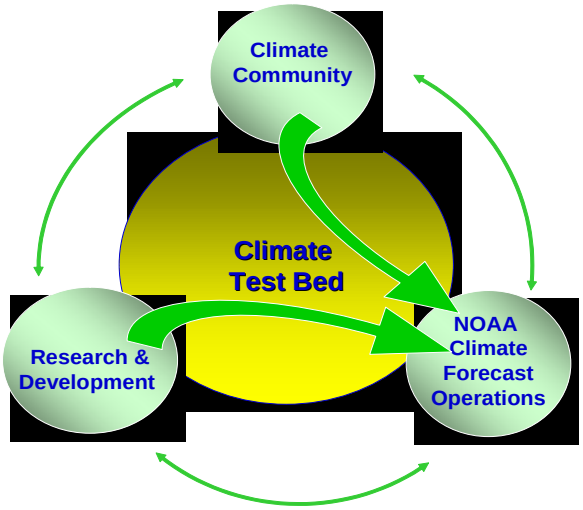
NOAA Climate Test Bed (CTB)

Part I. Science Plan and Implementation Strategy
Part II. Management and Operations Plan



Mission: to accelerate the transition of research and development into improved NOAA operational climate forecast products and applications.

Mission: To accelerate the transition of scientific advances from the climate research community to improved NOAA climate forecast products and services.

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

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NOAA CTB Science Plan & Implementation Strategy
NOAA CTB Management and Operations Plan

March 2006 – Draft 3

Table of Contents

Page

Executive Summary

NOAA/NCEP is the lead agency with responsibility for improving our Nation's operational climate predictions on time scales ranging from weeks to years. Improvements in predictions are envisioned in the coming years that will lead to "A Seamless Suite of Forecasts" spanning weather, intraseasonal, interannual, and multi-decadal timescales. The mission of the CTB is to facilitate this outcome by accelerating the transition of scientific advances from the climate research community to improved NOAA climate forecast products and services. This document describes the CTB science plan and the associated implementation strategy.

The science plan is intended to be an evolving document. It was developed in consultation with NCEP and NCPO Senior Management to ensure that it is consistent with the relevant NOAA Mission and Support Goals encapsulated here in terms of four programmatic priorities for improved climate prediction consisting of:

- NOAA/NCEP Climate Forecast System (CFS) Improvements
- Multi-Model Ensemble Prediction System
- Climate Reanalysis – An Ongoing Analysis of the Climate System
- Climate Forecast Products for Decision Support

The CTB science plan recognizes that progress must be made in each of these four areas. Specifically, the CTB must foster improvements in CFS by accelerating the transition of the relevant process level advances in our weather prediction model (the Global Forecast System or GFS) to CFS, and by supporting targeted research and development by the science community. These advances must be integrated and fully validated in CFS; a critical step that requires long-term reanalysis data. Reanalysis data are also required for calibrating the CFS predictions, and for integrating them with other forecasting tools using a multi-model ensemble approach that ultimately combines all known sources of independent skill. Finally, the science plan recognizes that the development of climate forecast products, including consolidated forecasts and regional products, is a fundamental aspect of the transition to applications for decision support.

A list of potential science priority areas that the CTB endorses is given below for each programmatic theme. It is important to emphasize that the CTB is not (and cannot be) active in all of these areas: priorities will be developed and evolve over time as outlined in the implementation strategy.

NOAA/NCEP Climate Forecast System (CFS) Improvements

- Accelerate near-term assessment of potential enhancements to the next generation CFS (ocean model and assimilation; land surface model and assimilation; physics; resolution);
- Seek venues and resources that enable partnerships between NCEP modelers and the research community on future improvements to the GFS and the CFS;
- Develop hardware/software tools and data policy for disseminating climate information on publicly accessible server;

- Develop a standard diagnostics package for CFS assessments (including surface, atmospheric, and oceanic variability);
- Participate in field experiments and work with the various Climate Process Teams to improve CFS physics.

Multi-Model Ensemble Prediction System

- Establish a systematic community based multi-model forecasting capability & infrastructure using National models (NCEP-CFS,GFDL-CM2.1,NASA-GEOS, NCAR-CCSM, others);
- Develop dynamical understanding of trends;
- Systematic predictability studies to establish sources and limits of predictability and skill;
- Develop intraseasonal forecasting capability (improve week 2 skill scores; develop a capability to predict extremes for weeks 2,3,4; develop predictive understanding of the impacts of climate on the statistics of extreme events, including hurricanes);
- Improving Forecasts of Weather – Climate Connection (multi-model Case Study approaches to improved understanding and prediction of extreme events);
- Seek partnerships with other international multi-model programs (e.g. IRI, European Union, APEC).

Climate Reanalysis – An Ongoing Analysis of the Climate System (OACS)

- Develop implementation plans and seek resources for OACS (data archaeology and stewardship; real-time analysis and monitoring; periodic reanalysis; data dissemination; applied research; forecast verification; development of operational statistical models);
- Coordination of reanalysis activities within NOAA (e.g. NCEP, NCDC, CDC), nationally (e.g. NASA, NSF) and internationally (e.g. ESMWF); establish program / project management.

Climate Forecast Products for Decision Support

- Consolidation of multi-method seasonal forecasts at CPC (includes skill masks, objective seasonal forecast tool, and objective verification of extended-range, monthly and seasonal outlooks);
- Establish "Climate Prediction Products and Services Team" to identify, prioritize and meet customer requirements for new and improved climate forecast products (includes verification statistics; improvements to basic predictand products; risks of high-impact weather events in a month or season by ENSO phase);
- Develop regional hydrologic products (includes drought monitoring & prediction capability for NIDIS; Regional Climate Model (RCM) seasonal forecasts; multi-model ensembles for hydrologic forecasts).

The implementation strategy is centered around three "core" projects that align the CTB activities with the above programmatic themes. These are:

Core Project 1: Climate Forecast Products for Decision Support:
Core Project 2: CFS Improvements & Multi-Model Ensemble Prediction System
Core Project 3: Climate Reanalysis – Ongoing Analysis of the Climate System

The functional core of the CTB is the "Transition Project Teams". The mission of the teams is to make progress on key components of the core projects (based on a priority ranking) by providing a mechanism for coordinating and completing CTB activities (including science experiments that require computer resources), and by enhancing collaboration between internal and external participants on the CTB.

The SP&IS will evolve to a Science and Implementation plan as CTB mission requirements and capabilities are refined and established. Given the relatively new status of the CTB, the current version of this document should not be considered as a science review. In the future we plan to highlight the CTBs most recent scientific accomplishments, the most important new or emerging areas of interest to NOAA, and the extent of collaborations between CTB and the external community.

Part II of this document is the CTB Management and Operations Plan, which provides details on the CTB organization and institutional framework that has been put in place to achieve the CTB objectives.

For additional information on the CTB, including a "White Paper" and "Terms of Reference" documents, the reader is referred to the CTB webpage: http://www.cpc.ncep.noaa.gov/products/ctb.

PART I. SCIENCE PLAN AND IMPLEMENTATION STRATEGY

1. SCIENCE PLAN

In 2004 NOAA's National Centers for Environmental Prediction (NCEP) and Climate Program Office (NCPO; formerly Office of Global Programs) jointly established a Climate Test Bed (CTB) facility to accelerate the transition of research and development into improved NOAA climate forecasts, products and applications. The relationship among CTB, NCEP and NCPO is shown in Fig. 1 and discussed below.

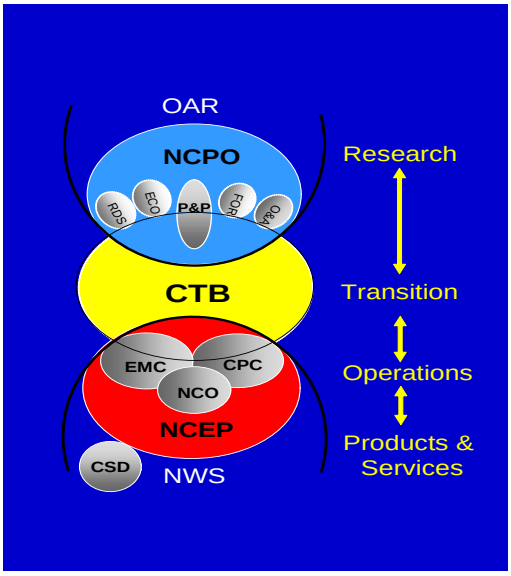

Figure 1. Relationships among CTB, NCEP and NCPO. NCPO Programs are given in Fig. 2.

The CTB facility provides an operational infrastructure (computing support, Transition Project Teams (TPTs), and competitively-funded transition projects) to accelerate improvements in NOAA climate predictive capabilities, with an increased range of applicability for management and policy decisions by end users. CTB transition projects are carried out jointly by scientists from NCEP, other NOAA organizations and the broader research community. While the CTB facility is currently located at the NOAA Science Center in Camp Springs, MD, it will be moving to the NOAA Center for Weather and Climate Prediction at the University of Maryland's M-Square campus in College Park in early 2008. This presents the CTB with tremendous opportunities and emerging management challenges in the near future.

1.1 Vision and Mission

The CTB strategy centers around its Vision and Mission.

What is the CTB Vision?

To significantly increase the number and skill of NOAA's operational climate forecast products. This involves accelerating improvements in the fully coupled NOAA Climate Forecast System and other Earth system models within the framework of a multi-model ensemble system. It also involves working with the applications community to provide new and improved climate forecast products that enhance decision making.

The multi-model system used to produce forecast products will be based on a community model approach. Since the component models of the atmosphere, the oceans, land surface, hydrologic cycle, and biogeochemical cycles are at greatly varying stages of maturity, hierarchies of less detailed models and statistical models must also be employed. All of these activities are aimed at the fundamental goal of enhancing our collective interdisciplinary ability to understand and predict the state and evolution of the Earth system.

What is the CTB Mission?

To accelerate the transition of scientific advances from the climate research community to improved NOAA climate forecast products and services.

1.2 Relationship to NOAA Strategic Plan

How is the CTB Vision related to the NOAA Strategic Plan?

The NOAA Strategic Plan "New Priorities for the 21st Century" (see http://www.spo.noaa.gov/pdfs/NOAA%20Strategic%20Plan.pdf) is centered upon 4 Goals and a Support Goal:

- Protect, restore, and manage the use of coastal and ocean resources through an ecosystem approach to management;
- Understand climate variability and change to enhance society's ability to plan and respond;
- Serve society's needs for weather and water information;
- Support the nation's commerce with information for safe, efficient, and environmentally sound transportation;
- Provide critical support for NOAA's mission.

These strategic goals are frequently referred to as Ecosystems, Climate, Weather and Water, Commerce and Transportation, and Mission Support.

The CTB Vision speaks most directly to NOAA's Climate Goal, but also to the Weather and Water, Ecosystems and Commerce Goals, and is closely aligned with the

Support Goal. The NOAA Strategic Plan also lists 5 essential activities that it refers to as "crosscutting priorities". The CTB Vision contributes directly to two of these: "Ensuring sound, state-of-the-art research", and "Integrating global observations and data management". Finally, the plan also discusses outcomes, performance measures, strategies and activities associated with each Goal. CTB outcomes and performance measures are discussed in Part I, Section 5. The CTB programmatic and science priorities (Part 1, Section 1.5) and implementation strategy (Part I, Section 2) are discussed below.

The CTB Vision also aligns with NOAA's Five-Year Research Plan focus on Earth System Modeling (link weather & climate; oceans & land; biochemical processes; regional ecosystem models) and observing systems and networks to support Earth system modeling (NOAA will take the lead in Global Earth Observing System of Systems or GEOSS)

How are the CTB Vision and Mission aligned with the NOAA Climate Goal Programs?

The NCEP / CTB Vision and Mission are closely aligned with the mission requirements, capabilities, strategy and desired end states of the NOAA Climate Program (Fig. 2), and especially the desired end state of the Climate Predictions and Projections Program to provide "**A Seamless Suite of Forecasts"** (Fig. 3) on intraseasonal, interannual, and multi-decadal timescales and applications using ensembles of multiple climate models in support of the mission outcome "*a predictive understanding of the global climate system*."

The CTB Vision and Mission also align with the ten year NOAA Modeling Vision to embrace a unified Earth system modeling and data assimilation approach based on a common framework that maintains the U.S. as a recognized world leader in global Earth system modeling and meets the NOAA mission within the state of the science to meet customer requirements.

The CTB will embrace Earth system models used to analyze and predict the state of the atmosphere, the oceans, land surface, hydrologic cycle, and biogeochemical cycles within the framework of a unified multi-model system. This implies an increasing alignment with the Climate and Ecosystems Program to "Understand and predict the consequences of climate variability and change on marine ecosystems."

The CTB programmatic priorities (Part I, Section 1.5) include an ongoing analysis of the climate system that contributes directly to the Observations and Analysis Program to "Describe and understand the state of the climate system through integrated observation, analysis, and data stewardship. Finally, the CTB programmatic priorities also include applications of climate forecast products that contribute to the Regional Decision Support Program to "Increase availability of climate forecast products and services to enhance decision making."

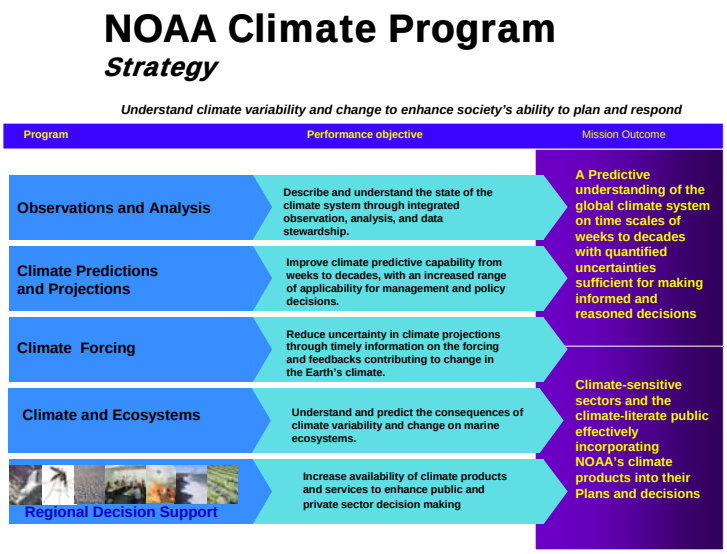

Figure 2. NOAA Climate Program strategy.

