EUROPEAN COMMISSION
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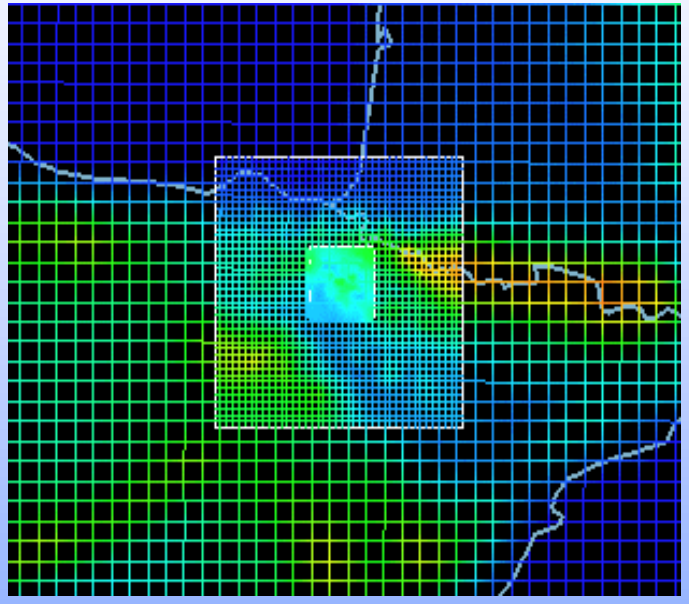

Short-term Forecasting Using Advanced Physical Modelling

The Results of the Anemos Project

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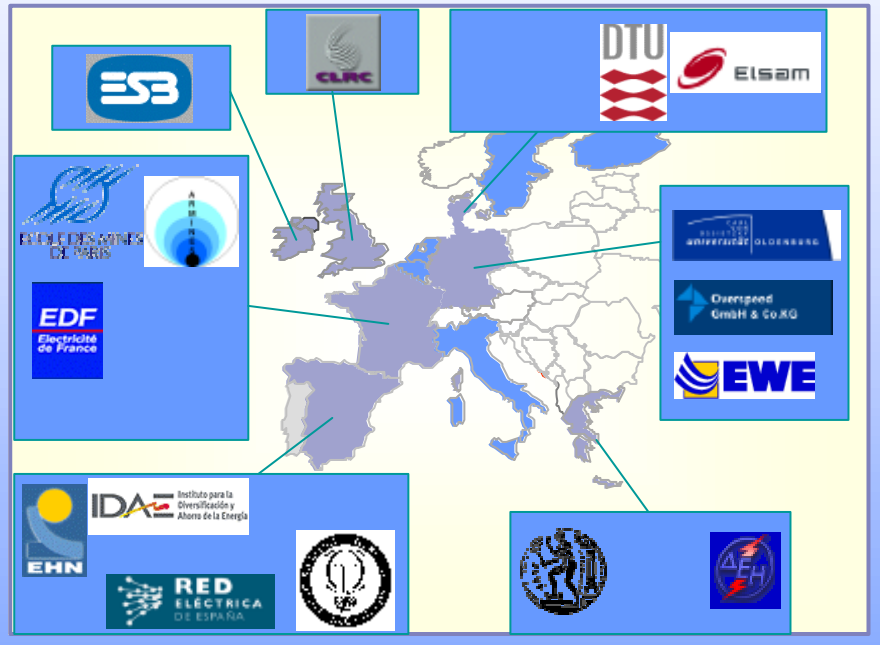

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Motivation

- **The largest error comes from the NWP** (Numerical Weather Prediction)
- **Typical NWP have only in the order of 10 km horizontal resolution**
- **In complex terrain, this is not enough.**
- **Therefore: nest higher resolution models for the area in question**, such as meso-scale models (MM5, KAMM, RAMS), CFD or simple flow models

- **But what *is* complex?**
- **Is there a "rule of thumb" when to use it?**

Overview

- **Three test sites: Alaiz, Corsica, Crete**
- **Look-up table vs nested model**
- **Plenty of individual results (abbreviated! :)**
- ... including long-term forecasting
- **Some common conclusions**

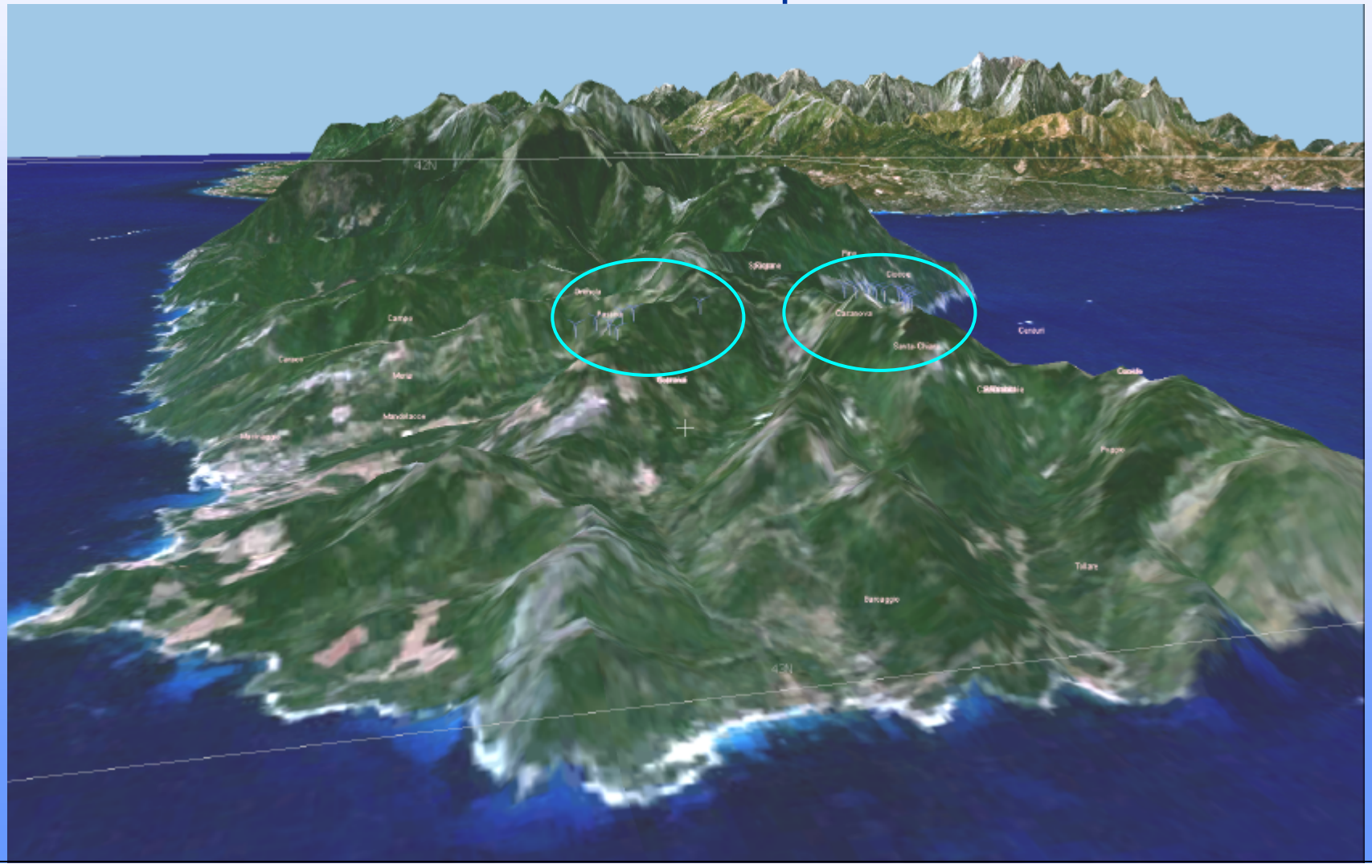
Test cases: Alaiz (Spain)

Very complex terrain, 50 turbines / 33 MW, December 2003

Image done using WorldWind / NASA.

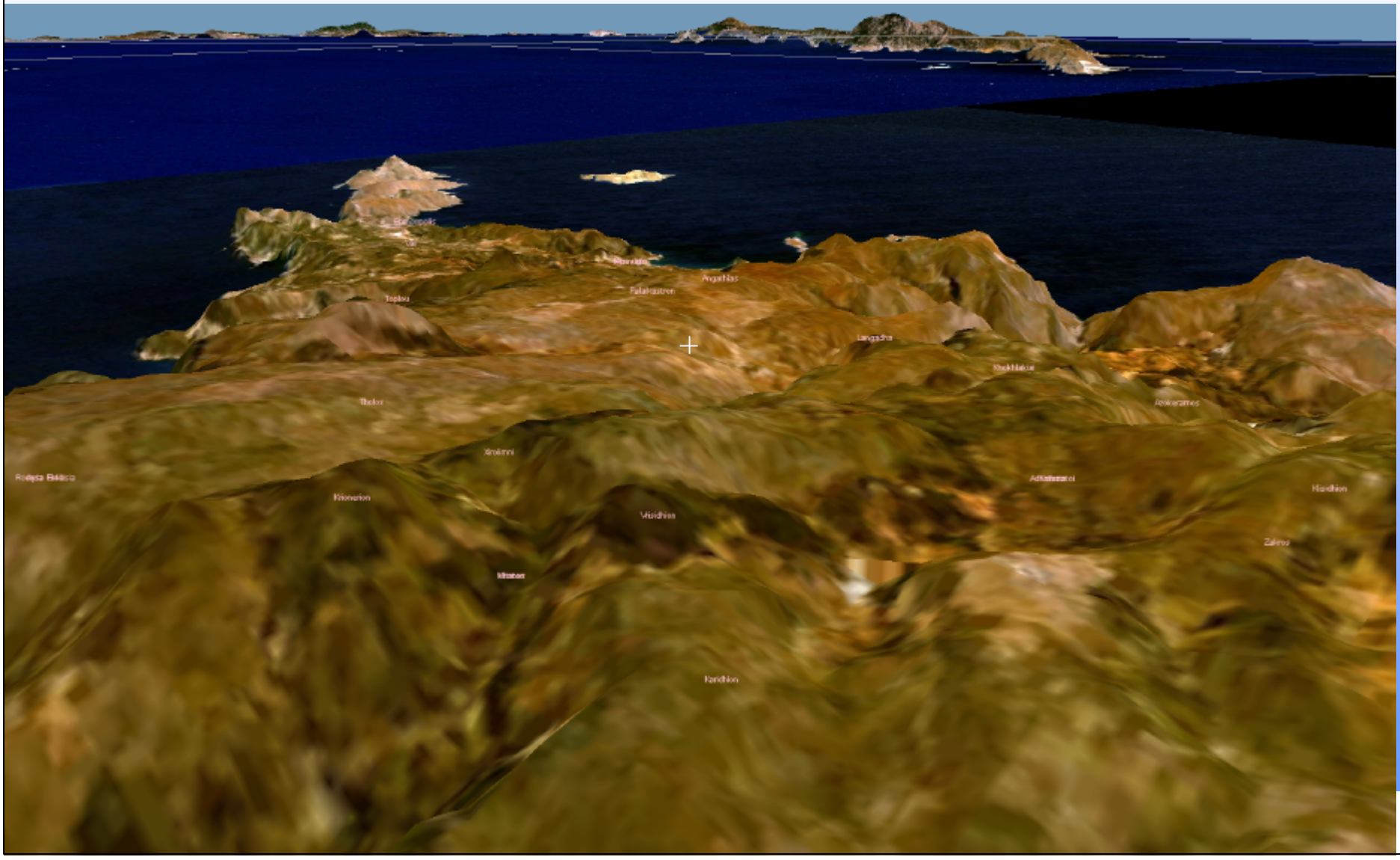
Test cases: Corsica (FR)

