WG 3a activities in radiation and microphysics

Ulrich Blahak (DWD)

Radiation activities

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

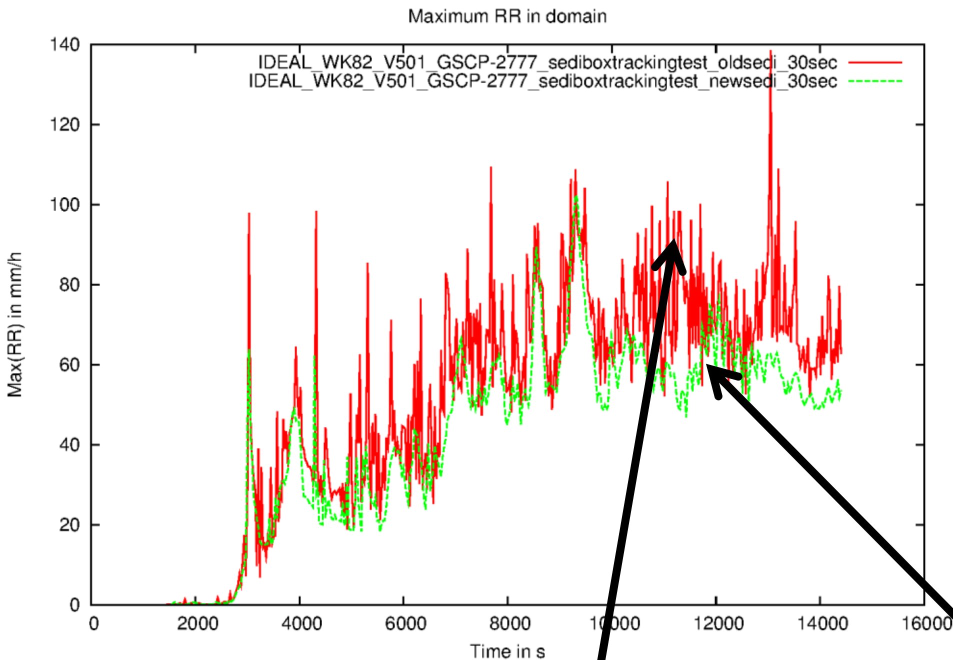
- **PT RC², revised cloud radiation coupling (see extra presentation):**
  - Porting of the code additions from COSMO 4.22 test version to COSMO 5.1_beta test version. Use of svn for code exchange (UB).
  - Revised optical properties of ice hydrometeors, based on single particle scattering data provided by Quiang Fu from University of Washington (HM, UB):
    - Extended size validity range up to D_{ge} = 600 µm, suitable for snow and graupel.
    - New formulation of asymetry parameter as function of mean axis ratio, not D_{ge} as we had used last year.
  - Idealized and real-case sensitivity studies towards identifying the most „sensitive“ tuning parameters (PK, UB).
  - Continuation and extention in a larger PP T²RC² as collaboration of colleagues from IMS, RosHydromet, Moscow State University, MeteoSwiss and myself under the leadership of Harel Muskatel, IMS.
- **Technical:**
  - Code refactoring to blocked data structure to be released in COSMO 5.3 (US, XL, OF).

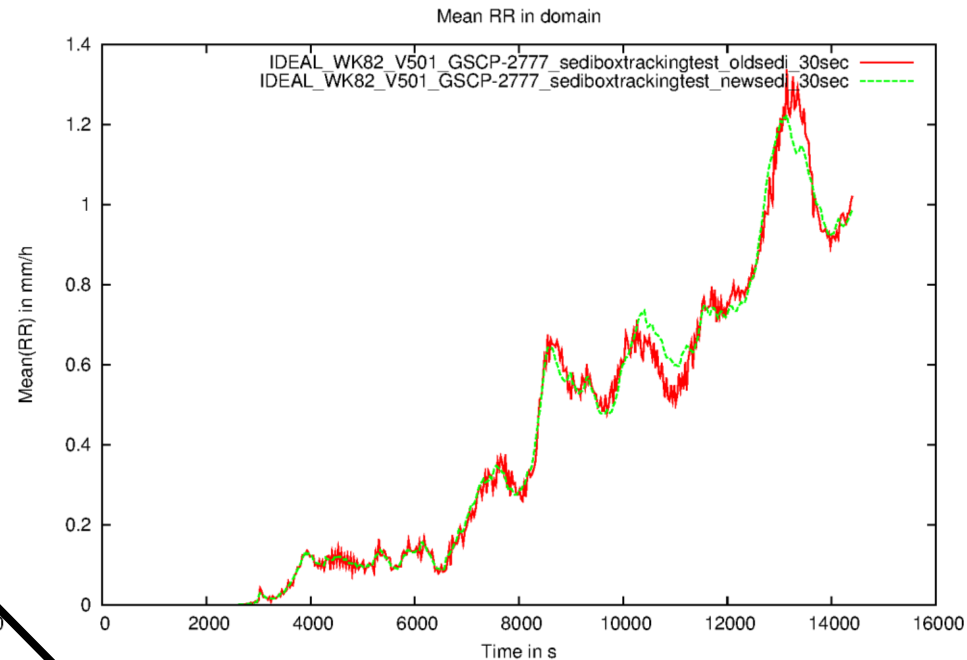
Microphysics activities

- **Physics:**
  - New explicit sedimentation scheme for the **2-moment scheme**, mitigating problems with rainrate spikes for longer timesteps (>~ 15 s), available in COSMO 5.3 (UB)
  - In our RC2 test version for the **1-moment schemes**: coupling of cloud number concentration to Tegen aerosol climatology instead of using a fixed value everywhere. Will come „for free“ after possible implementation of RC2 changes in official version (UB)
  - Implementation and testing of the **Lightning Potential Index (LPI)** after Lynn et al. into the COSMO output. Will be vailable in COSMO 5.3, yvarml = ‘LPI‘ (UB)
- **Technical:**
  - **Unified COSMO/ICON code and block data structure** since COSMO 5.1 for the 1-moment schemes (includes changes of ice nucleation, ice sedimentation and supercooled liquid water from F. Rieper, which I have presented last year) (US, XL, OF)
  - Old modules still available in the code for comparisons
- **Other:**
  - Study on explicit forecast of a severe hail storm (publication together with M. Kunz form KIT). For us: stressing the need for better data convective scale data assimilation (UB)

New explicit sedimenation for the 2-moment scheme

- ➔ Weisman-Klemp supercell simulation, 2.8 km resolution, 50 levels, dt=30 s
- ➔ Now used by COSMO-ART, where it could even cure some model crashes





Rain rate spikes with old sedim.

No spikes with new sedim.

Cloud number concentration coupled to Tegen aerosol climatology and W_{cb}

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- ➔ Instead of using the fixed namelist parameter cloud_num (default 500 kg^{-1}), which effectively switches off the warm rain process!
- ➔ Combines cloud nuclei derived from Tegen (1997) aerosol climatology with cloud activation parameterization by Segal and Khain (2006) based on cloud nuclei and cloud base updraft speed.
- ➔ Improves situation in stratiform orographic rain in warm climates (e.g., Oman has reported drastic underestimation for the rain-forest region of Salalah)
- ➔ In higher latitudes, where precipitation is formed mainly over the ice phase, it can cause a spatial shift but no difference in the mean.
- ➔ Will come „for free“ after possible implementation of RC^2 changes in official version.

