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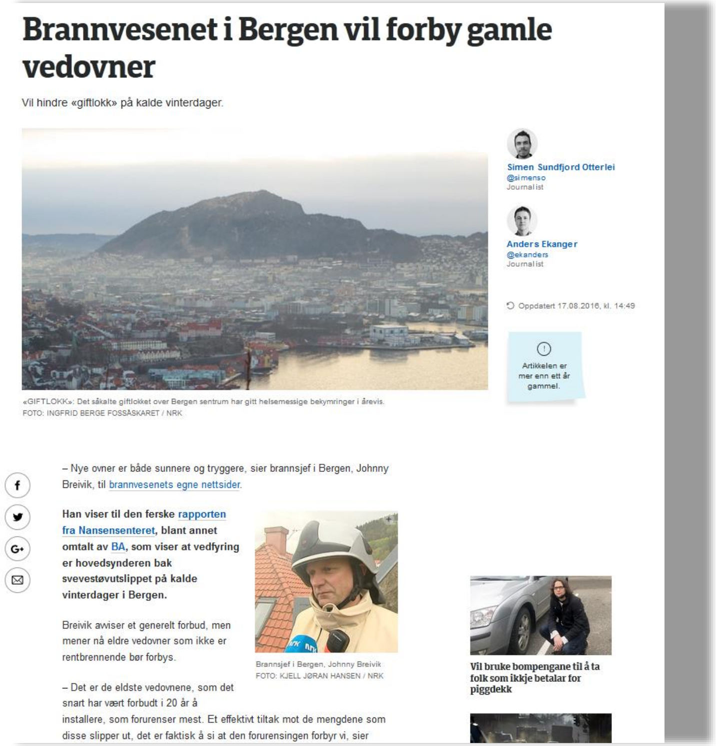
High-Resolution Urban Climate Service for Early Identification of Optimal Policy Measures:

A prototype demonstration in a mid-size Nordic city

Aims and Challenges

Public request: ***How can we share limited economic incentives the most efficiently?***

- Public authorities wants to eliminate/reduce concentrations that exceed a given/prescribed threshold (40 mkg m^{-3})
- Public authorities have limited economic incentives (50 MNOK) and limited policy instruments (a directive to install new-type wood-burning ovens)
- The task is to evaluate air quality outcomes resulting from implementation of the designed policy scenarios
- The challenge (an optimization problem) is to find an optimum scenario that provides for the most within the available resources.



Brannvesenet i Bergen vil forby gamle vedovner

Vil hindre «giftlokk» på kalde vinterdager.

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Oppdatert 17.08.2016, kl. 14:49

Artikkelen er mer enn ett år gammel.

«GIFTLOKK»: Det såkalte giftlokket over Bergen sentrum har gitt helsemessige bekymringer i årevis.
FOTO: INGFRID BERGE FOSSÅSKARET / NRK

– Nye ovner er både sunnere og tryggere, sier brannsjef i Bergen, Johnny Breivik, til brannvesenets egne nettsider.

Han viser til den ferske rapporten fra Nansensenteret, blant annet omtalt av BA, som viser at vedfyring er hovedsynderen bak svevestøvutslippet på kalde vinterdager i Bergen.

Brannsjef i Bergen, Johnny Breivik
FOTO: KJELL JØRAN HANSEN / NRK

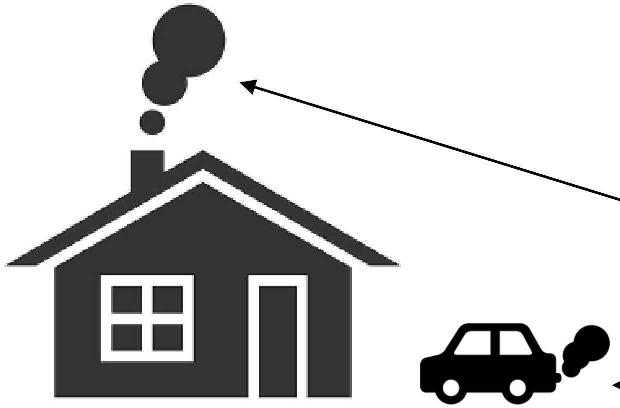
Breivik avviser et generelt forbud, men mener nå eldre vedovner som ikke er rentbrennende bør forbys.

