Offshore wind farm wakes in global circulation model MPAS compared with WRF and measurements

Marc Imberger, Xiaoli Guo Larsén, Neil Davis

DTU Wind Energy, Technical University of Denmark (DTU)

Introduction

- Topic: Evaluation of MPAS capabilities for wind resource assessment in comparison with currently used method (WRF nesting)
- MPAS: Model for Prediction Across Scales
- WRF: Weather Research and Forecasting
- WRF successful and established tool with known limitations
- MPAS tackles limitations but introduces other challenges
- Leading question:Assessment of MPAS capabilities for wind resource assessment
- Capabilities analyzed in different areas, today: wind farm wakes

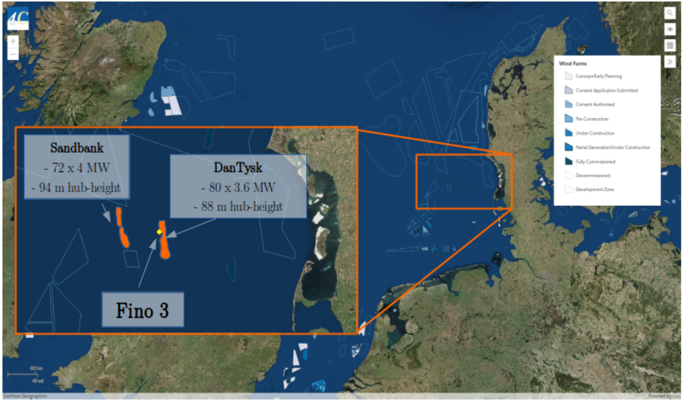
Motivation

- Increasing wind farm size and density, especially offshore
- Farm to farm interaction becomes important
- Need for accurate and reliable modeling across scales (time and space)
    - Economic impact
    - Impact on local/regional environment

Source: 4Coffshore, Global Offshore Renewable Map , https://www.4coffshore.com/offshorewind/

Measurements

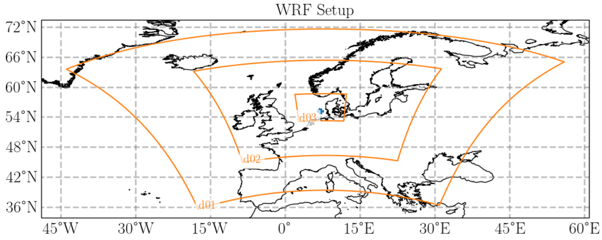
- Sandbank & DanTysk: SCADA Data from individual turbines, among others
  - wind speed (hub-height)
  - nacelle orientation
  - power production
- SCADA provided by Vattenfall
- Fino 3: Meteorological and oceanic quantities at several heights, among others
  - wind speed (several heights)
  - wind direction (several heights)



Model Setup I - Structural Differences

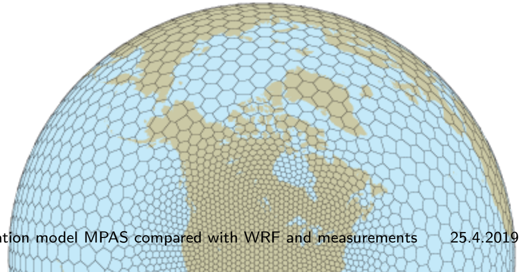
	WRF (V3.7.1)	MPAS (V6.1)
model type	limited area model	global model
hor. discretization	regular lat/lon grid	unstructured centroidal Voronoi mesh
vert. discretization	pressure based, terrain following	height-based, hybrid
mesh refinement	one-way nesting, 18km/6km/2km	circular refinement region, approx. resolution: 3.8km, 225282 cells

WRF



MPAS

(example, source: https://mpas-dev.github.io/)



Model setup II - Simulation Framework and Post-processing

- simulation time (WRF/MPAS)
  - 6 day total simulation time (2017-02-12 to 2017-02-18)
  - 24h spin-up
  - initialized by CFSv2 forecast product
- lateral boundaries (only WRF)
  - 6-hourly update interval
  - CFSv2 forecast product
- Vertical interpolation (WRF/MPAS) to fixed height above sea level
- Horizontal regridding using bi-linear interpolation (MPAS)

