The NOAA Climate Test Bed

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1.0 Introduction

The operational Seasonal-to-Interannual (S/I) forecast is a challenging scientific problem that has primarily been the province of sophisticated statistical forecast algorithms, with a lesser role given to fully dynamical forecast systems. The relative lack of skill in dynamical forecast systems has dissuaded efforts at extending operational forecasts past the traditional predictability limit of two weeks. Despite many important applications, not the least of which is the prediction of tropical intraseasonal variability (e.g. the Madden-Julian Oscillation), and despite considerable research aimed at improving prediction on 2 week to 12 month time scales, progress has been slow.

Recent developments in coupled atmosphere-ocean-land surface forecast systems for S/I climate prediction, however, have reinvigorated attention on this critical NOAA product area. For example, in the past year NOAA has implemented a coupled Climate Forecast System (CFS), composed of the NCEP Global atmospheric Forecast System (GFS) model and the GFDL Modular Ocean Model (MOM3), that is a significant step forward in forecasting ENSO related SST variability in the Tropical Pacific using dynamical forecast systems and, indeed, shows skill at least equal to that of current statistical algorithms (***Fig. 1***). Moreover, recent tests with fully coupled climate forecast systems have demonstrated that atmospheric forecasts extending beyond 10-14 days also show increased skill. This advancement provides a major motivation to extend current "Week 2" forecasts into monthly, and longer, time domains. Considerable scientific investigation and development will be needed to accelerate improvements in these forecasts and provide useful products and applications on the 3 week-to-S/I time scales.

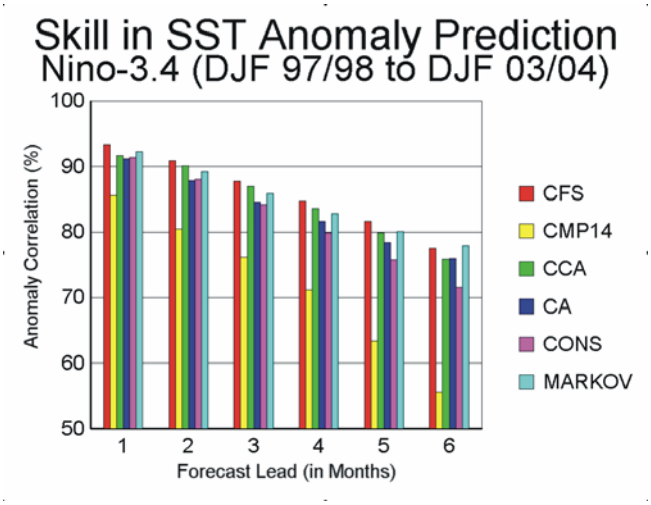

Figure 1. *Forecast anomaly correlation for NINO3.4 SST for all months (25 seasons) over the period DJF 1997-1998 to DJF 2003-2004. CFS: new NCEP coupled Climate Forecast System; CMP14: old NCEP coupled system; CCA: Canonical Correlation Analysis (statistical); CA: Constructed Analog (statistical); CONS: official CPC consolidation forecast; MARKOV: Markov (statistical) technique (Courtesy Huug VandenDool, CPC).*

Building on recent momentum, it behooves NOAA to encourage and facilitate

faster improvement of NOAA operational climate forecast systems, and at the same time increase the exposure of NOAA climate forecast products in an attempt to link them to application models, and thereby, extend the utility and scope of NOAA climate services.

It is now clear that, having achieved at least parity with statistical algorithms, coupled numerical forecast systems have the greatest potential for improving climate forecasts. Moreover, they now appear mature enough to be used as realistic vehicles for basic research on predictability of the "Earth" (atmosphere-ocean-land surface-cryosphere) system. Supporting the NOAA climate forecast systems for use by climate researchers is an optimal way to leverage the expertise of the external scientific community as well as that of NOAA researchers in order to accelerate the necessary improvements.

The "Predictions and Projections" component of the FY05 NOAA Climate Program Plan has identified support for a systematic research to operations transition program as a key deficiency. The plan emphasizes that there is a lack of support to transition research and operational climate models to a community based infrastructure to accelerate model advances from the external and internal research communities to operations. In order to achieve this synergistic blend of internal and external research and development efforts required to accelerate improvements in NOAA operational climate forecast systems, a Climate Test Bed (CTB) facility has been organized.

2.0 Mission

The mission of the NOAA Climate Test Bed (CTB) is to accelerate the transition of research and development into improved NOAA operational climate forecasts, products, and applications.

3.0 Operations Concept

The CTB mission is intended to provide more traction and visibility to intraseasonal-to-decadal research and development efforts by accelerating the transition of this research into NOAA climate forecast operations. The CTB will provide an operational testing environment to support projects that result in a direct influence on NOAA climate forecast operations and provide infrastructure and resources for (long term, competitive, community-wide) projects on broader research issues affecting NOAA climate forecast operations.