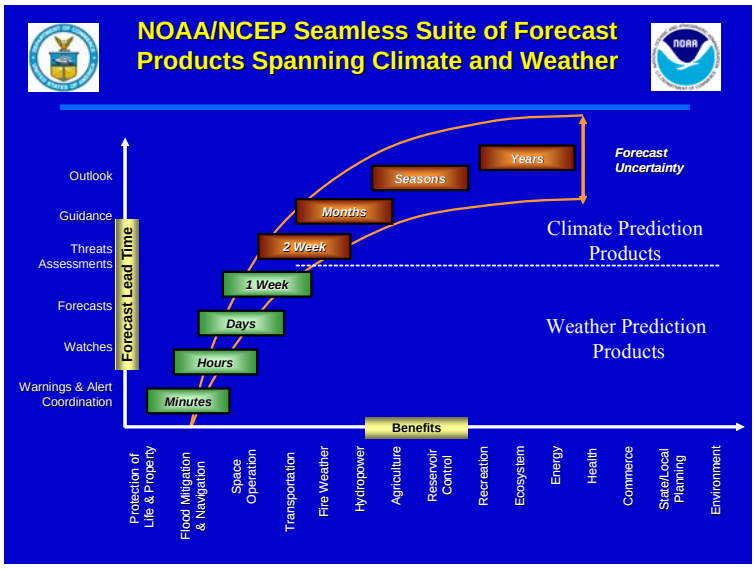

Figure 3. NOAA/NCEP Seamless Suite of Forecast Products.

1.3 Objectives

To accomplish its mission, the CTB will provide a means to accelerate the transition of scientific advances from the climate research community to improved NOAA climate products and services. CTB objectives are

- to accelerate the synthesis and implementation of advances in climate model improvements, multi-model techniques, forecaster tools, data sets, and observing

systems into NOAA climate forecast operations;

- to provide the climate research community with access to operational models, forecast tools and data sets to enable collaborative research that accelerates additional improvements of NOAA climate forecast products;
- to provide new and improved climate forecast products to the applications community for use in planning and decision making.

1.4 Requirements to Improve Climate Prediction

NOAA/NCEP is the lead for providing operational climate prediction on time scales ranging from weeks to years. These predictions are aimed at enhancing our collective interdisciplinary ability to understand and predict the state and evolution of the climate system, including linkages between climate and weather (including weather extremes) on all time scales. Weather and climate extremes impact lives, property and the economy at levels which are many times larger than the investments needed for improving climate prediction.

Improvements in Intraseasonal-to-Interannual (ISI) prediction depend on a balance of new and existing resources dedicated to a few specific priorities (discussed below). Accelerating improvements in ISI predictions requires a simultaneous attack from both short-term weather models and long-term climate models and their modeling research strategies. The limited skill of both approaches must be integrated with other forecasting tools using a multi-model ensemble approach, to integrate all possible known sources of independent skill. Numerical weather prediction models must be extended to climate time scales, and general circulation models being developed for climate change projections must produce skillful simulations at S-I time scales.

To achieve these objectives, the CTB will acquire the capability to run and support, for external users, the operational coupled Climate Forecast System (CFS) and other Earth system models in a multi-model ensemble framework, to support other climate model components and to provide the public, including the CTB, access to experimental data and model components.

Some details on NOAA/NCEP requirements for improved climate prediction:

NOAA/NCEP Climate Forecast System (CFS) Improvements: The CFS (Saha et al. 2006) is the first NOAA 1-tier fully coupled atmosphere-ocean-land surface forecast system for ISI climate prediction to show skill at least equal to that of statistical seasonal prediction tools (Fig. 4). 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 beyond day 7. Considerable scientific investigation and development will be needed to accelerate improvements in the skill of these forecasts on ISI time scales. While NCEP/CPC and NCEP/EMC have allocated resources to improve the CFS, the CTB facility provides the infrastructure to accelerate improvements in the CFS and the capability to carry out the requisite transition to operations. Unique resources for the "home research institution", the CTB and NCEP Central Operations (NCO) are required to carry out the code conversions, model calibration, skill assessments, parallel testing and operational implementation required for smooth transitions (see Appendix A). The CFS contributes a significant portion of the current

skill in predicting phases of the ENSO phenomena and their resultant impact on United States and global weather and climate. A CTB "White Paper", available on the CTB web page (http://www.cpc.ncep.noaa.gov/products/ctb/ctb-documentation.shtml), provides additional justification for a programmatic focus on CFS.

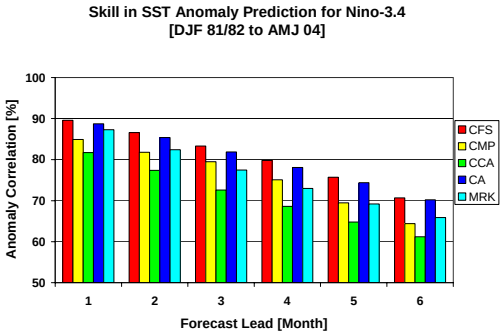

Figure 4. Forecast anomaly correlation for NINO3.4 SST for all months over the period DJF 1981-1982 to AMJ 2004. CFS: new NCEP coupled Climate Forecast System; CMP14: old NCEP coupled system; CCA: Canonical Correlation Analysis (statistical); CA: Constructed Analog (statistical); MARKOV: Markov (statistical) technique

Multi-Model Ensemble Prediction System: Following recent studies by Krishnamurti et al. (1999), Palmer et al. (2004), and others which have shown that the forecast skill of a multi-model system is higher than that of all of the individual models, the international scientific community has rallied around the multi-model ensemble approach to improve climate prediction. Several multi-model ensemble programs are underway around the world, notably those at EU (Provost / Demeter / Ensembles) and at the APEC Climate Center in Korea. To maintain its status as a world leader in global Earth system modeling, NOAA should develop a systematic multi-model based prediction and projection capability and infrastructure. The NOAA/CTB is a natural lead to develop the strategy. Such a capability will allow focused research on phenomena that have been demonstrated by predictability studies to have the greatest potential to improve forecast skill on ISI time scales. Increased availability of improved fully coupled models, access to data sets from multi-model experiments, and experimental prediction activities will result in new capabilities for the research community at large to contribute to predictability studies and an understanding of climate variability and change based on intercomparisons of model and observational data sets. This capability includes an improved dynamical understanding of trends that are the physical basis for operational seasonal forecasts when ENSO is absent. In addition, there is an increasing need to provide skillful climate change projections that can support policy decisions on air quality, ecosystem impacts, water-related issues, climate variability, and abrupt climate change. By FY12 NOAA needs an Earth system model that provides an increased range of climate products for regional applications and decision support using these projections. The future vision is centered around a capability to produce a seamless suite of products that span operational climate predictions, based substantially on output from multi model ensembles with significant utilization of Earth system models, and extending to a suite of

new forecast products of impacts on the environment and ecosystems with quantification of skill level at global and regional scales.

Climate Reanalysis – An Ongoing Analysis of the Climate System (OACS): NOAA Climate Program has requested the lead on developing new climate reanalysis data sets and to deliver explanations for the causes of observed climate variability and change. This effort is a key NOAA contribution to the CCSP goal of improving knowledge of the Earth's past and present climate and environment, including its natural variability, and to improve understanding of the causes of observed variability and change (US CCSP, 2003). This work will enable NOAA to deliver a high priority interagency CCSP synthesis product: "Reanalyses of historical climate data for key atmospheric features. Implications for attribution of causes of observed change." This program component supports NOAA's Mission Goal to "Understand climate variability and change to enhance society's ability to plan and respond".

NOAA lacks adequate capacity to provide global climate analyses that are required to describe major features of 20th-century climate and the capacity to address the causes of observed regional climate variations that are crucial to informing policy decisions. The first-generation reanalyses, based on mid-1990s models and data assimilation systems, lack adequate spatial resolution and contain known deficiencies which limit their usefulness for identifying climate trends and assessing causes of observed change. Advances in models, improved climate data assimilation methods, and new data sources make it desirable and feasible for NOAA to develop and continually update global reanalyses datasets. An assessment of the causes of observed changes will complement the data set development and enable NOAA to meet CCSP synthesis product requirements.

The benefits of an ongoing program include: (i) new quality controlled data products for use in the next generation reanalyses; (ii) production and dissemination of improved climate reanalysis data products for assessing climate variability and change; (iii) long term consistent reanalyses for initializing and verifying model hindcasts - a critical exercise for calibrating model forecasts; (iv) fulfillment of NOAA's commitment to the CCSP goals; (v) new diagnostic tools to link the behavior of climate and forcing mechanisms in a physically consistent manner; (vi) regular and systematic explanations of past, current, and evolving climate conditions, and (vii) enhanced climate prediction capabilities that enable regional and national decision makers and resource managers to better plan for impacts of climate extremes, variability, and change. Developing improved climate reanalyses and attribution capabilities requires strong links among NOAA's observational, research, and operational prediction efforts. CTB can play a vital role in this arena by coordinating ongoing reanalysis activities within NOAA, across agencies and internationally in order to determine the"best way(s)" to carry out the next historical reanalysis.

Climate Forecast Products for Decision Support: Though the fraction of the total variability of the coupled atmosphere-ocean-land-cryosphere system that is concentrated at ISI timescales is a small fraction of the total variability, the theoretical predictability limits are not currently realized due, in part, to limitations in the current generation of statistical and dynamical forecast tools. However, additional improvements in skill can be realized with existing forecast tools by defining objective probabilities, calibrating

existing forecast tools, consolidating the tools, and developing new products. As these products become available, they will be increasingly utilized for regional and sectoral applications (e.g. health, agriculture, energy, urban, coastal, sustainability, human dimensions) and Regional Decision Support (e.g. emergency management NWS/Weather Forecast Offices, Regional Integrated Science and Assessments, Regional Climate Centers).

Partnerships between the NOAA operational centers, the CTB, and intermediaries will be established and enhanced to identify and meet user needs for new and improved climate forecast products. Responsible brokerage of climate forecast products is an important undertaking. CPC should convey product limitations and performance characteristics as a function of region / season / situation. User feedback on product improvements and new products is vital. It behooves NOAA to encourage and facilitate faster improvement of NOAA climate forecast systems, and at the same time to increase the exposure of NOAA climate forecast products linked to application models that extend the utility and scope of NOAA climate services.

The four component efforts above are required as part of a balanced approach to improve ISI climate forecasts, products and applications. If any component is not funded, or funded entirely to the detriment of the others, the loss of the non-supported component(s) will cause the entire interdependent system to fail.

1.5 Programmatic and Science Priorities

In the remainder of the Science Plan the four component efforts identified as NOAA/NCEP requirements for improved climate prediction (Part I, Section 1.4) are referred to as programmatic priorities:

- NOAA/NCEP Climate Forecast System (CFS) Improvements
- Multi-Model Ensemble Prediction System
- Climate Reanalysis – An Ongoing Analysis of the Climate System
- Climate Forecast Products for Decision Support

An examination of the number of CTB projects by programmatic theme (Fig. 5) gives an indication of the current balance of activities on the CTB. A suggested priority ranking for future CTB programmatic and science priorities is given in the implementation strategy (Part I, Section 2). Advice on the relative balance of these activities is welcome.

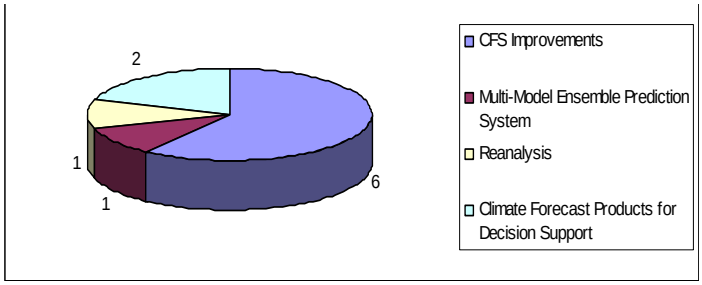

Figure 5. Number of current CTB projects by programmatic theme.

The CTB implementation strategy (Part I, Section 2) is based on a set of Core Projects that include specific science priority areas that contribute to the programmatic themes listed above. The procedures for establishing and focusing CTB science priorities on an annual basis are as follows:

- The CST Co-Chairs, TPT Chairs, and PIs report progress on current CTB activities to CTB Management, the OB, the SAB and the climate community at Annual SAB Meetings (Summer to early Fall);
- The SAB, in consultation with the broader community, evaluates CTB progress and provides expert advice to the CTB on future science priorities (early November);
- CTB Management reviews and responds to SAB advice, and updates the Science Plan and Implementation Strategy (early Winter);
- CTB science priorities are shared with agencies and programs participating in the CTB for use as guidance in annual Announcements of Opportunity as appropriate (late winter).

A list of potential science priority areas that the CTB endorses is given. It is important to emphasize that the CTB is not (and cannot be) active in all of these areas: priorities will be developed and evolve over time as outlined in the implementation strategy.

NOAA/NCEP Climate Forecast System (CFS) Improvements

- Accelerate near-term assessment of potential enhancements to the next generation CFS (ocean model and assimilation; land surface model and assimilation; physics; resolution);
- Seek venues and resources that enable partnerships between NCEP modelers and the research community on future improvements to the GFS and the CFS;
- Develop hardware/software tools and data policy for disseminating climate information on publicly accessible server;
- Develop a standard diagnostics package for CFS assessments (including surface, atmospheric, and oceanic variability);
- Participate in field experiments and work with the various Climate Process Teams to improve CFS physics.

Multi-Model Ensemble Prediction System

- Establish a systematic community based multi-model forecasting capability & infrastructure using National models (NCEP-CFS,GFDL-CM2.1,NASA-GEOS, NCAR-CCSM, others);
- Develop dynamical understanding of trends;
- Systematic predictability studies to establish sources and limits of predictability and skill;

- Develop intraseasonal forecasting capability (improve week 2 skill scores; develop a capability to predict extremes for weeks 2,3,4; develop predictive understanding of the impacts of climate on the statistics of extreme events, including hurricanes);
- Improving Forecasts of Weather – Climate Connection (multi-model Case Study approaches to improved understanding and prediction of extreme events);
- Seek partnerships with other international multi-model programs (e.g. IRI, European Union, APEC).

Climate Reanalysis – An Ongoing Analysis of the Climate System (OACS)

- Develop implementation plans and seek resources for OACS (data archaeology and stewardship; real-time analysis and monitoring; periodic reanalysis; data dissemination; applied research; forecast verification; development of operational statistical models);
- Coordination of reanalysis activities within NOAA (e.g. NCEP, NCDC, CDC), nationally (e.g. NASA, NSF) and internationally (e.g. ESMWF); establish program / project management.

