Forecasts of Surface Temperature and Precipitation Anomalies over the U.S. Using Screening Multiple Linear Regression

contributed by David Unger

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Screening multiple linear regression (SMLR) is used to predict seasonal temperature and precipitation amounts for locations over the mainland United States. Predictor data consist of northern hemisphere 700-mb heights, near global SSTs and station values of mean temperature and total precipitation amount from the 3-month period prior to the forecast initial time of March 1, 1996. Forecasts for the mean temperature and total precipitation are made for a series of 13 overlapping 3-month periods, at one month intervals. beginning with Apr-May-Jun (AMJ) 1996 and extending through AMJ 1997. Regression relationships were derived from data for the 1955-95 period. Forecasts were produced from single station equations for 59 stations approximately evenly distributed throughout the mainland U.S.

All predictors and predictands were expressed as standardized anomalies relative to the developmental data. Precipitation amounts were transformed by taking their square roots prior to standardization in order to help normalize their distribution. Twenty-five candidate predictors, selected from gridpoint values in regions of known importance for climate prediction, were offered for screening in the regression development. A few predictor locations were chosen on the basis of data examination of the first 20 years of the sample, referred to here as the base period. Information from the most recent 20 years was never used for selection of candidate predictors (Unger, 1996a).

Initial testing indicated that cross-validation cannot be used for SMLR (Unger 1996b) so a variation of a retroactive real time (RRT) validation technique was used. To estimate skill by RRT, a forecast equation was derived from the base period and applied to the next year's data to obtain independent data results. The case was then added to the developmental sample, a new relationship was derived and applied to the following year's data. Independent data statistics accumulate on a year by year basis in exactly the same way as an operational forecast procedure, except retroactively. Forecasts were then obtained for the base period years by application of RRT in reverse: deriving from the "future" years and applying to the most recent year in the withheld period (now the first half of the sample). Each earlier case was then included in the development sample, the relationships re-derived and applied to the next earlier case. This bi-directional RRT (BRRT) validation technique provides that each available case contribute to a skill estimate as independent data in a way similar to cross-validation except with a great reduction in the distortion of results due to redundant sampling (Unger, 1996b).

A forward selection screening procedure was used for equation development. The top 5 terms were selected for each equation. Separate statistics were accumulated for each equation length, so that results for all the one, two, three, four and five term equations were calculated. The optimum equation length was then estimated by an objective learning procedure that used the past performance at each RRT trial to "predict" which equation would perform the best on the next. Verification statistics from this "best guess" forecast were also kept separately and were used to obtain the final skill estimate of the forecasts.

The verification used was the temporal correlation coefficient between forecast and observation on the 40 independent cases at each of the 59 stations. An average correlation coefficient was computed from the root mean squared correlation coefficient with the signs retained both in the squaring process and the final square root. Field significance was measured by comparison of scores from actual target years against scores determined from 500 randomly shuffled target periods. Field significance expresses the percentage of time that the random forecast series outperformed the actual forecasts.

The final forecasts are post-processed to obtain an estimate of the likelihood of the above, normal, or below class being observed, as defined by the terciles of the distribution for each forecast element and location. A forecast is assigned a class on the basis of the forecast distribution and skill. An estimate of the increased likelihood of a given class is made to place the forecast in a format similar to the operational long lead forecasts issued by the CPC (O'Lenic, 1994). Currently these probability assignments are obtained from the relationship between probability of a given class being observed, the inflated SMLR forecast and the predictive skill. (Inflation sets the forecasts variance equal to observed variance at each station.) This relationship is based on forecast performance on independent data. If the correlation skill of the forecast is under approximately .3, the forecast is not assigned to a class and is regarded as a climatological forecast.

The forecasts for AMJ 1996 are shown in Figs. 1 and 3 with the corresponding skill estimates for each station shown in Figs. 2 and 4. Temperature forecasts for JJA 1996 and the associated skill are shown in Figs. 5 and 6 respectively. Shading indicates areas of sufficient skill to assign a tercile category to the forecast. Contours within the shaded areas on the forecast maps indicate estimates of a 5 and 10 percent probability anomaly for the category. Note that the skill estimates are based on the actual forecasts, and not the post processed category assignments, which are presented only for clarity of presentation.

The numbers plotted in Figs. 1, 3, and 5 indicate station values of the regression forecast for the standardized anomaly of temperature or the square root of precipitation amount. Forecasts are damped according to the forecast-observation correlation on independent data so that the squared error between forecast and observation will be minimized. Non-zero numbers plotted outside of shaded regions generally indicate forecast anomalies of substantial magnitude at stations with some skill, but lower than the skill threshold to choose a forecast category with confidence.

Temperature forecasts (Fig. 1) show below normal temperatures along the North Pacific coast, and above normal temperatures in scattered locations in the southern U.S. and eastern New England. The average correlation for this forecast is .25 with a field significance of .000. The forecasts show some contradiction near the Great Lakes, where areas of below normal, near normal and above normal temperatures neighbor each other in a region where the spatial correlation of temperature anomalies are quite high.

Because the regression forecasts are derived from single station equations, inconsistencies, such as those near the Great Lakes for AMJ 1996 can be considered to be similar to an ensemble forecast for the region, with the variability in the forecasts introduced by the station to station variability in the development sample. Thus, different forecasts where temperature anomalies are spatially correlated might be considered to be different "opinions", or possibilities, for the region. While the contradictory predictions may provide useful guidance to assess uncertainty, they diminish the value of the forecasts by failing to provide a realistic final assessment for the region. Future work will be required to provide an objective method to locate and resolve inconsistent forecasts.