In order to accomplish its mission, the CTB has the following objectives:

- to assess scientific advances (models, tools, data sets, observing systems) that have potential for a direct influence on NOAA operations;
- to accelerate the synthesis and implementation of these advances for NOAA operational climate forecasts;
- to develop new tools and applications in a quasi-operational environment subject to metrics that mandate good scientific performance while meeting ease-of use criteria and time constraints;
- to utilize advanced statistical and numerical model output, and stimulate model improvements in climate analysis and forecasting applications;
- to facilitate the transfer of tested

software into the NCEP development cluster while incorporating adjustments necessary to generate climate forecast products that are forecaster-friendly and time-efficient;

- to prepare documentation, training materials, and evaluations of performance characteristics of successful products to facilitate their use by NOAA climate forecast operations staff.

The CTB framework includes both "infrastructure" and "transition projects". CTB infrastructure includes computing support (e.g. the NCEP Research Supercomputer), software support (e.g., models, data, diagnostics), contractors, technical assistants, system administrators, management and administrative staff. CTB infrastructure will support the exchange of climate forecast system software (e.g. models, data assimilation, codes, testing data sets, etc.). This software will be donated by NCEP and others who wish to participate in the CTB. Augmentation funding for CTB infrastructure will be needed to support this software. The CTB infrastructure will also support a capability for generating and producing multi-model ensembles (subject to CTB implementation guidelines). The CTB will maintain Earth System Modeling Framework (ESMF) compatible software when it becomes capable of supporting a full S/I forecast system and the software has been converted to ESMF-compatible structures. While the bulk of the computing resources will be supplied by the NOAA "Research computer" resource, augmentation funding for supporting infrastructure, such as system administration, will be required.

Scientific work in the CTB will be accomplished via transition projects, that include both base funded activities and Announcements of Opportunity. Base funded activities will generally be *near-term* activities, funded by NOAA organizations, that are likely to influence NOAA climate forecast operations within 1 year. These projects have definite outcomes and lifecycles. They will be selected by CTB management in consultation with the Oversight Board (see below). Announcements of Opportunity (AO's) will support *long-term, competitive, reviewed* community wide activities that are likely to influence NOAA climate forecast operations in 2-3 years. These activities will be funded by NOAA and potentially other U.S. agencies, proposed and selected through a formal review process. Proposal selection and peer review will be managed by the NOAA Climate Program Office. If other organizations contribute, their input is considered in the selection process.

Science priorities for base funded activities include climate forecast system assessments (e.g. model diagnostics and testing), and climate products and applications (e.g. consolidation of forecast tools, skill masks, objective verification, product development for climate monitoring and assessment). AO's will support community-wide participation in the CTB on broader science issues such as

- Multi-model ensemble system development; MM climate forecasts and applications; Attribution;
- Model development through Climate Process and modeling Teams;
- Climate product and applications development (e.g. predictability studies, drought monitoring and prediction, extreme events);
- Climate reanalysis and data impact;
- Advanced forecast capabilities (e.g. ecosystems; air chemistry; carbon cycle; fisheries)

Collaboration, via AO-driven proposals, with organizations maintaining climate-relevant software will be encouraged. In the more distant future, expansion to international climate forecasting by adding ECMWF, Canadian, Met Office, and Meteo France products is a major goal.

The CTB will maintain strong linkages to CLIVAR, GEWEX, and joint CLIVAR-GEWEX programs such as the Climate Prediction Program for the Americas (CPPA), the GEWEX Americas Prediction Project (GAPP), Pan American Climate Studies (PACS), CLIVAR Atlantic and Pacific, Variability of the American Monsoons (VAMOS), the Climate Dynamics and Experimental Prediction (CDEP) program and others. Some specific examples include:

1) CLIVAR/Climate Process and Modeling Teams (CPT's)

The CTB is closely related in concept to the CLIVAR Climate Process and modeling Teams (CPTs). The CTB priority of improving physical parameterizations in NOAA climate forecast models can be considered as the NOAA implementation of the CPT concept by providing computing resources and an operational testing environment to address high priority science issues that are common among operational climate prediction models. The NOAA Climate Test Bed emphasizes S/I time scales and is uniquely oriented towards applications that can be transitioned to operational implementation at NOAA. The NOAA CTB will support competitive, peer reviewed proposals oriented toward contributions to NOAA operational missions. With this strategy, the CTB will maintain a focus on areas of investigation most likely to directly improve NOAA's operational numerical forecast systems yet remain open to advanced technologies that may produce additional breakthroughs in forecasting.

2) ESMF

The recent emergence of the Earth System Modeling Framework (ESMF) provides an excellent opportunity for the CTB to investigate new model components and to improve operational climate forecast systems using ESMF compatible software. GFDL's climate forecast codes are becoming ESMF compatible. NASA is building an ESMF compatible model and NCEP is constructing ESMF-compatible versions of its next-generation global model.

