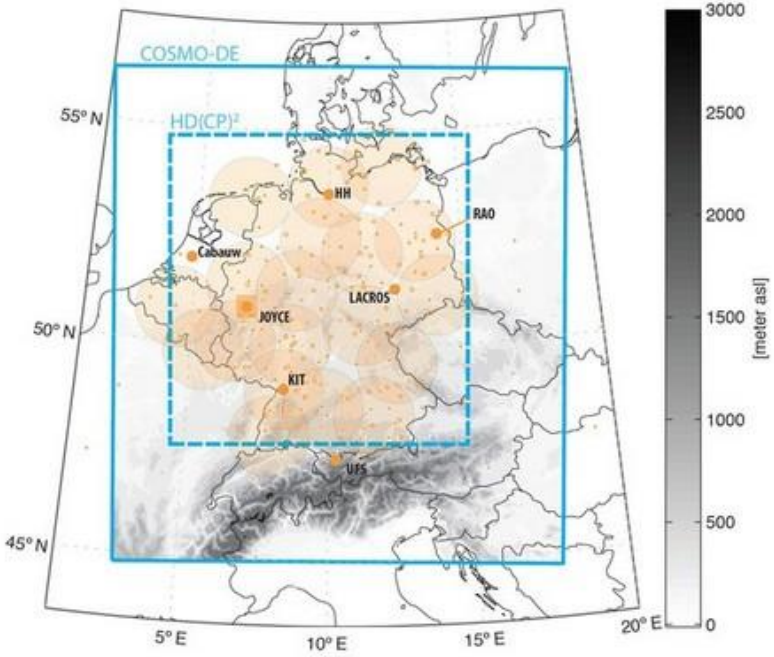
LES simulations with ICON:

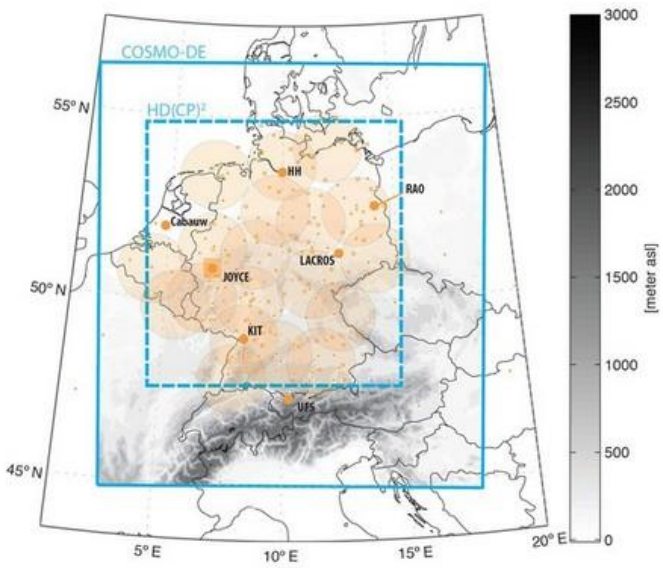
the HD(CP)² project



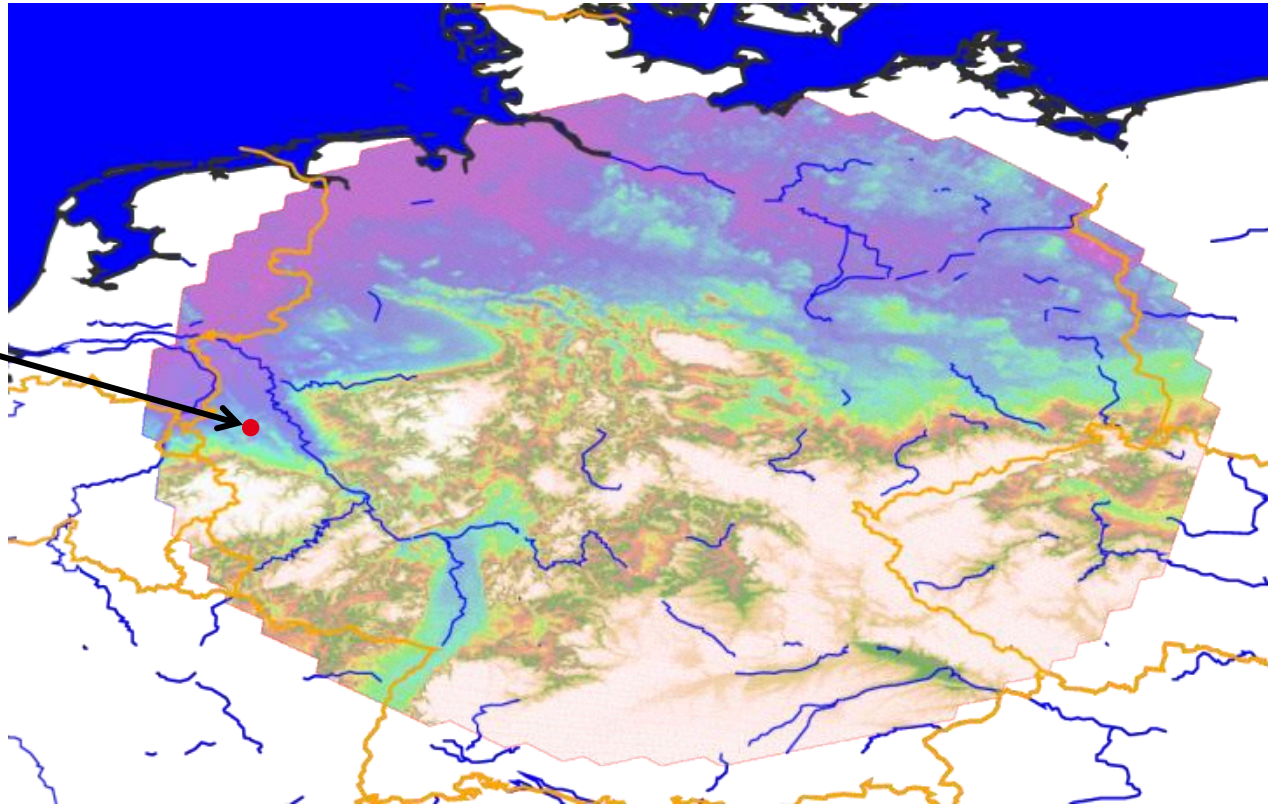
Daniel Klocke

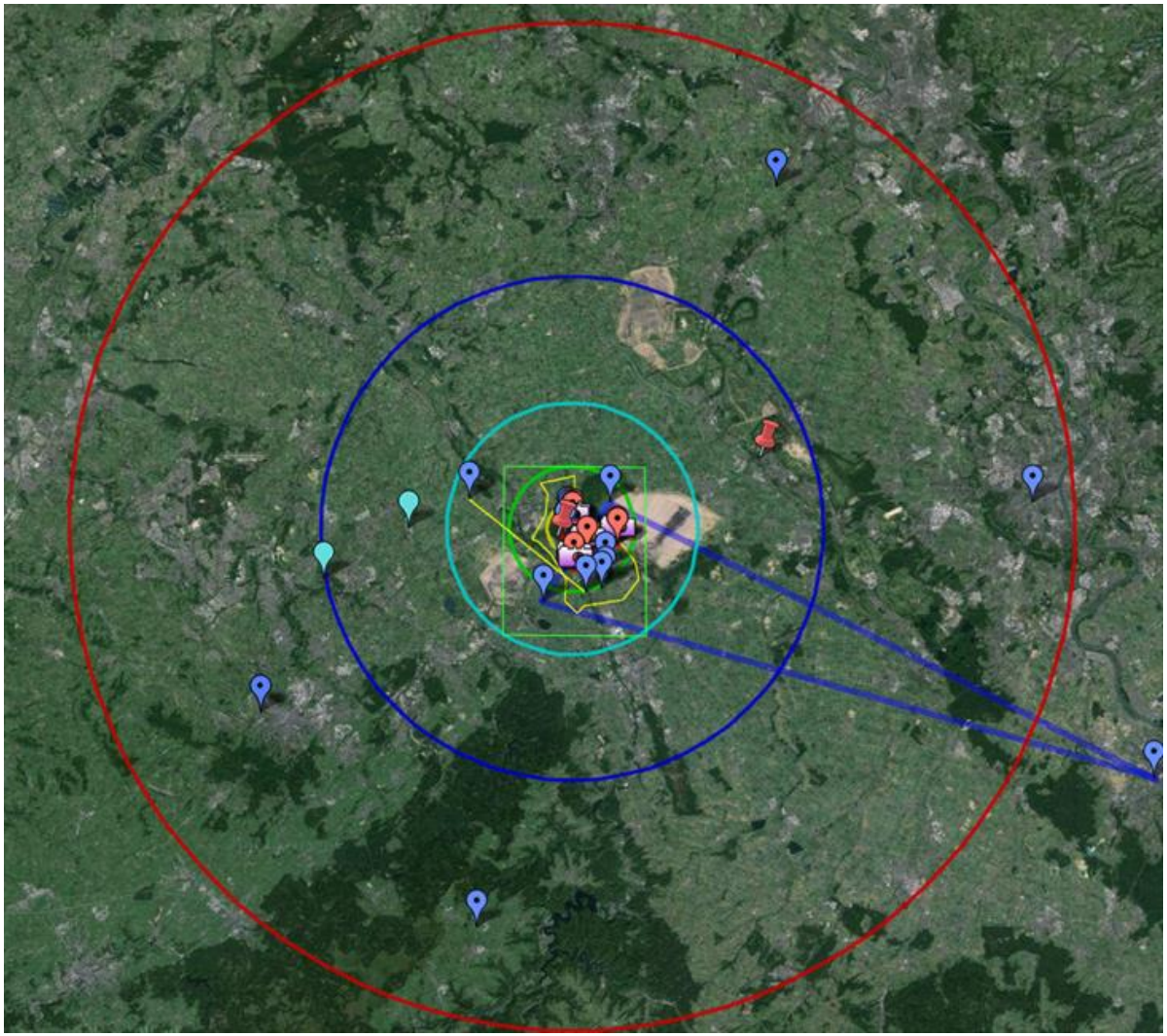
- German wide BMBF funded project.
- HD(CP)2 will strive to build and use a model capable of very high-resolution simulations.
- Horizontal grid spacing of 100m over domains of 1000km, offers the possibility to leap over the so-called grey-zone encompassing most of the scales of parameterized physics.
- Semi-empirical basis for advancing parameterization development.

