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COMPARISON OF OVER-LAND ATMOSPHERIC DISPERSION (OLAD) FIELD TEST DATA TO HPAC PREDICTIONS

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Abstract: A maintenance build of the HPAC5 (HPAC5 MB) modeling tool has been developed for use by the Defense Threat Reduction Agency (DTRA) Reachback personnel and is undergoing the verification and validation process. This build of HPAC5 MB is the first official revision of that model since the release of HPAC5.0 SP1 in January, 2008, and it incorporates updates to the various model components, including changes to the SWIFT meteorological pre-processor. Previous work completed by other analysts(Chang and Tang, 2009) using unreleased developmental versions of the Joint Effects Model (JEM), which includes versions of HPAC 5 dispersion modules, noted significant changes to predictions for the Dipole Pride 26 and Over-land Atmospheric Dispersion (OLAD) field tests and suggested that those changes were consequences of the changes implemented in SWIFT. The changes that were introduced in the JEM developmental builds have been carried into the HPAC5 MB. We present comparisons of predictions for the OLAD field experiments obtained using three versions of HPAC5: the last official release, an intermediate build, and the maintenance build. We will also present comparisons of the sets of predictions to the observations collected during the OLAD field experiments.

Key words: *model validation, atmospheric transport and dispersion, Over-land Atmospheric Dispersion field test, OLAD.*

INTRODUCTION

The Defense Threat Reduction Agency (DTRA) has developed the Hazard Prediction and Assessment Capability (HPAC) software as a tool for predicting both the transport and dispersion of hazardous materials released into the atmosphere and the effects of the dispersed material on exposed populations (DTRA, 2001). DTRA is currently developing a maintenance build (HPAC 5MB) of this modelling tool for use by DTRA Reachback personnel. The HPAC 5 MB (also denoted by Build 125 throughout this paper) is the first official revision of the HPAC model since the release of HPAC5.0 SP1 (denoted by Build 82), and incorporates updates to the various model components, including changes to the meteorological pre-processor. The Institute for Defense Analyses is providing assistance with independent verification and validation of this model build. Previous work (Chang and Tang, 2009) that was completed as part of the independent validation effort for the Joint Effects Model (JEM) using an unreleased developmental version of JEM 1.1 (based on HPAC 5 Build 99), found significant differences between the Build 82 and Build 99 predictions for the Dipole Pride 26 (Biltoft, 1998) and Over-land Atmospheric Dispersion (OLAD) (Biltoft., et al., 1999) field tests.

