A comparative and quantitative assessment of South Africa's wind resource – the WASA project

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A comparative and quantitative assessment of South Africa's wind resource – the WASA project

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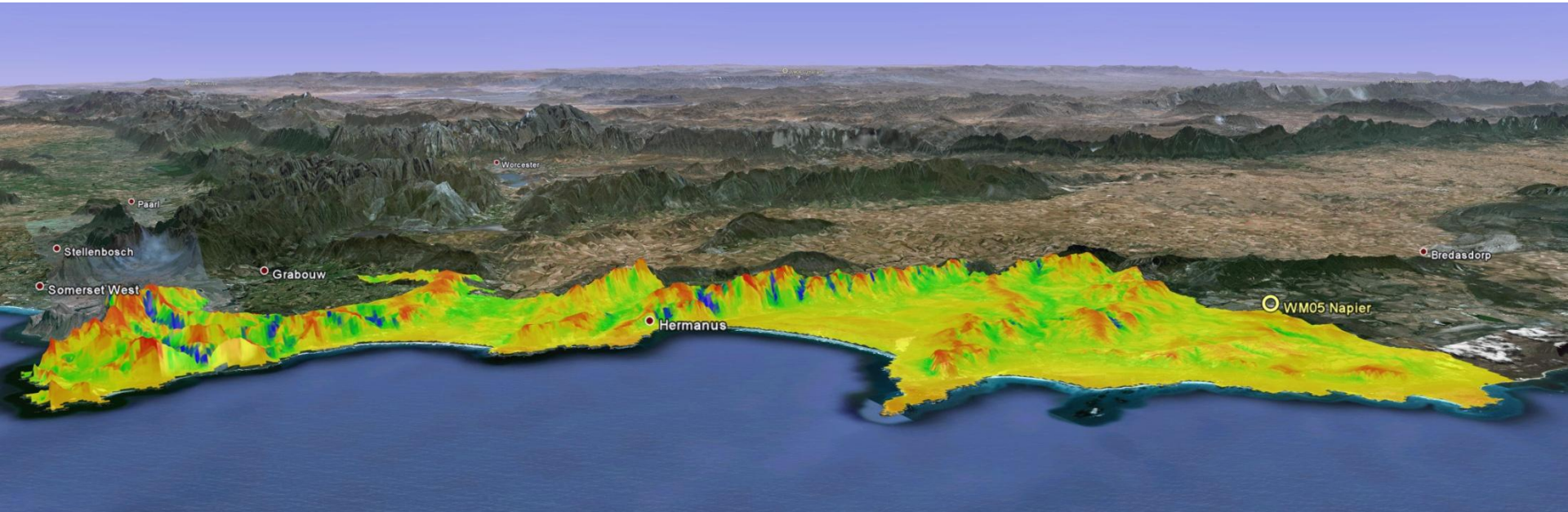
Windaba 2011, Cape Town, South Africa



Acknowledgements

The Wind Atlas for South Africa (WASA) project is an initiative of the South African Government - Department of Minerals and Energy (now DoE) and the project is co-funded by

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

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CSIR, UCT, SAWS, and Risø DTU

Introduction and outline

- Wind Atlas for South Africa (WASA)
  - WASA project overview
  - Mesoscale modelling
  - Extreme wind climate
  - Measurements at 10 WASA masts
  - Microscale modelling

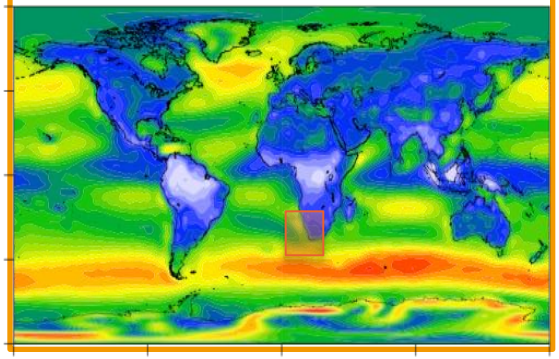
- Preliminary assessment of South Africa's wind resource
  - Capacity factors and potential
  - South Africa compared to other countries

