Conference: "The role of market design for the achievement of the 20% Renewables Target", Brussels, 10.06.2010.

The uncertainty of wind output – how it declines during the day.

State of the art and research priorities in wind power forecasting

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ARMINES

MINES ParisTech

Outline

1. Introduction

2. General principles of wind power forecasting

3. Typical accuracy of state of the art models

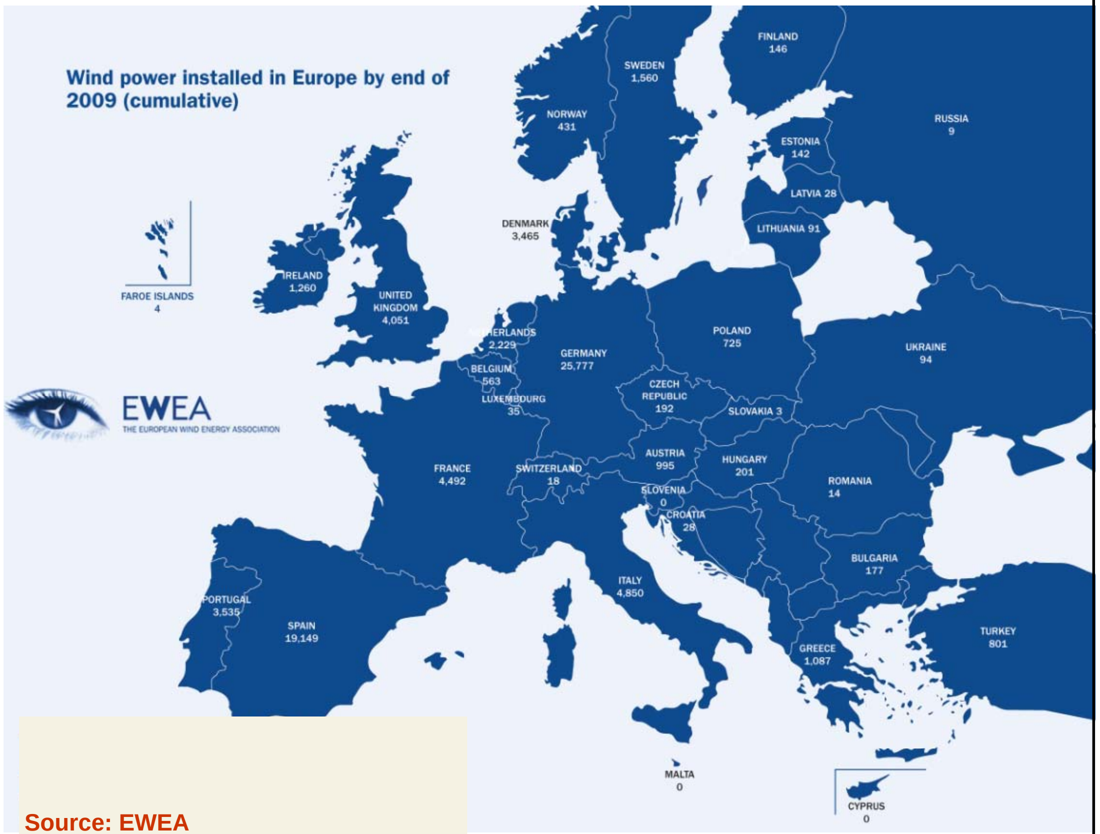
4. R&D projects & priorities

Introduction

2002 **20 GW**

2010 **74.7 GW**

2020 **230 GW (!!)**



Source: EWEA

Challenges

- **Reliable large-scale integration**
- **Economic and secure management of a power system**
- **Competitiveness of wind energy in a liberalised electricity market**

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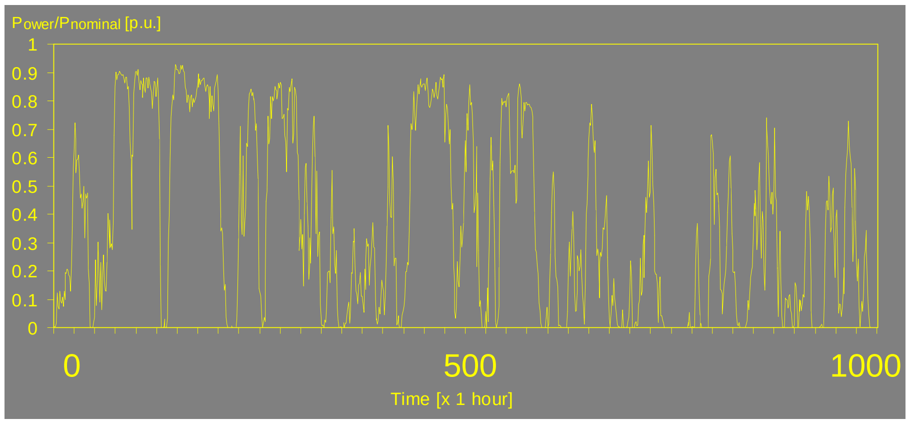
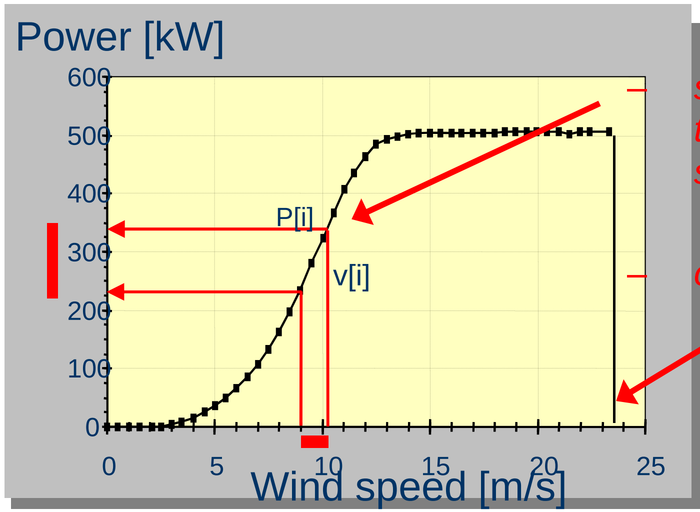
Introduction

