Characterising Offshore Atmospheric Turbulence: From Meso-Scale Models to Large Eddy Simulations

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With the financial support of:

Context

- Difficulty in obtaining reliable turbulence information for the wind industry:
  - Weather models can be useful

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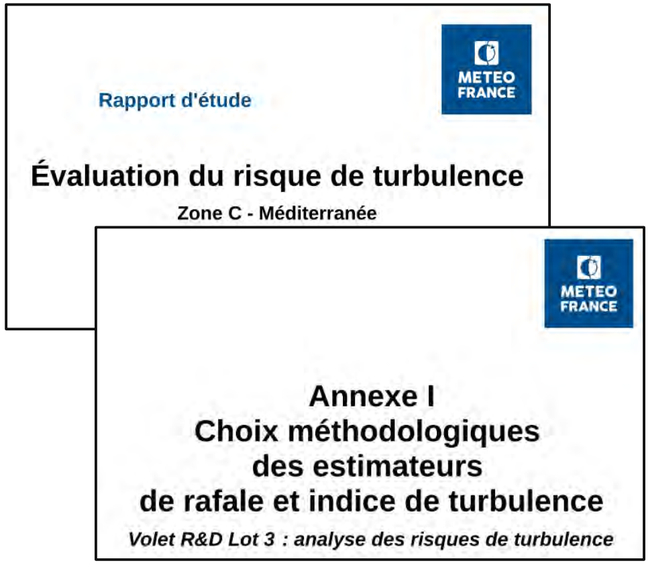
  - Weather models can be useful
  - Example with AROME
    - Fine-resolution operational Numerical Weather Prediction model at Météo-France
    - Used in the wind-turbulence characterization studies realized by the Direction Générale de l'Energie et du Climat (DGEC) and Météo-France

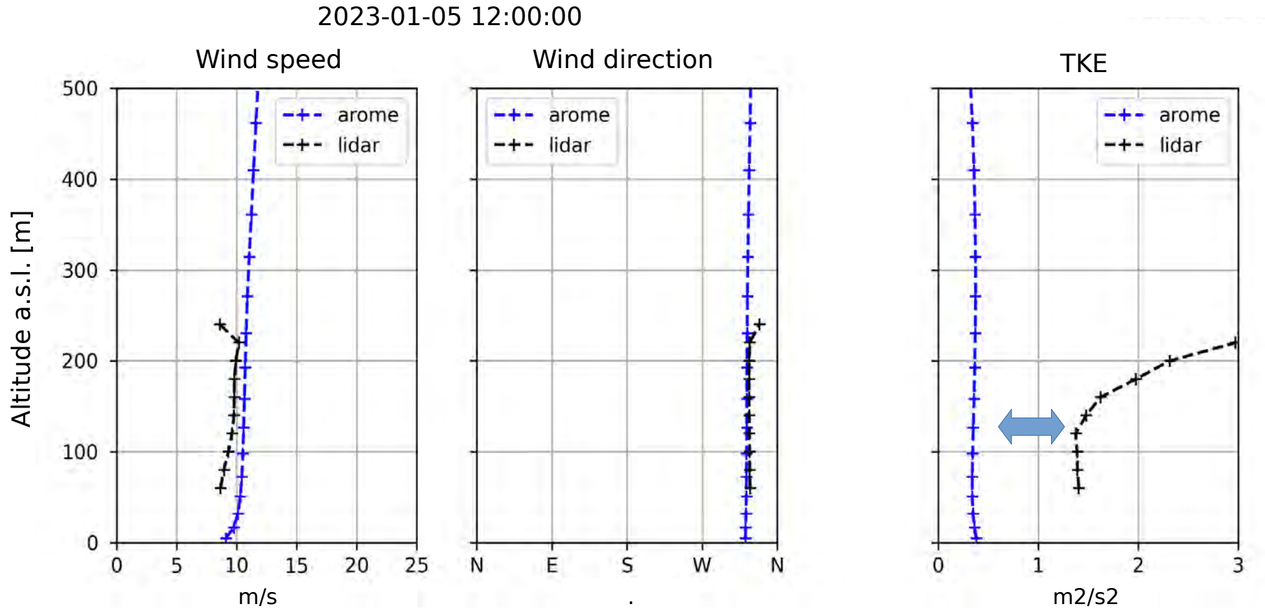


"With regard to the model gust intensity estimator, the comparison at 100 m with the Rampion meteorological mast [...] gives good results. However, the results are mixed for the LIDARS at sea, ***although it is not clear whether this is due to the behaviour of the AROME model or to a problem with the quality of the LIDAR measurements at sea.***"

Roullle, 2021

Context

- Difficulty in obtaining reliable turbulence information for the wind industry:
  - Weather models can be useful
  - Example with AROME
    - Fine-resolution operational Numerical Weather Prediction model at Météo-France
    - Discrepancy between modelled and observed Turbulent Kinetic Energy (TKE):



