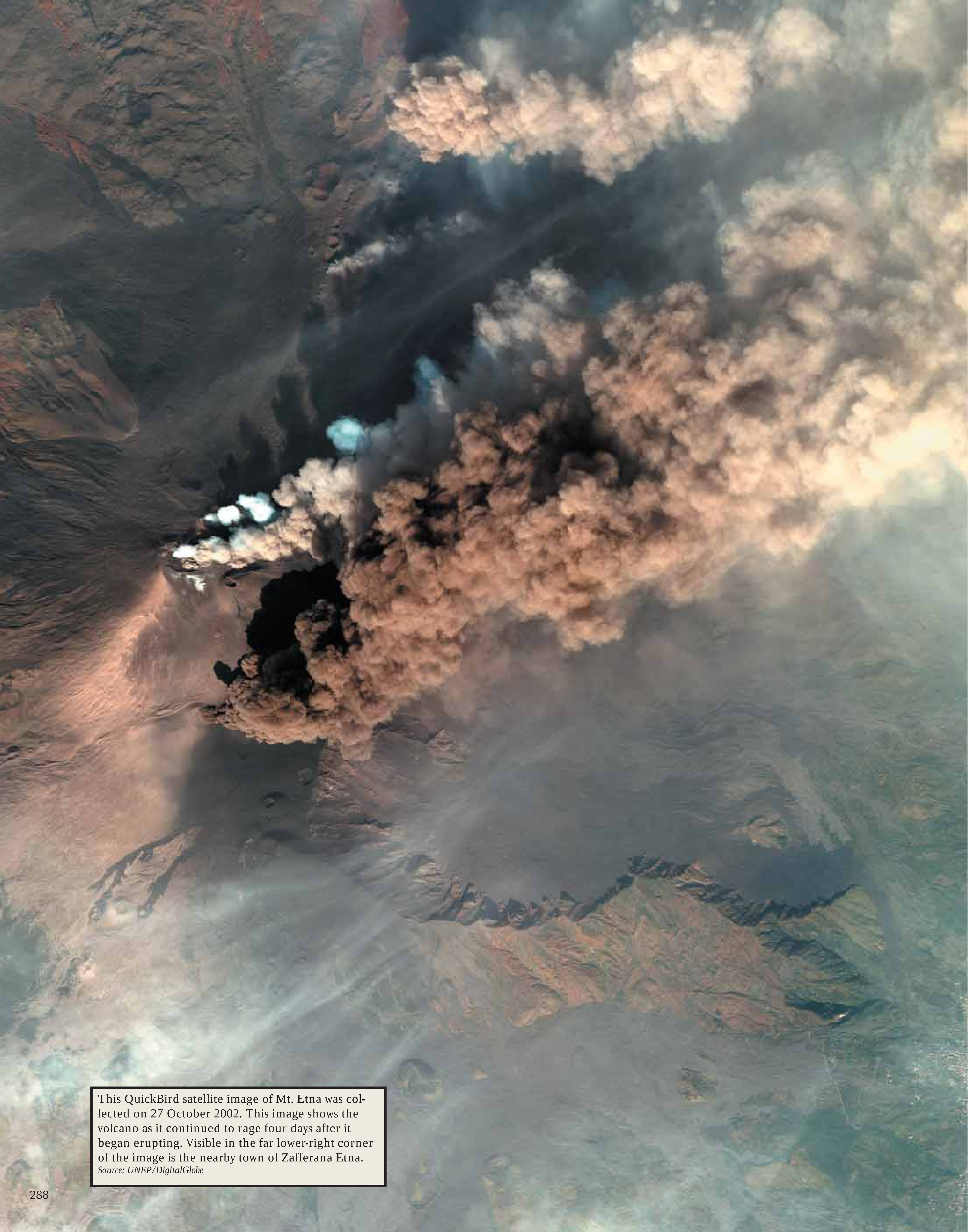
Earthquake Map of the World

Credit: UNEP / USGS GTOPO30, NEIC


Major Earthquakes, 1995-2004
Eastern hemisphere
Magnitude 7.0 - 7.9 8.0 - 8.9 9.0
The sole 9.0 earthquake shown is the
Northern Sumatra earthquake of December 26, 2004.



This QuickBird satellite image of Mt. Etna was collected on 27 October 2002. This image shows the volcano as it continued to rage four days after it began erupting. Visible in the far lower-right corner of the image is the nearby town of Zafferana Etna.
Source: UNEP/DigitalGlobe

4 Natural and Human–induced Extreme Events

Extreme events, whether natural or human-induced, can cause significant environmental change, not to mention their impacts on peoples' lives. But many types of natural hazards are also exacerbated by environmental degradation caused by humans. The examples illustrated by the pictures and stories in this chapter highlight the links between population growth and distribution, environmental damage, and natural disasters. They underscore the need to protect the natural environment of this, our only planet, and to strengthen its capacity to resist the impact of both increasing numbers of people and destructive natural events.

Extreme environmental events, or "natural" disasters, have generally been regarded as unpredictable and uncontrollable "acts of God." Increasingly, however, it is becoming clear that human activity can aggravate natural events. With a growing population, more people living in hazard-prone regions, and increased environmental degradation, the intensity, frequency, and impacts of natural hazards are also heightened. As forests are cut down, wetlands built over, and coral reefs disappear, for example, these ecosystems can no longer function as protective controls on the forces and impacts of hurricanes, floods, and tidal waves. Both the poor, sometimes pushed into vulnerable regions by economic and political forces, and the wealthy, who build expensive homes where they wish, move into disaster prone areas and are affected when natural events occur. With stricter building codes and generally less densely populated settlements, fewer deaths occur in developed nations than they do in developing countries, where these events cause very large numbers of

Tornado. Credit: Unknown / UNEP / NOAA

Lightning Credit: Unknown / UNEP / NOAA

casualties and homelessness. Financial losses are easier to measure in developed countries; while the economic ramifications in developing nations may be extensive, they are more difficult to calculate. Finally, global climate change resulting from human activity is expected to increase the intensity, frequency, and impacts of weather-related "natural" hazards (UN / ISDR 2004).

Many countries are now engaged in disaster risk reduction and this activity is likely to increase in the wake of the Asian tsunami of 26 December 2004. The scientific community is making efforts to monitor numerous parametres related to hazardous events. By studying and understanding past events and monitoring on-going ones, we can glean information that will help to minimize the risk of disaster. While most natural hazards are inevitable, disasters are not (UN / ISDR 2004). Satellite imagery, aerial photography and Geographic Information Systems (GIS) technology are important tools in monitoring and in providing early warning information about these natural hazards and the impacts they may have so that preventive measures can be taken against impending disasters (UN / ISDR 2004). This chapter includes case studies based on remote sensing data, providing visual examples of each type of extreme event discussed.

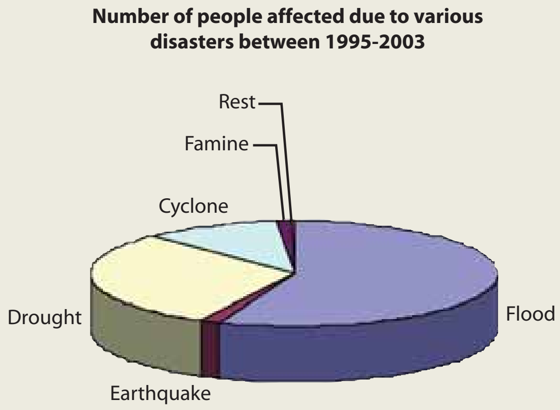


Figure 4.1: The number of people affected as a result of different types of natural hazards between 1995 – 2003. Floods were the most destructive hazard, followed by droughts, cyclone / hurricane / typhoons and earthquakes. *Source: UN/ISDR 2004*

Extreme events are hazards that occur as consequences of the impacts of natural or a human-induced hazard. In this publication, extreme events are divided into three categories:

- Geo-hazards: volcanoes, earthquakes, tsunamis, landslides / mudslides;
- Climatic hazards: floods, drought, hurricanes, tropical cyclones, tornadoes, ice storms;
- Industrial hazards: oil spills, nuclear, and industrial accidents.

All of these events can expose people and ecosystems to danger. Proportionally, they tend to hurt the poor most of all. This is because the poor outnumber the rich and live in greater density in more poorly built housing on land most at risk. They also have fewer resources and capacity to prevent or cope with the impacts (UNEP 2002a). The number of disasters has increased more than four-fold since the 1960s, from an average of 44 disasters a year to an average of 181 disasters a year by the 1990s. Although some of this increase may be due to improved reporting of events, it is likely that the number, severity, and frequency of natural disasters is increasing. In addition to improved reporting, the substantial growth in world population and the increasing vulnerability of marginal groups is a significant factor in the growth of natural disasters (Kasperson et al. 2001).

Since 1900, natural hazards have caused over 50 million deaths. Between 1995 and 2003, they affected 6 000 million people (some 2 500 million in Asia alone) and caused over 6 million deaths. Floods affect by far the most people (Figure 4.1). While the number of disasters appears to be increasing, the number of fatalities is declining. This fact may be attributed to improved forecasting, better preparedness, and quicker response to disasters. On the other hand, the number of persons affected has increased. This is not surprising, given the rapidly growing populations of most developing countries and the millions of people who depend directly on the natural resources in their immediate environments to sustain their livelihoods. When these resources disappear or are degraded in floods, earthquakes, tsunamis, and other disasters, the economies of families and whole communities are devastated.

Economic losses from natural disasters have also increased over the past 50 years. Part of this upward trend is linked to socioeconomic factors, such as population growth in, and migration to, large cities in vulnerable areas, and the increased wealth of some populations that choose to live in hazard-prone areas. Another factor is linked to climate change, such as changes in precipitation and flooding events that destroy property and businesses (OWF n.d.).

4.1 Geo-hazards

Volcanoes

A volcano is a vent in the surface of the Earth through which magma and associated gases and ash erupt; also, the word refers to the form or structure (usually conical) that is produced by the ejected material (UND n.d.). Volcanic eruptions are among the most impressive natural disasters, due to their unpredictable nature, which includes flying debris, streams of molten lava, emissions of toxic gases, seismic effects, and the many impacts these have on the people, animals, and plants in their way.

About 550 volcanoes have erupted in the Earth's recorded history and an equivalent number of dormant volcanoes have only erupted in the past 10 000 years. Both dormant and "active" volcanoes have the potential to erupt again. On any given day, about ten volcanoes are actively erupting (Camp 2000). Explosive eruptions give little warning, while effusive eruptions, which send out gently flowing lava, allow time for people to escape (Francis 1993).

Of all natural hazards, volcanic eruptions and earthquakes are the least exacerbated by human activity. These powerful events fit more neatly into the definition of truly "natural" disasters. Nevertheless, human activity can increase the risk of damage caused by such events. For example, volcanic regions are attractive sites because the soils are fertile and they provide valuable minerals, water reservoirs, geothermal resources, and scenic beauty. People become more vulnerable when they settle too close to active volcanoes. Poor people may move closer to these potentially dangerous sites as their populations grow and or when they have no access to other land. Out of necessity, they may cut trees on volcano slopes, increasing the danger from lava flows when they happen (Benson 2002).

A massive volcanic explosion can have important environmental consequences also, due to the blast of huge clouds of ash, dust, and gases into the atmosphere. Volcanic debris in the lower atmosphere falls out or is rained out within days. Volcanic gas can be directly harmful to humans, animals, plants, agricultural crops, and property. The most common consequence is the movement of large numbers of people fleeing the lava flow.

Environmentally, the hazards from volcanic gases are most severe in the areas immediately surrounding volcanoes, especially on volcano flanks downwind of active vents and fumaroles. These hazards can persist for long distances downwind, however, following large eruptions, or from volcanoes erupting gas-rich magma (McGee et al. 1997). The resulting veil of pollution in the upper atmosphere can have long-term and geographically extensive impacts on climate. Such pollution is in the stratosphere and may remain for several years, gradually spreading to cover much of the globe. The particles reflect energy from the sun back into space, preventing some of the sun's rays from heating the Earth, thus reducing global warming. The Mount Pinatubo eruption of 1991 was such a case. An individual eruption may generate global cooling amounting to two or three tenths of a degree Celsius with effects lasting for a year or two (Kelly 2000; Santer et al. 2001). Millions of tonnes of sulfur dioxide gas may reach the upper atmosphere where it transforms into tiny particles of sulfuric acid, known as aerosols, that can lead to acid rain (Kelly 2000; CSIRO 2002). Major eruptions have not been common this past century, occurring once every ten to twenty years, so the long-term influence has been slight (Kelly 2000).

Volcano Credit: HVO / UNEP / USGS

Case Study: Kilauea Volcano Eruption, Kalapana, Hawaii 1983-1991

An example of the kind of damage wrought by volcanoes is the eruption of Kilauea Volcano in Hawaii. Between 1983 and 1990, erupting lava repeatedly invaded communities along the southern coast of the Big Island of Hawaii, destroying more than 180 homes, a visitor center in Hawaii Volcanoes National Park, highways, and treasured historical and archaeological sites.

Source: USGS 2000; USGS 2002

Credit: J.P. Eaton/UNEP/USGS

These photos show the ecological effects of the eruption, including defoliated papaya plants in an orchard at the north edge of the Saefuji orchid farm. The leaves have been abraded and sheared off by falling pumice from the lava fountain in the background. The ridge between the orchard and the fountain in the photo on the right was formed by the advancing `a`a flow (an Hawaiian term for a type of lava flow that leaves rough-edged, porous lava). *Photos by J.P. Eaton/UNEP/USGS Source: http://hvo.wr.usgs.gov/kilauea/history/1960Jan13*

Maps of lava-flow field from the Pu`u `O`o and Kupaianaha vents of Kilauea Volcano, Hawaii, January 1983 - January 1991

Orange colour shows areas covered by lava erupted from Pu`u `O`o between January 1983 and June 1986. Red colour shows areas covered by lava erupted from Kupaianaha between July and October 1986.