Cloud number concentration coupled to Tegen aerosol climatology and W_{cb}

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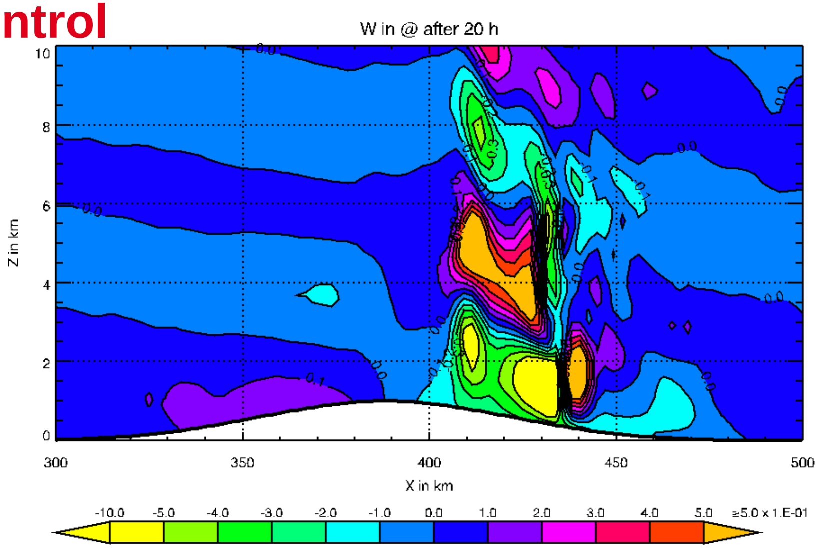
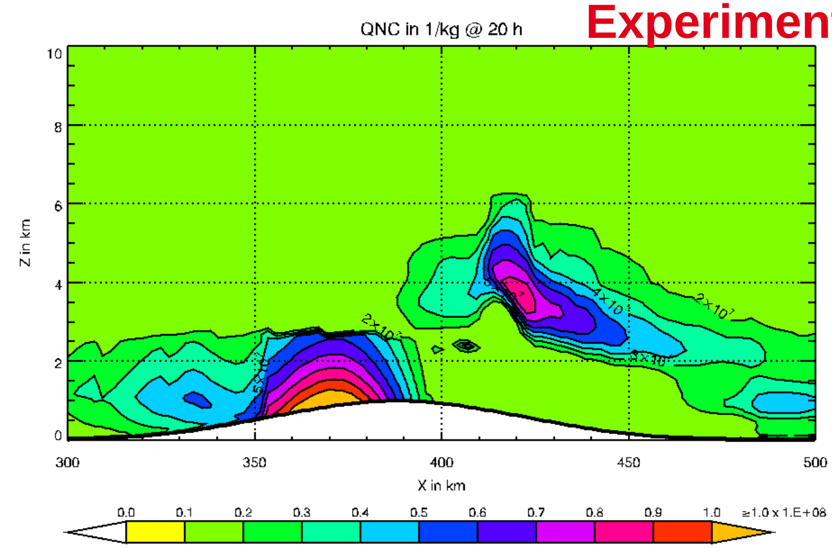
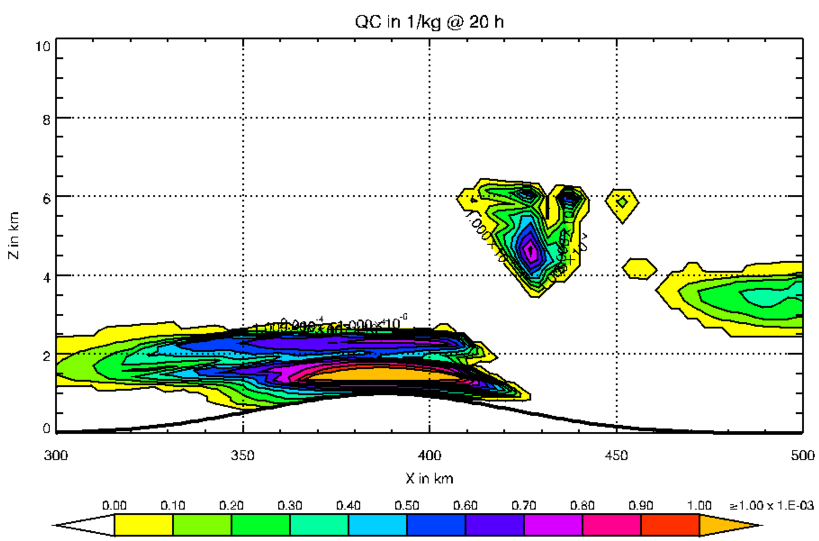
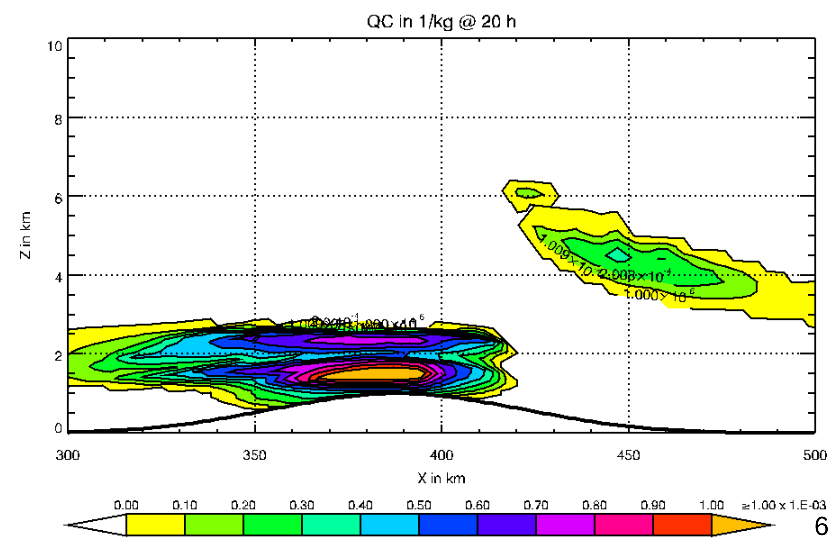
Idealized mountain flow, maritime situation

Control | **Experiment**









Cloud number concentration coupled to Tegen aerosol climatology and W_{cb}

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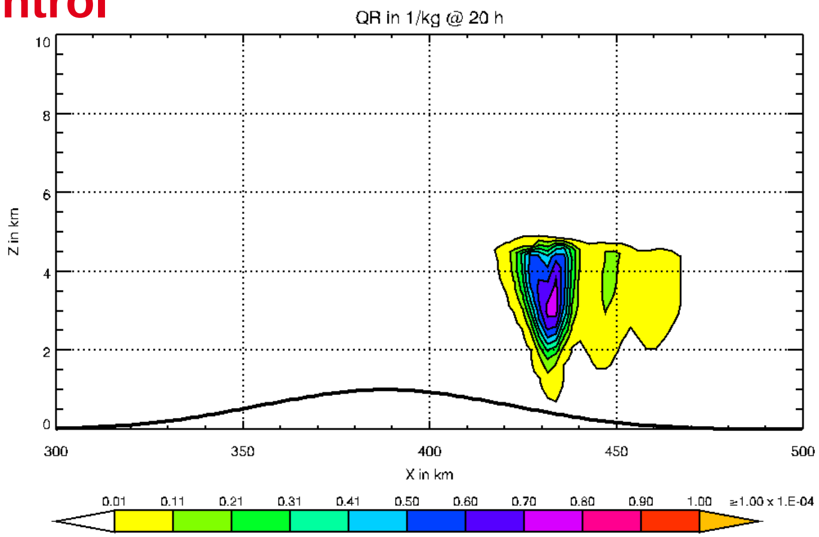
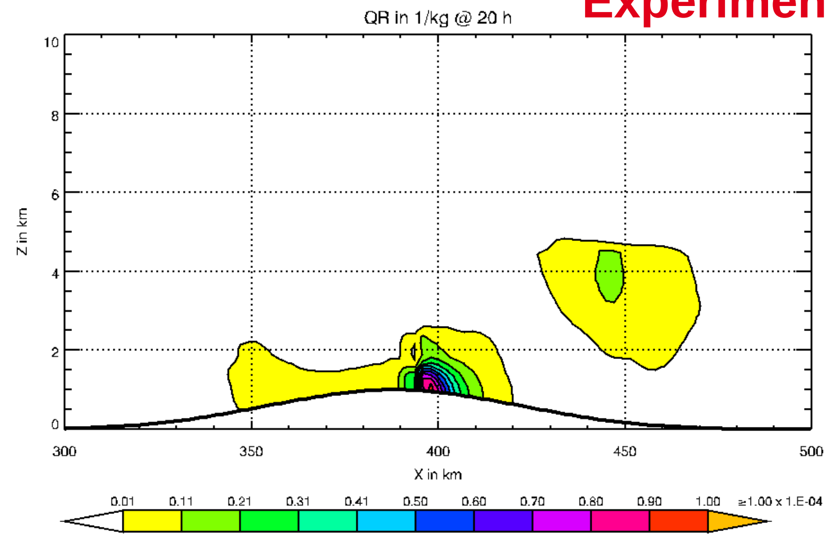
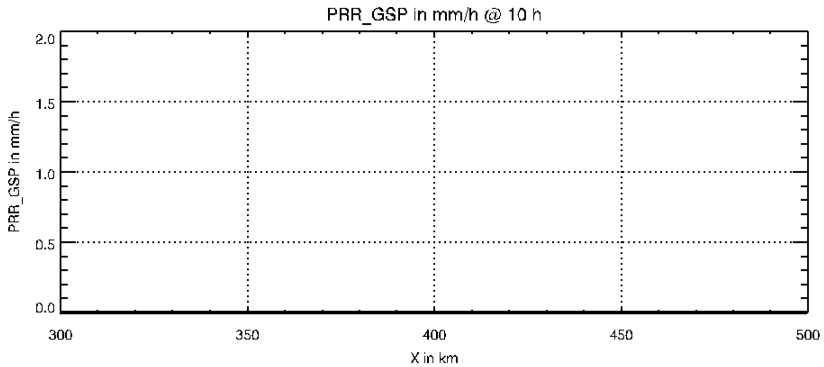
Idealized mountain flow, maritime situation

