Deutscher Wetterdienst
Wetter und Klima aus einer Hand

Towards new microphysical parameterizations for the COSMO model

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Overview

- Why new schemes?
- What are the new schemes?
- What do we gain?
- What does it cost?
- Where will we go from here?

Why new schemes?

The current one-moment schemes

- ➔ have limitations, e.g. evaporation of raindrop is dominated by the drop size, which is not a prognostic variable.
- ➔ are outdated, e.g. homogeneous nucleation is missing, heterogeneous nucleation is from the 70s.
- ➔ have certain weaknesses, e.g. melting of snow is often too fast.

The two-moment scheme

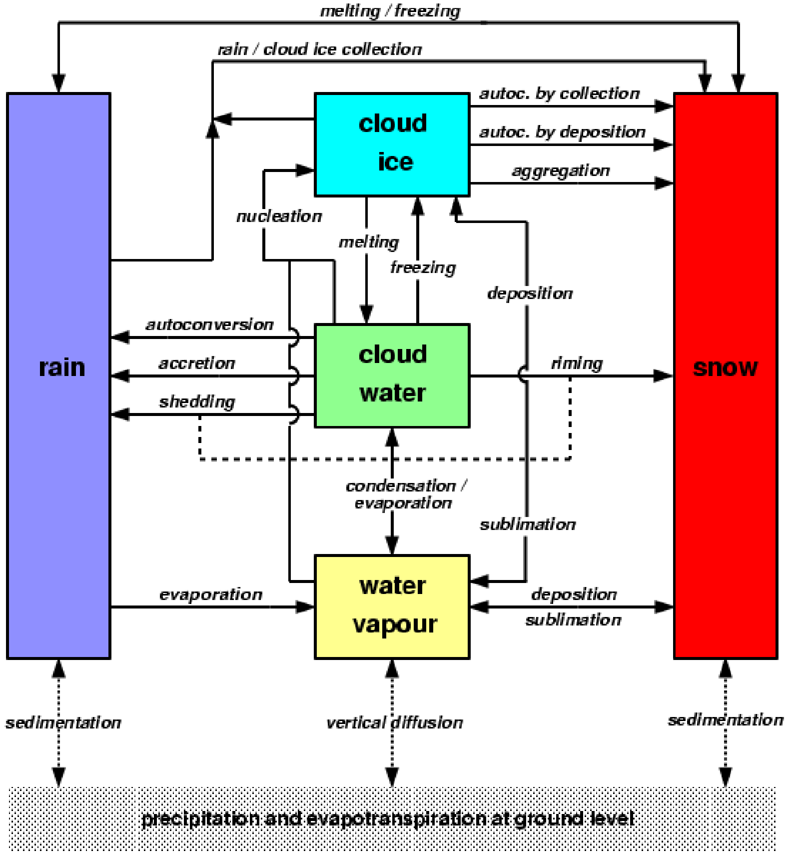
- ➔ even after vectorization, it is too expensive for operational use
- ➔ and maybe overly complicated for most NWP applications.

What are the new schemes/options?

1. **Two-moment rain extension of the graupel scheme.**
2. **Two-moment rain and two-moment cloud ice including homogeneous and updated heterogeneous ice nucleation** (cloud ice effective diameter can be used in radiation).
3. **SB2006 two-moment scheme with hail** (including cloud-radiation interaction by effective diameter).
4. **New melting scheme for falling snow** (will be implemented in both COSMO schemes)

Schemes (1), (2) and (3) are finished, but not yet in the official COSMO code. The new melting scheme (4) is still in an early stage.

The COSMO two-category ice scheme (also known as the 'cloud ice scheme')

