E4: Land surface model

palm group

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The aim of this exercise is to get to know the land surface model.

You will study two different cases:

1. You will look at a **short and simple** setup showing the influence of free convection on the soil temperature. Additionally a user defined quantity shall be calculated here for training the handling of user-defined code.
2. You will simulate full **diurnal cycles** and observe night-time dewfall on vegetation.

The following lectures are required:

- Land surface model
- Radiation model
- User defined code

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└ Part 1 – Setup

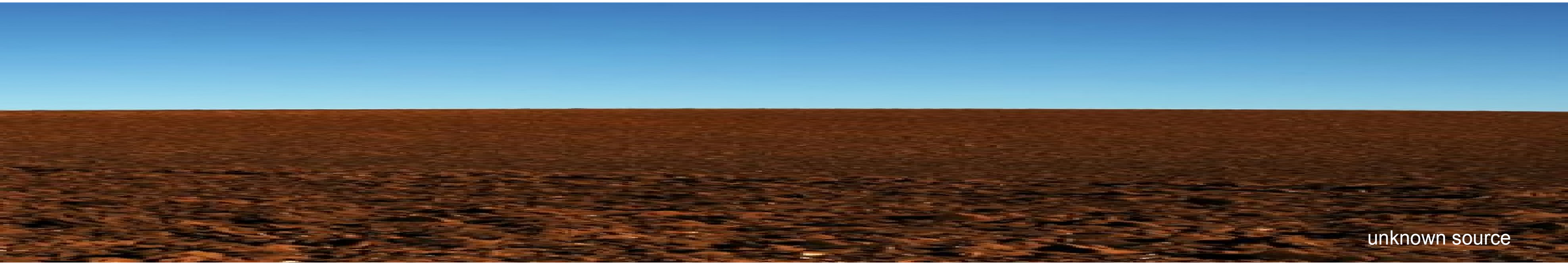
Summary of the most relevant namelist settings:

Land surface model
- default 8-layer soil setup
- constant soil temperature profile
- no moisture
- bare soil

Atmospheric boundary layer
- free convection (convective boundary layer without background wind) driven by the net radiation at surface
- neutral stratification capped with an inversion at z=800m
- no humidity

Runtime
- 2 hours
- high-frequent output of surface and three-dimensional data

Radiation model
- clear-sky around noon
- time step = 20.0 s



Questions:

Look at cross-sections of `theta, w, t_soil, shf, ghf, us*` and `t_surf*` which are found in the in the `_3d` and `_xy` files:

- How do the different variables correlate with one another?
- Down to which depth does the soil feel the boundary layer turbulence?
- What is the influence of a thinner/thicker first soil layer on the reaction of the surface temperature under atmospheric changes?

Output of user-defined 2d cross sections or 3d volume data

For learning how to output user-defined quantities, the absolute value of the horizontal velocity* (`v_h`) shall be calculated in this exercise as an example and output as 2-D cross sections and 3-D volume data.

1. Add the parameter `data_output_user` in the namelist `&user_parameters` in `e4_LSM1_p3d`.
2. Create directory `palm/current_version/JOBS/e4_LSM1/`**`USER_CODE`**
3. Copy the file user_module.f90 (`palm_model_system-v.../packages/palm/model/src/`) to the directory `USER_CODE`
4. Modify the file user_module.f90 as described in https://palm.muk.uni-hannover.de/trac/wiki/doc/app/userint/output

If you want to shorten steps 1 to 4, we provide a modified user code user_module.f90 along with the steering files of this exercise, where only some question marks (??) need to be replaced!

* Since 2020 this quantity is available as standard output (wspeed), but here it should just serve as an example and therefore be calculated again using the user interface

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Part 1 – Hints

Look up new variables in the PALM documentation!

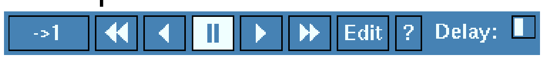
Be sure that you are aware of what you see and understand how the output is calculated

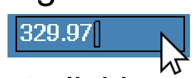
palmplot commands

- xy-cross sections:

```
palmplot xy file_1=e4_LSM1_xy.000.nc format_out=pdf \
  file_out=e4_LSM1_plot_xy var='tsurf*_xy ghf*_xy shf*_xy'\
  no_rows=3 no_columns=1 \
  start_time_step=1.0d end_time_step=1.0d
```

ncview

- The high-frequent output in this exercise allows you to have a look at the development of turbulence in the LES. You can loop the cross-sections over the output times in ncview and adjust the speed (“Delay” bar). 

