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The TRANSALP experiment tracer release and transport simulation

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Abstract

The pollutant transport associated with the TRANSALP experimental tracer release, conducted in South Switzerland on 29 September 1990, is simulated. The region in which the experiment (i.e. the release and the concentration measurements) took place belongs to a complex topographical structure. The TRANSALP release was made at a critical site of the terrain, i.e. at the beginning and near the base of a major valley (Leventina valley) while a quite dense network of ground tracer samplers was installed along the valley's axis, as well as at several significant surrounding points. The simulation is made using the DEMOKRITOS Transport Code System, consisting of the Topography Simulator DELTA, the Mesoscale Atmospheric Model ADREA and the Lagrangian Dispersion Model DIPCOT-II. The predicted concentration patterns are compared with the observations, indicating that the major dispersion features are well reproduced.

Introduction

In large mountain regions the topography is usually highly complex with irregularities covering a wide range of sizes. The irregularities can influence considerably the regional pressure gradients and induce mechanical effects on the wind systems[1]. The air/ground interaction in terms of energy and humidity exchange is highly variable due to rapid changes on surface orientation or altitude or even land use. As a sequence the wind system evolution over the mountains is of multiscale character both in space and time especially in the case of thermally developed winds.

A pollutant release advected by such multiscale wind systems can generate a quite complicated air pollution patterns. The question that this paper is trying to address partly is whether we are in position to predict numerically such complicated air pollution patterns especially when the release is occurring in "the middle of a mountain range where everything around looks quite complicated."

The TRANSALP experiment having the above mentioned characteristics refers to the Alpine region and it was designed to study the transport of atmospheric transport constituents over the Alpine barrier from the Western Po Valley to the Swiss Plateau and vice versa.[2,3]. The particular area in which the experiment (i.e. the release and the concentration measurements) took place belongs to the complex topographical structure of the central Alpine area,

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including the upper part of the Italian Po valley with the first hills and lakes up to the main Alpine ridge and a large fraction of the Swiss Plateau. This area is often subjected to well developed mesoscale atmospheric systems, generated along the slopes and the valleys during the days of weak synopting forcing.

The study is focused on the September 29th, 1990. The meteorological conditions at that day was characterized by a mobile anticyclone moving from West Europe to East. The associated upper level winds at the same time showed an increased intensity taking a SW direction. Moist air from Adriatic Sea and Po valley was advected into the region contributing some low level clouds over Agno south of the release which affected the full thermal wind development over the area[2].

The tracer was released near Giornico at the beginning and near the base of the Leventina valley (see fig.1) at the altitude of 360 m. The source was located 8 meters above ground. The tracer used was perfluoromethylhexane PP2 (C_7F_{14}). The material was released at a rate of 8g/s starting at 10:00 LST together with the development of the valley breeze and lasted for two hours.

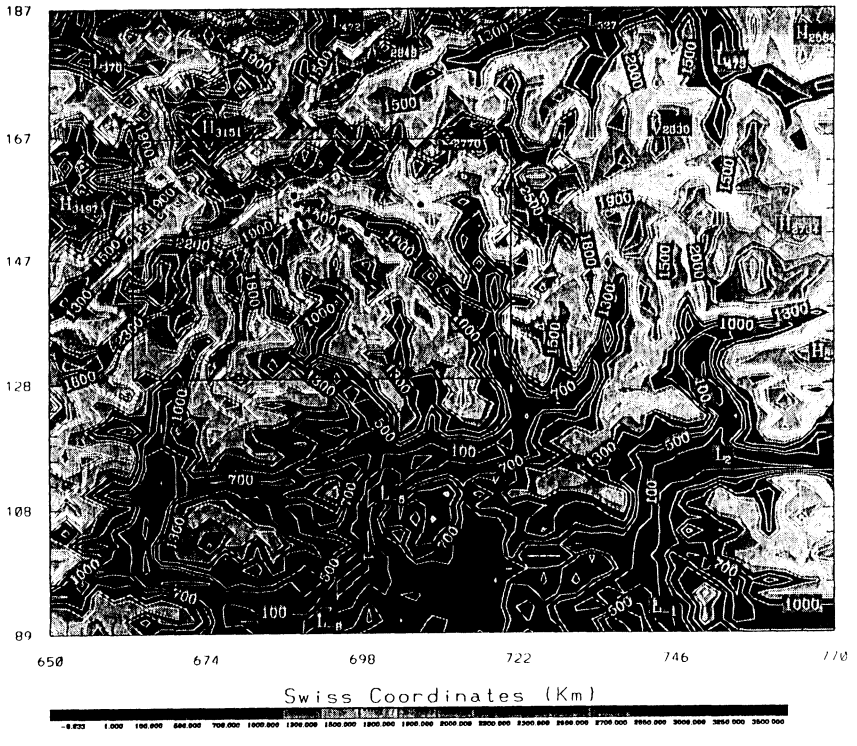

Figure 1: Geographical simulation of the area of interest including the positions of ground concentration samplers.