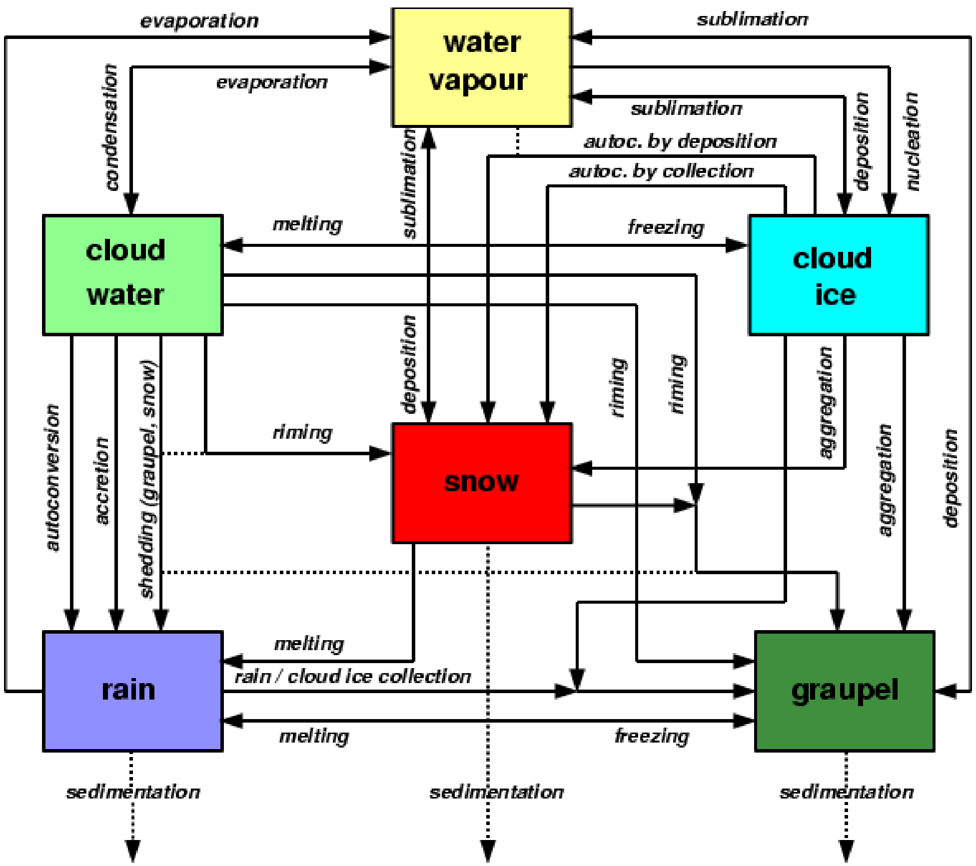


subroutine: hydci_pp

namelists: itype_gscp=3
lprogprec=.true.

- ➔ Includes cloud water, rain, cloud ice and snow.
- ➔ Prognostic treatment of cloud ice, i.e., non-equilibrium growth by deposition.
- ➔ Developed for the 7 km grid, e.g., DWD's COSMO-EU.
- ➔ Only stratiform clouds, graupel formation is neglected.

The COSMO three-category ice scheme (also known as the ‘graupel scheme’)



subroutine: hydci_pp_gr

namelist setting:

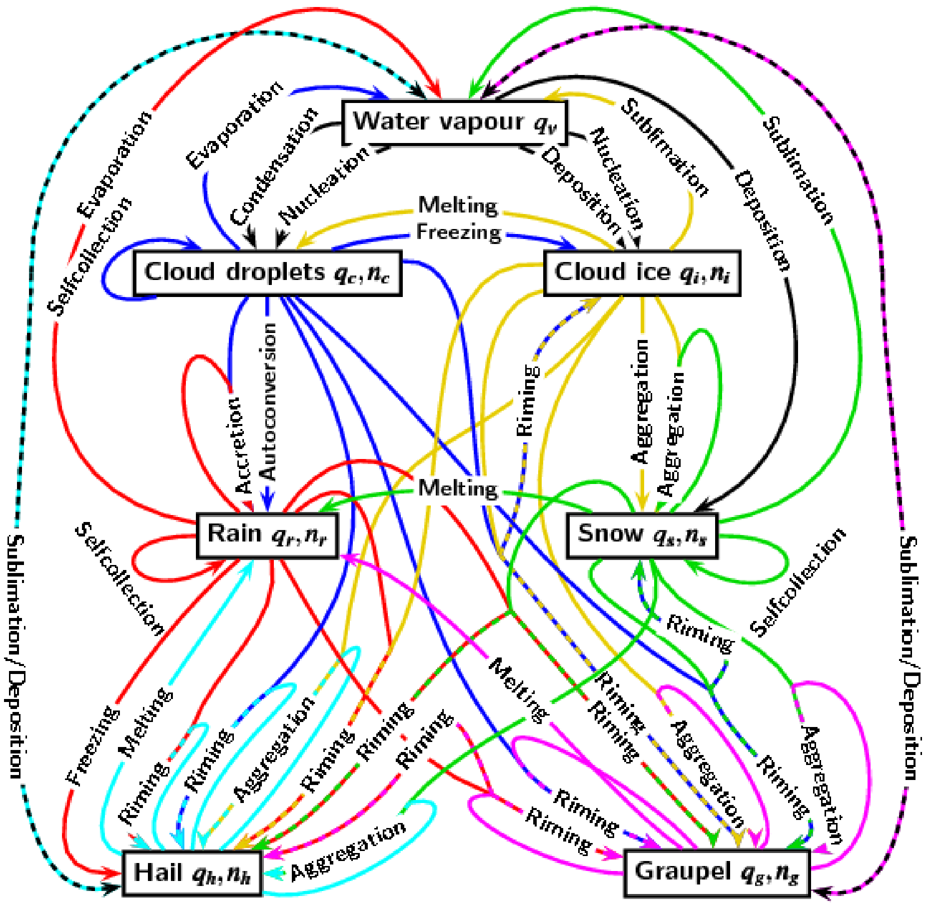
itype_gscp=4

lprogprec=.true.

