



Energy research Centre of the Netherlands

# **Ontwerpsoftware voor Windenergietoepassingen**

**CWI in Bedrijf:**

**“Energy, Mathematics & Computer Science”,  
11 november 2011, in Amsterdam.**

**P.J. Eecen**





Energy research Centre of the Netherlands

CWI, 11 november 2010

## Ontwerpsoftware voor windenergietoepassingen

Peter Eecen



[www.ecn.nl](http://www.ecn.nl)



## Outline

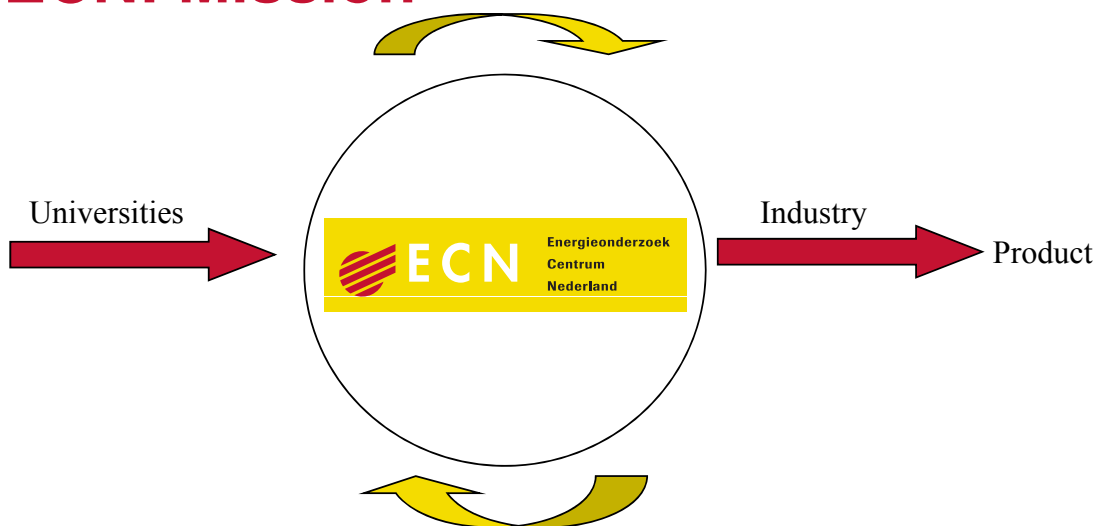
- Introduction to ECN
- Introduction to Wind Energy
- Examples of research activities
  - Rotor aerodynamics – dedicated codes
  - Wind farm aerodynamics CFD developments
  - Rotor aerodynamics – Ansys CFX

## Petten: Energy research capital of Europe





## ECN: Mission



Mission: ECN develops and **brings to market** high-quality knowledge and technology for a sustainable energy system



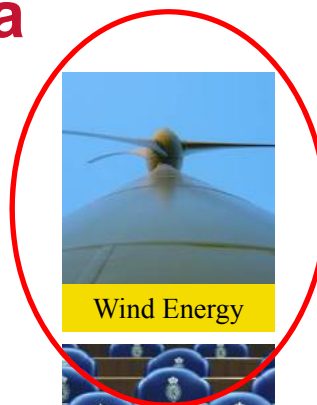
## ECN: Trias energetica



Solar Energy



Biomass



Wind Energy



Efficiency & Infrastructure



H2 & Clean Fossil Fuels



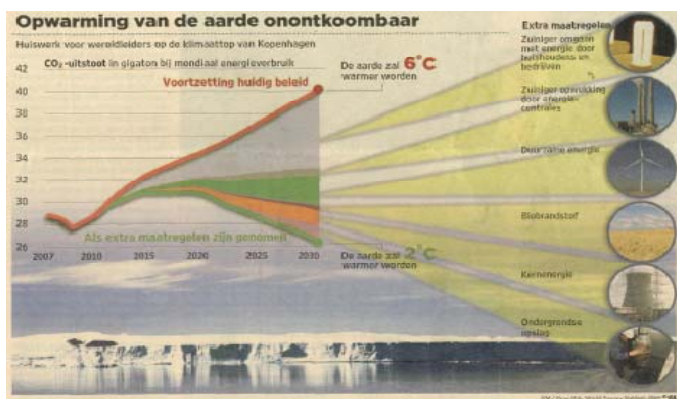
Policy Studies

Engineering & Services

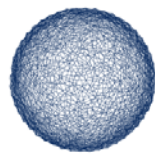
# Why Wind Energy ?







