Assessment of wind resources and annual energy production of wind farms

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Assessment of wind resources and annual energy production of wind farms

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I acknowledge colleagues!

Content

- Wind power in Europe – key numbers
- Assessment of wind resources
- Annual energy production (AEP) of wind farms
- Earth Observation data
- Summary

DTU Wind Energy has 240 employees since 1st January 2012.

Merger:
Former Risø DTU Wind Energy at the National Laboratory for Sustainable Energy merged with people from DTU MEK and Risø Material Science Department.

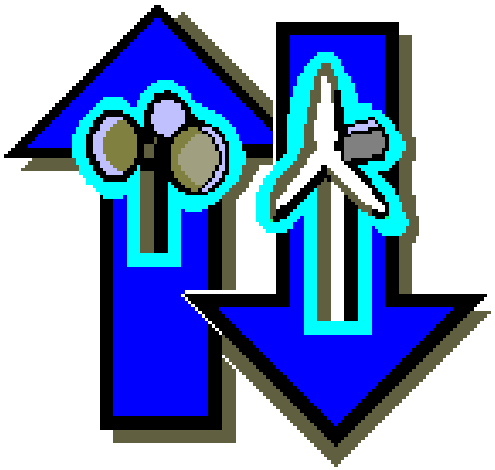
Wind power in Europe – key numbers

- The total wind power capacity in Europe is 96 GW with 9 GW new onshore and 0.8 GW new offshore in 2011.
- Wind energy has an annual growth of 15.6% during the last 17 years.
- In EU 6.3% share of total electricity consumption is powered by wind energy (2011).
- Denmark plans to increase from 26% (2011) to 50% (2020) share of wind energy.

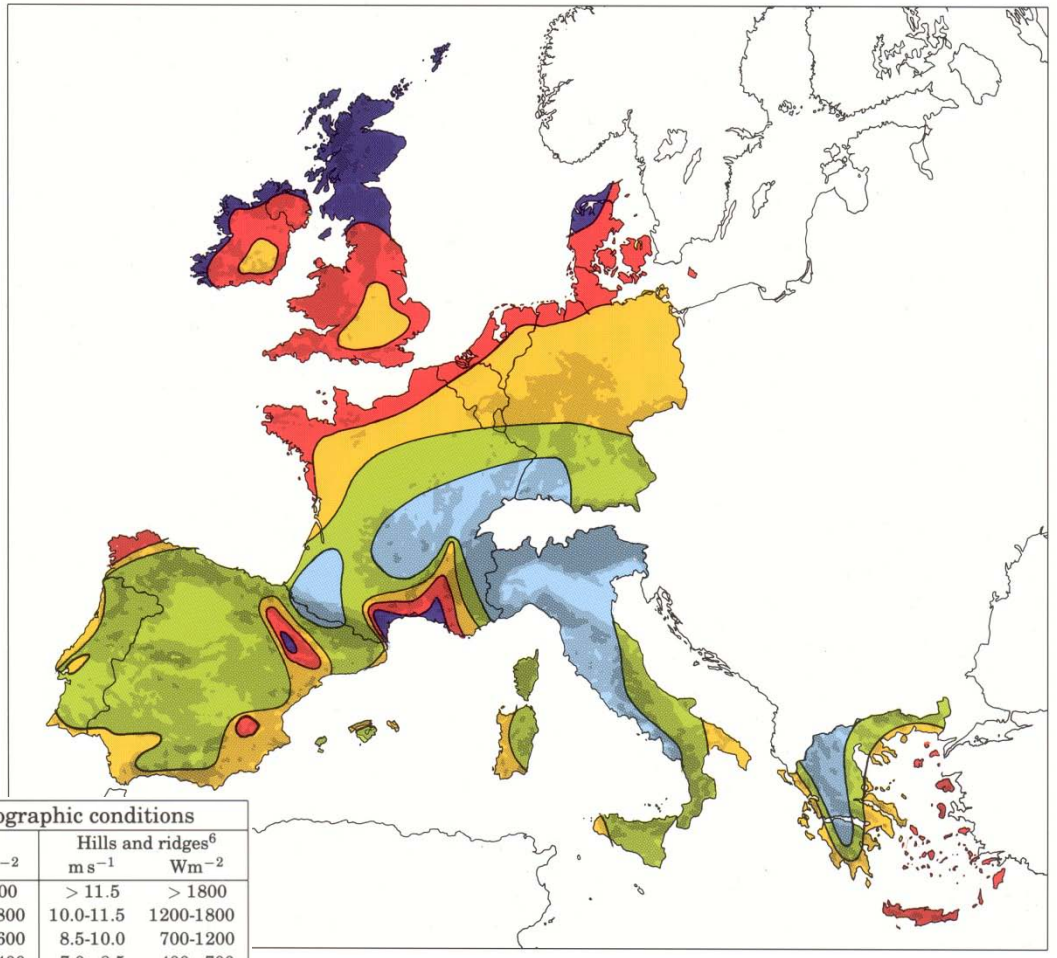
Source: EWEA

Assessment of wind resources

European Wind Atlas (1989)



WAsP icon



Wind resources[1] at 50 metres above ground level for five different topographic conditions

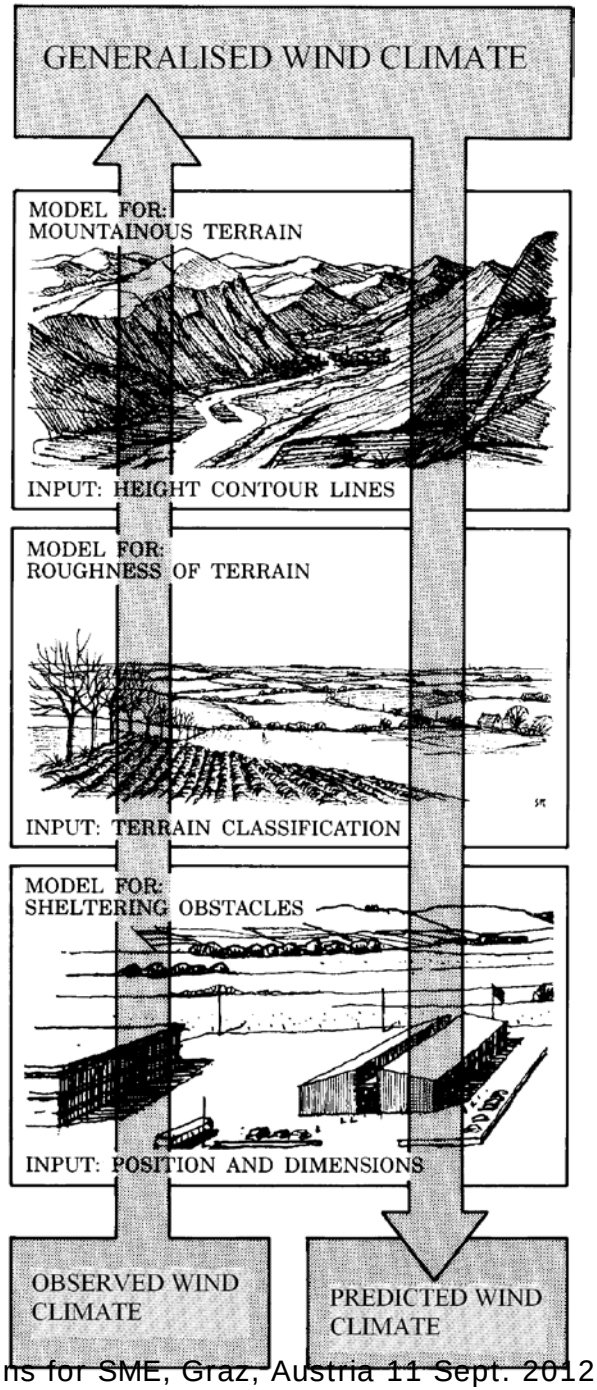
	Sheltered terrain[2]		Open plain[3]		At a sea coast[4]		Open sea[5]		Hills and ridges[6]	
	$m\,s^{-1}$	Wm^{-2}	$m\,s^{-1}$	Wm^{-2}	$m\,s^{-1}$	Wm^{-2}	$m\,s^{-1}$	Wm^{-2}	$m\,s^{-1}$	Wm^{-2}
	> 6.0	> 250	> 7.5	> 500	> 8.5	> 700	> 9.0	> 800	> 11.5	> 1800
	5.0-6.0	150-250	6.5-7.5	300-500	7.0-8.5	400-700	8.0-9.0	600-800	10.0-11.5	1200-1800
	4.5-5.0	100-150	5.5-6.5	200-300	6.0-7.0	250-400	7.0-8.0	400-600	8.5-10.0	700-1200
	3.5-4.5	50-100	4.5-5.5	100-200	5.0-6.0	150-250	5.5-7.0	200-400	7.0- 8.5	400- 700
	< 3.5	< 50	< 4.5	< 100	< 5.0	< 150	< 5.5	< 200	< 7.0	< 400