Photos by J.P. Eaton. Source: http://hvo.wr.usgs.gov/kilauea/history/1990Kalapana/#heart

January 1983 - October 1986

January 1983 - December 1986

January 1983 - December 1989

January 1983 - January 1991

23 April 1990

6 June 1990

13 June 1990

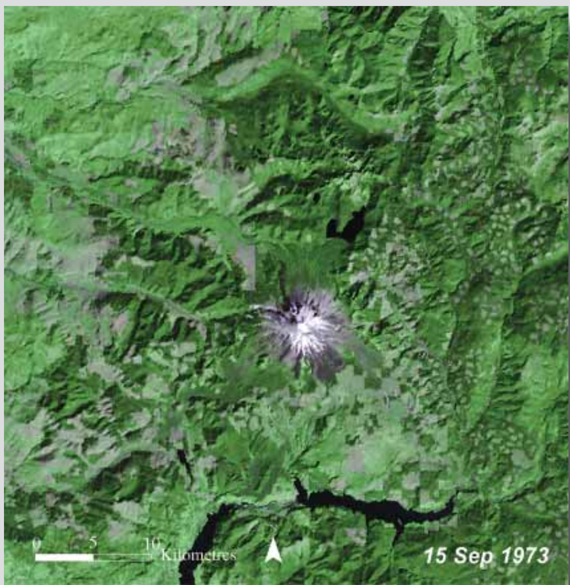
Case Study: Eruption of Mount St. Helens 18 May 1980

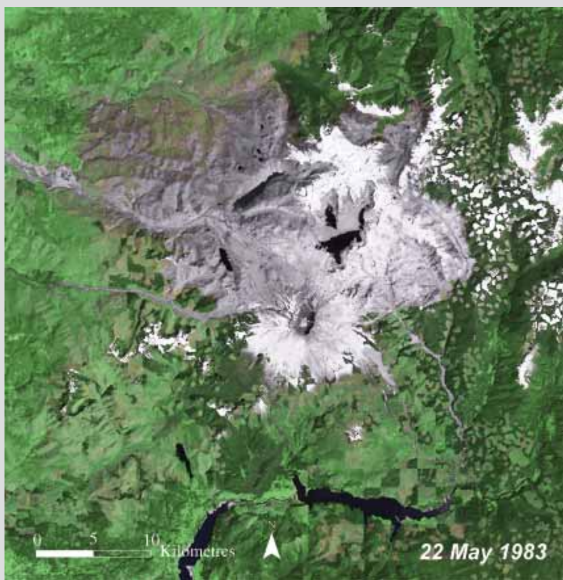
Mount St. Helens is located in the state of Washington on the west coast of the United States. It is part of the Cascade Range, which is dominated by periodically active volcanic peaks. For most of the 20th century, the snow-covered mountain was known for its quiet beauty, until on 18 May 1980, the top 420 m (1 300 ft) disappeared within minutes. The blast leveled 400 km^2 (249 square miles) of forest, formed a deep horseshoe crater, and sent thousands of tonnes of ash into the upper atmosphere. A major debris flow filled a valley along 24 km (15 miles). Sixty-two people were dead or missing. This eruption of Mount St. Helens was the most destructive in the history of the United States, with total economic losses estimated at US$1.2 billion (NGDC 2004).

Growth of the new lava dome inside the crater of Mount St. Helens continues, accompanied by low rates of seismicity, low emissions of steam and volcanic gases, and minor production of ash (USGS 1999). Lessons learned from this and other volcanic activity in the Cascade Range will be invaluable to scientists for predicting such events and anticipating their ecological impacts (UNEP 2003).

Mount St. Helens and the devastated area is now within the Mount St. Helens National Volcanic Monument, under jurisdiction of the United States Forest Service. Visitor centers, interpretive areas, and trails are being established as thousands of tourists, students, and scientists visit the monument daily. Mount St. Helens is once again considered to be one of the most beautiful and interesting of the Cascade volcanic peaks.

Credit: Photograph taken on May 19, 1982. Lyn Topinka/UNEP/USGS Source: Poland 2002





Credit: Space Imaging

Credit: Space Imaging

Earthquake destruction Credit: News Photo / UNEP / FEMA

Earthquakes and Tsunamis

Earthquake refers to volcanic or magmatic activity or other sudden stress changes in the earth. The term is used to describe both a sudden slip on a fault and the resulting ground shaking and radiated seismic energy caused by the slip (USGS 2002).

Earthquake impacts are many and varied, ranging from minor structural damage in a few buildings to complete devastation over huge areas. The most powerful earthquakes are capable of annihilating major urban centers and severely disrupting the social and economic fabric of nations. For example, the Kobe Earthquake of 1995 resulted in over 6 000 deaths and estimates of repair costs in the range of US$95 billion to US$147 billion (EQE 1995).

Table 4.1 – Five largest earthquakes in the world since 1900

Year	Magnitude	Country
1960	9.5	Chile
1964	9.2	Prince William Sound, Alaska
1957	9.1	Andreanof Islands, Alaska
1952	9.0	Kamchatka
2004	9.0	Banda Aceh, Indonesia

Source: NEIC 2004, http://neic.usgs.gov/neis/eqlists/10maps_world.html December 30, 2004.

A tsunami (soo-NAH-mee) is a series of extremely long traveling ocean waves generated primarily by underwater ground displacement due to an earthquake or volcanic eruption. In the deep ocean, tsunami waves propagate at speeds exceeding 800 km / h (500 mph). Here, the wave height is only a few tenths of metres(<1 foot) or less. Tsunamis differ from ordinary ocean waves because of the great distance and time between wave crests, which are often separated geographically by more than 100 km (60 miles) in the deep ocean and in time by 10 minutes to an hour. As they reach the shallow waters of the coast, the waves slow down and the water can pile up into a wall of destruction. The effect can be amplified where a bay, harbor, or lagoon funnels the wave as it moves inland. Large tsunamis have been known to rise over 30 m (100 ft). Even a tsunami 3–6 m (10–20 ft) high can be very destructive and cause many deaths and injuries.

Table 4.1 shows the five largest earthquakes since 1900 as measured on the Richter scale. Although it is the fifth largest, the Banda Aceh earthquake-tsunami that originated in Indonesia on 26 December 2004 affected two continents and led to the largest number of deaths.

According to long-term records (since about 1900), we can expect about 18 major earthquakes (7.0 - 7.9 on the Richter scale) and one great earthquake (8.0 or above) in any given year (NEIC 2003). The U.S. Geological Survey, however, estimates that several million earthquakes occur in the world each year. Many go undetected because they occur in remote areas or have very small magnitudes. The National Earthquake Information Center (NEIC) now locates about 50 earthquakes each day, or about 20 000 a year (NEIC 2004). An increase in the number of seismograph stations and the more timely receipt of data has allowed scientists to locate earthquakes more rapidly and to detect ever-smaller seismic events (NEIC 2003).

The number of earthquakes and tsunamis resulting in fatalities has increased approximately in proportion to global populations, and although a decreasing fraction of the global population has been killed by earthquakes in the 20th century compared to past centuries, seismic risk in certain regions has increased substantially. The cause of the apparent paradox lies in the growth of urban agglomerations where most of the world's growing population will live, and the location of many of these cities near plate boundaries where earthquakes occur quasi-periodically (Bilham 1995).

The growth of giant urban cities near regions of known seismic hazard is a new experiment for life on the Earth. With few exceptions, recent large earthquakes (M>7.5) have spared the world's major urban centers. This will not persist indefinitely. The recurrence interval for damaging earthquakes varies from 30 years to 3 000 years; if population densities remain high in the 21st century, several megacities will be damaged by significant earthquakes (Bilham 1995).

Tsunamis are a threat to life and property for all coastal residents. There has been massive migration to coastal areas, and today, more than half the world's population lives close to the sea (Global Oceans 1999). This has caused the rapid degradation of these areas. As protective natural features, such as coral reefs and mangroves, are removed by human development for tourist hotels and shrimp

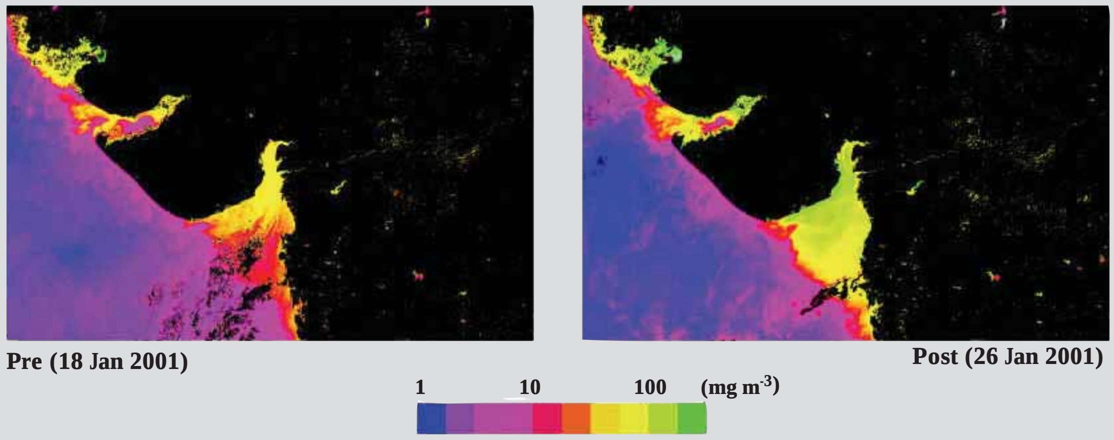
Case Study: Bhuj Earthquake, India 26 January 2001

R. P. Singh, S. Bhoi, A. K. Sahoo

The magitude 7.6 Bhuj earthquake that shook the Indian Province of Gujarat on the morning of 26 January 2001 was one of the two most deadly earthquakes to strike India in its recorded history. One month after the earthquake the death toll had reached 19 727, and the number of injured reached 166 000 with at least 600 000 people left homeless. Government estimates placed direct economic losses at US$1.3 billion. Other estimates indicate losses were as high as US$5 billion. The earthquake brought significant changes to the land and surrounding ocean water bodies.

The images above show changes in chlorophyll concentration prior to and after the earthquake. High concentrations of chlorophyll, together with high ocean surface temperature, are favorable conditions for catching fish. The significant increase in the fish caught in February around the Gujarat coast after the earthquake was found to be double that of the normal February fish catch. *Source: Singh et al. 2002*

Chlorophyll Concentration



Mud volcano observed in Gujarat earthquake of 26 January 2001. *Credit: Ramesh P. Singh/UNEP/Indian Institute of Technology, Kanpur*

A big tentional crack (approximately 30 cm deep) in a nearby field on Bhuj, Khewda. Salt water had come up to the surface through the crack due to liquefaction. *Credit: Ramesh P. Singh/UNEP/Indian Institute of Technology, Kanpur*

acquaculture farms, for example, so the shoreline becomes increasingly vulnerable to the impacts of wave action and potential tsunamis. Coastal areas are also increasingly at risk due to the effects of burning of fossil fuels; climate change threatens to trigger more powerful storms and raise sea levels, exposing coasts to erosion (Doyle 2004). Global warming, poorly planned coastal development, and other threats over which humans have some control are weakening the coast's ecological defenses against natural disasters.

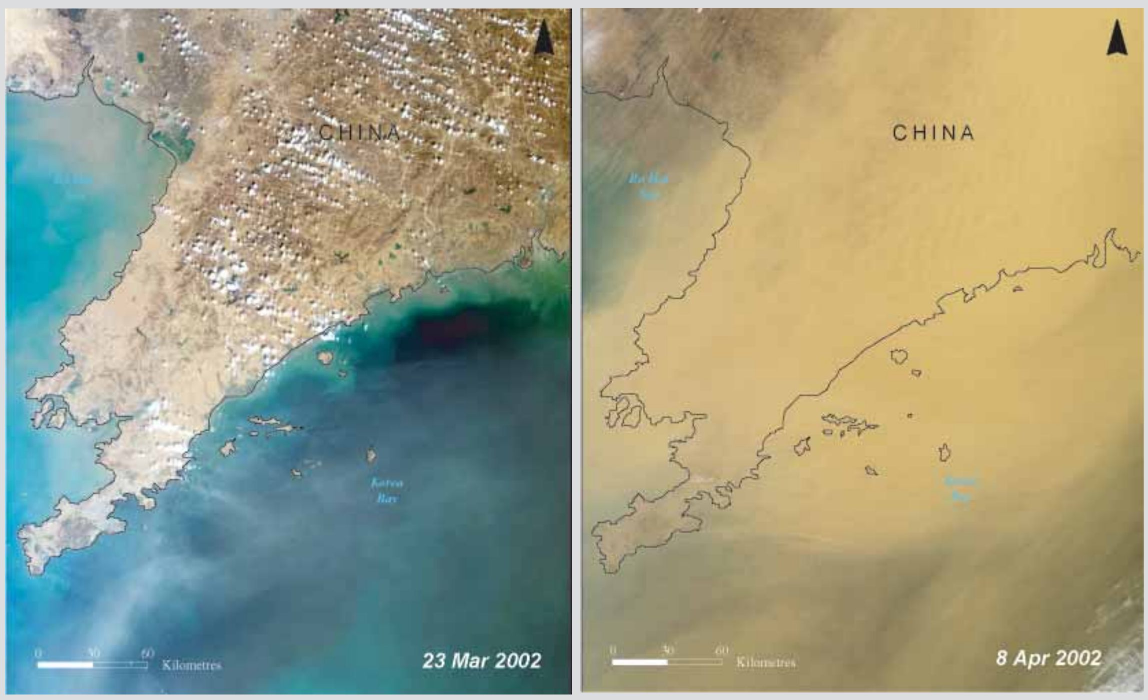
Of course, tsunamis can cause immeasurable damage to marine and terrestrial ecosystems, including coral reefs, mangroves, and forests. This in turn affects the livelihoods of coastal populations who depend directly on natural resources such as fish, food from household gardens, and forest products.

Case Study: Dust Storms Over China March and April 2002

Dust storms are increasing globally with far-reaching consequences for the environment and human health. Severe dust storms can reduce visibility to zero, making travel impossible, and can blow away valuable topsoil, while depositing soil in places where it may not be wanted. Drought and, of course, wind contribute to the emergence of dust storms, as do poor farming and grazing practices. The dust picked up in such a storm can be carried thousands of kilometres.

This pair of images, acquired 16 days apart, covers the Liaoning region of China and parts of northern and western Korea. They contrast a relatively clear day (23 March 2002) with one in which the skies were extremely dusty (8 April 2002). In the later view (right image), the dust obscures most of the surface, although the Liaodong peninsula extending between the Bo Hai Sea and Korea Bay is faintly visible at the lower left. Wave features are apparent within the dust layer.

