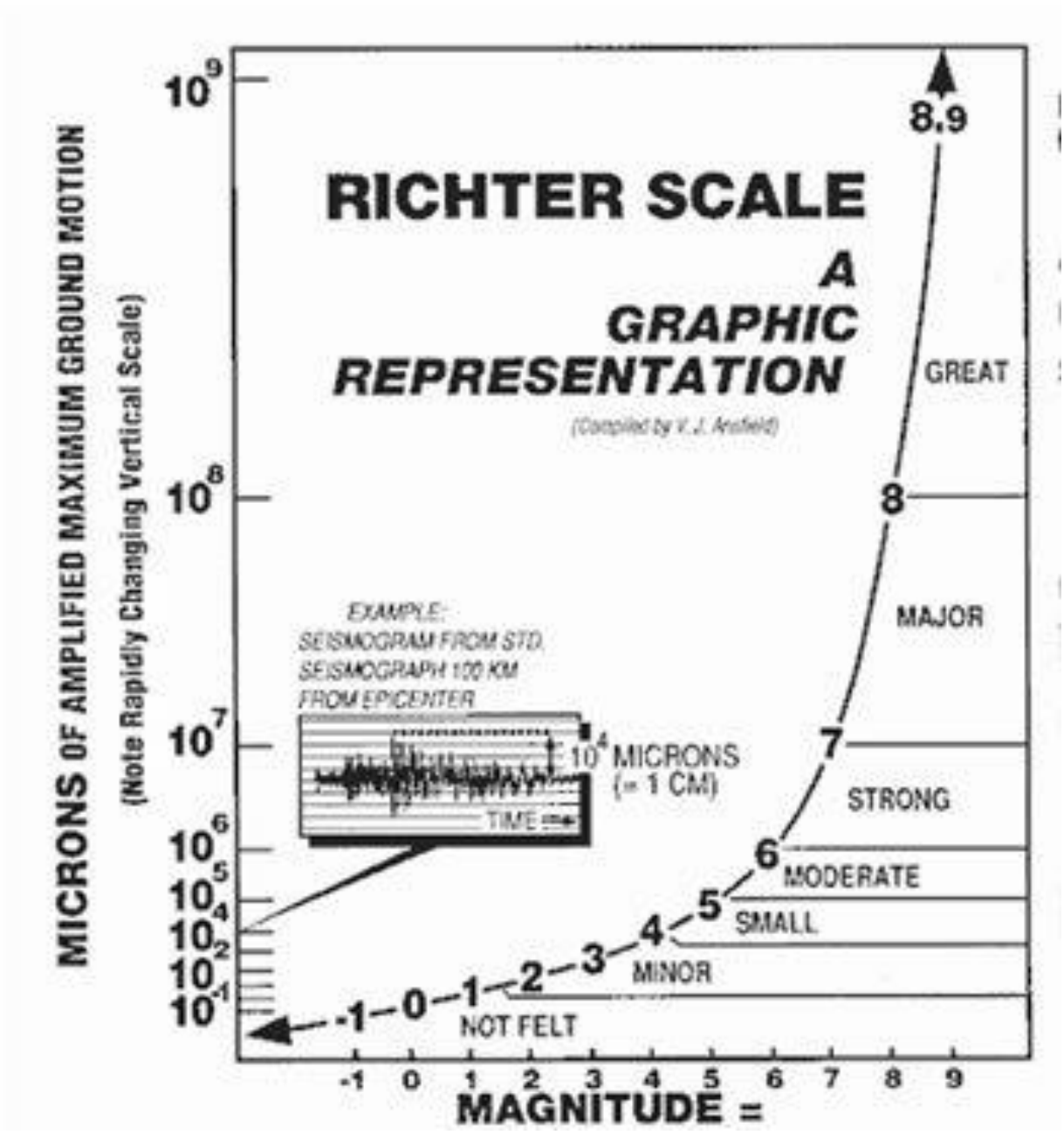
TSUNAMI

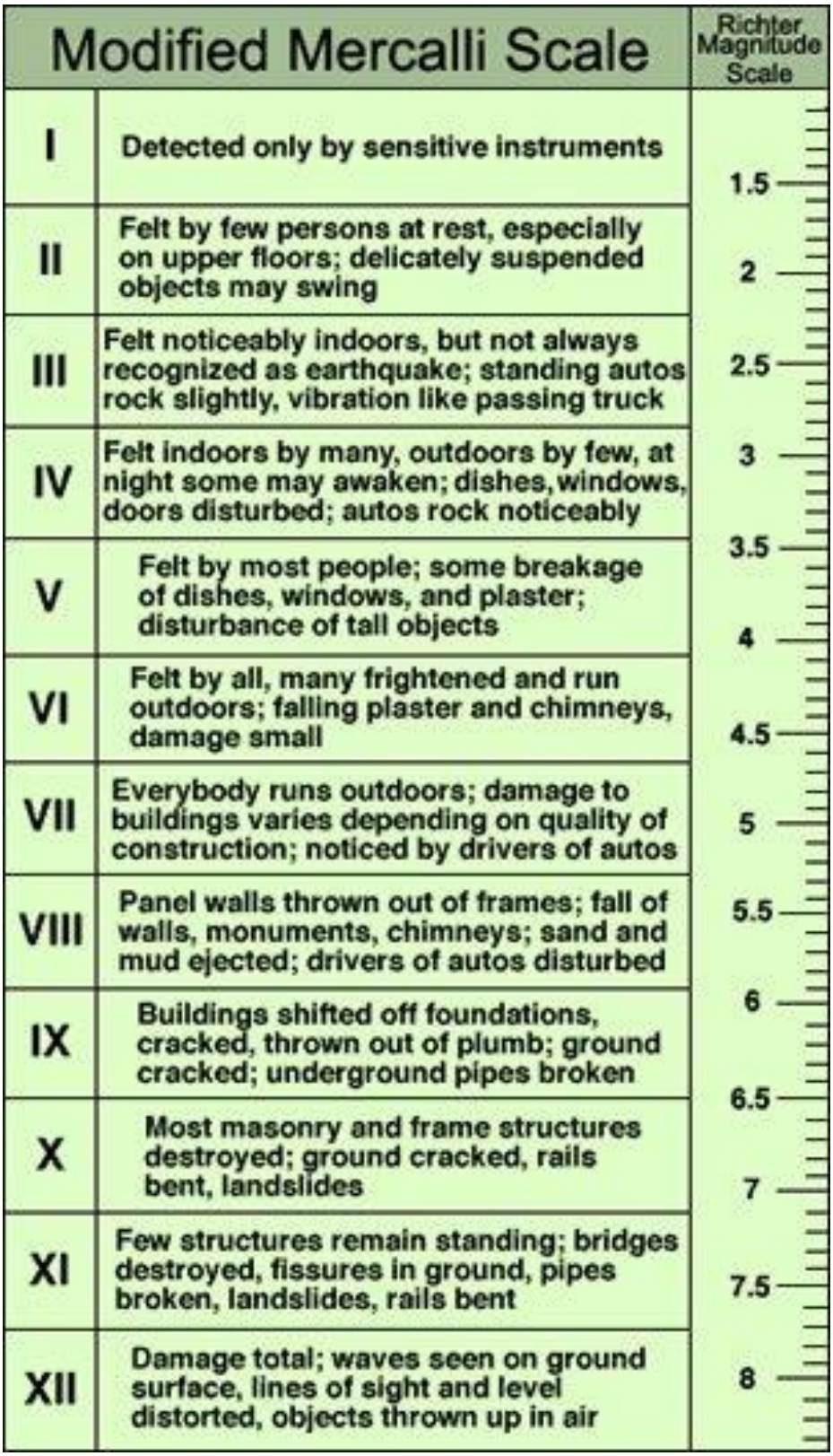
Tsunami: These are caused by displacement – usually undersea earthquakes, landslides, meteor strikes. Tsunami are not like wind driven waves, but are caused by a change in the basin in which the ocean lies.

Earthquakes are measured on the Richter Scale or the Mercalli Scale. The Richter Scale measures the amount of energy released whereas the Mercalli measures the amount of damage the earthquake is capable of. Here again scales are scientific artifacts produced with a specific goal in mind. Neither is right or wrong nor in conflict with the other.


RICHTER SCALE
A GRAPHIC REPRESENTATION
(Compiled by V. J. Anfield)
MICRONS OF AMPLIFIED MAXIMUM GROUND MOTION
(Note Rapidly Changing Vertical Scale)
MAGNITUDE =
EXAMPLE:
SEISMOGRAM FROM STD. SEISMOGRAPH 100 KM FROM EPICENTER
10⁴ MICRONS (= 1 CM)
TIME
8.9
GREAT
8
MAJOR
7
STRONG
6
MODERATE
5
SMALL
4
MINOR
-1 0 1 2 3
NOT FELT

RICHTER SCALE

Magnitude	Description	What it feels like	Frequency
Less than 2.0	Micro	Normally only recorded by seismographs. Most people cannot feel them.	Millions per year.
2.0–2.9	Minor	A few people feel them. No building damage.	Over 1 million per year.
3.0–3.9	Minor	Some people feel them. Objects inside can be seen shaking.	Over 100,000 per year.
4.0–4.9	Light	Most people feel it. Indoor objects shake or fall to floor.	10,000 to 15,000 per year.
5.0–5.9	Moderate	Can damage or destroy buildings not designed to withstand earthquakes. Everyone feels it.	1,000 to 1,500 per year.
6.0–6.9	Strong	Wide spread shaking far from epicenter. Damages buildings.	100 to 150 per year.
7.0–7.9	Major	Wide spread damage in most areas.	10 to 20 per year.
8.0–8.9	Great	Wide spread damage in large areas.	About 1 per year.
9.0–9.9	Great	Severe damage to most buildings.	1 per 5-50 years.
10.0 or over	Massive	Never Recorded.	Never recorded.


