Air Pollution Forecasting Seminar NETCEN 6 May 2004

Applications of Fuzzy Based Approaches to Environmental Regulation under Uncertainty

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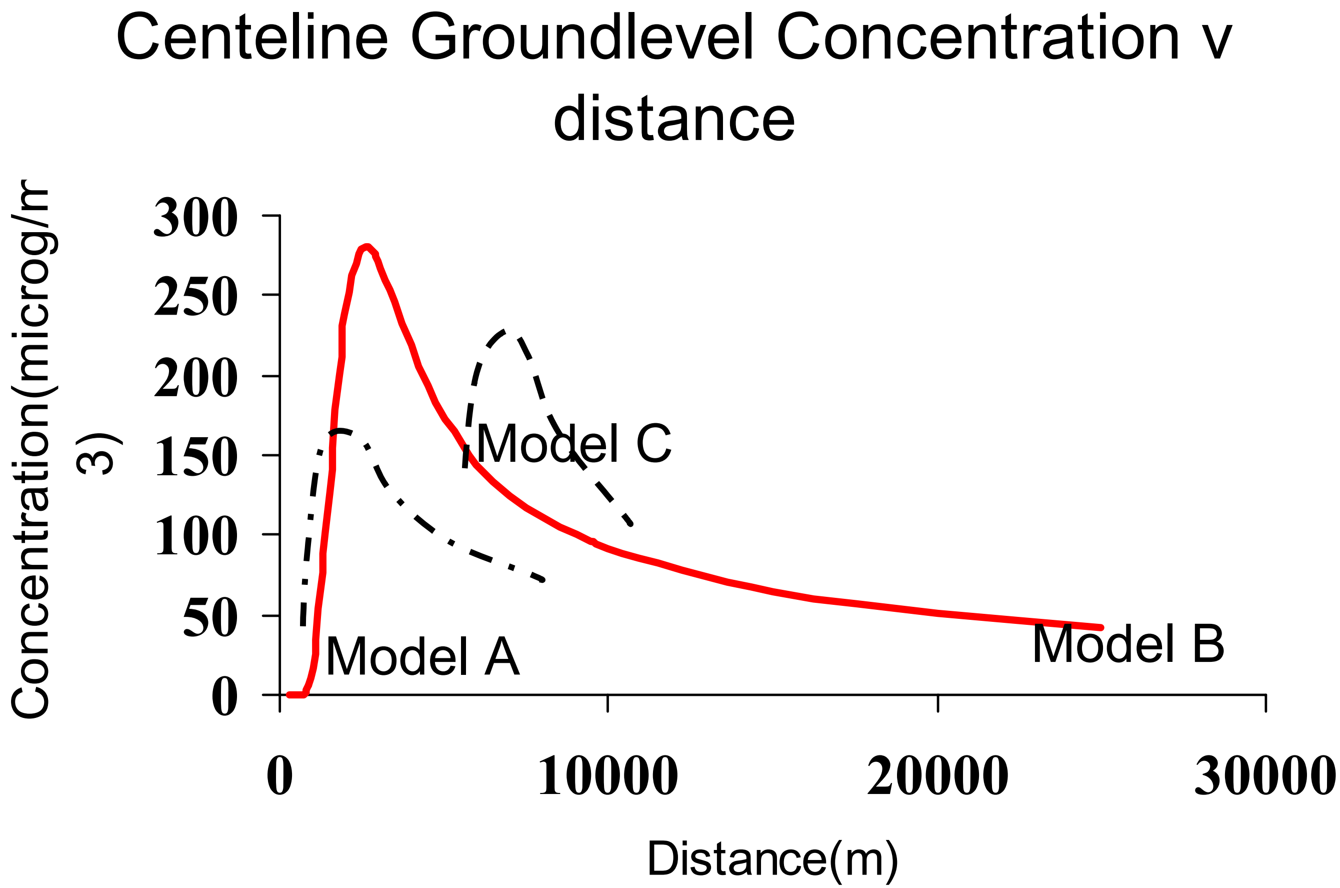
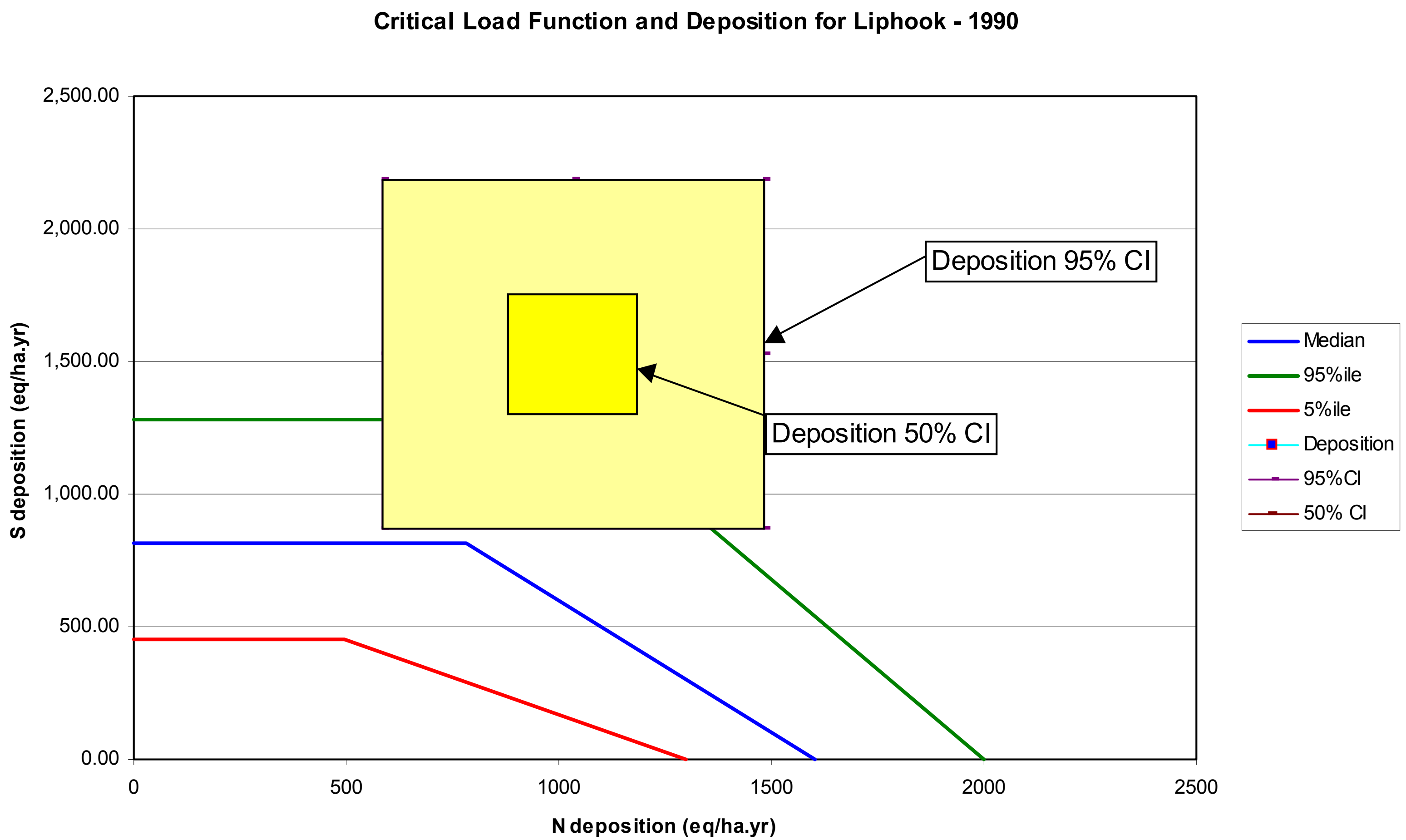
Risk and Forecasting

