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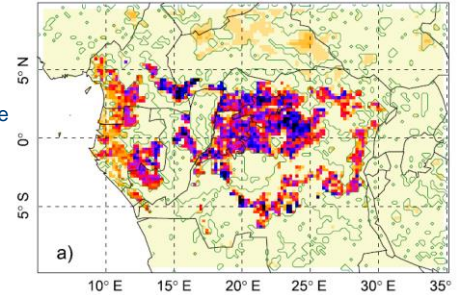
Regional climate modelling at the convection permitting scale: Climate response to increasing greenhouse gasses and land use change

Prof. Nicole van Lipzig
With input from Sam Vanden Broucke, Hendrik Wouters, Matthias Demuzere



GHG emissions and land use are drivers of climate change

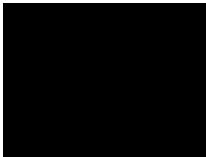
Impact of deforestation 2050 in the Congo basin: Ground-surface warming of about 0.7°C; local hot spots up to 1.25°



Akkermans, Thiery and van Lipzig, 2014

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Now Convection Permitting Models (CPM) become available



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

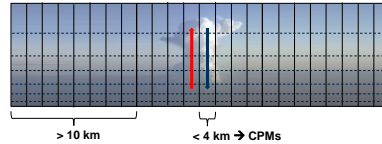
Surface contours:
Updraft (red); Downdraft (blue)

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What are the theoretical advantages of CPS?

$\Delta x > 4\text{km}$ leads to "grid-scale storms" without convection parametrization (Weisman et al. [1997])

1.) Omit error prone deep convection parameterizations



2.) Improved representation of orography and surface fields (coastlines, lakes, ...)
3.) Improved representation of land-use change (urbanization, deforestation,...)

Previous research shows better representation of precipitation: daily cycle, extreme precipitation, precipitation variability,

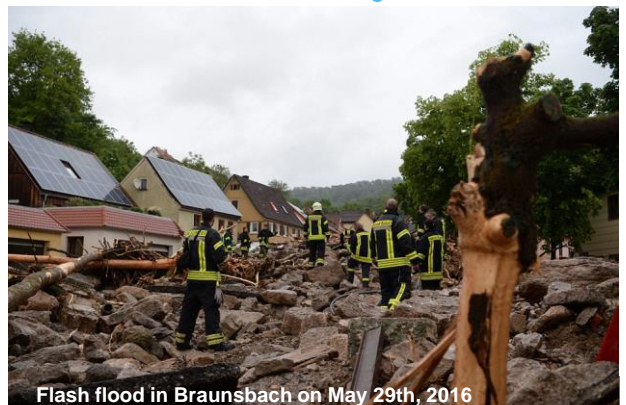
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How different is the climate change signal in CPM models?

GHG-induced climate change
Land use change: Deforestation
Urbanization

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GHG-induced climate change: State of the art



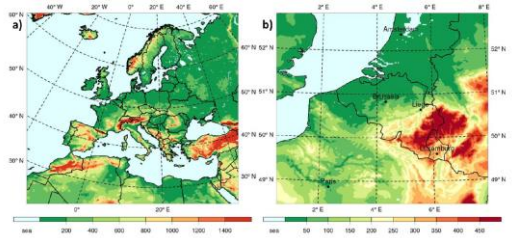
Flash flood in Braunsbach on May 29th, 2016

GHG-induced climate change: State of the art

- Most CPS climate projections have been done for one decade
- Most CPS climate projections have been done with one member
- Robustness of climate change projections depends on region
 - UK and Brussels: larger increase in hourly extremes for CPS
 - South-West Germany, Alps: hourly extremes similar

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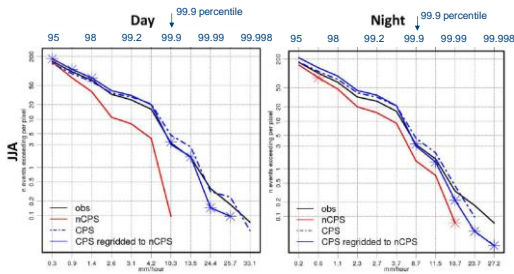
CORDEX.be project – coordinated by Piet Termonia Royal Meteorological Institute of Belgium



