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

September 7, 2016 | Klaus Goergen[1,2], Sebastian Knist[2,3,4], Stefan Kollet[1,2],
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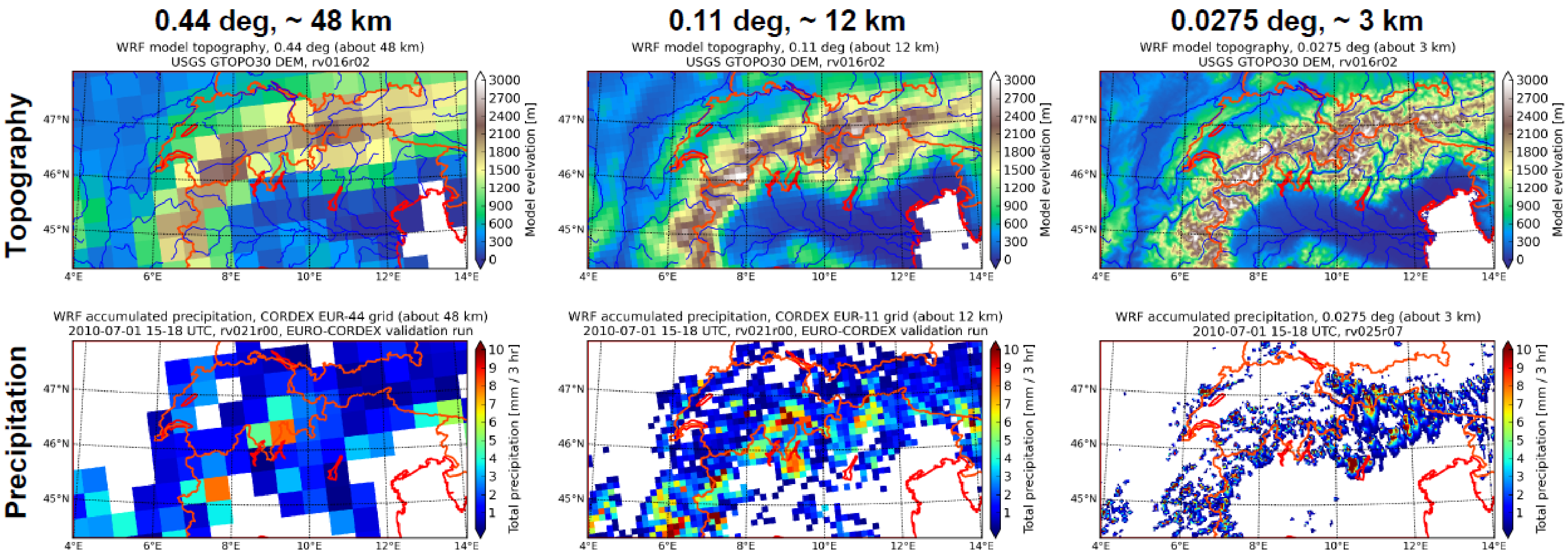
WRF convection-permitting runs – added value

Evaluation of precipitation

Land-atmosphere coupling

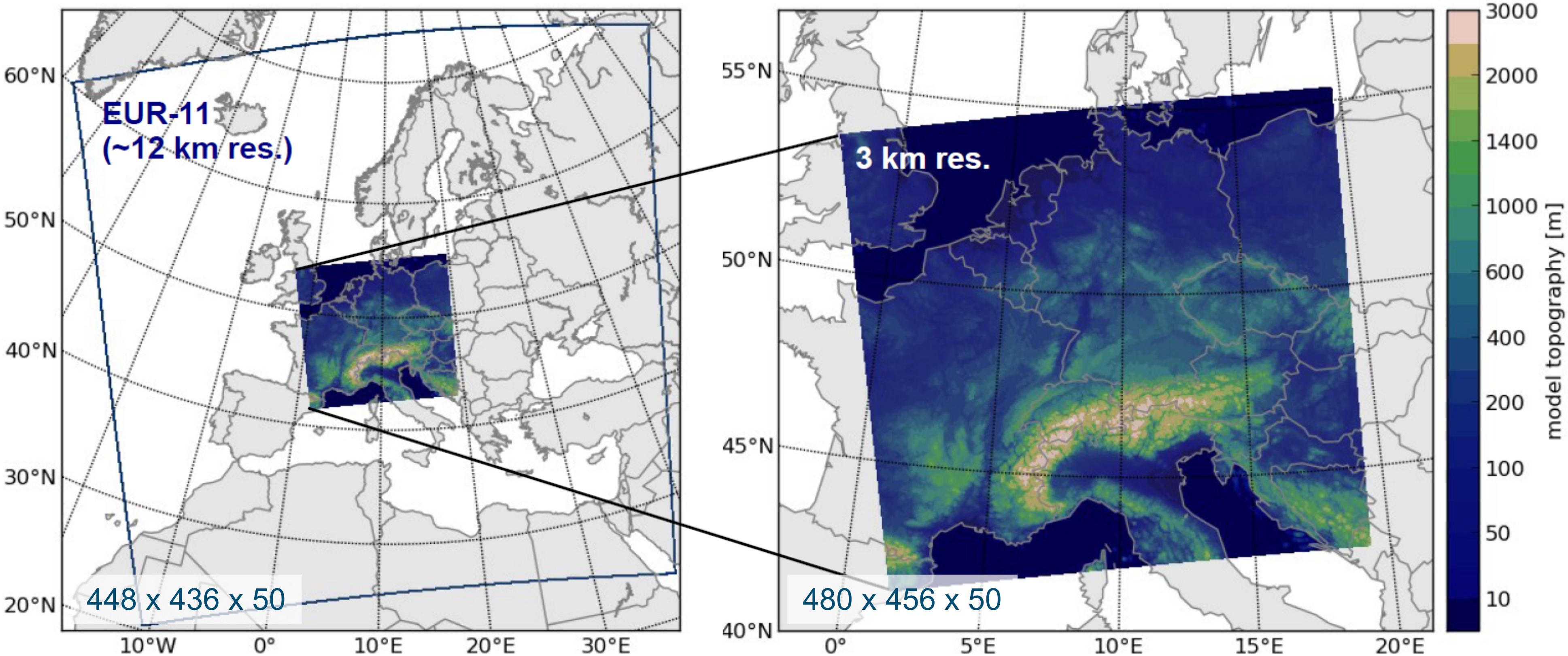
Coupling strength comparison

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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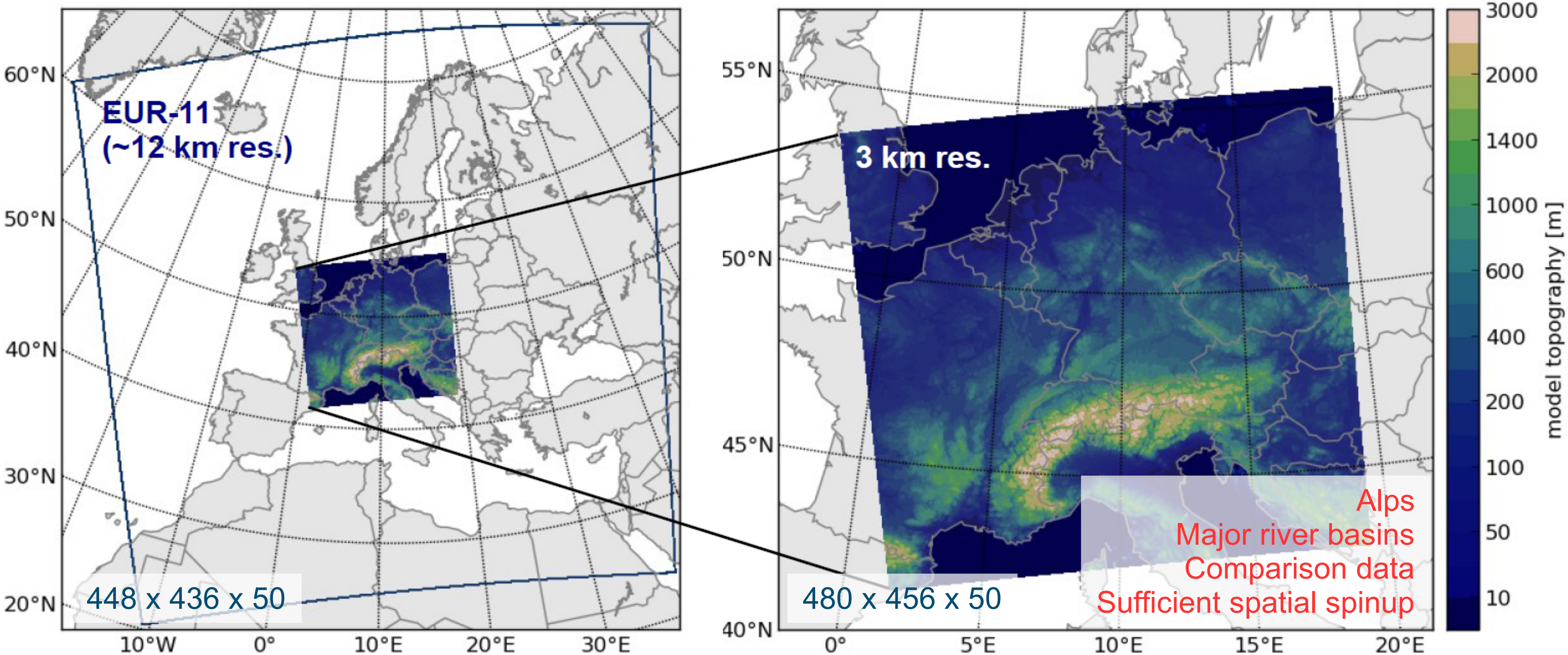

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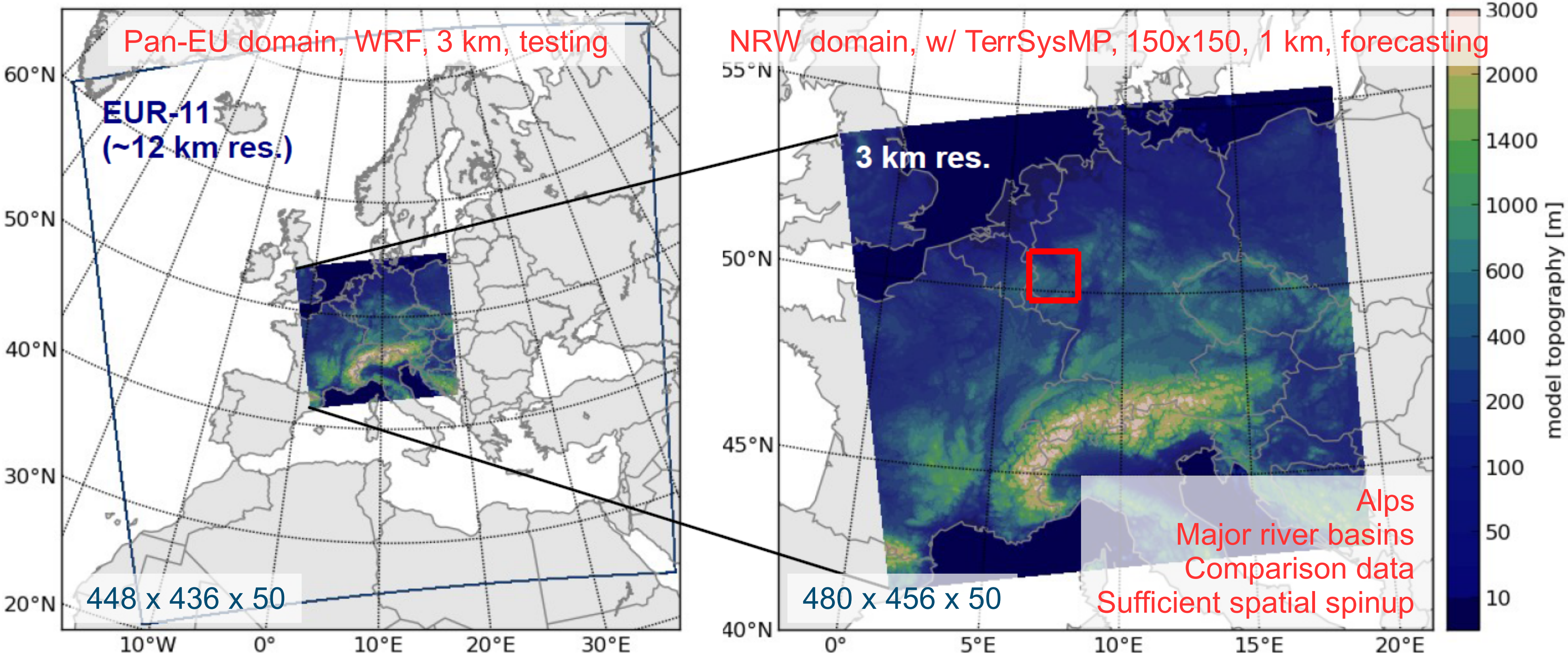