Storms such as this transport mineral dust from the deserts of China and Mongolia over great distances, and pollution from agriculture, industry and power generation is also carried aloft. Thick clouds of dust block substantial amounts of incoming sunlight, which in turn can influence marine phytoplankton production and have a cooling effect on regional climates. *Source: NASA n.d.; Planetary Photo Journal; Wikipedia n.d.; Vince 2004.*



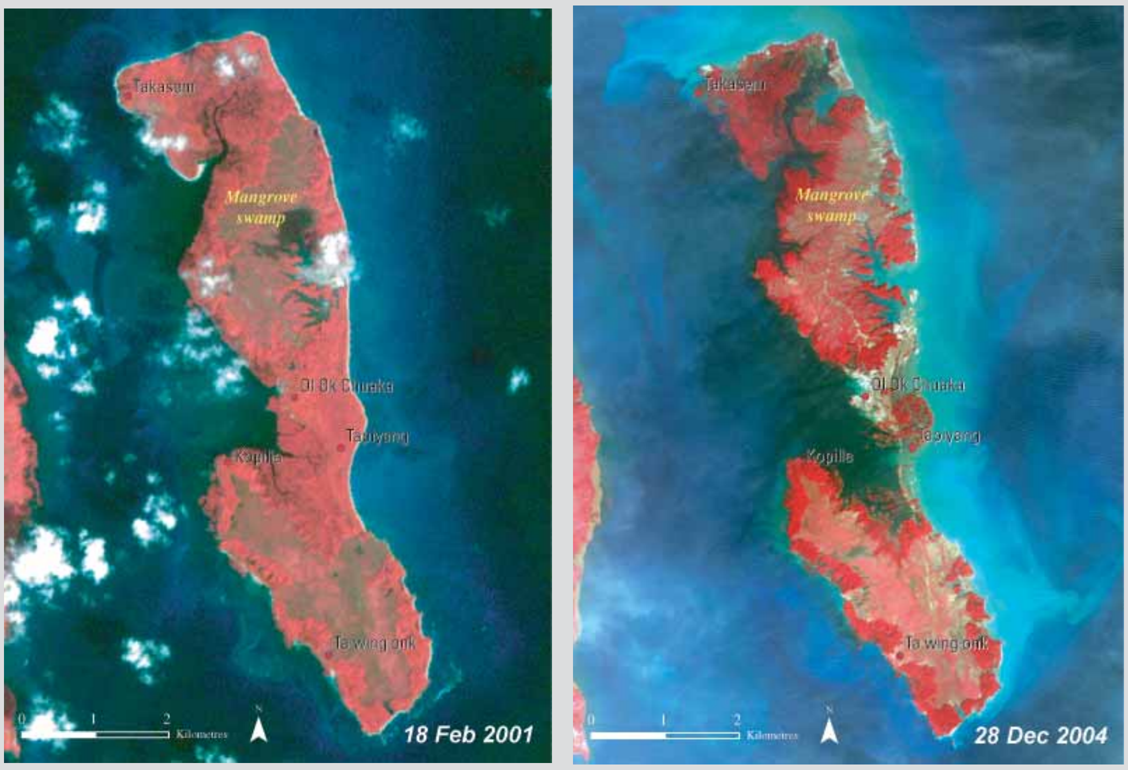
Satellite images courtesy NASA/GSFC/LaRC/JPI, MISR Team

Credit: Unknown/UNEP/FAO

Case Study: Indian Ocean Tsunami 26 December 2004

On 26 December 2004, an undersea earthquake measuring 9.0 on the Richter scale took place in the Indian Ocean, off the west coast of northern Sumatra, Indonesia. It caused one of the deadliest disasters in recent times. Resulting tsunami waves crashed into the coastlines of twelve countries bordering the Indian Ocean, causing massive losses in human life and infrastructure, and damage to marine and terrestrial ecosystems. It is estimated that the tsunami killed more than 200 000 people, left up to 5 million in need of basic services, and caused billions of dollars of damage.

The effects of the disaster include massive changes in the physical environment. For example, it is possible that the ocean depth in parts of the Straits of Malacca, one of the world's busiest shipping channels off the coast of Sumatra, was reduced from about 1 200 m (4 000 feet) to perhaps only 30 m (98 ft), a depth that is too shallow for shipping (AP 2005).



The island of Trinkat, part of the Nicobar Islands, India, appears to have been cut in half by the tsunami with a new channel of water approximately 5 km (3 miles) long stretching from the settlement of Tapiyang to a point on the opposite coast just west of Ol Ok Chuaka. Another channel has possibly been opened up to the southeast of Takasem separating the large mangrove area from the inhabited northern end of the island. The mangrove appears to be relatively intact though several inlets have been created in the east. The extensive coral reefs visible along the west and east coasts of Trinkat before the tsunami are largely obscured by large plumes of sediments presumably washed from the land. The coastline has retreated along the east coast enlarging the lagoon. This scouring of terrestrial matter into the lagoon and onto the reefs could have serious consequences for shallow water habitats if sediments settle for longer periods. *Source: UNOSAT*

Photo taken in Kulmunai Kuddi on Sri Lanka's east coast. *Credit: Unknown/UNEP/USGS*

The city of Banda Aceh, Indonesia, suffered catastrophic damage as a result of the tsunami that struck on 26 December 2004. These QuickBird Natural Colour images on 23 June 2000 and on 28 December 2004 (below) clearly show the city before the devastation and the extent of the damage after the tsunami. *Source: Digital Globe: http://www.digitalglobe.com/images/tsunami/Banda_Aceh_Tsunami_Damage.pdf*

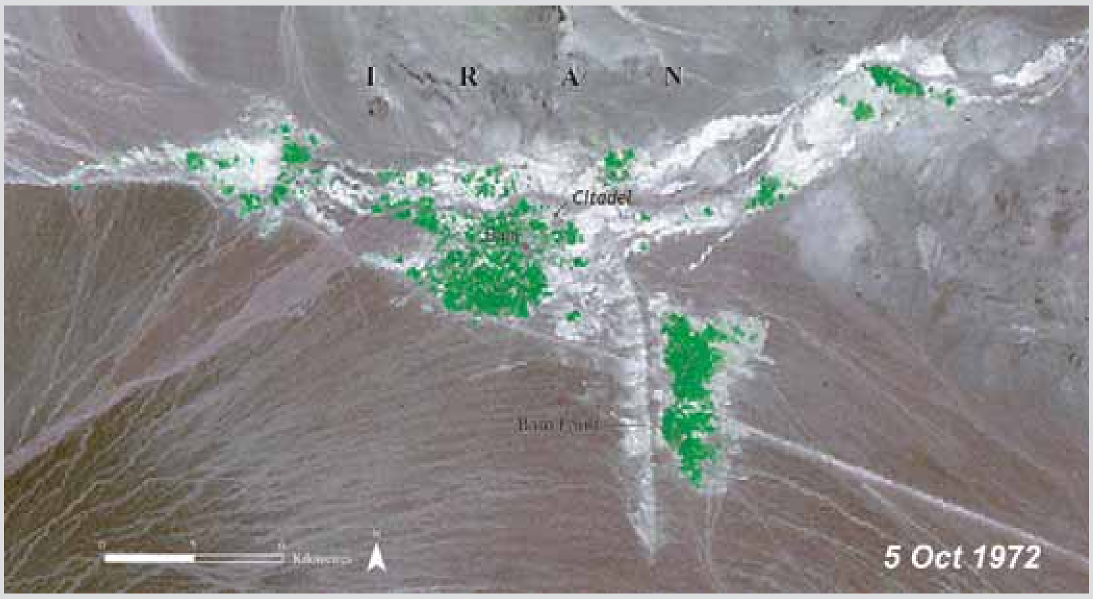
These images are of the southwestern coast of Sri Lanka, taken shortly after the tsunami struck the coastline. The image dated 26 December 2004 was taken shortly after the shoreline was struck by the tsunami, while the second image was taken after the ocean returned to normal. *Source: http://www.digitalglobe.com/images/tsunami/Sri_Lanka_Tsunami_Damage.pdf*

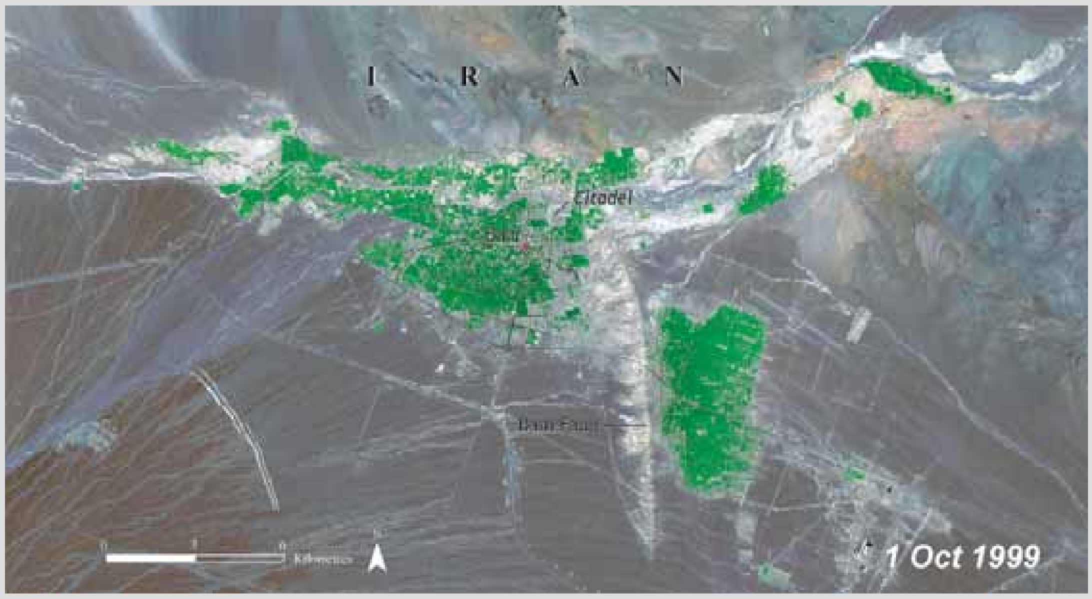
Case Study: Bam Earthquake 26 December 2003

Bam is located in the southeastern corner of Kerman province in Iran. Maintaining its position in the middle of the southern trade route, this small, fortified city on the outskirts of the vast Dasht-é-Lut Desert is just 350 km (217 miles) west of Pakistan and 450 km (280 miles) north of the Persian Gulf. Eighty-thousand people make their homes within Bam's boundaries.

A 6.6 magnitude earthquake struck southeastern Iran on 26 December 2003, killing over 40 000 people, injuring 16 000, leaving 70 000 homeless and destroying much of the city of Bam, the earthquake's epicenter. The quake destroyed the ancient citadel of Arg-e-Bam, located on the historic Silk Road and thought to be over 2 000 years old. This citadel was said to be the largest mud brick structural complex in the world. Apart from the toll on human lives, the loss of this ancient site represents an important cultural loss.

Although Iran is subject to frequent large quakes, it does not have strong building codes and buildings generally do not withstand the impact of these events. As a result, casualties and damage are much higher than might be expected from a similar quake elsewhere in the world (The Earthquake Museum 2003). *Source: NASA 2004e*





Credit: Unknown/UNEP/IIEES

Healthy Vegetation

In a region famous for the scarcity of its water, Bam thrived with extensive palm groves and citrus gardens (see images above). Benefiting from subterranean water reserves, surfacing through a number of several–km–long water canals, Bam was essentially an agricultural city famous for, and a major producer of, the very best date fruits in all of Iran. After the earthquake of 26 December 2003 that flattened the citadel and the mud-brick houses and destroyed 85 per cent of the city's buildings, just about the only things left standing tall above the ruins of Bam were the mainstays of the local economy: date palms. The date harvests that produced thousands of tonnes of dates each year were left undamaged in plantation fields and house gardens, offering hope for an agricultural-based recovery. Irrigation repairs have begun and agriculturists are optimistic that future date harvests could be as large as those before the earthquake. *Source: USGS n.d.*

Credit: Unknown/UNEP/IIEES

Mudslide Credit: News Photo / UNEP / FEMA

Landslides and Mudslides

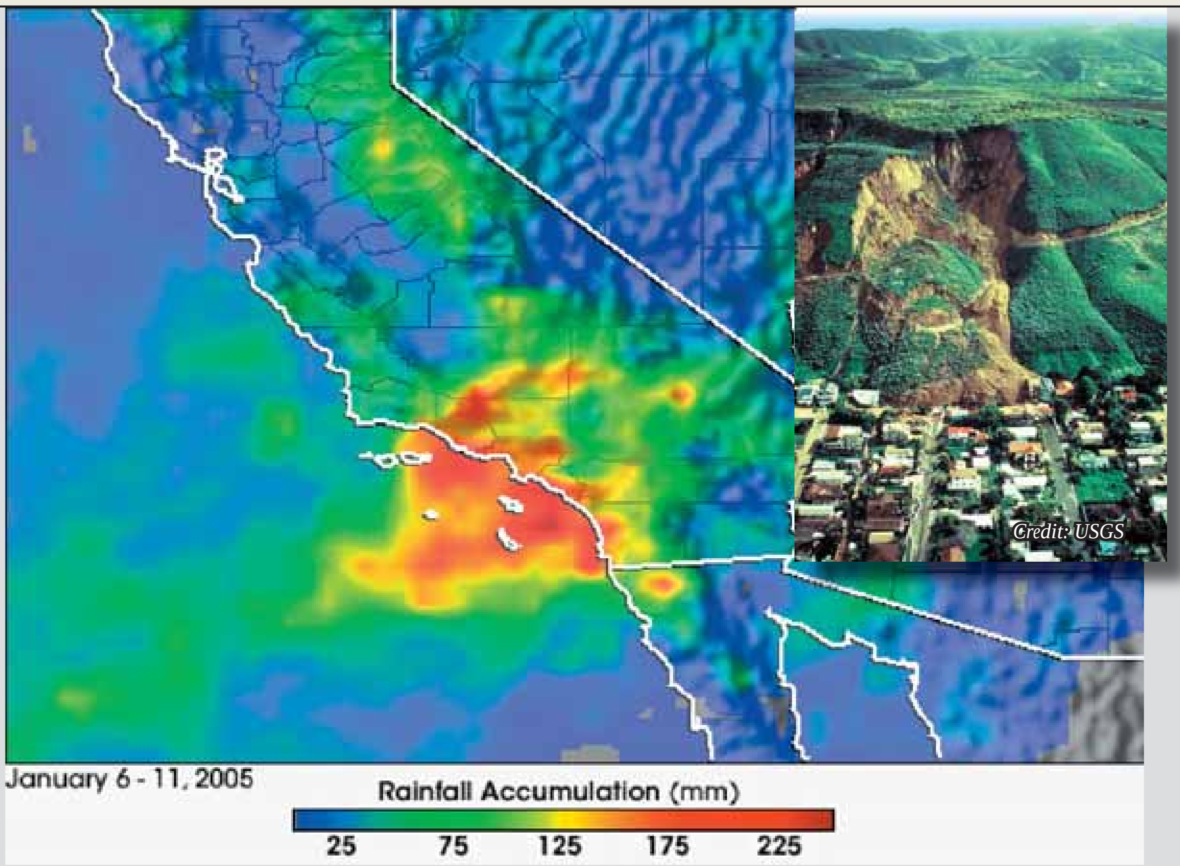
Worldwide, thousands of people die every year from landslides and mudslides. In the United Sates alone, they cause an estimated US$1 billion in damage and kill 25 to 50 people every year. Earthquakes, volcanoes, and a number of types of weather events can trigger landslides, which are characterized by lethal mixtures of water, rocks, and mud. The two largest landslides in the world in the 20th century occurred at Mount St. Helens, Washington, in 1980 and at Usoy, Tajikistan, in 1911. Although Mount St. Helens was the largest landslide recorded in historic time, fewer than 60 people were killed because most residents and visitors had been evacuated. The Usoy landslide, also triggered by an earthquake, moved 2.4 km^3 (1.5 cubic miles) of material and built a dam 573 m (1 880 feet) high (half again as high as the Empire State Building) on the Murgob River in Tajikistan; the dam still impounds a lake nearly 64 km (40 miles) long. This landslide took place in a sparsely populated area and thus caused few deaths (USGS 1999).

