A REVIEW ON REGIONAL CONVECTION PERMITTING CLIMATE MODELING: DEMONSTRATIONS, PROSPECTS, AND CHALLENGES

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Based on the article:

A. F. Prein, W. Langhans, G. Fosser, A. Ferrone, N. Ban, K. Goergen, M. Keller, M. Tölle, O. Gutjahr, F. Feser, E. Brisson, S. Kollet, J. Schmidli, N. P. M. van Lipzig, and R. L. Leung (2015) A review on regional convection-permitting climate modeling: Demonstrations, prospects, and challenges. Rev. Geophys., 53, 323–361, doi:10.1002/2014RG000475.

Brisson, E., K.Van Weverberg, M. Demuzere, A. Devis, S. Saeed, M. Stengel, N.P.M. van Lipzig, 2016. How well can a convection-permitting climate model reproduce decadal statistics of precipitation, temperature and cloud characteristics? Climate Dynamics, DOI: 10.1007/s00382-016-3012-z

Brisson, E., Demuzere, M., Van Lipzig, N. (2015). Modelling strategies for performing convection-permitting climate simulations. Meteorologische Zeitschrift, 25(2), 149 – 163

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Publications available from http://ees.kuleuven.be/geography/rcs

or sent an email

Outlook

1. **Introduction** to Convection Permitting Model (CPMs) Simulations
2. **Critical components**
3. **Added value** of CPMs
4. Influences on the **climate change signal & feedback processes**
5. Applications in **impact studies**
6. Major **challenges** and **outlook**

Goal: synthesis of activities on CPMs

Basis for future coordinated projects

What are Convection Permitting Model (CPM) Simulations and which theoretical advantages do they have?

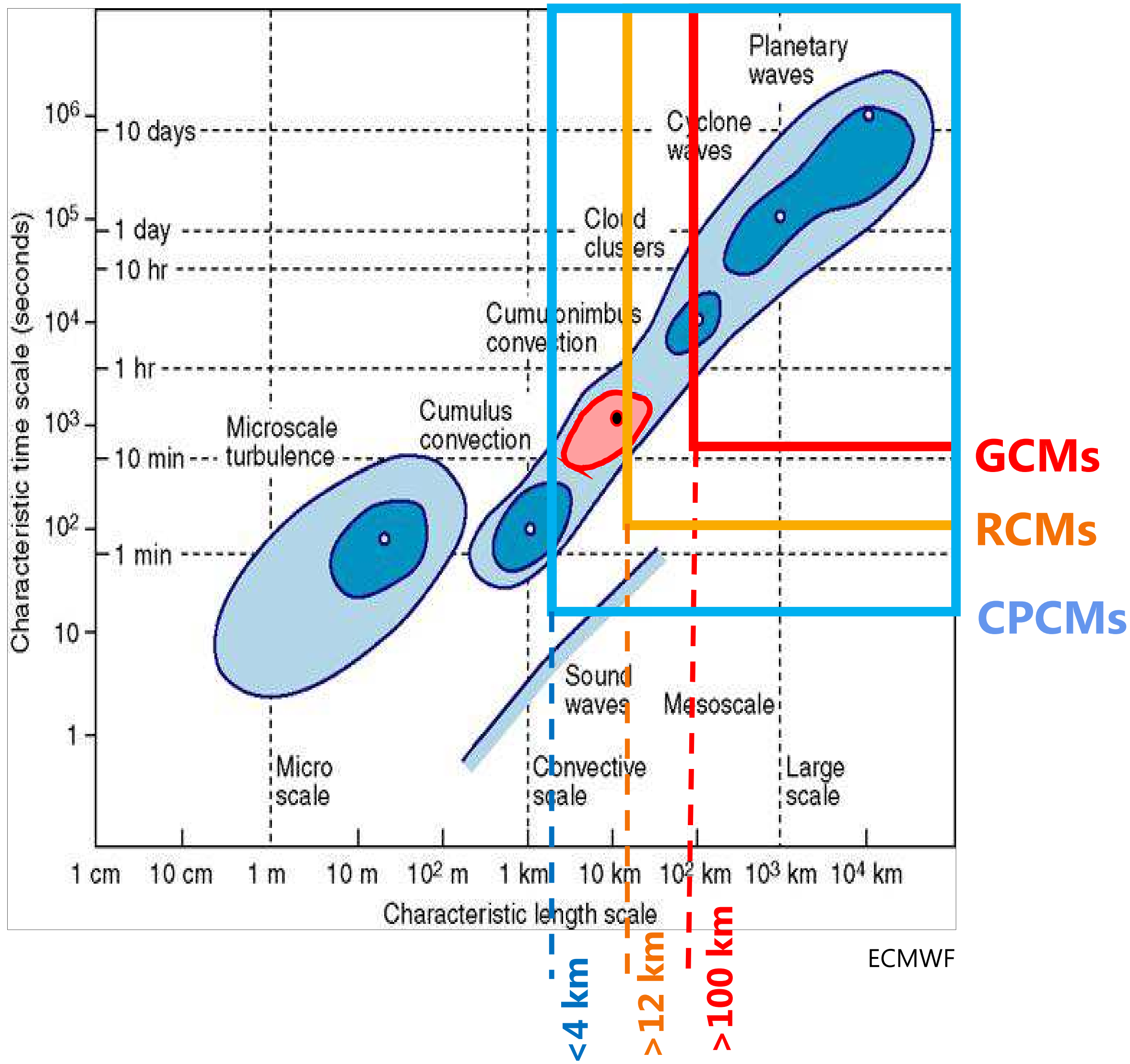
What are Convection Permitting Model (CPM) Simulations and which theoretical advantages do they have?

Light gray: Ice
Dark gray : Graupel
Red: Snow
Blue: Rain + Cloud water

Surface contours:
Updraft (red); Downdraft (blue)

What are Convection Permitting Model (CPMs) Simulations and which theoretical advantages do they have?

