Machine Learning algorithms in Meteorology and Climatology Applications

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- **Introduction:**
- Machine Learning and Soft-Computing techniques.
- Problems which can be tackled.
- Characteristics of Machine Learning algorithms.

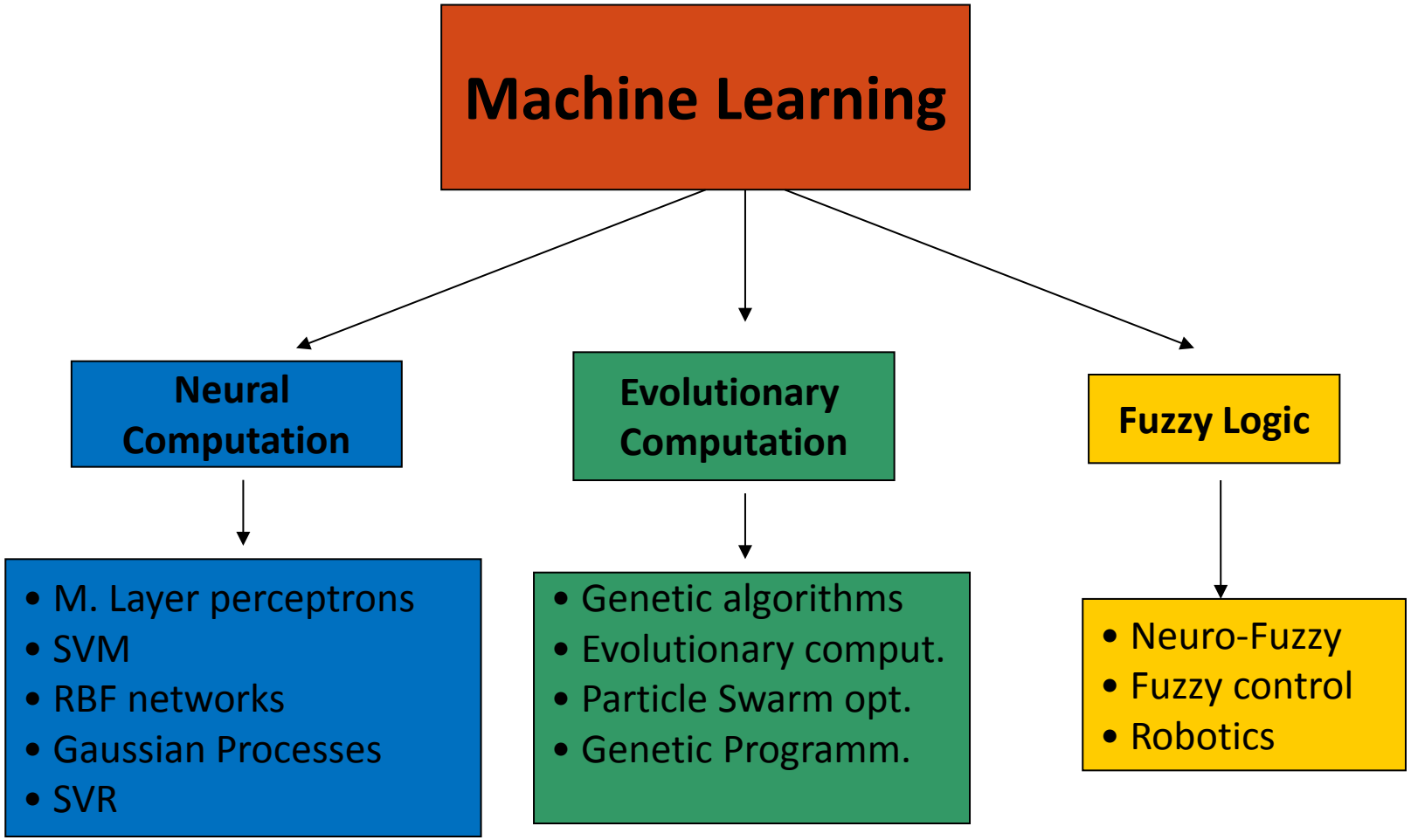
- **Application examples**
- Wind speed prediction in wind farms with neural computation.
- Summary of alternative problems in Meteorology and Climatology with ML.

