Weather and Climate

Jim Keller & Paul Belanger

Classroom assistant: Fritz Ihrig

Week 7: February 26th , 2019

LECTURE 20 Ocean Influences on Weather and Climate

LECTURE 21 Tropical Cyclones

LECTURE 22 Light and Lightning

Announcements

- **Fritz Ihrig; classroom assistant, liaison to OLLI:**
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- **Paul Belanger:**
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The Great Courses

Lecture Chapters

About the Professor

Meteorology: An Introduction to the Wonders of the...

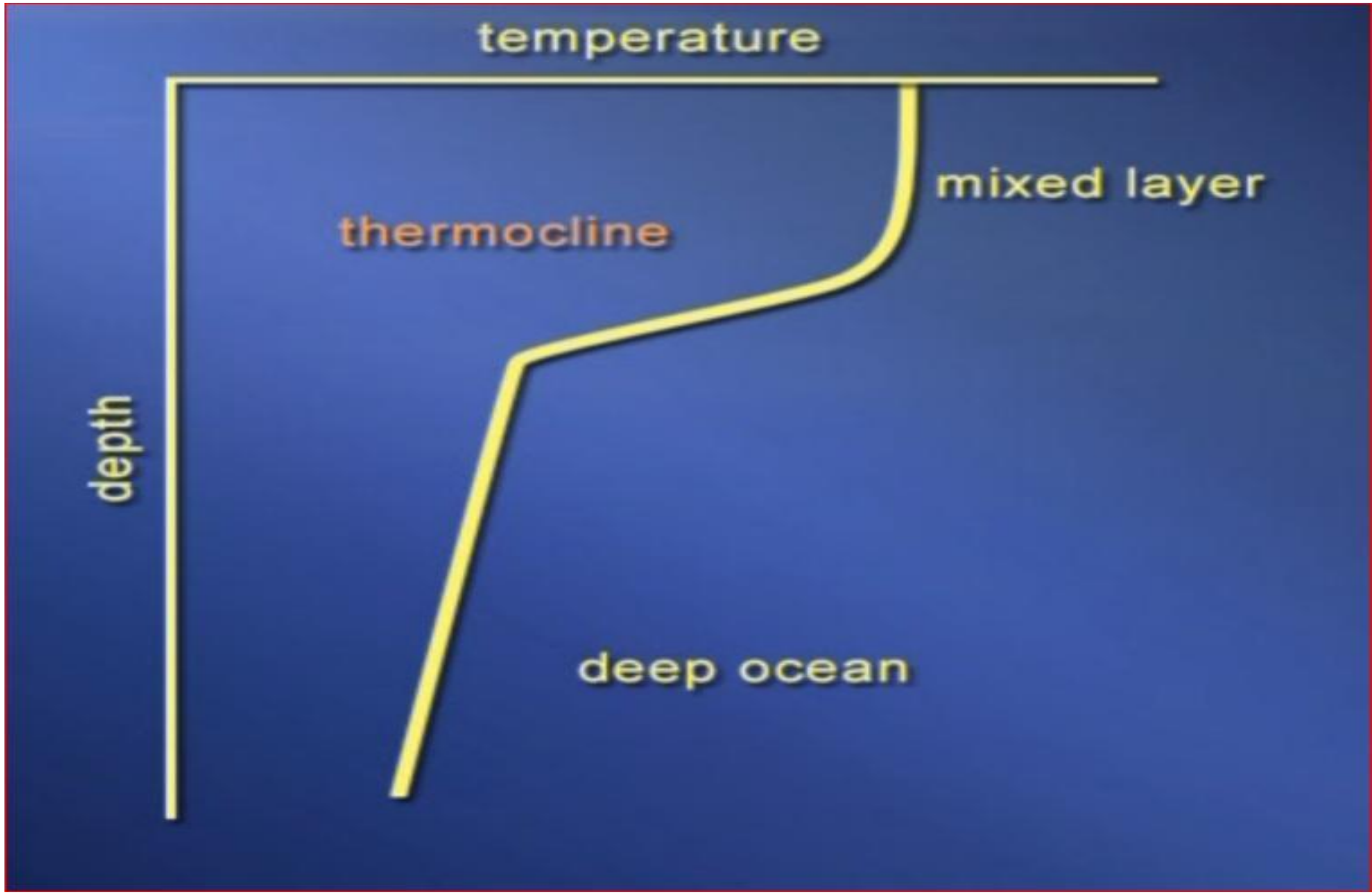
THE TEACHING COMPANY®

Characteristics of the Oceans

- Thermal capacity ~ 1 calorie per gram per degree centigrade, about five times that of, e.g. concrete, sand, rocks.
- Always in motion – thermal/density/salinity driven currents.
- Density displacement: temperature vs. salinity (salt concentration)
- 33 feet of pure water, ~ 32 feet of sea water = 1 atmosphere of pressure, 14.7 pounds per square inch. At 100 feet of depth, ~3 atmospheres, ~45 psi.

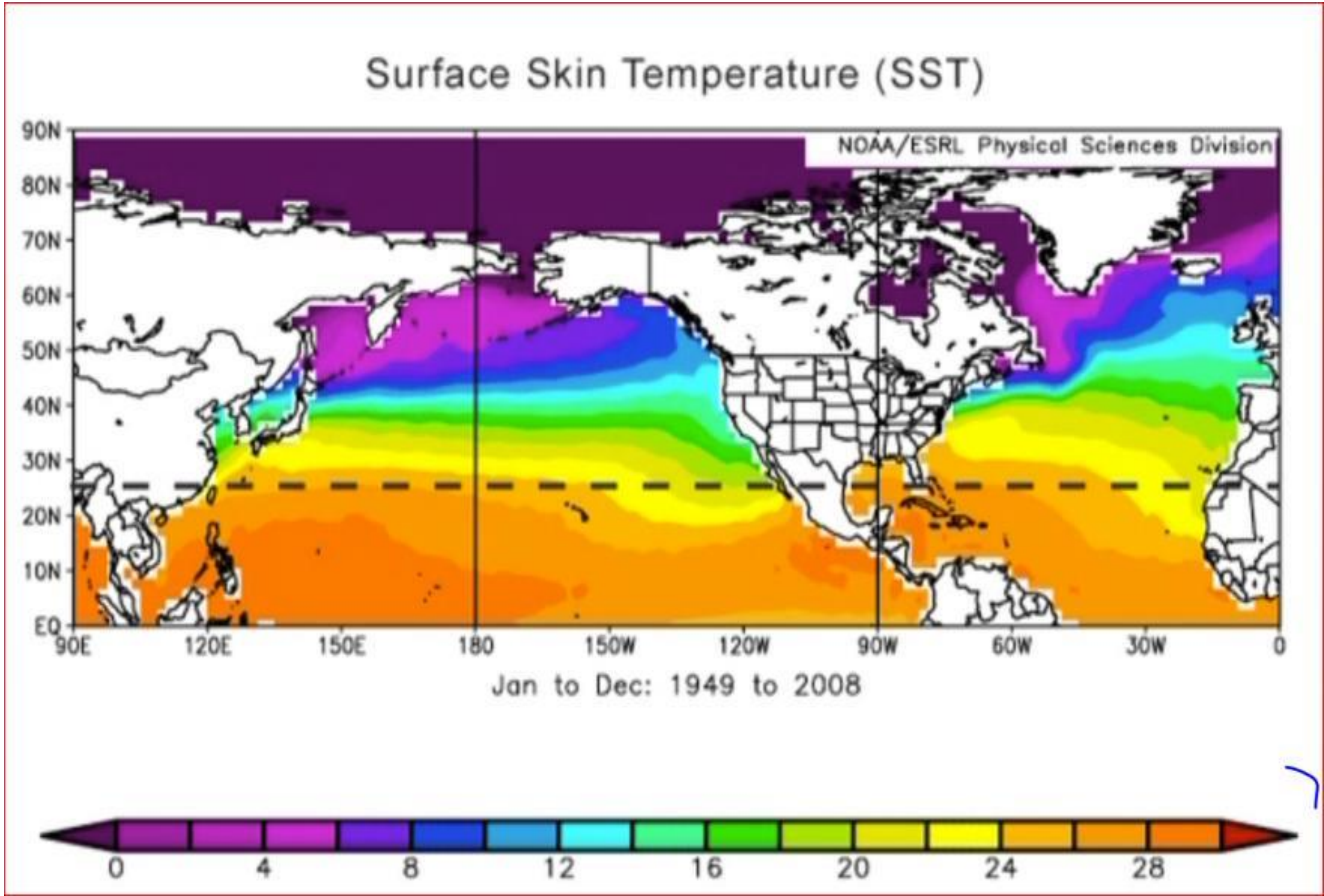
Temperature at Depth is Cold

- Thermocline varies in depth by latitude, longitude and season
- Below the thermocline there is not too much temperature variation



Sea Surface Temperature (SST)

- Line drawn at 25 degrees north latitude to note the greater warmth in the west vs east parts of each ocean basin



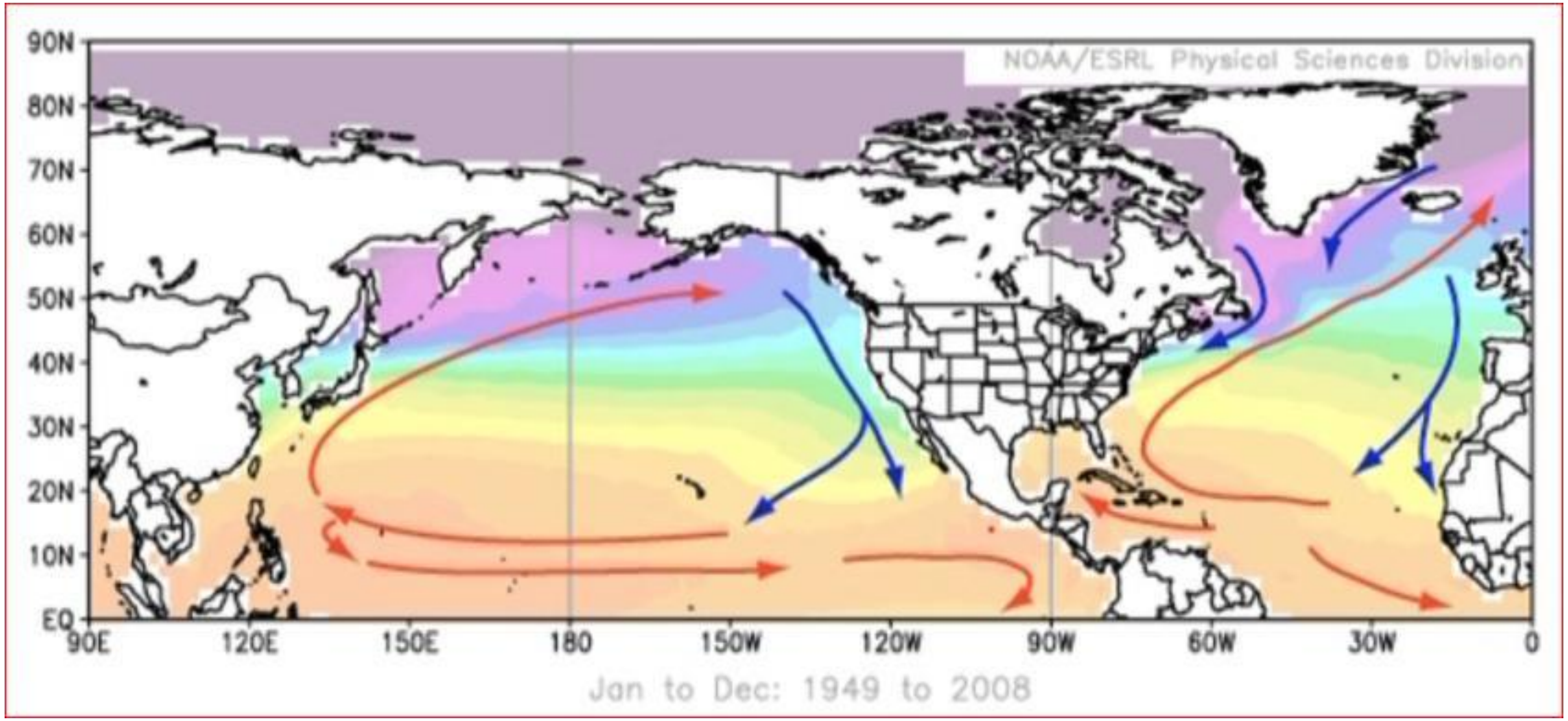
Northern Hemisphere Ocean Circulation

Pacific Ocean:

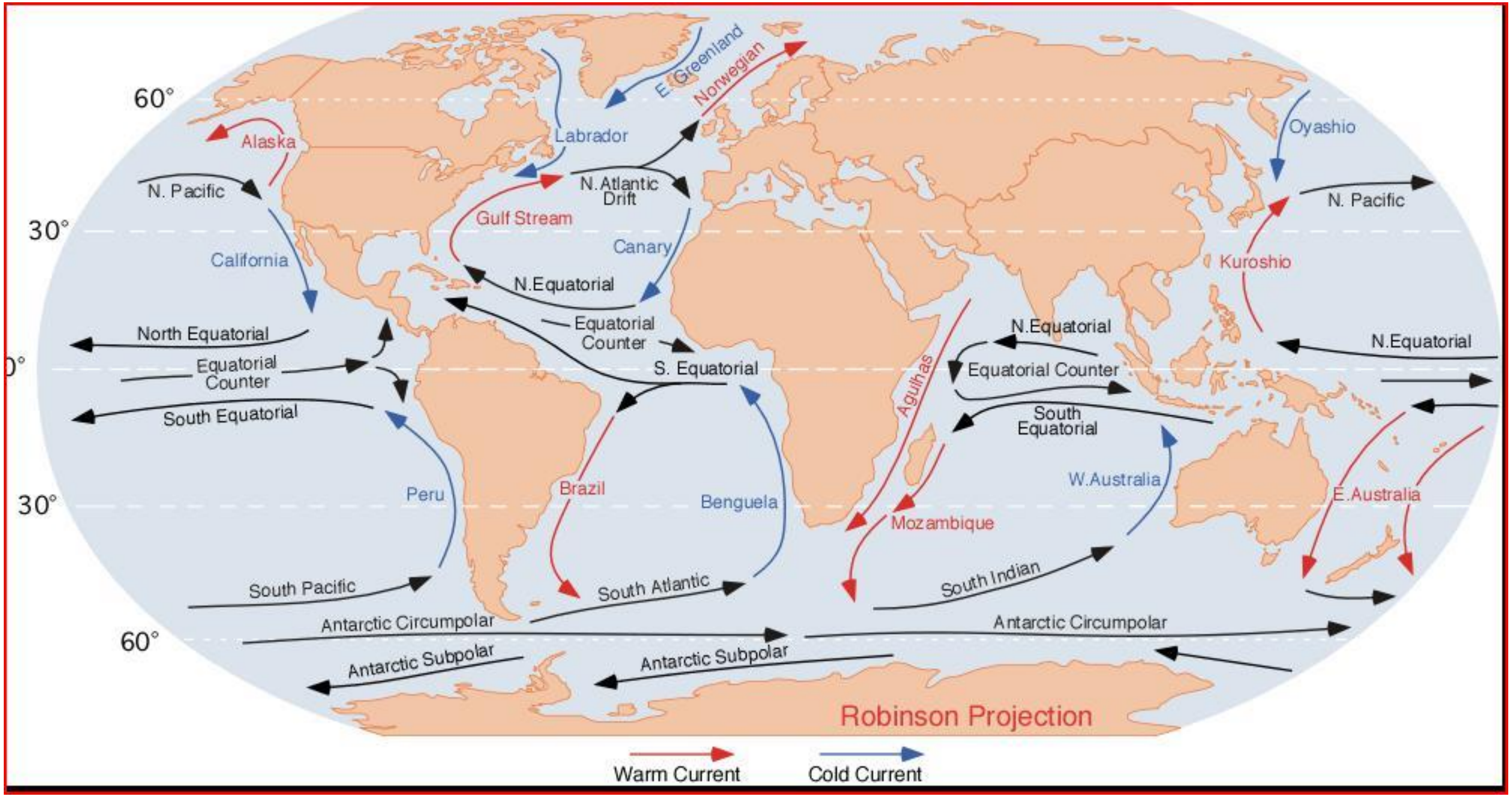
- North Equatorial Current
- Kuroshio Current (means black tide in Japanese)
- California Current
- Note equatorial countercurrent

Atlantic Ocean:

- Gulf Stream/North Atlantic Drift
- East Greenland & Labrador current
- Canary current



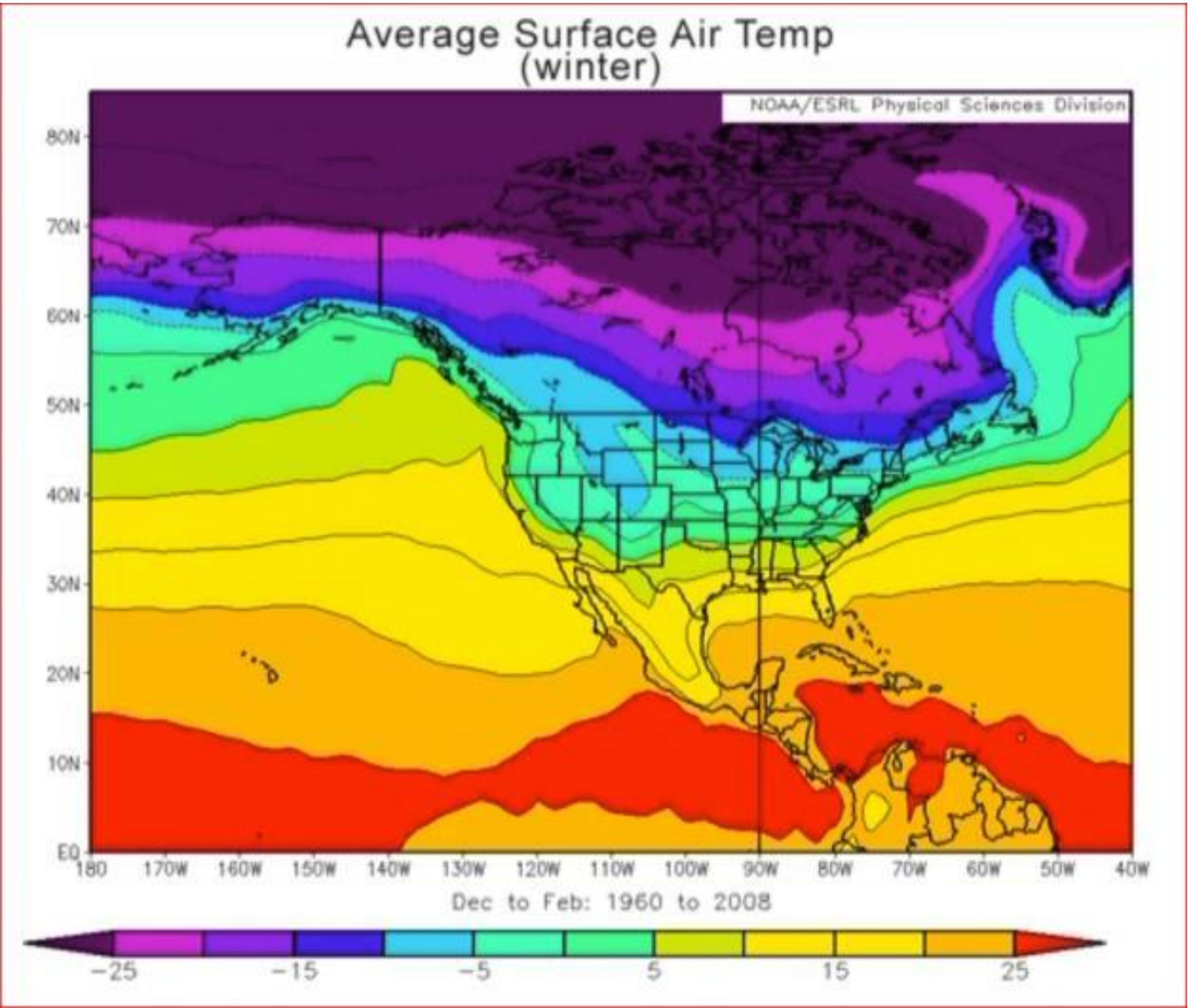
Winds & Coriolis Force Drive Surface Currents

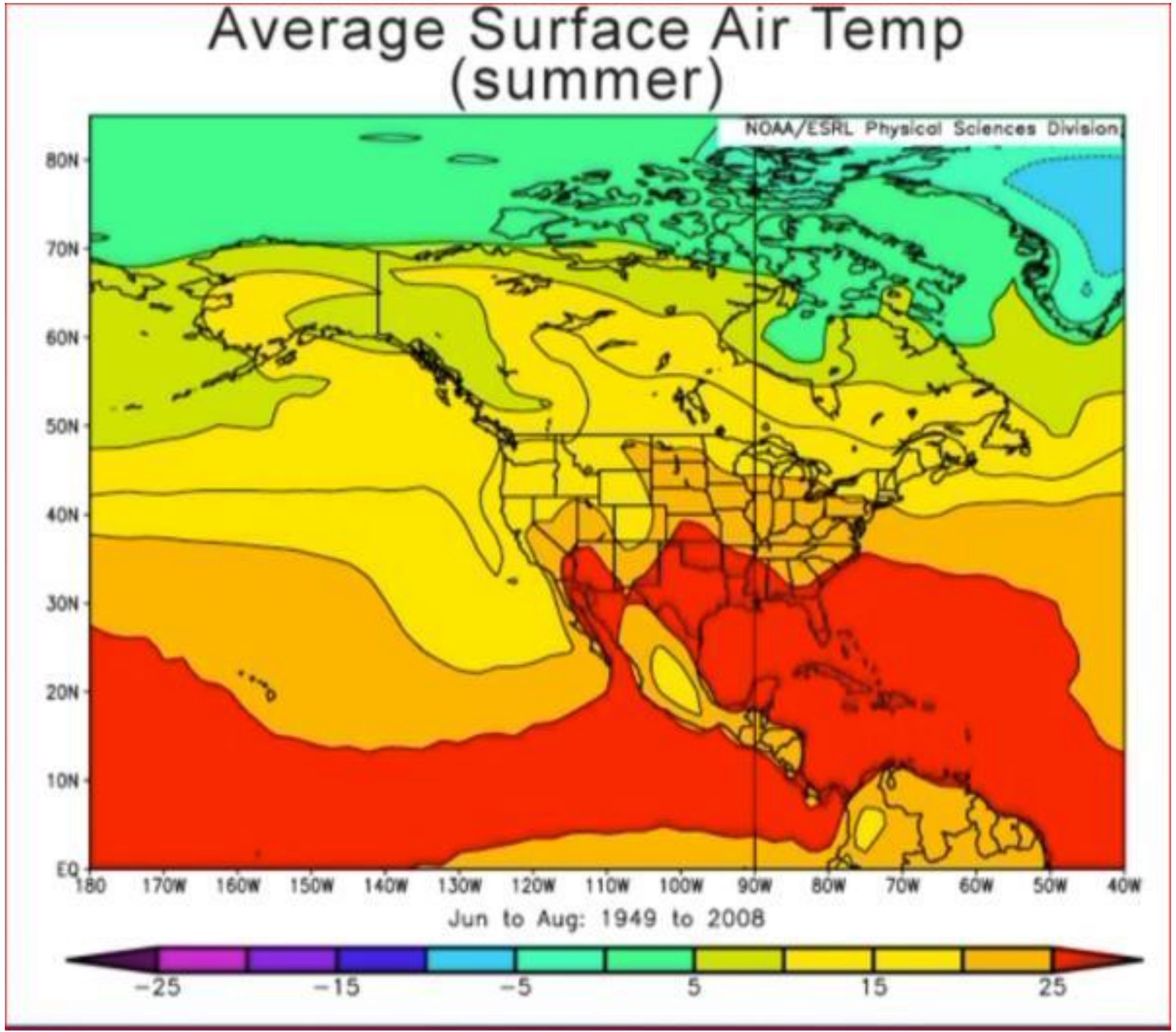


https://en.wikipedia.org/wiki/Ocean_current#/media/File:Corrientes-oceanicas.png

Winter vs. summer temperatures

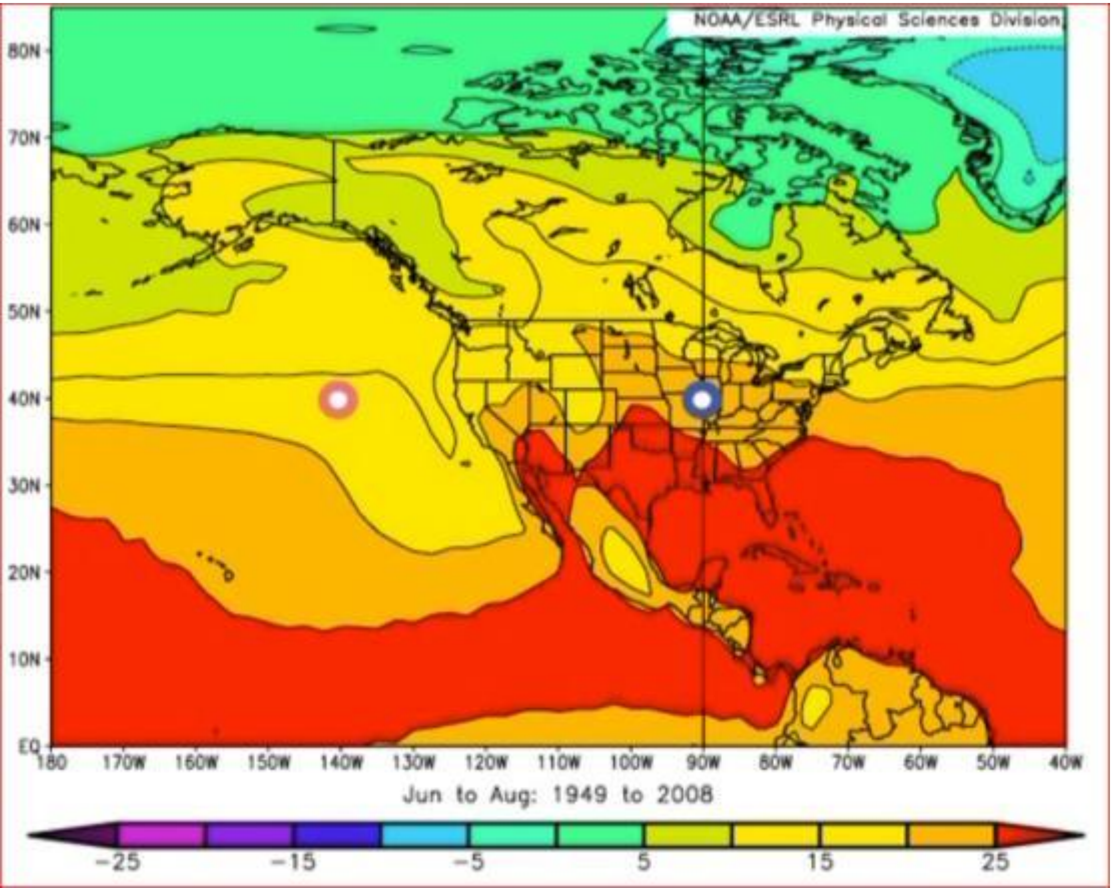
- Note continental variations much greater than oceanic variations