Modified Mercalli Scale
Richter Magnitude Scale
I
Detected only by sensitive instruments
II
Felt by few persons at rest, especially on upper floors; delicately suspended objects may swing
III
Felt noticeably indoors, but not always recognized as earthquake; standing autos rock slightly, vibration like passing truck
IV
Felt indoors by many, outdoors by few, at night some may awaken; dishes, windows, doors disturbed; autos rock noticeably
V
Felt by most people; some breakage of dishes, windows, and plaster; disturbance of tall objects
VI
Felt by all, many frightened and run outdoors; falling plaster and chimneys, damage small
VII
Everybody runs outdoors; damage to buildings varies depending on quality of construction; noticed by drivers of autos
VIII
Panel walls thrown out of frames; fall of walls, monuments, chimneys; sand and mud ejected; drivers of autos disturbed
IX
Buildings shifted off foundations, cracked, thrown out of plumb; ground cracked; underground pipes broken
X
Most masonry and frame structures destroyed; ground cracked, rails bent, landslides
XI
Few structures remain standing; bridges destroyed, fissures in ground, pipes broken, landslides, rails bent
XII
Damage total; waves seen on ground surface, lines of sight and level distorted, objects thrown up in air
1.5
2
2.5
3
3.5
4
4.5
5
5.5
6
6.5
7
7.5
8

Tsunami do not look like breaking waves. Rather they look like an extremely high incoming tide. They appear as though someone has been adding more and more water to the ocean and the level keeps rising.

Some serious Tsunamis:

Santorini (Thera)
An enormous volcanic eruption which produced a tsunami Somewhere around 1628 BCE Evidence from Greenland, California tree rings Climate affected – crop failure in Chine, part of Egypt impacted, (information appears on the stele of Ahmose). Some felt that this ended Minoan Civilization but archaeological evidence finds Minoan culture after the eruption. It is possible that the society was so damaged that it became perhaps too weak to defend against a very militant Mycene. There is some speculation that this eruption is the bases of Plato's Atlantis myth.

Lisbon
1755 Nov, 1st at 9:40 am. (All Saints Day) Earthquake followed by a tsunami. People reported seeing the tide go out far enough to expose some ship wrecks. Churches where many had fled for protection were destroyed. Many candles which had been lit helped ignite fires all over. Many other cities hit. About 200,000 people in Lisbon. About 30,000 to 40,000 people killed about 10,000 more in Morocco. This event triggered the beginning of the science of seismology

in Germany, Led to many theological problems – why did this happen on a High holy day (All Saints Day) destruction of Churches and people looking for refuge in them being killed.

Krakatoa
or Krakatau August 27 1883. The eruption of Krakatoa was preceded by minor rumblings and ventings. Then on Aug 27 there was the first major eruption which generated a cloud plume 20 miles high and triggered several tsunami. The following day there were 4 major eruptions in a 4 and a 1/2 hour period. The last is credited with being the largest sound recorded on Earth. It was heard in Australia and an island called Rodrigues 3,000 miles away. Villages on Java and Sumatra were destroyed. An estimated 35,000 people died. Chunks of coral weighing 600 tons were found on the shore. Tsunami went nearly around the world with places. Thousands of miles away having large waves. Sunlight in the immediate area was blocked for several days and within weeks people all over the world saw the sun a strange color. This was caused by the dust in the stratosphere. Global temperatures fell for several years as a result of the reduced sunlight from the ash. Krakatoa basically blew itself apart but a new volcano called Anam Krakatoa is forming at the crater of about 5 inches a week.

Indonesian Earthquake and Tsunami or Indian Ocean Earthquake and Tsunami Dec, 26, 2004 (9.1 - 9.3 on Richter Scale) The death toll across 14 countries was about 230,000 people. It was the third largest earthquake ever recorded and lasted 8.3 to 10 minutes. Indonesia was the hardest hit, with Sri Lanka, India and Thailand also suffering

major losses. In 1960 the Great Chilean Earthquake registered 9.6 and the 1964 Good Friday Prince William Sound Earthquake which registered at 9.2 are the only greater earthquakes recorded.

There was great ecological impact both in the ocean itself and along the coastlines. Scientifically there has been the development of a much greater warning system in the Indian Ocean.

Tohoku earthquake and Tsunami March 11, 2011
A 9.0 earthquake off the coast of Tohoku (N.E. Japan) resulted in a tsunami the struck Fukushima, Iwate Prefecture. The number of confirmed deaths is 15,891 as of April 10, 2015, according to Japan's National Police Agency. Most people died by drowning. More than 2,500 people are still reported missing.
It was estimated that in one part of Iwate Prefecture, the tsunami may have been 127 to 133 feet high.

VIDEO TSUNAMI

Sendai (the major city in Fukushima) has an airport near enough to the water that wave washed cars and planes away at the airport.
The Japanese, as the only people against whom nuclear weapons of mass destruction have been used (in Hiroshima and Nagasaki near the end of WWII) have a great deal of concern about nuclear matters and there is a split in the population about nuclear reactors. The Fukushima Daiichi Nuclear Power Plant suffered a meltdown and a good deal of radioactive material was washed into the ocean. In

Fukushima, Tochigi, Gunma, Tokyo, Chiba, Saitama, and Niigata prefectures, there were reports that radioactive material was found in tap water. The fishing of some species of fish was also banned because they were found to have radioactive material in them.

Nuclear meltdown:
The tsunami caused a cooling system failure at the Fukushima Daiichi Nuclear Power Plant, which resulted in a level-7 nuclear meltdown and release of radioactive materials. The electrical power and backup generators were overwhelmed by the tsunami, and the plant lost its cooling capabilities. In July 2013, TEPCO, the Tokyo Electric Power Company, admitted that about 300 tons of radioactive water continues to leak from the plant every day into the Pacific Ocean.

