A carbon sink-limited model of tree growth

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What is a tree?

"An upright woody plant with
a dominant stem that reaches
a height of at least 3 m"

Körner 2012

Guiding Question

What causes treelines?

Bounded Question

What are the (mostly) above-ground environmental factors and eco-physiological processes that constrain the tree growth form?

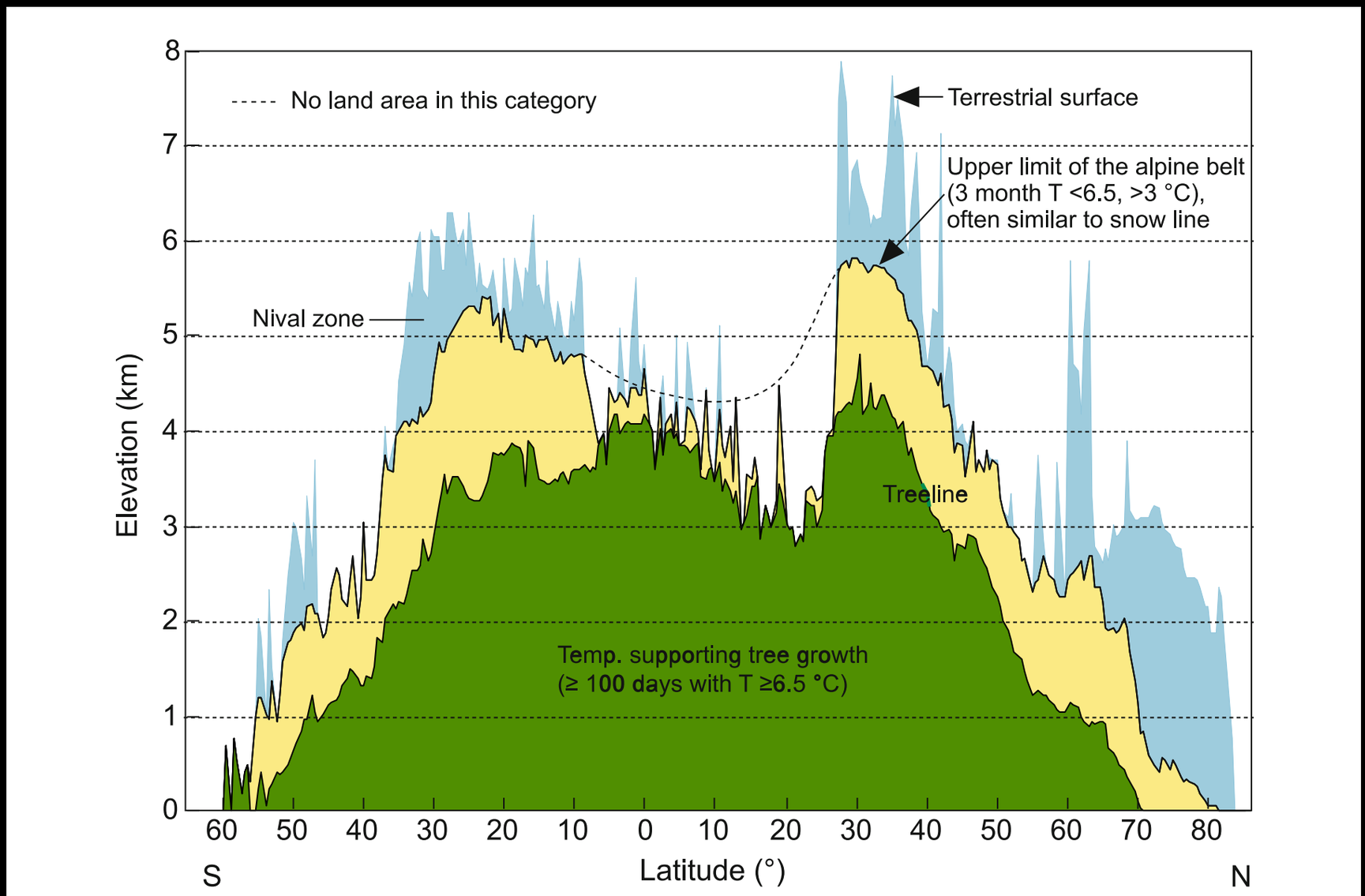
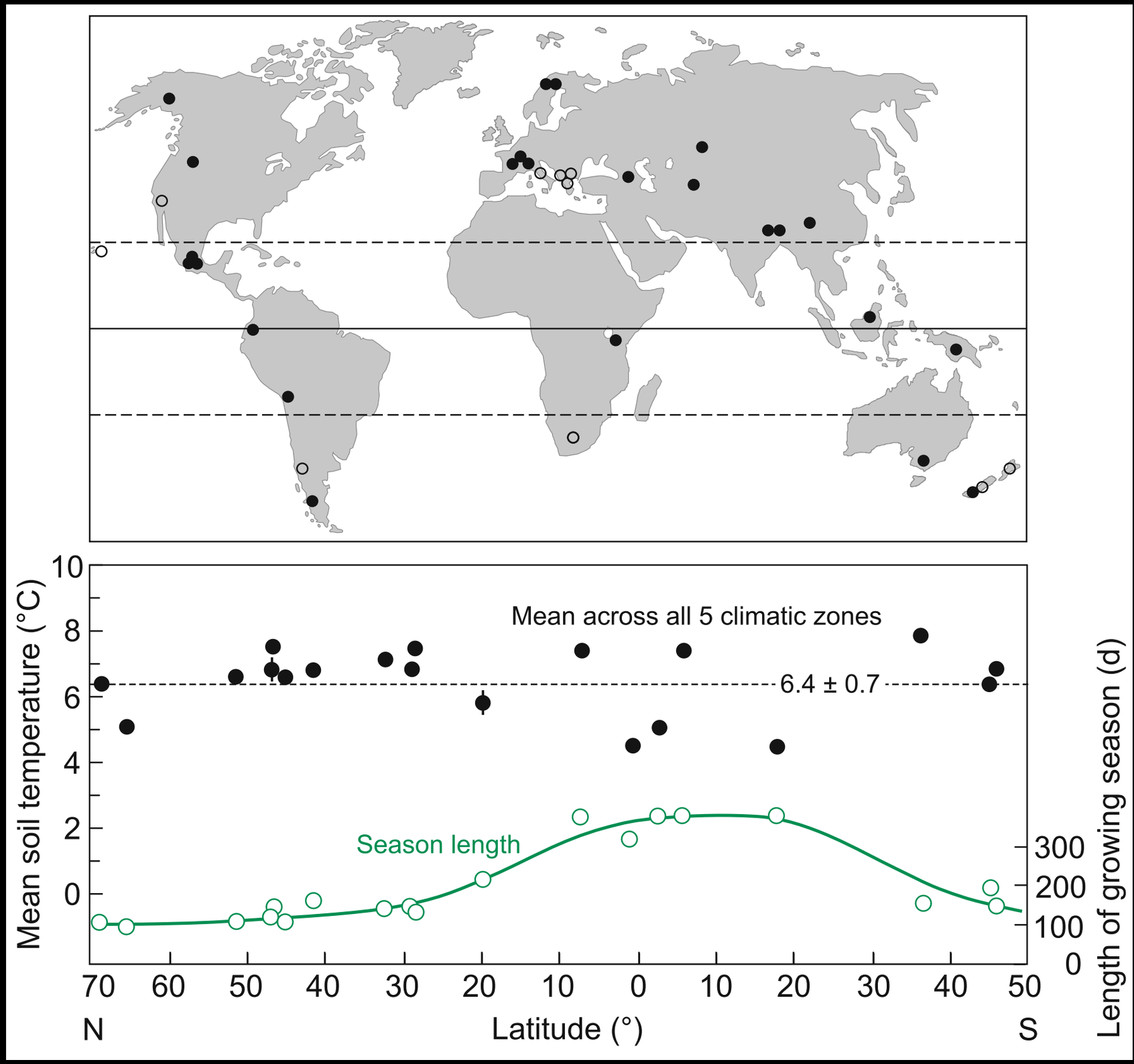


