Missouri Basin Climateer

A Quarterly Newsletter about

Decadal Climate Variability and the Missouri River Basin

June 2009 Volume 1 Issue 2

Editor's Note

While global climate change and its possible consequences grab headlines in the news media, it is often forgotten that the Earth's climate has always been characterized by natural variability at multiyear to multicentury timescales. Natural climate variability includes decadal climate variability (DCV), which is manifested throughout the world in "cycles" or events of long-persistent droughts and wet periods. The Missouri River Basin (the Basin hereafter) is a prime example of a region in which the effects of DCV events are evident. Anecdotal and recorded evidence show that these droughts, wet periods, and other weather-climate consequences of DCV events significantly impact water resources, agriculture, economy, and society in the Basin. The purpose of this quarterly newsletter, ***Missouri Basin Climateer***, is to continuously inform the Basin farmers, water managers, other stakeholders, and policymakers about what's currently happening with DCVs, related droughts and wet periods, and their possible impacts on the Basin. We have also created a special section for this project on the Virtual Center for Decadal Climate Variability (DecVar; www.DecVar.org/MRB_project.php). ***Missouri Basin Climateer*** and other materials about this project are available from DecVar.

Articles in this issue of ***The Climateer*** briefly describe two major decadal climate variability phenomena, the tropical Atlantic sea-surface temperature gradient oscillation and the Pacific Decadal Oscillation; the association of steady corn yields in Iowa during the so-called "benign period" of year-to-year weather variability during 1957 to 1973; how biomass as a crop in the Missouri River Basin can help in mitigation of and adaptation to slowly-changing climate; and describe a technical analysis of impacts of interannual ENSO by the Pacific Decadal Oscillation.

We welcome feedback from readers, including brief (1-2 page) articles for future issues from farmers, water managers, researchers, policymakers, and others interested in DCV impacts in the Basin. Please send your articles and other contributions for the next issue before 1 September 2009 to mrb@crces.org.

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1. Introduction to Major Decadal Climate Variability Phenomena; Part I: The Tropical Atlantic Gradient Variability and the Pacific Decadal Oscillation

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Following the general background on decadal climate variability (DCV) in the first issue of *The Climateer*, we now look at some major DCV phenomena, hypothesized causes, and known impacts on global climate and society. Two DCV phenomena are described in this issue: the tropical Atlantic sea-surface temperature gradient variability (TAG hereafter for brevity) and the Pacific Decadal Oscillation (PDO).

Research on the TAG dates back to the 1960s, when researchers first found associations between variations in the TAG pattern and rainfall variability in northeast Brazil and west Africa. Since then, as more and better ocean and atmosphere observations have become available, it has been found that variability of many atmosphere and ocean variables are associated with the sea surface temperature (SST) variability shown in Figures 1a and 1b, such as winds in the lower troposphere, heat transferred between the Atlantic Ocean and the overlying atmosphere, cloudiness, rainfall in northeast Brazil and west Africa, Atlantic hurricanes, and water vapor influx and rainfall in the southern, central, and midwestern U.S..

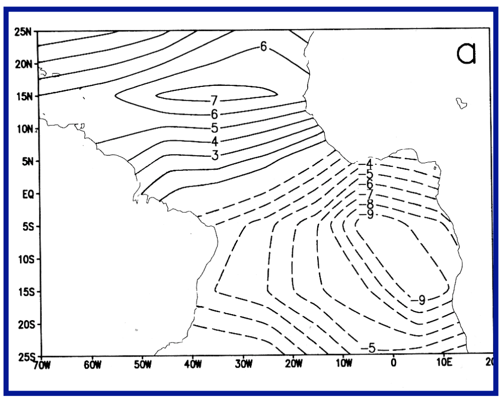

Figure 1a: The dominant pattern of tropical-subtropical Atlantic sea-surface temperature (SST) variability between 1881 and 1990 shows positive (solid line) and negative (dashed line) SST anomalies in North and South Atlantic, with maximum variability in the zone between 15°N and 15°S.

