PUBLISHER'S NOTE

Salem Press's *Earth Science: Earth's Weather, Water, and Atmosphere* provides a two-volume introduction to the major topics of study in climate, bodies of water, and atmosphere. These volumes provide a comprehensive revision and update to an earlier edition with the same title, which was published by Salem Press in 2001.

The essays in this collection cover a wide range of subject areas, including the components of the atmosphere, with important developments in the study of greenhouse effects and weather patterns, the study of waters within and on the surface of the earth, and the impact of sedimentology in the formation of Earth surfaces. The coeditors of the volume have reviewed each article for scientific authority and have ensured each article's currency.

Designed for high school and college students and their teachers, these volumes provide hundreds of expertly written essays supplemented by illustrations, charts, and useful reference materials, resulting in a comprehensive overview of each topic. Librarians and general readers alike will also turn to this reference work for both foundational information and current developments.

Each essay topic begins with helpful reference information, including a summary statement that explains its significance in the study of the earth and its processes. *Principal Terms* define key elements or concepts related to the subject, and the text is then organized following informative subheadings that guide readers to areas of particular interest. The background and history of each subject are provided and detail important contextual information on the topic. An annotated *Bibliography* closes each essay and refers the reader to external sources for further study that are of use to both students and nonspecialists. Finally, a list of *Cross-References* directs the reader to other subject-related essays within the set. At the end of every volume, several appendices are designed to assist in the retrieval of information, including a *Glossary* that defines key terms contained in each set, and tables such as *Atmospheric Pressure, Oil Spills Timeline*, *Bodies of Water Data Sheet,* and *Major Weather Events.*

Salem Press's *Earth's Weather, Water, and Atmosphere* is part of a series of Earth science books that includes *Physics and Chemistry of the Earth, Earth's Surface and History*, and *Earth's Materials and Resources.*

Many hands went into the creation of these volumes. Special mention must be made of its coeditors, Margaret Boorstein, Ph.D., and Richard Renneboog, M.Sc., who played a principal role in shaping the reference work and its contents. Thanks are also due to the many academicians and professionals who communicated their expert understanding of Earth science to the general reader; a list of these individuals and their affiliations appears at the beginning of the volume. The contributions of all are gratefully acknowledged.

INTRODUCTION

The planet Earth is a complex set of living and nonliving systems connected by the cycling of matter and flows of energy. The solid earth, or the lithosphere; the gaseous layer surrounding the solid earth, or the atmosphere; and the waters of the earth, or the hydrosphere, are all connected with one another and with the biosphere, or living things. Presented in alphabetical order, the articles in *Earth Science: Earth's Weather, Water, and Atmosphere* discuss and explain important components of these four realms, with a particular emphasis on the influences that people, industry, and commerce around the globe have on Earth's systems.

The evolution of the atmosphere is explained, along with its present structure and internal movements. The relationship between the earth and sun, including revolution and rotation, are discussed, as well as how the changing orientation of the earth's axis with respect to the sun over the course of a year creates seasons. An article on the greenhouse effect describes its necessity to life on Earth. Other articles provide insight into how human activities have interfered with natural balances, leading to global warming, climate change, and ozone depletion. Such distinctions are important to acknowledge so that individuals, through their formal governments, economic activities, and informal alliances, can make decisions about adaptation, mediation, or inaction.

A number of articles examine motions of matter and transfers of energy within the atmosphere. The dramatic consequences of energy transfer are discussed in the articles about hurricanes, tornadoes, lightning and thunder, and monsoons. El Niño/Southern Oscillation (ENSO) has been shown, through decades of gathering detailed weather statistics combined with modern measurement technologies, to have a worldwide impact on climate and weather. Essays about more mundane features of the atmosphere, such as clouds, winds, and climate basics, provide an understanding of their properties and importance to the atmospheric system. The government of the United States devotes human and fiscal resources to advance scientific research as well as improve weather forecasting. Anyone in the United States with access to the Internet can see satellite imagery; interpret and analyze local, regional, and national forecasts; and read discussions of the models that contributed to their creation.

