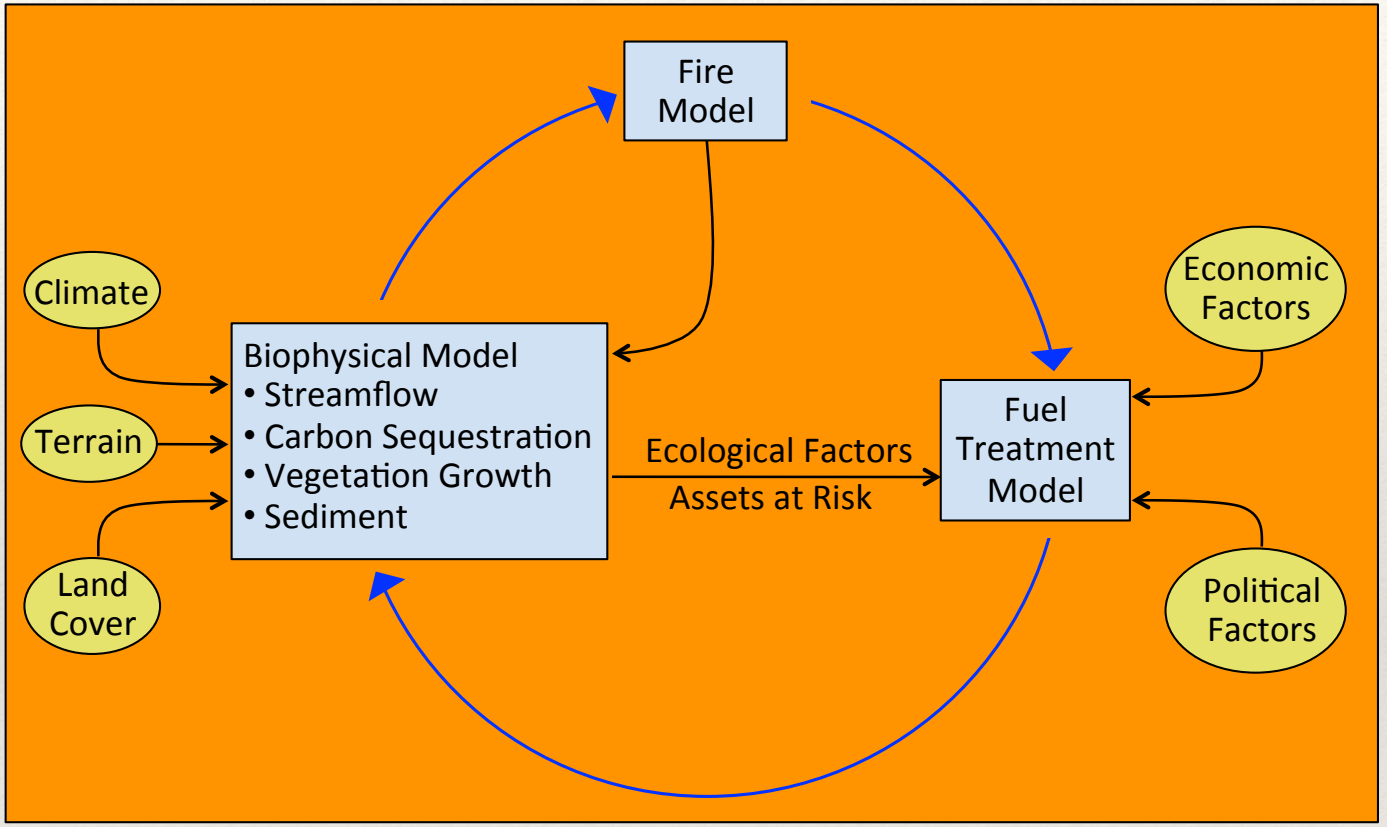
(at global scales ΔS includes streamflow since that water is still "stored" in the earth

Conceptual Models

How much you resolve a given component (of the water balance in this case) depends on what you are interested in what is the Q?



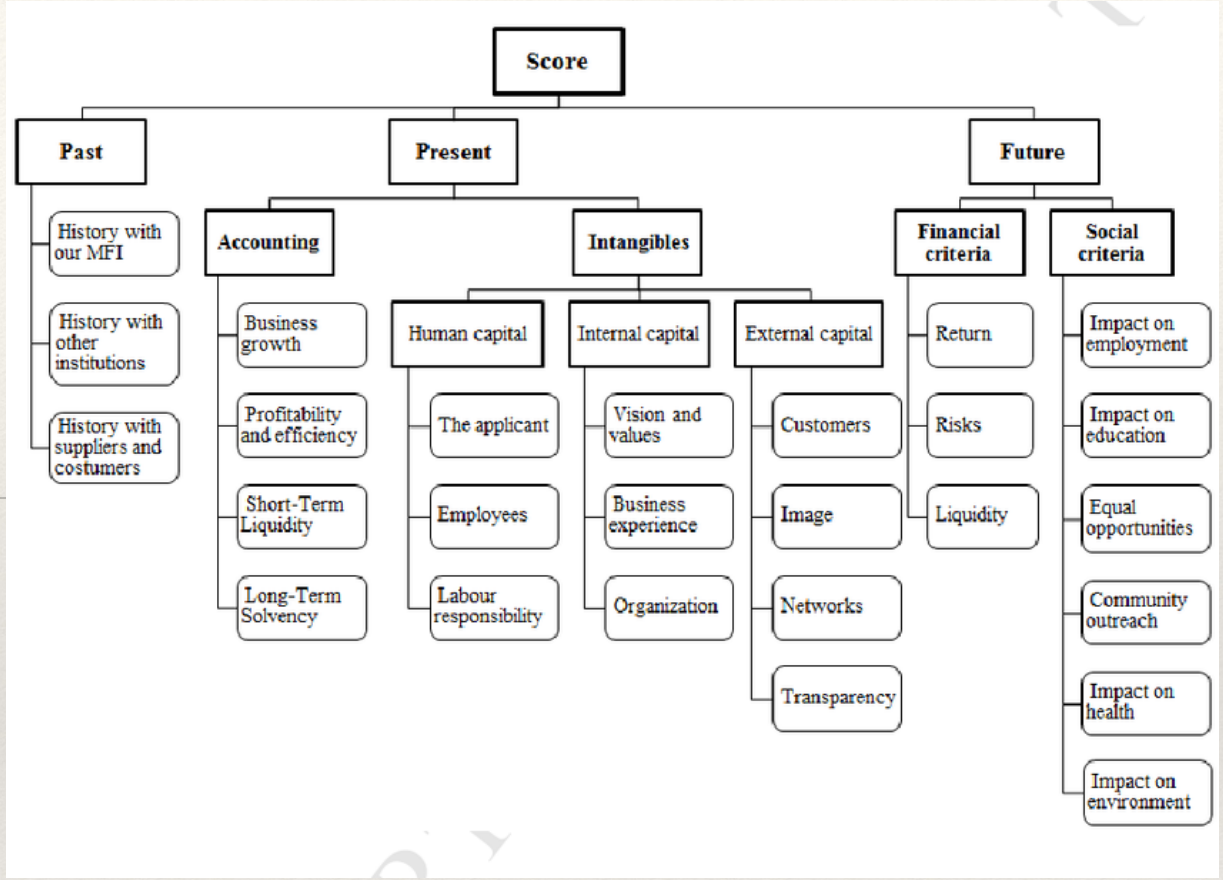
Conceptual Models can be Hierarchical (submodels)



