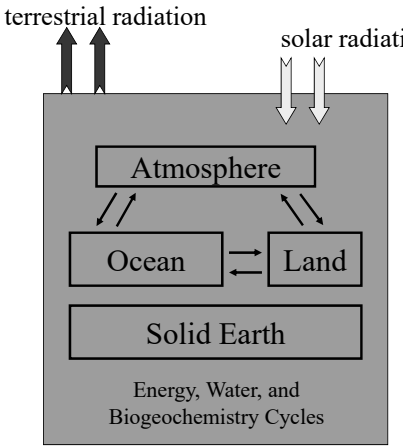
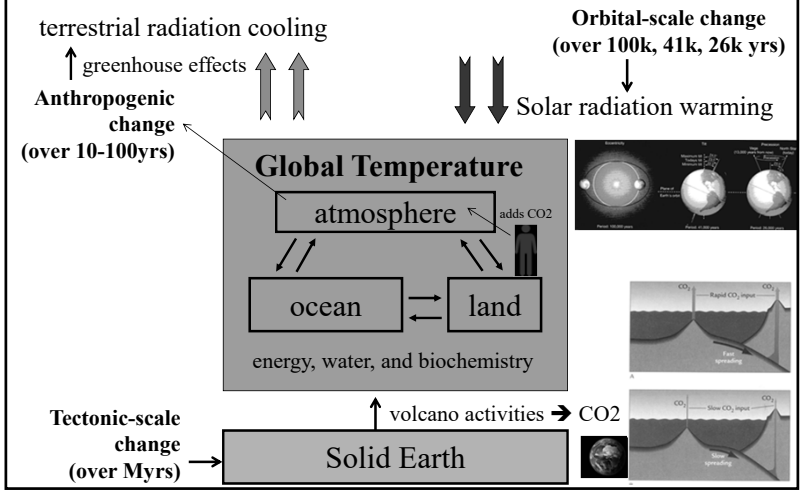
Lecture 2: Earth's Climate System



- ❑ Sub-components
- ❑ Global cycles
- ❑ What comes in
- ❑ What goes out

Components of the Climate System

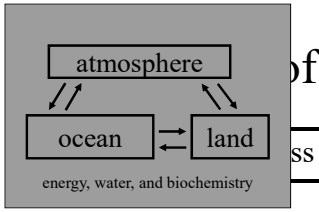


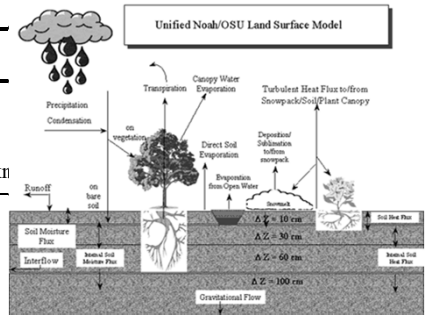
Pop Quiz

- ❑ How thick is Earth's atmosphere?

(a) 1 km (b) 4 km (c) 10 km (d) 150 km

of the Subcomponents





Atmosphere	5.14×10^{18} kg (~ 100-150 km	
Oceans	1.39×10^{21} kg (~ 4 km)	
Solid Earth (Land Surface)	5.98×10^{24} kg (~ 100s meters)	Vegetation, snowcover, and soil conditions affect the local and global climate. More changeable than oceans.

Subcomponent: the Atmosphere

Composition →

Vertical Structure

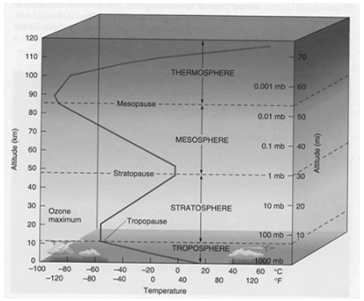


Table 3.1. Composition of the atmosphere. Constituents are listed with an indication of whether they are radiatively active, with a mixing ratio representative of the troposphere (trop.) or stratosphere (strat.), how they are distributed vertically, and controlling processes.