- Three modules:
  - Model development
  - Observations
  - Synthesis



HDCP2 domains

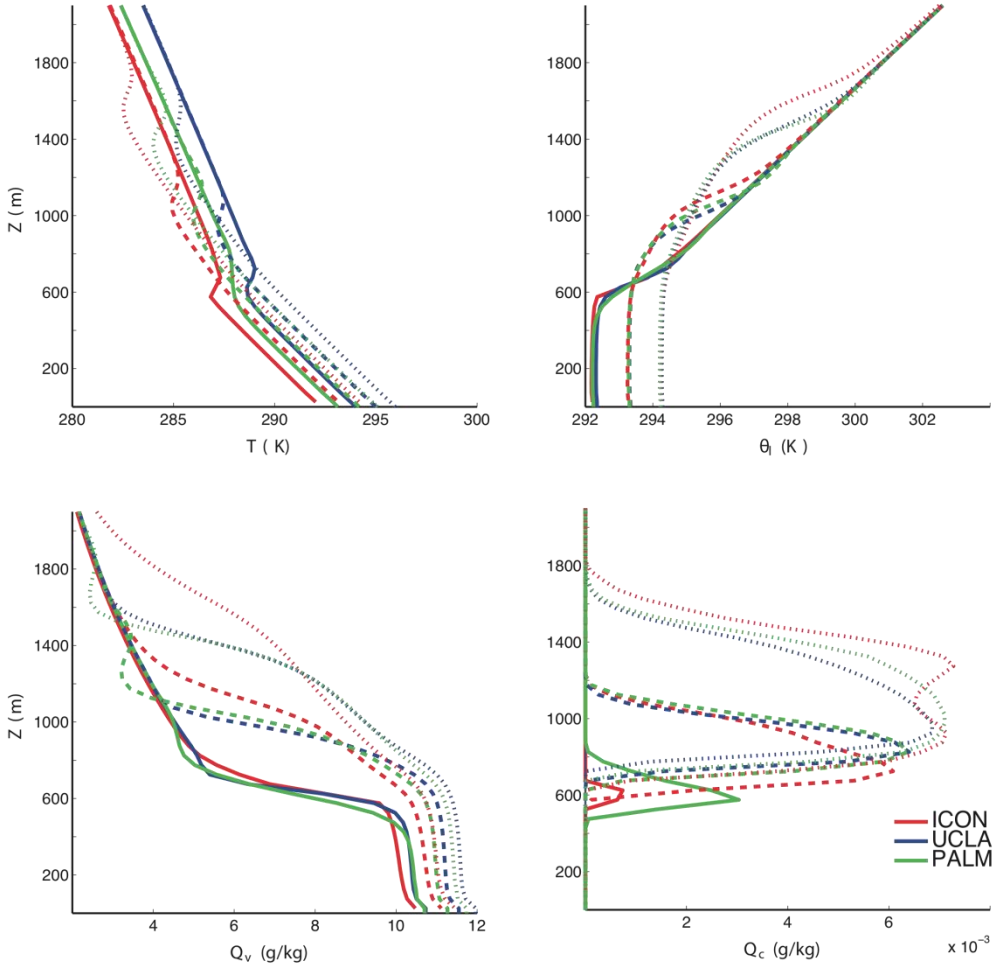




3D Turbulence scheme:

- **Classical Smagorinsky turbulence with stability correction due to Lilly 1962.**
- **Fully 3D.**
- **Horizontal momentum diffusion is applied on VN (edge normal velocity) and not on U and V like the existing turbulence scheme.**
- **Vertical momentum is diffused through W.**
- **Temperature diffusion is applied on potential temperature.**
- **Tracer diffusion is performed on QV and QC, but others can be included.**

Idealized case of cloud topped boundary layer:



08 hrs
16 hrs
24 hrs

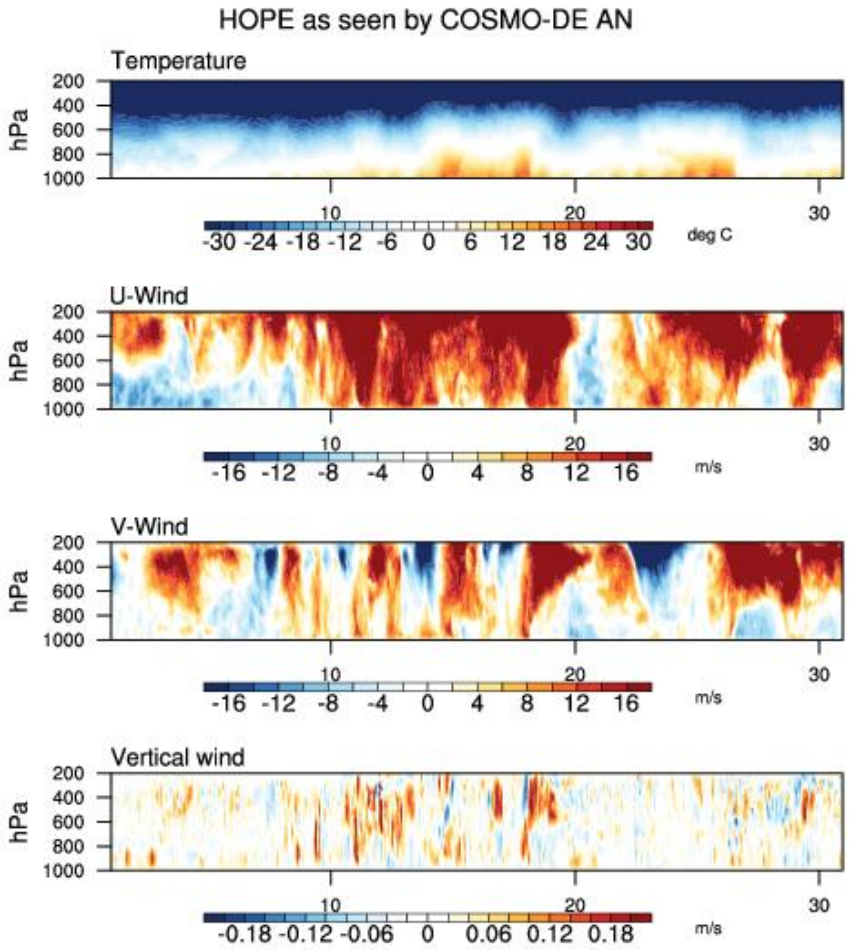
Turbulence scheme - issues:

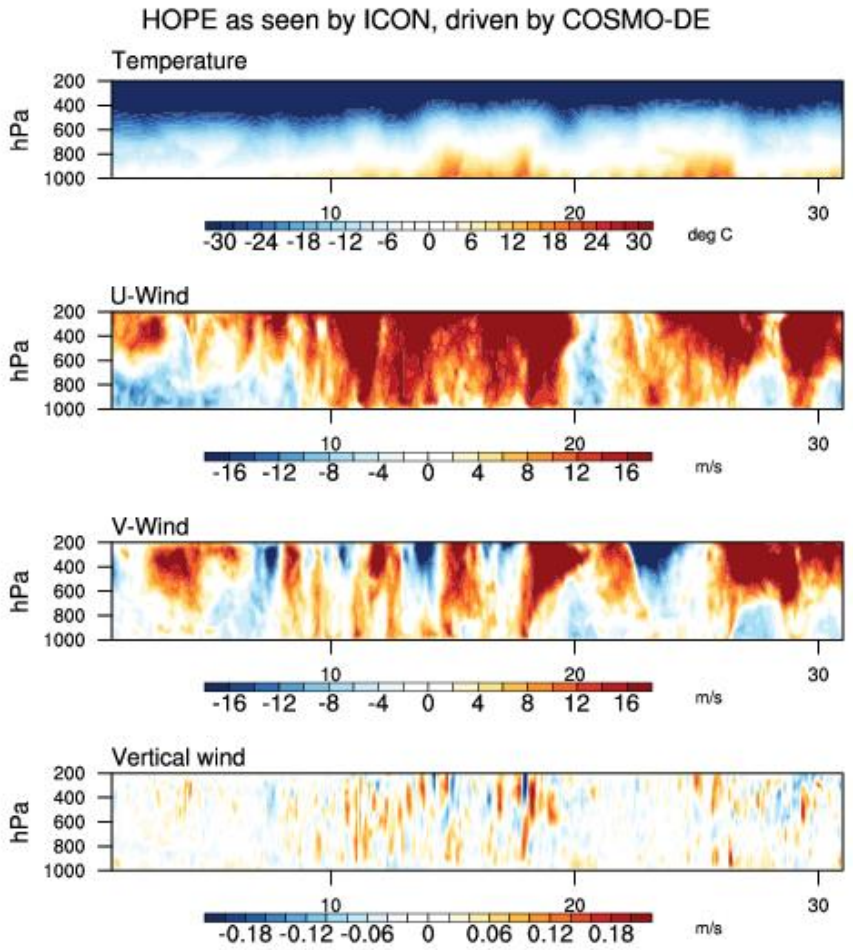
- **Preliminary runs with real initial and boundary conditions show that the scheme is unstable over topography.**
  - **… work is ongoing …**

Simulation setup

- ‚Cologne': 220km radius, R2B10 – R2B15 (2.5km to 75m)
- ‚Germany': 680km radius, R2B09 – R2B14 (5km to 156m)
- Initialization with COSMO-DE (2.8km) at 00 from forecasts at lead time 0
- Lateral boundary nudging with COSMO-DE (3 hourly data)
- Extpar data (ASTER topography, GLOBCOVER land-use)
- NWP physics, but no convection parameterization