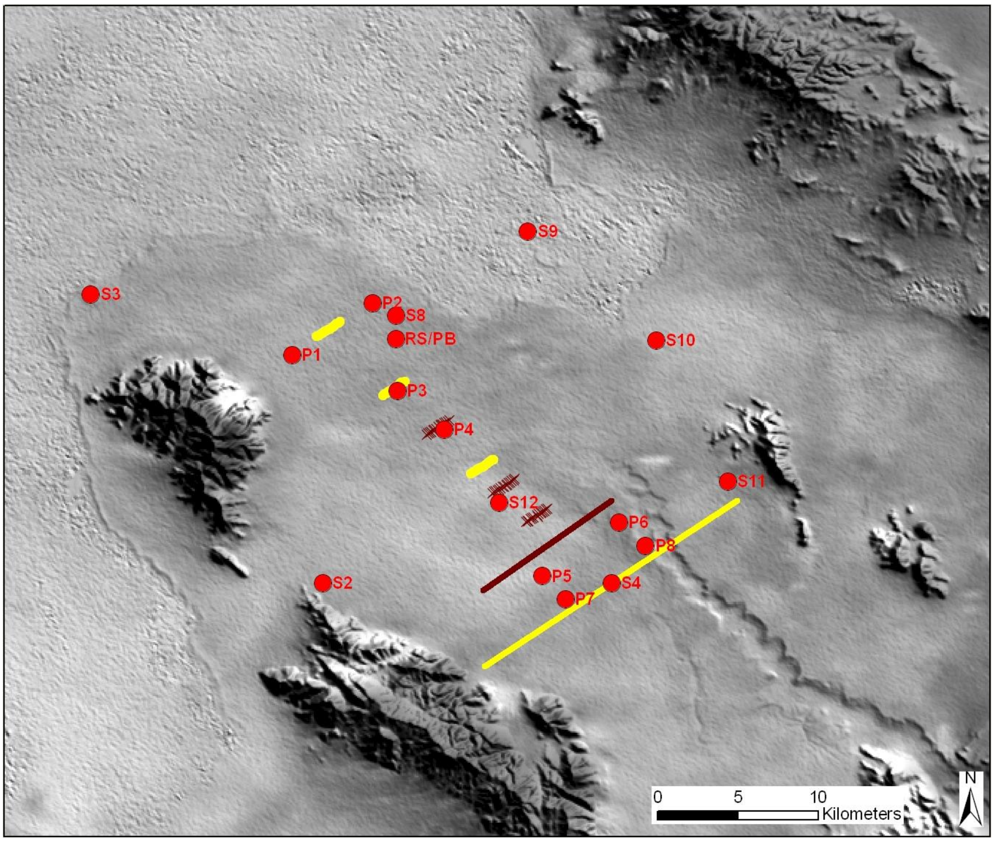

Fig.22: Layout of the OLAD Trial. Long lines denote line source releases (aircraft – yellow, truck – brown). Short lines consisting of “x” denote three sampler lines (aircraft releases – yellow, truck releases – brown). Red circles denote locations of meteorological stations (“P” denotes locations of PWIDS,”S” denotes locations of SAMS and “RS/PB” shows the location of the radiosonde and pibal balloons station).

For this analysis, we considered twelve line releases from the OLAD experiment. The OLAD experiment was conducted in September 1997 at the West Desert Test Center, US Army Dugway Proving Ground in Utah. These tests involved relatively short-duration line releases of SF_6 from either a truck (approximately 10 km line released over about 600 seconds) or an aircraft (approximately 20 km long line released over about 200 seconds). There were three sampling lines at distances of 2-10 km for truck releases and 10-20 km for aircraft releases. Each sampling line consisted of 15 individual whole-air bag samplers spread over approximately 1.5 km. The primary goal of the OLAD experiment was to study tracer dispersion over open terrain along the direction of the wind. For that reason, the source release lines were oriented across the prevailing wind direction and were much longer than the sampling lines. The long release lines were designed to ensure that the source cloud would eventually cross the sampling lines and to minimize the impact of dispersion edge effects upon the center of the cloud. Each sampler collected averaged concentrations over 15-minute sampling intervals for a total of twelve measurements spanning 3 hours. Samplers at the farthest line were turned on thirty minutes after the start of each release to account for approximate tracer gas travel time to the farthest arc. Surface meteorological data was collected at eight Portable Weather Information and Display Systems (PWIDS) and eight Surface Atmospheric Measurements Systems (SAMS). Vertical profile data collected during the experiment included pilot balloon (pibal) and radiosonde data. Figure 1 illustrates the layout of the OLAD field trials. The meteorological data were subsequently screened for inconsistencies and corrected(Chang, et al., 2001). Chang and Tang provided us with the JEM project files that were used in their 2009 study. We extracted the HPAC project files from the JEM projects and ran three sets of predictions using three different builds of HPAC 5: Build 82, Build 99 and Build 125.

METHODOLOGY

The primary goal of this analysis is to see what overall effectsthe numerous updates that have been made to the HPAC modelling software since the last official release (HPAC 5.0SP1 Build 82) in January 2008 have had on the quality of OLAD predictions. For this analysis, predictions and observations paired in space and time – referred to as the 'point-to-point' protocol – were compared. For each release and each sampler location there are at most twelve 15-minute average concentrations that were collected. In some cases, data were removed from the experimental set as suspect due to problems encountered during data collection or analysis. Additionally, when possible (i.e., no suspect data) we combined two, six or twelve of these measurements into 30-, 90- and 180-minute average concentrations. This merging of the measurements into higher time duration average concentrations lessens the effects of potential temporal misalignment between predictions and observations. We used a two-dimensional user-oriented Measure of Effectiveness (MOE) (Warner et al., 2004) that allowed for the statistical assessment of the ability of the model to predict either the "hazardous" region (i.e., region above a concentration threshold of interest) or total average concentration. For the calculation of the area threshold based MOE, three thresholds of 40, 200 and 1000 ppt were selected. Table 1 shows fractions of valid observations that exceeded these thresholds either for individual 15-minute averaged observations or for an average over the combination of all twelve consecutive measurements. We also employed scatter plots of observations and predictions to subjectively compare different sets of HPAC predictions.