Those articles devoted to hydrology focus on the study of waters that move within the earth's crust and on its surface. The movements of groundwater and the properties of aquifers—layers of rocks or sediment in which water is stored and flows—are discussed, along with consequences of their depletion and deterioration. Because freshwater is vital not only to human survival, but also to functioning economic systems, several articles discuss surface water, wells, water tables, and water quality. The technologies and environmental impact of desalination, dams and flood control, and floods also are important to societies around the world. Waterfalls, frequently spectacular in their beauty and haunting in their long-term erosion, can be and are often harnessed to produce electricity. Yet, erecting power lines to transport electricity from remote waterfall locations involves all sorts of economic, political, and environmental choices. Watersheds, or areas drained by a stream, need to be understood and monitored closely because so many competing uses depend on the waters that flow within them. Neither freshwater nor the intricacies of its movements and the consequences of its contamination are taken for granted today.

Oceans cover approximately two-thirds of the surface of the earth. It is said that less is known about the ocean floor than is known about space. Federal government agencies, including the National Aeronautics and Space Administration (NASA) and the National Oceanic and Atmospheric Administration (NOAA), have been expanding that awareness, especially in the last decade. Articles in this volume explain how heat is transported through wind-driven surface currents and thermal and salinity-driven deep ocean currents. The interactions of water and the tectonics of the ocean floor are discussed in articles about turbidity currents, seamounts, and hydrothermal vents. The danger of tsunamis to human life has always existed. The article about the tsunamis of December 26, 2004, and March 11, 2011, describes the unimaginably wide-ranging damage that occurred, as well as the resulting possible courses of action to mitigate casualties and damage in the future. Current ocean-atmospheric interactions are important influences on climate today. From the perspective of geologic eons, oceans serve as long- and short-term storehouses of carbon and other elements that are part of nutrient cycles vital to life on Earth. With recent human interference in these natural processes have come unforeseen effects on current atmospheric and oceanic processes. As global warming intensifies, sea level will be of greater concern not only to those populations that have to be evacuated and the areas to which they move, but to those who are dependent on the natural resources lost to rising seas.

More extensive discussions of specific oceans and seas provide descriptions of their origins and current geology and geography. The story of the Aral Sea in the former Soviet Union serves as a morality tale. Once the fourth largest body of freshwater in the world, it decreased greatly in size and deteriorated into a body of water with a higher saline concentration than the oceans. In contrast, Hudson Bay has been left relatively untouched, but that situation may change as demand for mineral resources and water power increases. The Atlantic and Indian Oceans, along with their climate influences and economic importance, have fascinating geologic features and marine ecologies. The Arctic Ocean illustrates the severity of the intensification of the greenhouse effect. As Arctic ice melts at alarming rates, less sunlight is reflected and more is absorbed by the ocean waters, thereby accelerating global warming. Yet, the economic benefits to countries and commercial interests include easier winter shipping and the opening of once-ice-blocked harbors. The global community must decide between apparent short-term advantages and long-term dangers. The Gulf of Mexico is a rich fishery and source of petroleum. As illustrated by the August 2010 oil-well blowout and spill, proper safety and environmental precautions have not always been balanced with economic expediency. Hurricanes intensify in the Gulf, again leading to questions about the possible impact of global warming on human populations and economies.

Lakes and rivers are also covered herein. The enormity of freshwater flow and the influences on plant and animal life are explained for the Amazon, Ganges, Yellow, Mississippi, and Nile Rivers, as are consequences of misguided interference by people. The Great Lakes, which hold approximately 20 percent of the freshwater in the world, are important for fishing, recreation, and freshwater supply. They have also facilitated the economic growth of both the United States and Canada, with four of the five lakes sharing a border that features both countries' manufacturing belts and agricultural core. Contamination of the waters by excessive fertilizer and pesticide use, combined with industrial runoff, contributed to significant declines and contamination of the commercial and recreational fisheries. Cooperation by both countries and the neighboring states and provinces have alleviated these problems, but fish contamination remains.

Finally, sedimentology, including the influence of running and standing water on sediments and resulting landforms, is presented. Depositional systems such as alluvial systems and deltas create valuable farmland but, in turn, are related to streams or rivers overflowing their banks. Evaporites and deep-sea sedimentation both result in valuable resources for human use. The growing recognition of the ecological value of reefs has resulted in global-scale efforts to lessen atmospheric warming as well as regional attempts at physical protection. The challenges of weathering and erosion from careless farming, as well as the threat of beach erosion, will continue as long as people eat and fish and place a premium on living along the beautiful coast.

