THE NCEP CLIMATE FORECAST SYSTEM

Suru Saha and many others in the

THE ENVIRONMENTAL MODELING CENTER

NCEP/NWS/NOAA

Four essential components:

1. Development and testing of an upgraded data assimilation and forecast model for the new system.
2. Making a new Reanalysis of the atmosphere, ocean, seaice and land over the 42-year period (1979-2020), which is required to provide consistent initial conditions for:
3. Making a complete Reforecast of the new CFS over the 39-year period (1982-2020), in order to provide stable calibration and skill estimates of the new system, for operational subseasonal and seasonal prediction at NCEP
4. Operational Implementation of the new system

An upgrade will involve changes to all components of the CFS, namely:

- **Major improvements to the data assimilation of the atmosphere and to the physics and dynamics of operational NCEP Global Forecast System (GFS)**

- **Major improvements to the data assimilation of the ocean and seaice with the NCEP Global Ocean Data Assimilation System, (GODAS) and a new ocean and seaice model**

- **Major improvements to the data assimilation of the land with the NCEP Global Land Data Assimilation System, (GLDAS) and upgrades to the NCEP Noah Land model**

Example: MILESTONES for CFSv2
(6 ½ years)

Aug 2004:	**CFSv1 was implemented into operations.**
Aug 2004 - Dec 2006:	**Test version of the CFSv2 ready. Upgrades to virtually every part of the data assimilation and forecast model developed over 2 ½ years.**
Jan 2007 - Dec 2007:	**Pilot studies and testing of the full data assimilation and forecast system at low resolution (1 year)**
Nov 2007:	**CFSRR Science Advisory Board Meeting**
Jan 2008 – Dec 2009:	**CFS Reanalysis complete for 31 years 1979-2009 (2 years)**
Jan 2010 – Dec 2010:	**CFS Reforecasts complete for 28 years 1982-2009 (1 year)**
Dec 2010 – Mar 2011:	**NCO parallel implementation of CFSv2 (4 months)**
March 30, 2011:	**Operational implementation of CFSv2**

CFS VERSION 3

- *Introduction of a global hybrid ensemble-variational data assimilation system*

NCEP implemented its global hybrid data assimilation system in Spring 2012. This system uses an Ensemble Kalman Filter (EnKF) to generate flow-dependent covariances used in the variational analysis.

An extension of the current operational hybrid system to a four-dimensional capability using the 4-D Hybrid EnVar is expected in 2015.

The more interesting aspect may be to extend the observation window to something like 12 hours or more. The window may not be symmetric, so observations from the previous 12 hours could be used to extract more temporal information.

CFS VERSION 3

- *Increase the specification of analysis uncertainty*

The EnKF also provides error bars on the accuracy of the Reanalysis, something entirely missing in the present CFSR.

The recently developed enhanced bias correction methods at EMC will prove extremely useful in reanalysis mode, as it can spin up much more quickly and consistently.

We should also think about how to address the issues that came about with the significant change in the observing system in the late 1990s with the introduction of the AMSU satellite data.

CFS VERSION 3

- *Improve analysis coupling*

The operational CFSR uses a coupled atmosphere-ocean-land-sea ice forecast for the analysis background but the analysis is done separately for each of the domains.

In the next reanalysis, the goal is to increase the coupling so that, e.g., the ocean analysis influences the atmospheric analysis (and vice versa). This will be achieved mainly by using a coupled ensemble system to provide the background and the EnKF to generate structure functions that extend across the sea-atmosphere interface.

The same can be done for the atmosphere and land, because assimilation of land data will be improved for soil temperature and soil moisture content.

CFS VERSION 3

- *Improve analysis coupling (contd)*

According to my colleague Daryl Kleist and I quote: “Strongly coupled data assimilation will be the next frontier, and a significant breakthrough could yield significant gains, if it can be cracked.”

CFS VERSION 3

- *Increase the analysis variables to provide more climate-relevant quantities*

The next CFSR will provide aerosol and chemical constituents such as dust, black carbon, sulfates, carbon dioxide, methane, nox, and other green house gases. In the ocean, some biogeochemical constituents will be possible with remote sensing of “ocean color.”

CFS VERSION 3

- *Increased resolution of the system*

The resolution of all parts of the system will be increased in proportion to the increased computing power currently available, with the possibility of exploring cheaper cloud computing options.