The deadliest landslide this century was also the result of an earthquake, which occured in western Iran on 20 June 1990. It caused 40 000–50 000 deaths. One of the world's other major landslides includes the rock and snow avalanche triggered by a magnitude 7.8 earthquake at Mount Huascaran, Peru, on 21 May 1970 that buried the towns of Yungay and Ranrahirca, killing perhaps as many as 20 000 people (NASA 1999).

Case Study: Mudslides in California 6-11 January 2005

Many days of storms across California in January 2005 led to flooding, mudslides, and huge snowfall totals. On 10 January, a landslide struck the town of La Conchita in Ventura County, destroying or seriously damaging 36 houses and killing ten people. It was not the first destructive landslide in the area and future landslides are likely to occur. The area is a narrow coastal strip of land between the shoreline and a high bluff above which rises a terrace covered by avocado and citrus orchards (Jibson 2005). Despite the landslide risk, a growing and generally wealthy population has expanded into fragile or risk-prone areas such as these in California, often building expensive homes like those destroyed in La Conchita. The population of Ventura County, for example, grew by five per cent in 2003, from 753 197 in 2000 to approximately 790 000 (US Census Bureau 2004).

In the image at right, Multi-satellite Precipitation Analysis (MPA) rainfall totals are shown for the period 6–11 January 2005. The red areas just off of the coast indicate the highest totals of more than 225 mm (about 9 inches) of rainfall. *Source: NASA 2005*



NASA Earth Observatory: http://earthobservatory.nasa.gov/NaturalHazards/natural_hazards_v2.php3?img_id=12669 7 February 2005

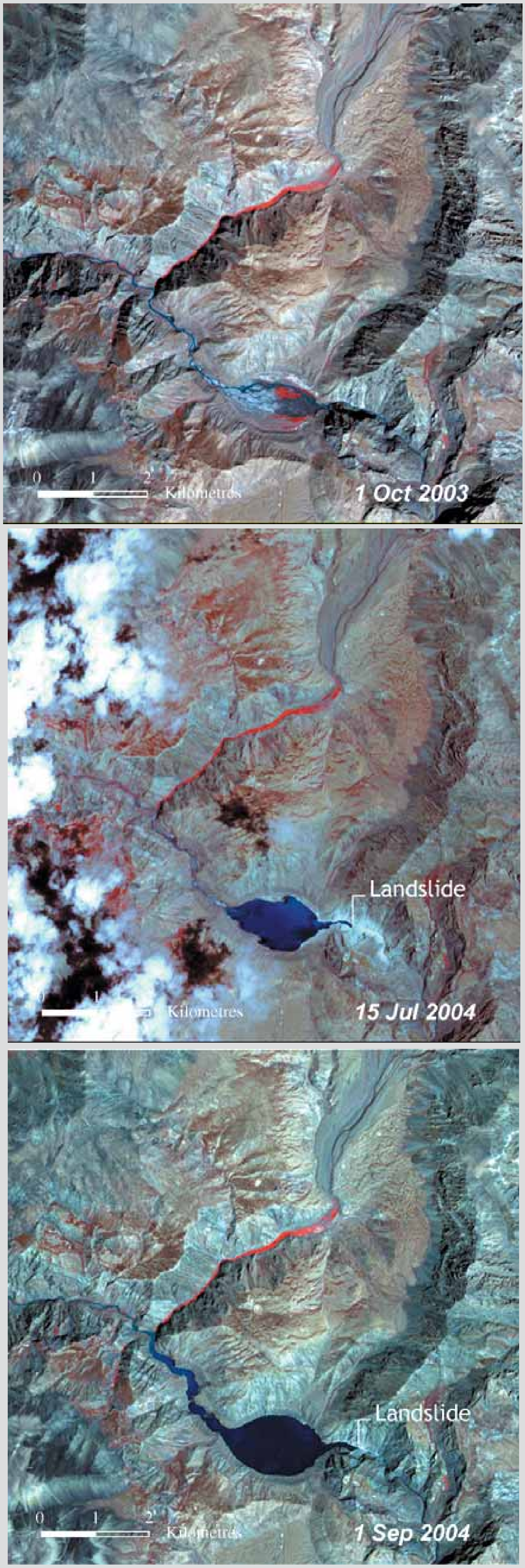
Case Study: Landslide Creates Lake in Tibet 2004

Tibet is the major source of Asia's great rivers. It also has the Earth's loftiest mountains, the world's most extensive and highest plateau, ancient forests, and many deep valleys untouched by human disturbance.

In early summer of 2004, a landslide in the Zaskar Mountains, a range of the Himalayas, created a natural dam blocking the Pareechu River in its course from the Tibet Autonomous Region of China to the Himachal Pradesh State of northern India. The dam is 35 km (22 miles) from India's border with China. The water is slowly building behind the dam, creating an artificial lake in the remote mountain region. By 13 August, the lake had spread over 188 hectares and had reached a depth of 35 m (115 feet), with water levels rising daily.

The new dam and lake pose a threat to communities downstream in northern India. Indian and Chinese officials fear that the unstable dam will burst, releasing a torrent of water on these populated regions. The remoteness of the area and the ruggedness of the terrain have precluded preventative measures that could control the potential catastrophic release of water, although people have been evacuated from villages in both the Chinese and Indian parts of the region (NASA 2004a).

These images show the area before the landslide (top) and the growing lake following the landslide (center and bottom) on 15 July 2004 and 1 September 2004. What previously had been a river valley around the meandering Pareechu River on has been entirely covered with dark blue water.



Satellite images courtesy NASA/GSFC/MITI/ERSDAC/JAROS, and U.S./Japan ASTER Science Team

Source: Zhu Pingyi/UNEP/ICIMOD and RRC-AP

4.2 Climatic Hazards

Climatic hazards include storms, floods, heat waves, droughts, and ice storms. The majority (two-thirds) of all natural disasters are climate or weather-related, principally through drought, flooding, and storms. Furthermore, of all natural hazards, human activity affects weather-related hazards the most. With a changing climate influenced by the burning of fossil fuels, extreme weather events are projected to increase in frequency and / or severity during the 21st century (IPCC 2001). Combined with population growth and increased settlement in risk-prone areas, the impacts of such events on humans and ecosystems will also increase.

A storm is a low pressure in the atmosphere marked by wind and usually by rain, snow, hail, sleet, or thunder and lightning. One of the most violent and destructive is the cyclone or hurricane.

A tropical cyclone is a large-scale closed circulation system in the atmosphere above the ocean with low barometric pressure and strong winds. The winds rotate clockwise in the southern hemisphere and counter-clockwise in the northern hemisphere. The system has wind speeds of 119 km / h (73 mph) or more (UN-DHA 1992).

Tropical cyclones are called "hurricanes" in the western Atlantic and "typhoons" in the western Pacific. These dangerous storms can be found in three of the Earth's four oceans and in both hemispheres. Even though Atlantic Ocean tropical cyclones (hurricanes) receive a lot of attention, only 12 per cent of tropical cyclones worldwide are located here. The northwestern Pacific Ocean averages more than 25 cyclones (typhoons) each year. Another location with great activity is the Indian Ocean. No other part of the world has so much activity in such a small area. The Southern Hemisphere also experiences tropical cyclones. However, they are confined to the Western Pacific and Indian Oceans (DAS n.d.).

A tropical cyclone's storm surge is the most destructive aspect of the storm. It kills the most people, destroys buildings, and erodes coastal shorelines. Hurricane Andrew, which landed in south Florida in 1992, was the most expensive cyclone to date, causing US$25 billion in property damage and killing 26 people. The cyclone that caused the highest mortality in the 20th century was an unnamed typhoon that struck Bangladesh in 1970, killing about 300 000 people.

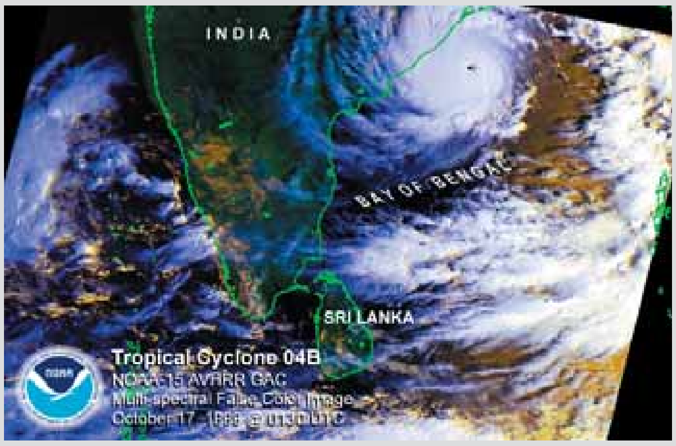
Scientists predict that global warming will cause warmer ocean temperatures and associated increased moisture in the atmosphere—two variables that work to power hurricanes. As a result, more intense hurricanes that cause even more damage when they hit land are predicted (Henderson-Sellers et al. 1998).

Tropical cyclones also cause flooding. A flood is a significant rise of water level in a stream, lake, reservoir, or coastal region (UN-DHA 1992). Human actions can cause or contribute to flooding events through the impacts of dams, levees, the removal of wetlands (that store water), deforestation (resulting in erosion), and other means.

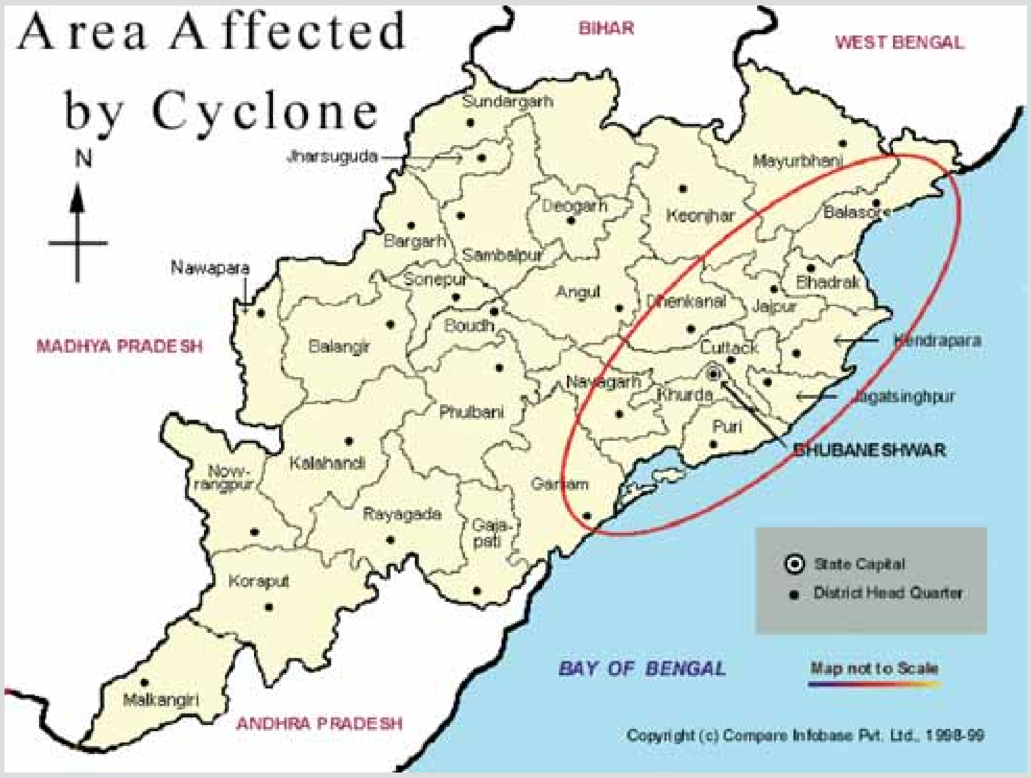
Flooding Credit: Andrea Booher / UNEP / FEMA

Case Study: Supercyclone hits eastern India 29 October 1999.

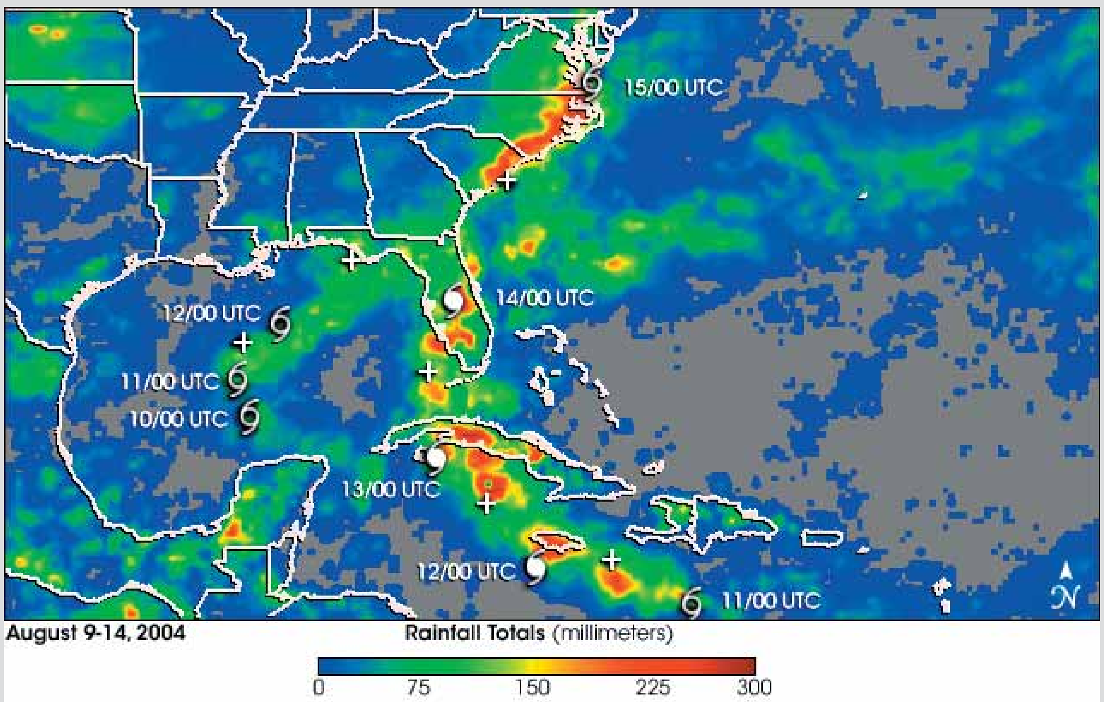
On 29 October 1999 a supercyclone with winds in excess of 257 km / h (160 mph) swept in from the Bay of Bengal to hit the eastern state of Orissa, India. An estimated 15 million people were left homeless by the storm, which had a death toll as high as 10 000.



