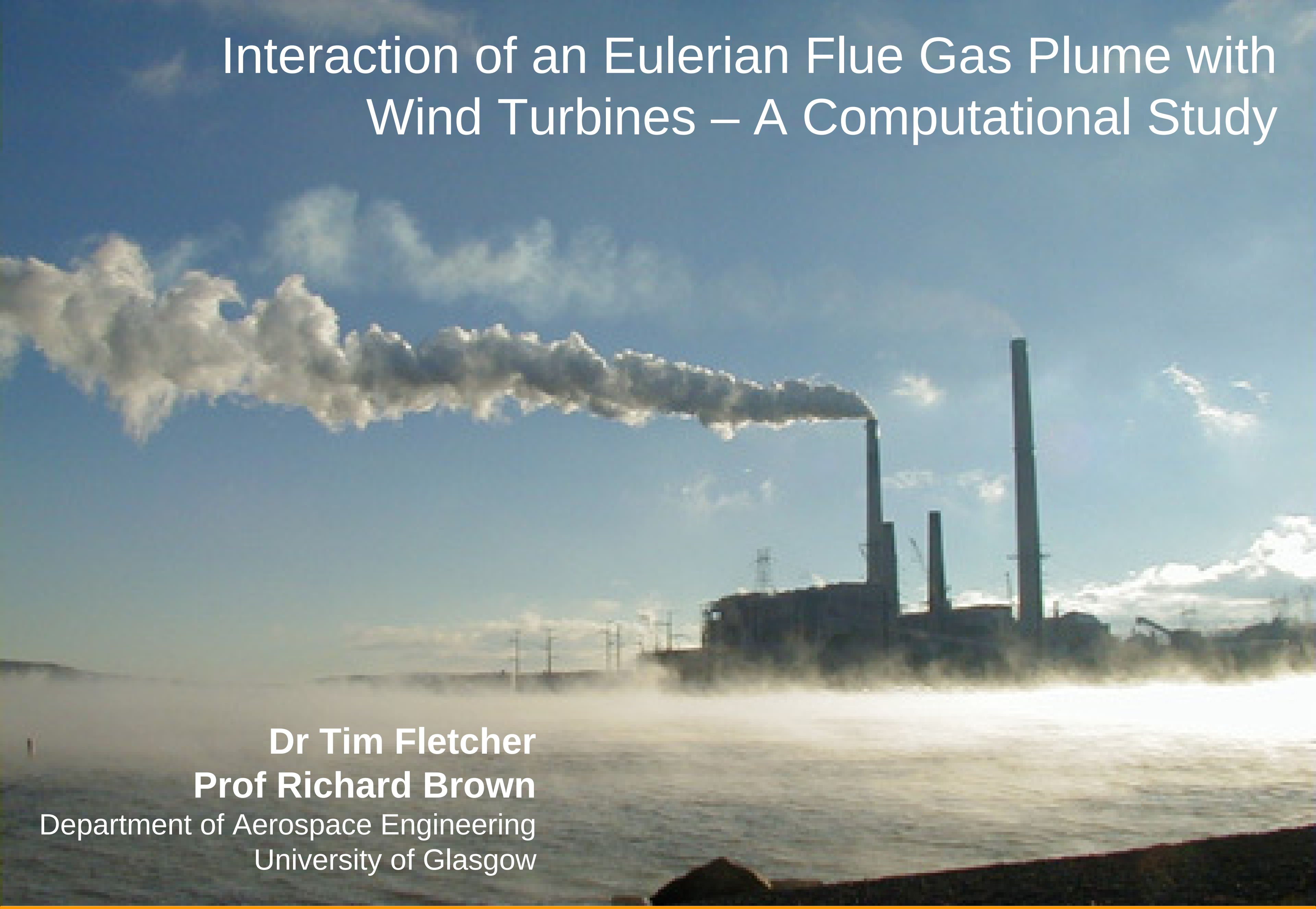

Interaction of an Eulerian Flue Gas Plume with Wind Turbines – A Computational Study

