El Niño 1C

El Niño is a disruption of the ocean-atmosphere system in the tropical Pacific that has important consequences for global weather patterns. It usually occurs every two to seven years and is associated with a warming of the equatorial Pacific Ocean. The El Niño Southern Oscillation (ENSO) refers to the cycle between the warm El Niño phase and the cold phase known as La Niña.

Peruvian fishermen gave the name El Niño, Spanish for "boy child" and a reference to the infant Jesus, to the warm ocean current that typically appears around Christmas time and lasts for several months. Fish are less abundant during this time, so fishermen traditionally spend time ashore repairing their equipment. In some years the water is especially warm and the break in the fishing season persists until May or June. Scientists now use the term El Niño to describe these exceptionally strong warm intervals.

How El Niño occurs

Normally, trade winds blow from east to west across the tropical Pacific, pushing water away from the South American coast and piling it up around Indonesia. As a result, sea level is usually about half a metre higher in Indonesia than it is on the coast of Ecuador and Peru. The offshore movement of surface water causes cold, nutrient-rich water to well up from the ocean depths to replace it. This upwelling accounts for the high productivity of Peruvian waters, as the nutrient-rich water encourages the growth of dense phytoplankton blooms, which are food for small pelagic fish such as anchovetta and pilchard.

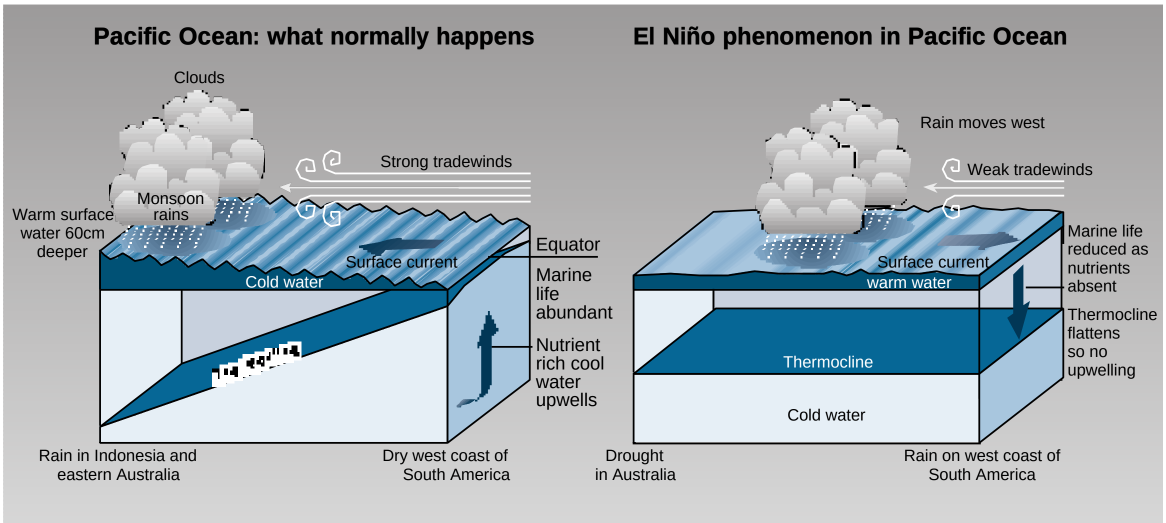
During El Niño, the trade winds slacken, and may even reverse direction. The warm water sloshes back across the Pacific and the thermocline (the transition layer between warm surface water and cold bottom water) flattens and deepens. Together with the cessation of wind-driven offshore movement of surface water, the thermocline inhibits upwelling, so sea surface temperatures rise rapidly and phytoplankton production decreases. As a result, pelagic fish move elsewhere in search of food, causing a ripple effect throughout the food chain and disrupting fishing.

