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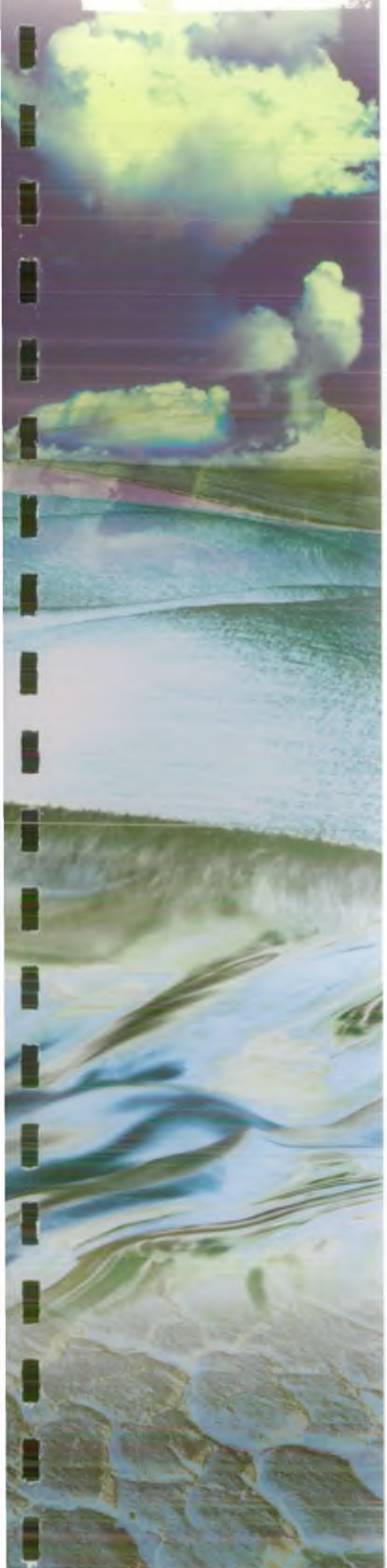

ENVIRONMENT
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National Centre for Risk Analysis And Options Appraisal

WORKSHOP ON NEW TECHNIQUES IN ENVIRONMENTAL MODELLING

Monday 7th December 1998

Programme and Abstracts

Report No 4

National Centre for Risk Analysis and Options Appraisal
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National Centre for Risk Analysis and Options Appraisal

ENVIRONMENT AGENCY

WORKSHOP

NEW TECHNIQUES IN ENVIRONMENTAL MODELLING

on

Monday 7th December 1998

at

Church House
Westminster
London

Chair Dr Jan Pentreath
Chief Scientist and Director of Environmental Strategy
Environment Agency

NEW TECHNIQUES IN ENVIRONMENTAL MODELLING

Monday 7th December 1998
Program

09:45	*Coffee*	
10:15	Introduction	
Session 1	*Neural Networks and Databases*	
10.30	*Recent Advances in the Data-Based Modelling of Environmental Systems*	Dr Peter Young, Lancaster University
11:00	*Environmental Applications of Artificial Neural Networks*	Dr Steve Dorling, University of East Anglia
11:30	*Preliminary work on:- The use of new statistical modelling techniques in soil science*	Dr Igor Dubus, Soil Survey
12:00	*Discussion*	
12.30	*Lunch and Demonstrations*	
Session 2	*Uncertainty and Decisions*	
13:45	*Assessing the Risk of Model Prediction Errors: Generic Techniques for Uncertainty Estimation for Nonlinear Environmental Models*	Professor Keith Bevan, Lancaster University
14.15	*Genetic Algorithms in Decision Support Systems*	Dr Zhengfu Rao
14.45	*Discussion*	
15.00	*Coffee*	
Session 3	***Developing the Ideas***	
15.15	*Advances in Process-based water quality modelling*	Professor Paul Edwards and Dr Steve Chapra, University of Reading
15:45	*A New Method of Simulating Destratification in Reservoirs*	Dr Jackie Maskell, Hydraulics Research
16:15	*MIRA - Oil spills Risk Assessment Model*	Dr Robin Pitblado, Det Norske Veritas
16:45	*Discussion and Close*	
	Demonstrations	
	Using the Juniper Methodology for Risk & Uncertainty Modelling in water Management	Gerald Rosenberg, University of Bristol
	Turbulent Fluctuations and Uncertainty - ADMS 3	Christine McHugh, CERC

New Techniques in Environmental Modelling

Introduction

The Agency makes extensive use of modelling techniques for predicting the impact of point source discharges, which are generally based on stochastic techniques. Over the years, the number of models in use has increased and the range of questions to be answered has diversified. The links between water, land and air can now be modelled, allowing integrated assessment of the impacts of industrial processes.

The Agency will always be a practical user of modelling techniques to answer questions such as:-

Will the air emissions from this plant impact on a special protection site?
Will contamination from this liquid spill reach the local groundwater?
Will removing phosphorus from these sewage effluents prevent future algal blooms in this lake?

In the future, however, the Agency will need to improve its modelling of links between media, address the spatial and temporal resolution issues this raises and improve its assessment of the uncertainties involved in modelling.

As part of its forward planning, the Agency is beginning the process of reviewing the modelling techniques currently available and under development, with the present and future modelling requirements of the Agency in mind.

The aims of this Workshop are

- To provide the Agency with an appreciation of the progress of new environmental modelling techniques
- To provide an informal and supportive forum for the presentation of new ideas
- To produce a report for the Agency with recommendations for future work

Some of the techniques presented will be "work in progress", others more fully developed methodologies ready for practical testing. The day aims to be informal, with time for demonstrations of techniques and extended discussions.

Recent Advances in the Data-Based Modelling of Environmental Systems

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The paper will introduce the concept of Data-Based Mechanistic (DBM) modelling and discuss how it has been applied to environmental and engineering systems in various areas of the environment. One advantage of the DBM approach is that it yields physically meaningful linear or nonlinear stochastic, dynamic models in which the uncertainties on the model parameters and inputs are quantified in a convenient manner and so can be utilised evaluate the effects of uncertainty on model predictions. For example, such models can be used as a basis for Monte Carlo simulation and Bayesian uncertainty analysis, if necessary exploiting the power of Markov Chain Monte Carlo (MC^2) methods. As such, they provide a vehicle for many kinds of uncertainty analysis, including the evaluation of risk and options appraisal.