Table 7. Fraction of observations exceeding thresholds for "Exceedance based MOEs"

a) Average Concentration Obtained from Individual 15-minute Samplers

	Thresholds, ppt		
SamplerLine	**40**	**200**	**1000**
Closest	**38%**	**30%**	**14%**
Middle	**35%**	**24%**	**14%**
Farthest	**38%**	**24%**	**9%**

b) Twelve 15-minute Samplers are Combined to Create Average Concentration

	Thresholds, ppt		
SamplerLine	**40**	**200**	**1000**
Closest	**100%**	**56%**	**33%**
Middle	**88%**	**42%**	**22%**
Farthest	**65%**	**24%**	**4%**

PRELIMINARY RESULTS

Figures 2 and 3 show MOE comparisons of three sets of HPAC predictions for threshold based and average concentration based MOEs. Panels on the right plot MOEs calculated based on twelve individual 15-minute average concentrations and panels on the left plot MOEs calculated based on total average concentration obtained during the trials. Top panels correspond to MOE values calculated for each individual release, while bottom panels correspond to averaged MOE calculated by taking the vector average of individual trial MOEs. Black plus signs denote Build 82 predictions, red squares denote Build 99 predictions, and green diamonds denote Build 125 predictions. A brief examination of the "Averaged MOEs" reveals that there are relatively modest changes in the quality of HPAC predictions since the last official release of HPAC. Furthermore, the individual MOEs reveal significant scatter in two-dimensions with a significant fraction of MOEs lying very close to the (0,0) point revealing poor correlation between observations and predictions. Since the majority of individual MOE values are above the diagonal line, there is an overall tendency for the prediction to significantly under-predict observations both in terms of the threshold based MOE and a total observed dosage MOE across the three lines of samplers.