LITUYA BAY ALASKA (1958)

Lituya Bay megatsunami occurred in Lituya Bay Alaska in 1958. It was a 7.8 earthquake which caused a landslide dumping 40 million cubic yards, and about 90 million tons) to fall from several hundred meres into the narrow inlet of Lituya Bay, Alaska. This displacement of water by the slide caused a wave to form which measured 1710 feet at the inlet to the bay (Empire State Building 1,250′, 1,454′ to tip).

TIDAL WAVES

Tidal waves are not tsunamis. A tidal wave is a wave that forms when the tide comes in and forms a wave. Sometimes they will form in a river as the tide pushes its way inland. These are sometimes called “tidal bores” These can be dangerous to people because in narrow beaches with high hills or cliffs, a person or an animal might not be able to escape in incoming tide. Bay of Fundy Tidal Bore

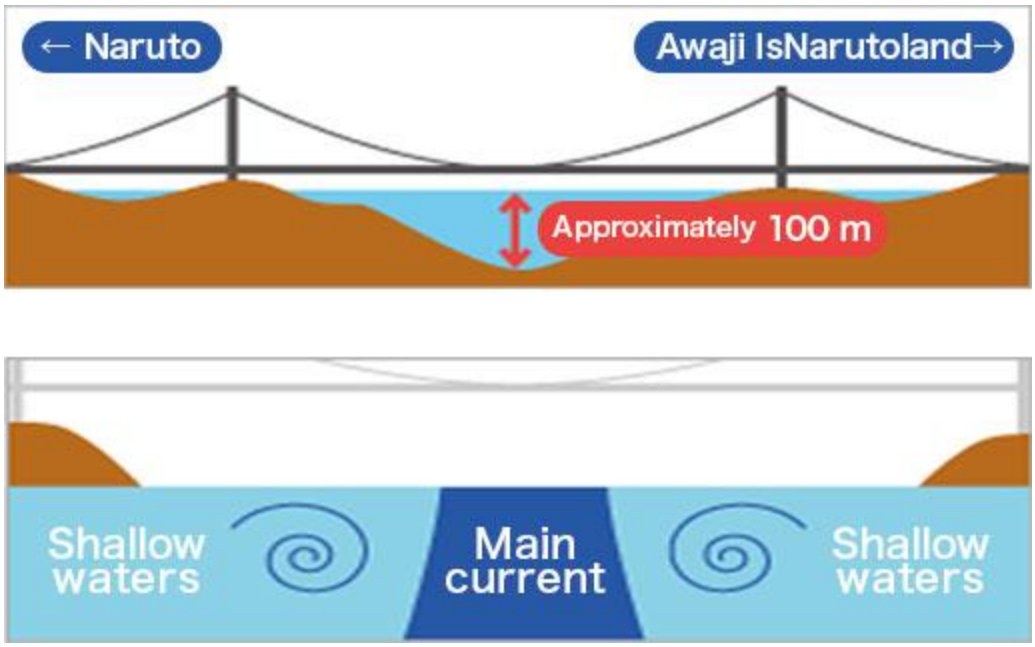
https://www.youtube.com/watch?v=YDNg101oLkE

In Cuxhaven in Germany, the shore is almost horizontal, so the tide comes in suddenly and with great speed.

Watt in Cuxhaven

https://www.youtube.com/watch?v=yTpzaZa9vhs

Whirlpools In addition, the changing of the tides can create another hazard known as a “whirlpool”. These are created when the water from two opposing currents meet and form a vortex. (This is NOT what happens in the sink or bathtub).



whirlpool_narutao_formation

Whirlpools become columns of circulating water, but without an "exit" so boats and ships are not "sucked down into them. Large ships can plow through them and small boats may be spun around by them. For a small boat this is very dangerous in that it can become swamped – that is water may flood into the boat and cause it to sink.

Whether or not the whirlpool appears and how rapidly it spins are a function of the tides. High tides and especially spring tides produce the most intense whirlpools. The figures given below are “highs”. In some cases, these have become tourist attractions with boats taking passengers out to see the whirlpool “up close”

whirlpool_narutao_tourists

The largest whirlpools are Saltstraumen (23 mph) in Norway,

Whirlpool_Saltstraumen_Norway

Moskstraumen (17.3) also in Norway, although there are those who think this is more an “eddy” than a whirl pool

and Corryvreckan in Scotland found off the west coast between Jura and Scarpa. It has speeds of about 12 mph

Whirlpool_Corryvreckan

A dramatic encounter with Corryvreckan can be seen in the film I Know Where I’m Going. On the US/Canadian border lies Old Sow (17.1 mph) between Deer Island in New Brunswick and Moose Island, Eastport Maine. The US Coast Guard Station in Eastport regularly rescues boats that have gotten too close and do not have enough power to move them out of the current.

whirlpool_Oldsow

Near Awaji Island in Japan lie the Naruto whirlpools which have speeds of up to 12 mph.

Whirlpool_Naruto

Edgar Allen Poe's Descent Into the Maelstrom and other fictional works have boats being sucked down into the whirlpool, but this is just fiction.