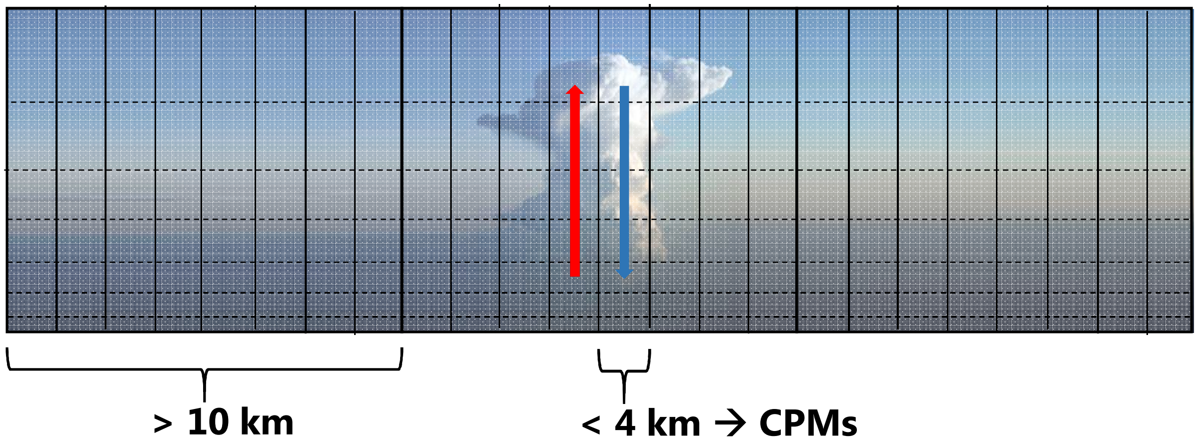
Weisman et al. [1997]: Δx>4km leads to "grid-scale storms" without convection parametrization



ECMWF

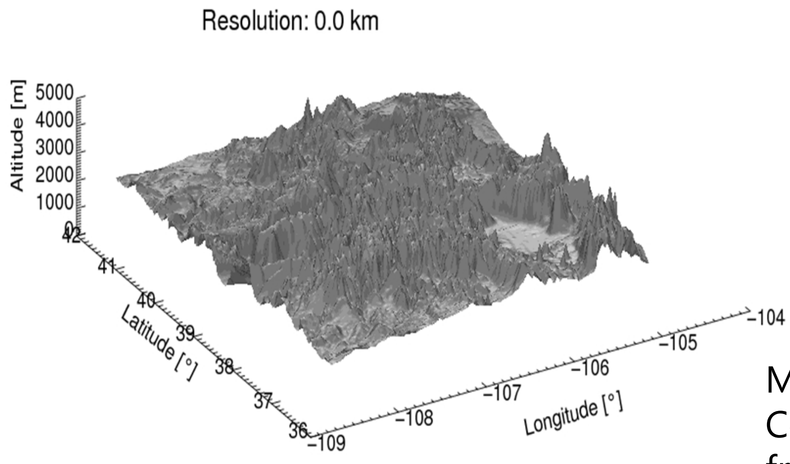
What are Convection Permitting Model (CPM) Simulations and which theoretical advantages do they have?

1.) Omit error prone deep **convection parameterizations**



What are Convection Permitting Model (CPM) Simulations and which theoretical advantages do they have?

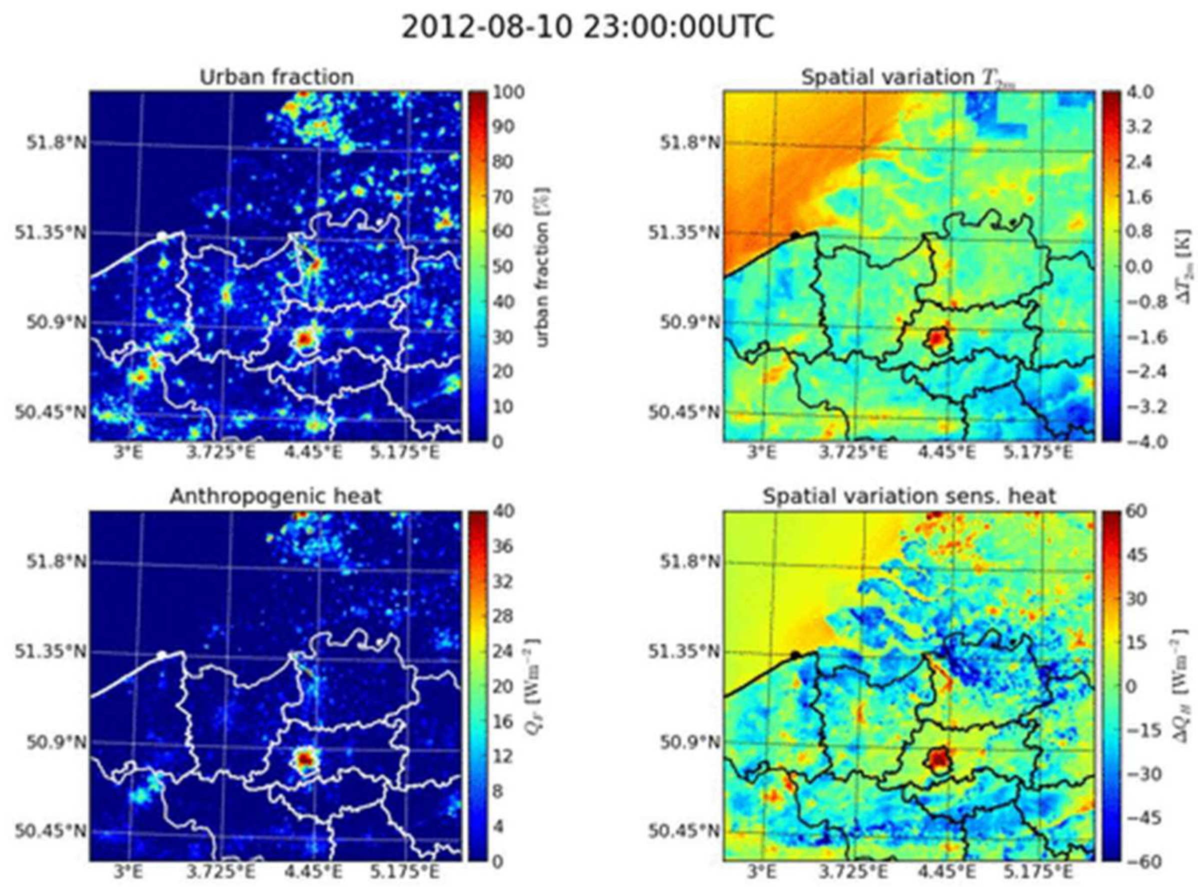
2.) Improved representation of **orography** and surface fields (coastlines, lakes, …)



Model orography in the Colorado Rocky mountains from Δx=1 km → 100 km

What are Convection Permitting Model (CPM) Simulations and which theoretical advantages do they have?