## IEA waarschuwt voor klimaatramp



COP15  
COPENHAGEN  
UN CLIMATE CHANGE CONFERENCE 2009



## Why Wind Energy ?

- no** geo-political risk
- no** external energy dependence
- no** energy imports
- no** fuel costs
- no** fuel price risk
- no** exploration
- no** extraction
- no** refining
- no** pipelines
- no** resource constraints
- no** CO<sub>2</sub> emissions

And.....



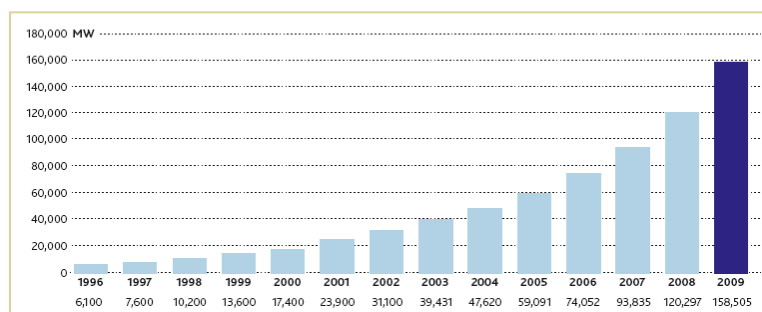
....because wind energy is beautiful



## The Facts

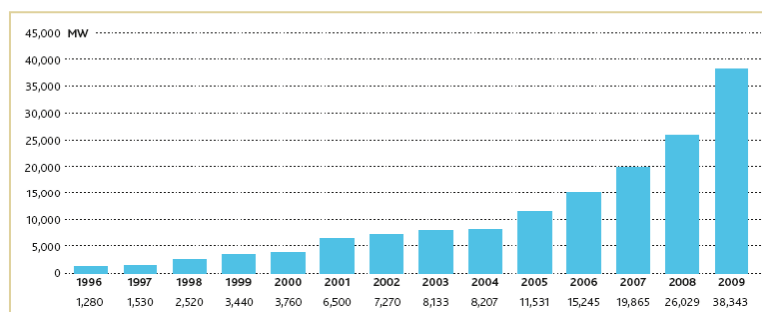
Global cumulative  
installed capacity

GLOBAL CUMULATIVE INSTALLED CAPACITY 1996-2009



Global annual installed  
capacity

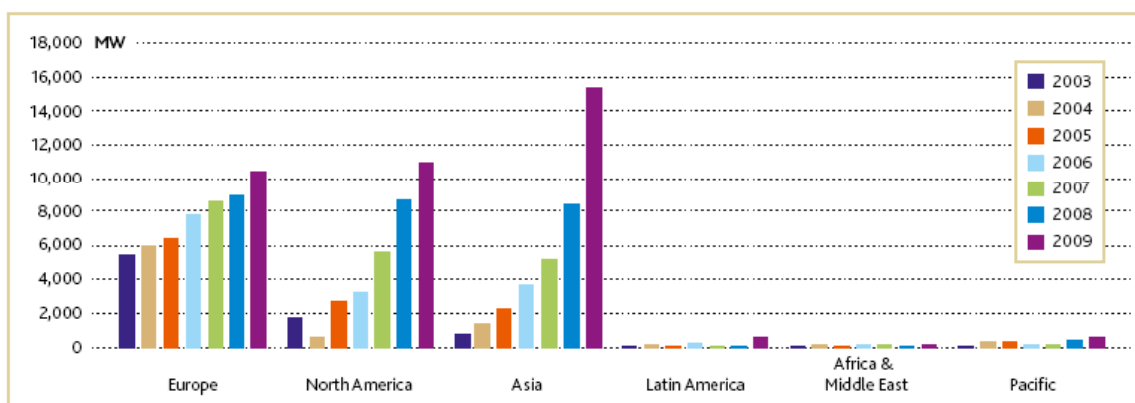
GLOBAL ANNUAL INSTALLED CAPACITY 1996-2009



From: GWEC –  
Global Wind 2009 Report

## The Facts

ANNUAL INSTALLED CAPACITY BY REGION 2003-2009

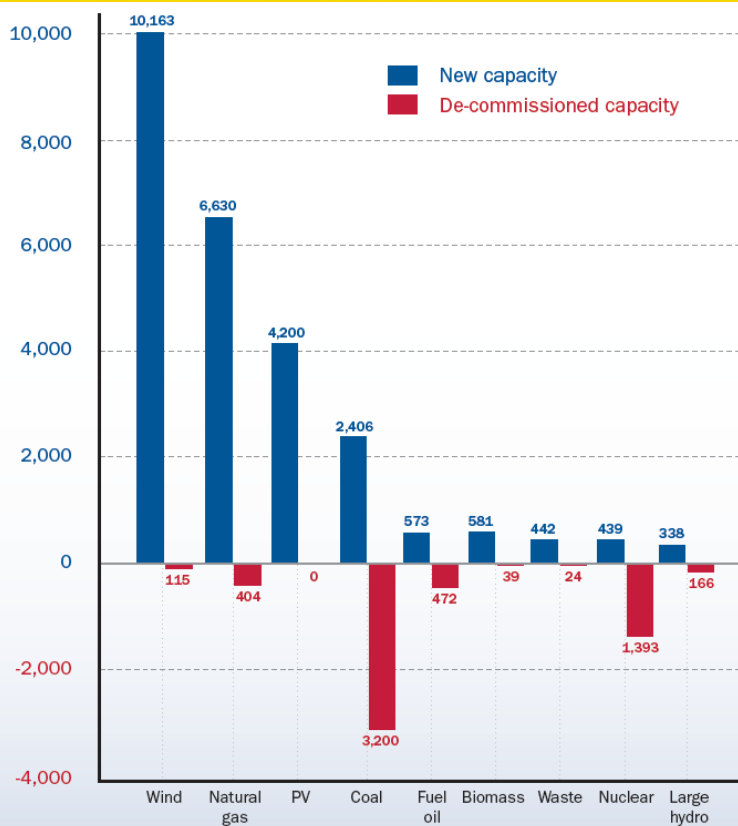


From: GWEC – Global Wind 2009 Report

## The Facts

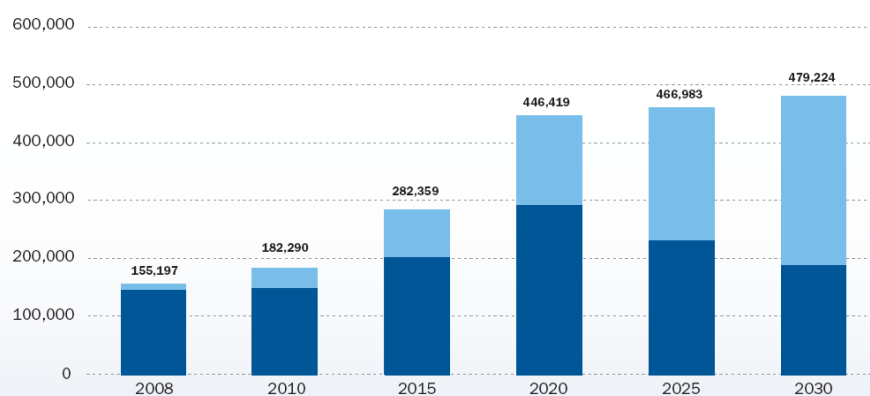
- New installed capacity and de-commissioned capacity in EU 2009 in MW.
- Total 25,963 MW

From: Wind Energy Factsheets  
By the European Wind Energy  
Association – 2010  
[www.ewea.org](http://www.ewea.org)



## The Facts – employment

Wind energy sector employment (2008-2030)



■ Onshore	143,782	148,057	200,870	290,276	228,104	185,478
