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EDITORIAL

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# Editorial: Atmospheric processes and applications in urban, coastal and mountainous terrain

**Meinolf Kossmann**[1] | **Lorenzo Giovannini**[2]

[1]Climate and Environment Consultancy, Deutscher Wetterdienst, Offenbach, Germany

[2]Department of Civil, Environmental and Mechanical Engineering, University of Trento, Trento, Italy

**Correspondence**
Meinolf Kossmann, Deutscher Wetterdienst, Climate and Environment Consultancy, Offenbach, Germany.
Email: meinolf.kossmann@dwd.de

**Abstract**

This editorial introduces the contributions to the Special Issue 'Atmospheric processes and applications in urban, coastal, and mountainous terrain' of the journal *Meteorological Applications*. The scientific background and motivation for this Special Issue are described and followed by a brief summary of the 15 articles of this Special Issue. The conclusions of this Editorial summarise the approaches taken and address future developments expected in process-oriented studies and for the development of applications in complex terrain.

## 1 | INTRODUCTION

Atmospheric processes over urban, coastal and mountainous areas, despite presenting their own peculiarities, share a main common feature: they are characterised by a larger spatio-temporal variability than those over flat and homogeneous terrain. Indeed, the atmosphere over these regions, which can be collectively identified as complex terrain, responds to surface heterogeneities at a range of different scales, from synoptic forcing and mesoscale circulations to the micro-scale of turbulent fluctuations. Therefore, both observational and numerical modelling techniques present additional challenges when applied over complex terrain. These techniques need to be carefully evaluated by testing their reliability for different kinds of applications.

The aim of this Special Issue is to collect new studies on the applicability of numerical simulation models, downscaling methods, experimental techniques and decision-making tools for different meteorological applications, and to highlight the additional challenges induced by the terrain complexity. In particular, the papers published in this Special Issue explore how advances in environmental monitoring and progress in high-resolution modelling of the atmosphere over complex terrain can offer promising ways to solve many challenges in the field and be beneficial for a wide range of applications.

## 2 | URBAN AREAS, HEAT STRESS AND AIR POLLUTION

Urban areas are affected by the presence of the urban heat island (UHI), that is, higher temperatures in the city than in the surrounding rural areas, which may contribute to human discomfort and health threats, especially during summertime. These issues are expected to be amplified by global warming, considering the projected increase in long-lasting and intense heat waves. These aspects are tackled by a series of papers in this Special Issue, using state-of-the-art models and experimental measurements to evaluate local alterations induced by urban areas and the related issues for the urban population.

Modifications in urban climate conditions can be caused by local land cover changes and alterations in the background climate, that is, by global warming. Vitanova et al. (2021) explore the first aspect by means of simulations with the Weather Research and Forecasting (WRF) model, to evaluate the effects of urban growth on the UHI and human thermal sensations in the city of Sofia (Bulgaria). The authors highlight that past land cover changes (from 1878 to 2012) had a significant effect on urban temperatures, while weaker variations are estimated for the future since the growth of the urban area is expected to be less significant. On the other hand, the effects of ongoing climate change on urban conditions are evaluated by Wang et al. (2021), who analyse data from 174 meteorological stations in the Beijing-Tianjin-Hebei region (China) to evaluate trends in six ETCCDI indices. The authors highlight increasing trends for most of the indices, also showing the significant contribution of urbanisation. As heat stress issues will become more and more frequent in the future, studies evaluating the effectiveness of climate adaptation strategies in urban areas are increasingly needed. In this regard, Kusaka et al. (2022) compare the effects of wisteria trellises and tents in locally reducing overheating in urban areas, showing that the former can be an effective measure to adapt cities to climate change, significantly reducing the heat stress.

Urban areas are a hot-spot not only for heat-related problems but also for air quality issues since most emissions are concentrated inside cities. Evaluating pollutant dispersion in cities is particularly complex, due to the modification of the thermal stratification induced by the urban area and the highly complex wind field, especially in the urban canopy layer, that is, below the roof level. In this Special Issue, the connection between thermal stratification, vertical wind shear and air pollutant concentrations is evaluated by Kiseleva et al. (2021) for the city of Stuttgart (Germany), located in moderate mountainous terrain, considering in particular $NO_x$ and $O_3$ concentrations as a function of the bulk Richardson number. Filioglou et al. (2022) focus on the ability of numerical weather prediction models, analysis systems and large-eddy simulations (LES) to reproduce the wind field in the coastal city of Helsinki (Finland), highlighting that LES can potentially resolve the wind field in the urban canopy layer, given pre-computed scenarios of atmospheric conditions.

