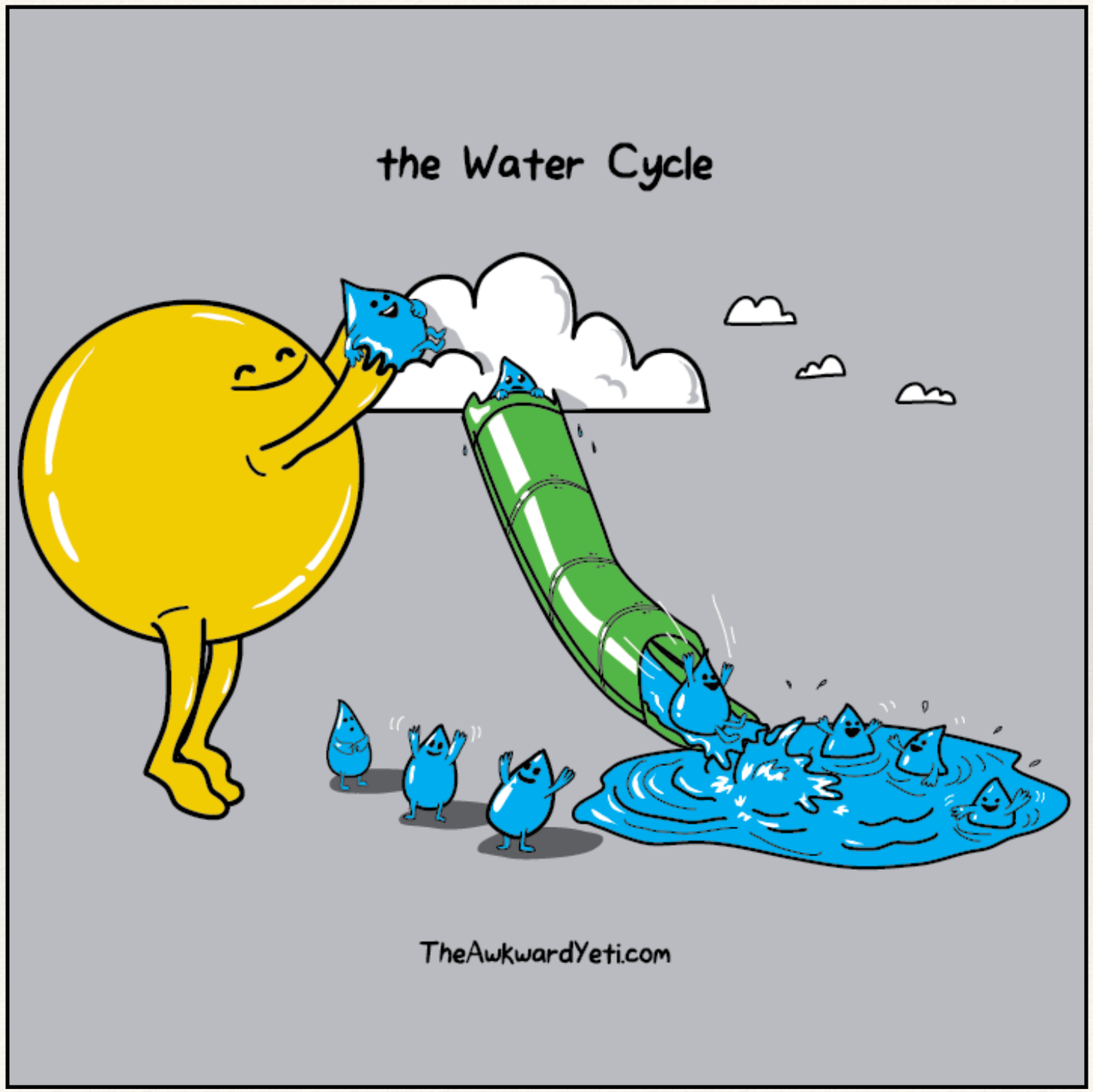
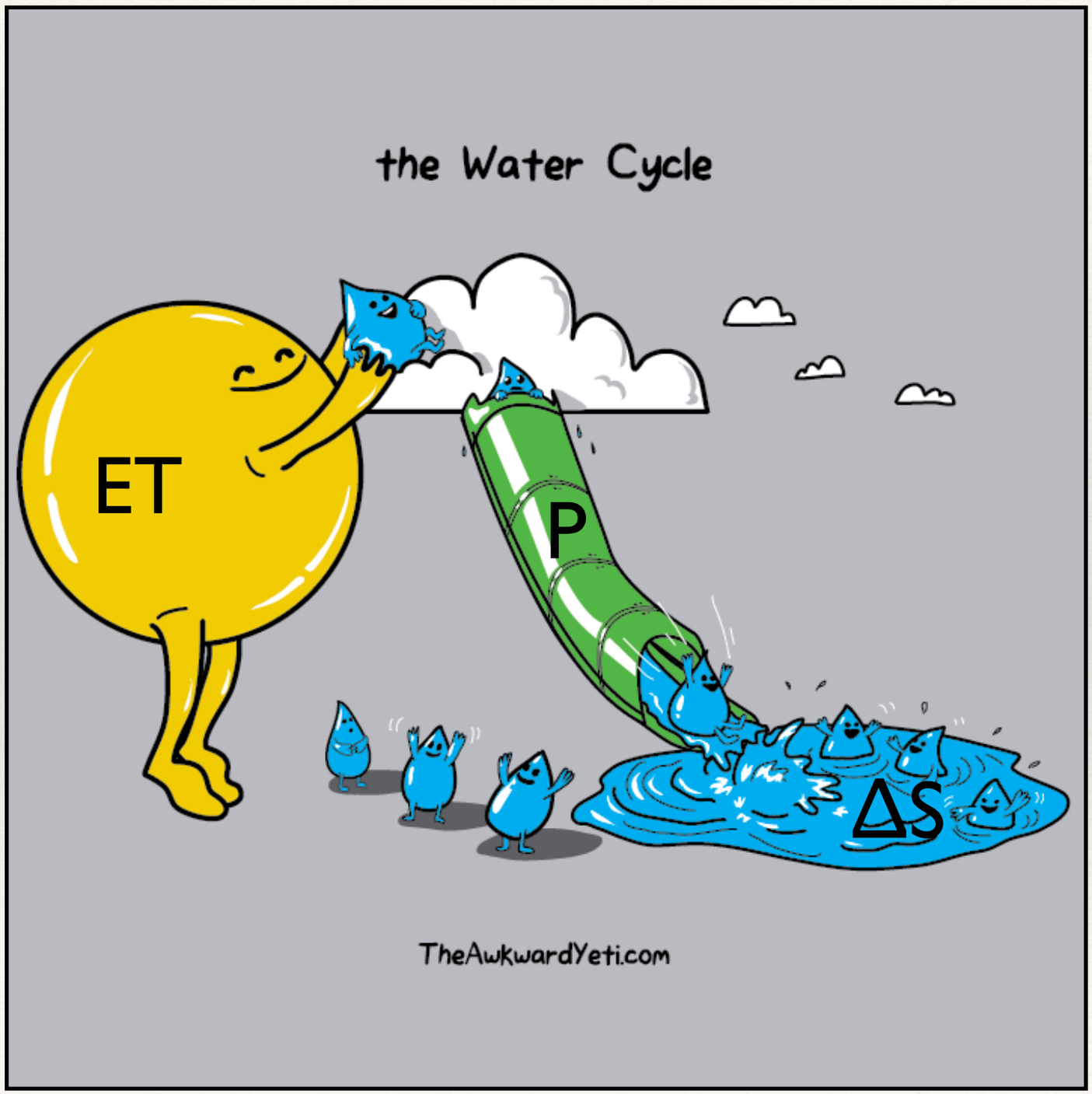
What is a model?