■ Offshore	11,415	34,232	81,489	156,143	238,879	293,746

Wind Energy Factsheets By the European Wind Energy Association – 2010, [www.ewea.org](http://www.ewea.org)



## Size evolution of wind turbines over time

In 25 years wind energy technology has developed enormously. With more R&D investment it can continue to become even more efficient and high performing.

From: Wind Energy Factsheets  
By the European Wind Energy Association – 2010  
[www.ewea.org](http://www.ewea.org)



## Blade sizes of today (61.5 m)

### LM 61.5 P

#### Product specifications

Blade type	LM 61.5 P
Rotor diameter (max.)	126.3 m
Blade regulation	Pitch
Length	61.5 m
Max. chord	4,600 m
Profiled area	183.0 m <sup>2</sup>
Weight	17,740 kg*
Number of bolts	128
Size of bolts	M36
Bolt circle diameter	3,200 mm

\*Preliminary data





## Research Programme



Energy research Centre of the Netherlands

**Knowledge  
Centre**

**WMC**

*Wind turbine Materials and Constructions*



- Rotor- and Farm Aerodynamics
- Integrated Wind Turbine Design (software)
- Operation & Maintenance (Condition monitoring / O&M Tool)
- Material research (WMC)

## Research line: Rotor & Farm Aerodynamics

### Rotor aerodynamics

- Theoretical and experimental research
- Use of CFD
- Development of industrial codes

