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Fluidics, the Coanda Effect, and Some Orographic Winds

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With 4 Figures

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Summary

The Coanda Effect was a major contribution to fluidic technology first described in the 1930's. It explains the result of a jet passing through a nozzle into a large chamber and the consequent pressure distribution. This principle was applied to airstreams over the Carpathians and Transylvanian Alps [2]. A second paper [3] described the results and consequences of the Effect on the weather, vegetation and agriculture of the lower Danube valley. These results are presented here and the principle is applied to two other cases by the author: the strong winds which have been described at Big Delta, Alaska, and the mistral of the Rhone valley. The possible effects are described and a plea is made for detailed mesoscale studies in areas where a Coanda Effect may occur.

Zusammenfassung

Der Coanda-Effekt und spezielle orographische Winde

Der Coanda-Effekt ist zuerst 1930 als Beitrag zur Strömungstechnologie beschrieben worden. Er erklärt die Wirkung eines durch eine Düse in eine größere Kammer strömenden Strahlstromes und die daraus folgende Druckverteilung. Das Prinzip ist auf Luftströmungen über die Karpaten und Transsilvanischen Alpen angewendet worden [2] und die Auswirkungen auf Wetter, Vegetation und Landwirtschaft in der Donauniederung von Rumänien sind beschrieben worden [3]. Darüber wird hier referiert und das Prinzip wird vom Autor auf Starkwinde bei Big Delta in Alaska und auf den Mistral im Rhonetal angewendet. Die möglichen Auswirkungen werden beschrieben und es wird ein Vorschlag für Mesoscale-Detailuntersuchungen in Gebieten, wo der Coanda-Effekt zu vermuten ist, gemacht.

In the early 1960's some theoretical work on the Coanda effect was carried out in Romania [5, 6] and in 1970 this was applied to airflow induced by the Carpathian mountains [2]. Since this work was written in Romanian and published in Bucharest it has not had a wide circulation in English-speaking countries. However in the published proceedings of the fifth conference on the meteorology of the Carpathians an article appeared in French [3] which described the airflow to the east of the Carpathians where the Siret valley opens out into the Baragan Steppe area of the lower Danube valley.

But what has fluidics and the "the Coanda effect" to do with airflow near the Carpathians ? Writing in 1970 Stewart said "within the past decade the terms pneumatic logic and fluidics were practically non-existent . . . the word "Fluidics" is derived from the words "fluid" and "logic" and is used specifically to describe the technology of the control of fluid force components" [7]. Thus fluidics are an all-fluid system working on aerodynamic principles which offer a degree of sophisticated control which previously could only be provided by the logic functions of electronics. A basic principle of

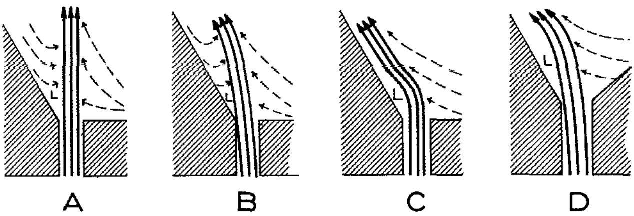

Fig. 1. The Coanda effect

fluidics is the "Çoanda effect" which is named after Henri Marie Coanda (1885–1972) who was a Romanian aeronautical engineer and inventor. In the 1930's he made a major contribution to fluid technology when he observed that when a free jet emerges from a nozzle or orifice it will tend to be attracted to a nearby curved surface. This is best explained by Fig. 1. Here a free jet (solid lines) passes through a narrow opening into a large chamber where it entrains fluid molecules (dashed lines) from both sides (A). In the chamber less air is available for entrainment to the left of the jet than to the right because of the angle of the nearby surface. Thus a partial vacuum or low pressure area forms to the left of the jet and tends to attract the jet towards the angled surface (B). As long as the supply of molecules on the other side remains constant the low pressure area continues to attract the jet and forces it to flow closely to the angled surface (C) until additional molecules can be introduced into the low pressure area. The effect only works when the curvature or angle is not too sharp. If both sides of the nozzle are angled (D) the low pressure area tends to form on the side with smallest angle.

