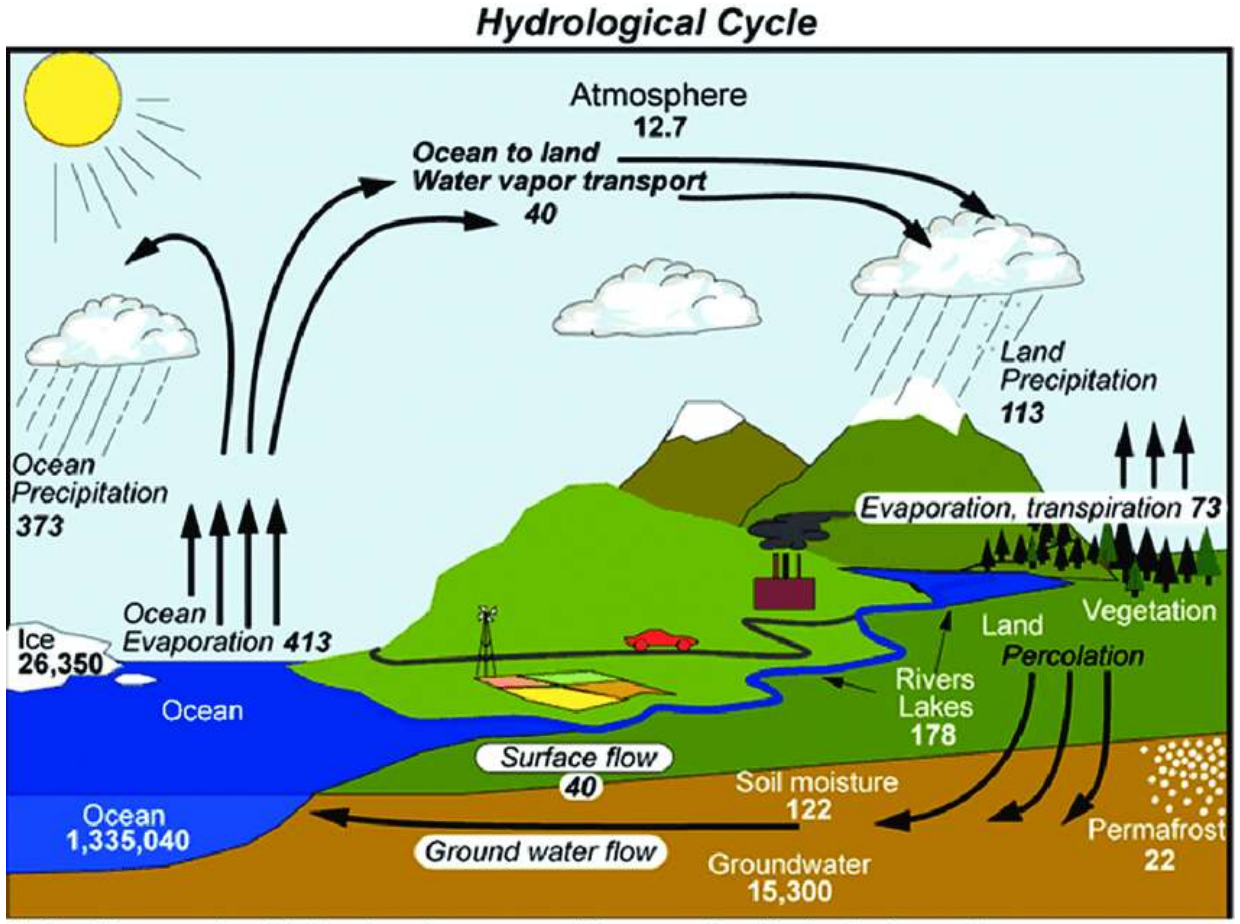
Understanding how the land surface affects both climate and weather systems around the world by Eleanor Blyth emb@ceh.ac.uk

Contribution from my colleagues at UKCEH: Josh Talib, Doug Kelley, Doug Clark, Toby Marthews, Chris Taylor, Bethan Harris, Guillaume Chagnaud, Sonja Folwell, Srinidhi Jha and Reading University: Emily Black.

Classic diagram of the water cycle – note different to the layman's concept.



Highlights:
Land Precip: 113,000 km3/year

Only 35% from oceans.

Land Evaporation: 73,000 km3/year

River flow: 40,000 km3/year

The hydrological cycle (TRENBERTH et al. 2007, https://doi.org/10.1175/JHM600.1)

Spatial patterns are key. What if climate change shifts the spatial patterns?

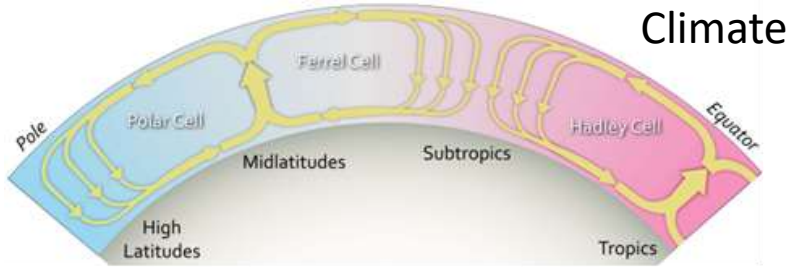
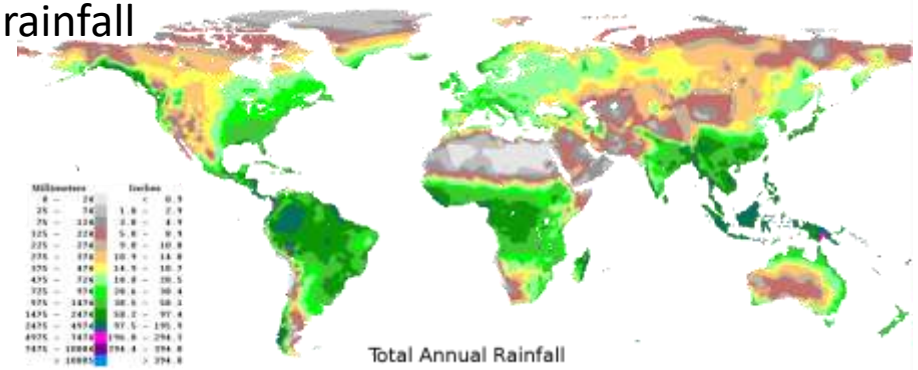


Figure 2.1. Mean meridional circulation in the troposphere, viewed in an exaggerated cross-section, and the corresponding climatic regions at Earth's surface.