WAsP

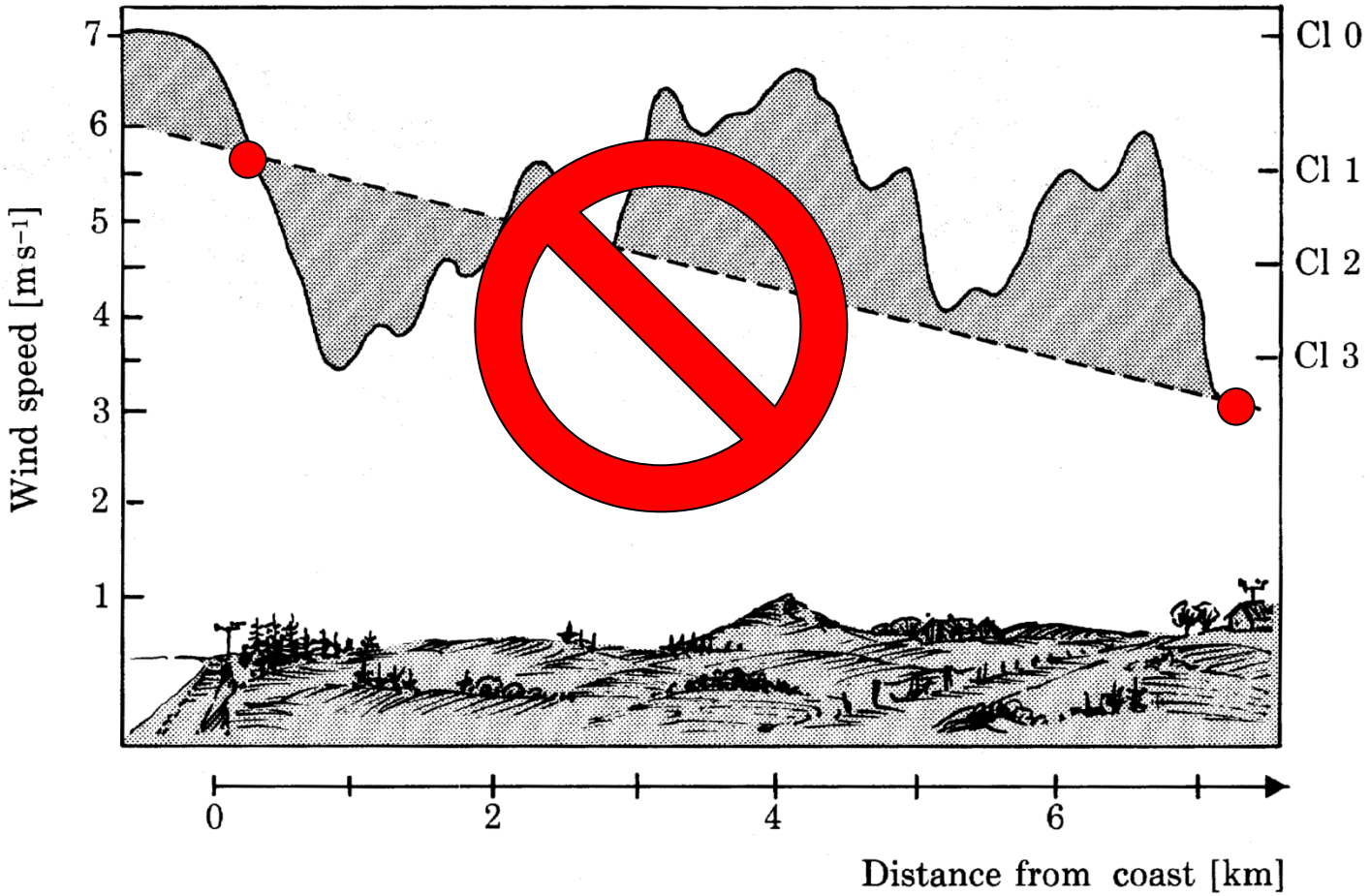
- Analysis procedure (⇑)
  - **Observed Wind Climate**
    - + sheltering obstacles
    - + roughness map
    - + elevation map
  - ⟶ **Generalised Wind Climate**

- Application procedure (⇓)
  - **Generalised Wind Climate**
    - + sheltering obstacles
    - + roughness map
    - + elevation map
  - ⟶ **Predicted Wind Climate**

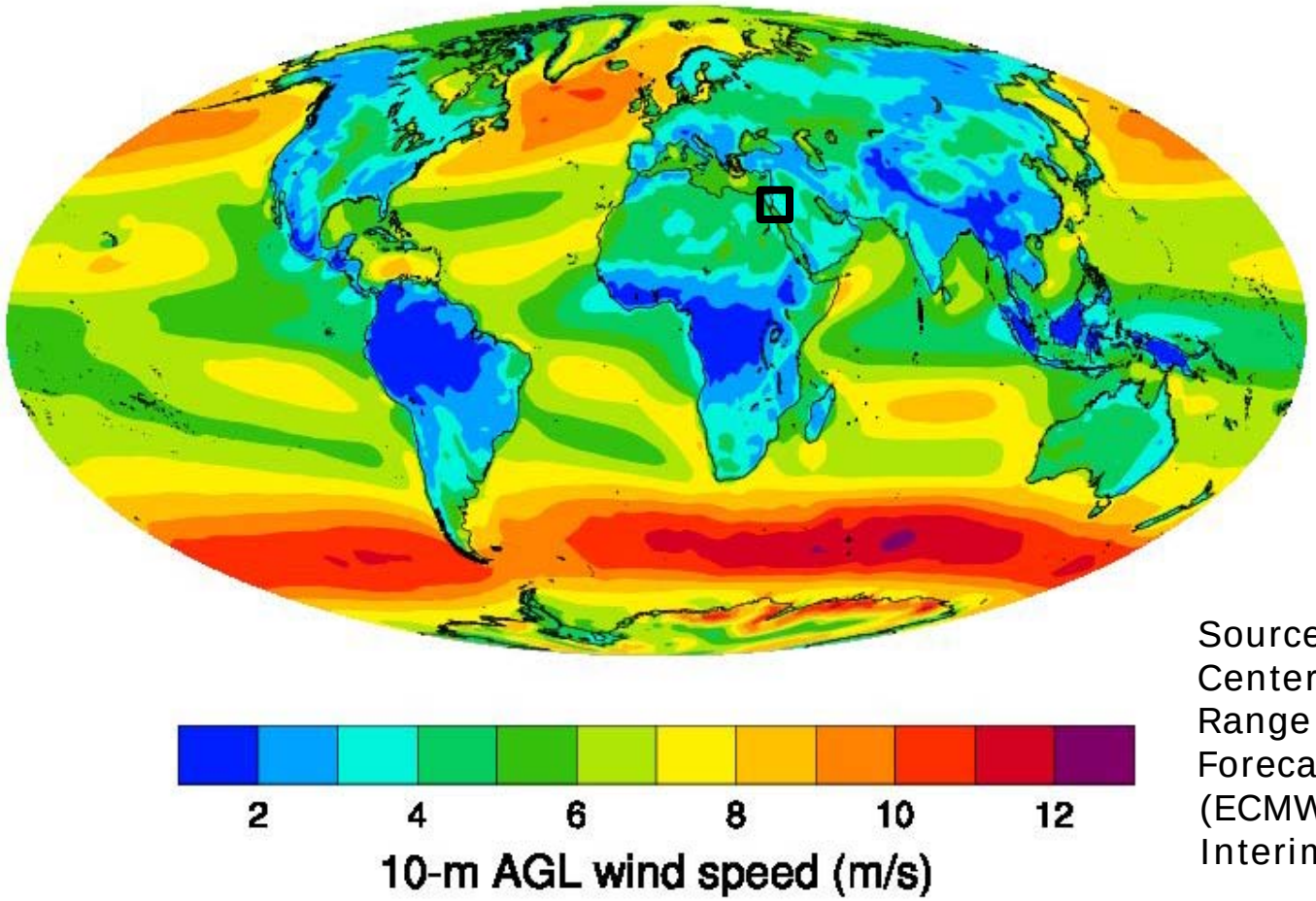
- Wind farm production
  - **Predicted Wind Climate**
    - + power and thrust curves
    - + wind farm layout
  - ⟶ **Predicted wind farm AEP**



