Accounting for Uncertainty in Dispersion Modelling

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Discussion applies to NOx for Road Scheme Assessments

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The Language of Dispersion Modelling

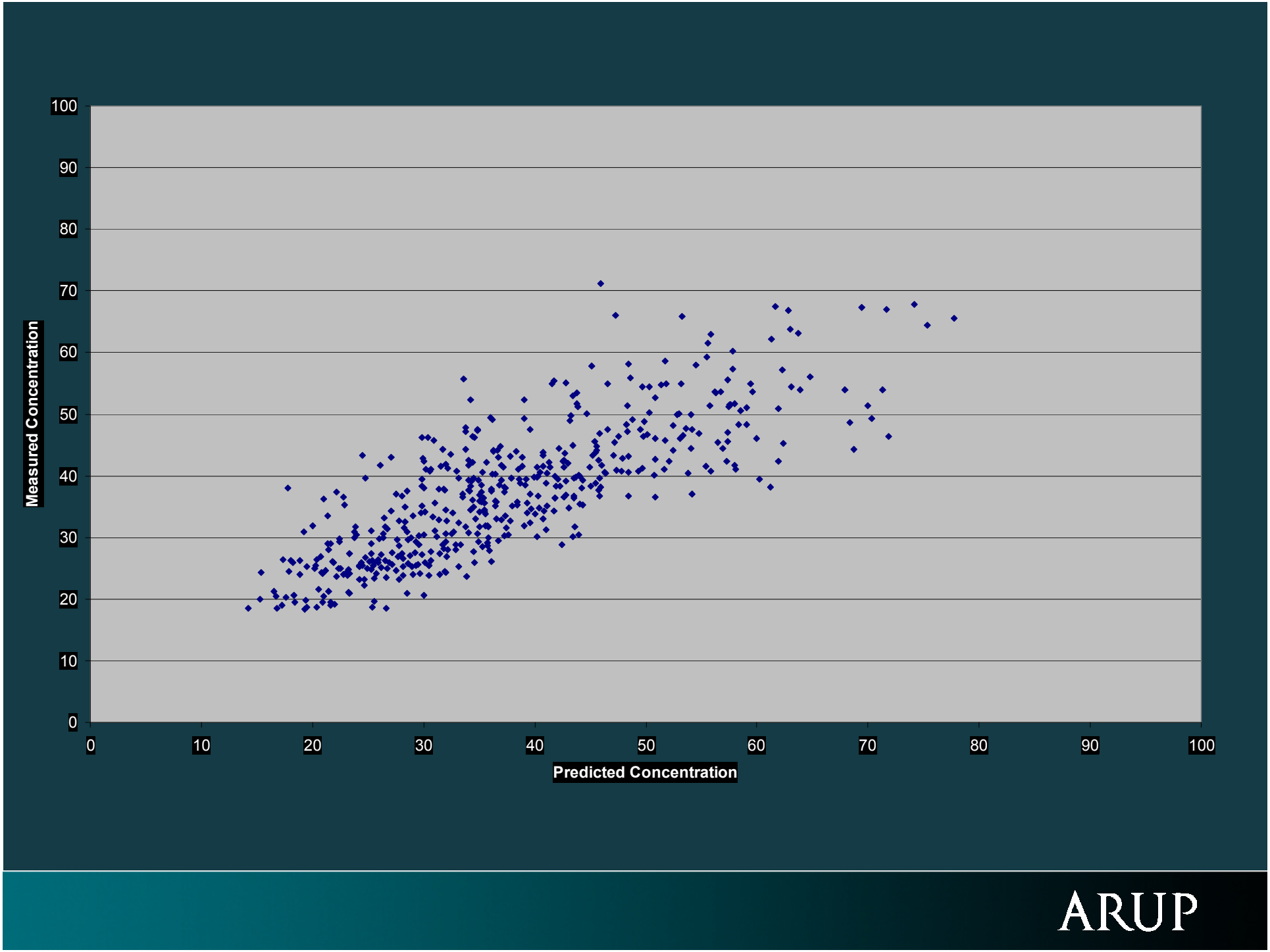
- Sir Ernest Gower in the Civil Service handbook on writing plain English noted that environmental science is one of several branches of learning that has "*spouted luxuriantly*" but "*have not done language much good*"
- Environmental scientists "*strain after expert language … because they are afraid if they are lucid their matter will be despised as elementary*"
- Dispersion modellers are keen to use language such as "*detailed*", "*advanced*" and "*complex*" to suggest rigorous and accurate assessment
- Perhaps it's time to face up to reality and become lucid!

Perfection?

- The perfect model and the perfect monitoring system do not exist
- EU Directives require an accuracy of ±15% for nitrogen dioxide
- Diffusion tube monitoring approximately ±25%
- Automatic monitoring estimated at ±8% in TG01 in 2000
- Dispersion modelling accuracy – reported by ADMLC as 0.5-2.0 in their 7th Report but a wide range of values reported

What Can You Really Expect

- Assume the model has a ±50% accuracy
- Assume the monitoring method has ±20% accuracy
- Assume an underlying 1:1 relationship between the monitoring and modelling results
- What would you expect?