Impact on weather systems

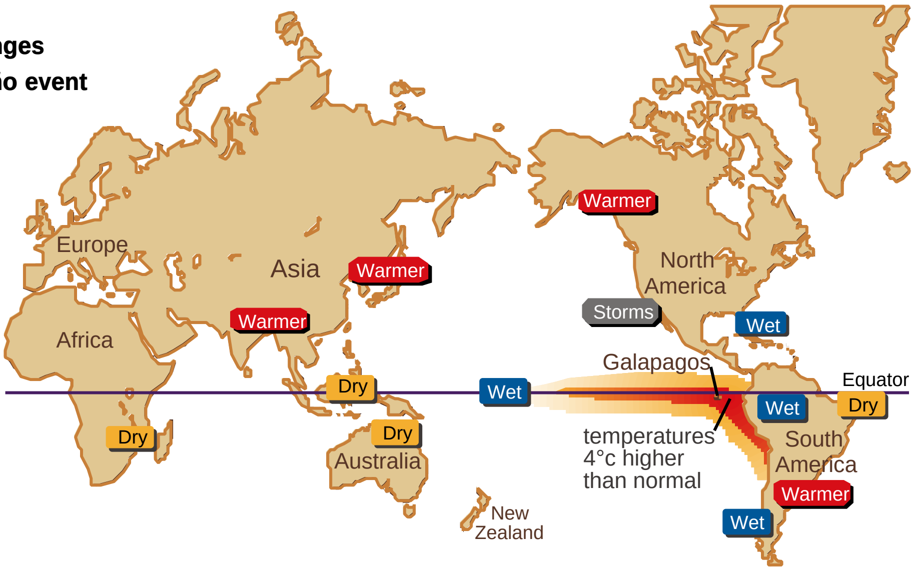
Evaporation from warm sea surfaces increases moisture content in the air above, resulting in cloud formation. In normal years, this leads to monsoon rains over Indonesia and dry conditions along the west coast of South America. During El Niño, however, the rain clouds follow the warm water eastward, bringing heavy rain to Chile and Peru and leaving behind drought, dust storms and wildfires in Indonesia and Australia. The dense tropical rain clouds also distort the flow of high-altitude winds, or jet-steams, which affect global atmospheric circulation, causing unseasonable weather patterns as far afield as North America and southern Africa.

Ecological impacts

The 1982-83 El Niño, the second worst on record, had severe ecological impacts. As the sea level rose in the east, it dropped in the western Pacific, exposing and destroying the upper layers of the fragile coral reefs surrounding many islands. Pelagic fish in the waters off Ecuador and Peru moved south, causing seabirds to abandon their young and scatter over a wide expanse of ocean in search of food. By the end of the El Niño, 25% of the region's fur seal and sea



Worldwide changes during an El Niño event



lion adults and all of the year's pups had died of starvation. Meanwhile, heavy rain transformed the coastal deserts of Ecuador and northern Peru into grasslands dotted with lakes. The lush vegetation attracted swarms of locusts, which in turn caused population explosions of frogs and birds, as well as malaria-carrying mosquitoes.

1997-98 El Niño

Following the 1982-83 event, El Niño reappeared in 1987, 1992-93, and 1997-98. This most recent El Niño was the strongest on record, and developed more rapidly than any other over the past 40 years. Ocean temperatures across the central and east-central equatorial Pacific averaged at least 28°C. This abnormally warm water spanned more than a quarter of the distance round the globe, and during September 1997 covered an area exceeding 24 million square kilometres. Sea levels rose in the Galapagos Islands and Ecuador causing flooding.

The El Niño was blamed for drought in Indonesia and floods in Chile, where torrential rains lasting nearly six weeks caused Humboldt penguins, listed as a threatened species, to abandon their nests at the large Algarroba colony. Prior to the storms there were 200 active nests, but afterwards only one bird with two chicks remained. In northern Chile, about 4000 brown pelicans invaded the town of Arica, causing traffic jams as they wandered the streets in search of food, as their normal food source of pelagic fish had migrated south. The El Niño also caused migrations of other species: off the Californian coast, fishermen reported unusual catches of warm-water species such as swordfish and Albacore tuna, while oceanic frigatebirds and petrels were observed close inshore. In Galapagos iguana and bird populations were decimated due to shortages of food. Fortunately, the summertime drought expected in southern Africa did not materialise.

Predicting El Niño

Worldwide, the 1982-83 El Niño caused economic losses of US$8 billion and about 2000 deaths through drought, floods and mudslides. These dire consequences, and the possibility that global warming will trigger more frequent and more severe El Niños, have motivated scientists to refine their ability to predict El Niño occurrences. The Tropical Oceans and Global Atmosphere (TOGA) programme initiated in 1985 uses data from automatic tide gauges, moored buoys that monitor winds and water temperatures, as well as drifting buoys that measure temperatures and movement of surface seawater. In addition, some merchant ships voluntarily take ocean soundings. This data is relayed via satellite to weather prediction centres around the world, where it is fed into numerical prediction models. As such computer simulations become more accurate and predictions of El Niño can be used for strategic planning of agricultural activities and management of food supplies, fisheries and water resources.

