A hybrid solution for wind resource assessment

- predict offshore wind from limited onshore measurements

Xuerui Mao, Basem Elshafei, Jie Ren

University of Nottingham

Alfredo Pena, Jake Badger

Technical University of Denmark

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Outline

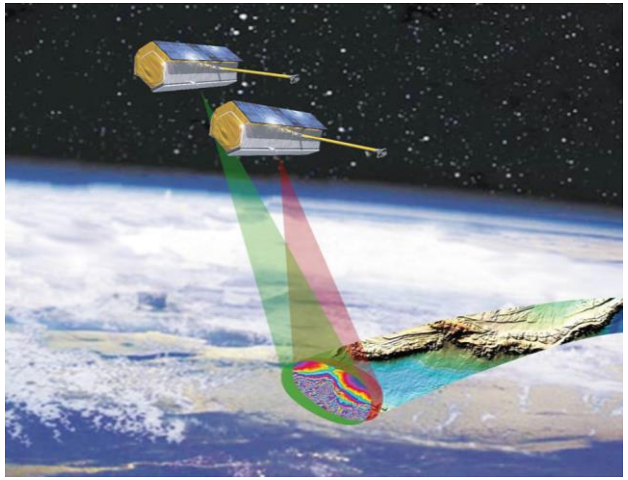
1. Introduction of wind resource assessment
2. Algorithms on data fusion
3. Test case description
4. Data pre-processing
5. Data fusion for predicting offshore wind from limited onshore data

1 Introduction – Direct wind resource assessment

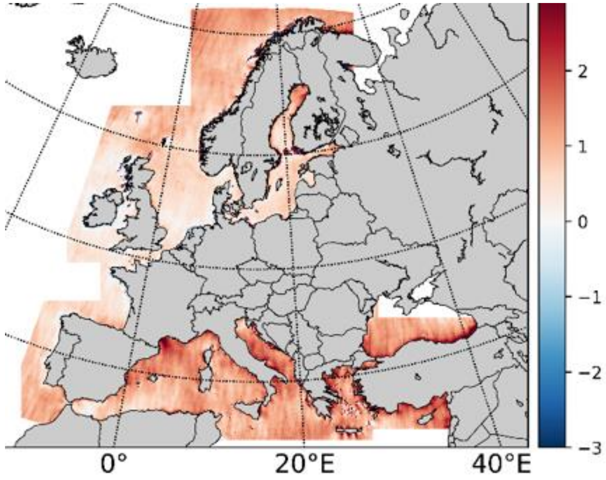
Current approaches for offshore wind resource assessment:

Mast:
$15m!

Floating lidar:
Low reliability



SAR images:
Need a satellite!