- Scientific modeling is a scientific activity, the aim of which is to make a particular part or feature of the world easier to understand, define, quantify, visualize, or simulate. (en.wilkipedia.org/wiki/Scientific_modelling)
- Models of theory (process, physically based)
- Models of data (derived from observations, statistics)

This is a model



Mathematical Representation of this model



Precipitation = Evapotranspiration + Change in Storage

$$P = ET + \Delta S$$

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

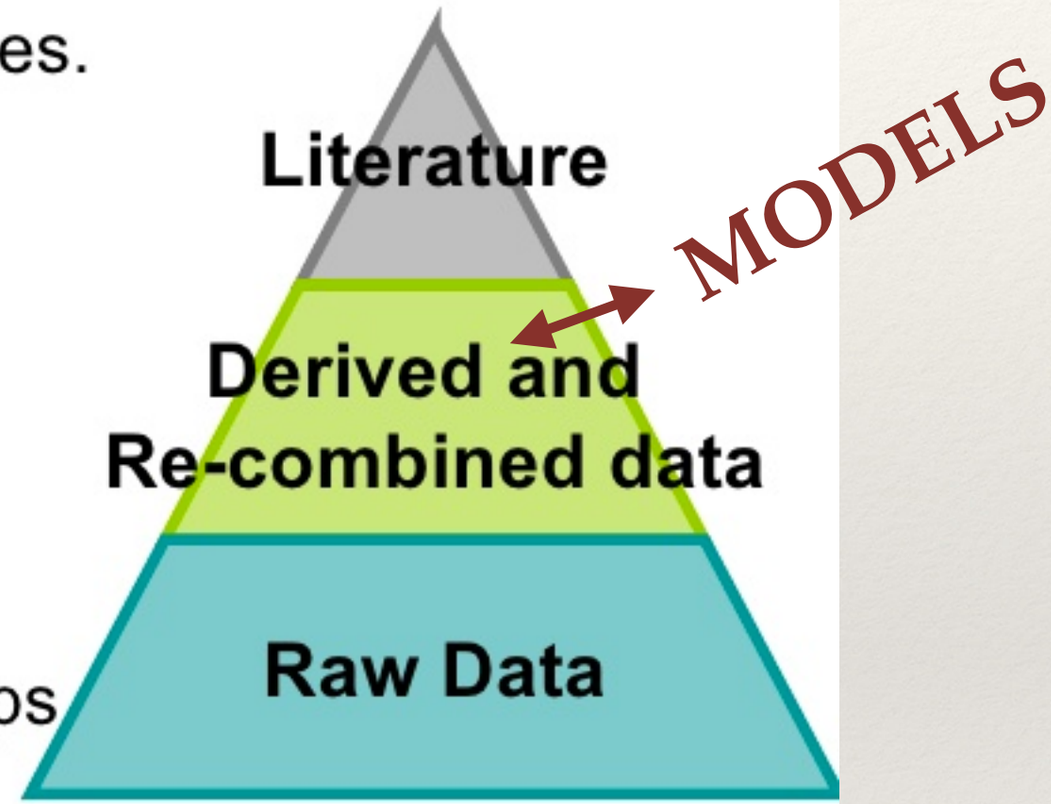
Water balance can tell you a lot

What are models?

- A set of ideas that describe a process/phenomena
- A simplified representation of some aspect of the world
  - Uses
    - understanding a pattern, process, phenomena in the world - especially when there are many interacting elements/controls on this phenomena