Precipitation forecasts for AMJ 1996 show considerably less skill than for temperature forecasts, with an average correlation of .11 and a field significance of .11. Forecasts show a weak tendency for below normal precipitation over the East coast and in central Texas.

The summertime temperature forecast for the U.S. is shown in Figure 5. The East coast and southwestern U.S. show a tendency to be warm, with some pockets of near normal scattered in some localized regions. The average correlation for this map is .23 and the field significance is .002. Precipitation forecasts for summer (not shown) hint at continued dry conditions extending from Ohio to Virginia.

REFERENCES

O'Lenic, E., 1994: A new paradigm for production and dissemination of the NWS's long lead-time seasonal climate outlooks. Proceedings of the Nineteenth Annual Climate Diagnostics Workshop. College Park, Maryland, November 14-18, 1994. 408-411.

Unger, D. A., 1996a: Long lead climate prediction using screening multiple linear regression. Proceedings of the Twentieth Annual Climate Diagnostics Workshop. Seattle, Washington, October 23-27, 1995 (in press).

Unger, D. A., 1996b: Skill assessment strategies for screening regression predictions based on a small sample size. Preprints, Thirteenth Conference on Probability and Statistics in the Atmospheric Sciences. San Francisco, CA., February 21-23, 1996. 260-267.

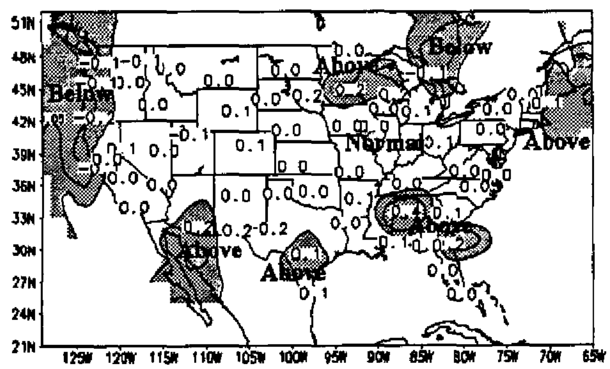

Figure 1. *A 1-mo lead screening regression-based temperature forecast for AMJ 1996. Contours are estimated probability anomalies of the specified tercile. Shaded areas delineate the area of correlation skill greater than .3. Plotted numbers are station values of the standardized anomaly.*

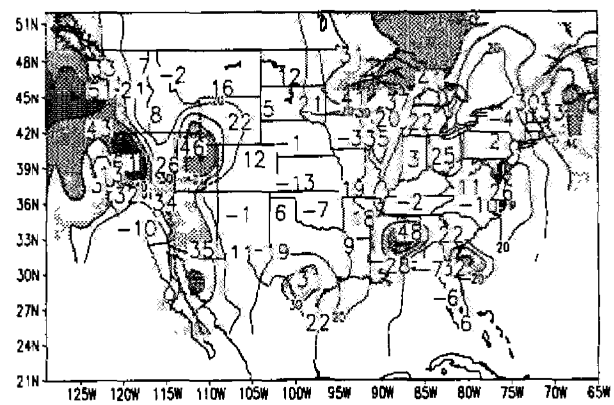

Figure 2. *Distribution of skill for the 1-mo lead regression forecast for AMJ 1996 temperatures. The values shown are the correlation between forecast and observation for the 1956-1995 period.*

