Erosion and Siltation 1B

The crash of waves on rocks and the swish of breakers swirling up sandy beaches are the dynamic agents of erosion and siltation that shape our coastline. Waves around the world generate a collective force equivalent to a 50 megaton nuclear blast each day. The constant motion of the water is crushing rocks and wearing down and polishing pebbles and then transporting the resulting sand to be deposited in calmer areas. Rivers are constantly changing their courses and, when in flood, carry enormous quantities of top-soil into the sea. These dynamic activities are of constant concern for coastal managers, for beaches and fore dunes can vanish after massive storms, rivers can be closed, intake pipes clogged and breakwaters can alter the flow of currents creating dangerous rip currents and the erosion of beaches.

Coastal erosion

Next time you sit on a rocky promontory, mesmerised by the motion of the waves, watch how the water from each wave runs away by following cracks and weaknesses in the rocks, relentlessly wearing away the seemingly hard surface. Look at how the different types of rocks are eroded. Table mountain sandstone, a sedimentary layered rock, erodes into pinnacles and blocks. Granite weathers into rounded boulders of varying sizes. At places such as Arniston and northern KwaZulu-Natal, the rocks are soft because they are formed from consolidated beach sand. At such locations waves cut flat platforms, backed by steep cliffs. On flat rocky platforms pebbles constantly tossed by the sea have acted as grinding stones carving out a myriad of pools where sea creatures shelter. Caves and blowholes have been patiently worn in rocky cliffs by spurts of water.

Half-heart bays and breakwaters

Half-heart bays are a common feature of southern African shores, and are formed where a rocky headland deflects the longshore currents, which are driven by prevailing winds. As a result the beach is eroded away near to the headland and builds up on the opposite side of the bay. A good example is Algoa Bay near Port Elizabeth. Artificial breakwaters projecting into the sea have the same effect, so that the beach builds up on one side of the breakwater and is eroded away on the other side. Breakwaters and piers across Durban beach deflect the long shore current and also prevent the input of sediment so that in some areas the beaches have become built up while in others they have been eroded away and have to be artificially replenished by sand dredged offshore. At Monwabisi resort in False bay, in the Cape, a breakwater was built to protect the beach but it has resulted in rip currents next to the break-water and a number of people have drowned. On some beaches the sand is scoured out by long-shore currents and is replaced by sand blown in from the

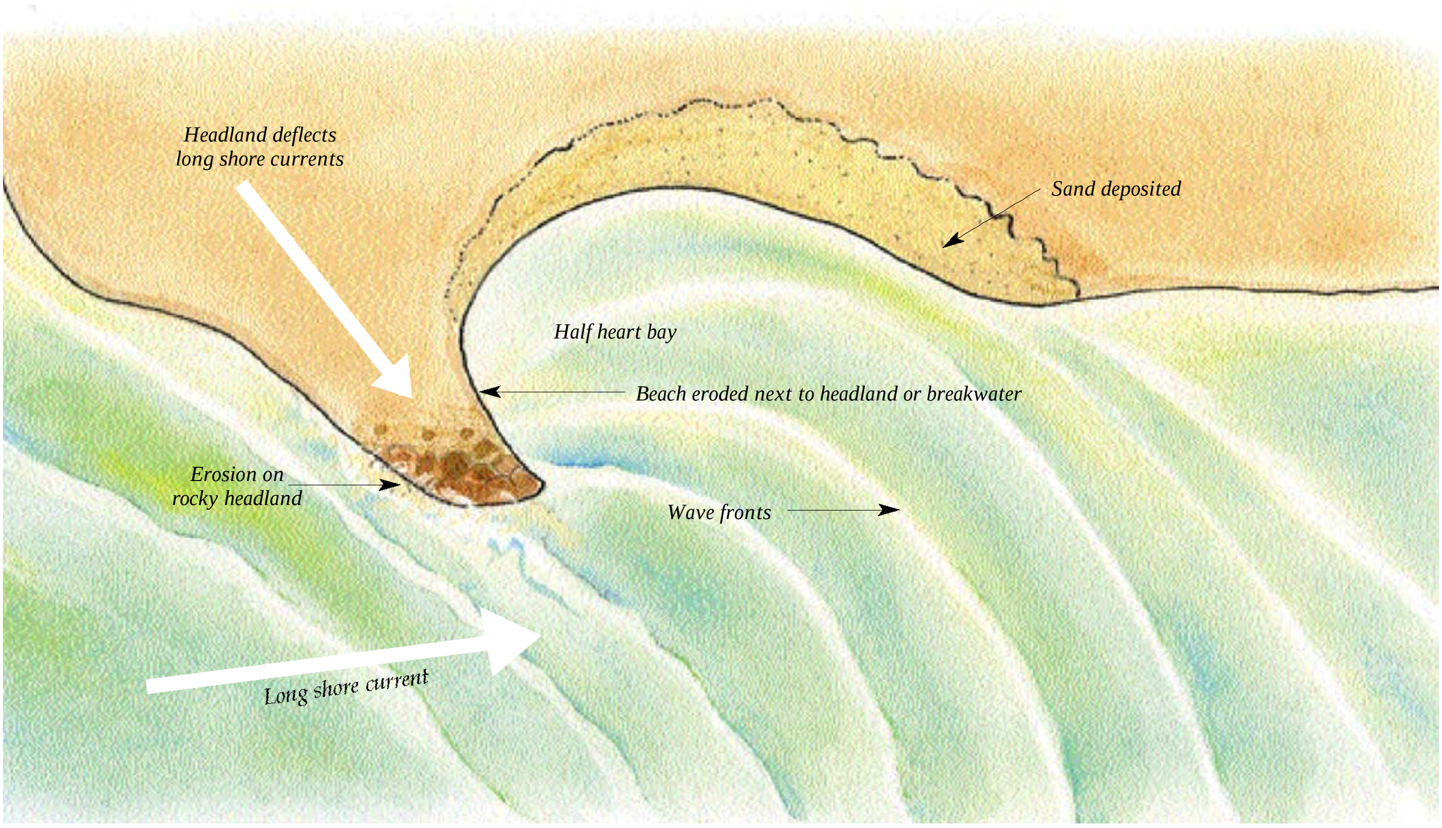

PHOTO: G.BRANCH

Carriage Rock at Kenton has been eroded by waves and sand.

neighbouring dunes. At Arniston when the dunes were stabilized with vegetation, the supply of sand to the beach was cut off and the beach was scoured away and turned into a boulder beach. The problem has been solved by removing the artificial vegetation from the dunes. These examples underline the need for impact assessments before building any structures that alter the flow of the sea or the movement of sand.

Erosion in river catchments

One of the most serious problems in South Africa is erosion in river catchments. Rainfall in many places is irregular and often falls as short sharp storms on parched earth with the result that top-soil is washed away down erosion channels. Several agricultural practices have contributed to severe erosion in the past: In KwaZulu-Natal the riverine vegetation was cleared and sugar cane planted right to the banks of rivers and there was severe bank erosion and loss of top-soil. Over-grazing by live-stock and the creation of paths directly down slopes has led to dramatic erosion channels in places like the Transkei. Where exotic trees, like pines, have been planted on the edges of mountains there has been rapid runoff of surface water causing erosion. Where found, the indigenous fynbos vegetation on the other hand protects the soil and has a spongy root system that traps and holds the water letting it seep away slowly over an extended period. In estuaries reed beds act as silt traps and filters. In a large river with a gradual gradient, like the Nile, the top-soil is deposited in a delta and overflow from the river in times of flood creates a rich fertile agricultural area. But in South Africa there are few deltas. The rivers on the east coast flow steeply down the escarpment, cutting valleys, and the top-soil is washed away into the sea. On the west coast there are few rivers and their flow is often disrupted by dams. The top-soil is collected in the dams and is lost to agriculture, while reducing the capacity of the dams. In the Orange River flood of 1988 over 3.6 million tons of sediment were deposited at sea within a few kilometres of the river mouth.