Constituent	Tropospheric mixing ratio	Vertical distribution (mixing ratio)	Controlling processes
N_2	0.7808	Homogeneous	Vertical mixing
O_2	0.2095	Homogeneous	Vertical mixing
* H_2O	≤0.030	Decreases sharply in trop. Increases in strat. Highly variable	Evaporation, condensation, transport Production by CH_4 oxidation
Ar	0.0093	Homogeneous	Vertical mixing
* CO_2	345 ppmv	Homogeneous	Vertical mixing Production by surface and anthropogenic processes
* O_3	10 ppmv[$]	Increases sharply in strat. Highly variable	Photochemical production in stratosphere Destruction in troposphere Transport
* CH_4	1.6 ppmv	Homogeneous in trop. Decreases in middle atmos.	Production by surface processes Oxidation produces H_2O
* N_2O	350 ppbv	Homogeneous in trop. Decreases in middle atmos.	Production by surface and anthropogenic processes Dissociation in middle atmos. Produces NO Transport
* CO	70 ppbv	Decreases in trop. Increases in strat.	Production anthropogenically and by oxidation of CH_4 Transport
NO	0.1 ppbv[$]	Increases vertically	Production by dissociation of N_2O Catalytic destruction of O_3
* CFC-11 * CFC-12	0.1 ppbv	Homogeneous in trop. Decreases in strat.	Industrial production Mixing in troposphere Photodissociation in stratosphere
ClO	0.1 ppbv[$]	Increases vertically	Production by photodissociation of CFCs Catalytic destruction of O_3

* Radiatively active
[$] Stratospheric value

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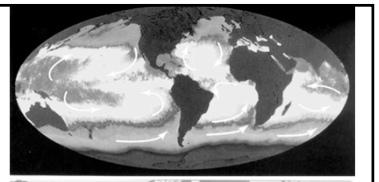
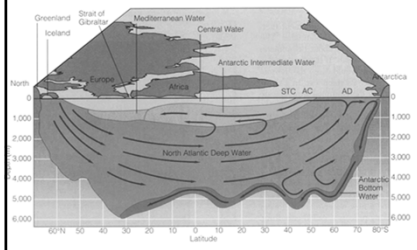
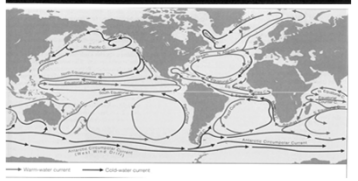
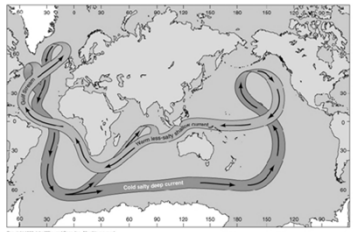
Subcomponent: Global Oceans









Pop Quiz

- ❑ What is the average depth of oceans?

(a) 1 km (b) 4 km (c) 100 km (d) 1000 km

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Subcomponent: Land Surface

Topography

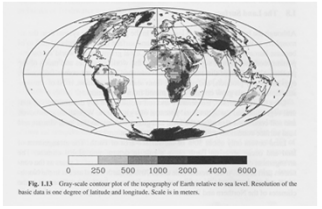

Fig. 1.13 Gray-scale contour plot of the topography of Earth relative to sea level. Resolution of the basic data is one degree of latitude and longitude. Scale is in meters.

Vegetation Type

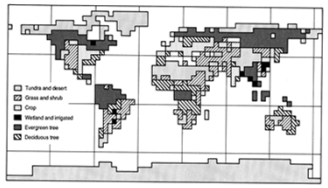

Fig. 5.14 Distribution of general ecotypes on a 5° × 5° grid (Olson et al., 1983).

- ❑ Not important for thermal energy because of its low heat capacity and negligible horizontal transport.
- ❑ Important for moisture exchange with the atmosphere because of greater surface roughness.

