Climate prediction and climate service for Hawaii and the U.S. Affiliated Pacific Islands (USAPI): Tony Barnston's contribution

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Climate Prediction Center
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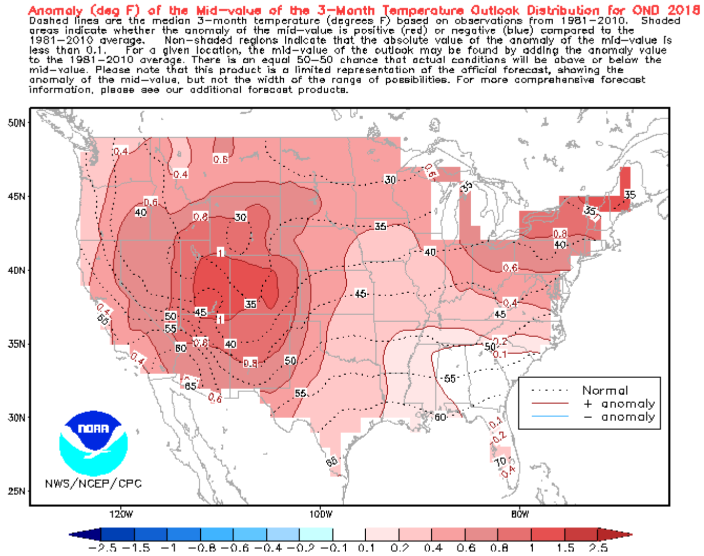
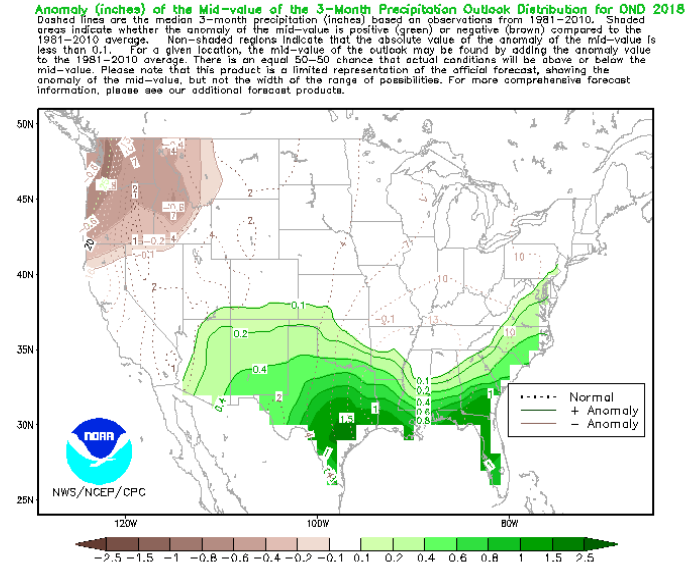
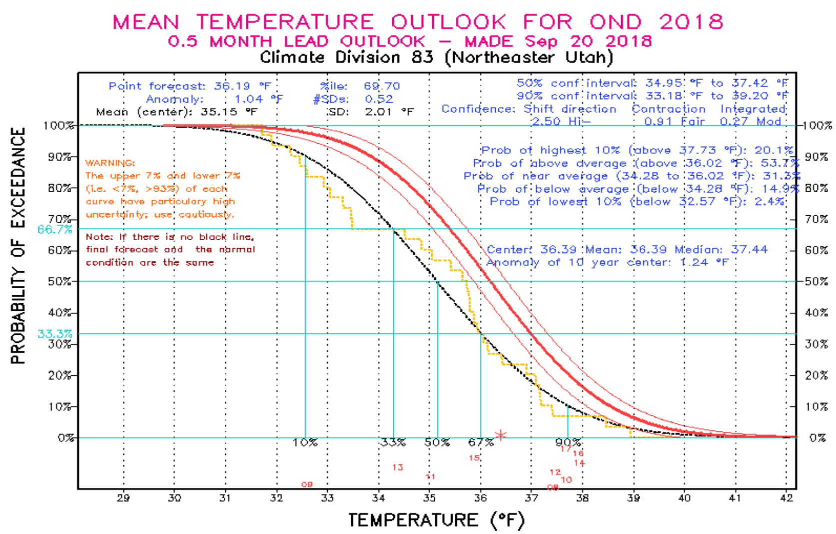
43rd Annual Climate Prediction and Diagnostics Workshop
October 24, 2018

Probability of Exceedence (POE)







344 CD, 13 x 102 x 2 =2652
Cumulative density for the defined 30-year normal
Cumulative density for the climatology plus the current decadal signal

Cumulative probability density for the final forecast
Gaussian and symmetric distribution, error envelope, details, useful information

Probability of Exceedence (POE)

An Improved Seasonal Forecast Product from Climate Prediction Center (CPC)

Yuxiang He, Anthony G. Barnston & David A. Unger
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Washington, DC 20233

23rd CDPW , Miami, October 26-30, 1998

A Forecast Product that Maximizes Utility for State-of-the-Art Seasonal Climate Prediction

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Climate Prediction Center, NCEP/NWS/NOAA, Camp Springs, Maryland

ABSTRACT

The prediction of seasonal climate anomalies at useful lead times often involves an unfavorable signal-to-noise ratio. The forecasts, while consequently tending to have modest skill, nonetheless have significant utility when packaged in ways to which users can relate and respond appropriately. This paper presents a reasonable but unprecedented manner in which to issue seasonal climate forecasts and illustrates how implied "tilts of the odds" of the forecasted climate may be used beneficially by technical as well as nontechnical clients.

1. Introduction

It is well known that the weather averaged over an extended period, such as a three-month season, is ordinarily able to be predicted in advance only with a modest level of accuracy (Gilman 1985; Livezey 1990). During the most recent decade progress has been made in recognizing when opportunities for relatively more confident forecasts of extended period climate conditions present themselves. A recent example appeared in the Northern Hemisphere summer and fall of 1997 when a strong El Niño had developed and was virtually certain to persist through the upcoming winter when it would have predictable climate impacts in portions of North America and elsewhere. The director of the Department of Commerce's Climate Prediction Center (CPC) appeared on national television, warning that Florida and California would have a rainy winter 1997/98. While this unprecedented "climate alert" provoked controversy, the forecast verified favorably (Changnon 1999; Barnston et al 1999; Mason et al. 1999).

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In final form 27 December 1999.

There are other, more subtle, ways in which climate anomalies have some predictability. Gradual trends in temperature and precipitation, which may be due to natural and/or anthropogenic causes, appear for specific regions and seasons. Forecasts of such a trend's continuation are often correct despite a lack of knowledge of many of the superimposed faster-acting climate-determining factors, or even the cause of the trend itself.

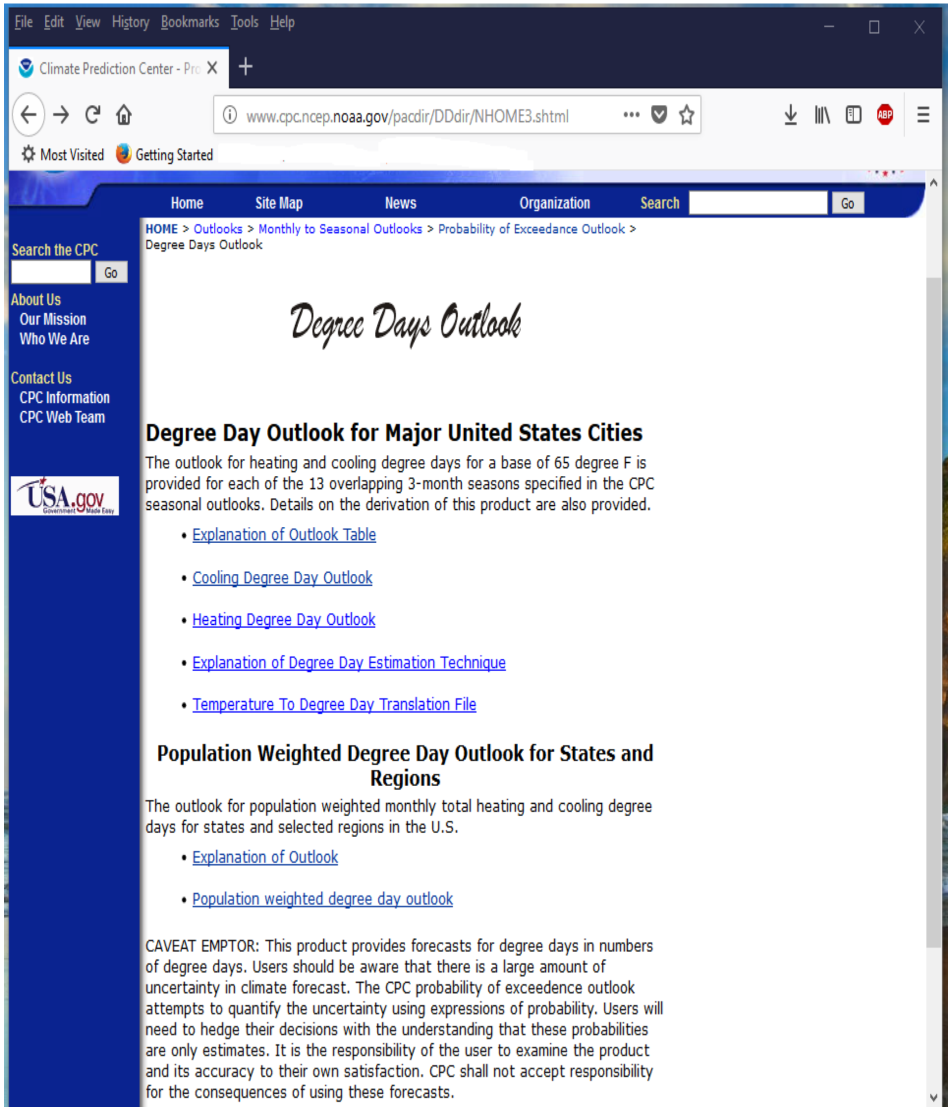
The primary reason for the normally low level of forecast skill is that much of the atmosphere's natural variations making up a seasonal average are due to individual weather events (e.g., fronts, low pressure systems), as opposed to longer-lived climate tendencies. Weather events are generally only usefully predictable up to about one week into the future. However, statistical and physical modeling approaches can extend a certain amount of predictability out to much longer ranges based on the more consistent influences of boundary conditions such as sea surface temperature (e.g., El Niño or La Niña) that can tilt the odds in a specific direction of climate anomaly. While we cannot say on which day a rainstorm or unseasonable warmth will occur in a given region 3 months from now, we may be able to say that the rainfall or the temperature over the season as a whole is more likely to be above than below normal. Such a forecast inherently carries considerable uncertainty.

Because of their normally modest skill, climate forecasts have not usually been issued in the concrete

Gaussian and symmetric distribution, but skew fitted for precipitation, CR
technical and nontechnical users.
provide more details for present and future applications of the PoE

Heating and Cooling Degree Day Outlook

city degree day outlook & population weighted outlooks



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Climate Prediction Center - Pro

www.cpc.ncep.noaa.gov/pacdir/DDdir/NHOME3.shtml

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HOME > Outlooks > Monthly to Seasonal Outlooks > Probability of Exceedance Outlook > Degree Days Outlook

Degree Days Outlook

Degree Day Outlook for Major United States Cities

The outlook for heating and cooling degree days for a base of 65 degree F is provided for each of the 13 overlapping 3-month seasons specified in the CPC seasonal outlooks. Details on the derivation of this product are also provided.

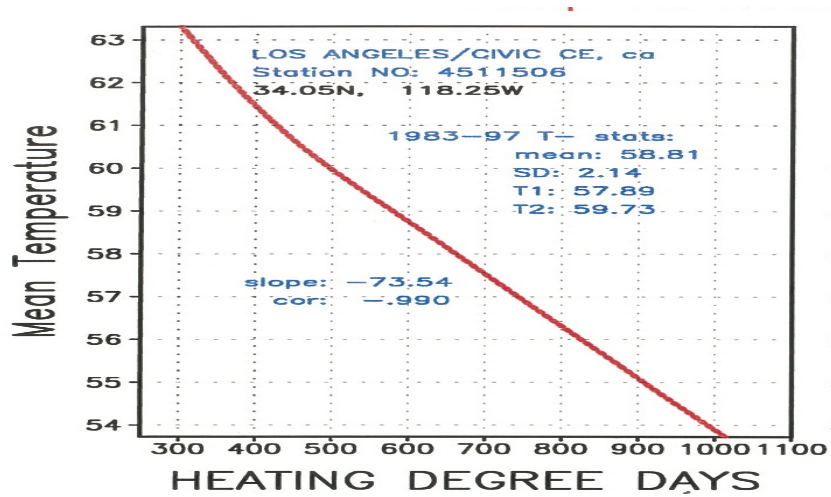
- Explanation of Outlook Table
- Cooling Degree Day Outlook
- Heating Degree Day Outlook
- Explanation of Degree Day Estimation Technique
- Temperature To Degree Day Translation File

Population Weighted Degree Day Outlook for States and Regions

The outlook for population weighted monthly total heating and cooling degree days for states and selected regions in the U.S.

- Explanation of Outlook
- Population weighted degree day outlook

CAVEAT EMPTOR: This product provides forecasts for degree days in numbers of degree days. Users should be aware that there is a large amount of uncertainty in climate forecast. The CPC probability of exceedence outlook attempts to quantify the uncertainty using expressions of probability. Users will need to hedge their decisions with the understanding that these probabilities are only estimates. It is the responsibility of the user to examine the product and its accuracy to their own satisfaction. CPC shall not accept responsibility for the consequences of using these forecasts.



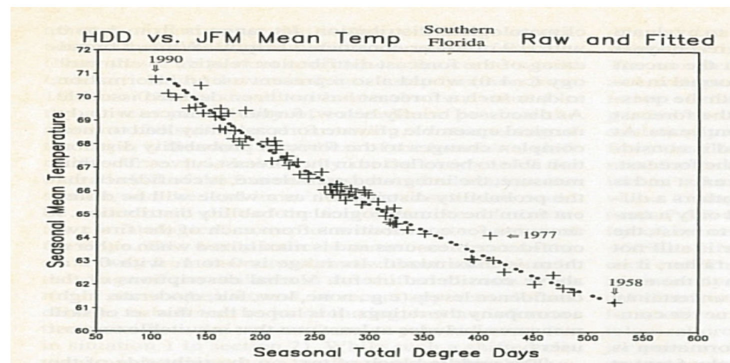


FIG. 3. Correspondence between observed 3-month mean temperature (°F) and heating degree days (with 65°F base) in southern Florida for the Jan–Mar period. The crosses show observed data points for the 1931–98 period, and the dots illustrate a smoothed fit to the data points using a running weighted mean filter.

User's questions, utility company, stock trading company.
Users like, feedbacks from users.

Impacts of the NAO on U.S. and Canadian Surface Climate; Implications for Seasonal Prediction

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Using seasonal mean Northern Hemisphere sea level pressure (SLP) and 700 mb height fields, and North American surface climate data for the 1950-95 period, the North Atlantic Oscillation (NAO) is defined and the associated U.S. and Canadian surface temperature and precipitation patterns are examined. Associations between the NAO and Atlantic sea surface temperature (SST) anomalies are inspected, and the combined effects of the NAO and ENSO are discussed. Finally, the NAO's interannual autocorrelation is examined for NAO prediction potential.

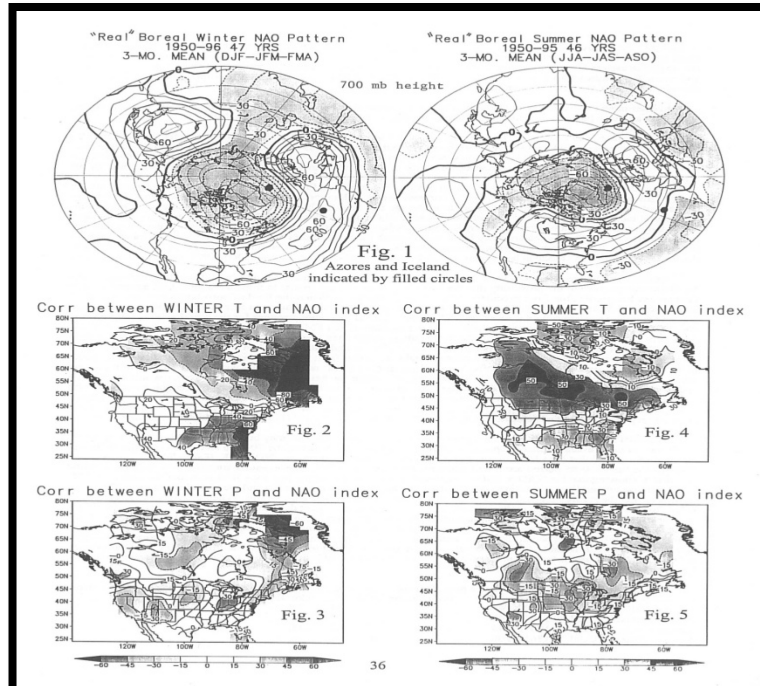
The NAO is a massive atmospheric phenomenon having widespread surface climate impacts. The strongest atmospheric pattern in the Northern Hemisphere at nearly all times of the year, the NAO influences large portions of the North Atlantic, non-western North America and Europe. During the 1950-95 period it has varied at lower frequency than the ENSO, tending to remain in one phase for several consecutive winters. Rotated principal component (RPC) analysis is used to define the NAO pattern in the 700 mb height and SLP fields for 1950-95. The resulting patterns for winter and summer for 700 mb height are shown in Fig. 1, where winter is defined as (DJF+2*JFM+FMA)/4, and summer as (JJA+2*JAS+ASO)/4.

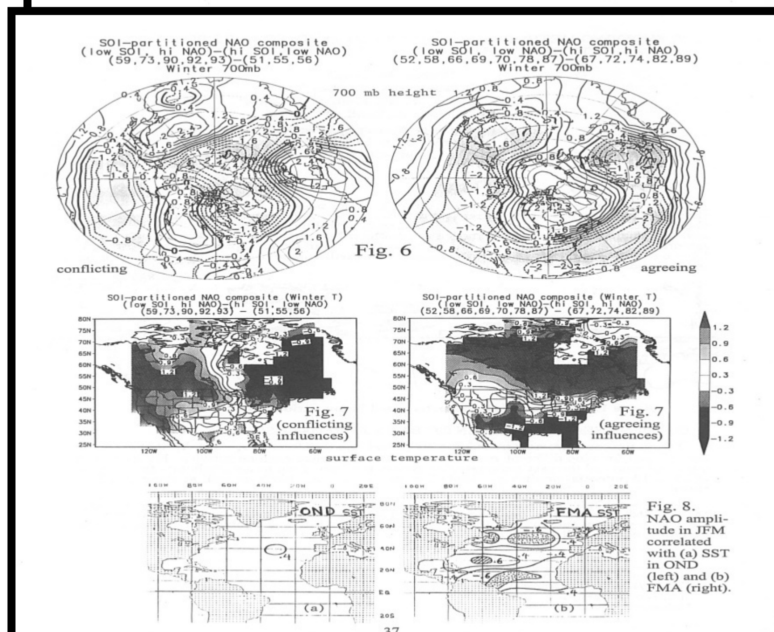
Autocorrelations of winter-to-winter NAO amplitudes are weakly but consistently positive for lags of 1 to 4 years: .24, .10, .11 and .04, respectively. Summer-to-summer NAO amplitudes lack consistent positive autocorrelation. This low frequency persistence among winters suggests modest skill for 3-season lead seasonal climate forecasts. However, as shown in Hurrell and Van Loon (1996, *Climate Change*), positive interannual autocorrelation has not always existed for running 60-year periods spanning back to 1865 if one uses a two-point SLP index of the NAO (the Azores [Ponta Delgada] minus Iceland [Stykkisholmur] index). The comparability of the Azores-Iceland index with the RPC amplitude time series is described by correlation coefficients: the SLP and 700 mb height RPC amplitudes are highly correlated (.95 in winter, .87 in summer) and the SLP RPC and the Azores-Iceland index are correlated well in winter (.85) but only moderately (.61) in summer. If there were no changes in observing practices or station locations resulting in discontinuities or biases in the SLP during 1865-1949, the two-point index in winter can sensibly be used back to 1865, or concatenated with the RPC amplitudes. We assume that given a choice, a full field pattern produced by an established technique such as RPC analysis (Fig. 1) is preferable to a two-point index of the NAO. The seasonal change in the location of the NAO, contracting to the north in summer as compared with winter, is noted in Fig. 1. The northern migration in summer is substantial in North America and the western Atlantic but only slight in Europe and eastern Greenland. The seasonal movement is shown in greater detail in Barnston and Livezey (1987, *Mon. Wea. Rev.*). An NAO-related center of the same anomaly sign as that of Europe and the eastern U.S. in winter appears over eastern Mongolia/Manchuria in winter, and is nearly absent in summer (Fig.1).