Author: Sue Matthews September 2000

FURTHER INFORMATION: • Nash, J. M. 1997. Is it El Niño of the century? Time Magazine, Vol 150 (7). www.elnino.com/link.html • Oceanography Department, University of Cape Town, Rondebosch 7706 • Suplee, C. 1999. El Niño La Niña Nature's vicious cycle. National Geographic vol 195 No. 3 Washington D.C.

RELATED FACTSHEETS: • Upwelling • Ocean Currents • Weather and the Sea

Red Tide 1C

Red tides are a natural and seasonal phenomena which occur widely off the coast of Namibia and South Africa as a result of nutrient enrichment from intense upwelling. Most red tides represent useful contributions to plankton production, but some produce harmful results. Harmful Algal Blooms (HABs) are the type we read or hear about most frequently in the media.

In recent years, HABs have caused increasing concern around the world because they frequently result in large scale fish mortalities, or shellfish poisoning which can adversely affect fish farming enterprises, coastal tourism and fisheries. Globally there is a belief among many experts that the scale and complexity of HABs is increasing. Some believe that this may be due to an escalation in nutrient enrichment from the land due to agriculture and sewerage effluent, or the result of climate change. Other experts attribute the apparent increase in HABs to heightened awareness and improved surveillance of the phenomenon.

In South Africa red tides and HABs occur most frequently along the west coast in late summer and early autumn, when prevailing winds blow surface water offshore, causing cold, nutrient-rich water to rise up from the deeper reaches of the ocean to take its place. This process is called upwelling.

Red tide organisms

Phytoplankton are microscopic, single-celled organisms that float in the sea. They are able to photosynthesise and form the basis of food chains in the oceans. There are three types of red tide organisms: dinoflagellates, diatoms and ciliates.

Dinoflagellates usually lie dormant on the seabed until they are lifted to the surface during upwelling where the ideal conditions of temperature and light trigger their germination. The dinoflagellates begin to grow and divide until there is a rapid increase in their numbers, sometimes to millions of cells per litre of water. This is known as a phytoplankton bloom. The concentration of the bloom by winds and currents leads to the formation of a red tide, which may colour the water red, orange, yellow, brown or even purple. (Water discolouration varies with the species of phytoplankton, its pigments, size and concentration and the time of day and angle of the sun.)

It is important to note that red tides are not the result of a sudden population explosion of phytoplankton, but rather the concentration of phytoplankton following normal population increases. If calm weather follows a bloom the plankton may become trapped in a bay, use up all the nutrients and die.

Mass mortalities of marine life

Certain types of red tide kill shellfish and cause huge mortalities of abalone, white mussels and black mussels. Other HABs do not harm the mussels but are stored and concentrated in their bodies so that they become poisonous if eaten by humans. Mussels remain contaminated for about four months. Most of the mass mortalities of fish and rock lobster, however, are due to oxygen depletion, either because their gills become clogged or because the oxygen in sea water is used up when the red tide dies and rots. During the decay process aerobic bacteria soon deplete the oxygen in the water and are replaced by anaerobic bacteria. Anaerobes obtain their energy by converting sulphur into toxic hydrogen sulphide gas. This gas smells of rotten eggs, turns the water black and poisons the remaining organisms. A “black tide” event in St Helena Bay killed 95% of all marine life.

Rock lobsters are particularly susceptible to oxygen depletion because they are unable to swim to the surface of the water where oxygen levels are higher. Their only refuge is in the surf zone, where wave action generates oxygen-rich water, but where they are easily left stranded when the tide retreats.

In 1997 the largest ever stranding of rock lobster on the South African west coast followed the decay of a massive bloom of the dinoflagellate, *Ceratium furca*, at Elands Bay. The total loss was estimated to be 2000t and concerns were raised about the future of the commercial rock lobster fishery in this area. Of particular concern was the fact that almost all of the stranded animals were under the legal size. Strandings of rock lobster, as a consequence of low oxygen events, are common on the west coast and are most frequent in the vicinity of Elands Bay, one of the richer rock lobster grounds.

