The Use of El Niño Information in Forecasting Grain Yields in the Canadian Prairie Provinces

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The purpose of the Weather and Crop Surveillance Department of the Canadian Wheat Board (CWB) is that of grain yield and quality forecasting on a global scale, with special reference to the Canadian prairies. Its primary role, since it was established in the early 1970s, has been that of an early warning system for potentially big production swings in major foreign markets. Its purpose is to provide an independent in-shop expertise on global weather and crop conditions to assist CWB in its marketing functions and maintain a competitive edge for Canadian wheat in the world market. Much effort is devoted to the impact and risk assessment of weather parameters on crops around the world. The department generates an internal *Crop Production Forecast Summary* each week for about 50 countries in key grain growing areas of the world. Weather data is received on a day-by-day basis through the World Weather Watch Program of the World Meteorological Organization. Weather and Crop Surveillance is a small department consisting of a Director and three research analysts. The CWB has recently initiated (in collaboration with Environment Canada and research scientist Madhav L. Khandekar) a project to monitor large-scale atmospheric and oceanic anomalies such as Eurasian snow cover (ESC), the quasi-biennial wind oscillation (QBO), NINO3 sea surface temperature anomalies, the Southern Oscillation, and Pacific North American (PNA) teleconnection index. These forecasting techniques have only been introduced recently with limited success, but with just these five indices, it is felt the next North American heat wave will not develop without foreknowledge at the Canadian Wheat Board.

Weather-Related Concerns

A principal weather-related concern of E.R. Garnett is that of improving the early warning system for North American spring rains. The Long-Range Weather and Crop Forecasting Group, formed in Canada in 1993, is working toward forecasting the Canadian spring wheat and possibility the USA corn crop a season or quarter in advance, modeling the success that has been achieved in India in forecasting the monsoon in recent years (Gowariker et al., 1989; Thbiyal and Kulshrestha, 1992). The approach used in India relies heavily on teleconnections that have been established through the use of statistical analysis and that have a dynamical and thermodynamical basis. It is felt that a similar seasonal forecasting technique should be developed for the Canadian prairies and possibly the USA corn belt.

A number of similar indices are being investigated for incorporation into a teleconnection-based statistical model for the Canadian prairies. Some research has been conducted in consultation with Jeff Babb, a biometrician at the Canadian Grain Commission in Winnipeg, who is incorporating NINO3 sea surface temperature anomaly data and PNA teleconnection data into the modeling of Canadian hard red spring wheat yields.

Problems Being Faced

There is a definite need for more reliable forecasts with a lead time of 3 to 6 months. There have been many times at CWB when a 5- to 10-day forecast from Environment Canada would have been useful in selling and pricing grain, but there has been reluctance on the part of the Weather and Crop Surveillance Department to present this information to commissioners, given the unreliability of these forecasts. In certain weather market situations, there are often times when various weather forecasts can drive the market. Most weather offices express little confidence beyond 5 days, since the forecasting skill is too low to be of any value.

Is this the case with climate prediction? Grain yield is often regarded as a proxy variable of climate. At CWB, there is often much interest in what kind of summer or growing season we are likely to have, which is more related to climatology than meteorology and is more the focus of our Long-Range Weather and Crop Forecasting group. Predicting average temperature and precipitation for a region three to six months in advance does not violate the predictability limit which restricts the utility of numerical weather prediction to two or three weeks at most. Canadian prairie weather is of great interest to the CWB in selling the Canadian crop year round, and we need to know the size, quality and any hazardous risks to the crop as soon as possible. The extremely cold prairie summers of 1992 and 1993, and the poor quality of those two crops presented extreme marketing challenges for CWB. Climate and related yield prediction would seem to require an emphasis on large-scale circulation and oceanic anomalies as wet out in a recent study by Garnett and Khandekar (1992), which examines the impact of large-scale atmospheric features and anomalies on crop yields.

There is a strong need to make the forecast products more user-friendly. The methodology used by North American government agencies in their monthly and seasonal outlooks is not clear, and their products are not user-friendly. Their approach appears to be based on that of persistence and the monthly outlooks have not proven to be reliable. Examples are the US Weather Service Monthly and Seasonal Weather Outlook for the USA in July 1994 and Environment Canada's forecast of the Canadian prairie summer temperatures in 1993, both of which were misleading. There has been some effort at CWB to avoid the "black box" and to develop some in-shop expertise in longer-range weather and crop forecasting. There is a very large communication gap between the scientists doing the research and the end users. Very few end users can comprehend the mathematics and physics involved in computer-based prognosis, creating a major problem. There needs to be much more discourse between end users and basic scientists to lessen this credibility problem. End users tend to be skeptical of forecasts and distrust much of what is issued in various forecast products, given the rather poor track record.

Coupled atmosphere-ocean models are now in a rapid stage of development and have been especially successful in explaining and predicting aspects of the El Niño/Southern Oscillation a year or so in advance. Many expect that progress in such modeling will accelerate as computers become more and more capable. Also, as satellite-based measuring systems become more operational, oceanographers will continue to think differently about the oceans. If it were possible to predict sea surface temperatures a year or so in advance, then the statistics of the atmosphere a year or so in advance would be partially determined. At this point in time, it appears that statistical/empirical techniques seem to be better suited for long-range forecasting techniques. For example, a simple graph of Canadian and Australian wheat yields portrays how ENSO events are embedded in the wheat yields of these two countries, strongly suggesting that the Canadian prairies can expect lower yields in the next few years. Also, a simple accumulation of the PNA index was one of the factors used to correctly speculate on a cool summer in 1994 on the Canadian prairies.

What We Would Like to See from El Niño Research Communities

Those involved in El Niño research need to become much more precise in predicting the start and finish of each El Niño/Southern Oscillation (ENSO) event. Once an event is in progress, many phenomena around the world can then be anticipated. The 1991-94 ENSO event is an excellent case in point. There were some false alarms put out in 1990 that an event was occurring, but the event did not actually begin until 1991. Also, the event has been very prolonged. At the CWB, it has been referred to as the "George Burns" of ENSO events. In early 1992, there were indications that the event was dying, but then it reemerged in late 1992 and continued into 1993 and 1994. While statistical models such as the Cane-Zebiak model used by the Climate Analysis Center have proved successful at predicting the onset of warm phases a year or so in advance, its limitations were evident in failing to predict the detailed evolution of the El Niño resurgence in early 1993. This writer hypothesizes that this resurgence in early 1993 was a factor in the US Midwest flooding and believes that Jacob Bjerknes in 1969 was correct in stating that regular monitoring of the sea surface temperatures in the tropical east Pacific is indispensable for long-range forecasting in North America and South America. ENSO prediction itself presents a major challenge to research communities such as the Scripps Institution of Oceanography in California and the National Center for Atmospheric Research in Colorado. There is interest in Canada in examining indices related to ENSO, such as the Pacific North American teleconnection index, North Pacific Oscillation, and North Atlantic Oscillation and relating these to North American climate and yields. It is felt that some headway in longer-range weather and crop forecasting can be made by analyzing teleconnection indices related to ENSO and seeking sound statistical relationships.

Predicting the onset and length of El Niño events in the next decade or so could be of immense economic value as the La Niña phase of the ENSO periodicity represents the greater drought risk to North America. La Niña situations in 1983 and 1988 have been associated with $10 billion droughts in the US corn belt. Being able to accurately forecast the trends in warming and cooling seasons in advance within the NINO1, 2, 3, and 4 areas as defined by the Climate Analysis Center in Washington would be extremely helpful.

Recent studies (e.g., Khandekar, 1991; Yasunari and Seki, 1992) suggest an impact of the Indian and Asian monsoon on ENSO and the global climate system. More research needs to be done to determine the role of the Indian and Asian monsoon.

Extremely warm winters occur over the Canadian prairies during ENSO events. Advance knowledge would be of great planning value to companies involved in heating businesses. The extremely mild winter of 1991-92 came as a surprise to many of us on the Canadian prairies, and we need to be much better alerted by those doing research with the next ENSO event.

