

Decision Support and THORPEX

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Theme 4: Decision Support and THORPEX

1. Introduction

“THORPEX is an international research programme to accelerate improvements in the accuracy of 1-day to 2-week high-impact weather forecasts. These improvements will lead to substantial benefits for humanity, as we respond to the weather related challenges of the 21st century” (Shapiro and Thorpe, 2004). As this statement from the THORPEX International Science Plan suggests, the success of THORPEX and that of many other atmospheric research and development programs ultimately depend on the ability of new data, information, understanding and knowledge to affect changes in the way society—its individuals, enterprises, and institutions—manages its affairs.

For all the past improvements in weather forecasting, achieved through the development of numerical modeling and investments in global observations, telecommunications, science, and forecaster training, as acknowledged in Shapiro and Thorpe (2004) and elsewhere, one is left wondering whether a concomitant degree of value has been imprinted on society. This may be because, until recently, the societal and economic value and use of weather information have been understudied, rarely measured, or simply “assumed to exist” by those purportedly funding or conducting societal problem-oriented atmospheric research. In this regard, the concept of actually considering societal and economic research and applications (henceforth referred to as SERA) in the early stages of a large atmospheric science program is a credit to those who have conceived THORPEX. As the saying goes, however, the proof will be in the pudding.

Although few in number, many of those who have examined applications and benefits observe that decision makers underuse weather and climate information, including forecasts (Stewart, 1997; Hansen, 2002; Pielke and Carbone, 2002; Stewart et al., 2004; Changnon, 2005; O'Connor et al., 2005; Rayner et al., 2005). Much remains to be done to realize this latent potential let alone capitalize on future improvements in weather forecasts that may result from programs such as THORPEX. This presents a clear challenge for the SERA community and one that relates directly to the role of decision support (DS), the subject of this paper.

This paper briefly introduces and defines the concept of DS and, within the context of weather information, probes a few of the issues related to its effectiveness. Challenges for THORPEX and the potential role of SERA activities are noted in a series of questions in the closing discussion section.

2. Decision support systems and decision support

In many cases, weather- or climate-related applications are not labeled or self-described as formal decision support systems (DSSs) but rather focus on an element of a DSS (e.g., value of information model) or decision-making process. This distinction is consistent with a broader interpretation of DS that is adopted for this paper and recommended for THORPEX—one that includes formal DSSs as well as less formal processes, mechanisms, and heuristics that also serve to integrate multiple sources and forms of information toward the solution of a weather or climate-related problem for a given user. The user might be an agency, business, organization, group, or individual. This expanded notion of DS as essentially any form of decision aid has also been acknowledged in other fields, including agricultural and rural resource management (e.g., Walker, 2002).

Weather-related applications of DSSs are most prominent in the meteorological forecast community itself with very sophisticated tools in place to assist weather forecasters (e.g., Joe et al., 2004; Jacobs and Maat, 2005). Further down the user chain, weather-related applications and analyses of DSSs are most common in agriculture (e.g., Ziervogel, 2004) and water management (e.g., Levy et al., 2005; Rayner et al., 2005). Studies have also been conducted for energy (e.g., Roulston et al., 2003; McSharry et al., 2005), transportation (e.g., Kuchar et al., 2002; Mahoney et al., 2005; Pisano et al., 2005), natural hazard management (e.g., avalanche risk—Roeger et al., 2004; forest fires—Lee et al., 2002; warning systems—Sorensen, 2000), health (e.g., UK Met Office, 2002; Sheridan and Kalkstein, 2004), and tourism and recreation (e.g., Johnson et al., 2000).

Formal definitions of DSSs are firmly rooted in the theories, concepts, and discourse of the information technology, management, and organizational behavior sciences.[†] A DSS typically consists of a computer-based platform that is used to integrate problem-relevant data and analytical modeling/simulation programs to help decision makers structure a problem and objectively identify and evaluate a series of decision alternatives (Eierman et al., 1995; Reich and Kapeliuk, 2005). In addition to permitting the rapid manipulation, retrieval, organization, and storage of data, advances in computer technology over the past decade have facilitated the development of more sophisticated interactive user interfaces and decision analysis tools and thus the treatment of more complex problems.

