WRF in wind energy and possibilities for prediction of wind flow with the new cluster

Andrea Hahmann

Thanks to the WRF modelers of DTU Wind:

Poul Astrup, Jake Badger, Neil Davis, Rogier Floors, Xiaoli G. Larsén, Martin Rosgaard, Claire Vincent, Patrick Volker

18 March 2014

Risø Campus, Roskilde, Denmark

DTU Wind Energy
Department of Wind Energy

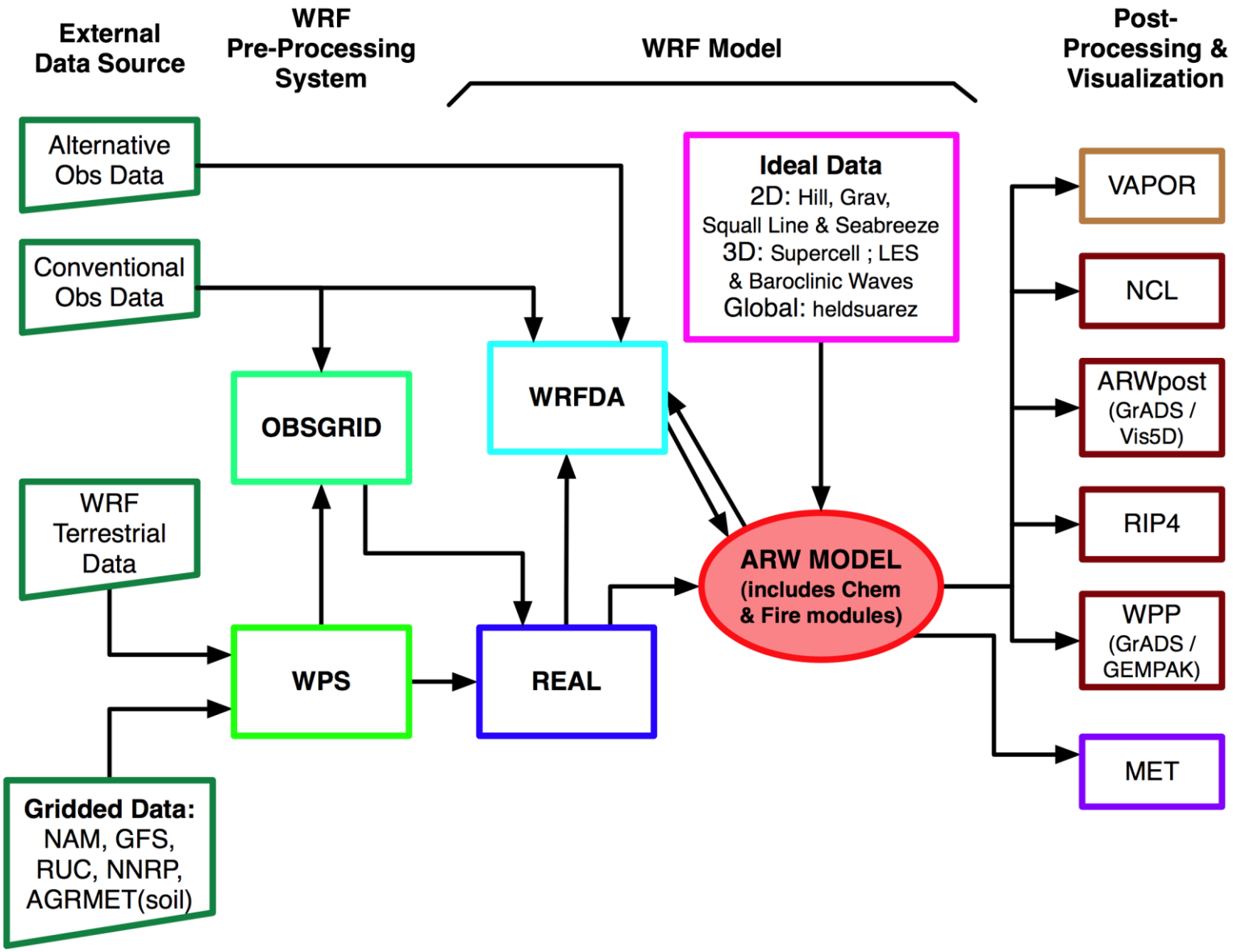
What is WRF?

- WRF: Weather Research and Forecasting Model
  - Used for both research and operational forecasting
- It is a supported "community model", i.e. a free and shared resource with distributed development and centralized support

What can WRF be used for?

- Two dynamical cores: ARW (Advanced Research) and NMM (Nonhydrostatic Mesoscale Model)
  - Atmospheric physics/parameterization research
  - Case-study research
  - Real-time NWP and forecast system research
  - Data assimilation research
  - Teaching dynamics and NWP
- ARW only
  - Regional climate and seasonal time-scale research
  - Coupled-chemistry applications
  - Global simulations
  - Idealized simulations at many scales (e.g. convection, baroclinic waves, large eddy simulations)