3.) Improved representation of **land-use change** (urbanization, deforestation,..)



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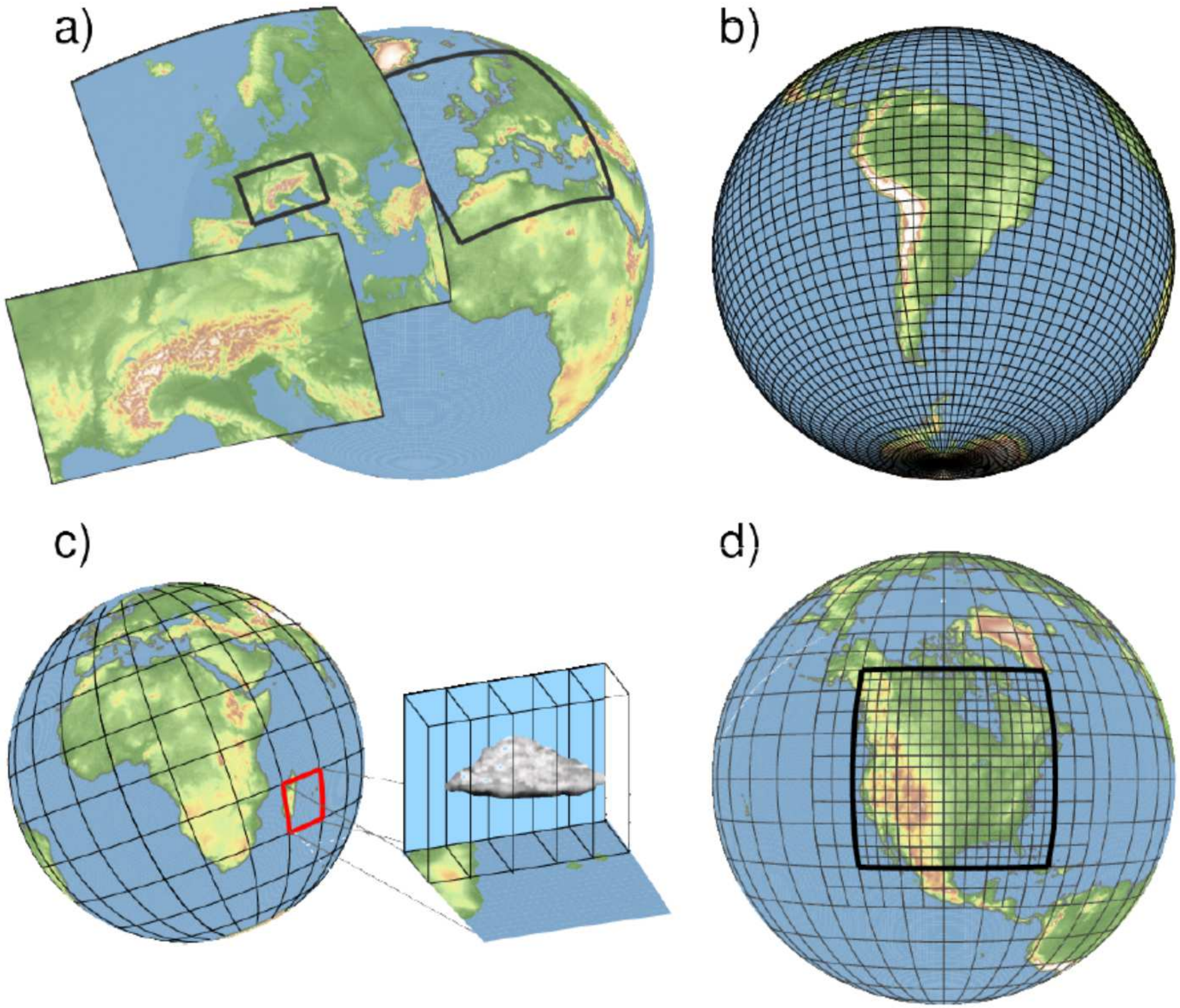
Different modeling approaches for CPM climate simulations



CPM approaches

a) limited-area modeling
b) global CPM climate simulations
c) Superparameterizations
d) Variable resolution global models