Machine Learning and Soft Computing Techniques

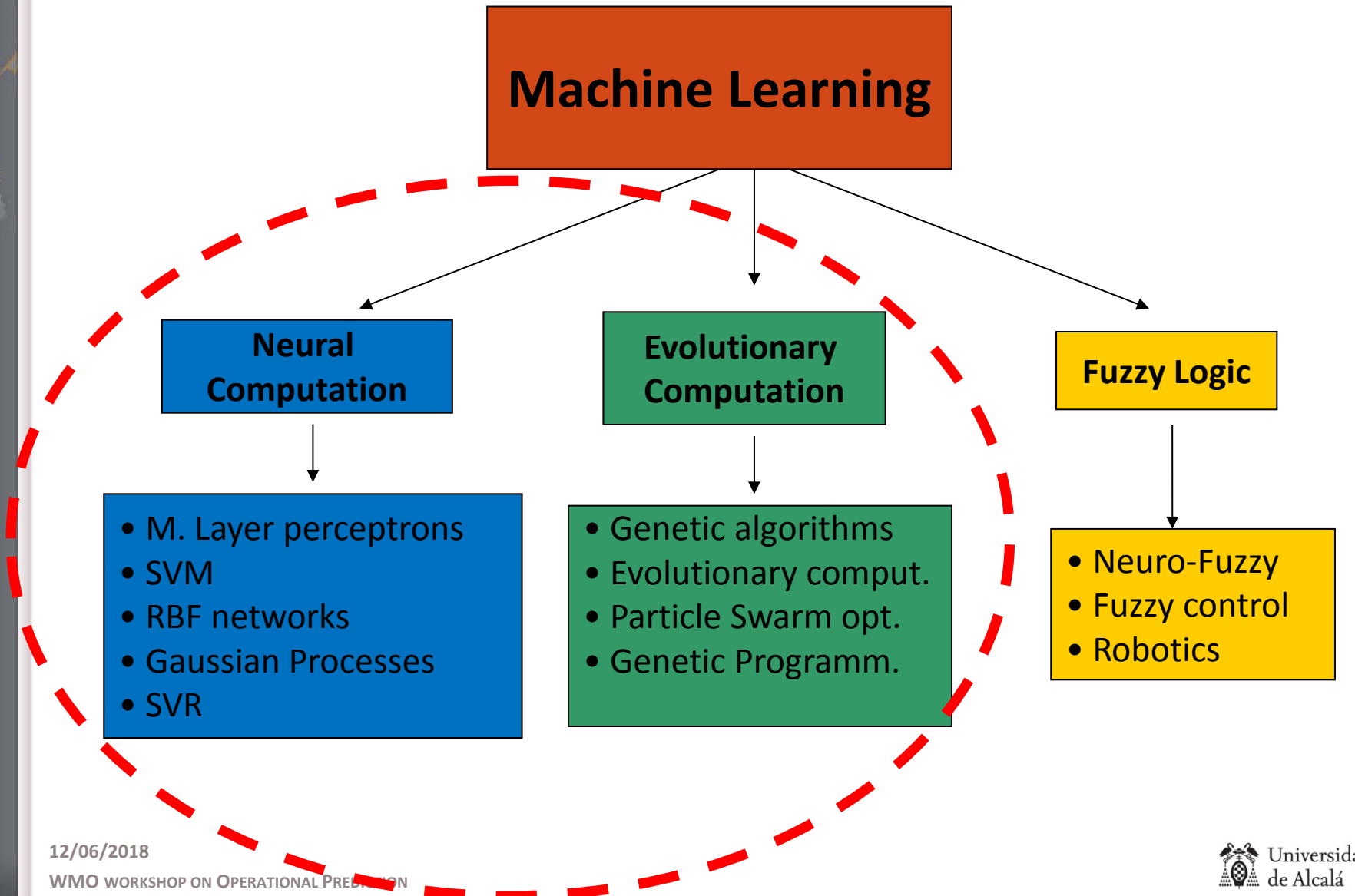
INTRODUCTION

- **Characteristics of Machine Learning algorithms:**
  - Algorithms and Systems (many) which try to from robust problem-solving approaches similar to human knowledge
  - They are able to **learn**!!! By extracting information from training samples:
  - Many of these systems use previous data to learn future outcomes of a system.
  - They are able to produce intelligent decisions.
  - Many of them are able to **combine different data sources**.
  - The Learning process can be also obtained by means of optimization of a given objective function.
  - Many of these systems imitate the learning process of humans, or are based on well-known natural processes such as species evolution.

INTRODUCTION



INTRODUCTION



INTRODUCTION