Fig. 3.4. The latitudinal variation of treeline and snowline modelled by climatic drivers (Körner 2007a; see also Chap. 5). Note the parallel trend in the biological boundary (treeline) with the purely physics-driven snowline

Treelines Globally



Explanations

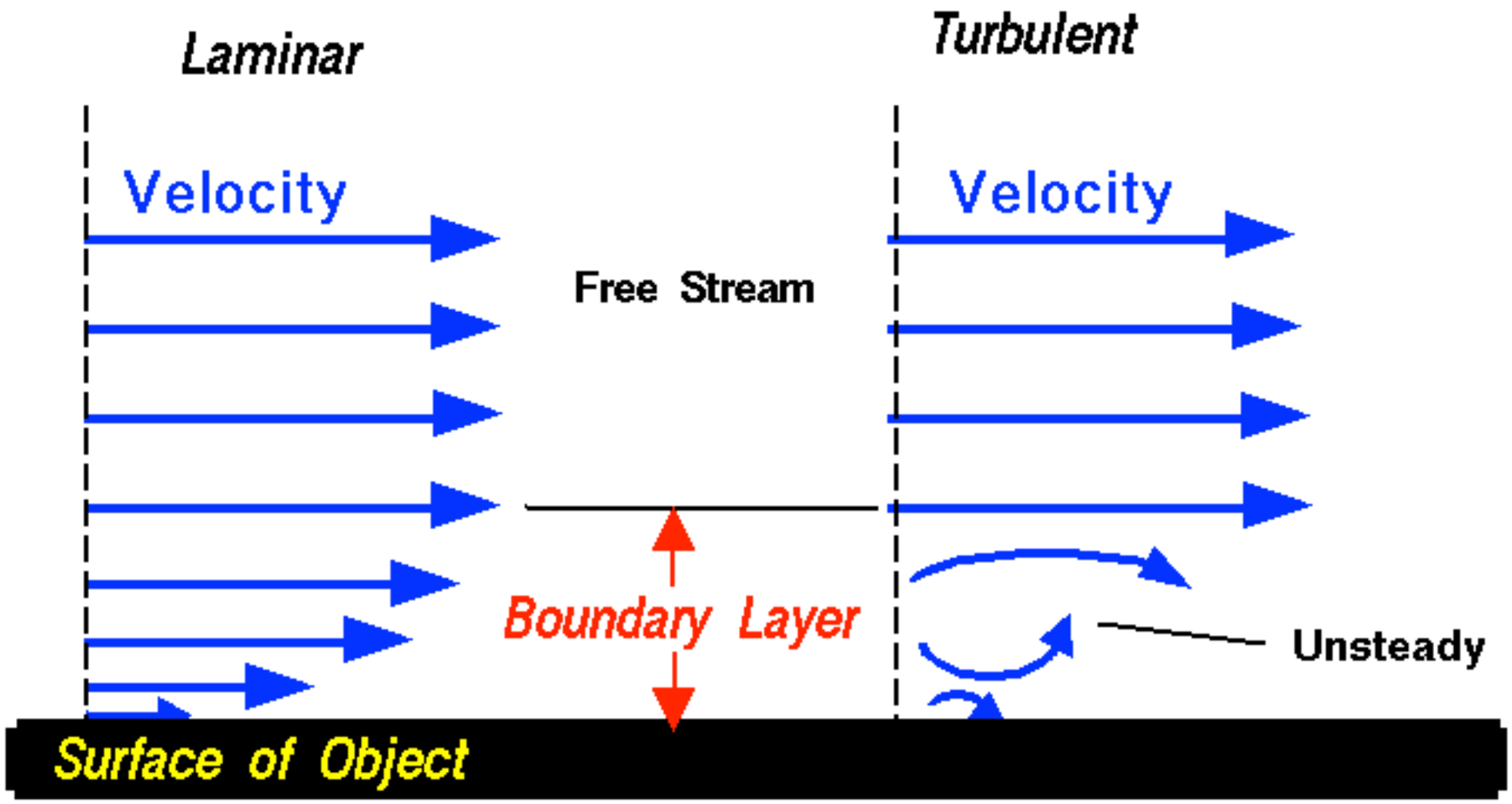
Tree stature causes alpine treeline because tall trees are more closely coupled to the temperature of the free atmosphere than are low-stature plants.

“Treelines will be understood once the functional difference between a tree and a shrub is”

