Summary Report
The CFSv3 Planning Meeting
August 25-26, 2011

Background

The National Centers for Environmental Prediction (NCEP) implemented the Climate Forecast System version 2 (CFSv2) in March 2011. CFS is a global, coupled climate model used for operational intraseasonal-to-interannual (ISI) prediction at NCEP. The current version of CFS, which took 7 years to develop and implement, includes many improvements in all components, including the latest developments in the global atmospheric model (NCEP GFS, also used for medium range weather prediction), coupling with a new version of the global ocean model (GFDL MOM4), a sea ice model, and an improved land surface model (NCEP Noah). The development cycle for CFSv2 also included a new reanalysis (CFS-R) of the 1979-2010 period that, for the first time, included data assimilation of atmospheric, oceanic and land surface observations with a coupled climate model generating the first guess. The CFS-R data set, which was intended to provide initial conditions for hindcasts to calibrate the CFSv2 forecasts, is already in wide use by the research and application communities as a source of assessing climate variability for the past 30 years.

The purpose of this planning meeting was to bring NCEP scientists and the external research community together to develop a strategy for the next generation of CFS (CFSv3), in advance of the development cycle for CFSv3. There were 48 participants in this meeting including scientists from NCEP (EMC and CPC), NOAA management, US modeling centers (GFDL, NCAR, NASA/GSFC), international modeling centers (ECMWF, Italy/CMCC, India/IITM, Taiwan/CMB), other centers/labs of NOAA (PMEL, NWS/OST, ESRL, NWS/OHD) and scientists from universities and non-profit research institutes (COLA).

The meeting discussions were focused on the following questions:

- What are the NOAA requirements for CFS?
- What is the need for a new version of CFS (CFSv3)?
- Should CFSv3 be a community model?
- What should be the CFSv3 development strategy?

This report summarizes the discussions during the meeting and the key recommendations on the vision and strategy for the CFSv3 development.

What are the NOAA requirements for CFS?

- NOAA has two climate model development centers (NCEP and GFDL). NOAA has a requirement for real-time operational climate forecasts and information at intraseasonal-to-interannual (ISI) time scales on a regular basis. The emerging concept of Climate Service requires both decadal outlooks and centennial-scale projections of climate change. Currently NCEP develops, maintains and operates

CFS to serve as the operational coupled dynamical climate model that can deliver the required real-time, on-time, every time climate predictions. CFS will contribute to the emerging multi-model ensemble (MME) ISI prediction system with NCEP operational support.

- Recognizing NOAA's mission to "understand and predict changes in climate, weather, oceans, and coasts", and the National Weather Service mission to "protect life and property and enhance the national economy", CFS provides a scientific basis for proactive resource (water, agriculture and energy) management and adaptation at the ISI time scale. CFS has a substantial downstream user community, both in the research and education sector and in the private sector.

- ISI forecasts based on CFS can also provide insights and justification for climate observing systems.

What is the need for a new version of CFS (CFSv3)?

- The assessment of CFSv2 conducted by CPC determined that it was superior to the original version of CFS (referred to herein as CFSv1), thereby enabling it to go operational in March 2011. Further preliminary CFSv2 evaluations have shown improvement in surface temperature and MJO simulation. On the other hand, CFSv2 continues to have strong biases in several fundamental climate variables, for example, seasonal precipitation prediction has not improved over CFSv1.

- User requirements to go beyond the current level of accuracy and resolution suggest that further research and development is needed to provide reliable regional climate predictions at ISI time scales, such as weather and climate extremes and their environmental impacts.

- Research by the scientific community, including university-based researchers and national and international modeling centers, has demonstrated that increasing model resolution, inclusion of additional climate-relevant processes in the prediction model, improved data assimilation, and a larger ensemble size, can all contribute to providing superior climate forecast information. This forms a scientific basis for potential model improvement over the current CFSv2. It was recognized in the meeting that thorough evaluations of CFSv2 are needed to identify key model biases and deficiencies and define priorities for the future CFS development.

- As a lesson learned from the CFSv2 development and implementation experience, planning for the next generation of CFS should take into account the end-to-end requirements to account for the multiple purposes of reanalysis and reforecasts.

Should CFSv3 be a community model?

While CFS development has in the past sought to leverage the expertise and experience of global weather prediction modelers, the meeting participants acknowledged the benefits of the NCAR CCSM/CESM as a community model. It is also recognized that the very high cost of such an enterprise and the budget limitations in NOAA make supporting CFS as a community model very challenging. The general recommendation is for NCEP to improve CFS model documentation, accessibility, code readability and usage by the external community, and interactions and collaborations with the external science community. This is consistent with the recommendations of the UCAR Review of NCEP conducted in 2009-2010. It was further suggested that the best aspects of the CCSM/CESM community activity could be "borrowed" to support a CFS community at a minimal level. For example, a moderated community of people interested in fast time-scale processes could be entrained for climate model development – the so-called seamless prediction paradigm. Another suggestion was to consider the opportunity to build on the successes of the Joint Center for Satellite Data Assimilation (JCSDA) to support community data assimilation for climate prediction and to leverage Development Test Center (DTC) resources to test CFS,

What should be the CFSv3 development strategy?

