Regional Cooperation for
Limited Area Modeling in Central Europe

LACE
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Cloudiness: status, unification attempts and perspectives

Ján Mašek, Radmila Brožková

DHMZ SHMU OMSZ ZAMG ROMANIA ANM

Current status

- In ALARO, we have historically two cloud schemes:

1. Cloud scheme used for precipitating processes

2. Cloud scheme used for radiative transfer

- Both schemes – their stratiform part - are based on the Xu-Randall cloud scheme proposal with some differences.
- We shall describe below each of them.

Precipitating processes

- In ALARO, we still have the possibility to use a deep moist convection parameterization and so we have to count with two inputs:
  - “resolved” condensation computed in the so-called thermodynamic adjustment;
  - “sub-grid” condensation computed in parameterized convective updrafts.
- Both condensation processes of course yield cloud cover, which is combined and enters the microphysics – geometry of cloud and falling precipitation computations.

Thermodynamic adjustment (1)

- **Equilibrium point** for stratiform (resolved) condensation-evaporation of prognostic cloud water $q_c = q_l + q_i$
- It is based on classical methods using a PDF of moisture within the grid-box, in our case this PDF is not given but a profile of a critical relative humidity HU_c needs to be set.
- A simplified XU-Randall formula is used to compute cloud cover:

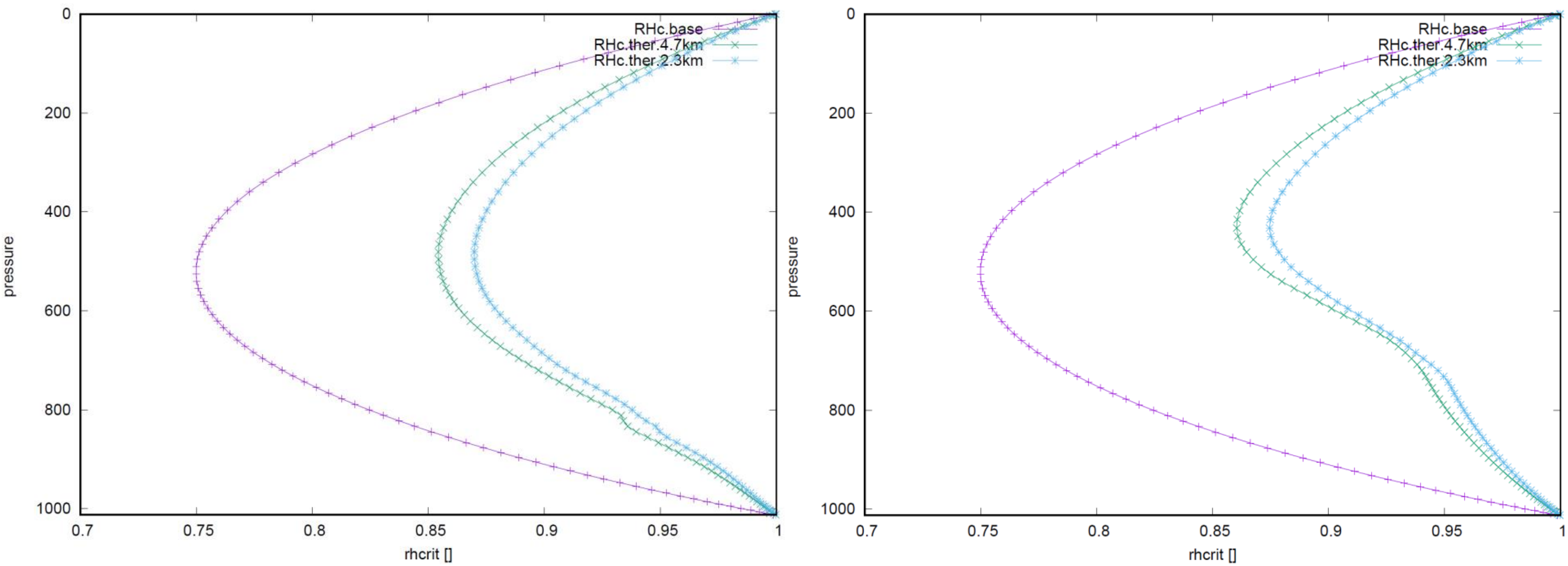
$$N_{str} = \left(\frac{q_v}{q_w}\right)^r \frac{\alpha q_c}{\alpha q_c + (q_w - q_v)^\delta}$$

With r=0.25; δ=0.5; $\alpha$is a tunable parameter of the order of 100. q_w is water content of exact saturation taking into account latent heat release or storage.

Thermodynamic adjustment (2)

- Option to protect convective cloudiness during the adjustment – why?
  - PDF of moisture distribution of unresolved updraft is different (hidden thinking of Tompkins?) => danger of re-evaporation of cloud water created by these drafts in previous time-step;
  - Current solution is to treat in the adjustment the "non-convective" part of the grid box, assuming a random overlap.
- Critical relative humidity profile
  - depends on the model mesh-size => increasing the horizontal resolution means higher values of HU_c;
  - There is an additional modulation for solid and liquid condensations.

