Tropical Pacific SST Predictions with a Coupled GCM

contributed by Ben Kirtman, Bohua Huang, J. Shukla and Zhengxin Zhu

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The Center for Ocean-Land-Atmosphere Studies (COLA) has recently developed an anomaly coupled prediction system, using sophisticated dynamical ocean and atmosphere models, that produces skillful forecasts of the tropical Pacific sea surface temperature anomaly (SSTA) up to 1.5 years in advance. The details of this coupled prediction system are described by Kirtman et al. (1996b) and a brief description of the overall skill of the 30 hindcast predictions was given in the March 1995 issue of this Bulletin. The atmospheric component is the COLA atmospheric general circulation model (AGCM; Kinter et al. 1988) that includes a state-of-the-art land surface model (Xue et al. 1991) and physical parameterizations of radiation, convection, and turbulence. The AGCM is a global spectral model that is horizontally truncated at triangular wavenumber 30 and has 18 unevenly spaced sigma levels in the vertical. The oceanic component is a Pacific basin version of the Geophysical Fluid Dynamics Laboratory (GFDL) ocean model (Pacanowski et al. 1993). In the ocean model there are 20 levels in the vertical with 16 levels in the upper 400 m. The zonal resolution is 1.5° longitude and 0.5° latitude between 20°N and 20°S. Further details of the ocean model are provided in Huang and Schneider (1996).

We have separately tested the ocean and atmosphere component models in order to evaluate their performance when forced by observed boundary conditions and improvements have been made that are also incorporated into the coupled prediction system. The effects of atmospheric model zonal wind stress errors have been ameliorated by using the zonal wind at the top of the boundary layer to redefine the zonal wind stress at the surface (Huang and Shukla 1996). We have also developed an iterative procedure for further adjusting the zonal wind stress, based on the simulated SSTA errors, that improves initial conditions for coupled forecasts (Kirtman et al. 1996a).

The Niño 3 SSTA root mean squared error (RMSE) and correlation as a function of forecast lead time was shown in the March 1995 issue of this Bulletin. The RMSE and the correlation are computed with respect to the observed SSTA. The correlation in the Nino 3 region remained above 0.6 for lead times of up to 12 months and was larger than that of the persistence forecast for all lead times greater than 3 months.

Figure 1 shows the time series of the predicted SSTA in the Niño 3 region for the three forecasts initialized on December 1, 1995, January 1 and February 1, 1996. Each forecast is run through February 1997. All three forecast show a consistent evolution with relatively cool temperatures in the boreal winter of 1995-96 and a fairly rapid transition to relatively warm temperatures in the boreal winter of 1996-97. The predicted SSTA anomalies are near normal during summer 1996. In the forecasts initialized in December 1995 and February 1996, the warm anomalies plateau during the boreal winter of 1996-97 while the forecast initialized in January 1996 shows continued warming. The warming trend seen in all three of these predictions is consistent with forecasts initialized in September 1995 and November 1995 shown in the December 1995 issue of this Bulletin.

The ensemble mean (average of all three forecasts) horizontal structure of the predicted SSTA for the boreal summer of 1996, fall of 1996 and winter of 1996-97 are shown in the three panels of Fig. 2. The ensemble averaged forecast indicates warm SSTA beginning in the boreal fall of 1996 with anomalies in excess of 1°C over much of the central Pacific between 5°S-5°N during winter 1996-97. During summer 1996 the conditions are near normal with weak cold anomalies in the western Pacific.

Acknowledgments: This research is part of a larger group effort at COLA to study the predictability of the coupled system. Many members (D. DeWitt, M. Fennessy, J. Kinter, L. Marx and E. Schneider) of this group have provided invaluable advice. L. Kikas assisted in managing the data. This work was supported under NOAA grant NA26-GP0149 and NA46-GP0217 and NSF grant ATM-93-21354.

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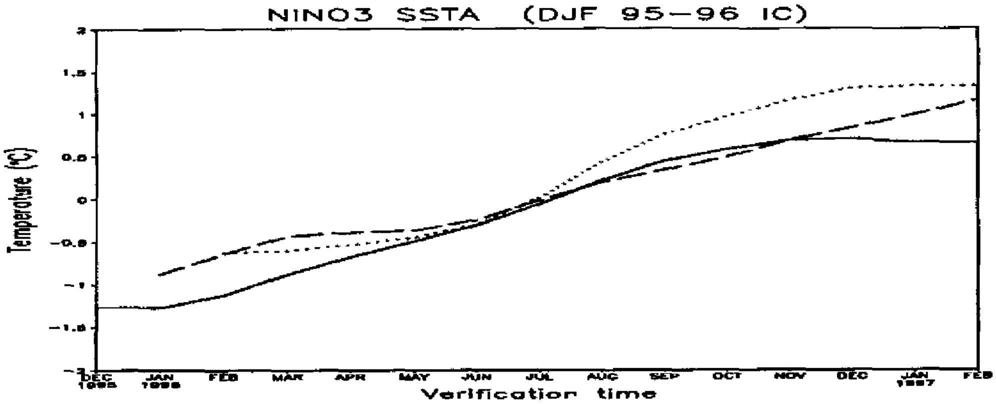

Fig. 1. *Time evolution of the Niño 3 SSTA forecast. The solid (dashed) [dotted] curve corresponds to the forecast initialized in December 1995 (January 1996) [February 1996].*

