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

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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°C

Akkermans, Thiery and van Lipzig, 2014

Now Convection Permitting Models (CPM) become available

What are the theoretical advantages of CPS?

$\Delta x > 4$ 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.

How different is the climate change signal in CPM models?

GHG-induced climate change
Land use change: Deforestation
Urbanization

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

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

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

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
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?

Model integrations

- COSMO-CLM3.5 (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

Energy balance decomposition

- Surface energy balance
  \[ \epsilon_r \sigma T^4_a = [1 - \varepsilon_a] S W_{in} + L W_{in} - L E - H - G - I \]
- Linearization:
  \[ \Delta T = \frac{1}{4 \kappa \sigma T^4_a} [1 - \varepsilon_a] S W_{in} + L W_{in} - L E - H - G - I - \Delta T_{obs} \]

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

Decomposition of deforestation signal

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

Decomposition of deforestation signal

- Cooling missed in COSMO-CLM
- Observed difference in L SW not in the model
- Effect of lower sensible heat exchange well represented
- Winter (not shown) very similar
Does CPS improve the representation of LUC impact?

Decomposition of deforestation signal for summer day
- Warming due to decreased cloudiness overestimated in nCPS
- CPS responds better to observed climate
- Feedbacks on G, H, δTs

Decomposition of deforestation signal for summer night

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

How different is the climate change signal in CPM models?

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

Mid-century increase in heat stress

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

GHG-induced climate change

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LUC-induced climate change

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