# Modelling wake effects using two CFD techniques

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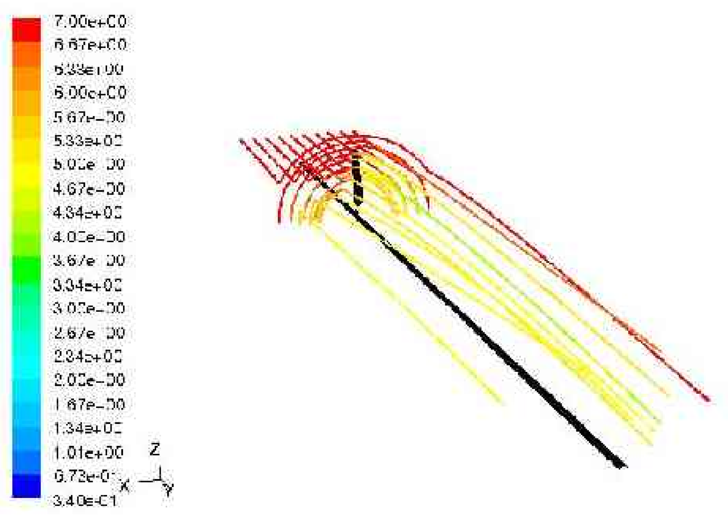
OBJECTIVE: Validation of BEM-CFD coupling through a Moving Reference Frame (MRF) simulation

## CFD approaches to simulate the rotor disks of wind turbines

### Moving Reference Frame (MRF)

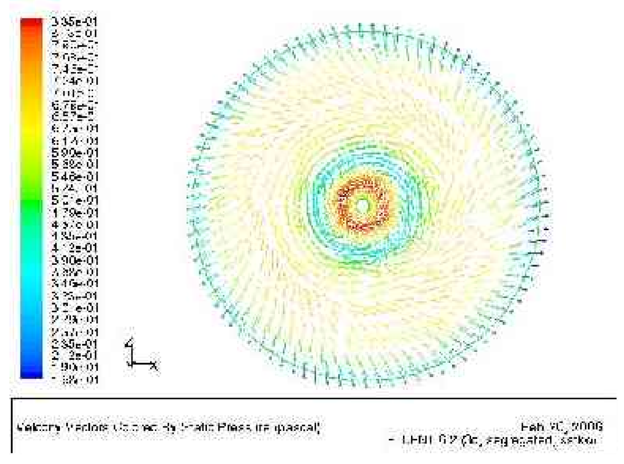
- Blade geometry explicitly modelled
- Rotation effects taken into account through source terms (Coriolis force and centripetal) in the momentum equations

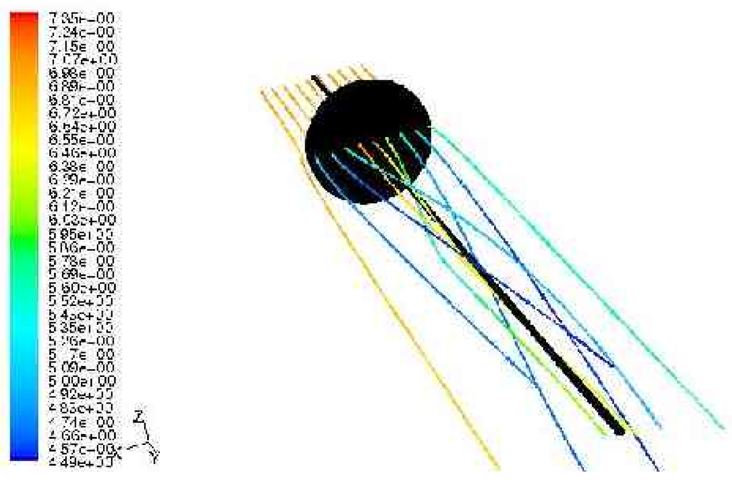


Cell count: 2,745,000

### Virtual Blade Model (VBM)

- BEM (Blade Element Theory) -CFD coupling
- Blade geometry implicitly modelled (Cl-α, Cd-α required)
- No need to generate individual meshes over each of the rotor blades -> reduction of cell count