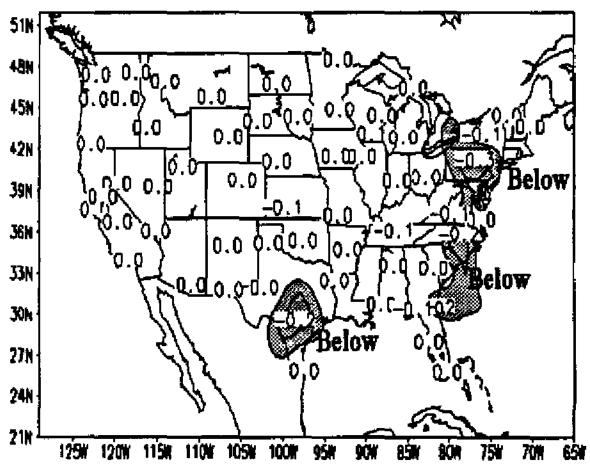

Figure 3. *Same as Fig. 1 except for precipitation forecasts.*

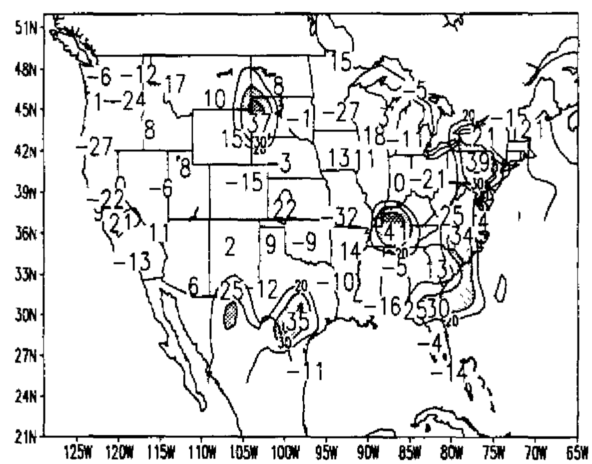

Figure 4. *Same as Fig. 2 except for precipitation skill.*

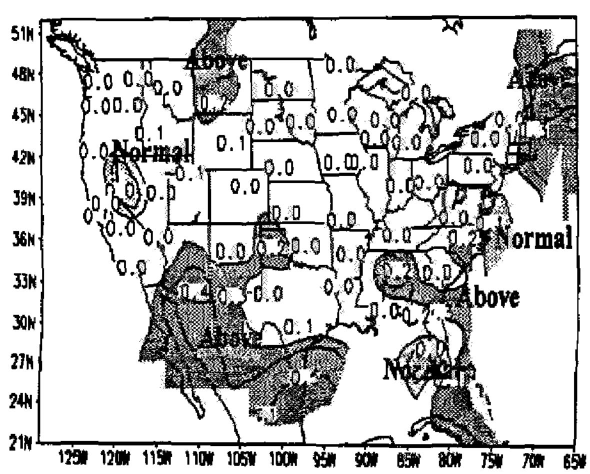

Figure 5. *Same as Fig. 1 except for JJA 1996.*

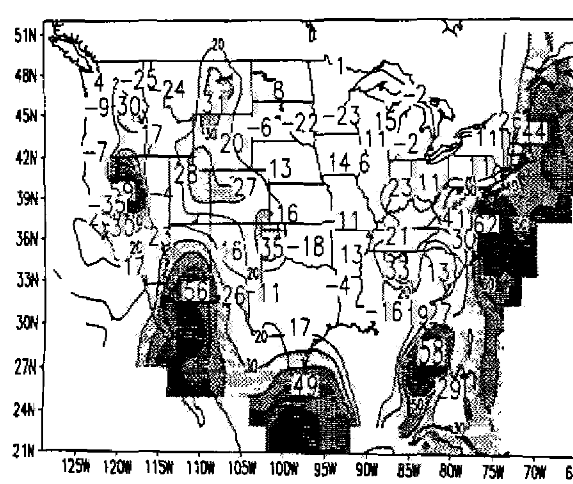

Figure 6. *Same as Fig. 2 except for JJA 1996.*

Constructed Analogue Prediction of the East Central Tropical Pacific SST through Fall 1997

contributed by Huug van den Dool

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Because excellent naturally occurring analogues are highly unlikely to occur, we may benefit from constructing an analogue having greater similarity than the best natural analogue. As described in Van den Dool (1994), the construction is a linear combination of observed anomaly patterns in the predictor fields such that the combination is as close as desired to the base. Here, we forecast the future SST anomaly in the ENSO-related east-central tropical Pacific ("Niño 3.4", or 5°N-5°S, 120-170°W). We use as our predictor (the analogue selection criterion) the first 5 EOFs of the global SST field at four consecutive 3-month periods prior to forecast time. Predictor and predictand data extending from 1955 to the present are used.

For any given base time (i.e. previous ones extending back to 1955, or the current "operational forecast" ending with February 1996), a linear combination is made of the global SST patterns (using the first 5 EOFs) from all 39 years (excluding the base year), so as to match the SST pattern of the base time as closely as possible. This is done by classical least-squares multiple regression, with each year's SST state as a predictor to which a weight is assigned, determined by inverting the 39 X 39 (available years) covariance matrix. The weights assigned each year to reconstruct the base SST state are then applied to the subsequently occurring Niño 3.4 SST in the predictand period for these years, thereby constructing the forecast for the base year's predictand period.

Additional detail about the constructed analogue method is found in the September 1994 issue of this Bulletin and in Van den Dool (1994). In the latter paper it is shown that constructed analogues outperform natural analogues in specification mode (i.e. "forecasting" one meteorological variable from another, contemporaneously). This advantage may be expected to occur in actual forecasting also, as long as the (linear) construction does not compromise the physics of the system too much. Brief discussion of the skill of the constructed analogue method in forecasting SST is given in Van den Dool and Barnston (1995).

The forecasts for Niño 3.4 for 0 to about 1.5 years lead using constructed analogues are shown in Fig. 1, using data through February 1996. The expected cross-validated skill is also shown. The skill is competitive with those of other empirical as well as dynamical methods (Barnston et al. 1994). In Fig. 1 the SST anomaly observed during Dec-Jan-Feb 1995-96 is plotted as the earliest "forecast" value. For Jan-Feb-Mar and Feb-Mar-Apr the observed SST for Dec-Jan-Feb enters into the plotted forecast with a 2/3 and 1/3 weight, respectively, providing continuity with the known initial condition.

The present below normal SST conditions are forecast to dissipate by middle to late spring 1996, becoming slightly above normal from fall onward with a weak but broad peak centered in spring 1997. The specification for Dec-Jan-Feb (not shown) is only about a third of the observed negative anomaly. Reasons for this are likely similar to those which caused the same behavior three months ago, discussed in the December 1995 issue of this Bulletin. It was concluded that the most probable cause of the positive specification error is the uniqueness of the current SST developments.

Table 1 provides information about the role of each of the past years in the construction process for the current forecasts. The inner product shows the degree of similarity (or, if negative, dissimilarity) of this year's predictor periods to those of the other years. The weight shows the contribution of each year's pattern to the constructed analogue. The inner products and the weights, while similar, are not proportional. This is because, for example, two analogues having the same *kind* of similarity are unnecessary; only one of them may been assigned the appropriately high weight, leaving the other with little to contribute.