- **Wind power forecasting** for the next minutes to days is recognised today as a necessary tool for 'smooth' wind integration
- However, forecasting wind power is a complex problem. Some of the reasons…

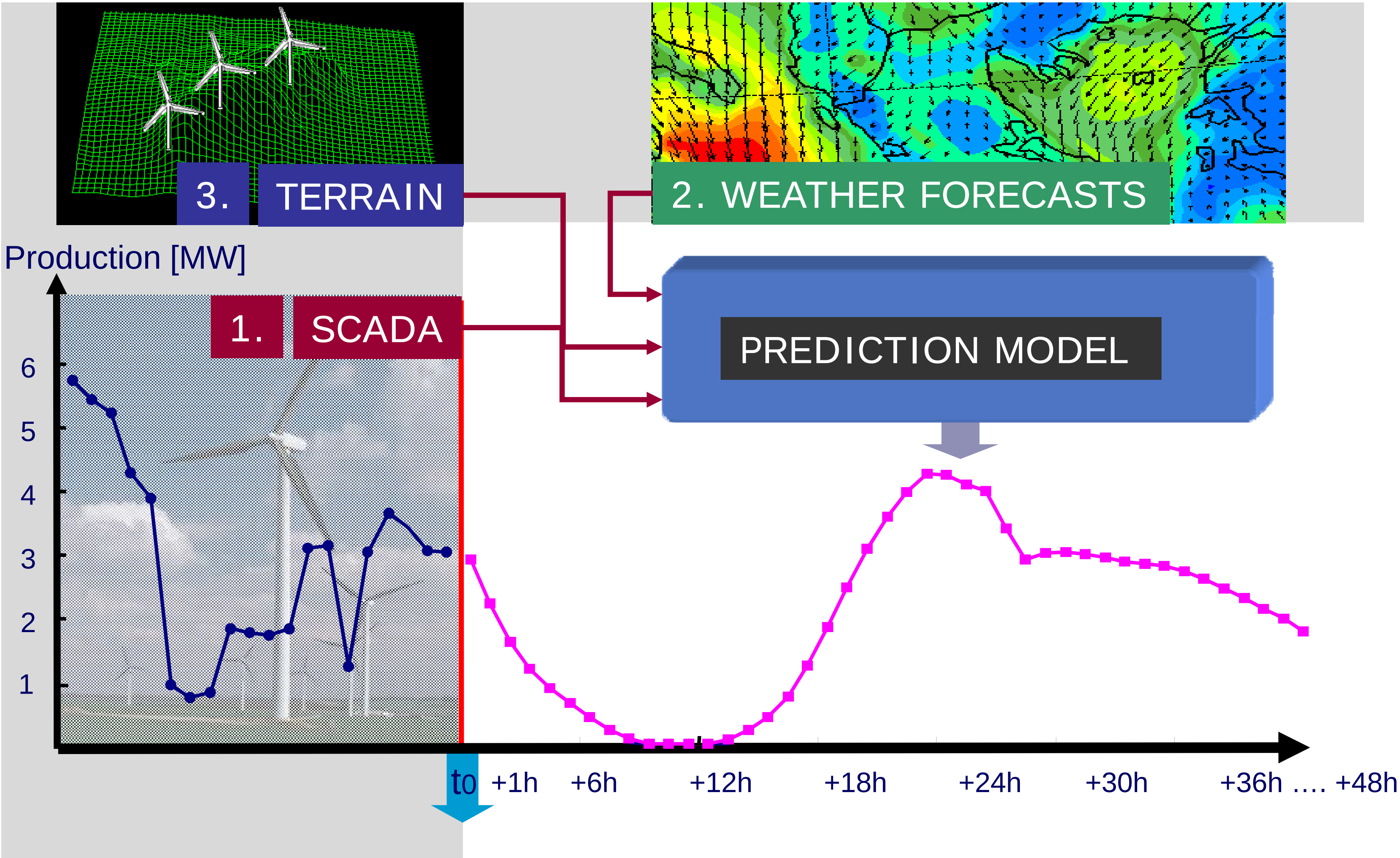


Wind is highly variable by nature… (example: wind production of a wind farm during a month)

