

MEETING SUMMARIES

NOAA THORPEX SCIENCE WORKSHOP

BY ZOLTAN TOTTH AND SHARANYA J. MAJUMDAR

The Observing System Research and Predictability Experiment (THORPEX) is a global atmospheric research and development program sponsored by the World Meteorological Organization that is aimed at accelerating improvements in the skill and utility of 1–14-day forecasts of high-impact weather (for details on THORPEX and its North American counterpart, see www.wmo.int/thorpex/ and www.ucar.edu/na-thorpex/, respectively). Such improvements are envisaged by advancing research related to four main components of the forecast process: the observing system, data assimilation, predictability and numerical forecasting, and socioeconomic applications. To achieve its goals, THORPEX encourages collaboration between the research and operational communities, as well as among scientists working in the above research areas at the national, regional, and international levels. After a long planning phase, the decade-long implementation phase began in 2005, encompassing demonstration projects and field campaigns such as the International Polar Year (IPY; 2007–09) and the THORPEX Pacific Asian Regional Campaign (T-PARC; 2008).

AFFILIATIONS: TOTTH—Environmental Modeling Center, NOAA/NWS/NCEP, Camp Springs, Maryland; MAJUMDAR—RSMAS Division of Meteorology and Physical Oceanography, Miami, Florida

CORRESPONDING AUTHOR: Sharanya J. Majumdar, RSMAS Division of Meteorology and Physical Oceanography, 4600 Rickenbacker Causeway, Miami, FL 33149
E-mail: smajumdar@rsmas.miami.edu

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WHAT: Nearly 70 scientists discussed research activities, including adaptive use of observations, ensemble-based data assimilation, model-related uncertainties, high-impact modeling, socioeconomic applications, and the transition of successful research into weather forecasting operations.

WHEN: 17–19 January 2006

WHERE: Camp Springs, Maryland

In 2004, the National Oceanic and Atmospheric Administration (NOAA) formally started its participation in THORPEX by establishing its own related program (the NOAA THORPEX Web site, including a link to the workshop and presentations, is online at www.emc.ncep.noaa.gov/gmb/ens/THORPEX.html). The primary objective of NOAA THORPEX is to develop a new forecast paradigm with unprecedented two-way interactions among the main components of the forecast process, illustrated by the addition of the red arrows in Fig. 1. An important element in NOAA THORPEX has been the support of 12 grants for investigators at universities and research laboratories. The supported projects are highly relevant to NOAA's forecast service improvement goals, with an expected transition of successful research into operations. Because the projects had reached their halfway point, this workshop was convened at the National Centers for Environmental Prediction (NCEP) at the beginning of 2006 to review progress, exchange ideas, and make recommendations. This work summarizes the activities of the workshop.

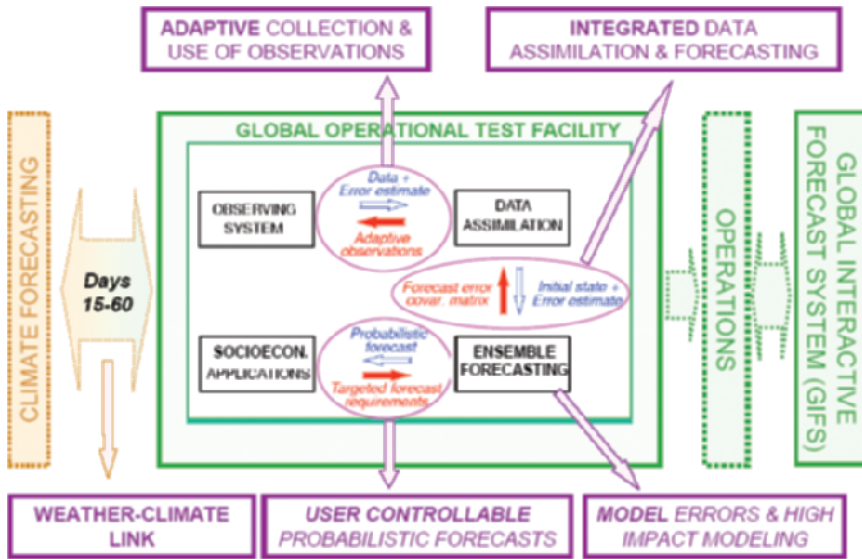


FIG. 1. A schematic of the new THORPEX paradigm for an adaptive (situation-dependent configuration), integrated (two-way interactions between components), and user-controllable (responsive to user requirements) weather forecast process. Priority NOAA research areas are highlighted in purple squares. Linkages to climate forecasting and NOAA's contribution to a future international forecast system are indicated on the left and right sides of the panel, respectively. Contributions from the broader research community are through a global operational test facility.

WORKSHOP THEMES. A common theme in many NOAA THORPEX projects is the realization that for more useful public forecasts, uncertainties must be explicitly accounted for at each step within the forecast process. Consequently, most of the projects are related to ensemble forecasting, which is commonly accepted as a critical tool in assessing and conveying forecast uncertainty.

Ensemble-based data assimilation. The first day of the workshop was dedicated to the techniques for ensemble-based data assimilation (Ens-DA). The Ens-DA community considers a flow-dependent anisotropic error covariance matrix based on ensembles to be an appealing, algorithmically simple alternative to either the current three-dimensional variational data assimilation (3D-VAR) techniques, which use the quasi-isotropic stationary matrix, or four-dimensional variational data assimilation (4D-VAR) techniques, which can be expensive to maintain. Among the advantages of Ens-DA is its ability to provide realistic analyses of high-impact weather features as well as initial conditions for probabilistic forecasts.