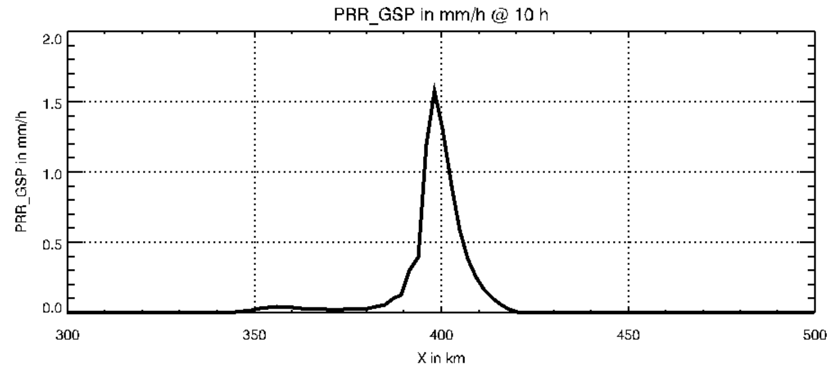
Control



Experiment



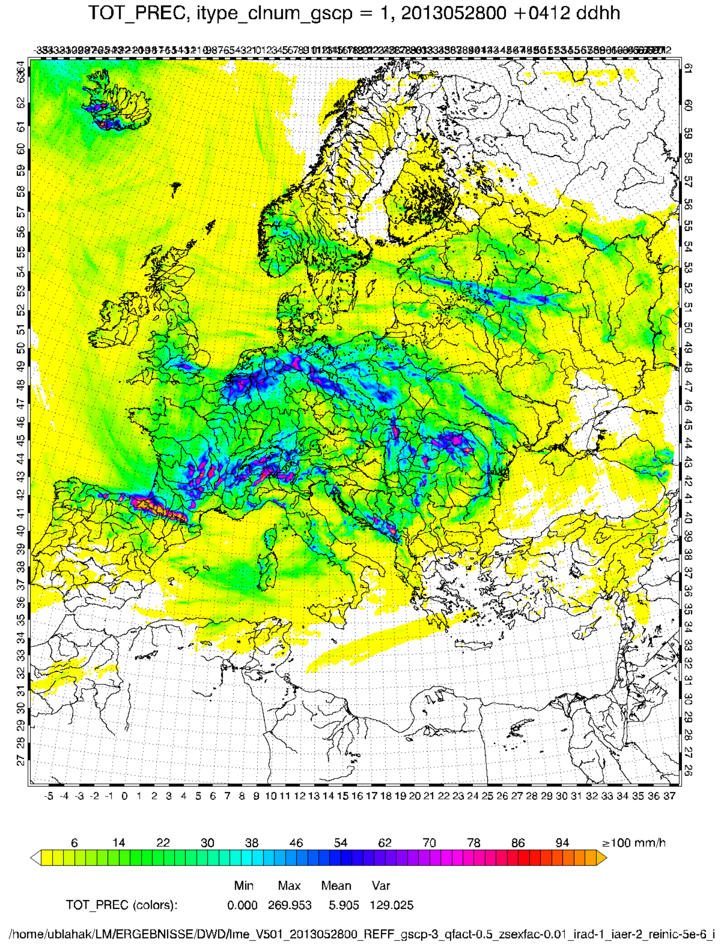




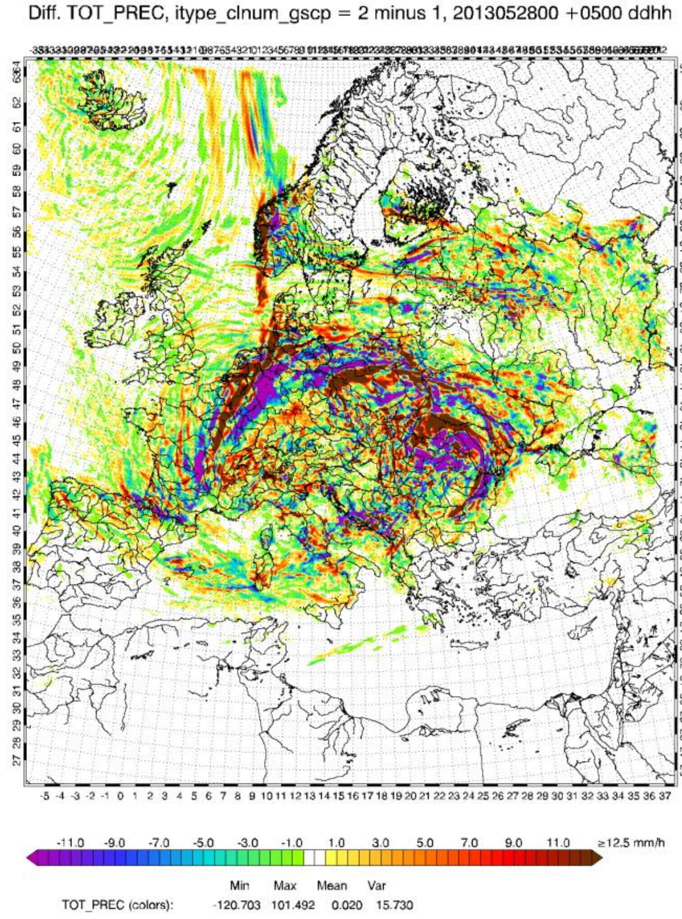
Cloud number concentration coupled to Tegen aerosol climatology and W_{cb}