There seems to be a point at which ENSO events "lock in," tied in some way to the annual cycle which scientists need to understand more clearly. Also, ENSO events seem to persist through the annual cycle, possibly through the crucial flywheel effect of oceanic sea surface temperature anomalies.

K.M. Lau in 1988 and W.M. Gray et al. in 1992 have suggested that there may be a link between the QBO and ENSO, the QBO having a 24- to 30-month periodicity half that of ENSO. Any possible link between these two important forcing functions needs further research.

Major heat in the North American Great Plains occurs with eastern equatorial sea surface cooling and PNA blocking. Since 1964, the three hottest summers on the Canadian prairies were 1988, 1983, and 1970, all of which were foreshadowed by PNA blocking seasons in advance. The US corn crop was also devastated in 1983 and 1988. If a ridge is being thrown over North America, the PNA index captures it nicely. The PNA index tends to accumulate negatively during El Niño and positively during La Niña. The research community needs to figure out what causes PNA blocking, as it is a multi-billion-dollar question.

There is a teleconnective link between the Pacific, Bermuda, and Azores highs, which in this writer's experience occurs with the La Niña phase or east equatorial sea surface temperature cooling. These highs, their development, and interaction need to be better understood in relation to the ENSO periodicity.

Another teleconnection related to ENSO, which needs to be better understood, is that of the long wave positioning between 180°W over the North Pacific Ocean and the west coast of North America. The long wave position pattern in July on the west coast of North

America is crucial to the Canadian spring wheat crop, troughing being favorable, and ridging being unfavorable for drawing moisture from the Gulf of Mexico and over the Rocky Mountains. Troughing on the west coast of North America in July typically occurs during ENSO conditions. Scientists need to address further the question of what causes this ridging and troughing at 180°W and the related teleconnection to the west coast. Additional analysis of equatorial and North Pacific sea surface temperatures, together with an analysis of related atmospheric indices, such as the PNA, is presently being carried out at the CWB to identify useful predictors with longer lead times.

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Weather-Related Concerns of Chiquita Brands, Inc.

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Overview

The banana industry is quite big. It is the fresh fruit most consumed and most exported. Bananas grow best around 15 degrees either side of equator. In almost every country of Central America, the banana industry is the biggest single employer. It is the single most profitable item in supermarket. It is a capital intensive crop. It takes 2,500 to 3,000 year/hectare to grow and is also expensive to ship. Bananas grow year around. In 1960 we have switched to a shorter variety. We harvest every month. We allow certain maximum age. This is affected by climate; they like a lot of water.

Exports are increasing all the time. 1982-83 ENSO kept 82 flat and there was a decline in '83. It wasn't until '85 that we started to recuperate. Thus the effect of weather is significant. Chiquita has 24% of market share worldwide. Yield is 3,000 boxes per hectare. We diversify ports to ship out from, partly due to weather. The further the voyage, the younger they are harvested. We also ship to Japan and New Zealand. Some bananas are grown and consumed in Australia.

How does weather affect us? We pre-sell our fruit. In the short term, when the fruit is promised and the ship is ready, if we get a cold front and temperatures go down to 65, the fruit will stop growing and will not get up to grade. The optimum temperature is between 68 and 90 degrees. Winds are also a big factor. With our shorter varieties, fruit is only 10 feet above ground and wind is less important. Floods can also really affect us. With long-term winds we have plant losses. With floods that stand 48 hours or more, there will be a yield reduction.

What we would like to see is what the weather will be next 90 days: forecast of above normal or below normal precipitation, and wind prediction. We had a couple of private weather forecasters offering to help. We have good records that should be of some value to somebody.

Weather-Related Concerns

1. Agriculture

   - Production timing and fruit quality (forecasting)
   - Disease (Sigatoka) control, i.e., early warning as to potential outbreaks.

2. Economic -- production volumes versus market demands

    - Ship scheduling and ship chartering
    - Replanting due to floods or rehabilitation due to wind damage.

3. Early warning -- ship movements, employee and equipment safety

    - Alternative fruit supply

Problems in Chiquita's Areas of Concerns (Central and South America)

The following would be very helpful:

- 30, 60 and 90 day trend forecasts, i.e., rainfall more or less than normal.

- Temperature expectations, especially the low ranges and more especially those days that would drop to 60 degrees Fahrenheit or lower.

- Early warning on storms or tropical depressions that have potential to dump 5.0+ inches rainfall over short periods of time.

- Warning of weather systems that have potential of high winds in the range of 35 mph or higher.

- Would like to see at least a six-month rolling forecast on rainfall and temperature predictions for various regions of Central America and South America.

    - Areas would be Atlantic Coast of Panama and Costa Rica 100 km on either side of the border; i.e., from Almirante in Panama to the Limon/Guapiles area of Costa Rica.

    - Pacific areas of Panama and Costa Rica 150 km on either side of the border.

    - Sula Valley of Honduras from San Pedro Sula to Tela.

    - Guatemala -- Puerto Barrios area.

    - Columbia -- Uraba area and Santa Marta/Sevilla areas.

El Niño Forecasting and El Niño Research Communities

Would like to see:

1. Continuously updated long-term projections as to what areas would be affected by El Niño and what the most likely effects would be.

2. Four-to-six month lead time for the Peruvian/Ecuadoran coastal areas and what effects could be expected in Colombia and Central America both on the Atlantic and Pacific coasts.

3. More reliable rainfall predictions in the Guayaquil/Machala areas of Ecuador during the build up of El Niño conditions.

4. What changes scientists see in prediction models in the next five years.

Water Supply Forecasting and El Niño Forecast Needs

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Weather-Related Concerns

My group's primary activity is water supply forecasting including snowmelt runoff, and (jointly with the NWS River Forecast Center) flood forecasting on the major rivers of northern California. The former is a longer range forecast about six months into the future (or to the end of the water year on September 30) which could employ longer range weather forecasts if sufficient skill existed. The type of precipitation projection used for flood forecasting is a much shorter outlook (in hours) and probably not a target for ENSO type information.

The water supply forecasts are used by water project operators to schedule reservoir operations and water system deliveries. For the State Water Project, an initial conservative estimate of delivery capability is made in December which is adjusted (hopefully upward) as the winter rain and snow season progresses. However, most crop planting decisions are usually made in February when hydrologic uncertainty (the amount of water they will get) is still very large.

Potential Benefits from ENSO Forecasting

From a water operation standpoint, there are two thresholds of long-range forecasts which would be particularly useful in California. The first would be a reliable wet season (or remainder of set season through April) forecast early during the current water year (the water year is the 12 month period which begins October 1 and extends through September 30). A good monthly forecast of future precipitation by December 1 extending out 4 or 5 months would be very helpful to water operators and users. Such a forecast would still be very valuable on January 1, but in February at about the 60-65 percent point of precipitation accumulation for the water year, many of the major operational and planting decisions are made and, generally, only smaller adjustment are made as a result of later events. At that point, the major benefit would shift to a reliable forecast of the subsequent wet season (a 15 month forecast) which could affect the amount of reservoir carryover to save for a possible second dry year.

The second threshold of usefulness would be reliable long range forecasts out to seven years or so. This would enable water people to build facilities, and adjust market infrastructure to fit oncoming drought or surplus. Since it is doubtful any forecast of that length would be totally reliable, the interesting problem of how to deal with partial skill is posed.

Problems

Our water supply forecasts depend on accurate input data on precipitation, snowpack, and runoff to date. Future precipitation is assumed to be the historical median or some percentile of that (for example, the amount which has been exceeded in 90 percent of the years for a dry outlook). Obtaining reliable real time information from the watershed in time is one concern. Since the forecasting methodology is based on regression procedures, consistency with historical data is of paramount importance. There is real-time data from remote hydrologic stations, primarily rainfall and snow water content, which is telemetered into our office; this provides a good sense of what is happening, but we do not now rely on the remotely sensed data for the quantitative seasonal forecasts made on the first of the month during the late winter and spring forecasting season. Our monthly forecasts depend heavily on manual measurements of snow water content and precipitation in the mountain watersheds.

