PALM's Canopy Model

PALM group

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  - leaf area density,
  - drag coefficient.

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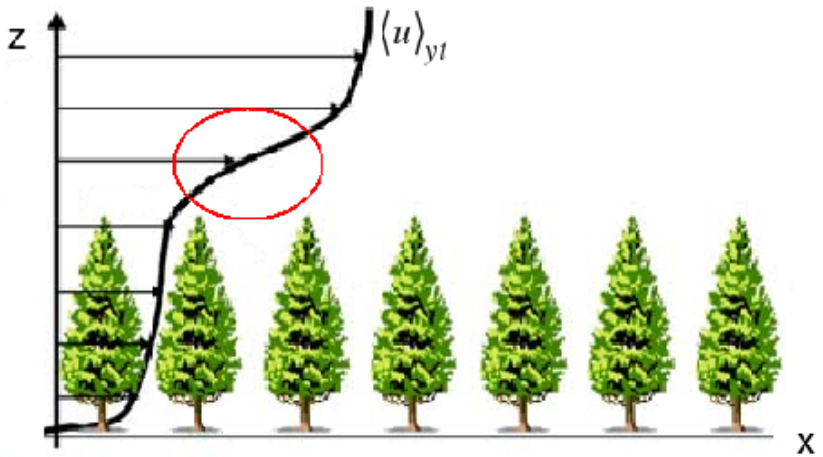
- The effectiveness of momentum absorption depends on the amount of leaf area per unit volume and the aerodynamic drag.
- Due to the aerodynamic drag, the flow is decelerated within the canopy, leading to an inflection point in the vertical profile of the horizontal velocity at the canopy top.



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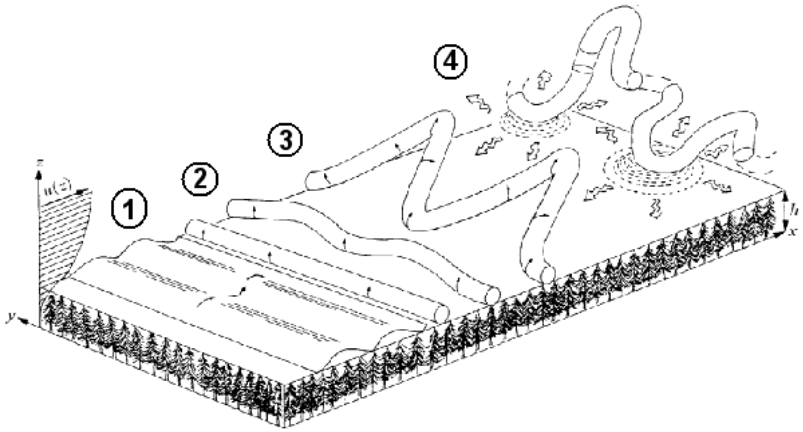
- Wave breaking induces further instabilities, whereby a longitudinal component is added to the developing turbulence structures (② & ③).
- Due to the persistent instabilities the turbulence structures develop a distinct three-dimensionality (④).
- The large turbulence structures developing due to the inflection point instability significantly contribute to the vertical mixing of in-canopy and above-canopy air.



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Note: The canopy model does not resolve the effect of single plant elements.

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- The effect of the canopy on the subgrid scale turbulence is accounted for by adding a sink term to the prognostic equation for the subgrid scale turbulent kinetic energy:

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- It is assumed that the subgrid scale turbulent kinetic energy is dissipated by the canopy due to the rapid dissipation of wake turbulence in the lee of canopy elements (e.g. Watanabe, 2004).

Methods (III)

- If desired, the effect of the canopy on the sensible heat transport can be considered. A source term is added to the prognostic equation for potential temperature:

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- The source strength S_θ is defined as the vertical derivative of the upward kinematic vertical heat flux Q_θ, given by (Shaw and Schumann, 1992):

$$Q_\theta(z) = Q_\theta(h) exp(-\alpha F) \ , \ Q_\theta(h) : \text{Heat flux at canopy top}$$

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  - $F = \int_z^h a \, dz$ (downward cumulative leaf area index)

Methods (IV)

- The canopy might act as a sink or source for other scalars q (e.g. humidity, passive tracer). Therefore, an additional term is added to the scalar transport equation:

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  - c_q : scalar exchange coefficient
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Basics (I)

- The canopy model is switched on by setting the parameter `plant_canopy = .TRUE.` within the &inipar `NAMELIST` in the parameter file (`PARIN`).