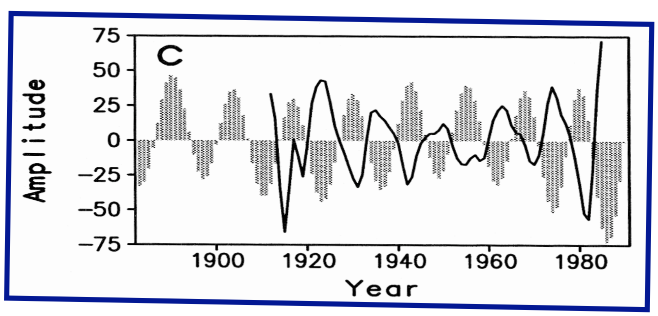

Figure 1b: The SST time series (bars) modulating this pattern shows decadal-to-multidecadal variability. Rainfall in northeast Brazil (solid line) shows opposite phase variability with respect to the SST time series.

In the late 1920s Sir Gilbert Walker of the India Meteorological Department first discovered a phenomenon he termed the North Pacific Oscillation (NPO). Sir Gilbert wanted to find precursor signals to predict the Indian monsoon rainfall and the NPO was an atmospheric pressure seesaw he found during his studies using worldwide atmospheric pressure measurements. Subsequently, when long-term SST data in the Pacific Ocean became available in the 1990s, a number of researchers found that the dominant pattern of SST variability in the extratropical (outside of the belt between 23.5° south latitude and 23.5° north latitude) Pacific varied at time scales of one or more decades and that this SST pattern corresponded to the NPO in the atmosphere. This SST pattern, shown in Figure 2a, is called the PDO and the time series modulating this SST pattern is shown in Figure 2b.

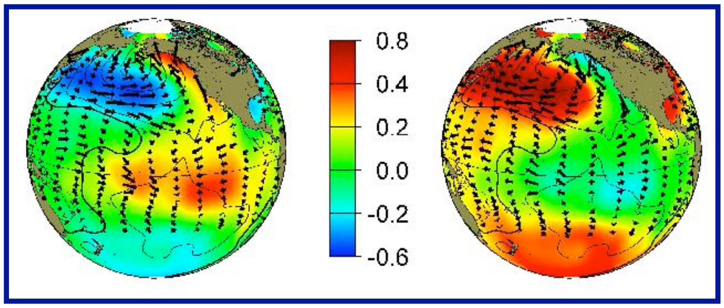

Figure 2a: SST departures (°C)from average conditions in the PDO in the positive phase (left) and the negative phase (right). Courtesy Nathan Mantua and Stephen Hare, University of Washington.

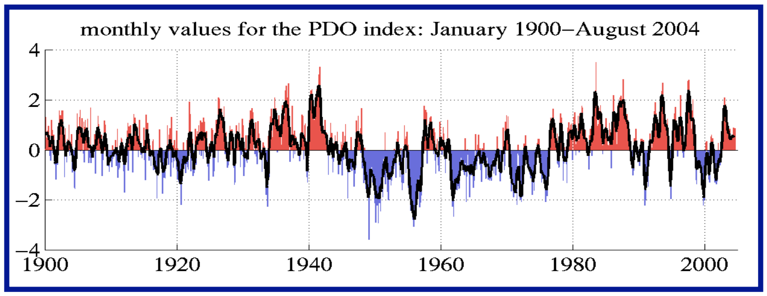

Figure 2b: Time series of SST monthly departures associated with the PDO. Courtesy Nathan Mantua and Stephen Hare, University of Washington.

Among the phenomena associated with the PDO are winds in the lower troposphere (the atmospheric region below approximately 10-15 km height), heat transferred between the Pacific Ocean and the overlying atmosphere, cloudiness, occurrence of Pacific typhoons (a hurricane-like storm), and droughts and floods in the western U.S. and the Missouri River Basin. Major changes in northeast Pacific marine ecosystems have been correlated with phase changes in the PDO; warm eras have seen enhanced coastal ocean biological productivity in Alaska and inhibited productivity off the west coast of the contiguous United States, while cold PDO eras have seen the opposite north-south pattern of marine ecosystem productivity.

Scientists hypothesize that the principal cause of the TAG and the PDO is the variability of heat transported by currents and slow-moving waves in the Atlantic and Pacific Oceans, as a result of their interactions with the atmosphere. Both these phenomena are associated with decadal droughts, floods, and associated variability of crop yields in the Missouri River Basin.