– Det er de eldste vedovnene, som det snart har vært forbudt i 20 år å installere, som forurenser mest. Et effektivt tiltak mot de mengdene som disse slipper ut, det er faktisk å si at den forurensingen forbyr vi, sier

Vil bruke bompengane til å ta folk som ikkje betalar for piggdekk

Complications:

- Emissions come from different sources
- Policy measures change not only emissions but also behavior of people
- Scenario evaluation should be transparent and cost efficient



Chimney emission ~ 10 m

Car emission ~ 0.5 m

High-Resolution Model

*We explore the potential of the **Parallelized Atmospheric Large-eddy simulation Model (PALM)** (Maronga et al., 2015; Wolf et al., 2020) in urban air quality research and applications.*

PALM is:

- Large-eddy simulation class model to resolve the most energetic part of turbulence explicitly
- Solves 3D primitive hydro-thermo-dynamical equations
- Resolves both structural details of the complex urban surface and turbulent eddies larger than **10 m** in size.

The PALM runs have been set up with:

- Real relief from 1 m laser-scan digital elevation model
- Selected typical (not average!) profiles of wind velocity and temperature
- Real land use – land cover surface types obtained from authorities
- Real configuration and activity of the emission sources obtained from road traffic, ships and household fireplaces

Details of methodology and emission inventory is described in Wolf et al. (2020).

The most influential scenarios for model assessment were worked out in co-production with Bergen administration and chamber of commerce.

The PALM model system has been mainly developed and is maintained by the ***PALM group*** at the Institute of Meteorology and Climatology (IMUK) of Leibniz Universität Hannover, Germany.

A mid-size Nordic City:
The Case of Bergen, Norway

A middle-sized (275.000 inh.) Norwegian city embedded in a coastal valley.

The hills are rather steep of typical height of 300 m (645 m max); distance between hills 1-4 km.

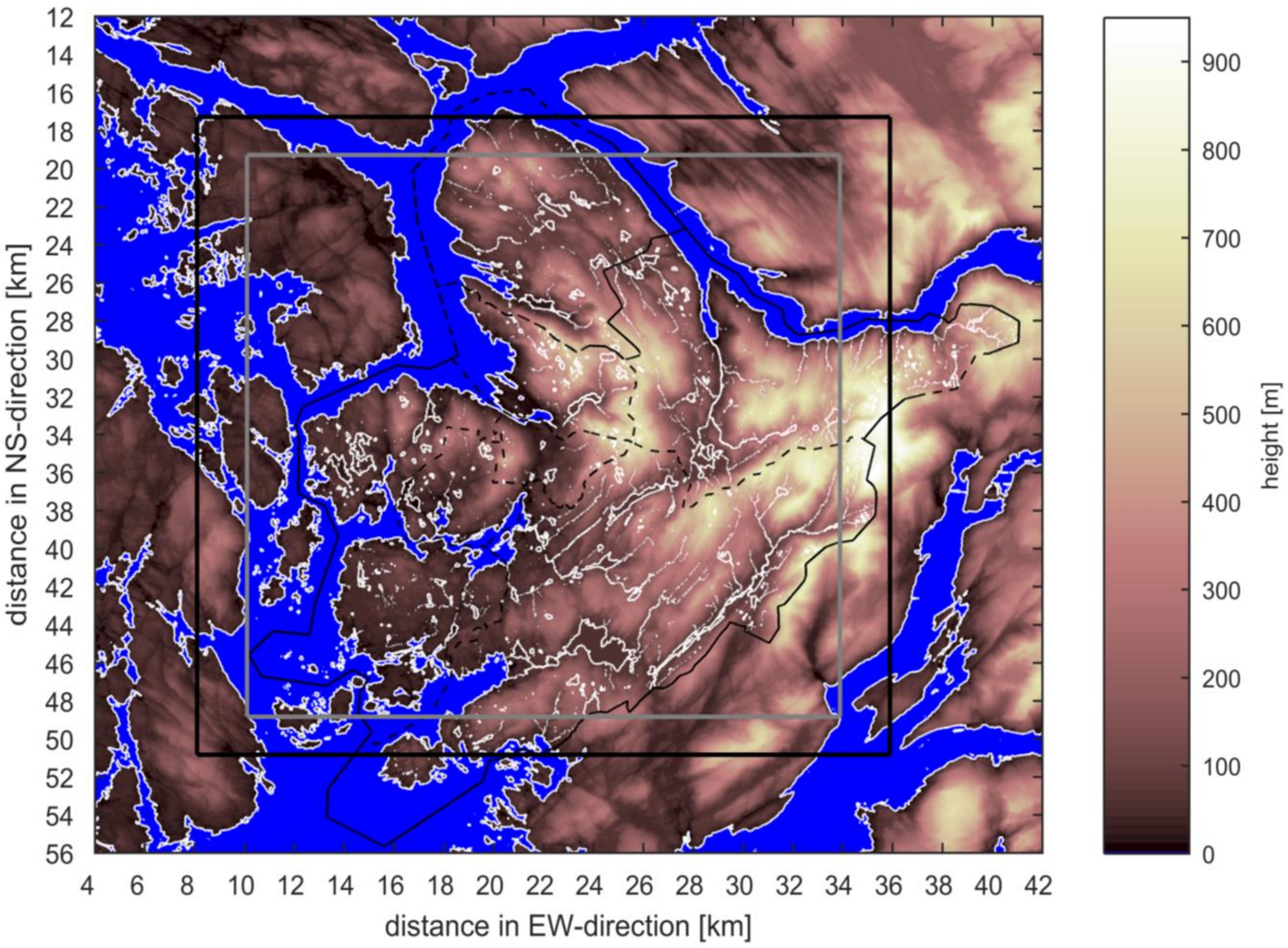
Polluted air during cold winter days tends to accumulate and stagnate in the valley, whereas local circulations redistribute the pollutions across the central city districts.

