THE ENDLESS VOYAGE

"Going With the Flow" Episode 111

My personal feeling is that the mystery of El Niño is likely to be solved by some kid who is now in the sixth grade someplace and not by any of the scientists working on the problem now.

You can predict some average flow, but to try to predict how every little bubble and every little piece, every little weather system moves, is very difficult and, in fact, impossible.

When you first look at ocean circulation, there's a tendency to find a globe and look at the arrows and see where things go, and tend to think of that as a kind of steady system that's just always doing what it's doing. And we educate ourselves beyond that point pretty rapidly.

NARRATOR:
THE NOTION THAT A DROUGHT IN INDONESIA OR THE PHILIPPINES COULD BE CAUSED BY THE SAME CONDITIONS THAT PRODUCE TORRENTIAL RAINS IN THE UNITED STATES, PERU AND CHILE, MIGHT APPEAR TO THE CASUAL OBSERVER TO DEFY LOGIC. BUT IN FACT, THAT'S EXACTLY WHAT CAN HAPPEN DURING THE EXTRAORDINARY CHAIN OF EVENTS KNOWN AS EL NIÑO.

MICHAEL "MICKEY" GLANTZ, Ph.D., National Center for Atmospheric Research (NCAR):
El Niño is the appearance from time to time of warm water in the central and eastern Pacific Ocean. Normally, there's a pool of warm water in the western Pacific, and that's because of the way the earth turns and the winds blow. Water piles up in the western part of the basin, the sea level along Indonesia and the Philippines is higher by 60, 50 centimeters than it is off the coast of Peru. So what happens is, the winds keep blowing. The water piles up. It heats up in the western part of the Pacific. But then, once in a while—it could be every two years apart, it could be 10 years apart—that wind weakens, and that warm water that's piled up sloshes back towards the central and eastern Pacific. Where the warm water is is where you get your evaporative processes—evaporation and clouds that produce rainfall.

DAVID PIERCE, Ph.D., Scripps Institution of Oceanography, UCSD:
Now that has an affect locally, as you can imagine. Ordinarily, with all those rain clouds over Indonesia, there's a lot of rain in that region, there's rain over Australia. It's fairly dry in the east. During an El Niño, where you've got all this…convective precipitation over the east, it can rain a lot in that region. You can have flooding in Peru. Conversely, you have drought over Indonesia and Australia. It can also have affects pretty far away, and the reason that happens is the atmosphere can support these wave-like motions. It's just like dropping a pebble in a stream. Although the pebble is at one little place, you

know, the ripples can go very far away. So those ripples can extend, say, over North America and change how the weather patterns over North America are.

How much what you're telling us today about El Niño…being renewed…

NARRATOR:
IN RECENT YEARS, EL NIÑO EVENTS HAVE BECOME THE FOCUS OF INTENSE SCRUTINY AND DISCUSSION, NOT ONLY AMONG SCIENTISTS, BUT WITHIN THE RANKS OF THE MEDIA AND THE GENERAL PUBLIC AS WELL. IN FACT, HOWEVER, THE CONDITIONS THAT GIVE RISE TO THESE EVENTS HAVE BEEN OBSERVED FOR WELL OVER A CENTURY.

GLANTZ:
El Niño was named by the Peruvians. Actually, the first time we've been able to find it in print, looking through Peruvian newspapers, et cetera, has been 1891, 1892, 1894, 1895. It's the 1890's—early 1890's when it took hold. And it is because during the Christmas season that winter—December, January, February—the winds would become weaker—just seasonally weaker. And as a result, fish would disappear, the fisherman would fix their boats and their nets and that kind—they would lay off of fishing. And because it came around Christmas time, they called it El Niño with capital "E" and a capital "N," which means the Christ child.

STEPHEN RISER, Ph.D., University of Washington:
The original term El Niño was a much more limited term that had to do with the flow along the coast of Peru and Chile along South America. Now we know that this is not just a local event, it's a much larger scale event. It certainly encompasses the whole equatorial Pacific, maybe has some ramifications in the Indian and Atlantic Ocean as well.

NARRATOR:
ALTHOUGH SCIENTISTS UNDERSTAND A GREAT DEAL MORE ABOUT EL NIÑO EVENTS THAN THEY ONCE DID, THERE ARE STILL MANY UNANSWERED QUESTIONS. ONE OF THE MOST BASIC CONCERNS THE PRECISE MECHANISM THAT TRIGGERS AN EL NIÑO.

