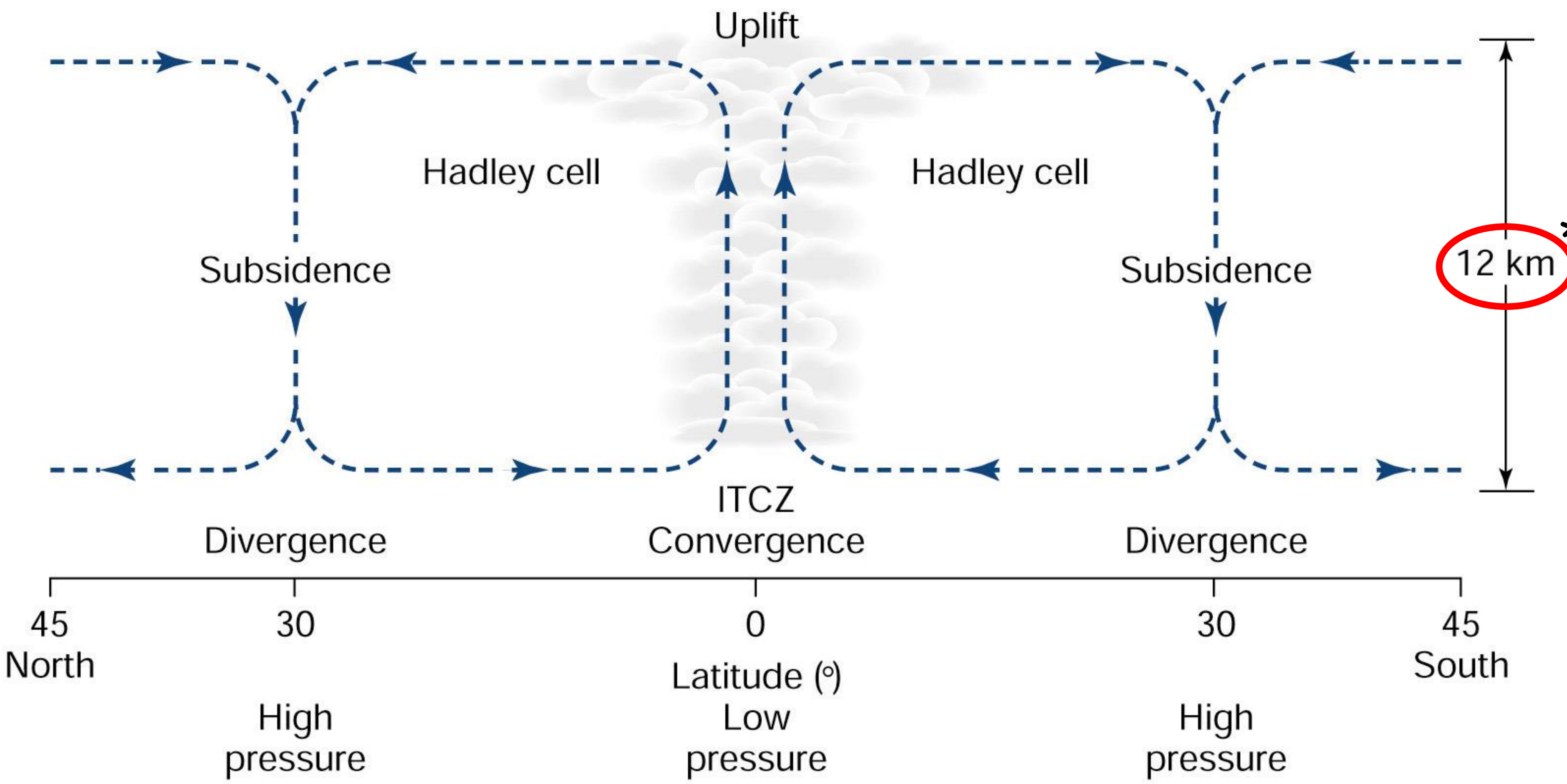
This Week

- Seasonality of Hadley Circulation
- Midlatitude circulation – variable weather
- Land/Ocean Contrasts

Modified Hadley Circulation



Horizontal motions

convergence: coming together

divergence: spreading apart

Vertical motions

upwelling: rising air

subsidence: sinking air

Hadley Circulation Summary

- **Upwelling** in tropics with surface convergence → **ITCZ rainy**

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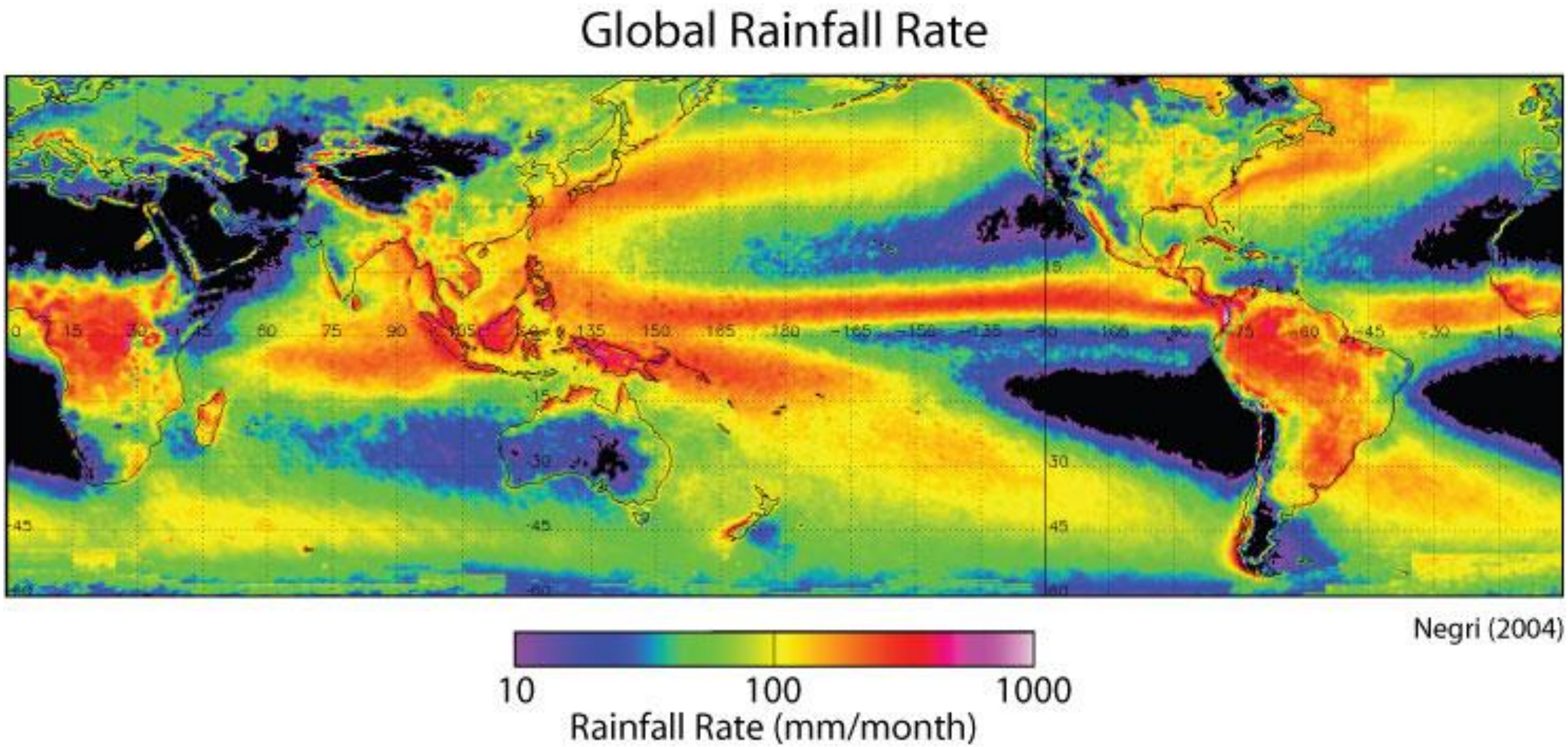
- Subsiding branches located around 30^{o} N and 30^{o} S → **MAJOR DESERTS**
- ***Low altitude*** flow, converging equatorward is northeasterly to easterly in NH and southeasterly to easterly in SH→ tropical "**TRADE WINDS"**

"Seeing" Hadley Circulation: Precipitation

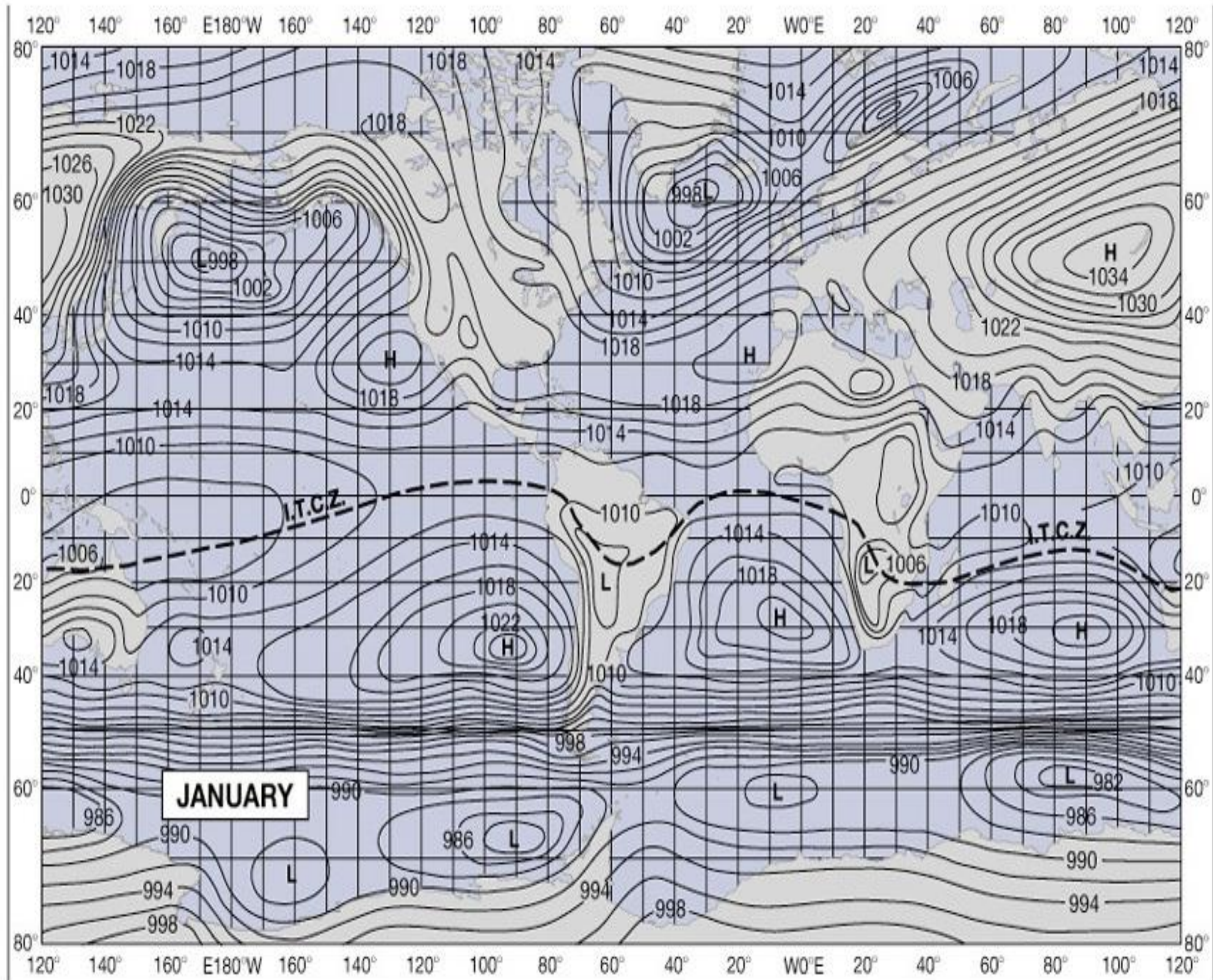


“Seeing” Hadley Circulation: Pressure

Lines of constant pressure (isobars).

More closely spaced lines: steeper change in pressure

Average Pressure Contours at Surface



(a)