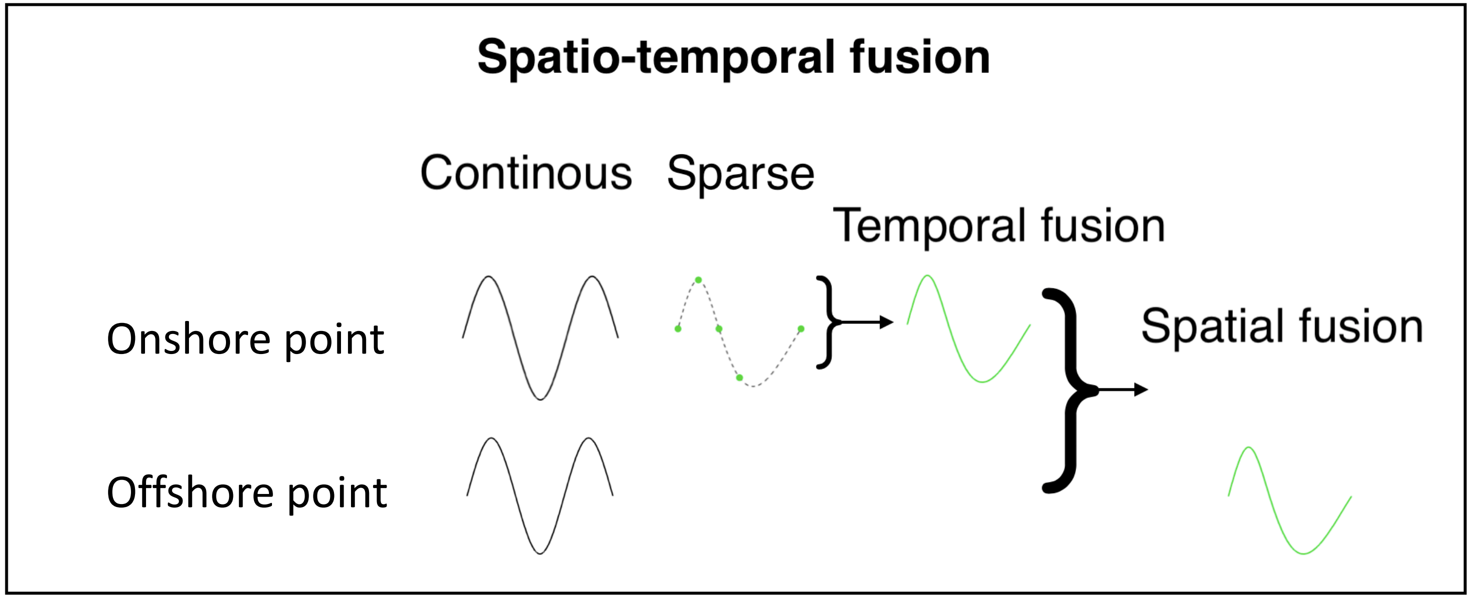
Meso-scale simulation:
Low fidelity

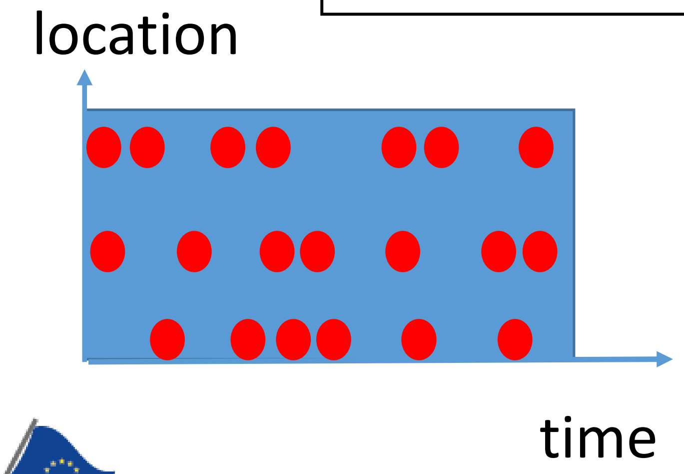
1. Introduction – indirect assessment

Can we bypass the direct offshore measurements?

Input	method	output
onshore measurements LiDAR, mast, met station, etc. (sparse, high-fidelity) Onshore + offshore WRF simulations (cheap and abundant, low-fidelity)	**Speed-up** **(cheap, inaccurate)** **Multi-fidelity Fusion** **Adjoint** **(Expensive, accurate)**	Offshore wind

1. Introduction – Data fusion





Continuous data: simulations, low-fidelity.

Sparse data: measurements, high-fidelity

2. Algorithm – temporal fusion

Multi-fidelity Gaussian Process Regression:

*Considering the high-fidelity data, F_h, is a function of time **t** and the low fidelity data F_l.*

$F_h(t) = g\,(t, F_l(t)) \sim \mathrm{GP}(m, k)$

m is the mean function, and *k* is the covariance matrix function.