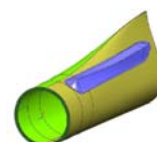
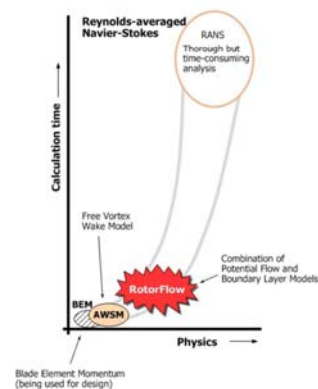
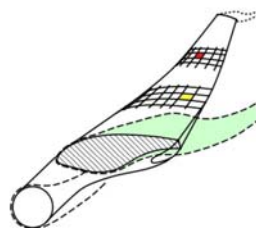
### Wind farm aerodynamics

- Theoretical modelling
- Use of CFD
- Experiments (wind tunnels, scaled wind farm, full scale)

### New ideas

- Strip on blade root
- Wind Farm control strategies
- Synthetic jets

RotorFlow  
Aerodynamics





## Research infrastructure




**ECN The ECN AWSM code**

- Numerical code based on the Generalized Prandtl's Lifting Vortex Line Method

Able to include:

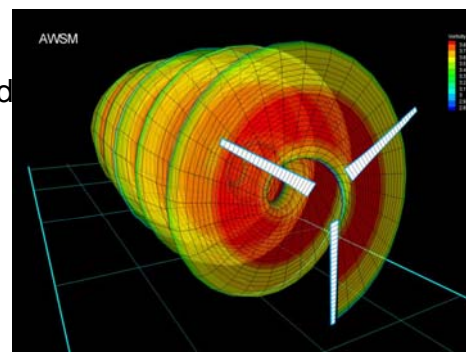
- Analysis of multi-body configurations
- General-shape geometries
- Steady and unsteady analysis
- Yaw, pitch misalignments
- Non uniform wind conditions (local gusts and wind shear)

Coupled to ECN Aeromodule

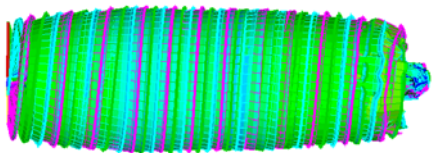
Arne van Garrel: Development of a wind turbine aerodynamics simulations tool, ECN report



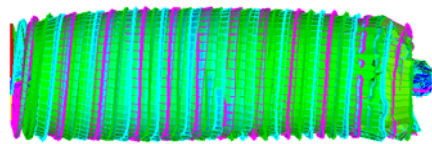
AWSM developed by: Arne van Garrel  
Extended and used by: Francesco Grasso