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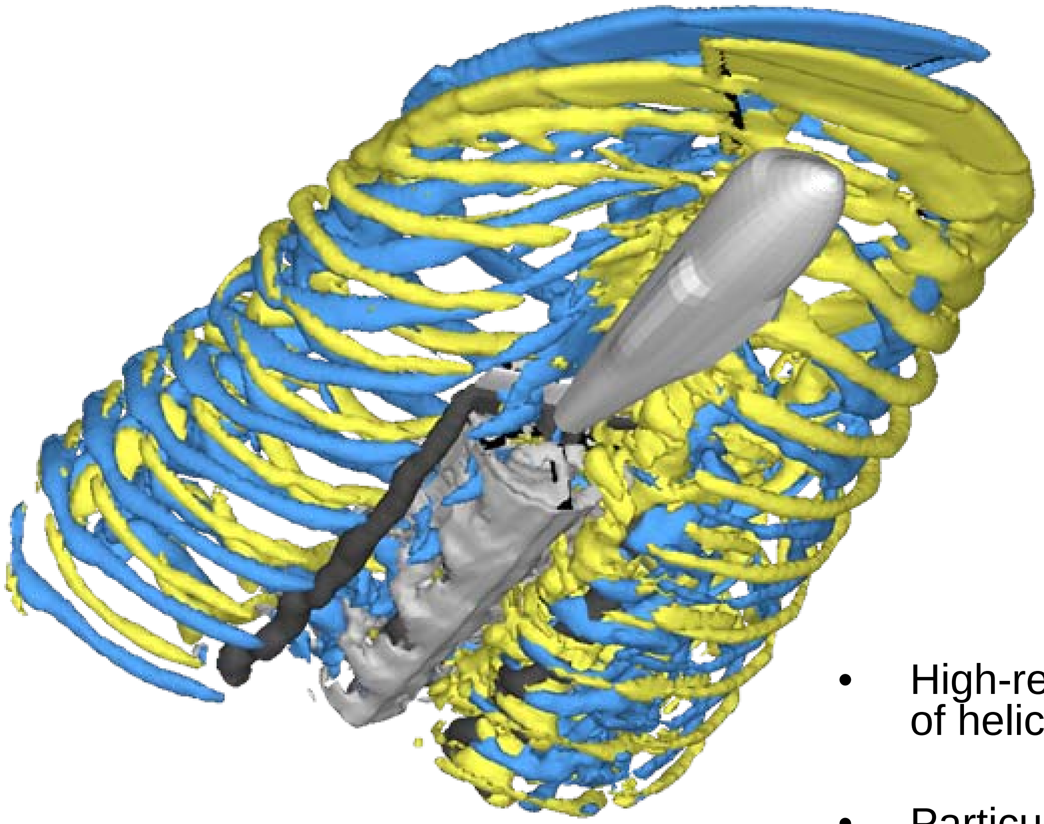
Wind Turbines and Pollutant Dispersal

- An **acknowledged environmental concern** is the effect of nearby wind turbines in modifying the dispersal of pollutants from industrial sites (**plumes from flue stacks** in particular)
- The dispersal pattern is likely to be strongly affected by the aerodynamics of the turbine (principally the wake induced by its rotor)
- Plume thermodynamics (buoyancy etc.)
- Atmospheric conditions / Weather?
- Local topography?
- Current predictive methods do not yield very good estimates for the dispersal pattern of pollutants once entrained into the turbine wake

