# BRIDGING THE GAP BETWEEN WEATHER AND CLIMATE FORECASTING: RESEARCH PRIORITIES FOR INTRA-SEASONAL PREDICTION

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**[DATA BOX, first page…]**

TITLE: NOAA THORPEX Science Planning Meeting on Weather-Climate Links

WHAT: A group of NOAA and external leading experts along with interested scientists met to discuss the links between numerical weather prediction and climate forecasting, and to devise scientific questions, development tasks, and implementation activities aimed at improving weather and climate predictions in the 10-60 day time range.

WHEN: 27 April 2006

WHERE: Camp Springs, Maryland

The focus of the National Oceanic and Atmospheric Administration (NOAA) program known as THORPEX (THe Observing system Research and Predictability Experiment)[1] is to improve the skill and utility of forecasts over the 3-14 day lead-time range. No hard barrier, however, exists at day 14. Users require a forecast product suite that is seamless across different time ranges; and, scientifically, predicting weather at shorter ranges, or its various statistics at longer time ranges, is based on the same laws of physics.

In the past, various methodologies have been used to predict the weather at different time ranges. Numerical Weather Prediction (NWP) was first applied at short time ranges. With improved initialization and modeling techniques, the time range of useful NWP forecasts has been consistently expanding. The goal of THORPEX is, in fact, to accelerate this expansion from the current 7- to 10- day-limit out to 14 days by the introduction of a new forecast paradigm.

Beyond the skillful range of NWP-based forecasting, an array of statistical methods has been traditionally used for longer range predictions. During the past decade, however, Numerical Climate Prediction (NCP) activities have gained ground. Like the models used in NWP, Atmospheric General Circulation Models (AGCMs) are coupled with ocean and land surface models for seasonal climate prediction applications. Such NCP forecasts, after they are statistically corrected

[1] THORPEX is a World Weather Research Program under direction of the World Meteorological Organization (WMO).

for systematic errors, are now competitive with the best statistical methods at predicting future climate conditions at and beyond 2 months lead-time.

The links between numerical weather and climate forecasting are, therefore, key to the broader discussions covering the connections between weather and climate. This report provides a brief summary of workshop discussions, along with a list of open questions identified as most important in bridging the gap between weather and climate forecasting.

**Similarities and differences in numerical weather and climate prediction**

The different sub-systems of the coupled atmosphere – land surface – ocean (ALO) system continually interact with each other and at any one time the conditions of a component depend not only on its own past but also that of the other sub-systems. Of the three main subsystems, the atmosphere, if uncoupled from the influence of the others, exhibits changes on the fastest time scales (or, alternatively, has the least persistence or memory in a general sense). In contrast, the land surface (for up to a season) and especially the ocean subsystem (yearly and decadally) exhibit much slower time scales and more memory. Correspondingly, the atmosphere is often referred to as the fast component and the ocean as the slow component of the coupled ALO system.

Forecasts of future atmospheric conditions, irrespective of whether they are for the shorter or longer (i.e., seasonal) lead-time ranges, attempt to predict the same reality: the weather (or some statistics of it) based on the same physical principles. In either case an initial value problem is solved: the analyzed state of the system is projected into the future. *An important observation is that at shorter lead times (say for less than 7 days), the future state of the atmosphere is sensitive mainly to the initial condition of the fast atmosphere, while at longer lead times (say beyond 90 days) it is sensitive to the initial condition of the slow ocean (and possibly the intermediate land surface) component(s) only.*

The current practice of using two different approaches for NWP and NCP applications exploits the differences in sensitivity to initial conditions as a function of lead times described above. In the NWP application, the most accurate initial conditions are sought for the atmosphere while ignoring or oversimplifying changes in the slowly varying ocean conditions. In contrast, NCP applications focus on capturing the initial conditions of the slowly varying components of the coupled system (i.e., the ocean and land surface, and their atmospheric response) at the expense of poorer initialization and short-range forecasts of the rapidly varying components of the atmosphere.