    - estimation of what might happen to a phenomena in the future (or if something changes) “what if” scenarios

Fourth Paradigm of Science

- Many disciplines overlap and use data from other sciences.
- Internet can unify all literature and data
- Go from literature to computation to data back to literature.
- Information at your fingertips For everyone-everywhere
- Increase Scientific Information Velocity
- Huge increase in Science Productivity



Jim Gray (eScience: A Transformed Scientific Method)

Pollution abatement

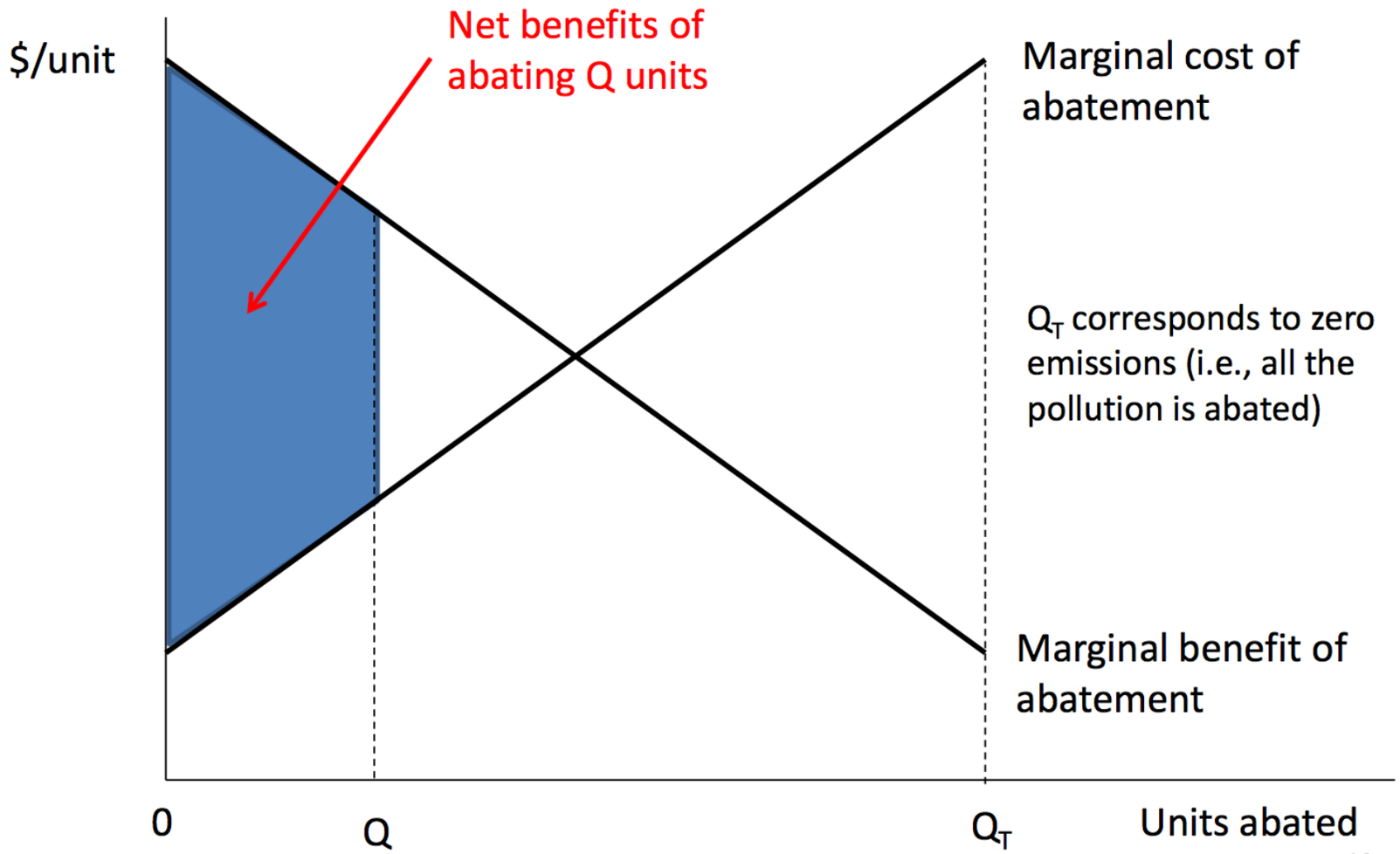
- Pollution abatement – reductions in the emissions of a pollutant
- Marginal cost of abatement – the costs of eliminating another unit of emissions
- Marginal benefit of abatement – the benefits of eliminating another unit of emissions