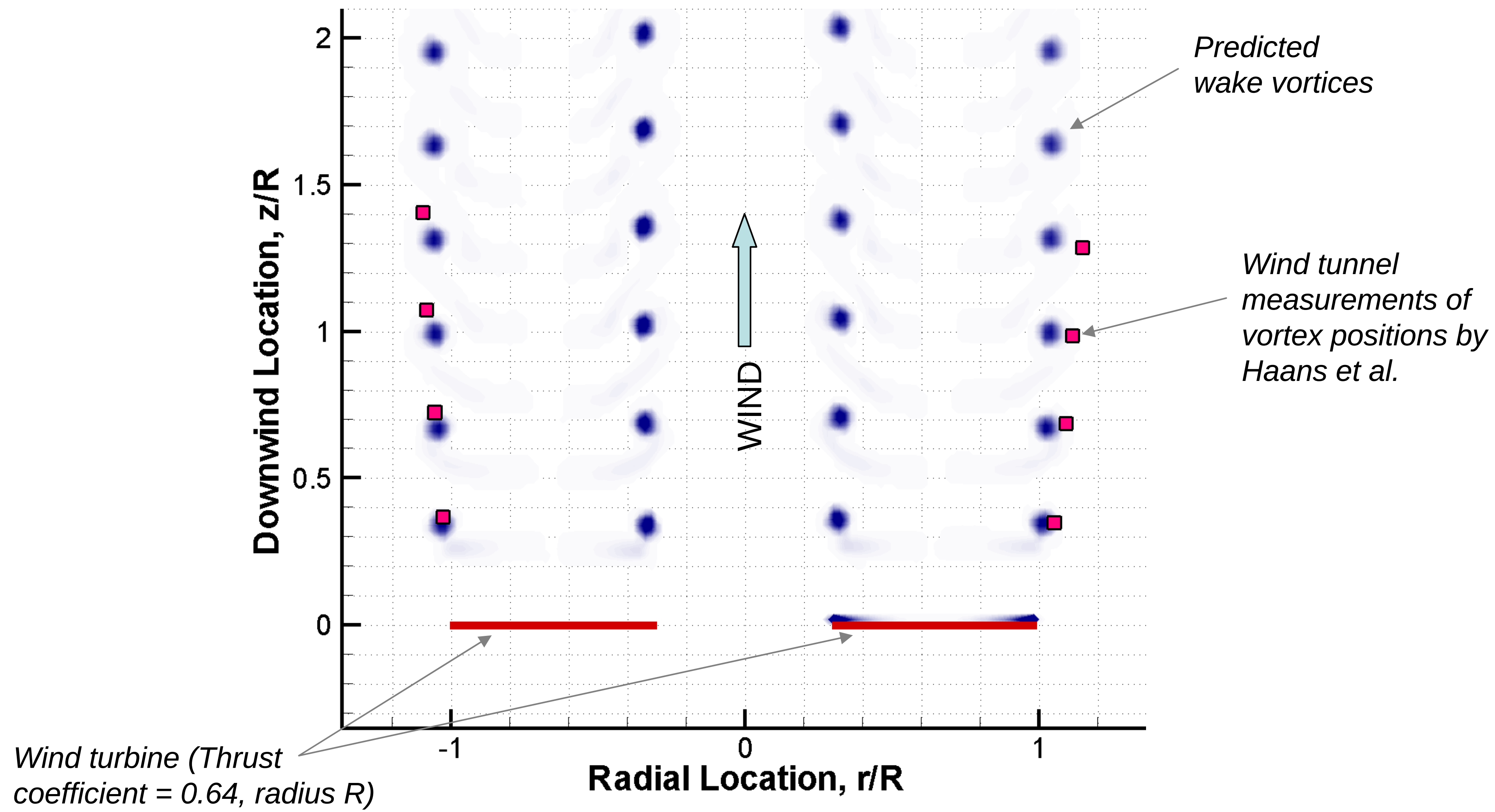
Our Expertise: Helicopter Aerodynamics



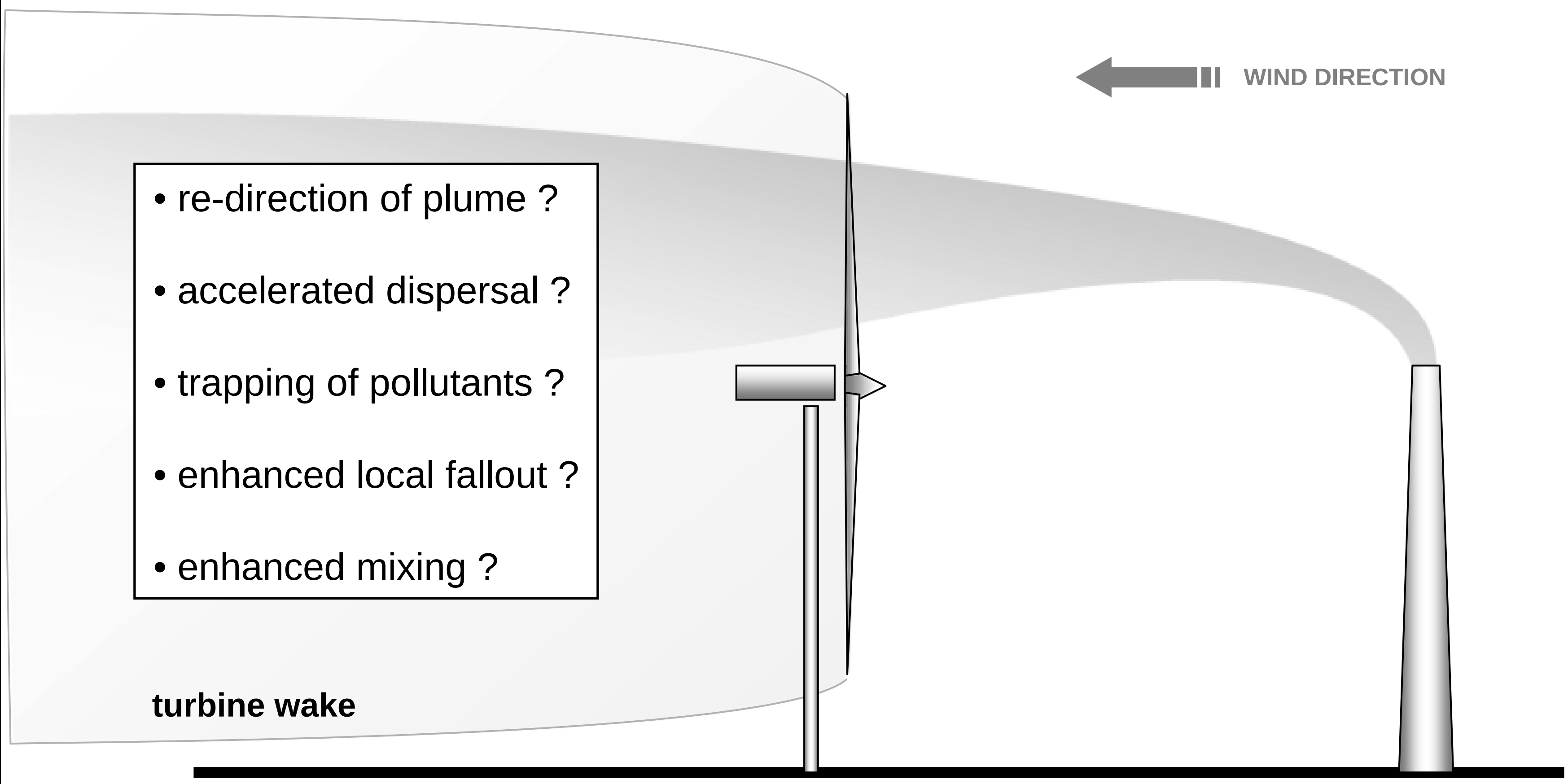
Sikorsky X2 configuration

- High-resolution computational modelling of helicopter aerodynamics
- Particular interest in modelling helicopter interactions with their immediate environment
- The approach used at Glasgow University is significantly different to that adopted elsewhere