Cologne

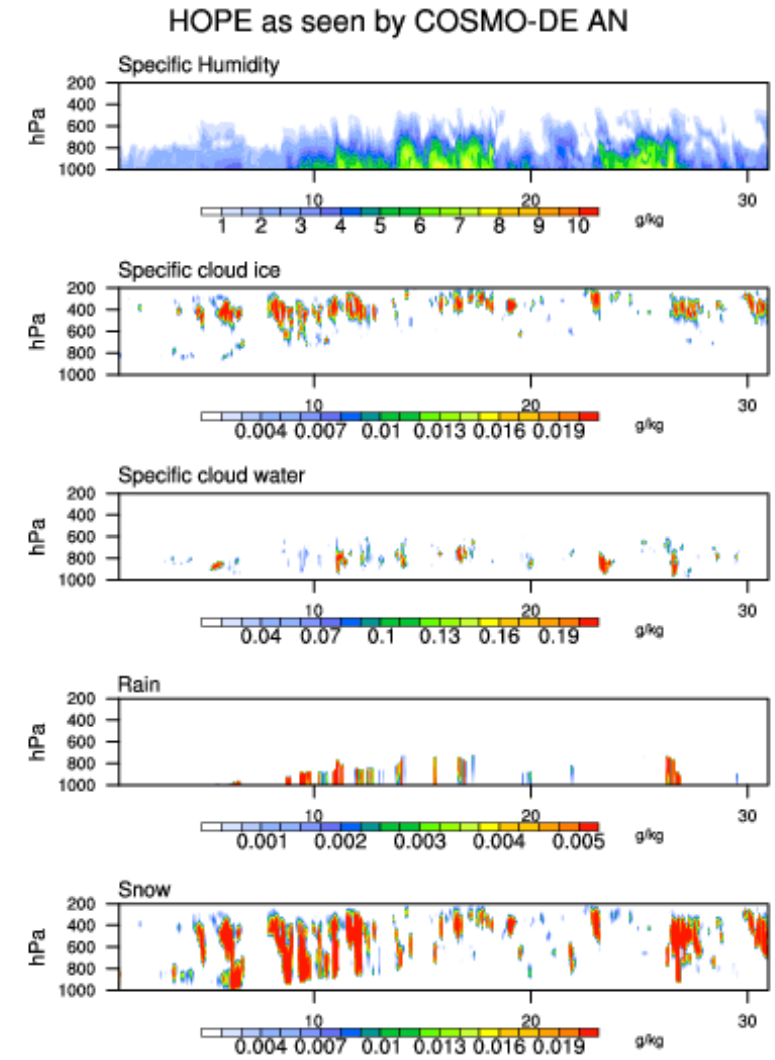


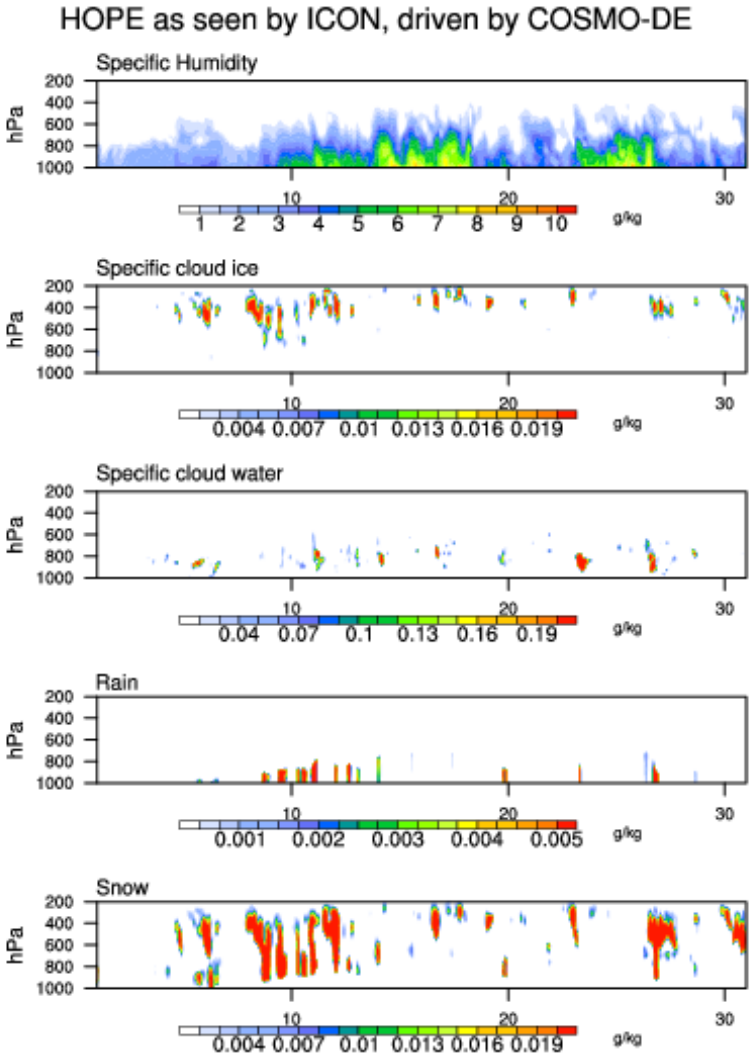


April 2013: initialized and nudged with COSMO-DE: Nudging is working properly!

Average over a 0.25˚ x 0.25˚ box around Jülich

Cologne



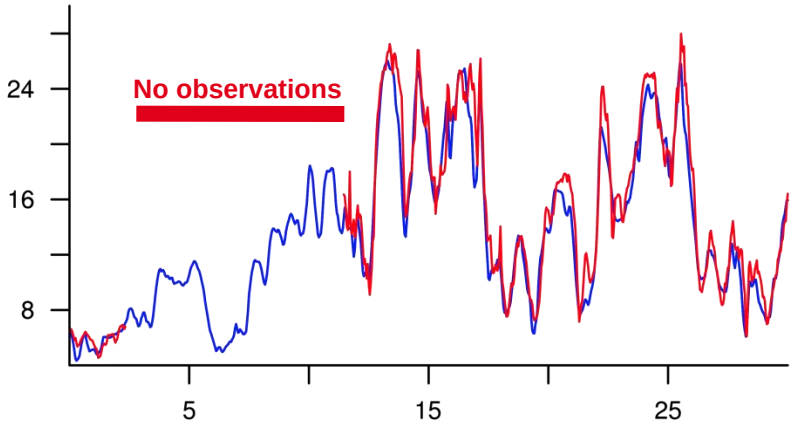


Also ‘free variables’ look reasonable (different micro physics!)

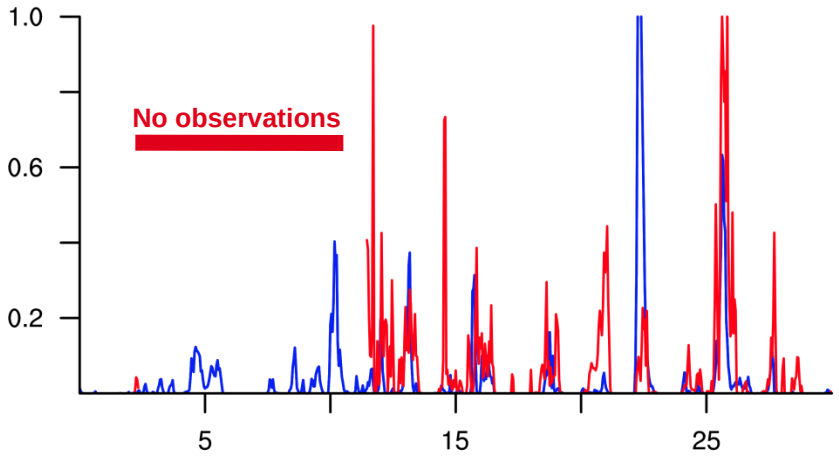
HATRPO microwave radiometer

Observations
ICON-JL

Total column water vapor [kg m^{-2}]



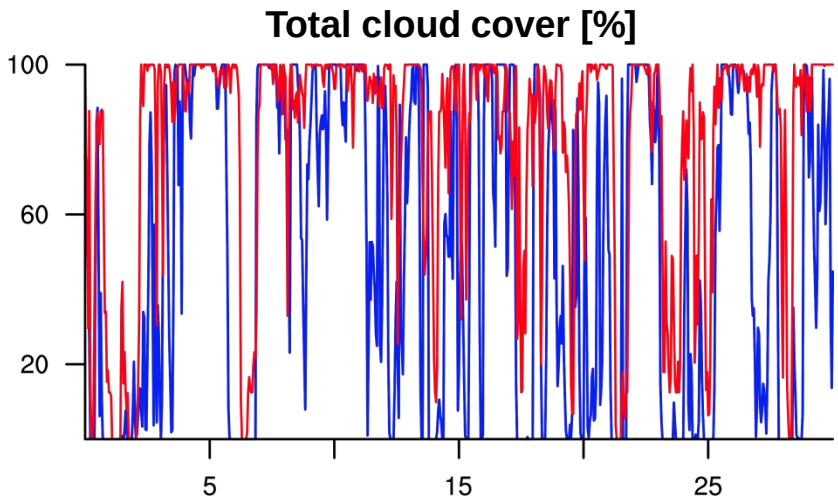
Total column liquid water [kg m^{-2}]