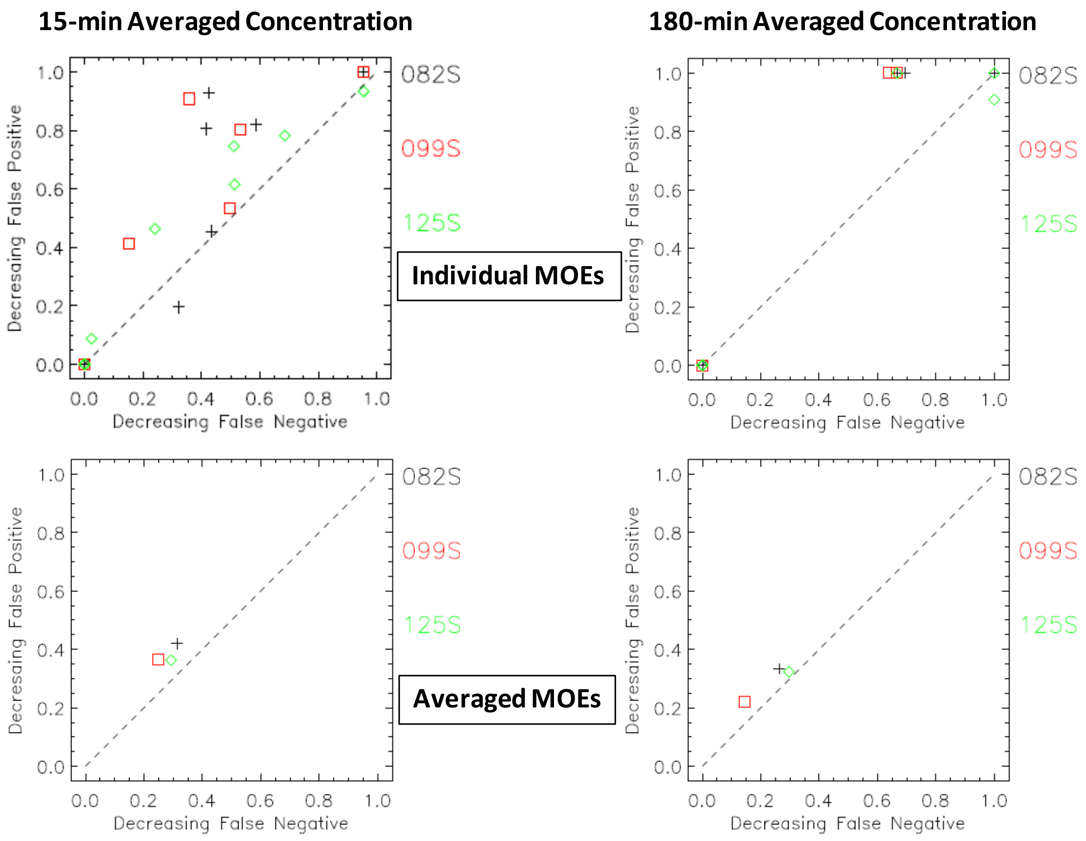

Fig.23: Threshold "Exceedance MOE" for threshold set to 200 ppt.

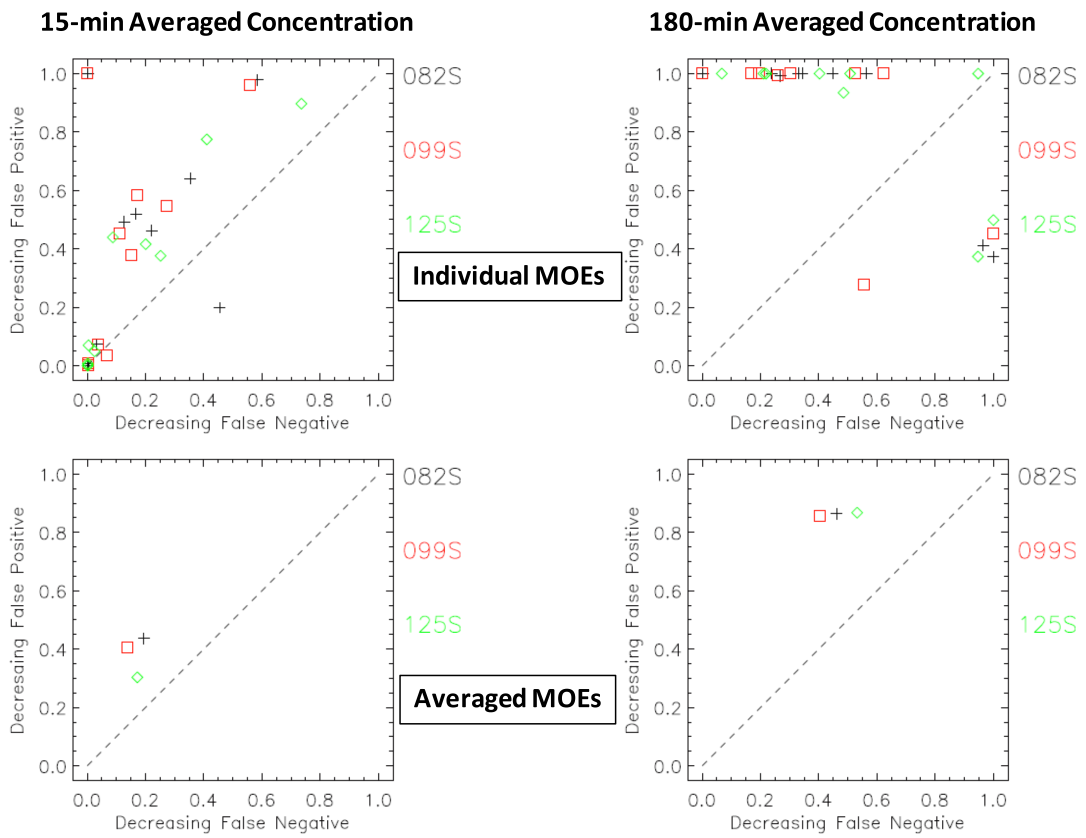

Fig.24: Average concentration MOE plots.

To further investigate why predictions seem to correlate poorly with observations, we examined scatter plots of observations versus predictions as illustrated in Figure 4. Black plus signs correspond to samplers in the closest sampling line, red squares correspond to the middle sampling line, and green diamonds correspond to the samplers in the furthest sampling line. Panels on the right are scatter plots in log-log space constructed using individual 15-minute averaged concentrations while scatter plots on the right are constructed using averaged concentrations obtained during the full release. Different sets of HPAC predictions are qualitatively similar to each other – there is a significant scatter between observations and predictions especially for individual 15-minute averaged concentrations. As expected, combining twelve individual 15-minute measurements into a single averaged concentration for the full release helps significantly with reduction of the scatter. This may imply that there is a significant temporal mismatch between the observed and predicted plumes.

