Added value and land-atmosphere coupling in convection-permitting WRF climate simulations over a Middle European domain

September 7, 2016 | Klaus Goergen\textsuperscript{1,2}, Sebastian Knist\textsuperscript{2,3,4}, Stefan Kollet\textsuperscript{1,2}, Clemens Simmer\textsuperscript{3,4}, Harry Vereecken\textsuperscript{1,2}

\textsuperscript{1} Institute of Bio- and Geosciences, Agrosphere (IBG-3), Research Centre Jülich, Jülich, Germany
\textsuperscript{2} Centre for High Performance Scientific Computing in Terrestrial Systems, Geoverbund ABC/J, Jülich, Germany
\textsuperscript{3} Meteorological Institute, University of Bonn, Bonn, Germany
\textsuperscript{4} SimLab TerrSys, Jülich Supercomputing Centre, Research Centre Jülich, Jülich Germany
WRF convection-permitting runs – added value

Evaluation of precipitation

Land-atmosphere coupling

Coupling strength comparison
Motivation

Benefits of high-resolution RCM simulations

- Better capture of small scale surface heterogeneities, orography, etc.
- More realistic representation of dynamical processes, e.g. local wind systems
- Error-prone convection parameterisation (esp. deep convection) switched off
- Better reproduction of intensities, timing, spatial distribution of precipitation (e.g., Ban et al., 2014; Kendon et al., 2014; Prein et al., 2014), etc.
WRF high resolution runs at JSC/MIUB
Continuation of EURO-CORDEX simulations

- One-way **double-nesting** setup: 3 km model domain inscribed in 12 km CORDEX EUR-11 model grid, **ERA-Interim driven**, fair comparisons between resolutions
- Identical, climate-mode settings, switched-off deep convection scheme in 3 km runs
- **Time slices**: 1993-1995, 2002-2003, 2010-2013, hourly – used for this study
- Done also MPI-ESM-LR RCP4.5 downscaling (1995-2005, 2040-2050, 2090-2100)
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Example of typical precipitation event
Impact of resolution on precipitation, 3 km vs. 12 km

- Here: Typical frontal system with stratiform precipitation
- Smaller differences for grid scale precipitation
- Some local differences but spatial distribution, intensity, amounts fairly similar
Example of typical precipitation event
Impact of resolution on precipitation, 3 km vs. 12 km

- Here: Convective events during summer
- Larger differences in spatial pattern, local intensity and daily temporal evolution
- More precipitation in 12 km, smaller intensities
Evaluation of 3 km added value for precipitation
Sub-daily precipitation statistics

1096 German Weather Service (DWD) synop stations, hourly

- blue ≤ 400 m a.s.l
- green > 400 m a.s.l
- red > 900 m a.s.l

Other comparison datasets, e.g.
HErZ re-analysis
≈6 km, ≈2.2 km
(Bollmeyer et al., 2015)
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Boxes: analysis regions for Lowlands, Uplands and Alps

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Precipitation diurnal cycle during Summer Comparison to DWD station data

- Wet bias in all simulations during daytime, larger in 12 km
- Improved timing and shifted diurnal cycle of precipitation in 3 km resolution

Mean diurnal cycle averaged over all stations (nearest neighbour gridpoint)

JJA, 9 years

Including dry days
Precipitation diurnal cycle during Summer
Topography-related differences (analysis boxes)

**Entire domain**
- Larger shift in mountains
- Higher amplitude in 12 km

**Lowlands**
- Small differences during daytime for lowlands

**Uplands**

**Alps**
- Larger shift in mountains
- Higher amplitude in 12 km
Hourly precipitation distribution and extremes
Comparison to DWD station data, Summer

Added value of 3 km WRF most obvious in terms of intensity and amount in frequency distribution

- Wet bias of 12 km WRF: too much light rain (< 1 mm/hr)
- Underestimation of heavy precip (> 5 mm/hr)

3 km WRF on 12 km grid also improved
Hourly precipitation distribution and extremes
Comparison to DWD station data, Winter

Hourly precipitation distribution, all GP where synop stations, DJF

<table>
<thead>
<tr>
<th>Percentile</th>
<th>90</th>
<th>99</th>
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<tr>
<td>WRF12</td>
<td>0.33</td>
<td>1.70</td>
<td>3.39</td>
<td>4.29</td>
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<tr>
<td>WRF3_12</td>
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<td>6.07</td>
</tr>
<tr>
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Prevailing stratiform precipitation
Smaller differences, still wet bias with all resolutions during winter