It is this fluidic principle which Ion Bordei applied, initially, to northerly airstreams above the Moldavian Plateau. Because of the configuration of the arc formed by the Carpathians and the Transylvanian Alps a Coanda effect might be expected, the northerly air streams being diverted towards the southwest (Fig. 2) and a low pressure area should appear. His 1972 paper shows all these features and also discusses a number of consequences which are summarised as follows. The cold air penetrates further to the southwest than would be expected in reaches places such as Bucharest which appear to be sheltered from their influence. However nearer the mountain arc the low pressure area has more complicated effects. One of these is to intensify any föhn effect in the lee of the Carpathian arc. Ion Bordei describes how the low pressure and the föhn together produce a Mediterranean enclase ("enclave d'éléments méditerranéens des Souscarpates de courbure"). This enclave has typically Mediterranean flora, fewer days of snow lying, slightly less frequent preci-

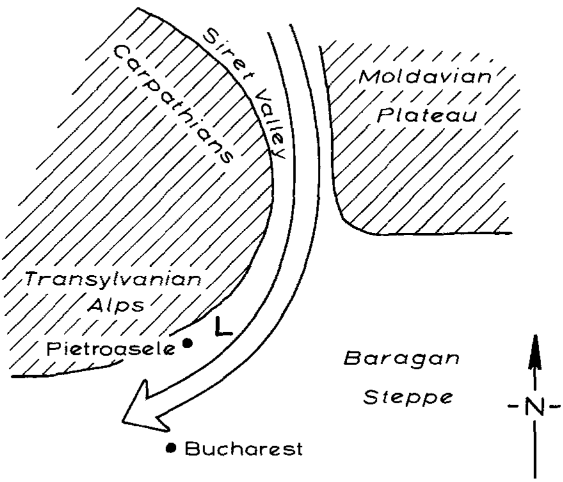

Fig. 2. The Carpathian arc

pitation, temperature 1° to 3°C higher than the surrounding regions, and is one of the largest wine and fruit growing regions of Romania. At Pietroasele, at the centre of the low pressure area, the vines do not require protection during the winter. Theoretically, and practically, these effects will result with air streams from all directions except those from the south-east. Nevertheless, those with a northerly component produce the greatest differences between the low pressure area and the rest of the Danubian Plain.

A second example where the Coanda effect could operate is in Alaska (Fig. 3). In 1953 Ehrlich [1] briefly discussed a local wind at Big Delta which was described as similar to "a stream of water coming from the nozzle of a hose". Three years later Mitchell [4] described this wind in much greater detail and showed that it resulted when the weather pattern was such as to produce east-southeast or south winds over this part of Alaska. The descriptions by both these authors indicate that the "jet" tends to flow towards Nenana, i. e.

it follows the curve of the Alaska Range rather than to flow directly on to the Tanana Plain in the direction of Fairbanks. Ehrlich points out that in two separate periods in November 1951 Fairbanks reported 215 hours of calm while Big Delta was experiencing winds almost continuously over 20 knots and gusting to 75 knots and winds at Nenana averaged over 10 knots with gusts over 30 knots.

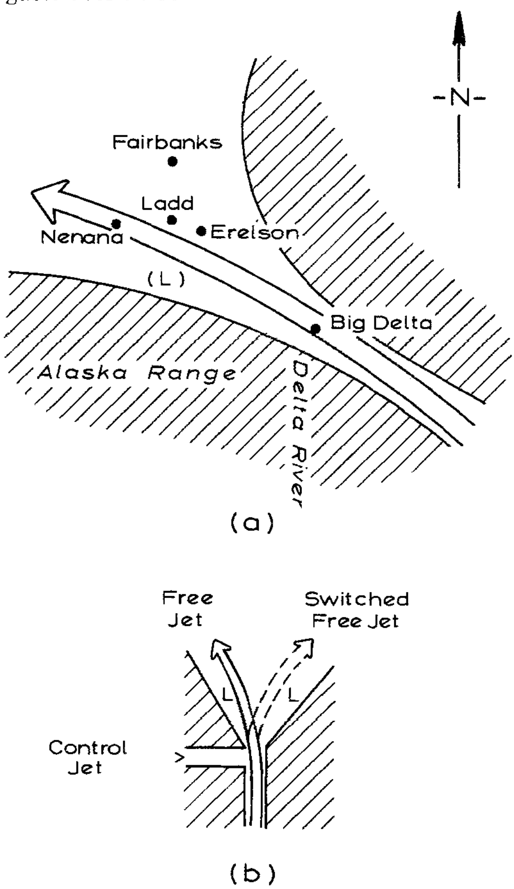

Fig. 3. The Alaska range

If the Coanda effect operates one would expect the "jet" to attach itself to the Alaskan Range and a low pressure area should appear in the lee of this range between Big Delta and Nenana (in Fig. 3a). In both articles the position of the jet supports this hypothesis but no direct evidence is given for the low pressure area. Mirchell discusses the high incidence of south-winds to the west of Big Delta in terms of a föhn-type flow across the Alaskan Range and mentions that föhn-wall cloud and rapid surface temperature increases usually accompany such winds: "the south current is sometimes observed to encorach steadily into the region previously occupied by the southeast current". This situation is analogous to a westerly or northwesterly flow over the Carpathian arc intensifying the föhn effect in the low pressure area. In the Alaskan situation, however, a part of this föhn wind is channelled by the Delta River