By inspecting cases in which the amplitude of the 700 mb NAO RPC disagrees with the Azores-Iceland index, the lower average summer correspondence is found to occur because (1) the summer NAO pattern is less coherent than the winter pattern, with smaller scale anomalies sometimes overshadowing the NAO signal in the Azores-Iceland index, and (2) the subtropical center migrates northward to approximately 40-52°N at 25°W longitude in summer (Fig. 1), making the Azores a less favorable location than in winter to represent the subtropical pole of the NAO.

Simultaneous correlations between the winter 700 mb height-based NAO amplitude and the mainland U.S. and Canadian mean surface temperature and precipitation for the same weighted winter period are shown in Figs. 2 and 3, respectively. The winter NAO pattern affects U.S. surface temperature (Fig. 2) most strongly in the Middle Atlantic and Southeastern states, extending westward into the country's midsection (southern, central and northwestern plains). The opposite relationship with temperature anomaly is found in eastern Canada north of 50°N. The effect of the NAO on precipitation (Fig. 3) is considerably weaker than on temperature. The U.S. Midwest (Kentucky, Ohio, Indiana) as well as eastern maritime Canada show warm/wet (or cold/dry) associations--opposite of what would be expected on the basis of the amount of solar radiation received at the surface. The association of warmth with wetness in the U.S. Midwest in winter has been noted before (e.g. Van den Dool 1988, *Utilitarian Atlas*; Barnston 1993, *NOAA Atlas No. 11m*), and is related to the NAO: The strength of the winter westerlies in the Midwestern U.S. is anomalously weak with a negative NAO, tending to produce warm/wet weather (infrequent arctic air mass intrusions, Gulf moisture inflow, slow-moving storms out of Gulf of Mexico or lee of Rockies), and for a positive NAO stronger than normal westerlies produce cold/dry weather (arctic fronts, and fast-moving, dryer "Alberta clipper" storms).

The specification correlations for the summer surface temperature and precipitation are shown in similar fashion in Figs. 4 and 5. Comparing Fig. 4 to Fig. 2 for temperature, the effects of the winter-to-summer northward migration





RPCA (defining the NAO). First examined NAO and associated U.S and Canadian surface T & P patterns, associations between the NAO and Atlantic sst anomalies, the combined effects of the NAO and ENSO. NAO interannual autocorrelation for NAO prediction potential,

The Complications of Defining the NAO; Influences on Northern Hemisphere Climate

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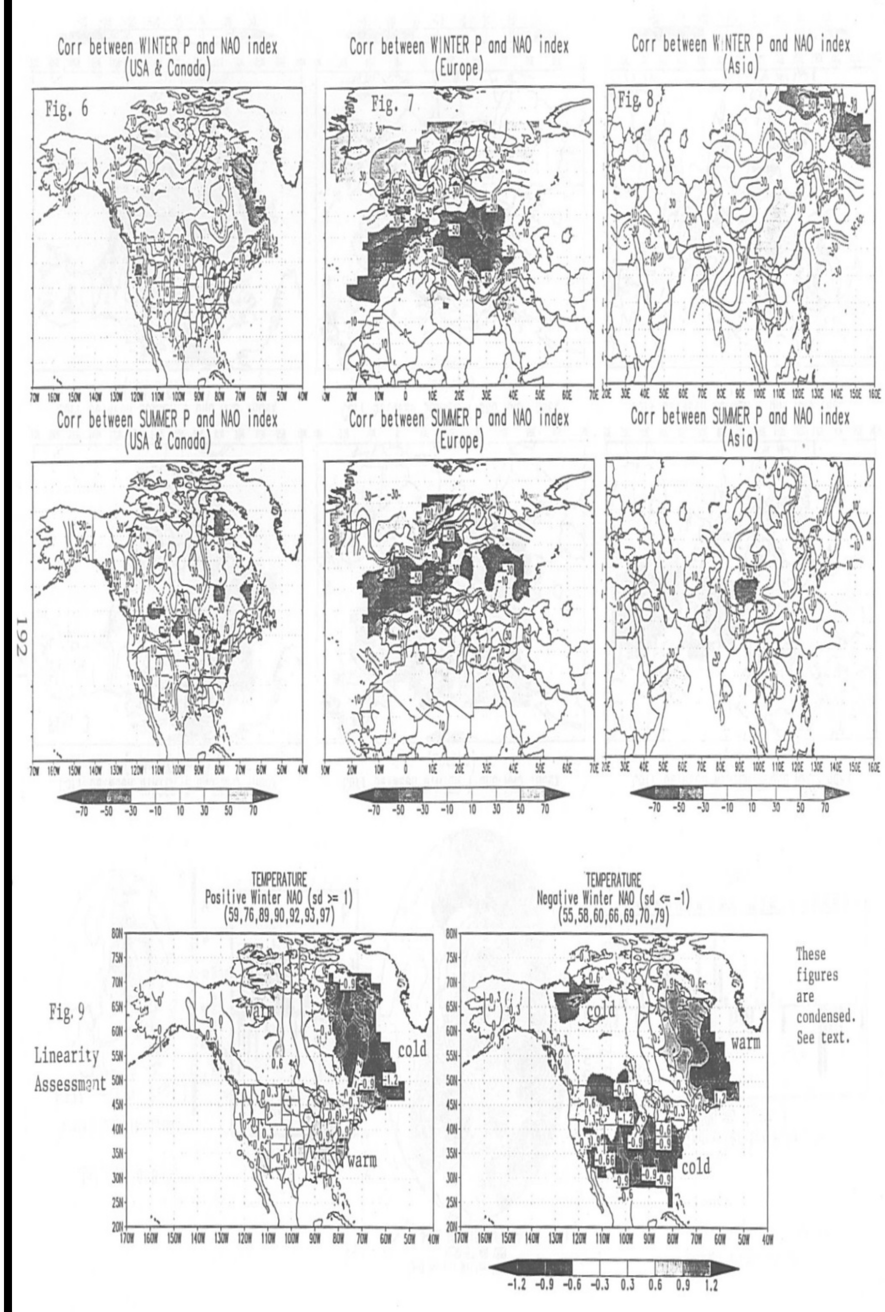
This is a continuation of the NAO study presented in last year's Climate Diagnostics and Prediction Workshop (Barnston and He, p. 34-37). The North Atlantic Oscillation (NAO) influences the surface climate over an enormous area including eastern and central North America, much of the North Atlantic, and most of Europe and northern Africa. It is thus worth examining and, if possible, predicting. Unlike the Pacific/North American (PNA) pattern, the NAO is not obviously associated with a pattern of tropical or global SST anomaly other than one that it causes itself in the North Atlantic at 1-2 months' lag. Again unlike the PNA pattern, the NAO pattern's definition has uncertainty, depending noticeably not only on the season, but on the period of record, the averaging period (e.g. 3-month vs. 1-month means), and the choice of analysis domain. Difficulty in defining the NAO is partly due to the large longitudinal extent, and amorphous nature, of the southern pole of the pattern. Because rotated principal components analysis (RPCA) yields patterns very similar to those derived from teleconnections, RPCA is used here to guide the process of defining the NAO. Because the time series of the NAO amplitude depends strongly on the NAO pattern definition, major diagnostic ambiguities occur for some years as a result of differing definitions.

Figure 1 shows the NAO spatial pattern defined by RPCA when the 1964-96 period is used on Northern Hemisphere (NH) 700 mb heights for the cold season (after Halpert and Bell, 1997, *Bull. Am. Meteor. Soc.*, S1-S49; hereafter HB97). Specifically, 1-month mean data for November, December, January and February are pooled together for this RPCA, making a sample size of 132 (4 x 33) cases. The time series (shown to right of pattern) is produced by projecting the 700 mb height data for each of the four months of a given winter period onto the pattern and then averaging the four resulting amplitudes. Amplitudes for 1950-63 were computed even though these years were not used to derive the RPCA pattern.

Figure 2 shows our NAO pattern, defined also by RPCA on NH 700 mb heights, but with the following differences from HB97's analysis: (1) The 1950-97 period was used instead of the 1964-96 period, (2) 3-month mean data were used to form the individual cases instead of 1-month mean data, and (3) the pattern represents the weighted average of the patterns resulting from RPCAs using Dec-Jan-Feb, Jan-Feb-Mar, and Feb-Mar-Apr input data, using the weights 1-2-1. The weighted averaging is used to smooth out noticeable differences in the patterns of each of the 3 consecutive running 3-month periods, yielding a presumably more representative, general cold season NAO structure. The time series shown to the right of the pattern is produced by projecting the 700 mb height anomaly data for the weighted (1-2-1) average of the 3 seasonal periods onto the spatial pattern. (Note that the the time series ends 1 year later than in Fig. 2 than Fig. 1.)

Major differences in both the spatial pattern and the amplitude time series are found between the two NAO definitions. While both versions show the northern center positioned over and around Greenland, important differences appear in the southern center: HB97's southern center stretches along the 40°N latitude circle from the U.S. to southwestern Europe, while our southern center has a larger longitudinal extent and is noticeably farther south in the western portion (near 33°N in western Atlantic) and farther north in the eastern portion (near 50°N near Poland). The loadings over Europe are much stronger than those of HB97's pattern, and a strong secondary southern center appears near Mongolia that is absent in HB97's pattern. The last two features appear in HB97's RPCA as a separate mode referred to as the Polar Eurasian pattern, which has its strongest center over the North Pole and northern Greenland. These differences in NAO definition lead to substantial differences in the amplitude time series: e.g. the HB97 pattern has a strong negative amplitude for winter 1995-96 (shown as the 1996 winter in Fig. 1), while our pattern indicates an only slightly negative amplitude for the 1996 winter. Major discrepancies are also found between the time series for other years.

Similar RPCA sensitivity tests for the Pacific/North American (PNA) pattern reveal considerably less pattern dependency on the period of the data record and the averaging period (1-month vs. 3-month), as also evidenced in most of the PNA-related literature over the last two decades. We conclude that while there is some instability inherent in the RPCA approach, a major difference between the PNA and the NAO patterns is that **the NAO is more loosely defined than the PNA**. This may be related to the NAO's larger longitudinal extent, and its being largely a manifestation of the internal dynamics of the atmosphere as opposed to being demonstrably forced by SST boundary conditions as the PNA has been



Further exam NAO influences on Northern Hemisphere climate, linearity and and predicting, Composite of surface climate associated with the two extremes of the NAO (sd> 1), discuss the next steps for this study (e.g., assess the statistical significance of the composite，detect remote teleconnection of NAO in the southern Hemisphere and the Tropics)

Use of Discriminant Analysis for Seasonal Forecasts of Surface Climate in the United States

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The Climate Prediction Center presently uses a mixture of empirical tools and a dynamical tool to develop its long -lead forecasts for U.S. 3-month mean surface climate. One of the empirical tools is Canonical Correlation Analysis (CCA), which models predictor-predictand pattern relationships linearly with respect to both the predictor and the predictand. This constrains responses to equal-but opposite predictor anomalies to be equal-but-opposite predictand anomalies. For example, the temperature anomalies to a warm ENSO event is the same as that to a cold ENSO event, but with reversed sign. In a nonlinear dynamical system such as our ocean-atmosphere system, we seek an empirical model that can accommodate some asymmetry in predictor-predictand relationships while minimizing the potential for severe data overfitting in the fairly short recent (~40-year) period of quality predictor SST observations.

Discriminant analysis (DA) is a multivariate statistical model that identifies distinct clusters of anomalies in a set of predictors that discriminate linearly maximally among several categories of a single predictand. Differences from CCA include: (1) Predictands are treated one at a time rather than on a pattern level. (2) Rather than being allowed to vary

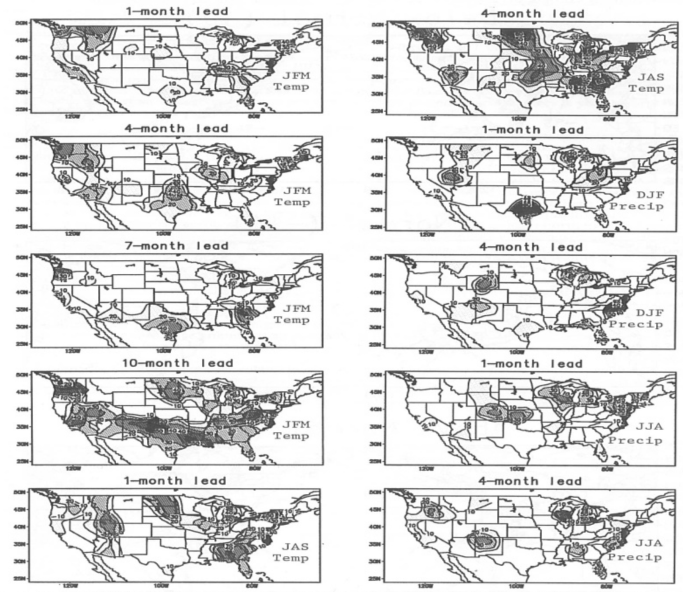
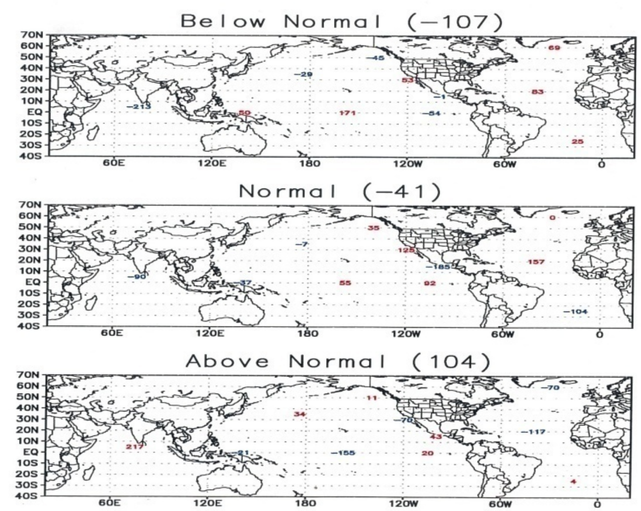


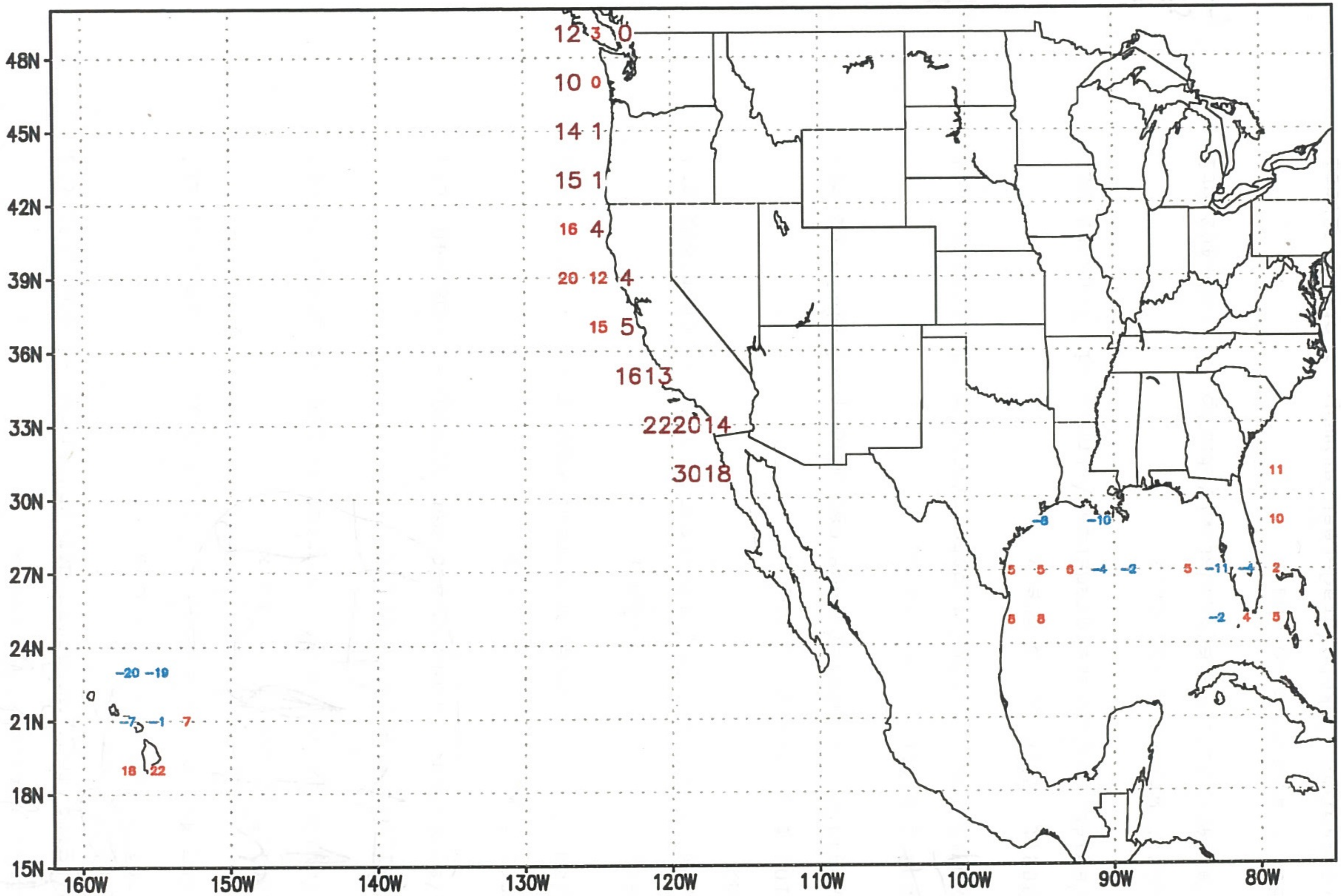
Fig. 2. Geographical distribution of cross-validated DA skill in forecasting 3-month U.S. surface temperature and precipitation using 11 SST regions and the predictand itself at the earlier time.



