Using Plume Rise Schemes To Model Highly Buoyant Plumes From Large Fires

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Outline of talk

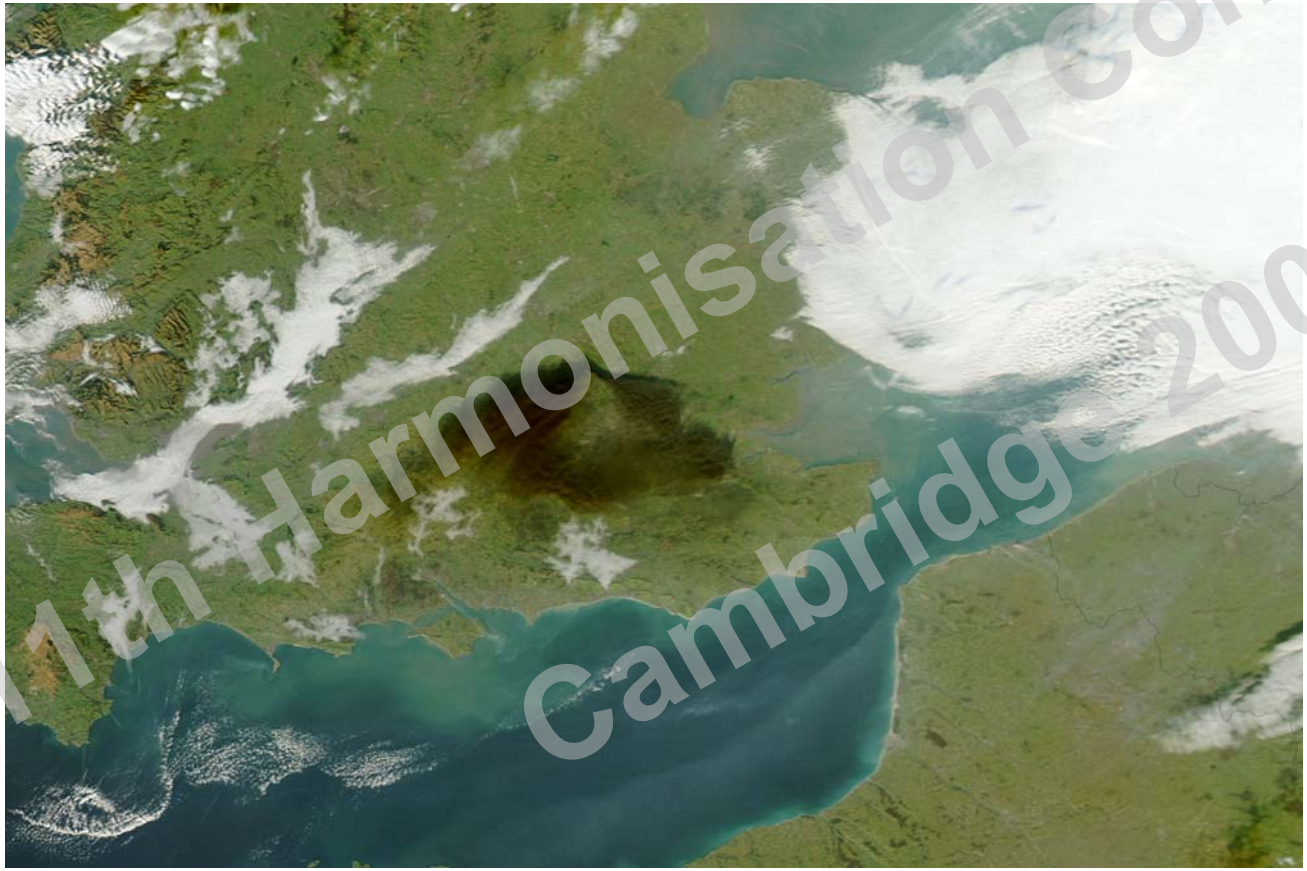
- Buncefield oil depot explosion
- NAME modelling of incident
- Plume rise modelling inaccuracies
- Conclusions

The Buncefield Oil Depot Explosion

06UTC Sunday 11th December 2005
Hemel Hempstead, UK

- Largest peacetime fire in Europe to date
- ~40 million litres of fuel burnt
- At height of fire, 20 large fuel storage tanks on fire
- Fires burned for 4 days
- Thick black smoke plume visible from space