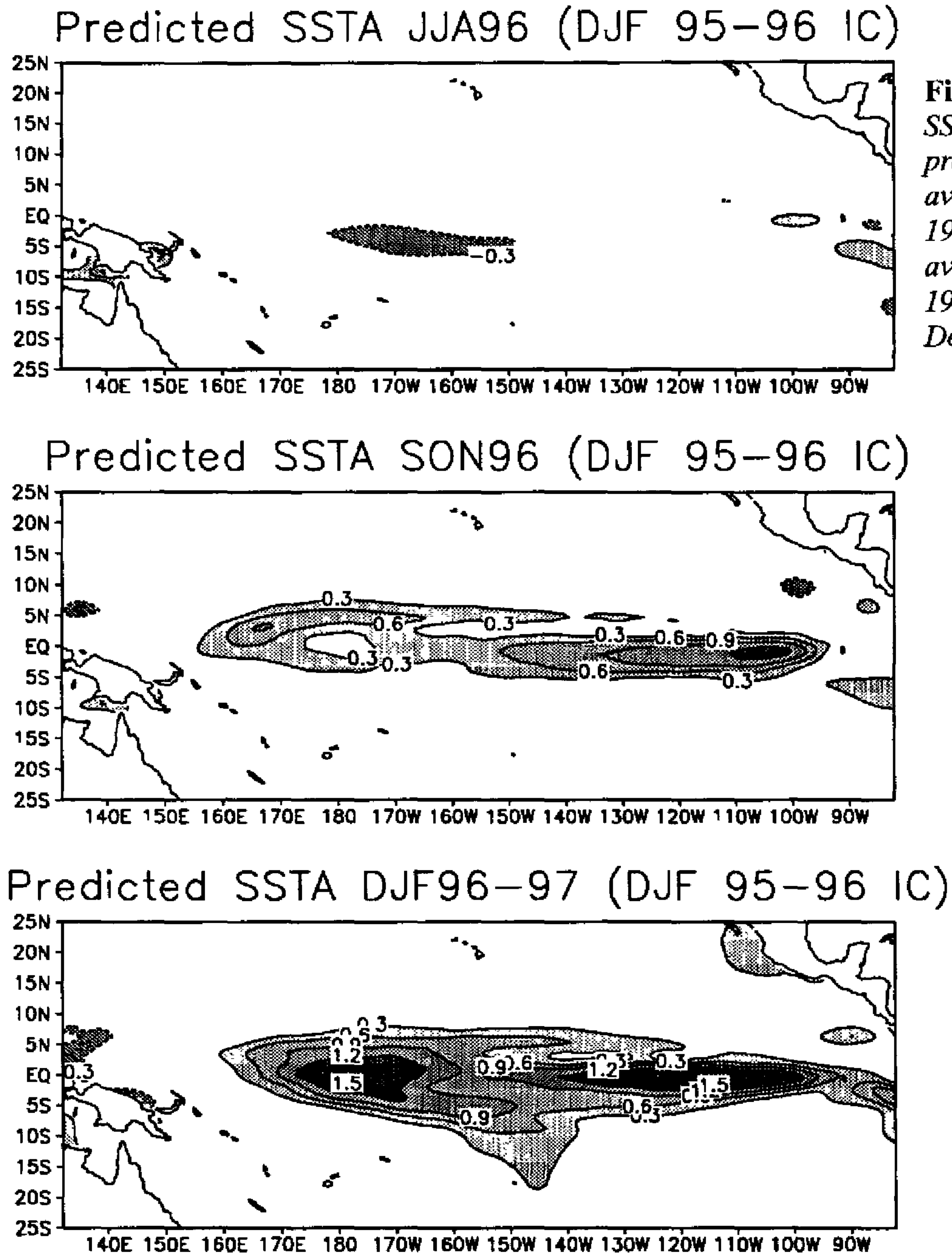

Fig. 2. *The ensemble mean SSTA. The top panel shows the predicted ensemble mean averaged over Jun-Jul-Aug 1996, the middle panel averaged over Sep-Oct-Nov 1996, and the bottom panel Dec-Jan-Feb1996-97.*

Forecasts of Tropical Pacific SST Using a Dynamical Ocean Model Coupled to a Statistical Atmosphere

contributed by Magdalena Balmaseda[1], David Anderson[2] and Michael Davey[3]

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An intermediate dynamical ocean-empirical atmosphere coupled model is currently being used in the Atmospheric, Oceanic and Planetary Physics Department at the University of Oxford to predict sea surface temperature (SST) anomalies in the tropical Pacific. The model, whose detailed description and performance are documented in Balmaseda et al. (1994), consists of a tropical Pacific ocean model with two active layers coupled to a statistical model that relates SST anomalies, heat content (HC) anomalies, and surface wind stress anomalies. The anomalies are relative to monthly climatology. The ocean model is first forced by observed wind stress (based on data from Florida State University [FSU], Goldenberg and O'Brien 1981) during the period 1961-91. The output of this simulation run is used to build the statistical atmospheric model, which assumes that the wind stress anomalies are a linear function of the first 6 principal components (PCS) of the model SST and HC anomalies, with seasonal variation.

The hindcast skill of the model has been tested using a set of 252 hindcast experiments, each of 24 months duration, with initial conditions taken from the simulation run at one month intervals during the period 1970-91. The correlation skill (sk) and root mean square error (RMSE) for hindcasts of SST anomalies versus observed values have been calculated using ensemble means of hindcasts from three consecutive months.

The model shows good reliability in regions of the central equatorial Pacific--in particular, in the regions Nino 3 and Eq2 (130-170°W, 5°N-5°S). Figures 7-1a and 7-1b in the December, 1994 issue of this Bulletin show the correlation and RMSE skills, respectively, for model hindcasts of the SST anomalies in the Nino 3 and Eq2 regions. Correlation skill at 6 months lead is about 0.59 for Nino 3 and about 0.62 for Eq2, while at 12 months lead they are about 0.50 and 0.55, respectively. The error in the initial conditions is quite high, because only wind information is used to obtain the model initial state.

