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Outstanding Open Problems in Short-term Climate Prediction

Climate S&TI, Office of Science and Technology

NOAA/National Weather Service

Introduction

The National Weather Service (NWS) is developing a seamless suite of products and services from weather and water warnings and forecasts to short-term climate prediction to meet a broad spectrum of societal needs for various applications. Due to the complexity of the weather-climate system, prediction skill beyond week-1 is still limited. A rapid increase of uncertainties with forecast lead time has been attributed to the interaction of inadequacies in models and observations with the chaotic nature of the system. A grand challenge for research is to distinguish the potentially predictable part of the problem that can be improved upon from the chaotic unpredictable part. Often this is more hopefully done by case studies. Toward this end, the NWS/Office of Science and Technology (OST) Science and Technology Infusion Climate Bulletin has established a ***Board of Outstanding Open Problems***. The purpose of the Board is to encourage research interest in cases identified by operational climate forecasters to help improve the operational prediction. In this poster, two cases are presented: (1) a difficult ENSO phase transition prediction, and (2) a week-2 forecast that was opposite to what occurred.

1. Difficulties in Prediction of ENSO Phase Changes and Impact on Outlooks of 2006 North Atlantic Hurricane Season & 2006/07 DJF US Drought

Background

In addition to interdecadal variability/trend, the predictive ENSO condition is very important information for forecasters when making seasonal outlooks. Usually, the prediction skill of tropical SST is high due to persistency after April for next winter forecast. The persistence is low from fall into the next year past April. Forecasters found that all tools are too much like persistence, according to which too late phase transition would also occur in the forecast, the events starting too late and then lasting beyond the time they should. Following is a recent case, showing forecasts of ENSO phase transitions in late 2006 and early 2007 and the influence on the outlooks of 2006 North Atlantic hurricane season and 2006/07 DJF US precipitation. The focus is on the NCEP Climate Forecast System (CFS), though other dynamical and statistical models have similar problem as seen in the ENSO prediction plume graph produced routinely by the International Research Institute for Climate and Society (IRI).

Problems

2006 North Atlantic Hurricane Season Outlook

i) The 2006 May outlook called for a good chance of an above normal season (Fig.1) mainly based on prevailing ENSO neutral condition (Fig.2 upper panel) and warming trend.

ii) In early August forecast update, the interpretation of already less favorable atmospheric conditions continued to be possibly due to unfavorable intra-seasonal activity with at best a weak El Nino development (Fig.2 middle panel), hence reluctant to downgrade the earlier active season forecast (Fig.1).

iii) In mid September NOAA declared that El Nino had already developed and was likely to continue. (Fig.2 lower panel)

iv) The 2006 hurricane season was finally classified as a near-normal season. (Fig.1)

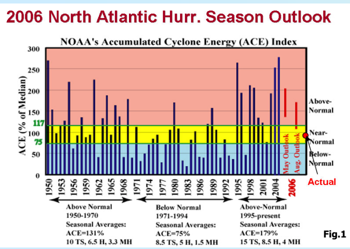


Fig.1

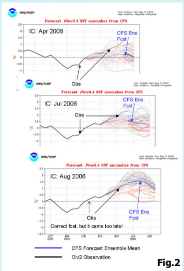


Fig.2

2006/07 DJF US Drought Outlook

El Nino faded out rapidly in 2006/07 winter. CFS ensemble forecast didn't catch such change until January (Fig.3), causing problems in DJF precipitation forecast (Fig.4), which degraded the seasonal drought outlook.

(*The above cases were provided by Muthuvel Chelliah and Douglas Lecomte of CPC/NCEP.*)

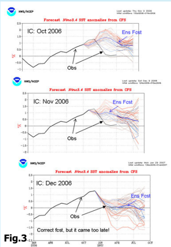


Fig.3

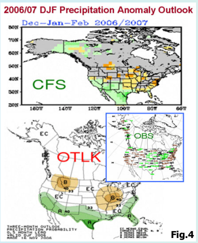
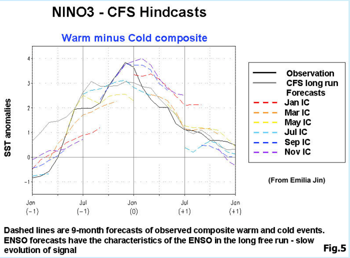


Fig.4



Dashed lines are 9-month forecasts of observed composite warm and cold events. ENSO forecasts have the characteristics of the ENSO in the long free run - slow evolution of signal

Fig.5

Lead discussions

1. Systematic bias

The model behavior toward elongating ENSO events (both cold and warm) in time has also been seen in the past in the CFS hindcasts. When the initial state is, say, cold, the CFS tends to persist it and misses the transition to warm. The same problem occurs in the opposite transition direction. Figure 5 from an analysis of CFS hindcasts shows how cold states and warm states tend to be overly persistent.