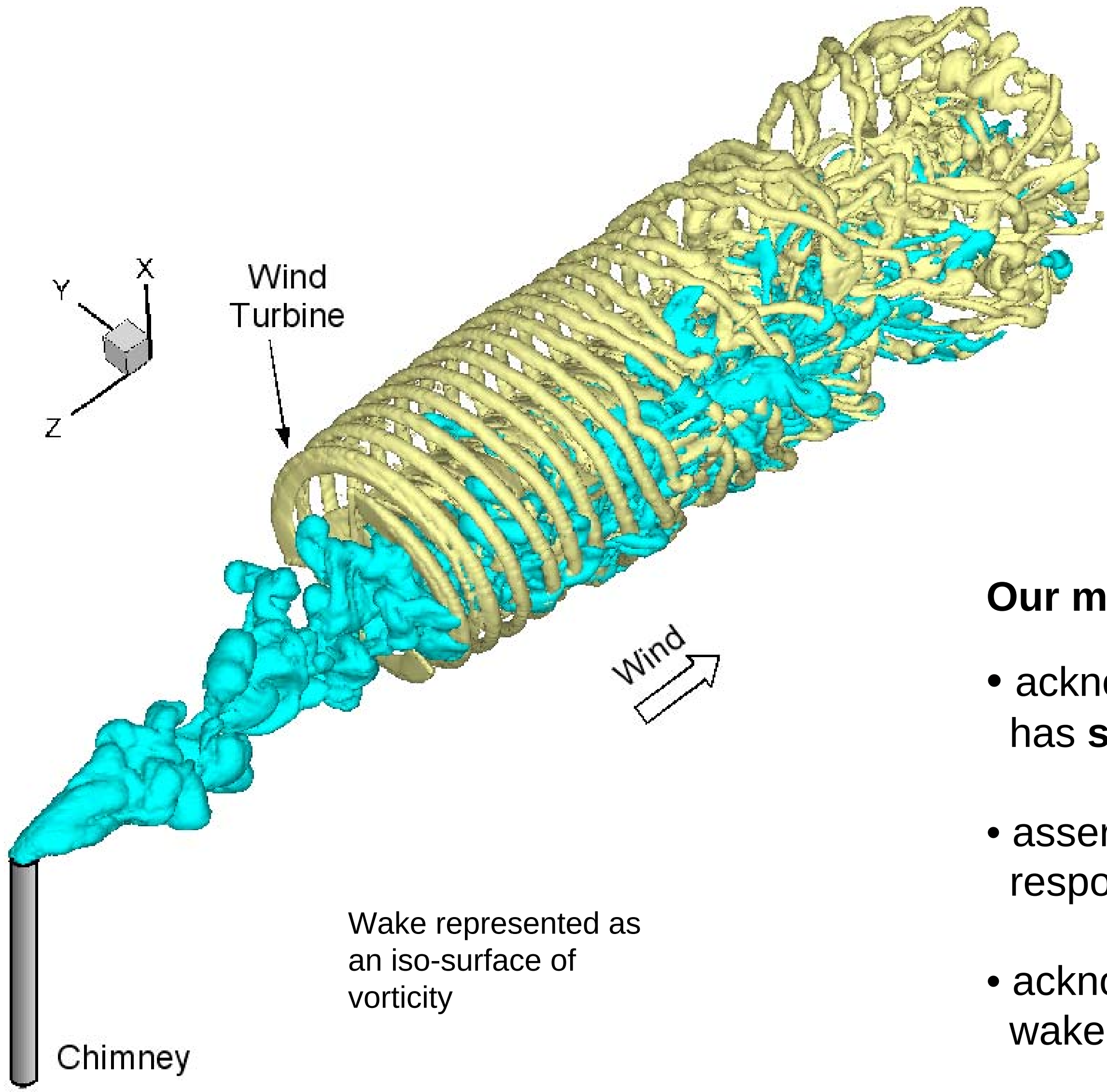
Wind Turbine Modelling: Validation of Wake Development