Linear interpolation…

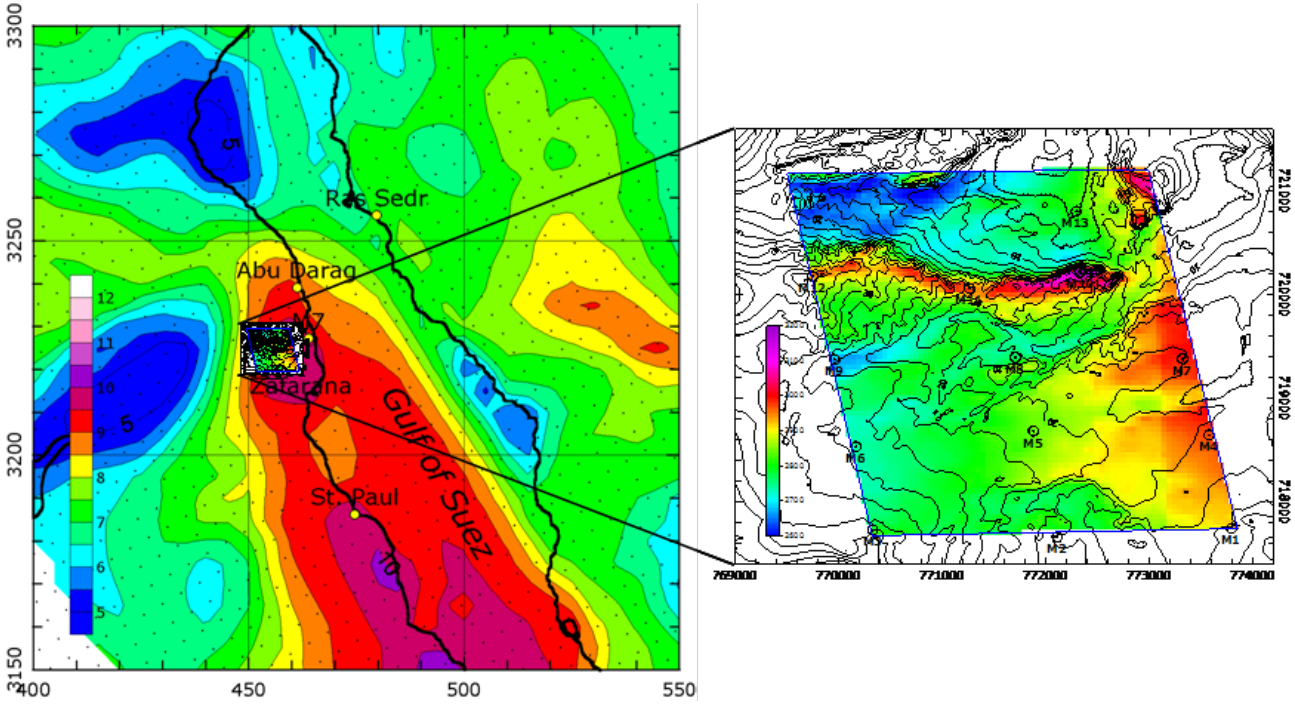


Global annually averaged 10-meter wind map



Source: European Center for Medium Range Weather Forecasting (ECMWF) - ERA Interim reanalysis

