

Final Project



B E T S Y M C C A L L



Basic Elements of the Atmosphere



PART 1



Contents

Origin of the Atmosphere

Composition of the Modern Atmosphere

Anthropogenic Changes and Climate

Energy Balance

Role of Energy in the Atmosphere



Introduction

Part 1 introduces the elements of the atmosphere that relate to the final project.



2022



FINAL PROJECT PART 1



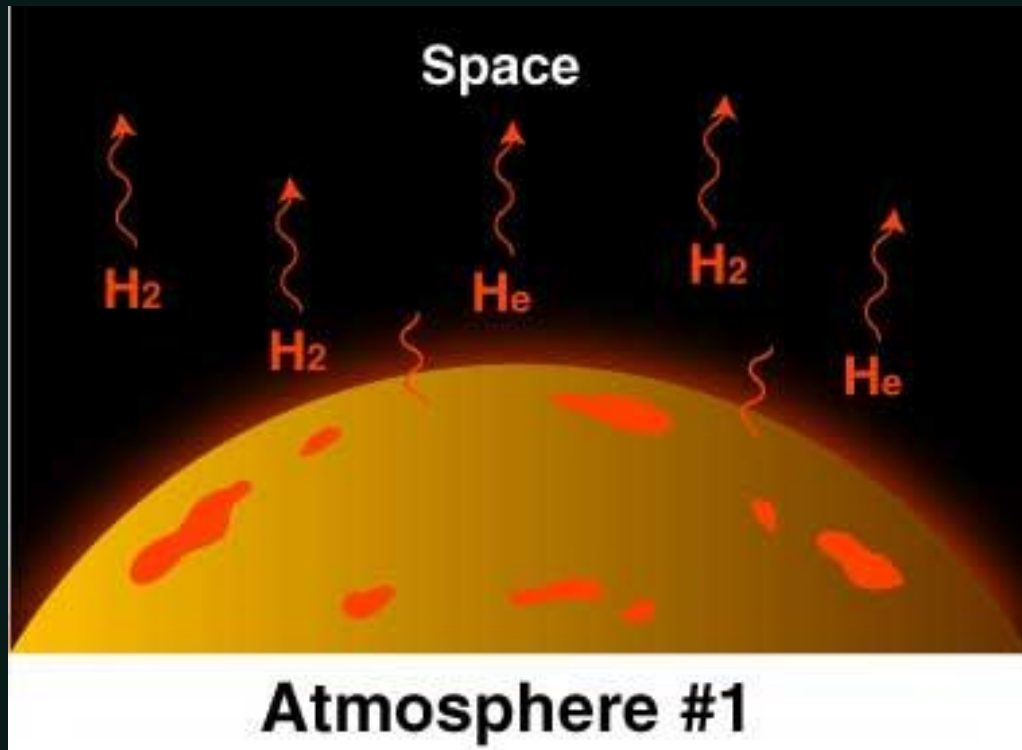
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Origin and Composition of the
Atmosphere

And how have humans
altered it?

Origin of the Atmosphere

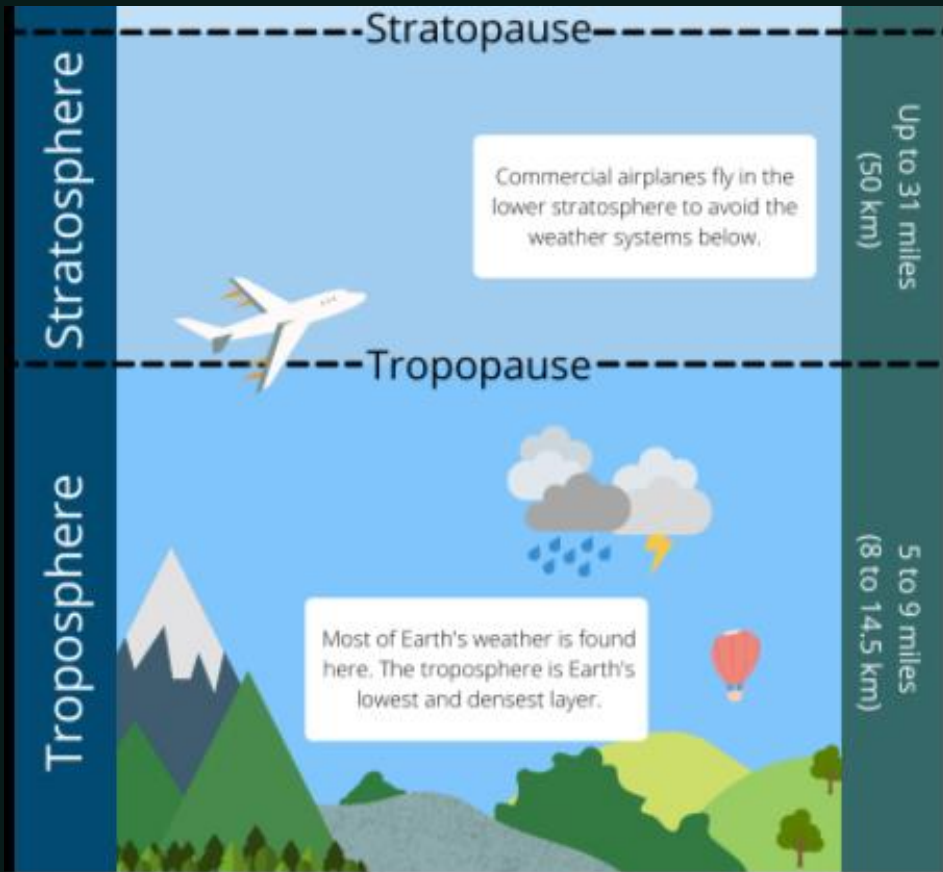


(How did Earth's atmosphere form?, n.d.)

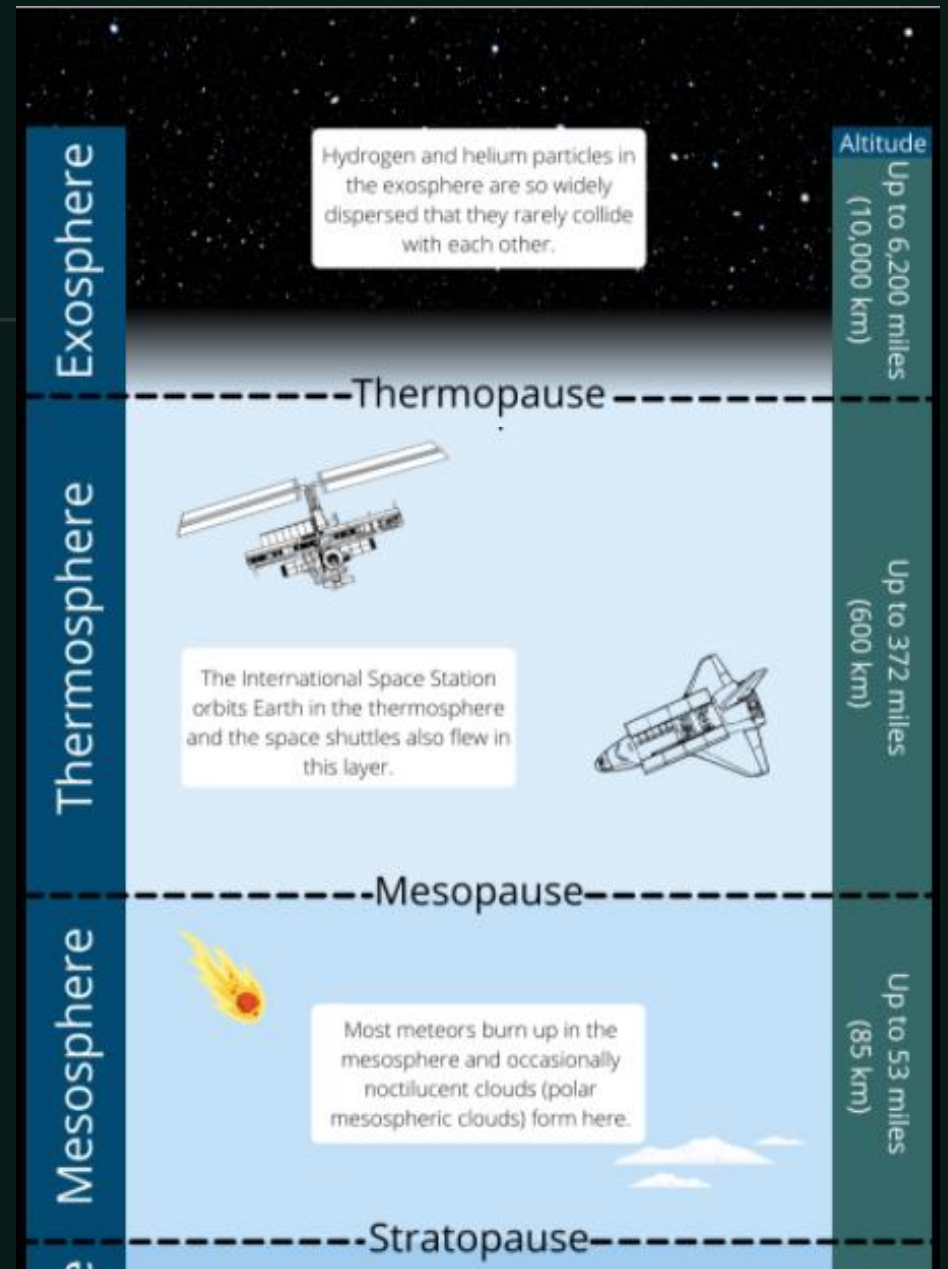


(The Earliest Atmosphere, n.d.)

