

The 3MT Scheme

Radmila Brožková and Ján Mašek, with deep acknowledgment to Luc Gerard

The 3MT Moist Deep Convection Scheme

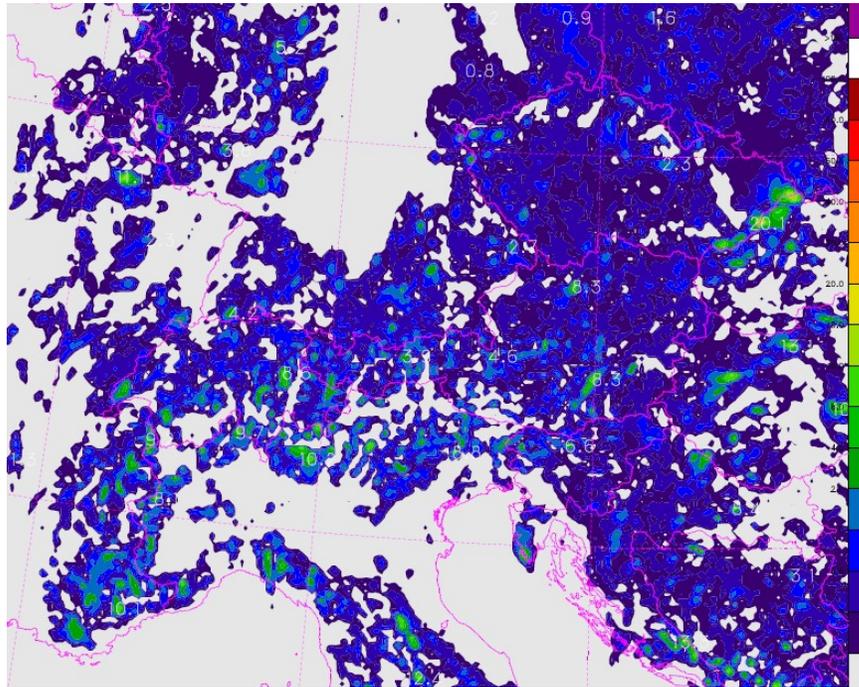
What the **acronym** stands for:

- **M**ulti-scale: the scheme should also work at model resolutions where moist deep convection is *partly resolved* – the *grey zone*;
- **M**odular: within the scheme frame, flux-form interface of the physics, and respecting the set of basic thermodynamic assumptions, individual processes could be parameterized differently;
- **M**icrophysics and **T**ransport: instead of separating scales (unnatural), moist and dry processes are separated.

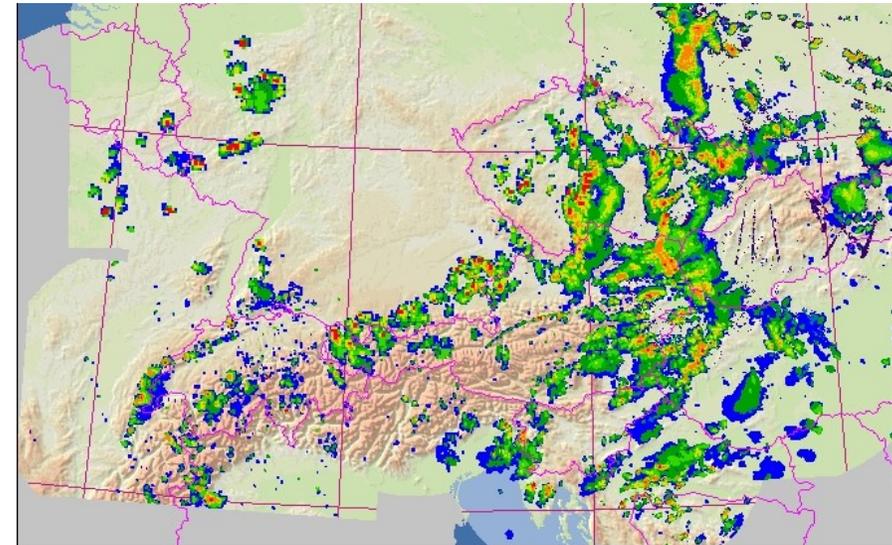
Ideas:

- work on the multi-scale aspects by Luc;
- work on the interfacing by Jean-Francois and Bart;
- catalyzing idea of separating microphysics and transport proposed by Jean-Marcel.

