***R**egional **C**ooperation for*
***L**imited **A**rea Modeling in **C**entral **E**urope*

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New developments in microphysics/graupel

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Outline

Prognostic graupel modifications

Comparison of ALARO and ICE3 microphysics

Temperature drop in Ostrava

Prognostic graupel modifications

Prognostic graupel modifications

- added to the DDH budget
- new fall speed relation
- optimizations for vectorization
- small bug-fixes

New variables in the DDH budget

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PQGRAUPEL	Graupel mass ratio (q_g)
PFPLSG	Stratiform graupel precipitation flux
PFPLCG	Convective graupel precipitation flux
PFHPSG	Stratiform graupel enthalpy flux
PFHPCG	Convective graupel enthalpy flux
PFHSSG	Sensible heat flux
PFPEVPG	Stratiform graupel sublimation/evaporation flux
PFPEVPCG	Convective graupel sublimation/evaporation flux
PFPFPG	Autoconversion and collection flux
PFCQGNG	Term to correct negative flux

List of modified routines

ADIAB/CPG	Grid point calculations (GPC), calls CPG_DIA and CPG_GP.
ADIAB/CPG_DIA	GPC, their diagnostics.
ADIAB/CPG_GP	GPC: initial part of not lagged grid-point calculations.
ADIAB/GPINISLB	PQGRAUPEL is computed here.
DIA/INIAPFT_BP002	Preparing descriptors of fluxes or tendencies, for usage in DDH. For ALARO only.
DIA/SUNDDH	Initialization of permanent pointers for DDH.
MODULE/YOMTDDH	Description of fields in the DDH budget.
DIA/CPPHDDH	Computation of dynamic fluxes and tendencies due to physical parametrizations, soil computations.
DIA/CPDYDDH	Computation of atmospheric variables, tendencies and adiabatic fluxes.
DIA/PPFIDH	Write results to file.
DIA/PPEDDH	Prints.

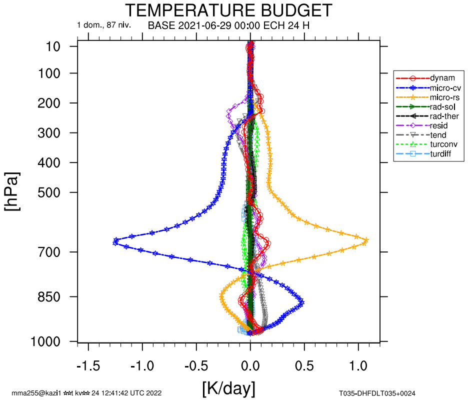
Changed counters (SUNDDH.F90)

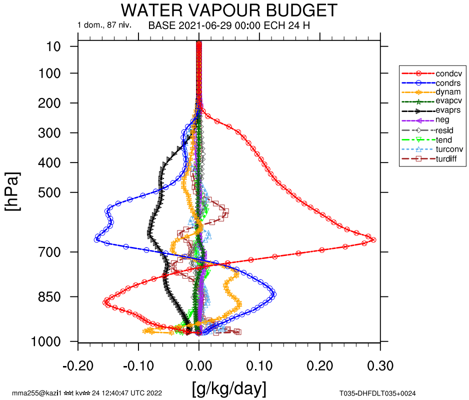
- number of hydrometeors: $\mathtt{NHDQLNVA}, \mathtt{NHDQLNVA}, \mathtt{NHDQLNVA} = 5\ (4+1)$
- physical fluxes: $\mathtt{NHDQLNFP} =$ NHDQLNFP+9 if L3MT=.T. or NHDQLNFP+7 if L3MT=.F. (and two options: loss of mass compensated by dry air?)
- physical fluxes at the ground: $\mathtt{NDHFSP} = 19\ (17+2)$