Atmospheric Composition



(Sharp & Dobrijevic, 2021)



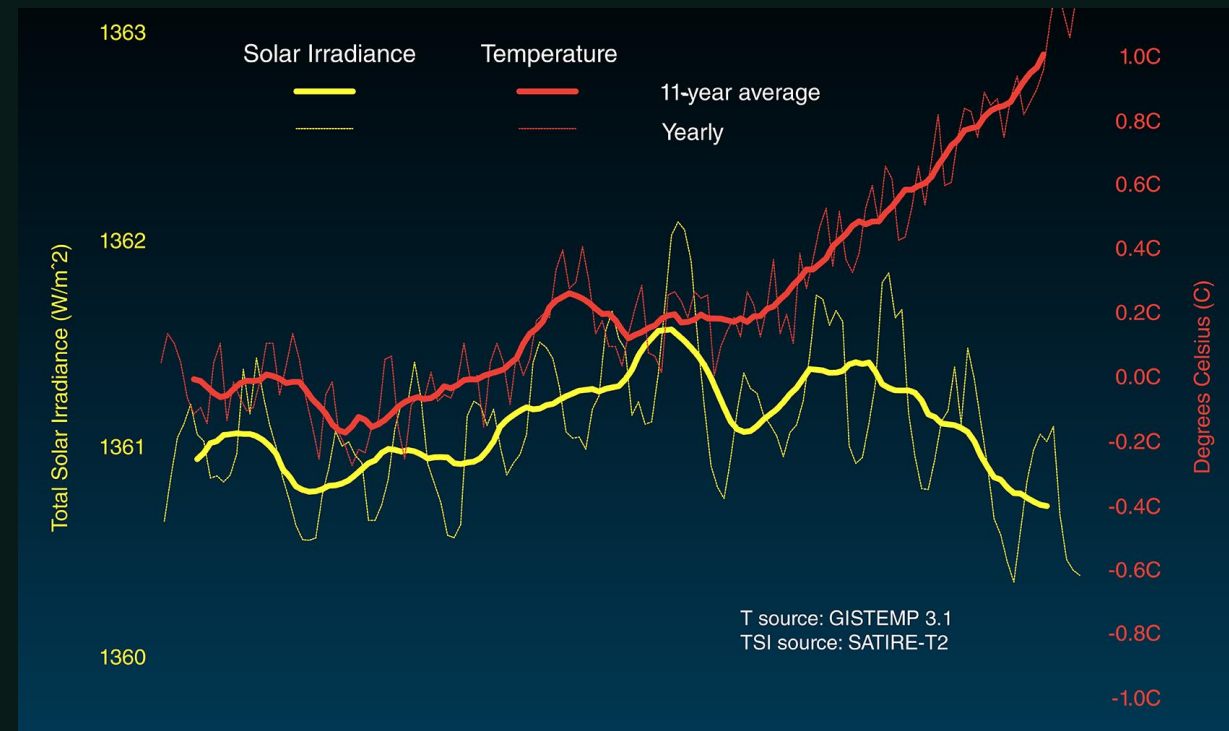
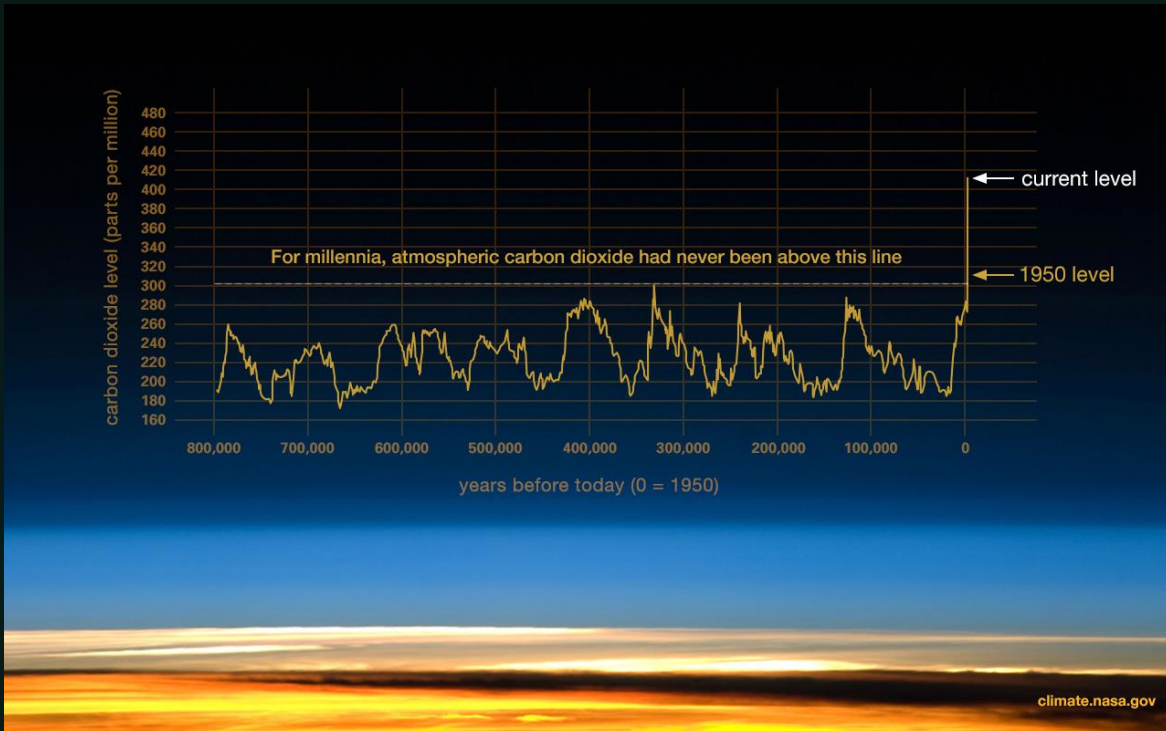


Climate Change

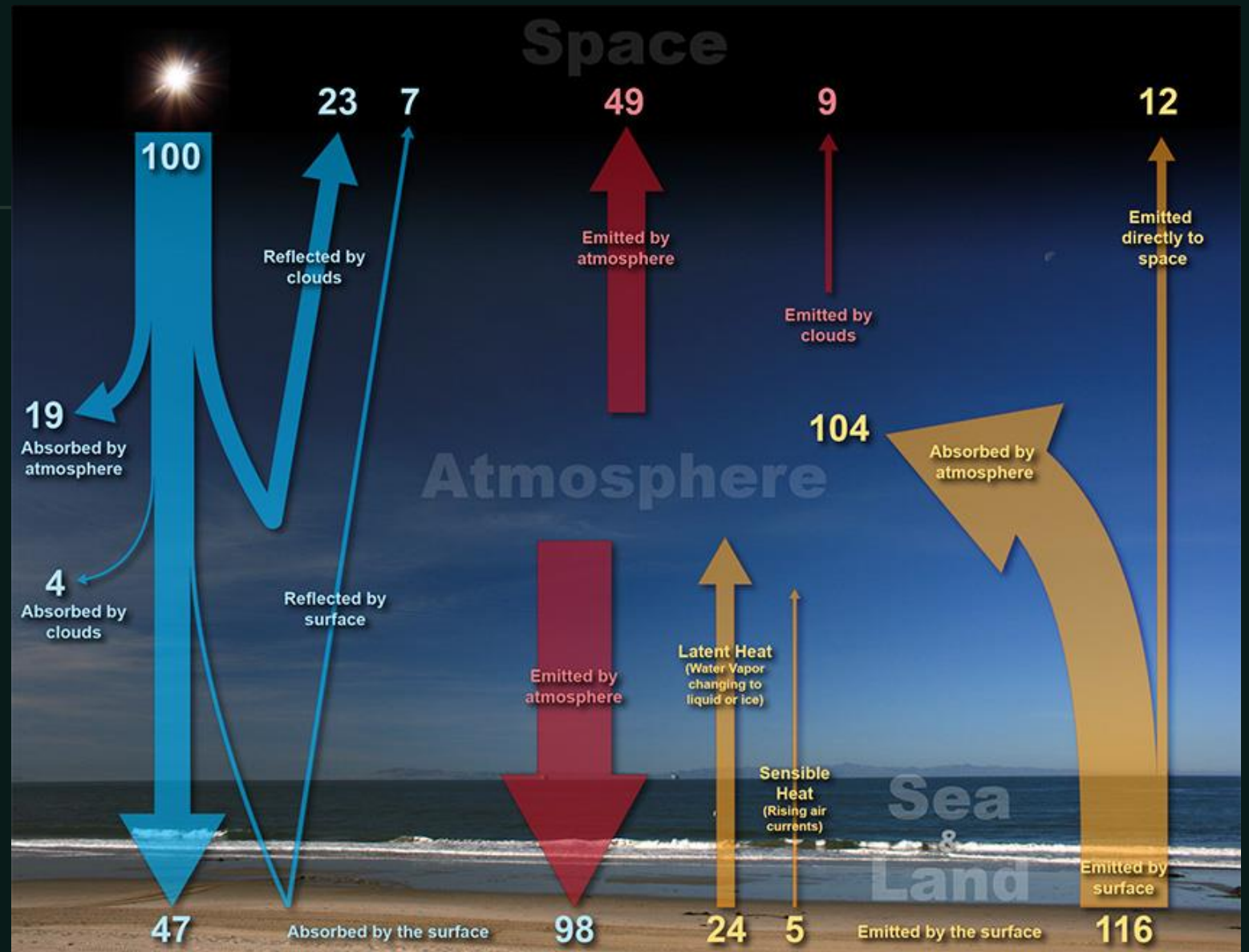
What have we done?