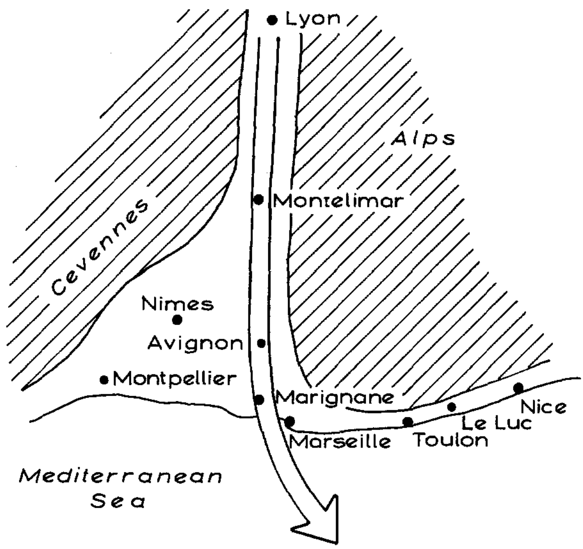

Fig. 4. The Rhône valley

valley and could act as a control jet. Fluidic theory shows that a pulse of air from a control jet situated close to the orifice will switch the free jet to the opposite wall (Fig. 3 b) because it effectively changes the low pressure area to one of relatively high pressure. In the terminology of electronics this system acts as a monostable flip-flop. From the evidence available it seems that this does not happen. Apparently the air flow down the Delta River valley during the föhn periods is insufficient to switch the direction of the free jet so that it crosses Eielson and Fairbanks, or it is too far from the "orifice" or opening of the Tanana valley for it to affect the low pressure area as fluidic theory predicts. Confirmation of this explanation of the Big Delta winds in terms of fluidic theory requires a detailed analysis of the local weather and/or vegetation in the area between Nenana, Ladd and the foothills of the Alaska Range.

A final example of a valley directed wind which may be explained in terms of fluidic theory is the mistral of the Rhône valley (Fig. 4). There is both direct climatological and indirect economic evidence showing that this wind blows primarily along the east of the Rhône delta as it hugs the Alps – the side with the least-angled surface. The meteorological stations in the middle Rhône, such as Montelimar and Orange, have north as the predominant wind direction as do Avignon and Salon in the lower Rhône. Nearer the coast at Istres and Marignane northwest becomes the predominant direction. On the western side of the lower Rhône at Nîmes and Montpellier north and northwest remain the major wind directions but do not predominante to such a great extent. On the occasions when a strong mistral occurs most of the stations in the Rhône valley south of Montelimar report either N or NNW winds at speeds in excess of 40 knots. These winds back to WNW at Toulon, Le Luc and St. Raphael as the mistral rounds the Calanque Coast. At Nîmes and Montpellier N winds are most common at these times and only occasionally is the wind reported from a NNE direction.

Indirect economic evidence for the position of the mistral is provided by the new port of Fos which was constructed in the late 1960's, the low-level air corridors of the civil and military aerodromes of the region, and the agricultural wind breaks. The port of Fos at present consists of the two large docks and an approach channel dredged and capable of taking supertankers up to the half megaton size. Ships of this size have manoeuverability problems which are made worse in strong winds so the approach channel and the new docks were aligned NW–SE so that supertankers, ore carriers and container ships could approach the dock head-on to the mistral when it was blowing. The low-level air corridors at Istres, Marignane and Salon are all to the NNW of the respective aerodromes although there are no major physical obstacles in other directions. The profusion and density of agricultural wind breaks on the eastern side of the lower Rhône are also indicative of this predeliction of the mistral for this side of the valley rather than for the western side.

From fluidic theory this is the expected pattern. Because of the topography there are no strong winds which might act as a control jet affecting the mistral from the east. On the west, however, there is the Carcassone Gap and winds blowing through this towards depressions in the Mediterranean would act as a control jet ensuring that the mistral remained attached to the Alps, with a low pressure area forming in the area between Orange and Marseille. Unfortunately the large-scale pressure patterns favourable to the initiation of the mistral militate against local valley winds or pre-Alp föhn winds blowing into such a local low pressure area. Once again its presence may only be ascertained from a mesoscale study of pressure patterns in an area of great topographical complexity.

This article has described three cases where the principles of fludics have been applied to topographically directed winds. In the example from the Carpathians the work of Ion Bordei has shown that a low pressure area produced in accordance with the Coanda effect does alter the mesoscale pressure pattern and indirectly affects the vegetation and economy of a small area north of Bucharest. In the other two examples no such detailed investigation has taken place but climatological and meteorological evidence suggests that in both cases the Coanda effect is present, and the writer postulates the approximate position of the resultant low pressure area. Readers will no doubt think of numerous other examples, on a variety of scales, where the flow of air out of a valley might be explained in terms of fluidic theory.

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