The important positive (+) and negative (-) contributors to the description of the global SST over the last 4 seasons (MAM 1995 to DJF 1995-96) are, in chronological order, 1966(-), 1973(-), 1976(-), 1983(-), 1986(+), 1988(+), 1989(+), 1990(+) and 1991(+). An interdecadal variability is suggested in this analogue time series, as a grouping of like-signs is evident. The weights are positive from 1984 to the present, suggesting that the present SST configuration is typical for the last 11 years and rather atypical for the years before 1984 except for 1956 and 1969-70.

The net result is a set of forecasts for a quick dissipation of the presently below normal Niño 3.4 SST, followed by a period of weak warmth from next fall through summer 1997. Looking at some of the strongly weighted years, we note that one of the positively weighted years was strongly cold (e.g. 1989, which denotes the period of Mar 1988 to Feb 1989), cold/neutral (1986), or neutral to neutral/warm (1990, 1991) However, 1988 was strongly warm and rapidly cooling. Three of the four strongly negatively weighted years were moderately to strongly warm (1966, 1973 and 1983); however, 1976 was clearly cold. While the weights are roughly similar to those shown for the constructed analogue forecast issued 3 months ago, this is the case to a lesser extent than usual. Negative weights are now assigned more clearly to warm episode years, and vice versa. Apparently the current cold period now occupies a sufficient portion of the 1-year set of predictor periods to match past cold (warm) episodes with fairly high (low) likelihood. That this does not occur as a "clean sweep", however, reminds us that phenomena other than ENSO are governing the weighting process. The weights shown in Table 1 suggest that one or more of such phenomena vary on decadal or still longer-term time scales

Table 1. Inner products (IP; scaled such that sum of absolute values is 100) and weights (Wt; from multiple regression) of each of the years to construct an analogue to the sequence of 4 consecutive 3-month periods defined as the base (MAM 95, JJA 95, SON 95, and DJF 95-96). Years are labeled by the middle month of the last of the four predictor seasons.

Yr	IP	Wt	Yr	IP	Wt	Yr	IP	Wt
56	-0	8	69	0	9	82	4	1
57	-3	-6	70	3	8	83	0	-10
58	-1	1	71	0	1	84	3	6
59	0	1	72	-4	-5	85	4	4
60	-1	4	73	-3	-10	86	4	10
61	-1	3	74	1	4	87	2	2
62	0	-1	75	-5	-7	88	3	10
63	1	5	76	-3	-12	89	4	14
64	0	-2	77	-5	-9	90	5	13
65	-3	-4	78	-6	-9	91	7	16
66	-5	-13	79	-4	-6	92	3	4
67	0	2	80	0	-2	93	2	2
68	-3	-4	81	2	1	94	3	5

Barnston, A.G., H.M. van den Dool, S.E. Zebiak, T.P. Barnett, M. Ji, D.R. Rodenhuis, M.A. Cane, A. Leetmaa, N.E. Graham, C.F. Ropelewski, V.E. Kousky, E.A. O'Lenic and R.E. Livezey, 1994: Long-lead seasonal forecasts--Where do we stand? *Bull. Amer. Meteor. Soc.*, *75*, 2097-2114.

van den Dool, H.M., 1994: Searching for analogues, how long must we wait? *Tellus*, *46A*, 314-324.

van den Dool, H.M. and A.G. Barnston, 1995: Forecasts of global sea surface temperature out to a year using the constructed analogue method. *Proceedings of the 19th Annual Climate Diagnostics Workshop*, November 14-18, 1994, College Park, Maryland, 416-419.