Controlling erosion

There are many practical ways in which erosion can be reduced. Farmers can practice contour ploughing around hills (and not up and down) so that the water is prevented from running down the slopes. Paths should also zigzag down hills to avoid creating runnels. The natural vegetation should be maintained along river banks and in catchment areas to prevent rapid runoff. When dams are built it is better to have a deep dam with a small surface area to reduce evaporation and the effects of siltation. Over-grazing should be avoided so that there is a healthy ground cover of plants to trap and hold rain. When marinas or harbours are built in estuaries the reed beds should be preserved to trap the silt and prevent the estuary from becoming shallow and turbid.

Author: Margo Branch 2000

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• Branch, G. M. & Branch, M. L. 1981. *The Living Shores of Southern Africa*. Struik, Cape Town.
• Water catchment display at Two Oceans Aquarium, Waterfront, Cape Town. Tel (021) 418-3823 Fax: (021) 418-3952, E-mail aquarium@twoocean.co.za

RELATED FACTSHEETS:

• Estuaries and Lagoons • Orange/Gariep River Mouth • Rocky Shores • Sandy Beaches • Sea Sand • Estuary Management

Tides 1B

The daily fluctuations in sea level, known as tides, have a profound influence on the animals and plants inhabiting South Africa's shores. They are also important for human users of the coast, as low tide allows better access to the shore for activities such as bait collection or beach driving, while boat-launching is best done at high tide. For this reason, the Naval Hydrographer produces tide tables each year, which detail the state of the moon and the predicted times and heights of low and high tides.

How tides work

Tides are the result of the gravitational force of both the sun and moon on the earth's oceans. The moon has the greater influence as it is much closer to the earth than the sun, so the tides are said to follow a lunar cycle.

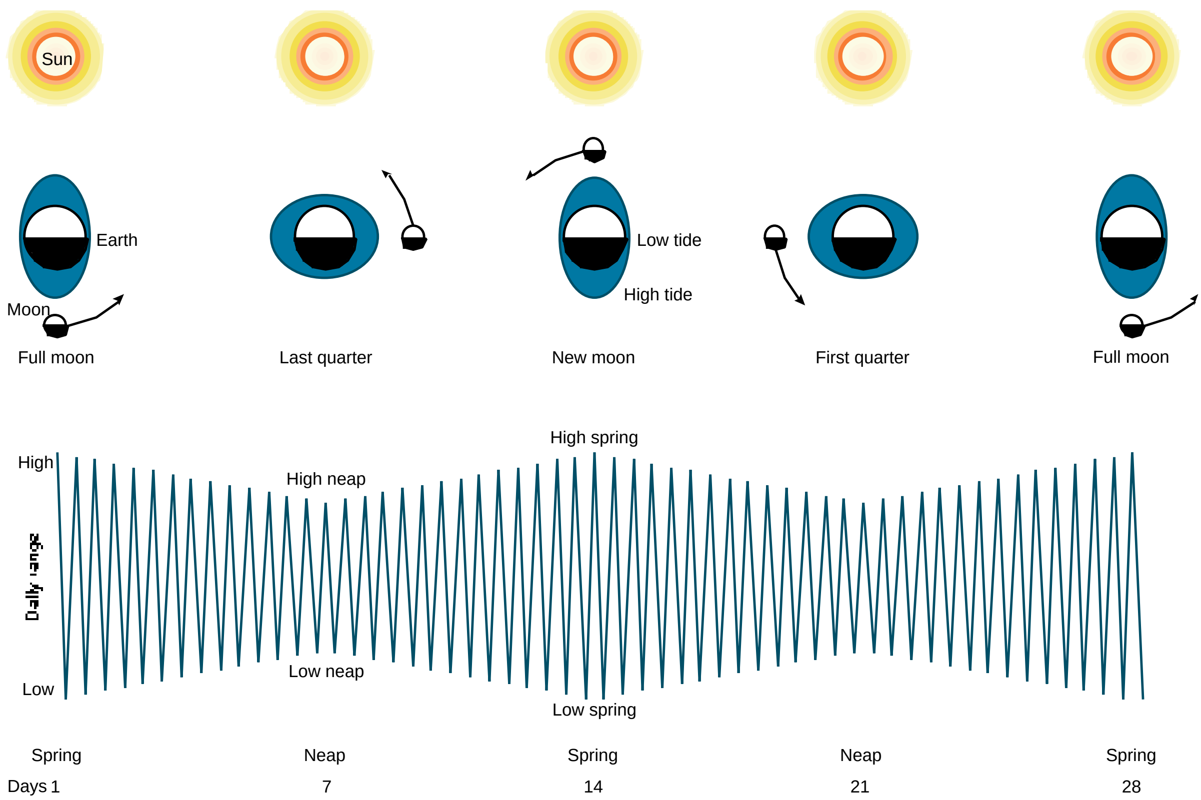
The moon's gravity pulls a "bulge" of water towards it, with the result that high tides occur on the side of the earth closest to the moon. On the opposite side, the water bulges out because of centrifugal force as the earth and moon spin around one another. Since the earth rotates, each point will experience two high tides per day – one due to gravitational pull and the other due to centrifugal force. As the water bulges out in these areas, it is drawn away from others, causing low tides there.

The moon takes 28 days to orbit the earth, moving a little further round the earth each day. High tides therefore occur about 50 minutes later each day, or 25 minutes later each tide.

Spring tides are extra-high and -low tides that occur every two weeks throughout the year, at new and full moon. At these times, the sun, moon and earth are in line with one another, and their combined gravitational pull creates an extra-large "bulge" at high tide. A greater area of shoreline is exposed at spring low tides, which in South Africa occur at about 10 am and 10 pm.

Between the spring tides are neap tides, when the difference between high and low tides is not as marked. Neap tides occur during the first and last quarters of the moon, when the moon is at right angles to the sun and their gravitational pulls cancel each other out.

The tidal range – the distance between the low- and high-water marks – varies enormously from one part of the world to another. In the Bay of Fundy in Canada, the spring high tide is 15 m above the low-tide mark, while a range of 6-12 m is not uncommon in parts of the British Isles and north-west France. Tidal range is lowest in enclosed seas such as the Mediterranean, where it seldom exceeds half a metre. In southern Africa, tidal range is usually 1.2-2.5 m.



In estuaries that are open to the sea, tidal range is largest in those with a wide, deep mouth. In the Knysna system, for example, the spring tidal range often exceeds 1.5 m more than halfway up the estuary. The delay in time for the tide to move up an estuary also depends on the mouth's depth and width, as well as other estuarine features, but generally takes up to 30 minutes per kilometre to reach any point upstream of the mouth.

Life in the intertidal zone

The area of shore between the high- and low-water marks is known as the intertidal zone. On rocky shores this area is characterised by particularly harsh conditions, which the resident animals and plants must be adapted to in order to survive. Twice per day they are submerged in cold water and subjected to battering waves when the tide rises, only to be exposed to desiccating winds and the blazing sun when the tide recedes. The distribution of species on rocky shores is largely determined by their ability to withstand these physical stresses. Those found low on the shore, where they are only exposed for a short time at low tide, are not adapted to survive conditions higher up, where only the hardiest species, such as the tiny snail *Littorina* and the seaweed *Porphyra*, occur.