  - At 120m:
    - $TKE_{AROME} = 0.35\ m^2s^{-2}$
      → $TI_{AROME} = 6.8\ \%$
    - $TKE_{Lidar} = 1.3\ m^2s^{-2}$
      → $TI_{Lidar} = 13\ \%$

Context

- Need for a better understanding of weather models behaviours in terms of turbulence over the sea:
  - Characterization of spatial variability of turbulence near the coast
  - Exploration of ways to improve low-level atmospheric turbulence diagnostics in models

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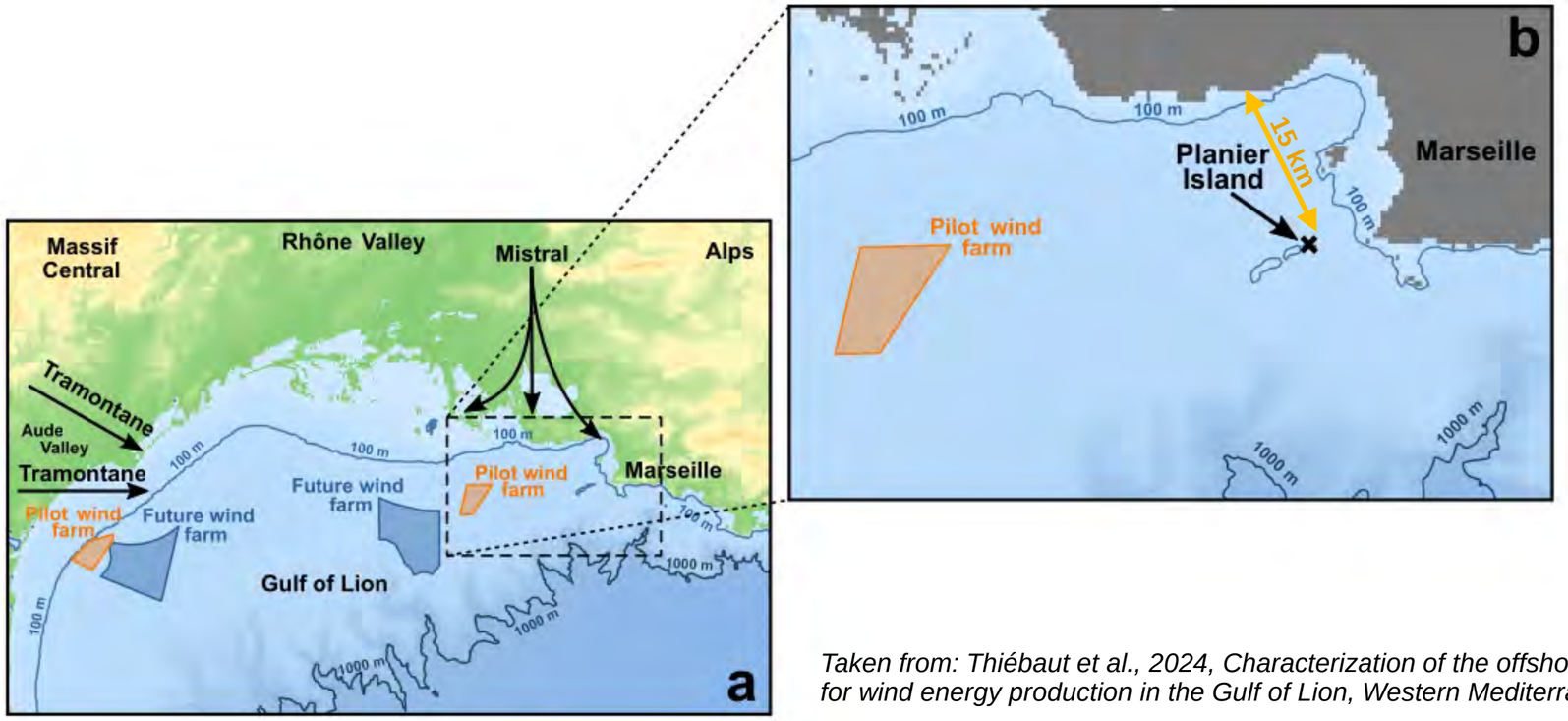
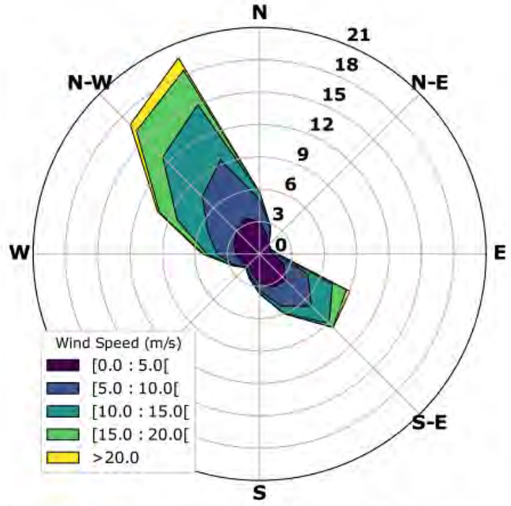
- Methodology:
  - Based on Meso-NH, research weather model used for the development of AROME
  - Case studies at :
    - **Le Planier island, Marseille, Mediterranean Sea**
    - National Offshore Anemometry Hub (NOAH), Blyth, North Sea
      - Collaboration with Fraunhofer IWES
  - Comparison of model outputs with available observations

