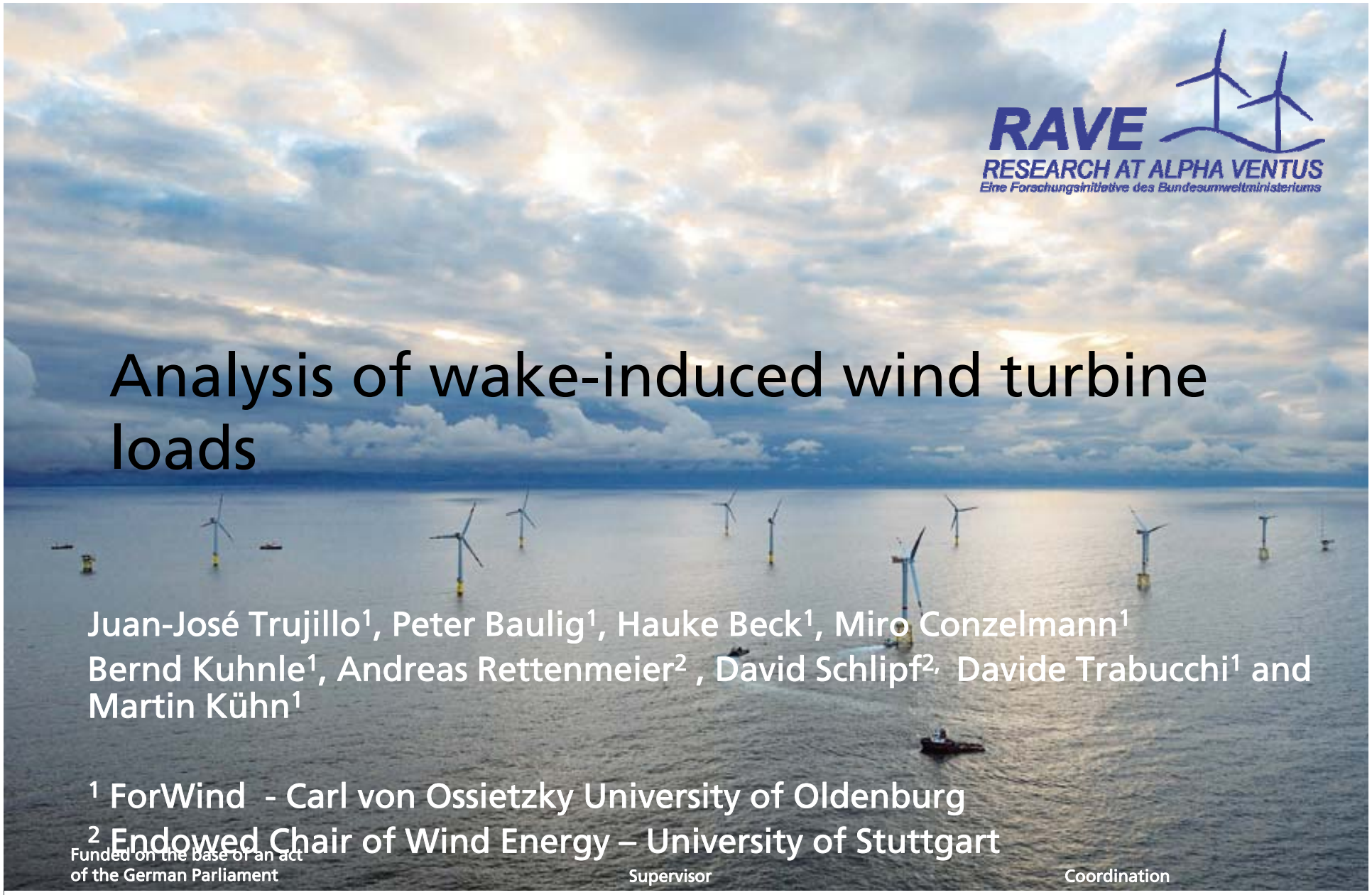

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RESEARCH AT ALPHA VENTUS
Eine Forschungsinitiative des Bundesumweltministeriums

Analysis of wake-induced wind turbine loads

Juan-José Trujillo[1], Peter Baulig[1], Hauke Beck[1], Miro Conzelmann[1]
Bernd Kuhnle[1], Andreas Rettenmeier[2] , David Schlipf[2], Davide Trabucchi[1] and Martin Kühn[1]

[1] ForWind - Carl von Ossietzky University of Oldenburg
[2] Endowed Chair of Wind Energy – University of Stuttgart

Funded on the base of an act of the German Parliament

Supervisor

Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit

Coordination

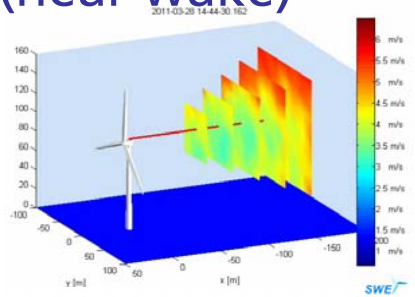
ptj Projektträger Jülich Forschungszentrum Jülich

Fraunhofer IWES

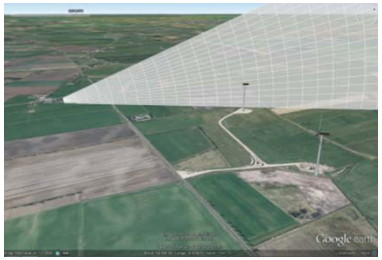
RAVE-OWEA approach

Improvement through accurate wind field calculation in wake

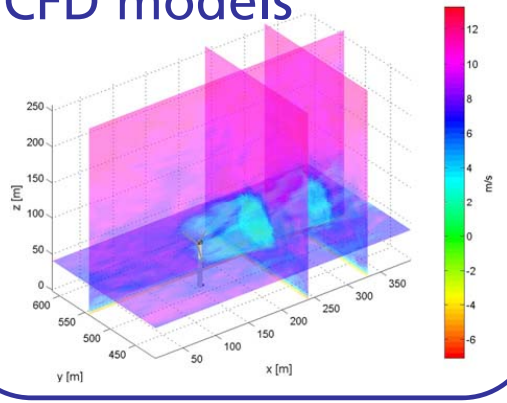
Lidar measurements (near wake)



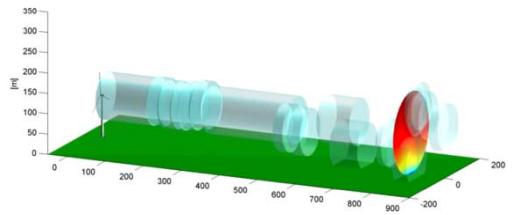
Lidar measurements (far wake)