Climate Systems gives spatial patterns of rainfall



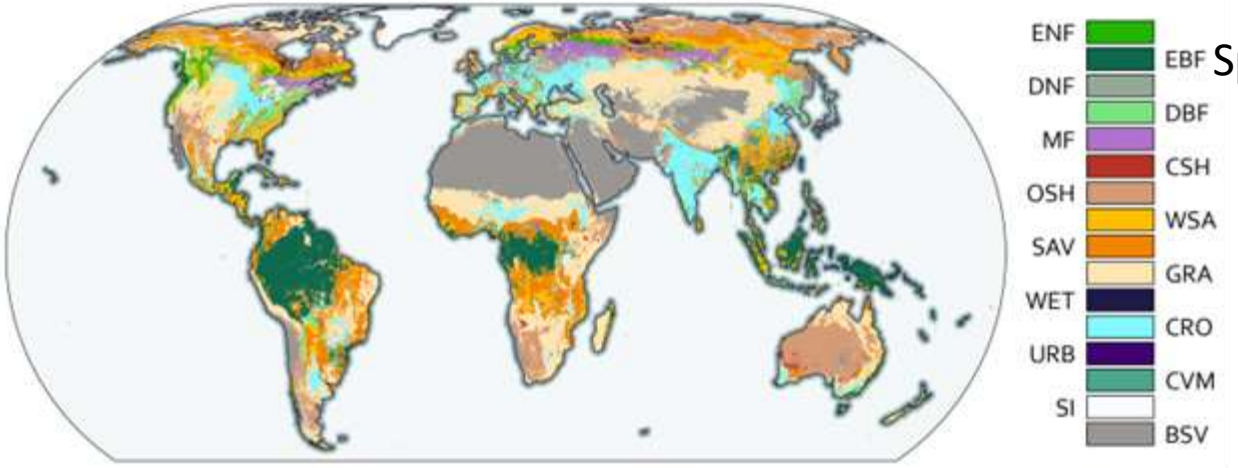


Figure 2.9. Global map of IGBP land cover types from MODIS/Terra+Aqua Land Cover for 2021: EBF: evergreen broadleaf forest; DBF: deciduous broadleaf forest; ENF: evergreen needleleaf forest; DNF: deciduous needleleaf forest; MF: mixed forest; CSH: closed shrublands; OSH: open shrublands; WSA: woody savannas; SAV: savannas; GRA: grasslands; WET: permanent wetlands; CRO: croplands; URB: urban area; CVM: cropland/natural vegetation mosaic; SI: snow and ice; and BSV: barren or sparsely vegetated. [doi:10.5067/MODIS/MCD12C1.061]

Spatial patterns of rainfall give patterns of vegetation

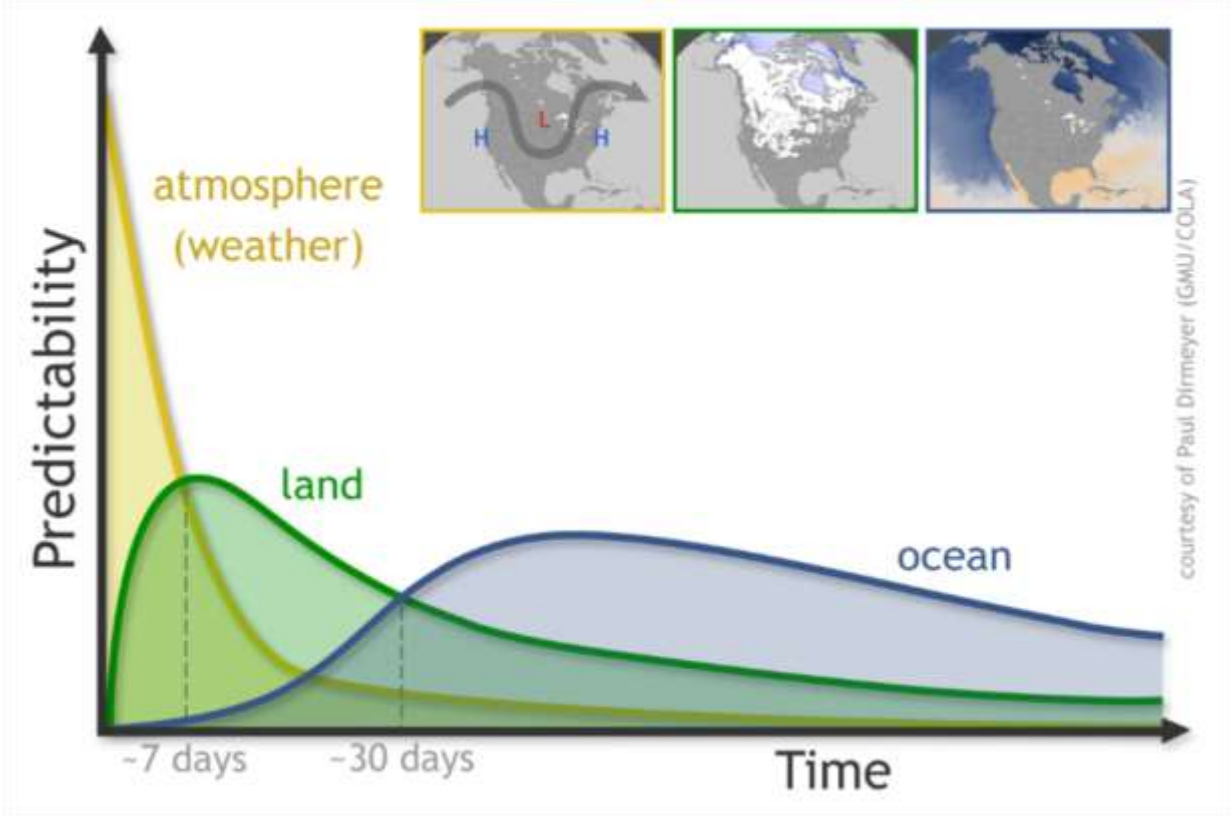
Do spatial patterns of vegetation give patterns of rainfall?

Within that large system is a smaller-scale system. We call it the Land Atmosphere System.

