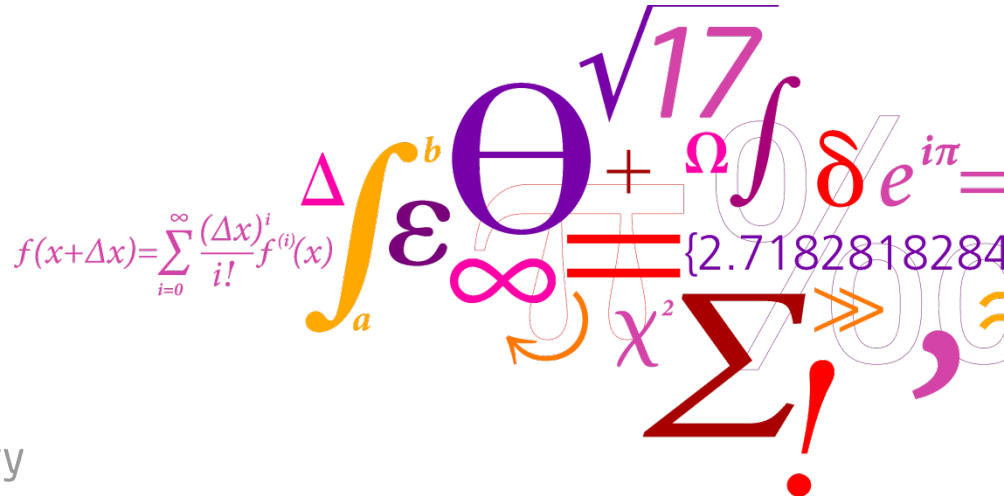
New linearized wake model.

Søren Ott, Morten Nielsen & Jacob Berg



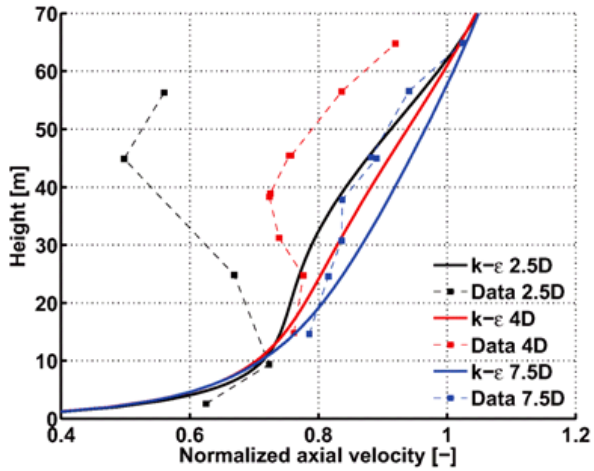
Risø DTU
National Laboratory for Sustainable Energy

Linearized model features

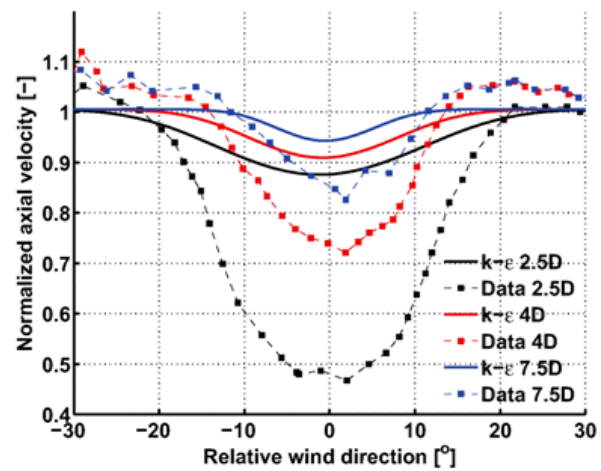
- Solves a linearized CFD model: Mixing length, k-ε or 'simple' ($\nu_t = \kappa u_* z$)
- Mixed-spectral formulation
- Intensive use of look-up-tables (LUTs) and preLUTs (used to make LUTs)
- Superposition of wakes
- No numerical diffusion
- No mean pressure gradient
- Many times faster than CFD

But is CFD any good?

