Using convection permitting climate models for evaluation of climate robustness of buildings

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Introduction
Motivation

- Climate Change impacts energy use and thermal comfort in buildings
- The building sector is responsible for a large part of emissions of greenhouse gasses



Delphine Ramon:
interdisciplinary PhD
Department of Architecture
and department of Earth and
Environmental Sciences

Mitigation and adaptation to climate change
I will focus on the first part

Introduction
Design of climate robust buildings

- Early design phase: cooling and heating degree days without building energy simulations
- Mature design phase: weather files needed for building energy simulations

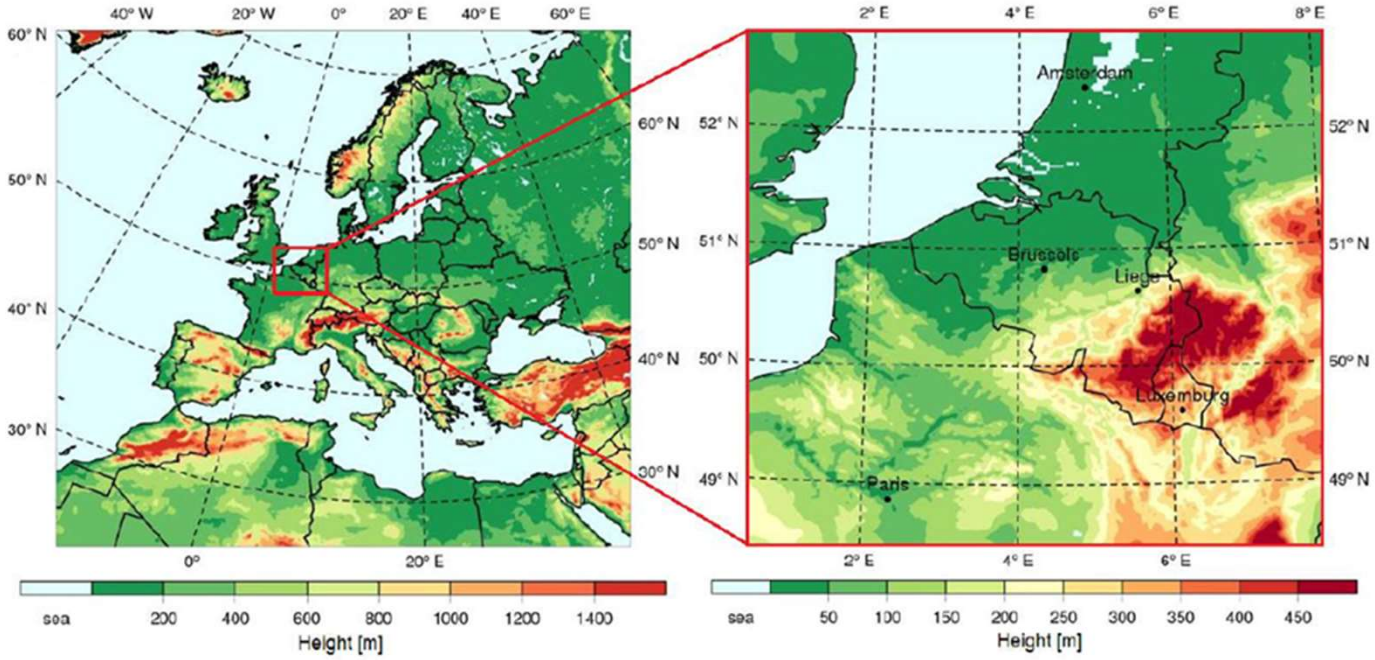
We decided to work with CPM data

Why convection permitting model?

- Better representation of land-use (urban heat island, orography, land-sea contrast)
- Data available at high temporal resolution
- Better representation of clouds