The land may play a critical role on the atmosphere when/where there is a coincidence of temporal responsiveness

Resonance:

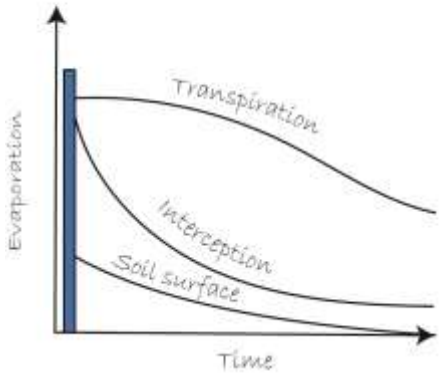
Where?
When?
What?
Why?
Does it matter?

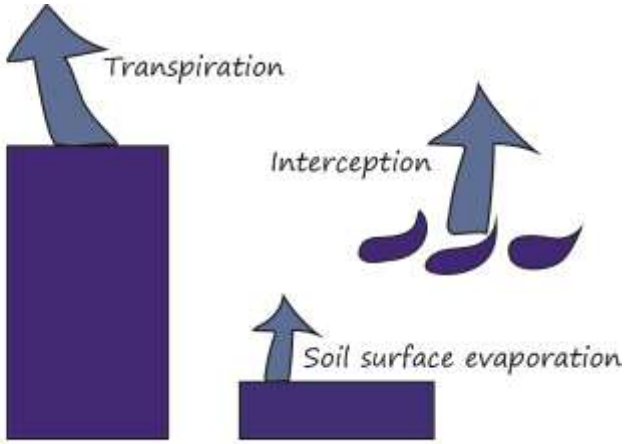


Evaporation – components and timescales

Different components of evaporation have different timescales.

- Interception – fast (24 hours)
- Bare soil – medium (a few days)
- Transpiration – slow (seasonal)
- Snow sublimation – medium (week)





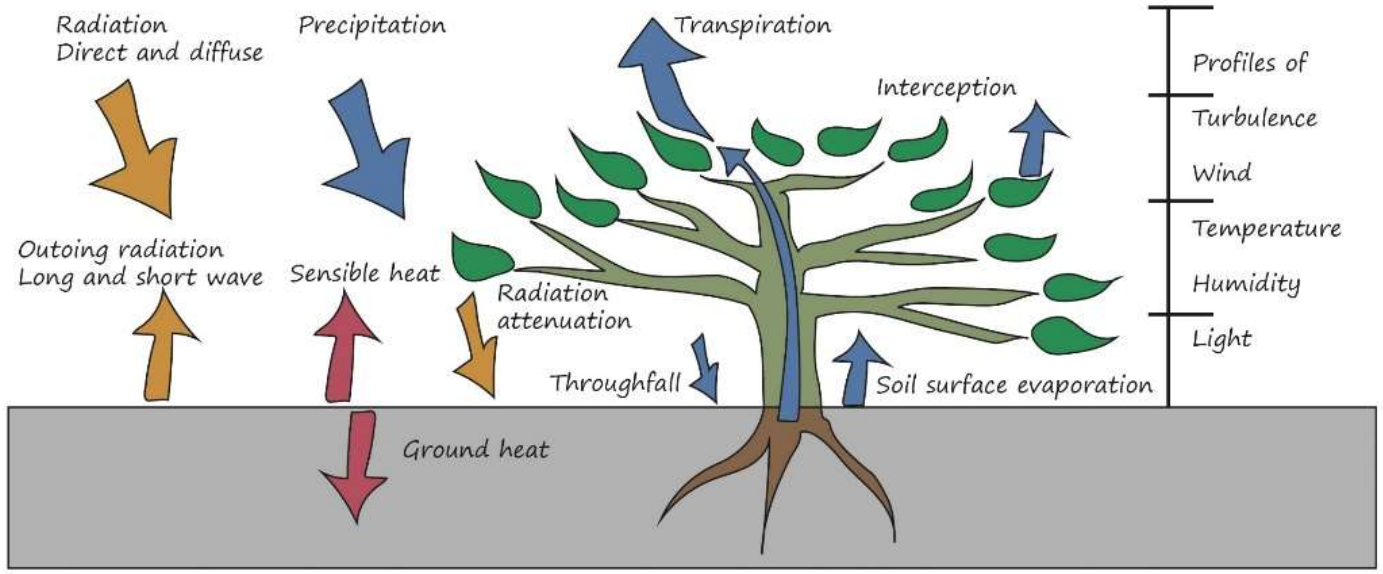
NOTE:

When Evaporation goes down, Heat goes up.

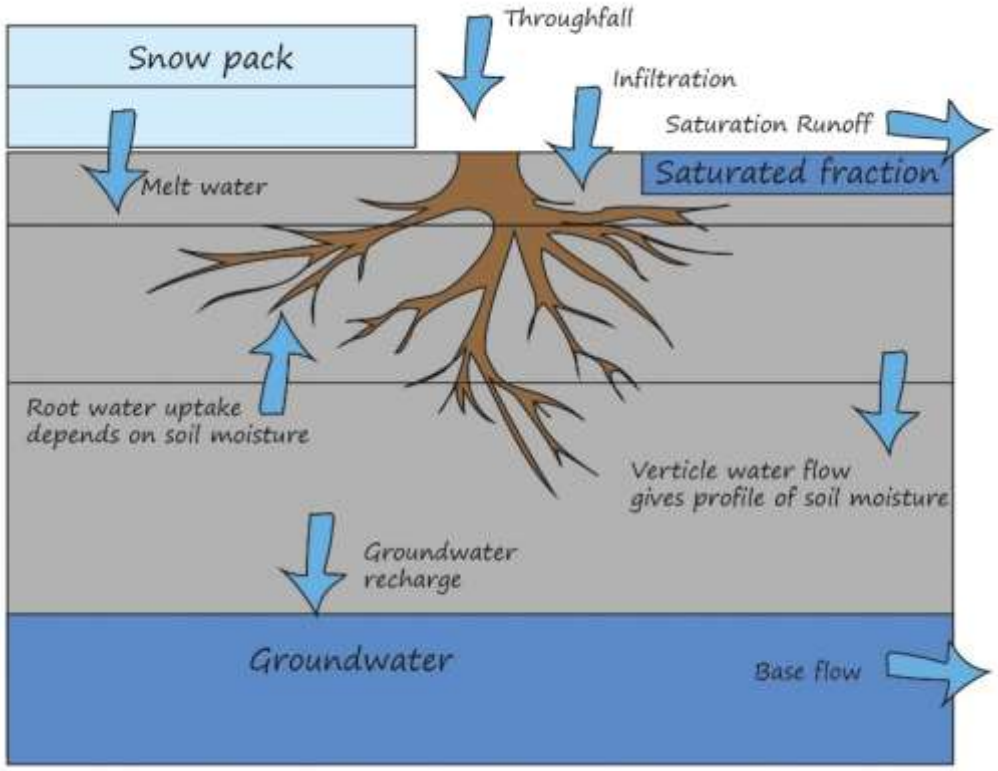
So patterns of wetness become patterns of heat, which create 3-D structures in the sky.