Mass stranding of rock lobsters at Elands Bay

Shellfish poisoning of humans

Toxins produced by certain dinoflagellates are among the strongest poisons known to human beings. Shellfish such as mussels, clams and oysters are particularly vulnerable to red tides because they feed by filtering particles, including phyto-plankton, from the water. Toxic phytoplankton accumulate in the digestive systems of these filter-feeders and, although they do not harm the shellfish, they can cause illness or even death to birds, marine mammals and humans who consume contaminated shellfish. There are four distinct types of shell-fish poisoning.

Paralytic Shellfish Poisoning (PSP) In South Africa, PSP is associated with the dinoflagellate, *Alexandrium catenella*, which produces toxins that disrupt normal nerve functions. The resulting symptoms usually appear between one and five hours after eating contaminated seafood; they include tingling and numbness of the mouth, lips and fingers, accompanied by general muscular weakness and lack of coordination. Death may result from respiratory paralysis.

Paralytic shellfish poisoning is the most dangerous type of shellfish poisoning to occur in South Africa. Red tide warnings should be taken extremely seriously. Even a single mussel contaminated with the PSP toxin can result in death. Cooking only slightly lessens the toxicity of affected shellfish.

Diarrhetic Shellfish Poisoning (DSP) The dominant symptoms of DSP include diarrhoea, nausea, vomiting and abdominal pain. Because these symptoms are often confused with those of gastroenteritis, it is likely that Diarrhetic shellfish poisoning has gone unreported on many occasions.

Neurotoxic Shellfish Poisoning (NSP) In 1989 30 tons perlemoen were poisoned by the dinoflagellate *Gymnodinium nanasafeinse* and could not grip the rocks. The noxious effects of NSP may be carried by seaspray. During the 1995/96 December holiday season, visitors to False Bay, outside Cape Town, reported symptoms such as stinging eyes, difficulty in breathing, coughing and sneezing after they had come into contact with contaminated seaspray.

Amnesic Shellfish Poisioning (ASP) To date ASP has not been observed in South Africa although the species responsible for ASP is thought to occur in here. The symptoms are abdominal cramps, disorientation and memory loss.

Before eating shellfish contact the Redtide Hotline at (021) 402 3368. A recorded message will tell you whether it is safe to collect and eat shellfish.

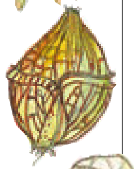
Author: Claire Attwood September 2000

RED TIDE SPECIES

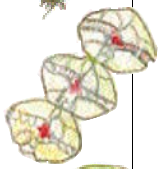
Dinoflagellates have two whip-like flagellae that pro-pel them through the water.

The decay of *Ceratium furca* caused a massive stranding of rock lobsters

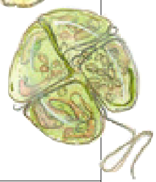
Gonyaulax polygramma can cause death when large blooms die off



A chain of cells of *Alexandrium catenella*, the most dangerous paralytic red tide organism, which is stored in mussels making them poisonous

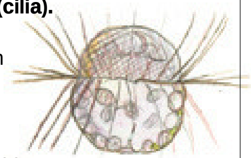


Gymnodinium species are responsible for neurotoxic poisoning.

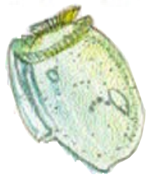


Ciliates swim using fine hairs (cilia).

Mesodinium rubrum is a common photosynthetic ciliate responsible for non-toxic red tides. Its die off can cause low oxygen events when large numbers of fish and shell fish die.



Dinophysis acuminata, one of four species that cause diarrhoea.



Diatoms

Pseudonitzschia pungens causes memory loss.

FURTHER INFORMATION: • Pitcher, G.1998. *Harmful Algal Blooms of the Benguela Current*. Sea Fisheries S. Africa, Dept Environmental Affairs
• Van der Vyver, I and Pitcher, G. 1993. *Red Tide and Shellfish Poisoning*. Sea Fisheries S. Africa, Dept Environmental Affairs