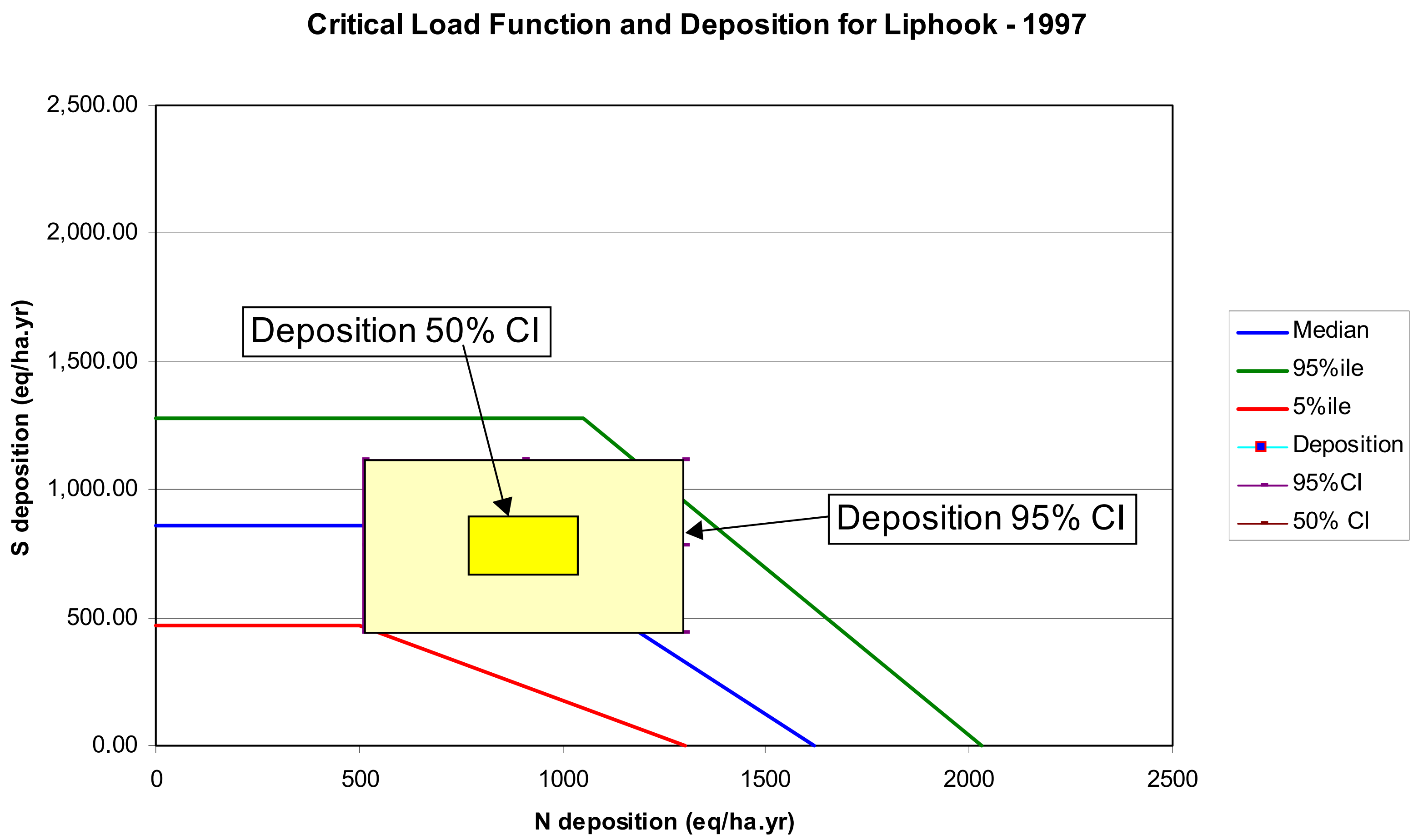
ENVIRONMENT AGENCY

Comparison of dispersion models Hall et al R&D P353, P362





