TURBAN – Observational datasets for studies of urban air quality hazard scenarios in Bergen, Norway

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Abstract

An observational dataset for studies of urban air quality hazard scenarios combines a selection of meteorological, air quality, and geospatial (urban features) data. The data are sampled for two distinct periods:

- Summer – covers 2019-07-20 to 2019-07-27 when one of the strongest historical heatwaves with maximum air temperatures exceeding +30°C affected Bergen.
- Winter – covers 2021-02-04 to 2021-02-15 when one of the strongest historical coldwaves with temperatures below -10oC and ice covering some the fjords (not observed since 1986) affected Bergen

The dataset combines the observations and surface features within the central urban area – the Bergen valley and Byfjorden where (1) air quality observations are available and (2) the most of available data records are found.

The project study area

The central part of Bergen (see Figure 1) is found in a narrow, curved valley on the Western coast of Norway, at about 60°N and 5°E. Around the city center the valley is oriented in a south-east, north-west direction and opens towards a large sea inlet called Bergen fjord. The valley floor is minimum around 1 km wide and the surrounding mountain tops are between 344 m and 642 m high. While the valley shelters the city from extreme wind events from most directions, it also favours the existence of persistent ground-based temperature inversions during wintertime. Bergen has more than 275 000 inhabitants. More than 75 000 (~ 30%) of them reside in the central districts, located in the elongated central Bergen valley – Bergenhus and Årstad districts – the focus of this project. The valley opens toward a sea inlet (Byfjorden) in the northwest. It widens towards a large brackish water lake and more residential areas in the southwest.

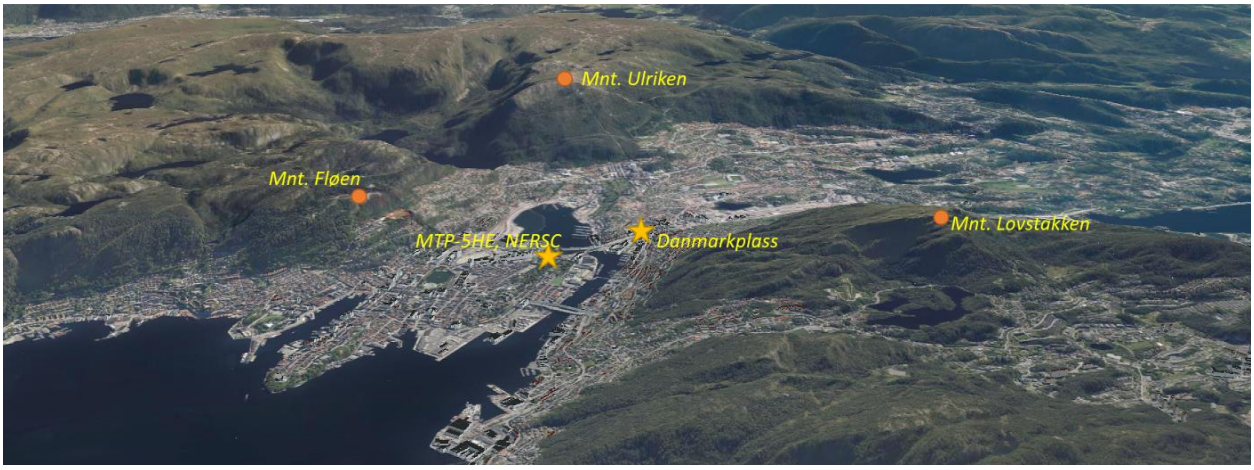


Figure 1. The 3D map of the project domain in central Bergen with landmarks. The map is obtained from http://3d.kommunekart.com/?x=60.39792752867001&y=5.173621406716338&z=3711.597144909886&head=98.16236294721145&pitch=-19.3814018762369 86&roll=0.006973996339505789

Figure 2 shows the relief of the studied area, the model simulation domain, as well as the location of the major air pollution sources in the city. The domains include areas of required project application cases: Bergen Port; Tunnel entrances (Fjelltunnelen, Damsgårdtunnelen, Bytunnelen, Arnatunnelen); Major road conjunctions (Bystasjon, Danmarksplass, Puddefjordsbroen); Major parking houses; Major cultural objects (UNESCO Bryggen, Grieghallen) and shopping malls.