On sandy shores the intertidal zone is slightly less harsh, as animals can burrow into the sand at low tide. Many have tidal or lunar rhythms to help them survive. The plough snail migrates up and down the beach with the tides to feed on stranded animals, while the mole crab and some types of sand mussel migrate with the tides to ensure that they remain in the surf zone – the best place for filter-feeding. Isopods and ghost crabs are most active at night, thereby reducing the risk of predation and desiccation, and only emerge at low tide to avoid being swept away by waves.

In estuaries, animals and plants not only have to be adapted to alternating periods of exposure and submersion, but also to daily fluctuations in salinity as the tide ebbs and flows. This limits the number of species that can survive in estuaries, which are subject to even greater changes of salinity during droughts and floods. Those that cannot cope with widely fluctuating salinity are known as stenohaline species, while highly tolerant species are termed euryhaline. Some animals, including fish and swimming prawns, migrate to escape unfavourable conditions, while other less mobile species, such as crabs and the mud prawn, are able to survive by regulating the concentration of salt in their body fluids. Temperature extremes and water loss are other factors that must be contended with during low tide. Some crab species can cool themselves by evaporation of body water, while hairs on their legs and chest are efficient at absorbing water from damp sand and passing it to the gill chamber for oxygen extraction.

Author: Sue Matthews September 2000

The intertidal life is exposed at low tide

PHOTO: G.BRANCH

FURTHER INFORMATION: • Branch, G. & Branch, M. 1981. *The Living Shores of Southern Africa.* Struik Publishers, Cape Town
• *Tide Table and Bait Collection Guidelines,* Booklet published annually by Coastcare, Marine & Coastal Management, Private Bag X2, Roggebaai 8012
http://www.environment.gov.za/sacoast/

RELATED FACTSHEETS: • Rocky Shores • Sandy Beaches • Estuaries and Lagoons • Rock Pools

Upwelling 1B

Upwelling, as its name suggests, is the movement of water from relatively deep in the ocean into the surface layers. Three processes may induce upwelling:

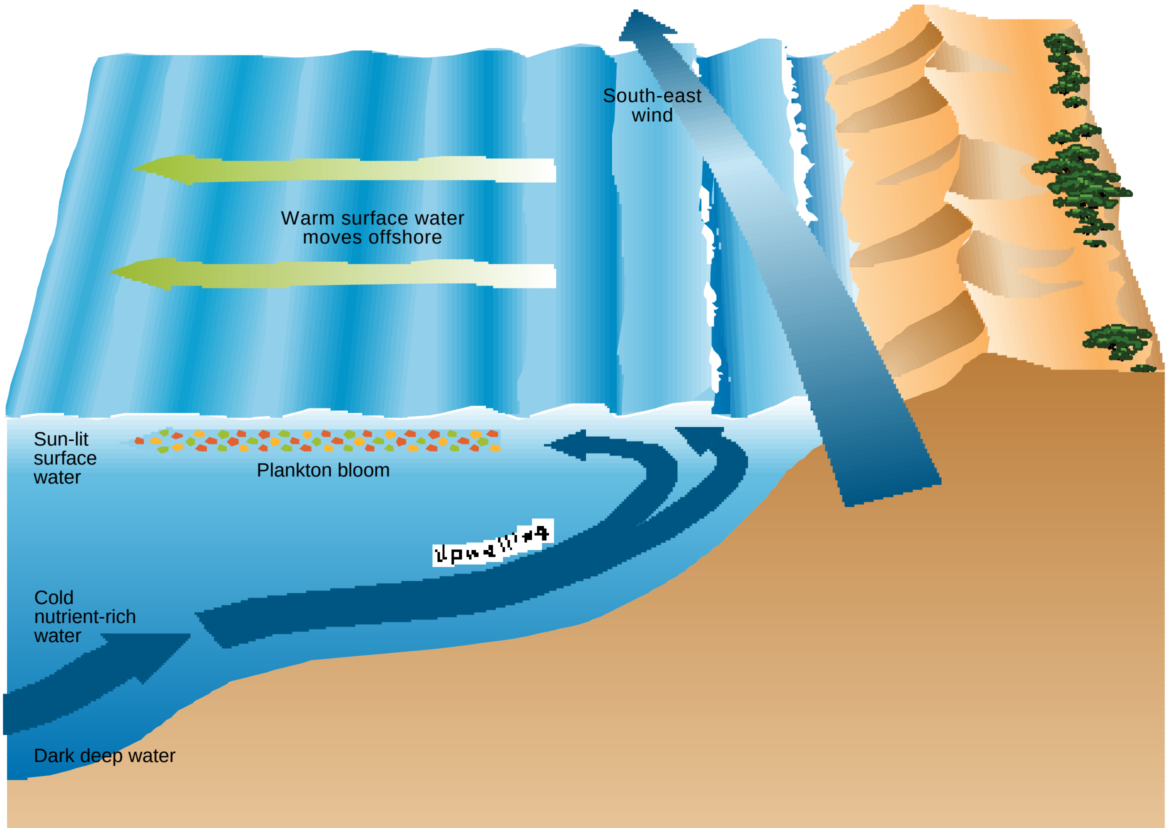
- *Deep currents meeting an obstacle such as a mid-ocean ridge will be deflected upwards*
- *In areas of divergence, for example immediately north and south of the equator where surface water is moved apart because of Coriolis force, water upwells to fill the resulting 'hole'*
- *Most importantly, when surface water is driven away from a coastline by wind action, water upwells to replace it.*

Both the north-east trade winds in the northern hemisphere and the south-east trade winds in the southern hemisphere have the effect of driving water away from the western coasts of continents. Wind-induced upwelling therefore occurs along the western coasts of the USA, central South America, Australia, and north-west and south-west Africa. The west coast of South Africa experiences the strongest upwelling in the world, ten to fifteen times that found off California and Chile.

Upwelling on the west coast of Southern Africa

Along the west coast of southern Africa, conditions favourable for upwelling occur as far north as southern Angola, but the south-easter – the prevailing wind from spring to autumn – is stronger and blows from a slightly different direction in some areas because of topographic variation. Maximum upwelling therefore occurs where winds are strongest and the continental shelf is narrowest and deepest. These so-called "centres of upwelling" are found at Cape Frio, Luderitz, Hondeklip Bay, Cape Columbine and the western seaboard of the Cape Peninsula.

The south-easter blows parallel to the west coast, pushing the surface layer of seawater before it in a northerly direction. However, because of Coriolis force (generated by the earth's rotation to the east) this surface water is deflected offshore, and cold, deep water upwells to replace it. Freshly upwelled water is a clear, turquoise colour because it contains no phytoplankton, the microscopic plant life of the sea. Phyto-plankton cannot survive in the dark depths as it requires light for photosynthesis. However, the upwelled water is rich in nutrients, especially nitrogen in the form of nitrates. This is a by-product of the decomposition of organic material that has rained down to the seafloor.



Once the deep water has upwelled into the well-lit surface waters, the nutrients enhance the growth and multiplication of phytoplankton, forming dense 'blooms' that provide abundant food for zooplanktonic animals. Both types of plankton are consumed by small pelagic fish such as anchovy and pilchard, which in turn are a food source for predatory fish such as hake, as well as seabirds, seals and dolphins. As a result, the west coast is an extremely productive environment, and is the centre of South Africa's purse-seine and trawl fisheries. The nutrient-rich water also encourages the growth of dense kelp beds, which provide habitat for the commercially important west coast rock lobster.