CFD models



Engineering models



Aeroelastic models

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Contents

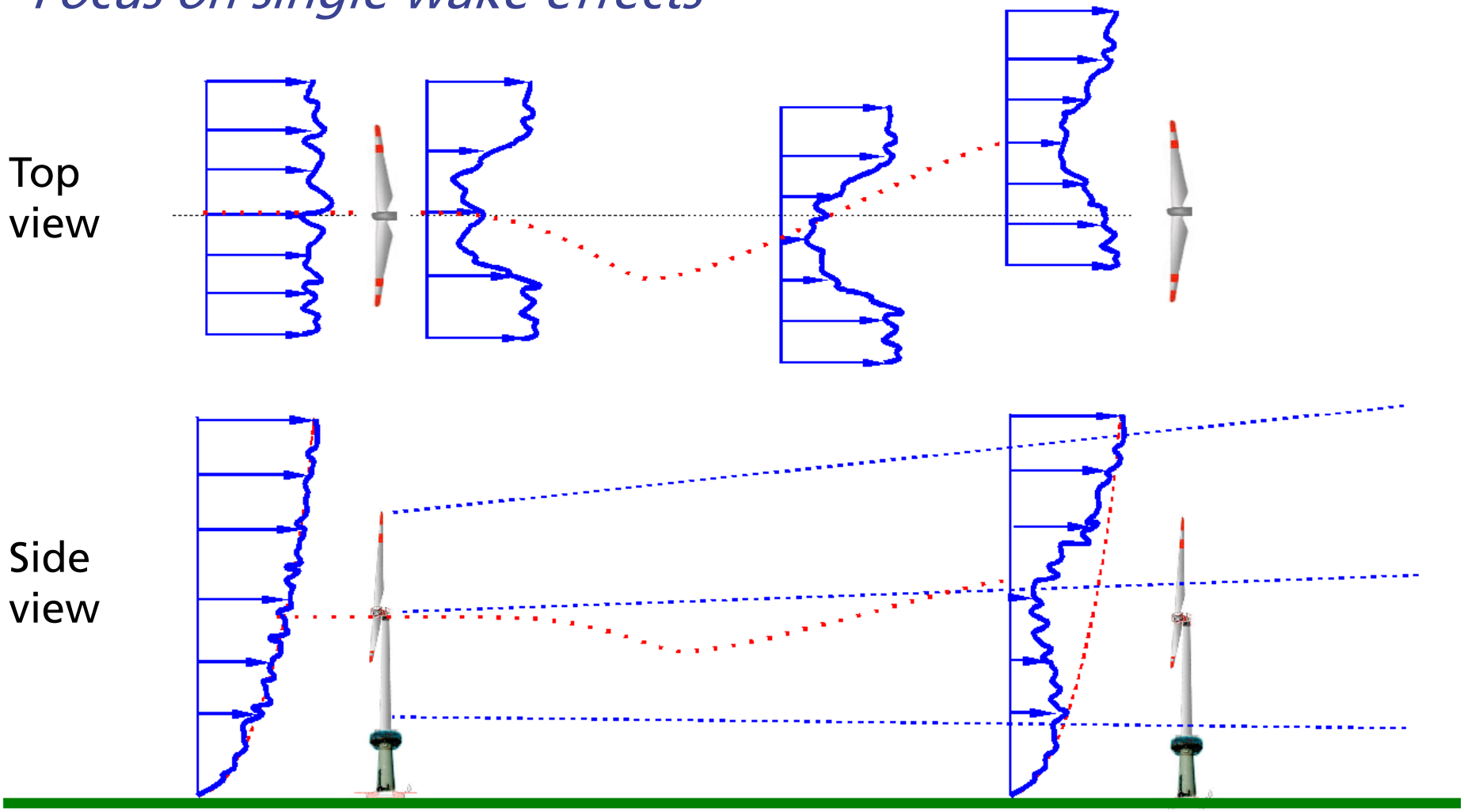
- Engineering models for wake meandering
- Steady wake wind field calculation
- Meandering simulation setup
- Simulation results
- Conclusions

Dynamic wind turbine wake

Focus on single wake effects

Top view

Side view



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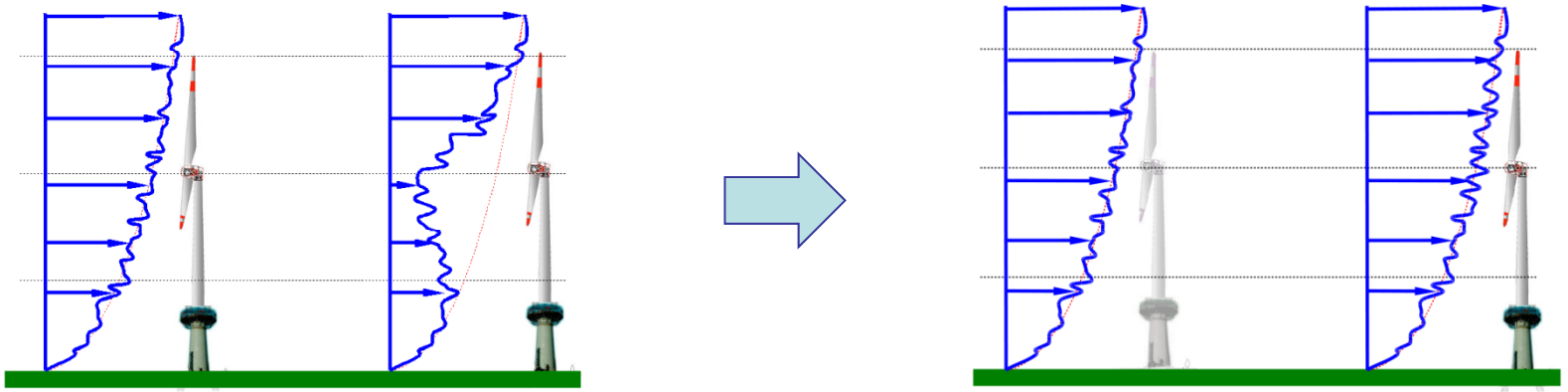
Present wake engineering models

