EL NINO AND TUNA

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Ladies and gentlemen, after you have your tuna sandwich
and company talk, I want to take you away from the tuna and
bring you into another area of research. And, that is, I
want to tell you something about the changes that are going
on in our climate system.

In fact, the ocean and the atmosphere are the two
largest components in a large heat engine and the vacillations
of these heat engines determine the changes of our climate.
And one of the biggest signals in these up and down climatic
changes is El Nino. And this is what I want to report to
you today.

I'd like to tell you what El Nino is. I want to tell you
what the ocean responses during El Nino are and I want to
outline them on the example of the 1982 El Nino event. I
want to show you then what the atmospheric responses and I'd
like to discuss somewhat the causes of El Nino. There are
many possible causes and we don't really know what the main
causes are. I want to tell you then something about the
consequences of El Nino. And, last not least, I want to make
a few comments on how they might affect our local situation
and the tuna situation in the Pacific.

Now, El Nino is a short form of Hispanic for El Nino
de Jesus. And this is a small name that the local fishermen
on the coast of Peru and Ecuador have given to a coastal
current that runs south along the coast every year around
Christmas time. (first slide)

As you see here along the coast of Northern Peru and
Ecuador, every year at Christmas time, warm water transgresses
southward along the coast of Peru. And the local fishermen
have noticed (the phenomenon) a short time ago, over 200 years
or so, as long as statistics have been taken. Soon the
scientists recognized that El Nino was not occurring at the
same intensity every year. But there have been times when
El Nino was much more strong, when it was more long and people
called it catastrophic El Nino events. During that time,
fishery changed drastically. You have terrestrial rainfalls
in the coastal areas of Peru and Ecuador and flooding in the
low lying country. Now it was not until about the 1950's
or 1960's that people realized that El Nino was not a local
phenomenon in the waters of Peru, but that it was related to
much larger events in the ocean atmosphere system. (next slide)

And it was a Norwegian meteorologist at UCLA, who showed that whenever El Nino occurs, there are large changes in the entire system. The trade winds here and the northeast trades that are blowing over Hawaii and the southeast trades that are blowing from the coast of Peru into the Western Pacific. They are changing, and these changing patterns of ocean center of atmospheric circulation cause in turn, changing patterns of ocean circulation underneath. And it was this meteorologist who found these relationships and made the reference that the large oscillations in the ocean atmosphere system are related to the local event of El Nino.

He showed (next slide) that whenever in the Pacific Ocean, there is a large shelf of circulation with the trade winds blowing from the coast of America, Indonesia, there's a rising air and large amounts of air follow to Indonesia, and there is a return flow in the upper atmosphere and the sinking over the Eastern Pacific. This circulation has been called the water circulation. And it's one of the largest circulations systems that we have on the globe.

Now whenever this circulation system changes in intensity, then it has an effect on the underlying ocean. And that's what the UCLA meteorologist hoped to claim and could demonstrate on the basis of observations from various islands in the Pacific.

Now, my involvement with El Nino didn't really start until about 1970. But I was the only physical oceanographer in a group of population dynamicists who met in Lima in Peru to discuss the fate of the anchovy fishery.

The next slide will show you the dramatic effect that El Nino had on this fishery. In the 1950's and early 1960's, the anchovy fisheries started to develop in the waters off Peru. And it rose from almost nothing over one decade, to 1970, to the largest fishery on a single species, catching in the order of 10 million tons of anchovy each year.

