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ABSTRACT

On 12 June 1998, the Atmospheric Release Advisory Capability (ARAC) learned from news reports about the accidental release of cesium-137 from a steel mill near Algeciras, Spain. We used the U.S. Navy Operational Global Atmospheric Prediction System (NOGAPS) gridded data for meteorological input into our diagnostic models. To better resolve near-release location and coastal meteorological conditions, we blended four days of WMO surface and upper air observations with the gridded data.

Our calculations showed the plume initially traveled eastward over the Mediterranean Sea, turned northward into central Europe, and was split by the Alps. We determined the timing and amount of cesium released by fitting our modeled air concentrations to the available set of measurements. Accuracy statistics from a small set of ratios of measured to computed air concentrations paired in space and time were similar to those achieved from larger data sets in previous ARAC model evaluation studies on the continental scale.

Notification of the Accident

On 9 June 1998, the Swiss government announced that radiation levels up to 1000 times background had been detected in their national monitoring network and that the source was unknown; France and Italy reported similar measurements. On the next day a steel mill near Algeciras, located near the extreme southern tip of Spain, notified the Spanish Nuclear Security Agency (CSN) that they had detected radiation in one of their oven filtration systems. On 12 June the Spanish government revealed that a medical radiotherapy source of Cs-137 was apparently melted in the Acerinox steel mill scrap metal furnace and subsequently released into the atmosphere. However, the CSN did not observe elevated radiation levels in their network. The amount and the time of the release were unknown, but the incident was thought to have taken place during the last week of May 1998. On 12 June the International Atomic Energy Agency (IAEA) Emergency Response Centre issued a bulletin announcing the occurrence of the radiological incident, and the possible connection to elevated levels of Cs-137 detected at the end of May and early June in southern Europe.

ARAC became aware of the incident when news services reported the accident on 12 June in the United States. These news stories indicated that elevated levels of Cs-137 had been detected in France and Switzerland, and in a related update bulletin, that the steel-mill near Algeciras was the suspected source. We began by accessing our archived gridded meteorological data from the area, but did not begin modeling the incident until we received some initial measurement data from several countries.

Cs-137 Measurement Data

We were provided with CS-137 air concentration measurements throughout Europe. Only values greater the instrument threshold were used. The measurement averaging durations ranged from one day to two weeks, the majority of which did not have the measurement times. In this case, we chose a start time and end time of 1200 UTC for the averaging periods. Figure 1 shows the locations for the 24 measurements available by 18 June for the first calculation. By 6 June a total of 124 average air concentration measurements from 70 locations were assembled. We eliminated 24 of these due to problems or inconsistencies with the data.

Source Term Assumptions

Initially no source information was available; consequently, we back-calculated a source term based on the first small set of 24 measurements. A 110 Ci release amount appeared to fit the first measurements well. Over the next several weeks we continued to refine the source estimate based on the additional measurement data received. On 26 June we determined that a 50 Ci release rate best matched the 100 available measurements.

On 30 June CSN provided ARAC with detailed information including the exact location of the Acerinox plant, located very near Gibraltar Strait, as well as stack parameters. Additionally, CSN indicated the most likely release rate was 8-80 Ci between 0100 UTC (0300 local) and 0300 UTC (0500 local) on 30 May. For our third and final calculation, which we present in this paper, we continued to use a 50 Ci release of 30 minute duration. To coincide with the CSN information, we moved our release time 10 hours forward to 0130 UTC on 30 May 1998.

Model Grid

As we continued to receive measurements at over 70 locations across Europe, we expanded the model domain to 2600 km. This produced a terrain resolution of 32.5 km in the horizontal, which was just adequate to resolve the sea-level Gibraltar Strait. The vertical dimension we used was 3 km, with 100 m resolution that was constant with height.

Synoptic Weather Pattern

The release occurred during a fairly weak and persistent summertime weather pattern. Winds aloft and at the surface were westerly over Gibraltar Strait and southern Spain. In general, a southwesterly wind flow over Spain and the western Mediterranean Sea, with westerly flow south of the Alps, and southerly flow over France, prevailed over the next several days.

Meteorological Data

Initially we used 1° NOGAPS gridded data, but later we added observations to the gridded data for coastal areas of the western Mediterranean for the first four days of the simulation (until most of the model plume was over southern Europe). We used the observations to clarify flow near the source, and to improve the representation of coastal influences on the edge of the plume.

Dispersion Parameters

We characterized the diurnal cycle with four different meteorological periods. A 9-hr daytime period from 0900 to 1800 UTC first, the second a nighttime period from 2100 to 0500 UTC, and the last two a 3-hr afternoon and 4-hr morning transitional periods. We used observed upper-air sounding data from stations near the Mediterranean that were closest to the plume center to determine boundary layer heights. As the plume was mostly over the continent after four days, we modified boundary layer heights to reflect continental effects. We increased the heights to 1700 m for daytime, to 1000 m for the evening transition, and 500 m at night and for the morning transition. We selected a neutral daytime stability while the plume was over the Mediterranean Sea with slightly stable at night. After four days, when the plume was mostly over the continent, we chose a slightly unstable stability for the daytime.