2. Prediction obstacle

One should not fault CFS for not predicting a transition at all times. The plume diagrams of Figure 6 show that CFS did a fine job when the initial states passed the spring predictability barrier for the four years of 82, 83, 97 and 98. However, the critical point of such prediction obstacle can occur in any seasons (such as that between July and August as well as that

(cont. on right)

(cont. from left)

between November and December in 2006). Besides, forecasts of weak events continue to be difficult by any verification scores that are a signal to noise ratio measure. The weak El Nino of last summer could be just something that the failed hurricane forecast could blame on. There is more to it as other researches indicated.

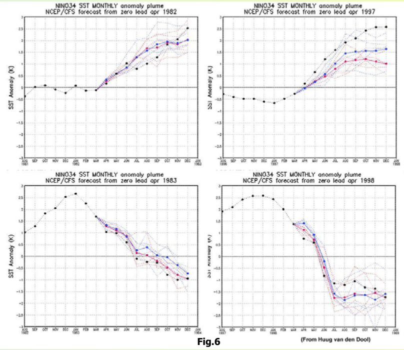


Fig.6

3. Exploration and suggestion

Figure 7 shows Hovermoeller diagrams of SST along the equator in the Pacific for a case study of the 1983 event for two different models, namely, CCSM on the left and CFS on the right. The CCSM hindcast ensembles have been run from real ocean initial states (MOM3 ODA) initialized with AMIP atmosphere and land initial states in Jan 1983. The OISSTv2 was used as verification for both CFS and CCSM and the systematic error of both models has been corrected, based on the cases in the set (19 cases for CCSM and 25 cases for CFS). The two models each have 8 panels with the observed (verification) in the upper left, the ensemble mean in the upper right and six individual ensemble members below. (The CFS picked the first six members from its hindcast set of 15 members.). This figure indicates that in the 1983 case, the CCSM did a more creditable job of predicting the transition not only by the ensemble mean but also by individual members.

Figure 8 is the same as Figure 7, except for the 1997 case with Jan 1997 ocean initial state. The CCSM also did a fairly good job, although it underestimated the amplitude and displayed the characteristic excessive westward propagation of anomaly phase that is a systematic behavior of CCSM in ENSO events. Since the six CFS members selected by the designated way could be underrepresented, an additional check of the latest 10 members ensemble mean was made and shown in Figure 9. Again, the forecast held on to the initial cold anomaly too much and significantly delayed the onset of El Nino.

Figure 10 shows the CCSM predicted the transition from cold to warm in the middle of 2006. This admittedly limited set of results suggests that the multi-model approach could be invaluable for the purpose of providing better information to forecasters whose concern is, say, six-month lead forecasts of ENSO that are used as guidance for hurricane and/or drought outlooks

(*The above discussions were provided by Huug van den Dool of CPC/NCEP and James Kinter of COLA/GMU*)