Now we met there in Lima in 1970, because there were discussions going on under the sponsorship of FAO whether or not to limit the fishery. The government wanted to allow a limit of 12 million tons. The experts from their fields suggested 10 million tons. And they of course agreed to an average of 11 million tons. And that solution didn't have to be implemented. In fact, in 1972, came El Nino and El Nino wiped out the fishery. The following year, only two or three million tons of anchovy had been caught. And ever since that time, the Peruvian anchovy fishery has not recovered.
Now El Nino doesn't affect only the anchovy fishery. It affects also the birds that are feeding under normal conditions on the anchovy. And you see that before the anchovy fishery even started, there were about 28 million birds in the area of Peru. And there was another El Nino event in 1957-58, when the bird population dropped down to about six million birds. It slowly recovered until in 1965, the next largest El Nino occurred and then it dropped down to about four million birds. It recovered very little in the following year when fishing intensity was very high. And then in 1972, it dropped down to less than four million birds. And that is where it is still now. So you see that an event in the physical environment of our earth has such dramatic consequences to the ecosystem, to the fishery, and to the bird life.

Now at about that time in the years after that, we started to accumulate data on the 1972-73 El Nino, in order to try to explain. And in the next slide, you will see a few of these data that we could accumulate. Here you see sea level, on both sides of the Pacific, in the Galapagos Islands, in the east and far in the west in the Solomon Island during the period from 1970-1973. And what you see here is that in the years preceding El Nino, sea level is somewhat higher, only about 10 centimeters. That's so much in the Western Pacific Ocean because the trade winds are blowing stronger and sea level is being built up. And sea level is slightly below, about five centimeters below in the Galapagos Islands. So the Pacific is filled with output. That's a normal tilt of 40 centimeters from east to west across the Pacific.

Now when El Nino comes, the southeast trade winds collapse, very strongly reduce in intensity. And then suddenly sea level rises in the east by about 20 centimeters in the Galapagos Islands and it drops in the west over the duration of one year by about 30 centimeters. That means the flow, the eastwest flow at sea level becomes much less.

The next slide will show you in the schematic rate, this situation. In the other diagram, you see the normal situation. Normally, this normal rinse will have a slope of about 40 centimeters on the surface. And then at the same time the thermocline sinks down to the west. The trade winds that are blowing from the east to the west are accumulating warm water in the Western Pacific Ocean. They are thickening the surface layer who underneath keeps the warm layer. In the east, it's only about 50 meters.

Now when you have a very strong trade wind, this situation is intensified. You are getting more warm water in the Western Pacific and in the Eastern Pacific, the thermocline rises closer to the surface. At the same time, sea level
drops here and sea level increases here. Now when the wind system relaxes or collapses, then the water from the west, the warm water that has accumulated in the Western Pacific Ocean sloshes back like a surge from the Western to the Eastern Pacific. It deepens the thermocline, it raises sea level in the east, and over the course of events, the warmer water becomes less thick in the west and sea level in the west drops. And large masses of water float from west to east across the Pacific Ocean. And that is what we observe as El Nino on the eastern side of the ocean.

Now this situation has actually, in the next slide, been modeled by theoretical models and hydrodynamic models that can simulate the behavior of the ocean when the wind collapses. Here you see one of these computer models by the theory, and what is being done. You are modeling the winds from the ocean, the depression of the thermocline, then you relax the wind, and the ocean is free to behave. Water from the west is moving eastward, transgressing the thermocline, and the wave takes about two months to travel from the Western Pacific to the Eastern Pacific. After two months, it has reached the coast of Ecuador and then it starts to spread north and south along that coast. The thermocline after three months is depressed by about 50 meters along the coast of Ecuador. And at the same time, in the Western Pacific, the thermocline rises. And after almost a year, the eastern side of the ocean, the thermocline is deep and the water is warm, and then in the western side, the thermocline has risen. So we know that this actually happens, as the physics of that mechanism are quite well known.

And now I want to show you in a sequence of observations from the present 1982 El Nino event, how sea level behaved. What you see here are sea level observations, daily means at four stations. Ponape shows you the behavior of the Western Pacific, north of the equator. Christmas Island shows you the behavior of sea level at the equator. Santa Cruz in the Galapagos Islands shows you what happens on the eastern side of the ocean and Funafuti in the Southwest Pacific, a little bit north of Fiji, shows you the western behavior.

