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A new method for dynamical downscaling of heatwaves by convection-permitting models: event-based downscaling

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Background:

- The record 2018 summer raised awareness of heatwave impact in Sweden (750 excess deaths).
- Simulating a couple of such events poses a significant computational challenge, due to the initialization of high-res Convection-Permitting Models.

Questions:

- What will heat wave events in the present climate resemble in the future, such as in a world with a 2K/3K warming?
- How to optimize the initialization process for computationally demanding CPMs when simulating a couple of extreme events (e.g., heat wave)?

Experiments design

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Selection of 3 summers in Southern Sweden, representing different climate conditions

2017: average summer

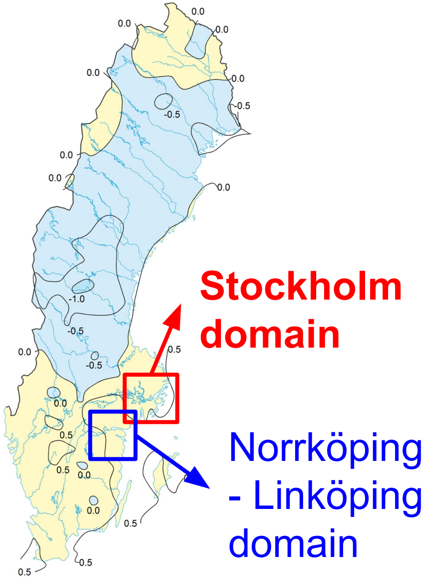
2022: average heat wave

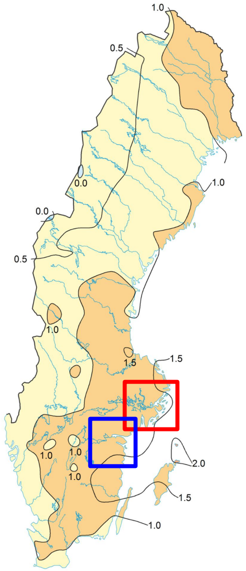
2018: extreme heat wave

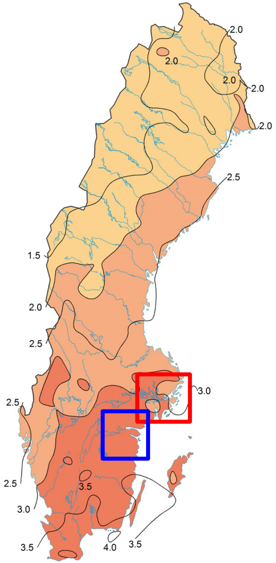
Deviation of average temperature during summer.

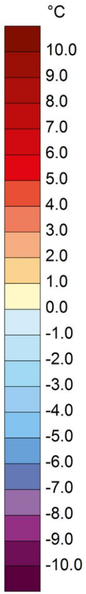
Normal period 1991-2020.

Source: https://www.smhi.se/data/meteorologi/kartor/avvikelse/arstidsmedeltemperatur-avvikelse/sommar









Experiments design

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Selection of 3 summers in Southern Sweden, representing different climate conditions

2017: Average summer

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These events were downscaled under 3 SWLs by the PGW approach