We use CPM both in early and mature design phase

Convection permitting model



Cordex.BE model integration

Δx =12 km→

Δx =2.8 km

Cities represented by TERRA-URB

Driven by EC-EARTH

Quantile bias correction used

Early design phase
Definition of heating and cooling degree days

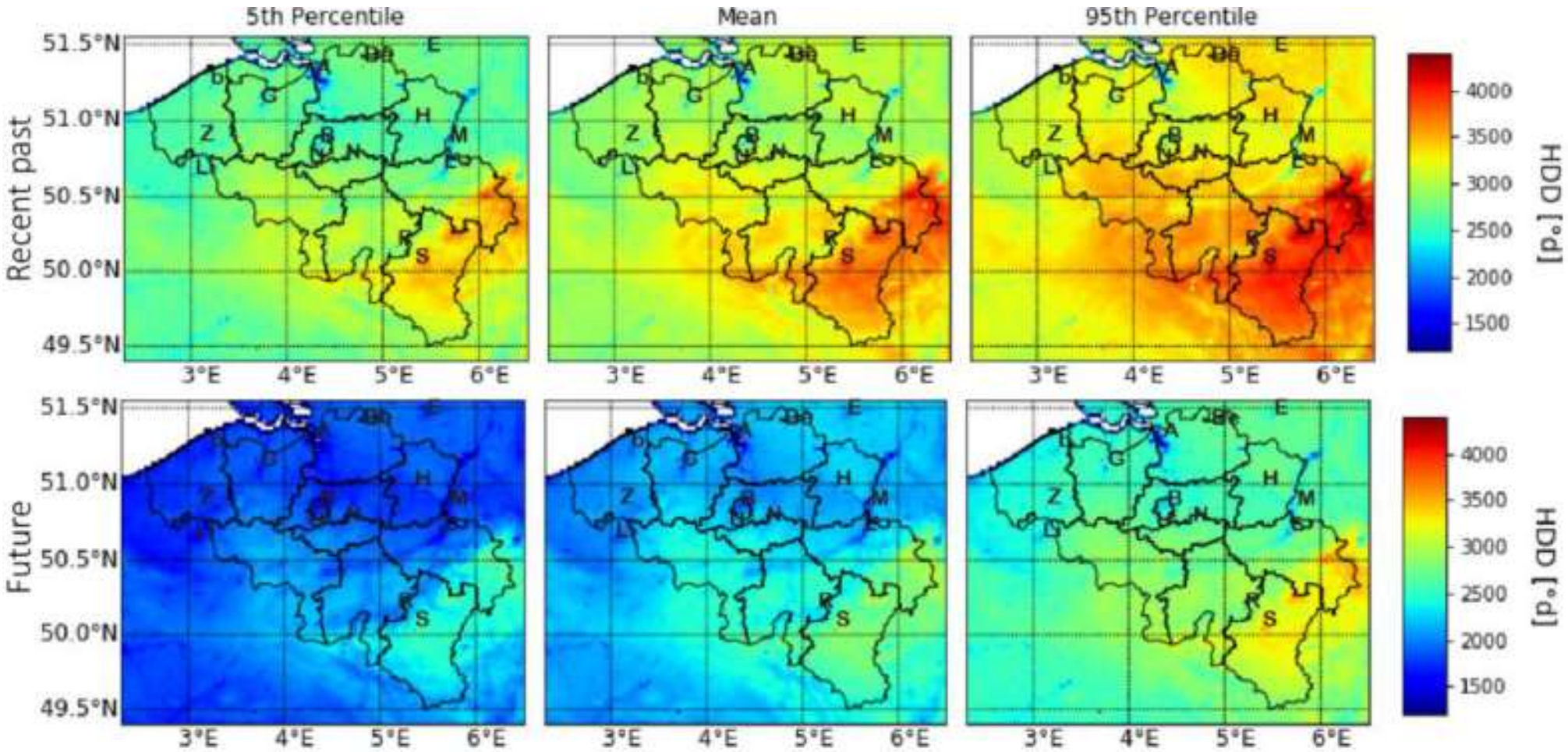
$$HDD = \frac{\sum_{j=1}^{N} (\theta_b - \theta_e)_{((\theta_b - \theta_e) > 0)}}{N}$$

$$CDD = \frac{\sum_{j=1}^{N} (\theta_e - \theta_b)_{((\theta_e - \theta_b) > 0)}}{N}$$

θ_e: outdoor hourly temperature [°C]