- WASA plans and milestones

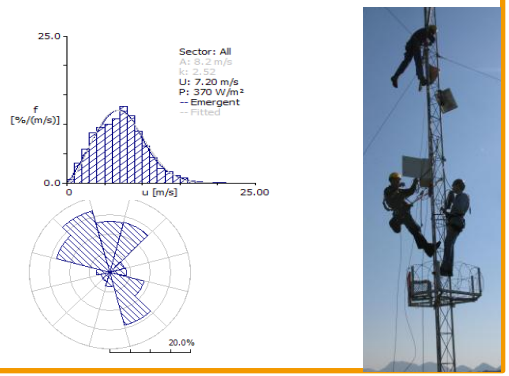
- Concluding remarks

Wind Atlas for South Africa (WASA) project overview

Global



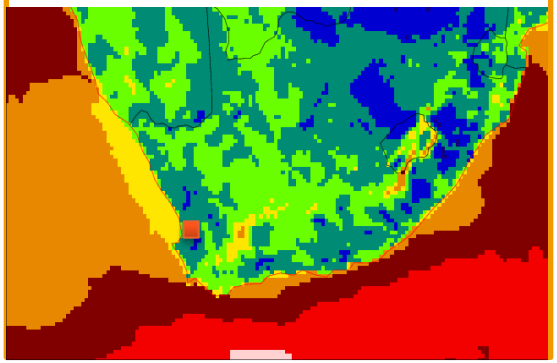
Measurements



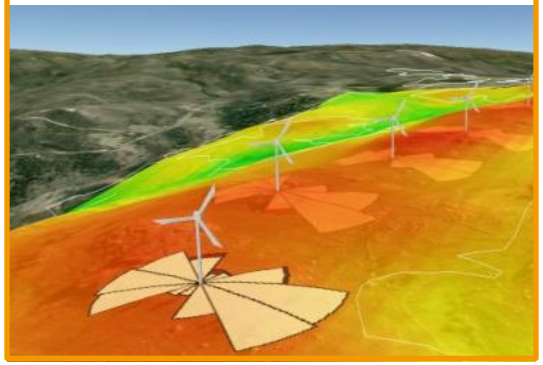
Mesoscale modeling

Microscale modeling

Regional wind climate



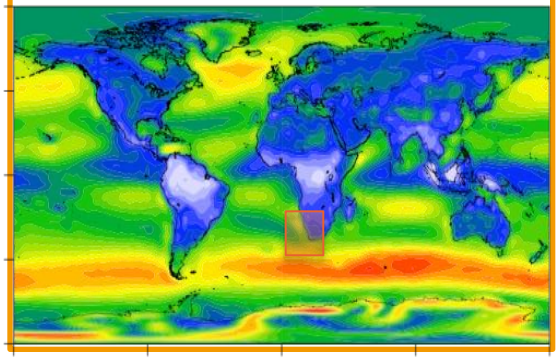
Local wind



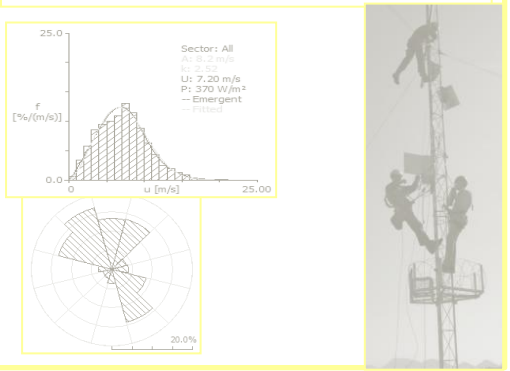
wind farm

Wind Atlas for South Africa (WASA)