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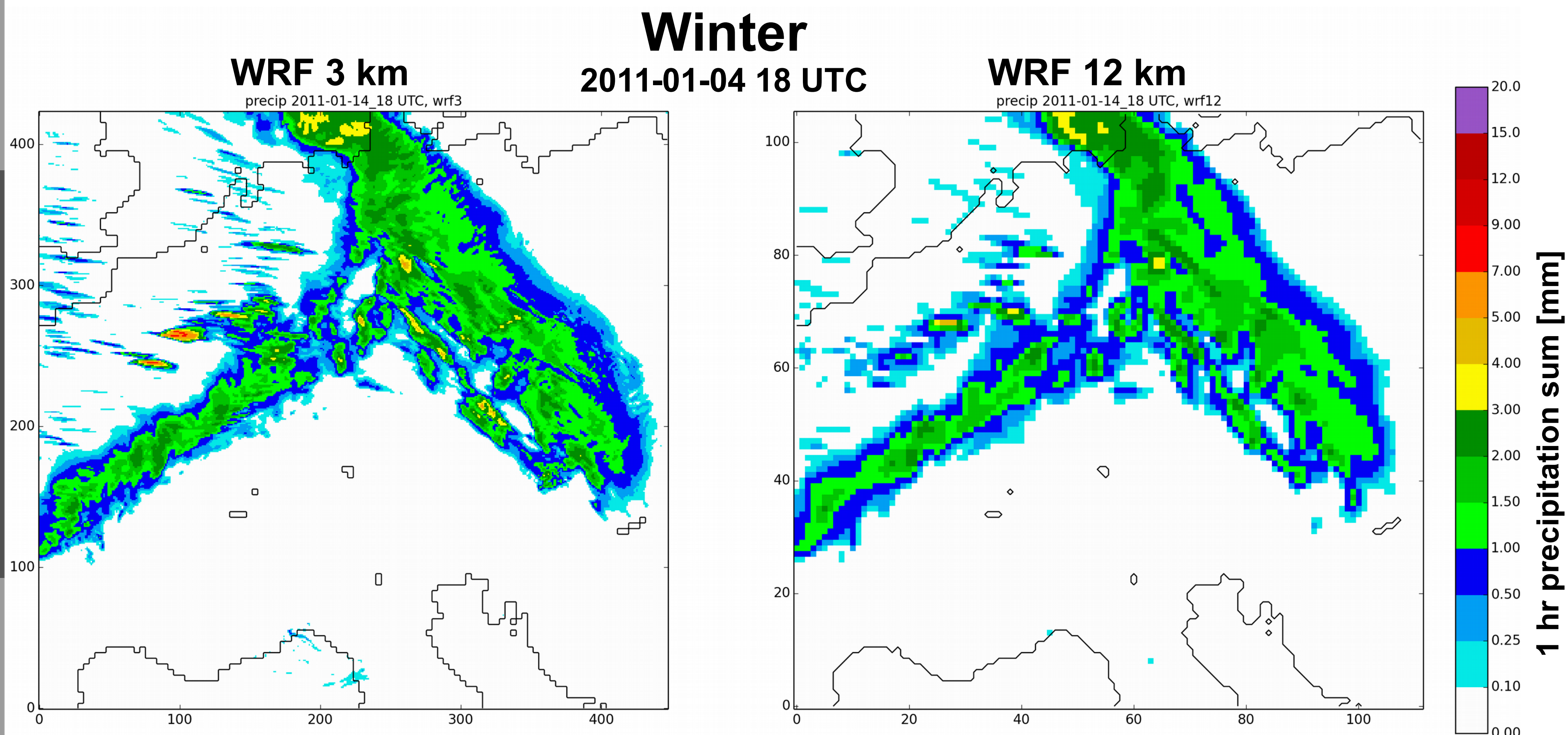
Example of typical precipitation event
Impact of resolution on precipitation, 3 km vs. 12 km



- Here: Typical frontal system with stratiform precipitation
- Smaller differences for grid scale precipitation
- Some local differences but spatial distribution, intensity, amounts fairly similar

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Example of typical precipitation event
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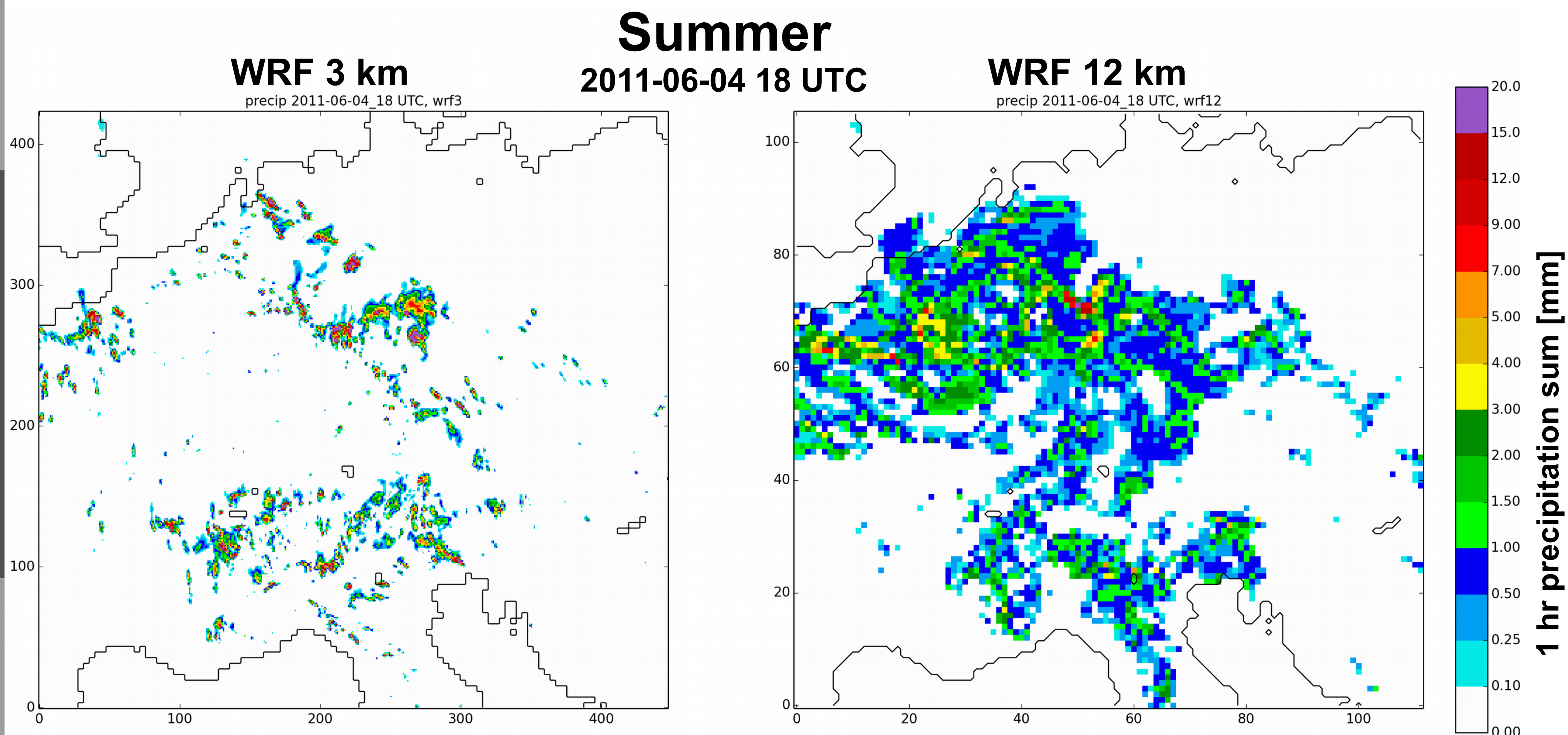
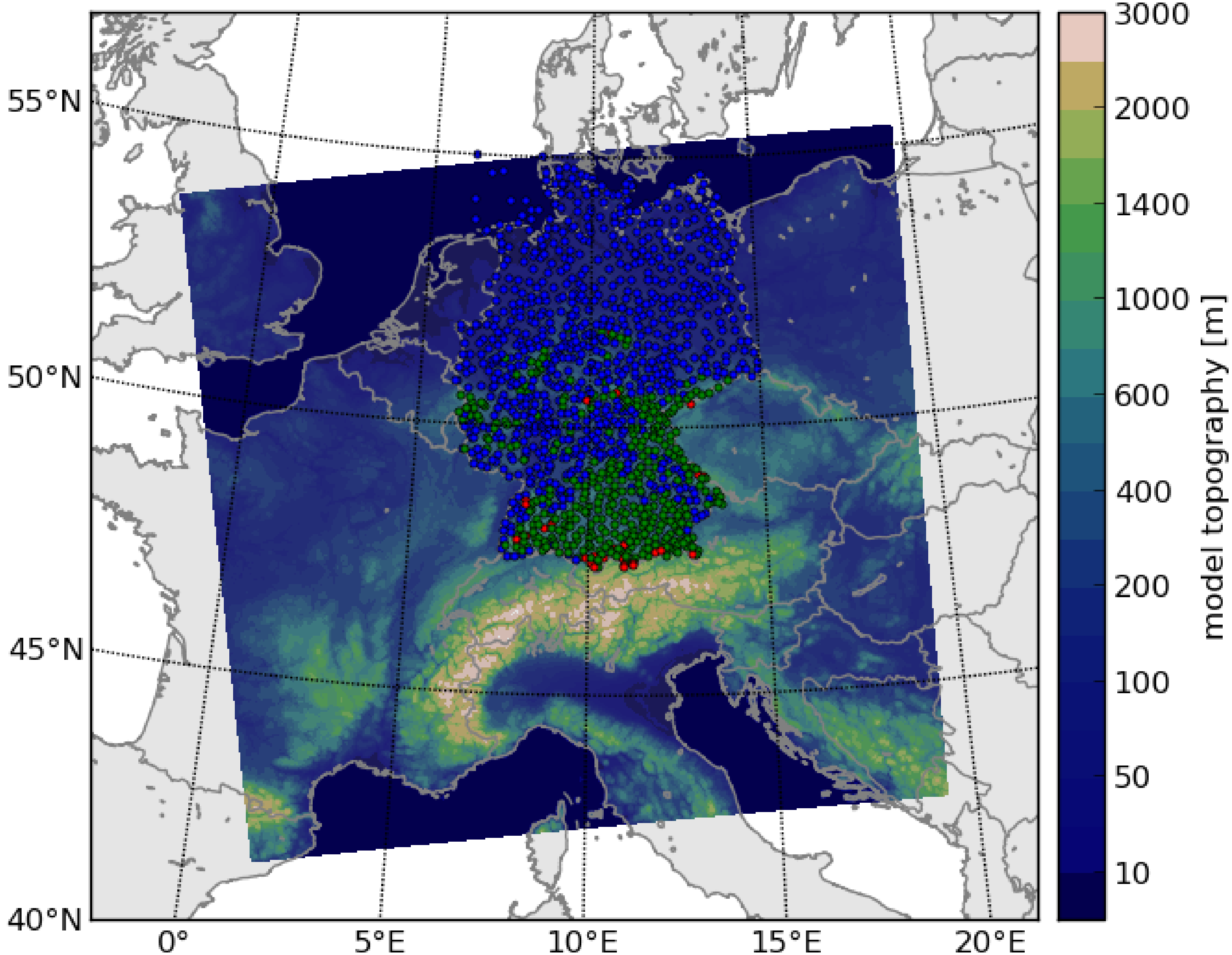


- Here: Convective events during summer
- Larger differences in spatial pattern, local intensity and daily temporal evolution
- More precipitation in 12 km, smaller intensities