IEC Standard recommendation

- Effective turbulence intensity

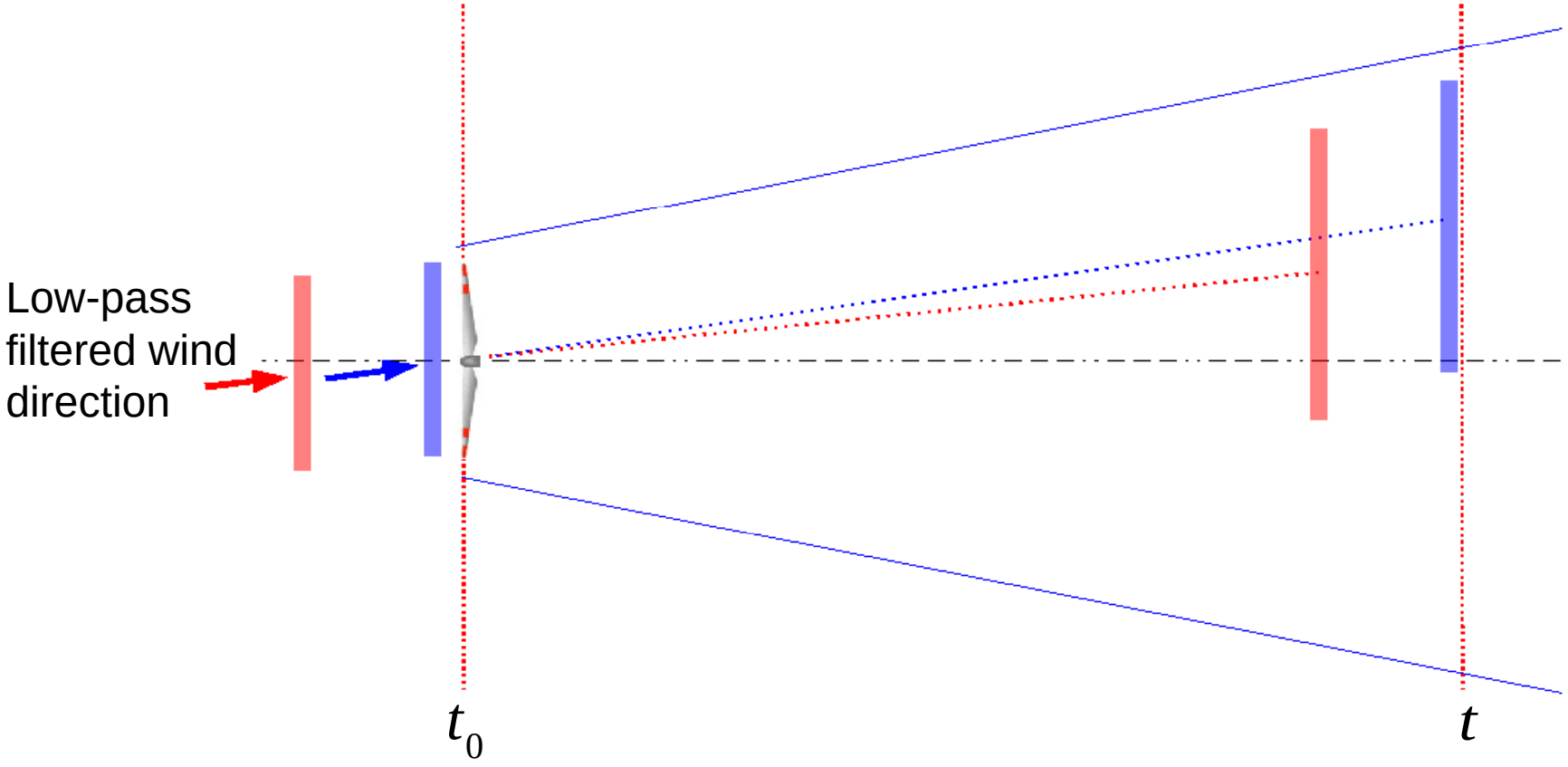


Simplified physical models

- Dynamic Wake Meandering (Larsen et al. DTU Wind Energy)
- Disk Particle Model (Trujillo et al., now at University of Oldenburg)

Dynamic Wake Meandering Model (DWM)

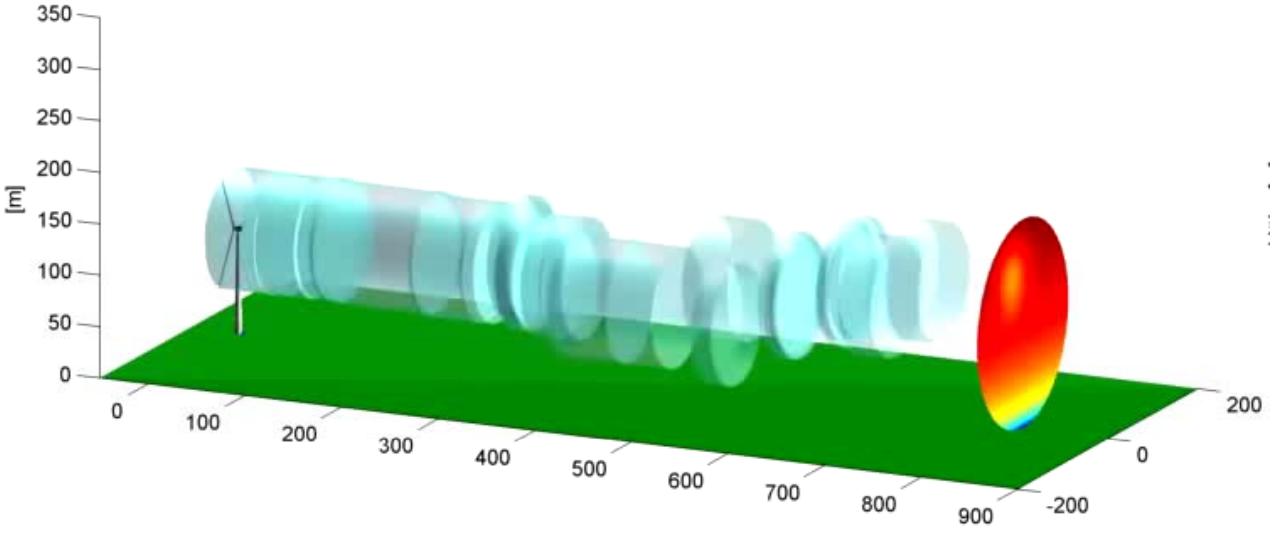
DTU Wind Energy



Extended Disk Particle Model (EDPM)

University of Oldenburg

- Wind volumes following Lagrangian paths
- Influence of atmospheric stability
- Adaptive volume size
- Steady wake deficit based on modified Ainslie approach