Our country and our world need an informed and scientifically literate public that understands environmental processes and can evaluate human solutions, whether proposed by governments, official and nonofficial agencies, or ordinary people. *Earth Science: Earth's Weather, Water, and Atmosphere* will help in that task as it provides basic knowledge and explanations and analysis of the interconnections of the solid earth, the atmosphere, the waters, and living inhabitants.

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HUDSON BAY

Although considered an extension of the Atlantic Ocean, Hudson Bay, a shallow gulf covering 827,000 square kilometers in the northern part of east-central Canada, is often treated as a separate entity because of its isolation. The area remains a vast, essentially unspoiled wilderness and preserve for wildlife. Uplift of lands surrounding Hudson Bay has provided earth scientists with clues about processes associated with the retreat of ice sheets, especially crustal rebound.

PRINCIPAL TERMS

- **Canadian Shield:** the geologic core of North America, extending over north-central Canada, that experienced glaciation during the Pleistocene epoch; characterized by an undulating surface of moderate relief and containing the oldest dated rock formations on the planet
- **craton:** an area of the land surface that has been stable for millions of years
- **entisol:** a weakly developed soil layer that does not exhibit distinct horizons or stratification layers
- **histosol:** soil composed primarily of organic material
- **ice sheet:** a broad, flat glacial mass with relatively gentle relief; ice sheets once covered extensive portions of North America
- **inceptisol:** relatively recent soil deposits that exhibit the first signs of horizon differentiation
- **isostatic rebound:** a process based on the opposing influences of buoyancy and gravity within Earth's crust by which the surface adjusts itself vertically until these forces are balanced and isostatic equilibrium has been reached
- **Pleistocene epoch:** the most recent ice age period, during which Earth experienced cycles of continental glaciation
- **spodosol:** an acidic soil characterized by subsurface accumulations of humus complexed with aluminum and iron

LOCATION AND DISCOVERY

Ranking twelfth in area among Earth's seas and oceans, the horseshoe-shaped Hudson Bay is approximately 1,370 kilometers long and 1,050 kilometers wide. The southern end of Hudson Bay extends into a smaller bay of almost identical shape—a "bay within a bay"—called James Bay. The Hudson Bay is bounded by the Canadian provinces of Quebec to the east and south, Ontario to the south, Manitoba to the southwest, and Nunavut to the northwest (Nunavut was formed in 1999 by partition of the Northwest Territory). The bay is linked to the Atlantic Ocean by Hudson Strait and to the Arctic Ocean by the Foxe Channel and Roes Welcome Sound. Hudson Bay and its islands are administered by the District of Keewatin, a region within Canada's Nunavut Territory. Its largest islands are Southampton (41,214 square kilometers) and Mansel (3,181 square kilometers), both located in the north. Other large islands include Coats (5,499 square kilometers), located on the southeast side of Fisher Strait, and Akimiski (3,002 square kilometers) within James Bay. Island groups include the elongated Belcher Islands and smaller Nastapoka Islands positioned in the southeastern portion of the bay and the Ottawa Islands to the west of Ungava Peninsula.

Early exploration of the bay was driven by the hope of locating a northwesterly shortcut to Asia. Systematic investigations of such a route began with John Cabot's visit to Canada's eastern shore in 1497. Hudson Bay was discovered by and named for English navigator Henry Hudson. During his first expedition in 1607, Hudson and the crew of his ship, the *Hopewell*, landed on the shores of Greenland and the Svalbard Islands, later turning north in an unsuccessful attempt to find a route to East Asia by way of the Arctic Ocean. He returned the following year to renew the search, passing the Novaya Zemlya Islands in the Barents Sea. Hudson began his last expedition in 1610, during which he reached Hudson Bay and spent three months investigating its eastern shores and islands. Pack ice prevented a departure from the bay, and, after a winter of extreme deprivation, the crew of his ship mutinied. Placed in a boat and set adrift by the mutineers, Hudson and eight others were never seen again.

