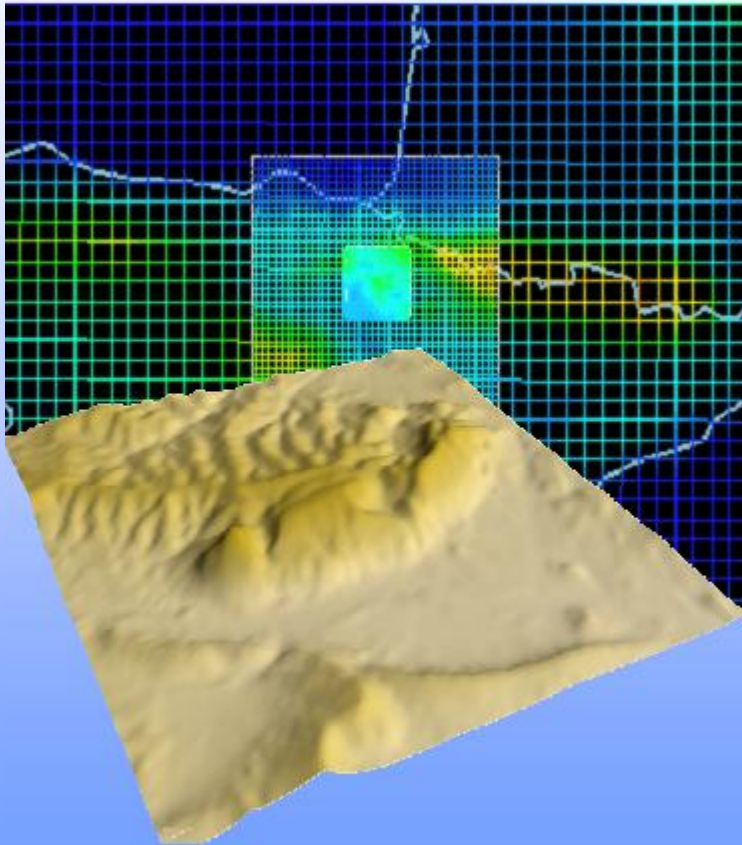




EUROPEAN
COMMISSION

Community research

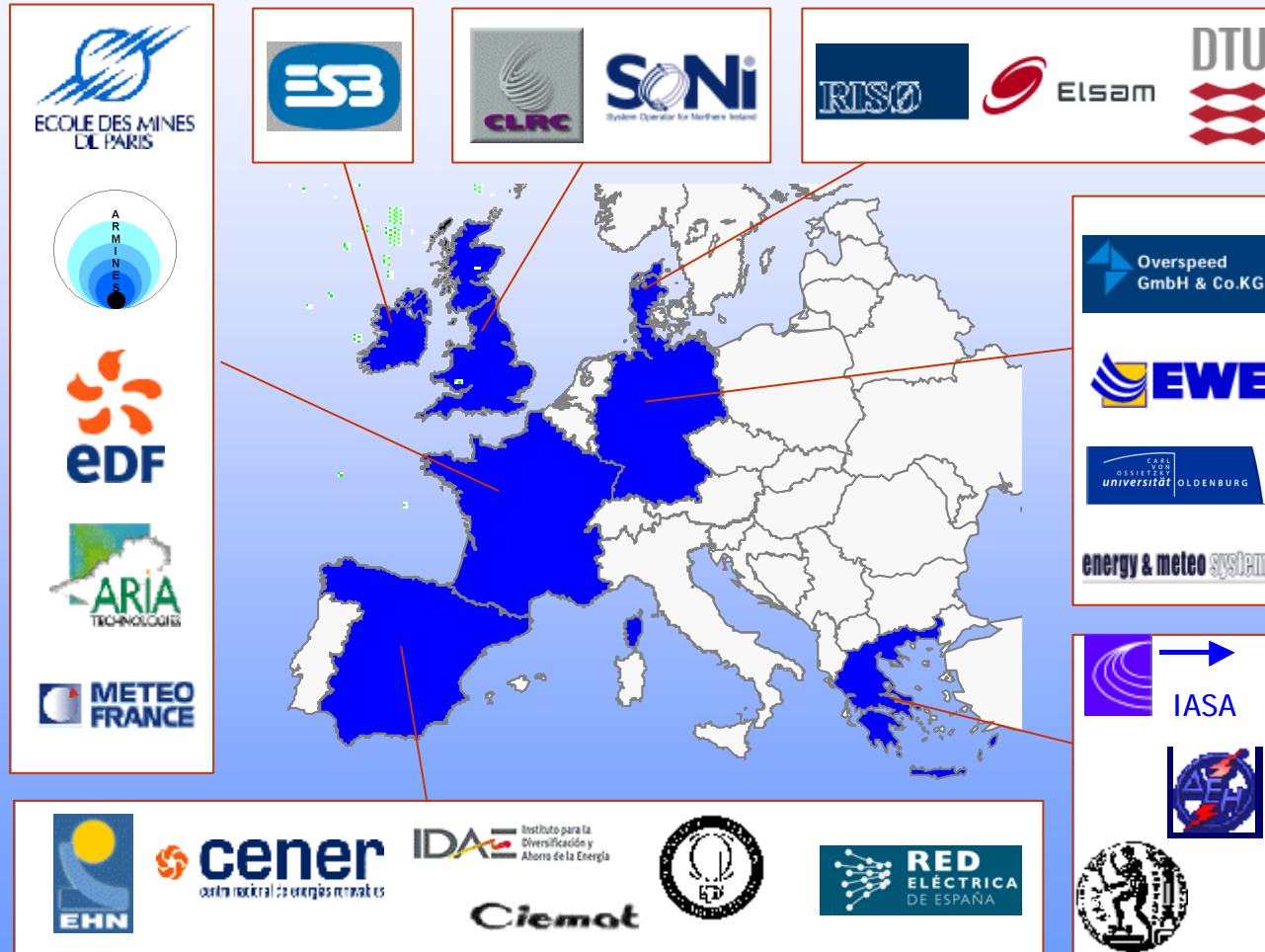


Next Generation Wind Power Forecasting. Overview of the Anemos Project.

George Kariniotakis,
Ecole des Mines de Paris, France
georges.kariniotakis@ensmp.fr

European Wind Energy Conference

Athens, 27 Feb. – 2 Mar. 2006.



2002-2006

**7 countries,
23 partners**

End-users (8)

Industry (3)

Meteorologists (2)

Research (5)

Universities (5)

Coordinator:
Dr. George Kariniotakis,