Example: RHESSys-FIRE

Conceptual models can be of a processes (decision, assessment)

Figure 1. Flowchart of the social and environmental microcredit scoring decisional process. The model includes financial assessment and social impact assessment.



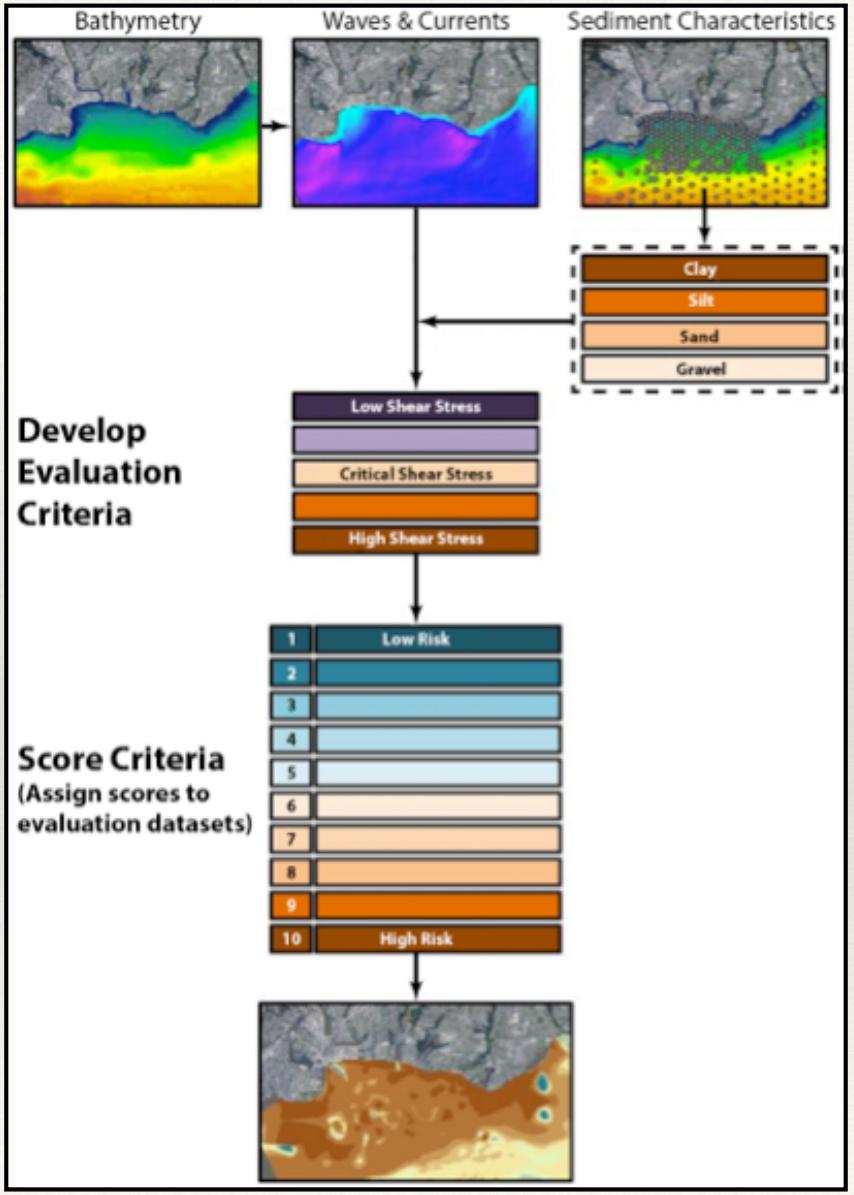
Serrano-Cinca C, Gutiérrez-Nieto B, Reyes NM, A Social and Environmental Approach to Microfinance Credit Scoring, Journal of Cleaner Production (2015), doi: 10.101

Academic paper (PDF): A Social and Environmental Approach to Microfinance Credit Scoring. Available from: https://www.researchgate.net/publication/282855291_A_Social_and_Environmental_Approach_to_Microfinance_Credit_Scoring [accessed Apr 5, 2017].

http://energy.sandia.gov/energy/renewable-energy/wind-power/offshore-wind/offshore-wind-rdd-sediment-transport/