Local circulations are likely to determine air quality and health risks for the districts' populations (Wolf-Grosse et al., 2017)

Winter haze in Bergen. Photo by Tobias Wolf, January 2016

Urban districts in Bergen

The Model Domain and Setup



Topographic map of the Bergen area. The black square indicates the final model domain used for the PALM simulations; the gray square indicates the focus area for the analysis of the PALM simulations.

Periodic lateral boundary conditions.

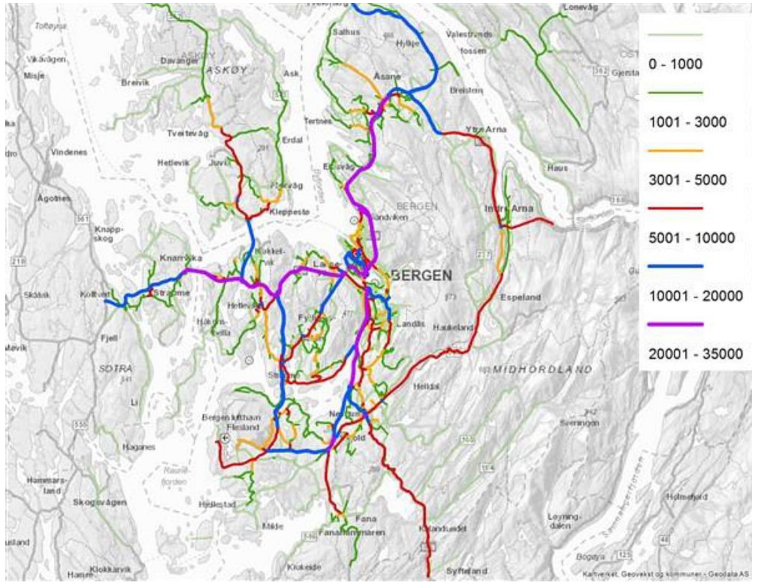
The total domain size is 28800 x 34560 m^2 in the zonal and meridional directions, respectively, including buffer zones for linear interpolation between the periodic boundaries of 1000 m width.

The horizontal grid cell resolution is 10 m.