Figure 1 shows current forecasts of SST anomalies for 0, 3, 6, and 9 months lead. The vertical bars are two RMSE in length, based on the 1970-91 period. The forecasts for Niño 3 (left column) and Eq2 (right column) at all lead times show some recovery of the SSTs with respect to the strongest negative anomalies. The observations have recently recovered slightly from their recent lows. The recovery in the SST forecasts follows minimum values that are considerably lower than present anomalies. In the short lead forecasts these cold SSTs are already supposed to be occurring, while in the longer lead forecasts they are called for toward summer of 1996.

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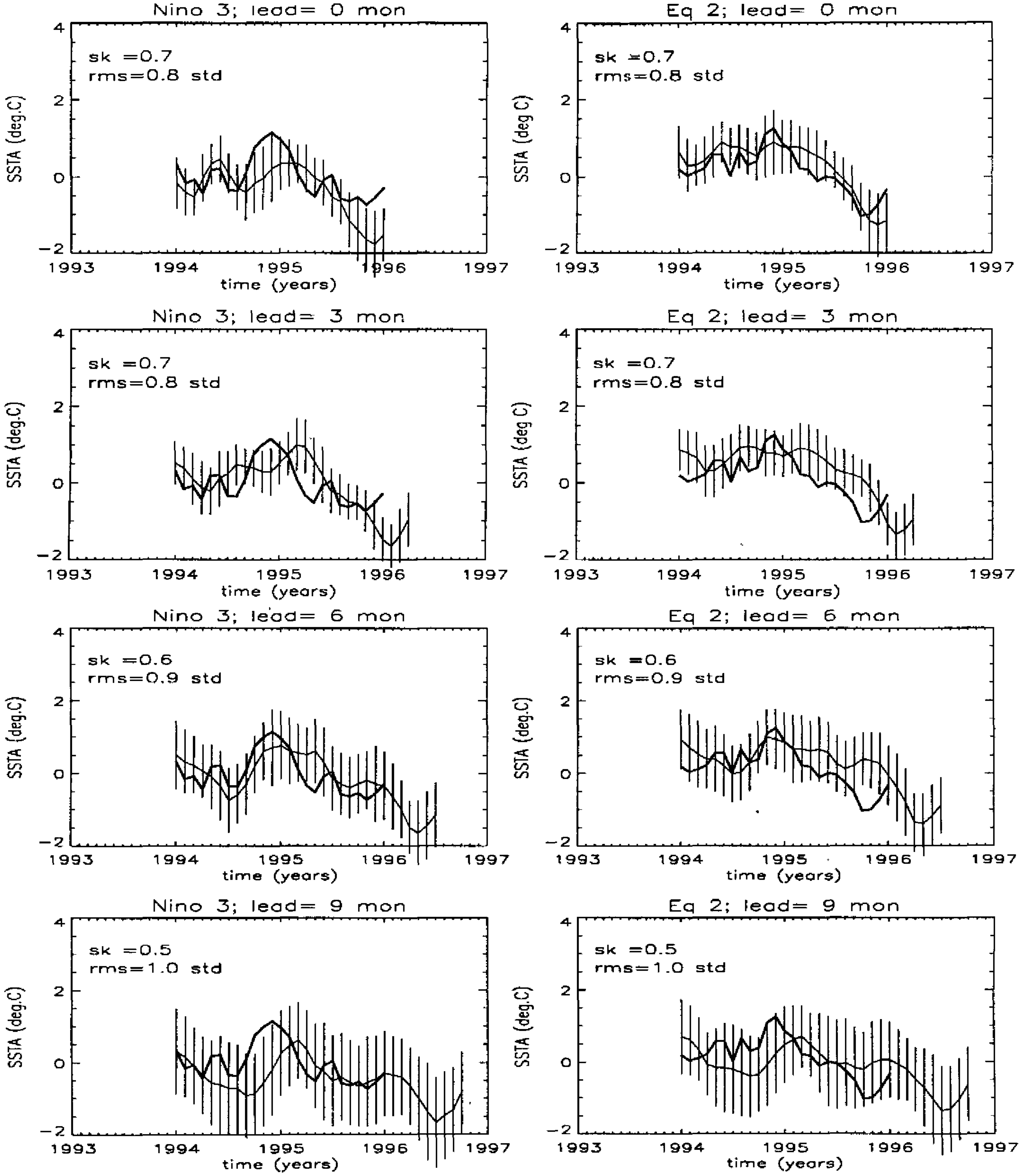

Fig. 1. *Oxford coupled model forecasts of the SST anomalies in the Nino 3 (left column) and Eq2 (130–170°W; right column) regions for 0, 3, 6 and 9 month leads. The latest forecast was initialized in January 1996. The vertical bars represent the RMSE-based confidence intervals for the relevant lead time, based on predictions for 1970–91. Each prediction is the average of forecasts from three consecutive months. Correlation skill (sk) and RMSE values (fractions of observed standard deviation, or std) are indicated in each panel. Thick lines indicate observed SST anomalies.*

Forecasts of Niño 3 Tropical Pacific SST Using a Low Order Coupled Ocean-Atmosphere Dynamical Model

contributed by Richard Kleeman

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A simple coupled ocean/atmosphere model has recently been developed at the Bureau of Meteorology Research Center (BMRC) (Kleeman 1993) in order to explore the physical basis of ENSO predictability. In particular, a variety of very simple ocean models with varying thermodynamical equations governing SST have been coupled to a simple atmospheric model which performs well when forced by a full range of ENSO SST anomalies (Kleeman 1991).

The coupled models are somewhat similar to that of Cane and Zebiak (see the Cane and Zebiak forecast in this issue, Cane and Zebiak 1987), but differ in aspects of the coupling, atmospheric convection and heating, and ocean thermodynamics.

The hindcast skill of these coupled models was tested using the ocean models initialized at regular 3 month intervals between January 1972 and July 1986 using FSU winds, and it was determined that optimal skill was obtained when the ocean model SST was determined purely by equatorial thermocline perturbations.