Ecole des Mines de Paris,
ARMINES,
France.

Ambitious targets for wind energy in the EU* :



(*) European Wind Energy Association

However.....

CHALLENGE ▶ Wind is a highly fluctuating resource.

ANEMOS ▶ **Forecasting** contributes to an **economic** and **secure** large-scale wind integration in a power system.

Ambitious targets for wind energy in the EU* :



(*) European Wind Energy Association

But also...

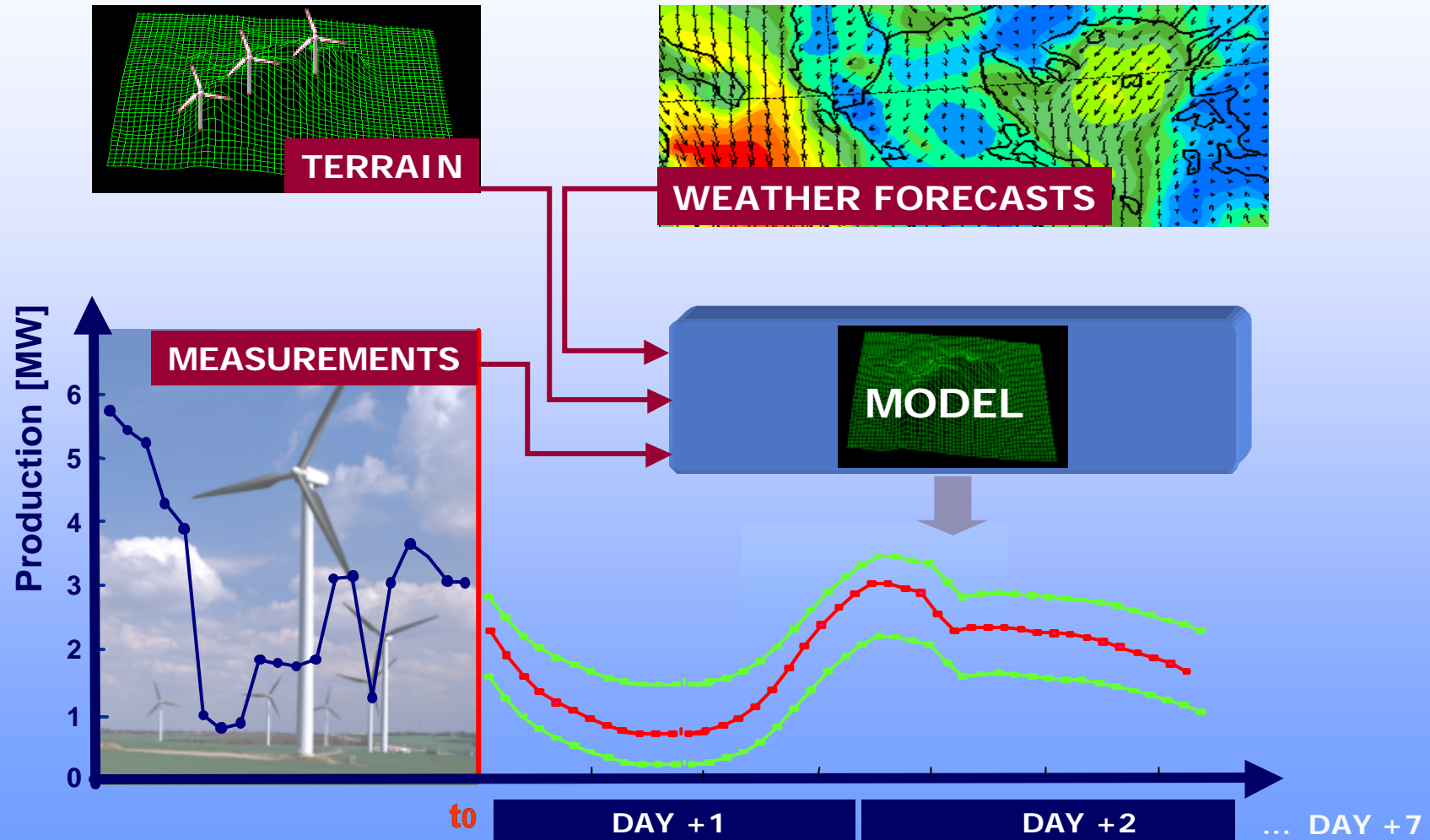
CHALLENGE

Deregulation of electricity markets.