Predictor anomaly clusters leading to each of the three predictand categories of temperature for Shreveport, Louisiana, at 10 month lead

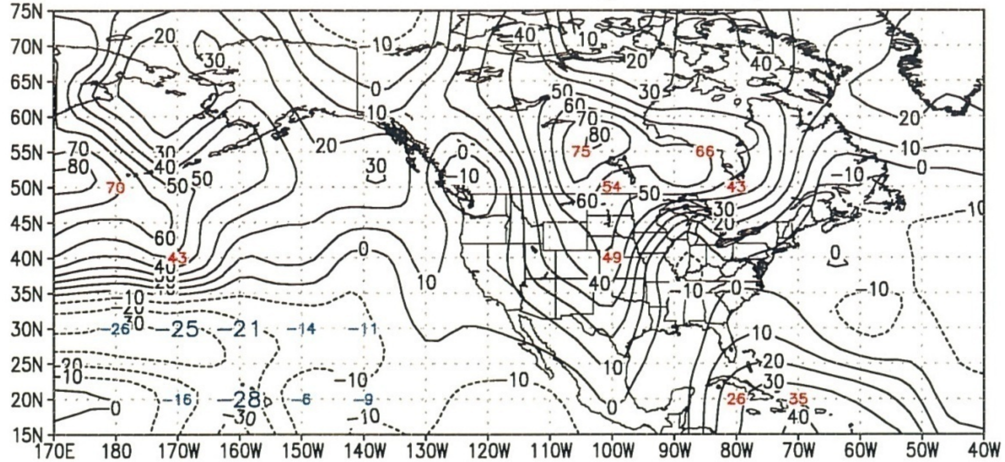
catch some info for nonlinearity and asymmetry

(a) COASTAL SST ANOMALY FORECAST USING CCA
0.5-month lead (DJF 96)

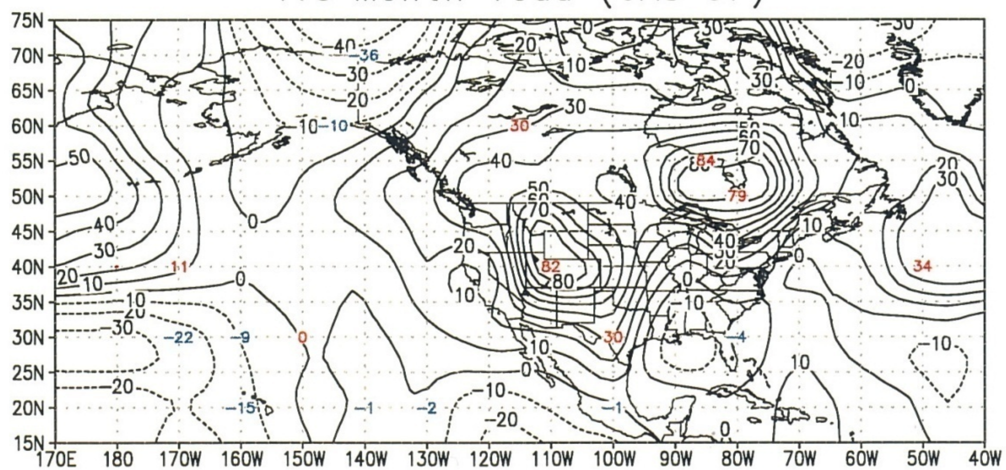


west coast, gulf coast, Hawaii

(1) 700MB (PNA) ANOMALY FORECAST USING CCA
0.5–month lead (JJA 97)



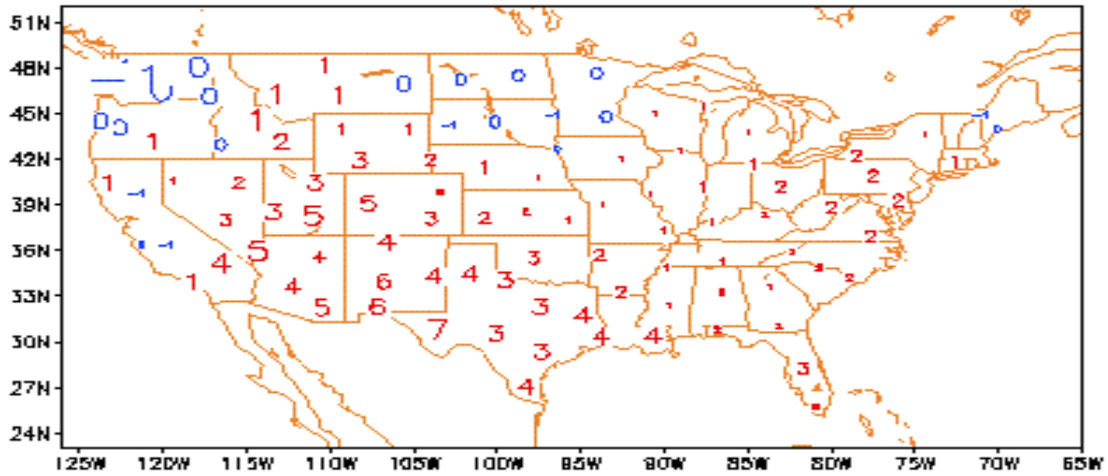
(2) 700MB (PNA) ANOMALY FORECAST USING CCA
1.5–month lead (JAS 97)



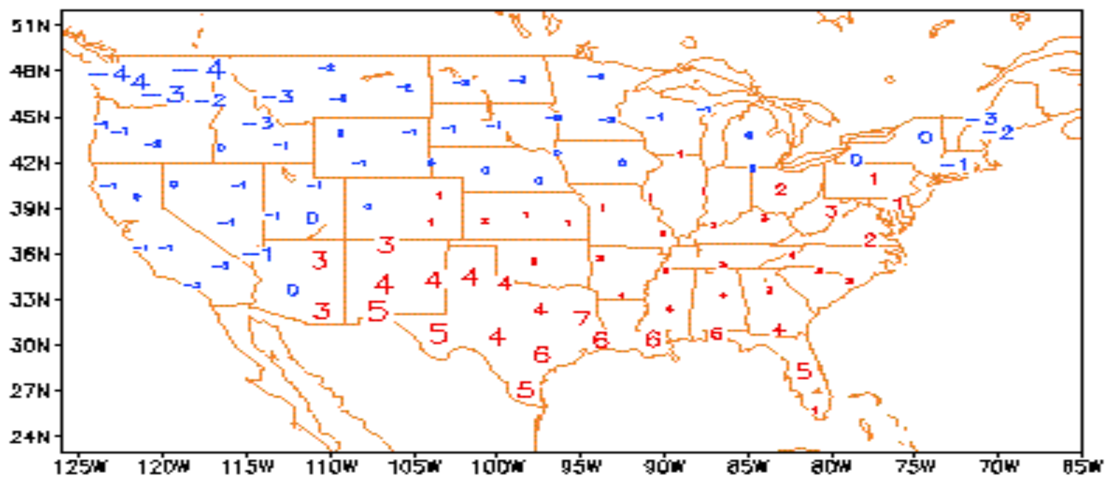
both coastal sst and 700mb cca forecast - skill

Developed a detrended (High Frequency/Low Frequency) CCA tool for CPC climate prediction for US with a nine year centered running mean applied to obtain the low frequency in consistent with OCN

7.5 Month CCA T FORECASTS FOR MAM 2002



7.5 Month CCA T
DETRENDED FORECAST (high frequency)
MAM 2002



This is very helpful! The split in hf and lf is what the CPC doctor ordered!

CPC's Pacific Region Activities

(1) January 1995, CPC began to issue the climate outlooks (Temperature & Precipitation), 13 leads with half-month lead time up to one year in advance for Hawaii (CCA, OCN, CMP)

PROGNOSTIC DISCUSSION FOR LONG-LEAD HAWAIIAN OUTLOOK
CLIMATE PREDICTION CENTER NCEP
NATIONAL WEATHER SERVICE WASHINGTON DC
3 PM EDT THURSDAY APRIL 13 1995

PROGNOSTIC DISCUSSION OF HAWAIIAN OUTLOOKS

MONTHLY OUTLOOK DISCUSSION - MAY 1995

LATEST DATA FROM THE TROPICAL PACIFIC SHOW THAT THE WARM ENSO EPISODE HAS JUST ABOUT ENDED SO THE ATMOSPHERIC RESPONSE SHOULD CONTINUE TO WEAKEN RAPIDLY OVER THE NEXT FEW MONTHS DUE TO THE LAG BETWEEN OCEAN AND ATMOSPHERIC RESPONSE. WARMER AND DRIER THAN NORMAL SPRINGTIME CONDITIONS ARE USUALLY ASSOCIATED WITH A WARM ENSO EVENT. STATISTICAL FORECASTS FROM CANONICAL CORRELATION ANALYSIS (CCA) GIVE MODERATE AMPLITUDES OF ABOVE NORMAL TEMPERATURES AT ALL STATIONS WITH MODERATE CONFIDENCE - ALTHOUGH THERE IS NO SIGNIFICANT SIGNAL AT ALL THIS LATE IN THE SEASON FOR PRECIPITATION.

	TEMPERATURE			PRECIPITATION			
	FCST	AVE	LIM	FCST	BLW	MEDIAN	ABV
HILO	A8	74	0.6	CL	6.8	8.9	11.3
HONOLULU	A4	77	0.6	CL	0.2	0.5	1.1
KAHULUI	A4	76	0.7	CL	0.2	0.4	0.8
LIHUE	A3	76	0.6	CL	1.4	2.2	3.5

SEASONAL OUTLOOK DISCUSSION - MAY-JUN-JUL 95 TO MAY-JUN-JUL 96

TEMPERATURE FORECASTS FROM CCA INDICATE THAT TEMPERATURES WILL MOST LIKELY CONTINUE TO HAVE AN ENHANCED PROBABILITY OF BEING IN THE ABOVE NORMAL RANGE THROUGH THE JAS SEASON OVER MUCH OF THE STATE - AS THE DIRECT EFFECTS OF ENSO GRADUALLY DIE AWAY - PERHAPS PROLONGED A BIT BY SLIGHTLY ABOVE NORMAL SEA SURFACE TEMPERATURES IN THE VICINITY OF HAWAII. ABOVE NORMAL SEASONAL MEAN TEMPERATURES ARE PREDICTED TO END AT ALL LOCATIONS EXCEPT HONOLULU BY FALL - WHERE THEY ARE EXPECTED TO CONTINUE THROUGH OND. WARMTH IS NOT FORECAST TO RETURN UNTIL LATE NEXT SPRING AT MOST LOCATIONS - AND NO SEASONS HAVE A SIGNIFIACNT INDICATION FOR BELOW NORMAL TEMPERATURES.

CCA FORECASTS FOR PRECIPITATION DO NOT INDICATED ANY SIGNIFICANT DEPARRTURE FROM CLIMATOLOGICAL PROBABILITIES EXCEPT AT HILO WHERE AN INCREASED CHANCE OF WET CONDITIONS ARE EXPECTED IN MJJ AND AGAIN IN JAS AND ASO - AND AT KAHULUI ONLY IN JAS. FORECASTS OF BELOW MEDIAN PRECIPITATION AMOUNTS AT HONOLULU FOR JFM AND MAM 1996 HINT AT A RETURN TO DRY LATE WINTER AND SPRING CONDITIONS THERE IN EARLY 1996.

CLARIFICATION. CL IS CLIMATOLOGICAL PROBABILITIES - WHICH MEANS THAT NO PARTICULAR TILT OF THE ODDS TOWARD ABOVE - NEAR - OR BELOW NORMAL CONDITIONS IS FORECAST. A5 (EXAMPLE) MEANS A 5% HIGHER THAN NORMAL CHANCE THAT TEMPERATURE OR PRECIPITATION WILL BE IN ABOVE CLASS. B3 (EXAMPLE) MEANS A 3% HIGHER THAN NORMAL PROBABILITY THAT TEMPERATURE OR PRECIPITATION WILL BE IN BELOW CLASS. N2 (EXAMPLE) MEANS A 2% HIGHER THAN NORMAL PROBABILITY THAT TEMPERATURE OR PRECIPITATION WILL BE IN NEAR NORMAL CLASS.

NOTE
HAWAIIAN FORECAST IS BASED ON CCA TOOL ONLY

HILO

	TEMPERATURE			PRECIPITATION			
	FCST	AVE	LIM	FCST	BLW	MEDIAN	ABV
MJJ 1995	A6	75	0.5	A2	20.5	24.5	29.0
JJA 1995	A6	76	0.4	CL	19.7	23.8	28.5
JAS 1995	A3	76	0.4	A5	22.0	26.2	30.9
ASO 1995	CL	76	0.4	A2	23.3	26.6	30.3
SON 1995	A2	75	0.4	CL	25.7	31.2	37.4
OND 1995	CL	74	0.4	CL	27.1	33.9	41.7
NDJ 1995	CL	73	0.4	CL	30.2	38.5	48.2
DJF 1995	CL	72	0.5	CL	19.8	27.1	36.1
JFM 1996	CL	72	0.5	CL	22.8	30.2	39.1
FMA 1996	CL	71	0.6	CL	30.5	37.2	44.7
MAM 1996	CL	73	0.5	CL	30.4	36.8	44.1
AMJ 1996	CL	74	0.5	CL	24.2	29.4	35.4
MJJ 1996	CL	75	0.5	CL	20.5	24.5	29.0

HONOLULU

	TEMPERATURE			PRECIPITATION			
	FCST	AVE	LIM	FCST	BLW	MEDIAN	ABV
MJJ 1995	A2	79	0.5	CL	1.1	1.7	2.5
JJA 1995	A2	80	0.5	CL	0.9	1.3	1.8
JAS 1995	A3	81	0.5	CL	1.3	1.7	2.1
ASO 1995	A2	81	0.5	CL	1.8	2.8	4.0
SON 1995	A3	79	0.5	CL	3.6	5.1	6.9
OND 1995	A3	77	0.5	CL	6.0	8.0	10.4
NDJ 1995	CL	75	0.4	CL	6.0	8.0	10.4
DJF 1995	CL	73	0.4	CL	6.2	8.3	10.9
JFM 1996	CL	73	0.5	B2	5.0	6.9	9.1
FMA 1996	CL	73	0.6	CL	3.7	5.1	6.8
MAM 1996	N2	76	0.5	B2	2.5	3.8	5.5
AMJ 1996	A2	78	0.5	CL	1.5	2.4	3.6
MJJ 1996	A5	79	0.5	CL	1.1	1.7	2.5

KAHULUI

	TEMPERATURE			PRECIPITATION			
	FCST	AVE	LIM	FCST	BLW	MEDIAN	ABV
MJJ 1995	A5	77	0.6	CL	0.6	1.0	1.6
JJA 1995	A3	79	0.5	CL	0.6	0.9	1.3
JAS 1995	A2	79	0.5	A2	0.8	1.1	1.4
ASO 1995	CL	79	0.5	CL	1.2	1.7	2.4
SON 1995	CL	77	0.5	CL	2.4	3.4	4.8
OND 1995	CL	76	0.5	CL	4.8	6.3	8.1
NDJ 1995	CL	74	0.4	CL	6.1	7.8	9.8
DJF 1995	CL	72	0.5	CL	6.9	9.0	11.5
JFM 1996	CL	72	0.5	CL	6.7	8.7	11.1
FMA 1996	CL	72	0.6	CL	4.7	6.4	8.5
MAM 1996	CL	74	0.5	CL	3.0	4.4	6.1
AMJ 1996	CL	76	0.5	CL	1.1	1.9	3.1

The demands for climate information and products over the Pacific region, especially Hawaii and the USAPI, have dramatically increased during the last two decades because of the Importance of accurate climate information for public safety/disaster management, freshwater resources, public health, ecosystems, and biocultural resources.

NWS Pacific Region/Department of Interior provided 3 years funding (1996-1998) to support CPC's activities for the climate forecasting (especially for the long-range precipitation forecasting) for the Pacific region; users and partners/available tools, user feedback , leeward/windward, trade wind…,

designed first cpc official temperature and precipitation for Hawaii in January 1995.

Reprinted from JOURNAL OF CLIMATE, Vol. 9, No. 9, September 1996
American Meteorological Society

Long-Lead Forecasts of Seasonal Precipitation in the Tropical Pacific Islands Using CCA

YUXIANG HE AND ANTHONY G. BARNSTON

Climate Prediction Center, National Centers for Environmental Prediction, NWS/NOAA, Washington, D.C.

(Manuscript received 19 October 1995, in final form 15 February 1996)

ABSTRACT

A potentially operational system for 3-month total precipitation forecasts for island stations in the tropical Pacific has been developed at NOAA's Climate Prediction Center using the statistical method of canonical correlation analysis (CCA). Routine issuance of the forecasts could begin during 1996; presently they are issued experimentally. The levels and sources of predictive skills have been estimated at lead times of up to one year, using a cross-validation design. The predictor fields, in order of their predictive value, are quasi-global sea surface temperature, Northern Hemisphere 700-mb height, and prior values of the predictand precipitation itself. Four consecutive 3-month predictor periods are used to detect evolving as well as steady-state conditions.

Modest forecast skills are realized for most seasons of the year; however, moderate skills (correlation > 0.5) are found for certain stations in the northern Tropics at lead times of 3 months or less in late northern winter, especially in the western Pacific. CCA generally outperforms persistence, even at short leads. The El Niño–Southern Oscillation (ENSO) phenomenon is found to play the dominant role in the precipitation variability at many tropical Pacific islands. During especially the late northern winter of mature warm (cold) episodes, precipitation is suppressed (enhanced) in a horseshoe-shaped region surrounding (to the north, west, south) the central and eastern equatorial zone, which is anomalously wet (dry).

A secondary source of predictive skill, most important for northern summer, is a pattern with like-signed SST anomalies over the Tropics of all three ocean basins. While this pattern may encompass ENSO episodes, it varies at lower frequencies than the ENSO phenomenon on its own.

1. Introduction

The potential utility of forecasts of seasonal precipitation anomalies on many of the populated tropical Pacific islands is clear, given their agricultural and otherwise water-dependent economies. Past observational studies (e.g., Ropelewski and Halpert 1987, 1996) have indicated a strong response in the tropical Pacific to the El Niño–Southern Oscillation (ENSO) phenomenon. This is reasonable in view of the close proximity of the ENSO-related SST anomalies and, more broadly, all aspects of the Walker circulation (Walker and Bliss 1932) that are influenced by ENSO episodes. The need for useful forecasts, coupled with an ability to forecast ENSO episodes with modest but usable skill (Barnston et al. 1994), make this region a logical target for routine operational forecasts. This study provides a base for such forecasting at the Climate Prediction Center (CPC), National Centers for Environmental Prediction (NCEP), which could begin operationally during 1996.

Because of the strength and reliability of ENSO-related precipitation responses in tropical regions, either dynamical or empirical forecast approaches would be expected to have success out to the first three to five months of lead, due to their moderate ability to forecast the ENSO itself (Barnston et al. 1994). Using a dynamical approach, for example, success has been demonstrated in Graham (1994) for northeast Brazil using SST persisted from initialization time. Using an empirical approach, many portions of the Tropics are relatively well forecast using canonical correlation analysis (CCA) (Barnston and Smith 1996). Because dynamical and empirical approaches deliver approximately the same skill levels at our present state of knowledge, we opt to use an empirical approach here for practical reasons. We choose CCA, both because of its skill capability and its extensive set of diagnostics that offer some insight into the physical bases of the relationships used to form the predictions.

CCA is a multivariate linear statistical model that defines predictive relationships between evolving large-scale patterns in the Northern Hemisphere (NH) 700-mb circulation and near-global sea surface temperature (SST) fields (predictors), and subsequent patterns in the seasonal mean tropical Pacific precipitation. The precipitation anomalies occurring during the predictor periods is used as still another source of infor-

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American Meteorological Society

Skill of Canonical Correlation Analysis Forecasts of 3-Month Mean Surface Climate in Hawaii and Alaska

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Climate Prediction Center, National Centers for Environmental Prediction, NWS/NOAA, Washington, D.C.

(Manuscript received 21 June 1995, in final form 8 April 1996)

ABSTRACT

Statistical short-term climate predictive skills and their sources for 3-month mean local surface climate (temperature and precipitation) in Hawaii and Alaska have been explored at lead times of up to one year using a canonical correlation analysis (CCA). Four consecutive 3-month predictor periods are followed by a variable lead time and then a single 3-month predictand period. Predictor fields are quasi-global sea surface temperature, Northern Hemisphere 700-mb height, and prior values of the predictand field itself. Forecast skill is estimated using cross-validation.

Short-term global climate fluctuations such as the El Niño–Southern Oscillation (ENSO) phenomenon are found to play an important role in the climate variability in Hawaii and the southern half of Alaska. During the late winter and spring of mature warm (cold) ENSO events, Hawaii tends to be anomalously warm and dry (wet and cool), while southern Alaska tends to be warm (cold). Hawaii's responses occur more strongly the year after a mature ENSO event rather than the year of the event, even if the opposite phase of ENSO has already begun. Persistence is the best seasonal temperature prediction for Hawaii at short leads. Winter and spring temperature (precipitation) can be predicted up to one year (a few months) in advance with modest but usable skill for Hawaii, where temperature forecasts are generally more skillful. Southern Alaska has temperature prediction possibilities up to 7–10 months in advance. While Alaskan seasonal precipitation prediction is poor on the large spatial scale, forecasts on terrain-dependent local scales may be more fruitful using methods other than CCA.

1. Introduction

The demand for prediction of Hawaiian and Alaskan surface climate has risen in the last decade. This study provides a base for the operational seasonal prediction for both states at the Climate Prediction Center (CPC), National Centers For Environmental Prediction (NCEP) in early 1995. Canonical correlation analysis (CCA), a multivariate linear statistical model, is used to describe predictive relationships between evolving large-scale patterns in the Northern Hemisphere (NH) 700-mb circulation and near-global sea surface temperature (SST) fields (predictors) and subsequent patterns in the Hawaiian and Alaskan seasonal mean surface temperature and precipitation. A variable lead time is placed between a series of four consecutive 3-month predictor periods and a single 3-month predictand period. Objective evaluation of the sources and the strength of such predictive relationships is our primary motivation.

a. Hawaii

Fluctuations of Hawaiian surface climate have received much attention because of their impact on agriculture, tourism, construction, and certain local industries. Drought has been a recurrent and troublesome problem for the state, often resulting in low crop yield and the need for strict water rationing. Seasonal prediction of rainfall has been recognized as an important element for strategic water resources planning and management for the Hawaiian decision maker (Chu and He 1994).

Several investigations have sought to identify relationships between Hawaiian rainfall and global short-term climatic phenomena—especially the El Niño–Southern Oscillation (ENSO). As early as 1932, Walker and Bliss found that rainfall in the Hawaiian Islands tended to be below (above) normal during the negative (positive) phase of the Southern Oscillation (SO). Meisner (1976), as well as Wright (1979), found a negative correlation between the SST in the central and/or equatorial eastern Pacific and winter rainfall in Hawaii. Lyons (1982) showed that most El Niño winters were dry in Hawaii. Chu (1989) claimed that while the Southern Oscillation index (SOI) in spring is not significantly correlated with rainfall in the following seasons, the summer and autumn SOI is positively correlated with rainfall in the following winter or spring.