2. The Benign Interval: Recurrent Periods of "Benign Climate" in the Midwest

Elwynn Taylor
Iowa State University

Corn yields during the period 1957-1973 were more consistent from year to year than during the previous or subsequent score of years. This interval has been termed the period of "benign climate" (Baker, Ruschy, and Skaggs, 1993). It was determined that weather conditions during this period improved the year-to-year consistency of crop yields; increased and less inter-annual variability in yields was not due, as some insisted, solely to improved crop genetics and management (i.e. technology).. The yield impact of changing composition of the atmosphere (due to, for example, increasing carbon dioxide concentration) was not considered in this analysis. Authors associated the variability of crop yield with the standard deviation from average annual temperature and identified a 13-year grouping of deviation categories that was later described in greater detail (Skaggs, Baker, Ruschy, 1995).

It appears that 1995 marked the end of a period of high variability in annual yields that began arpound 1973. Figure 1 presents the USDA assessment of Corn Yield in Iowa since 1945. The "benign" period described above is clearly apparent between 1950 and 1970. A similar yield consistency has been observed in Iowa and other Midwest states since 1995. Although technology is thought by many producers to be the reason for more consistent year-to-year yields, the seasonal crop weather pattern gives a strong indication of another period of benign climatic conditions.

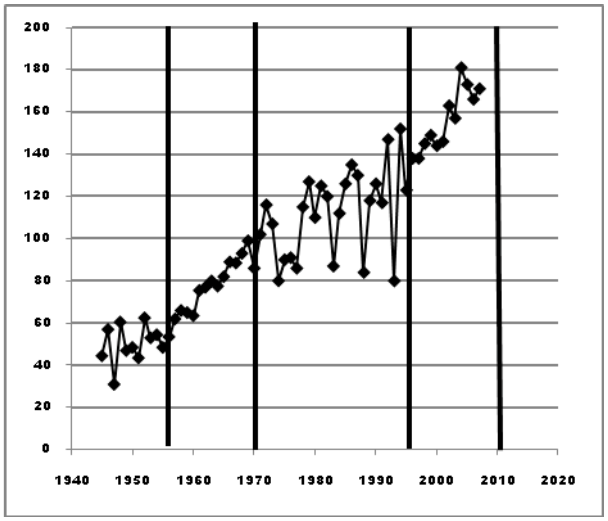

Figure 1: Iowa corn yield 1945-2008 expressed in bushels per harvest acre. The recurrence of consistent crop yields since 1995 is an indication of decadal scale climatic cycling. Data from NASS.USDA.gov.

Corn yield records for the U.S. begin in 1865. Over the period of record 4 benign intervals are apparent. The yield deviations as a percent of the roughly determined yield trend over the period of record show 4 major intervals when yields did not drop drastically (15%) below the trend and 3 intervals when substantially diminished crop yields were apparent.

The 'take-away message', Dear Reader, is that, while technology is certainly the driver of the remarkable increase in Iowa corn yields over time, weather still matters. The decadal-scale alteration of periods of highly variable and periods of less variable weather is closely related to the occurrence of the DCV.