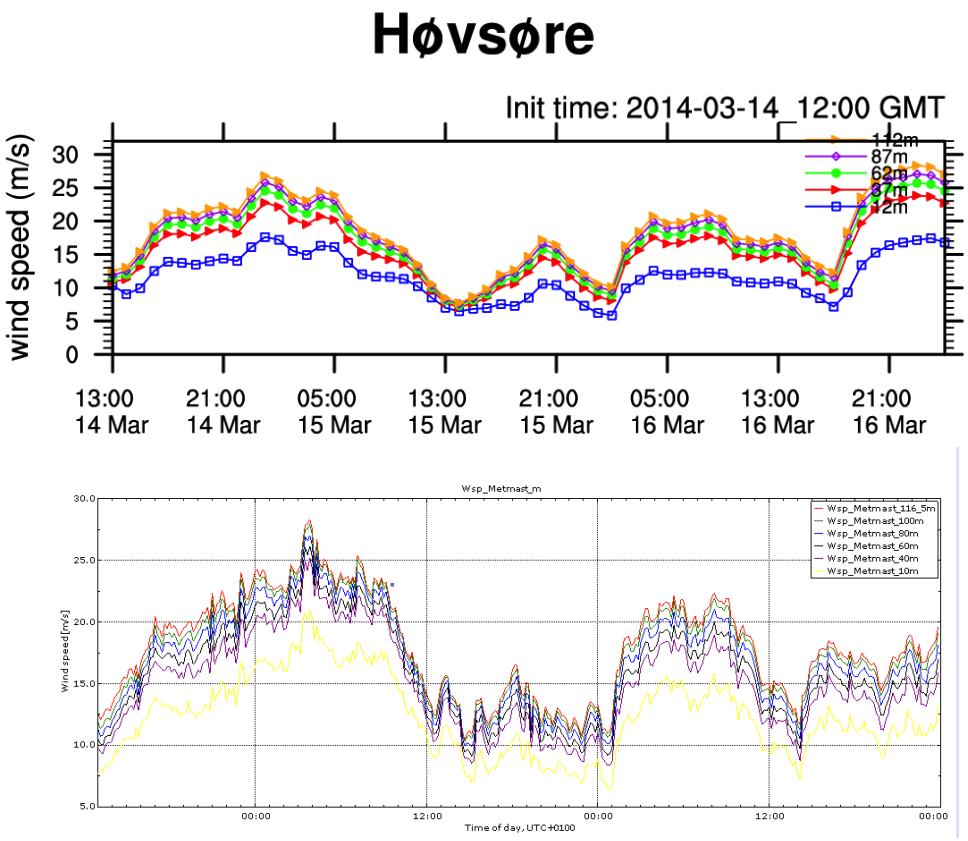
WRF Modeling System Flow Chart

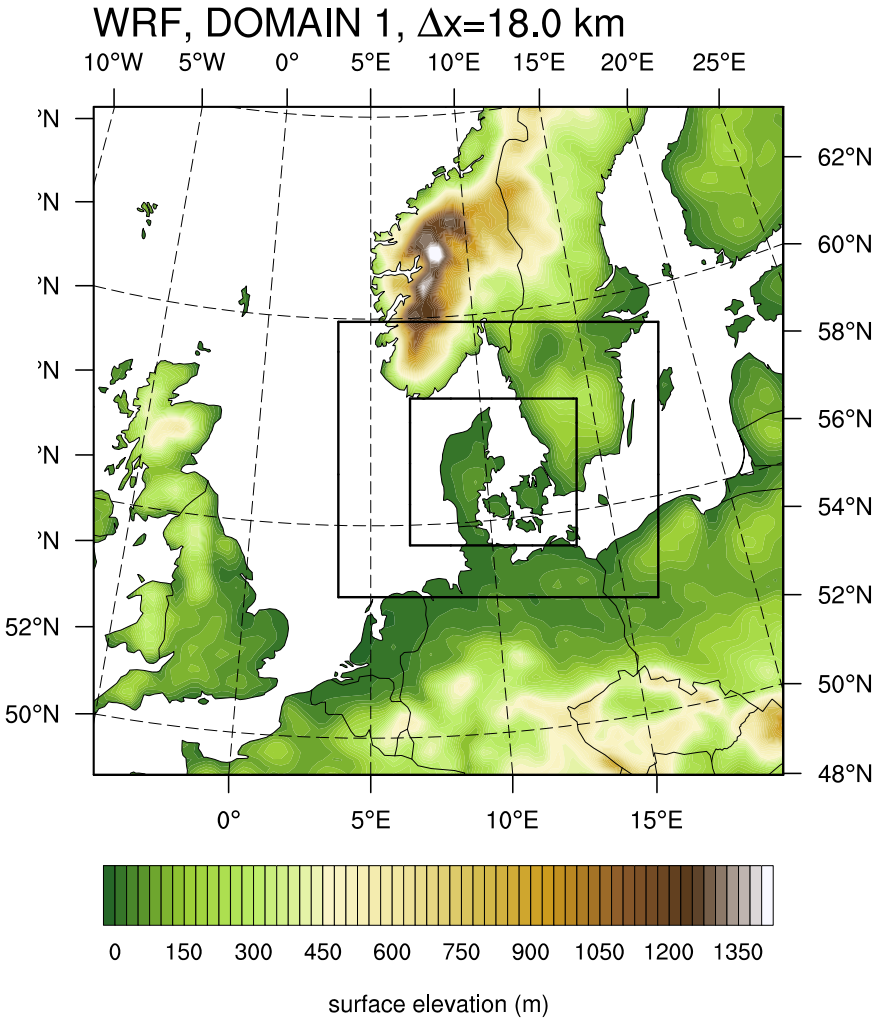


What have we used WRF at DTU Wind?

- Used in 4 completed PhD thesis (Claire Vincent, Caroline Draxl, Joakim Refslund, Rogier Floors)
- 2 more near-completion (Patrick Volker, Neil Davis)
- Probably many more to come…
- Used in many projects (I won't try to name them all)
  - weather forecasting; forecasting turbine loses from icing
  - wind resource atlas, wind variability
  - extreme winds, extreme wind gusts
  - validation against tall masts, wind lidar
  - data assimilation
  - dispersion of noxious chemicals
  - study of wind farm wakes…
- Where?
  - North Sea, Denmark, South Africa, Brazil, Portugal, Greenland, Sweden, Germany, Lesotho, California, Europe, India, China, Egypt
- A few examples

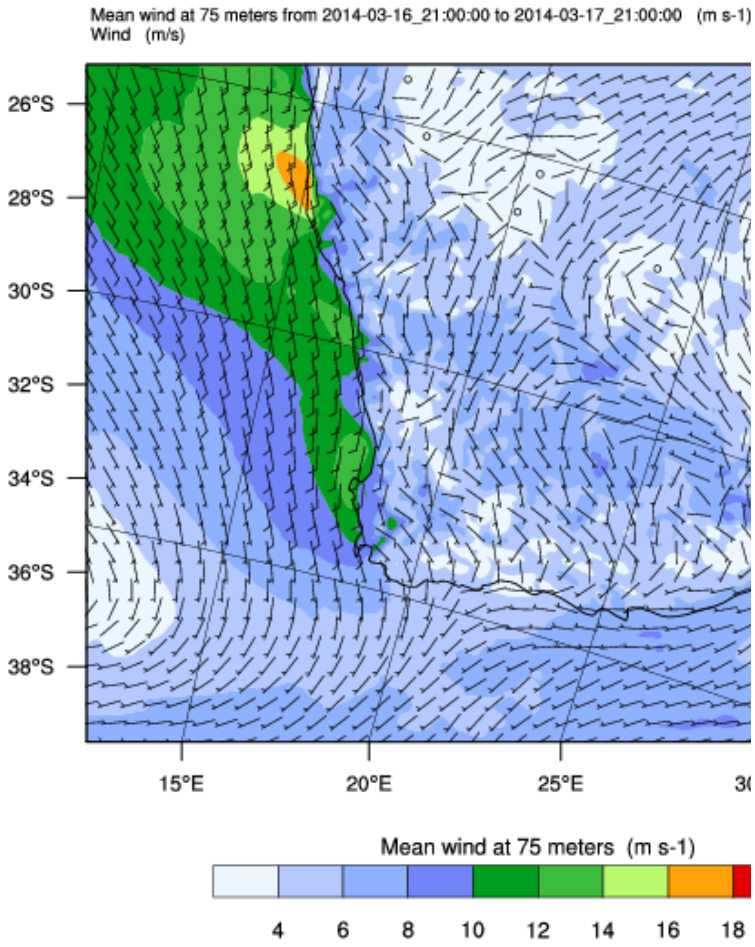
WRF for wind forecasting for Denmark twice daily





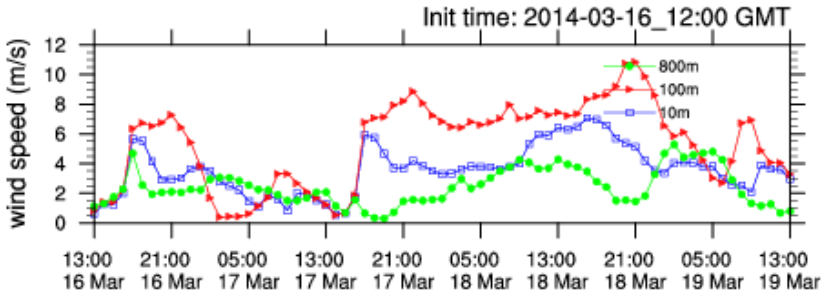
Real-time forecast of storm Carl
wind speed (m/s) at Høvsøre

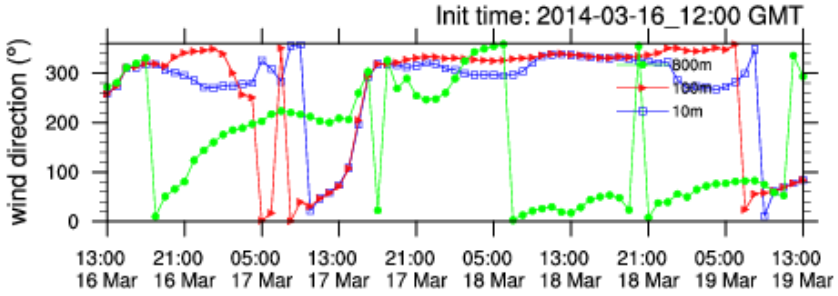
REAL-TIME WRF

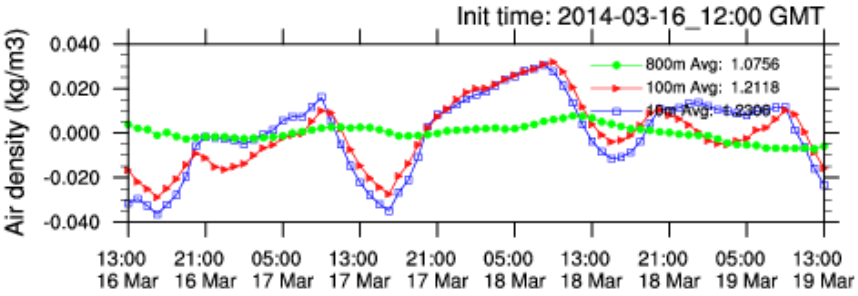


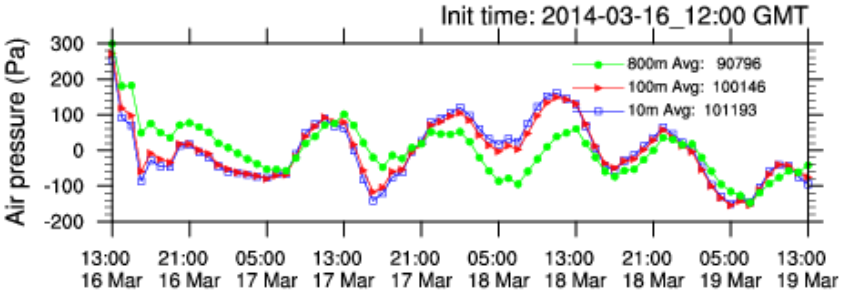
OUTPUT FROM WRF V3.5.1 MODEL
WE = 241 ; SN = 181 ; Levels = 41 ; Dis = 9km ; Phys Opt = 8 ; PBL Opt = 1 ; Cu Opt = 1