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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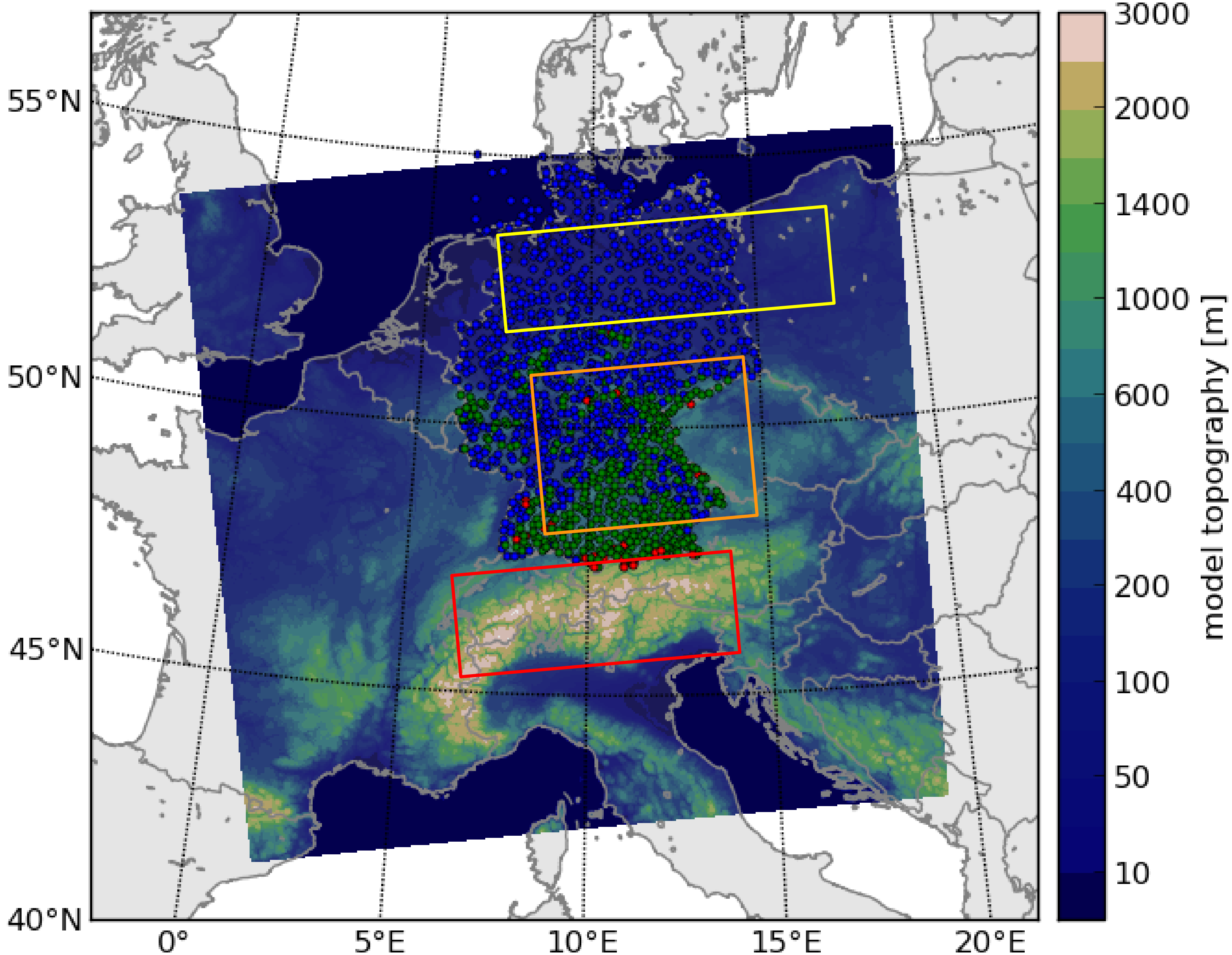

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Boxes: analysis regions for Lowlands, Uplands and Alps

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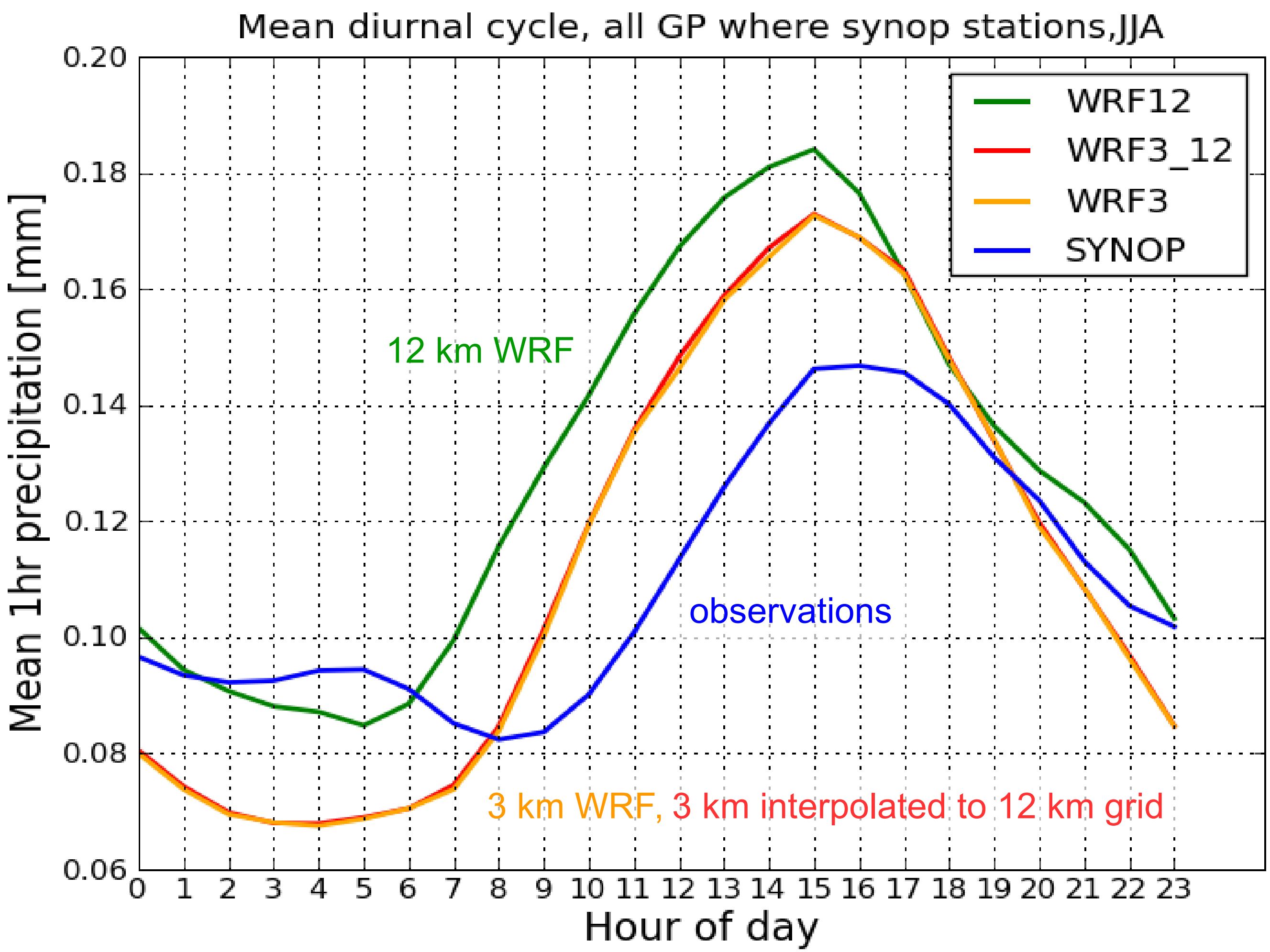
Precipitation diurnal cycle during Summer Comparison to DWD station data



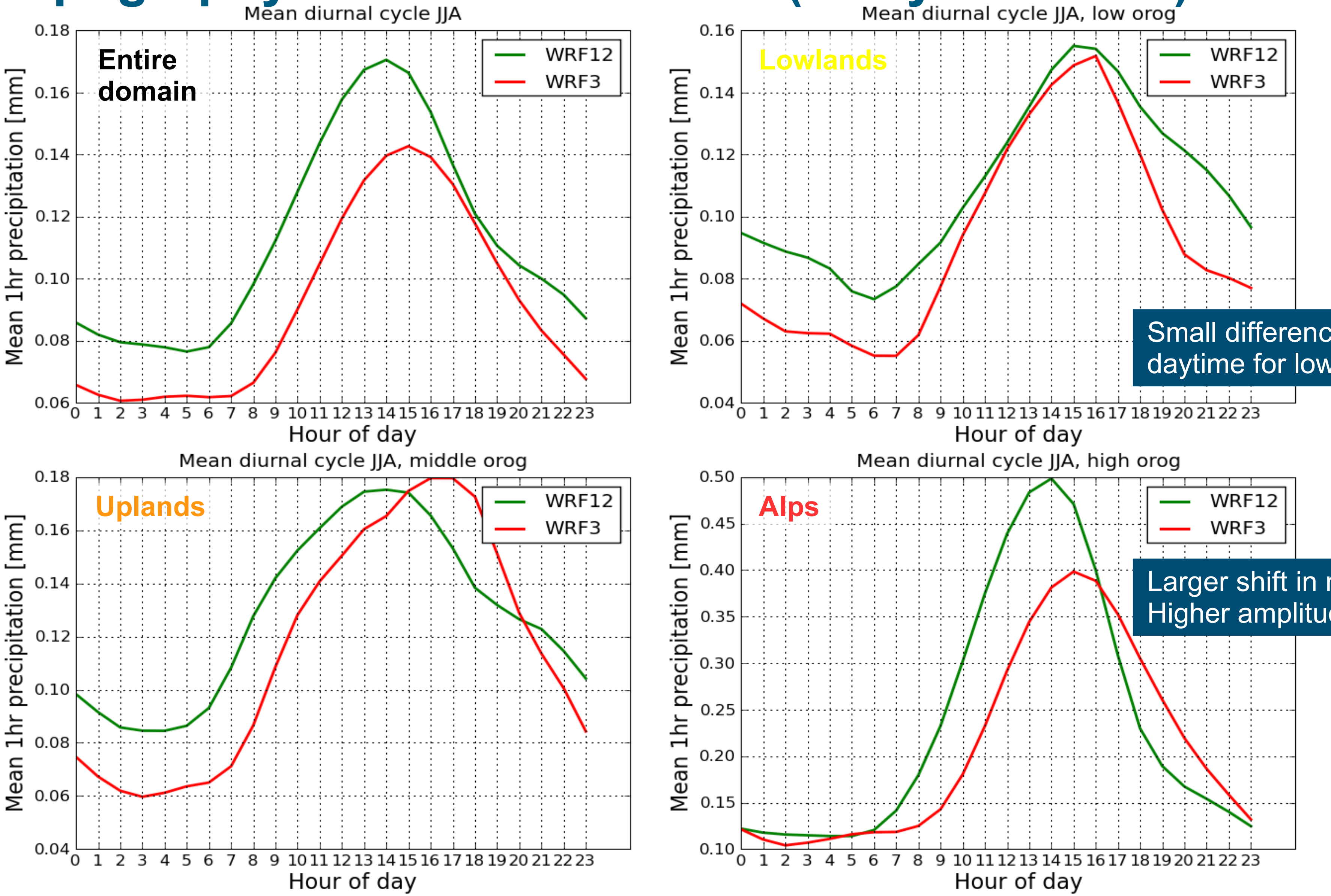
Mean diurnal cycle averaged over all stations
(nearest neighbour gridpoint)