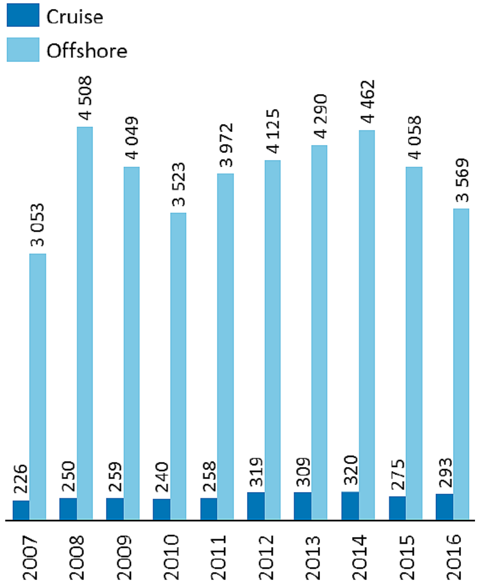
The vertical resolution is 10 m up to a height of 660 m. Above that the vertical resolution increases by 1 % for each additional grid level. The total domain height is 160 levels or 2239 m.

Digital elevation model (DEM) from the Norwegian mapping authority in the GeoTIFF format. We used ArcGIS in order to process the data and create a complete topography data set at 10 m horizontal resolution; linear interpolation to fix small gaps due to missing laser data.

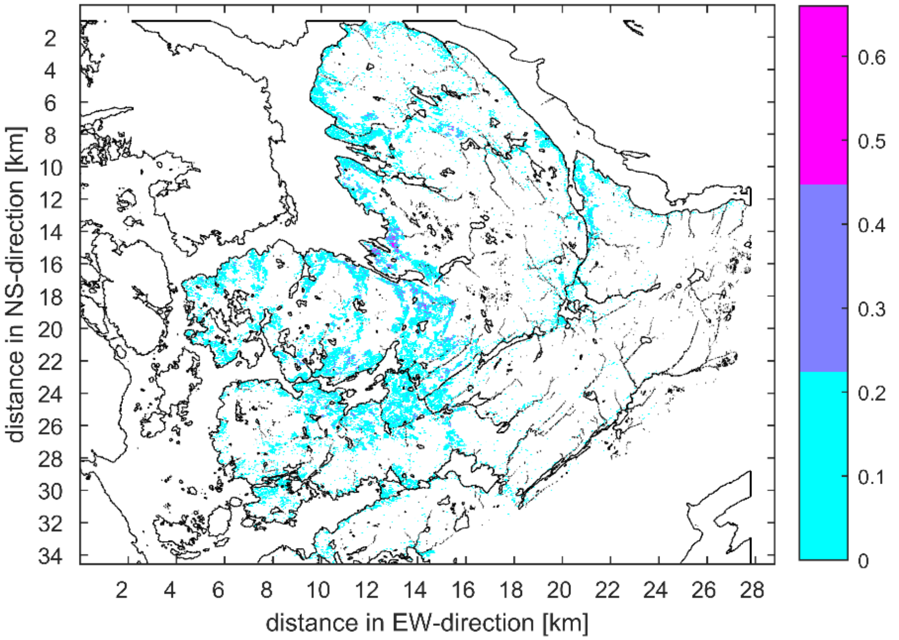
Emission Inventory in Bergen



Mean daily road traffic in Bergen
Source: NILU report no15, 2017

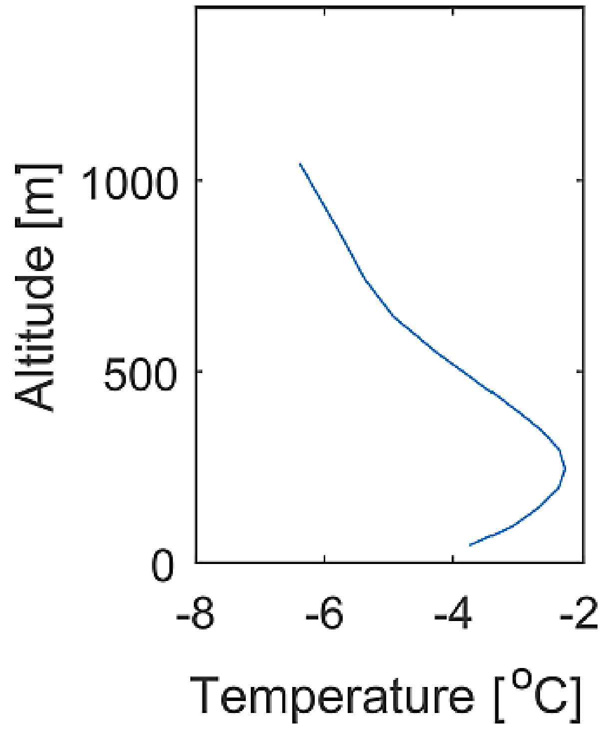


Total annual number of ships in the Bergen Harbour



Map with the locations of wood ovens in Bergen within the modelled domain (centred over Bergen).
The colour shading indicates the number of properties with a registered wood oven per 10 x 10 m^2 grid box when averaged over 3 x 3 boxes. Black lines indicate the waterfront. Based on data from Bergen Municipality and Fire department, respectively.