How we represent the physics of the Land in our computer models

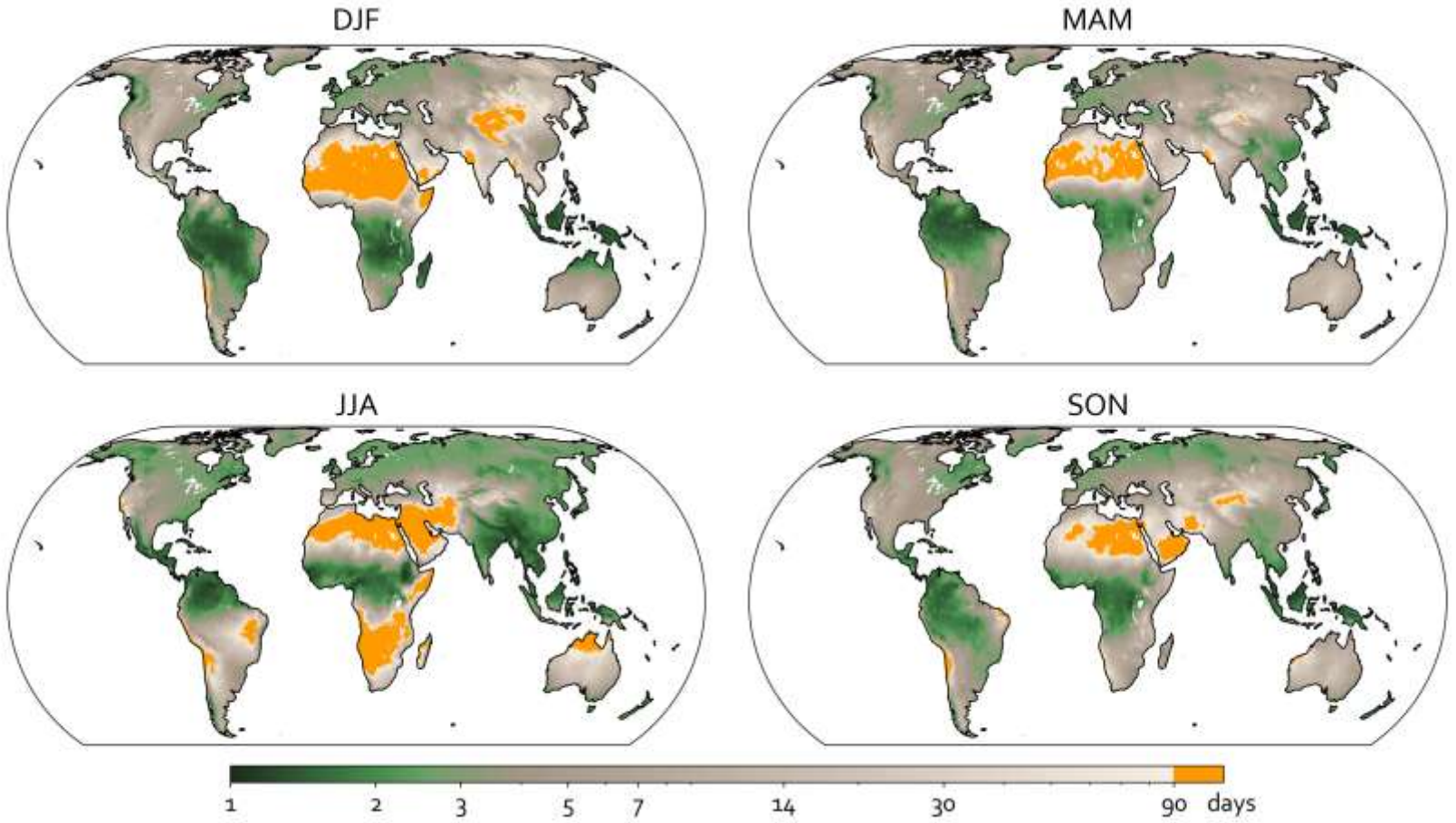
Canopy processes and surface exchange



Snow and soil physics



Frequency of Rain by Season

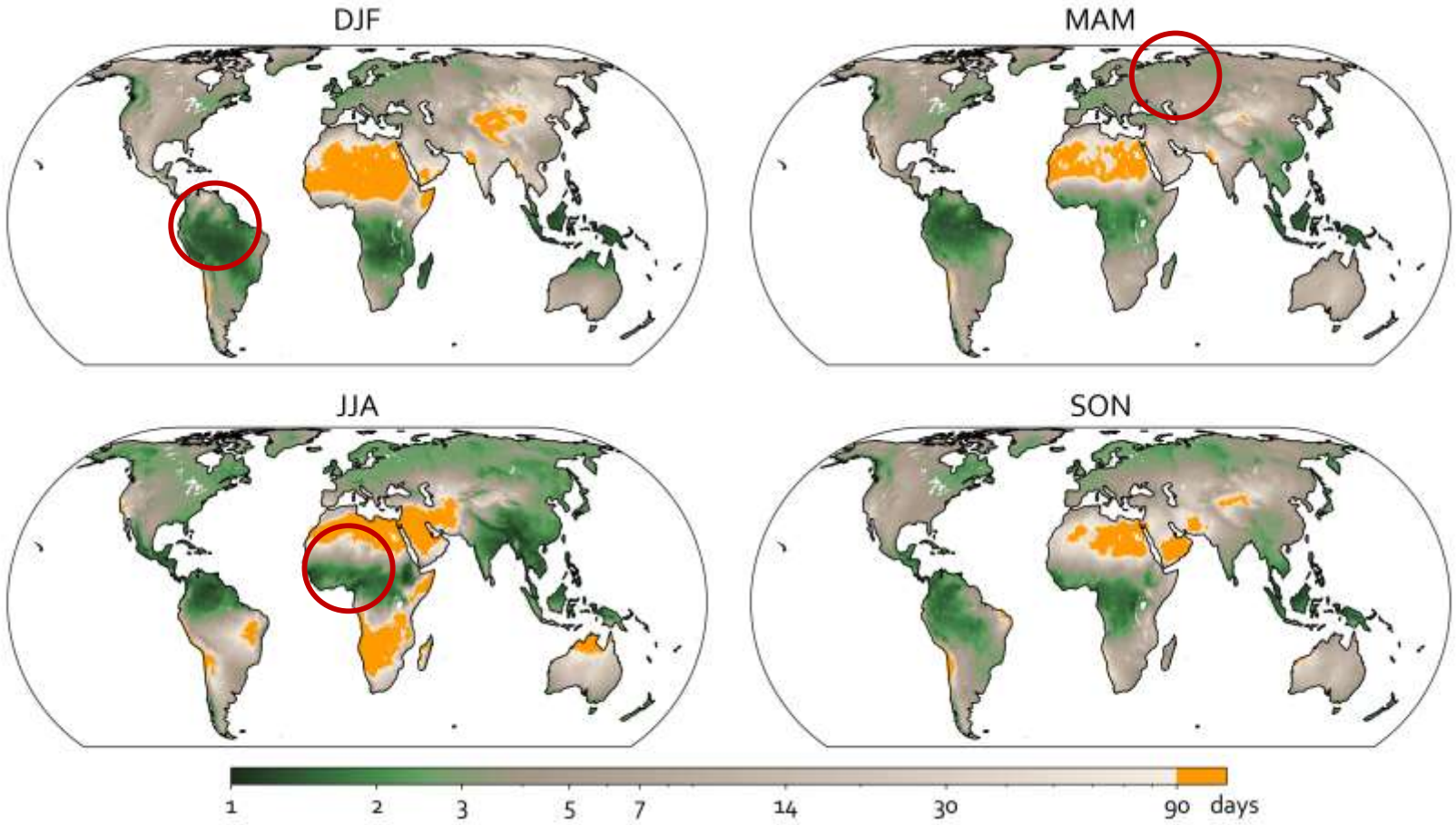


Affected by large-scale weather systems mainly related to ocean temperatures.

This figures shows the usual pattern of the number of wet hours per month. This is an indication of the frequency of rainfall.

- Dark green areas are raining daily
- Light green roughly every few days
- Brown bi-weekly to annual

Frequency of Rain by Season



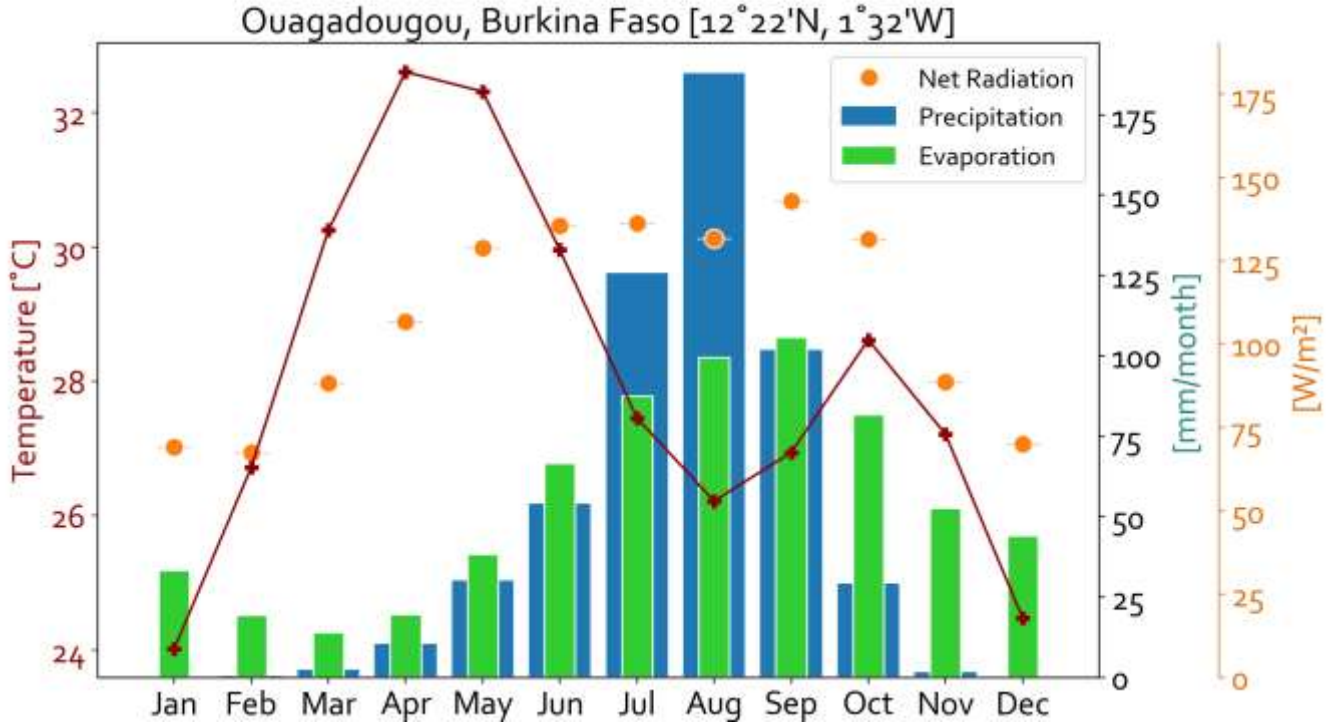
Three regions to illustrate the processes.

Sub-tropics or Semi-arid: JJA: 3 day rainfall

Boreal/Arctic: MAM: Increasingly early spring/snow melt

Tropics: DJF: Daily rainfall

Case study 1: Sub-tropics or semi arid: rains every 3 days. Convective rain affected by surface heating.



Land Atmosphere System effect

Sparse shrubs results in lots of exposed bare soil. Very sensitive to soil properties.

Evaporation from Soil Moisture affects atmospheric structures that resonates with 3-day monsoonal rains

How rainfall intensity affects the water budget: drainage and interception

Rainfall comes in clumps, not evenly spread.