(Climate Change: How Do We Know?, n.d.)

(The Causes of Climate Change, n.d.)



Energy Balance



(The Earth-Atmosphere Energy Balance, n.d.)

Energy Transfer in the Atmosphere

CONVECTION

- The circulations of the atmosphere and oceans brings cold air/water up from the bottom and moves it to the top and takes the warm air/water down.
- Circulation across latitudes also moves warmed equatorial air to colder polar air and vice versa. Oceans currents do the same.
- Conduction is another method of heat transfer important in the lower atmosphere.

RESULTS

- Vertical circulation can produce large thunderstorms
- Weather fronts and large storms like hurricanes are mechanisms of heat transfer.
- The ground temperature heated by the sun can radiate energy back into the atmosphere (cities are hotter than the country).

Circulation



PART 2



Contents

Atmospheric Forces

Winds

Cloud Development

Condensation

Precipitation



Introduction

Part 2 introduces the elements of the atmosphere that produce circulation of the atmosphere and the effects of that circulation.





Forces that produce circulation

Causes and effects

What causes the air to move at large scales?

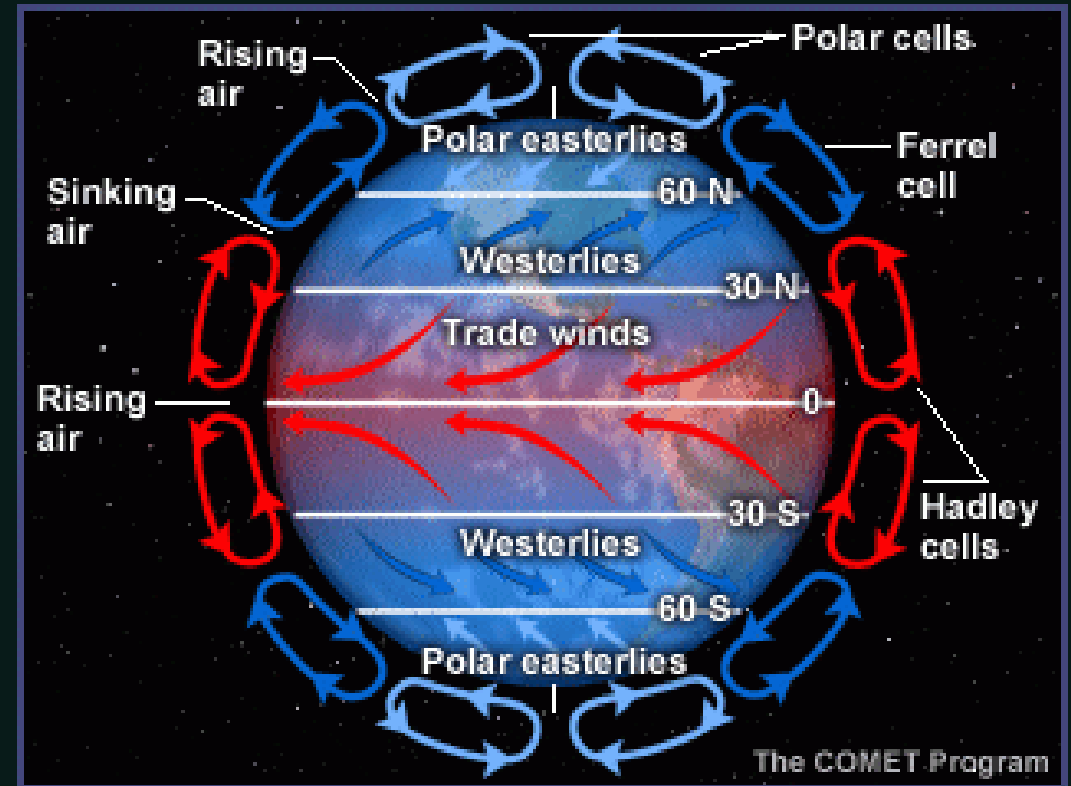
- Three major forces cause air to move (or resist movement):
 - **The Pressure Gradient Force**
 - The pressure gradient force causes air to move from an area of high pressure to an area of low pressure
 - **The Coriolis Force**
 - This force is caused by the rotation of the Earth
 - **Friction**
 - This force resists air movement and can be caused by interaction with the land (or other particles of air) (Thornton, 2011)
- Pressure gradients are created from convection

Convection

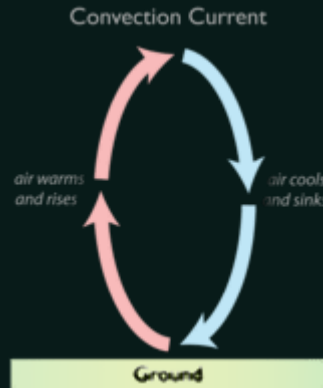
HEAT TRANSFER

- Convection is a method of heat transfer
- Other methods are conduction and radiation
- Warm air rises, cools down, and then sinks, creating circulation (UCAR, 2022)

GLOBAL VIEW

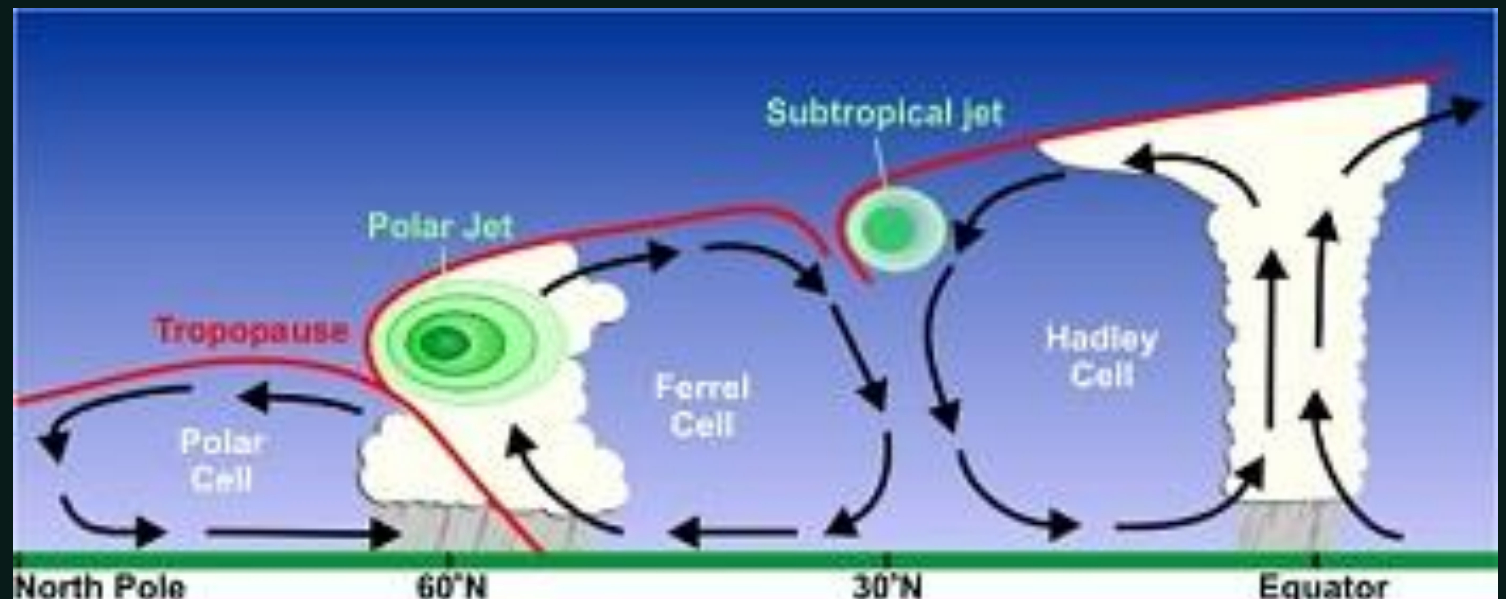


Circulation Cells



- Location of convection cells determines locations of other major wind patterns such as the polar jet, prevailing winds and the subtropical jet

- Changes to heat distribution due to climate change can cause changes in these patterns. We see the effects with the shifting jet streams and the polar vortex.

