

Project presentation

- Topic has to be chosen before 31 May
- Start early → topics need refinement
- Presentation of 15 mins total
 - 12 mins talk + 3 mins Q&A
- Presentations in English
- Evaluation criteria:
 - Clarity, creativity, integrity
 - Results not important
- **Two people pair up for a project**
 - **Joint report with author contribution statement**
 - **Joint presentation**

WORKLOAD

- 3 ECTS Course
- 90 h in total for the entire semester
 - 90 h = 30 h lecture + 60 h self study
- 6 h per week for 15 weeks
 - 6 h = 2 h lecture + 4 h self study
- **Division of self study workload (60h)**
 - **Per person:**
 - **Lecture comprehension: 15 h**
 - **Project work: 30 h**
 - **Project presentation & report: 15 h**
 - **Per project team (of two members):**
 - **Project work: 60 h**
 - **Project presentation & report: 30 h**

LECTURE 2:

Introduction to the earth's climate

ML-4430: Machine learning approaches in climate science

28 Apr 2021

What is Climate

1

- Weather, on average?
- The climate system

The Atmosphere

3

- Vertical structure
- Meridional Structure

Components of the climate system

2

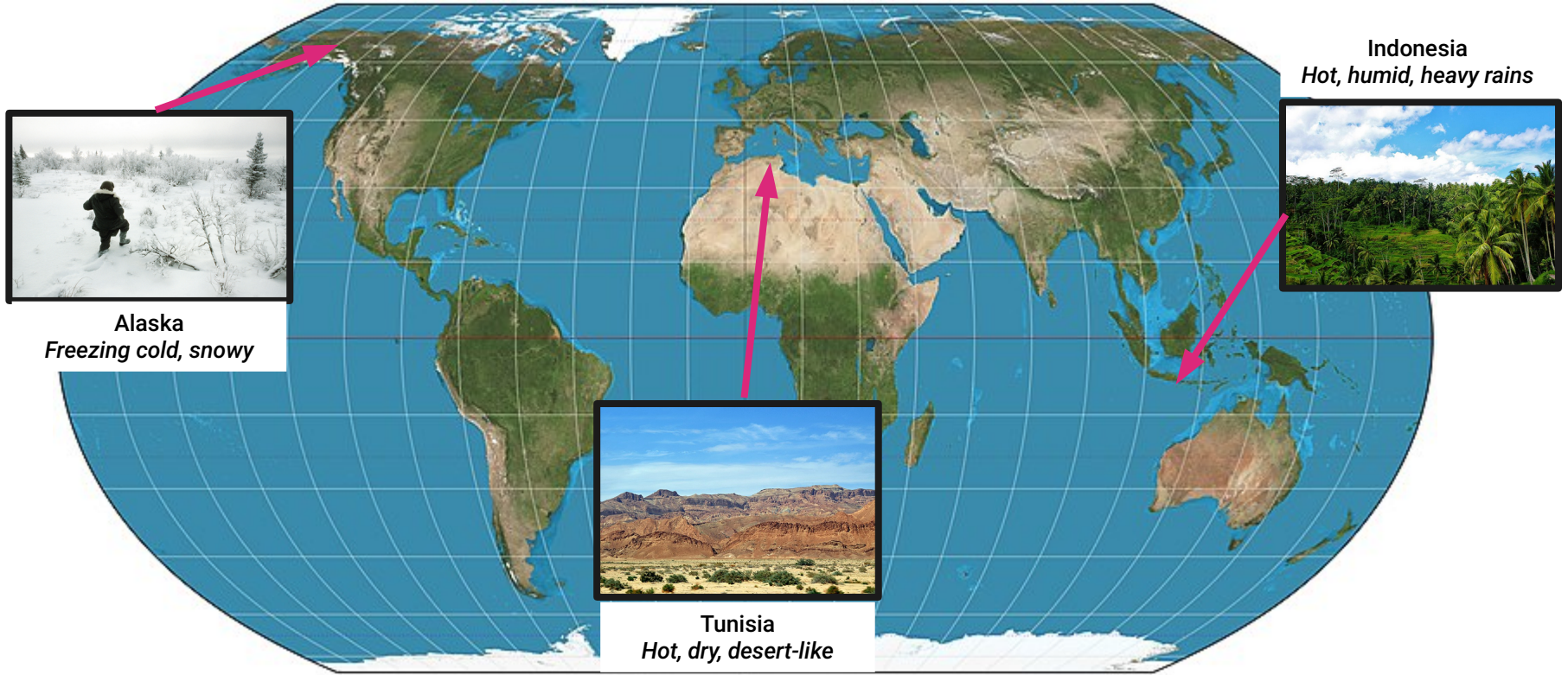
- Atmosphere
- Ocean
- Land
- Cryosphere
- Biosphere
- Anthroposphere

Additional topics

4

- Climate Forcings
- ~~Climate Feedbacks~~
- Climate Sensitivity



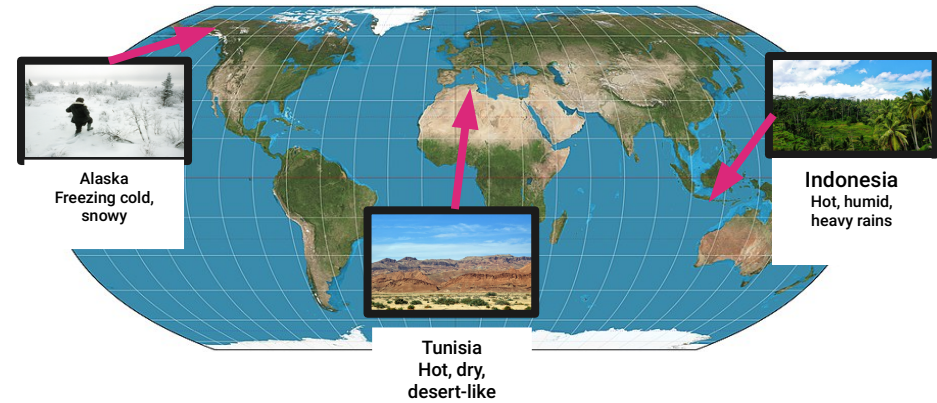


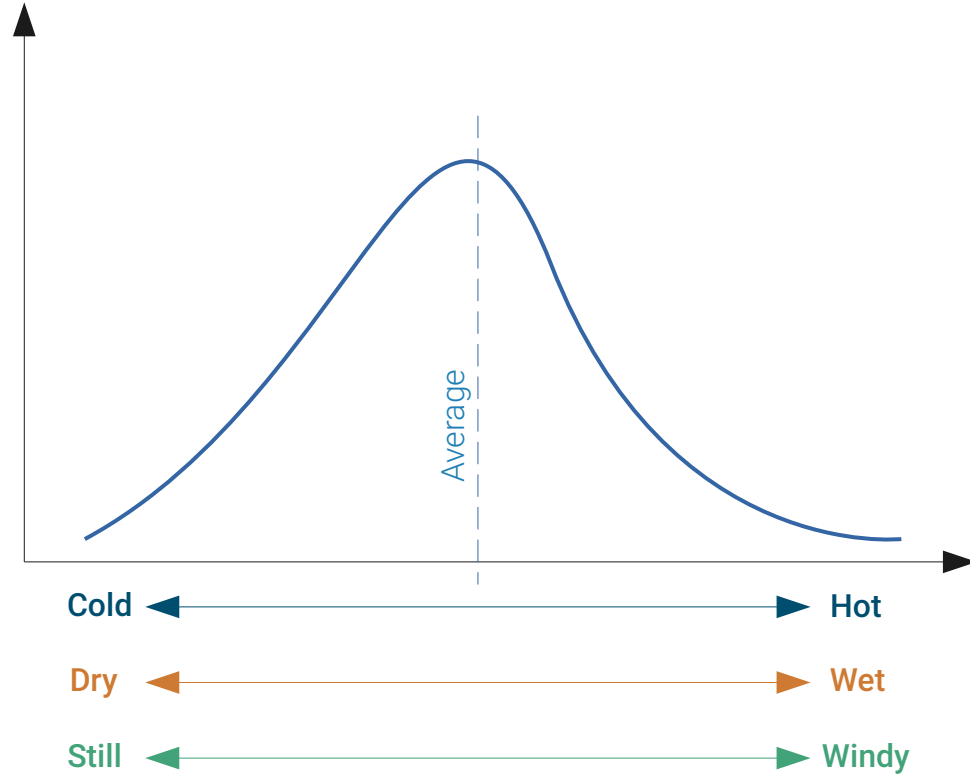
1. What is climate → Weather, on average?



Several questions arise:

- Is the weather the same all year around?
- Does it differ depending on time of day?
- Do certain weather events (droughts, floods, blizzards, etc.) repeat at longer intervals such as decades or centuries?
- What about longer time scales?

