

Multi-scale transport and exchange processes in the atmosphere over mountains – programme and experiment (TEAMx)

Memorandum of Understanding

Participants

1. This Memorandum of Understanding is made between the organisations listed in Annexes A and B, collectively referred to herein as the **Partners**.

Summary

2. The Partners have identified opportunities and benefits to be gained by working collectively towards a large research programme on atmospheric processes over mountainous terrain. In particular, the Partners propose to bring together the observational and modelling infrastructures across multiple nations to advance the understanding of mountain-atmosphere interactions across a wide range of scales. The programme will build on the success of previous large campaigns such as ALPEX, PYREX and MAP, exploiting the latest observational and modelling technologies and addressing the latest priorities in prediction and impact. Through this Memorandum of Understanding the Partners express an intention to work collectively and with others to advance understanding and capability in this important area of atmospheric science.

Introduction

3. Mountainous areas contribute in major ways to multi-scale atmospheric processes (e.g., orographic precipitation; gravity wave drag; thermally driven flows). The reliability of weather prediction and climate simulation models depends on accurate representation of these processes. Indeed, mountain-induced atmospheric processes are one of the major uncertainties in Earth System modelling. Important internationally coordinated activities in the past (e.g. ALPEX, PYREX, MAP) have addressed some of these uncertainties and have substantially advanced our knowledge of the impact of mountainous terrain on the atmosphere. Computational and scientific progress since the previous major activities has increased the demands from modelling activities, both in terms of required spatial/temporal resolution and the range of physical processes which must be represented. At the same time, advances in measurement technology now allow the use of in situ and remote sensing data (from both airborne and satellite platforms) to quantify the relevant processes at a wide range of spatial/temporal scales. Hence there now exists a realistic prospect of modelling in a physically consistent manner what traditionally is called 'earth-atmosphere exchange', i.e., the coupling between the surface and the atmosphere – *even over complex mountainous terrain*. While this task has some commonality with concepts of boundary layer meteorology used over flat terrain, it *includes processes at distinctly different scales* (from synoptic and meso-scale to the local boundary layer and near-surface micro-scales), as well as *their interactions* over mountainous terrain.
4. Output of numerical models (Numerical Weather Prediction, NWP) is nowadays used to provide point-specific weather information, an extremely challenging task in mountainous terrain. Increasingly NWP output is *also* used as input for applied models for, e.g., hydrology (flood warning, hydro power), health-related forecasts (heat stress, air pollution), energy smart-net management (solar, wind, hydro), economic decision models (airport management systems, agricultural models, energy management systems) or ecological budgeting (CO₂ source/sink apportionment, anthropogenic/biogenic aerosol sources). All these applied models have in common that not only does the 'bulk impact of the surface' on the atmosphere need to be modelled appropriately, but also the state of the atmosphere and surface at any potential location needs to be accurately

represented. Thus, the extension of NWP models from pure weather prediction applications to, *additionally*, Earth System Services calls for the addition of another dimension, i.e. extending our attention from surface-to-atmosphere impact to two-way *surface-atmosphere exchange*. This again is a particular challenge over mountainous terrain.

5. In parallel with these scientific and technological advances, the ongoing *climate change* due to anthropogenic modification of the atmosphere's composition calls for our ability to correctly model scenarios for future climate states. Mountainous areas not only seem to exhibit a stronger climate sensitivity (e.g., stronger presently observed temperature increase over mountains than in the global average) and are thought to be particularly vulnerable, but also pose a particularly challenging task to the climate modelling community due to unresolved processes, terrain representation and scale interactions. Due to the long integration times, climate predictions are likely to be particularly sensitive to systematic errors in the surface-atmosphere exchange.
6. All these developments make it highly timely to plan and execute – some twenty years after the last major international project on mountain meteorology, MAP¹ – a new internationally coordinated project focusing on the investigation, experimental assessment and numerical modelling of the *exchange of energy, mass, and momentum between mountainous terrain and the free atmosphere at all scales and especially their interactions*. This Memorandum of Understanding expresses the shared intention of the Partners to work collectively to achieve this goal.

Purpose

7. The purpose of this Memorandum of Understanding is to bring together organisations which share a common interest in advancing the understanding of the interactions between mountains and the atmosphere. In particular, the Partners seek to work collectively and with others to enable a new internationally coordinated project focusing on the investigation, experimental assessment and numerical modelling of the *exchange of energy, mass, and momentum between mountainous terrain and the free atmosphere at all scales and especially their interactions* to be achieved on the time scale of 5-8 years. The Memorandum sets out a high-level framework for working together towards this common goal. The working title of the proposed international scientific programme is TEAMx: Multi-scale transport and exchange processes in the atmosphere over mountains – programme and experiment.