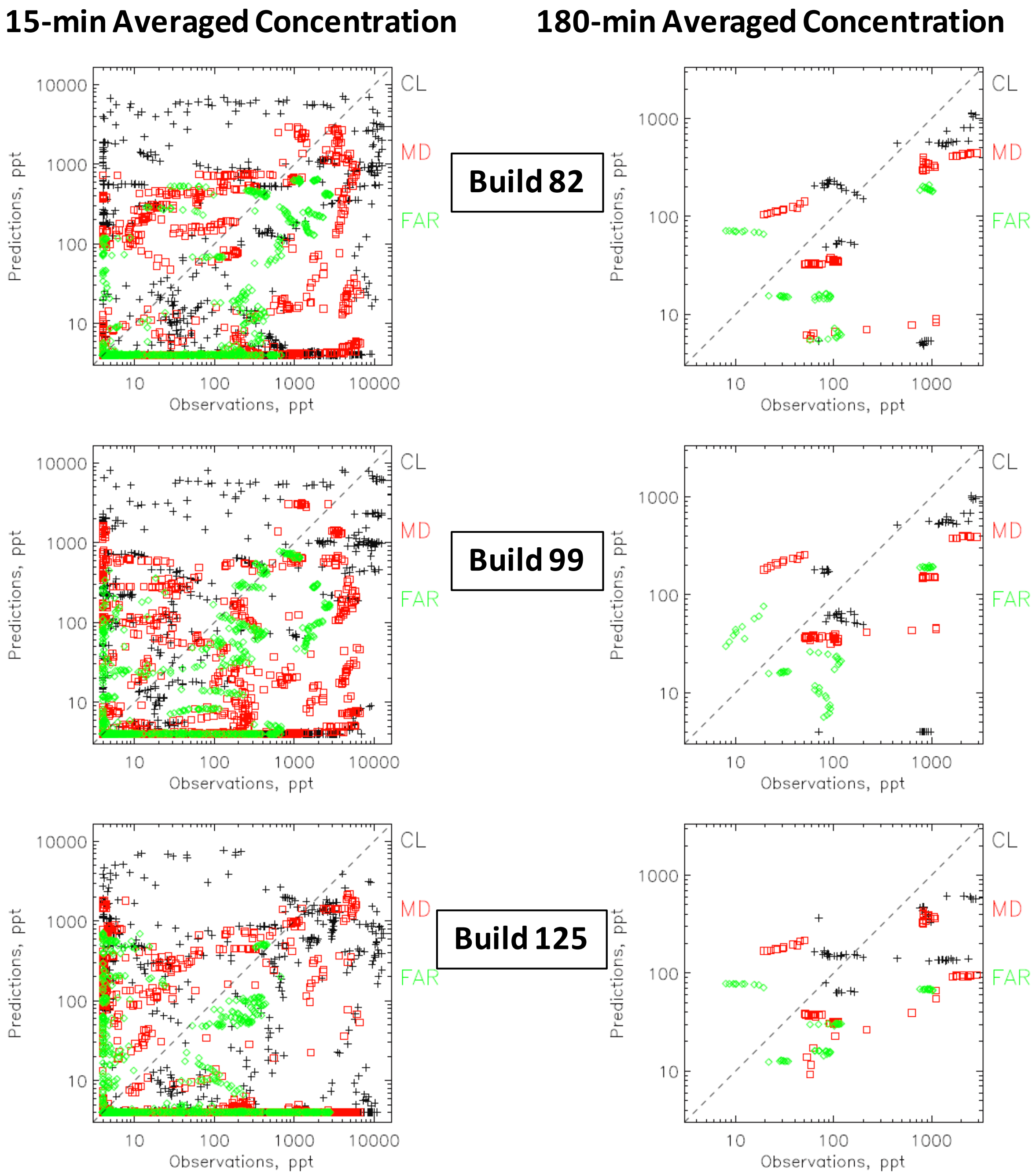

Fig.4: Plots of predictions versus observations.