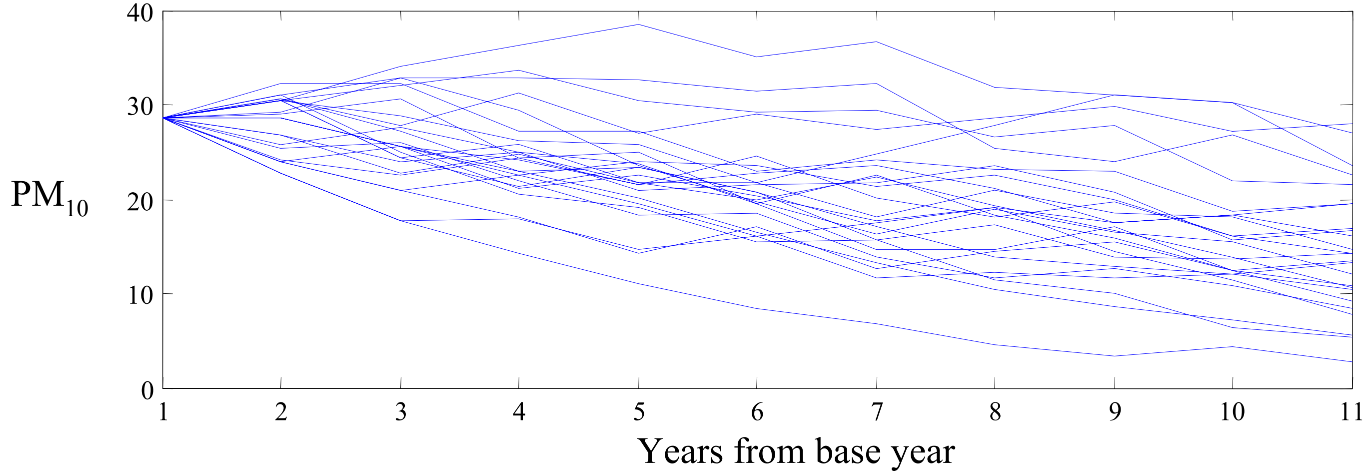
Uncertainty acid depn & CL Abbott et al P4-083(5)



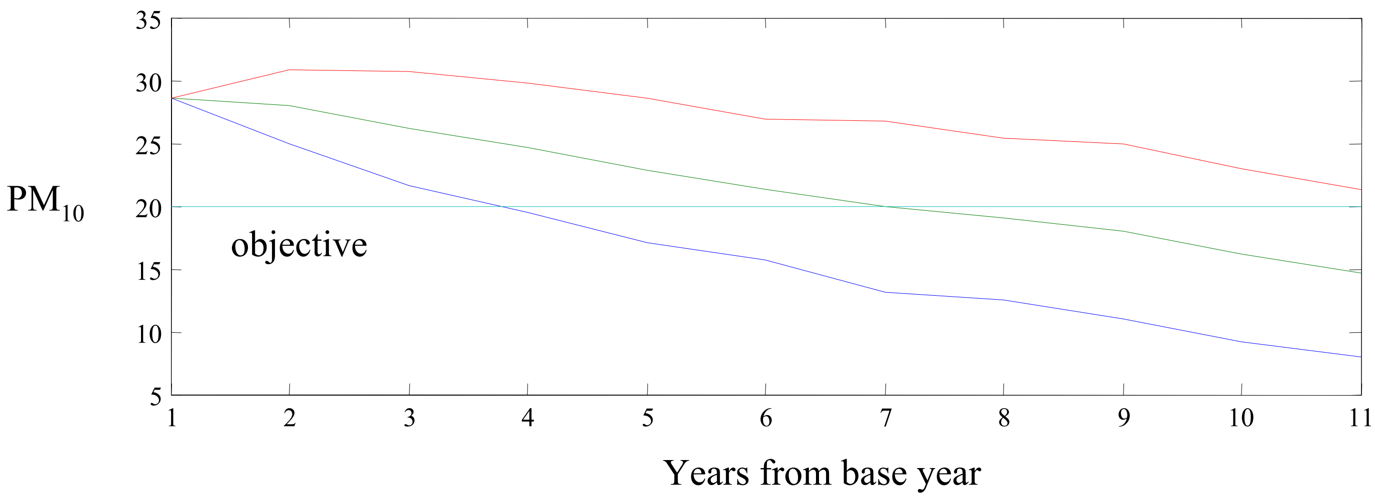
Abbott et al P4-083(5)