ANEMOS

Forecasting **enhances competitiveness** of wind power compared to other forms of dispatchable generation.

The Principle



- ◆ **Accurate short-term forecasting** of wind parks production up to 2-3 days in advance especially for:
 - complex terrain (not easy to predict...),
 - extreme weather conditions (cut-off risk)
 - offshore (high impact to the grid)

- ◆ **Demonstrate the economic and technical benefits** from the use of wind prediction tools at national, regional or single wind farm level.





R&D Approach



- ◆ **Broad analysis of needs**
- ◆ **Interaction with research in meteorology**
- ◆ **Pre-standardisation**
- ◆ **Benchmarking of 10 state-of-the-art prediction systems plus models developed in Anemos.**

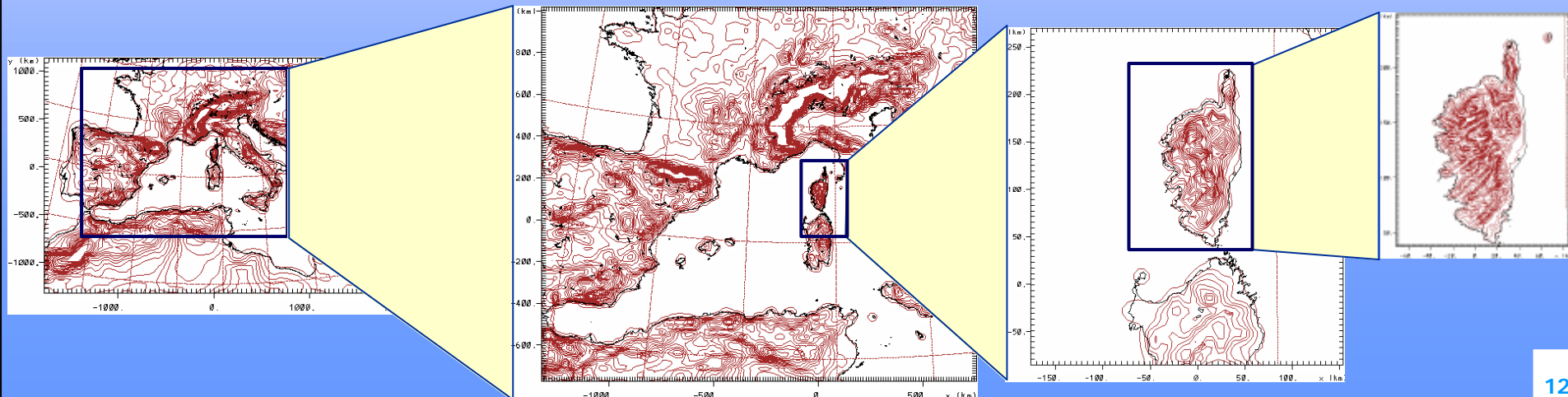
◆ Research on two mainstream approaches:

statistical

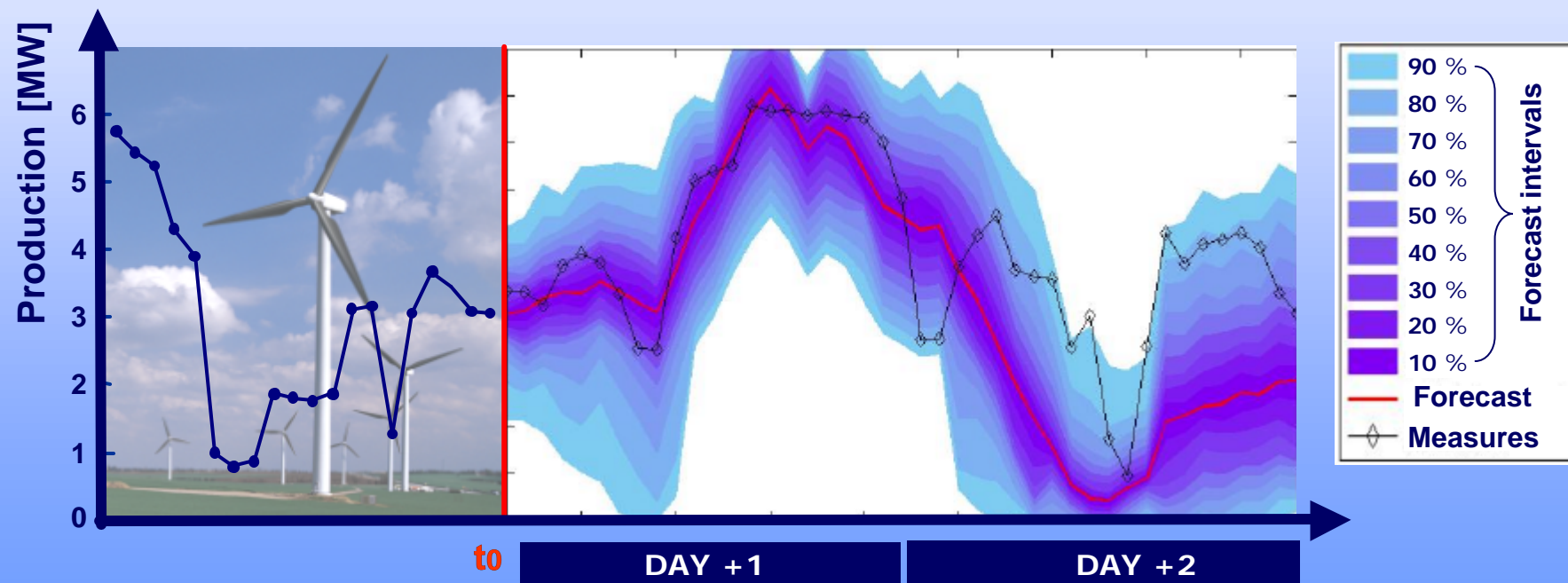
models try to represent the information in the available data
(*i.e.* artificial intelligence techniques)