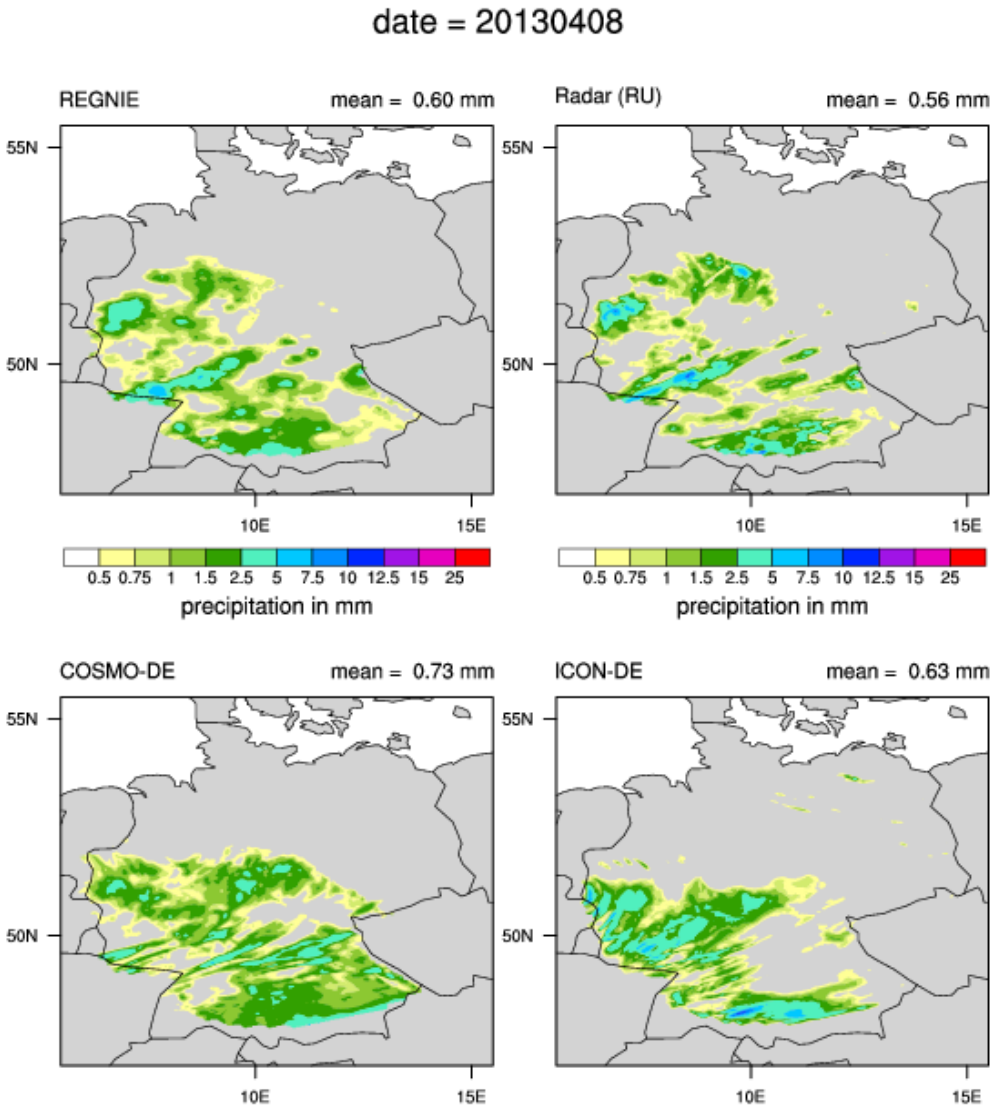


Day in April 2013

Ceilometer

Observations
ICON-JL



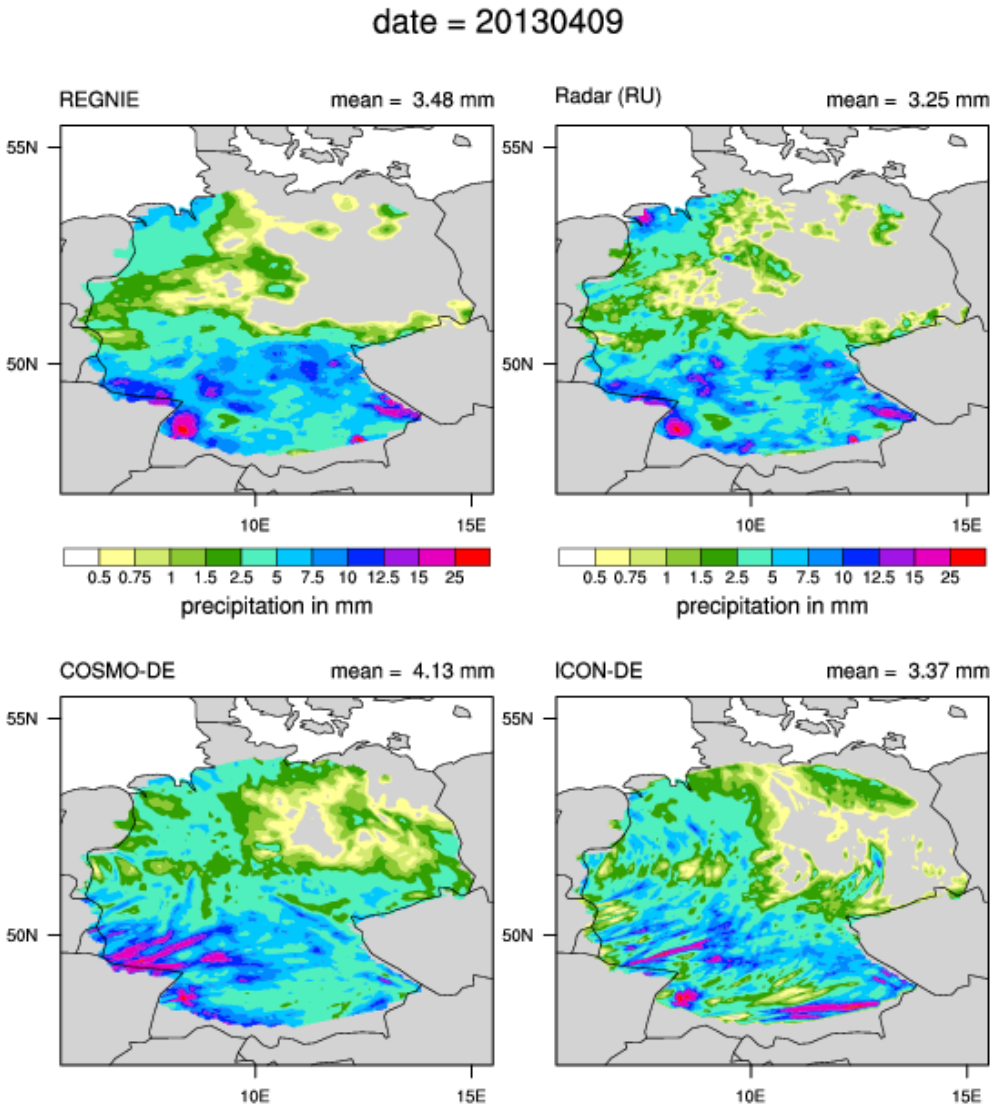


24h accumulated precipitation:

30h forecasts, precipitation is accumulated from 6:00 to 6:00 next morning.

ICON: 1250m resolution. Nudge boundaries are in the evaluation domain, hence some artifacts.