Climate Forecast Products for Decision Support

- Consolidation of multi-method seasonal forecasts at CPC (includes skill masks, objective seasonal forecast tool, and objective verification of extended-range, monthly and seasonal outlooks);
- Establish "Climate Prediction Products and Services Team" to identify, prioritize and meet customer requirements for new and improved climate forecast products (includes verification statistics; improvements to basic predictand products; risks of high-impact weather events in a month or season by ENSO phase);
- Develop regional hydrologic products (includes drought monitoring & prediction capability for NIDIS; Regional Climate Model (RCM) seasonal forecasts; multi-model ensembles for hydrologic forecasts).

2. IMPLEMENTATION STRATEGY

2.1 Core Projects

The CTB Implementation Strategy is centered around 3 "core" projects that align the CTB activities with the above programmatic themes. These are:

Core Project 1: Climate Forecast Products for Decision Support:
Core Project 2: CFS Improvements & Multi-Model Ensemble Prediction System
Core Project 3: Climate Reanalysis – Ongoing Analysis of the Climate System

A rationale for the Core Projects and a brief description of each project are given below.

2.2 Rationale

The CTB Core Projects map onto the CTB NCEP Technical Operating Plans (NTOPs) (see Part II, Section 5.1) to leverage NCEP contributions of human and computing resources. The CTB NTOPs are somewhat broader than the individual Core Projects. In addition, the Core Projects align with the mission requirements, strategy, and performance objectives of the NCPO Predictions and Projections Program. This includes the goals and priorities of the associated Competitive Research Programs (i.e. Climate Dynamics and Experimental Prediction Program (CDEP); Climate Prediction Program for the Americas (CPPA); Climate Variability and Predictability Program (CVP)). As such, the Core Projects will contribute directly to the desired end states of NCEP and the Climate Predictions and Projections Program goal to provide "**A Seamless Suite of Forecasts"** on intraseasonal, seasonal, interannual, and multi-decadal timescales and on regional, national and global spatial scales.

The current set of Core Projects constitutes a near-term implementation strategy. They are based on where we are now, our short term goals and where we want to be in five years. The CTB will continue to rely on the SAB and OB for advice as the implementation strategy evolves to an implementation plan.

In addition to the programmatic alignment, the Core Projects are subject to other constraints:

- **Available resources must be commensurate with the Core Project programmatic and science priorities:**

NOAA/NCEP has made a considerable investment in the institutional framework of the CTB by providing computer resources ($1/3^{rd}$ of the NOAA "Red" research supercomputer) and by realigning 21 FTEs onto the CTB NTOPs. The CTB Core Projects must map onto the CTB, CPC and EMC NTOPs in order to leverage the human and computing resources that are available. Significant new NOAA base resources, beyond those already committed, are unlikely prior to the FY08 budget cycle, so achieving CTB short term programmatic and science goals is highly contingent on the effective use of existing resources.

- **The roles and responsibilities of the host institution and the operational center must be defined:**

The path to implementation of changes in the NCEP operational climate model suite involves a set of Research to Operations (R2O) guidelines (Appendix A) that must be carried out. These guidelines consist of 7 discrete steps that establish the roles and responsibilities of the home research institution, the CTB, EMC, and NCEP Central Operations (NCO) in the transition process. The guidelines involve a significant investment of time and resources for all parties to ensure smooth transitions. Based on work in progress to transition the GFDL model to the multi-model framework, it appears that it will take 1-2 years per model to complete testing, generate hindcasts, and ensure ESMF compliance.

- **Human resources must be accountable to project requirements:**

The CTB Director is a Federal Employee who has supervisory authority over the CPC component of CTB personnel. In particular, the CTB Director provides input to the GWPS workplans of these personnel and participates in annual evaluations - both in proportion to the employee's role in the CTB - from 100% to some smaller percentage. For CTB personnel who have significant commitments outside the CTB, a "matrix management" approach is used to evaluate the employee.

The CTB currently has 1/3rd of the NOAA "Red" research supercomputer. This is a considerable investment of NOAA/NCEP resources. The CTB works with NCEP senior management, and the CST to ensure that this resource is properly managed and utilized. The CST co-chairs prepares quarterly reports that detail the status of CTB experiments and CU usage.

- **Organizations outside NCEP must be engaged:**

Several mechanisms ensure that organizations outside NCEP are engaged in Core Projects:

- Transition Project Teams (TPTs) blend internal and external activities. CTB PIs are required to join a TPT in order to ensure the proper balance (see Part I, Section 2.4).

- A "Climate Prediction Products and Services Team" has been organized to identify and prioritize customer demands for climate forecast products that enhance decision making (Part I, Section 3). The TPTs are engaged in this process through the Core Projects.

- CTB personnel participate in large annual meetings (e.g. AMS, CLIVAR, GEWEX) and topical Workshops to engage the research community.

- The CTB SAB provides independent expert advice on CTB science priorities.

2.3 Project Description and Readiness

A brief description of each of the Core Projects is given below. Each of the projects is required as part of a balanced approach to improve ISI climate forecasts, products and applications. However, it is necessary to consider what we can do now and where we would like to go. For this reason, a priority ranking based on readiness is included. The CTB will continue to seek the advice of the SAB and the broader community as it focuses the implementation strategy into an implementation plan.

Core Project 1. Climate Forecast Products for Decision Support

Recent efforts to develop a consolidated multi-method climate forecast tool (vandenDool, PI) that combines existing statistical and dynamical climate forecasts into a

more skillful climate forecast are a top priority for the CTB. Consolidation of multiple forecasts is necessary for a number of reasons:

- to make the best possible official CPC forecasts out of a number of different forecasts by taking advantage of the independent skill of each forecast tool;
- to assist operational forecasters who cannot absorb all of the available statistical and dynamical forecasts in the available time to formulate the official forecast;
- to incorporate new tools (CFS, multi-model ensembles, others developed by the climate research community) with those already used at CPC; and
- to meet user demands for more skillful climate forecast products used in decision making in a timely manner.

As new forecast tools become available (e.g. next generation CFS; multi-model ensembles; tools developed externally), they are incorporated into the consolidation if they offer independent skill. The CTB Operations to Applications (O2A) guidelines (Appendix B) provide the path for incorporating new tools in the consolidation. External participants interested in contributing a tool to the consolidation must work with the CTB to carry out the O2A guidelines, which includes the generation of hindcasts used to determine the appropriate skill weights used in the consolidation. Specific Core Project 1 activities include carrying out the O2A guidelines for each tool used in the consolidation, and objective verification of the individual forecasts (including the official forecast).

Core Project 1 activities also include developing partnerships between the NOAA operational centers, the CTB, and intermediaries to identify, prioritize and meet user requirements for more skillful climate forecast products used in decision making. For example, CTB, CPC and NWS Climate Services Division have formed a "Climate Prediction Products and Services Team" to develop a "Regional Decision Support Implementation Plan". The team is developing a list of climate forecast products that meet specific user requirements across the broad spectrum of the applications community. The team will identify those products with the greatest "value", develop milestones, and vet priorities in a "white paper" and by holding topical workshops with potential users. The team is also responsible for conveying product limitations & performance characteristics to users. The CTB will engage the TPTs to work closely with intermediaries (e.g. Regional Integrated Science and Assessments program, Regional Climate Centers, International Research Institute, etc.) to develop and deliver new and improved climate forecast products identified in this process.

Regarding readiness, CTB has the framework for the consolidated forecast tool in place, so results flow into CPC operations without difficulty. The tool is clearly in the interests of CPC and the broader climate research and applications communities. Overall, it behooves NOAA to encourage and facilitate faster improvements in the skill of NOAA climate forecast products, and at the same time to increase the exposure of NOAA climate forecast products linked to application models that extend the utility and scope of NOAA climate services. The activities described above can be achieved in the near term for relatively little cost. The payoff is at levels that are many times larger than the investments needed for improving the climate forecast products. The CTB will continue to seek the advice of the SAB on other science priority areas to support this programmatic theme.

Core Project 2. A primary longer-term objective is to continue to increase the skill of NOAA operational climate forecasts by improving the forecast tools. The desired end-state of the Climate Predictions and Projections Program is a "Seamless Suite of Forecasts" (Fig. 3) and applications using ensembles of multiple climate models in support to the mission outcome "*a predictive understanding of the global climate system*." Towards this, CTB Management recommends that the programmatic themes "CFS Improvements" and "Multi-model Ensemble Prediction System" be ranked equally as the second priority for CTB Core Project 2. An overall objective is to accelerate improvements of CFS and other climate models that eliminate bias in simulations and increase the skill of climate forecasts. CTB provisional milestones (Part I, section 5.1) indicate some discrete steps that contribute to the programmatic objective. Coordination of model assessment and development activities for CFS improvements prior to implementation of the next version of CFS is an especially important science priority for the Transition Project Teams (see Part I, Section 2.4). The number of CTB projects by programmatic priority (Fig. 5) indicates that there is currently more emphasis on CFS improvements than on the multi-model ensemble prediction system. The CTB will continue to seek the advice of the SAB on the relative balance of science activities for this Core Project.

Core Project 3. There are numerous benefits of an ongoing analysis program (see Part I, section 1.4 for a list). Several of these benefits contribute directly to Core Projects 1 and 2 above. Thus the CTB Management recommends that "Climate Reanalysis – An Ongoing Analysis of the Climate System" be ranked as Core Project 3. Development of the implementation strategy for OACS and coordination of existing activities within NOAA are two science priority areas where the CTB can play an especially important role.

2.4 Transition Project Teams

The CTB Transition Project Teams (TPTs) are the functional core of the CTB (see Appendix D for TPT Terms of Reference) and hence are central to progress on the CTB Core Projects. The mission of the teams is to provide a mechanism for coordinating and completing CTB activities (including science experiments that require computer resources), and to enhance collaboration between internal and external participants on the CTB. Internal and external participants include CTB personnel, other NCEP employees, other NOAA employees, contractors, external PIs from competitive research programs, and members of the user community. CTB PIs are required to join a TPT in order to ensure that their activities are included, especially when computing resources are involved.

Each TPT has a chair, who has been appointed to lead the team and to report progress to the CTB management and the CTB Climate Science Team (see Appendix D for CST Terms of Reference) as necessary. The bulk of CTB personnel (19 of 21 FTEs as of this writing) are focused on TPT activities (see Part I, Section 2.4). Thus, the TPTs play a central role and are organized as a core activity for the CTB.

Seven TPTs have been organized under 3 of the 4 programmatic priorities:

NOAA/NCEP Climate Forecast System Improvements:

- Model Parameterization Team;
- Model Sensitivity Team;
- Assessment Team;
- Ocean Data Assimilation Team;
- Land Data Assimilation Team;

Multi-Model Ensemble Prediction System

- Multi Model Ensembles Team

Climate Forecast Products for Decision Support

- Climate Prediction Products and Services Team

Some of the teams straddle more than one programmatic priority (e.g. the Land Data Assimilation Team); in these cases the primary linkage to the programmatic priorities is indicated.

It is important to emphasize, that the TPTs will naturally evolve to reflect the balance of internal (base funded) and competitive (AO-driven) activities on the CTB. As a consequence, TPTs can be combined, expanded or eliminated to align with CTB programmatic and science priorities. As the CTB continues to focus its activities and manpower, commensurate with resources, the TPTs will adjust. Adjustments under consideration in the near term include combining the parameterization, sensitivity and assessment teams under programmatic priority 1 and adding a Reanalysis team.

Considerable effort has been made to ensure that CTB personnel on the TPTs are carrying out unique CTB projects, not EMC model development work or CPC operational product development or forecasting activities. The CTB primary functions, to accelerate improvements in the number and skill of climate forecast products, are uniquely CTB. The CTB has its own Annual Operating Plan (see Part II, Section 5), in which NCEP human resources devoted to the CTB have been mapped onto NCEP Technical Operating Plans (NTOPs) to avoid duplication with other NCEP center activities. These plans are reviewed by NCEP senior management to ensure efficient use of limited resources. Through its participation in this process, the CTB has fostered many new joint activities between NCEP centers (e.g. transition projects, meetings, and milestones) that would not have occurred without the CTB.

How TPT projects are selected, ranked and completed:

On an annual basis, each TPT chair is asked to prepare a team-wide list of planned projects or activities keyed to science priorities, with scientific justification, computational requirements, expected impact on operations, and milestones. The TPT chairs ensure that all CTB-related transition projects are represented to cover the range of ISI prediction issues and product development of interest to the CTB. Because the TPT

membership includes both internal and external CTB participants, the set of activities naturally and accurately reflects the collection of CTB transition projects at any given time. The activities that have been undertaken by the TPTs in FY06 are summarized in Table 1. As of this writing (January 2006) the track record of the TPTs remains limited, as the first set of CDEP/CTB competitive transition projects has just been funded.

The CST collects the requested information from the TPT team chairs and uses teleconferences and e-mail correspondence to prioritize experiments based on relevance to CTB objectives and availability of CTB computer resources. The CST ensures that competing requirements (e.g. increased model complexity and/or resolution and/or ensemble size) are properly weighed. However, in cases where difficulties arise, the CTB Oversight Board has the final word. The above process is carried out each fiscal year after new CTB competitive transition projects come on board. The CST co-chairs work with the TPT chairs to ensure that experiments are completed. The procedures for initiating CTB collaborative transition projects are discussed in Part II, Section 4.

TPT chairs are also required to provide an Annual Progress Report to the CST Co-Chairs (usually in summer or early fall) that summarizes progress on experiments, computer usage, and expected impact on climate forecast operations. This information is reported by the CST co-chairs at the Annual SAB Meeting and reviewed by the SAB.

FY07 Plans:

In order to make progress on the CTB Core Projects, CTB Management will implement the following changes to the TPT's and the NCEP Technical Operating Plan (NTOP's) (see Part II, section 5.1) during FY07:

TPTs:

- Consolidate the Model Parameterization, Model Sensitivity and Assessment Teams into one team to promote coordination and acceleration of assessment and development activities aimed at next generation CFS;
- Promote joint participation of CTB, CPC and EMC personnel in climate meetings held in the respective centers;
- Form a TPT for Reanalysis.

NTOPs:

- Reallocate several CTB FTE's from Climate Model Improvements (NTOP 18) to Climate Forecast Products for Decision Support (NTOP 20).
- Accelerate development and delivery of new and improved climate forecast products for decision making as identified by the Climate Prediction Products and Services Team (see Part I, Section 3.0) .
- Develop joint CTB, CPC, EMC milestones that map onto the CTB NTOPs and Core Projects.