Upwelling provides conditions most suitable for phytoplankton blooms made up of diatoms. These large cells often grow in chains or have spikey shapes to slow their sinking rate. Turbulence generated by upwelling also helps them to remain in surface waters. Between upwelling events the sea becomes calmer and warmer, and these are conditions more suitable for phytoplankton blooms dominated by dinoflagellates – protozoa that can maintain their position in surface waters by beating their flagella. In addition, the upwelled water may contain large quantities of dinoflagellate cysts, the resting stages of these organisms that over-winter in the sediment of the seafloor. The cysts germinate and the dinoflagellates already present in the water begin growing and dividing, forming blooms that may be further concentrated by winds and currents. These sometimes become so dense that they discolour the water various shades of red, orange, brown or purple, although they are commonly known as 'red tides'. Some red tides are toxic, poisoning human consumers of mussels, clams and oysters, which accumulate the toxins as they filter-feed. Red tides can also suffocate fish by clogging or irritating their gills so that they cannot extract oxygen from the water, or deplete oxygen levels in the water when they decompose.

Kelp forests

The nutrient rich water that upwells on the west coast also fertilizes extensive kelp forests and rich growths of seaweed. In the intertidal zone herbivores such as limpets and sea urchins thrive, while mussels, sponges and Cape reef worms sieve the small particles and spores of the seaweeds from the water. This is a very fast growing, productive system.

The rock lobster fishery is sometimes impacted by rock lobster 'walk-outs', which are indirectly caused by upwelling. The large phytoplankton blooms resulting from the upwelling of nutrient-rich water eventually die and sink to the seafloor, where their decomposition by bacteria depletes oxygen in the water. The bottom water over much of the continental shelf is therefore low in oxygen, and there is also a southward movement of low-oxygen water from Angola at 300-400 m depth. When this water is advected close inshore, large numbers of rock lobster migrate into shallow areas in search of oxygen. They find refuge in the surf zone, where wave action saturates the water with oxygen, but are then susceptible to stranding at low tide. The largest walk-out recorded to date was in April 1997 when 1 200 tons of rock lobster stranded on the beaches of Elands Bay. A further 1 800 tons washed ashore a month later, but more than 600 tons were transported to areas unaffected by low-oxygen water and returned to the sea.

Upwelling on the east coast

The region near Cape Padrone on South Africa's east coast experiences irregular but dramatic changes in sea surface temperature, which have been known to cause mass mortalities of marine animals. The cold waters are attributed to an upwelling of deep water onto the continental shelf as the fast-flowing Agulhas Current passes from a narrow part of the shelf to a much wider area. Periodically, north-easterly winds move the warm upper layer offshore, exposing the underlying upwelled water. These winds alternate with those from the south-west, which force a layer of warm surface water from the Agulhas Current onshore, covering the cold, upwelled water. This explains the large fluctuations in sea surface temperature at the so-called Port Alfred upwelling cell.

Author: Sue Matthews September 2000

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• Payne, A. I. L., Crawford, R. J. M. & Van Dalsen, A. 1989. *Oceans of Life off Southern Africa.* Vlaeberg Publishers, Cape Town.

RELATED FACTSHEETS: • Ocean Currents • Red Tides • Plankton • Kelp Forests • Fishing Industry

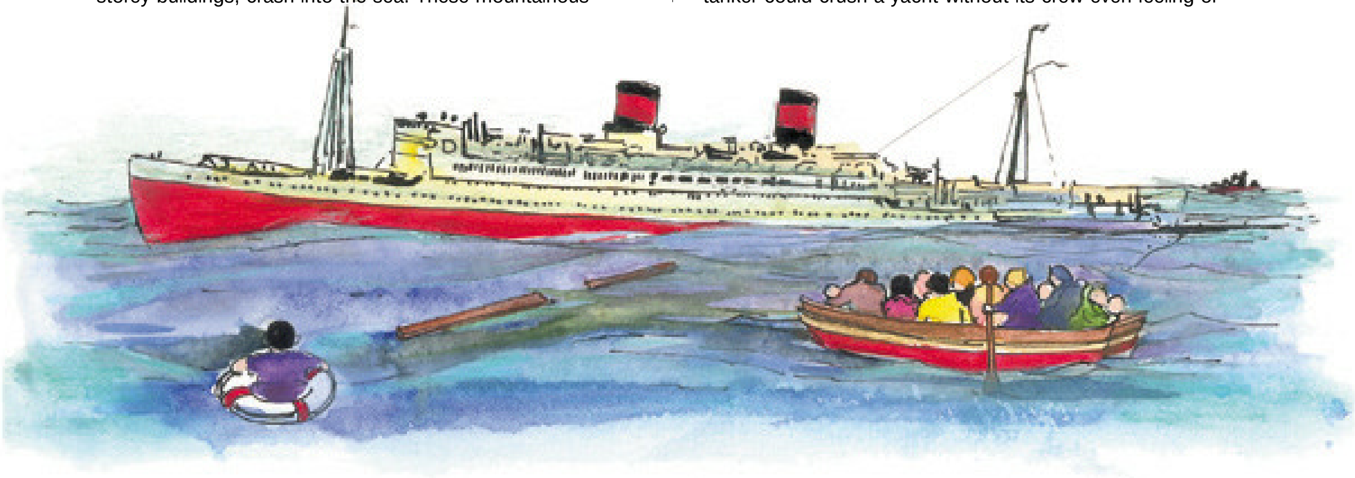
Ocean Hazards 1B

*Ocean hazards – one has only to examine the demise of the **Titanic** (the unsinkable ship) by watching the film in all its Oscar-winning drama, to learn of the dangers awaiting those that venture on the sea. None of the 2200 partying people aboard the vast, floating hotel could have imagined that they were in danger. In fact the evening was so calm that there were no waves to splash a foamy warning at the base of the enormous iceberg that loomed out of the north Atlantic. The sheer size of the Titanic added to its danger, as the ship could not respond quickly enough to the reverse and avoidance actions taken. The iceberg struck and ruptured the buoyancy compartments along the side of the hull and as the bows filled, the water flooded successive compartments. The danger was compounded by the inadequate number of lifeboats. The 700 people who got a berth in the lifeboats had to watch in horror as the 11-storey, ocean giant broke in half and sank, catapulting the remaining passengers into the sea. Twenty minutes later the turmoil was replaced by an eerie sea of floating corpses, killed by the icy, minus-3°C water. The ship hit the iceberg at 11.40 p.m., it sank at 2.20 a.m., at 4.10 a.m. the first lifeboat was picked up by the **Carpathia** and the last at 8.30 a.m. The final death toll was about 1500. As Walter Lord expressed this classic 'Greek' tragedy "What troubled people especially was not just the tragedy – but the element of fate in it all. If the Titanic had heeded any of the six ice messages on Sunday … if the night had been rough or moonlit … if she had seen the berg 15 seconds sooner … if she had hit the ice any other way …if her watertight bulkheads had been one deck higher … if she had carried enough boats … if the **California** (only 10 miles away) had only come. Had any of these "ifs" turned out right, every life might have been saved." The ocean is unpredictable!*

Hurricanes, tornadoes, and cyclones wreak tremendous havoc and it is imperative for sailors to keep informed about weather conditions. Winter storms in the Cape can blow up in a very short time and many ships and small boats have been wrecked along South Africa's shores. The coast between Durban and the southern tip of the continent, Cape Agulhas, is particularly hazardous. The mighty Agulhas current flows southward, at a speed of 5 knots, like a river in the ocean. Sometimes it is pitted against strong, south-easterly winds that blow massive waves before them. The opposing effects of the current and the wind are to shorten the distance between the waves, accentuating their height. At times two waves are superimposed and giant waves, as tall as a five-storey buildings, crash into the sea. These mountainous killer-waves have destroyed ships and are thought to be the cause of the mysterious disappearance of the *Waratah* on its maiden voyage.