DDH budget lists

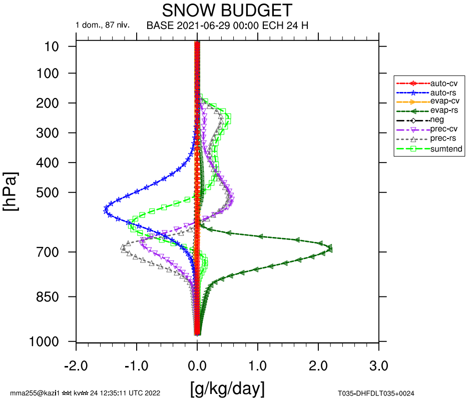
- DDH budget lists for `ddhtoolbox` have been changed
- after adding graupel: not backward compatible with `LGRAPRO=.F.`
- the former ones can be used for `LGRAPRO=.T.` - graupel is a part of the residuals

DDH: `LGRAPRO=.T./.F.`





DDH: `LGRAPRO=.T./.F.`



New fall speed relation for graupel (1/3)

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- kept under key `LFVGICE3` (Fall Velocity Graupel)
- fall speed relation similar to ICE3
- now assuming Marshall-Palmer size distribution for graupel (D is the drops diameter and λ is the slope parameter)

$$N(D) = N_0 e^{-\lambda D}, \quad N_0 = 4 \cdot 10^{-6}\, m^{-3} \cdot m^{-1} \tag{1}$$

New fall speed relation for graupel (2/3)

- the fall speed relation is

$$w(D) = 124 \cdot D^{0.66} \left(\frac{\rho_0}{\rho}\right)^{0.4} \rightarrow w(R) = 0.46 \cdot \Omega \left(\frac{R}{\rho^3}\right)^{\frac{1}{7}} \quad (2)$$

with R denoting the precipitation flux and $\Omega = \texttt{FSPRAIN} = 13.4$ is a constant to compute the spectrum of fall velocities of rain

- consequently, collection of cloud species by graupel is modified to

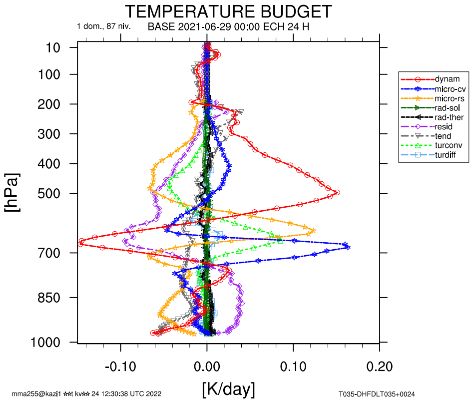
$$\frac{dq_g}{dt} = 0.453 \cdot E^g_{ff} \left(\frac{R}{\sqrt{\rho}}\right)^{0.8} \quad (3)$$

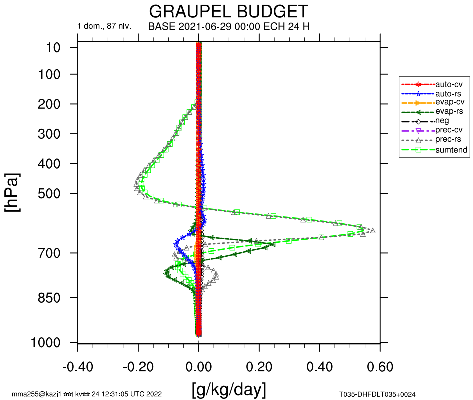
- efficiency E^g_{ff} perhaps should stay between 0.1 (snow) and 0.2 (rain), now $E^g_{ff} = 0.15$

New fall speed relation for graupel (3/3)

- around three times more graupel (q_g) in strong convective events
- very small impact on graupel precipitation
- subtle improvement of scores in convective and winter cases (10 days periods)
- better for lightning diagnostics (not so flat field)
- less pronounced windward effects on precipitation
- not sensitive to small variations of parameters in the fall speed relation
- not much sensitive to the concrete choice of the collection efficiency E^g_{ff}
- evaporation stays the same