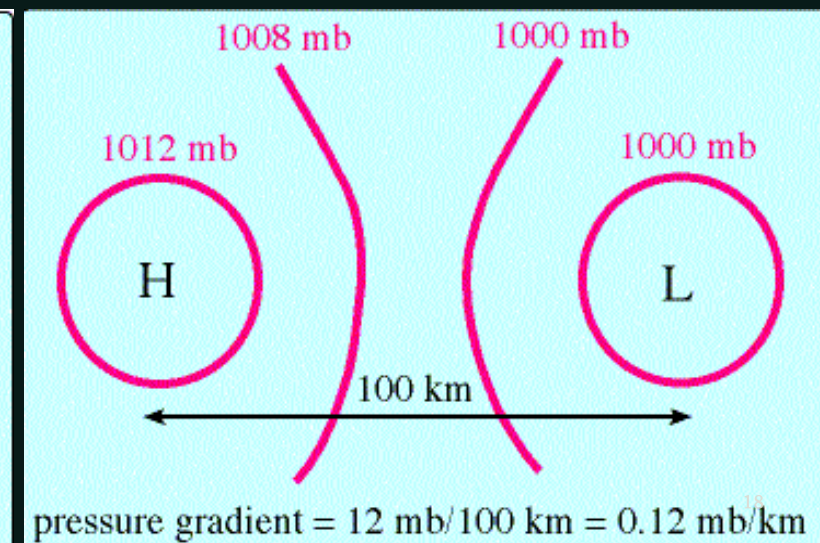
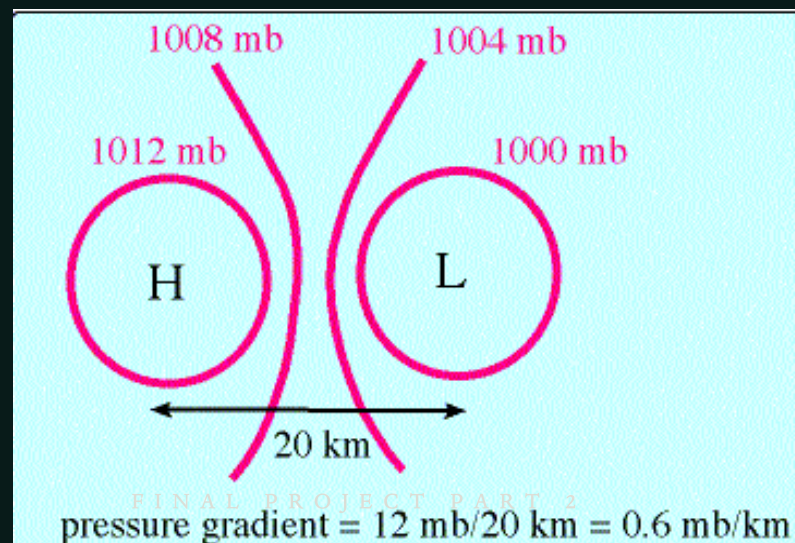
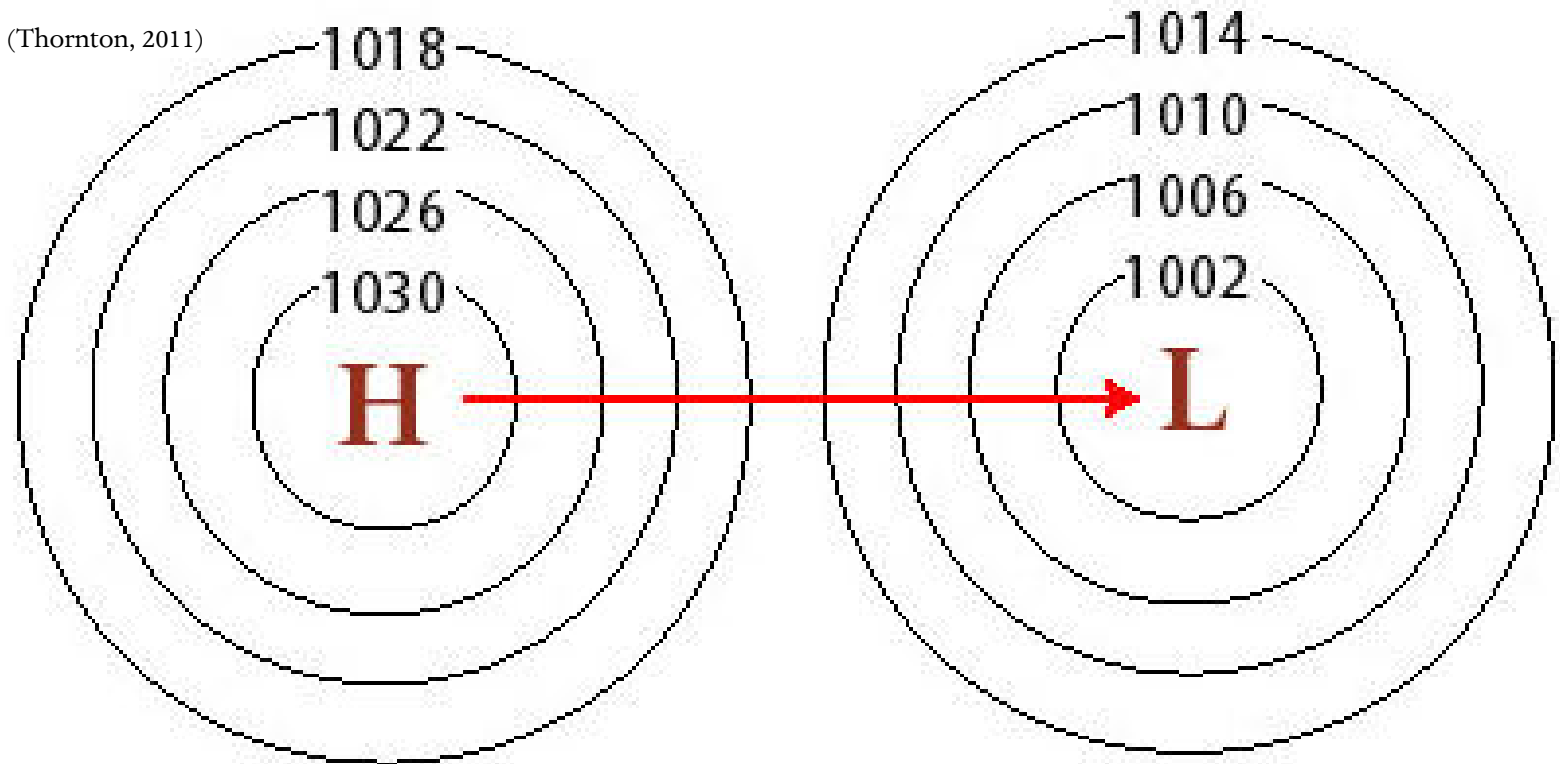


Pressure Gradient



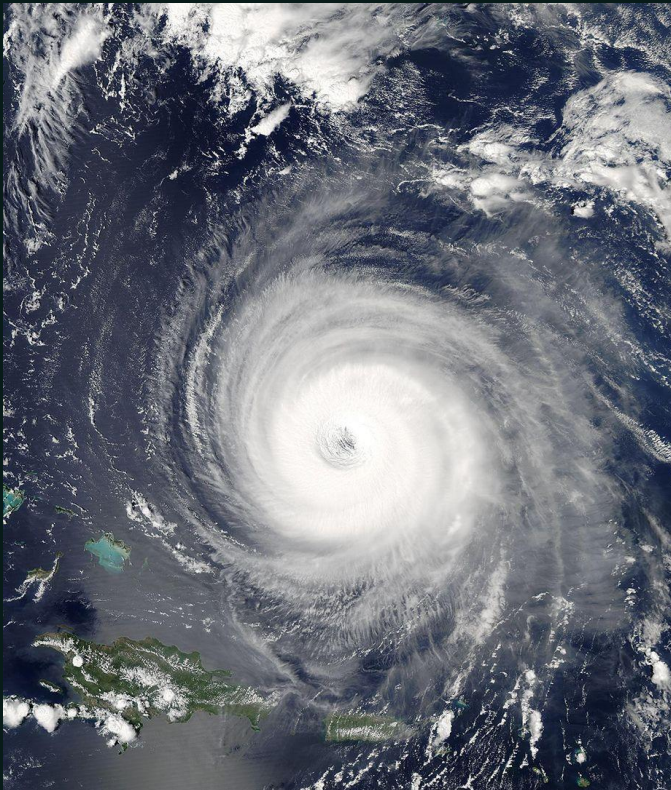
ATMOSPHERE SEEKS
EQUILIBRIUM

(Thornton, 2011)

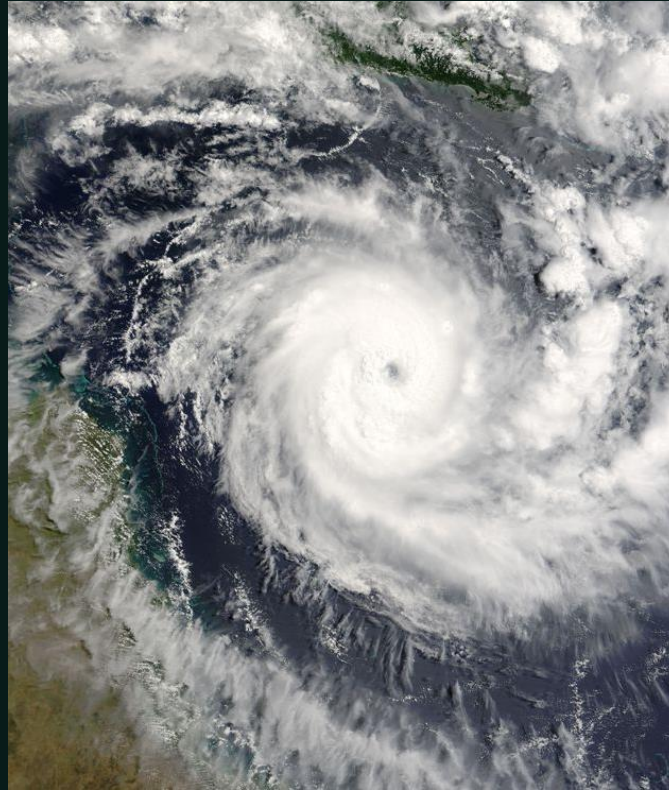


Coriolis Force

CYCLONES



ANTI-CYCLONES



ROTATION

- The rotation of the Earth imposes a force that increases with distance from the equator. This causes prevailing westerlies in Northern Hemisphere and prevailing Easterlies in the Southern Hemisphere.



