UCRL-JC-131200
PREPRINT

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This paper was prepared for submittal to the
American Nuclear Society 7th Topical Meeting on Emergency Preparedness and Response
Santa Fe, NM
September 14-17, 1999

May 28, 1999

Comparison of gridded versus observation data to initialize ARAC dispersion models for the Algeciras, Spain steel mill Cs-137 release

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SUMMARY

On May 30, 1998 scrap metal containing radioactive Cesium-137 (Cs-137) was accidentally melted in a furnace at the Acerinox steel mill in Algeciras, Spain. Cs-137 was released from the mill's smokestack, and spread across the western Mediterranean Sea to France and Italy and beyond. The first indication of the release was radiation levels up to 1000 times background reported by Swiss, French, and Italian authorities during the following two weeks. Initially no elevated radiation levels were detected over Spain.

A release of hazardous material to the atmosphere is the type of situation the Atmospheric Release Advisory Capability (ARAC) emergency response organization was designed to address. The amount and exact time of the release were unknown, though the incident was thought to have taken place during the last week in May. Using air concentration measurements supplied by colleagues of ARAC in Spain, France, Switzerland, Italy, Sweden, Russia and the European Union, ARAC meteorologists estimated the magnitude and timing of the release (Vogt, 1999).

Correctly locating the downwind footprint is the most important goal of emergency response modeling. In this study, we compare predicted results for the Algeciras event based on four wind data sources: (1) US Navy Operational Global Atmospheric Prediction System (NOGAPS) data alone, (2) surface and upper air observations alone, (3) NOGAPS data together with surface and upper air observations, and (4) forecasts from ARAC's in-house execution of the U.S. Navy Operational Regional Atmospheric Prediction System (NORAPS) (without surface or upper air observations). We compare the resulting dispersion predictions from ARAC's diagnostic dispersion modeling system to the measurements supplied by our European colleagues to determine which data source produced the best results.

1.BACKGROUND

The ARAC program at Lawrence Livermore National Laboratory is an operational emergency-response service for the U.S. Department of Energy. ARAC provides real-time calculations of the dispersal of hazardous material to the atmosphere (Sullivan et. al. 1993). These calculations are made using a 3-D Lagrangian dispersion model driven by a mass-consistent wind field model initialized either from gridded or observational data.

ARAC is very interested in the issue of which data sources produce the best dispersion forecasts, and the Algeciras event provided an opportunity to study this question. ARAC receives both observational data and global forecast model gridded data, and we can use either during an emergency response. An additional option is to use forecasts from regional scale or mesoscale weather models, and for this purpose ARAC operates the NORAPS hydrostatic model and the non-hydrostatic Coupled Ocean-Atmosphere Mesoscale Prediction System (COAMPS). However, for most events NORAPS or COAMPS won't be available for an initial assessment, since ARAC must move a NORAPS or COAMPS window to the area of the release unless a release occurs in an area where NORAPS is already running. NOGAPS, with global coverage, is more likely to be the first gridded wind field used. ARAC continuously updates its worldwide observational data file, so observations are also available for our initial response, at least over most land areas and littoral regions.

Several factors need to be considered when choosing between gridded data and observations, one of which is resolution. Nasstrom and Pace (1998) studied the effects of spatial and temporal resolution using two wind field sources, NOGAPS data at 2.5 deg resolution and ECMWF model forecasts at 0.5 deg resolution. In this study, six runs were compared to measurement data from the first run of the European Tracer Experiment. In four of these, the ECMWF data were modified to have degraded temporal, horizontal, or vertical resolution to approximate the NOGAPS data resolution. The NOGAPS data produced the worst results, indicating that even though the ECMWF data were degraded to have the same resolution, the data points remaining were still based upon a higher-resolution simulation. This work indicates that increasing the resolution of meteorological fields provided to a dispersion model can improve predictions of concentrations. The superiority of using high resolution meteorological input was also demonstrated in an extensive study by Brandt (1998). Stohl (1998) summarizes how trajectories can be calculated, how accurate they are typically and how their accuracy can be assessed. He states that accuracy has been improved with Lagrangian particle dispersion models which use wind fields from numerical weather prediction models. Traditional diagnostic wind field models (ARAC's MEDIC/MATHEW) can do little more than interpolate radiosonde measurements and adjust them for mass consistency. Therefore, their resolution is limited to that of the radiosonde network. Stohl found that on the synoptic level, the most accurate wind field available is one provided by numerical weather prediction.

2. METHOD

We tested ARAC's dispersion model using an identical source term with four wind field inputs:

1. NOGAPS
2. Combination of NOGAPS and observations
3. Observations alone
4. NORAPS

We chose to study the Algeciras Cs-137 release because of the variety of wind fields available and a set of ground level air concentration measurements to compare with model output. The winds supplied by each method were used as input to ARAC's MEDIC/MATHEW wind models. MEDIC linearly interpolates input wind data vertically to grid levels, and then interpolates data horizontally using a three-point, inverse-distance-squared weighting scheme. MATHEW achieves mass consistency and minimizes divergence by adjusting the horizontal winds and generating vertical winds. The source was estimated from information supplied by the Spanish authorities and an iterative process described in Vogt (1999).