Critical RH profiles



- Winter (left) and Summer (right) typical profiles of the critical relative humidity.
  - Violet – basic profile;
  - Green and Blue – modulated profiles for respectively 4.7 and 2.3km resolutions.

Thermodynamic adjustment (3)

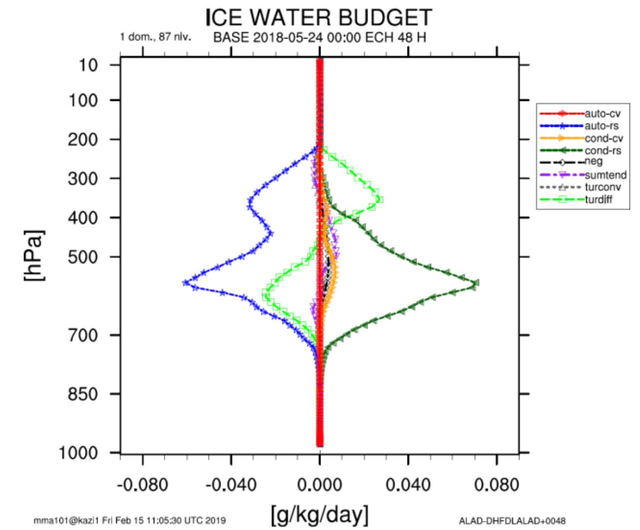
- Nominal ALARO option is the approximated Xu-Randall scheme as described above; switch LXRCDEV;
- Other coded options for completeness:
  - Smith – Gerard scheme, based on Smith QJRMS 1990 and modified; it takes into account the moist deep convective cloudiness in a simple way; switch LSMGCDEV;
  - Rasch – Kristjansson scheme from HIRLAM; coded but not really tested; switch LRKCDEV;
  - Smith scheme as used in the ARPEGE model, it takes into account the moist deep convective cloudiness in a simple way; switch LSMITH_CDEV.

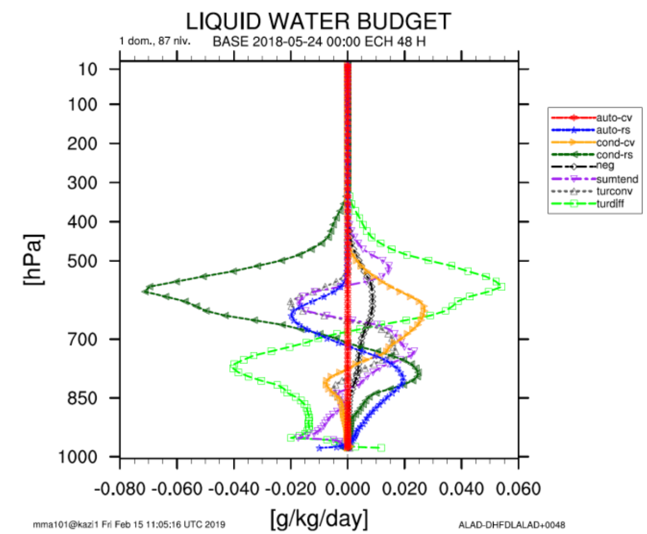
Input to microphysics

- Thermodynamic adjustment provides:
  - Condensation-evaporation flux of "resolved" prognostic cloud water;
  - "resolved" cloud fraction;
- Convective updraft provides:
  - Convective condensation flux;
  - Convective cloud fraction as a sum of updraft area fraction and "historical" detrained fraction;
- The two inputs are combined:
  - For cloudiness, the basis is a combination based on a random overlap within the grid box; in addition, there is a modulation pending the condensation fluxes;
  - Resulting cloudiness enters the microphysics – important for geometry => hypotheses on overlaps must be adopted.

Sedimentation of cloud water

- Prognostic cloud water species q_l and q_i can sediment using the sedimentation scheme of APLMPHYS (microphysics; switch LSEDCL);
- Falling speeds:
  - 8 cm/s for q_i ;
  - 2 cm/s for q_l .
- The impact of switching it off is shown on DDH for a summer case.
- In general, high cloudiness (also radiative) increases a bit because of prevailing ice content.





Cloudiness in radiative transfer

- For historical reasons, this cloud scheme had to exist before the prognostic cloud water became part of NWP models;
- In ALARO, the decision was to keep the two cloud scheme separated and then proceed to unification when ready with shallow (non precipitating) convection part;
- First unification attempts were not successful since some parts of the radiative cloudiness computation were not assessed carefully enough and/or were (wrongly) not considered.