Demonstration of the grey zone problem



*1 h precipitation sum forecast from +14 h to +15 h, starting 29 June 2009 at 0 h UTC. Classical convection scheme used **at 4.7 km**; spread of weak rain, local high maxima.*



Radar instantaneous reflectivity snap shot at 15 h UTC on 29 June 2009.

Central Europe

The grey zone problems and M-T separation

Why is this important ...

- In the model, the dynamics computes **resolved vertical velocity**;
- This resolved vertical velocity controls the **grid-scale condensation**, but it is **irrelevant for moist deep convection**, till this one gets fully resolved;
- In the **grey zone**: the arbitrariness of the scale separation becomes obvious. An idea to make one step forward is to apply a **single call of the microphysics on a merged input from grid-scale and sub-grid-scale (unresolved updraft) condensation processes**. The flux interface eases this step, since fluxes are additive.

What about a possible sub-grid nature of precipitating processes ...

- **Geometry of clouds and precipitation** is some answer to this (perhaps a hidden way of Tompkins approach to account for processes' dependent moisture distribution in the grid box); see the next slide.

Microphysics with cloud and precipitation geometry



Within the grid-box, we have categories of cloudy and clear sky fractions, seeded or not seeded from above, with the assumption of exponential-random vertical overlap.

Other important ingredients of 3MT (1)

- **Prognostic treatment where possible, abandoning the stationary cloud hypothesis (i. e. also the Quasi Equilibrium approach, typical for a statistical treatment of convective plumes):**

Prognostic equations for updraft and downdraft velocities;

Prognostic equations for mesh area fractions occupied by drafts, BUT keeping them vertically constant;

=> We get **prognostic handling of the average mass flux:**

intermittent behavior is avoided;

more continuous model feedbacks on deep convection, evolving along several time-steps.

- **Entrainment and Detrainment:**

Entrainment is parameterized. Having the prognostic computation of the mass flux, **detrainment does not need to be determined**, on the contrary.