Materials and methods

- Site of Le Planier Island:
  - Topography and wind climatology





Taken from: Thiébaut et al., 2024, Characterization of the offshore wind dynamics for wind energy production in the Gulf of Lion, Western Mediterranean Sea

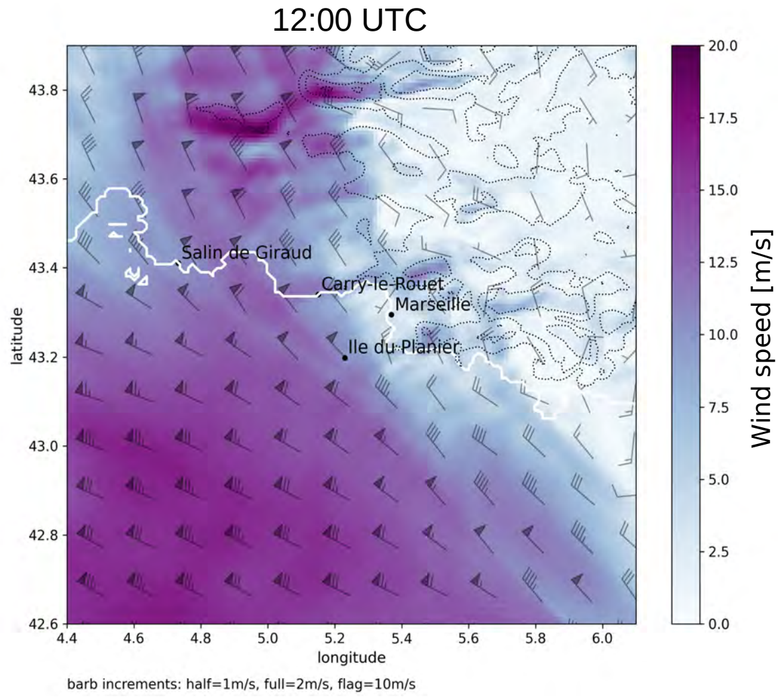
Materials and methods

- Observational data:
  - Wind profiling lidar
    - Sampling rate: 1Hz
    - Measurement heights from 60 to 220m a.s.l.

Materials and methods

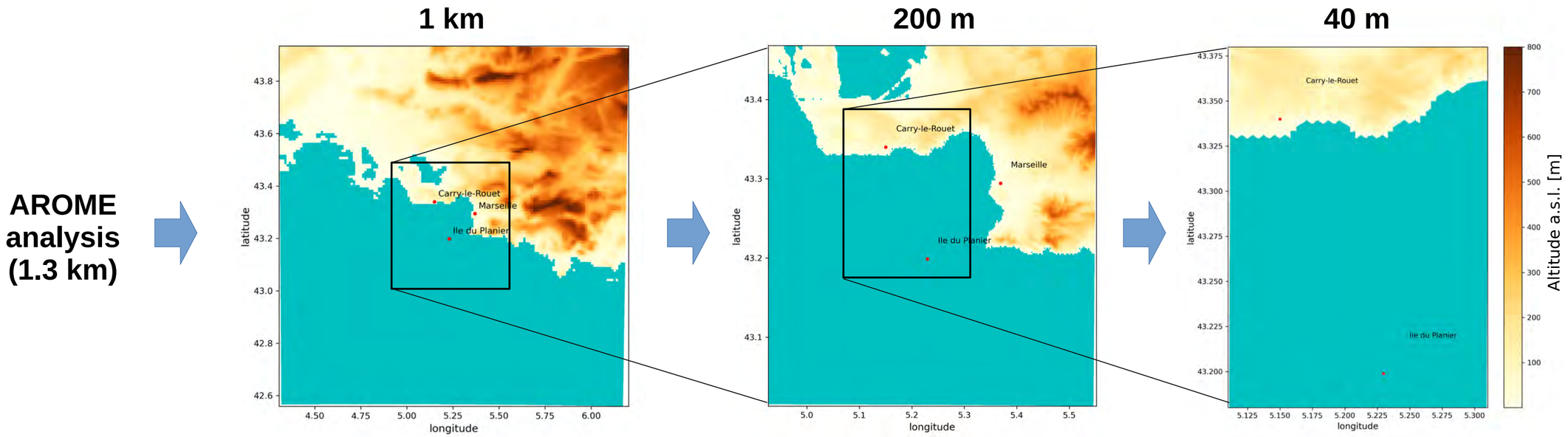
- Meso-NH:
  - Limited-area, non-hydrostatic weather model specifically designed for atmospheric research purposes
  - Well adapted for mesoscale (medium resolution) and Large Eddy Simulations (LES - very fine resolution)