This intensity means that small areas are saturated, rather than all areas a bit wet.

This speeds up the drainage which is very non-linearly dependent on soil moisture.

When this was accounted for in the model, the rainfall predictior was improved.

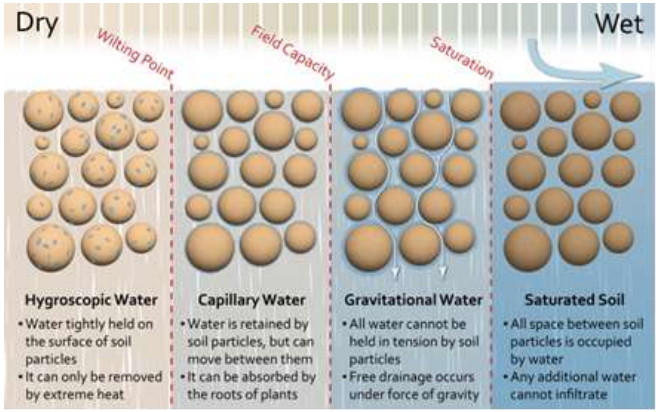


Figure 10.33. Water adhesion and movement in relation to soil particles at various soil moisture levels. The spheres represent soil grains, water is shaded blue.

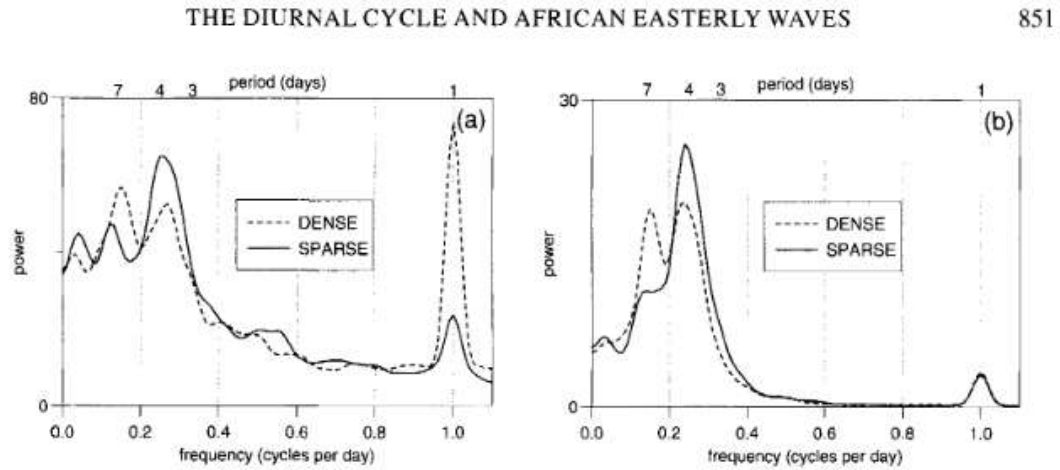


Figure 4. Spectra of (a) rainfall and (b) meridional wind at 700 hPa, averaged over each member of the two ensembles during July to September in the western Sahel (16.9°W–9.4°E, 11.3–18.8°N).

Taylor and Clark, QJRMS, 2001.

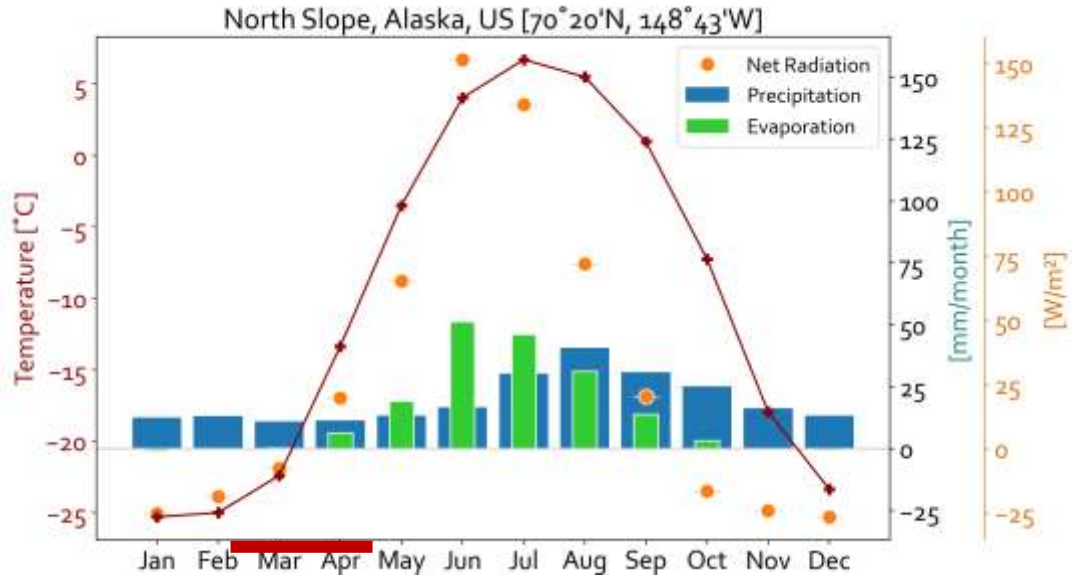
Case study 2: Boreal or Arctic: Energy exchange dominated by snow cover.

<u>Land Atmosphere System effect</u>

Snow takes months to melt out.