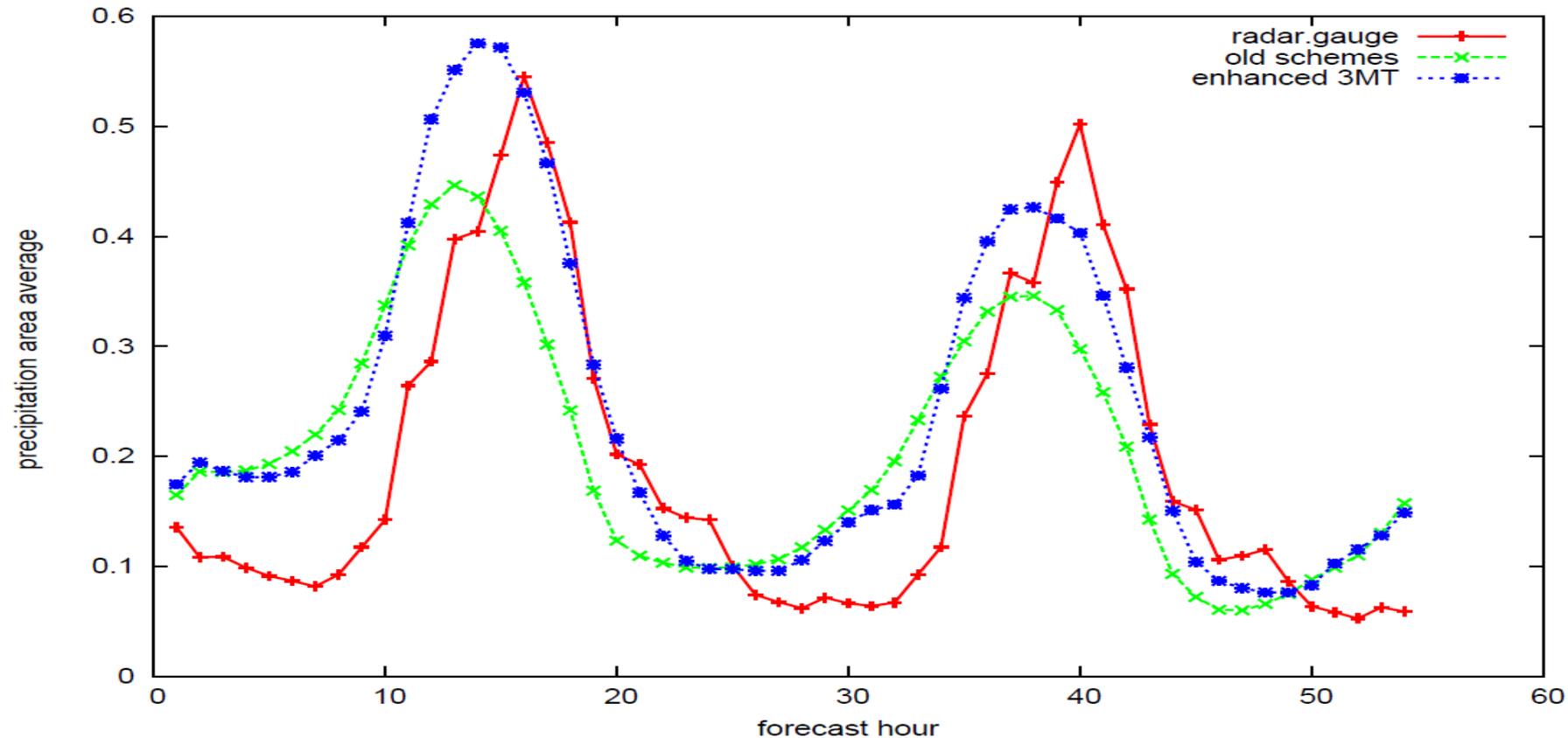
This is another consequence of relaxing the stationary cloud hypothesis. Model feedbacks take care of detrainment implicitly.

Other important ingredients of 3MT (2)

Closure - Newtonian type to specify the 2D area-fractions (Lagrangian tendency = storage = forcing minus dissipation):

- Storage is given by difference between moist static energy of updraft and environment;
- Input is based on the moisture convergence:
 - Resolved contribution by dynamical advection;
 - Local contribution by turbulent transport;
 - Moisture circulation within the updraft.
- Consumption of moisture is given by gross condensation in the updraft;
- **The relative moisture consumption rate onset is controlled so that not all arriving fuel is immediately used =>** this delays the scheme activity when there are relatively small updrafts in the grid-box. It helps to **improve the convective daily cycle in the model.**

First improvement of convective daily cycle



Strong convective period in June-July 2009 over Central Europe. Activity is enhanced and better maintained. Time phase shift is partially reduced.

Organization of the time step: 3MT frame

Cascade:

- **Grid-scale condensation/evaporation** (thermodynamic adjustment); fluxes modify the local moisture and temperature fields used in the following computations;
- **Updraft** => **sub-grid-scale condensation**, mass-flux transport;
- **Sum of condensation fluxes** enters the **microphysics**;
- **Downdraft** => **sub-grid-scale evaporation**, mass-flux transport.