5-day simulation COSMO-EU setup starting 28.5.2013 00 UTC

TOT_PREC Control 5 days



DIFF Experiment - Control



Cloud number concentration coupled to Tegen aerosol climatology and W_{cb}

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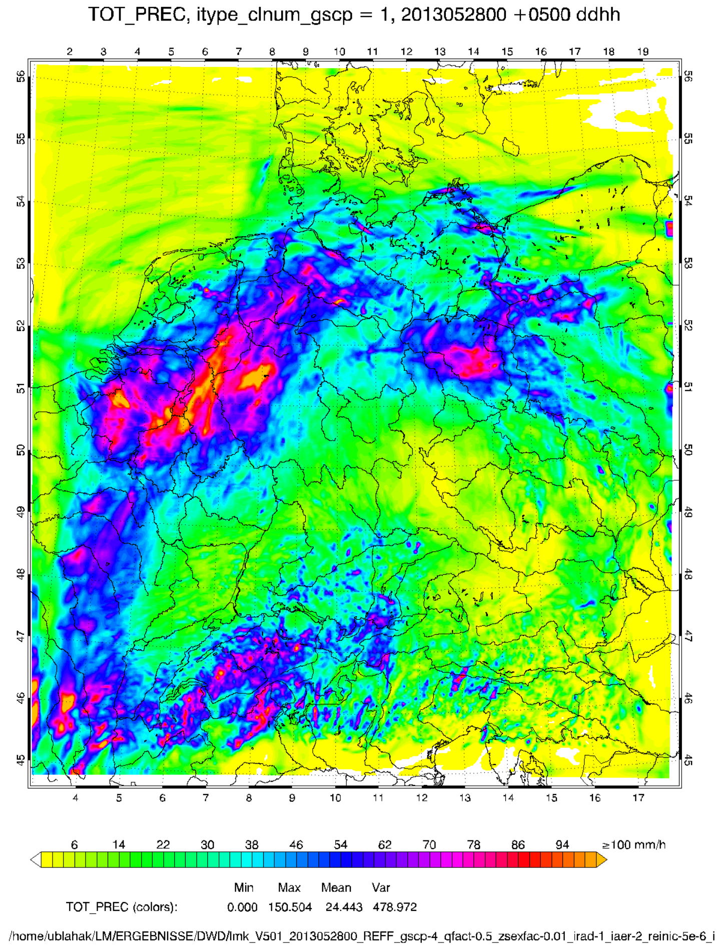
Wetter und Klima aus einer Hand

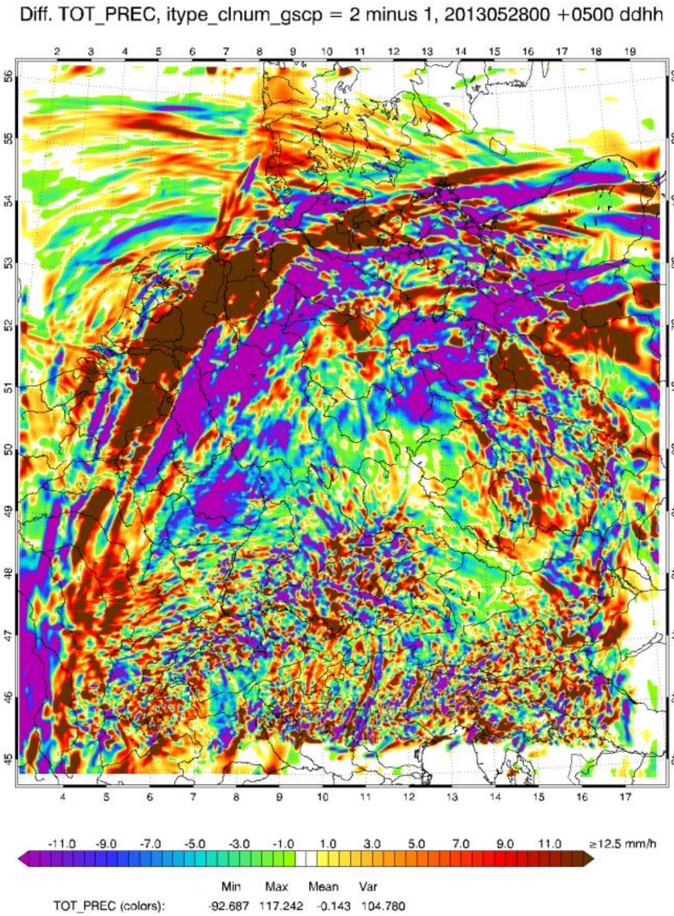
DWD

5-day simulation COSMO-DE setup starting 28.5.2013 00 UTC

TOT_PREC Control 5 days



DIFF Experiment - Control



Lightning potential index

- Definition taken from literature (e.g., Lynn et al. 2010) and improved for COSMO-model by some spatial smoothing (neighbourhood criteria f1 and f2):

$$\mathrm{LPI} = \boxed{f_1\ f_2} \frac{1}{H_{-20^\circ\mathrm{C}} - H_{0^\circ\mathrm{C}}} \int_{H_{0^\circ\mathrm{C}}}^{H_{-20^\circ\mathrm{C}}} \epsilon\, w^2\, g_{(w)}\, dz$$

$$\epsilon = \frac{2\sqrt{q_L\, q_F}}{q_L + q_F}$$

$$q_L = q_c + q_r$$

$$q_F = \frac{q_g}{2}\left[\frac{2\sqrt{q_i\, q_g}}{q_i + q_g} + \frac{2\sqrt{q_s\, q_g}}{q_s + q_g}\right]$$

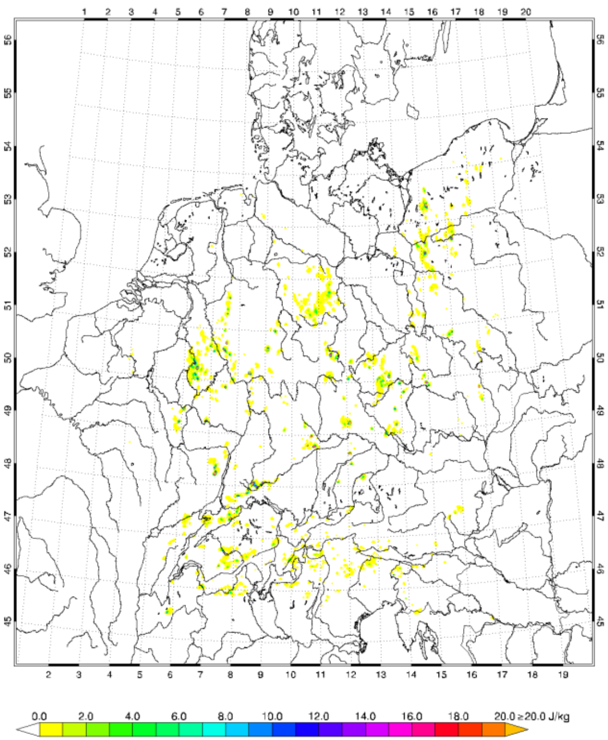
- **f1:** majority of neighbouring (10x10 km^2) grid columns must have $w_{max} > 1.1$ m/s
- **f2:** mean „stability“ within 20x20 km^2 neighbourhood must be below a threshold

Lightning potential index

CDE-Routi: **LPI_2** **LPI_4 (without f_2)** **Obs LINET t +- 15 min**

LPI COSMO-DE no neighbourhood crit.

