Why WASA – an introduction to the wind atlas method and some applications

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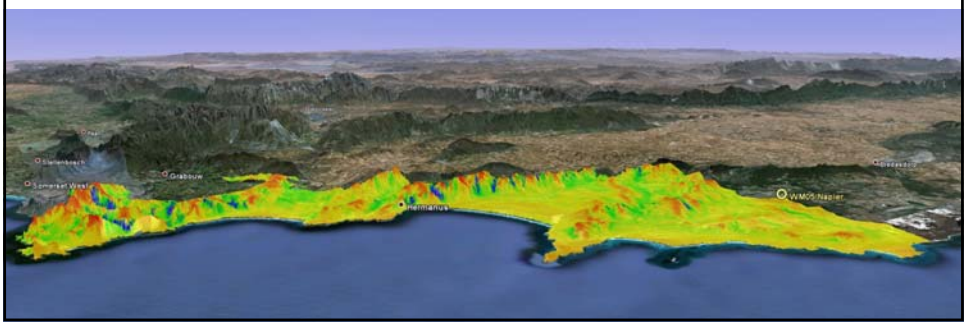
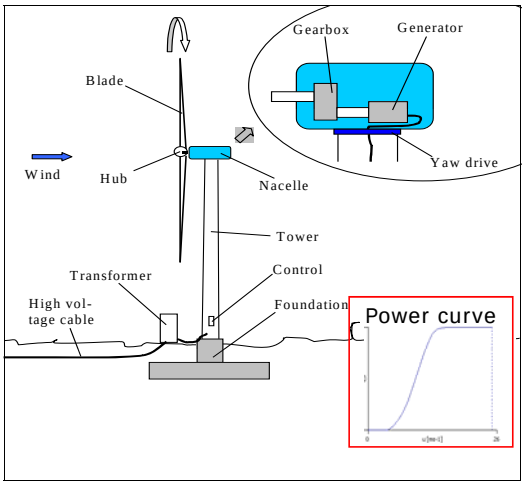


Outline

- Introduction - wind energy
- Challenges and needs - wind resources
- Why and how basics - wind atlas
- WASA Verified Numerical Wind Atlas (VNWA)
- Applications
  - Wind resource mapping and wind farm energy production estimation
  - Wind power planning and integration

- The WASA Work Packages
- The WASA Team

The wind turbine – air mass and speed



3 MW wind turbine

Nominal revolutions: 16 rpm

Weight
Nacelle: 70 t
Rotor: 41 t
Towers: 100 m - 250 t

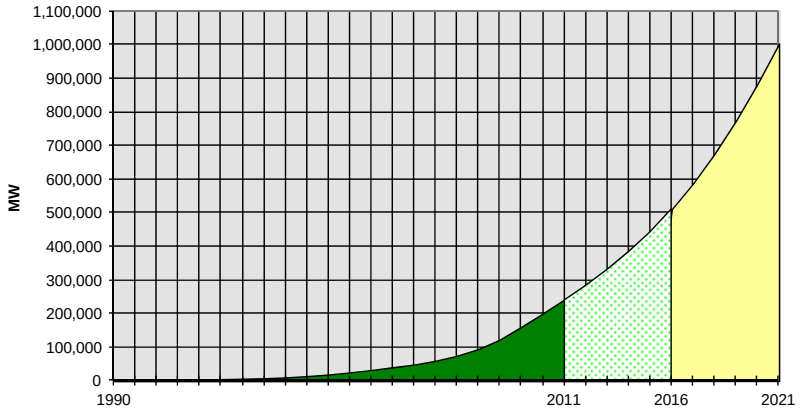
Rotor
Diameter: 90 m
Area swept: 6,362 m²

Football field: 68 x 105 = 7,140 m²

Mass flux at wind speed of 10 m/s:
10 x 6362 x 1.225 = **77935 kg/s**
at air density of 1.225 kg/m³

The challenge

Cumulative Global Wind Power Development
Actual 1990-2011 Forecast 2012-2016 Prediction 2017-2021



Source: BTM Consult - A Part of Navigant - March 2012

International wind turbine standards - IEC

a) Safety & functional requirements

↓

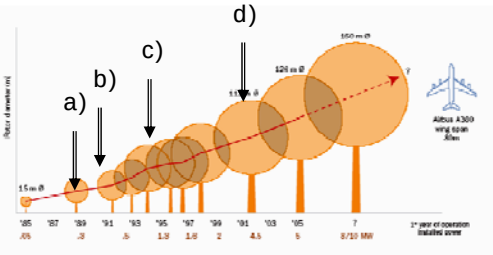
b) Test methods

↓

c) Certification procedures

↓

d) Interfaces & Component



IEC TC88: IEC 61400 series:

- IEC 61400-1 Design requirements
- IEC 61400-2 Small wind turbines
- IEC 61400-3 Design requirements for offshore wind turbines
- IEC 61400-4 Gears for wind turbines
- IEC 61400-(5) Wind Turbine Rotor Blades
- IEC 61400-11, Acoustic noise measurement techniques
- IEC 61400-12-1 Power performance measurements
- IEC 61400-13 Measurement of mechanical loads
- IEC 61400-14 Declaration of sound power level and tonality
- IEC 61400-21 Measurement of power quality characteristics
- IEC 61400-22 Conformity Testing and Certification of wind turbines
- IEC 61400-23 TR Full scale structural blade testing
- IEC 61400-24 TR Lightning protection
- IEC 61400-25-(1-6) Communication
- IEC 61400-26 TS Availability
- IEC 61400-27 Electrical simulation models for wind power generation

Wind energy – Global and Africa

Installed capacity in 2010 and 2011 (Global)

	Installed MW 2010	Accu. MW 2010	Installed MW 2011	Accu. MW 2011	% of installed MW 2011
Total Americas	6,639	46,990	9,573	56,563	22.9%
Total Europe	10,980	87,565	10,226	97,588	24.5%
Total South & East Asia	21,130	58,277	21,005	79,282	50.4%
Total OECD-Pacific	478	5,368	694	6,062	1.7%
Total Africa	98	1,112	133	1,245	0.3%
Total other continents and areas:	79	208	81.6	290	0.2%
Annual MW installed capacity	39,404		41,712		
Cumulative MW installed in the world		199,520		241,029	

Africa

Source: BTM Consult - A Part of Navigant - March 2012

Egypt	0	552	0	552
Morocco	9	263	29	292
Tunisia	87	247	30	277
Rest of Africa: Algeria, Cape Verde, Ethiopia, Libya, South Africa, etc.	2	51	74	125
Total Africa	98	1,112	133	1,245

Wind energy forecast – Global and Africa

Forecast for wind power development 2012-2016 (Global)

	Cumulative installed capacity (MW) by end of 2011	Installed capacity (MW) in 2011	Forecast 2012-2016 (incl. Offshore)					Installed capacity 2012-2016	Cumulative installed capacity (MW) by end of 2016
	2011	2011	2012	2013	2014	2015	2016	Sum	Accu.
Total Americas	56,563	9,573	11,450	11,700	13,850	14,850	17,350	69,200	125,763
Total Europe	97,588	10,226	11,100	13,075	13,625	16,500	18,750	73,050	170,638
Total South & East Asia	79,282	21,005	19,150	20,400	21,500	21,900	26,500	109,450	188,732
Total OECD-Pacific	6,045	694	900	1,500	2,000	2,650	3,050	10,100	16,145
Total other areas	1,553	215	595	1,130	1,585	2,280	2,455	8,045	9,598
Total MW new capacity every year:		41,712	43,195	47,805	52,560	58,180	68,105	269,845	510,874
Accu. capacity (MW)	241,029		284,224	332,029	384,589	442,769	510,874		

Africa

Source: BTM Consult - A Part of Navigant - March 2012

Introduction
Why wind energy and resource assessment

- Sustainability
- Power system - long term and large investments
- Value of location of best wind resources
- Temporal and spatial wind power distributions

- Traditional climatology, global models, wind data availability and quality - insufficient and inappropriate

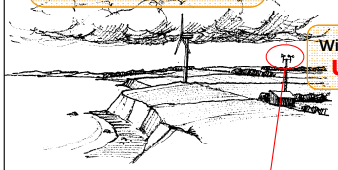
Authorities
Planners
Investors, owners and banks
Developers (small and large)
Industry (small and large)
Power sector
Consultants
Academic community

All need the Wind Atlas, using WAsP or similar micro-scale model to calculate estimated energy production from wind farms as part of project and planning decisions.

Why wind resource assessment - 2?

Energy in wind
$P = \frac{1}{2}\rho U^3$ [W/ m²]

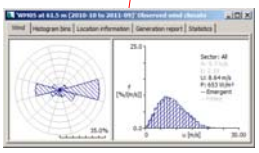
Wind speed
U [m/s]



Wind provides the income in cost-benefit

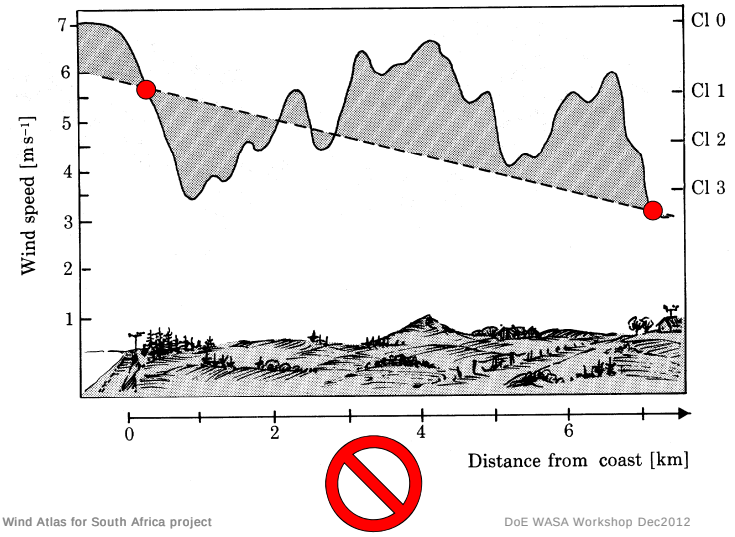
- Investment costs
- Operation and maintenance costs
- Electricity production ~ Wind resources
- Turbine lifetime
- Discount rate
- Environmental benefits

