ØRESUND REVISITED BY RIMPUFF

Soeren Thykier-Nielsen and Valena Coelho Olsen
Wind Energy Department, Risø National Laboratory, DK-4000 Roskilde, Denmark

INTRODUCTION

In 1984 the Øresund experiment was carried out with the purpose of investigating the perturbations in the wind fie1d and the atmospheric dispersion over a region with cold water and warm land surfaces. One of the goals of the experiment was to obtain a data set that can be used for verification of mesoscale models in a coastal environment.

Until 1984, the experimental evaluation of RIMPUFF, the Risø Mesoscale PUFF diffusion model, had been restricted to data, representative only of short to medium range diffusion conditions. Because mesoscale dispersion is controlled by features and parameters often to be neglected on the small or local scale, simple extrapolations into the mesoscale range cannot readily be justified, except under very exceptional conditions. Therefore, the Øresund experiment provided an excellent opportunity to make a thorough experimental evaluation of the mesoscale calculations with RIMPUFF.

More than 15 years have passed since these evaluations of RIMPUFF. During this time RIMPUFF has been evaluated against several other experiments. As a result the model has been improved in several ways and is now a part of LSMC (Local Scale Model Chain). LSMC is now used in the Danish Nuclear Decision Support System ARGOS2000 (Hoe et al., 2000) and in the EU DSS RODOS.

In order to confirm the credibility of RIMPUFF and LSMC on mesoscale calculations, it was decided to redo the simulations of three of the Øresund experiments using all available data.

THE ØRESUND EXPERIMENT

The experimental campaign was carried out over the Øresund, the strait between Denmark and Sweden.

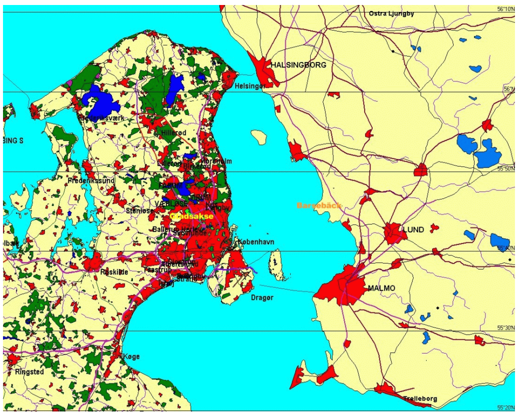

Figure 1. The Øresund area

The measurement campaign took p1ace during the period 16 May to 14 June 1984. During 4-10 June a special intensive measuring programme was carried out. From a scientific point of view, the Øresund region is well suited for an investigation of dispersion over a land-water-land region as the coastlines on both sides of the strait are rather straight and practically parallel, and the land area is fairly flat. The width of the strait is about 20 km.

Several meteorological measurement methods where applied: Doppler sodar, radiosondes, tethered ballons etc.. The quatities measured were wind, turbulence, temperature, humidity etc.

The atmospheric dispersion was investigated by carrying out SF6 (sulphurhexafluoride) tracer experiments. A total of nine tracer experiments were carried out during the campaign. The tracer was released at 95 m height from the meteorological mast at Barsebaeck at easterly winds and at 115 m from the mast at Gladsakse at westerly winds. Time-averaged tracer concentrations were measured at ground level by automatic tracer sampling units. The consecutive tracer samples by the various groups were taken in a way such that the total averaging time was l hour. The tracer sampling units were positioned in an arc close to the water front, i.e. at positions where the plume is not influenced by the land, and in an arc about 2 km inland such that the tracer plume had already been influenced by the land.

The results of all measurements (meteorology and tracer) were collected in a computer databank. This databank is presently available on a CD.

DISPERSION MODELLING

The tracer experiments have been modelled by several different models. Risø used the 1984 version of its puff model, RIMPUFF, for the first simulations.

RIMPUFF

RIMPUFF (Mikkelsen et al., 1984) is a fast and operational puff diffusion code that is suitable for real-time simulation of puff and plume dispersion during time and space changing meteorology. Also optimized for fast response on a PC this model is provided with a puff splitting feature to deal with plume bifurcation and flow divergence due to channelling, slope flow and inversion effects in non-uniform terrain.

