CHAPTER 12: WIND AND WEATHER


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WEATHER VERSUS CLIMATE


Variables used to determine the state of the atmosphere:
1. Temperature
2. Air pressure
3. Humidity
4. Cloudiness
5. Wind speed and direction

CLIMATE: THE AVERAGE WEATHER CONDITION OF A PLACE (LONG TERM).
WIND is the air movement that arises from differences in air pressure. Wind is the result when air flows from a place of high pressure (more dense air) to one of low pressure (less dense air).

Therefore, the movement of air as a result of pressure differences is closely associated with both temperature and density, and horizontal movement is always associated with at least some vertical movement of air.
FACTORS AFFECTING WIND SPEED AND DIRECTION

1. **Pressure-gradient force** is the drop in air pressure/unit distance.

2. **Coriolis force** is the deviation from straight line in the path of a moving body due to the Earth's rotation.

3. **Friction** is the resistance to movement when two bodies are in contact.
A pressure gradient is determined from the **ISOBARS** (lines of equal air pressure) on a weather map.
A. Widely spaced isobars indicate a slow pressure drop over a long distance and thus a low-pressure gradient and low-speed winds. Closely spaced isobars indicate a steep pressure gradient; high-speed winds are the result. B. Symbols used on weather maps to indicate wind direction and speed. The orientation of the stem indicates wind direction, and the barbs indicate speed. If more than one barb is on the wind stem, add the barbs together to get the wind speed.
A geostrophic wind. A high-altitude wind is deflected by the Coriolis effect until a balance is reached between the direction of flow due to the pressure gradient and the direction due to the Coriolis deflection, at which point flow is parallel to the isobars. It is not influenced by friction.
A parcel of air is subjected to a pressure-gradient force and a Coriolis force; the resultant vector determines the direction of movement of the air.

The parcel of air moves in response to a pressure gradient. At the same time, it is turned progressively sideways until the pressure-gradient force and the Coriolis force balance, producing a geostrophic wind, whose flow is parallel to the isobars.
This map of North America shows upper-atmosphere wind flow. The lines represent the air pressure contours in millibars, at a height above sealevel of 5.5 km. Note that winds are nearly all parallel to the isobars and therefore are geostrophic.
Adjacent to any solid body, such as a human arm, there is a thin layer of air held stationary by friction. Away from the body, wind speed, indicated by the length of the arrows, increases as the effects of friction become weaker and weaker.
Air spirals into a low and out from a high. Lows are centers of convergence, while highs are centers of divergence. Note that in both lows and highs the flow direction is oblique to the isobars because of friction.
Convergence in a cyclone causes a rising updraft of air and with it clouds and probably precipitation. Divergence in an anticyclone draws in high-altitude air, creating a downdraft; clear skies and fair weather are the result.
Global circulation as it would happen on a non-rotating Earth. Huge convection cells would transfer heat from equatorial regions, where the solar energy per unit area is greatest, to the poles, where the solar input is least. The equatorial region would be a zone of low pressure, while the poles would be high-pressure zones.
Earth rotates, with the result that the flow of air toward the poles and the return flow toward the equator are constantly deflected sideways. This results in three major set of circulating masses: Hadley cells, Ferrel cells, and Polar cells.
Rossby waves are created when winds flow in great undulating streams; these undulations resemble the meanders of streams and rivers.

Rossby waves in the jet stream pull masses of cold air south as meanders form. (a) The axis of the jet stream starts out flowing to the east in a nearly straight line. (b) and (c) Undulations grow into gigantic meanders that pull masses of cold polar air down over the United States.
MONSOON

A regional weather system characterized by seasonally reversing winds.

(A) Winter  Sun is overhead in the Southern Hemisphere.  (B) Summer  The land heats up and winds flow from South.
EL NIÑO
SOUTHERN OSCILLATIONS (ENSO)

Non-El Niño

El Niño

Normal Conditions December 1993

El Niño Conditions December 1997
Watch the YouTube video called

“El Niño”
Normal years: persistent tradewinds blow westward across the tropical Pacific from a zone of upwelling water off the coast of Peru. The water warms up as it is transported westward to form a large warm-water pool above the thermocline in the western Pacific. The warm water causes the moist maritime air to rise and cool, bringing abundant rainfall to Indonesia.

El Niño event: the tradewinds slacken and the pool of warm water moves eastward to the central Pacific. Descending cool, dry air brings drought conditions to Indonesia, while rising moist air above the warm-water pool greatly increases rainfall in the mid-Pacific. Surface waters in the eastern Pacific become warmer, and downwelling shuts off the supply of deep-water nutrients, adversely affecting the normally productive fishing ground off the coast of Peru.
La Niña is characterized by unusually cold ocean temperatures in the Equatorial Pacific, compared to El Nino, which is characterized by unusually warm ocean temperatures in the Equatorial Pacific.