Friction

When air moves over the surface of the earth, it encounters friction just like people do. The more irregular the surface, the greater the resistance. Mountains and vegetation included. This can deflect the wind or slow it down.

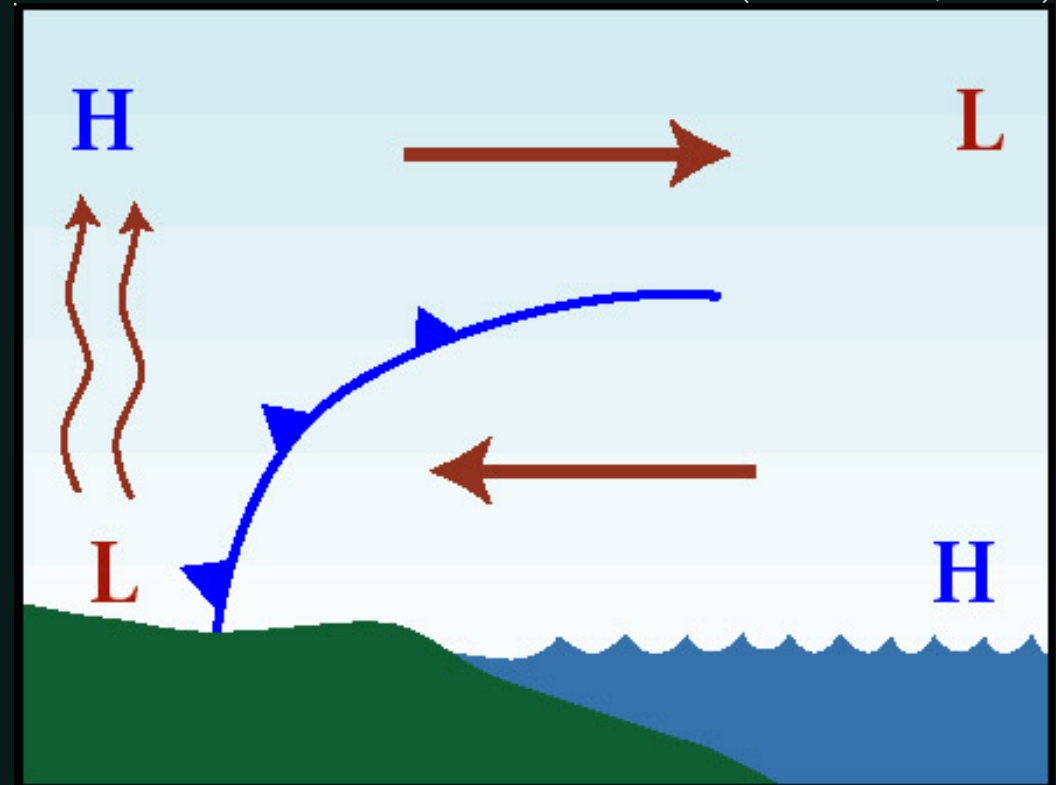


What about at more local scales?

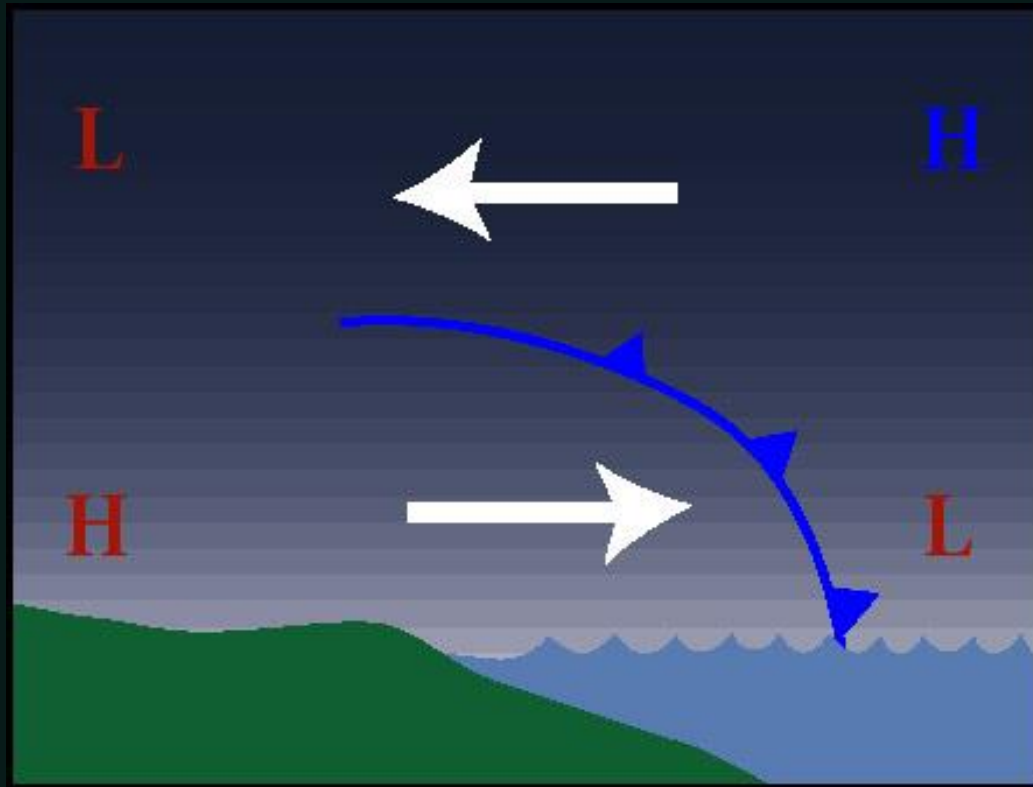
SEA BREEZE

- When pressure gradients are small, wind at the interface of large water bodies with the land can create their own winds
- Land heats more quickly than the water, causing a local drop in pressure.
- This causes the air to flow from the water (sea, lake or ocean) onto the land.

(Thornton, 2011)



What about at more local scales?



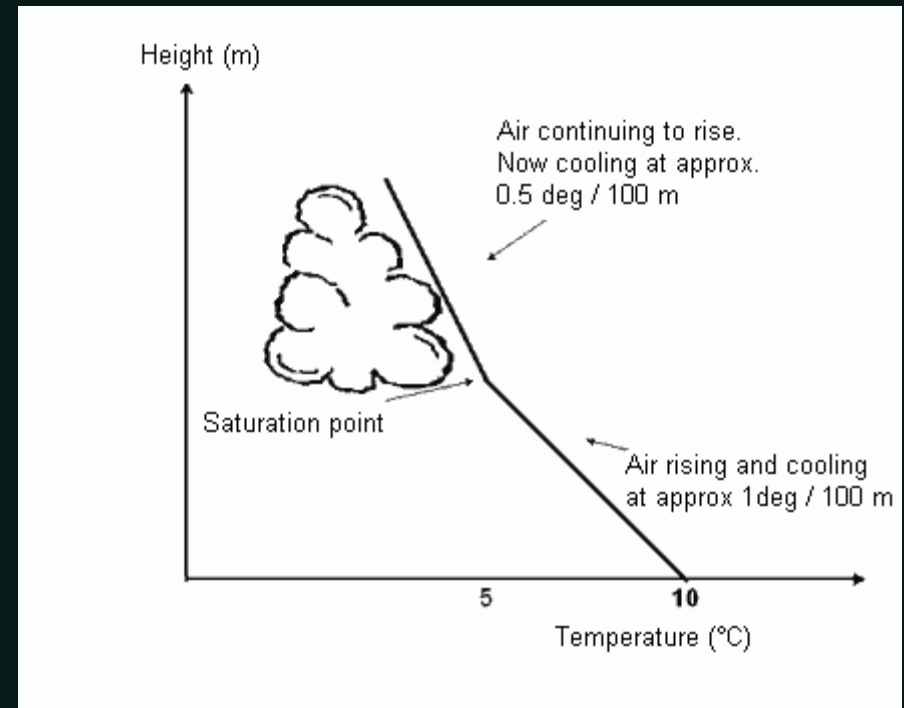
LAND BREEZE

- At night, the land cools more quickly than the water does, if the water remains warmer than the land, this can cause a local low pressure over the water, generating a land breeze.
- One of type of breeze may be more common than the other for different bodies of water and at different times of the year. (Thornton, 2011)