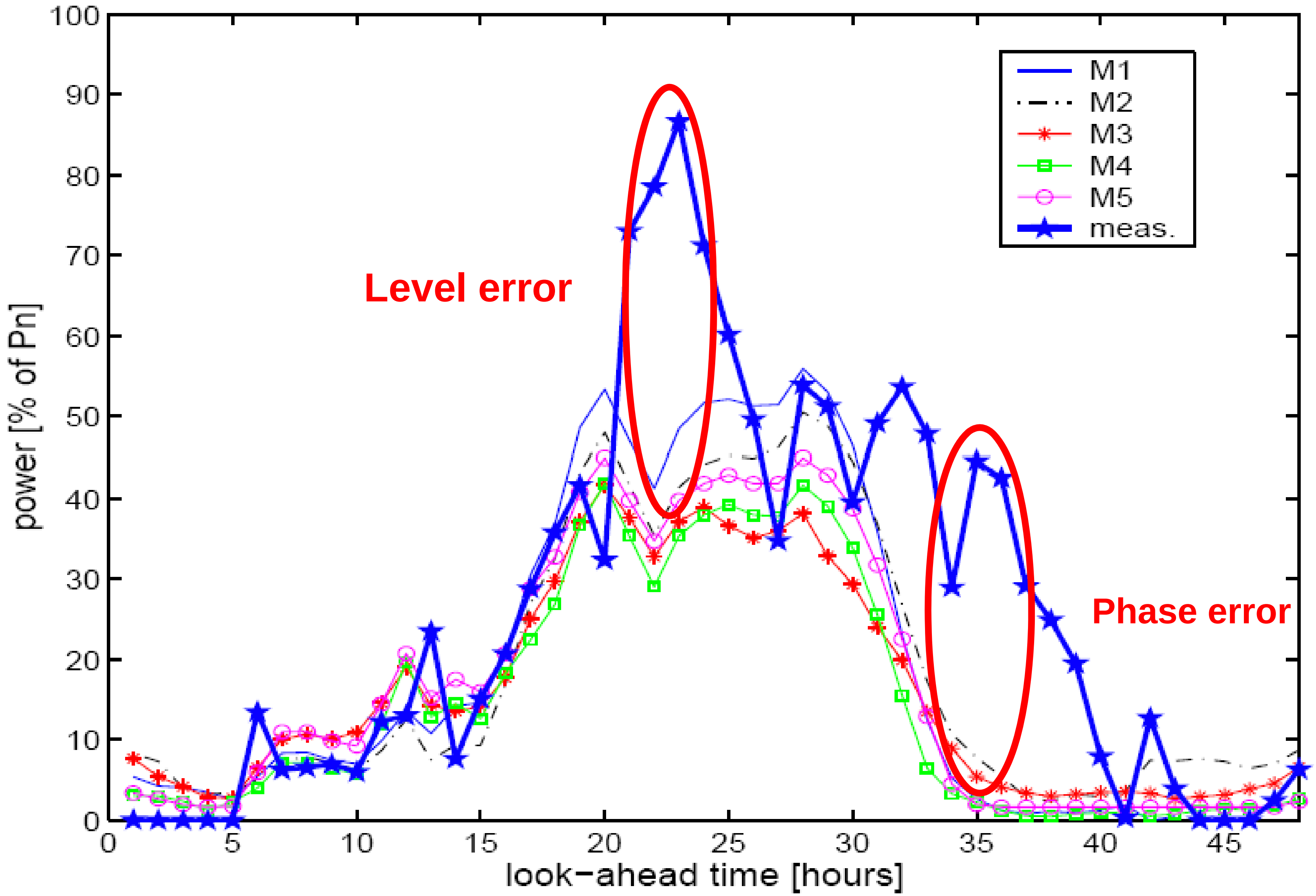


The wind turbine characteristic curve introduces important non-linearities.

The principle



Types of forecast errors



M1-M5: wind power predictions by statistical and physicam models

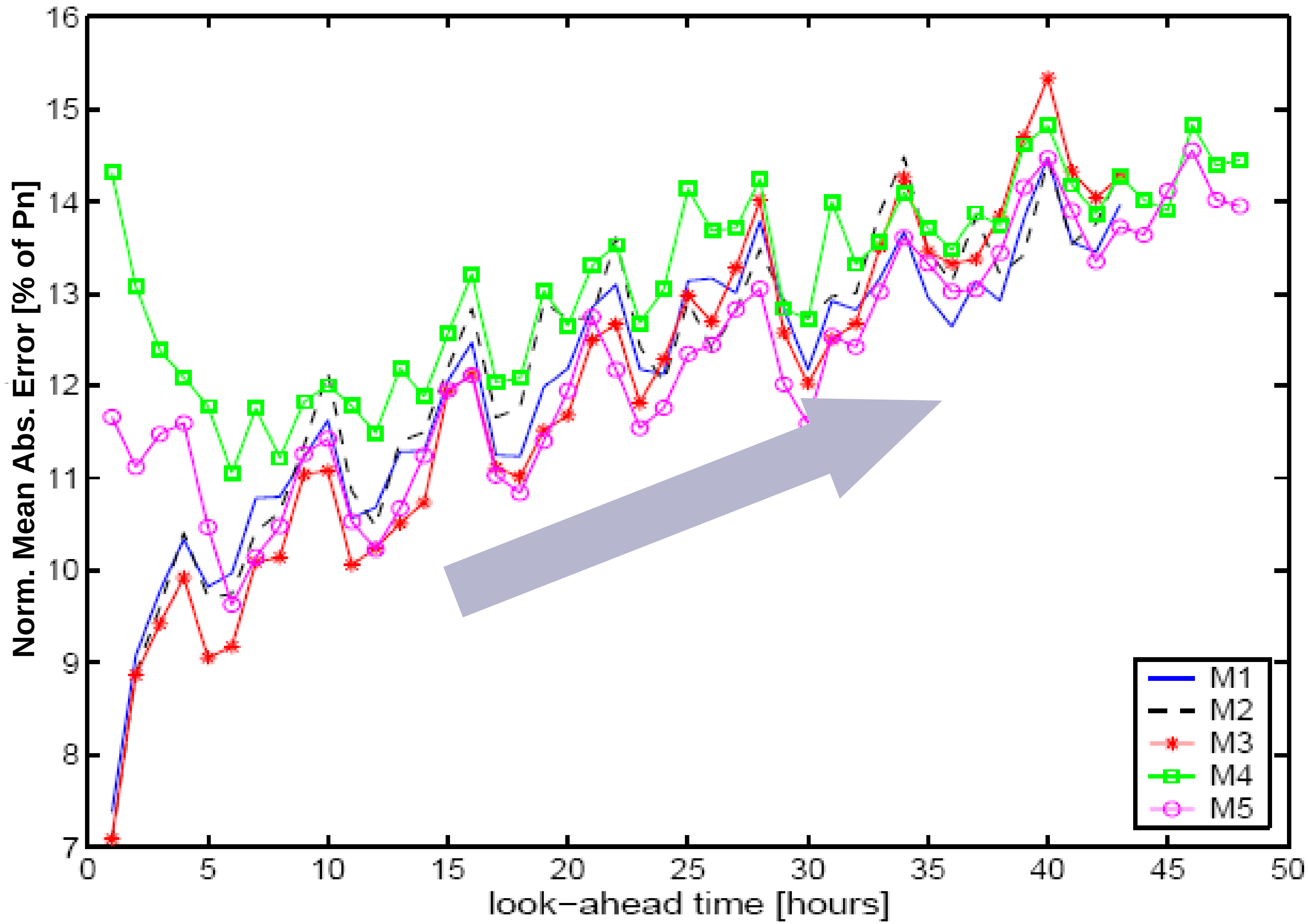
Factors affecting accuracy

- ✓ Prediction horizon
- ✓ Time of the year (climatic conditions)
- ✓ Terrain complexity
- ✓ Types of inputs/types of models
- ✓ Spatial smoothing effect
- ✓ Level of predicted power and speed
- ✓ ….

