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1.3 AIRFLOW WITHIN MAJOR RIVER VALLEYS ON THE SOUTH SIDE OF THE ALPS AS OBSERVED DURING THE MAP SPECIAL OBSERVING PERIOD

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1. INTRODUCTION

The Special Observing Period (SOP) of the Mesoscale Alpine Program (MAP) documented the precipitation and airflow structure over a section of the Mediterranean side of the Alpine range and its major river valleys (Bougeault et al. 2000). This was achieved in part by means of a nested array of operational and research radars. In the Lago Maggiore region, the Swiss Monte Lema and several Italian operational radars, and research radars from the U.S., France, Germany, and Switzerland documented the precipitation systems as they approached and moved over the Alpine barrier. These detailed ground-based radar observations were complemented by airborne measurements, and data collected by the surface and upper-air meteorological networks.

The fix-installed radars either scanned above the ridges and mountain crests, and thus were not able to see what was happening within the major river valleys, or they pointed only vertically. Thus, the Doppler-on-Wheels (DOW), a mobile X-band scanning Doppler radar platform (Wurman et al. 1997), was crucial for the documentation of the airflow and precipitation within individual river valleys (Figure 1).

2. DOW OPERATIONS

During the MAP SOP, the DOW was primarily operated from two sites in the Ticino and one site in the Toce river valley (Table 1). The times of operation and scanning strategies are summarized in Tables 2 and 3. The radar scanning was based on a repetitive sequence of one multi-elevation volume scan (PPIs), followed by several vertical cross-sections (RHIs) spread up, down, and across the valley. The spatial resolution was approximately 1 deg in azimuth and 75 m in radial direction. Data were collected from 320 range gates per radial beam, and for each range gate 128 pulses were integrated.

Table 1. Primary DOW locations.

Location	*Lat/Lon*	*Valley*
Magadino, MAG	46.1610/8.8715	Ticino
Lodrino, LOD	46.2921/8.9920	Ticino
Pieve Vergonte, PIE	46.0122/8.2747	Toce

Table 2. DOW operation periods (yymmdd/hhmm) and scanning type (letter refers to Table 3).

IOP	*Location*	*DOW Operations*
pre	MAG	990826/1650-990826/2320
1	standby	none
2a	MAG	990917/1430-990918/1200, A
2b	MAG	990919/1630-990921/0500, A
3	LOD	990925/1645-990926/1445, A
pbl	LOD	990929/1040-990929/1530, B
4	LOD	990930/1015-990930/1815, A
5	MAG	991003/0645-991003/2315, A
6	VER	991013/1030-991013/1330, A
7	PIE	991018/0630-991018/1715, A
8	PIE	991020/2000-991021/1945, A
9	PIE	991022/2115-991023/1400, A
10	PIE	991024/0745-991024/1530, A
11	standby	none
12	standby	none
13	standby	none
14	PIE	991103/0545-991104/1715, A
15	PIE	991106/0230-991106/1900, B
16	-	after end of operations
17	-	after end of operations

The DOW participated in the pre-SOP ("pre") radar intercomparison measurements centered on

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the Osservatorio Ticinese at Locarno-Monti. Other special observations were carried out on October 13 (IOP 6), when the DOW, on its transfer from Switzerland (Ticino) to Italy (Toce), was visiting the NCAR S-Pol radar (Lutz et al. 1997) site near Vergiate (VER; lat/lon = 45.720/8.730) to make some collocated intercomparison measurements. In addition, clear air observations were made on September 29 ("pbl") in support of the ground-based and airborne (MetAir Dimona motorglider) measurements carried out by the Planetary Boundary Layer groups operating in the Riviera stretch of the Ticino river valley.

Table 3. Dow scanning strategies.

	Type A	*Type B*
PRF	3000 Hz	2000 Hz
Nyquist	16 m/s	24 m/s
Rotation	15 deg/sec	10 deg/sec
PPIs	22 tilts, 1-82 deg	12 tilts, 2-45 deg
RHIs	4 x 9, 360 deg	1 x 9, 360 deg
Duration	15 min	10 min

November 6 (IOP 15) marked the end of the DOW operations for the MAP SOP. Scientific and technical notes taken in the field can be found in the Joint Office for Science Support (JOSS) Data Catalog (http://www.joss.ucar.edu/map/catalog). There are illustrated *DOW Operation Notes* for each IOP.

