3.8 THE NEW SEASONAL FORECAST MODEL AT NCEP

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1. INTRODUCTION

The Global Climate and Weather Modeling Branch of the Environmental Modeling Center (EMC) develops and improves operational global numerical weather and seasonal forecasts. Every six hours the National Centers for Environmental Prediction (NCEP) generate 16-day forecasts with a global atmospheric model and observed sea surface temperatures (SST) damped to climatology in the forecasts. For seasonal forecasts NCEP runs coupled ocean-atmosphere models out to nine months. EMC is developing a new seasonal forecast system, unifying the atmospheric models used for weather and seasonal forecasts.

The new global coupled atmosphere-ocean forecast system (CFS03) consists of a T62 64 level version of the operational NCEP atmospheric Global Forecast System (GFS03) and the Geophysical Fluid Dynamics Laboratory (GFDL) Modular Ocean Model 3 (MOM3). CFS03 is expected to replace the currently operational seasonal forecast system this year. Simulations with the coupled model have been run for over 30 years without flux correction. Increasing the number of vertical levels in the atmospheric model resulted in substantially better simulation of equatorial sea surface temperature with a bias of less than 1°K. The model realistically simulates ENSO variability with amiplitude and frequency comparable to that observed.

A 23-year database of hind-casts is being generated to provide the model climatology for real-time prediction bias corrections and to provide estimates of real-time forecast reliability. Results from the hind-casts indicate more skill in forecasting SSTs in the equatorial Pacific than the currently operational seasonal forecast system.

2. THE CFS03

The atmospheric component of the CFS03 is the operational Global Forecast System of 2003 with a spectral truncation of 62 waves (T62) in the horizontal (equivalent to a 200 km grid) and a finite differencing in the vertical with 64 sigma layers. Information on the model can be found at http://www.emc.ncep.noaa.gov/gmb/.

The oceanic component is the GFDL MOM3 (Pacanowski and Griffies, 1998). Its domain extends from 74S to 64N and has a zonal resolution of 1°. Its meridional resolution of 1/3° between 10S and 10N gradually increases until it is fixed at 1° poleward of 30S and 30N. There are 40 levels in the vertical with 27 in the upper 400 m.

The atmospheric and oceanic components exchange daily averaged quantities once a day; no flux adjustment is used. Sea ice extent is prescribed from observed climatology.

Twenty-three years of coupled hindcasts by the CFS03 for 1981-2003 are being produced. A nine-month seasonal forecast is being produced for each month. Each seasonal forecast has 15 ensemble members using three initial ocean states for each month and daily atmospheric conditions from the NCEP-2 reanalyses centered about the ocean analysis dates. The initial ocean states are from the new NCEP global ocean data assimilation system (GODAS) (Behringer, personal communication). GODAS uses MOM3 and is forced by wind stress, heat flux and precipitation minus evaporation from NCEP-2. SST is relaxed to the weekly NCEP SST analysis. To complete the hind-casts will require over 3000 years of coupled model integration.

Operational seasonal forecasting at NCEP currently uses a two-tier system. The coupled ocean-atmosphere model generates an SST forecast that is then used as a boundary condition for an atmospheric model to generate seasonal forecasts of surface temperature and precipitation over the United States. Use of an atmospheric model only in Tier 2 permits a larger ensemble of forecasts. The two-tier system will be replaced by a

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one-year when the CFS03 is implemented later this year. In operations one 10 month forecast will be made daily with the CFS03 using initial conditions from the NCEP-2 reanalysis run as CDAS-2 and a daily GODAS analysis. Monthly mean skill estimates will be available from the 23 years of hindcasts

3 . 30-YEAR SIMULATIONS

The CFS03 was integrated for more than 30 years starting from initial conditions for 1 Jan. 2002. Two simulations, one with 28 vertical levels in the atmospheric model and one with 64, are compared here. The results are compared with observations for the last few decades.

Fig. 1 shows the differences between SST from the first 23 years of the simulations and the mean SST from the NCEP/NCAR reanalysis for 1979-2001. The simulation with 64 levels shows much less cold bias near the equator than the simulation with 28 levels. Both simulations show substantial biases near the Gulf Stream and Kuroshio, perhaps reflecting the need for higher resolution in the ocean