Conceptual models can be of a decision making processes

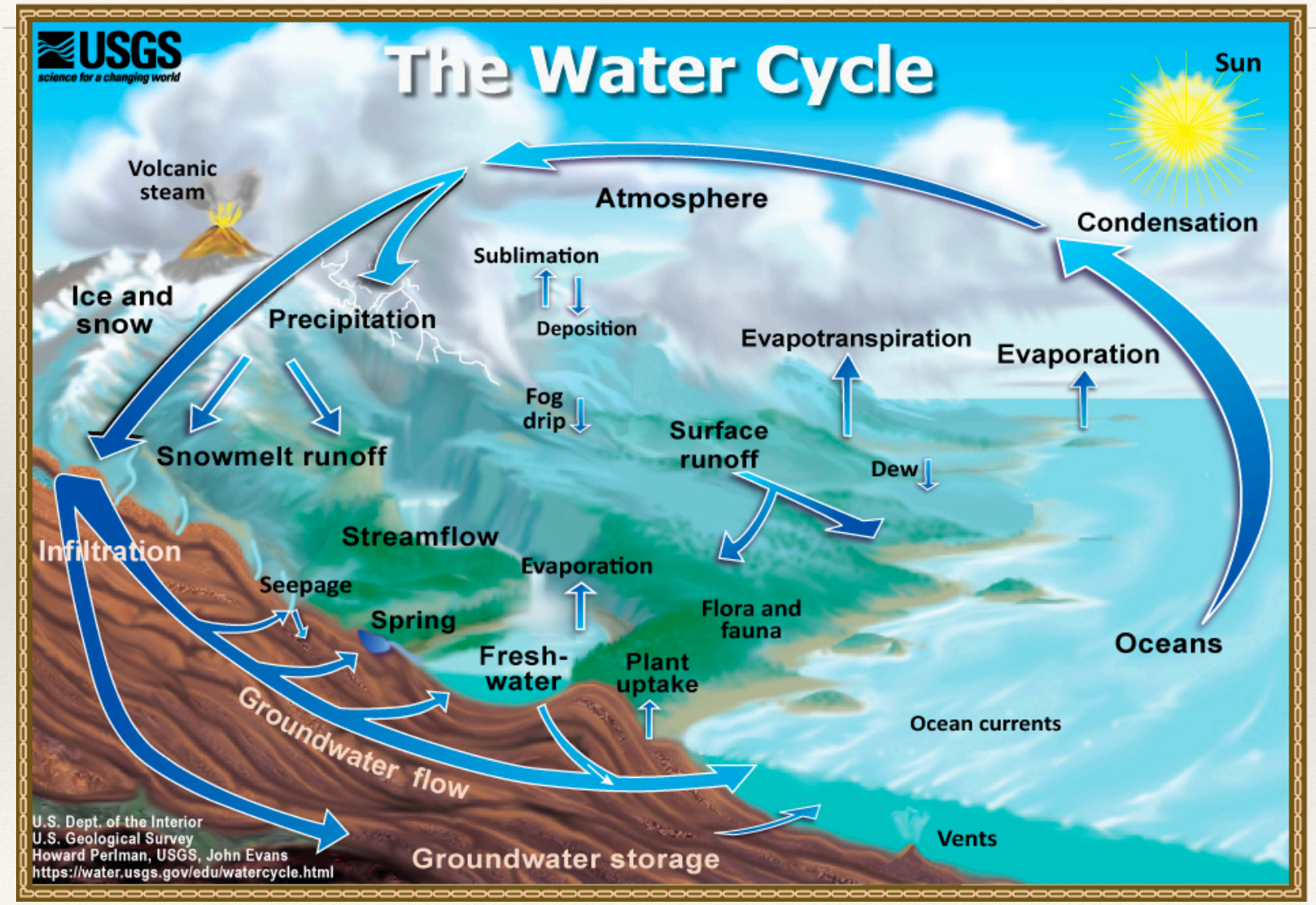
Another example



Model assessment

- A diagram of the conceptual model is key -it tells you what the model designer thinks is important!
- When reading papers…selecting models…designing models

Conceptual models of the hydrologic cycle



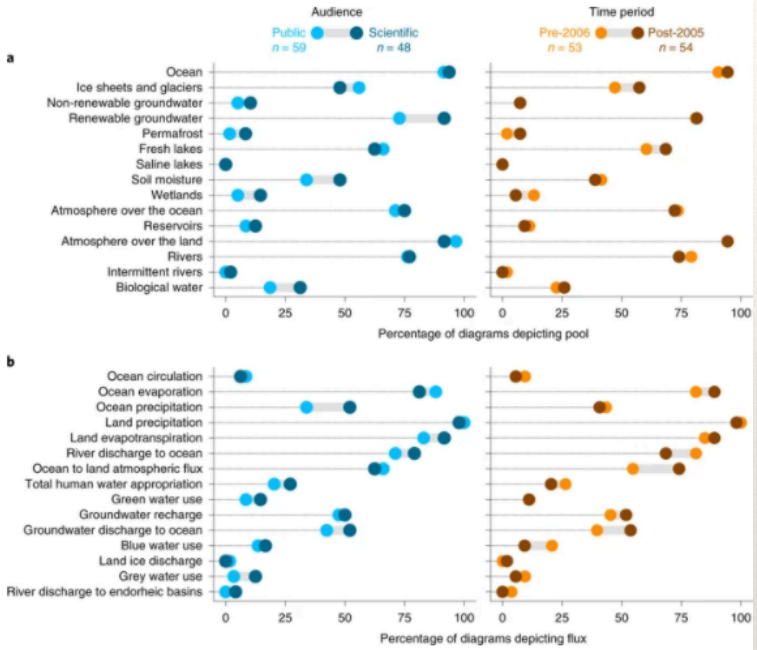
https://water.usgs.gov/edu/watercycle.html

USGS

Critique?

Conceptual models - you can learn a lot by comparing

Fig. 2: Pools and fluxes represented in water cycle diagrams.



a,**b**, Percentage of water cycle diagrams that represent major pools (**a**) and fluxes (**b**) in the global water cycle. Pools and fluxes are ordered by size based on Fig. 1, starting with the largest pool (ocean) and flux (ocean circulation). We categorized diagrams by intended audience and time period. Public diagrams include those made for advertising, advocacy, government outreach and primary or secondary education, whereas scientific diagrams were made for higher education textbooks and peer-reviewed publications. We compared the diagrams made before and after 1 January 2006, which corresponds with the publishing of several high-profile papers that advocated increased integration of social and hydrological systems. The grey bar between points is visible for differences greater than 10 percentage points.

"Here we compiled a synthesis of the global water cycle, which we compared with 464 water cycle diagrams from around the world. Although human freshwater appropriation now equals half of global river discharge, only 15% of the water cycle diagrams depicted human interaction with water

Only 2% of the diagrams showed climate change or water pollution—two of the central causes of the global water crisis—which effectively conveys a false sense of water security""

From AGU abstract Abbott et al., (2019)

Abbott, B.W., Bishop, K., Zarnetske, J.P. et al. Human domination of the global water cycle absent from depictions and perceptions. Nat. Geosci. 12, 533–540 (2019). https://doi.org/10.1038/s41561-019-0374-y

Types of Models

- Once you know what the question is (GOAL), you can choose or design your model
- Helpful to be aware that there are different types of models - and to be able to identify the kind of model you need to provide the information you need!