### Ground Effect

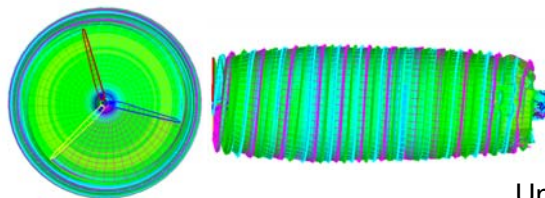


No ground

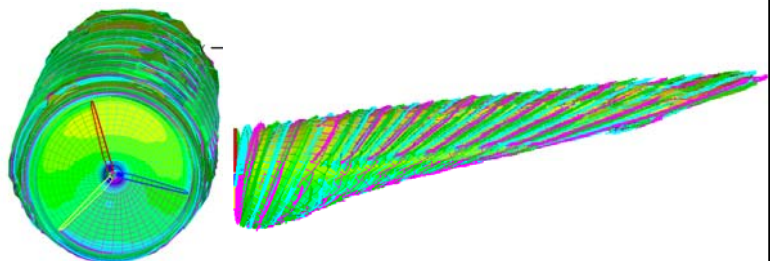


Ground

### Shear Effect



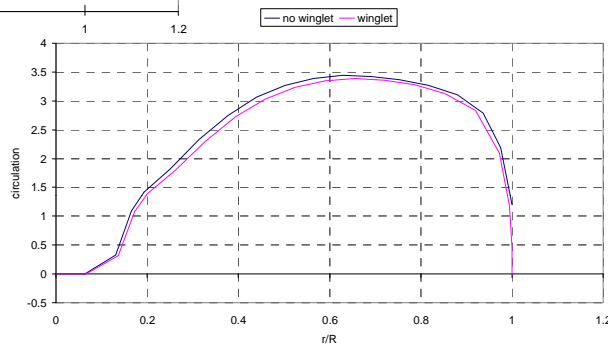
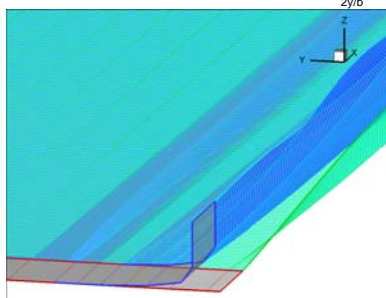
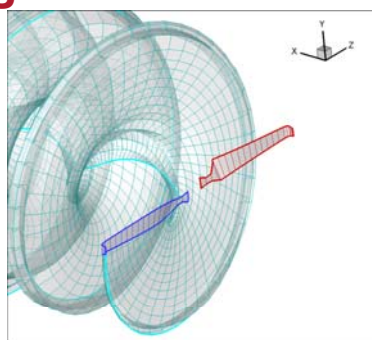
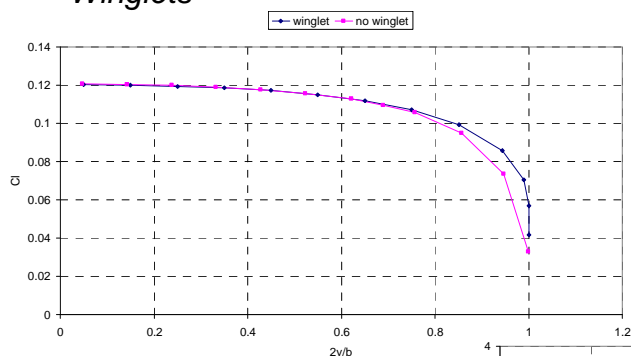
Uniform wind



Wind shear

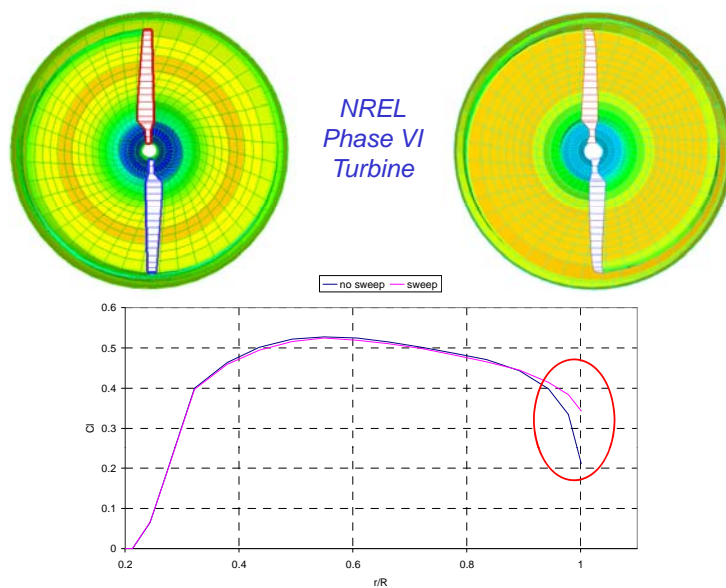
## Non conventional configurations

### Winglets



## Non conventional configurations

*Swept blades*

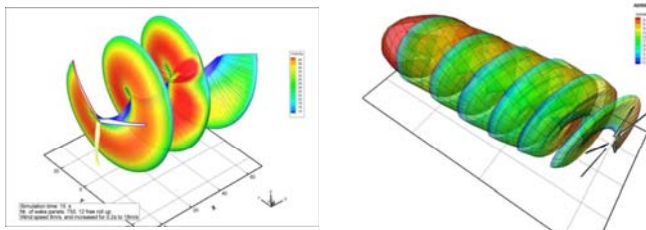




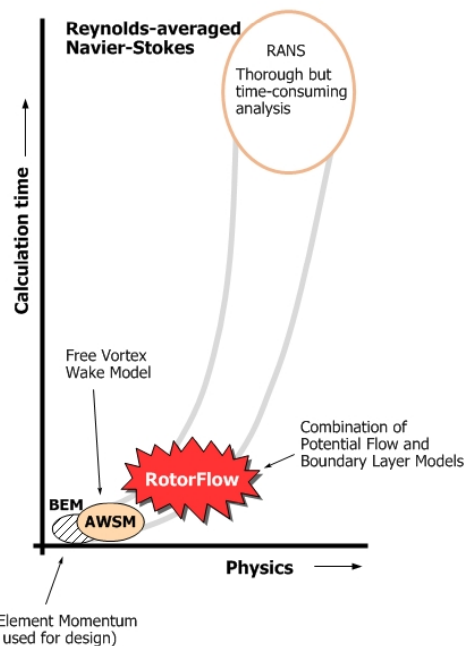
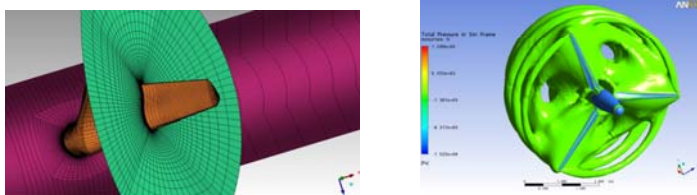
# ROTORFLOW - development

