TXU

Predicting Ambient Concentrations of Sulphur Dioxide

Sulphur Dioxide in the UK

- 65% of total emissions are from coal-fired power stations
- Majority of the rest is from other industrial point sources
- Traffic is <5% of total & falling
- Contrast with far wider range of sources of particulates and nitrogen oxides

Impacts of Sulphur Dioxide Emissions in UK

- Annual averages in all locations are low (< 5ppb) - even beside large point sources
- Short-term peak concentrations can exceed AQS objectives locally around sources
  - Most onerous is objective of < 35 exceedances of 100 ppb 15 minute concentration
- Elsewhere, AQS objectives are already achieved - ahead of 2004/5 deadlines

Predicting Sulphur Dioxide concentrations

- Only specific locations close to point sources are of concern
- Predictions of interest are for short-term peak concentrations from these point sources
- Prediction example: Coal-fired power stations

Ground level concentrations are determined by:

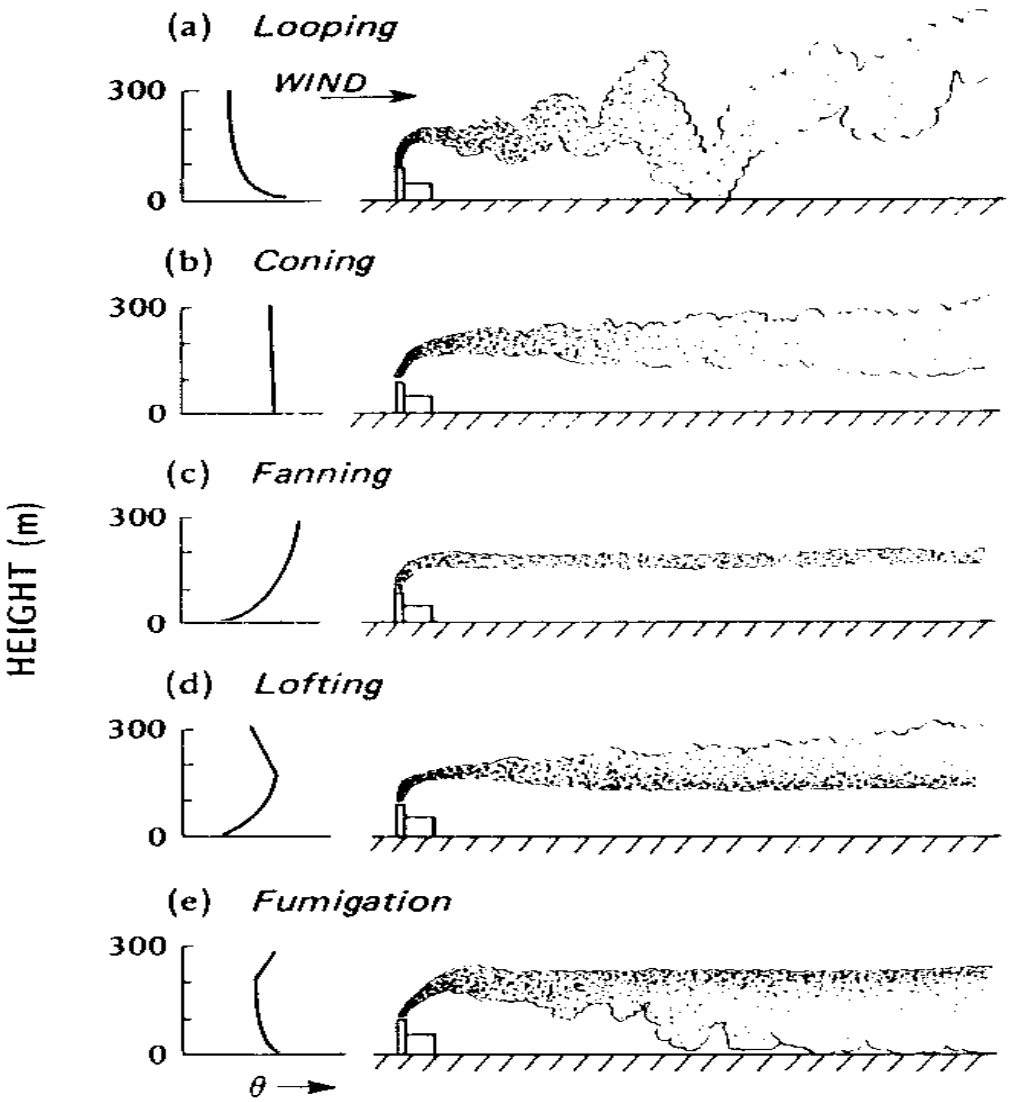
- Emission rate of pollutant
  - predictable, relatively constant
- Rate of dispersion of plume through atmosphere
  - depends on stack exit conditions, atmospheric conditions, (topography, buildings)
  - atmosphere is unpredictable, constantly varying