Körner 2012

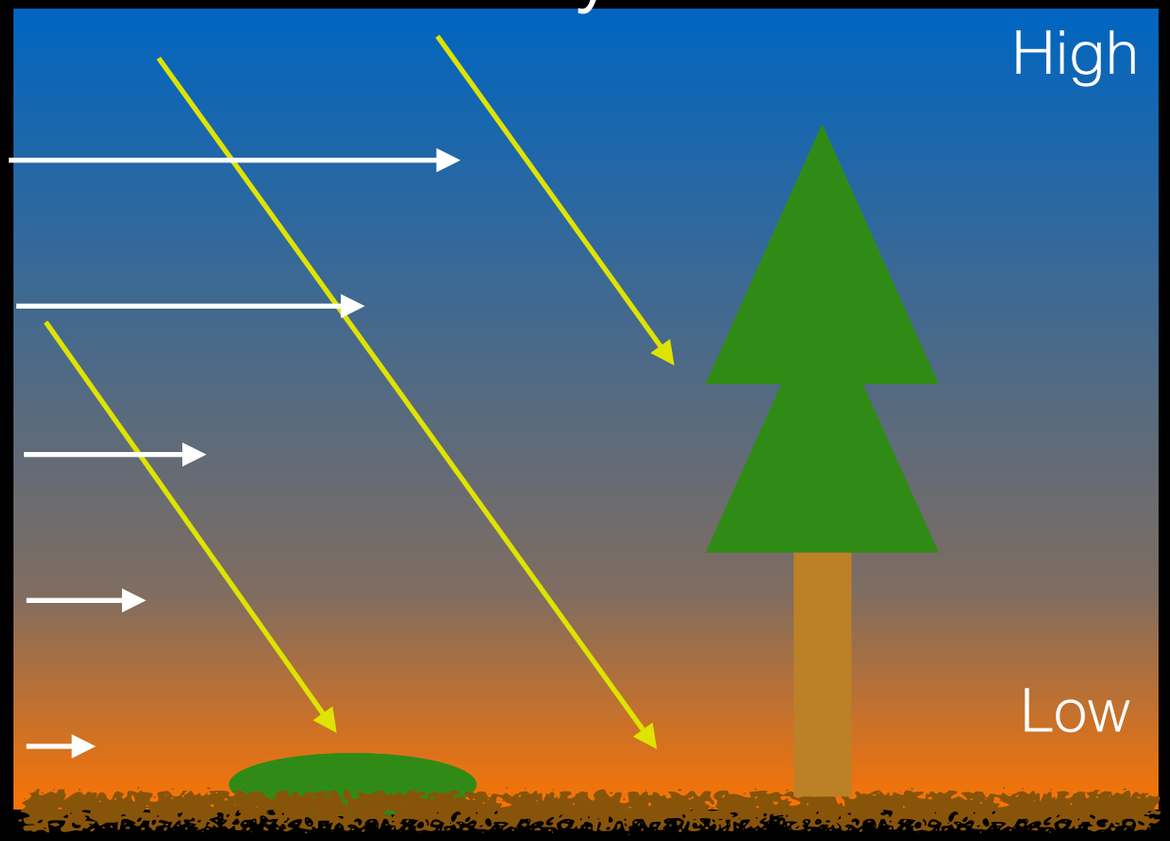
Boundary Layer

Glenn Research Center



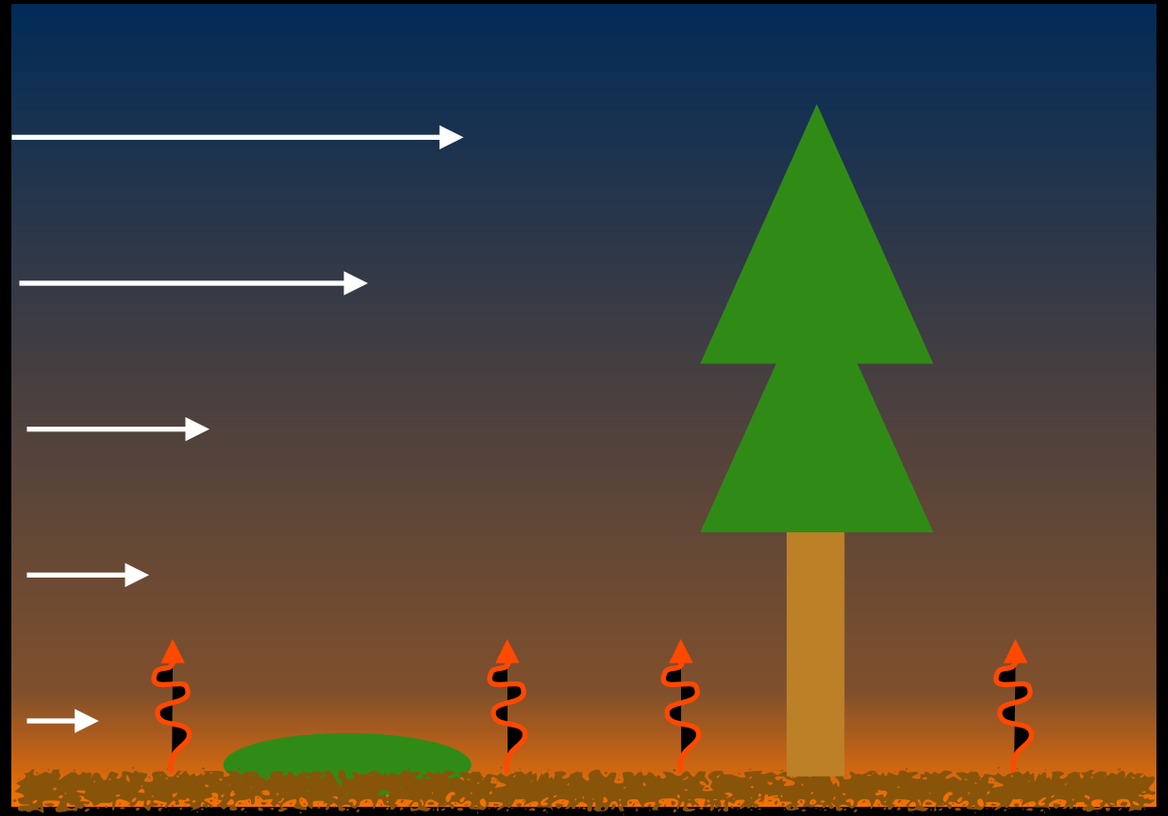
Velocity is zero at the surface (no – slip)