- Sometimes you might need to adjust the range of the shown output under Range. Leave the mouse cursor over the text box to edit the range. 

- You can get some decent time series by just clicking somewhere in the output.

The palmplot-commands are just examples an may need to be adjusted to answer the questions!
Also the p3d-file may need to be edited to get appropriate outputs!

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└ Part 2 – Setup

Land surface model
- default 8-layer soil setup
- constant moisture and temperature
- 95% covered with short grass
- no heat capacity of skin-layer

Atmospheric boundary layer
- constant initial profiles of
  - wind (value of geostrophic wind)
  - virtual potential temperature
  - humidity (no clouds/precipitation)

Runtime
- 2.5 days
- output designed for analysis of time series and profiles

Radiation model
- clear-sky
- start on June 21st at 12:00 UTC

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Part 2 – Analysis

Questions:

Can you observe dewfall? (time series: `qsws_liq`, xy-section: `c_liq`)

- What happens at night? (time series: `ol`, `z_i`, `w*`, `E`, `umax`; profiles: `u`, `v`, `theta`, `q`, `w*theta*`)
- Is it really an LES? (`E*`, `e`, `e*`)

Additional tasks:

- Calculate the relative humidity at initialization (use the Magnus formula…)
- Make a guess and start a new simulation with less humidity. How much humidity is needed for night-time dewfall?

Part 2 – Hints

Look up new variables in the PALM documentation!

Be sure that you are aware of what you see and understand how the output is calculated

palmplot commands

- time series:

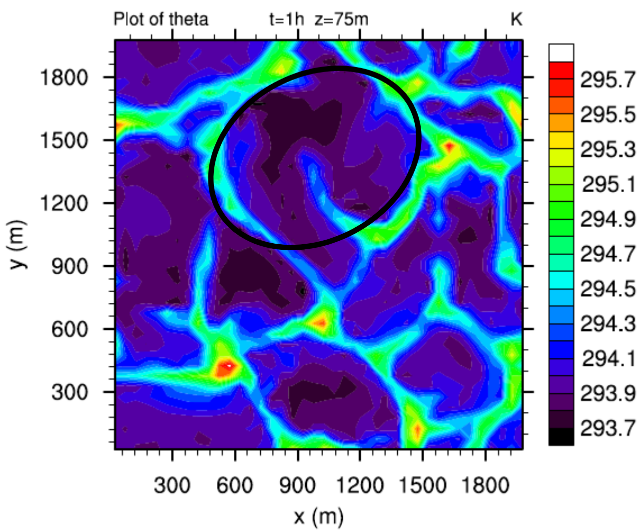
```
palmplot ts file_1=e4_LSM2_ts.000.nc format_out=pdf \
  file_out=e4_LSM2_plot_ts var='qsws_liq rad_sw_in zi_theta E E*' no_rows=5
```

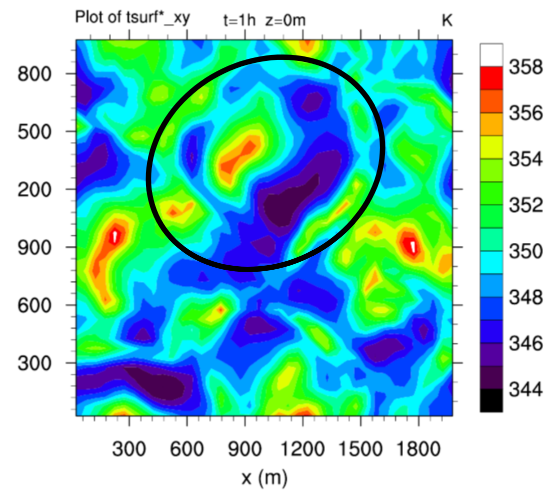
- profiles:

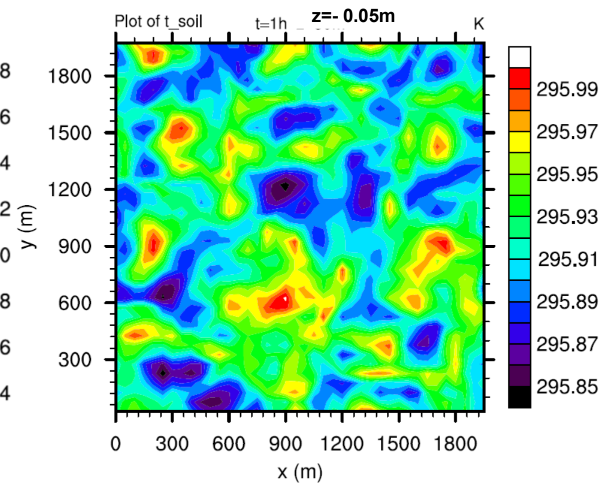
```
palmplot pr file_1=e4_LSM2_pr.000.nc format_out=pdf \
  file_out=e4_LSM2_plot_pr var='wu w*u* w"u" theta'
```

The palmplot-commands are just examples an may need to be adjusted to answer the questions!
Also the p3d-file may need to be edited to get appropriate outputs!

How does the surface and the soil react to the atmospheric turbulence?







Characteristics of a turbulent atmosphere:

- typical hexagonal cells
- higher temperature at edges
- lower temperature inside

Patterns at the surface:

- hexagonal cells
- higher temperature at edges
- but additional temperature maximum in the center
- lower temperature in-between

In the soil:

- surface patterns persist in upper soil
- in -5 cm surface patterns combine with others and become indistinguishable from oneanother

Part 1 – Answers

What is the influence of a thinner/thicker first soil layer on the reaction of the surface temperature under atmospheric changes?

- It changes the storage term *S* and the ground heat flux *G*. The thinner the first soil layer, the smaller the heat capacity of the first layer and the greater the ground heat flux. A finer soil configuration can react faster to the atmosphere.