10% error on speed ⇨ 30% error on energy



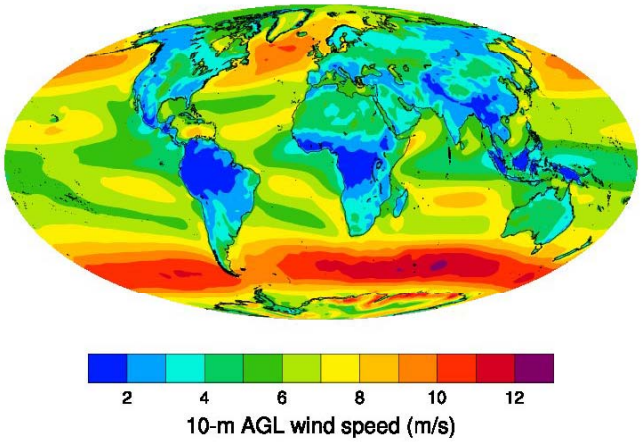
Modelling is necessary and it must be good

Measurements + Linear interpolation = NO



Why wind resource assessment - 1?

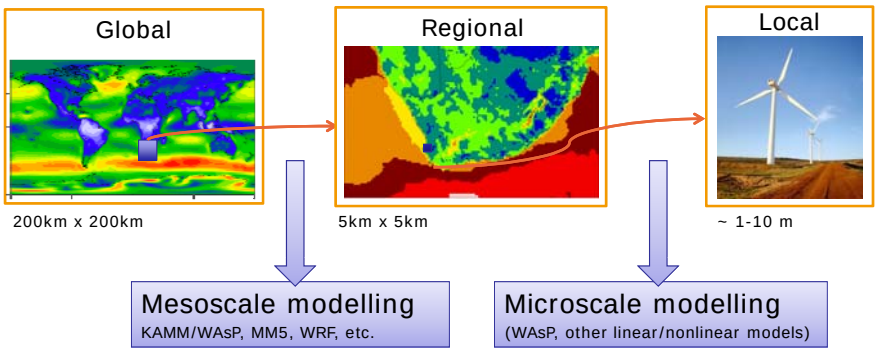
Traditional climatology and global models (GCM) do not provide the answer



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

Numerical Wind Atlas

Downscaling from global reanalysis data



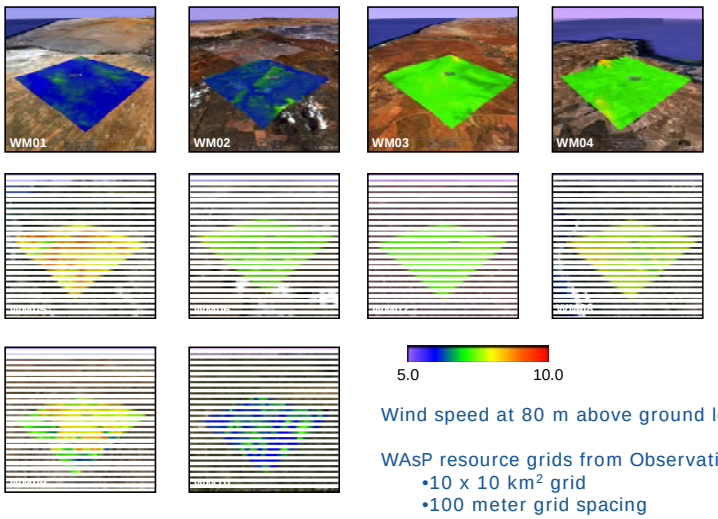
10 WASA masts
2 years of data by 30 Sep 2012

2 YEARS period 2010-10-01 to 2012-09-30; except WM09 and WM10 for which 1 YEAR is available with data recovery above 90% as indicated.

WASA	U_{mean} @ 61.5m - 1 YEAR	U_{mean} @ 61.5m - 2 YEARS*	ΔU	Data recovery
	(m/s)	(m/s)	%	%
WM01	5.86	6.02	2.7	100
WM02	6.21	6.10	-1.8	100
WM03	7.09	7.09	0.0	100
WM04	6.59	6.65	0.9	100
WM05	8.64	8.57	-0.8	97.9
WM06	7.02	7.13	1.6	100
WM07	6.85	6.87	0.3	100
WM08	7.36	7.38	0.3	100
WM09*	7.58	7.81	3.0	98.1
WM10*	6.55	6.55	0.0	92.4

