The response of global forest evapotranspiration to canopy height

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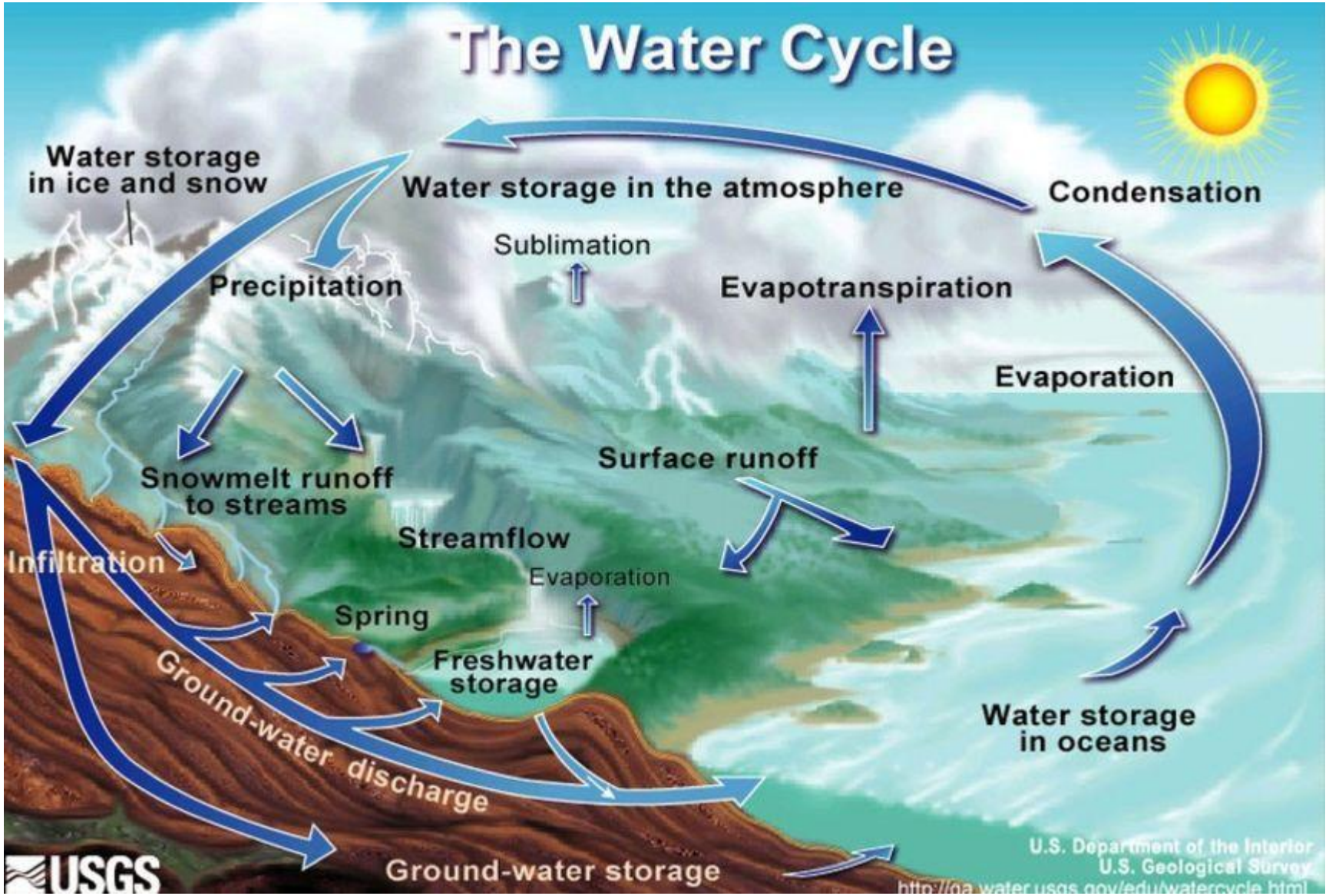
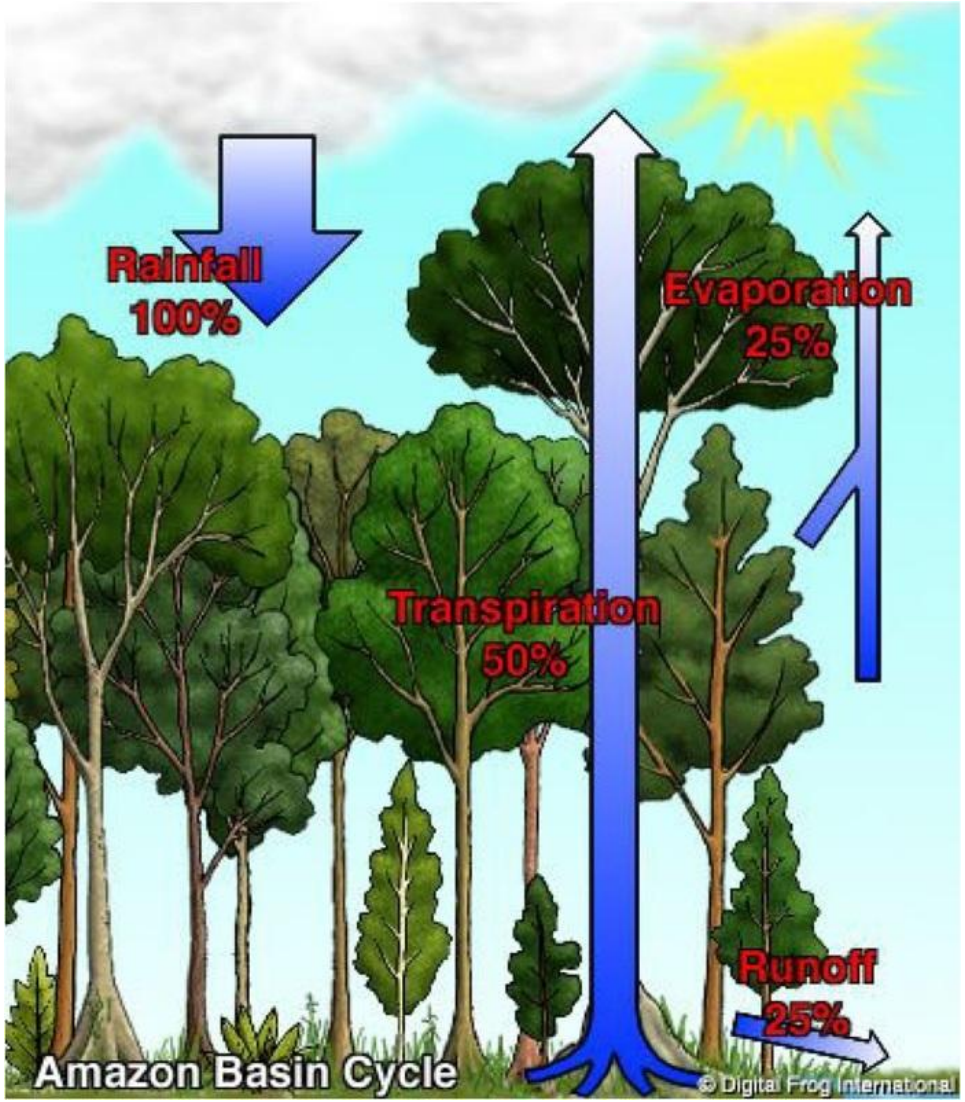
Global Change Research Laboratory
For better understanding the complex interactions in the Earth system