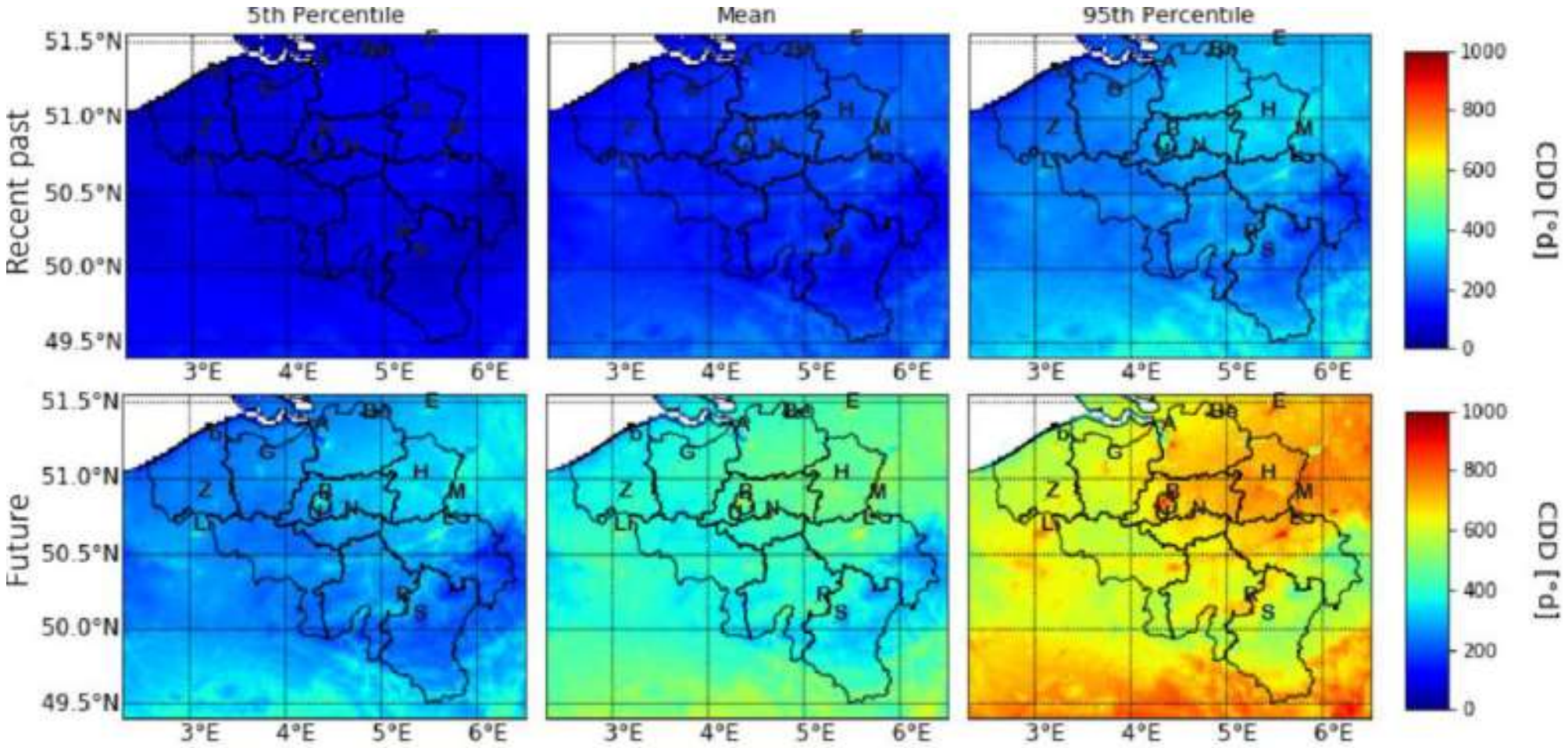
θ_b: base temperature [°C] = 18 °C

N: the hours of the time series



Heating degree days

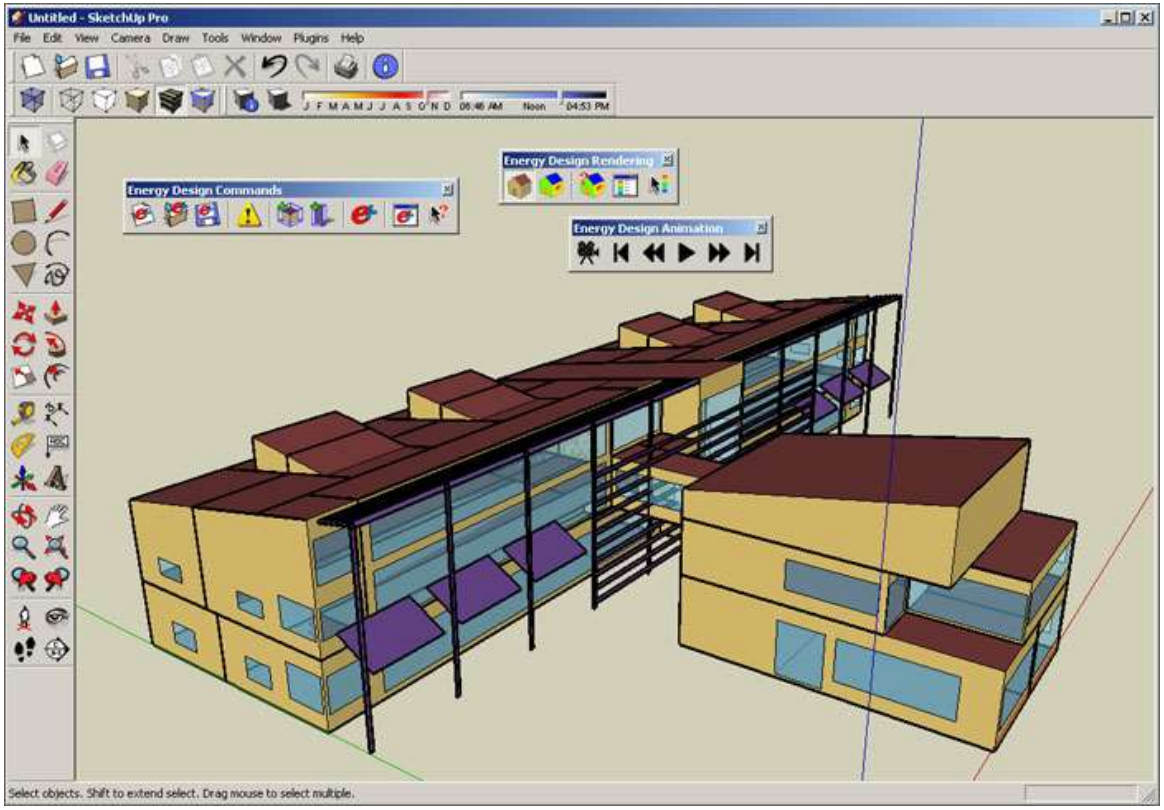
Percentiles refer to distribution of the 30-year period
HDD related to altitude; low HDD in cities and valleys
Strong reduction in HDD of 27%