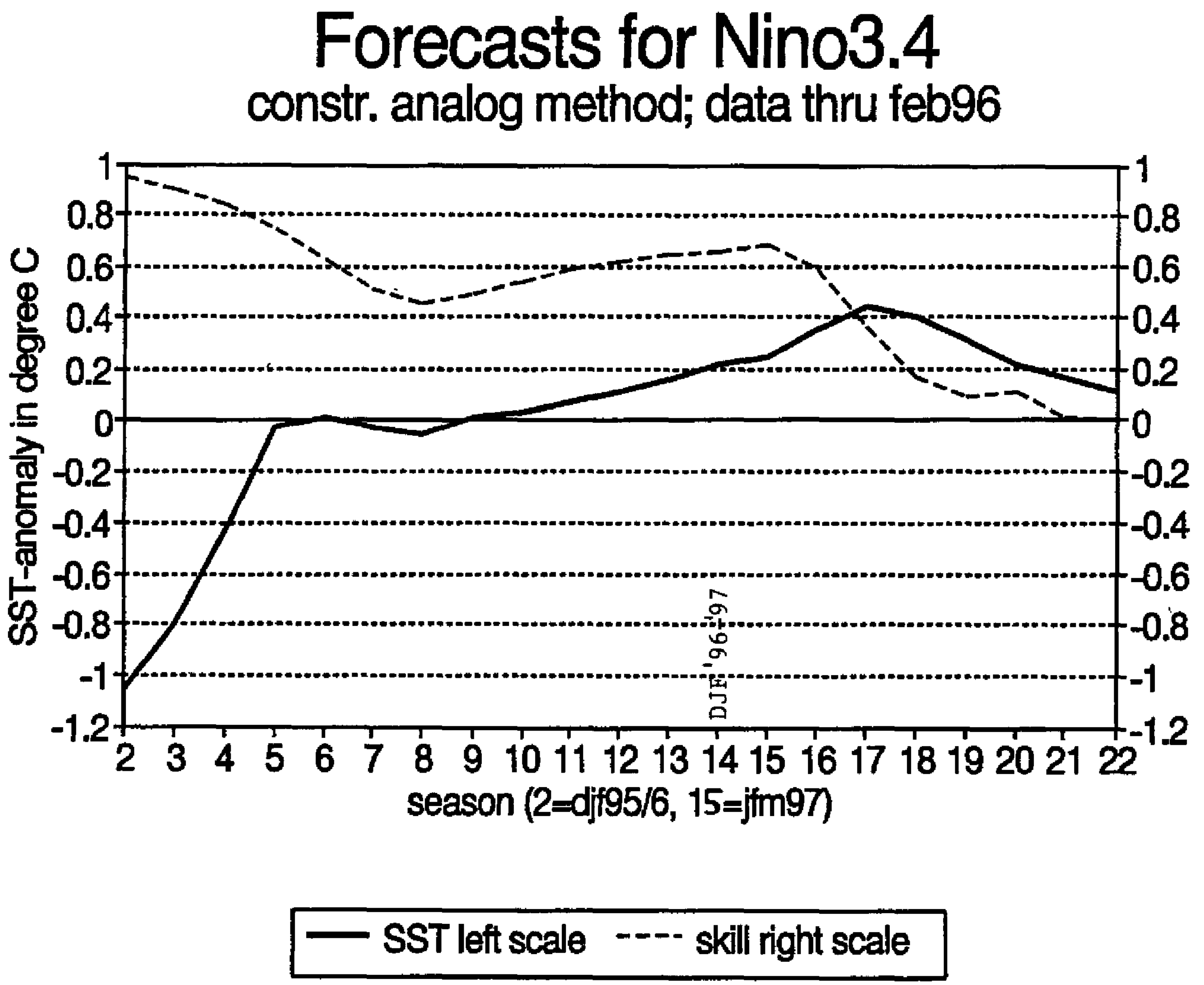

Fig. 1. *Time series of constructed analogue forecasts (solid line) based on the sequence of four consecutive 3-month periods ending in February 1996. The dashed line indicates the expected skill (correlation) based on historical performance for 1956-95. Numbers on the x-axis represent the ending month number for 1995, the ending month number plus 12 for 1996, etc. (Example: 8 is Jun-Jul-Aug 1996.) The verifying observation is shown instead of the constructed analogue specification for Dec-Jan-Feb 1995-96, and this observation also contributes partially to the Jan-Feb-Mar and Feb-Mar-Apr plotted values (see text).*

Consolidated Forecasts of Tropical Pacific SST in Niño 3.4 Using Two Dynamical Models and Two Statistical Models

contributed by David Unger, Anthony Barnston, Huug van den Dool and Vern Kousky

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In this Bulletin we find a fairly large number of forecasts for the east-central tropical Pacific SST for the coming year Some predict continuation of the current cold episode throughout 1996. Others forecast a rapid dissipation, followed by varying degrees of warming as boreal winter 1996-97 approaches. The direction of the forecast is not related to the type of model--either statistical or dynamical models may go either way. Which models are we to believe this time, or any time?

One approach to the problem is to combine, or consolidate, the forecasts of several models into a single forecast. This could be done on the basis of the past behavior of each contributing model, as well as the overlap of information among the models. There are several methods by which this can be done. A common method, and the one used here, is linear multiple regression. In effect, a statistical scheme is used to combine outputs of entire models whose natures themselves may be statistical, dynamical, or a mixture of the two. In this case we use four input models. Two are dynamical: the Lamont-Doherty Earth Observatory's simple coupled model (the improved LDEO2; Chen et al. 1995; Cane and Zebiak 1986), and the NCEP coupled model (Ji et al. 1994). The other two models are statistical: the NCEP constructed analogue (CA) model (Van den Dool 1994, Van den Dool and Barnston 1995), and the NCEP canonical correlation analysis (CCA) model (Barnston 1994). The individual forecasts of each model are shown elsewhere in this Bulletin issue.

To derive the multiple regression equations for each target season for each lead time, histories of the forecasts of each model were obtained. The CCA and CA models have histories covering 1956-1995. The Lamont coupled model has a 1972-95 history, and the NCEP coupled model 1982-95. To circumvent the problem of the differing units and climatologies used, all forecasts were converted to actual °C forecasts. The observations were expressed likewise. The regressions are based on forecasts for the Niño 3.4 region (5°N-5°S, 120-170°W), except for the Lamont model, from which we receive forecasts for the Niño 3 region. The Niño 3 forecast histories from the Lamont model were used as a predictor for Niño 3.4 in the equation development. The regression coefficients compensate for the slight differences between Niño 3 and Niño 3.4 to obtain the least squares fit for Niño 3.4. We expect to begin receiving gridded forecast fields from Lamont shortly, and will then be able to use Lamont's Niño 3.4 forecasts directly.

The desired lead times of the consolidated forecasts range from 0.5 months to 12.5 months by 1 month increments, where lead time is defined as the time skipped between the time of the forecast and the *beginning* of the forecasted (target) period. For example, the forecasts shown here, which are issued in the middle of March 1996, have target periods including Apr-May-Jun 1996, May-Jun-Jul 1996, ..., Apr-May-Jun 1997. Three of the four individual models have forecast histories whose leads range to 12.5 months or greater, while one (the NCEP coupled model) has a maximum lead of only 7.5 months. Consolidated forecasts for lead times higher than 7.5 months, therefore, are based only on the other three models; a slight discontinuity in the forecast time series may thus be expected between the Nov-Dec-Jan and the Dec-Jan-Feb 1996-97 forecasts.