Collisions

As with the *Titanic*, floating and submerged objects are a hazard. It is important to keep a continual watch, especially when sailing uncharted waters. Recently a series of enormous logs from a ship, sunk off Madagascar, floated south in the Agulhas current. A child was killed whilst bathing and several boats were damaged by these floating logs, submerged just beneath the surface. The danger of collisions between vessels is greatest in the busy highways of the ocean where a vast tanker could crush a yacht without its crew even feeling or



hearing the thud. Furthermore the time it takes to manoeuvre large vessels often makes it impossible to avoid a collision. Because there can be no rigid 'roads' in the ocean it is important for vessels to observe the navigational codes – where the boat on the port tack gives way to the boat on the starboard tack. Power gives way to sail and smaller easily manoeuvrable boats give way to large vessels.

Lighthouses flash and moan mournfully, warning passing vessels of rocky headlands and dangerous reefs. But sometimes ships are helpless to avoid the rocks because of high seas, faulty steerage or damaged engines.

Unsafe boats

Corrosion is severe in the salt laden atmosphere and maintenance is an important part of ocean safety. Old metal boats, can become a danger as their hulls become rusty and weakened. Their equipment is old and worn and they are less able to withstand the rigours of ocean storms.

One should never put to sea in an unsafe boat with inadequate buoyancy and safety measures. Skippers should have skippers tickets, navigational skills, emergency equipment, life jackets and lifeboats.

Language can be a problem when ships try to communicate with one another or call for help. When the old Chinese ship the *Apollo Sea* sank off the west coast in 1994, only one station picked up their distress signal – a station on the other side of the world in Beijing. All hands on board were lost. It took over a year and R25 million to clear up the oil that inundated Cape beaches and almost 10 000 adult penguins were lost and as many chicks starved to death.

Water everywhere

The water itself is a danger especially if sailors cannot swim or do not wear life jackets. If the water is cold the survival time for a person is short and it always takes time for a ship to turn and find a man-overboard, hidden by choppy waves. It is best to take up a huddled position to reduce heat loss as much as possible. In warmer seas the survival time is greater, but there is more danger from lurking sharks and sun exposure.

Surprisingly one of the greatest hazards for ocean adventurers is the lack of fresh water. Vessels have to carry their water supplies, catch rainwater or use de-salinators to provide their fresh water needs. Woe-betide a voyager whose water runs out. The heat and the long days in the sun soon dehydrate the body and one is tempted to take a sip from the sea of salt water available, but this only spells death. A human's kidneys require 4 cups of fresh water to flush the salt in one cup of seawater from the body.

Pollution

Discarded nets and plastic debris can entangle and choke marine animals. Such debris can also entangle boat propellers. Toxic waste dumped in the sea can seep out and poison the surrounding water. Marine life is killed and edible species may be contaminated. Sewerage is the biggest health risk in coastal waters. Rich in nitrogen, sewerage waste often includes toxic chemicals, heavy metals and pathogens as well. Yet much sewerage is untreated before it is discharged into the sea. Excess quantities of nutrients from sewerage and run-off from agricultural fertilisers can damage marine ecosystems by promoting explosive population growth of some species at the expense of others. This can lead to an increase in toxic red tides.

International safety measures

To make the oceans safer, nations co-operate in predicting weather conditions, compiling weather bulletins and in rescue operations. Laws are in place to prevent pollution, to control wastewater treatment and monitor bathing water quality. There are international codes for right of way for shipping and for emergency communications such as the Mayday or SOS signals as well as a code of flags and flares when calling for assistance. The oceans demand the alert respect of all who travel or swim in them.

Author: Margo Branch April 2000

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- South African Navy, Tokai Cape, Town. (for charts, signal, tide-tables, light fog and radio signals etc.
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RELATED FACTSHEETS:

• Safety at Sea • Lighthouses • Sunburn • Red Tide • Marine Pollution • Sharks • Plastic Pollution • Tsunami • Weather and the Ocean • Dangerous Sea Creatures

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

Salt and the Sea 1B

Many substances make up the salt in seawater, but sodium chloride is by far the dominant compound. The proportions of the salts in the sea are relatively constant - sodium chloride (77.8%), magnesium chloride (9.4%), magnesium sulphate (6.6%), calcium sulphate (3.4%) and potassium chloride (2.1%). There are also small amounts of many other compounds. The salt content of the seawater is similar to the body fluids of most animals. Life itself probably started in salty seawater.

Where does the salt come from?

The salts in the ocean are the result of millions of years of disintegration of the igneous rocks of the earth's crust. The soluble materials are washed via rivers into the ocean. The question is often asked, "Why doesn't the sea get more and more salty?" This is a valid question because the water of the ocean is continually recycled, by evaporation and precipitation, leaving behind the salts that are being continually added to the sea, by run off. There is no evidence, however, that the sea has become saltier with time. Instead, the sea must be a vast recycling bin accepting salt and other materials while removing them in insoluble forms. Not all elements are affected by the same processes. Some, like calcium and silicon, are incorporated in the skeletons of living organisms, later to sink to the ocean floor; whereas others, like potassium, react to form clay minerals on the ocean floor. The rate of biological or geological processing is different for each element, leading to varying times of residence for each dissolved constituent in seawater. Aluminium and iron have a short residence time of a few decades. Calcium persists for about a million years, sodium for about 68 million years and chlorine almost forever. Thus the seawater tastes salty because sodium chloride has a longer residence time than most other constituents.

Recent discoveries about the movements of the plates of the earth's crust have drastically altered the perspective that rivers feed the sea all its dissolved constituents. At the spreading centre of oceanic ridges the crust is being pulled apart and is riddled with cracks and conduits that allow cold seawater to circulate down into the hot crust of the earth. Once heated, this water then migrates back up to the surface and escapes via submarine hot springs. This circulation affords opportunities for chemical interactions. Some elements are dissolved from the rocks and added to the seawater and others are removed by reactions with hot rocks. For example sodium and magnesium are removed from the seawater and iron and manganese are increased. As the water emerges from the submarine hot springs many of the dissolved metals immediately precipitate in contact with the cold ocean and these vents build up pipes of precipitated sulphides. Often strange animals live associated with these sulphide vents. Thus the composition of seawater may be largely controlled by its interaction with rocks of the ocean floor, in addition to what rivers discharge into it.

Rock salt

Salts can be re-deposited by the evaporation of seawater, a process used today in the manufacture of table salt. Huge deposits of rock salt (crystalline sodium chloride), some of them many hundreds of feet thick, occur in parts of Africa, Europe and America. These deposits were probably laid down in partly enclosed shallow bays of the sea, where evaporation was greater than the inflow of fresher water. Because of its great solubility in water, rock salt is dissolved in rain. In wet areas it is only preserved if it is under a thick rock cover, but can be found close to the surface in arid regions.

How is salinity measured?

The salt content of water, known as the salinity, is measured as the amount of dissolved salt in a kilogram of sea water (0/00 or ppt) and is usually between 32 and 37 parts per thousand in the open ocean. Around South Africa the range is even narrower, 34-36 ppt. The salinity of the oceans is higher at the equator especially in the Persian Gulf and the Red Sea due to evaporation, and beneath ice at the poles during winter, when water is locked up in the ice. Salinity is low where there is extensive river drainage or where ice melts during summer. In estuaries the salinity varies daily with the tidal flow and seasonally with the river flow. Salinity can be measured by chemical titration but is usually recorded by measuring electrical conductivity at different temperatures. Oceanographers can take continuous records of temperature and salinity through the water column using special probes and this gives information about different currents and water bodies.