Some attempts have been made to use long range three month weather forecasts to improve a hydrologic forecast, using the skills which have been demonstrated from a period of record. Skill scores have really been too low for this to be useful; the reservoir operators may just as well look at the charts and say there is a suggestion of wetter, near normal, or dry future conditions and hedge operations accordingly if they have maneuvering room. The evaluations we have made of a 15-year experimental effort indicate some skill, in a three part system, on the order of 20 percent better than chance for winter and spring, but none for summer and fall. Skills were better in the late 1970s and early 1980s, then decreased to not much better than chance the last five years of the experiment.

Northern California is the main source of water for California's farms, cities, and wildlife. We have not seen any good relationship between El Niño years and our winter season precipitation. Some El Niño years are wet (notably 1983), some are dry.

Principal Weather-Related Concerns for the Upper Colorado River Basin States

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Weather-Related Concerns

The principal weather related concerns for the Upper Colorado River Commission and the Upper Basin States are drought and floods. Agricultural decisions regarding type of crops and time of planting could better match water supply availability if some type of reliable long-range forecast could identify periods of short water supply. Even though the Colorado River system has a great deal of storage capacity, many of the points of diversion are upstream of major storage reservoirs and are subject to site-specific runoff conditions. Therefore, short-term (one year) drought periods can create large impacts (example - 1977 drought). Investments in seed, fuel and labor could be saved with sufficient long-range prediction.

Floods also create structural concerns at these same diversion points unprotected by upstream regulation. Although floods are more difficult to mitigate, an advance warning would allow the completion of maintenance and temporary protection measures such as sand bags and Gabian Basket structures to minimize structural damage to diversion and conveyance facilities.

Problems

The reliability of magnitude and timing of forecasts is of greater concern to the system-wide operation of the Colorado River system. During the period 1965-1980 while Lake Powell was filling. the accuracy of forecasts was not an issue. Releases were limited to compact requirements and the remaining runoff was stored. However, when the system reservoirs are full or near full, the amount and timing of runoff become very important. Water years 1983 and 1984 are a perfect example. In early spring of 1983 the forecast predicted a runoff just slightly greater than normal. Although the forecast volume increased somewhat between January and May 1, the actual runoff exceeded the April and May forecasts by over 7 million acre-feet(maf), or about 200%. This additional 7 million acre feet created unprecedented spills of water from Lake Powell that could have been passed through the power plant earlier in the year by releasing in anticipation of such a large runoff.
Not only was a great deal of electrical energy lost, but approximately 40 million dollars of damage was done to the spillway tunnels. Cavities extending as much as 70 feet below the spillway tunnel floor and up to 200 feet downstream were eroded in bypassing the unexpected

runoff. In order to minimize this damage, spillway gate extensions (flashboards) were installed to allow an additional eight feet of storage in Lake Powell. The resulting downstream releases in excess of 95,000 cubic feet per second (cfs) also caused extensive changes in the riverine environment in the Grand Canyon.

The runoff of 1984 exceeded that of 1983! However, its magnitude was forecast early in the operating period and its volume and timing were near perfect. Even with the need to release an extra 1.5 maf of water in surcharge, the 1984 runoff was controlled with no water being released through the spillways, much less water bypassing the power plant and downstream releases only exceeding power plant capacity at 45,000 cfs for a few weeks. Even under less extreme runoff conditions the accuracy and timing (monthly volume) of runoffs are critical. The Criteria for Coordinated Long-Range Operation of Colorado River Reservoirs generally require Lake Powell and Lake Mead to fill together. When the two reservoirs are near the same capacity, releases from Lake Powell may exceed the "criteria" minimum objective release of 8.23 maf to accomplish this goal. These equalization releases are generally scheduled through the forecast period making the accuracy of even near average runoff forecasts important.

El Niño Forecasting

Our simple understanding of the present forecasting method is that the forecast is controlled by measured products. These products are snow on the ground, rain in the bucket and moisture in the soil profile. Other than some educated estimate of temperature trends, few long-range weather events go into the production of existing forecasts. The assumption is: today's moisture, tomorrow's temperature and average future conditions through the forecast period. That leaves a lot of inaccuracies in January 1 forecasts. Does El Niño help? Does such a technique hold promise to solve or soften the above concerns? Can periods of drought and surplus finally be predicted with some long-range accuracy and confidence?

We hope that the technique has arrived or has the real potential that its utilization and demonstration could be expedited. We are very dependent on the National Weather Service (NWS) for our runoff information. The data technology and transfer should be accepted at an early stage in NWS forecasting, and water users must be educated to the benefits and risks that such a process might invoke.

On the surface such a concept sounds scary! We must remember, however, that runoffs at present are considered mostly a "roll of the dice." Periods of drought and flood, drought and drought and flood followed by flood are real. Historical runoff data show little or no significant linkage between runoff events. There are no drought or flood cycles as some believe that are supported statistically. If the El Niño technique can unlock the mysteries of runoff cycles, the operation of the Colorado River system would be greatly enhanced. In addition, those water users in the Upper Basin that are not supported by reservoir storage would also benefit greatly. We hope it's reality.

Hydro-Quebec's Climate-Related Concerns

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Introduction

Hydro-Quebéc is one of North America's largest electric utilities. It generates, transmits, and distributes almost all the electricity consumed in Quebéc, and also sells and purchases electricity under agreements with neighboring systems in Canada and the United States. Hydro-Quebéc conducts research and markets its technological innovations and expertise, often in partnership with outside firms. It is active, too, in promoting energy conservation. Hydro-Quebéc is a publicly owned utility constituted by an act of the Quebéc legislative assembly in April 1944. In 1981, it became a joint stock company with a single shareholder: the Quebéc government. Hydro-Quebéc has become a driving force in the Quebéc economy as well as a corporation expanding on international markets.

Weather-Related Problems

Quebéc has an abundance of large waterways, which offer a reliable, renewable, and clean source of energy. The first hydroelectric generating stations in Quebéc were built at the turn of the century. Today, hydroelectricity makes up about 95% of Hydro-Quebéc's generation. Demand for electricity in Quebéc is highest in winter, when natural waterways are at their lowest levels. For this reason, we have built reservoirs for most of our generating stations. These reservoirs enable us to store the water needed for winter generation, while building up additional reserves. At year-end 1993, we had enough water stored to generate over 97 billion kilowatt hours.

At the end of 1993, Hydro-Quebéc had 84 generating stations in operation: 54 hydroelectric stations, 1 nuclear plant (Gentilly-2), 1 conventional oil-fired plant (Tracy), 3 gas-turbine stations, 25 diesel plants generating power for off-grid systems. Energy reliability problems related to hydroelectric generating facilities are not the same as those with a thermal system. In a thermal power system, when capacity requirements have been satisfied, energy needs can generally be met, unless there are serious problems in obtaining fuel supplies. In a system that is substantially hydroelectric, like Hydro-Quebéc's, the situation is quite different. Water inflows, not the operating capacity of the generating stations, limit annual energy output. The use of an energy reliability criterion thus becomes necessary.

The present Hydro-Quebéc power system has a very high hydroelectric component, as Table 1 shows.

Table 1
Generating Capacity of the Hydro-Quebéc System in 1992

	Power		Energy	
	MW	%	TWh	%
Hydroelectricity (includes Churchill Falls)	31,000	95	166.5	97
Thermal	1,750	5	5	3

Figure 1 shows the average distribution of monthly inflows and energy loads throughout the year. The energy load is higher in wintertime due mainly to the local heating (around 80% of Quebéc locals are electrically heated), while, on the contrary, the inflows are the highest in spring-summer.