And now let us go through the sequence of tide. In 1981, the first third of that slide, very little happened at sea level at all these stations. And then in about June-July, 1982, the wind fields started to collapse in the Western Pacific ocean, in the Philippine Sea, and the area north of New Guinea. And this started to set up a wave. Sea level started to drop in the Western Pacific and Ponape. A couple of months later, in August, you see the sea level suddenly rising at Christmas Island. And you see here a period of about six months, when sea level is very high at Christmas Island. Sea level in Santa Cruz in the Galapagos Islands doesn't rise until about October-November. And it reaches
a first peak in December of 1982, when the surge of water from the Western to the Eastern Pacific reaches the eastern side of the ocean. Then by about the turn of the year, '82-'83, the wind field westerly winds actually shifted into the South Pacific Ocean. And there between the equator and about 10° south, you have a period when there are not trade winds blowing. They are actually from the west. And that triggered another wave that came from the South Pacific Ocean from the area between the Solomon Islands and Funafuti and it left to a drop of sea level of 40 centimeters. That's over a foot of mean sea level at Funafuti and to a second peak of sea level in Santa Cruz of the eastern side. Now I will show you that this situation is not only limited to the area near the equator, but is actually a very widespread signal that we are observing.

The next slide shows you the sea level deviation from normal, and the numbers are millimeters. And it shows you at the beginning of the El Nino when we suddenly got westerly winds over what is north of New Guinea and to the Philippine Sea, that sea level decreases here by about 15-20 centimeters in this area. The same time, a heap of water forms near the equator, blown by these westerly winds and this heap of water, also about 15 centimeters in height, starts to migrate eastward along the equator.

The next slide will show you the situation in September, '82. Now the area of a negative anomaly, that means of a drop in sea level, there's a maximum of 20 centimeters here is being much larger. We have a heap of water of about 20 centimeters near Christmas Island. You see, little entries so far on the eastern side, but there is already a signal here in San Diego and off the coast of Chile.

But if you come to the next slide, during that time, we have a very lucky coincidence. A colleague of mine from the Department of Oceanography, has embarked on a series of measurements, measuring ocean currents to the south of Christmas Island on the equator.

And this is a slide that shows the measurements of these currents. Normally, under normal conditions we have near the surface, the south equatorial current, the water flows from east to west under the influence of the trade winds. Anomalies at the depths of about 100 meters, you find a current, the under-current that flows at the equator from west to east. This normal situation is observed in the first half of 1982. And then suddenly in August of 1982, you'll find easterly flow in Christmas Island, totally unusual experience that they make. Easterly flow as high as 120 centimeter per seconds, that is four feet per second that water flows there for a period of about three months. And if you calculate out how far that water got, an individual water particle would have traveled
5,000 kilometers or 15° of the longitude along the equator. So here is direct measured evidence of the fact that water is actually moving from the Western Pacific to part of the Eastern Pacific in this big surge. You see it goes down to over 100 meter depths and it lasts for about three months with a mean speed of about 70 centimeters per second. Now let us go on with looking at the sea level. (next slide)

What is the response in December, 1982, after that wave has passed Christmas Island? Sea level is now over 300 centimeters. That is more than a foot higher. In the Galapagos Islands and along the coast of South America here, it is now negative over vast area of the Western Pacific. But largely north of the equator, 20 centimeters below normal. And this is all the water that has moved across.

Now we go on in time to the next slide, and you will see here in May, 1982, between about December and generally February, the wind field has moved from the northern to the southern hemisphere. And we have large area of westerly winds here. At that time, we have the formation of hurricanes that swept down into Tahiti and the Marqueses Islands over there, connected with that flow of westerly winds south of the equator. And now the sea level is dropping in this part of the world around Funafuti, the Solomon Islands and over to Tahiti. And all that water is now traveling east, giving us a sea level that is 40 centimeters above normal in the Galapagos forming the second peak of sea level. Now by July, 1983, the wind system has come back to normal, but the ocean has not yet recovered that fast. The recovery of the ocean takes a much longer time, you see that even in August, we have a depression of 30 centimeters in sea level in the Western Pacific. So you see that these responses of the ocean to the wind field are really large.