- Includes cloud water, rain, cloud ice, snow and graupel.
- Graupel has much higher fall speeds compared to snow
- Developed for the 2.8 km grid, e.g., DWD’s convection-resolving COSMO-DE.

Seifert and Beheng two-moment scheme

Version by Blahak, Noppel, Beheng and Seifert (2008)



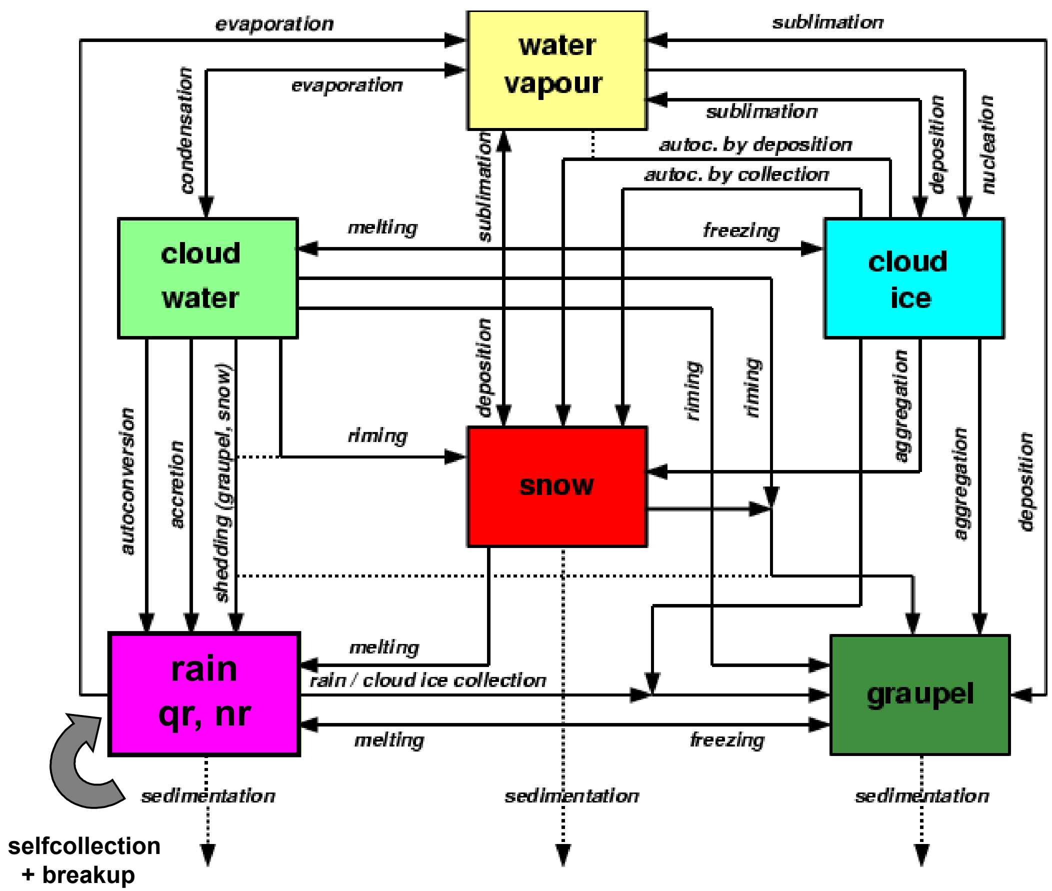
Number and mass concentrations of 6 different species

- cloud droplets
- rain drops
- cloud ice
- snow
- graupel
- hail (new!)

Drop activation/nucleation scheme Segal&Khain (2006) parameterization.
New raindrop evaporation scheme (Seifert 2008).
Hail formation by spectral partitioning of freezing processes (Blahak 2008)

But very expensive increasing the total runtime by almost a factor of 2.

Extending the COSMO graupel scheme with two-moment rain parameterization



Two-moment rain advantages:

- New rain evaporation scheme
- Gravitational sorting of raindrops
- Explicit selfcollection and breakup of raindrops
- Improved autoconversion and accretion