Types of Models: WHAT's in the BOX

Conceptual.....Mathematical

Static……Dynamic :*TIME*

Lumped.....Spatially Distributed: *SPACE*

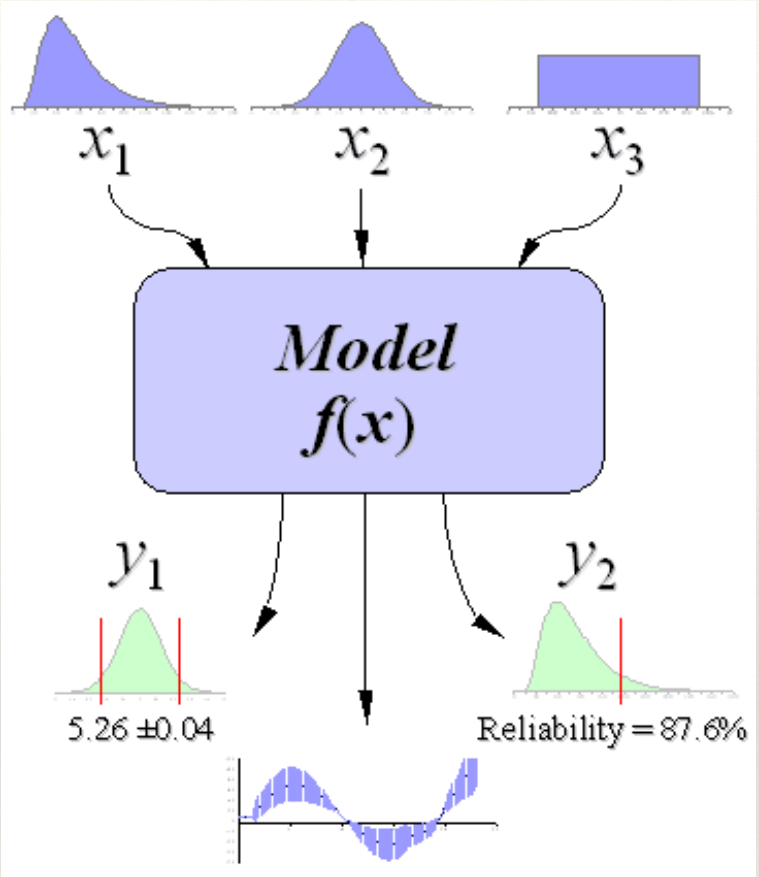
Stochastic.....Deterministic

Abstract……Physically/Process Based

but biggest differences may often be the degree specific processes/parameters are accounted for

Stochastic - Deterministic

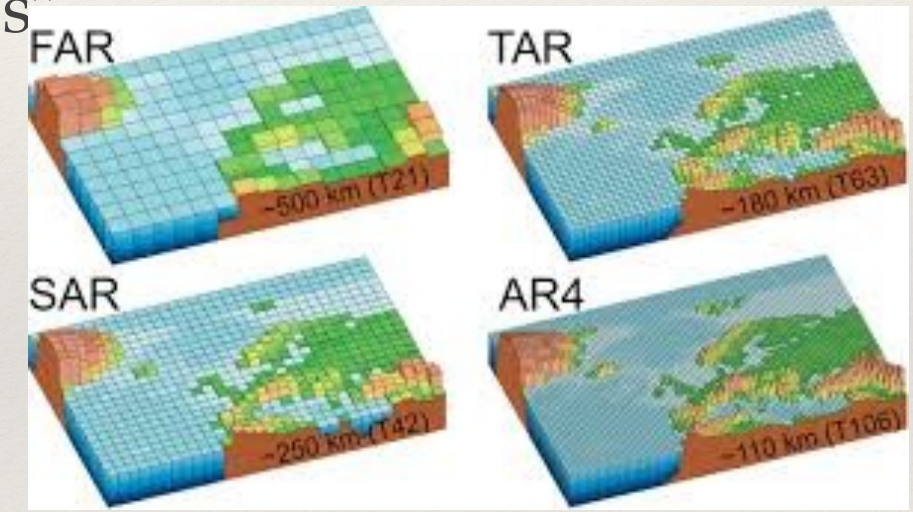
- *Stochastic*: Model output is the probability of flood events of a magnitude greater than 500 m^3/s given rainfall probability distribution (artificial or generated from data) for a 100km2 watershed; Model inputs are probability of rainfall intensity
- *Deterministic*: Model output is the depth of flood given a time series of rainfall for a 100km2 watershed



http://www.vertex42.com/ExcelArticles/mc/MonteCarloSimulation.html

Lumped …Spatially distributed

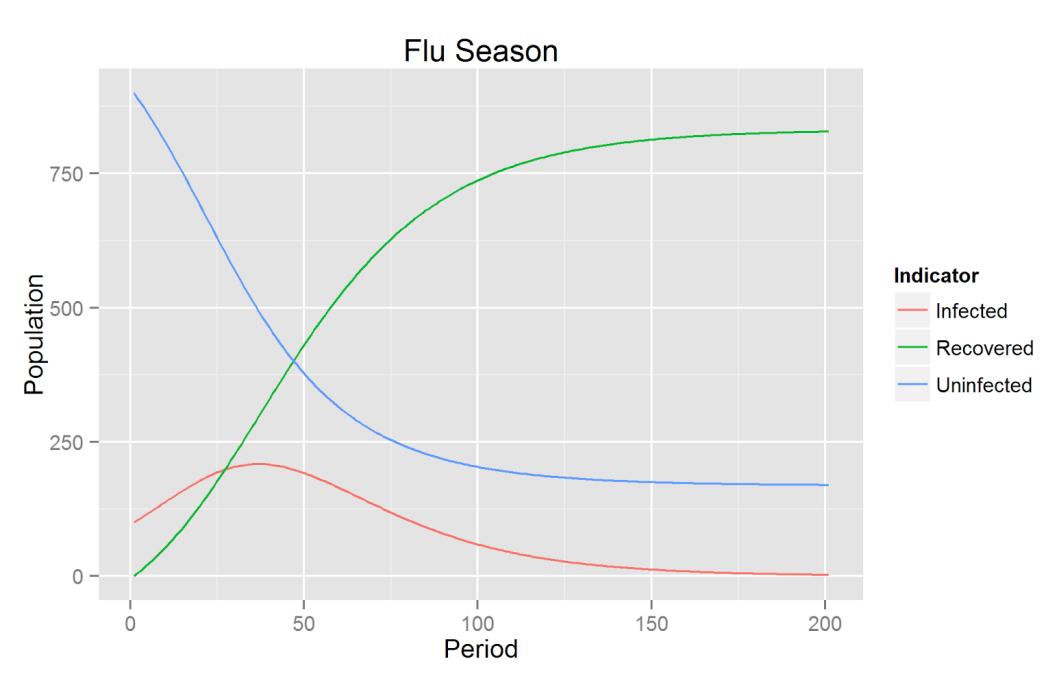
- *Lumped* - single point in space, or space doesn't matter
- *Spatially distributed* - model is applied to different "patches" in space
  - spatial units are independent
  - spatial units interact with each other



http://eo.ucar.edu/staff/rrussell/climate/modeling/climate_model_resolution.html

Static- Dynamic Time Varying

- *Static* - Processes or Variables modeled do not evolve with time
  - total # of people who catch the flu at some point in the season
- *Dynamic* - model elements evolve through time - and variables/ results at one time step typically depends on previous time step
  - Number of people with flu at any given time



http://www.econometricsbysimulation.com/2013/05/sir-model-flue-season-dynamic.html