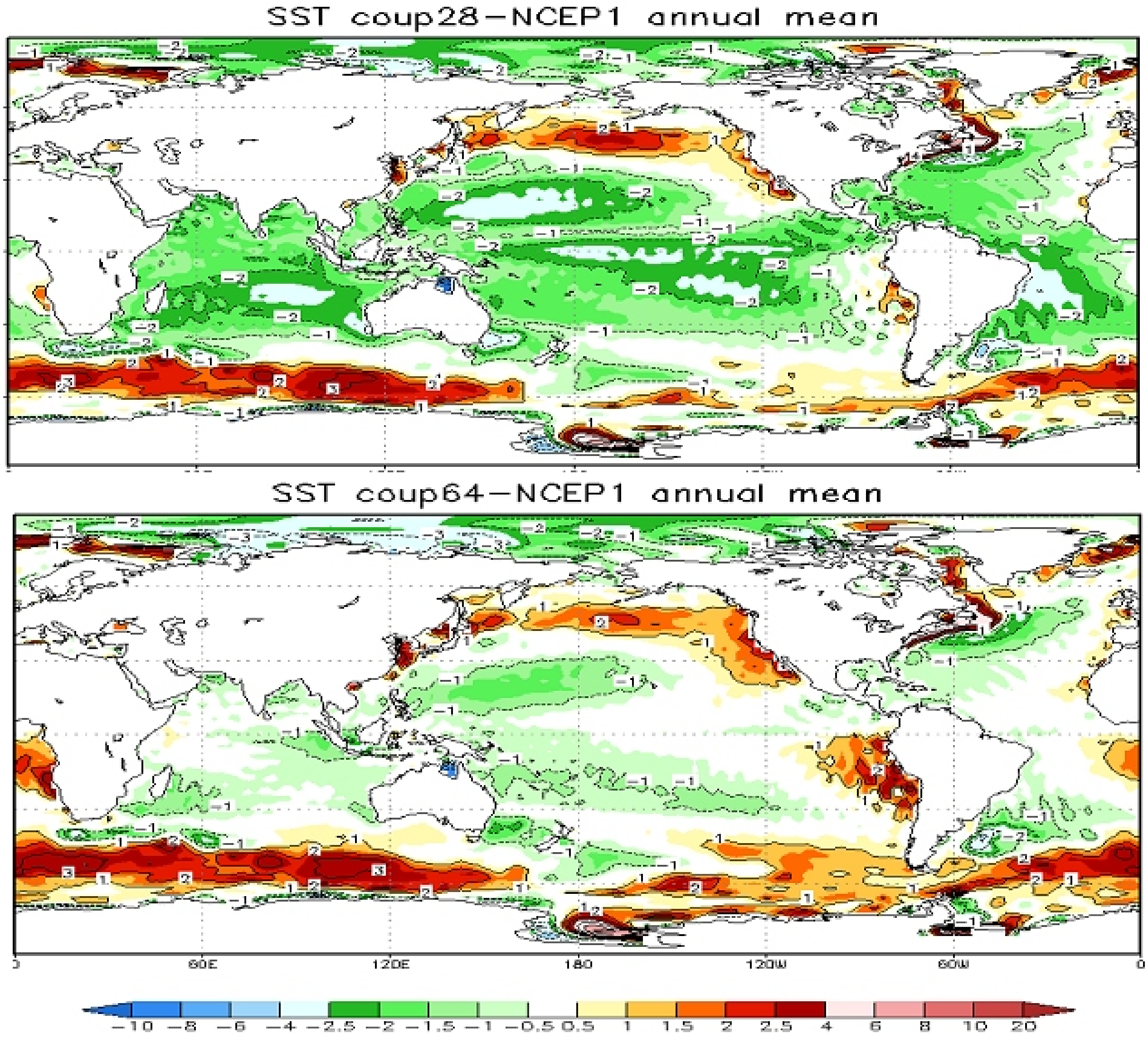

Fig. 1 Difference between mean SST in the first 23 years of coupled model simulation with (top) 28 levels and (bottom) 64 levels in the atmospheric model compared to mean SST for 1979-2001 from the NCEP/NCAR reanalysis in ^{o}K.

