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SMOKE PLUME FROM FIRE LAGRANGIAN SIMULATION AND VALIDATION USING GROUND-BASED LIDAR DATA

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Abstract: In this work we performed a numerical simulation of the plume dispersed from a fire. A field experiment, carried out in August 2013 in Idaho (USA), was considered for comparison. The numerical model is a Lagrangian particle model with a new plume rise scheme able to dynamically simulate the buoyancy effect due to the high temperature of the plume. Comparisons of model results with lidar ground-based measurements are shown.

Key words: *Smoke plume, plume rise, dispersion model, lidar measurements*

INTRODUCTION

Fire plume rise is a critical aspect of appropriately characterizing both the near and far-field impacts of smoke. In the current operational models, the plume rise is computed assuming an air parcel's rise based only on the buoyancy terms (Briggs, 1975) using the fire heat release, the wind velocity, and the friction velocity during the day and the static stability at night. The smoke particles are released at the final plume height from the center of each emission grid cell that contains the fire location. These assumptions can lead to big approximations. In fact, the plume is likely to reach the top of the boundary layer during the day and to partially penetrate above the temperature inversion layer at the top of it (Weil et al. 2002). We propose to use the method suggested by Alessandrini et al. (2013) for the buoyant plume rise simulation based on the Lagrangian description of plume temperature and momentum. The plume is split into many parts represented by cubic grid cells. At each time step the temperature and the momentum difference between the plume and background atmosphere is computed for each grid cell of the plume. At each cell an independent computation of the plume rise is performed and the particle elevations are adjusted accordingly. This method, which takes into account for the whole 3D temperature and wind fields, allows a better simulation of the plume rise, particularly when dealing with non-uniform conditions (e.g., with strong wind shear, or a temperature inversion at the top of the boundary layer). We compare the model results with the field experiment organized by the US Environmental Protection Agency (EPA) in Idaho on August, 2013. In these experiments, the ground-based mobile elastic scanning lidar and data-processing methodology have been used to determine the heights of smoke plume columns and smoke layers and the temporal changes of the plume rise heights.

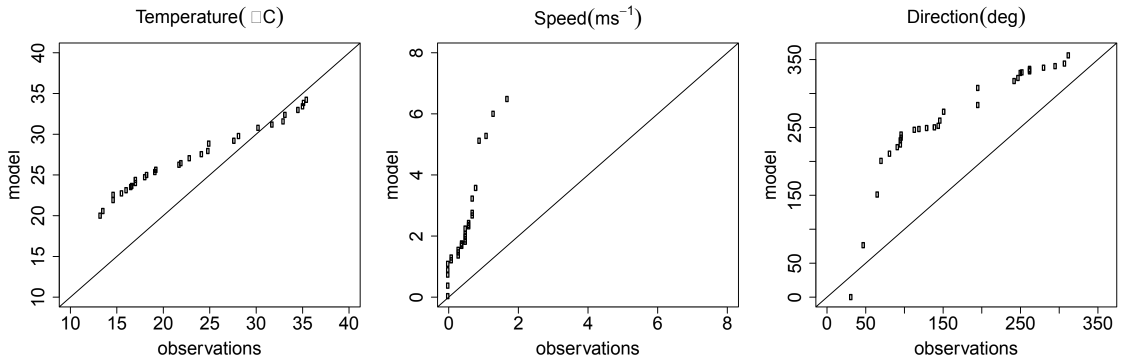

Figure 1. qqplots of temperature, wind speed and direction between model results and measurements at the Kamiah station

THE FIELD EXPERIMENT

The experiment was carried out in a complex terrain area in Idaho. Different fire experiments were conducted and the plume height was measured using a lidar. Each fire was consisting of differ burns and the whole experiments lasted about one hour. The burning area was 66 ha. We estimated the buoyancy flux from the heat flux (BTU/hr) following Pouliot et al 2005 and calculated the corresponding initial plume vertical velocity needed as dispersion model input.