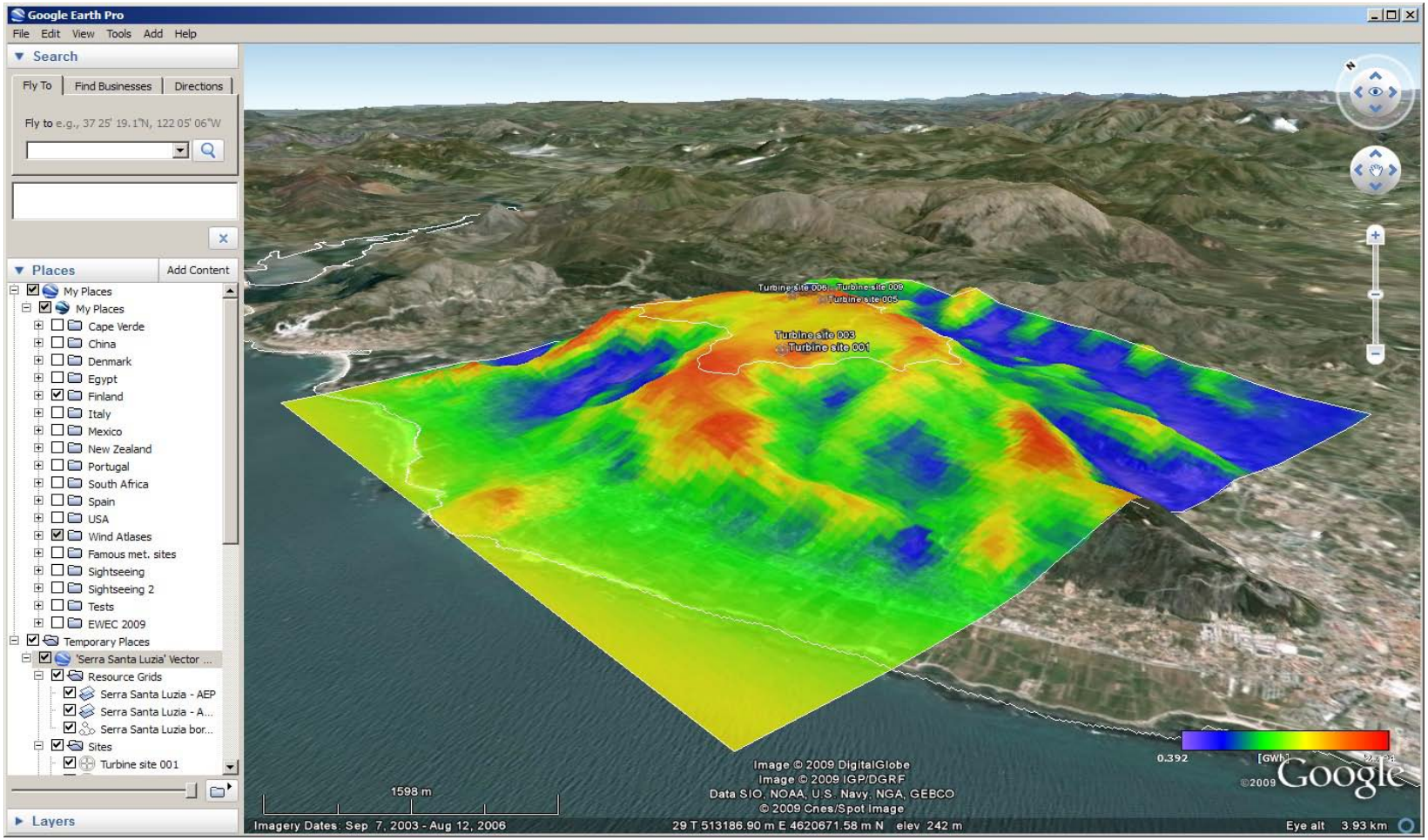
Regional and local wind map Egypt



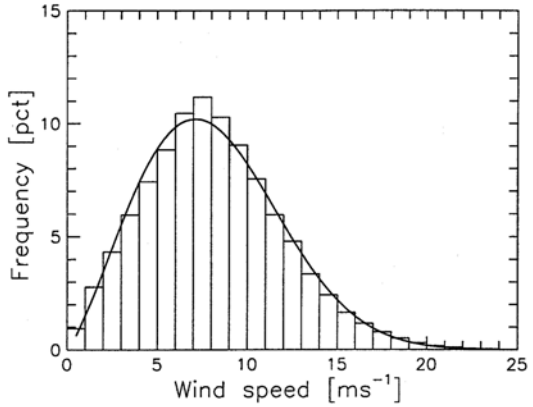
Mesoscale wind map

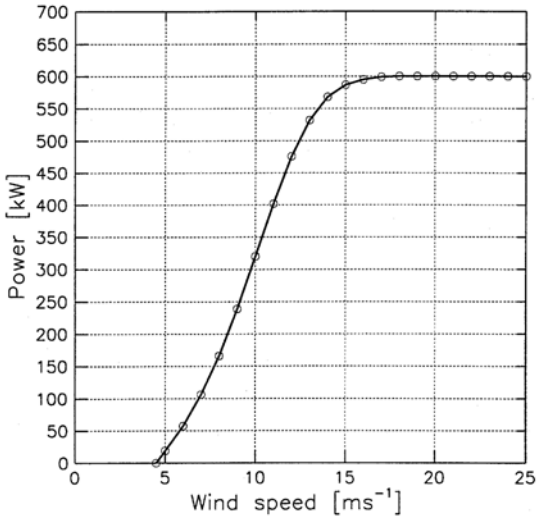
Microscale wind map

Example winds in mountains



Annual energy production (AEP) of wind farm





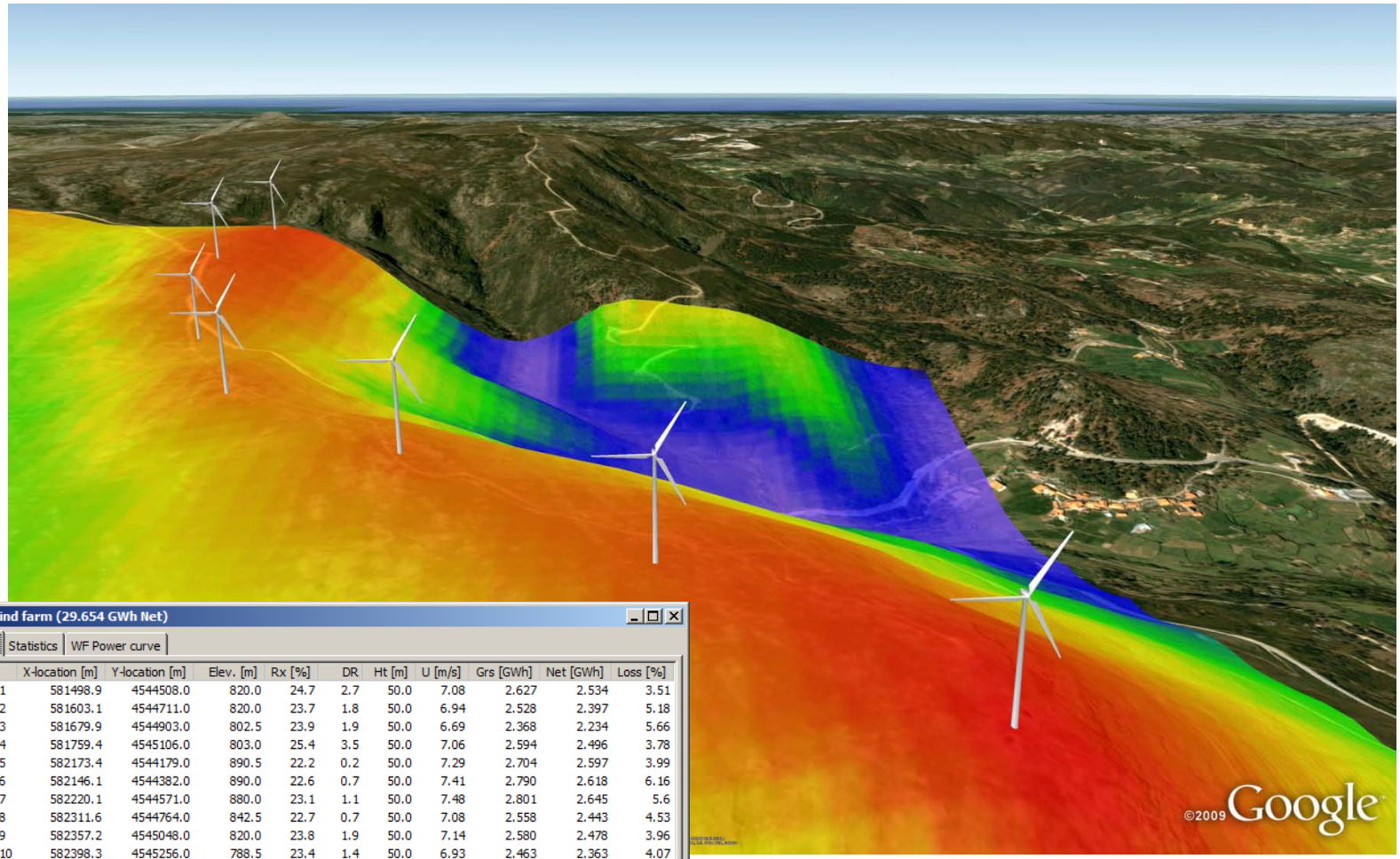
Wind speed distribution at hub height

+ wind turbine power curve

= AEP calculation and prediction

- Based on *n* previous years
- Valid for wind turbine lifetime (20 year)