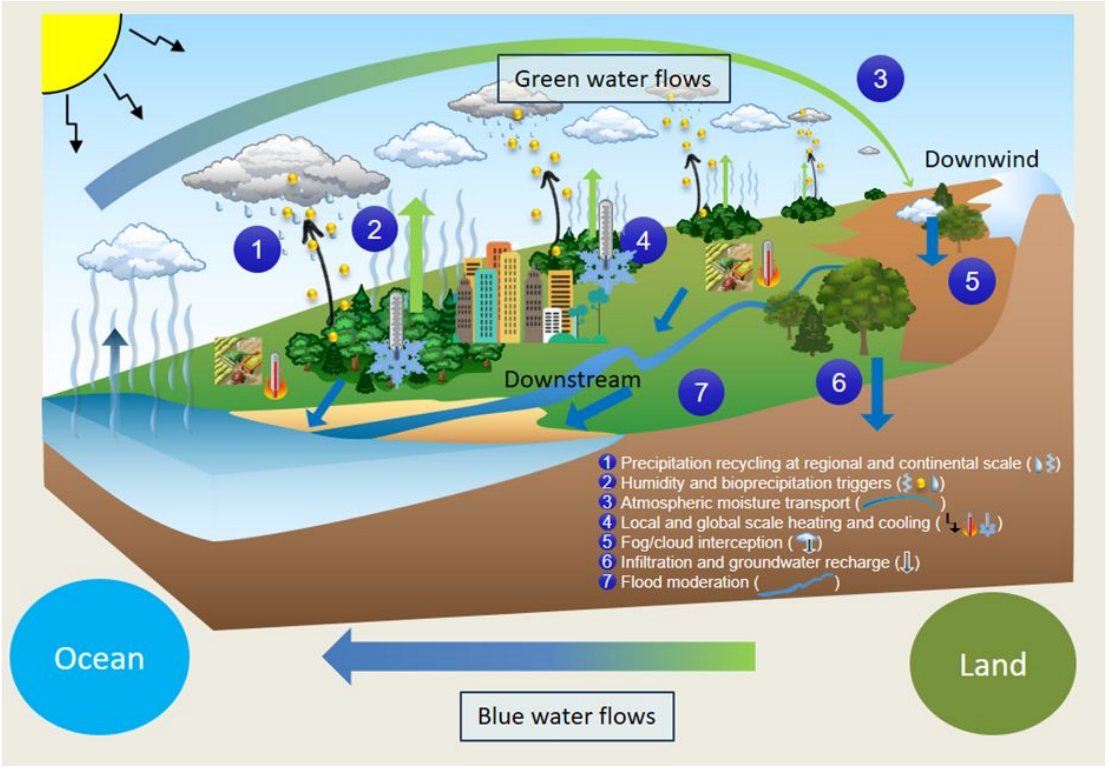
Water is one of the key elements of life on Earth. About 75% of our planet is covered by water or ice. The water cycle is an endless process that connects all water from oceans, land and atmosphere.



Water cycle in forests



Plant transpiration contributes 10% of the water in the Earth's atmosphere.
Scott et al. found transpiration is by far the largest water flux from Earth's continents, representing 80 to 90 % of terrestrial evapotranspiration.

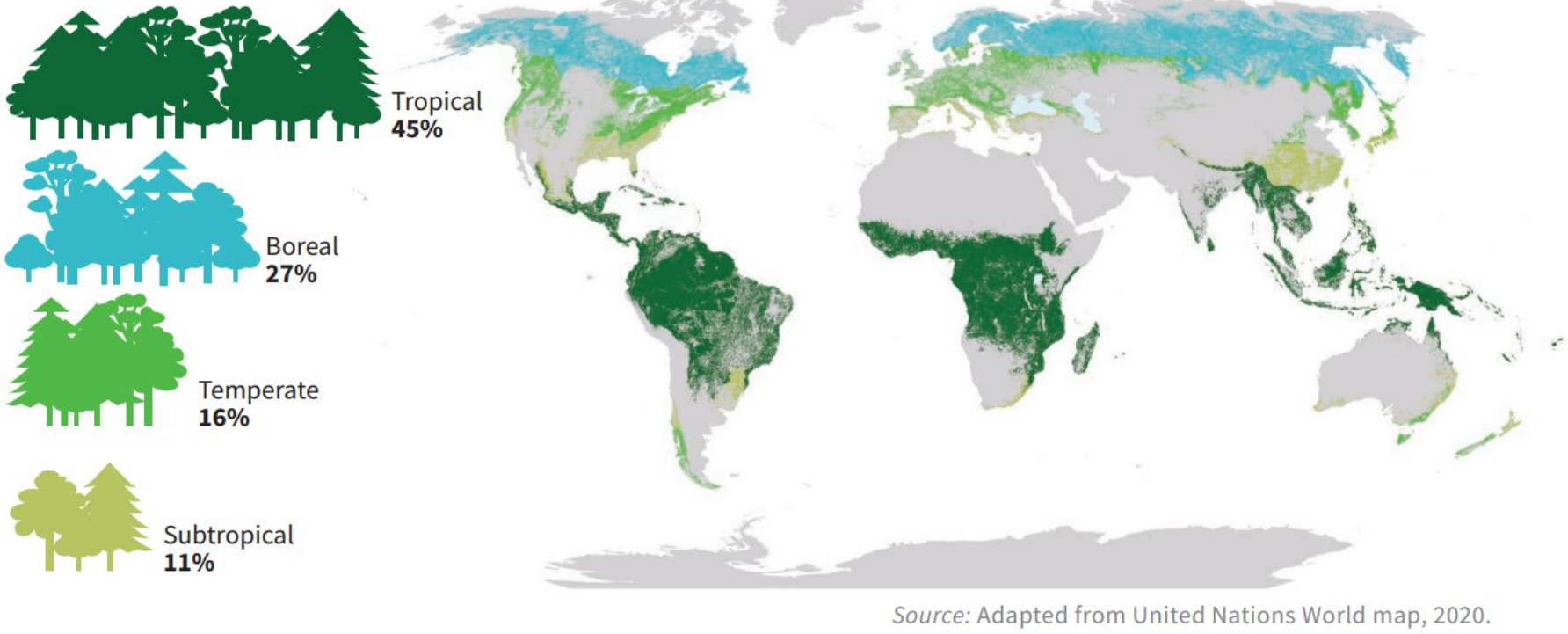


(Ellison et al., 2019; and Falkenmark and Rockström, 2005)

Water cycle in forests

Forests cover nearly 1/3 of land globally.