Further exploration of the bay was carried out by Sir Thomas Button, who reached the western shore of the bay near present-day Churchill, Manitoba, in 1612. The following summer, Button departed from the bay, passing Southampton Island on his way to Hudson Strait. Others who explored the bay included William Baffin in 1615 and Luke Fox and Thomas James in 1631. In 1662, Pierre Esprit Radisson and Médard Chouart de Groseillers became the first to reach Hudson Bay using an overland route. Since its first exploration, the bay has served as a graveyard for many mariners. Numerous sunken vessels, along with the only stone military fortification in the Arctic, are part of the bay's historical legacy.

Geology

Hudson Bay is located within a depression of the vast Canadian Shield and is underlain with ancient Precambrian rocks that are more than 500 million years old. Covering 4.8 million square kilometers in Canada and the northern United States, the shield encompasses Labrador, Baffin Island, and portions of Quebec, Ontario, Manitoba, Saskatchewan, the Northwest Territory, Nunavut, Wisconsin, Minnesota, New York, and Michigan. The oldest region within the North American crustal plate, the shield is considered a craton, an area of the land surface that has been stable for many millions of years and perhaps even from the original formation of the continental masses. Radiometric dating of some Canadian Shield formations has yielded an age of 4.5 billion years, which is nearly as old as the planet itself is believed to be. Hudson Bay is bordered by Paleozoic limestone, sandstone, and dolomitic rocks. Rocks of sedimentary origin within the Canadian Shield contain the fossils of some of the earliest forms of life on Earth.

The bay is believed to have been formed by glacial activity during the Pleistocene epoch, which began about 2.4 million years ago. Centered over what is now Hudson Bay, the Laurentide ice sheet stripped away soil and deposited glacial drift as it moved across the landscape. The enormous weight of accumulated ice on the continent depressed that portion of the crust, causing it to sink into the underlying plastic layer of the mantle. As the ice sheet began to melt, numerous remnants were left in the form of till deposits and long, sinuous ridges of sand and gravel called eskers. The retreat of ice sheets of the Wisconsin glacial period began about 13,000 years ago, although large portions of glacial ice remained until about 7,000 years ago. As the ice melted, relatively warm seawater invaded Hudson Bay through Hudson Strait, further shrinking the ice mass. Eventually, the ice sheet was split into the Labrador and Keewatin ice centers, which disappeared completely between 6,500 and 5,000 years ago. As the ice melted, the depressed crust began to slowly undergo isostatic rebound, slowly returning to its natural level as determined by the buoyancy of the continental mass on the mantle layer. Isostatic adjustment within the Hudson Bay region is not complete, and the entire area surrounding the bay continues to rise at a rate of about 0.6 meter per century. Uplifting of the landscape is especially obvious along portions of the coast where lines representing former beaches run parallel to the shore. The rapid rate of rebound suggests that Hudson Bay will become much shallower and may disappear when isostatic equilibrium has eventually been reached.

The underwater physiography of Hudson Bay demonstrates broad contours that are generally concentric with its periphery. The bay averages 128 meters in depth, with a deepest known depth of 183 meters. Its floor is predominantly smooth but is incised with cuts and banks in some places. There are a few submarine troughs and ridges with trends that are controlled by the geologic structure. The basin forming Hudson Bay has a north-south elongation, which is a reflection of its bedrock structure.

Marine currents are the most significant agents of sediment transport within the bay. Because Hudson Bay is covered by snow and ice during several months of the year, the normal movement of sedimentary discharge from streams is inhibited during those periods. In some cases, sediments, coarse gravel, and boulder-sized rocks are carried by moving ice away from shore in a process known as ice rafting. Although concentrated within 30 to 36 kilometers of the shoreline, materials carried by ice rafting are strewn over the entire floor of the bay. In most places within the bay, but particularly in the western half, postglacial sedimentation has become a less important factor than marine erosion in shaping underwater physiography.

COASTAL LANDSCAPE AND WATER

Typical shoreline areas of the northern portion of the bay are low in elevation, rocky, and indented with numerous inlets and small islands. In other areas, the bay is surrounded by a broad, flat plain. A few higher areas (with elevation exceeding 305 meters) are located to the north and northeast on Southampton Island and Quebec's Ungava Peninsula. The size of Hudson Bay's drainage basin is more than 3,800,000 square kilometers. Shoreline areas on the west and southwest coasts form an extensive region of drowned swampland. Deltas and estuaries are common, and, in some locations, tidal flats extend up to 9 kilometers inland. Tundra surrounding much of the bay is, in essence, a cold desert in which moisture is scarce. Plant cover in the tundra includes grasses, lichens, and a scattering of low-growing shrubs. Muskeg or bogs with small black spruce trees are found in the south, especially around James Bay. Plants must complete their annual cycles during the brief summer in waterlogged environments, which are the result of poor drainage tied to the underlying permafrost. Soils on land areas surrounding the bay include infertile entisols, histosols, inceptisols, and spodosols. A discontinuous region of permafrost extends southward to 54 degrees north latitude on the western side of Hudson Bay and 61 degrees north latitude on the eastern side.