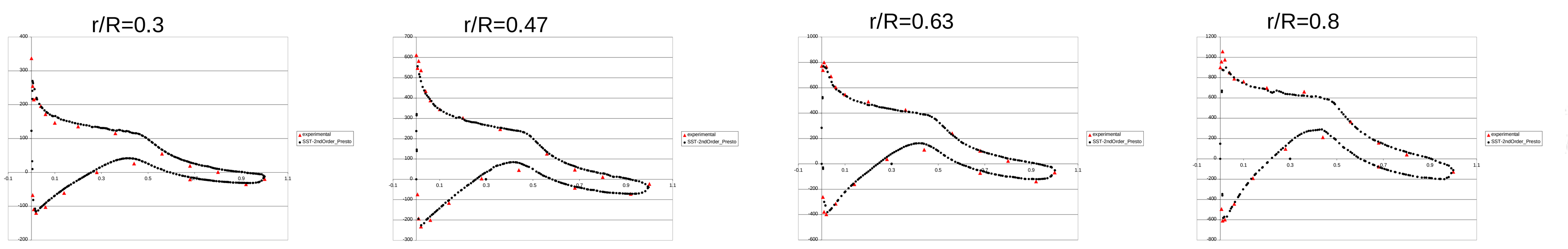
Cell count: 677,000

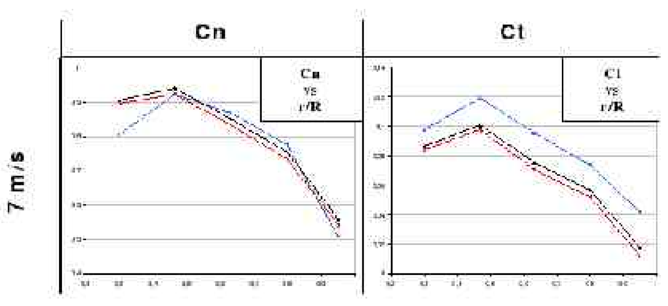
- Momentum sources obtained from BEM as a function of twist, chord and airfoil types along the radius [2] [3]
- VBM replaces rotor systems with the momentum sources on an actuator disk

## Simulation features

- **Dimensions of domain:** 5Φ upstream - > 8Φ downstream
- **Mesh:** Non structured
- **Turbulence model:** kω SST
- **Discretization:**
  - 2nd order upwind: momentum X, momentum Y, momentum Z, TKE and ε.
  - PRESTO: pressure

## Validation data on forces and pressures over the blades for MRF from NREL Phase VI wind tunnel data



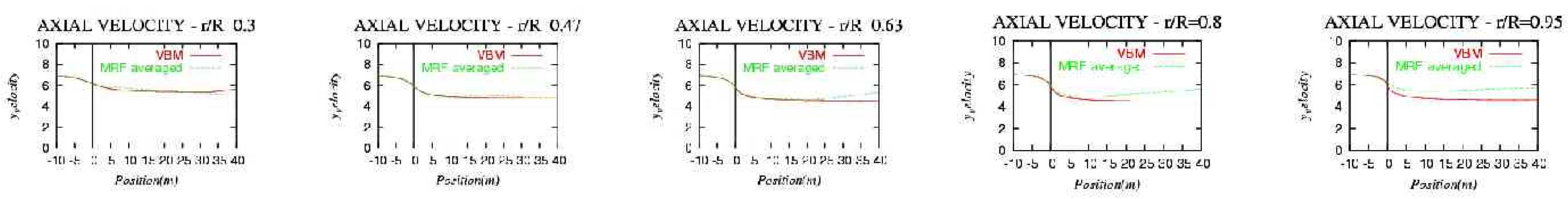




- S809 airfoil
- Sequence S, averaged values for azimuths from -90º to 90º
- Inlet velocity = 7 m/s

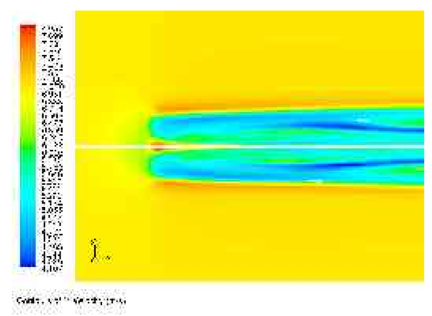
Accurate prediction of pressure and forces distribution -> Supposed good description of velocities and pressure downstream [1]