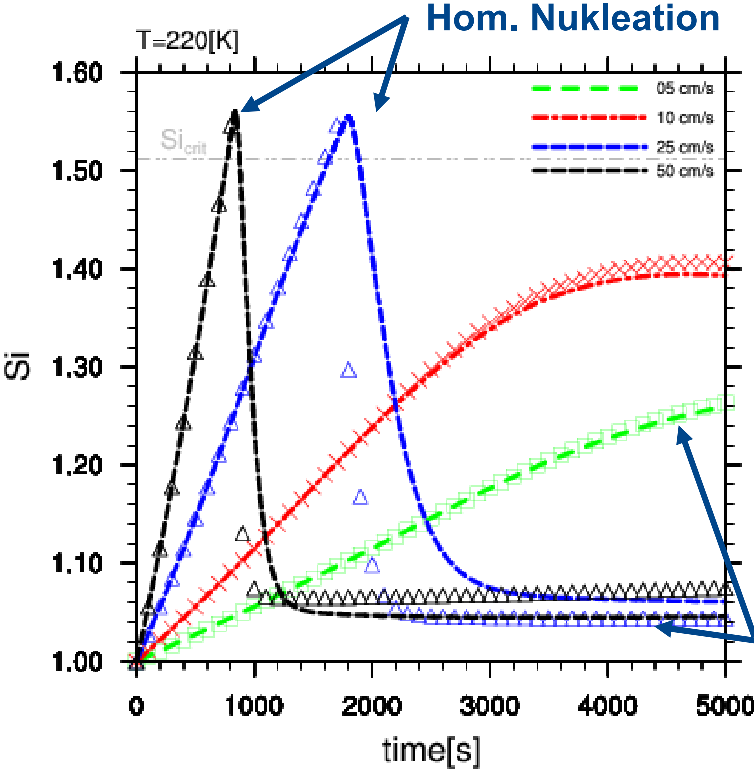
Simplifications:

- Pre-defined mean raindrops diameters for:
  - melting of graupel (1 mm)
  - melting of snow (0.3 mm)
  - shedding (0.1 mm)
- Assume that other mixed-phase collection processes do not change the mean size of raindrops.

New two-moment ice nucleation scheme:

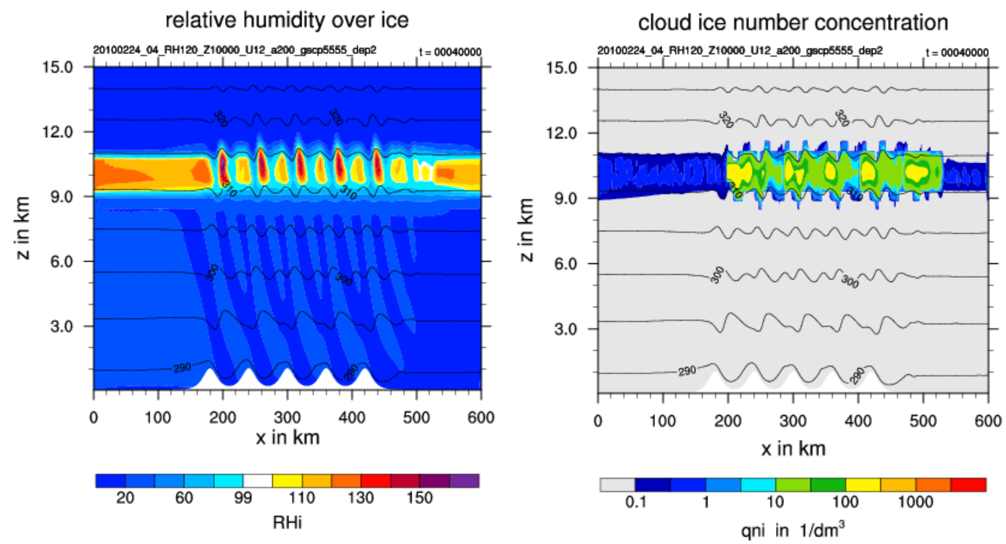
Parcel model:

Hom. Nukleation



Het. Nukleation

Idealized cirrus COSMO simulations:



New melting scheme with prog. liquid water fraction

- Currently melted water from snowflakes is transferred to rain.
- Using a prognostic melted water mixing ratio for snowflakes may improve the representation of the melting layer and the forecasts of precipitation phase.

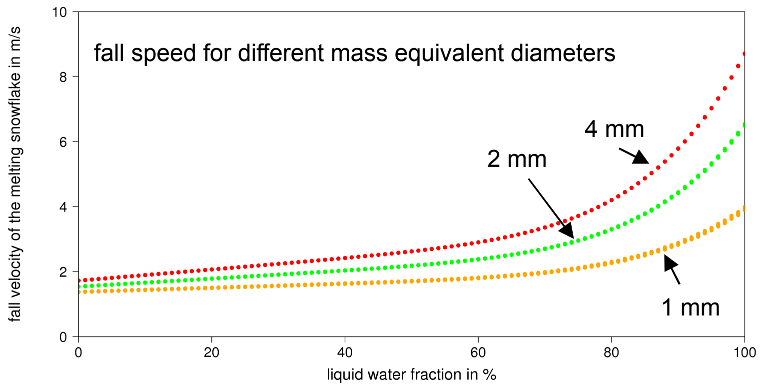
$$\left.\frac{\partial \mathcal{L}_{s,w}}{\partial t}\right|_{melt} = \int_{m_*}^{\infty} \left.\frac{dm_w}{dt}\right|_{melt} f(m_s)\, dm_s$$