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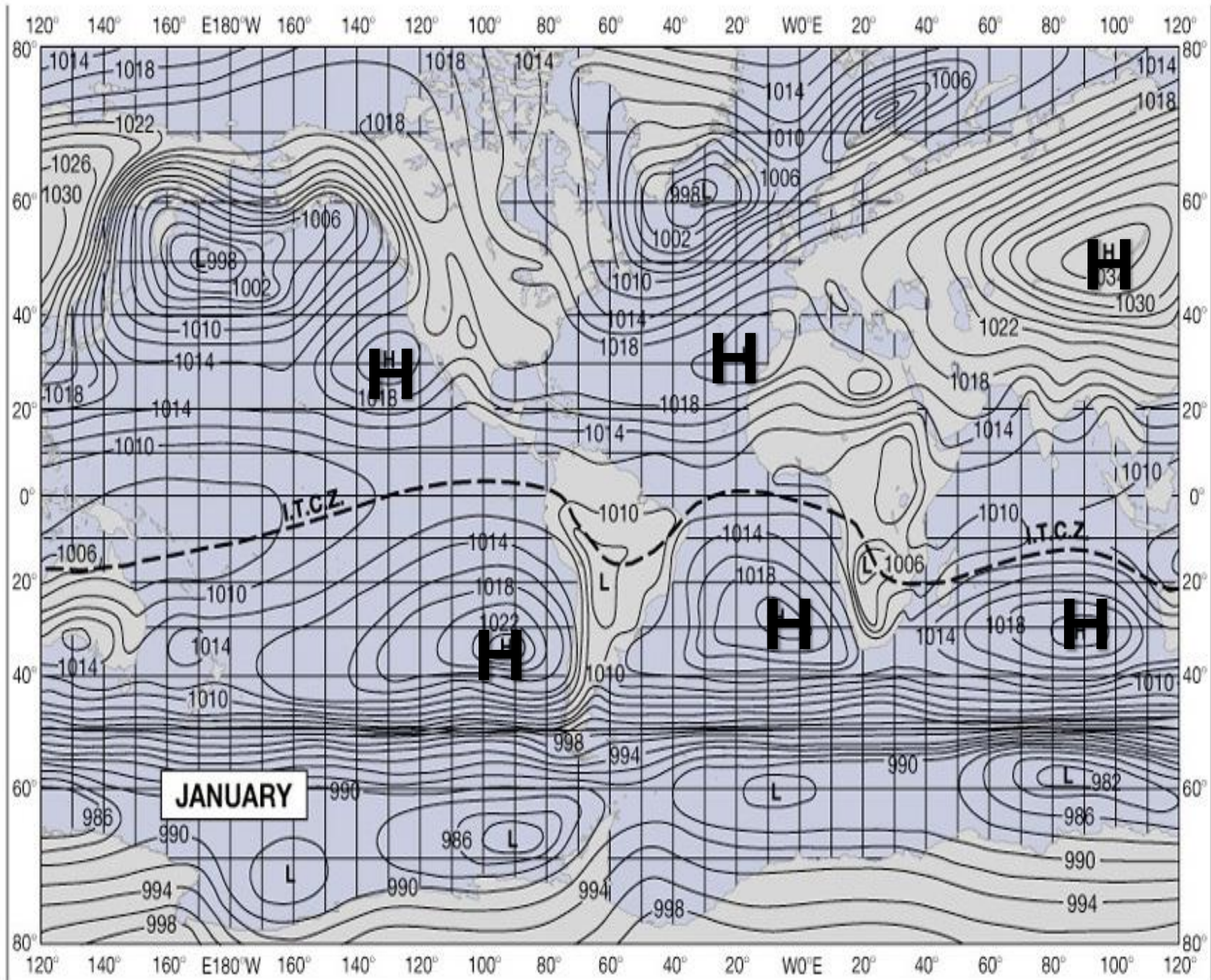
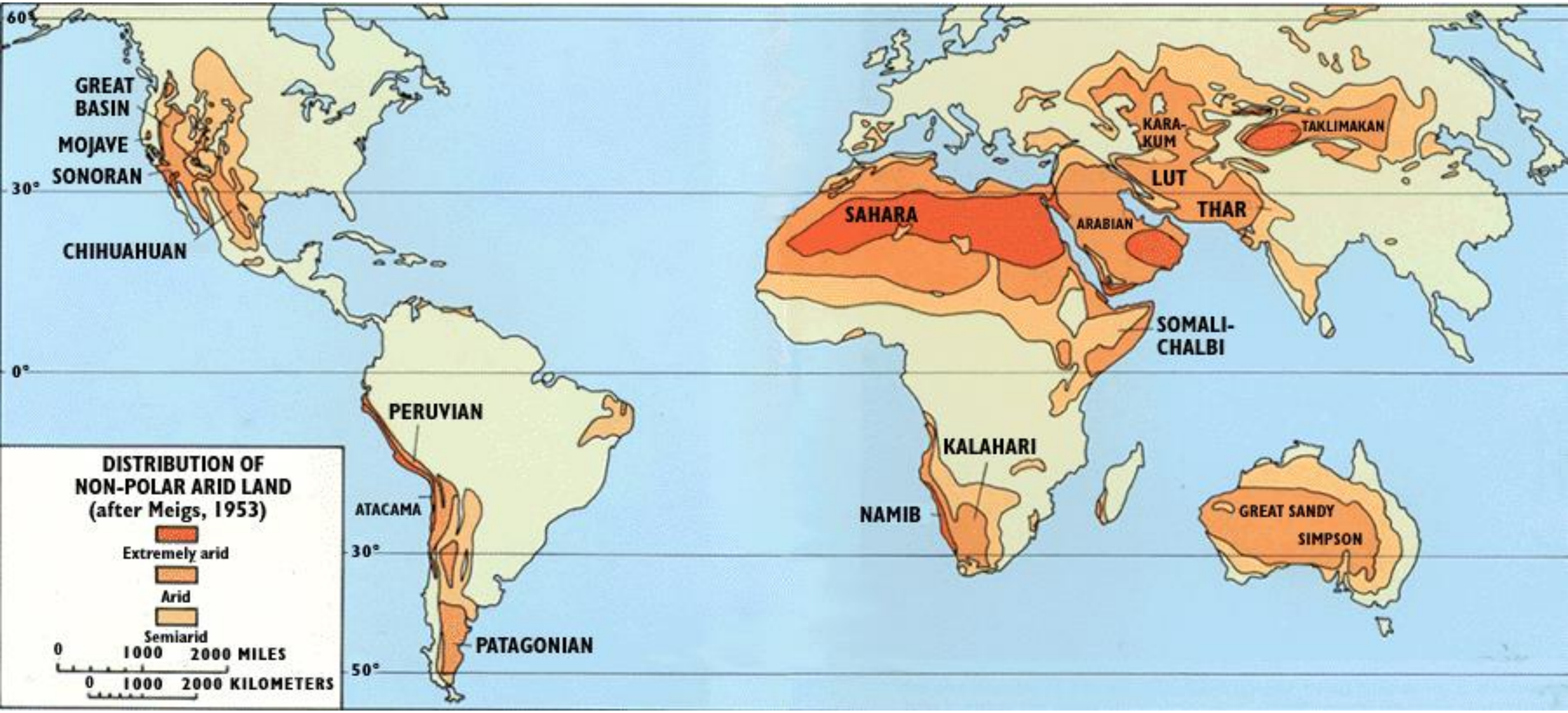


(a)

World's Deserts



Not shown: Polar Regions!

Some of the deserts at 30^{o}N/S

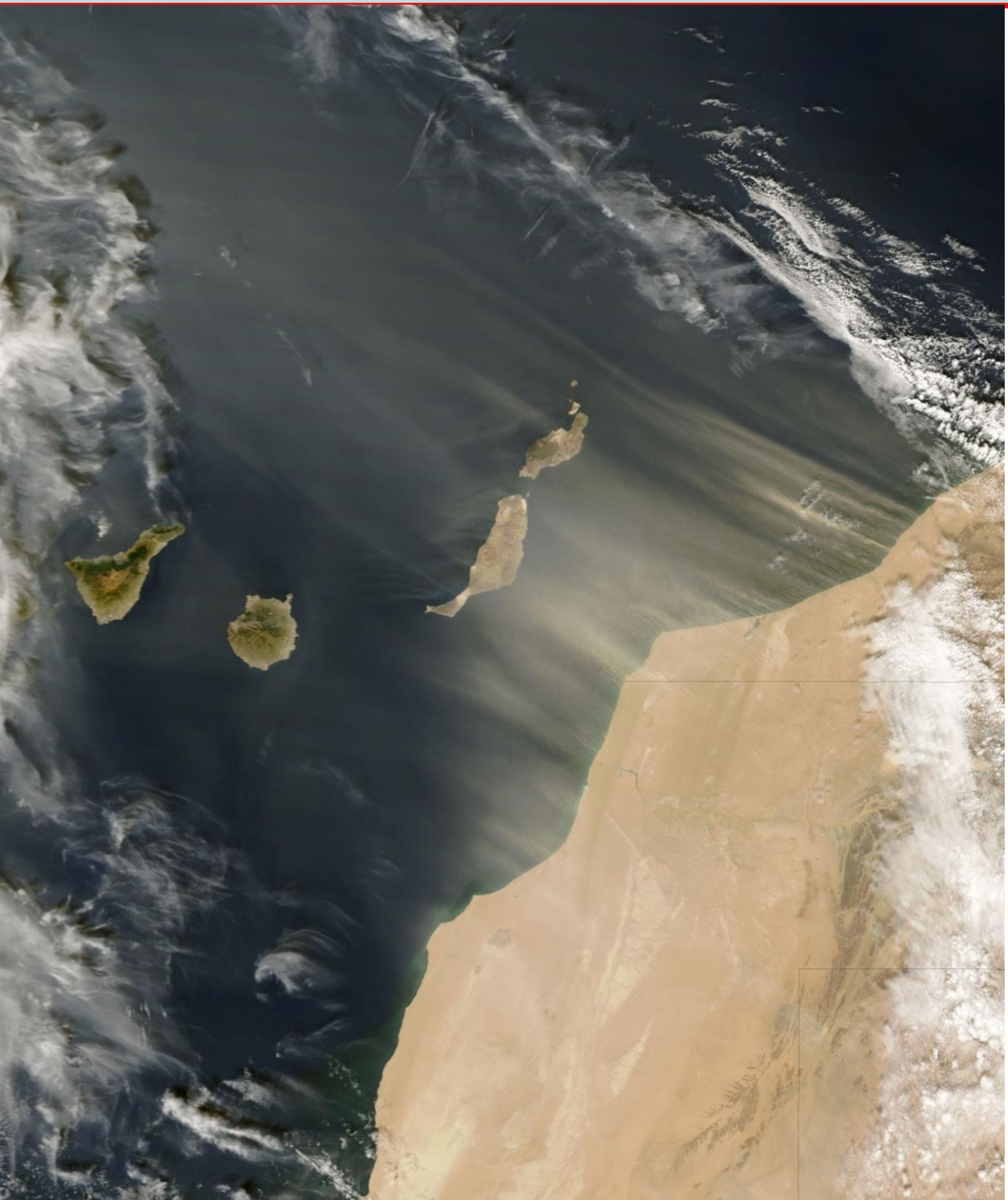

Namib (Africa)


Great Sandy (AUS)


Thar (India/Pakistan)

Sahara
(N. Africa)

World’s Deserts



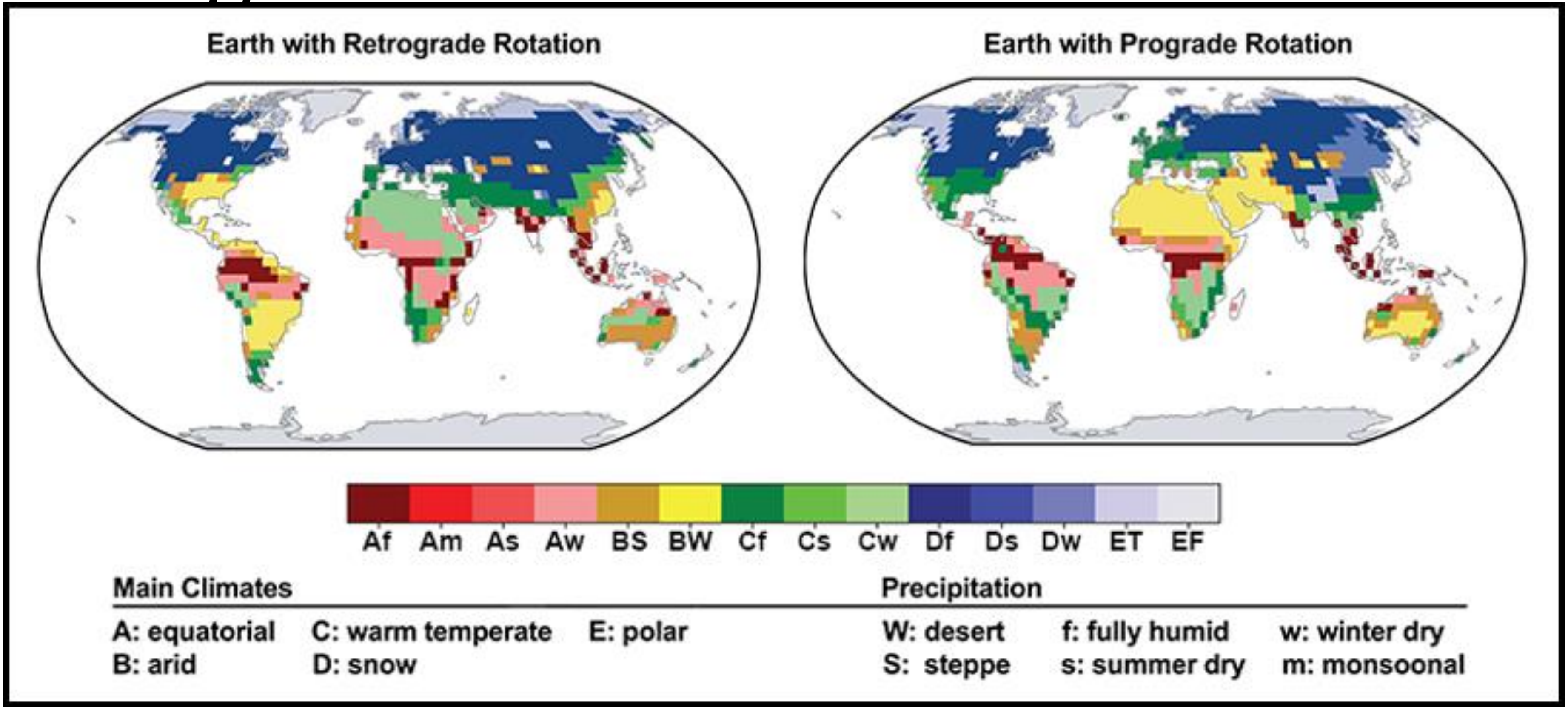
Desert dust blows from W. Sahara and N. Morocco over Canary Islands (in picture).

Desert dust is a source of nutrients to ocean and land biota (often ½ a world away).

What if the Earth rotated in the opposite direction?

https://eos.org/articles/reversing-earths-spin-moves-deserts-reshapes-ocean-currents

opposite rotation ***normal rotation***



Poll Question

Suppose you wanted to the take February vacation in the sunny and warm tropics. Because you want sunny dry weather you choose

When poll is active, respond at **PollEv.com/joelathornto254**

Text **JOELATHORNTO254** to **22333** once to join

Costa Rica (NH)

Amazonia (SH)

Total Results: 0

Shifting ITCZ?

[TRIMM Rainfall]

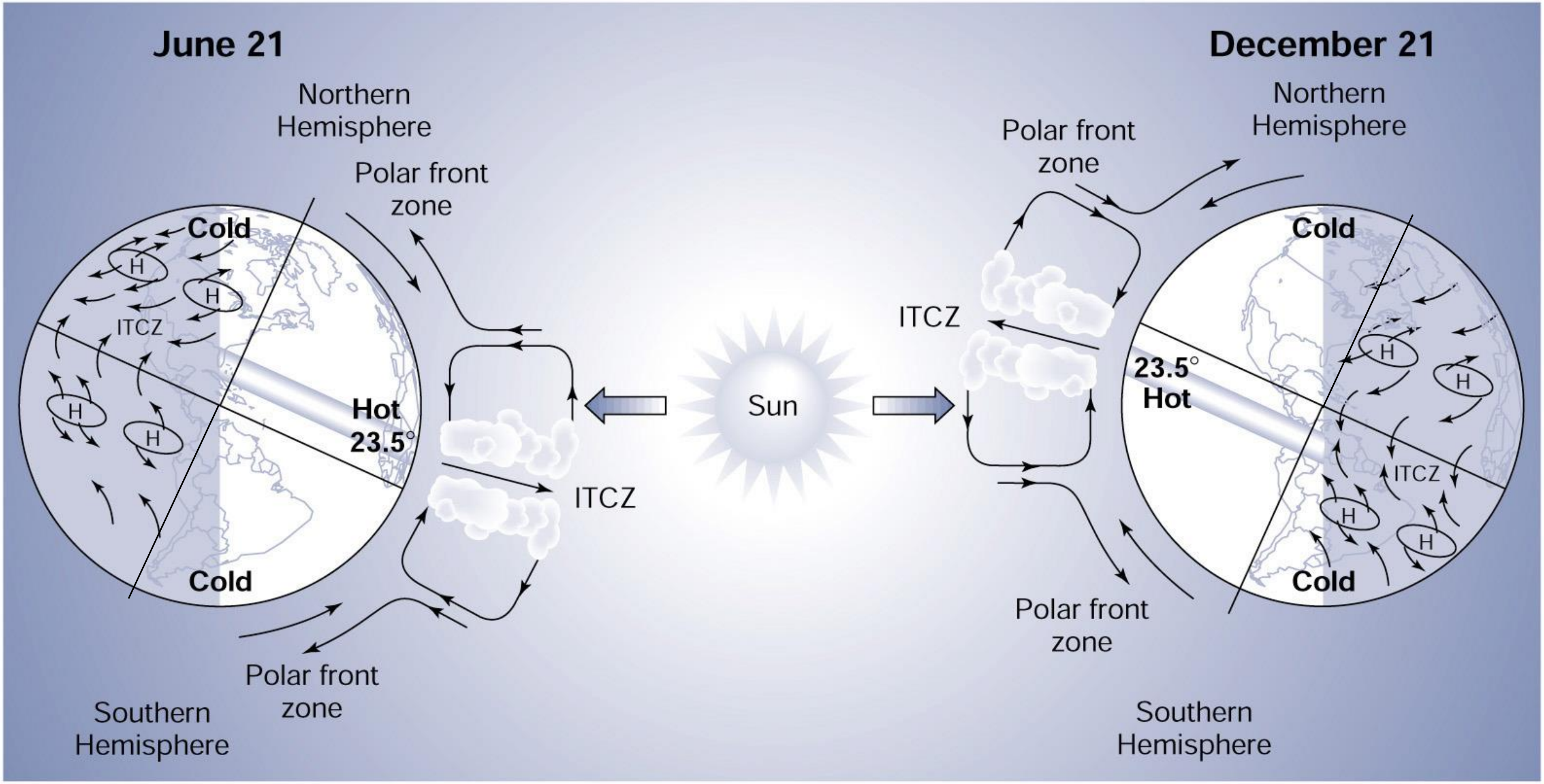
http://eoimages.gsfc.nasa.gov/images/globalmaps/data/mov/TRMM_3B43M.mov

[NDVI Global Vegetation]

https://youtu.be/tuKTLB0Soys

Seasonality

Seasonal Shift in Hadley Circulation



ITCZ location shifts N-S depending on season.
Leads to wet and dry seasons in the tropics.