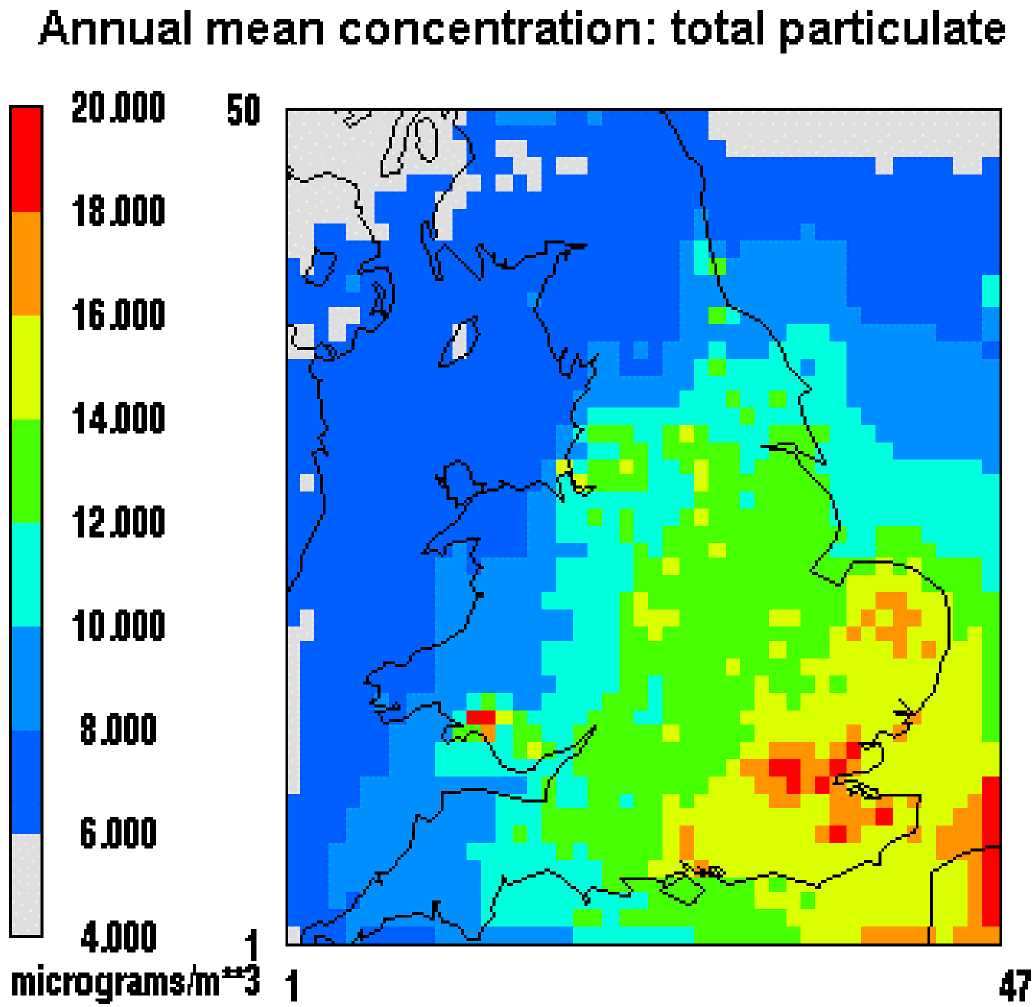
Stochastic forecasting of PM

Possible trends in PM10 concentrations at Bloomsbury taking account of random fluctuations