It appears to begin as an atmospheric event, which quickly transforms into an oceanic event. As the water masses in the equatorial Pacific redistribute themselves in response to changes in the wind, this redistribution of mass results in flows, which is what we call currents. But the redistribution of mass associated with that is also a redistribution of heat. And as the heat is moved around, this then feeds back into the atmosphere, and over quite long distances.

NARRATOR:
WHILE OCEAN CURRENTS PLAY A SIGNIFICANT ROLE IN THE CREATION OF EL NIÑO EVENTS, THEIR GLOBAL IMPACT EXTENDS WELL BEYOND WEATHER.

LIBE WASHBURN, Ph.D., University of California, Santa Barbara:
Ocean currents are very important for delivering nutrients, especially along coastlines. A good example is the California current system, which has a very strong upwelling along the coast, and the cool nutrient-rich water is brought to the surface and it is distributed along the coastline by the California current system. Organisms also depend upon currents for moving around. Many organisms have a planktonic phase where they drift freely in the ocean or swim very weakly, and they rely upon ocean currents for their movement.

NARRATOR:
SURFACE CURRENTS ARE INFLUENCED BY SEVERAL PHYSICAL FORCES, PERHAPS NONE MORE IMPORTANT THAN THE WIND.

PIERCE:
The winds blow on the surface of the ocean, and that causes what we call a wind stress, which is just a tendency to push the water in the direction that the wind's blowing. Now of course, the earth is rotating, so there's the Coriolis Effect, which means that the ocean water, when pushed by the wind in one direction, doesn't tend to go directly in that direction—it tends to go to the right. And as the combination of the direct pushing of the wind, the Coriolis effect, and the fact that water can get piled up against coastlines and provide a pressure gradient—which tends to push the water in a different direction—those combinations of factors determine where the surface ocean currents move.

NARRATOR:
THE INTERACTION OF WIND ENERGY AND THE CORIOLIS FORCE RESULTS IN WHAT WAS AT ONE TIME CONSIDERED TO BE A RATHER PUZZLING FORM OF OCEAN CIRCULATION—THAT IS, UNTIL THE EARLY PART OF THE 20TH CENTURY, WHEN A YOUNG SWEDISH OCEANOGRAPHER NAMED VAGN EKMAN DECIDED TO INVESTIGATE.

LEE-LEUNG FU, Ph.D., Jet Propulsion Laboratory:
The Coriolis force tend to push water sideways, but winds will push the water along the direction of the winds. When the two forces eventually balance each other, the compromise is the currents will move to the right of the wind, about 90 degrees. Instead, it's 45 degrees. So at the surface, this is called Ekman surface flow. And below the surface, the frictional force will decelerate the currents. Therefore, the direction of the deeper currents progressively deviate from the surface and create a spiral-like profile of a current over depths. It was first discovered by Ekman when he started drifting ice in the Arctic Ocean, always wondering why the ice flow doesn't follow the wind and it's to the right.

NARRATOR:
FROM VAGN EKMAN FORWARD, OCEANOGRAPHERS HAVE TRIED TO GAIN A GREATER UNDERSTANDING OF THE MOTION AND DIRECTION OF OCEAN CURRENTS.

People tend to think of the ocean circulation as organized into these recirculating gyres. And what I mean by "gyre" is a region where the ocean's circulation goes around in more or less in a circle.

PETER NIILER, Ph.D., Scripps Institution of Oceanography, UCSD:
Ocean currents circulate in large, circular patterns. Some places they upwell—that means they come up from depth—other places they sink. That means they downwell. In this process of circulating horizontally and vertically, they move heat from the equator toward the pole.

The largest dynamical features in the open ocean are the—what we call the sub-tropical gyres that occur in the major ocean basins. Good examples are in the North Atlantic and North Pacific basins.

Gyres tend to be forced by wind stress, which is the winds just blowing on the surface of the ocean, and also the Coriolis effect, which is the way water tends to move to the right in the northern hemisphere. Now the balance of the pressure gradient, which is water piled up in one region, you know, trying to push water away from high pressure, and the Coriolis Effect is called the geostrophic balance. Gyres tend to exhibit geostrophic balance, which is another way of saying that if you look at what factors are involved in pushing these gyres around, it tends to be a balance between pressure and the Coriolis Effect.

NARRATOR:
WHILE GYRES LOOM LARGE IN THE OVERALL SCHEME OF OCEAN CIRCULATION, PATTERNS OF SURFACE CURRENT MOTION CAN OFTEN BE QUITE VARIED.