Factors affecting accuracy: Prediction horizon

Average error increases with horizon

Case Study: wind farm in Ireland

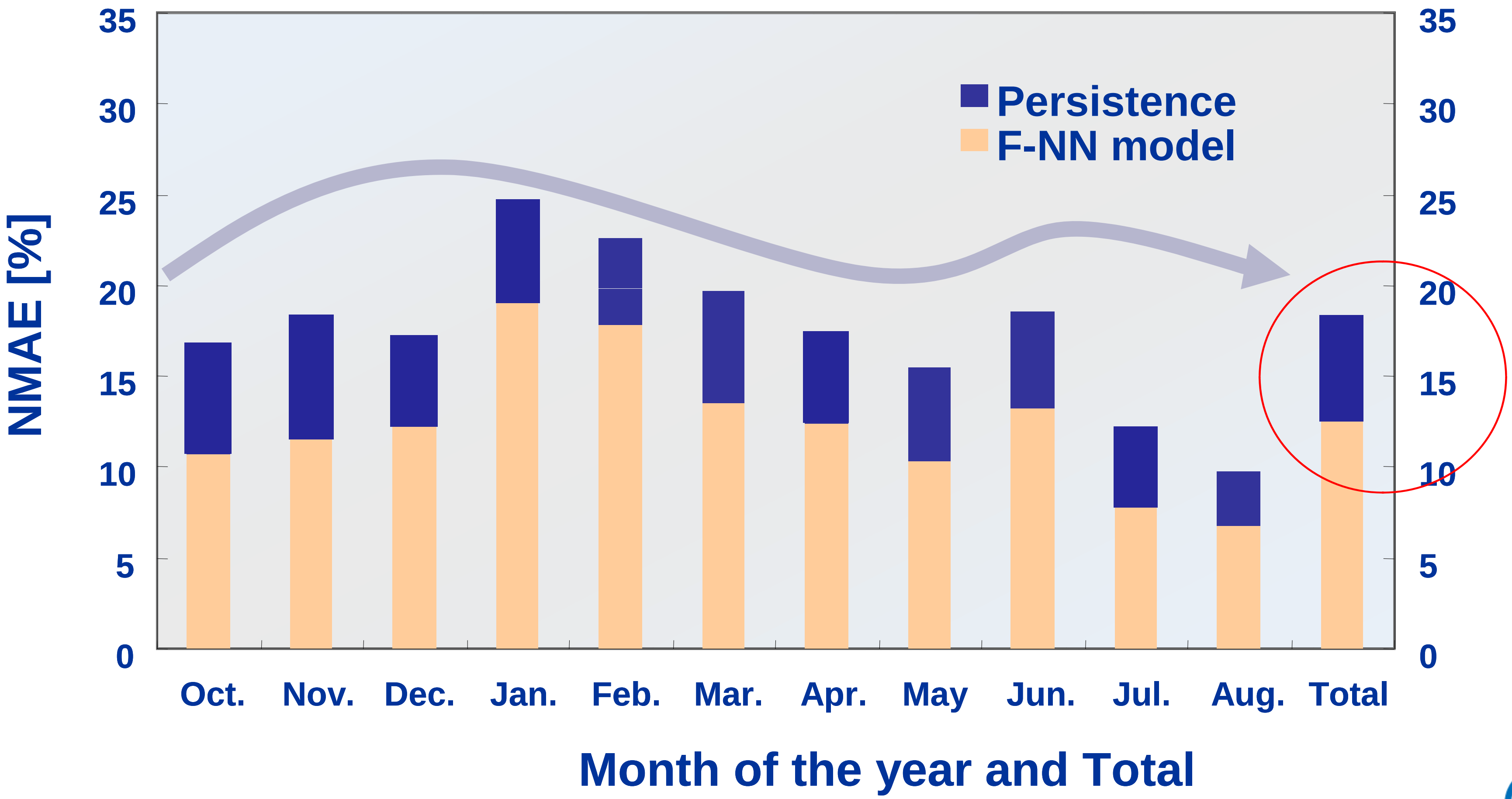


Comparison of 3 statistical (M1-M3) and 2 physical (M4-M5) models

Factors affecting accuracy: Time of the year

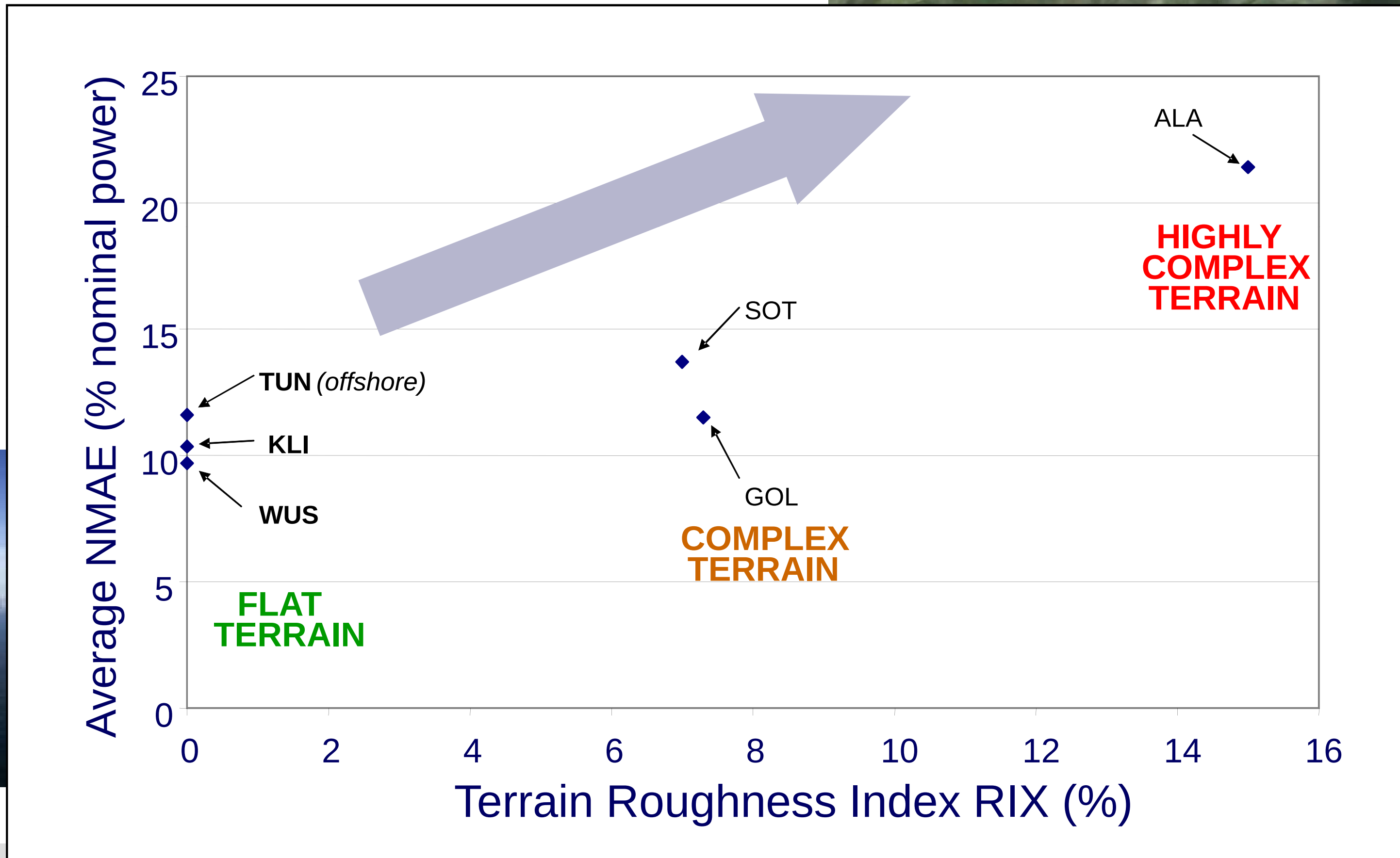
- Error varies throughout the year

Case Study: wind farm in Ireland



Factors affecting accuracy : Terrain complexity