- Three stages of pollution abatement
  - end-of-pipe treatment
  - changes in production processes
  - reductions in output

Models for understanding (understanding why there are tradeoffs)

How to think about why there might be different strategies for abatement (where? when?)

Net benefits of pollution abatement



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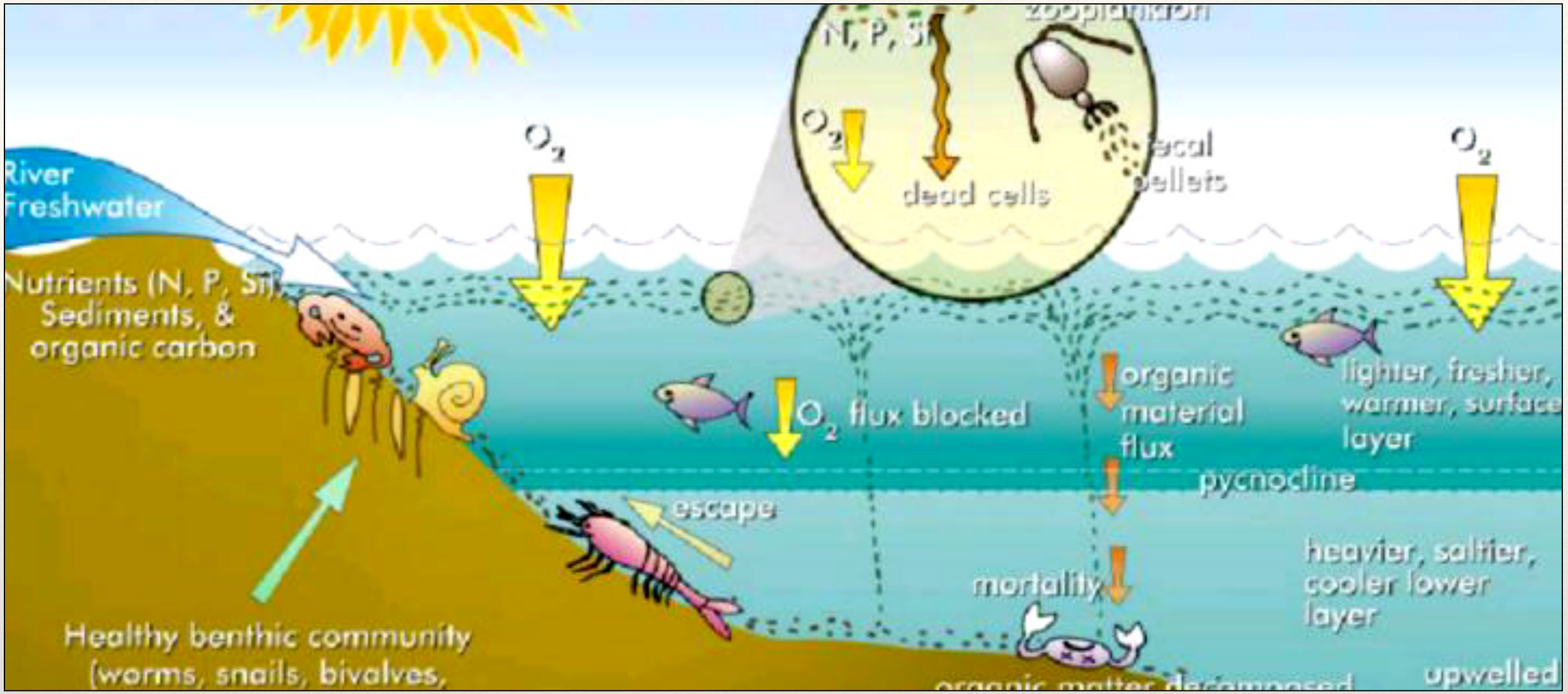
Models for understanding (understanding why there are tradeoffs)