SWL0.9 (historical)
0.9°C warmer than in pre-industrial time

SWL2
2°C warmer than in pre-industrial time

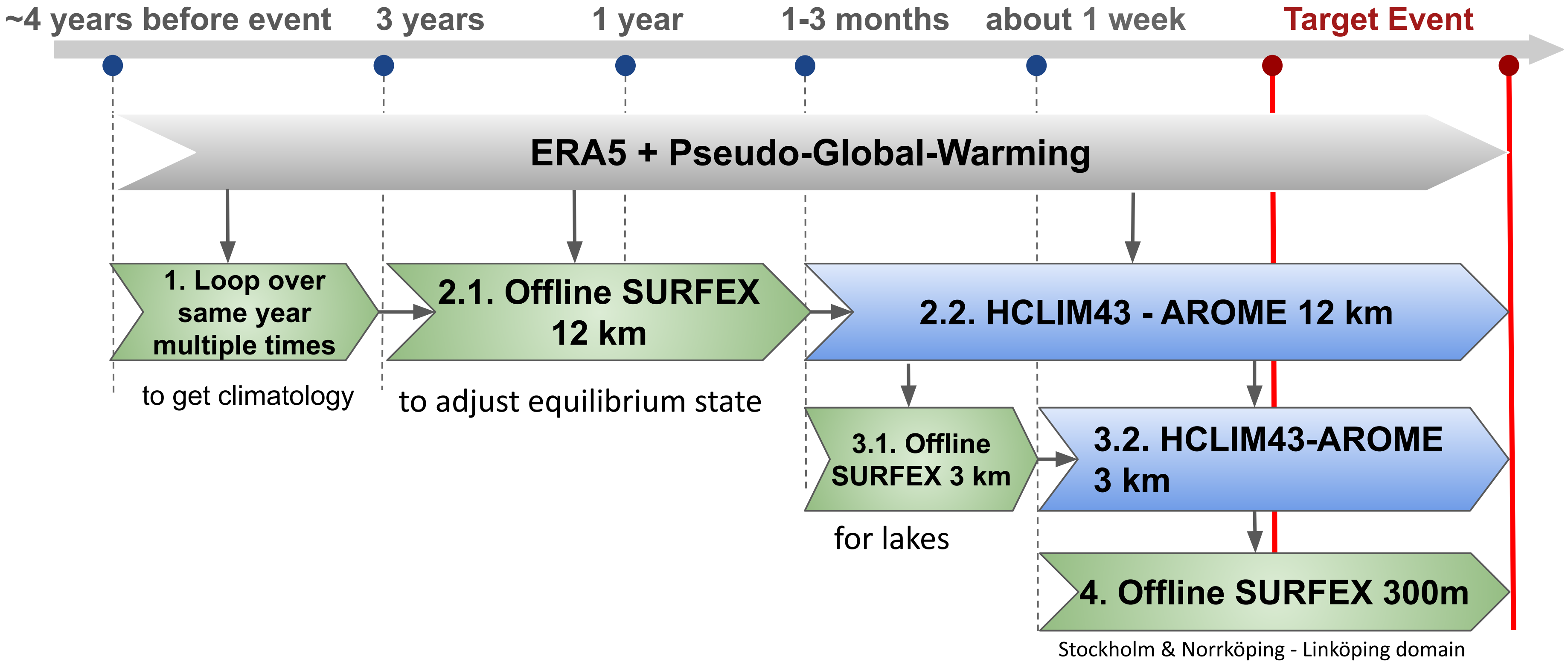
SWL3
3°C warmer than in pre-industrial time

Specific Warming Levels (SWLs) correspond to specific temperature increase regardless of when this point is reached.

Pseudo-Global Warming (PGW) imposes the large-scale GCM-based climate change signal on the boundary conditions of a regional climate simulation

Model: HCLIM43-AROME with SURFEX as land component.

Optimised event-based dynamical downscaling method



- Use the less expensive **SURFEX** model to accelerate the initialization process of **HCLIM**
- With 576 CPUs, simulation time for HCLIM spinup reduced from ~7.3h (traditional method with ~1 year spinup) to ~1.8h per event in our case (150 x 150 grids, 75s time step).