Measured Concentration
Predicted Concentration
0
10
20
30
40
50
60
70
80
90
100

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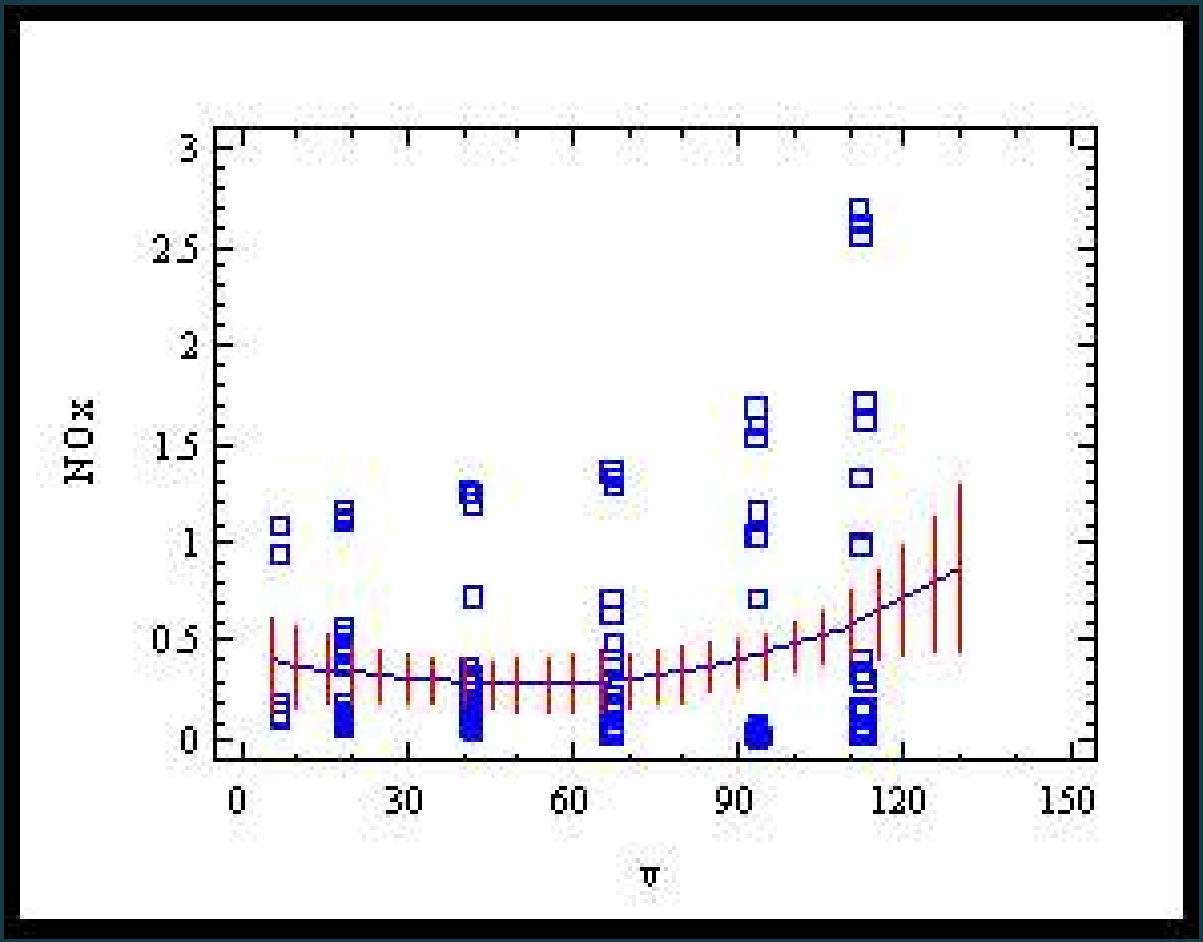
Accuracy in Traffic Flow Prediction

- Individual flows should be within 15% for flows between 700 and 2700 vehs/hr;
- Individual flows should be within 100 vehicles for flows less than 700 vehs/hr;
- Individual flows should be within 400 vehicles for flows greater than 2700 vehs/hr
- Relate to a model of existing conditions and not to predictions of future flows
- Traffic Speeds????

Uncertainty in Vehicle Emission Factors



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Range of Uncertainty in Meteorological Data

Parameter	Uncertainty
Wind Speed	±2 m/s over a region
Wind Direction	±20° over a region
Mixing Layer Depth	±50%
Stability	± Pasquill Stability Category

Source : 7th Report of a Working Group on Atmospheric Dispersion, NRPB R199, 1986