- **When and why using Machine Learning algorithms?**
  - There are problems where traditional techniques do not work well!
  - Data-driven problems involving Regression or Classification tasks.
  - Hard optimization problems with discrete encoding and non-linear objective functions.

- **What does Machine Learning offer?**
  - Wide possibilities of algorithms to solve such problems.
  - Possible hybridization of techniques to improve the performance on different problems.
  - Low complexity algorithms, with very good results in difficult problems.

INTRODUCTION

Neural Computation

- **Classification**
- **Regresssion**
- **Prediction problems**

Evolutionary Computation

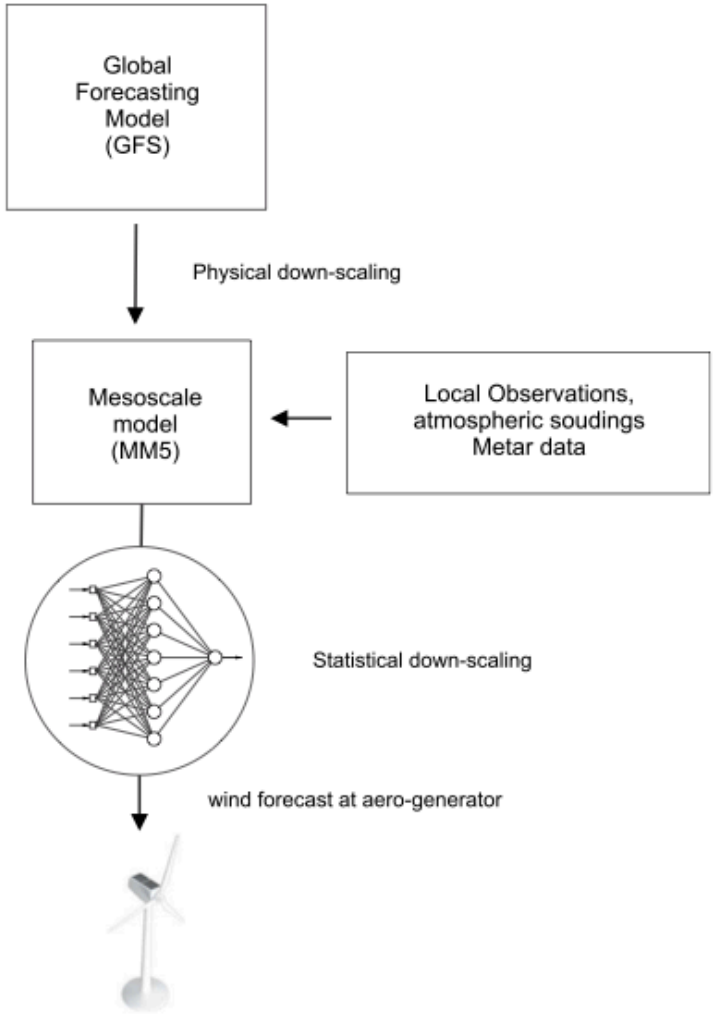
- **Systems optimization**
- **Discrete and continuous problems**
- **Clustering**

Hybrid techniques
(Many different problems)