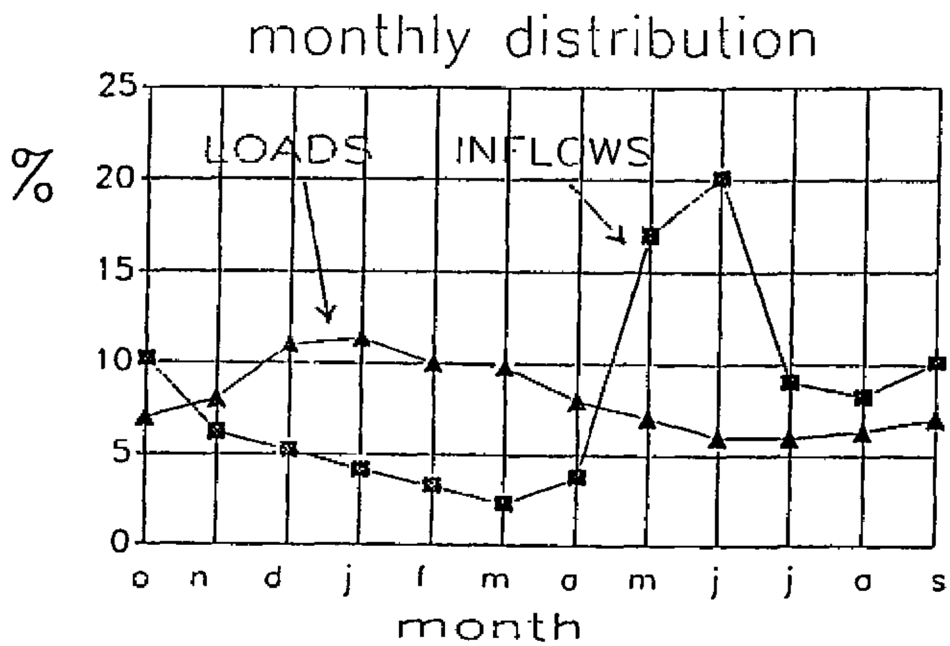

Figure 1. Average distribution of monthly inflows and energy loads throughout the year.

The annual energy supply has a standard deviation of 10% of the mean annual supply. Figure 2 shows the 1943-93 variations of the whole Hydro-Quebéc hydroelectric supply, and Table 2 indicates the inferred probability distribution of energy deficits for periods of one to 'our years.

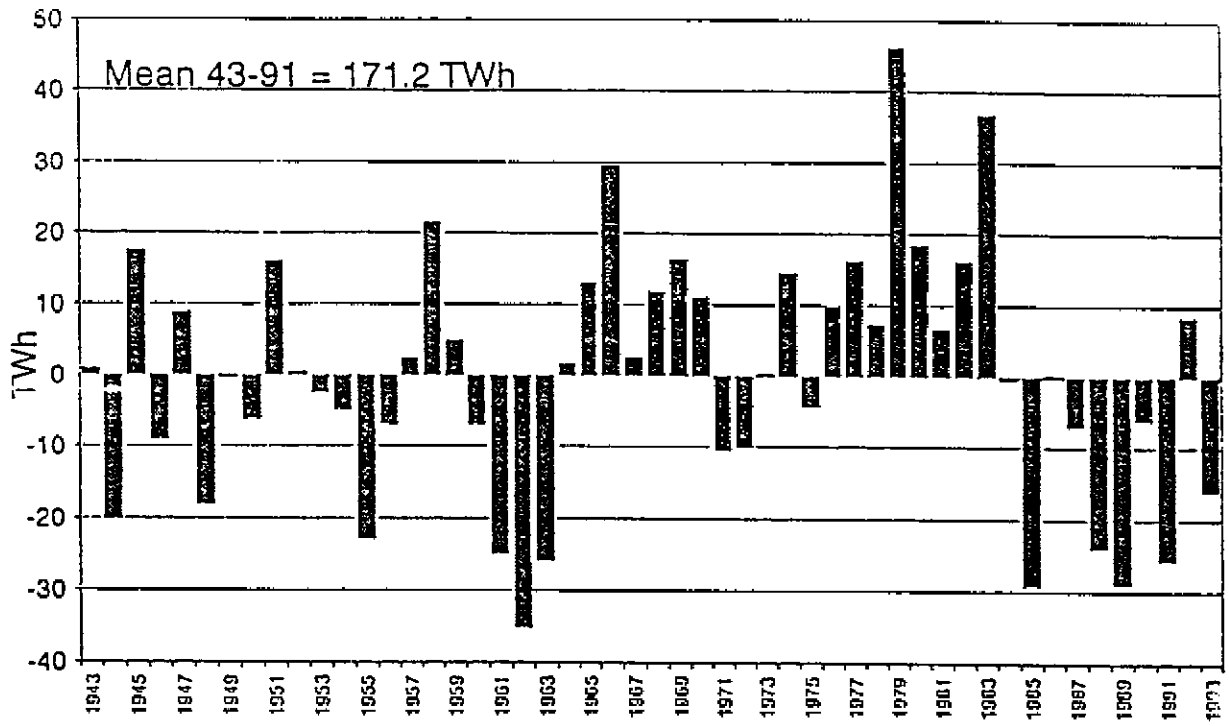

Figure 2. 1943-1993 variations of hydroelectric supply (Hydro-Québec).

Table 2
Probability Distribution of Deficits in TWh

Prob%	1 Year	2 Years	3 Years	4 Years
1	-40	-66	-88	-109
5	-28	-47	-64	-80
10	-22	-37	-51	-62
15	-18	-30	-40	-49
20	-14	-24	-32	-40

El Niño Forecasting

Energy load and inflows are related to weather elements as air temperature, wind, cloudiness, and precipitation. In fact, models relating these four parameters with inflows and load (and hourly electric consumption as well) have been developed and are used in our day-to-day operations.

What is required from the long-term forecast is its standard deviation or confidence limits. A forecast without its limitations can hardly be useful when we have to estimate the energy reliability of our system. We have calculated that a 1% decrease of the standard deviation of the energy supply for the next ten years could mean a $20 million benefit to Hydro-Quebéc.

El Niño forecasting has been proved to be feasible and will likely be reliable. Its effects are more apparent for the West than for the eastern portions of North America, especially for the Northeastern part, like the Province of Quebéc. However, delayed teleconnection between the West and the East weather seems to be an element of research for using somewhat indirectly the El Niño forecasts in the eastern portion of the continent.

Summary Comments

Hydro-Quebec is one of North America's largest electric utilities. It generates, transmits and distributes almost all the electricity consumed in Quebec; it also sells and purchases electricity with neighboring systems in Canada and the US.

The main part of its energy (60%) comes from the northern area of the province. Inflows are very low in wintertime and high during summertime while load, on the contrary, is very high in wintertime and low in summer.

The weather affects the load and the inflows. If a way is found to forecast long-term weather, it would be good news to Hydro-Quebec. Long-term forecast is used to calculate the price of water stocked in the reservoirs. The stock is variable throughout the years accordingly to precipitation, and at its maximum value can supply approximately one full year need of electricity for Quebec.

Figure 1 shows energy supply for the last 50 years. This energy is the potential energy of the inflows, calculated by applying the production factors of the power plants along the river. It has been quite variable throughout the years but for the last few years, inflows have remained below normal. Is it a normal pattern or change of mean? Is it related to ENSO? We are not sure. Hydro-Quebec is reacting to this new data, by incorporating it in the calculation of load supply reliability in the future years and is modifying its equipment program accordingly.

Very little significant correlation seems to exist in Eastern Canada with ENSO, while in the prairies and the West Coast of Canada, ENSO correlates principally with winter precipitation. Also significant simultaneous correlations were found between large atmospheric circulation indices as the PNA index, and both temperature and precipitation in western Canada.

More study is needed for Eastern Canada.

El Niño Forecasts and the Fishmeal Exporters Organization

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Due to its geographical positioning on the Equator, the ENSO signal in Peru is easier to detect than in the US. Also, as our resource (pelagic fish) is located in the ocean, it makes it easier to watch it. In spite of these favorable aspects, lots of questions remain unanswered on the relationship between the ENSO signal and actual resource availability.