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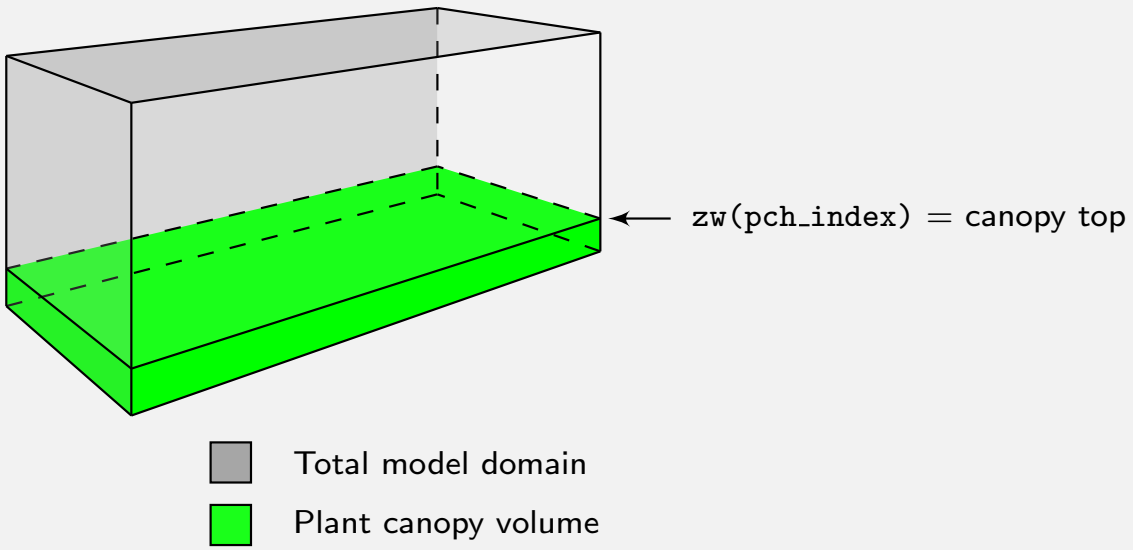
  (http://palm.muk.uni-hannover.de)
- The following slides will describe how to set up a simulation with a simple horizontally homogeneous canopy block covering the entire model domain surface. In this case, `canopy_mode = 'block'` must be set in &inipar `NAMELIST`.

Basic canopy parameter (I)

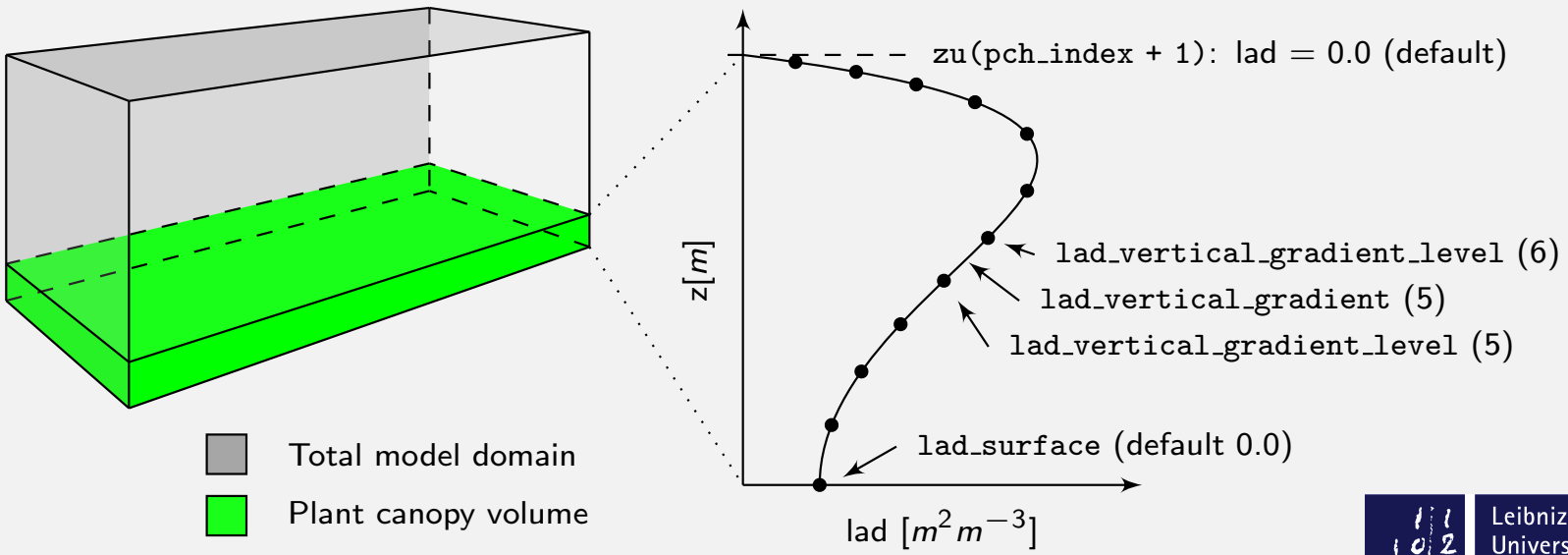
The parameters for steering the canopy model have to be added to the &inipar NAMELIST in the parameter file (PARIN).