Warmer winters have the highest absolute reductions in HDD
Warmer regions have lower absolute reductions in HDD

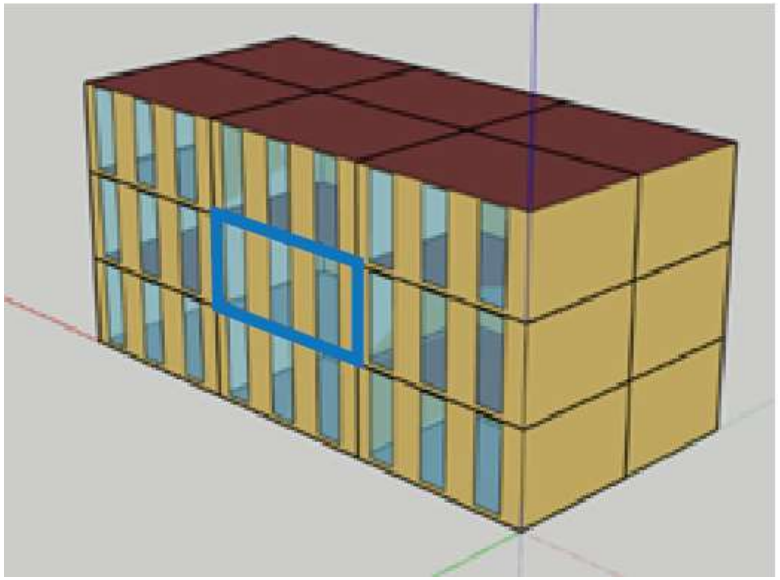


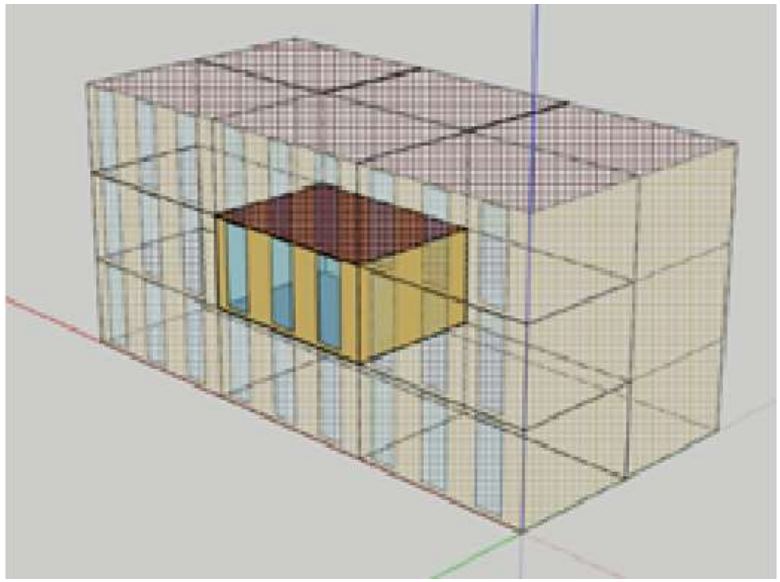
Cooling degree days

Low number CDD
Larger CDD in urban regions especially during warm years
Future shows 3-fold increase in CDD
Cities show largest increase in CDD