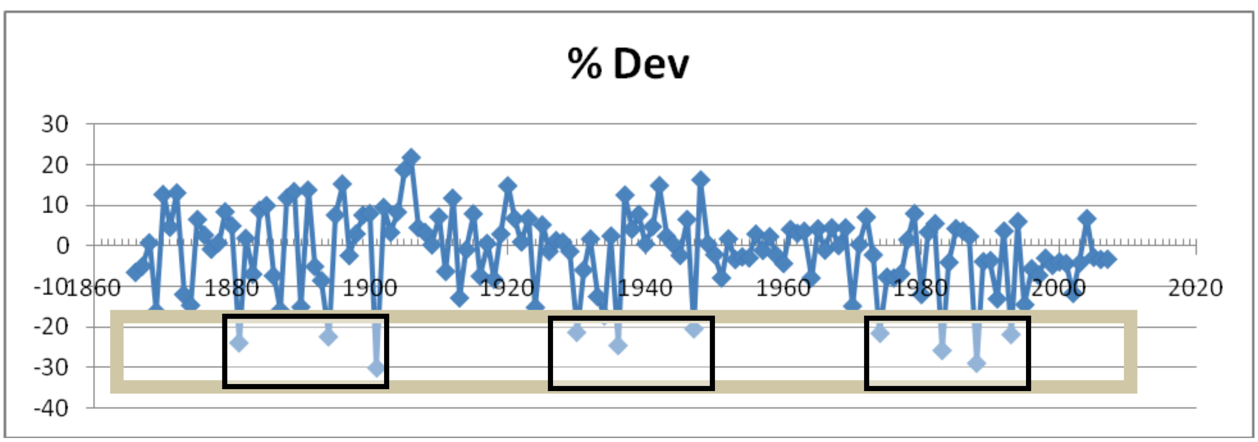

Figure 2: Percent deviation of U.S. (total national crop) from trend 1865-2008. Three high risk (low yield) intervals are delineated; each interval displays 3 droughts, with the latest interval also including the diminished yields associated with the flood year of 1993. The 3rd benign interval (includes 1960) is unique in that no outstandingly high yields were experienced.

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3. Biomass in the Missouri River Basin: Mitigation and Adaptation to Climatic Change and the Impacts of Extreme Decadal Climate Variability

Norman J. Rosenberg

Center for Research on the Changing Earth System[1]

Much of the MRB[2] lies in the northern portion of the Great Plains. As a long-time professor of Agricultural Meteorology at the University of Nebraska-Lincoln (1961-1987) and as a student of climate change impacts on agriculture and water resources, both at the university and subsequently[3], I have concluded that the region of interest to readers of *The Climateer* can play an important role in combating climate change and, in so doing, reduce its vulnerability to the extreme impacts of existing natural decadal climate variability.

The emission of carbon dioxide from fossil fuel combustion and tropical deforestation and the rising concentrations of other greenhouse gases make global warming a virtual certainty in this century; indeed the evidence is strong that a warming is already discernible. Global warming will lead to climatic change and, while the geographic distribution of this change is not yet knowable, most general circulation models (GCMs) suggest that mid-continental regions in the northern hemisphere (such as the MRB) are likely to become drier as well as warmer. The MRB, encompassing one of the world's major bread-baskets, is subject to periodic droughts and other climatic stresses associated with decadal-scale climatic variability--stresses that may worsen with global warming. Thus, it is prudent, if only for their own benefit, that the people and governments in the MRB seek ways of reducing the emissions of greenhouse gases.

There are many climate change mitigation strategies under consideration. These include expansion of nuclear power production, capture of fossil fuel carbon at the smokestack and its transport to and sequestration in geologic strata and the oceans, afforestation, solar and wind power, sequestration of carbon in soils in the form of organic matter and production of biomass as a substitute for fossil fuels. Each of these options has associated physical, environmental and economic risks. Soil carbon sequestration and biomass production are among the most environmentally benign options and are well suited to the MRB.

Fossil fuels burden the atmosphere with carbon drawn from ancient geologic storages. Biomass recycles CO_2 from the atmosphere through photosynthesis and returns it when the vegetation or its derivative products are consumed. adding little or no additional carbon to the

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[1] This editorial is based on findings from Norman J. Rosenberg. A Biomass Future for the North American Great Plains:Toward Sustainable Land Use and Mitigation of Greenhouse Warming. 2007. Springer (Dordrecht).

[2] But for a small segment of Minnesota, the western quarter of Iowa, the southern half of Kansas and about half of Missouri (northern and western).

[3] Senior Fellow. Resources for the Future in Washington, DC and Laboratory Fellow Emeritus, Joint Global Change Research Institute, a collaboration of Pacific Northwest National Laboratory and the University of Maryland-College Park

atmosphere. . Whether combusted for boiler-fuel or converted to liquid transportation fuels such as ethanol, biomass essentially recycles carbon from and back-to the atmosphere

Ethanol, a fuel made from biomass is now produced in portions of the MRB and adjacent regions primarily from the starch in grain corn. The ethanol so produced may have an energy content 25-50% greater than the energy used to produce it.

Energetically much more efficient is ‘cellulosic ethanol’ which can contain 2 or 3 times as much energy as is needed to produce it. Cellulosic ethanol can be made from corn stover, wheat straw, grasses and wood and wood wastes. Enzymes are used to break the strong bonds between sugar molecules that make up the cellulose structure. New enzymes, genetically engineered for that purpose, are coming onto the market. When petroleum was at $60-70 dollar per barrel (and for sure when it ran up to $150) even ethanol from grain appeared competitive. How much more so cellulosic ethanol!

