LONG-RANGE TRANSPORT OF RADIOISOTOPES IN THE ATMOSPHERE AND THE CALCULATION OF COLLECTIVE DOSE

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In calculating collective dose and in considering, under Article 37 of the Euratom treaty, possible trans-frontier effects of unplanned releases, it may be necessary to model the dispersion of atmospheric releases of radionuclides over considerable distances - out to 1000 km or more from the source. Unfortunately it is difficult to extrapolate simple modelling techniques used close to the source and based on source meteorology because, in general, material will not move steadily on along straight line trajectories and spreading and dilution, and depletion by dry and wet deposition will vary along each trajectory in accordance with changing meteorological conditions. Under a EURATOM/CEA contract and with added support from the European Commission we have developed a model which takes account of these varying effects; this model, called MESOS, uses a data-base of real meteorological data over Europe and, although not sufficiently sophisticated to use in a predictive mode if and when an accident should occur, gives adequate derivation of probability distributions of different degrees of contamination for hypothetical accident studies. By summing the effects of consecutive short releases, maps of exposure from continuous routine releases are also deduced and combined with population density and food production matrices to yield collective dose.

THE MESOS MODEL AND DATABASE

The MESOS database (1) currently covers most of the year 1973 for the area of Europe shown in Figure 3; it supplies pressure fields and other meteorological data including cloud cover, precipitation intensity deduced from "present weather" codes, and temperature, at 3 hourly intervals from observations at synoptic stations and ships. A new database for 1976 covering a larger map area, including the Mediterranean region, is in preparation.

In the model, puffs released at 3 hourly intervals are tracked through the evolving pressure fields using quasi-geostrophic techniques. Along each trajectory a puff is treated as a vertical column expanding laterally, and evolving vertically according to the state of the boundary layer as deduced from local meteorological data and the underlying surface of land or sea. Depletion by decay, dry deposition and wet deposition when it rains, are also included.

A continuous release over a 3 hour period between successive tracked puffs is treated as a series of puffs following intermediate trajectories and dispersion. Thus the area between calculated trajectories is exposed, representing the lateral spreading in the synoptic scale wind field. Integrated atmospheric concentrations are calculated for Kr85, Xe133, Xe135, Cs137 and I131, and dry and wet deposition for the last 2 nuclides. Exposure for longer term releases is calculated by summing the effects of consecutive 3 hour releases. More detailed descriptions are given in references (2) and (3).

SIMULATION OF WINDSCALE INCIDENT ON 10th OCTOBER 1957

The Windscale incident (3) provides one of the few instances in which monitoring (of I131 over Europe) allows comparison between measurements and predictions from the MESOS model (see Figure 1). Assuming a pattern of release from a 120 metre stack of about 30,000 Ci of I131 in total, with peaks late on October 10 before passage of a weak front, and after 9 hours on October 11 when water was poured on the pile, the model predicts that most of the first part of the release crossed over to the East of

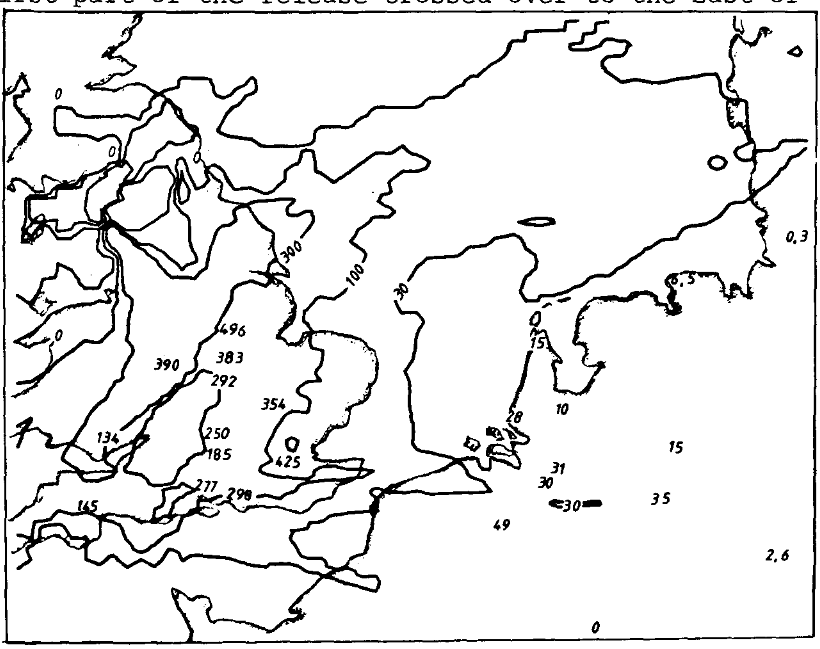

Figure 1. Measured time integrated air concentrations of I131 (p Ci, d.m^{-3}), resulting from the 1957 Windscale release, compared with predicted contours.