Ota







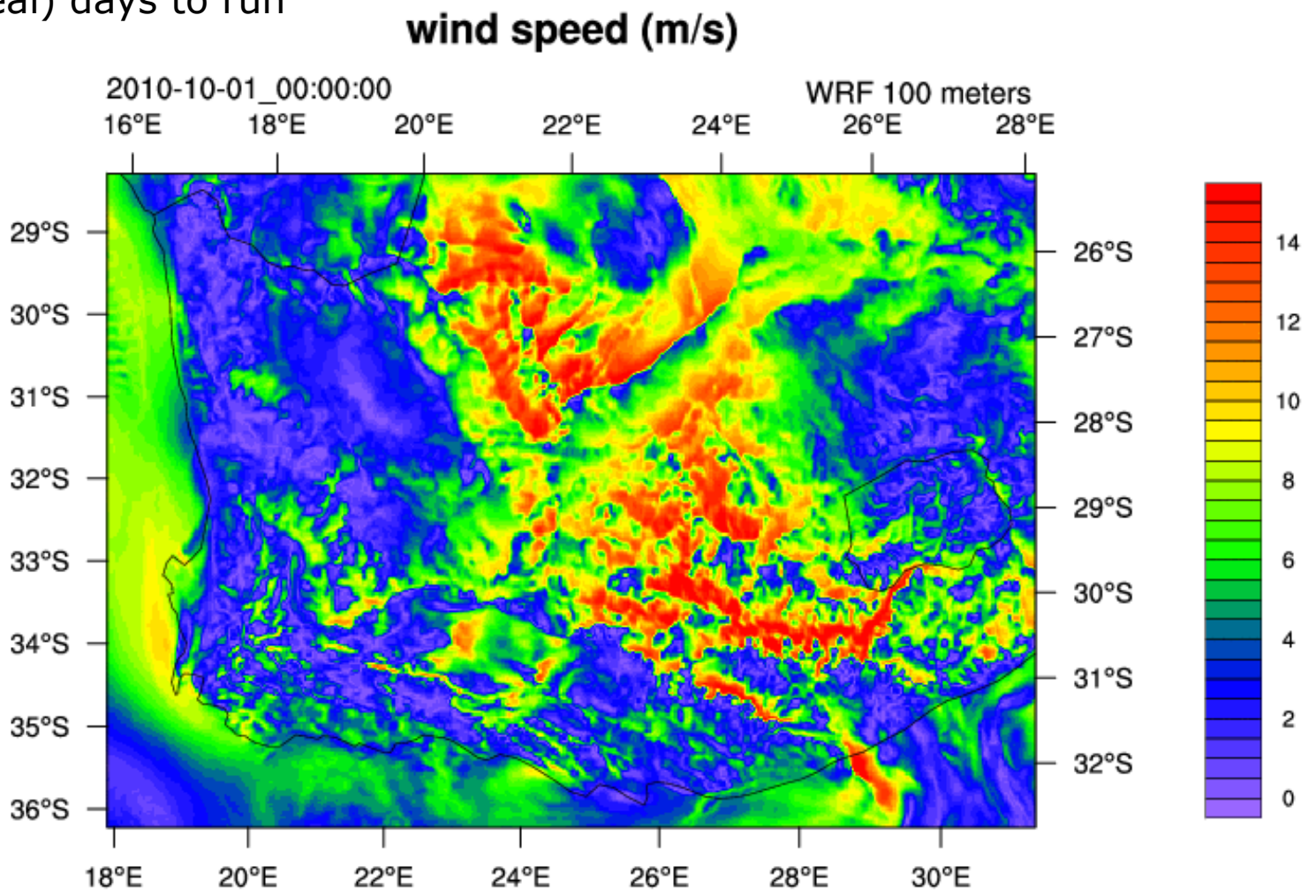


WRF Simulations for the WASA project

Very large (309 x 435) inner grid (3 km x 3 km grid spacing)
Oct 2005 – Sep 2013
Took 18 days (real) days to run

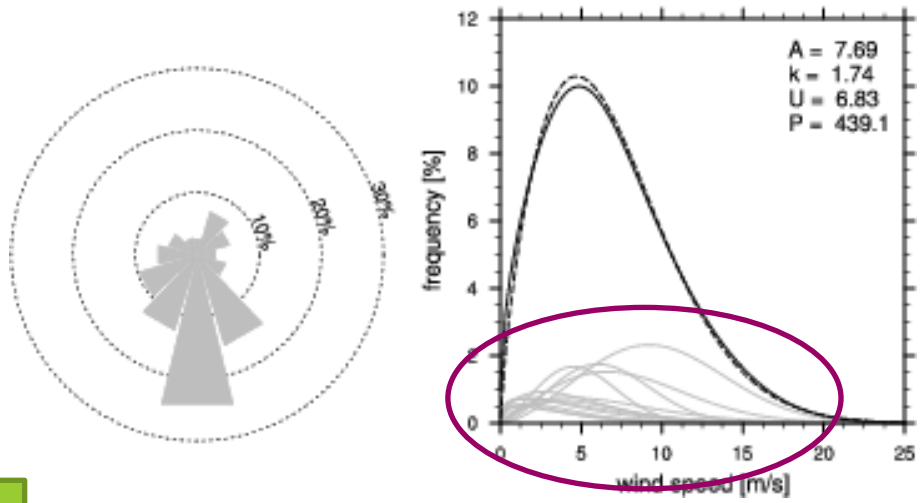
A total of 293 runs: Each 6 hours on 8 nodes

Post processing took even longer!

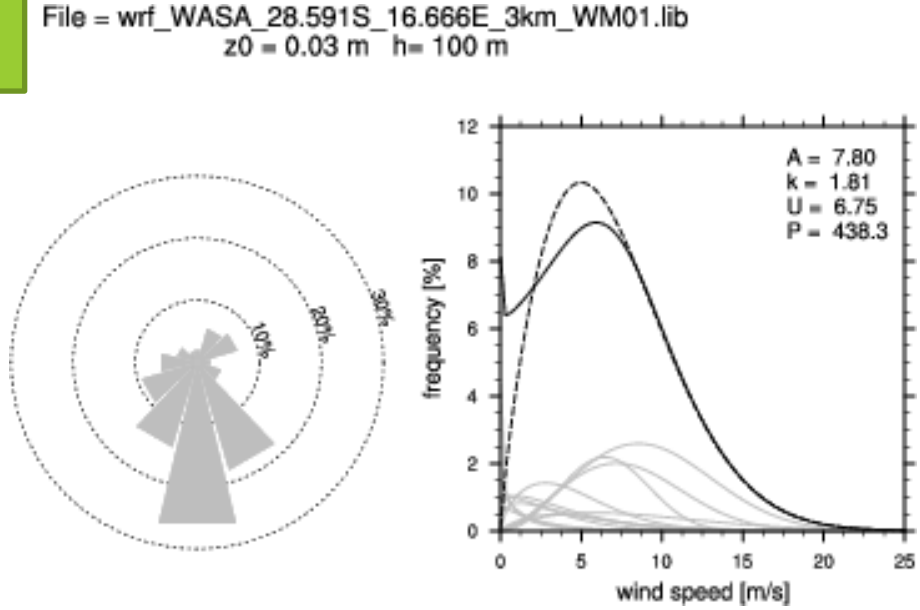


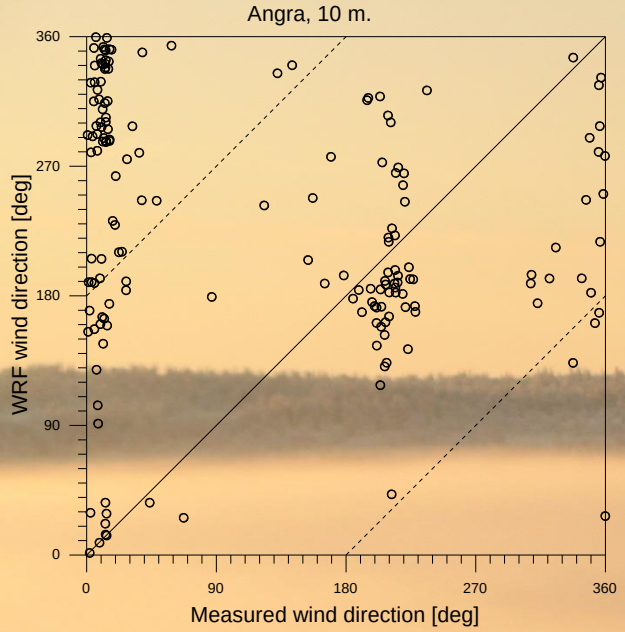
Example: WASA site 1, far northwest, generalized wind climate