Difference of `LFVGICE3=.T.` and `LFVGICE3=.F.`





Comparison of ALARO and ICE3 microphysics

Comparison of ALARO and ICE3 microphysics

- ICE3 consider much more processes, some of them are three particle ones:
  - wet/dry growth of graupel, heavy rimming of snow to graupel
  - collisions of precipitationg particles with cloud particles can change the category of precipitating particles
  - snow melting contributes to graupel
  - mutual collection of precipitating particles
- ALARO: autoconversion from q_l to a solid phase (WBF process)

Basic differences

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- ALARO: mass ratios
- ICE3: mixing ratios
- ALARO: MP distribution, gamma (`LAB12=.T.`) for rain (better representation of drizzle)

$$N(D) = x_1 \lambda^{x_2} e^{-\lambda D}, \quad x_1 = 0.22, \quad x_2 = 2.2 \tag{4}$$

- ICE3: MP distribution for precipitation, generalized gamma for cloud species

Autoconversion

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- ICE3: Autoconversion following Kessler

$$\frac{dq_r}{dt} = \alpha \left(q_l - q_l^{crit}\right) \quad if\ q_l > q_l^{crit}. \tag{5}$$

- in `rain_ice.F90` also available Khairoutdinov & Kogan (2000) for rain:

$$\frac{dq_r}{dt} = 1350 \cdot \alpha q_l^{2.47} N_c^{-1.79}, \tag{6}$$

where N_c is cloud drop concentration and $\alpha = 10$.

- ALARO: following Sundqvist

$$\frac{dq_r}{dt} = \alpha q_l \left(1 - e^{-\frac{\pi}{4}\left(q_l/q_l^{crit}\right)^2}\right). \tag{7}$$

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Collection

- ICE3:
  - different collection efficiencies for cloud ice and cloud water, specially for graupel collecting cloud ice is 100 times less than for cloud water
  - collection of precipitating particle by another precipitating particle
  - $(r_r + r_i)_{col} \Rightarrow r_g$
- ALARO:
  - efficiencies are determined by the precipitating particle
  - only collection of cloud particles
  - precipitating particle never change its phase

Evaporation and melting: ALARO

- ALARO: evaporation based on Kessler (Smitsonian Meteorological Tables)

$$\frac{dM}{dt} = \left[2\pi D\left(1+\frac{2FD}{s}\right)\right]\left[d_v\left(\rho_v^{sat}-\rho_v\right)\right] \tag{8}$$

where D is the drops diameter,
F the ventilation factor,
s the equivalent thickness of air sorrounding the drop,
d_v is the diffusivity of water vapour.

- interpolation and fitting leads to (same for snow)

$$\frac{d\sqrt{R}}{d(1/p)} = E_{vap}(q_v^{sat}-q_v), \quad E_{vap} = 4.8\cdot 10^6 \tag{9}$$

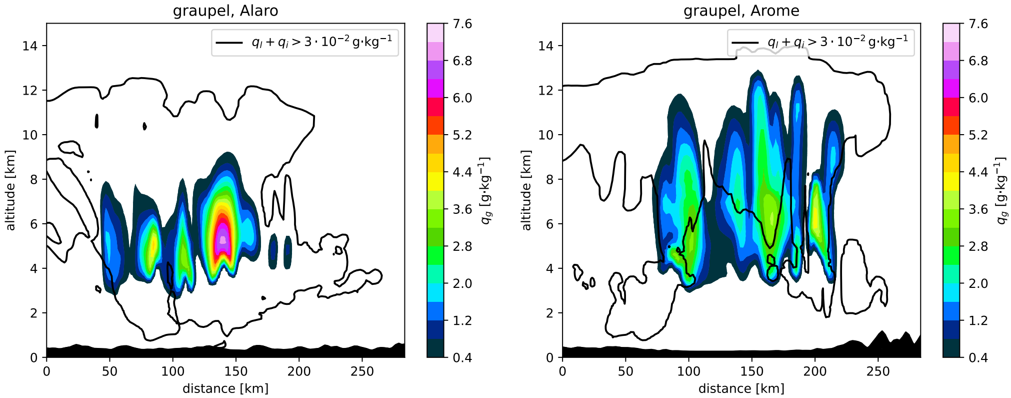
Evaporation and melting: ICE3

- ICE3: Using a more common formula:

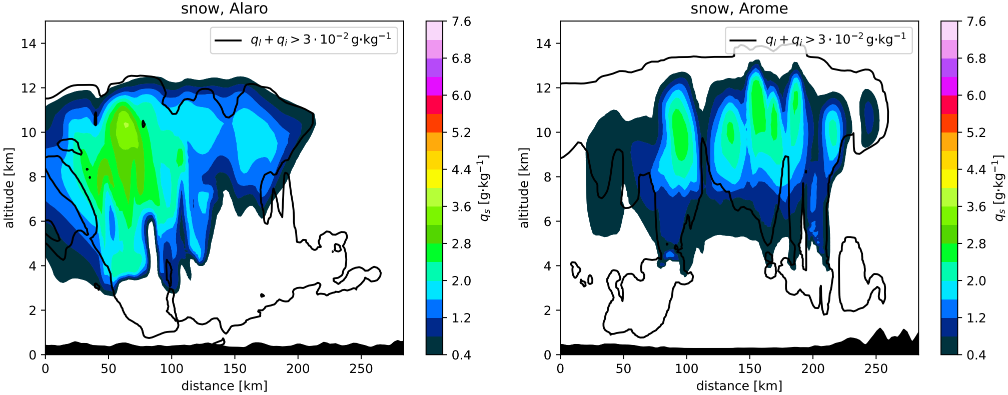
$$D\frac{dD}{dt} \approx \frac{4F}{\frac{R_v T}{e_s d_v} + \frac{L_v^2}{k_a R_v T^2}}, \tag{10}$$

where S is the surface of the hydrometeor,
L_v the latent heat of the phase change,
e_s the saturation vapour pressure
k_a the heat conductivity of air.