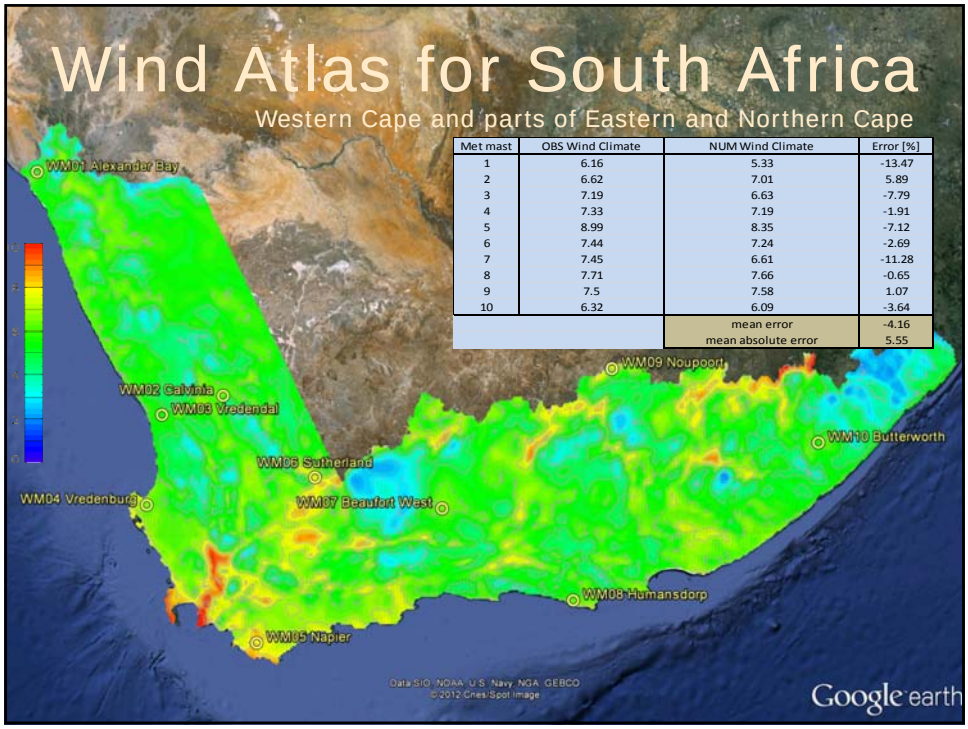
* Not a 2-years period for WM09 and WM10
WM09: 2010-09-01 to 2011-07-31 plus August 2012,
WM10: 2010-10-01 to 2011-09-30.

Observational Wind Atlas (OWA)
database and report available through
wasadata.csir.co.za/wasa1/WASAData



Wind speed at 80 m above ground level

WAsP resource grids from Observational Wind Atlas
- 10 x 10 km^2 grid
- 100 meter grid spacing

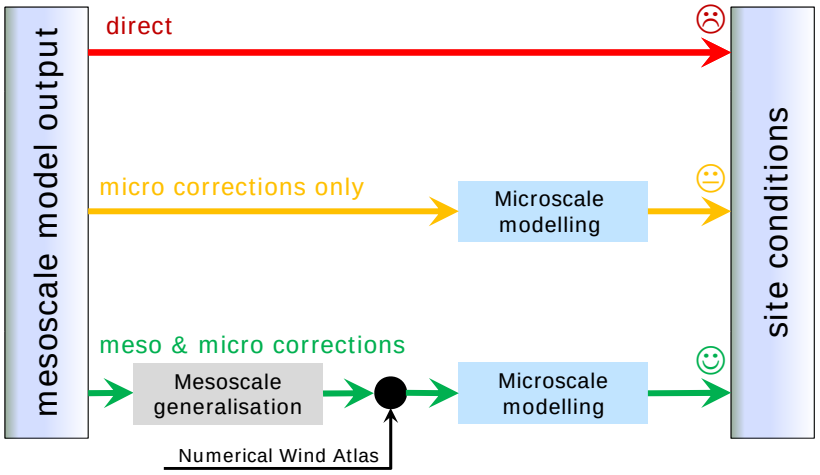


Met mast	OBS Wind Climate	NUM Wind Climate	Error [%]
1	6.16	5.33	-13.47
2	6.62	7.01	5.89
3	7.19	6.63	-7.79
4	7.33	7.19	-1.91
5	8.99	8.35	-7.12
6	7.44	7.24	-2.69
7	7.45	6.61	-11.28
8	7.71	7.66	-0.65
9	7.5	7.58	1.07
10	6.32	6.09	-3.64
		mean error	-4.16
		mean absolute error	5.55