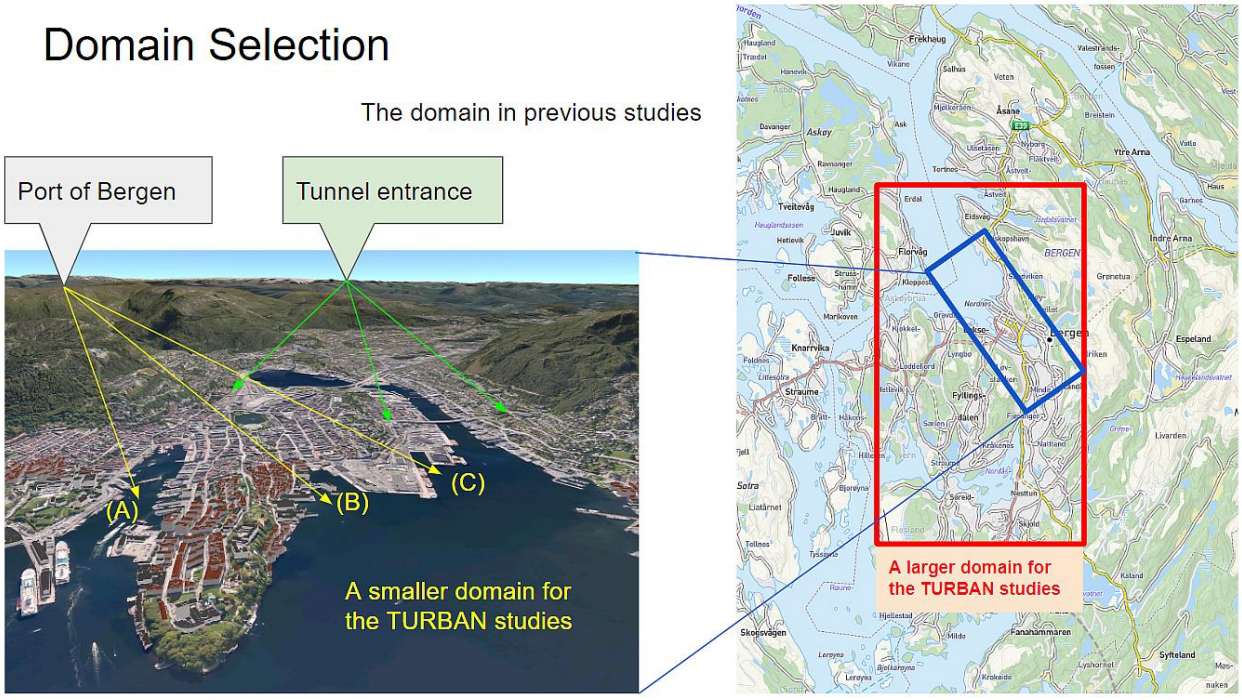


Figure 2. The project study area with indication of points of interest.

Episode scenarios

Winter episode	04 – 15 February 2021 (Julian Days, JD, 35-46)	Persistent anticyclonic weather conditions
Summer episode	20 – 27 July 2019 (Julian Days, JD, 201-208)	Persistent anticyclonic weather conditions

The most severe air pollution event has occurred in January 2010. Persistent temperature inversions led to hourly mean NO2 concentrations above 400 µg m^{-3} and exceedances of the national target for air quality of hourly mean concentrations of 150 µg m^{-3} at least once per day during 19 days in January 2010. Since 2010, several severe air quality hazards have occurred in Bergen. It is important to take into account that air pollution sources causing the hazards in 2010 (NO2 exhaust of diesel personal cars), 2019 (NO2 exhaust of large cruise ships), and 2021 (PM2.5 exhaust of wood-burning stoves in households) were different. All episodes triggered public and media attention from the local up to the national levels. This attention justifies our choice of the two latest episodes for the project case study.

The winter episode 2021-02-04 through 2021-02-15 (Julian days 35-46) is characterized by persistent cold anticyclonic weather, high air pollution, particularly from domestic wood-burning. The summer episode 2019-07-20 through 2019-07-27 (Julian days 201-208) is characterized by persistent hot anticyclonic weather, high air pollution, particularly from cruise ships in the city central districts.

Figure 3. Illustration of typical weather conditions during the winter (left) and summer (right) episodes.

Data sets

The observational datasets consist of meteorological time series (in situ observations, ground-born and satellite remote sensing, air quality observations) and geo-spatial data (digital elevation model, geomorphological data, and special socio-economic and environmental data).

Figure 4 present a map with locations of time series available in the project. The EXCEL table **`landmarks.xlsx`** provides geographical coordinates of all data collecting instruments and other important locations used in this project. Observe that coordinates of the NETATMO stations are given together with the NETATMO dataset.