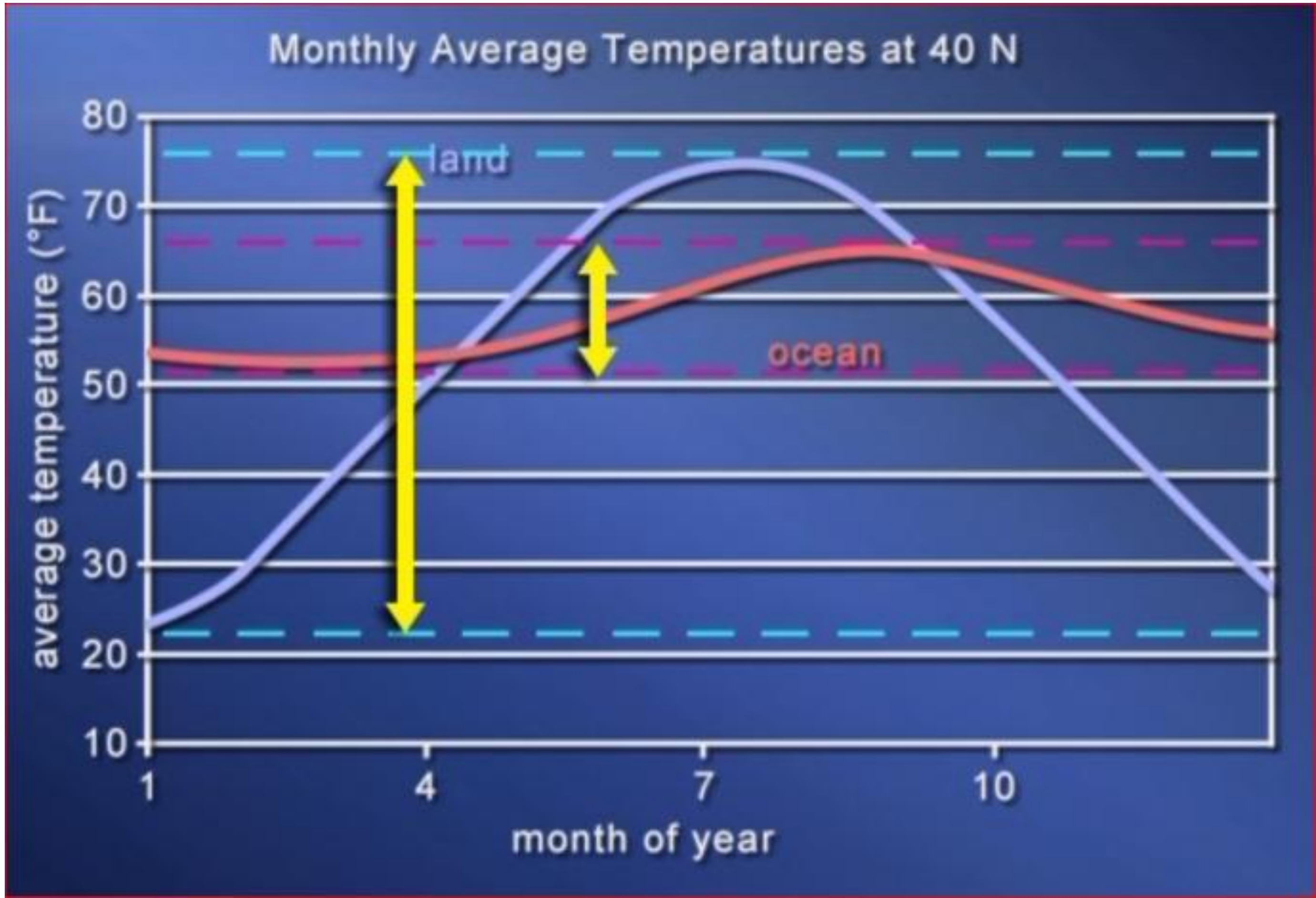




Contrast of 2 points at same latitude

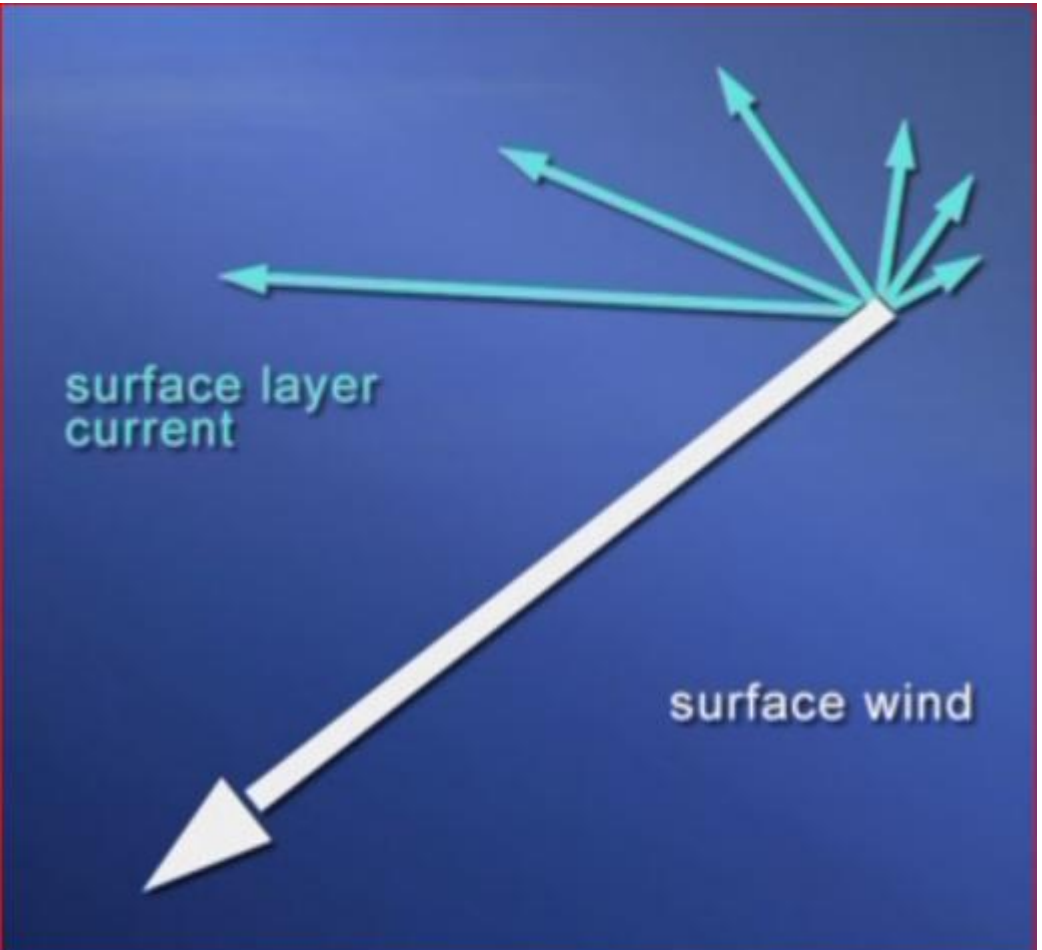
- Note the lag of peak temperatures; oceans warmest in September and coolest in March

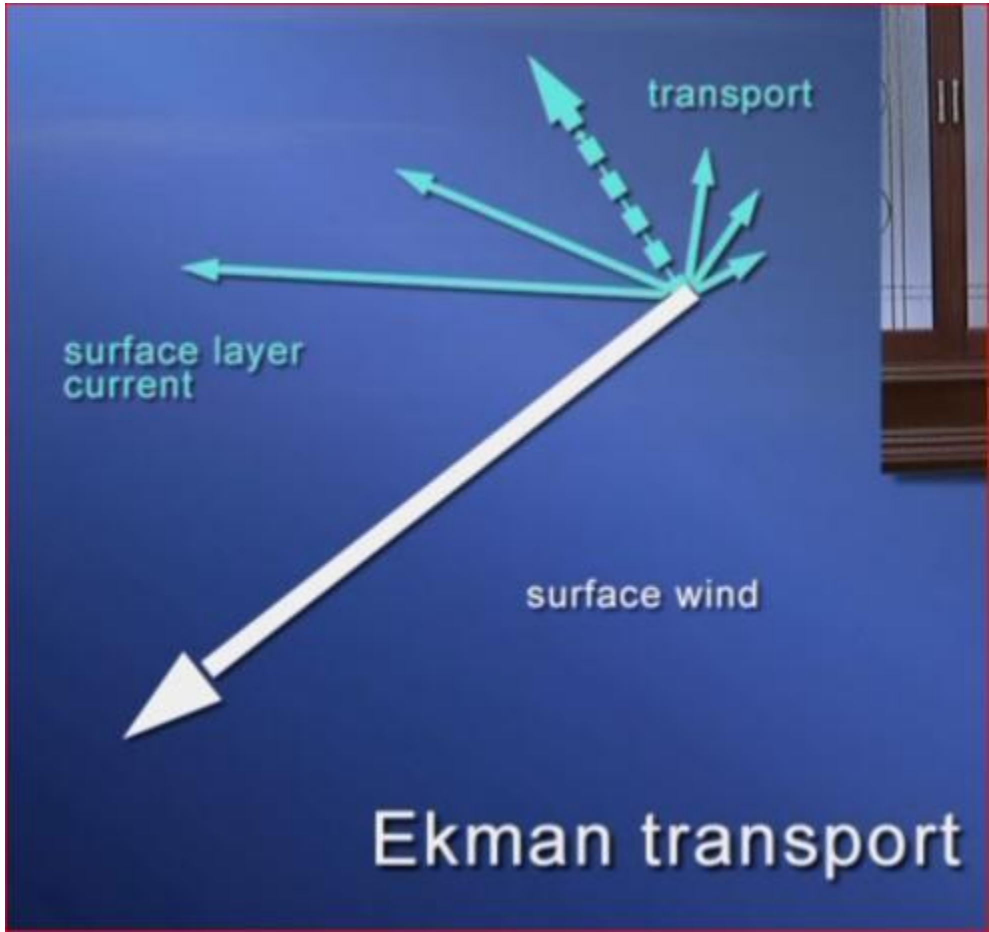




Surface winds vs ocean currents

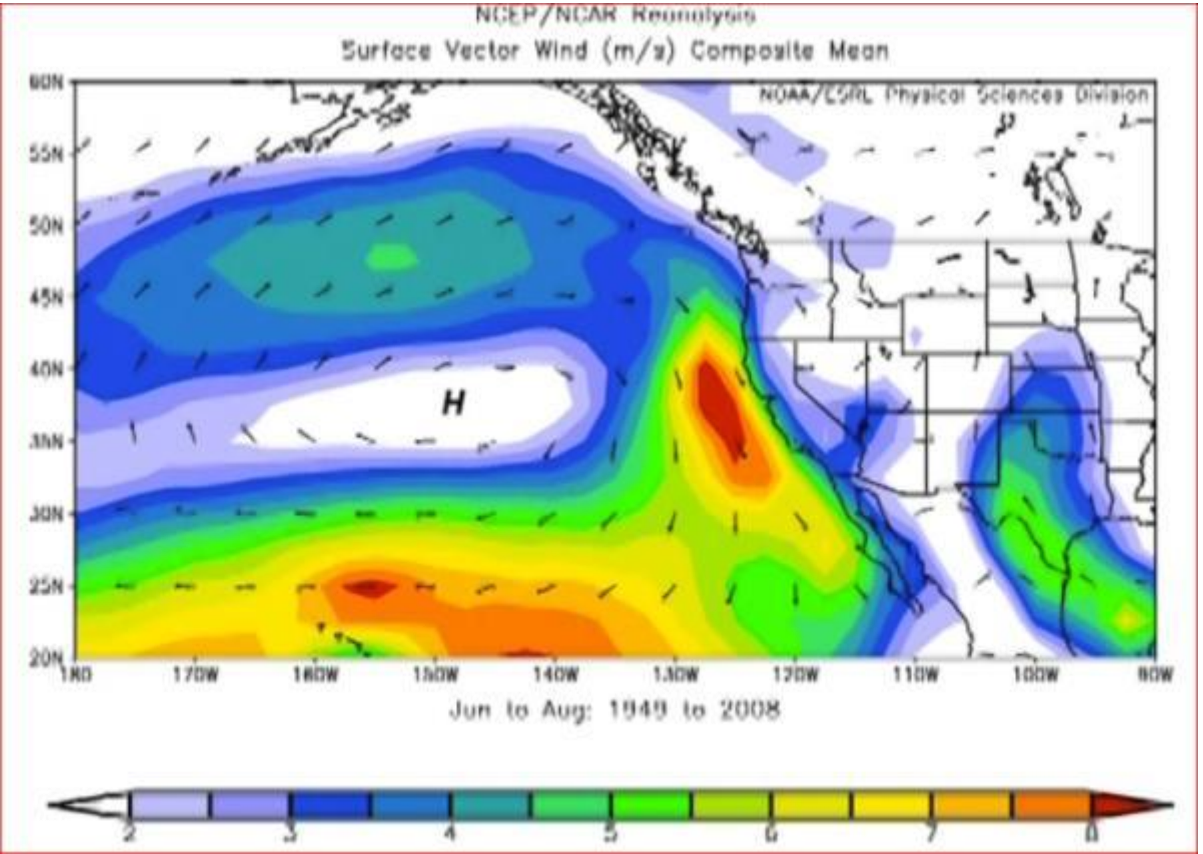
- Coriolis forces ultimately cause a countercurrent about 100m down = Ekman Spiral
- Dashed line shows average flow perpendicular to the wind

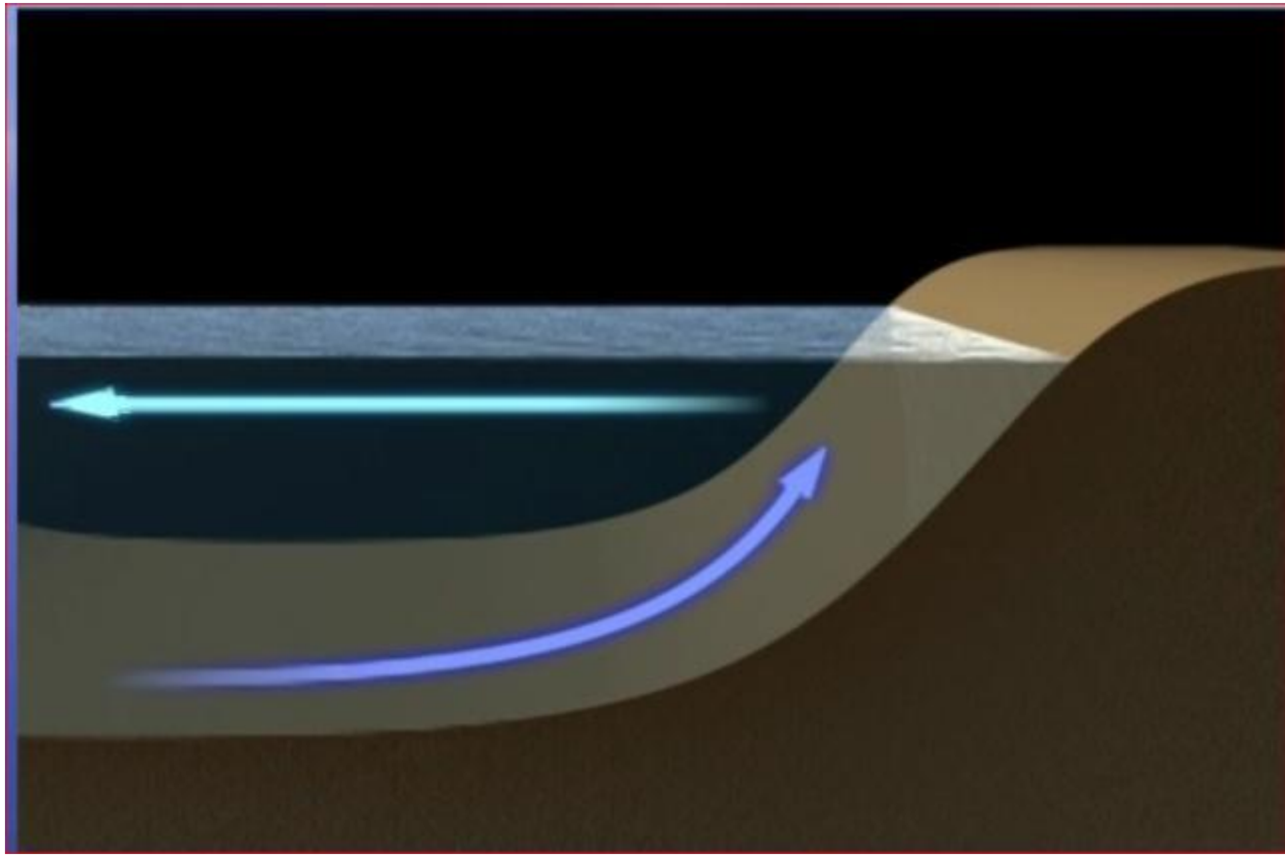




Southerly Surface Winds Cause Westward Surface Current

- Pushes water away from shore – allowing cooler nutrient rich waters to come (upwell) to the surface

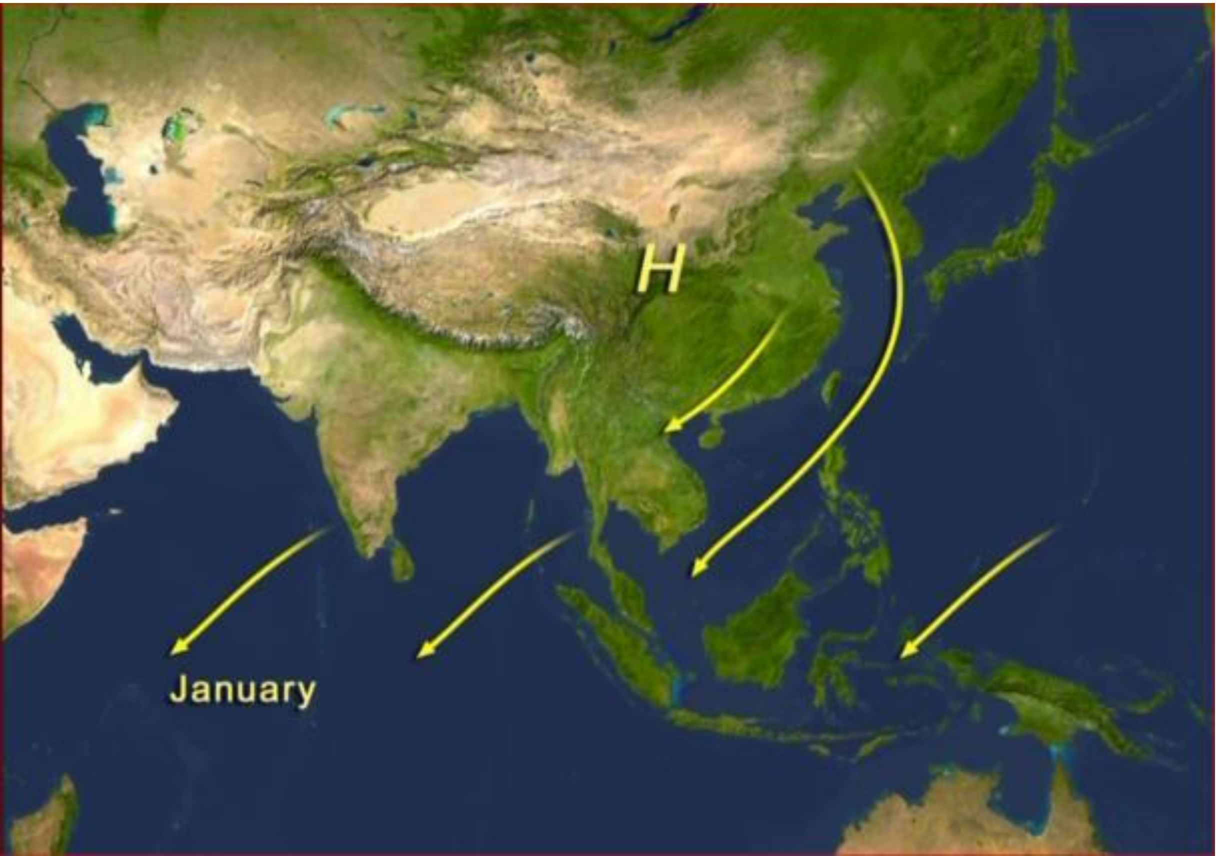




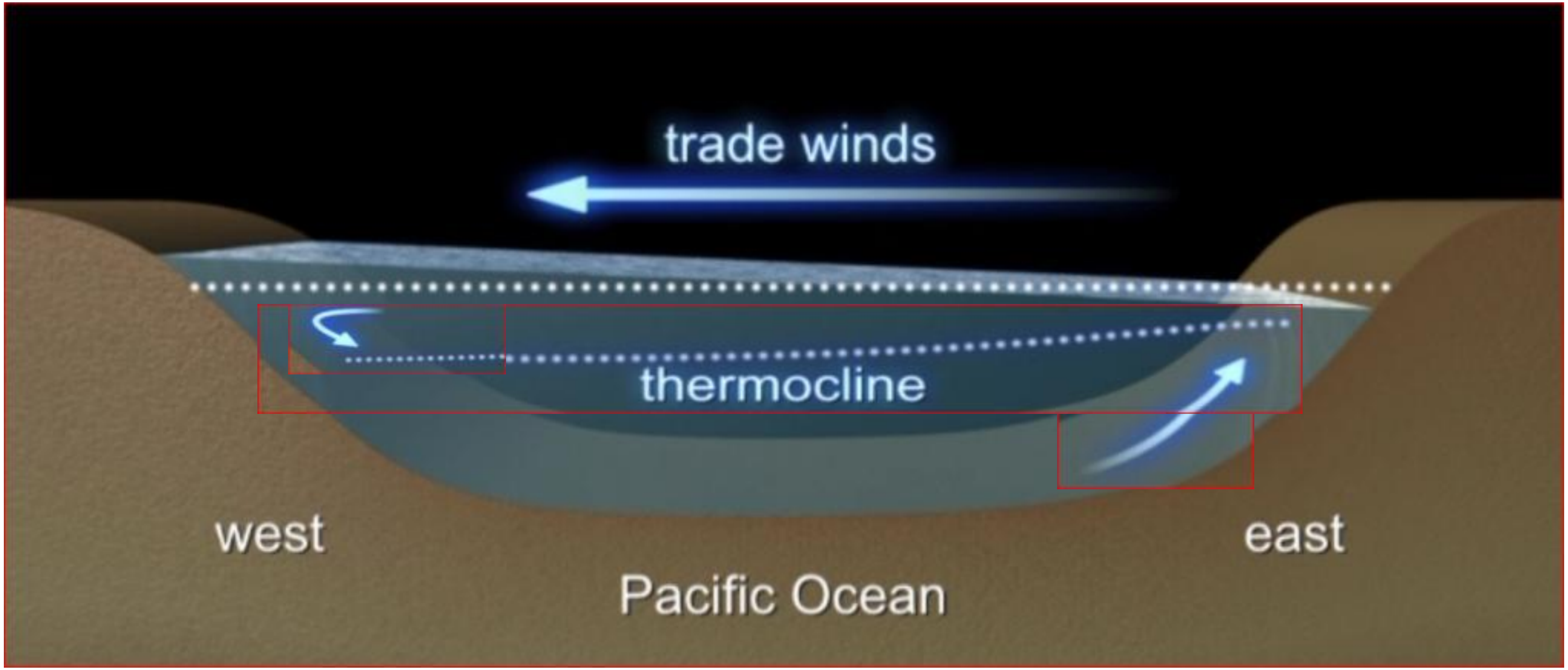
Monsoon winds

https://www.nationalgeographic.org/encyclopedia/monsoon/
https://en.wikipedia.org/wiki/Monsoon

- Seasonal or daily flow as a result of extreme contrasts between land and sea.