3 km WRF matches extremes better

DJF, 9 years
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3 km WRF matches extremes better

DJF, 9 years

Wet bias remains, less in 3 km during Summer

3 km WRF (also interpolated to 12 km) is closer to observation pdf during Summer and Winter
WRF convection-permitting runs – added value

Evaluation of precipitation

**Land-atmosphere coupling**

Coupling strength comparison
Land-atmosphere coupling analysis
Connection of (sub-)surface to the atmosphere

Terrestrial segment of feedback loop:
Sensitivity of surface fluxes to soil moisture states
Focus here: soil moisture-temperature coupling (e.g., relevant for heat waves)
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Different integrative metrics for coupling strength: e.g. correlation of sensible and latent heat flux (alternative, e.g., corr(T2,LE))
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**Corr. of latent and sensible heat flux, JJA, FLUXNET**

Strong coupling: corr(H,LE) < 0
weak coupling energy limited

strong coupling moisture limited
Coupling strength corr(H,LE), 3 km WRF, JJA
Contrasting individual years
Coupling strength $\text{corr}(H, \text{LE})$, 3 km WRF, JJA

Contrasting individual years

Contrasting years: 2002, wet, cloudy (weak coupling) vs. 2003, dry, hot (strong coupling) with heat wave in August

Cooler, more moist mountain areas stand out
Coupling strength corr(H,LE), 3 km WRF, JJA

Contrasting individual years

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2002, wet, cloudy (weak coupling) vs.
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Cooler, more moist mountain areas stand out

Large inter-annual variability consistent with weather conditions in the individual years
Coupling strength, 3 km WRF, JJA, 2002 vs. 2003
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Additional cpl. strength metric
\( I_c = \beta_{LE,sm} \sigma_{sm} \)
Dirmeyer (2011)

sdv soil moisture *
linear regression
soil moisture and LE
Coupling strength, 3 km WRF, JJA, 2002 vs. 2003

2002

2003

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Surface characteristics
more pronounced

E.g., weaker coupling
of cooler, more moist
forest areas
Coupling strength, 3 km WRF, JJA, 2002 vs. 2003

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Surface characteristics more pronounced

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Consistent with H-LE correlation method

Large contrast for different landuse types
Coupling strength, JJA, 2003, 12 km vs. 3 km

Impact of surface heterogeneity
**Coupling strength, JJA, 2003, 12 km vs. 3 km**

![WRF 12 km](image1)

![WRF 3 km](image2)

Impact of surface heterogeneity
Coupling strength, JJA, 2003, 12 km vs. 3 km

WRF 12 km

WRF 3 km

Impact of surface heterogeneity

Stronger cpl. in 3 km resolution

Consistent with wetter conditions (more rain) in 12 km run
Coupling strength, JJA, 2003, 12 km vs. 3 km

Impact of surface heterogeneity

Sensitivity studies with combinations of coarse and fine resolution soil, landuse and orography ongoing; explore interactions further

Stronger cpl. in 3 km resolution

Consistent with wetter conditions (more rain) in 12 km run
Summary and outlook

- **WRF convection-permitting evaluation runs** (3 km, Central Europe)
  - Added value of convection-permitting resolution
  - Better reproduction of sub-daily precipitation statistics
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  - Large interannual variability for Central Europe consistent with climate conditions
  - Slightly stronger coupling in 3 km resolution, needs further investigation
Summary and outlook

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- **Ongoing**
  - Influence of land use and its heterogeneity on land-atmosphere coupling, sensitivity studies, low vs. high-resolution soil, vegetation, topography data
  - High-resolution climate change control and projection runs (MPI-ESM RCP 4.5 downscaling, 1993-2005, 2038-2050, 2088-2100) – analysis pending
  - Coupling strength in context of climate change in EURO-CORDEX RCM ensemble future scenario runs
  - Link to EURO-CORDEX FPS “Convective phenomena at high resolution over Europe and the Mediterranean”
Other ongoing CPM activities and an open position

k.goergen@fz-juelich.de
www.hpsc-terrsys.de

Vacancy:

Experienced PostDoc as Scientific Coordinator of SimLab Terrestrial Systems at Juelich Supercomputing Centre

www.geoverbund.de

Closing: 30 September 2016