Table 1. List of accessed data sources

Link to a data source	Type of data	Comments
https://seklima.met.no/observations/ (manual download in EXCEL formats) https://frost.met.no/index.html (automatic download in JSON format)	Observations at meteorological station (air temperature, wind, pressure, precipitation, etc)	Records are complete and quality controlled if the station was functional
https://veret.gfi.uib.no/	Meteorological observations at the Geophysical Institute of University in Bergen Meteorological temperature profiler MTP-5HE data	Diverse observations, mostly (but not always) complete and quality controlled
https://www.bergensveret.no/status/	Meteorological observations at the amateur school stations	A sparce dataset for the selected episodes
https://luftkvalitet.nilu.no/historikk		

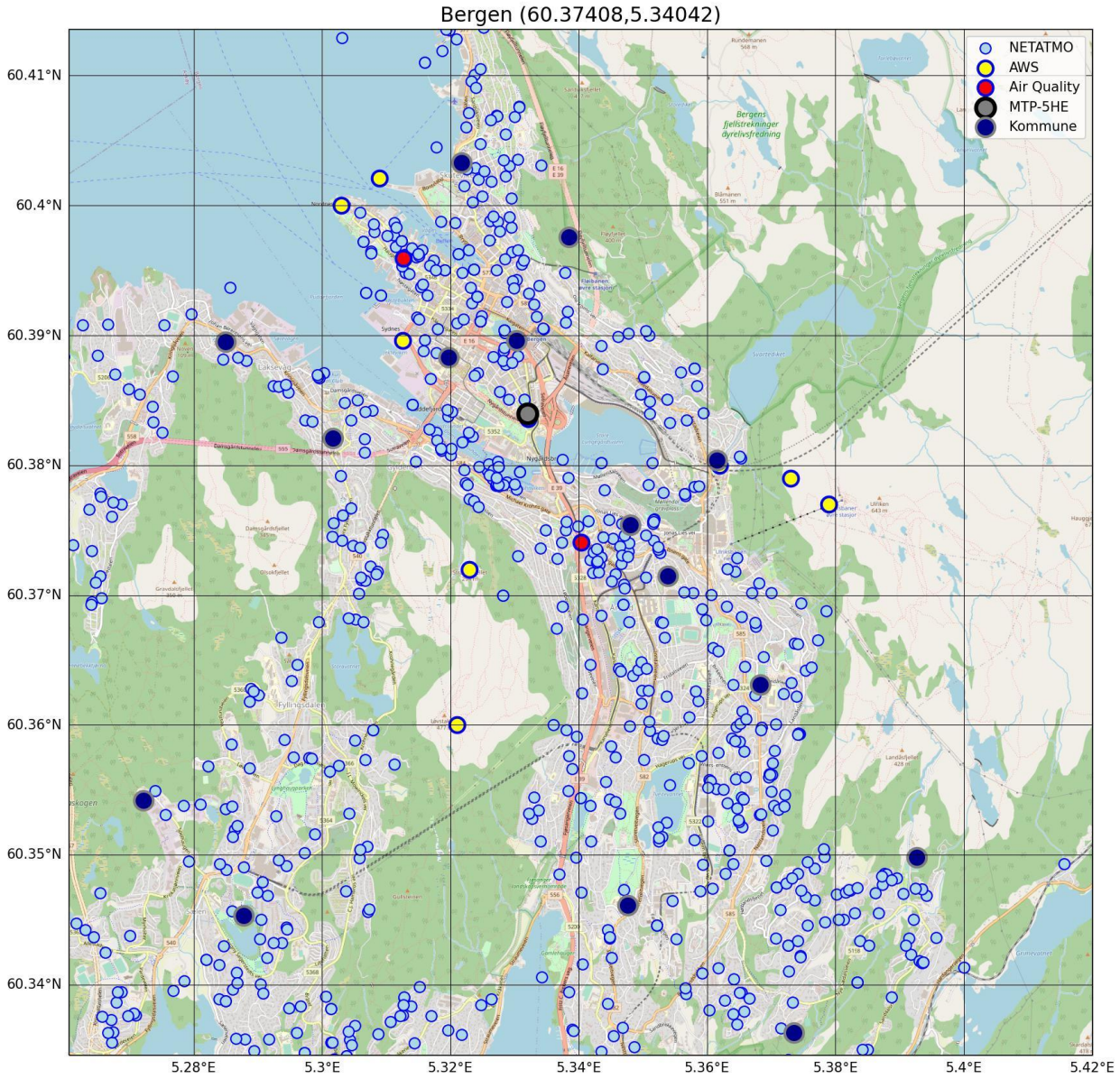


Figure 4. Locations of all time series (meteorological and air quality) in the project domain (the central part of Bergen municipality). NETATMO is the citizen (amateur) temperature sensor network; AWS is the professional certified automatic weather station network; Kommune is the educational (amateur) weather station network based on DAVIS VANTAGE PRO stations. MTP-5HE is the meteorological temperature profiler. Air Quality is the network of air quality observing stations. Observe that actual accessibility and quality of data vary.