$$S = R_{net} - G - H - LE$$

$$S = \rho c_p dz_{soil,1} \frac{dT_0}{dt}$$

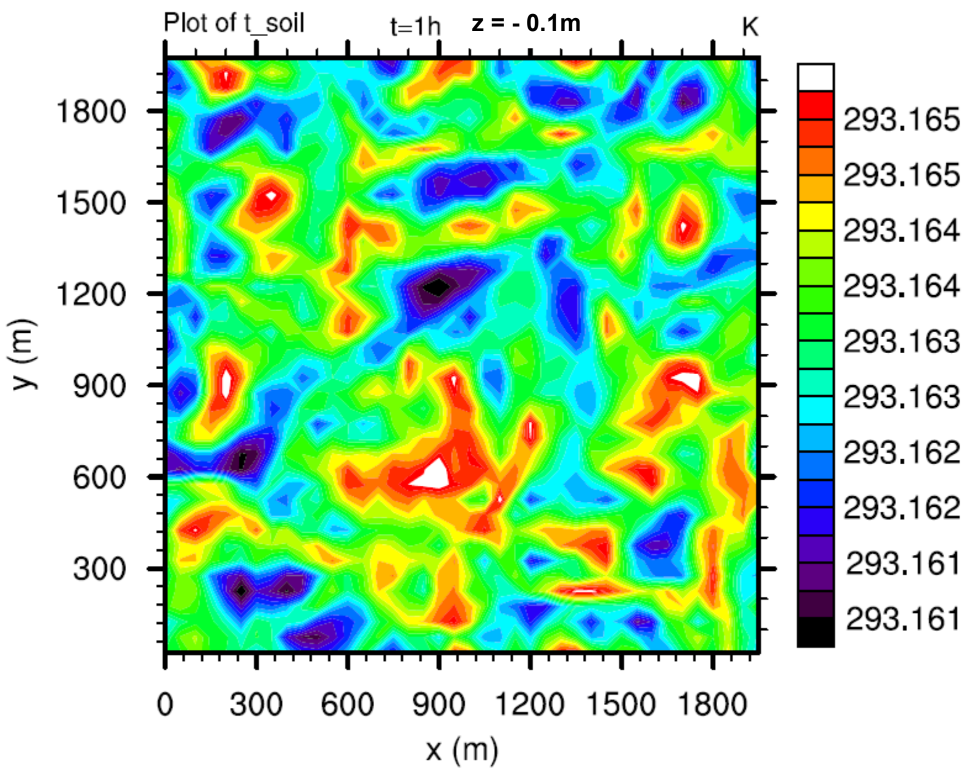
$$R_{net} = const.$$

$$G = \frac{\lambda}{dz_{soil,1}} \left(T_0 - T_{soil,1} \right)$$

$$H = \frac{\rho c_p}{r_a} \left(\theta_1 - \theta_0 \right)$$

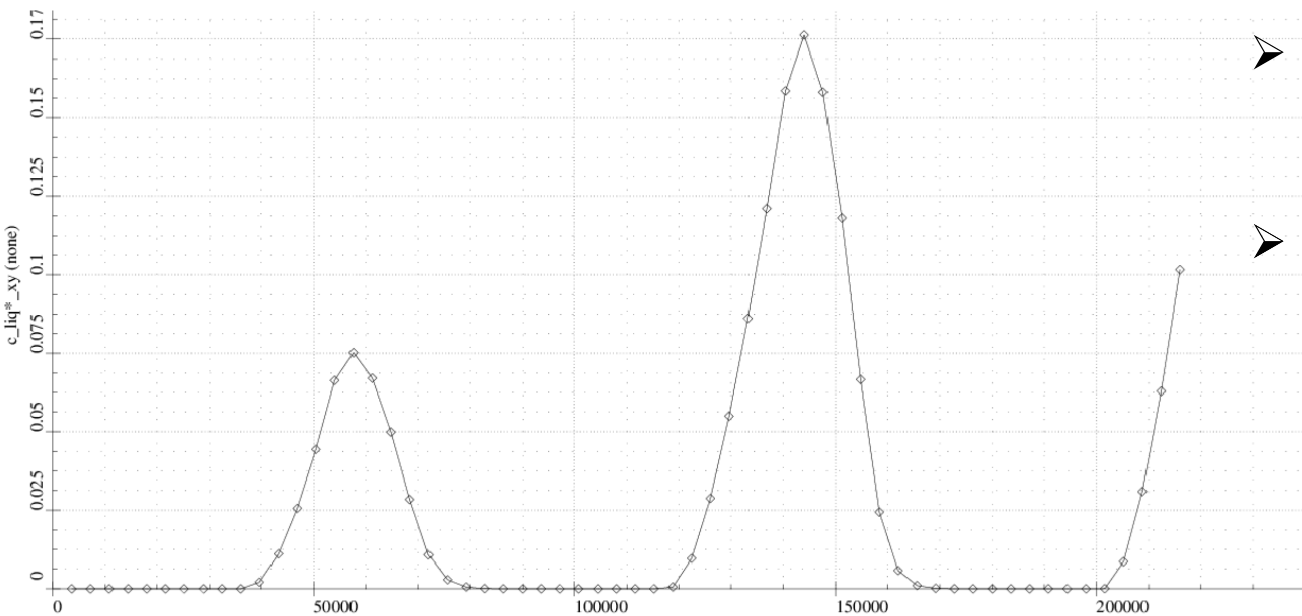
$$LE = 0$$

Down to which depth does the soil feel the surface forcing?

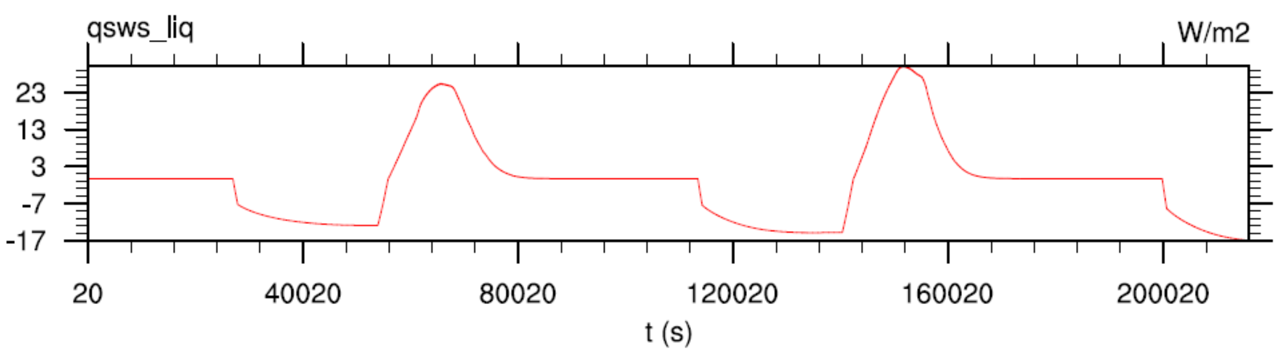


At 10 cm depth, the temperature variation is less than 0.5 K.