The uses of salt

Known as common salt, sodium chloride is of great importance to man as a condiment that improves the flavour of food. To ensure that table salt remains free flowing, small quantities of sodium carbonate or trisodium phosphate are added. In South Africa a small quantity of potassium iodide is also added, to overcome iodine deficiency. Salt is essential for the health of our bodies. Sodium and chloride, together with potassium, are the ions necessary for nerve conduction. Workers and sportsmen exposed to high environmental temperatures are liable to experience cramps due to the excessive loss of sodium chloride in the sweat. Cramping may be cured or prevented by taking salt tablets or a 'sportsman's' drink' enriched with salts. A diet rich in meat and milk requires little extra salt but a cereal or vegetable diet calls for a supplement of salt. Wild and domestic animals use salt licks to obtain essential salts.

Other uses of salt include the preservation of meat and fish and for curing hides. Salt is an ingredient for the manufacture of washing soda (sodium carbonate), baking soda (sodium bicarbonate), caustic soda (sodium hydroxide), bleaching powder and chlorine. It is also used in the manufacture of glass, soap and glazes.

Manufacture of salt in Southern Africa

In many countries salt is mined from rock-salt deposits. In dry maritime regions salt can be extracted from seawater by evaporation. There are salt works at Walvis Bay, along the west coast and near Port Elizabeth. Preliminary concentration of the seawater is achieved by channelling seawater into a series of shallow ponds. As the water evaporates the brine becomes more concentrated and the different salts separate out as each reaches its point of saturation in the solution. The order of deposition is calcium carbonate, calcium sulphate, sodium chloride, magnesium sulphate, carnallite and magnesium chloride. The solution is concentrated to a specific gravity of about 1.21, after which the sand, clay and less soluble salts calcium carbonate and calcium sulphate are removed. The remaining clear concentrated brine is run into a succession of crystallising pans, usually three, where the salt is deposited. In the first pan, when the brine reaches a specific gravity of 2.5, the best grade 'table salt' is produced (96% sodium chloride and 1% calcium sulphate). In the second pan second-grade salt, for the chemical industry, is produced. In the third pan the brine reaches a specific gravity of 1.275 and third-grade salt (91% sodium chloride and 1% each of magnesium sulphate and magnesium chloride and traces of other salts) is used for pickling fish etc. The salt in each crystallising pan is raked into rows and then heaps and drained for several days, before being lifted from the pans and dried in hot-air rotary dryers.

Living in salty water

Seawater is in many ways a comfortable medium in which to live. The water provides support to submerged plants and animals so there is less need for supportive tissue like bones or wood, than in land-dwellers. As a result seaweed may be soft and floppy and sway in the waves and whales can grow much bigger than land animals. While fresh-water inhabitants face the difficulty of gaining excess water from the dilute solution in which they live, land animals have the problem of loosing water to the air. Marine plants and animals do not have these problems of water gain or loss because their body fluids have similar salt concentrations to those of the salt water in which they live. Water and salts can move freely into and out of plants and soft animals such as anemones, worms and jelly-fish. The body fluids of bony fish are slightly less salty than seawater and they continually lose water from the body by osmosis. As a result, bony fishes must drink often, but in the process they collect excess salt that has to be excreted through the gills by special glands. Sharks and rays achieve equilibrium by quite a different method. They increase the osmotic pressure of their blood by retaining the waste product urea, so that they do not loose water to the surrounding sea and have no need to drink.

Mangrove trees and salt-marsh plants are salt tolerant. The black mangrove actively excludes the uptake of salt by the roots and any salt that is taken up is concentrated in old leaves that are subsequently shed. The red mangrove cannot prevent salt uptake and contains over 100 times more salt than most land plants. Its leaves exude a concentrated salty fluid. Marine birds and turtles have special salt glands, situated above the eye, that excrete excess salt in tear-like drops.

Desalination of seawater

We humans are not able to survive by drinking sea-water, as our kidneys require four times as much fresh water to flush out the salt that is taken in. A sip of salt water just makes one more thirsty. A challenge of the future in this dry land, is the cost-effective desalination of seawater.

Author: Margo Branch September 2000

FURTHER INFORMATION: • Branch, G. M. & Branch M. L. 1981. *The Living Shores of Southern Africa.* Struik, Cape Town. • Payne, A. I. L. Crawford, J.M. 1995. 2nd edition. *Oceans of Life off Southern Africa.* Vlaeberg Publishers, Cape Town.

RELATED FACTSHEETS: • Mangrove Swamps • Estuaries • Salt Marshes

Ocean Currents 1B

Currents on the ocean's surface are usually driven by the prevailing winds, but these have little effect on the large-scale movement and mixing of seawater. The major currents in the sea are caused by differences in density owing to variation in temperature and/or salinity - cold seawater is denser than warm seawater while full-strength seawater is denser than that diluted by fresh water. Thus temperature changes between the equator and the poles, and salinity changes because of rain, evaporation, freezing of seawater and melting of ice, all play a role in ocean circulation.

Global surface currents

On a global scale, the earth's rotation and the position of the continents constrain large ocean currents to follow an almost circular pattern, called a gyre. Each ocean gyre is made up of a westward-flowing equatorial current, an intense poleward-flowing western boundary current, an eastward-flowing subpolar current, and a diffuse equatorward-flowing eastern boundary current. In other words, gyres flow clockwise in the northern hemisphere and anti-clockwise in the southern hemisphere. This can be attributed to the Coriolis effect, caused by the earth's rotation toward the east. The precise position of the polar current is determined by the direction of the macro-scale wind circulation. The equatorial currents are warm while polar currents are cold.

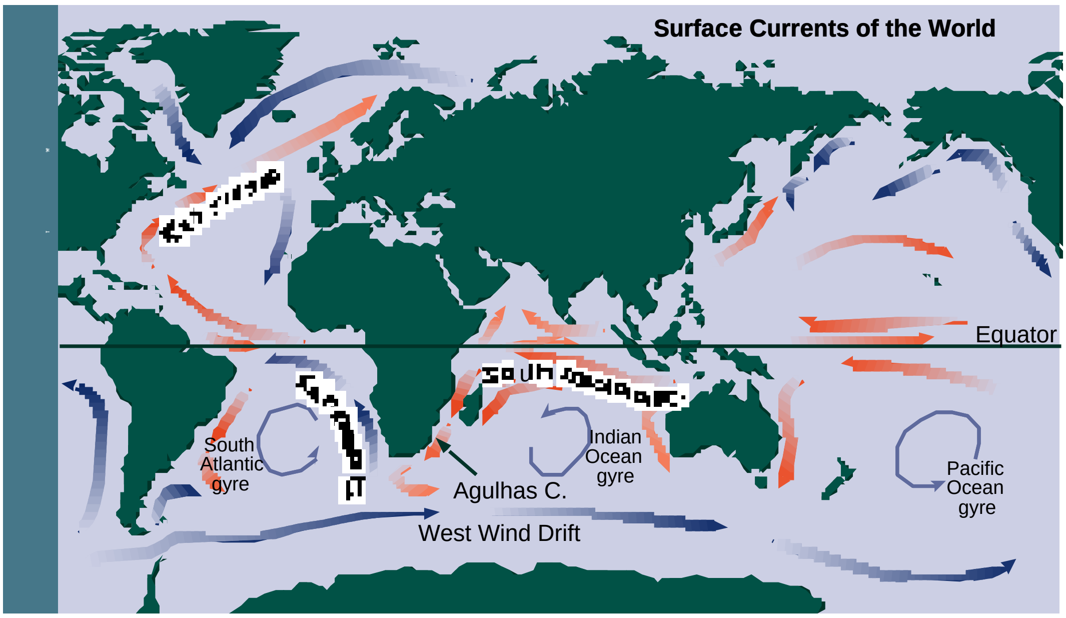
Equatorial currents flow at 3-6 km per day and usually extend 100-200 m below the surface. The equatorial counter current, which flows towards the east, is a partial return of water carried westward by the north and south equatorial currents. In El Niño years, this current intensifies in the Pacific Ocean.