Overall: Good performance!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mean = 3.25 mm
55N
50N
10E
15E
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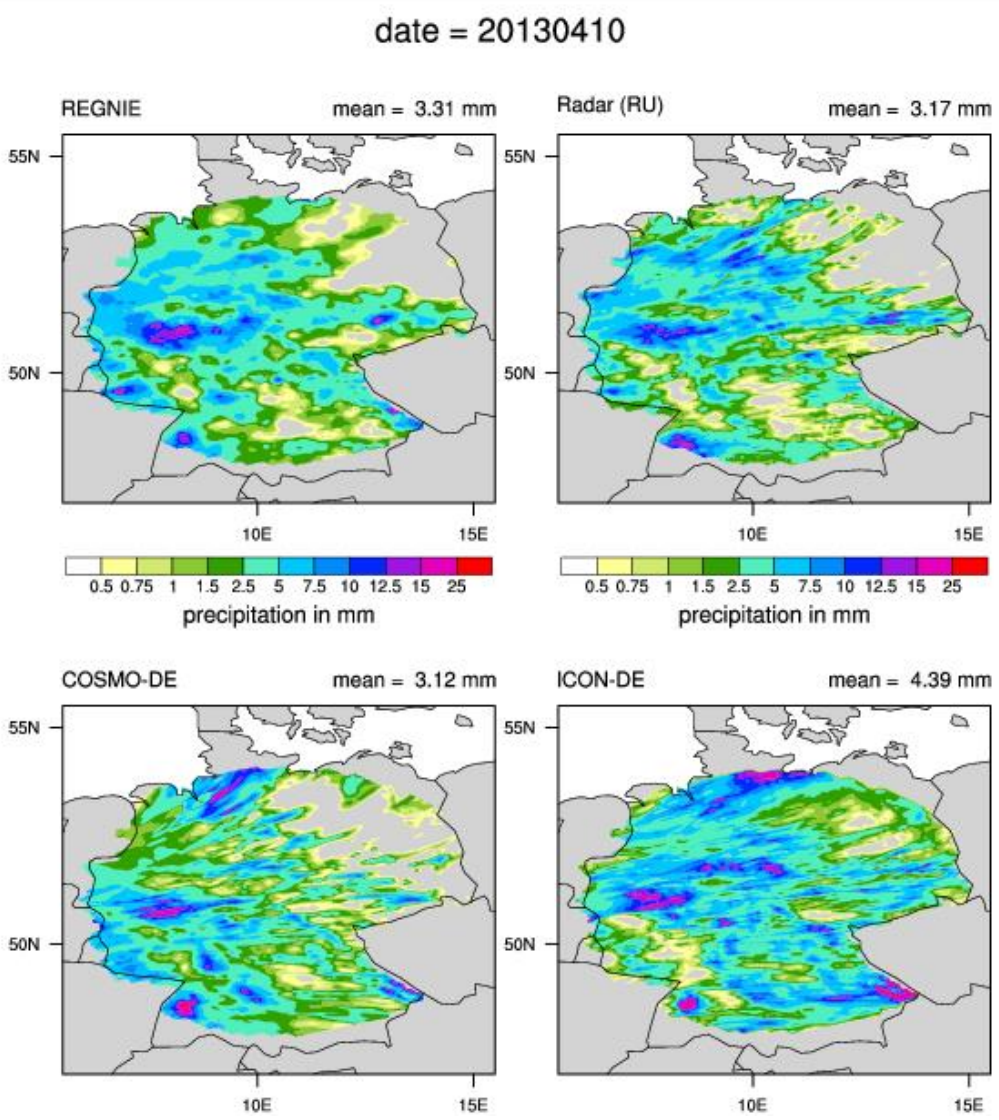
precipitation in mm
COSMO-DE
mean = 4.13 mm
ICON-DE
mean = 3.37 mm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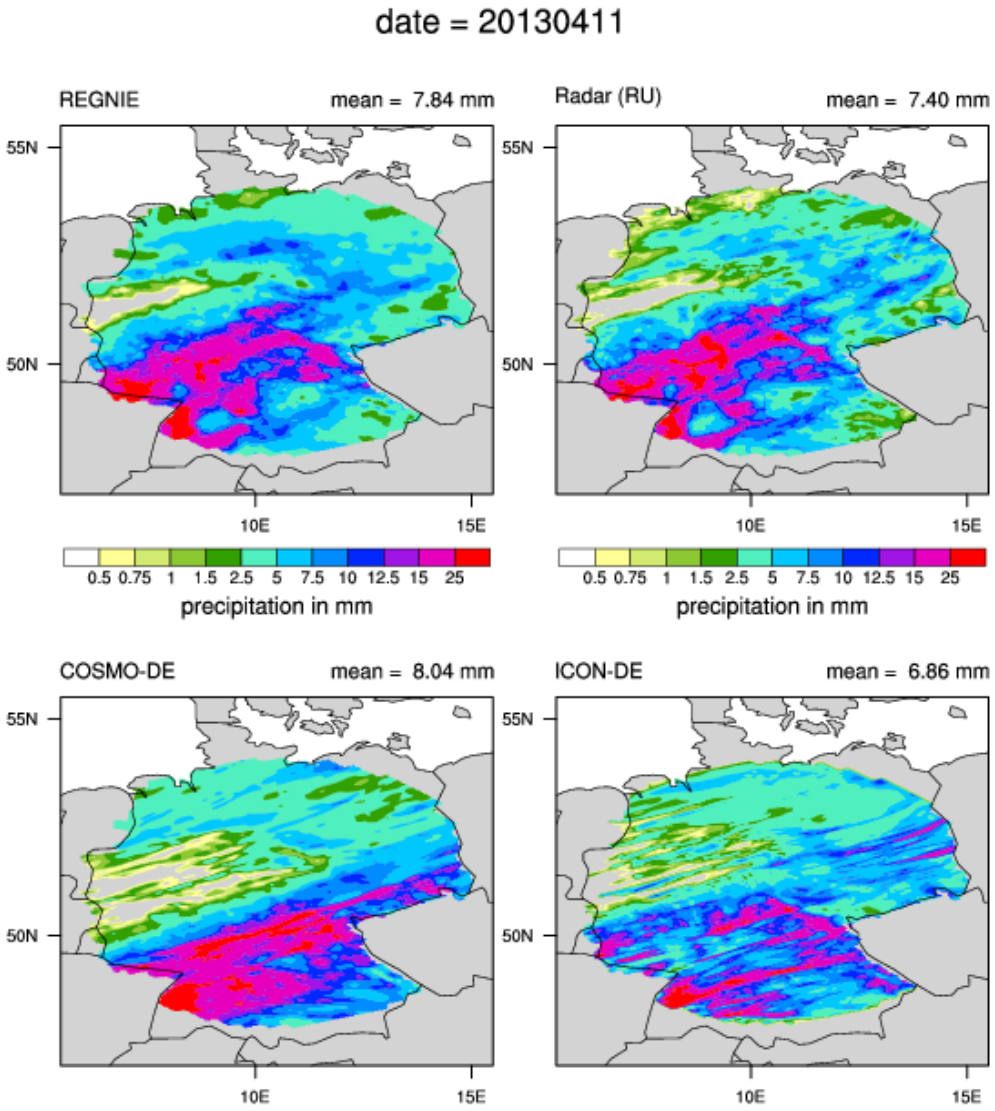
50N
10E
15E
0.5 0.75 1 1.5 2.5 5 7.5 10 12.5 15 25
precipitation in mm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50N
10E
15E
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precipitation in mm
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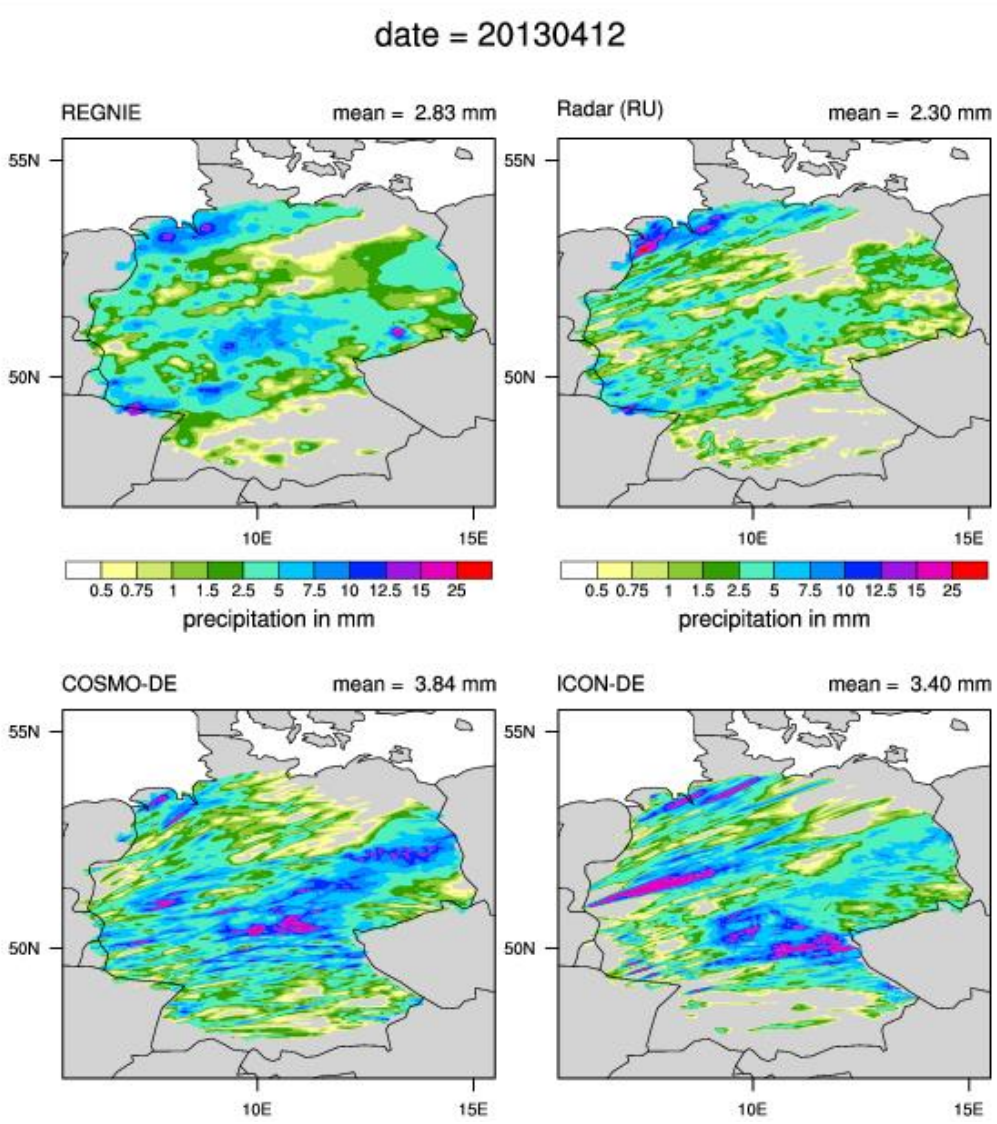
ICON-DE
mean = 6.86 mm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mean = 3.84 mm
ICON-DE
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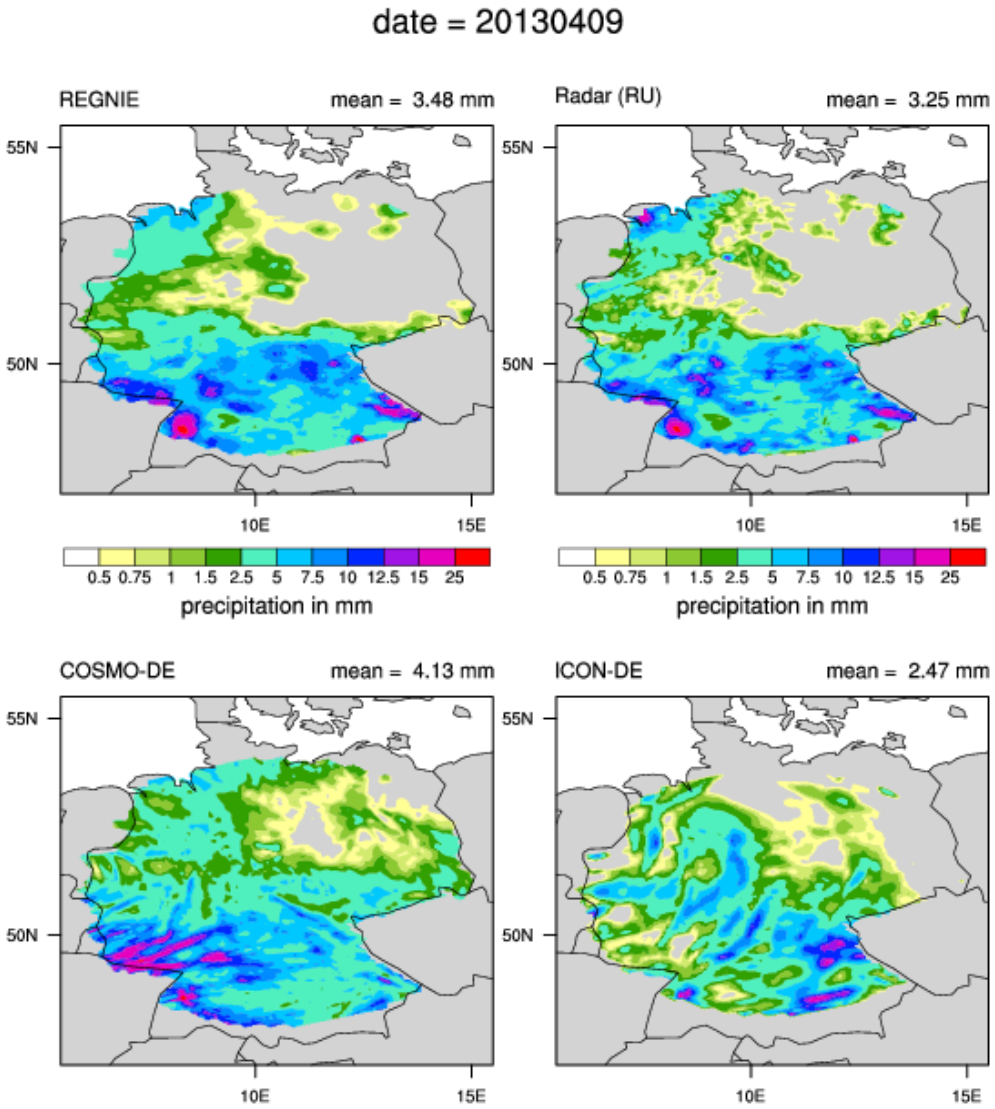
55N
50N
10E
15E
0.5 0.75 1 1.5 2.5 5 7.5 10 12.5 15 25
precipitation in mm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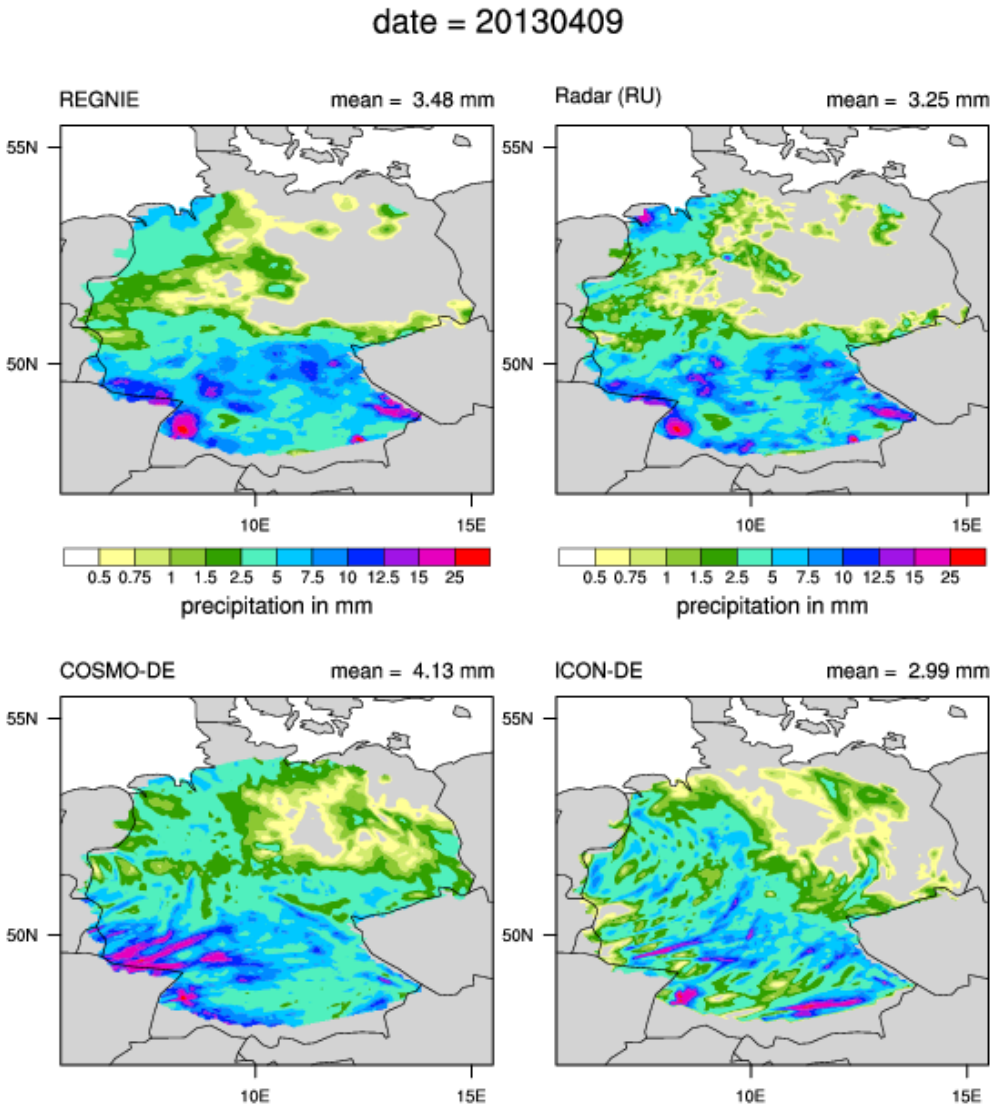
50N
10E
15E
0.5 0.75 1 1.5 2.5 5 7.5 10 12.5 15 25
precipitation in mm
COSMO-DE
mean = 4.13 mm
ICON-DE
mean = 2.47 mm