Can you observe dewfall? (time series: `qsws_liq`, xy-section: `c_liq`)

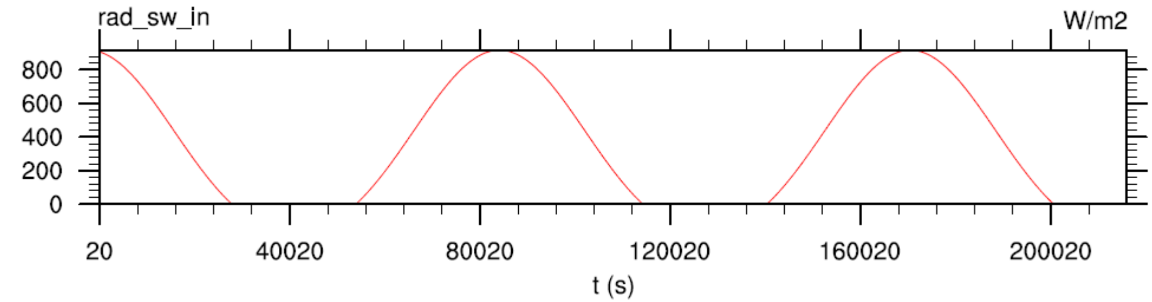


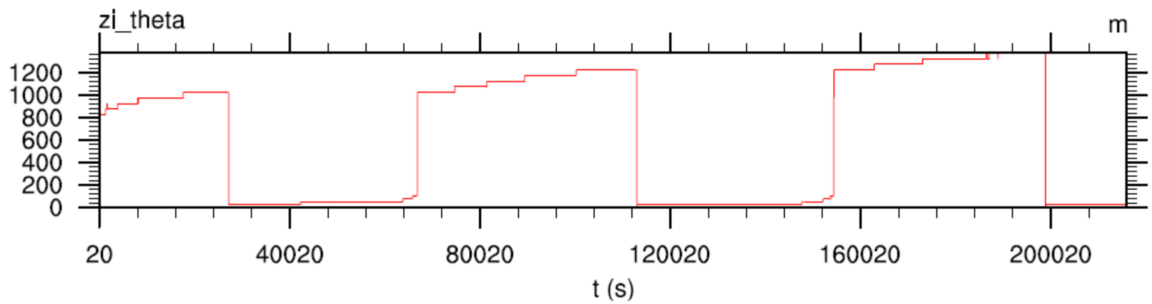
- Up to 10% of the vegetation is covered with dew.
- Dewfall sets in at 21:10 UTC (33000 s) and the vegetation is dry again at 10:20 UTC (80400 s) the next day.

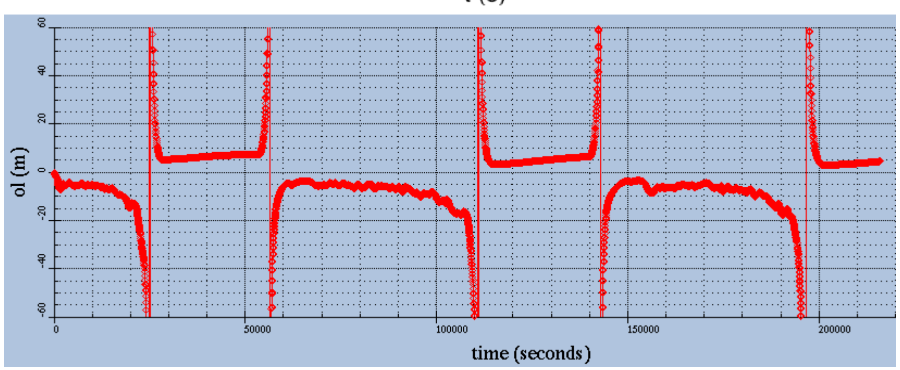


└ Part 2 – Answers

What happens at night?
(time series: `ol, zi_theta, w*, E, umax`; profiles: `u, v, theta, q, w*theta*`)







- Boundary layer collapses at 19:30 UTC (27000 s), develops again at 7:30 UTC (70200 s) the next day.
- The Obukhov length shows that the ABL is unstable during day and stable at night.