3.0 SCIENTIFIC PARTNERSHIPS

To be successful, the CTB must continually enhance partnerships with the research and applications communities. Both the internal (NOAA) and external research communities must be involved through bi-directional flow of climate information and opportunities to influence the CTB decision-making process. The CTB must engage the applications community to meet demands for new and improved climate forecast products that enhance decision making. It is self-evident that the improved climate forecast products generated by the CTB must be of practical value. Thus, it is essential that the stakeholder community be engaged and permitted to develop a sense of ownership of CTB. In addition, the private sector and the international research community have a lot to offer the CTB by way of partnerships and information gathering and sharing. The CTB will endeavor to enhance these relationships, for example by broadening SAB membership to include these communities.

Some specific activities and programs with established and/or strengthening relationships with partners include:

- *University of Maryland M-Square Campus*

In early 2008 the CTB facility will be moving along with NCEP to the NOAA Center for Weather and Climate Prediction at the University of Maryland's M-Square campus in College Park in early 2008. In addition to the NOAA Center, a second building immediately adjacent to the NOAA building will house the Earth System Science Interdisciplinary Center (ESSIC), the Cooperative Institute for Climate Studies (CICS), the DOE Joint Global Change Research Institute, personnel from the NASA/Goddard Modeling and Assimilation Office, and possibly others. As stated in a recent white paper, this combination of climate researchers will establish the M-Square campus as a "National Center of Excellence for Environmental Research, Education, Applications and Operations". The CTB welcomes this opportunity to work closely with this world class team of scientists.

- *Climate Prediction Products and Services Team*

CPC, CTB and NWS Climate Services Division have formed a "Climate Prediction Products and Services Team" to develop a Regional Decision Support Plan. The objective is to identify, prioritize and meet user demands for new and improved climate forecast products. Responsible brokerage of climate forecast products is an important team activity. CPC will convey product limitations and performance characteristics as a function of region / season / situation. User feedback on product improvements and new products is vital. The team is developing an initial list of climate forecast products that meet specific user needs. The team will identify those products with the greatest "value", develop milestones, and vet priorities in topical workshops and a "white paper". The CTB will engage the TPTs to work closely with intermediaries (e.g. Regional Integrated Science and Assessments program, Regional Climate Centers, International Research Institute, etc.) to develop and deliver new and improved products.

- *NCPO Competitive Research Programs*

The NOAA Office of Global Programs (OGP) Climate and Global Change (C&GC) Program contributes to evolving national and international programs designed to improve our ability to observe, understand, predict, and respond to changes in the global environment. This program builds on NOAA's mission requirements and long-standing capabilities in global change research and prediction. Several of the C&GC Program elements are strongly linked to the CTB mission and science priorities, including the Climate Dynamics and Experimental Prediction (CDEP) Program, the Climate Prediction Program for the Americas (CPPA), and the Climate Variability and Predictability (CLIVAR) Program. Details on these and other components of the C&GC Program are found on the OGP website (www.ogp.noaa.gov).

- *Relationships to other NOAA Centers and Testbeds*

The NASA-NOAA-DOD Joint Center for Satellite Data Assimilation (JCSDA) has considerable expertise and infrastructure in several areas of interest to the CTB, including atmosphere, ocean, land surface data assimilation, and the use of satellite data in support of climate applications, reanalysis, and the global observing system. The CTB will collaborate with the JCSDA to develop improved data assimilation techniques for CTB applications. Common software will be maintained jointly between the JCSDA and CTB, with the JCSDA focusing on the data assimilation modules 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.

The NOAA Hydrometeorological Testbed (HMT) will accelerate the implementation of operational hydrometeorological products and services, including enhancing and extending forecast skill for high-impact weather, especially precipitation, by facilitating interactions among researchers and operational forecasters. The CTB will collaborate with the HMT in several areas, especially improved warm season precipitation forecasts, use of ensemble model output and forecaster generation of probabilistic products, and improved operational monitoring and prediction of weather–climate linkages. With advancements in land surface modeling, the hydrometeorological community has also made considerable progress in streamflow prediction, drought monitoring, and anticipating extreme events. The CTB will endeavor to use the CFS forecasts to enhance hydrometeorological applications. The CTB will work together with the OHD, NCTP, and the broader research community to develop these applications for end users.

A number of other test beds with themes relevant to the CTB will have ongoing parallel activity. It is important that the CTB Management work closely with other test bed directors and advocate projects that may have a direct bearing on the climate forecast problem. The Joint Hurricane Test Bed is expected to coordinate its activities with those of other NOAA centers such as the NOAA Labs and Cooperative Institutes, NCAR and NASA. Experience gained and advanced at other climate research and development centers should be shared to the mutual benefit of improving climate forecast products.

- *National and International Climate Programs and Panels*

The CTB has strong linkages to several national and international CLIVAR, GEWEX and joint CLIVAR-GEWEX Programs, including the Variability of the American Monsoons (VAMOS) Program, the North American Monsoon Experiment (NAME), Monsoon Experiment South America (MESA), VAMOS Ocean Cloud Atmosphere Land Study (VOCALS), and the Coordinated Enhanced Observing Period (CEOP). Linkages with these and other programs are expected to continue to intensify as the CTB ramps up over the next several years.

The CTB is closely related in concept to the CLIVAR Climate Process and modeling Teams (CPTs), which bring observationalists together with climate and process modelers to focus on key problems in climate models. The CTB priority of accelerating improvements in NOAA climate forecast models and reducing biases in NOAA climate model simulations and forecasts can be considered as the NOAA implementation of the CPT concept. Linkages to existing CPT-like efforts at NCEP (e.g. the NAME CPT; the GAPP Core Project CPT for land) are likely to be enhanced in the future.

CTB Personnel are also members of various CLIVAR and GEWEX Panels, both in the US and internationally, including the US CLIVAR Predictions Predictability and Applications Interface (PPAI) Panel, the Climate Prediction Program for the Americas (CPPA) Science Panel, and the international CLIVAR VAMOS Panel. As one measure of the importance of these linkages for the CTB, the CTB Director is currently serving as co-chair of the CLIVAR VAMOS Panel, and Chair of the NAME Science Working Group (SWG).

The CTB welcomes the convergence of weather and climate research and forecasting activities proposed by COPES/THORPEX. These activities will accelerate NCEP's ability to deliver products that link weather and climate information (e.g. ENSO influence on the frequency and intensity of Nor'easters, severe weather outbreaks, beach erosion; AO/NAO influence on winter precipitation and temperature extremes in the eastern US) using the NCEP GFS, NCEP CFS and other Earth system models within the framework of a multi-model ensemble prediction system. These products will help meet demands for new and improved regional and sectoral applications of weather and climate forecast products that enhance decision making.

- *Earth System Modeling Framework (ESMF)*

NOAA is migrating to a software framework provided by the Earth System Modeling Framework (ESMF). ESMF is a structured collection of software building blocks that can be used or customized to develop Earth system model components, and assemble them into applications. The simplest view of the ESMF is that it consists of an *infrastructure* of utilities and data structures for creating model components, and a *superstructure* for coupling them. In order to be consistent and relevant to NOAA's future software framework, which will itself accelerate the ability to support a multi-model ensemble forecast capability, the CTB will support CFS components within the ESMF and promote the introduction of other system components such as the GFDL/CM2.1, NASA/GEOS and NCAR/CCSM global coupled models.

- *International Polar Year (IPY)*

The International Polar Year (IPY) 2007-2008 will be an intense, internationally coordinated campaign of polar observations, research, and analysis that will further our understanding of physical and social processes in the polar regions, examine their globally-connected role in the climate system, and establish research infrastructure for the future. The CTB will establish strong linkages to IPY scientific activities, including Arctic Reanalysis and the development and verification of Arctic climate forecasts, in order to ensure maximum impact on NOAA climate forecasts.

3.1 Grand Challenges

As part of the climate, weather, and water planning process, NOAA/ NWS has identified a set of "Challenges for Science-based Climate Information Services". These challenges are stated briefly below:

- **Climate Prediction**

Grand challenges: (1) To increase the skill of ISI climate forecasts based on both statistical and dynamical tools; (2) To identify performance (skill) measures that are useful for decision makers, and that are not penalized or boosted by natural variability.

Known dependence: (1) Boundary conditions (SST anomalies; soil moisture; snowpack); (2) Atmospheric initialization especially in the tropics and stratosphere; (3) Model improvements (Grand Challenge 2); (4) CO_2 and other trace gases

Ongoing Research Areas: (1) Monitoring, assessment and prediction of the leading patterns of intraseasonal *(*MJO; AO/NAO), interannual (ENSO) and decadal (PDO) variability; (2) Warm season precipitation prediction; (3) Linkages between weather extremes, climate variability and long-term trends; (4) Relative influence of oceanic and land surface boundary forcing; (5) Stratosphere - troposphere interactions; (6) Multi-model ensembles (including consolidation techniques and objective verification).

- **Climate Modeling**

Grand challenge: Eliminate biases and improve simulations and forecasts of the leading patterns of variability in coupled models.

Known Dependence: (1) Missing physics - thermal dynamic and dynamic sea ice; stratospheric chemistry and transport; cloud physics important to the MJO; (2) Problematic physics - clouds and radiation (lower stratus deck); topography; gravity waves; (3) Model dynamics – sigma vs. hybrid vertical coordinates; vertical and horizontal resolution; (4) Coupling issues (L-O-A-I)

On-going Research Areas: (1) Process modeling; Climate Process and modeling Teams (CPTs); (2) Model initialization; (3) Land surface model – atmosphere coupling.

- **Climate Data**

Grand challenge: Reduce eliminate climate data discontinuities / inhomogeneities

Known dependence: (1) Deploy new instruments (radiosondes, satellites, buoys…); (2) Assimilate new data types in data assimilation systems (L-O-A-I).

On-going Research Areas: (1) Continuity – e.g. radiosonde replacement; (2) Data mining / recovery; (3) Data assimilation; (4) Observing System Simulation Experiments (OSSE); (5) Reanalysis – Ongoing Analysis of the Climate System

- **Climate and Hydrology**

Grand challenge: Define and implement a strategy for meeting the goals of the National Integrated Drought Information System (NIDIS)

On-going Research Areas: (1) Hydrologic Ensemble Prediction Experiment (HEPEX); (2) Drought monitoring, assessment and prediction; (3) Precipitation and soil moisture analysis; (4) Land data assimilation.

- **Climate Variability and Weather Extremes**

Grand challenge: Improve understanding and prediction of weather-climate linkages (links between weather extremes, climate variability, and climate change), including hurricanes, tornados and winter storms.

- **Regional Decision Support**

On-going Research Areas: (1) Downscaling - dynamical, statistical; (2) Regional modeling; (3) Regional Reanalysis; (4) Regional and sectoral products (e.g. energy, agriculture, health, water resources, human dimensions).

The grandest challenge for the CTB is "making it all useful." The success of the CTB will depend on the efficiency of the process CTB develops for transition of research to operations, and the degree of "buy in" from the non-NOAA participants in making this happen.

Future of the CTB:

The CTB is currently focused largely on the skill of ISI precipitation and temperature forecasts. In the future, we envision a much broader role for the CTB that takes advantage of Earth system models with advanced forecast capabilities (e.g. ecosystems, air chemistry, fisheries, etc.). The CTB could be housed at NCPO, with components in each of the participating line offices (e.g. NWS, NESDIS, etc). The NOAA Matrix Management approach would work well, with a Director at NCPO and Deputy Directors

in each of the participating line offices. The benefits to NOAA in terms of improved climate products and services would be at levels that are many times larger than the investments needed to develop these capabilities.

4.0 TECHNOLOGY TRANSFER

NOAA is working on a "Research to Operations Policy" that includes an overarching view of NOAA's research and development, a better understanding of how to apportion resource allocations, and operational and life-cycle support for research items transitioned to operations (Fig. 6). The NCEP service delivery "Concept of Operations" to provide "*A Seamless Suite of Forecasts*" (Fig. 3) is consistent with the NOAA Research to Operations Policy.

NCEP is uniquely positioned to provide an operational infrastructure for the model transition process. EMC and NCO have critical roles in the transition from NOAA R&D to operations (Fig. 7), while CPC is one of several service centers that deliver products to users. Defining responsibilities and providing resources for the host research institution, the operational center, and the applications community are required to ensure smooth transitions. A fundamental role of the CTB is to identify and delineate the different types of transition (Part I, Section 4.1) whose guidelines must be systematic (Part I, Section 4.2). The transition process also requires a comprehensive data policy for NCEP climate data sets (Part I, Section 4.3) to enhance collaboration and joint projects between internal and external participants on the CTB. The CTB relies on traditional formal and semi-formal scientific vehicles for communicating interim and final results (Part I, Section 4.4).

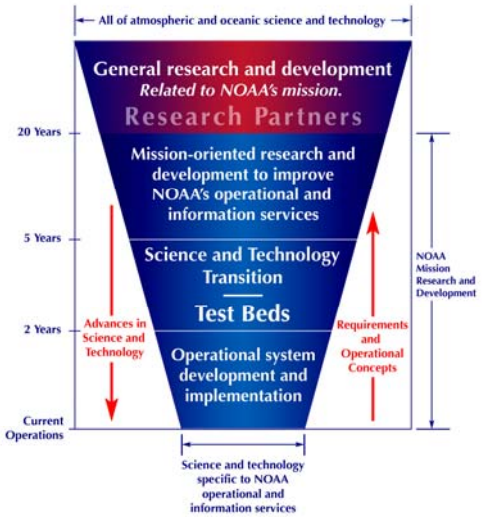

Figure 6. NOAA's Research and Development Policy "funnel".

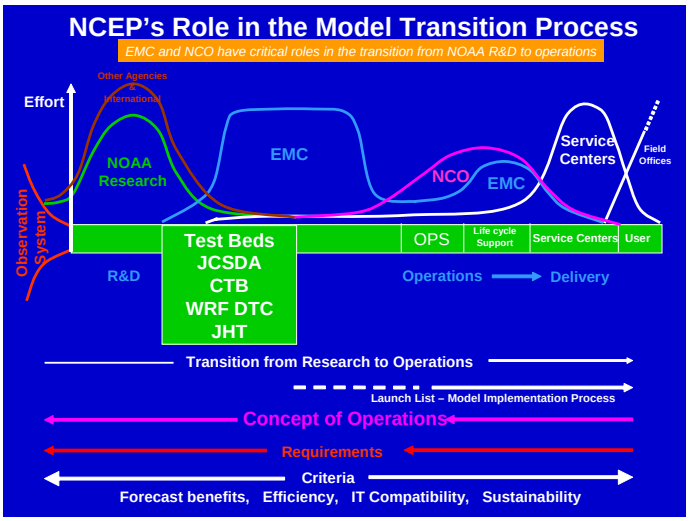

Figure 7. NCEP's role in the model transition process.