It has been strongly argued that agriculture as currently practiced in the MRB is unsustainable. Although soil erosion has been reduced by conservation strategies implemented since the ‘dirty-thirties’, overuse of chemical fertilizers and pesticides and the mining of ground water resources create serious environmental problems in this as in many other agriculturally intensive regions of the world. For these reasons some scholars have suggested that large portions of the Great Plains should be returned to its native vegetation and fauna and that a ‘Buffalo Commons’ replace its farms and ranches.

While the world faces a problem of consequential climatic change, it also faces population pressures and expected improvements in worldwide living standards that will increase demand for both energy and agricultural products. Thus, diversion of land to grass or to biomass energy production raises the question of how needed food, feed and fiber will be provided in the future.

Perennial biomass crops such as *switchgrass* and *poplar* are suited to the eastern portion of the MRB. Switchgrass has been grown successfully as far north as central N. Dakota. Many other species such as the warm season grasses *big bluestem* and *Indiangrass* and cool season grasses such as *intermediate wheatgrass*, *smooth bromegrass* and *crested wheatgrass* are easily established in the western, drier portions of the region, All of these species require less tillage and fewer pesticide and fertilizer applications. And as the roots of crops-- particularly perennials--decay, they deposit carbon in the soil, some of which is sequestered for very long periods of time. These grasses, most of them native to the region tend to be more drought tolerant than traditional crops. Existing irrigation infra-structure, much of it unused in recent years, can be mobilized to assist in establishing these grasses. Once established the grasses can be harvested once or twice a year for upwards of ten years. Biomass cropping in portions of the MRB may well be more sustainable than the traditional crops they might replace (as well as being more popular and politically feasible and likely of implementation than a ‘Buffalo Commons’).

In addition to the environmental benefits of biomass for energy, a reliable income stream for farmers can be developed and badly-needed employment opportunities created in transportation of biomass, in biorefineries to produce liquid fuels and in local power plants fueled with biomass.

In short, ecological, environmental and economic arguments support the need for a significant conversion of much of the MRB, and the North American Great Plains generally, back to grass cover, to biomass cropping, or both. However, two important questions need to be fully addressed: 1) can genetic modification of biomass crops increase their productivity to the point of economic competitiveness? and 2) can the productivity of traditional (or new) crops be increased sufficiently to compensate for decreases due to conversion of substantial areas of agricultural land to biomass production?

Watch this space for answers!

4. Technical Article: The Interannual and Interdecadal Variability of Climate in Missouri

Patrick E. Guinan and Anthony R. Lupo
University of Missouri - Columbia

The interannual and interdecadal climatic variability in Missouri climate is fairly complex, but studies performed by the Missouri Climate Center and the Global Climate Change Group at the University of Missouri have found some interesting relationships. We have correlated year-to-year variability in both temperature and precipitation variations to the El Niño and Southern Oscillation (ENSO) in general , and in some cases this record goes back to 1900[1]. However, the correlation is fairly weak when looking at the entire data set. When the data sets are stratified by phase of the Pacific Decadal Oscillation (PDO), the ENSO variability manifests itself more strongly [1] especially in the positive phase of the PDO. In particular, across the northern (southern) part of the region, El Niño winters are much warmer (slightly cooler) than La Niña or neutral winters during the positive phase of the PDO, and this result is comparable to other studies. During the negative phase of the PDO, there is relatively less (no change) ENSO variability in winter temperatures across the northern (southern) part of the region. These results are consistent with ENSO variability in the jet stream as manifest through East Pacific blocking events[2].

Previous research [3] has demonstrated that monthly average Pacific Region Sea Surface Temperatures (SSTs) and the shape of the monthly SST anomalies can be separated into seven general classifications (A-G). SST types B and G (C, D, and F) [A and E] were shown to be generally representative of La Niña (El Niño) [neutral] type SST distributions (Fig. 1). Further, an analysis of the SST patterns from 1955 – 1993 demonstrated that clusters A – D were prominent from 1955 – 1977, while types E and F dominated the later period [3]. In retrospect, this shift during 1977 corresponds roughly with a change in phase of the Pacific Decadal Oscillation (PDO). After updating the analysis to include the 1994 to 2008 period, there was a corresponding change in the predominant SSTs associated with a possible change in phase of the PDO during 1999 and 2000 [4],[5]. The results show that SST patterns did evolve from predominantly E and F-type anomalies in 1994 into A, B, D, and G-type anomalies from about 2000 through 2008. Thus, these results suggest that A through D-type (C, E, and F-type) SST types are characteristic of the negative (positive) phase of the PDO.