Applications

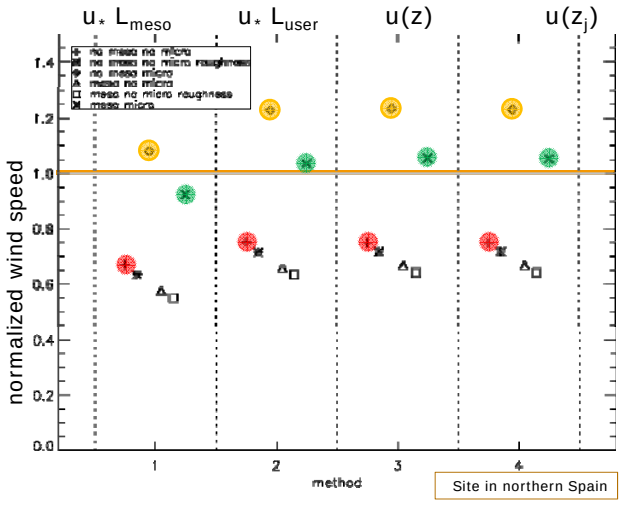
- Wind resource assessment
- Wind farm energy production estimation

From mesoscale model to site conditions



Verification of mean wind speed

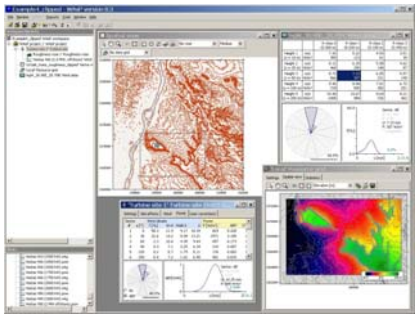
Mesoscale 'local' corrections and microscale local corrections give best agreement with measurements



Application at high resolution

Wind climate

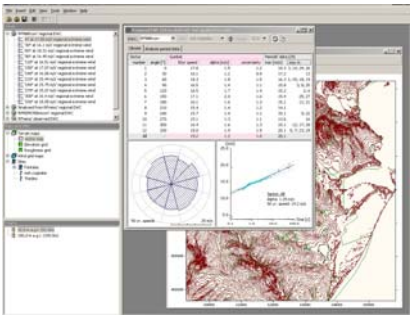
WAsP



Design wind conditions

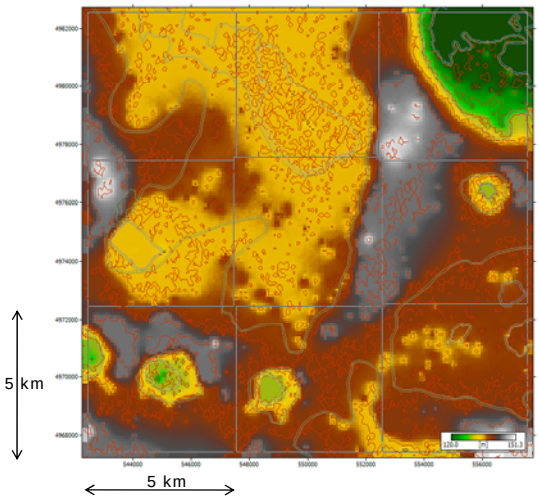
Extremes and turbulence

WAsP Engineering



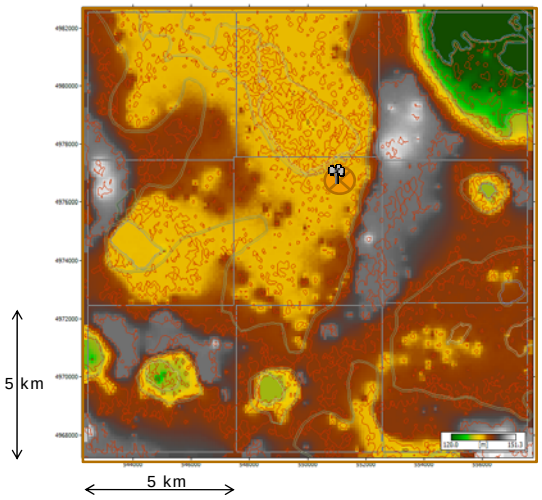
Application – wind resources

Terrain – digitised orography and roughness



Application – wind resources

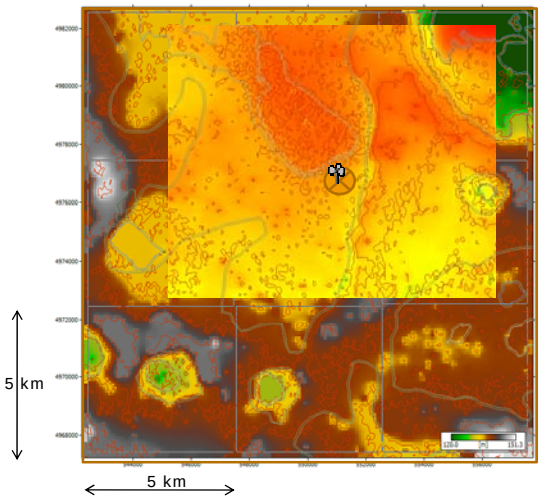
Mast – Observed Wind Climate and Observed Wind Atlas



