(1) PALM - PArallelized Large-Eddy Simulation Model for Atmospheric and Oceanic Flows

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(3) Available modes for the model runs: Research /NERSC, UHEL/, User-services /NERSC/

(4) Components & processes: Atmosphere & Physical, Chemical; **scales** – micro, minutes to hours; -> services & end-users, assessments

(5) Brief model description

PALM has been developed at the University of Hannover, Germany under Sigfried Raasch's (raasch@muk.uni-hannover.de) group (Maronga et al., 2015; Raasch and Schröter, 2001) (https://palm.muk.uni-hannover.de/trac). The model is based on the non-hydrostatic, filtered, incompressible Navier–Stokes equations in their Boussinesq approximated form. The pressure gradient term of the momentum equation is replaced by an expression for the geostrophic wind via the geostrophic balance. Discretisation is done with the finite difference method on a horizontally equidistant Arakawa staggered C-grid. Topography is represented by bottom-surface mounted obstacles occupying full gridcells. The turbulence closure in PALM is a 1.5-order sub grid scale (SGS) closure (Deardorff, 1980; Moeng and Wyngaard, 1988; Saiki et al., 2000). PALM is used by a large user community and has been applied repeatedly for the simulation of urban flows (Esau, 2012; Keck et al., 2014; Kondo et al., 2015; Park et al., 2015a, 2015b). The model has also been validated for urban and urban like flows (Kanda et al., 2013; Letzel et al., 2008).

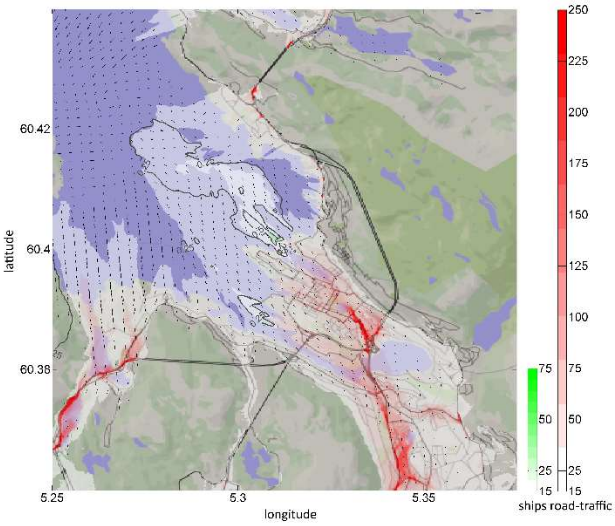

Figure 1: Overlay plot of surface layer (centred at 5 m above the surface, terrain following) pollution concentrations in µg/m^3 from local emissions sources for NO_2 (left) for the baseline meteorological scenario for atmospheric temperature inversions in Bergen, Norway. The impact from ships in port is given in green shading, the impact from road traffic emissions is shown in red shading. Black contours indicate the relative contribution to the total local air pollution by ships. The background map is downloaded from Google Maps. Concentrations below 15 µg/m^3 are omitted (Wolf et al., 2016).

The **NERSC team** uses PALM for the simulation of flows in complex topographic settings (urban and valley topography). Using a LES model in such conditions has the distinct advantage to actually resolve the relevant flow structures determining e.g. penetration of momentum or dispersion of pollutants within the topographic features. An example from a recent project is given in Fig. 1 describing the dispersion of pollutants from ships and car traffic during a typically observed high pollution situation in Bergen, Norway, under the influence of atmospheric temperature inversions.

(The model is mainly used for research purposes but also for user services. Some results are available under most recent publication https://www.atmos-chem-phys.net/17/7261/2017/acp-17-7261-2017.html.

The **UHEL team** uses PALM to study turbulence, turbulent flux footprints and pollutant dispersion in urban areas (Auvinen et al. 2017, Kurppa et al. 2018). Currently, the team is including aerosol processes to be simulated in the model, and use it to understand what kind of building structures, materials and green spaces are most optimal for sustainable urban planning.

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