Arctic in nature, waters found within Hudson Bay demonstrate fairly uniform temperatures that average near freezing. Decreasing from the periphery of the bay to the center, temperatures are slightly warmer over underwater shoals and cooler over deeper areas, reflecting seasonal warming near the surface layer. The general pattern of water circulation is counterclockwise. River outflow maintains an influx of freshwater that inhibits saline Atlantic waters from entering Hudson Strait, resulting in the low salinity of Hudson Bay waters, especially in spring and summer months. The difference between high and low tide ranges from just less than 1 meter to greater than 4 meters in the western portion of the bay. Pack ice blankets the water from October to June each year. Strong prevailing winds along most of the shoreline help to separate land from pack ice. The bay has historically been navigable for a short period of time extending from early July to October, though in recent years this period has steadily lengthened, presumably due to the effects of global warming, and a fully closed ice pack has not formed.

Hudson Strait connects Hudson Bay with the Atlantic Ocean to the east. Unlike in the bay, water within the strait is predominantly deep, with recorded depths of up to 500 meters. Undersea cliffs and canyons are found near the strait's shoreline. Water from the West Greenland Current mixes with water passing out of Hudson Bay within the strait, creating conditions that support plankton and a diversity of invertebrate and fish species.

CLIMATE

Hudson Bay's climate is influenced by cold, dry, and stable continental polar and Arctic air masses. During much of the year, the bay is normally covered with a bleak and inhospitable blanket of snow and ice. A diagonal line running from Chester Inlet in the northwest to the Belcher Islands in the southeast divides Hudson Bay into two climatic regions. To the northeast, the bay has a Köppen classification of ET (tundra), while the southwest is classified Dfc (continental taiga climate). Average January temperatures for most of the land area surrounding Hudson Bay range from −30 to −20 degrees Celsius. In contrast, average July temperatures range from 10 to 20 degrees Celsius. The coldest land area adjacent to the bay is located on its northwest side, extending from Manitoba's border with Nunavut to Southampton Island. Precipitation totals throughout the region surrounding Hudson Bay are highest in the summer. The influence of the bay's continental climate can be illustrated in a comparison with Scotland, which is located at about the same latitude. In contrast to conditions around Hudson Bay, Scotland's maritime climate, moderated by the Atlantic Ocean, supports pastures for cattle and sheep.

WILDLIFE AND HUMAN OCCUPATION

During the summer months, the fauna of Hudson Bay is dominated by birds and insects, especially mosquitoes and flies. The rocky coastline and islands, along with tidal flats and inland marshes, provide nesting sites for one of the world's largest concentrations of migrating waterfowl and shorebirds. Along with almost one-half of the eastern Arctic's population of lesser snow geese are Canada geese, Brant geese, old-squaws, loons, black guillemots, and common eiders. Also found within the area are gulls, Hudsonian godwits, whimbrels, snowy owls, horned larks, ptarmigan, and the world's largest concentration of peregrine falcons. Caribou, arctic hare, and lemmings are also found on its shores. One of the highest densities of polar bear denning in Canada is found adjacent to Churchill, where a large number of bears gather during the autumn to await the return of the ice and better feeding. More than forty freshwater, Arctic, and subarctic marine fish species are found within the bay. Examples include capelin, Arctic cod, ogac, and Arctic char, as well as salmon, cod, halibut, and plaice. Also inhabiting the bay are seals, whales, dolphins, walruses, and beluga whales.