Wind speed prediction in wind farms with Neural Computation

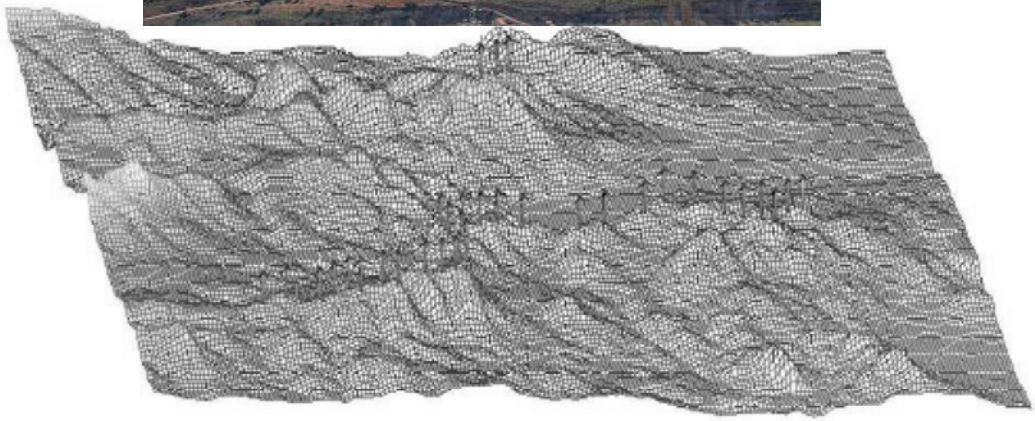
WIND SPEED PREDICTION

- **Problem definition:**
  - Wind speed prediction at wind turbine level. Downscaling from a Meso-scale model (WRF).
  - **Neural Networks.**



WIND SPEED PREDICTION

- We present some results in the wind fam *La Fuensanta* in Albacete

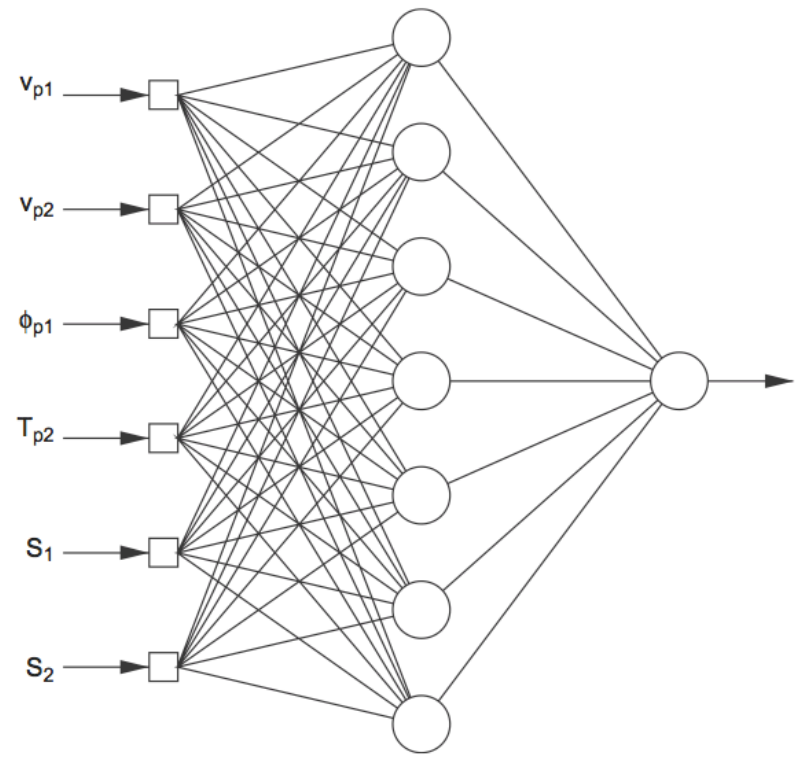


WIND SPEED PREDICTION

- Neural network model
- Inputs
  - Wind speed module in two points near the wind farm.
  - Wind direction and temperature in one point.
  - Two dummy temporal series to catch the prediction hour:

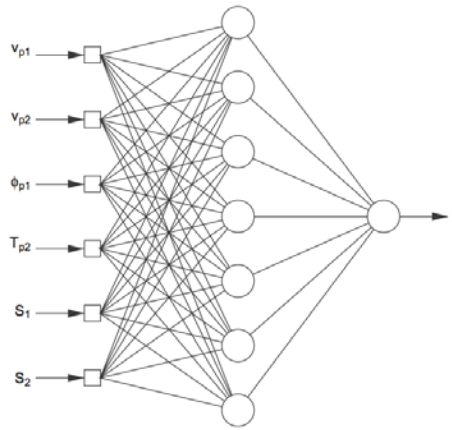
$$S_1 = \sin\left(H\frac{2\pi}{24}\right)$$

$$S_2 = \cos\left(H\frac{2\pi}{24}\right)$$



WIND SPEED PREDICTION

- Output data available
  - Hourly wind speed data in each of the 33 wind turbines of the farm, year 2006.
  - After cleaning the database (remove missing data, etc.).
    - *4750 training samples.*
    - *1570 Validation and test samples.*



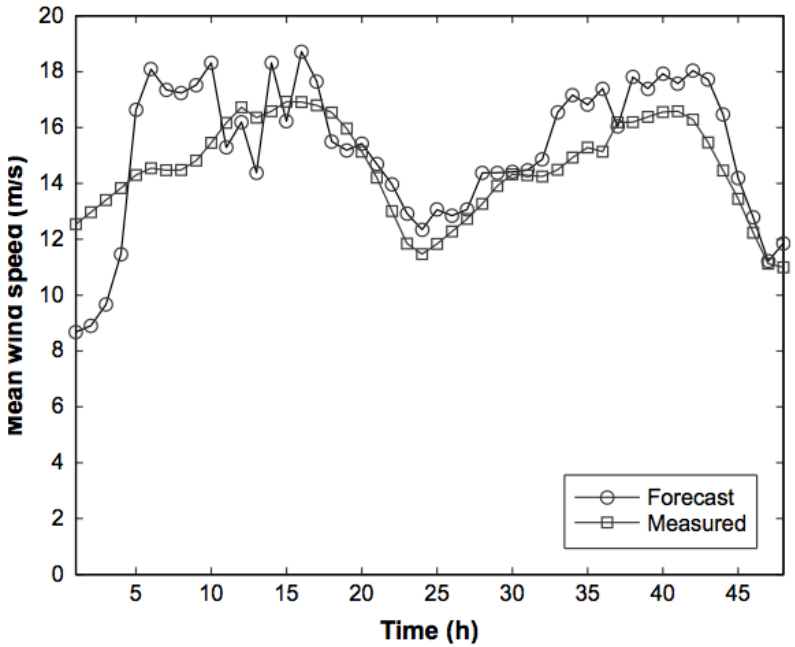
WIND SPEED PREDICTION

- Results: MAE (mean): 1.728, MAE (best): 1.425

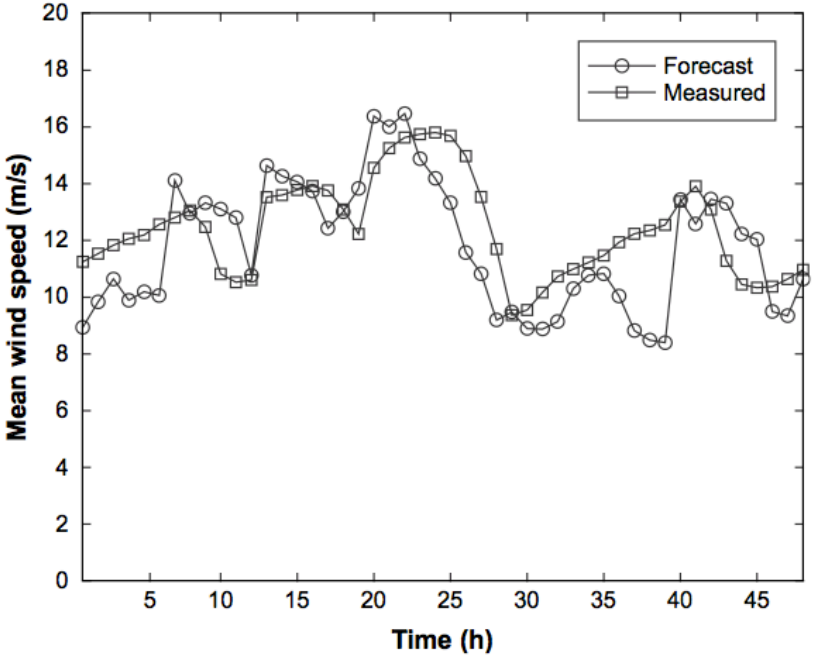
Turbine number	Number of neurons in the hidden layer						
	9	10	11	12	13	14	15
1	1.9136	1.9182	1.9113	1.9064	1.9120	1.9233	1.9086
2	2.0004	2.2284	2.0063	2.0081	2.0060	2.0024	2.0049
3	2.0098	2.0127	2.2384	2.0110	2.0002	1.9919	2.0039
4	1.8071	1.8084	1.8144	1.8138	1.8122	1.8015	1.8005
5	1.6860	1.7018	1.8829	1.6901	1.6748	1.6773	1.6876
20	1.6789	1.6722	1.6685	1.6794	1.6721	1.6607	1.6787
21	1.8021	1.7952	1.7897	1.7914	1.8075	1.8005	1.7969
22	1.7658	1.7559	1.7647	1.7594	1.7664	1.7645	1.7555
31	1.4730	1.4554	1.4676	1.4575	1.4559	1.4591	1.4555
32	1.7404	1.5513	1.5473	1.5478	1.5484	1.5529	1.5506
33	1.5914	1.5910	1.5938	1.5901	1.5868	1.5921	1.5899