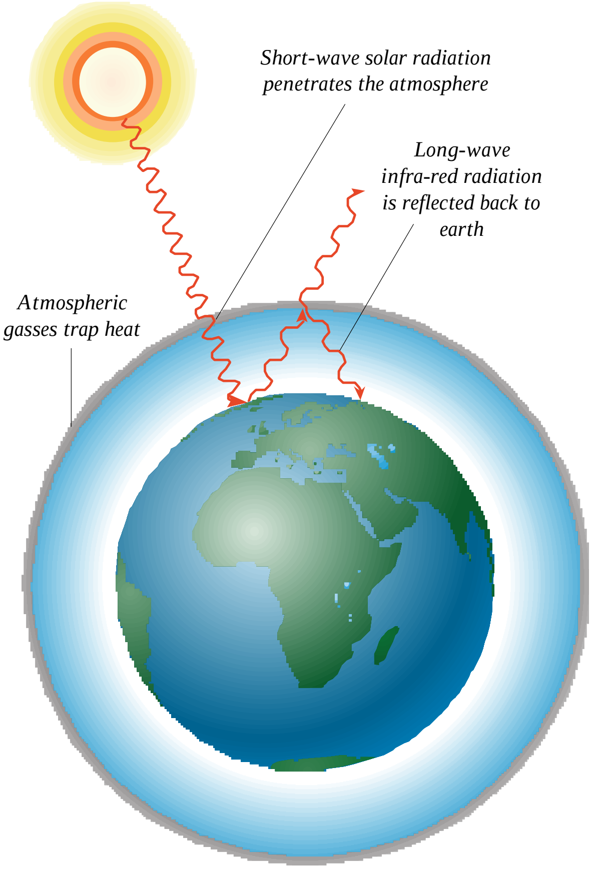
RELATED FACTSHEETS: • Bivalves • Ocean Currents • Upwelling • Rock Lobsters • El Niño • Plankton • Classification of Marine Species

Global Warming and Sea Level Rise 1C

The Earth's average surface temperature has risen approximately 0.6°C in the last 100 years, and the nine warmest years on record have all occurred since 1980. Many scientists believe that human activities are causing this global warming through an enhanced greenhouse effect.

The greenhouse effect is a natural process that prevents the world from freezing. Atmospheric gases such as carbon dioxide (CO_2), methane, (CH_4), nitrous oxide (N_2O) and ozone (O_3) allow short-wave solar radiation to pass through them, but trap the long-wave infra-red radiation reflected back from the earth's surface. These so-called greenhouse gases insulate the earth, which would be about 33°C cooler without their effect.

However, during the last century greenhouse gas concentrations have increased dramatically because of human activities, such as the burning of fossil fuels and the destruction of forests. With the aid of sophisticated computer models, the Inter-governmental Panel on Climate Change (IPCC) has predicted that the increased insulation of the earth by these gases will cause average global temperatures to rise by between 1.0 and 3.5°C by the year 2100.



It is feared that this will disrupt weather patterns, triggering more severe El Niños, increasing the frequency of natural disasters and decreasing crop production. Furthermore, while the overall productivity of the oceans and the global total harvest of marine species are unlikely to change, the distribution of fish stocks and the relative importance of different species is likely to alter, with consequent economic impacts on the countries that depend on these fisheries.

Predicted side-effects of global warming therefore include more frequent droughts and floods, food and water shortages, as well as disease, red tides, forest die-backs, species extinctions and sea level rise.

Sea level rise

Sea level has fluctuated dramatically over geological time. It was 2-6 m above the present level during the last interglacial period 125 000 years ago, but 120 m below present during the last Ice Age, 20 000 years ago. In the last 100 years it has increased by 10-25 cm.

But sea level rise is likely to accelerate because of global warming. As atmospheric temperatures increase, thermal expansion of the oceans and melting glaciers and ice sheets cause sea levels to rise. The IPCC has predicted that by 2100 sea level will have risen by 15 to 95 cm, with a "best estimate" of 50 cm.

People living in low-lying areas are most at risk from sea level rise, as stronger storm surges will exacerbate the damage from hurricanes and tropical storms. Coastal cities, ports and wetlands are expected to face more frequent flooding. Beach erosion will increase, while coastal streams and aquifers will be vulnerable to saltwater intrusion.

Small islands are particularly threatened by sea level rise. For example, the Maldives, made up of 1 200 tiny islands spread over an area of 90 000 sq km, is the flattest country on earth. No island stands more than three metres above sea level, and most are less than one metre high. The country relies largely on its tourism industry for generating foreign exchange, but many of its holiday resorts would be threatened by rising seas. In addition, the main supply of freshwater on the islands is from the underground water table. On small islands the lens of freshwater floating on top of the underlying sea-water is only a few centimetres thick, so just a small rise in sea level will greatly reduce the freshwater available to the Maldives' inhabitants and tourists.