- Error increases with terrain complexity



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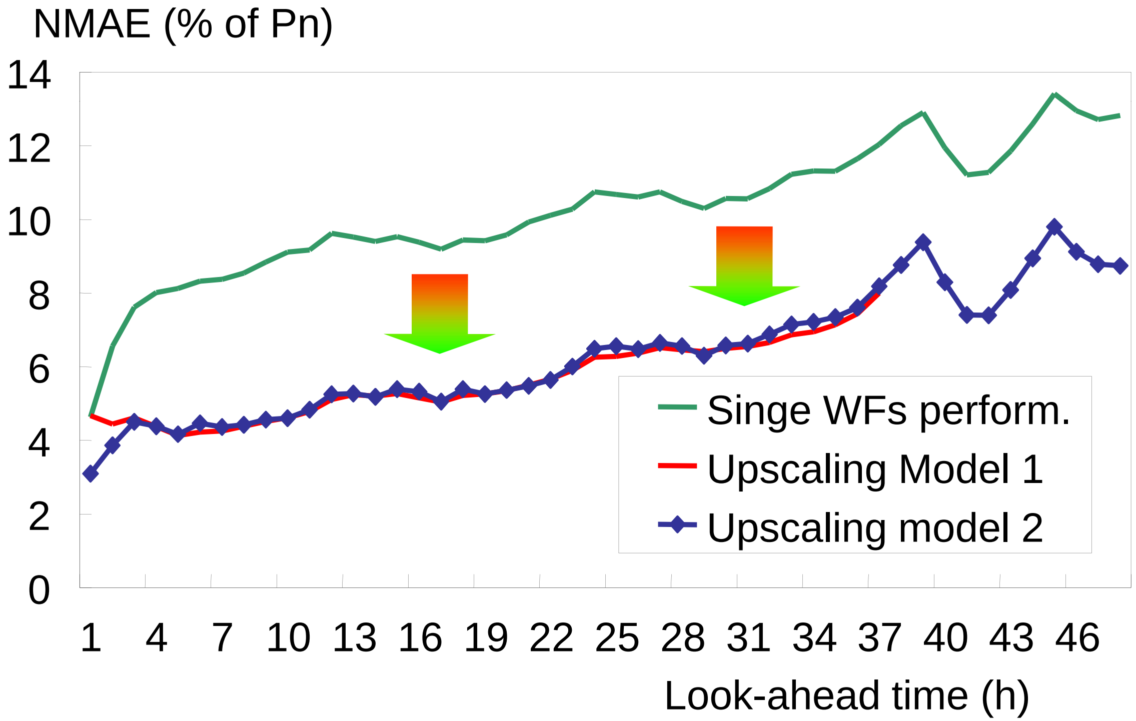
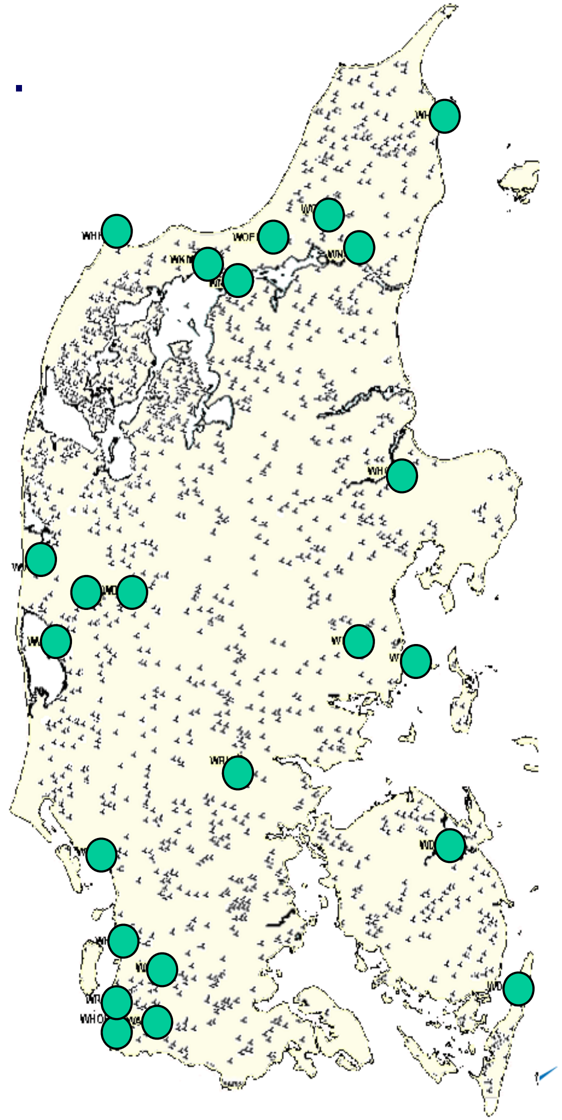
Factors affecting accuracy: Spatial smoothing effect

Example :

Prediction of 2200 MW in Jutland area in DK

- SCADA measurements only from 23 WFs (~200 MW) .
- Differenced measurements of the total production.
- Prediction of 23 WFs output
- Then upscale to the total area.