Annual Energy Production (AEP) of wind farm



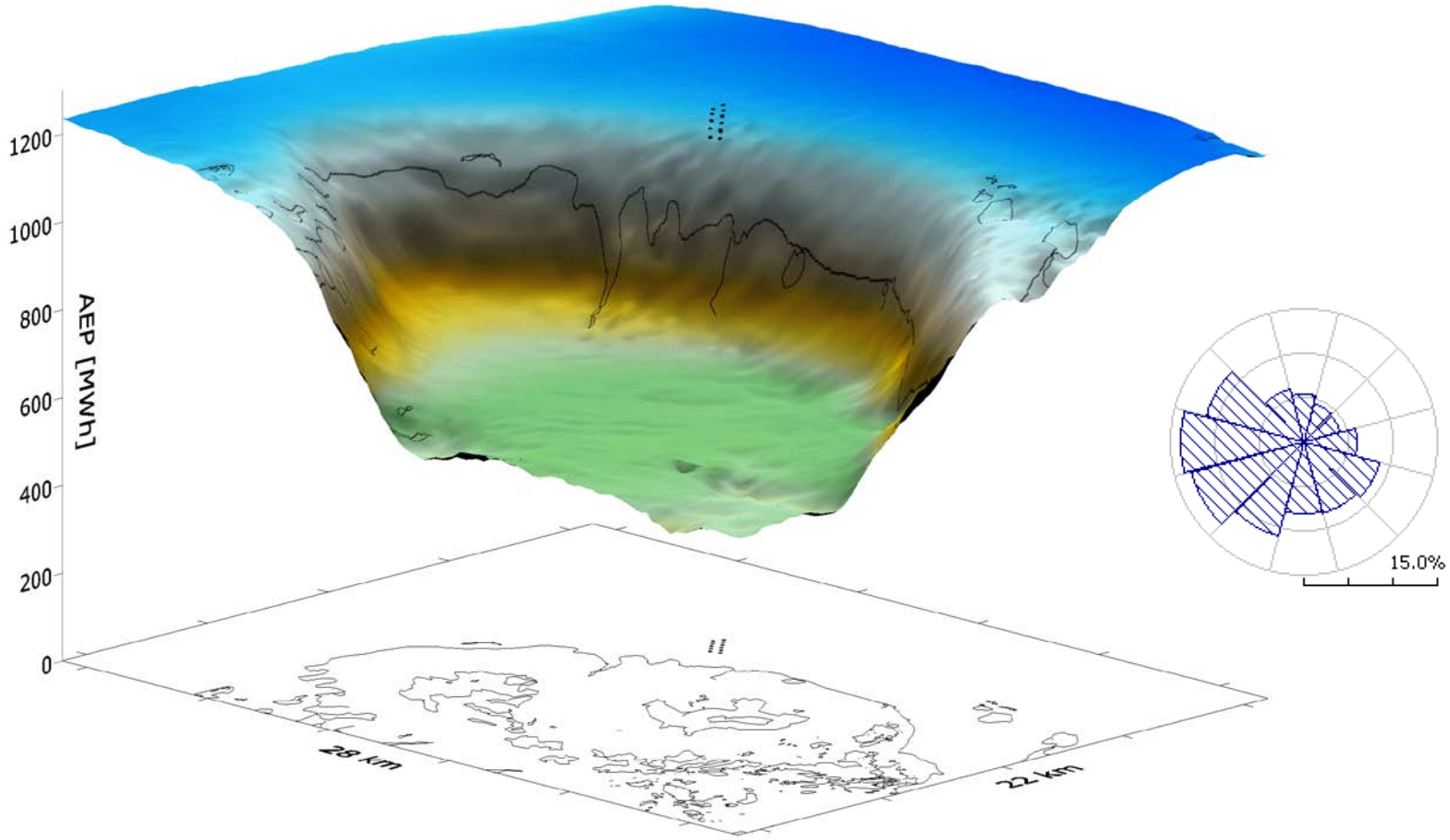
'Wind farm' Wind farm (29.654 GWh Net)

Settings | Site list | Statistics | WF Power curve

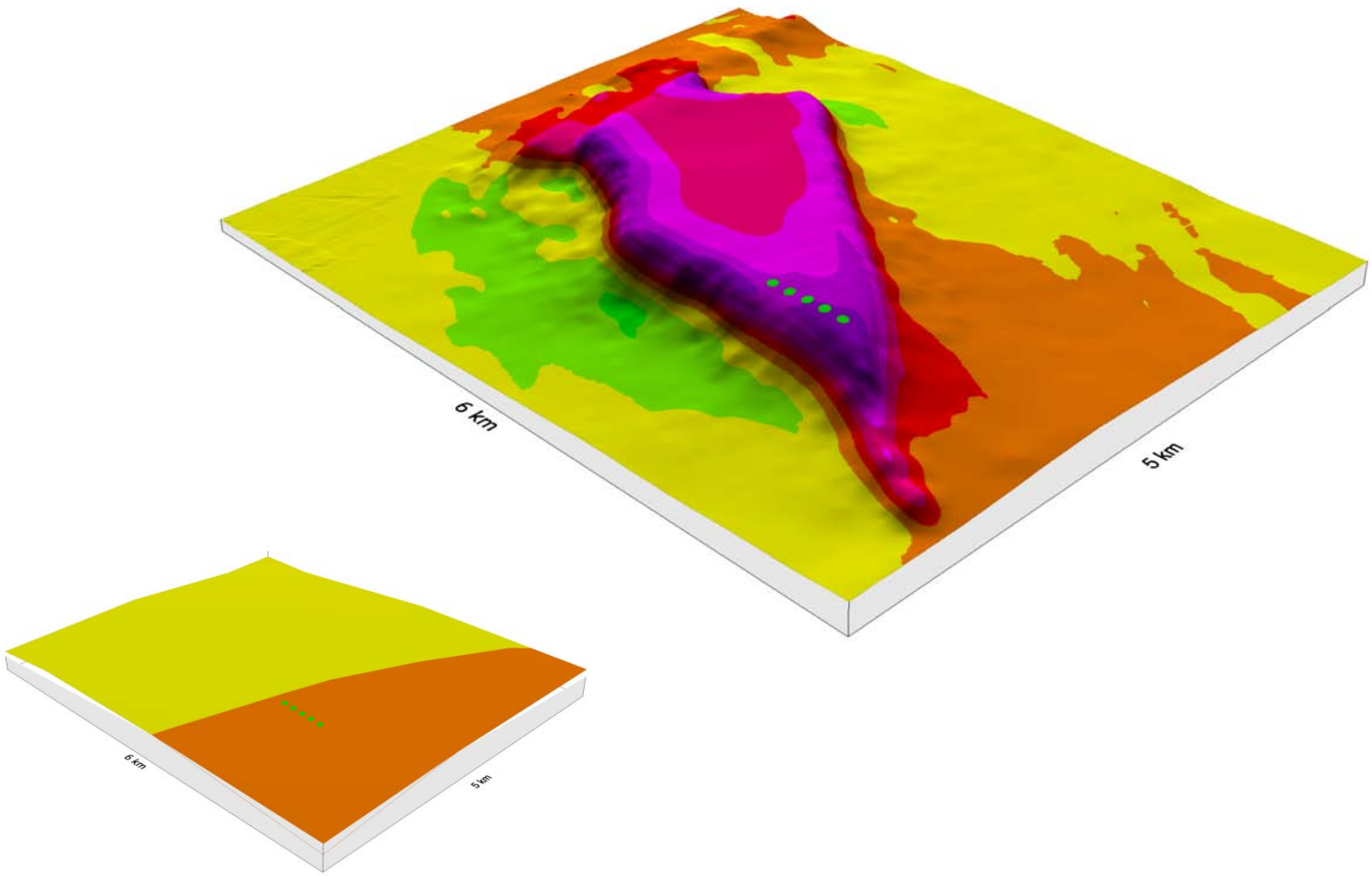
Site ID	X-location [m]	Y-location [m]	Elev. [m]	Rx [%]	DR	Ht [m]	U [m/s]	Grs [GWh]	Net [GWh]	Loss [%]
Turbine site 1	581498.9	4544508.0	820.0	24.7	2.7	50.0	7.08	2.627	2.534	3.51
Turbine site 2	581603.1	4544711.0	820.0	23.7	1.8	50.0	6.94	2.528	2.397	5.18
Turbine site 3	581679.9	4544903.0	802.5	23.9	1.9	50.0	6.69	2.368	2.234	5.66
Turbine site 4	581759.4	4545106.0	803.0	25.4	3.5	50.0	7.06	2.594	2.496	3.78
Turbine site 5	582173.4	4544179.0	890.5	22.2	0.2	50.0	7.29	2.704	2.597	3.99
Turbine site 6	582146.1	4544382.0	890.0	22.6	0.7	50.0	7.41	2.790	2.618	6.16
Turbine site 7	582220.1	4544571.0	880.0	23.1	1.1	50.0	7.48	2.801	2.645	5.6
Turbine site 8	582311.6	4544764.0	842.5	22.7	0.7	50.0	7.08	2.558	2.443	4.53
Turbine site 9	582357.2	4545048.0	820.0	23.8	1.9	50.0	7.14	2.580	2.478	3.96
Turbine site 10	582398.3	4545256.0	788.5	23.4	1.4	50.0	6.93	2.463	2.363	4.07
Turbine site 11	582453.1	4545448.0	769.8	24.4	2.4	50.0	7.04	2.529	2.419	4.32
Turbine site 12	582398.3	4545660.0	741.7	25.1	3.2	50.0	6.96	2.494	2.431	2.53