UNDERSEA WAVE

Undersea waves These are waves which occur underwater as a result of two layers of water of different densities moving against each other the way that air and water do on the surface. These waves can be dangerous to submarines

STORM SURGE

Storm winds cause storm surge by pushing the ocean up onto the shore. These are most intense with hurricanes. The speed and intensity of hurricane winds is measure by a scale called the SAFFIR SIMPSON HURRICANE SCALE

Scale Number (Category)	Sustained Winds (MPH)	Damage	Storm Surge
1	74-95	**Minimal:** Unanchored mobile homes, vegetation and signs.	4-5 feet
2	96-110	**Moderate:** All mobile homes, roofs, small crafts, flooding.	6-8 feet
3	111-130	**Extensive:** Small buildings, low-lying roads cut off.	9-12 feet
4	131-155	**Extreme:** Roofs destroyed, trees down, roads cut off, mobile homes destroyed. Beach homes flooded.	13-18 feet
5	More than 155	**Catastrophic:** Most buildings destroyed. Vegetation destroyed. Major roads cut off. Homes flooded.	Greater than 18 feet

There is a separate scale for tornados called the Fujita scale that has been enhanced.

Fujita Scale	
F–0	40–72 mph winds
F–1	73–112 mph
F–2	113–157 mph
F–3	158–206 mph
F–4	207–260 mph
F–5	261–318 mph

fujita-tornado-scale

Enhanced Fujita Scale	
EF–0	65–85 mph winds
EF–1	86–110 mph
EF–2	111–135 mph
EF–3	136–165 mph
EF–4	166–200 mph
EF–5	>200 mph

enhanced-fujita-tornado-scale

These are more intense, but more localized and can occur on the water where they form “water spouts”.

Water spouts

Hurricanes are winds around an extreme low-pressure area. The air being warmed and rising causes a low pressure. Winds then move into the low-pressure area moving to the right (counterclockwise) in the Northern hemisphere and the reverse in the Southern. This is the result of the Coriolis force or effect. Winds in the northern hemisphere veer to the right, in the southern hemisphere to the left.

This is caused by the fact that a sphere which is rotating moves faster near the "equator" than at the poles. At one foot from the pole, one can walk 360 degrees in a few steps, but at the equator the person would have to walk 24,000 miles or so. Since the world rotates on its axis once in approximately 24 hours, the part near the equator must cover about 1000 miles an hour, whereas at the poles it travels only a few feet in 24 hours.

If you imagine a line of skaters or dancers that is revolving around the center of the line, you realize the people toward then

center move much slower than those at the outside. The people at the ends of the line must travel very fast while the people in the center go rather slowly. If the line rotates counter-clockwise (as the Earth does if you were to look down at the North Pole from space) the line of dancers/skaters would curve to the right as they try to catch up.

VIDEO OF SKATERS

If you looked at the Earth from outer space from over the South Pole, it would appear to rotate clockwise. A line of dancers/skaters rotating clockwise would bend to the left.

So hurricanes in the North rotate counterclockwise, since the air moving into the low pressure center begins to veer to the right.

Hurricanes season lasts officially from June 1 to Nov. 30. September is the generally to most active month. This because these are the times when the ocean temperature is higher. The hurricanes in the Atlantic begin as low pressure centers coming off the coast of Africa and then they move out over the ocean where they gain energy from the warm water. The air heats and rises causing the low pressure to drop even lower. Because of the pressure gradient (the difference in pressure horizontally in the air) the air moves into the lower pressure areas (air moves from higher to lower pressure). As it move in, the Coriolis effect causes the air moving in moves to the right, and the low pressure center has a counter clockwise turn. The water produces moisture as well and the low pressure area may intensify and when winds reach 74 miles an hour, the event is labeled a hurricane.

The eye is center of the rotation and the area immediately around it is the eye wall. On land, the eye is rather calm, but on the ocean it is an area of violent wave activity since the waves

are formed by wind direction and the winds are blowing from all directions around it.

For ships at sea, being in the eye of the hurricane is the worst place to be. Waves are large and come from all directions.

On September 30th of 2015, the 791-foot long freighter, El Faro, at 791 feet long, left Jacksonville Florida en route to Puerto Rico with 391 shipping containers. AT the time, a tropical storm Joaquin in the Atlantic was building and expected to become a hurricane by the next day. The ships course would have taken it into the path of the hurricane which was rapidly intensifying. The ship took on water, began listing and then lost propulsion. The Emergency Position Indicating Beacon (EPRIRB) sent messages as to where the ships was. Two databases indicted slightly different positions, and one put the vessel in the eye wall just before all contact was lost.

Hurricane Hunters and the US Coast Guard aircraft began a search for El Faro and later they were joined by a Coast Guard vessel and a Coast Guard helicopter, but no trace of the ship was found. On October 3rd while flying in hurricane force winds, a life ring was recovered. Debris and some bodies and a damaged life boat were found. On Oct 7th the search was discontinued. On Oct 31 soundings located a vessel at 15,000 feet deep which turned out ot be the ship.

There were 33 people on the ship 28 Americans and 5 Poles. All hands were lost.

When hurricanes come on shore, they often produce large storm surges in which the water level rises dramatically. If the coast is steep, the water may not move far inland, but if the shore is gently sloping the water may move quite a distance inland. Current thoughts are that under the "right" circumstances, storm

surge could raise the water level in Brooklyn so that there would be water as far inland as Ave. I.