Coal Station Plume Dispersion

- **Extensive dilution of plume in transit**
- **Very low ground level concentrations for vast majority of time (annual average SO_2 ~1-2 ppb)**
- **Very occasional high peaks during adverse meteorological conditions**
- **99.9th percentile (worst 8 hours of year) can be >100 ppb**
- **Maximum concentrations typically occur 3 to 6 km from stack in very localised zones**

When do power stations cause high concentrations?

- **Low boundary layers (300 - 500m) with some convection**
- **Some highly convective situations**
- **Sometimes in strong winds (> 8 m/s)**


(a) Looping
WIND
300
0
(b) Coning
300
0
(c) Fanning
300
0
(d) Lofting
300
0
(e) Fumigation
300
0
θ
HEIGHT (m)

Short-term sulphur dioxide peaks

- Peaks are very sharp
- Peak events are of short duration (2 hours at most)
- Peak events are localised, not regional
- Concentrations before and after peak often close to annual average
- Presents a major challenge for prediction

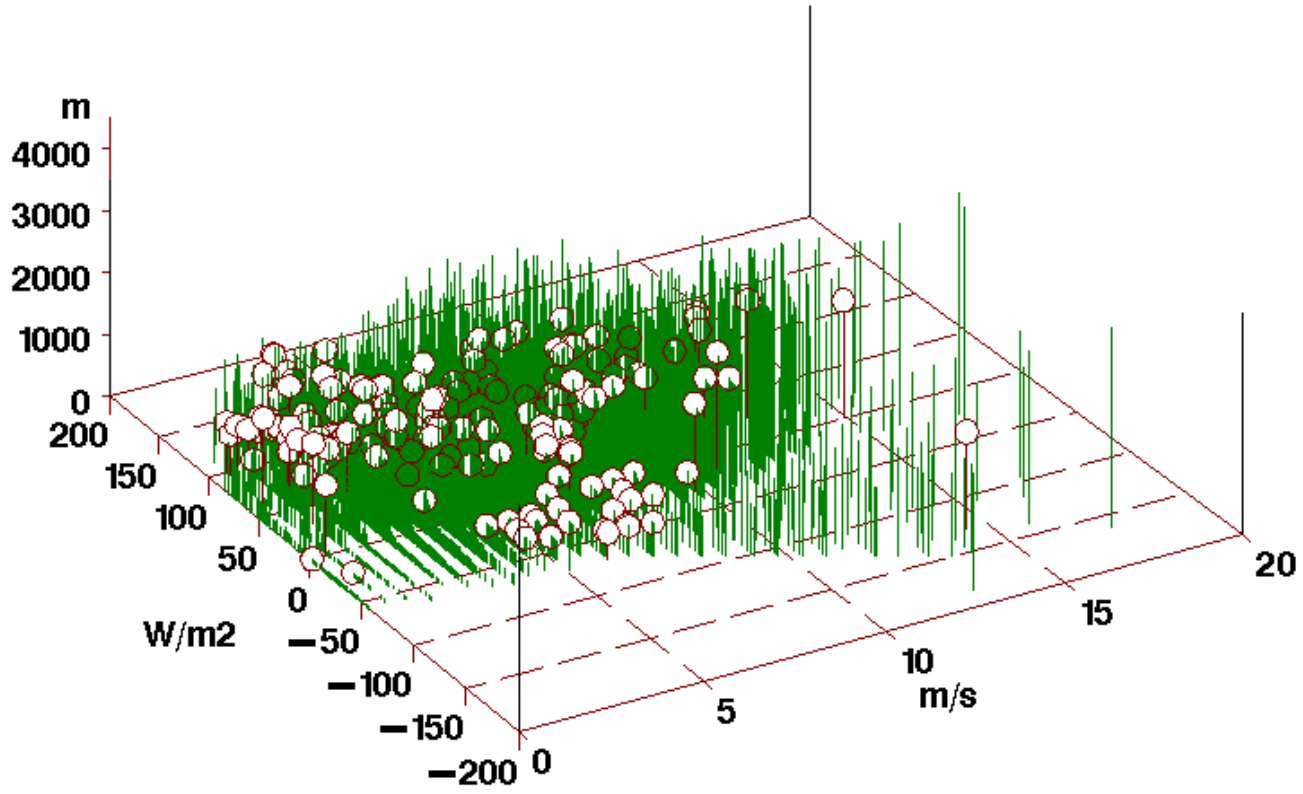
Predicting Plume Dispersion

- General correlation of monitored events with specific meteorological parameters
- But too random for individual short-term peak event predictions
- Prediction requires some form of dispersion modelling (e.g. ADMS, Aermod)

Thorney 1995 and 1996 data

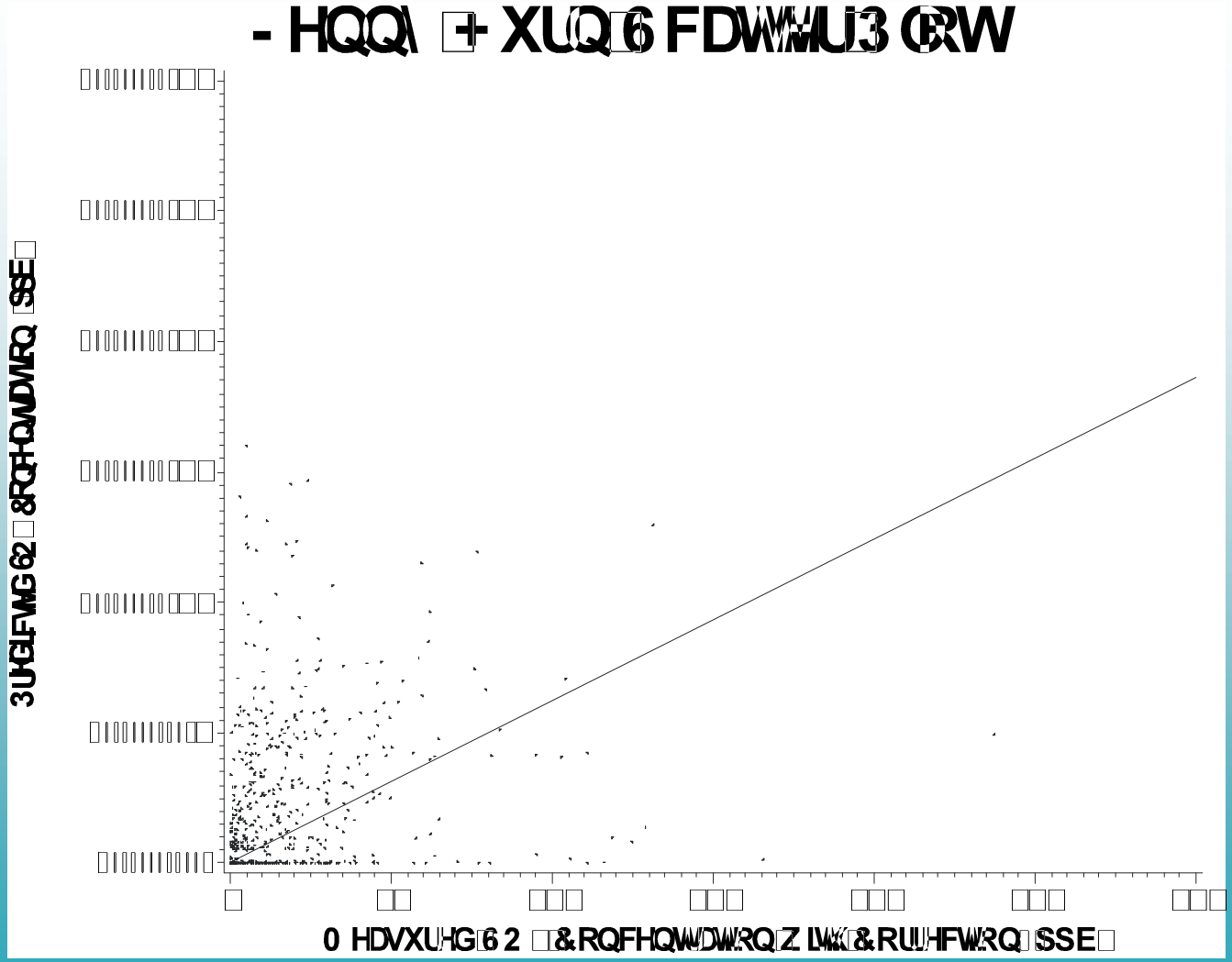
Boundary Layer Height (m) as a function of Wind Speed (m/s) and Heat Flux (W/m2)