Day

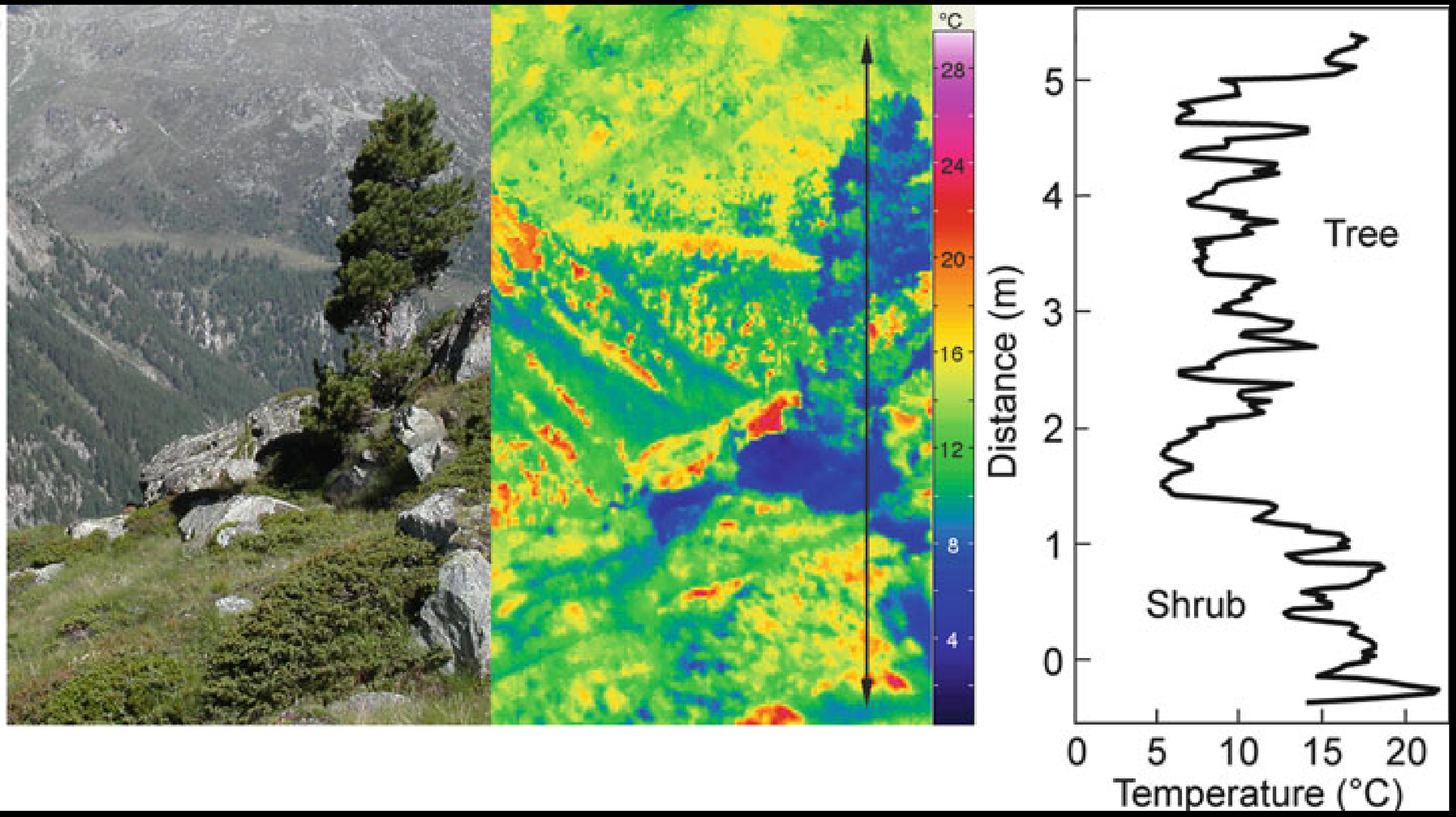


Convective cooling

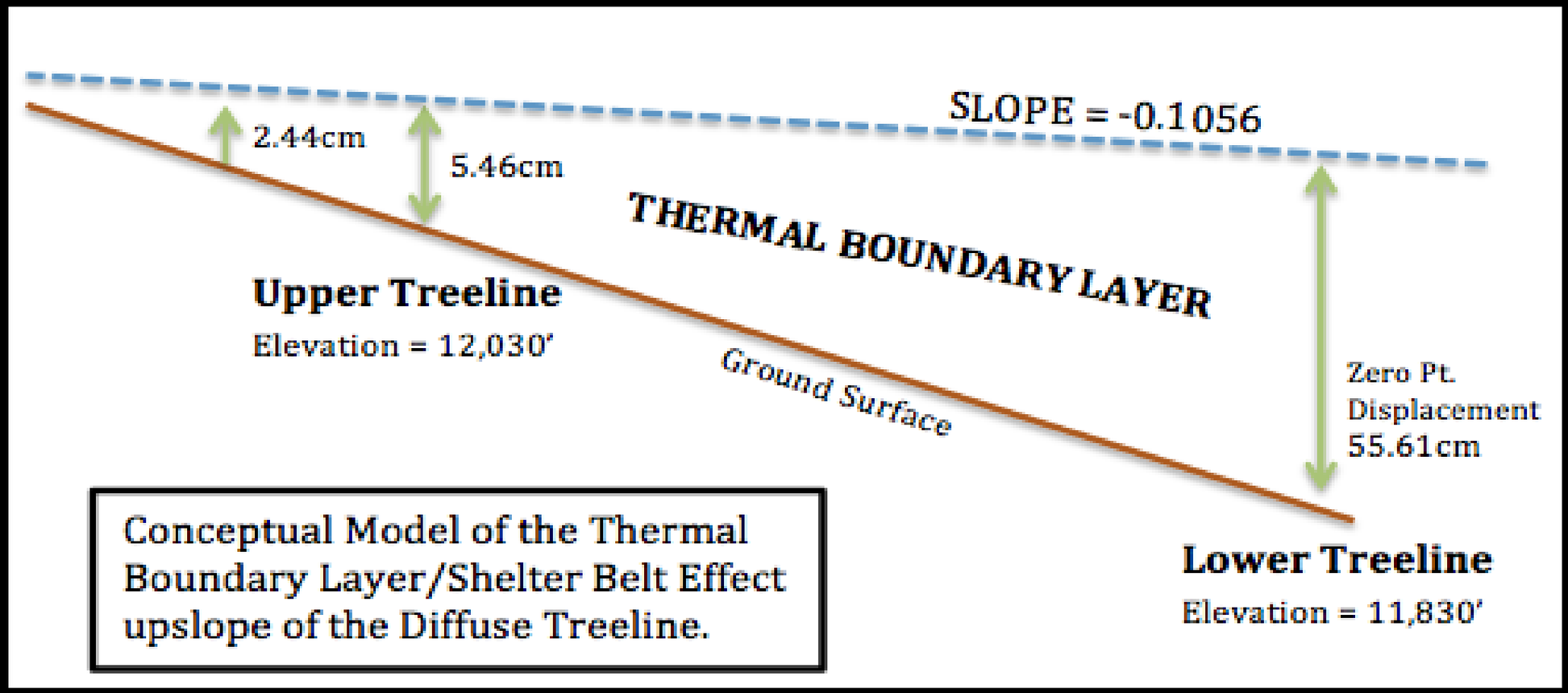
Night



Temperature Constraints on Trees



Shrinking boundary layer with elevation



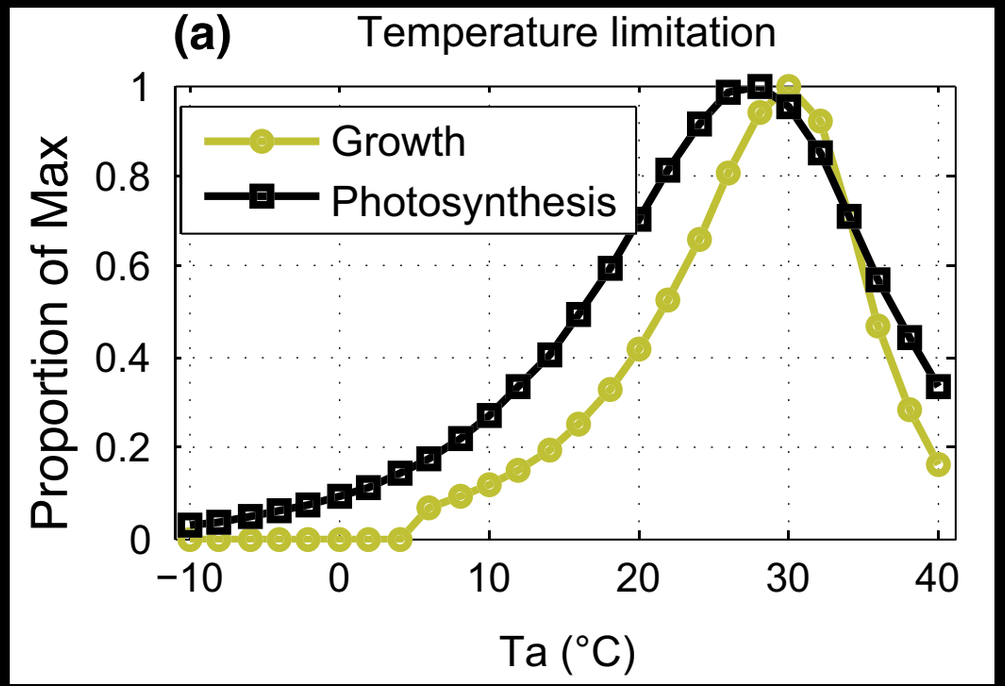
Conceptual Model of the Thermal Boundary Layer/Shelter Belt Effect upslope of the Diffuse Treeline.