Visible Satellite Imagery

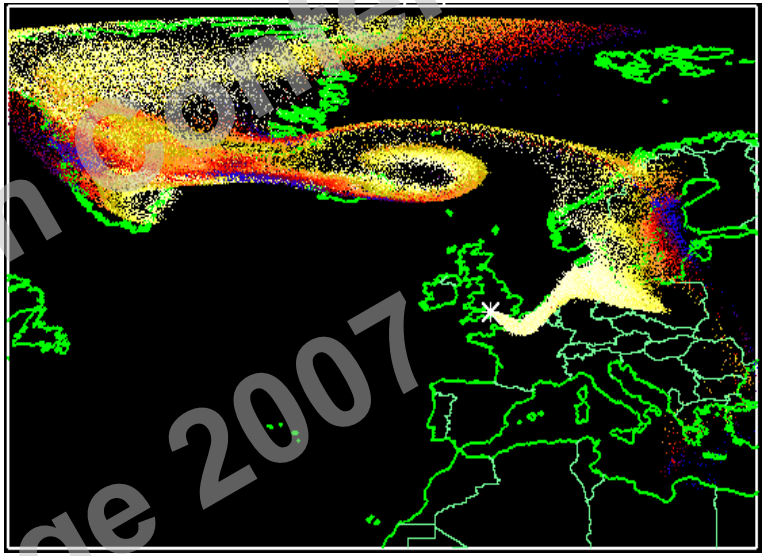


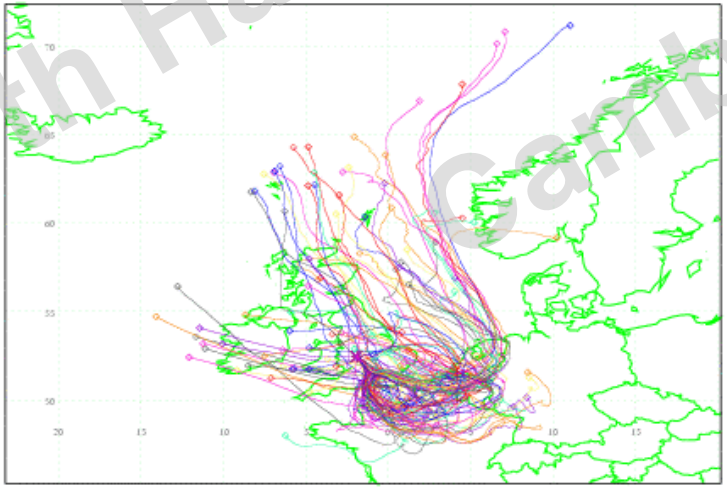
- Significant vertical wind shear
  → fan-like plume

3-D modelling essential

NAME – Numerical Atmospheric-dispersion Modelling Environment

- Lagrangian particle model
- Particles carried along by the ambient 3-D wind
- Random turbulent wind components represent effects of turbulent diffusion processes



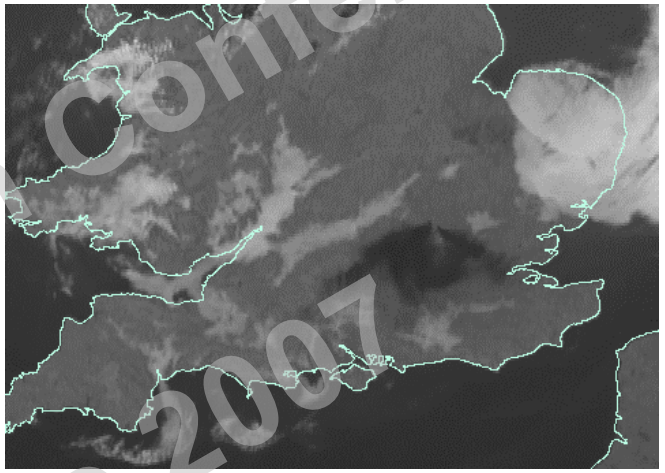


- NAME used to predict the transport and spread of the Buncefield plume

Initial NAME Modelling

- Uncertainties
  - Source / release details
    - Composition
    - Quantity of material
    - Plume rise
- Initial modelling
  - Unit release of tracer
  - Utilising observations to best estimate plume height
    - Aircraft
    - Satellite imagery
  - Simple elevated source
  - Use NWP meteorological data
    - 12 km horizontal resolution