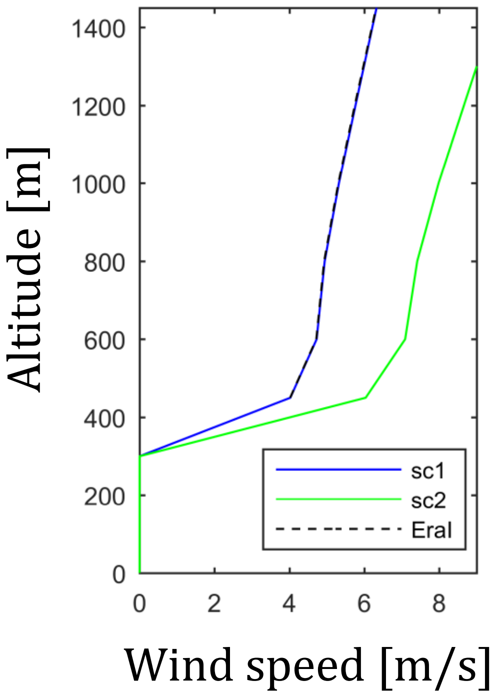
The Bergen study: Scenarios

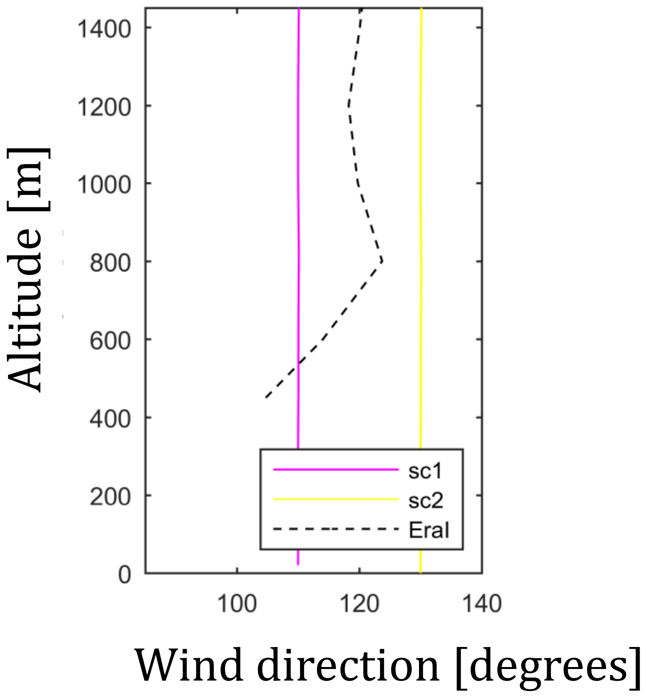


The mean vertical temperature profile used for nudging in the PALM model domain.