- Simulation of specific case studies:
  - Example on 2023-01-05:
    - Northwesterly flow
    - Atmospheric properties influenced by the upstream conditions over land



Materials and methods

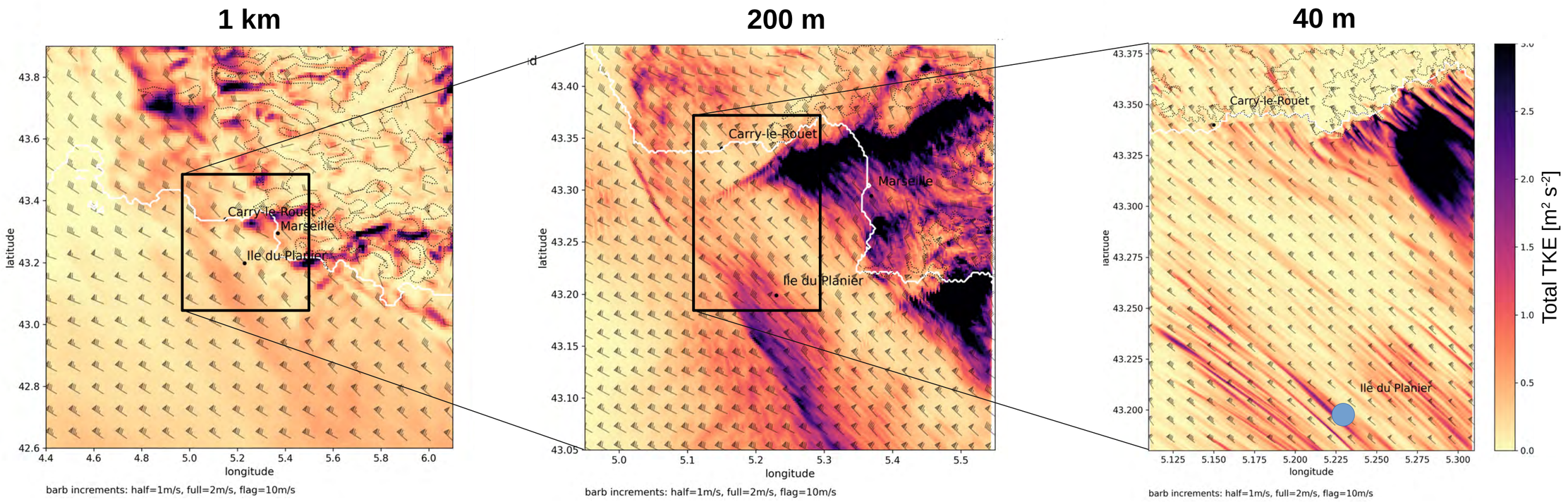
- Meso-NH:
  - At the mesoscale (10 – 1km) models cannot explicitly represent the atmospheric turbulence
    - Parameterizations are used to represent it
  - Need to refine the resolution to explicitly model the large eddies of the turbulence
    - Dynamic downscaling approach to reach the Large Eddy Simulation (LES)



Preliminary results

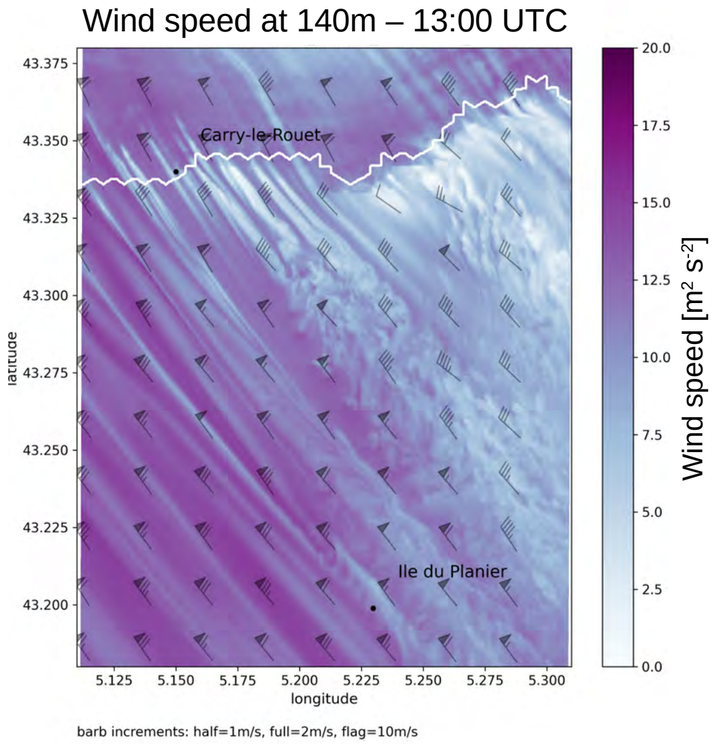
- Outputs from the model
  - TKE maps:
    - Confirmation of the difficulty of modelling turbulence at the mesoscale