WIND SPEED PREDICTION

- Turbine 3

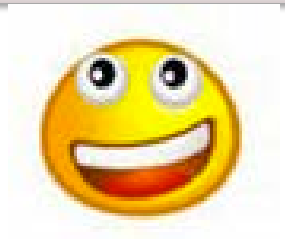


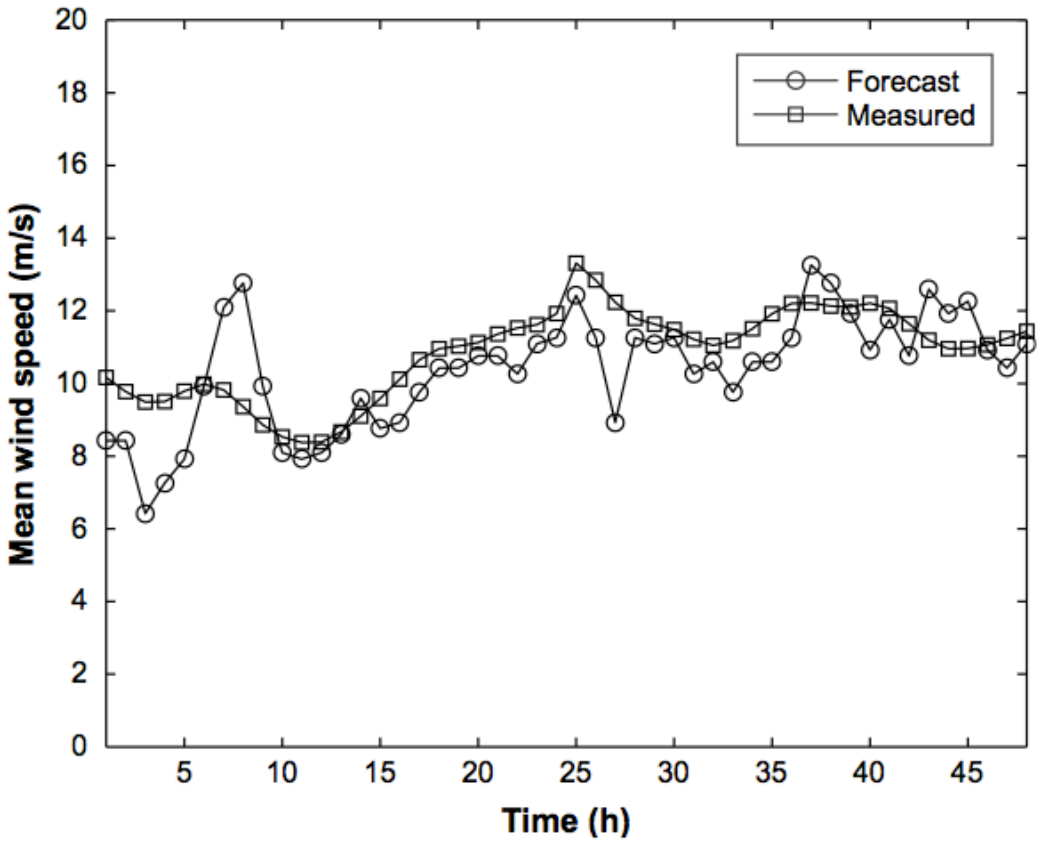
- Turbine 21



WIND SPEED PREDICTION

- Turbine 31





WIND SPEED PREDICTION