Higher transpiration rates, together with higher interception rates, result in trees having more evapotranspiration than other vegetation types (Verstraeten et al. 2005).



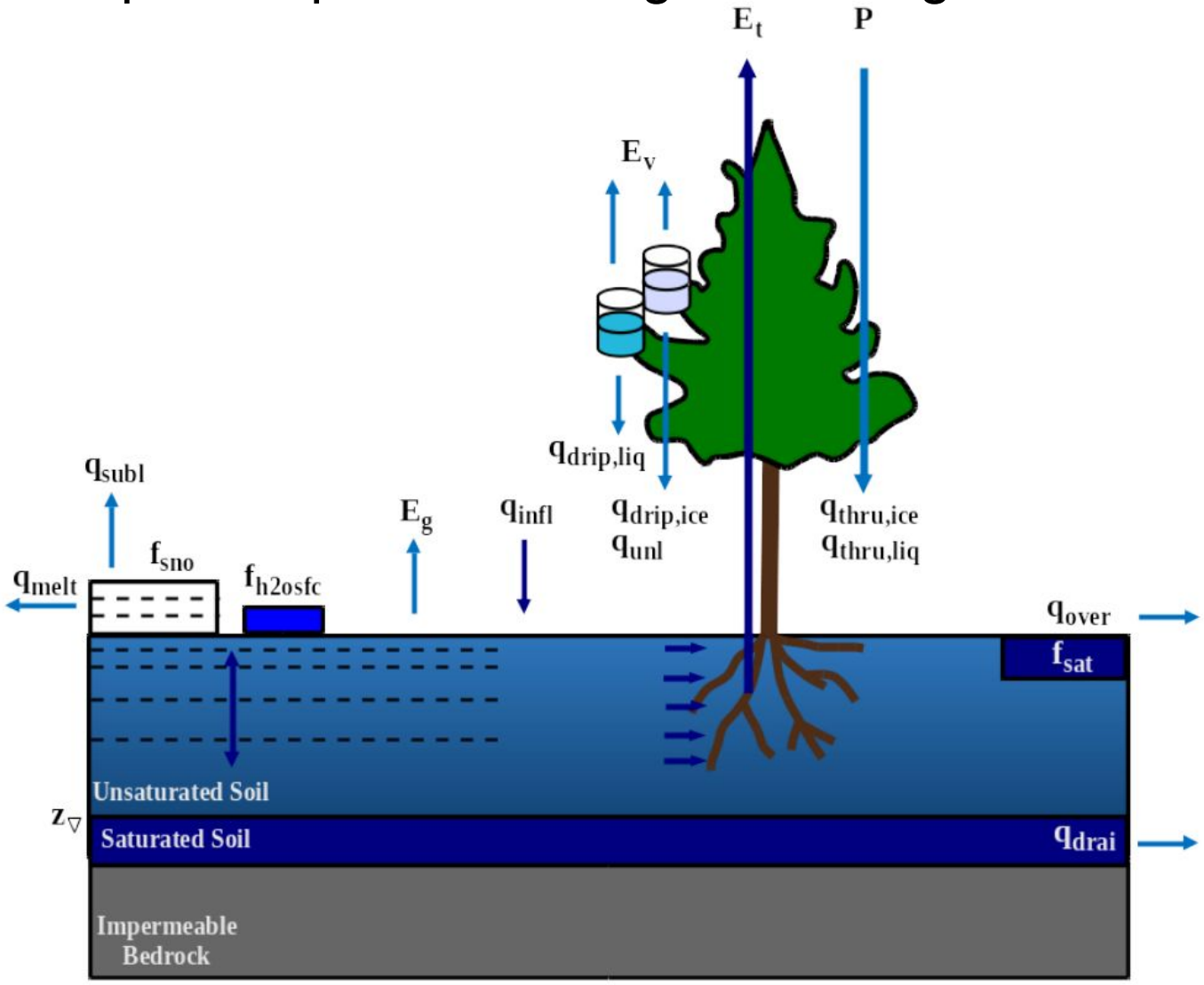
Source: Adapted from United Nations World map, 2020.

Forests play an important role in terrestrial evapotranspiration.

Quantifying forest evapotranspiration through modeling.

Land surface models like CLM5 enable us to separate and quantify these processes, even though they are intertwined in the real world.

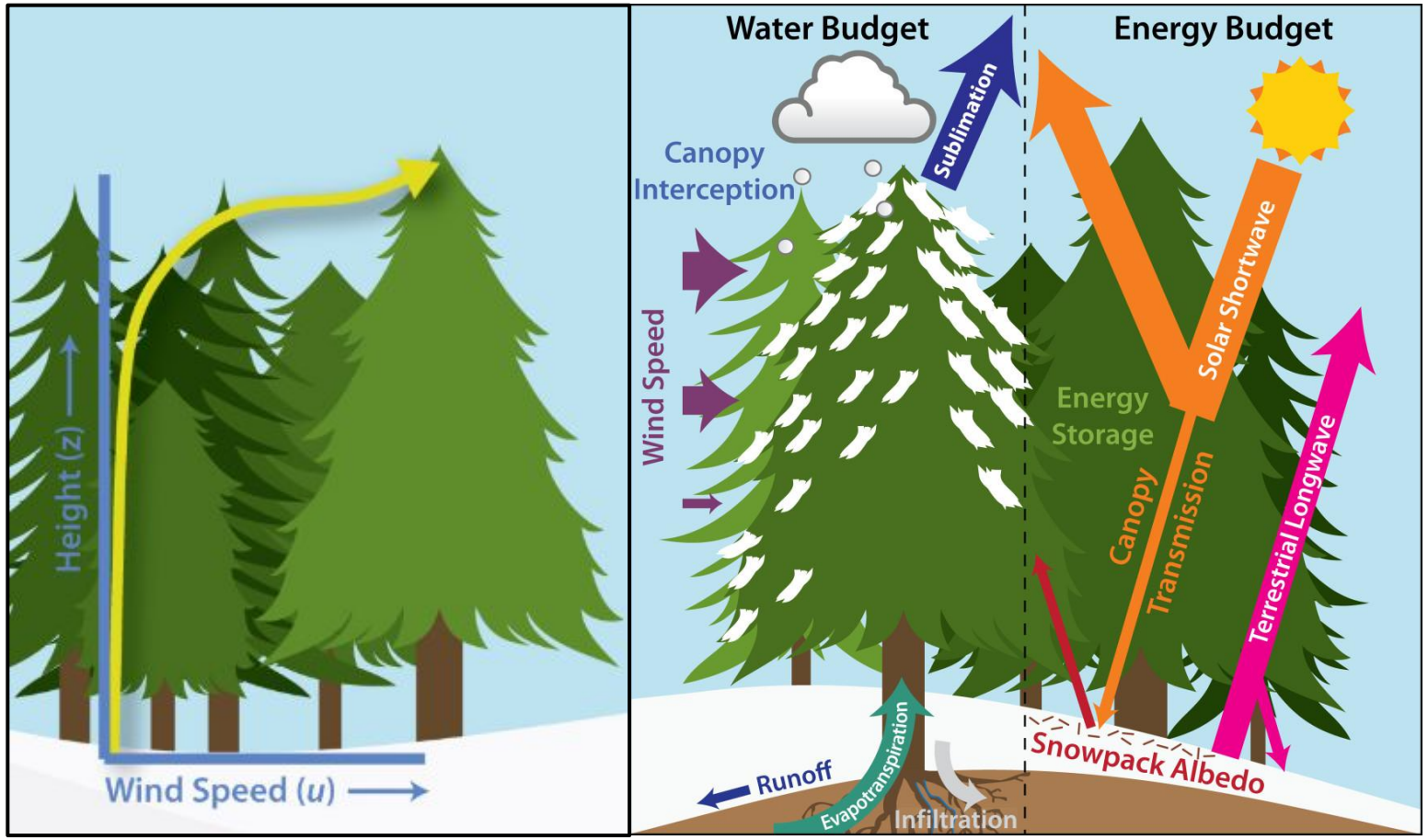
Why is the canopy height remaining constant in the model? And how does canopy height affect evapotranspiration?