Wind Atlas for South Africa project

Application – wind resources

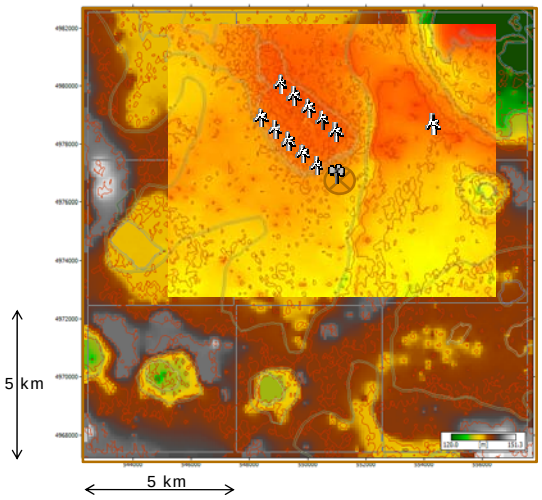
Wind resource – wind predicted from Mast



Wind Atlas for South Africa project

Application – wind resources

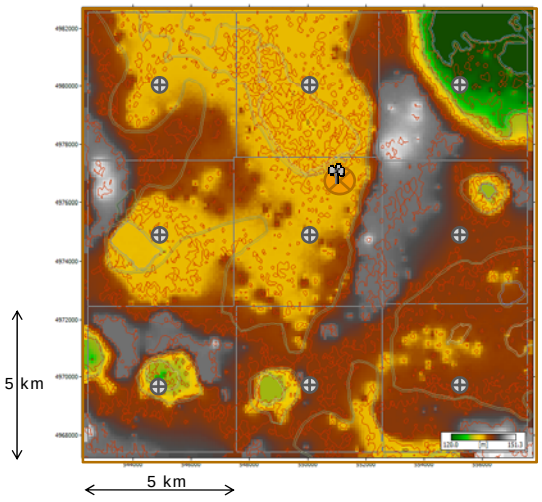
Wind farm at mast – AEP and IEC



Wind Atlas for South Africa project

Application – wind resources

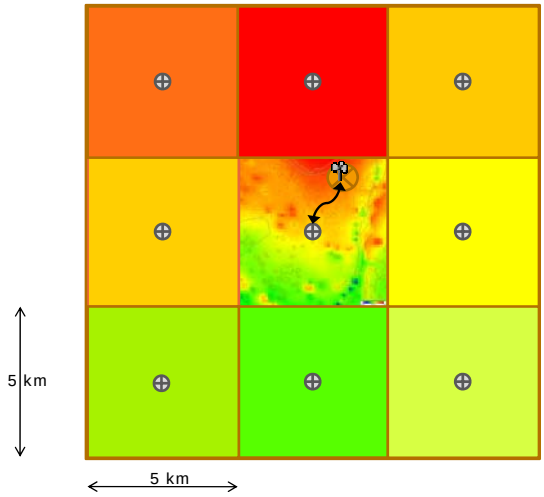
Mesoscale modelling – 5 km x 5 km grid



Wind Atlas for South Africa project

Application – wind resources

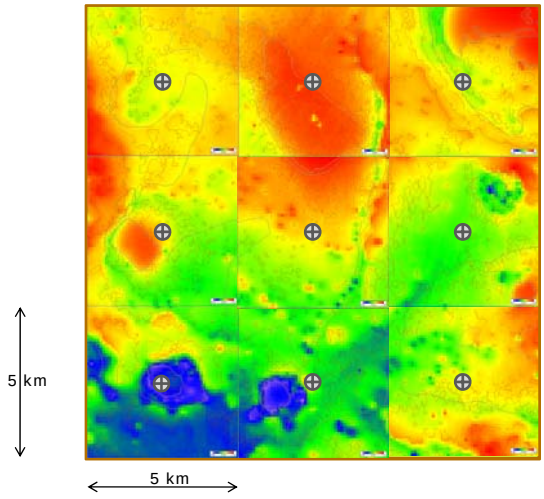
VERIFICATION – compare Numerical Wind Atlas for nearest cell to measurements



Wind Atlas for South Africa project

Application – wind resources

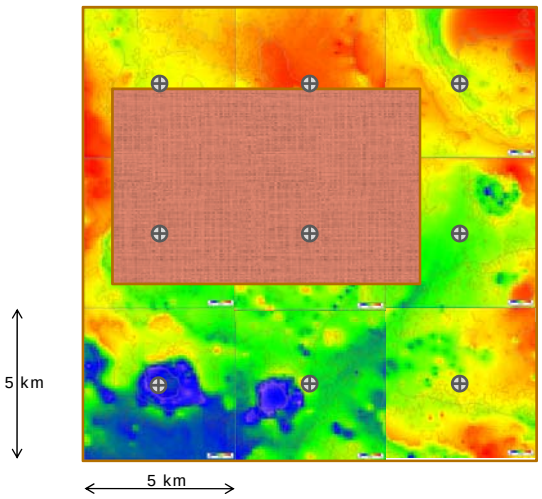
Numerical Wind Atlas applied in each cell