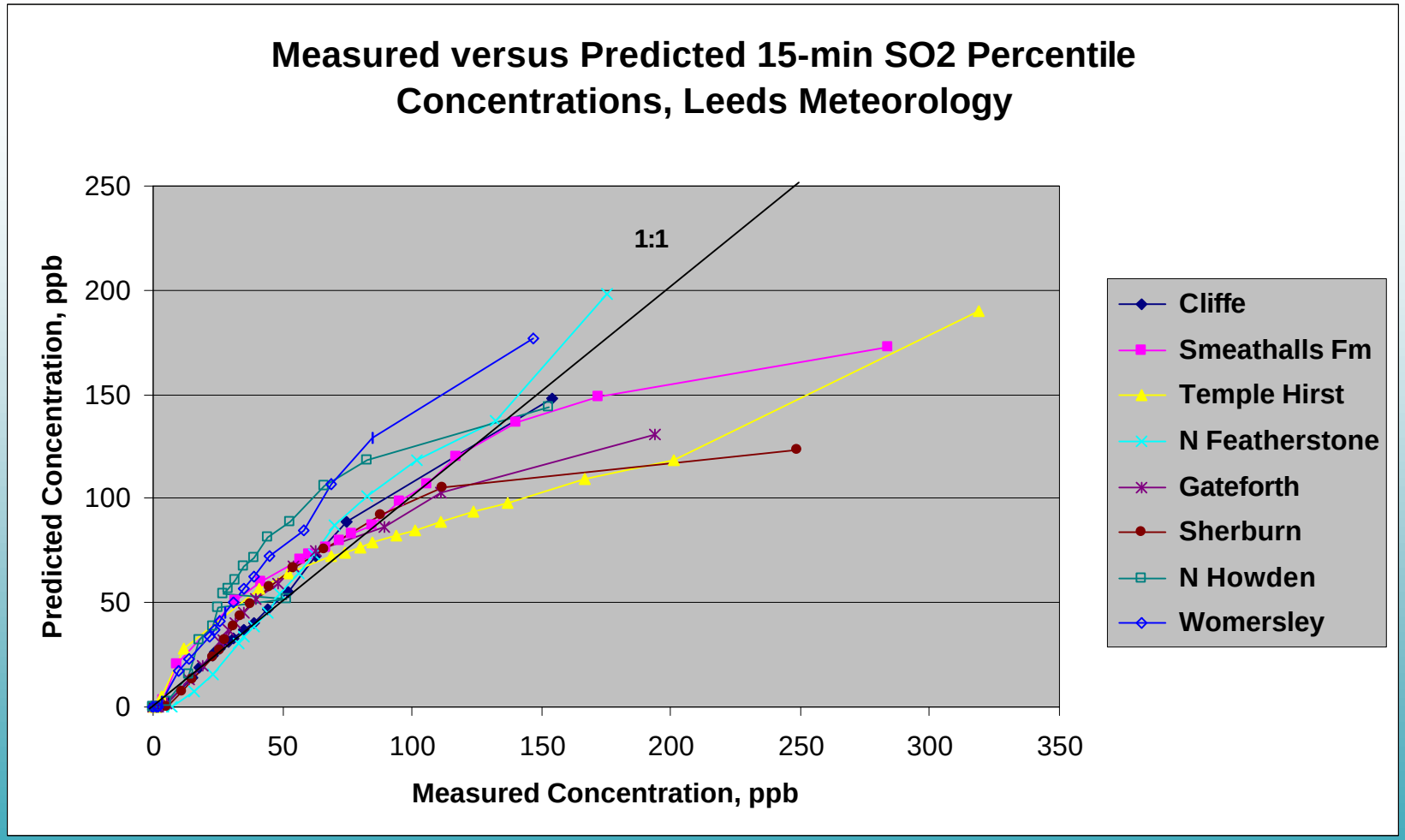
Exceedances of 100ppb in red (with sphere)