## Results

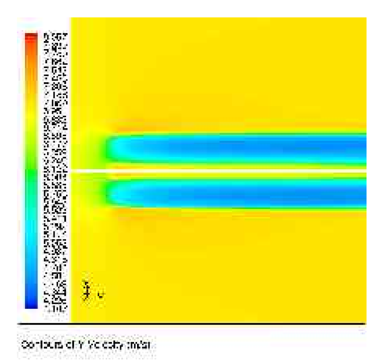
### Axial Velocity




MRF – Axial_V

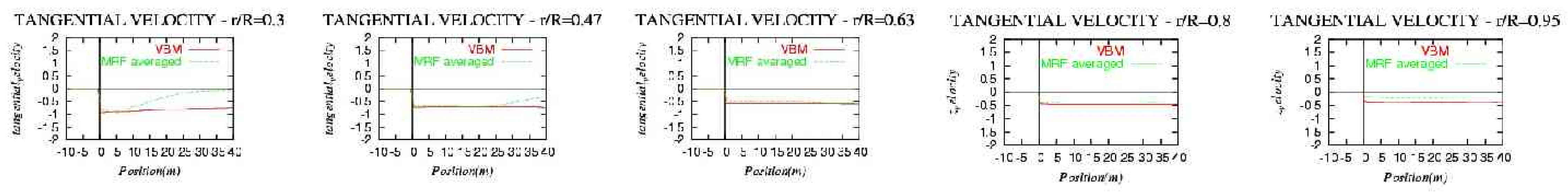


VBM – Axial_V

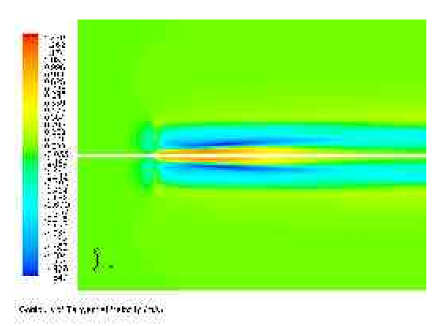


-Accurate estimation for sections near the root and medium sections
-Slight deviation at 80% and 95% due to tip effect (tip effect correction disabled in VBM)