Region has massive winter-summer difference

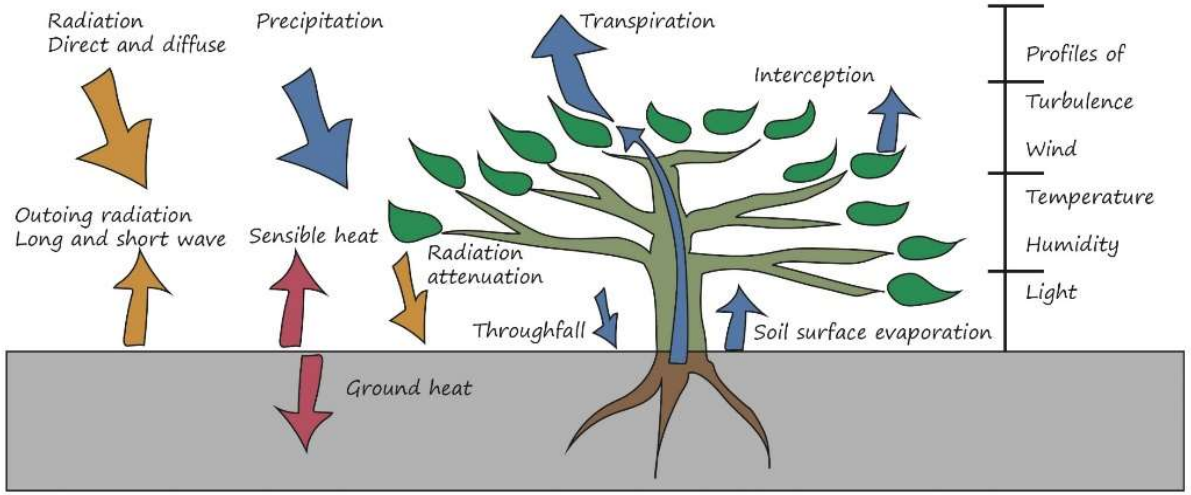
Resonates as snow keeps air temperature low



Critical time

<u>Snow falls below the tree canopy vs snow covers tundra</u>

Radiation balance affects snow pack



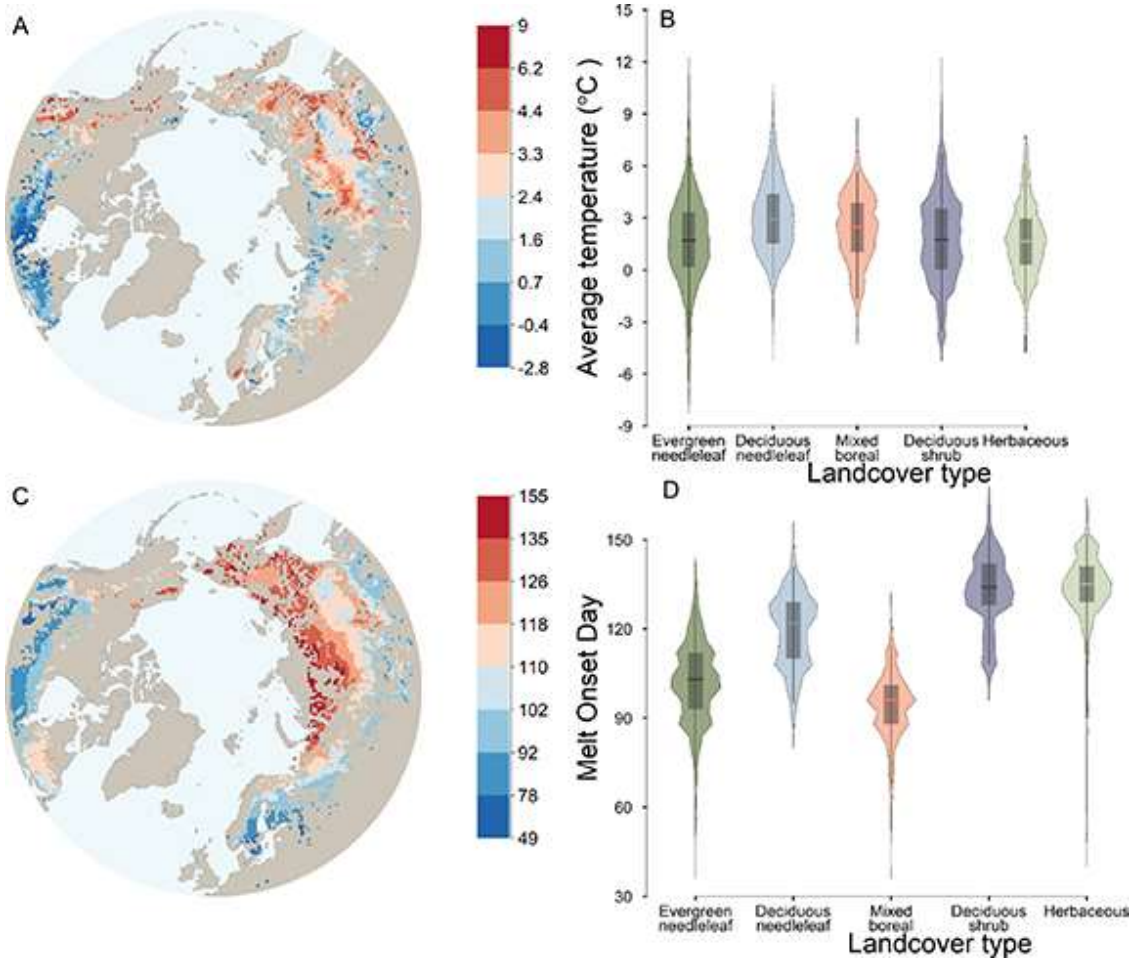
Trees shelter snow from shortwave radiation but increase overall absorption of energy.

Which one wins out?

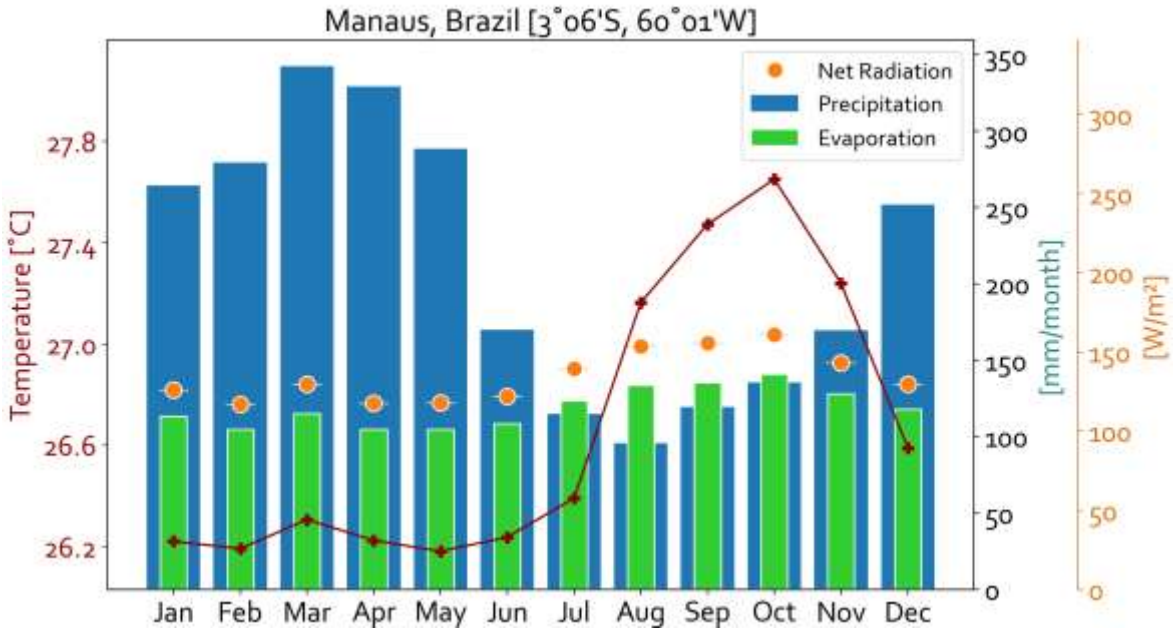
Modelling study at UKCEH (Turton, PhD) indicates that the energy absorbed by trees is transferred to the snow.