Over the last decade, a family of Ens-DA techniques has been developed using simplified models or incomplete observations. Several techniques are now sufficiently mature to be tested with operational quality

models and data. NOAA THORPEX is supporting a multi-investigator Ens-DA intercomparison project using the NCEP Global Forecast System. Methods of covariance localization and assimilation in local domains include increasing ensemble size, assimilating satellite radiances, intelligently prioritizing observations, minimizing the influence of localization on balance in the analysis, and maximizing computational efficiency. Ens-DA results have been compared with those from 4D-VAR in Canada. The consensus view is that Ens-DA holds considerable promise for the future.

Variational schemes continue to improve, however. For example, an anisotropic, flow-dependent background

error covariance matrix has been tested at NCEP. In addition, NCEP has recently upgraded its long-standing “breeding” method of ensemble initialization with an “ensemble transform” method to provide an improved probability distribution of the initial atmospheric state that is consistent with operational analysis error statistics.

Representing model-related uncertainties in ensembles. Forecasts with imperfect models, even if started with perfect initial conditions, will develop model-related errors. It is desirable to capture the range of all possible errors at their source in an ensemble, yet, unlike for initial condition error, no well-established theory exists on how to achieve this.

A conceptual method to minimize model errors via mapping the model state to and from nature was presented at the workshop, as were stochastic methods to represent truncation and parameterization errors in ensembles. NCEP is developing a technique that constructs stochastic perturbations from tendencies in ensemble perturbations. A method for correcting systematic model biases was also proposed. In addition, contrasting techniques to “inflate” the background error covariance matrix in Ens-DA and to shift analysis ensemble deviations back toward the background state estimate were shown. In summary, all of these tech-

niques have shown promise in being able to represent various aspects of model-related uncertainty, but a comprehensive approach has yet to emerge.

High-impact modeling. Accurately simulating and predicting high-impact weather events requires an accurate representation of processes specific to the phenomenon. One means is via multiscale, dynamically adaptive model grids. Alternatively, models may be extended to handle the connection between weather and climate systems on regional scales. The question of whether to enhance resolution in global models or adopt a regional, limited-area model approach remains open.

At NCEP, efforts are under way to model surface conditions, including data assimilative sea ice, land surface, river flow, and ocean wave models that will be incorporated into global ensemble forecasts. A joint National Aeronautics and Space Administration (NASA)–NCEP land information system, which includes the assimilation of satellite data, is under development.

Adaptive collection and use of observations. It was argued that prior to the specification and deployment of new observational platforms, the effects of assimilating these data on numerical forecasts must be assessed. Among the new data types presented were high-density rapid-scan wind vectors and the constant-pressure “driftsonde” balloon, containing miniature in situ dropwindsondes.

Observing System Simulation Experiments (OSSEs) generate synthetic observations that allow for the testing of existing and planned observing types, data assimilation, numerical modeling, and user application systems in a broader range of configurations than is possible in real experiments. A sophisticated NOAA THORPEX OSSE is being prepared for community use and for smaller OSSEs under development. To select cost-effective locations and times to collect and/or process observations, information about the observation types can be coupled to an adaptive sampling technique. It was then shown that ensemble-based techniques have the potential to predict the influence of observations on 3–7-day forecasts.

Socioeconomic applications. The value of improved weather forecasts and the characteristics of forecasts (e.g., type, frequency, and accuracy) that appeal most to users remain open to question. Moreover, the value of communicating uncertainty in forecasts has yet to be embraced by the majority of forecasters, broadcasters, and the public. Probabilities of quantities, such as precipitation amount, significant wave height, and severe storm activity, are being considered.

Forecasting in high latitudes brings unique challenges. For example, sustained anomalously warm conditions in Alaska have led to frequent storms and thaws, and the needs of residents in a changing climate warrant new types of forecasts. It was suggested that progress toward understanding large-scale connections, such as the influence of tropical convection on high-latitude weather to improve weather prediction, may be achieved through IPY and T-PARC.

The time constraints faced by forecasters require the automatic generation of high-quality probabilistic guidance. It is anticipated that their efficiency and accuracy will improve with the establishment of the North American Ensemble Forecast System (NAEFS), which is being developed jointly by the Meteorological Services of Canada, Mexico, and the United States.

CONCLUDING REMARKS. The workshop achieved its three main objectives; it a) brought together numerous (68) scientists within and outside NOAA to work on operational and research aspects of THORPEX; b) facilitated the exchange of ideas by providing ample time for discussions; and c) contributed to the development of recommendations to be used within the NOAA THORPEX planning process.

As the federal agency providing operational weather and water forecast products in the United States, NOAA must continually strengthen its partnership with the external research and user communities. THORPEX offers a great opportunity for this, and by articulating operational needs, NOAA is reaching out to the broader research community to engender a collaborative approach for solving the challenging tasks of THORPEX research. This approach involves the development of a protocol to help external research contributions benefit operations. In particular, requirements that new observing, data assimilation, forecasting, or application methods will have to meet before they can be considered for testing in a quasi-operational environment are being formalized.

An operational test facility with access to OSSE and other NWP tools, jointly used by the THORPEX community and the Joint Center for Satellite Data Assimilation, could greatly accelerate the transfer of research results into NOAA operations. The newly implemented NAEFS offers a unique opportunity to link research and operations by providing an operational outlet, delivery mechanism, and ultimate performance measure of all types of THORPEX research for the North American community, and eventually, as NAEFS contributes to the development of the future THORPEX Global Interactive Forecast System, at the international level.