The Contextual Importance of Uncertainty in Climate-Sensitive Decision-Making

Toward an Integrative Decision-Centered Screening Tool

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Outline

- How do we find out when/which uncertainties matter to decision-making?
- Decision Uncertainty Screening Tool (DUST)
- Test case: Adaptation to impacts of climate change on the coast [of a Really Great Lake]
- Implications
- Benefits of DUST
Goals

- Create better links between uncertainty analyses in weather forecasts, projections of climate variability and change, impact analyses, decision science, and “on-the-ground” decision-making.
- Develop a systematic approach to determining where and when uncertainties matter to decisions, and how best to assess them.
- Give scientists and decision-makers a better understanding of how (uncertain) science can most effectively support decision-making. “Science in service of society”
DUST – Decision Uncertainty Screening Tool

A stepwise, iterative process for matching (uncertain) science with decision needs

- Premises
  - place the decision-maker, decision process and context at center
  - credible, relevant, and accessible scientific information can be an important input into decision-making, but is surely not the only one
  - does not assume a particular normative approach to decision-making under uncertainty
  - does not favor a “top-down” or “bottom-up” approach to assessments

- Objectives
  - work for all kinds of weather and climate-sensitive decisions
  - applicable in a variety of decision-making contexts
  - work for a range of decision-makers
  - applicable at a variety of scales
Step 1: Identify the stage in the decision process where climate science could enter

- Stage of Decision-Making Process
- Nature of Science’s Influence

Source: Vogel, Moser, Kasperson and Dabelko, forthcoming in GEC
Step 2: Ensure that scientific input is truly useful

Source: Based on Jones et al. (1999)

Science-practice communication from the start!
Step 3: Identify the type of decision problem the decision-maker faces

**OPTIMIZATION** – What decision (i.e., what strategies or choices) will produce the desired outcome?

**EVALUATION** – What outcome does a given (set of) decision(s) produce?

[Hybrid: ROBUST ADAPTIVE PLANNING -- Which management strategies avoid major system failures, breakdowns, or surprises?]

<table>
<thead>
<tr>
<th>Optimization</th>
<th>Evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>$O_c (+E) \Rightarrow C_a f(P, X)$?</td>
<td>$C_a \Rightarrow O_c (+E) f(P, X)$?</td>
</tr>
</tbody>
</table>

Key:
- O: Outcome / Objectives
- c: Criteria that would satisfy the outcome
- C: Choice Set / Management Options
- a: Attributes that describe the choices
- P: Present Conditions / State Variables
- X: Decision Constraints
- E: Externalities
Step 4: Identify the specific decision challenge

A three-dimensional typology of climate-sensitive decisions
### Step 5: Identify necessary uncertainty analyses

<table>
<thead>
<tr>
<th>Type of decision</th>
<th>Policy/decision analyses</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>One-time, near-term optimization</td>
<td>Optimization with resolved (known) uncertainty</td>
<td>Special case of stochastic dynamic optimization</td>
</tr>
<tr>
<td>One-time, long-term optimization</td>
<td>Finite-horizon, stochastic optimization</td>
<td></td>
</tr>
<tr>
<td>Sequential, near-term optimization</td>
<td>Infinite-horizon (dynamic) stochastic optimization</td>
<td>May be conceptually too demanding</td>
</tr>
<tr>
<td>Sequential, long-term optimization</td>
<td>Infinite horizon (dynamic) stochastic optimization</td>
<td>Computationally quite demanding</td>
</tr>
<tr>
<td>One-time, near-term evaluation</td>
<td>Single-period/multi-policies decision analysis, single-policy unc. analysis</td>
<td></td>
</tr>
<tr>
<td>One-time, long-term evaluation</td>
<td>Single-period/multi-policies decision analysis, single-policy unc. analysis</td>
<td></td>
</tr>
<tr>
<td>Sequential, near-term evaluation</td>
<td>Multi-period decision analysis</td>
<td></td>
</tr>
<tr>
<td>Sequential, long-term evaluation</td>
<td>Multi-period decision analysis</td>
<td></td>
</tr>
</tbody>
</table>

Source: Based on Kann and Weyant (2000); Morgan and Henrion (1990)
Step 6: Conduct identified uncertainty analyses

