Exercise 10:
Cumulus Cloud With Bulk Cloud Physics

PALM group

Institute of Meteorology and Climatology, Leibniz Universität Hannover

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- Initialize the simulation with a marine, cumulus-topped, trade-wind region boundary layer.
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- Parameterize condensation using a simple bulk cloud physics scheme.
- Learn how to carry out conditional averages.

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- grid size: $50\,\mathrm{m}$ equidistant
- simulated time: $1800\,\mathrm{s}$

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with the locations:

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- Think parallel: Mind that the domain of each PE extends only from `nxlg` to `nxrg` and `nysg` to `nyng`! (Note that the just mentioned dimensions include ghost points)

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- The liquid water is diagnosed by $q_\mathrm{l} = \max(0, q_\mathrm{t} - q_\mathrm{s})$: If the total water content q_t exceeds the saturation water content q_s, all supersaturations condensate immediately to liquid water. On the other hand, no liquid water is present in subsaturated conditions.

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- `cloud_scheme = 'kessler', precipitation = .FALSE.`

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What kind of conditional average are you going to derive?

- You will derive vertical profiles of **cloud cover** and **cloud core cover**. These profiles are the basis for more complex profiles (e. g., the cloud core vertical velocity).
- Cloudy grid cells are defined as grid cells with a non-zero liquid water content ($q_\mathrm{l} > 0$, `ql(k,j,i) > 0.0`). Cloud core grid cells are defined as cloudy grid cells, which are also positively buoyant with respect to the slab average ($\theta_\mathrm{v} > \langle\theta_\mathrm{v}\rangle$, `vpt(k,j,i) > hom(k,1,44,sr)`).

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- Do not forget to adapt user_check_data_output_pr (for defining your user-profiles) and your parameter file (userpar namelist) for the output (with the parameter data_output_pr_user = 'your_profile')!
- Check the online documentation of PALM for more detailed information on the implementation of user profiles:
  http://palm.muk.uni-hannover.de/trac/wiki/doc/app/userint/output#part_1
  Further examples are also provided within the subroutines user_statistics and user_check_data_output_pr.

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- Output instantaneous yz-cross sections of `ql` and `w` at `section_yz = 0`. (`pt`, `q` and `vpt` are also interesting!) An output interval of 60 s is adequate.

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- Answer the following questions:
  - How does the cloud develop?
  - Can you identify the *actively growing* and the *decaying stage* of the cloud's life cycle by comparing the profiles of cloud and cloud core cover profiles? (Mind the profiles' definitions and physical implications!)

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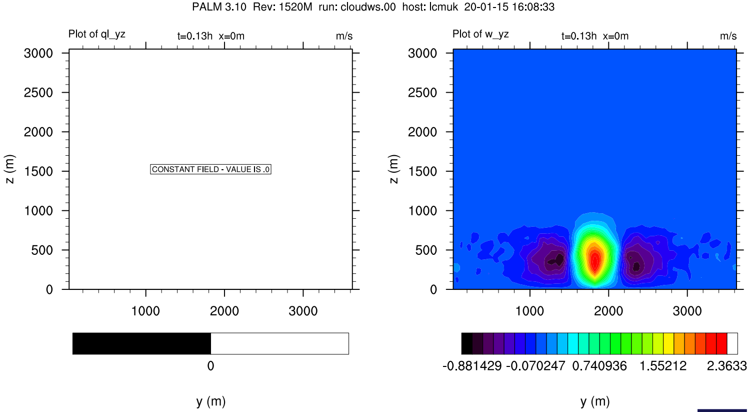
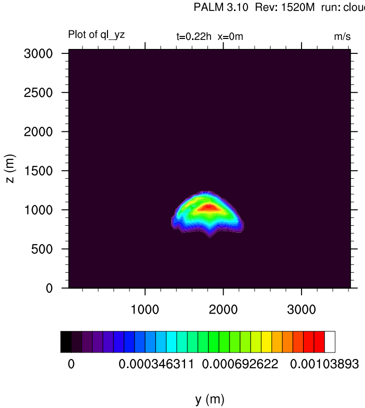
- If you are really fast: What changes during the cloud's development turning on precipitation (`precipitation = .TRUE.`)?