Nonlinear auto-regressive Gaussian Process (further taking into account the derivations of the low fidelity data)**:**

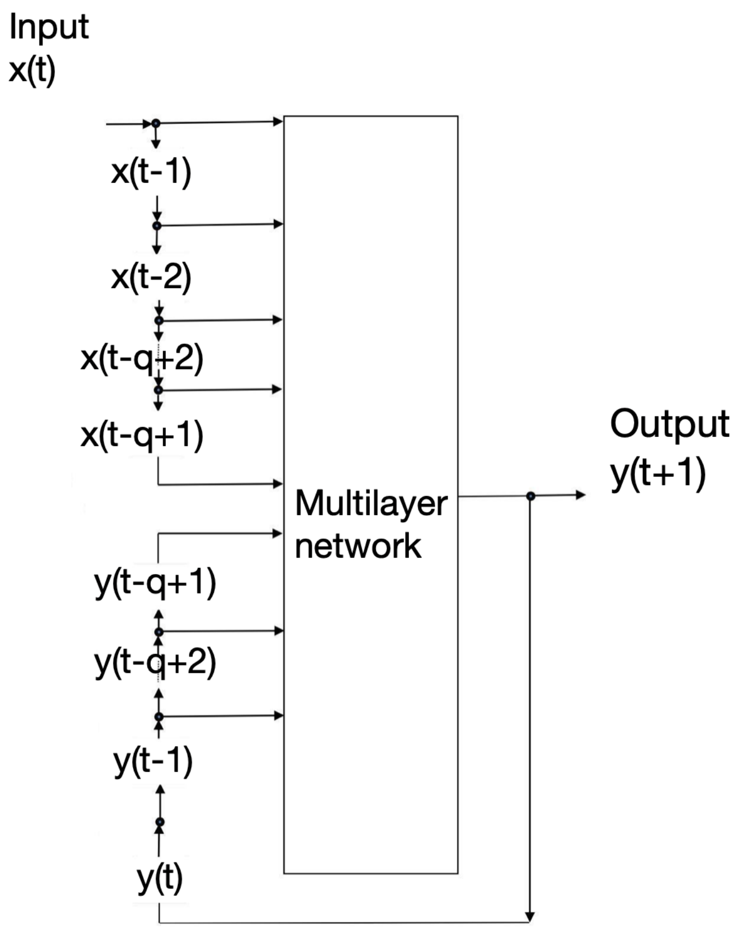
$F_h(t) = g\,(t, F_l(t), F^1{}_l(t), F^2{}_l(t), F^3{}_l(t), \ldots)$

2. Algorithm – spatial fusion

Nonlinear auto-regression with external input (NARX):