5000m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15E
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precipitation in mm
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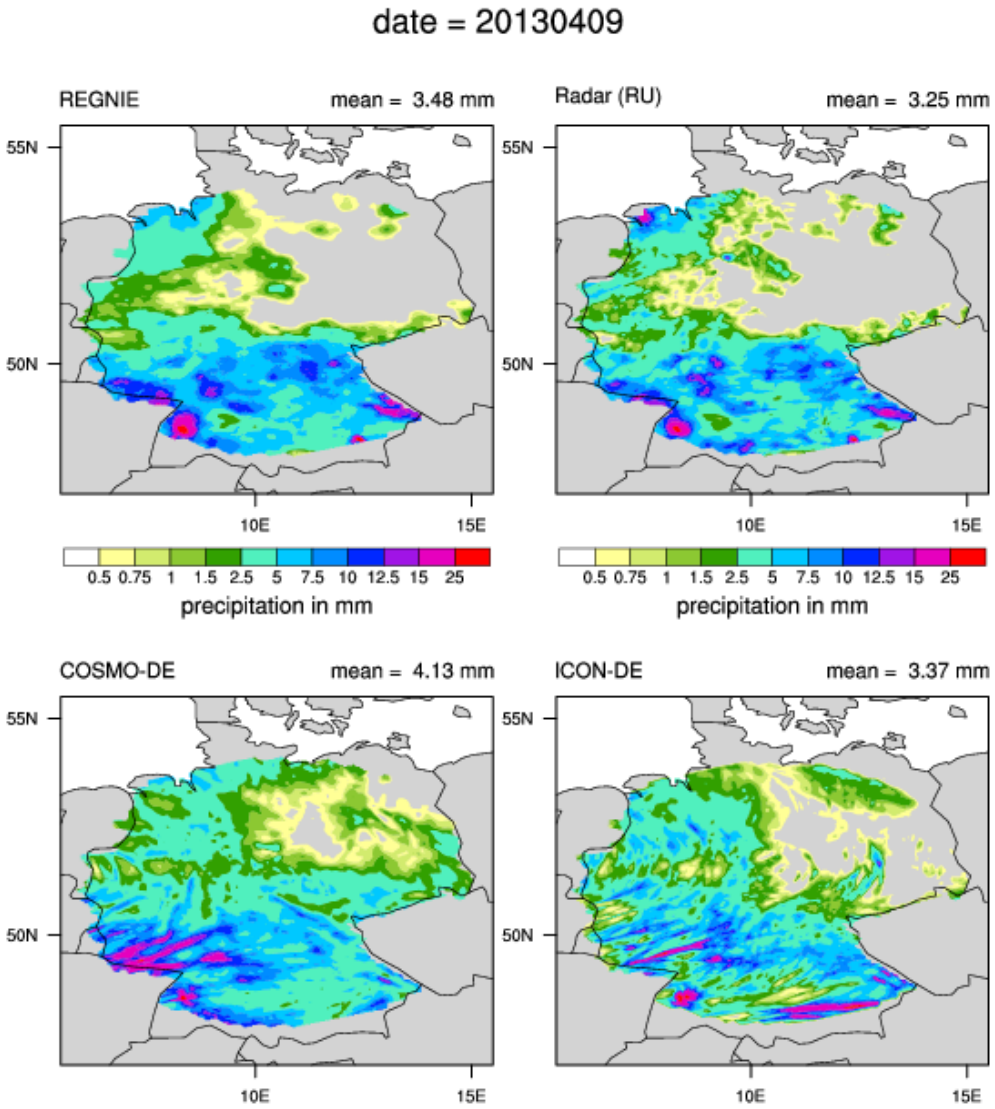
ICON-DE
mean = 2.99 mm

2500m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Radar (RU)
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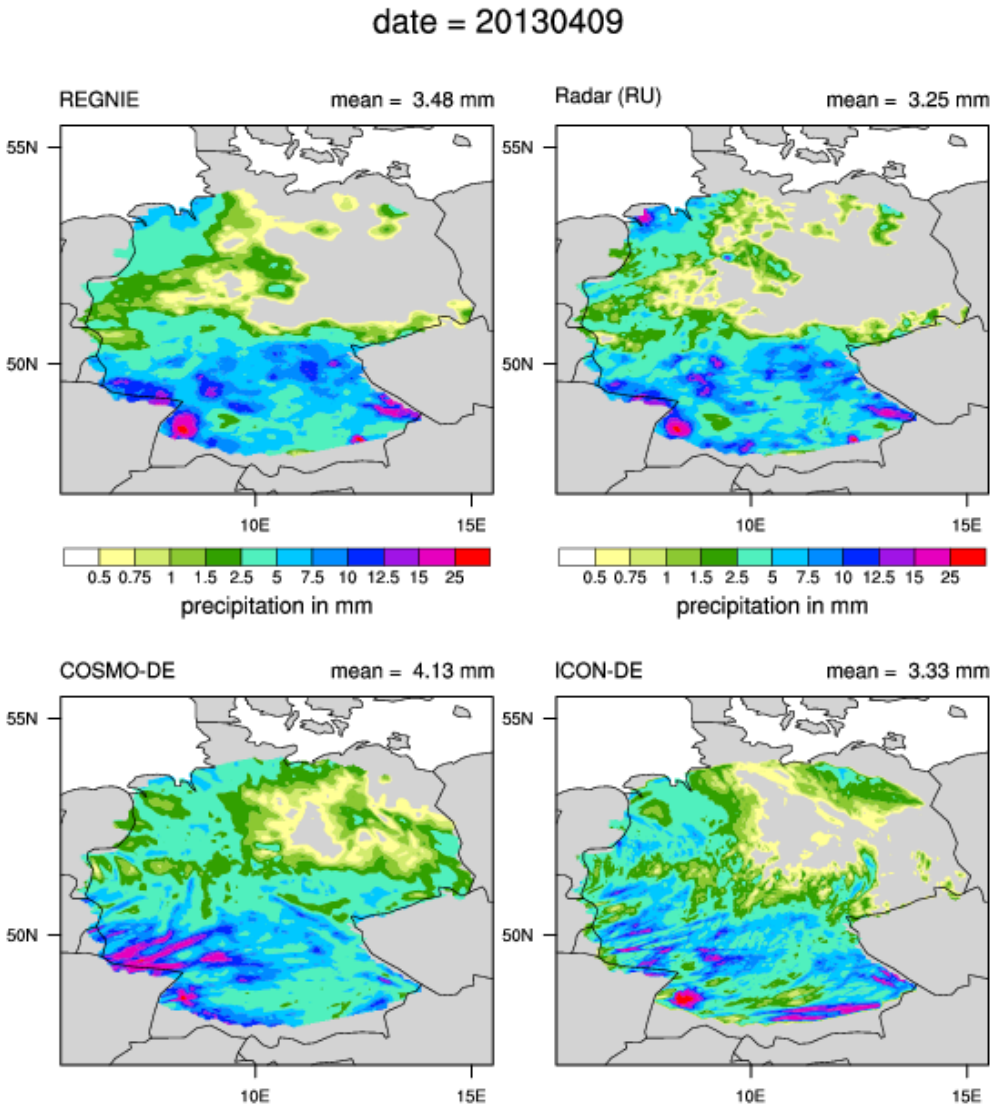
50N
10E
15E
0.5 0.75 1 1.5 2.5 5 7.5 10 12.5 15 25
precipitation in mm
COSMO-DE
mean = 4.13 mm
ICON-DE
mean = 3.37 mm

