MEETING SUMMARIES

FORM—IDEAS FOR FUTURE FOEHN RESEARCH

BY SIMON TSCHANNETT AND MARKUS FURGER

Foehn in the Rhine Valley during the Mesoscale Alpine Programme (MAP) (FORM) was a sub-project of MAP with the goal of improving the understanding and forecasting of the life cycle of foehn-related phenomena, including their three-dimensional structure and associated boundary layer processes. Results of the project, as well as open questions that require future research, are communicated in this summary to a wider audience to promote ideas for spawning new research initiatives.

Prior to the workshop,¹ participants were invited to send in solved and unsolved problems in foehn research. The outstanding issues, which largely cover phenomena observed in the Rhine Valley but also comprise foehn topics that are of more general

¹ The FORM Field Group gathered for its ninth meeting in Bad Ragaz, Switzerland, which is within the target area of the project.

NINTH MAP FORM MEETING

WHAT: Ten scientists from three different Alpine countries use the results of foehn research during the Mesoscale Alpine Programme as a backdrop to discuss remaining questions in foehn research

WHEN: 3–4 November 2005

WHERE: Bad Ragaz, Switzerland

interest, were then discussed and broadened at the workshop.

WORKSHOP RESULTS. *Foehn phenomena.* Much information about foehn phenomena has been acquired during the MAP special observing period (SOP) in 1999, for example, foehn flow splitting at the bifurcation of the Rhine and Seez Valleys, and vertical structure and multilayering of the flow within the valley. Still, open or at least controversial questions include the real mechanism or mechanisms for the removal of the cold-air pool, the meandering of the foehn flow within the valley, and the asymmetric penetration of the foehn flow into the valley. The lack of understanding largely is a consequence of the inherent difficulties in numerical modeling. The cold air may be blocked in the valley, but only slightly moved aside. Such finescale behavior, like the movement and removal of cold-air “lenses” and the tilting of their upper transition zone, has not yet been well described. Topography often forces the flow into confinement and several modes of foehn flow seem to exist, between which the flow can switch back

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and forth. In such cases, the foehn state depends on its prehistory, similar to a hysteresis effect (or lag in cause and effect). The contribution of tributary valleys to the flow in the main valley and vice versa is not yet well understood. Wave patterns on the surface of the cold air during foehn in 4D resolution also deserve more detailed study. Regarding air quality, a broader investigation of meteorological conditions leading to critical dispersion states would require knowing the climatology of inversions and dynamically or convectively induced wind shear. Long-range transport of aerosols and air pollutants and their exchange with locally produced pollutants might be considered helpful tracers of air mass exchange between different airflow regimes. Such exchange is often blocked by elevated stable layers separating the different regimes. Whether an air mass index coupled with ozone could or should be developed also should be studied. At larger scales, the relevance of an inversion over the Alps in connection with foehn, that is, its implications on the predominance of the cold front over the foehn air, should be discussed. Not every cold front has a (shallow) foehn phase in advance, but the reason for that is not yet clear.

Observational data and networks. Foehn has been recognized as a 4D phenomenon requiring an appropriately dense network of measurements. Continuous operation of such a network is a prerequisite for capturing interesting phenomena, because the most interesting cases never occur during an SOP. Ground-based measurements alone do not provide a sufficient set of information to describe the spatial structure of foehn. An appropriate number of either continuously operating upper-air sounding systems or, even better, integrated remote sensing systems might remedy this situation. However, the latter are not yet available and would need further development and improvement before deployment. Moreover, implementation and operational costs of such systems are high. Hence, only episodic measurements with tethered balloons (in a transect) and various airborne platforms such as instrumented model aircraft are available immediately or in the near future to deliver the necessary information with sufficient resolution. The placement of surface stations can be optimized with respect to forecast model input, and such calculations can then be done using the available MAP data. A series of surface stations along the valley walls might provide the temperature and humidity profiles below crest height that are needed for the initialization of numerical simulations. Each observation system has a representativeness error

that has to be quantified to determine its usefulness in the forecasting assimilation process. Additional and complementary information should be extracted from satellite measurements. Discussion also focused on the need for a new data format for the exchange of measured data. Such a format should contain 4D coordinates for each date plus a quality flag to prevent errors, such as wrong units, wrong time, etc.

Modeling. With the advent of highly space- and time-resolved numerical models, progress has been achieved in the study of foehn dynamics within a valley. Small-scale foehn modeling (≤ 1 km grid size) may be improved with the increasing use of large-eddy simulation (LES) approaches. Four-dimensional variational data assimilation (4DVAR), however, may be too expensive for local-scale data assimilation in the Alpine region. Instead, an intelligent nudging technique that maintains the full model resolution during the assimilation phase might be more effective. This also requires a suitable representation of the Alpine topography. However, a lack of dense measurements so far has prevented a thorough evaluation and quality control of the model results. Furthermore, higher model resolution requires new parameterizations that again have to be tested for their applicability. In other words, today's models are ahead of observational networks with respect to their resolution. In this context, foehn studies could help by including the mountaintop stations in high-resolution NWP forecast models. Such models could be applied to study the transition between the foehn and Alpine pumping.

WIDENING THE PERSPECTIVE. Many of the aspects mentioned may be better understood when widening the scope to also cover flow phenomena beyond foehn. Cold-air pools also exist in other weather situations, for example, mild westerly flow in winter, and they may be maintained in some parts of the valley and not in others. Further progress might be expected from a better understanding of the behavior of stratus clouds that often occur at the interface between foehn and the cold-air pool. Such issues are very important to local-scale forecasting. It should be borne in mind that foehn is only one phenomenon in a whole spectrum of interacting weather phenomena, such as gravity wave dynamics, hydraulic flow dynamics, cold-pool interactions, local flow channeling, flow separation, precipitation variability, and so on. A better understanding can only be achieved when studying these phenomena together.

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