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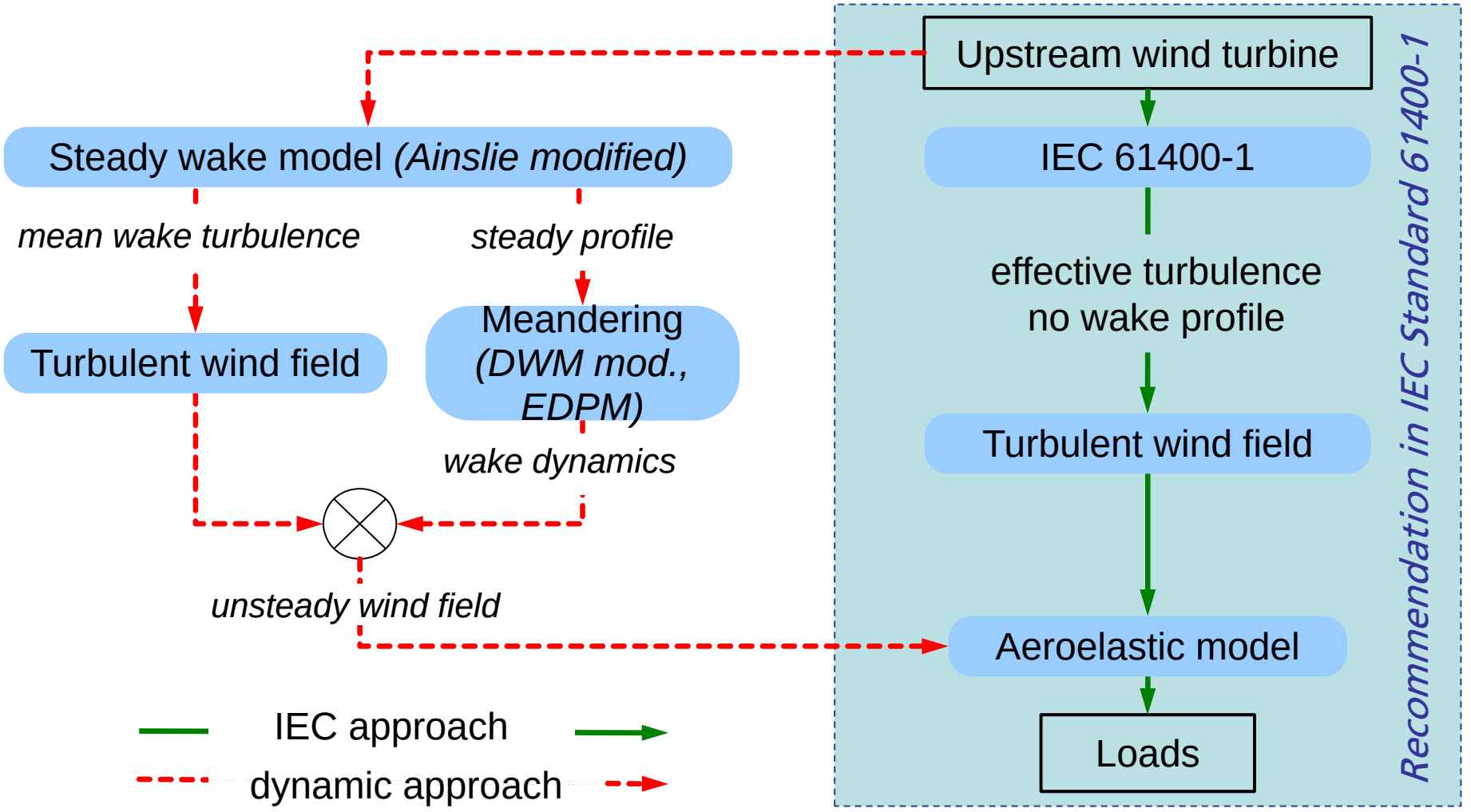
Load calculation procedure



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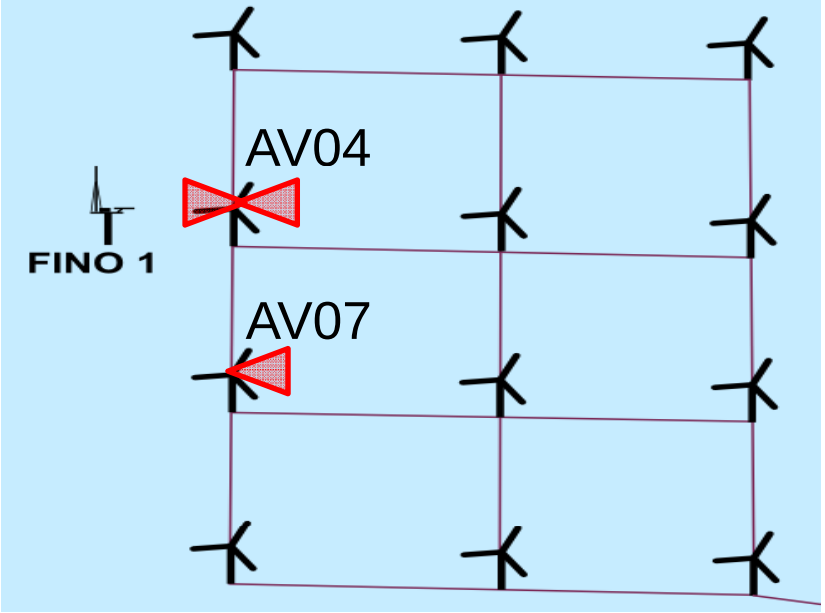
Lidar wake meassurements at alpha ventus