<table>
<thead>
<tr>
<th>Types of analysis</th>
<th>What can be learned</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exploratory modeling/Computer-assisted reasoning</td>
<td>Reveals model-based uncertainties and unknowns, used to explore plausible futures where little is known about them</td>
</tr>
<tr>
<td>Multi-model comparison</td>
<td>Reveals model-based uncertainties; important when model structures are less well known</td>
</tr>
<tr>
<td>Sensitivity analysis</td>
<td>Reveals the impact of varying model inputs (through single or joint variation); important when model structure is well known</td>
</tr>
<tr>
<td>Multi-scenario comparison</td>
<td>Reveals the impacts of different assumptions about the world (can be understood as a subset of the sensitivity analysis)</td>
</tr>
<tr>
<td>Propagation of uncertainty in input variables through deterministic (or stochastic) modeling</td>
<td>Reveals the spread (frequency and/or probability) of outcomes due to this uncertainty in the input variable</td>
</tr>
<tr>
<td>Value of Information, Value of Uncertainty techniques</td>
<td>Reveals the impact of having perfect knowledge or having knowledge about uncertainty on a specified outcome</td>
</tr>
<tr>
<td>Model validation/comparsion against empirical data or analogues in time or space</td>
<td>Suggests a level of confidence one can have in model results</td>
</tr>
</tbody>
</table>
Step 7: Communicate uncertainties back to the decision-maker

- Familiarity
- Format
- Link back to decision problem
  * Impact of uncertainties?
  * Explanation of uncertainties
- Mindful of how people process uncertain information
Communicating Climate Change

Key challenges and strategies for effective communication of climate change:


http://www.isse.ucar.edu/communication/
A test case: information needs of California coastal managers

- Projected impacts from climate change
  - Sea-level rise 11–72 cm (4.3–28 in)
  - Changing coastal storms
  - Increasing coastal erosion, flooding, cliff retreat
  - Changing rainfall and runoff patterns into the coastal ocean
  - Increases in coastal/stream water temperatures
  - Species and habitat shifts (e.g., wetland squeeze)

Source: California Climate Change Center (2006)
Data Sources

- Interviews with 18 state, regional, and federal coastal managers
- Comprehensive mail survey of 299 municipal and county coastal managers
  - 18-page, pre-tested survey
  - 46.1% overall response rate, 135 useable responses
  - answers from 89% of cities, 89% of counties

Key questions asked:
- Current coastal management challenges
- Attitudes and knowledge about global warming
- Expected impacts of GW
- Efforts to deal with impacts of GW
- Information use and needs
- Background on state, municipality, county, respondent
Step 1: Identify the stage in the decision process where climate science could enter.

Source: Vogel, Moser, Kasperson and Dabelko, forthcoming in GEC
Step 1 (cont.) : Knowledge about climate change and impacts

<table>
<thead>
<tr>
<th>Expected impacts</th>
<th>% moderate to high likelihood</th>
</tr>
</thead>
<tbody>
<tr>
<td>rainfall pattern changes</td>
<td>93.8%</td>
</tr>
<tr>
<td>higher rate of sea-level rise</td>
<td>89.4%</td>
</tr>
<tr>
<td>more algae blooms</td>
<td>87.9%</td>
</tr>
<tr>
<td>more frequent storms</td>
<td>84.8%</td>
</tr>
<tr>
<td>water quality changes</td>
<td>84.4%</td>
</tr>
<tr>
<td>sea temperature increases</td>
<td>84.4%</td>
</tr>
<tr>
<td>more flooding</td>
<td>82.2%</td>
</tr>
<tr>
<td>air temperature increases</td>
<td>82.0%</td>
</tr>
<tr>
<td>marine life impacts</td>
<td>81.7%</td>
</tr>
<tr>
<td>spawning time changes</td>
<td>79.8%</td>
</tr>
<tr>
<td>less flooding unlikely</td>
<td>76.0%</td>
</tr>
<tr>
<td>runoff pattern changes</td>
<td>74.0%</td>
</tr>
<tr>
<td>less frequent storms unlikely</td>
<td>71.7%</td>
</tr>
<tr>
<td>stream temperature increases</td>
<td>67.7%</td>
</tr>
<tr>
<td>other</td>
<td>5.6%</td>
</tr>
</tbody>
</table>

How well informed do you feel you are about global warming?
- 12% Not well informed
- 18.8% Well informed
- 0.8% Don't know
- 68.4% Moderately informed
Step 2: What scientific input would be truly useful?

Information Types (ranked in order of usefulness) to Coastal Managers

- Information on how to assess the vulnerability of community's coastal resources.
- Specific projections of climate changes, such as changes in rainfall, temperatures, sea level, etc.
- Weather and/or seasonal climate forecast
- Climate projections for the next few years

Percent:
- Very useful
- Fairly useful
- Not very useful
- Not at all useful
But just in case: Information Needs Regarding Uncertainty

- Uncertainty ranges around climate change impact projections to indicate scientific confidence
- Well founded distinctions between more and less likely impacts (e.g., “at-least” sea-level rise vs. “maybe-as-much-as” sea-level rise)
- Explanation of reasons for uncertainty
- Scientific basis for uncertainty buffers (e.g., additional setbacks, extra capacity for storm water runoff)
More than “just” information