JJA, 9 years

Including dry days

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

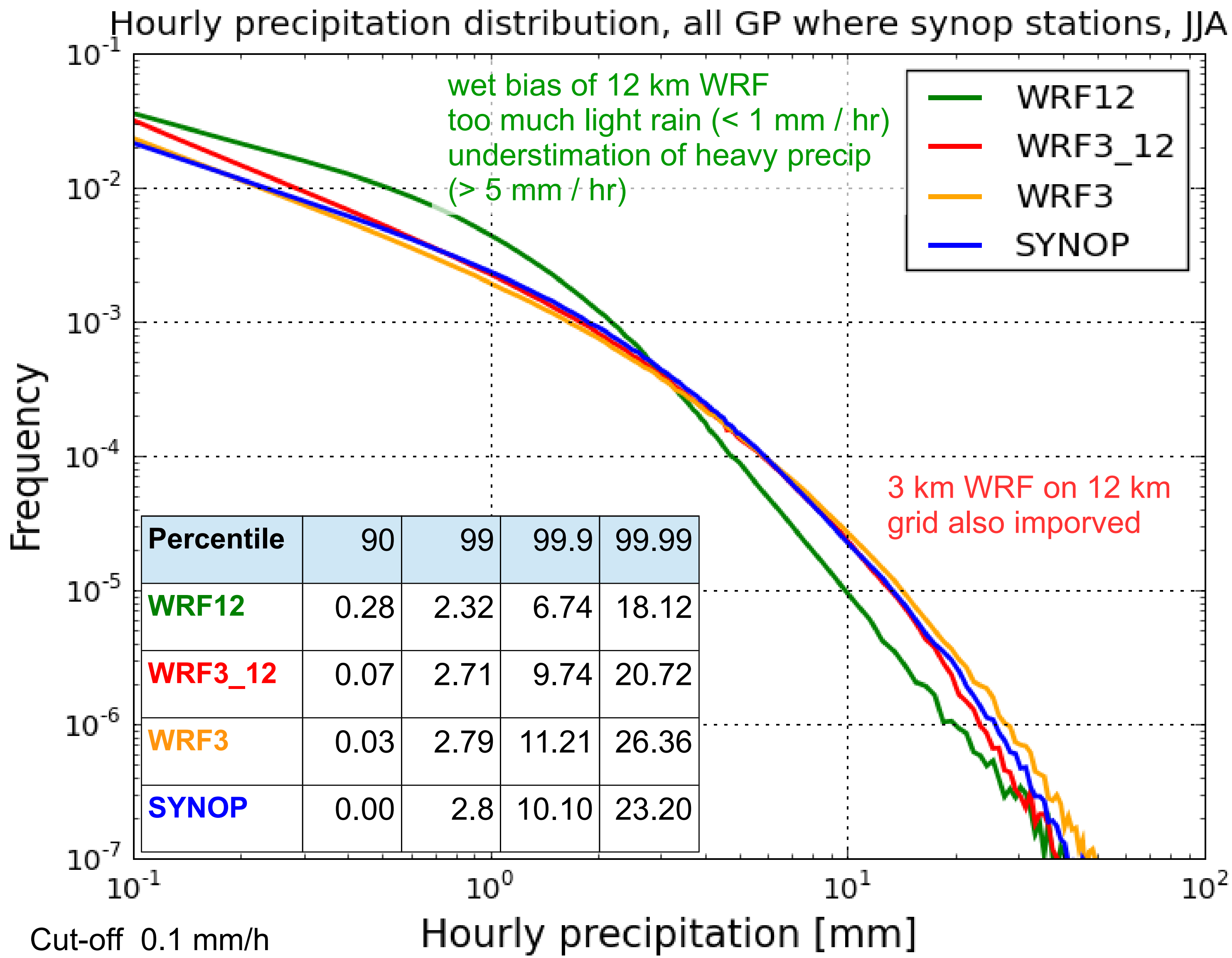
Precipitation diurnal cycle during Summer
Topography-related differences (analysis boxes)



Small differences during daytime for lowlands

Larger shift in mountains
Higher amplitude in 12 km

Hourly precipitation distribution and extremes Comparison to DWD station data, Summer



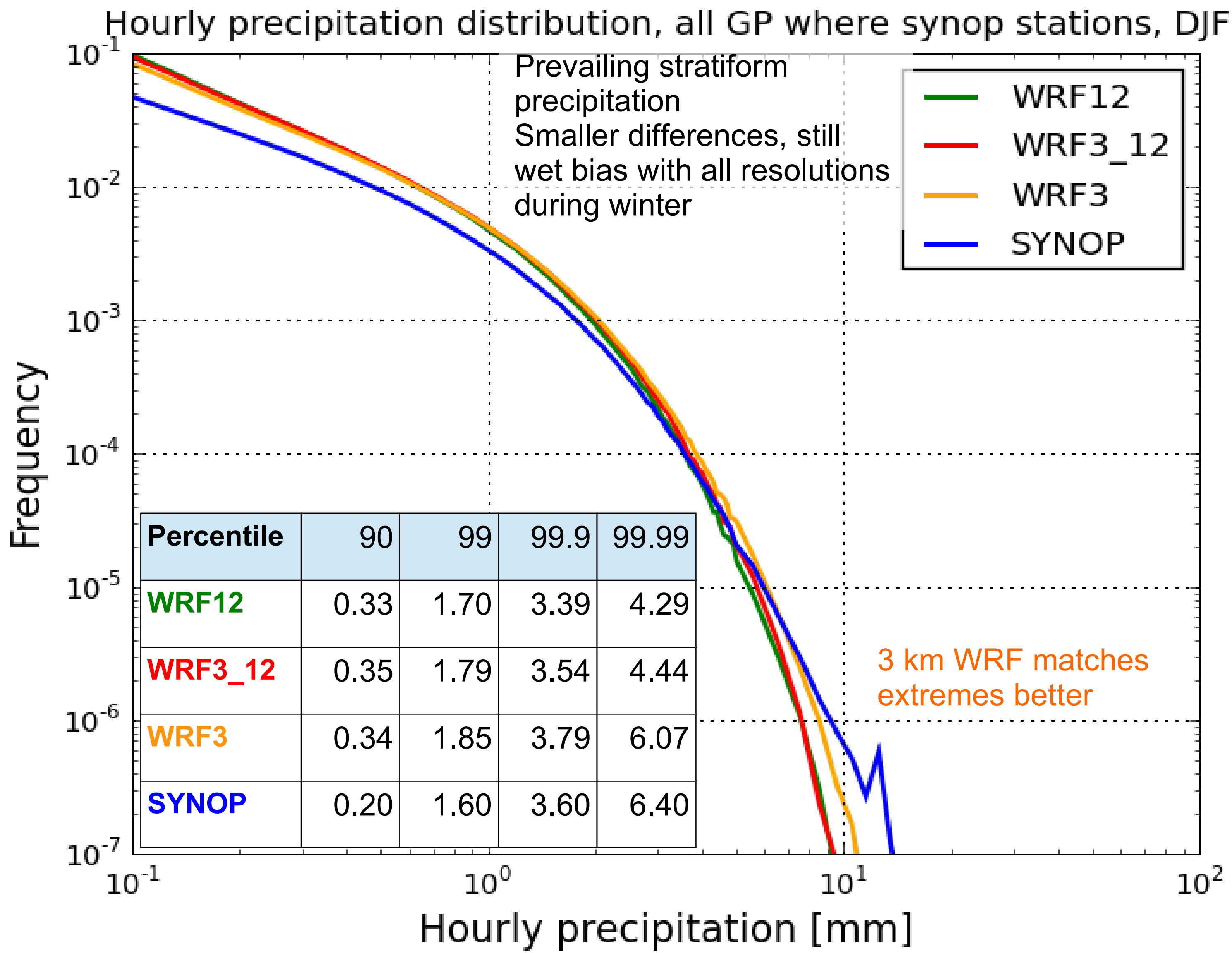
Percentile	90	99	99.9	99.99
WRF12	0.28	2.32	6.74	18.12
WRF3_12	0.07	2.71	9.74	20.72
WRF3	0.03	2.79	11.21	26.36
SYNOP	0.00	2.8	10.10	23.20

Cut-off 0.1 mm/h

JJA, 9 years

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

Hourly precipitation distribution and extremes Comparison to DWD station data, Winter



Percentile	90	99	99.9	99.99
WRF12	0.33	1.70	3.39	4.29
WRF3_12	0.35	1.79	3.54	4.44
WRF3	0.34	1.85	3.79	6.07
SYNOP	0.20	1.60	3.60	6.40

DJF, 9 years

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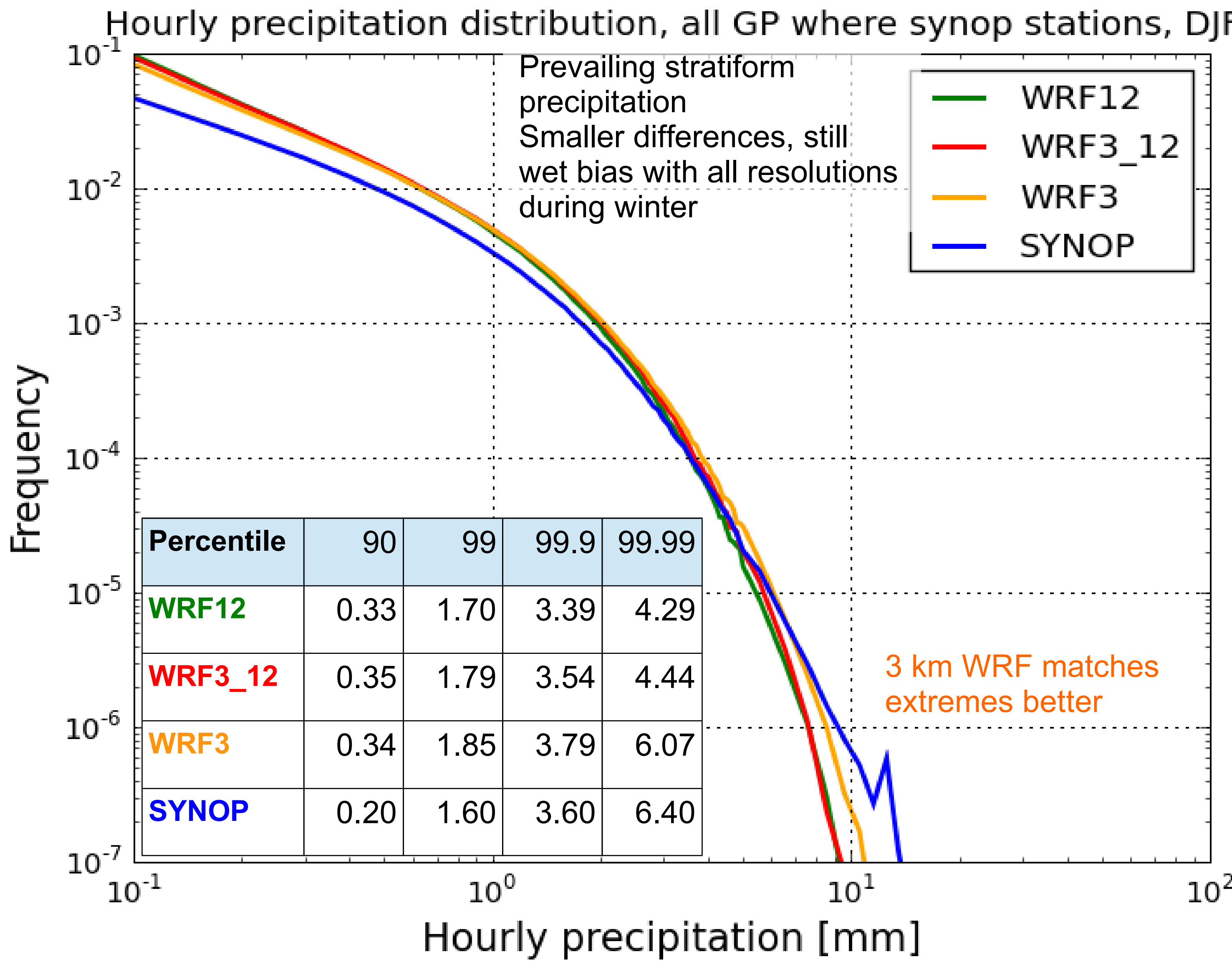

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DJF, 9 years

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

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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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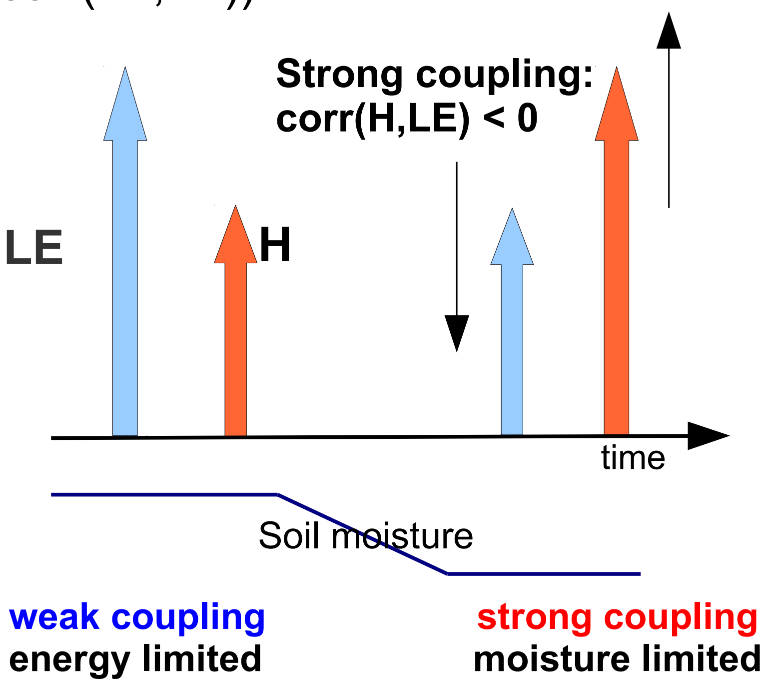
Different integrative metrics for coupling strength: e.g. correlation of sensible and latent heat flux (alternative, e.g., corr(T2,LE))