During the time when these very low values of sea level appeared there, we got many letters from the islands in the Western Pacific asking us what is happening. Is the island rising? We are finding that temperatures are becoming too shallow that fish cannot move in and out of the lagoons anymore. That the large amounts of reefs are dying off because it's exposed during low water everyday and otherwise it's covered with water. And they've been asking why is all that happening. These are depressions of sea level that we have never seen before as long as sea level measurements have been made on some of these islands.

Now let me show you the response of the surface temperature in the ocean during this event. Under normal conditions, we have the warmest water in the ocean in the Western Pacific. And it is in March, at the end of the southern summer, usually in the southern hemisphere more than 29° Celsius and in September, it is largest in the northern hemisphere. This is the normal expanse of 29° Celsius water.
But during the 1982-83 El Nino event, it was quite different. And I will show you a sequence of maps showing only the area to the east of the date line. You will note that in a normal year, the 29° water, the very warm water, is basically limited to the west of the date line, and in the area of Costa Rica and Southern Mexico.

Now when we come to the next slide, to that year 1982, there's a much larger area of warm water already in existence before the 1982 El Nino event. And then as the wind goes on, the area increases. You may see a progression of warm water from both sides of the equator and then at the equator to the Eastern Pacific Ocean by October.

In the next slide, you will see the progression from November-December, when all the water to the Galapagos Islands is potentially covered with water warmer than 29° C. So this is a tremendous change and since it's actually the warm water that has been surging from the Western Pacific toward the east.

Now I want to tell you something about the atmospheric response, which will explain to you in a certain way why this event that is centered in the Central Pacific Ocean has repercussions worldwide.

Now what you see here is in the middle of the Pacific and it's an idealized picture, an area of very strong cloud formation. That means an area where we have vertical movements in the atmosphere, a rise of warm air, moist air that leads to very strong rainfall. This area is normally over Indonesia. But when it comes to be situated in the Central Pacific Ocean, then we are getting an enormous development of atmospheric circulation. Theoreticians have calculated the response of the atmosphere to such a heat source.

It shows you here in this picture, how the circulation and about 10 kilometers altitude will change. That is the altitude where the jet fly and where the jet stream is in existence. The jet stream is a flow of air that goes from west to east all around the world, both in the northern and southern hemispheres. But that shows you the deviation when you have a heat source, and equatorial heat source situated in the Pacific Ocean, you will get an enormous flow from the east at that high level. You will get an enormous flow from the west in the mid-latitude. That means the mid-latitude jet stream will be intensified in both hemispheres.

In contrast, the water circulation which has a wind blowing from west to east above the equator, will be weakened. Now this pattern extends over the entire globe. And for that reason, we have changing weather patterns almost everywhere.
The rainfall that no longer occurs over Indonesia. Most of the rainfall occurs over the Central and Western Pacific Ocean. So you get a drought in Indonesia. You get also a drought in Australia because the pattern there has been changed. You get an intensification of the jet stream in mid-latitude. That means in that winter, we got a large intensification of outer tropical storms and these were the storms that were causing all the swells that destroyed the beaches in the Southern California and along the West Coast of the United States or the heavy surf you have heard about. These are the storms that have been traveling along here.

You have another development of an anti-cyclonic system there that is called the airflow changes over North America. The airflow changes over North America will either bring you a very cold or very mild winter. And these are the global repercussions. You have of course, at the same time, this terrestrial rainfalls that are usually connected to El Nino over the coast of Ecuador.