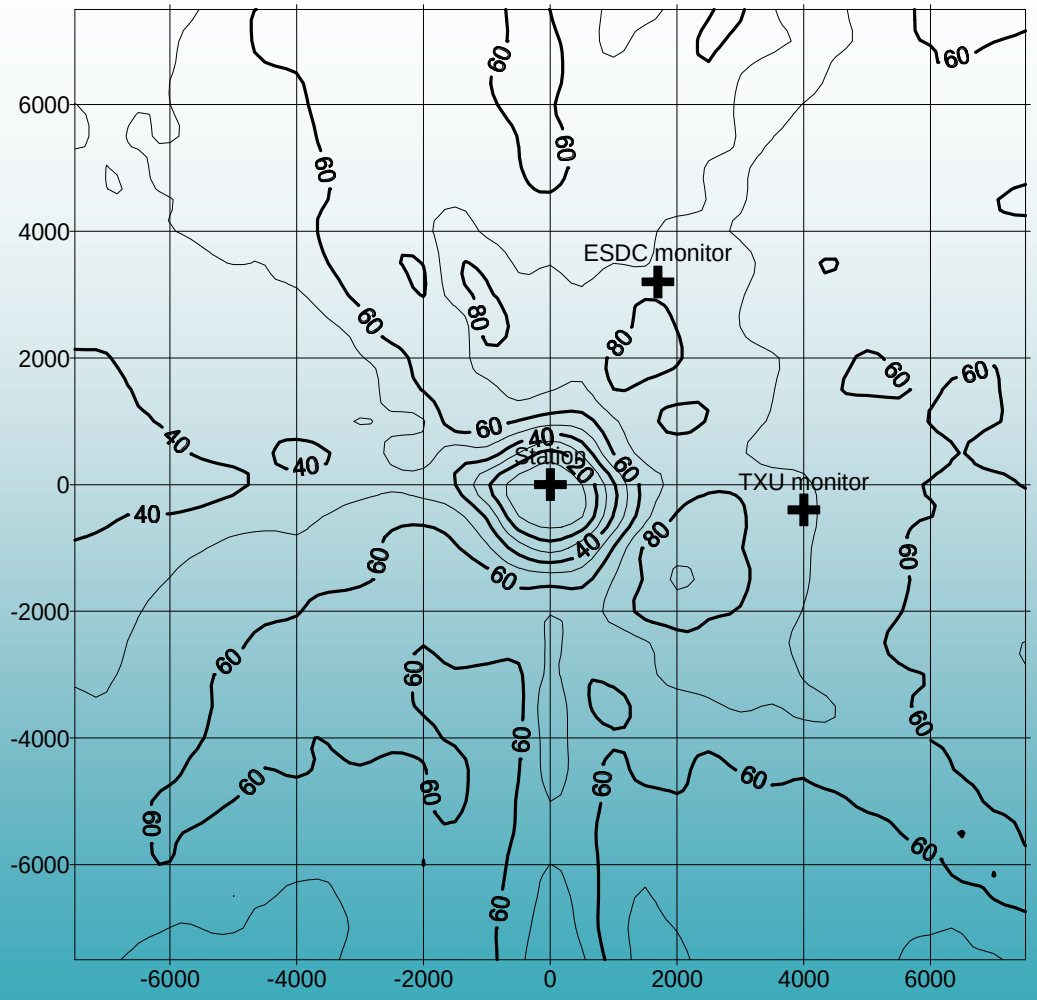
Challenges for modelling short-term peak concentrations