Fishmeal is a protein for feed use, the best available on the world market, for poultry, pigs, aquaculture and now dairy cattle. Its present value is about $370 per metric ton, $450/MT at the level of the end-user. It competes with other proteins, particularly soybean meal which is presently cheaper.

Fishmeal is a small commodity, with a world production of about 6.5 million metric tons, fluctuating moderately over the years. Peru is the largest world producer, closely followed by Chile. Other producers include the USA, Scandinavia, the ex-USSR, and Japan, the latter two showing a sharp decline of their production.

World catches processed into fishmeal represent about 30 million metric tons of fish, about one third of total world catches.

Fishmeal is highly traded worldwide, with more than 50% of its production reaching international trade channels. Over time, it has become a highly competitive industry, particularly through the development of new technology.

The fishmeal industry is the leading sector of the present Peruvian economic recovery, which is showing one of the highest growth in Latin America (in 1994, the Peruvian economic growth will be higher than that of Chile).

As the world fishmeal market is essentially controlled by both supply/demand variability and physical stocks on hand at the origin, the producers are faced with two levels of uncertainty in the management of their industry: worldwide market fluctuations and resource variability under a highly unpredictable type of production system, fishing.

Thirty-four years ago, the major world fishmeal exporters founded the Fishmeal Exporters Organization (FEO) to create an information network allowing some transparency on the market. Although we have contacts with governments, it is exclusively financed by the world major producers/exporters, corresponding to about 40 processing companies. In fact, F.E.O. is a producer of supply/demand statistics through weekly and monthly statistical gathering systems. We also inform the members regarding the evolution of the world markets of competing commodities. We do little market forecasting work, although, we have developed a six-month forecast system, not built on econometric models, but rather on an opinion poll type of system, as is frequently used in the commodity environment.

One major problem for the industry is resource uncertainty on the supply side. A number of factors affect supply:

- it all starts with the ocean conditions, for which the input is climate and oceanographic conditions.

- then comes the biomass level, i.e., the pelagic stocks, including recruitment. Research has shown that such physical factors as the wind are important for pelagic fish recruitment (anchovies or sardines). The concept of optimum window developed by Curry et. al. allows a better understanding of how such criteria as sea surface temperature, wind, etc., may affect the reproduction cycle of the pelagic fish.

- the "fishing effort" is the third "upstream" factor which affects the resource. At this level, we include such resource management tools as fishing quotas or fishing bans, as well as the policies associated with vessel modernization and renewal.

Although the above three factors affect supply one way or the other, they have no direct impact in terms of market. The reason is that, in our industry, the first real market factor is the effective catch. And, in this respect, we have not been able yet to relate catch with ENSO signals or with the changes in biomass levels.

Processing is the first stage following catch. It is a market factor in the sense that it involves technology, source of market segmentation between the standard and the prime fishmeal. For example, the Peruvian industry which has traditionally been a producer of standard fishmeal, has moved through a modernization process into the special fishmeal market, therefore upgrading significantly the average value of its production.

Physical stocks in the hands of the producers represent the last supply stage prior to entering the worlds market. This factor is a key determining factor for the future equilibrium of the market.

We know, by experience, that ENSO has an impact on fish resources. For example, the correlation between ENSO and the anchovy biomass appears quite clearly in Figure 1. However, the impact of the last ENSO "warm event" (1991/1993) is not so clear. The episode did not really affect production in 1992. As a matter of fact, production dramatically expanded during the last months of the year.

As we can see on Figure 2, 1993 was not a bad year for Peru, although not as good as 1994. Retrospectively, though, maybe could we interpret the relative decline shown during the 2nd Quarter 1993 as associated with the ENSO signal? It was reported that, during that quarter, the fish were lean, small and had very low, if any, oil content, typically appearing to be under a stress. All this seems quite consistent with an ENSO event. But it comes to us as a surprise to note that the 1991/1992 "warm event" may have impacted the resource only in 1993. Obviously, other factors also played a role.

Chile and Peru produce about 2/3 of the world fishmeal and about 80% of the world exports. We know that the biomass is sensitive to ENSO signals. We are trying to understand how to relate them with our market but seem to be far away from a good correlation.

Obviously, in view of the above, the announcement of a possible 1995 new "warm episode" keeps our members very concerned. My question is: how will this new event develop? Can we already forecast any impact in our assessment of future production levels?

PERUBIOM Graphique 1

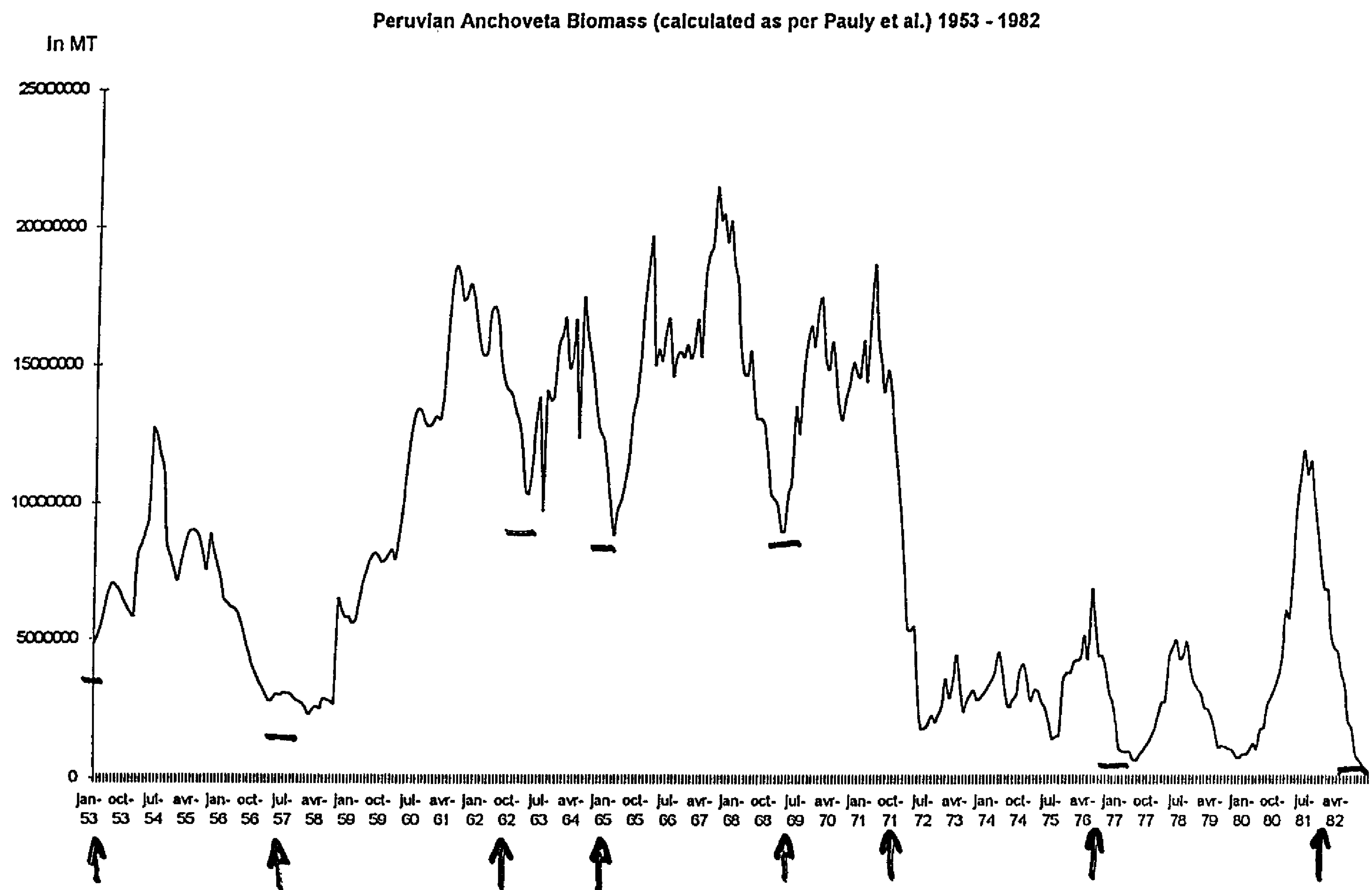
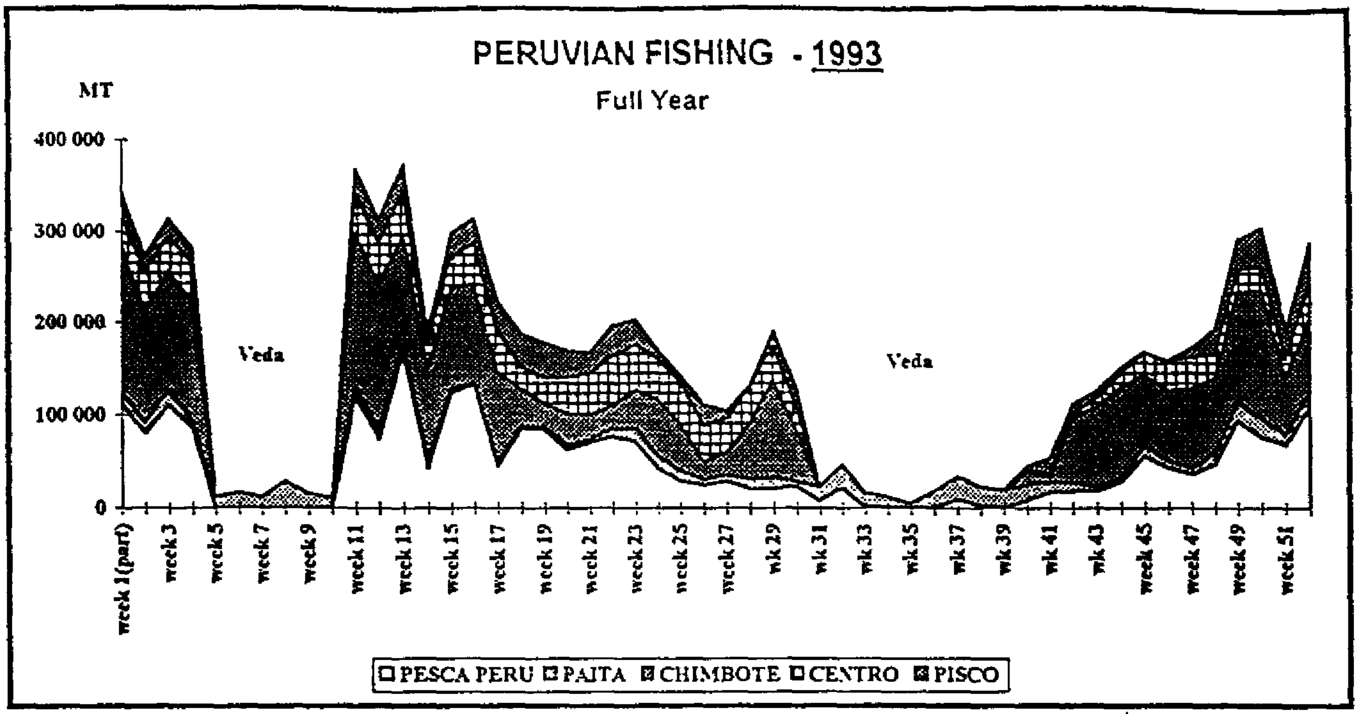