- 30-year climate projections
- mini ensemble: Alaro, MAR, COSMO-CLM
- Region with different orographical complexity

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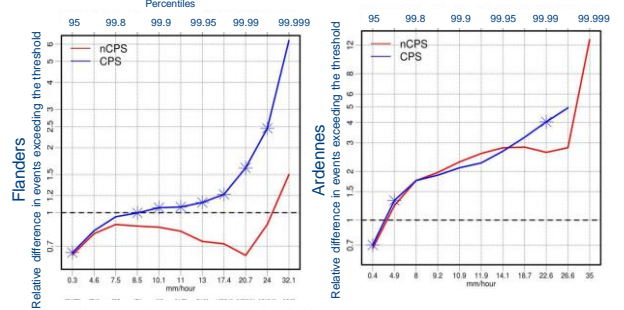
Evaluation summer hourly precipitation



- CPS represents extreme precipitation better
- Aggregation to nCPS grid does not deteriorate performance
- CPS convective systems are shorter but more intense than nCPS

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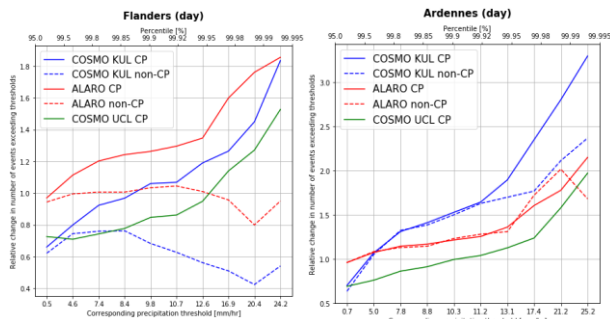
Projected increase in summer hourly precipitation



- Increase in extremes despite drying
- Replicated only in the Ardennes by nCPS
- Triggers: surface heating; large-scale weather fronts; orography

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Same signal in ALARO model



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How different is the climate change signal in CPM models?

GHG-induced climate change

- Orography (not the model) determines the discrepancy between CPS and nCPS
- In the flatlands, hourly summer extremes increase more in CPS
- In the hills, increases in hourly summer extremes is similar

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Journal of Geophysical Research: Atmospheres

Research Article

New insights in the capability of climate models to simulate the impact of LUC based on temperature decomposition of paired site observations

DOI: 10.1029/2017JD026888

Climate Dynamics

1 October 2017, Volume 45, Issue 2.0, pp 1740–1761 (22 pp)

Do convection-permitting models improve the representation of the impact of LUC?

Authors: **Sam Verbeke-Broekmans, Nicole Van Looy**

How different is the climate change signal in CPM models?

Land use change: Deforestation

Can models represent the impact of land use change? Do CPS models outperform nCPS?

FLUXNET paired sites

Same background climate

Tharandt

Klingenberg

Model integrations

- COSMO-CLM² (v4.8, CLM3.5) 0.22° grid spacing
- 6-year period (2003-2008)
- Two model integrations:
 - Twin-site grid boxes prescribed as forest
 - Twin-site grid boxes prescribed as grass or cropland

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Energy balance decomposition

- Surface energy balance

$$\epsilon_s \sigma T_s^4 = [1 - \alpha_s] SW_{in} + LW_{in} - LE - H - G - I$$

- Linearization:

$$\delta T_s = \frac{1}{4\epsilon_s \sigma T_s^3} [-SW_{in} \delta \alpha_s + (1 - \alpha_s) \delta SW_{in} + \delta LW_{in} - \delta LE - \delta H - \delta G - \delta I - \sigma T_s^4 \delta \epsilon_s]$$

- Albedo
- Incoming shortwave radiation
- Incoming longwave radiation
- Latent heat flux
- Sensible heat flux
- Ground heat flux
- Imbalance term
- Thermal emissivity of the surface