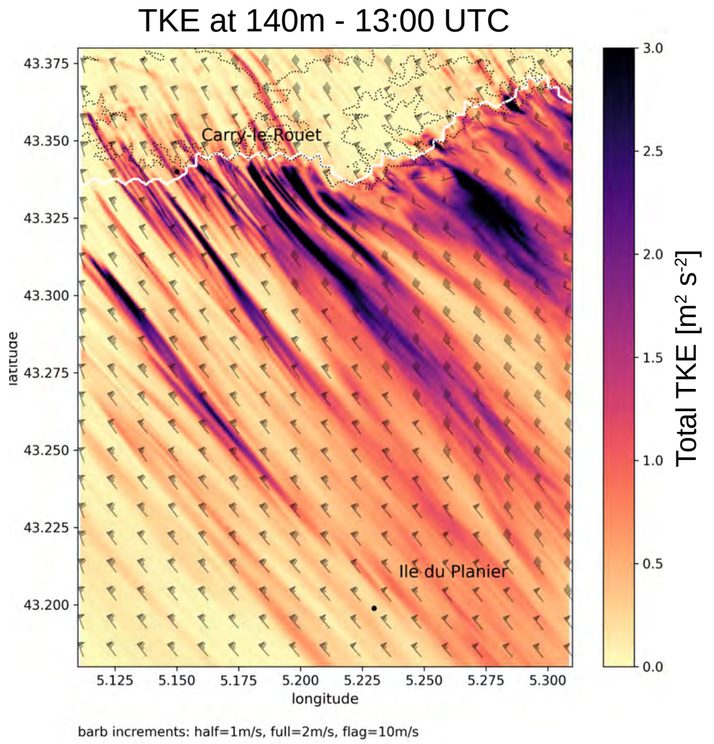
TKE at 140m
- 09:00 UTC



Preliminary results

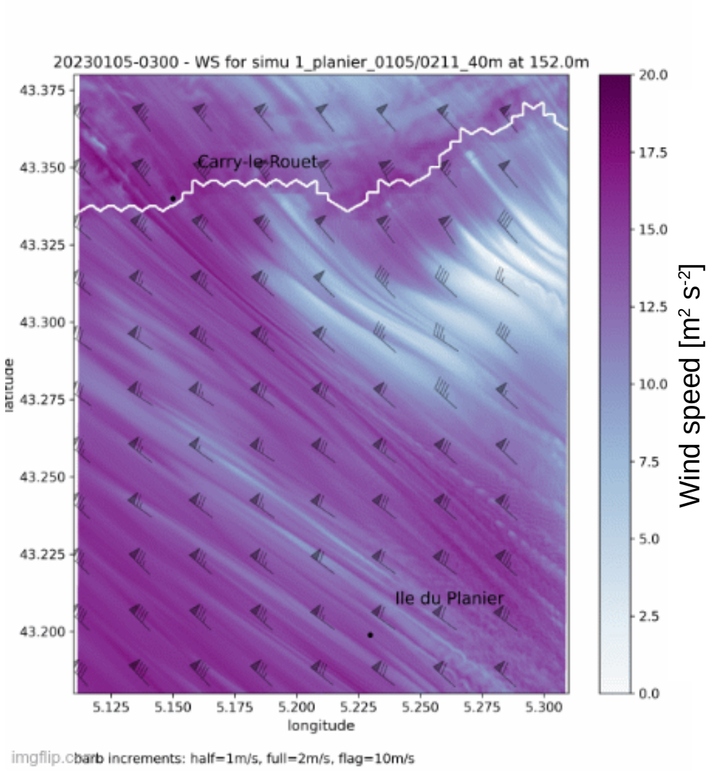
- Outputs from the model
  - Example of wind speed and TKE fields in the LES