PETER RHINES, Ph.D., University of Washington:
The ocean circulation is sometimes portrayed as a series of gyres and conveyor belts, which is an attempt at making sort of a mechanical story out of it. They're not really conveyor belts or simple rotating phonograph records—CDs, excuse me—but they're—they do have preferred pathways and they're somewhat chaotic. They're irregular and they're changing with climate, but they do have favorite pathways.

The surface currents have basically three spatial—what we call spatial scales. The strongest currents are along the western boundaries of all the basins. Those currents are typically 10 times stronger than any other part of the ocean. The next strongest currents are near the equator. And then the rest of the ocean contains kind of a broad flow. And this broad flow is punctuated by lots of turbulence and eddies.

Things like, the bottom topography of the ocean steers ocean currents in tremendously crucial ways. You'll find along the rim of almost every major ocean—on all sides you'll find interesting and strong currents. There's some tendency for these to pile up in the western sides, where the Gulf Stream is in the Atlantic, and the Kuroshio in the Pacific, and the Somali current in the Indian Ocean, but generally speaking, wherever you find a sloping ocean boundary, you'll find currents.

NARRATOR:
DEPENDING ON LOCAL CONDITIONS, CURRENTS CAN TAKE ON MANY DIFFERENT FORMS.

DAVID PIERCE, Ph.D., Scripps Institution of Oceanography, UCSD:
In some regions the surface water is actually moving directly in the opposite way that the wind is blowing. That's called a countercurrent. A famous example of that is the northern equatorial countercurrent. The winds are blowing from east to west, but the water is moving from west to east. Now the reason the water is moving that way is because water is basically pushed around by pressure gradients. Now you can also have undercurrents. The most famous example of that is the equatorial undercurrent. The equatorial undercurrent is this pretty thin ribbon of water which moves very fast from the west off Australia to the east towards South America. Now, it's under the ocean. It's about 100 to 200 meters below the surface, and it's moving quite rapidly, say, at about a meter and a half per second. It's this thin little strip of water. And again, that's forced by pressure gradients. Usually the wind is blowing from east to west at the surface of the tropical Pacific, so water piles up in the western parts. That makes high pressure there. And the water moves from the high-pressure region to the low-pressure region, making this under current.

NARRATOR:
GIVEN THE IMPORTANCE OF OCEAN CURRENTS IN THE MARINE ENVIRONMENT, OCEANOGRAPHERS HAVE TRIED FOR YEARS TO ACCURATELY MEASURE THEM, BUT THE CHALLENGES ARE FORMIDABLE.

Current measurements are among the most difficult oceanographic measurements to make, and the reason for this is that the current speeds are small. They require instrumentation that has to sit out in the ocean for long periods of time, or it requires that instruments be made from ships that are moving. And these ships are typically moving at speeds that are much greater than the ocean currents, which are the object of the measurement. Originally, current measurements were made with drifters or particles that were placed in the water, and their position was tracked over time. This could give an estimate of a current speed. Ship drift was an early method for measuring ocean current.

Of course, ships don't sail everywhere, and therefore we had much more data along ship-sailing routes than we had in other parts.

STEPHEN RISER, Ph.D., University of Washington:
In recent years, people have tried to make more direct measurements of currents. That is, to put an instrument in the water that will actually measure the flow.

And the current meter has evolved substantially over the years. Early on, current meters were propeller devices, much like a windmill, and the speed of rotation of the current meters would give an indication of the current speed.

NIILER:
This was done by the Europeans, mostly. And it was applied by the turn of the century.

LIBE WASHBURN, Ph.D., University of California, Santa Barbara:
Now we use acoustic techniques primarily, in ocean current measurement. And one of the revolutionary devices is called the Acoustic Doppler Current Profiler, which is a means of measuring ocean currents over the water column of the ocean—over depths up to a few hundred meters using sound energy. And these techniques have the advantage that they do not require instruments to be placed at several places in the water column, but often a single instrument can be moored or it can be placed on the bottom, and currents can be determined in the water column extending hundreds of meters above the instrument.

NARRATOR:
BUT EVEN WITH ADVANCEMENTS IN CURRENT METERS AND ACOUSTIC TECHNOLOGY, THE TASK OF MEASURING CURRENTS HAS PROVEN DIFFICULT.