4.1 Types of Transition

To accelerate improvements and applications of NOAA climate forecast products, the CTB must define a process to clearly identify and communicate the scope of responsibilities for the climate research community, the NOAA operational centers, and the applications community. In particular, it must clearly define the different types of transition:

> *Research to Operations:* define where the operational center picks up responsibility, and at what juncture a "hand-off" from the research community occurs (see Appendix A).
>
> *Operations to Applications:* define where the applications community picks up responsibility, and at what juncture a "hand-off" from the operations community occurs (see Appendix B).

It is important to recognize that transitions work in both directions. The transition of research to the applications community, and user feedback proceeds via the R2O and O2A transition steps.

4.2 Transition Guidelines

The CTB has established "Research to Operations (R2O) Guidelines" (see Appendix A) that specify the path to implementation of changes in the NCEP operational climate model suite. Procedures for testing changes in parameterizations in the NCEP GFS/CFS are given at the end of Appendix B. The CTB has also established some "Operations to Applications (O2A) Guidelines" that specify the steps for operational tools to be

consolidated into the CPC seasonal forecasts and the steps for delivery of models, tools and datasets to a diverse user community (see Appendix B). Collectively, these guidelines establish the roles and responsibilities of the host research institutions, the operational center, and the applications communities.

4.3 Data Policy and Access

The NCEP/CTB Climate Data Policy for access to operational and non-operational climate data sets is given in Part II, Section 4.4. The policy applies to all climate data sets produced by NCEP.

Dissemination and archiving of CTB climate data sets is 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. One of the CTBs early successes has been to provide a complete CFS hindcast data set, including daily resolution for selected fields and monthly means for the entire set of variables and levels. In the future the CTB will avail itself of other avenues for providing online access. There needs to be an open process for determining when and how best to share data from CTB activities, including the nature of the data sets to be shared (output frequency, variables, etc.), the requirement and allocation of resources for quality control of research data sets, and how data sets generated outside NCEP are to be handled. The NCEP/CTB Data Policy for climate data sets will continue to be improved as part of this process.

4.4 Communicating Results

Results from CTB Transition Projects are disseminated in a number of ways. During the initial stages, CTB scientists often present preliminary ideas and results at internal meetings with NCEP colleagues and TPT members. The collocation of EMC, CPC and CTB at NCEP, as well as the collocation of NOAA, NASA, U Md COLA, and GMU greatly facilitates these types of interactions. The CTB also relies on traditional informal and semi-formal scientific vehicles for communicating interim and final scientific results with NOAA and the broader scientific community. These include:

- ***Seminars*** – CTB scientists are frequent participants in the regular NCEP CPC and EMC seminar series and in seminars elsewhere (e.g. COLA, CICS, ESSIC, etc).
- ***Informal Publication*** – CTB personnel contribute to a wide range of scientific newsletters, such as CLIVAR Variations, the VAMOS Newsletter and GEWEX News. Over the past 2 years the intention has been to inform the community about the CTB. In the future we anticipate that this will be a vehicle for communicating immediate results (including availability of models and datasets) to the broad scientific community.
- ***Reports*** – CTB reports on each of its projects on an annual basis by collecting information from the TPTs and PIs. Starting in FY07 the CTB Management will also provide Annual Reports that summarize important developments and research results during the preceding year.

- ***Atlases*** – From time to time, the CTB produces compendiums of multi-year data sets (such as CFS hindcasts) that make intercomparisons and assessments of model improvements more convenient.
- ***Formal Publications*** – CTB personnel place a high priority on publications in refereed journals. A list of recent publications will be included in the next draft of the SP&IS.
- ***Workshops*** – The CTB participates in the Annual Climate Diagnostics and Prediction Workshop, with several sessions dedicated to reporting the results of CTB science activities. In addition, the CTB holds annual SAB meetings to discuss CTB progress and request advice on future science priorities. The CTB Director organizes the annual VAMOS Panel Meeting, which includes frequent reports on CTB progress and plans. In the future the CTB will hold annual PI meetings, either as stand alone meetings or in conjunction with other NCPO competitive research programs. Also, CTB personnel are increasing their participation in large annual meetings and topical workshops aimed at enhancing communication between producers and users of climate forecast products.

Although NOAA communicates its programmatic interests to the CTB in numerous ways (e.g. NOAA Strategic Plan, Annual Guidance Memorandum, Five Year Research Plan, 20 Year Research Vision, other planning documents created by NOAA line offices), the CTB continues to search for methods that enhance communication with NOAA scientific partners. Annual "NCPO-NCEP Dialogue meetings" (since 2004) have been effective vehicles for communicating priorities and developing strategies for improved ISI predictions. The "Climate Prediction Products and Services Team" (Part I, Section 3.0) is another example where success is anticipated. The CTB Management seeks other avenues that enhance CTB awareness of NOAA and community wide research priorities.

5.0 PROGRESS ASSESSMENT

Criteria used to measure progress in accomplishing CTB objectives:

Internal evaluation of CTB progress is done in two ways: through the annual evaluation of individual scientists by the CTB Director and through the periodic meetings of CTB Management, OB and SAB. The assessment of success of individual scientists is based on completion of items in individual GWPS workplans that contribute to the CTB mission. Contributions to the CTB Core Projects and collaboration with the external community are important components. In addition, the evaluation is based on other, more traditional measures, including publication of scientific results in peer-reviewed journals, and success in proposing research to operations tasks to NOAA and other funding institutions.

Though the CTB is new, the rapid increase in the number of CTB projects (Appendix C) and CTB-related publications (not shown) indicates the level of enthusiasm for the CTB concept as well as the increasing diversity and volume of our scientific work. Many of the projects have non-NOAA colleagues as PIs, which demonstrates the early success

of the CTB. Many of these collaborations will accelerate improvements in NOAA operational climate activities.

The Terms of Reference for the CTB OB are given in Appendix D. One of their functions is to review and approve the research and development themes and priorities of the CTB. CTB management prepares an Annual Report that summarizes CTB activities during the preceding fiscal year to facilitate this.

Another criterion used to measure CTB success is contributions to the NOAA mission. Key expected results from CTB transition projects are selected and defined based on their potential to contribute to NOAA Goals. The links to the objectives include a set of discrete steps, or milestones (Part I, Section 5.1), for achieving these improvements.

5.1 Milestones

The current set of CTB provisional milestones for FY06-FY10 are tied to the CTB Core Projects:

FY06: Complete availability of twice-daily CFS hindcast data on publicly accessible Server;
FY06: Set up GFDL S/I hindcast system on NCEP computer and begin to test reproducibility of data compared to runs on GFDL computer;
FY06: Upgrade the seasonal forecast consolidation tool to improve its use independent of skill information;
FY07: Make accelerated progress on developing and implementing the next version of the NCEP CFS/GFS;
FY07: Develop a prioritized list of products that meets specific user needs;
FY08: Complete experimental testing of tier-1 multi-model ensemble forecast system (NCEP+GFDL);
FY09: Implement operational drought monitoring and seasonal prediction capability for NIDIS;
FY09: Transition CCSM (NCAR) model to CTB;
FY09: Transition NASA (GEOS) model to CTB;
FY10: Complete experimental testing of tier-1 multi-model ensemble forecast system (NCEP+GFDL+NCAR+NASA).

The milestones above are from selected activities, and hence do not cover all CTB Transition Projects. The milestones are updated on an annual basis as part of the NCEP Annual Operating Plan (Part II, Section 5). Progress on CTB milestones is reported each quarter to NCEP management.

5.2 Performance Objectives

The CTB will be a major factor in increasing the number and skill of climate forecast products for the NOAA Climate Program. The effectiveness of the CTB will be judged, in part, through its contributions to NOAA performance measures. Some background on one of these measures for the NOAA Climate Predictions and Projections Program (i.e.

improvement in climate predictive skill over a range of time scales) is given in Appendix E. Another performance objective, in the Climate Decision Support Program, is to "increase the number and use of climate products and services to enhance public and private decision making". The CTB contributions will be linked to the expected results of CTB transition projects in its Annual Operating Plan (Part II, Section 5).

5.3 Expected Outcome

The CTB will contribute directly to the NOAA Goal to "Understand climate variability and change to enhance society's ability to plan and respond". Specific CTB contributions to the desired end state will include:

- New and improved data sets and components for NOAA operational climate forecast systems;
- New and improved tools and methods to provide more skillful climate forecasts;
- Greater understanding of operational model strengths/weaknesses via assessment and detailed analyses of model diagnostics;
- Enhanced use of climate observations for new and improved climate forecast products;
- New and improved climate forecast products for use in decision making;
- Evaluation and refined requirements for global observing systems.

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PART II. MANAGEMENT AND OPERATIONS PLAN

1.0 FRAMEWORK

The CTB framework consists of infrastructure, internal (base funded) transition projects, and competitive (AO-driven) transition projects focused on key science priority areas (see Part I, section 1.4) A balance among the three categories that make up this framework is essential to ensure the overall success of the CTB.

1.1 Infrastructure

The CTB infrastructure includes computing resources, management and administrative staff, Transition Project Teams (TPTs), system support team, and a Visiting Scientist program (detailed Terms of Reference are given in Appendix D). CTB infrastructure will support the exchange of climate models and data with the external community. Augmentation funding for system support is required to facilitate these exchanges. The CTB infrastructure will support a capability for generating and producing multi-model ensembles (subject to the CTB transition guidelines given in Appendices B and C). The CTB will support and maintain Earth System Modeling Framework (ESMF) compatible software for global coupled models participating on the CTB. The CTB will support outreach, through the applications community, for the purpose of increasing the number and skill of climate forecast products for decision makers.

CTB computing support includes 1/3rd of the NOAA "Red" research supercomputer cluster. If one unit is the CPU time for a 10 year run of the fully coupled CFS run at a resolution of T126L64 (this is a higher resolution than the current operational model, which is run at T64L28), then this resource is equivalent to 120 units or 120 / 10 year runs per Fiscal Year.

NCEP contributions to the CTB include 21 Full Time Equivalent (FTE) employees for the management and administrative staff (1.6 FTEs), and TPTs (19 FTEs) which includes both system support and science personnel. TPT science projects make up the CTB Annual Operating Plan (Part II, Section 5) which is part of the NCEP Technical Operating Plan to avoid duplication of effort with other NCEP centers. Since 2004 the NCPO has provided augmentation funding for 1 additional system support staff person (to prepare and disseminate CFS hindcasts).

NCPO competitive research programs provide a venue for scientists in the external research community to work with CTB personnel on NCEP climate models, including the CFS, climate forecasts, products and applications. While the bulk of the computing resources are supplied by NCEP, there is limited manpower to provide system support to the external community (e.g. to transfer models and data and to maintain computing infrastructure). CTB relies on augmentation funding for this. CTB transition projects are carried out by the TPTs, PIs participating in competitive research programs, and their NCEP sponsors (when appropriate). Grants may support contractors and Visiting Scientists. Terms of Reference for CTB teams and the Visiting Scientist Program are given in Appendix D.

1.2 Transition Projects

The scientific work in the CTB is accomplished via collaborative transition projects, which include both internal "base" funded activities and competitive research programs (Announcements of Opportunity). Base funded projects will generally be *short-term* activities, with potential for direct impact on NOAA climate forecasts, products and applications in 2 years or less. They are generally accomplished using reallocated FTEs from NCEP and other line offices. These projects have definite outcomes and lifecycles. They are selected by CTB management in consultation with NCEP senior management. Competitive Annual Announcements of Opportunity (AOs) for the CTB support *long-term* competitive transition projects, with potential for impact on NOAA climate forecasts, products and applications in 2 or more years. NCPO will undertake administrative tasks. These projects can include NOAA or external lead PIs. The procedures to identify competitive transition projects are discussed in Part II, Section 4. Proposal selection and peer review will be managed by NCPO. If other agencies contribute, their input is considered in the selection process.

1.3 Facility

The CTB facility is currently located at the NOAA Science Center in Camp Springs, MD. The CTB has a dedicated physical space and computer facilities. In early 2008 the CTB will be moving along with NCEP to the NOAA Center for Weather and Climate Prediction at the University of Maryland's M-Square campus in College Park, MD. At that facility the CTB will also have dedicated physical space for CTB personnel, and computing facilities. Whereas a core of researchers, contractors, visiting scientists and a small administrative staff will be housed at the CTB, other researchers and their associated contractors and focal points may be distributed both geographically and organizationally.

1.4 Organization

The CTB includes a Director, a Deputy Director for Administration, a Deputy Director for Transition to Operations, an Oversight Board (OB), a Program Manager, an Administrative Staff, a Climate Science Team (CST), Transition Project Teams (TPTs), a System Support Team, and a Visiting Scientist Program. CTB Personnel include civil servants, contractors, visiting scientists and students. An external Science Advisory Board (SAB) provides scientific advice and reviews CTB activities annually. A schematic of the CTB organization and Terms of Reference for CTB management, boards and teams are found in Appendix D.

2.0 STAFF

Since CTB is not formally an administrative element of NCEP, identification of CTB staff is subject to some ambiguity. The CTB Director, Deputy Directors and Program Manager are considered to be CTB staff. In addition, NCEP employees and contractors who work on CTB NTOPs (see Part II, Section 5.1) or who are supported by CTB grants

are considered to be CTB staff. Any students, visiting scientists, or non-NCEP employees who are supported by a CTB grant are also considered to be CTB staff. External PIs who participate on the CTB, but who are not paid by their grants, are not considered to be CTB staff for counting purposes.

The Director, Dr. Wayne Higgins, Deputy Director for Administration, Dr. Mel Gelman, Deputy Director for Transition to Operations, Hualu Pan are all half time CTB staff members (1.6 FTEs). Currently, there is no CTB Administrative staff (this is an important issue). In addition, there are 19 FTEs serving on the TPTs (both federal and contract employees), which includes both system support and science personnel. Many of the TPT and system support team members work part time on the CTB and part time on other NCEP tasks, so the number of personnel involved in CTB-related transition projects is somewhat larger than the numbers indicated above.