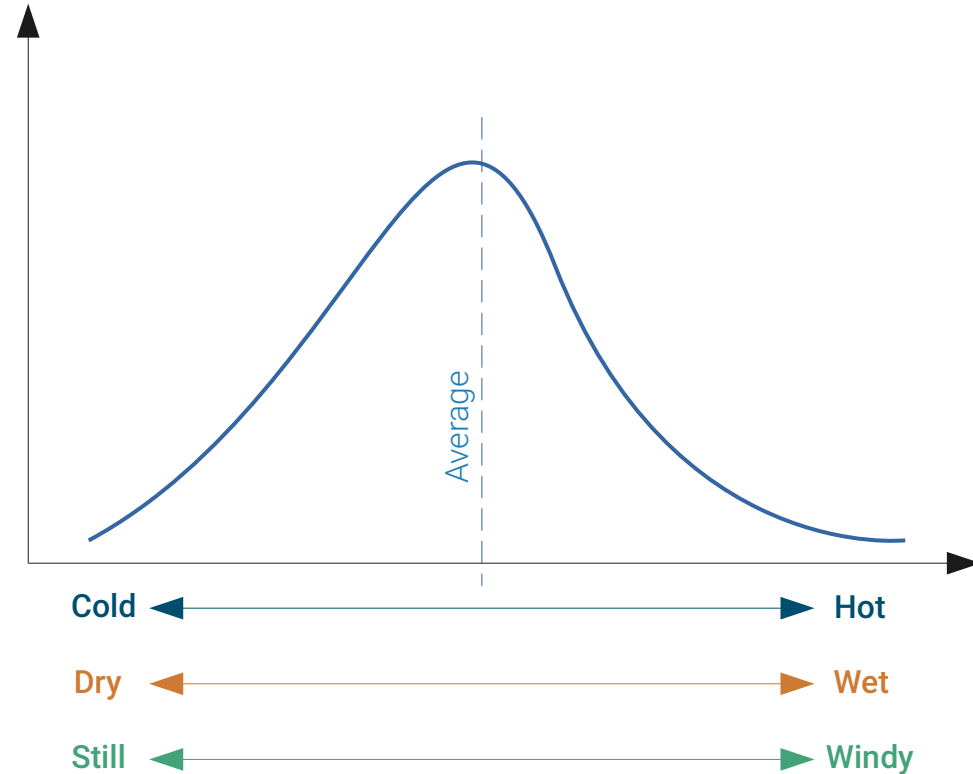




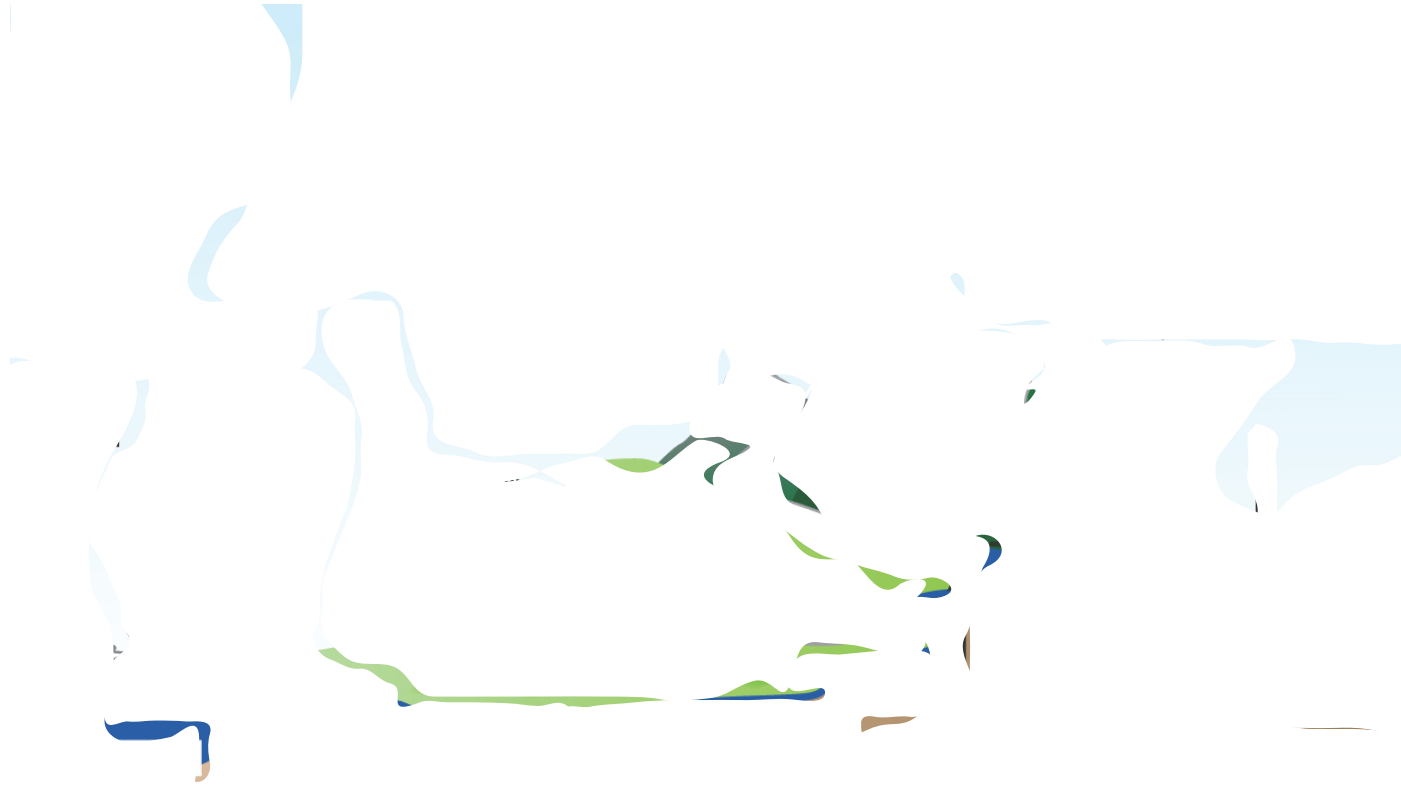
1. What is climate → Weather, on average?

Climate is a distribution of (weather) states

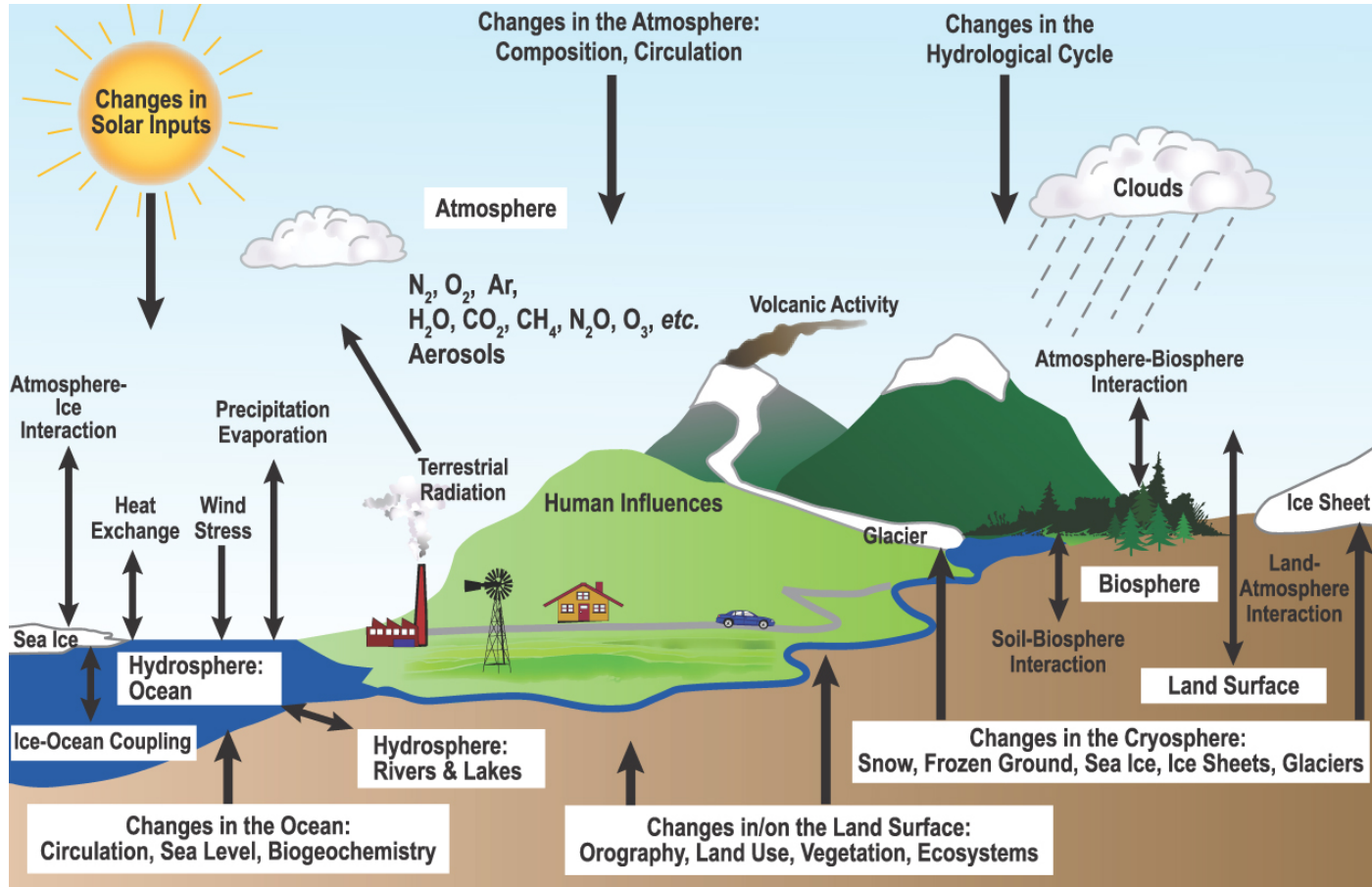
- Given a particular location or region
- Given a particular temporal scale (daily, weekly, annual, decadal, etc.)
- Climate change is thus *a change in the distribution* of weather states
- A change in the mean is only one (of many) indicator of climate change



1. What is climate → Weather, on average?



1. What is climate → The climate system



1. What is climate → The climate system

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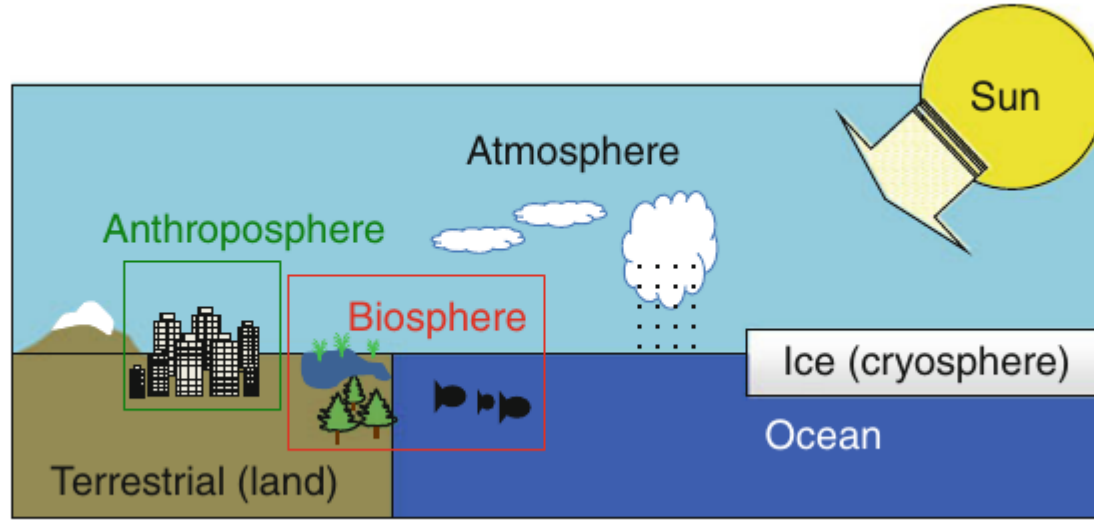
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Additional topics