An analysis was performed to see if there was any statistical association between temperature and precipitation anomalies in the mid-Mississippi region and prolonged SST type regimes (these needed to persist longer than three consecutive months) (Table 1). The B, D and G anomalies were associated with warmer-than-normal conditions, while C and E type anomalies tended to be associated cooler than normal conditions across the region. C, D, F, and G anomalies were associated with drier than normal conditions, and this is especially true for D and G types and during the summer season [4],[5].

Research also shows that there are interannual and interdecadal variations in the mid-Mississippi and Missouri region in the snowfall records [6], [7], as well as the occurrence of severe weather such as tornadoes [8] that can be associated with the ENSO and PDO. In northern Missouri [6], there is little variation in year-to-year snowfall occurrence during the negative phase of the PDO, while there were strong ENSO variations during positive phase.

More specifically, there are fewer snowfall events during El Niño years in the positive PDO, and there is a greater tendency for these storms to originate in the Pacific and Southwest US as compared to other years. This reflects a tendency for a strong zonal subtropical jet to anchor in over the southern tier of states, which is a result found by many investigators. Across the southern part of the region [7] (Table 2), when winter seasons were stratified by phase of the PDO, the interannual variability of snowfall events associated with ENSO changed when comparing the earlier years in the data set with the later years. During the negative PDO phase (1949-1976, and 1999 - 2003), El Niño winters produced more snowfalls. La Niña and neutral winters produced more snowfalls during the positive PDO period (PDO1 - 1977-1999), and this result was significant at the 90% confidence interval when testing the means. El Niño winters also produced more "southwest origin"-type low pressure systems. These snow events were associated with lower snowfall-to-liquid ratios and high snowfall totals simultaneously. A recent examination of SGF snows up to the winter of 2008-2009 revealed that these years were no different from the negative PDO years[9].

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Table 1: Number of months in which a) temperature and b) precipitation in the study region for each SST classification were above or below (A/B) normal. These results are also stratified by season.

a. temperature

Class	Spring	Summer	Fall	Winter	Total
A	13 / 9	7 / 10	5 / 7	6 / 6	31 / 32
B	10 / 5	7 / 7	9 / 7	9 / 9	35 / 28
C	7 / 3	0 / 5	2 / 4	2 / 6	11 / 18
D	7 / 6	3 / 3	7 / 2	10 / 7	27 / 18
E	4 / 8	6 / 6	9 / 14	6 / 8	25 / 36
F	3 / 13	6 / 9	4 / 10	13 / 4	26 / 36
G	4 / 7	5 / 4	3 / 3	7 / 2	19 / 16

b. precipitation

Class	Spring	Summer	Fall	Winter	Total
A	11 / 11	9 / 8	4 / 8	5 / 7	29 / 34
B	8 / 7	4 / 10	7 / 9	11 / 7	30 / 33
C	8 / 1	1 / 4	3 / 3	3 / 5	15 / 14
D	3 / 10	4 / 2	3 / 6	5 / 12	15 / 30
E	6 / 6	5 / 7	9 / 14	7 / 7	27 / 34
F	6 / 10	8 / 7	6 / 8	7 / 10	27 / 35
G	6 / 5	0 / 9	0 / 6	5 / 4	11 / 24

Table 2: The total number (first number) and average number per year (second number) of snowfalls versus El Nino / La Nina phase for the southwest Missouri sample, negative PDO (1949-1976, 1999-2009), and positive PDO (1977 - 1998) period.

	All	Moderate	Heavy	Extreme
(La Nina)				
Total	67 / 4.2	36 / 2.3	19 / 1.2	12 / 0.8
PDO2	61 / 4.1	34 / 2.3	16 / 1.1	11 / 0.7
PDO1	6 / 6	2 / 2	3 / 3	1 / 1
(Neutral)				
Total	144 / 4.8	92 / 3.0	38 / 1.3	14 / 0.5
PDO2	57 / 3.8	36 / 2.4	16 / 1.1	5 / 0.3
PDO1	87 / 5.4	56 / 3.5	22 / 1.4	9 / 0.6
(El Nino)				
Total	64 / 4.6	37 / 2.7	17 / 1.2	10 / 0.7
PDO2	61 / 5.1	21 / 2.6	13 / 1.6	7 / 0.9
PDO1	23 / 3.3	16 / 2.3	4 / 0.6	3 / 0.4
All				
Total	275 / 4.6	165 / 2.8	74 / 1.2	36 / 0.6
PDO2	159 / 4.2	91 / 2.4	45 / 1.2	23 / 0.6
PDO1	116 / 4.8	74 / 3.1	29 / 1.2	13 / 0.5