Results

Figure 2 shows the average CS-137 near-ground air concentration for the first 7 days. The axis of the plume remains entirely over the Mediterranean Sea, passing over the Balearic Islands. The aerial coverage extends from eastern Spain northward over central France, then northeastward over central Germany and the Czech Republic. The eastern section of the plume covers all of Italy except Sicily, as well as the Balkans, Romania and Bulgaria.

Statistical evaluation of the model results compared with 100 Cs-137 air concentration measurements indicate the model computed air concentrations were within a factor of two 44%, a factor of five 70%, and a factor ten, 84% of the time.

Ispra, Italy was the only location that provided enough contiguous daily data to evaluate both the model timing and magnitude. Figure 3 shows a comparison of measured daily-averaged air concentrations to computed concentrations at Ispra for five consecutive days. At Ispra the model lagged the observed peak by one day, although the predicted plume arrived over central Italy on 01 June. The one-day delay at Ispra could be due to slightly offset (to the south of northern Italy) direction of transport of the elevated plume or possibly model under-advection.

One inconsistency is that our model indicates significant air concentrations on the Balearic Islands where measurements at a single location indicate below detection threshold values. We could not resolve the inconsistency between a good fit to data in central Europe and the large difference at the Balearic site. Results are discussed more completely in Vogt et. al. 1998.

Conclusions

We used the ARAC emergency response modeling system to simulate the accidental release of Cs-137 from a steel mill in southern Spain near Gibraltar. Our goal was to reconstruct the source term using the sparse air concentration data that became available after the accident. After receiving 100 air concentration measurements at downwind distances to 2500 km, we prepared a final model run using a 30 min release and a time estimated by the Spanish Government. We blended observed meteorological data with gridded data and produced the best comparison with the measurements. Our estimated source amount of 50 Ci based on fitting model output to measurements compared very well with the 8-80 Ci range provided by the Spanish Government.

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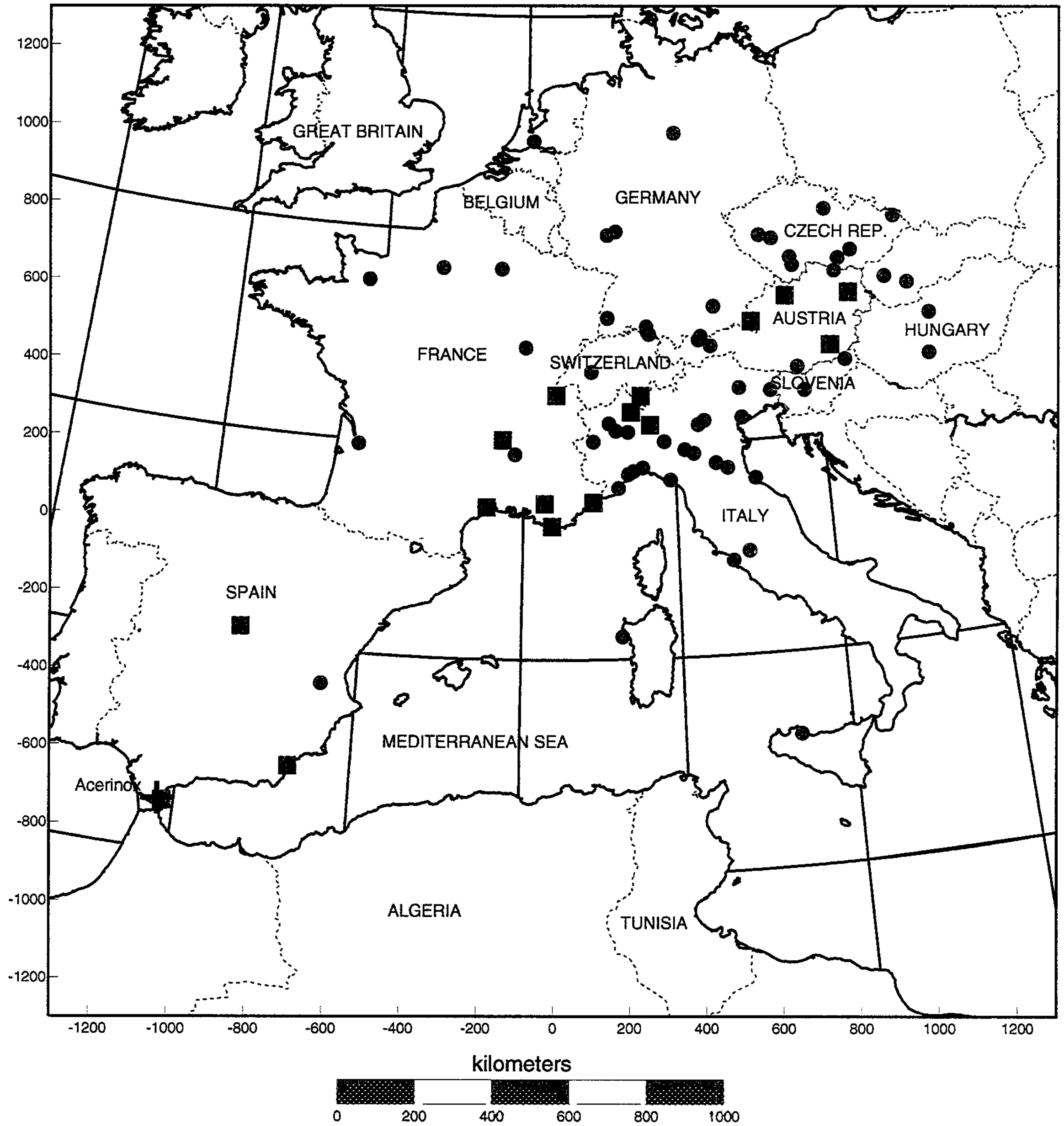