Complex terrain, near-shore, two clusters at Ersa and Rogliano, 20 turbines / 12 MW, various short periods



Test cases: Crete

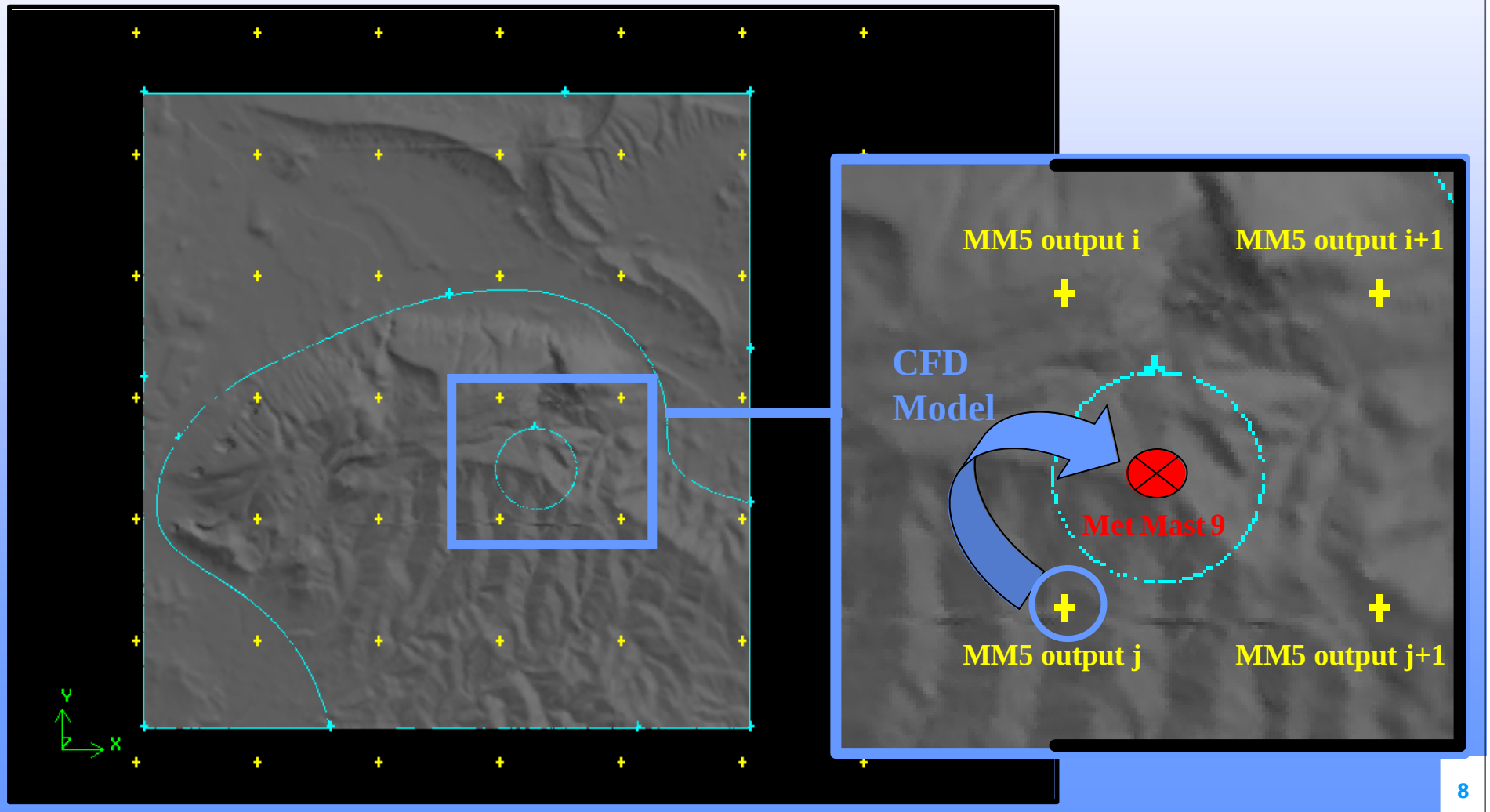
Complex terrain, 4 wind farms (mostly Rokas), various dates



The idea of smaller scale physical modelling

Numerical Weather Prediction (NWP) has limited resolution

Therefore has to average over complex terrain

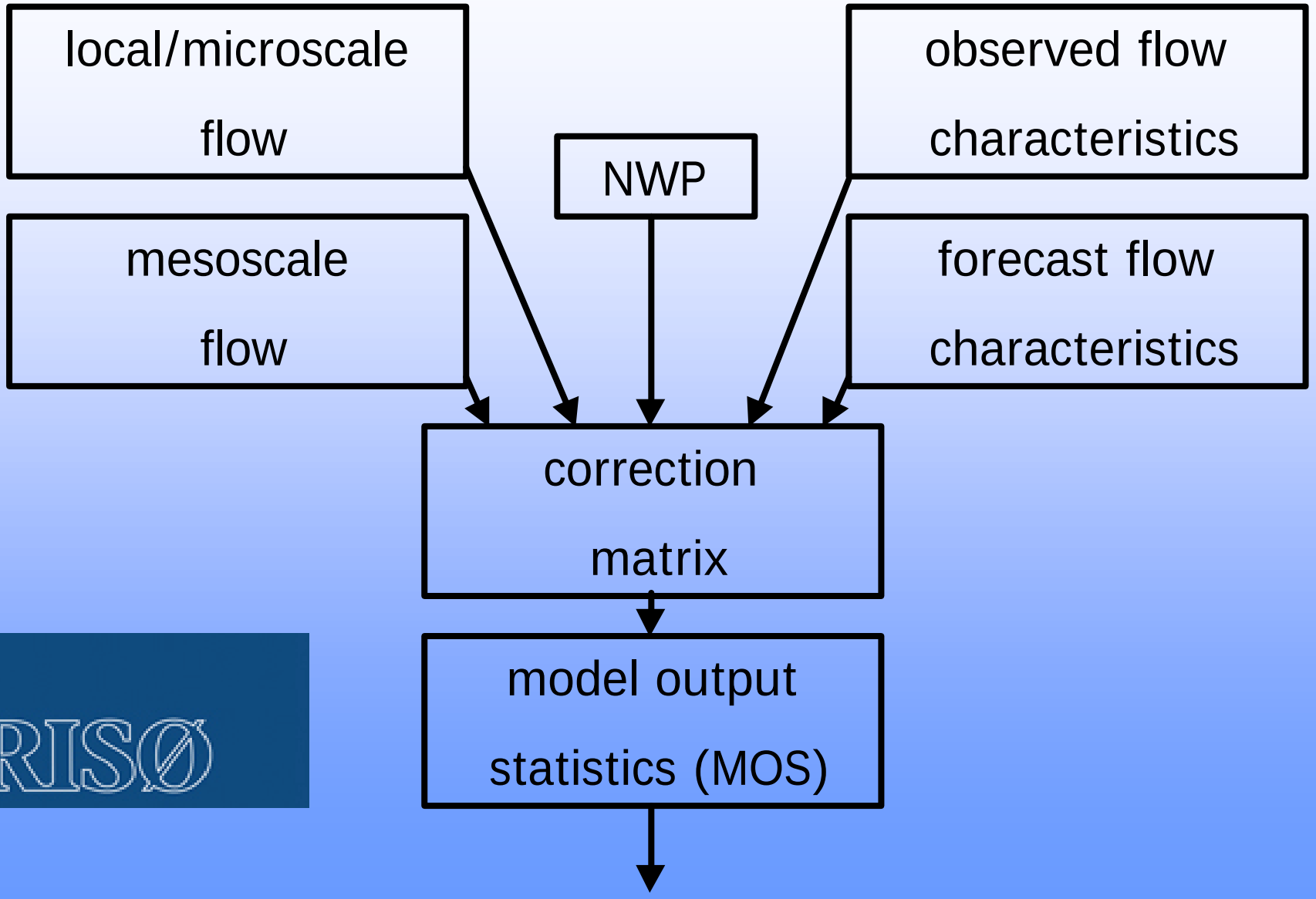


Look-up table vs dynamic

Two approaches to downscaling:

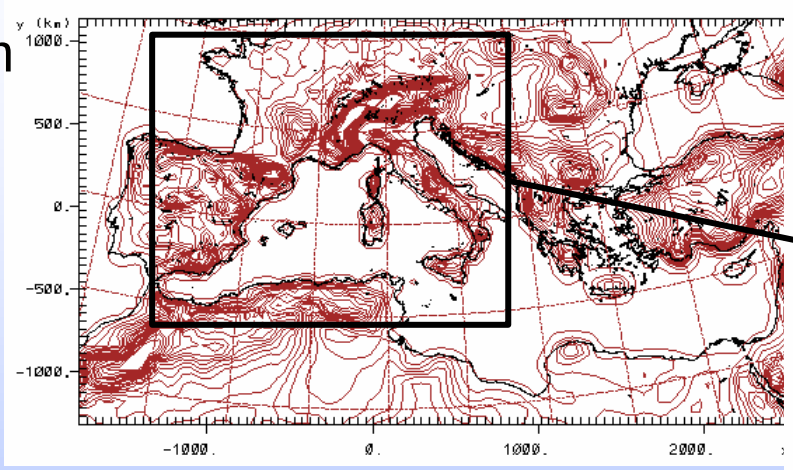
- **Look-up table**
  - Does the heavy calculations once
  - Then tries to establish connection between overall wind situation and local wind field
  - Ends up with a look-up table
  - Examples: KAMM, CFD models
- **Dynamic downscaling**
  - Runs the model every time a new NWP result is available
  - Numerically quite heavy, but potentially better
  - Examples: MM5, WRF, ...