## 3 | CHALLENGES IN THE SIMULATION OF METEOROLOGICAL PROCESSES OVER THE MOUNTAIN AND COASTAL REGIONS

Reproducing the observed wind field with numerical tools is a challenge not only in urban areas but also over the mountain and coastal regions, limiting their applicability in different fields. In this Special Issue different papers focus on the assessment of the reliability of modelling data sets and tools in reproducing the wind field over complex terrain for a wide range of applications. Thomas et al. (2021) evaluate the ability of three global reanalysis data sets (ERA-Interim, ERA5 and MERRA-2) to reproduce wind observations in different coastal regions of Mexico for wind resource assessment, highlighting lower performance in regions characterised by complex coastal topography. Asano and Kusaka (2021) show how simulations with the WRF model can be applied to support agricultural practices, evaluating the damaging impact of foehn wind, a typical and well-known mountain phenomenon, on rice crops in Yamagata Prefecture (Japan). Another typical mountain phenomenon, that is, dynamic airflow channelling, is analysed by Sato and Kusaka (2022) in the valley-like topography of the Kitakami Basin (Japan). They find that the occurrence of forced channelling or pressure-driven channelling strongly depends on surface geostrophic wind direction in relation to the orientation of the along-valley axis, but is also influenced by geostrophic wind speed and thermal stratification in the valley. Chan et al. (2021) present the results of LES to reproduce a case of severe low-level windshear at the Hong Kong airport, to evaluate the possibility of using real-time LES for windshear alerting. Similarly, Chan et al. (2022) evaluate the ability of the WRF model to reproduce a supercell tornado in the Hong Kong adjacent waters, showing that simulations with sufficiently high spatial resolution are able to capture the main features of the supercell, thus proposing the model as a reliable tool for providing flight hazard warnings, such as low-level wind shear alerts, to air traffic control units and pilots.

A reliable estimate of the availability of water resources is important for different applications (e.g., agriculture, hydroelectric production, etc.), especially over mountain areas, which can be considered as water towers for the surrounding regions. In this regard, it is important to evaluate the reliability of models at different spatial and temporal scales, which can be used as decision-support tools for adequate planning of water usage. In this Special Issue, Feudjio Tchinda et al. (2022) focus on seasonal forecasts, assessing the predictive skill of the North American Multi-model Ensemble (NMME) in Central Africa, while Onwukwe et al. (2022) evaluate the performance of year-long simulations with the WRF model to reproduce precipitation in a coastal valley in British Columbia (Canada). Furthermore, long-term planning and strategic decisions can be supported by the climatological assessment of rainfall trends from the analysis of sufficiently long time series. In this Special Issue Abebe et al. (2022) present results from the analysis of data from 43 weather stations in the period 1960–2019 in the Tekeze River basin (Ethiopia), characterised by high orographic complexity, whereas Konduru et al. (2022) analyse data from a combination of different sources, including TRMM satellite, MERRA-2 reanalysis and gridded in-situ surface observations, to study the climatology of the spatial movement of the diurnal precipitation peak over south India during the summer monsoon.

Finally, a great challenge for meteorological models is represented by the forecasting of fog, fundamental for applications related to road management and security. Ohashi and Suido (2021) present an application of the WRF model to reproduce upslope fog in a coastal region in the Oita Prefecture (Japan), proposing a practical technique for fog prediction.

## 4 | CONCLUSIONS

The scientific contributions of this Special Issue highlight the increasing importance of high-resolution observations (e.g., scanning lidar and radar systems) and numerical models (e.g., LES models) to capture the spatio-temporal variability of meteorological processes and support a wide range of applications in complex terrain. Considering climatological applications, different works point out the inhomogeneity and poor representativeness of local observations in complex terrain, especially in developing countries. In these cases, reanalysis and satellite products can be valuable tools to obtain reliable information on climate variables, even if these products sometimes do not exhibit yet the resolution needed to fully capture their spatial variability. A possible approach to cope with the additional challenges related to atmospheric processes over complex terrain and to develop applications and services, proposed in some contributions of this Special Issue, is the adoption of hybrid approaches or data sets. Combinations of in-situ and remote-sensing data, or combinations of observations, simulations, analysis systems or reanalysis products, can be used to overcome the limitations of the single methods, tools or products. It is expected that such multi-method approaches in future studies and applications in urban, coastal, or mountainous terrain will benefit from current developments in instrumentation (e.g., high-resolution remote sensing instruments), harvesting of crowd-source-data (e.g., from low-cost sensor networks), allowing for denser monitoring, an increase in computer power for higher resolution simulations and new simulation methods, including techniques based on artificial intelligence and machine learning.

## AUTHOR CONTRIBUTIONS

**Meinolf Kossmann:** Conceptualization (equal); writing – original draft (equal); writing – review and editing (equal). **Lorenzo Giovannini:** Conceptualization (equal); writing – original draft (equal); writing – review and editing (equal).

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## ORCID

*Meinolf Kossmann* https://orcid.org/0000-0001-5727-3817

*Lorenzo Giovannini* https://orcid.org/0000-0003-1650-0344

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