Figure 1


PERUVIAN FISHING - 1993
Full Year
MT
400 000
300 000
200 000
100 000
0
Veda
Veda
week 1(part)
week 3
week 5
week 7
week 9
week 11
week 13
week 15
week 17
week 19
week 21
week 23
week 25
week 27
wk 29
wk 31
wk 33
wk 35
wk 37
wk 39
wk 41
wk 43
week 45
week 47
week 49
week 51
PESCA PERU
PAITA
CHIMBOTE
CENTRO
PISCO

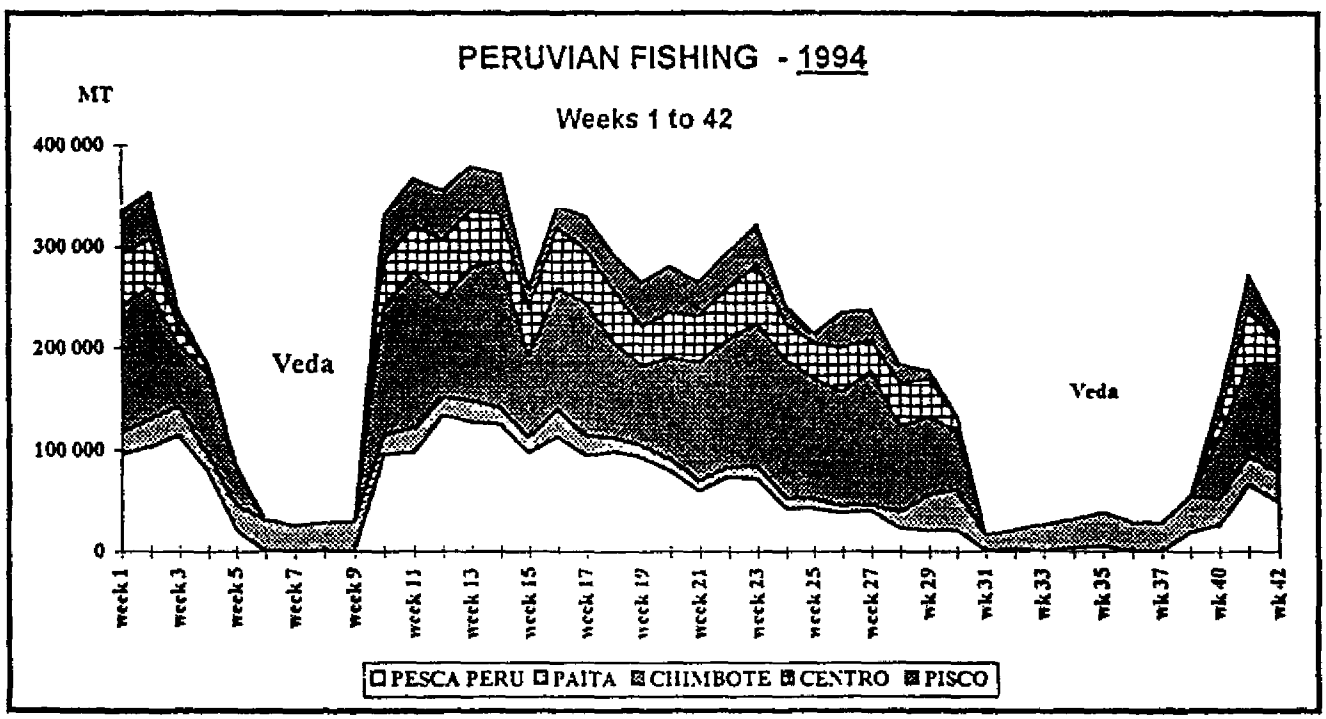

PERUVIAN FISHING - 1994
Weeks 1 to 42
MT
400 000
300 000
200 000
100 000
0
Veda
Veda
week 1
week 3
week 5
week 7
week 9
week 11
week 13
week 15
week 17
week 19
week 21
week 23
week 25
week 27
wk 29
wk 31
wk 33
wk 35
wk 37
wk 40
wk 42
PESCA PERU
PAITA
CHIMBOTE
CENTRO
PISCO

Figure 2

El Niño and the Media

John Cox
The Sacramento Bee
Sacramento, CA

Probably more than any other state, California relies for its basic agricultural, urban and industrial needs on the large-scale storage and transportation of water. Billions of dollars in dams and aqueducts and enormous pumping facilities have been built to deliver water from the mountains of Northern California, where most of the precipitation occurs, hundreds of miles to the heavily populated desert of Southern California.