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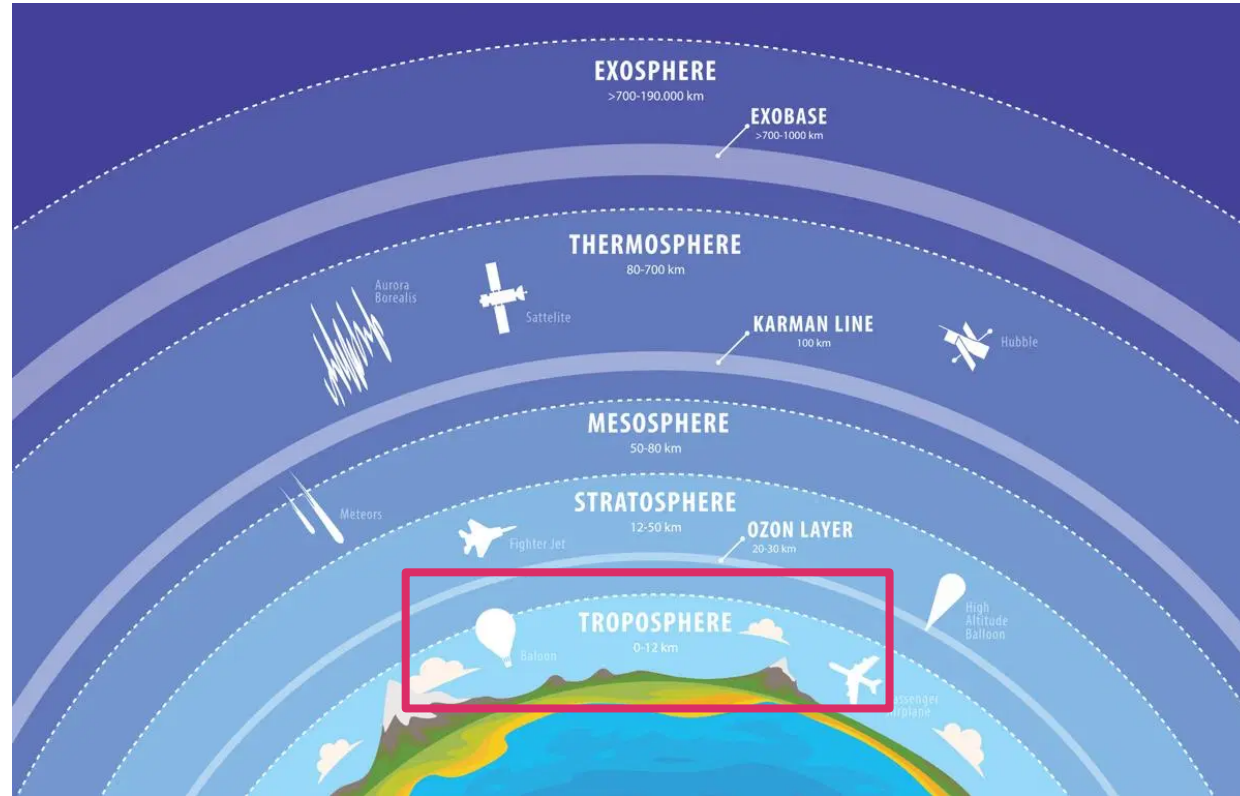
- › Climate Forcings
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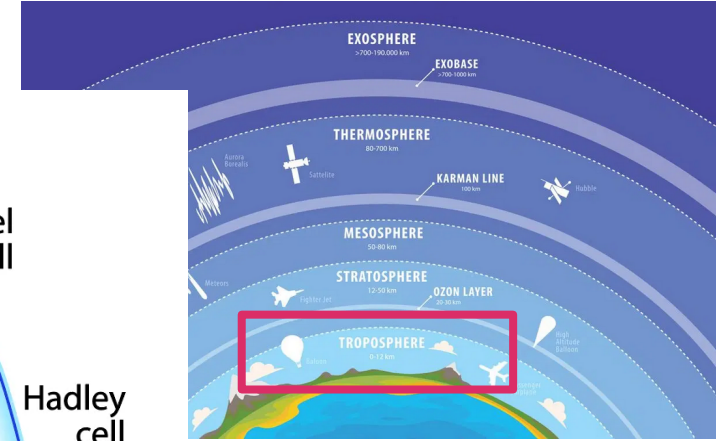
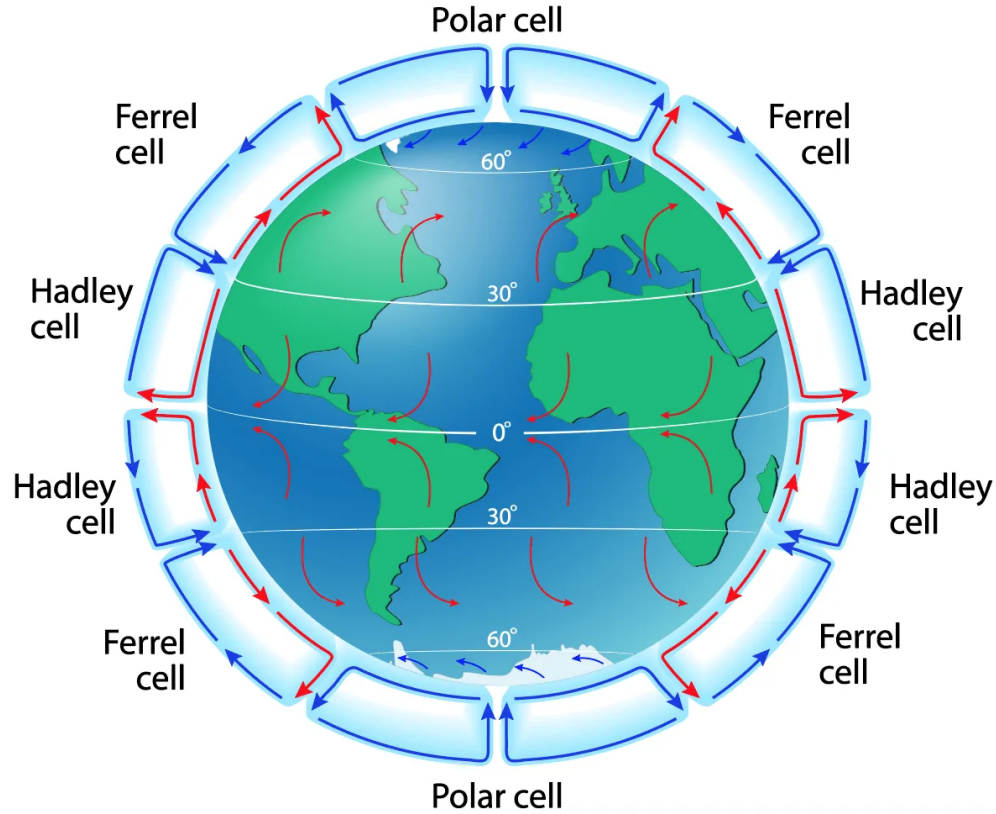
2. Components of the climate system





2. Components of the climate system → Atmosphere

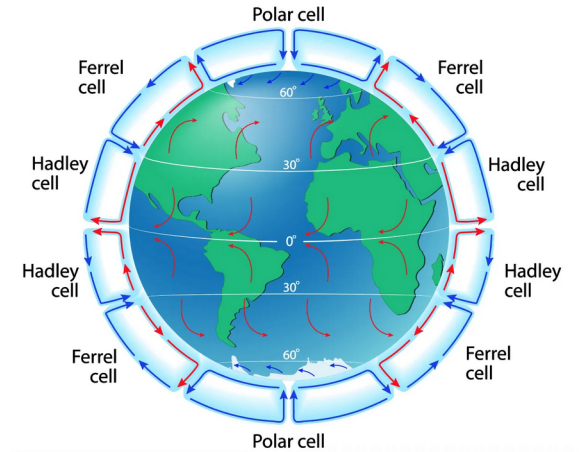
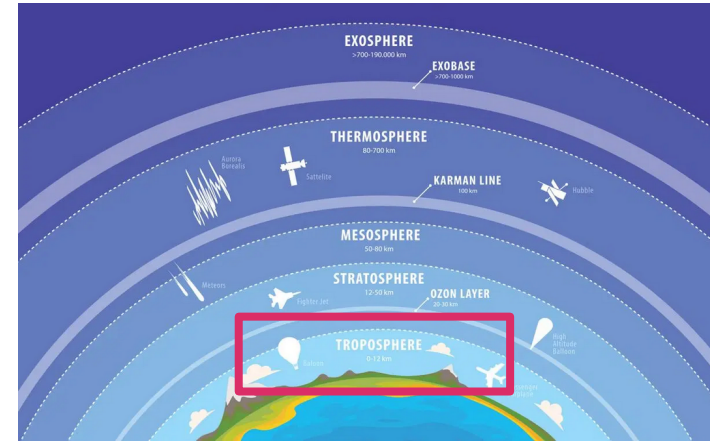