The stand-alone version of RIMPUFF is driven by wind data from a network of meteorological towers. The mesoscale wind field in the simulation region is then calculated by the method of objective wind analysis, i.e. weighted interpolation on a regular grid.

The puff or plume diffusion processes are in RIMPUFF controlled by local turbulence levels, either provided directly from on-site measurements, or provided via pre-processor calculations (Mikkelsen and Desiato, 1993). The turbulence intensity is introduced in the calculations in the form of standard deviations of the lateral and vertical wind direct ion fluctuations, (or alternatively, inferred from the Pasquill-Turner scheme).

RIMPUFF is further equipped with standard plume rise formulas, inversion and ground level reflections, gamma dose algorithms and wet/dry depletion.

LSMC

RIMPUFF is part of the Local Scale Model Chain (LSMC) (Mikkelsen et al.,1998). LSMC comprises a meteorological pre-processor (**pad**), which calculates deposition parameters, stability parameters and wind fields based on the data provided either by meteorological masts or by the Danish HIRLAM model. The HIRLAM data set used consist of data from 13 layers of the HIRLAM model. These layers (no. 20 to 31) cover the height interval from 30 to approx 2000 metres above ground. The data used are: Precipitation intensity, Boundary layer height, surface sensible heat flux, surface momentum flux, land cover, surface roughness and wind speed and direction (for all 13 layers). These data are pre-processed and interpolated by **pad** to yield data input fields for RIMPUFF.

The wind fields are interpolated either by the linearized flow model LINCOM or by $1/r^2$ weighting. LINCOM is only used close to the source. Wind fields for 3 or more heights are provided for RIMPUFF to enable calculations of wind shear.

The stability parameters provided for RIMPUFF pertains to the so-called similarity parameterization, which gives a continuous atmospheric stability spectrum. In RIMPUFF the stability parameters are further limited for large source distances.

RIMPUFF calculates gamma dose and concentrations. Wind shear is accounted for in RIMPUFF by vertical and horizontal splitting of the puffs.

HIRLAM data are not available for 1984. Therefore the simulations of the Øresund experiments are based only on data from meteorological masts.

SIMULATIONS OF THE EXPERIMENTS

3 experiments have been selected for the simulations with LSMC/RIMPUFF : June 4 and 5 where the wind was steady easterly and June 14 where the primarily westerly wind turned about 30 deg during the experiment. Data (10 min averages) from all masts within the simulation area were used.

Results are shown on Figures 2 to 4. Further these figures show the results from the original simulations with the 1984 version of RIMPUFF. For all experiment simulations the agreement is good between the positions of the measured and calculated plumes. Further there is a substantial improvement compared to the earlier simulations. This main cause for this improvement is the use of data from more masts and an improved interpolation scheme for the wind field.

It can also be seen that the width of the simulated plume is in fair agreement with the measurements in all experiments.

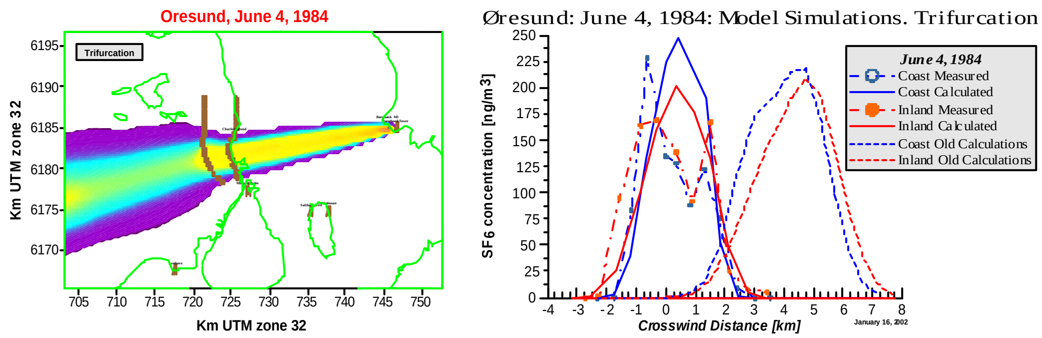

Figure 2. The calculated puff concentration pattern on June 4, 1984 with the sampling arcs overlaid (left figure). Coordinates in UTM zone 32. Right figure shows coastal and inland arcs, measured and calculated by LSMC and RIMPUFF 1984 respectively.