Campaign	Status	AV04	AV07
1	finished	inflow	wake
2	planned	inflow + wake	



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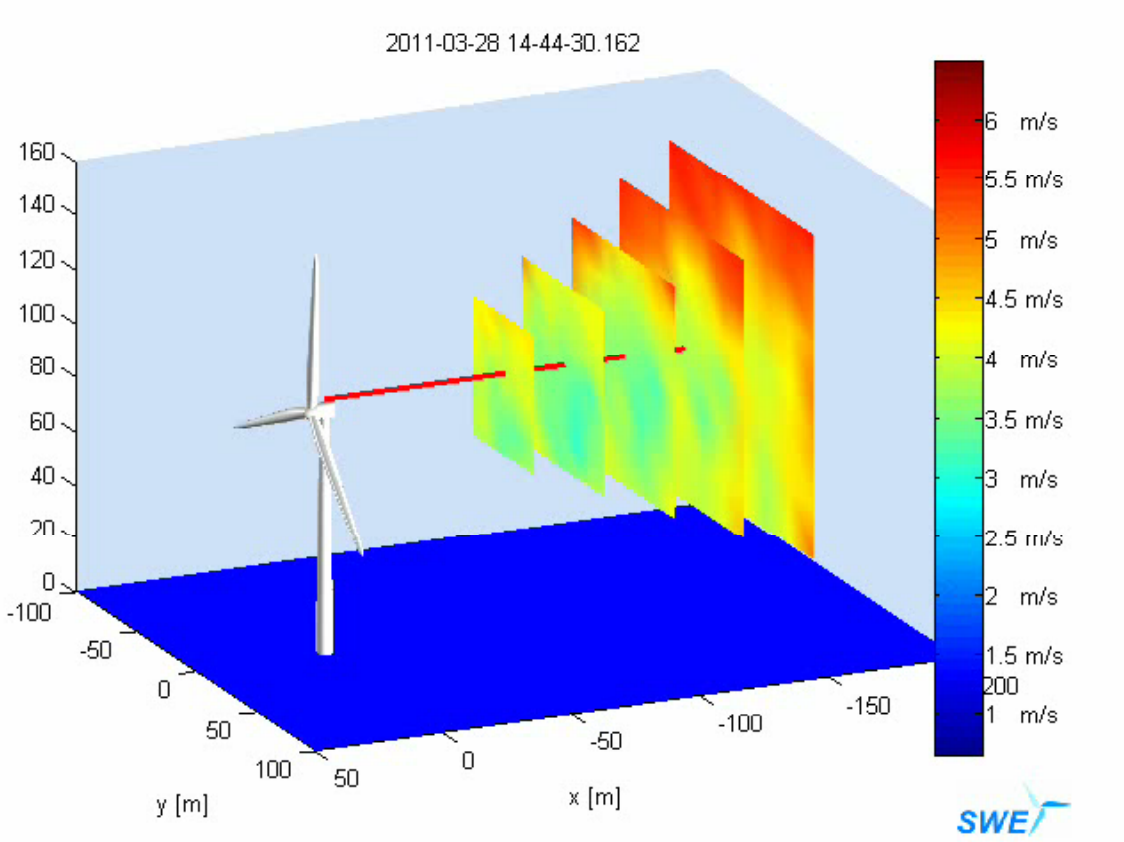
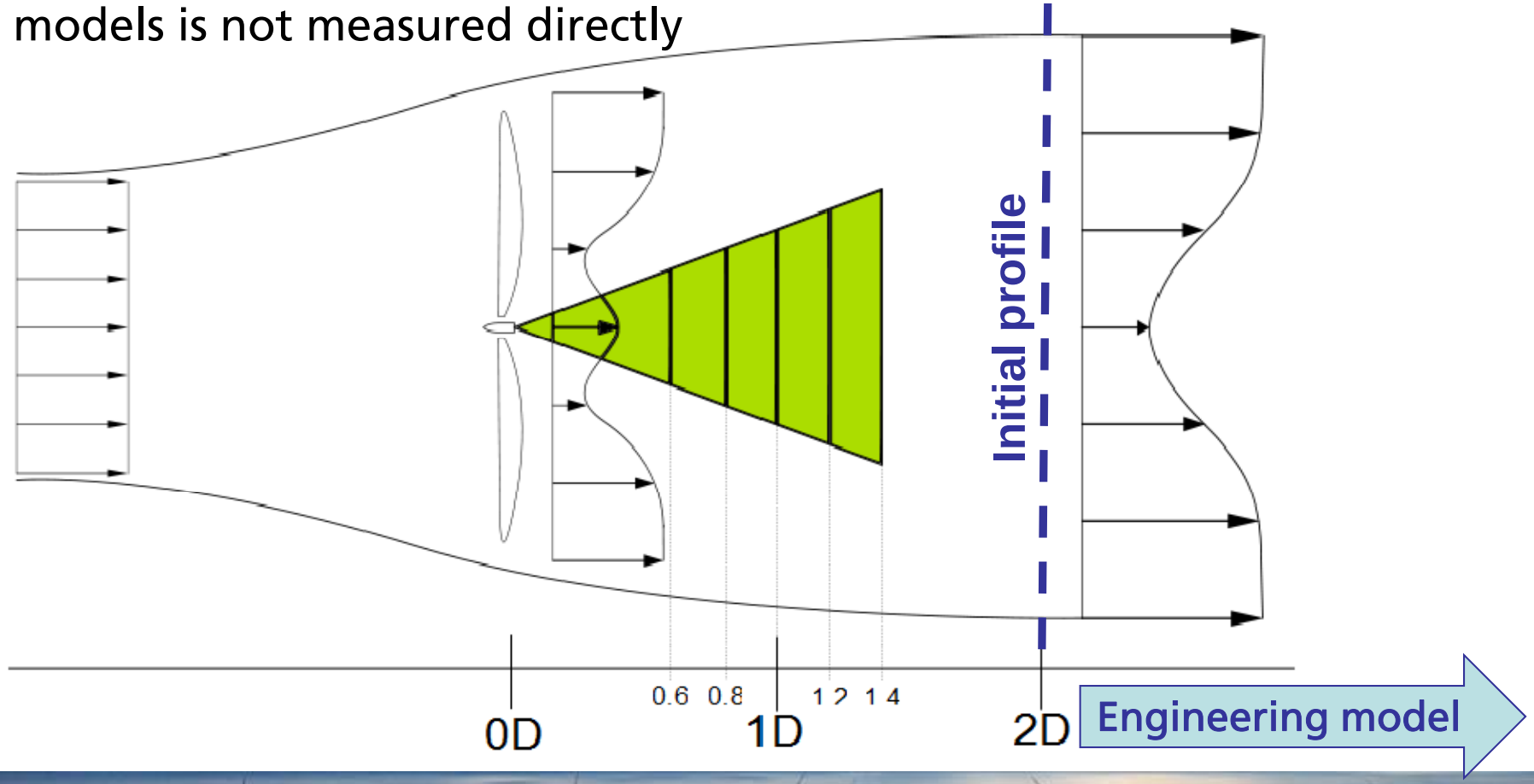
Lidar wake measurements at alpha ventus