Calculate

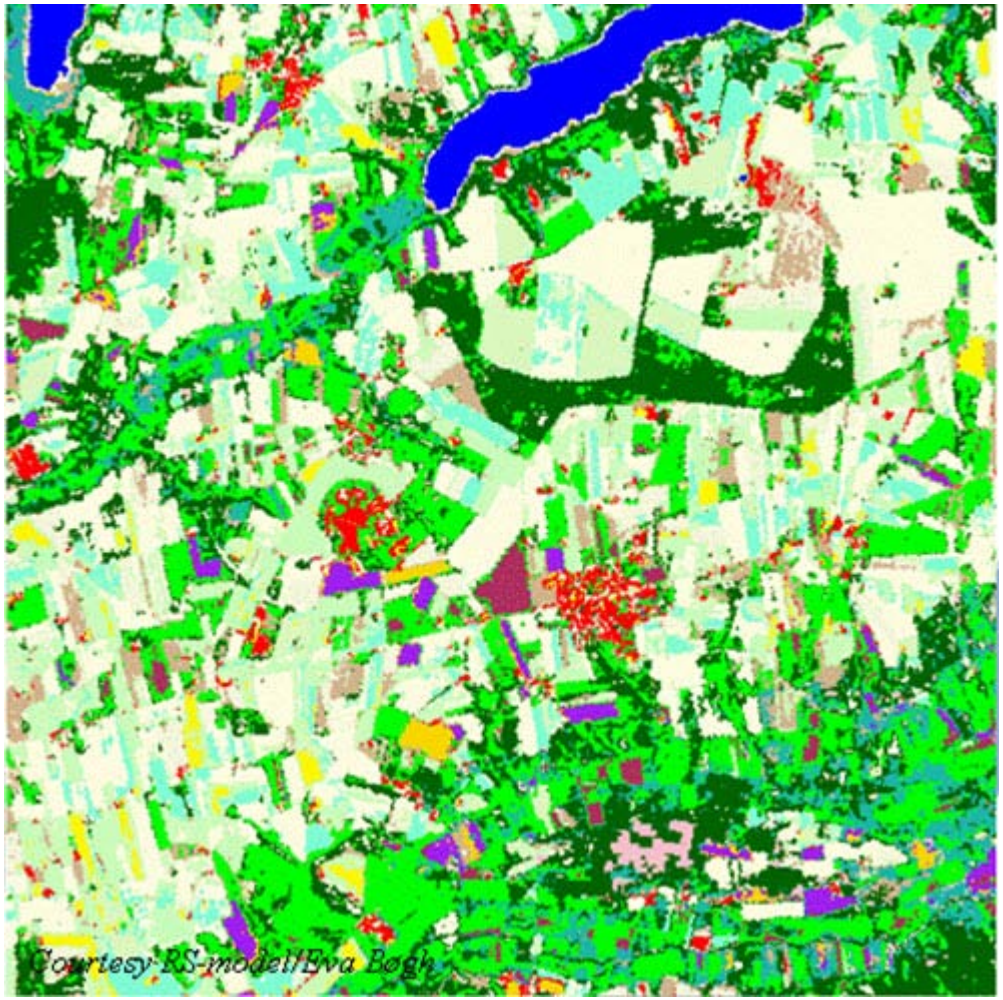
Example offshore



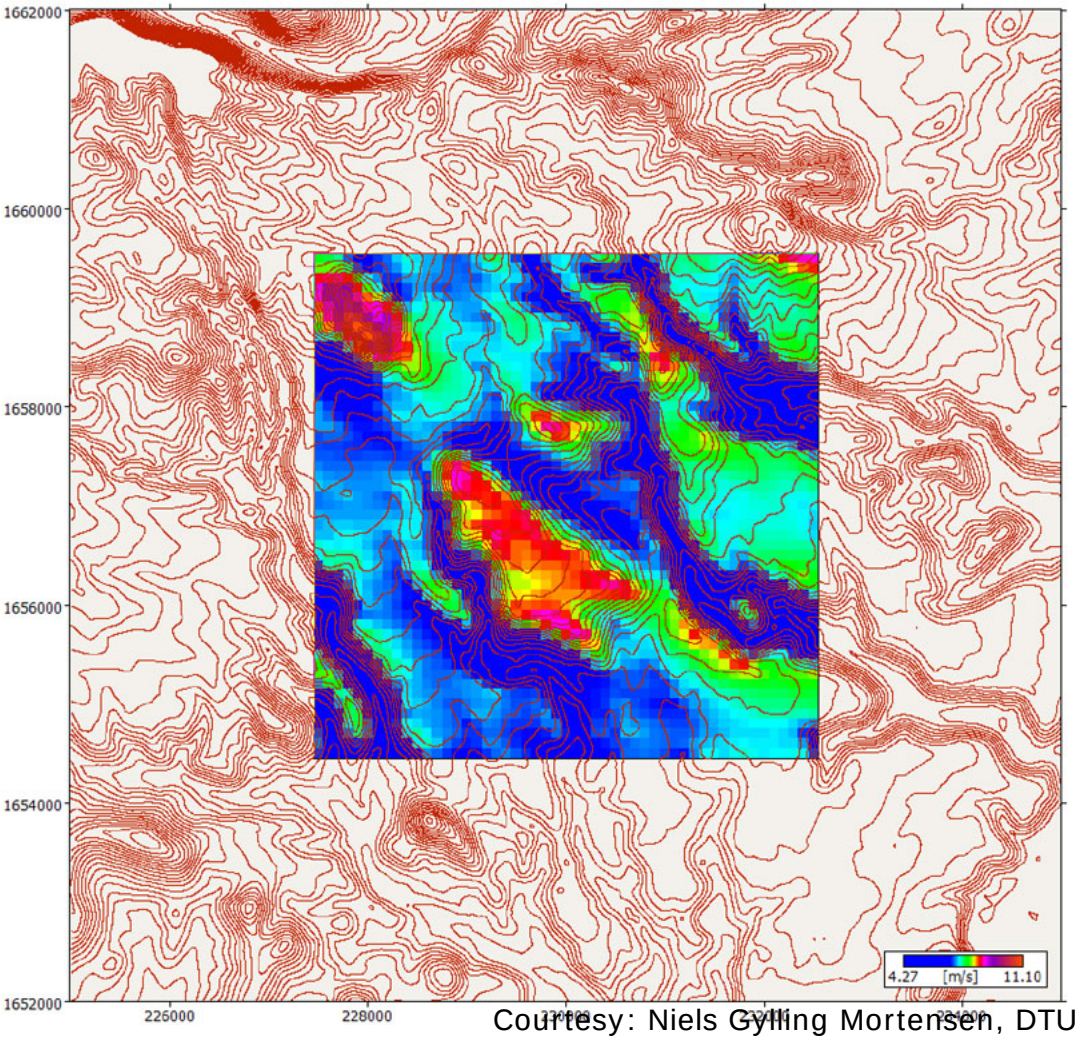
Land information at sufficient scale



Earth Observation – roughness from land cover



Elevation – using Shuttle Radar Topography Mission

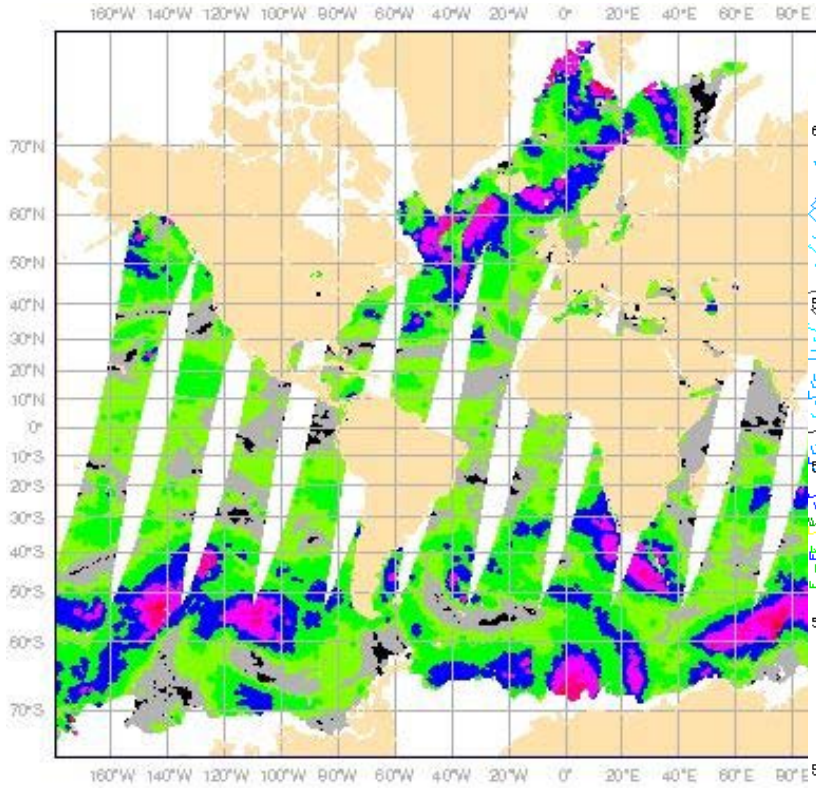


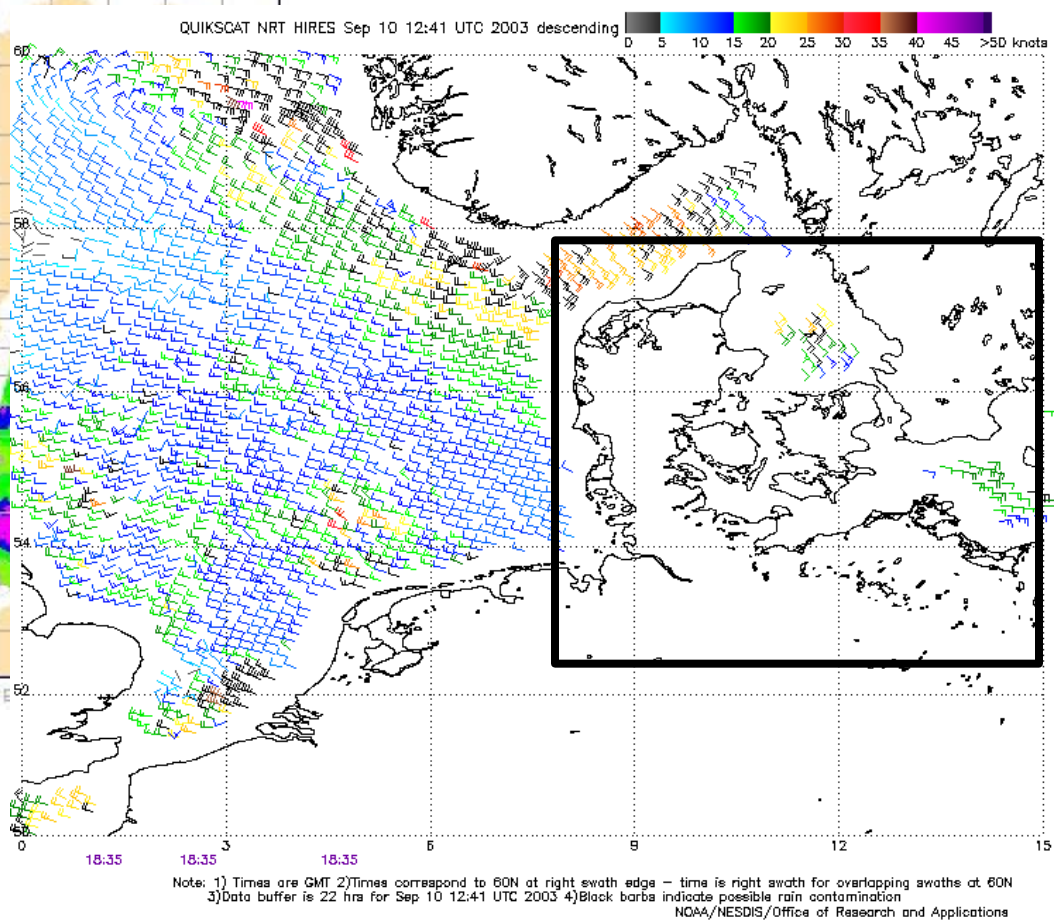
Courtesy: Niels Gylling Mortensen, DTU Wind Energy

Offshore