Different modeling approaches for CPM climate simulations

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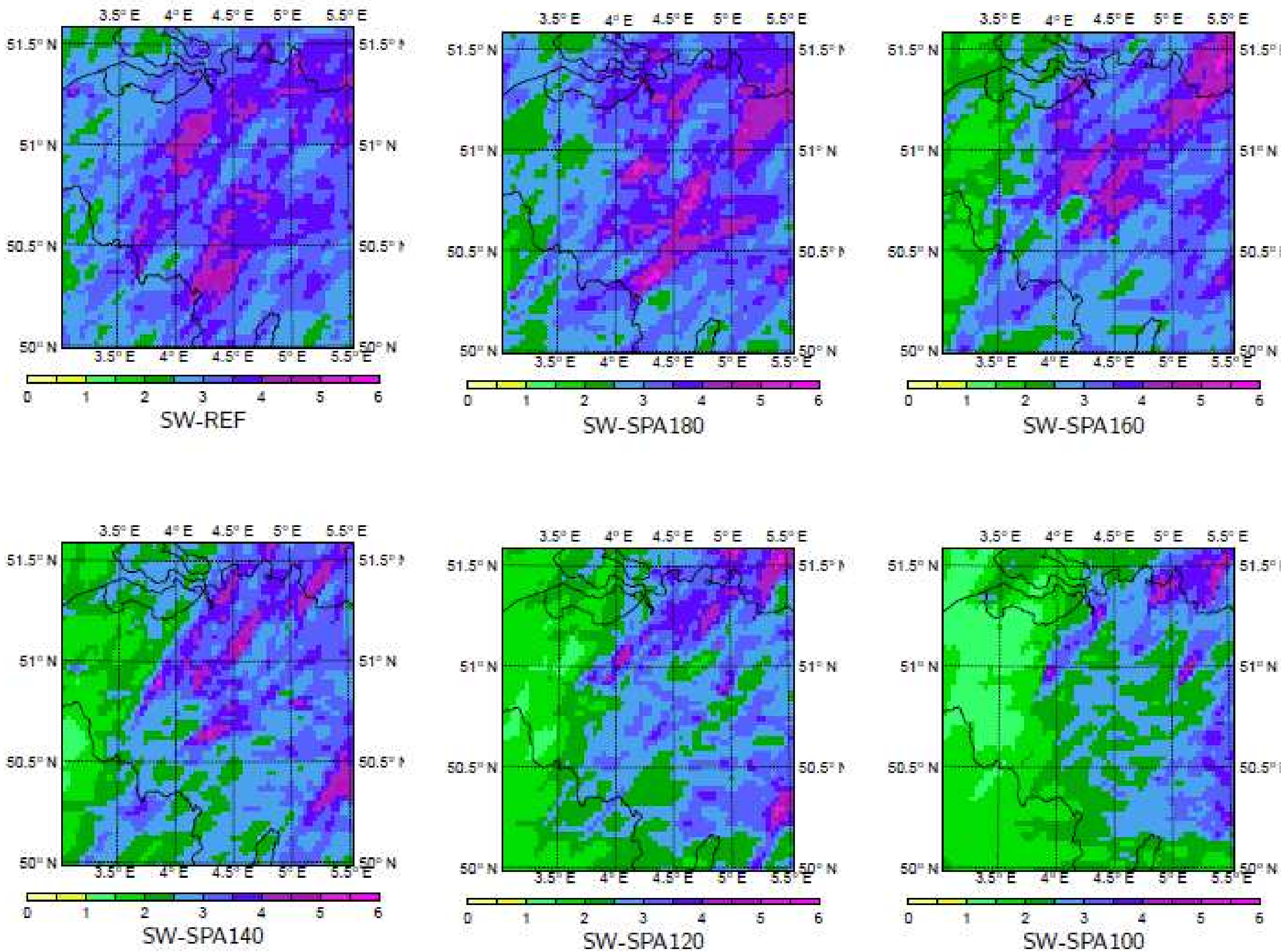
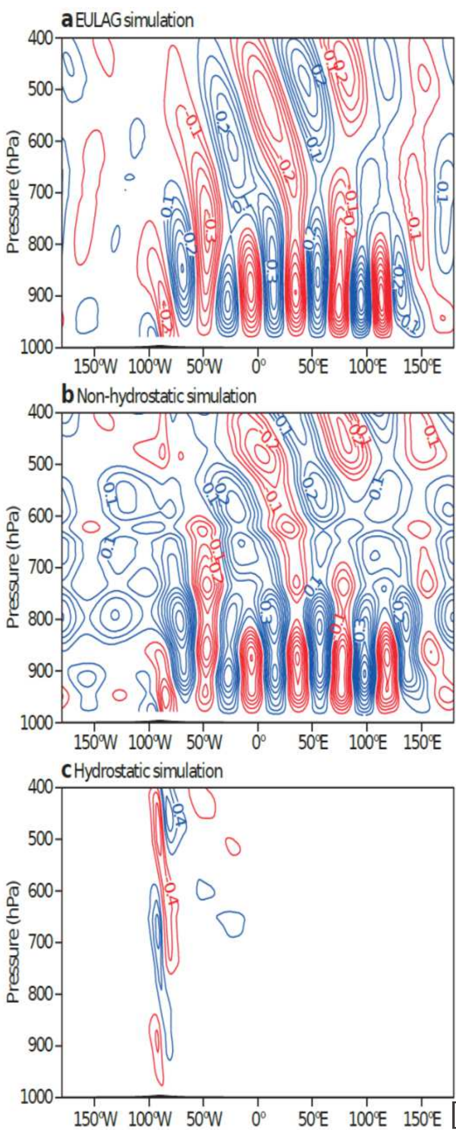
Critical components: Downscaling strategies

JJAS 2007 COSMO-CLM simulation at 2.8 km Brisson et al., 2015]

- 150 km spatial spin-up necessary
- Graupel necessary
- Nesting step < 1:12
- Avoid grey-zone (4-10km)



Critical components: Numerics



Nonhydrostatic EULAG Anelastic reference model

Nonhydrostatic IFS

Hydrostatic IFS

[Wedi and Malardel , 2010]

Hydrostatic approximation

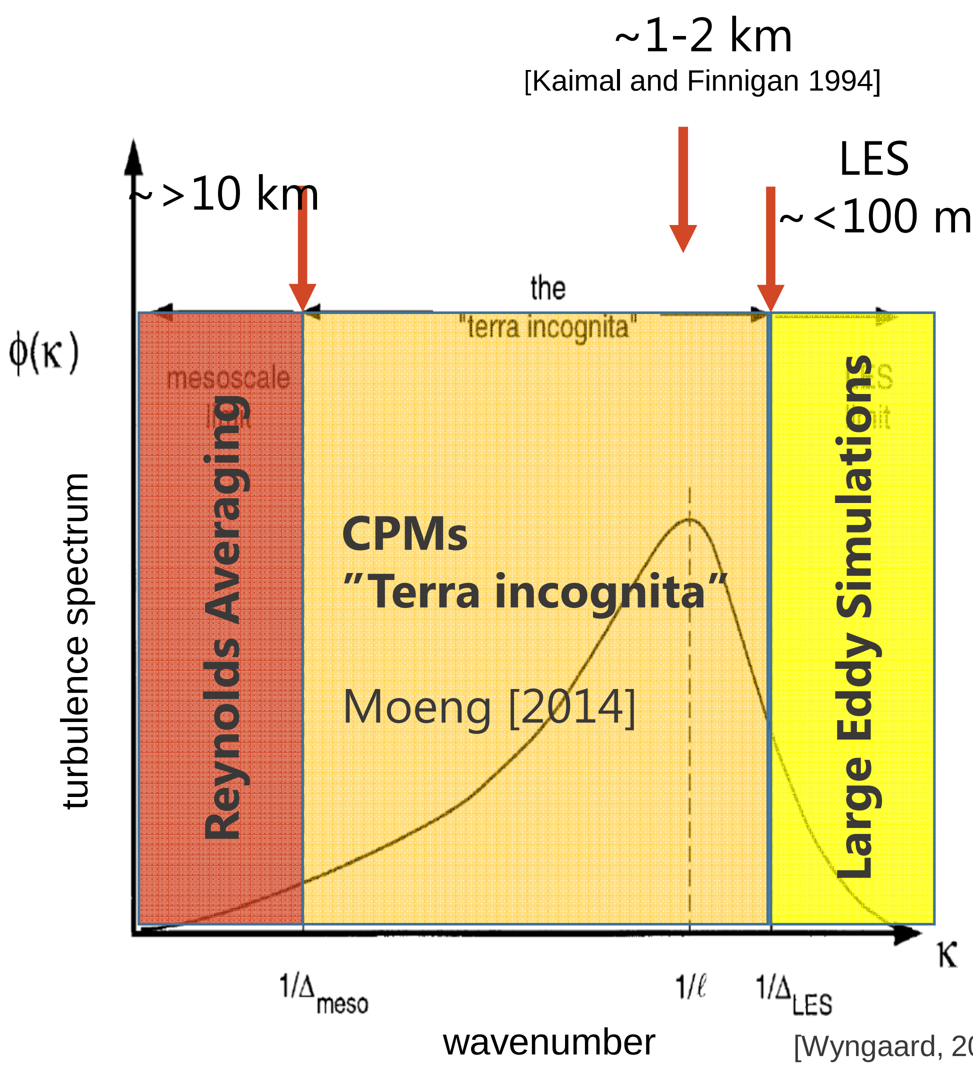
$$\frac{\partial p}{\partial z} = -\rho g$$