3. PRELIMINARY RESULTS

One of the most intriguing observations obtained with the DOW was a persistent and sometimes quite strong flow of air down and out of the valley (Table 4), generally against the flow of air aloft. This down-valley flow, observed during most IOPs (albeit in variable strength and depth), may likely have been enhanced—if not initiated—by the evaporation of precipitation, cooling the air within the valley and causing subsidence.

This down valley phenomenon was particularly pronounced on October 20-21 (IOP 8), when highly stable air was pushed towards the Alps and the atmospheric stability apparently prevented the air from crossing over the barrier. This particular down valley flow was approximately 10 m/s in magnitude and 1-1.5 km deep (Figure 2), resulting in roughly 50 km^3 of air being pushed out of the Toce river valley (approximately 1 km wide) per hour, and this for several hours. Moreover, outflow from several different valleys was observed by the S-Pol radar during IOP 8, indicating that this phenomenon was not unique to the Toce river valley, where the DOW was located.

Table 4. Valley flow observations.

IOP	*Flow Characteristics Within Valley*
2a	early >10 m/s up the valley; later ~10 m/s down, ~3 km deep
2b	>10 m/s up
3	~5 m/s down, ~1 km deep
pbl	~3-4 m/s up
4	early up; later ~10 m/s down, ~1.5 km deep
5	10-20 m/s down, ~1-3 km deep
7	up, with eddy inside bend
8	~10 m/s down, ~1.5-2 km deep
9	early up; later ~5 m/s down, ~1.5 km deep
10	<5 m/s down, ~1-1.5 km deep
14	5-10 m/s down, ~1.5-2 km deep
15	early 10 m/s up, with eddy inside bend; later ~20 m/s down, ~4-5 km deep

The atmospheric stability for the IOPs earlier in the SOP was more favorable for convective activity, while rainfall during the later IOPs was more stratified. A noticeably different situation was occurring on November 6 (IOP 15), when a strong cold front crossed over the Alps, pushing cold and very dry air down and out the valleys.

Another interesting flow observation made in the Toce river valley was a vortex structure (eddy) inside around the bend that developed under up-valley flow conditions (Table 4). Figure 3 shows such a situation on November 6 (IOP 15) approximately two hours before the Alp-crossing cold front was pushing through and out the valley. The return flow inside around the bend occurred over a distance of 5-10 km, was at least 1 km deep, and the clouds in that area were clearly moving down the valley.

4. OUTLOOK

Using the DOW data, we analyze the airflow within the major river valleys. In particular, we seek to determine connections between the flow within the valley (up- or down-valley, strength, and depth in relation to the surrounding mountain crest line) and the environmental flow (strength, direction relative to the valley orientation, and atmospheric stratification) impinging upon the Alps.

Many questions need to be answered, such as: What are the physical mechanisms controling the air flow within a valley? To what extent can evaporational cooling enhance or even initiate down valley flow? How (if at all) is the valley flow connected to the environmental flow above the mountain crest line and the atmospheric stability? What is the relevance of the down valley flow to orographic precipitation processes? Does this down-valley flow constitute an important feedback mechanism of orographic precipitation; for example, by contributing to maintain cold air pools, aiding the lift of warm moist air (possibly removed from the topographic barrier) and thus precipitation formation (or enhancement)? And last but not least, how much of the valley flow (direction, strength, and depth) can be revealed by the sparse surface station network?

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Figure 1. DOW radar truck at the Lodrino Airport site in the Ticino valley on September 26, 1999 (IOP 3). [Photo by Scott Richardson]