Figure 1. Measurement locations. Squares indicate measurements used to assess the initial source term, circles represent all measurements used.

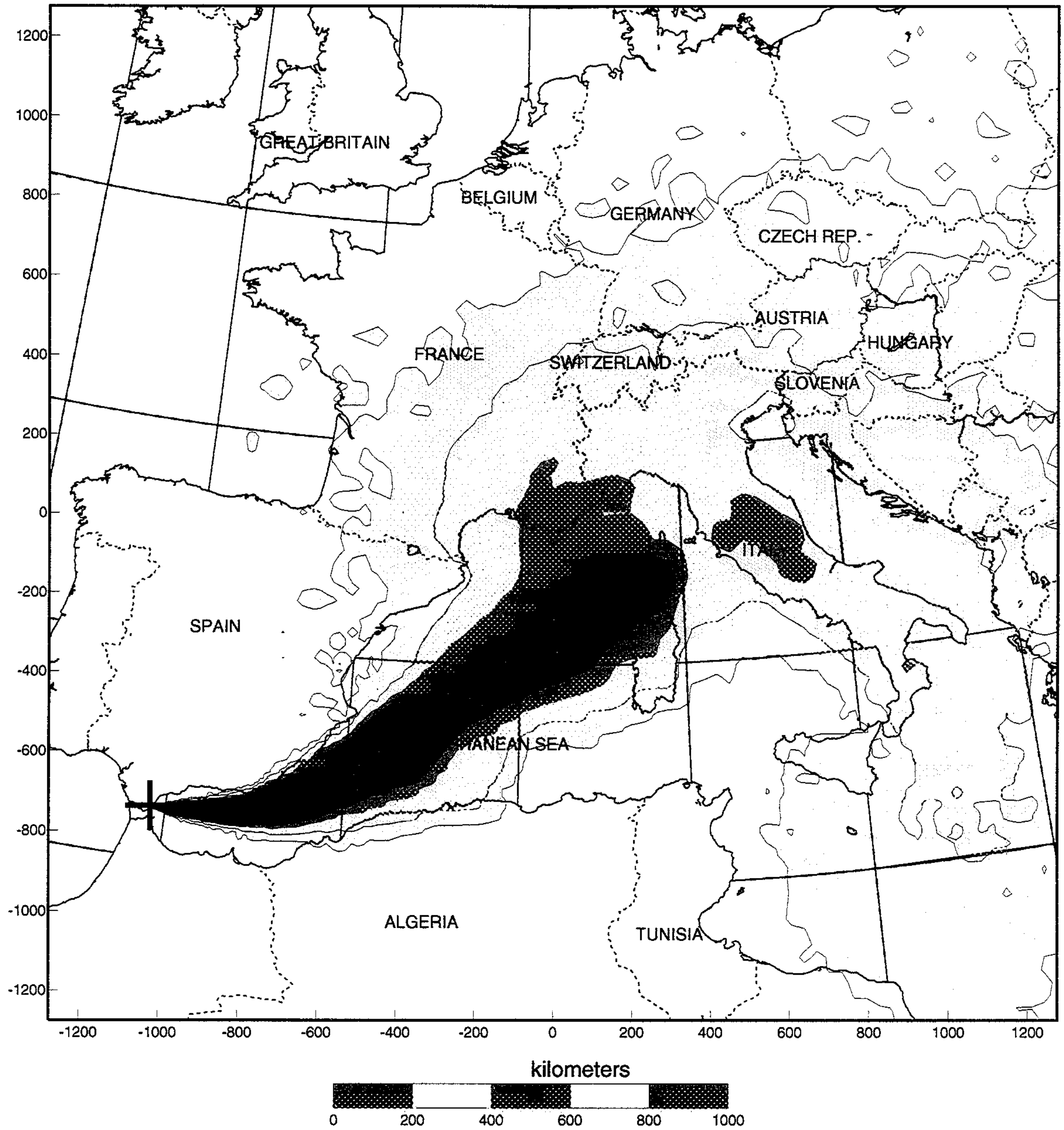

Figure 2. Seven-day average air concentration at 1200 UTC on 5 