Methodology

The simulation of the above mentioned experiment has been performed by utilizing the DEMOKRITOS Transport Code System [3].

The calculation domain covers an area 121x101 km^2 as shown in Fig 1. It includes the upper part of the Po Valley in Italy, with the first hills and lakes up to the main Alpine ridge, as well as a large fraction of the Swiss Plateau, up to the city of Luzern and the region around Zurich. The area includes the network of ground measurements and the two main valleys, located in the middle of the simulated area. The horizontal grid selected for the atmospheric calculations is symmetrical around the station Giornico (G), starting with a horizontal mesh of 1km (within the first 5km in both axes) and increasing towards the boundaries with a geometrical progression relation of ratio 1.15 approximately, up to the maximum value of 5km.

In the vertical axis, a non-homogeneous grid spacing is set, with minimum interval of 50m (over ground) and maximum of 500m (near the top). The height of the domain is about 9.5km.

The Cartesian grid has been selected instend of a terrain following one since it allows for surged resolution giving the ability to include subgrid details in the structures permitting more realistic air/ground interaction especially in the energy budget related directly to thermal wind systems evolution.

The topographical information was provided by the DELTA/GAIA module, with a sub grid resolution of 16 triangles per bottom-boundary surface to allow more detailed description of the ground topography[3].

For the wind flow prediction the mesoscale nohydrostatic compressible mesoscale model ADREA-I has been utilized [4,5]. The wind flow prediction details are given elsewhere [6].

We should mentioned here that the calculations were performed, using typical initial conditions for the wind, temperature and humidity, corresponding to those prevailing during the examined day. The initial wind was set equal to 2m/s (measurements within the boundary layer). This low value was kept for the whole domain, so that the daytime mesoscale effects could be reproduced with the minimum large-scale effect. The simulation started at 0700 LST (near the sunrise) and continued until 1800 LST (approximately time at which the daytime mesoscale systems are dispersed).

The wind flow model provided the dispersion model with the velocity components and the substance diffusion coefficients based on the 1-Eq turbulent model [4].

The particular option of the Lagrangian particle model DIPCOT-II utilises the consept for eddy diflusivity to produce the random walk of the particles. The complete trajectory of a particle can be given as [7].

$$dX_i = u_i dt + \sqrt{2K_i}\, d\xi_i$$

Where is u_i the mean Eulerian velocity in the *ith* direction, k_i is the eddy diffusivity along the same direction and $d\xi$ is a random term generated from a suitable statistical distribution such as Gaussian or rectangular.

Results

Concerning the wind field predictions, details of data comparisons are given in [6]. The model has quite accurately reproduced the major features of the day time wind systems especially in the area where the pollutant cloud was present.

Indicative are the results of figure 2 illustrating the predicted surface wind field at 12:00 LST . The above figure shows the development of the up valley wind which is in qualitative agreement with the fact that the stations that measured non-zero concentrations where lying mainly within the valley upward the release point (see fig.1).

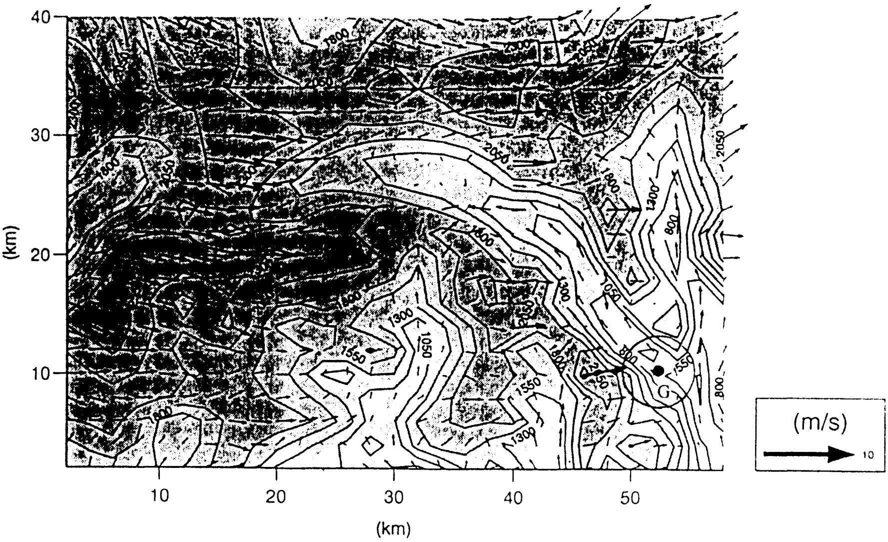

Figure 2: Surface Wind Field at the area of interest (12:00 LST).