Cloudiness in radiative transfer - input

- For radiation input we have to combine cloudiness originating from all processes:
  - "resolved" or "stratiform" condensation/evaporation N_{str};
  - "unresolved" moist deep convective cloudiness N_{cv};
  - "unresolved" shallow convection cloudiness N_{scc}.
- In comparison to the previous case of cloudiness entering precipitating processes, there are shallow, non-precipitating clouds in addition.

Stratiform radiative cloudiness – status (1)

- First, there is a computation of the stratiform cloud water content q_c (first part of the ACNEBN routine), computed as a super-saturation;
- Main inputs:
  - Total water $q_t = q_v + q_l + q_i$;
  - Critical relative humidity HU_c ;
  - Saturation moisture QSAT (not q_w here);
- There are substantial differences w.r.t. the thermodynamic adjustment computations:
  - Profile of HU_c is the BASIC one, with no modulation by the horizontal resolution (clearly a problem);
  - Parameterization of additional effects and/or heuristic approaches to get more realistic radiative response.

Stratiform radiative cloudiness – status (2)

- Additional effects included in resolved cloud water radiative computation:
- Mimicking the temperature inversion reinforcements to get more low clouds
  - This is driven by two parameters; the one switching this mechanism on is RPHI0 (1250), multiplying the temperature gradient and the second one to set a typical geopotential depth (1750) over which the calculation is done to avoid a flip-flop.
  - Saturation moisture is then computed for lowered temperature.
- Mimicking the shallow convection clouds
  - Parameter QSSC (set to 400 since ages – difference in dry static energy to account for "sub-inversion" moisture) is there to replace the missing N_{scc} input;
- Modulation of cloud water with height
  - Parameter QSMODC (when set to higher value than one) diminishes linearly the super-saturation effect with height.

Combination with convective input

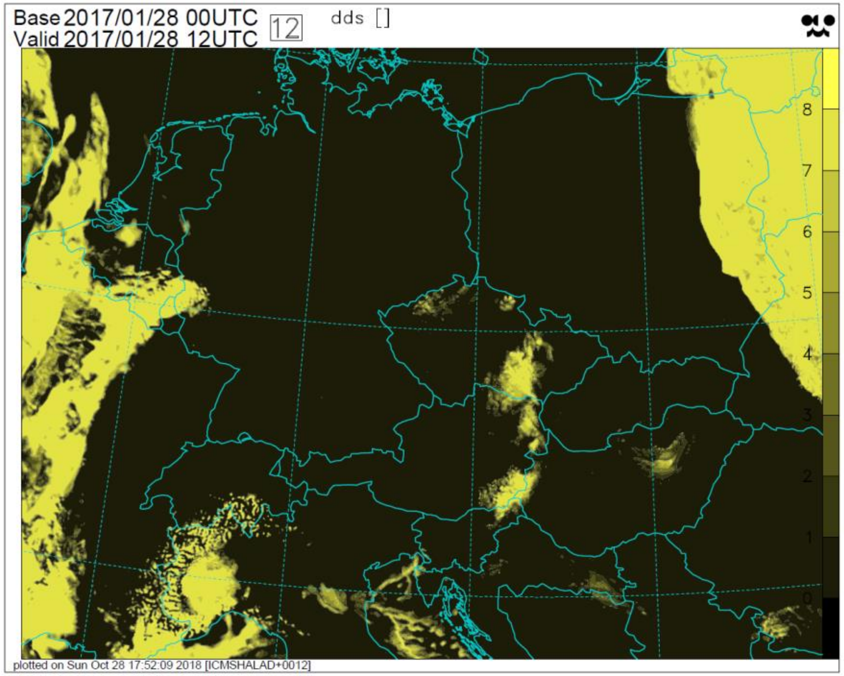
- Currently we have the input from moist deep convection available from the previous time-step (due to the parameterizations call sequence);
- We get N_{cv}, from which the corresponding cloud water is computed by inversing the simplified X-R formula;
- The two cloud water contents (stratiform and convective) are added (assuming a random overlap within the grid-box) to enter the radiation scheme;
- Final cloud cover is recomputed back;
- In addition, within this computation, the option LQXRTGH makes the relative humidity going asymptotically to one, so that resulting cloudiness has more intermediate values;
- There is no shallow convection cloudiness input (see QSSC).