Background

8. The success of previous large programmes to study the interaction between mountainous terrain and the atmosphere lies in the international cooperation. The scale of such programmes, in terms of physical infrastructure and expertise, is such that no single institution, or indeed country, can realistically undertake such activities alone. In this context, working together also means being able to present common objectives and implementation plans to a diverse range of funders and users of the new scientific knowledge generated. Previous international programmes focusing on mountainous and complex terrain, such as ALPEX and MAP, have demonstrated how the development of a truly effective international plan with appropriate funding can take several years of coordinated action. The Memorandum of Understanding expresses the intention of the Partners to work towards a new experiment – TEAMx – on atmosphere-mountain interaction, to have its observation phase within the timespan 2022-2025.
9. The Partners will seek to work with as wide a range of other organisation as is required to fulfil the stated objectives in paragraphs 11-13. This includes not only research organisations and institutions

¹ The Mesoscale Alpine Programme, MAP, was one of the first Research and Development projects of the World Weather Research Programme, WWRP, of WMO.

which will bring their scientific capabilities to the experiment, but also formal and informal international bodies such as the World Meteorological Organisation (WMO), the Steering Committee of the International Conference on Alpine Meteorology (ICAM) and the Committee on Mountain Meteorology of the American Meteorological Society (AMS).

10. The Partners recognise that international cooperation such as that outlined in this Memorandum of Understanding not only enables an ambitious mountain-atmosphere research programme to be undertaken but also acts as a focus for growing and developing expertise in all aspects of surface-atmosphere exchange in regions of mountainous and complex terrain.

Objectives

11. **Objective 1:** To advance the understanding of the processes of interaction between mountains and the atmosphere by establishing a **research programme** of coordinated observations and numerical modelling.
12. **Objective 2:** To design and coordinate the research programme in order to serve the needs of numerical weather prediction, regional climate modelling and other Earth System Services applications.
13. **Objective 3:** To meet these objectives by promoting the collaborate use of the latest observational and computational technologies at very high resolutions in space and time, including an intensive observation campaign and an associated coordinated programme of numerical modelling.

Actions and Mechanisms for Cooperation

14. The Partners will work collectively to achieve the TEAMx objectives set out in paragraphs 11-13 by organising and promoting activities which will include, but will not be restricted to, the following:
 - developing and communicating the TEAMx plan, building upon current knowledge and identifying gaps in understanding;
 - holding workshops;
 - organizing scientific meetings;
 - planning, preparing and submitting coordinated and individual funding applications;
 - establishing agreements with other organisations.

Management

15. The Partners have established a TEAMx Coordination and Implementation Group (CIG). The CIG may co-opt additional members as the planning of the proposed scientific programme progresses and needs arise. The CIG will undertake activities which will include, but will not be restricted to, the following:
 - acting as a coordination and implementation group for the objectives of this Memorandum of Understanding;
 - setting up of appropriate supervisory and advisory boards for the proposed scientific programme;
 - admitting new signatories to this agreement (see paragraph 21).

Duration

16. This Memorandum of Understanding will be effective for three years from the date of completion of the signatures in Annex A. It may be renewed indefinitely by mutual agreement of the Partners.

Intellectual Property

17. This Memorandum does not affect the ownership of a Partner's Intellectual Property, which will remain the property of such Partner.
18. In the event that any activities with the scope of this agreement require the use of another Partner's intellectual property or proprietary information, the Partners will in good faith enter into negotiations seeking to arrive at mutually agreeable terms. Such terms are not part of this Memorandum of Understanding.

Other terms

19. No funds are committed by this Memorandum of Understanding. Any binding commitment for any transfer of funds shall be made under a separate funding agreement.
20. No legal obligations are created by this Memorandum of Understanding.
21. Additional Partners may join this Memorandum of Understanding upon signature of Annex B, subject to agreement of the CIG.

Variation

22. Modifications to this Memorandum of Understanding may be made upon agreement in writing of at least 80% of the Partners.

Termination

23. Any Partner may terminate their participation in this Memorandum of Understanding by giving notice in writing of their withdrawal to all other Partners.
24. This Memorandum of Understanding may be terminated at any time by agreement of at least 80% of the Partners.

Representatives

25. Annex A lists the Founding Partners and their representatives.
26. Annex B lists the Partners and their representatives who have signed the Memorandum later than the date on which it became active.
27. Representatives of Partner organisations may change from time to time simply by communication of the change to all other Partners.