Abstract - Physically/Process based

- *Abstract* - relationship between inputs and output depends on parameters that don't necessarily have a physical meaning
- *Physically based* - parameters do have a physical meaning (could be measured) - relationships derived from first principles (theory) of how things work

Abstract - Physically/Process based

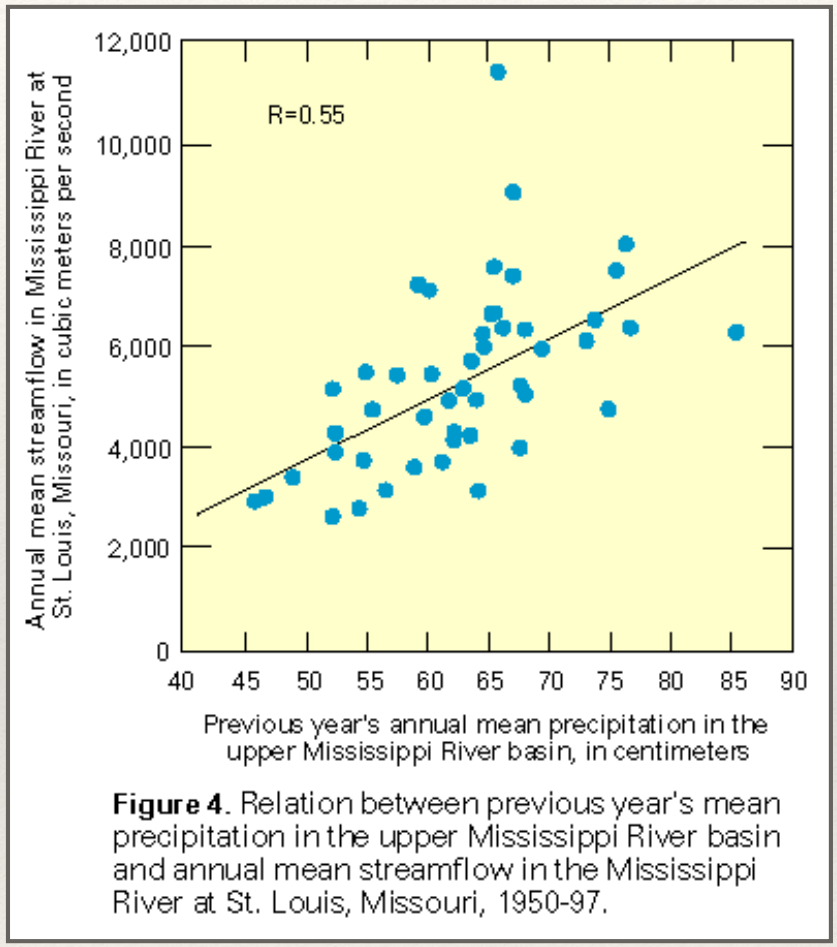
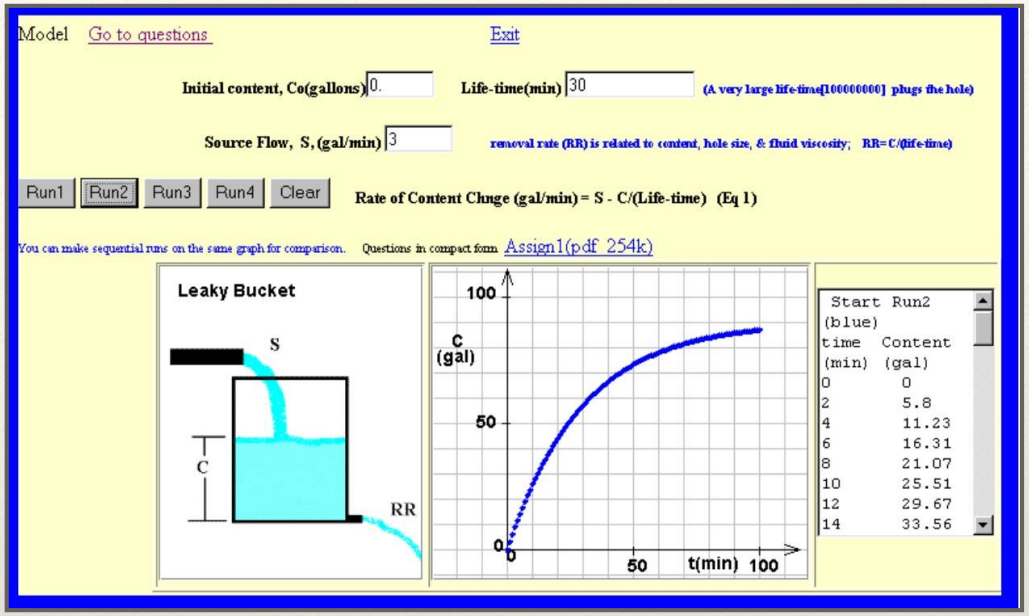


Figure 4. Relation between previous year's mean precipitation in the upper Mississippi River basin and annual mean streamflow in the Mississippi River at St. Louis, Missouri, 1950-97.