Example of ten minute average of longitudinal wind speed



Sketch of lidar wake measurement of the AV07

Initialization profile for engineering models is not measured directly



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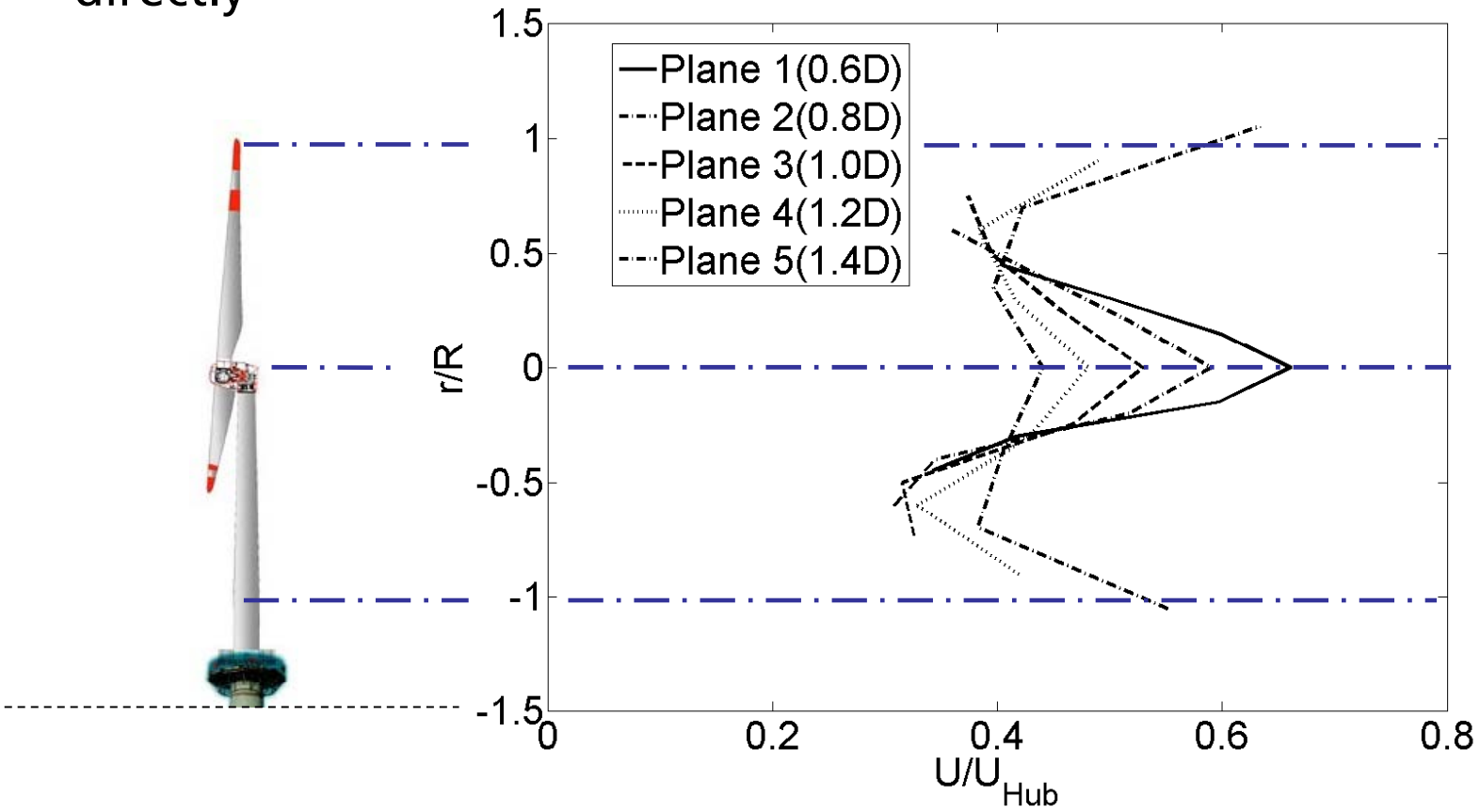
Lidar wake measurement of the AV07

Initialization profile for engineering models at 2.0D is not measured directly



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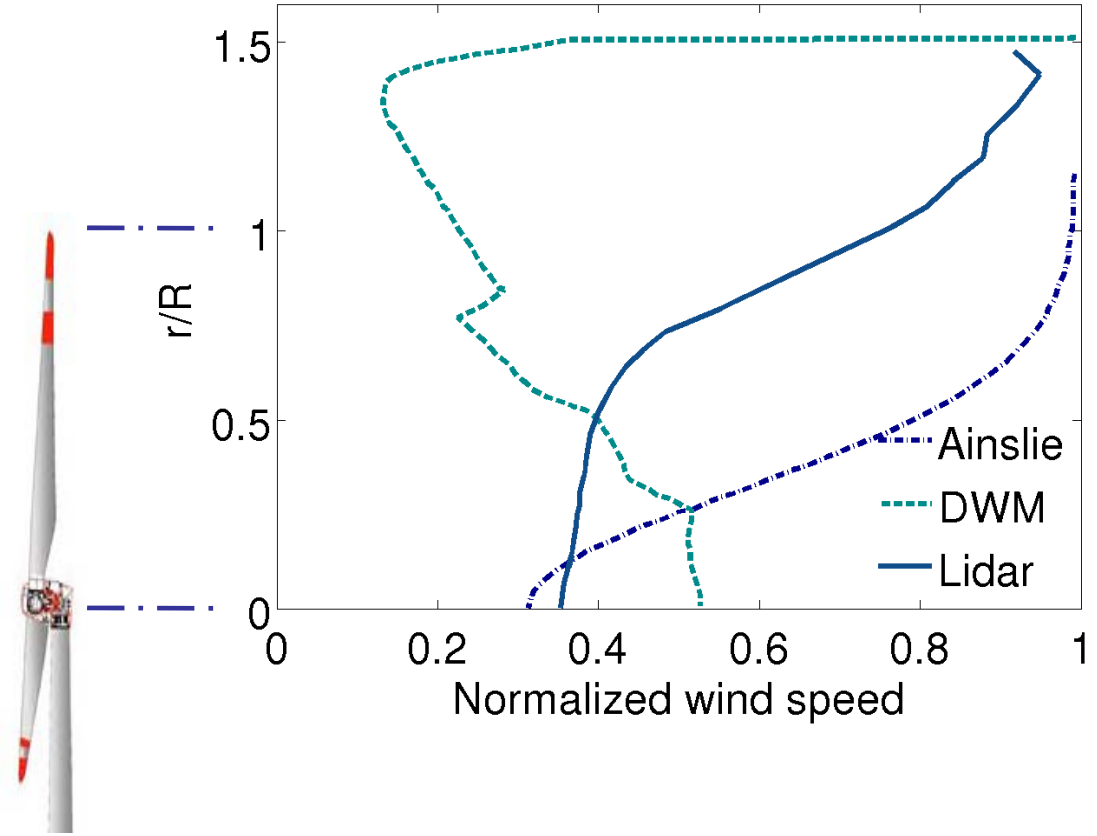
Estimation of wind speed at 2D downstream
Model and extrapolated lidar measurement

- Profiles from models differ from lidar measurements
- Linear extrapolation method of lidar measurements is being verified with simulations



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Simulations setup of a reference offshore turbine

Wind turbine model

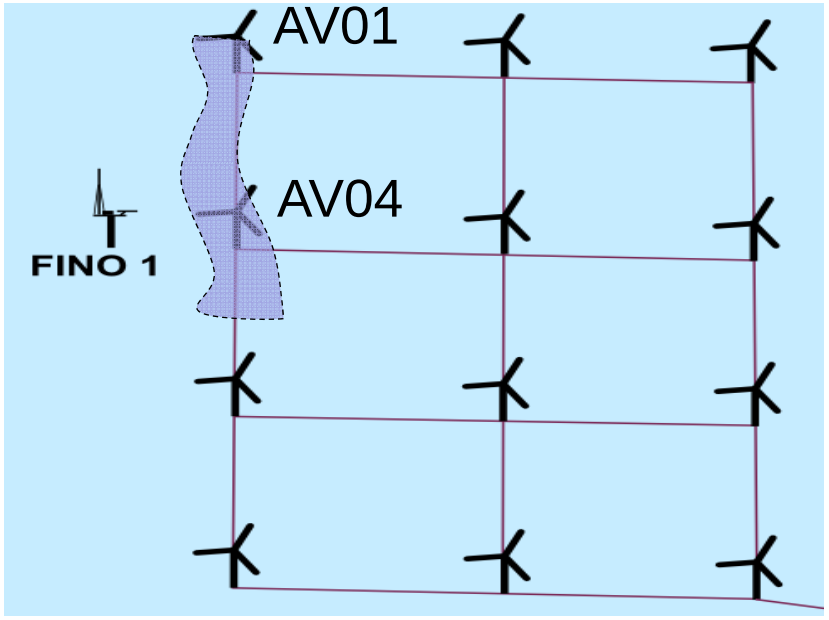
- NREL 5MW
- Support structure set similar to the REpower 5M (eigenfrequency)