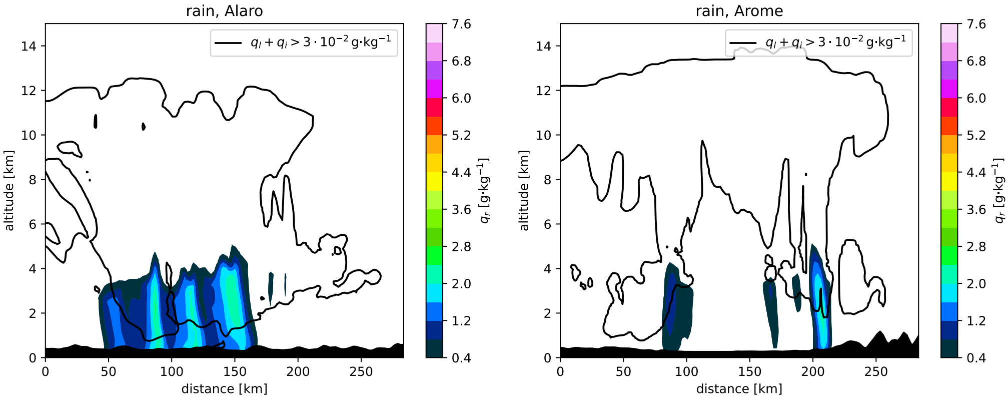
Vertical cross section of graupel



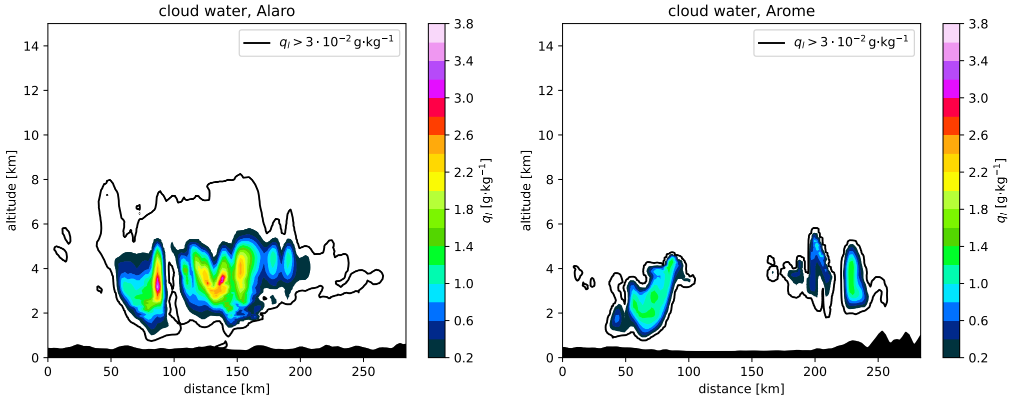
Vertical cross section of snow



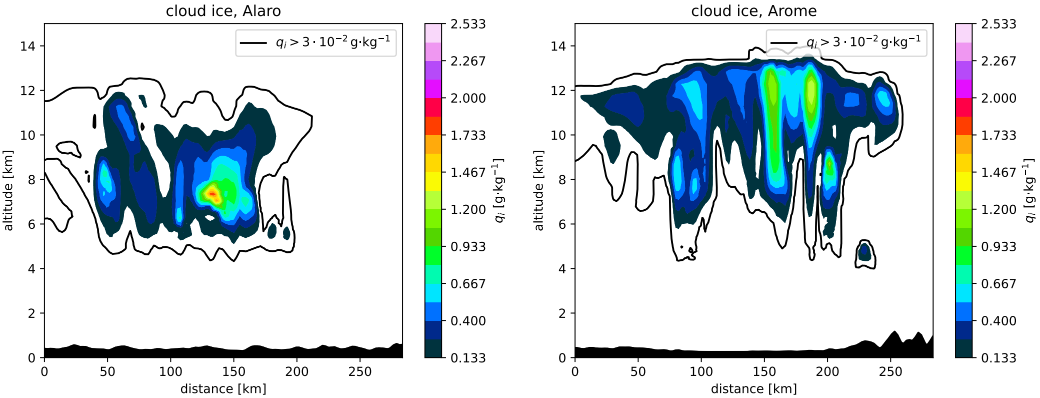
Vertical cross section of rain



Vertical cross section of cloud water



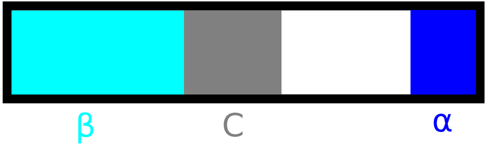
Vertical cross section of cloud ice



Temperature drop in Ostrava

Cloud overlap: brief description

- four parts: seeded or non-seeded cloud and seeded or non-seeded clear sky
- both non-seeded parts can contain residual precipitation (advection, previous timestep)
- computations at the interface of two layers
- great explanation is given in [1]



Cloud overlap: deccorelation parameter

- max-random with a decorrelation parameter

$$\varepsilon = \texttt{ZCLOV} = \exp\left(\frac{p^* - p}{\texttt{RDECRD}}\right), \qquad (11)$$