[†]Example journals include *Decision Support Systems*; *International Journal of Information Management*; *International Journal of Forecasting*; *Information Technology and People*; *Organizational Behaviour*, and *Human Decision Processes*.

In proposing the working elements of a theory of DSSs, Eierman et al. (1995) present a useful series of constructs or foci for the somewhat disparate efforts within DSS research:

- Environment or contextual setting that influences users and developers (e.g., organizational culture, goals, stability, resources, constraints)
- Task (i.e., specific work to be accomplished through DSSs)
- Implementation strategy or method of integrating DSSs into the work environment (e.g., lifecycle approach)
- DSS capabilities (e.g., accuracy, timeliness, representation form)
- DSS configuration (hardware, software)
- User (e.g., level of task/technology expertise, expectations, mental models)
- User behavior (i.e., various approaches to complete tasks)
- Performance (i.e., evaluation of outcomes generated in terms of quality or effectiveness, user satisfaction and confidence, economic value, efficiency).

Breakdowns or limitations for any of these DSS elements may explain in part the limited uptake or incorporation of DSSs and why DSSs sometimes fail to meet user expectations, as noted generally in the broader DSS and information technology literature (Cox, 1996; Walker, 2002; Reich and Kapeliuk, 2005).

3. Elements of successful decision support

What are the qualities of good DS? Ultimately this is a question for the intended user; the literature, however, points to a few key issues that influence effectiveness. Beyond the technical elements (DSS configuration, DSS capabilities), the foci listed previously (Eierman et al., 1995) boil down to three essential considerations that this author interprets as being fundamental in developing successful DS:

- A need for well-defined problems, user-needs and decision-making context
- Matching methods and underlying paradigms with user needs
- Engagement of users and their constituents.

a. Well-defined problems, user needs, and decision-making context

While seemingly obvious, it is critical to consider in depth the nature of the problems and objectives for which the decision assistance is being developed. Others may refer to these as user needs (e.g., Stewart et al., 2004). With few exceptions (particularly where consideration of weather is regulated, e.g., aviation safety, emergency preparedness/evacuation), it can be safely assumed that most potential users of weather information are not “beating down the doors” of meteorologists, clambering for decision support. As such academic, government, or private sector researchers and service specialists developing pilot DS tools incorporate considerable interpretation of weather-related needs and underlying problems. Unfortunately, many DS “solutions” are conceived, funded, and developed without much thought of the specific problems facing the intended benefactor, sometimes referred to colloquially as “solutions looking for a problem” or “build it and they will come.”[‡]

Whether working with an eager user or exploring new weather-sensitive sectors, those involved in defining the problem in a decision-making context should elicit information concerning the following:

- Outcomes or consequences of concern to the user (e.g., safety of citizens, units of production, profitability) and associated measures (e.g., casualty rates, crop yields)
- Important relationships between weather, climate, and outcomes (i.e., source of key variables, transfer functions, or “events”)

[‡]This includes many weather or climate severity indices (e.g., Murdock et al., 2001).

- Responses or alternatives available for the user to manage risks or take advantage of opportunities (including characteristics of those responses, e.g., tactical, operational, or strategic; frequency; duration; flexibility)
- Role of weather or climate information in current or potential responses (i.e., how is it used; required levels of precision, accuracy, frequency)
- User values, beliefs, and worldviews
- Organizational, sociocultural, financial, technical, legal, and political factors in user environment that may constrain or facilitate adoption of response options.

Descriptive decision research (e.g., Stewart, 1997), surveys, or inventories of user needs (e.g., Ipsos-Reid Corporation, 2001a, 2001b; OFCM, 2002), hazard and risk assessment literature (e.g., Burton et al., 1993; Cutter, 1996; Mileti 1999), and weather- or climate-impact assessment studies (Kates et al., 1985) all serve as possible sources of information that will contribute to problem definition and assist with identifying the range of alternatives available to specific users to address the problems. For instance, hazards research has produced a number of general typologies of responses (or adjustments, adaptations) to a wide assortment of natural and human-induced risks (Burton et al., 1993). Looking at Figure 1, which shows a series of categories and subcategories of general responses, one can apply the example of an insurance broker who responds to the problem of excessive claims due to severe convective storms. The broker may invest in reinsurance policies (*share the loss*), reposition or call in extra claim agents (*prevent the effects, on-site operations/administrative*), conduct or commission research on historical claims (*research*), or contact key commercial or industrial clients to advise them of the risks and encourage adoption of exposure-reducing measures (*education, behavior*). Weather forecast and climate information at various temporal and spatial scales may influence the adoption and levels

of investment in these responses. Weather forecasts, including those considered within the 1–14 day realm of THORPEX, may contribute to only a portion of the total response of a given individual, business, agency, or organization. Often this information will be used as a formal or informal input into existing DS tools and will not be explicitly treated as a separate DS tool—another reason for understanding the broader response context of the user.