$$= G(T,e) \int_{m_*}^{\infty} C_s(D_s, LWF)\, f_v(D_s, LWF)\, f(m_s)\, dm_s$$

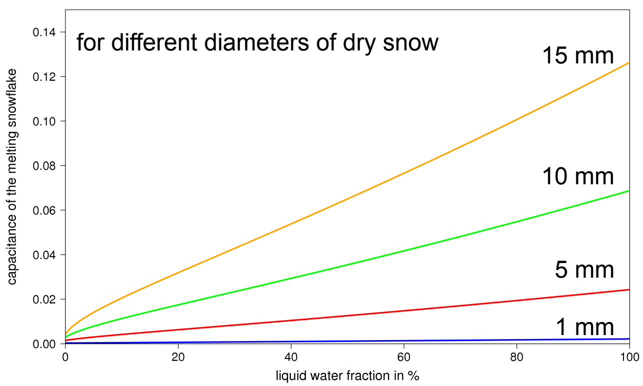
- Need to specify the capacity ***C***, the ventilation coefficient $\boldsymbol{f_v}$ and the terminal fall velocity $\boldsymbol{v_T}$ for wet snowflakes

New melting scheme with prog. liquid water fraction

Terminal fall velocity



capacitance



- ➔ Next step will be the numerical solution and tabulation of the melting integrals
- ➔ A first version of the scheme should run at the end of the year.

What do we gain from the new schemes?

→ **two-moment rain** schemes can better represent the formation of cold pools and the organization of convection (squall lines, MCSs etc.)

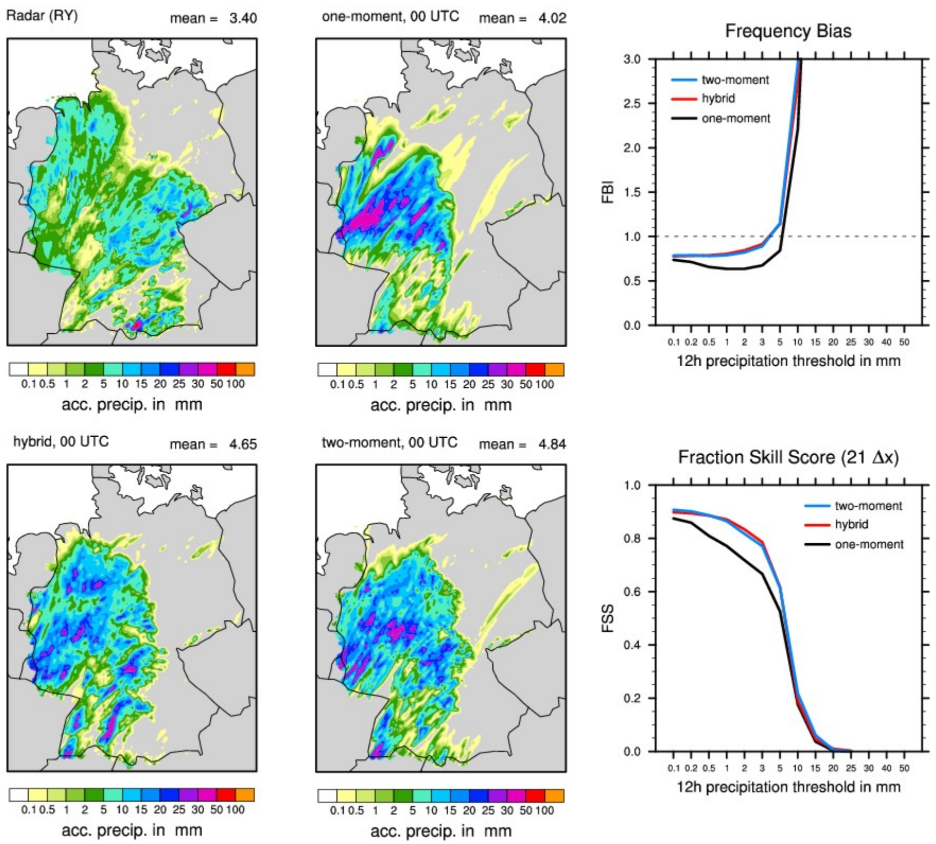


Figure: COSMO-DE case study 20 July 2007. Shown is the 12h accumulated precipitation from radar and three COSMO simulations, as well as the FBI and FSS scores.

What do we gain from the new schemes?

➔ **Two-moment cloud ice** with the **new ice nucleation** seems to have a positive impact on cloud-radiative effects, as seen by an improved T2m at noon, but the full two-moment scheme is even better.
(or maybe this is just cancellation of errors).