The earliest occupants of the area were the nomadic Inuit people, who lived in igloos and skin tents. In 1670, the Hudson's Bay Company received a charter from the English crown for exclusive trading rights within the watershed of Hudson Bay. Soon after, trading posts were constructed at the mouths of the Moose and Albany Rivers. Between 1682 and 1713, the French attempted to force the British out of the bay. However, by the terms of the 1713 Treaty of Utrecht, the French handed over all posts in the area to the British. In 1929, the Hudson Bay Railway was completed to the town of Churchill, facilitating shipments of grain produced in Canada's prairie provinces by boat to world markets. During World War II, the United States operated an air base near Churchill on the western side of the bay. The shoreline of Hudson Bay remains sparsely settled, with a few small trading villages located at the mouths of rivers entering the bay in Quebec, Manitoba, and Ontario. Pack ice filling the bay makes villages on its shores inaccessible for much of the year. The shoreline has a population density of fewer than three people per square mile.

Thomas A. Wikle

FURTHER READING

Dickson, R. R., Jens Meincke, and Peter Rhines, eds. *Arctic-Subarctic Ocean Fluxes: Defining the Role of the Northern Seas in Climate.* Dordrecht: Springer, 2008. Describes the Hudson Bay's role as a major oceanic body and one of the largest of Arctic seas. Examines the bay's notable impact on the climate of northern Canada, as well as its global climate influences. Collects much of the evidence needed for the development of climate models that accurately incorporate the influence of the northern seas.

French, Hugh, and Olav Slaymaker. *Changing Cold Environments: A Canadian Perspective.* Oxford: Wiley-Blackwell, 2012. Directed at upper-level undergraduate students. Provides a comprehensive overview of the changing nature of Canada's "cold environments," such as the Hudson Bay region, and discusses the implications of ongoing global climate change for cold environments globally.

Hood, Peter J., ed. *Earth Science Symposium on Hudson Bay.* National Advisory Committee on Research Geological Survey of Canada Paper 68-53 (1968). Although somewhat dated, this compendium of scientific papers on Hudson Bay provides a good overview of the geomorphology of Hudson Bay and the Hudson Bay Lowlands.

Levinton, Jeffery S., and John R. Waldman. *The Hudson River Estuary.* New York: Cambridge University Press, 2006. Discusses the geology, physics, and chemistry of the Hudson Bay, including sedimentary processes of the estuary, as well as microbial and nutrient dynamics and primary production of the estuary. Covers ecology and conservation efforts. Well organized and well indexed.

Middleton, Gerard V., ed. *Encyclopedia of Sediments and Sedimentary Rocks.* Dordrecht: Springer, 2003. Cites a vast number of scientists, who are listed in the author index. Covers biogenic sedimentary structures, Milankovitch cycles, deltas and estuaries, and vermiculite. Provides an index of subjects as well. Designed to cover a broad scope and a high degree of detail useful to students, faculty, and professionals in geology.

Mills, Eric L. *The Fluid Envelope of Our Planet: How the Study of Ocean Currents Became a Science.* Toronto: Toronto University Press Inc., 2009. A detailed account of the history of oceanography, in which the study of current flow in Hudson Bay has played a significant role.

Pienitz, Reinhard, Marianne S. V. Douglas, and John P. Smol. *Long-Term Environmental Change in Arctic and Antarctic Lakes.* Dordrecht: Springer, 2004. Written for students and advanced researchers studying earth, atmospheric, and environmental science. Focuses on paleolimnology as a source of environmental records in research.

Riley, John L. *Flora of the Hudson Bay Lowland and Its Postglacial Origins*. Ottawa: National Research Council (Canada) Research Press, 2003. Discusses recent research on the Hudson Bay lowlands, documenting the region's biodiversity. Covers geological history and ecology of the area. Examines the climate of the wetland. Provides many maps and color illustrations to supplement the text.

Ruddiman, W. F., and H. E. Wright. *North America and Adjacent Oceans During the Last Deglaciation*. Boulder, Colo.: Geological Society of America, 1987. Examines physical processes and causes associated with ice-sheet erosion in North America during Pleistocene glaciations, as well as the long-term history of North American ice sheets. Includes detailed charts, diagrams, and maps.