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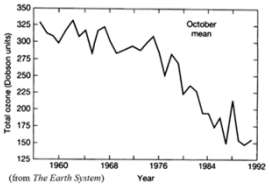
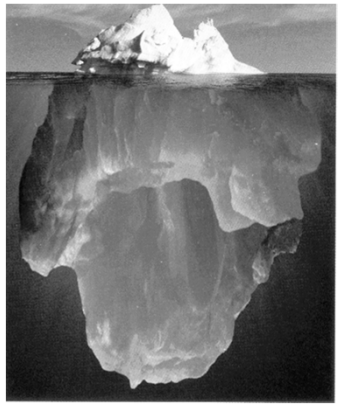
The 1997 Ozone Hole

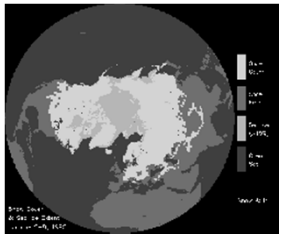


Subcomponent: Cryosphere

Sea Ice



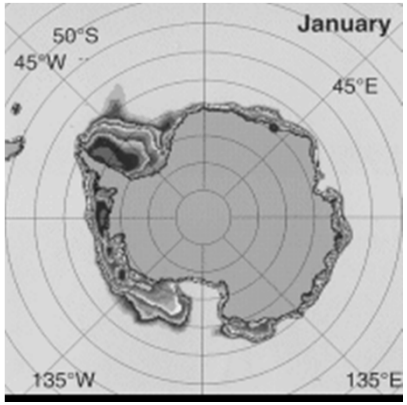
Land Ice



- ❑ The cryosphere is referred to all the ice near the surface of Earth: including sea ice and land ice.
- ❑ For climate, both the surface and the mass of ice are importance.
- ❑ At present, year-round ice covers 11% of the land area and 7% of the world ocean.

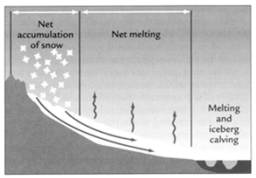
(from *The Blue Planet*)

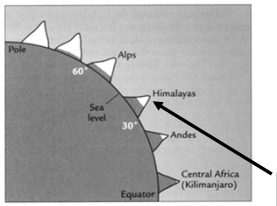
Seasonal Cycle of Antarctic Ice



(figures from Gloersen, P. et al. 1992; animated by D. B. Reush)

Land Ice





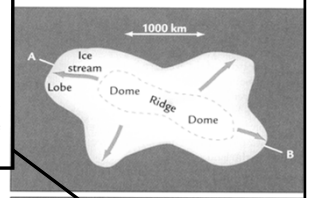
(from *Earth's Climate: Past and Future*)

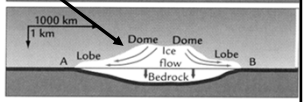
- ❑ **Continental Ice Sheets:**

  100-1000 km in horizontal extend.

  1-4 km in thickness.

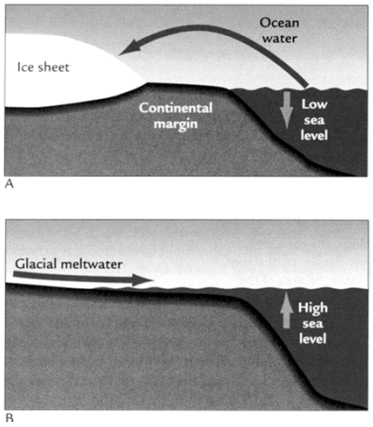
  Two larges sheets: Antarctic Ice Sheet and Greenland Ice Sheet.





- ❑ **Mountain Glaciers:** a few kilometers in length and 10-100 meters in width and thickness.