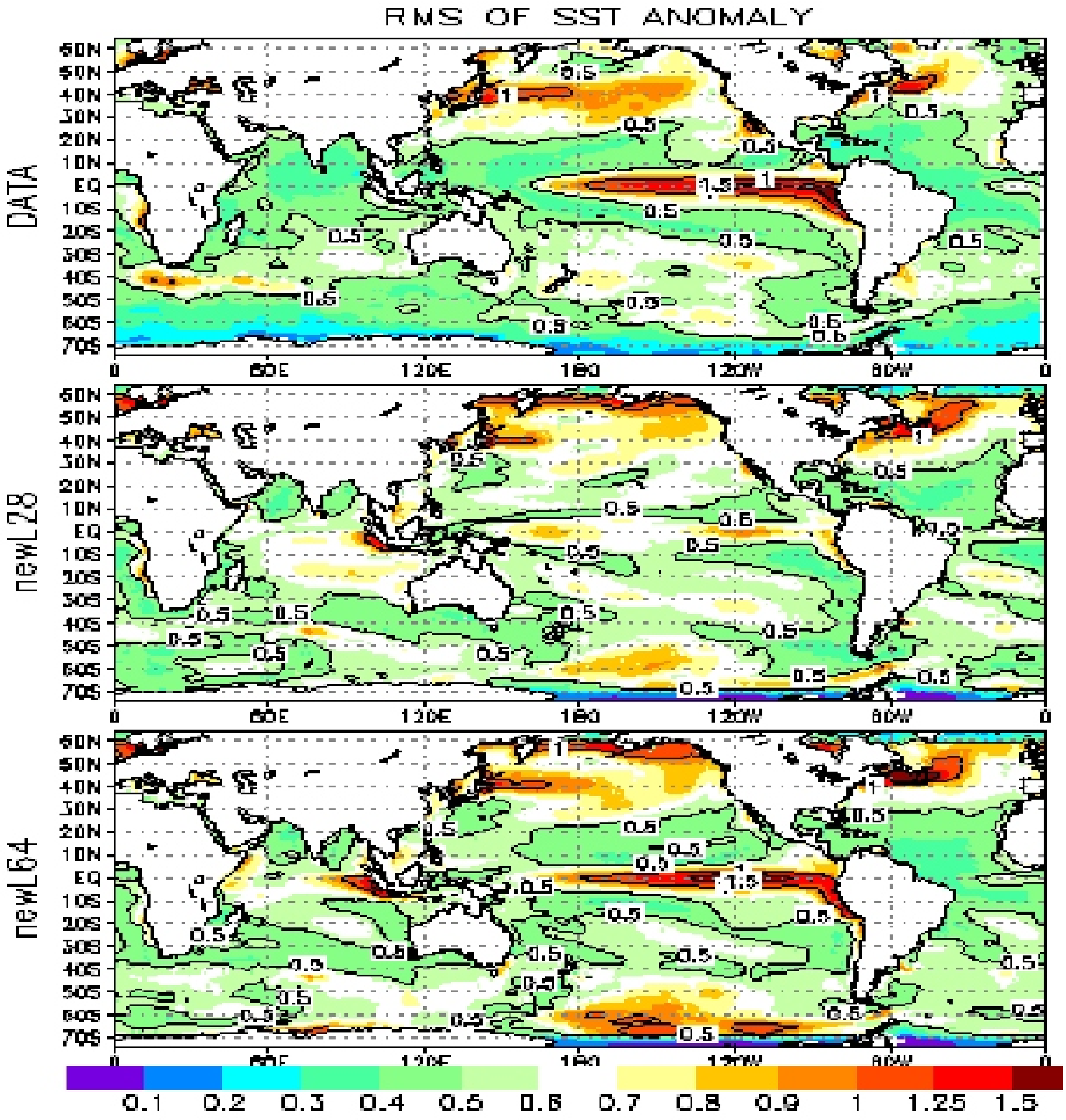

Fig. 2 RMS of monthly SST anomalies from (top) observations and coupled model integrations with (middle) 28 levels in the atmosphere and (bottom) 64 levels in the atmosphere in ^{o}K.

model to resolve the warm boundary currents correctly. The simulations also show a substantial warm bias near Antarctica, perhaps reflecting the lack of sea ice processes.

Fig. 2 compares interannual variability in SST anomalies from observations and from the model simulations. The simulation with 64 levels has much more realistic variability in the eastern equatorial Pacific where ENSO occurs. These plots indicate the need for higher vertical resolution in the atmospheric component of the CFS03; the need for higher vertical resolution will be further investigated. Increasing horizontal resolution appeared to have less impact.

Fig. 3 compares precipitation in the coupled simulations with an observational estimate (CMAP). The simulation with 28 levels is much too dry along the equator in the eastern Pacific and has too strong an ITCZ in the eastern Pacific. The 64 level pattern is more like CMAP in the equatorial Pacific.

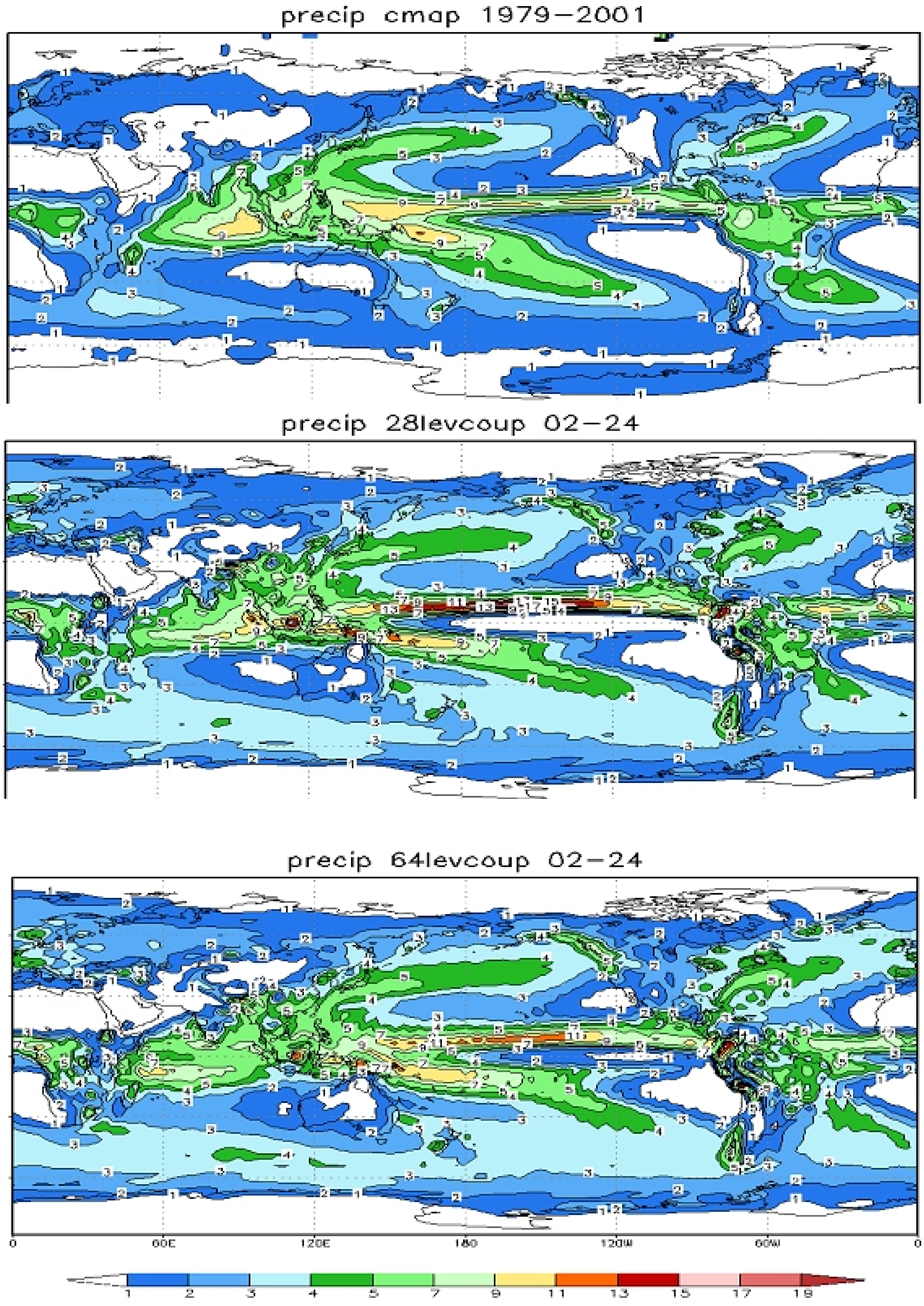
precip cmap 1979–2001

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Fig. 3 23-year mean precipitation from (top) CMAP and coupled simulations with (middle) 28 and (bottom) 64 vertical levels in atmospheric model in mm/day.