Recently (Kleeman et al. 1995) the initialization of the coupled model has been improved by using a space-time variational (adjoint) technique to assimilate sub-surface thermal data, as well as the usual wind data, into the ocean model. This has resulted in a significant increase in the skill of the model as seen in Fig. 1 which shows the skill of the old system, the new system and persistence for forty forecasts with start dates from 1982 to 1991, inclusively.

Displayed in Fig. 2 is the most recent forecast of Niño 3, which uses the FSU winds and sub-surface thermal data up to January 1996 to initialize the model. The forecast shows that mildly cool conditions are expected in the next 3 months but after that there is a trend toward warm conditions in the second half of 1996. Compared to the previous forecast in the December 1995 issue of this Bulletin, the warming is now somewhat later.

Kleeman, R., 1991: A simple model of the atmospheric response to ENSO sea surface temperature anomalies. *J. Atmos. Sci.*, **48**, 3-18.

Kleeman, R., 1993: On the dependence of hindcast skill on ocean thermodynamics in a coupled ocean-atmosphere model. *J. Climate*, **6**, 2012-2033.

Kleeman, R., A.M. Moore and N.R. Smith, 1995: Assimilation of sub-surface thermal data into an intermediate tropical coupled ocean-atmosphere model. *Mon. Wea. Rev*, **123**, 3103-3113.

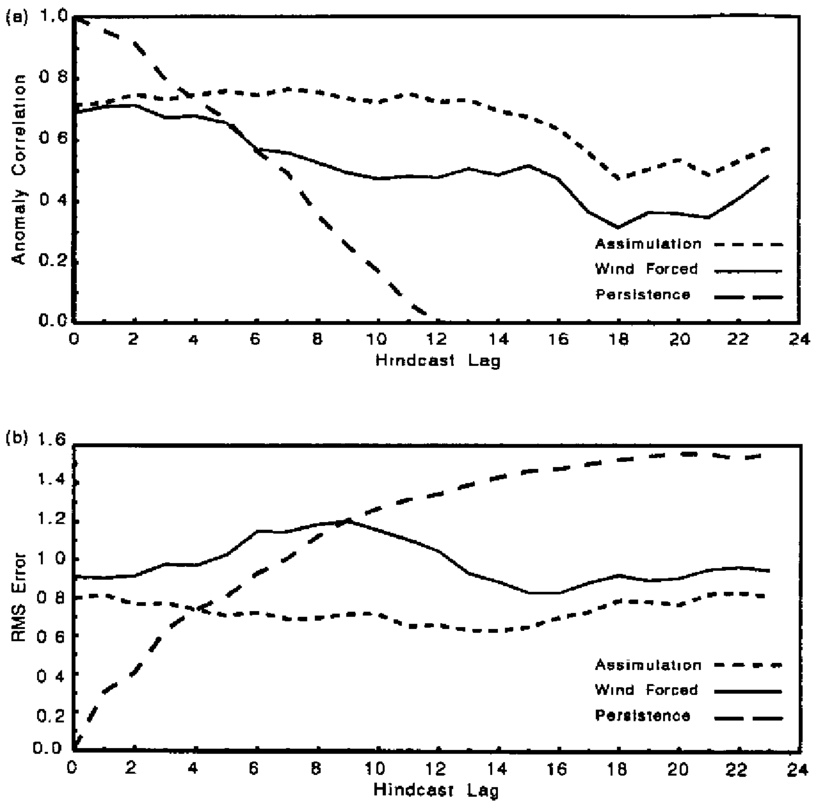

Fig. 1. *Hindcast skill as a function of lead time for the low order coupled ocean–atmosphere model used at Australia's Bureau of Meteorology Research Center (BMRC) in Melbourne. Skill for the new SST data assimilation version of the model is compared with that for the previous wind forced SST initialization system, and both of these are compared with persistence skill.*

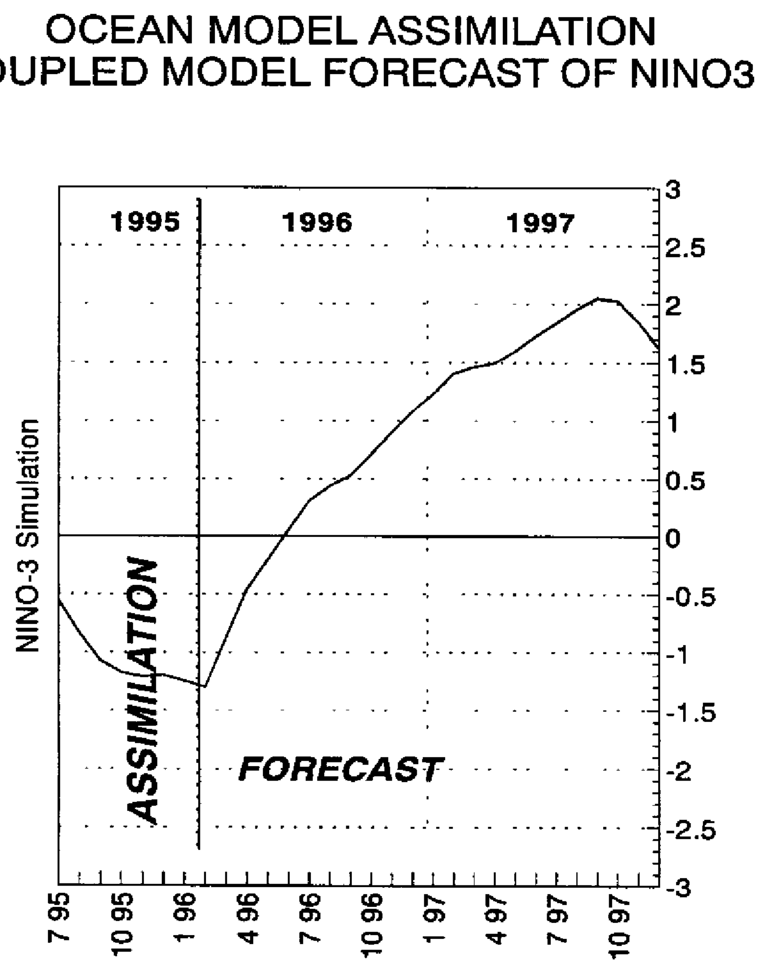

Fig. 2. *Current forecast for Niño 3 SST using the BMRC low order coupled model. FSU winds and sub–surface thermal data up to January 1996 are used for intialization.*