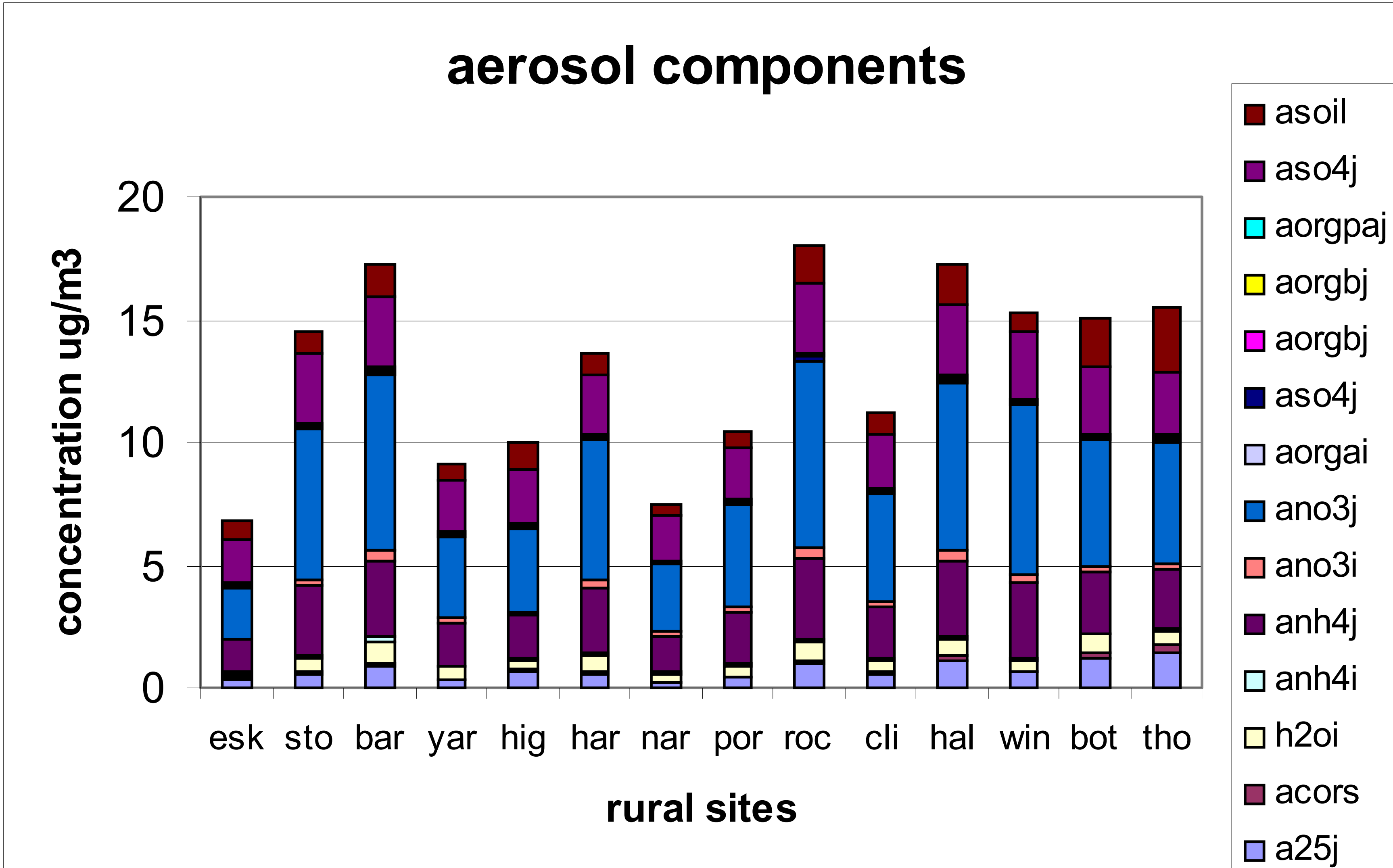


Mean forecast and standard deviation around the mean

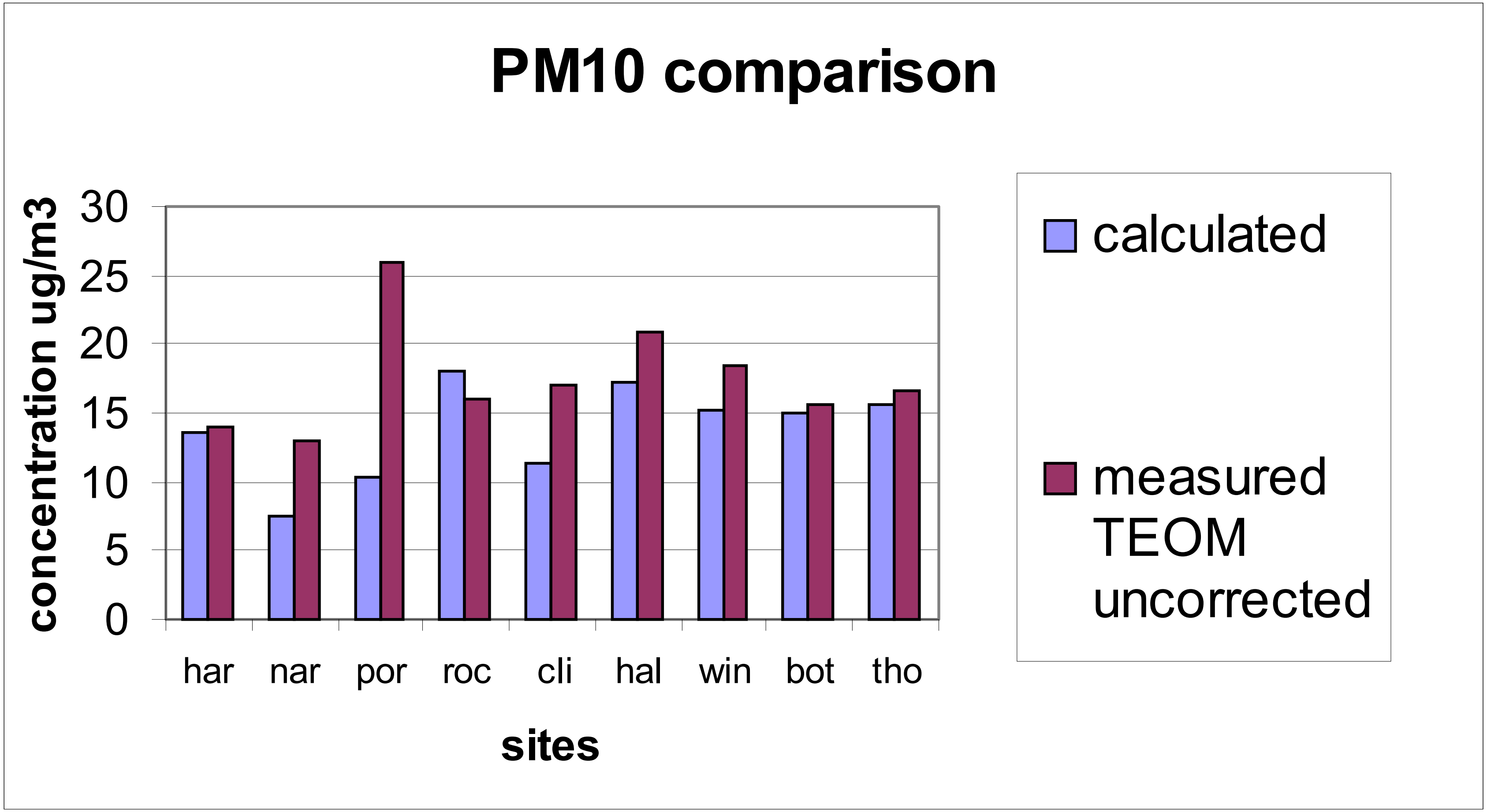




Models-3 calculation for 1999 R&D report Cocks et al



Models-3 PM speciation



PM10 validation for 1999

Uncertainty, fuzzy logic and decision making

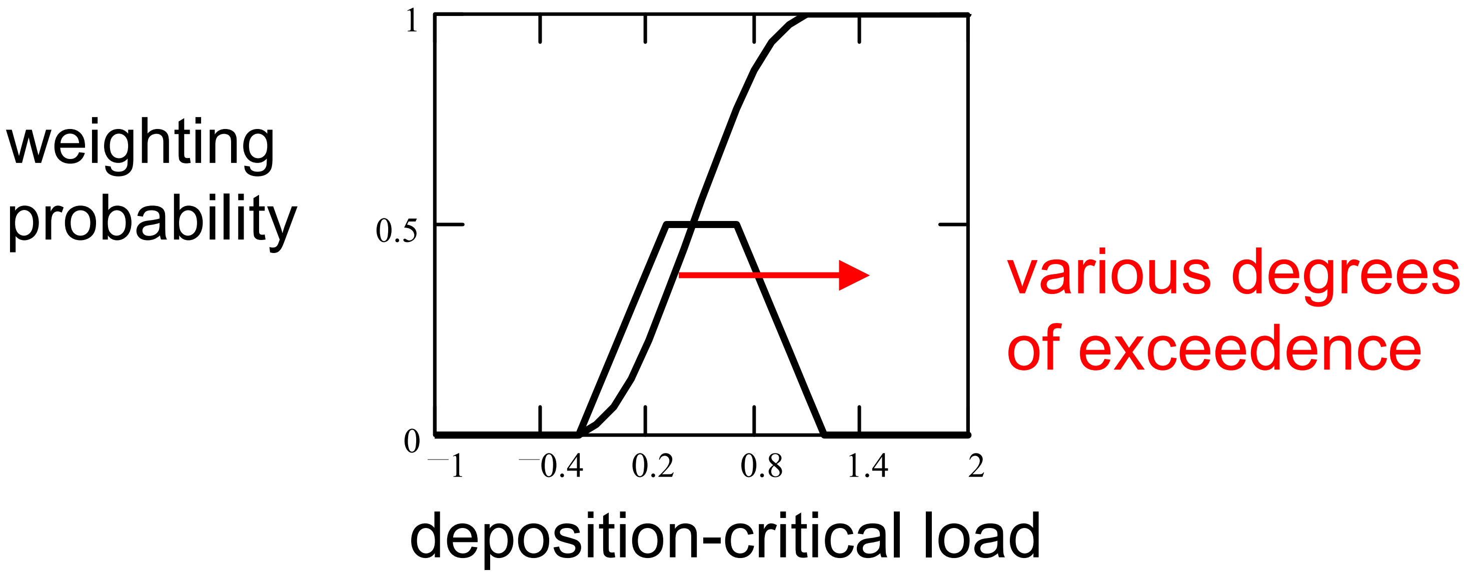
Reductionist approach v fit for purpose

Degree of acceptable uncertainty depends on decision to be made

Fuzzy logic approach when decision involved because other factors assume importance such as speed, efficiency, scenarios, optimisation, soft computing. Explicitly includes judgement.

Reductionist approach implies single answer

Application to critical loads



Monte Carlo estimate of the difference between deposition (uniformly distributed between 0.5 and 1.4) and the critical load uniformly distributed between (0.2 and 0.7).