England above an inversion, penetrating to ground level with fumigation the next morning, whereas the second part gave rise to a plume down the W.Cumberland coast. Subsequent travel was influenced by an anticyclone moving East over N.France, and the release was eventually swept off East in moderate winds. The model predictions are sensitive to exact trajectories; for example a small increase in backing angle from the geostrophic direction would have implied reduced levels over N.Wales and higher values over S.England. Nevertheless the trajectories, predicted concentrations, and times of arrival of activity are in reasonable agreement with observation.

APPLICATIONS OF THE MESOS MODEL

The MESOS model is currently being applied to a few widely distributed hypothetical sites in European Community countries. Illustrative results are given here for MOL which is conveniently central in the study area. Figure 2 shows frequency distributions of different degrees of contamination by dry deposition from 24 hour

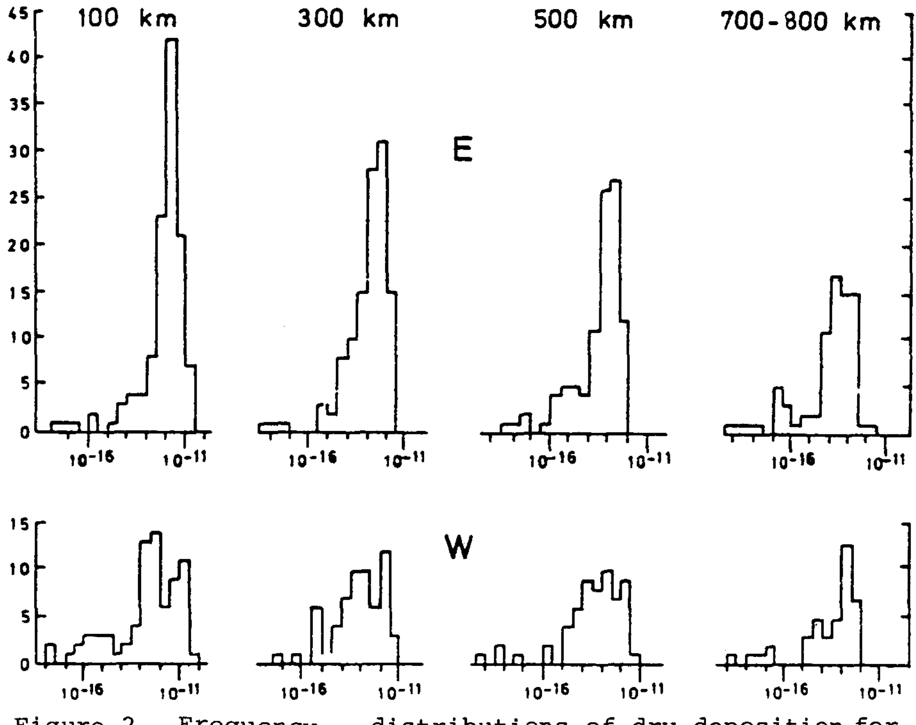

Figure 2. Frequency distributions of dry deposition for hypothetical releases of 1 Ci of I131 over 24 hours from MOL. Dry deposition (horizontal axis) is divided into half decade intervals in Ci m^{-2}.

releases of I131 at 4 distances East and West from MOL. For this nuclide 0.3 cm s^{-1} was assumed for the basic dry deposition velocity, and a washout coefficient $\Lambda=1.6.10^{-4} J^{0.8}$ where J is the rainfall rate in mm/h.

Figure 3 shows contours of estimated annual wet deposition per Ci of I131 released. The distribution of dry deposition is similar to that of atmospheric concentrations, but wet deposition is greater to the N. and E. and lower to the S. where dry anticyclonic trajectories contribute more. Rainfall patterns are important; for example, orographic rain over Norway.

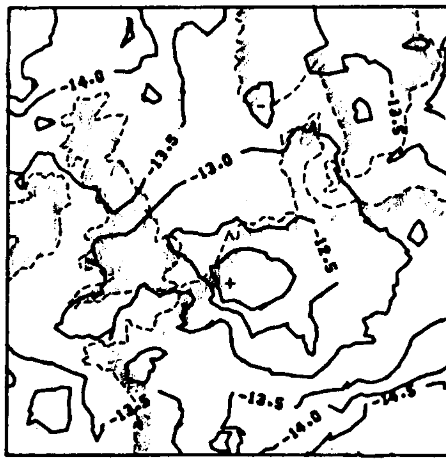

Figure 3. Contours of $\log_{10}$ (annual wet deposition in Ci m^{-2}) per Ci of I 131 released from MOL as a notional release site.

CONCLUSION

MESOS provides a more realistic model of atmospheric dispersal over long distances, and application to the 1957 Windscale incident produces encouraging comparison with measurements. For short-term releases MESOS is yielding useful statistics for hypothetical accident studies e.g. across a frontier. Data on population and food production supplied will enable us to estimate collective dose and its geographical distribution for routine continuous releases.

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