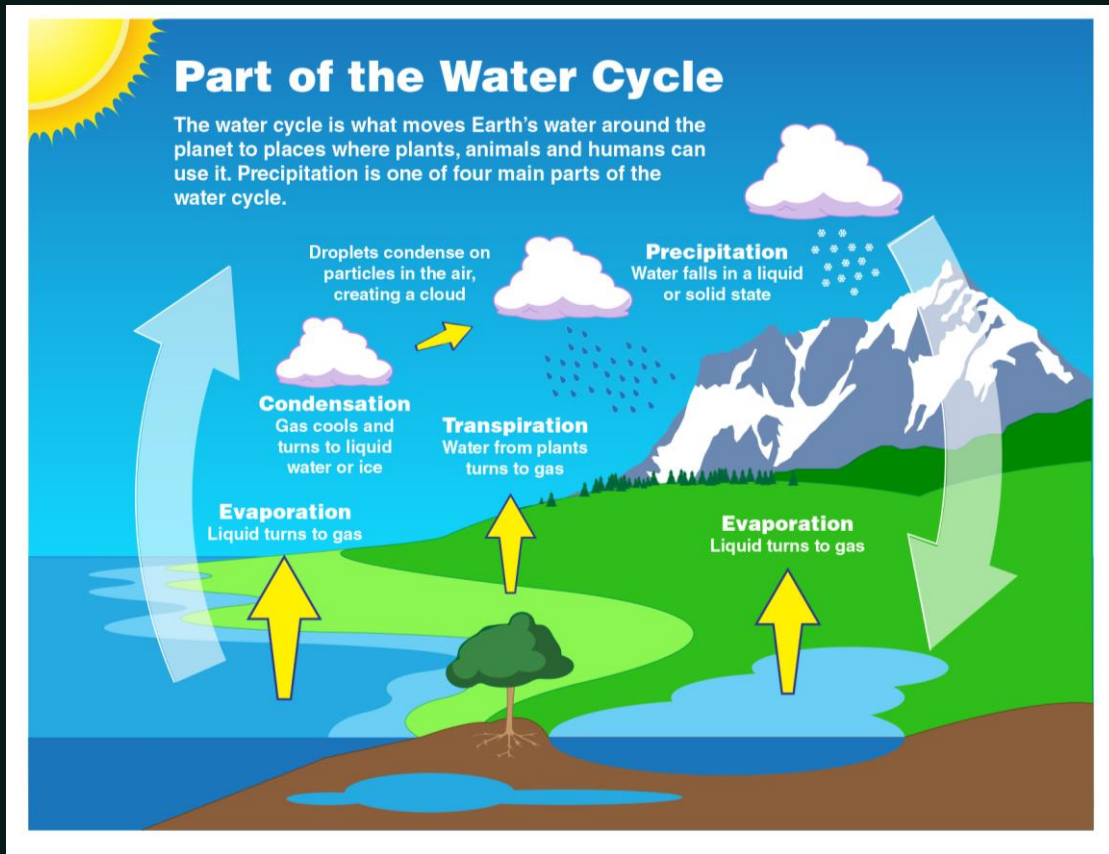
Cloud Development

CLOUD FORMATION

- When water vapor in the air reaches saturation, molecules cling together to form water droplets or ice crystals.
- Several factors can lead to air rising and cooling:
 - Surface heating
 - Topography
 - Frontal (weather front)
 - Convergence
 - Turbulence



Precipitation



NOAA, 2022

P R E C I P I T A T I O N

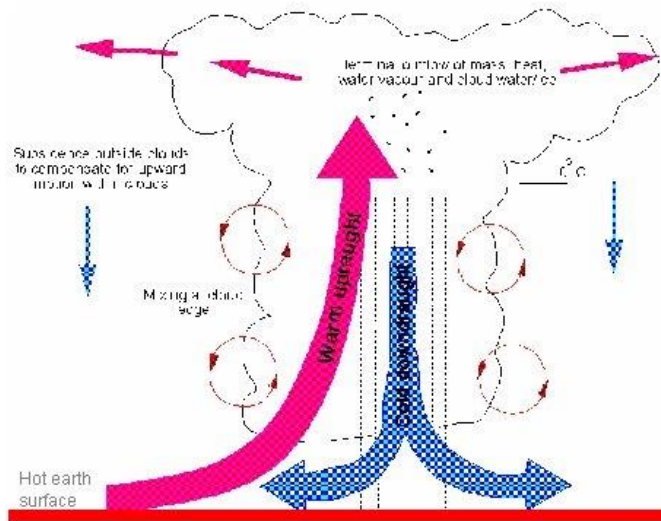
- As droplets condense, they become too heavy to be held aloft, and they fall to the ground as precipitation.
- Rain if the water droplets are liquid.
- Snow if the water crystalized in the atmosphere.
- And there are a variety of variations such as mist, freezing rain, hail, sleet, etc.

Precipitation Mechanisms

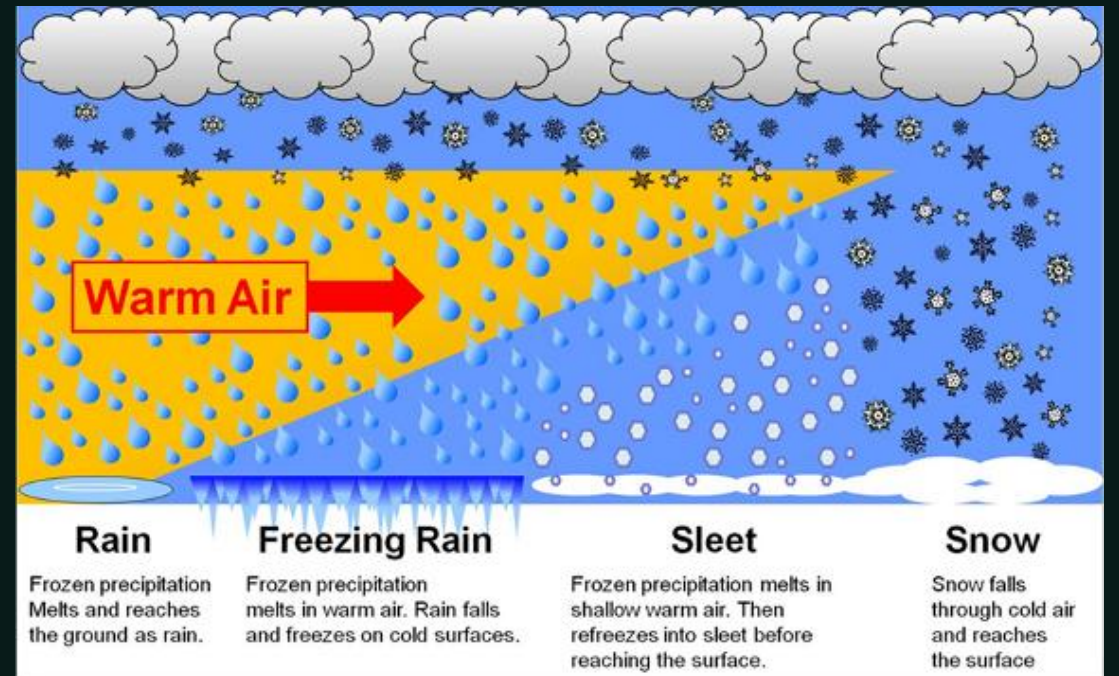
CONVECTIVE UPLIFT

Convective lifting

Convective precipitation occurs when the air near the ground is heated by the earth's warm surface. This warm air rises, cools and creates precipitation.