From Pierre-Elouan Réthoré's PhD thesis:



(a) Normalized axial velocity profile by inflow hub height velocity $\frac{U}{U_\infty}$



(b) Normalized axial velocity centerline by inflow hub height velocity $\frac{U}{U_\infty}$

Figure 4.2: Axial velocity in the wake of the Nibe B wind turbine.

Also: Kasmi & Masson, J. of Wind Eng. and Ind. Aerodyn. 96 (2008) 103–122

Lessons learnt form TOPFARM

- The k-ε and similar RANS CFD models have serious flaws. They don't work for wakes.

- Eddy viscosity does not represent meandering properly

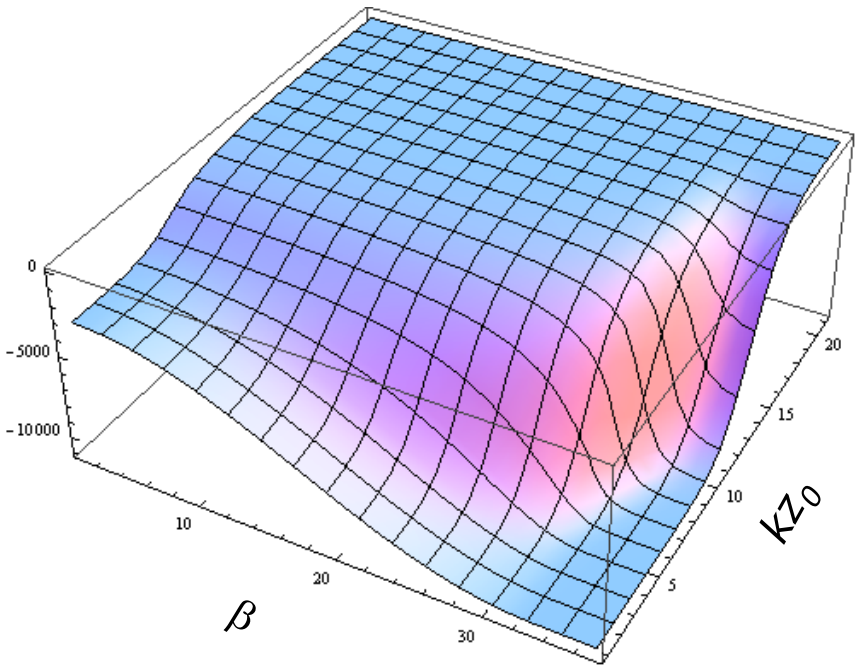
- Isotropic $\langle u_i u_j \rangle$?

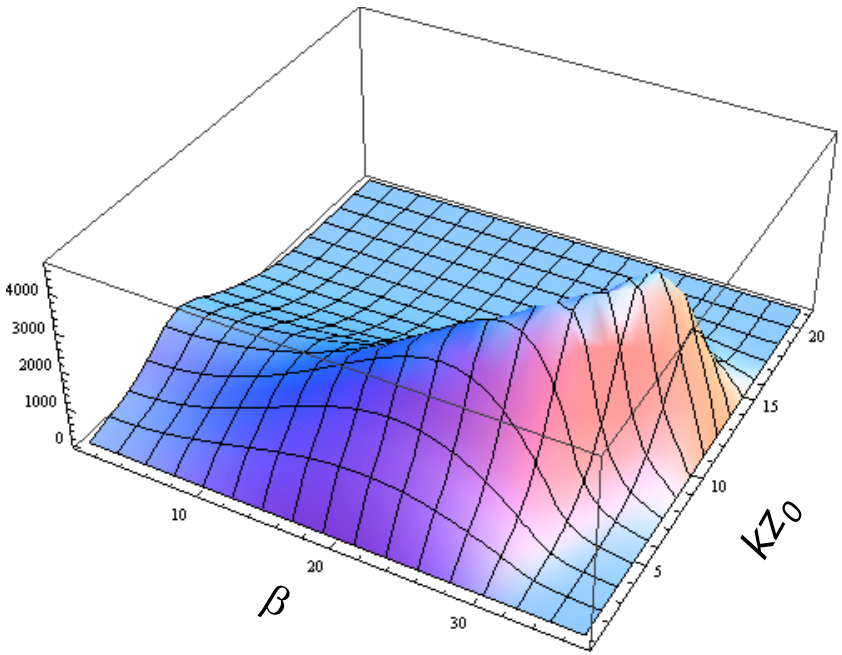
- Problems with the response to large pressure gradients .