Supercyclone approaching Orissa coast, India, October 1999



Coastal areas of Orissa were hard hit by the supercyclone. The oval outline encloses major areas affected by this supercyclone. *Source: Maps of India, 2004. http://www.mapsofindia.com/maps/mapin-news/22101999.htm July 18, 2004*



Hurricane Charley blew ashore over Punta Gorda, Florida, on 13 August 2004, with winds topping 233 km / hr (145 mph). Two days later, the Ikonos satellite captured the top image above. The image shows the destruction the Category 4 hurricane wrought on the coastal city. Debris is scattered across roads, parking lots, and yards, giving the scene a "messy" appearance compared to the crisp, neat neighborhoods shown in the lower image, taken two years earlier on 28 July 2002. *Source: NASA 2004b, http://earthobservatory.nasa.gov/Newsroom/NewImages/images.php3?img_id=16639*

Case Study: Hurricane Charley August 2004

Hurricane Charley developed from a tropical wave that emerged off the African coast early in August 2004. It hit the western tip of Cuba and by the time it reached the greater Havana area, maximum sustained winds were nearly 165 km / hr (105 mph). Western Cuba suffered more than US$1 billion in property damage and three people died.

The map above shows Charley's path between the 9th and 14th of August 2004 as it traveled up from the Caribbean into Florida and the southeast United States. The map shows Multi-satellite Precipitation Analysis (MPA) rainfall totals for the period. A swath of 7–12 cm (3–5 in) rainfall (green area) extends from the central Gulf of Mexico into northern Florida as a result of Tropical Storm Bonnie, which landed in Florida on the 12th of August. A heavier swath of rain containing 7–25 cm (3-10 in) amounts (darker red areas) extends from the north central Caribbean up through Cuba across Florida and merges with a heavy rain area along the Carolina coast.

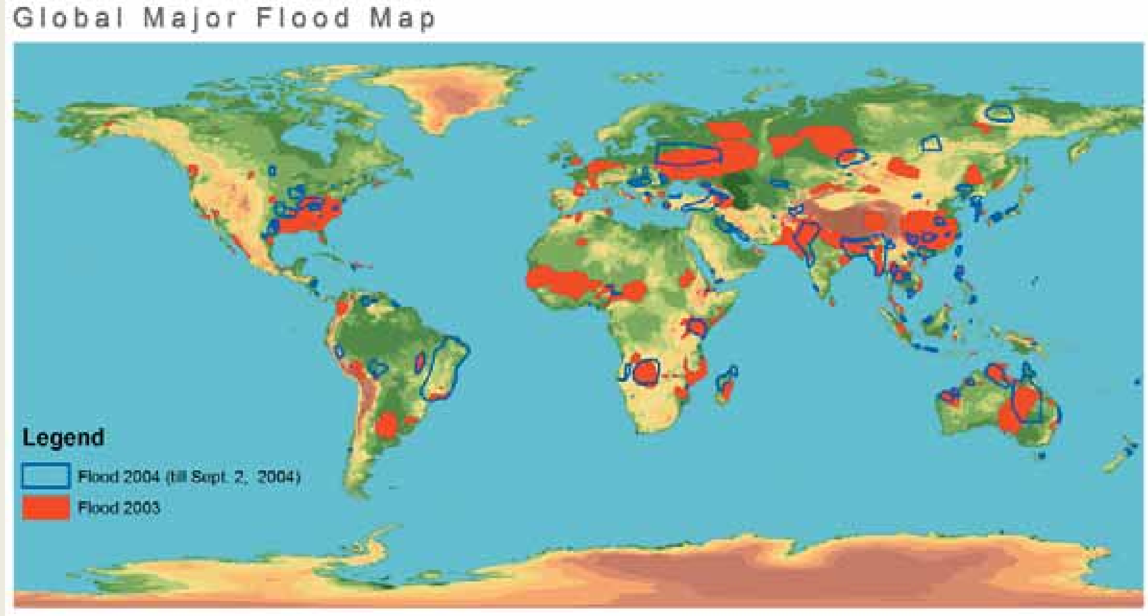
In Florida, 25 of the state's 67 counties were declared federal disaster areas. Estimated insured losses from Charley were US$7 billion, while total economic loss was estimated at nearly US$15 billion. Charley was blamed for 22 deaths.

Despite its history of hurricanes, Florida's warm weather and beaches attract migrants, retirees, and tourists. Florida's population grew by 6.5 per cent between 2000 and 2003 (U.S. Census Bureau 2004). In some coastal areas, tourists and "snow birds" (northern Americans and Canadians who spend the winter in the south) swell populations by 10 to 100 fold. Large parts of densely populated coastal areas are subject to the inundation caused by hurricane storm surges and on numerous occasions have experienced heavy economic losses from these events (NOAA n.d.). *Source: NASA 2004b, http://earthobservatory.nasa.gov/NaturalHazards/natural_hazards_v2.php3?img_id=12339, NASA 2004b*

Floods

Worldwide, the number of major flood disasters has grown significantly, from 6 cases in the 1950s to 26 in the 1990s. With the changing climate, global precipitation has increased by about two per cent since 1900; during this time, rain patterns have changed, with some places becoming wetter and others, such as North Africa south of the Sahara, drier (Cosgrove 2003).

From 1971 to 1995, floods affected more than 1 500 million people worldwide, or 100 million people per year. In the most calamitous storm surge, the flood in Bangladesh in April 1991 killed thousands of people. The United Nations estimates that by 2025, half the world's population will be living in areas at risk from storms and other weather extremes (Cosgrove 2003).



Major flood events around the world in 2003 and 2004 (updated through September 2, 2004)
Data Source: DFO 2004, http://www.dartmouth.edu/%7Efloods/Archives/index.html

Case Study: Flooding in Mozambique 2000 and 2001

The years 2000 and 2001 saw massive flooding in Mozambique, particularly along the Limpopo, Save and Zambezi valleys. In 2000 half a million people were made homeless and 700 lost their lives. The floods destroyed crops and overwhelmed water and sanitation infrastructure in many areas.

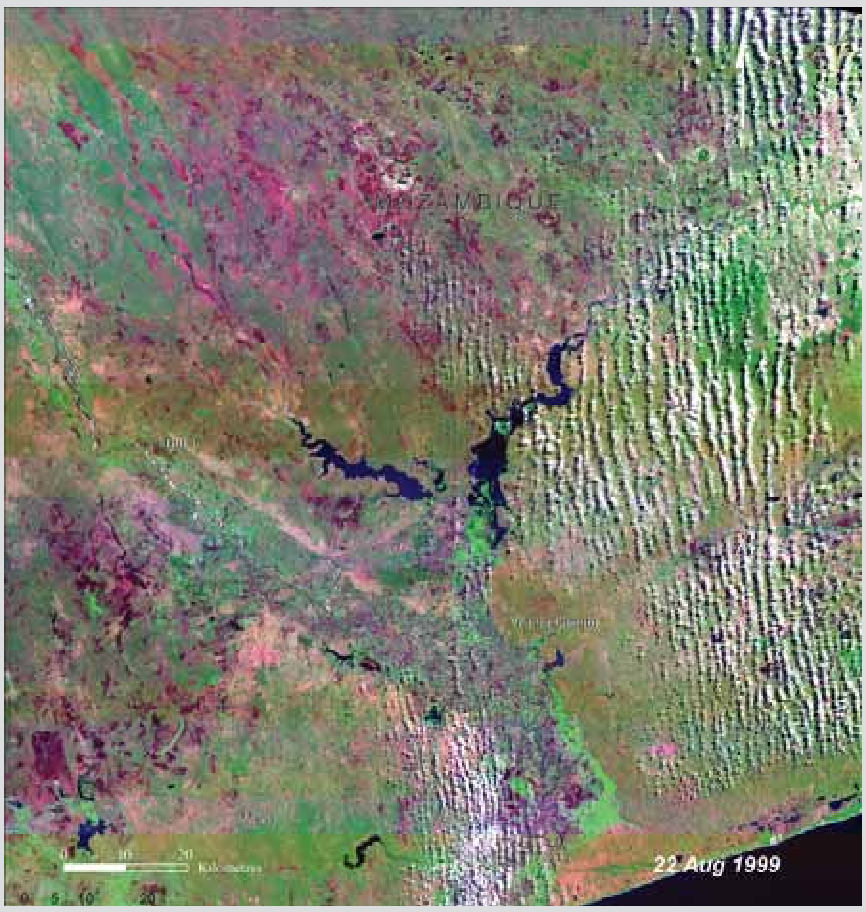
Southern Mozambique bore the full impact of the rains and rising waters. In the capital, Maputo, tens of thousands of people were forced to flee their homes. The worst hit were people living in makeshift homes in the slums around the capital. Maputo, the capital city of one million, was literally isolated as a result of the floods, and entry into the city was impossible.

Further north, hundreds of thousands of people were left homeless in Gaza province. Roads, homes, bridges and crops were destroyed. Electricity supplies were disrupted and towns left without clean water supplies after their pumping stations were swept away.

These two images show an area in Mozambique before the onset of flooding and during flooding. The 2000 image reveals a large area around the towns of Vila De Chibuto and Guija submerged under flood water from the Limpopo River. *Source: BBC 2000, Oxfam 2001, FEWS Net 2001. Satellite image: Kwabena Asante–SAIC-USGS National Center for EROS.*

Credit: Philip Wijmans/UNEP/ACT-LWF Trevo

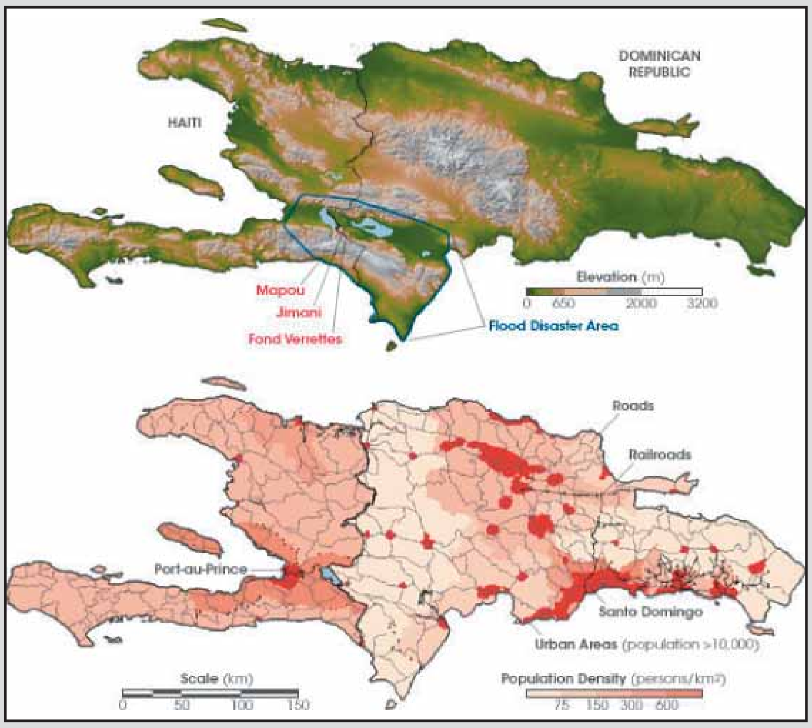
Credit: Philip Wijmans/UNEP/ACT-LWF Trevo



Credit: Cpl. Mike Escobar/UNEP

Case Study: Severe Flooding in Haiti and the Dominican Republic 23 – 25 May 2004

Several days of heavy rains in late May 2004 caused rivers to overflow in areas near the southern border between the Dominican Republic and Haiti. Heavy rains in this region of deforested hillsides generated rapid run-off and severe flooding. Floods and landslides devastated large areas of the island of Hispaniola, which the two countries share. The flooding demolished entire communities, caused massive loss of life, displaced tens of thousands of people on both sides of the border, and resulted in sizeable crop and livestock losses.