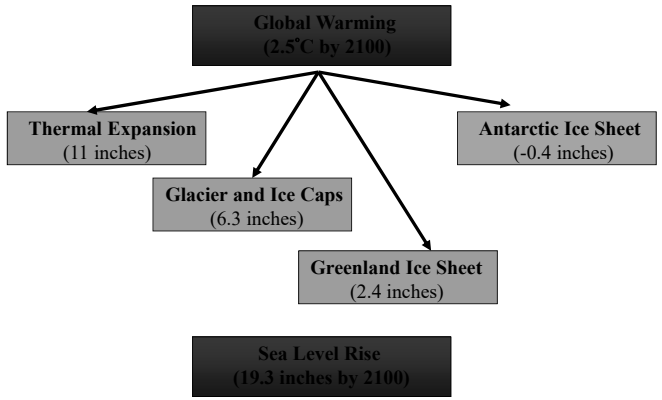
Land Ice and Sea Level



(from Earth's Climate: Past and Future)

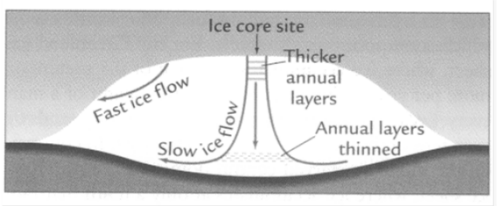
- The Antarctic Ice Sheet holds the equivalent in seawater of 66 meters of global sea level.
- The Greenland Ice Sheet holds the equivalent of 6 meters of global seawater.

Global Warming and Sea-Level Change



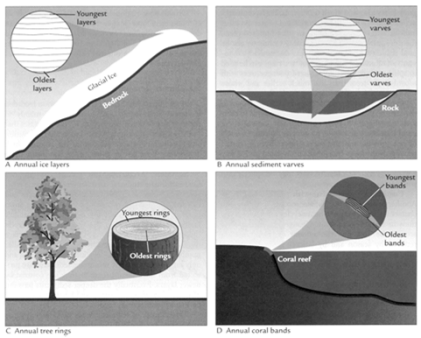
Glacial Ice

(from *Earth's Climate: Past and Future*)



- Ice cores retrieve climate records extending back thousands of years in small mountain glaciers to as much as hundreds of thousands of years in continental sized ice sheets.
- The Antarctic ice sheet has layers that extend back over 400,000 years.
- The Greenland ice sheet has layers that extended back 100,000 years.

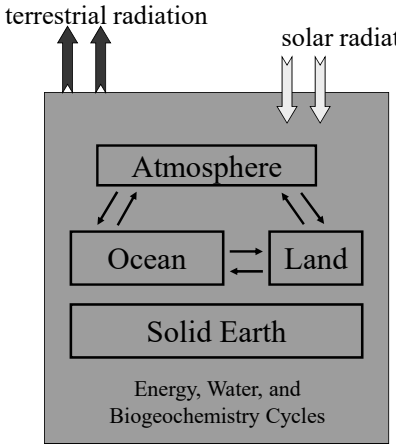
Climate Archives



(from *Earth's Climate: Past and Future*)

- Much of climate history is recorded in four climate archives:
  (1) Sediments
  (2) Ice
  (3) Corals
  (4) Trees
- How are those records dated?
- Hoe much of Earth's history each archive spans?
- What is the resolution of climate history yielded by each?

Global Cycles



❑ The ultimate driving force to Earth's climate system is the heating from the Sun.

❑ The solar energy drives three major cycles (energy, water, and biogeochemisty) in the climate system.

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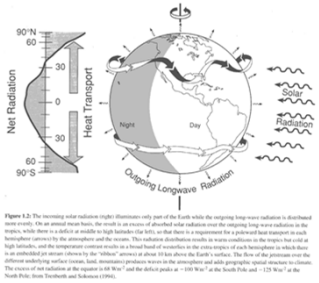
Global Energy Cycle



(from *Climate Change 1995*)

- **Sunlight drives air motions in the atmosphere**

➔ Winds blow over oceans to drive currents

➔ Air and ocean motions together keep the tropics from too warm and the poles from too cold.