Plume/Rotor Interaction - Issues



Plume/Rotor Interaction - Modelling



Wake represented as an iso-surface of vorticity

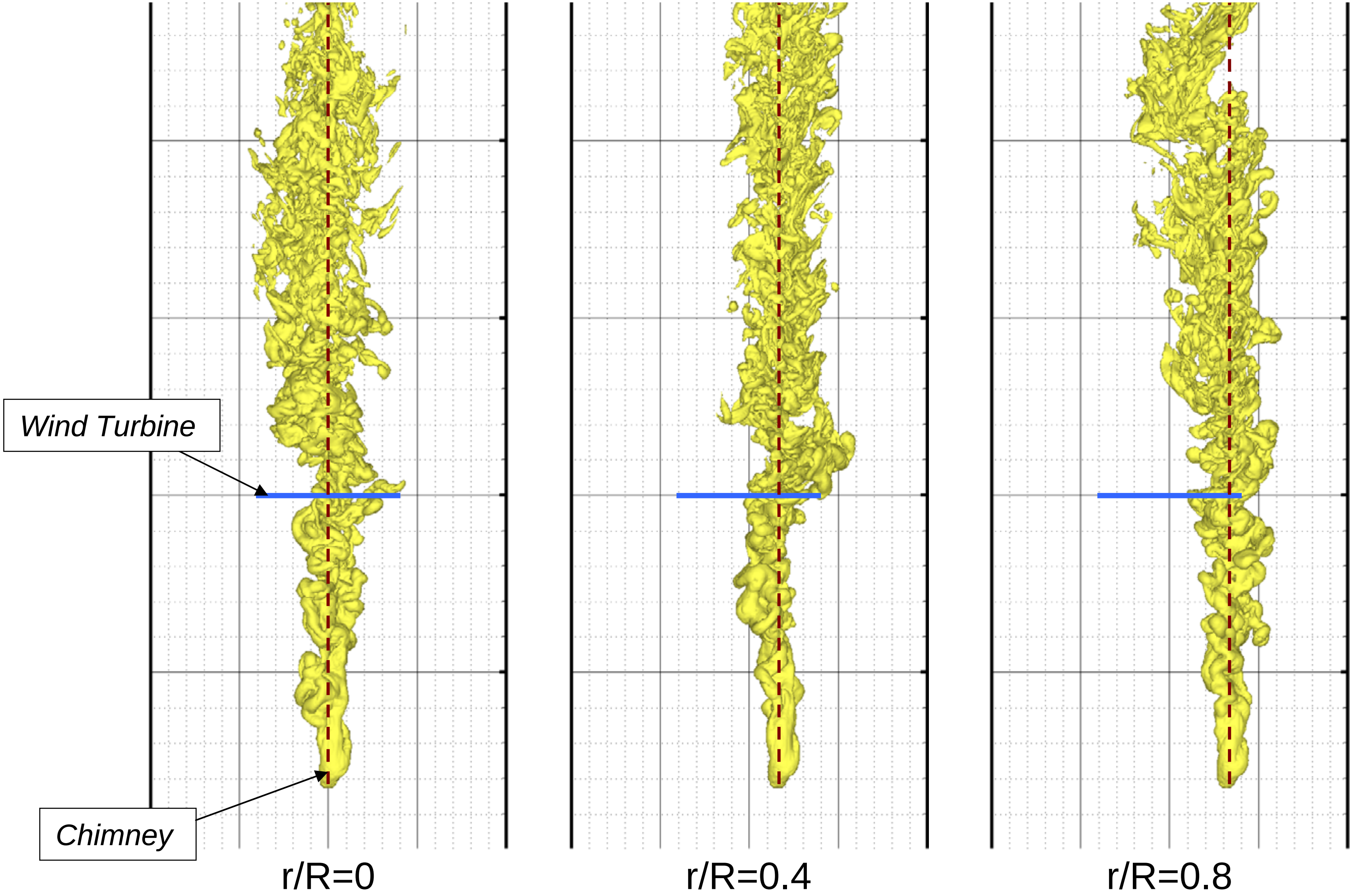
Conventional CFD models

- assume wake is uniform & mixing is turbulent

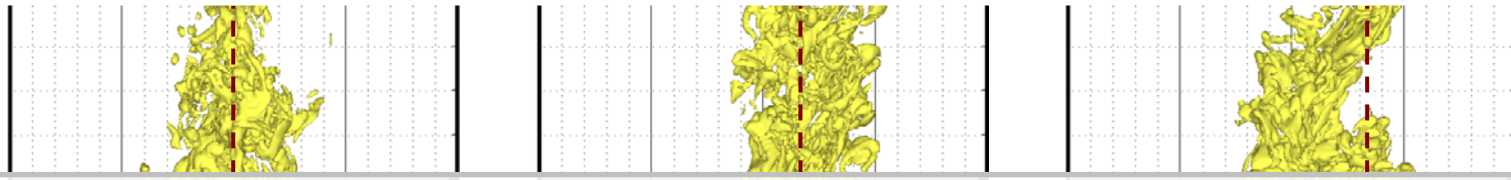
Our model

- acknowledges that the wake has **structure**
- asserts that wake structure is responsible for swirl, re-direction
- acknowledges that mixing in the wake is **not** primarily turbulent

Variation of Plume Dispersal with Chimney/Turbine Orientation



Variation of Plume Dispersal with Chimney/Turbine Orientation

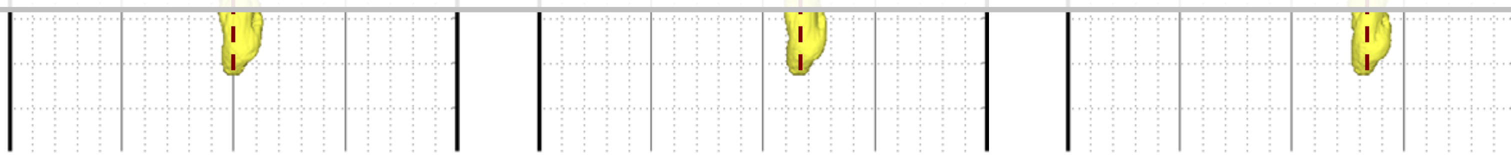


Data for the dispersal of neutral plumes suggests the following:

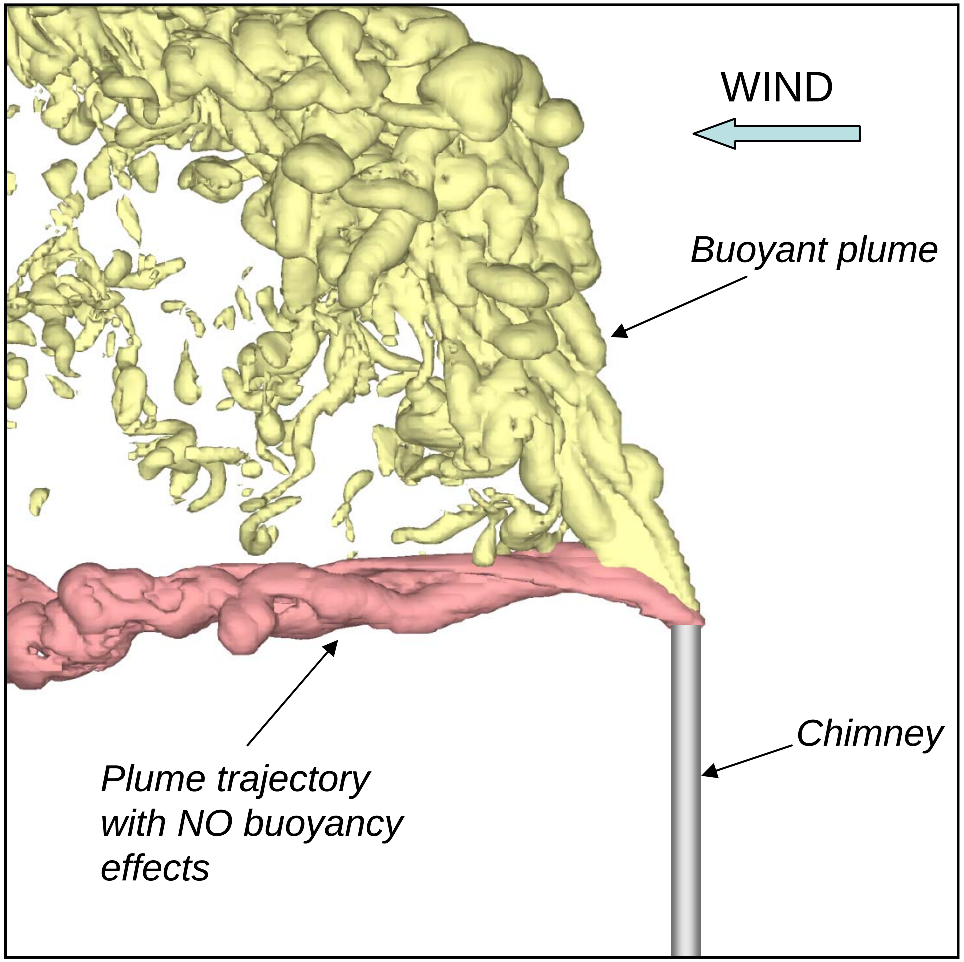
• Need to establish whether individual plume-turbine interactions are significant, or the cumulative effects within large wind farms

• Concentration of pollutant is of interest ⟶ we have simulated the transport of dust within helicopter wakes and can use a similar method to model pollutant particles (including fall-out etc.)

• Can quantify the variations in pollutant concentration – this is likely to be influenced by the operating conditions of the wind turbine, such as its thrust



Inclusion of Buoyancy Effects



Vorticity Transport Equation

+ BAROCLINIC VORTICITY SOURCE

$$S_{baroclinic} = -\frac{1}{\rho T}\nabla T \times \nabla P$$

If we assume the only non-zero pressure gradient to be

$$\frac{\partial P}{\partial h} = -\rho g$$

Then the baroclinic source can be computed using **gravity**, **temperature** and the **horizontal temperature gradients**

- Wind speed / chimney ‘induced’ velocity = 5 / 3
- Chimney temperature 30% higher than ambient temperature

What we would like to do

- **Develop** a version of our model that
  - Accounts properly for turbine wake dynamics
  - Accounts properly for plume buoyancy effects
  - Incorporates the atmospheric thermal boundary layer (inversions, stable/unstable lapse rates)
  - Incorporates the atmospheric velocity boundary layer
- **Use** this model to
  - Understand the fluid mechanics of rotor-plume interactions, and how dispersal effects vary with operating conditions
  - Develop heuristics that can aid the regulatory process
- **Exploit** the model directly in specific instances where it may be of help

Conclusion

- **Modelling of pollutant dispersal is a tough problem but is crucial in order to address environmental concerns**
- We have a unique capability in helicopter and wind turbine aerodynamic modelling
- We are developing our model to enable the interaction between pollutant plumes and wind turbines to be simulated
- Initial results show that even the dispersal of neutral plumes in idealised atmospheric conditions is influenced by the operation of wind turbines in close proximity
- **We hope to continue this research by working with companies and regulatory authorities**