Work by: Hüseyin Özdemir  
Arne van Garrel  
Henny Bijleveld

- Engineering tools: *not accurate enough*  
Blade Element Momentum (BEM), Vortex line method (AWSM), XFOIL, RFOIL



- CFD tools (CFX): *too expensive, too much time*  
- Several weeks on cluster



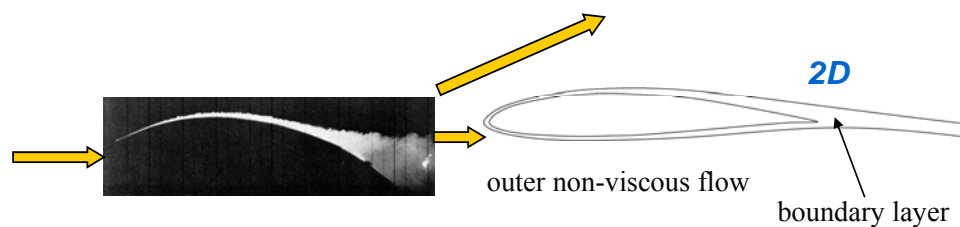
## Development of RotorFlow code

Work by: Hüseyin Özdemir  
Arne van Garrel  
Henny Bijleveld

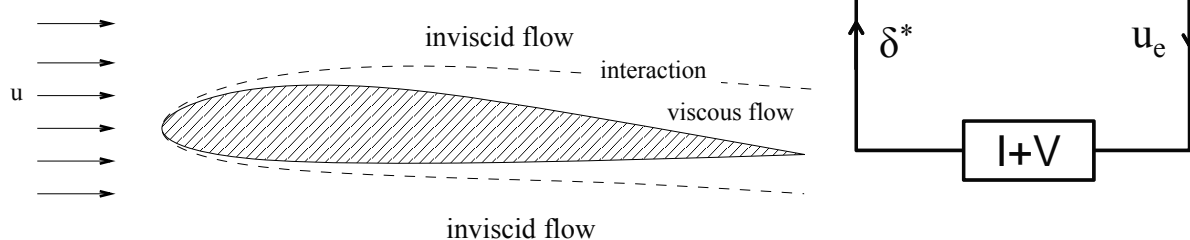


- **Boundary Layer:**
  - *Integral boundary layer method (IBL)*
- **Potential outer layer:**
  - *Panel method*
- **Viscous – Inviscid Interaction (VII):**
  - *Strong quasi-simultaneous interaction scheme*

3D

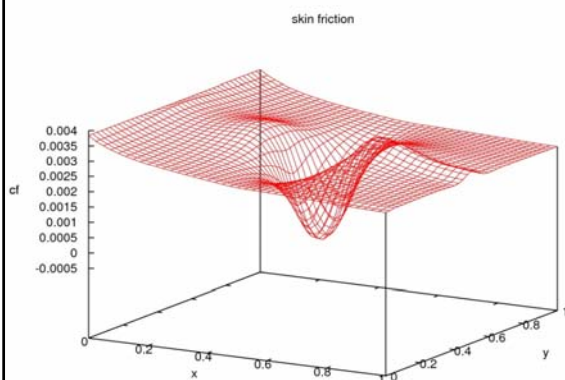


## RotorFlow VII: Quasi-simultaneous interaction



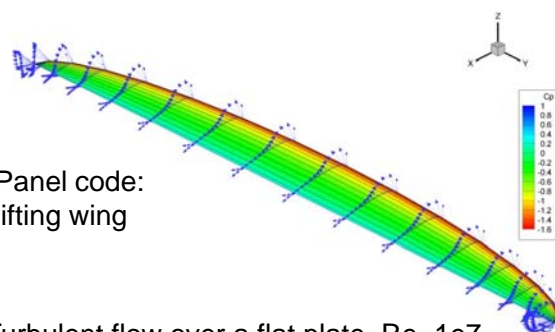
- Combines advantages of direct and simultaneous method
- Interaction law (I): approximation of inviscid flow (E) solved together with the boundary-layer equations (V)
- Interaction law is an algebraic equation