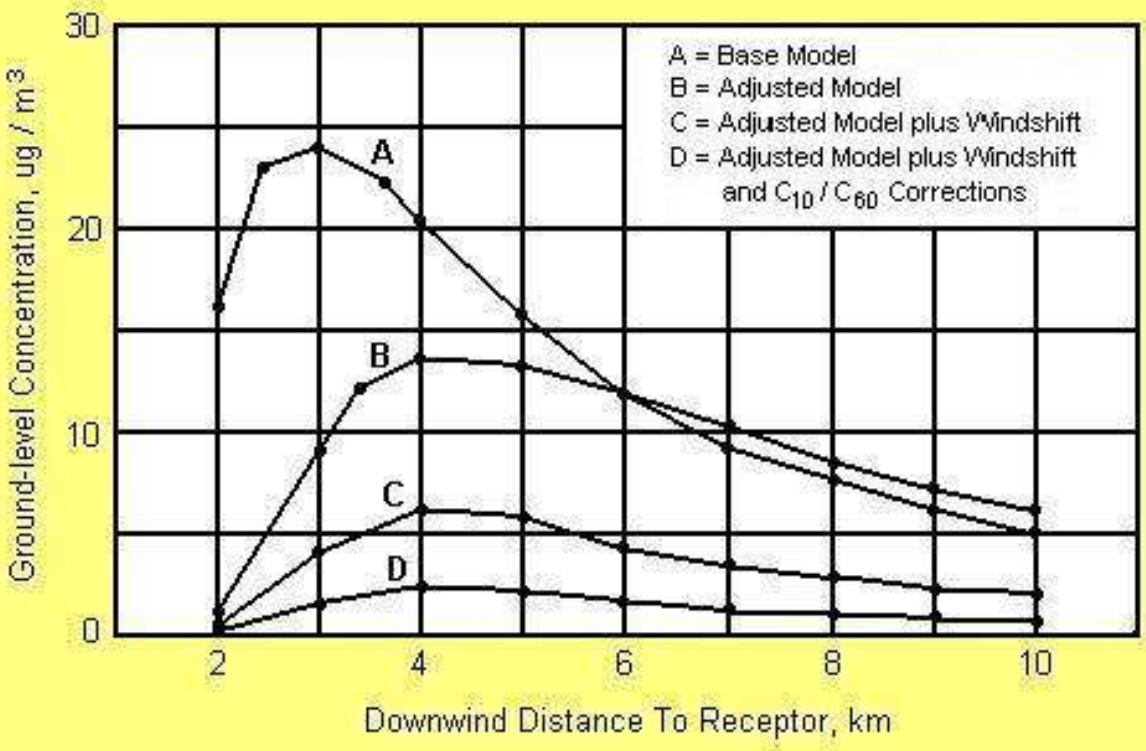
Implicit Model Errors

- Vertical plume spread ±25%
- Horizontal plume spread ±25%
- Many models assume constant wind speed and direction over the modelling domain
- Similarly several models assume constant atmospheric turbulence

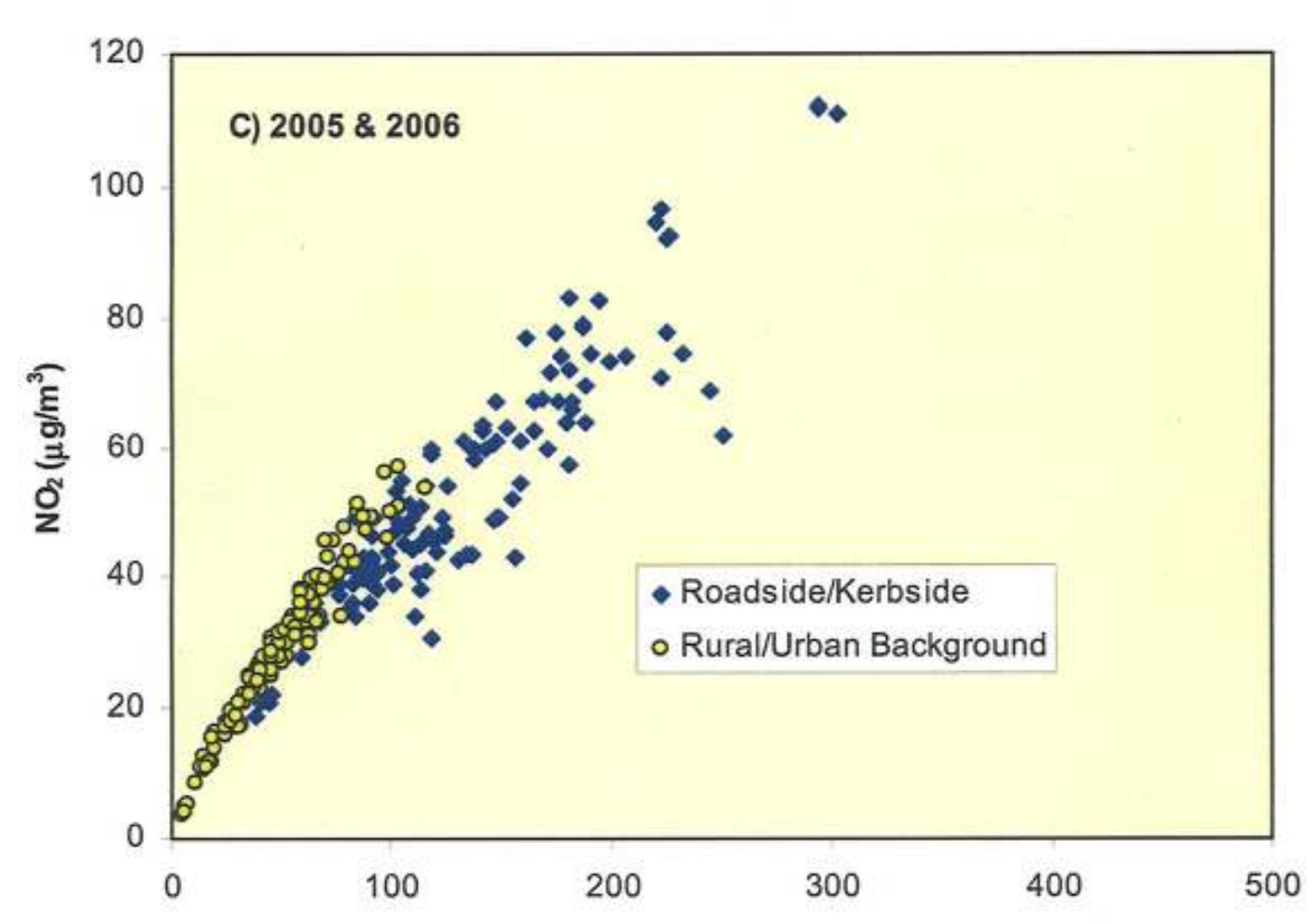
Source : 7th Report of a Working Group on Atmospheric Dispersion, NRPB R199, 1986 and Milton Beychok – Error Propagation in Air Dispersion Modelling (Self Published)