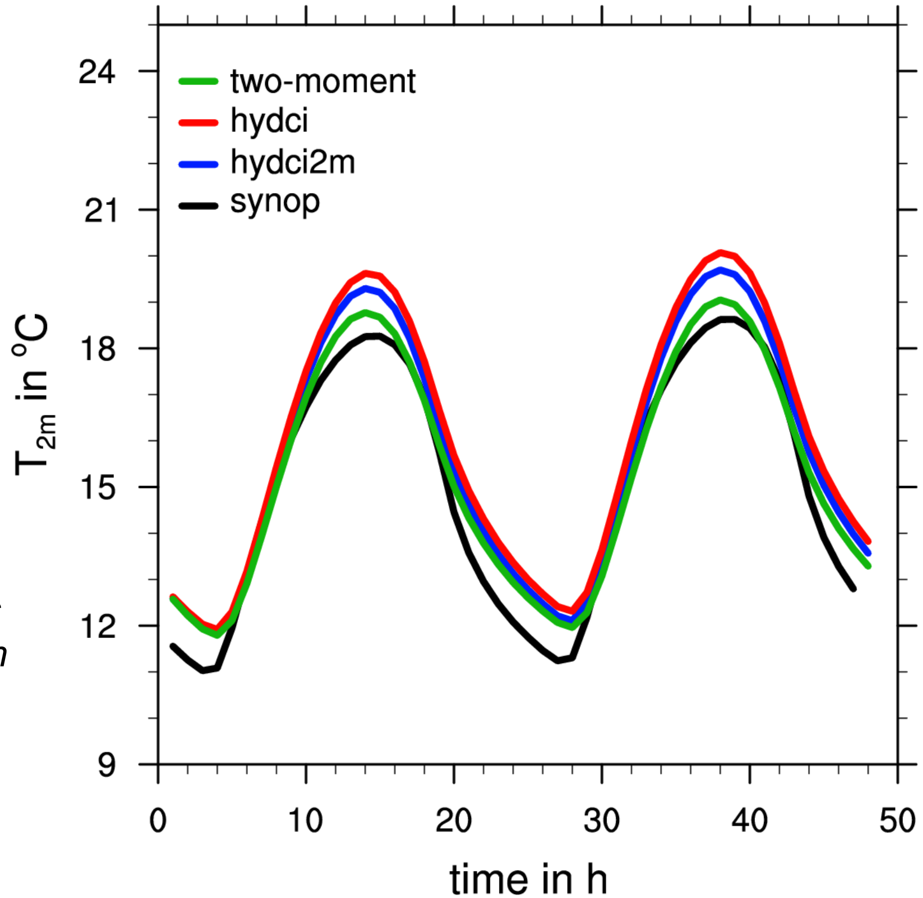


Figure: COSMO-DE experiments for July 2009. Shown is the mean 2m-temperature for Germany averaged over the whole month.

What do we gain from the new schemes?

- But all the two-moment rain hybrid schemes have a dry bias compared to the operational COSMO-DE.

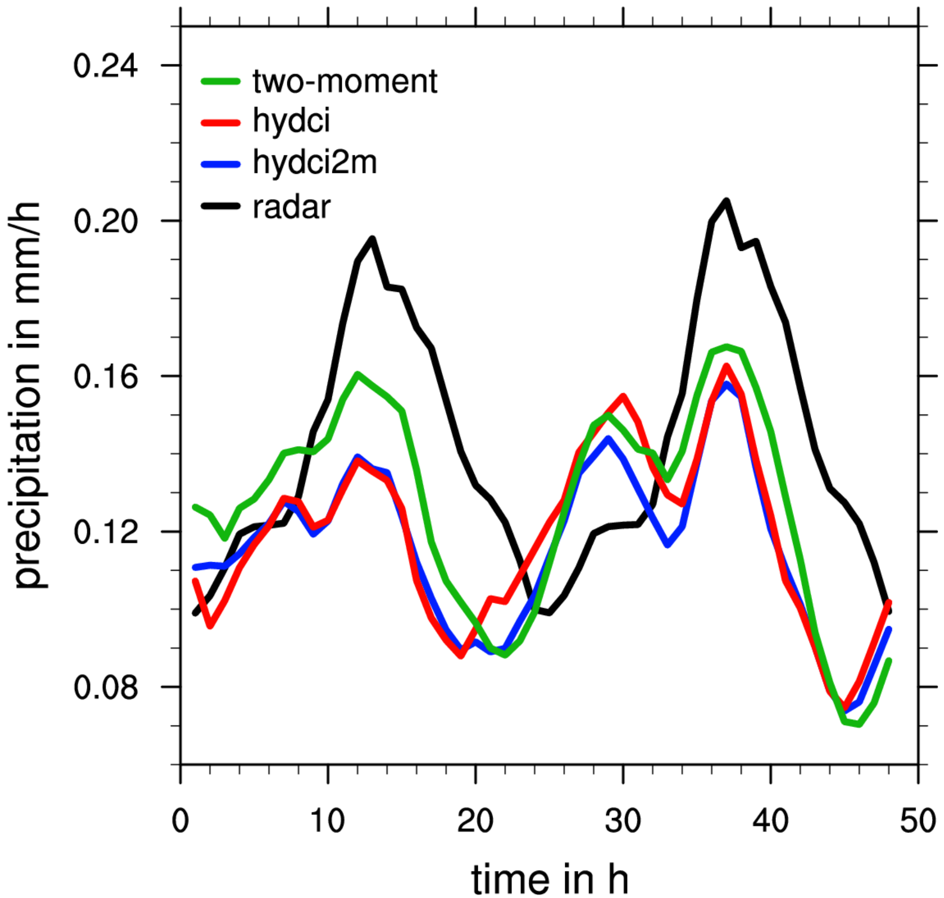


Figure: COSMO-DE experiments for July 2009. Shown is the hourly precipitation rate for Germany averaged over the whole month.