Now how does this come about? And now the next slide will show you something about the causes. Today, we can measure with satellites, many things in the atmosphere. First of all, we can measure the outgoing radiation. That means we know where the heat is being reflected from the atmosphere. And that tells us where all the very high cloud covers are. And where the high cloud covers are, that's where all the rain falls. And this is where the atmosphere gains all its energy, where the thick heat engine is located that is driving atmospheric circulation. But you see here that during December, 1982-February, 1983, this heat source, and the "w" stands for wet and the "d" stands for dry at that level. That means we have here many, many highly reflected clouds that show the location of the rainfall pattern and of the heat source. Whenever you have a heat source over that area, you have low level winds. That means the trade winds, the winds near the surface that are converging towards that heat source. And these winds at the same time, are causing surface water to converge towards that heat source or underneath the rain area. And when water in the tropics converges, then the area is warmer.

Now as you see here, that there is an association between events in the atmosphere and events in the ocean. This was the claim of people in the past. We have warm water in the equatorial Pacific and therefore we have a convergence of the wind and therefore we have rainfall and rising air and the divergence in the higher layers. And the ocean is driving this system.

Today, most people believe in particular meteorology that the atmosphere is causing a heat release. The atmosphere is gaining the heat. It is raining and the surface winds are the consequence. And the surface winds are pushing the
water together and makes the ocean warmer. And so you have here a coexistence between circulation states in the atmosphere and in the ocean. And this, most likely, is the situation that most things are necessary, that we have a positive effect between ocean and atmosphere that allows that situation to exist and it maintains the situation over long periods of time.

This pattern of heat release in the atmosphere is a big heat source. This, during the 1982-1983 El Nino migrate from Indonesia where it's usually situated to the Western Pacific between June and August to the Central Pacific in December and February and even further east into the Eastern Pacific between March and May, 1983. This was a time when you had all the severe hurricanes in the southern hemisphere. And earlier, you will recall we had Hurricane Iwa here in the Hawaiian waters which was a very rare situation.

Now in the next slide, I will show you a little bit on the effect of that pattern on global circulation. I mentioned already before in the color slide that I showed you, that an equatorial heat source is changing the pattern of global circulation at high levels and this has an effect on the lower levels. This is what people call tailing connections. That means if something changes in the atmospheric system in one location, it will have consequences in other locations, because the atmosphere is a global situation. In contrast to the ocean, we have ocean basins and they are somewhat separated from each other.

Now in this case, you may notice here that on this diagram, if this is the Western Pacific Ocean here, here is California, that we in the Hawaiian Islands are given by the fact that we have weaker trade winds, less clouds, less rain in larger parts of the Hawaiian Islands, that will show up as drought conditions. And this happens in the winter of the year 1982-83 for instance, when we had those kind of conditions. We are getting less rain through Kona storms and therefore have drought conditions.

Now in the next slide, you will see the largest scale patterns of winds that we are observing. Really, the area over Indonesia is the largest heat release area on the globe.

And that brings me to the question of explaining El Nino. And this is a very tricky one because there are many possible effects. Today, most of us believe that we have a large heat engine, ocean and atmosphere, which is a real turbulent system. And this turbulent system is subject to fluctuations.

Now in Indonesia, we have a low pressure system that is there most of the year. But this low pressure system
migrates north and south. In January-February, it is in the southern hemisphere over New Guinea and north of Australia. As you can see, the wind system as it converges toward that area of the world and that is where all the rain falls. In July-August, the system that converges is situated in the northern hemisphere over the China Sea partly and over the Pacific. And you see that the southeast trade system and the monsoon system over the Indian Ocean are converging towards that area. Now this is a process that happens every year. The swing of that convergence or rainfall between the southern and northern hemisphere. But in a certain year, this system will also make fluctuations east and west. And when this system happens to move over the Western Pacific Ocean, somewhat more to the east, then it apparently gets into that feedback system that I explained before. That means where the winds are causing anomalies in the warmer ocean, this warmer ocean feeds back on the atmosphere. And it's a self-reinforcing process. And once that process is being sent up by these random fluctuations of the Indonesian low, then we are getting the start of an El Nino.