The probability density function (straight lines) and cumulative probability (curved line) of the deposition minus the critical load

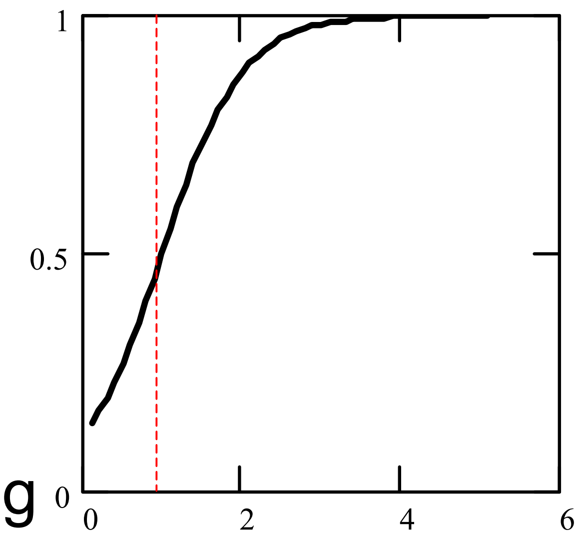
Answer is not just a single number, or yes/no.

Sigmoid weighting to represent uncertainty

Sure of failure

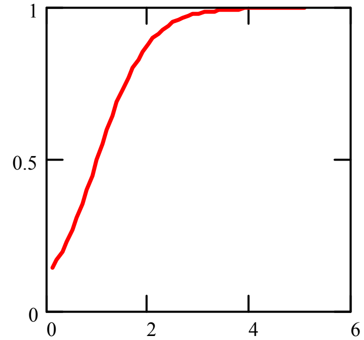
weighting/
probability

Sure of passing



← acceptable - not acc (sharp decision) →

Membership functions depending on the estimate of the deposition/critical load ratio >1 does not absolutely imply failure.
The curved line is the membership function for the unacceptable set described by the sigmoid function $\mu(x)=1/(1+e^{\beta(x_0-x)})$, where x is the ratio of the deposition/critical load, $\beta=2$ describes the fuzziness or uncertainty in setting the criterion. Strict criterion is defined by $x_0=1$.