LPI 20140804120000 UTC +00020000

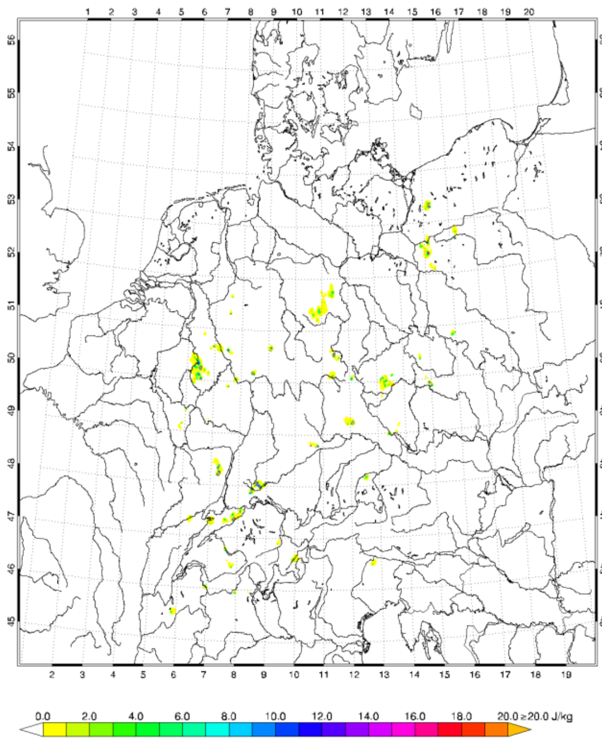


	Min	Max	Mean	Var
LPI (colors):	0.000	120.605	0.032	0.714

$W_{thresh,neigh}$ = NaN

LPI COSMO-DE neighbourhood crit.

LPI 20140804120000 UTC +00020000

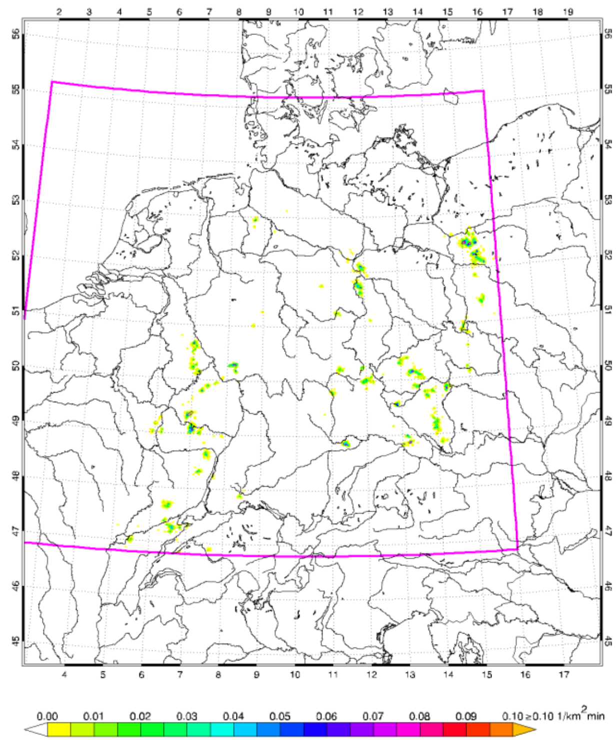


	Min	Max	Mean	Var
LPI (colors):	0.000	120.605	0.020	0.509

$W_{thresh,neigh}$ = 1.1 ms

FLR +- 15 min LINET

FLR [1/km^{2}min] 20140804140000 UTC +/- 15 min



	Min	Max	Mean	Var
FLR (colors):	0.000	0.358	0.000	0.000

Averaging window = +/- 15 min

Lightning potential index

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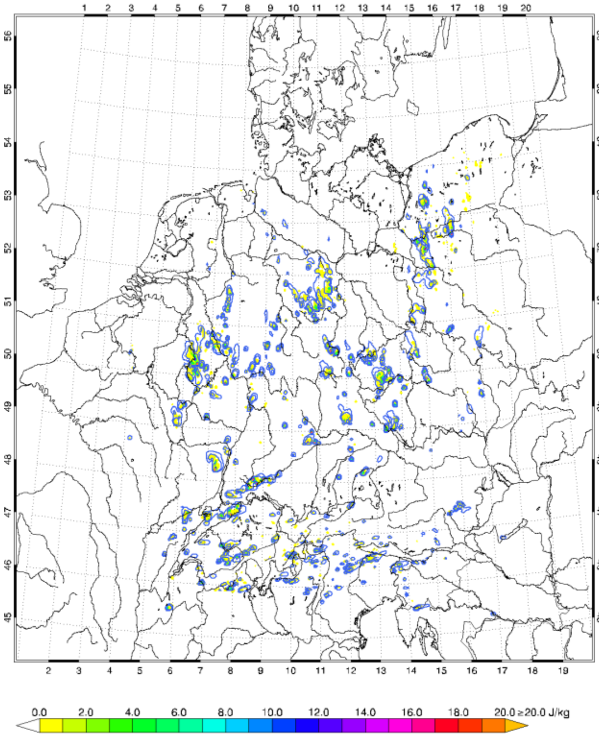
DWD

CDE-Routi: LPI$_2$ | LPI$_4$ (without f$_2$) | Obs LINET t +- 15 min

LPI COSMO-DE no neighbourhood crit.

LPI, TQG, 20140804120000 UTC +00020000

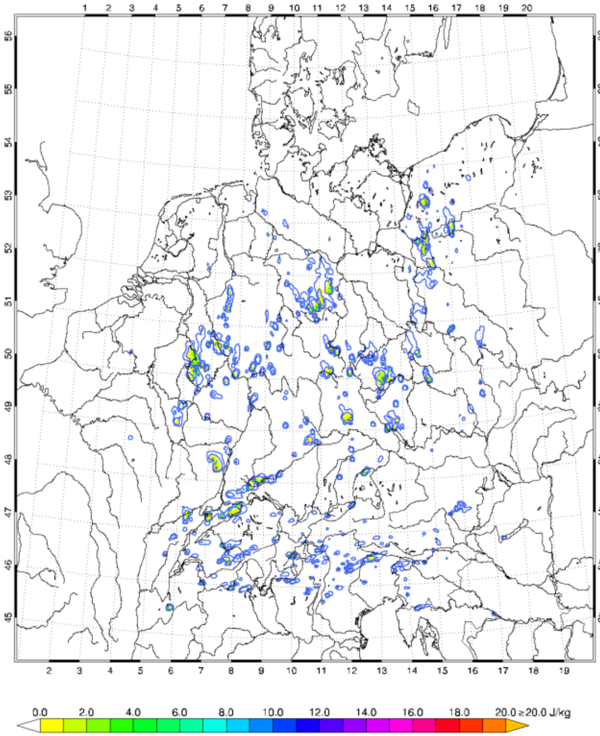


	Min	Max	Mean	Var
LPI (colors):	0.000	120.605	0.032	0.714
TQG:	0.000	25.668	0.057	0.374

$W_{thresh,neigh}$ = NaN

LPI COSMO-DE neighbourhood crit.

LPI, TQG, 20140804120000 UTC +00020000

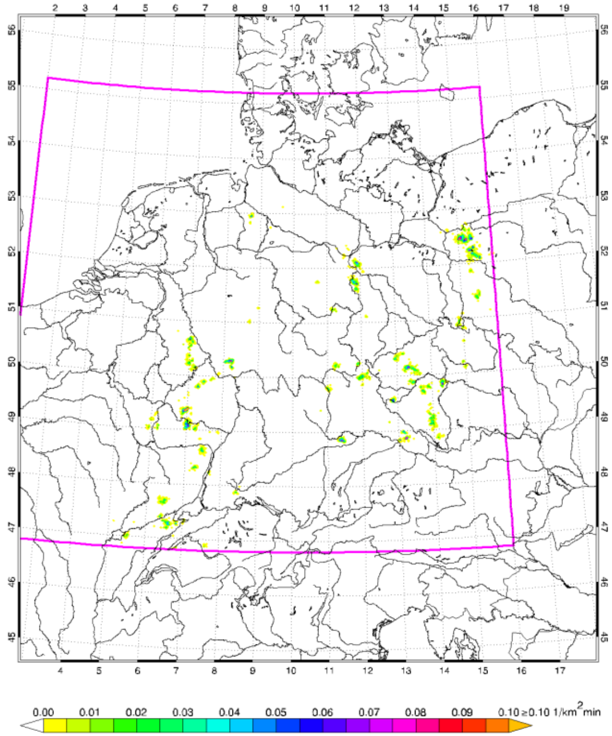


	Min	Max	Mean	Var
LPI (colors):	0.000	120.605	0.020	0.509
TQG:	0.000	25.668	0.057	0.374