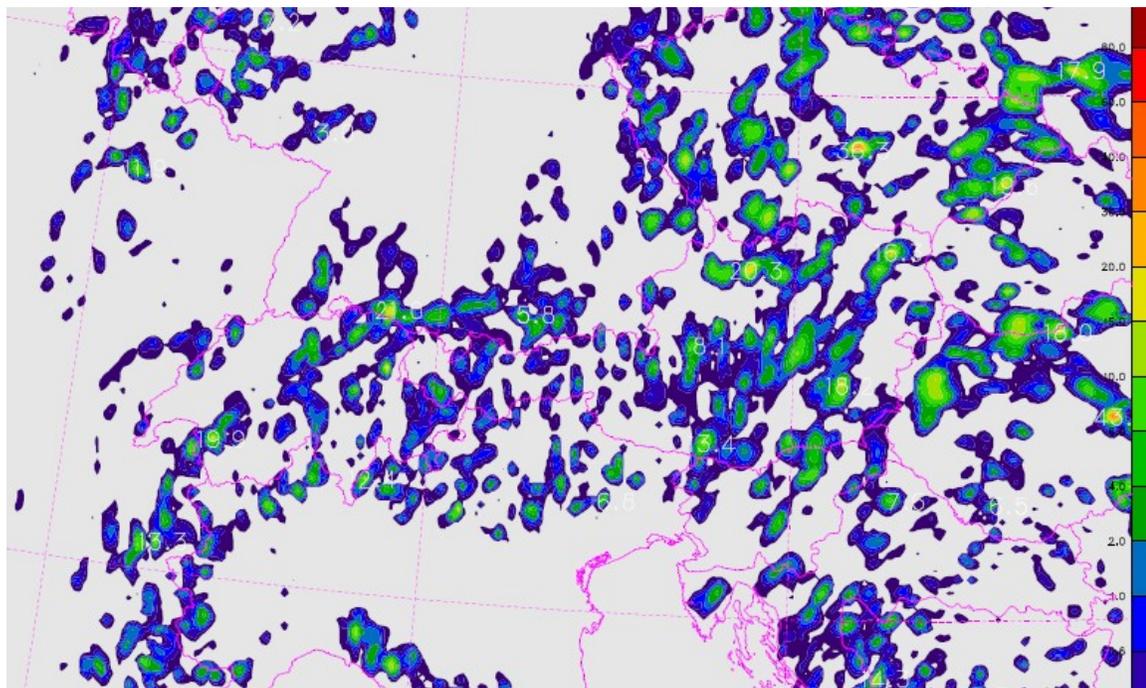
Downdraft closure is also 2D, giving the tendency of downdraft area fraction:

storage = moist static and kinetic energy; input = evaporation of precipitation computed in microphysics; consumption = buoyancy.

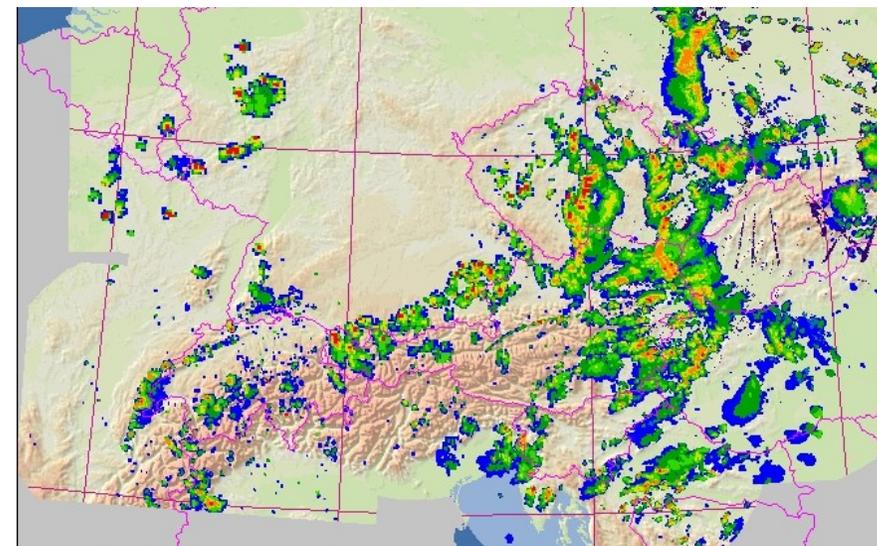
Another interesting consequence of the 3MT frame:

- Downdraft can start independently of an updraft existence.

