Interests of regional modelisation for wind power forecasting

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4th Belgian Geography Days,
October 22nd 2010, K.U.Leuven
B2b – Meteorology for sustainable energy production
Context:

- Climate
  - Greenhouse gases from fossil fuels:
    - Temperature of the Earth

- Energy
  - Extremely dependant on fossil fuels
    - Oil reserves
    - Price of energy

- One of the multiple solutions: Use of the Wind Energy!
Problematic of wind energy

- The wind energy is dependant on the weather conditions:
  - This implies:
    - As you know
      - if the wind speed drops: Production also drops
      - If there is no wind: There is no production
    - But, if the wind speed is too high: Production stops

Production (in kWh) of 5 wind turbines near Amel in Belgium on September 2010
Problematic of wind energy

Therefore, we must:
- forecast the wind speed
  - Minimum one day in advance
  - Every 15 minutes

to use efficiently the wind power

Who are the users of the wind forecasts?
- Managers of electric grids
  - To balance the production and consumption of electricity
- Producer / Provider of electricity
  - To negotiate the best price on the electricity market
Forecast Models

 fête

GFS (Global Forecast System):
- Global Meteorological Model
  - Available over the world
- Resolution outputs: 0.5° and 3h
- Outputs are provided by the NOAA
  - We can’t change the parameters of the model

WRF (Weather Research Forecast model):
- Regional model forced by GFS
  - Centred over Belgium (defined by the user)
- Resolution (defined by the user): 4 km and 15 min
- Original code is provided by the NCAR/NCEP
  - Open Source code
  - We can adapt the code/parameters as we wish
GFS Method

❖ GFS:
  - ~20min to obtain forecasts at +24h

Tunings to adjust the wind forecasts + Transform the wind speed into electric production

GFS outputs 0.5° and 3h

Linear interpolation every 15 min

Wind power production forecasts

● Tunings depend on:
  - Roughness roses
    - According to roughness of the terrain
  - Air density
  - Some instability parameters
WRF Method

❖ WRF:
   - ~1h to obtain forecasts at +24h

WRF outputs:
4km and 15min

WRF model:
regionalisation

GFS outputs
0.5° and 3h

Static data

Few tunings to adjust the wind forecasts
+ Transformation of the wind speed into electric production

Wind power production forecasts

❖ Tunings
- Slightly reduce the wind speed
- Not use of roughness rose
  - WRF integrates the topography roughness
Evaluation

- **Four evaluation indexes:**
  - **RMSE** (Root Mean Square Error):
    \[
    \sqrt{\frac{1}{n \sum (obs - forecast)}
    \]
  - **r^2** (coefficient of determination):
    \[
    \left(\frac{\left(n \sum (obs \times forecast) - \sum obs \sum forecast\right)^2}{\left(n \sum obs^2 - \sum obs^2\right) \times \left(n \sum forecast^2 - \sum forecast^2\right)}\right)
    \]
  - **PC** (Percentage)
    \[
    \sum (1 - ABS\left(\frac{obs - forecast}{obs}\right))
    \]
  - **PC60** (Conditioned Percentage)
    \[
    \text{If}\ (obs \geq 60\% \text{ max prod}) \text{ then } \sum (1 - ABS\left(\frac{obs - forecast}{obs}\right))
    \]
WRF has better forecasts
- Except for PC

- WRF has better forecasts when the production is high
  - Indicated by the PC60
  - The high production events are more important

* These results may not be significantly different
Results

- Seasonally
  - January to February
    |       | GFS | WRF |
    |-------|-----|-----|
    | RMSE  | 1695| 1662*|
    | $R^2$ | 0.65| 0.66*|
    | PC    | 2860| 3001|
    | PC60  | 528 *| 524 |
  - March to May
    |       | GFS | WRF |
    |-------|-----|-----|
    | RMSE  | 1629| 1593*|
    | $R^2$ | 0.49| 0.53|
    | PC    | 4003| 3597|
    | PC60  | 458 | 534 |
  - June to September
    |       | GFS | WRF |
    |-------|-----|-----|
    | RMSE  | 1490| 1340 |
    | $R^2$ | 0.46| 0.51 |
    | PC    | 4811| 4609 |
    | PC60  | 259 | 323 |

* : These results may not be significantly different
Results

Examples

Example of GFS and WRF forecasts (kWh) compared to observations (kWh) for May
Examples

- Production peaks are better forecasted with WRF than with GFS

**Example of GFS and WRF forecasts (kWh) compared to observations (kWh) for May**
Examples

- Some remarkable periods are not modelled neither by WRF nor by GFS
  - The pass of a cold front or a convective zone
Results

Examples

- Wrong forecasts

![Graph showing GFS and WRF forecasts compared to observations for May]

- Halt of one or more wind turbines
Conclusions

- **Interests of using WRF:**
  - Outputs are available in a resolution of 4km and 15 min
    - Decrease the errors created by the spatial and temporal interpolation
  - Production peaks are successfully forecasted
    - High production events are more important for the users of these forecasts
  - Influences of the topography are integrated in the WRF calculation
    - Roughness rose is not needed
  - Configurable as we wish
    - We are not dependent on another meteorological organism

- **Disadvantage of WRF**
  - Forced by GFS
    - If the GFS forecasts are wrong → the WRF forecasts will also be wrong
Thanks for your attention