Mature design phase
Building energy simulations
EnergyPlus v8.7

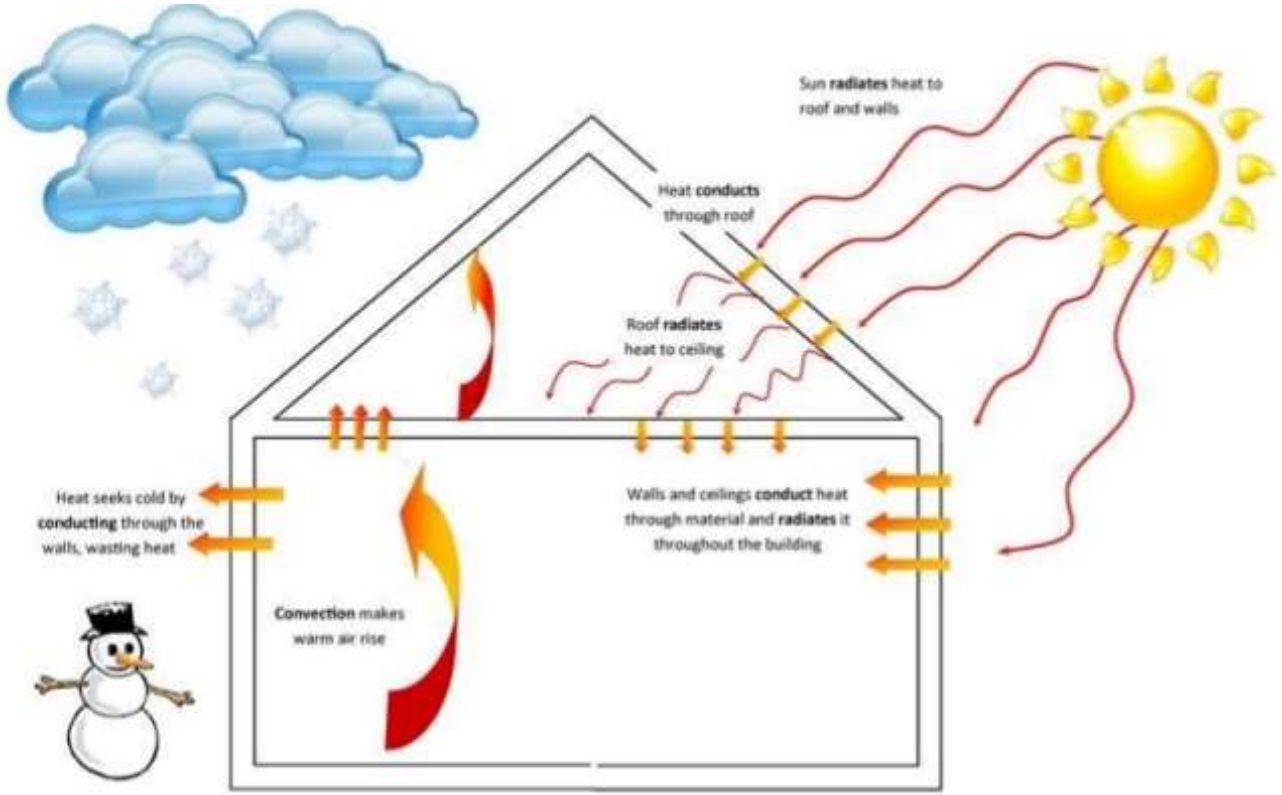






Used in industry

Building energy simulations: EnergyPlus v8.7



Meteorological data as input

Weather files
Input to building energy simulations

- Energy use → typical years
- Dimensioning systems → extreme years
- Comfort → extreme years

- Method is based on the select of representative or extreme months based on statistical properties of a selection of hourly meteorological variables

Jan	Feb	Mar	Apr	Mei	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1986	1999	1983	1985	1997	1990	1991	1998	1983	1983	1983	1998