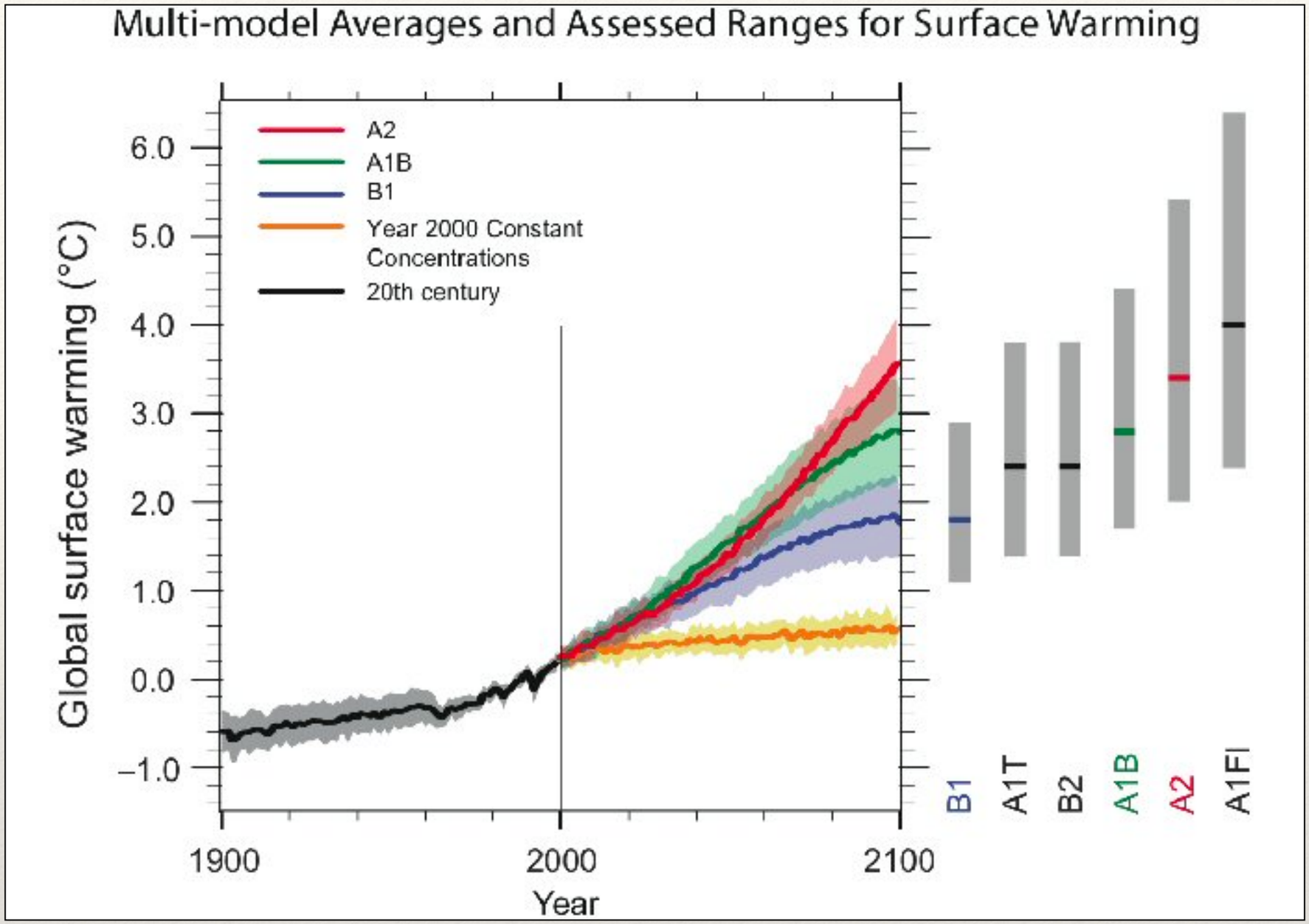
Why there might be an "optimal" choice for amount of pollutant abatement