Sea Surface Height (SSH) measurements from the TOPEX/Poseidon satellite
EL NIÑO

Jet Streams

Trade Winds

LA NIÑA

Jet Streams

Trade Winds
More than half-century record of ENSO events (1950-2010), showing the irregular frequency and magnitude (strength) of the events. The strongest recorded El Niño events (warm phase) were those of 1982-1983 and 1997-1998. La Niña events are the cold phase.
A. During the day, the land heats up more rapidly than does the sea. Air rises over the land, creating a low-pressure area. Cooler air flows in to this area from the sea, creating a sea breeze.

B. During the night, the land cools more rapidly than the sea, and the reverse flow, a land breeze, occurs.
Hurricanes form in those places in the world where the right conditions of ocean water temperature and the Coriolis effect occur. Arrows show the usual directions followed by hurricanes once they form.
CLIMATOLOGY OF HURRICANES
Watch the YouTube video called “How a hurricane is born”
HURRICANE STRUCTURE AND FORMATION

- Convection currents
- Eye
- Cool dense air
- Hurricane winds and rain
- Warm moist air

- Spiral rainbands
- Eyewall
- Counterclockwise rotation

- Eyewall
- tropopause
- Cold air
- Rainbands
- Eye
- Warm air
<table>
<thead>
<tr>
<th>Category</th>
<th>Sustained Winds (mph)</th>
<th>Storm Surge</th>
<th>Damage</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>74-95</td>
<td>4-5 feet</td>
<td>Minimal</td>
<td>Danny-1997 (AL)</td>
</tr>
<tr>
<td>2</td>
<td>96-110</td>
<td>6-8 feet</td>
<td>Moderate</td>
<td>Georges- 1998 (FL-MS)</td>
</tr>
<tr>
<td>3</td>
<td>111-130</td>
<td>9-12 feet</td>
<td>Extensive</td>
<td>Fran-1996 (NC)</td>
</tr>
<tr>
<td>4</td>
<td>131-155</td>
<td>13-18 feet</td>
<td>Extreme</td>
<td>Andrew-1992 (FL)</td>
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<tr>
<td>5</td>
<td>&gt;155</td>
<td>&gt;18 feet</td>
<td>Catastrophic</td>
<td>Camille-1969 (MS)</td>
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</table>

**Central Pressure and Winds (mph) - Surge Damage**

<table>
<thead>
<tr>
<th>Category</th>
<th>Central Pressure</th>
<th>Winds (mph)</th>
<th>Surge</th>
<th>Damage</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>&lt; 920</td>
<td>&lt; 27.17</td>
<td>&gt;155</td>
<td>&gt;18’</td>
</tr>
<tr>
<td>4</td>
<td>944-920</td>
<td>27.88-27.17</td>
<td>131-155</td>
<td>13-18’</td>
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<tr>
<td>3</td>
<td>964-945</td>
<td>28.47-27.91</td>
<td>111-130</td>
<td>9-12’</td>
</tr>
<tr>
<td>2</td>
<td>979-965</td>
<td>27.91-28.50</td>
<td>96-110</td>
<td>6-8’</td>
</tr>
<tr>
<td>1</td>
<td>≤ 980</td>
<td>≤ 28.94</td>
<td>74-95</td>
<td>4-5’</td>
</tr>
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</table>
CARIBBEAN REGION
# Hurricanes that have impacted Puerto Rico since 1989 and their incurred losses

<table>
<thead>
<tr>
<th>Event</th>
<th>Date</th>
<th>Category</th>
<th>Incurred Losses</th>
</tr>
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<tbody>
<tr>
<td>H. Hugo</td>
<td>Sept. 1989</td>
<td>4</td>
<td>$685 M</td>
</tr>
<tr>
<td>H. Hortencia</td>
<td>Sept. 1996</td>
<td>1</td>
<td>$79.9 M</td>
</tr>
<tr>
<td>H. Georges</td>
<td>Sept. 1998</td>
<td>3</td>
<td>$1.16 B</td>
</tr>
<tr>
<td>T.S. Jeanne</td>
<td>Sept. 2004</td>
<td>N/A</td>
<td>$26 M</td>
</tr>
</tbody>
</table>

Source: Insurance Commissioner’s Office
SATELLITE ORBITS

AVHRR / MODIS

Polar Orbits

Geosynchronous Orbit

GOES
The Moderate Resolution Imaging Spectroradiometer (MODIS) on NASA’s Terra satellite captured this image of Isaac in the Gulf of Mexico at 11:30 a.m. Central Daylight Time (16:30 Universal Time) on August 28, 2012.
GOES is operated by the U.S. National Environmental Satellite, Data, and Information Service (NESDIS) and supports weather forecasting, severe storm tracking, and meteorology research. It uses geosynchronous satellites since the launch of SMS-1 in 1974.
FOUR GOES SATELLITES ARE CURRENTLY AVAILABLE FOR OPERATIONAL USE:

GOES-12 is designated GOES-South, currently located at 60°W over the Atlantic ocean.
GOES 13 is designated GOES-East, currently located at 75°W over the Atlantic ocean.
GOES 14 is currently in on-orbit storage at 90°W.
GOES 15 is designated GOES-West, currently located at 135°W over the Pacific Ocean.