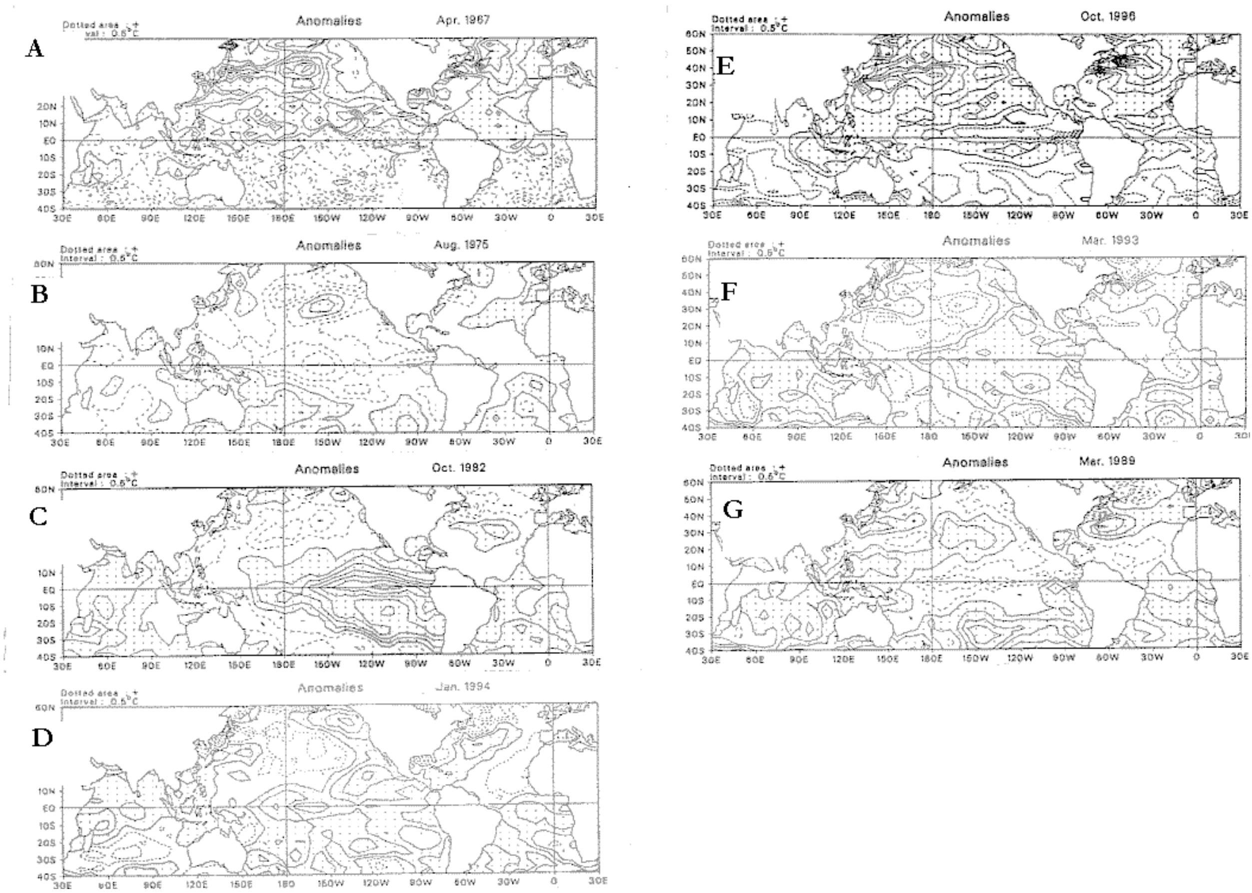

Figure 1: The seven identified types of SST (A-G) anomalies similar to Fig. 1 in [2], except using an observed monthly SST map as an example. The dashed contours (solid contours) represent cooler (warmer) than normal temperatures. Warmer than normal waters are also stippled.