Horel and Wallace (1981) proposed a model relating dryness in the Hawaiian Islands with tropical Pacific SST. They assumed that during a northern winter characterized by a warm SST in the central and eastern

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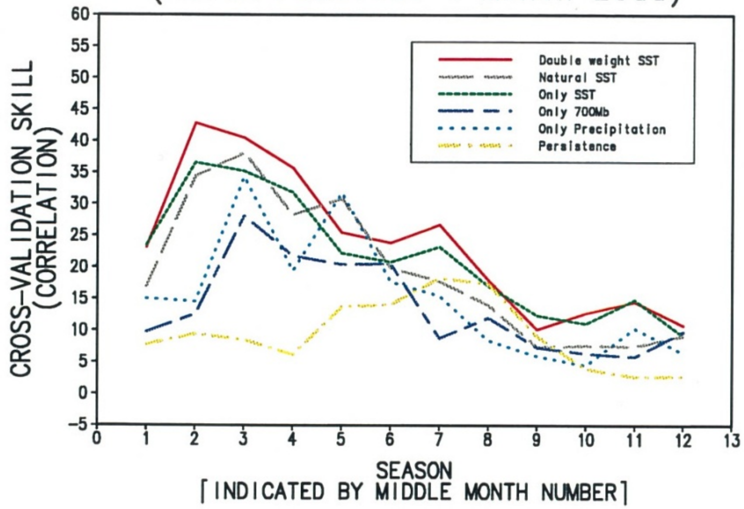
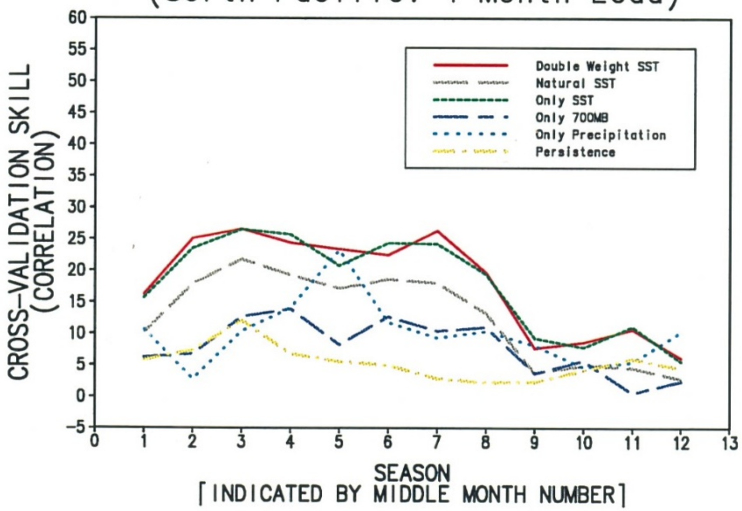
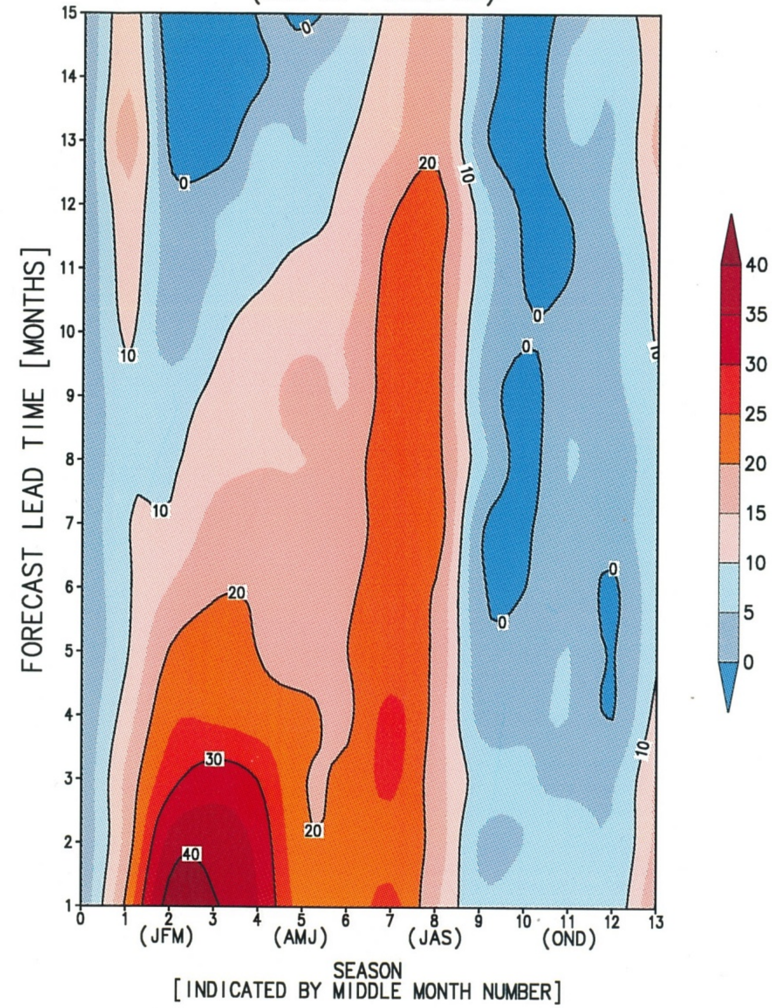
CCA CV ACC – PRECIPITATION
(North Pacific: 1 Month Lead)



(Sorth Pacific: 1 Month Lead)



CCA CV ACC – PRECIPITATION
(North Pacific)



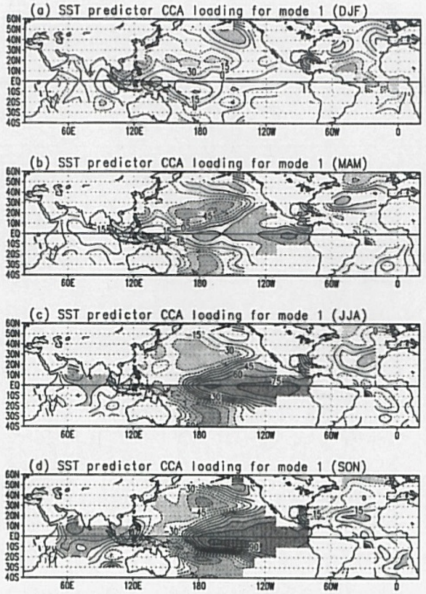


Fig. 5. SST predictor CCA loadings for mode 1 for prediction of Jan-Feb-Mar tropical Pacific precipitation at 1-month lead. Panels (a), (b), (c), and (d) show loadings for the first (Dec-Jan-Feb), second (Mar-Apr-May), third (Jun-Jul-Aug), and fourth (Sep-Oct-Nov) predictor periods, respectively. Units are relative.

with one element per year, are called the predictor and predictand canonical components.

d. Lead times

The lead time, or amount of time ''skipped'' between the end of the latest predictor season and the beginning of the predictand season, is varied from 1 to 13 months by 1-month increments. A forecast whose target period begins at the time of the forecast is defined as having a zero lead. The lead time structure used here is illustrated in Fig. 3 of Barnston (1994).

e. Verification

Overfitting of random variability in the relatively short total period of record (40 years) can create artificial skill. To control for overfitting, cross validation (Michaelsen 1987) is used in evaluating forecast skill. Each of the 39 years from 1956 to 1994 is held out in turn, and CCA is used to develop a prediction model using the remaining 38 years. (Note that there are only 39 years to use for hindcasting, because the sequence of predictors uses up the prior year, making 1955 unavailable as a predictand year.) The withdrawn year plays no part in any of the preparatory (e.g., pre-EOF) steps or the CCA. The predictor data for the withheld year are then projected onto the predictor CCA loading patterns, and predictand values are generated and verified against observed data for the withheld year. The observed data are expressed in terms of the climatology formed without the withheld year—that is, the climatology is redefined each time a new year is held out as the forecast target. A temporal correlation between the forecasts and the observations is used as the verification measure, leading to an estimation of the percentage of variance explained by the CCA forecasts.

Recent research has indicated that while cross validation has been regarded as a major step in controlling for artificial skill, it may underestimate true skill when skill is low (Barnston and Van den Dool 1993), and also may overestimate skill in certain circumstances, such as when using multiple regression or especially screening regression (Unger 1996). Thus, we emphasize that the skills reported here are our best *estimates* of what to expect for forecasts on truly independent (future) cases. In a recent comparison between cross-validated skill and simulated real time skill in which only forward-looking forecasts were allowed (Barnston et al. 1994), CCA appeared to produce unbiased skill estimates using cross validation.

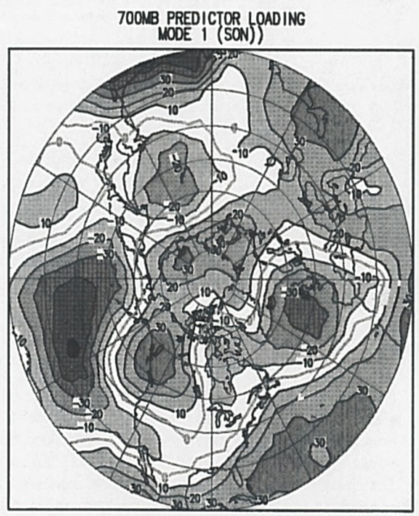


Fig. 6. As in Fig. 5 except for 700-mb predictor loadings for mode 1 for the fourth predictor period (Sep-Oct-Nov) for forecasts of Jan-Feb-Mar tropical Pacific precipitation.

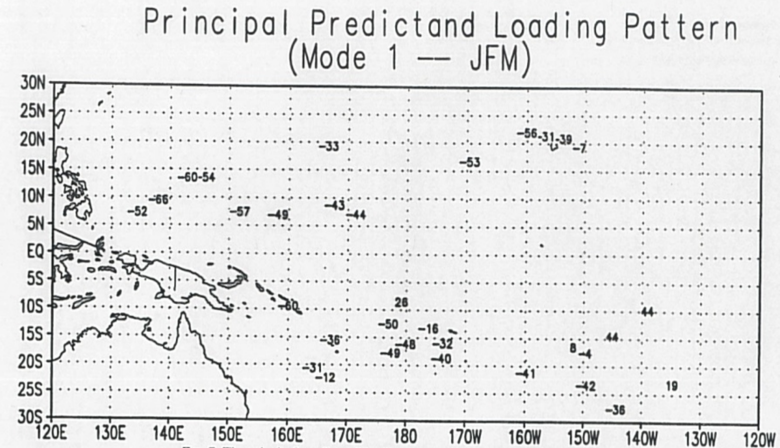


Fig. 7. The principal predictand loading pattern for mode 1 for the prediction of Jan-Feb-Mar tropical Pacific precipitation at 1-month lead.

Persistence forecasts are used as a competitor for the CCA forecasts. These persist the predictand values during the fourth predictor period. The persistence forecasts are cross validated to put them on an equal design footing with the CCA forecasts. To cross validate persistence forecasts, they are damped in accordance with the autocorrelation (i.e., correlation skill of persistence) based on all years except for the forecast target year. This implies a slightly different damping for each year that is held out. Because the correlation is used as the verification measure for the final set of all years' damped persistence forecasts, the variable damping used in cross-validating slightly decreases the persistence verification scores as compared with uniform damping (or, equivalently, an absence of damping). This use of a regression-like design for the persistence forecasts mimics that of the CCA.

4. Results

The seasonal march of CCA correlation skill for the 33 tropical Pacific stations is shown in Fig. 2 for 1-, 4-,

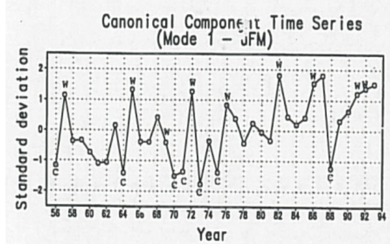


Fig. 8. The canonical component predictor time series for mode 1 for the prediction of Jan-Feb-Mar tropical Pacific precipitation. Symbols along the curve denote warm and cold ENSO events, defined by the year prior to the late northern winter being forecast.

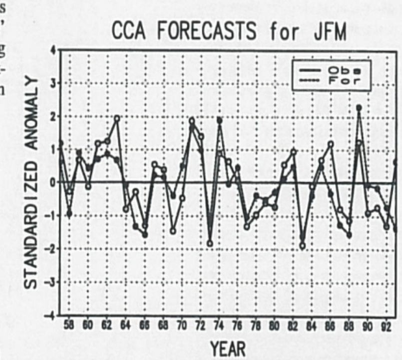


Fig. 9. Yearly time series of forecasts and observations for Yap Island in the northwestern tropical Pacific (9°N, 138°E) Jan-Feb-Mar standardized precipitation anomaly. Forecasts made at 1-month lead (i.e., at end of November; dashed line) and observations (solid line) are shown; correlation is 0.73. Forecasts are inflated to make their variance equal to that of the observations.

January 1996, Seasonal rainfall forecast for US-Affiliated Pacifc islands are published quarterly in Experimental Long-Lead Forecast Bulletin;

EXPERIMENTAL LONG-LEAD

FORECAST BULLETIN

SEPTEMBER 1997

Vol. 6, No. 3

National Weather Service

National Centers for Environmental Prediction

CLIMATE PREDICTION CENTER

Precipitation Forecasts for the Tropical Pacific Islands Using Canonical Correlation Analysis (CCA)

contributed by Yuxiang He and Anthony Barnston

Climate Prediction Center, NOAA, Camp Springs, Maryland

Canonical correlation analysis (CCA), identifies linear relationships between multicomponent predictors and multicomponent predictands. In practice, these are often pattern-to-pattern relationships in space and/or time. Like simpler forms of linear regression, CCA minimizes squared errors in hindcasting the predictands from the predictors.

During the last decade, CCA has begun being used increasingly in the atmospheric sciences (e.g. Barnett and Preisendorfer 1987; Graham et al. 1987a, 1987b; Barnston and Ropelewski 1992; Barnston 1994, Barnston and He 1996).

Here, CCA is used to predict 3-month precipitation anomalies in the Pacific Islands out to a year in advance, as described in He and Barnston (1996). Because rainfall in the tropical and subtropical Pacific is strongly related to ENSO (Ropelewski and Halpert 1987, 1996), it is reasonable to expect usable skill in seasonal Pacific rainfall forecasts, and thus worthwhile to establish a real-time prediction system for the benefit of agricultural and commercial interests in the Pacific Islands. The experimental forecasts shown in this quarterly Bulletin are provided a monthly basis on the Internet at address: **http://nic.fb4.noaa.gov:80 /products/predic-tions/experimental/pacific**.

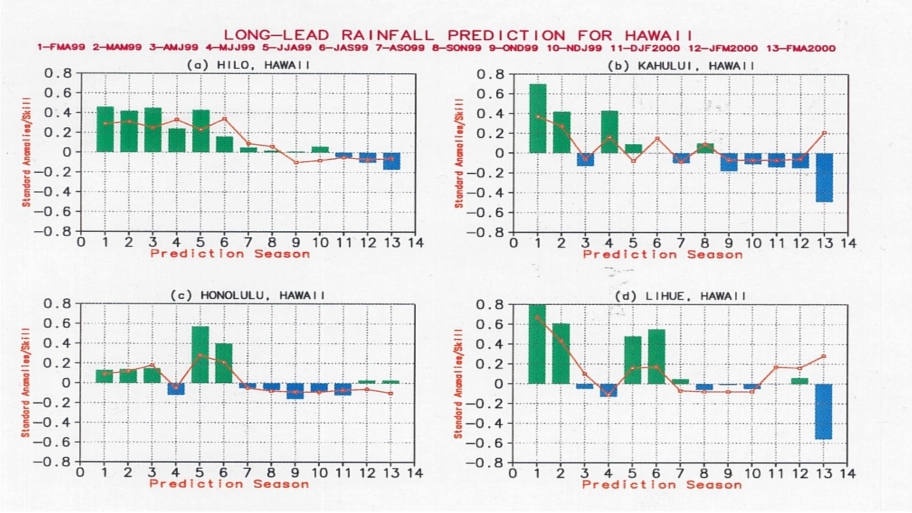
The predictor fields used for the forecasts include quasi-global sea surface temperature (SST), Northern Hemisphere 700 mb geopotential height, and the predictand precipitation itself (33 island stations) at an earlier time. CCA sensitivity experiments indicate that the SST field is the most valuable predictor field, with 700 mb heights and prior precipitation somewhat helpful. Further details about the skills, the underlying relationships, and the predictors are provided in He and Barnston (1996). The set of predictors is configured as four consecutive 3-month periods prior to the time of the forecast, followed by a variable lead time, and then a single 3-month predictand period. The predictand includes 3-month total rainfall at 33 Pacific Island stations within 25ºN-30ºS, including 4 Hawaiian stations (Fig. 1). The lead time is defined as the time between the end of the final (fourth) predictor period (i.e., the time of the forecast) and the *beginning* of the 3-month predictand period.

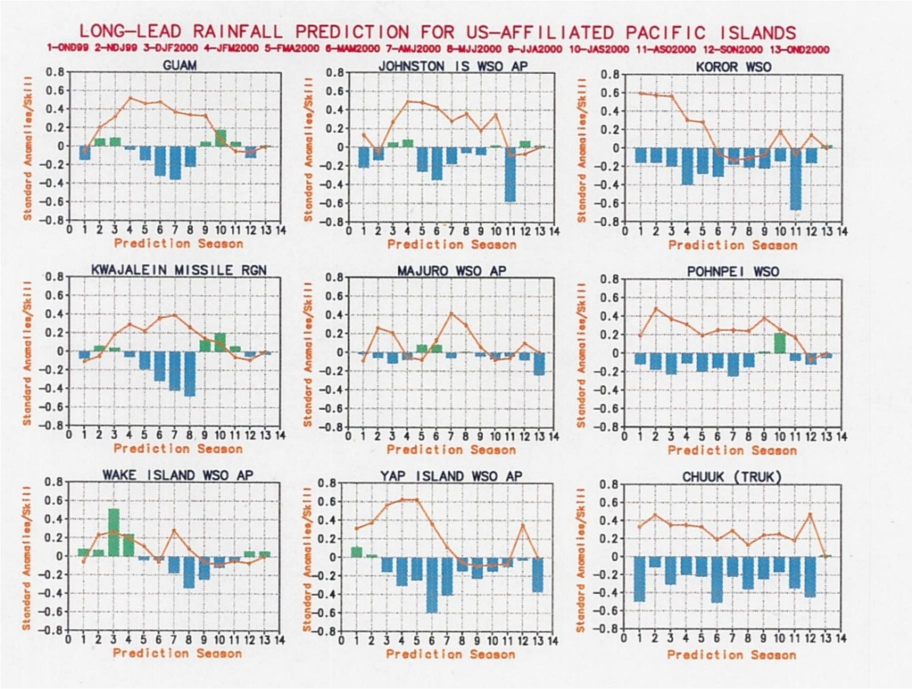
The expected skill of the forecasts was estimated using 1-year-out cross-validation (see He and Barnston 1996). These skill estimates indicated that at 1 month lead time the highest correlation skill across the Pacific Islands occurs in Jan-Feb-Mar at 0.44 (0.29) averaged over all stations north (south) of the equator, and the lowest occurs from September through December at about 0.15 (0.30) for stations north (south) of the equator. At four months lead, skills are only slightly lower except for the Jan-Feb-Mar average skill north of the equator which drops significantly to 0.26.

