# P3.7 TEMPORAL EVOLUTION AND STRUCTURE OF GAP FLOW IN THE WIPP VALLEY ON 2 AND 3 OCTOBER 1999

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## 1. INTRODUCTION

The MAP gap-flow experiment was organized to study southerly flow through the Brenner Pass, a major north-south gap in the Alps. To the north of the pass, the gap extends through the Wipp Valley Brenner Pass to Innsbruck.
We investigated two foehn events during MAP, a shallow foehn on 2 October, and a deep foehn on 3 October. The detailed analysis of the flow structure on both days is based on the extensive dataset from instrumentation deployed during the MAP SOP, including 70 surface stations, the NOAA ETL Doppler Lidar, in situ aircraft measurements from the NOAA P3, rawinsondes, and pilot balloons.

A pressure gradient across the Alps with high pressure to the south was established in the evening of 1 October, after a warm front swept north of the Alps. The pressure gradient led to the start of a shallow foehn in the night of 1 to 2 October. Atypically, no pool of cold air was seen to the south of the Alps, and the pressure gradient was caused by the large-scale pressure field with a deep trough over northern Europe. As commonly seen, a strong inversion decoupled the foehn flow from the west-southwesterly geostrophic winds aloft on 2 October.
The inversion rose during the night of 2 to 3 October and caused the transition to a deep foehn. Then the inversion dissolved in the early morning hours of 3 October and the foehn flow was not decoupled from the winds aloft anymore. Additionally, geostrophic winds intensified to 30 $ms^{-1}$, turned to southwesterly on 3 October and seemed to strengthen the foehn flow.
Finally the foehn event was terminated by the passage of a cold front in the afternoon of 3 October.

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## 2. SHALLOW FOEHN ON 2 OCTOBER

The foehn event of 2 October showed the typical characteristics of a shallow foehn, although tendencies of a deepening were already observed during the day. A strong inversion was seen at ~3500 m ASL at the main Alpine crest and subsided to ~2500 at Innsbruck. The lidar data showed a good collocation of this inversion and the shear layer between the southerly gap flow and west-southwesterly winds aloft.

The detailed flow structure could be documented with the Doppler lidar. Wind speeds were up to 20 $ms^{-1}$, and accelerated nearly 5 $ms^{-1}$ from the southern to the northern part of the valley. A ~500 m deep jet layer was seen in the valley. This layer flowed through the southern part of the valley as an elevated jet, but descended to the surface, as it passed the lidar at Gedeir, about half way between Brenner Pass and Innsbruck. A wavy structure of this jet layer was often seen in the southern part of the Wipp Valley. This was interpreted as a gravity wave, induced by the mountain Noesslachjoch and the flank of the mountain Blaser.

The flow over Noesslachjoch, a small mountain close to the Brenner gap, showed an interesting hydraulic structure. A thinning and descending of the jet layer was seen to the lee of the mountain. A region with very low or even negative radial velocities was seen above the descending jet layer, and a sudden deepening of the foehn layer further downstream. The regions with negative velocities (= northerly wind components) were interpreted as rotors, the sudden deepening of the foehn layer was seen as indication of a hydraulic jump. Low-level wind speeds showed increased velocities beneath this hydraulic jump, which contradict this explanation. But these higher wind speeds can be explained with the lateral contraction due to the flank of the mountain Blaser. Evidence of rotors was also seen downstream of two other mountains, the Patscherkofel and Blaser.

The northern part of the valley showed significantly higher wind speeds on the eastern side. This phenomenon, which was also seen on several other days during MAP SOP, is still under investigation. So far three possible explanations have been put forth:
1.) Light outflow could be documented in the upper levels of the Stubai Valley, a western side valley of the Wipp Valley. Presumably this was only a small component of a stronger outflow, because the lidar could only see the component in the direction of the lidar beam. This (westerly) outflow could push the foehn flow eastwards in its exit region. The outflow seemed to be the result of foehn air flowing through several passes to the south of the Stubai Valley. Furthermore a possible interaction between southwesterly geostrophic winds and the high mountain group southwest of the Stubai Valley was shown by Flamant (2001).
2.) Strong downslope winds commonly occur to the lee of the small mountain Waldrastjoechl (1880 m ASL), to the south of the Stubai Valley exit region. This strong descent could lead to a hydraulic jump in the western part of the Wipp Valley, and therefore to lower wind speeds (Gohm, private comm.).
3.) The Wipp Valley turns slightly westwards at Gedeir. Therefore higher wind speeds in the eastern part of the valley could also be explained with the inertia of the southerly flow forcing the air against the turning of the valley. Also lateral constriction due to the flank of the mountain Patscherkofel presumably caused higher wind speeds in the eastern part of the valley.

But, as mentioned, more research needs to be done to understand this phenomenon, and to quantify the importance of these three possible explanations.

## 3. DEEP FOEHN ON 3 OCTOBER

The foehn event of 3 October showed the typical characteristics of a deep foehn. The transition from the southerly foehn flow to southwesterly geostrophic winds was seen around 4000 m ASL. But it was more a gradual turning, than a sharp shear layer as on 2 October. The jet layer was seen significantly higher than on the previous day, and the flow over smaller mountains, as Noesslachjoch, Blaser and Patscherkofel, did not show rotors. The jet layer did not descend to the surface after Noesslachjoch, but flowed through the valley as an elevated jet and the over Patscherkofel and its shoulder to the north.
A cold front passed the western part of the Alps in the morning of 3 October, and led to a Genoa cyclogenesis. This caused a pressure fall south of the Alps and a decrease of the pressure gradient and a weakening of the foehn after 1200 UTC. Then the front passed Tyrol from north to south in the afternoon of 3 October, and terminated this foehn event.

## 4. REFERENCES

Flamant, C., P. Drobinski, L. Nance, R. Banta, L. Darby, J. Dusek, M. Hardesty, J. Pelon, and E. Richard, 2001: Gap flow in an Alpine valley during a shallow south foehn event: Observations, numerical simulations and hydraulic analog. Q. J. R. Metorol. Soc., 127, 1– 44.