What do we gain from the new schemes?

- With the new ice nucleation scheme the precipitation amounts from SB2006 two-moment scheme show a weak sensitivity to aerosol assumptions affecting ice nuclei (less for the one-moment scheme).

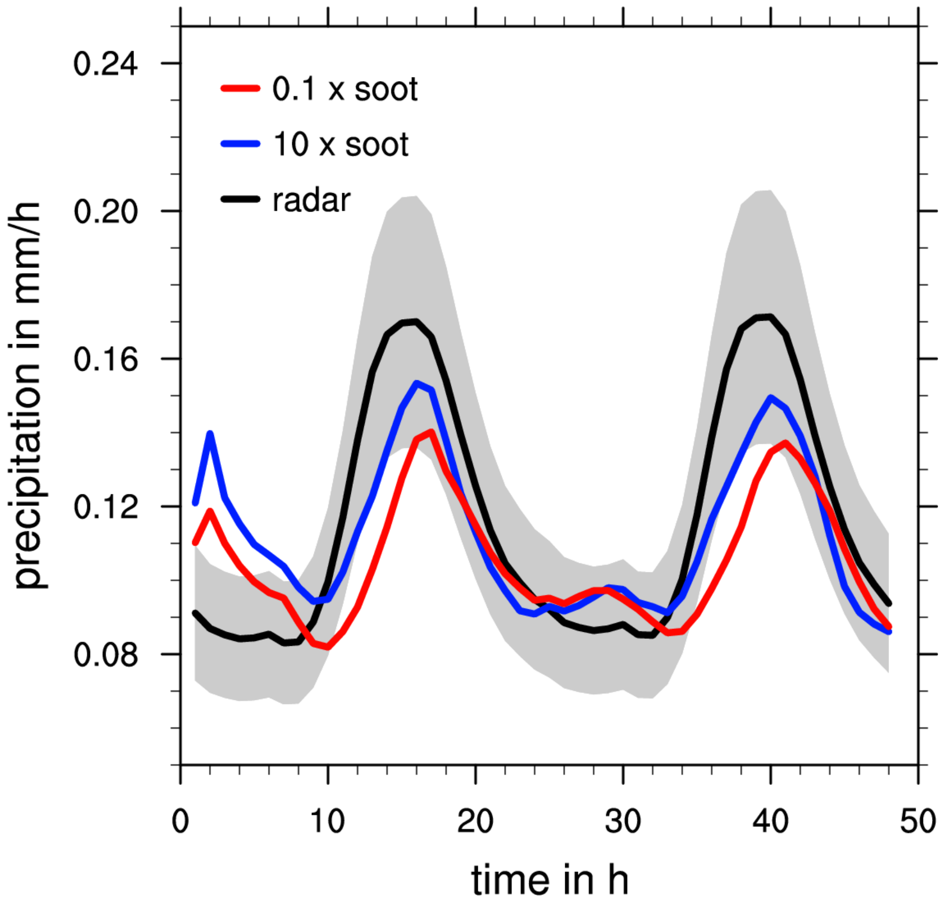


Figure: COSMO-DE experiments for JJA 2008/2009. Shown is the hourly precipitation rate for Germany averaged over the whole month and 2 summer periods. Grey area indicated uncertainty of observations.

What do we gain from the new schemes?

➔ FBI, ETS, and FSS show only marginal improvements with more sophisticated schemes. But those statistical scores are dominated by synoptic scale structures which might hide improvements for convective precipitation.