physical

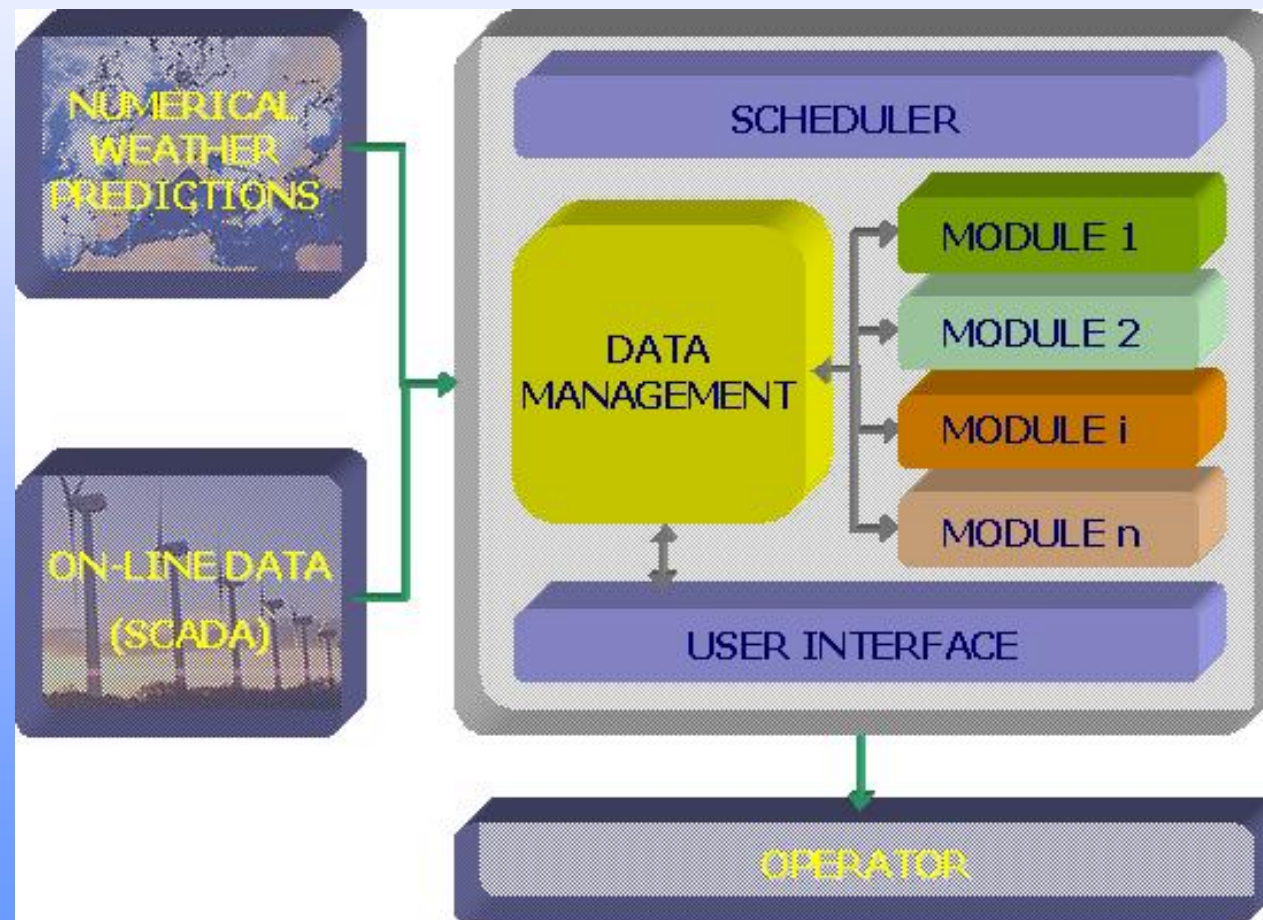
models try to represent the physical laws
(*i.e.* modelling of wind flow on the terrain)