Western boundary currents (flowing along the east coasts of continents), such as the Gulf Stream, Kuro Shio, Brazil, East Australia and Agulhas currents, are all warm-water currents with generally narrow, jet-like flows travelling at speeds of 40-120 km per day, and extending down to depths of 1 000 m.

Eastern boundary currents, including the Canary, California, Peru, West Australia and Benguela currents, are generally broad, shallow-moving flows that travel at speeds of 3-7 km per day.

The subpolar currents in the northern hemisphere – the east-flowing North Pacific Current and North Atlantic Drift – move water back across to the starting point of the gyres. In the southern hemisphere this function is performed by the South Pacific, South Indian and South Atlantic Currents – all associated with the Antarctic Circumpolar (West Wind Drift) that flows in a continuous motion around Antarctica.

For example, in the South Atlantic Gyre the warm-water Brazil Current flows south along the east coast of South American, before meeting up with the north-flowing Falklands Current, where both currents turn to the east and together become the South Atlantic Current. Near the southern tip of Africa this current splits, some of the flow going northward and the rest continuing into the Indian Ocean. The northward flow forms the Benguela Current, up the west coast of South Africa, which joins the South Equatorial Current System to reconnect to the Brazil Current, thus closing the gyre.



South Africa’s currents

While South Africa’s east coast is washed by the warm Agulhas Current, which flows southward from tropical latitudes off Mozambique and Madagascar, the west coast is bathed in the cold waters of the Benguela Current System.

The Agulhas Current follows the edge of the continental shelf as it flows swiftly down the east coast of South Africa, transporting about 75 milllion $m^3.sec^{-1}$. Between Port Shepstone and East London, where the shelf is narrow, the current reaches its maximum velocity of about 2.5 m. sec^{-1}. At the southernmost tip of the continent the current leaves the shelf edge at the shallow Agulhas Bank and turns back on itself in a loop known as the Agulhas retroflection. Most of the water returns to the Indian Ocean, but sometimes the loop pinches off a huge eddy, about 300 km in diameter. This so-called Agulhas Ring moves into the Atlantic Ocean, where it may interact with the Benguela Current System. It is thought that this may impact the commercial fishing industry by transporting the eggs and larvae of pelagic fish species from their nursery areas on the West Coast to the less productive waters offshore, where they are lost from the system.

The Benguela Current System is a slow northerly movement of water that transports only 15 million $m^3.sec^{-1}$ and moves at average speeds of 15-20 cm. sec^{-1}. Along the west coast, strong southerly winds blowing parallel to the coastline in spring and summer drive the upwelling of cold, nutrient-rich water from the depths to the surface, making the Benguela a highly productive system. The rich nutrients encourage the growth of dense phytoplankton blooms, which support huge schools of pelagic fish, such as anchovy and sardines. These are in turn food for larger fish, seabirds, dolphins and seals.

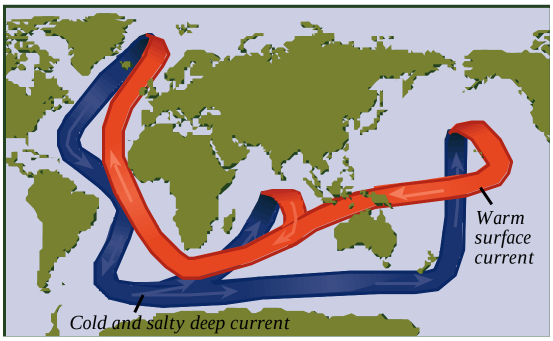
Measuring surface currents

Because ocean circulation transports heat from the equatorial regions to the subtropical zones, it has a major affect on the world’s weather. Global climate change is predicted to alter weather patterns, which will impact humankind in a variety of ways, from decreased crop production and water resources to increased natural disasters.

As recently as 1955, the message-in-a-bottle method was still being used by oceanographers attempting to understand ocean circulation. These bottles were strongly influenced by choppy seas, as they were buffeted about by the waves and wind. Drift bottles were replaced by drift cards, which were lighter and thought to respond better to currents. In South Africa, regular releases of drift cards continued until 1973, with only about 1.6% of the 50 000 cards ever returned.

Today, oceanographers have a wide variety of sophisticated techniques and instruments for studying surface currents. These include satellite-tracked drogues, satellite altimetry, feature-tracking from successive satellite images, Doppler current meters mounted on ships, backscatter radar used from coastlines and satellites and current meters moored on surface floats. Radio- and visually-tracked drogues are used for studies of circulation in bays, estuaries and lakes.

It is important to remember that these only measure surface currents – deeper in the ocean, water may be moving in the opposite direction as part of the “global ocean conveyer belt”.



Global ocean conveyor belt

The conveyor belt plays an important role in global heat transfer by transporting warm ocean water from the Pacific Ocean through the Indian Ocean and into the Atlantic Ocean. In the north Atlantic, the warm water that is carried from the equator by surface currents turns very salty due to evaporation during the journey and cools as it approaches the pole. Cold, salty water has a greater density, so it sinks and forms a deep ocean current that flows south to the vicinity of Antarctica. There it is diverted to the Indian and Pacific Oceans by the Antarctic circumpolar current. The deep-water current eventually comes to the surface in the northern Indian and Pacific Oceans before returning to the Atlantic Ocean by a series of surface currents. A complete loop of the conveyer belt may take 1000 years. *Author: Sue Matthews September 2000*

FURTHER INFORMATION: • Payne, A. I. L., Crawford, R. J. M. & Van Dalsen, A. 1989. *Oceans of Life off Southern Africa*. Vlaeberg Publishers, Cape Town.

RELATED FACTSHEETS: • Upwelling • Weather and the Sea • Safety at Sea • El Niño

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

Weather and the Ocean 1B

Our planet earth is unique because of its ocean, which covers over 71% of the earth's surface and its atmosphere. The interactions between the earth's atmosphere and its oceans are the driving force underlying climate and weather patterns and make our planet habitable for life, by circulating heat between the equator and polar regions.

Both the earth and the atmosphere gain and lose heat faster than the ocean. Although the atmosphere stores very little heat, its winds can move heat around the planet relatively quickly. The earth's rotation deflects air masses into ribbons that spiral around the globe forming the North East and South East Trades on either side of the equator and the Westerlies near the poles. Heat also causes air to rise, creating convection currents and resulting in areas of low pressure. Cool conditions result in dense air that sinks, creating areas of high pressure. Winds move from high to low pressure areas.

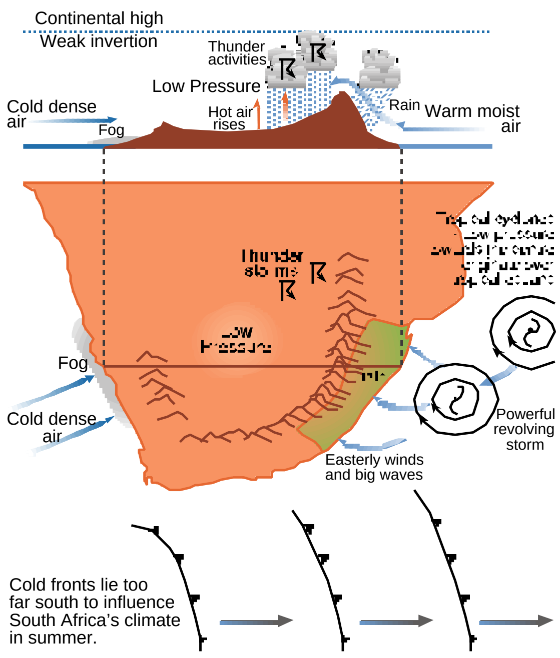
The oceans have a moderating effect as water stores 1 000 times more solar heat than air and can slowly release it. The upper 2.5 m layer of the oceans stores the same amount of heat as all of the air in the atmosphere. It also takes about 3 200 times more energy to heat a given volume of water than air. The enormous capacity of water to store heat is fundamental to the role of the oceans in influencing the earth's climate as it results in temperature differences between the ocean and the atmosphere that cause winds and rain. The sea is warmest near the equator because solar heating there is strong, while at the poles solar radiation is reduced, resulting in a cold environment. Ocean currents circulate warm equatorial water towards the poles and cold water towards the equator. The oceans also moderate seasonal differences as they are able to store heat absorbed during summer and then release it during winter. Consequently, coastal regions experience warmer winters and cooler summers than inland places.