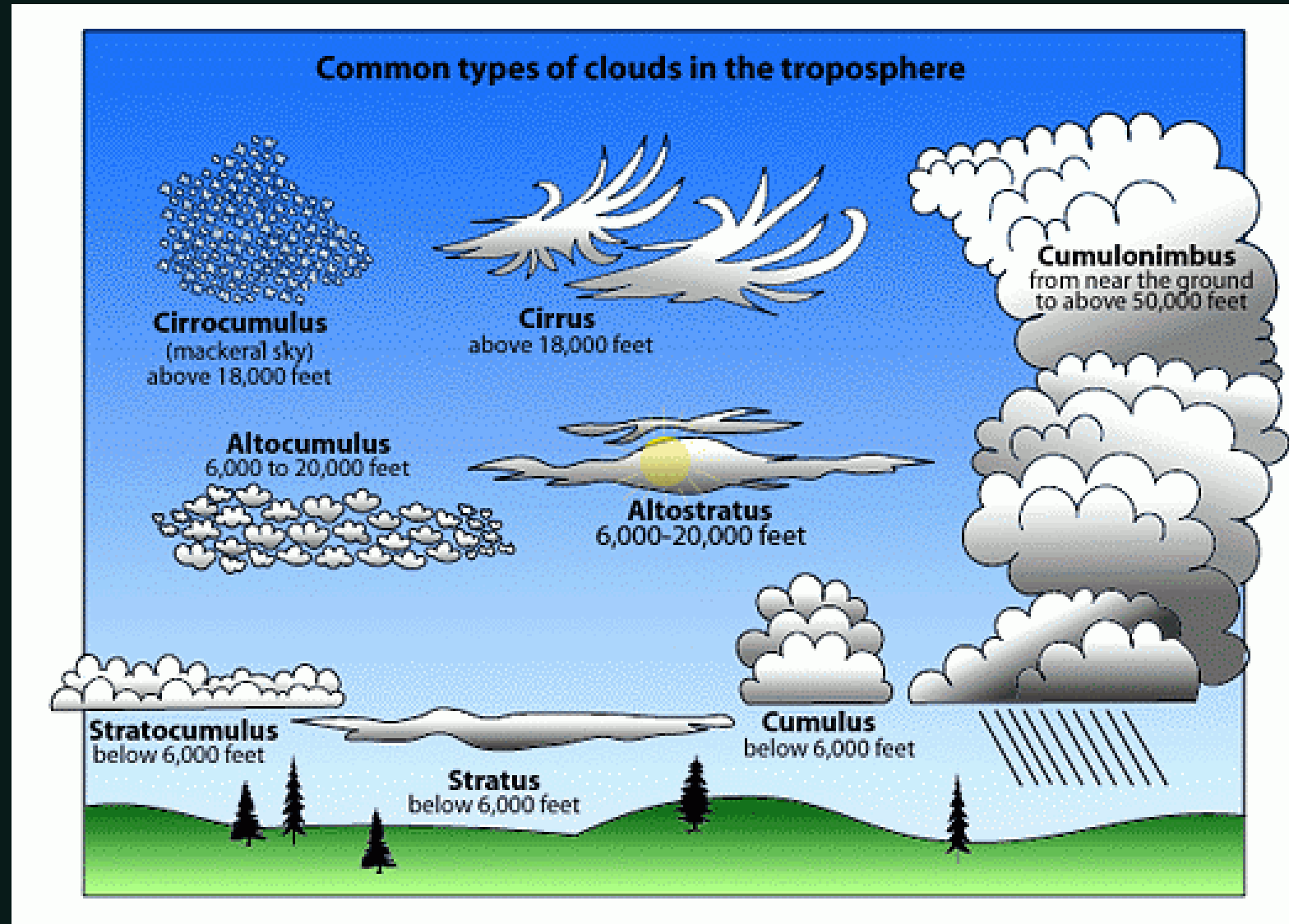


STRATIFORM / ORTHOGRAPHIC



Cloud Types

- Stratus (strato) ~ Layered, sheetlike
- Cumulus (cumulo) ~ Puffy, heaped
- Nimbus (nimbo) ~ Dark, rainy
- Cirrus (cirro) ~ Curly, featherlike
- Alto- ~ High (middle elevation)
- Fracto- ~ Broken (Weather.gov, n.d.)



Storms: Cyclones



PART 3



Contents

Three-Cell Model

Semi-Permanent Pressure Cells

Wind and Pressure

Ocean-Atmosphere Interactions

Storms



Introduction

Part 3 is aspects of circulation that relate to storms.



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29

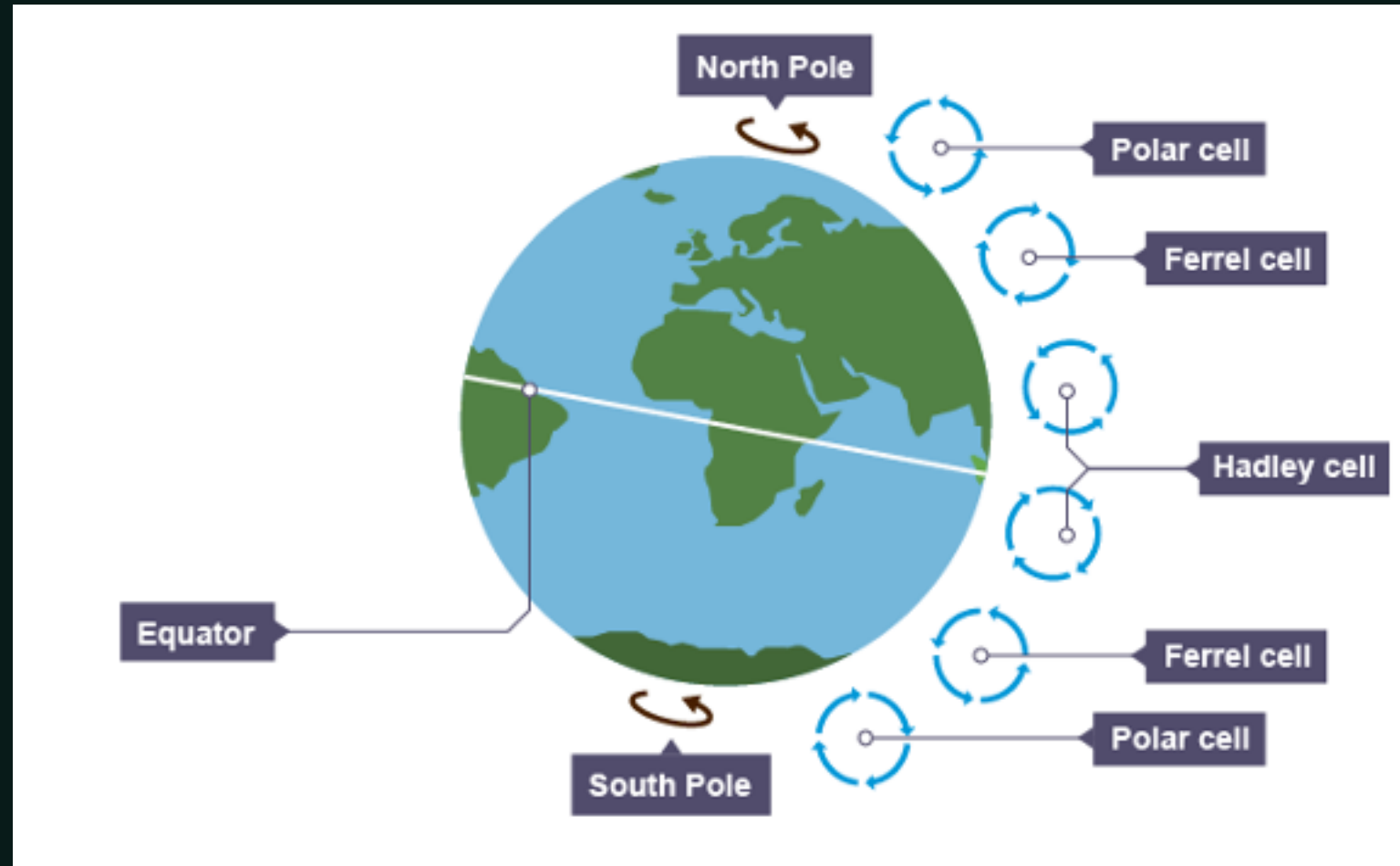


Storms

Circulation and severe
weather

Three-Cell Model

Three cells of circulation per hemisphere are used to explain high level properties of the atmosphere and storm formation.

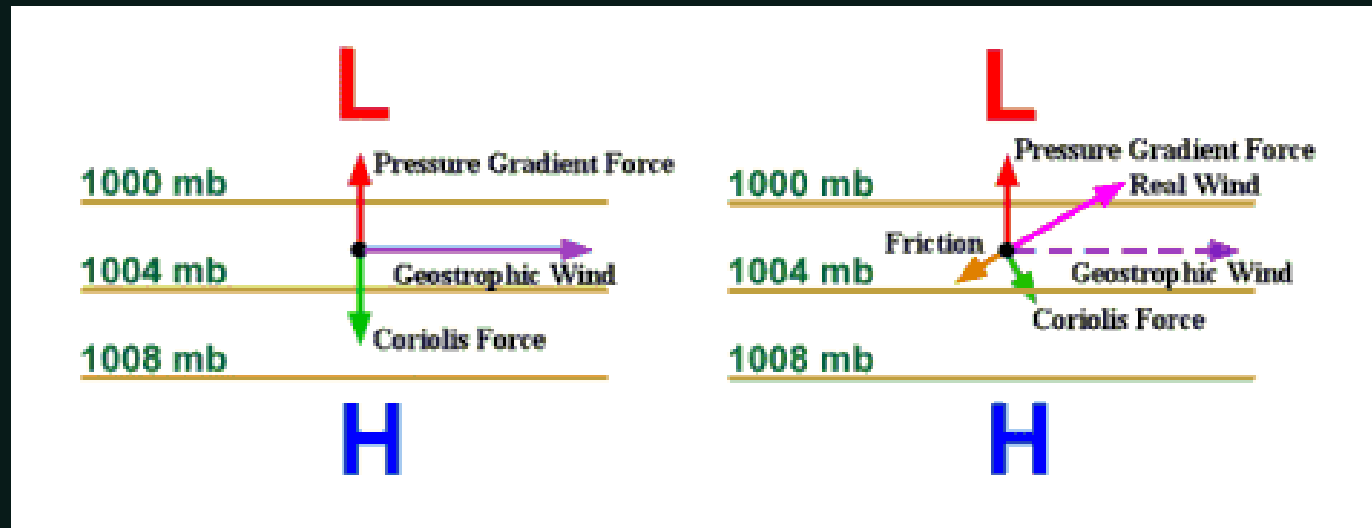


Semi-permanent Pressure Cells

- You've probably heard about some of these before if you pay attention to the weather. Where high or low pressure persists for a long time due to large circulation cells, they are semi-permanent and get special names. Examples include:
 - Aleutian Low
 - Icelandic Low
 - Bermuda High
 - Pacific High

Wind and Pressure

“There are two main forces which affect the movement of air in the upper levels. The pressure gradient causes the air to move horizontally, forcing the air directly from a region of high pressure to a region of low pressure. The Coriolis force, however, deflects the direction of the flow of the air (to the right in the Northern Hemisphere) and causes the air to flow parallel to the isobars. Winds in the upper levels will blow clockwise around areas of high pressure and counterclockwise around areas of low pressure. The speed of the wind is determined by the pressure gradient. The winds are strongest in regions where the isobars are close together.” (Weather.gov, n.d.)