◆ Emphasis on modelling uncertainty in predictions



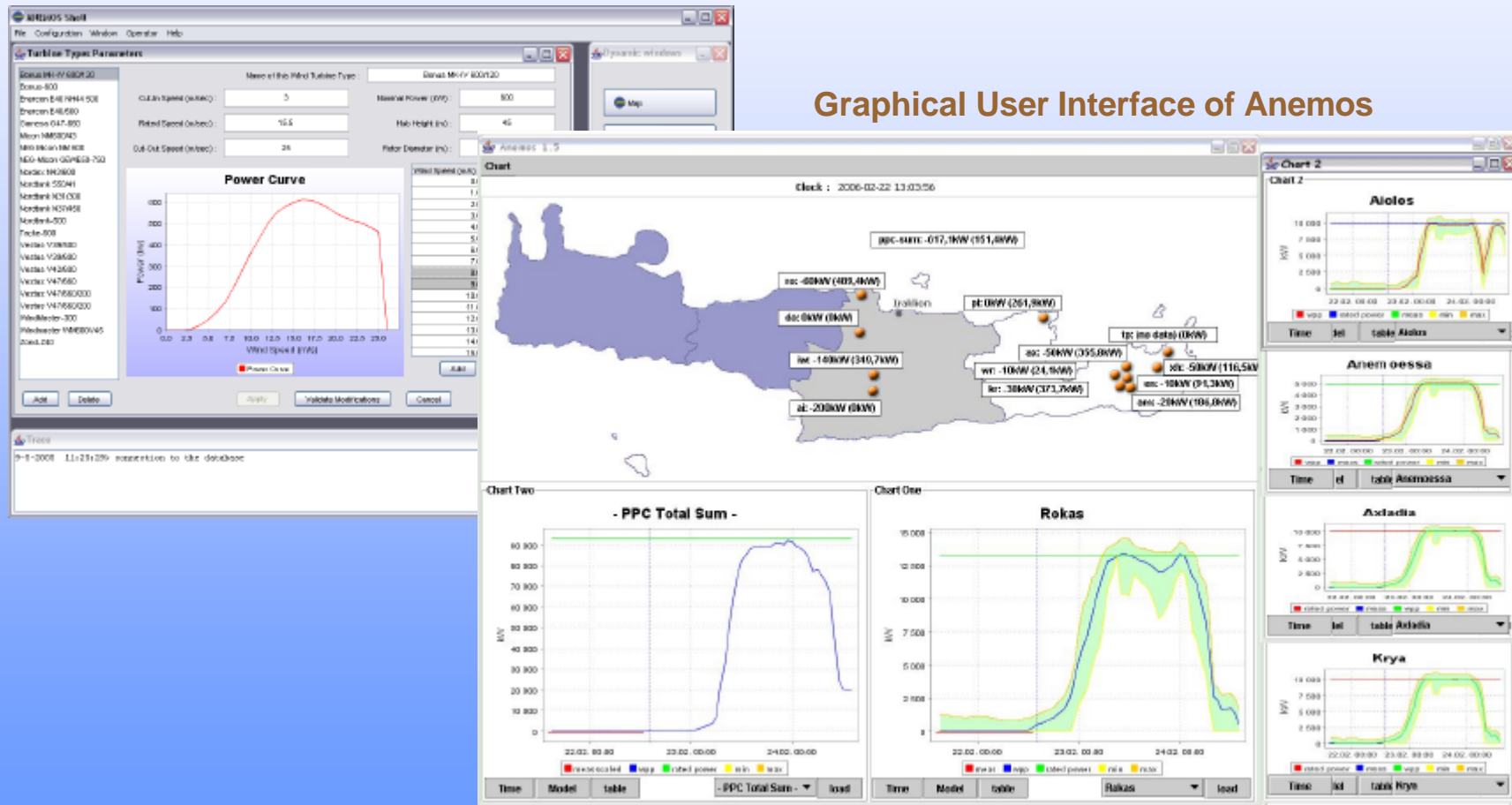
◆ Development of an advanced prediction platform



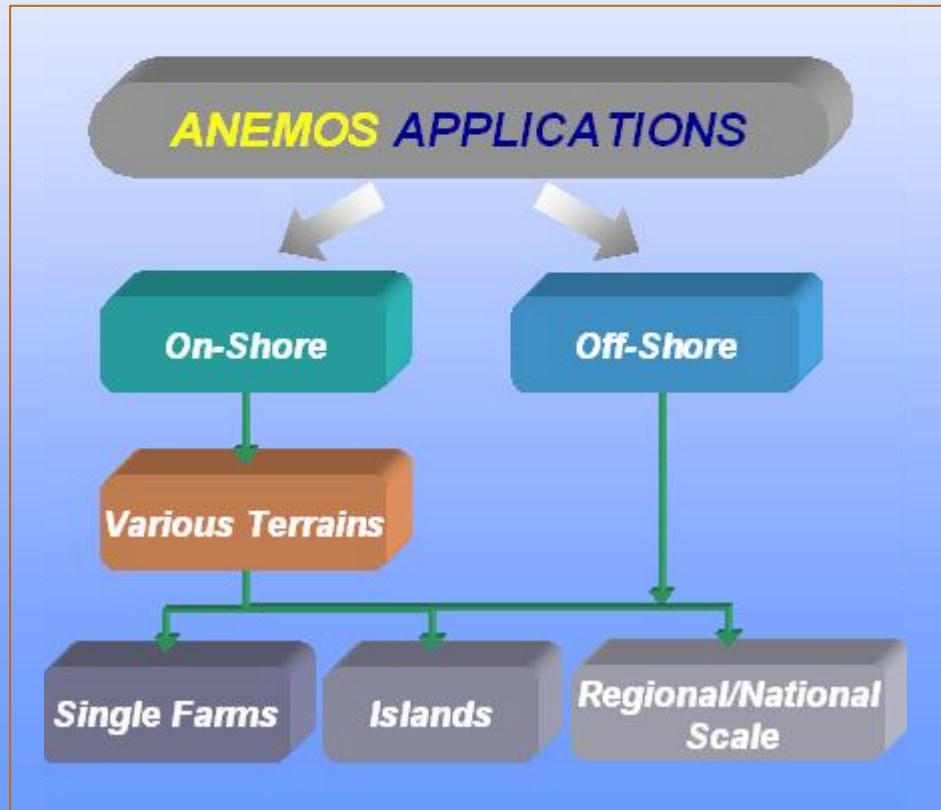
Generic configuration of the platform.