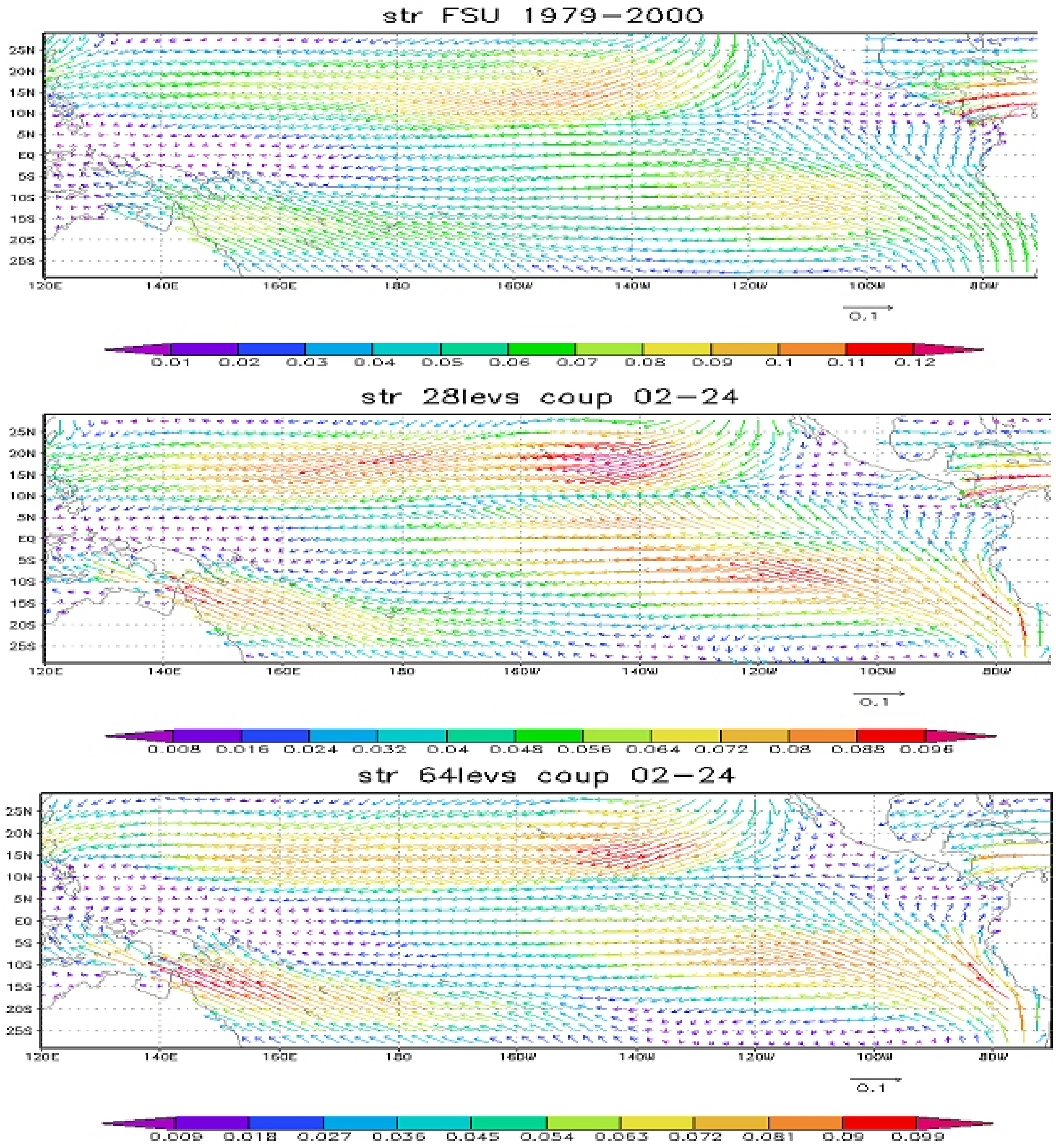
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Fig. 4 Mean surface stress in the tropical Pacific from (top) 22 years of FSU analyses and 23 year CFS simulations with (middle) 28 and (bottom) 64 atmospheric levels.

Consistent with its stronger ITCZ, the simulation with 28 levels shows much stronger cross-equatorial surface stress in the eastern equatorial Pacific than the FSU analyses or the simulation with 64 levels, as shown in Figure 4. The simulation with 64 levels has a much more reasonable pattern of surface stress in the equatorial Pacific. As Figure 5 shows, the excessive stress in the simulation with 28 levels produces too much Ekman pumping and too much upwelling near the equator, producing the cold bias shown in Fig. 1. The use of greater vertical resolution in the atmospheric model yields a much more realistic climatology in the tropical Pacific.

