Land Surface and Biosphere

Land-Atmosphere Interaction

- Evapotranspiration (latent heat flux) from land is both a water flux and an energy flux, and soil moisture is both a water and energy storage.
- The land energy and water balances are coupled through the evapotranspiration term. Soil moisture thus plays a key role for both the water and energy cycles.
- These effects are, however, only important in regions where soil moisture is the main controlling factor for evapotranspiration.
- Other impacts: soil moisture-albedo feedback; soil moisture interaction with biochemical cycle; non-local impacts of soil moisture (via changes in large-scale circulation or moisture advection)

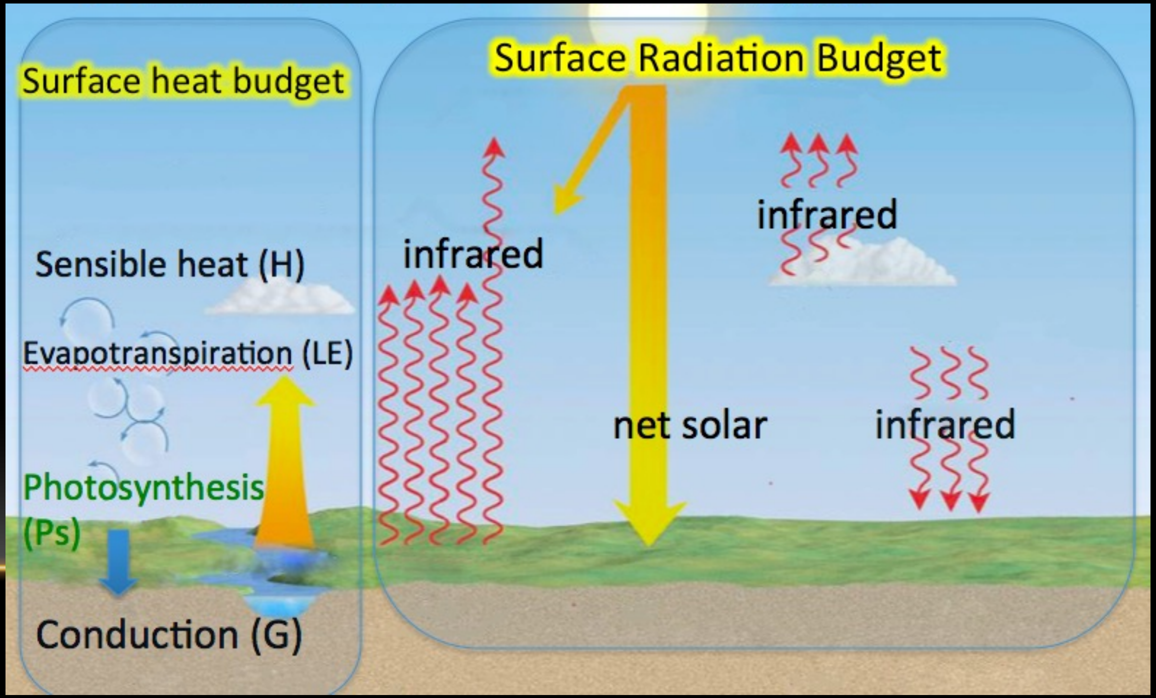
Land Energy Budget

- The land energy balance for the surface soil layer can be expressed as:

$$\frac{dH}{dt} = R_n - \lambda E - SH - G$$

- dH/dt is the change of energy within the considered surface soil layer including temperature changes and phase changes associated with soil freezing/melting or snow melt.
- Rn is the net radiation

  (net solar – upward infrared)
- λE is the latent heat flux
- SH is the sensible heat flux,
- G is the ground heat flux to deeper layers



https://www.atdd.noaa.gov/sebn/

Why are we interested in soil conditions?

- Soil moisture is a source of water for the atmosphere through processes leading to evapotranspiration from land, which include mainly plant transpiration and bare soil evaporation.
- Evapotranspiration is a major component of the continental water cycle, since it returns as much as 60% of the whole land precipitation back to the atmosphere (e.g. Oki and Kanae, 2006).
- Evapotranspiration is also an important energy flux, and land evapotranspiration uses up more than half of the total solar energy absorbed by land surfaces (Trenberth et al., 2009).
- Soil moisture has important impacts on climate processes, in particular on air temperature, boundary-layer stability and in some instances on precipitation.

Biosphere

- The biosphere is made of the parts of the earth where life exists – all ecosystems
- *How does the biosphere affect the physical climate system?*
  - Vegetation cover affects the surface albedo, evapotranspiration, water and energy budget.
  - The biosphere interacts with the atmosphere through exchanges of GHGs (e.g., CO_2, CH_4, N_2O), water, energy or precursors of short lived-climate forcers (e.g., ozone (O_3) and secondary organic aerosol (SOA)).
  - The biosphere interacts with oceans through processes such as the influx of freshwater, nutrients, carbon and particles.
  - These interactions affect precipitation frequency and distribution, frequency and intensity of heatwaves, and air quality. The biosphere is modified by global and regional climate change. It in turn affects atmospheric composition, surface temperature, hydrologic cycle and thus local, regional and global climate.
- Examples are provided next to demonstrate the interactions between the physical climate system and the biosphere.