(Lawrence, et al. 2018)

How does canopy height affect evapotranspiration?

- Canopy height
- 👇
- Surface roughness
- 👇
- Wind speed to canopy(leaves)
- 👇
- Energy & mass flux



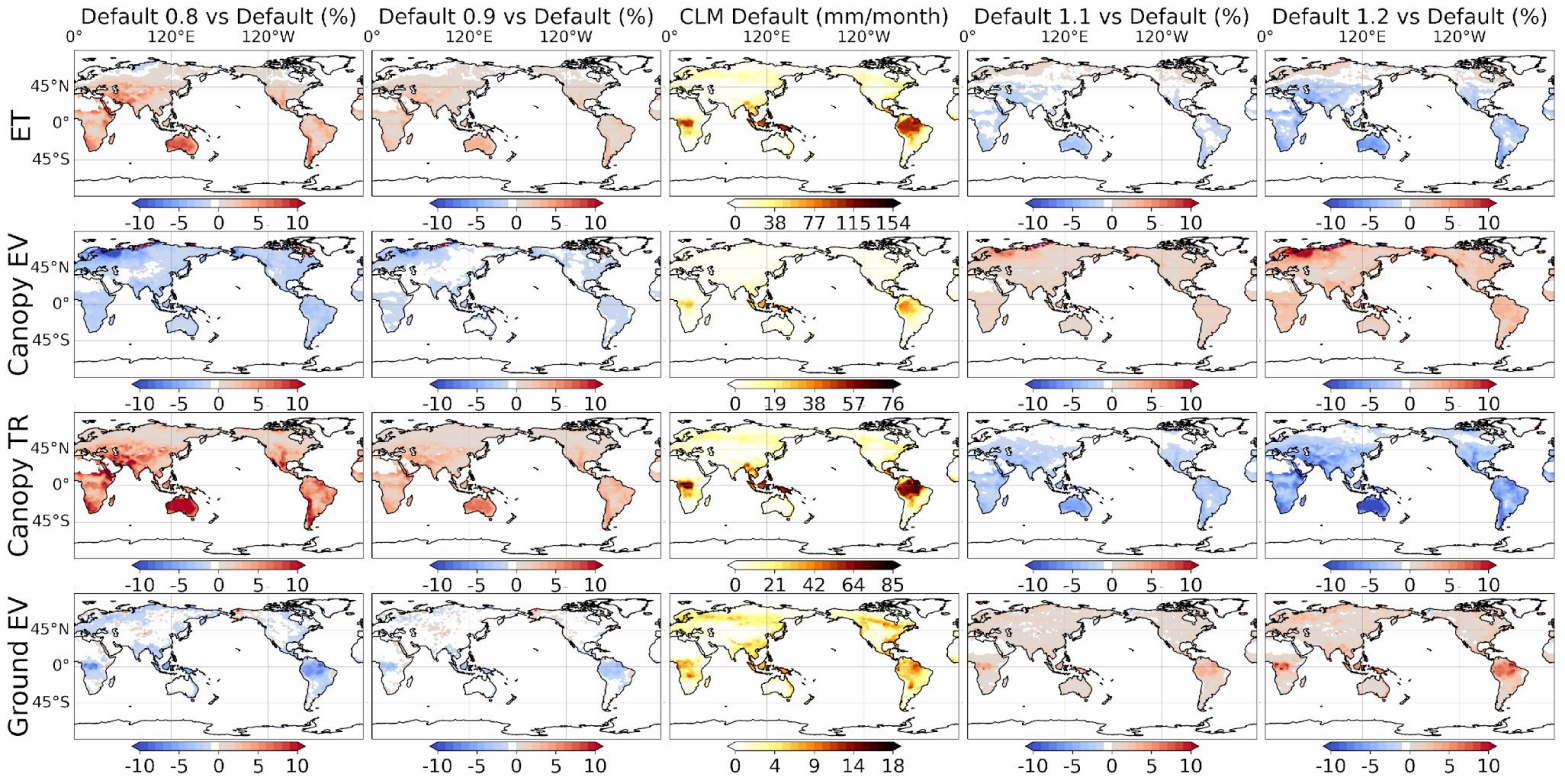
(Pugh & Gordon, 2013)

Sensitivity tests for partial ET to canopy height.

Increase in canopy height leads to decreased transpiration and increased evaporation.

Overall evapotranspiration reduces due to higher transpiration versus evaporation rates.

Arid regions are particularly sensitive to changes in canopy height, and correspondingly wet regions are insensitive to changes in canopy height.