Data-based Mechanistic (DBM) modelling (see e.g. Young, 1993; Young and Lees, 1993; Young and Beven, 1994, Young, 1998) is a statistical approach to environmetric (or other systems) analysis which exploits advanced methods of time-series analysis in a manner which enhances the model builder's ability to interpret the identified model in physical environmental terms. The DBM approach is widely applicable: DBM methods have been applied successfully to the characterisation of numerous environmental systems including the development of the Aggregated Dead Zone (ADZ) model for pollution transport and dispersion in rivers (e.g. Wallis et al., 1989; Young, 1992); rainfall-flow modelling and forecasting (Young, 1993; Young and Beven, 1994; Young *et al*, 1997a,b); and adaptive flood warning (Lees *et al*, 1994). Other applications considered in CRES over the past few years include: the modelling of water quality in rivers; the modelling and control of climate in glasshouses; the modelling of ecological and biological systems; the modelling and control of inter-urban road traffic systems; and business/economic forecasting. In the limited time available, the paper will describe one or two of these applications, with the choice guided by the views of the Workshop organisers.

The statistical and other tools that underpin DBM modelling can be utilised for other environmental purposes. For example, they can provide a rigorous approach to the evaluation and exploitation of large simulation models, where the analysis provides a means of simplifying the models. Such simplified can then provide a better understanding of the most important mechanisms within the model (generalised or regional sensitivity analysis); or they can provide 'dominant mode' models that can be used for control and operational management system design, adaptive forecasting, or data assimilation purposes (see e.g. Young *et al*, 1996; Parkinson and Young, 1998; Shackley *et al*, 1998). The DBM data analysis tools can also be used for the statistical analysis of nonstationary data, of the kind encountered in many areas of environmental science (see Young, 1993). For example, they have been applied to the analysis and forecasting of trends and seasonality in climate data (e.g. Young *et al*, 1991); and the analysis of palaeoclimatic data (Young and Pedregal, 1998).

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Environmental Applications of Artificial Neural Networks

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Collaboration between the Schools of Environmental Sciences and Information Systems, supported by the University of East Anglia and the European Union, is leading to the successful application of Artifical Neural Networks (ANN) to two specific environmental problems. One is a 'Classification' problem, the second involves 'Function Estimation' (Regression). These are two of the three modes in which ANNs can be applied (the third being forecasting). Both are examples of non-linear problems (with extensive spatial and temporal information) to which ANNs are suited. Our long term aim is the provision of 'turnkey' solutions for end users who may not have the original expert knowledge utlilised in building the models. We regard expert knowledge as a key ingredient in the success of model development (particularly input data selection) to achieve optimum results. This work has entailed both writing of in house computer code and use of the Stuttgart Neural Network Simulator software under the UNIX Operating System.

Our own 'Classification' application involves the training of ANNs to reproduce and extend into the future a subjective daily classification of states of the NW European atmospheric circulation developed by the late Hubert Lamb[1]. Presently we have improved modestly but significantly upon an existing rule-based system. The Lamb classification has been used extensively by other Environmental Scientists to explain temporal variations in air quality, acid deposition and wind energy availability for example. It is important that the index can be continued both for these types of studies and for climate research in general. Our ANN model consists of a Multilayer Perceptron (MLP) network which uses sea-level pressure data as input (across a domain covering the NE Atlantic and NW Europe). The input data is linearly scaled to zero mean and unit variance. The hidden and output units incorporate the standard symmetric logistic activation function while the Rprop training algorithm has been found to be both efficient and reliable.

Perhaps closer to the work of the Environment Agency is our work aimed towards predicting air quality in an operational mode. We believed that the non-linear relationship between weather conditions and air quality was not being optimally accounted for by existing modelling techniques. We have used local weather station data as the predictors for atmospheric concentrations of NO_X, O_3 and PM_{10} using an MLP ANN with the scaled conjugate gradient training algorithm. This particular algorithm avoids the need for numerous subjective parameter selections by the inexperienced user. Additional input data has included time of day, day of week and day of year to help simulate the important diurnal, weekly and seasonal variations. The results [2-6] have demonstrated considerable improvements over traditional modelling approaches in reproducing variations in air quality on the hourly timescale. Air quality forecasting is now being addressed through the use of forecast meteorological conditions (whose inaccuracies will affect the final results). By accounting for the meteorological variability in air quality conditions we are able to consider important policy evaluation issues such as the response of surface ozone concentrations to changes in precursor pollutant emissions. We are particularly concerned with developing models to predict extreme conditions where the public is at risk; it is well known that ANN models will otherwise tend to underpredict these conditions as a result of relatively small numbers of extreme training examples. The work is also of great relevance to Local Authorities currently tasked with modelling air quality in their areas as part of the National Air Quality Strategy; the relatively simple and accessible data requirements offer an attractive way ahead.

Of course a major criticism of ANNs is the difficulty in interpreting results in scientific terms. We have found that by experimenting with variations in input data, careful analysis of model residuals and supporting findings using other non-linear statistical techniques (eg decision trees and non-linear regression) that this serious problem can be significantly addressed. We also believe that ensemble modelling techniques can help here. We feel that ANNs also have much to offer by way of simulating subsets of modelling problems where much of a system is understood through current scientific knowledge but where a sub-component is poorly described with knock-on negative impacts on the accuracy of the whole model. We anticipate collaborating in the near future with other colleagues in the School of Information Systems with expertise in data mining and fuzzy logic.

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Environmental Applications of Artificial Neural Networks

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Talk Structure

- Introduction (SD)
- Neural Networks - What are they and why use them ? (MG)
- Neural Networks Applied to Air Quality (MG)
- Neural Networks Applied to Climate Change (SD)
- Discussion of Technical Expertise at UEA and Conclusion (GC)

Introduction

- UEA Interdisciplinary Approach
  - Multi-domain expertise
  - Sound Science
- Ongoing Projects - Air Quality Modelling and Climate Variability
- New Developments and Plans - Risk and Air Quality Prediction

Neural Networks - What are they ?

A neural network can be thought of as a general framework for the representation of non-linear functional mappings between a set of input variables and a set of output variables - Bishop 1995

$$\begin{bmatrix} x_{11} & x_{12} & \cdots \\ x_{21} & x_{22} & \cdots \\ x_{31} & x_{32} & \cdots \\ \vdots & \vdots & \ddots \end{bmatrix} \rightarrow \begin{bmatrix} y_{11} & y_{12} & \cdots \\ y_{21} & y_{22} & \cdots \\ y_{31} & y_{32} & \cdots \\ \vdots & \vdots & \ddots \end{bmatrix}$$

- A statistical modelling technique
- Neural networks are trained to learn the relationship between input data $[X]$ and output data $[Y]$ in a supervised manner
- Many different types of network
- Here consider the **Multilayer Perceptron** neural network

Neural Networks - Why use them ?