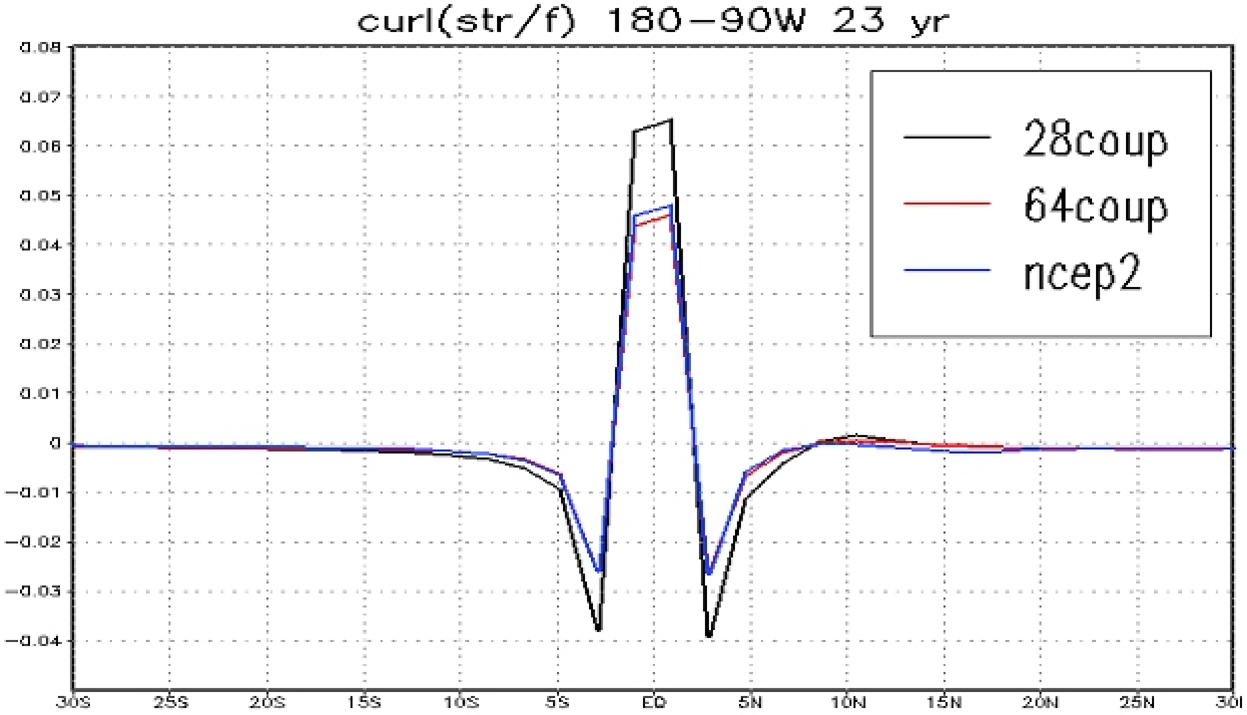


Fig. 5 Time-mean curl of the the surfsce stress divided by the Coriolis parameter, proportional to Ekman pumping, from 23 year climatologies of the NCEP-2 reanalysis and of CFS simulations with 28 and 64 layers in the atmosphere.

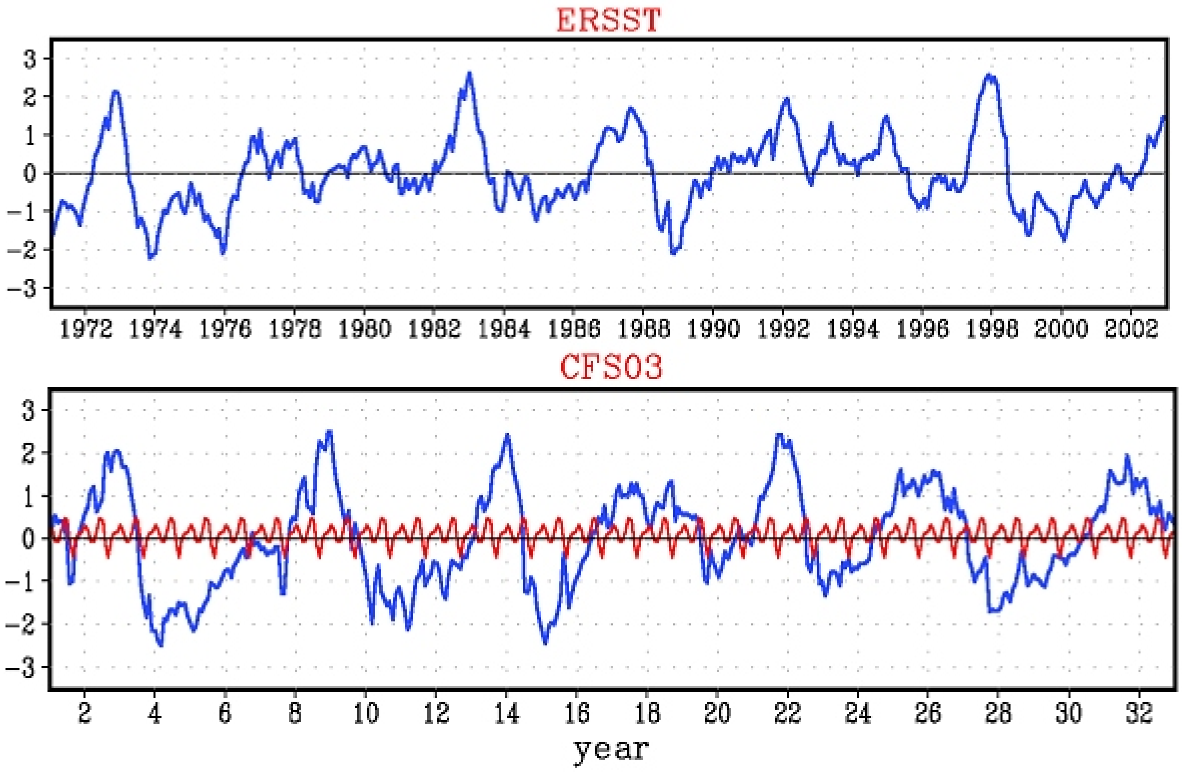


Fig. 6 SST anomalies in Nino3.4 (5S-5N, 190-240E) from (top) analyses and (bottom) the CFS03 simulation with 64 vertical atmospheric layers. The red curve indicates the 23-year mena monthly bias in the CFS03.