Ocean-Atmosphere Interactions

OCEAN TO ATMOSPHERE

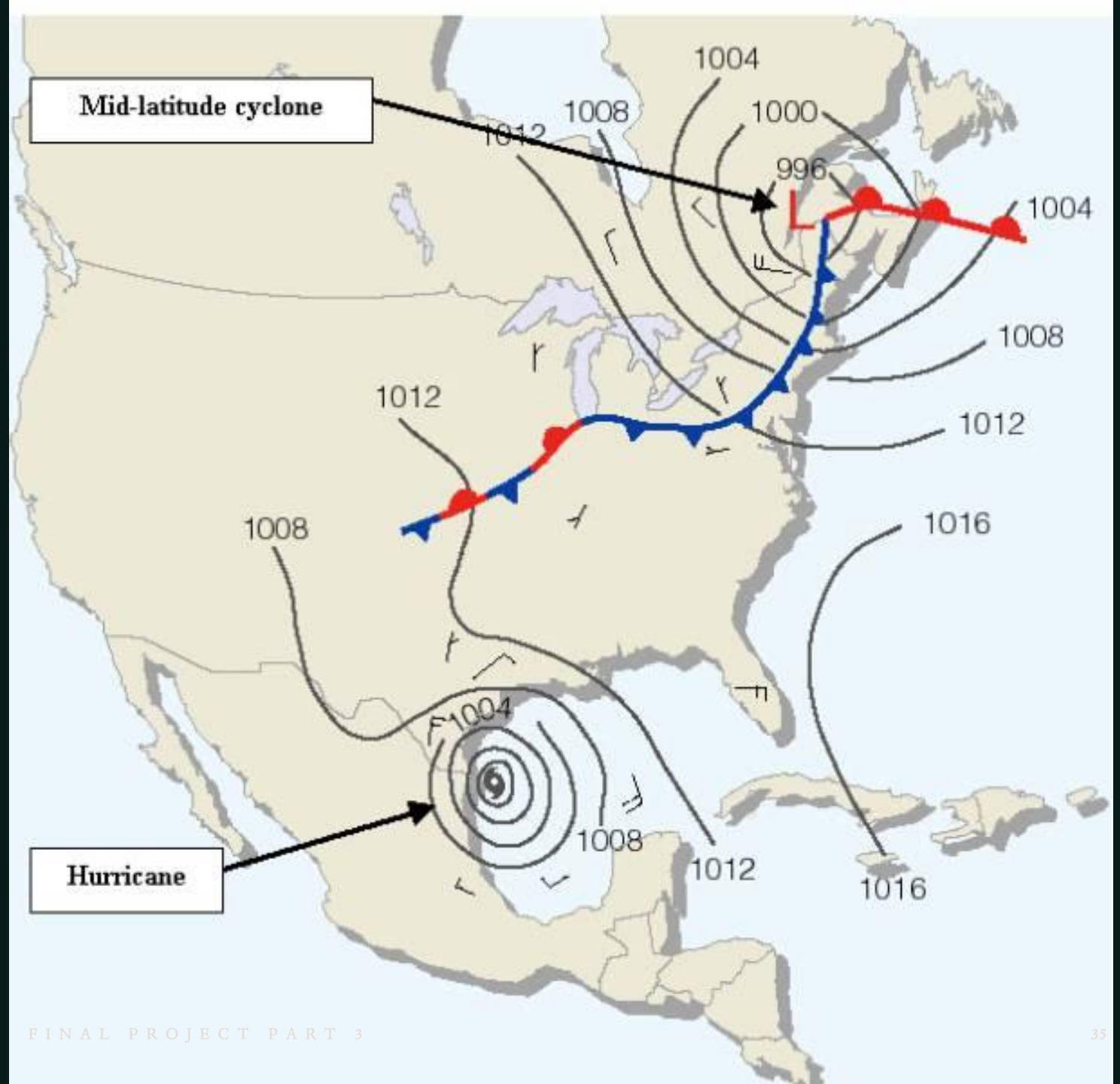
- Water evaporates (or sublimates from floating ice) adding moisture
- When the ocean is warmer than the atmosphere it can return heat and create airflow
- Changes in temperature can change sea level and ability of the air to hold moisture

ATMOSPHERE TO OCEAN

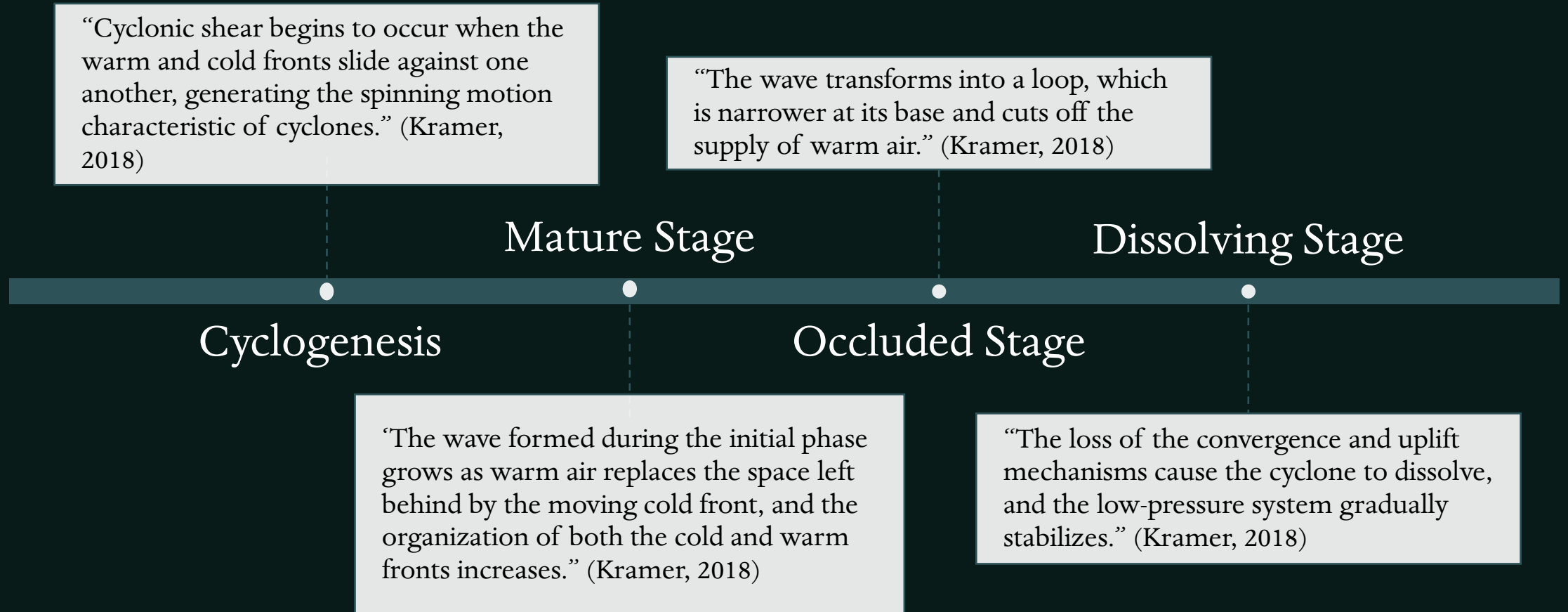
- Precipitation can return water directly to the ocean
- When the ocean is cooler than the atmosphere it can absorb heat, and create airflow
- Both further interact with the land

Storms: Mid-Latitude Cyclones

A mild low-pressure system that sets up in the mid-latitudes. The isobars are less dense than a tropical storm or hurricane. It rotates in the same direction. Is associated with precipitation events.



Storms: Life Cycle



Storms: Causes

- In the jet stream, weak vertical (downward) motion begins.
- Leads to a mid-level vortex of counterclockwise circulation (in Northern Hemisphere)
- Moved around by local wind and pressure conditions
- Air is forced to rise ahead of the motion, dropping the pressure
- Upward motion produces clouds and rain/snow
- Storm will intensify until it becomes stationary
- Precipitation may continue for a while after, but storm system is now in decline

Types of Storms

MAJOR CLASSES

- Thunderstorms
- Hurricanes
- Tornadoes
- Winter Storms

SOME SUBTYPES

- Derecho Storms
- Blizzards
- Ice Storm
- Lightning Storm
- Hailstorm
- Thundersnow

Severe Weather

Primary causes of death and property damage from each type of storm.



(National Weather Service, n.d.)/(CNN, 2019)

- Hurricanes : water (flooding, storm surge) (Erdman, 2021)
- Thunderstorms : lightning (National Weather Service, n.d.)
- Tornadoes : flying debris (Missouri Storm Aware, n.d.)
- Winter Storms : driving (Disaster Center, 1999)



Storms: Mitigation

Mitigation efforts can be improved by better prediction methods.

Improved flood mitigation (better levies, for example)

Storm drainage systems

Build electrical lines under ground to prevent wind damage

Improved building techniques





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[odds#:~:text=Lightning%20is%20a%20major%20cause,have%20suffered%20irreversible%20brain%20damage.](https://www.weather.gov/safety/lightning-odds#:~:text=Lightning%20is%20a%20major%20cause,have%20suffered%20irreversible%20brain%20damage.)

Thank you

Betsy McCall