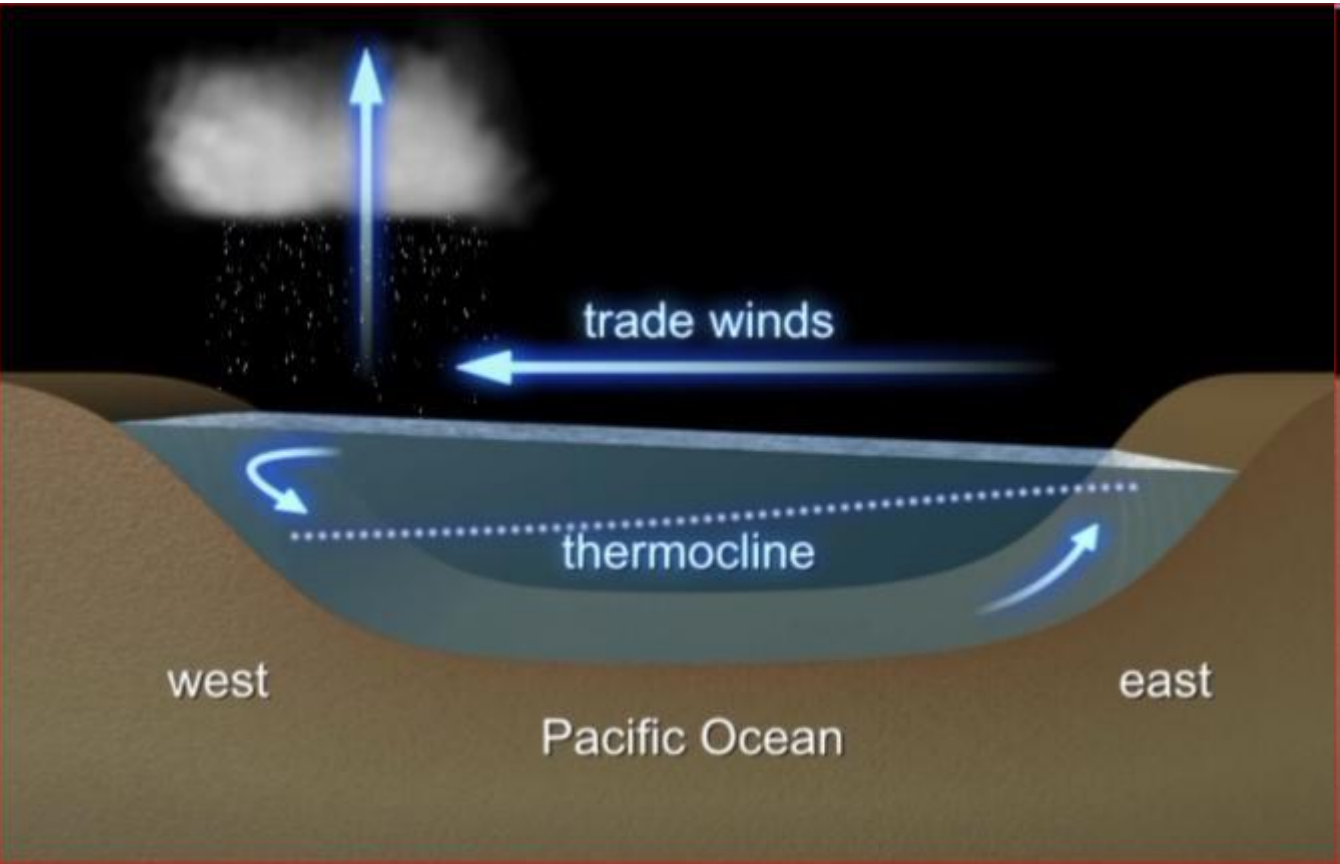


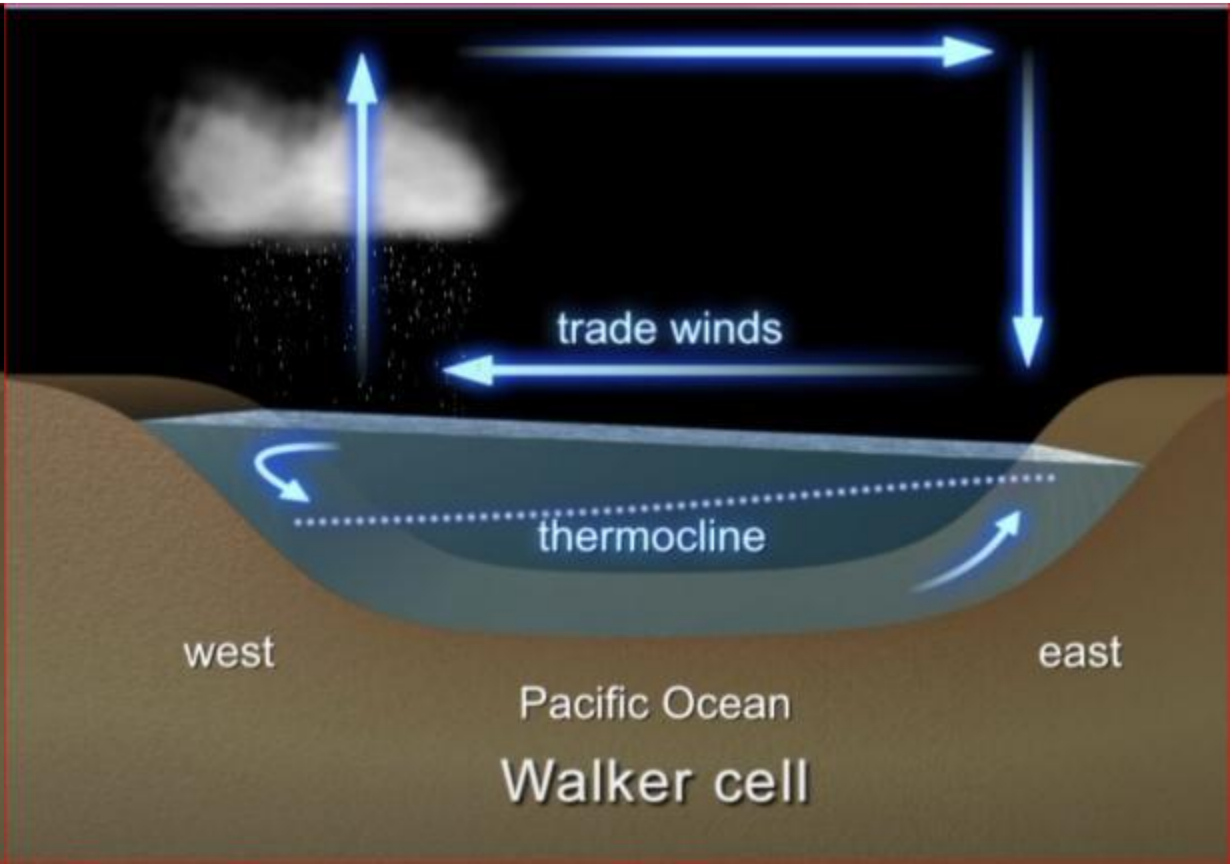
Trade wind effects: 1 – 1.5 meter diff; upwelling in east; thermocline shallows in east and warm waters deepen in west



Southeast Trades Cause Westward Ocean Surface Flow

- Thermocline tipped up to East; Ocean warmer in west. Walker Cell circulates hot air in west to descending air in eastern Pacific
- https://en.wikipedia.org/wiki/El_Ni%C3%B1o#/media/File:ENSO_-_normal.svg





CLIMATE CHANGE INFO REGARDING CHANGES THROUGH TIME

- At 30 degrees latitude, the Himalayas are an important influence on global climate. When insolation is great the monsoons are great in the Himalayas but the melt is also great; in Africa the monsoon is also weaker.
- When insolation is weaker the summer monsoons are weaker, but the ice/glacial build is greater; in Africa the winter monsoons are stronger and the rainfall at the source of the Nile is greater creating more nutrients in the Nile and ultimately the Mediterranean Sea.

Similar Walker cell effect for Somalia and Amazon Forest

https://en.wikipedia.org/wiki/El_Niño–Southern_Oscillation

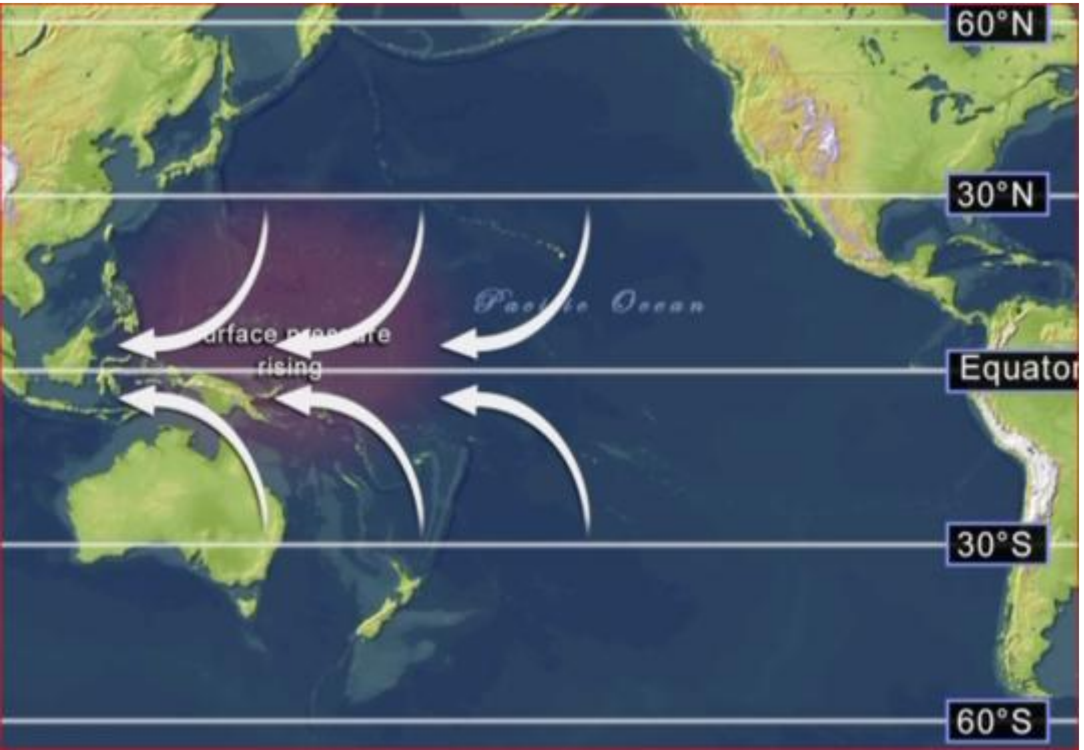
- East – West Pressure Gradients
- Called Southern Oscillation

El Nino (Warm)/ La Ninas (Cold) – opposite extremes

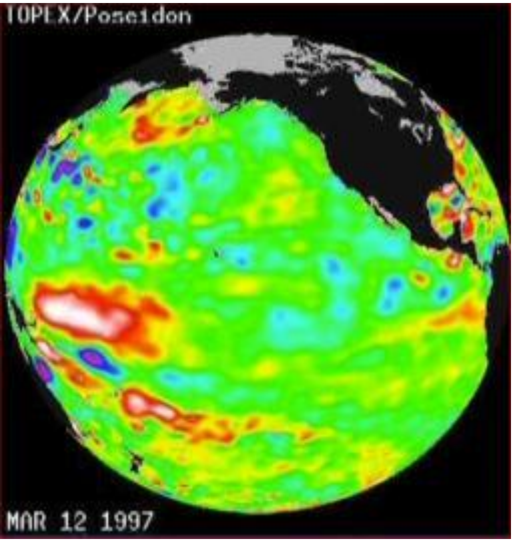
https://en.wikipedia.org/wiki/El_Ni%C3%B1o
https://en.wikipedia.org/wiki/1997%E2%80%9398_El_Ni%C3%B1o_event

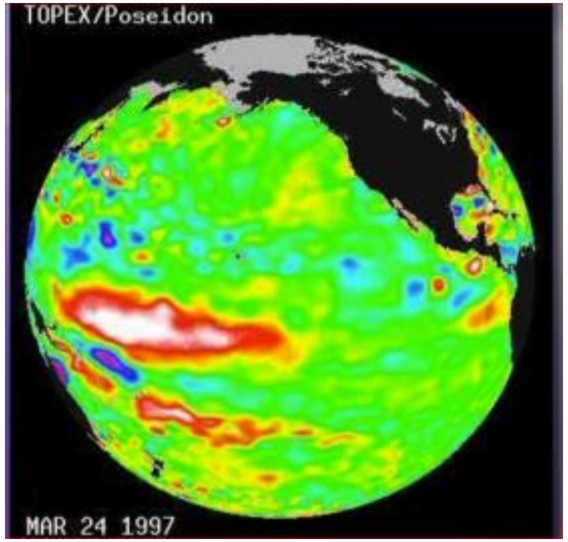
Development of an El Nino

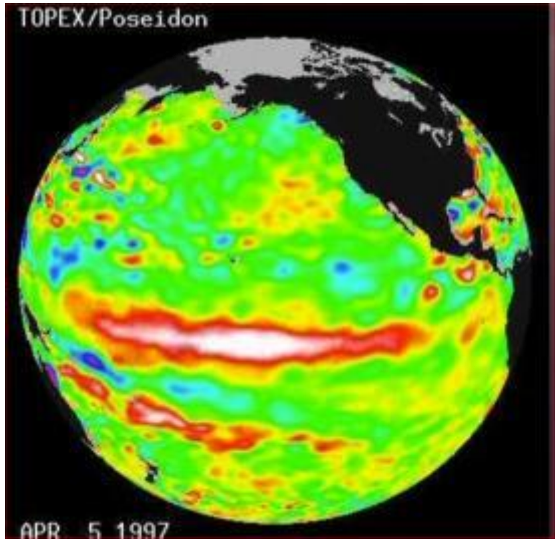
- ~ 3 years before: Surface pressure rises in west Pacific and weakens the trades winds
- Then easterly currents increase leaving east Pacific warm temperatures while drought conditions develop in Indonesia, Philippines and Australia
- Feedback to an effect on development of Atlantic hurricanes

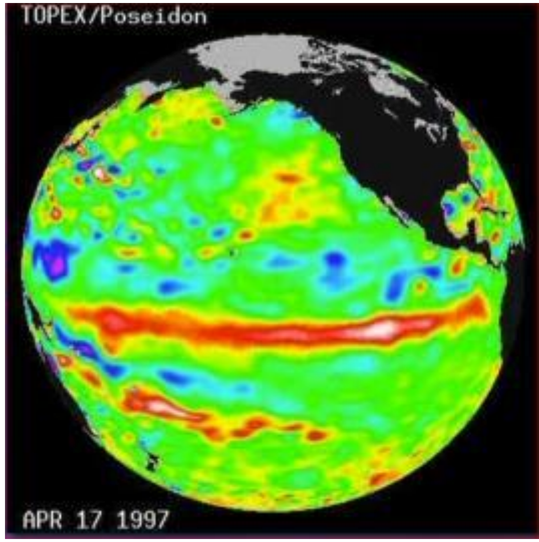


1997-1998 El Nino Development:
12 Day series: 3/12/97, 3/24, 4/5, 4/17

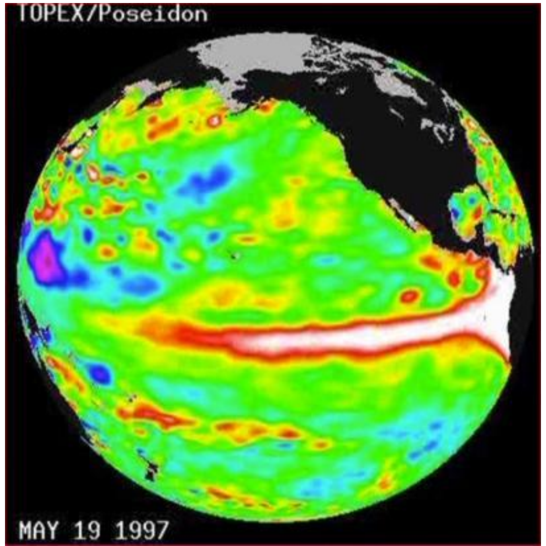








And skipping to 5/19/1997



- 6 years at 6 month intervals:

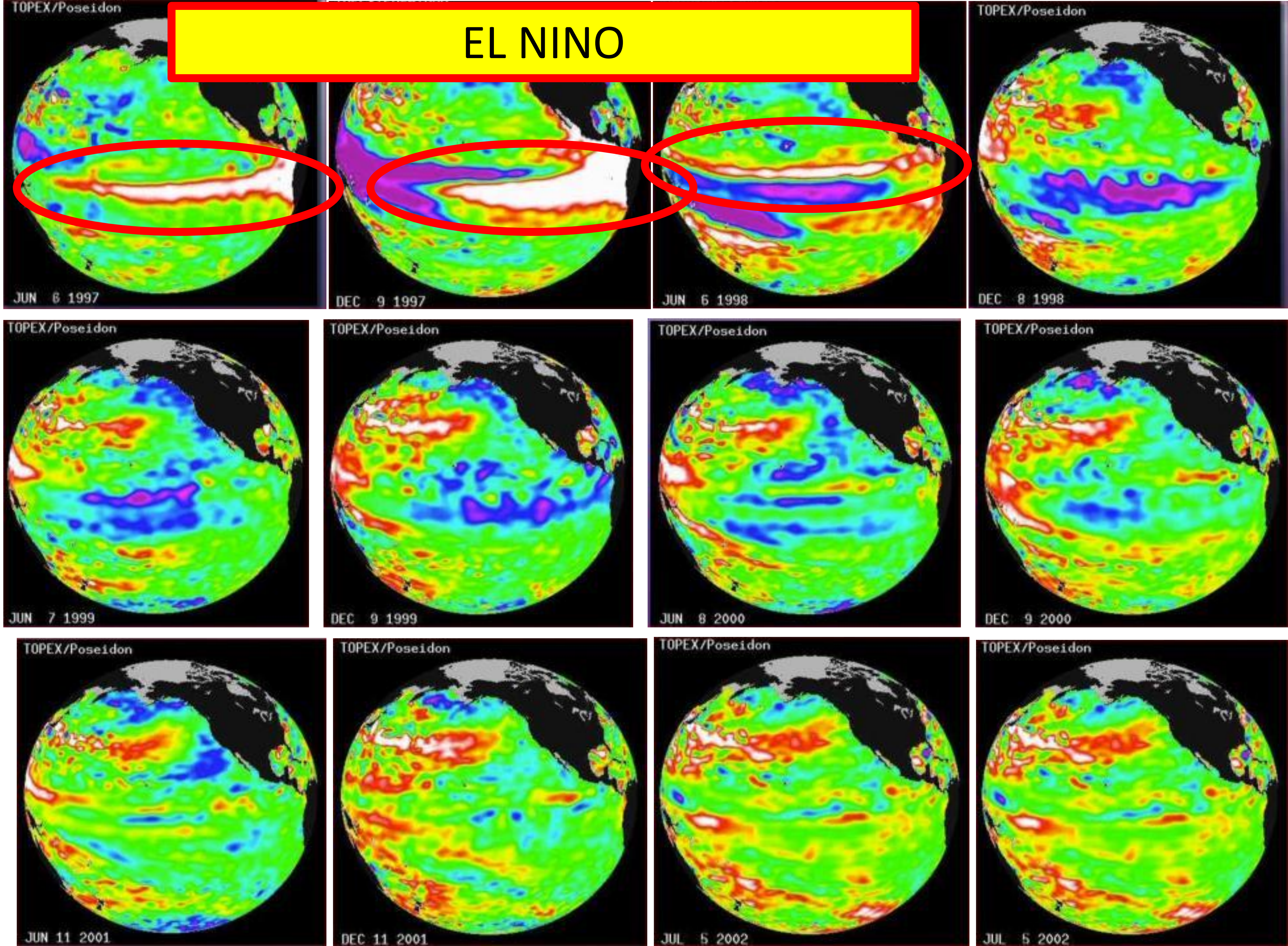
June 1997, 12/97

6/98, 12/98

6/99, 12/99

6/00, 12/00

6/01, 12/02



Physical Oceanography

- **Kelvin waves & Rossby waves**

https://en.wikipedia.org/wiki/Physical_oceanography

Kelvin Waves *Main article: Kelvin wave*

A Kelvin wave is any progressive wave that is channeled between two boundaries or opposing forces (usually between the Coriolis force and a coastline or the equator). There are two types, coastal and equatorial. Kelvin waves are gravity driven and non-dispersive. This means that Kelvin waves can retain their shape and direction over long periods of time. They are usually created by a sudden shift in the wind, such as the change of the trade winds at the beginning of the El Niño-Southern Oscillation.

Coastal Kelvin waves follow shorelines and will always propagate in a counterclockwise direction in the Northern hemisphere (with the shoreline to the right of the direction of travel) and clockwise in the Southern hemisphere.