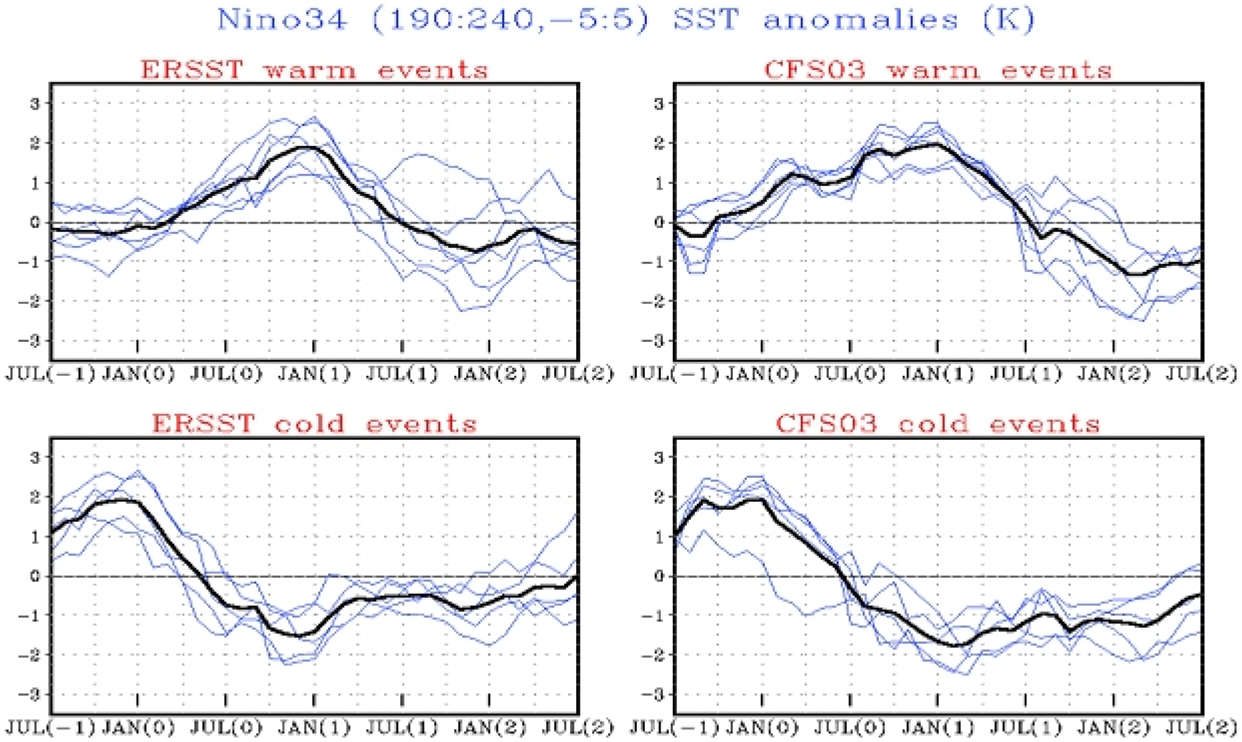


Fig. 7 Individual (thin curves) and composite (thick curves (top) warm and (bottom) cold events from 32 years of (left) SST analyses and (right) the CFS03 simulation with 64 atmospheric layers. Units are K.

Why the vertical atmospheric resolution makes such a difference will be investigated in further studies.

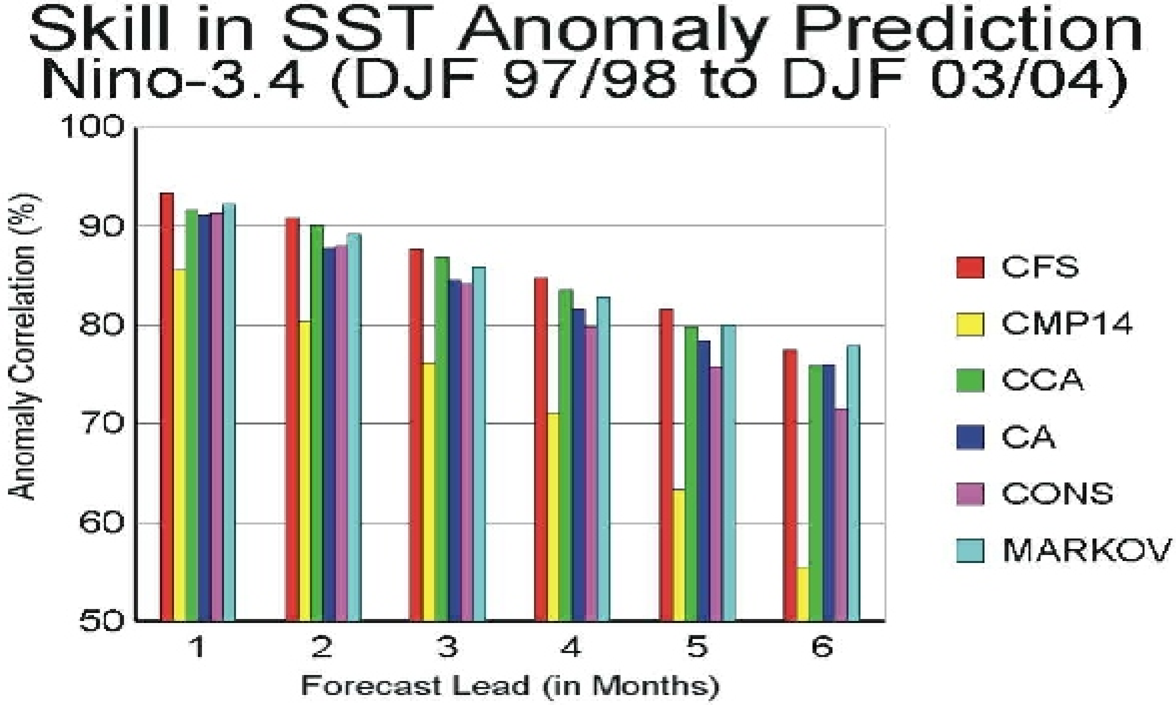
The CFS03 simulation with 64 atmospheric layers produces very realistic ENSO events, as Figures 6 and 7 display. SST anomalies in the Nino3.4 area are dominated by the alternation between warm and cold events with a period of 3-7 years. The amplitude in observations and the simulation is comparable, but the simulated events appear more regular. Fig. 7 shows the phase locking of the ENSO event to the seasonal cycle in the observations and the simulation. The simulated warm events tend to start about 3 months before the observed warm events; the cold events persist longer in the simulation that in the observations. The simulated warm events show less spread that the observed warm events, suggesting that the dynamics in the model are more restricted than in nature.