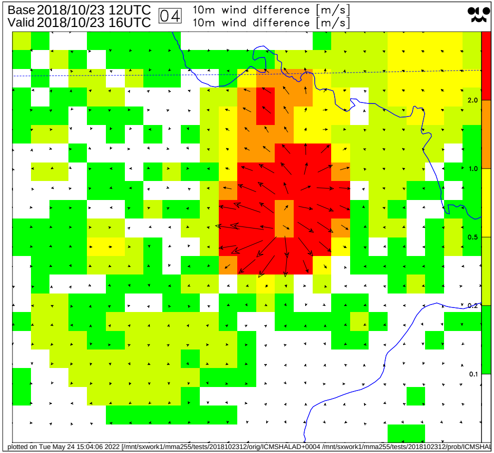
where p^* is the pressure on the above layer and p in the current layer, $\texttt{RDECRD}$ is a parameter to modulate the strenght (if ≤ 0, then computation as in radiation considering solar angle)

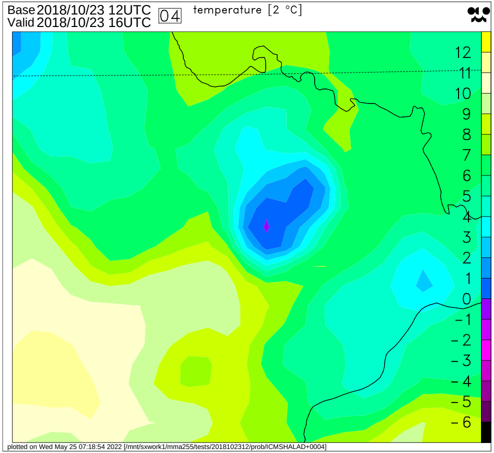
- all recomputations at the end of `APLMPHYS`

Temperature drop in Ostrava: Overview (1/2)

- significant temperature drop in one timestep (4 Kelvins)
- occurs only if the decorrelation parameter is high enough

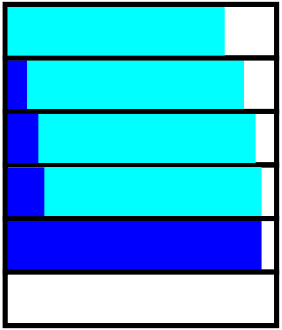
Temperature drop in Ostrava: Overview (2/2)





Temperature drop in Ostrava: Causes (1/2)

- after all precipitation evaporates in the seeded clear sky part, $\mathtt{ZPRPLE} = \alpha$ forced to zero $\Rightarrow$ stretching of the non-seeded part
- density fluxes in the non-seeded part can be remarkable, total contribution to the total precipitation flux is small
- but the stretch would produce huge total precipitation flux
- more probable if the overlap is (partially) random



Temperature drop in Ostrava: Causes (2/2)

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- in this case, both snow and rain were present
- this caused excessive melting of snow $\Rightarrow$ false rain
- that led to the sudden drop in temperature
- cure: after $\texttt{ZPRPLE} = \alpha = 0$ after the second pass of `acevmel`:

$$\texttt{ZOPLR\{L,N,G\}E} = \texttt{ZOPLR\{L,N,G\}E} \cdot [1 - (\alpha^* - \alpha)]$$

Test of `RDECRD=0`.

- period of convective storms over Central Europe (2021-06-21 $\rightarrow$ 2021-06-30)
- cold bias in the troposphere (-)
- more cloudiness (+)
- higher RH due to enhanced evaporation (+)
- higher geopotential below 700 hPa (-)
- conclusion: $\sim$ neutral

References

[1] J. Van den Bergh, J.-F. Geleyn & R. Brožková (2011). Improving the Cloud Overlap Scheme in APLMPHYS. 21st ALADIN Workshop, April 2011, Norrkoping, Sweden.
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[2] J.-F. Geleyn, B. Catry, R. Brožková & C. Wittmann (2007). APLMPHYS and its ingredients. *Technical note*.
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[3] Meso-NH Scientific documentation version MASDEV5-5 (version 09 June 2022). Part III: Physics.
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[4] M. Van Ginderachter (2014). Selected issues in Microphysics. *Presentation*. Alaro-1 Working Days, May 2014, Vienna, Austria.
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Thank you for your attention.

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