How do people deal with uncertainty in models?

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Advanced Water Education Workshop:
Using Models to Simplify the Complex Interactions of Water in the Valley
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educators at all levels recognize the need to teach students to understand complex systems that are interactive, dynamic and hierarchical.
models are increasingly used to represent, understand, and communicate complex systems
models are recognized as an integral tool for understanding complex systems – such as the water and climate systems – and for education and decision making
http://www.cmmap.org/learn/modeling/whatIs2.html
The Very, Very Simple Climate Model Activity

http://spark.ucar.edu/activity/very-very-simple-climate-model-activity
efforts to enhance the contributions of water and climate models to decision making, however, have met with mixed success
Essentially, all models are wrong, but some are useful.

- George E. P. Box
one major challenge stems from differences in how scientists and decision makers understand, communicate and visualize uncertainty.
Uncertainty (Pielke, 2007)

• In a particular situation more than one outcome is consistent with our expectations
  – Ignorance - We simply do not know – is fundamentally irreducible
  – Risk – We know the probability distributions of possible outcomes – is quantifiable

• Objective uncertainty – complete and accurate characterizations of the entire set of outcomes associated with a particular set of expectations

• Subjective uncertainty – our judgments about how to characterize the entire set of outcomes

• In almost all situations outside closed systems, science is limited to providing a rigorous, formalized expression of subjective uncertainties
**FIGURE 2**

Historical Supply and Use\(^1\) and Projected Future Colorado River Basin Water Supply and Demand\(^1\)

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\(^1\) Water use and demand include Mexico’s allotment and losses such as those due to reservoir evaporation, native vegetation, and operational inefficiencies.

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Scenario Analysis

% Annual Demand (regional) Met by Groundwater

Scenario: Strong Groundwater and Demand Management

Scenario: Water Infrastructure for Megapolitan Development

Total Riverine Flows
Colorado and Salt-Verde (maf a⁻¹)

Simulation Year

Simulation Year
Case Example: Phoenix, Arizona

Scenario: Strong Groundwater and Demand Management

Scenario: Water Infrastructure for Megapolitan Development
scientists tend to frame uncertainty in probabilistic terms and communicate uncertainty through statistical methods
whereas decision makers may also frame uncertainty in political terms based on perceived costs of being wrong
while uncertainty is being reduced in some climate science domains, uncertainty is increasing in other areas
“The uncertainty in AR5’s climate predictions and projections will be much greater than in previous IPCC reports…”
in addition to scientific uncertainty, decision makers must incorporate social, political and economic uncertainties
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we need to help students to learn to frame, describe, and represent uncertainty
Techniques for Visualizing Uncertainty

• Use multiple formats, because no single representation suits all members of an audience.

• Illuminate graphics with words and numbers.

• Helpful narrative labels are important. Compare magnitudes through tick marks.

• Use narratives, images, and metaphors that are sufficiently vivid to gain and retain attention, but which do not arouse undue emotion.

Techniques for Visualizing Uncertainty

• Interactivity and animations provide opportunities for adapting graphics to user needs and capabilities.

• Avoid chart junk, such as three-dimensional bar charts, and obvious manipulation through misleading use of area to represent magnitude.

• Most important, assess the needs of the audience, experiment, and test and iterate toward a final design.

Fig. 3 Visualizations of probabilities for discrete events.

- **A**
  - Leicester v. C. Palace
  - POS: 10th LEI, 21st CPA
  - Probabilities: 2-6 (1.4%), 3-5 (1.8%), 4-4 (2.0%), 5-3 (2.0%), 6-2 (1.4%), 7-1 (1.4%), 8-0 (1.4%), 9-2 (1.4%), 10-1 (1.4%), Draw (22%)

- **B**
  - Results: Prostate cancer
  - Compared to a typical man your age, your risk is below average

- **C**
  - Decision: No Additional Therapy
    - Green: 78 out of 100 people are alive in 5 years.
    - Red: 12 out of 100 people die because of cancer.
    - Blue: 10 out of 100 people die of other causes.

- **D**
  - Decision: Chemotherapy
    - Green: 78 out of 100 people are alive in 5 years. Plus...
    - Yellow: 5 out of 100 people are alive because of therapy.
    - Red: 7 out of 100 people die because of cancer.
    - Blue: 10 out of 100 people die of other causes.

- **Spiegelhalter et al. Science 2011;333:1393-1400**
Fig. 4 Visualizations of the predictive accuracy of a screening test.

D Spiegelhalter et al. Science 2011;333:1393-1400
Fig. 5 Visualizations of probability distributions for continuous quantities.
“...deeper uncertainties do not readily translate into visualizations. In fact, the more attractive a depiction is made, the more people may believe it represents the whole truth rather than being a construction of limited knowledge and judgment. So perhaps the greatest challenge is to make a visualization that is attractive and informative, and yet conveys its own contingency and limitations.”

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