Equatorial Kelvin waves propagate to the east in the Northern and Southern hemispheres, using the equator as a guide.

Kelvin waves are known to have very high speeds, typically around 2–3 meters per second. They have wavelengths of thousands of kilometers and amplitudes in the tens of meters.

Rossby Waves *Main article: Rossby wave*

Rossby waves, or planetary waves are huge, slow waves generated in the troposphere by temperature differences between the ocean and the continents. Their major restoring force is the change in Coriolis force with latitude. Their wave amplitudes are usually in the tens of meters and very large wavelengths. They are usually found at low or mid latitudes.

There are two types of Rossby waves, barotropic and baroclinic. Barotropic Rossby waves have the highest speeds and do not vary vertically. Baroclinic Rossby waves are much slower.

The special identifying feature of Rossby waves is that the phase velocity of each individual wave always has a westward component, but the group velocity can be in any direction. Usually the shorter Rossby waves have an eastward group velocity and the longer ones have a westward group velocity.

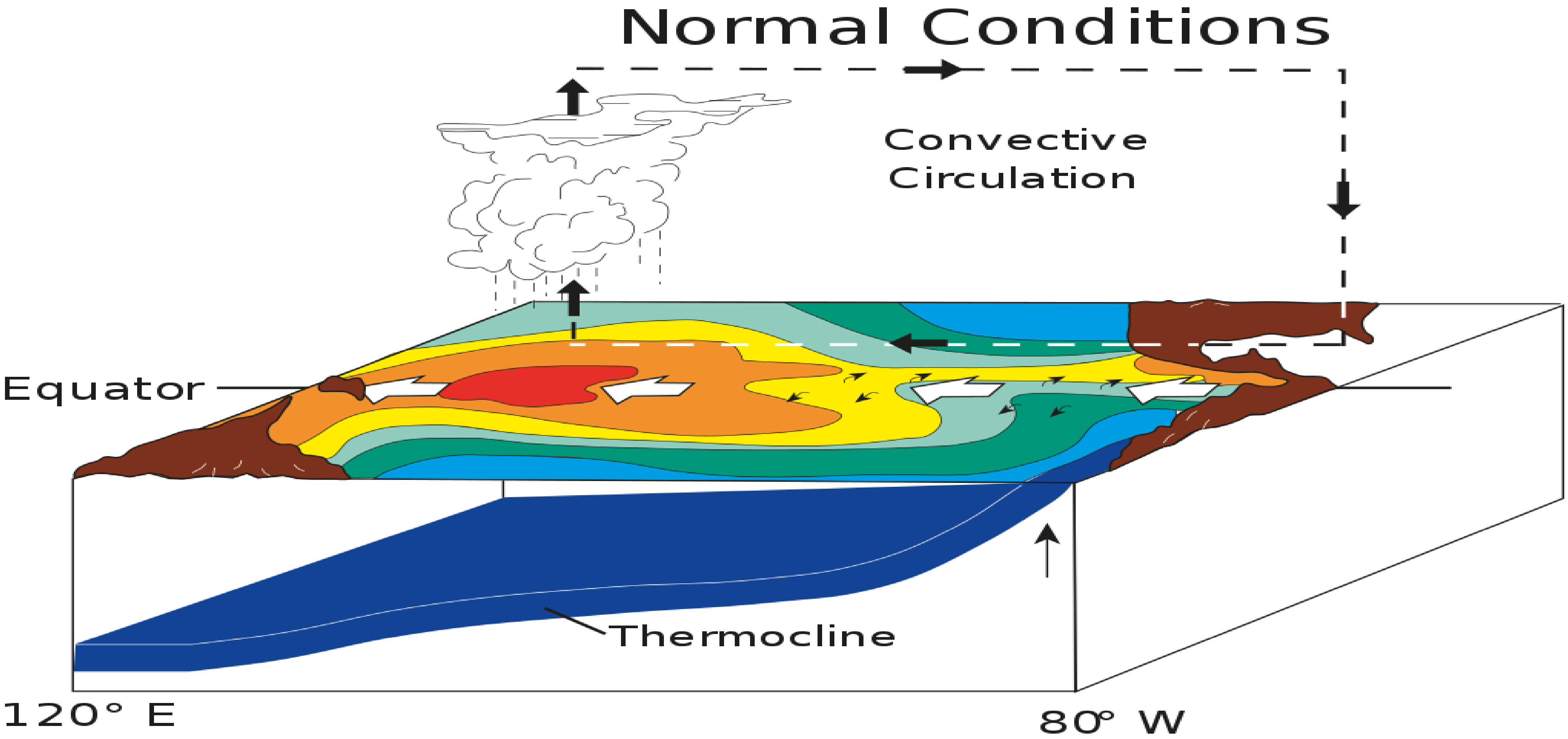
Thermohaline circulation: circulation caused by temperature and salinity changes

- "CONVEYOR BELT"
- 1600 YEAR TURNOVER

- **"CONVEYOR BELT"**
- **1600 YEAR TURNOVER**

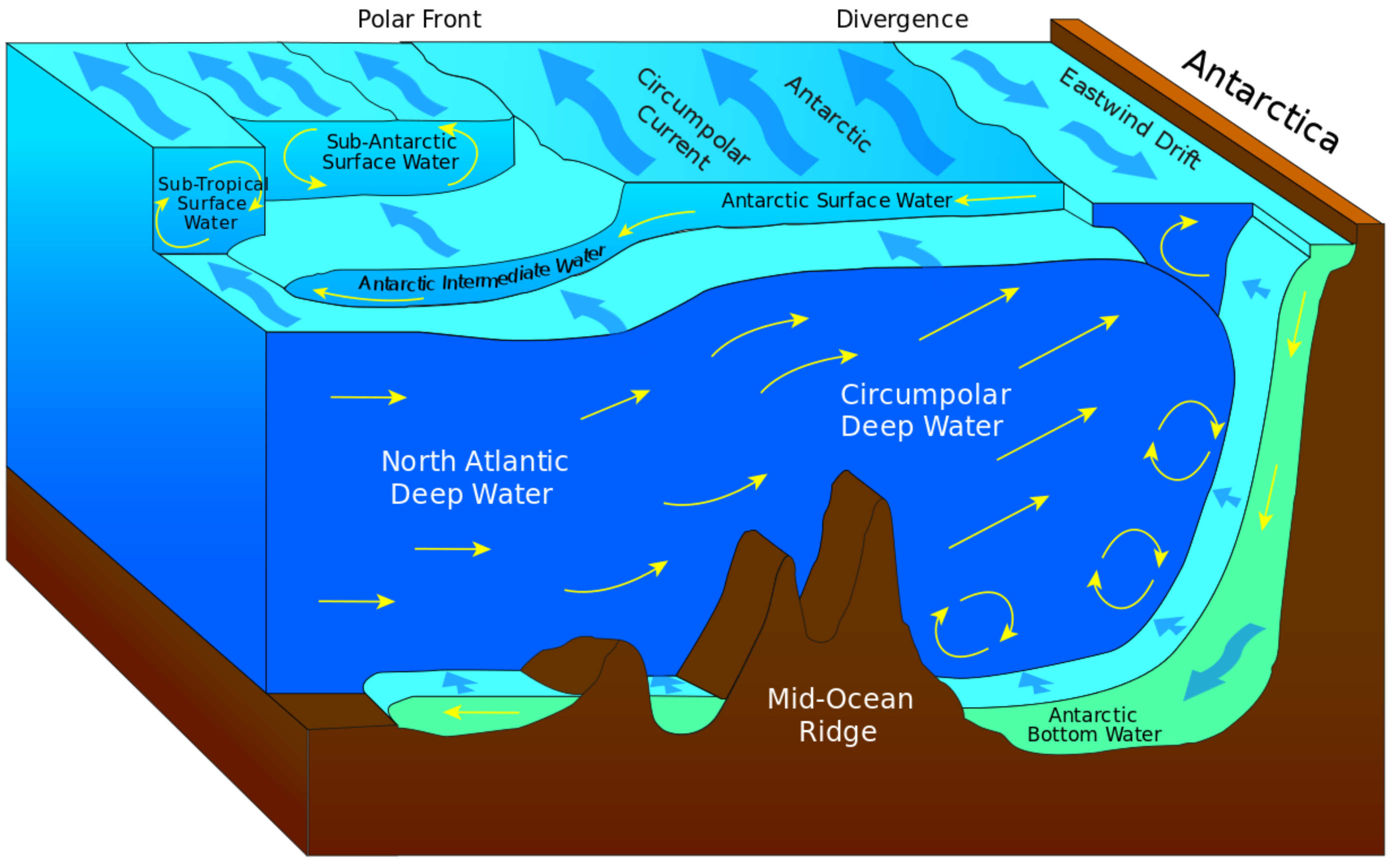
Normal Pacific pattern: Warm pool in the west drives deep atmospheric convection. Local winds cause nutrient-rich cold water to upwell along the South American coast. (NOAA / PMEL / TAO)

- https://en.wikipedia.org/wiki/El_Ni%C3%B1o#/media/File:ENSO_-_normal.svg



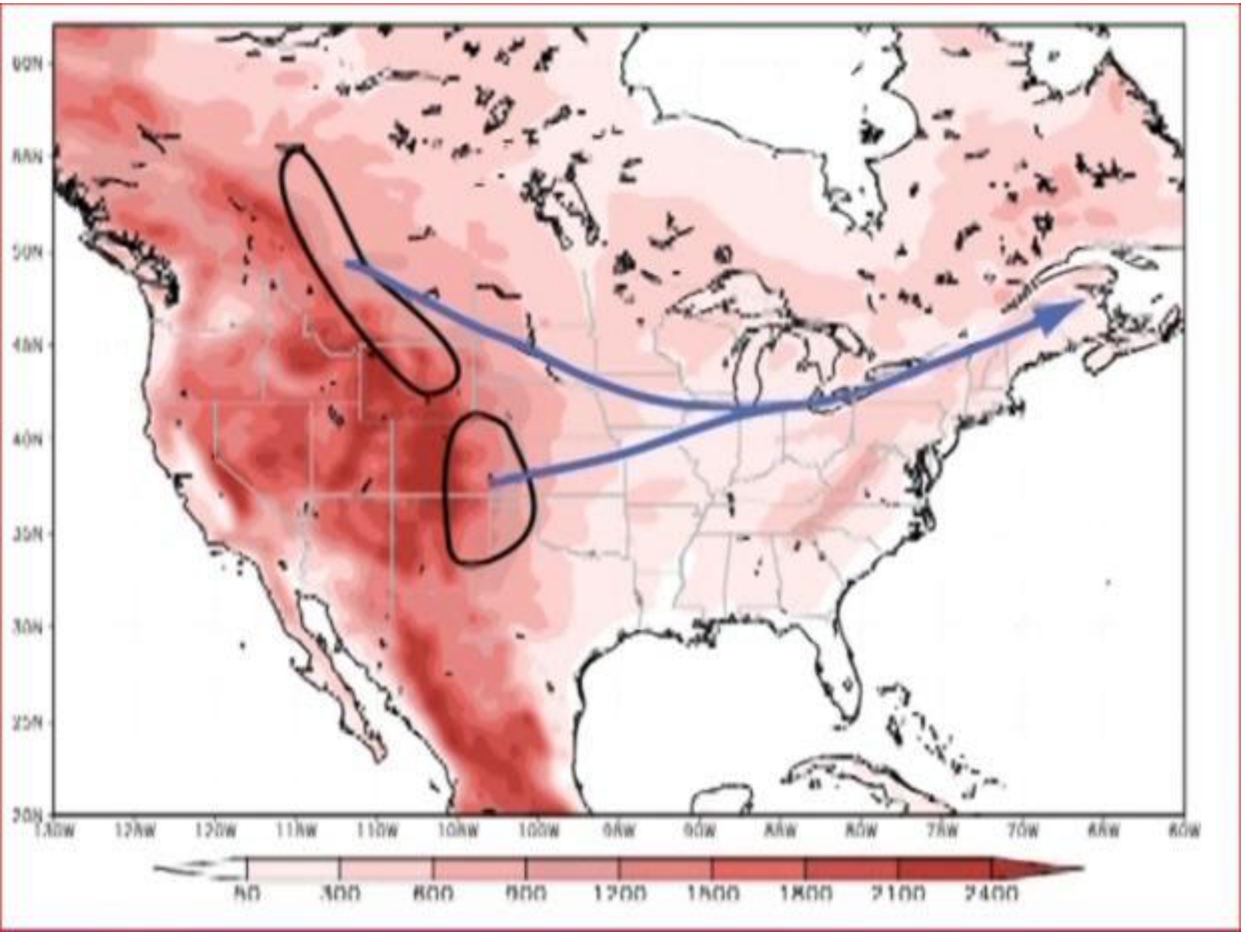
Antarctic Bottom Water and the Complexities of Ocean Circulation

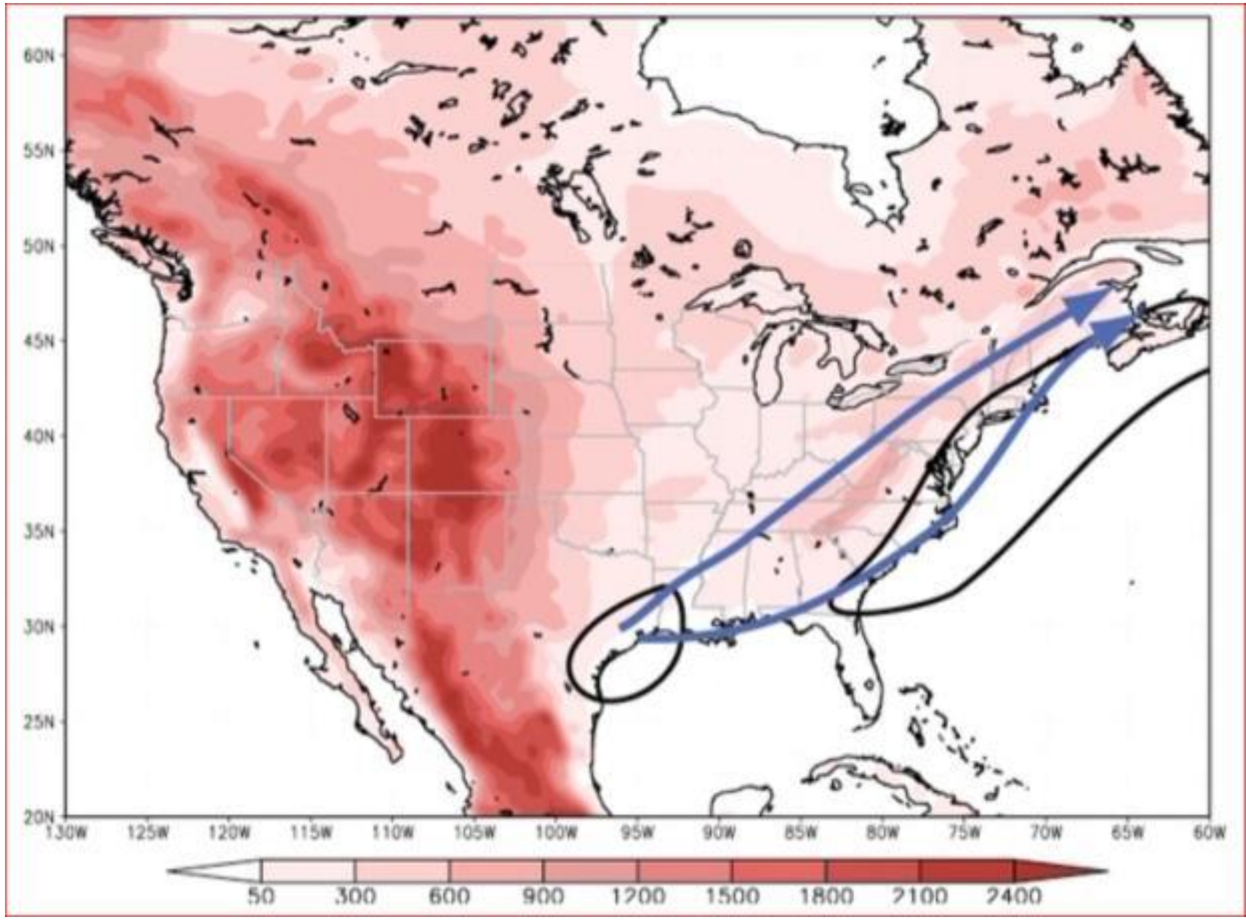
By Fred the Oyster, CC BY-SA 4.0,
https://commons.wikimedia.org/w/index.php?curid=35204554



Extratropical cyclones: 2 areas of development discussed

- They favor development along fronts





Summary

Eckman Spiral - https://en.wikipedia.org/wiki/Ekman_spiral

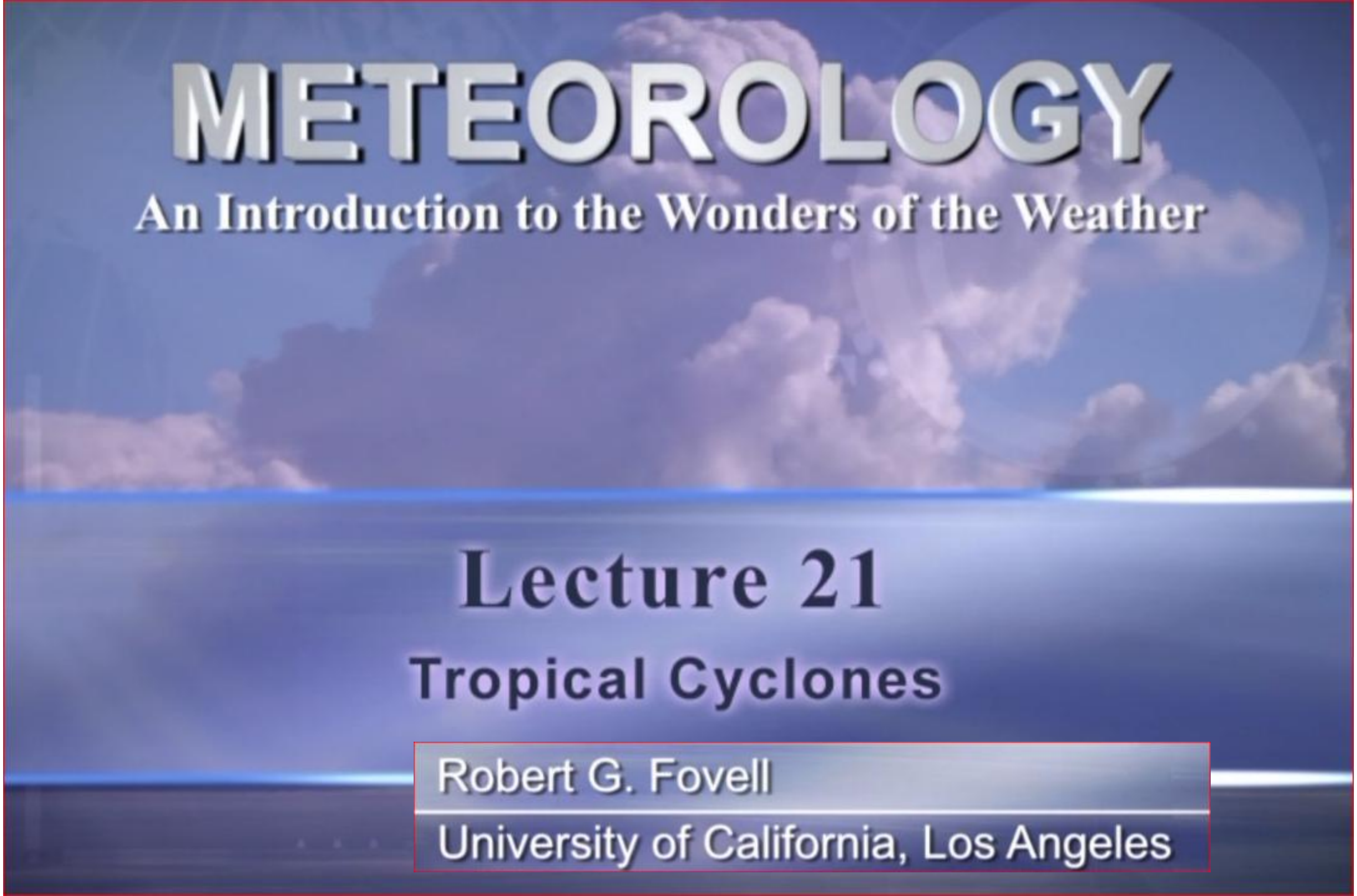
Walker Cell - https://en.wikipedia.org/wiki/Walker_circulation

Milankovitch Cycle -https://en.wikipedia.org/wiki/Milankovitch_cycles

- Ocean Circulation
- Winds & Coriolis on ocean
- 10 m = + 1 atmosphere
- Thermocline – varies, upwelling close to surface and deeper
- Clockwise circulation in Northern atmosphere
- Water flows 90 degrees to winds – Eckman circulation
- Walker circulation
- Thermohaline circulation takes hundreds of years
- If Gulf stream diverted – what would happen
- Influence of insolation on ocean circulation – Orbital parameters – aka Milankovitch cycles: Precession~20 Kyrs, Obliquity/Tilt ~41Kyrs and Eccentricity ~100Kyrs

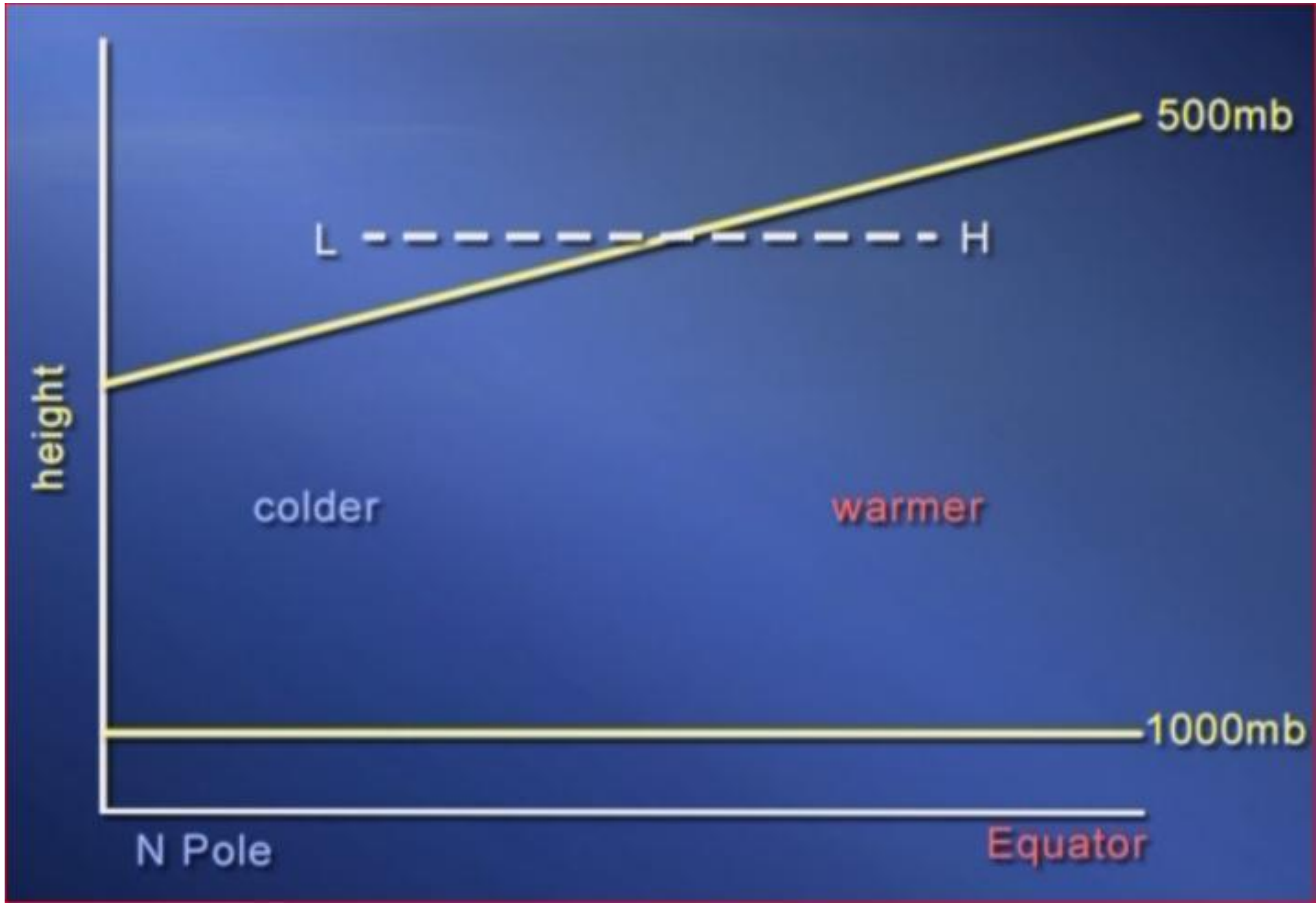
Looking ahead

- Influence of Tropical Cyclones – next lecture


METEOROLOGY
An Introduction to the Wonders of the Weather
Lecture 21
Tropical Cyclones
Robert G. Fovell
University of California, Los Angeles