US EPAL http://www.newworldencyclopedia.org/entry/File:Eutrophication.jpg

Models for understanding (big #'s, little #'s as controls on phenomena)

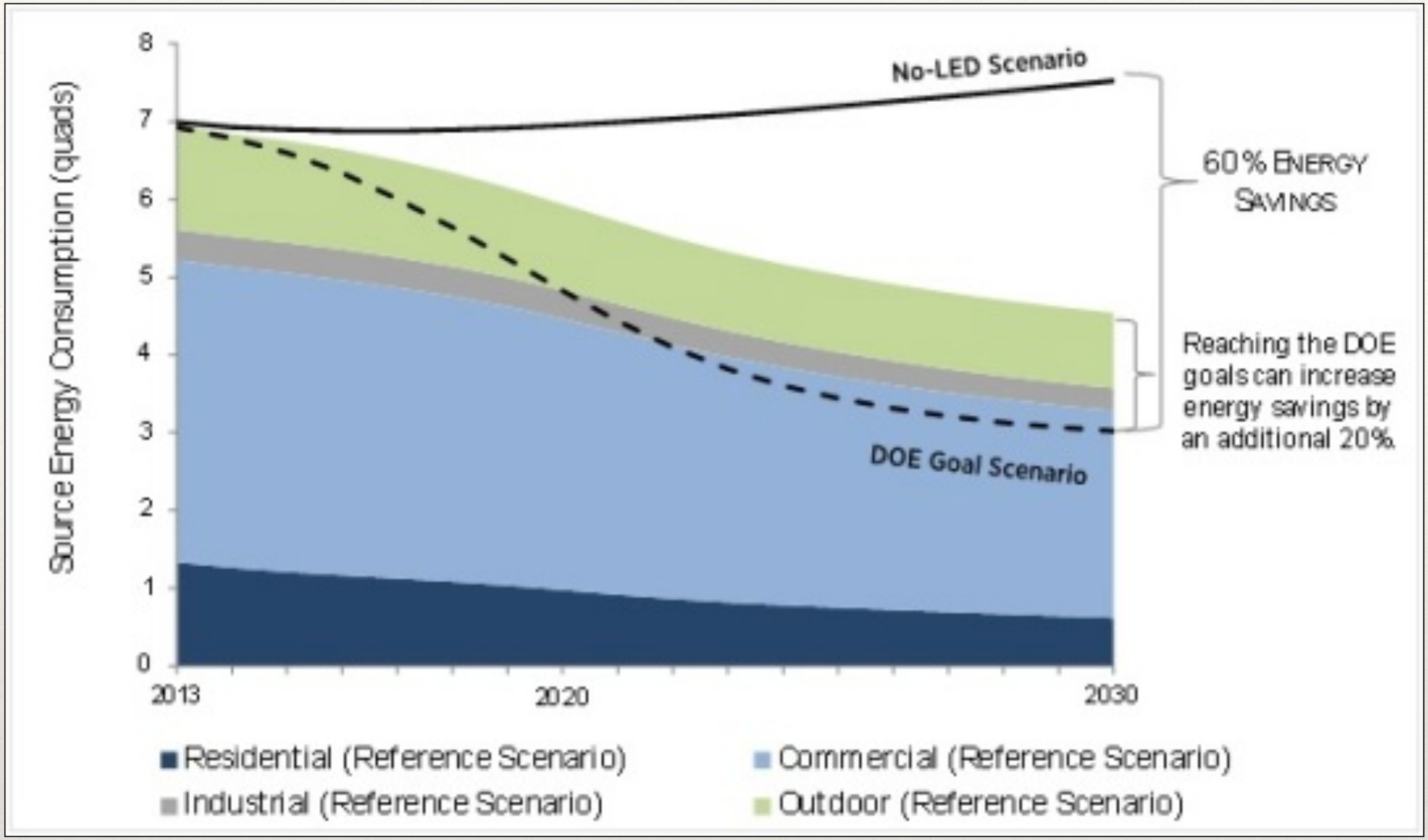
In a particular place (Baltimore Harbor), would temperature often be a limiting factor in eutrophication?
(so at what times of year, would N-export matter less?)



http://narccap.ucar.edu/about/figures/IPCCProjections.jpg

Models for estimation and what if scenarios

Estimate of global temperatures over the next 100 years



http://www.lightnowblog.com/2014/10/forecasted-energy-savings-from-led-lighting/

Models for estimation

Estimate of energy savings from LED adoption

GOALs: Modeling for Problem Solving in Environmental Science

- There is something you need to know in order to solve the problem
  - Answer to a question -
    what if?
    how much?
    which alternative?
  - Test of a hypothesis
- **Start by clearly defining what that question is!!**
- Examples?