## Preliminary results

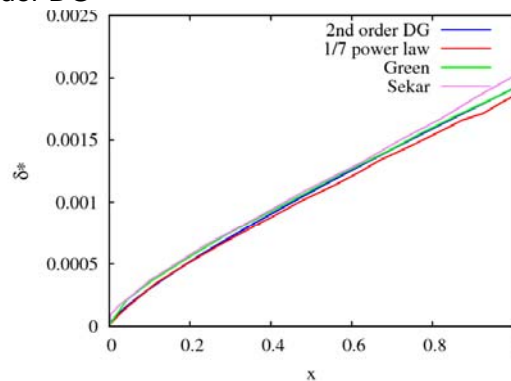


Flow over dented plate:  $Re = 11.5 \cdot 10^6$   
Separation in middle of the dent

Panel code:  
lifting wing



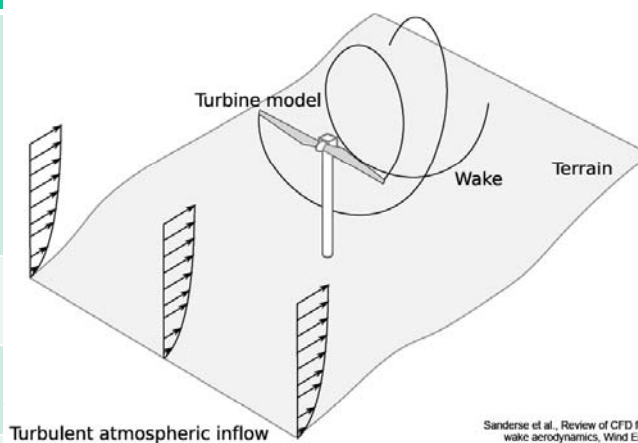
Turbulent flow over a flat plate,  $Re=1e7$   
2<sup>nd</sup> order DG



Work by: Benjamin Sanderse

## Development of a wind farm CFD code

Physical phenomenon	Numerical model
Wake model	Energy conserving discretization and Large Eddy Simulation
Turbine model	Actuator method
Atmospheric inflow	Precursor simulation
Terrain	Immersed boundary method



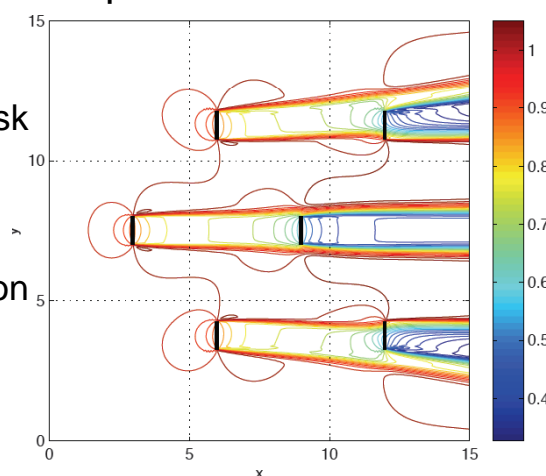
Sandersse et al., Review of CFD for wind-turbine wake aerodynamics, Wind Energy 2010

## Energy conserving discretization of fluid flow

- Wakes are important to wind farm aerodynamics
- Dissipation must be limited to 'keep' the wakes

Code to be developed is dedicated to task

- Energy conserving discretization
- LES approach
- actuator method
- Atmospheric inflow: Precursor simulation
- Terrain by immersed boundary method



## Wind farm aerodynamics CFD code

- Development CFD tool requires work in many areas:
  - Suitable discretization schemes
  - Turbulence models
  - Terrain modeling
  - Actuator modeling
- Atmospheric turbulent inflow, coupling with mesoscale model

To answer simple questions:

Optimum distance between turbines

Optimum wind farm lay-out

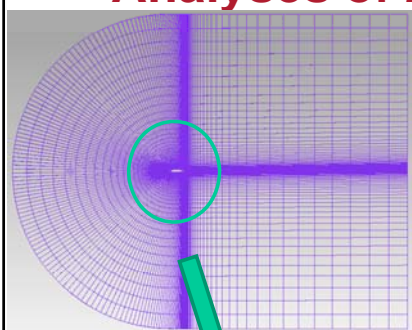
Influence of wind farm on local climate

Assessment of control strategies

Farm-Farm interaction

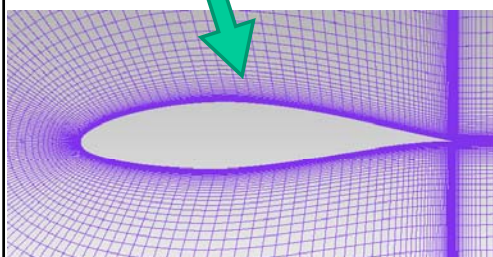
Design specifications (mechanical loads in farm)