Penalty function/utility function/objective function is fuzzy

It represents the membership function of a fuzzy set
e.g. the classification between success/failure is not sharp

Applications
wherever decision involves some subjective judgement
(1) Flooding
(2) Flood defence especially intangible factors
(3) Ecology of catchments
(4) Urban quality of life

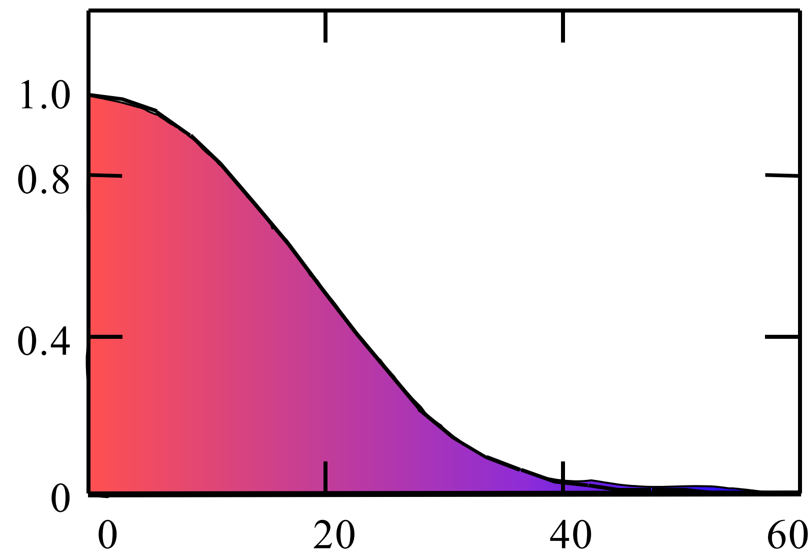
Example of fuzzy set defining AQMA

Membership function

High weighting

$\mu_{AQMA}(x)$

Low weighting



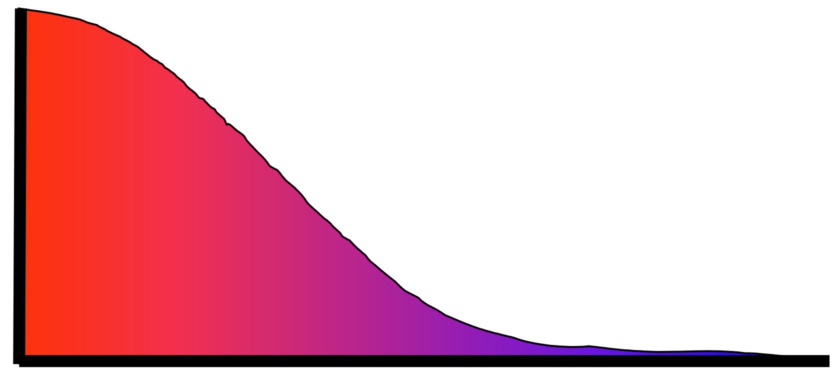
Choose degree of precaution

Location km

Membership depends on AQ standard, concentration and uncertainty.
Fuzzy set defined over region e.g. distance from central London.

Combining two fuzzy sets is the big problem- aggregation

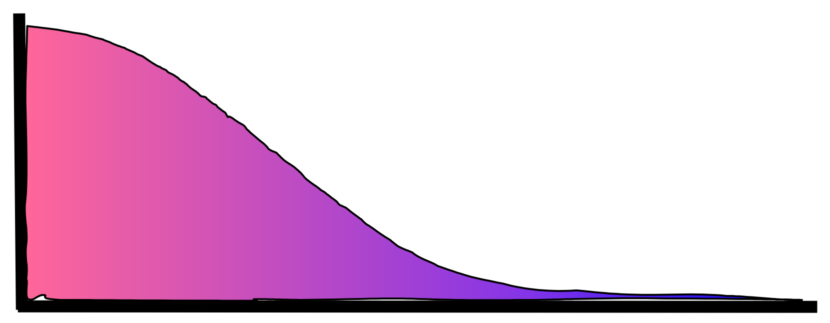
Value of quality criterion A $\mu_A(x)$ e.g. health