Method 1 (NOGAPS): The NOGAPS model (Hogan and Rosmond, 1991) is a T159 spectral model with 18 vertical levels. The NOGAPS data used in this work are analyses and forecasts of the mean wind supplied at 1.0 degree latitude, longitude (approximately 111 km) horizontal resolution at the standard vertical pressure levels, and at 6 hour intervals (analysis at 00 and 12 UTC and 6 hour forecasts in between at 6 and 18 UTC) obtained from the U.S. Navy Fleet Numerical Meteorology and Oceanography Center (FNMOC).

Method 2 (NOGAPS/OBS): We obtained observational data from World Meteorological Organization stations within a 1500 km radius of the source. Surface reports were available every 3 hours and upper air reports every 12 hours. Over 400 stations were available in this domain, and we selected 200 surface and 10 upper air stations in the area covered by the plume calculated using NOGAPS data. We collected data from 30 May at 00 UTC to 2 June at 06 UTC and combined them with the NOGAPS gridded fields.

Method 3 (OBS): We used observational data as described above alone (not combined with gridded data) from 30 May at 00 UTC to 2 June at 06 UTC. After this time, we used he NOGAPS gridded fields.

Method 4 (NORAPS): The NORAPS model is a hydrostatic model based on a sigma-p coordinate with variable vertical grid spacing. Horizontal spacing is uniform and may contain up to three nests. We ran NORAPS using a two-nest configuration. The outer nest was a 103 x 103 grid at 36 km grid spacing, and the inner nest was a 115 x 103 grid at 12 km grid spacing. Both nests used 36 sigma-p levels in the vertical. Forecasts were made beginning every 12 hr, from 29 May at 00 UTC until 7 Jun. at 12 UTC. Each forecast extended 24 hr into the future. Hourly forecast files from each run were archived, and the 5 hr through 17 hr forecasts from each run supplied the wind fields used in ARAC's dispersion model system. A limited set of 12-hr forecasts of surface fields (e.g. ground wetness and ground temperature) from the previous run were used as first guess conditions to initialize each succeeding run. No surface or upper air observations were used. Except for the surface first guess fields, all initial conditions were derived by interpolating

NOGAPS model analyses to the NORAPS grid. For each run, the NOGAPS analysis and forecasts at 6-hr intervals supplied the boundary tendencies.

Our dispersion simulations were done on a 2560 x 2560 km grid with a depth of 3000 m. WE used a 81x81x15 grid with 32 km horizontal and 200 m vertical resolution. We ran the models for 10 days with a 30-min 50 Ci release beginning at 0130 UTC on 30 May 1998 with the same boundary layer and dispersion parameters for each case.

ARAC received over 100 measurement reports (Vogt, 1999) which had widely variable sampling times ranging from 1 day to 14 days. This was a real world event and therefore not comparable to extensive tracer studies such as ETEX or ATMES. In addition to using the inclusive data set, we did a comparison using only the 1-day average measurements. In this study, there were 24 such reports received from France and Italy. These data provide a more rigorous challenge for comparison in space and time as the data wer shorter averages and came with start and stop times.

3. RESULTS

The results of the simulations are compared to measurements in three ways. We calculated the percentage of predicted concentrations within factors of 2, 5, and 10 of measured near-surface concentration (paired in space and time) first with the entire measurement set and second with the 1-day averaged measurements only. Third, we compared our predictions to the series of 1-day averaged measurements taken at Ispra, Italy.

Figure 1 shows that compared with all measurements, NORAPS (method 4) had the best percentage within factors of 2, 5 and 10. NOGAPS and NOGAPS/OBS (methods 1 and 2) were similar with NOGAPS/OBS having more hits within a factor of 2. Observations (method 3) compared well but not so much as the gridded wind fields. The run based solely on observations did not preform as well partly due to the fact that the plume travelled over the Mediterranean Sea for the 1st few days.

In comparison to 1-day average measurements (Figure 2), NOGAPS/OBS (method 2) had the highest percentage within a factor of 2, but performed the worst within factors of 5 and 10. NORAPS (method 4) resulted in the best fit to measurements within factors 10. NOGAPS and OBS (methods 1 and 3) had similar results.

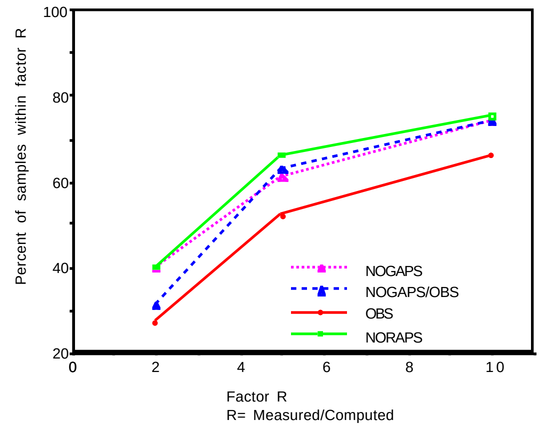

Figure 1. Percentage of modeled concentrations within factors of 2, 5, and 10 of the measured concentration for each method using all measurements.