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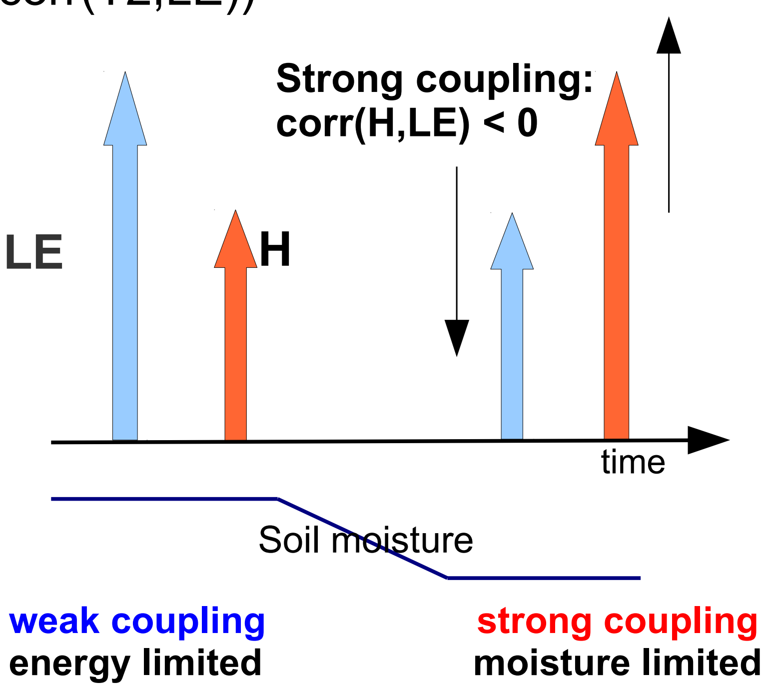
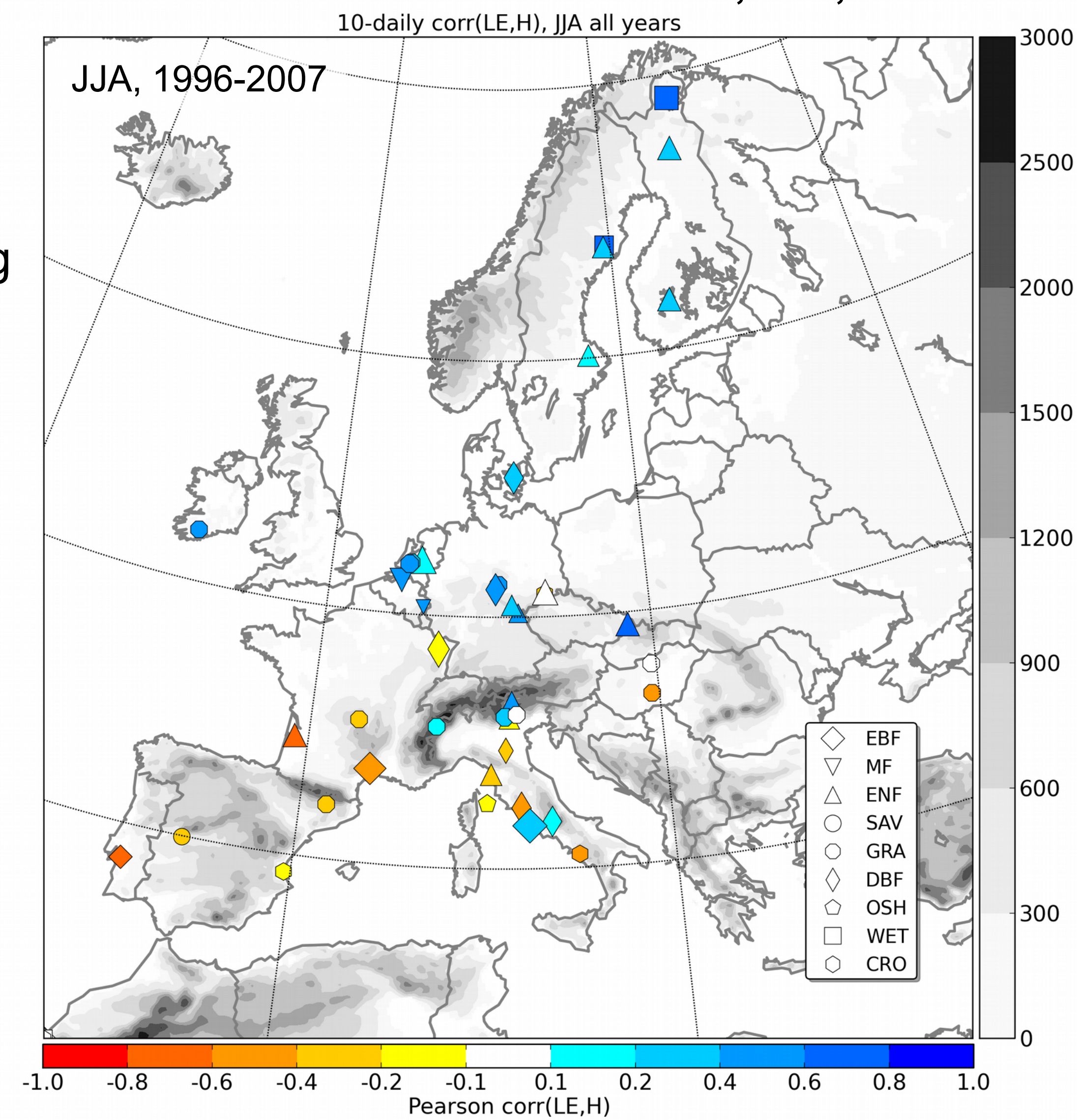
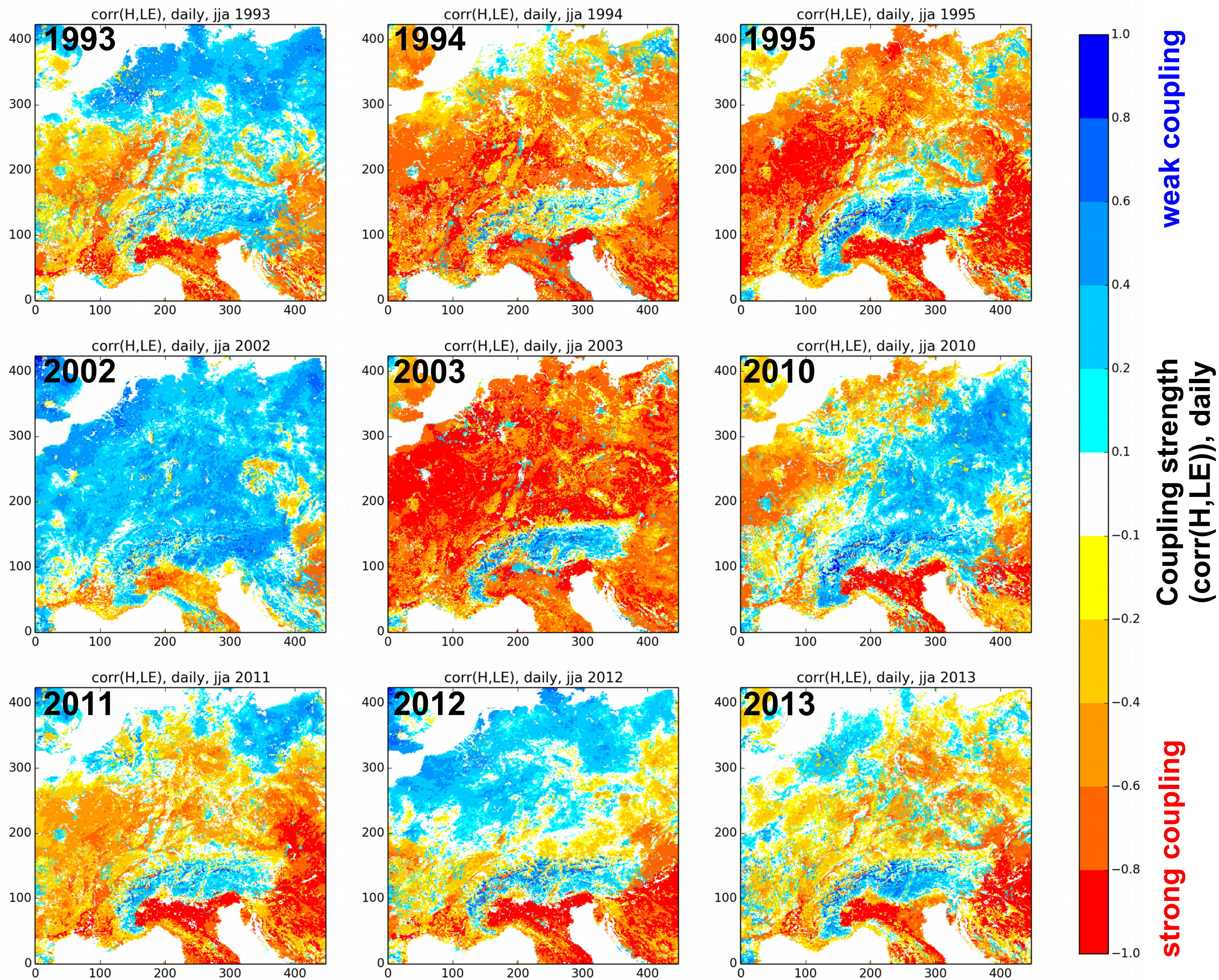


Corr. of latent and sensible heat flux, JJA, FLUXNET



Coupling strength corr(H,LE), 3 km WRF, JJA
Contrasting individual years



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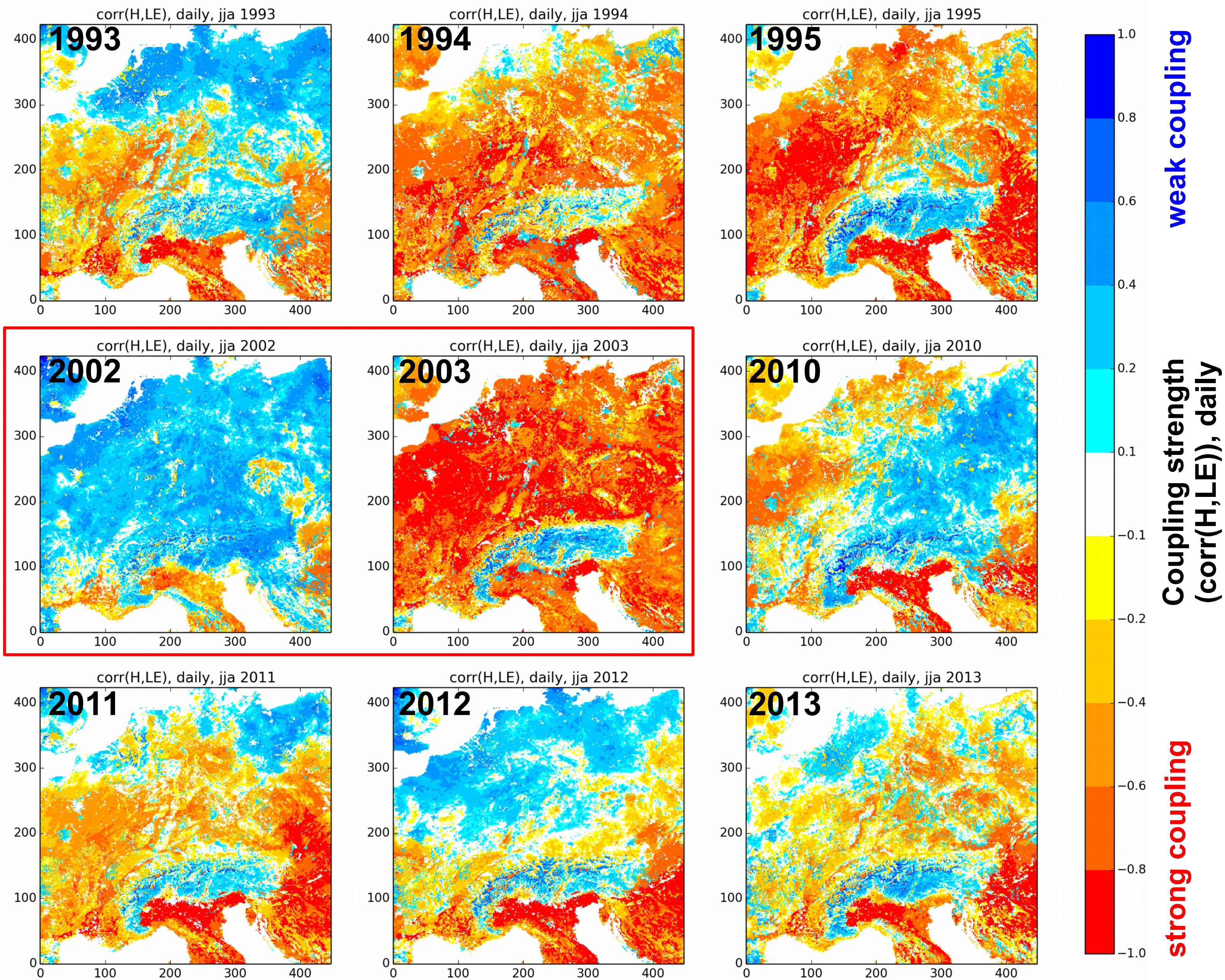