predicts *y(t)* from its history and additional input *x(t):*

$$y(n+1)=F[y(n), y(n-q+1), u(n), u(n-q+1)]$$

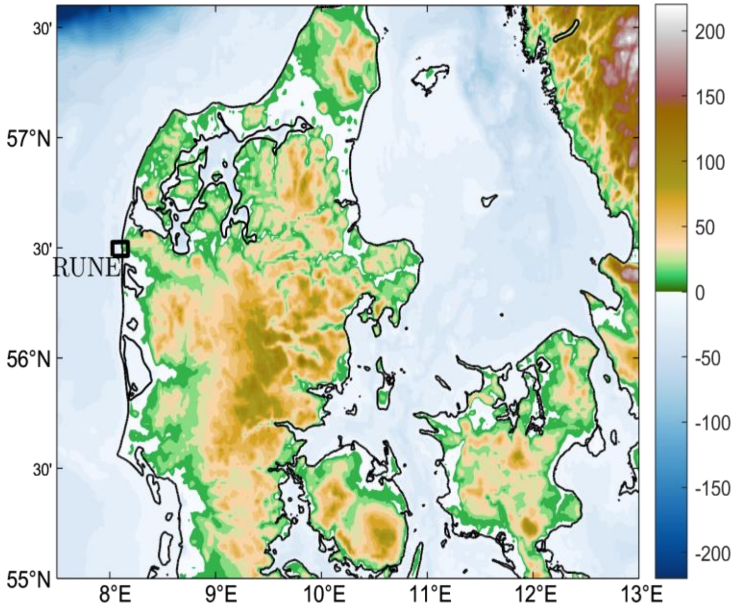


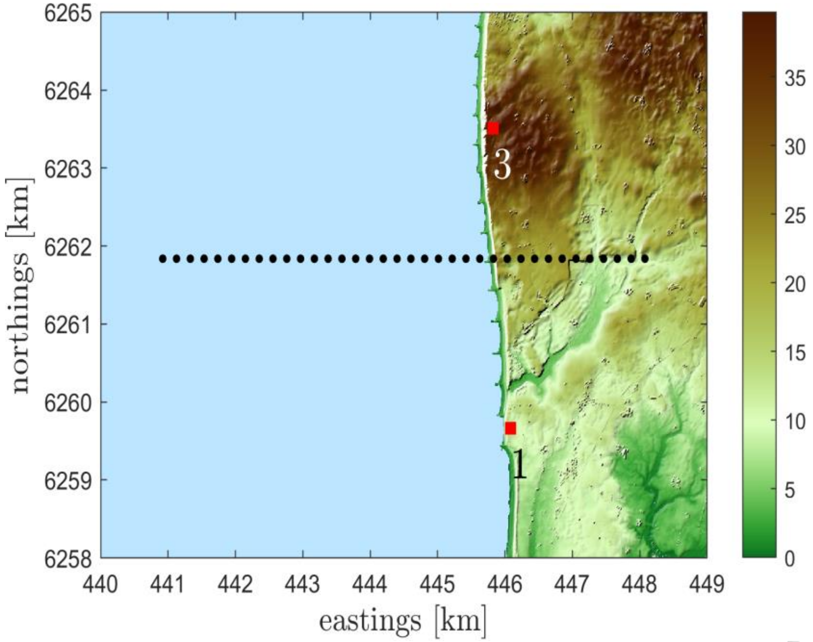
Framework for NARX model

3. Case description

West coast of Denmark, wind condition collected in the RUNE project:

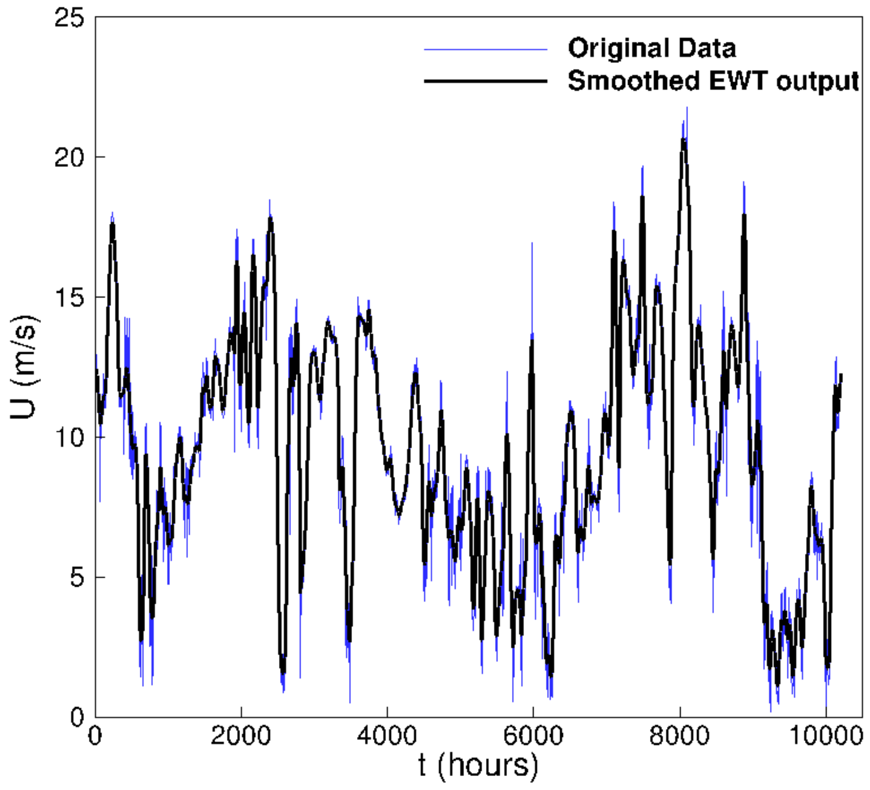
- **Lidar measurements**
- **WRF simulations**