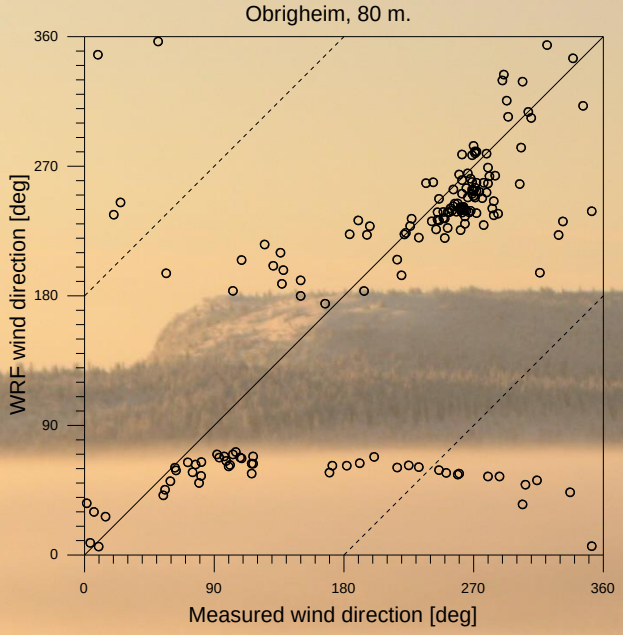
Observed wind atlas

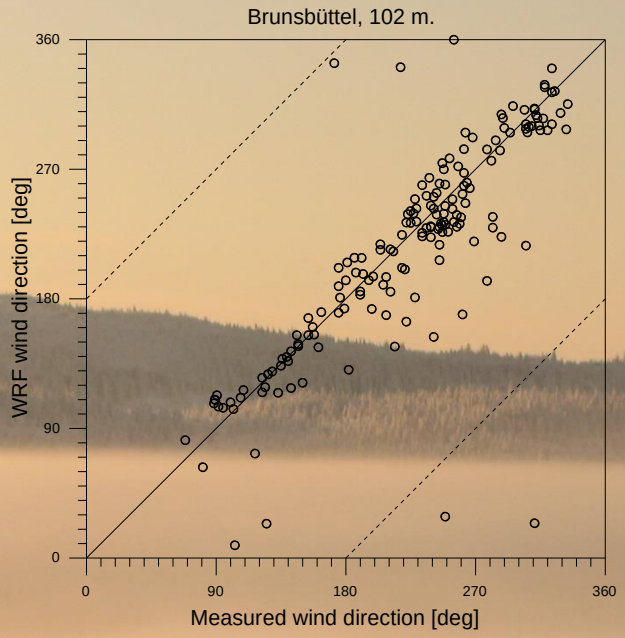


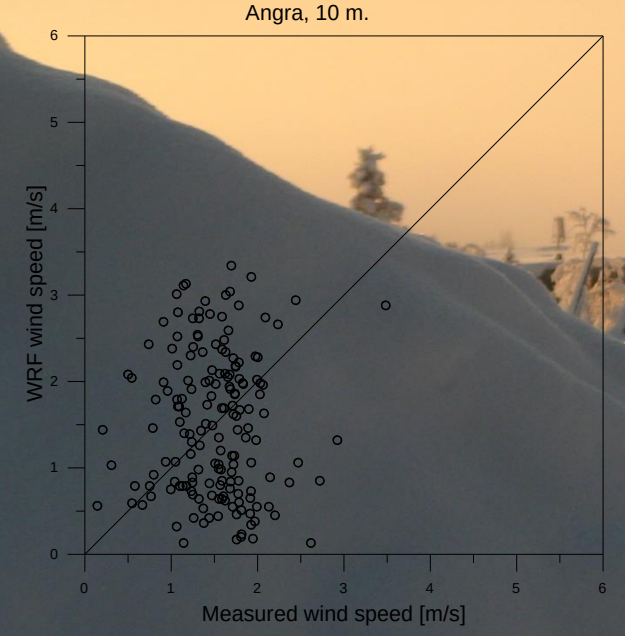
Numerical wind atlas WRF

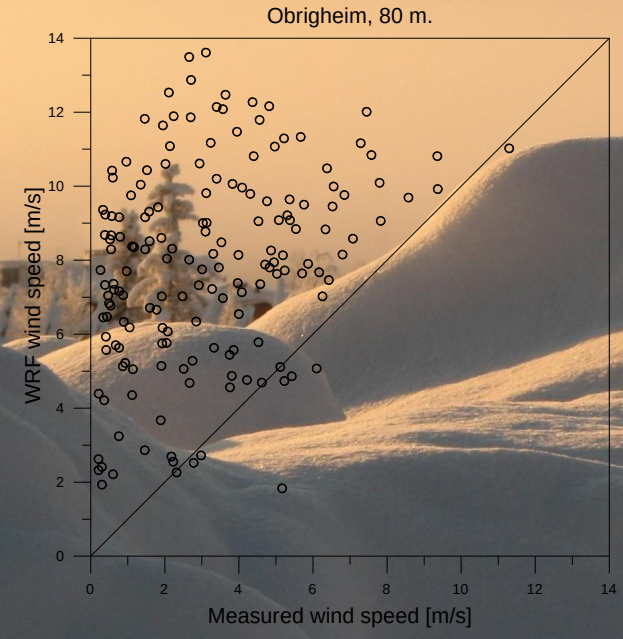


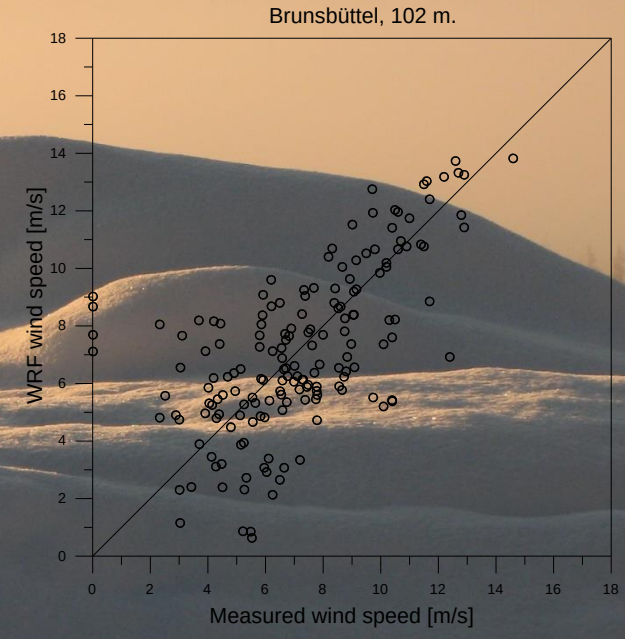








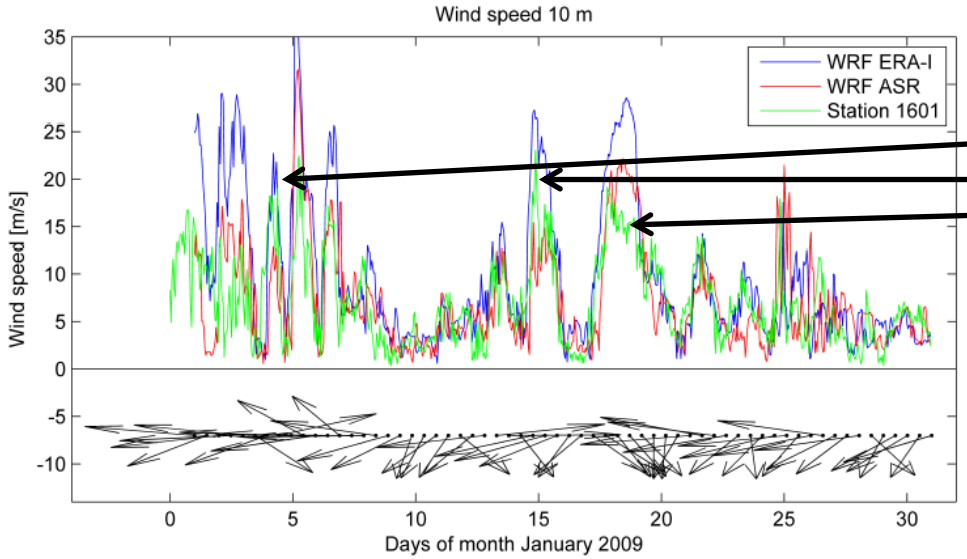




WRF results for places with very different topography

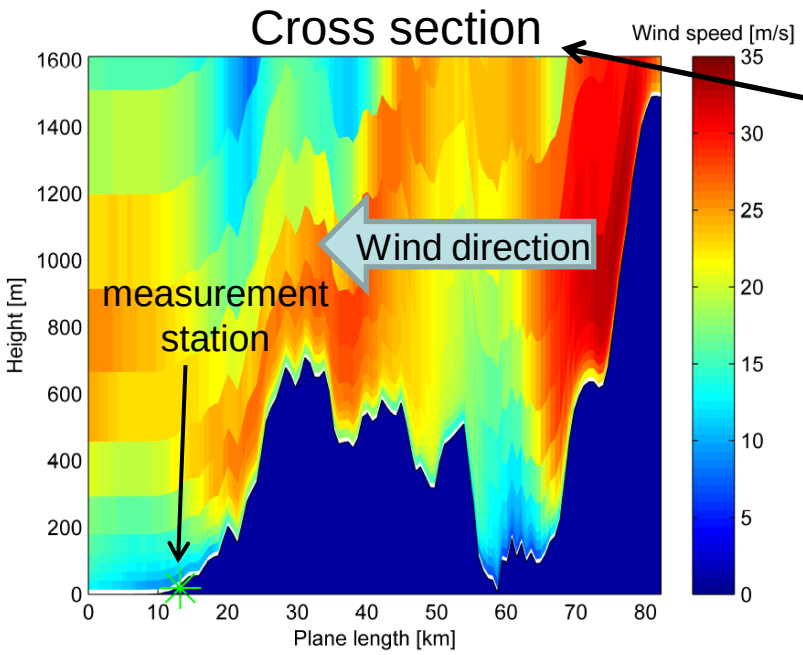
Poul Astrup, 2013

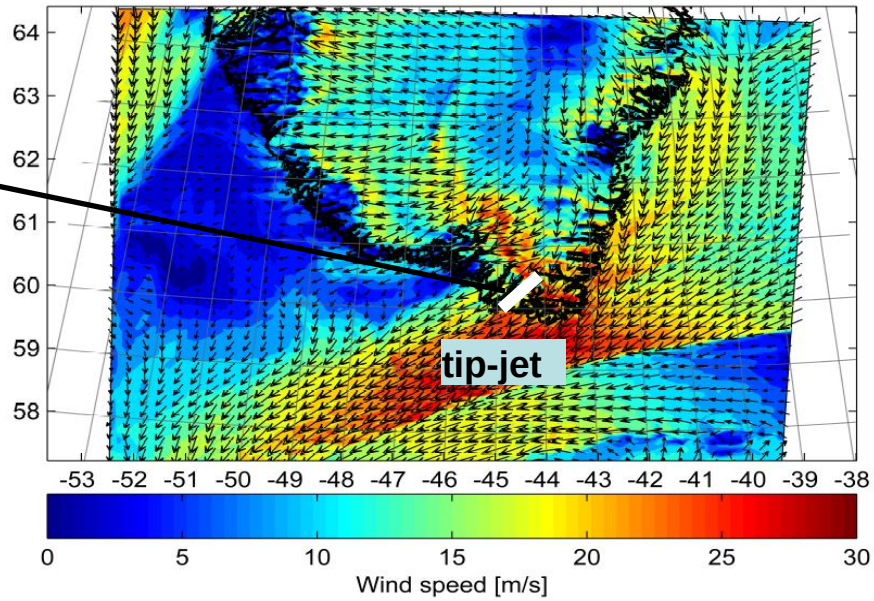