Contrasting years:
2002, wet, cloudy (weak coupling)
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Cooler, more moist mountain areas stand out

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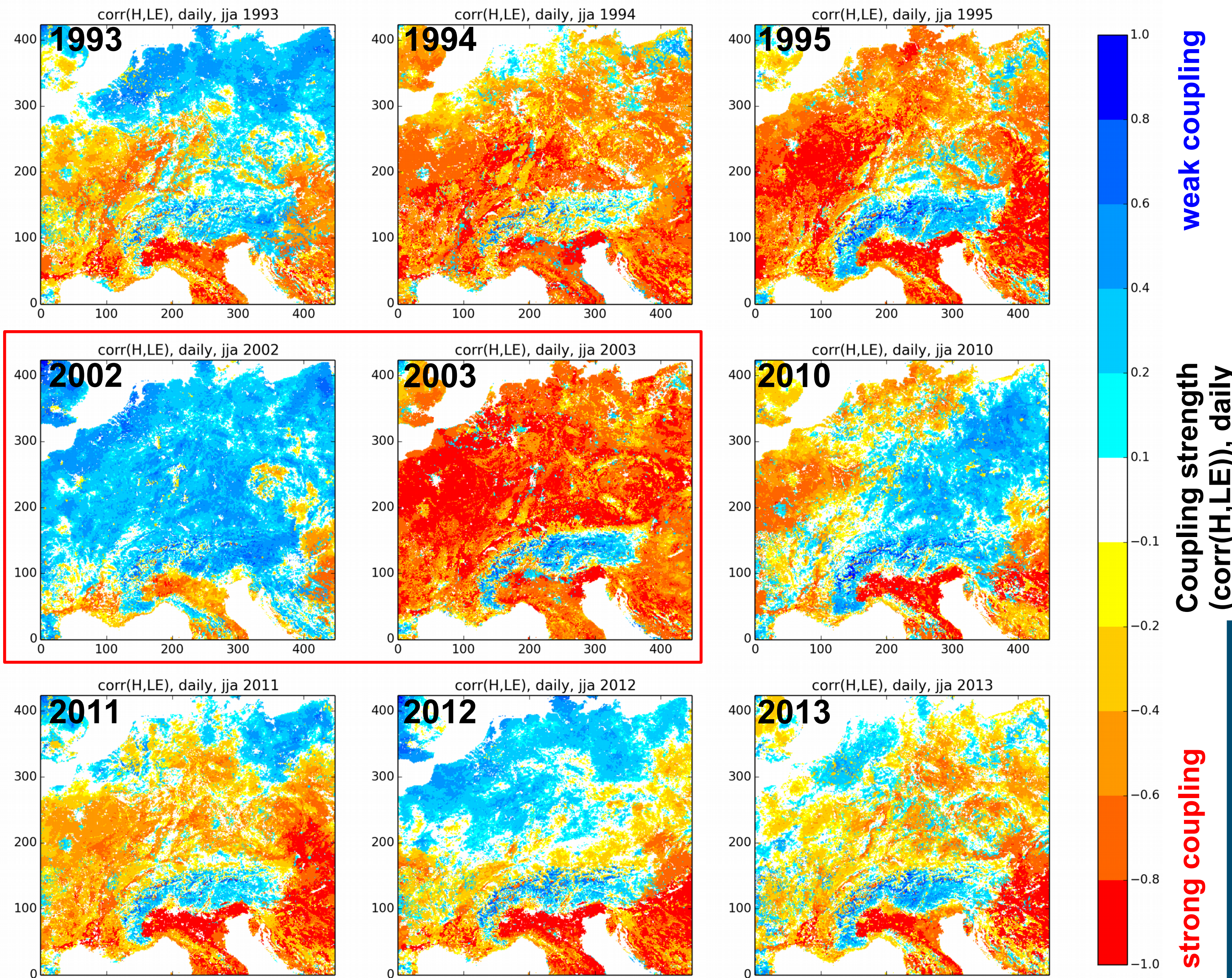

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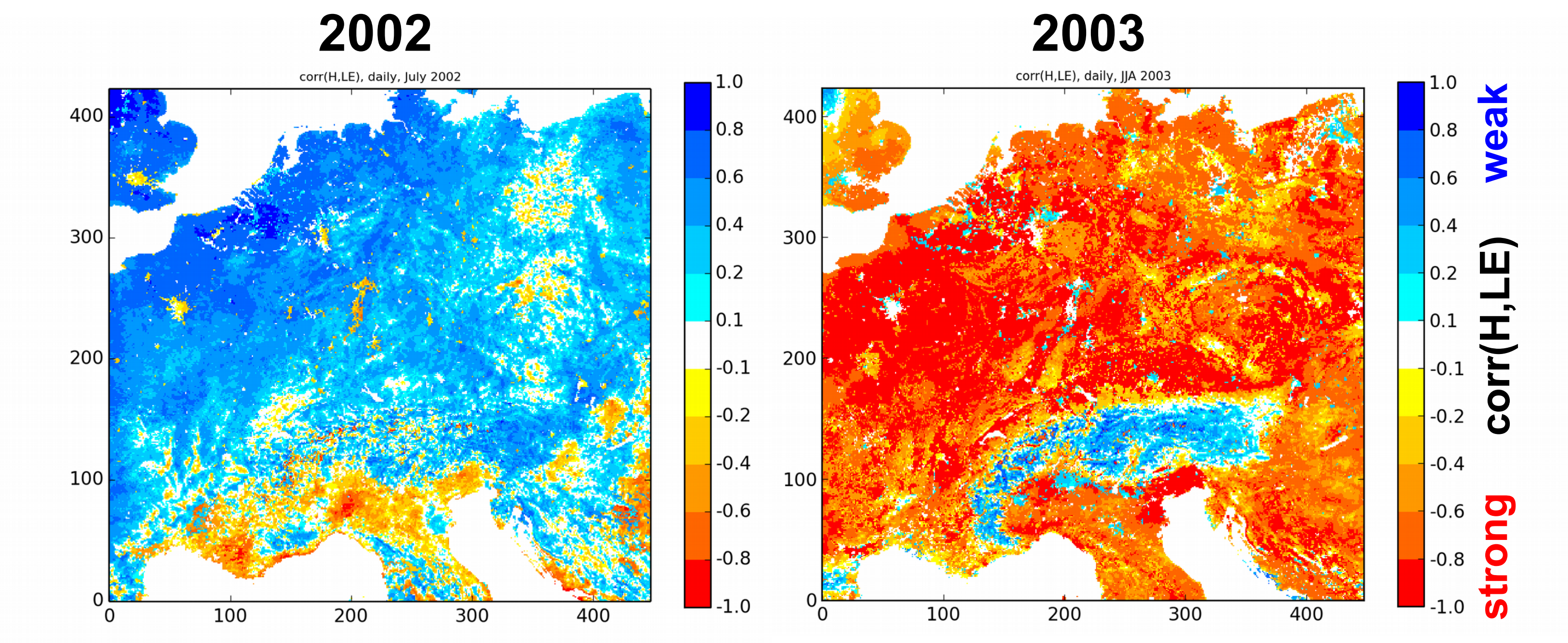
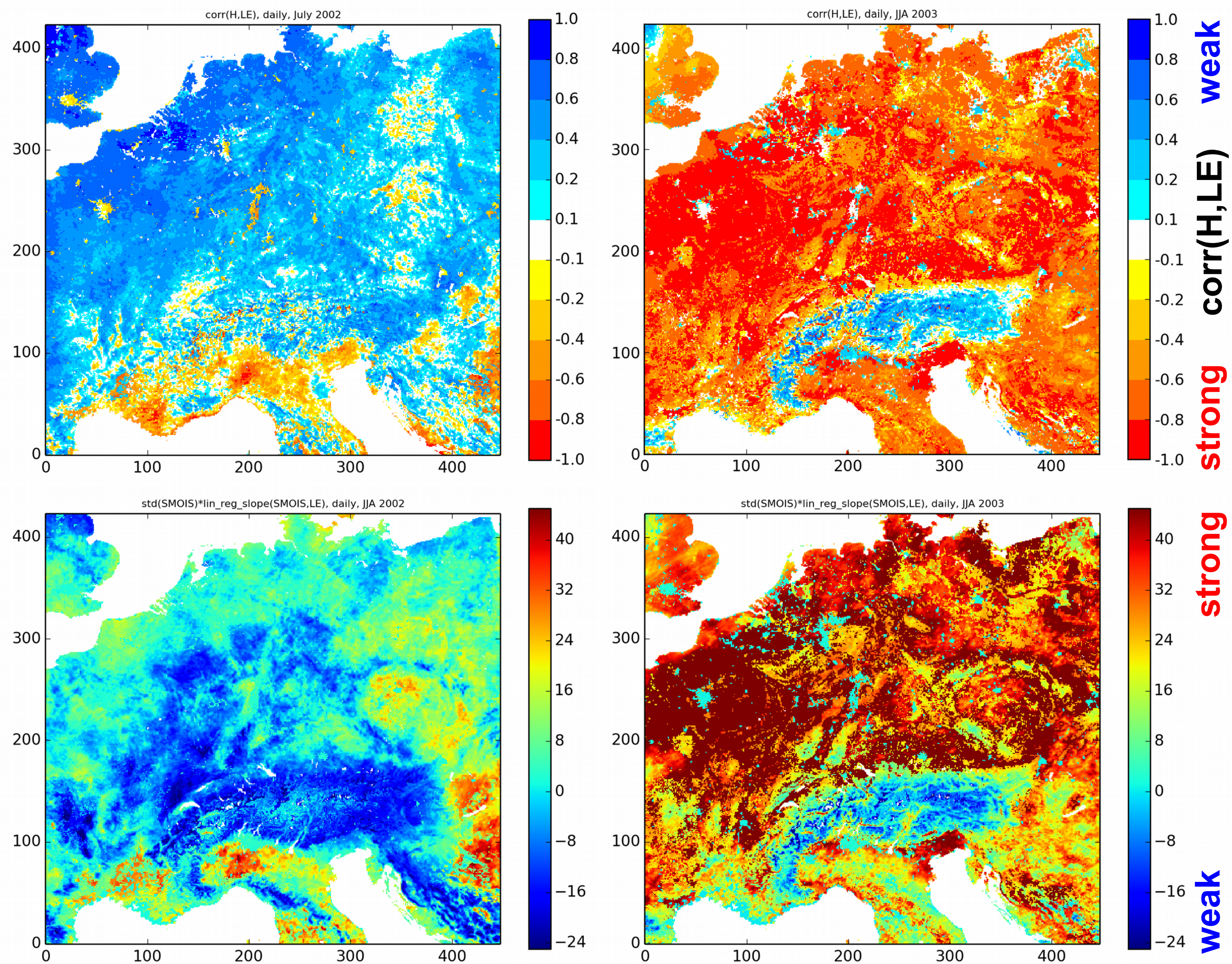
Large inter-annual variability consistent with weather conditions in the individual years

Coupling strength, 3 km WRF, JJA, 2002 vs. 2003



Coupling strength, 3 km WRF, JJA, 2002 vs. 2003

2002 | **2003**



Additional cpl. strength metric

($I_C = \beta_{LE,sm}\, \sigma_{sm}$)