- Step I: Define the upper boundary of the plant canopy layer using the parameter `pch_index (grid point index, default 0)`. `pch_index` specifies the number of grid points resolving the canopy layer in the vertical direction.



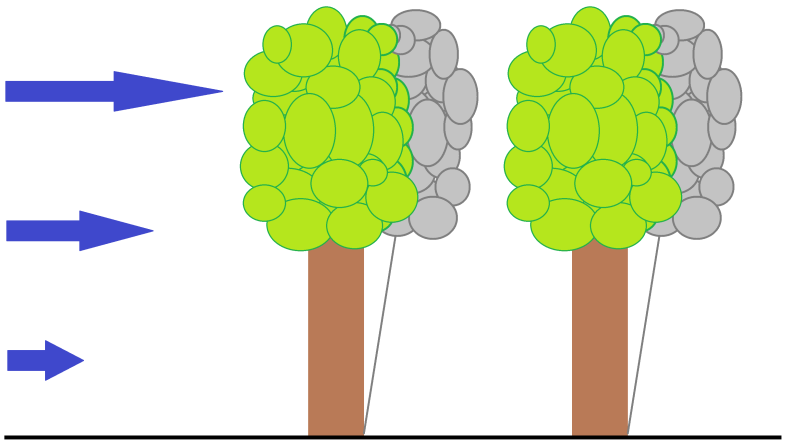
Basic canopy parameter (II)

- Step II: Construct the vertical profile of the leaf area density (lad) to prescribe the distribution of leaf area within the plant canopy volume.
  The canopy top is located between `zu(pch_index)` and `zu(pch_index + 1)` because this is the transition between the in-canopy grid point and the above-canopy grid point.

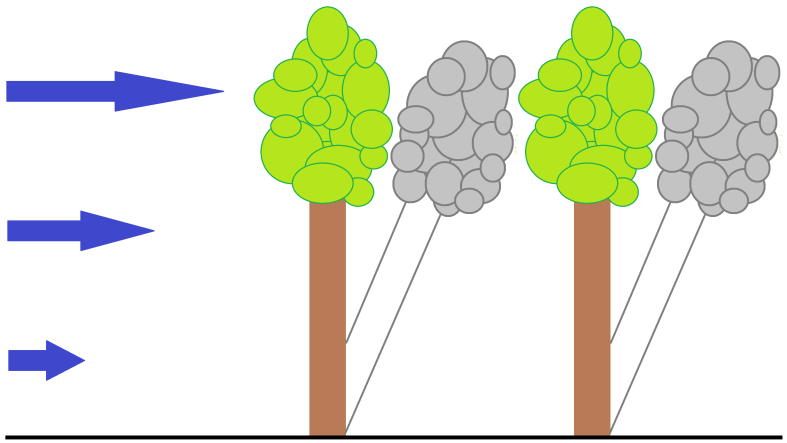


Basic canopy parameter (III)

- Step III: Prescribe a value for the parameter `drag_coefficient` (`default 0.0`). The drag coefficient is a dimensionless factor describing the magnitude of the form drag by the canopy working against the flow. A larger form drag results in a greater momentum reduction.