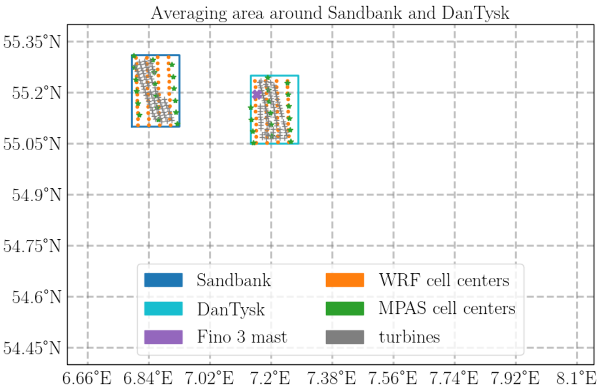
Model setup II - Physics

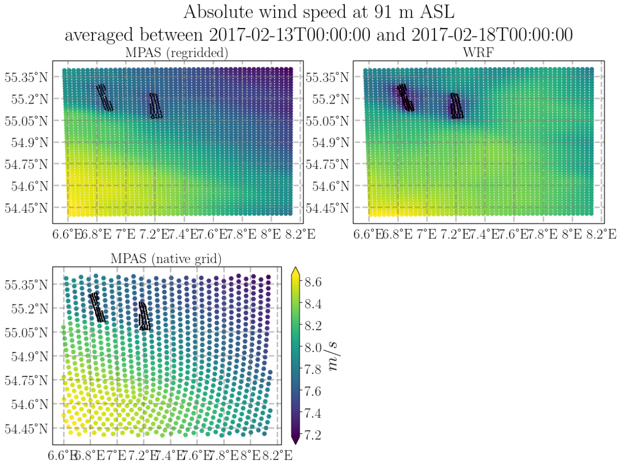
Parameterization	WRF	MPAS
similar:		
Microphysics	Thompson (non-aerosol aware)†	
Land surface	Noah	
Boundary layer	MYNN3	
Surface layer	MYNN3	
Radiation	RRTMG†	
Wind farm wake	Volker et al. 2015	
different:		
Cumulus	Kain-Fritsch (only d01)	scale-aware Grell-Freitas
Cloud fraction	off	Xu and Randall 1996

† versions differ

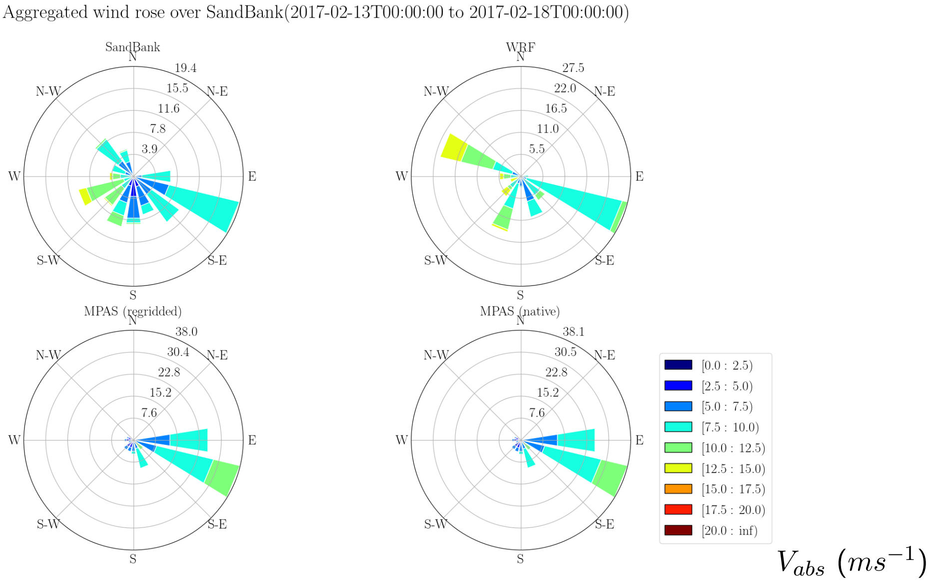
Results

Wind Farm Wake Representation





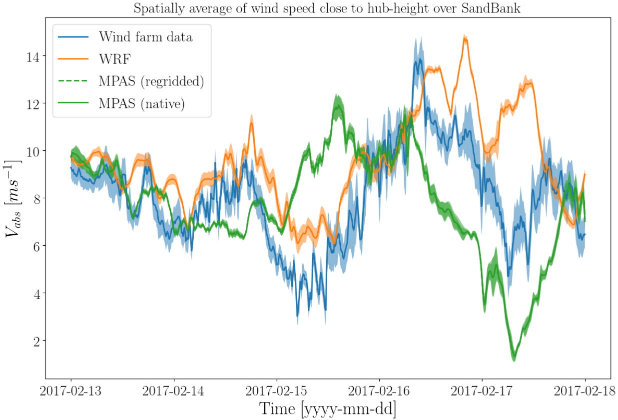
Wind farm aggregated comparison (Sandbank)