FIGURE 1

EFFECT OF ASSUMPTIONS
ON DISPERSION PREDICTIONS

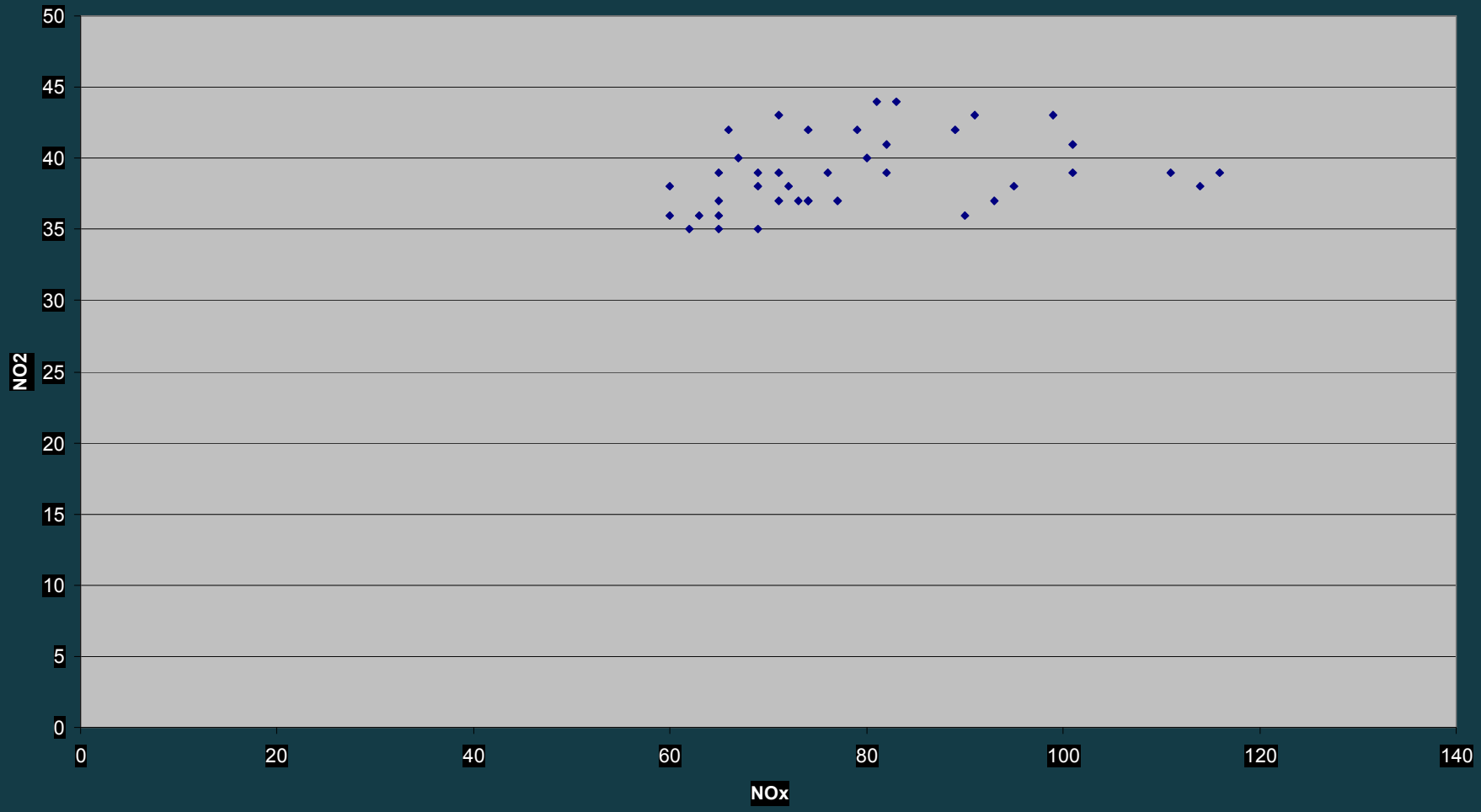


NO_x/NO_2 Conversion



Source – An Updated Approach to Deriving NO2 from NOx for Air Quality Assessments of Roads. Air Quality Consultants 2007

Observed NOx/NO_2 Relationship



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Observations by others

- *Many, if not most, models of atmospheric dispersion and associated risk assessment now used by governments and regulatory authorities are, quite simply, wrong, both scientifically and practically, since they place undue emphasis on mean concentrations. Little or no recognition is given to fluctuations*
- *the issue of uncertainties in atmospheric dispersion modelling has so far been addressed by the scientific community in rather general terms only, and we are still far from established practices*
- *most models predict the average dispersion (over a large number of realizations of the given situation) and not the event-to-event variability about that average. As a result, even a good atmospheric transport model may have single-event errors of more than a factor of ten*

Differences between modelling and monitoring data

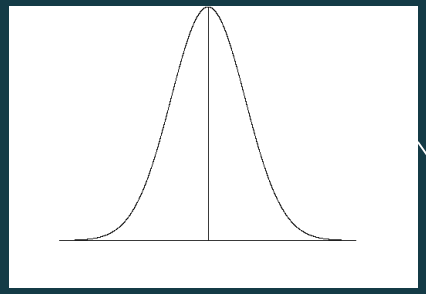
- Models predict a theoretical (ensemble) mean <c>
- Actual observed mean c = <c> + c´
- c´ is a fluctuating component
- Monitoring measures “c”
- Monitoring data is conceptually different from model output – even with perfect input data model output would still differ from observed values
- Also have to account for input data errors

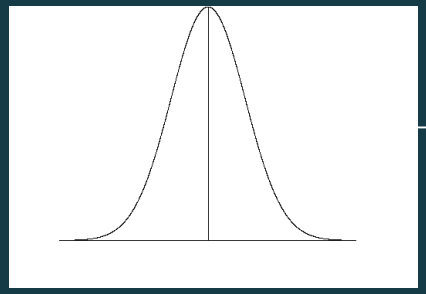
Source – Air Pollution Modelling, Paolo Zannetti, 1990