◆ Development of an advanced prediction platform

Graphical User Interface of Anemos



- ◆ Installed in 7 countries for real-time operation.



Denmark



France



Germany



Greece



Ireland



Spain

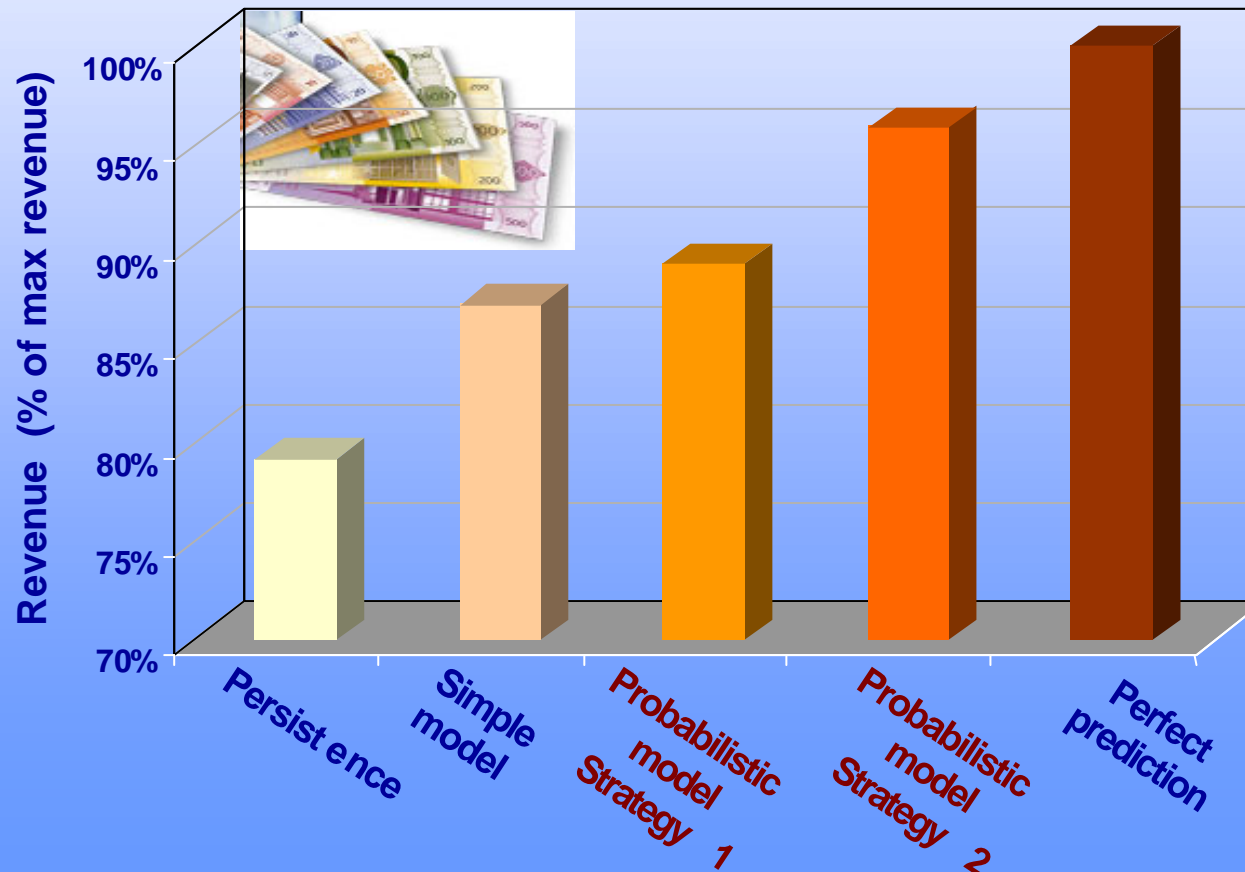


UK



◆ Demonstrate the **value** of wind prediction

- ❖ Trading example: Increase benefits by the use of advanced bidding strategies



- ◆ **Extends technology from :**
 - ❖ **Deterministic forecasting** -> towards probabilistic
 - ❖ **Classic model chain** -> new solutions (combined models, multiple NWP, ensemble predictions)
 - ❖ **Accuracy oriented** -> Accuracy + value
 - ❖ **Research tools** -> standardized pre-industrial tools



Impact of the Project



- ◆ **'Familiarisation'** of end-users with the wind forecasting technology.
- ◆ **Accurate 'mapping'** of the wind forecasting technology useful for developing grid and market regulations.
- ◆ **New actors** in the marketplace that commercialise the tools:
 - ❖ two new spin-off created in DE and DK by partners of ANEMOS
 - ❖ Interest from non-EU countries for the ANEMOS products.
 - ❖ First commercial installation of Anemos agreed.