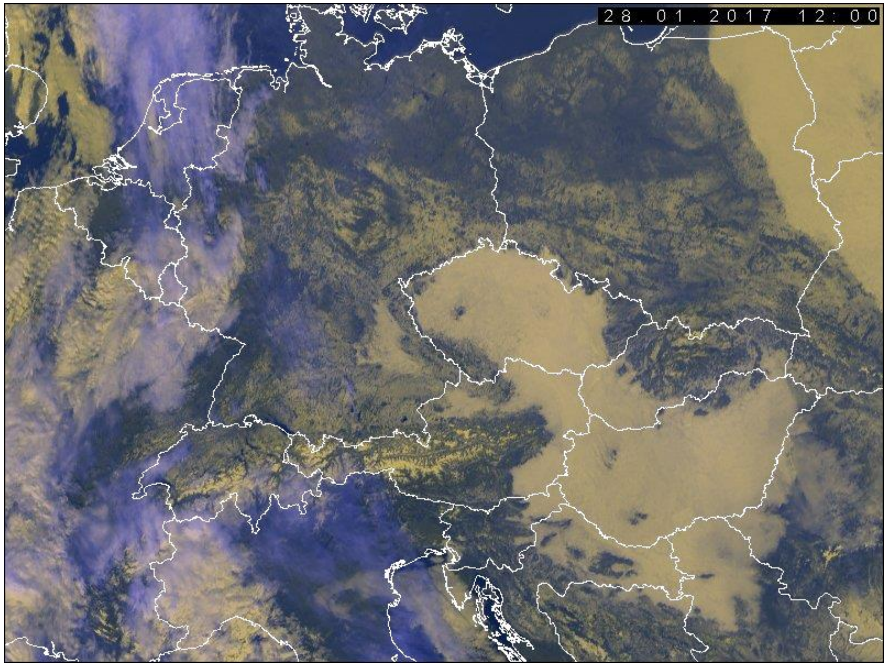
Cloudiness unification

- Comparing cloud schemes used for microphysics and radiation, there are some first ideas how to proceed with their unification:
  - Possible for the "stratiform" cloudiness N_{str};
  - Moist deep convective input N_{cv} is in both cases treated separately and disappears when the moist convection scheme is switched off;
  - Shallow convection input N_{scc} is still a missing piece – it is now mimicked on the radiation side but there is no equivalent on the microphysics side (because being not-precipitating by construction; consequences on thermodynamics) – the likely unification can thus happen between turbulence and radiation computations.

Getting stratiform cloudiness closer

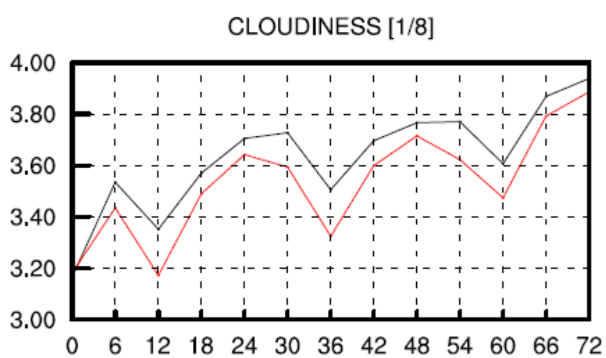
- Unify the HUc profiles – anyway there is a need to make the resolution dependency on the side of the radiative cloudiness;
- Get rid of the additional tricks – first results show even aggravated lack of low level clouds

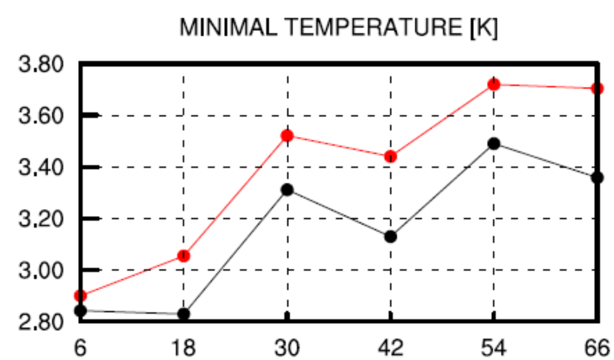




First attempt - results

- Surprisingly, winter scores (January 2017) were not that bad except missing cloudiness; these "good" scores were however misleading;
- Another trial was to put back clouds by re-using the RPHI0;
  - It resulted in bad scores of screen level temperature; Here below are RMSE scores with improved cloudiness and deteriorated temperature.
  - It has shown that mastering the radiative feed-back of cloudiness is quite complex.