Poll Question

Seasons on Earth occur because the Earth's of rotation tilts back and forth over a year

Visual settings

Activate

Show results

Poll locked. Responses not accepted.

Show correct

Lock

True

Clear results

Fullscreen

False

Next

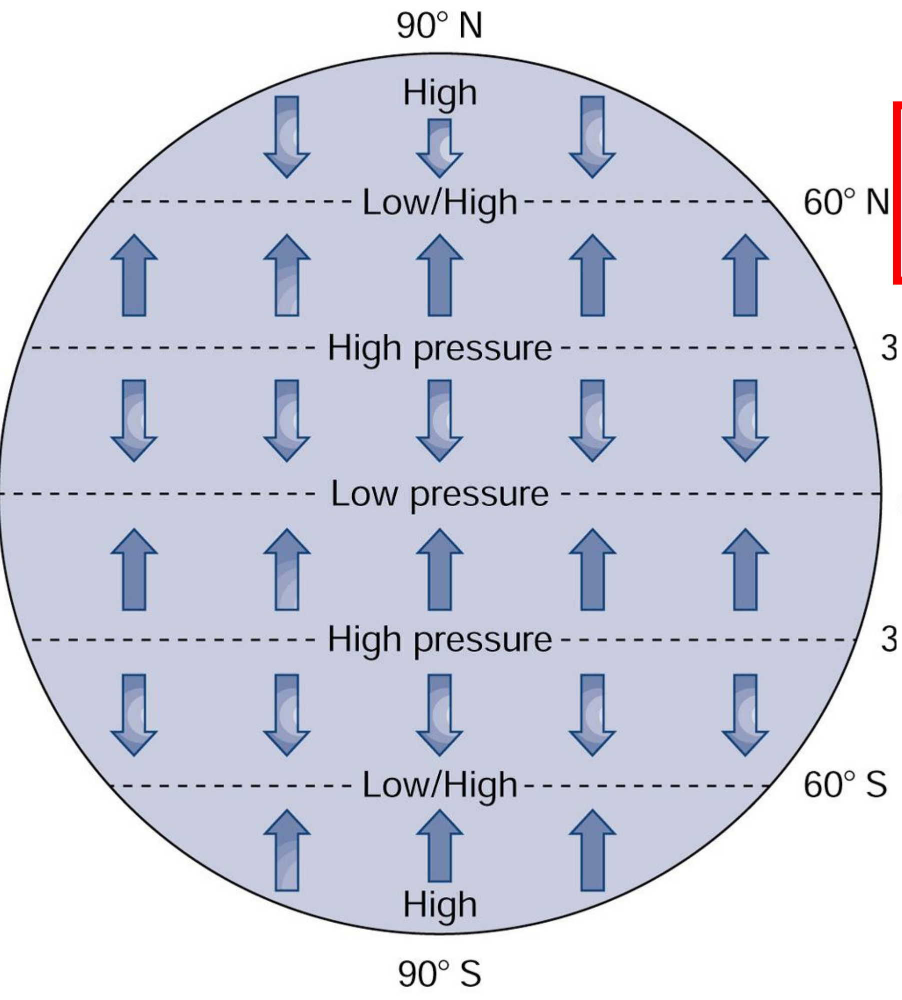
Previous

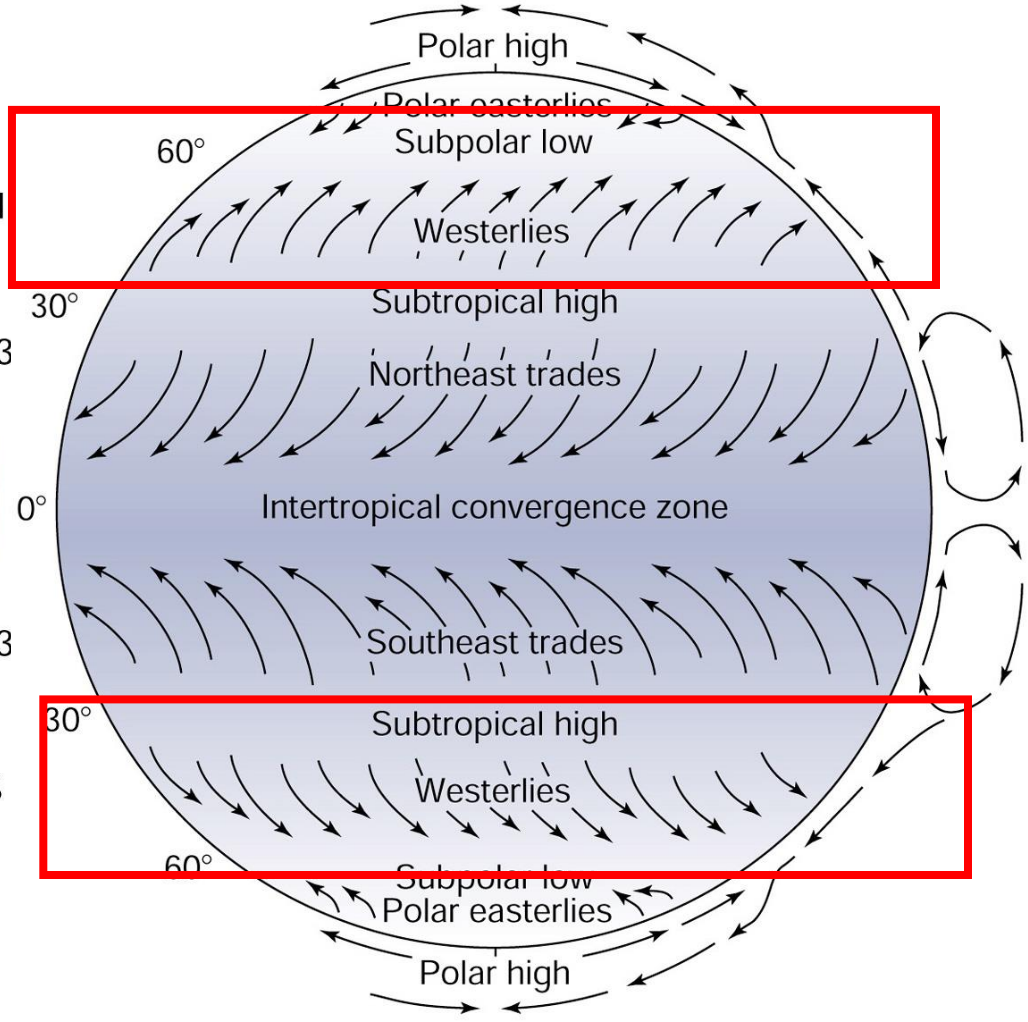
Total Results: 0

Mid-latitude Circulation

- Westerly flow both NH and SH
- Strong temperature gradient gives rise cold/warm fronts (moving air masses)
- Cyclones and Anticyclones