Encouraging 3MT result



1 h precipitation sum forecast from +14 h to +15 h, starting 29 June 2009 at 0 h UTC. 3MT scheme used at 4.7 km; much more realistic simulation.



Radar instantaneous reflectivity snap shot at 15 h UTC on 29 June 2009.

Central Europe

As usual, details are important as well - examples

- **Cumulative effect of phase changes within the ascent:**

parameterized by an iterative treatment – a call to simplified microphysical processes; one iteration is enough;

- **Sub-grid-scale nature of convective cloud and associated condensates:**

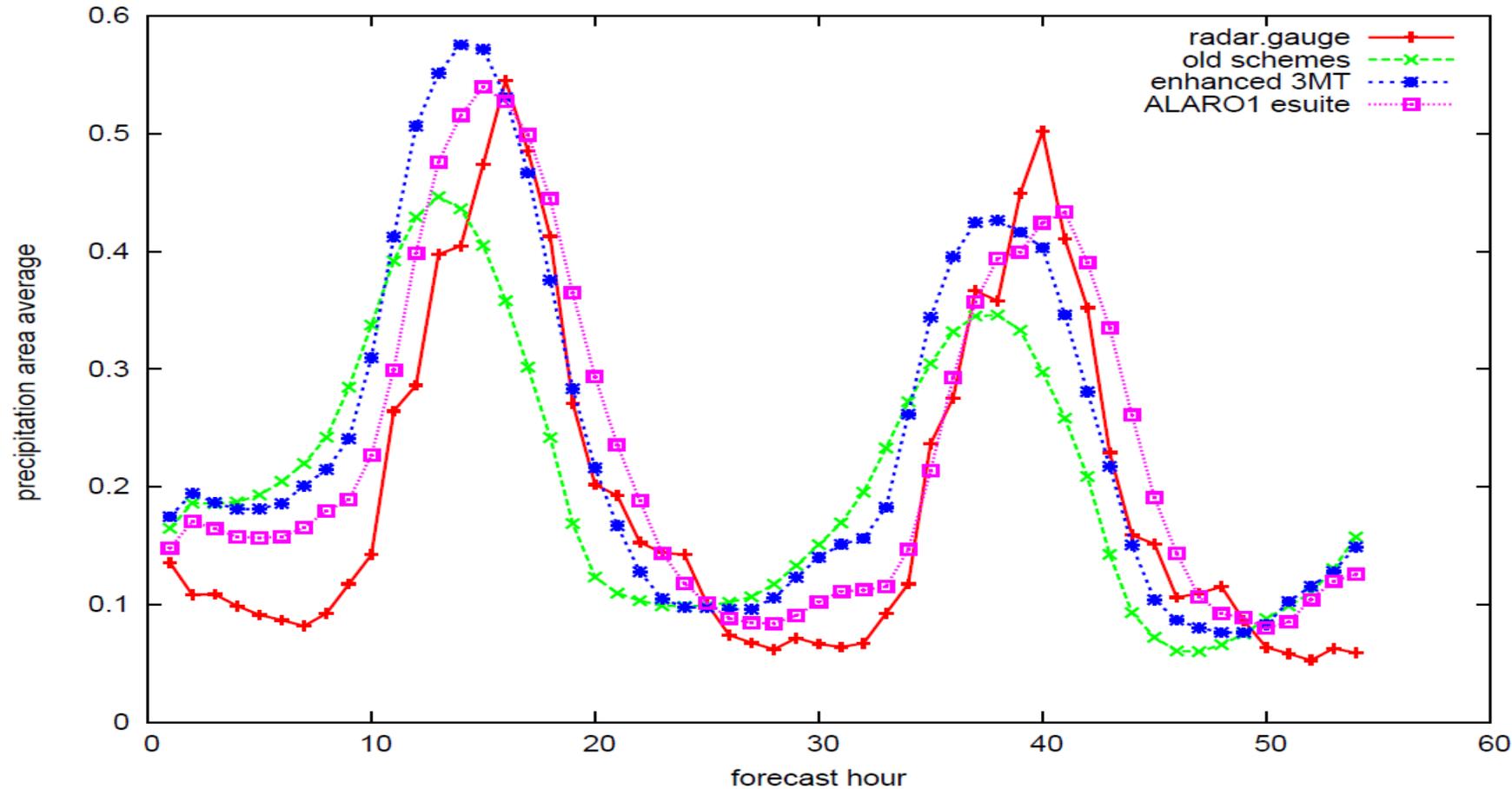
a very simple parameterization protecting the existing convective cloud against its re-evaporation in the next time step call to the thermodynamic adjustment (again Tompkins ...);