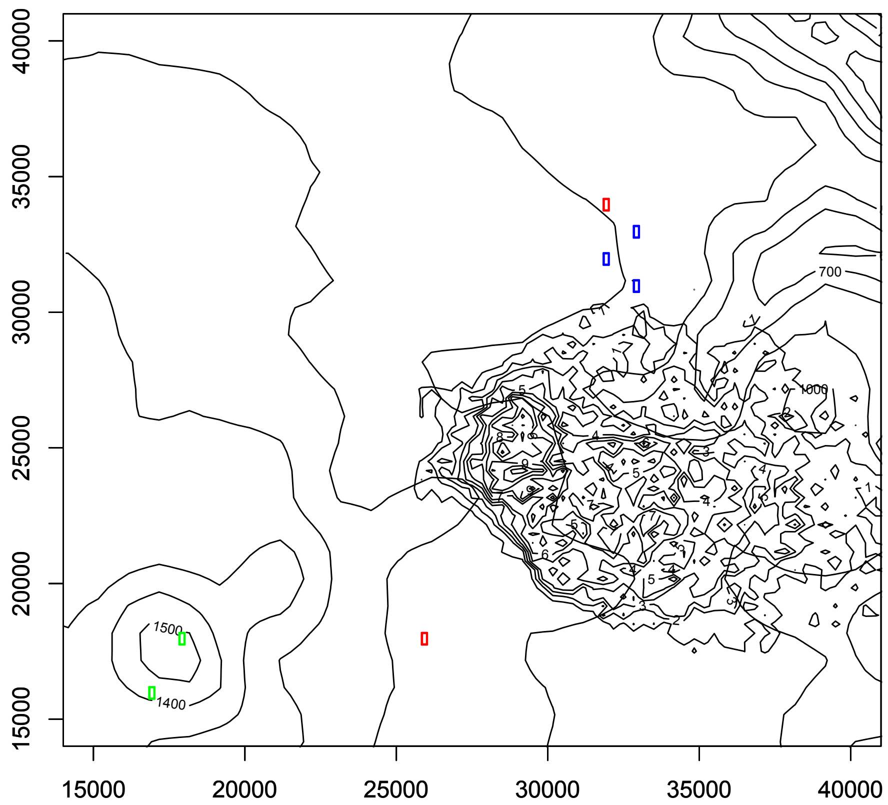

Figure 2. Ground level concentration field. Blue circles indicate the fire locations, red circles the air quality stations, green circles the lidar positions.

RESULTS

For this work we used a dispersion model chain, where the meteorological input is provided by WRF, the dispersion is simulated by the Langrangian Stochastic model SPRAYWEB and the turbulence fields by WSI (WRF-SPRAYWEB Interface) which also interpolates the wind and temperature profiles read from the WRF output, on the SPRAYWEB grid. In the WRF simulation the horizontal grid space of the inner most grid was about 1 km with 61 grid points, while in the vertical direction there were 38 grid points. The model was initialized with the ECMWF high-resolution (0.125 deg) data.