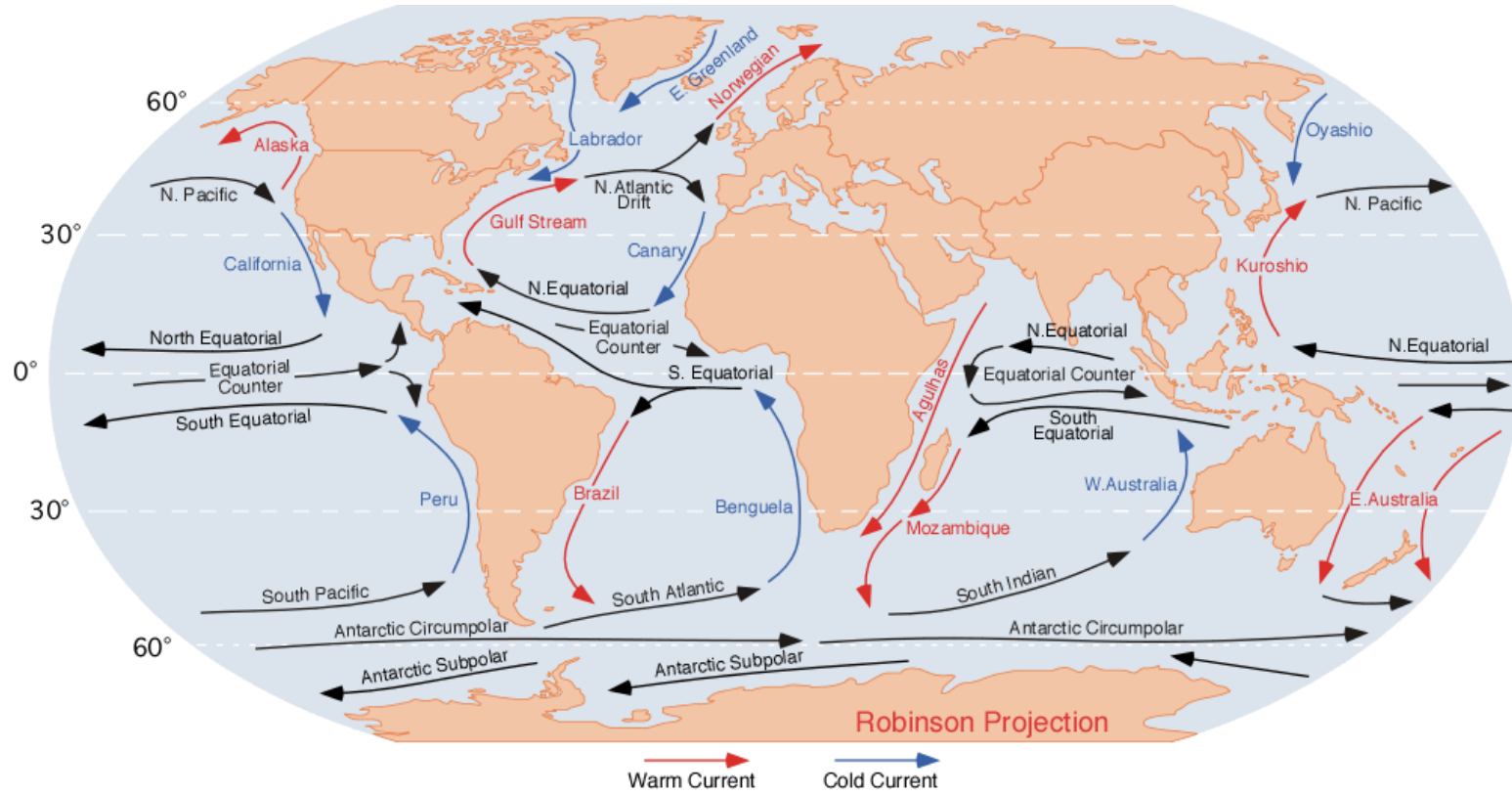


2. Components of the climate system → Atmosphere

Atmosphere

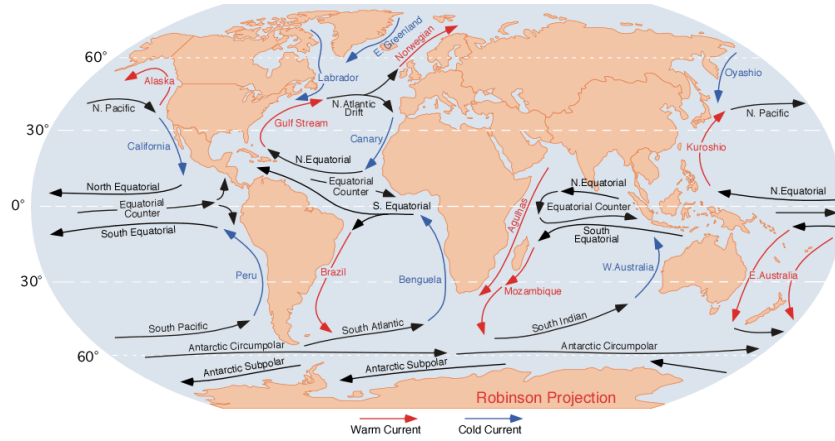
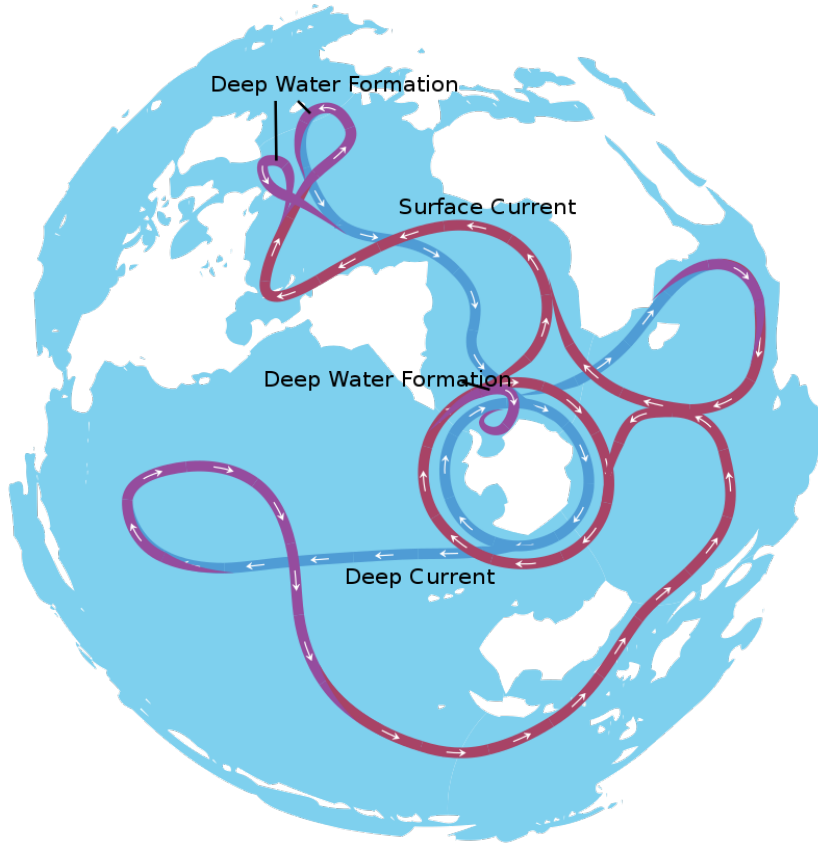
- Most relevant climate dynamics in the troposphere
- Exchange of heat and energy with land, ocean, cryosphere, and the sun
- Marked by dominant and stable patterns of wind circulation
- Greenhouse gases: Water and CO₂ → both are cycled through the atmosphere





2. Components of the climate system → Ocean



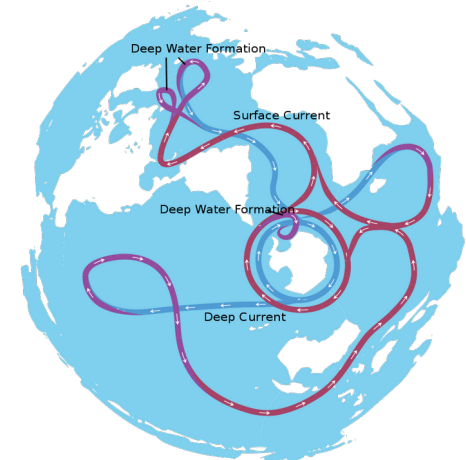
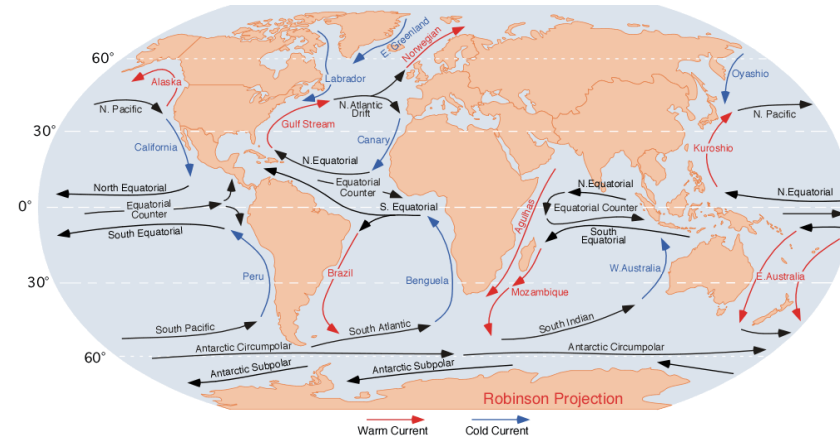


2. Components of the climate system → Ocean

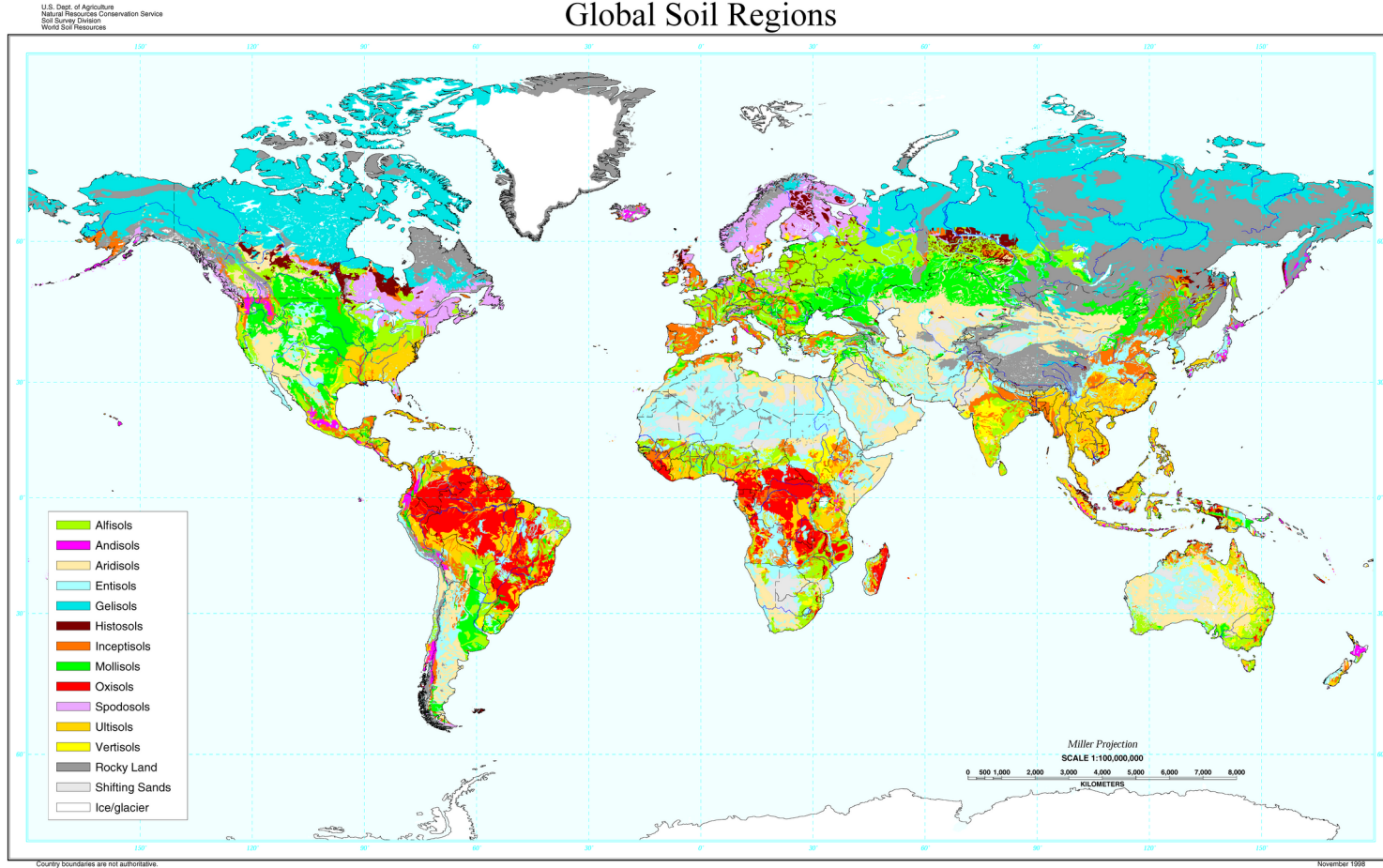


Ocean

- Dynamics composed of surface currents and deep water (thermohaline) currents
- Surface currents forced by earth's rotation and surface winds
- Thermohaline circulation forced by density (and thus salinity) and temperature differences
- Dominant mode of northward transport of heat in the Atlantic