Source: http://www.4coffshore.com/offshorewind/

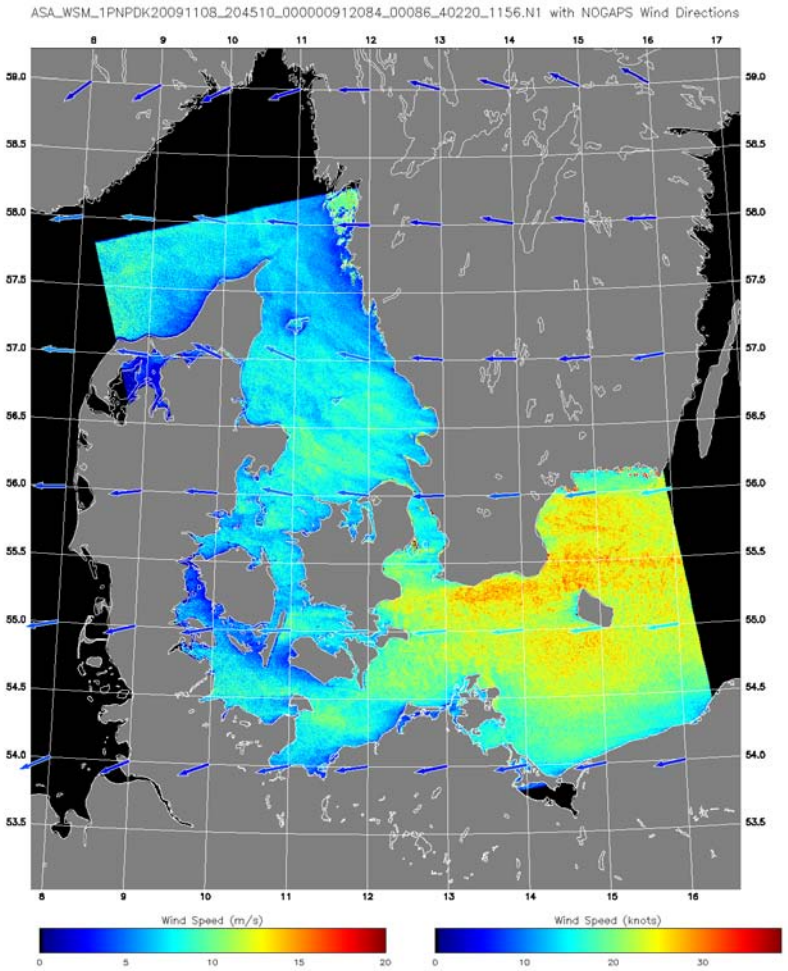
Satellite SAR wind ocean surface wind maps





QuikSCAT

Satellite SAR wind ocean surface wind maps



DTU Wind Energy
Johns Hopkins University

Envisat

FP7 project NORSEWIND at www.norsewind.eu contains offshore wind atlas for Northern European Seas based on 9000 Envisat ASAR wind maps valid at 10 m.