4. HIND-CASTS

Figure 8 displays the skill of seasonal forecasts originating in Dec.-Feb. In forecasts for the last 7 years, the CFS03 substantially out-performs the currently operational seasonal forecast system and is slightly better than the statistical methods used by the Climate Prediction Center. Hind-casts for previous years display less skill, perhaps reflecting the lack of observations in the tropical Pacific before the TOGA TAO array was in place. Fig. 9 compares observed SST anomalies in Nino 3.4 to SST anomalies forecast by the CFS03. Fig. 10 displays the most recent forecast originating in June 2004. Five ensemble members were run from initial atmospheric conditions a day apart at the beginning of June with one ocean initial condition and five were run from initial conditions in the middle of June.

5. CONCLUSIONS

The new seasonal forecast model displays realistic MJO and ENSO activity and has considerable more forecast skill for recent years than the current seasonal forecast model. It is scheduled to be implemented this fall. An extensive archive of fields from the hind-casts available to the scientific community is planned. Why increasing the number of atmospheric vertical layers improves the CFS climate will be investigated. Work on a replacement to the CFS03 will begin soon and will include the introduction of MOM4, a sea-ice model, improved stratus clouds, and higher resolution.



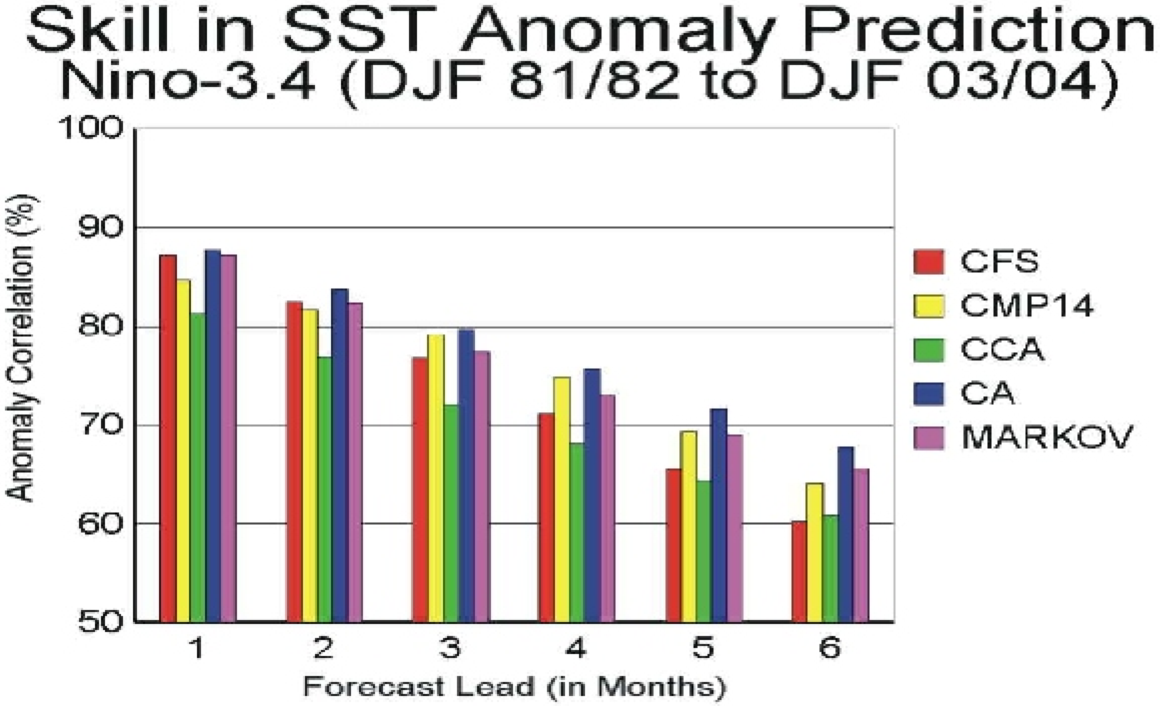


Fig. 8 Skill in predicting SST anomalies in Nino-3.4 for CFS03 (CFS), the currently operational seasonal forecast model (CMP14), three statistical methods used by the Climate Predication Center (Canonical Correlation Analysis (CCA), Constructed Analog (CA), and Markov, and the official CPC consolidated forecast (CONS) for forecasts originating in DJF for (top) 1997/98 to 2003/04 and (bottom) 1981/82 to 2003/05.