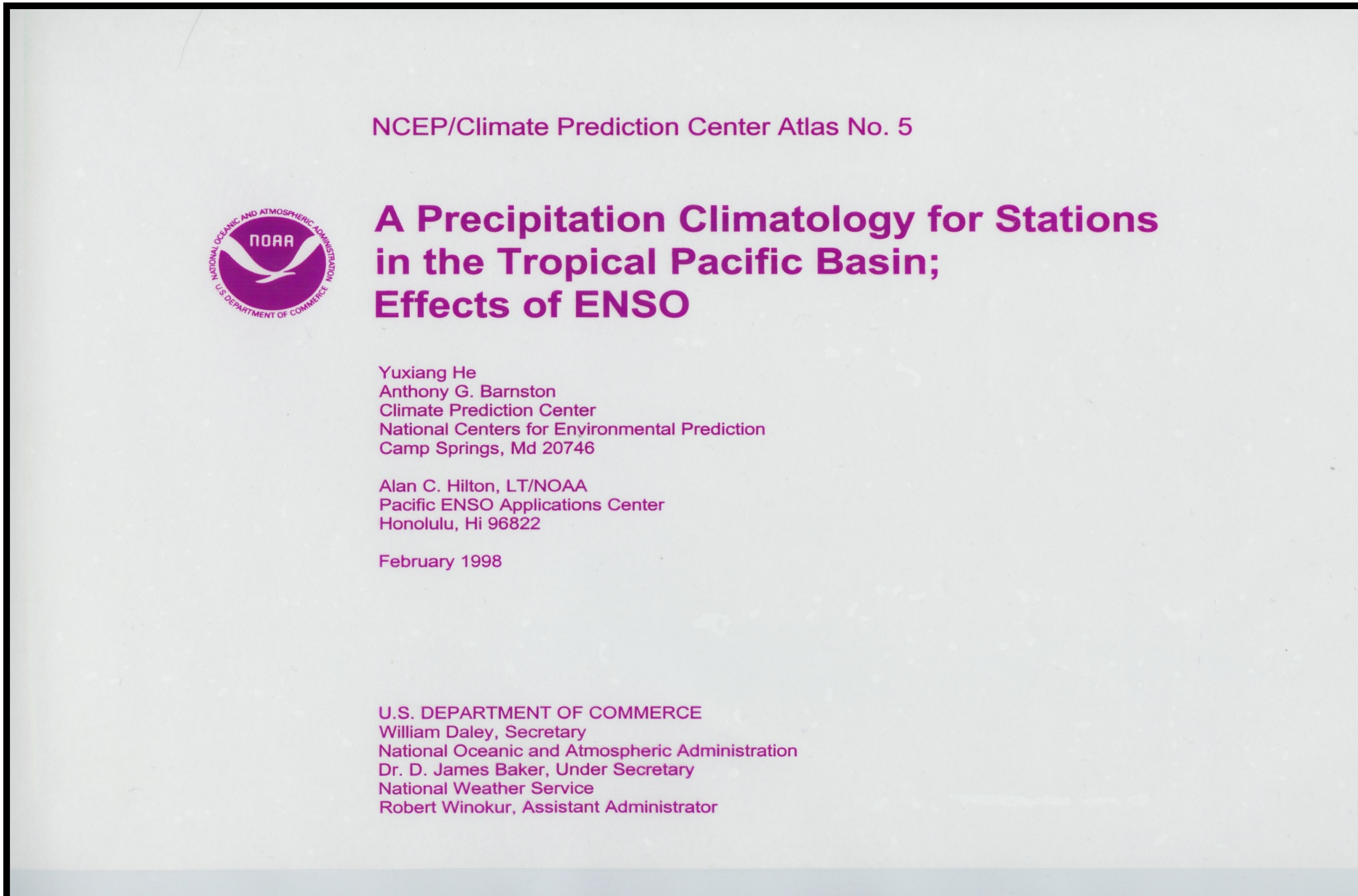
Figure 2 shows forecasts of the standardized precipitation anomaly (X100) for 33 Pacific Island stations using data through August 1997. The top panel shows the forecast for Oct-Nov-Dec 1997 (1 month lead), the middle panel for Jan-Feb-Mar 1998 (4 months lead), and the bottom for Apr-May-Jun (7 months lead). The expected skill for these forecasts, based on cross-validation, is shown by the size of the numerals (as opposed to their value, which is the forecast itself): Small numerals indicate low skill (correlation below 0.3), medium sized numerals usable but modest skill (correlation between 0.3 and 0.45), and large numerals moderate or better skill (0.45 and higher). Dryness at off-equator locations, and enhanced rainfall at the stations closest to the equator near and east of the date line, is being forecast; this is especially clear in the Jan-Feb-Mar 1998 forecast. This pattern is associated with the El Niño conditions that developed in spring 1997, which the CCA implicitly expects to continue at high strength through early 1998. Skill is mainly modest, but is moderately high at some of the stations whose influences from ENSO is strongest. Skills would be higher if most years were either warm or cold ENSO years; the presence of many neutral years enables rainfall variations of random or unknown cause to lower the overall correlation skill. If much of the existent skill comes from ENSO (which appears likely), and if we are quite sure there will be a warm ENSO event in winter 1997-98, then our confidence in the qualitative pattern shown in this forecast should be higher than that reflected in skills based on all years.

More detailed forecasts for 9 U.S.-affiliated and 18 non-U.S.-affiliated Pacific Island stations are shown in Fig. 3. In Fig. 3, long-lead rainfall forecasts from 1 to 13 seasons lead are shown (solid bars), along with their expected skills (lines). The horizontal axis reflects the lead time, whose corresponding actual target period for this forecast is indicated in the legend along the top of the figure (e.g. 1=Oct-Nov-Dec 1997). The same ordinate scale is used for both forecasts and skills (standardized anomaly and correlation, respectively). Sometimes skill may increase as the lead is increased because a more forecastable target season has been reached. The forecasts and their skills differ not only due to general location differences the Pacific basin, but also differences in orientation with respect to the local orography (if any).

Dry conditions are forecast at many of the U.S. affiliated stations for boreal winter 1997-98 through spring 1998, due to the strong El Niño that is expected to dominate the climate. Among stations shown here, dryness is especially marked at Johnston, Guam, Koror and Yap. Skill tends to peak during winter or spring at these locations. **South of the equator at**


LONG-LEAD RAINFALL PREDICTION FOR HAWAII
1-FMA99 2-MAM99 3-AMJ99 4-MJJ99 5-JJA99 6-JAS99 7-ASO99 8-SON99 9-OND99 10-NDJ99 11-DJF2000 12-JFM2000 13-FMA2000
(a) HILO, HAWAII
(b) KAHULUI, HAWAII
(c) HONOLULU, HAWAII
(d) LIHUE, HAWAII
Standard Anomalies/Skill
Prediction Season


LONG-LEAD RAINFALL PREDICTION FOR US-AFFILIATED PACIFIC ISLANDS
1-OND99 2-NDJ99 3-DJF2000 4-JFM2000 5-FMA2000 6-MAM2000 7-AMJ2000 8-MJJ2000 9-JJA2000 10-JAS2000 11-ASO2000 12-SON2000 13-OND2000
GUAM
JOHNSTON IS WSO AP
KOROR WSO
KWAJALEIN MISSILE RGN
MAJURO WSO AP
POHNPEI WSO
WAKE ISLAND WSO AP
YAP ISLAND WSO AP
CHUUK (TRUK)
Standard Anomalies/Skill
Prediction Season



NCEP/Climate Prediction Center Atlas No. 5

A Precipitation Climatology for Stations in the Tropical Pacific Basin; Effects of ENSO

Yuxiang He
Anthony G. Barnston
Climate Prediction Center
National Centers for Environmental Prediction
Camp Springs, Md 20746

Alan C. Hilton, LT/NOAA
Pacific ENSO Applications Center
Honolulu, Hi 96822

February 1998

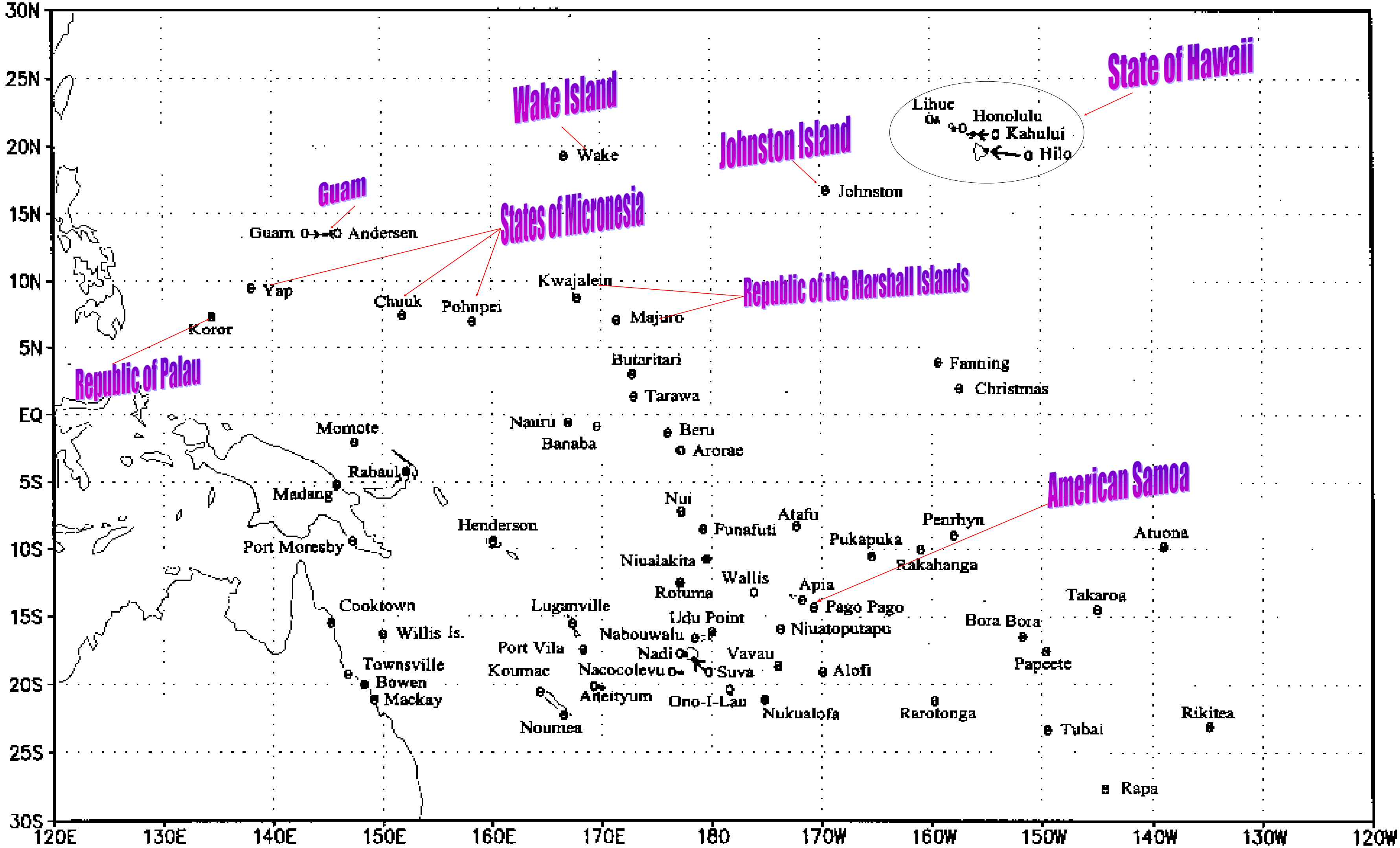
U.S. DEPARTMENT OF COMMERCE
William Daley, Secretary
National Oceanic and Atmospheric Administration
Dr. D. James Baker, Under Secretary
National Weather Service
Robert Winokur, Assistant Administrator

In 1998, A comprehensive Pacific Rainfall Atlas was published through the cooperative work among CPC, PEAC, and other tropical Pacific islands.

Motivation

- To give users a good picture about the drought intensity and frequency, seasonal/interannual/decadal rainfall variability, effect of ENSO for the Pacific region.
- To establish a solid background and have a good reference for the long-lead rainfall forecast for Pacific islands.
- 2003, NOAA administrator Admiral Lautenbacher to meet Hawaii Governor Lingle

RAINFALL STATIONS FOR PACIFIC ISLANDS



1955, 66 stations, running 3-month total，both USAPI & Non-USAPI

Phone : 22-401
AFTN : NFTNYMYX
Telex : 66269 PRIMO TS
FAX : 24145
24145

Ministry of Civil Aviation
TONGA METEOROLOGICAL SERVICE
P. O. Box 345
Queen Salote Road
Nuku'alofa
TONGA.

FACSIMILE MESSAGE

TO: Mr Tony Barnston
Climate Prediction Center, NOAA/NCEP
NOAA NWS W/NP51 Room 604
Washington, DC 20232-9910

FROM: Paea Havea

FAX: 301 763 83 95

No. of pages incl. this page: 2

DATE: 25 August 1997

SUBJECT: Station Nuku'alofa Rainfall (mm) 1946/96:

91792 (ɑ) -21.1 -175.20

Dear Tony

Thank you for your fax of 21st this month, concerning the above.

I sent you a fax together with Nuku'alofa rainfall on 16th July, since you were asking for it while we were in Apia, but it was sent to Room 806. However, this will be faxed and airmailed to you in order to make sure this will arrive the right place this time.

I sent Nuku'alofa Rainfall to Mr Bill Clements who just sent me a reply saying it's a most interesting data. He was attending at the Climate Change and Sea Level Rise Meeting in Noumea, NC. Also to Mr Alan Hilton of NOAA in Honolulu, but no reply yet.

There is no need for you to worry if these figures are not readable for this will be airmailed to your address in your fax.

Well Tony, I think that's all I have to say at this moment. It is vitally important and most delightful to have many good friends on earth. Best wishes to you and your dear family.

Yours sincerely

P Havea
Chief Met Officer
for Secretary for Civil Aviation & Met Service.

16/09 '97 11:31 ☎678 22310 METEO OFFICE ☎001

fax + 301-763-8395

REPUBLIC OF VANUATU *formerly New Hebrides*

VANUATU METEOROLOGICAL SERVICE
Private Mail Bag 54, Port Vila

VMS

Telephone : (678) 22331, 22932, 23866
Fax : (678) 22310

(Address Correspondence to Director)

(already have Luganville)
16/09/97

To: Mr. Tony Barnston
Climate Prediction Centre
NOAA NWS W/NP51 Room 604
Washington, DC 20233 - 9910
U.S.A

3 stations:
Port Vila (1 mo. msng)
Aneityum (2 mo. msng)
Port Patteson (5 mo msng)

From: Vanuatu National Meteo Services

Dear Sir,

Re - Monthly Rainfall Records for Vanuatu

Please to send you another four (4) stations of monthly rainfall records of Vanuatu namely :
i) Port Vila
ii) Aneityum
iii) Isangel
iv). Port Patterson

Hope this will give us a better rainfall predication which is in line with El Nino situation

Yours faithfully

M Nalawas

Mercy Nalawas

'97 11:31 ☎678 22310 METEO OFFICE

VANUATU METEOROLOGICAL SERVICE

first 3 yrs '55,'56,'57 msng

Monthly Rainfall (in millimetres)
Island: TANNA
Station: ISANGEL

[Jan 1959 - Aug 1972]
19°33'S 169°16'E
97 metres above msl

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
1958							65.0	31.0	68.0	75.0	23.0	11.0	
1959	367.3	226.3	110.0	93.2	54.4	99.6	40.9	115.8	24.9	185.7	125.0	368.6	1811.7
1960	283.5	120.1	615.2	157.2	290.5	67.4	32.3	115.3	33.3	45.4	13.7	35.8	1928.0
1961	353.6	143.0	303.5	124.5	212.6	90.9	74.9	231.4	46.2	93.7	90.4	123.7	1668.4
1962	339.9	238.0	369.3	98.3	131.5	65.3	148.1	73.9	10.4	116.4	106.7	178.3	1860.1
1963	332.0	177.3	324.1	324.6	209.0	157.0	215.6	133.9	38.4	51.8	111.3	10.2	2085.2
1964	26.2	179.6	216.7	332.0	29.5	80.0	14.7	190.2	84.1	62.7	89.1	74.4	1361.2
1965	163.6	256.1	224.8	64.5	95.3	60.8	65.0	103.1	77.7	24.1	53.3	104.4	1314.9
1966	254.0	303.8	86.9	63.5	84.8	35.9	46.0	16.8	2.5	37.5	72.1	295.9	1303.1
1967	160.3	282.4	339.9	181.0	74.4	94.5	43.7	112.5	85.1	88.4	30.0	163.3	1635.8
1968	111.5	289.5	190.2	52.1	111.0	156.6	132.8	23.9	17.5	25.7	14.7	135.4	1270.6
1969	87.1	286.0	174.0	38.1	154.9	22.1	64.8	69.9	78.7	21.1	185.9	35.3	1237.9
1970	99.3	359.2	155.7	166.4	101.9	125.2	44.5	55.9	70.6	72.4	61.7	97.0	1409.8
1971	267.5	325.9	724.7	163.6	45.3	128.4	136.1	25.4	52.5	62.5	99.1	160.3	2191.8
1972	141.0	260.9	214.4	188.7	82.0	331.0	28.7	27.4	*?*	*relocation?*			
1972									151.6	46.0	15.0	73.9	716.2
1973	62.2	68.2	143.5	32.4	111.4	62.3	361.1	196.8	48.4	19.1	180.3	123.8	1411.5
1974	261.6	311.5	93.6	35.6	332.5	146.4	35.5	13.8	52.1	400.2	105.2	91.0	1909.0
1975	146.3	118.3	228.6	372.4	191.7	74.7	24.0	122.1	48.3	168.5	139.6	279.7	1916.2
1976	379.5	138.4	216.5	206.9	20.9	67.3	58.6	155.6	110.1	82.7	41.8	7.5	1485.5
1977	346.6	173.2	188.0	110.3	29.6	55.9	16.2	187.4	60.9	5.4	53.9	47.9	1275.3
1978	119.1	25.8	150.2	54.9	144.5	74.3	63.8	91.1	24.9	35.2	85.3	110.7	979.8
1979	510.6	165.5	143.7	78.0	97.5	102.7	36.9	1.8	48.2	34.1	0.7	18.7	1208.4
1980	257.8	426.3	195.1	162.4	39.5	138.0	87.3	31.1	75.9	44.3	15.5	46.6	1519.8
1981	169.6	265.0	242.2	25.0	86.6	59.7	12.4	42.7	21.2	65.8	30.2	229.6	1250.2
1982	174.3	156.3	167.9	48.3	18.9	142.6		35.7		2.4	41.1	37.9	896.4
1983	44.9	284.6	285.0	17.1	8.9	21.6	5.3	18.2	0.5	30.4	88.3	65.6	871.4
1984	94.1	158.4	55.5	37.8	98.6	100.9	26.6	12.8	16.7	19.5	78.5	54.7	752.3
1985	189.4	63.4	122.8	120.2	153.6	156.5	51.3	9.4	110.7	37.5	342.4	56.3	1415.5
1986	64.1	235.6	134.7	68.2	52.1	24.5	5.3	54.8	21.3	0.6	23.4	91.0	795.6
1987	51.3	511.6	193.2	16.3	5.2	24.8	17.1	10.0	17.9	32.3	45.1	37.9	963.7
1988	373.1	181.1	276.4	145.9	90.6	120.1	55.0	67.6	4.4	91.0	207.6	220.6	1801.6
1989	154.7	604.4	227.5	122.8	180.1	40.4	58.1	83.0	129.7	34.1	92.0	96.1	1820.9
1990	161.2	240.4	140.3	51.7	5.2	26.5	2.1	60.3	28.1	38.2	68.4	82.7	905.1
1991	111.4	309.6	209.3	57.5	86.5	87.8	57.6	19.0	9.2	14.1	17.9	44.3	1026.0
1992	72.9	90.8	233.2	164.0	22.8	160.5	37.4	29.1	8.1	8.3	15.9	46.5	869.5
1993	60.1	49.9	111.5	106.6	115.2	25.0	59.8	36.8	8.7	18.9	0.6	11.1	606.6
1994	371.8	108.5	254.8	21.3	12.5	73.4	54.9	26.6	1.2	0.5	137.2	28.3	1101.2
1995	38.5	87.1	255.8	73.5	29.5	83.6	36.5	17.3	61.8	11.5	34.5	148.3	877.9
1996	251.1	85.6	502.5	67.3	40.5	77.1	140.5	19.2	66.6	92.0	52.8	118.2	1534.4
1997	50.3	106.3	86.1	102.4	68.6	53.7	59.1						

NCEP/Climate Prediction Center ATLAS No. 5

A Precipitation Climatology for Stations in the Tropical Basin; Effects of ENSO

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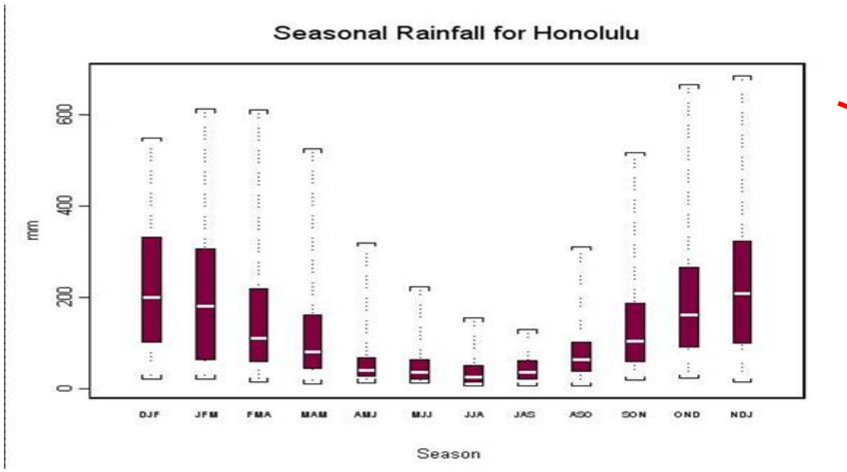
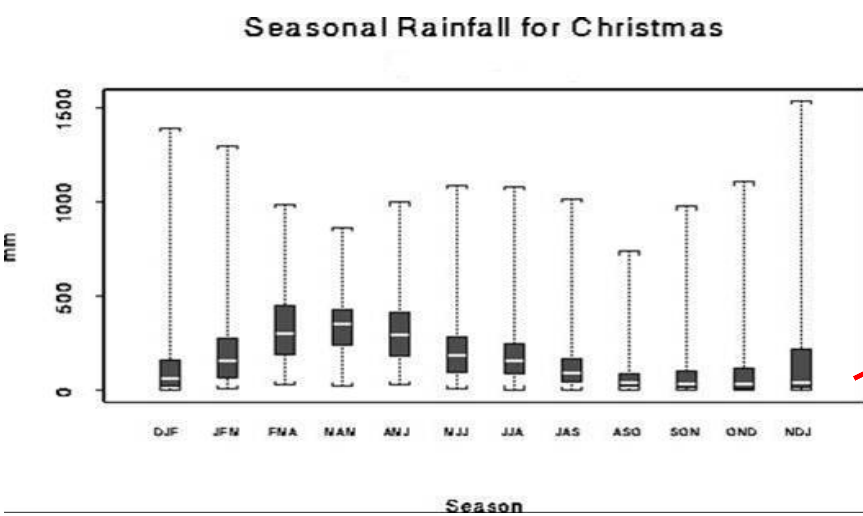
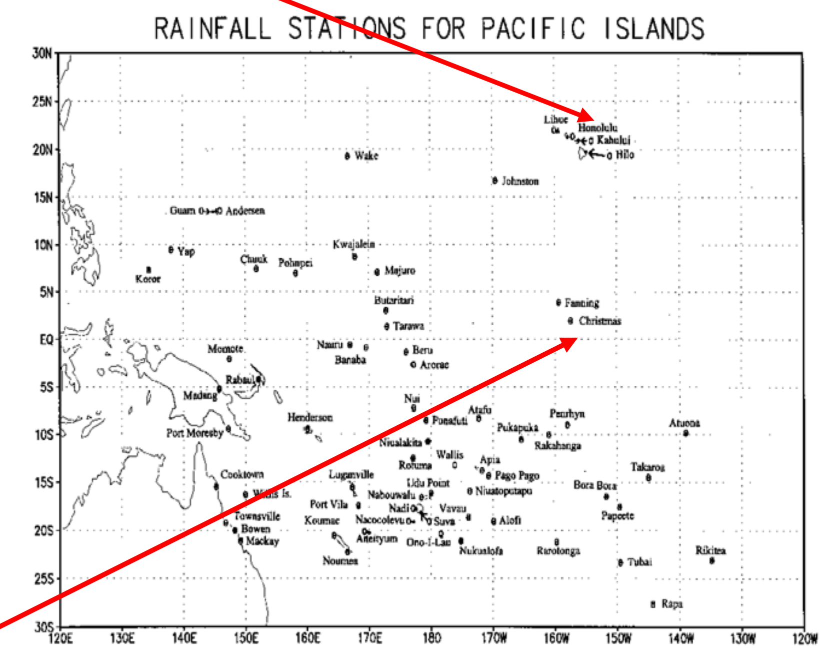
http://www.cpc.ncep.noaa.gov/pacdir/NINDEX22.shtml