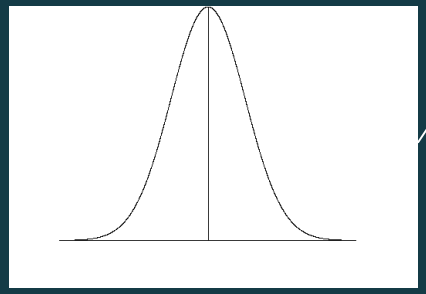
What should we expect

- Even with perfect input data a model isn't wrong if it doesn't predict the same as observed concentrations
- Our expectation (with perfect input data) should be that "on average" models will match observed concentrations but that individual results will not
- If individual results do not match observed concentrations then this is not necessarily an indication the model is wrong or needs adjustment

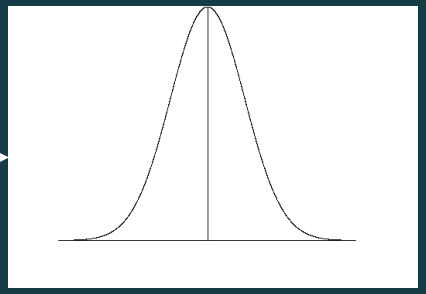
Accounting for imperfect input information
Monte Carlo approach (Bottom up approach)







Model samples from input distributions

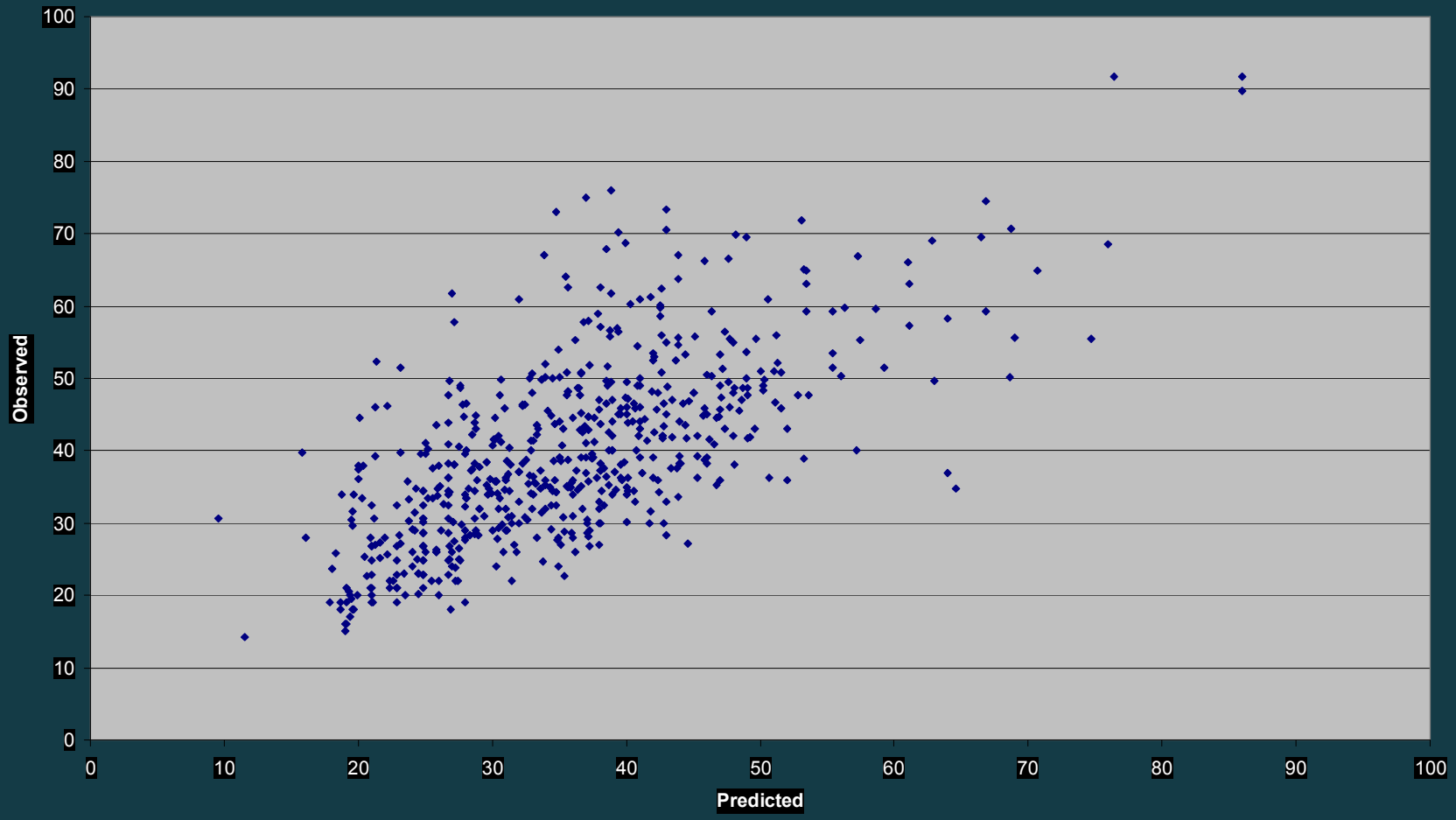


Output as probability distribution

Monte Carlo Approach

- Requires input information as a probability distribution
- Currently this information is not readily available
- Requires repeated model runs, must be sufficient runs to get a valid output distribution
- Difficult to apply for most models owing to computer run times required
- Does not account for internal model error although results could be processed to assess this
- Would however, give good information on the range of possible results and their probability