Dirmeyer (2011)

sdv soil moisture * linear regression soil moisture and LE

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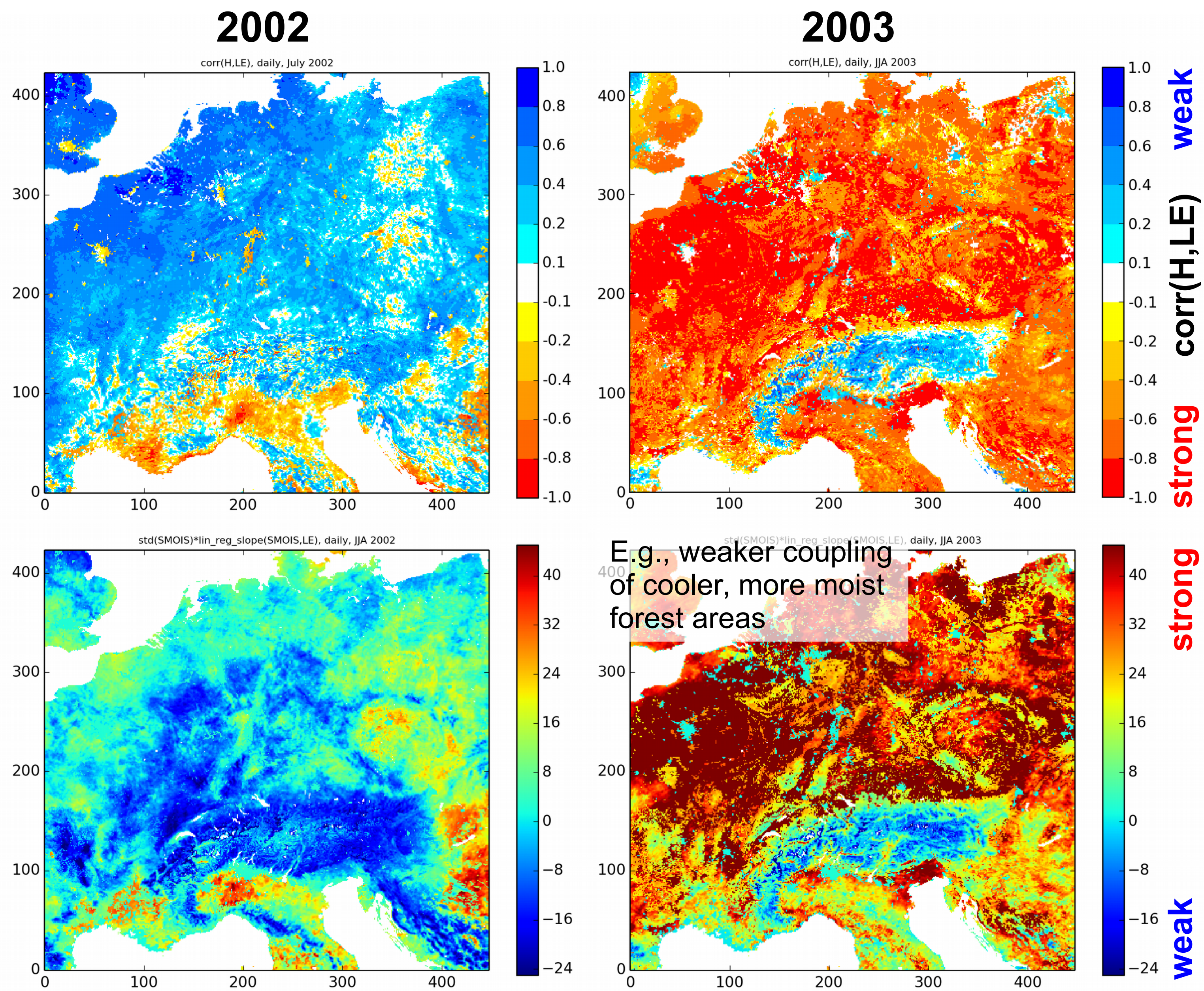

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Surface characteristics more pronounced

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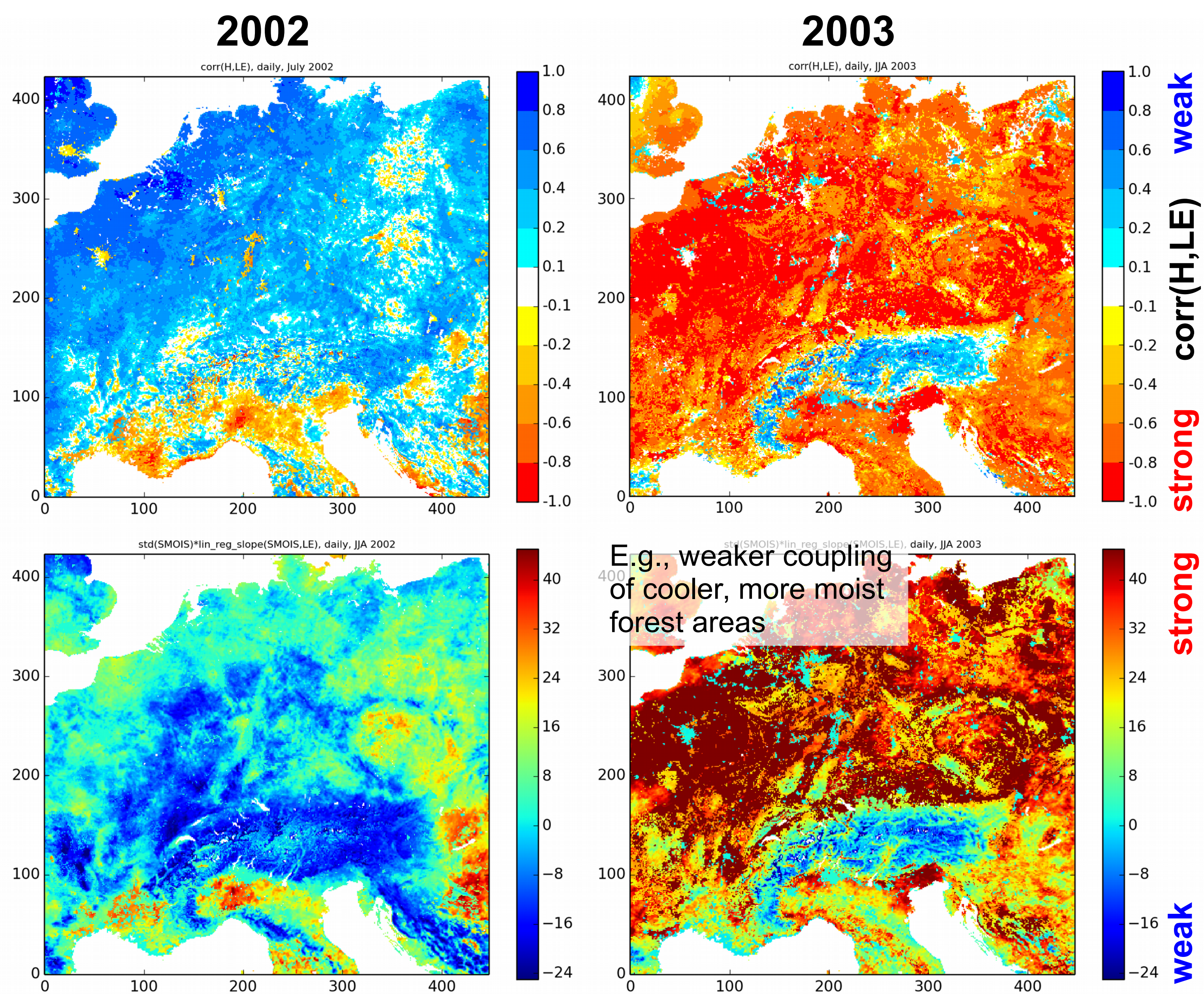

E.g., weaker coupling of cooler, more moist forest areas

Additional cpl. strength metric ($I_C = \beta_{LE,sm}\,\sigma_{sm}$) Dirmeyer (2011)

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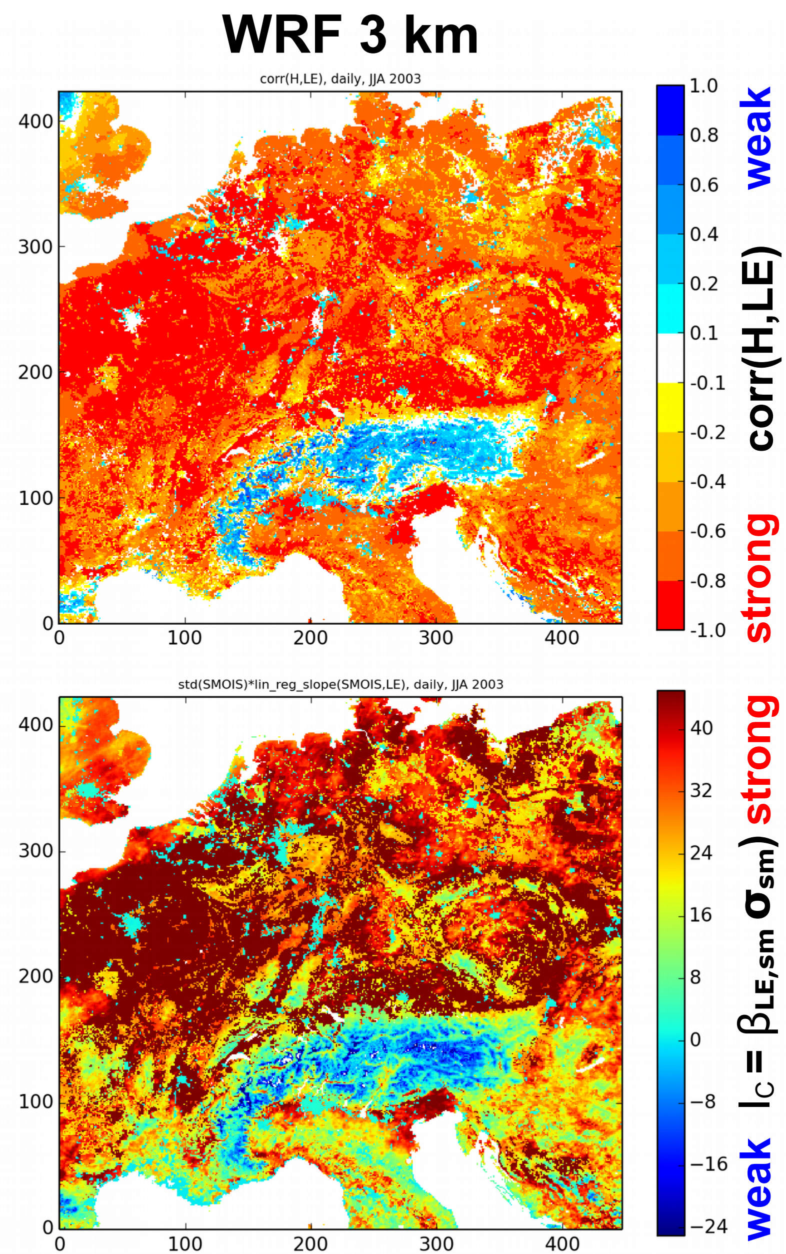
Surface characteristics more pronounced