CONCLUSIONS

In this paper, three sets of HPAC predictions for the OLAD field trial were compared against each other and actual observations. The sets of predictions include: the last official HPAC release 5.0SP1 (Build 82) available since January, 2008; HPAC 5 Build 99 from November, 2009 that was developed for inclusion into JEM 1.1; and HPAC 5 MB (Build 125) which forms the basis of the HPAC Maintenance Build that was released in January, 2011. A quick look at the OLAD predictions reveals that: a) there is no overall significant change in terms of statistical performance among different sets of predictions, and b) all sets of HPAC predictions considered here have relatively poor performance when the point-point protocol is used for the comparisons, especially when the temporal correlation between the observed and predicted plumes is considered.

Although the overall statistical performance among HPAC builds is similar, it is still possible that HPAC builds could still have significant differences between them. We demonstrate this in Figure 5 where averaged concentrations for OLAD trial 12 for HPAC Build 82 and Build 125 are plotted. Solid crosses denote locations of the three sampling lines used in this trial.

One interesting feature in these results is that they do not demonstrate what one might expect in terms of predictions improving as one moves from the far sampling line to the middle sampling line and then to the closest sampling line. Rather, the predictions appear to be similarly poor for all of the sampling distances. We are currently analyzing the OLAD predictions for indicators of reasons for the poor performance and for the apparent differences between model builds. We have also computed the metrics (based on line max dosages) that were used by Chang and Tang in their 2009 JEM work, and find that our results for the earlier builds (82 and 99) are in good agreement with theirs.

We are also in the process of analyzing HPAC predictions to Dipole Pride 26 field trials that involved a series of instantaneous puff releases (Biltoft, 1998). Our future work will look for the reasons for the HPAC performance we observed.

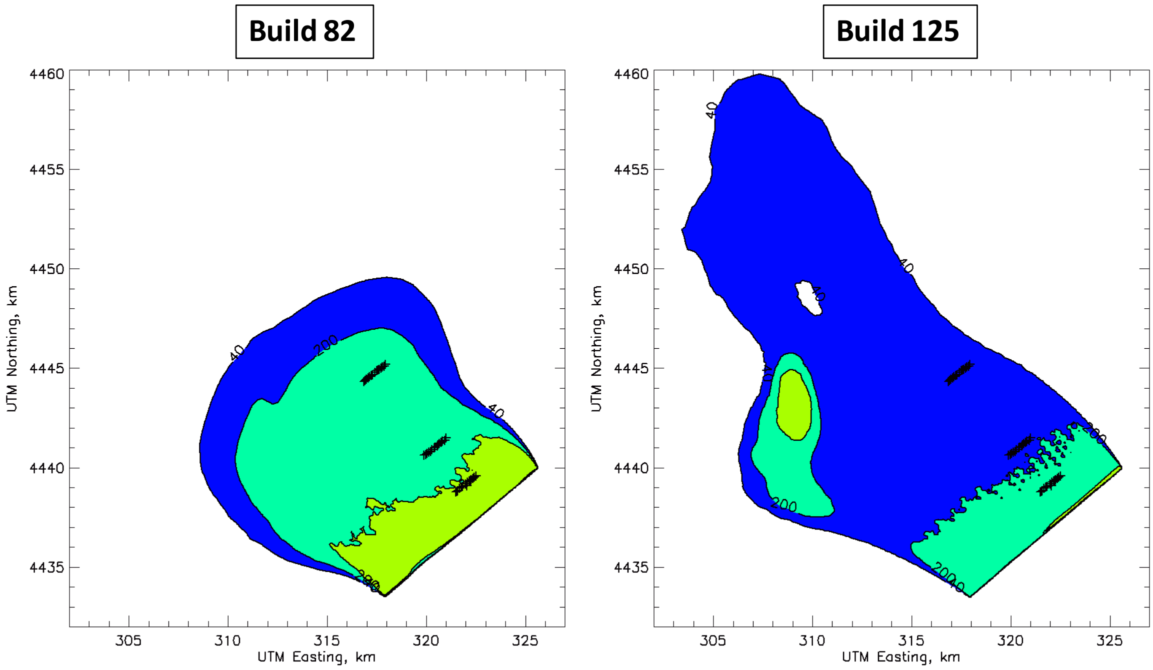

Fig.5: Average concentration contour plots of HPAC predictions for OLAD trial 12 involving truck release. Contour levels are 40, 200, and 1000 ppt.

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