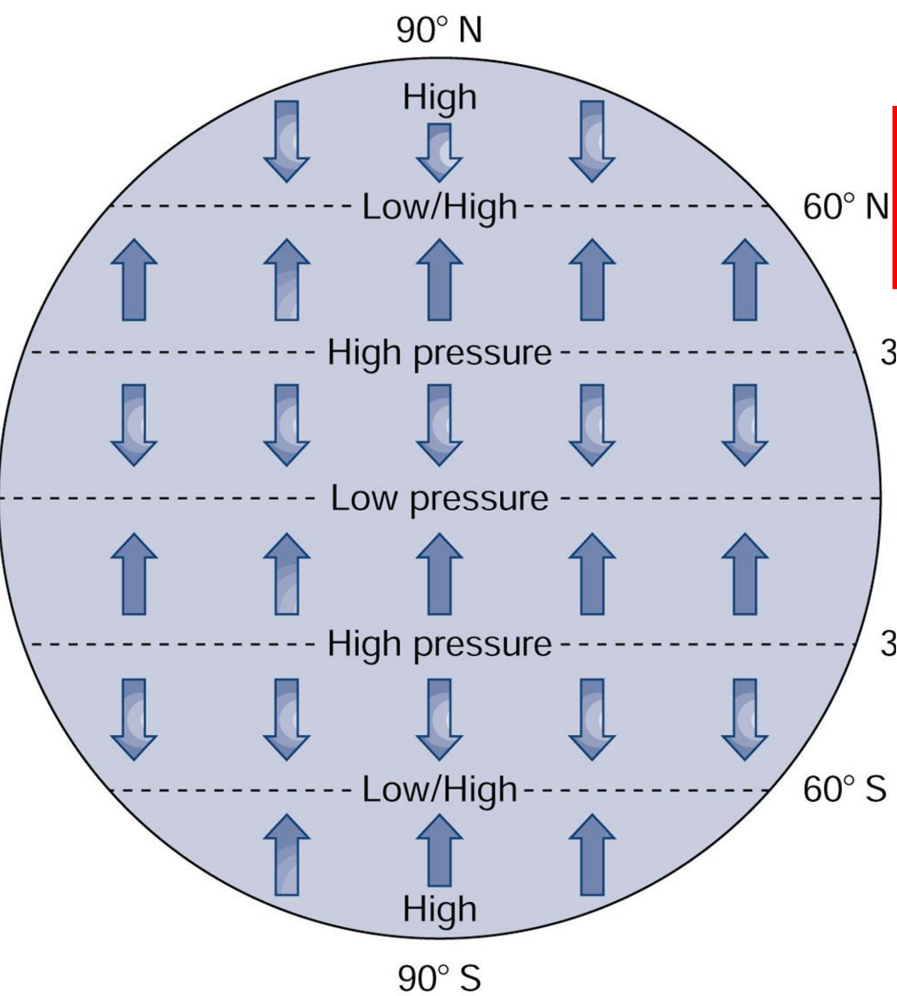
Mid-latitude Westerlies

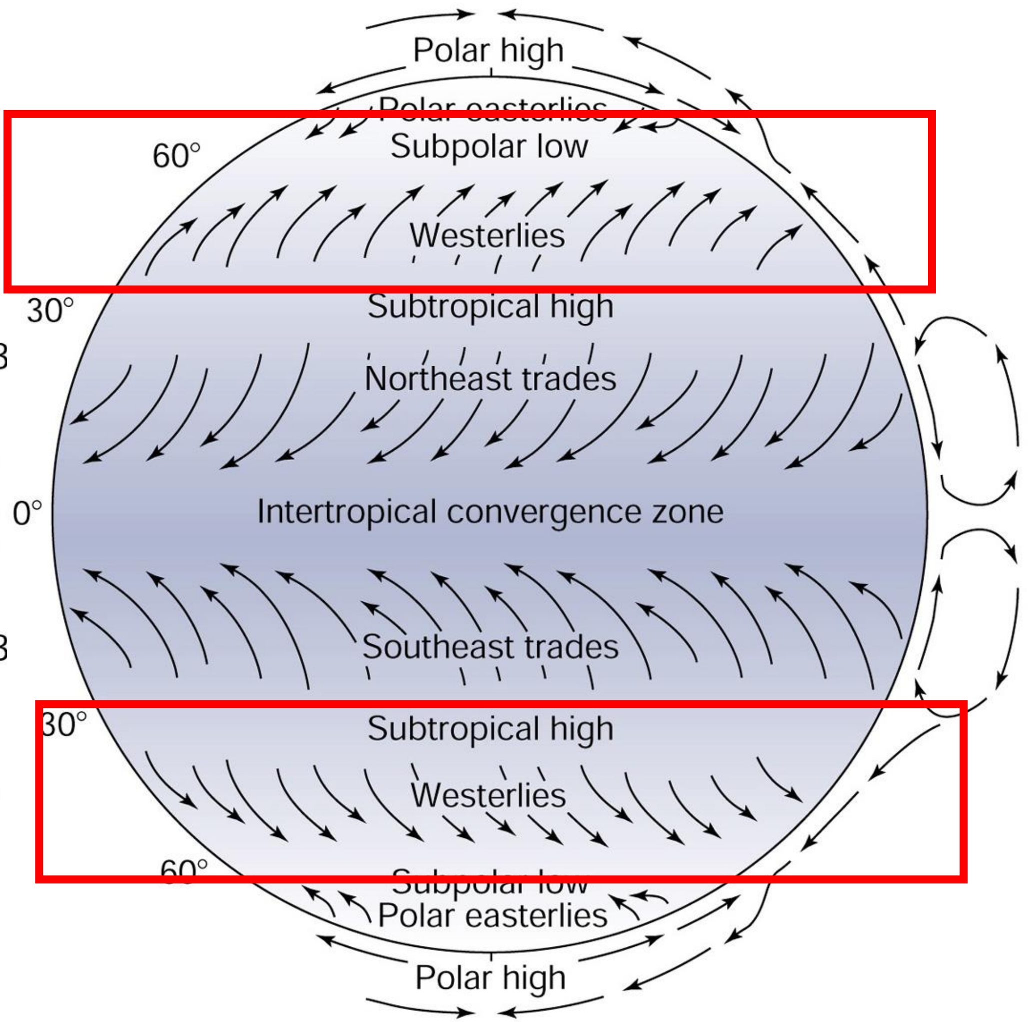




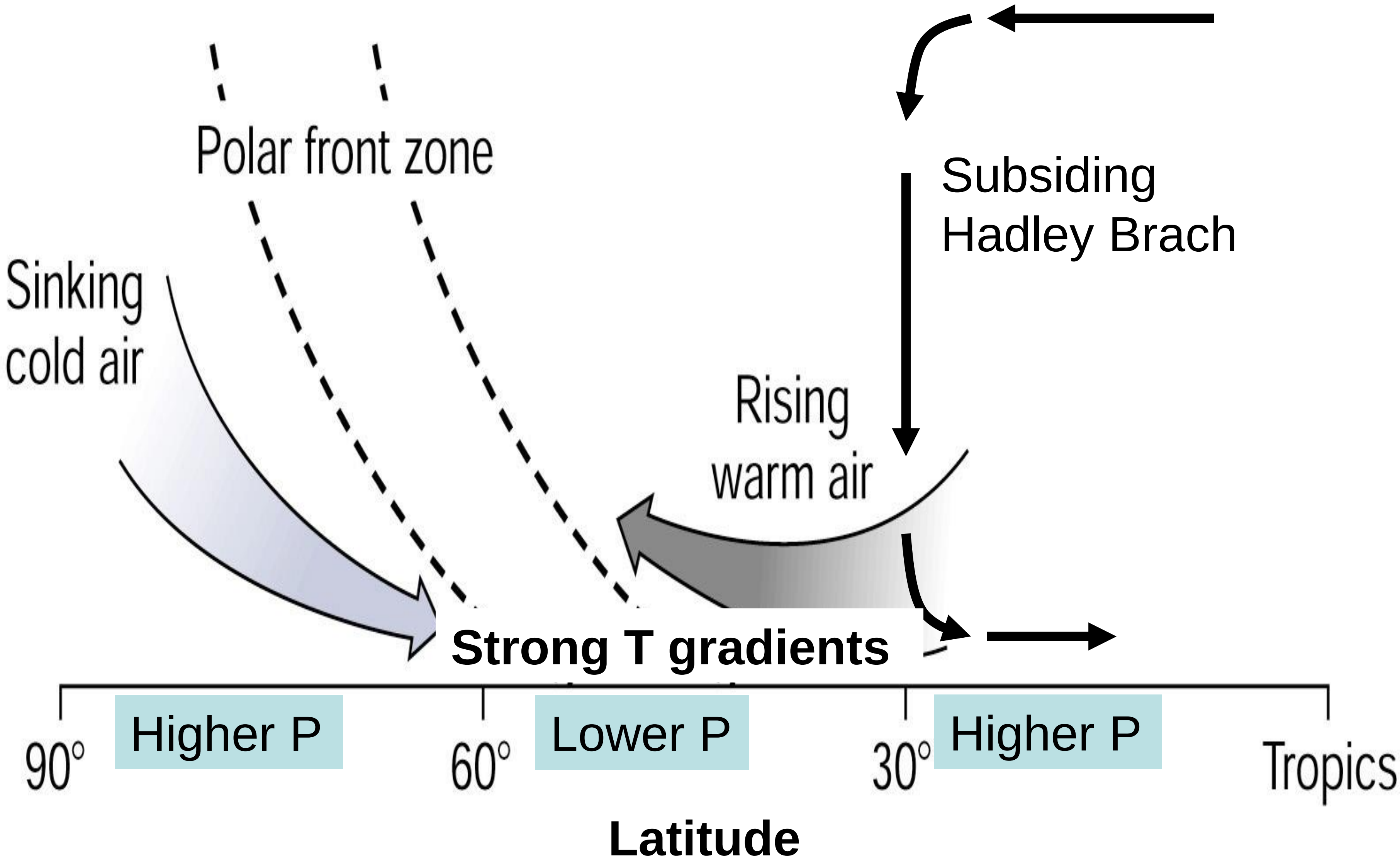
Mid-latitude weather "fronts"

Mid-latitude Westerlies





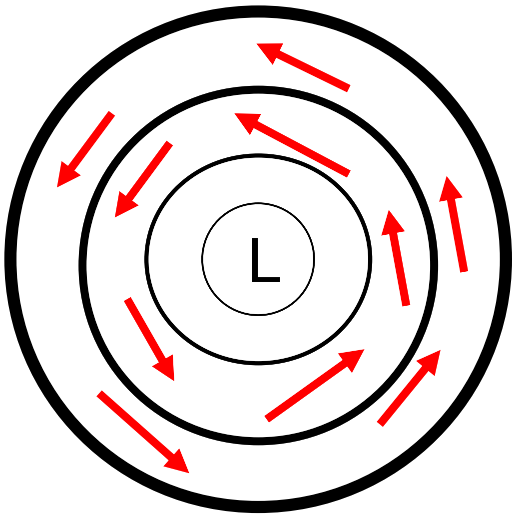
Warm/Cold Fronts



Flow Around High and Low Pressure Centers

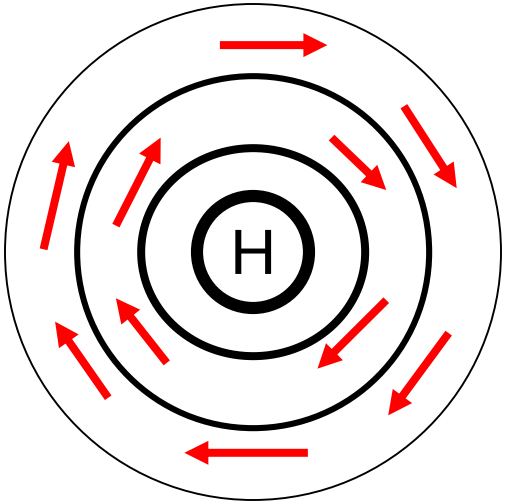
Upper-level flow is **geostrophic**: parallel to isobars.

In NH flow counterclockwise around Low→**cyclonic flow**



Low Pressure Center

In NH flow clockwise around High→**anticyclonic flow**



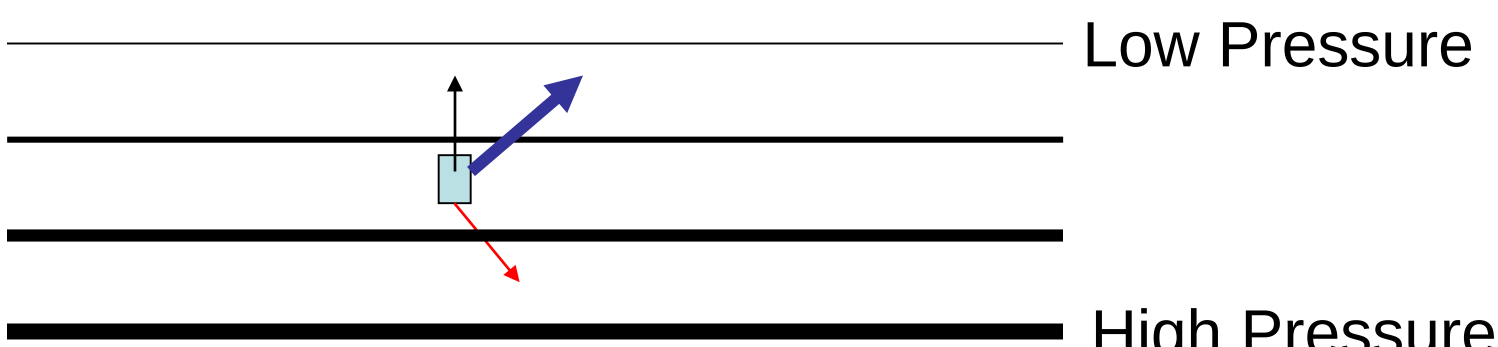
High Pressure Center

Surface Flow Impacted by *Friction*

Forces

PGF **Coriolis**

Actual Flow direction

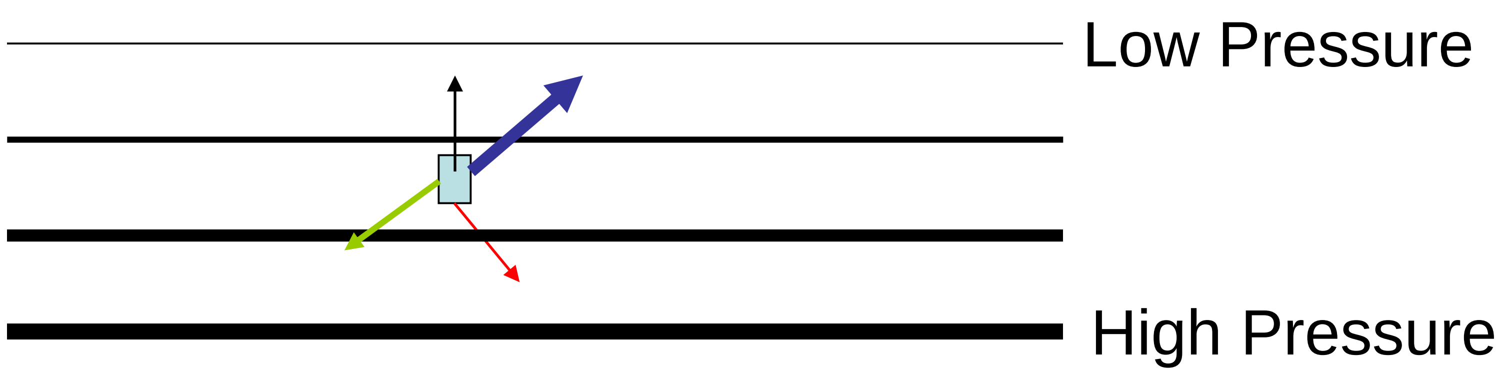


Surface Flow Impacted by *Friction*

Forces

PGF Coriolis Friction

Actual Flow direction

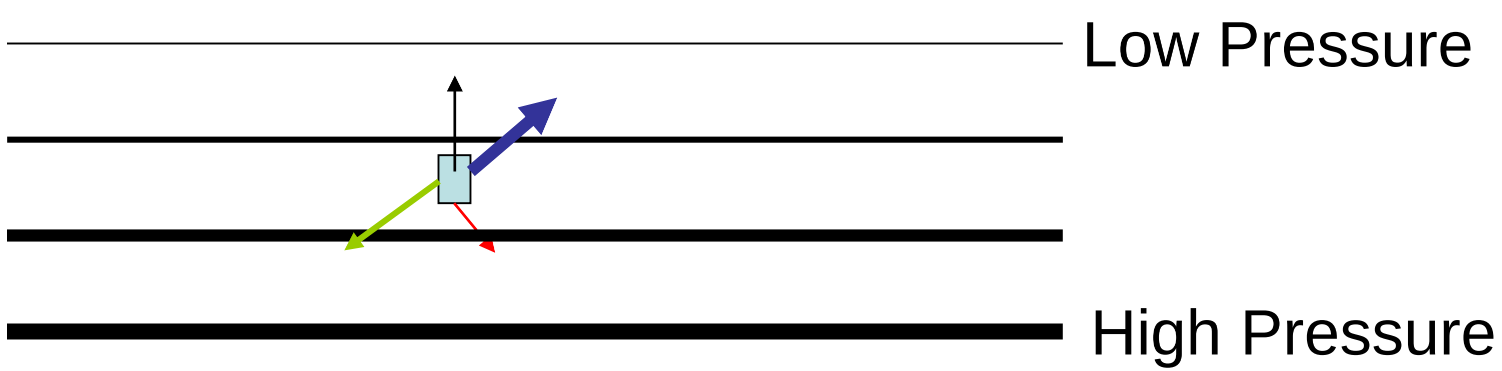


Friction acts opposite to flow direction, causes *<u>slower flow speed</u>* and thus *<u>smaller Coriolis effect</u>* (doesn’t curve as much)

Surface Flow Impacted by *Friction*

Forces

PGF **Coriolis** **Friction** **Actual Flow direction**

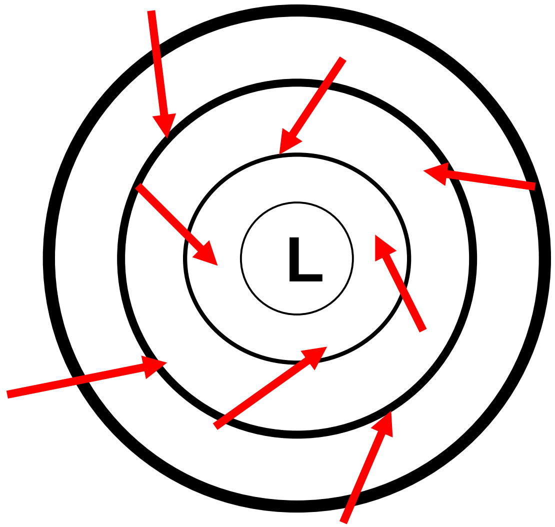


Friction causes flow at Earth’s surface to move ***away*** from high pressure (diverge) and ***towards*** (converge) low pressure.

Surface-level Flow affected by Friction

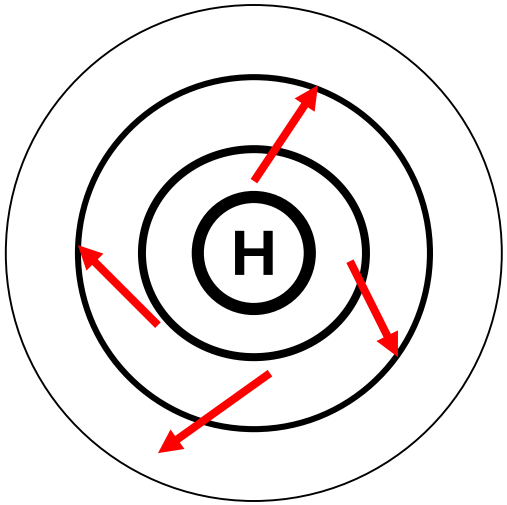
Centers of **low** or *high* pressure at surface induce flow that spirals **in** or *out*, respectively.

Convergence/uplift
Stormy Weather



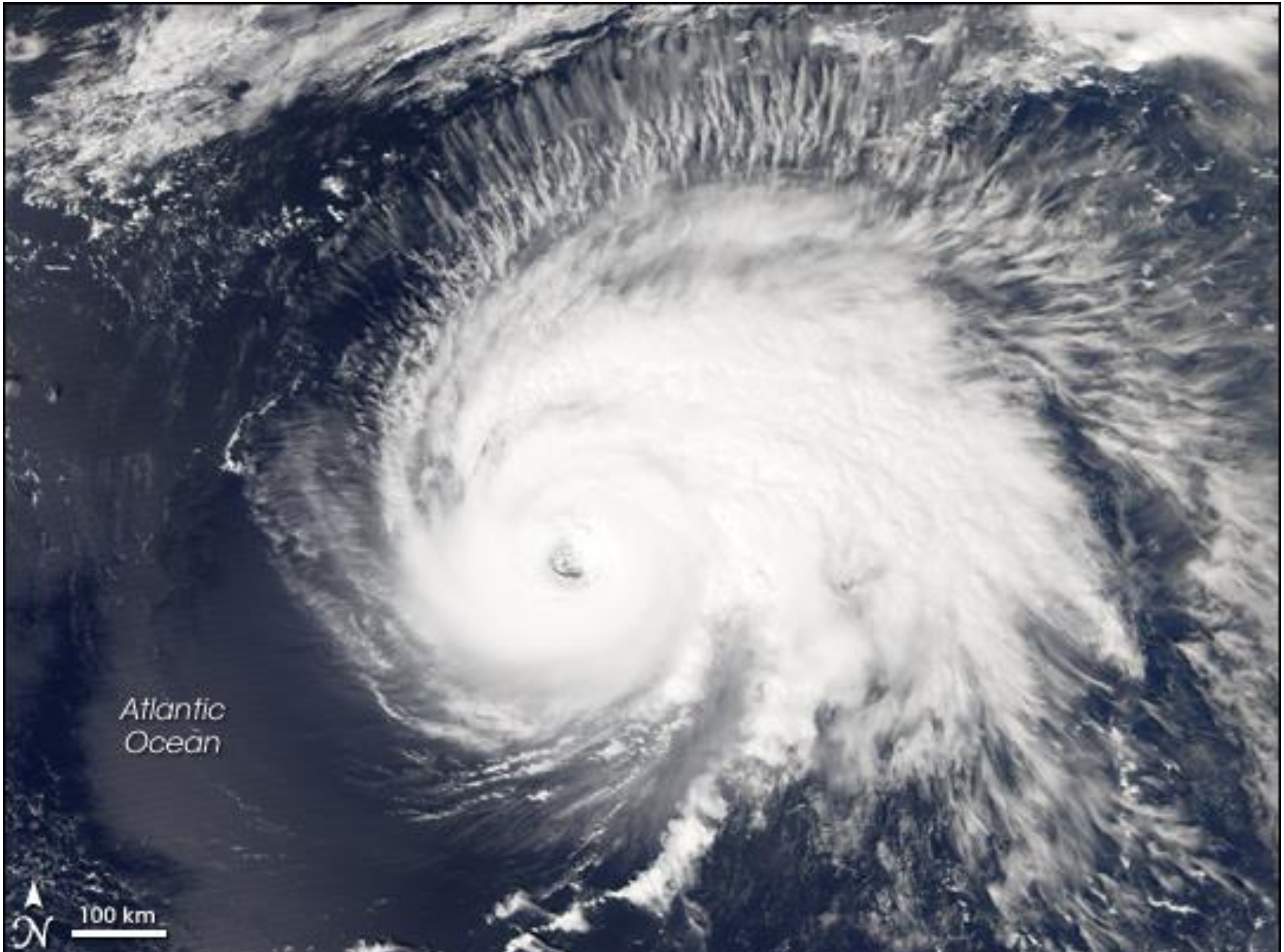
Low Pressure Center
cyclones

Divergence/Subsidence
Sunny / Dry Weather



High Pressure Center
anticyclones

Tropical Cyclone—Hurricane Gordon



Midlatitude Cyclones

Poll Question

The satellite images of midlatitude storms sho lecture correspond to

Visual settings

Activate

Show results

Show correct

Lock

Clear results

Fullscreen

Poll locked. Responses not accepted.