The Ocean Biological Pump

- One example of the influence of biological activity on climate is the role of marine life in determining the chemical composition of the atmosphere.
- The ocean biological pump: CO2 is absorbed during photosynthesis by marine organisms in the ocean's euphotic zone, and then transferred deeper into the ocean's interior when the organism dies.
  - Some of this CO2 sequestration is temporary, and the CO2 is returned to the ocean waters to increase the partial pressure of CO2 when organisms decompose within the euphotic zone. But some of the CO2 sequestration is for very long periods, such as CO2 bound into clam shells.
  - This settling of decaying phytoplankton and zooplankton, fecal pellets, shells, and various other particles is referred to as the detritus rain, and it transports significant amounts of CO2 into the deep ocean.
- The overall effect of the ocean biological pump is to reduce the partial pressure of dissolved CO2 in the surface waters, allowing the additional uptake of CO2 from the atmosphere. If the ocean biological pump were not operating, it is estimated that the current atmospheric CO2 concentration would be 25% greater.

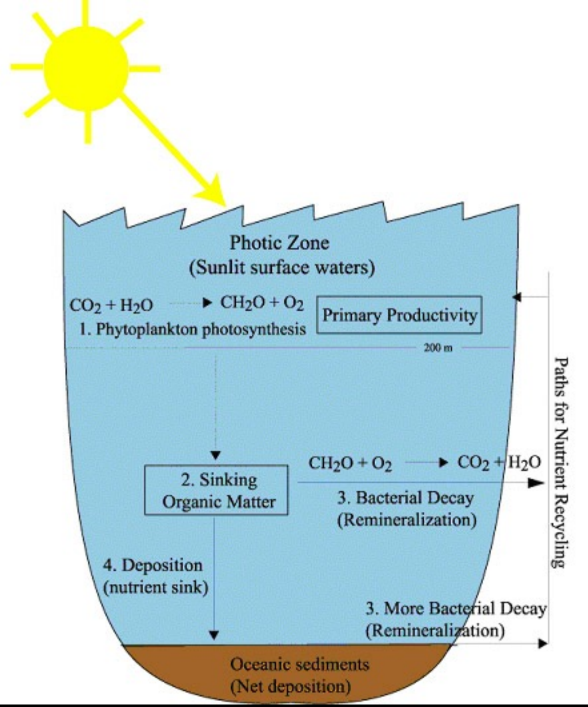


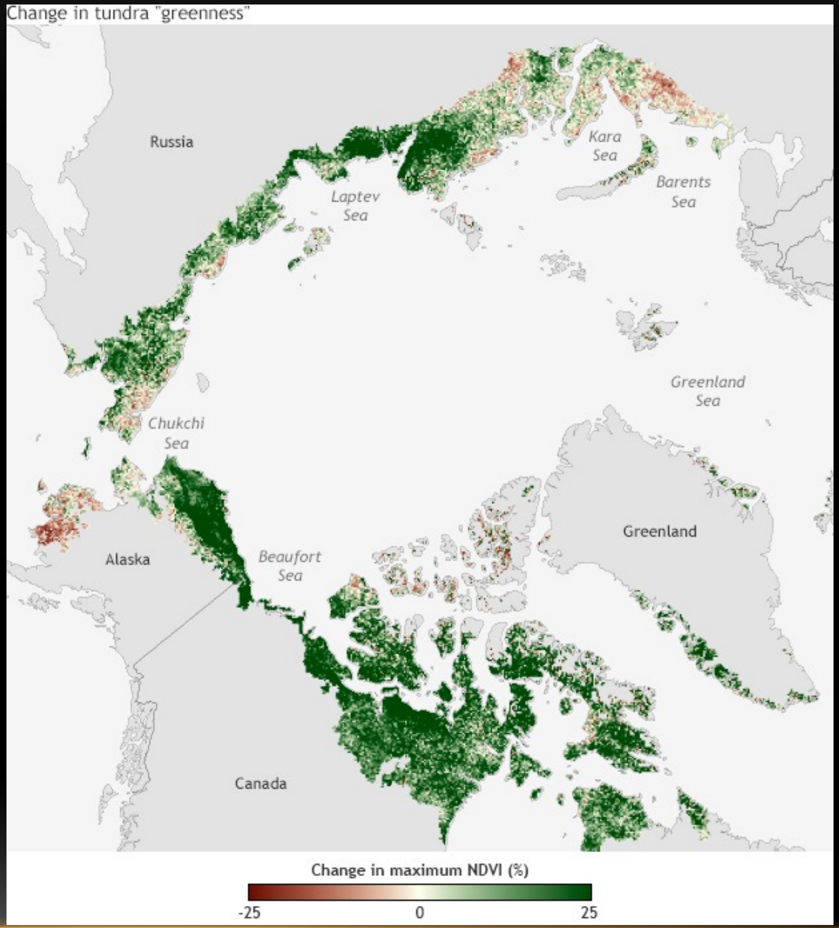
Figure source: http://earthguide.ucsd.edu/virtualmuseum/climatechange1/06_2.shtml