Lessons retained

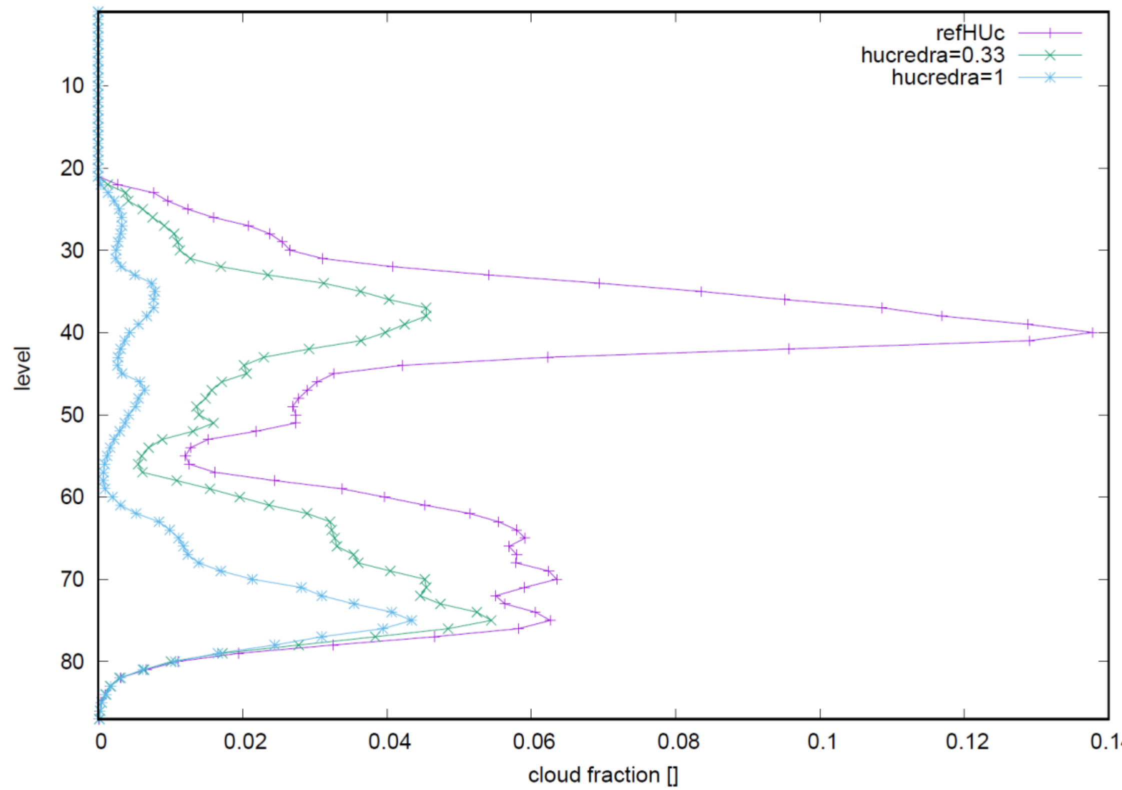
- The HU_c profile used in the radiative cloudiness needs to be *dx* dependent anyway;
- The temperature gradient enhancement trick of *RPHI0* should be used with quite some care – its impact is of course situation dependent and also it is dependent on the tuning of other cloudiness parameters and feedbacks;
- Till we have another solution for the shallow convective cloudiness, can we improve the situation anyway?

List of main tunings for radiative N_{str} (1)

- The HU_c profile – distribution of moisture within the grid-box and which could be unified with the thermodynamic adjustment;

- The effect on cloud fraction profile – horizontal average over Central Europe, using the existing tuning parameter HUCREDRA, acting as follows (denoted as β):

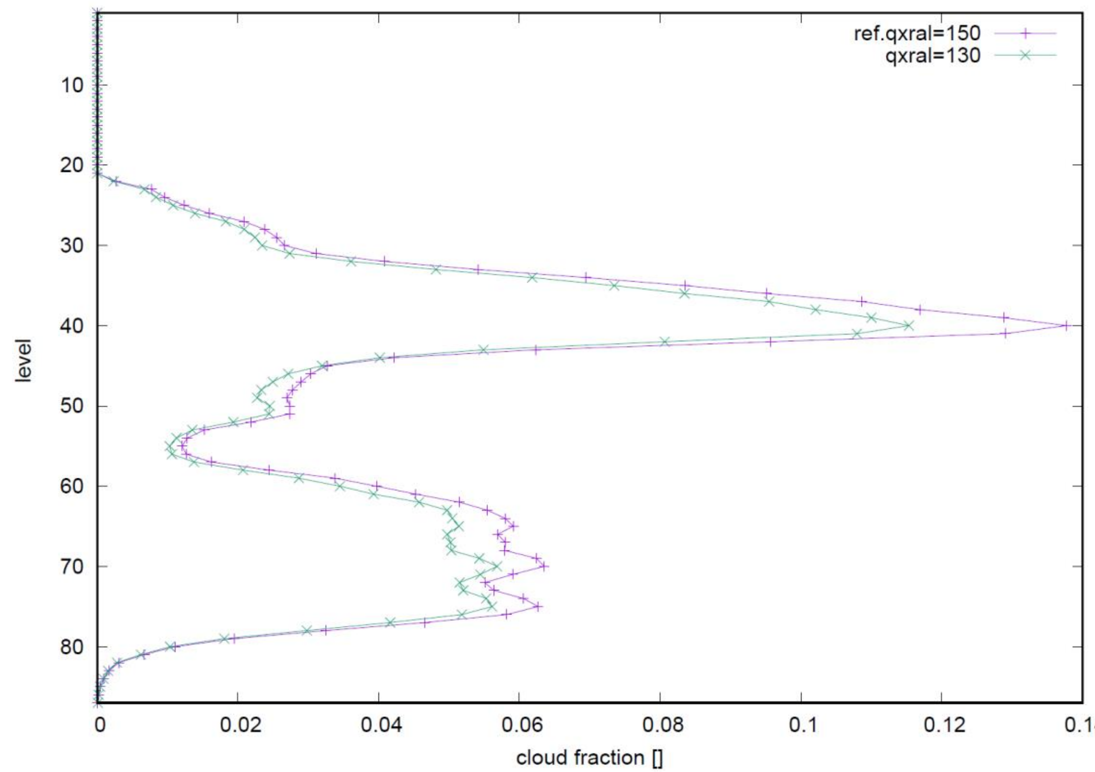
$$HU_c = \frac{HU_{c\_base} + \beta}{1 + \beta}$$