This basic fact of life has formed much of California's modern history. It continues to shape much of the state's economic activity and to color much of its politics.

As the last eight years all but one of them drought years have made painfully apparent, climate and weather are big news in California. When "normal" precipitation in the Cascades and the Sierra Nevada fails to materialize, major economic, environmental and social dislocations can ensue. The competition for scarce water, of course, plays itself out in the media.

In the last several years especially, the challenge for California science and environmental journalists has been to accurately portray weather-related developments and climate studies in the larger context of the state's precarious water-supply conditions. But drought, or no drought, year in and year out, climate and weather news are major media products in California.

All of this is governed, of course, by events in the Pacific Ocean, and so by El Niño. We know we are in the path of these forces, but we don't know what that means to California.

The most recent story about El Niño to be published in The Sacramento Bee was a brief Associated Press dispatch from Los Angeles that appeared in the back of the paper September 16.

"El Niño may appear again this winter," it said, "and forecasters are trying to determine whether the wild card of weather patterns will bring drought, floods, or moisture in moderation."

The article then goes on to quote analyst Vernon Kousky of the National Weather Service to the effect that the emergent El Niño "could go either way." Kousky observes that, more often than not, El Niño events tend to make Southern California wetter than normal.

The story points up two areas of difficulty for the California media in relating El Niño events. The first and most obvious, of course, is exactly what to make of something that may bring drought or may bring floods or may bring moisture in moderation. Of what value is this story to the average newspaper reader? Does it tell the reader to be prepared for the possibility of weather extremes this winter? Perhaps, perhaps not. Phrased the way it is, one might be surprised that it appeared in the paper at all.

The story lacks important context. It is a little ironic that while the story contains the obligatory paragraph explaining the Peruvian roots of the name itself, it does not attempt to explain how the same event in the equatorial Pacific can produce opposite effects in Southern California. Moreover, in the ninth year of sustained water shortage, it mentions nothing about the potential effects of El Niño on the region of the state that is the source of most water supplies. Heavy rains in Southern California can cause floods that threaten life and property and impede travel. But unless snow falls in the Sierra Nevada hundreds of miles to the north, drought persists throughout the state.

Like most science news, climate research is not congenial to brevity or to the kind of "sound bite" treatment a lot of weather news gets. Still, El Niño research is very interesting science news, especially in formats that allow for graphic presentation such as ocean maps and drawings of El Niño effects on the ocean and atmosphere. Science writers of *The Sacramento Bee* have written numerous stories about El Niño and associated atmospheric research in recent years.

While its impact on specific human populations seems to remain elusive at least in California atmospheric scientists have more confidently described the effects of El Niño on the marine environment. We have written about how El Niño dislocates the cool California Current, curbing upwelling of nutrients along the coast, disrupting the food chain, causing die-offs of seabird populations and the appearance of warm-water species such as sea turtles and barracuda off San Francisco.

The role of the media is that of a conduit between El Niño researchers and a population composed of groups with various specific uses of the research information. In this regard, our needs from the scientific community have to do with access and accuracy.

If the most recent story to appear in The Sacramento Bee is an indicator, the state of the science of El Niño research does not suggest that forecasters are about to come up with a user-friendly consumer product on the subject. So there won't be an El Niño Index alongside the new Ultraviolet-B Radiation Index in our pages anytime soon.

Readers of this summary may notice that, beyond the science coverage, much of the interest of general circulation newspapers in El Niño research and forecasting is regional, if not downright parochial, in nature, like so much of weather news.

With few exceptions, media interest in climate and weather news is likely to remain regional in character, which must pose special challenges to scientists attempting to characterize global-scale phenomena. It would not surprise me to find that media interest in general, and newspaper coverage in particular, become more parochial rather than less as editors struggle to build readership with more "news you can use" type products. Reporters in general, including science writers, are under occasional pressure to bring their coverage "closer to home," or to relate it more directly to an increasingly urban readership.

We understand the state of the science to be model-refining, to be absorbing what must have been the enormous data set accumulated by the work of the many participants in the Coupled Ocean-Atmosphere Response Experiment in the western Pacific two years ago. If scientists are able to develop forecasts which accurately predict the regional impact of El Niño events in the years ahead, they will find a welcome audience among the media, especially in California.

El Niño is mentioned in California weather stories, of course, but also in stories about the catches of commercial fishermen along the coast, in stories about federal fisheries management decisions, in environmental stories about the endangered runs of salmon or die-offs of seabirds or mysterious beaching of marine mammals. Its mentioned in stories about the state's precarious water supplies.

It has been the subject of many science stories in The Sacramento Bee in the past few years. Most recently, our science coverage of El Niño research was an August 15 story about the report in Nature by oceanographer Gregg A. Jacobs at the Naval Research Laboratory at Stennis Space Center that remnants of the 1982-83 El Niño are still evident in the form of Rossby waves in the north Pacific.

ENSO and Its Effects on the Insurance Industry

Richard Roth
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Chicago, IL

Weather-Related Concerns

The prevention of loss of life and injuries is an important concern to the insurance industry. Thus, the issues of public safety and early warning are essential. Fortunately, the advances in early warning forecasts and the education of the public has been notable over the past few decades. the improvement in the forecasting of adverse weather and the universal accessibility to television have been important factors in this progress. Short-term forecasts are valuable for early warning to prevent deaths and injuries, but they do not significantly reduce insured property losses. There is benefit from the temporary protection of property (e.g., hurricane shutters), but there are many other factors which cause the destruction.

Insurance companies issue policies which cover loss to structures against a number of perils among which are wind, hail, and freezing. These are generally for terms of one year or more. Thus, the knowledge that a hurricane will hit a particular location within certain hours or days will not affect the amount of insurance in force. It is not possible, even if a company should so desire, to cancel insurance coverage on short notice. Not only would public reaction make this untenable, but it would not be allowed by the insurance regulator for the particular state.

The most important weather-related financial concern of property-casualty companies at present is the dramatic increase in losses to residential and commercial structures by wind, hail, and freezing. This has been influenced by the following factors:

- There has been a great increase in the population along the coastlines over the past two decades.
- The unusually low frequency of hurricanes in the past few decades has resulted in a weakening of building codes and their enforcement.
- The building of structures out of the urban areas into brush and forested locations in significant numbers.
- The failure to develop hail-resistant roofing materials.
- The lack of building code requirements to properly insulate water pipes in areas subject to infrequent severe freezes.

Problems Faced

Forecasts a year in advance of above-average occurrences of severe weather would assist individual insurance companies in modifying their marketing plans for increasing their exposure. This is particularly important since insurance is closely regulated in most of the states. Once additional policies are taken on, it is difficult to reduce the exposure. For these forecasts to be useful, the following conditions would have to be met:

- A reasonable degree of skill would have to be evidenced.

- Geographic areas likely to be affected would have to be identified.

However, even without forecasting skill, more accurate climatological probabilities would assist the various insurance companies to evaluate their individual rate level requirements. Rates for structures today are based almost solely on their fire characteristics with little consideration given to severe weather vulnerabilities. It would also help persuade model building code organizations to strengthen their building codes where needed.

Possible Contributions from El Niño Forecasting

The usefulness to the insurance industry will depend upon the degree of skill in forecasting the start and end of El Niño and the anticipated weather associated with it. A year's lead time is almost essential for any action that companies may take.

There are two different responses that would take place if sufficient skill is demonstrated. The first would be the response by an individual insurance company that recognizes the value of the forecasts and is willing to incorporate them in their marketing and pricing plans. There would be no concerted movement since strict federal anti-trust laws apply to insurance company marketing and pricing. A forward-looking company could gain advantage by:

- Plan to either increase their exposure or decrease it depending upon the outlook.

- Purchase more or less reinsurance depending upon the forecast.

- If the financial futures market for insurance catastrophes continues to grow, an individual company could hedge its risks.

Because of the strict regulation of insurance, the total exposure for the insurance industry as a whole will probably not decrease. However, the following favorable results for everyone could accrue:

- Insurance commissioners would be much less likely to put unreasonable caps on rates for severe weather perils.