Now an explanation that is being based on the randomness of such a system is of course very unappealing for many scientists. People want to have explanations that you can show a cross effect relationship and where you can say "b" follows from "a." It doesn't seem to be so. I think that the Indonesian system is just undergoing random fluctuations and this is what we have to expect. But some people still like to say that, "No, there's some warm anomaly before it happens in the Western Pacific Ocean that will actually trigger that system."

Now warm anomalies, warm temperature anomalies in the Western Pacific besides the effect of the Western Pacific which is always warm, are occurring all the time. They have very little magnitude and amplitude, and therefore, we can't really say which of these anomalies will eventually develop into an El Nino.

And I show you how this convergence of the wind system actually looks during the 1982-83 El Nino. (next slide) Here you see a case during the '71-'72 El Nino where data have been processed. You see here in the case of 1971, when the wind here was actually abnormal in terms of having a thick divergence near the equator. Winds were going away from the equator. And that means we have a very cold equator.

In contrast, in September-October of 1972, we have those very strong convergence of winds in the Western Pacific and that is the situation that reinforces the El Nino situation in ocean and atmosphere.

Now there are other possible explanations. (next slide) I'll show you something about the randomness of this process.
Here you see what people call the Southern Oscillation. The Southern Oscillation is a shifting between air masses, between the Indonesian area and stemming over to India and the area of Easter Island. And between these two areas, we have changes of atmospheric pressure. When atmospheric pressure is low here, it is high there and we have very strong trade winds flowing. The southeast trade winds over the Pacific, from over the Pacific Ocean and they accumulate all that warm water in the west.

On the other hand, when atmospheric pressure is relatively high here, and not so high over there, then the difference is small and the trade winds are weak. Now this is what people call the Southern Oscillation.

And the next slide will show you the time setting of that Southern Oscillation. And it shows over the period of 1950-1978, the fluctuations of the Southern Oscillation and how they are related to changes in the wind at the equator. Now these changes in the wind on the ocean can change by 50% between periods of a high intensity in the Southern Oscillation and periods of a low intensity. And you see that these come in instances of about several years high to eight years. And they are quite randomly distributed. People have not yet found any regularity and I think we don't really expect any regularity in the occurrence of El Nino.

Now there are other possibilities and other ideas in which El Nino might be affected. First of all, the next slide will show you something about the CO$_2$. You know that here, not far from you and Mauna Loa, you have an observatory that measures the CO$_2$ content of the high atmosphere. And we know that since people started to burn fossil fuels, the CO$_2$ content has been nothing but going up.

So we may have here an indication that the world is becoming warmer. But so far, we do not really know. Our information on both the ocean and the atmosphere over the last 50 or so years are not adequate at this time to tell us whether or not the global atmosphere or the global ocean has deviated significantly from a trend which is in the order of about one or two degrees in 50 years. This has not yet been established with certainty.

Nonetheless, there are indications that at least certain parts of the world have increased in temperature. Now this is ascribed to the increase of CO$_2$, and that may give us oceanographers, the idea that probably El Nino events have been becoming more frequent in the last few decades. We gain our information, our statistics are not really precise enough to test such ideas.

There is another possibility that is being mentioned by many people. And that is a connection between El Ninos
and volcanic activity. (next slide) Here you see the major eruptions of volcanoes. And you may have read that just in time for the 1982 El Nino, El Pilon erupted in South Mexico. And it blew tremendous amounts of dust into the atmosphere. There are some people who want to say that many of these eruptions preceeded El Nino events in the past.