- A more flexible statistical modelling framework
  - They allow full interaction between input variables
  - They can model highly non-linear functions
- Residuals
  - Not due to inappropriate model design
  - Actually represent unexplained variance
- Better statistical models

Neural Networks Applied to Air Quality

- Coincident meteorological and pollutant data
  - Inputs : meteorological and temporal data
  - Output : pollutant concentration
- Pollutants : O_3, NO_x, NO_2, CO, PM_{10}
- Meteorological data : dependant on pollutant
- Locations : UK, US and New Zealand
- Temporal Resolution : hourly and daily

Decompostion of Urban NO_X Time Series

- Two models were developed to model urban NO_X
  - Model 1 : MET inputs
  - Model 2 : MET + TOD + DOW inputs
- Comparison between the models illustrates what Model 2 has learnt due to the additional TOD + DOW inputs
- TOD + DOW inputs enable Model 2 to learn the pattern of primary NO_X emissions
- NO_X emissions are unrelated to meteorology but contain diurnal and weekly cycles

Trends in Surface Ozone due to Emission Controls

- Difficult to detect (secondary pollutant, meteorology)
- Collaboration* enabled development of neural network approach to meteorologically adjust ozone time series
  - inputs : daily summary meteorological data and time of year
  - output : daily maximum ozone concentration
  - residuals = meteorologically adjusted ozone
  - method removed more of the meteorological effects than alternative techniques when applied to same data
- Applied in UK since UK trends not yet identified

* with Prof.S.T.Rao, Office of Science and Technology, New York State Department of Environmental Conservation, USA

Future Work

- Extend models into forecast mode ..
  - use forecast meteorological data
- Integrate models into a decision support system
- Combine with Fuzzy Logic to incorporate user/data uncertainties
- Bayesian training methods - output confidence intervals

Neural Networks Applied to Climate Change

- Funded by UEA and the European Union - Atmospheric Circulation Classification and Regional Downscaling (ACCORD)
- How to classify the atmospheric circulation ?
- How to link circulation to local weather conditions ?
- How to cope with the volume of simulations generated by the climate modelling community ?
- How to generate climate change scenarios in which we have the greatest confidence ?

Summary - Neural Networks

- Projects : ACCORD, linking meteorology and air quality
- Advantages :
  - Universal approximators
  - Statistically meaningful output
  - Bayesian and Markov Chain Monte Carlo methods to deal with uncertainty
  - Can be used without expert domain knowlege
- Disadvantages : Opaque

Summary - Data Mining

- Projects : monthly/seasonal temperature prediction, ACCORD
- Advantages :
  - efficient - simulated annealing, genetic algorithms, tabu search
  - rules generated are easily interpretable
- Disadvantages : Less expressive power than neural networks

Summary - Bayesian Belief Networks

- Projects : Risk assessment in food safety/toxicology
- Advantages :
  - Explicit modelling of uncertainty
  - Constructed using expert knowledge
- Disadvantages: Constructed using expert knowledge

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The use of new statistical and modelling techniques in environmental modelling and soil science

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The Soil Survey and Land Research Centre has been conducting environmental research and quantifying the nation's soil resources for the last 50 years. The use of statistical tools is inherent in most of its projects and includes a wide range of mathematical and statistical techniques (e.g. ANOVA, Multiple Linear Regression, Monte Carlo sampling, Inverse modelling, Multivariate analysis, Clustering techniques, Artificial Neural Networks, Fuzzy Logic). Increasing user-friendliness of statistical and mathematical packages has resulted in the wider use of statistics within the organisation.

Deterministic modelling has started to show its limitations in complex non-linear systems such as the environmental fate of contaminants in heterogeneous media. For example, traditional paradigms such as Richards' equation and Darcy's law which have been used for many years to describe soil hydrology are often found to be inadequate for quantifying real water-flow phenomena. Furthermore, deterministic models do not take into account the uncertainty and heterogeneity of the system. New modelling techniques that are capable of managing uncertainty thus appear attractive.

Artificial Neural Networks (ANNs) show great potential for application in the domains of environmental modelling and soil science. Possibilities of development include i) the mimicry of complex computer-intensive models, in order to decrease running time, thus enabling the development of detailed risk assessments at national scales ; ii) the development of model sub-routines where deterministic approaches show limitations ; iii) the development of new models using comprehensive experimental datasets.

Fuzzy logic has been recently used as an alternative to Monte Carlo, Bayesian approaches and First Order Uncertainty Analysis for estimating uncertainty in a contaminant fate model. Although further investigations are required, the technique has shown some promising results. In particular, only a limited number of model runs is required to evaluate the range of imprecision and the degree of confidence in model results. The imprecision arising from simplification, approximation and extrapolation required when using complex mathematical representations is included in the technique.

Although a National Soil Map at 1:250,000 scale is available, it does not provide the detailed spatial distribution of soil types, which will be an indispensable tool for conducting reliable environmental risk assessment in the future. A variety of statistical techniques, including multivariate discriminate analysis, decision tree statistics, discretisation techniques, ANNs and Fuzzy Logic, has recently been applied to investigate new ways of predicting detailed soil patterns from landscape features. Relationship between the spatial distribution of soils and geological/morphological characteristics were identified, and work now concentrates on the integration of second-degree landscape parameters. ANNs and Fuzzy Logic appear to be the most promising techniques for this particular classification exercise.

Application of statistical tools of different complexity to solve specific problems will be presented, with particular emphasis on the use and potential of Fuzzy Logic and ANNs. A strategic framework for incorporating new statistical techniques into environmental modelling and assessment will be proposed.

Assessing the Risk of Model Prediction Errors: Generic Techniques for Uncertainty Estimation for Nonlinear Environmental Models

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Outline

The work of the Environment Agency involves the use of nonlinear predictive models in many different situations. However "physically-based" these models, the calibration of parameter values and the specification of boundary conditions are often subject to considerable uncertainty. In addition model structural errors will necessarily result in uncertainty in model predictions. In critical cases, the use of "best estimates" in making model predictions will become increasingly difficult to defend. Thus, techniques are required to estimate the uncertainty in model predictions that can be easily implemented for a wide class of models. The Generalised Likelihood Uncertainty Estimation (GLUE) technique developed at Lancaster University is a novel use of Monte Carlo simulation that has been applied to problems ranging from rainfall-runoff modelling, groundwater transport modelling, real-time flood inundation forecasting, critical load prediction, and modelling land surface to atmosphere fluxes of sensible and latent heat (see list of references).

