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THE BOLZANO TRACER EXPERIMENT (BTEX): AN EXPERIMENT ON TRACER GAS DISPERSION FROM AN INCINERATOR STACK AND ON ITS REAL-TIME MODELLING

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Abstract: On February 14th 2017, the Bolzano Tracer Experiment (BTEX) was conducted in Bolzano, a town in the Eastern Italian Alps. The experiment consisted in two 1-h-long releases of a tracer from the stack of the local incinerator plant and in the measurements of tracer ground concentrations in the surroundings. Before and during the releases, a modelling chain was run in order to have a real-time forecast of both meteorological conditions and tracer concentrations at the ground. The experiment was conducted in the framework of a wider project, supported by the incinerator company and the local environmental protection agency, with the final aim of locating a permanent air-quality stations network for monitoring purposes. This contribution aims at presenting the experimental setup, the data collected and the results from the numerical modelling chain.

Key words: *tracer dispersion, complex terrain, dispersion experiment, real-time dispersion modelling***.**

INTRODUCTION

Bolzano lies in a basin where four different valleys merge together being surrounded by alpine peaks reaching 2000 m above m.s.l.. The complex terrain of the investigated area makes the collected dataset of concentrations unique and at the same time represents a challenge for both meteorological and dispersion modelling. During the experiment, two tracer releases were performed: the first one during the early morning, under stable meteorological conditions and weak Northerly winds, and the second in the early afternoon, with conditions of more enhanced, but still weak, convection and weak Southerly winds. During the experiment, a modelling chain was run coupling the Weather Research and Forecasting (WRF) model (Skamarock et al., 2008) with two different dispersion models: the CALPUFF semi-Lagrangian Gaussian puff model (Scire et al., 2000) and the SPRAYWEB particle Lagrangian model (Tinarelli et al. 2000; Alessandrini and Ferrero 2009).

STUDY AREA

The city of Bolzano (262 m a.s.l.) lies in the middle of a wide basin at the junction of the Adige Valley, mainly north-south oriented, with the Isarco Valley, joining from the East, and the Sarentino Valley, from the North. Figure 1 shows the study area in the Bolzano basin, its tributary valleys and all available meteorological measurement stations. In the considered study area, the Adige Valley is approximately 2-3 km wide while the Sarentino and Isarco Valleys are V shaped and very narrow. The sidewalls of the Adige Valley are very steep, especially on the Eastern side of the valley. Mountain peaks reach between 1000-2000 m MSL heights. The climate of Bolzano is continental, characterized by warm summers and cold winters. Wind regimes are dominated by terrain effects (Dosio et al. 2001), developing thermally-driven winds (de Franceschi and Zardi 2009), which however are mostly absent or very weak during wintertime (de Franceschi et al. 2009). This aspect, in connection with the frequent occurrence of ground-based inversions at the valley floor, determines frequent critical conditions for air quality. The incinerator is located 2 km Southwest of the town of Bolzano, very close to the western sidewall of the Adige Valley (see Figure 1b). The waste incinerator plant became operative in July 2013, with a maximum waste treatment capacity of 130000 t y^{-1} and a flow rate of 85000 Nm^3 h^{-1} released at 60 m above ground level at 413 K. This new plant required policy makers to improve the forecast of dispersion processes in the area (Ragazzi et al., 2013), with the aid of both atmospheric and dispersion modeling.