June 1998. Contours >10 (outermost or lightest), >100, >500, and >1000 uBq/m3 (innermost or darkest).

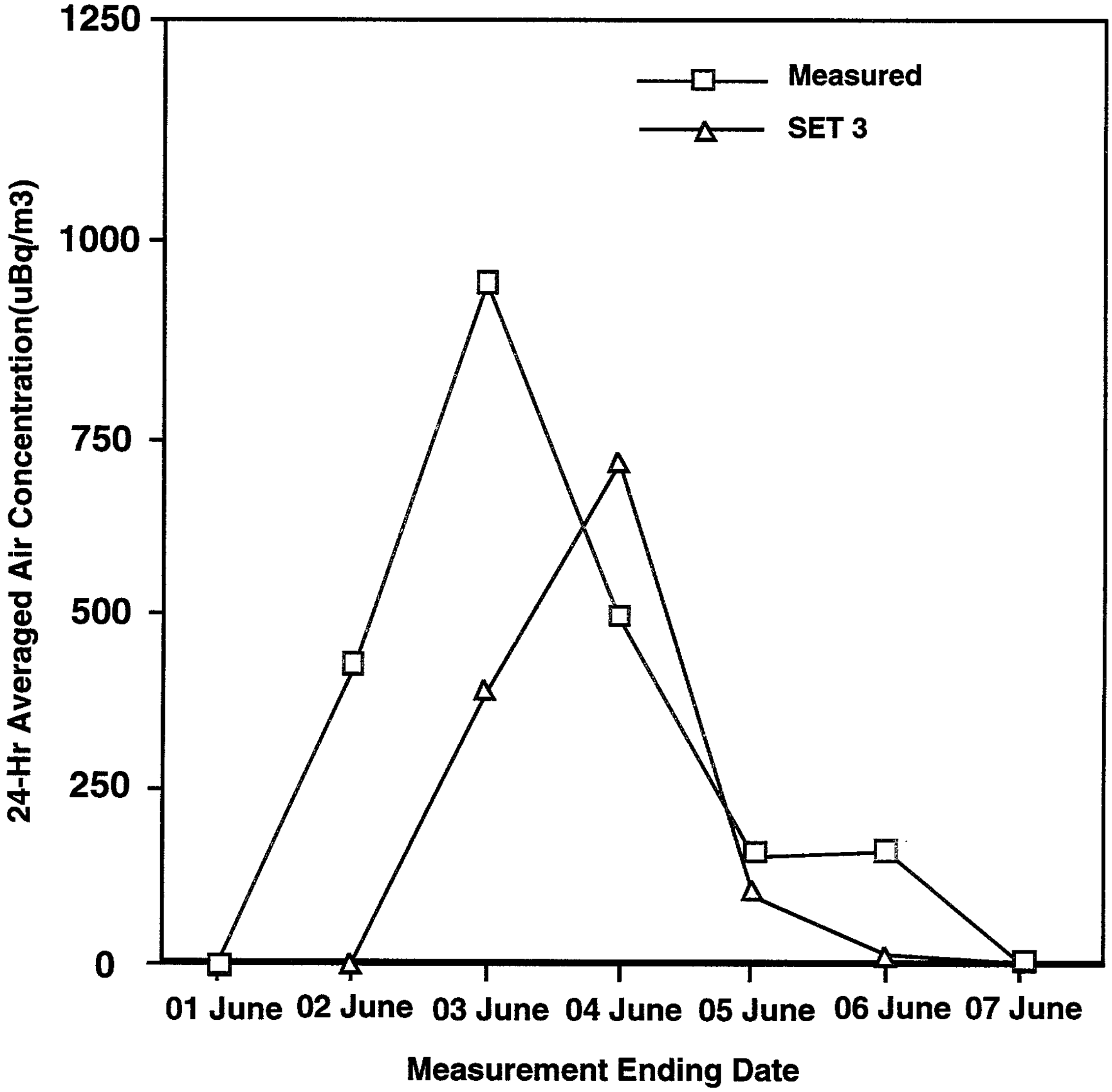

Figure 3. Comparison of computed with measured daily average air concentrations at Ispra, Italy for 1-7 June.