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VERTIKATOR

AFO 2000

Flow modification and mesoscale transport caused by "Alpine Pumping"

Corsmeier, U.[1], Kottmeier, Ch.[1] , Winkler, P.[2] , Lugauer, M.[2] , Reitebuch, O.[3] , Drobinski, Ph.[4]

[1] Institut für Meteorologie und Klimaforschung, Forschungszentrum Karlsruhe/Universität Karlsruhe, [2] Deutscher Wetterdienst, MO Hohenpeißenberg, [3] DLR, IPA, Oberpfaffenhofen, [4] Universite Pierre et Marie Curie, Paris

Objectives

The mesoscale circulation "Alpine Pumping" (ALP) is formed in summer during high pressure conditions over the Alps. Due to higher radiation transfer at the slopes, convection causes a flow towards the mountains. The horizontal extension of the flow is up to 100 km, its vertical expansion covers the PBL. At strong ALP a reverse flow to the North is found above the PBL. ALP causes a mass exchange of polluted PBL air from North of the Alps to the free atmosphere (FA) over the inner Alps. The diurnal cycle of the ALP flow structure is shown. The mass transport from the alpine foreland to the mountain range via advection and convection is calculated.

Experimental Setup

In July 2002 in the framework of the AFO 2000 program VERTIKATOR, a field campaign was carried out in the area between Munich and Innsbruck and between Kempten and Kufstein. Data from operational meteorological and air quality networks, readings from additional ground based stations and vertical profilers, results from radiosonde launchings and measurements made onboard of four research aircraft operated by DWD, DLR and Forschungszentrum Karlsruhe (DO 128) were used to identify the daily cycle and the transport efficiency of the "Alpine Pumping".

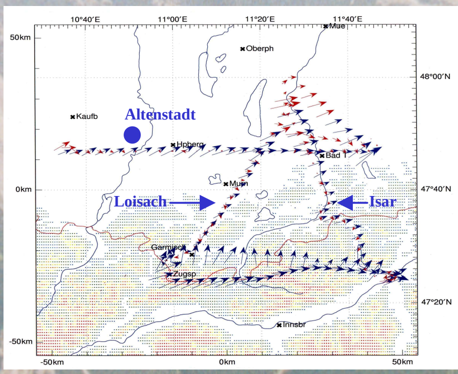

Fig. 1: Horizontal wind, measured at noon by the DO 128 in 2 levels at July 8, 2002, between Munich and Innsbruck. Red arrows indicate wind below and blue arrows wind above 2000 m msl.

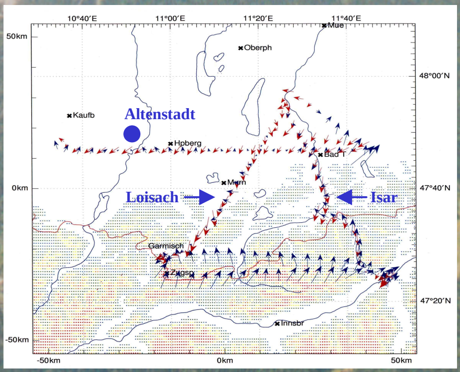

Fig. 2: The same as Fig. 1 but flight in the late afternoon, when the ALP has fully developed.

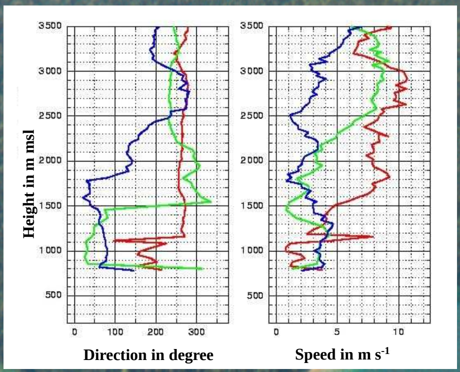

Fig.3: Vertical development of ALP seen from three radiosonde profiles with wind direction and wind speed at Altenstadt in the alpine foreland. Red: 07 UTC; green: 13 UTC; blue: 18 UTC.

The "Alpine Pumping" on July 8, 2002

An anticyclone was observed over central Europe while low pressure was located over Great Britain. A moderate southwesterly flow over the Alps prevailed. The wind measurements made onboard the DO 128 (Figs. 1, 2) and the vertical wind profiles at Altenstadt (Fig. 3) clearly indicate the development of the pumping regime.