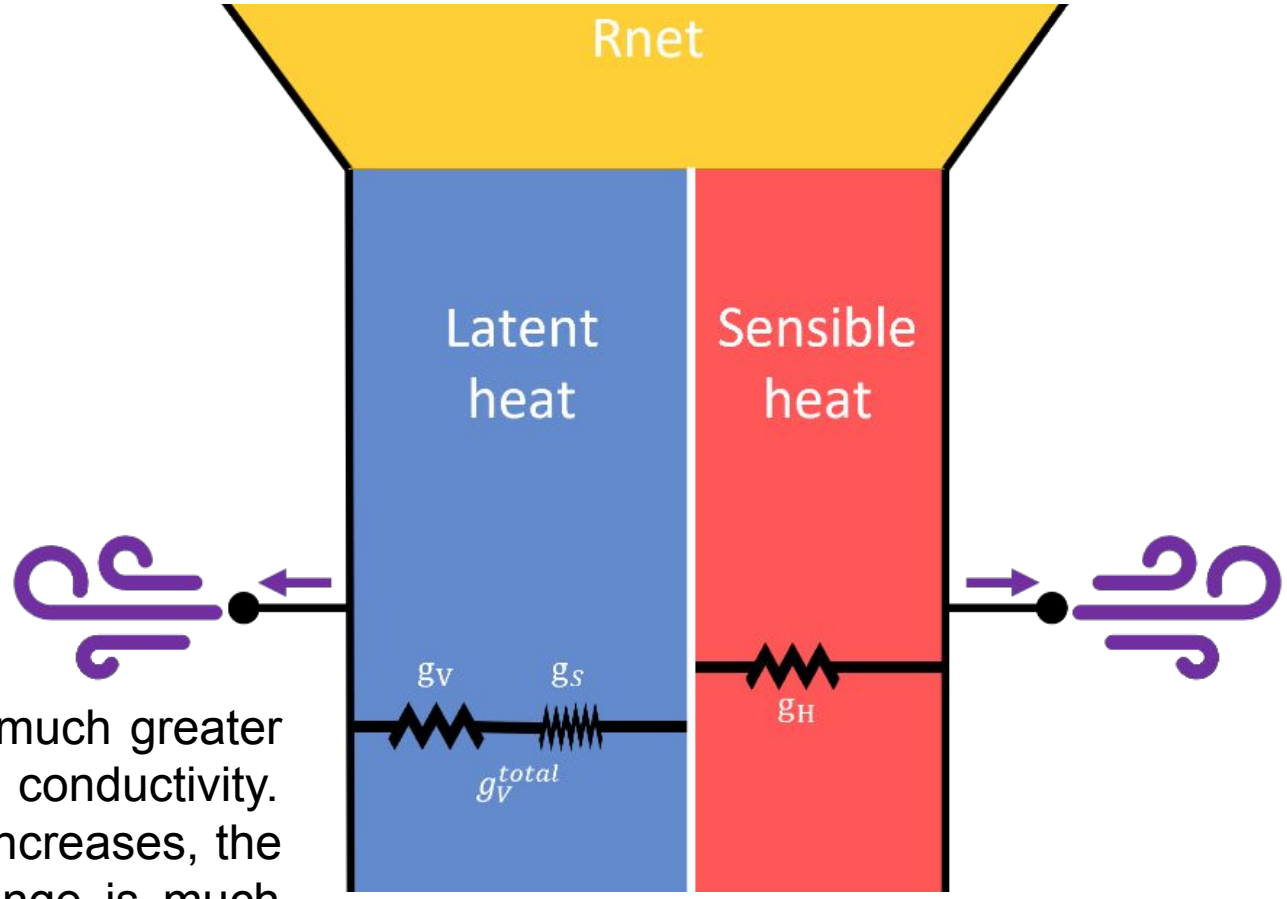
You, et al. (Manuscript in preparation)

Schematic of canopy height on ET

Increasing Canopy height bring more wind speed to the canopy.

An increase in wind speed is correlated with a rise in latent heat during the process of evaporation, and this increase is further magnified under conditions of high VPD.

The sensitivity of sensible heat to wind speed is much greater than latent heat due to the influence of stomatal conductivity. Therefore, in some cases, when the wind speed increases, the change in sensible heat is greater, and this change is much greater than the change in net radiation, which leads to a decrease in the change in latent heat. Since wind speed increases the sensible heat, the latent heat decreases in this case.



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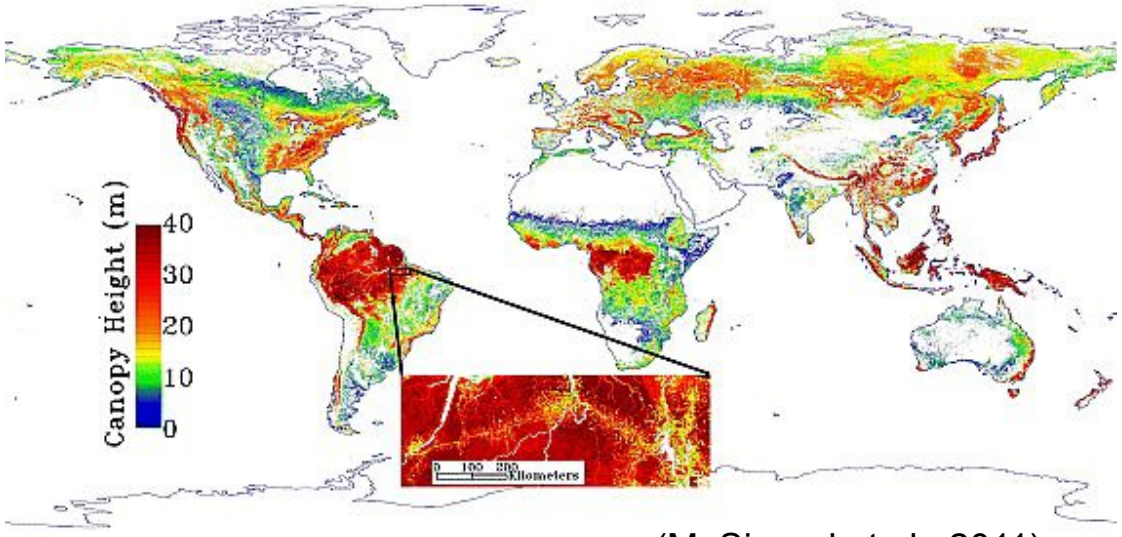
Canopy height data form LiDAR remote sensing

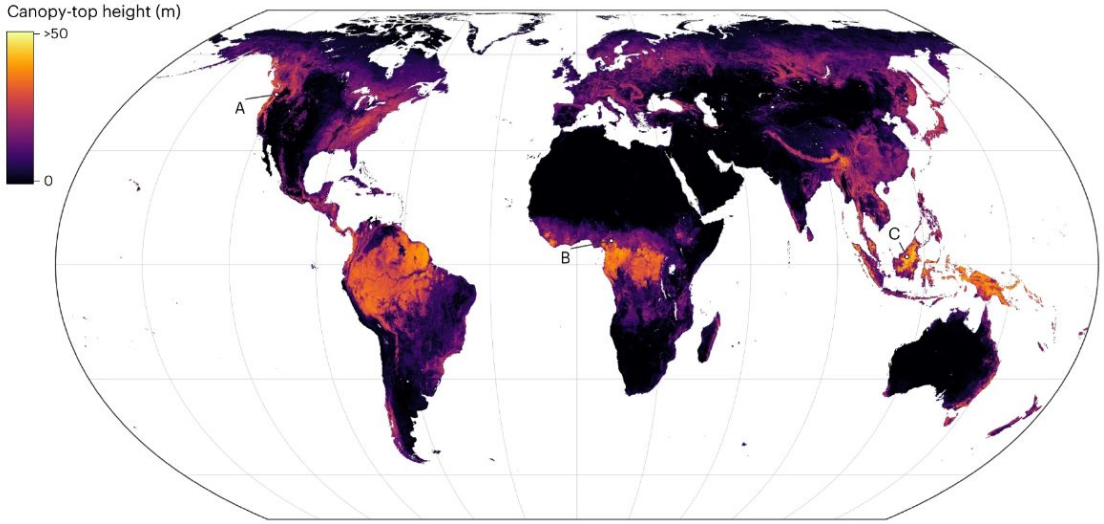
Simard's canopy height map



(M. Simard et al., 2011)