Multiple Regression, Discriminant Analysis and Unevaluated AGCM Predictions of Mar-Apr-May 1996 Rainfall in Northeast Brazil

contributed by Andrew Colman[1], Michael Davey[1], Michael Harrison[2] and David Richardson[2]

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Seasonal rainfall in the North Nordeste in northeast Brazil occurs mainly from February to May, with heaviest amounts in March and April. Experimental forecasts of North Nordeste rainfall at 1 and 0 month leads are issued using November-January and January-February predictor data, respectively. Two predictors found to deliver substantial forecast skill are (1) the 30°N-30°S portion of the third covariance-based EOF of Atlantic SST for all seasons, and (2) the first EOF of Pacific SST for Dec-Jan-Feb. Both of these EOF patterns are shown in the March 1993 issue of this Bulletin. The Atlantic EOF pattern reflects the SST anomaly immediately off the North Nordeste east coast and the large scale north-south SST gradient structure, while the Pacific EOF pattern serves mainly as an index of the ENSO situation. The amplitude time series of these predictors are used to predict North Nordeste rainfall both with multiple regression (giving a point forecast) and discriminant analysis (giving probabilities for each of five climatologically equiprobable [for 1951-1980] rainfall amount categories).

Details about the EOF analyses, the physical relevance of the predictors, and the two forecasting methods are given in Ward and Folland (1991). Multiple regression develops optimal weights for each predictor in order that the resulting linear equation minimizes squared errors between forecasts and corresponding observations over the training periods (1913-94, 1946-94). In discriminant analysis, categories of rainfall amount are defined, and, given values of the predictors, probabilities of each of the rainfall categories are determined using Bayes' theorem. Less linear constraint is imposed here than in multiple regression, as the probabilities do not necessarily change smoothly as a function of category.

Forecasts are made for three separate North Nordeste rainfall predictands: Nobre (for Feb-May), Hastenrath (Mar-Apr) and Fortaleza/Quixeramobim (FQ) (Mar-May). These are illustrated in Fig. 1. Each of these forecasts is done using both multiple regression and discriminant analysis. The forecasts presented here are only for the two predictands whose periods begin in March, making for a long-lead forecast: Hastenrath and FQ. The Hastenrath rainfall area occupies a central portion of the north Nordeste, while FQ is the rainfall averaged over the two stations, one of which is in the Hastenrath area.

If the amplitudes of the predictor EOFs are changing rapidly during the Nov-Jan period, values from Dec-Jan or only January may be used as predictors, if the more recent SST anomalies are expected to persist. In early March updated forecasts for the predictand periods are issued, using SST data through February.

To estimate forecast skill, multiple regression and discriminant analysis hindcasts for FQ based on the SST for Nov-Jan were made for the 1971-92 period using data from 1913-70, and for the 1981-92 period using data from 1913-80. The eigenvector patterns, computed from 1901-80 data, cause a slight dependency in the first experiment but complete independence in the second. The discriminant analysis forecast skill was assessed by comparing the observed category with the most likely category according to the hindcasts over the period 1971-92 (Table 1), while the point estimate rainfall amounts predicted by multiple linear regression were correlated with observed values. The resulting correlation for the 1971-92 experiment is 0.715 with a bias of +0.09 standard deviations and a root mean squared error (RMSE) of 0.62 standard deviations. For the totally independent (including the eigenvector pattern) period of 1981-92, the correlation is 0.662, with bias of +0.07 and RMSE of 0.70 standard deviations. While the latter results are not quite as high, it is shown in Ward and Folland (1991) that independence of the eigenvector patterns is not nearly as critical to estimation of independent forecast skill as independence of the periods used for statistical model development and for forecast testing.

		Observed				
		Q1	Q2	Q3	Q4	Q5
	Q1	4	2	0	2	0
	Q2	0	0	0	0	0
Hindcast	Q3	0	1	1	0	0
	Q4	0	0	0	0	0
	Q5	1	2	0	3	6

Table 1. Hindcasts (i.e. forecasts for already observed times, but with model derived without target years) of FQ rainfall index for 1971-92 using linear discriminant analysis. THE Q's are quintiles (Q1=very dry, Q5=very wet).

Experimental real-time forecasts for FQ using the methods discussed here have been made for each rainfall season since 1987. The forecasters combine the forecasts from discriminant analysis and multiple regression to determine the official forecast category. The forecast-observation correspondence from 1987 to 1995 is very good for the preliminary forecast (hit rate 6.5 out of 9), and slightly worse for the updated forecasts (4.5 out of 9). (Over a large number of cases the updated forecasts would be expected to have more skill.) Table 2 shows the record of real-time forecasts for 1987-95. It is clear that the FQ rainfall index is fairly skillfully predicted from the two SST EOFs--in fact, as much so as most any variable in the extratropical Pacific/North American region in any season.

Year:	87	88	89	90	91	92	93	94	95
Prelim forecast	1	4	5	2	4	1.5	2	5	4
updated forecast	1	5	5	3	4	2	2	4	4.5
observed	1	4	5	2	4	1.5	1	4.5	5

Table 2. Verification of experimental real time forecasts of NE Brazil rainfall (predictions of March-May rainfall at FQ). 1=very dry, ..., 5=very wet. The number of correct categorical forecasts out of 9 (hit rate) is 6.5 for the preliminary (1 month lead) forecast, and 4.5 for the updated (zero lead) forecast.