Time series

The dataset includes sampling of time series of meteorological observations from regular and irregular (amateur) stations, from the meteorological temperature profiler MTP-5HE, and from the air quality stations. The basic time series – the most complete and quality-controlled ones – are obtained from Florida AWS, Danmarkplass NILU air quality station, and MTP-5HE at GFI. Figure 5 show the combined presentation of the meteorological and air quality data during the winter episode.

Table 2 list all time series data in this dataset, their features and access to the data sources.

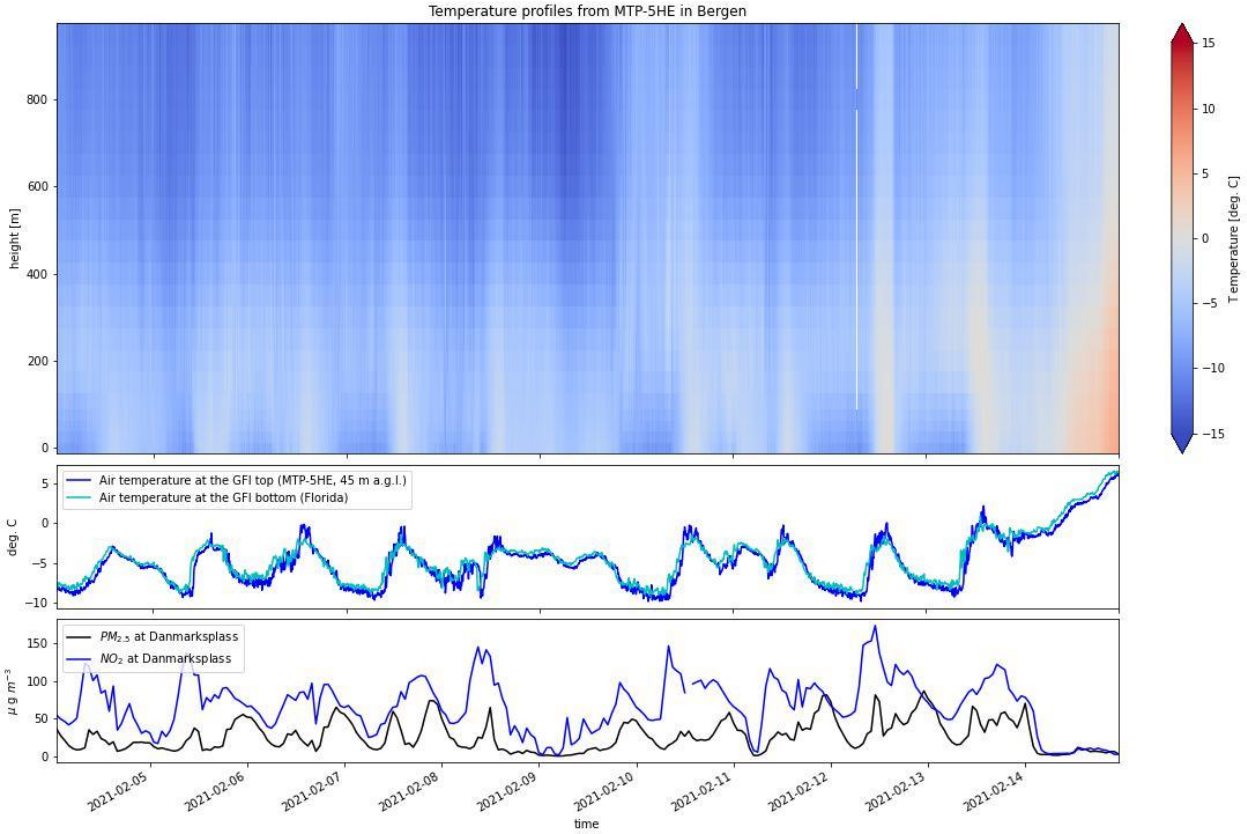


Figure 5. Combined presentation of the meteorological and air quality conditions during the winter episode.