Scale is also an important consideration in establishing weather-outcome relationships relevant to user decisions. For example, causal mechanisms may be understood at a population, industry (sector), or regional level, but little analysis or documentation may exist at the individual or local scale to account for variability among user circumstances and exposures (Andrews et al., 2004). Goals and objectives at one level of decision-making may conflict with those of others or at different scales (e.g., farm-level decisions/improved efficiency can lead to overall greater yields and lower prices; individual resource conservation decisions vs. profitability of utility; developed–developing world contexts; reductions in use of road salt versus maintaining road safety). The fundamental interpretation of the problem may vary considerably between groups of users or even within the same organization, institution, or business (Pielke, 1997).

b. Matching methods and underlying paradigms with user needs

One of the more commonly cited reasons for the failure of DS and DSSs relates to a perceived “mismatch” between the needs of users and the paradigm from which DS developers select and apply models of decision-making behavior to evaluate and recommend options. The reductionist paradigm and prescriptive modeling approach that underlie most formal DSSs generally assume that problems of interest can be clearly defined and separated from other issues; decision-maker goals, values, and objectives, along with a complete range of alternative

solutions are known and can be ranked; consequences of each alternative can be determined, compared, and ranked; and based on the comparison, the decision maker will select the alternative that maximizes net expectations (Mitchell, 1989). In essence, decision making is modeled in an idealistic manner in which decision makers behave rationally.

Given the scientific roots of numerical weather prediction science, it is not surprising that a reductionist, normative paradigm is common in weather information-related DS applications (although often not acknowledged by developers as such). Implicitly this occurs wherever forecasters and developers provide information under the assumption that users will take full advantage of the attendant opportunities to reduce exposure to risks or maximize benefits. Explicitly, decision-analytic models in particular have been used to evaluate, optimize, and prescribe specific solutions to problems that are sensitive to weather information (see Theme 3 paper; Johnson and Holt, 1997). The strength of this normative approach is its ability to specify optimal, best-case decisions and, where outcomes are expressed in monetary terms, the relative value of a decision with and without the application of weather information of a certain quality (Wilks, 1997). Although such models can be adjusted to account for the risk aversion of decision makers (i.e., some degree of bounded rationality), they have been criticized for an inability to simulate real-world decision making (Stewart, 1997; Wilks, 1997; Rayner et al., 2005; Finucane and Holup, 2006). If users are similarly convinced, then the results from DS based on such methods become irrelevant and may not be considered, let alone adopted.

Alternative subjectivist paradigms and associated descriptive models or social constructs can also be used to explain patterns of decision making and judgment behavior (Stefanovic, 2003). Biographical, phenomenological, ethnographic, and descriptive studies are examples of qualitative approaches used by researchers in resource management or natural hazard fields

(Cresswell, 1998; Mitchell, 1989). Such methods often emphasize the role of “affectual” (i.e., emotional states/feelings), experiential, and situational factors that shape and influence judgments rather than the cognitive (i.e., analytic) aspects of information processing (Finucane and Holup, 2006). To the author’s knowledge, only descriptive decision studies have been employed to probe the value of weather information and thus offer contributions to DS. Stewart (1997) elaborates how anecdotal reports, case studies, user surveys, interviews, protocol analysis, and decision experiments have contributed to descriptive accounts of the weather forecast user. The strength of these approaches lies in their ability to account for and contextualize the subjectivity and complexity of real decisions and thus an understanding of the conditions and prerequisites of forecast use—they are unlikely, however, to provide quantified estimates of forecast value or, by implication, recommend an optimal solution.