1996 Forecast

Figures 2 and 3 show the monthly time series of the Atlantic and Pacific SST anomaly predictors used in the regression and discriminant analysis prediction models. Both predictor values are near average at the end of 1995, with little change between December and January.

Atlantic: SST has been mostly above average between the equator and 30°N since November 1995. SST was also above average off the southeast coast of Brazil in January and in the Gulf of Guinea in November. Elsewhere SST is near average. These SST anomalies (apart from the Gulf of Guinea) favor drier conditions in NE Brazil.

Pacific: SST is below average in the equatorial central and east Pacific, in a pattern that is normally associated with above average rainfall in NE Brazil. However, there are negative SST anomalies north of 25°N that have the opposite rainfall influence, and the net effect of this predictor is weak.

Example multiple regression equations for the 1-month lead forecast for the Hastenrath (for Mar-Apr) and FQ (for Mar-May) rainfall indices (standardized rainfall anomaly units), based on 1913-1995 data, are:

$$\text{Hastenrath} = 0.020 - 0.719A - 0.101P$$
$$\text{FQ} = -0.015 - 0.847A - 0.088P$$

where the EOF time coefficients (A=Atlantic EOF, P=Pacific EOF) are not standardized. (The Atlantic series varies between about -2.5 and 1.4 between 1981 and 1995, while the Pacific series varies between about -4.0 and 9.7).

For the 1-month lead linear regression predictions, we calculate the average of predictions made using training periods 1913-95 and 1946-95, and SST anomalies for November, December and January. The result is:

predictand	forecast	quint	quint range	stand. error
Hastenrath	-0.12	3	-.16 to .27	0.57
FQ	-0.19	2	-.70 to -.16	0.65

The Hastenrath forecast is just above the Q2/Q3 (dry/average) quintile boundary, and the FQ forecast is just below the Q2/Q3 boundary. The multiple regression forecast for the Nobre (Feb-May) predictand is also very close to the Q2/Q3 boundary. The standard errors (in standard deviation units) associated with these forecasts express the inherent uncertainty based on the training period statistics.

The discriminant analysis produces the following probabilities that the Hastenrath and FQ indices will be in each of the quintiles for the 1-month lead time:

	very dry	dry	average	wet	very wet
Hastenrath	.14	**.33**	.29	.17	.07
FQ	.25	.25	.17	**.26**	.07

The discriminant analysis predictions are less consistent than the linear regression predictions, with some bimodal behavior, but all favor below average rainfall.

Our **best estimate forecast is for DRY/ AVERAGE conditions (quint 2/3 boundary)** for each of the rainfall indices (Hastenrath, FQ, Nobre).

As in 1994 and 1995, a dynamical prediction of Northeast Brazil rainfall was made using a version of the UKMO climate atmospheric general circulation model (AGCM). A similar version of the AGCM showed very high skill in simulating interannual variability of Northeast Brazil rainfall when forced with observed SST. The 1994 and 1995 AGCM forecasts were in good agreement with the statistical predictions. However, skill with persisted SST anomalies has not yet been fully assessed. The AGCM was run from Jan 23, Jan 31 and Feb 1 start dates, using persisted January SST anomalies, to the end of May. All three samples give below average March-May rainfall for NE Brazil, with a net value about 10% below average for the season compared to the model climatology.

Although there is agreement between the statistical and dynamical predictions, confidence in predictions of near-average conditions is generally lower than that for extremes, so **overall confidence in this forecast is moderate.**

UPDATED (ZERO-LEAD) FORECASTS, WITH INCLUSION OF FEBRUARY DATA

While zero-lead forecasts are not encouraged for this Bulletin, they appear here as auxiliary information accompanying long-lead forecasts for the same targets. In February the Atlantic predictor decreased sharply while the Pacific predictor increased slightly (see Figs. 2, 3). Consequently the **zero-lead statistical forecasts indicate wetter conditions (average at the time of writing)** than the 1-month lead forecast.

Ward, M.N. and C.K. Folland, 1991: Prediction of seasonal rainfall in the North Nordeste of Brazil using eigenvectors of sea surface temperature. *Int. J. Climatol.*, **11**, 711-743.

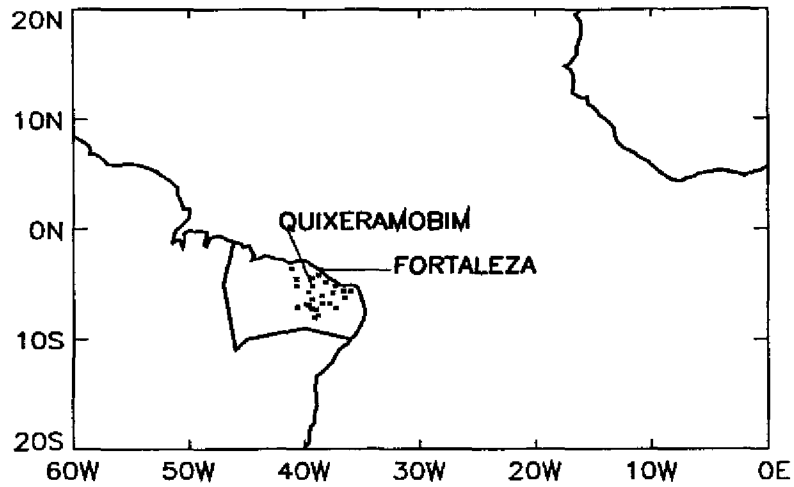

Fig. 1. *Locations of the stations used in the Hastenrath rainfall time series, and the Fortaleza and Quixeramobim stations. The Nobre rainfall time series is based on stations throughout the bounded region indicated.*