MSG 12:00UTC 11 Dec



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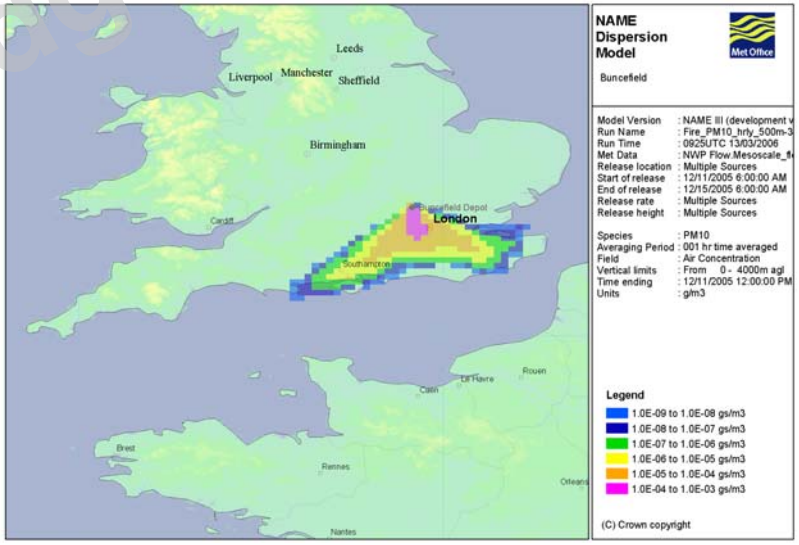

Plume rise modelling

- NAME plume rise scheme
  - Conservation equations of
    - Mass
    - Momentum
    - Heat
  - Simulates the initial rise due to buoyancy using estimates of the heat release rate

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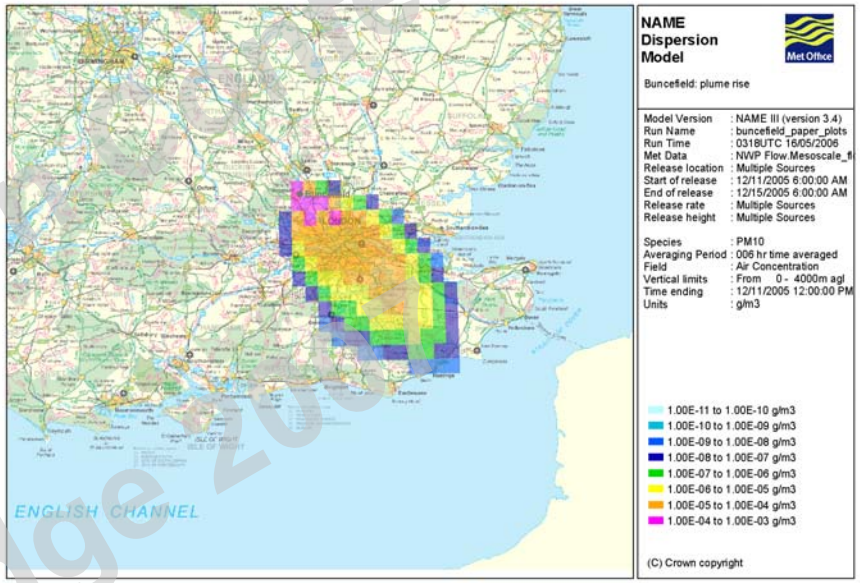

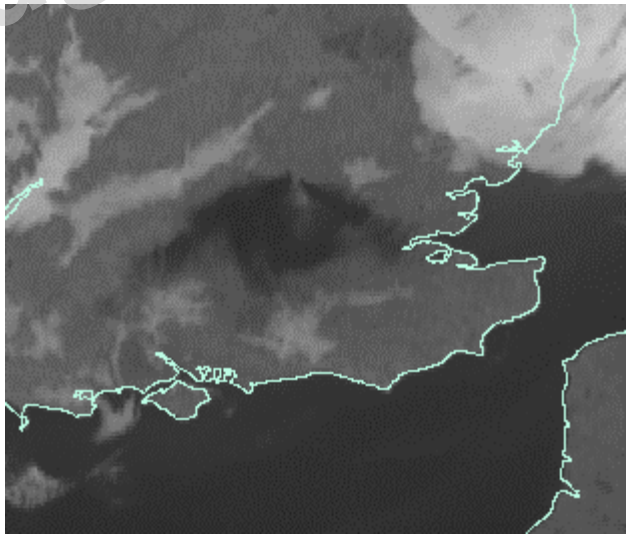

- Maximum height too low
- Insufficient vertical spread

Inaccurate heat release rate estimate?