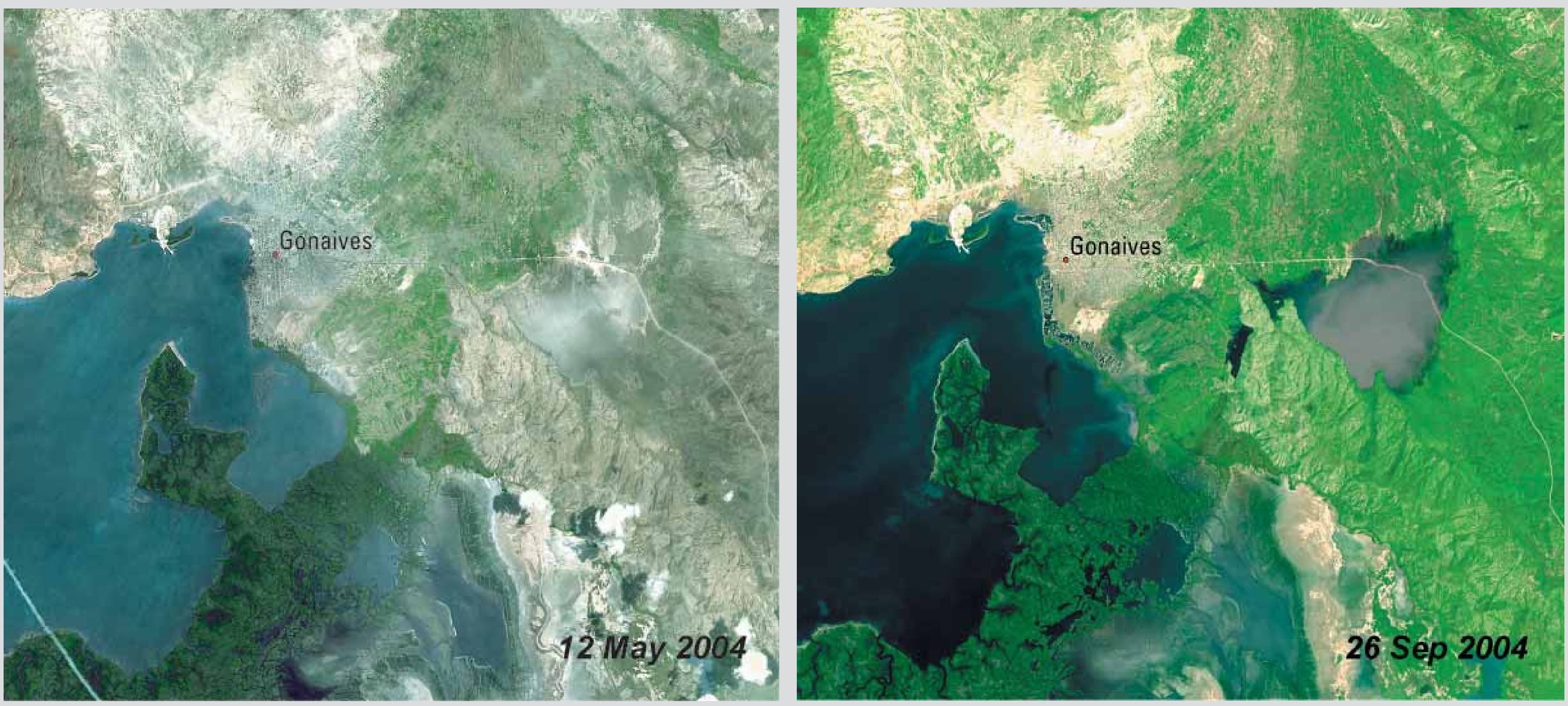
Tropical storm Jeanne struck the Island of Hispaniola on 18 September 2004; a wall of water and mud buried much of Gonaïves, Haiti as shown in this Ikonos imagery captured four days later, on 22 September 2004. Roads visible on 17 September 2000 image have disappeared, as have a number of buildings and adjacent farmlands submerged by water and mud. Note the damaged ship and changes in the water colour in the 22 September 2004 image. *Credit: Ikonos imagery provided on spaceimaging.com, courtesy of NASA's Earth Observatory*

Flooding as a result of this hurricane is blamed for over 3 000 lives lost, including 2 826 in the coastal city of Gonaïves, Haiti (USAID 2004).

Haiti, which is the poorest country in the Americas, has a population of about 8 million and is prone to deadly floods because 98 per cent of its forests have been chopped down, largely to make charcoal for cooking (Sustainable Institute 2004).

These maps (left) compare the topography of Hispaniola (top) with the island's population density (bottom). The flood disaster area around the Massif de la Salle is outlined in blue. *Source: Flood disaster hits Hispaniola, NASA 2004c*

These two Landsat images (below) contrast the two time periods during and after the floods. In the 12 May 2004 image, most of the region is covered by water (grayish colour) while the 26 September 2004 image water has receded, leaving behind green healthy vegetation especially in the area south and east of Gonaives. *Source: NASA Earth Observatory*



Drought Credit: Somkiat Sirvi / UNEP / Topfoto

Drought

A drought is a period of dryness, especially when prolonged, that causes extensive damage to crops or prevents their successful growth. Droughts are often caused by heat waves. A heat wave is a period of unusually hot weather. High temperatures exacerbate the effects of drought, damage crops and their establishment, and reduce yields (FAO 1996). Climate change will potentially increase the likelihood of droughts in dry and semi-arid regions. There is already evidence that a number of such regions have experienced declines in rainfall. Droughts result in decreases in soil fertility and agricultural, livestock, forest, and rangeland production. They also exacerbate the process of desertification. (IPCC 2001).

Throughout history, various parts of the globe have suffered drought and subsequent famine, resulting in huge humanitarian and economic losses.

Case Study: Lake Mead–Drought in the Western United States 2003

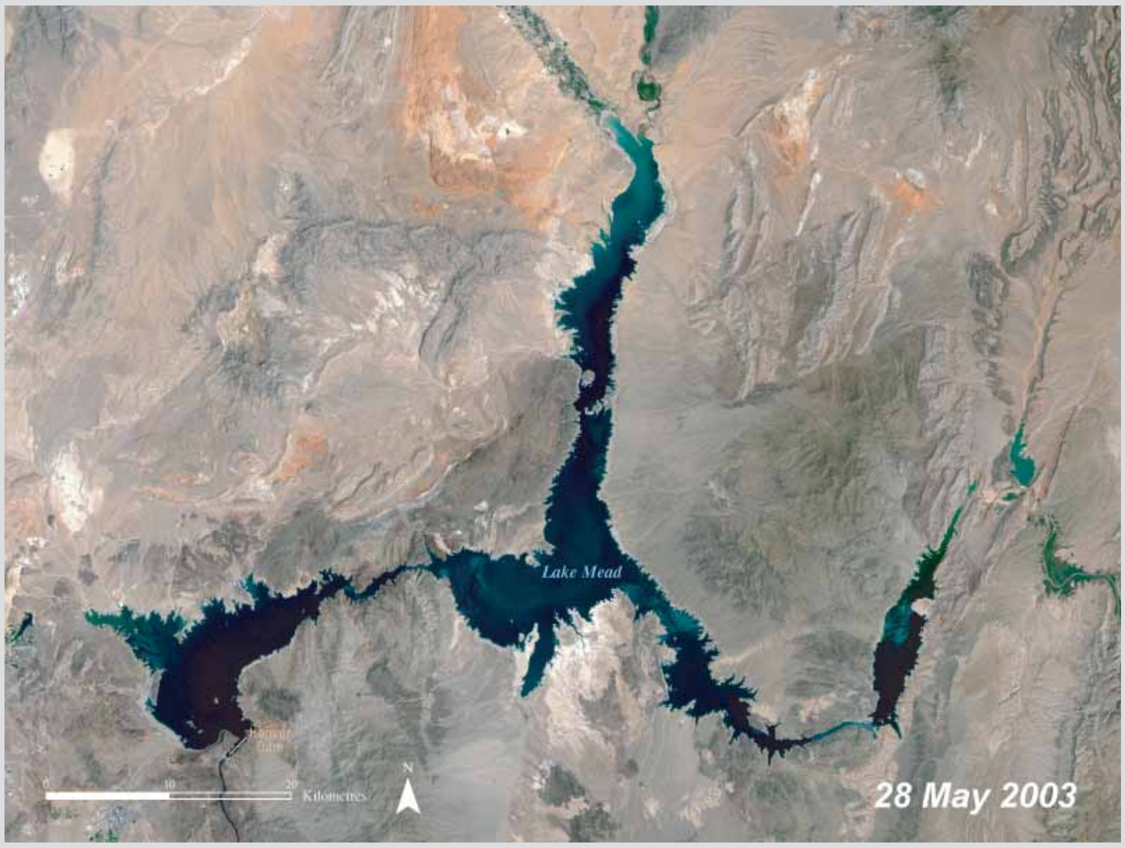
The western half of the United States has suffered a sustained drought over the past several years, which has caused withering vegetation, more frequent and severe forest fires, and falling water levels in major reservoirs throughout the region.

This image of Lake Mead, Nevada, dramatically captures the result of decreased rainfall and snow in the western United States. As of 2003, water levels at Lake Mead dropped 18 m (60 ft). Lake Mead is formed by the Hoover Dam and is an important water source for the states of Arizona, Nevada, and California. About 25 million people live in the region and the lake supplies over 80 per cent of Las Vegas' drinking water. Population growth, the building of water-hungry golf courses, and the needs of irrigated agriculture in the region are taxing its water resources, however. Las Vegas is the country's fastest growing city and Nevada is its fastest growing state. Although temperatures in the Las Vegas Valley rise to 32°C (90°F) or more on more than 125 days of the year and it receives less than 1 000 mm (39 in) of rain a

Credit: Lynn Betts/UNEP/NRCS

year, Las Vegas has the highest per-capita consumption of water in the world (UNEP 2002b).

The combined effect of drought, population growth, unsustainable development, and climate change in this arid region of the United States could be a recipe for more disastrous droughts and potential conflict. Recently, conservation awareness campaigns and water–use restrictions have helped to lower water use, despite the addition of more than 60 000 new residents in 2003 (SNWA 2004). *Source: Images and text by NASA's Earth Observatory*

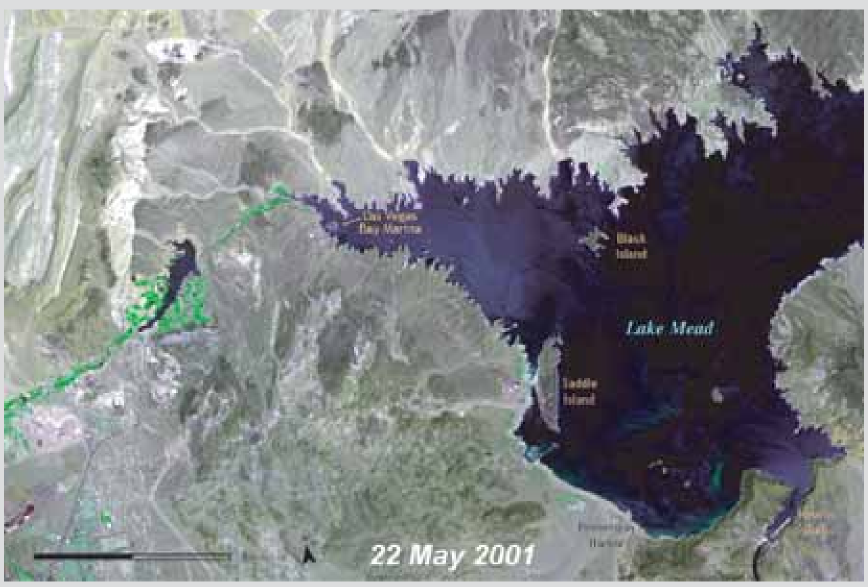


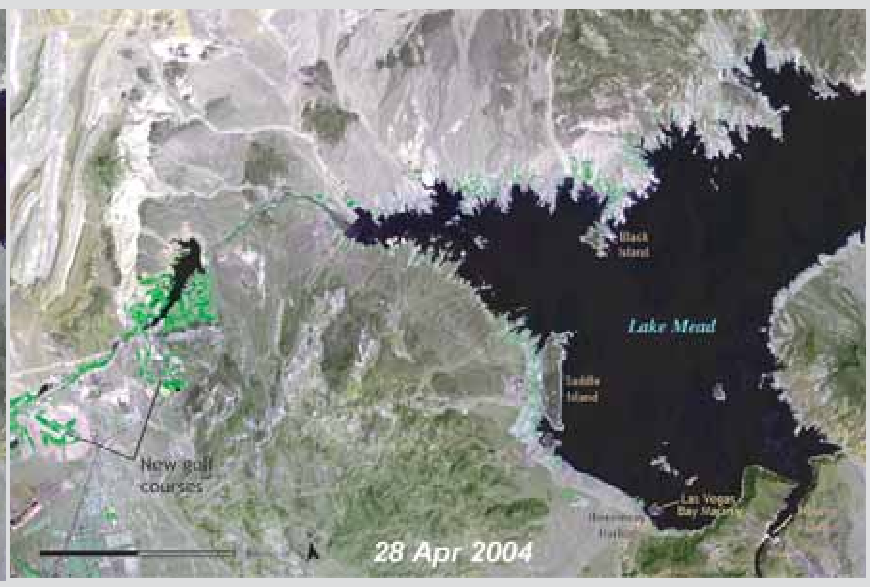
The image to the right, acquired by the Landsat 7 satellite, shows the shoreline of Lake Mead in May 2000.

Water levels in the lake during the 3-year-span illustrated by the 2001, 2003, and 2004 images dropped 18 m (60 ft). In the Boulder Basin of Lake Mead, the lower water level has connected former islands like Saddle Island to the shoreline. *Source: UNEP/GRID - Sioux Falls*

Credit: Lynn Betts/UNEP/NRCS

Brilliant green golf course fairways contrast sharply against the drought-stricken landscape of the Boulder Basin. Despite the region's third-worst drought in recent history, new courses continue to be developed. *Source: UNEP/GRID - Sioux Falls*

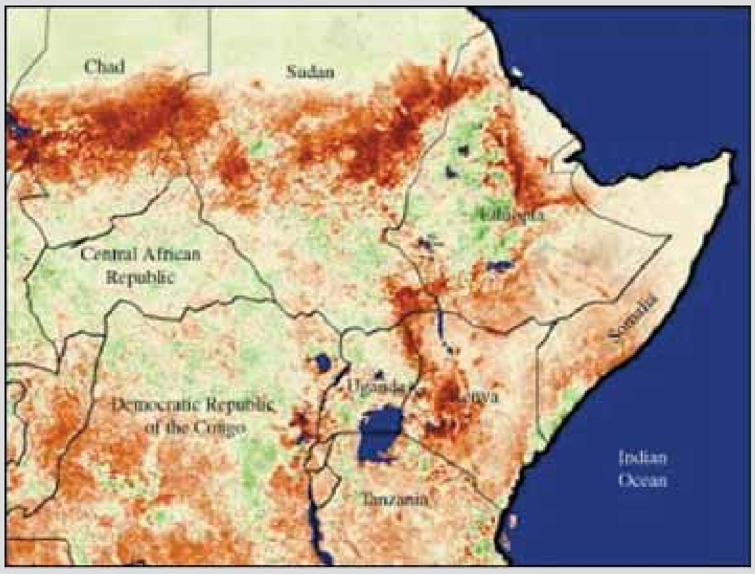


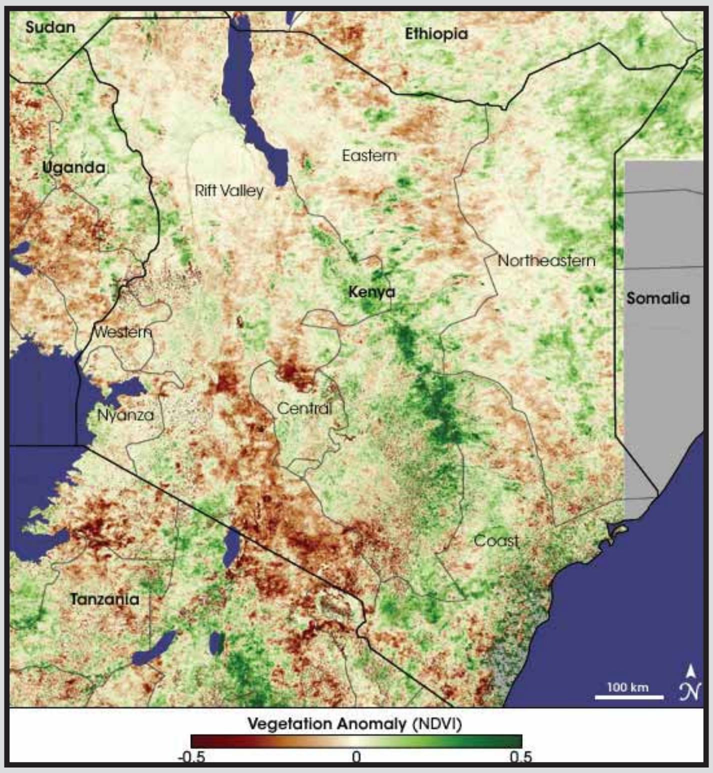


Case Study: Drought in Horn of Africa

What makes drought in the Horn of Africa an issue of global interest is its perennial recurrence and its extensive humanitarian impact. Poor agricultural practices and environmental degradation (catchments degradation) have greatly compounded the problem leading to serious food crises in the region. In 1984 and 1985, the Horn of Africa experienced one of the worst droughts of the twentieth century with a resultant famine that killed 750 000 people.