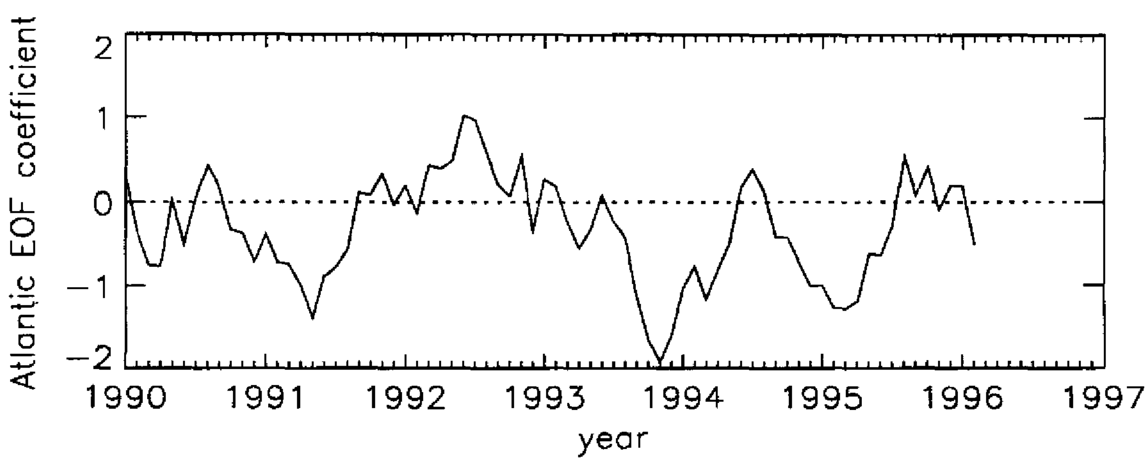

Fig. 2. *Amplitude time series for the Atlantic eigenvector for Jan 1990 to Feb 1996. Positive values (e.g. SST anomalies warm in north tropical Atlantic, cool in south tropical Atlantic) are associated with drier conditions.*

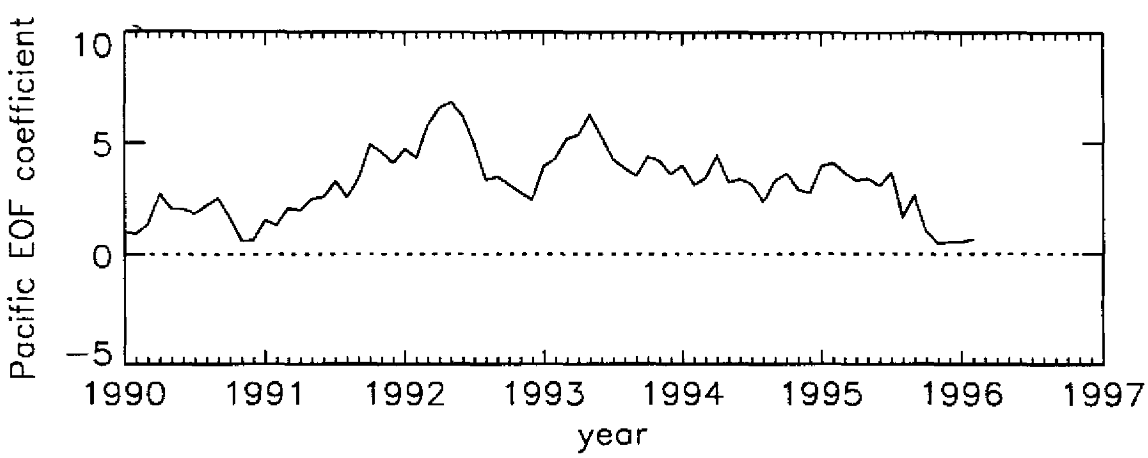

Fig. 3. *Amplitude time series for the Pacific eigenvector for Jan 1990 to Feb 1996. Positive values (e.g. SST anomalies warm in the central–east equatorial Pacific, cool in the northwest and southwest Pacific) are associated with drier conditions.*

Multiple Regression and Discriminant Analysis to Predict Mar-Apr-May-Jun 1996 Rainfall in Northeast Brazil

contributed by Larry Greischar and Stefan Hastenrath

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In the approach used at the University of Wisconsin to forecast March-to-June precipitation in the Nordeste, several predictors are used with stepwise multiple linear regression and linear discriminant analysis. The predictand includes 27 selected stations in the Nordeste (Hastenrath and Greischar 1993), shown in Fig. 1 The forecasts shown here are made at one month lead--i.e., using data no later than January 1996. The potential predictors of March-June Nordeste rainfall (not all of which are necessarily used in a given prediction model) are listed below along with their correlations with the predictand over the training period, 1921-57. Correlation coefficients are in hundredths, with one and two asterisks indicating significance at the 5% and 1% levels, respectively.

(1) October-January precipitation at the 27 predictand stations. +55**
(2) An index of January meridional surface wind component over the tropical Atlantic, 30°N-30°S. -35*
(3) An index of January SST in the equatorial Pacific. -11
(4) An index of January SST in the tropical Atlantic, 30°N-30°S. -57
(5) An index of Nov-Dec-Jan SST in the tropical Atlantic, 30°N-30°S. -70**

As shown above and described in Hastenrath and Greischar (1993), March-to-June rainfall in the Nordeste is correlated positively with the first and negatively correlated with all the other predictors. This pre-season, predictor values have been: (1) slightly positive precipitation departure, (2) somewhat positive anomalous meridional wind component (i.e. southerly wind anomaly), (3) slightly negative tropical Pacific SST anomaly, (4) moderately strong positive tropical Atlantic SST index for January (i.e. warmer/colder North/South Atlantic SST), and (5) somewhat positive tropical Atlantic SST index for Nov-Dec-Jan (as in (4)). The Atlantic SST field and meridional surface wind component indicate slightly dry March-June 1996 conditions, while pre-season Nordeste rainfall and the equatorial Pacific SST point to wetter conditions.