The look-up table approach

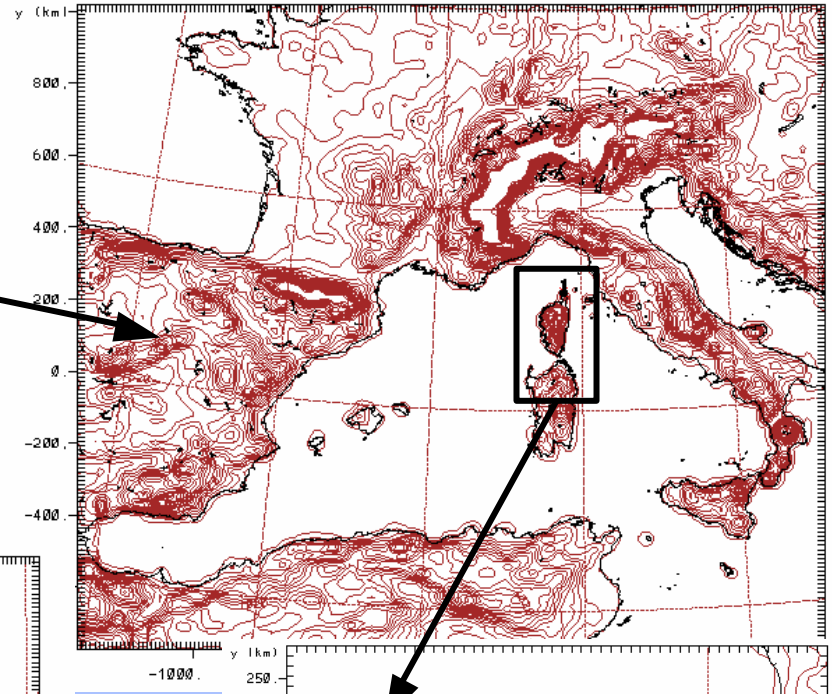


The nesting approach

48 km



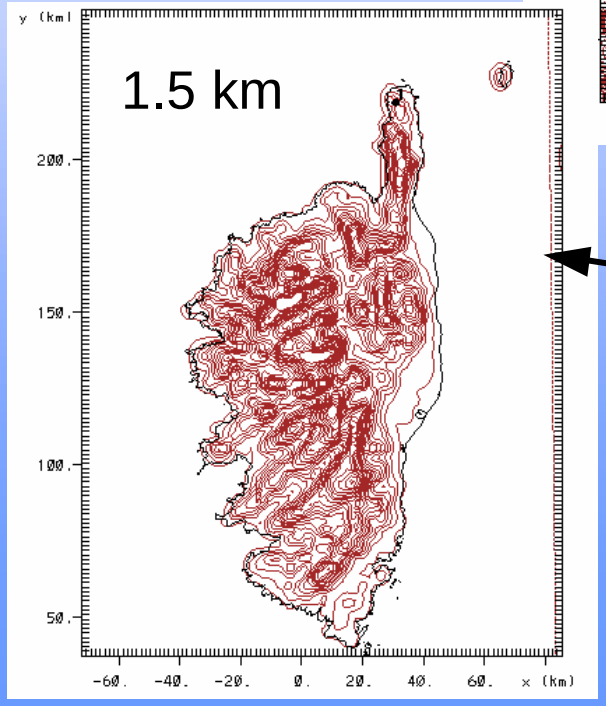
12 km

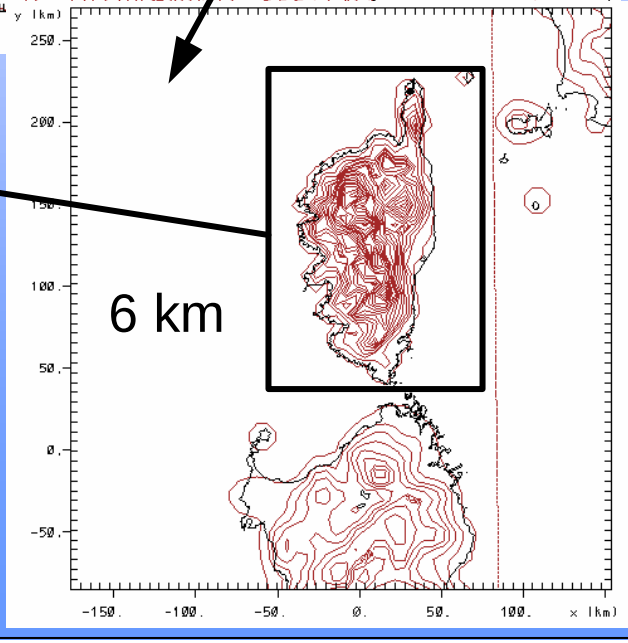


Corsica with RAMS model

ERSA: 42.97 N, 9.38 E, H = 553m

16-18 Jan 2003





From here on:

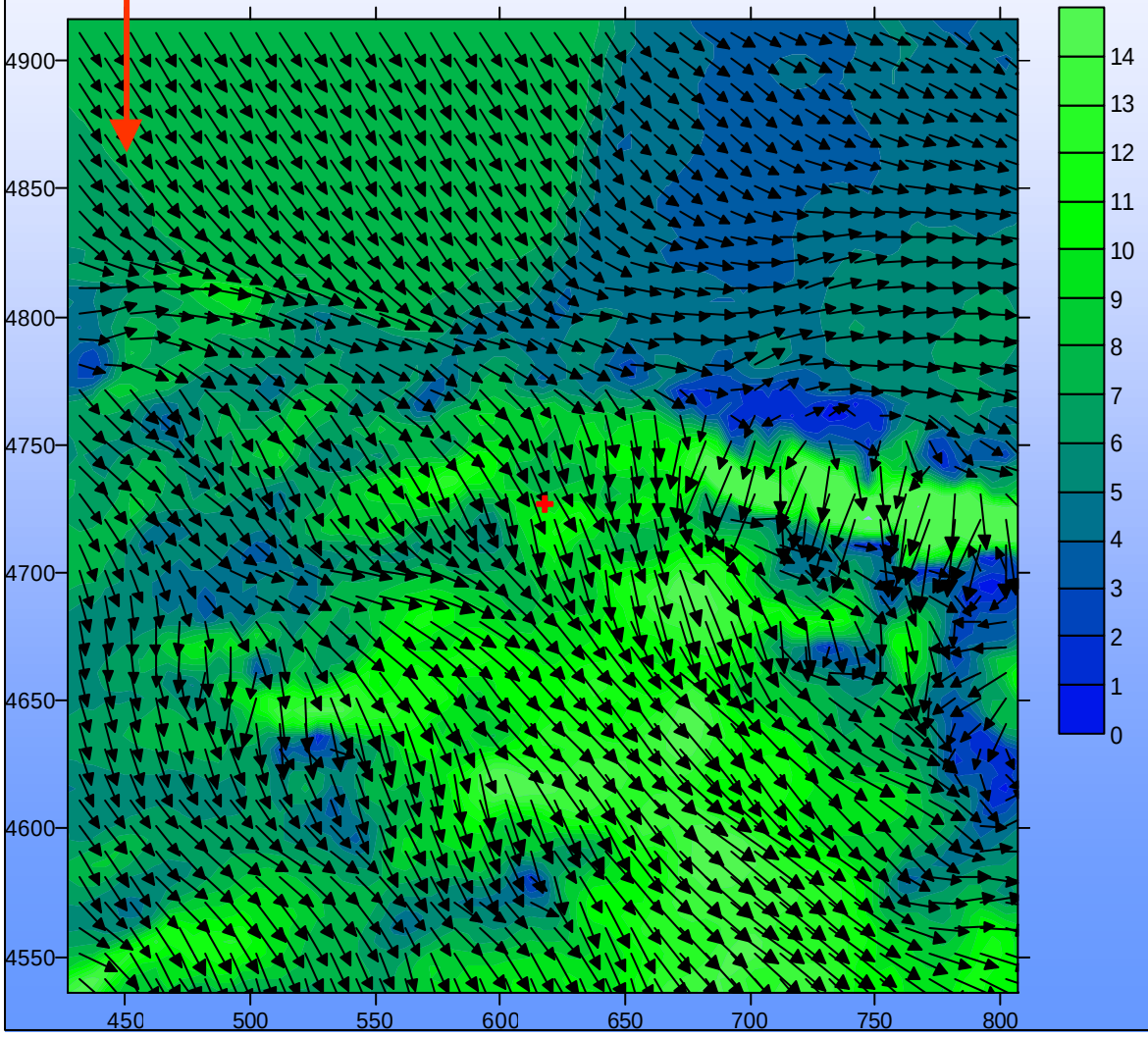
RESULTS

(must be quick – 23 slides to go!)

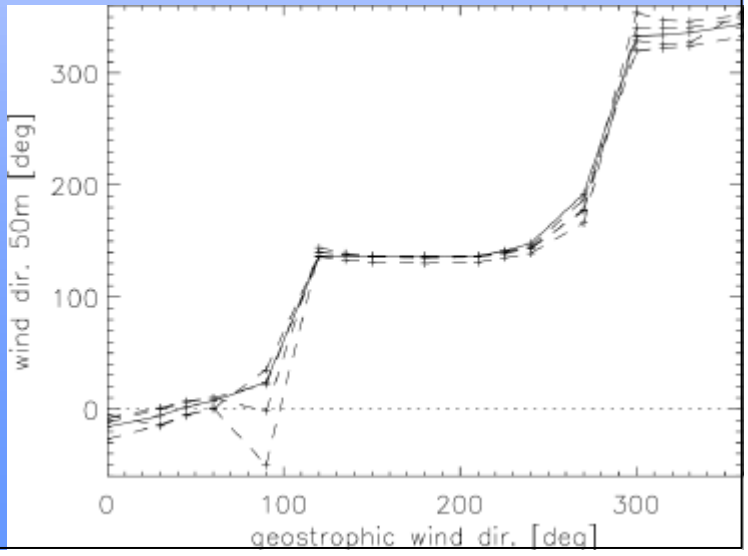
Please read the 130 page report on anemos.cma.fr for plenty of details!

Risø: KAMM

Domain size 400x400 km² required for Alaiz (200x200 not enough)



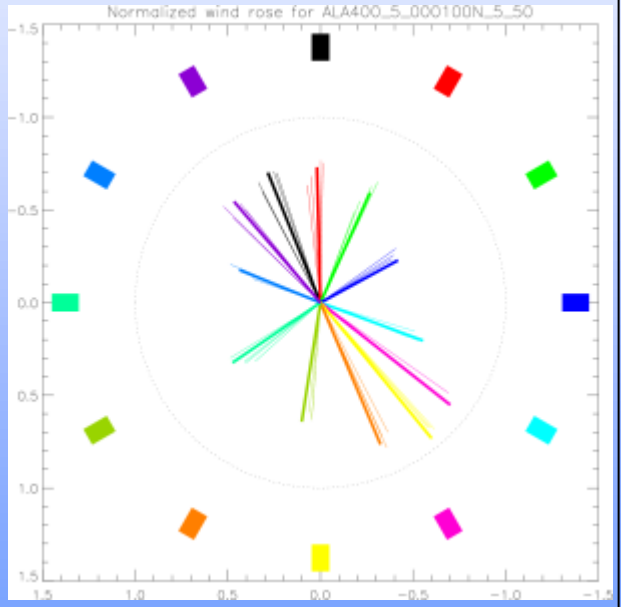
KAMM yields strong speed and turning effects, very consistent with observations. Dependence on temperature profile.



KAMM Conclusions for Alaiz and Corsica

KAMM simulations qualitatively capture the region flow behaviour at the sites.

It is not straight forward to transfer this qualitative interpretation to a quantitative improvement in prediction skill. This may be due to setting up the system – how the correct adjustment is selected.