- Source uncertainties
  - Underestimate of heat release rate?

Maximum height of the plume increased

But…

Still insufficient vertical spread of the plume

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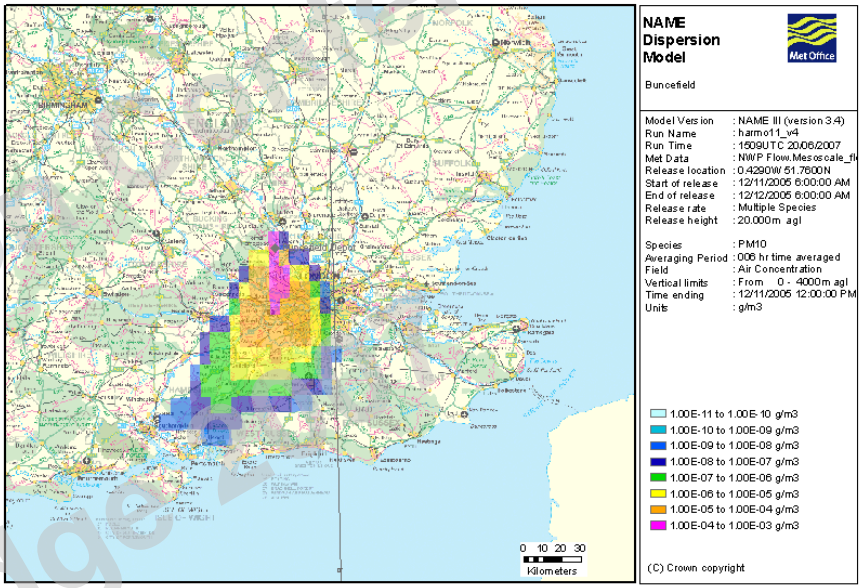
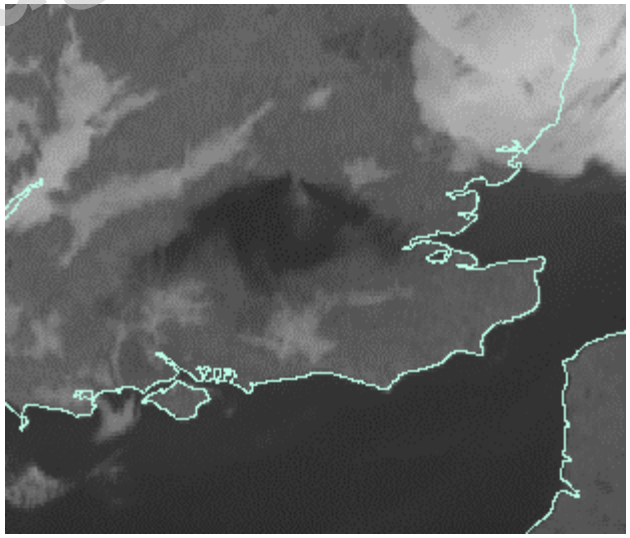
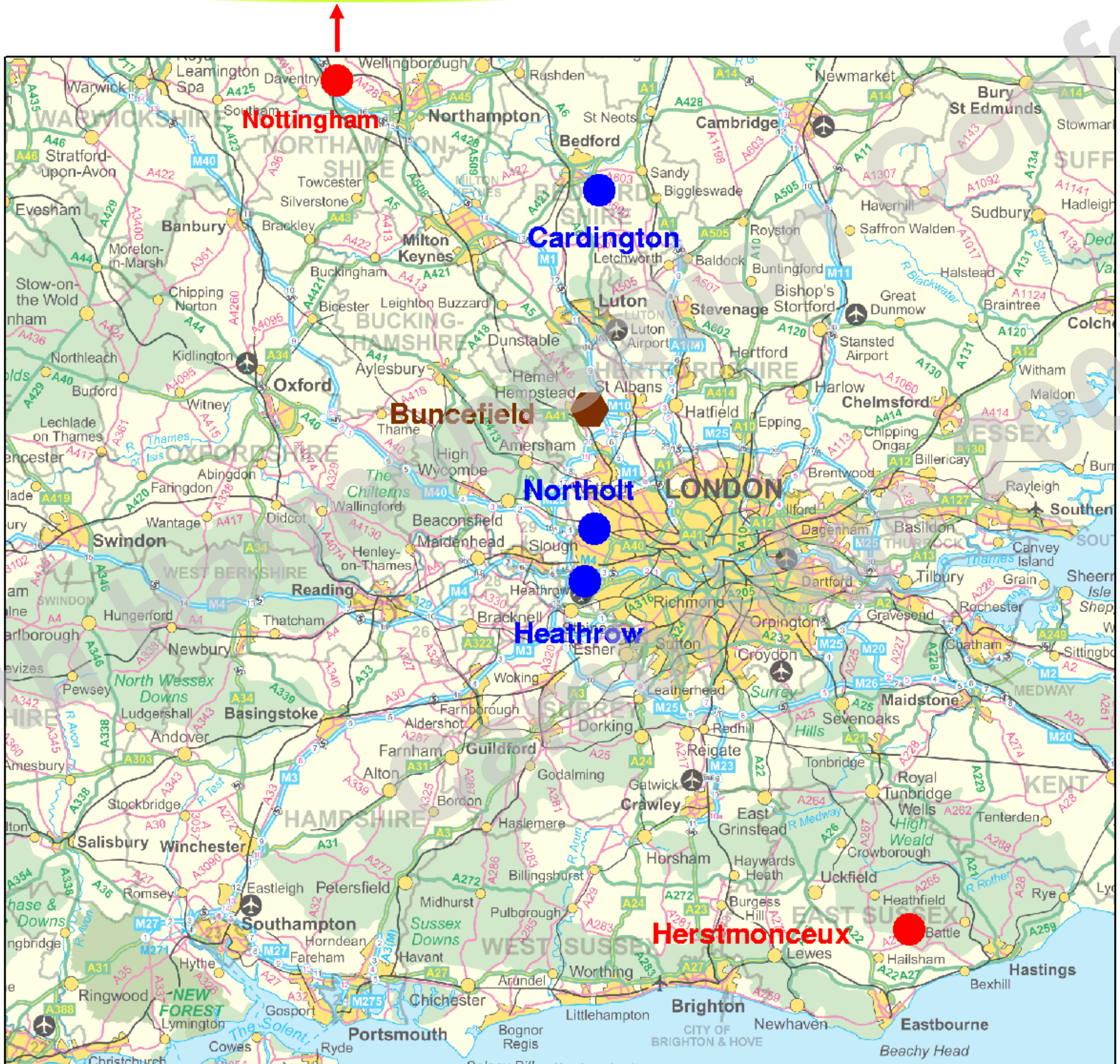