- A SH storm on the left, and NH on the right
- A SH storm on the right, and NH on the left
- Both in the SH
- Both in the NH

Next

Previous

Total Results: 0

Midlatitude Average Circulation (Summary)

- Westerly flow 35 – 55 N/S
- Large latitudinal temperature gradients – warm and cold fronts induce storminess
- Low pressure centers are wet/rainy (storms) high pressure centers are dry/sunny

Poll Question

Which location has a colder winter

When poll is active, respond at **PollEv.com/joelathornto254** Text **JOELATHORNTO254** to **22333** once to join

Prince Rupert British Colombia (53N)

Omaha Nebraska (41N)

Total Results: 0

Questions

- **Why is Seattle a milder climate than Boston? (Seattle is if anything further north)**

- **Why can I drive 1 hour from the coast and be much hotter than at the coast in the summer?**

- **What causes torrential rain for days in places like India, Southeast Asia and even SW N. America during certain seasons?**

Atmosphere-Ocean Couplings

1. **Heat Exchange**

2. **Mass Exchange (water and carbon cycles)**

3. **Momentum Exchange (surface wind stress)**

Land/Ocean Contrasts

Ghostly Continents

Contours show difference between average summer and winter temperature: $T_{summer} - T_{winter}$

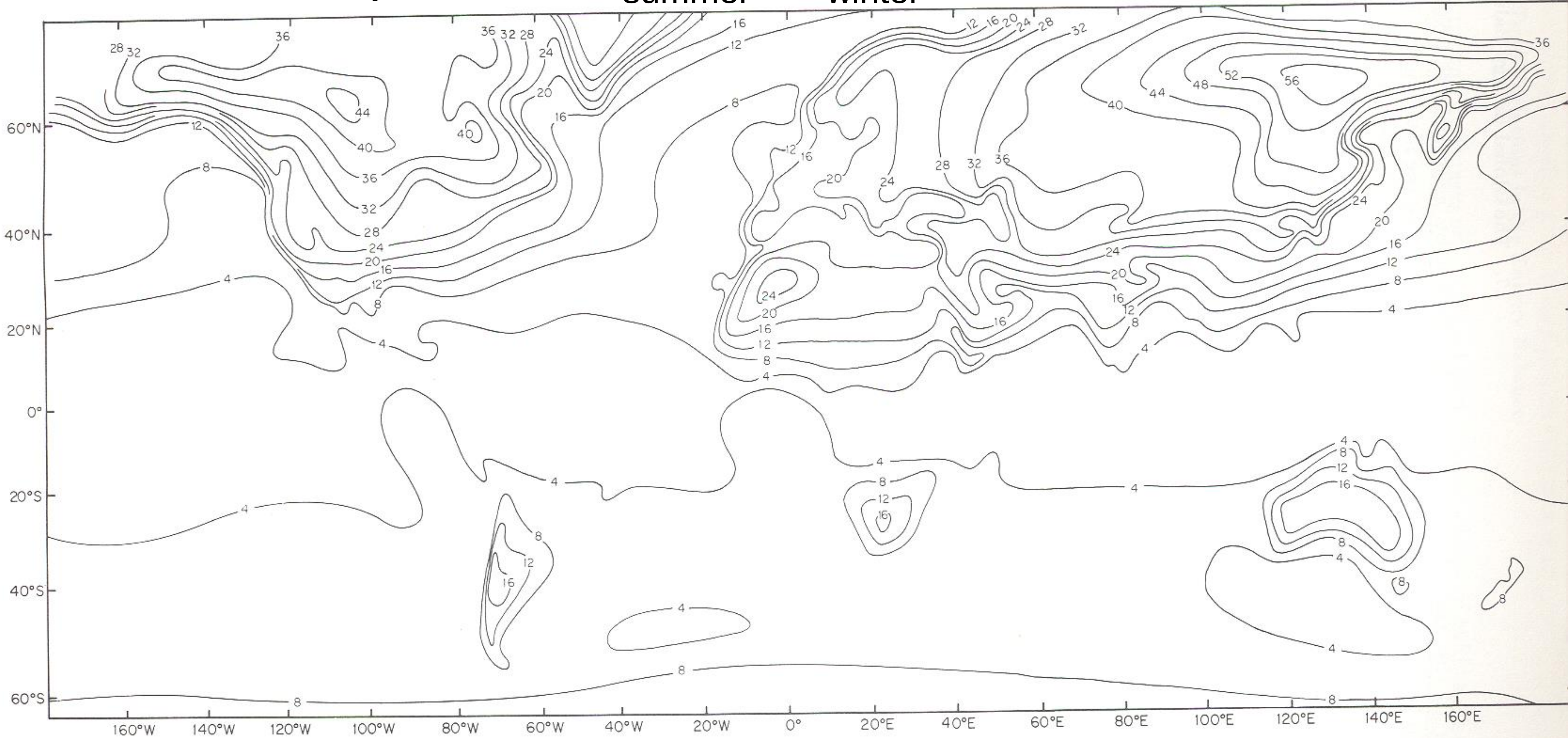


Fig. 7.20 The "Find the Continents" game! Annual range in temperature at the earth's surface, in degrees Celsius. (Adapted from a figure by A. S. Monin and P. P. Shirshov which appeared in Report No. 16, *GARP Publications Series*, World Meteorological Organization—International Council Scientific Unions, p. 203.)

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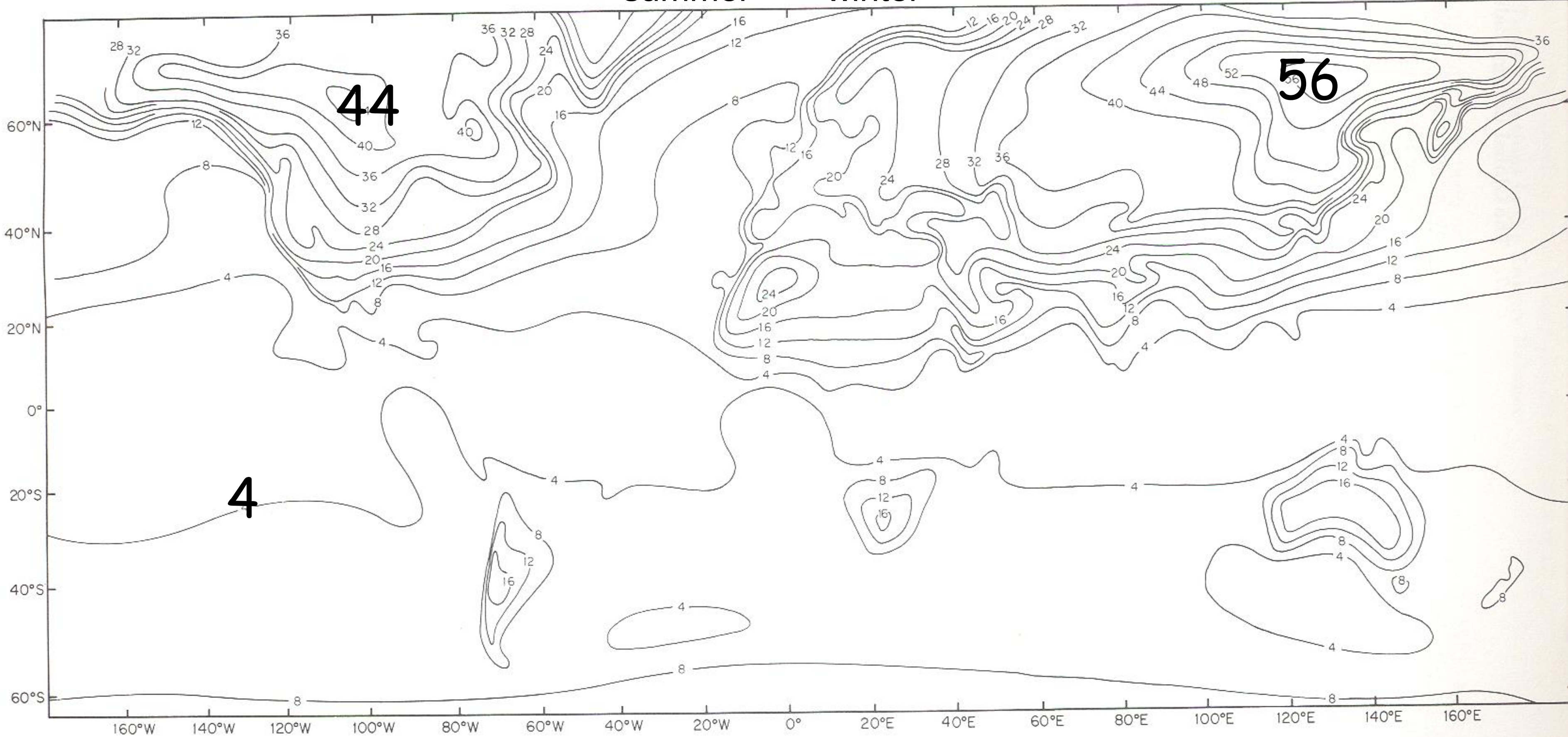

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Continentality → Heat Capacity and Westerly Flow

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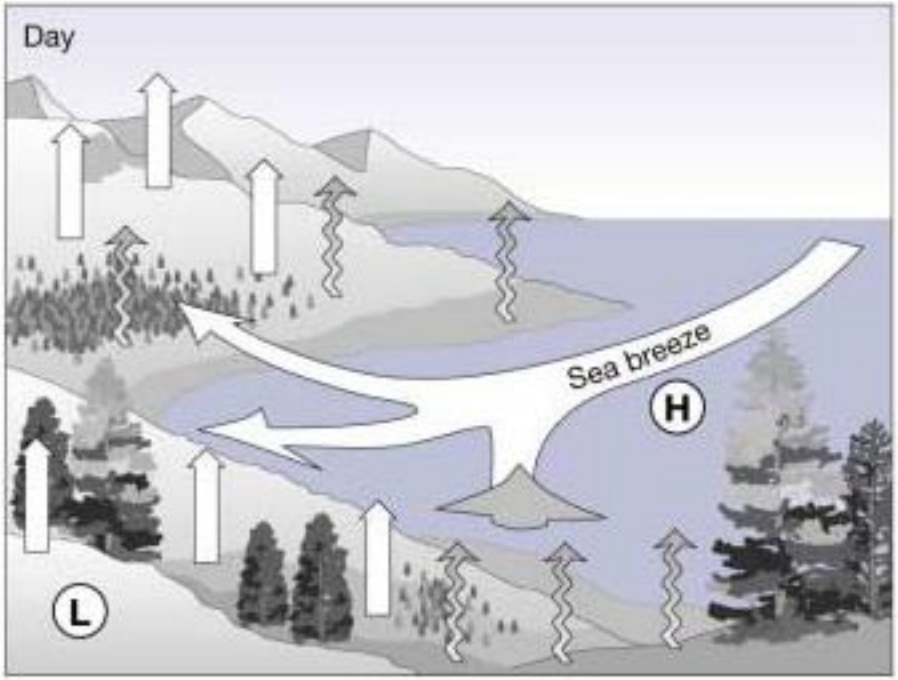
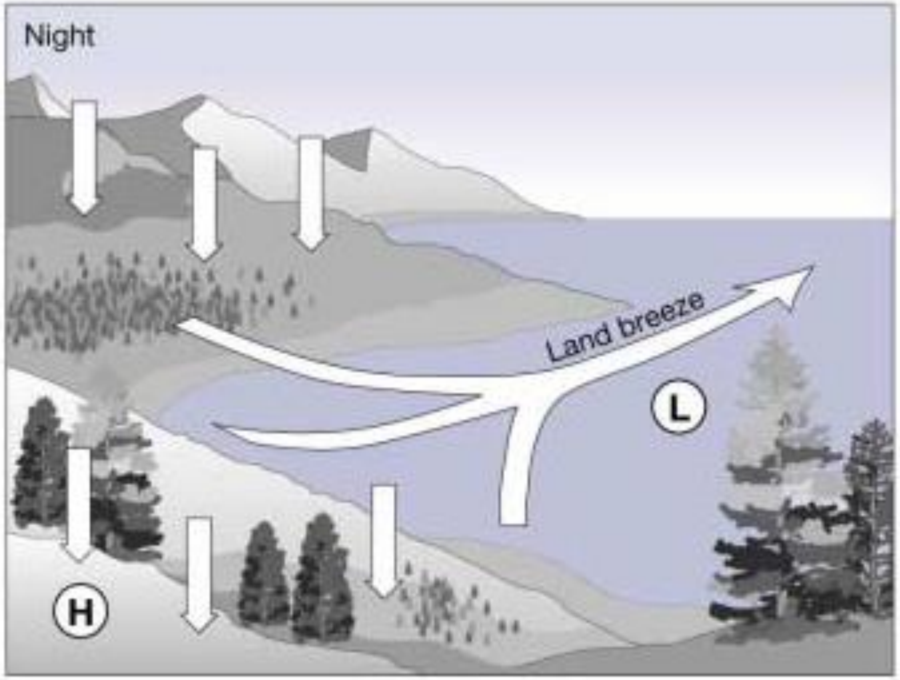
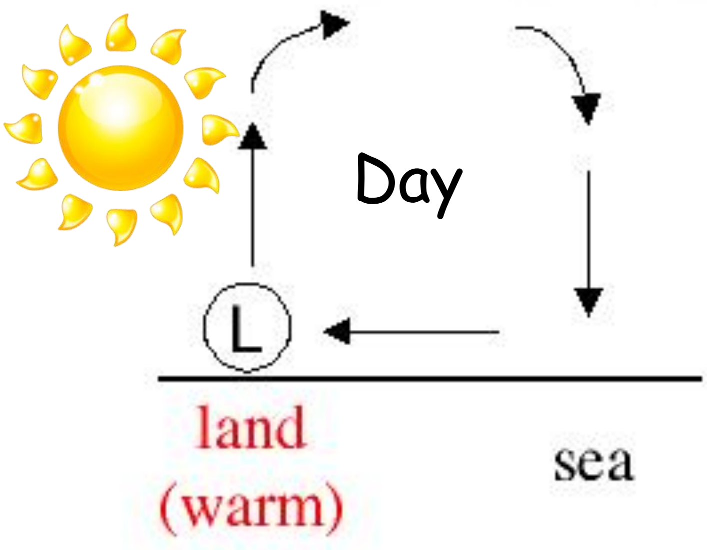
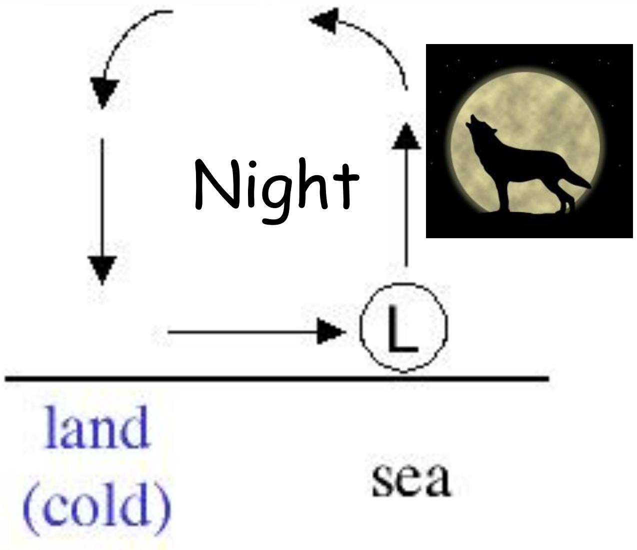
Small-Scale Continentality: Coastal Climates