The concept underlying GLUE is that model simulations should be compared with the available observations and assessed in terms of an appropriate performance criteria that provides a likelihood or probability of being an acceptable model. Thus, in assessing many different models with randomly chosen parameter sets, a distribution of likelihood measures is built up that can be used to weight the predictions of those models. The result is an assessment of the risk of a certain prediction, conditioned on the available data. Traditional likelihood measures can be used within this framework but have often been found to give a too restricted view of the acceptability of models, since acceptable or behavioural models are often found throughout the model parameter space. Multiple measures of performance are easily incorporated into this methodology by the use of Bayes equation. Fuzzy measures and operators can also be used within this methodology. Different model structures can be evaluated, provided that they can be compared using the same likelihood measures. Sensitivity analyses can also be carried out using the same Monte Carlo runs.

A major advantage of GLUE is that it is conceptually simple to understand and easy to implement. There is a cost in terms of computing power but this is becoming less restrictive with implementation on low cost parallel PC systems with greater than 1 Gflop processing power. At Lancaster we use a 20 processor 333 MHz Pentium system (costing < £20k) dedicated to this type of calculation. Some demonstration Windows software designed to illustrate the uncertainty estimation and sensitivity analysis within the GLUE methodology can be downloaded from our Web site at http://www.es.lancs.ac.uk/es/Freeware/Freeware.html

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Integrating Artificial Neural Networks and Mechanistic Models for Modelling Water Environmental Systems

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Abstract

Water quality dynamics in general and flow and contaminant transport processes in particular are highly nonlinear, time-varying, spatially distributed and not easily modelled by simple models. Conventionally, two broad approaches for modelling water quality dynamics have been explored, namely mechanistic (analytic) models in which the physical system is represented by a series of linked, internal sub-processes and empirical models (sometimes refer to as 'black-box' models) which do not attempt to postulate any physical reality. Owing to the difficulties associated with nonlinear model structural identification, parameter estimation and traditional numerical methods, such models are inefficient computationally and ill-suited to the introduction of optimisation techniques for solving environmental planning and management problems which require a large number of flow and contaminant transport simulations.

The use of artificial neural networks(ANNs) for modelling such a complex process is an attractive approach that has been successfully applied in various studies. However, in many cases the use of an ANN alone may be inadequate and inaccurate when data are insufficient because the ANN black-box model relies completely on the available data. As a result, a hybrid neural network and mechanistic modelling scheme has been developed, combining a simplified mechanistic water quality simulation model which incorporates the available prior knowledge about the process being modelled with a neural network which serves as an estimator of unmeasured process parameters from the mechanistic model that are difficult to model. This hybrid model has better properties that standard neural networks models in which it is able to interpolate and extrapolate much more accurately, is easier to analyse and interpret and requires significantly fewer training examples.

The resultant modelling scheme has been shown to be effective in the applications related to modelling water quality dynamics in river systems and obtained so far flow and contaminant transport in the unsaturated zone. Based upon the results it is expected that the methodology developed will be equally applicable to other field-scale applications.

Integrated Catchment Models of Hydrology and Microbiology – INCA

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Aquatic Environments research Centre, University of Reading, Whiteknights PO Box 227, Reading

A new model has been developed for assessing multiple sources of nitrogen in catchments. The INCA model is process based and uses mass balance and reaction kinetic equations to simulate the principal mechanisms operating. Modelled processes include mineralisation, nitrification, denitrification. immobilisation, plant uptake and nitrogen fixation. Both surface soil zones and groundwater zones are simulated together with leaching of water into the river system. The land phase and river channels are modelled so that a semi-distributed description of oxidised and reduced nitrogen across the catchment can be obtained.
The model can simulate up to six different land uses; forest, arable, surface vegatation (grazed or fertilised) and moorland. Sources of nitrogen can be from atmospheric deposition (ie. from local or remote sources such as power stations, industry or vehicles), from point sources such as sewage discharges, from distribute sources such as agricultural fertilisers or from natural organic sources of nitrogen.
INCA is a daily simulation model with built in hydrological mass balance equations. Daily time series of model outputs at any reach boundary can be obtained and compared with observed data. Other outputs include statistical summaries, distribution graphs of water quality and profiles down the river system. INCA enables the user to calculate nitrogen loads from different land uses and information on annual and daily fluxes can be obtained.

In addition, it is possible to evaluate scenarios of environmental change to assess impacts on flow, loads and water quality. Scenarios to be tested can include land use change (eg. moorland to forest), changing atmospheric deposition (eg. impacts of new atmospheric emission protocols), or changing agricultural practice (eg. decreasing/increasing fertiliser applications).

The model is user friendly with a simple menu system and high quality graphical displays. INCA is a valuable tool for research to evaluate nitrogen balance in catchments and river systems or in experimental plot studies. It is also a valuable teaching tool as it enables the user to ask questions about catchment dynamics, groundwater/surface water interactions, processes controlling nitrogen behaviour and environmental change issues.

Process-Based Modelling of Sediment Water Interactions

Professor Steve Chapra
Aquatic Environments research Centre, University of Reading, Whiteknights PO Box 227, Reading

A new model has been developed for water quality in rivers using the latest knowledge on processes, particularly those relating to sediment water interaction. The model has been applied initially to the Thames River System and results of this application will be presented during the workshop.

A new Method of Simulating Destratification of Reservoirs

Dr Jackie Maskell
HR Wallingford Ltd, Howberry Park, Wallingford

Reservoirs have been constructed in the UK with jets, bubblers and selective withdrawal facilities to help control the quality of the outflow. Until recently it has not been practical to simulate or predict the detailed effects of mixing facilities on the day to day water quality at the outlet tower in such a reservoir under critical adverse design conditions. As a result, the operation of the mixing devices is based on experience and rule of thumb procedures.

In 1997, HR decided to the upgrade the hydraulic engine of their existing 3D seasonal model (3DSL) using a fully implicit solution technique. This allows the user to transfer flow to and from any point or level in the reservoir. The model can simulate full thermal balance and water quality in a typical reservoir over a whole year with a 1 minute timestep in about 12 hours.

The model is also applicable to any stratified water body where destratification is considered eg saline stratification behind tide overtopping barrages.

Inflow jets

The model can simulate the mixing effect of jetting pumped inflows into the near bed layers, by computing the rate of entrainment by the jet of water from the relevant level in the reservoir and then inserting the enlarged and diluted inflow into the appropriate part of the water column above the inlet depending on its buoyancy. The model also applies the momentum of the incoming jet to the appropriate layer of water.

Recirculation jets

The model simulates the effect of forced interflows – pumping water from one level in the water column and injecting it in another – in a similar fashion.