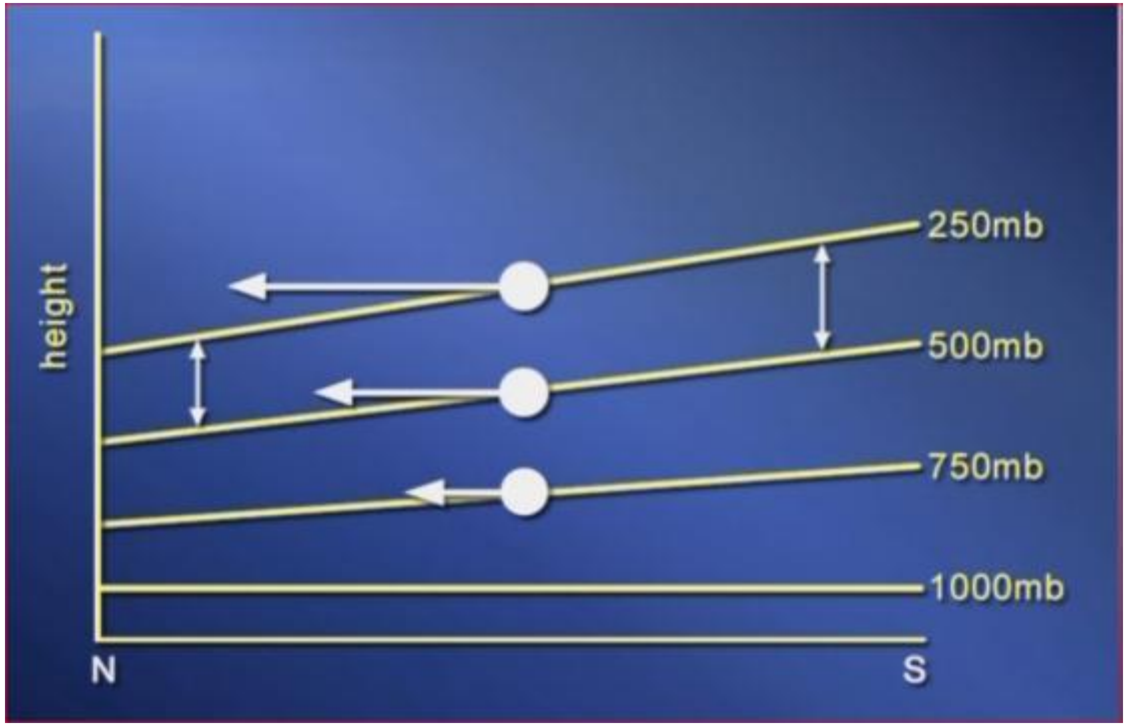
Previously Reviewed Life Cycle of the Extratropical cyclone

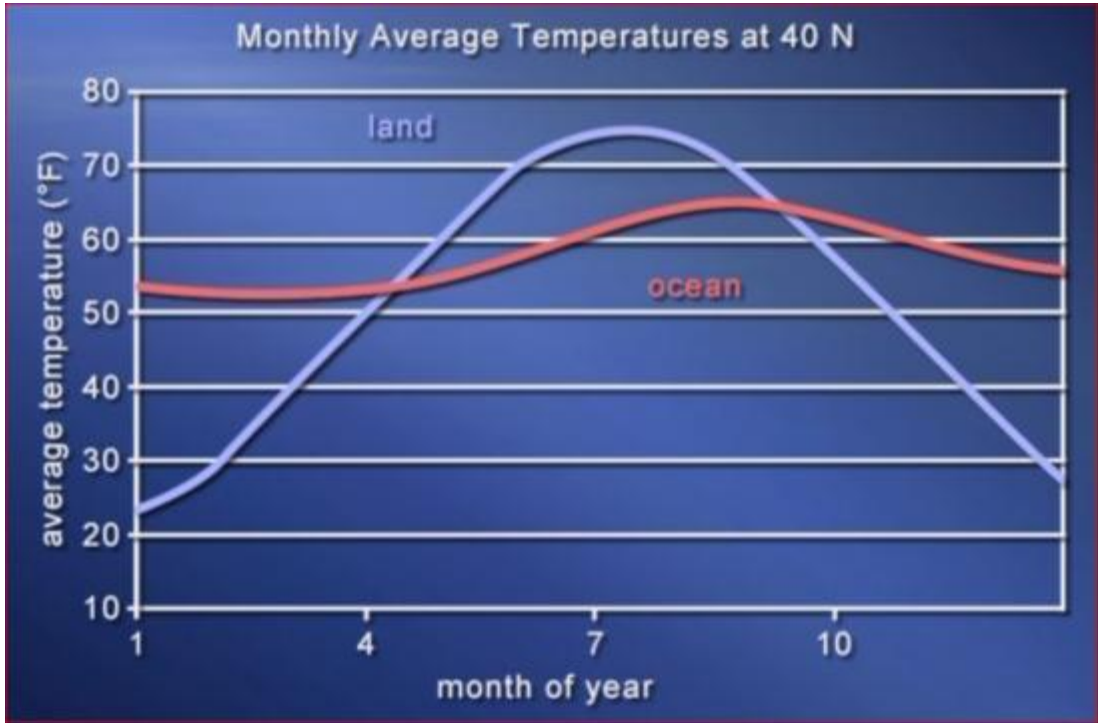
- A mid-latitude phenomena connected to fronts and fueled by horizontal pressure and temperature gradients and intensified by sources of spin and upper level diversion (positive vorticity advection and warm advection)
- The thickness between 2 isobaric pressures reflect the temperature differences



Also reviewed:

- Horizontal temperature gradients
- Oceanic Influences by latitude, season and that there is notable lag





Tropical Cyclones (TC)

tropical cyclones (TC)
hurricanes
typhoons

- More circular than extratropical cyclone
- Low pressure
- Nevertheless counterclockwise winds in N. Hemisphere
- Different – doesn’t have a lot of vertical wind shear
- Tropical cyclones need the ocean for sources of energy

gradient wind balance
pressure gradient,
Coriolis, centripetal forces

Wind speeds decrease with height in the fully formed tropical cyclone—the opposite of what we typically find in midlatitude cyclones.

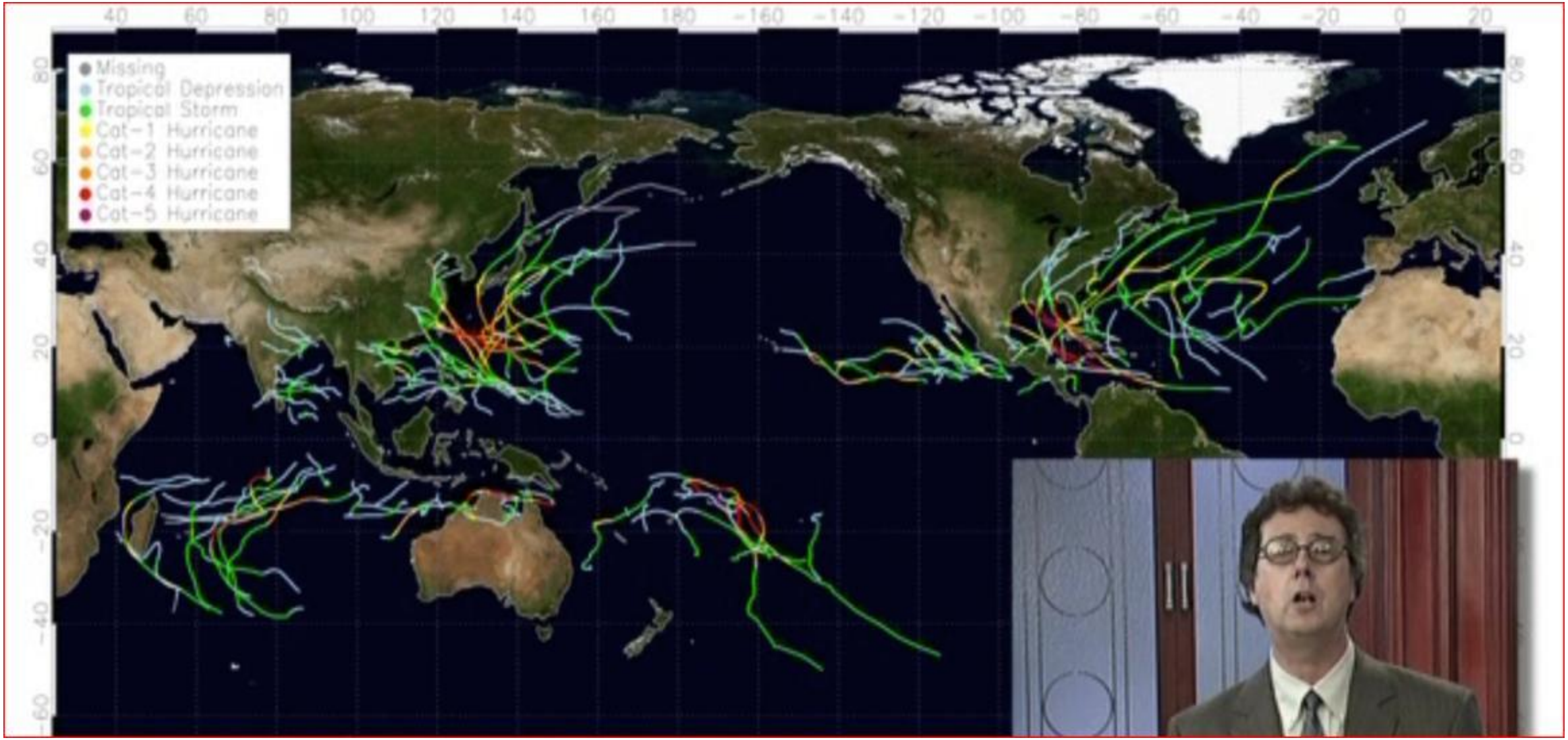
Tropical Cyclones

- Atlantic and Eastern Pacific: called Hurricanes
  - Note they curve to NE in Atlantic and elsewhere but NOT in eastern Pacific where they encounter cold water from the California current
- Western Pacific: called Typhoons
- Indian ocean: called Cyclones

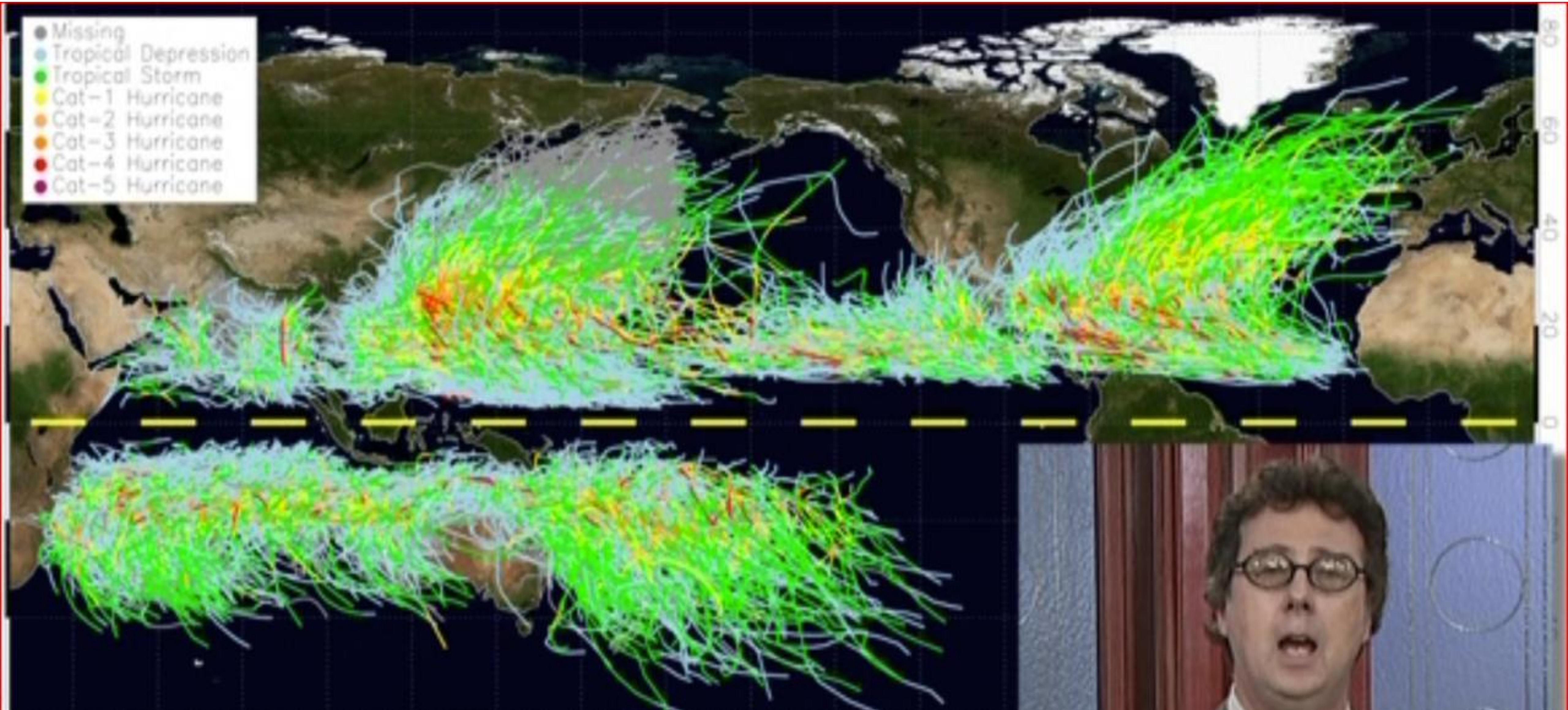
When, Where and How Hurricanes form

- Ocean Surface Temperature: > 26^{o} C 79^{o}F – summer and fall
- High vapor pressure of warm water makes atmosphere moist and unstable – latent heat of water condensation drives cyclones

Worldwide tracks of TCs in 2005



TCs for 61 years: 1947-2007, by intensity



What explains the absence of tropical cyclones near the equator?

- **Tropical cyclones** are not formed in +/- 5 degree N-S area **near equator** due to **absence** of Coriolis Force.
- But away from the equator, Coriolis force is responsible for the formation of a wind system over oceans, since trade winds get deflected due to this force in both the hemispheres.

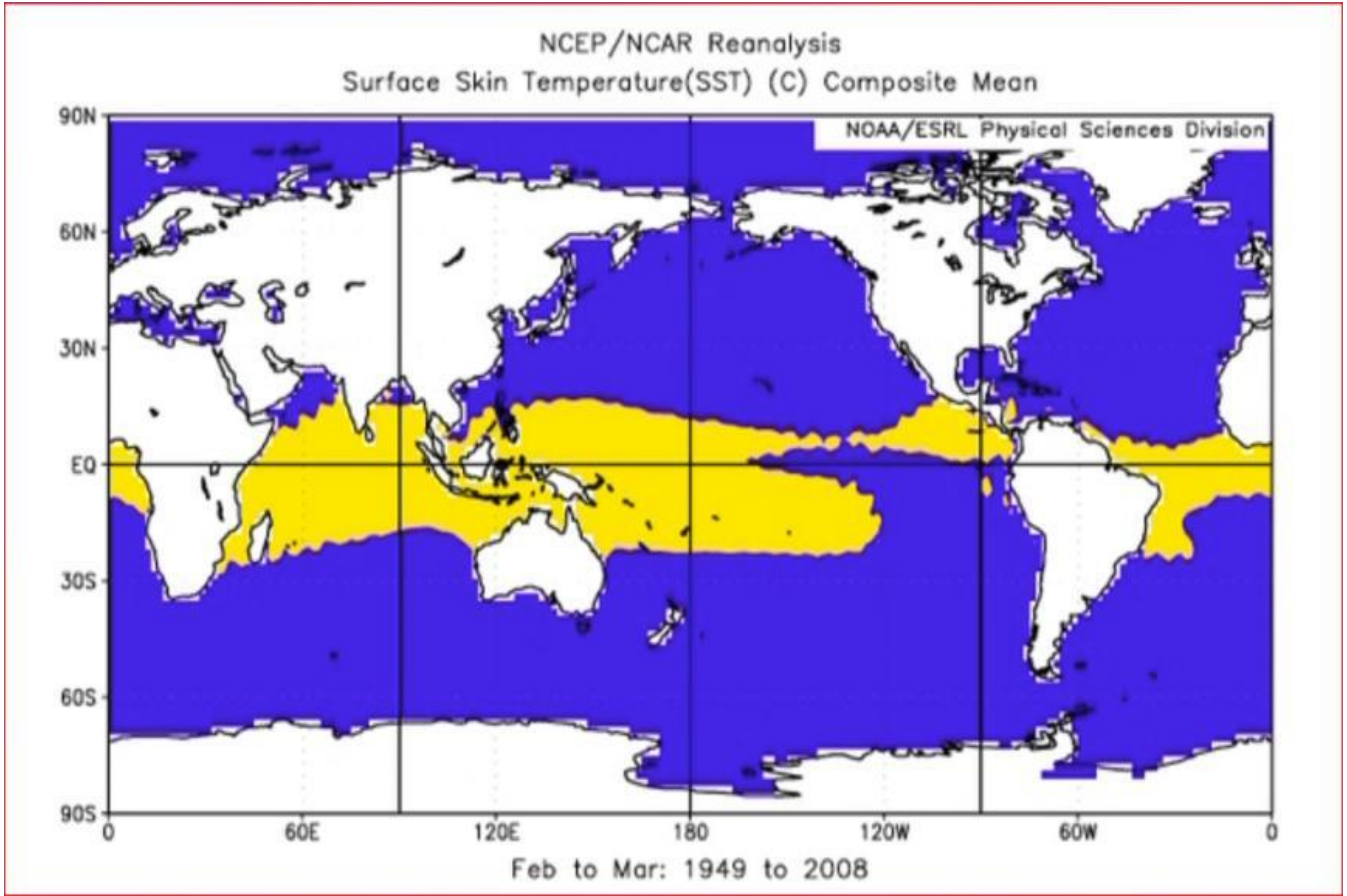
Saffir-Simpson Hurricane Scale

- U.S.: Sustained winds = 1 minute average
- Other areas: 10 minute average

Saffir–Simpson Hurricane Scale

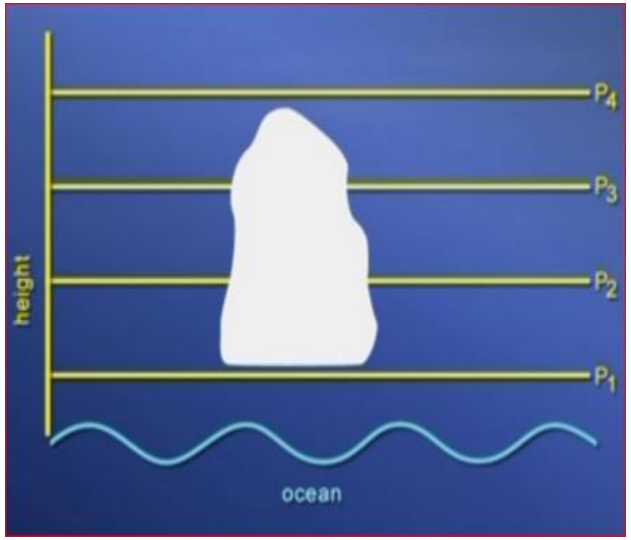
Category	Wind Speed mph (km/h)	Storm Surge ft (m)
5	≥ 156 (≥ 250)	> 18 (> 5.5)
4	131 – 155 (210 – 249)	13 – 18 (4.0 – 5.5)
3	111 – 130 (178 – 209)	9 – 12 (2.7 – 3.7)
2	96 – 110 (154 – 177)	6 – 8 (1.8 – 2.4)
1	74 – 95 (119 – 153)	4 – 5 (1.2 – 1.5)
Additional Classifications		
tropical storm	39 – 73 (63 – 117)	0 – 3 (0 – 0.9)
tropical depression	0 – 38 (0 – 62)	0 (0)

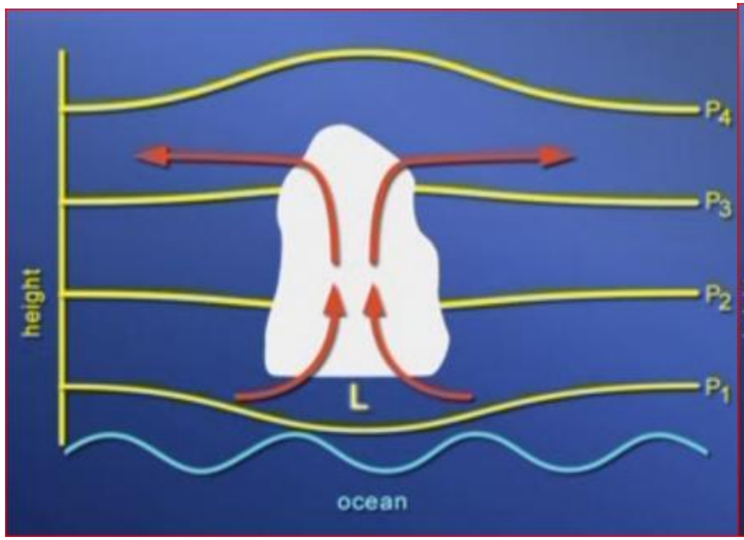
Ocean surface is insufficiently warm in SE Pacific and South Atlantic to have TC development