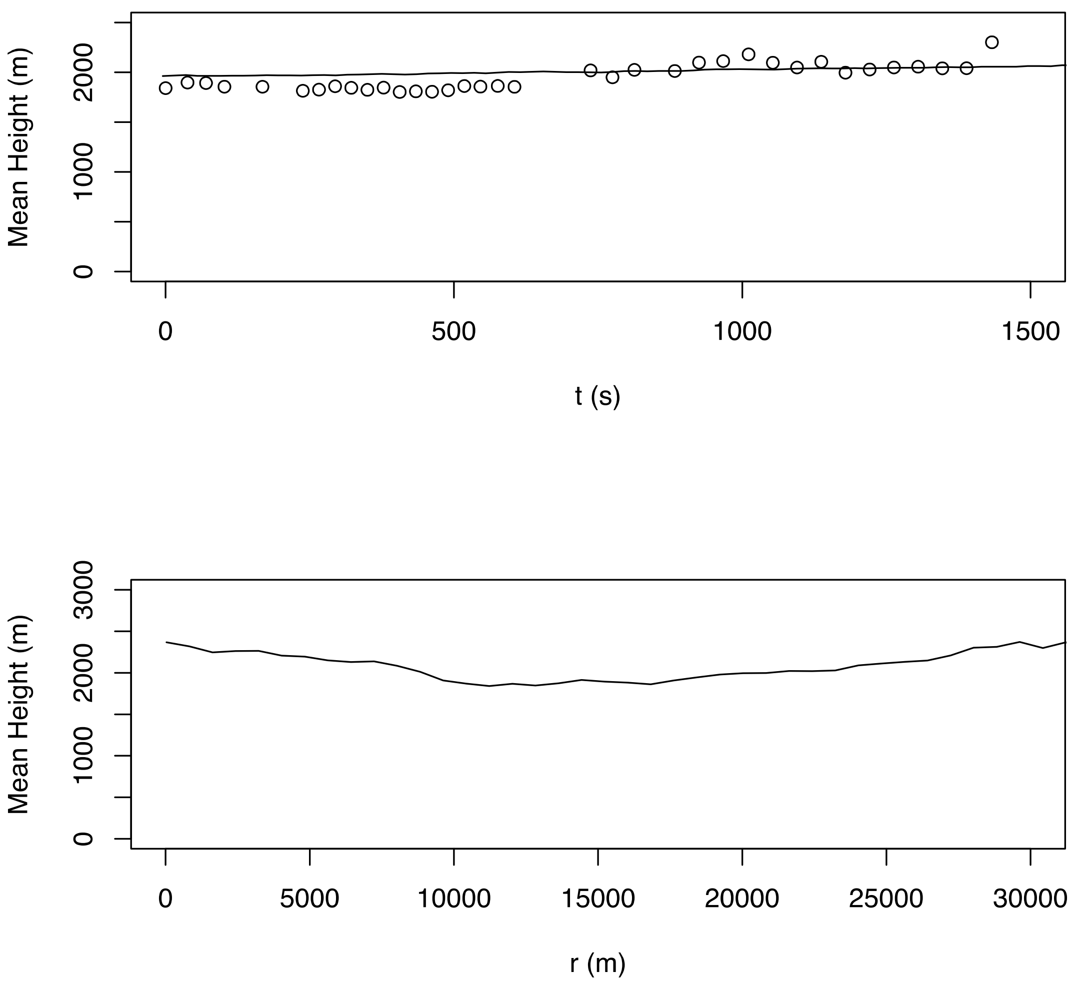

Figure 3. Plume mean height as a function of the time (top) and of the distance (bottom). Circles indicate the lidar measurements

Figure 1 shows the comparison between measured and calculated temperature, wind speed and direction, in term of qq-plots. It can be observed, that the temperature is overestimated for low values and agree for higher values. Wind speed is overestimated, particularly the higher values. As for wind direction some discrepancies appear. It can be noted that, the same analysis in other stations show different results as for example better agreement for wind speed and higher overestimation of the temperature. This is partly due

to the complex terrain, which strongly influence the local flow near the surface. It may useful to stress that, at this stage, WRF run was performed without data assimilation.
For the dispersion simulation the WRF innermost coincided with SPRAYWEB domain. The turbulence parameters, wind velocity component standard deviations and Lagrangian time scales were provided by WSI through the Hanna (1982) parameterisations. The huge amount of particles dispersed by the model allowed calculating the concentration field.
Figure 2 shows the contour plot of the concentration field calculated by SPRAYWEB together with the fire locations (blue circles) the lidar positions (green circles) and the air quality measurement stations (red circles). From the dispersion model output we are also able to estimate the mean plume height. In figure 3 the computed mean plume height is presented both as a function of the time (top) and of the distance from the fire (bottom). The lidar measurements are also shown for comparison. It can be observed that the model results agree very well with the observation at least for the first 1500 s when measurements where available.

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