Sea level rise is also expected to have profound ecological impacts. Destruction of wetland systems will result in the loss of bird habitat as well as important breeding grounds on which many marine species depend. Coral reefs rely on abundant sunlight for their survival, so if their growth cannot keep pace with rising water levels these ecosystems too will die, causing further losses of marine and coastal biodiversity. The Antarctic ecosystem may also be severely affected, because krill, the primary food of baleen whales, depend on the margins of the ice sheets for protection from predators and for grazing ice-algae. The melting of the ice sheets would thus have a ripple effect throughout the Antarctic food web.

Sea Level Rise in South Africa

Research has shown that the most vulnerable areas to the effects of sea level rise along South Africa's coast are:

- The Greater Cape Town area, from Melkbosstrand to Gordon's Bay
- The south Cape coast from Mossel Bay to Nature's Valley Port Elizabeth
- The Kwazulu-Natal South Coast and Greater Durban area from Southbroom to Ballitoville.

The greatest risk is posed from a combination of rising sea levels and extreme storm events, especially in relatively sheltered environments such as tidal inlets, estuaries, coastal wetlands and marinas.

For example, in the Cape Town area, the Woodbridge Island (Milnerton lagoon) and Marina Da Gama (Sandvlei) housing developments would be at increased risk of storm damage. Along the False Bay coastline, coastal erosion would reduce the size and safety of bathing beaches, and threaten recreational facilities and car parks. Large areas of the Cape Flats, where the existing water table is in places less than a metre from the surface, would be subject to waterlogging and flooding.

In Durban, which relies heavily on its bathing beaches to attract tourists, sea defences would need to be constructed to provide shelter from wave action and beach nourishment programmes implemented to replace eroded sand. Spring tides and sea storms would raise the level of the Umgeni estuary, causing flooding of the adjacent development.

Along the Cape south coast, private housing and roads surrounding the area's many river mouths, estuaries and lagoons would be the first victims of sea level rise, mainly because of extreme storm and flood events. By contrast, the main risk to the Kwazulu-Natal south coast would be posed by coastal erosion, threatening beachfront commercial properties, swimming pools and service roads, as well as the agriculturally important coastal railway line.

By ratifying the United Nations Framework Convention on Climate Change, South Africa has agreed to implement measures for adapting to the effects of sea level rise and other effects of climate change. Coastal zone managers and engineers have four main options at their disposal.

- Land-use planning strategies to prevent the siting of new developments in high-risk areas (e.g. encouraging nodal rather than ribbon development along the coast)
- Development control conditions to reduce the risk of damage (e.g. setback lines, flood protection measures)
- Construction of protective works to prevent damage to properties at risk (e.g. seawalls, groynes, breakwaters)
- Rehabilitation and management of dune systems (e.g. revegetation to prevent erosion of dunes, which form a natural buffer against storm damage).

Author: Sue Matthews September 2000

FURTHER INFORMATION:

• Houghton, J. 1994. *Global Warming - the complete briefing*, Lion Books, Oxford.

RELATED FACTSHEETS:

• Setback Lines • Sandy Beaches • El Niño • Ecosystems in the Sea • Red Tide • Islands around South Africa

For more information, please contact: The Coastal Management Office, Marine and Coastal Management, Department of Environmental Affairs and Tourism, Private Bag X2, Roggebaai 8012, Cape Town, South Africa. Tel: +27 (0)21 402-3208 Fax: +27 (0)21 418-2582 e-mail: czm@mcm.wcape.gov.za Website: http://sacoast.wcape.gov.za

Tsunami 1C

The Japanese, whose islands have felt the destructive power of giant waves for centuries, gave the name tsunami (pronounced 'soo-nah-me') to one of nature's most awesome forces – a series of waves capable of racing across an entire ocean at speeds of up to 900 km/h. Today the word tsunami is used internationally. It is more accurate than the English term,'tidal wave', because the great waves of the Pacific are unrelated to the tides.

Natural disturbances, like earthquakes, volcanic eruptions and landslides may cause tsunamis. Man-made disturbances, such as the underwater atomic explosions of 1946 can also set off the powerful waves, but the most frequent cause, by far, is an earthquake. Nowhere is the tsunami more in evidence than along the 'Ring of Fire' – the belt of frequent earthquakes and volcanic eruptions that circles the pacific. Every island and coastal settlement in the Pacific Ocean is vulnerable to the onslaught of the great waves.