Wind resource simulations in Southern Greenland



Easterly and Westerly tip-jet events have an enormous impact on the wind speed.

We modelled tip-jet events using **polar WRF**





Claire Louise Vincent
Kasper Rønnow Jakobsen

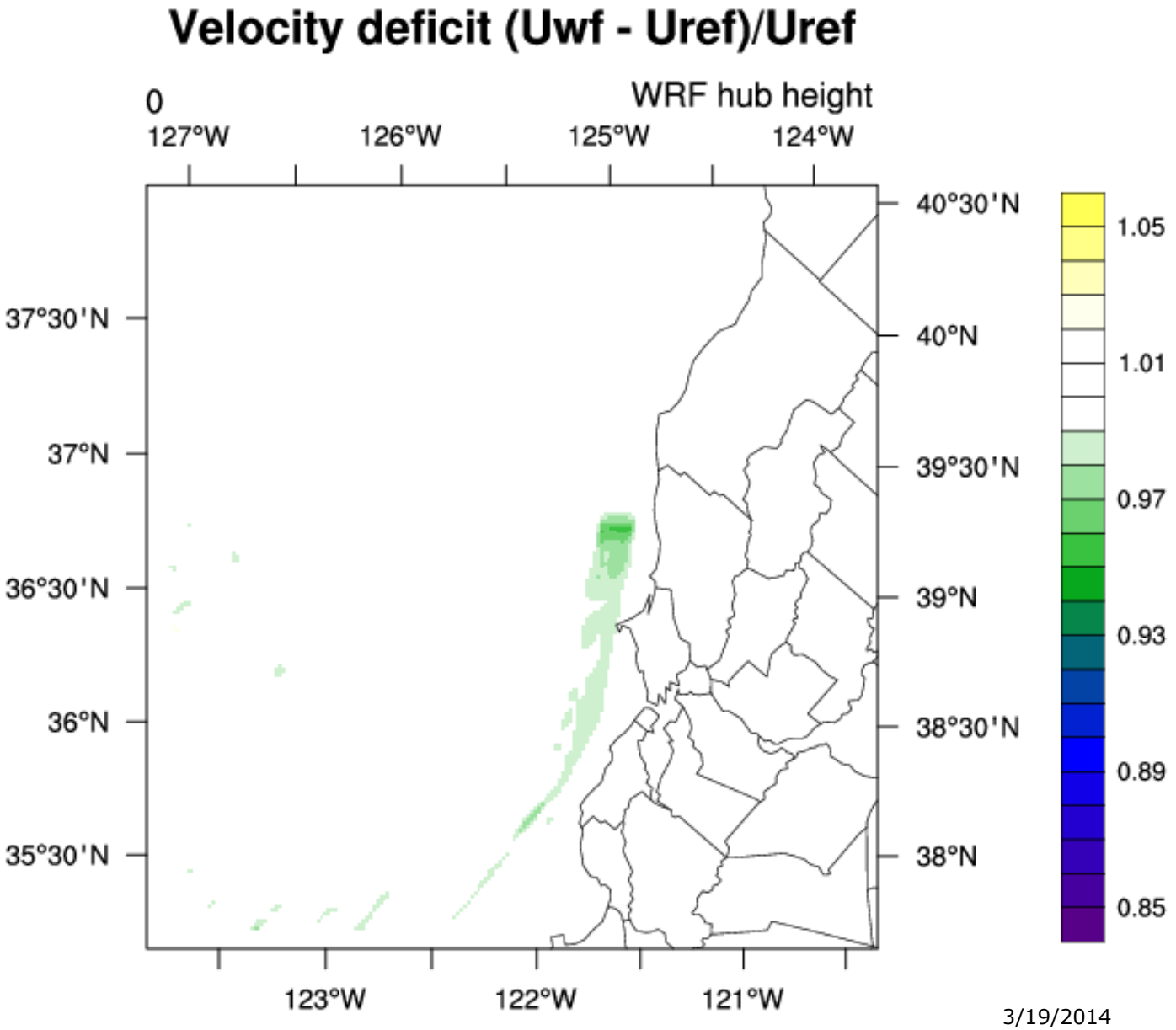
Impact of a wind farm offshore

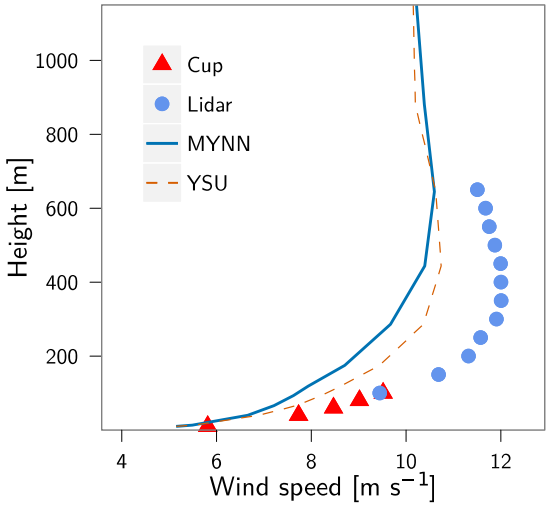
DTU

Hypothetical wind farm along the California coast

Wind farm of 200 turbines:

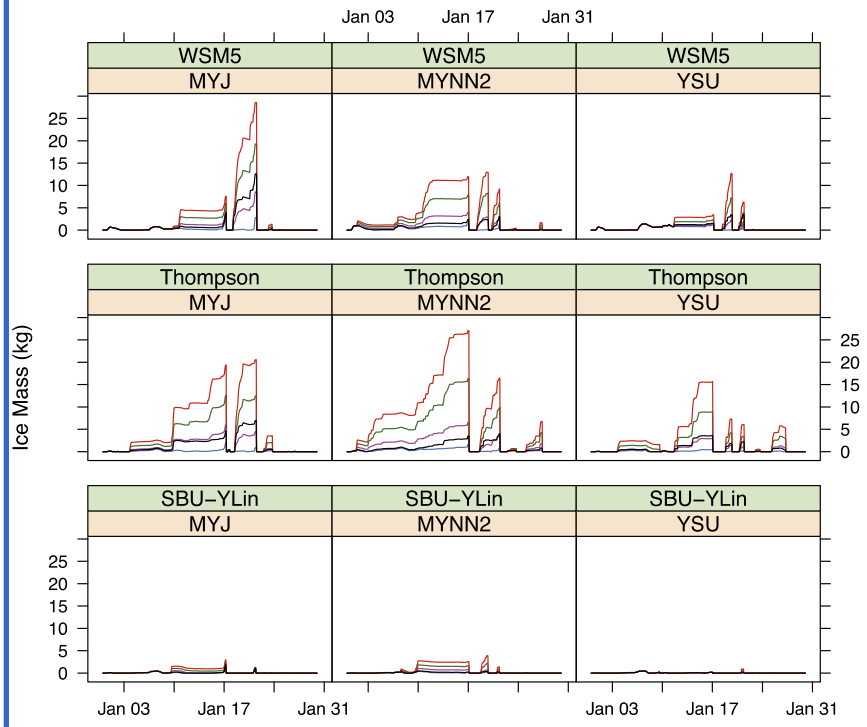
10 E-W x 5 N-S grid cells
126 m diameter
125 m hub height





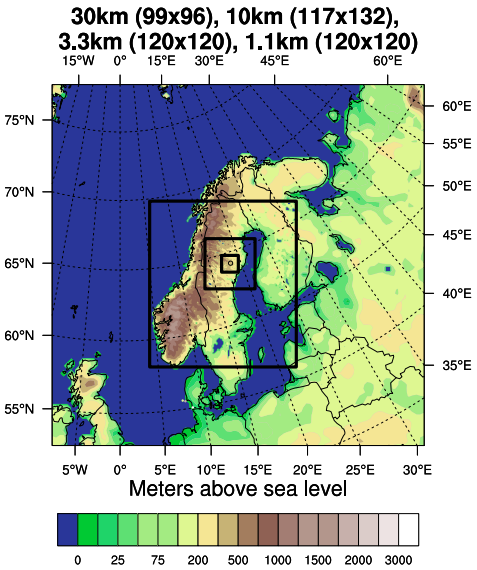
Verifying WRF simulations against lidar measurements

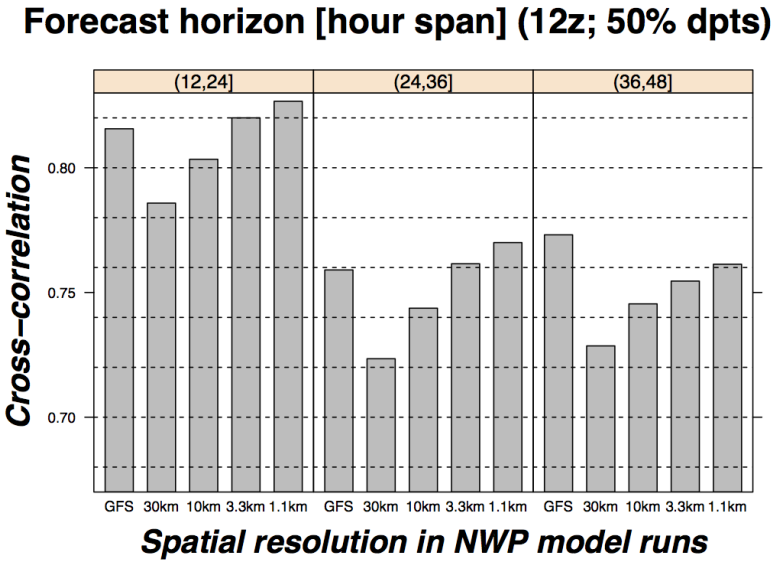
Rogier Floors



Ice mass forecasts using diff parameteriz.