Table 2. Complete list of time-series in the present dataset

Dataset	Instrument/sensor	Description	Comments
MTP_winter_TURBAN.nc MTP_summer_TURBAN.nc	Meteorological temperature profiler MTP-5HE[1] from ATTEX[2] Installed at the roof of the Geophysical Institute (GFI) of University in Bergen (UiB), Bergen, Norway[3] Latitude: 60.384 Longitude: 5.332 Elevation above sea level: 48 Elevation above ground: 30	Number of stations: 1 Method: Passive microwave radiation measurements at around 56 GHz emitted by the atmospheric oxygen; The sensor scans in angular steps along directions from 0° (horizontal) to 90° (vertical). See technical description in (Khaikin, 2010; Khaikine et al., 2006) Retrieval: Solution of inverse integral-differential problem. Measured radiative brightness temperature is converted into meteorological air temperature of a layer of air. See details in (Westwater et al., 1999) Sampling frequency: 5 minutes Resolution: The range of operation 48 m to 1048 m above the sea level. Vertical resolution 25 m in the lowest 100 m and 50 m above it. See details in (Wolf et al., 2014) Data: current data are available at https://veret.gfi.uib.no/?action=mtp (last accessed 13.01.2023); historical data are available upon request aa well as provided with this dataset (Feb 2021 – July 2022).	The instruments accuracy deteriorates in clouds and precipitation layers, therefore, the readings in such periods are excluded from the dataset. See details in (Ezau et al., 2013) There were no such periods in the selected scenarios. Read and convert script: MTP_data_TURBAN.py
School stations/	Automated weather station (AWS) amateur (school) observational network based on DAVIS VANTAGE PRO instruments[4]	Number of stations: max 54 but many are not providing during the scenario periods. Therefore, only the most complete key stations are selected for the project.	Many stations have very irregular sampling and not available over longer periods. Data are more regular since 2022.

[1] The main characteristics of the instrument could be found on http://attex.net/EN/mtp5HE.php last access on 11.01.2023
[2] The web site of ATTEX is http://attex.net/EN/index.php last accessed on 11.01.2023
[3] MTP-5HE web page (https://www.uib.no/en/rg/meten/54892/microwave-temperature-profiler-attex-mtp-5) last accessed on 11.01.2023
[4] Real time data are available at http://bergensveret.no last accessed 12.01.2023; the data use is regulated by the Norwegian license for public data (NLOD) 2.0

		Data: https://veret.uib.no/lastned/ School stations with large gaps: 2013-on List and coordinates https://www.bergensveret.no/stasjonsliste/ Active status https://www.bergensveret.no/status/	
Meteo/	Automated weather station (AWS) of professional quality observational network based on AAnderaa instruments, see (Wolf et al., 2014)	Number of stations: 7 (5 stations of the Norwegian Climate Service Center and MET.NO)[5]; 2 stations (Ulriken and Florida) of Geophysical Institute (GFI) at UiB. Data: https://seklima.met.no/observations/ for manual download in EXCELL formats and https://frost.met.no/index.html for automatic download in JSON format (both last accessed on 13.01.2023); GFI stations and other data are available for download at https://veret.gfi.uib.no/?action=download (last accessed on 13.01.2023)	Many stations have incomplete sampling and not available over shorter periods. The Ulriken station did not provide data during both episodes. The basic WMO station is Florida at the ground at GFI.
NETATMO_Bergen.zip	NETATMO amateur citizen observational network	Number of stations: 597 (unique identifiers) The number of observing stations strongly varies on hourly basis. The quality controlled NETATMO dataset for the project area has been provided by © Urban Climatology, Ruhr-University Bochum, Germany[6] Figure 6 provides the map of the stations Figure 7 provides the information on the data completeness for the two selected periods. Figure 8 characterizes the surface temperature through observations.	The data set has been provided as a collection of CSV files and the PDF document with description. See description and details also in (Fenner et al., 2021) Read and plot script: details_NetatmoBergen.py

[5] Norsk Klima Service Senter at https://klimaservicesenter.no/ last accessed on 13.01.2023
[6] The unit web site is https://climate.rub.de/ last accessed on 11.01.2023; personal acknowledgments to Jonas Kittner

air_quality_data_Winter.nc air_quality_data_Summer.nc Air Quality.zip	Air quality monitoring network of the Norwegian Institute for Air Research (NILU)[7]	Number of stations: 5 (2 stations in the project area, see Figure 4)	Data are quality controlled Read and convert script: air_quality_NetCDF.py