Although admittedly this attempt to polarize paradigms and contrast methods is somewhat artificial (i.e., a continuum exists and there is substantial debate on the appropriateness of specific methods), the implicit paradigms (and values, beliefs, worldviews) of the DS developer and the user affect the choice of methods employed and the interpretation of results (Stefanovic, 2003). Different approaches seem to offer different advantages for users. Rational prescriptive methods seem more likely to be useful in situations where the weather information-sensitive decisions are more routine, operational, or tactical in nature, whereas subjective and descriptive approaches appear to be more suited to longer term strategic and policy-oriented decisions.

Some researchers noted the complementary nature of different approaches, for instance, descriptive and prescriptive decision studies (Stewart, 1997; Wilks, 1997), and it is worthy of further exploration within the context of DS. Similar suggestions have been made in other disciplines; for example, Finucane and Holup (2006) advocate a “risk-as-value” perspective that

combines analytic and affective evaluations rooted in psychological theories of cognition and emotion to assess perceived risk and develop new process models of judgment and decision-making.

Regardless of approach, the onus is on the investigator or developer to appreciate how their methods and approaches to DS are received and understood by users (Fischhoff, 1994). Although debate about the merits of particular methods can be constructive and should be encouraged, simply emphasizing the desirability for investigators to give a “clear description of their research problem and method of attack” would also be very useful (Mitchell, 1989, p. 43).

c. Engagement of users

The applied nature of DS necessitates some level of involvement from the user community. Not incorporating users in the DS development process increases the risk of giving irrelevant information, primarily through misinterpretation of user problems, needs, and decision-making context. Even DS based entirely on secondary data sources and normative or theoretical constructs must at some point be vetted, tested, and implemented by users if they are to achieve anything beyond academic value. At a minimum, exploiting the potential value as derived from prescriptive models requires regional information and user training (Kim and McCarl, 2005).

The climate adaptation community has given considerable attention to stakeholder engagement and participatory research methods (Dempsey and Fisher, 2005; Cohen et al., 2006), and these are no less important for weather information over shorter timescales. Although greater user participation and engagement should lead to higher rates of adoption and acceptance of specific recommendations from a particular DS tool, the most significant benefit is the facilitation of mutual learning on the part of users and researchers (Cox, 1996; Hansen, 2002;

Walker, 2002). In this sense, DS tools are simply a means to an end—that being the assimilation and adaptation of weather information, knowledge, or insight into a user’s “business-as-usual” practice (i.e., capacity building).

This process is continuous and iterative[§] because user needs are dynamic and, in addition to changing nonweather variables, likely to adjust as the potential utility of weather-related information is revealed through experience.^{**} Much more than developing and transferring a technology, full engagement in decision support demands the forming of a substantive relationship with the user. This is reflected in the long-term (>5 years) approaches characteristic of successful, in this author’s opinion, examples of decision support (e.g., heat-health watch warning system in Toronto, Smoyer-Tomic and Rainham, 2001; Maintenance Decision Support System, Mahoney et al., 2005, Pisano et al., 2005).

4. Directions and opportunities for THORPEX SERA

Several starting points for initial deliberation of THORPEX priorities related to decision support can be stated as questions. As with the previous discussion, this is not comprehensive.

- **Basic definitions:** What are appropriate working definitions of decision support and decision support systems for THORPEX, given its focus on 1–14 day forecasts?
- **Users:** Are there boundaries on the range or type of users that should be considered in THORPEX research and applications? Should it include reference to informal decision support at the individual citizen level or perhaps be restricted to large organizations?

[§]Morss et al. (2005) emphasize this in their description of an “end-to-end-to-end” approach to conducting interdisciplinary research with and for decision makers.

^{**}This is borne out in observations from Changnon (2004), who describes a series of projects designed to develop climate information products for 28 decision-making organizations and entities—more than half of the products were modified over time.

Given their role in transferring information and knowledge, should human forecasters be explicitly treated in THORPEX decision support efforts? Should and how might THORPEX take on an active role in capacity building, internationally and within North America?