- Dispersion models are most accurate for long-term mean ensemble predictions
- Good agreement of cumulative percentile predictions with monitoring data - for full year
- But the correspondence between individual hourly predictions is close to random


- HQQ\ + XUQ6 FDWWHU3 ORW
3UHGLFWHG62 &RQFHQWUDWLRQ SSE
0 HDVXUHG62 &RQFHQWUDWLRQ SSE


Measured versus Predicted 15-min SO2 Percentile Concentrations, Leeds Meteorology
Predicted Concentration, ppb
Measured Concentration, ppb
0
50
100
150
200
250
300
350
1:1
Cliffe
Smeathalls Fm
Temple Hirst
N Featherstone
Gateforth
Sherburn
N Howden
Womersley

ADMS Predictions



Trial “Protocol”

- **Trial “Protocol” for predicting sulphur dioxide dispersion by power industry in 1998**
- **Scheme formed part of IPC Improvement conditions set by Environment Agency**
- **Objective was to investigate:**
  - **whether a predictive management scheme could produce a reduction in numbers of EPAQS 100 ppb exceedances**

Basis of Protocol

- **Protocol based on modelled predictions of "event days" using forecast Met data**
  - **Event day = a day in which an EPAQS exceedance occurred**
- **Avoids need to predict exact hour of event**
- **Avoidance action taken through entire day**
- **Would extended one day "action window" sufficiently reduce overall uncertainty?**

Protocol Features

- **Complex system - in essence:**
  - **Automated day ahead air dispersion modelling with predicted Met data**
  - **Check whether expected emissions would lead to AQS exceedance event**
  - **If so, adjust planned plant operation/fuelling to reduce emissions & avoid event**
  - **Full Year “Virtual” Trial carried out at 3 stations during 1998 as a JEP project**

Findings from Protocol

- Poor correlation between predicted & actual events - and overprediction of event numbers
- Best available forecast data limits correct day-in-advance prediction of exceedances to about 50%
- Modelling uncertainty reduces correlation further
- False positive “action days” could be as high as 65% of all days
- Extended one day “action window” does not sufficiently reduce overall uncertainty

Conclusions of Protocol

- **Protocol initiating action too often & too randomly to be effective**
- **Costs of unnecessary load reduction would be very high - similar to FGD - but FGD guarantees AQS compliance**
- **Makes a system of local air quality management based on forecast meteorological data and computer modelling very inefficient and expensive**

Outcome of Protocol

- **Protocol clearly not BATNEEC**
- **More flexible approach needed to achieve SO_2 AQS objectives in 2004/5**
- **Operators proposed a combination of new A limits & "AQS Management Plan"**
- **Based on Annual Mean Ensemble modelling predictions**

AQS Management Plan

- From modelling - derive AQS “envelope of compliance” scenario with annual emission “A limit”
- Establish monitoring sites at locations of modelled maximum station impacts
- Annual Review compares modelling & monitoring and refines future scenario predictions
- Iterative convergence on actual impacts in 2004/5

AQS Management Plan Strategy

- **Management of the overall “risk” (or probability) of total no. of exceedances over the full year**
- **Not the individual exceedance events**
- **May include assessment of differing seasonal risk**
- **Ultimate compliance is judged by monitoring**

Conclusions

- **Hourly & daily predictions of concentrations from point sources have low accuracy**
- **Largely inherent in model sensitivity & limited accuracy of Met parameter forecasts**
- **Very extreme events are even less predictable**
- **Best prediction & management of sulphur dioxide peak concentrations is on an Annual Mean Ensemble basis**