Global



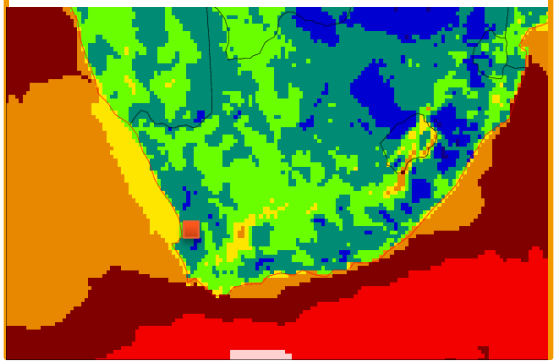
Measurements



Mesoscale modeling

Microscale modeling

Regional wind climate

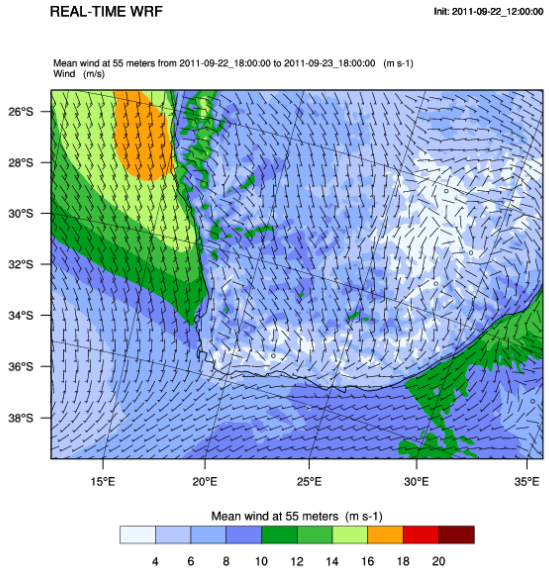


Local wind

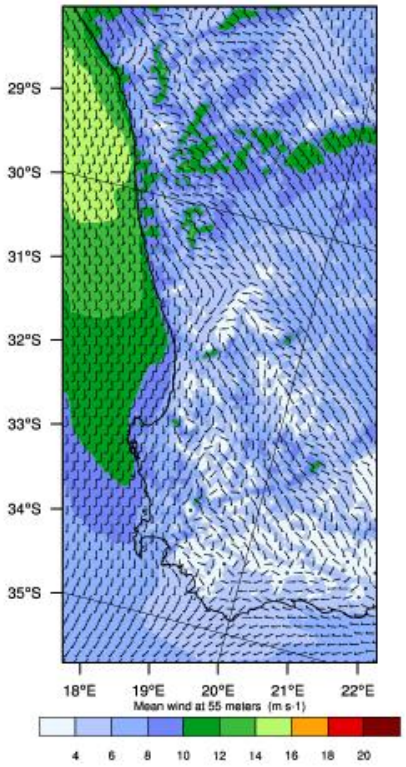
wind farm

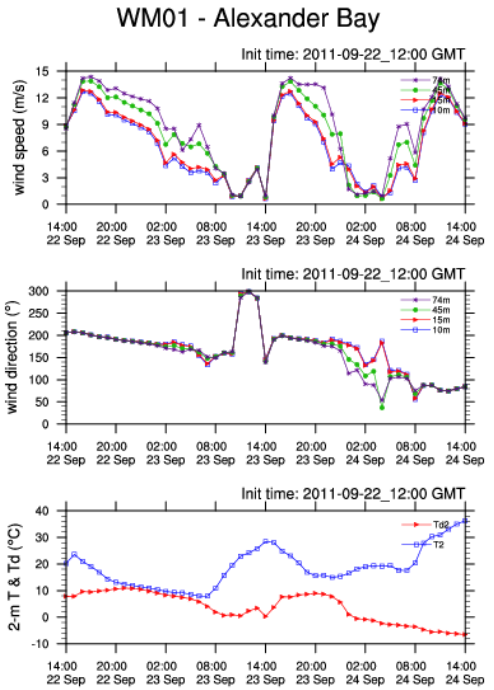
Mesoscale modelling

- Since 2009, UCT and Risø DTU have run daily wind forecasts (see examples on the right) over South Africa to understand the different wind regimes that occur over this region (Forecast images may be released subject to approval and disclaimer).
- This knowledge will help in the setup of the models being used in the wind resource assessment for South Africa (phase 2 commencing Jan2012).
- Work in progress:
  - Wind resource atlas using previously validated method developed by Risø DTU
  - Verification against the 10 WASA met stations
  - Release is scheduled for Feb2012.