THE FUTURE: GOES-R series of spacecraft is in the development phase. The first GOES-R series satellite is scheduled for launch in fiscal year 2015 and is expected to remain operational through December 2027.
GOES OBSERVATIONS OF THE CARIBBEAN

http://www.goes.noaa.gov
Madeline and Lester visit Mexico
17 October 1998

GOES project
Formed: August 23, 2005
Dissipated: August 30, 2005
Highest winds: 175 mph (280 km/h) (1-minute sustained)
Lowest pressure: 902 mbar (hPa; 26.64 inHg)
Fatalities: 1,836 confirmed
Damage: $81.2 billion (2005 USD) $90.1 billion (2010 USD) (Costliest hurricane in US history)
Areas affected: Bahamas, South Florida, Cuba, Louisiana (especially Greater New Orleans), Mississippi, Alabama, Florida Panhandle, most of eastern North America
As the large Hurricane Sandy moved north along the U.S. East Coast, the waves it generated churned up sediments from the continental shelf and left turbid water in its wake. By mid day October 30, 2012, the skies over coastal Florida, Georgia, and South Carolina had cleared enough to reveal the turbidity to the orbiting VIIRS instrument on the Suomi NPP satellite. Meanwhile, the remnants of the storm were battering the northeastern states.
If the typhoon death toll is confirmed, it would be the deadliest natural catastrophe on record in the Philippines.

Entire villages were destroyed and cities devastated by huge waves and winds of nearly 150 mph.
Typhoon Haiyan in Philippines is One of the Most Powerful Ever Recorded
THUNDERSTORMS develop when a updraft of warm, humid air (called a cell) releases a lot of latent heat very quickly and becomes unstable.

LIGHTNING AND THUNDER are due to electrical charges being released in the thunderstorms.
These images were made using data from the Tropical Rainfall Measuring Mission (TRMM) satellite. The image on left shows the heavy rain brought by the storms as observed by the TRMM Thermal Imager and Precipitation Radar. The most intense rain is shown in red and yellow, while lighter rainfall is blue. A line of heavy rain stretches through Louisiana, Mississippi, and Alabama. White crosses show where tornadoes were reported along the path of the thunderstorms. A larger cross shows where a powerful tornado occurred earlier in the morning over Magee, Mississippi.

The right image is a side-on, three-dimensional view of the clouds made using data from TRMM’s Precipitation Radar. The tallest of the towering clouds are associated with the most intense thunderstorms, the heaviest rain, and possibly tornadoes over Louisiana and Mississippi.
TORNADOES are violent windstorms produced by a spiraling column of air that extends downward from a cumulonimbus cloud. They commonly develop from large thunderstorms that have multiple updrafts, which are called supercell thunderstorms.
Watch the YouTube video called “How tornadoes form”
1. Tornadoes are formed when hot air and cold air are mixed in the atmosphere.
2. The clouds grow larger and larger then finally, a thunderstorm brews up with a strong updraft.
3. The moisture in the warm air rises and condenses into large clouds.
4. Then a huge funnel of air forms in the atmosphere and destroys everything in its path.
REMOTE SENSING OF TORNADOES
Super Tuesday 2008 Tornado Outbreak
DESIerts AND ATMOSPHERIC CIRCULATION

- Hot arid (desert) climates
- Semiarid climates
- Cold (polar desert) climates

Map showing major deserts around the world:
- Sonoran
- Atacama
- Sahara
- Gobi
- Rub’ al Khali
- Namib
- Kalahari
- Takla Makan

Circulation patterns:
- Descending cold, dry air
- Descending cool, dry air
- Rising warm, moist air
DUST STORMS
EFFECT OF THE SAHARA DUST
EFFECT OF THE SAHARA DUST
A massive sandstorm blowing off the northwest African desert has blanketed hundreds of thousands of square miles of the eastern Atlantic Ocean with a dense cloud of Saharan sand. The massive nature of this particular storm was first seen in this SeaWiFS image acquired on Saturday, 26 February 2005 when it reached over 1,000 miles into the Atlantic. These storms and the rising warm air can lift dust 45,000 feet or so above the African deserts and then out across the Atlantic, many times reaching as far as the Caribbean where they often require the local weather forecast to issue air quality alerts as was recently the case in San Juan, Puerto Rico. Recent studies by the U.S. Geological Survey have linked the decline of the coral reefs in the Caribbean to the increasing frequency and intensity of Saharan Dust events. Additionally, other studies suggest that Saharan Dust may play a role in determining the frequency and intensity of hurricanes formed in the eastern Atlantic Ocean (http://www.illinois.edu/role.html).

Provided by the SeaWiFS Project NASA/GSFC and ORBIMAGE.
EFFECT OF THE SAHARA DUST
EFFECT OF THE SAHARA DUST
EFFECT OF THE SAHARA DUST

Acquired
April 22, 2010
EFFECT OF THE SAHARA DUST
Watch the YouTube video called “GOES-R Mission Overview”