Typical performance

Case Study: wind farm in Ireland

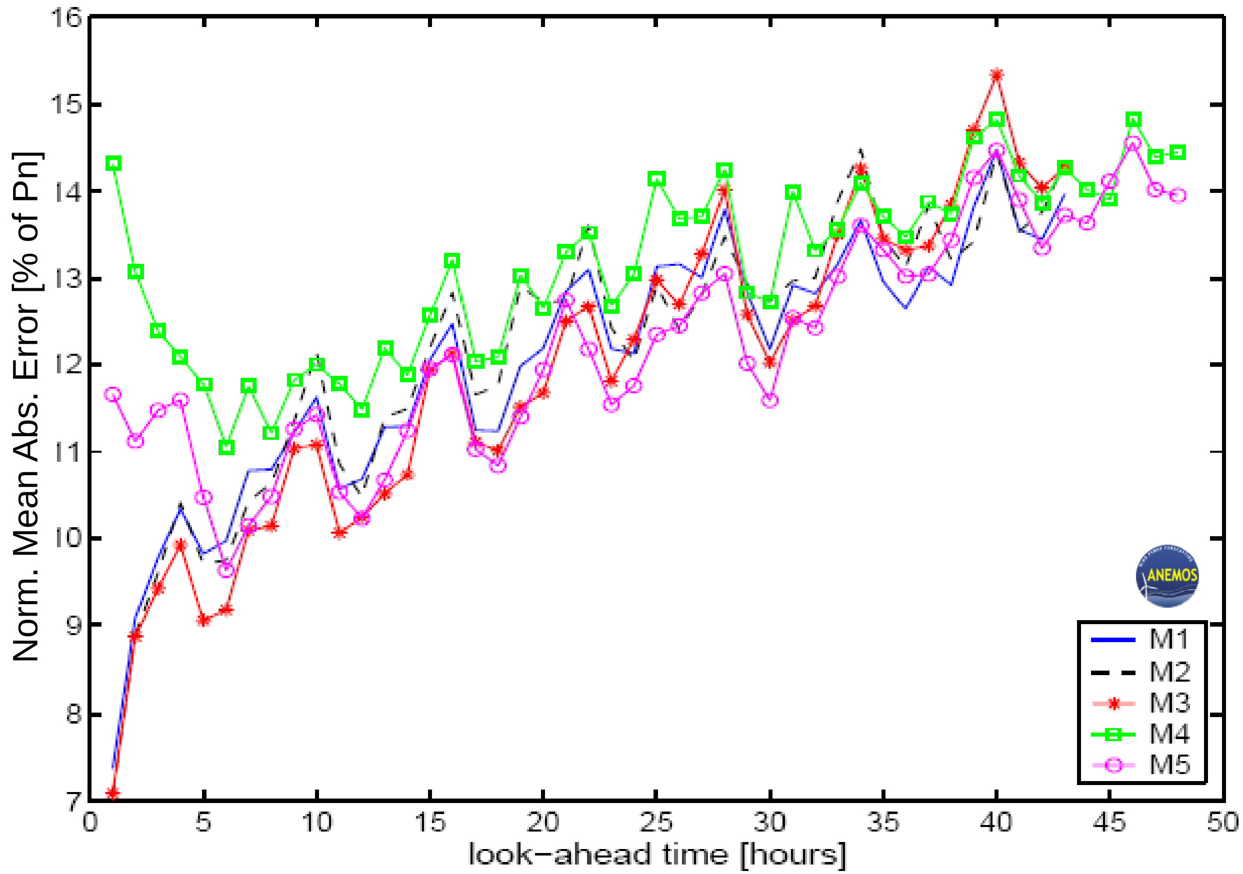
MEASURE :

- Normalised Mean Absolute Error (NMAE)

TYPICAL VALUES :

- 4% -18% for a single wind farm in complex terrain.

Comparison of 3 statistical (M1-M3) and 2 physical (M4-M5) models



- Much lower error for regional/national forecasting due to spatial smoothing effect for horizons >4-6 hours. ~5-10% for 24-48 hours.

Outline

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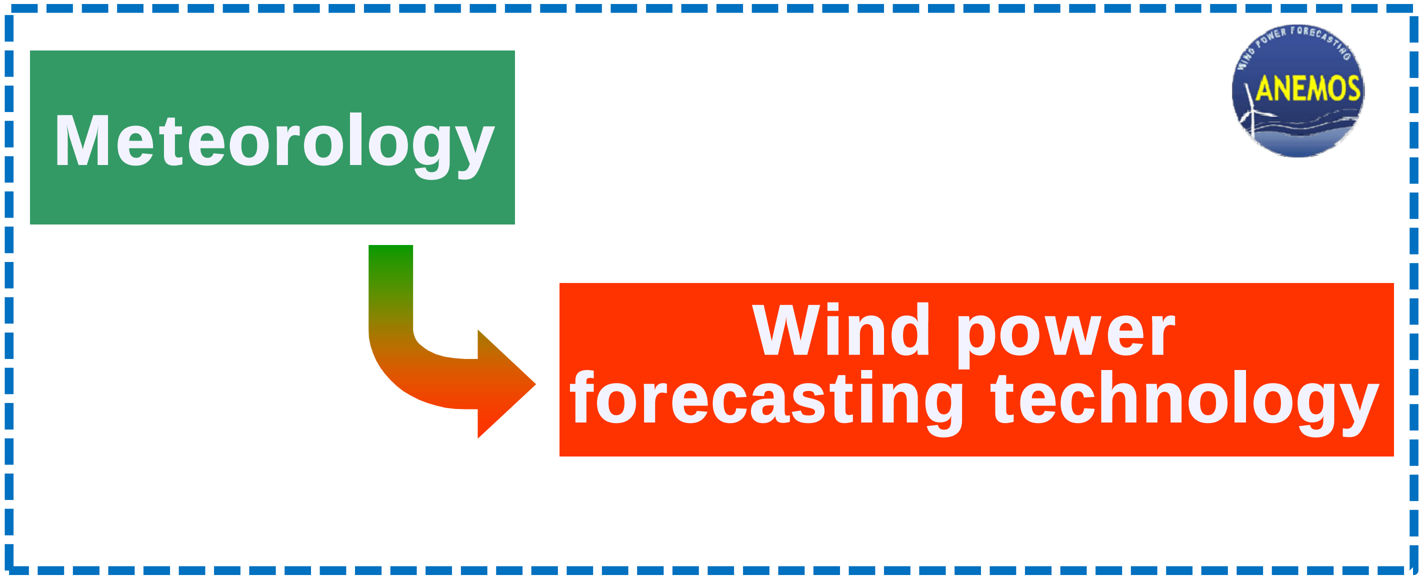
4. **R&D projects & priorities**