Selective withdrawal from a tower

The model simulates selective withdrawal by simply withdrawing water from a pre-selected layer at the site of the tower and lets the model compute the flow towards the outlet, thereby taking into account stratification effects.

Natural mixing processes

The model simulates the effect of solar heating, diurnal cooling, wind mixing, and vertical instability and overturning when the surface water cools.

MIRA - Oil spills Risk Assessment Model

Dr Robin Pitblado
DNV Ltd, Palace House, 3 Cathedral Street, London

DNV in Norway has developed a methodology (known as MIRA) for assessing the environmental risks from oil spills in the Norwegian Continental Shelf. MIRA has been further developed into a Windows based software tool known as EMDROPS (Emergency Management, Display and Response Operation Planning System). EMDROPS is an integrated software tool that can be used for:

- Oil spill transport and fate modelling.
- Accessing natural resource information and determining damage.
- Environmental risk assessment (MIRA).
- Oil spill contingency planning.
- Oil spill response actions and training.

The presentation will discuss the development of MIRA and EMDROPS in Norway and how it is used by Norwegian offshore operators and regulators as part of the offshore planning process. Further development of a UK version of EMDROPS as part of the internationalisation of the product will also be presented.

MIRA

ENVIRONMENTAL RISK ASSESSMENT METHODOLOGY FOR OIL SPILLS

Mark Vine, Det Norske Veritas Ltd.

New Techniques in Environmental Modelling

Environment Agency Workshop, Monday 7th December 1998

DET NORSKE VERITAS

DNV - 1998-12-04 - No. 1

CONTENTS

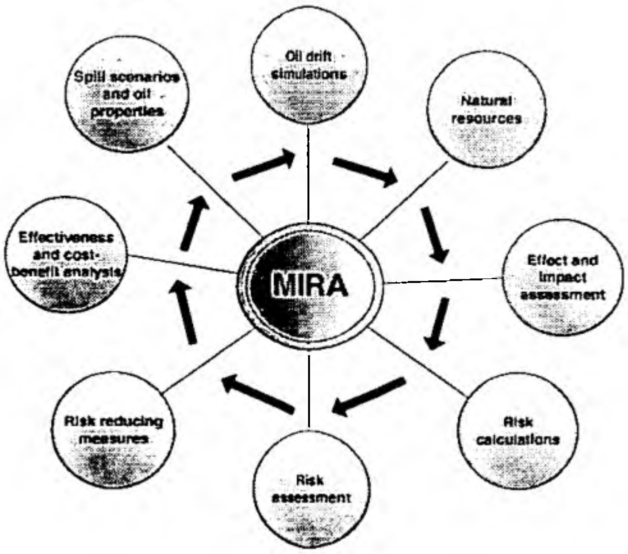
DET NORSKE VERITAS

DNV - 1998-12-04 - No. 2

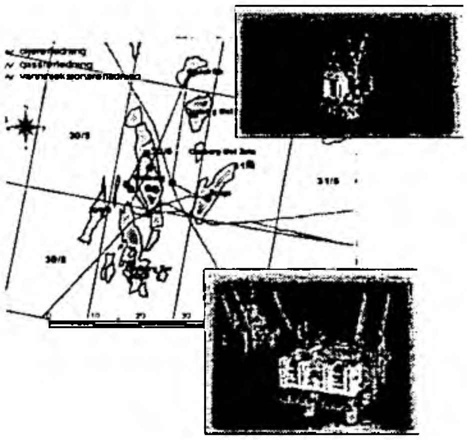
MIRA HISTORY

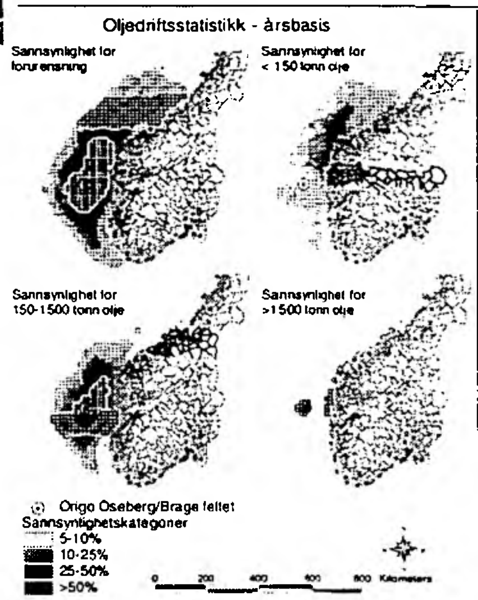
- Developed by DNV in Norway.
- OLF Funded (Norwegian Offshore Operators).
- Environmental Risk Assessment (ERA) required by offshore authorities in Norway.

Elements of the MIRA Methodology



SPILL SITE AND DRIFT SIMULATIONS





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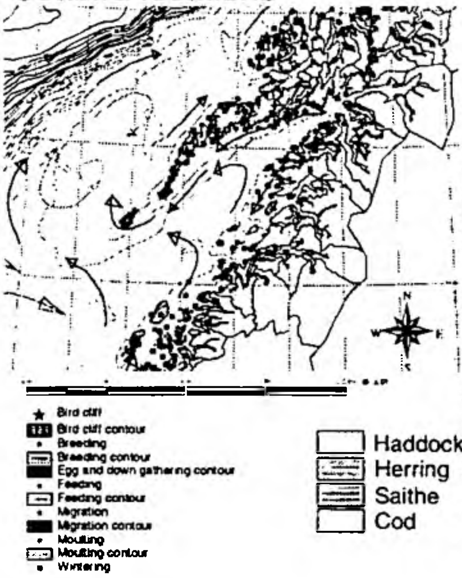
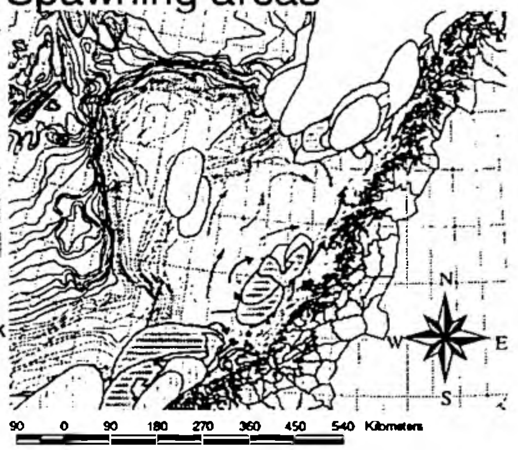
Seabird locations