Presence of trees impacts onset of snow melt

This observational study also indicates the same:
Kropp at al, 2022. Presence of trees bring snow-melt earlier



Case study 3: Tropics: Daily rainfall, imported from oceans. Are they maintained through rainfall recycling?



Land Atmosphere System effect

Large leaved evergreen trees results in high (fast) evaporation rates.

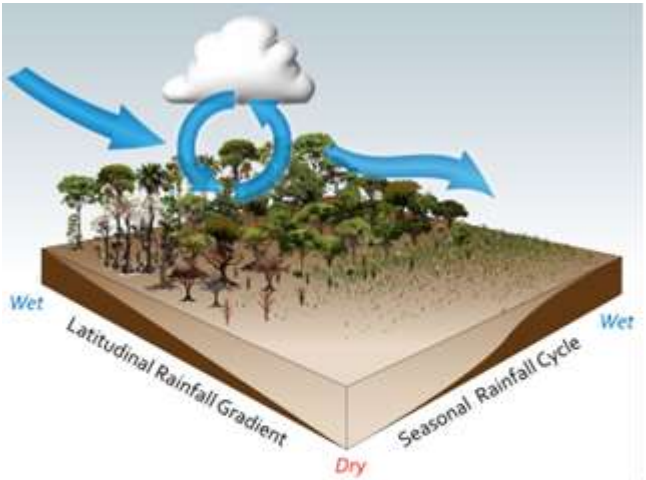


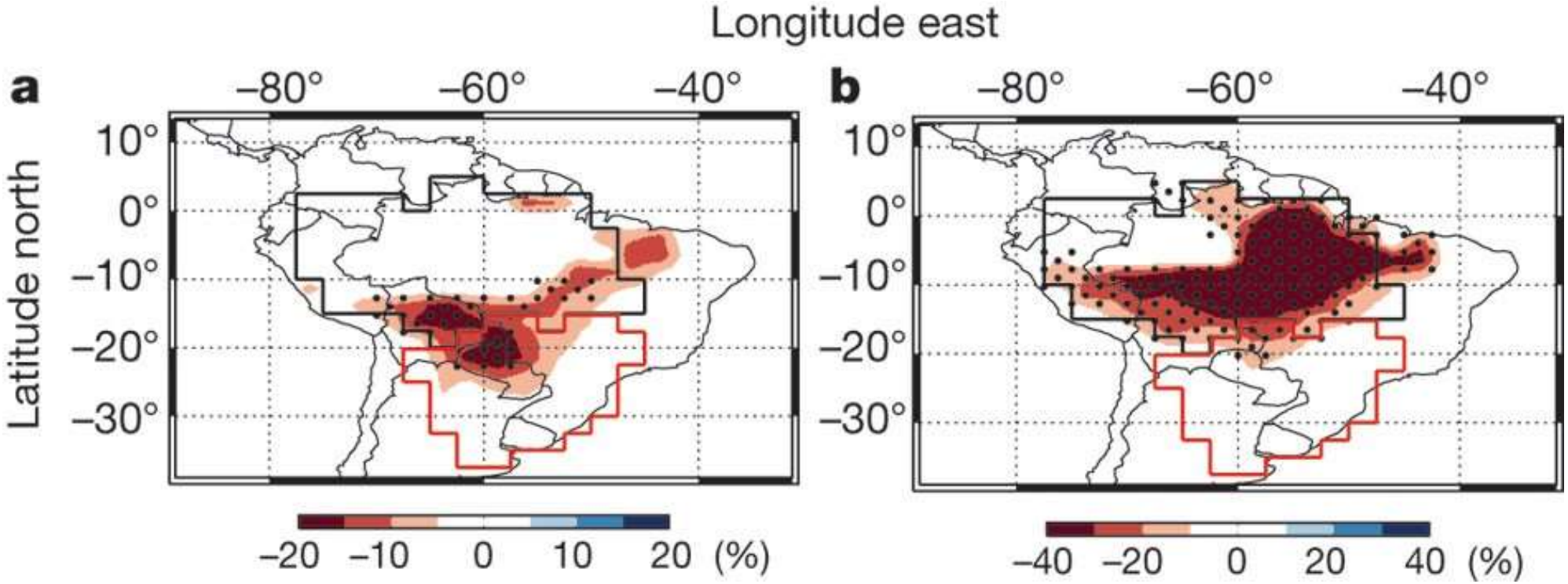
Figure 3.7. At low latitudes, gradients in rainfall with latitude (wet near the equator, dry toward the Tropics of Cancer and Capricorn) and the seasonal cycle of rainfall largely determine vegetation density and growth cycles, respectively.

When precipitation occurs, some of the water returns to the atmos nd evaporation.

Observations of increased tropical rainfall preceded by air passage over forests, Spracklen et al, Nature, 2012.

Using remote sensing and atmospheric back-trajectory modelling, they showed that air passage over dense forests produces about twice as much rain as passage over sparse vegetation.

Simulated percentage change in precipitation due to 2000–2050 business-as-usual deforestation of the Amazon basin.



a, Wet season; **b**, dry season. Stippling denotes regions where the simulated precipitation anomaly differs from the present-day (1998–2010) rainfall by more than 1 s.d. The Amazon (black) and Rio de la Plata (red) basins are

Timing of the energy balance at the surface is critical for the atmosphere.

The way that water flows through or is held by the surface has a crucial role.

Thank you for listening!