ICESAT DATA in 2005
(Default data in CLM5)

Lang's canopy height map



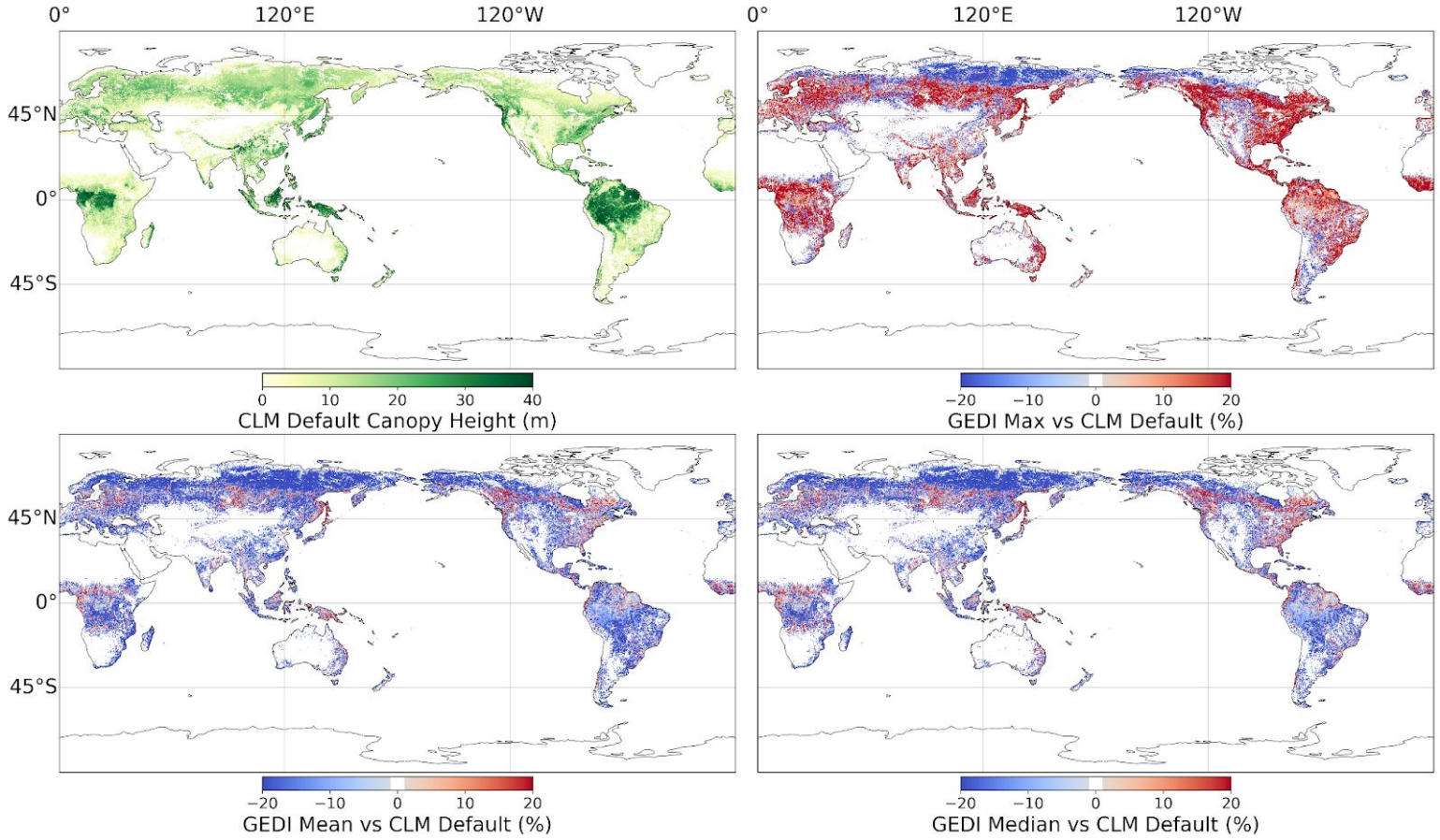
(Lang et al., 2023)

GEDI DATA in 2020

Generate canopy height data for CLM5

Aggregate GEDI data from 10-m resolution into 500-m resolution aligned with MODIS PFT map.

- **Maximum (GEDI Max)**: Captures the tallest trees, useful for dominant species identification.
- **Mean (GEDI Mean)**: Averages canopy heights, informative for forest density and structure.
- **Median (GEDI Median)**: Provides a typical tree height, effective in diverse vegetation areas.