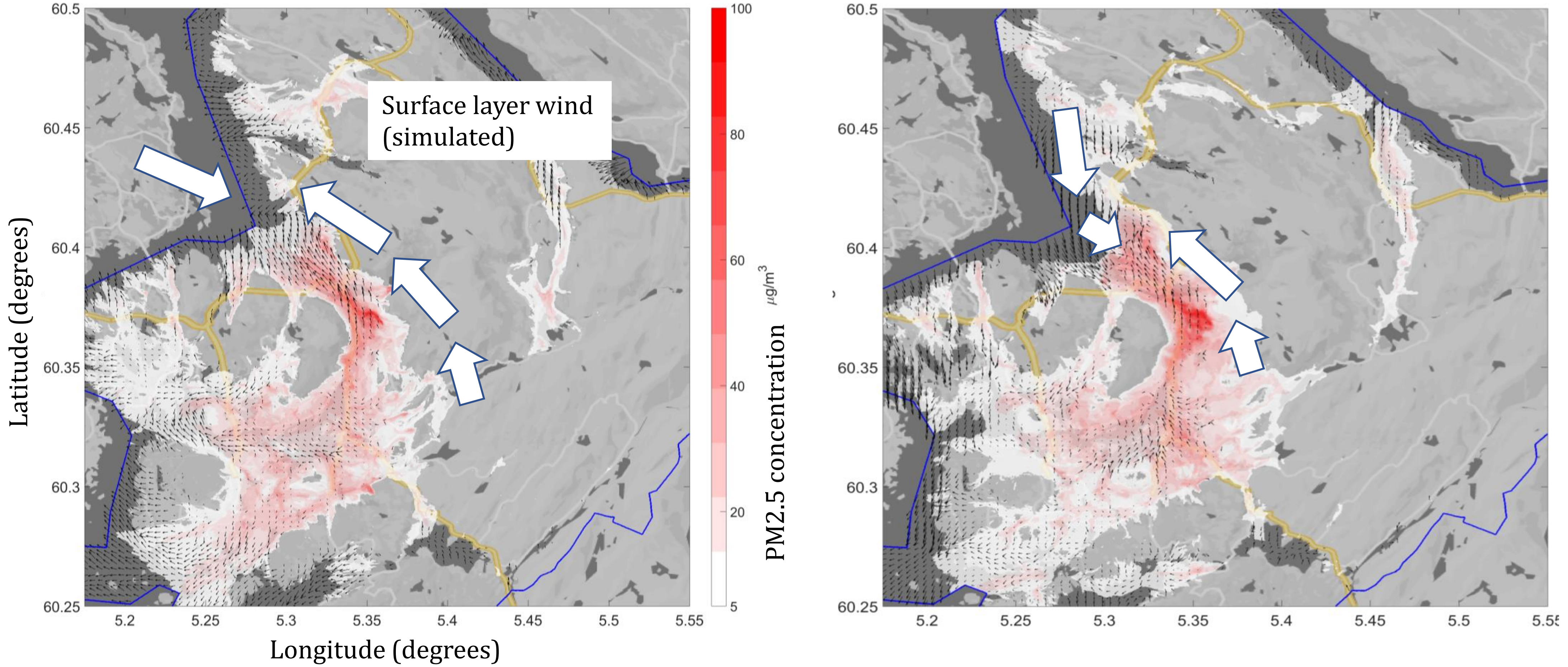
The First Scenario (sc1): Low speed south-eastern wind with sea surface temperature by 2.5°C warmer than the land surface temperature

The Second Scenario (sc2): Low-to-middle speed more southern wind with equal sea surface and land surface temperatures – *characterize air stagnation in the city centrum*