**Opportunities for consolidation**

The current practice of using distinct approaches for weather forecasting and seasonal climate forecasting works reasonably well for both the shorter (less than 7-day NWP) and longer (more than 90-day NCP) lead times. However, evidence is accumulating to suggest that neither approach is tenable for the intermediate, 10-60 day, Intra-Seasonal (IS) lead-time forecast range. Arguably, atmospheric conditions in this intermediate lead-time range, situated between the traditional weather and seasonal climate ranges, are influenced by initial conditions of both the fast (atmosphere) and the slow and intermediate (ocean and land surface) components of the coupled system. Recognizing the limits of both of the current approaches (NWP or NCP), one can seek further forecast improvements by exploiting initial value information from both the fast and slower components of the coupled ALO system.

The 10-60 day IS time range is a natural meeting ground between scientists who have been primarily working on the shorter weather or the longer climate applications. The weather and climate forecast communities must work together to realize the full predictability within the IS lead-time range. Converging and eventually unifying weather and climate forecasting approaches that have been developed somewhat separately over the past decades is a difficult task not only from a scientific but also from a cultural point of view.

However, the enhanced collaboration and the ensuing closer ties between the two communities have great potential. Beyond improving IS forecasting, the collaboration may, at least in some situations, also have a positive effect on short 1-7 day forecasts (e.g., improved hurricane intensity forecasting due to more realistic ocean temperature forecasts) and on longer than 60-day forecasts (e.g., capturing the initiation or modulation of an ENSO cycle by the Madden-Julian Oscillation). In addition, a unified approach may also contribute to the establishment of a seamless suite of probabilistic weather, water and climate products, ranging from hours to seasons ahead.

The NOAA THORPEX program will engage in collaborative research with all interested partners in the weather and climate forecast communities to achieve these challenging goals. Continued separate development of the NWP and NCP approaches or the addition of yet a third new approach for IS forecasting may in the short term bring improved performance. The maintenance and continued development of two or three separate forecast systems, however, has its own costs. And to realize the full potential of weather and climate forecasting will eventually require the development of a more unified approach. How to balance within operational forecasting the goal of immediate skill improvements with the goal of laying the groundwork for longer-term advances when the available resources are limited is a challenge all by itself.

The current dual approach and distinct techniques for weather and climate forecasting reflect a knowledge gap in our understanding of the coupled system and how it can be captured in our numerical modeling systems. To accelerate improvements in the 10-60 day forecasting range, the NOAA THORPEX program promotes joint research by the weather and climate communities aimed at closing the existing knowledge gap.

Additional information on this and related NOAA THORPEX workshops is available online at http://wwwt.emc.ncep.noaa.gov/gmb/ens/meetings.html.

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## Open science questions[2]

The questions below were highlighted in the workshop for each priority research area of IS forecasting. Such questions fostering multiple hypothetical answers will lead efforts to develop a unified weather-climate numerical forecast system for the next 8-10 years.

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[2] For more details on the workshop recommendations, see Toth, Z., M. Peña, and A. Vintzileos, 2007: Bridging the gap between weather and climate forecasting: Research priorities for intra-seasonal prediction. Preprints of the AMS Forum: Climate Variations and Change Manifested by Changes in Weather, AMS, San Antonio, Texas, 15-18 January 2007. Available online at: http://ams.confex.com/ams/pdfpapers/119747.pdf via http://ams.confex.com/ams/87ANNUAL/techprogram/paper_119747.htm

***Observing system***

*What observations of the coupled atmosphere - land surface – ocean (ALO) system are needed for capturing details of the initial conditions for successful predictions in the 10-60 day lead-time range?*

***Data assimilation***

*What are the best approaches that avoid the well-known problem of initialization shock due to the typically strong model drift (spin-up) characteristic of most coupled modeling systems?*

***Numerical model simulation***

*What are the most promising ways for improving the realism of coupled ALO models for IS prediction?*

***Predictability***

*How does information contained in the initial condition of the fast (atmosphere) and slower (land and ocean) sub-components of the ALO system support predictability in the IS range?*

***Ensemble prediction***

*What is the best forecast system configuration to realize the maximum skill given the inherent limits in predictability of the coupled system and the limitations in its numerical modeling?*

***Post-processing***

*What are the best methods of a posteriori enhancing the value of numerical IS forecasts?*

***Socio-economic applications***

*How can the existing gap between providers and users of IS forecasts be narrowed?*

***Value of forecasts***

*What is the potential socio-economic value of improved forecast information at different lead-time ranges?*

**[END SIDEBAR]**