RHINES:
Those are all great solutions, but they're also costly, and when you see the size of the oceans, and particularly the small size of the ocean currents and the eddies—100 kilometers, 50 kilometers—you've got the Pacific 10,000 kilometers wide and you've got hundreds of these structures. How do you map that out? It's really tricky. And there are few modern answers which are certainly worth mentioning. One is satellite altimeters are now orbiting the earth and telling us very accurately the height of the sea surface. Now that gives you a very good estimate of the surface circulation of ocean currents, and it's global and it repeats every couple of weeks. So that's been an amazing, amazing advance.

NARRATOR:
SINCE THE LATE 1970s, NOAA, THE NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION, HAS BEEN ACTIVELY INVOLVED IN STUDYING OCEAN CIRCULATION IN THE TROPICAL PACIFIC. IT HAS MADE EXTENSIVE USE OF SATELLITE-BASED COMMUNICATIONS TECHNOLOGY IN THIS EFFORT. MOST RECENTLY, IN PARTNERSHIP WITH JAPAN, NOAA HAS POSITIONED AN ARRAY OF BUOYS, KNOWN AS THE TAO-TRITON ARRAY, THAT EXTENDS FROM THE WESTERN PACIFIC TO THE COAST OF SOUTH AMERICA.

ED HARRISON, Ph.D., National Oceanic and Atmospheric Administration:
What the Tao Array is is a collection of about 70 moored systems. There's a mooring at the surface which is buoyant, which contains sensors that let us measure surface

temperature, surface wind, surface humidity—the things that meteorologists are concerned about who want to understand how the ocean and atmosphere interact. It also is moored down on the bottom of the ocean with wire and rope, and along that wire, in the upper part of the ocean, we have sensor systems like these which measure temperature conductivity, and other sensors that measure pressure. So we know the depths from which these measurements come. And they're coupled inductively through this system here. So the information makes its way back up to the buoy at the surface. The buoy talks to satellites which send the data back. They're collected, packaged together, sent to us, as well as sent to the weather forecasters of the world.

NARRATOR:
THE JET PROPULSION LABORATORY ALSO MAKES EXTENSIVE USE OF SATELLITE TECHNOLOGY TO BETTER UNDERSTAND OCEAN CURRENTS. THE JASON-ONE SATELLITE WAS LAUNCHED TO REPLACE THE AGING TOPEX-POSEIDON, BUT WHEN THE OLDER SATELLITE CONTINUED TO FUNCTION WELL PAST ITS EXPECTED TERMINATION DATE, SCIENTISTS AT J.P.L. FOUND A WAY TO UTILIZE BOTH SYSTEMS SIMULTANEOUSLY.

LEE-LUENG FU, Ph.D., Jet Propulsion Laboratory:
During the first phase, the two satellites basically measured the same spot of the ocean with only 60 seconds apart. So that it allowed us to see the same spot of the ocean with nearly identical oceanographic and atmospheric conditions. Therefore, we can compare the two to calibrate the new against the old and make sure that the measurements continue without any bias or differences. After this calibration phase, if Topex-Poseidon is still functioning, the plan is to move the satellite sideways to a new orbit. Therefore, with the two satellites, we can double the spatial resolution to study the details of the circulation never achieved before.

NARRATOR:
THE SATELLITE-BASED TECHNOLOGY USED BY BOTH THE JET PROPULSION LABORATORY AND NOAA HAS MADE AN EXTRAORDINARY CONTRIBUTION TO THE STUDY OF OCEAN CIRCULATION. BUT THIS TECHNOLOGY IS NOW BEING CALLED UPON TO PLAY A MAJOR ROLE IN WHAT SOME SCIENTISTS THINK MAY NOT BE POSSIBLE—THE SUCCESSFUL FORECASTING OF EL NIÑO EVENTS.

HARRISON:
Once an El Niño event gets rolling, we have a pretty good idea of how it's going to behave over the next six to nine months. But the particular details of what lead us into an El Niño still are things that require scientific attention, as well as improvements to our models, in order to make the kinds of skillful forecasts that we'd like.

1997 El Niño was the first one predicted with the input from sea surface height measurement. And it showed better skill. It's not a whole lot, and that's because we're still learning how best to use this kind of information. It's a very involved computation, because the model itself has millions of variables already. Now you have to ingest millions of bits of satellite observation of the ocean into this very complicated machinery.

Predicting El Niño is challenging for a number of reasons. One of the main ones is El Niño has various things that influence when it comes and especially how strong it's going to be. So it can be relatively harder to predict exactly how strong it's going to be, for example.