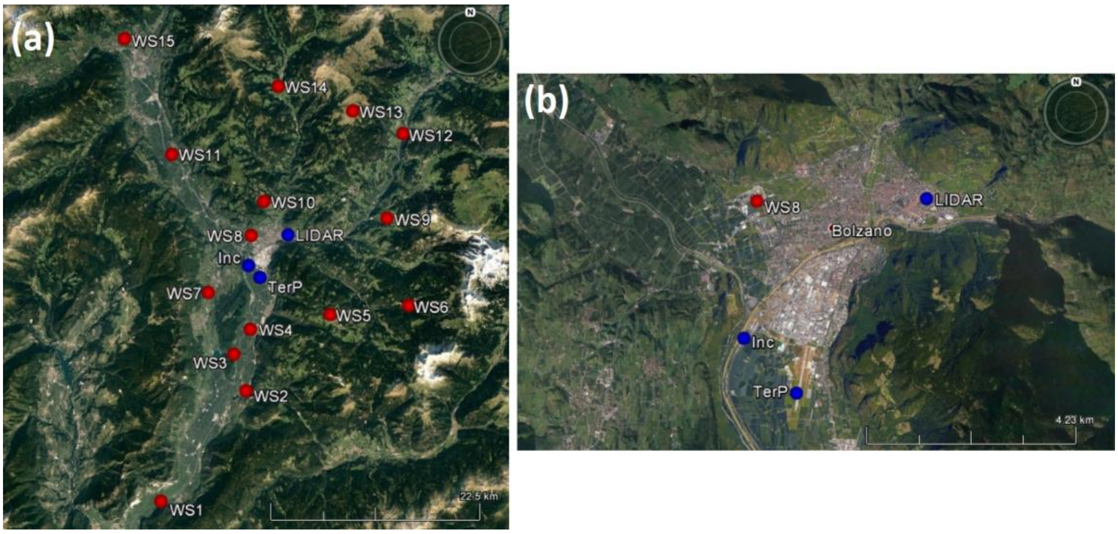

Figure 1. Bolzano basin with its tributary valleys. Locations of the available weather stations are also highlighted: "Inc" incinerator plant and SODAR; "TerP" thermal profiler; "LIDAR" LIDAR instrumentation; "WS" ground weather stations (background map from **Google Earth**).

STUDY PERIOD

The measurement field campaign of BTEX focused on the 2017 winter season during which both meteorological and tracer gas concentration at the ground were collected. The tracer gas releases were performed on February 14th, 2017. The first tracer release took place in the early morning, with a weakly stable atmosphere and weak north-westerly winds at the incinerator plant. The second release took place in the early afternoon, in weakly convective conditions and weak southerly winds. During both releases, the sky was clear and no strong synoptic forcing occurred.

METEOROLOGICAL DATA SET

The meteorological data set collected during BTEX and used in the present analysis is a collection of data coming from a set of permanent weather stations, from a permanent thermal profiler and from specific instrumentation deployed for the experiment. The permanent station network and the thermal profiler are both managed by the local meteorological service. Their location is shown in Figure 1a, where the weather stations are numbered with increasing latitude. These stations collect both 2-m temperature and 10-m wind speed and direction observations. The thermal profiler (RPO Attex Mod. MTP 5-HE) measures temperature up to ~1000 m with a spatial resolution of 50 m. It is located close to the airport, in the center of the Adige Valley, 3 km southwest of the city of Bolzano. The instrumentation specifically deployed for BTEX consists in a SODAR and a LIDAR wind profilers. The SODAR instrumentation (Scintec Mod. MFAS-64) was located on the roof of the incinerator plant (40 m a.g.l.), in order to have information of the wind vertical profile close to the stack. The instrument was able to measure up to ~300 m above the roof-top (i.e. ~340 m above ground level) with a spatial resolution of 10 m and a temporal resolution of 10 min. The LIDAR instrumentation (Leosphere Sas Mod. WINDCUBE 3D 100S) was installed at the exit of the Isarco Valley, in the northwestern part of the town of Bolzano (see Figure 1). This location is of particular interest as the analysis carried out demonstrated the existence of a nocturnal valley jet blowing along the Isarco Valley during cold winter nights. When activated, this strong valley jet crosses the Bolzano basin, flowing from the North-East towards the South, passing over the incinerator plant. In order to have a precise depiction of the Isarco Valley jet, the LIDAR instrumentation was deployed. It measured vertical profiles of wind speed and direction up to ~1100 m, every 10 min, with a spatial resolution of 10 m. Temperature observations from the thermal profiler showed that the atmosphere was weakly stable throughout the whole day and almost neutral from 10 to 16 LST. Figure 2 presents the measurements taken by the SODAR. The observations show from 5 to 10 LST a drainage

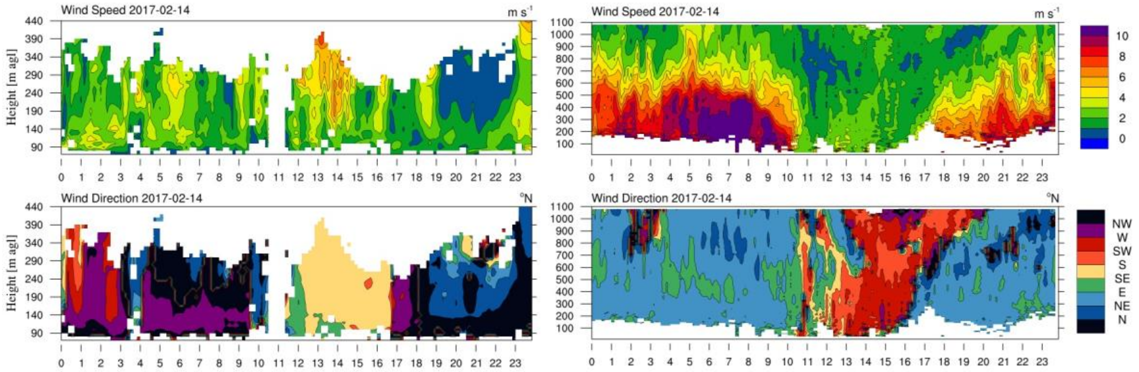

Figure 2. Time-height diagrams of wind speed (top panels) and direction (bottom panels) measured by the SODAR (left panels) and the LIDAR (right panels).