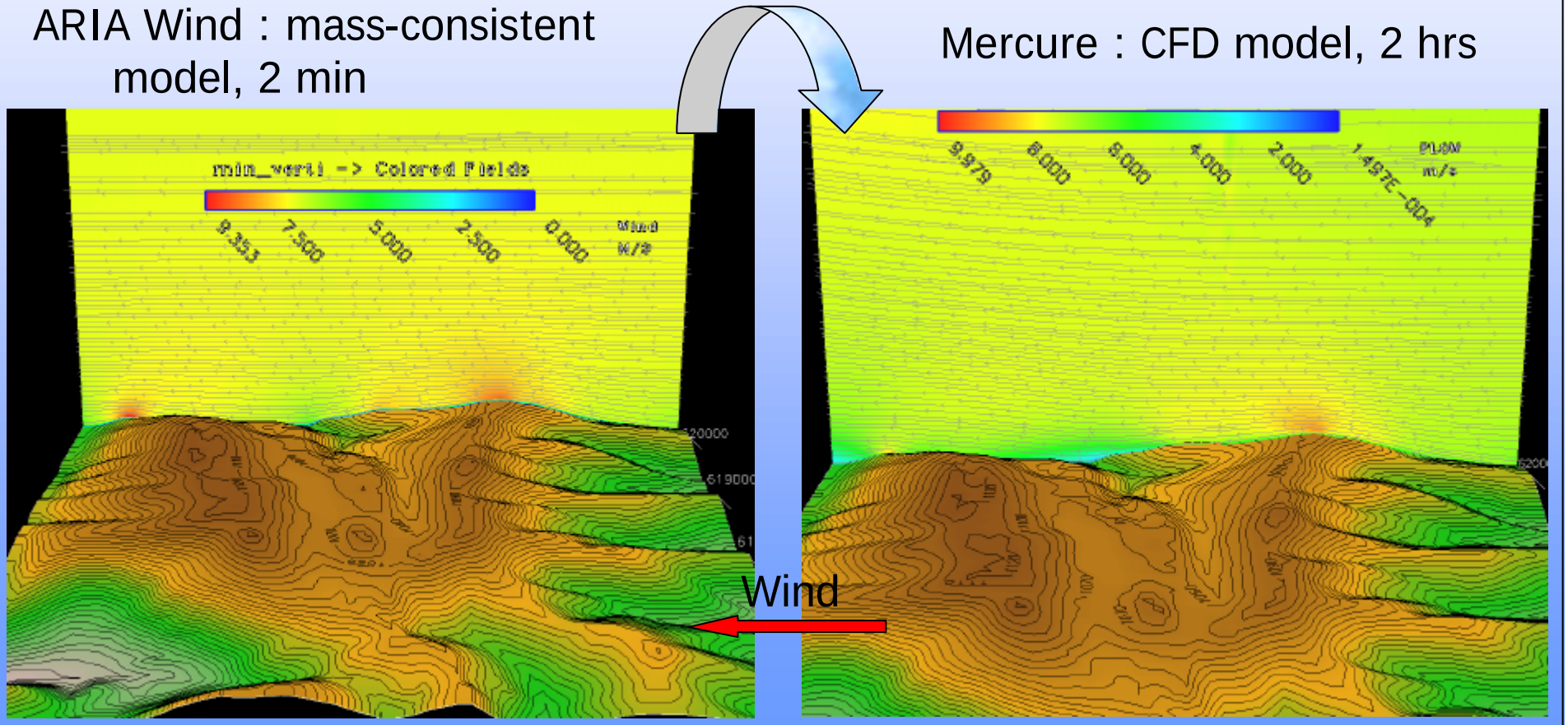


Initialise CFD with MC model

Alaiz: 7,5 m/s at 55 magl / WD 160°
Neutral vertical atmospheric profile
Horizontal resolution 50m x 50m

ARIA Wind : mass-consistent model, 2 min

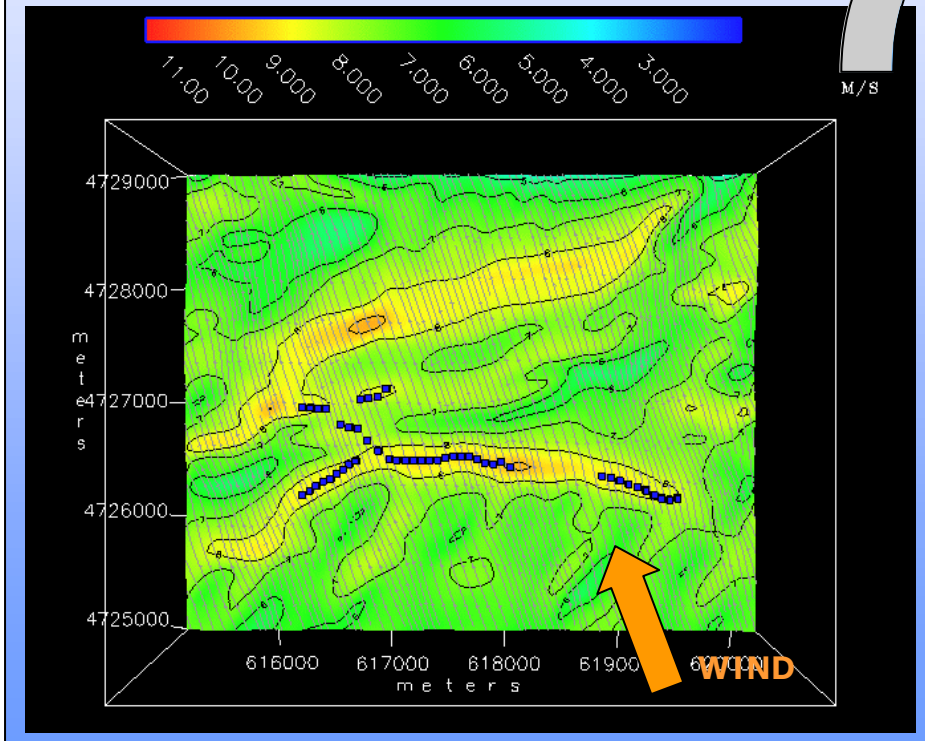
Mercure : CFD model, 2 hrs



ARIA Results

CFD initialisation with mass-consistent model
reduces calculation time (4h ➔ 2h),
improves results of CFD calculations

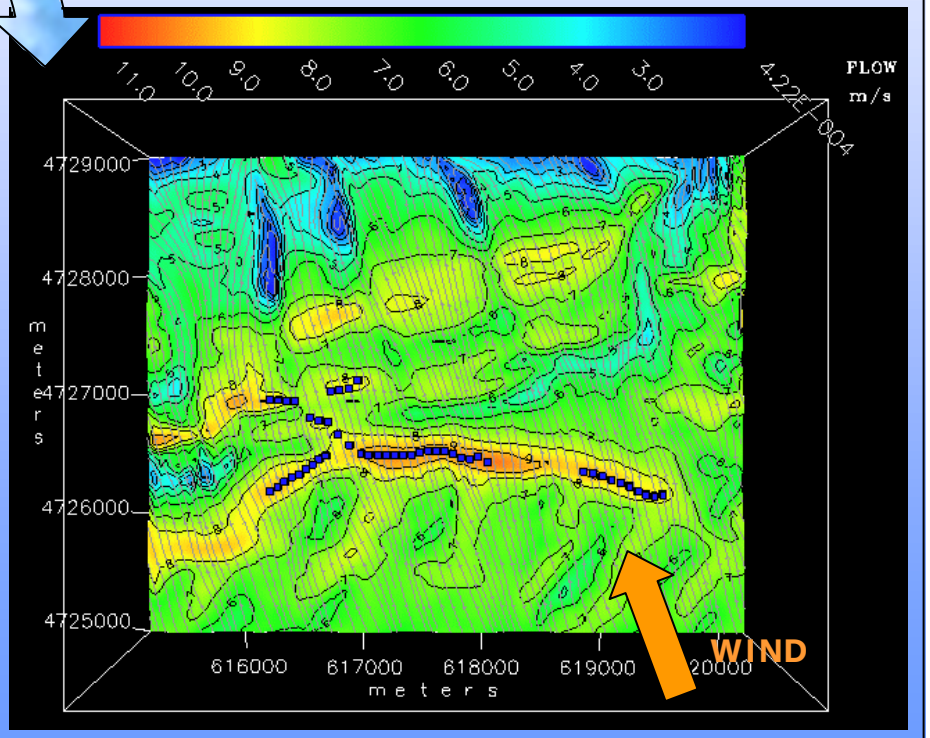
ARIA Wind :



9.3<U(m/s)<3.8

horizontal slice 50 m. agl

Mercure :



9.9<U(m/s)<4e-3
Mountain wake effect

Conclusion Minerve / Mercure

Initialise Mercure (CFD) with the wind field from ARIA Wind for Alaiz:

- **The CPU time** for Mercure wind field solution decreases (initialisation by ARIA Wind field)
- ARIA Wind field is a first solution interesting for this case.
- Mercure wind field is more accurate : wake effect – speed up (physical model more complete)

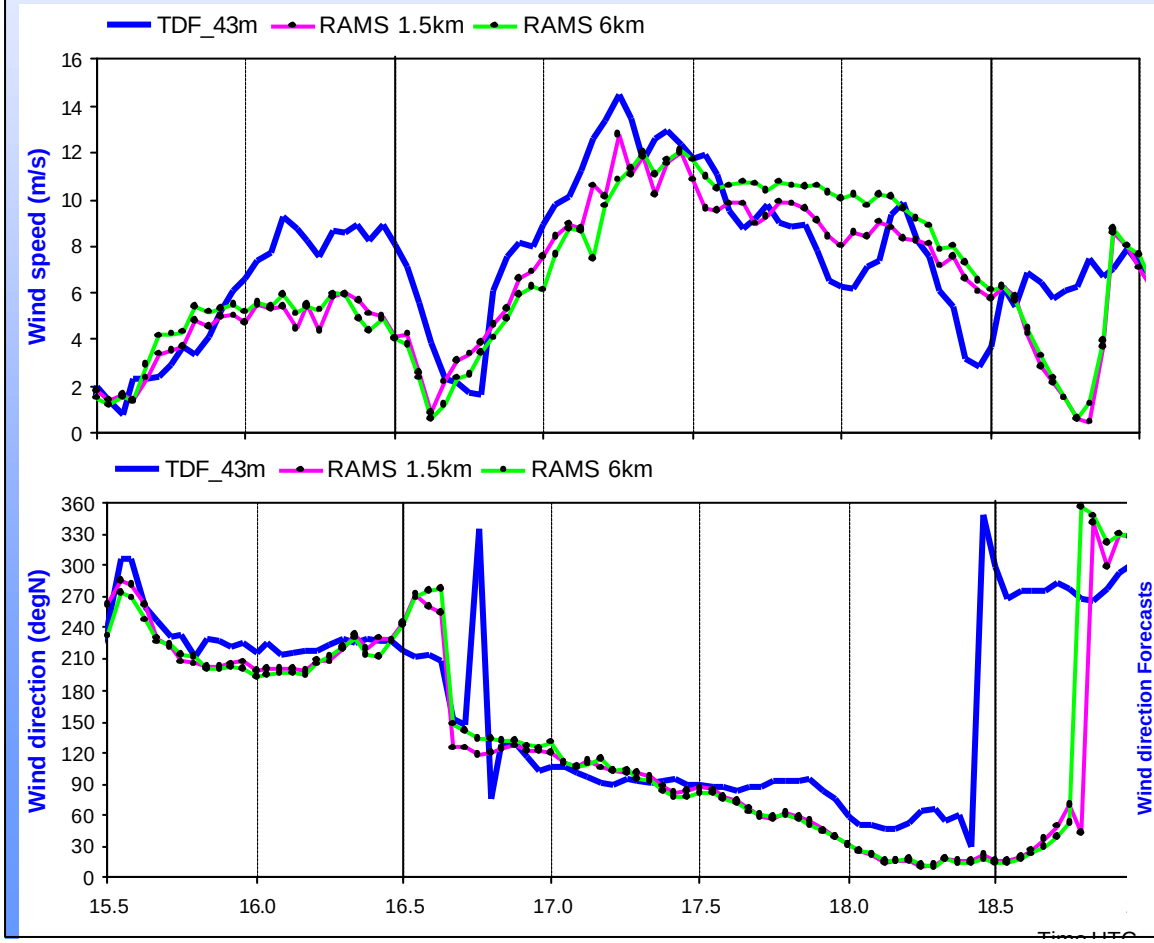
Minerve results for Corsica:

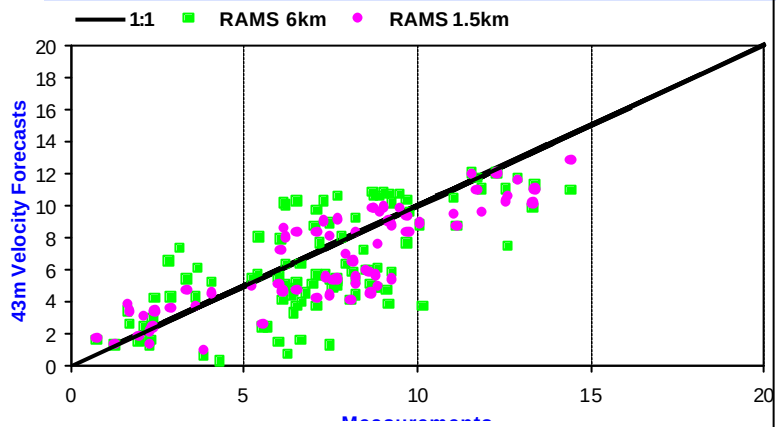
- This MM5 configuration (economic) permit to forecast each day 48 hours Horizon on a classical computer
- The results are respectable
- The nesting between Minerve Model and MM5 Model is interesting. Minerve improve the first solution of MM5 model.