4. Data pre-processing

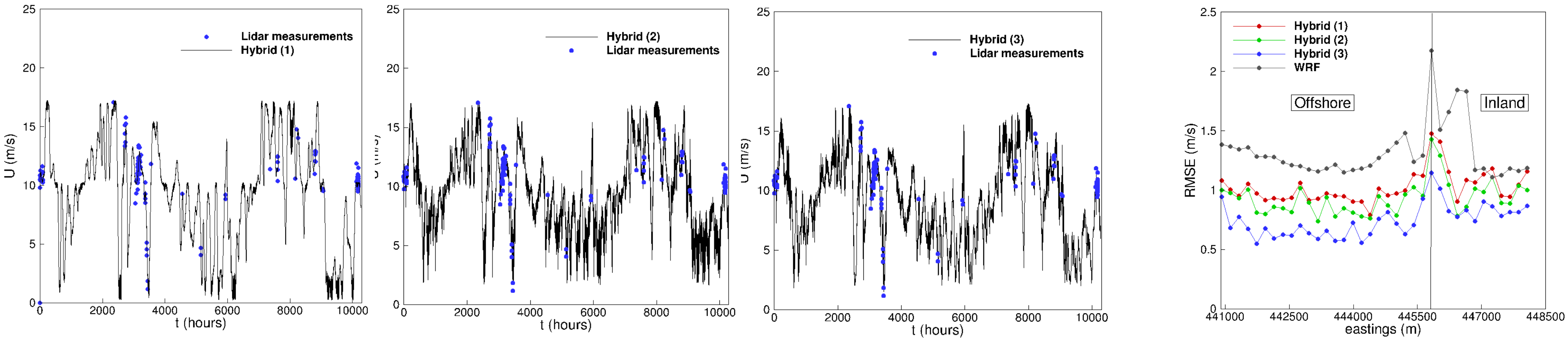
The WRF data was pre-processed using empirical wavelet transform to smooth the given wind speed time-series (ensure the data sequence is differentiable).



5. Fusion -- Temporal

Fusion of continuous WRF and intermittent lidar:

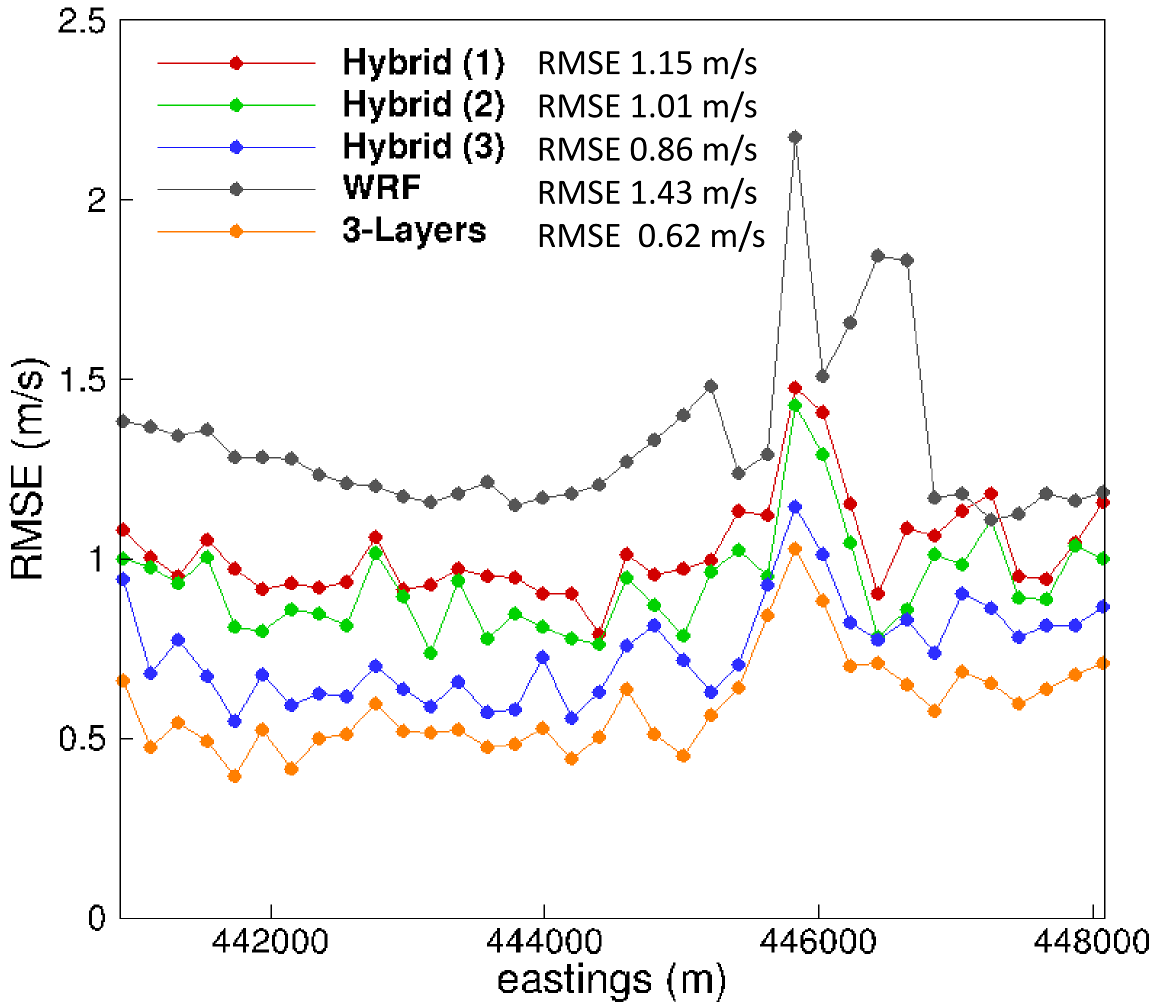
- Hybrid (1): WRF + lidar (wind magnitude)
- Hybrid (2): WRF, its 1st and 2nd derivatives + lidar (wind magnitude)
- Hybrid (3): WRF, its 1st and 2nd derivatives + lidar, with EWT and two horizontal velocity components.