Because the NCEP coupled model forecast only has a 1982-95 history, the training period for the regression is limited to that period and thus results in greater uncertainty in the coefficients than would be the case if a longer history could be used. When that model is not included in the consolidation process for the longer lead times, the 1972-95 period is used to derive the regression equations, making for a more favorable training sample.

The consolidated forecast for Niño 3.4 resulting from the multiple regression run in mid-March 1996, expressed as a standardized anomaly, is shown in Fig. 1. The box and whisker intervals for the forecasts at each time indicate the one and two error standard deviation, based on estimated skill following shrinkage of the dependent sample skill results in accordance with the sample size and number of predictors. The SST is expected to remain cold through fall 1996 before returning to normal in early spring 1997 and then switching to a weak positive anomaly.

Examination of the regression coefficients reveals that the statistical models are relatively heavily weighted in boreal winter. The Lamont model is the most heavily weighted input for target periods in and around boreal summer. The CCA and CA models, whose forecasts are fairly highly positively correlated (>0.8 during the cold season when their skills are highest), often create some instability in the coefficients such that one of them (usually CA) is positively weighted while the other (CCA) is negatively weighted by roughly the same magnitude. This instability could be alleviated by (1) eliminating one of the two statistical models, (2) forming a simple combination (e.g. an average) of the CCA and CA forecasts prior to the regression, or (3) keeping both models but "ridging" the diagonal of the variance-covariance matrix (increasing the diagonal elements) to make for a more stable matrix inversion. Presently we do not entirely understand the problem or its solution, and are studying these. We do know that the amount of colinearity between CA and CCA is not enormous.

In the present forecast, intuition is lacking in the sense that as CCA predicts rising SST between spring and fall of 1996, its negative regression weight contributes to the decrease in the consolidated forecast in that time interval (Fig. 1). In the coming months the consolidation procedure will be further developed and, it is hoped, made more trustworthy as well as intuitively reasonable.

Acknowledgments: We are grateful to Stephen Zebiak and Mark Cane of Lamont Doherty Earth Observatory, and Ming Ji and Ants Leetmaa from the National Centers for Environmental Prediction, for providing the forecast histories from their respective dynamical models, as well as their current real-time forecasts.

Barnston, A.G., 1994: Linear statistical short-term climate predictive skill in the Northern Hemisphere. *J. Climate*, **5**, 1514-1564.

Cane, M., S.E. Zebiak and S.C. Dolan, 1986: Experimental forecasts of El Nino. *Nature*, **321**, 827-832.

Chen, D., S.E. Zebiak, A.J. Busalacchi and M.A. Cane, 1995:An improved procedure for El Nino forecasting: *Implications for predictability. Science*, **269**, 1699-1702.

Ji, M., A. Kumar and A. Leetmaa, 1994: An experimental coupled forecast system at the National Meteorological Center: Some early results. *Tellus*, **46A**, 398-418.

van den Dool, H.M., 1994: Searching for analogues, how long must we wait? *Tellus*, **46A**, 314-324.

van den Dool, H.M. and A.G. Barnston, 1995: Forecasts of global sea surface temperature out to a year using the constructed analogue method. *Proceedings of the 19th Annual Climate Diagnostics Workshop*, November 14-18, 1994, College Park, Maryland, 416-419.