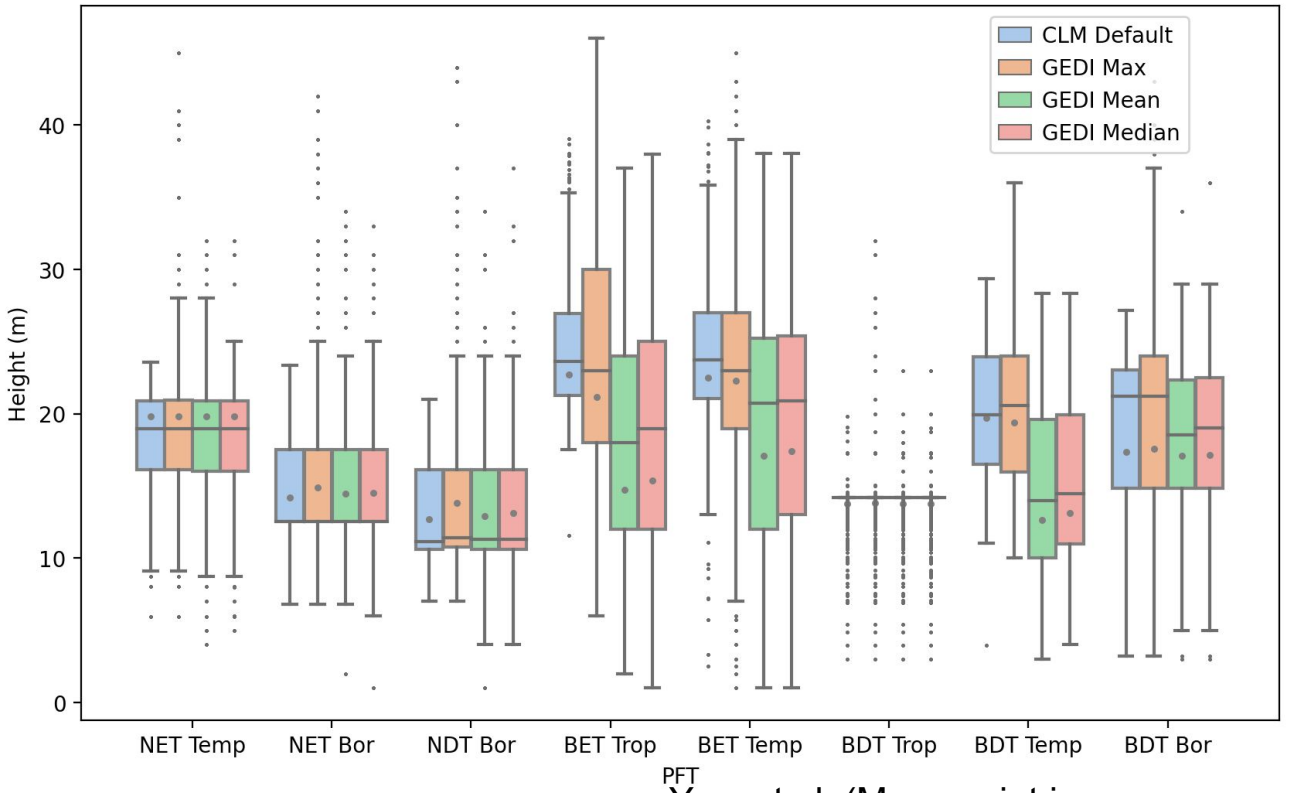


You, et al. (Manuscript in preparation)

Canopy height comparison across PFTs.

- Focused on four datasets: the CLM5's default canopy height and three derived from GEDI using max, mean, and median aggregation methods.

- Comparisons across PFTs showed:
  - GEDI mean and median closely matched with each other, while GEDI max is close to the CLM5's default canopy height.
  - GEDI max and CLM default were most similar, likely due to the low spatial resolution of the global tree height data from IceSAT capturing only the tallest trees.
  - BET trop, BET temp, BDT temp and BDT bor vary a lot across different canopy height data.



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Variations of evapotranspiration using different canopy height data.

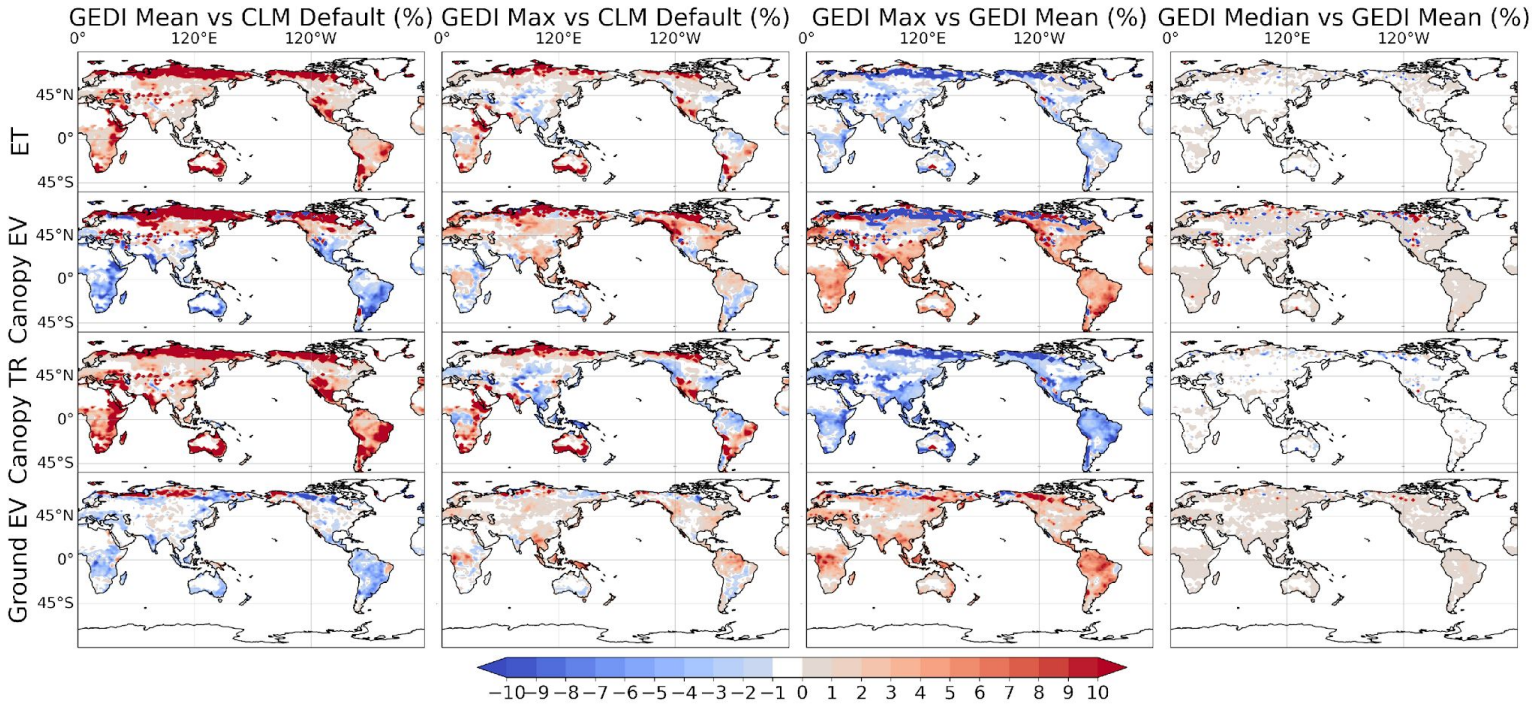
In distribution, variation in evaporation and transpiration follows the variation of canopy height data.

The comparison between GEDI Max and GEDI Mean revealed more significant differences, indicating aggregation method matters!

GEDI Median vs. GEDI Mean shows minimal difference.

Transpiration varies slightly more than evaporation across different datasets.