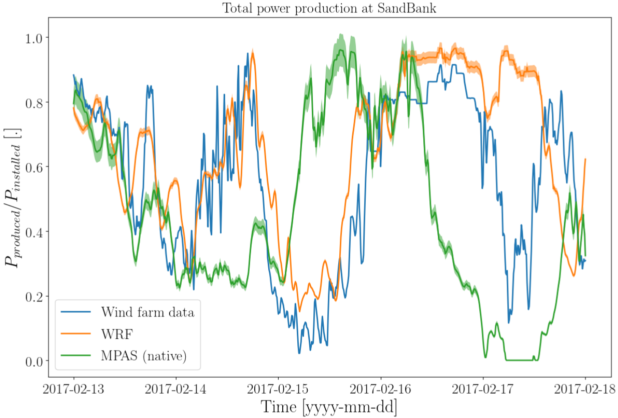
Results

Wind farm aggregated comparison (Sandbank)

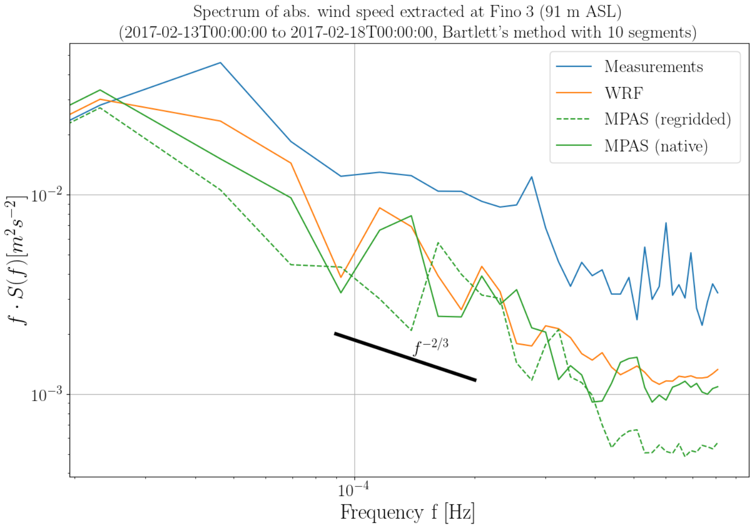
Wind speed



Normalized power production

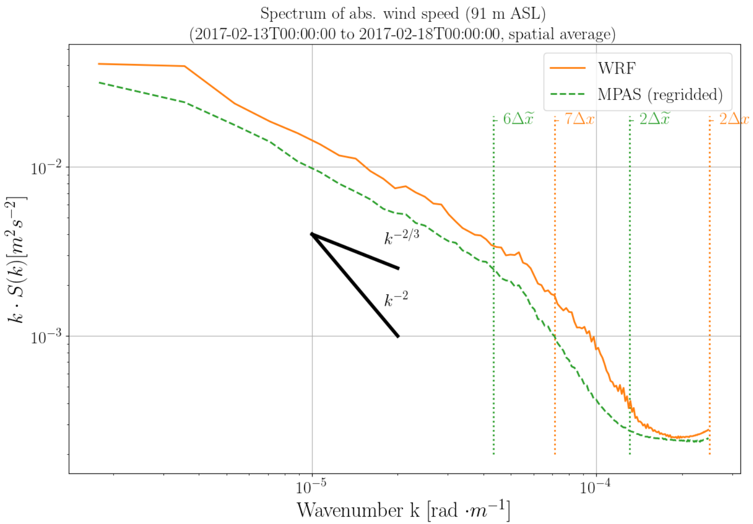


Spectral Analysis (Frequency domain)



- Expected slope of $f^{-2/3}$ present in measurements and models
- generally reduced energy content in higher frequencies in simulations
- regridded MPAS indicates lack in high frequency components, could be introduced by smoothing due to spatial interpolation
- Relatively short simulation time, further confirmation needed

Spectral Analysis (Wavenumber domain)



- Tendency as expected from measurements (Nastrom & Gage 1985) and theory
- WRF effective resolution of $7\Delta x$(Skamarock 2004) matches
- MPAS effective resolution $6\Delta\tilde{x}$ (Skamarock et al.2014) based on approx. resolution conservatively approximated
- Energy content in regridded MPAS generally lower than WRF (possible variance reduction due to smoothing effect and lower resolution)

Conclusion & Further work

- MPAS shows promising results on larger temporal and spatial scales (considering resolution)
- Challenges in local scales and time domain (phase shifts, reduced variability), difficult to compare
- Knowledge transfer not straight forward
- Representative resolution of unstructured mesh difficult to quantify

- Impact of regridding on analysis needs to be addressed
- Longer and more refined MPAS simulation

Thanks!

References:

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