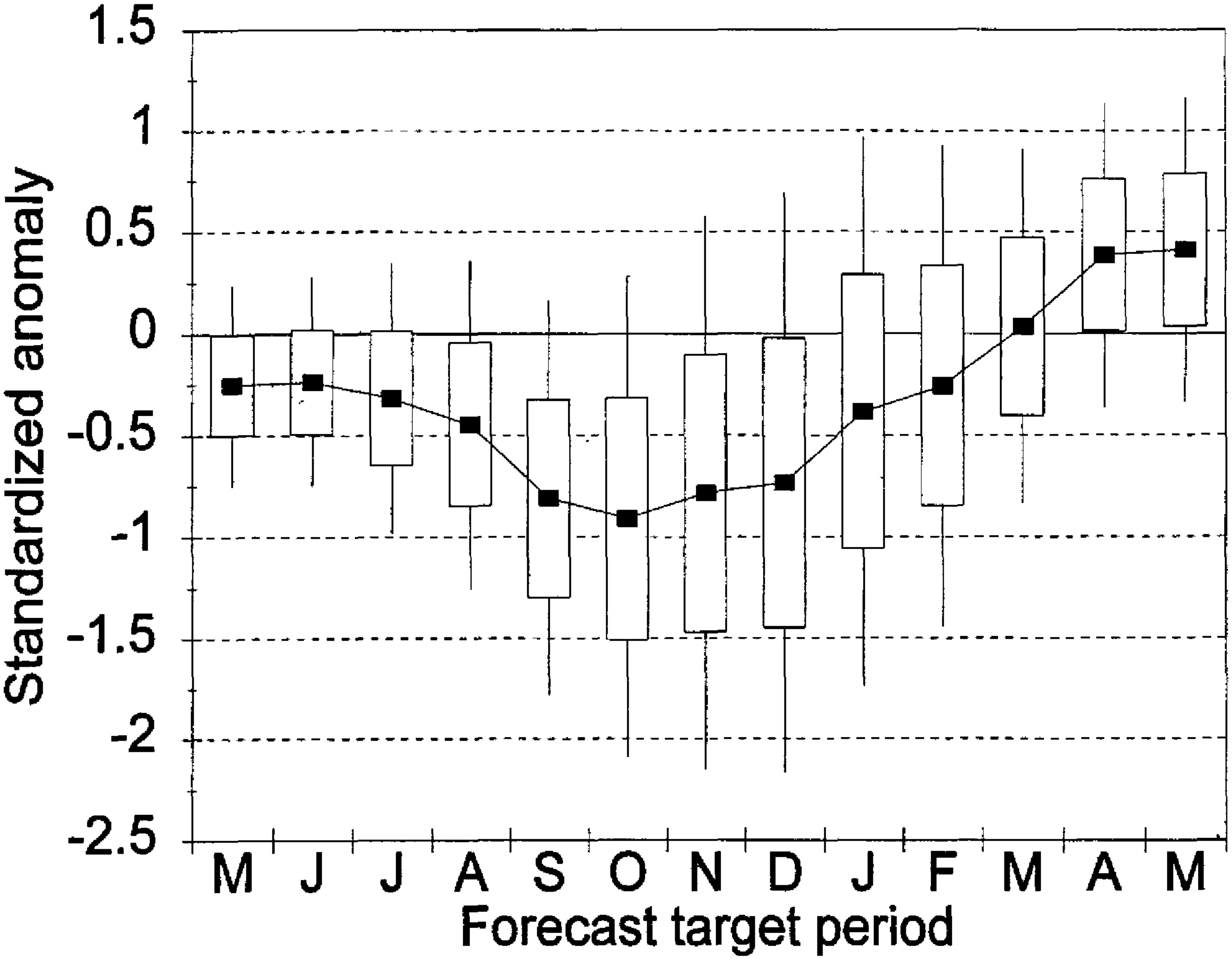

Fig. 1. *Consolidated forecast for the standardized anomaly of the SST in the Niño 3.4 region (5°N–5°S, 120–170°W) for the next 13 running 3–month periods. Month labels on the abscissa denote the middle month of the 3–month predictand period. Box and whiskers for each point forecast indicate the one and two error standard deviation intervals, based on estimated cross–validated skill.*

Brief Summary of NCEP's Canonical Correlation Analysis (CCA), Optimal Climate Normals (OCN), and NCEP Coupled Model Forecasts for U.S. Surface Climate

contributed by Anthony Barnston

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Because the CCA (Barnston 1994) and OCN (Huang et al. 1995) methods are now being used for the official operational long-lead seasonal forecasts issued by the Climate Prediction Center of NCEP, they will no longer be presented in detail in this Experimental Forecast Bulletin. However, a brief summary of these forecasts, as well as that of the NCEP coupled model (Ji et al. 1994a,b), for Apr-May-Jun and Jul-Aug-Sep 1996 is provided. For further information about the official NCEP forecasts, the following U.S. Regional Climate Center (RCC) Offices may be contacted:

Northeastern RCC	607-255-5950
Southeastern RCC	803-737-0800
Southern RCC	504-388-5021
Midwest RCC	217-244-8226
High Plains RCC	402-472-8294
Western RCC	702-677-3106

The forecasts themselves are contained in the Climate Outlook, available on Internet with address: http://cops.wwb.noaa.gov. (The previous address, http://nic.fb4.noaa.gov, will soon be discontinued.)

U.S. Surface Climate Forecasts for Apr-May-Jun '96

Temperature: CCA predicts anomalous warmth in Texas, the Southwest, much of the far West, and all of Hawaii except for near normal at Lihue. OCN forecasts warmth in the Pacific Northwest, the Northeast and mid-Atlantic states; cold in Florida panhandle; near-normal in the southern Appalachians. The coupled model dynamical forecast is not used explicitly this time due to a possible cold bias over land. Its 500mb height forecast, which is trusted, implies coolness over the northern tier of states.

Precipitation: Both OCN and CCA predict wetness in the Pacific Northwest; CCA forecasts normal wetness in Honolulu. The coupled model height forecast implies wetness over the Great Lakes.

U.S. Surface Climate Forecasts for Jul-Aug-Sep 1996

Temperature: CCA predicts anomalous warmth in the mid-Atlantic, the Florida peninsula, Reno and central California, the southern and panhandle coasts of Alaska, and most of Hawaii. OCN forecasts warm in Southwest, most of East. The same comment applies to the coupled model as that given for Apr-May-Jun.

Precipitation: CCA predicts anomalous wetness at Hilo, and dryness in central Alaska. OCN predicts above median rainfall in Michigan, below median in North Carolina and parts of the western Great Basin. The same comment applies to the coupled model as that given for Apr-May-Jun.

Note: The above forecast descriptions include only regions whose estimated cross-validated correlation skill exceeds 0.3. Highest local skills are usually in the neighborhood of 0.6, but this varies with season, lead time and forecast tool.

ENSO-Related SST

CCA (Barnston and Ropelewski 1992, Smith et al. 1995) predicts below normal SST conditions in Nino 3.4 (120-170°W, 5°N-5°S) for spring 1996, normalizing by summer 1996 and then switching to a weak positive anomaly (with low confidence) by winter 1996-97. Specifically, the forecast calls for standardized anomalies and estimated cross-validated correlation skills as follows:

	forecast	skill
Mar-Apr-May 1996	-0.76	0.78
Jul-Jul-Aug 1996	-0.03	0.32
Sep-Oct-Nov 1996	0.50	0.31
Dec-Jan-Feb 1997	0.74	0.43

The forecast for Mar-Apr-May 1996 is a skill-weighted average of CCA and simple persistence of the anomaly observed in Dec-Jan-Feb, because the skills of persistence and CCA are roughly equivalent for that case. The longer lead forecasts reflect only CCA, which has substantially higher expected skill than persistence. The global field of SST anomaly for March 10-16, 1996 (Fig. 1) shows the currently below normal SST in the eastern and central equatorial Pacific.