flow from the Adige Valley, up to ~150 m agl. In the upper layers, instead, a strong northerly wind flows over the incinerator. These measurements clearly state that, over the plant, two different wind regimes exist at different heights, with completely different speed and direction. This evidence highlights that modeling the dispersion of the emitted pollutants is extremely complex, as small differences in the calculation of the effective release height can lead to completely different impact scenarios. From 11 till 16 LST, an up-valley wind flows in the Adige Valley, with southerly direction. In this period the SODAR measures very high wind speed, especially in the upper layers. However, these observations are not reliable, as with a southerly wind the plume is flying over the SODAR and its very high temperature (140°C) interferes with the instrument, compromising its observations. Nevertheless, the direction of the measurements is not affected by the air temperature. In the late afternoon the wind looses strength and the direction turns again to north/northeast. The LIDAR instrumentation recorded observations above 300 m MSL and detected a strong drainage flow descending the Isarco Valley (which is north-easterly oriented) during the night until 10 LST. The wind speed is very high, with intensities greater than 10 m s^{-1}, and the jet reaches heights of 800 m MSL. In the late morning the jet flow ceases, while an up-valley, south-westerly wind takes place. Its intensity is lower, but it extends through a deeper layer, reaching heights above 1 km. After 16 LST the up-valley wind starts to decrease gradually from the lowest to the highest layers and the north-easterly jet wind grows again. It is likely that the strong drainage wind along the Isarco Valley flows into the Bolzano Basin and is forced to change direction by the orographic constrains, which channel it in the Adige Valley. The strong, northerly-oriented flow recorded by the SODAR in the morning, and in the late afternoon, is therefore the jet from the Isarco Valley.

TRACER CONCENTRATION DATA SET

On 14 February 2017, two releases of tracer gas were performed, one in the early morning, at 7:00 LST, and one in the early afternoon, at 12:45 LST. The first release lasted 1 h, the second 1.5 h. The tracer gas used is sulfur hexafluoride (SF_6). This gas is particularly suitable for this kind of experiments as it is strongly inactive, non-toxic, odorless, colorless, non-flammable and extremely stable at both ambient air and emitted smoke (140°C) temperatures. In addition, it is not naturally present in the atmosphere with concentrations higher than 10 pptv. The releases were performed by inserting 99% pure SF_6 at the basis of the incinerator stack, before the ventilation system which guaranteed a uniform mixing of the tracer in the smoke emitted by the plant. The inflow of SF_6 as regulated, so that the concentration of gas at the emission was constant. In order to have the precise value of the tracer concentration emitted at the chimney, continuous and real-time measurements were taken right before the exit of the smoke from the stack, with two mass spectrometers. The sampling procedure consisted in the deployment of 14 sampling teams distributed in the Bolzano Basin and its tributary valleys. 7 sampling teams maintained the same location during both the releases, forming a fixed sampling grid. The location of these sampling teams was chosen on the basis of the expected area of impact of the plume and of the distribution of the population. The remaining seven sampling teams were located in different locations during the two releases, forming the moving sampling grid. These sampling teams were located on the basis of the results of a real-time modeling chain run during the experiment day. The modeling chain consisted of

WRF simulations with observational nudging, coupled with two different dispersion models, CALPUFF and SPRAYWEB. Each of the sampling team collected sampling of ambient air with a set of 1-l vacuum-filled glass bottles with automatic filling valves. Sampling of 1 h or 20 min were collected with this equipment. Three of the sampling teams also collected an additional set of measurements, during the experiment, by means of teflon bags filled by air pumps. The timing and choice of sampling type were again decided on the basis of real-time dispersion forecast. The 79 collected samples were analyzed by the laboratories of EcoResearch and Mario Negri Institute by means of mass spectroscopy analysis with a detection limit of 30 pptv.