Diurnal (Daily) Sea Breeze



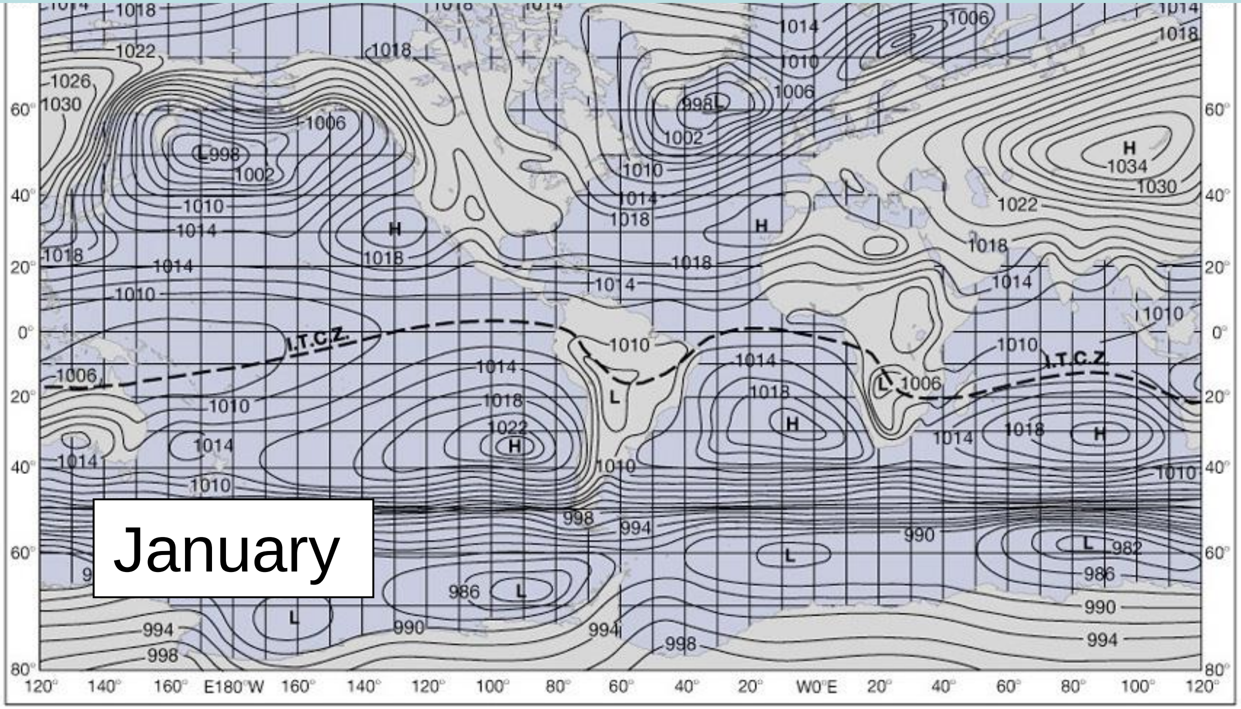






Monsoonal Circulation

Similar to diurnal sea breeze but on larger spatial and temporal (seasonal) scales.



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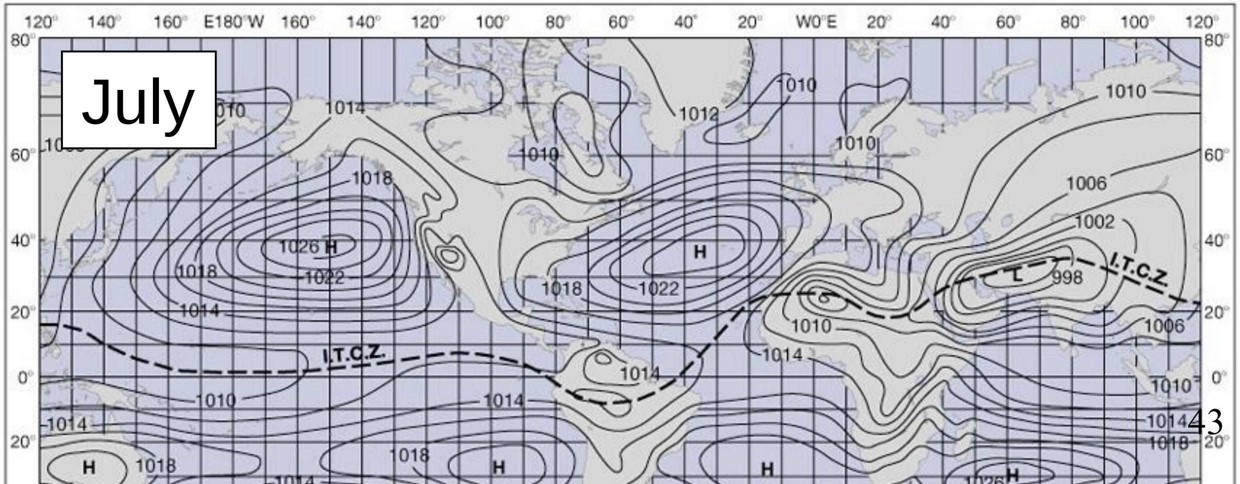

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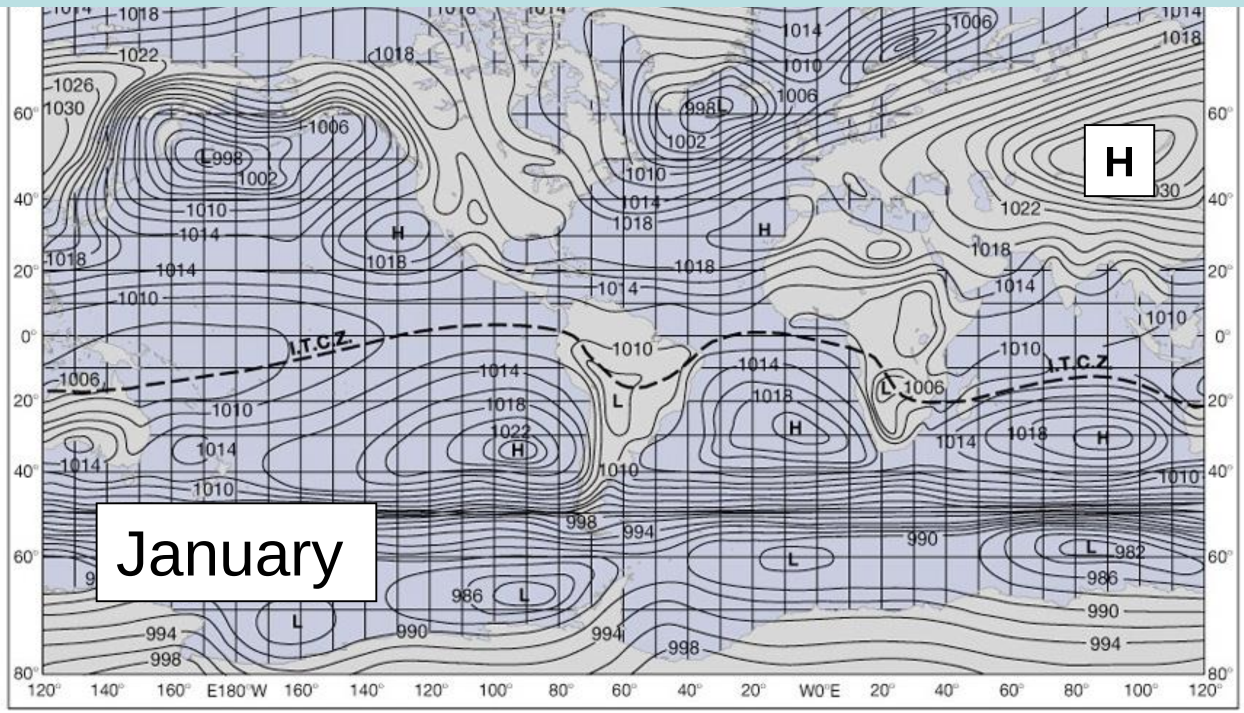

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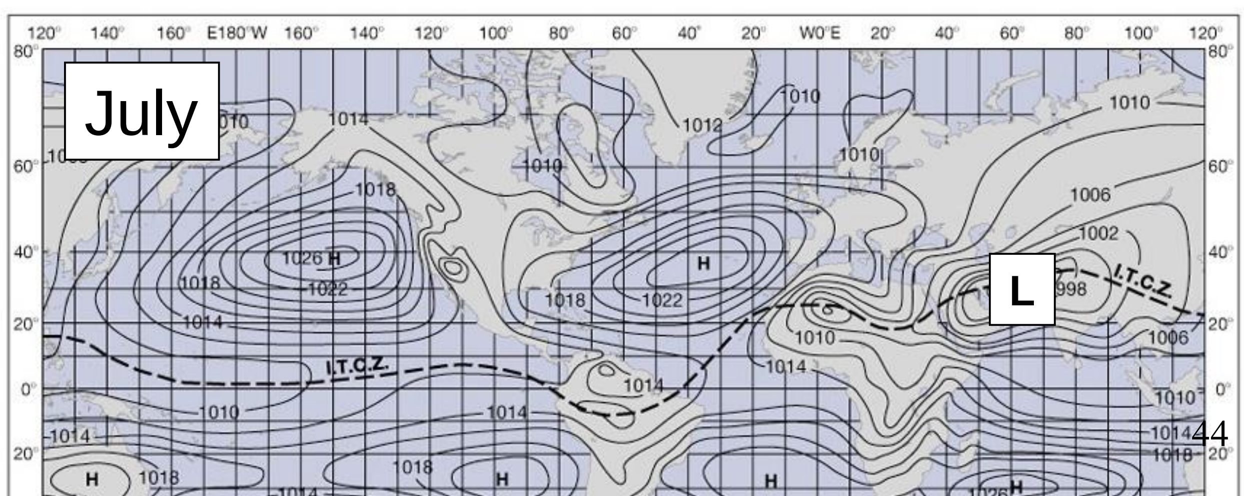
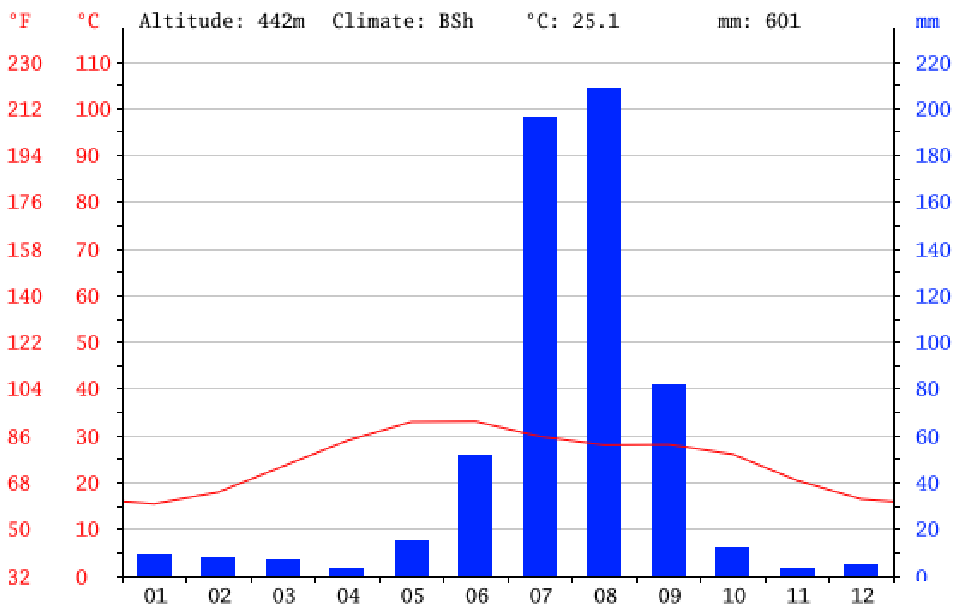


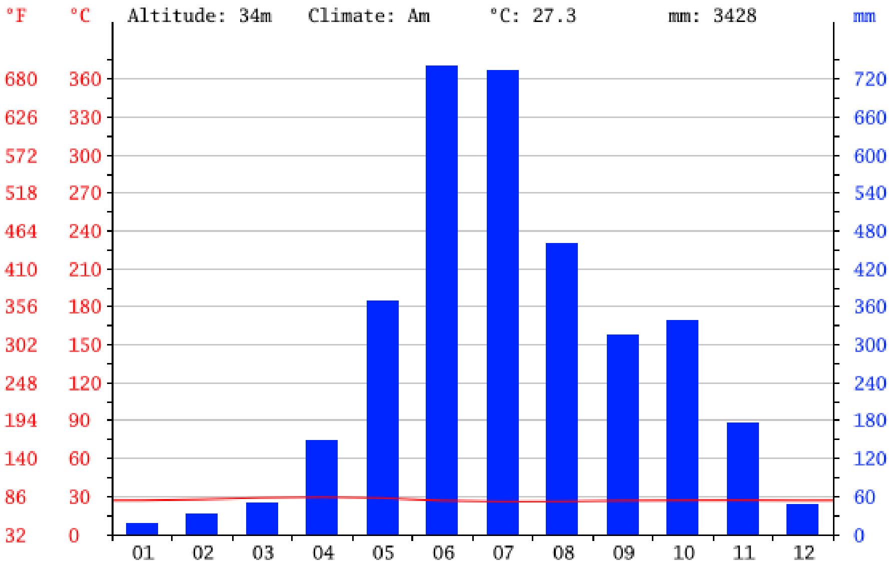
Monsoonal Circulation

Rainfall in Western India



Jaipur (NW India)

Kolenchery (SW India)



Monsoonal Rain

[Monsoon Rain](https://www.youtube.com/watch?v=bETUbu7pXgs)

https://www.youtube.com/watch?v=bETUbu7pXgs

Poll Question

Pollution from India, China, etc enhances airborne particulate matter, which contributes to haze. Haze acts like clouds, increasing albedo.