3.0 FUNDING

The CTB has attracted new funding for transition projects via competitive research programs managed by the NOAA Climate Program Office (NCPO). The funding profile for these projects since 2004 is as follows: $100K in FY04; $300K in FY05; $450K in FY06. In addition, there are several CTB-related projects (totaling $500K) funded by the NCPO Climate Prediction Program for the Americas (CPPA) that are aligned with CTB science priorities.

4.0 COMPETITIVE TRANSITION PROJECTS

4.1 Initiation Procedure

CTB Programmatic and Science Priorities are identified using the procedures discussed in Part I, Section 1.5. These priorities are provided to agencies participating in the CTB to be used as guidance in preparing Announcements of Opportunity (AOs) for competitive transition projects. CTB AOs will also indicate how much computer time (total for all proposals) is available under that announcement, so that PIs will have an indication of what they can potentially request.

CTB competitive (AO-driven) projects go through the normal merit review process. This begins with the submission of a Letter of Intent to the Program Manager. The Program Manager, in consultation with CTB Management, identifies LOIs that fit CTB Science Priorities and contacts the PI to encourage or discourage a full proposal.

The CTB Program Manager conducts the merit review process, and makes funding decisions in consultation with the CTB Management. A “Computer Resource Request” must be submitted to the CST co-chairs at the time of proposal submission, to be taken into account as part of the proposal resource evaluation (see Part II, Section 4.2).

If a proposal is recommended for funding, and obtains the required CTB computer resources, then the proposal is funded.

4.2 Computer Resources Request

Final approval of a proposal depends on both the merit review and on the availability of computer resources. A “Computer Resource Request” must be submitted to the CST

co-chairs at the time of proposal submission. The required elements of the "Computer Resource Request" are:

- Name and contact information for PIs;
- The CTB Transition Project Team (TPT) and contact person at NCEP;
- A brief (200 words or less) description of the project;
- A brief (200 words or less) description of computer experiments;
- A justification for CTB computer resources;
- Specific computer time request (one unit=CPU time for a 10 year CFS (CMIP) run at T126L64; at present CTB has 120 units per Fiscal Year)

Once a proposal has been selected based on merit (Part II, Section 4.1), the CST Co-Chairs convene a panel made up of non-conflicted members of the CST as well as independent scientists. The panel determines the allocation of computer time based on available resources (but NOT based on a proposals scientific objectives). The evaluation of CTB science objectives and priorities will have taken place as part of the merit review process (Part II, Section 4.1).

Panel recommendations are forwarded to the CTB Management (including CTB Program Manager(s) and the OB for final approval (generally no later than 1 November each Fiscal Year). The CST Co-Chairs oversee progress of the TPTs, which carry out the experiments and provide Annual Reports to the CST and CTB Management. CTB SAB meetings, Special Sessions (e.g. as part of the Climate Diagnostics and Prediction Workshop) and PI meetings (future) are used to report progress on TPT Experiments and CTB Projects (Part II, Section 5.4).

4.3 Computer Access

The computer resource request procedure (Part II, Section 4.2) is the basis for allocation of CTB computing resources for CTB projects. The procedures meet with the approval of the OB and adhere to NCEP guidelines. NCEP/NCO will provide management of the computing resources (user access, accounting, etc) according to established NCEP policies. An NCEP Computing Resource Board, consisting of the NCEP/NCO Director, the NOAA Environmental Modeling program manager, the NCEP/EMC Director, and the NCEP/CPC Director, enforces NCEP computing resource policies, including those of the CTB.

4.4 Data Policy and Access

The NCEP/CTB Climate Data Policy for access to operational and non-operational climate data sets is as follows:

- All climate data sets produced by NCEP on NCEP computers are public property;
- Climate data sets produced by NCEP Central Operations are available on operational servers and maintained 24/7;

- Climate data sets produced by EMC, CPC and CTB competitive transition projects will be made available on request, on non-operational servers during regular business hours (8/5);
- Requests for climate data sets should be in writing to CTB Management (Director or Deputy Director). Once per month the CTB Management summarizes requests for climate data sets and seeks advice for filling requests from the individual Center Directors;
- EMC, CPC and CTB will make non-operational datasets available as quickly as possible, but users should expect a turnaround of 90 days or more depending on the availability of human and computer resources;
- If resources are an issue, and longer turn around time is necessary, the CTB will promptly inform the requester of any delays;
- Because storage for non-operational datasets is limited, each non-operational data set will be available for three months before it is removed;
- A list of CTB projects and investigators will be maintained by the CTB management;
- During the initial data analysis period (6 months after the data were produced), no data produced by CTB competitive transition projects will be provided to a third party (journal articles, presentations, research proposals, other investigators) without the consent of the investigator who produced the data. This initial analysis period is designed to provide an opportunity to adequately quality control the data set.

  The CTB data policy applies to all climate information provided by CTB.

4.5 Conflicts of Interest

Conflict of interest is a very serious concern of the CTB. The Terms of Reference for the CTB management and the various CTB boards and teams (Appendix D) are chosen to minimize potential conflicts of interest.

The CTB Management (Director, Deputy Directors and Program Manager) and CST co-chairs may not submit CTB proposals to competitive research programs. However, the SAB and the OB may submit proposals and be selected as CTB investigators in free and open competition. The SAB advises the OB, and the Directors of the NOAA Climate Office and NCEP on issues pertaining to CTB activities. This advice is more in the nature of broad policy or other guidance on science priorities as opposed to specific proposal reviews, or working level resource decisions (i.e. areas where conflicts most naturally arise). As with any other panel activity, where there are real or perceived conflicts on any specific issue, SAB members are asked to excuse themselves from discussions on that specific issue. The same arguments hold for the OB.

Another conflict of interest issue pertains to the composition of the TPTs. Consistent with practices at NASA and other agencies, the TPTs consist of CTB members at NCEP, external PIs, contractors and users. The TPT membership should reflect the balance of CTB base funded and AO-driven transition projects.

5.0 ANNUAL OPERATING PLAN

The CTB Annual Operating Plan (AOP) maps CTB infrastructure (human and computing resources) onto NCEP Technical Operating Plans (NTOPs). Careful attention to the AOP, which is prepared early in the Fiscal Year, helps the CTB avoid duplication with other NCEP centers and makes maximum use of limited resources.

5.1 NTOPs

The NCEP Technical Operating Plans (NTOPs) include internal (base) funded contributions to the CTB transition projects. The components of the NTOPs include objectives, lead coordinator, relationships to the NOAA strategic plan, relationships to NCEP centers, and expected results.

During FY06 the CTB had 4 NTOPs: (1) Climate Test Bed Directors Office; (2) Climate Model Improvements; (3) Multi Model Ensemble Prediction System, and (4) Climate Forecast Products for Decision Support. During FY06 a total of 19 FTEs from the TPTs and 1.6 FTEs from the Directors Office are contributing to the 4 CTB NTOPs. It is important to note that the CTB Core Projects (Part I, Section 2.1) map onto the CTB NTOPs, which are somewhat broader than the Core Projects. Specific objectives and components of the CTB NTOPs are given on the CTB web page.

5.2 Milestones

Expected Results in the CTB NTOPs are selected and defined based on their potential to contribute to NOAA Goals. The links to the Performance Goals should include a set of discrete steps, or milestones, for achieving these improvements. The current set of CTB provisional milestones for FY07-FY11 is given in Part 1, Section 5.1. The CTB milestones are updated on an annual basis as part of the CTB AOP.

Progress on CTB milestones is reported each quarter to NCEP management. In addition, annual progress on CTB milestones is included in the CTB Annual Report (Part II, Section 5.5), which is sent to the OB as well as the Directors of NCEP and NCPO.

5.3 Budget

The CTB prepares and oversees an annual budget as part of its Annual Operating Plan. The annual budget maps resources onto expected results and related deliverables. Major components of the CTB budget are infrastructure (administration, system support, TPTs, visiting scientists), Announcements of Opportunity (AOs) and internally funded projects.

5.4 Meetings

Science Advisory Board (SAB) Meetings

SAB Meetings will be held at least once per year. The purpose of these meetings is to gather independent expert advice on CTB progress and future science priorities.

Expected outcome includes a SAB written summary report, with recommendations to CTB Management and the OB. CTB Management will provide a formal response to the SAB, and will use advice to update the SP&IS document and provide guidance to the agencies on future science priorities.

Special Sessions and PI Meetings

CTB Special Sessions with themes tied to CTB Core Projects will be held in open meetings. CTB has an established relationship with the Annual Climate Diagnostics and Prediction Workshop which is held each October. CTB will expand its participation in large annual meetings (e.g. AMS Annual meeting) and topical workshops. As the number of competitive transition projects grows, the CTB may establish annual PI meetings, either as stand alone meetings, or in conjunction with another NCPO competitive research program.

Management Team Meetings

The CTB Management Team (Director, Deputy Directors and Program Manager) holds routine monthly meetings to discuss CTB progress and plans. Advice from the SAB, OB and the broader climate community is discussed at these meetings. CTB personnel are encouraged to participate and to provide their ideas to the SAB, OB or Management Team at any time for consideration.

Teleconferences

The CST, SAB, OB and TPTs hold occasional teleconferences on focused topics. PowerPoint presentations or meeting minutes associated with CTB teleconferences are posted on the CTB website.

The CTB "Meeting and Annual Reporting Calendar" for FY06-07 appears in Appendix F.

5.5 Reports

Science Plan and Implementation Strategy (SP&IS) Updates

The CTB SP&IS document will be updated on an annual basis, normally early in the calendar year. The schedule depends on incorporation of the following input:

- TPT Progress Reports
- SAB review of SP&IS and TPT reports
- Annual SAB Meeting
- SAB written report with advice on future CTB science priorities
- CTB response to SAB

The CTB "Meeting and Annual Reporting Calendar" for FY06-07 appears in Appendix F.

Transition Project Team Progress Reports

Each of the TPTs prepares a progress report prior to the annual SAB meeting that includes an overview of accomplishments on science experiments (mapped against plans), computer usage, expected impact on operations, and future plans. These reports are provided to CTB Management and to the SAB prior to annual SAB meetings.

Annual Reports

The CTB Management Team will prepare an Annual Report summarizing CTB activities during the previous year. The report is evaluated by the OB, and then forwarded to the Directors of NCEP and the NOAA Climate Program Office. The CTB Annual Report will generally be available early in the calendar year.

5.6 Webpage

The CTB webpage (www.cpc.ncep.noaa.gov/products/ctb) is a one-stop-shop for everything CTB, including personnel, documentation, calendar, organization, directory, meetings transition projects, Announcements of Opportunity, etc.

Users are strongly encouraged to contact the CTB webmaster (Viviane.Silva@noaa.gov) or CTB Management (Wayne.Higgins@noaa.gov) with questions or suggestions for the CTB webpage.

APPENDIX A. Research to Operations Guidelines

The CTB "Research to Operations (R2O) Guidelines" establish the path to implementation of changes in the NCEP operational climate model suite. They establish the roles and responsibilities of the "home research institution" and the CTB in this process. Significant resources for the home research institution and the CTB are required to carry out smooth transitions. The R2O Guidelines, which indicate the path to implementation of changes in the NCEP operational climate model suite, consist of the following seven steps:

1 **Model development and refinement**
2 **Preliminary assessment**
3 **Calibration**
4 **Interface with operations**
5 **Final skill assessment**
6 **Parallel tests**
7 **Approval**

While most of the steps are identical to the way EMC implements a majority of the changes in other suites of models, the calibration step is unique to the climate model suite. Some of the changes may not need to go through all of the steps. The three NCEP center directors (NCO, EMC and CPC) will have to approve changes to the procedures. In the end, the NCEP director will make the final decision to approve a change. Details of each step are described below.

1 Model development and refinement

The key issue is additional, independent information to supplement operationally available products. The development and refinement are to be performed at model host institutions. For funded transition projects with a commitment of computer resources from the Climate Test Bed (CTB), the CTB computer resource will be used.

For tier-1 systems: Make 30- to 50-year CMIP (Coupled Model Intercomparison Project) runs, for comparison with the NCEP CFS, to demonstrate improved simulation of the seasonal-to-interannual (El Niño/Southern Oscillation) and intraseasonal (Madden-Julian Oscillation) signals, and a set of 1-year retrospective forecasts for January, April, July, and October for 1981-present (with a 30-member ensemble) to demonstrate skill in addition to the CFS benchmark.

For tier-2 systems: Make a set of 1-year retrospective forecasts for January, April, July, and October for 1981-present (with an ensemble of 30 or more members) using predicted SST from operational dynamical model retrospective forecasts from NCEP, other operational centers (when such forecasts become routinely available to NCEP), or one of the CPC statistical SST forecasts to demonstrate skill in addition to the CFS benchmark.

For modifications to the CFS model, the general guideline is that the changes must first be implemented in the NCEP Global Forecast System (GFS). This means that the model changes will be evaluated in both the weather and the climate arena. EMC has a well-established evaluation criterion on model changes so a close working relationship with the EMC staff is important. Evaluation tools under development by CPC and its partners on the CTB will be used to decide on the added value of each new model.

RESOURCES: The development and refinement are to be performed at the model host institution. AO-driven projects may seek computing resources from the CTB using the NOAA "Red" computer. Retrospective forecasts are expensive and are currently not part of the resources allocated to either NCEP or the CTB, so developers need to work with NCEP to ascertain the necessary resources.

NCEP participation: EMC scientists should participate in projects involving model changes while CPC scientists should participate in projects involving evaluations and product development from the start of the project.

2 Preliminary assessment

Participants on the CTB should provide the complete retrospective forecast results (including raw monthly-mean fields) to NCEP and work with CPC and EMC to assess whether additional, independent information from the retrospective forecasts exists in relation to existing operational dynamical and statistical predictions. Iterations back to Step 1 may be necessary if the results do not provide the additional, independent information.

Statistically significant improvements obtained by the above steps would lead to an initial plan for implementation. A team of scientists from the external institution, CPC and EMC will work together to make the decision to go forward or iterate back to step 1.

RESOURCES: CTB AOs will provide limited resources for preliminary assessment activities. These projects will be competitive and peer reviewed. The CTB will provide computer resources and system support for funded projects. A plan for transition to operations at NCEP will be written and approved by NCEP and NWS management. The plan must include personnel and infrastructure (desktop computing, travel, training, etc) resources for operational maintenance and enhancement as well as computing (cpu, disk, dissemination, archive).

NCEP participation: The team of scientists will report to the directors of NCO, EMC, CPC and CTB on the results of the preliminary assessment and seek their approval to initiate the implementation. NCO Production Management Branch will initiate an implementation plan and track the progress of the plan upon the approval of the directors.