[7] The Air Quality Monitoring Data Service is provided by NILU at https://luftkvalitet.nilu.no/en last accessed 12.01.2023

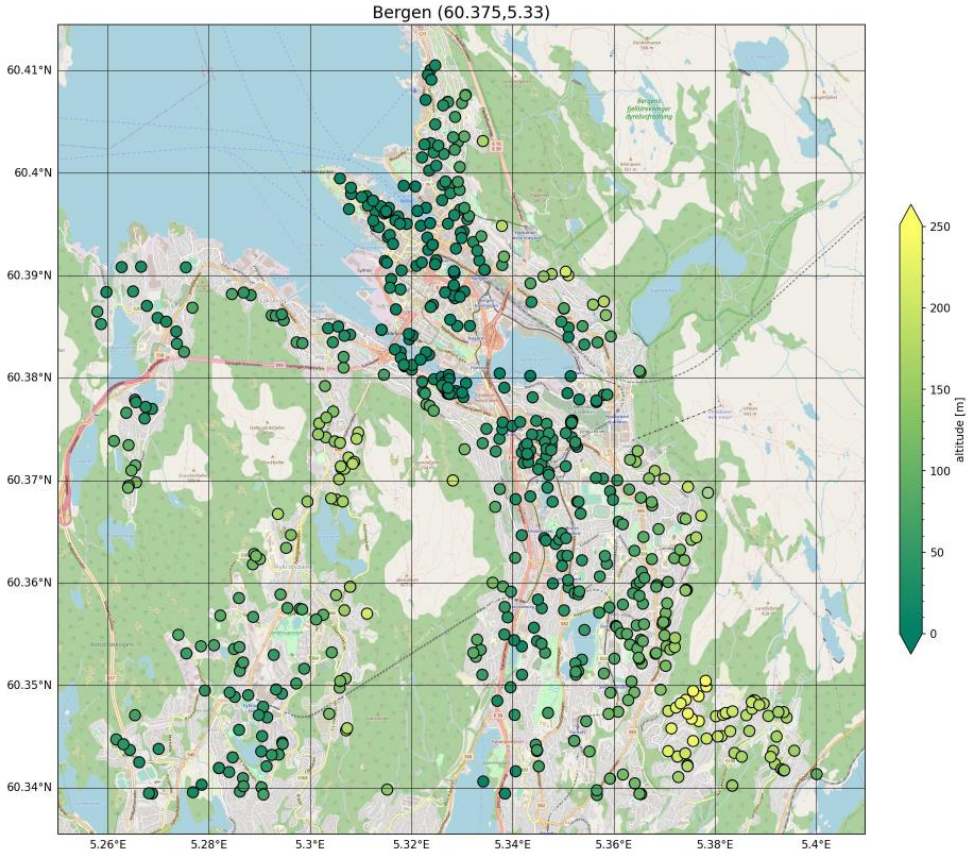


Figure 6. All NETATMO stations in the selected colored by their altitude above sea level.

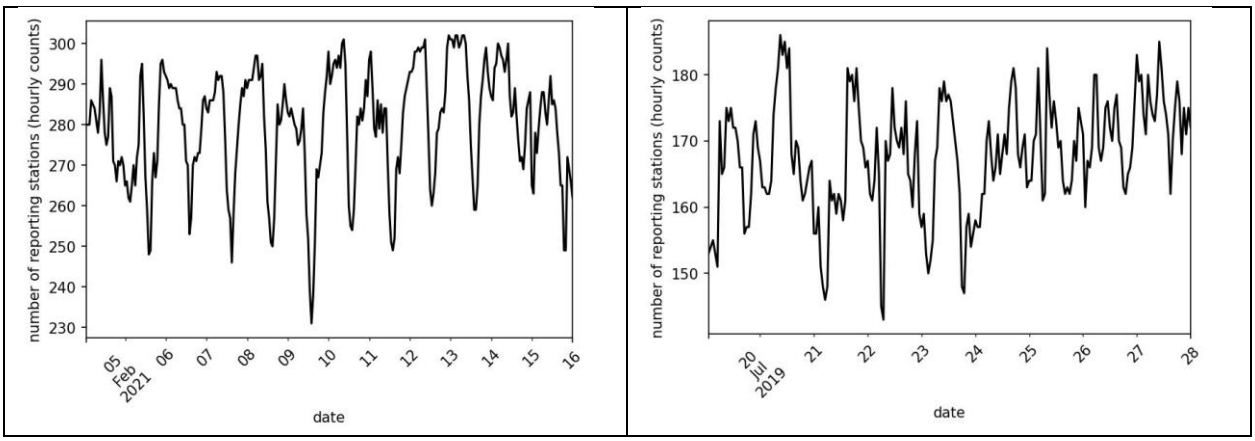


Figure 7. Variations in the number of reporting quality controlled NETATMO stations in winter (left) and summer (right) episodes.