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

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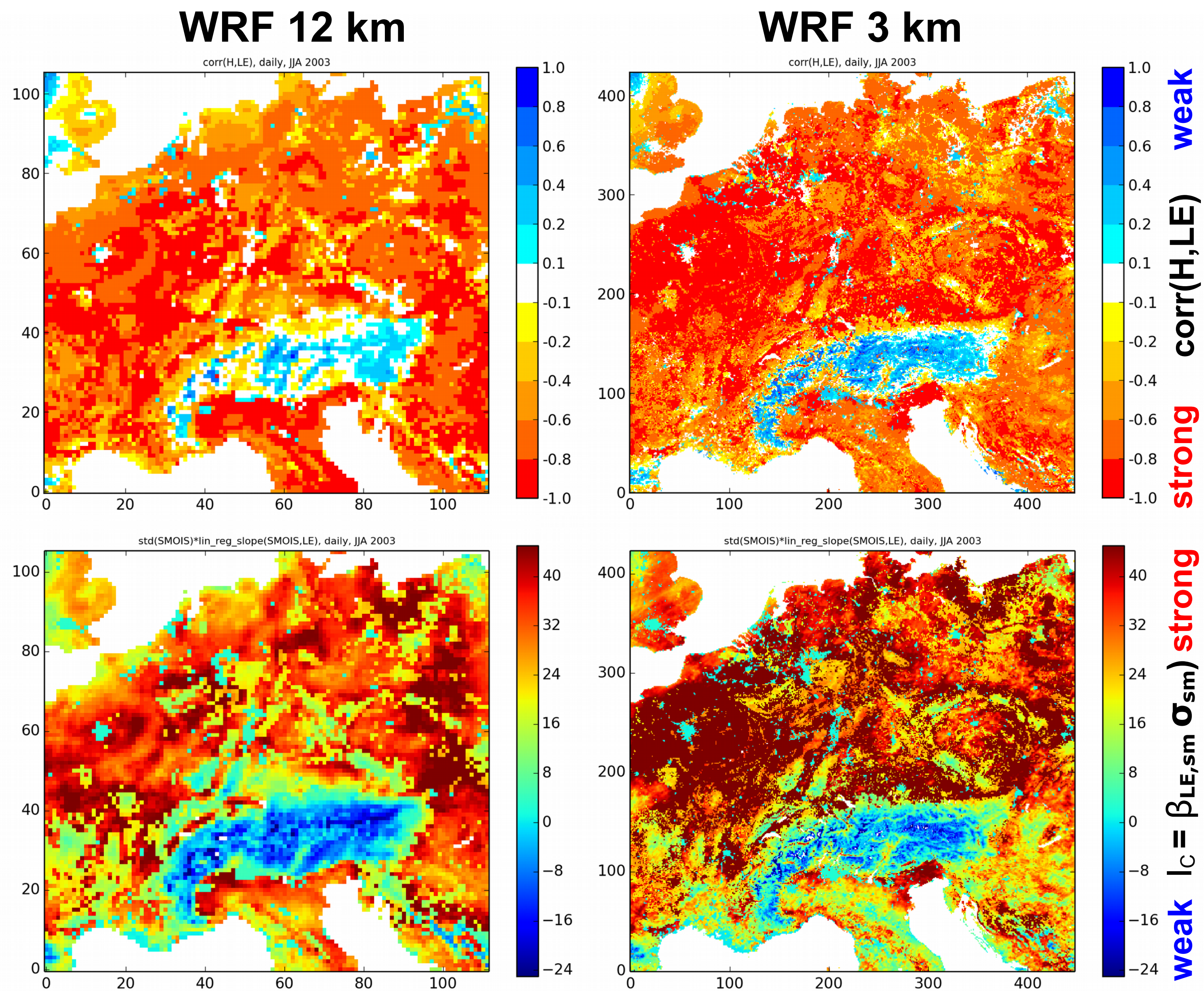

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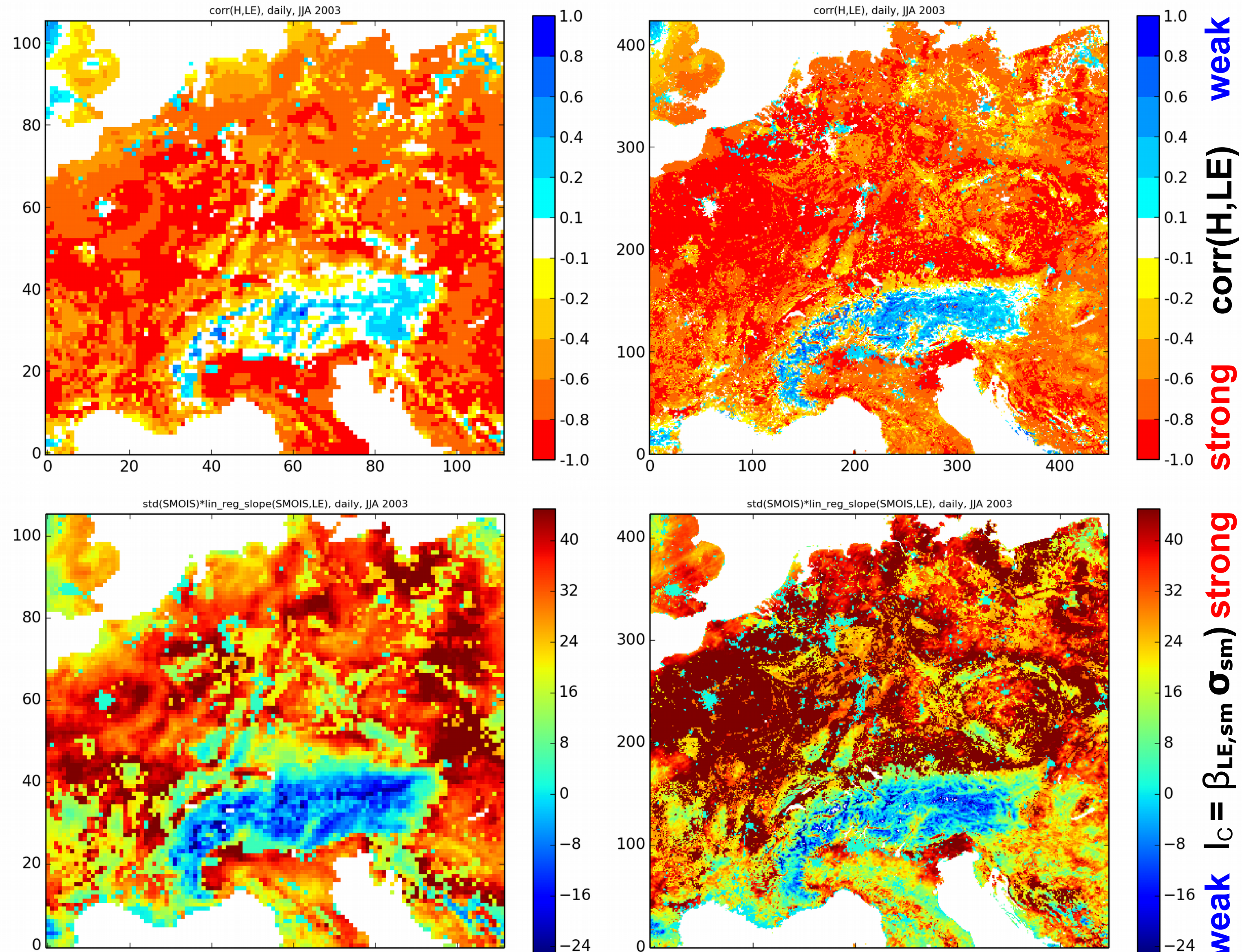
WRF 12 km | **WRF 3 km**



Impact of surface heterogeneity

Stronger cpl. in 3 km resolution

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

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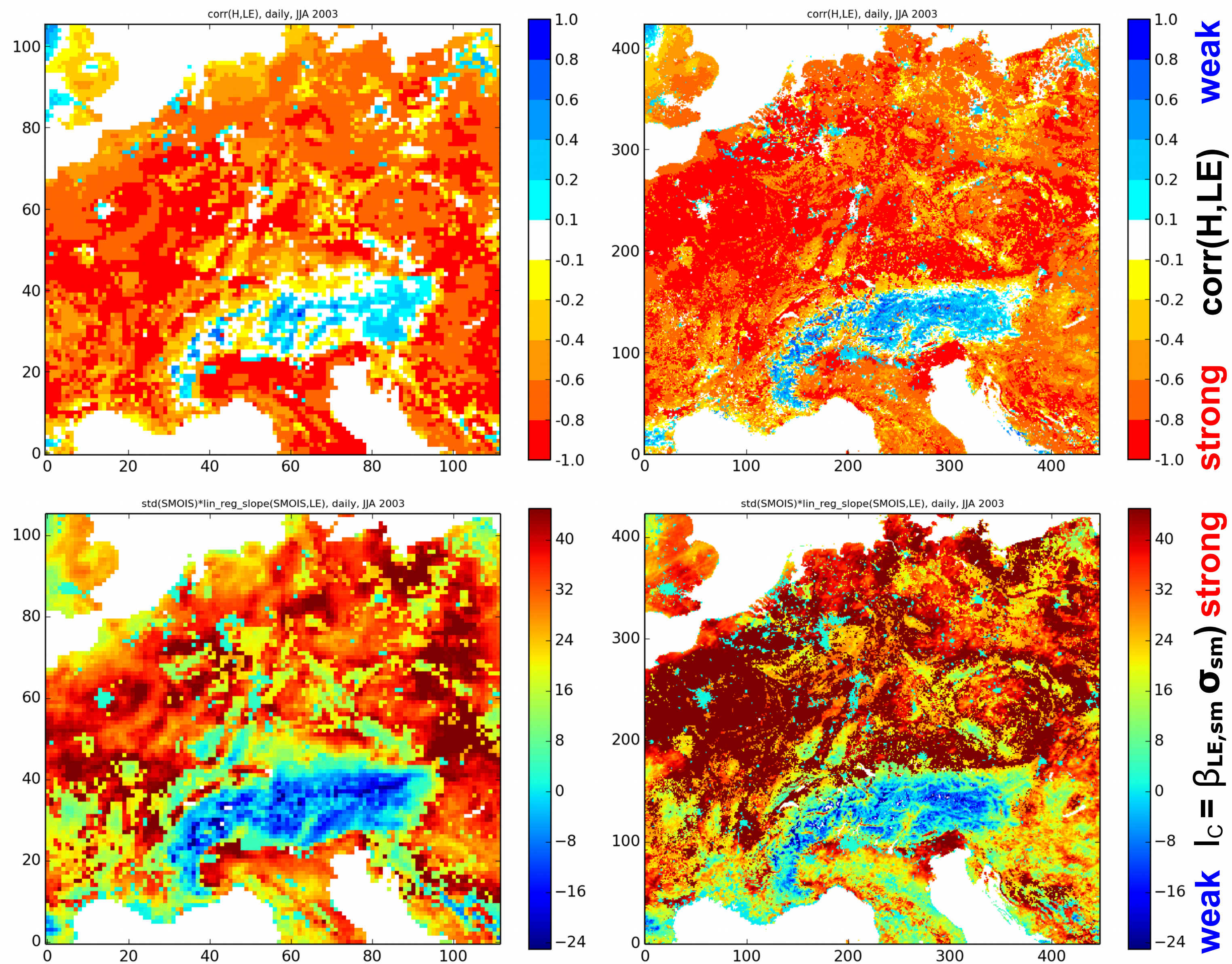

Impact of surface heterogeneity

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

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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

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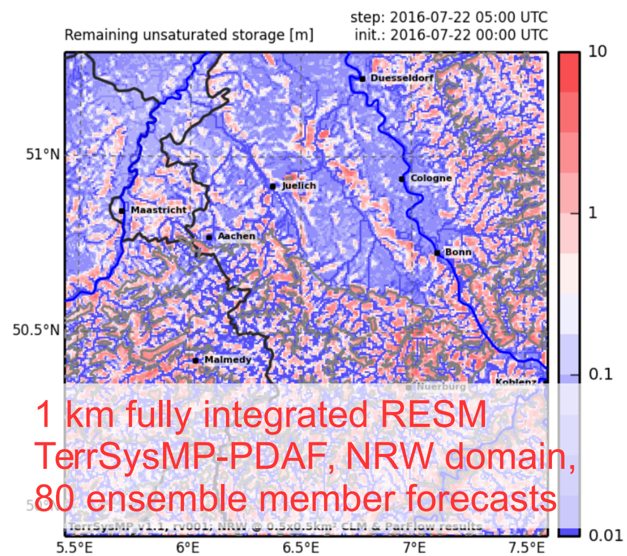

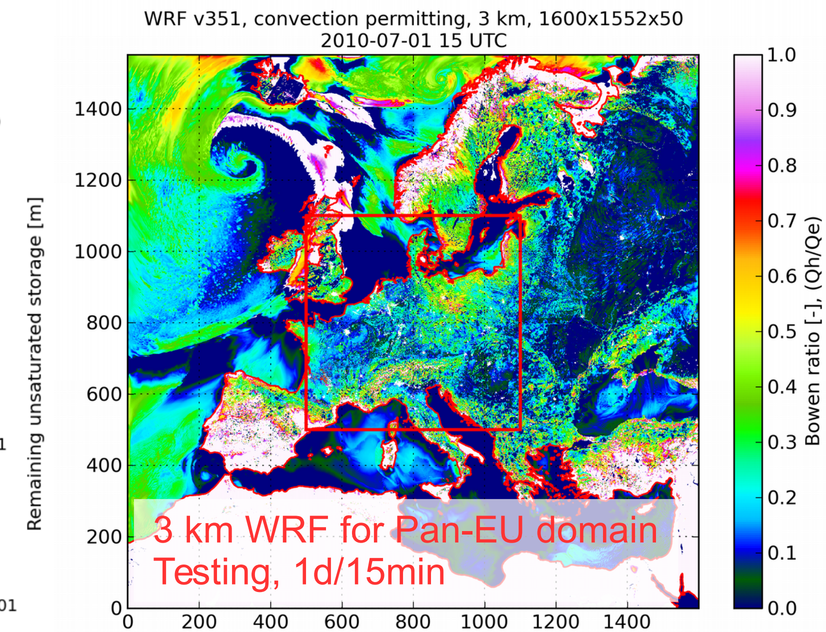

Vacancy:

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