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summer daytime

Decomposition of deforestation signal

- Effect higher albedo balances that of lower sensible heat exchange
- Artificial increase Swin due to decreased cloudiness
- Winter (not shown) model has smaller albedo effect due to lower frequency of snow cover

model? ↑ more sensible heat

↓ model = more SWin

↑ more reflection

↓ model = more LE

Mean over all paired sites over six years: Only high-quality data were included

summer nighttime

Decomposition of deforestation signal

- Cooling missed in COSMO-CLM
- Observed difference in Lwin not in the model
- Effect of lower sensible heat exchange well represented
- Winter (not shown) very similar

↑ model = more LWin

↓ more sensible heat

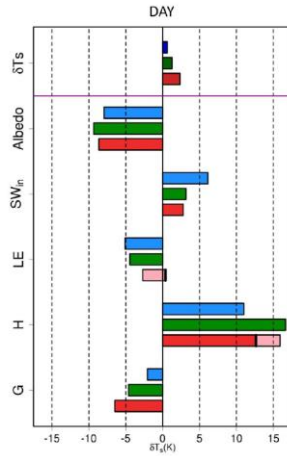
↑ more heat release

Mean over all paired sites over six years: Only high-quality data were included

Does CPS improve the representation of LUC impact?

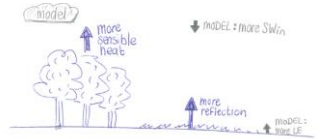


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Decomposition of deforestation signal for summer day

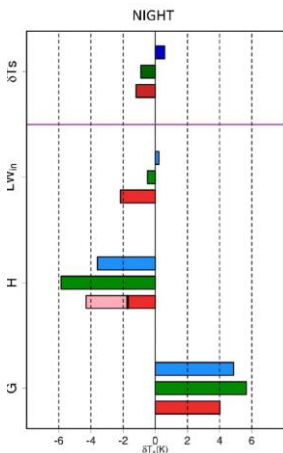
- Warming due to decreased cloudiness overestimated in nCPS
- CPS responds better to observed S_{win}
- Feedbacks on G, H, δT_s



Mean over one paired site over five years. Only high-quality data were included

■ nCPS
■ CPS
■ observed

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Decomposition of deforestation signal for summer night

- Bias L_{win} remains
- Possible causes:
 - Background climate
 - Clouds
 - Atmospheric humidity
 - Forest emissions of biogenic volatile organic compounds (BVOC)



Mean over one paired site over five years. Only high-quality data were included

■ nCPS
■ CPS
■ observed

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How different is the climate change signal in CPM models?

LUC-induced climate change

- LUC-induced change in cloudiness and incoming shortwave radiation too large in nCPS and more realistic in CPS
- Observed decrease in nightly incoming longwave radiation due to deforestation not well represented, possibly due to missing BVOC emissions

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Geophysical Research Letters

Heat stress increase under climate change twice as large in cities as in rural areas: A study for a densely populated midlatitude maritime region

1425

How different is the climate change signal in CPM models?

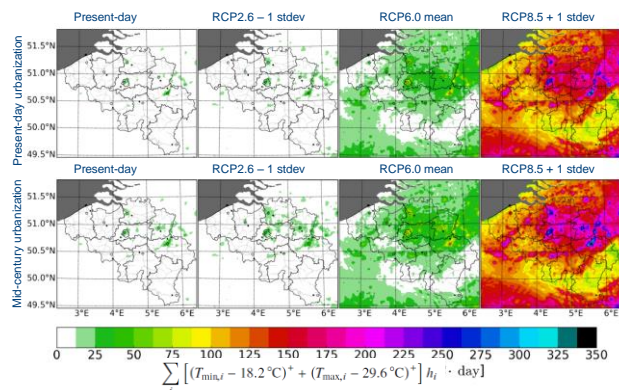
Land use change: Urbanization

Innovation:

- Combining CMIP5 with modelling at the convection permitting scale
- Combining GHG-induced climate change (in CMIP5) with urbanization-induced climate change

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Mid-century increase in heat stress



How different is the climate change signal in CPM models?

LUC-induced climate change: urbanization

- Heat-stress increase towards the mid-21st century is twice as large in cities compared to their surrounding rural areas

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- Orography (not the model) determines the discrepancy between CPS and nCPS

LUC-induced climate change

- LUC-induced change in cloudiness and incoming shortwave radiation too large in nCPS and more realistic in CPS

LUC-induced climate change: urbanization

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