- **Nice possibilities to enhance the memory of the scheme:**

the cold pool effect is parameterized using the total evaporation flux from the previous step to modulate the cloud profile – more precipitation activity leads to higher clouds;

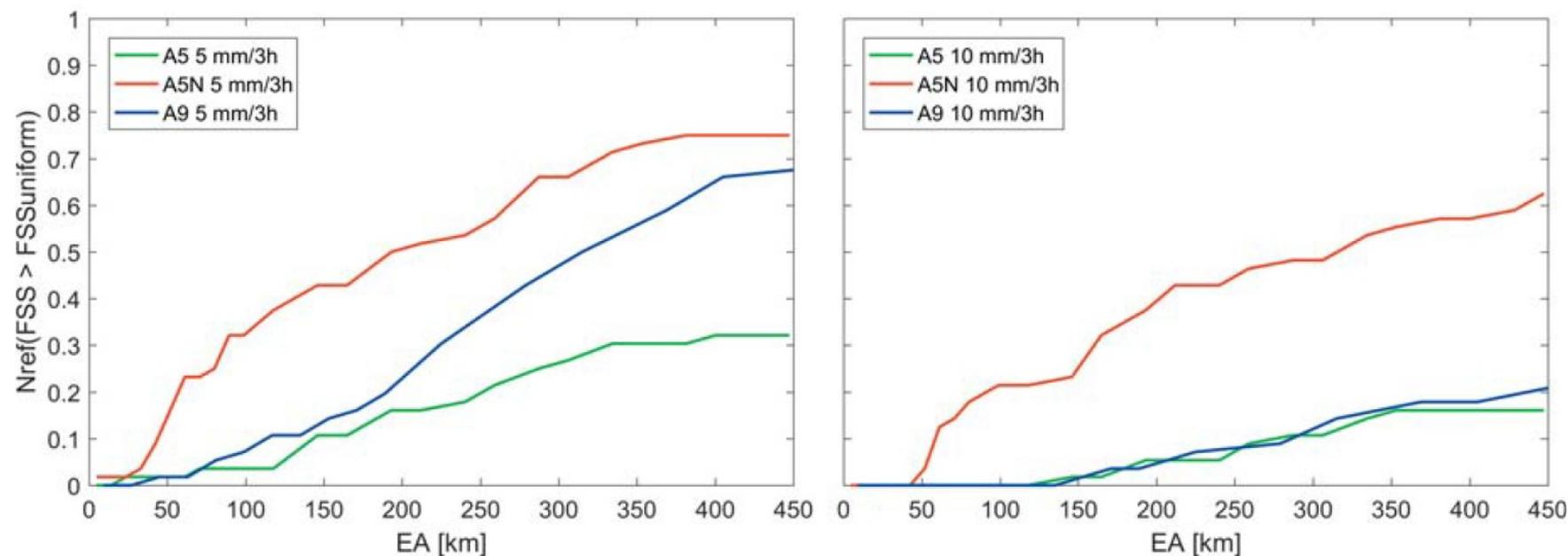
- **Combination with more enhanced turbulence and radiation schemes (TOUCANS and ACRANE2) leads to a correct timing of the convection.**