List of main tunings for radiative N_{str} (2)

- The *QXRAL* parameter of Xu-Randall formula, multiplying cloud water content, and which could be unified with the thermodynamic adjustment (*QXRAL_ADJ*);

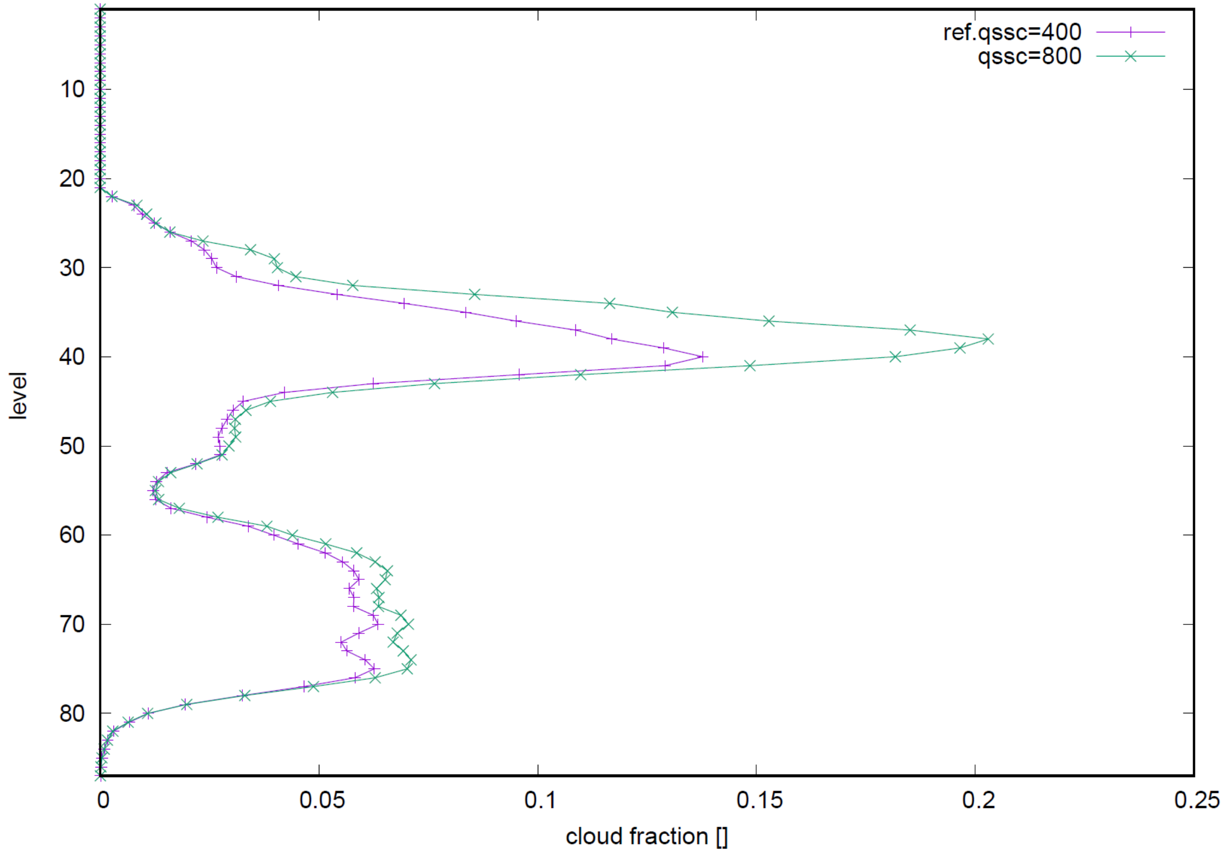
- The impact on cloud fraction profile (again a horizontal average over Central Europe) shows rather a proportional effect despite feed-backs at work (profile is taken after 12 hours of the integration).



List of main tunings for radiative N_{str} (3)

- The *QSSC* parameter to mimic sub-inversion clouds; it can be removed provided we get N_{scc} from TOUCANS.