Aeroelastic model

- Simulations with GH-Bladed®
- Wind fields produced externally

Simulation case

- Wake of AV01 on AV04
- Downstream distance 6.5 D



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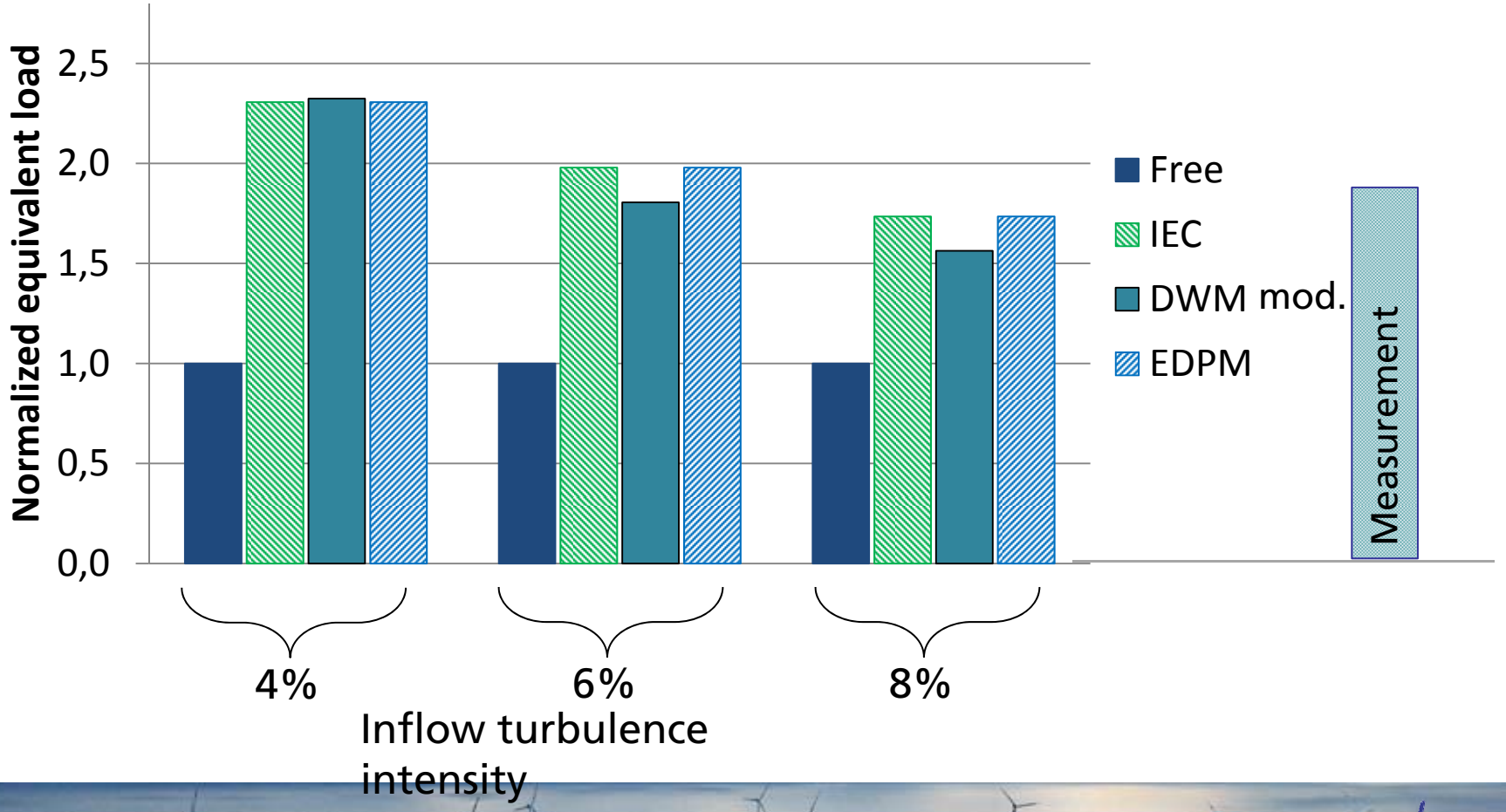
Damage equivalent loads