Since the hurricane is rotating in a counterclockwise direction being on the NE corner is the worst part of the storm. At that point the water is pushing higher into the land. On the NW side, the winds are pushing away from the land. In addition to the shape of the shore line, and which part of the storm is arriving (NE or NW quadrant), there are other factors to consider. Among these is the forward speed of the storm, the speed of the wind, the nature of the land where the hurricane comes ashore (rocky, sandy etc.) and the amount of rain. Clearly a slow moving storm stays longer and hence dumps more rain. Attempts to block incoming seas imitate some natural phenomena like sand bars by building breakwaters - a kind of wall in the water. Some hurricanes have overtopped the walls, or destroyed the walls. Such walls however have an effect on beach erosion. Some of the land has plant life which has long roots and help stabilize the ground and keep it from washing away. In some cases the building of houses on the shore line leads to the loss of such plants and the destruction of sand dunes which may also help control water movement.

On Sept. 8th 1900 Galveston was struck by a hurricane struck causing incredible damage.

The city of Galveston was a hub of businesses with a population of about 36,000 people. It has a natural harbor which helped its growth. It was built basically on a sandbar, with highest point being some 8.7 feet above sea level. Some concerned citizens had suggested the building of a seawall (a wall on the beach basically) to protect the city but the majority of the population thought it unnecessary and so one was not built. There had been a good deal of building going on in the city which led to the

destruction of sand dunes to fill in low areas of the city and in this way what protection there was destroyed. There had been storms before which the city had survived which led to some complacency. Isaac Cline of the weather bureau thought it would not be possible for the city to be struck by a hurricane. The weather service at that time had little information about weather at sea and relied on reports from ships.

Cuba forecasters were predicting the storm that they were experiencing, would head toward San Antonio, but the US weather bureau argued that the storm would curve and strike Florida. Isaac Cline's role and that of his meteorologist brother Joseph have been a bone of contention with some people crediting them with giving a hurricane warning before the central office approved it, while others claim their role was negative in that they resisted the idea of building the sea wall.

When the storm surge hit, the waters rose over 15 feet - almost twice the depth of the highest piece of land. The entire island was submerged and over 3,600 hundred buildings were destroyed. Estimates of the death toll rose to somewhere between 6,000 and 12,000 people (official reports claim 8,000) making it the greatest natural disaster to strike the U.S.

Disposing of the dead was a major problem and bodies were weighted and placed on barges and dumped at sea. The currents brought many of the bodies back to shore and the survivors were reduced to building funeral pyres and burning the bodies. This went on day and night for weeks after the storm.

It is reported that there were more people killed in this storm than in all the other cyclones to have struck the US.

CURRENTS:

Currents are moving water. Major currents are driven by wind and tides and differences in density. As a result currents can be on the surface or under water

So how does the wind operate? Hot air at the equator rises and starts to move north in the N. hemisphere and south in the southern hemisphere. At about 30 degrees from the equator, the air has cooled enough and become dense enough to sink down to the ground. Since the cool air is denser than the warm air toward the equator, the pressure gradient moves the air south.

Currents also operate as heat transport.