Accurate representation of meteorology?

Met Office



Oil depot

Radiosondes

Surface observations

Accurate representation of meteorology?

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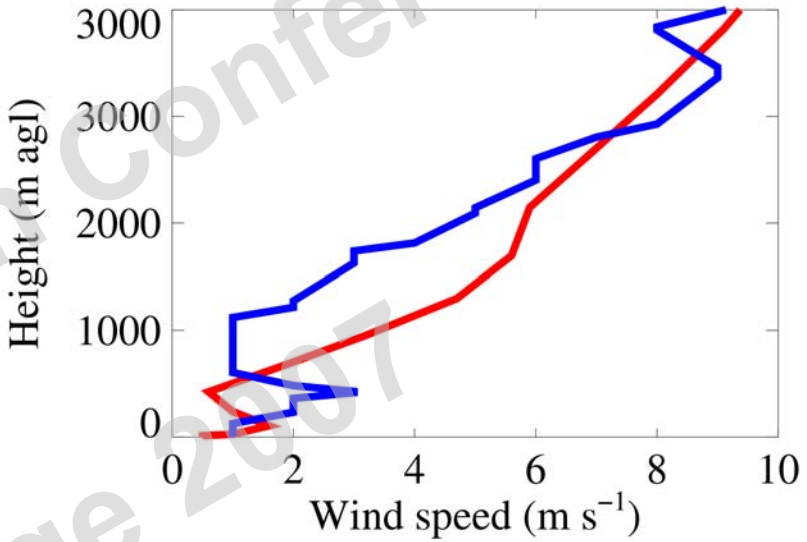
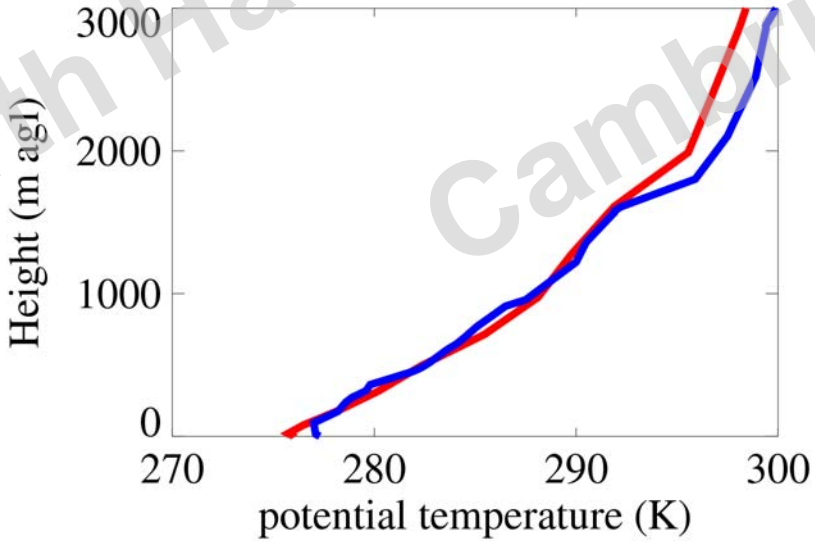
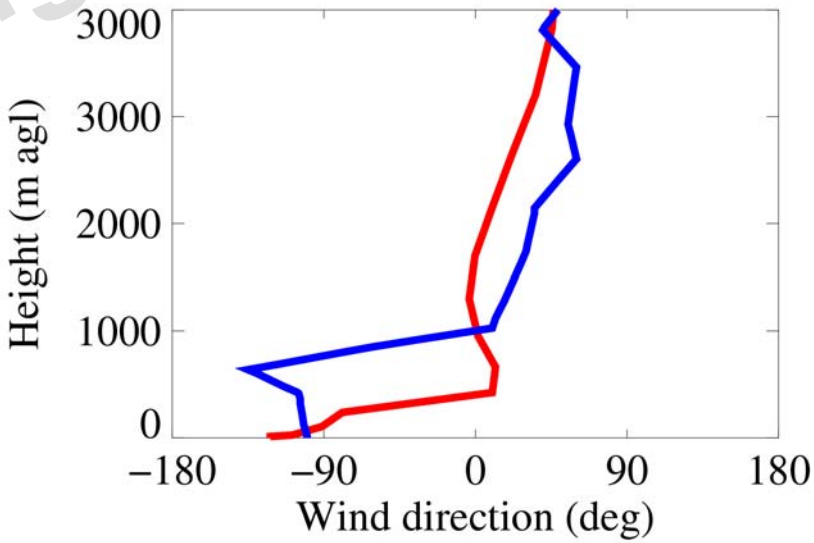


Radiosonde profiles NWP profiles





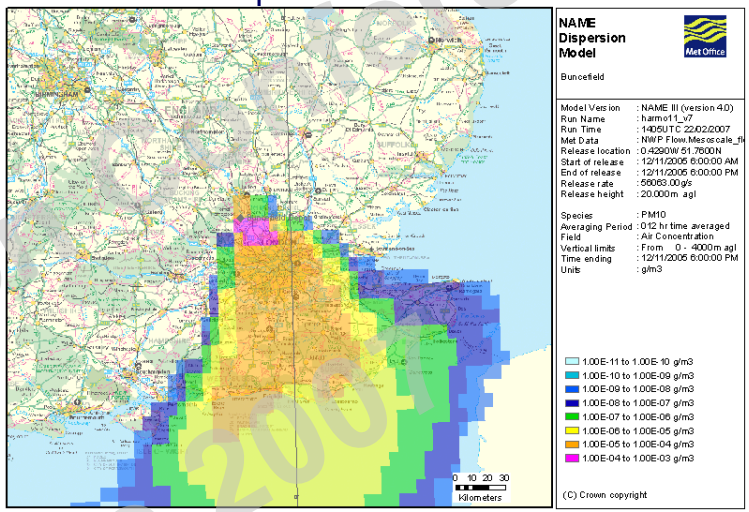
Plume rise scheme – sensitivity to entrainment parameters