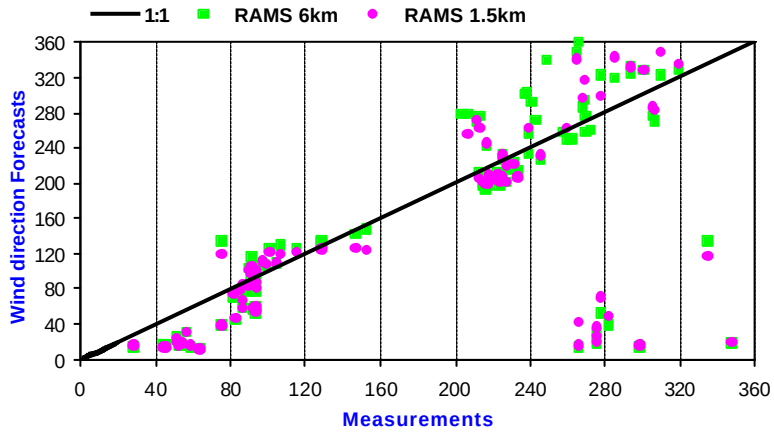
IASA: Results for Corsica

Green line and dots: further out than the pink line and dots. Means: the higher resolution works in this case

Other: the 43-m level works better than the 10-m wind







Crete case

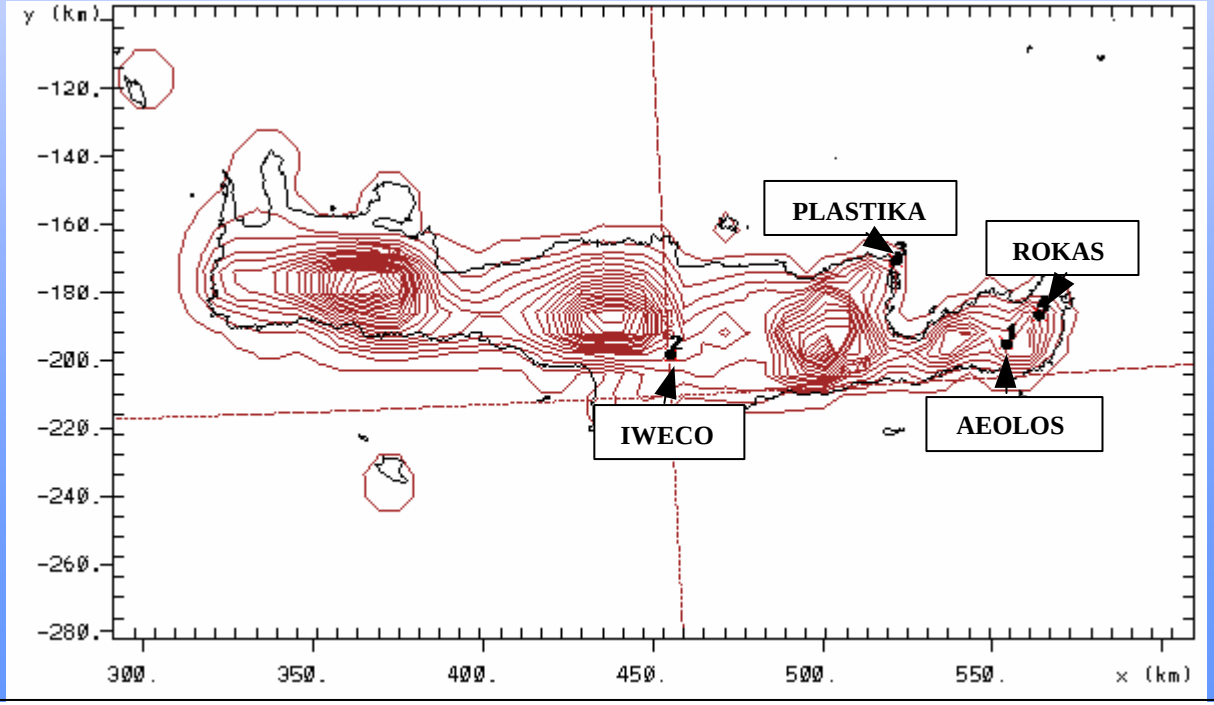
Down to 500 m resolution, but with 1000 m terrain DB

Not much difference between 0.5 and 1.5 km resolution, but both are better than 6 km

Resolution more important for temperature (like in Corsica)

Uniformity of terrain is very important parameter!

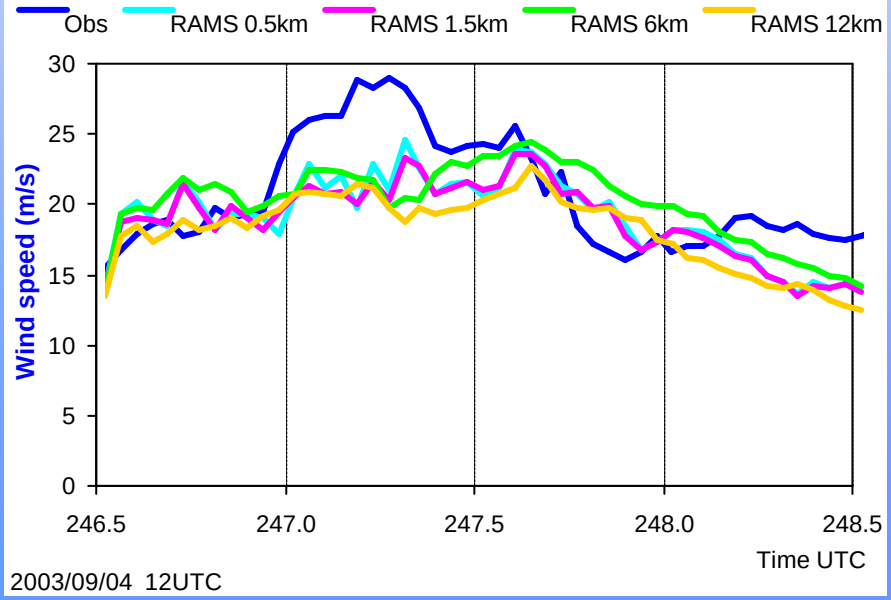
And how representative is the measurement station?



IASA: Results for Crete

For Rokas wind farm:

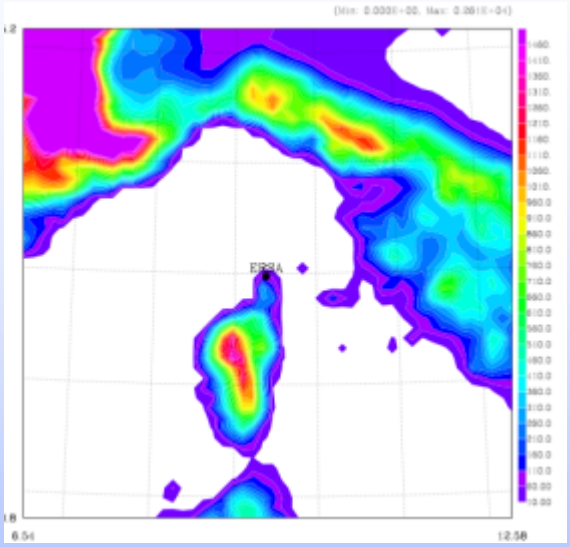
- ✓ Regional and mesoscale features of the airflow are captured satisfactorily by the coarser grids (12km and 6km).
- ✓ The small scale features (e.g. topography induced) are better described by the finest grids (1.5km and 0.5km).
- ✓ However, **the benefits gained beyond 6km resolution are not always worth the computational expenses**.

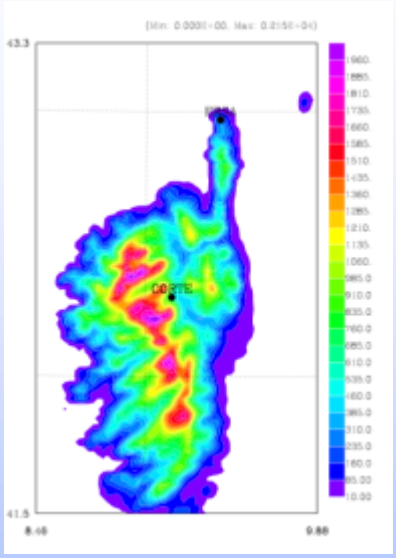


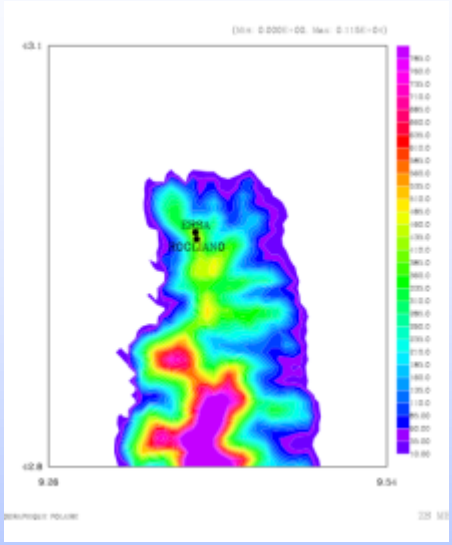
Summary High-Res modelling with RAMS in Crete

- RAMS runs down to 0.5km horizontal resolution for Rokas/Crete
- The wind at the second model level is closer to the observations for all grids and all three runs performed.
- Model-observations comparison is subject to spatio-temporal scales.
- The highest resolution grid (0.5 km) and especially for the run initiated at 12 UTC on 4/9/2003 (3rd run) performs better than the lower resolution grids capturing mostly the airflow characteristics.
- A model underestimation is obtained for wind speeds greater than 25m/s. This threshold is reduced for model resolution greater than 0.5 km.
- The CPU time required for a 48-hour run with 5 two-way nested grids in 3 nodes (6 CPUs) was approximately 48 hrs. The critical question still remains:
  - Is it worth using expensive computational facilities to get this level of information for operational purposes?
  - What are the alternatives? => Kalman filtering