$W_{thresh,neigh}$ = 1.1 ms

FLR +- 15 min LINET

FLR [1/km^{2}min] 20140804140000 UTC +/- 15 min



	Min	Max	Mean	Var
FLR (colors):	0.000	0.358	0.000	0.000

Averaging window = +/- 15 min

Lightning potential index

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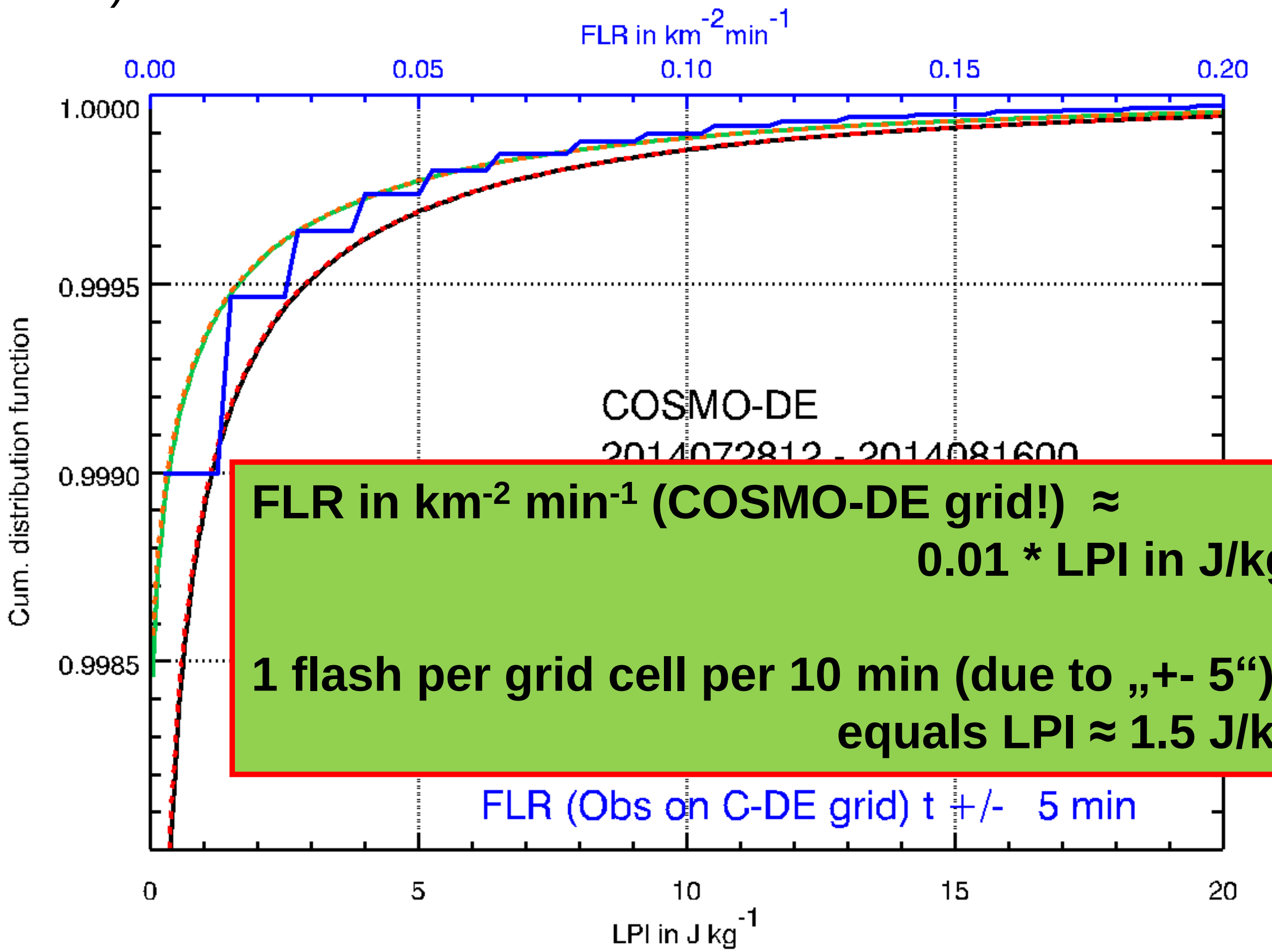
➔ Cumulated space-time distribution function of the 3-weeks period (only KONRAD-domain):

Relative scale of FLR to LPI „by eye“ in such a way, that it leads approximately to a constant factor.



FLR in km^{-2} min^{-1} (COSMO-DE grid!) ≈ 0.01 * LPI in J/kg

1 flash per grid cell per 10 min (due to „+- 5“) equals LPI ≈ 1.5 J/kg

Lightning potential index

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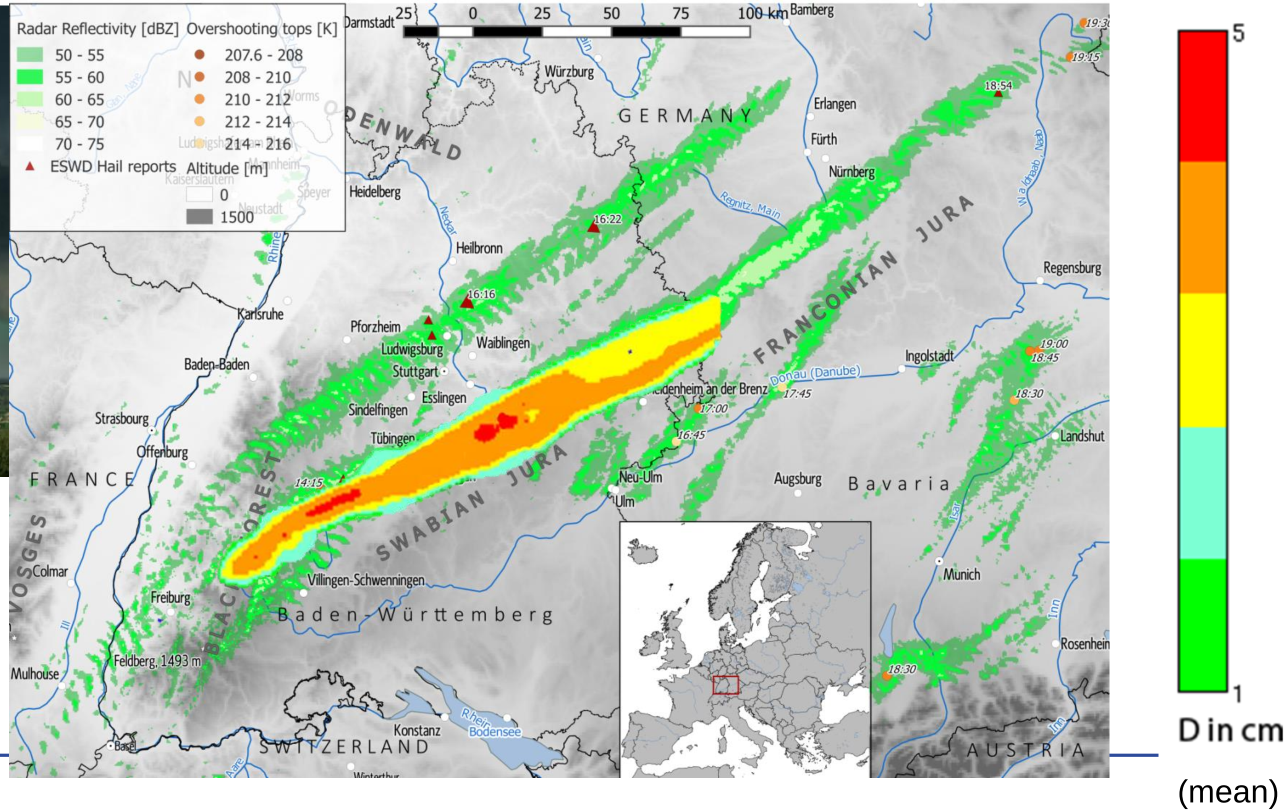
- LPI requires explicit simulation of deep convection (high resolution), and microphysics including graupel („graupel“-scheme or 2-moment scheme).
- LPI correllates well with observed flash rates and gives realistic space-time distributions of flash signals.
- Compared to, e.g., QG alone, it gives different signals: not every shower which contains QG, leads to an LPI signal.
- Implemented in COSMO 5.3 output (‘LPI‘). Slight increase in model runtime (~1%) due to horizontal field exchange necessary for the neighbourhood criteria.
- Possible applications:
  - Product for the forecasters, possibly also in an ensemble context
  - Forward operator for assimilation of lightning data
  - …

