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The dispersion of the Buncefield oil fire plume: An extreme accident without air quality consequences

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Abstract

The dispersion of pollutants from the huge Buncefield oil depot fire that occurred on 11 December 2005 is simulated using a regional Eulerian chemistry-transport model. We analyse the transport and mixing of the fire plume. We show that the hot plume never reached the ground. Instead, it pierced the thin wintertime boundary layer and was injected into the free troposphere at higher altitudes. This is in agreement with data from many air quality stations. This high injection was fortunate because the fine aerosol particles (PM_{10}) mass column generated by the fire smoke exceeded that of ordinary pollution by an order of magnitude. Our regional chemistry-transport modelling is able to predict the early development of the plume dispersion, as shown by a qualitative comparison between simulated PM_{10} columns and a satellite image obtained by the EOS-TERRA-MODIS sensor.

If the accident had occurred in summer when boundary layers are much deeper and convective, a severe degradation in air quality due to PM_{10} could have occurred, as shown by a sensitivity simulation assuming a similar fire during one of the hottest days of August 2003. The modelled impact of the fire on regional and European air quality levels strongly depends on the altitude reached by the buoyant plume, as shown by a set of sensitivity simulations with variable injection heights. However, in all cases we found that the fire only affected surface aerosol concentrations without increasing photochemical pollution.

Keywords: Buncefield; Smoke plume; Air quality; Transport model; Particulate matter

1. Introduction

Bad air quality and its health consequences are due to regular pollutant sources (industries, traffic, etc.) but also on occasion to large pollutant releases due to wild fires or accidents. Major industrial accidents can have very dangerous environmental consequences. One of the deadliest events was the Bhopal leakage of a poisonous gas. The melting of the nuclear reactor in the Chernobyl power plant was one of the most frightening due to the large quantities of radionuclides released into the

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atmosphere. Release of toxic chemicals by explosion (for example, in Toulouse, France, 2001) or combustion of industrial facilities can similarly lead to large environmental and public health disasters. Even though they mostly release soot and carbon oxides, large oil or fuel fires could also considerably alter air quality (Husain and Amin, 1994; Brimblecombe, 1994), depending on their scale and other factors such as atmospheric dispersion. The Buncefield fire, which took place near London on 11 December 2005, was the largest oil fire in Europe since the Second World War, and as such deserves a special focus, as it represents a 'worst-case' accidental fire scenario.

At Buncefield, on 11 December 2005, overfilling of a depot tank led to a flammable vapour cloud that exploded early in the morning, around 06:03 h. The following huge fire burnt about 58,000 tonnes (75%) of the fuel stored in the depot and lasted up until 14 December. During the fire, large amounts of CO_2, CH_4, CO and black carbon aerosols were injected into the atmosphere. The black smoke from the oil fire formed a spectacular plume near the explosion site that rose up to about 3000 m, as reported by aircraft observers. A series of aerial pictures is available from http://flickr.com/photos/silyld/sets/1555657/. The plume was also measured from space by several Earth Observation satellites.

On the other hand, Targa et al. (2006) analysed a large amount of pollutant concentration measurements from air quality networks during the fire episode but found no sign of degradation in air quality, apparently due to the high buoyancy of the plume that got injected directly into the free troposphere above a thin wintertime boundary layer.

The magnitude and point location of the Buncefield fire leaves us with several open questions. First, is it possible that the particulate matter surface measurement network was not dense enough to capture parts of the smoke plume that would have reached the ground? Second, could such a plume have strongly altered air quality under different atmospheric dispersion conditions, e.g., in summer when the boundary layer is deep and convective? Third, are chemistry-transport models routinely used for predicting 'normal' pollution able to predict the dispersion of the accidental fire plume during the next few hours or days after the explosion?

These three questions are addressed in this article by a series of simulations of the Buncefield fire plume transport and mixing, using a regional air quality model representing the dispersion and reactivity of atmospheric gases and aerosols. Simulations are carried out for the 11 December 2005 case but also for another hypothetical fire with the same characteristics during an extremely stagnant summer period (9–11 August 2003) where deep boundary layers were present.

In Section 2, the model is briefly described. In Section 3, we analyse the results of the simulation for the 11 December 2005 Buncefield fire plume. In Section 4, we analyse the results of the simulation of the hypothetical summer fire. Section 5 contains a summary and a brief discussion.

2. The regional air quality model and the simulations

We used the CHIMERE regional chemistry-transport model which has been designed for spatial scales ranging from the continental scale (Schmidt et al., 2001) to the local, urban scale (Vautard et al., 2003). The model simulates the evolution of 44 gaseous species among which are the main regulated pollutants in Europe, ozone, nitrogen oxides, carbon monoxide, sulphur dioxide and lumped hydrocarbons. The model includes the evolution of aerosol primary and secondary particulate matter (Bessagnet et al., 2004), in six size bins up to 10 μm. Aerosols are composed of six species, nitrate, sulphate, ammonia, secondary organic aerosols, mineral dust and undifferentiated primary particulate matter (PPM). Primary soot particles are included in the PPM species.

Two nested grids are used in this study: a coarse continental grid with a $0.5^\circ \times 0.5^\circ$ resolution and a finer grid ($0.15^\circ \times 0.10^\circ$ resolution, about 10 km), which covers most of England, Northern France and The Benelux. Nesting is performed in a one-way manner: the coarse-resolution simulation is first carried out and then used to force the fine-resolution one by prescribing concentration boundary conditions. A 10-day spin-up period is carried out for each simulation, before the fire starts. In order to handle computer time and memory constraints, only eight vertical layers are considered from surface to 500 hPa, with approximate tops at 40, 100, 200, 400, 800, 1500, 3000 and 5000 m, using hybrid sigma-p vertical coordinates.

All simulations use 'regular' anthropogenic emissions taken from the gridded EMEP annual inventory (Vestreng, 2003) and use time variations