serc.carlton.edu

Physically based

http://ks.water.usgs.gov/pubs/reports/paclim99.html

Abstract

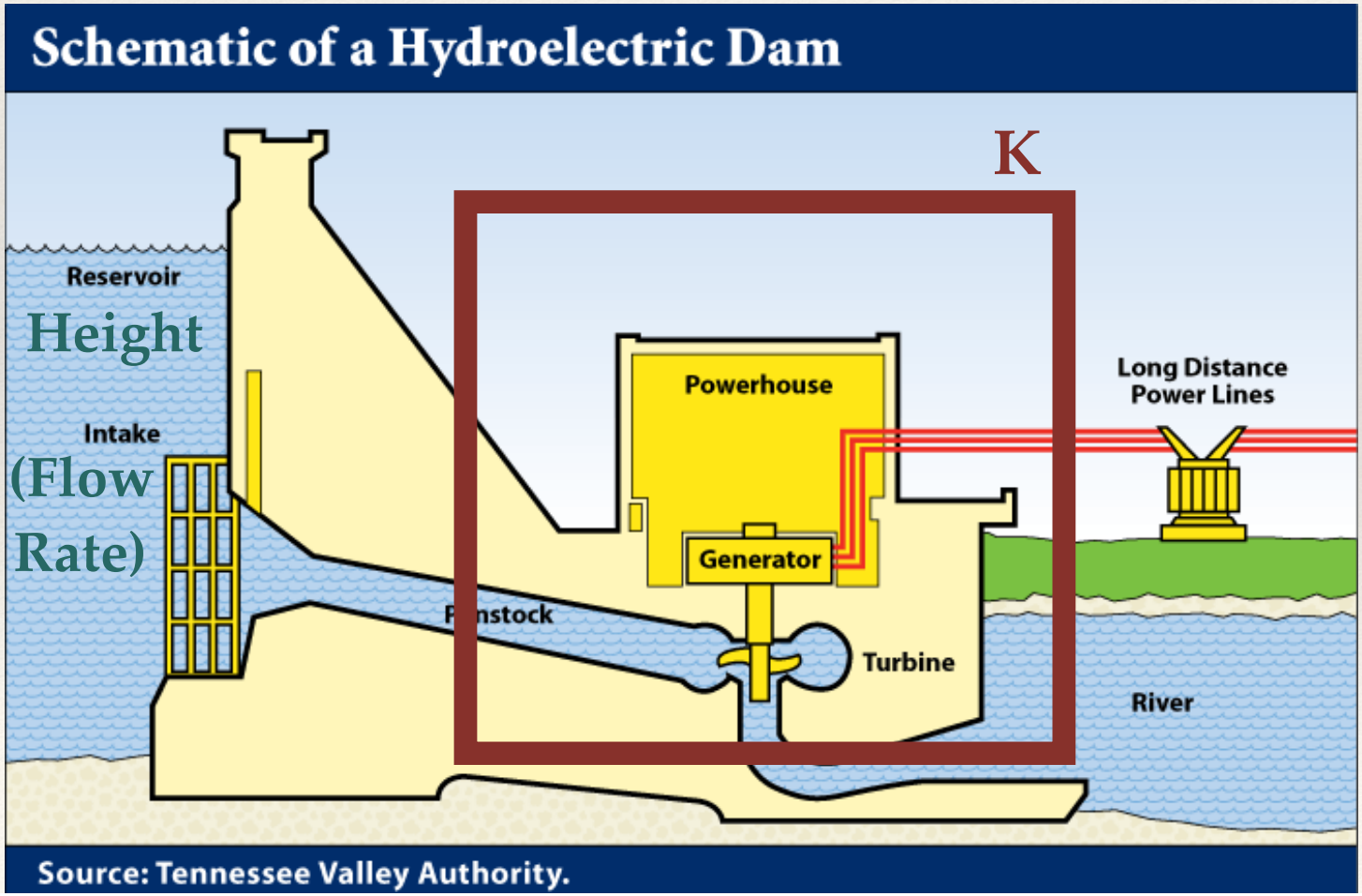
From conceptual model to flow chart/workflow

- Impact of smoke from fires on health of agricultural workers
- What is ‘smoke” What is “health”
- What is an “agricultural worker”. …leads to your conceptual model

- Answering these questions will tell you if model be spatial, dynamic or just dose response

Types of models: Example

- Input: Reservoir height and flow rate
- Output: Instantaneous power generation (W/s)
- Parameter: Reservoir Efficiency
- Conceptual model



Types of models: Example

- If we expand the model to compute power production over a year, where inputs were streamflow into the reservoir - *Dynamic Model*
- If we expand to model power production from all the reservoirs in California, accounting for spatial patterns of snowmelt inputs and upstream-downstream relationships - *Spatially Distributed Model*
- If we modified the model to estimate the probability distribution of power production, given a probability distribution of reservoir levels - *Stochastic Model*

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2. **Develop a conceptual model - draw it!**
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Conceptual models: What is the box

- When you are modeling - the conceptual model becomes your guide for model design and/or selection
- So we think about it in a particular way
- Inputs - transfer function - outputs
- Deconstruct the transfer function

Conceptual models: What is the box

- *Inputs and Outputs*
  - what
  - temporal resolution, extent
  - spatial resolution, extent
- *System boundaries*
  - determine what is I/O and what is internal

Conceptual models: Whats in the box

- *variables*
  - lego bricks
  - state, fluxes in a process model
  - pieces that make up inside our world/box
- *intermediate products*
  - I/O to different steps in a process

Conceptual models: Whats in the box

- *Relationships variables*
  - causal (warm temp increases mosquito growth)
  - feedback (soil water influences plant growth influences soil water)
- *Process*
  - sequential steps (prioritization of habitat quality)

Conceptual models: Composing

- Differentiate between inputs/outputs, variables (states vs products), intermediate products, relationships
- Relationships are often lines with arrows
- Use shape and color to differentiate I/O, variables …
- Vary level of abstraction (sometimes you start with variables that are submodes in themselves)

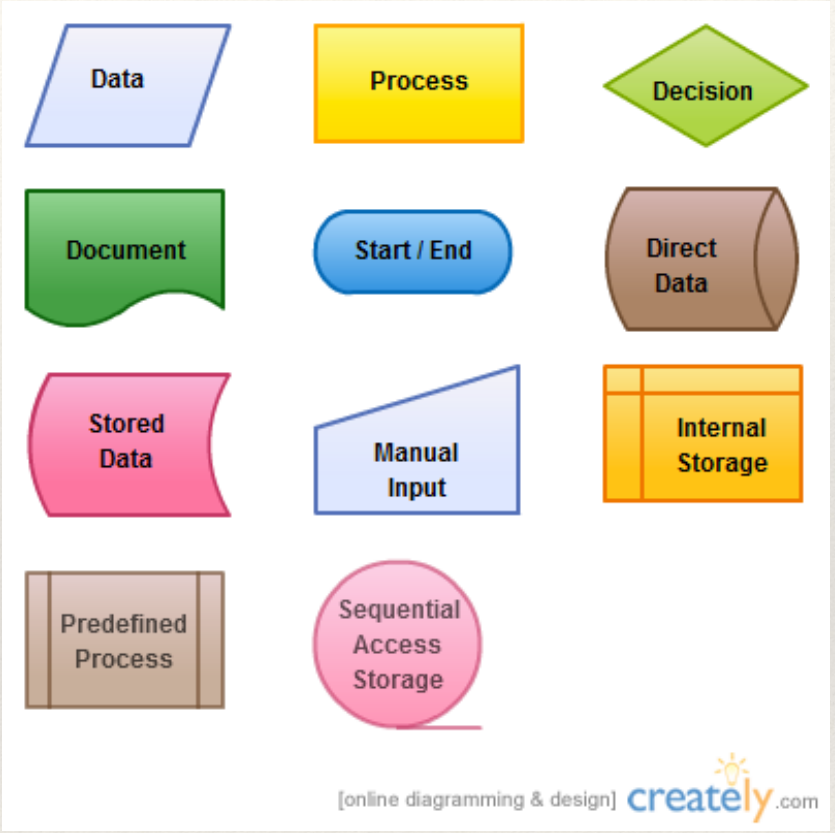
Conceptual models: Composing

- Pictorial representation of how you think about your system, whats included - will tell you really quickly if your model is appropriate for answering specific Qs