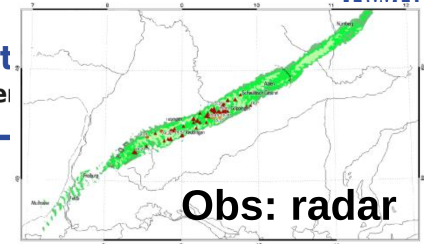
Case study: supercell with large hail

- 28.07.2013 longlived supercell in Southern Germany, pre-frontal, most expensive natural hazard in terms of insurance losses worldwide (~ 3 billion Euros, together with another supercell in Northern Germany)

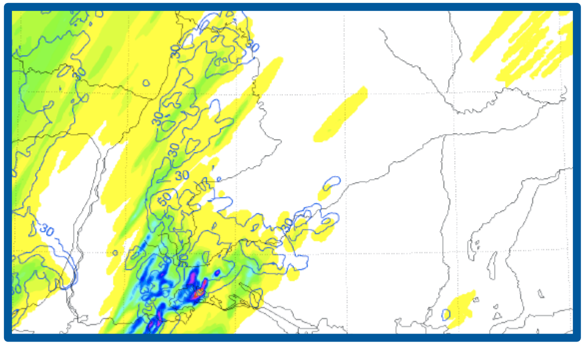
- Huge hail damage, maximum observed hail diameter > 10 cm

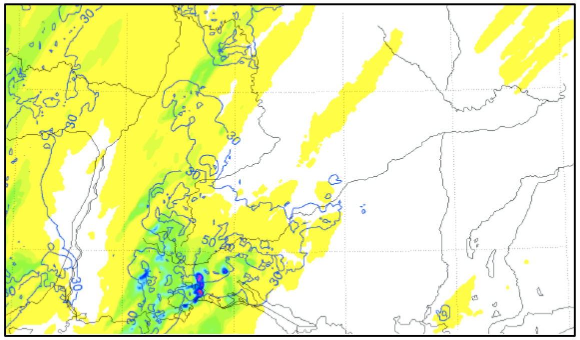


COSMO 1.1 km simulations with different setups

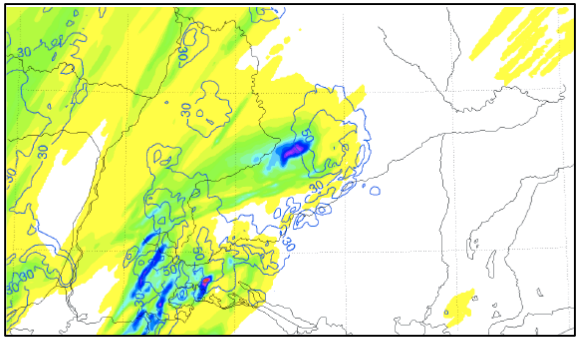


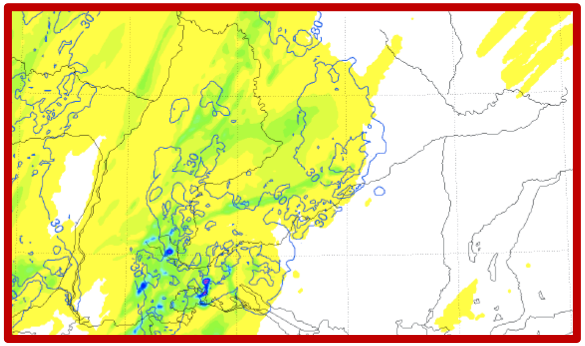
Standard model setup | Two-moment microphysics



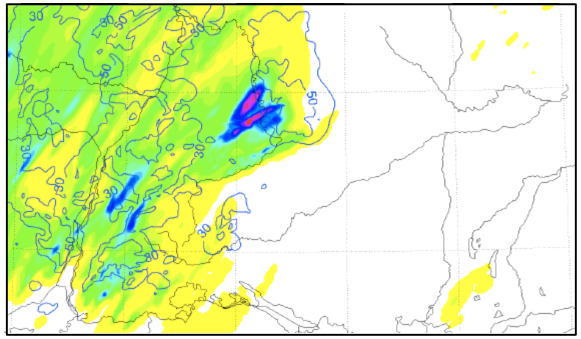


Initialized with COSMO-DE analysis





…
+ 2 warm bubbles



…
+ Latent heat nudging (radar)

16 UTC

COSMO-DE 1.1 km

Accumulated rainfall

0 10 20 30 40 mm

2-moment scheme, 2 „warm bubbles“: Obs. and sim. DBZ (PPI 0.5°)