MesoNH

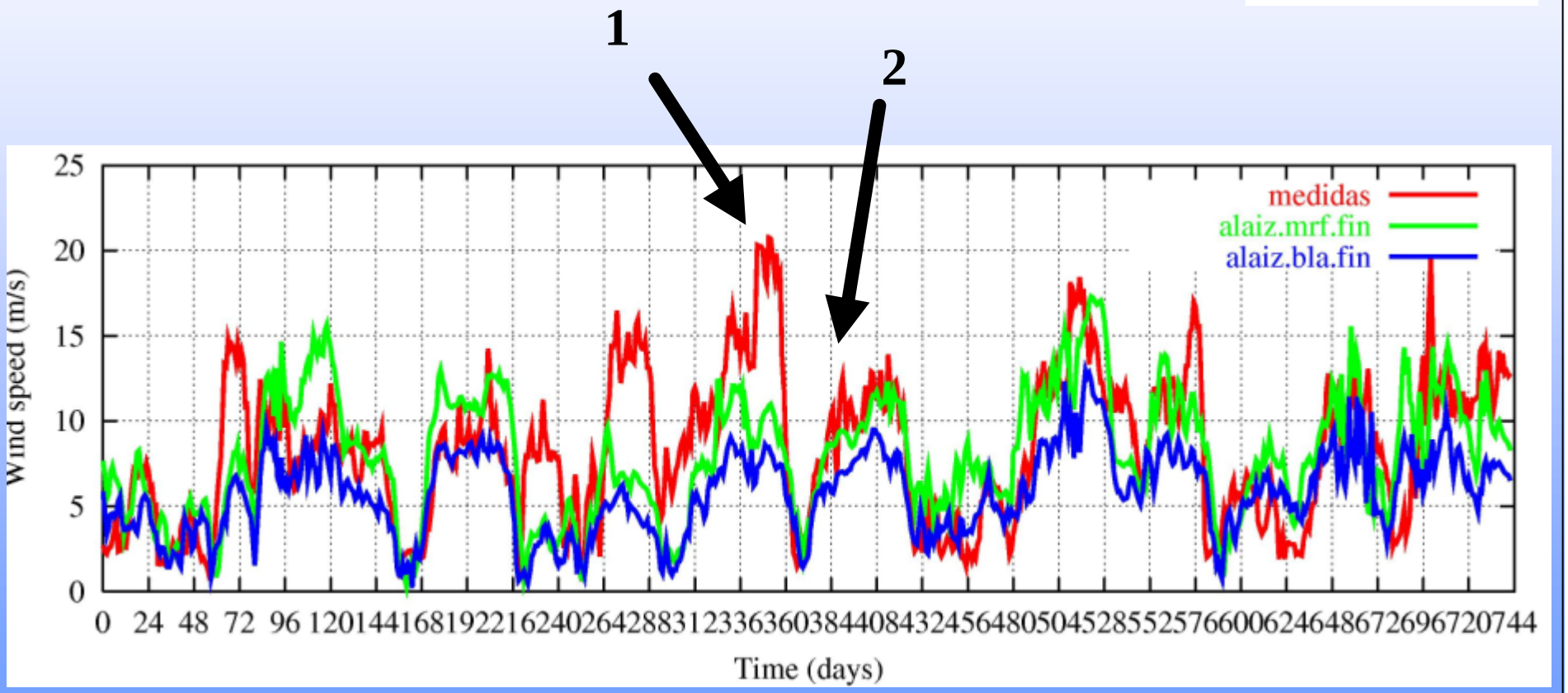




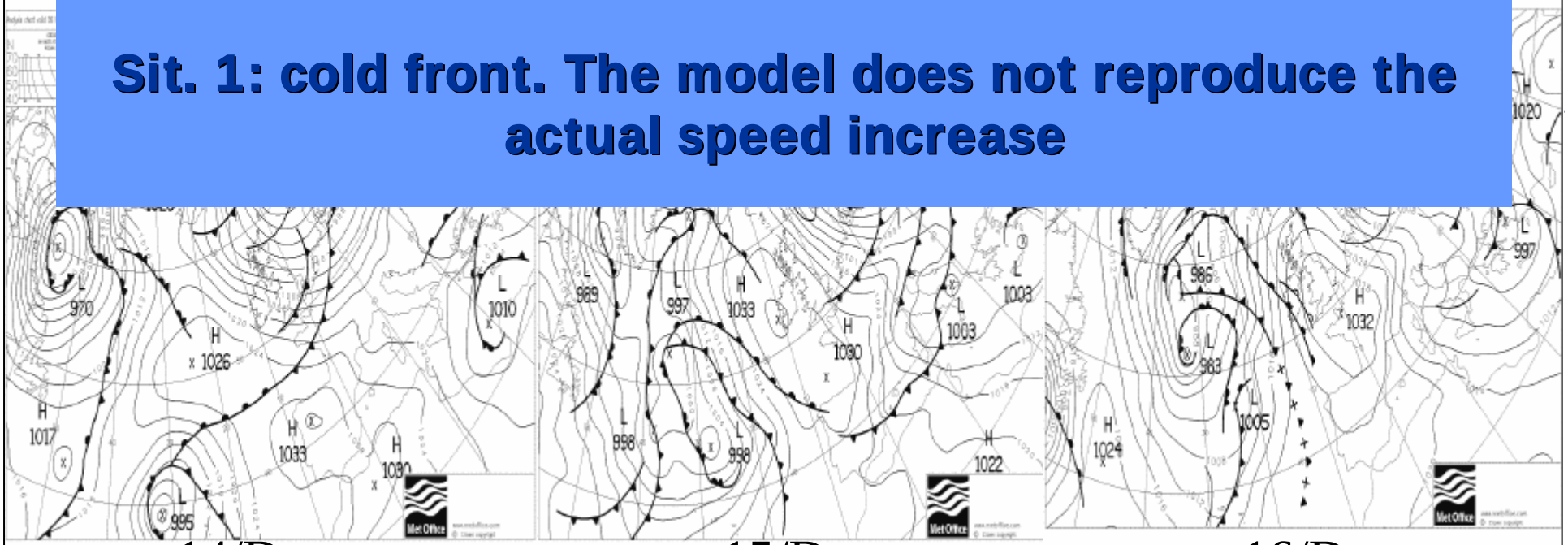


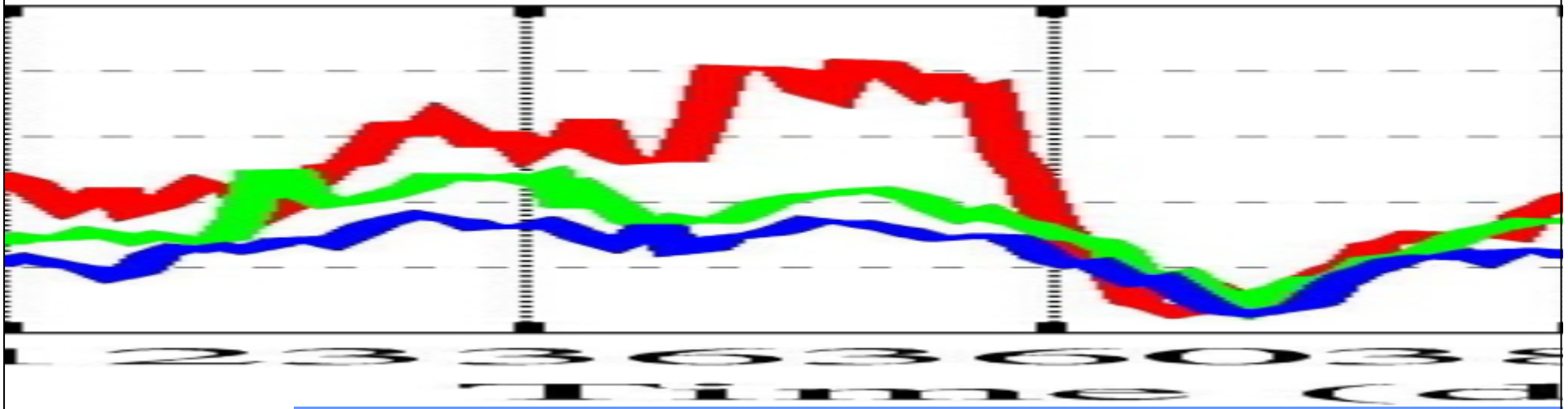
- 8 km, 2 km, 500 m (that's 2 seconds time step!)
- 2 periods
- Initialisation from Aladin forecast
- Compares fine with RAMS (needs comparision of turbulent fluxes, vertical profiles ...)
- More explanative of the weather situation than just looking at the time series

MM5 Alaiz


1
2
medidas
alaiz.mrf.fin
alaiz.bla.fin
Wind speed (m/s)
0
5
10
15
20
25
0 24 48 72 96 120 144 168 192 216 240 264 288 312 336 360 384 408 432 456 480 504 528 552 576 600 624 648 672 696 720 744
Time (days)