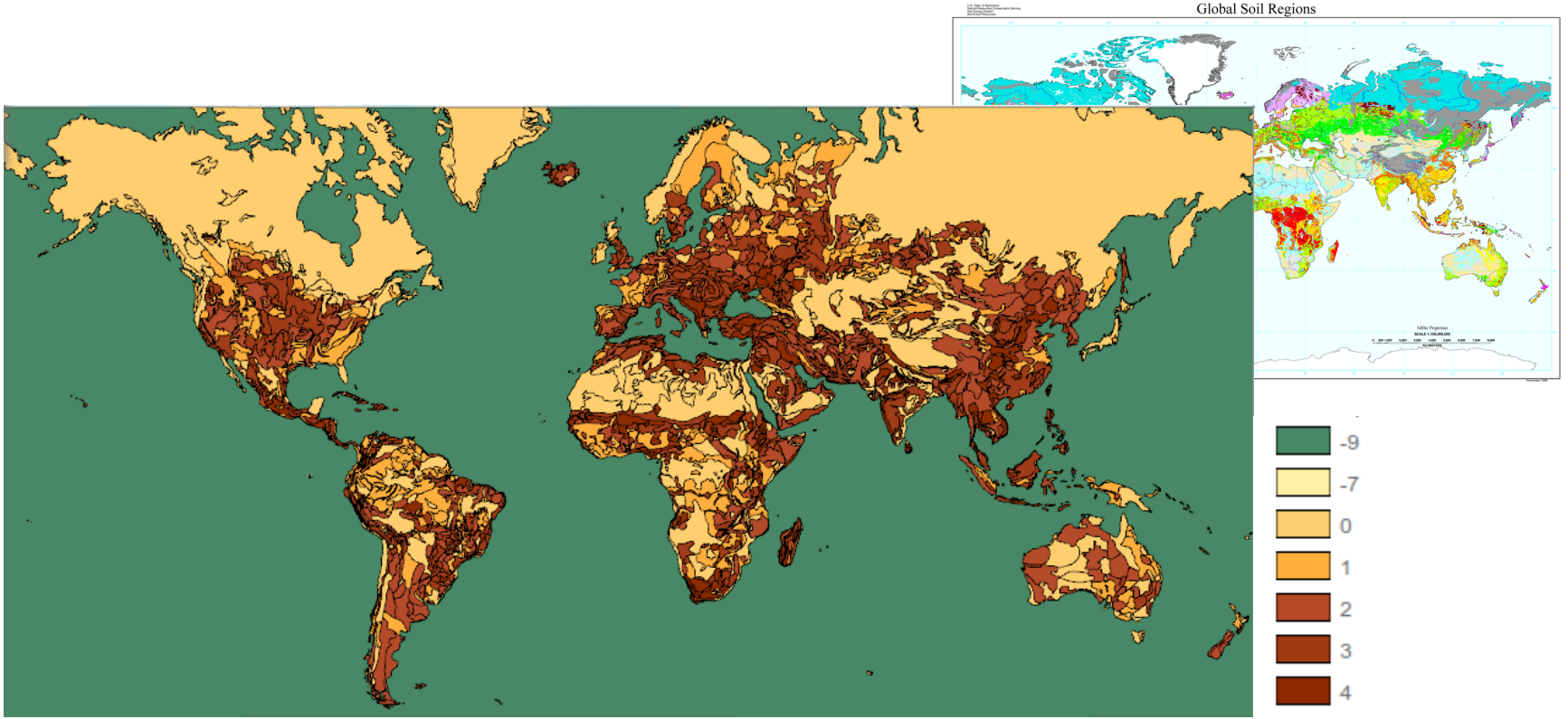


Global Soil Regions



2. Components of the climate system → Land



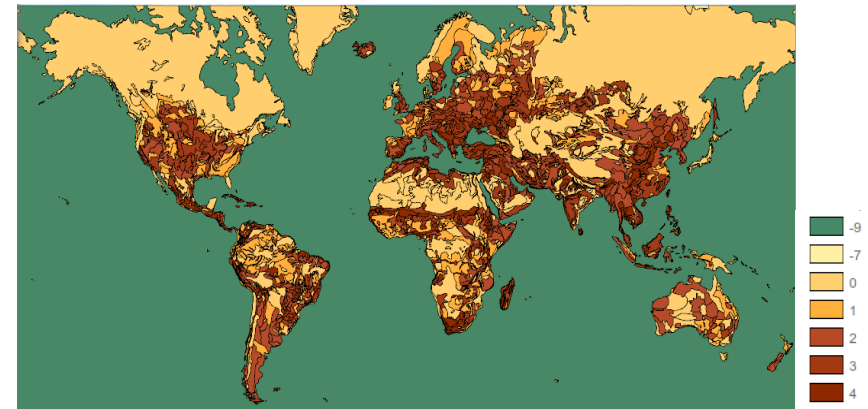
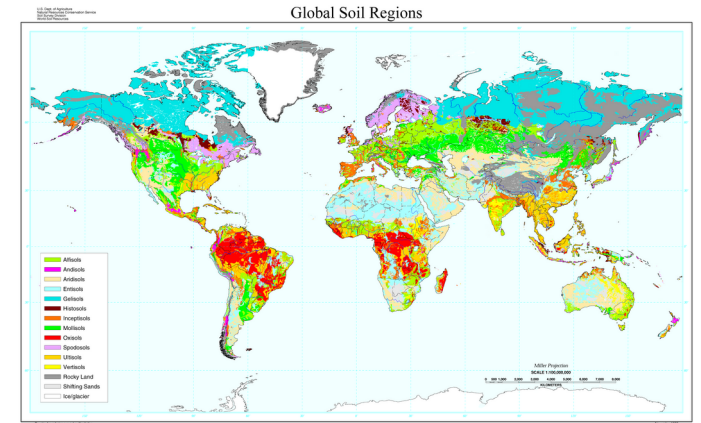


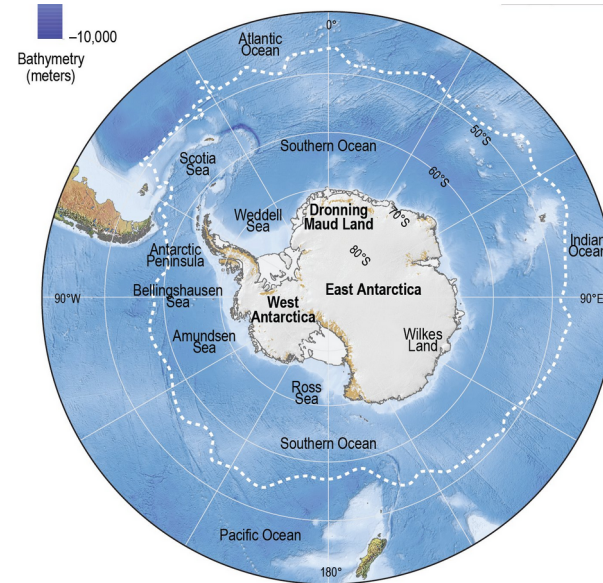
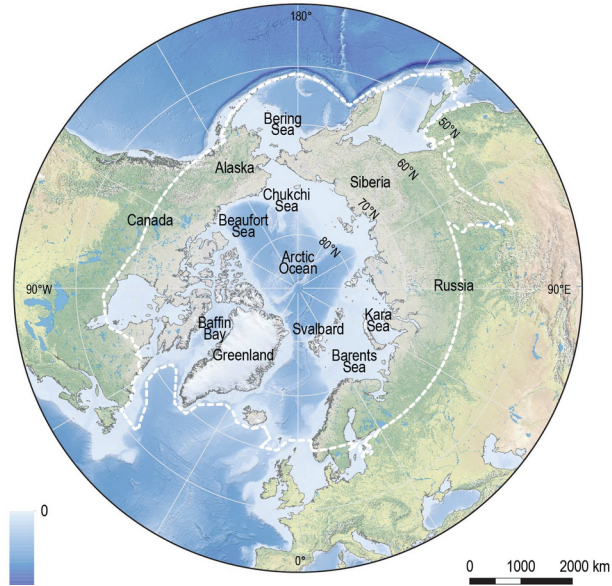
2. Components of the climate system → Land



Land

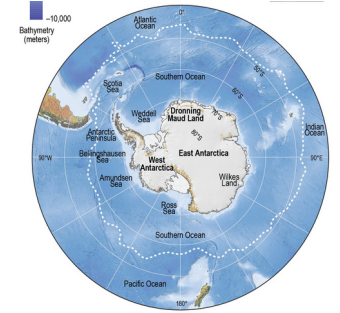
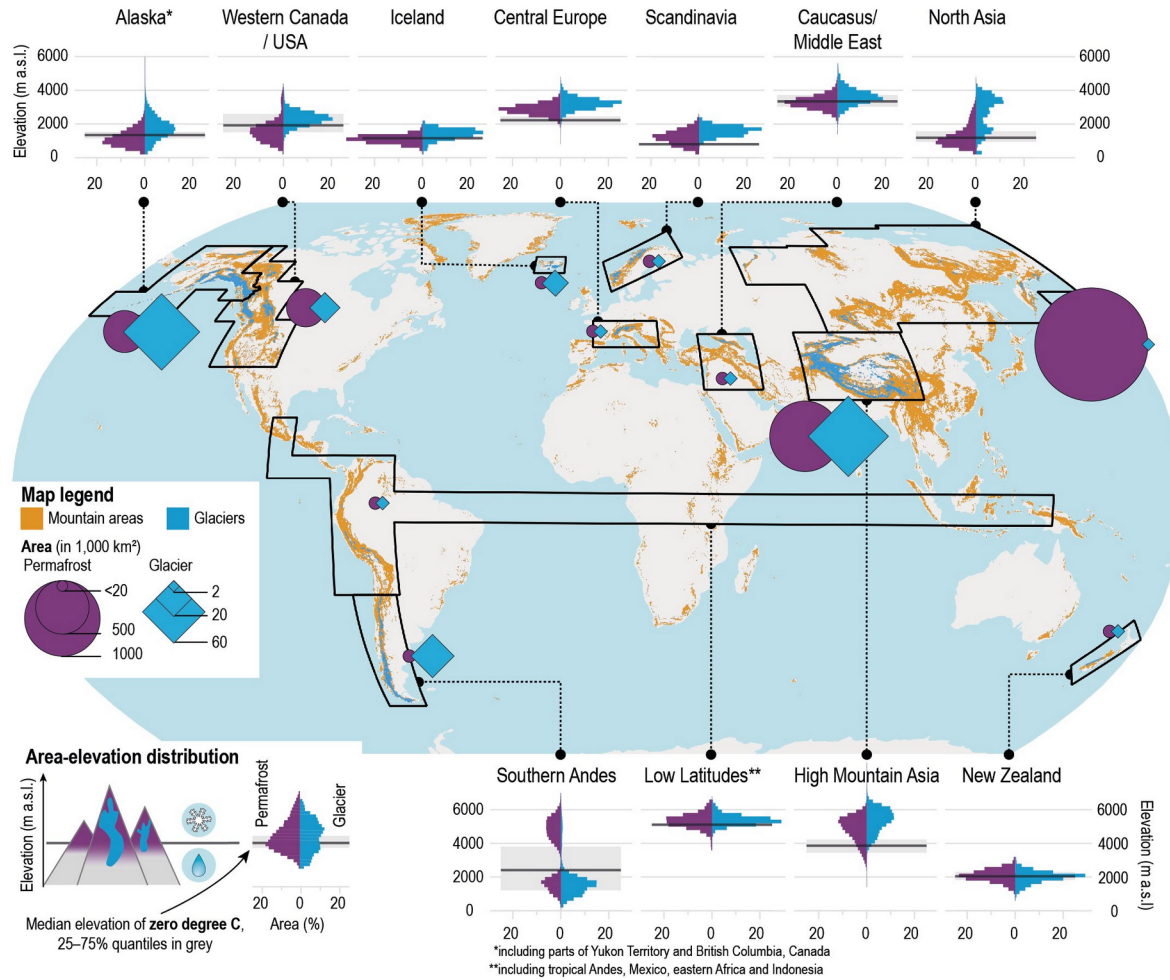
- Soil plays the most important role
- Modulates water, CO₂, and other important cycles
- Crucial determinant in climatological conditions
- Interface of atmosphere, cryosphere, ocean, and biosphere





2. Components of the climate system → Cryosphere

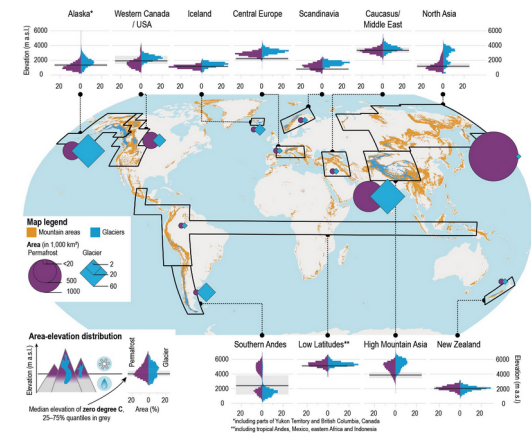
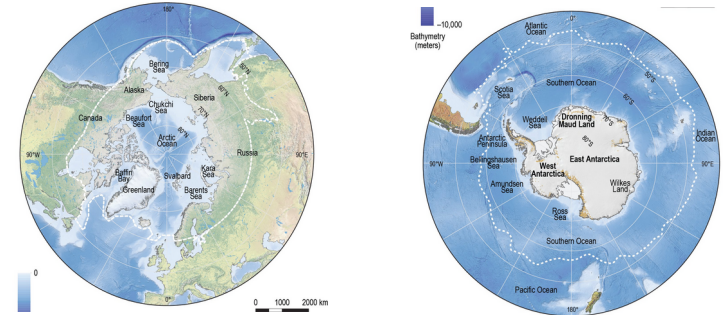