- Model building code organizations would be more aware of the potential for destruction during forecasted periods of increased storm activity.

- During expected periods of above-average severe weather an increased public education program could be launched.

The usefulness of the forecasts ultimately will depend on a clear understanding of the link between severe weather and El Niño.

FEMA's Need for Weather-Related Information

Frank Tsai
Federal Emergency Management Agency
Washington, DC

Every day, millions of people wake up, go to school, go to work, farm their land or go to ball games. But every so often, the unexpected will happen: a tornado, a fire, an earthquake or some other emergency. Routines change drastically, and people are suddenly aware of how fragile their lives can be.

There will always be emergencies. Mitigating them, planning for them, responding to them, and recovering from them are responsibilities shared by federal, state, and local governments and the private sector. Federal Emergency Management Agency (FEMA) is the central point of contact within the federal government for major emergencies or disasters of all types. FEMA's mission is to reduce the loss of life and property from all types of hazards.

Many disasters are climate-related events, such as droughts, floods, freezes, and blizzards. Therefore, FEMA is very interested and concern about weather-related information such as El Niño for public safety, early warning, fire control, and impact assessment, just to name a few.

The mission of FEMA Mitigation Directorate is to develop, coordinate, supper, and implement policies, plans, and programs to eliminate or reduce the degree of long-term risk to human life and property from natural and technological hazards. The goal of the National Mitigation Strategy is to cut by half the loss of life and property damage caused by natural disasters by the year 2020. Thus, FEMA needs new and better user-friendly weather-related information, data, and study methodology, so that more lead time for mitigation and response actions can be provided to state, local, and private emergency managers through more reliable forecasts.

Sailors in the 18th century told us about the warm southward-moving ocean current which appeared around Christmas time. But now scientists have identified a link between seasonal weather extremes in North America and the occurrence of El Niño off the coast of Peru in the Pacific Ocean. The Midwest floods in the summer of 1993 and floods in Georgia and surrounding states in the spring of 1994 and all teleconnected with "El Niño."

Homeowner's insurance does not provide coverage against damage by flooding. Homeowners must obtain flood insurance from a federal program known as the National Flood Insurance Program (NFIP) administrated by the Federal Insurance Administration (FIA), a part of FEMA. If the teleconnections theory is proved to be true, then the FIA can consider selling a seven-year (or is it eight-year) term El Niño flood insurance policy.

Seriously, I would like to learn more about El Niño. Specifically, the research that has been done on this subject and how to use the information about the linkage and, of course, the future progress of research on El Niño in the next decade.

ENSO Information for Disaster Early Warning

Maxx Dilley
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Office of U.S. Foreign Disaster Assistance
Washington, DC

El Niño/Southern Oscillation (ENSO) forecasts have potential uses in disaster early warning. Lately, international disaster response agencies from donor countries have been consumed with responding to complex emergencies involving civil strife, large population movements and socioeconomic breakdowns. Historically, however, droughts and floods have killed and affected by far the greatest numbers of victims of any hazards, natural or manmade (IFRC, 1993). The overwhelming majority of the victims have been in developing countries. ENSO teleconnections affect amounts and timing of precipitation and the frequency of tropical storms in many parts of the world. Tendencies in the spatial distributions of droughts and floods worldwide during ENSO years have been identified by Glantz et al. (1987) and others. Recent research at the USAID Office of U.S. Foreign Disaster Assistance suggests that ENSO events during their later stages are associated with drought disasters in Southern Africa and Southeast Asia (Dilley and Heyman, in preparation).

Unlike complex emergencies, which are difficult to predict and prevent, progress has been made in anticipating and preventing, mitigating or preparing for disasters caused by natural hazards. Seismic monitoring and geologic mapping of earthquake-prone areas provide information on which to base urban structural and non-structural mitigation measures, and for preparedness in the form of civil defense and public awareness campaigns. Volcano monitoring can predict eruptions and allow evacuation of threatened populated areas. Storm warning systems allow evacuation of coastal populations to inland shelters on higher ground. If ENSO forecasts could be linked to specific regional hazards such as droughts, floods, storms or pests, they could provide a valuable early warning period during which prevention, mitigation or preparedness activities could be undertaken.

Worldwide, the costs of natural disasters equal or exceed official development assistance annually. The demand for disaster relief far exceeds available resources. Prevention, mitigation and preparedness strategies are needed to reduce the human and economic costs of disasters, as well as the need for disaster relief.

Linking ENSO Information to Disaster Prevention, Mitigation and Preparedness Action

A disaster results when a triggering event strikes a vulnerable population. Vulnerability is a broad concept, including processes affecting the individual or household, power and resource-access differences between social groups, geographic location relative to hazards and temporal aspects -- of long-term versus temporary vulnerability.

If the vulnerability of a significant number of people in a hazardous area is high, even a modest event can cause significant loss of life and destruction. A population whose vulnerability is low can withstand events of greater magnitude without experiencing disruption leading to a disaster requiring outside assistance. Natural disaster prevention and mitigation strategies are most likely to succeed by reducing vulnerability, since the magnitudes and timing of the events are generally not subject to human control.

Early warning systems allow short-term actions to be taken which either reduce vulnerability, such as evacuating the area, or that increase preparedness. Early warning by itself does not reduce disaster impacts; it must be linked to effective pre-disaster response. The response alternatives of international disaster response agencies are extremely limited -- basically to providing goods, cash, information or services. Vulnerability reduction must be undertaken by the society at risk, a process which must begin well in advance of the triggering event. The specific measures depend on the hazard. Floods may be mitigated by building levees, zoning enforcement, designation of evacuation routes or improved building designs. Drought impacts can be lessened through the diversification of non-agricultural income sources, accumulation of sufficient food stocks or measures taken to reduce economic impacts such as livestock destocking. In the most vulnerable areas, however, poverty and lack of access to resources make it difficult for vulnerable populations to cope even during non-disaster times. Under these circumstances, vulnerability reduction is very hard to achieve. Thus options for reducing the disaster risk are few for the affected population as well as for outside disaster response agencies. The real constraints on implementing effective vulnerability- reduction measures are the most limiting factor impeding disaster prevention, mitigation and preparedness.

ENSO Forecasts: How Might They Help?

Forecasts should specify the affected countries and the nature of the hazards they may face as a result of the occurrence of an ENSO event. Some may experience heavy rains leading to riverine flooding, others increased storm activity and potential storm surges. Other countries may be affected by drought. The forecasts need to provide estimates of the probable magnitude of these events and of their degree of certainty.

A useful drought or flood disaster early warning ENSO forecast would suggest likely impacts of the event. The impacts of climate fluctuations on societies and differing production systems are complex. Vulnerability reduction and preparedness may require action across a broad spectrum of social levels. Therefore forecasts need to be as specific as possible to the local conditions under which they are to be applied.

International disaster response agencies may find such forecasts useful for preparedness and relief planning. These agencies are often too preoccupied with existing emergencies, however, to devote much attention to potential ones. The greater payoff of ENSO forecasting therefore is likely to be at the national level, where longer-term preparedness and vulnerability reduction measures can be undertaken. In countries where droughts and floods are recurring phenomena, structural and non- structural mitigation can be instituted as part of development efforts whether sponsored by communities, national governments or international donors.

Disaster reduction begins with development. When drought and floods strike in developed countries the costs may be high but loss of life and suffering are minimal compared with the devastation these hazards cause in poor countries. The greatest benefit of ENSO forecasts will be realized if developing countries can make use of them as part of their own efforts to reduce disasters and promote sustainable development. National weather services need to understand ENSO teleconnections in the context of other regional and local synoptic climate controls. Early warning needs to be linked to effective policies such as range destocking, flood warning systems and public evacuation that minimize economic loss and save lives. Attempts to promote ENSO forecasts for disaster early warning therefore need to include mechanisms for integrating them into the development process at the national level, giving ownership to those with the most at risk.

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