Building Models

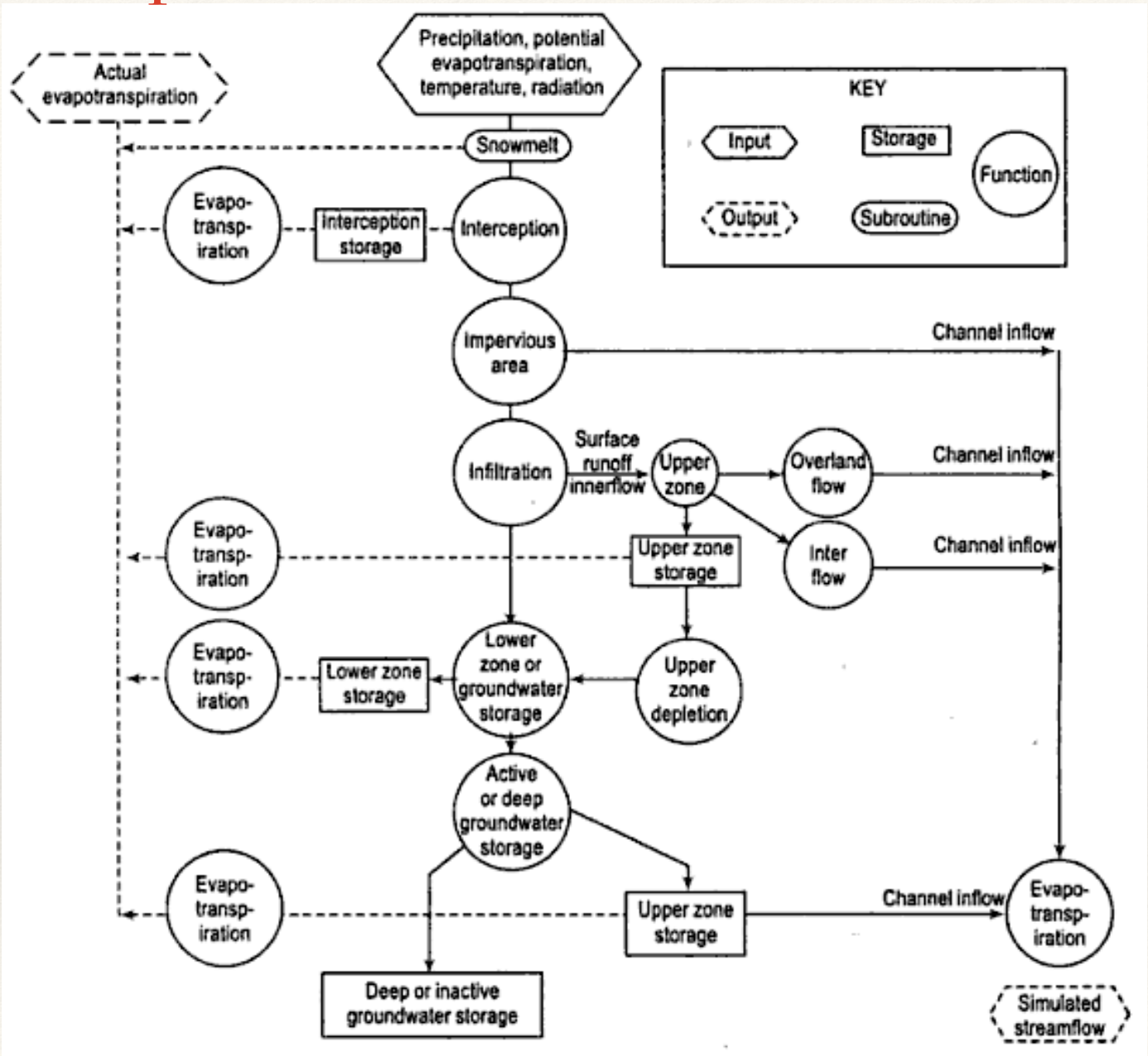
Return to conceptual model; expand to show how you will implement;