This will result in better assimilation of isolated data observed in the vicinity of steep topography.

CFS VERSION 3

- *Increased resolution of the system (contd)*

  It will also allow a better description of extremes over the period 1979-2020, along with changes in climate that can be guided by forcing functions (aerosols, GHGs), and observations amenable to assimilation.

  One example of an improved description of assimilating extremes would be hurricanes and storm surge events that become better resolved at high resolution.

  Another example is better hydrology to improve the realism of extremes in droughts, floods and river flow.

CFS VERSION 3

- *Increased resolution of the system (contd)*

Higher resolution and better topography, along with improved physics of the boundary layer and improvements to both shallow and deep convection, will help the analysis at the interfaces, ie. sea surface temperature, 2-meter air temperature and precipitation. Producing a better daily cycle in each of these three interface variables is absolutely necessary.

An increase in resolution and the embedding of regional models into the global domain will also help in make more realistic downscaling studies possible.

CFS VERSION 3

- *Increased resolution of the system (contd)*

Increased resolution of the coupled system will also improve the representation of waves, shallow coastal oceans and ecosystems.

Increased resolution into the stratosphere and higher comes at an opportune time, now that nature offers us an experiment with a quiet sun from 2008 onward, followed by an extremely weak solar cycle 24. This should yield insight into the chemistry of such vital elements as ozone, and give a better description of both the trend and interannual variation of the ozone hole from 1979-present.

Increased vertical resolution in the stratosphere will potentially help in the prediction/simulation of the QBO.

CFS VERSION 3

- *Mitigate some of the problems in the operational CFSR*

Among the toughest problems is the analysis of sea-ice. The period 1979-2020 offers hitherto hard to explain, variations in the extent and thickness of the sea-ice in both polar regions. The modeling of sea ice, shelf ice, sheet ice and glacial ice needs to improve.

Special attention has to be given to the coupling of seaice to fresh water from atmosphere and continental runoff, and its interaction with meridional overturning currents in all ocean basins (especially the North Atlantic) and marginal seas (Mediterranean, Baltic etc).

CFS VERSION 3

NEMS:

The NOAA Environmental Modeling System can be the vehicle used to make seasonal forecasts. The NEMS superstructure allows the coupling of multiple-model geophysical components for both weather and climate prediction.

Multi-model Ensemble:

The ensemble coupling strategy in NEMS is wrapped around the full Earth system components. That is, each member is a fully coupled geophysical component. The NEMS ensemble coupler supports stochastic state forcing among its full geophysical components, allowing controlled ensemble spread with consistent physical members.

CFS VERSION 3

Regional climate

A major advantage of a unified modeling system is the capability of supporting regional weather and climate models within the global system. The regional climate models will effectively downscale the global seasonal and climate predictions. The regional capability can also be seamless from daily to seasonal forecasting.

Data assimilation

The coupled hybrid ensemble Kalman filter data assimilation system will not only support consistent ocean and atmosphere observation analysis, it will also naturally support self-consistent ensemble initial conditions for both the weather and climate prediction capability.

CFS VERSION 3

Thrust on week3-week6 (monthly) Range

Every implementation of the CFS had a primary area of interest, apart from the obvious one of seasonal prediction.

CFSv1 tried to address the ***seasonal*** prediction of SSTs in the tropics and ENSO.

CFSv2 tried to address ***subseasonal*** prediction, example for the MJO.

CFSv3 will try to address the ***monthly*** prediction of surface variables, such as 2-meter temperature and precipitation of the United States, as well as the prediction of global seaice.

If CFSv3 is able to improve the predictions stated above, it will have considerable impact on many sectors, such as energy, transportation, hydrology, etc.

THANK YOU

CFS VERSION 3

Any project of this magnitude needs a champion. Traditionally, it had been the job of the EMC Climate Team Lead to be this champion, to prepare, execute and operationally implement plans for CFSv3. A new champion needs to be in place before any viable development can begin with a prototype of CFSv3 being built as soon as possible.

NOAA needs to fully support the development of CFSv3 by providing the required human and computer resources to get this huge project accomplished.

Strong collaborative efforts within NOAA and the external community, such as academia and the private sector, is also an essential component of this project.