1250m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10E
15E
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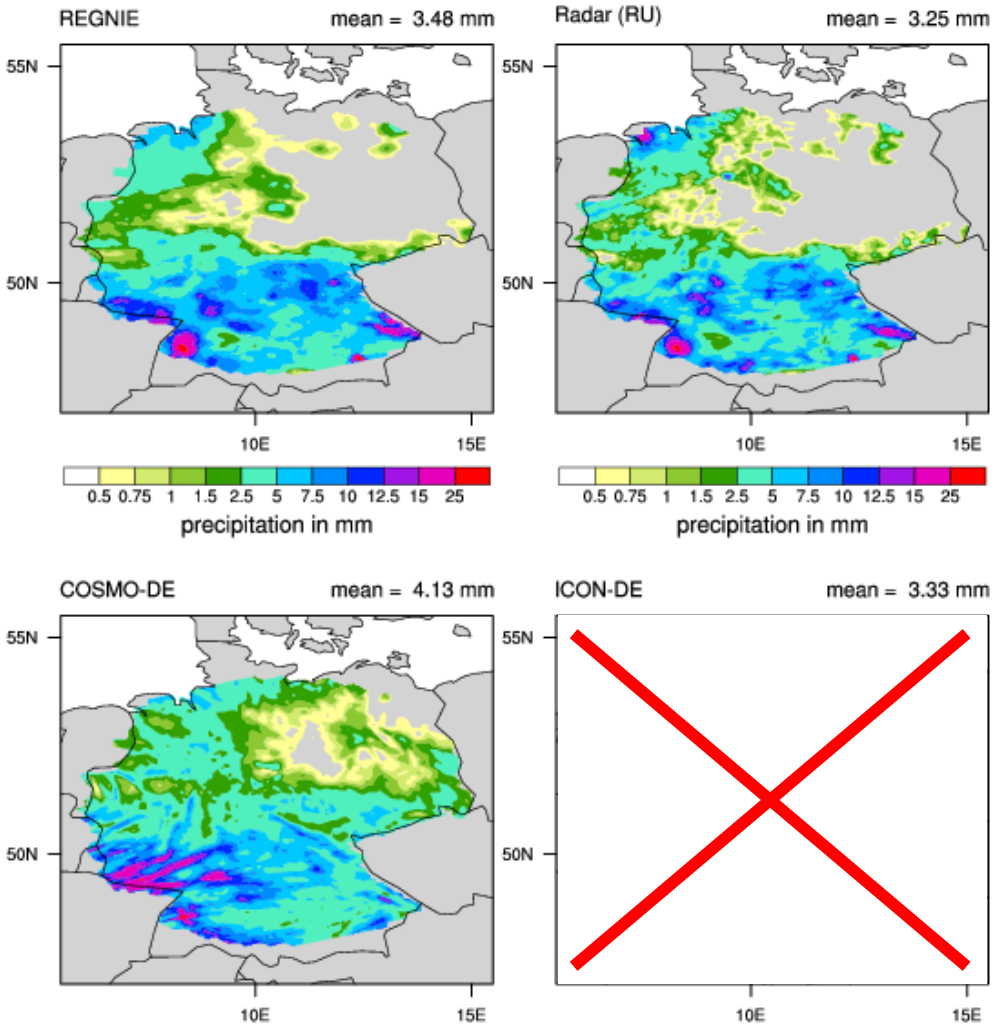
precipitation in mm
COSMO-DE
mean = 4.13 mm
ICON-DE
mean = 3.33 mm

625m

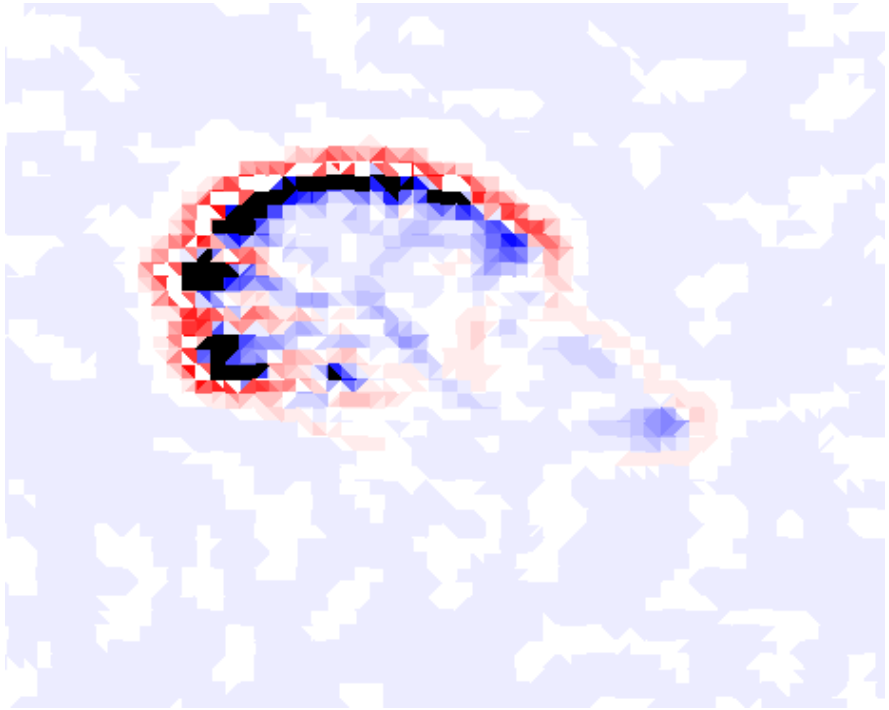
date = 20130409



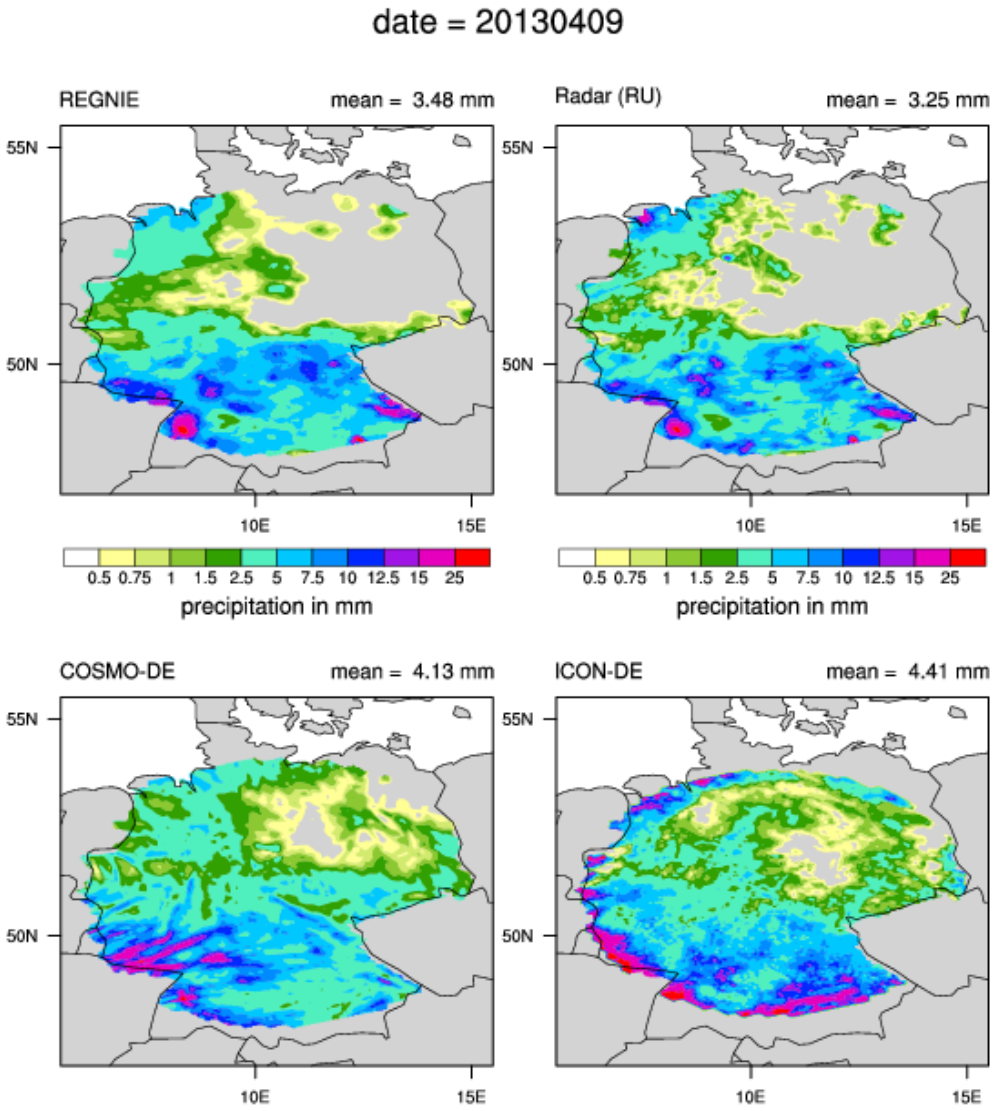
312m

3d turbulence necessary!

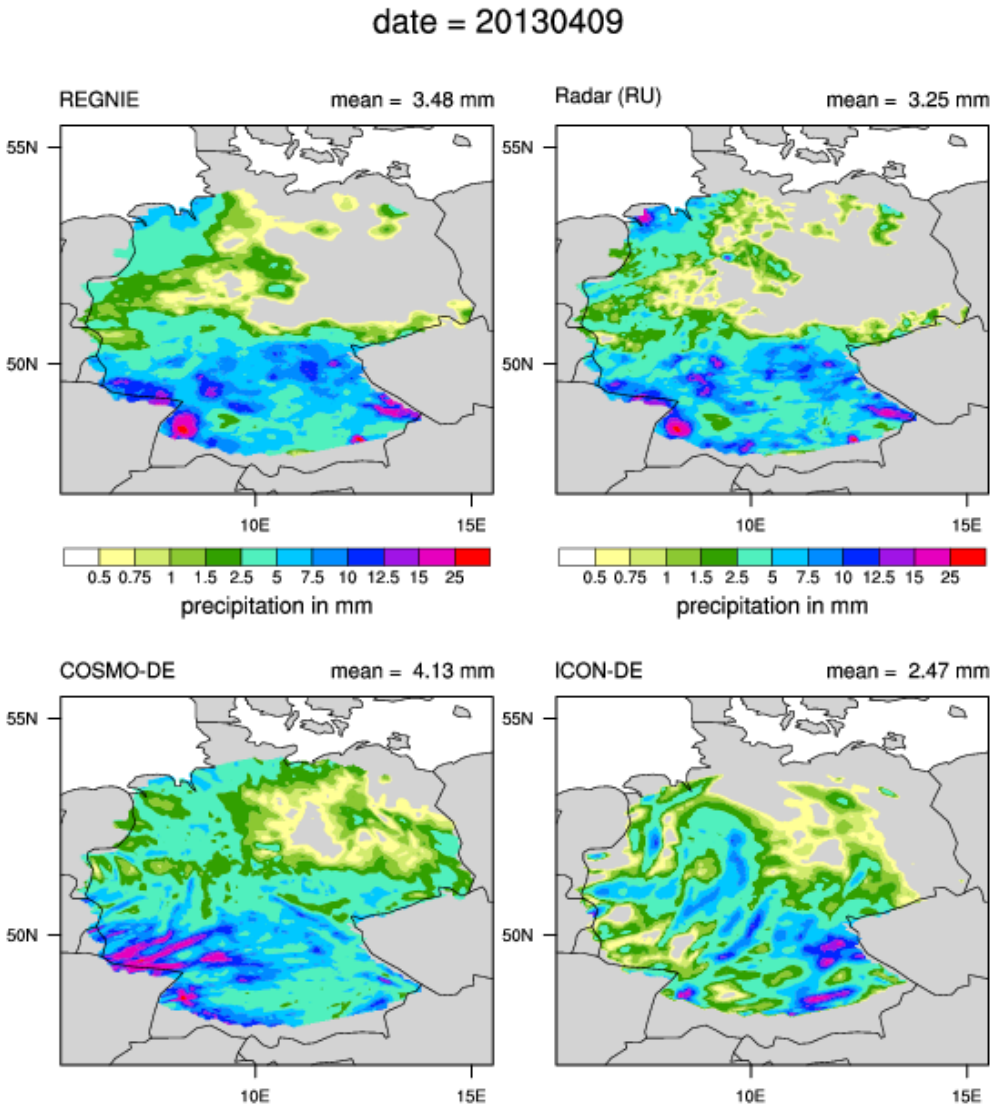
Vertical velocity [m/s] at model level 22 (~6800m)



Horizontal diffusion becomes important!