Some model designers uses standard symbols for the different

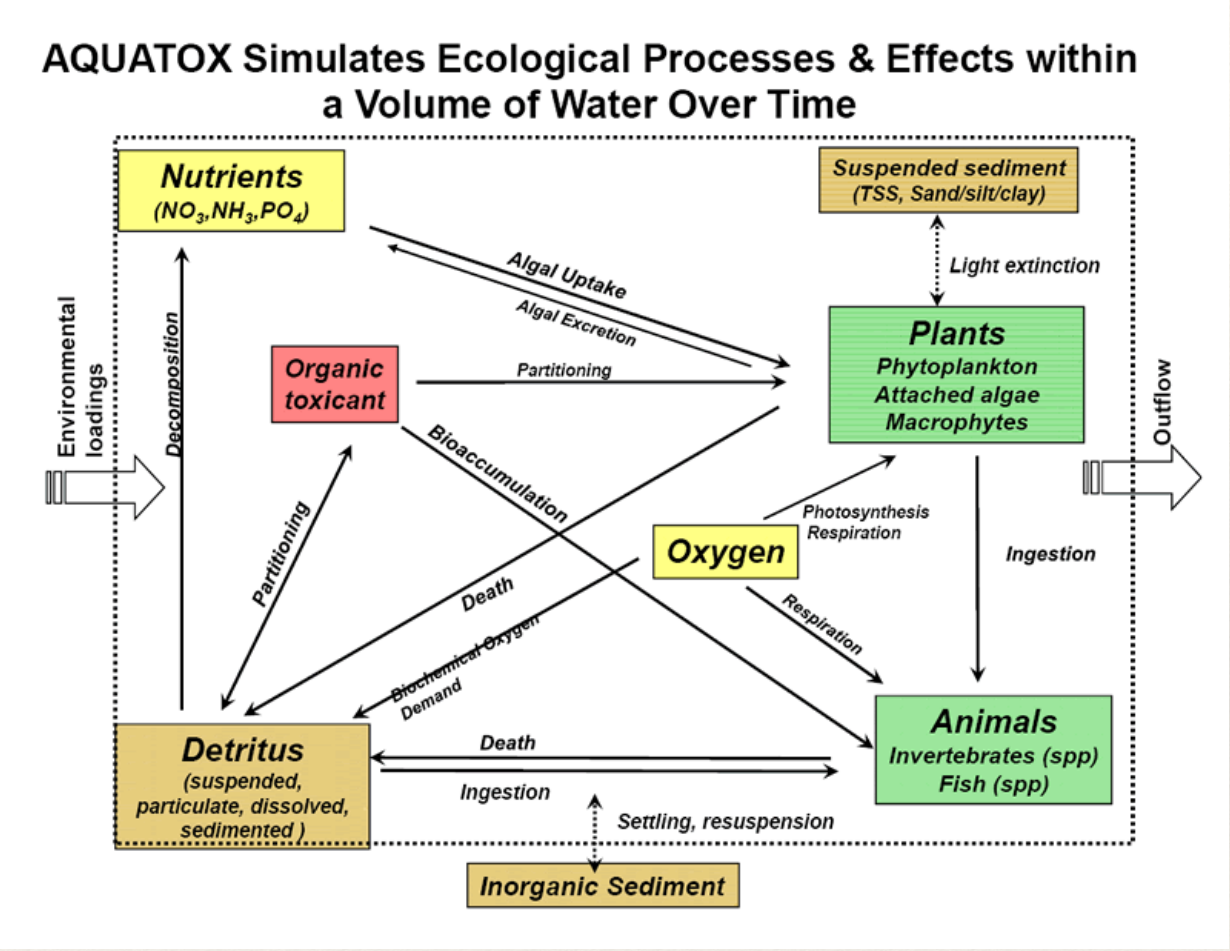


Conceptual Models

- PhD of Norman Crawford under supervision of Ray K Linsley at Stanford University in 1962
- Notice how the symbols help to understand what the model will do

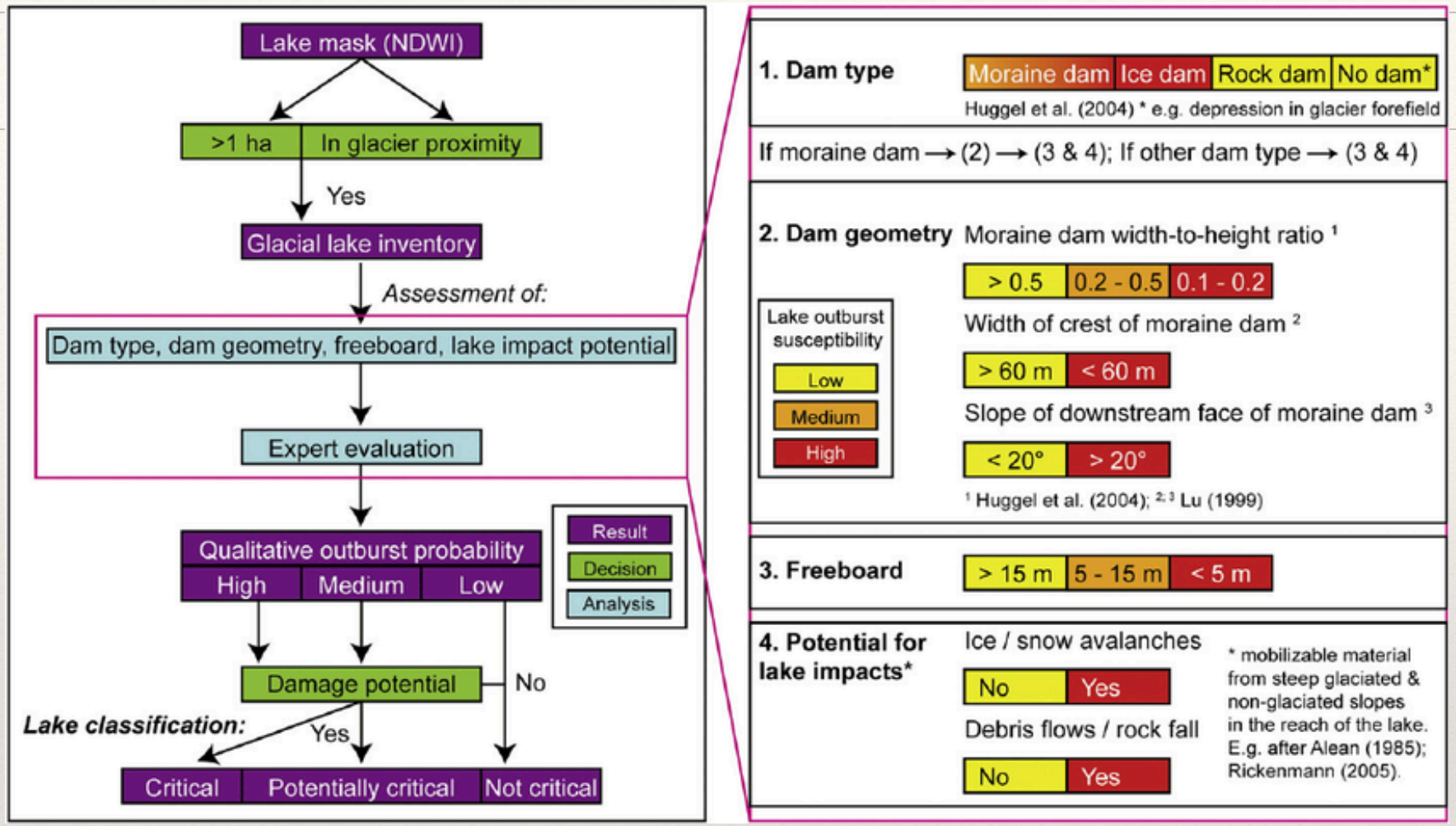


Conceptual models: for design of your system



The lines here tell you what the model will do

The boxes give you intermediate products (states)



Works for models that classify as well

Fig. 2. Flow-chart illustrating the working steps of glacial lake detection based on the normalized difference water index (NDWI), lake-outburst probability assessment and lake classification in the Indian Himalayas.
Rouce et al., Hydrol. Earth Syst. Sci., 20, 3455–3475, 2016 www.hydrol-earth-syst-sci.net/20/3455/2016/ doi:10.5194/hess-20-3455-2016

Assignment 1

- Work in groups of 2-3
- Identify an environmental problem that would benefit from information that could be provided by a model.
- Summarize the goal of the model in a single paragraph.
- Develop a conceptual model (and a pictorial representation of it) - You don't need to have the actual equation (or set of equations) just the conceptual model
- Describe what the inputs and outputs are, what kind of model is it? (stochastic/deterministic; spatially variable?)
- Include a short (1 paragraph) description of the model (in this paragraph describe key inputs and outputs are) and describe the type of model
- Submit the above on Gauchospace (April 7th)
- Make 1 slide to present your model in class - also add to Gauchospace before class on April 8