Neil Davis



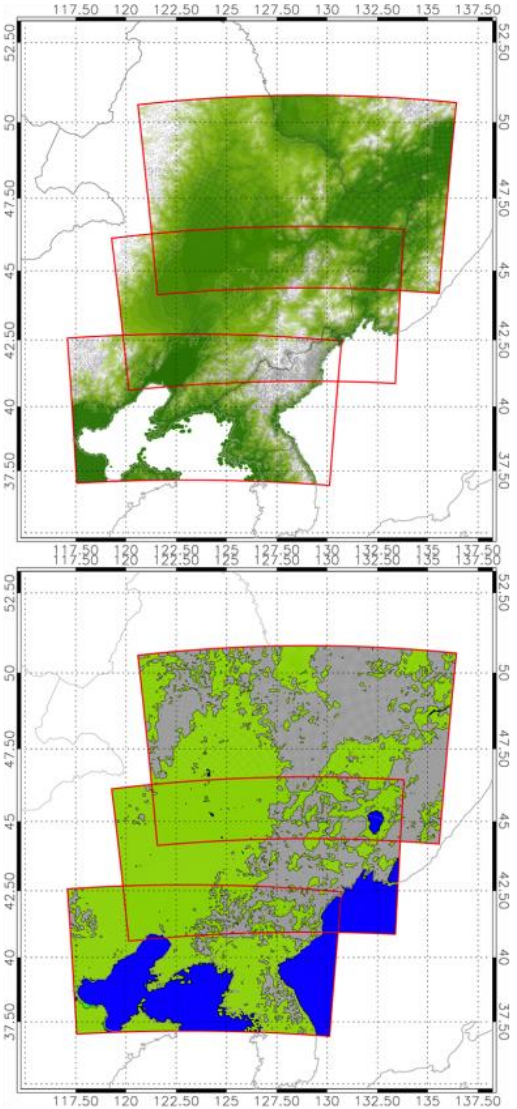


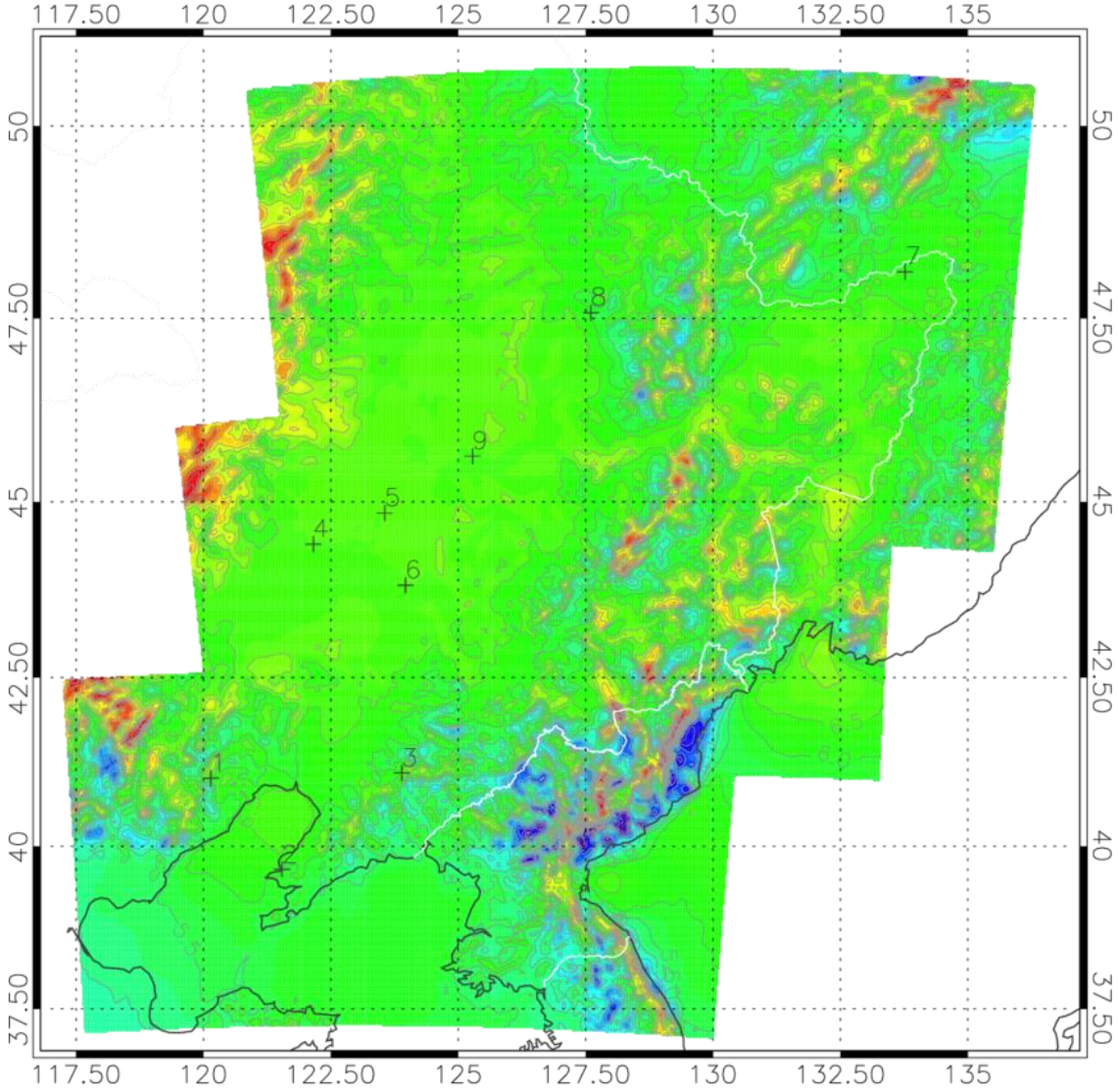
Investigating the effect of model resolution

Martin Rosgaard

What could we do in the future…

Wind Atlas for Northeast China (Dongbei)

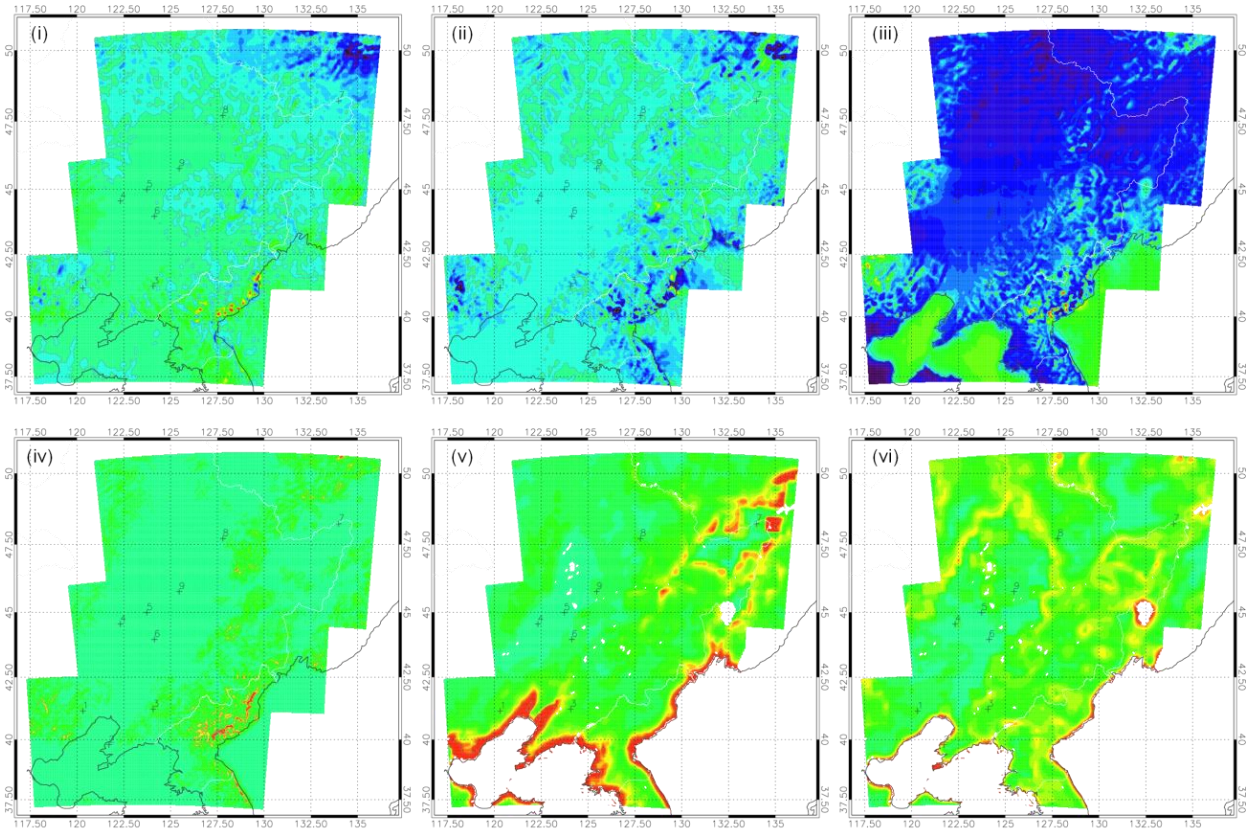




Jake Badger

Sensitivity maps and uncertainty

- Top 3 maps show sensitivity on wind resource result depending on model configuration (number of wind, stability classes and surface temperatures).
- Bottom 3 maps show indices for spatial variations of resource, orography and roughness length.



- Can sensitivity be used to determine uncertainty?

$$|\varepsilon_{\text{pred}}| = \alpha_0 + \sum_{i=1}^{N} \alpha_i |S_i|$$

Badger et al, Methods to assess uncertainty of wind resource estimates determined by mesoscale modelling EWEA Annual Event

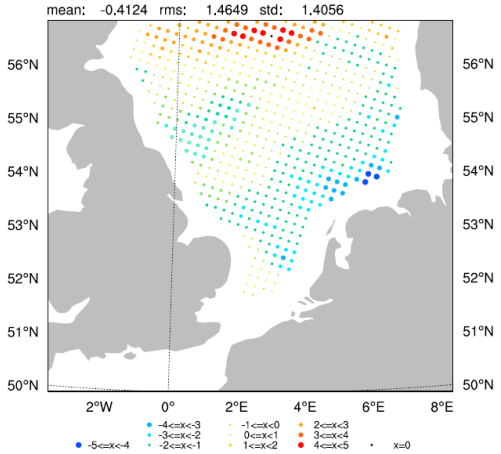
WRF 4DVar Data Assimilation

Combine the modelled and observed atmosphere in an optimal way

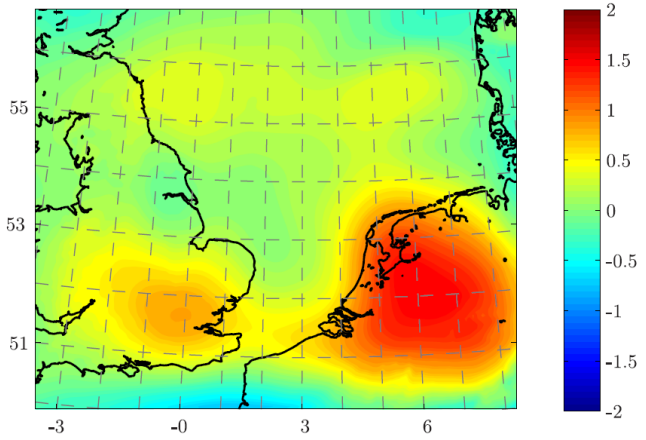
- Scatterometer winds over the sea
- Synop and aerodrome reports
- Aireps (upper)
- Soundings (weather balloons)
- Ship reports
- Buoys
- AMDAR reports