- ◆ As wind penetration increases, **wind power forecasting** is recognised as a solution for **improving** the **management** of power systems and for **reducing** the **risks** due to variable wind generation in terms of:
 - ❖ security of supply
 - ❖ public acceptability
 - ❖ financial competitiveness } higher confidence in wind energy

- ◆ The ANEMOS project has managed to provide advanced **operational** wind forecasting solutions and demonstrate the benefits from their application.



Dissemination



◆ <http://anemos.cma.fr>

The screenshot displays the ANEMOS project website. The main heading reads: "Development of a Next Generation Wind Resource Forecasting System for the Large-scale Integration of Onshore and Offshore Wind Farms". Below this, it states "Dissemination supported by the European Commission under the 6th Framework Program".

The page is divided into several sections:

- ANEMOS Project:** A brief description of the project's goal to develop accurate models for wind resource forecasting.
- Abstract:** A detailed summary of the project's objectives and the role of the ANEMOS system.
- The Consortium:** A map of Europe with logos of participating organizations such as E.ON, ENEL, and others.
- Dissemination:** A list of events and meetings, including:
 - 18-19 April 2005: 1st Contributors General Meeting in Pamplona, Spain.
 - 26 November 2004: 1st Theme Symposium Meeting in London, UK.
 - 26 Sept. - 01 Oct. 2004: 1st Contributors General Meeting in Paris, France.
 - 27-28 April 2004: 1st Contributors General Meeting in Heraklion, Crete, Greece.
 - 17-19 May 2003: 3rd Contributors General Meeting in Heraklion, Crete, Greece.



Dissemination




◆ <http://anemos.cma.fr>

◆ More than 50 papers

The screenshot shows the ANEMOS website interface. The main content area is titled "Official documents: Publications related to the ANEMOS Project" and lists 18 numbered entries. Each entry includes a title, authors, and a brief description of the publication. The list covers various topics such as model validation, forecasting systems, and wind energy production models.

- [1] Lange, M., et al. "ANEMOS - Vergleich und Verbesserung aneinander europäischer Anemologie softwarepakete - ANEMOS - Comparison and improvement of existing European Wind power production models", Proceedings of the 2002 DENK Conference, Warszawa, Poland, October 23-24, 2002.
- [2] Kariniotakis, G., et al. "ANEMOS: Development of a next generation wind power forecasting system for the large-scale integration of onshore & offshore wind farms", Proceedings of the IEEE-BUS 2002 assembly, 08-11 April 2002, Nice, France, Vol. 5, 1998.
- [3] Mads, H., Lange, M., Focken, U. "Special Group Concerning Wind Power Prediction for Offshore Wind Farms", Proceedings of the European Science Officers Wind Energy in Mediterranean and other European Seas (OWEES), Mainz, Thun, April 12-13, 2003. [Download presentation]
- [4] Kariniotakis, G., et al. "ANEMOS: Development of a Next Generation Wind Power Forecasting System for the Large-Scale Integration of Onshore & Offshore Wind Farms", CD-Rom Proceedings of the European Wind Energy Conference & Exhibition EWEC 2003, Madrid, Spain, June 16-19, 2003.
- [5] Diebel, G., Landberg, L., Kariniotakis, G., Brannstrom, R. "Short-Term Wind Power Prediction: A Tool for Short-Term Operation of Wind Energy Production", CD-Rom Proceedings of the European Wind Energy Conference & Exhibition EWEC 2003, Madrid, Spain, June 16-19, 2003.
- [6] Lange, M., Heisenmann, D. "Testing the consistency of short-term wind speed predictions to meteorological situations with methods from synoptic climatology", CD-Rom Proceedings of the European Wind Energy Conference & Exhibition EWEC 2003, Madrid, Spain, June 16-19, 2003.
- [7] Pinson, P., Neubert, N., Kariniotakis, G. "Forecasting of regional wind direction by a Dynamic Fuzzy Neural Network Based Modeling Approach", CD-Rom Proceedings of the European Wind Energy Conference & Exhibition EWEC 2003, Madrid, Spain, June 16-19, 2003.
- [8] Barquero, R. E. "The relevance of efficient wind power production prediction: Anemol project. Contribution to the 2004", CD-Rom Proceedings of the European Wind Energy Conference & Exhibition EWEC 2003, Madrid, Spain, June 16-19, 2003.
- [9] Pinson, P., Kariniotakis, G. "On-line Assessment of Prediction Reliability for Wind Power Production Forecasting", CD-Rom Proceedings of the European Wind Energy Conference & Exhibition EWEC 2003, Madrid, Spain, June 16-19, 2003.
- [10] Hameiri, J., et al. "Using the NMS model for wind prediction in a complex terrain area", CD-Rom Proceedings of the European Wind Energy Conference & Exhibition EWEC 2003, Madrid, Spain, June 16-19, 2003.
- [11] Terekhov, S., Focken, U., Lange, M., Heisenmann, D. "Predictive model for short-term wind power prediction: application to offshore sites", CD-Rom Proceedings of the European Wind Energy Conference & Exhibition EWEC 2003, Madrid, Spain, June 16-19, 2003.
- [12] Mads, H., et al. "Localised and regionalised, advanced tools for wind energy Short-term Wind Power Prediction Models Depending on the Characteristics", CD-Rom proceedings of the European Wind Energy Conference EWEC 2004, London, UK, 22-25 Nov. 2004.
- [13] Kariniotakis, G., et al. "Short-term Wind Power Prediction Models Depending on the Characteristics", CD-Rom proceedings of the European Wind Energy Conference EWEC 2004, London, UK, 22-25 Nov. 2004.
- [14] Pinson, P., Chevalier, C., Kariniotakis, G. "Optimizing benefits from wind power production in electricity markets using wind power forecasting: Enabled with Uncertainty Management Tools", paper accepted for publication at the European Wind Energy Conference EWEC 2004, London, UK, 22-25 Nov. 2004.
- [15] Bartholinis, R. J., Pryor, S. L. "Challenges in predicting power output from offshore wind farms", Journal of Energy Engineering on Sustainable Energy Systems (submitted), 2004.
- [16] Tamhke, J., Lange, M., Focken, U. "Forecasting Offshore Wind Speeds above the North Sea", Wind Energy Journal, vol. 8, pp. 3-16, Jan-Mar. 2005.
- [17] Skaerke, S. "Recursive estimation of dynamic models using GMM's algorithm, with application to wind energy Anemol", Technical report, in press (2005).
- [18] Skaerke, S. "Short-term prediction of wind energy production", International Journal of Forecasting, in press (2005).