- CFD has difficulties beating the *simplest closure:* $\nu_t = \kappa u_* z$. It works just as well as more 'advanced' closures – *without any tuning*.

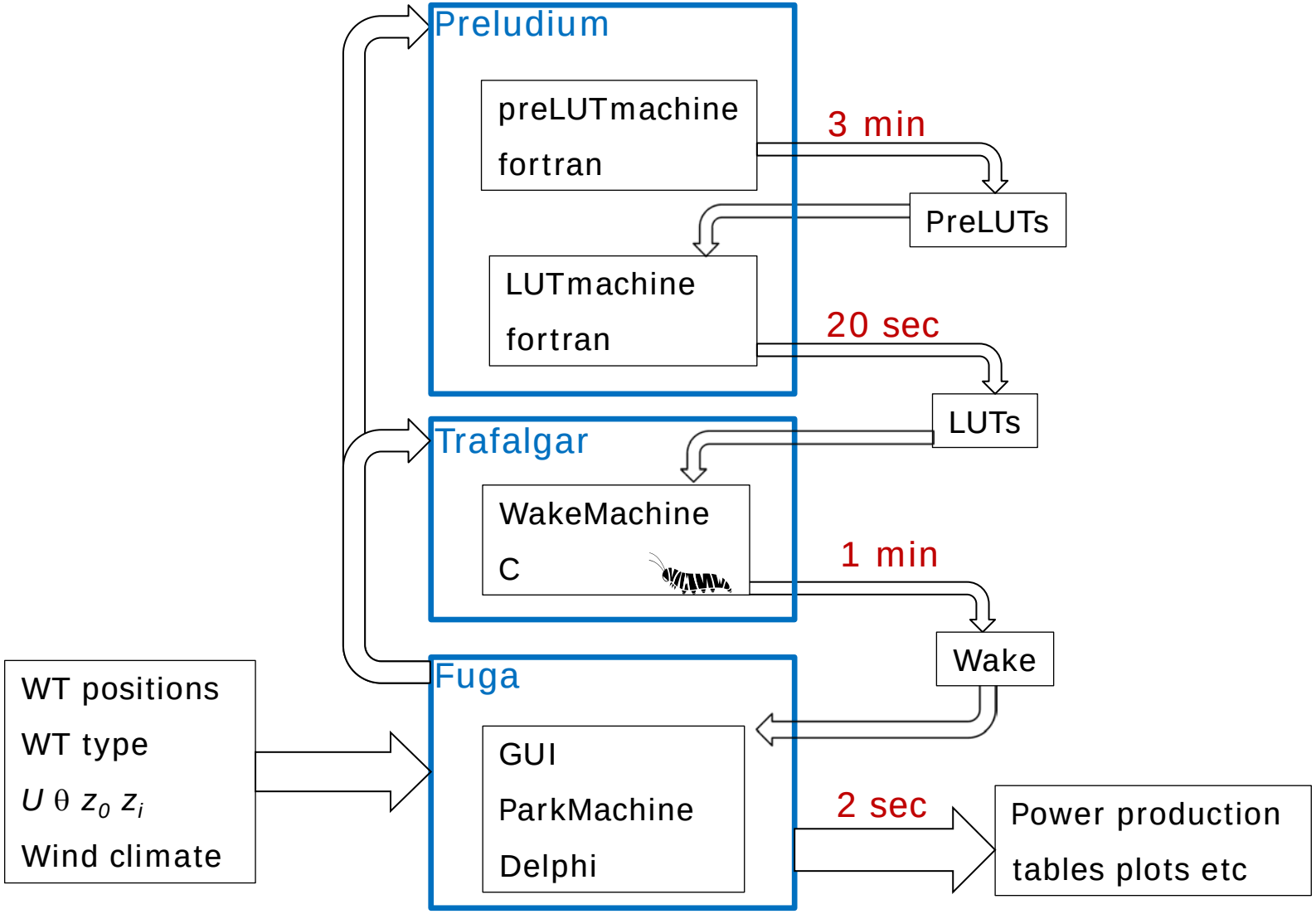
LUTs and preLUTs

- Intermediate results are stored for later use
- The linear equations are hard to solve!