NATURAL RESOURCES - MRDB®

Spawning areas



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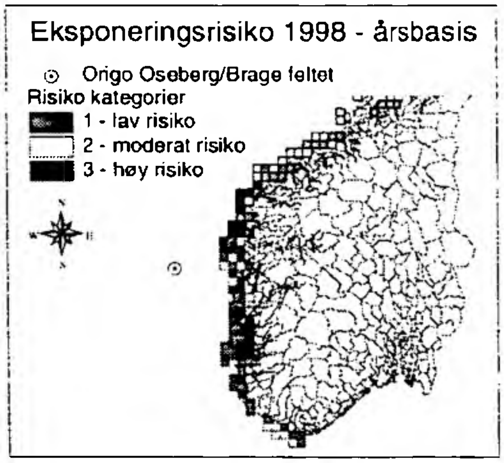
GEOGRAPHICAL PRESENTATION OF ENVIRONMENTAL RISK



EMDROPS

(ENVIRONMENTAL MANAGEMENT, DISPLAY AND RESPONSE OPERATION PLANNING SYSTEM)

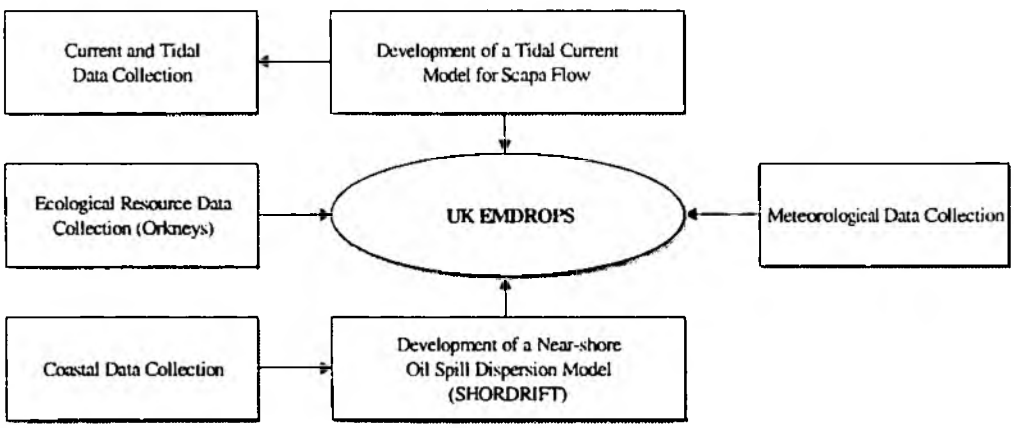
- Oil spill transport and fate.
- Assessing natural resource information and damage.
- MIRA.
- Contingency Planning.
- Oil spill response strategies and training.

http://www.dnv.com/seq/page7.html

UK EMDROPS DEMONSTRATION STUDY

- Internationalisation of EMDROPS.
- **Objectives:**
  - Initial transfer of EMDROPS technology and knowledge to UK using Orkneys as an example.
  - Further development of near shore oil dispersion model (SHORDRIFT).
  - Illustrate potential EMDROPS use in the UK through Elf Flotta Case Study.
  - Identify the needs of the UK market for EMDROPS.

DEVELOPMENT WORK



SHORELINE TYPES

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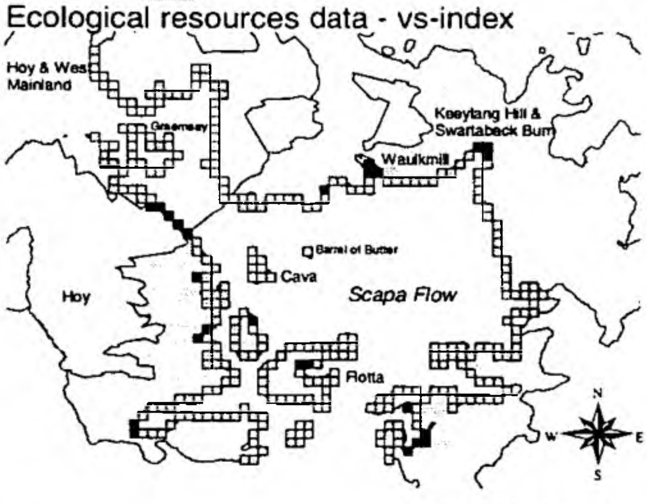
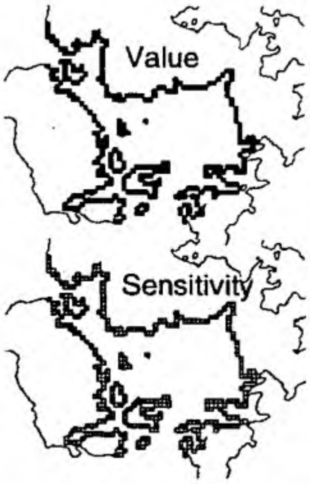
ECOLOGICAL RESOURCE DATA

Ecological resources data - vs-index





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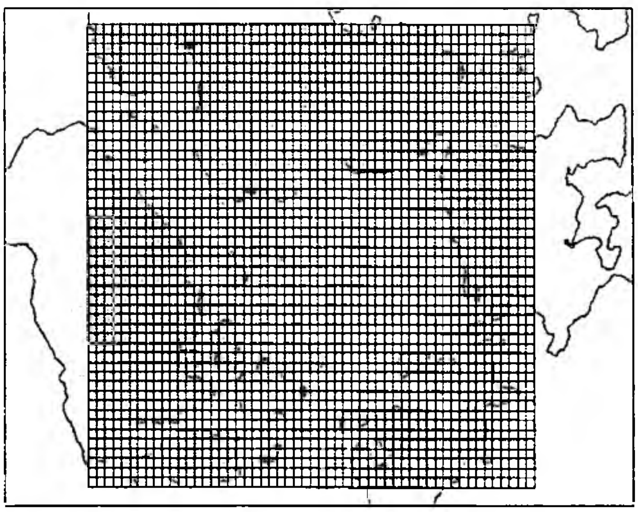
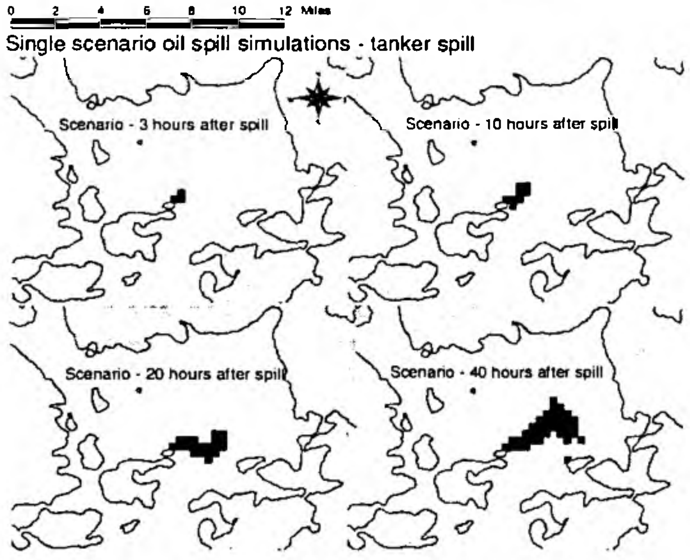
RISK ACCEPTANCE CRITERIA