- ◆ <http://anemos.cma.fr>
- ◆ More than 50 papers
- ◆ Highlights



Wind power predictions using advanced high-resolution meteorological models

Highlight results








- Benchmarking of alternative approaches
- Captured the air flow properties at three test sites
- Reduced computation time for CFD model by half
- Implemented advanced systems for online use

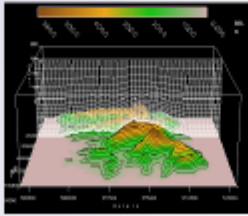
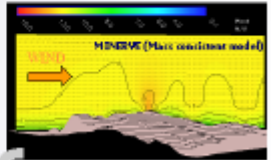
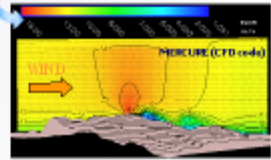
Next Generation Forecasting of Onshore & Offshore Wind Farms Production

Background:
Short-term forecasting of wind power is an established discipline of power system management by now. With small installed capacities and the easy sites of Denmark and northern Germany, wind power forecasting based on Numerical Weather Prediction (NWP) worked well. However, in recent times, forecasting was made more difficult by the use of more complex sites in mountainous terrain and different thermal stabilities. While local NWP models take some of these effects into account, they still are not good enough to model complex terrain in sufficient enough detail. One standard answer to that problem is the use of adaptive statistical models. However, not always can the statistical models have enough data to be trained, or pick out the peculiarities of a special site.

Interesting on the NWP model:
The solution comes in the form of high-resolution, advanced numerical flow models to try to improve on the NWP models shortcomings. These models can be linear flow models like Riso's WAsP, or AIAWind, meso-scale models like the well-known WAs community model, MeteoFrance's MesosM or IASA's RAMS model, or full-blown CFD models (Computational Fluid Dynamics) like Fluent or Mercury. The idea of all models is the same: use higher resolution calculation and input data bases plus a more complete physics descriptions than the NWP model to try to capture the local air flows, be it in the mountains or at a land-sea border. While NWP models typically have a horizontal resolution of 5-10km, the meso-scale models employed here can go down to 500m. This corresponds to time steps of 2 seconds!

Result realised by:

Copies terrain data to Corsica, France: visualization of the wind flow using the CFD-based Mercury model. To give CPU time, the model is reduced by the output of the meso-scale MINEVE model. Local atmospheric flow behavior effect of the mountains are better modelled by the higher resolution CFD model.

- ◆ <http://anemos.cma.fr>
- ◆ More than 50 papers
- ◆ Highlights
- ◆ EES-UETP Course
19-21/6/06
- ◆ End-users workshop:
(tentative: 7/9/2006)
- ◆ EU Project POW'WOW (CA)

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- Captured the air flow properties at three test sites
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Improving on the NWP model:
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Complex terrain used here is Corsica, France: MesosM is the wind flow using the CFD-based Mercury model. To give CPU time, the model is reduced by the output of the more economical MesosM model. Local atmospheric like offshore effect of the mountains are better modelled by the higher resolution CFD model.

MesosM (Mesoscale model)

Mercury (CFD model)

Result realised by:

The future of wind is...
in the forecast