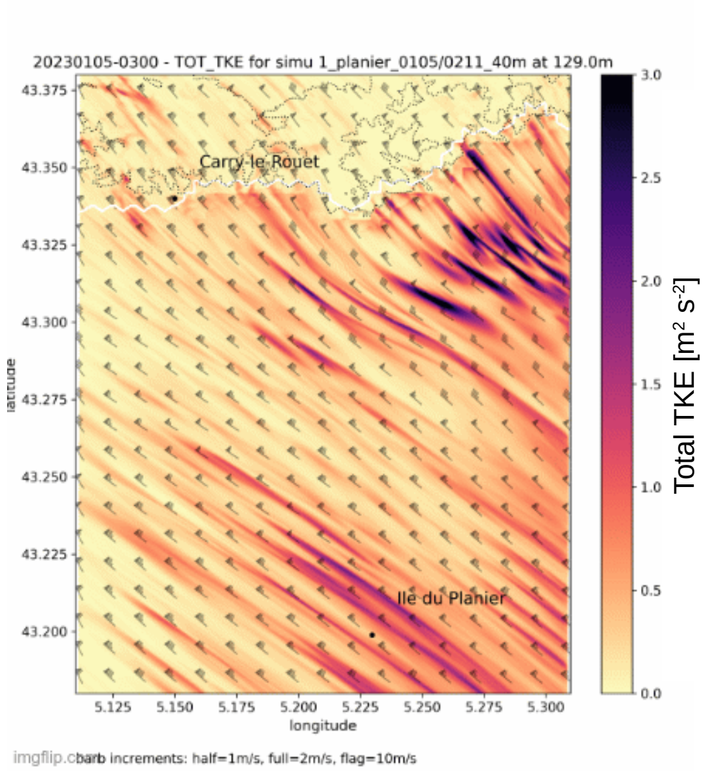




Preliminary results

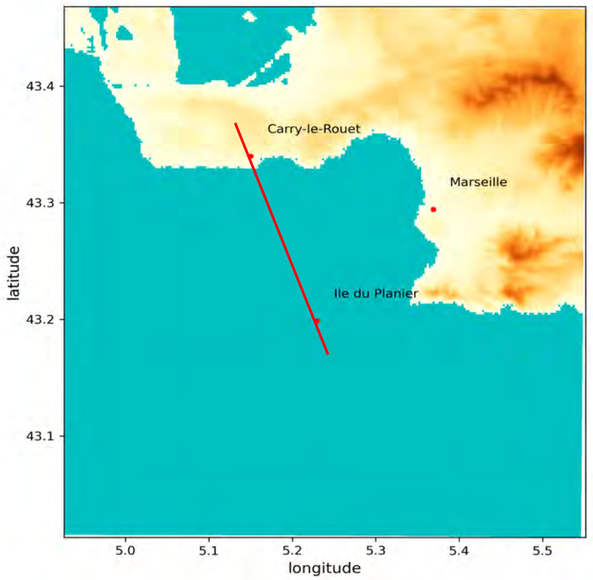
- Outputs from the model
  - Evolution along the day of wind speed and TKE in the LES (10min = 0.1s)