- Building energy simulations are forced with hourly meteorological data

Weather files
State-of-the art method applied to CPM

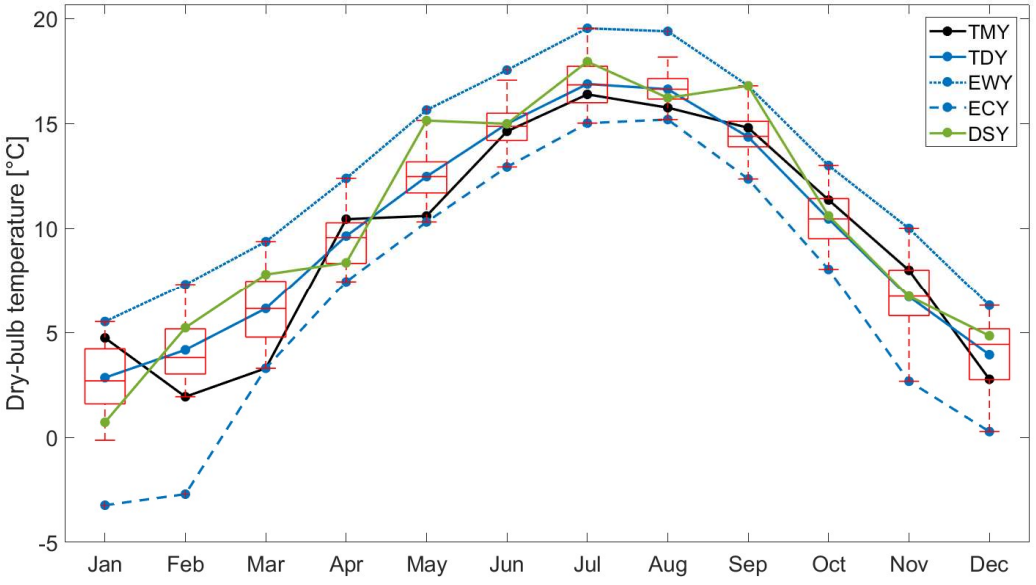
Table 1: Overview used typical and extreme years in the building simulations.

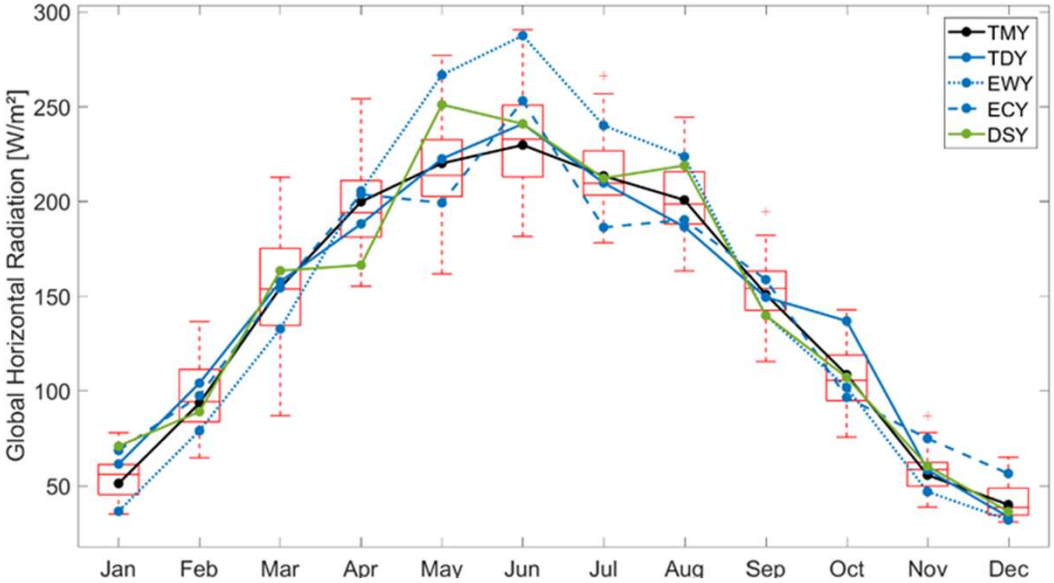
Acronym	Complete name	Weather variables + weights (in %)
TMY	Typical Meteorological Year (Thevenard and Brunger (2002))	T_{min} (5%), T_{max} (5%), T_{mean} (30%), TD_{min} (2.5%), TD_{max} (2.5%), TD_{mean} (5%), $W_{spd,max}$ (5%), $W_{spd,mean}$ (5%), R (40%)
TDY	Typical Downscaled Year (Nik (2016))	T
EWY	Extreme Warm Year (Nik (2016))	T
ECY	Extreme Cold Year (Nik (2016))	T

Notes:
(1) T= dry-bulb temperature, TD = dew-point temperature, Wspd = wind speed, R = radiation.
(2) Weather variables and related weighting factors changed over time for some of the methods and/or differ for different locations.