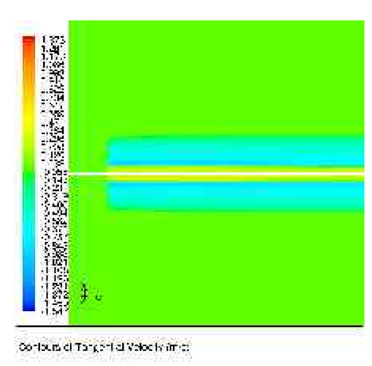
### Tangential Velocity




MRF – Tangencial_V

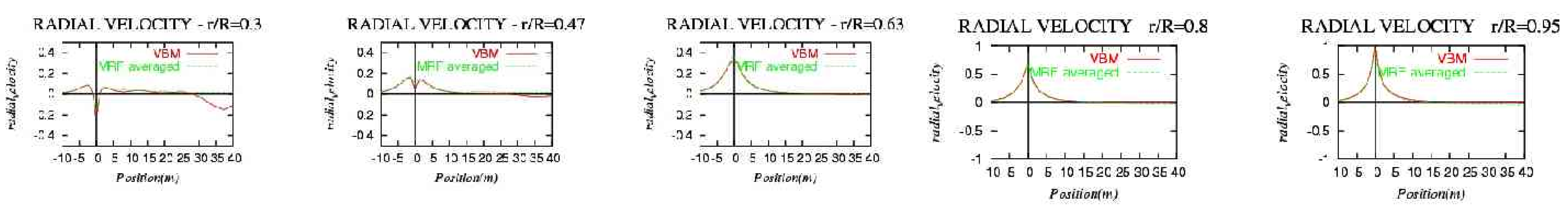


VBM – Tangencial_V

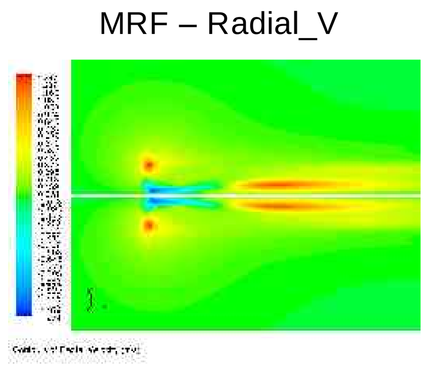


- Deviation of 1 m/s downstream at 30% due to 3D rotational effects

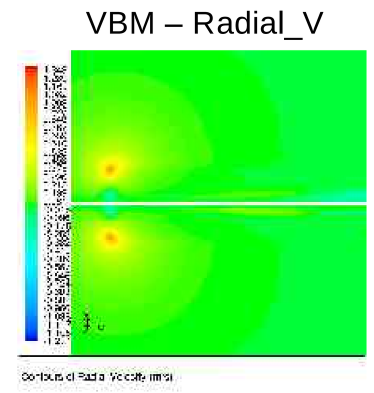
### Radial Velocity




MRF – Radial_V

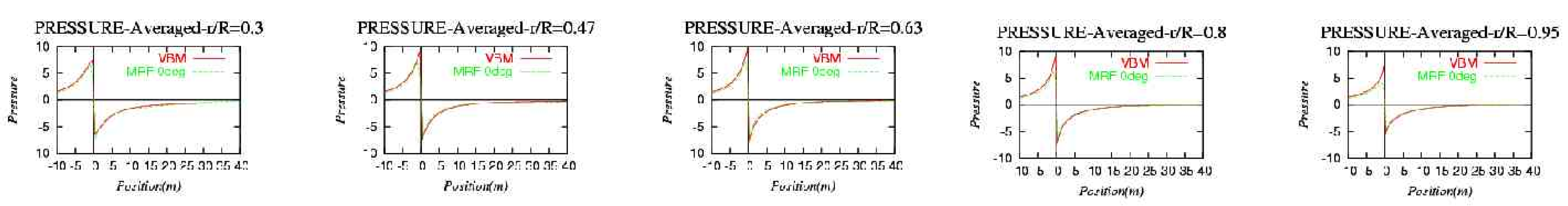


VBM – Radial_V

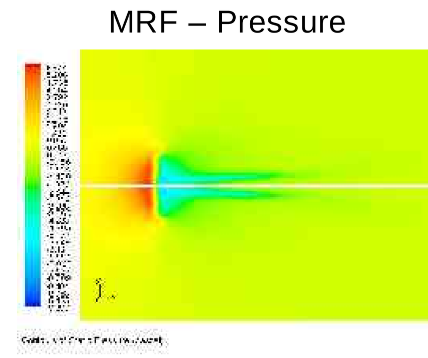


- Good representation of radial velocity at sections near the tip

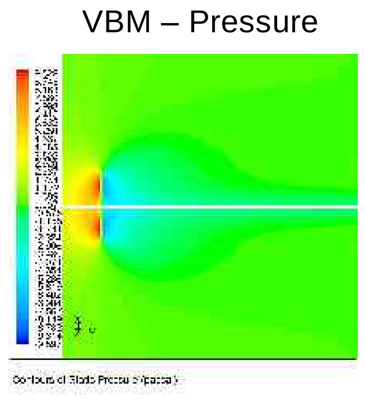
### Static Pressure




MRF – Pressure



VBM – Pressure



- Similar pressure jump
- Fair description with no important deviations

REFERENCES
[1] Ferrer E., Munduate X., *Preliminary CFD simulations of the NREL Phase VI Rotating Blade*,. European Wind Energy Conference (2006)
[2] Burton, T., Sharpe D., *Wind Energy Handbook*, John Wiley & Sons (2001)
[3] VBM Tutorial Guide, Fluent Inc.
[4] Alinot C., Masson C., *Aerodynamic Simulations of wind turbines operating in atmospheric boundary layer with various thermal stratifications*, AIAA-2002-0042
[5] Fluent Users Guide, Fluent Inc.

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