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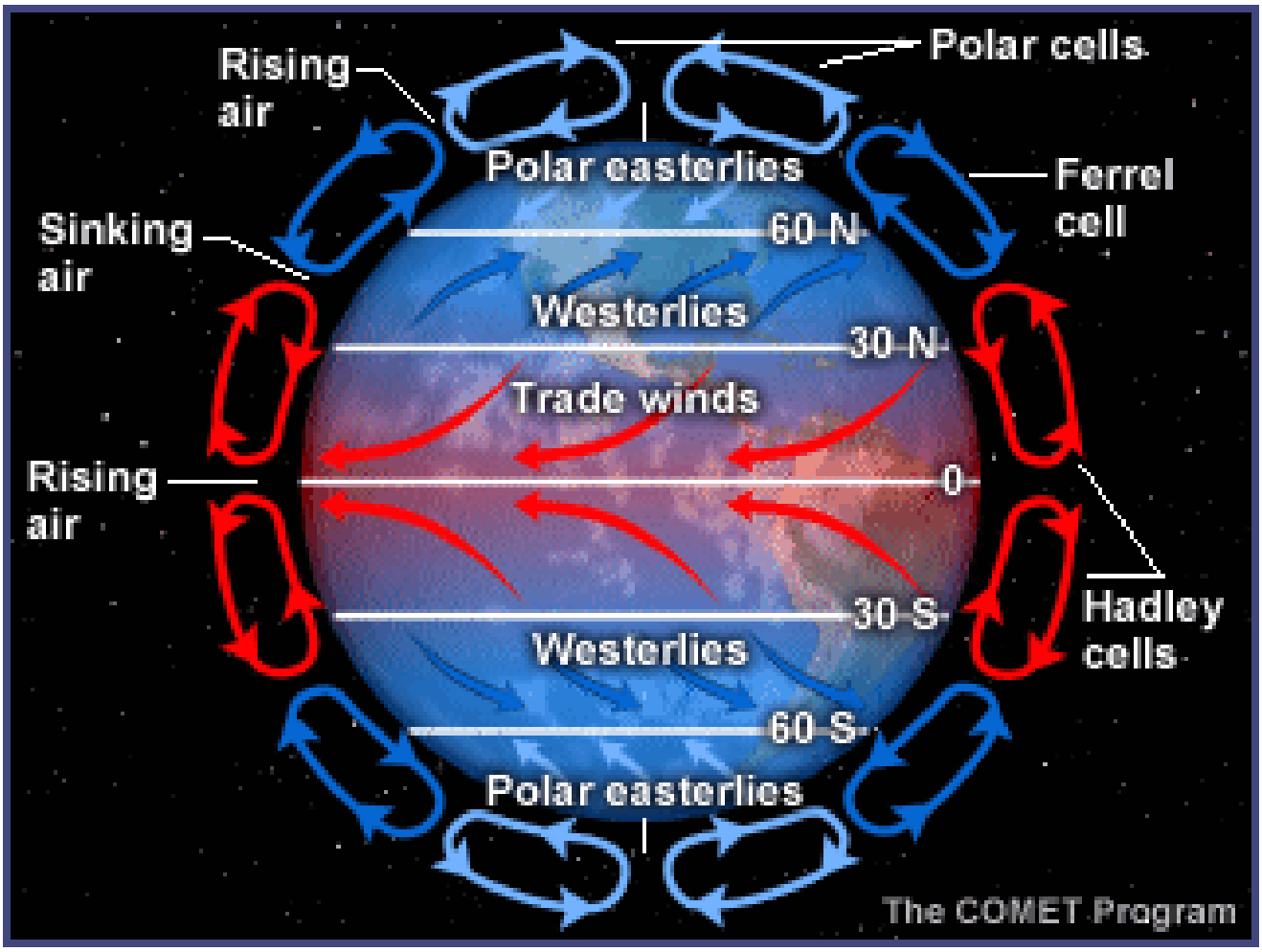
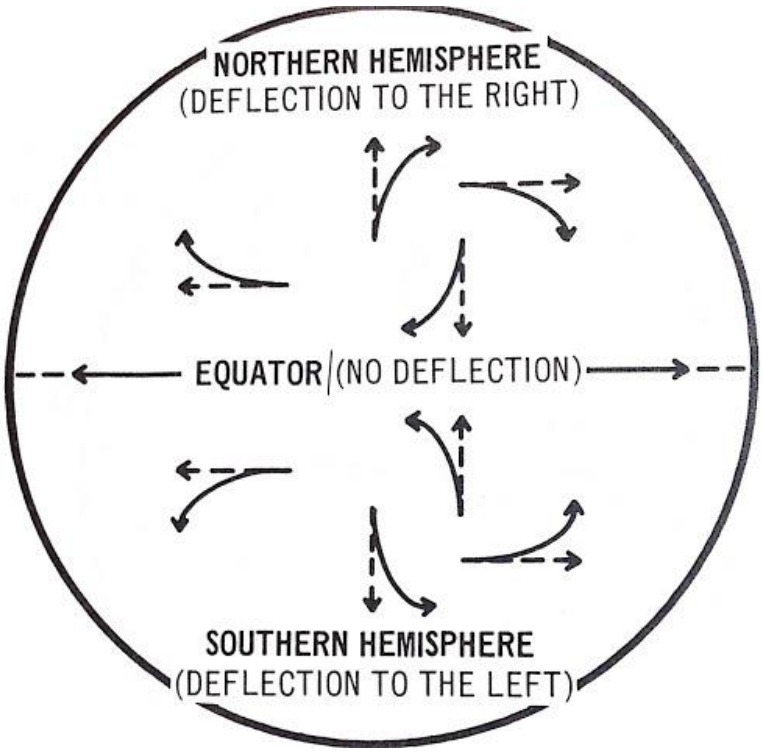


At the poles, the cold air over the poles sinks and moves south towards the warmer air. As it moves south it heats and rises at about 60 degrees from the equator. The air between the Hadley Cell and the Polar cell is moved like a gear between the two.