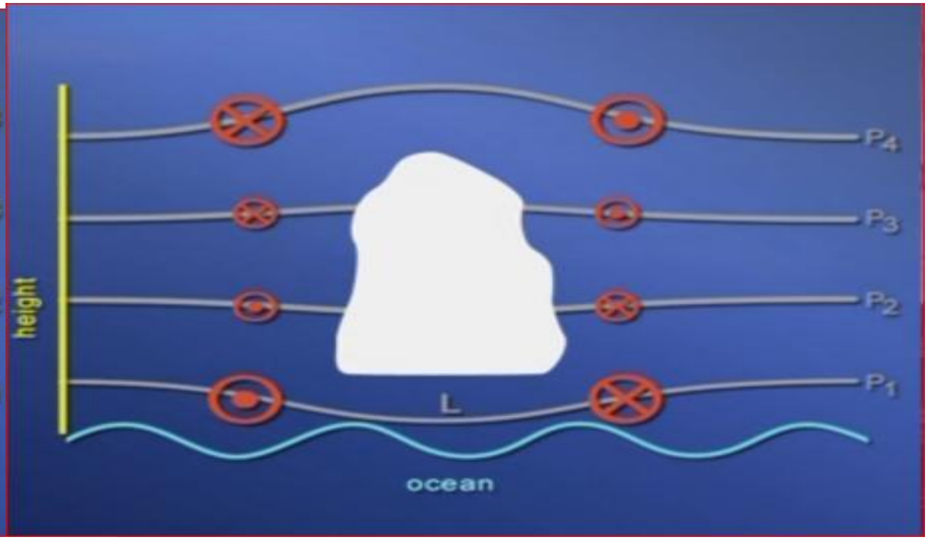


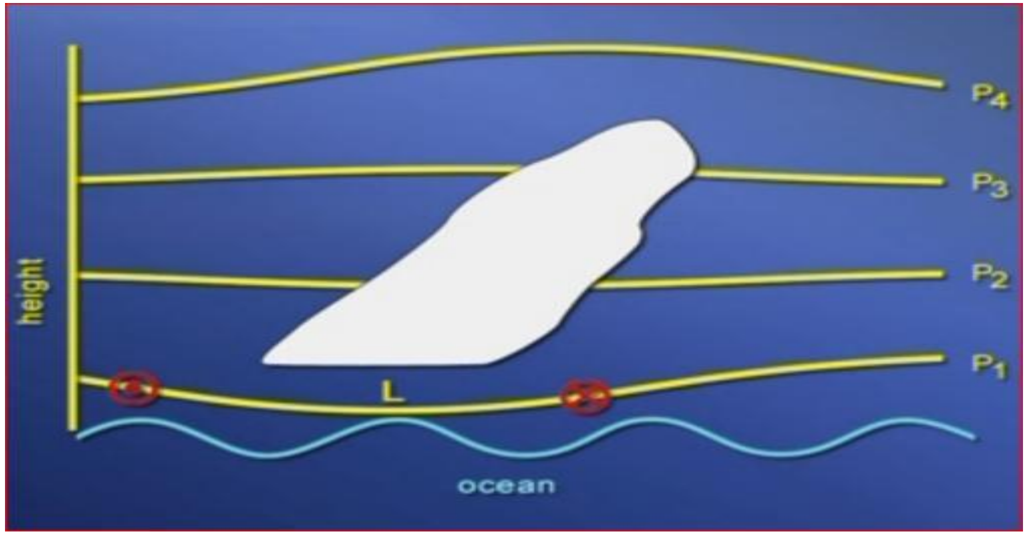
Why vertical shear is bad for TCs

- Note the decrease in deflection of pressure with height indicating wind speeds decrease with height
- But higher up the deflection of the isobar is up and means the winds have reversed
- Vertical shear distorts and weakens hurricanes to the point where they fizzle out; this is affected by El Nino



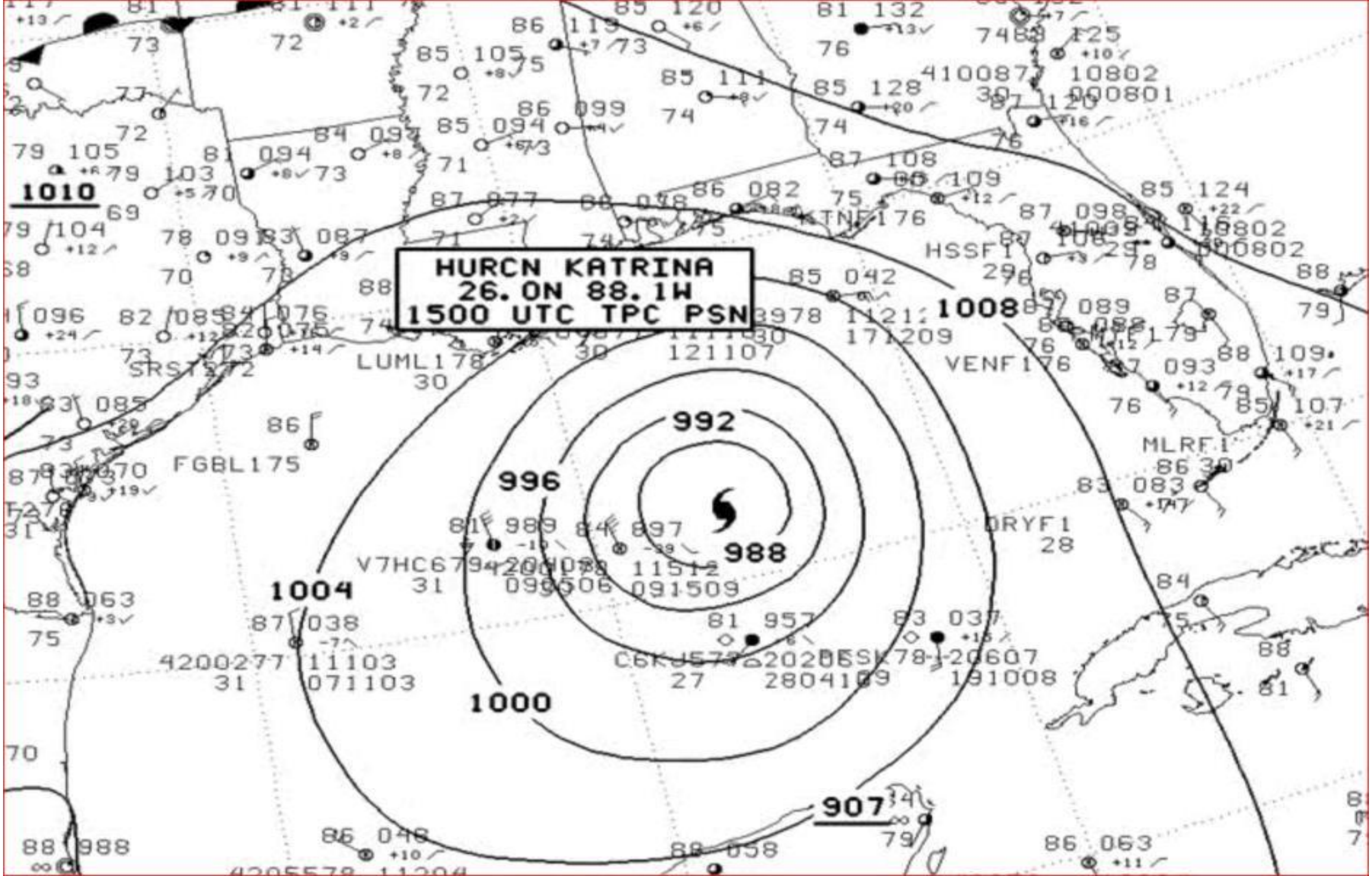






Katrina – 907 mb minimum pressure in Eye

https://en.wikipedia.org/wiki/Hurricane_Katrina



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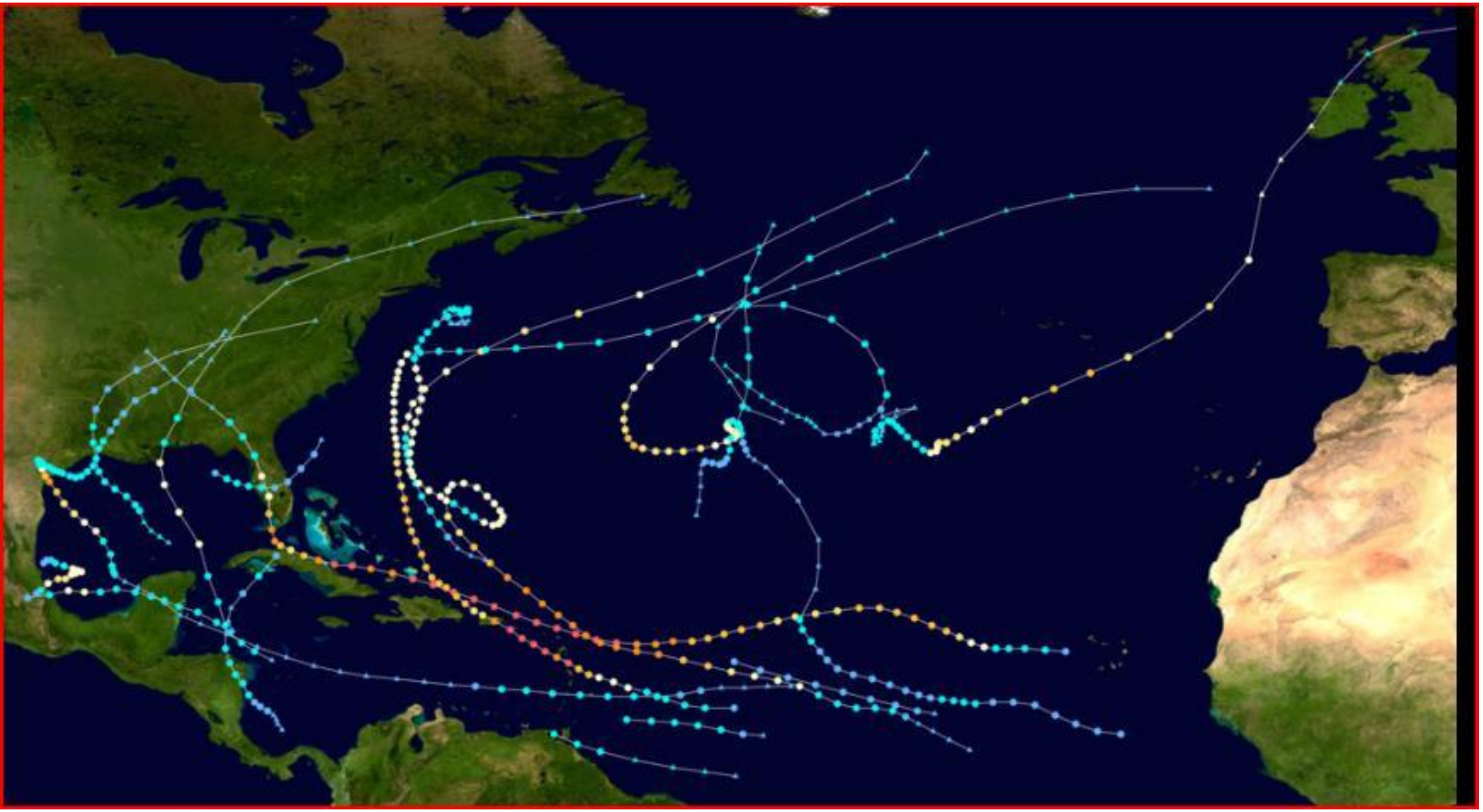
VENF1
MLRF1
DRYF1

2017 Hurricane season tracks

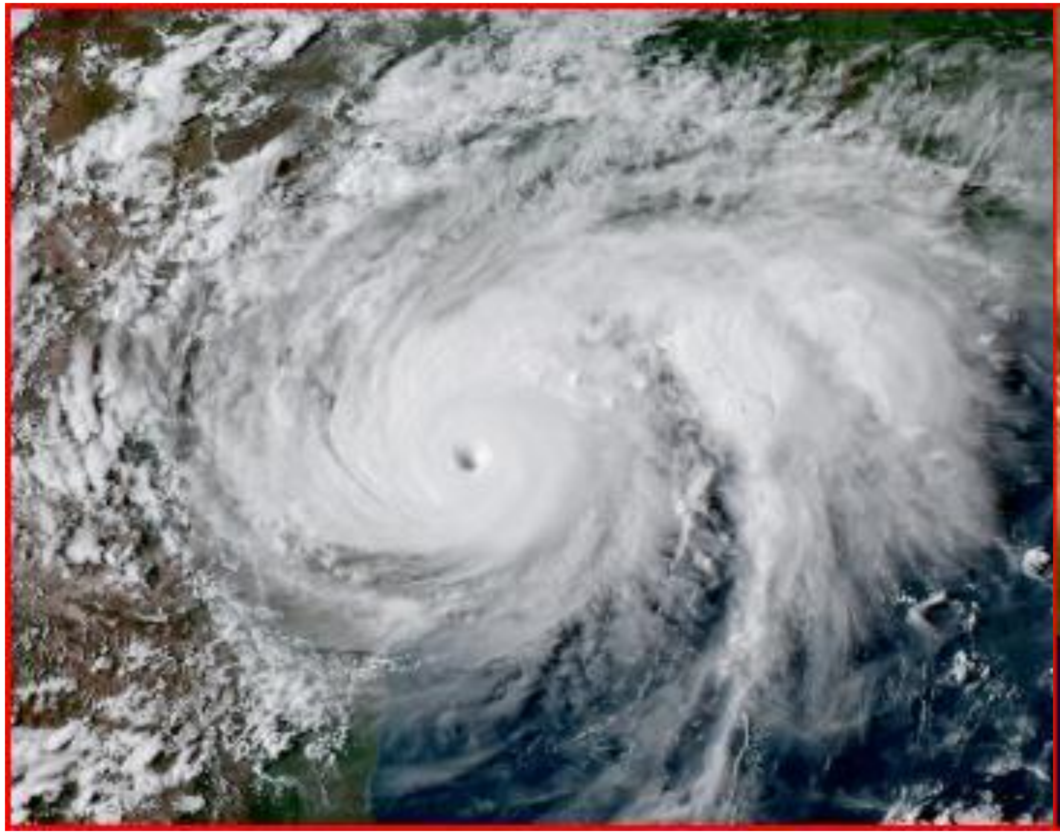


https://en.wikipedia.org/wiki/2017_Atlantic_hurricane_season

2017 Hurricane season

Three simultaneous hurricanes active on September 8, with Katia *(left)*, Irma *(center)*, and Jose *(right)*, the first such occurrence since 2010. All three were threatening land at the time.

Hurricane Harvey

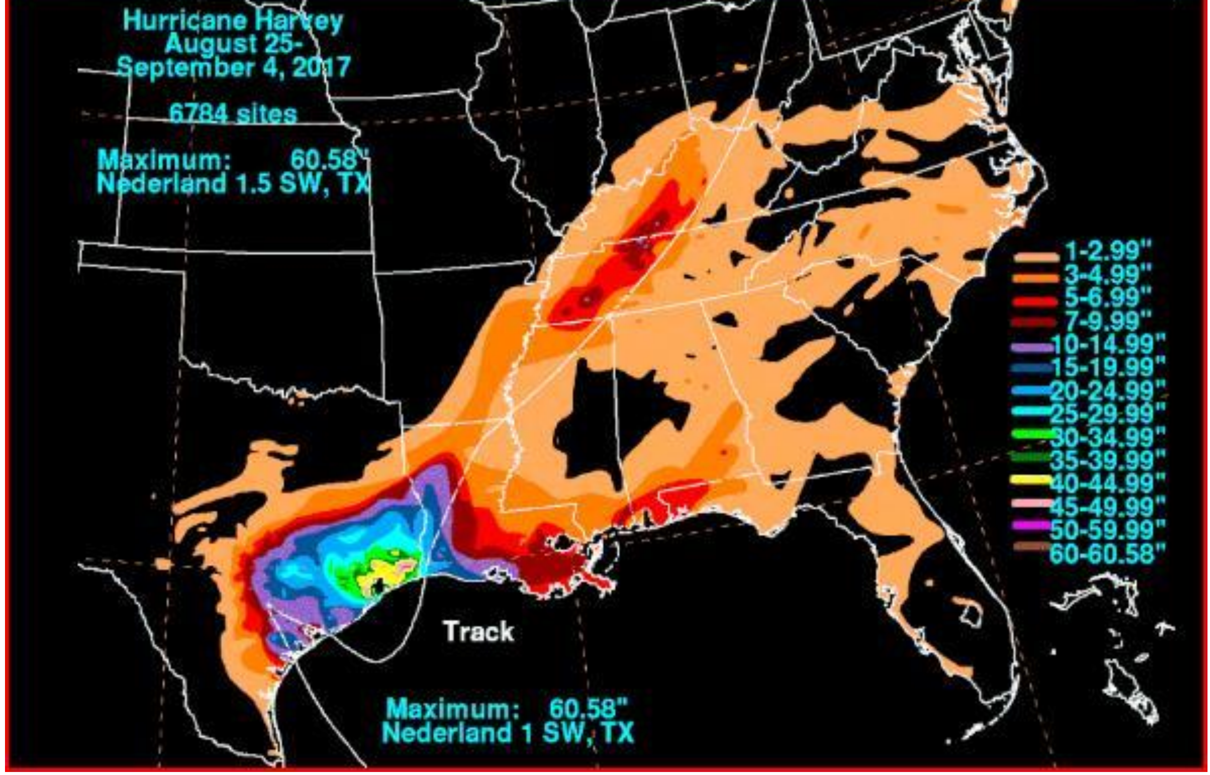


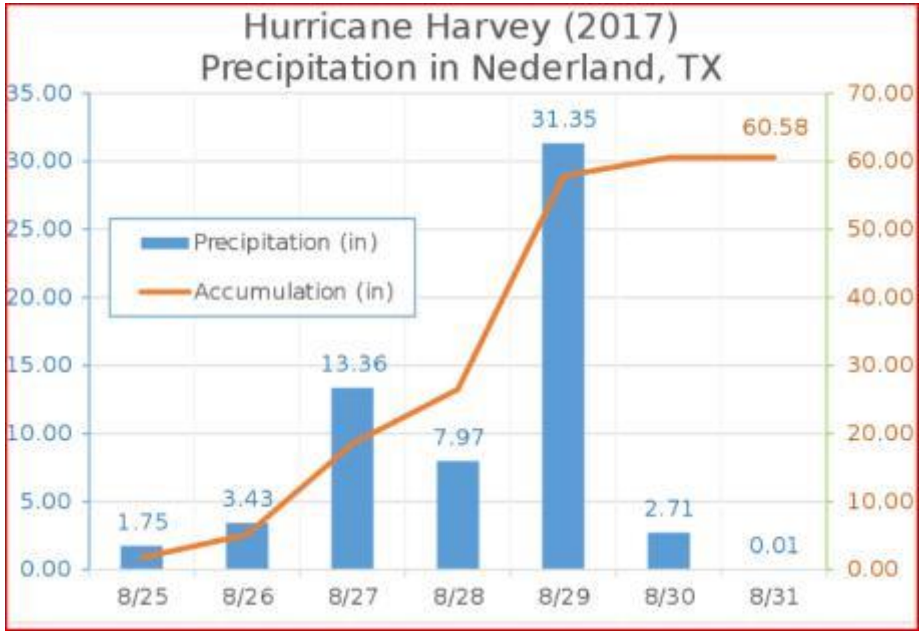
Animation:

https://en.wikipedia.org/wiki/Hurricane_Harvey#/media/File:Harvey_AVN_20170830_0145_UTC.gif

https://en.wikipedia.org/wiki/Hurricane_Harvey

Hurricane Harvey





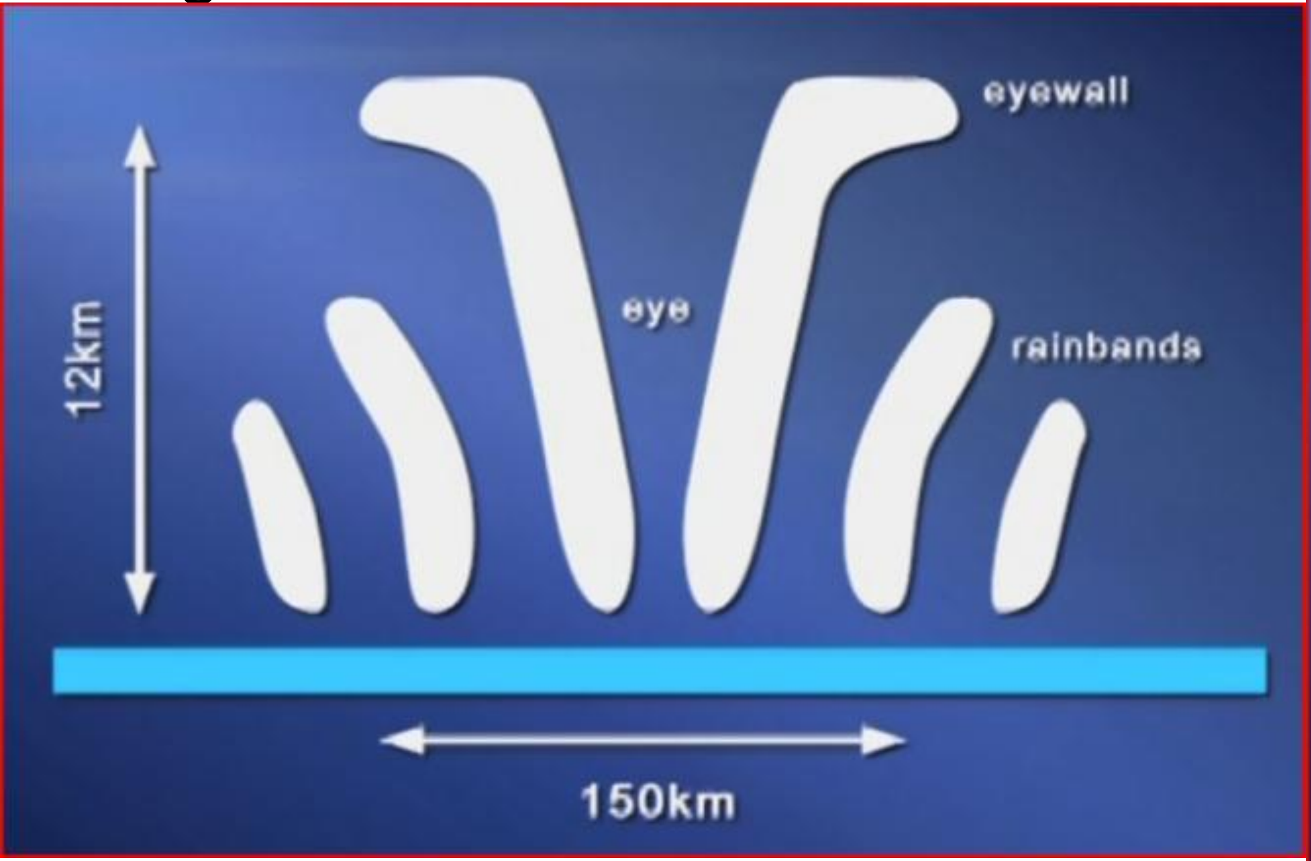
https://en.wikipedia.org/wiki/Hurricane_Harvey