Wind Atlas for South Africa project

Application – wind resources

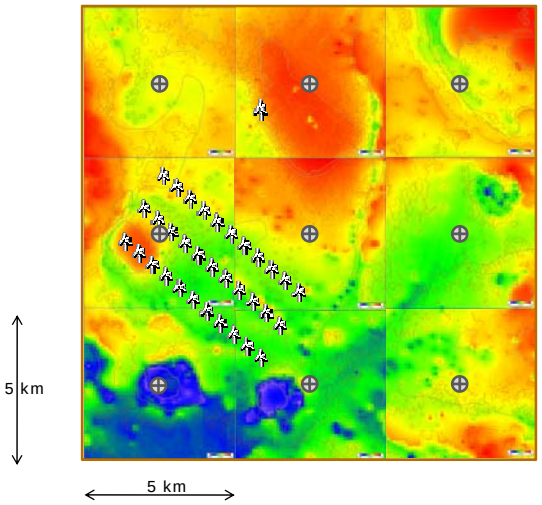
Planning anywhere in WASA domain



Wind Atlas for South Africa project

Application – wind resources

Wind farm projects – bankability ??



Wind Atlas for South Africa project

Applications

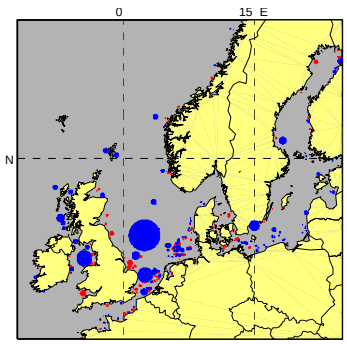
- Wind power planning and integration in power systems

Wind Power Variability
Offshore North Europe 2020 and 2030

TWENTIES WP16.2 – DTU study using Corwind and WRF

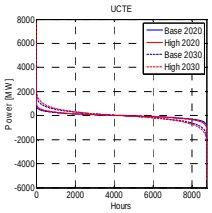
Scenarios - 379 wind farms

Power System Areas	2020 in MW		2030 in MW	
	Base	High	Base	High
UCTE	21,421	27,675	52,590	69,454
Nordel	4,924	7,019	15,009	20,512
UK+IR	15,130	21,500	37,920	52,090
Total	41,475	5,6194	185,519	142,056

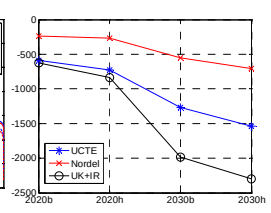


Variability

- 30 annual wind power time series for each area and each scenario
- Ramp rate - 15 min change in mean wind power production



Wind power duration curve



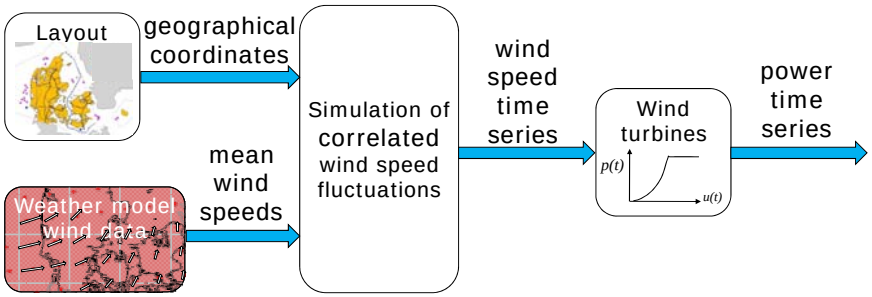
99% percentiles ramping

Power system area	2020		2030	
	Baseline	High	Baseline	High
UCTE	3%	3%	2%	2%
Nordic	5%	4%	4%	3%
UK+IR	4%	4%	5%	4%

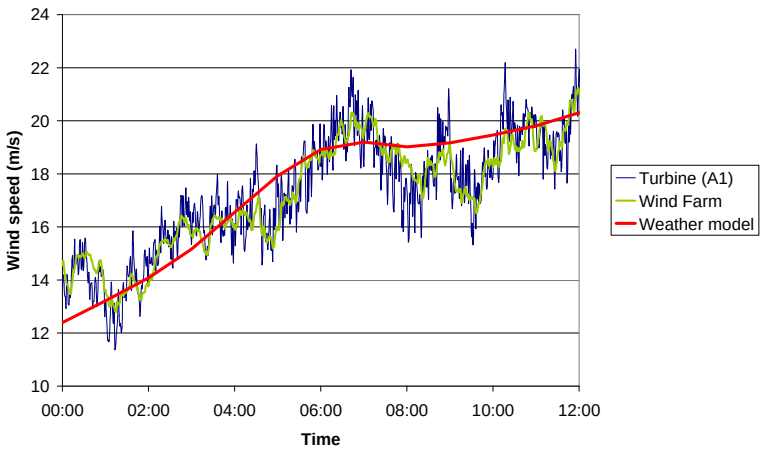
99% percentiles normalized wind power ramp rates

Corwind methodology

- Adds correlated random fluctuations to mean values calculated with mesoscale weather model