DSY: design summer year warm April-Sept

Weather files
Present-day bias corrected CPM data

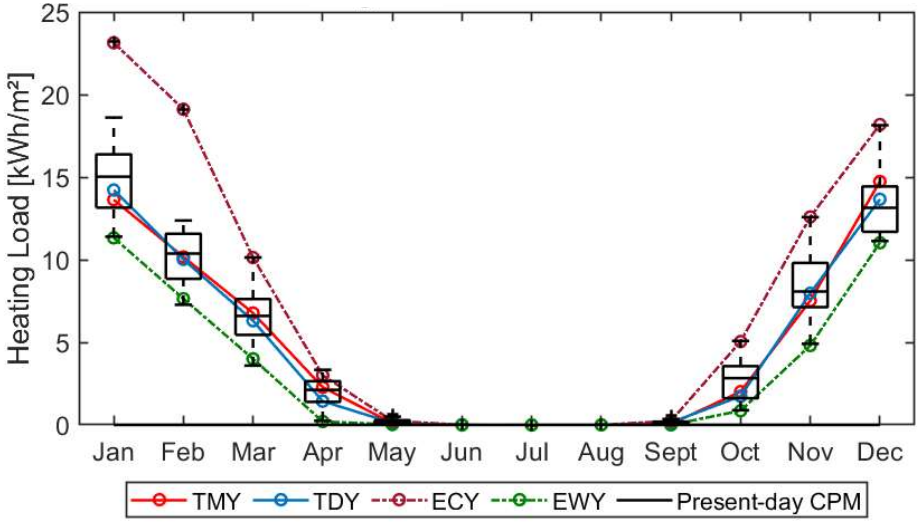


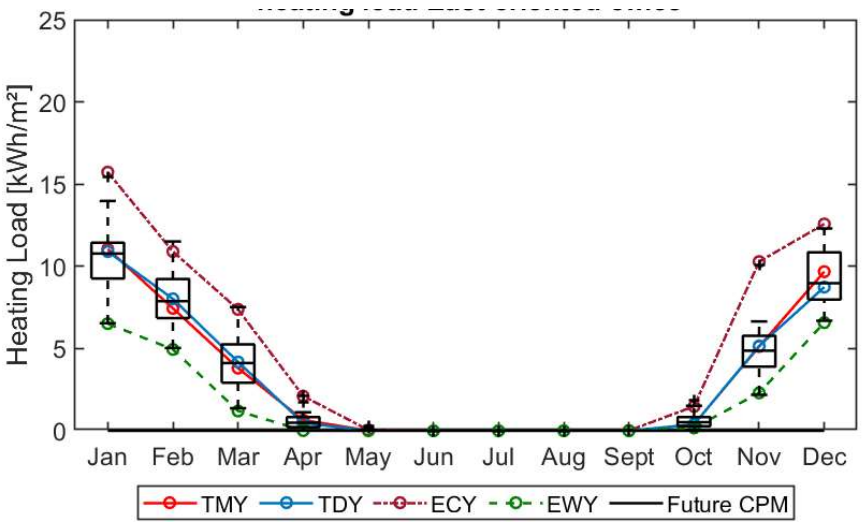


TMY: typical meteorological year
TDY: typical downscaled year
EWY: extreme warm year
ECY: extreme cold year
DSY: design summer year

Some deviations in temperature in the typical meteorological year (temperature only accounts for 40%)
Typical downscaled year only based on temperature
Extreme warm year has high SW radiation in summer, not in winter
Extreme cold year has perhaps tendency for low SW radiation in summer and high SW radiation in winter

Heating Load
Present-day versus future





TMY: typical meteorological year
TDY: typical downscaled year
EWY: extreme warm year
ECY: extreme cold year

typical meteorological and downscaled year follow median heating load
Substantial reduction in heating load also found for this office building