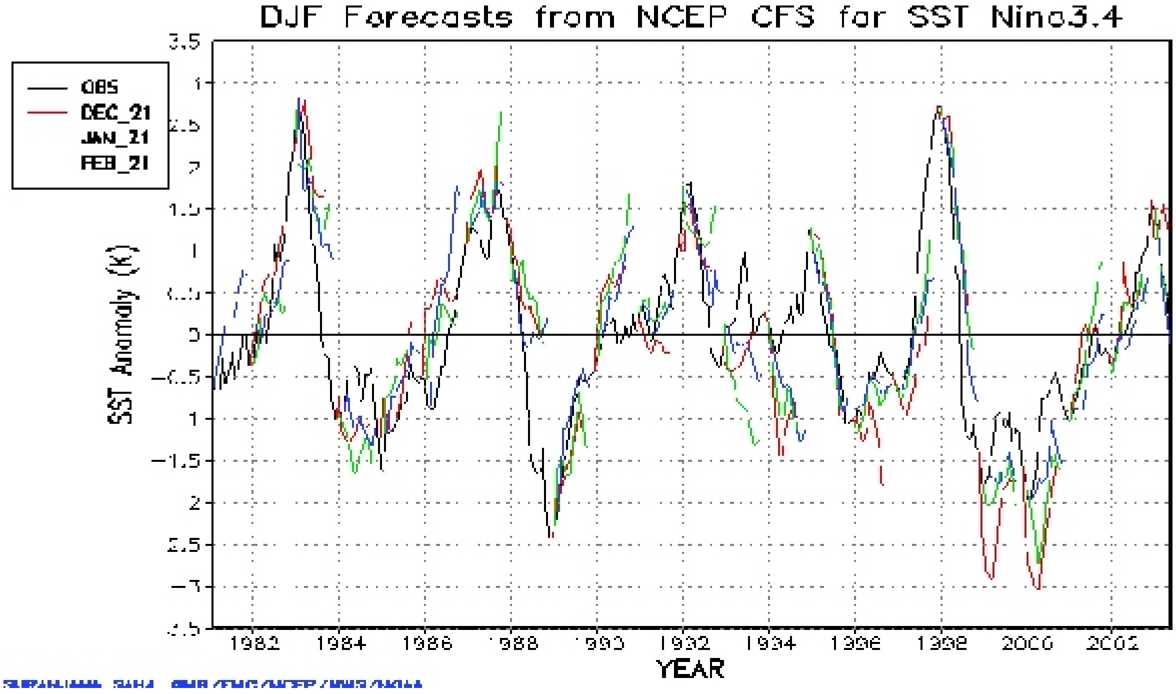


Fig. 9 Observed SST anomalies for Nino 3.4 compared to CFS03 hind-cast anomalies.

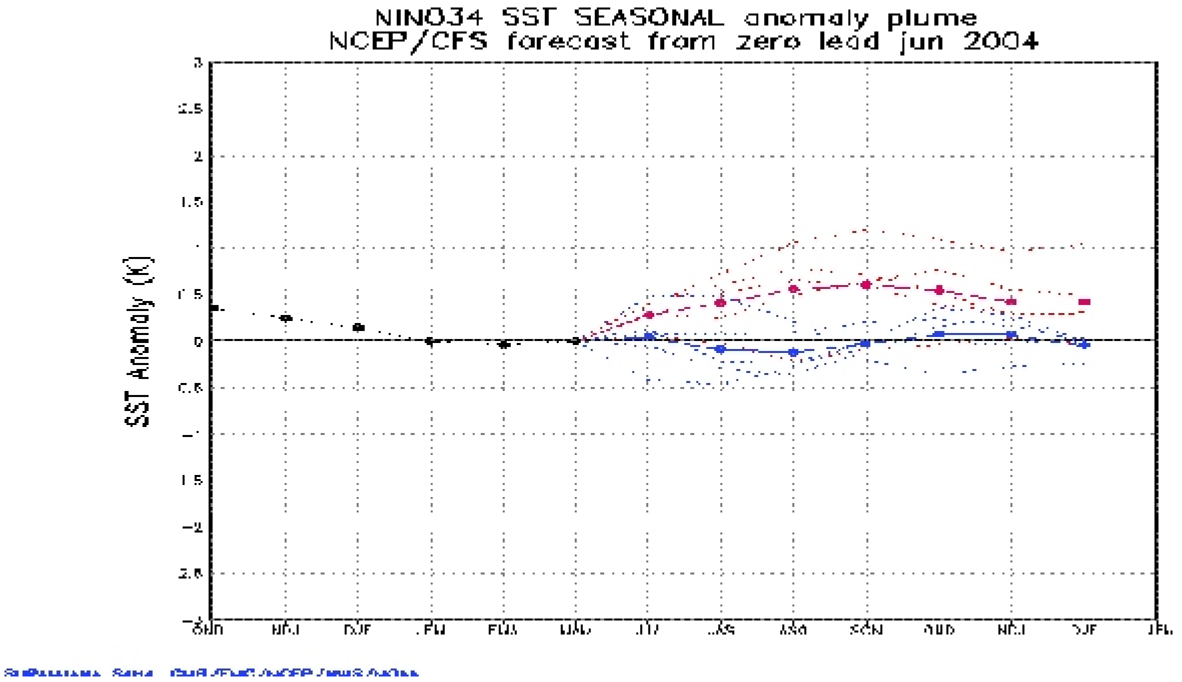


Fig. 10 CFS03 forecast of SST anomalies in Nino 3.4. Red lines are forecasts from 5 initial atmospheric(and one oceanic) conditions in the beginning of the month and blue lines are forecasts from 5 initial conditions in the middle of the month.