Annual Rainfall Cycle

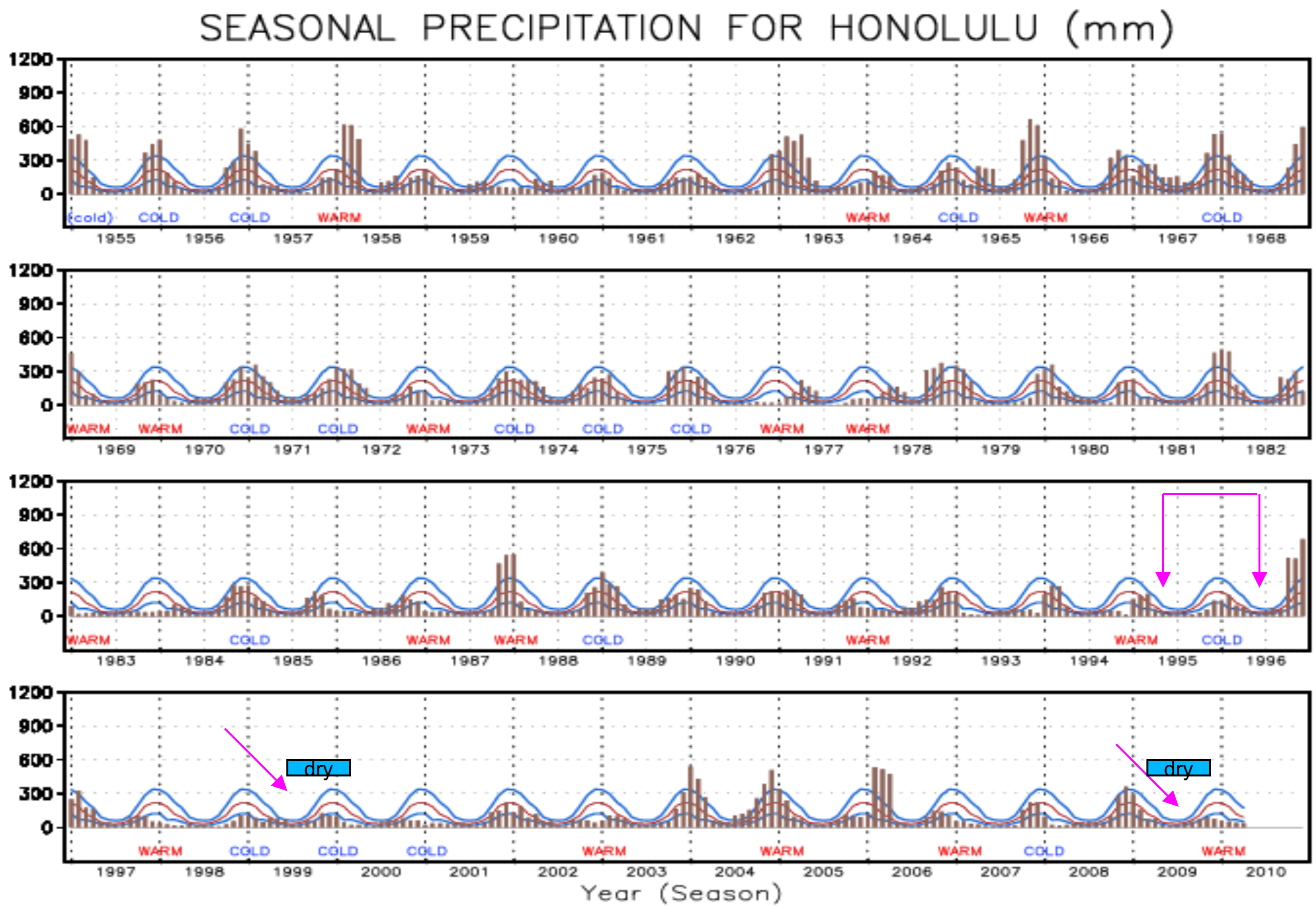






Box-and-whiskers plots (over 12 running 3 month periods): (a) Honolulu: relatively wet winters & dry summers; (b) Christmas island: surrounded by a somewhat cool ocean most of the year, receive fairly light climatological rainfall, but with very large positive deviations occurring during El Niño episodes.

Seasonal Rainfall Variation
Rainfall Anomaly Histograms



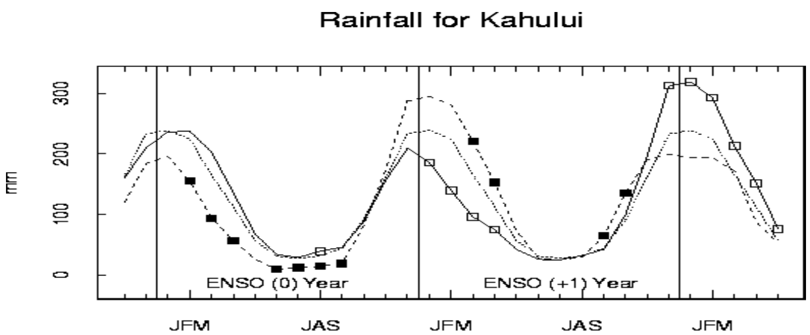
From March-Apr-May 1995 through May-Jun-Jul 1996 (spanning 15 running 3 month periods), the rainfall was at or below the median. (blue line -25% & 75%ile, brown line -50%ile)

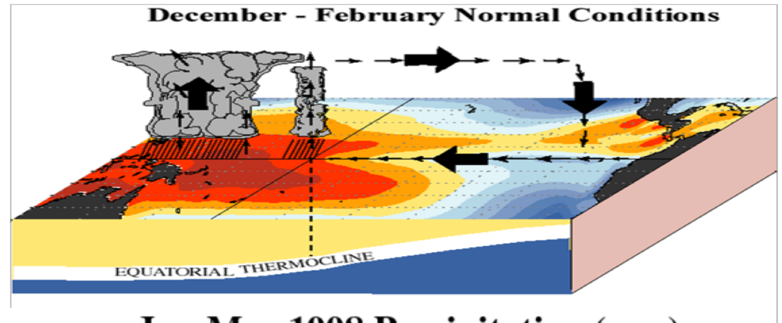
Frequencies of Rainfall Deficits of Given Intensity and Duration

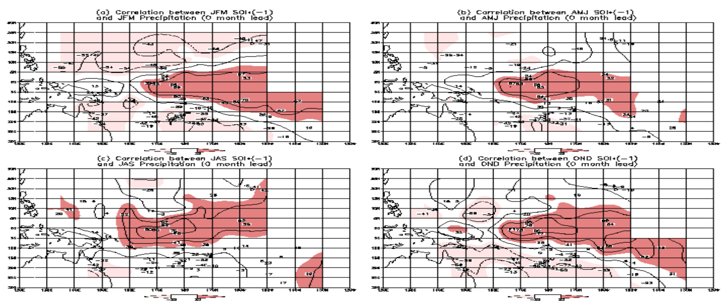
Honolulu
Percentile

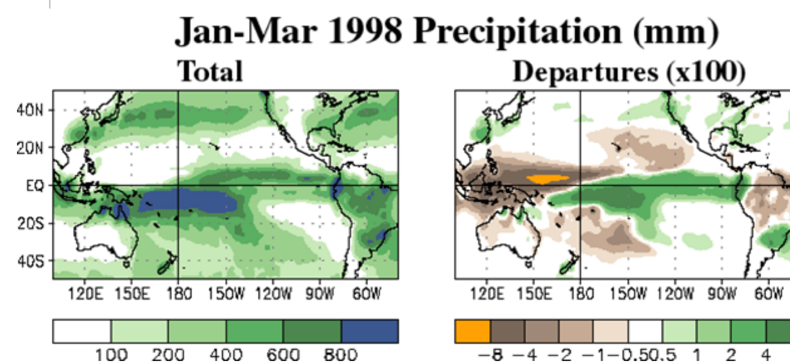
Number of Running Periods	10%	20%	30%	40%	50%
1	11	11	19	26	27
2	4	12	11	9	9
3	2	3	7	8	6
4	2	3	2	4	3
5	3	4	7	4	4
6	-	2	3	6	4
7	-	-	1	2	8
8	-	1	2	4	4
9	-	-	-	1	1
10	-	-	1	1	1
11	-	-	-	-	1
12	-	-	-	-	-
13	-	-	-	-	-
14	-	-	-	-	-
15	-	-	-	-	1

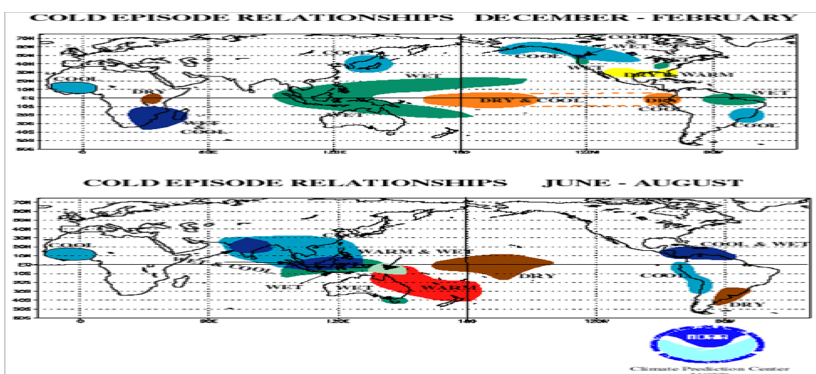
Effects of ENSO

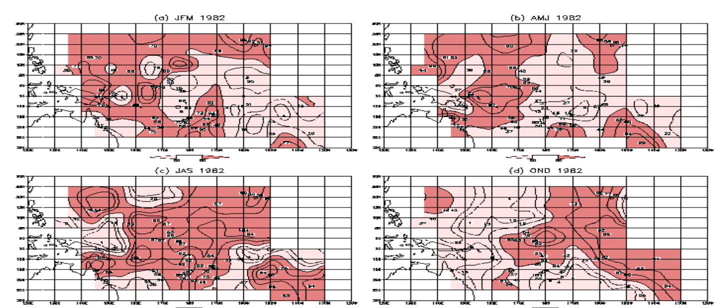






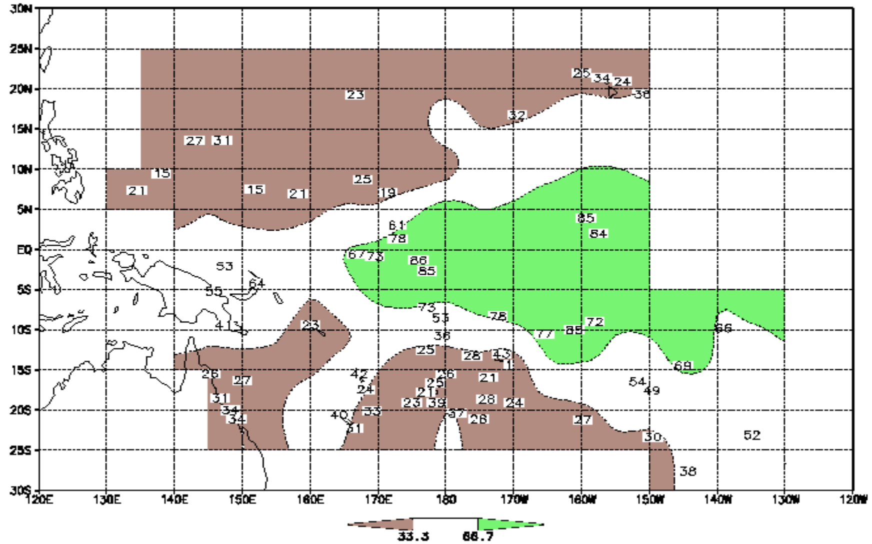


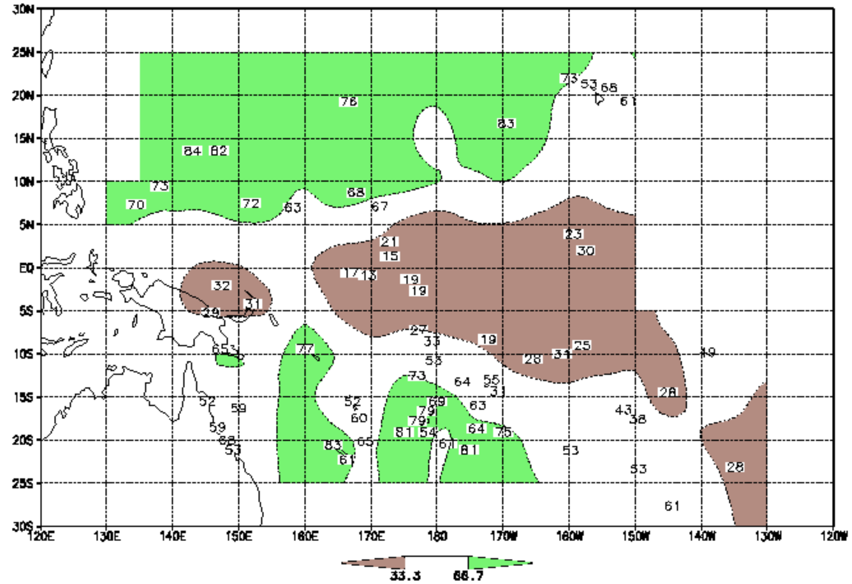




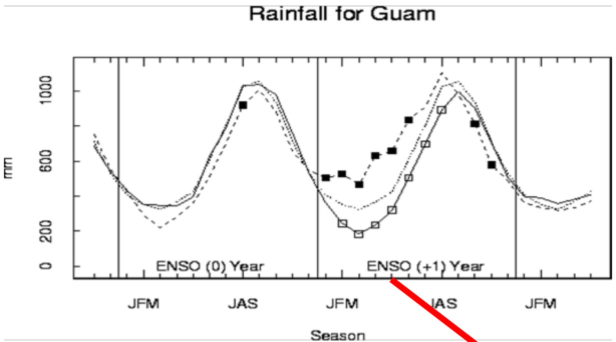
Short-term climate fluctuations, such as the ENSO phenomenon and its recurring warm and cold episodes, are found to play an important role in the climate variability over Hawaii and the tropical Pacific region.

El Nina and La Nina Composite Rainfall %iles
JFM

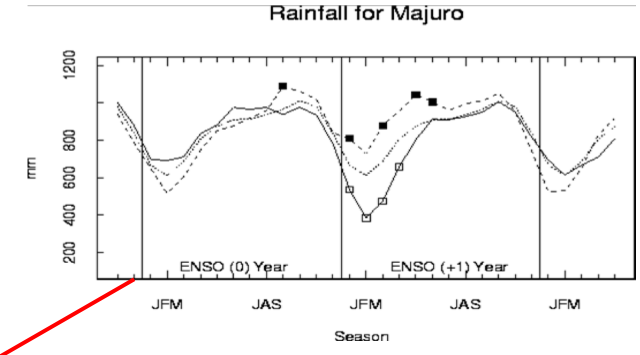




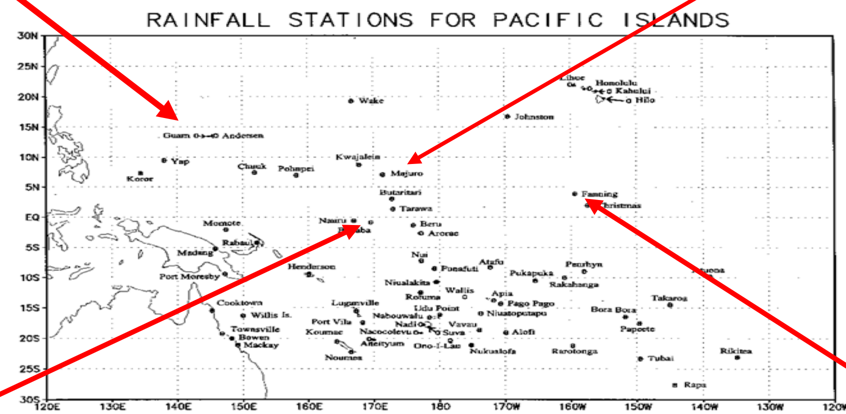
Effects of ENSO

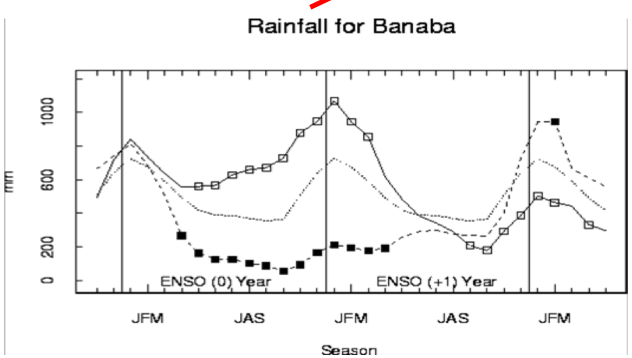


At the off-equator Stations (such as many of the U.S.-affiliated islands), warm ENSO is associated with below normal rainfall

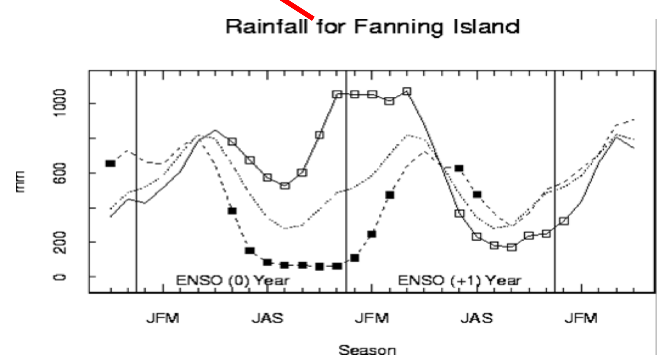


All of these effects tend to occur in reverse for cold ENSO episodes.