A priori analysis → Data Assimilation → New analysis

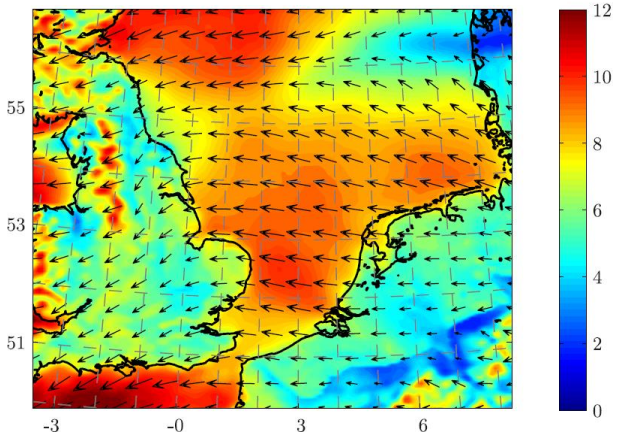
ASCAT background errors V wind component



Wind speed increments from assimilation (level 2)



Updated analysis (level 2)



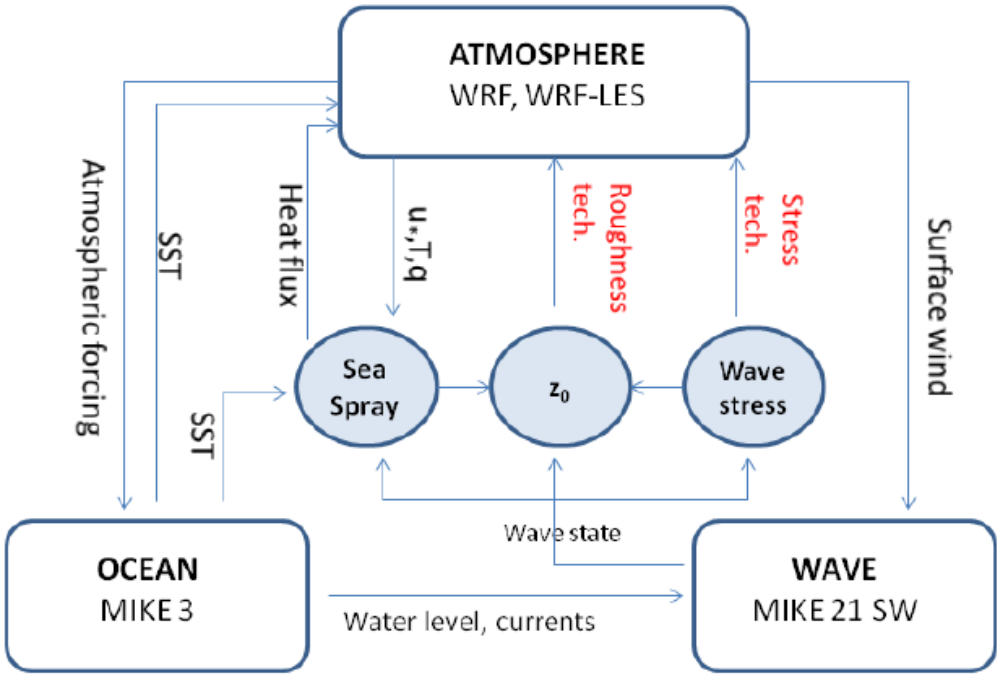
We cut down our domain size due to memory problems on Gorm. We still require 10 nodes and several hours to run a single case. Hoping for better performance on the new machine!

Claire Louise Vincent and Neil Davis

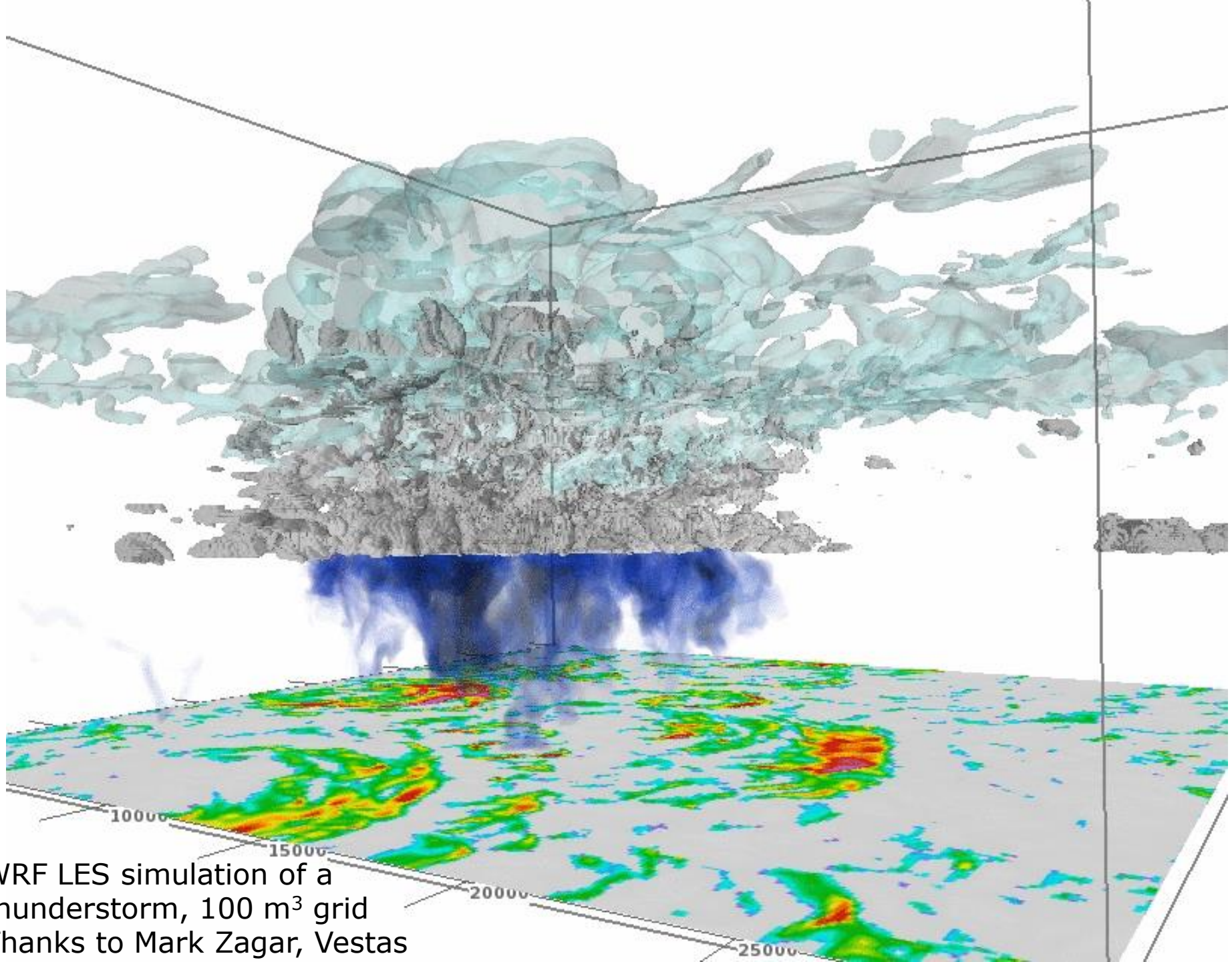
We are benefiting/have benefited from the Clusters for a number of projects, including these topics:

1. Coupling WRF (WRF-LES) and wave model MIKE
2. Modeling storms using WRF
3. Modeling gravity waves using WRF

To improve the modeling of wind and waves during storms in coastal zones



Xiaoli Guo Larsén



WRF LES simulation of a thunderstorm, 100 m^3 grid
Thanks to Mark Zagar, Vestas