p… pressure
ρ… density
g…gravitational acceleration

www.atmos.washington.edu South Sandwhich Islands

Critical components: Turbulence

CPM is too fine to assume all turbulence can be parametrized (Δx>10km)



[Wyngaard, 2004, Copyright 2004 AMS]

Too coarse to assume energy-producing turbulent motion is resolved (Δx<100m)

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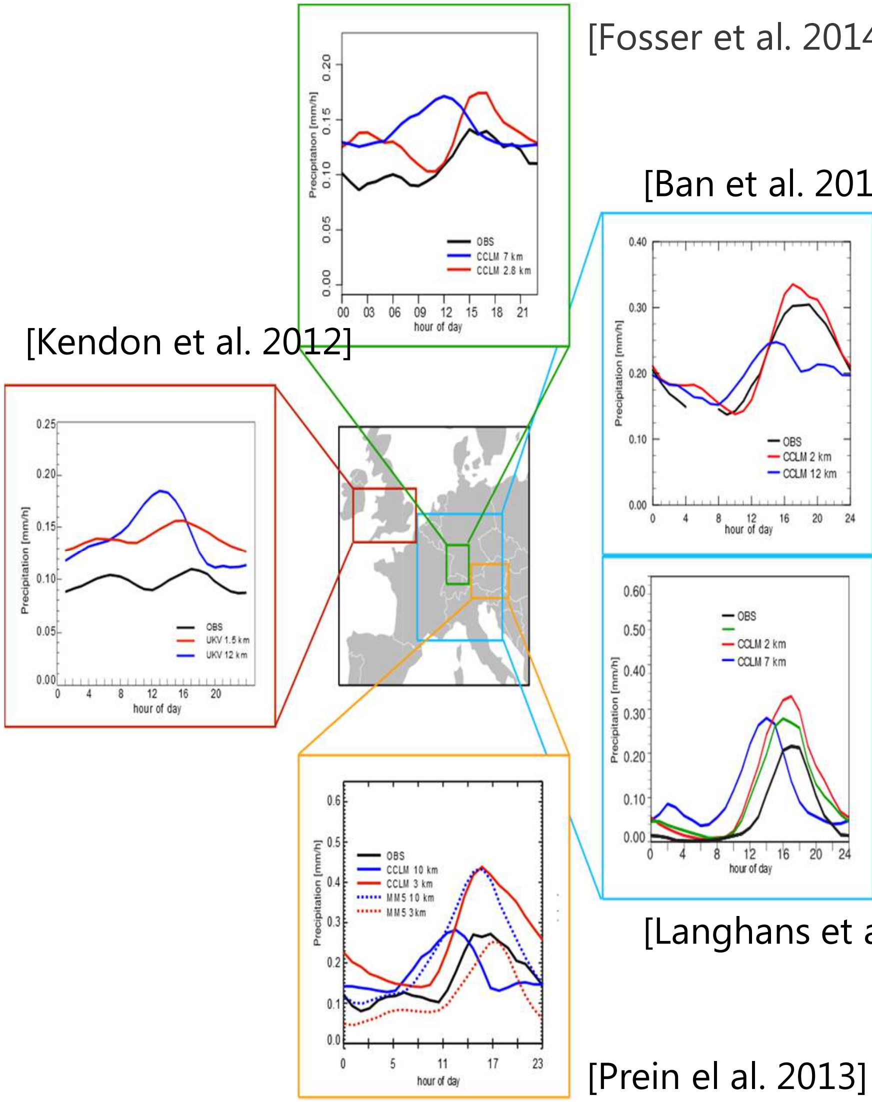
Added value of CPMs
Precipitation diurnal cycle

[Fosser et al. 2014]

[Ban et al. 2014]

[Kendon et al. 2012]

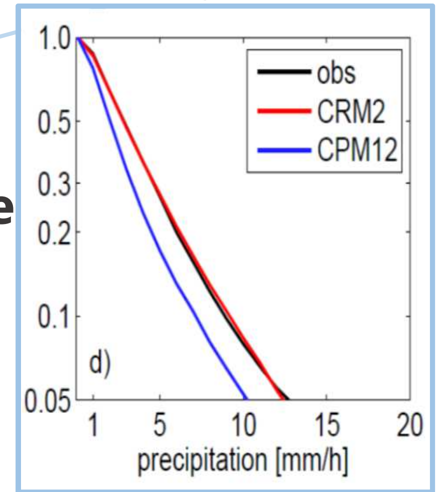


[Langhans et al. 2013]

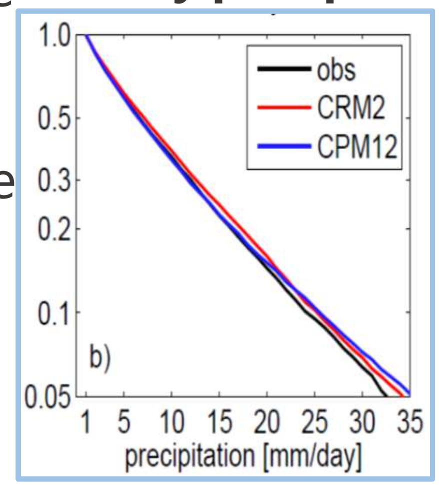
[Prein el al. 2013]

All CPMs **improve** shape (onset and peak) of precipitation **diurnal cycle** compared to large scale simulations but **not necessary** the **amplitudes**