5. Fusion – Temporal, more fidelity layers

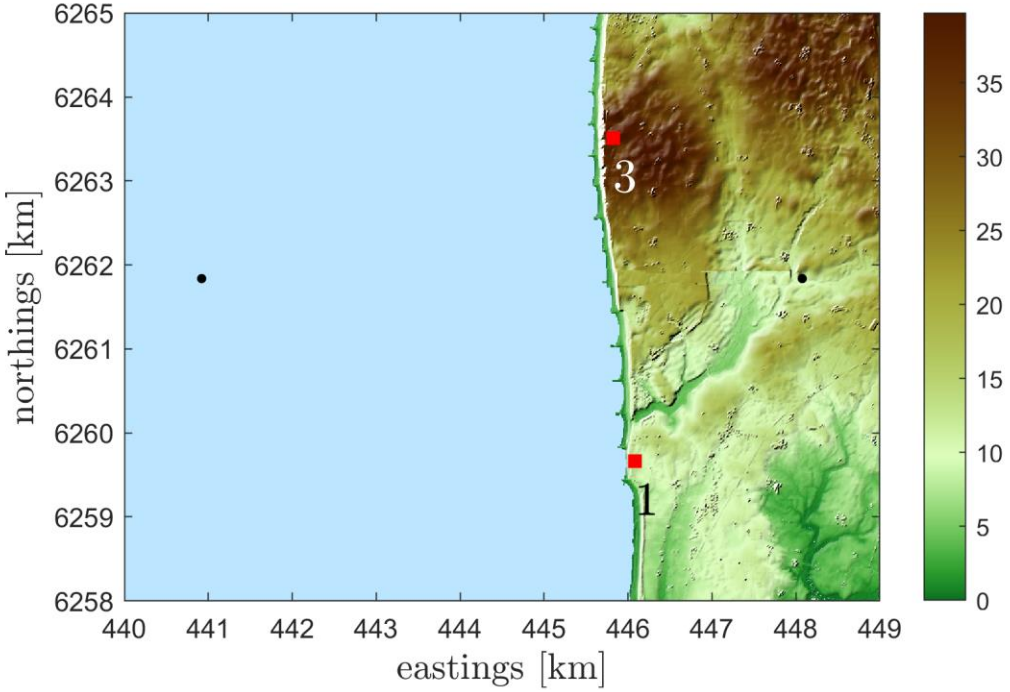
More layers of fidelity is considered:

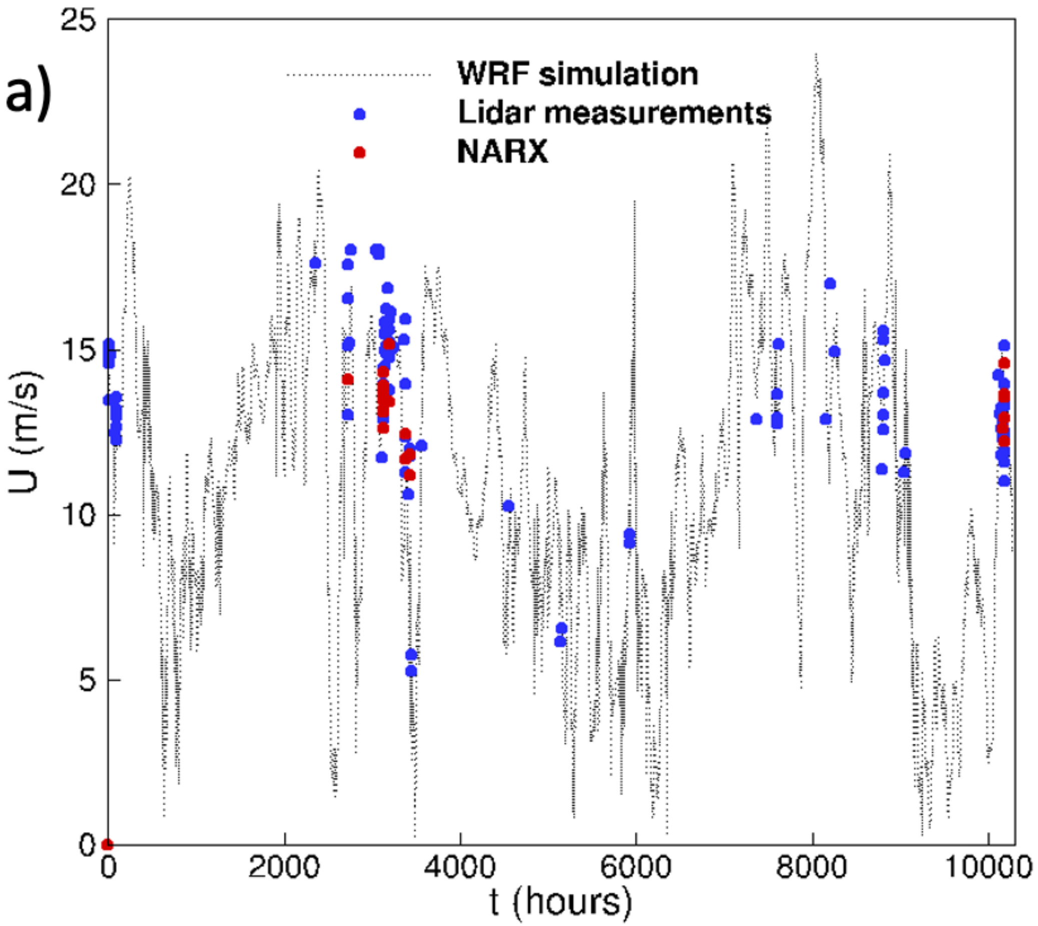
- ➢ Lidar (highest fidelity)
- ➢ High-resolution WRF (medium fidelity)
- ➢ Low-resolution WRF (low fidelity)