2. Components of the climate system → Cryosphere

Cryosphere

- Polar regions and high mountain areas
- Important source of freshwater
- Global ice extent modulates global climate
- Arctic and Antarctic ice extent crucial to maintaining polar fronts which influence extratropical climate
- Glaciers influence regional and hemispherical climate systems



2. Components of the climate system → Cryosphere

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- › Meridional Structure

Components of the climate system

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Additional topics

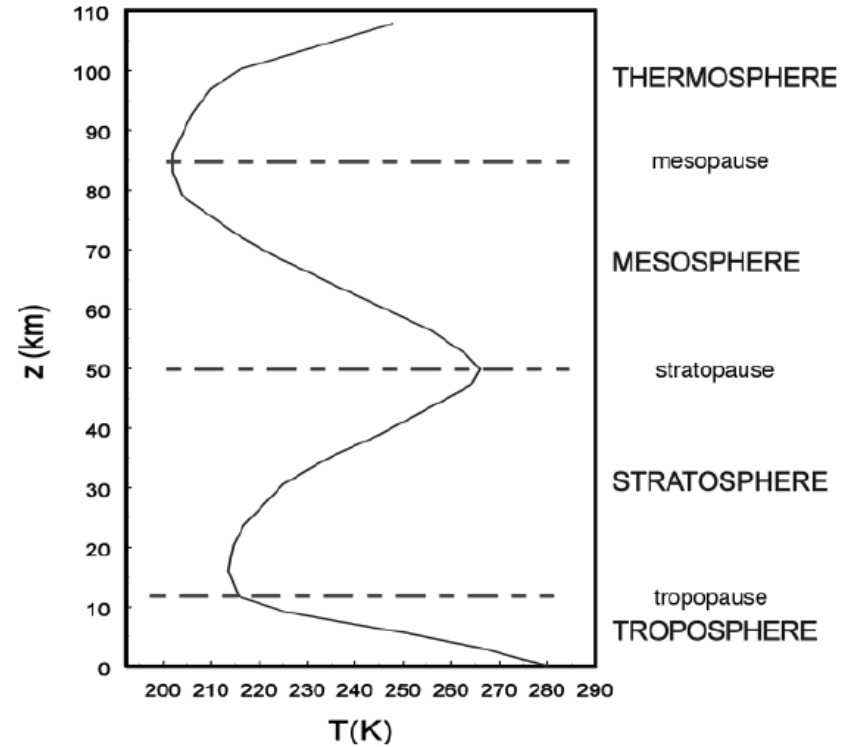
4

- › Climate Forcings
- › Climate Feedbacks
- › Climate Sensitivity



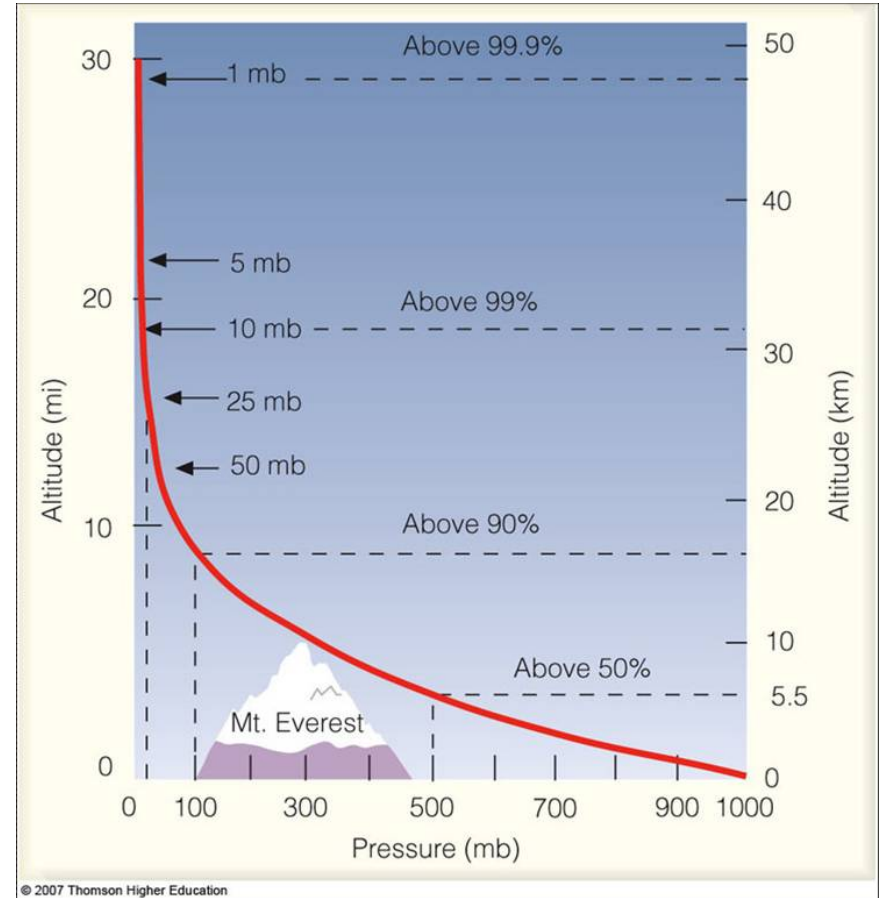
Vertical temperature profile

- 3 regions of warm temperature: surface, stratopause, and thermosphere
- Short wavelength UV absorbed in thermosphere (can get really hot)
- Medium wavelength UV absorbed in stratopause (by ozone)
- Stratosphere is stratified; little to no mixing
- Troposphere has all the water vapour; 85% mass of the entire atmosphere



Vertical pressure profile

- Decreases monotonically with altitude
- Pressure at surface is at 1000 mb (=hPa) by convention
- Tropopause (approx 10-16 km) is at around 100 – 200 mb pressure
- Allows a stratification of the atmosphere according to pressure levels (850 mb height, 250 mb height, and so on)
- Possible due to **hydrostatic balance**



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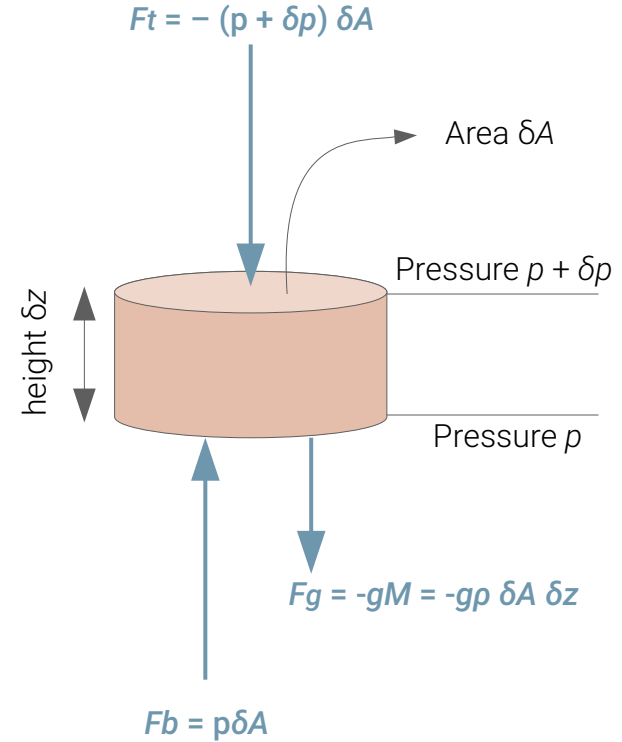


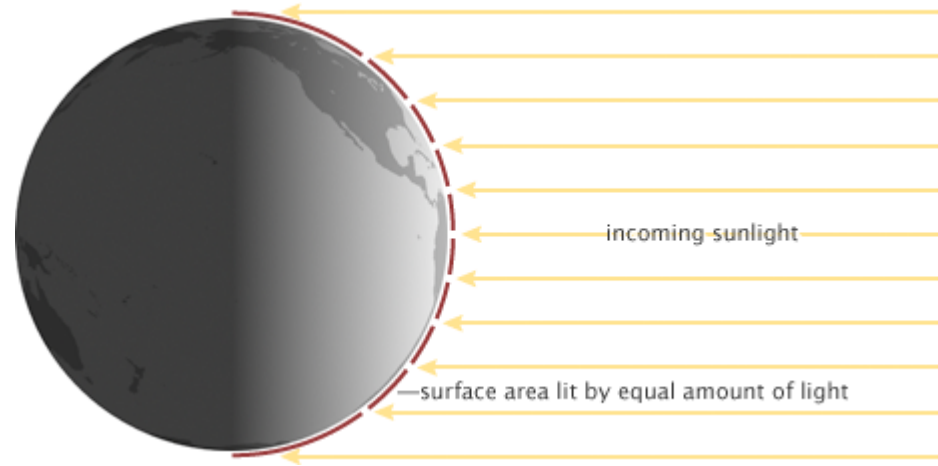
Hydrostatic balance

- Assume that there is no vertical acceleration, i.e. net force on the cylinder of air is zero
- $$F_t + F_b + F_g = 0$$

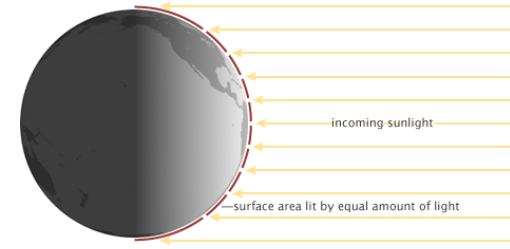
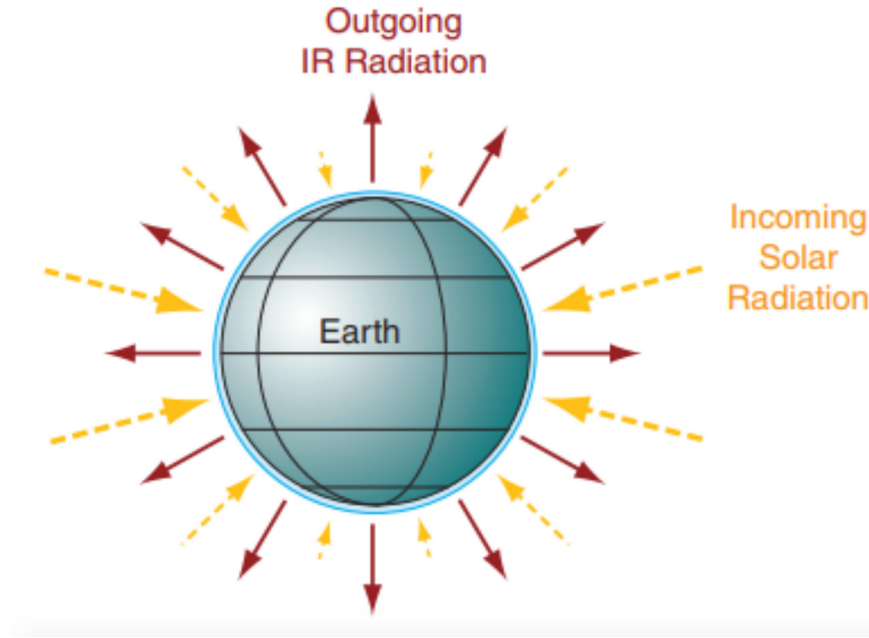
$$\Rightarrow -(p + \delta p) \delta A + p \delta A - g \rho \delta A \delta z = 0$$

$$\Rightarrow \delta p / \delta z = -g \rho$$
- Pressure decreases with height in proportion to the weight of the overlying atmosphere
- The atmosphere fades away ...