4998m: with convection parameterization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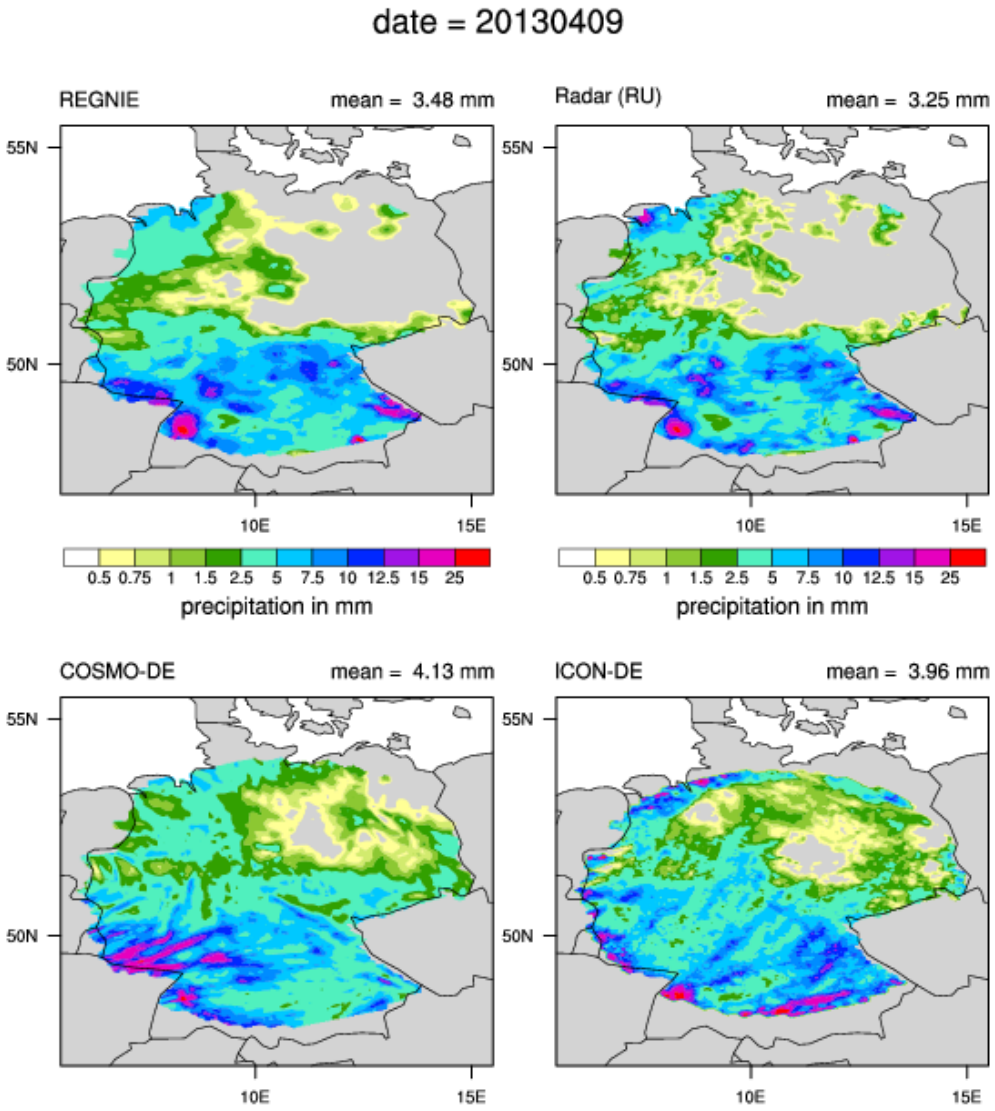
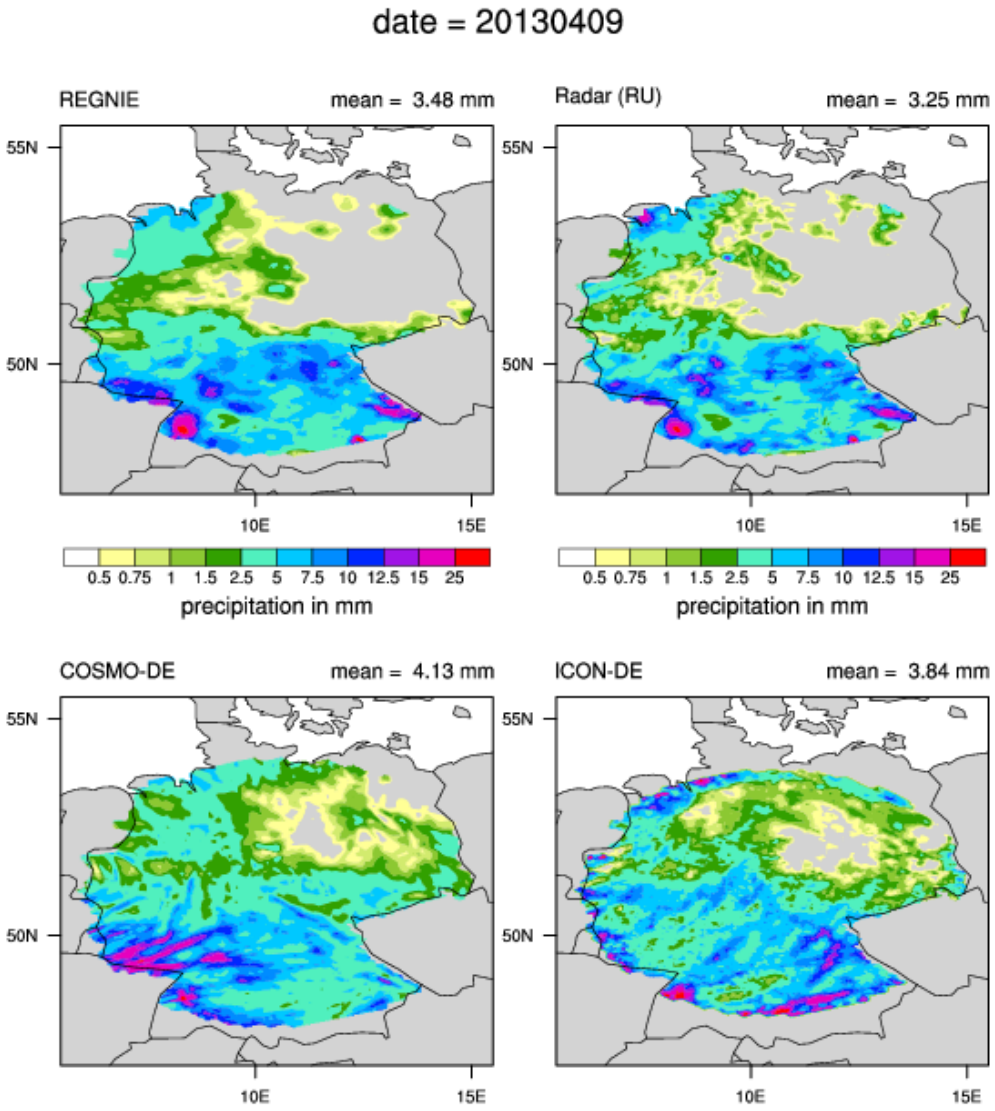
Radar (RU)
mean = 3.25 mm
55N
50N
10E
15E
0.5 0.75 1 1.5 2.5 5 7.5 10 12.5 15 25
precipitation in mm
COSMO-DE
mean = 4.13 mm
ICON-DE
mean = 2.47 mm

5000m



4998m: long adjustment time scale in CAPE closure (3h)



4998m: only shallow convection

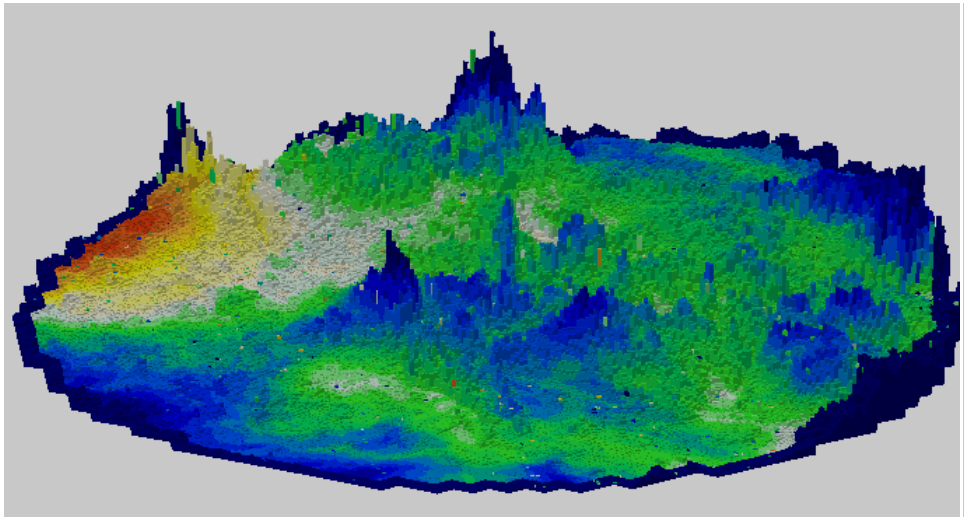
Conclusion:

- **ICON is working reasonable in limited area mode.**
- **Initialization and nudging with COSMO-DE works fine.**
- **High resolution improves the forecasts.**
- **We are getting closer to doing the fun stuff…**

Outlook:

- Make 3D turbulence work on realistic cases.
- Perform high resolution simulations as a benchmark for model development.
  - Realistic and idealized
- Utilize HOPE observation data to build confidence in ICON-LES simulations.
- Quantify uncertainty in terms of the representation of convective processes.
- Improve the representation of convective processes.
  - Also with the help of stochastic physics.

R2B10 (2500m) -Tqv



R2B11(1250m) - Tqv