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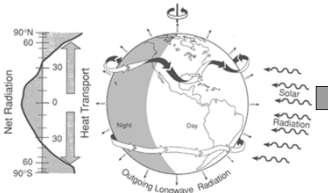
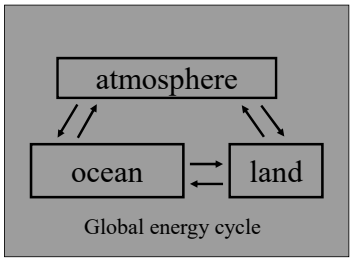
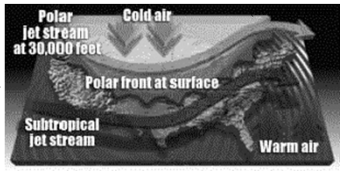
Global Energy Cycle



(from *Climate Change 1995*)



Atmospheric Circulation



Ocean Circulation

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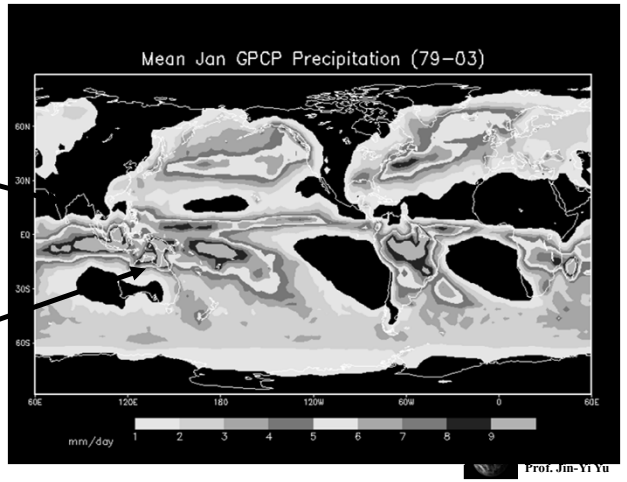
Seasonal Cycle of Rainfall



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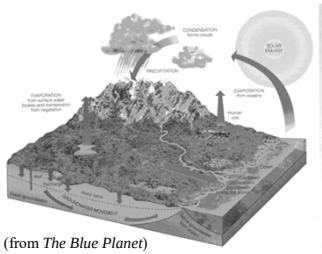
Global Water Cycle



(from *The Blue Planet*)

The water cycle describes the fluxes of water between the various reservoirs of the climate system.

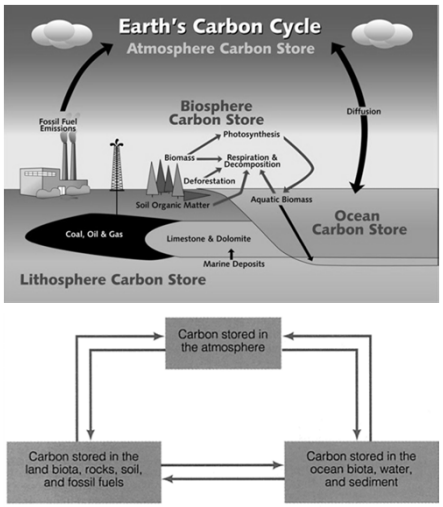
Water Reservoirs:

- Ocean (97.5% of global water)
- Polar Ice Sheet (2.01%; 77.2% of fresh water)
- Groundwater (0.58%; 22.1% of fresh water)
- Atmosphere & surface streams, lakes (very small fraction)

Water Fluxes:

- Evaporation (from ocean+land to atmosphere)
- Precipitation (from atmosphere to ocean+land)
- Transpiration (land to atmosphere via vegetation)
- Surface Runoff (land to ocean)

Global Biogeochemistry Cycle



Pop Quiz

❑ Where can we observe the ozone hole phenomenon?
Over the ____ (a) Arctic (b) Antarctic (c) Equator