A significant variation in evaporation and transpiration with changes in canopy height in high latitude regions



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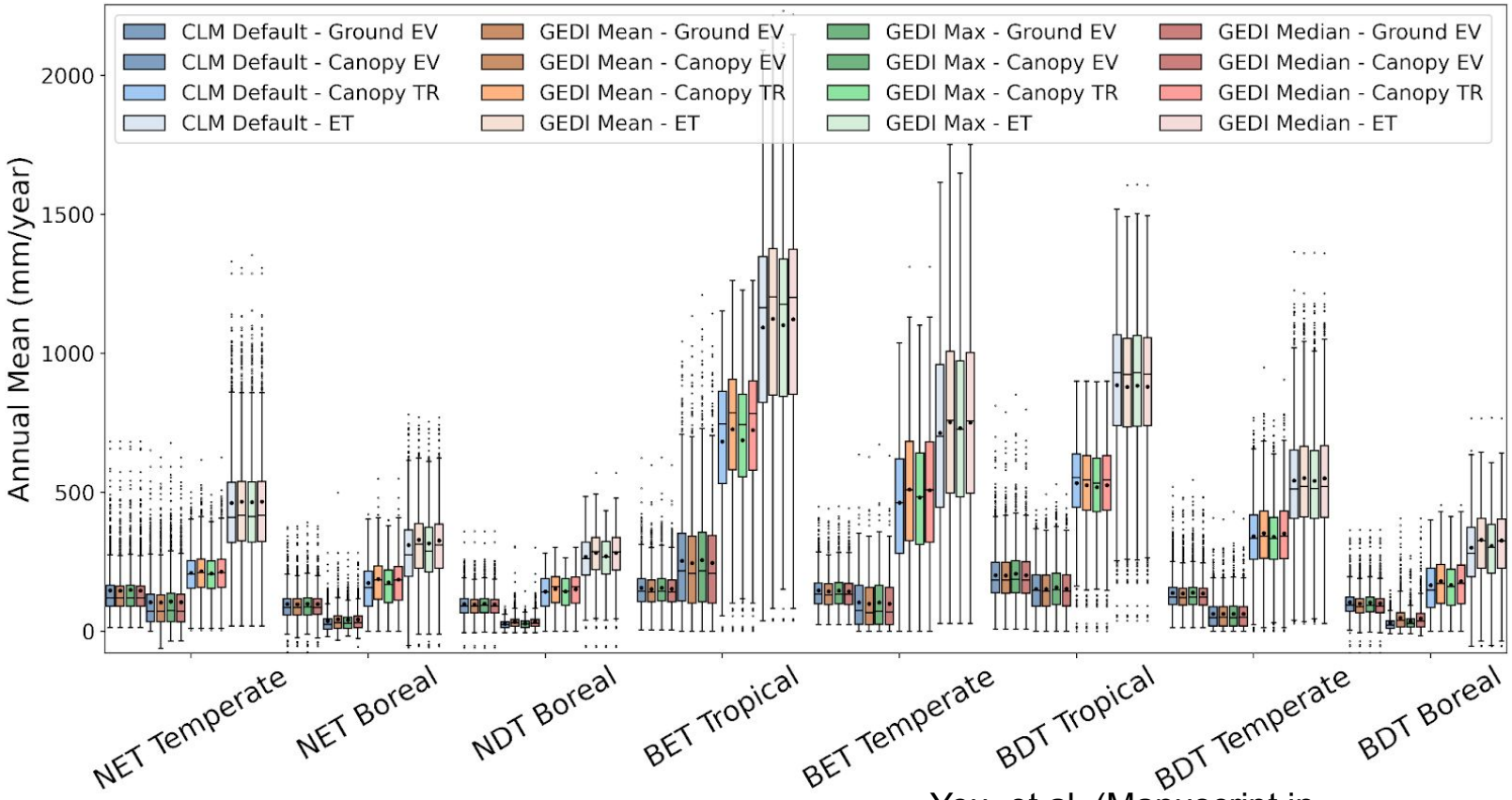
Variations of evapotranspiration using different canopy height data.

GEDI Median vs. GEDI Mean shows minimal difference.

While BET PFTs show stable ET totals despite tree height changes, boreal areas vary largely but contribute less to the global water cycle.



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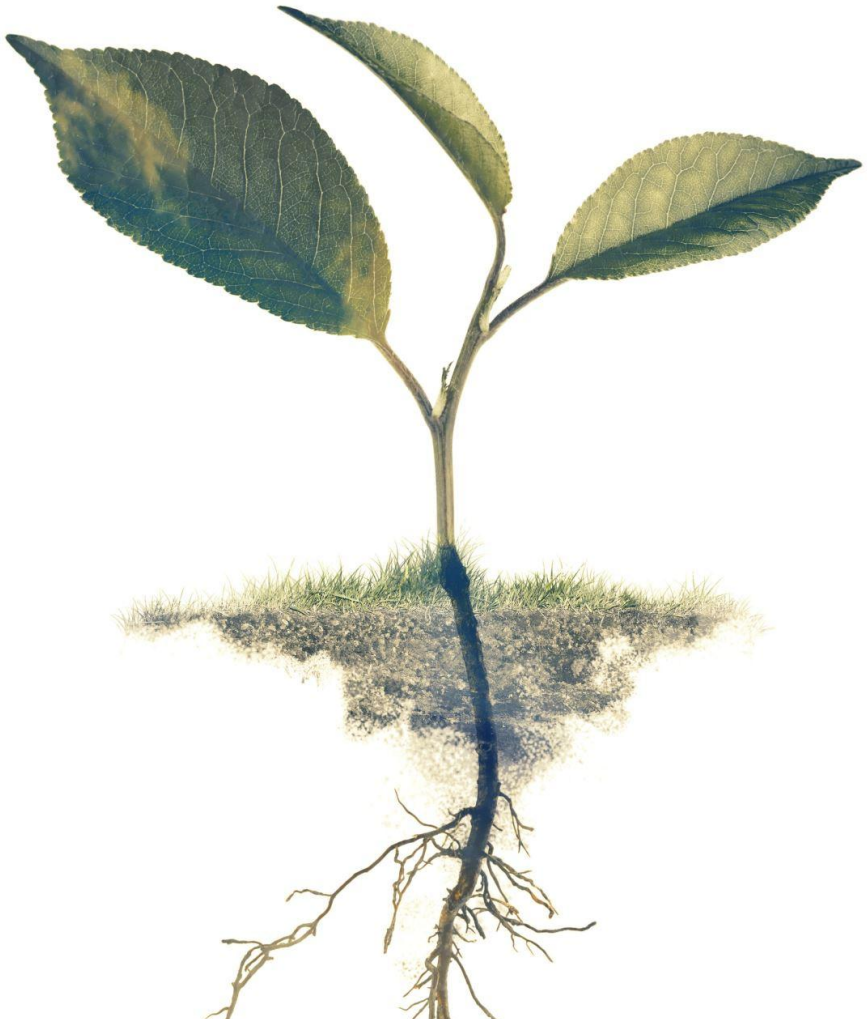
From left to right, is the evapotranspiration results from CLM5 SP mode running for 14 years (2001-2014), we picked the average output data from the last five years (2010-2015) for analysis.



Take home messages

- 1. Taller canopy height may enhance evaporation but limit transpiration.
- 2. Arid regions are particularly sensitive to changes in canopy height, and correspondingly wet regions are insensitive to changes in canopy height.
- 3. Canopy height varied from year to year in all regions but was relatively stable in the Amazon and Congo forests.
- 4. Aggregation methods when upscaling may bring large uncertainty, but hard to define the best aggregation method would be.

Thank you for your listening!

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