Earthquakes cause tsunamis

The most destructive tsunami in recent history was generated along Chile's coast by an earthquake in 1960. Every coastal town between the latitudes 36ºS and 44ºS was destroyed or severely damaged by the action of the tsunami and the earthquake. More than 2 000 Chileans were killed, 3 000 people were injured and two million others were left homeless. The tsunami caused 61 deaths in Hawaii, 20 in the Phillipines, and more than 100 in Japan.

Tsunamis may be caused by volcanoes

In 1883 a series of volcanic eruptions at Krakatau in Indonesia created a powerful tsunami. As it rushed towards the islands of Java and Sumatra, it sank more than 5 000 boats and washed away many small islands. Waves as high as 12-story buildings wiped out nearly 300 villages and killed more than 36 000 people. Scientists believe that the seismic waves travelled two or three times around the earth.

A landslide caused the world's highest waves

The highest waves ever recorded were caused by an enormous landslide that took place at Lituya Bay in Alaska. About 81 million tons of ice and rock crashed into Lituya Bay, creating a tsunami that swept across the bay. Waves splashed up to an astonishing height of 350 to 500m, stripping the trees off the mountain slopes. Miraculously only two fishermen were killed.

The destructive power of a tsunami, a giant 'tidal wave'

Earthquakes beneath the ocean

Unlike exaggerated or fictionalized accounts, a tsunami is not a single, monstrous wall of water that rises out of nowhere to engulf a ship or a coastal community. Tsunamis usually occur following a large shallow earthquake beneath the ocean, but there are a number of instances where the earthquake that produced the tsunami occurred inland.

In the case of submarine earthquakes, tsunami waves are generated in the following way: when the earthquake occurs there is a noticeable displacement of the oceanic crust; a sudden upheaval or subsidence of the ocean floor may be produced. If this happens, the sea surface over the ocean floor deformation area will show a similar deformation. But, while the ocean floor deformation is permanent, the sea surface deformation is not. The return of the sea level to its normal position generates a series of waves propagating in all directions from the initially deformed area. At sea the tsunami waves may be less than 60 cm high, not even perceptible from ships or planes. By contrast, their wavelength is often more than 160 km. These long-period, surface waves have a vertical component and transmit a significant portion of the earthquake energy.

The speed at which the tsunami travels depends on the water depth. If the water depth decreases, tsunami speed decreases. In the mid-Pacific, where the water depths reach 4.5 km, tsunami speeds can be more than 900 km per hour. As the tsunami enters coastal waters, the velocity of its waves diminishes and the wave height increases. Waves are also modified by offshore and coastal features; submerged ridges and reefs, the continental shelf, headlands, the shapes of bays and the steepness of the beach slope may modify the wave period and wave height, cause wave resonance, reflect wave energy, and/or cause waves to form and crash onto the shoreline.

Nature's warning

The arrival of a tsunami is often heralded by a gradual recession of coastal water, when the trough precedes the first crest. This is nature's warning that severe tsunami waves are approaching.

Refracted waves cause double disasters

When a tsunami travels a long distance across the ocean, it may have an effect on a distant shoreline. This is because waves that diverge near their source will converge again at a point on the opposite side of the ocean. An example of this was the 1960 tsunami whose source was on the Chilean coastline. As a result of the convergence of unrefracted wave rays, the coast of Japan suffered substantial damage and many deaths occurred.

Damage and protection

The destruction caused by tsunamis stems mainly from the impact of the waves, the flooding and the erosion of foundations of buildings, bridges and roads. Damage is magnified by floating debris, boats and cars that crash into buildings. Strong currents, sometimes associated with tsunamis, add to the destruction by freeing log booms, barges and boats at anchor. Additional damage takes the form of fires from tsunami-related oil spills and pollution from released sewage and chemicals.

It is impossible to fully protect any coast from the ravages of tsunamis. Some countries have built breakwaters, dykes and various other structures to try to weaken the force of tsunamis and to reduce their height. In Japan, engineers have built broad embankments and breakwaters around ports and harbours in an effort to divert or reduce the energy of the powerful waves. But no defence structures have been able to protect low-lying coasts. In fact, barriers can even add to the destruction if a tsunami breaks through, hurtling chunks of cement about like missiles.

Author: Claire Attwood September 2000

FURTHER INFORMATION:

• Marine and Coastal Management, Private Bag X2, Roggebaai 8012. Tel: (021) 402-3043. Fax: (021) 421 2520.

RELATED FACTSHEETS:

• Tides • Global Warming and Sea Level Rise • Weather and the Ocean • Ocean Hazards • Salt and the Sea • Setback Lines