Hourly precipitation



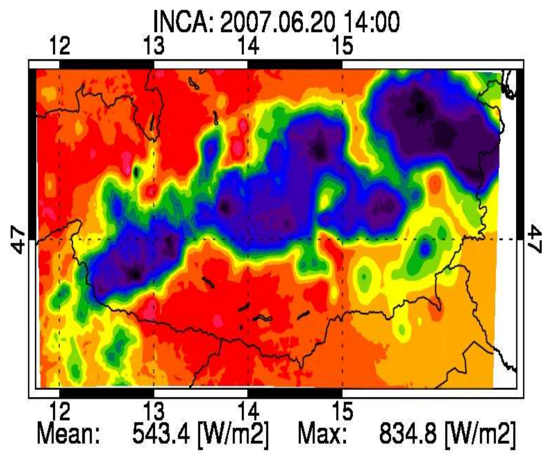
Daily precipitation

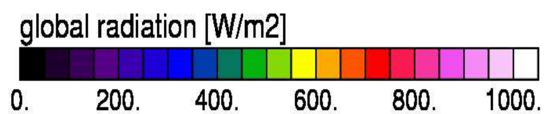


[Ban et al. 2014]

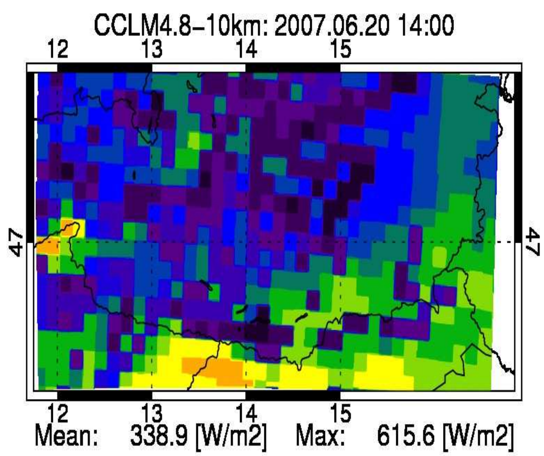
Added value of CPMs
Clouds and global radiation (GL)