3 Calibration

Participants on the CTB should provide the complete 1 year retrospective forecasts for the period 1981-present for all calendar months (with an ensemble of 30 or more members).

RESOURCES: The resources needed to complete such runs are very large. For major projects such as multi-model ensembles and regional climate models, the host model institution will provide the necessary resources. Additional resource needs at NCEP will have to be proposed and planned for well in advance of the calibration step.

NCEP participation: Collaborate with CPC and EMC to continue the skill assessment for these forecasts and to perform cross-validation. The key consideration will be the usefulness of the forecasts in providing independent, additional information to the products that are already operationally available. This includes whether a new product improves on the multi-model ensemble in US-temperature and precipitation prediction and whether it is at least as good as statistical/empirical methods.

4 Interface with operations

As the calibration and assessment work is completed, the provider will work with EMC and NCO to make all programs in the model comply with NCO standards and to make all model output comply with WMO and NCO standard formats.

RESOURCES: CTB AOs will provide limited resources for developing the interface with operations. These projects will be competitive and peer reviewed. The CTB will provide computer resources and system support for funded projects.

NCEP participation: EMC and NCO will assess the additional computer resources needed to put the runs into the operational job stream. The model provider will work with NCEP to obtain additional resources needed for the operational runs of new systems.

5 Final skill assessment

As the calibration runs are completed and the interface with operational standards is finished, CPC and EMC will work with the provider to complete the final assessment to determine if the change is ready for implementation. Assuming production resources are available for the additional runs, the parallel tests will begin.

RESOURCES: NCEP will provide the resources for this step.

NCEP participation: EMC and CPC will participate in all aspects of the final assessment.

6 Parallel tests

EMC staff will work with the code provider and NCO to bring all running scripts up to NCO production standards. NCO staff will run the new model in the parallel production environment and make routine near-real-time forecasts. CPC, EMC and the provider will verify that the parallel prediction products are the same as the provider intended. CPC forecasters will begin to evaluate the products in preparation for operational ISI forecasts.

RESOURCES: NCEP will provide the resources for this step.

NCEP participation: EMC and CPC will participate in all aspects of the final assessment.

7 Approval

NCO Production Management Branch staff will brief the director of NCEP on the technical evaluation of the new model. EMC Global Climate and Weather Modeling Branch staff will brief the director of NCEP on the scientific evaluation of the new model, and the CPC Prediction Branch staff will brief the director of NCEP on the operational evaluation of the forecasts from the new model. Four categories will be considered and checked off before the briefing takes place: 1) Forecast/analysis benefits; 2) Efficiency Assessment (especially important for NCO and CPC); 3) Compatibility with NOAA/NCEP IT assets; 4) Sustainability. Upon approval by the NCEP director, the new model will be scheduled for implementation in the NCEP production suite.

A.1 Testing Changes in (Atmospheric) Parameterizations in the GFS/CFS

For a proposed model change, make a set (3-4) of 45-day runs of the control and the new parameterization in the GFS using observed Sea Surface Temperature (SST) for January and July conditions. These runs are used to study the impact of the new parameterization (in a global sense) on the atmospheric circulation and various known model biases. If one finds gross problems with the new parameterization in these runs, then one will need to diagnose the problems and go back to the parameterization formulations to identify ways to alleviate the problems.

Computing resources for the runs should come from the modelers own institution. For CTB supported activities, CTB computer resources are also available.

1. Make several CFS runs with the control version of the CFS and with the new parameterization for one year. Compared to the runs in 1), these runs should reveal more about impact of the parameterization in the coupled model world. Special attention should also be paid to the transients generated in the model versus those generated in the control run. This is a key step in assessing the impact of changes in parameterizations in the CFS for seasonal forecasts. Extensive diagnoses will be performed to ensure that the new runs will not degrade the coupled model climate. Computing resources for the runs should come from the modelers own institution. For CTB supported activities, CTB computer resources are also available.

2. Put the new parameterizations in the current operational version of the GFS and perform a low-resolution global data assimilation system (GDAS) test for two months each for northern winter and northern summer using a version of the GFS at the resolution envisioned for the next version of CFS. There will also be a set of 10-day ensemble forecasts for each day of the assimilation. The forecast skill will be evaluated using both deterministic and probabilistic measures. The new parameterization must not degrade the forecast skill of the current operational GFS.

These runs should be made collaboratively with the EMC transition team. Computing resources for the runs may either come from the CTB computer or the EMC computer.

3. When the tests are positive, perform 1-2 40-year free runs of the CFS to compare the interannual tropical Pacific signal to ensure that the new parameterization does produce a robust interannual signal in the tropical Pacific. Computing resources should come from the CTB computer.

4. Pending positive results from the steps above, add the new parameterizations into the GFS parallel test schedule to allow for a full resolution parallel test for a select period. In addition, make full resolution parallel tests for a chosen hurricane season and work with the Tropical Prediction Center to ensure that the hurricane track predictions from the parallel tests are acceptable to the hurricane specialists. Computing resource for these runs will come from the EMC computer.

5. Pending successful outcome of the tests above, seek approval from NCEP Director for implementation in the GFS. In addition, the new package will be included in the next CFS model when tests of the new model begin. The new CFS will be taken from a version of the operational GFS that has been running for at least six months (for code maturity). Computing resource for the CFS upgrade will have to be planned by EMC and CTB since the resource needed is very significant.

APPENDIX B. Operations to Applications Guidelines

The Operations to Applications (O2A) guidelines discussed here provide the path to implementation of operational models in CPCs consolidated seasonal forecasts. Forecast models which are admitted to the consolidation must be accompanied by fairly-conducted hindcasts with the following qualities:

1. There must be reproducibility of retrospective forecasts made on the host computer to forecasts made on the NCEP computer. This is important for the application of calibration and weights for consolidation (which are derived from the retrospective forecasts) to real time forecasts which will be made on the NCEP computer.

2. Retroactive runs from *each* (initial) month during 1981-present for leads 1, 2, 3, 4, 5 etc. It is important that the retroactive runs are organized so as to be used optimally in operational real time forecasts. Forecasts runs from initial conditions past the 10th (of January say) cannot be used for the lead 1 FMA forecast. The number of members in the ensemble is up to the provider, but has to be at least 5.

3. Output variables must include: seasonal mean 2-meter temperature, precipitation, for US (including AK and HI; forecasts for other US interests are appreciated), global monthly mean fields of seasonal mean SST and, 850 and 200mb winds and 500-hPa heights.

4. The retroactive forecasts should be provided as total fields (i.e. not anomalies). CPC will use the normal (currently 1971-2000) it sees fit.

5. The latest runs should be available by the 10th of each month. The real-time system (model, input data etc) has to be identically the same as the frozen system that generated the hindcasts.

6. CPC will do a systematic error correction (each tool separately) and determine the regression coefficients under a three-years-out Cross-Validation approach. CPC will update the results each month.

7. If the weight assigned to a method is near zero, then we will redo the consolidation without that method and notify the originators of the method.

8. We require at least 5 members in the ensemble. The number of leads is up to the provider.

Appendix C. Current Projects

The CTB has attracted funding for transition projects via competitive research programs managed by the NOAA Climate Program Office (NCPO). The funding profile for these grants since 2004 is as follows: $100K in FY04; $300K in FY05; $450K in FY06).

CTB science priorities in FY06 were summarized in the **Climate Dynamics and Experimental Prediction** (CDEP) program element of the NOAA Climate and Global Change Program, and were aligned with the programmatic priorities above. An information sheet containing details on NOAA's CDEP program can be found at http://www.ogp.noaa.gov/mpe/cdep/.

At the present time there are several additional CTB-related projects (totaling $500K) funded by the NCPO Climate Prediction Program for the Americas (CPPA) that are aligned with CTB science priorities.

A list of CTB projects by programmatic theme gives an indication of the current balance of science activities:

1) NOAA/NCEP Climate Forecast System Improvements

- The Ocean Component of the NCEP ENSO CFS (PI: M. McPhaden; NOAA Collaborators: Y. Xue and D. Behringer)
- Improvement of the Global Ocean Data Assimilation System (GODAS) at NCEP (PIs: Y. Xue and D. Behringer)
- Using Initial Tendency Errors to Reduce Systematic Errors, Identify Model Errors, and Construct Stochastic Parameterizations (PI: T. Delsole, COLA; NOAA Collaborator: H. Pan)
- Development of Neural Network Emulations of Model Physics Components for improving the computational performance of the NCEP seasonal climate forecasts (PI: M. Fox-Rabinovitz; NOAA Collaborator: V. Krasnopolsky)
- NCEP Component of the NOAA Core Project for GAPP (PI: K. Mitchell) (Note: several of the "pillar initiatives" are CTB science priorities)
- The NAME Climate Process Team (PI: J. Schemm)

2) Multi-Model Ensemble Prediction System

- Developing Infrastructure for Multi-model Ensembles and Data Management for Seasonal-to-Interannual Forecasting at the NOAA Climate Test Bed (CTB) (PIs: A. Leetmaa, S. Lord and A. Kumar)

3) Climate Reanalysis – An Ongoing Analysis of the Climate System

- Regional Climate Data Assimilation System (R-CDAS) and NAME Data Impact and Prediction Experiments (PI: K. Mo)

4) Climate Forecast Products for Decision Support

- Consolidation of Multi method Seasonal Forecasts at CPC (PIs: Huug van den Dool, Malaquias Peña)

- A Drought Monitoring and Early Warning System for the United States (PI: K. Mo)

- The NOAA Climate Prediction Products and Services Team, to identify, prioritize and develop or transition new and improved products and services for operational production and dissemination.

Appendix D: Management Structure and Terms of Reference

The CTB includes a Director, a Deputy Director for Administration, a Deputy Director for Transition to Operations, an Oversight Board (OB), a Program Manager, an Administrative Staff, a Climate Science Team (CST), Transition Project Teams (TPTs) and a System Support Team (SST). Personnel consist of civil servants, contractors, visiting scientists and students. An external Science Advisory Board (SAB) provides scientific advice and reviews CTB activities annually. The CTB Organization is summarized in Figure D1.

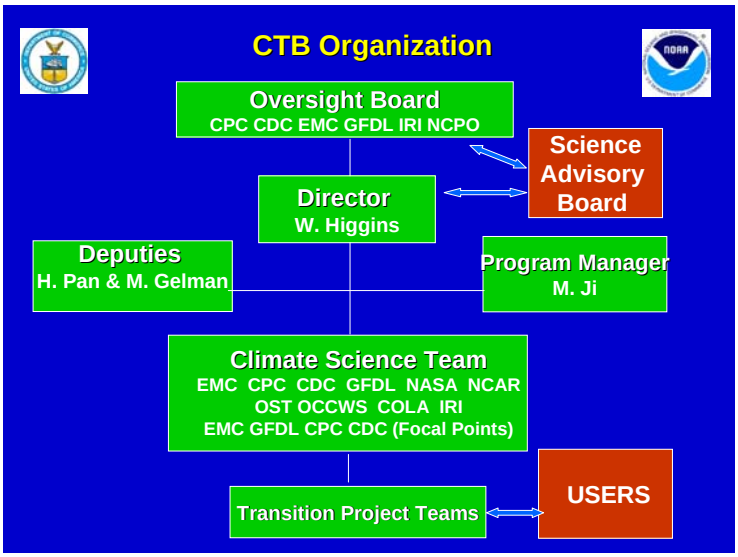

Figure D1. Organization of the NOAA Climate Test Bed facility.

Complete Terms of Reference for CTB Personnel, Boards and Teams are as follows:

CTB Director

The CTB Director shall be a civil servant selected by the NCEP Director in consultation with the OB. The responsibilities of the CTB Director are to:

- Provide scientific leadership and generate CTB activities to carry out the CTB mission;
- Manage and administer the CTB in a manner consistent with NOAA policies and guidelines;
- Identify and allocate resources for support of CTB activities, including computer resources and sponsorship by the NOAA Climate Program Office;
- Establish Annual Operating Plans (AOPs) that map resources onto expected results and related deliverables;
- Develop GWPS Workplans and evaluate CTB personnel;
- Work with the CTB Program Manager(s) to coordinate activities across agencies; and

- Prepare the annual report summarizing CTB yearly activities and present the results to the OB.

CTB Deputy Directors

The CTB will have a Deputy Director for Administration and for Transition to Operations. The CTB Deputy Directors shall be NOAA Civil Servants selected by the NCEP Director in consultation with the Oversight Board.

The responsibilities of the CTB Deputy Director for Administration are to:

- Assist the CTB Director and the CTB Program Managers in the day-to-day management of the CTB;
- Assist the CTB Director in preparing the Annual Operating Plan (AOP) for transition activities, infrastructure, deliverables, schedule, and budget.

The responsibilities of the CTB Deputy Director for Transition to Operations are to:

- Work with NCEP Central Operations (NCO), the operational centers and the principal investigators to negotiate the needs, milestones and timelines for transition to operations;
- Work with the CTB Director and the operational centers, to identify climate-related data, climate forecast products, and numerical/statistical modeling needs and coordinate these with the OB, CST, TPTs and other testbed directors to accomplish appropriate transitions to operational guidance products.

CTB Program Manager

The CTB Program Manager (PM) will be from the NOAA Climate Program Office. The functions of the PM are to:

- Work with the CTB Management and the SAB to determine science priorities and the scientific direction for competitive Announcements of Opportunity (AOs);
- Conduct the merit review process for AO proposals, and make funding decisions in consultation with the CTB Management;
- Execute AO awards to Principal Investigators (PIs);
- Work with CTB management to continue post-award management of PIs;
- Coordinate with other NOAA Climate Program activities;
- Work with the CTB Management and the SAB to ensure coordination with National and International climate research programs; and
- Assist the CTB director in preparing the annual report to the OB.

Administrative Staff

A Secretary will handle office duties such as travel, logistics for visitors and staff, messaging and other communications. A Program Assistant will work on presentations, program plans and other documents.

The Oversight Board

The responsibilities of the OB are to:

1. Report and make recommendations to the NCPO Director, and the NCEP Director concerning the CTB on an annual basis;
2. Facilitate and sustain cooperation between NOAA and other sponsoring institutions;
3. Review and approve the policies, research and development themes and priorities of the CTB;
4. Adopt and revise, as appropriate, the Terms of Reference (ToR) for the operation of the CTB;
5. Recommend to the NOAA Climate Program Office inclusion of other institutions in the CTB; and
6. Meet at least twice a year.