Working top down – Looking at what happens in practice



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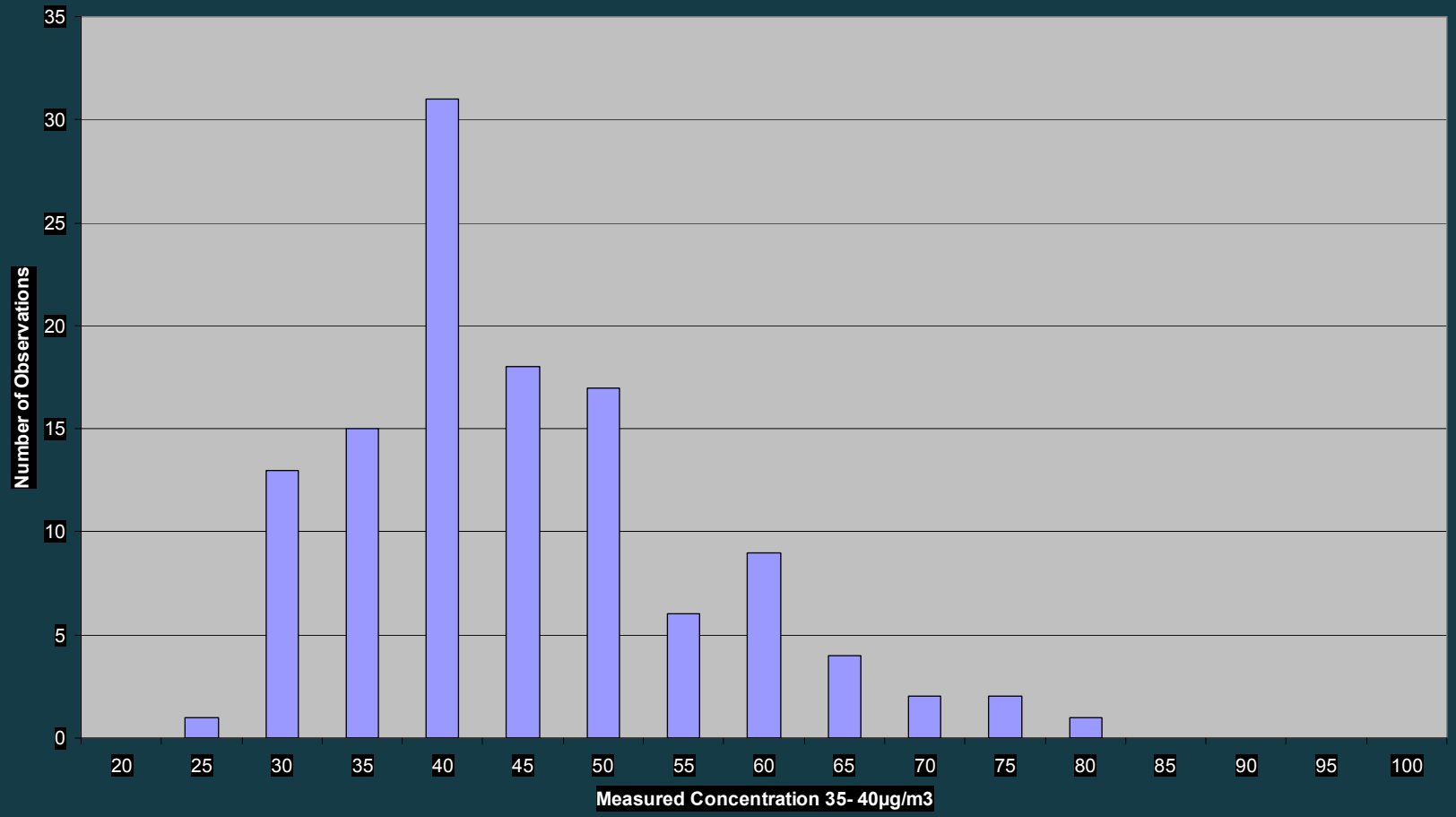
If you predict 35-40µg/m3 with a model?



