Overview of The Earth System

ATS 150
Lecture 2

The Earth System

The Earth’s climate results from the interaction of many properties and processes:

- Solar radiation and orbital geometry
- The size, gravitational force, and rotation rate of the planet
- The composition, structure, and internal dynamics of the planet
- The geography of continents, glaciers, mountain ranges, and oceans
- Ocean properties and circulation
- Atmospheric constituents, their chemical interactions, circulation, and the hydrologic cycle
- The living ecosystems that inhabit the planet, and the biogeochemical transformations they conduct

Origins

- Earth formed by gravitational accretion ~ 4.7 billion years ago
- Solar “constant” was ~ 30% less than today
- Impact heating kept surface hot and sterile
- Giant collision separated the Moon and helped differentiate chemical layers

Cross-Section of Our Dynamic Planet!
Plate Tectonics and Climate

- Continental plates are lighter (buoyant) and rise in collisions, whereas oceanic plates subduct.
- Rearrangement of ocean basins dramatically changes poleward heat transport.

Energy Reservoirs

- The oceans are about 4000 m deep.
- The top 10 m equal the mass of the atmosphere.
- The top 3 m equal the heat capacity of the atmosphere.

The state of the oceans determines the climate on time scales of thousands to millions of years!

Vertical Structure of the Oceans

- Warm buoyant “raft” floats at surface.
- Cold deep water is only “formed” at high latitudes.
- Very stable, hard to mix, takes ~ 1000 years!
- Icy cold, inky black, most of the ocean doesn’t know we’re here yet!

Sea-Surface Temperatures

- W. Pacific “Warm Pool”
- Effects of Western vs Eastern boundary currents!
Ocean Currents

- Midlatitude "gyres"
- W-E flow in tropics
- Circumpolar current

How are these known? Effects on poleward energy transport?

Ice and Snow

Land and Sea Ice

- Greenland is covered with ice to depths of several kilometers
- Permanent ice cover further north overlies an isolated ocean basin

Sea Ice
The Earth’s Hydrologic Cycle

Clouds of Many Kinds

Earth's Energy Balance

• Must be balanced by horizontal transport of energy by atmosphere and oceans!
The Job of the Atmosphere

is to let the energy out!

“Piles up” in tropics   “Escapes” near poles and aloft

The movement of the air (and oceans) allows energy to be transported to its “escape zones!”

If the Earth Didn’t Spin …

- Warm air rises (tropics)
- Cold air sinks (poles)
- Energy transported from equator toward poles

Jet Streams

- 2 Jet Streams
  - Midlatitude Jet gives us storms
  - Subtropical Jet weaker, higher up
**Atmospheric Circulation in a nutshell**

- Hot air rises (rains a lot) in the **tropics**
- Air cools and sinks in the **subtropics** (deserts)
- Poleward-flow is deflected by the Coriolis force into westerly jet streams in the **temperate** zone
- Jet streams are unstable to small perturbations, leading to huge eddies (**storms and fronts**) that finish the job

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**Climates of the World**

- **Deep Tropics**: hot and wet, with little seasonal variation
- **Seasonal tropics**: hot, with “summer” rain and “winter” dry (monsoon)
- **Subtropics**: dry and sunny, deserts and savannas, often with a well-defined rainy season (**summer or winter**)
- **Midlatitude temperate zone**: warm summers, cold winters, moisture varies by location but often comes in episodes throughout the year
- **Polar regions**: very cold, generally very dry, dark all winter!

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**Weather vs Climate**

- **Weather**: the state of the atmosphere at a place and time as regards heat, cloudiness, dryness, sunshine, wind, rain, etc.
- **Climate**: the weather conditions prevailing in an area in general or over a long period of time

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**Climate and Vegetation**
Land Vegetation

- Tropical Forest
  - Located in equatorial zone of mean rising motion and heavy precipitation during much of the year
  - Dark color (albedo), very strong energy absorption
  - Broadleaf evergreen trees with extensive understory, as many as 300 tree species per km²
  - The most productive ecosystems on Earth
  - Some are very deeply rooted (> 10 m) and can withstand periods of severe drought

- Tropics and Subtropics
  - Rainfall and its seasonal distribution determine the distribution of plant types
  - Savannas and grasslands are adapted to seasonal and longer dry periods
  - Landscape patterns strongly influence radiation budgets and climate

- Grasslands and Savannas
  - Subtropical sinking air
  - As much as 85% of biomass is belowground
  - Highly adapted to drought, fire, and grazing
  - Very productive in rare wet periods

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Deserts

- Little or no rainfall
- Little or no vegetation
- Very bright (high albedo)
- Negative energy balance
- Sinking air

Temperate and Boreal Zones

- Latitude and continentality are both very important
- Moisture, growing season, and human land use also play roles

Broadleaf Deciduous Forest

- Very productive forests located in midlatitudes
- Abundant precipitation, but growing season limited by long cold winters
- Leaf area equals that of tropical forests during growing season

Boreal Forest

- Mostly evergreen needleleaf trees with little understory
- Short growing season, susceptible to drought and fire
- Low evaporative demand, so surface may be wet (bogs and fens)
- Very low albedo
Tundra

- High latitudes; cold dry climates, but very little evaporative demand, so surface may be very wet
- Underlain by permafrost in many places
- Low-growing, non-woody plants
- Very short growing season
- Supports migratory mammals