Dickson 2013

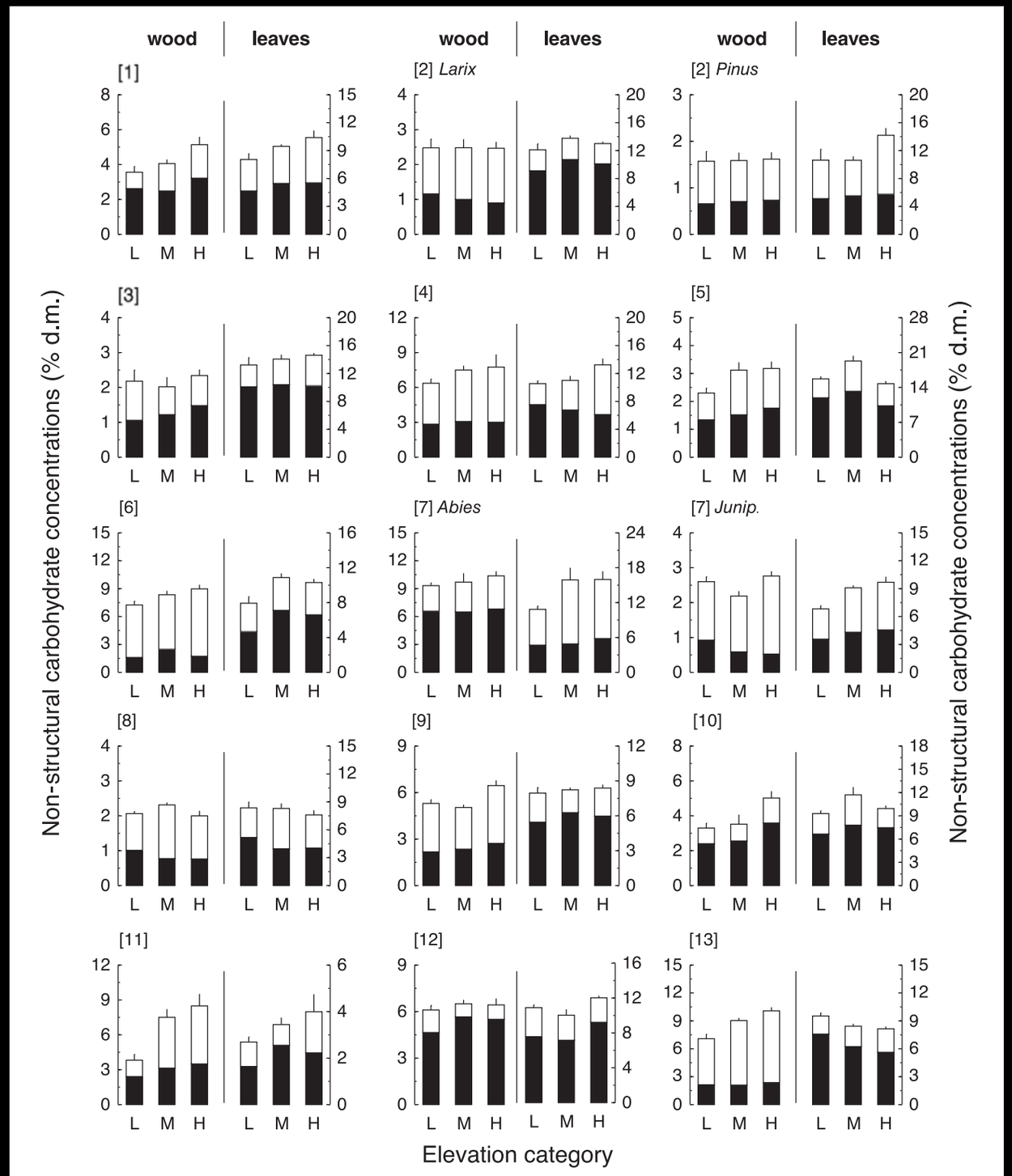
Explanations

Carbon-limitation hypothesis:
Photosynthesis is environmentally-limited such that trees at treeline do not have adequate C for growth - carbon source-limitation
(Stevens and Fox 1991)