Flap-wise blade bending moment 7 m/s free inflow



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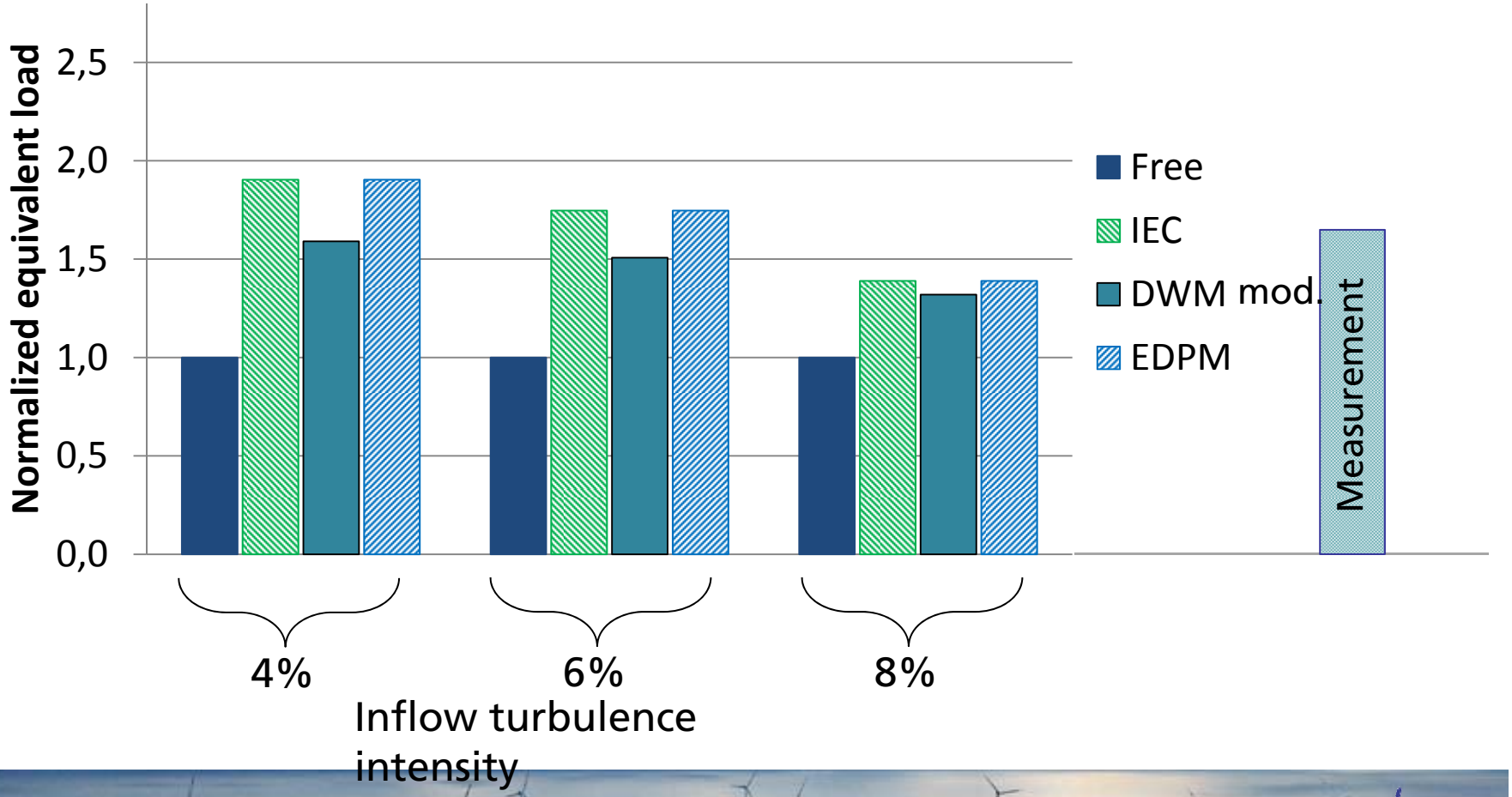
Damage equivalent loads

Flap-wise blade bending moment 11 m/s free inflow



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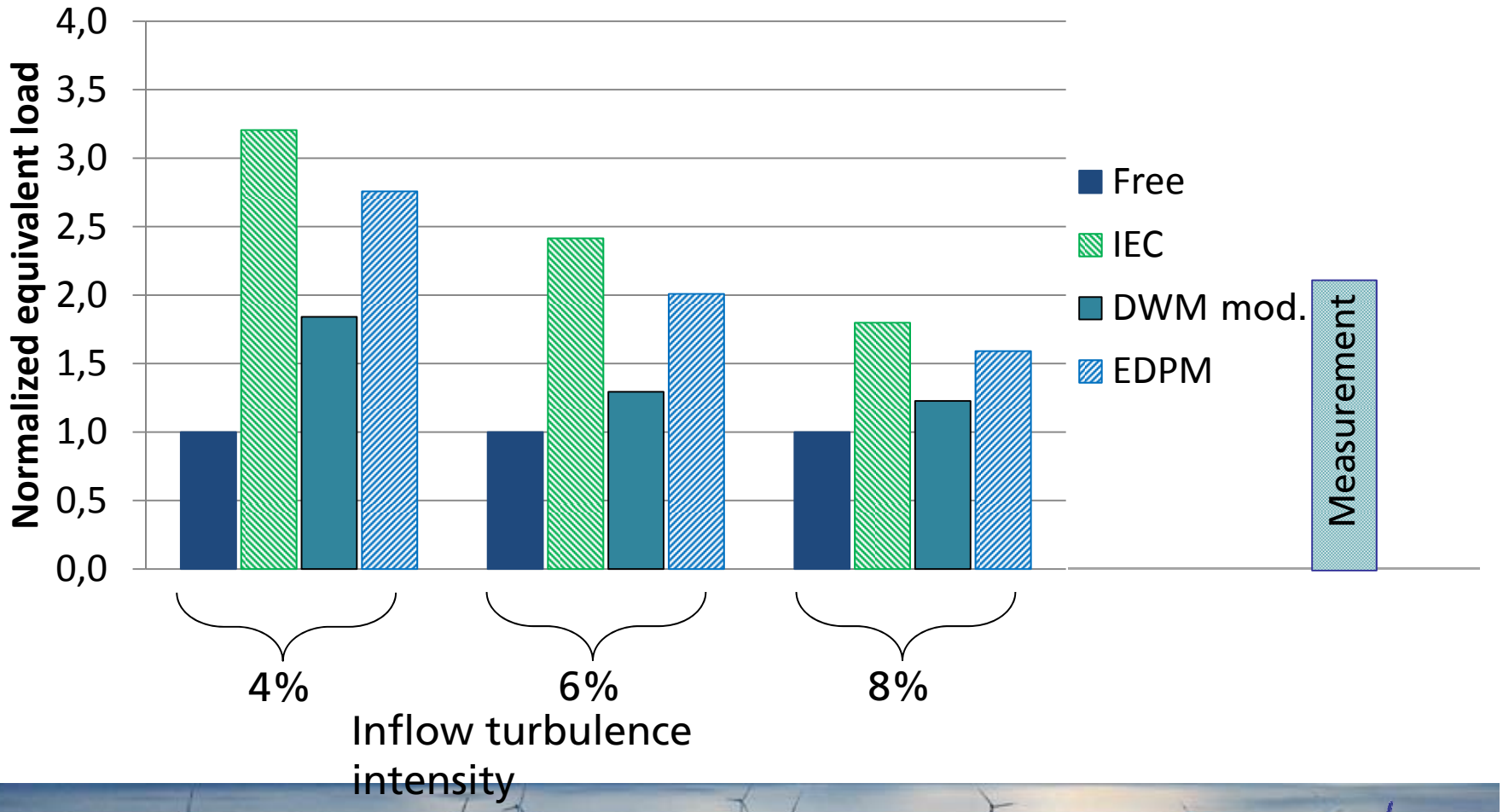
Damage equivalent loads

Fore-aft tower bending moment 7 m/s free inflow



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Conclusions

- Wind speed deficit in the near wake has been measured with lidar and used as initial condition for the steady wake model
- Parameterisation of the EDPM has to be further developed
- Damage equivalent loads of IEC, DWM and EDPM can differ considerably for different load components.

  => effect of atmospheric conditions and turbulence superposition method in the meandering models

Outlook

- Planned lidar measurements should give insight into the near/far wake behaviour, and differences between the models

Acknowledgements

- We thank the lidar team at the Endowed Chair of Wind Energy at the University of Stuttgart for the support in the near wake measurements used in our implementation of the Ainslie wake model.

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