RISK-CLASSES /-REGIONS		CONSEQUENCE CATEGORIES: Insignificant	Small	Moderate	Large	Very large
FREQUENCY PER YEAR	5 – often ($\geq 10^{-1}$)					Very high risk
	4 – few instances ($\geq 10^{-2}$)				High risk	
	3 – seldom ($\geq 10^{-3}$)			Moderate risk		
	2 – very seldom ($\geq 10^{-4}$)		Low risk			
	1 extremely seldom ($< 10^{-4}$)	Very low risk				

OIL SPILL MODELLING



- Tanker Grounding:
  - 1.5 t/hr Foinhaven crude
  - 48 hrs duration
  - $5x10^{-4}$ per year
- Foinhaven Oil Properties:
  - Oil Density 902 kg/m3
  - Asphaltene 0.06 wt%
  - Water uptake 70 wt%
  - Viscosity 0.019 kg/ms
- Model Parameters:
  - 500m by 500m grid
  - Time step 9 minutes
  - 5 particles per time step
  - 600 release scenarios



- Dimensioning accidental situations.
- Emergency response capacity and logistics.
- Priority areas and resources.

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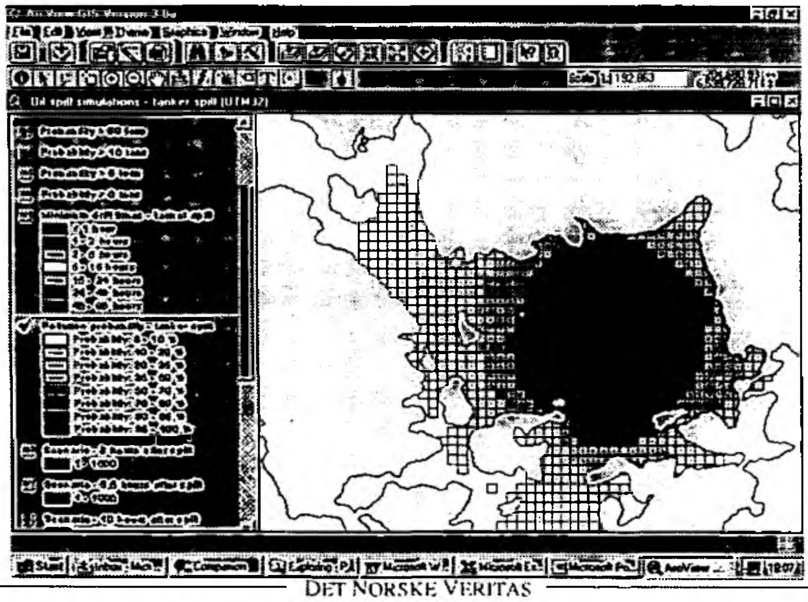

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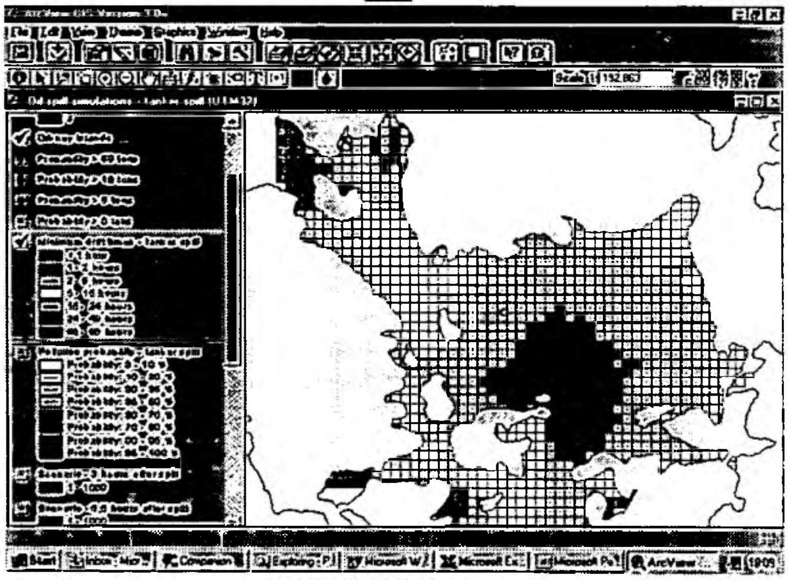

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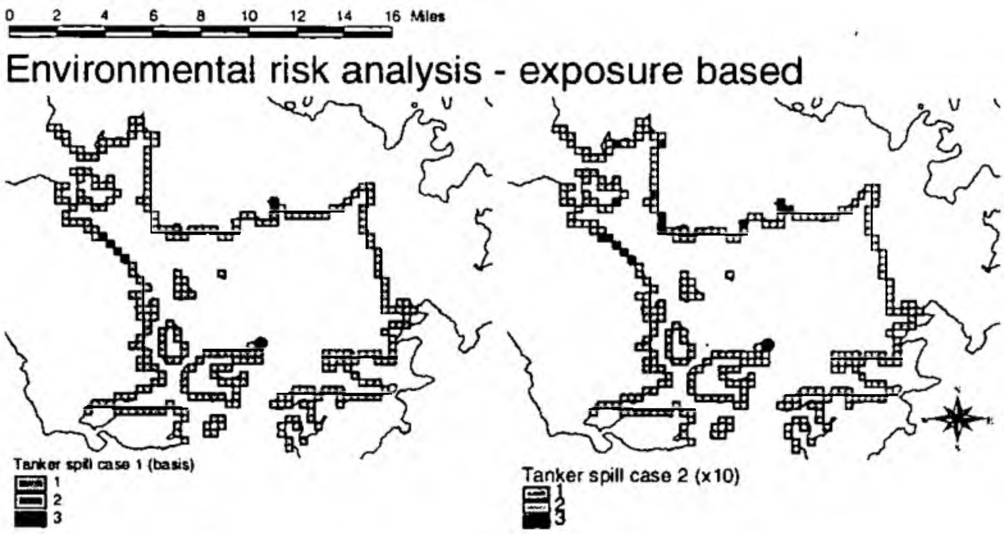
Environmental risk analysis - exposure based



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CONCLUSIONS

- SHORDRIFT model enhanced.
- UK EMDROPS is feasible:
  - Data and information is available.
  - Risk assessment is well understood.
  - Legislative drivers exist.
  - EMDROPS risk assessments efficient.
  - Cost/benefit in updates and revisions.
- UK resources and expertise available.
- Standardisation of ERA will reduce costs

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FUTURE WORK

- Integration of risks and exposure methods.
- Incorporate contingency planning module.
- QA of SHORDRIFT.
  - Reality check and comparison with OSIS.
- Improve user interface.
  - Flexibility for input data / preparation of resource data
  - Deterministic modelling (Training module).
- Gain acceptance for ERA approach in UK.
- Extension to rest of UK (prioritise e.g. West of Shetlands).