The OB shall include the following members:

- The NCEP Climate Prediction Center (CPC) Director;
- The NCEP Environmental Modeling Center (EMC) Director;
- The Director of the Climate Diagnostics Center (CDC);
- The Director of the NOAA Geophysical Fluid Dynamics Laboratory;
- The Director of the International Research Institute for Climate Prediction;
- A representative from the NOAA Climate Program Office;
- Appropriate representatives of other stakeholders.

The NCEP Director and the NCPO Director shall be invited to OB meetings (if available). Occasionally they will be asked to make executive decisions when the OB cannot reach consensus.

The Climate Science Team

The Climate Science Team (CST) is composed of technical experts from NOAA organizations (e.g. CPC, EMC, CDC, GFDL) and other active Numerical Forecast Centers (NFCs) in the CTB (e.g. IRI, NCAR, NASA, COLA). As a Team, the CST will have broad experience in the climate forecast problem, modeling issues, and product generation. The CST membership is recommended by CTB Director and Deputy Directors and approved by the OB. CST members will serve a 3-year term (except 3, 4 and 5 years initially to allow for a smooth rotation). The CST will:

- Guide CTB activities at the working level;

- Work with the TPTs to rank, monitor and track CTB experiments aligned with CTB objectives and resources;
- Provide advice on CTB contributions to the development path for NOAAs operational climate forecast systems and products;
- Monitor and evaluate results of CTB activities;
- Make recommendations to the CTB Director on computing resource usage priorities, and computing access policies; and
- Meet at least quarterly.

CST members will choose Co-Chairs (one internal to NOAA and one external to NOAA) who will have two-year terms. The Co-Chairs will rotate among different CST members. The CST should be an integral part of the CTB on a day to day basis. The CST currently has 13 members, including the Co-Chairs. The CST Co-Chairs will not be members of any of the Transition Project Teams.

Transition Project Teams

The CTB Transition Project Teams (TPTs) are the functional core of the CTB. They provide a mechanism for coordinating and completing CTB science experiments that require computer resources, and they enhance collaboration between internal and external participants on the CTB. TPT membership includes CTB personnel, other NCEP employees, other NOAA employees, contractors, external PIs from competitive research programs (including Focal Points (FPs) chosen for each model and product supported by CTB), and members of the user community. Each TPT has a Chair, who is appointed by CTB Management to lead the team and to report progress to the CTB management and the CST as necessary. CTB PIs are required to join a TPT in order to ensure that their activities are included, especially when computing resources are involved.

Specific functions of TPTs are to:

- Facilitate collaboration between internal and external participants on the CTB;
- Propose, coordinate and complete CTB transition project activities;
- Report progress to CTB management and the CST;
- Train outside users of CTB-supported software, including forecast systems, and products;
- Coordinate with CTB product developers and with forecast operations and applications activities.

The TPTs are not fixed in time and will naturally evolve to reflect the balance of internal (base funded) and competitive (AO-driven) activities on the CTB. TPTs may be combined, expanded or eliminated to align with CTB programmatic and science priorities. The current set of TPTs is rather broad and covers all possible areas of CTB interest. It is anticipated that the TPTs will adjust as the CTB continues to focus its activities and manpower.

System Support Team

CTB System Support Team (SST) personnel will include Technical Assistants (TAs), System Administrators (SAs) and Information Technology (IT) specialists to

- Support external users on NCEP's Supercomputing Cluster;
- Support users of CTB software, including the NOAA operational Climate Forecast System components, by providing code, scripts, computing information, training and debugging services;
- Request new accounts as required;
- Work with NCEP Central Operations (NCO), manage on-line and archive storage, including file organization and quotas, and act as a liaison to NCOs system administrators for CTB computing;
- Manage access to NCEP's climate information, including calibration runs, and work with EMC system administrators to put CTB output on NOMADS servers;
- Provide IT support for CTB PCs and workstations;
- Maintain the CTB Web page.

TAs may be contractors in the CTB, in other NOAA line offices or in other organizations.

Visiting Scientists

Visiting scientists and post-doctoral fellows from other organizations such as NSF, NCAR, Universities and foreign organizations (e.g. international desks) will participate in CTB transition projects. These visitors will be supported by their home institutions or by grants sponsored by NOAA or other agencies. Visiting Scientists can include postdoctoral candidates and graduate students.

Science Advisory Board

Independent scientific advice is provided by a Science Advisory Board (SAB). The SAB will work with the broader scientific community to recommend and review progress on high-priority scientific challenges for NOAA Mission Goals related to climate prediction and to review implementation strategies to meet these scientific challenges. The SAB should consider coordination between the CTB and existing National and International programs (e.g., CLIVAR, GEWEX) to ensure that CTB efforts are consistent and up to date with current scientific understanding, and to ensure that long-term investments in climate research are available to the CTB. SAB membership will include working scientists from a broad spectrum of national and international organizations including experts from active Numerical Forecast Centers. The SAB membership will have a 3 year rotation (except 3, 4 and 5 years initially to make the rotation work). The SAB will be chaired by a member of the non-NOAA Climate Community. SAB membership will be recommended by the SAB chair and approved by the OB. The SAB advises the CTB management and reports to the OB. The SAB will meet at least once a year and will write a report to the CTB management following the meeting. The SAB currently has 10 members, including the Chair.

Appendix E. Climate Predictive Index (CPI)

The following is extracted from a draft proposal for a Climate Predictive Index (CPI) that was written by Dr. Arun Kumar, NOAA/CPC.

E.1. Background

The focus of the Predictions and Projections (P&P) Program under NOAA's Climate Goal is to provide and improve climate forecasts and outlooks on multiple timescales ranging from intraseasonal through seasonal and interannual to decadal. To accomplish its mission, the P&P program is aligned along two subcomponents: 1) Predictions with a focus on intraseasonal, seasonal, and interannual timescales, and 2) Projections with a focus on decadal and longer time scales.

Currently, the success of the P&P program is assessed by a single performance measure, i.e., "The Seasonal Temperature Forecast Skill" over the continental US. Over the past few years, the following drawbacks inherent in the current performance measure as a comprehensive measure for the P&P program have emerged:

- Improvements in seasonal forecasts are incremental and can easily be masked by the natural variability in seasonal predictive skill, and therefore, progress made under the P&P program over one year, or even over a few years, is difficult to document;

- The current performance measure only focuses on the skill of climate outlooks on seasonal and interannual timescale, and does not take into account P&P efforts on intraseasonal timescales, decadal outlooks, and long-term climate change projections (or the attribution of past trends to known climate forcing);

- The current performance measure has little direct link to the various research efforts under the P&P program, and therefore, documenting improvements due to this research or from previous successes in research-to-operation transitions is difficult. This lack of connectivity between research efforts and the performance measure also leads to accountability issues.

To rectify shortcomings in the current performance measure for the P&P program, a new performance measure, the Climate Predictive Index (CPI) is proposed. CPI will truly represent the P&P program, since it will be a weighted average of skill evaluated on climate outlooks across all timescales from intraseasonal, through seasonal-to-interannual, to decadal.

E.2. Desired Attributes for the Performance Measure

The following are desirable attributes of the CPI:

- *The CPI should relate to operational forecasts*

- *The CPI should not be penalized or boosted by natural variability:* The CPI should be formulated in such a way that changes in the CPI due to changes in prediction methodologies will neither be penalized nor rewarded because of natural variability. For example, the "Seasonal Temperature Forecast Skill" measures predictive skills due to changes in seasonal prediction methodologies are overshadowed by the influence of natural variability.

- *The CPI should have a baseline:* CPI should have a baseline relative to which improvements in prediction methodologies are documented.

- *Testing and evaluation of promising new tools, or improved versions of existing tools, that could lead to improvements in the performance measure, should be feasible:* The time period over which the CPI is averaged should not be so long that the evaluation of promising new tools, or improvements in existing tools, becomes a daunting task. For example, the impact of general circulation model changes on the prediction skill must be tested for the same time period over which the baseline CPI is computed. If this period exceeds 10-15 years, then routine evaluation of dynamical tools can quickly become unfeasible. On the other hand, the feasibility aspect of reevaluating the CPI for new (or updated) tools has to be weighed against the requirement to average the CPI over a sufficiently long time period to reduce the influence of natural variability.

- *The CPI should have a projected improvement with time:* As a return on NOAA's investment in the P&P program, the CPI should have a projected improvement with time.

- *Improvements in the CPI should be linked to the research foci of the P&P program*: Activities under the P&P program, and their research foci, should be selected and defined with a direct link to improvements in the CPI. The link to the CPI should include a set of discrete steps for achieving these improvements, as well as a corresponding set of milestones.

E.3. Reporting frequency for CPI

Since the sample size of for climate predictions and outlooks is not large (for example, there are only 12 seasonal predictions that are verified every year), CPI will be reported on a yearly basis.

E.4. Components of the CPI

CPI is defined as a weighted average of three skill measures. The component skill measures will focus on the predictions on sub-seasonal, seasonal, and attribution on decadal time scale. In the beginning, an equally weighted average value of the three skill measures will be used in defining CPI. Alternative definitions for the CPI will then be considered and may include: (1) weights based on the economic utility of the forecast on

different time-scales; (2) weights proportional to the level of investment within the P&P Program that focus on the different time-scales. A desired outcome of P&P research efforts that focus on intraseasonal, seasonal-to-interannual, and decadal time-scales would be an increase in CPI over its baseline value. This increase can occur due to an increase in predictive skill from any of the component measures. Further, improvements can come either from development of new predictive tools or from improvements in existing tools.

The seasonal-to-interannual (SI) component measure of the CPI will be the skill of operational SI predictions averaged from 1995 to the end of the previous fiscal year. For example in FY05, the SI component will be the skill of the operational SI forecasts from October 1995-Sep 2004. This would form the baseline for the SI score that would get included in the baseline computation for CPI. For ease of understanding, the SI skill measure may be defined as the numbers of stations over which a correct forecast was made. This does not preclude an operational center (i.e., the Climate Prediction Center) from evaluating their seasonal forecasts based on more comprehensive probabilistic measures. At the end of each fiscal year, the SI score will be get updated as an average from 1995 to the end of most recent fiscal year. It is conceivable that once the averaging period gets too long (e.g., larger than 15 years), a running average over a fixed number of years will be used. This change in the base period is to meet the "constraint of feasibility."

The intraseasonal and decadal component measures of the CPI are under development.

Appendix F. Meeting and Annual Reporting Calendar

The CTB Meeting and Annual Reporting Calendar (as of Feb 06) is as follows:

2006

- Mar 21 — CTB Panel at CPAS Workshop (Tucson, AZ)
- Apr 1 — CTB SP&IS to SAB
- Apr 19-21 — CLIVAR SSG (Buenos Aires)
- Apr 22-23 — 9th VAMOS Panel Meeting (Brazil)
- Jun 1 — CTB Transition Project Team progress reports due to SAB
- Jun 29-30 — 2nd Annual CTB SAB Meeting (Washington, DC)
- Jul 1 — CTB FY07 Annual Operating Plan, budget, & milestones
- Jul 26-28 — US CLIVAR Summit (Keystone, CO)
- Aug 1 — SAB Written Summary Report due to CTB
- Aug 14-18 — CPPA PI / NAME SWG-8 (Tucson, AZ)
- Sep 1 — CTB written response due to SAB
- Oct 23-27 — CTB Special Sessions (with CDPW)
- Dec — 3rd NCPO-NWS Dialogue Meeting

2007

- Jan — CTB Annual Report due to OB
- Jan — CTB SP&IS update
- Feb — CTB priorities shared with participating agencies

Appendix G. Contact Information

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Appendix H. Acronyms

The following is a list of acronyms used in the text:

AO	Announcement of Opportunity
AOP	Annual Operating Plan
CA	Constructed Analog
CCA	Canonical Correlation Analysis
CDC	Climate Diagnostics Center
CDEP	Climate Dynamics and Experimental Prediction
CEOP	Coordinated Enhanced Observing Period
CFS	Climate Forecast System
CLIVAR	Climate Variability and Predictability
CMIP	Coupled Model Intercomparison Project
COLA	Center for Ocean Land Atmosphere Studies
CONS	Official CPC Consolidated Forecast
CPC	Climate Prediction Center
CPI	Climate Predictive Index
CPPA	Climate Prediction Program for the Americas
CPT	Climate Process and modeling Team
CST	Climate Science Team
CTB	Climate Test Bed
C&GC	Climate and Global Change
DOD	Department of Defense
DRI	Desert Research Institute
EMC	Environmental Prediction Center
ENSO	El Niño Southern Oscillation
ESMF	Earth System Modeling Framework
ESSIC	Earth System Science Interdisciplinary Center
FP	Focal Point
FTE	Full Time Equivalent
FY	Fiscal Year
GAPP	GEWEX Americas Prediction Program
GEWEX	Global Energy and Water Cycle Experiment
GFDL	Geophysical Fluid Dynamics Laboratory
GFS	Global Forecast System
GMAO	Global Modeling and Assimilation Office
IRI	International Research Institute
ISI	Intraseasonal-to-Interannual
IT	Information Technology
JCSDA	Joint Center for Satellite Data Assimilation
LOI	Letter of Intent
M&OP	Management and Operations Plan
MESA	Monsoon Experiment South America
MJO	Madden Julian Oscillation
MOM	Modular Ocean Model

NAME	North American Monsoon Experiment
NASA	National Aeronautics and Space Administration
NCAR	National Center for Atmospheric Research
NCDC	National Climatic Data Center
NCEP	National Centers for Environmental Prediction
NCO	NCEP Central Operations
NCPO	NOAA Climate Program Office
NFC	Numerical Forecast Center
NOAA	National Oceanographic and Atmospheric Administration
NOMADS	NOAA Operational Model Archive and Distribution System
NSF	National Science Foundation
NTOP	NCEP Technical Operating Plan
NWS	National Weather Service
OB	Oversight Board
OGP	Office of Global Programs
OHD	Office of Hydrology
PACS	Pan American Climate Studies
PI	Principal Investigator
PMEL	Pacific Marine Environmental Laboratory
P&P	Predictions and Projections
QC	Quality Control
R&D	Research and Development
RSIS	RS Information Systems
SA	System Administrator
SAB	Science Advisory Board
SST	Sea Surface Temperature
SST	System Support Team
S-to-I	Seasonal-to-Interannual
SP&IS	Science Plan and Implementation Strategy
SWG	Science Working Group
TA	Technical Assistant
TPT	Transition Project Team
VAMOS	Variability of the American Monsoons
VOCALS	VAMOS Ocean Cloud Atmosphere Land Study
WMO	World Meteorological Organization