## Use of commercial software Ansys-CFX Analyses of 2D configurations



Reference airfoil

NACA 64<sub>2</sub>418



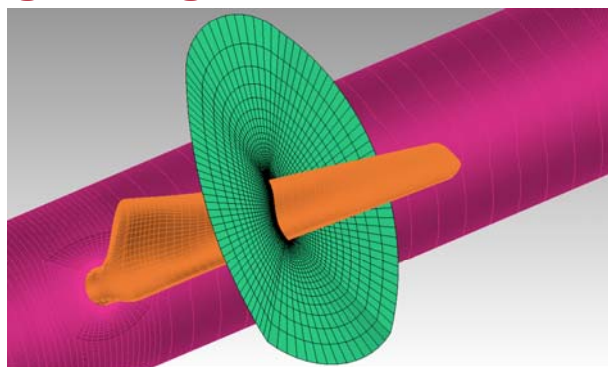
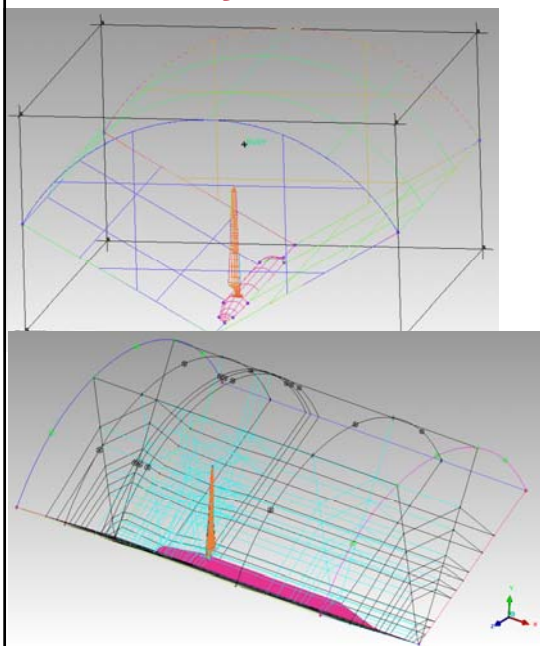
C-grid



O-grid



## Use of commercial software Ansys-CFX Analyses of 3D rotating configurations



•First cell thickness : 1mm

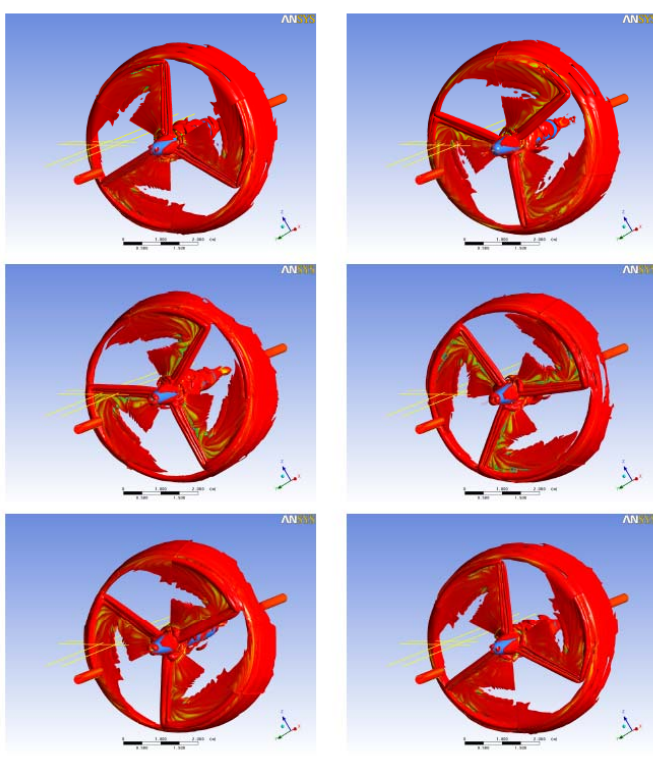
- *MEXICO rotor – mesh setup*

	Inner wedge	Outer wedge	Total
Number of Nodes:	1997919	691875	2689794
Number of Elements:	1953406	671328	2624734
Wedges:	4305	9744	14049
Hexahedra:	1949101	661584	2610685



# Visualisations – Ansys-CFX results

Work by: Marc van Raalte





**Wind Energy contributes to CO<sub>2</sub>- reduction ambitions.**



**QUESTIONS?**