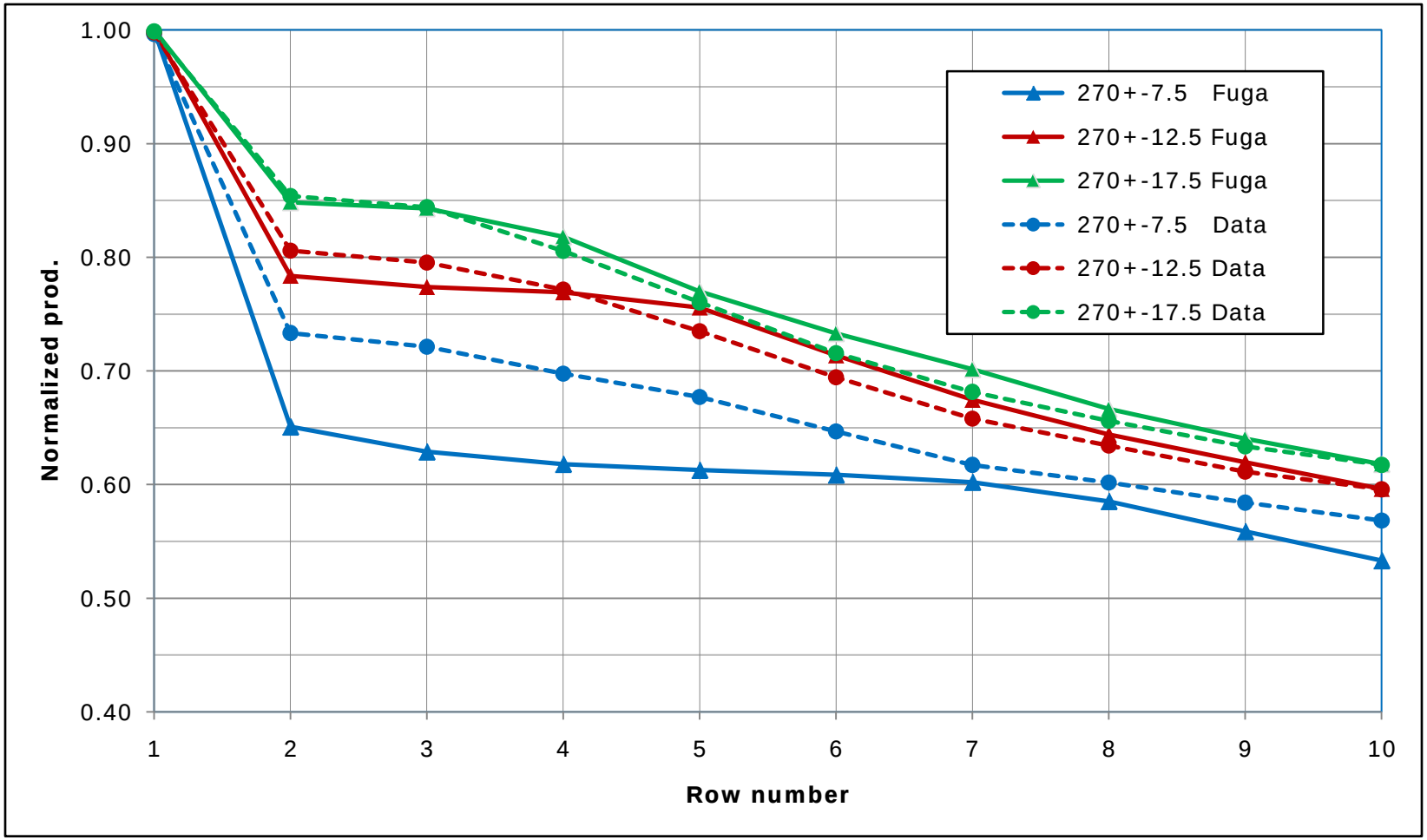




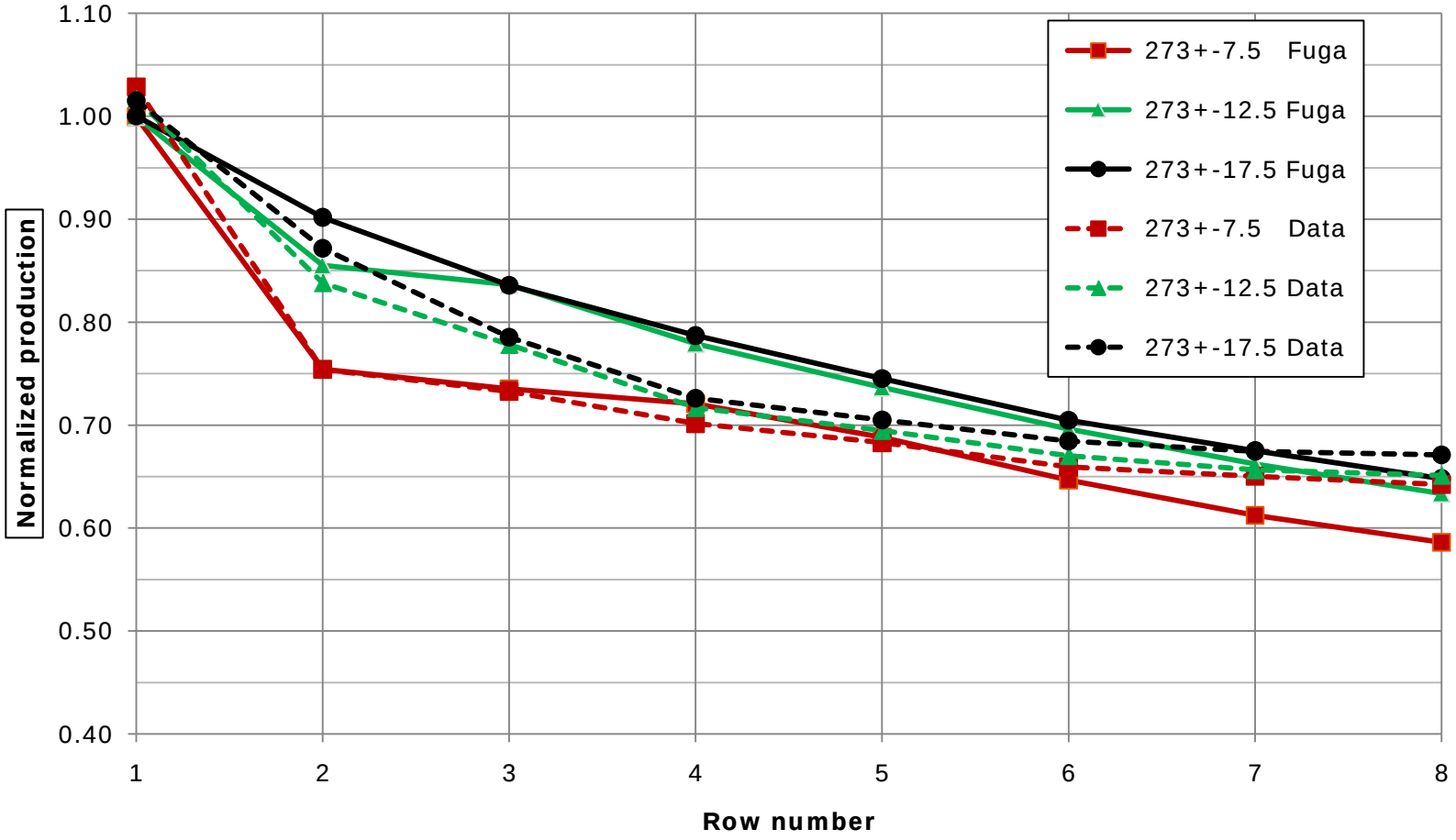
Block diagram



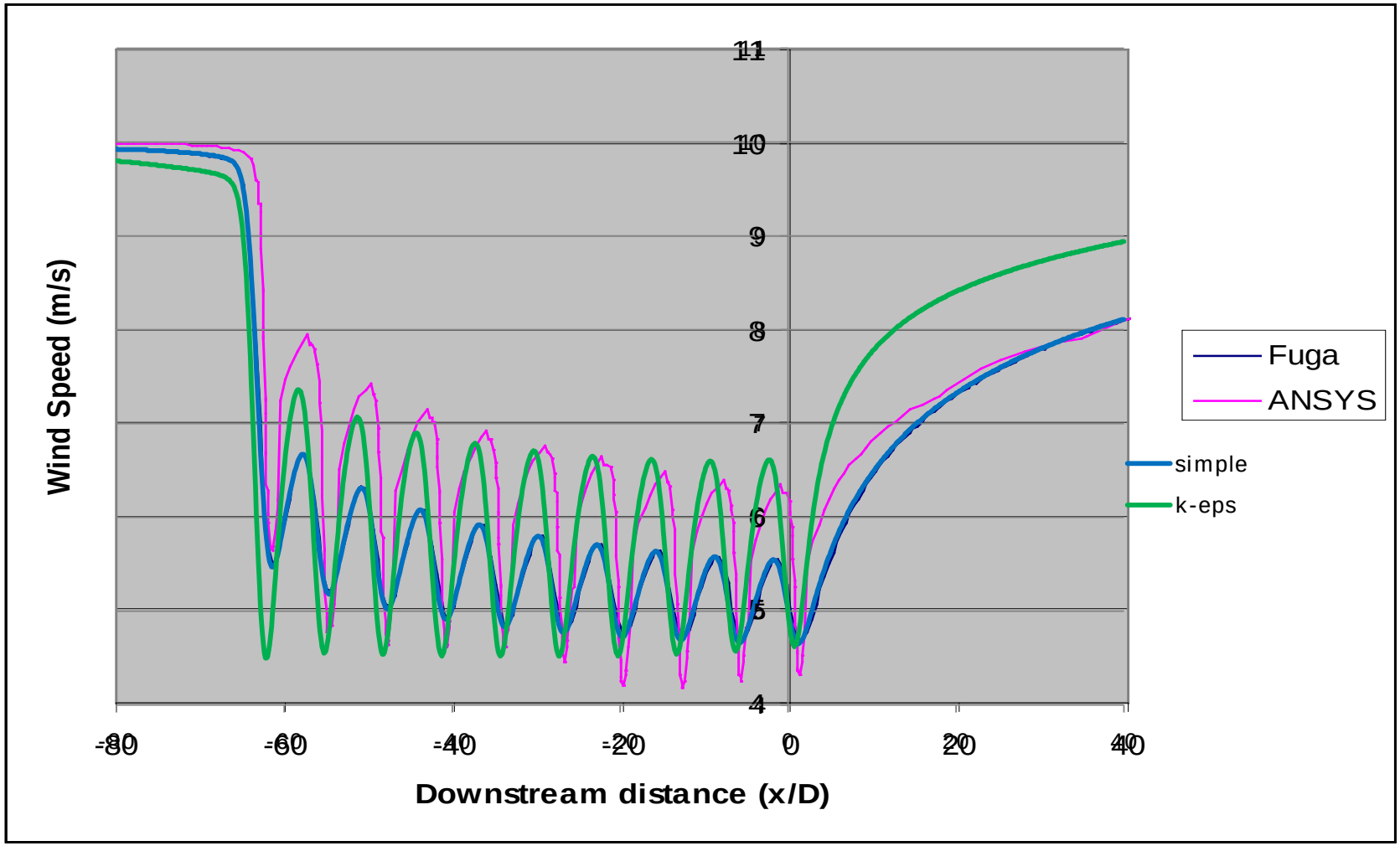
Horns Rev I. Simple closure