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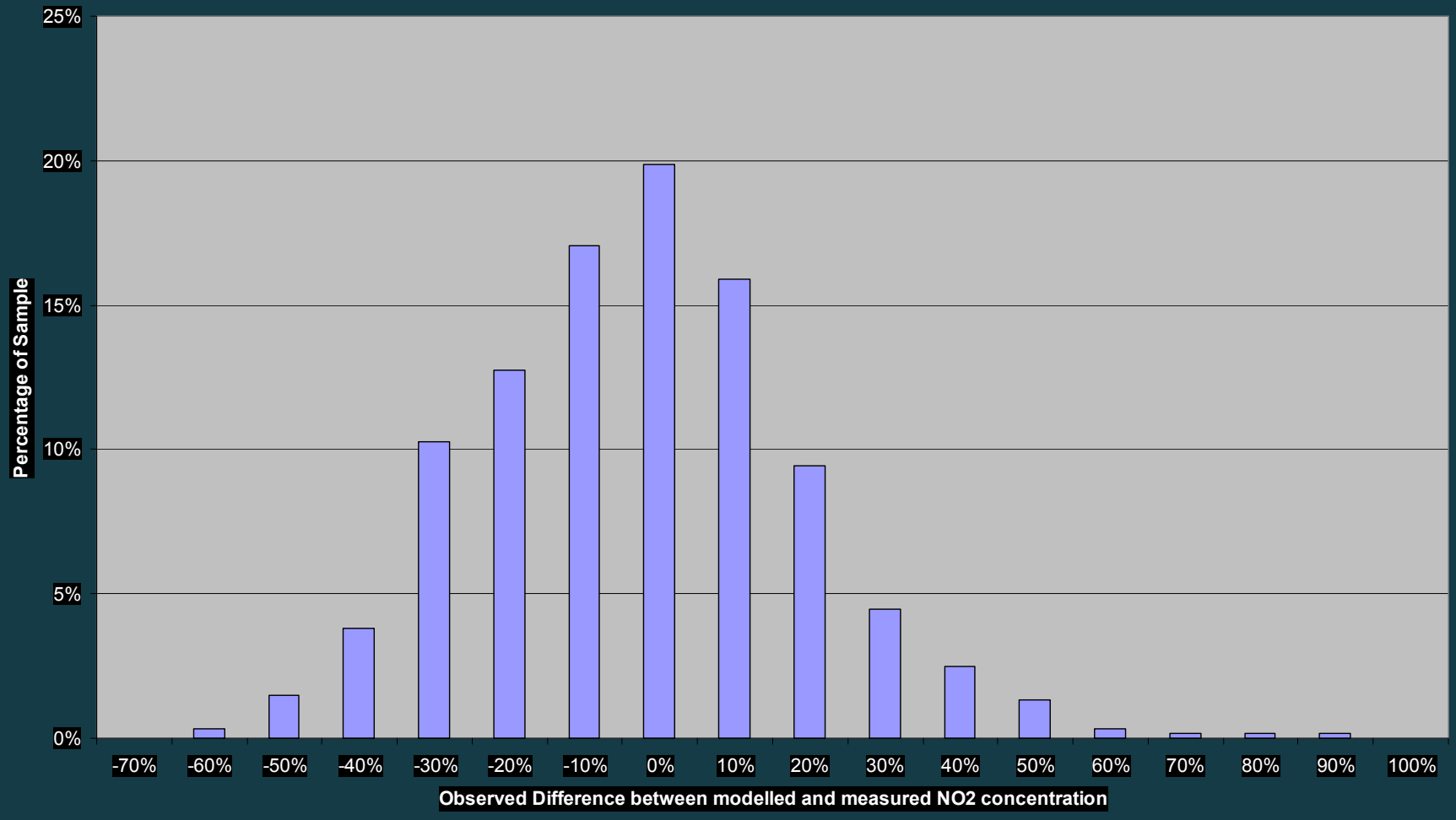
What can we do?

- Acknowledge we are dealing with a process that contains uncertainty
- Input data to models represent our best estimate of a range of possible values
- The processes within the dispersion models represent our best estimates of a range of possible values
- Use of best estimate values does not mean you calculate the most likely result
- Shouldn’t attempt to impose certainty on an uncertain system

We're not actually that bad



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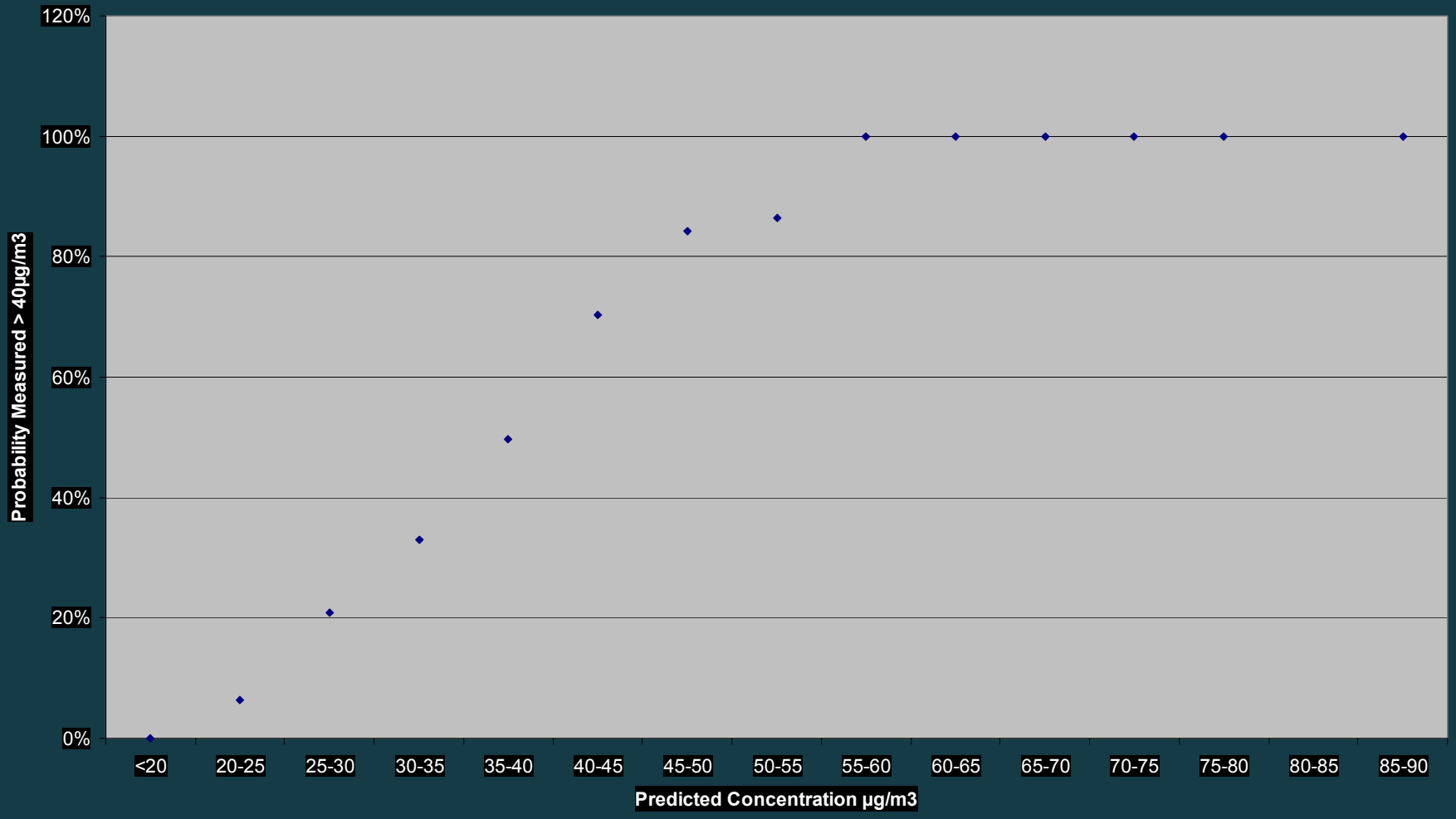
But ....