When poll is active, respond at **PollEv.com/joelathornto254** Text **JOELATHORNTO254** to **22333** once to join

Pollution has amplified monsoonal circulation

Pollution has suppressed monsoonal circulation

Total Results: 0

Land/Ocean Contrasts Summary

Ocean has higher heat capacity and thermal mass over which to distribute heat

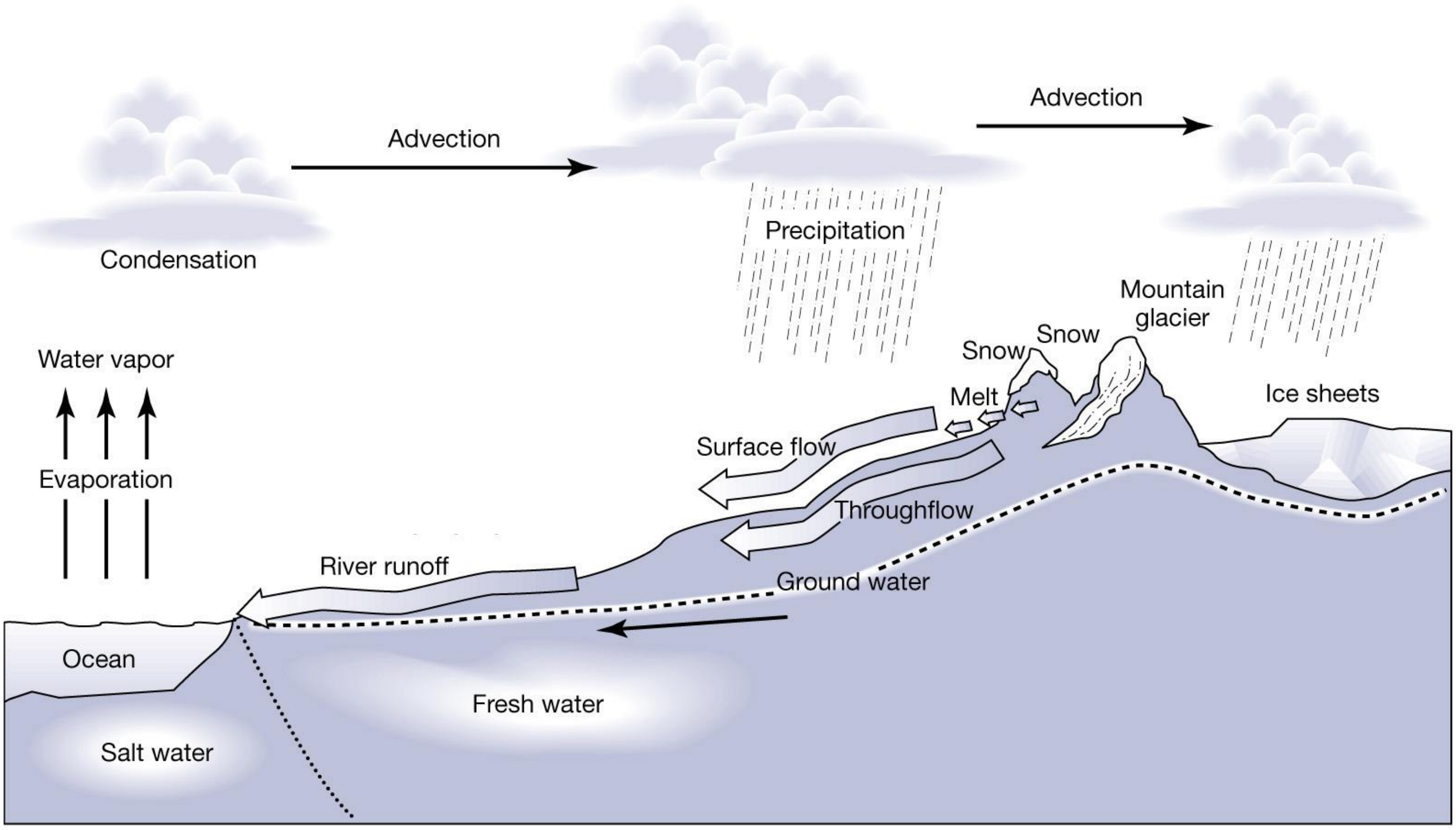
Oceans heat and cool more slowly and overall less than land for same energy input

→ climate is moderated over oceans; more extreme seasonality over land

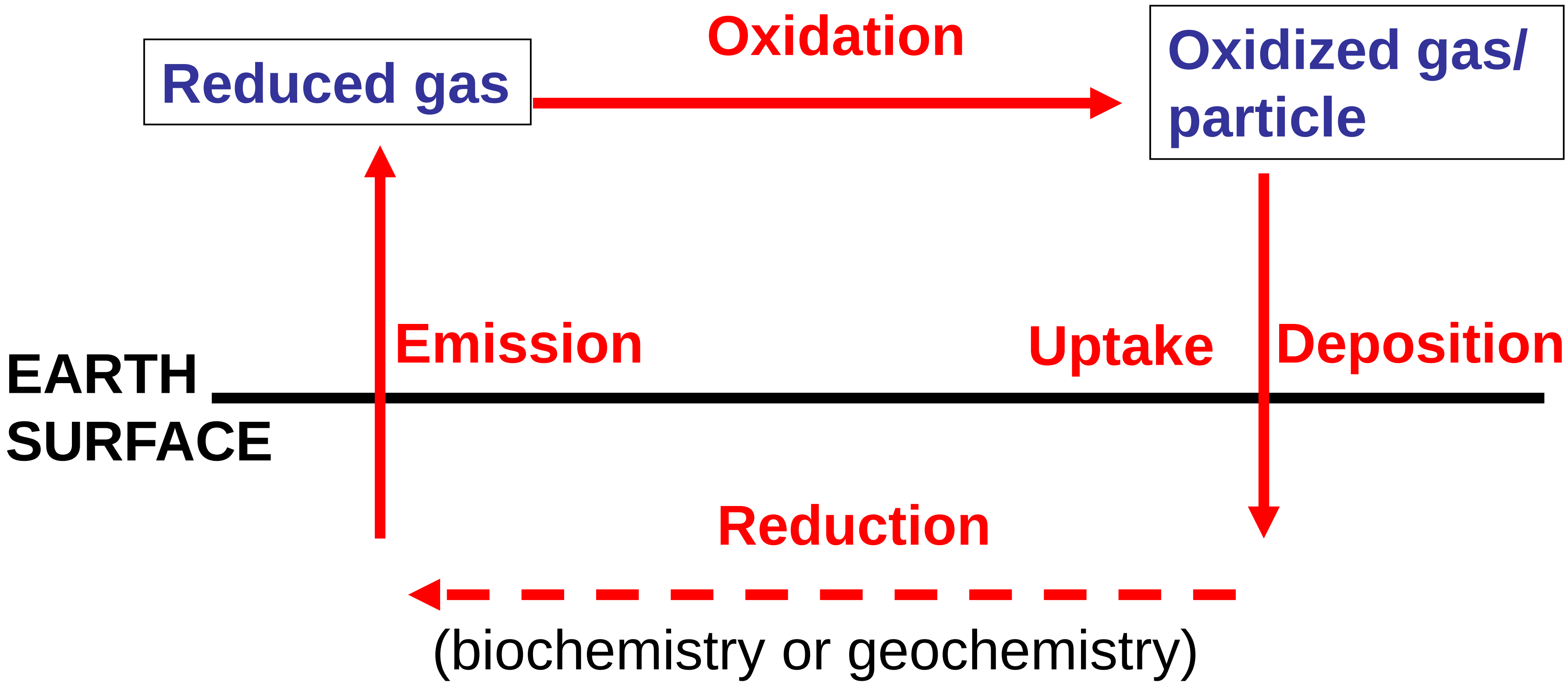
Contrast in surface heating gives rise to:

1. **Diurnal Sea Breeze**
2. **Continentality**
3. **Monsoon Circulations**

Hydrologic (Water) Cycle



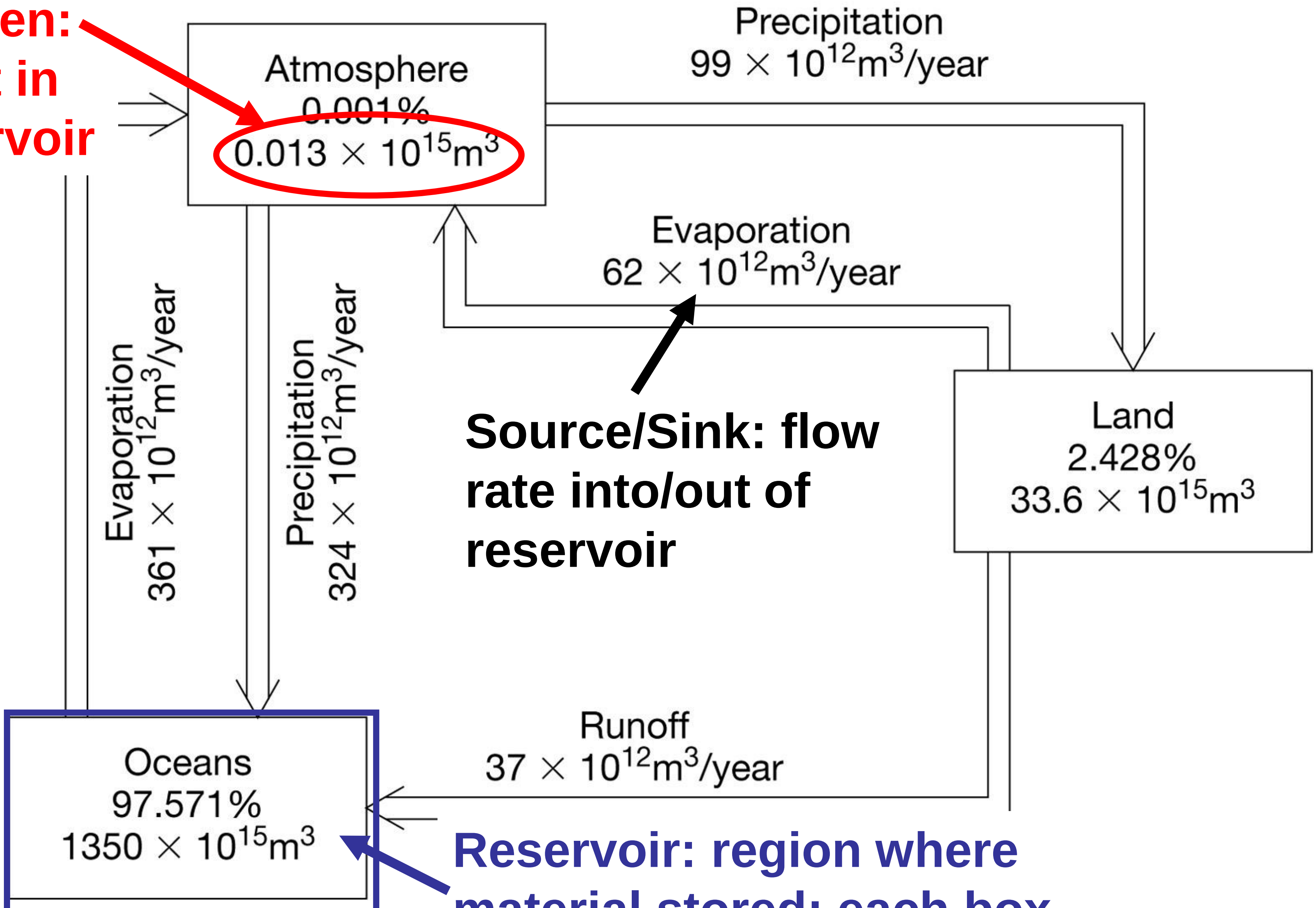
Global Biogeochemical Cycles



Water Cycle Reservoirs and Flows

Water Cycle "Box Model"