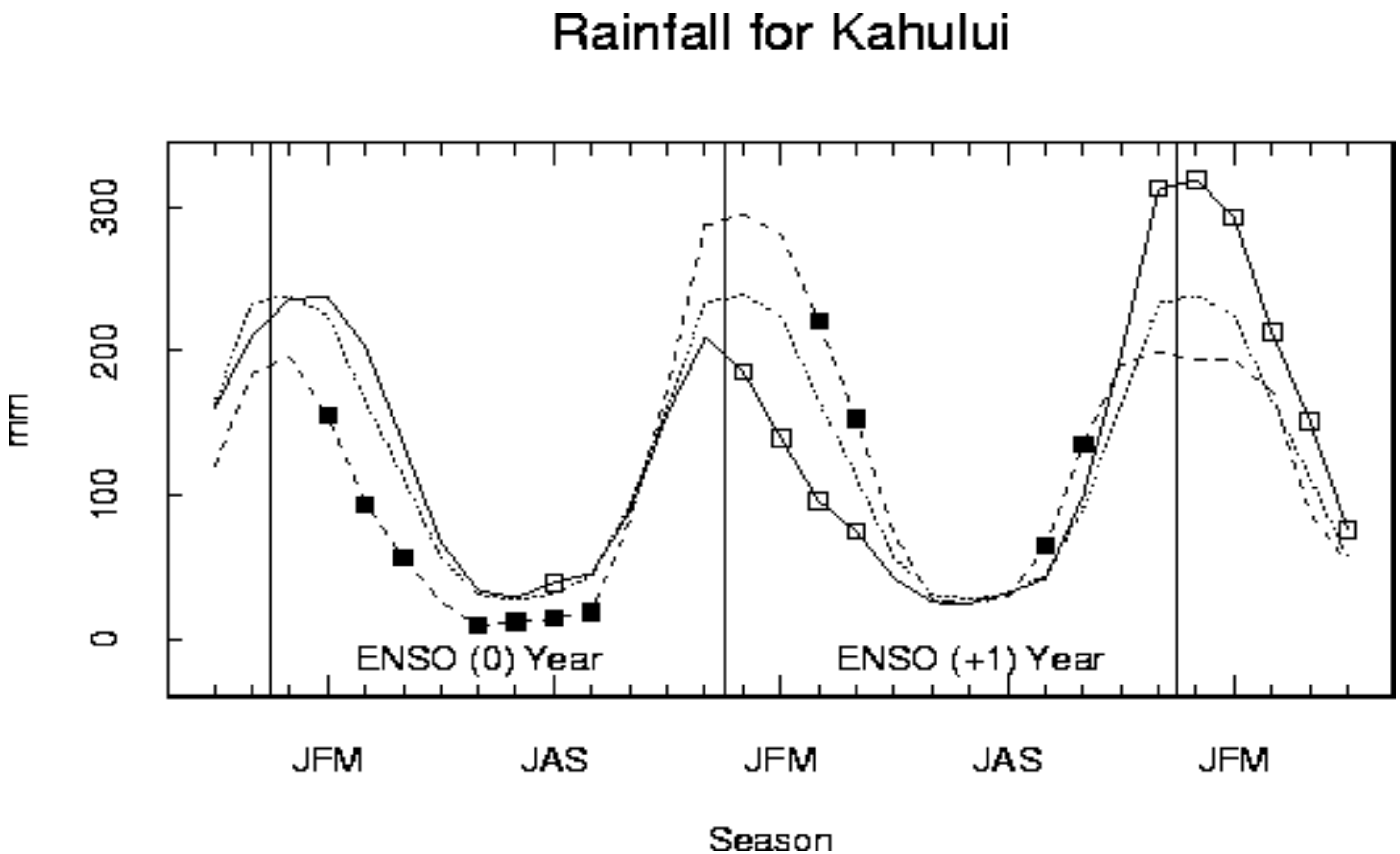




At the near-equatorial stations from the dateline eastward to the South American coast, rainfall is enhanced with El Nino.

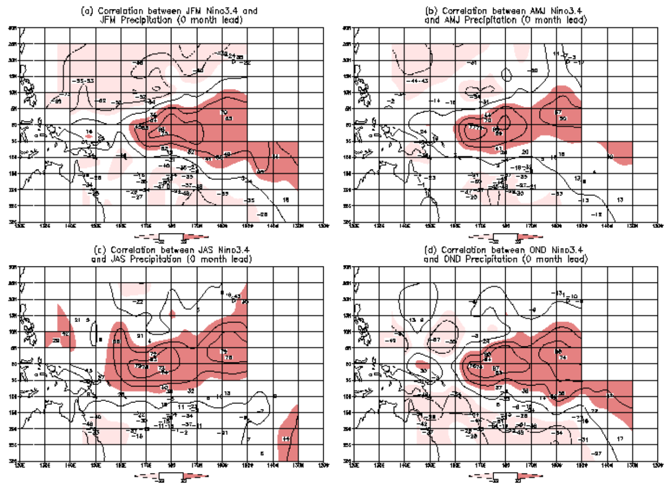


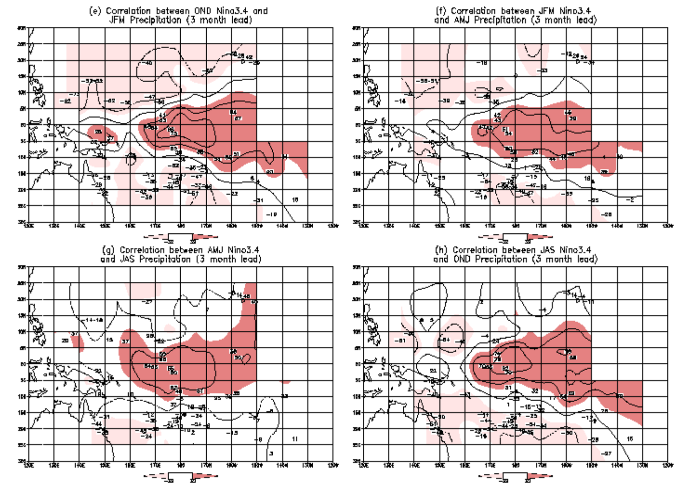
Rainfall ENSO composite. Dotted line – climatological mean; Solid line – rainfall composite of warm ENSO events; Dashed line – rainfall composite of cold ENSO events; Hollow square – rainfall warm ENSO composite passing the significant test at the 0.05 level;. Solid square – rainfall cold ENSO composite passing the significant test at the 0.05 level.

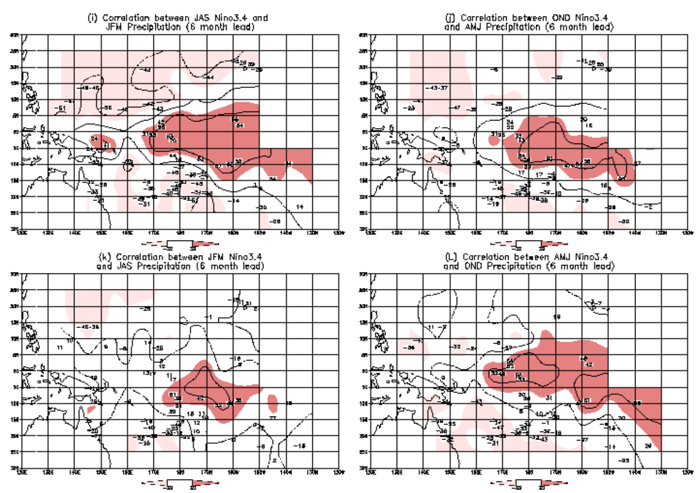


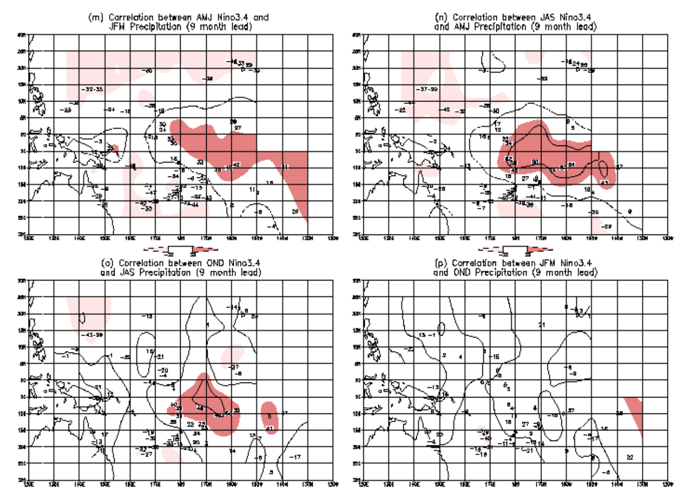
ENSO composite rainfall for Kahului, Hawaii. Rainfall ENSO composite. Dotted line – climatological mean; Solid line – rainfall composite of warm ENSO events; Dashed line – rainfall composite of cold ENSO events; Hollow square – rainfall warm ENSO composite passing the significant test at the 0.05 level;. Solid square – rainfall cold ENSO composite passing the significant test at the 0.05 level.

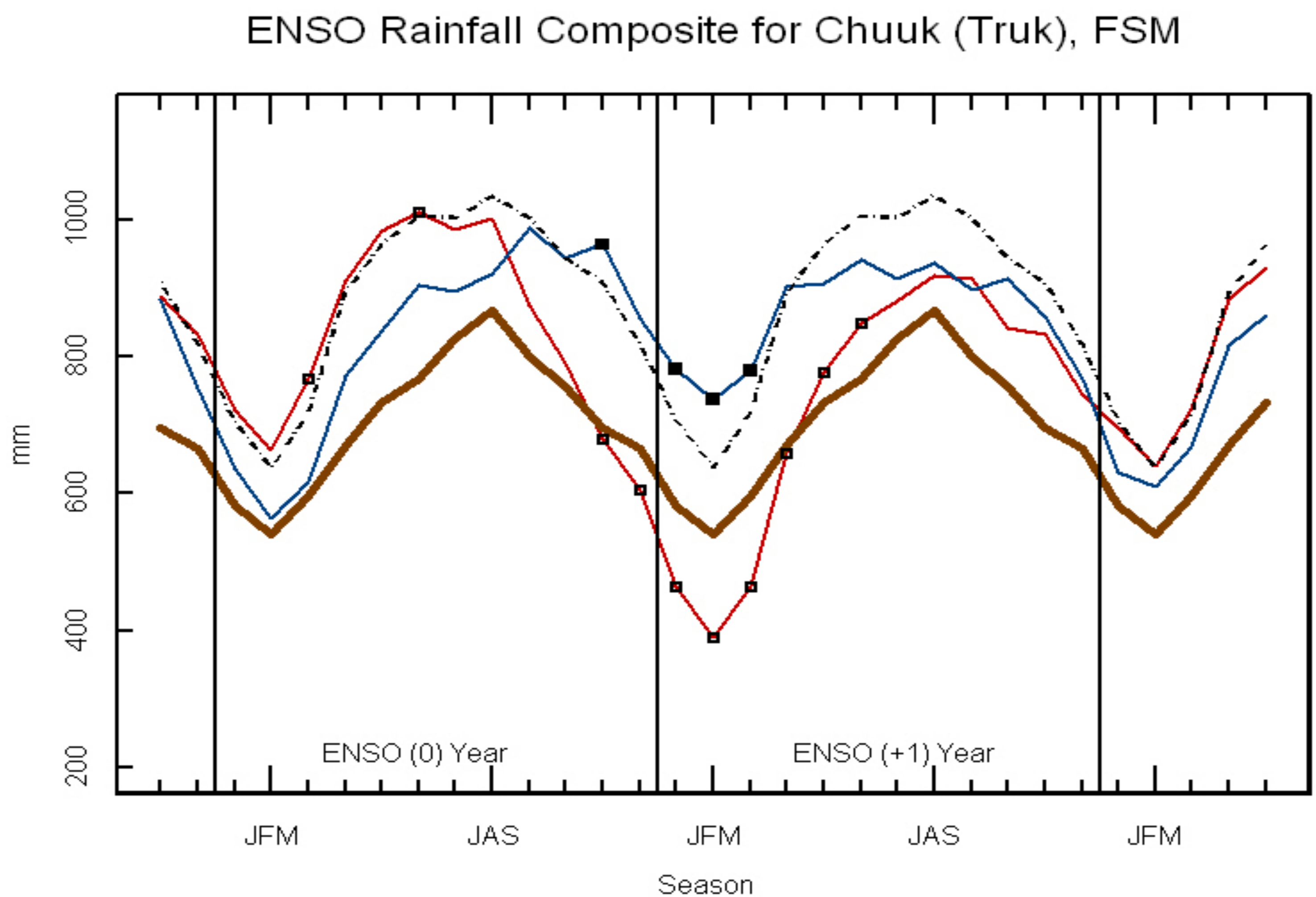
Near the time of the mature episode boreal winter at Kahului, warm episodes are significantly associated with below normal precipitation in Dec-Jan-Feb, Jan-Feb-Mar, Feb-Mar-Apr and Mar-Apr-May. Cold episodes associate significantly with enhanced rainfall only during Feb-Mar-Apr and Mar-Apr-May.


(a) Correlation between JFM Nino3.4 and JFM Precipitation (0 month lead)
(b) Correlation between AMJ Nino3.4 and AMJ Precipitation (0 month lead)
(c) Correlation between JAS Nino3.4 and JAS Precipitation (0 month lead)
(d) Correlation between OND Nino3.4 and OND Precipitation (0 month lead)


(e) Correlation between OND Nino3.4 and JFM Precipitation (3 month lead)
(f) Correlation between JFM Nino3.4 and AMJ Precipitation (3 month lead)
(g) Correlation between AMJ Nino3.4 and JAS Precipitation (3 month lead)
(h) Correlation between JAS Nino3.4 and OND Precipitation (3 month lead)


(i) Correlation between JAS Nino3.4 and JFM Precipitation (6 month lead)
(j) Correlation between OND Nino3.4 and AMJ Precipitation (6 month lead)
(k) Correlation between JFM Nino3.4 and JAS Precipitation (6 month lead)
(L) Correlation between AMJ Nino3.4 and OND Precipitation (6 month lead)

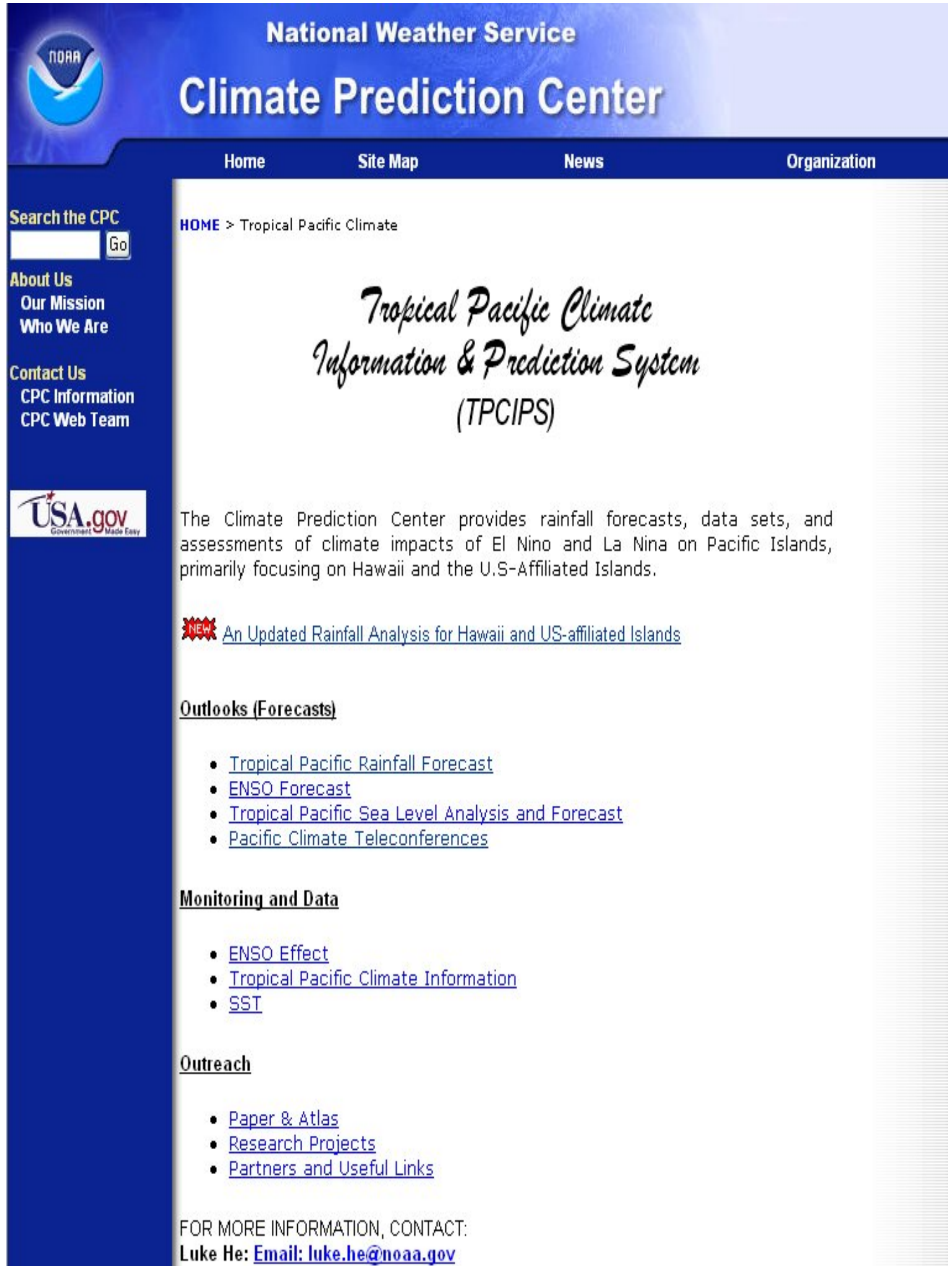

(m) Correlation between AMJ Nino3.4 and JFM Precipitation (9 month lead)
(n) Correlation between JAS Nino3.4 and AMJ Precipitation (9 month lead)
(o) Correlation between OND Nino3.4 and JAS Precipitation (9 month lead)
(p) Correlation between JFM Nino3.4 and OND Precipitation (9 month lead)



Brown line – OCN (1995-2009)- trend
Dashed Line – Long-Term Climatology
Red line – rainfall composite of warm ENSO events;
Blue line – rainfall composite of cold ENSO events

Water resource management
Disaster management
Agriculture
Health
Fisheries
Local ecosystems
Tourism
Economic growth

(user-friendly website specify for tropical Pacific islands so that users can easily access the climate information)



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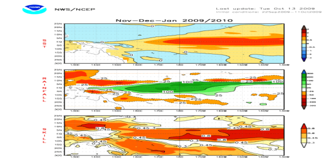
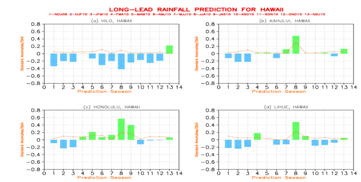
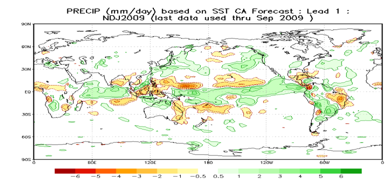
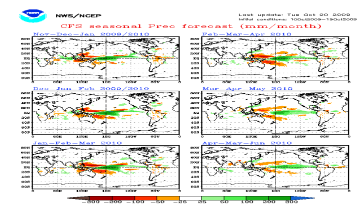
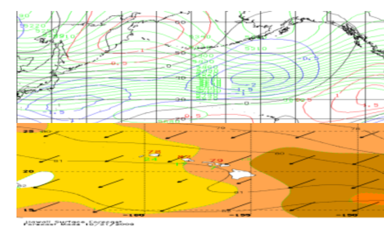
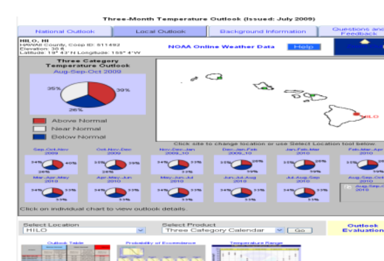












Pacific ENSO Application Center (PEAC) Regional Workshop: A Look to the Future

June 1-3, 2004
East-West Center, Honolulu, Hawaii

Sponsored by:

East-West Center
NOAA, Office of Global Programs
(NOAA Award #NA03OAR4310089)
NOAA, National Weather Service Pacific Region

Training, proposal, working group, steering committee

PaCIS

Pacific Climate Information System

Building Integrated Partnerships for End-to-End Climate Services

VISION

Resilient and sustainable Pacific communities using climate information to manage risks and support practical decision-making in the context of climate variability and change.

Mission Objectives

Clarify climate information needs to guide education, outreach, observations, research assessment; products and services;

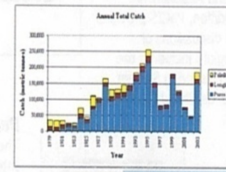
Provide access to critical data, research and new climate information products and services;

Translate research and assessment results into useful and usable climate information;

Interpret global and regional climate forecasts and projections for local applications;

Enhance regional and local capabilities to manage risks and support sustainable development in the context of climate variability and change; and

Enhance collaboration among national, regional and international institutions and programs involved in climate information services.



Fisheries are the primary industry in the Federated States of Micronesia (FSM). Declines in efforts and catch have been documented during El Niño years, which affects the normal migration of tuna species. Images courtesy Pangelinan, the National Resource Management Agency, FSM.

Stream flooding in Am. Samoa Photo courtesy American Samoa Coastal Management Program

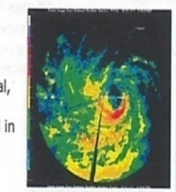


Image of Super Typhoon Chataan making landfall over Guam, July 4, 2002 Courtesy of NOAA NWS

Program Elements

To address the mission objectives, PaCIS will be implemented in the context of three program elements:

- **Education, Outreach and User Information Needs**
- **Operational Climate Observations, Products and Services**
- **Research and Assessment**

Implementation of these program elements will be guided by a PaCIS steering committee comprising representatives of NOAA climate programs, partners in other federal agencies and universities, representatives of key user communities in Pacific Island jurisdictions, and experts in climate science decision-support and operational services.