Figure 3 is the scattergraph of maximum concentrations at the stations shown in Figure 1. In most of the stations the results are quite satisfactory. The good prediction of the maximum concentration can be attributed mainly to i) the wind prognostic model which reproduced well the wind direction and ii) the turbulent model used which provided reasonable values for the 3-D eddy diffusivity coefficients.

On the other hand the arrival times proved to be less satisfactory. A model time delay of two hours was rather typical more or less for all station. Figure 4 shows the concentration time history in the station FOPPA (F) included in figure 1. The reason is that the model generally undepredicts the wind speed especially in the area near the source. Low space resolution as well as lack of good ground description could be a reason for such a discrepancy.

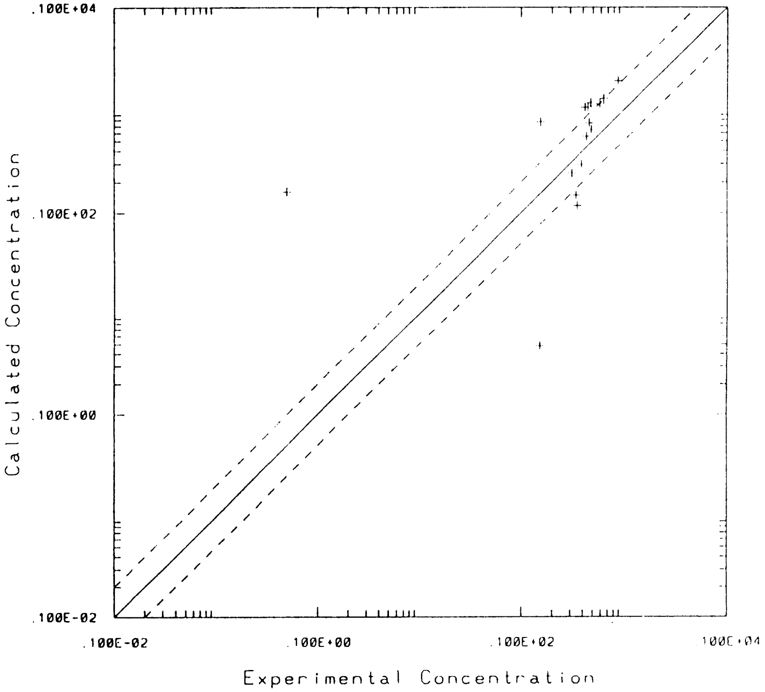

Figure 3: Scatter graph of maximum concentration

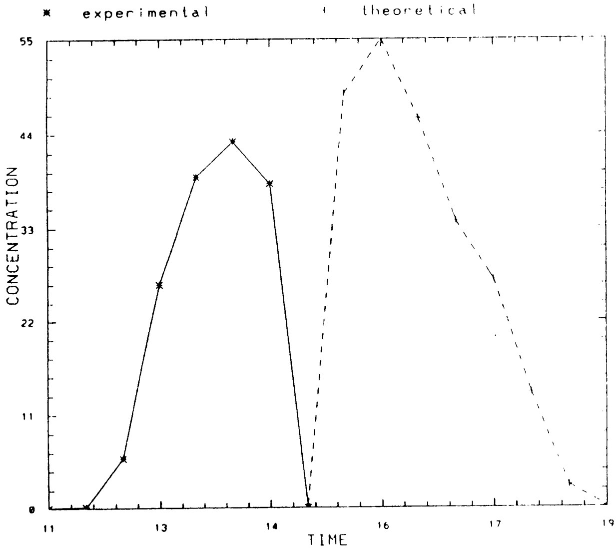

Figure 4: Typical comparison between theoritical (+) and experimental (*) consentration time history at FOPPA station (altitude 1270)

Conclusions

1. The present TRANSALP simulation excersise has shown that despite the high complexity of the domain and the lack of the precise knowledge of proper initial and boundary meteorological conditions, we were able to reproduce more or less the major dispersion features of the tracer released during the experiment.

2. The concentration levels were well predicted reflecting the reasonable estimation of the wind direction and eddy diffusivity.

3. The model performed worse on cloud arrival times where a two hours model delay was typical along the valley. Low space resolution and luck of good ground description could be the major factors for such a discrepancy.

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