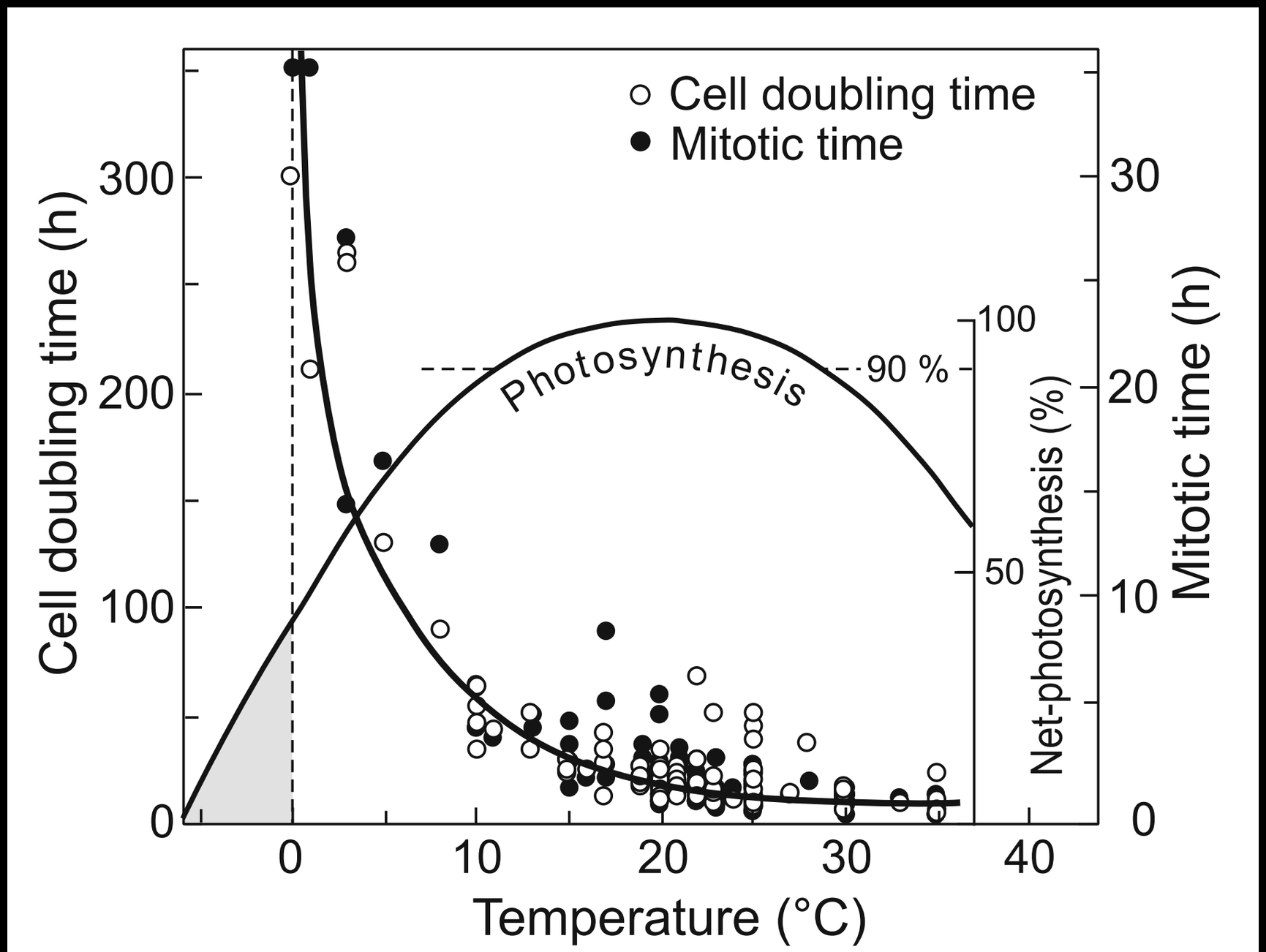
Growth-limitation hypothesis:
Cell and tissue formation is environmentally-limited such that trees at treeline cannot grow - carbon sink-limitation
(Körner 1998)