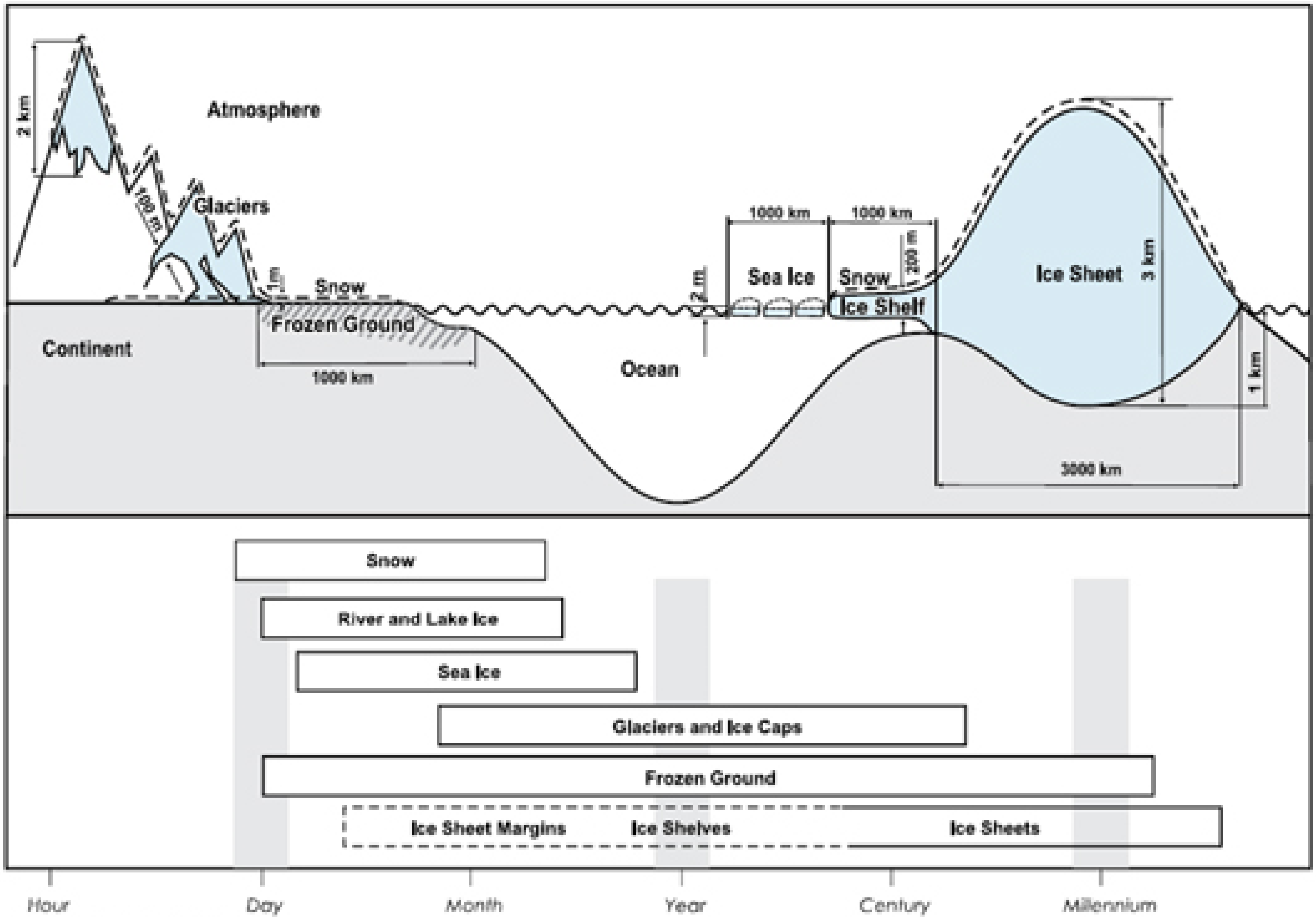
Burden: amnt in reservoir



Source/Sink: flow rate into/out of reservoir

Reservoir: region where material stored; each box

Cryosphere – where most water on land is



Source: IPCC AR4 Report

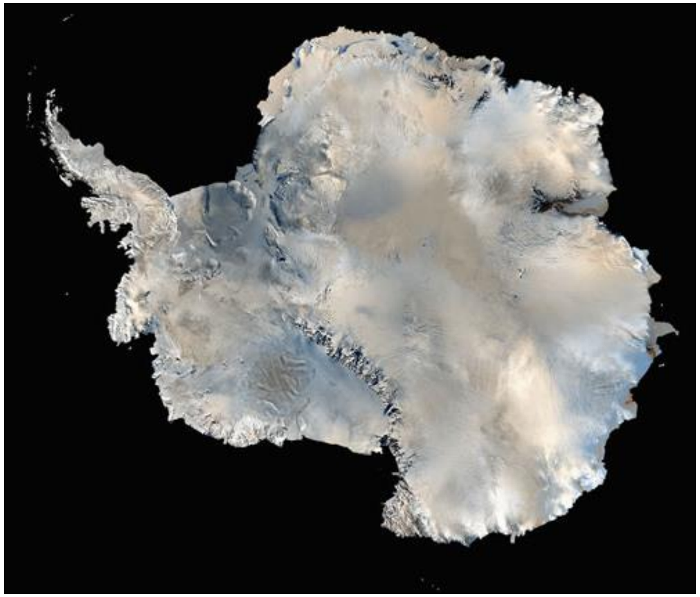
COMPONENTS OF THE CRYOSPHERE AND THEIR TIME SCALES

Cryosphere Examples

Glaciers on Mt. Rainier

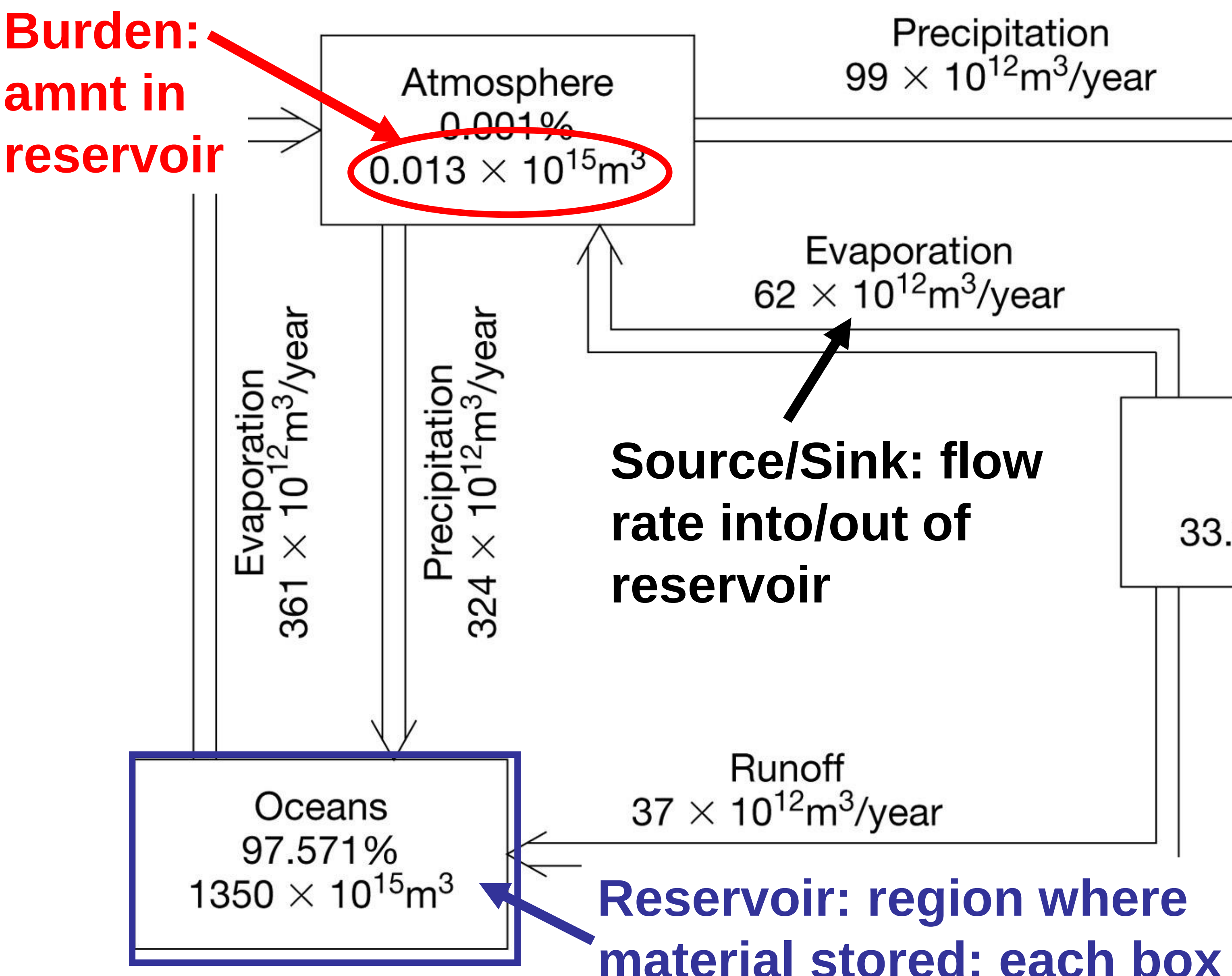
Arctic sea ice

Greenland ice sheet



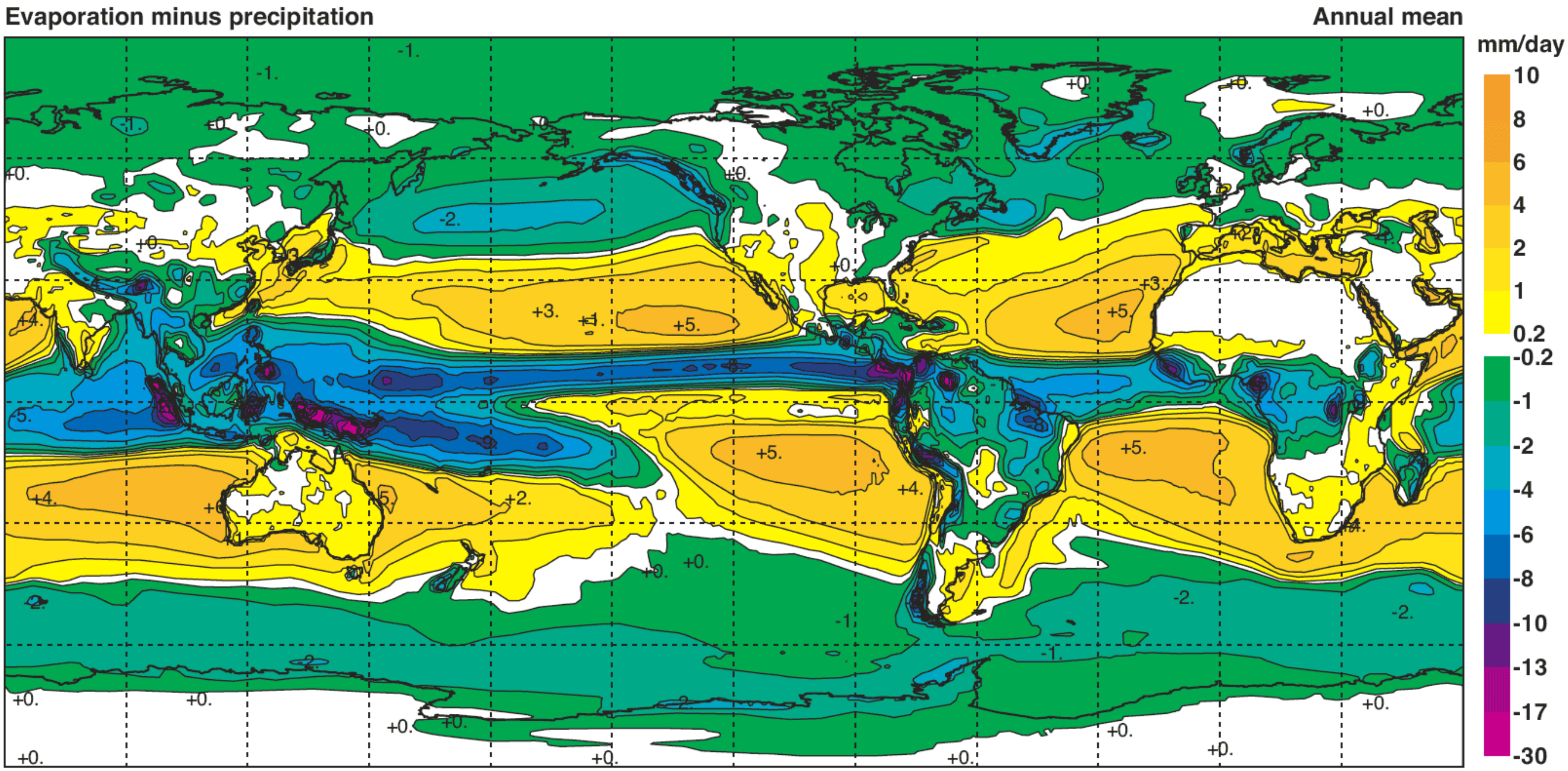
Antarctic ice Sheet

Water Cycle “Box Model”



Water Cycle Reservoirs and Flows

Evaporation Rate Minus Precipitation Rate



Yellow: net evaporation; Green/blue: net precipitation

Poll Question

There is approximately 6x10^12 cubic meters of H2O vapor in the N.H. troposphere, and 2.4x10^14 cubic meters of water precipitate per year in the N.H. How long does the average H2O reside in the air?

When poll is active, respond at **PollEv.com/joelathornto254**

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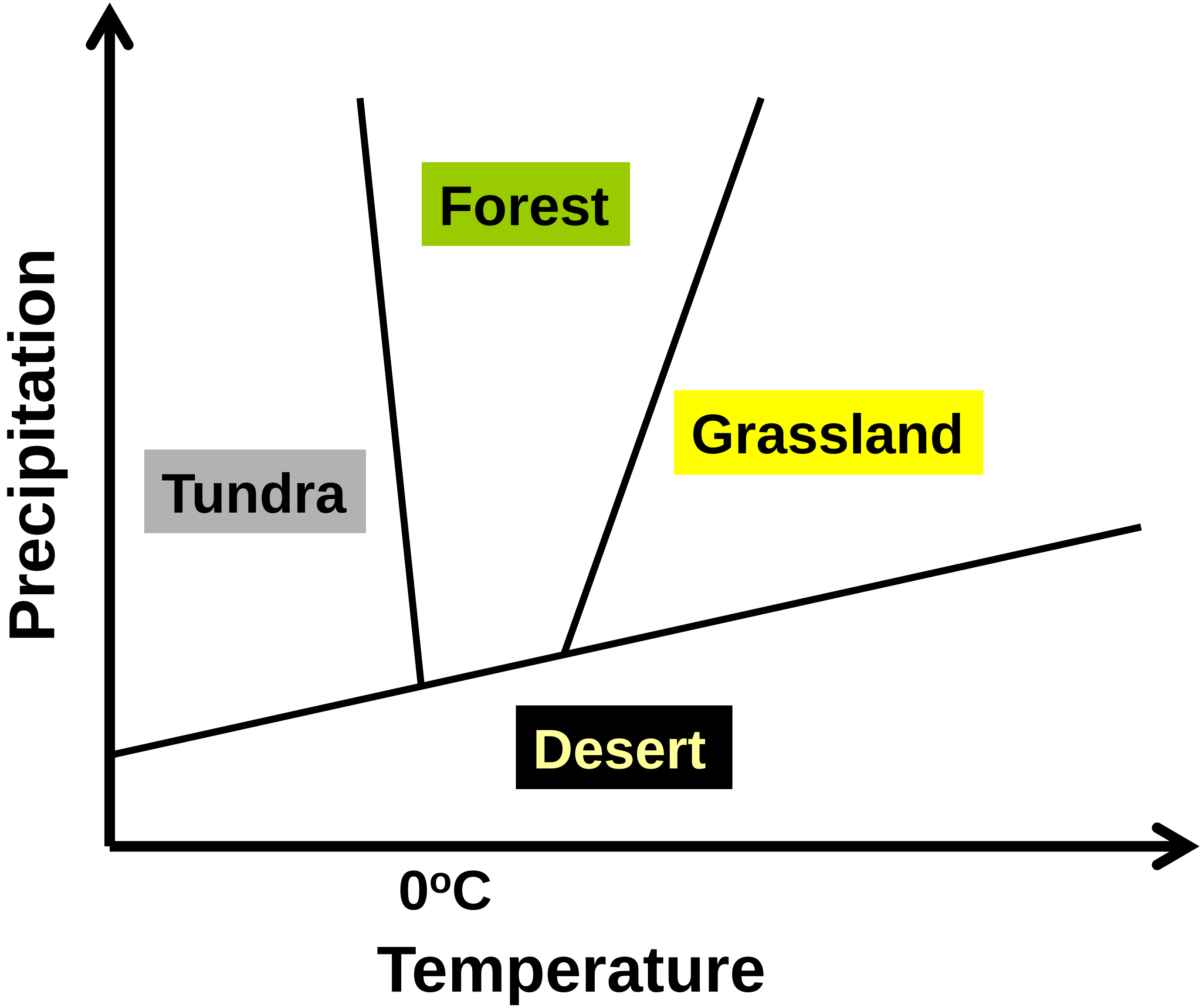
- 0.025 years
- 0.25 years
- 2.5 years

Total Results: 0

Ecosystems and Hydrologic Cycle

Water Cycle, Temperature, and, Terrestrial Biosphere



Poll Question

W

The Earth has been warming over the past century, and is expected to continue warming into the next century. Based on what you know so far about the water cycle, choose the best prediction about the future water cycle.

When poll is active, respond at **PollEv.com/joelathornto254**

Text **JOELATHORNTO254** to **22333** once to join

- Everywhere will receive more rain because of increased evaporation with warmer T, which means more water vapor in the air and thus more precipitation
- Atmospheric circulation patterns control where precipitation occurs. Thus, where it rains now will receive more rain, while where it is dry now will become drier, because of more evaporation.
- The increase in temperature expected over the next century (2 to 4 C, global average) is not enough to affect the water cycle significantly.

Total Results: 0

Hydrologic Cycle Responses to Forcings