MICHAEL "MICKEY" GLANTZ, Ph.D., National Center for Atmospheric Research (NCAR):
Forecasting onset only tells you some process has begun. It doesn't tell you anything about how long it will last, whether it's a 12 months, nine months, 18 months or 24 months or whatever. It doesn't tell you how intense it will be.

NARRATOR:
BUT WHILE SOME ASPECTS OF EL NIÑO EVENTS SEEM TO DEFY PREDICTION, THERE ARE CERTAIN PHYSICAL CHANGES THAT CAN BE RECOGNIZED IN ADVANCE.

DAVID PIERCE, Ph.D., Scripps Institution of Oceanography, UCSD:
There's a predictable part associated with transport of waves in the ocean. So these waves are not surface waves like you would see at the beach. These are waves that occur inside the ocean, and are very large-scale and slow. Now because they're so large and slow, some aspects of that can be predicted rather far in advance, like, say, maybe 12 to 15 months in advance.

PETER RHINES, Ph.D., University of Washington:
We know that Kelvin waves and Rossby waves propagate respectively eastward for Kelvin waves and westward for Rossby waves along the equator—the full length of the equator. And they give a sort of rhythm to the ocean circulation, driven by winds on the equator. And when the easterly winds fail then that releases a warm pool of water from the western pacific, which propagates eastward as a Kelvin wave. And it's such a powerful thermal event that it then interacts back on the east-west and north-south circulation of the atmosphere, and leads to a further step in the rhythm of El Niño.

Now other parts of the weather that influence El Niño are very short time-scale. They're like storms that you might see, you know, rainstorms, and those are not predictable beyond, you know, seven to 12 days, generally. So those things can't be included in the forecast. So when you're trying to predict El Niño, you try to incorporate that slow-moving, long-term information in your forecast, and you try to add in the short-term weather variability as it happens.

PETER NIILER, Ph.D., Scripps Institution of Oceanography, UCSD:
The problem is, you're trying to predict the movement of a turbulent fluid. Imagine you're trying to predict every little bubble and eddy and swirl in a creek that flows among the rocks. I think that's very difficult. In the atmosphere, the specific weather systems

cannot be predicted longer than about two weeks. Climate, or El Niño, is an accumulation or an average over many, many weather systems. And because…the fluid is turbulent, because we don't quite know where the initial condition—where we should start the prediction from, we don't have accurate enough, or enough measurements, and because the equations which we use for prediction are approximate. And they will always be approximate. We can't seem to predict El Niño unless—until it's started, almost.

The problem is that after El Niño, some scientists say, "Now we understand it." And the next one hits you in a different way. It starts sooner than you expected. It's bigger than you expected. It's longer than you expected. Okay? It's not as warm as you expected.

Each El Niño is different. If an El Niño were the same or, in fact, we found it was same, then prediction is easy. But simply the flow is chaotic in the ocean, the flow is chaotic in the atmosphere. You're trying to make what's called sensibility out of chaos, and that is called prediction. And that we know is not easy to do. There are now maybe about 15 models worldwide that are used for prediction of El Niño. They're all different. They all make different assumptions.

NARRATOR:
FORECASTING EL NIÑO EVENTS CONTINUES TO BE AT BEST AN ILLUSIVE UNDERTAKING. STILL, AS OCEANOGRAPHERS AND OTHER SCIENTISTS CONTINUE TO EXPLORE AND LEARN MORE ABOUT THE DYNAMIC AND COMPLEX ENVIRONMENT THAT SPAWNS THESE EVENTS, THE HOPE PERSISTS THAT PROGRESS WILL BE MADE.

ANTHONY MICHAELS, Ph.D., Wrigley Institute of Environmental Studies, University of Southern California:
The history of the science of the oceans is one of under-sampling. We're stuck with limited tools and a massive ocean. So we go out there and we dip a bucket in the water. We go out there and we lower something off of a line and collect a few bottles of water. And a lot of the big advances have come because the new technology gave us a completely different window. We used to look through light microscopes, and we were limited by the resolution of what light could do. When the fluorescence microscope came along, we could blast those plants or animals with one kind of light, and look at the light, the fluorescence, that they create. All of a sudden it opened up a complete new world for kinds of plants. Satellites were the same thing. We used to go dip our buckets in different spots and try and make a map out of a few locations. All of a sudden we get a synoptic view of a massive landscape of the ocean—transformed our understanding. These eddies, these swirls, all these different changes in what the ocean was doing that we didn't see until we had that look. So every time a new technology comes in, it gives us a fundamentally different understanding, and moves our field forward in quantum leaps.

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