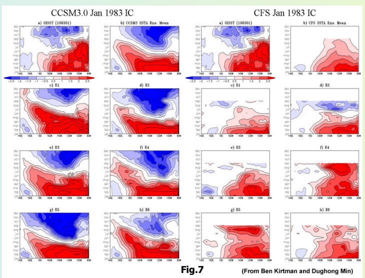


Fig.7

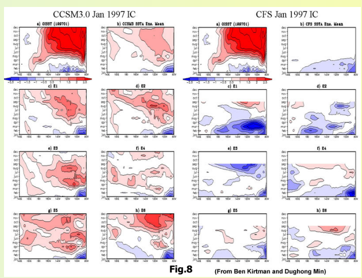


Fig.8

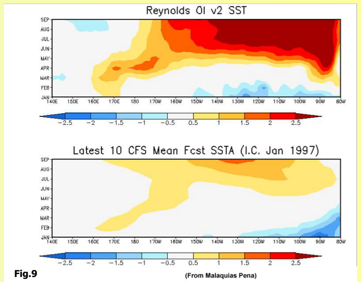


Fig.9

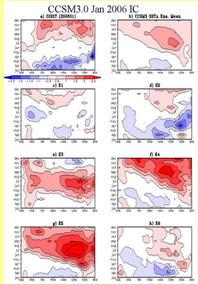


Fig.10

2. A case of week-2 forecast running to the opposite of the observation

Date of initial condition : 11/21/06

Forecast target period: 11/29-12/5/06

Predictant: Mean surface temperature anomaly

Model: NCEP GFS

Problems:

i) The model ensemble forecast was totally out of phase compared with the observation (Fig.1).

ii) Further examined the near-range forecast and found that the 6-10 day forecast from 11/26 initial condition can correctly capture the 500 hPa height observed pattern, while that from 11/25 initial condition cannot. (Fig.2)

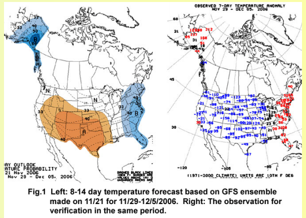


Fig.1 Left: 8-14 day temperature forecast based on GFS ensemble made on 11/21 for 11/29-12/5/2006. Right: The observation for verification in the same period.

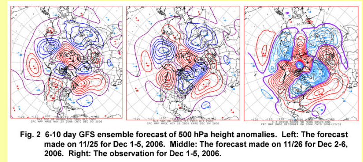


Fig. 2 6-10 day GFS ensemble forecast of 500 hPa height anomalies. Left: The forecast made on 11/25 for Dec 1-5, 2006. Middle: The forecast made on 11/26 for Dec 2-6, 2006. Right: The observation for Dec 1-5, 2006.

Interim summary of discussions

This week-2 forecast problem from routine operation has got broad attention in both weather and climate communities at ESRL, ARL, CPC, EMC, NCAR, UA and IU. The implication of emerging ideas has gone far beyond the scope of this special case. Following is an interim summary, which stringed important pieces of idea together.

1. What do we need to focus on for improving the week-2 forecast?

a. Upstream regimes of weather system development

When we extending our forecast range from week-1 to week-2, our focused area should be moved from NA to its upstream areas. According to the ECMWF recent practice, improving precipitation modeling over the continental US had large benefit to their 1-2 week forecast over Europe and including NCEP GFS also improve their multi-model ensemble prediction skill. It would be beneficial to investigate critical regions in NA's upstream, where weather system development influences the US w-2 forecast the most. In addition to those areas we've already paid a lot of attention to, e.g. tropical oceans, areas of AO/NAO, PNA, west of coasts ..., promising regions would also include the Tibetan Plateau, areas of prevailing Asian summer and winter monsoons, Eurasia snow cover, and the Arctic Ocean, where our model performance in each season is less assessed.

b. Day-1 forecast

As pointed out by Lorenz (1982), the best way to improve the weather forecast beyond day 1 is by improving the first day forecast. According to the critical information provided, the difference between the day-1 forecast started from 11/25 and that from 11/26 could be the key to understand the problem. If the difference looks like the random perturbation, the problem could be underestimated. Otherwise we may conjecture that some important regional weather system development in the upstream could be missing in the model forecast. This would possibly be the case, since usually the global day-1 forecast skill is high, which implies the large scale features between the forecast and the verification are alike globally. By focusing on day-1, we can isolate/identify the problem more effectively and make clearer thinking on model deficiencies in physics and dynamics.

2. Physical processes and interactions

Tropical forcing, energy propagation and interaction with the strength of atmosphere-land/ocean coupling along the developing path have been discussed for the potential causes of the model forecast failure. Since the global model is far from faithfully representing regional characteristics, the regional model designed for regional applications are more capable to catch the regional system development than the global model. In such consideration, developing nested model with that the embedded regional model having two-way interactive lateral boundary, instead of one-way downscaling like most regional models currently doing, should be set as a R&D challenge to the research community.

(*This case was presented by Mike Halpert at Review of the NCEP Products Suite, Camp Spring, 13 Dec. 2006*)

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