Strong trees offer a larger form drag to the flow.



Young / small trees offer a smaller form drag to the flow because they are more flexible.

Basic canopy parameter (IV)

- For steering the effect of the canopy sensible heat transfer, prescribe a value for the sensible heat flux at the canopy top, using the parameter `cthf` (see Methods (III)).

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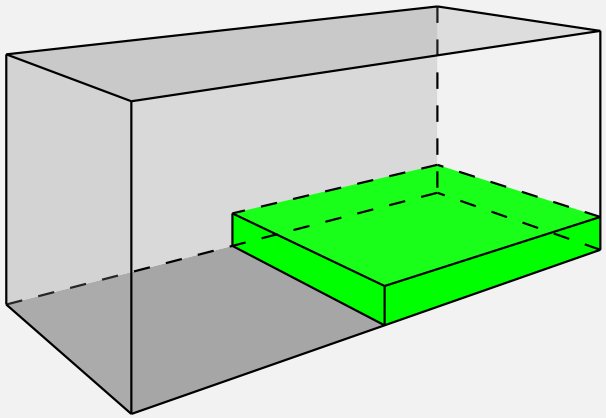
- For steering the effect of the canopy sensible heat transfer, prescribe a value for the sensible heat flux at the canopy top, using the parameter `cthf` (see Methods (III)).
- The sink/source effect of the canopy on other scalar quantities, such as humidity or a passive tracer can be steered by the parameters `leaf_surface_concentration` and `scalar_exchange_coefficient` (see Methods (IV)).

User-defined canopy

Do you want to simulate a more customized canopy, which e.g. covers only half the model surface?



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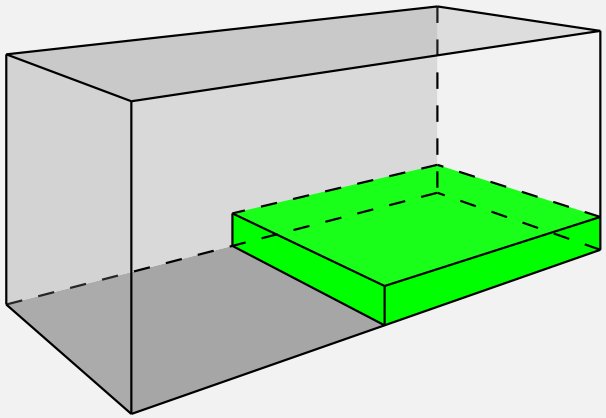

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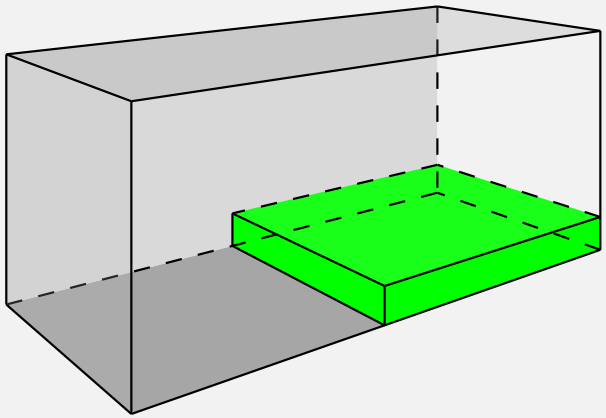

Total model domain

Plant canopy volume

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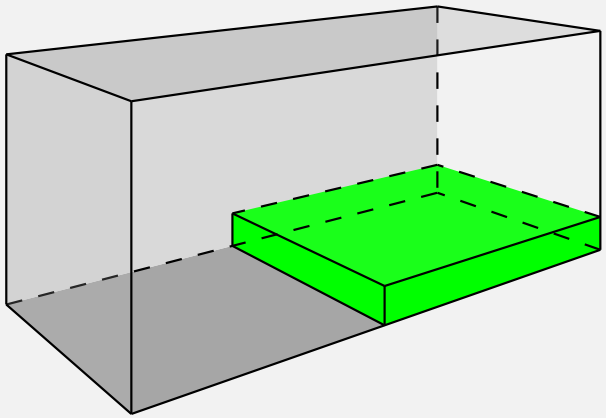

Note: You might have to make changes in other parts of your `USER_CODE` according to the changes / used parameters in: `user_init_plant_canopy.f90`