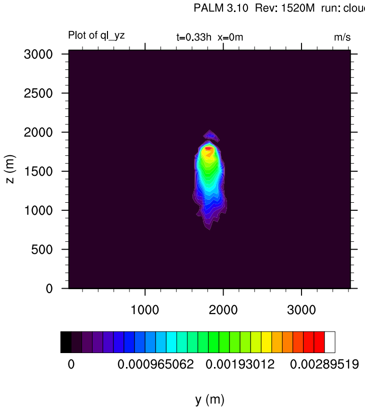
yz-cross sections at $t \approx 500\,\mathrm{s}$



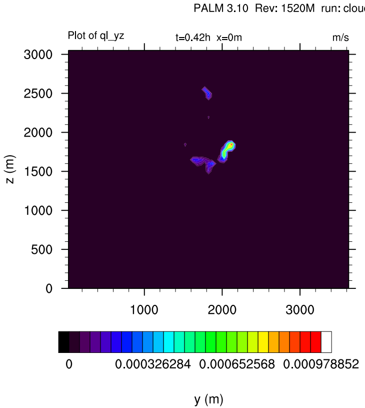
yz-cross sections at $t \approx 800\,\mathrm{s}$



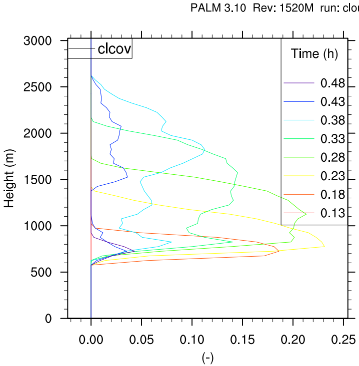
yz-cross sections at $t \approx 1200\,\mathrm{s}$

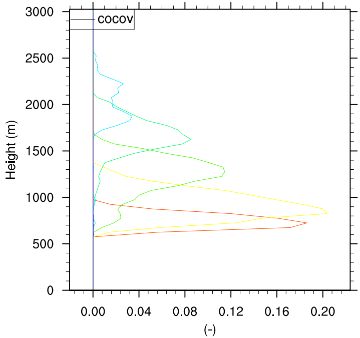


yz-cross sections at $t \approx 1500\,\mathrm{s}$



Cloud cover (clcov) and cloud core cover (cocov) profiles





Answers to questions I

How does the cloud develop?

- See frames 9 – 12: The clouds develops from a rising bubble of warm air ($t \approx 500\,\mathrm{s}$). Reaching the condensation level ($t \approx 800\,\mathrm{s}$), the cloud appears as the bubble's visible top. Afterwards, the cloud starts to grow more vigorously by the release of latent heat ($t \approx 1200\,\mathrm{s}$). In the end of the cloud's life-cycle, the cloud dissipates by turbulent entrainment of environmental air and the subsequent evaporation of the cloud ($t \approx 1500\,\mathrm{s}$).

Answers to questions II

Can you identify the (i) actively growing and (ii) decaying stage of the cloud's life cycle by comparing the profiles of cloud and cloud core cover profiles?

- See Frame 13: As long as the cloud core is present, i. e., a positively buoyant region producing upward motion, the cloud grows actively (until 1400 s). From 1500 s on, no cloud core is visible. As a result, the cloud's upward motion decelerates and the rate of condensation decreases. Thus, the cloud's dilution by the entrainment of environmental air can not be counterbalanced anymore. As a consequence, the cloud decays and finally dissipates.

Answers to questions III

What changes during the cloud's development turning on precipitation (`precipitation = .TRUE.`)?

- Almost nothing. The simulated cloud is very shallow, therefore no significant masses of rain are produced that might alter the cloud.