4) JCSDA

The NASA-NOAA-DOD Joint Center for Satellite Data Assimilation provides a leveraged resource for addressing climate data assimilation and modeling issues. The JCSDA supports observations and data assimilation (ocean, land-surface, atmosphere) software and proposals in this arena can be executed more efficiently due to the supported infrastructure.

5) NOMADS

Dissemination and archiving of CTB data sets will be done through the NOAA Operational Model Archive and Distribution System (NOMADS). GFDL and NCEP scientists have been part of a larger consortium that has been developing NOMADS capabilities for broad data set availability.

It is important to emphasize that the CTB will not take the lead on the following activities under the purview of NOAA climate forecast operations or the participating NFCs:

- Operational forecasting;
- Real-time monitoring or integrated climate assessments;
- NCEP operational climate forecast system development, integration, and calibration;
- Model development for participating NFC's.

4.0 Management Structure

The CTB management structure includes the following areas: oversight and scientific direction, programmatic and scientific management and computing. The CTB staff will include a Director, a Deputy Director, a Program Manager, Administrative Staff, Technical Assistants, Focal Points, and other associated personnel (e.g. Visiting Scientists and Students). Personnel will consist of civil servants, contractors, visiting scientists and students. Complete Terms of Reference (ToR) and responsibilities for CTB staff are found on the CTB web page at:

http://www.cpc.ncep.noaa.gov/products/ctb

The CTB also includes an Oversight Board (OB), a Climate Science Team (CST) and an external Science Advisory Board (SAB). These groups have unique responsibilities and charges that are briefly summarized as follows:

- **Oversight Board (OB):** to make recommendations to the Directors of the NOAA Climate Office and NCEP concerning the CTB on an annual basis;
- **Climate Science Team (CST):** to guide CTB activities at the working level, including evaluation of CTB activities and recommendations to CTB management on computing resource usage and access;
- **Science Advisory Board (SAB):** to coordinate with the broader science community and with other programs, and to provide "independent" advice on high-priority scientific challenges.

Complete ToR and responsibilities for the OB, CST and SAB are also found on the CTB web page.

5.0 Supported Software

NCEP's next generation model will be on the development path for upgrades to NCEP's operational climate forecast system. The large amount of testing necessary for putting any new system upgrade into operations, which includes lengthy calibration runs, ensures that these upgrades will occur every 3-4 years, rather than several times annually as in weather applications. Thus, the next upgrade to NCEP's system will probably occur in 2007. Therefore, there is now an excellent opportunity for the community to work with NCEP on its next operational upgrade. All components of NCEP's system are now in a position to be upgraded, including the atmospheric, ocean, land-surface and sea ice forecast models, standardized (formatted) observations, data assimilation systems (ocean, atmosphere, land-surface), post-processing and archive capability.

In order to improve NCEP forecasts from Week 2 to S/I, a multi-model ensemble strategy will be pursued in the CTB. The CTB will host an ESMF-compatible software framework that will promote the experimentation and development of multi-model ensemble products.

The CTB will collaborate with the JCSDA to develop improved data assimilation techniques for the CTB

applications. Common software will be maintained jointly between the JCSDA and CTB, with the JCSDA focusing on the data assimilation modules (primarily ocean and land surface) and the CTB focusing on specialized data sets and output products. Any Reanalysis capability will draw upon JCSDA software but be executed within CTB resources.

6.0 Resources

A three-year ramp up of CTB resources is planned. CPC and EMC FTEs have been reallocated to the CTB. As mentioned above, the bulk of the computing resources will be supplied by the NOAA "Research Supercomputer". Augmentation funding will be needed to support contractors in order to transfer and enhance CTB software and datasets, and to maintain computing infrastructure. The CTB management will establish an overall policy on allocation of computing resources (with approval by the OB). NCEP/NCO will provide the management of the computing resources (user access, accounting, etc) according to established policies.

Base funded activities will be funded by NOAA organizations to accelerate the transition of R&D to improved NOAA operational climate forecasts, products and applications. These activities are expected to directly influence NOAA climate forecast operations within 1 year, with definite outcomes and lifecycles. Visiting scientists will be supported by participating NOAA organizations (includes reassigned personnel from other centers). Annual Announcements of Opportunity (AO's) will be funded by NOAA and other agencies to support community wide participation on broader research issues. The NOAA Office of Global Programs will undertake administrative tasks.

NOAA Climate Office funding will provide a venue for scientists in the external research community to work on NCEP models and products through the CTB. NCEP has limited manpower to work with external PI's on AO-driven CTB projects and complete its own base funded projects. Thus, the CTB will require a few "bridge" scientists, to help infuse AO-driven research into operations.