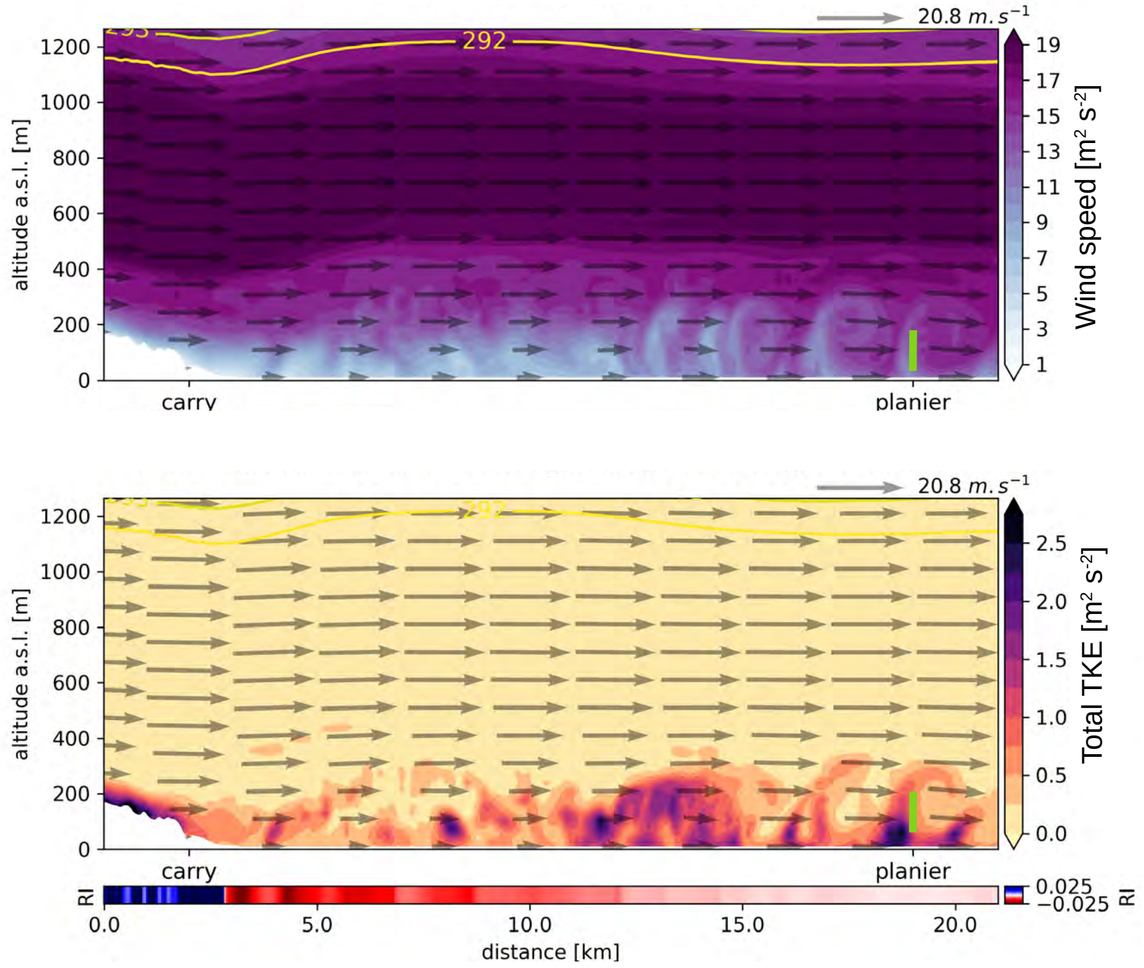
Preliminary results

- Cross-sections between coast and offshore
  - Transition from dynamic to thermal turbulence in this specific case



Wind speed

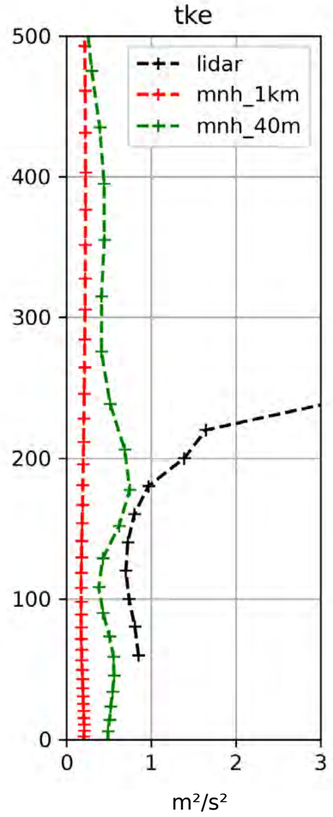
TKE



Preliminary results

- Critical view on the observational TKE data from wind profiling lidar

Vertical profiles above Le Planier on 2023-01-05 at 14:00 UTC



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- Critical view on the observational TKE data from wind profiling lidar
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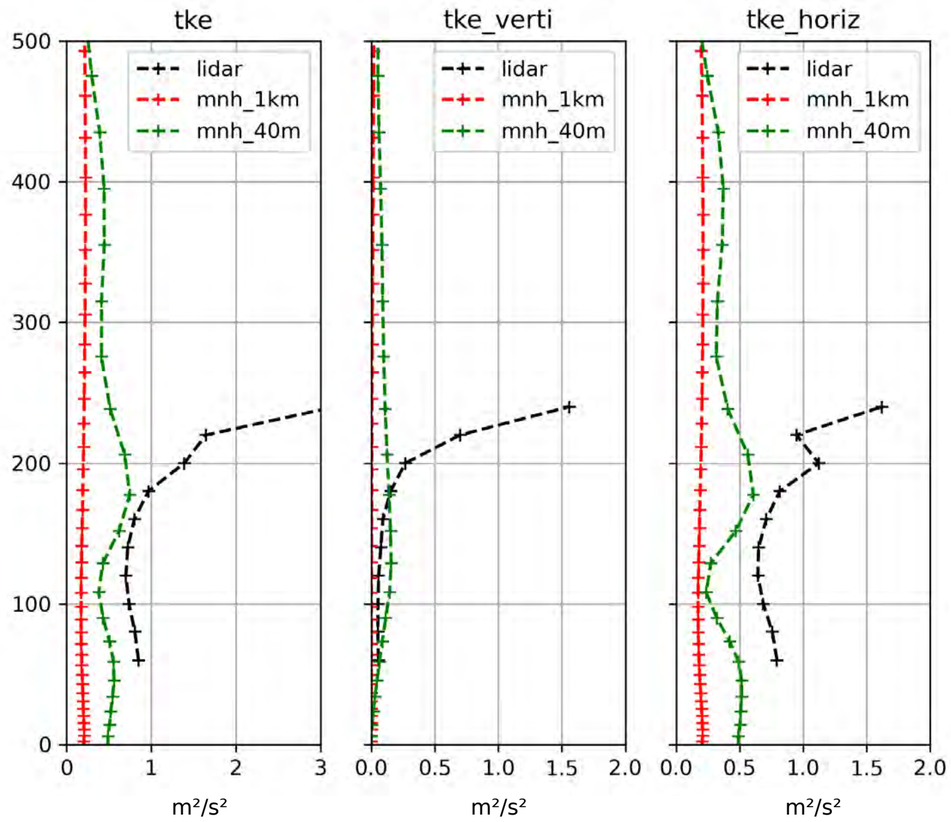