At about 11 UTC (Fig. 1), 25 km north of the hills up to 2300 m wind from Southwest was measured. On the East-West flight, 15 km north of the mountains, the wind was calm below 2000 m and southwesterly above. In the Isar and Loisach valley a northerly wind has still developed below 2000 m. Above southwesterly winds prevailed. Four hours later (Fig. 2) the ALP has fully developed. In the foreland Northeasterlies of ~3 ms^{-1} and in both valleys northerly winds of 5 ms^{-1} were measured in the lower flight levels. In the upper levels the synoptic flow was still prevalent. At Altenstadt, 15 km north of the foothills, the onset of the ALP began between 07 and 13 UTC. The maximal height was 1000 m at 18 UTC. The surface network indicated weak winds at noon, but at 15 UTC, all stations up to Munich, 70 km in the north, measured northeasterly winds greater than 3 ms^{-1}.

Interpolated vertical cross sections of the North-South wind speed are given in Figs. 4 to 6. Data from DO 128, DLR-Falcon WIND-LIDAR, radiosondes at Altenstadt, Munich and Lenggries, RADAR at Lichtenau and surface stations are included. At noon (Fig. 4) the ALP was low (~ 2 ms^{-1}) with upper boundary between 1500 m and 1800 m. At 16 UTC (Figs. 5, 6) the maximum wind of the ALP was 6 ms^{-1} with a height between 1800 m in the West and 2200 m in the East.

Mass Transport triggered by "ALP"

At the culmination of the regime the mean North wind in the "pumping layer" was 2.7 ms^{-1}. Thus a mass transport through the cross section (120 km length, 1100 m to 1500 m height) results for

Dry air	1.6×10^{12} kg h^{-1}
Water	1.4×10^{10} kg h^{-1}
NO_x	6.9×10^{3} kg h^{-1}

Air and trace gases passing the cross section can be expected about 4 h later to be incorporated in convective systems and clouds over the mountains.

Background: Zugspitze with Eibsee

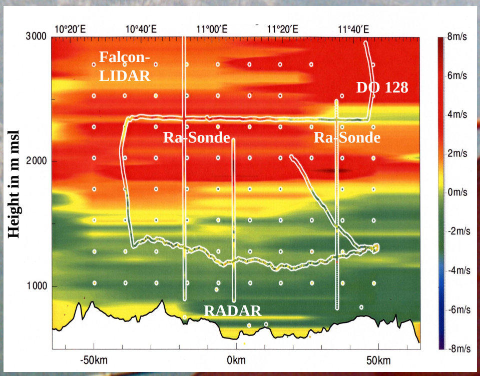

Fig. 4: Vertical cross section of the North- (negative) South- (positive) component of the horizontal wind in a plane 15 km north of the alpine foothills. Interpolated wind field with measured data encircled.

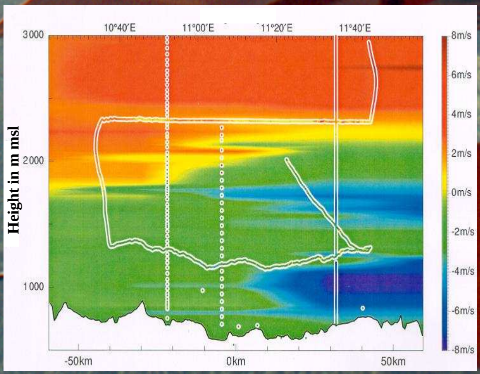

Fig. 5: The same as Fig. 4 but data used from afternoon flights and radiosonde launchings.

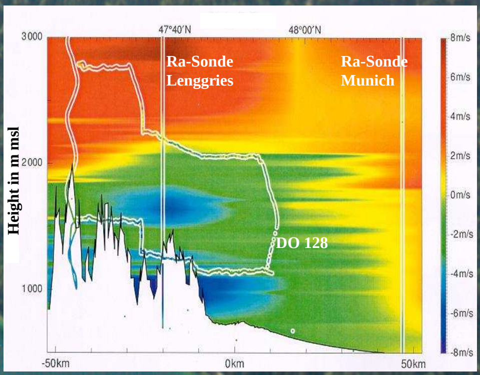

Fig. 6: Vertical cross section of the North- (negative) South- (positive) component of the horizontal wind in a plane from Munich (right) to the Inn valley (left). Interpolated wind field with measured data encircled.