Modeling for Problem Solving in Environmental Science

- Models for communication
- Similar to question driven - now what specifically do you want the model to communicate/illustrate?
- Examples?

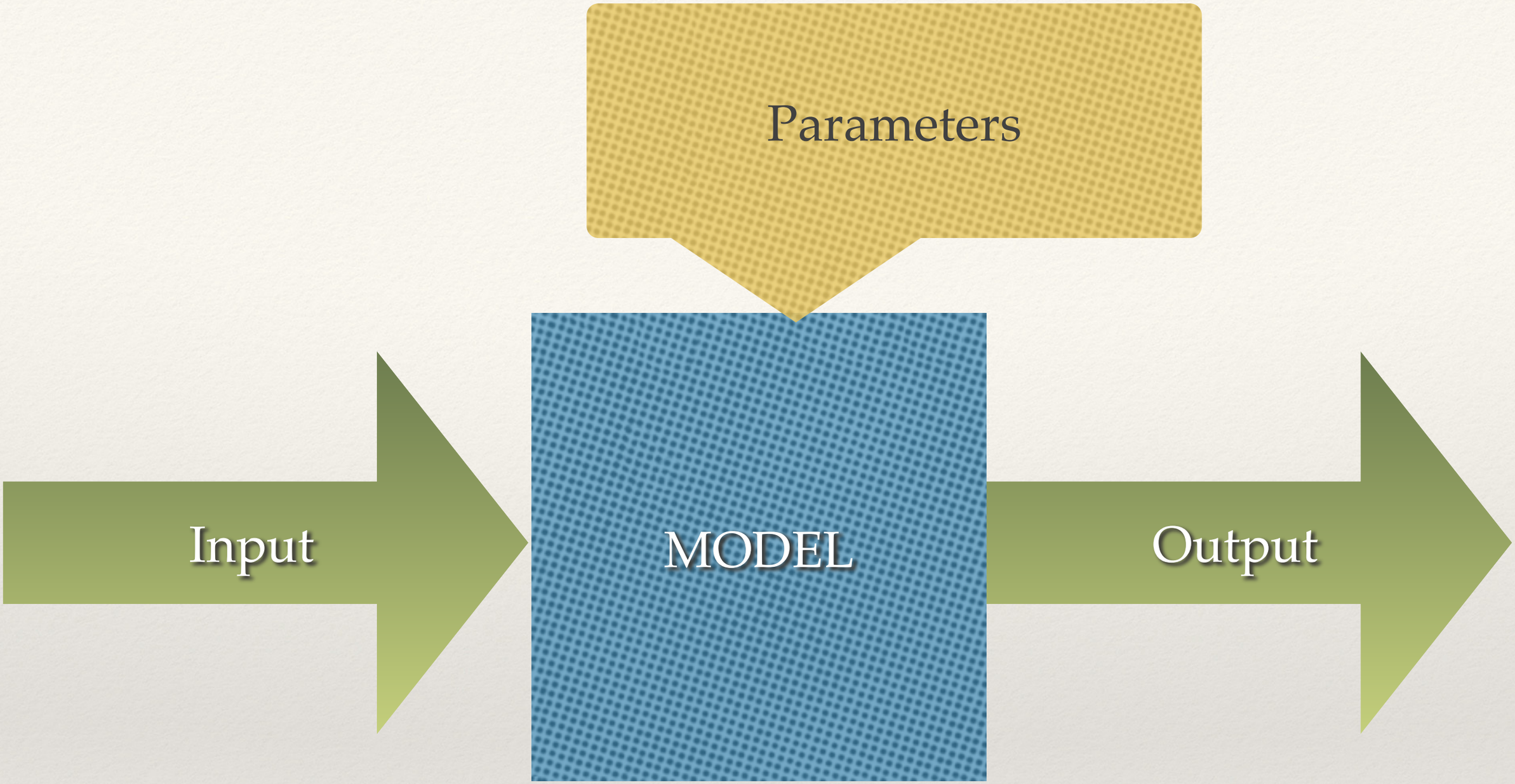
https://phet.colorado.edu/sims/cheerpj/glaciers/latest/glaciers.html?simulation=glaciers

Example:Glaciers

Goal: Help public understand why, even if temperature warms - glaciers might grow (due to increasing snowfall) - but a threshold temperature might be reached where glacier will shrink

Model Goals

- *Understanding* (how does something work, what are key drivers of responses, how do different drivers interact)
- *Estimation/Scenario* (what might be the consequences of decisions we make about the environment)
- *Communication* - contribute to education and broader understanding