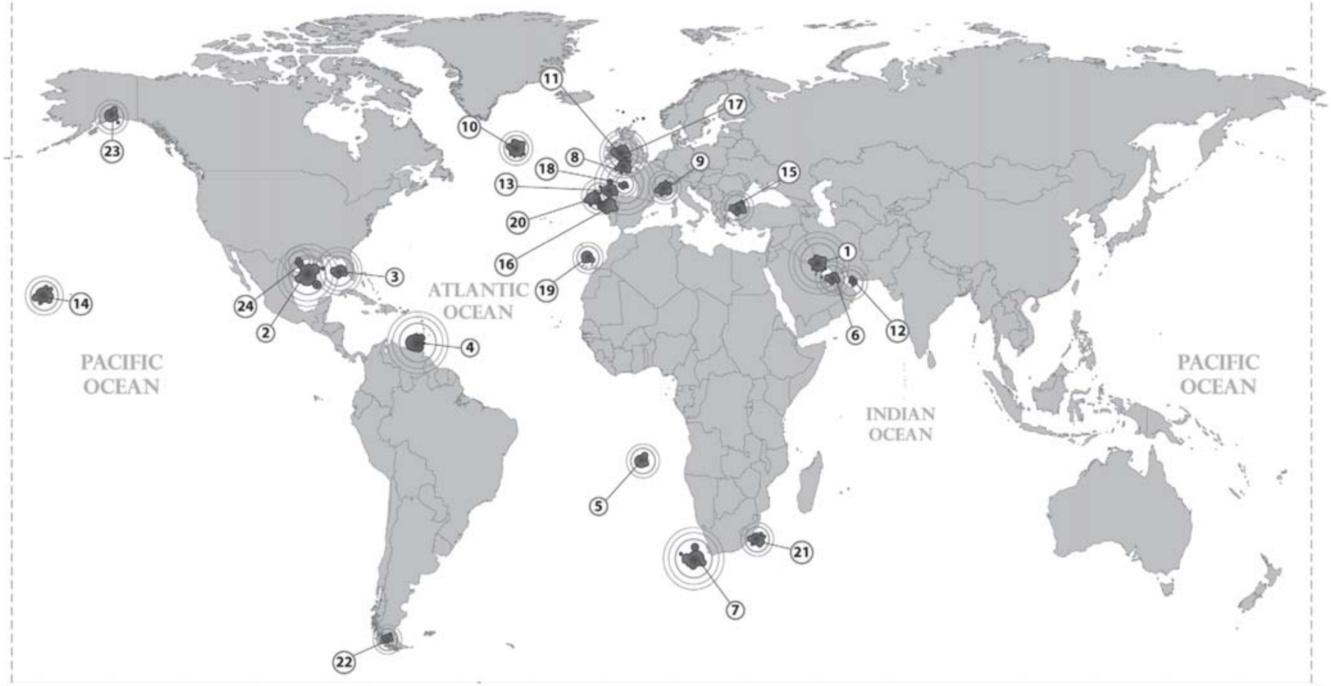
See also: Aral Sea; Arctic Ocean; Atlantic Ocean; Black Sea; Caspian Sea; Gulf of California; Gulf of Mexico; Gulf Stream; Hurricanes; Indian Ocean; Mediterranean Sea; Mississippi River; Monsoons; North Sea; Ocean Tides; Pacific Ocean; Persian Gulf; Red Sea

ATMOSPHERIC PRESSURE: ABOVE AND BELOW SEA LEVEL

The table below provides atmospheric pressure values in both pounds per square inch (psi) and atmospheres (atm). Pressure values are listed for varying altitudes above sea level and depths below sea level. These data are represented in the following graphs: Atmospheric Pressure (psi) and Atmospheric Pressure (atm).

Altitude (meters)	**Atmospheric Pressure**	
	psi	**atm**
30,510	0.16	0.01
27,459	0.25	0.02
24,408	0.41	0.03
21,357	0.64	0.04
18,306	1.05	0.07
16,781	1.33	0.09
15,255	1.69	0.11
13,730	2.15	0.15
12,204	2.73	0.19
10,679	3.47	0.24
9,153	4.37	0.30
7,628	5.46	0.37
6,102	6.76	0.46
4,577	8.29	0.56
3,050	10.10	0.69
2,746	10.50	0.71
2,441	10.91	0.74
2,136	11.34	0.77
1,831	11.78	0.80