5 Fusion – Spatial

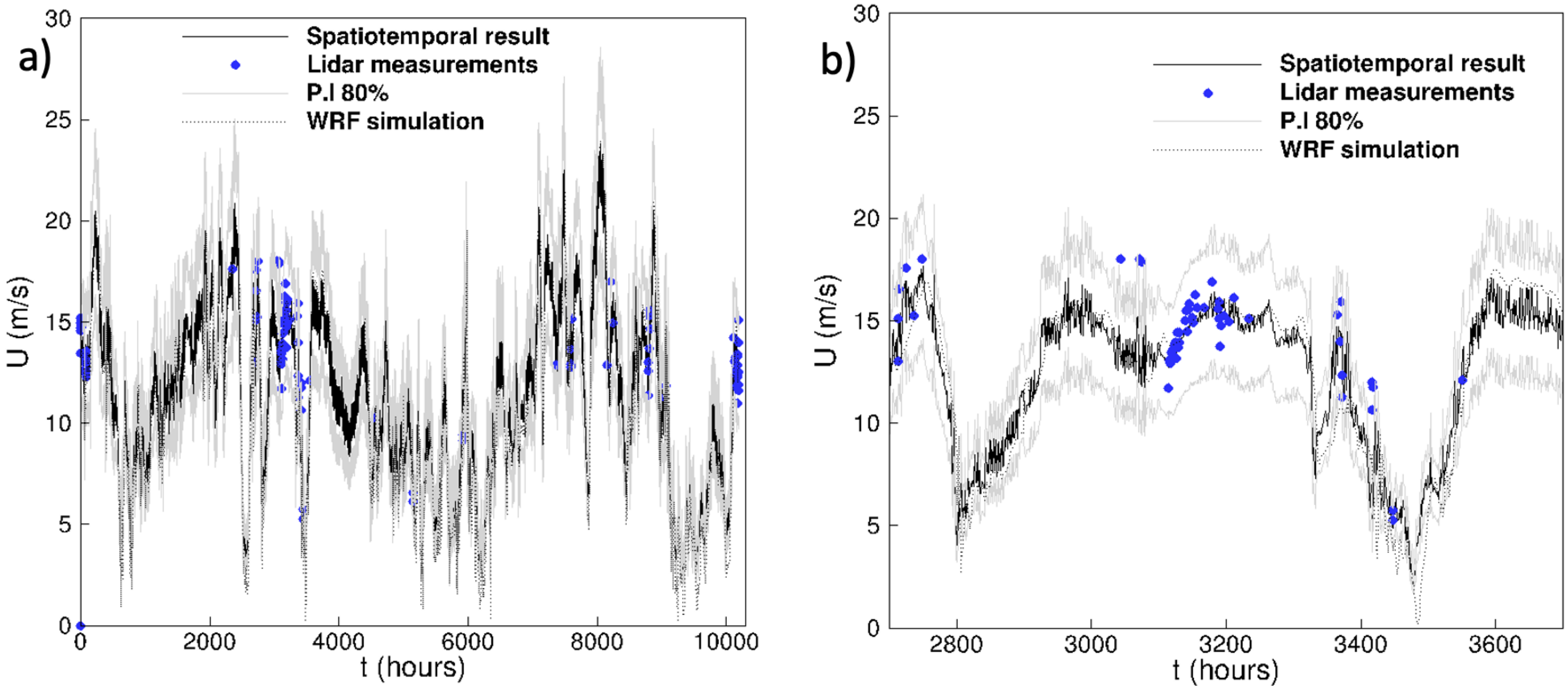
Extrapolation from onshore wind to offshore wind:





5. Fusion – Temporal + Spatial

The intermittent measurements at the most onshore point is used to estimate the wind at the most offshore point by exploiting the numerical data.



RMSE < 9%

Summary

- Intermittent lidar measured is completed and extended.
- Onshore measurement can be used to estimate offshore wind with RMSE 9%.
- **Future work:**
  - **multiple fidelity layers**
  - **fusion in full 4D domain**
  - **test in more wind sites: Perdigao, Santa Catarina in Brazil (HPCWE test cases).**

Contact HPCWE

Website: www.hpcwe-project.eu **(videos and PPT will be attached here!)**

Twitter: @HPCWE_project

LinkedIn: www.linkedin.com/company/hpcwe

Mail:

Xuerui.Mao@nottingham.ac.uk (Project Coordinator)

Nikolai.Worms@hlrs.de (Exploitation & Communication)

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Thanks for your attention!