Context – Research in Wind Power Forecasting

- Considerable research carried out in the last 20 years

HIGHLIGHT PROJECTS :

ANEMOS : FP5, 2002-2006



Context – Research in Wind Power Forecasting

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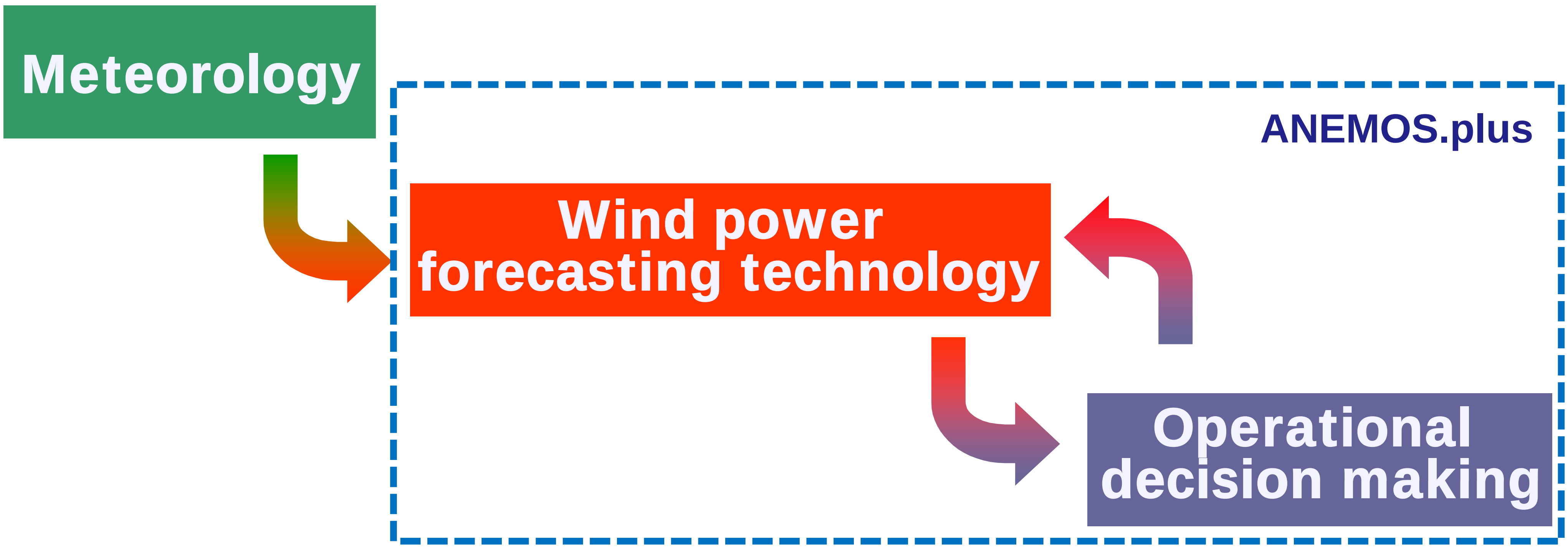
HIGHLIGHT PROJECTS :

ANEMOS : FP5, 2002-2006

ANEMOS.plus : FP6, 2008-2011



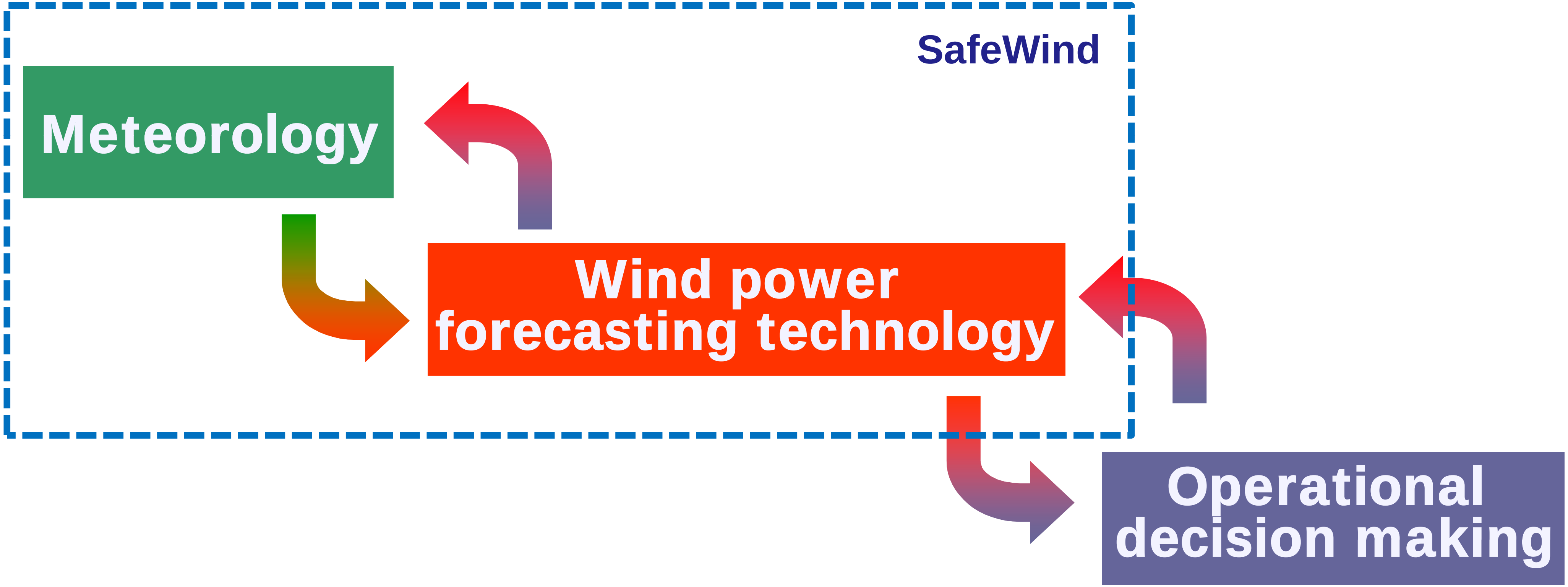
Context – Research in Wind Power Forecasting