Guiding Principles

The concept for the **Pacific Climate Information System (PaCIS)** is to create an integrated program of assessment, research, observations, operations, outreach, and education implemented through a network of climate science, services and applications experts including users, researchers, and government offices. The evolution of PaCIS is being guided by principles developed over a decade of climate experience in the region.

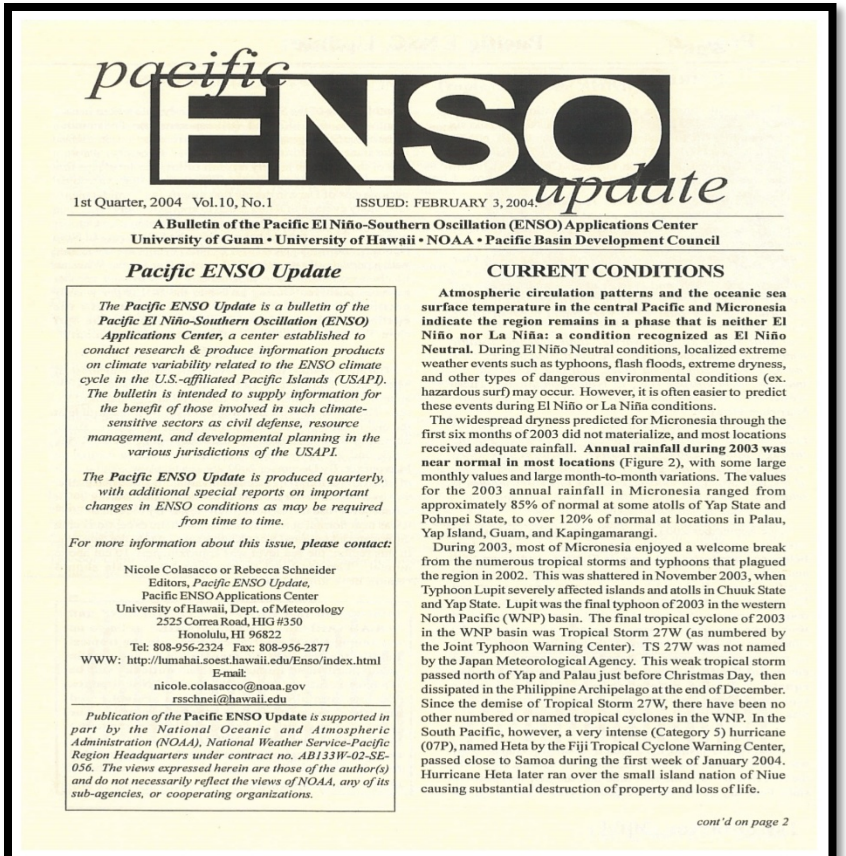
- Early and continuous partnership and collaboration with users to support shared learning and joint problem-solving.
- Building trust and credibility is a long-term endeavor.
- Sustained education, outreach and dialogue activities play critical roles.
- Forecasts or projections of future conditions must be set in an appropriate problem, application, historical, traditional, and decision-making context.
- Climate information to address today's problems and support long-term adaptation to changing climate conditions.

(1) Monthly Pacific ENSO Application Center Climate Audio Conference (8:30pm-9:30pm)

Participants: PEAC, CPC, IRI, University of Hawaii, University of Guam, International Pacific Research Center, NOAA NWS-Pacific Region WSFO (Honolulu, Guam, Chuck, Majuro, American Samoa, Phone….)

(2) Monthly Island Climate Teleconference (7:30pm-8:30pm)

Participants: New Zealand (NIWA), Australia (BoM) and other Southern Hemispheric island nations (Fiji, New Caledonia…), IRI, Pacific ENSO Application Center, CPC.



pacific ENSO update

1st Quarter, 2004 Vol.10, No.1 ISSUED: FEBRUARY 3, 2004.

A Bulletin of the Pacific El Niño-Southern Oscillation (ENSO) Applications Center
University of Guam • University of Hawaii • NOAA • Pacific Basin Development Council

Pacific ENSO Update

*The **Pacific ENSO Update** is a bulletin of the **Pacific El Niño-Southern Oscillation (ENSO) Applications Center,** a center established to conduct research & produce information products on climate variability related to the ENSO climate cycle in the U.S.-affiliated Pacific Islands (USAPI). The bulletin is intended to supply information for the benefit of those involved in such climate-sensitive sectors as civil defense, resource management, and developmental planning in the various jurisdictions of the USAPI.*

*The **Pacific ENSO Update** is produced quarterly, with additional special reports on important changes in ENSO conditions as may be required from time to time.*

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CURRENT CONDITIONS

Atmospheric circulation patterns and the oceanic sea surface temperature in the central Pacific and Micronesia indicate the region remains in a phase that is neither El Niño nor La Niña: a condition recognized as El Niño Neutral. During El Niño Neutral conditions, localized extreme weather events such as typhoons, flash floods, extreme dryness, and other types of dangerous environmental conditions (ex. hazardous surf) may occur. However, it is often easier to predict these events during El Niño or La Niña conditions.

The widespread dryness predicted for Micronesia through the first six months of 2003 did not materialize, and most locations received adequate rainfall. **Annual rainfall during 2003 was near normal in most locations** (Figure 2), with some large monthly values and large month-to-month variations. The values for the 2003 annual rainfall in Micronesia ranged from approximately 85% of normal at some atolls of Yap State and Pohnpei State, to over 120% of normal at locations in Palau, Yap Island, Guam, and Kapingamarangi.

During 2003, most of Micronesia enjoyed a welcome break from the numerous tropical storms and typhoons that plagued the region in 2002. This was shattered in November 2003, when Typhoon Lupit severely affected islands and atolls in Chuuk State and Yap State. Lupit was the final typhoon of 2003 in the western North Pacific (WNP) basin. The final tropical cyclone of 2003 in the WNP basin was Tropical Storm 27W (as numbered by the Joint Typhoon Warning Center). TS 27W was not named by the Japan Meteorological Agency. This weak tropical storm passed north of Yap and Palau just before Christmas Day, then dissipated in the Philippine Archipelago at the end of December. Since the demise of Tropical Storm 27W, there have been no other numbered or named tropical cyclones in the WNP. In the South Pacific, however, a very intense (Category 5) hurricane (07P), named Heta by the Fiji Tropical Cyclone Warning Center, passed close to Samoa during the first week of January 2004. Hurricane Heta later ran over the small island nation of Niue causing substantial destruction of property and loss of life.

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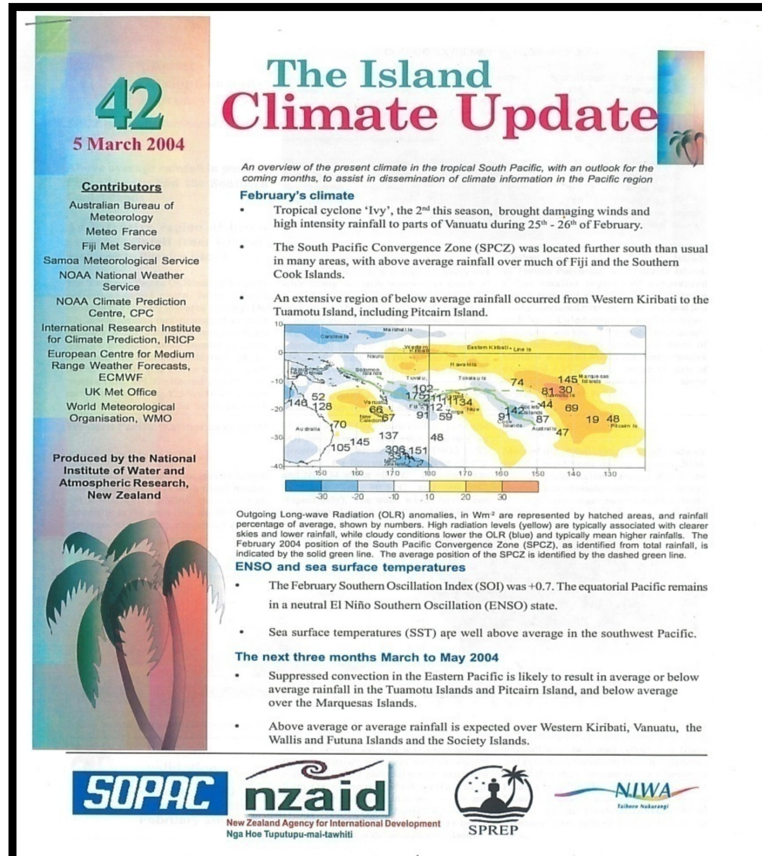

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5 March 2004

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UK Met Office
World Meteorological Organisation, WMO

Produced by the National Institute of Water and Atmospheric Research, New Zealand

The Island Climate Update

An overview of the present climate in the tropical South Pacific, with an outlook for the coming months, to assist in dissemination of climate information in the Pacific region

February's climate

- Tropical cyclone 'Ivy', the 2nd this season, brought damaging winds and high intensity rainfall to parts of Vanuatu during 25th - 26th of February.
- The South Pacific Convergence Zone (SPCZ) was located further south than usual in many areas, with above average rainfall over much of Fiji and the Southern Cook Islands.
- An extensive region of below average rainfall occurred from Western Kiribati to the Tuamotu Island, including Pitcairn Island.

Outgoing Long-wave Radiation (OLR) anomalies, in Wm^{-2} are represented by hatched areas, and rainfall percentage of average, shown by numbers. High radiation levels (yellow) are typically associated with clearer skies and lower rainfall, while cloudy conditions lower the OLR (blue) and typically mean higher rainfalls. The February 2004 position of the South Pacific Convergence Zone (SPCZ), as identified from total rainfall, is indicated by the solid green line. The average position of the SPCZ is identified by the dashed green line.

ENSO and sea surface temperatures

- The February Southern Oscillation Index (SOI) was +0.7. The equatorial Pacific remains in a neutral El Niño Southern Oscillation (ENSO) state.
- Sea surface temperatures (SST) are well above average in the southwest Pacific.

The next three months March to May 2004

- Suppressed convection in the Eastern Pacific is likely to result in average or below average rainfall in the Tuamotu Islands and Pitcairn Island, and below average over the Marquesas Islands.
- Above average or average rainfall is expected over Western Kiribati, Vanuatu, the Wallis and Futuna Islands and the Society Islands.

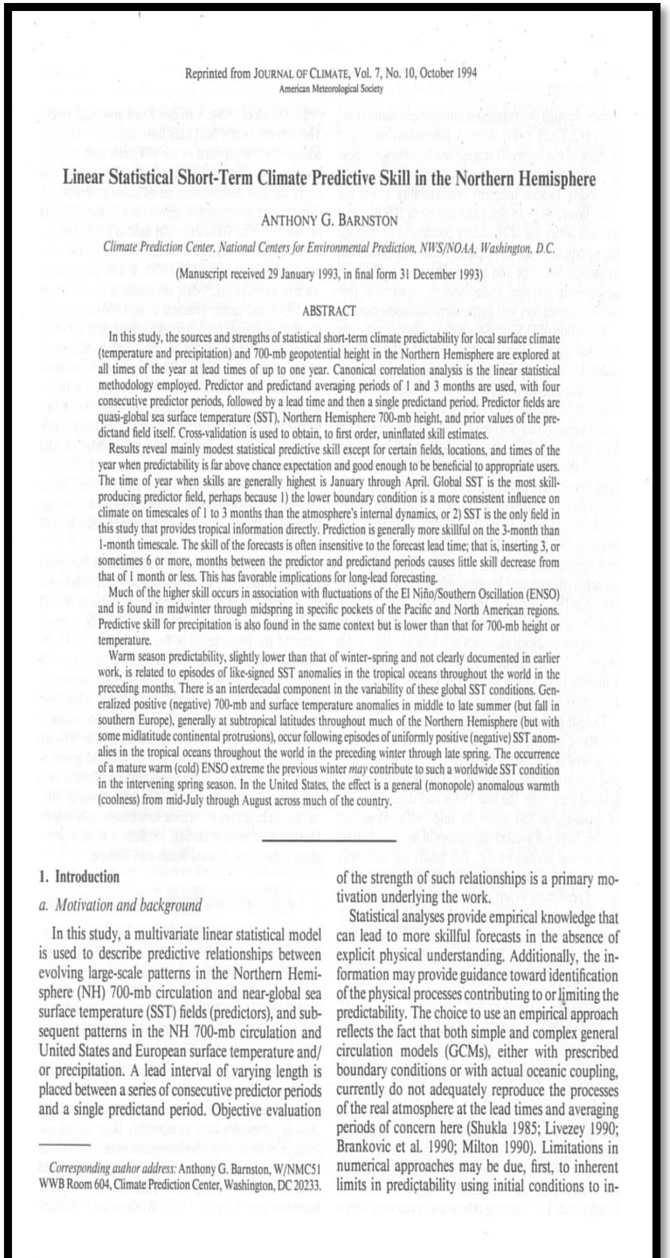
SOPAC nzaid New Zealand Agency for International Development Nga Hoe Tuputupu-mai-tawhiti SPREP NIWA Taihoro Nukurangi

I have known Tony for a long time while attending the CPC's Climate Diagnostics Workshops in the 1990s. I always enjoyed his presentation not only because of the content of his updated research but also his clear, loud and convincing manner. Tony came to Honolulu for the Pacific ENSO Applications Center workshop in 2004. He was the leader in the group for ENSO forecasts and whatever he said always seemed to be the final words in the workshop. He is also humble and open minded and really easy to talk to. At that time, he expressed an interest to come to Hawaii to continue his research. If I had position available, I would have not hesitated to recruit him. As we all know, Tony is a prolific writer. Recently, I have the fortune to read some of his more recent publications on ENSO forecasts. I was always struck by his new ideas in research and methodologies. His writing, although lengthy, is easy to follow and very comprehensive.

Tony, I want to congratulate you for your retirement. If you are still interested in coming to Hawaii, please let me know.

--Prof. Pao-Shin Chu, Department of Meteorology University of Hawaii, Hawaii State Climatologist

CCA forecast c-v skill for US (Temperature & Precipitation)
1-month lead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American Meteorological Society

Linear Statistical Short-Term Climate Predictive Skill in the Northern Hemisphere

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(Manuscript received 29 January 1993, in final form 31 December 1993)

ABSTRACT

In this study, the sources and strengths of statistical short-term climate predictability for local surface climate (temperature and precipitation) and 700-mb geopotential height in the Northern Hemisphere are explored at all times of the year at lead times of up to one year. Canonical correlation analysis is the linear statistical methodology employed. Predictor and predictand averaging periods of 1 and 3 months are used, with four consecutive predictor periods, followed by a lead time and then a single predictand period. Predictor fields are quasi-global sea surface temperature (SST), Northern Hemisphere 700-mb height, and prior values of the predictand field itself. Cross-validation is used to obtain, to first order, uninflated skill estimates.

Results reveal mainly modest statistical predictive skill except for certain fields, locations, and times of the year when predictability is far above chance expectation and good enough to be beneficial to appropriate users. The time of year when skills are generally highest is January through April. Global SST is the most skill-producing predictor field, perhaps because 1) the lower boundary condition is a more consistent influence on climate on timescales of 1 to 3 months than the atmosphere's internal dynamics, or 2) SST is the only field in this study that provides tropical information directly. Prediction is generally more skillful on the 3-month than 1-month timescale. The skill of the forecasts is often insensitive to the forecast lead time; that is, inserting 3, or sometimes 6 or more, months between the predictor and predictand periods causes little skill decrease from that of 1 month or less. This has favorable implications for long-lead forecasting.

Much of the higher skill occurs in association with fluctuations of the El Niño/Southern Oscillation (ENSO) and is found in midwinter through midspring in specific pockets of the Pacific and North American regions. Predictive skill for precipitation is also found in the same context but is lower than that for 700-mb height or temperature.

Warm season predictability, slightly lower than that of winter–spring and not clearly documented in earlier work, is related to episodes of like-signed SST anomalies in the tropical oceans throughout the world in the preceding months. There is an interdecadal component in the variability of these global SST conditions. Generalized positive (negative) 700-mb and surface temperature anomalies in middle to late summer (but fall in southern Europe), generally at subtropical latitudes throughout much of the Northern Hemisphere (but with some midlatitude continental protrusions), occur following episodes of uniformly positive (negative) SST anomalies in the tropical oceans throughout the world in the preceding winter through late spring. The occurrence of a mature warm (cold) ENSO extreme the previous winter *may* contribute to such a worldwide SST condition in the intervening spring season. In the United States, the effect is a general (monopole) anomalous warmth (coolness) from mid-July through August across much of the country.

1. Introduction

a. Motivation and background

In this study, a multivariate linear statistical model is used to describe predictive relationships between evolving large-scale patterns in the Northern Hemisphere (NH) 700-mb circulation and near-global sea surface temperature (SST) fields (predictors), and subsequent patterns in the NH 700-mb circulation and United States and European surface temperature and/or precipitation. A lead interval of varying length is placed between a series of consecutive predictor periods and a single predictand period. Objective evaluation of the strength of such relationships is a primary motivation underlying the work.

Statistical analyses provide empirical knowledge that can lead to more skillful forecasts in the absence of explicit physical understanding. Additionally, the information may provide guidance toward identification of the physical processes contributing to or limiting the predictability. The choice to use an empirical approach reflects the fact that both simple and complex general circulation models (GCMs), either with prescribed boundary conditions or with actual oceanic coupling, currently do not adequately reproduce the processes of the real atmosphere at the lead times and averaging periods of concern here (Shukla 1985; Livezey 1990; Brankovic et al. 1990; Milton 1990). Limitations in numerical approaches may be due, first, to inherent limits in predictability using initial conditions to in-

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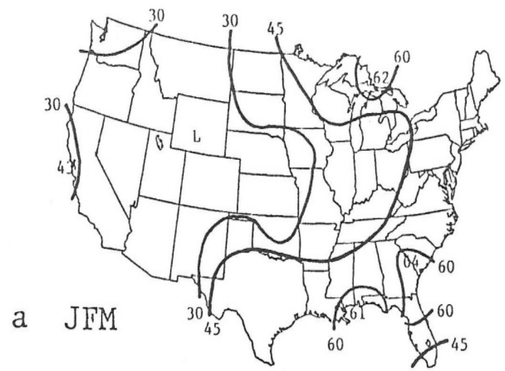
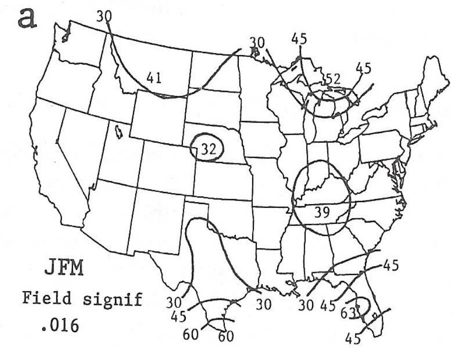
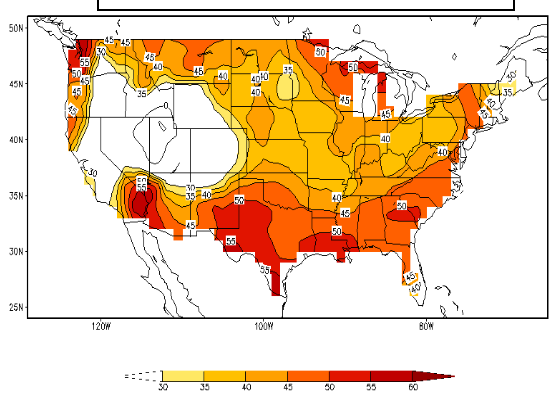


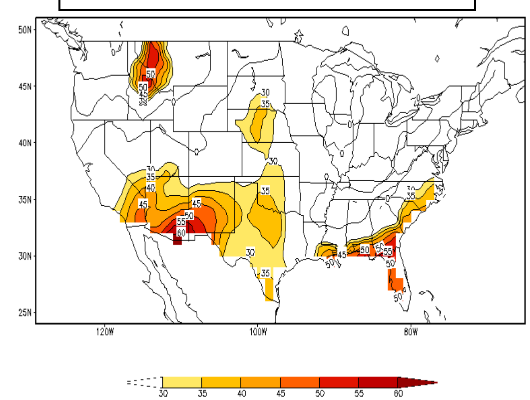


1955-1994

Temperature



Precipitation



1995-2014

Arizona, New Mexico, Kentucky, Tennessee
cca –a base tool for cpc operation forecast，increase vs. lost skill
skill source

Greatly appreciate Tony's help and work to set up a climate forecast system for Hawaii and USAPI. Wishing you all the best in your new retired life!!!