Now this in turn is a nice hypothesis. But the evidence for that is rather shaky. We do not know how the dust accumulation in the atmosphere actually affects atmospheric circulation. And unless people can make computer models that will tell us the difference between an atmosphere or the difference in atmospheric circulation between a period in which dust was injected and in which dust was not injected, we really don't have the proof for it. It's a nice hypothesis, but that is all that it is at that time. In any case, it is one that one cannot outright reject. But the energies that are being released during an El Nino cycle are really so large that they can only come from ocean atmosphere.

Now I have already mentioned the number of the consequences that come out of the fluctuations that's associated with El Nino. I told you about the droughts that we have in Indonesia, in Australia, and also in South Africa. But how? From the Southern Oscillation, you see the influences going well over into the Indian Ocean area. There are relationships to the Indian monsoon. But these relationships are not as clear as, for instance, the appearance of rain at Christmas Island and the appearance of rain in the waters off Ecuador. Also the association of North American winters is not so clear. There have been El Nino, yes, with which we have very severe winters over North America. There have been El Ninos in years when this was not the case. So the daily connections of which I spoke earlier are very much dependent on the location of the heat source in the atmosphere.

Now there are other events that I already mentioned. That means the storm activities and hurricane activities that were changed in the equatorial ocean.

But now let me say a few words to the impact on the fishery and the possible impact. We know that the warm water that is moving eastward across the Pacific Ocean is also spreading north and south up along the coast of California, as far north as British Columbia, and down south as far south as Chile. And there we had displacements of the fishery. And I think it's proper to call them displacements. We know that the tropical fish from the Eastern Tropical Pacific have been caught further north. We know that every fishery off Southern California is displaced further north. We have heard that the salmon captures along the coast of Oregon and Washington were much lower. And that the Canadian
catches were way up. The catches of king crabs were way down. And similar effects were spreading southward along the coast of South America.

Now what are the reasons for that? First of all, most of the fisheries are very strongly temperature dependent. And therefore, when water masses are moving, the different locations and displacements along the coast can be as high as 1,000 kilometers. And in the open ocean, displacements can also be quite substantial. And when that happens, the fish stop and their migration moves may change. At the same time, the large scale ocean circulation like gyres, the North Pacific gyres, the north equatorial current that is sweeping near the Hawaiian Islands is changing the location. And consequently, their migration patterns of the tuna will change.

Now of course, when people are always trying to tie the changes of the fisheries of the abundance of fish that is locally caught to local events. But you see that we have to keep in mind the effect that outer changes in the ocean atmosphere system, the changes in the circulation changes of the ocean are really very large scale events that affect the migration of the various species in a large scale and not only in a local situation. So local changes will not be the causes, but they are the large scale patterns that have shifted. Now what do we need for the understanding?

I'd like to mention one more point. And that is, I watched this morning when Dr. Klawe talked and showed us one slide on the world catch of fish. I was really surprised how small the year to year fluctuations in that world catch really were.

In contrast, you have seen from some of the slides that I showed that fluctuations in atmospheric and oceanographic parameters are so much larger from year to year. And you just have to allow the fact that our natural systems are undergoing very large year to year fluctuations.

And I think in order to drive a better understanding of these things, we need better statistics and better observations. And this is the way I think a lot of fishermen in the local industry can help scientists to improve their knowledge by providing information. Occasionally I hear from people, "Oh, we know so many things about the local currents in our waters." But when I asked them what are these changes, "Oh, we just know it," but it is no where documented. And I think people could contribute to the understanding of the local situation and of local effects by making detailed studies and report their observations.

Thank you very much.
Question: Where are we in respect to El Nino right now? Are we in a decline of that, is it continuing or what?

Answer: Well, El Nino in the atmosphere, stopped in about August, 1983. And ocean effects were over by December of 1983. Right now we have rather intensified trades again. I would say that the situation is completely back to normal.