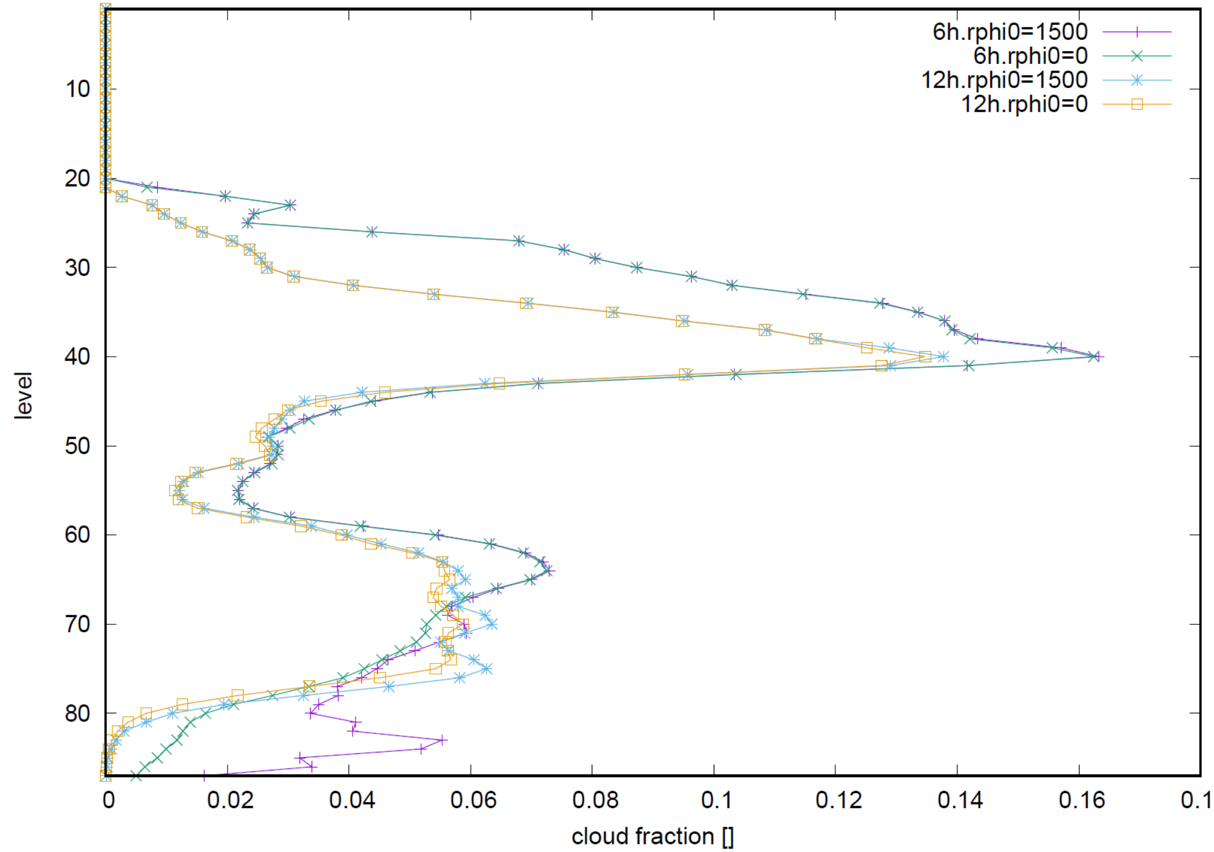
- The impact on cloud fraction profile (again a horizontal average over Central Europe) shows the enhancement of cloudiness at the tropopause inversion, and not only at the boundary layer top. The average is taken after 12h of integration at noon.



List of main tunings for radiative N_{str} (4)

- The *RPHI0* parameter enhancing the inversion temperature gradient to move saturation moisture limit.

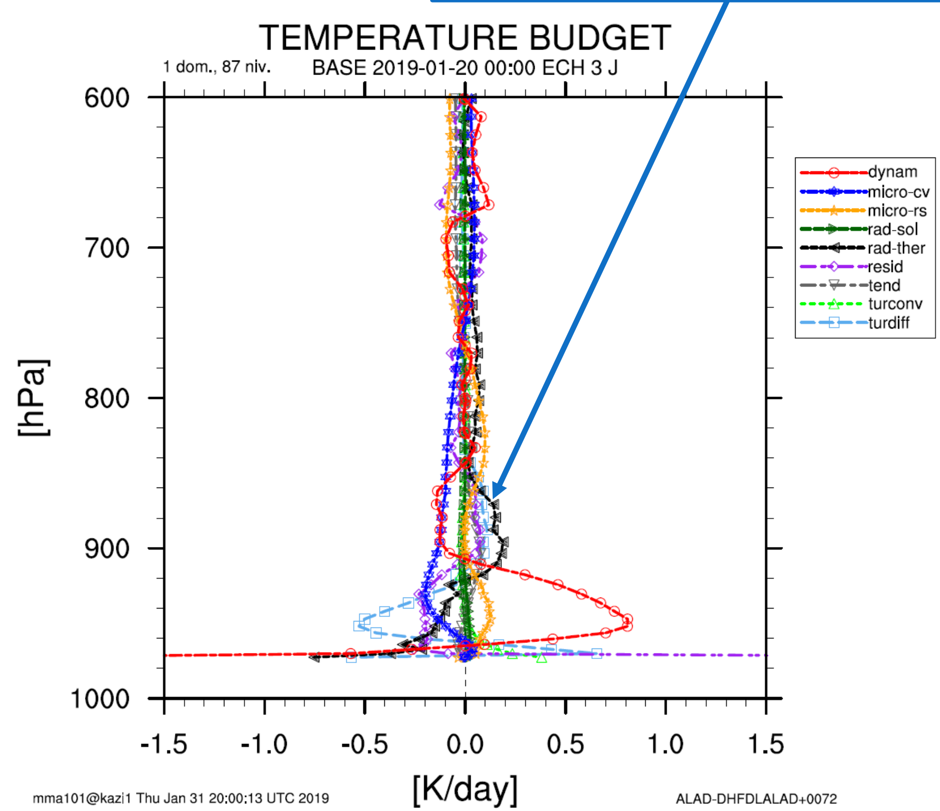
- The impact on cloud fraction profile is shown for morning (after 6h integration) and for noon (after 12h integration).
- The effect in the morning is much stronger; this parameterization is mainly simulating fog by radiative cooling.