- Considerable research carried out in the last 20 years

HIGHLIGHT PROJECTS :

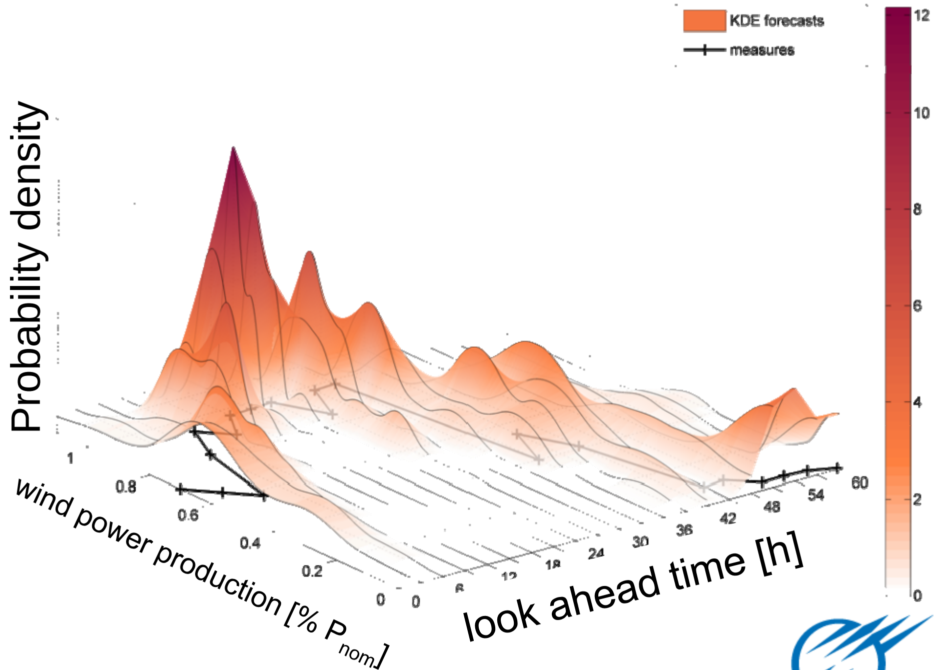
ANEMOS : FP5, 2002-2006 **SafeWind :** FP7, 2008-2012

ANEMOS.plus : FP6, 2008-2011



R&D priorities*

- Better estimation of uncertainty - Probabilistic forecasting - Ensembles
- Prediction of "extreme events" (i.e. ramps)
- Research in meteorology oriented to wind power forecasting
- Methods based on geographically distributed measurements
- Methods for alarming and warning
- Prediction risk indices
- Scenarios
- Reliable prediction systems



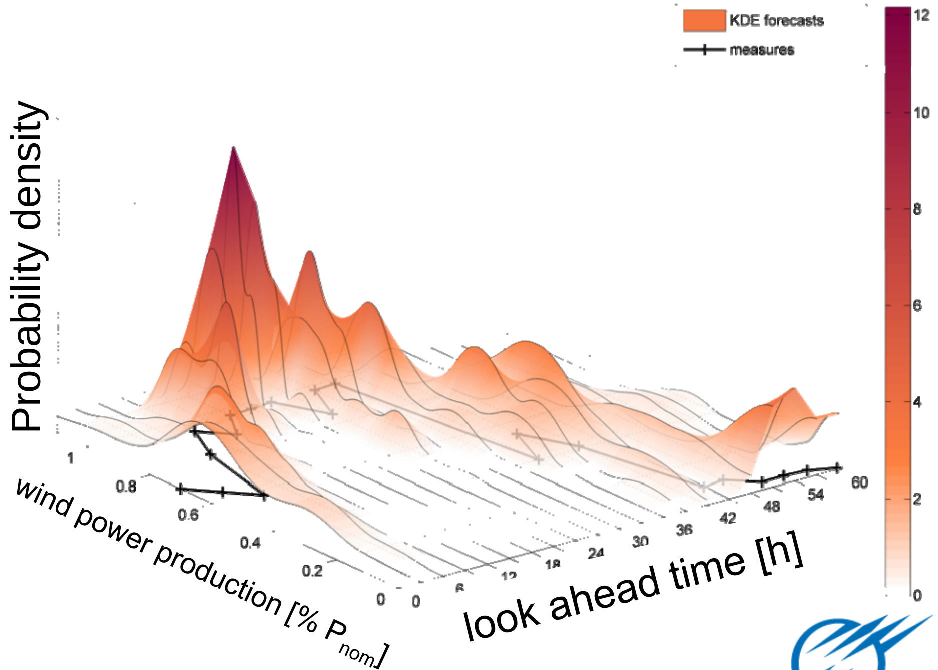
(*) priorities in Anemos.plus and SafeWind projects

R&D priorities*

- Decision making based on forecasts and uncertainty estimation

  Advanced tools are demonstrated in Anemos.plus for :

  - reserves estimation,
  - power system scheduling,
  - coordination of wind with storage,
  - congestion management,
  - strategic bidding in markets



(*) priorities in Anemos.plus and SafeWind projects

Thank you for your attention