- Parametrization of entrainment of ambient air

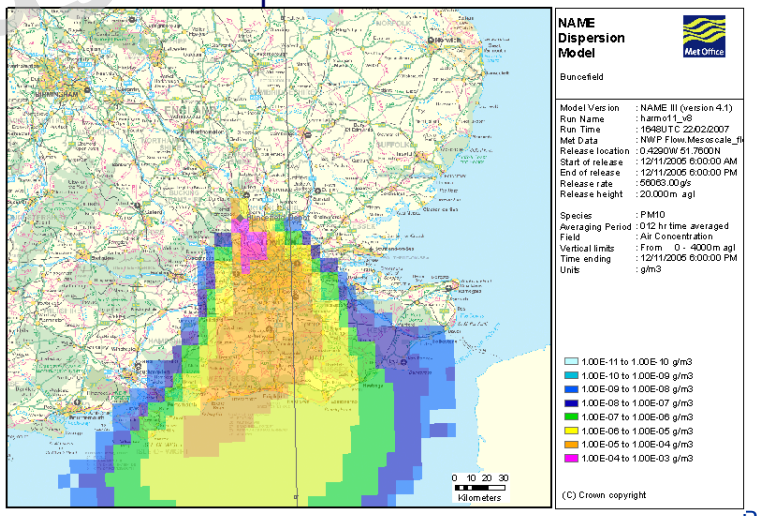
- Entrainment parameters
  - NAME: Briggs, Weil
    - α_1=0.11
  - ADMS
    - α_1=0.057

Less entrainment
=
More plume rise

α_1=0.11



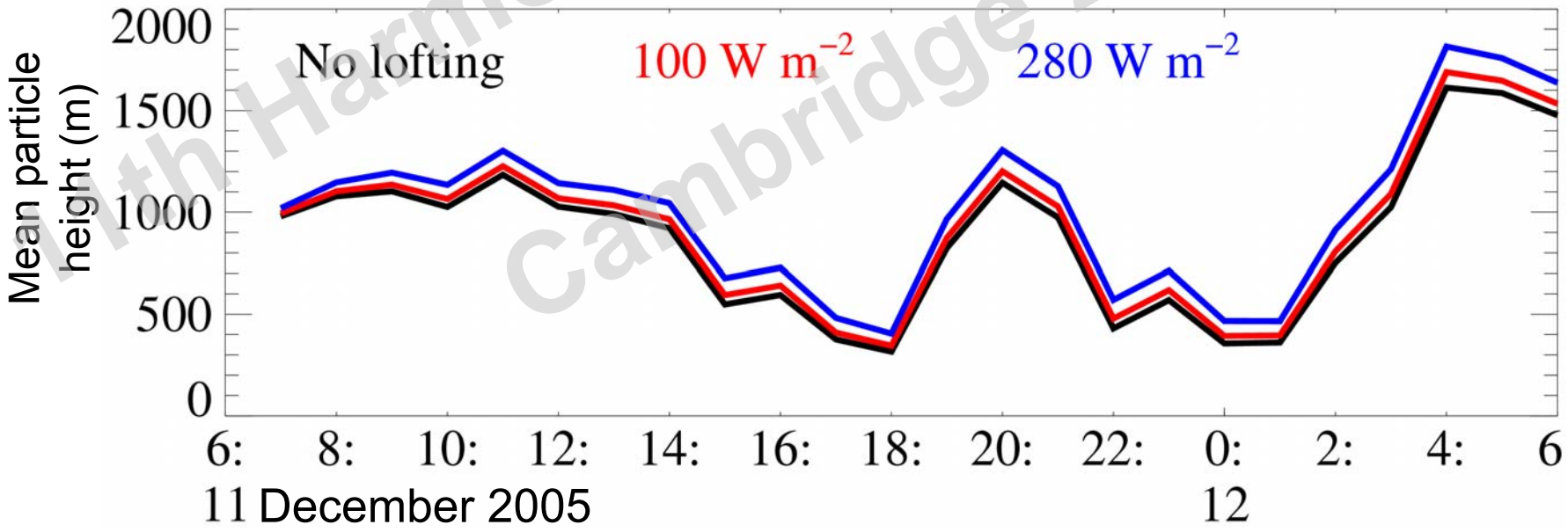
α_1=0.057



Lofting due to absorption of solar radiation

- Radiative transfer calculations
- NAME
  - Heat flux term added to plume rise scheme
- Irradiance measurements
  - 100 W m^{-2} absorbed by plume
- Total solar radiation flux
  - 280 W m^{-2}