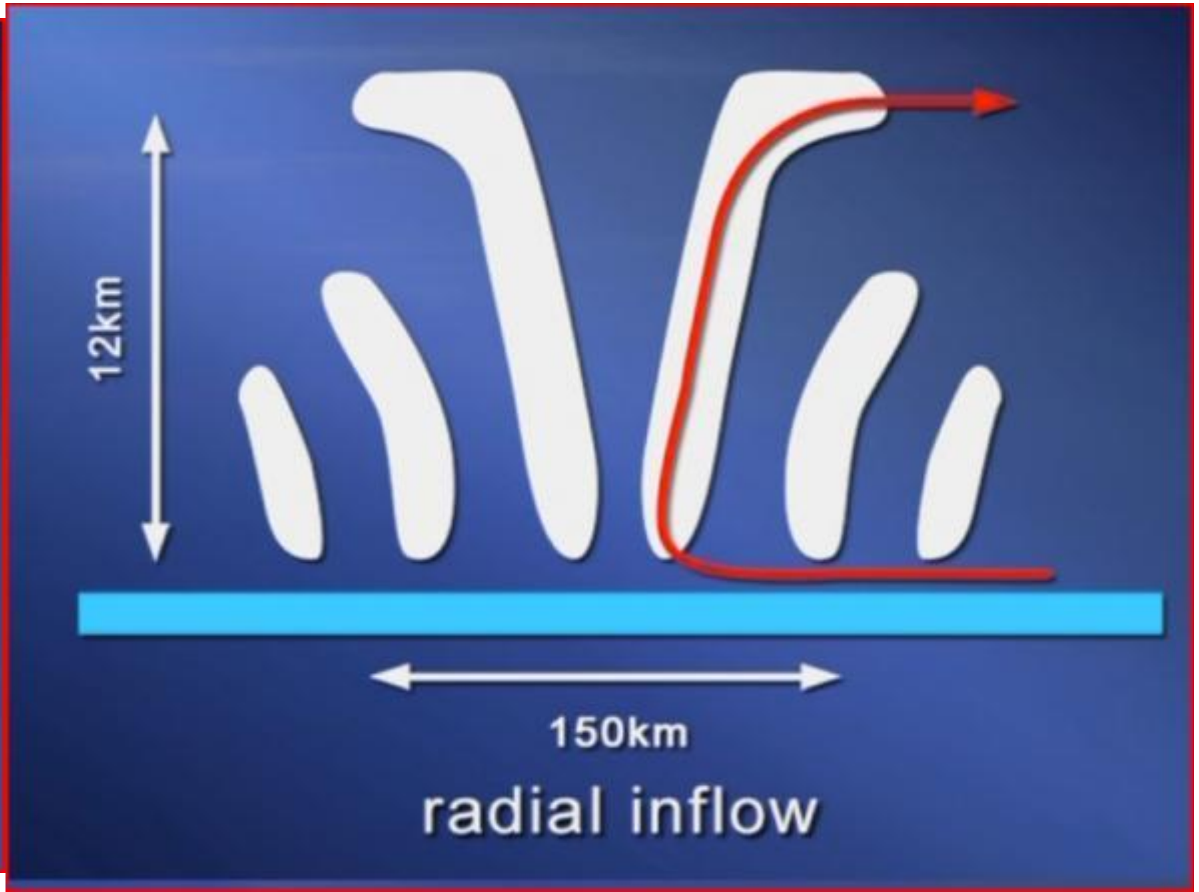
Hurricane Ivan’s double whammy

https://en.wikipedia.org/wiki/Hurricane_Ivan

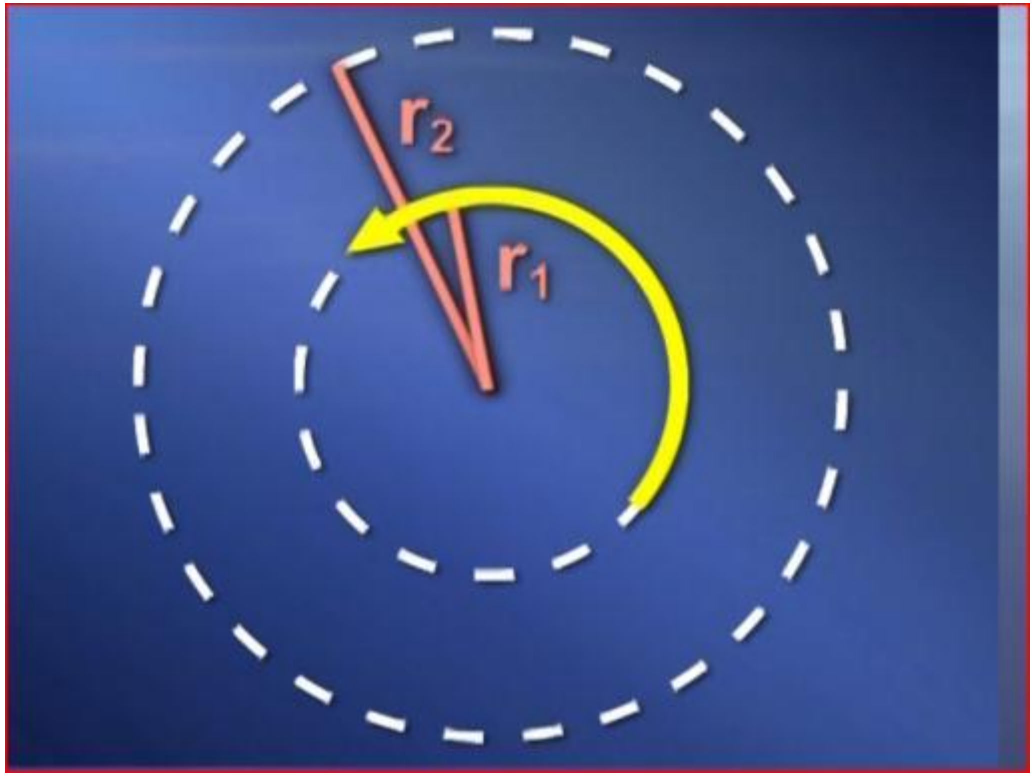
Vertical cross-section; most of flow is in circles around the eye, but importantly there's the radial inflow picking up moisture in the process

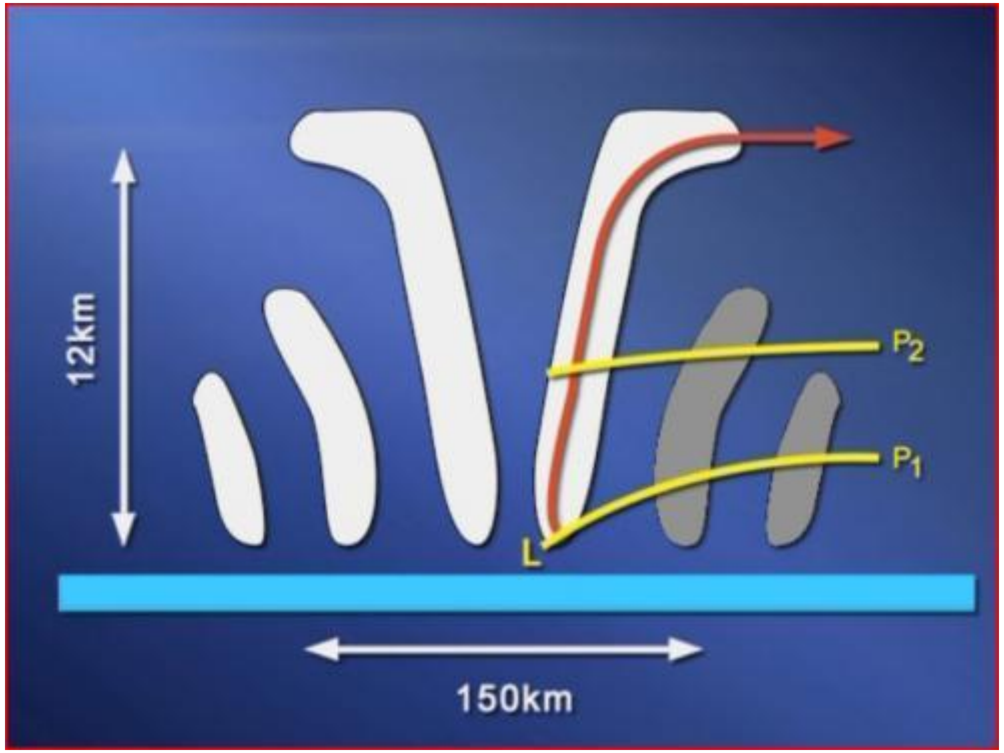
The eye wall slants due to decreasing wind and centrifugal force with altitude. Strongest winds are at surface.





- The eye wall slants due to decreasing wind with altitude for TCs
- r1 wind speed doubled from r2; note this is what happens with hurricane and why the eye wall slopes





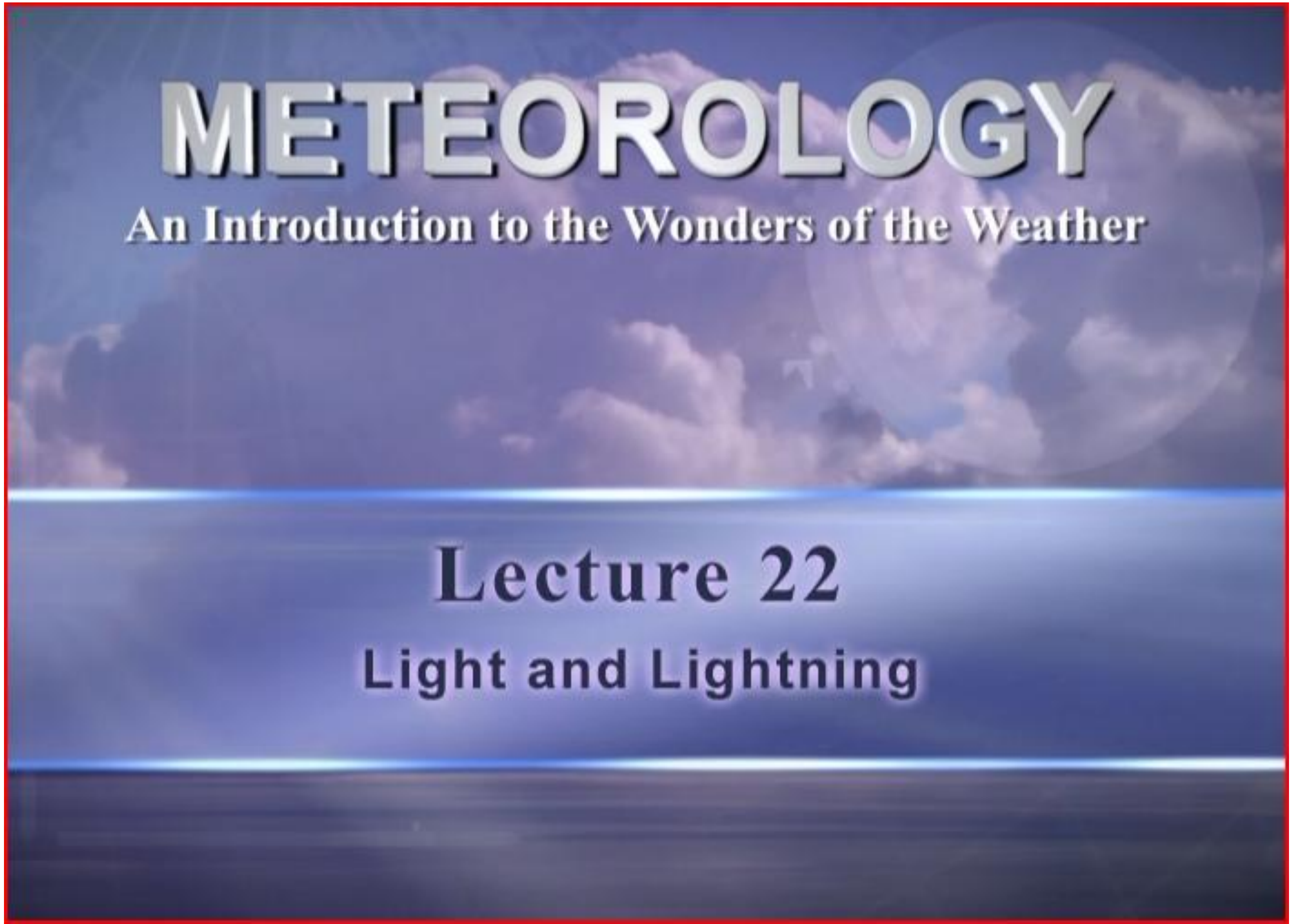
Tropical Cyclone naming

- See https://en.wikipedia.org/wiki/Tropical_cyclone_naming

  - Before the formal start of naming, tropical cyclones were often named after places, objects, or saints' feast days on which they occurred.[8] The credit for the first usage of personal names for weather systems is generally given to the Queensland Government Meteorologist Clement Wragge, who named systems between 1887 and 1907.[8] This system of naming weather systems subsequently fell into disuse for several years after Wragge retired until it was revived in the latter part of World War II for the Western Pacific.[8] Formal naming schemes have subsequently been introduced for the North Atlantic, Eastern, Central, Western and Southern Pacific basins as well as the Australian region and Indian Ocean.[8]
  - At present, tropical cyclones are officially named by one of eleven warning centers and retain their names throughout their lifetimes to facilitate the effective communication of forecasts and storm-related hazards to the general public.[9] This is especially important when multiple storms are occurring simultaneously in the same ocean basin.[9] Names are generally assigned in order from predetermined lists, once they produce one, three, or ten-minute sustained wind speeds of more than 65 km/h (40 mph).[1][4][5] However, standards vary from basin to basin, with some systems named in the Western Pacific when they develop into tropical depressions or enter PAGASA's area of responsibility.[3] Within the Southern Hemisphere, systems must be characterized by a significant amount of gale-force winds occurring around the center before they are named.[5][6]

Next: shed some light on Lightning

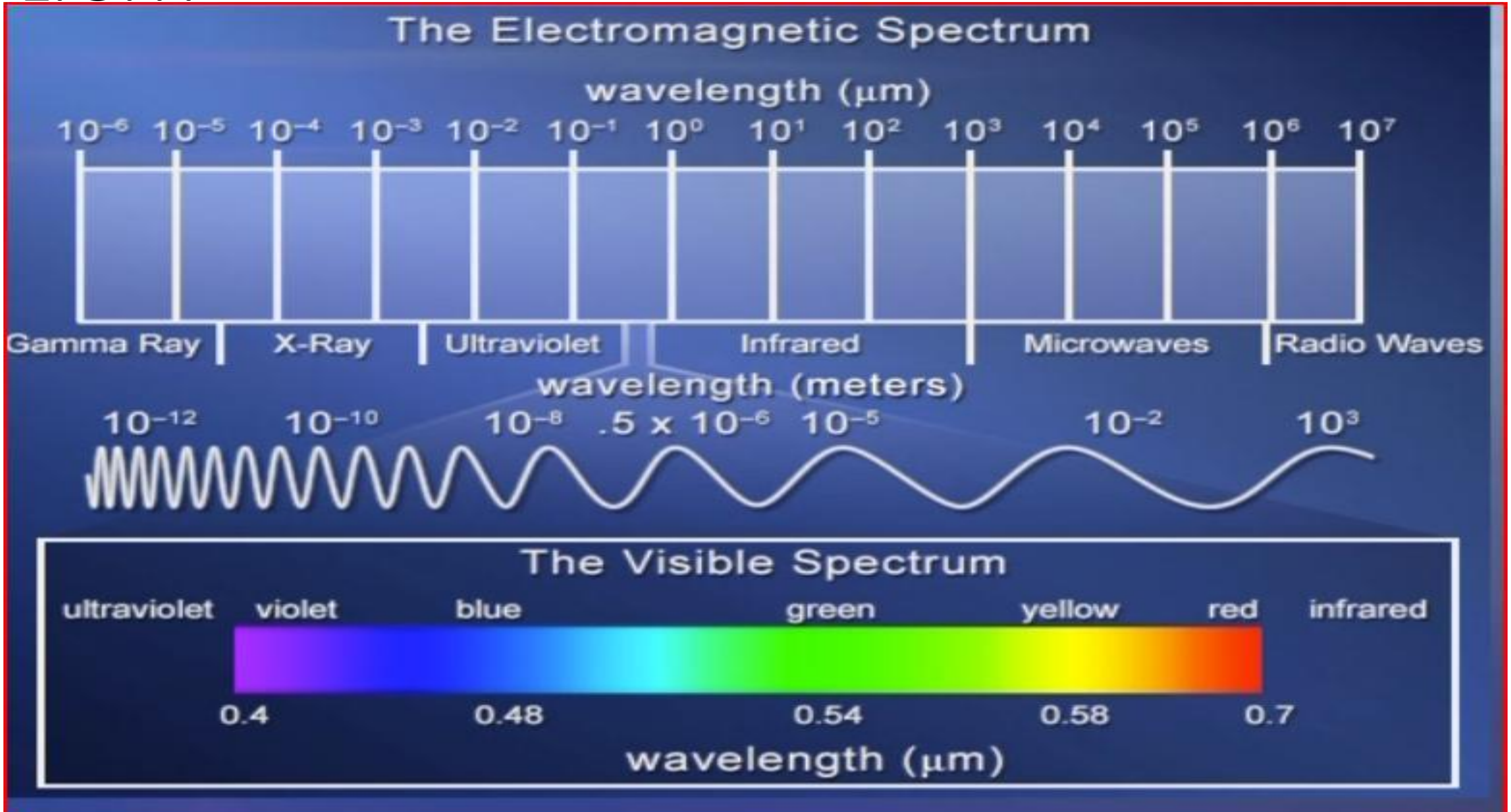
Light and Lightning



Light and Lightning

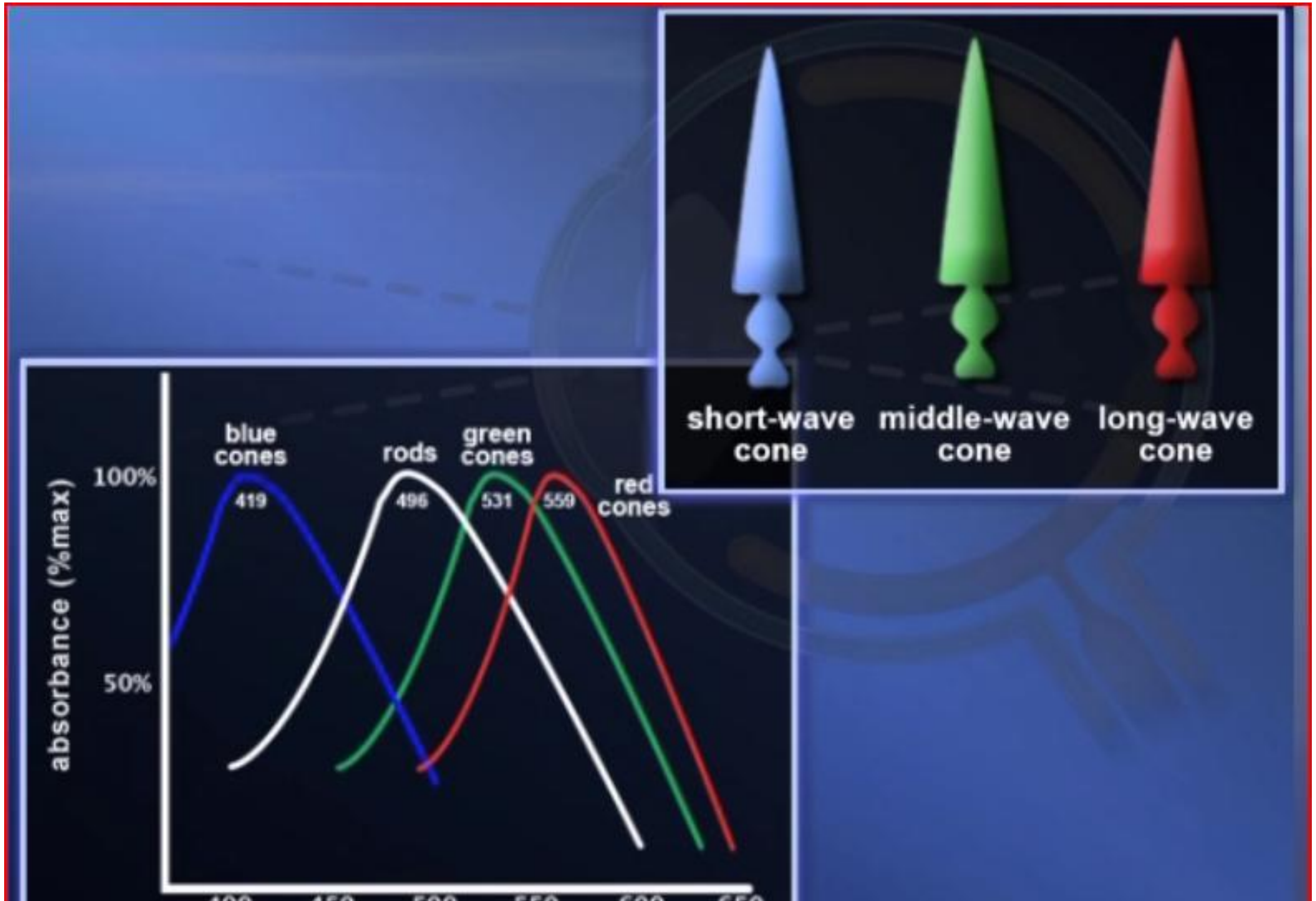
- Electromagnetic Waves, photonic from low-energy, many meters long radio and microwaves to very high energy X-rays and gamma rays with wave lengths very much smaller than the size of atoms. In the middle are what we can see, visible light and the infra red “heat waves” we and all materials emit.
- Scattering of short-wave, visible blue light from atoms and molecules gives the sky that color.
- Light is also refracted bent by passing through the atmosphere.
- Differential refraction and reflection light of different wave lengths by water droplets causes rainbows.

LIGHT



The Electromagnetic Spectrum
wavelength (μm)
10⁻⁶ 10⁻⁵ 10⁻⁴ 10⁻³ 10⁻² 10⁻¹ 10⁰ 10¹ 10² 10³ 10⁴ 10⁵ 10⁶ 10⁷
Gamma Ray
X-Ray
Ultraviolet
Infrared
Microwaves
Radio Waves
wavelength (meters)
10⁻¹² 10⁻¹⁰ 10⁻⁸ .5 x 10⁻⁶ 10⁻⁵ 10⁻² 10³
The Visible Spectrum
ultraviolet violet blue green yellow red infrared
0.4 0.48 0.54 0.58 0.7
wavelength (μm)

Perception of light by our eyes: Three cones sensitive to different wavelengths, the third the result of a long-ago, happy mutation for primates

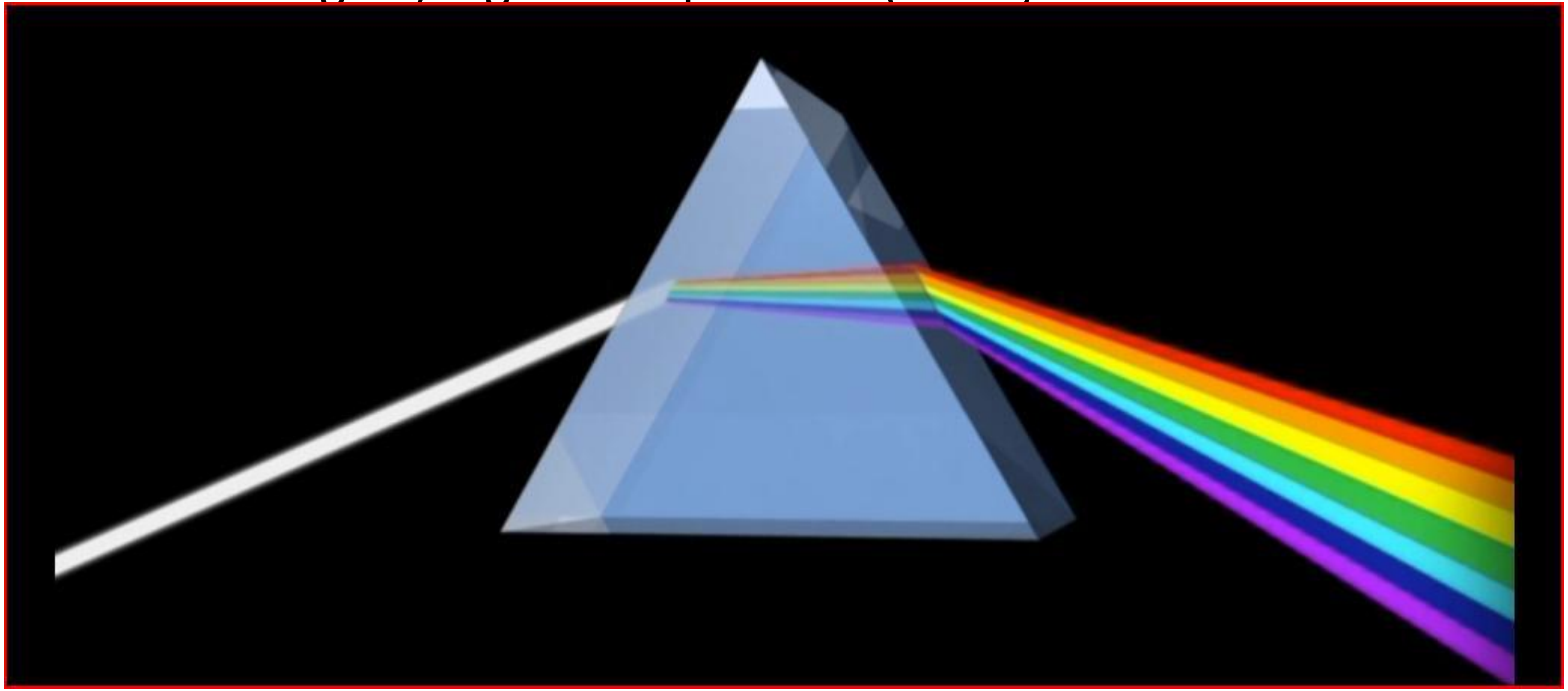


Wiki links here???