Sit. 1: cold front. The model does not reproduce the actual speed increase





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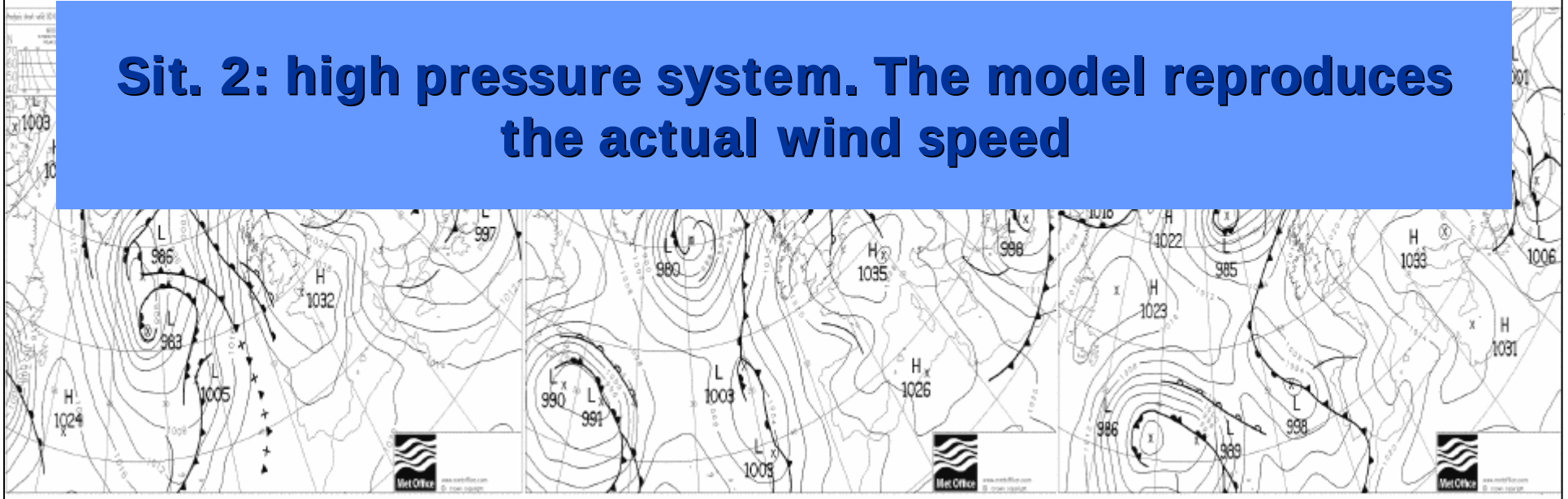
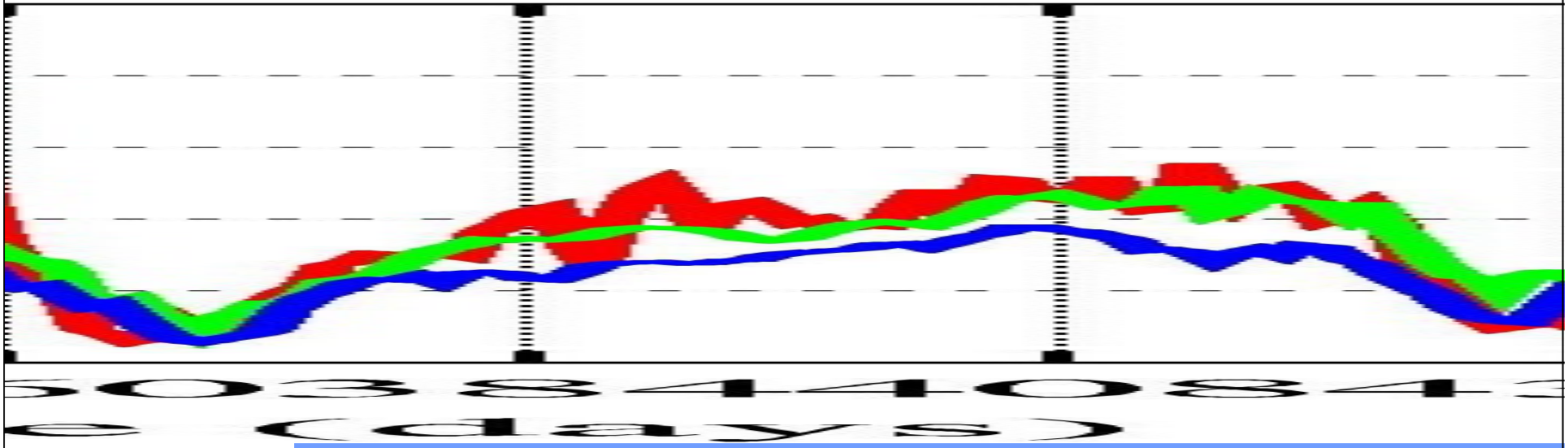
Sit. 2: high pressure system. The model reproduces the actual wind speed





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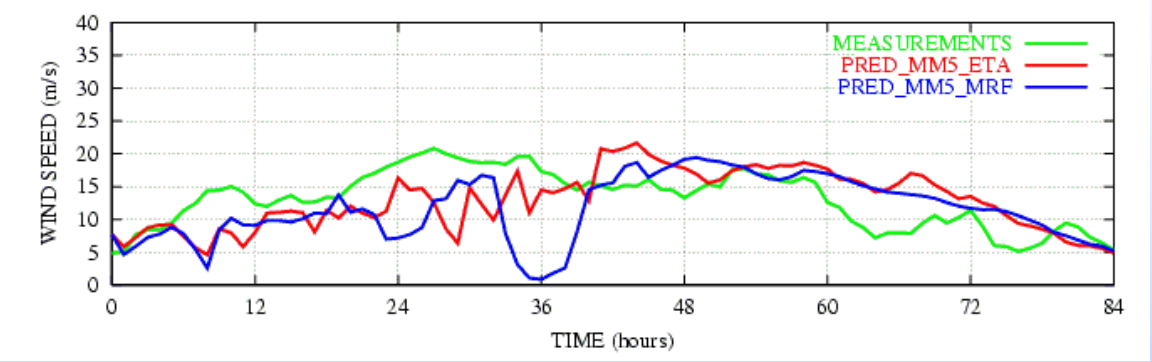
CONCLUSIONS MM5 (NCEP)

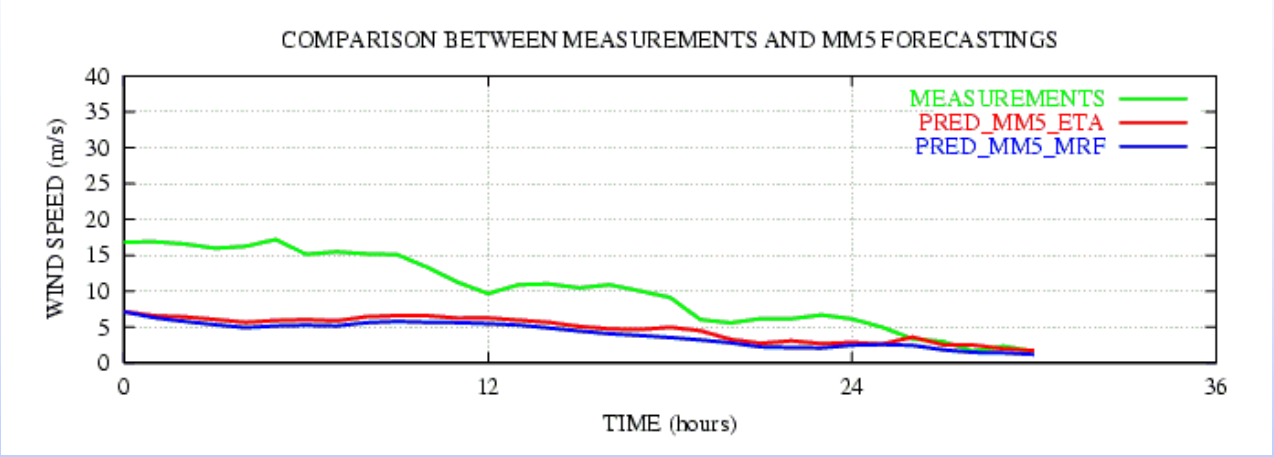
Analysed: MM5 for 6 short selected periods for Corsica case.



- The MM5 effectiveness in downscalling is different in each analysed period
- It cannot be concluded that one of the two parameterizations (MRF, ETA) is better than the other one. It depends on the period
- The MM5 curves are usually smoother than the measurements (the time step is 6 hours)
- In general, the MM5 curves are not capable of reproduce the variations of the measures

CONCLUSIONS MM5 (NCEP)

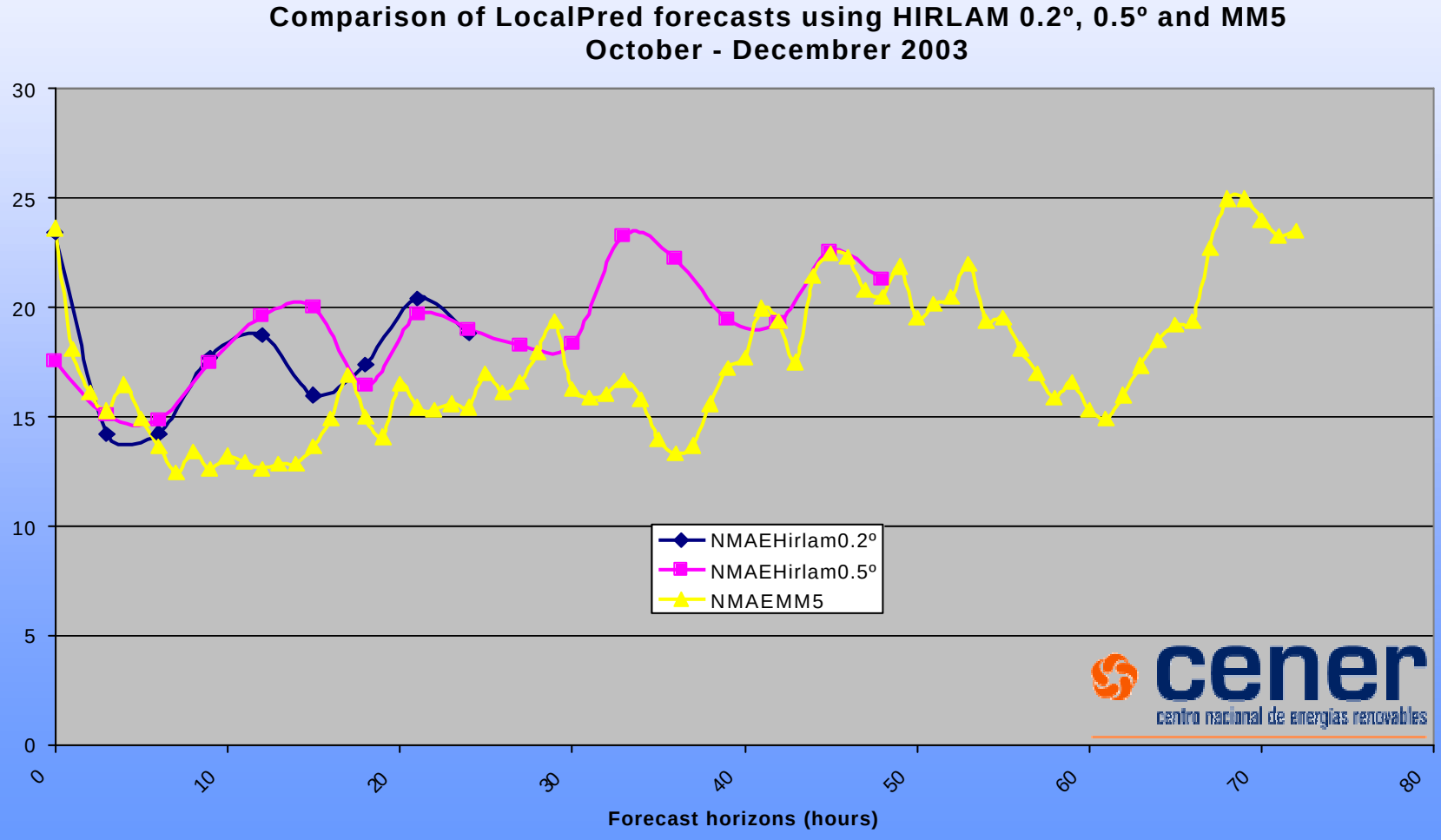
Analysed 4 short periods for Crete:



- The MM5 results always underestimate the actual measurements
- The bias is usually high
- The results of the two parameterizations (MRF, ETA) are very similar
- The MM5 curves are smoother than the measurements (the time step is 6 hours)
- The coefficients of determination are quite low
- The badness of the results can be due to the low quality of the topography input