Barnston, A.G., 1994: Linear statistical short-term climate predictive skill in the Northern Hemisphere. *J. Climate*, *5*, 1514-1564.

Barnston, A.G. and C.F. Ropelewski, 1992: Prediction of ENSO episodes using canonical correlation analysis. *J. Climate*, *7*, 1316-1345.

Huang, J., H.M. van den Dool and A.G. Barnston, 1995: Long-lead seasonal temperature prediction using optimal climate normals. *J. Climate*. *8*, in press.

Ji, M., A. Kumar and A. Leetmaa, 1994a: A multi-season climate forecast system at the National Meteorological Center. *Bull. Am. Meteor. Soc.*, *75*, 569-577.

Ji, M., A. Kumar and A. Leetmaa, 1994b: An experimental coupled forecast system at the National Meteorological Center: Some early results. *Tellus*, *46A*, 398-418.

Reynolds, R.W. and T.M. Smith, 1994: Improved global sea surface temperature analysis using optimum interpolation. *J. Climate*, *7*, 929-948.

Smith, T.M., A.G. Barnston, M. Ji and M. Chelliah, 1995: The impact of Pacific Ocean subsurface data on operational prediction of tropical Pacific SST at the NCEP. *Wea. Forecasting*, *10*, 708-714.

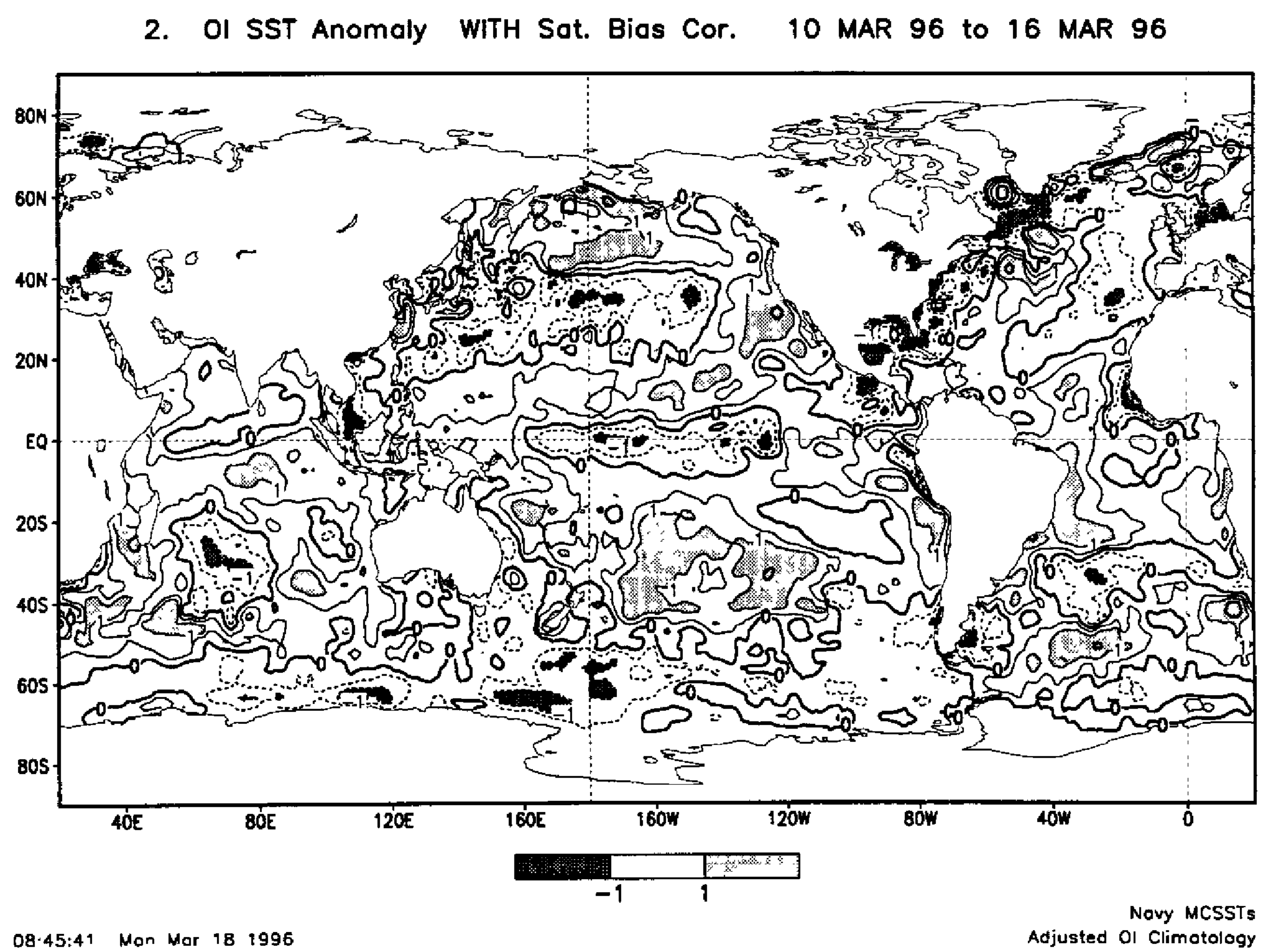

Fig. 1. *NCEP optimum interpolation (OI; Reynolds and Smith 1994) global SST anomaly field for the week of March 10–16, 1996.*