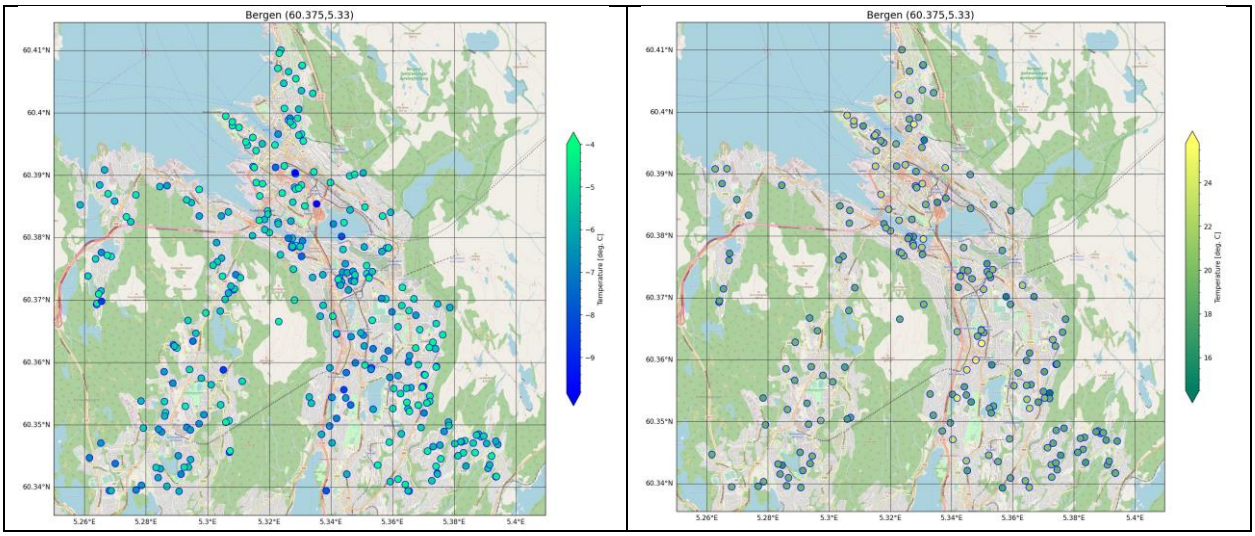


Figure 8. The mean surface air temperature at the NETATMO stations over the winter (left) and summer (right) episodes.

Geo-spatial and special data sets

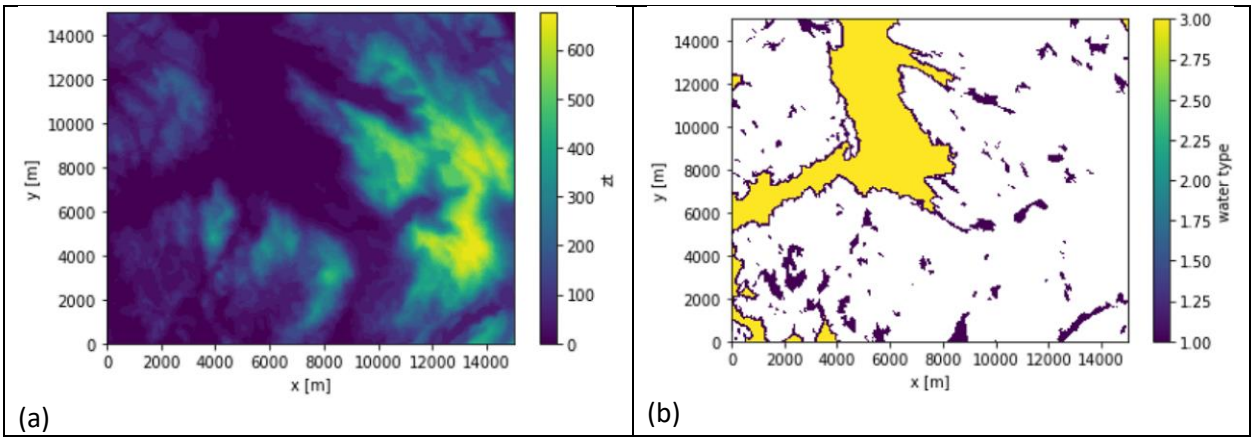
Digital Elevation Model (DEM)

The digital elevation model could be obtained from different sources. The quality-controlled DEM was obtained from the Norwegian mapping authority's (den Norske Kartverket) service. DEM is available in 1 m, 10 m and 50 m resolution in UTM33 projection (converted to EPSG:4326 and EPSG:3857). DEM of 10 m and 50 m are downloaded for this project. This data is used to setup the PAML model.