- Only 75% of the results are within 20% of the observed concentrations
- Need to acknowledge the possible range or the probability of exceeding a particular concentration.
- Shift to a risk based approach for reporting
- Acknowledge that sometimes a modelling approach doesn't work

Risk of exceedance observed by AEA

Predicted Concentration (µg/m3)	Chance of Exceeding Objective
<28	<5%
28-34	5-20%
34-40	20-50%
40-46	50-80%
46-52	80-95%
>52	>95%

Risk of exceedence of the 40µg/m3 objective Observed in UK Review and Assessment



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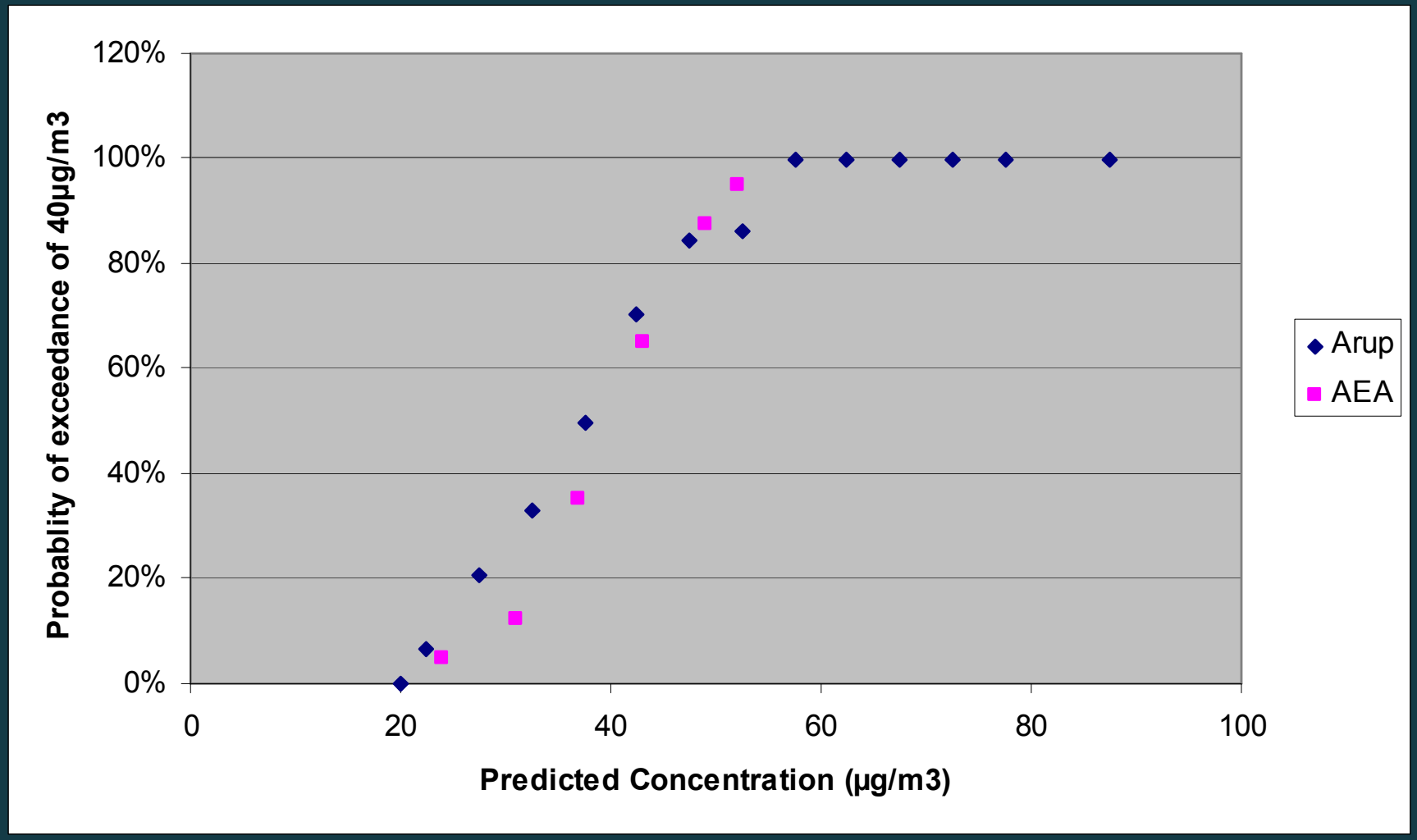
Comparison of risk datasets



Conclusions

- Face up to, rather than hide from uncertainty
- Be realistic about how to report results
- Using a risk based approach is an appropriate and honest method for reporting
- Consider use of probabilistic modelling approach