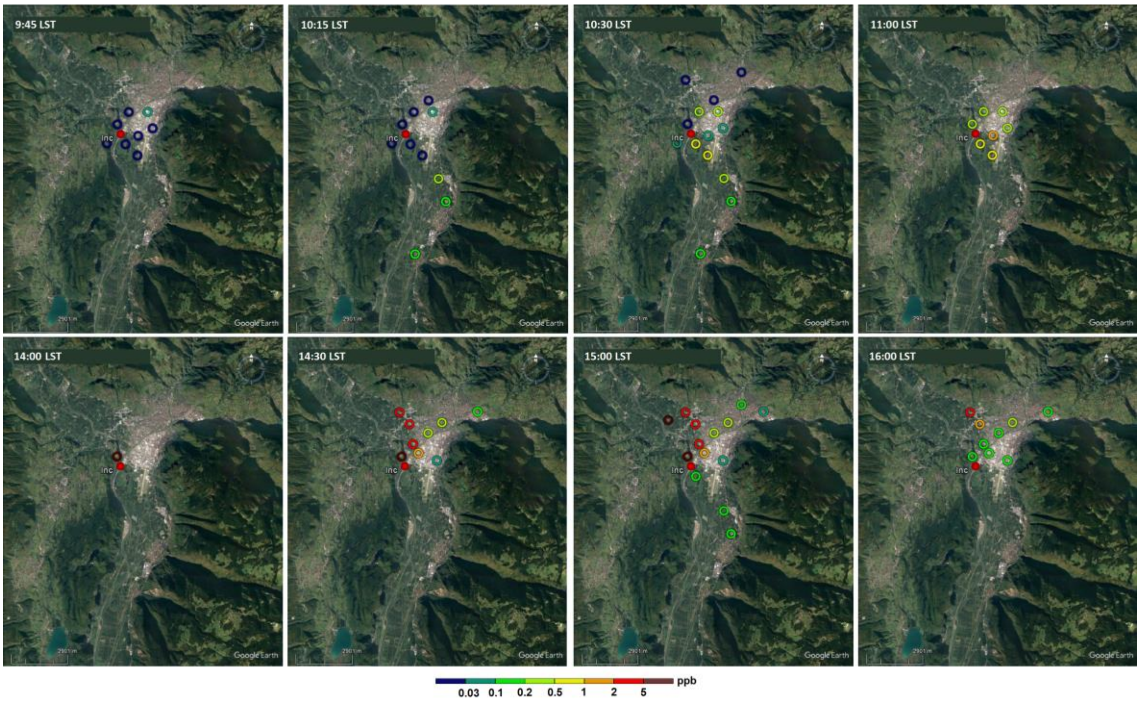

Figure 3. Time evolution of the tracer concentrations measured during the 1st (top) and 2nd (bottom) releases (background maps from Google Earth).

During the first release experiment, the sampling begun at 8:30 LST but detectable concentrations were recorded by only one sampling point, located North-east to the plant. As the release started at 7 LST, we can state that the tracer took at least 2 hours to reach the ground in most of the sampling points. This slow dispersion of the tracer is consistent with the stability of the atmosphere, discussed in the above sections. The measurements suggest that the plume moved firstly toward South-east and later diffused in the whole Adige Valley. The tracer never reached the furthest sampling points located to the North of the incinerator plant, consistently with the wind speed and direction measured in the area. During th second release, the earliest observations are registered only 30 min after the release started. This is again consistent with the slightly unstable state of the atmosphere, as recorded by the meteorological instruments. The highest concentration was measured in the sampling point close to the incinerator toward North-west. High concentrations follow in most of the sampling points to the North of the plant with peaks in the north-west locations. The observations therefore suggest that the plume moved towards the North-west, impacting the whole Bolzano basin. Only traces of SF_6 were detected in the sampling points located to the South of the plant.

THE REAL-TIME MODELLING CHAIN

During the experiment, a modelling chain was run coupling the Weather Research and Forecasting (WRF) model with two different dispersion models: the CALPUFF semi-Lagrangian Gaussian puff model and the SPRAYWEB particle Lagrangian model. The meteorological simulations ran with four nested domains down to a horizontal resolution of 500 m. In the innermost domain, observational nudging was used to assimilate data from 7 ground weather stations, the temperature profiler, the SODAR and the Doppler wind LIDAR. The CALMET model and a dedicated WRF-SPRAYWEB Interface (WSI) were then used to process the meteorological fields from WRF, creating the proper format for the dispersion models and computing some turbulent parameters not available from WRF. The ground concentrations were then calculated on a ~200-m grid. The modeled patterns of dispersion are consistent with the measuerd ones and the verification procedure against the measurements, by means of standard statistical indexes, is currently being processed.

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