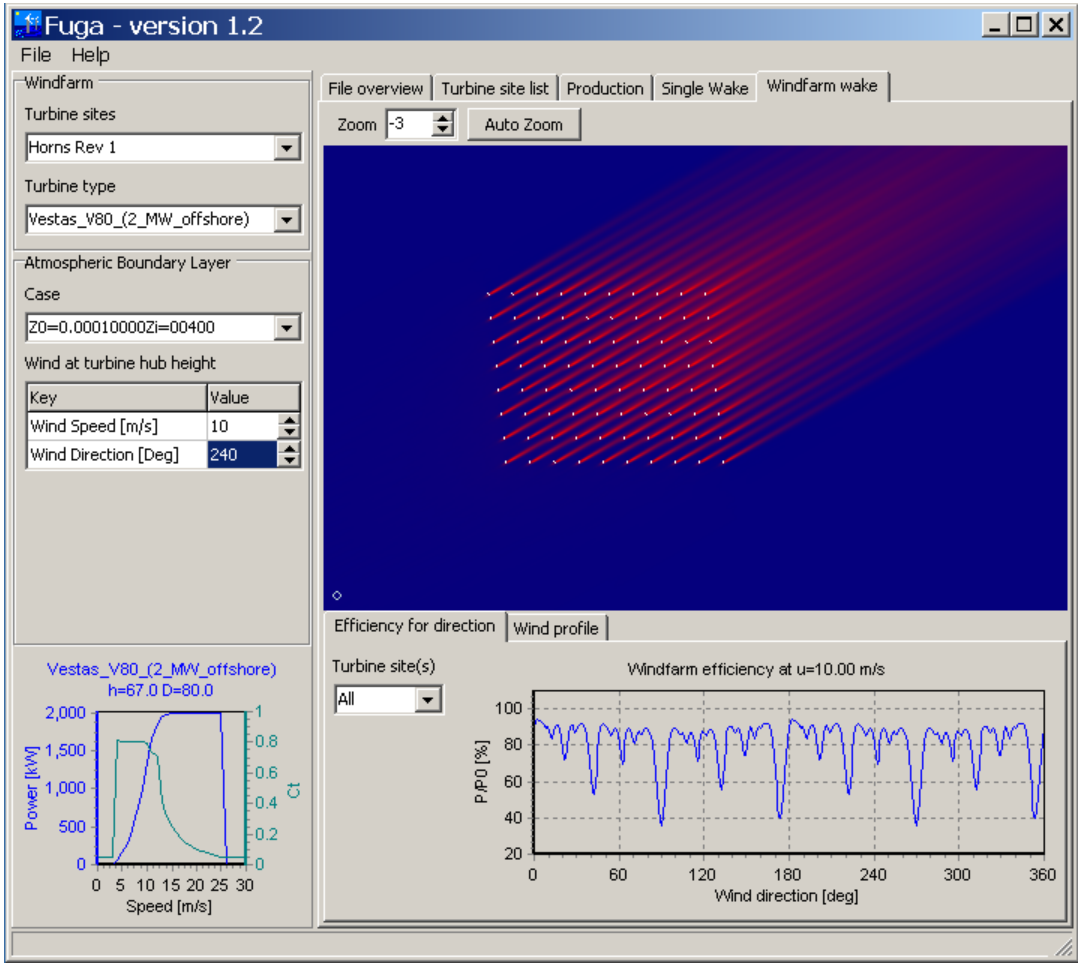
Nysted. Simple closure.



Linearized *k-ε* (Rados). Horns Rev I 270 deg.



Fuga GUI – interfacing with WAsP data



Conclusions

- The numerical difficulties with linearized CFD models are now largely overcome.

- Successful validation against
  - CFD results
  - production data (Horns Rev I, Nysted, OWEZ)
  - wind speed data (Vindeby)

- We have made a new tool predicting energy production in offshore wind farms and wind farm clusters.

- Enormous gain of speed compared to CFD.