- **Scope/project selection:** At the broader scale, how should THORPEX select case studies for pursuing decision support research and applications—should emphasis be placed on particular types of outcomes (e.g., health), risks/hazards (e.g., hurricanes, routine weather), or highly sensitive regions, populations, sectors? Given limited resources, there is a tendency to go where work has already been initiated and supported but greater benefit may result from targeting new users—if so, how should this be done?
- **Methods and approaches:** Should researchers representing a broad range of disciplines, approaches, and methods be encouraged to participate in THORPEX decision support activities? If so, how can this be facilitated over the next 10 years? Should a protocol, guide, or series of “better practices” for weather information DS be developed or abstracted from applications in other areas?
- **Interaction with other THORPEX activities:** Other working groups in THORPEX are developing new information products and approaches (i.e., through TIGGE, regional campaigns) and initial science and implementation plans committed the SERA working group to evaluate their value in supporting decisions. How might this be accomplished? Are there opportunities for joint research?
- **Specific resources and products:** Many of the previous questions refer to activities that may take several years to accomplish. What types of immediate resources and products might THORPEX produce that could support other activities (e.g., protocols for engaging

new users in decision support projects; inventories of weather information-related decision support applications, studies and user needs)?

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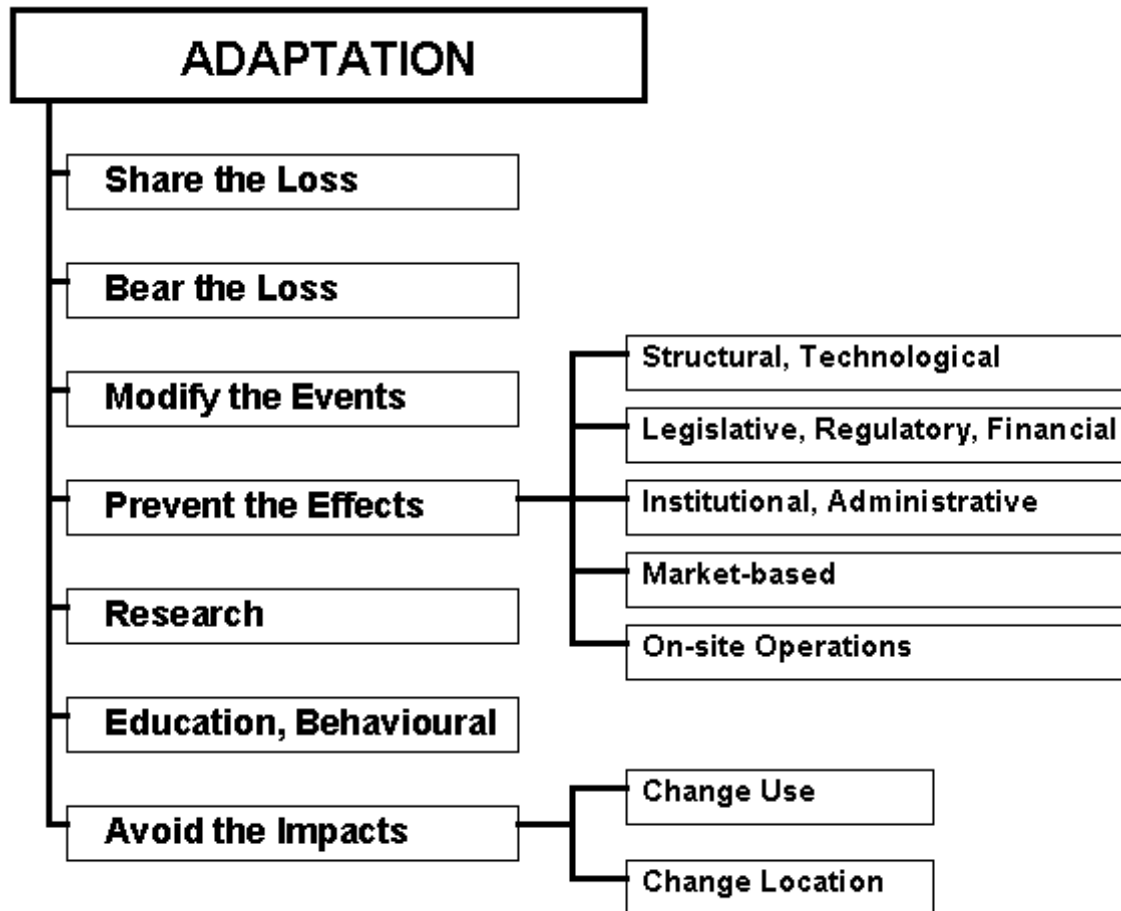


Figure 1. A typology of responses to natural hazards (modified from Burton et al., 1993)