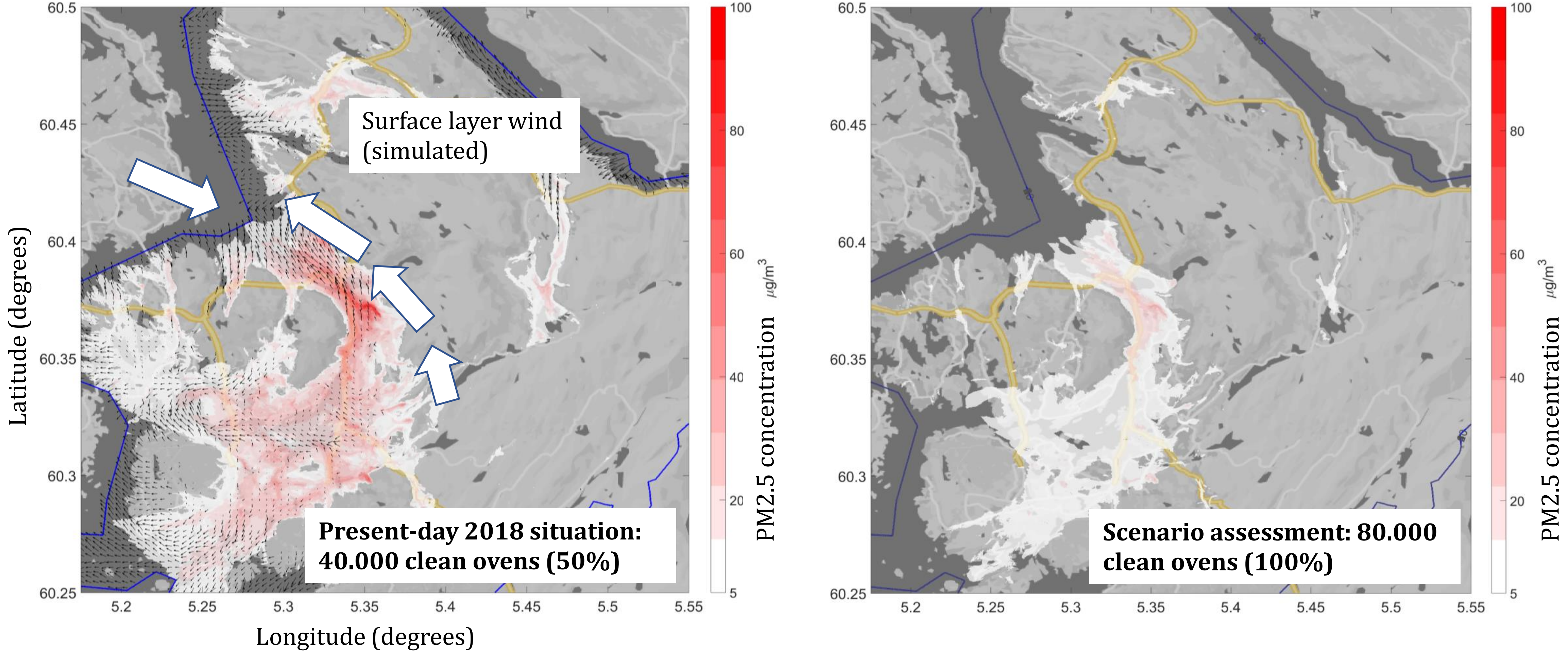


The Bergen study: Results



The PM2.5 concentrations from wood-burning household fireplaces (ovens) – current 2018 composition of the old and new (clean) ovens – in two typical **winter scenarios**