Location in city or catchment

How to combine cost functions μ_A & μ_B

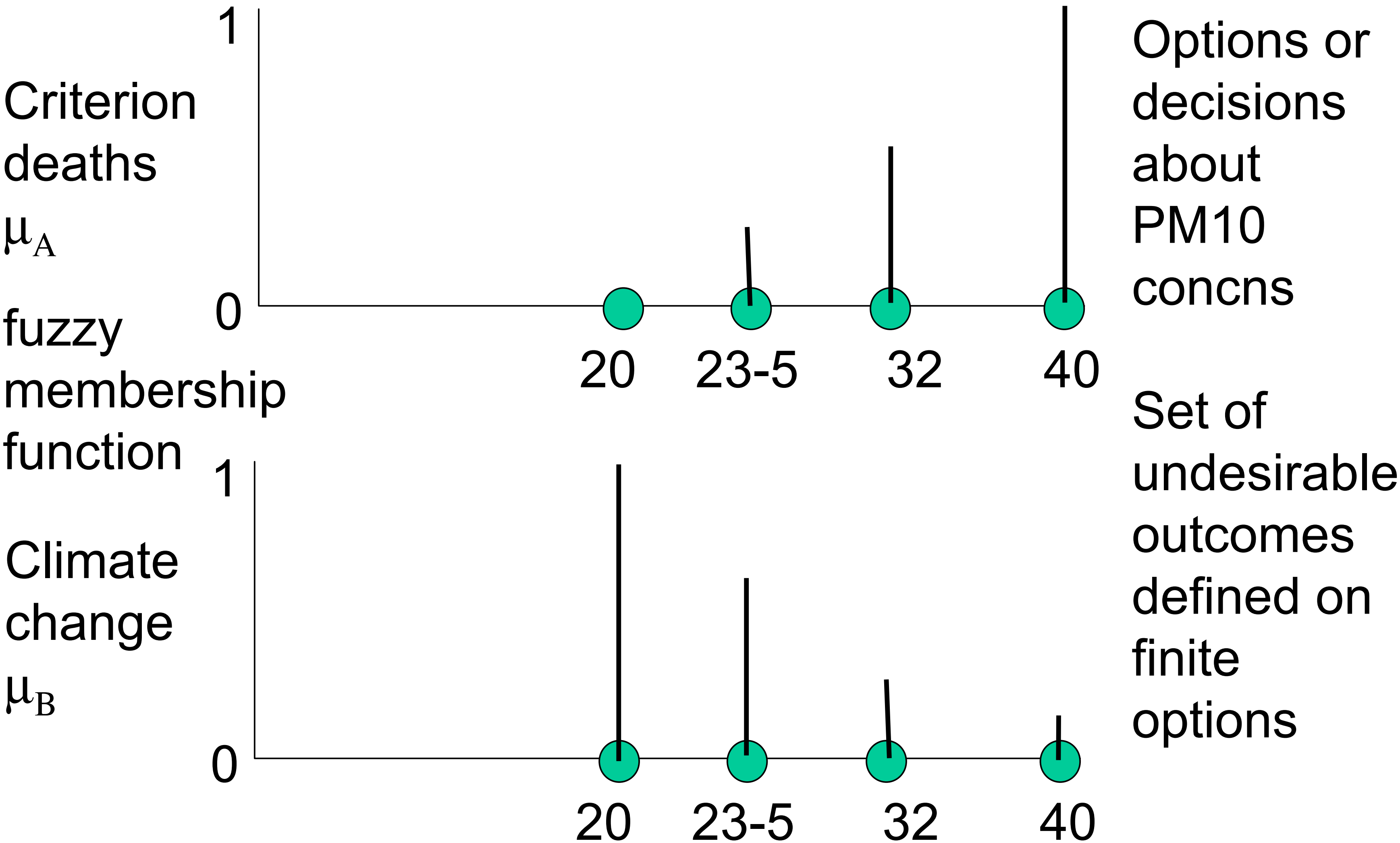
Value of quality criterion B $\mu_B(x)$ e.g. noise



Location in city or catchment

Or the values could be defined over a discrete domain of options

Weighted generalised mean $h(w_A, w_B, \mu_A, \mu_B)$



Weighted generalised mean $h(w_A, w_B, \mu_A, \mu_B)$

w_A w_B weighting functions, μ_A, μ_B criteria

$$h(w_A, w_B, \mu_A, \mu_B) = (\tfrac{1}{2}(w_A \mu_A^n + w_B \mu_B^n))^{1/n}$$

Aggregation

$n \to$ large positive, minimum membership function

$n \to$ large negative, maximum

$n = 1$ arithmetic mean

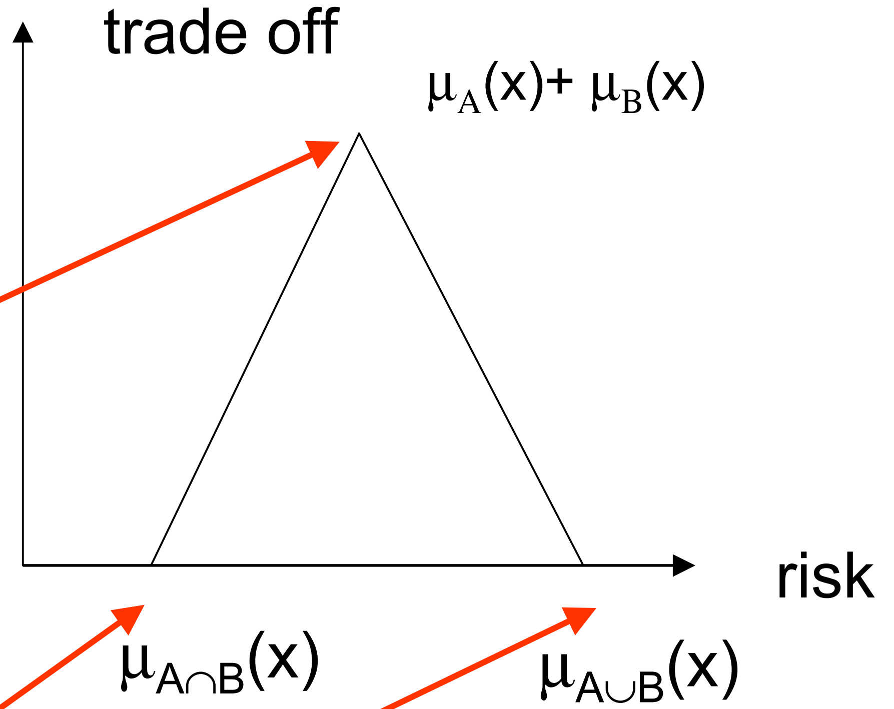
$n = -1$ harmonic mean

$n = 0$ geometric mean

Multicriteria A and B

Weighting criteria

Tradeoffs



Risk taking
AND intersection lowest score
OR union highest score

$x \in X$ where X is set of options, or region of space
Choice depends on decision maker

Conclusions

Large error bounds

Combined environmental criterion is a membership function of fuzzy set

Shape of membership depends on uncertainty

Consistent with other approaches e.g. MCA, environmental burdens

Permits criteria to be aggregated

Contrast with complex deterministic approach