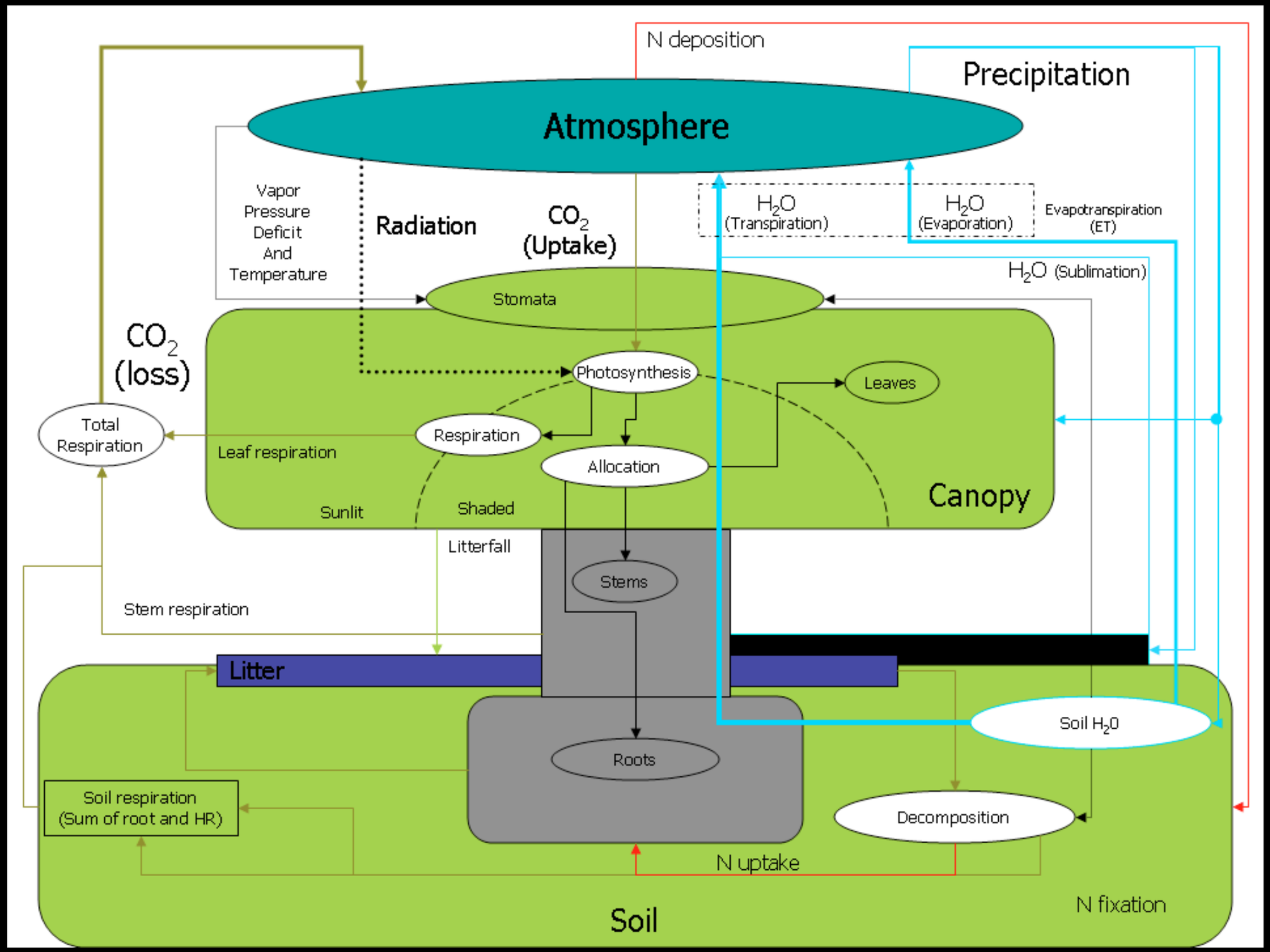
Fatichi et al. 2014



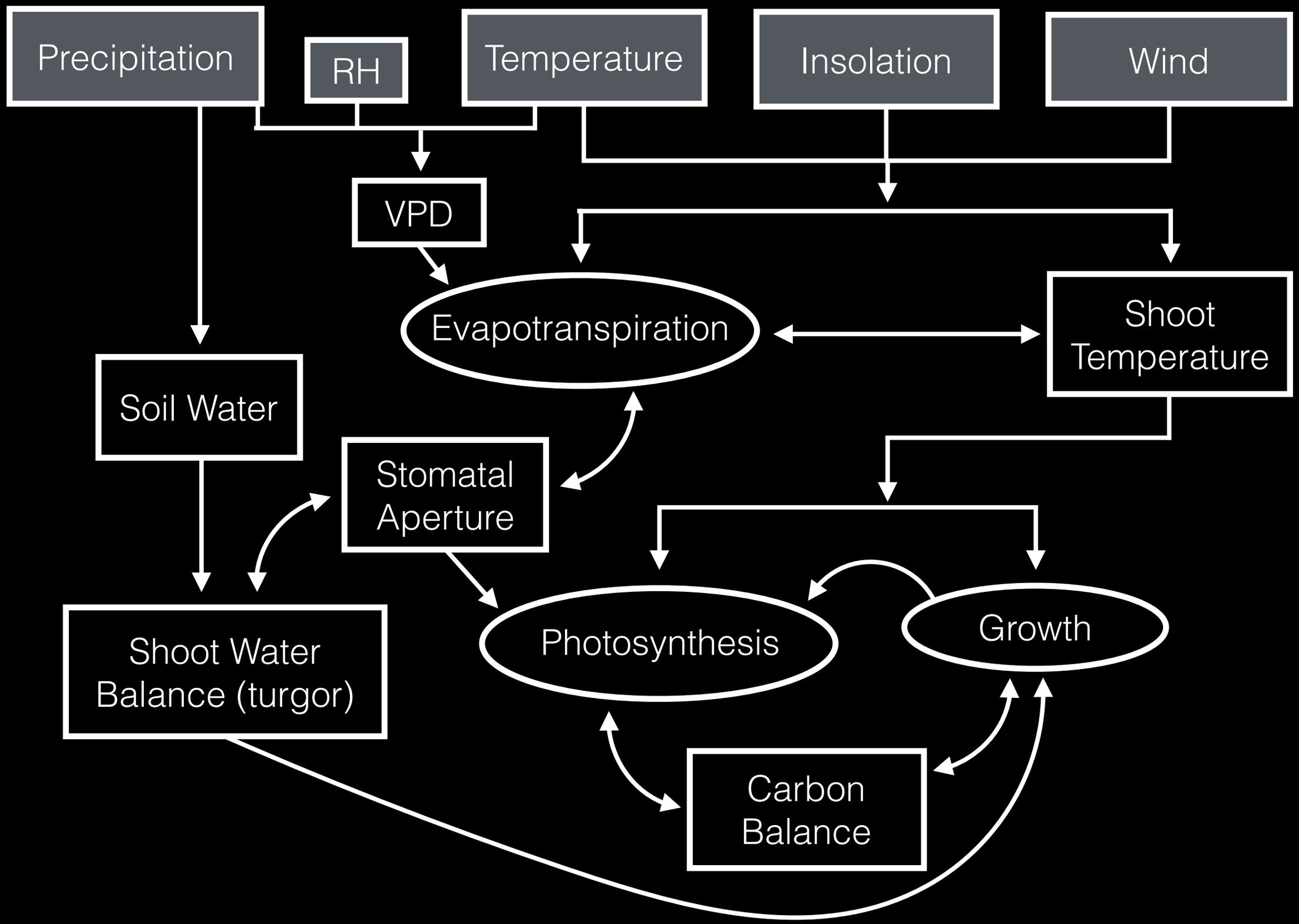
Hoch and Körner 2012


Cell doubling time
Mitotic time
Photosynthesis
90 %
Cell doubling time (h)
Net-photosynthesis (%)
Mitotic time (h)
Temperature (°C)
0
100
200
300
50
100
0
10
20
30
40

DGVMs simulate growth as a function of photosynthesis - assuming c-limitation of growth



Conceptual Model



Wind speed

Air temperature

Elevation

Height above ground

Adjusted wind speed

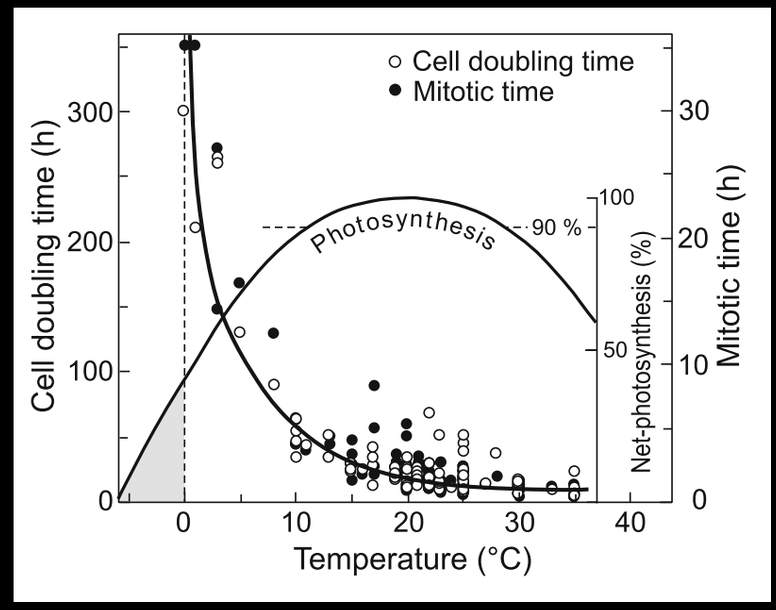
Adjusted air temperature

Evapotranspiration

Shoot Temperature

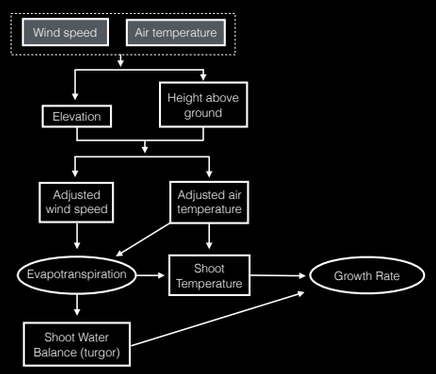
Growth Rate

Shoot Water Balance (turgor)