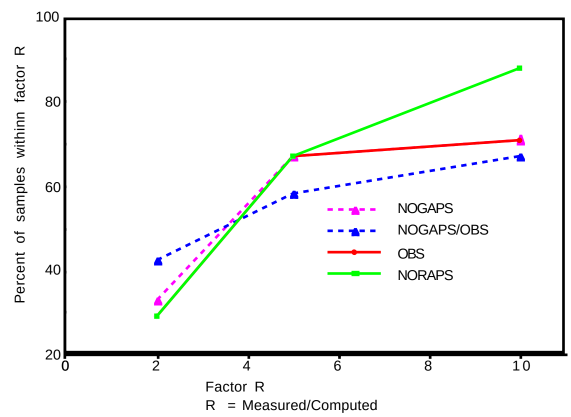

Figure 2. Percentage of modeled concentrations within factors of 2, 5, and 10 of the measured concentration for each method using 1-day averaged measurements.

The results from each method were also compared to the time series of measurements from Ispra (Figure 3). Plumes based on NOGAPS and observations both alone and combined (Methods 1, 2 and 3) were a day late reaching Ispra, with their peak values occurring on 4 June rather than 3 June. The plume based on NORAPS (Method 4) has a similar pattern to the Ispra data and has its peak value correctly occurring on 3 June. The modeled values are too high but this could be due to an overestimation of the release amount.

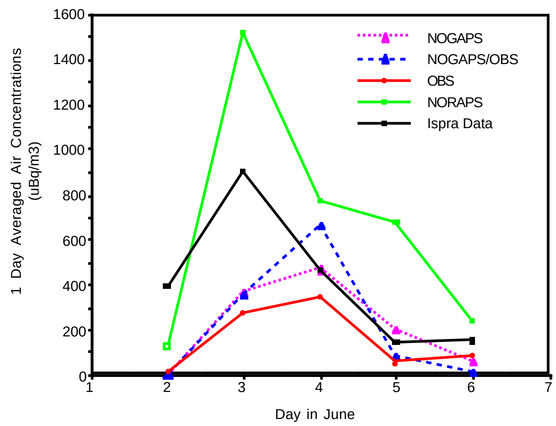

Figure 3. Comparison of computed to measured daily average air concentrations at Ispra, Italy for 2-6 June.

4. CONCLUSIONS
This study compared dispersion calculations for the Algeciras Steel Mill assessment, based on four wind field methods. Table 1 summarizes the wind methods used, their resolution, their ranking from this study and their value for emergency response modeling. Predictions based on NORAPS were the best match to measurements, while predictions based on NOGAPS, on observations together with NOGAPS, and on observations alone all did fairly well. The choice of which wind fields to use in an emergency response is a key decision. These results suggest that mesoscale model data should be used if available. In the absence of mesoscale model data, observational data, either alone or in combination with NOGAPS data, should be used, although review by a meteorologist is necessary to ensure the observations are valid.

Table 1. Summary of Wind Field Initialization Methods for Mesoscale Dispersion Modeling

Initialization Method	Type of wind field	Temporal Resolution	Horizontal Resolution	Qualitative Accuracy Ranking	Value for Emergency Modeling
NOGAPS	Global Model	6 hr	~111km	2	Efficient
NOGAPS/ OBS	Combined	Combined	Combined	3	Complex to construct and manage
OBS	Surface and Upper Air	1 hr 12 hr	25-50 km 200-400 km	4	Depends on density and quality
NORAPS	Mesoscale Model	1 hr	12km	1	Slowest but highest resolution

ACKNOWLEDGEMENT
This work was performed under the auspices of the U.S. Department of Energy Lawrence Livermore National Laboratory Contract No. W-7405-ENG-48

REFERENCES
1. J. Brandt, “Modelling Transport, Dispersion and Deposition of Passive Tracers from Accidental Releases”, PhD thesis. National Environmental Research Institute, Roskilde, Denmark. 307 pp. (1998).

2. T.F. Hogan and T.E. Rosmond. “The description of the Navy Operational Global Atmospheric Prediction System’s spectral forecast model”. *Mon. Wea. Rev.* **119**, 1789-1815. (1991).

3. J.S. Nasstrom and J.C. Pace. “Evaluation of the Effect of Meteorological Data Resolution on Lagrangian Particle Dispersion Simulations using ETEX Experiment”. *Atmospheric Environment* **32,** 4187-4194. (1998).

4. A. Stohl. “Computation, Accuracy and Applications of Trajectories - A Review and Bibliography”. *Atmospheric Environment* **32**, 947-966. (1998).

5. T.J. Sullivan et al., “Atmospheric Release Advisory Capability: Real-Time Modeling of Airborne Hazardous Materials”, *Bulletin of the Amer. Met. Soc*. **74**, 2343-2361. (1993).

6. P.J. Vogt et al., “ARAC Simulation of the Algeciras, Spain Steel Mill Cs-137 Release”. These proceedings; also LLNL UCRL-JC-131330 (1999).