Finding a good combination

- *HUCREDRA* – can simulate the HU_c increase due to *dx* change;
- *QSSC* – can enhance sub-inversions clouds;
- *LQXRTGH* – switching it off allows more solid cloudiness;
- *RPHI0* – a bit difficult tuning; lowering it helps to get colder morning minima

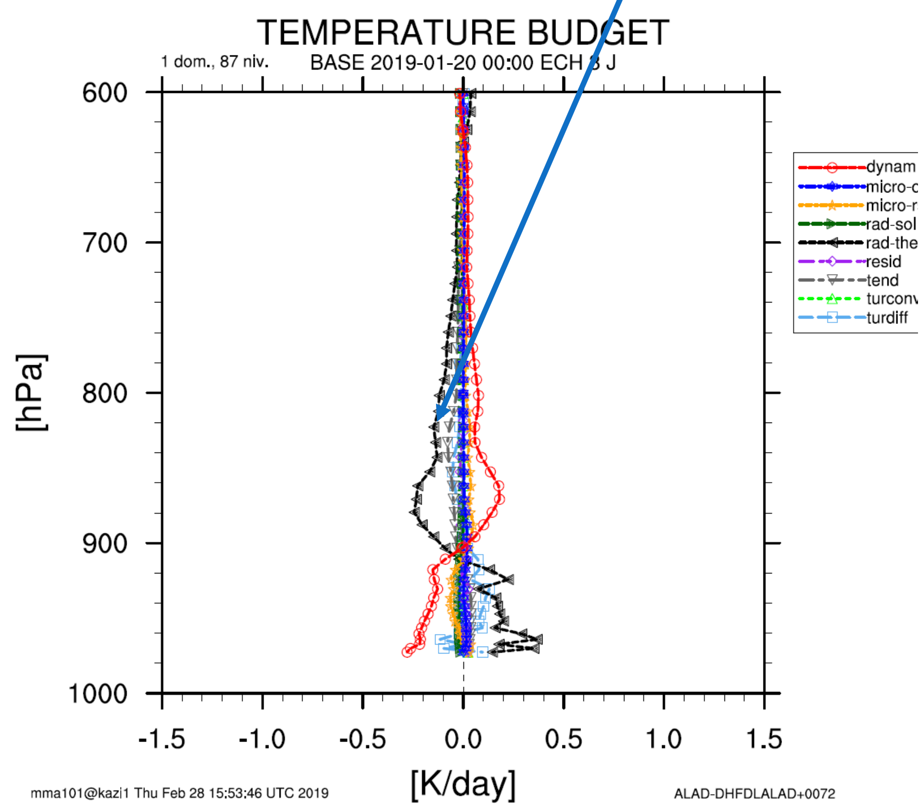
Problem of radiative heating by clouds above



Current tuning for 2.3km

- *HUCREDRA* = 0.33
- *QSSC* = 800.
- *LQXRTGH* = .FALSE.
- *RPHI0* = 600.

Effect of different vertical cloud structure



Conclusions and Outlook

- The proposed tuning of radiative cloudiness make first steps toward the unification of stratiform (resolved) cloudiness computation:
  - Adaptation of the HU_c profile in the right direction;
  - Removing the LQXRTGH option;
  - Lowering the RPHI0 coefficient.
- As a next step, we should try the unification of HU_c profiles;
- More difficult but necessary will be the replacement of QSSC extension by the shallow cloudiness coming from TOUCANS:
  - Cloudiness computed in TOUCANS is located at half-levels;
  - There is also a question which cloudiness should be used for diffusion of conservative variable – now it is $\hat{Q}$ but $C(\hat{Q})$ can be considered instead.