Reference: 1 km

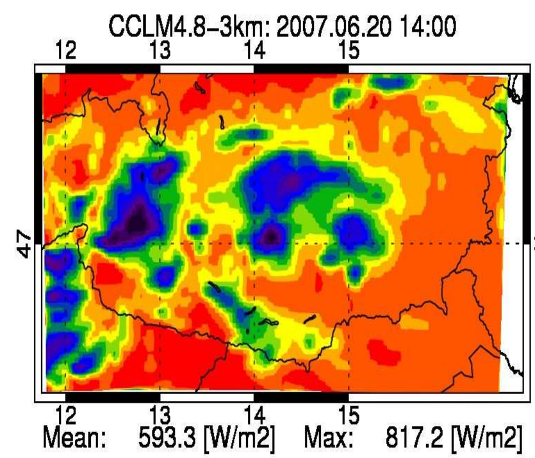




10 km Simulation

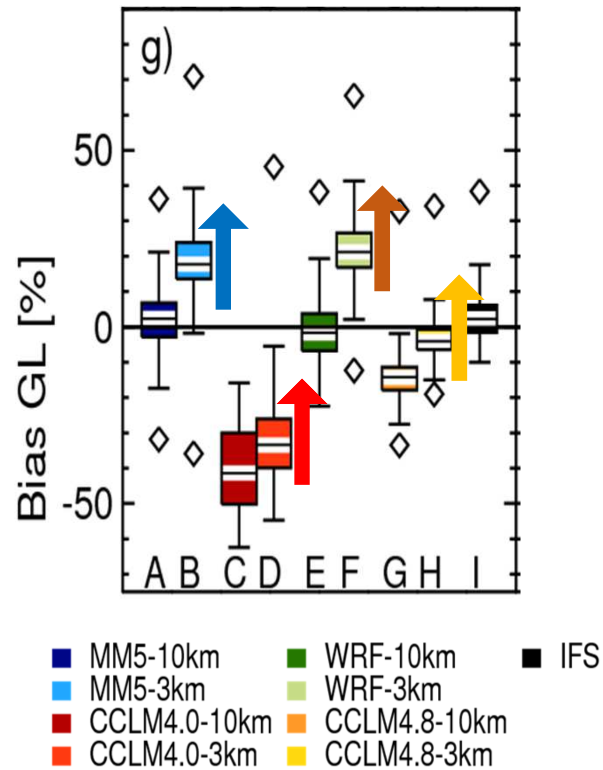


3 km Simulation



CPM: Cloud cover decreases
Smaller denser convective clouds

CPCM +14 % in JJA

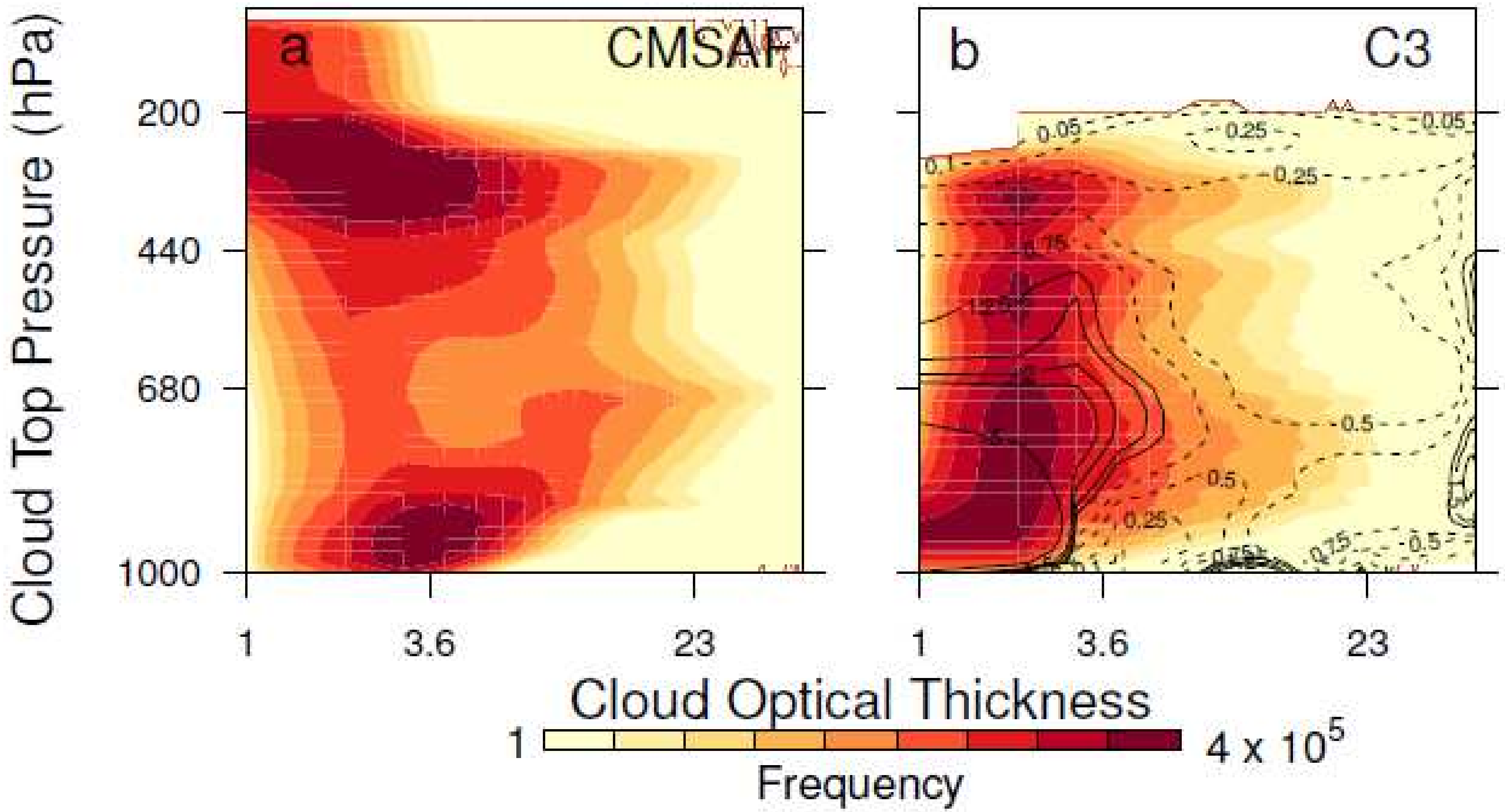


Added value of CPMs
Clouds

[Brisson et al., 2016, Clim. Dyn.]

- Too little high and intermediate, thick clouds
- Too much low, thin clouds

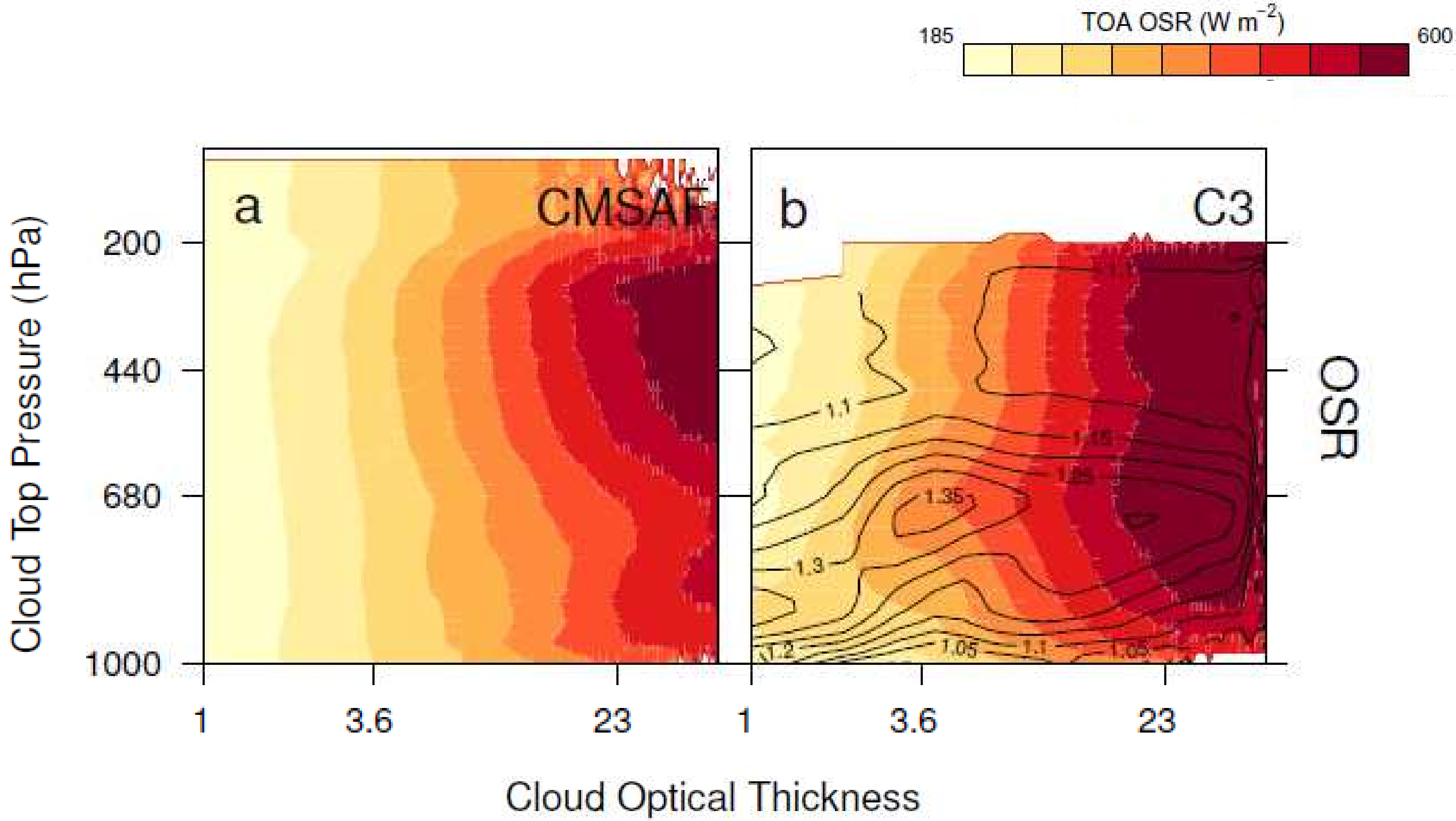
General CPM: overestimated high cloud cover in LSM reduced



Added value of CPMs
Clouds

[Brisson et al., 2016, Clim. Dyn.]