Question: The question I wanted to ask you, you see, when we had the drought year, right? There was also a drought in Fiji, Tonga, Samoa. A very bad one. But we've never had the least amount of rainfall that we had here. Yet on the other hand, just down here, beginning of the equator in the Line Islands, we had a tremendous increase of rain - in Fanning a Christmas. Now you say that we're back to normal, but we find our currents are still not right in the ocean. Our fish have not come back for three years. We don't see the bait that we normally have. I think we're still in a lot of trouble.

Answer: I have the feeling from your statement that if you say that your catches have been less than desirable for at least three years, that this situation has already started before El Nino. That means in the winter, '81-'82. ('81 was good, '82-'83 was bad) So El Nino didn't start until July, 1982. And so effects of El Nino, you could only expect that after that time. Now there are of course ocean effects that are lingering on. Waters off the coast of British Columbia are still above normal in temperature. And because these rates in ocean circulation are spreading very slowly. Now if you say that ocean circulation near the Hawaiian Islands is not back to normal, on what, you may experience probably here locally in the waters around Hilo. What has actually changed? (Well, our currents aren't running in the right direction. They don't change normally with the moon phases. Their currents are not nearly as strong now as they were two years ago.) Well, this is what I have in mind, if you could give us some documentation on, we could probably analyze that and learn something from it.

Question: You have observed, I think you mentioned in the beginning that the anchovy fishery off South America just did return after 1972-'73 El Nino. Have you made any observations in the permanent changes in the fishery, that obviously I'm talking about, our fishermen here, that's what I want to extrapolate. Is it common that these changes once begun by El Nino will not recover? Or is that estimates? You can generalize the question.

Answer: Well, once shouldn't blame El Nino for everything. I would say we have definite changes in parts of the world that are not El Nino related. There have been changes in the fishery around Iceland, and in the fishery in the Baltic or fisheries elsewhere in the world. And such changes are not
El Nino related. It is very difficult to say for a large area of the Pacific. And for our statistics, for information that goes back only about some 30 years, and in these 30 years, we have had perhaps five El Nino events. This is all what we have to build any statistical evidence. Now superimposed on these events of El Nino are of course, the influence of man. That means the fishing activities of man or any pollution problems or CO₂ increase. And such thinking is most difficult to separate on such a time scale, the recurring from the nonrecurring events. You see, El Nino is a recurring event. It happens sometimes five, sometimes ten years. And they are superimposed on that, they are trends in the development. And some of these trends are not reversible. And that is the reason why one can't easily separate what one does to the other.

Question: I have two questions. You mentioned about the randomness of the currents. What about the intensity of the phenomenon? Is it equilibrium or do you have, I've heard that this is one of the extreme events that we've been through now. What are some patterns with respect to that?

Answer: This El Nino event of 1982-'83, was the event of the century. The last event that had a similar magnitude was I think in 1878. Almost a hundred years ago. And all the events that are in our recorded history, that means where we have reasonably good oceanographic and meteorological informations have been weakened.

Question: My second question, because of this intensity in this past year, I remember seeing the slide that Dr. Brill put up there, in terms of the termal barriers for aku or skipjack. In terms of where a certain isotherm reached the surface, and also the mention of the lands in terms of that range of optimal water condition, when you have an El Nino phenomenon, and we have massive displacement of warm surface water heading towards the Pacific, towards the Eastern Pacific at the same time, deepening of that layer. It would seem like those little pockets of isolation in normal periods would just spill over and would lose some of those effects. So something like this on a large scale I think, might be very pronounced; it might stay with us in terms of age classes for skipjack for years to come. Or I suspect it in that regard. Has the volume of water actually increased for a certain temperature or has it newly been displaced and the fish can follow it in the water current?

Answer: That means, usually you get an increase of temperature and a thickening of the upper layer. These two events usually go hand in hand.

Question: Are the cold water upwellings back to normal now?
Answer: Yes, the cold water, the tongue of cold water that stretches from the Galapagos Islands to the date line over Christmas Island, this is back to normal. It's actually occurring of the last couple of months, it has been cooler than normal.