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Comparison against other data: Stockholm area

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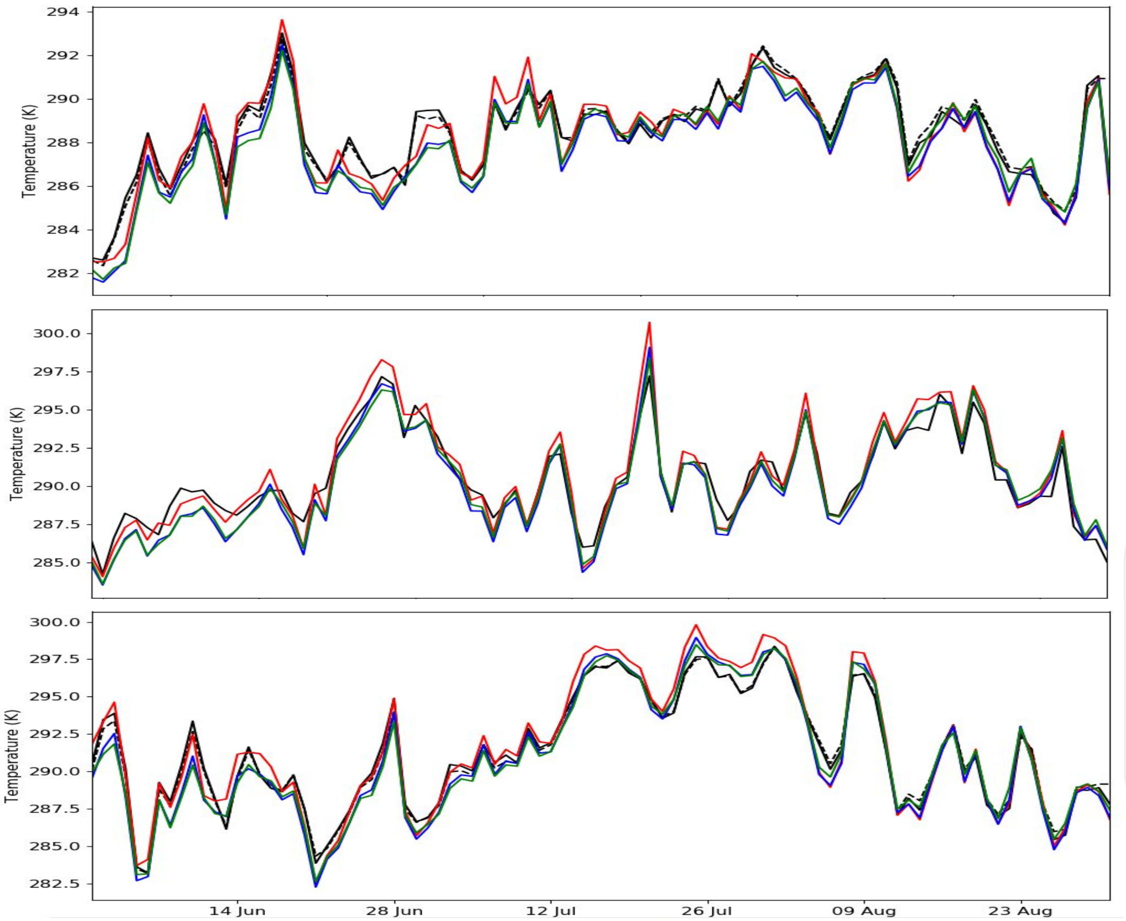
2017
Average summer

2022
Average heat wave

2018
Extreme heat wave



HCLIM 12km
HCLIM 3km
SURFEX 300m
EOBS27 0.1deg
NGCD 1km

2-m air temperature
Jun - Aug (daily)