The Bergen study: Assessment

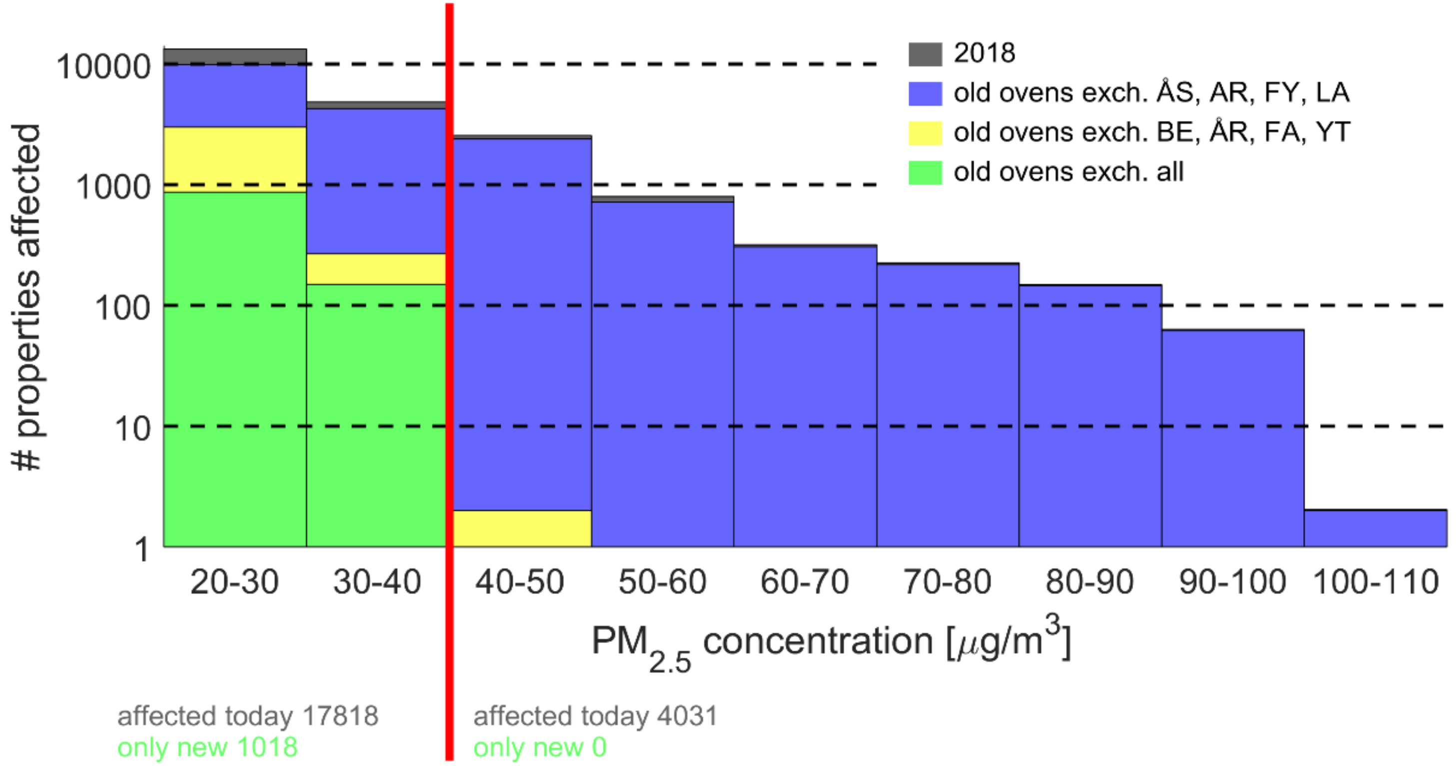


The PM2.5 concentrations from wood-burning household fireplaces (ovens): Present day oven composition impact (left panel) versus future composition impact (right panel) in the first typical **winter scenario**

The Bergen study: Effective Scenarios

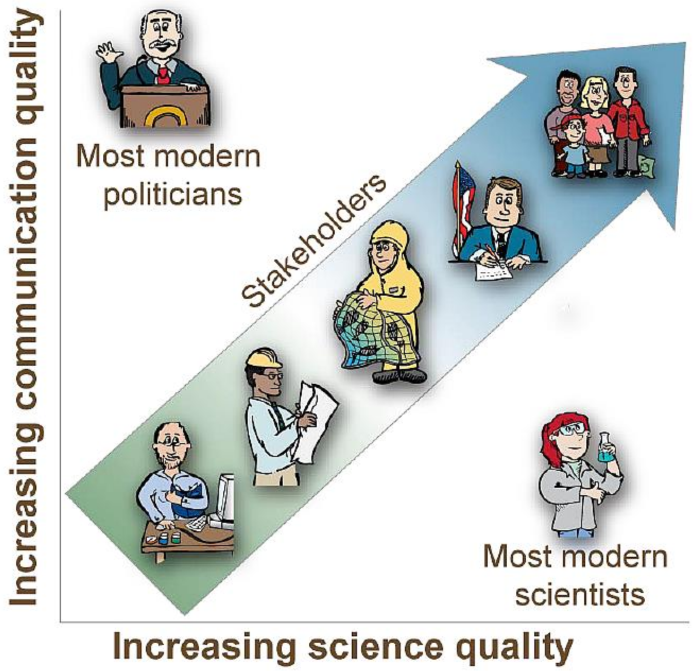
The effects of different policy measures (identified by colors) on the PM2.5 concentration exposures given in the number of affected households

Yellow policy measures: Policy and economic incentive focus on just a few central urban districts will lead to practical elimination of dangerous (40 mkg/m3 or more) level exposure of households



Conclusions

- The climate service prototype has demonstrated:
  - High-resolution large-eddy simulation model (LES) can ***successfully run*** for urban scenarios as well as for the past/present/future environmental quality (atmospheric pollution) assessments
  - The model simulations at 10 m spatial resolution answered ***influencial but previoesly unaccessible questions*** on the contribution of concrete emission sources into the observed concentrations of atmospheric pollutants
  - The simulated scenarios characterized pollution transport and impact ***across urban districts*** informing stakeholders on the most effective polity and economic measures
- Required further development of the prototype:
  - High-resolution models ***must be integrated*** into a downscaling chain to accomodate actual weather conditions in simulations
  - The ***model performance*** must be better explored; urban intercomparizon projects and campaigns are needed – now under development in several countries
  - Local data must be better integrated into the models; a kind of ***assimilation procedure*** is needed



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