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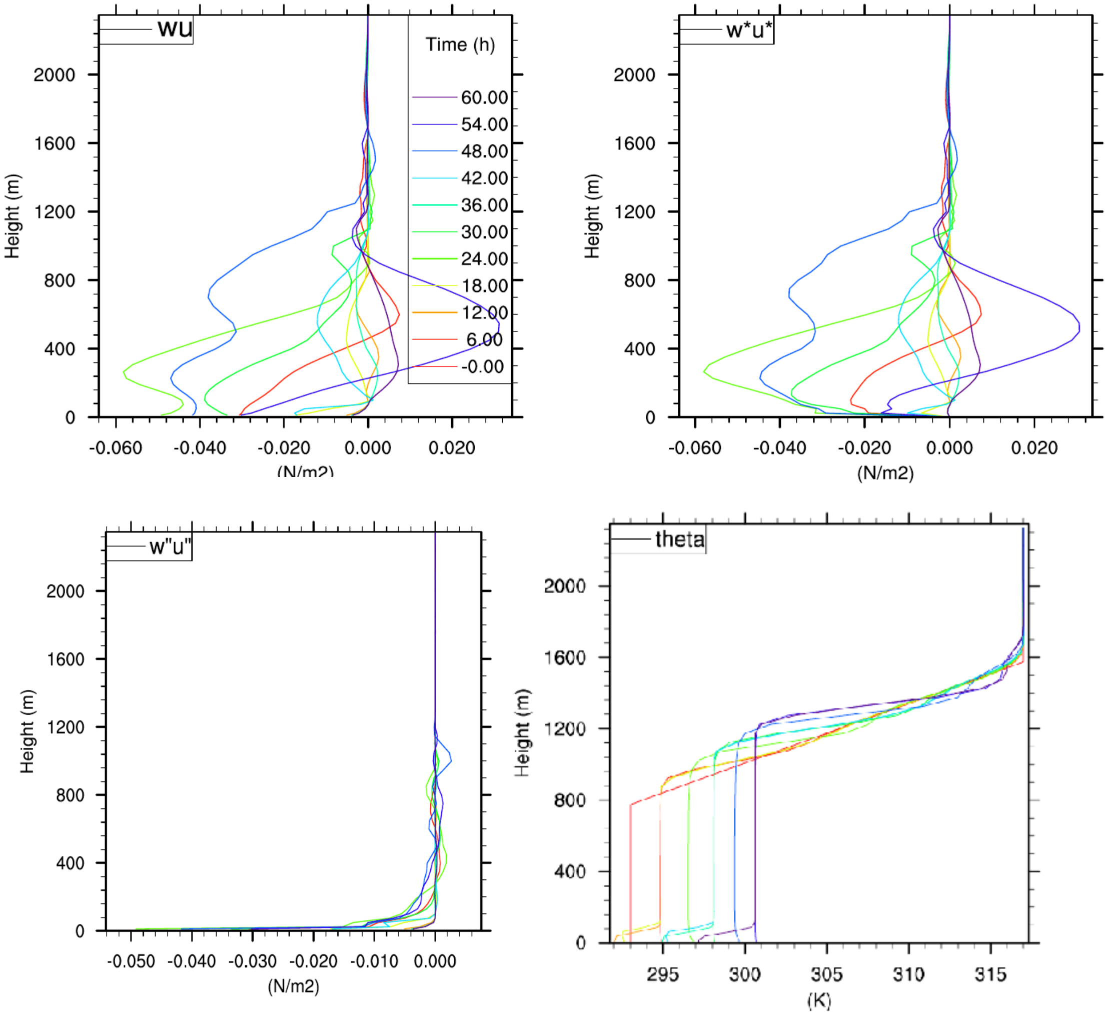
Part 2 – Answers



Is it really an LES?

- The nocturnal ABL is insufficiently resolved.
- Therefore, the simulation does not suffice the requirements of an LES at night.

- In the morning, convection develops and the LES results are reliable again (e.g., van Stratum, B. and B. Stevens, 2015).
- The analysis of night-time dewfall is not fully reliable. In reality, less or more dewfall could occur, if i.e. warmer or more humid air were mixed to the surface.
- Night-time ABLs are only resolved, if the LES uses a very small grid size (~1m)!

Part 2 – Answers

Calculate the relative humidity at initalization (use the Magnus formula…)

- ca. 88%

Make a guess and start a new simulation with less humidity. How much humidity is needed for night-time dewfall?

- With a mixing ratio of 0.009 (relative humidity 61%), dewfall only covers less than 1% of the vegetation