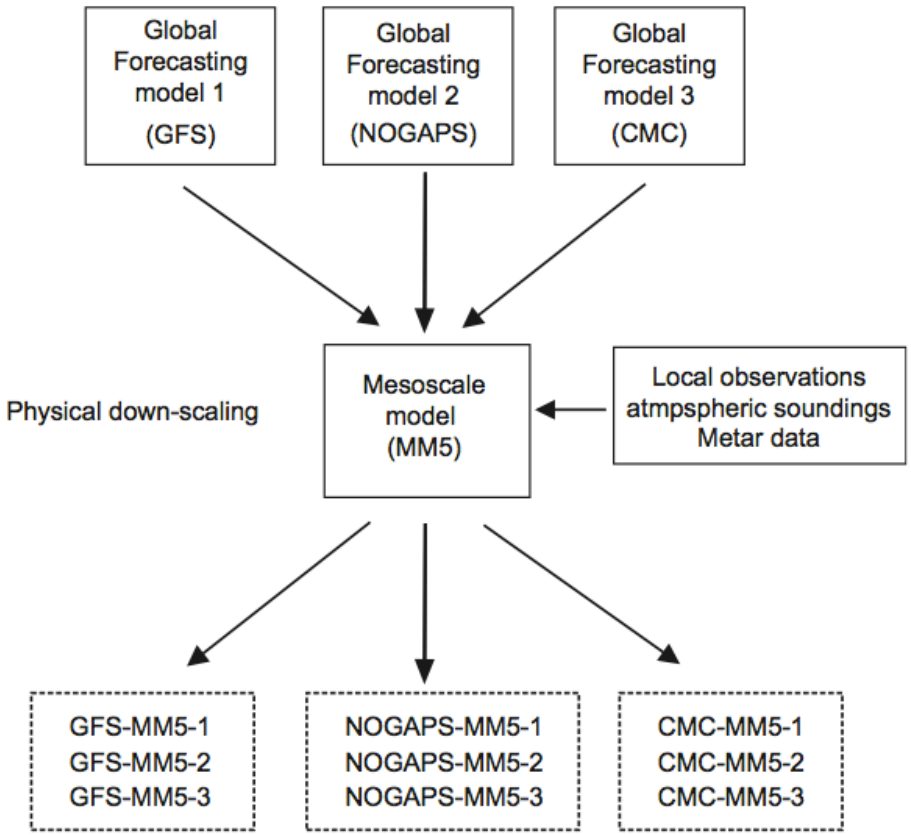
- Some hybrid alternatives.
  - NOGAPS
  - CMC

- In addition the output of the WRF model depends on different parametrizations (clouds, humidity, etc).