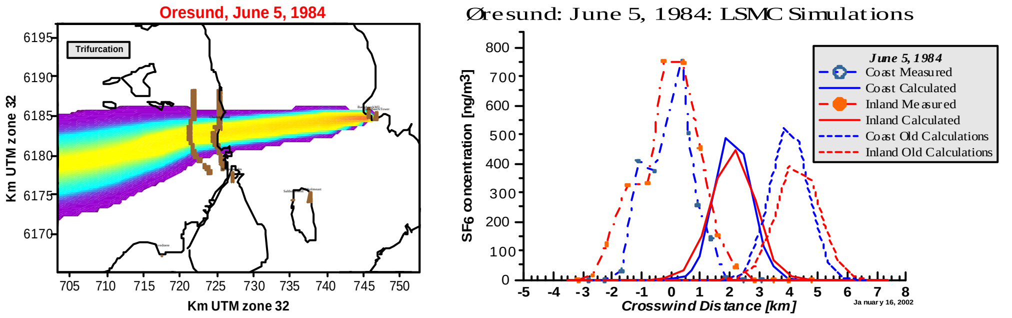

Figure 3. The calculated puff concentration pattern on June 5, 1984 with the sampling arcs overlaid (left figure). Coordinates in UTM zone 32. Right figure shows coastal and inland arcs, measured and calculated by LSMC and RIMPUFF 1984 respectively.

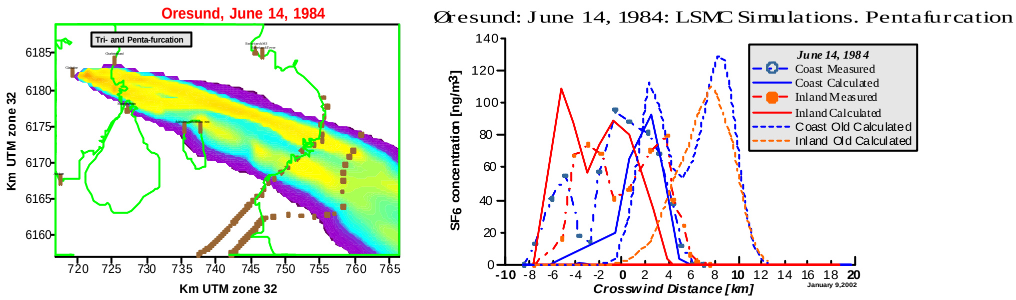

Figure 4. The calculated puff concentration pattern on June 5, 1984 with the sampling arcs overlaid (left figure). Coordinates in UTM zone 32. Right figure shows coastal and inland arcs, measured and calculated by LSMC and RIMPUFF 1984 respectively.

When comparing the simulated and the actually measured concentrations it is characteristic that the agreement, is good, considering the extremely complicated nature of the meteorology in the area. Even under such complicated meteorological situations the puff model produces rather accurate estimates of the concentration field.

CONCLUSION

Three of the tracer experiments that were carried out during the Øresund-experiment were simulated with the Local Scale Model Chain (LSMC/RIMPUFF) which includes the Risø mesoscale puff diffusion model RIMPUFF. The results of the simulation show that 1) the location of the actual plume is very well simulated, 2) the width of the plume is well predicted, and 3) the concentrations are well predicted.

Compared to the old RIMPUFF the calculated positions and concentrations are considerably improved. There is less difference in calculated plume width, considering that the use of similarity sigmas tend to yield narrower plumes than Pasquill-Gifford sigma's.

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