MAJOR OIL SPILLS IN MODERN HISTORY



① **GULF WAR SPILL:** 294,000,000 gal. Arabian Gulf, Kuwait, 1991

② **BP DEEP WATER HORIZON:** 205,800,000 gal. Gulf of Mexico, U.S.A., 2010

③ **IXTOC 1:** 147,000,000 gal. Gulf of Mexico, 1979

④ **ATLANTIC EMPRESS:** 88,300,000 gal. Trinidad & Tobago, West Indies, 1979

⑤ **ABT SUMMER:** 80,000,000 gal. Angola , Africa, 1991

⑥ **NOWRUZ OIL FIELD:** 79,000,000 gal. Iran, 1983

⑦ **CASTILLO DE BELLVER:** 78,200,000 gal. Saldanha Bay, South Africa, 1983

⑧ **AMOCO CADIZ:** 68,684,000 gal. Brittany, France, 1978,

⑨ **M/T HAVEN TANKER:** 45,000,000 gal. Genoa, Italy, 1991

⑩ **ODYSSEY:** 40,700,000 gal. Nova Scotia, Canada, 1988

⑪ **TORREY CANYON:** 36,120,000 gal. Lands End, England, 1967

⑫ **SEA STAR:** 37,500,000 gal. Gulf of Oman, 1972,

⑬ **URQUIOLA:** 30,786,000 gal. La Coruna, Spain 1976

⑭ **HAWAIIAN PATRIOT:** 29,900,000 gal. Hawaii, United States, 1977

⑮ **INDEPENDENTA:** 28,886,000 gal. Istanbul ,Turkey 1979

⑯ **JAKOB MAERSK:** 26,360,000 gal. Opoto, Portugal 1975

⑰ **SEA EMPRESS:** 22,000,000 gal. Milford Haven, U.K., 1996

⑱ **AEGEAN SEA:** 21,000,000 gal. A Coruna, Spain, 1992

⑲ **KHARK 5:** 20,000,000 gal. Canary Islands, 1989

⑳ **PRESTIGE:** 19,404,000 gal. Galicia, Spain 2002

㉑ **WORLD GLORY:** 20,000,000 gal. South Africa,1968

㉒ **METULA:** 15,400,000 gal. Strait of Magellan, Chile 1974

㉓ **EXXON VALDEZ:** 11,950,000 gal. Prince William Sound, Alaska 1989

㉔ **BURMA AGATE:** 10,689,000 gal. Texas, U.S.A. 1979

SEVERE WEATHER

The tables below provide data on severe weather events from modern history, including tornadoes, cyclones, hurricanes, and other significant storms. Tornado severity is categorized using the Fujita-Pearson scale (F0-F5) when applicable. Inc. indicates that the severity data are incomplete. Names of the cyclones, hurricanes, and other storms are provided and severity is categorized using the Saffir-Simpson hurricane scale (Category 1-Category 5) when applicable. The storms are organized chronologically, and all storms comparable using the impact information, including the number of deaths and/or wreckage.

Tornadoes

Year	Location	Severity	Impact
1912	Regina, Saskatchewan	Inc.	28 deaths; $1.2 million in property damage (1912 USD); 2,500 left homeless
1925	Missouri, Illinois, and Indiana (Tri-State)	F5	695 deaths; 219-mile-long path of destruction; the main part of a series of smaller tornadoes that day that killed almost 750 people in Kansas, Alabama, Tennessee, Kentucky, and Indiana; 2,027 injured
1932	Alabama Super Outbreak	F4	268 deaths; 1,874 injured; 98 homes destroyed; 2,000 left homeless
1936	Tupelo, Mississippi	F5	216 deaths; 700 left injured
1936	Gainesville, Georgia	F4	203 deaths; 1,600 injured
1947	Texas, Kansas, and Oklahoma	F5	181 deaths; 970 injured
1964	Magura-narail, Khulna Division, Bangladesh	Inc.	500+ deaths
1965	Indiana, Michigan, and Ohio	F4	265 deaths; $30 million in damage as eleven tornadoes moved through twenty counties (1965 USD)
1969	Dhaka, Bangladesh	Inc.	660 deaths; 4,000 injured; a second tornado from the same storm system brought the total death toll to 883
1970	Bulahdelah, New South Wales, Australia	F4-F5	Over 1 million trees destroyed; a 13-mile-long path of destruction
1973	Manikganj, Singair, and Nawabganj, Bangladesh	Inc.	681 confirmed deaths, but death toll could be as high as 1,000
1973	Brisbane, Australia	F3	1,400 buildings damaged