DET NORSKE VERITAS

Turbulent Fluctuations and Uncertainty

C. McHugh
Cambridge Environmental Research Consultants

In turbulent flows of air or water, a series of measurements of flow velocities or concentrations taken under apparently identical conditions will vary due to flow turbulence. For dispersion in air, the time scales of the atmospheric turbulence range from seconds up to tens of minutes and may be similar to the time scales over which air quality standards are assessed and the time scales over which odour or flammability thresholds might be exceeded. Peak values may therefore be significantly higher than ensemble mean values. Consideration of turbulent fluctuations is vital in predicting peak short time average concentrations. The ADMS model, which is used by the Agency in assessing stack emissions, is the only model of its type which models fluctuations in pollutant concentration due to short time scale atmospheric turbulence.

The National Air Quality Strategy (NAQS) objective for sulphur dioxide is specified in terms of a 15 minute average concentration. Successive 15 minute concentrations measured during a period in which meteorological conditions are constant will vary due to the movement of the plume and imperfect mixing within the plume caused by atmospheric turbulence. Guidance associated with the NAQS suggests use of a ratio to convert the hourly averages calculated by most air dispersion models to 15 minute averages. However, the variation in concentration will depend on the meteorological conditions, the height of the plume and the location at which concentrations are being measured or predicted. To assess properly the number of exceedences of the objectives by a process and hence compliance with the objective, the effect of turbulent fluctuations should be modelled.

Predicting the variability of concentrations over short time periods is important for odours, which affect people over short periods of seconds or a few minutes and flammable substances where ignition can occur if the flammability threshold is exceeded for just a short period of time. In each case an hourly mean value might be low enough to suggest there would be no problem from odour or ignition, yet a study of likely short term averages might highlight a risk.

The model of fluctuations used in ADMS is based on a "two-particle dispersion" concept whereby fluctuations are related to how two particles, initially close together, move apart. It builds on previous theoretical work which used a meandering plume model and on experimental results. In ADMS 2, the ability to model fluctuations is available for hour by hour calculations, not for analysing a whole year's data. ADMS 3, which is in the final stages of development, will have the ability to predict the long term consequences of fluctuations, importantly: the number of exceedences of a given concentration, for instance an air quality objective or an odour threshold, during a year.

As the National Air Quality Strategy is implemented by local authorities, it is likely that air quality professionals and the public will become increasingly interested in the question of peak concentrations and how fluctuations can be modelled.

Using the Juniper Methodology for Risk & Uncertainty Modelling in water Management

Gerard Rosenberg
University of Bristol

Juniper, a new approach to managing uncertainty in a decision making process, has been developed by the Systems Group in the Civil Engineering Department at the University of Bristol. This methodology was originally developed for the international oil industry, and has been successfully applied to assist engineers with the task of deciding whether or not to develop a Near Field Potential (NFP) oil reservoirs.

The Juniper approach seeks to encompass all significant issues that impinge on a decision. It provides a means of modelling the process, rather than just the data flow, and in so doing, handles non-technical and technical uncertainties through the attributes of the parent-process and its sub-processes. It is ideally suited to situations where data are sparse or incomplete, and where there may be conflicting knowledge.

The aim of the project is to apply the Juniper methodology and software to environmental risk management. Relevant case histories have been identified which will be used to demonstrate the applicability of the methodology in the area of water management, although if successful, the technique should be more widely applicable. Example applications will include appraisal of infrastructure investment options such as in schemes to reduce Combined Sewer Overflows (CSOs) and the selection of wastewater treatment sites.

The study will compare the effectiveness of this new methodology with traditional approaches to risk management, including probabilistic analysis and fuzzy set theory. The work will be undertaken within the newly formed Water Management Centre at the University of Bristol.

The benefits for participants in the project include the chance to influence the direction and content of the work programme in the light of the results of the research, to receive risk management support in areas of current concern, and to receive the reported results of the study. More generally, participants would benefit from access to the expertise in the Water Management Research Centre at Bristol.

Stochastic Modelling applied to Dispersion of Heavy Particles in the Atmosphere

V. Vesovic, TH Huxley School of Environment, Earth Sciences & Engineering, Imperial College of Science, Technology and Medicine, London, SW7 2BP;

There is a genuine need for practical models of heavy particle dispersion and deposition in the highly complex and turbulent flows associated with the environment. In order for such models to be realistic and accurate they should be based on a sound theoretical understanding of the underlying physics of particle-fluid interaction. Therefore, any development of practical models has to be preceded by a detailed investigation of the response of particles to turbulent eddies present in the fluid.

The overall objective of the work is to develop a theoretically sound computational model of the heavy particle motion in the atmosphere in order to tackle the problems associated with the dispersion of particulate matter under conditions of high turbulence and complex terrain.

The atmospheric dispersion of particles is different to that of passive gaseous pollutants, because the effect of gravitational forces imposes a downward settling velocity. In flows with high degree of turbulence and rapidly changing wind speeds, the dynamic response of particles to the turbulent fluid eddies is of considerable interest. This work examines the dispersion and deposition of particulate matter using Lagrangian modelling techniques. The particle trajectories are calculated by numerically solving Newton's equations of motion, while the wind velocity is modelled by means of a Lagrangian type model. At each instant the wind velocity is given by the sum of the average wind velocity and the turbulent wind fluctuations. The average wind velocity is obtained from the currently recommended wind profile for neutral atmospheric conditions, while the turbulent component, in each direction, is calculated by means of the Markov chain scheme. The results of simulation runs performed indicate that the effect of turbulence is very marked and leads to a large spread of particle landing positions downwind from the source. The comparison with scarce experimental data indicates that the proposed model is capable of quantitatively describing the ground-level concentration of particulate matter.

New Techniques in Environmental Modelling
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