Growth in Vertical Space

Daily calculations



Yearly summation to determine suitability for growth

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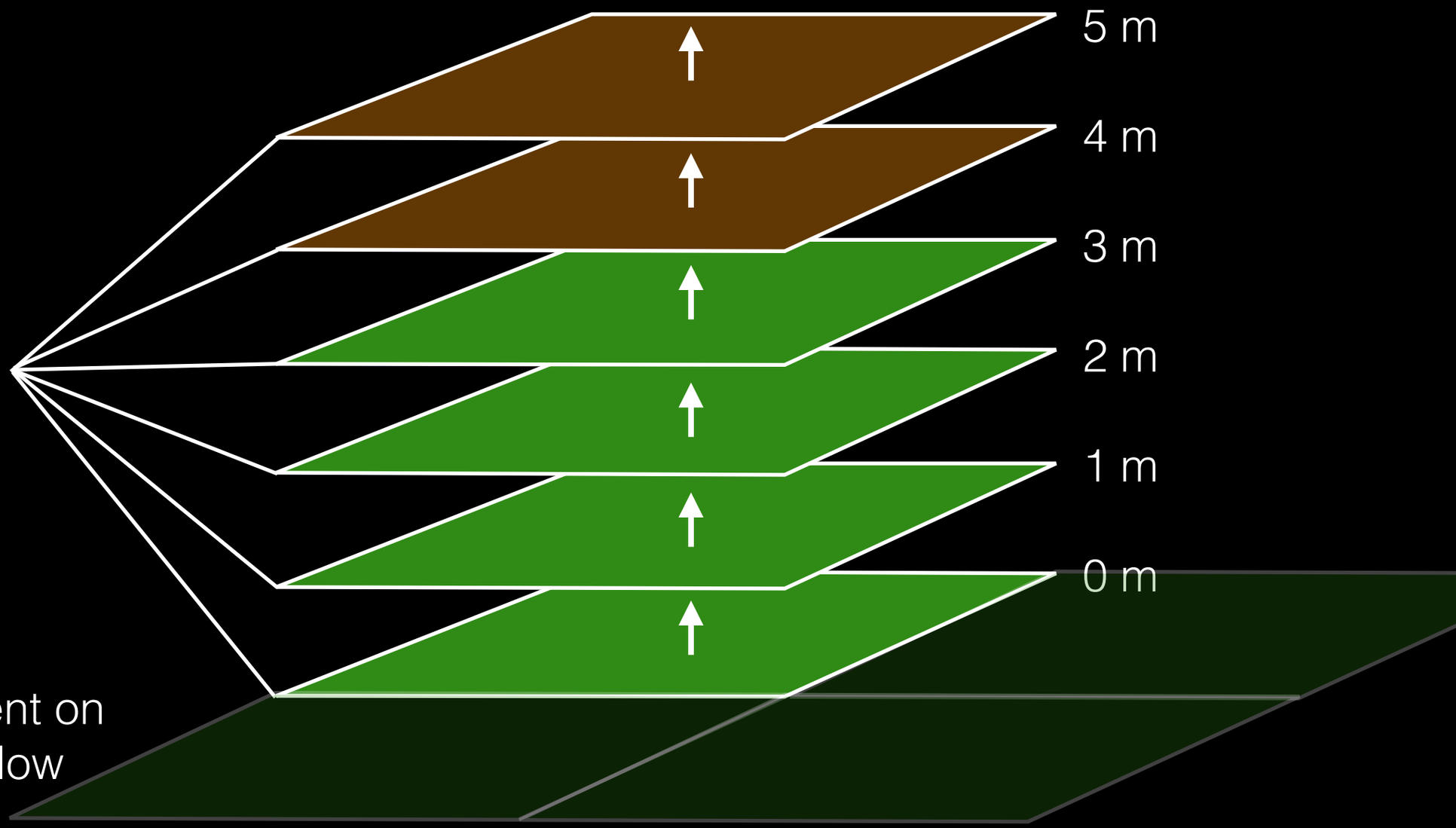
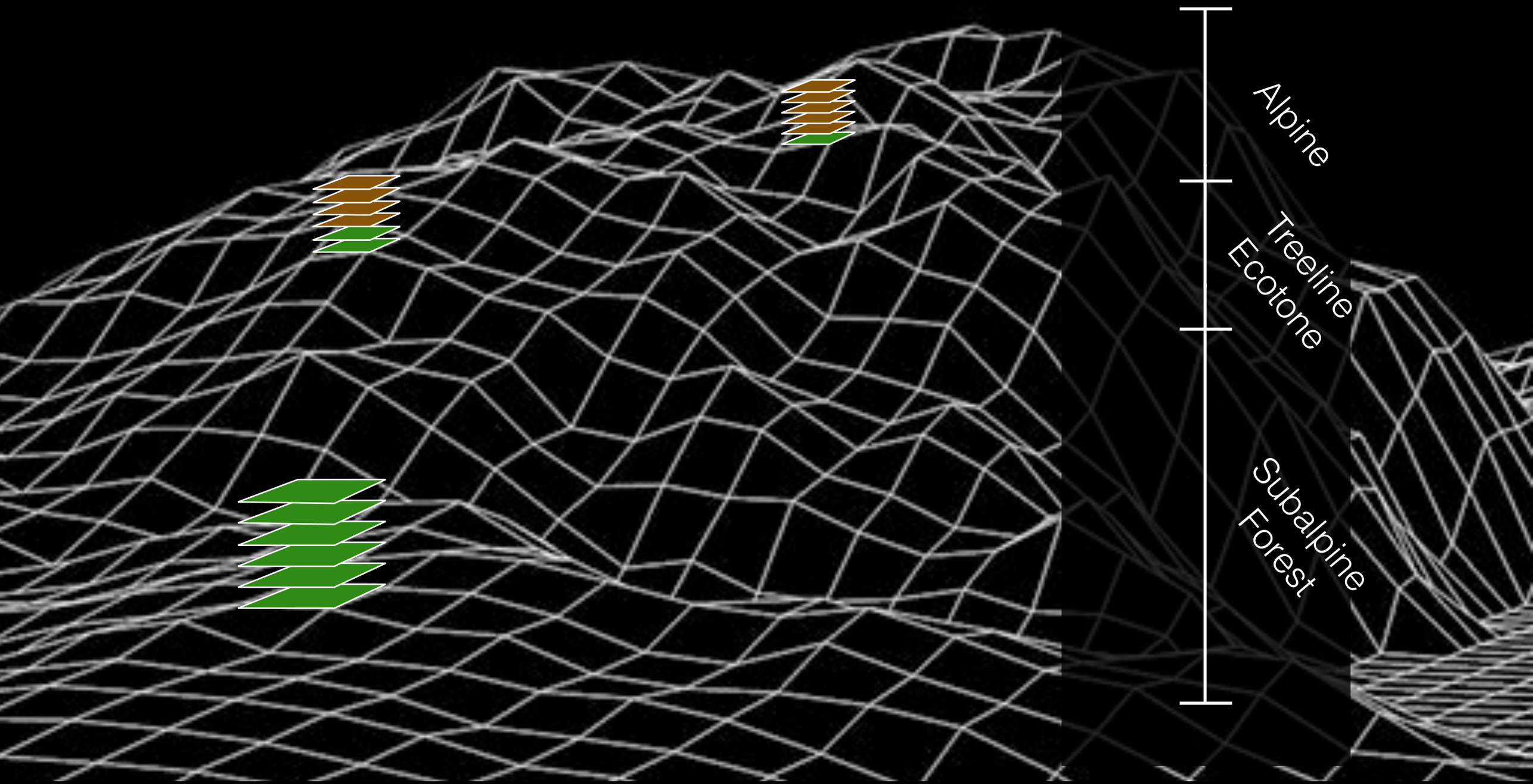


Each layer dependent on growth in layer below

Example model output on the landscape



Major Assumptions

Boundary layer dynamics determined only by wind speed - all land surfaces equal

Only ‘growing season’ matters (no winter damage effects)

No species-specific growth effects

Growth at treelines is growth (i.e., sink) limited, not photosynthesis (i.e., carbon) limited