Further improvement of convective daily cycle



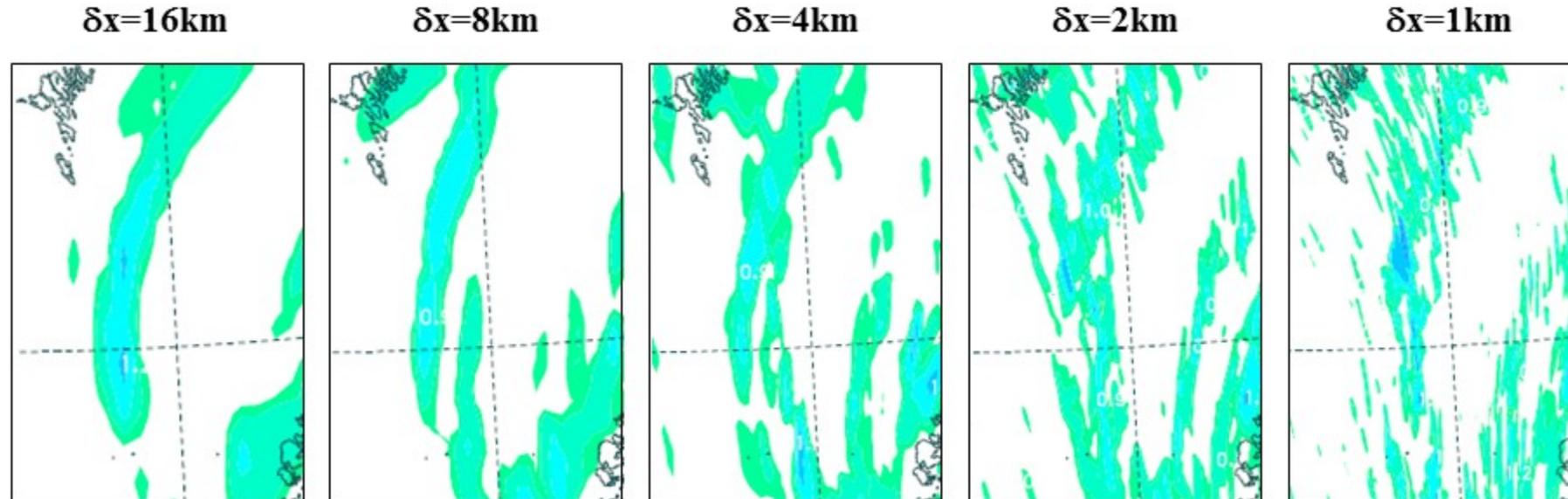
Strong convective period in June-July 2009 over Central Europe, average of 11 realizations. Combination of 3MT with TOUCANS and ACRANE2 sets the convection timing correctly.

A bit more results ...



Precipitation scores: relative frequency N_{ref} of Fraction Skill Score higher than a reference value. Higher value is better. Scores are shown for two threshold values of 5 mm/ 3 h (left) and 10 mm/ 3h (right), verification period is 22/06-05/07/2009 with an exceptional convective activity. Model versions are A9 (blue) of 9 km resolution, A5 (green) of 4.7 km resolution but previous convection scheme and A5N (red) of 4.7 km with the enhanced 3MT. Source: Zacharov et al., 2019.

And finally the WGNE Grey Zone Experiment Result



1 h precipitation sum from +30 h to 31 h, forecast base 30 January 2010, 12 h UTC, area between Faeroe and Orkney islands.

Thank you for your attention

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