- Refraction – bending of light by prisms, by water droplets to produce rainbows
- Differential Scattering
- Rayleigh Scattering – why our sky is blue
  - Blue indigo and violet scattered more than longer wave lengths/lower frequencies
- Why sunsets are red: having to do with optical path (long waves (red) least scattered)

Refraction https://en.wikipedia.org/wiki/Dispersion_(optics)

- Note – lower frequencies, longer wavelengths, (reds) bent less than shorter wavelengths, higher frequencies (blues)

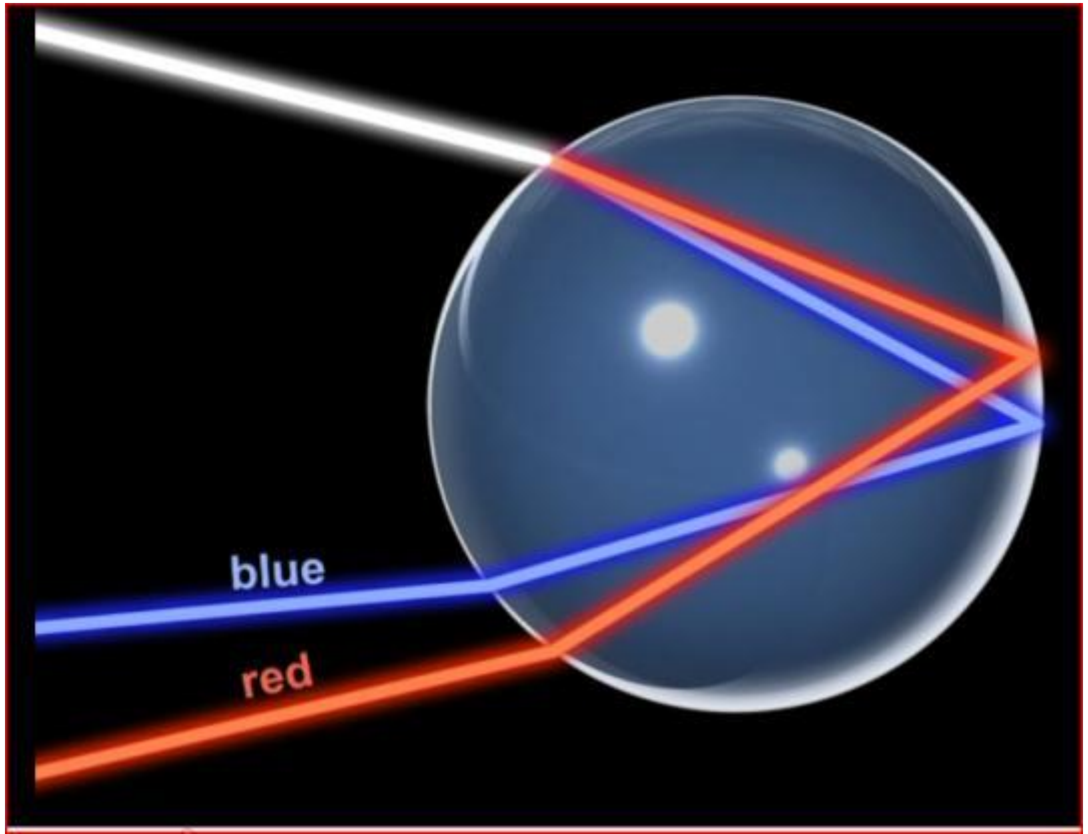


Green flash

- Green flashes are not always green; they can be yellow, green, blue, or even violet — see the color examples. But green is the hue seen most often. The basic cause of the color is *atmospheric dispersion*: refraction by air is larger at shorter wavelengths. So, at sunset, the refractive delay of the sunset is usually a second or two longer for blue and violet than for red. In general, then, the red image of the Sun (or of some miraged part of it) sets or disappears first, followed by yellow, green, blue and violet.
- So why isn't violet the last color to be seen at sunset? There is another effect at work: atmospheric *extinction*. Both air molecules and aerosol particles *scatter* the shortest wavelengths most strongly (which is why the sky is blue: the strongly-scattered blue light goes in all directions, so we see it when we look anywhere in the sky). At the horizon, the path length through the air is very long, and the shortest wavelengths are almost completely removed.
- Scattering by molecules alone is not quite enough to make the shortest wavelengths invisible; so if the air is very clear, violet is the last color seen. But usually there is enough haze in the air that violet, and even blue, is completely removed, so that green is the last color seen at sunset, or the first at sunrise. https://aty.sdsu.edu/explain/explain.html

Refraction in a water droplet

- Drop of water showing what happens with white light
- But the color you perceive is a factor of the cones of your retina



Double rainbows – colors reversed

- A double rainbow occurs when the light is reflected twice in the drop. It means you can see two different reflections, coming from different angles This leads to something that is actually really cool — instead of seeing red at the top and blue at the bottom like a regular ho-hum rainbow, the secondary rainbow (which is higher and lighter in color than the primary) has the colors reversed. https://science.howstuffworks.com/nature/climate-weather/atmospheric/double-rainbows-rare.htm

Haze

- Dry haze
- Haze along the water
- Salty air –droplets largely evaporate in air forming a haze of hydroscopic nuclei – wet haze; wet haze is white

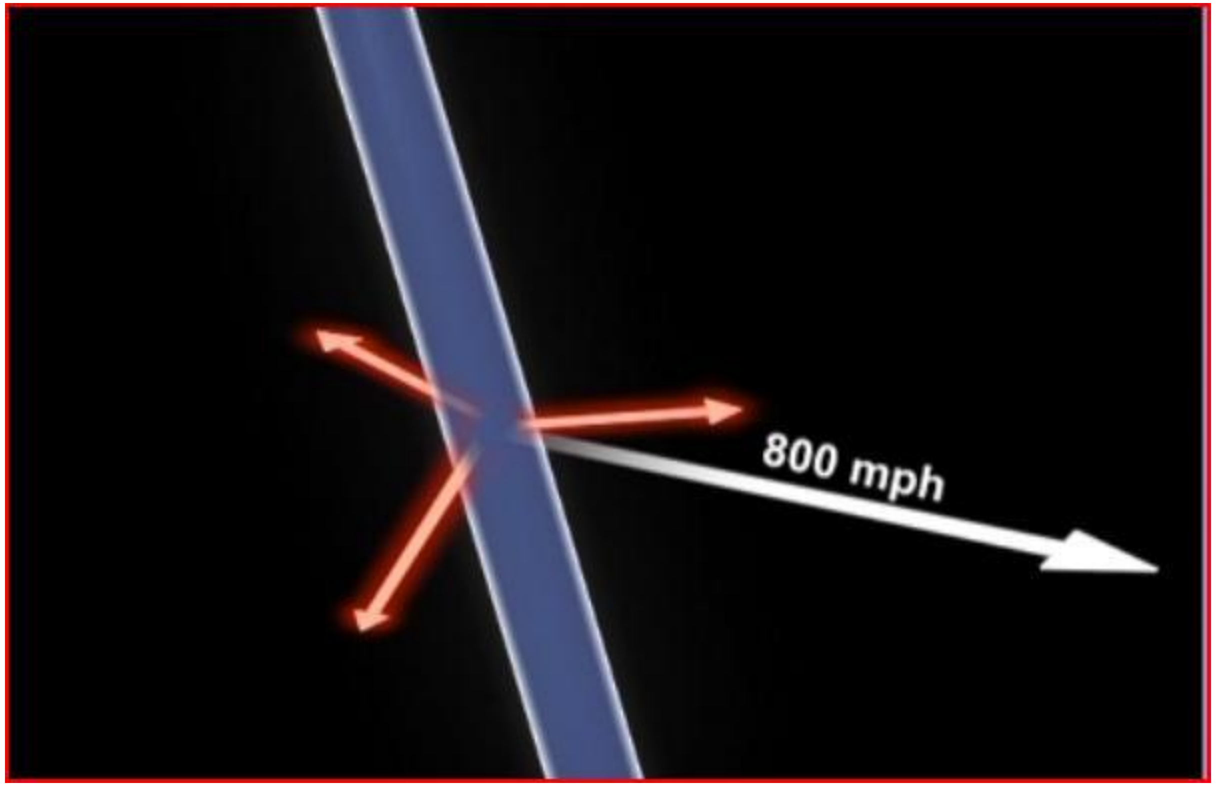
Twilight

file:///D:/Documents/Documents/OLLI/Weather/Ozone_and_UV_2009.pdf

- The blue hour = happy hour
- Role of ozone in absorption and color of sky
  - Day time – minimal
  - Twilight – Absorption of long waves (reds, yellows) much greater effect; 2/3 of it because of ozone
  - Ozone also absorbs non-visible (to us) ultraviolet, and its presence in the stratosphere protects us (mostly) from these high-energy damaging short waves.

Lightning – and electrical phenomena

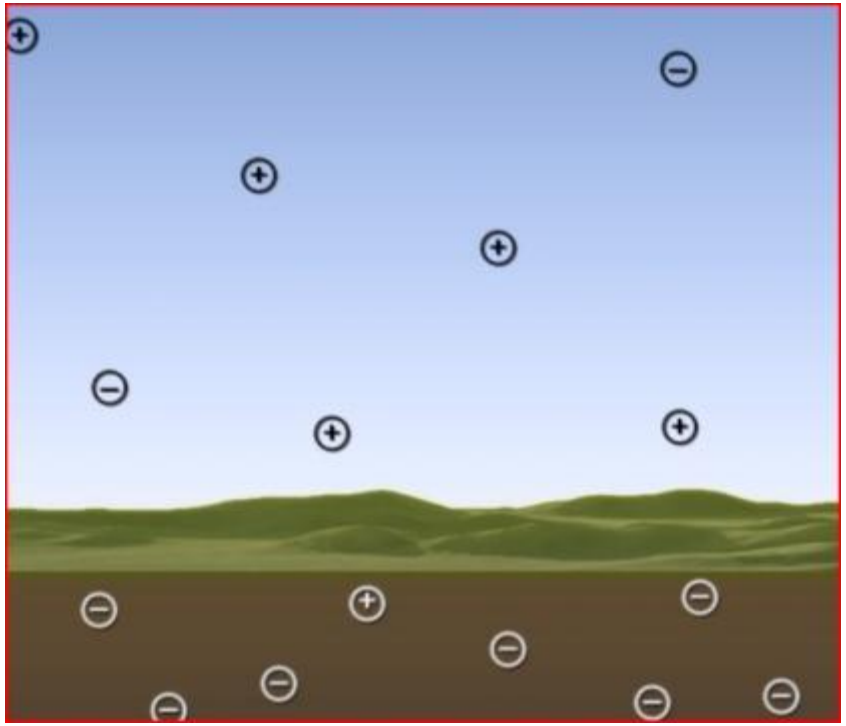
- Without lightning there is not thunder
- Air conductivity poor
- Need charge separation
- Ionization of air



https://en.wikipedia.org/wiki/Lightning

Lightning

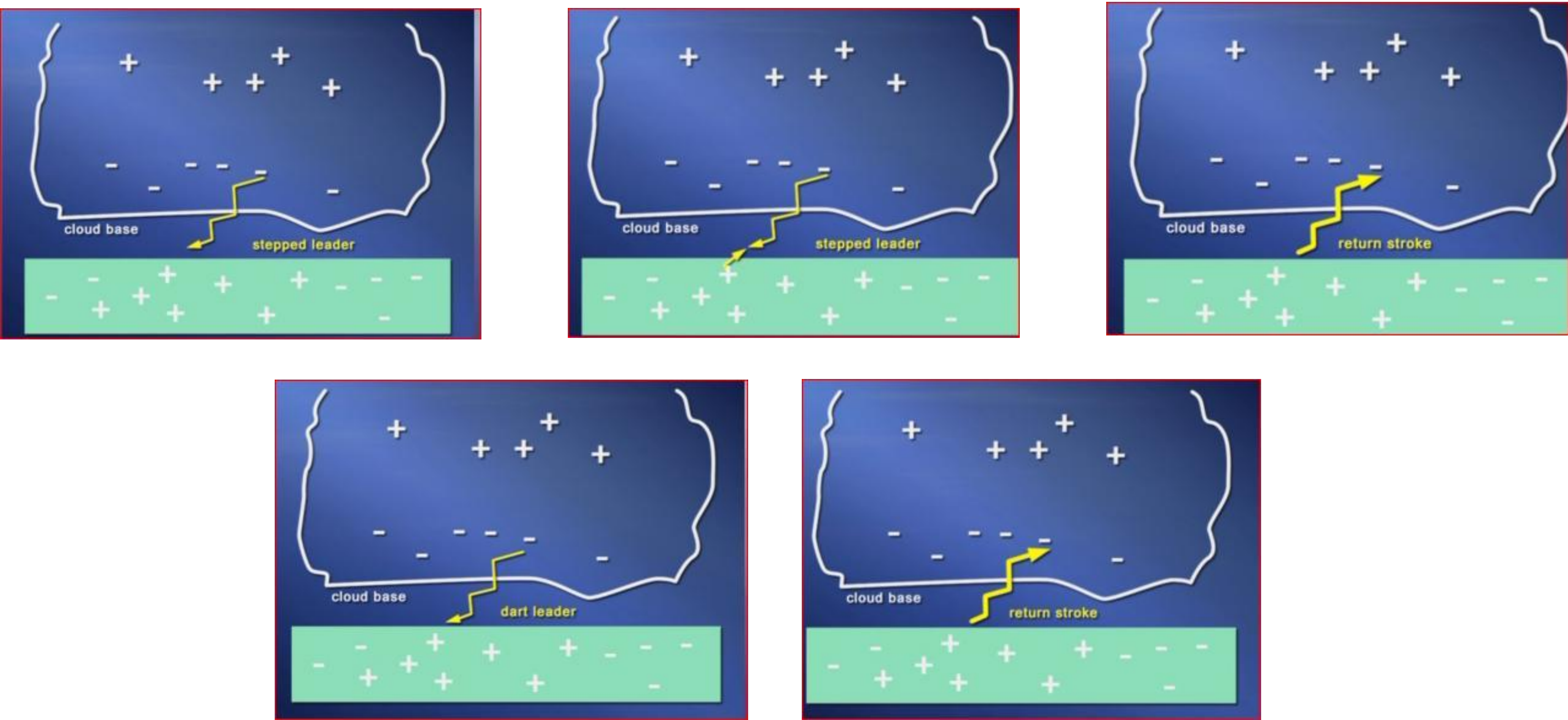
- Fair weather electric field – typically more negative in the ground; can be 100 volts per meter.
- Charge separation – having to do with phases of water: ice / liquid



Prelude to Lighning

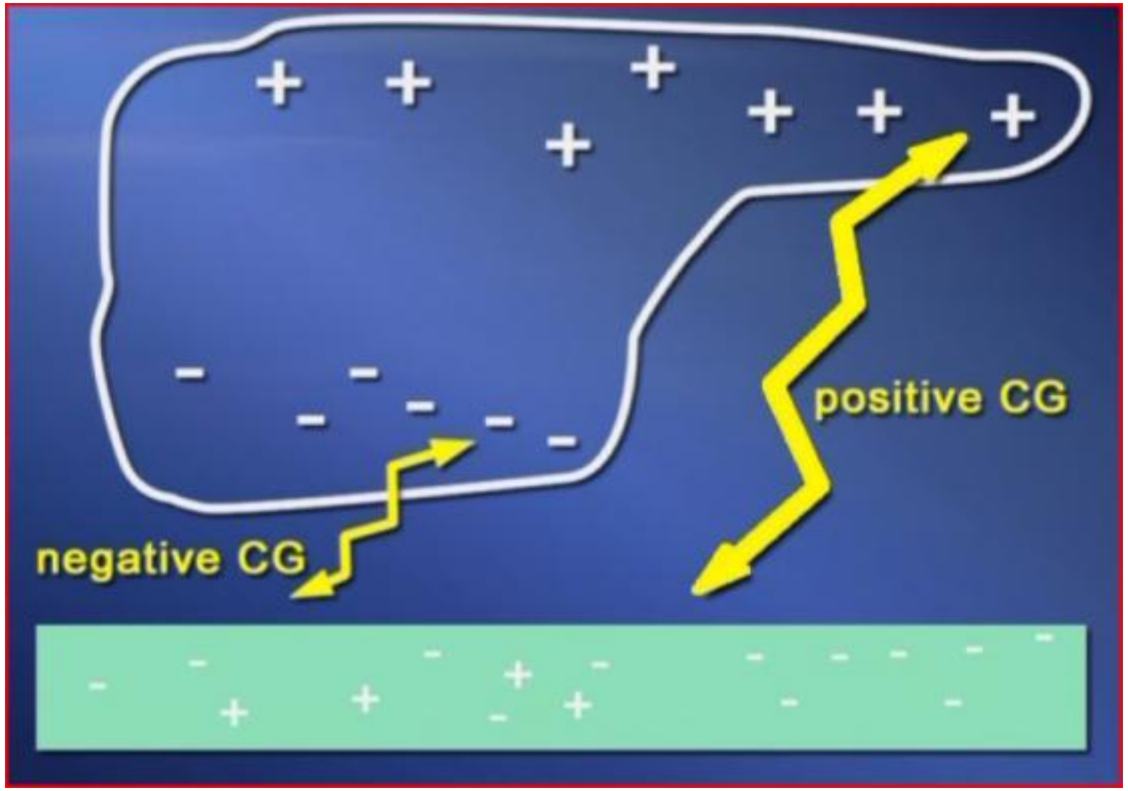
- Induction charging development leading to charge separation

Lightning and double strike/strobe effect

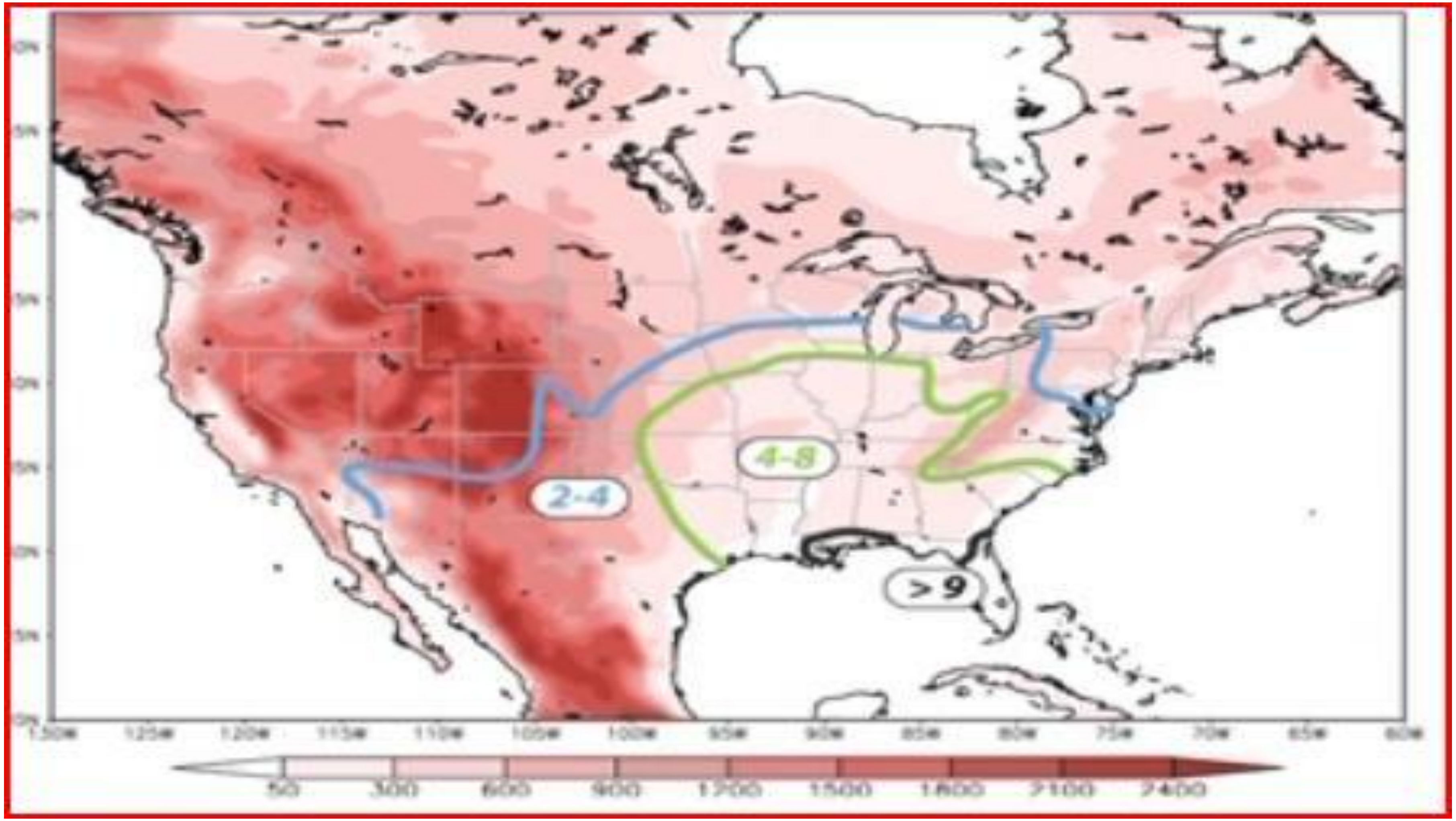


Pathway

- Most – negative cloud-to-ground lightning
- Rarer – positive cloud-to-ground lightning – but deadliest of all due to larger distance traveled – often from cloud anvil



Frequency of Thunderstorms/Lightning



Faraday cage effect https://science.howstuffworks.com/faraday-cage2.htm

- Charges on metal enclosures repel one another and exist only on the outside of the enclosures. That's what protects us when (often) planes are struck by lightning.

Hair raising - real

- Induced charges can cause a hair raising incident. The next incident can be a lightning strike.

Types of lightning

- Cloud to cloud lightning – sheet lightning
- Heat lightning – misnomer: distant storms
- Dry lightning – from heat caused by fire

Human cause?

- Aerosols we put in atmosphere

Influence of droplets size, pollution, etc. discussed

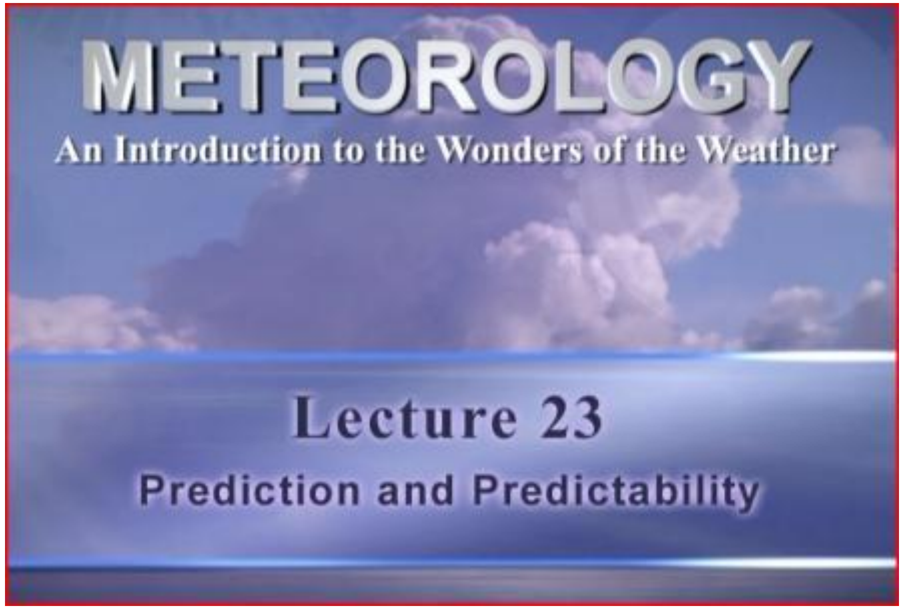
Summary of an electrifying lecture

- Light, color, refraction, absorption,disoersion
- Lightning
  - Causes
  - Charge separation
  - Types
  - Etc.

- “hope you got a big charge out of it”

Next – either in whole or summary

- Lecture 23: Prediction and Predictability – models, how made, etc.
- Lecture 24: The imperfect forecast
- Climate change



- END OF WEEK 7