Water grids excluded

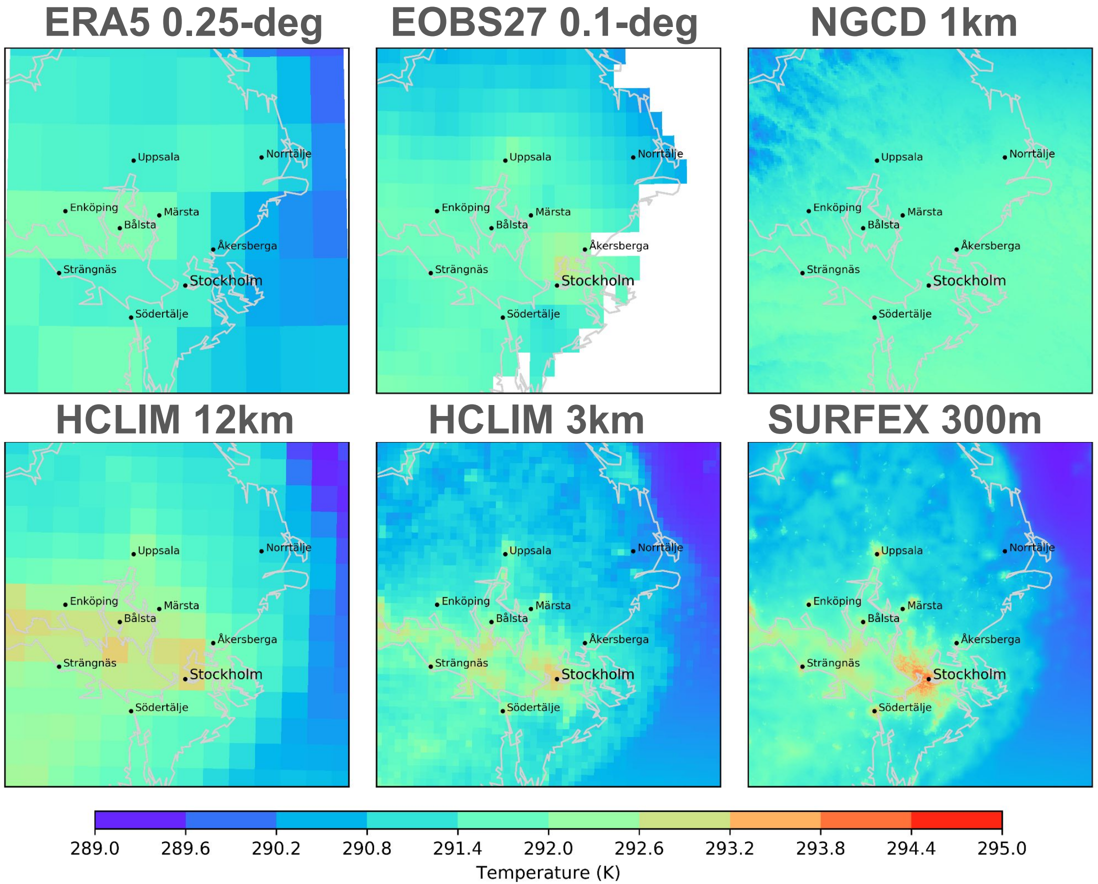
Comparison against other data: Stockholm area