Desirable opportunities to learn more

<table>
<thead>
<tr>
<th></th>
<th>hands-on training</th>
<th>user manuals</th>
<th>conferences</th>
<th>better college edu.</th>
<th>web clearing-house</th>
<th>dedicated listserves</th>
<th>in-house sharing</th>
</tr>
</thead>
<tbody>
<tr>
<td>very useful</td>
<td>47.2%</td>
<td>45.1%</td>
<td>40.7%</td>
<td>43.9%</td>
<td>47.2%</td>
<td>33.6%</td>
<td>29.5%</td>
</tr>
<tr>
<td>extremely useful</td>
<td>24.4%</td>
<td>13.9%</td>
<td>13.8%</td>
<td>9.8%</td>
<td>18.7%</td>
<td>15.6%</td>
<td>10.7%</td>
</tr>
<tr>
<td>Total</td>
<td><strong>71.6%</strong></td>
<td><strong>59.0%</strong></td>
<td><strong>54.5%</strong></td>
<td><strong>53.7%</strong></td>
<td><strong>65.9%</strong></td>
<td><strong>49.2%</strong></td>
<td><strong>40.2%</strong></td>
</tr>
</tbody>
</table>

Important capacity building opportunities
Step 2 (cont.) : Translation of climate change into actionable information

<table>
<thead>
<tr>
<th>From</th>
<th>To</th>
</tr>
</thead>
<tbody>
<tr>
<td>Projected sea-level rise, changes in coastal ocean, storm frequency, and wave climate</td>
<td>Shoreline retreat rates, increases in coastal erosion or bluff retreat over various planning- or project-relevant time horizons (5, 10, 20, 50, 75 years)</td>
</tr>
<tr>
<td>More reliable forecasting of El Niño events, and any changes in the frequency or severity of such events</td>
<td>Impacts on shoreline retreat rates</td>
</tr>
<tr>
<td>Different SLR scenarios</td>
<td>Remapping of flood zones under these different scenarios</td>
</tr>
<tr>
<td>Potential changes in runoff, pollution load, salinity, and near-shore coastal and estuarine water temperatures</td>
<td>Implications of such changes for water quality, water availability, aquatic ecology, and endangered/protected species</td>
</tr>
</tbody>
</table>
What actions are CA coastal managers taking to prepare for CC impacts?

- Only 2 counties and 1 city have plans in place that consider the impacts of climate change; none consider coastal impacts
  - San Luis Obispo Co.
  - Sonoma Co.
  - Berkeley

- 6 cities and 4 counties are currently preparing such plans, some (*) consider coastal impacts
  - Solana Beach*
  - Goleta*
  - Palo Alto
  - San Francisco*
  - Alameda
  - Arcata*
  - Contra Costa Co.*
  - Sonoma Co.* (new, update?)
  - Marin Co.*
  - Humboldt Co.*

- 72.4% of respondents said they had no plans (sometimes contrary to fact)

- 18.9% of respondents didn’t know
Why coastal managers don’t plan for climate change (yet)

Perceived Hurdles to Local Action on Global Warming Impacts

- Monetary constraints
- Insufficient staff resources
- Lack of funding from state/feds
- Currently pressing issues all-consuming
- Insufficient staff time
- No legal mandate
- Lack of perceived importance
- Lack of perceived solution options
- Lack of public awareness/demand
- Lack of technical assistance from state/feds
- Lack of social acceptability
- Science is too uncertain
- Legal pressures to maintain status quo
- Opposition from stakeholder groups

Hurdles

Percent

Big hurdle  Small hurdle  Not a hurdle
Step 3: Identify the type of decision problem the decision-maker faces

- Should we start thinking about it at all or not? (in a sense an “evaluation” decision)

- What is most vulnerable? (vulnerability assessment)

- What are our response options? (an “evaluation” decision; some one-time, some sequential, many long-term)
Implications

- Skip Steps 4-6 of DUST!
- Instead:
  - effectively communicate what is already known
  - advance understanding of vulnerabilities and risks
  - create information need for potential impacts and response options

>> move the decision process forward
- Eventually, more sophisticated analyses may be required
Summary of case findings

- Depending on the stage of the issue and the decision process
  - Scientific information may not matter
  - Uncertainty in that information may not matter

- Science in the service of societal decision-making may need fewer “bells and whistles” and more people doing the “on-the-ground” leg work

- Scientific uncertainty is rarely an obstacle to decision-making, not perceived as a major hurdle to preparing for climate change impacts

- Greater need to remove other barriers (lack of $, staff, time, legal mandate, institutional hurdles, political disinterest or opposition)
Conclusions

- DUST needs further testing “in the real world”; if it proves useful, it could:
  - Streamline and prioritize uncertainty analyses
  - Greater transparency and awareness of climate science, regional projections
  - Educational for scientists about decision needs
  - Educational for decision-makers of state of knowledge, process of doing science

- To increase the chance that (uncertain) science informs decision-making, we need
  - Better, ongoing scientist-practitioner relationships
  - Better mutual understanding of capabilities and needs
  - Incentives for both to work together

- Let’s stop assuming (uncertain) science matters to decision-making. Let’s find out!
Acknowledgements

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