Table 1 shows skill evaluations for eight prediction models, each using a different combination of the predictors listed above. The eighth model uses a neural network rather than stepwise multiple linear regression.

Model #/Type	Predictors Used	Skill (% Variance Explained): Training Period 1921-57	Forecast Period 1 1958-89	Forecast Period 2 1968-89	**Rainfall Forecast** Mar-Apr-May-Jun 1996
1 SMR	(1)	30	35	49	**+.44**
2 SMR	(1),(2)	38	49	69	**+.30**
3 SMR	(1),(4)	49	52	66	**+.04**
4 SMR	(1),(2),(4)	44	58	74	**-.08**
5 SMR	(1),(2),(3),(4)	50	61	74	**+.03**
6 SMR	(1),(3),(5)	62	61	71	**+.04**
7 SMR	(3),(5)	56	58	62	**-.19**
8 NN	(1),(2),(3),(4)	55	66	81	**+.15**

Table 1. Skill of eight prediction models for Mar-Apr-May-Jun Nordeste rainfall (expressed as a percentage of predictand variance explained), followed by the forecast standardized Nordeste rainfall anomaly for Mar-Apr-May-Jun 1996. The model type is SMR (stepwise multiple regression) or NN (neural network), and predictors numbers (1)-(5) are as shown above.

The models indicate near average Nordeste precipitation, with a slight tilt toward the high side of the normal. The 1912-56 historical mean and standard deviation are 500 and 60 mm, respectively.

Using the same sets of predictors, Nordeste rainfall was also predicted using linear discriminant analysis, in which five equiprobable categories of rainfall amount are defined and associated with predictor values using Bayes' theorem. In an individual forecast each of the categories is assigned a probability, given the pre-season values of the predictors. Table 11-2 in the March 1995 issue of this Bulletin shows, for predictor models 5 and 7, the five-by-five verification matrices obtained over the 1958-89 period using from the earlier years to develop the models. The hit rates are 0.34 and 0.38, corresponding to Heidke skills of 0.18 and 0.22 and expected correlation skills of about 0.55 and 0.65. **The quintile probability forecasts for Mar-Apr-May-Jun 1996** using each of these predictor models are:

		Probability of.....				
Model	Predictors	Q1	Q2	Q3	Q4	Q5
5	(1),(2),(3),(4)	.17	.20	.14	**.30**	.19
7	(3),(5)	.18	**.28**	.25	.21	.08

Model 5 shows a maximum likelihood of a somewhat wetter than normal 1996, although Q2 (somewhat dry) has the second highest probability. Model 7 indicates a tendency for somewhat drier than normal conditions. If the probabilities given by the two models are added for each category, the result is a forecast for an average season, but with considerable likelihood for a one-category deviation in either direction from the middle category.

In summary, both the field of meridional wind component and the SST pattern (and the associated OLR pattern that is not shown) in the Atlantic indicate slightly below normal March-June 1996 Nordeste precipitation, while the positive pre-season Nordeste rainfall anomaly and the cool tropical Pacific SST favor drier conditions. Based on the several stepwise multiple regression and linear discriminant analysis models, **near average conditions are forecast for the 1996 rainy season with standardized anomalies of -0.2 to +0.4.** This is comparable to the years 1978, 81, 87, and 91.

Hastenrath, S. and L. Greischar, 1993: Further work on the prediction of northeast Brazil rainfall anomalies. J. Climate, 6, 743-758.

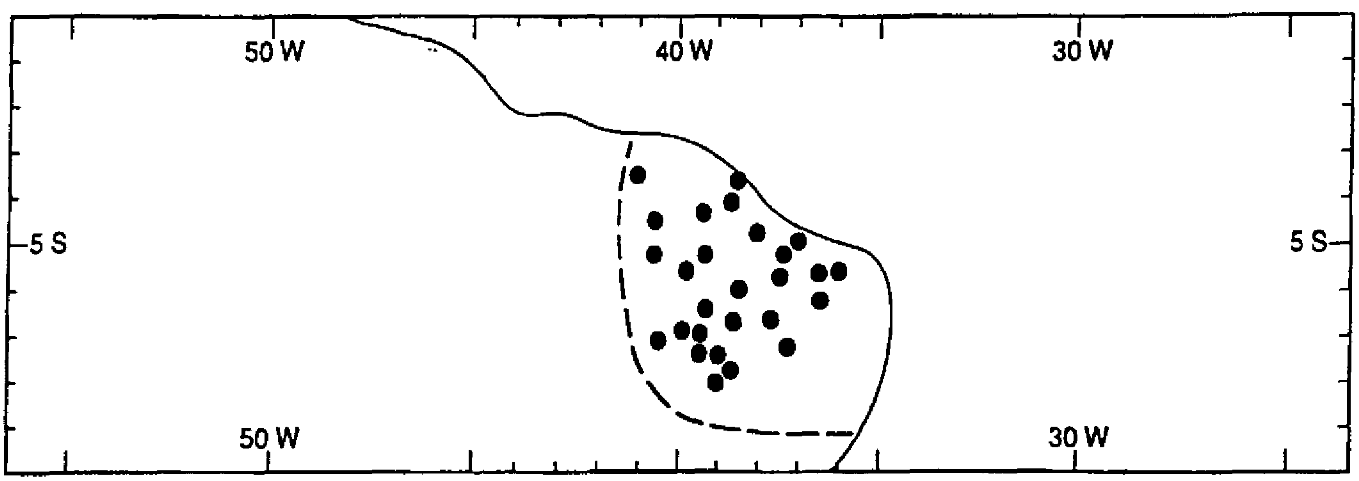

Fig. 1. *Locations of the 27 selected stations in the Nordeste, used as the predictand by Greischar and Hastenrath.*