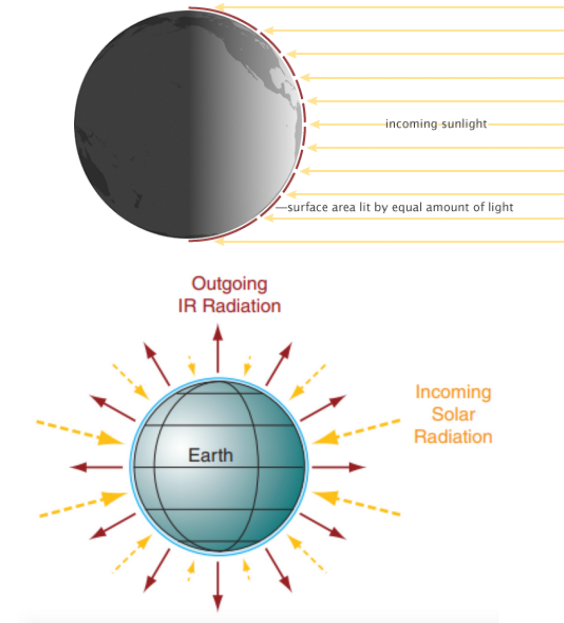
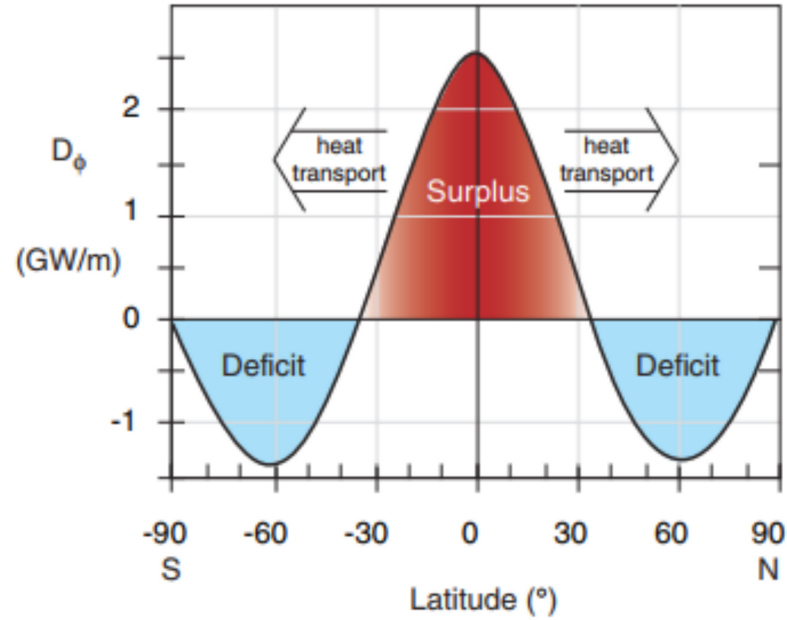


3. The Atmosphere → Meridional Structure



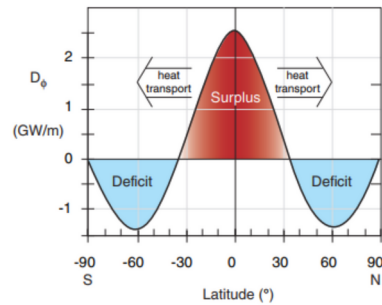
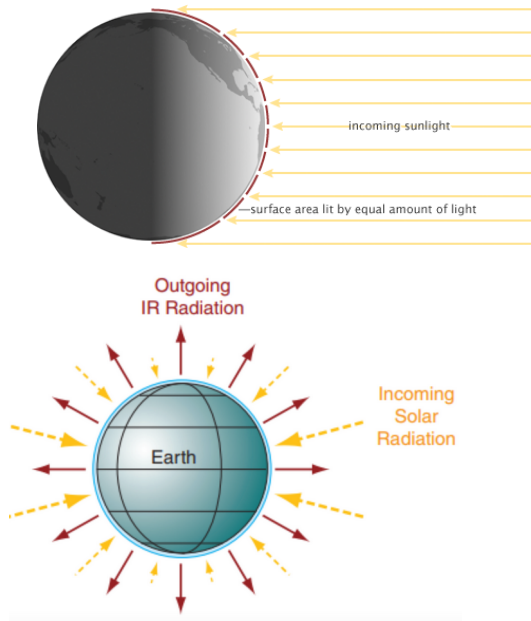
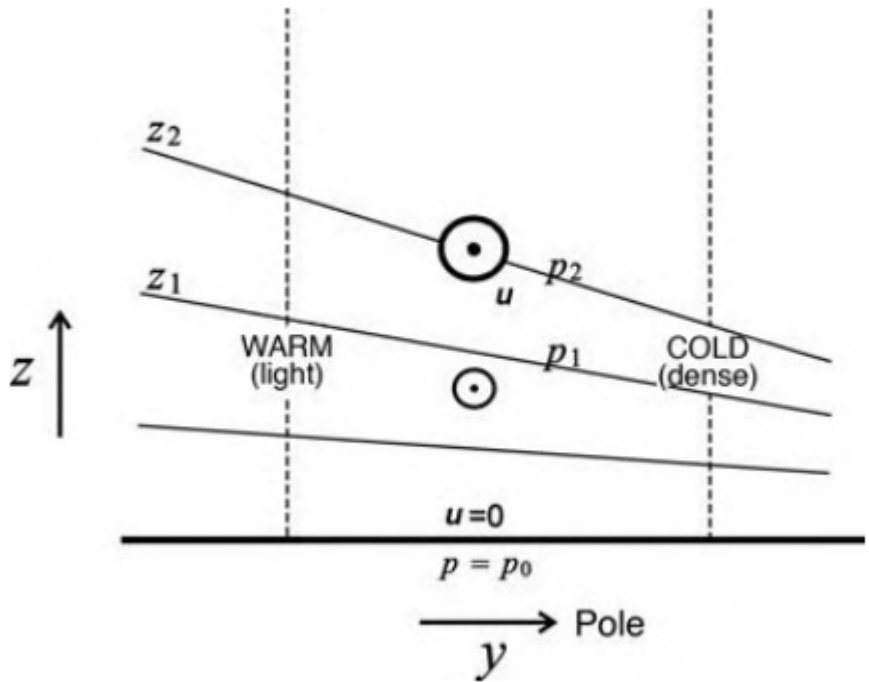
3. The Atmosphere → Meridional Structure





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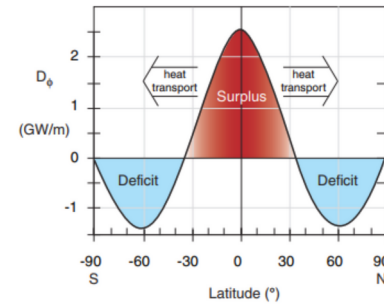
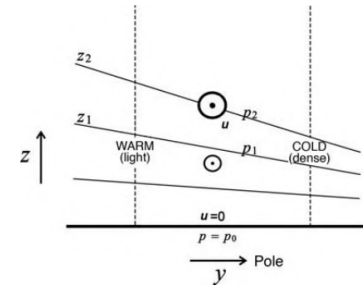
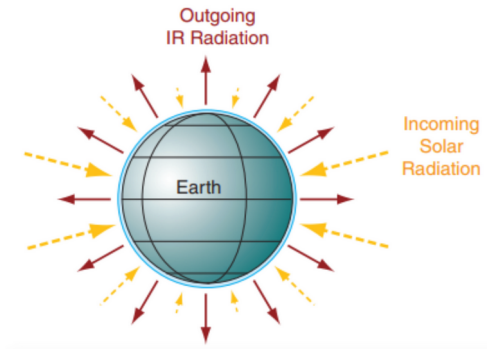
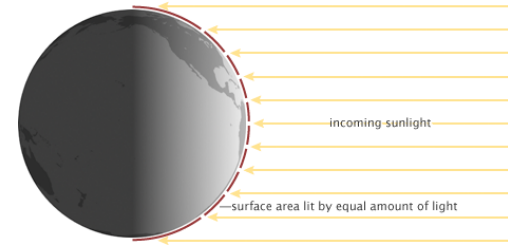


3. The Atmosphere → Meridional Structure



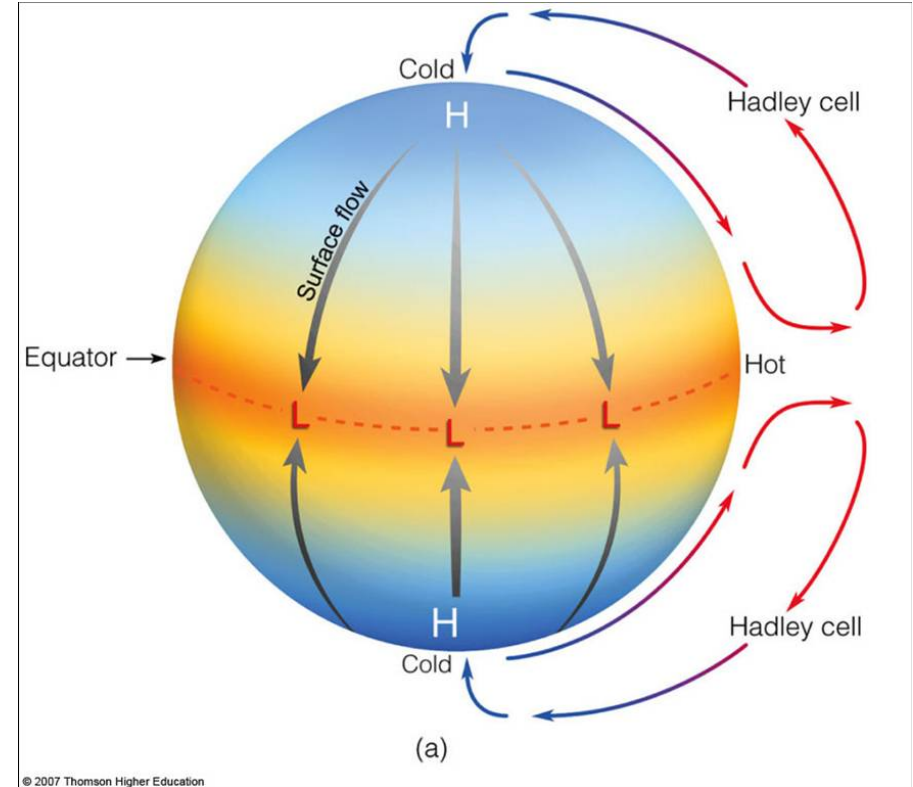
Meridional temperature and pressure gradient

- Sun heats up the equators more than the poles (due to the angle of inclination of sun rays)
- Outgoing IR radiation is more or less even
- Net radiation budget is such that there is a deficit at the poles and a surplus at equator
- Equator air is thus warmer, lighter and taller
- Polar air is thus colder, denser, and shorter
- Meridional pressure gradient is established