This Normalized Difference Vegetation Index (NDVI) image to the right shows the vegetation anomaly for August 1984. Dark red indicates the most severe drought, light yellow areas are normal, and green areas have denser than normal vegetation. *Source: NASA 2000, www.m-w.com, http://earthobservatory.nasa.gov/Library/DroughtFacts/*





Case Study: Drought in Kenya January 2005

Credit: Unknown/UNEP/African Wildlife Foundation

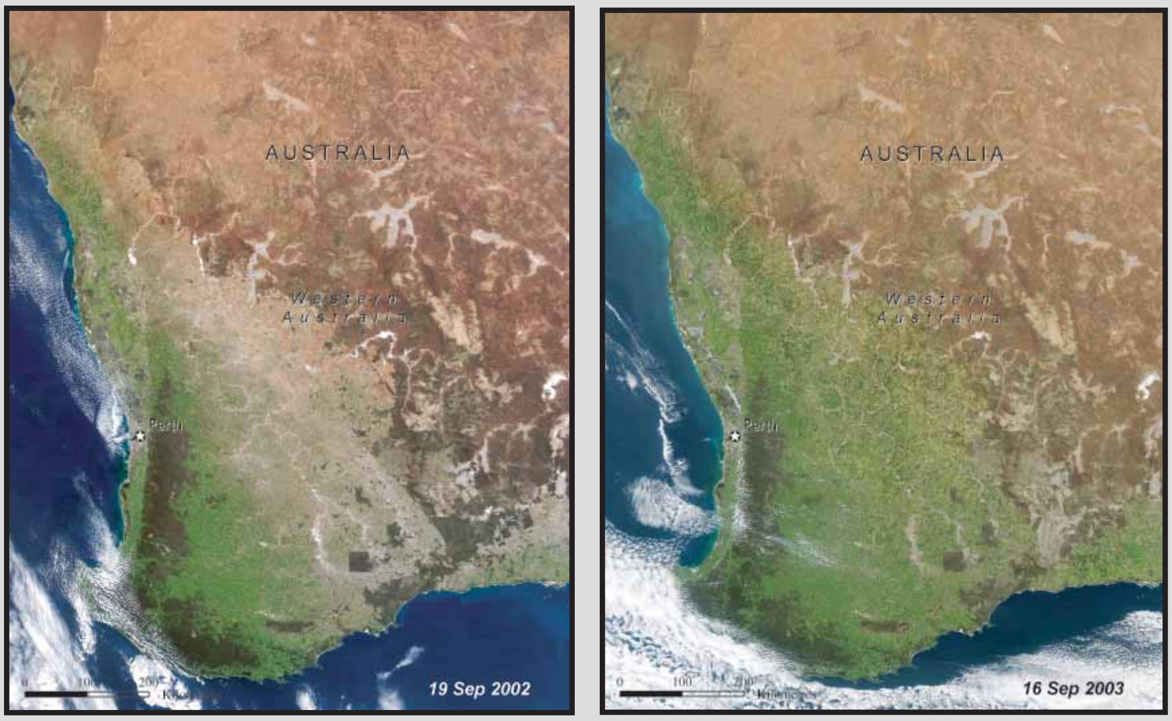
In Kenya, one of the countries in the Horn of Africa, drought has been looming for several years, leaving many regions of the country parched and hungry. As the 2004/2005 harvest drew to a close, the cereal deficit grew to 300 000 metric tonnes, which meant that up to 2.7 million people needed food aid that season—an unusually high number for Kenya. The second maize crop, scheduled to be harvested in March, was predicted to be 20 per cent below average because of a lack of rain. The 2005 shortages stem from a lack of rainfall during the short rainy season, which normally runs from November to January. Though some parts of Kenya received adequate rain, crop-growing regions in the Eastern, Central, and Coast Provinces received far-below-average rainfall. In Central Province alone, about 400 000 people face famine, according to government estimates. *Source: NASA 2004d, http://earthobservatory.nasa.gov/Newsroom/NewImages/images.php3?img_id=16816*

The impact of drought on the crops can be seen in this image, which shows the Normalized Difference Vegetation Index (NDVI) anomaly for Kenya as measured by the Moderate Resolution Imaging Spectroradiometer (MODIS) during the first two weeks of January 2005. NDVI is a measure of vegetation density and health. The anomaly image compares current conditions to average conditions in 2001, 2002, 2003, and 2004 during the first two weeks of January. Between 1-16 January 2005, brown clusters in the Coast and Eastern provinces show patterns of dryness where vegetation is less dense than it has been in the past. More pronounced drought areas surround Central Province. Grey pixels indicate regions where data were not available. An arch of green through the center of the country reveals where rainfall was plentiful and vegetation is thriving.

Case Study: Drought in Australia 2002-2004

After Australia's devastating drought in 2002, the 2003/2004 season saw record wheat and barley harvests, with the March crop up 119 per cent compared to the previous year's drought-stricken crop.

This pattern of large harvests after drought-stunted years is common. To recoup their losses, farmers increase the area they sow. In 2002, pasture land for livestock was so parched and the price of grain so high, that many farmers sold their livestock and converted their land to crops in 2003. In addition to the increase in cropland, well-timed rains in most parts of the country, particularly in Western Australia, combined to produce a bumper harvest that year. *Source: NASA 2003*



The difference between the two years is clearly visible in this image pair of the southwestern point of Australia, showing the expanded crop area. A larger portion of Western Australia is covered with greener vegetation in September 2003, right, compared to September 2002, a sign that all plants, including grain crops, were thriving in 2003. *Source: NASA 2003, http://earthobservatory.nasa.gov/NaturalHazards/natural_hazards_v2.php3?img_id=12010*

4.3 Industrial Hazards

Industrial hazards are threats to people and life-support systems that arise from the mass production of goods and services (Mitchell 1996). They can be intentional actions, such as the illegal discharge of oil into the environment, or accidental, such as toxic spills. Like natural hazards, they can expose people and ecosystems to danger, affecting lives, health, and socio-economic conditions (Draffan 2004).

One of the major industrial disasters occurred in Bhopal, killing at least 14 400 people and causing permanent disabilities to at least 50 000 others. In the early hours of 3 December 1984, gas leaked from a tank of methyl isocyanate (MIC), resulting in intense emission of toxic gases at a plant in Bhopal , India, owned and operated by Union Carbide India Limited (UCIL). This event is considered to be the worst chemical accident in history. In February 1989, the Supreme Court of India directed Union Carbide Corporation (UCC) and UCIL to pay a total of US$470 million in full settlement of all claims arising from the tragedy.

Oil spills

Fossil fuels (oil, natural gas, and coal) account for the vast bulk of global energy supplies. These fuels, formed over millions of years, are finite and non-renewable. Population growth and increased affluence and consumption increase the demand for fuel. In due course, these resources will become scarce and costly, requiring the introduction of replacement energy sources (MacKenzie 2000). In addition, disputes over their ownership already occur and there is significant potential for increased conflict.

Petroleum is an integral part of our lives. It provides 80 per cent of the world's transportation fuel, supplies nearly half the world's primary energy demand, and provides feedstock for the petrochemical industry. Petroleum products account for about a third of global oil use today.

The exploration for, development, transportation, and use of petroleum causes environmental problems worldwide. The most critical issue today is that fossil fuel burning emits gases that contribute to global climate change (Cohen 1990). Oil spills, the focus of this section, can harm life by poisoning, by direct contact, and by destroying habitats, especially in the marine environment.

As shown in Figure 4.2, about 37 per cent of oil in the world's oceans is

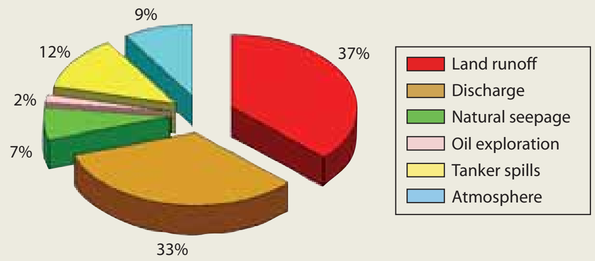


Figure 4.2: Sources of oil in the world's oceans. The highest contribution (about 37 per cent) results from urban run-off and the discharge from land-based industrial plants. These materials reach the sea via storm-water drains, sewage outfalls, creeks, and rivers. *Souce: APPEA n.d.*

the result of urban and industrial runoff. Another seven per cent is oil which seeps naturally out of fissures in the sea beds. About 14 per cent is caused directly by the

Oil spill *Credit: Khan Kuyucu/UNEP/Topfoto*

Credit: UNEP/GRID–Sioux Falls

Case Study: Gulf War
Kuwait and Persian Gulf
23–27 January 1991

During the Persian Gulf War, Iraq deliberately released 908–1 741 million litres (240–460 million gallons) of crude oil from tankers into the Persian Gulf 16 km(10 miles) off Kuwait. Oil spilled onto more than 1 287 km (800 miles) of Kuwait and Saudi Arabian beaches, devastating marine wildlife, especially birds (Krupa 1997).

The Persian Gulf war brought about some of the worst environmental pollution ever recorded as a result of oil spills and oil fires.

In the images, the blue shows water, green shows natural vegetation, light yellow shows desert areas and black shows pollution from oil spills and fire.

oil industry, of which 12 per cent is from accidents involving oil tankers. In the U.S., pipelines now spill considerably more than tankers. Another 33 per cent is the result of discharges to the environment and the remaining nine per cent of oil deposited in the oceans is absorbed from the atmosphere (APPEA n.d.).

As evident from Table 4.2, oil spills happen all around the world. Oil spills of at least 38 m^3 (125 cubic feet) have occurred in the waters of 112 nations since 1960. The top four “hot spots” for oil spills from vessels include the Gulf of Mexico (267 spills); the northeastern U.S. (140 spills); the Mediterranean Sea (127 spills); and the Persian Gulf (108 spills) (Etkin 1997).

Despite overall increases in oil transport, the numbers of marine oil spills and the amount spilled have decreased significantly over the last two decades, particularly in the last few years. The average number of large spills per year during the 1990s was about a third of that witnessed during the 1970s (ITOPF 2003). This decrease can likely be attributed to reduced accident rates due to preventive measures and increased concerns over escalating financial liabilities (Etkin 2001).

Table 4.2 – Major oil-related industrial accidents between 1970-2004

Year	Location	Industry	Loss/description
1976	Massachusetts, USA	Oil spill	Argo Merchant runs aground on the Nantucket Shoals off Cape Cod (Massachusetts USA), spilling 29 million litres (7.6 million gallons) of No. 6 fuel oil.
1978	France	Oil tanker	Amoco Cadiz tanker runs aground off the coast of France, spilling 1.6 million barrels of crude oil.
1984	Cubatao, Brazil	Oil pipeline	Oil fire - 508 deaths
1988	Piper Alpha, North Sea	Oil rig	167 deaths from explosion of offshore oil platform
1989	Alaska, USA	Oil tanker	Exxon Valdez tanker spills 42 million litres (11 million gallons) of crude oil into Prince William Sound (Alaska USA)
1994	Seoul, S. Korea	Oil fire	500 deaths
1995	Taegu, S.Korea	Oil & gas explosion	100 deaths
1998	Warri, Nigeria	Oil pipeline	Pipeline at Jesse, Nigeria exploded, instantly killing more than 500 people and severely burning hundreds more. Up to 2 000 people had been lining up with buckets and bottles to scoop up oil. The fire spread and engulfed the nearby villages of Moosqar and Oghara, killing farmers and villagers sleeping in their homes.
2000	Adeje, Nigeria	Oil pipeline	250 deaths

Source: Compiled from Mitchell and Cutter 1997, Anon. 2004, Draffan 2004, and Uranium Information Centre Ltd. 2004

Nuclear Accidents

With increasing concern over potential energy shortages and the impacts of burning fossil fuels, the debate about nuclear power has been renewed. Like hydroelectricity generation, nuclear power has the merit of being a clean energy source in terms of emissions, however, there are risks associated with the release of dangerous radiation from potential nuclear meltdown and from nuclear waste.

Between 1940 and 2000, there were at least 120 notable accidents involving nuclear material. These ranged from a container of uranium hexafluoride exploding in Oak Ridge, Tennessee, in the United States in 1944 killing two people and injuring three others to the worst accident in the history of the nuclear power industry – Chernobyl, Ukraine in 1986 (Anon n.d.).