Cooling Load

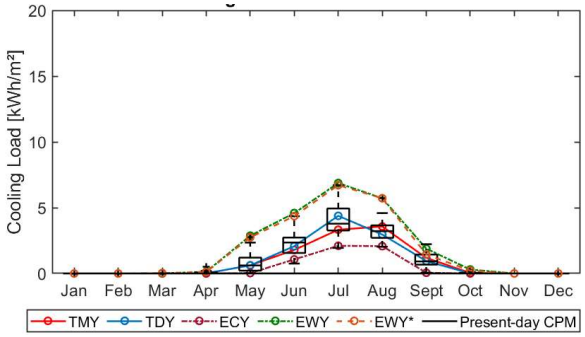
Present-day

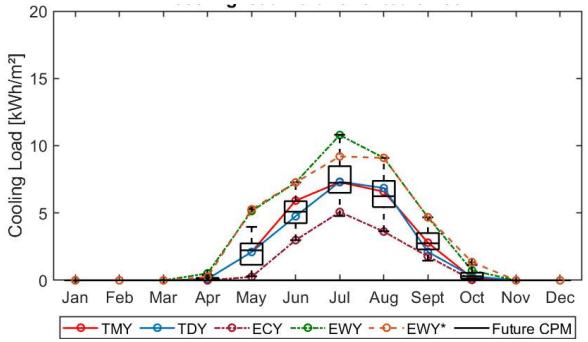
Future

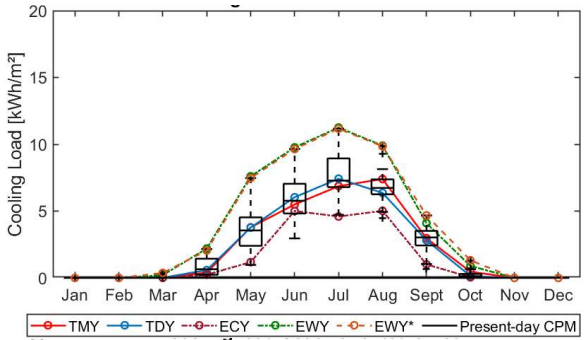
North orientation

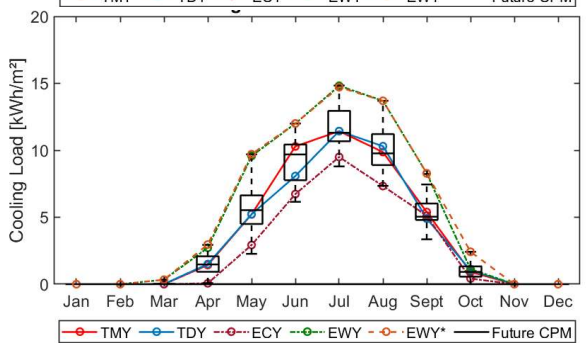
East

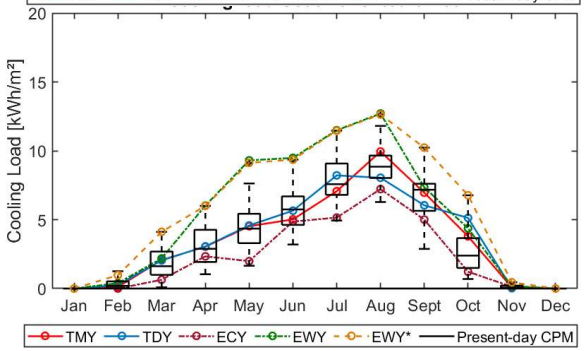
South

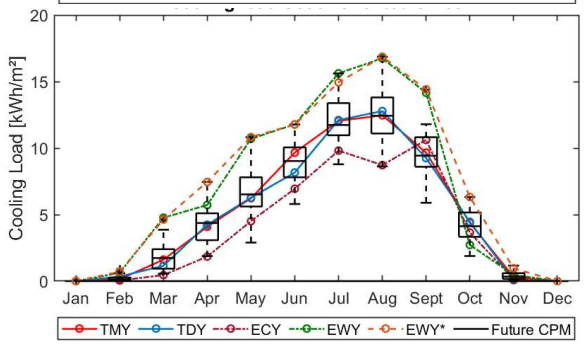












TMY: typical meteorological year
TDY: typical downscaled year
EWY: extreme warm year
EWY*: extreme warm year using radiation in selection
ECY: extreme cold year

Substantial increase in cooling load
Orientation matters
Largest increase in cooling load in southerly oriented offices
West orientation is similar to eastly oriented
Typical meteorological and downscaled year within 25-75th percentile
Extreme warm and cold year represent envelope except for south facing
Including radiations improves the predictive value of the cooling load for extreme warm years especially for the southerly oriented offices

Conclusions

Early design phase:

- Heating degree days for Belgium decrease with 27% and cooling degree days increase by a factor of 3
- Availability of hourly data from CPM more relevant for cooling than for heating
- Cooling degree days in this study increases more than in previous studies due to the use of hourly data

Advanced design phase:

- Methodology has been developed that makes use of hourly CPM data for weather files needed for building energy simulations
- Radiation is needed in the selection criteria for generating these weather files to calculate cooling load (not for heating loads)

Weather files
Present-day versus future bias corrected CPM data