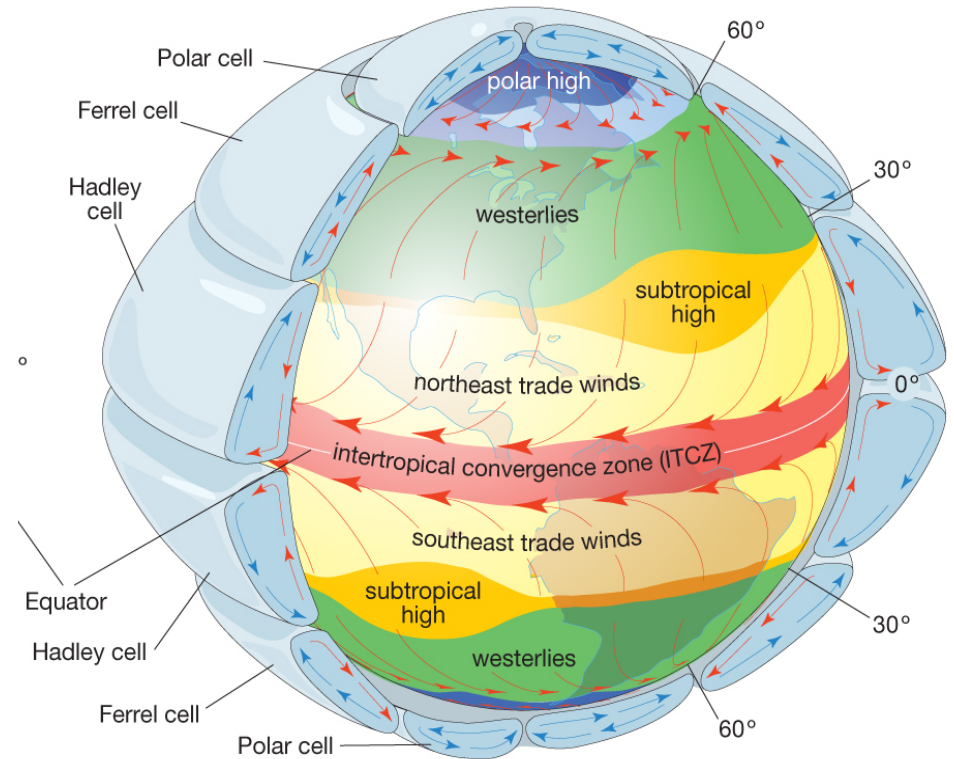
Single Cell Model

- Assumptions:
 - No land masses
 - No seasons
 - No rotation
- Thermally direct circulation: Hadley Cell
 - “thermally direct”: warm air rises and cold air sinks
- In presence of rotation, air is deflected eastwards due to Coriolis’s Force
- Air masses from equator never make it to the poles!



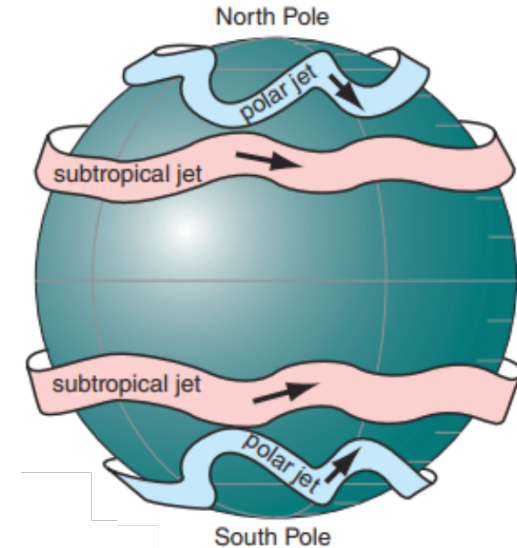
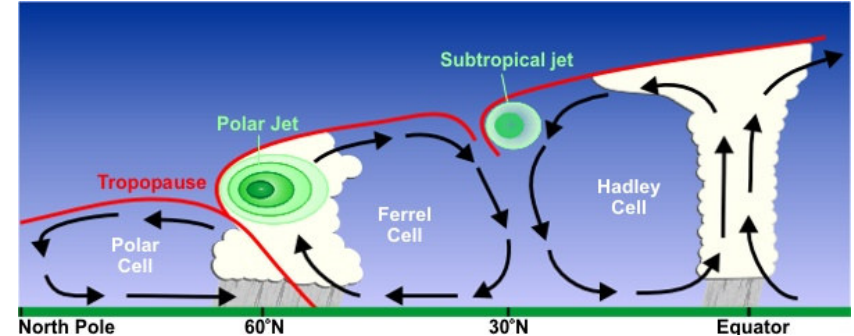
Three Cell Model

- Poleward moving air from the equator sinks at around 30N and 30S
 - This “subsidence” of dry air coincides with most deserts
- The subsiding air is again sent equatorward and poleward
 - The northeasterly and southeasterly “trade winds” converge around the equator → intertropical convergence zone
 - Poleward westerlies converge at the polar front at 60N and 60S



Jet Streams

- Westerly jets in the upper troposphere (around 250 hPa – 150 hPa)
 - Subtropical jet: 30N and 30 S
 - Polar jet: 60N and 60S
- Due to energy imbalance on either side of polar and subtropical fronts respectively
- Strong pressure gradient across the fronts causes intense wind speeds
- The subtropical jets do not extend till the surface



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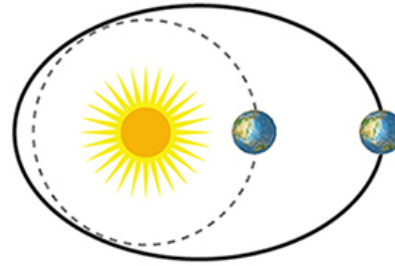
Additional topics

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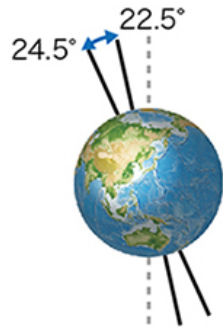


100,000 years



Eccentricity

41,000 years



Obliquity

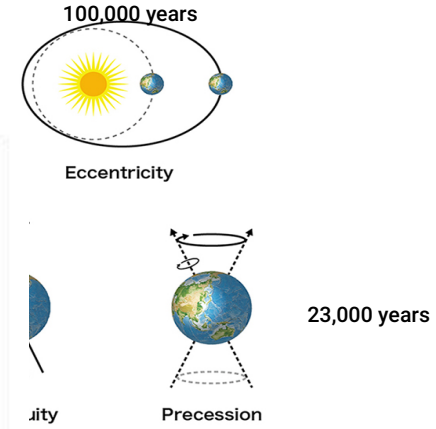
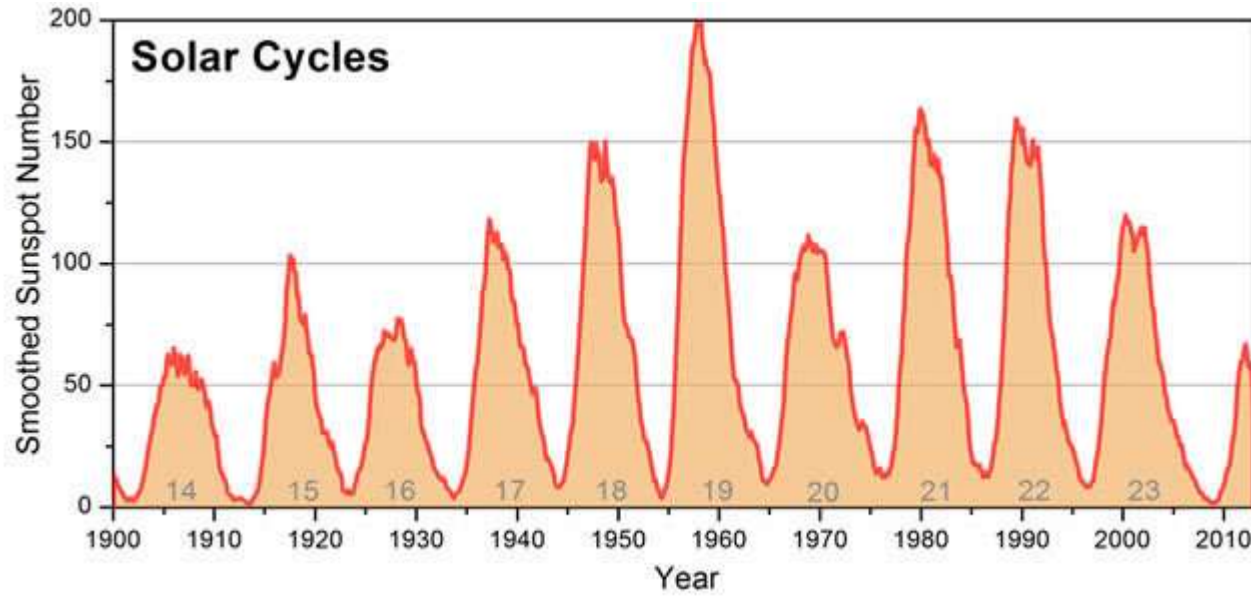
23,000 years



Precession

4. Additional topics → Climate Forcings





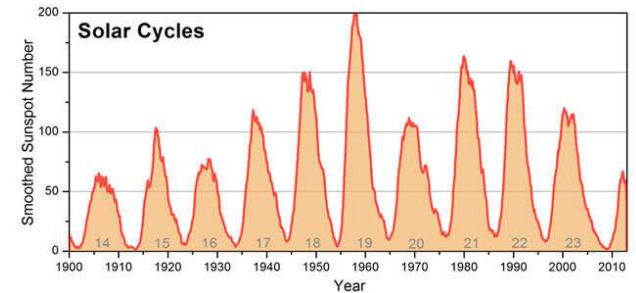
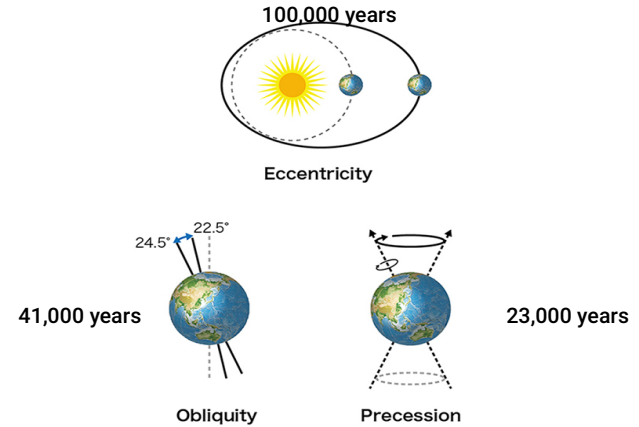
4. Additional topics → Climate Forcings



Climate forcings: External

- *Orbital forcings*, aka Milankovitch forcings
 - Changes in the earth's orbit changes the incoming solar radiation budget
 - Leads to changes in the climate

- *Solar cycles*, i.e., periodic ups and downs in the sun's activity leads to changes in incoming solar radiation, leading to changes in the climate



Climate Forcings: Internal

- *Anthropogenic*
 - Greenhouse gases
 - Stratospheric ozone
 - Tropospheric aerosols
 - Land surface change

- *Natural*
 - Volcanic aerosols
 - Thermohaline circulation



Climate sensitivity

- Change in a climate parameter for a given change in a climate forcing
 - Typical example: What is the climate sensitivity of temperature with respect to a doubling of atmospheric CO₂?
- Two kinds of climate sensitivity:
 - Transient Climate Response
 - Equilibrium Climate Sensitivity
- Estimated from:
 - Historical climate records
 - Climate models
 - Paleoclimate records

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Q&A