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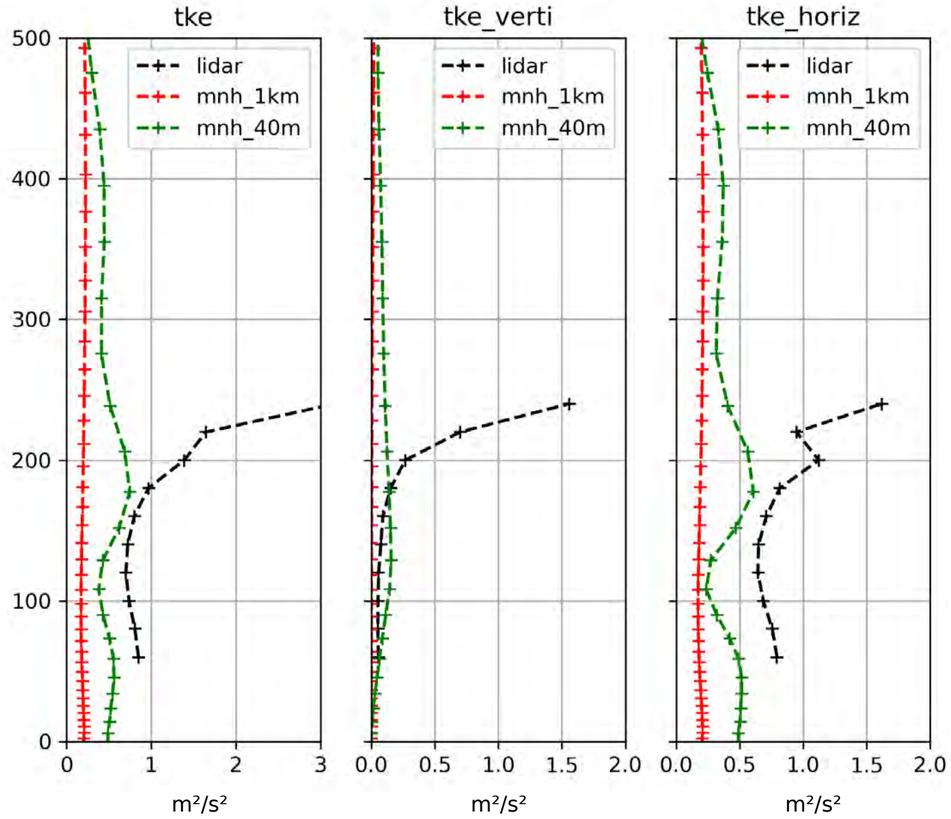

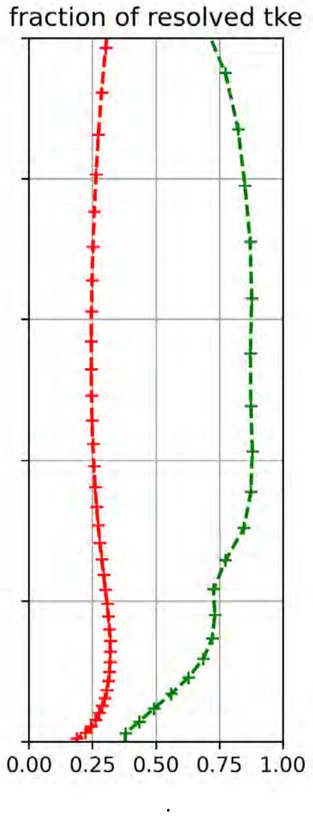

N.B.: At 40m, not an actual LES

Discussion / conclusion

- Preliminary results:
  - Mesoscale simulation does not capture well the dynamics of turbulence over the sea in coastal areas
  - Large Eddy Simulations (LES) allow to better model the atmospheric turbulence but are computationally expensive

Discussion / conclusion

- Next steps:
  - Run case studies (LES) based on typical weather situations
    - Typical weather situations chosen with K-means classification
    - Use LES as references for :
      - Improving our understanding of the spatial variability of atmospheric turbulence
      - Improving the modelling of turbulence at the mesoscale
  - Perform simulations on Blyth after the NEMO measurement campaign
    - Collaboration with Fraunhofer IWES

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Thank you for your attention