- Plan for a sustainable end-to-end effort:
  - Develop the vision, strategy and resource requirements for CFSv3, with full support of NOAA management.
    - The vision should be bold and far-reaching: include extension of climate prediction products to regional scales and extreme events.
    - The NOAA grants programs should play a strategic role in NOAA model development including CFS, by creating opportunities to bring together various NOAA labs/centers and the external community
    - NCEP needs to provide adequate resources for infrastructure support (e.g., model documentation, helpdesk, HPC, CTB Model Testing Facility) for CFS model development, testing and experiments.
  - Test all components and the full system. The testing phase needs to be started sooner to allow time and mechanisms for broader community input.
  - Integrate model diagnosis/evaluation into the model development process.
  - Establish some mechanisms to seek external science advice in identifying priorities for CFS development.

- Accelerate the CFS development cycle.
  For example, consider alternative strategies for reanalysis and model development,
  - De-couple the model development cycle from reanalysis (ECMWF)
  - Reanalyze/reforecast "on the fly" (U.K. Met Office)

- Involve the research community at the earliest possible stage of development

planning.

- Develop a suitable model for including the private sector in model development planning.

- Evaluate CFSv2 in a comprehensive and systematic fashion on its all aspects of its representation of climate (means, annual cycle, variability, and trends of climate variables at the surface, in the free atmosphere, in the upper ocean, and Arctic and Antarctic sea ice), its prediction skill and biases, and the consistency and value of products generated using CFSv2 forecast data.
    - The NOAA CPO/MAPP has issued a call for proposals for FY12 that includes an opportunity to evaluate aspects of the CFSv2 hindcasts.

- Improve the Operations-to-Research (O2R) environment to encourage the use of CFS by the external community
    - Improve software infrastructure, including use of NEMS, model documentation, user support and improved scalability to produce robust results at multiple scales.
    - Improve data archival system and the ease of user access.
    - Engage users to develop data requirement.
    - Be transparent about model development pathway, and the evaluation metrics and decision points before the model is frozen
    - Consider ways to ensure proper credit and protection of intellectual property rights, where appropriate, keeping in mind reward structures inside NCEP and for the external community.

- Improve Research-to-Operations (R2O) transitions. To facilitate this, it is necessary to increase openness of the model development process and develop two-way trust between the NCEP developers and the research community. Possible mechanisms include
    - Visiting scientists program
    - Annual CFS science workshops
    - Special journal issue
    - Climate Process Teams (CPTs), for example, testing physical parameterizations in different models (e.g., between NCEP and GFDL) for precipitation and MJO improvement.
    - Explore potential inter-agency funding (e.g., DTC, JCSDA), which is possible when more users use CFS as a research tool and as inputs for decision making.

- Develop CFS under a unified modeling framework
    - Climate processes affect variability on virtually all spatial and temporal scales. A key open question is whether the rectification effects of small-scale and high-frequency weather events can be adequately captured by climate models if the details are not explicitly resolved. Using IPCC class coupled climate models (such as the GFDL model) for predictions on time

scales from days to decades and using NWP class models for seasonal-to-decadal prediction (after modification to properly account for changing radiative forcing) will help to resolve this open question, and offers a pathway to improve linkages between weather and climate modeling and prediction.
    - Employ a science-based rationale to include data assimilation and initialization in the model development cycle. For example, continuity is a critical feature of reanalysis and re-forecasting, so reducing artifacts associated with data assimilation is critical.
    - Need to integrate the GFS and CFS development process, so that the improvements in the coupled CFS on ISI and longer timescales can be incorporated into the GFS itself, assuming they don't degrade its medium-range forecast performance (if they do, that is an indication of compensating errors that probably suggest the need for more careful model development). This is the path very successfully taken by UKMO for almost the last 20 years with their unified model.
    - Testing models, across time scales, across model components (including possibly single-column model testing and limited coupling – just A-O – experiments), and in anticipation of new observing system components that are being developed/deployed, will also help the NOAA modeling community (GFDL, NCEP) to work together.

Next Steps

- Develop a White Paper that outlines the CFSv3 development strategy: This workshop is viewed as a success in terms of its broad engagement of the research community and the open and frank discussions that were engendered. Several ambitious recommendations were articulated in the synthesis session of the meeting. To build on the momentum of the workshop, a core team will be assembled with representatives from NCEP and the broader research community to write a white paper that consolidates the findings and concisely states the recommendations for how to develop a strategic plan that can accelerate progress going forward. The white paper will be made available to meeting participants for comment and then sent to NOAA management as input for further planning.

- Hold a CFS Science Workshop in 2012 (suggested by EMC after the meeting).
    - The time is ripe to allow the community to analyze and evaluate CFSv2 Reanalysis and Reforecast (CFSRR) which is now available from NCDC. The workshop will focus on (i) demonstrating the progress in model performance from CFSv1 to CFSv2, (ii) identifying key model biases and deficiencies to focus future CFSv3 development; and (iii) designing a set of model experiments to further diagnose and reduce biases.

- Start the CFSv3 development process once the CFSv3 strategy is endorsed by NOAA management.