Research on lifting winds to hub-height is in progress.

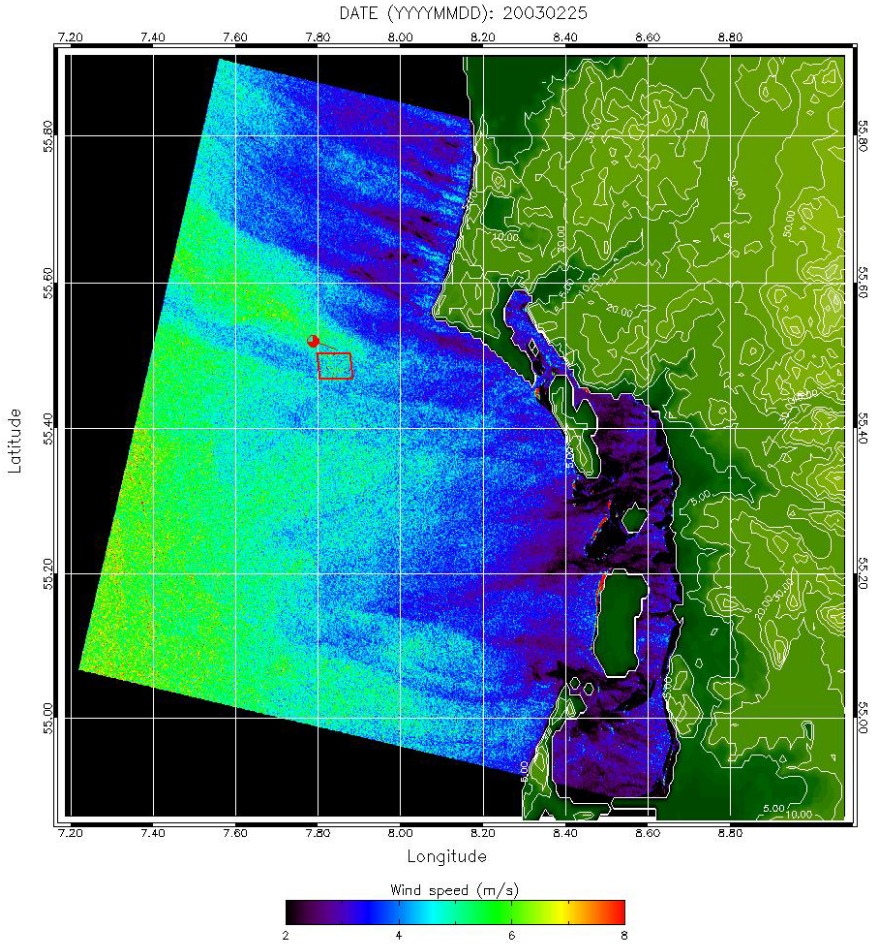
Wind farm wake observed from satellite

EERA DTOC

European Energy Research Alliance - Design Tools for Offshore Wind Farm Clusters

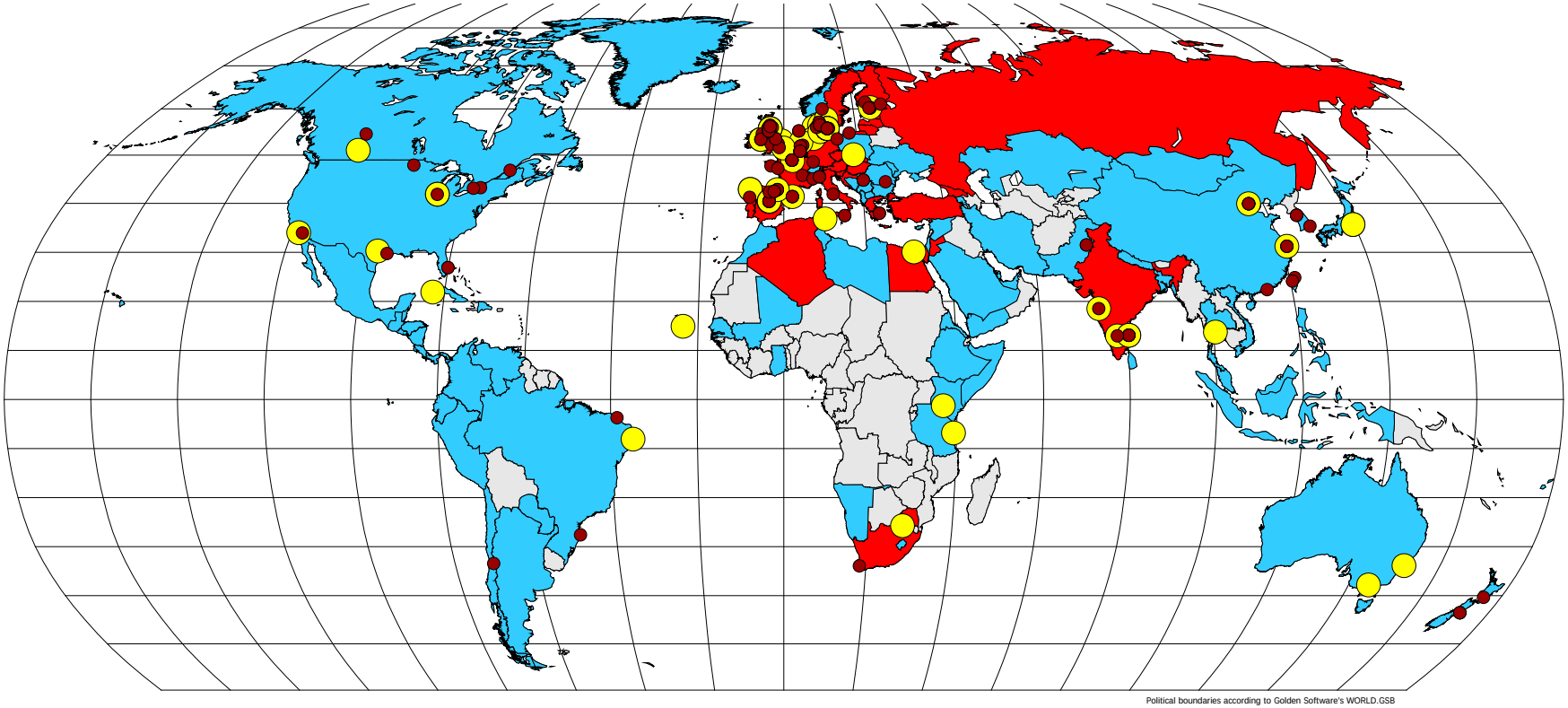
www.eera-dtoc.eu

FP7 project on wake and grid issues



Courtesy: Merete Badger, DTU Wind Energy

DTU Wind Energy: WAsP & WAsP Engineering



- WAsP/WEng software since 1987/2001
- More than 4000 licensed users
- Used in 110⁺ countries and territories

- WAsP/WEng courses since 1991/2001
- More than 100 courses in 25 countries
- 186 certified WAsP users in 27 countries

Summary

- Earth Observation data can be useful for the input to WAsP onshore.

- Earth Observation data can be useful for the offshore.