Biogeophysical Feedbacks: interactions between the atmosphere-ocean and chlorophyll

- Phytoplankton can reduce the ocean surface albedo and limit the shortwave penetration below the surface layer and increase upper ocean warming. The surface or upper ocean warming will modulate the ocean stratification and affect the oceanic circulation.
- Phytoplankton growth is primarily controlled by three key factors, temperature, light and nutrients, which are regulated by the atmospheric and oceanic circulation.

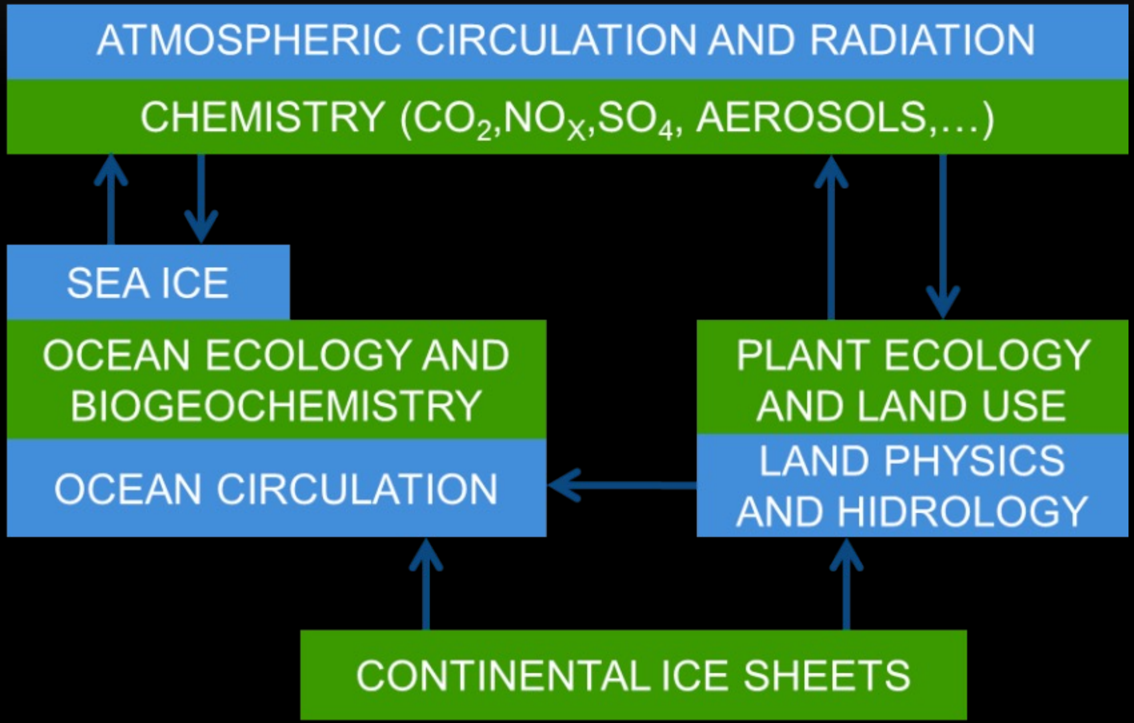
Tundra Shrubs Turn into Trees as Arctic Warms

- Warmer climate is driving Arctic greening, and warming also turns the Arctic tundra into forests in some regions.
- The advance of forest into Arctic tundra can increase Arctic warming.
    - During summer, the mean albedo of the forest canopy is lower than that of the tundra because of its darker color and more complex canopy structure.
    - The forest canopy can also mask snow, which leads to a smaller surface albedo.
- According to the NOAA Climate.gov, "*the greener, warmer, less icy Arctic of recent years is likely to be the new normal*"



https://www.climate.gov/news-features/featured-images/2013-arctic-report-card-greener-arctic-recent-years-likely-be-new

Earth System Prediction



https://www.climateurope.eu/earth-system-modeling-a-definition/

References

- Cook, K. H., 2013: section 2.6
- Santanello, et al, 2018: Land–Atmosphere Interactions: The LoCo Perspective, *Bulletin of the American Meteorological Society*, *99*(6), 1253-1272. https://journals.ametsoc.org/view/journals/bams/99/6/bams-d-17-0001.1.xml
- Arneth, A., Harrison, S., Zaehle, S. *et al.* Terrestrial biogeochemical feedbacks in the climate system. *Nature Geosci* **3,** 525–532 (2010). https://doi.org/10.1038/ngeo905