HIRLAM 0.5, 0.2 and MM5

Comparison of HIRLAM 0.2º+MOS, 0.5º+MOS and MM5(3x3 km)+MOS results

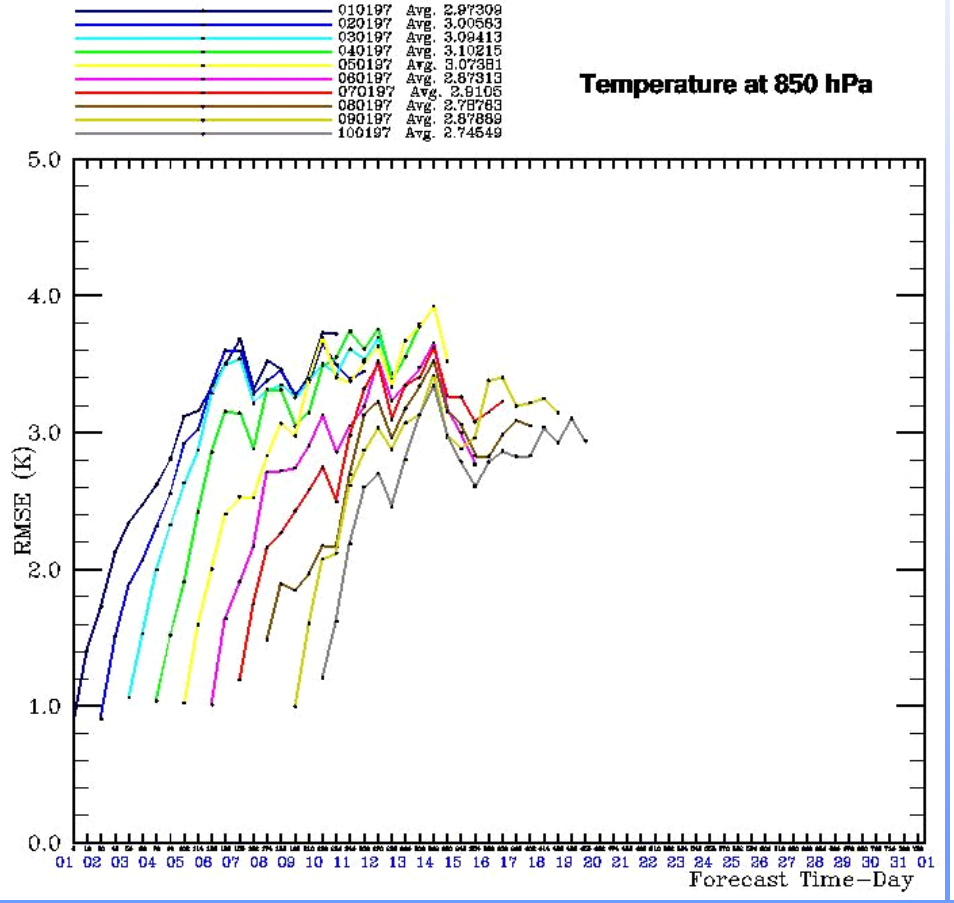


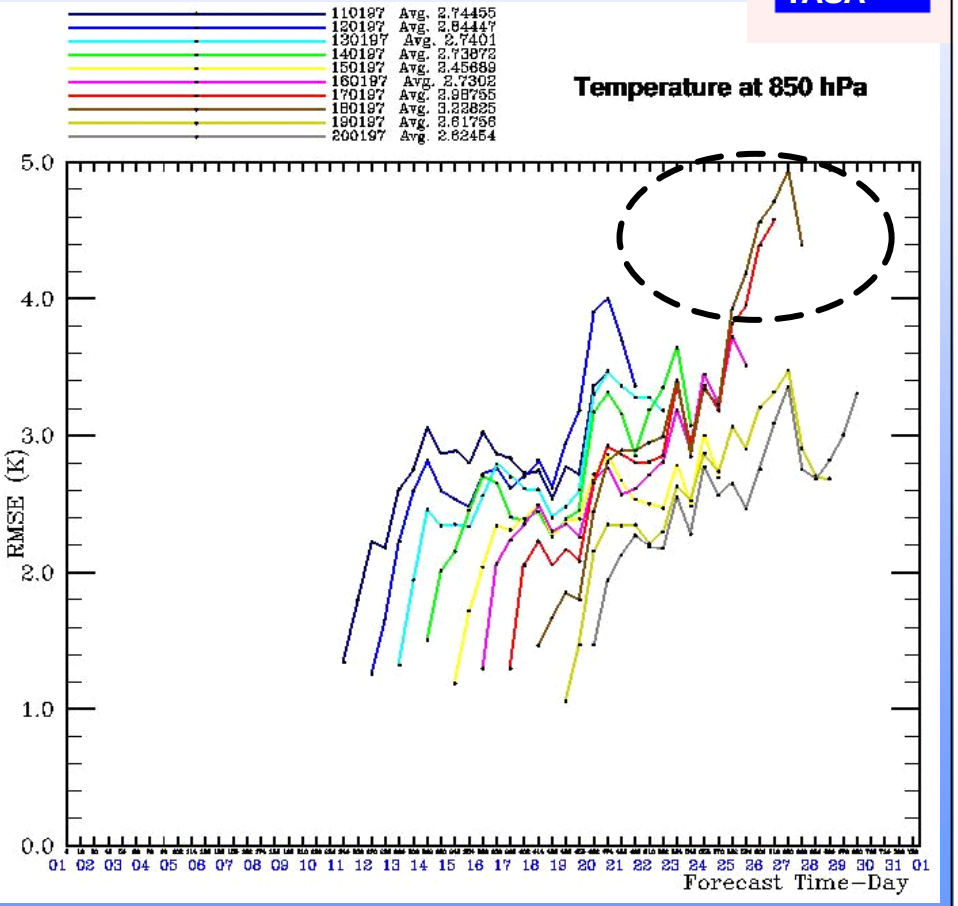
Conclusions MM5 (GFS)

- Selected inner most domain size: 25 x 25 points (best relation between quality and computational time vs 37 and 49 points)
- There is **no improvement** of the wind/power forecasts when comparing **9 km** last grid with **3 km** grid resolutions when run through LocalPred.
- MRF PBL parameterization gave the best results for wind/power forecasts
- The error of the power production forecasts is reduced when increasing the number of vertical levels in the first 100 m.

4.4: Long-Term forecasting

Skiron Long-Term Forecasting skill at 850hPa for various members (long term = 10 days)

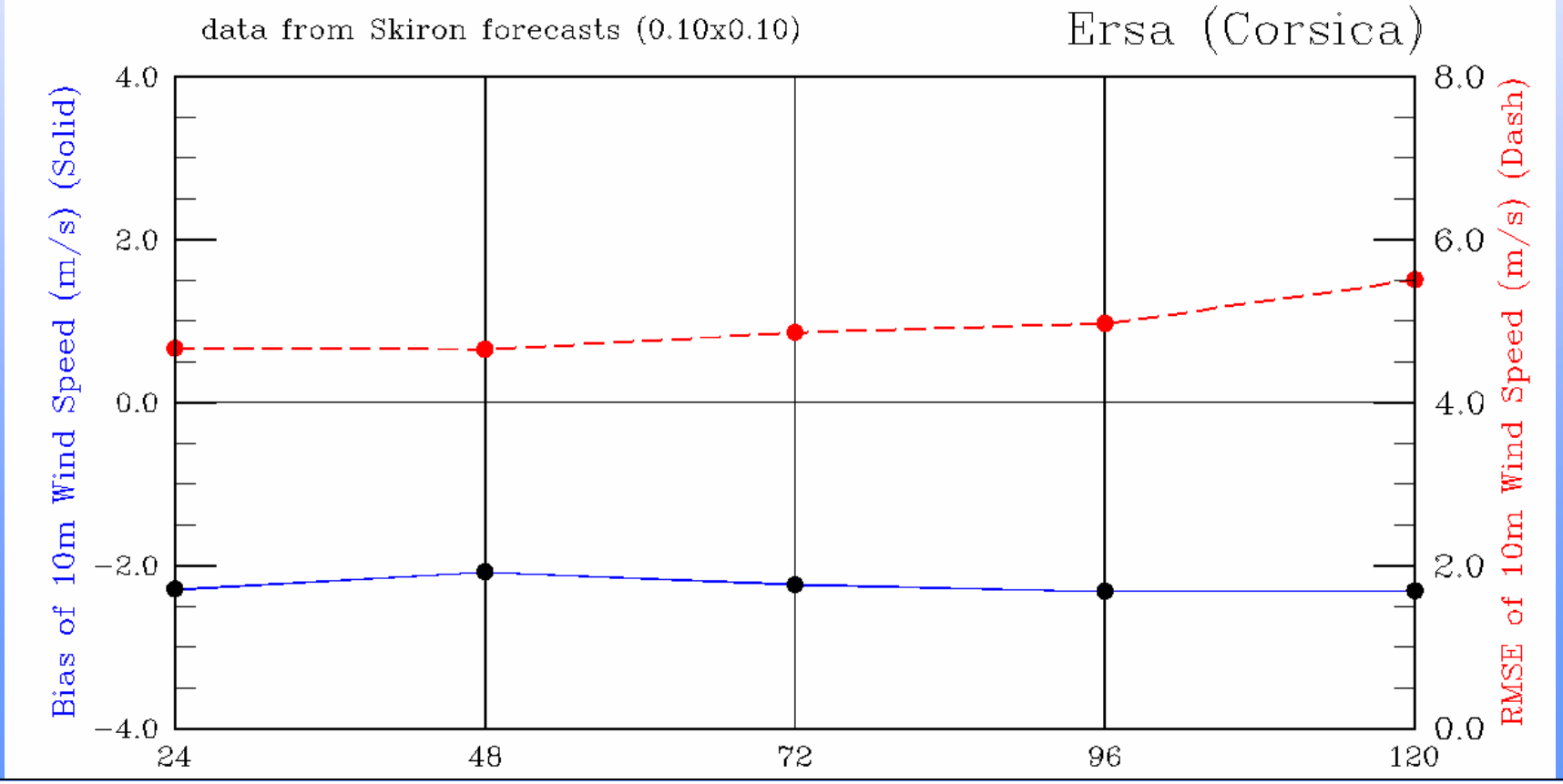




Katsafados P., 2003, Factors and parameterizations that determine the performance of limited area models in long-range forecasts. PhD Thesis, Dept. of Physics, Univ. of Athens, Athens, Greece, pp. 257 (in Greek).

Remarks for long-term forecasting

- **SKIRON run for all Mediterranean for 5 days – compared to Corsica.**
- **(One month study for 10-day forecasting.)**
- **SKIRON forecasting skill remains high even in long term, i.e. after 96 hours of prediction.**



More remarks for long-term forecasting

- **Deviations of SKIRON forecasts from the observations may be attributed to**
  - Comparison between two time series with different spatio-temporal characteristics.
  - Local phenomena, such as up (down) drafts and sea breezes resulted by the complex topography and special landscape features that the model does not resolve with the 10 km × 10 km resolution.
  - Errors in the initial and lateral boundary conditions provided by the global model.
  - Possible uncertainties in observations, such as errors due to instruments, or the location of the monitoring tower with respect to the position of the wind generators.

- ***SKIRON long-term forecasts show satisfactory performance for wind power purposes.***

Summary

- Benchmarking of alternative approaches
- Captured the air flow properties at three sites
- Reduced computation time for CFD model in half
- Optimised MM5 for Spanish situation forecasting use
- Implemented advanced systems for online use

- Calculations need large domains, often multiply nested
- Higher resolution only useful with high-res land database
- ... and reasonably good input (see GFS vs Reanalysis)
- No clear winner for MM5 PBL scheme
  (though MRF seems good)

Conclusions

- More vertical levels near the ground help performance
- Higher horizontal resolution not always better
- Look-up table needs more parameters than MOS to outperform it
- ... but the mesoscale models can give understanding of the important parameters

- Trade-off between higher resolution and computation time
- Not yet clear a priori when high-res modelling is needed
- Difficult to compare point measurements with area average forecasts

Acknowledgement: EU-Anemos (ENK5-CT-2002-0665)