Credit: Warren Gretz/UNEP/NREL

Case Study: Chernobyl Nuclear Power Plant Accident, Ukraine 25-26 April 1986

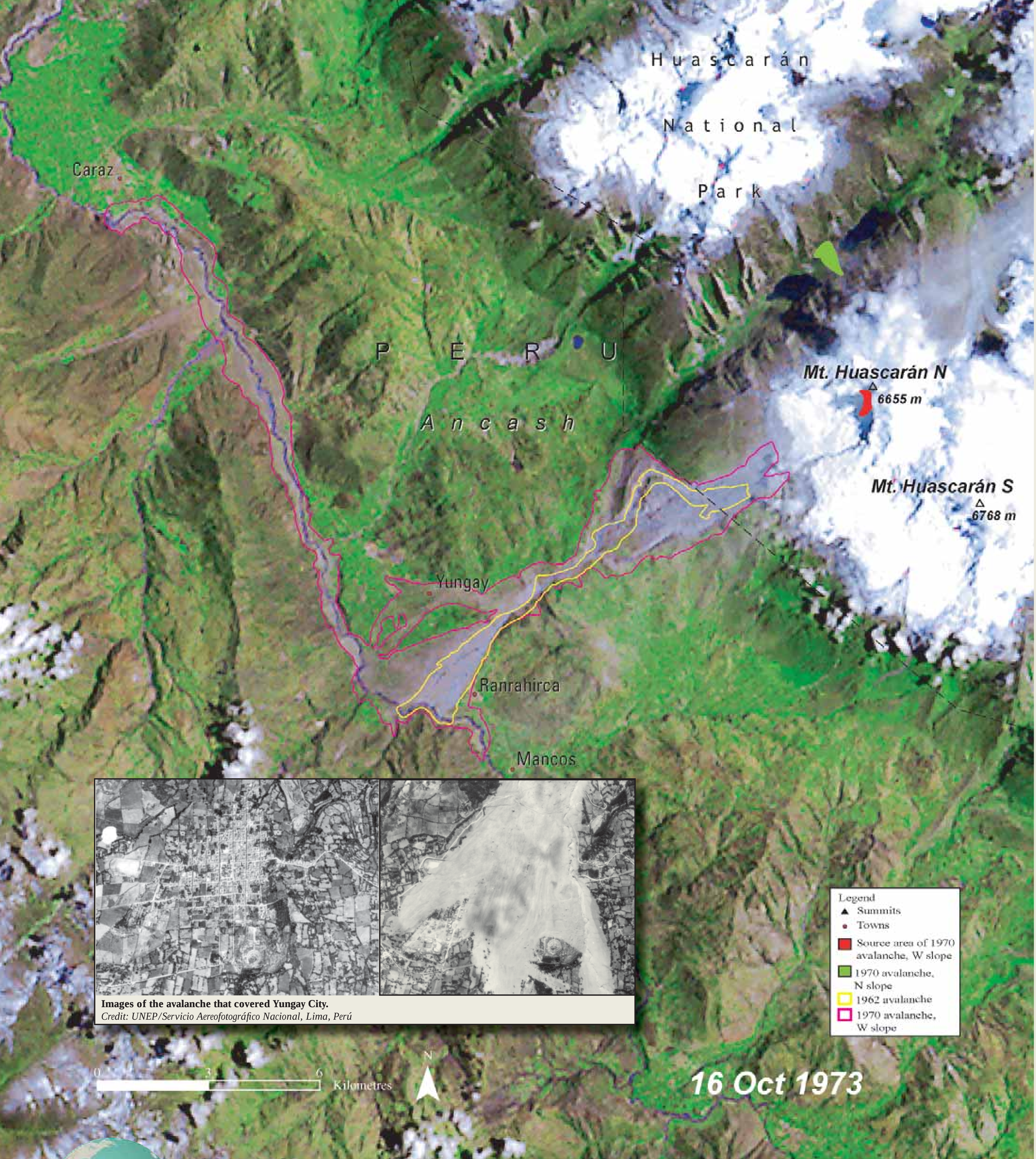
The world's worst nuclear power accident occurred at Chernobyl in the former USSR (now Ukraine) on 25-26 April 1986. While testing a reactor, numerous safety procedures were disregarded and a chain reaction resulted in explosions and a fireball, which blew off the reactor's heavy steel and concrete lid. The explosion and fire released radioactive material that spread over parts of the Soviet Union, Eastern Europe, Scandinavia, and later, Western Europe. The Chernobyl accident killed more than 31 people immediately, and as a result of the high radiation levels in the surrounding 32–km (20–mile) radius, 135 000 people had to be evacuated. Some areas were rendered uninhabitable for years. As a result of the radiation released into the atmosphere, tens of thousands of excess cancer deaths (as well as increased rates of birth defects) were expected in succeeding decades (Anon. n.d.).

Credit: Unknown/UNEP/Ukrainianweb

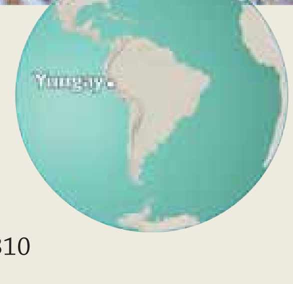
The 31 May 1986 image was acquired about a month after the nuclear accident at Chernobyl's Reactor Number 4. The Chernobyl nuclear plant is located on the northwest shore of a cooling pond. Much of the farmland surrounding the plant was heavily contaminated with radio active nuclides and subsequently abandoned. The areas have changed from red and white patterns indicating planted agricultural fields and bare soil in the 1986 image to tan-gray tones indicating natural vegetation in the 1992 image. More than 120 000 people from 213 villages and cities were relocated outside the contamination zone. Pripyat, an abandoned city with a 1986 population of 45 000, is located 3 km (2 miles) northwest of the Chernobyl Nuclear Power Station. The wavy white line north of the Chernobyl plant in the 1992 image is a levee built to prevent the flow of contaminated water and soil into the Pripyat River. *Source: Earthshots 2001; Sadowski and Covington 1987; Stebelsky 1995; Mould 1988; Medvedev 1990; Williams 1995; Schmidt 1995; Park 1989; Marples 1996.*

Credit: Elena/UNEP

The lines overlaid on the 1992 image show the approximate extent of Cesium-137 radiation levels according to 1990 data. Locations within the solid red lines have radiation levels greater than 40 Curies per km^2, too high for life, and this area has been almost completely abandoned by people.

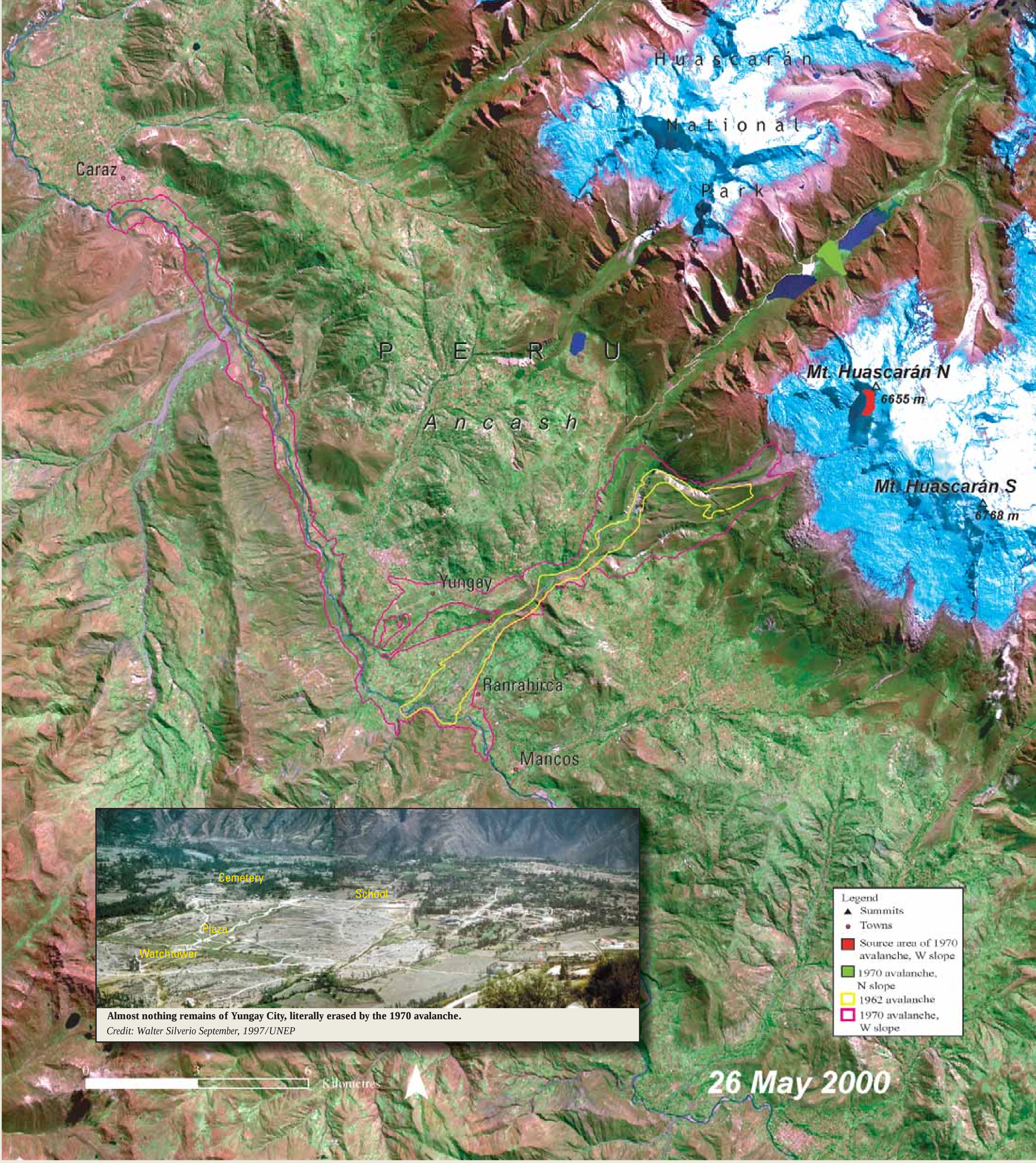


Images of the avalanche that covered Yungay City.
Credit: UNEP/Servicio Aereofotográfico Nacional, Lima, Perú



Avalanche
Yungay City, Peru

Andean glaciers have long been involved in numerous avalanches, which have caused considerable material losses and casualties by the thousands. The events of 1962 and 1970, originating from Mt. Huascarán's northern summit, were particularly deadly. On 31 May 1970,



Almost nothing remains of Yungay City, literally erased by the 1970 avalanche.

Credit: Walter Silverio September, 1997/UNEP

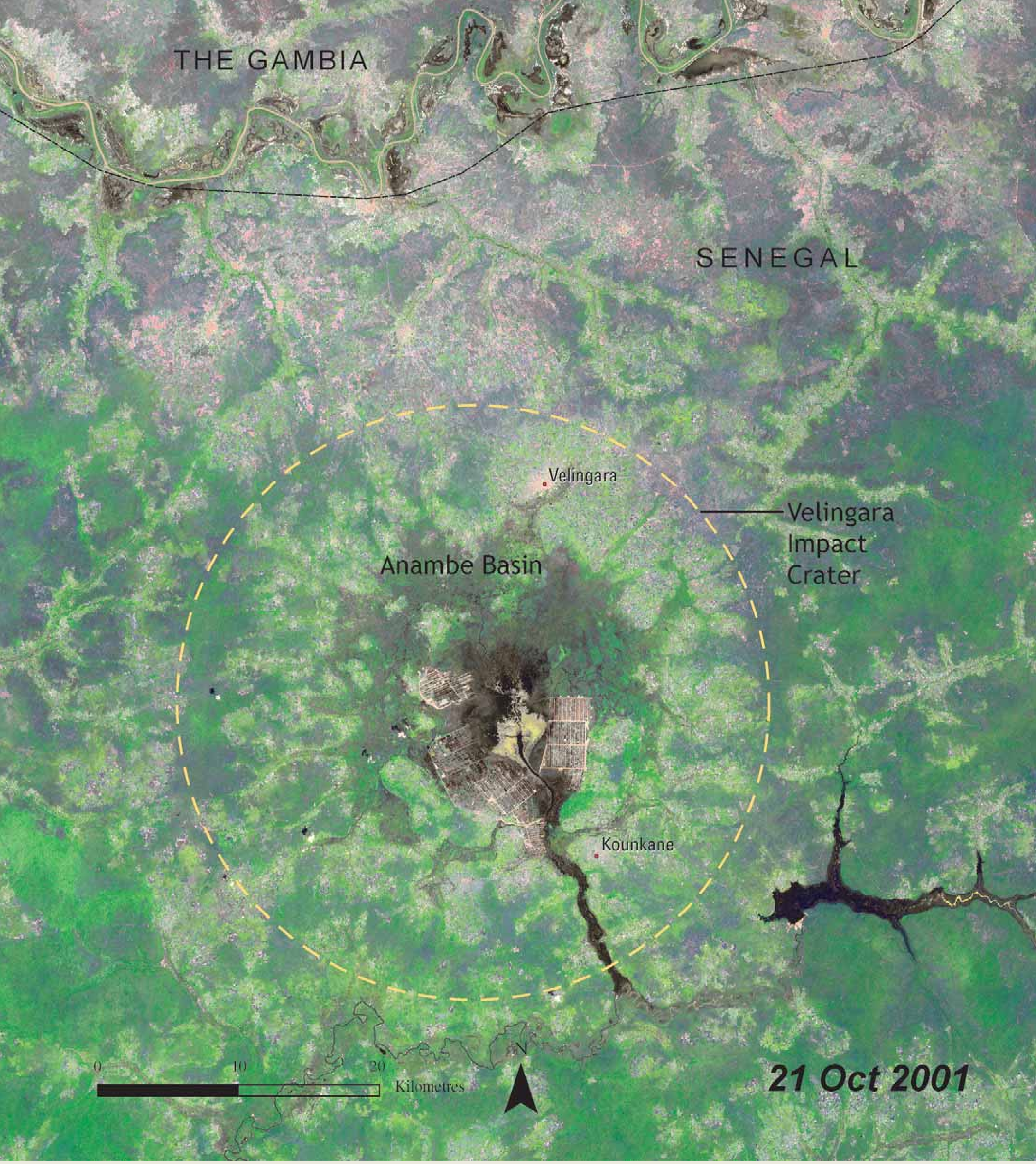
a 7.7 magnitude earthquake triggered a huge avalanche, 25 km (16 miles) long and moving at 280 km / h (174 mph), which wiped out the city of Yungay, claiming 18 000 lives. The scars are still visible today. Ice retreat has induced the formation of numerous peri-glacial lakes, dammed only by fragile moraine deposits. Subject to erosion, these walls may collapse, triggering flash floods—another threat for the local population.

The inset depicts elevation using radar data acquired from Space Shuttle Endeavour in February 2000. The Shuttle Radar Topography Mission provides science with a window of understanding previously unknown in areas such as Velingara, Senegal. Notice how the lighter colored(lower) elevations reflect the water features seen in the Landsat images. The dark ring reveals the higher elevations that enclose the basin.

Meteor Impact

Velingara, Senegal

Located in southern Senegal is a feature that appears to be a meteor-impact-generated structure, possibly millions of years old. It is a circular, multiple ring structure with an overall diameter of 48 km (30 miles) and centered about 12 km (7 miles) south-southwest of the town of Velingara.



The high rim structure of the Velingara Crater encloses the Anambe Basin. Water previously flowing out the south end of the basin was harnessed behind a dam in the mid-1970s as a source of irrigation for rice and other crops. The 1975 image predates the irrigation development. By 2001 intense agricultural systems had appeared near the center of the crater(right image), contrasting sharply with the swampy areas (dark green) nearby. The Velingara Crater was first detected using Landsat data in the early 1970s.

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