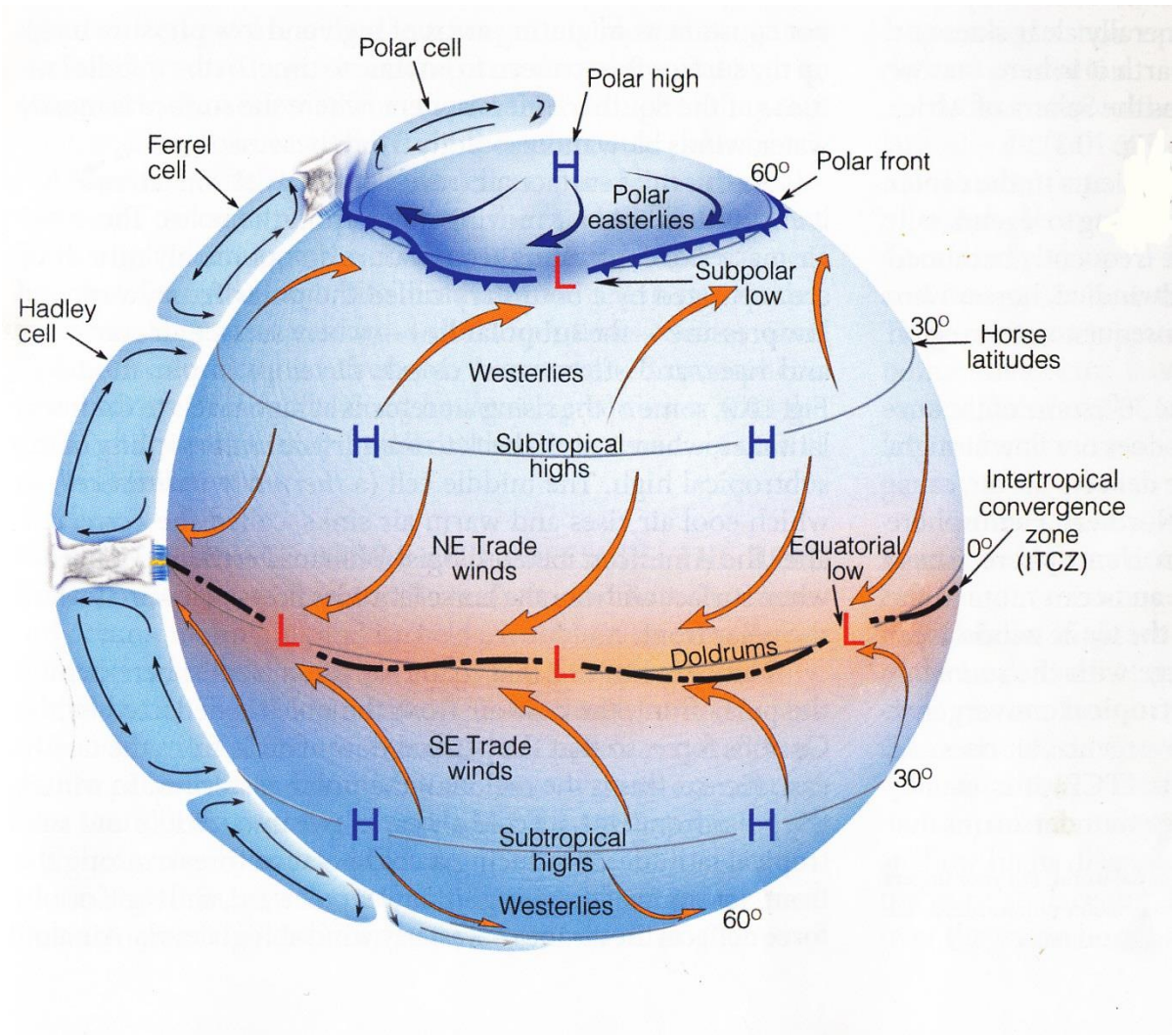
As the air on the surface of the earth moves north and south, the Coriolis Effect takes over and the winds in both directions veer off to the right.

Diagram 2



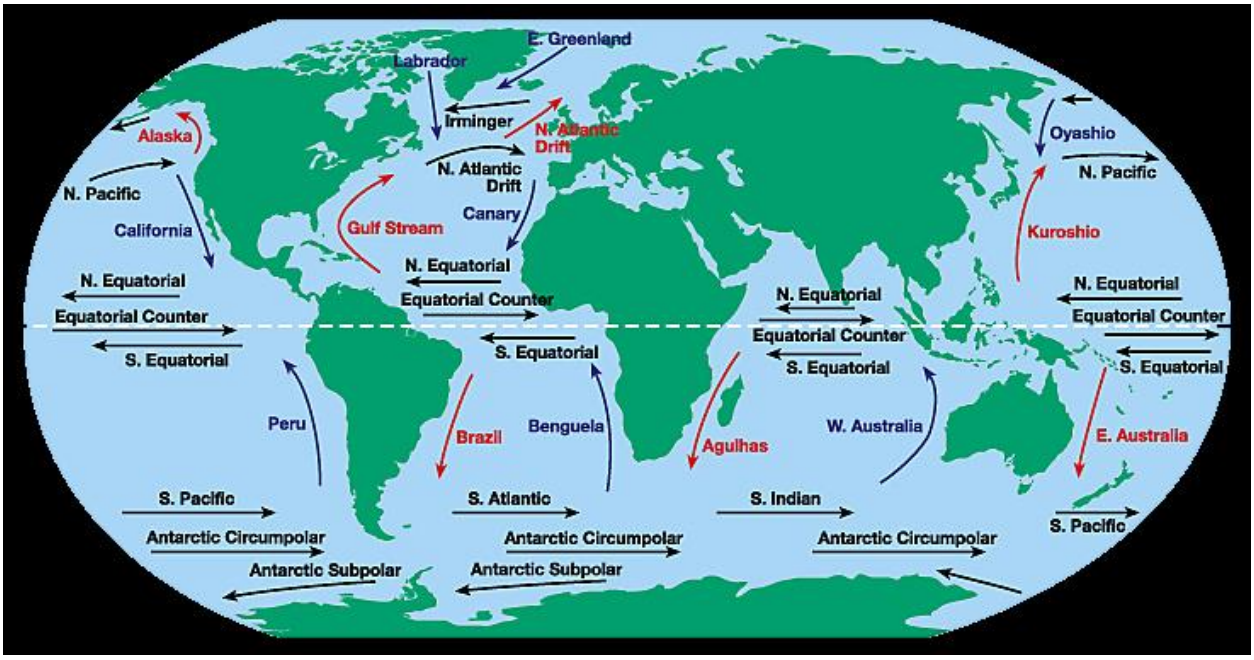
coriolis

This gives the general global wind patterns.



Hadley cells

As a result, ocean currents follow the pattern of the winds


E. Greenland
Labrador
Irminger
N. Atlantic Drift
Alaska
N. Pacific
California
Gulf Stream
N. Atlantic Drift
Canary
N. Equatorial
Equatorial Counter
S. Equatorial
Peru
Brazil
Benguela
Agulhas
W. Australia
E. Australia
Oyashio
N. Pacific
Kuroshio
S. Pacific
S. Atlantic
S. Indian
Antarctic Circumpolar
Antarctic Subpolar