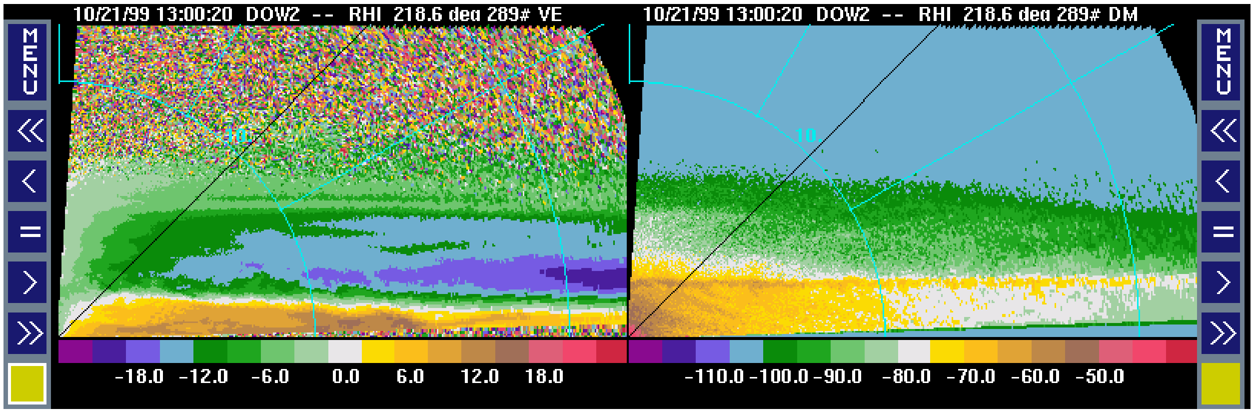

Figure 2. Vertical cross section (RHI) collected at 13:00 UTC on October 21, 1999 in the direction down the Toce river valley towards the Lago Maggiore. The DOW radar was located at the Pieve Vergonte site (left corner in the panels). The radial Doppler velocities are shown in the left panel and received power in the right panel. Range rings are indicated every 10 km.

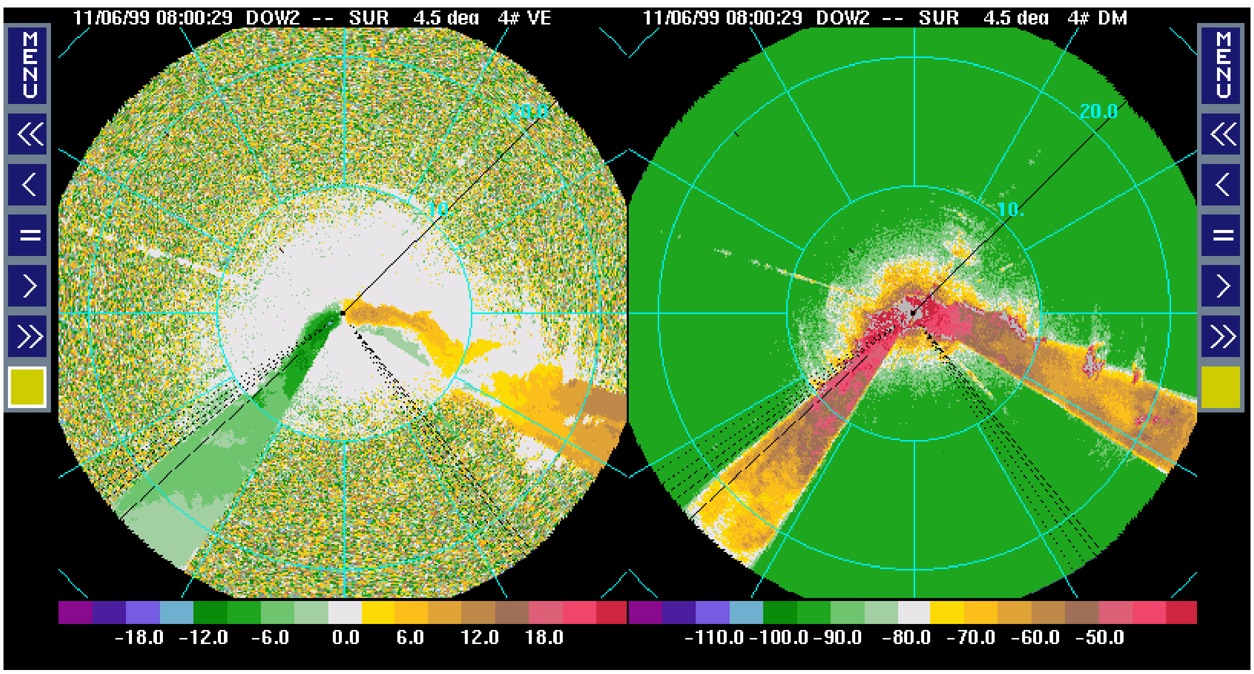

Figure 3. Low-elevation (4.5 deg) surveillance scan (PPI) collected at 08:00 UTC on November 6, 1999 in the Toce river valley. The DOW radar was located at the Pieve Vergonte site (center of the panels). The radial Doppler velocities are shown in the left panel and received power in the right panel. Range rings are indicated every 10 km. The topography restricted the radar observations at low levels to within the valley. Pieve Vergonte is located right at the bend of the Toce river valley. Down the valley is towards the bottom left (“220 deg”) and up the valley is towards the right (“120 deg”). [Note: 1) North in the data (“0 deg”) does not correspond to *true north* but rather where the DOW truck was pointing! True north is approximately in up-valley direction. 2) The received power indicated in the right panel is approximately 20 dB high compared to Figure 2 because of a removed signal attenuator without compensation.]