- **What can we do to improve the prediction?**

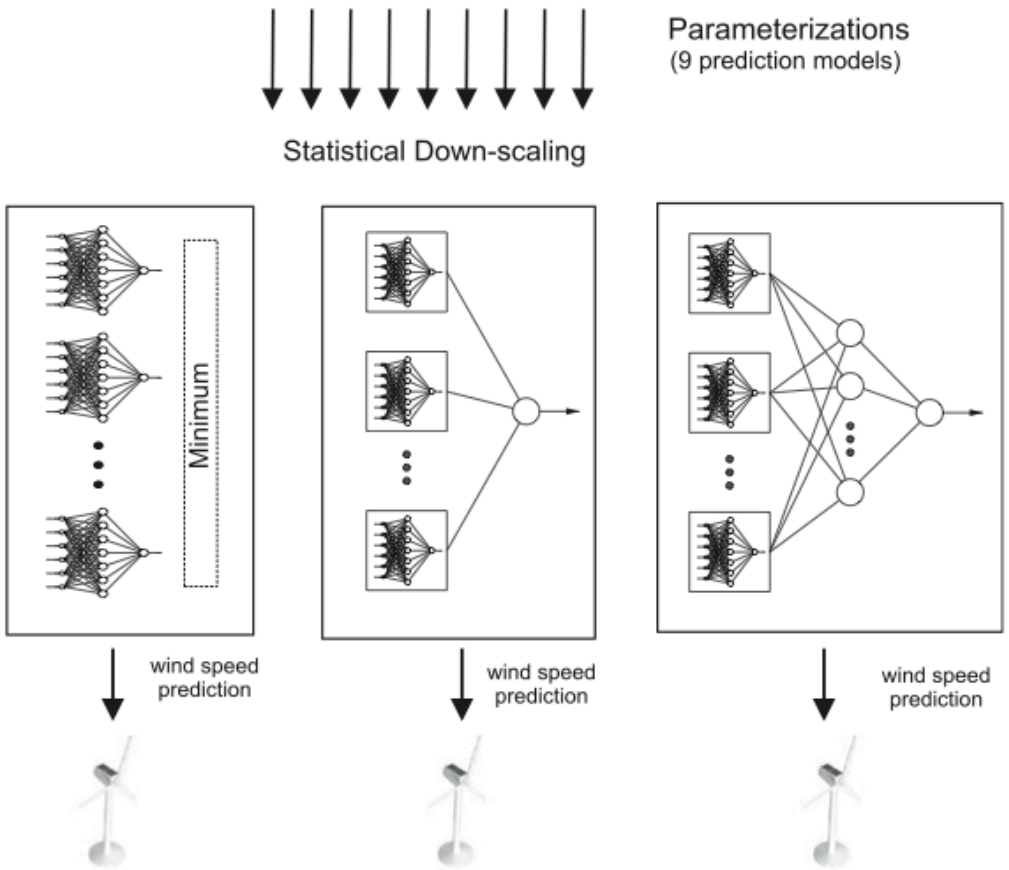
WIND SPEED PREDICTION

- We can generate different models (diversity)



WIND SPEED PREDICTION

- We can use this diversity to generate new models:



WIND SPEED PREDICTION

- Results diversity models: (MAE)

Wind turbine	Best out of nine	One-neuron bank	Hidden Layer bank
1	1.8233	1.7962	1.7946
2	1.9500	1.9210	1.9051
3	1.9778	1.9174	1.9044
4	1.7837	1.7504	1.7393
5	1.6853	1.6409	1.6346

- Comparison with
  - GFS
  - Initial model results →

Turbine number	15
1	1.9086
2	2.0049
3	2.0039
4	1.8005
5	1.6876

Other Problems with ML

- **Prediction**
  - Wind speed reconstruction from synoptic pressure structures.
  - Solar radiation from station measurements, satellite data or numerical methods.
  - Wave height prediction for energy applications.
  - Fog formation prediction.
  - Analysis of glaciation temperature in clouds from satellite data.

- **Clustering and optimization**
  - Selection of the best set of measuring points for reconstructing a given meteorological variable field.
  - Paleoclimate problems (selection of proxies, etc).

CONCLUSIONS

- In this talk the application of Machine Learning algorithms to problems in atmospheric physics and climatology have been described.
- A brief introduction to Machine Learning and Soft-Computing algorithms has been carried out.
- An example of application has been presented and analyzed:
  - Wind speed prediction in wind farms based on using neural networks for downscaling the output of numerical models.
- Other problems which can be tackled with Machine Learning methods have been briefly mentioned.

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