2-m air temperature

2018 extreme heat wave

Jun - Aug, daily mean

Warmer over urban than rural areas



Temperature change: Stockholm area, 2018 JJA

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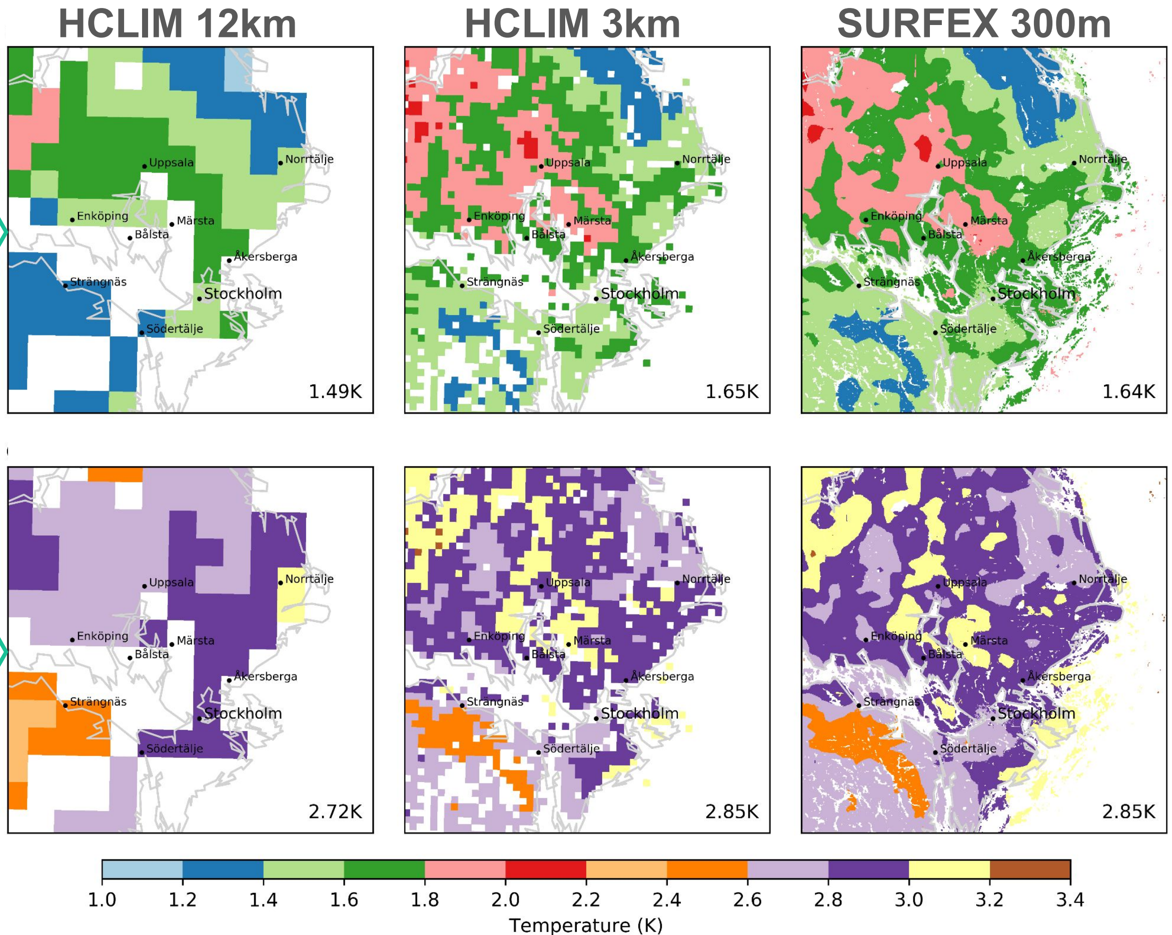
- **SWL2 - SWL0.9 (1.1K** diff in SWL globally)
- Local T increases by **1.49K** (12km), **1.65K** (3km), **1.64K** (300m)

- **SWL3 - SWL0.9 (2.1K** diff in SWL globally)
- Local T increases by **2.72K** (12km), **2.85K** (3km & 300m)



Conclusions

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- **How to accelerate spin-up of CPMs to simulate a couple of events?**
  - Event-Based dynamical Downscaling (EBD) method developed.
  - Lower computational cost: with 576 CPUs, simulation time for HCLIM spinup reduced from ~7.3h to ~1.8h per event (with 150 x 150 grids, 75s time step)
  - Most benefit when applied to a large ensemble of target events.

- **How heat waves change in the future, e.g. under 2K/3K warming?**
  - 2018 Stockholm summer, local temperature increases by ~1.5K or 1.65K under SWL2 & 2.7K or 2.85 K under SWL3 compared to SWL0.9 (global values for SWL).
  - Stronger warming for HCLIM 3km/SURFEX 300m than HCLIM12 km simulation

- **Next steps:**
  - Further test/improve the EBD method (other regions, precipitation, etc.);
  - More in-depth analysis: urban heat island, diurnal cycles, etc.

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FORMAS

Thank you.

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