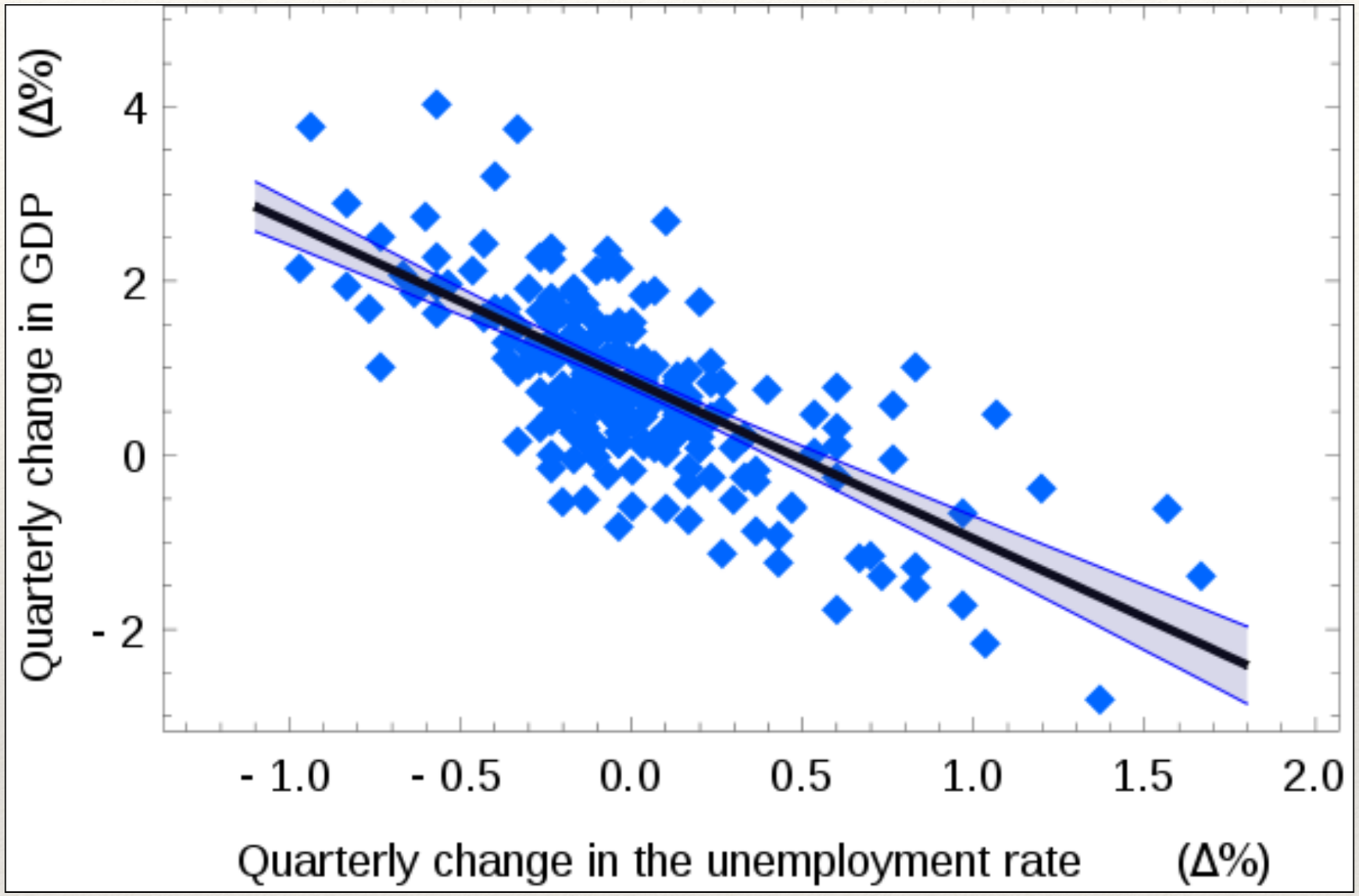
Basic components of models

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.



Simple model

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

STEPS: Modeling for Problem Solving in ES

1. **Clearly define your goal (a 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

Goals

- The goal will help you to define the core pieces of a model
- Often helpful to start at the end: Outputs
- Example:
  - Problem: which piece of land should be purchased to maximize biodiversity?
  - Outputs
    - monetary costs and benefits of different options in 2015 dollars, including “non-market” benefits

Goals

- The goal will help you to define the core pieces of a model
- Often helpful to start at the end: Outputs
- Example
  - Problem: how will forest carbon sequestration change if fire frequency increases with warming
  - Outputs
    - carbon sequestration for different fire frequencies

Exercise

- In groups, brainstorm about models that you are familiar with (or could imagine!); provide an example of
  - a model for estimation
  - a model for communication
  - a model for understanding
- For each one -
  - Briefly describe a goal for the model - be as specific as you can
  - Add your description to the gauchospace forum - *model examples*