- Underestimation of cloud amount is compensated by too much reflectivity of clouds



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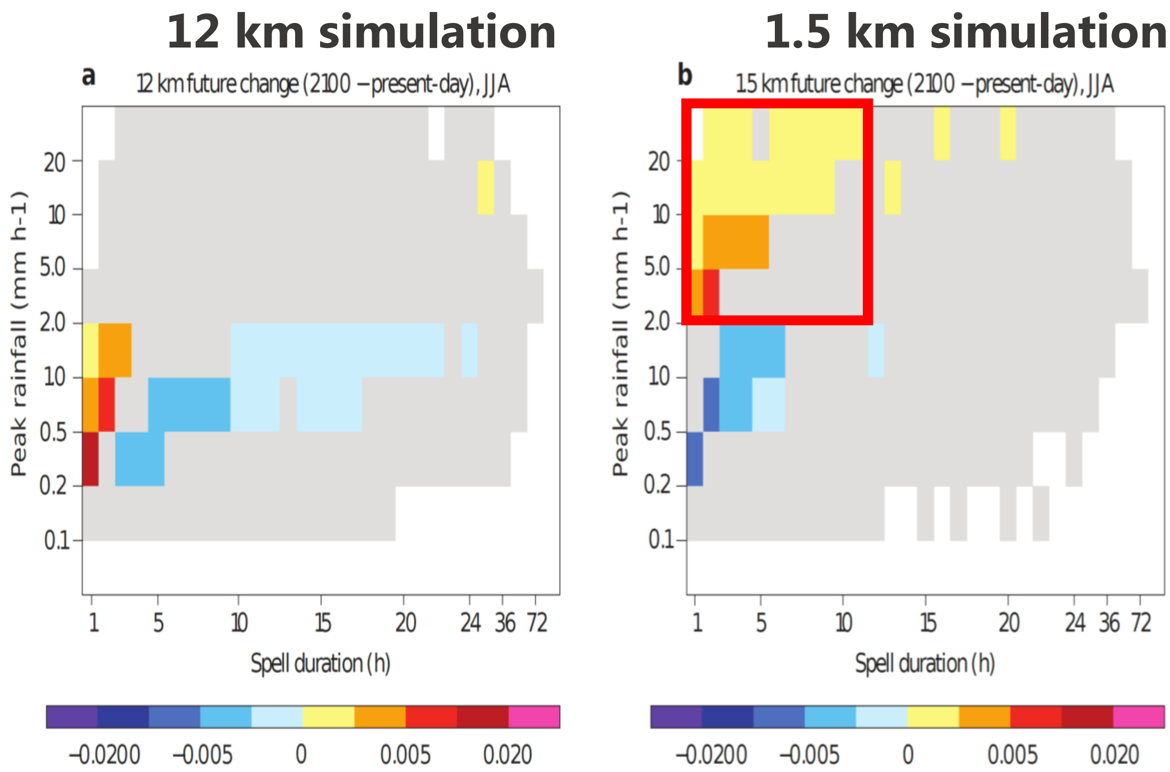
A1

Differences in Climate Change Signal & Feedback Processes Precipitation



[Kendon et al., 2014]

- ➢ Increase in short-term future extreme precipitation in the 1.5 km model (flashfloods)
- ➢ This is not seen in the 12 km model.

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A1 Author, 03/02/2015

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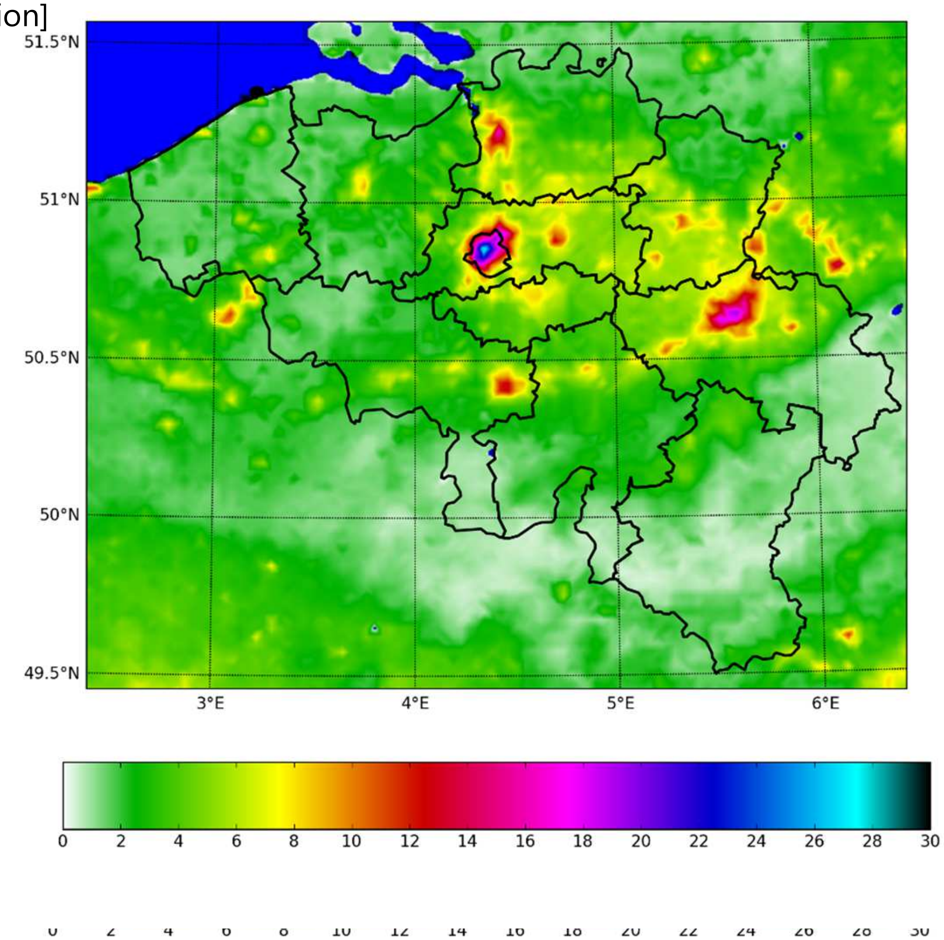
Applications in impact studies
Urban Modelling

Change in the number of days with T_{min}>20˚C in 2060 for a ''middle' climate scenario

[Wouters et al. in preparation]



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Major challenges

- **Short simulation periods** and large differences between experiments
  → impacts on climate time scales?
- Application of **NWP setup**
  → CPM are not fully tested on climate time scales
- **Observational data** sets
- **Microphysics, aerosols, radiation interactions**
  → missing fundamental understanding
- **Parameterization of turbulence**
- **Higher order numeric scheme**
- **Future computing systems and big data**
- **Coordinated efforts for climate impact studies**