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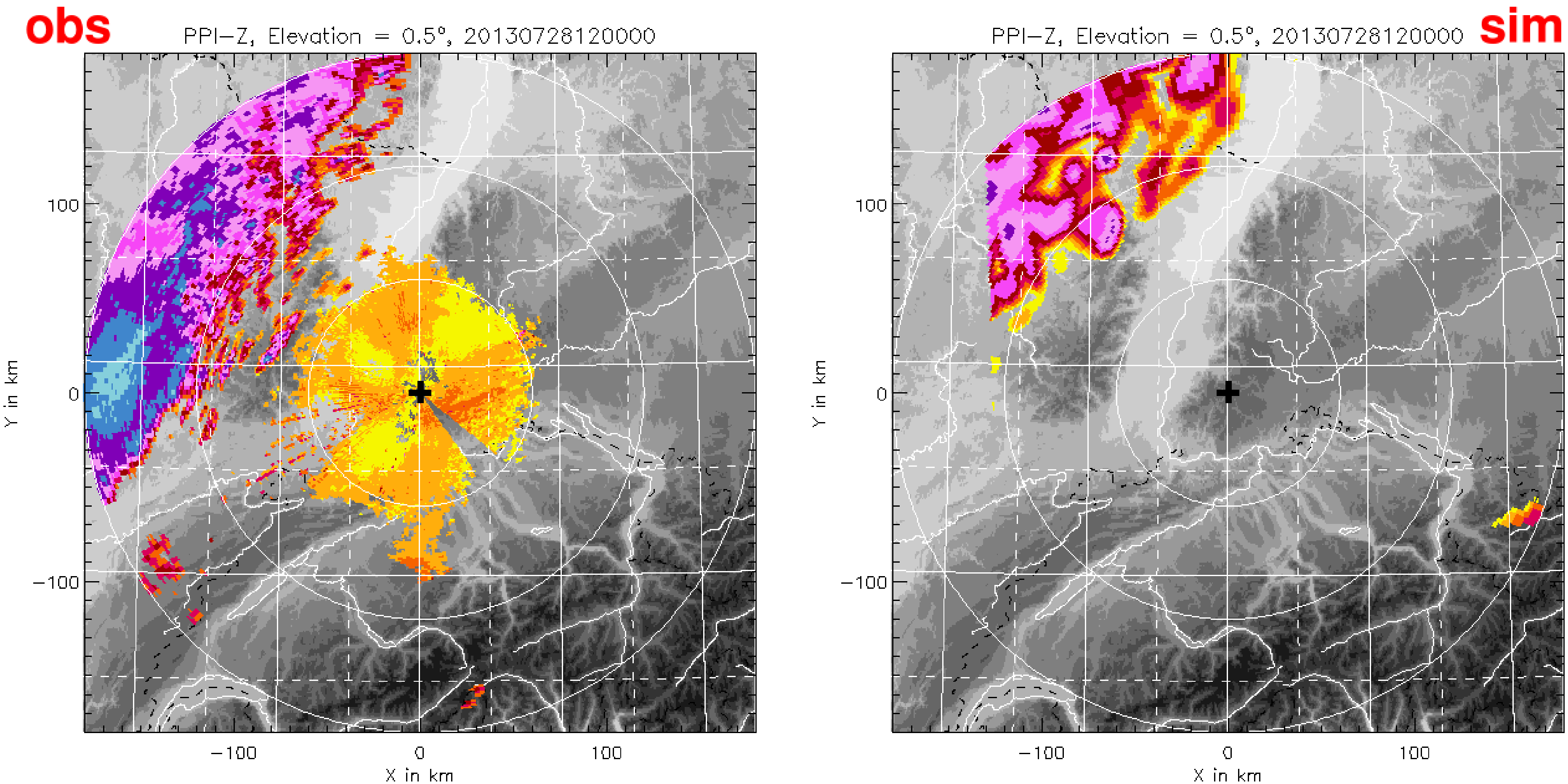
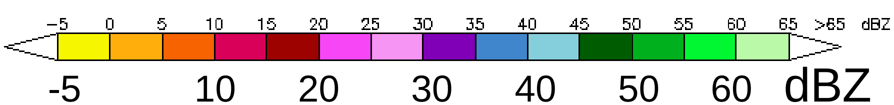
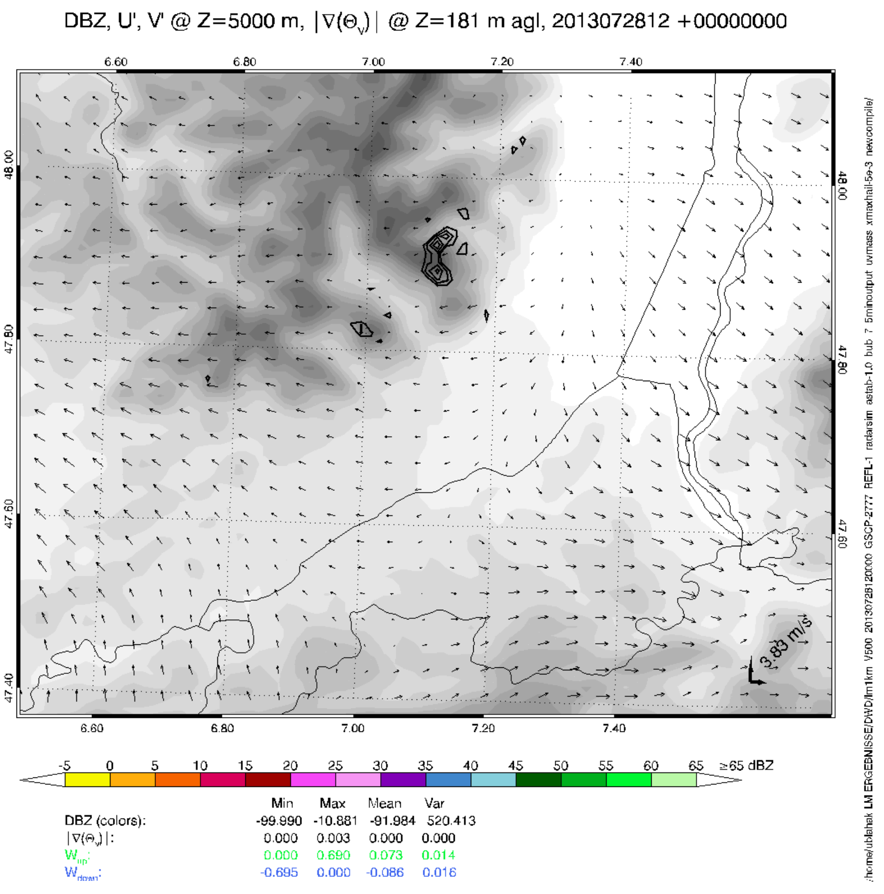
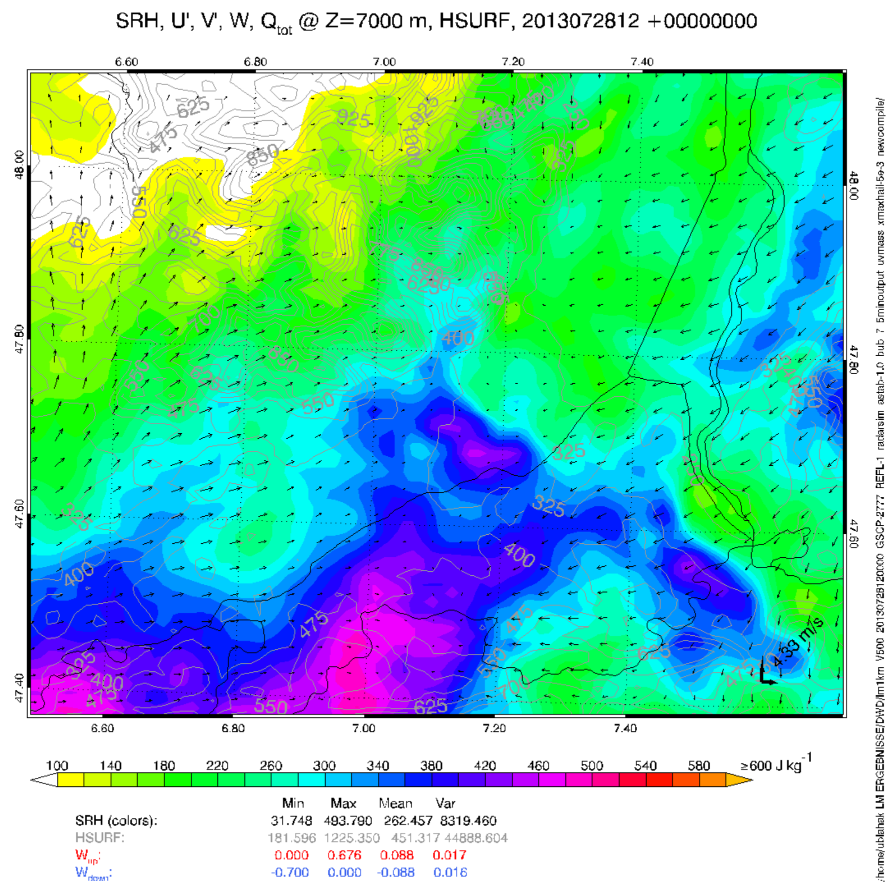




Radar reflectivity (PPI-Z), elevation = 0.5°
Radar Feldberg, beam attenuation taken into account

2-moment scheme, 2 „warm bubbles“: Obs. and sim. DBZ (PPI 0.5°)





Case study: supercell with large hail

- ➔ Rotating HP-supercell was formed by transition of smaller cells as they moved from the Upper Rhine Valley into region of locally high SRH over Black Forest.
- ➔ Operational deterministic COSMO-DE forecast had some problems, despite LHN. Probably there were signals in COSMO-DE-EPS, I did not check.
- ➔ Pre-convective environment was pretty good. The problem was the triggering.
- ➔ The cell did not spin up by itself. LHN suffered from application of the climatological heating rate profile which is not designed for convective cells.
- ➔ By just specifying 2 „warm bubbles“ in the PBL, a surrogate for „a more appropriate data assimilation“, the convective system developed realistically and it‘s track and severity was correctly forecasted over more than 5 hours.
- ➔ So there is hope for the future and motivation for data assimilation developments.