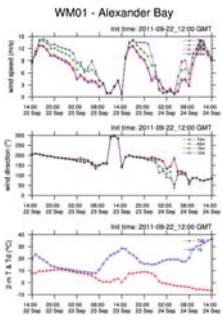


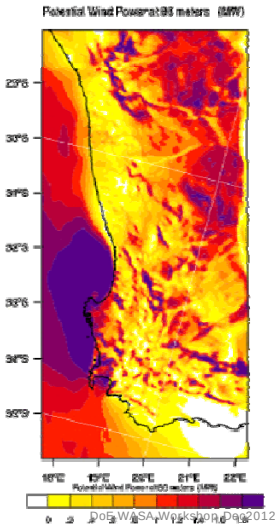
Corwind wind speed output example



Mesoscale modelling

- Daily wind forecasts to understand wind regimes. WRF wind forecasts: http://veaonline.risoe.dk/wasa
- Setup and run of mesoscale models
- Verification against data from the 10 WASA met stations
- Release of first verified version in February 2012





Acknowledgements

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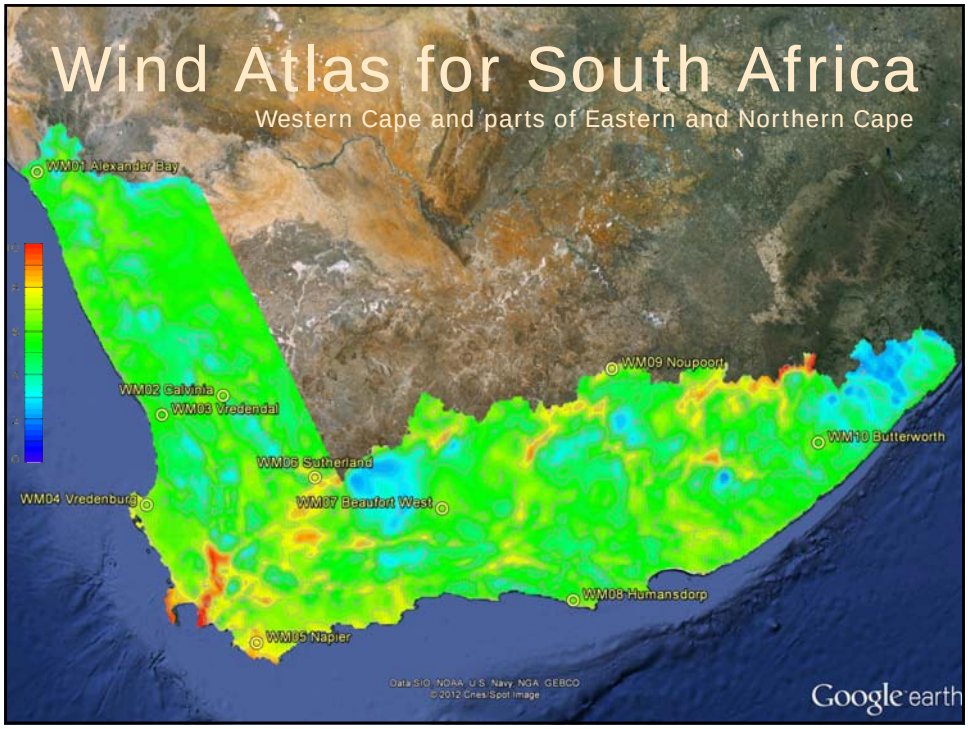
- UNDP-GEF through South African Wind Energy Programme (SAWEP)
- Royal Danish Embassy

WASA Project Steering Committee:

DoE (chair), DEA, DST, UNDP, Danish Embassy, SANEDI



Wind Atlas for South Africa (WASA)
Western Cape and areas of Northern and Eastern Cape

Work Packages

- **WP1 – Mesoscale wind modelling**
- **WP2 – Wind measurements**
- **WP3 – Micro scale wind modelling**
- **WP4 – Application for wind resource assessment**
- **WP5 – Extreme winds**
- **WP6 – Documentation and dissemination**

The WASA Project Team

- SANEDI *(South African National Energy Development Institute)*
  - executing agency – contracting the implementing partners
  - coordination and dissemination
- UCT CSAG *(Climate System Analysis Group, University of Cape Town)*
  - mesoscale modelling
- CSIR *(Built Environment, Council for Scientific and Industrial Research)*
  - measurements and microscale modelling
- SAWS *(South African Weather Service)*
  - extreme wind assessment
- DTU Wind Energy *(Dept of Wind Energy, Technical University of Denmark)*
  - partner in all activities

WASA Demonstration

1) www.wasa.csir.co.za
   - *Overview of site*
   - *Online graphical data and station descriptions (status)*
   - *Data download site*
   - *Registration*
   - *Reports and guides*
   - *How to download measured data from the 10 WASA masts*
   - *How to access and download VNWA lib-files*
2) How to make a wind resource tile
3) How does microscale and mesoscale compare
4) How to apply the VNWA to a wind farm project