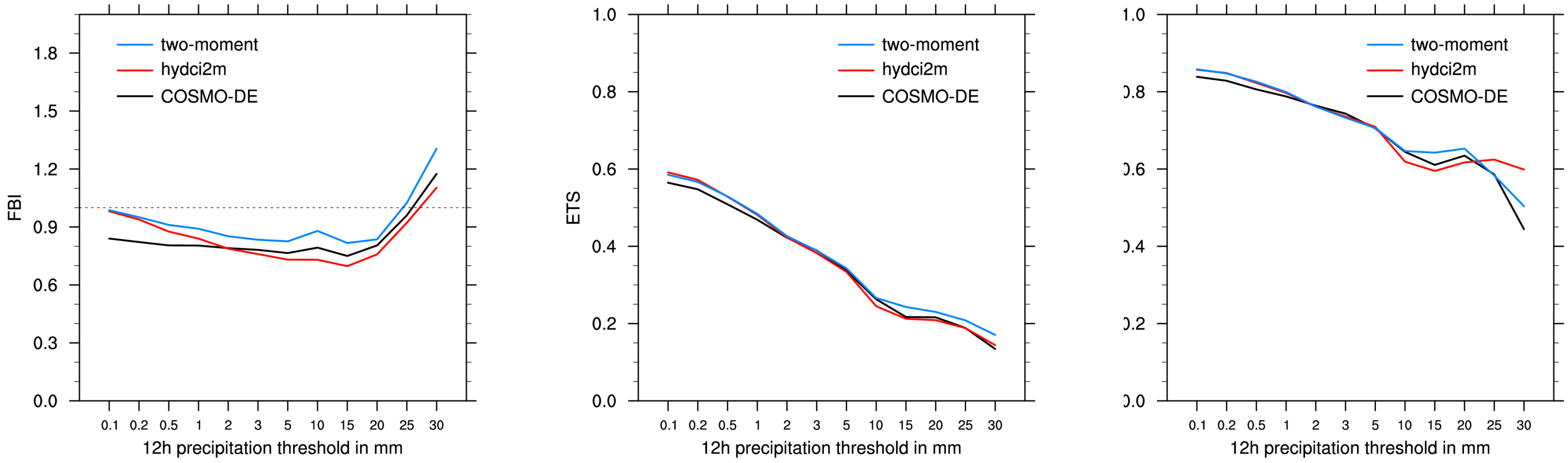


Figure: COSMO-DE microphysics experiments for July 2009.

What do we gain from the new schemes?

➔ Testing the two-moment scheme over 2 summer seasons shows almost no impact on the precipitation scores. But, again, there could be an improvement for convective cases.

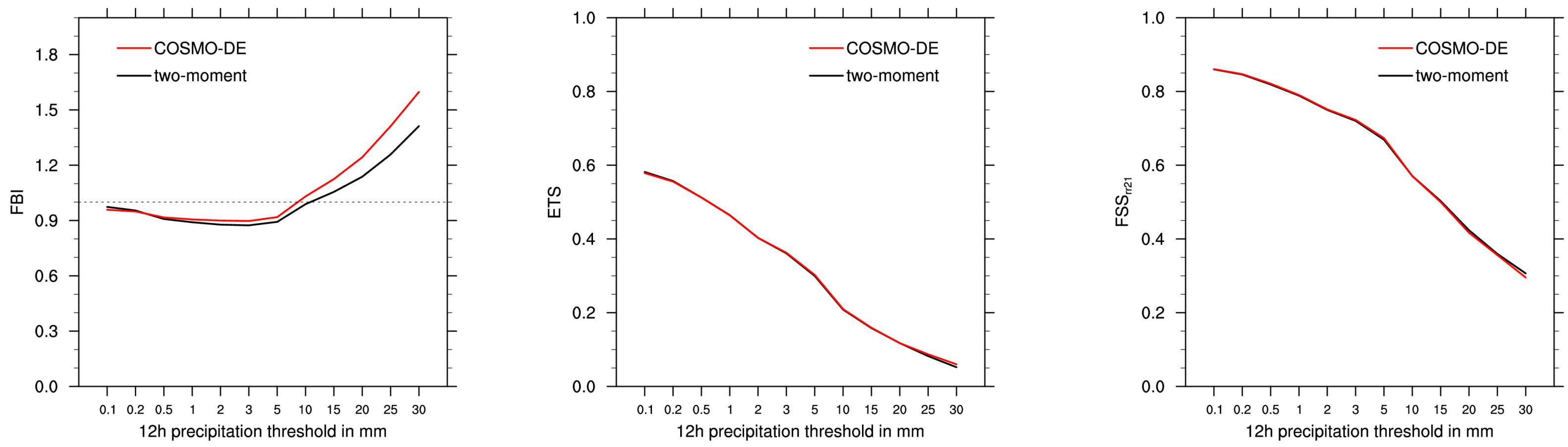


Figure: COSMO-DE microphysics experiments for JJA 2009/2010.

Computational costs

	Total run time
→ Graupel scheme:	100 %
→ Graupel + two-moment rain:	105 %
→ Graupel + two-moment rain and two-moment ice:	120 %
→ SB two-moment scheme	180 %

Actual performance depends on the case and the computer architecture.

Conclusions and Outlook

- New microphysics schemes of different complexity have been developed for the COSMO model. They might have some advantages, but a clear improvement in operational applications is hard to prove.
- New melting scheme is still under development, and has to potential to improve forecasts of precipitation phase (rain vs snow at the surface).
- Cloud-radiation effects need to be studied on more detail.
- Need for better diagnostic, to understand the effects of model changes, like microphysics, on the statistics of the forecasts.
- Currently the additional computational cost of 5-80 % total run time is maybe better invested elsewhere, e.g. more vertical levels, UTCS scheme, or even a higher resolution.
- In the long term development, it might depend on future computer architectures whether such schemes can be applied efficiently.