SOUTH AFRICAN WEATHER SYSTEMS

Having oceans on both sides of South Africa has a major influence on its weather. Maritime air moderates the coastal climate and also influences weather over the interior of the country. Durban and Port Nolloth occur at similar latitudes, on the east and west coasts respectively. However, their weather is completely different because of the influence of the ocean. The Agulhas Current sweeps down the east coast, transporting huge quantities of warm water and raising air temperatures and humidity. The average temperatures in Durban range between 23ºC in summer and 19ºC in winter and rainfall averages 1 000 mm per year, mainly in summer. On the west coast the cold Benguela current has the opposite effect, decreasing ambient temperatures and yeilding little rain. Coastal fog is common, but inland conditions are desert-like. Port Nolloth averages 17ºC in summer and about 13ºC in winter and the annual rainfall is a mere 61 mm, falling mainly in winter. Inland, at the same latitiude, Kimberley has high summer temperatures up to 37ºC and low winter temperatures down to –3ºC.

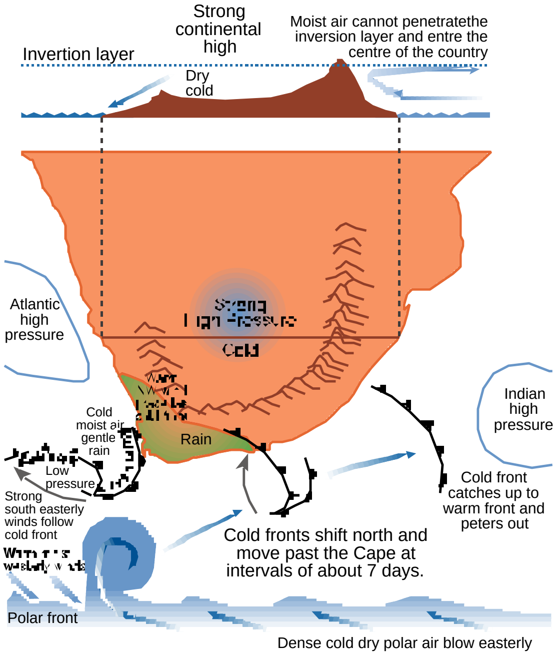
A typical synoptic chart for South Africa shows a low pressure (depression) system south of the country, with high pressure systems around 30ºS. In summer the high pressure system is weak over the hot land but strong over the sea. In winter, as the sun moves north, these low and high pressure systems migrate about 6º northwards. The centre of South Africa is then cooler and the high pressure belt is strong over both land and sea. The low pressure system influences the southern Cape primarily, but also affects weather patterns upcountry. A simplified explanation of rainfall patterns follows.

Summer conditions – Rainfall over the east and central parts of South Africa



During summer the hot land causes warm air to rise, creating a low pressure system over the centre of the country. The oceans are cooler and have high pressure cells. On the east coast easterly winds blow over the warm Agulhas Current picking up moisture. Rising up over the eastern mountains, they cool and form cumulus clouds. Thunderstorms are common in the interior. On the west coast the South Atlantic High Pressure Cell causes south-westerly winds over the cold Benguela Current. The cold water yields little moisture. Rain is rare and the land is arid. Periodic south-easterly winds drive surface waters offshore and deep cold water upwells to replace it. During summer the low pressure system and cold fronts are too far south of the country to influence weather.

Winter conditions – Rainfall over the south and western Cape



In winter the low pressure system south of the country shifts northwards and brushes the south western Cape, cold fronts bring rain as they move eastward. Each cold front is preceded by warm north-westerly winds, falling pressure and short showers. As the cold front passes there are gusty winds, a sharp drop in temperature and strong showers. After the front passes the wind veers around to strong south-easterly and the skies clear. Cold fronts move across the Cape roughly every 7 days. The cold fronts originate at the south polar front where westerly winds and cold, dry easterly polar winds blow in parallel but opposite directions. Troughs and ridges of pressure are formed by friction at their interface and pockets of cold polar air and warm westerly wind separate and move north-eastwards as clockwise spiralling low-pressure cells creating cold fronts. Another cause of winter rain is air descending from the interior to the low-lying western coast. It is warmed by compression, forming hot dry 'berg winds'. The coastal low that follows moves around the Cape and along the south coast bringing light rain. The centre of the country is dry during winter because a strong high pressure cell develops, creating a dense inversion layer which forms a 'blanket' preventing moist easterly air from rising over the mountains.

Cyclones Tropical revolving storms, known as cyclones in the Indian Ocean, hurricanes in the Atlantic and typhoons in the Pacific, often cause mass destruction due to very strong winds, torrential rain and huge waves. These storms may also produce torrential rain for several days. Although intensively studied, their formation remains partially a mystery. For the formation of a cyclone, the primary ingredients are a large ocean area with a sea surface temperature above 27ºC. An intensive low-pressure system develops over the ocean and draws in moist air, developing into a huge tropical storm. Off the east coast of South Africa, tropical storms commonly occur during summer and autumn and are usually only noticed as strong easterly winds and big waves. However, a few develop into true tropical cyclones. In 1984 cyclone Demoina wreaked havoc in KwaZulu-Natal, bringing devastating floods and strong winds. In early 2000 cyclone Eline caused the worst floods in living memory over Mozambique, leaving 100 000 people homeless, and swelling the Limpopo River from 800 m wide to a 30 km wide floodplain.

Land and sea breezes Land and sea breezes are caused by differential heating and cooling of the land and sea. During the day the land heats up quickly, warm air rises and is replaced by cool air from over the sea, creating an onshore sea breeze. At night the system reverses and the warm air over the ocean rises, being replaced by cool air from the land, creating an offshore land breeze. These daily sea breezes moderate coastal climates.

Cities and climate Large cities can be up to 9 ºC warmer than surrounding rural areas because of heat generated by industries, motor vehicles and fires, which is trapped beneath a blanket of pollutant smog. Coastal cities like Cape Town benefit when the strong south-easterly, known as the 'Cape Doctor', blows away the smog leaving the atmosphere relatively clean when compared to calm inland cities like Johannesburg.

Author: Judy Mann-Lang December 2000

FURTHER INFORMATION:

• South African Weather Bureau, P. Bag X097, Pretoria, 0001, Tel: (012)309 3029, Fax: (012) 309 3979.
• Pernetta, J. 1995. Phillips Atlas of the Oceans. Reed Consumer Books, London.
• Preston-Whyte, R.A. and Tyson, P.D. 1988. The atmosphere and weather of Southern Africa. Oxford University Press. Cape Town.

RELATED FACTSHEETS:

• Currents • Coastal Vegetation • Upwelling • Ocean Hazards • Safety at Sea • Lighthouses

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