There is also auxiliary DEM available from COPERNICUS EOBrowser and ASTER.

Static driver of the PALM model with a collection of surface data in the Bergen area

DEM from the Norwegian mapping authority has been included by the TURBAN Check partners in the collection of surface features used for generation of the static driver setup file for the PALM model: **bergen_lod01_static.nc**.



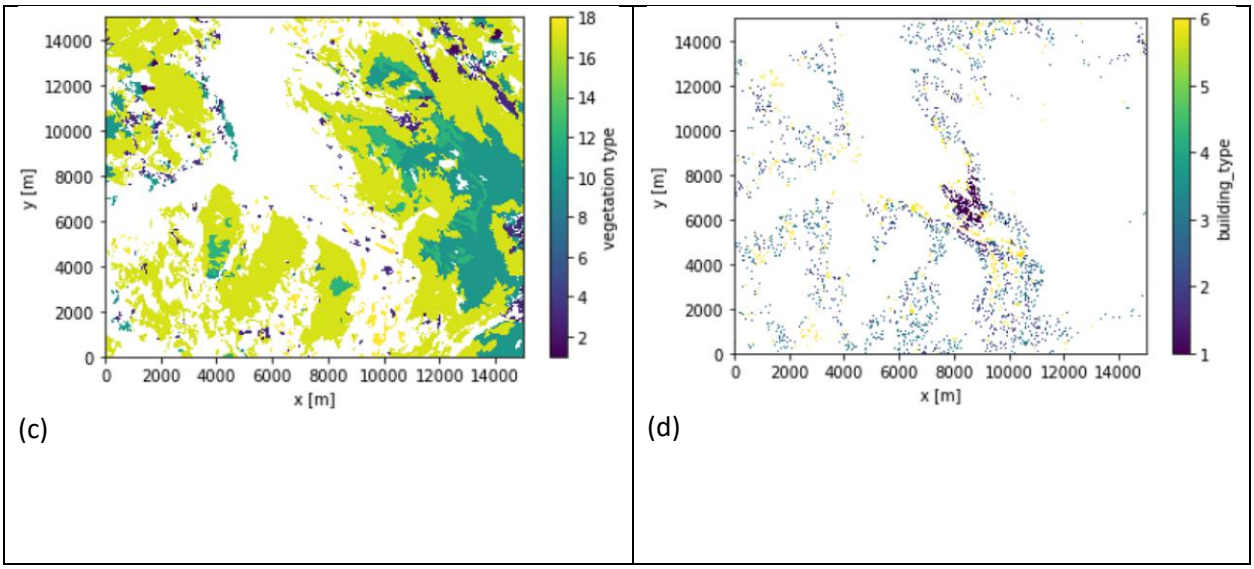


Figure 9. Urban surface features in the Bergen domain from PALM static driver dataset: (a) DEM; (b) Water surfaces (types); (c) Vegetation type; (d) building type. Aggregation at the spatial resolution of 25 m.

Other auxiliary sources of geospatial data

A number of urban feature geospatial datasets have been obtained from Bergen authorities. They are:

- Urban real-estate property codes
- Household warming installations
- Street density

They are not included in the dataset due to the large size.

Table 3. Sources of geospatial data

Description	**Reference**
Digital Elevation Model of the Norwegian mapping authority's (den Norske Kartverket)	https://www.kartverket.no/api-og-data/terrengdata DEM access: https://hoydedata.no/LaserInnsyn2/
High resolution interactive 3D map of Norwegian municipalities	http://3d.kommunekart.com
Detailed online municipality planning maps	https://kommunekart.com/?funksjon=vispunkt&y=-34413.22697587573&x=6715278.148425088&zoom=13&srid=32633
EU digital Elevation Model COPERNICUS EU DEM v1.1	https://land.copernicus.eu/imagery-in-situ/eu-dem/eu-dem-v1.1?tab=download