Lofting accounts for only a small increase in the height of the plume top

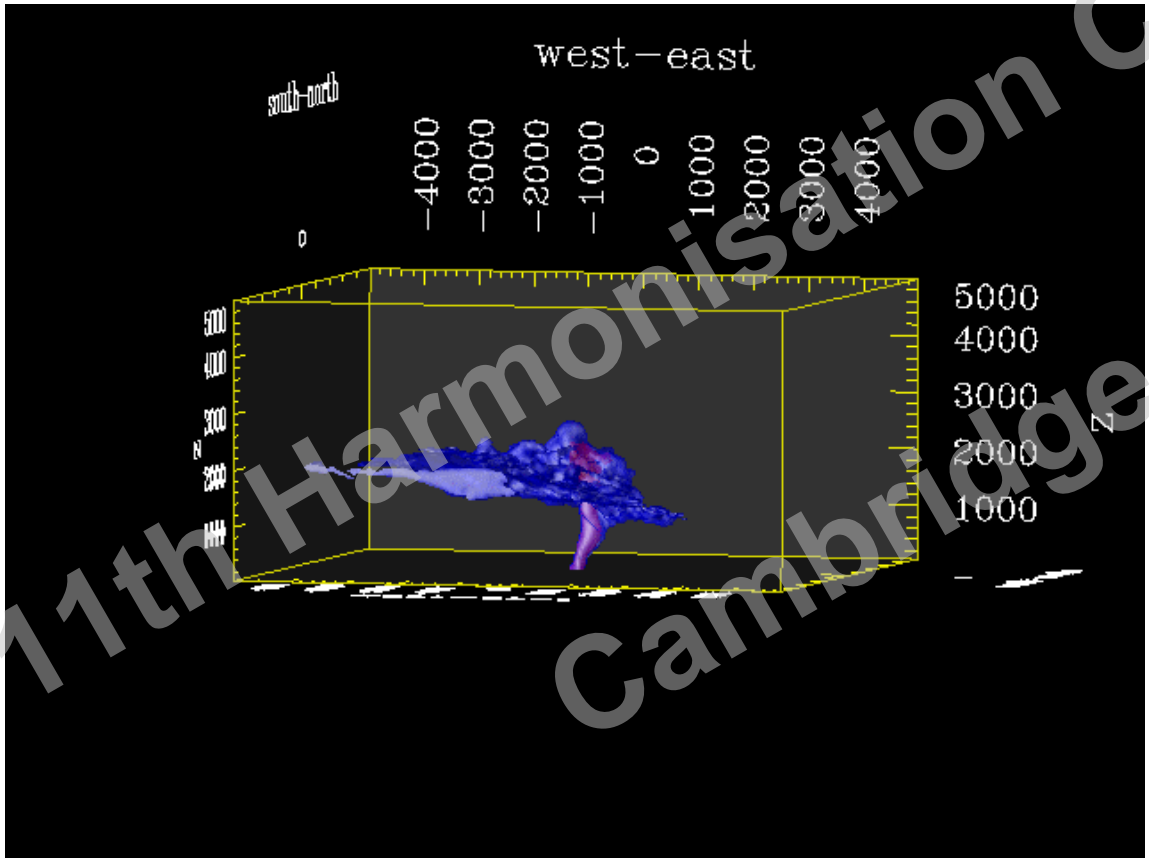


Latent heat release from condensing water vapour

Water in the plume

- Combustion process
  - Burning hydrocarbons produces water
  - Heat released from condensation of water produced by combustion of fuel
    - Small contribution to energy budget (~7% of heat released from burning fuel)
- Entrainment of moist ambient air
  - Reports of thick fog and high humidity levels
  - Modelled using Large Eddy Simulations
    - LES also models the effect of the fire on the meteorology

Large Eddy Simulations



- Boussinesq dry atmosphere
- Fixed meteorology
- Plume height: ~2500 – 3000 m
- Spread in SE - SW direction (consistent with observations)
- Moisture has small effect

Other possibilities

- Complex source
  - At height of fire 20 large fuel storage tanks alight
  - NAME modelling assumes simple homogeneous source
- Issues with the plume rise scheme?
  - Drift of particles back to neutral buoyancy
  - Reduction in plume vertical spread
- Any more ideas?

Conclusions

- Modelling plume from Buncefield incident
  - Simple elevated release
    - Good agreement with satellite imagery
  - Plume rise modelling
    - Appropriate magnitude of plume rise
    - Too little vertical spread
- In emergency response situations
  - Important information (e.g. source details) unknown
  - Utilise observations
  - Keep modelling simple