Daily-averaged wind speed

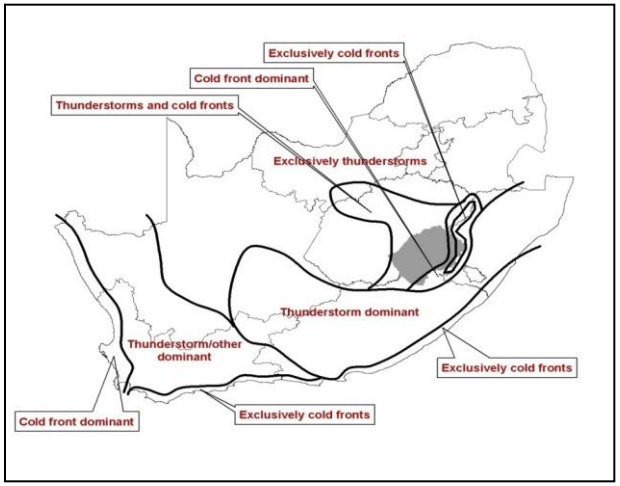




Extreme wind climate

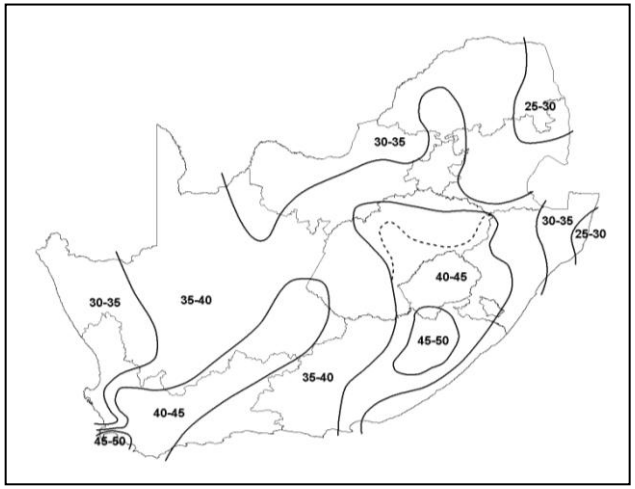
- Information on extreme winds essential in the design of wind farms – situated in areas with relatively strong winds
- Estimations from observations
- Long measuring periods and density of measurements should be adequate.

Some Results



Dominance of strong wind mechanisms on gust time-scale.

1:50 year gust quantiles from observed data.

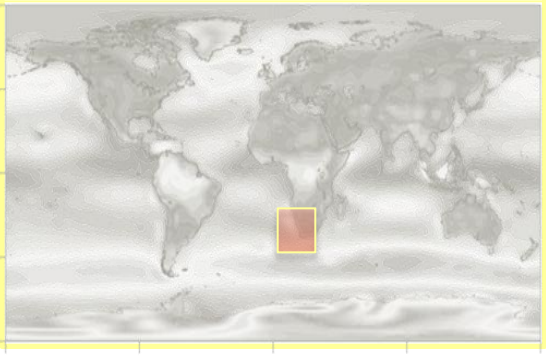


- Work in progress:

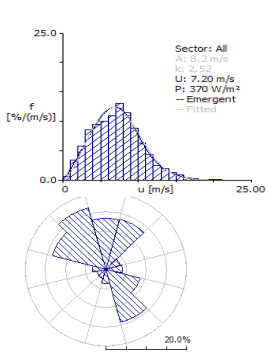
  Use of global reanalysis data, mesoscale modeling, SAWS data, WASA data and microscale modeling

Wind Atlas for South Africa (WASA)

Global



Measurements



Mesoscale modeling

Microscale modeling

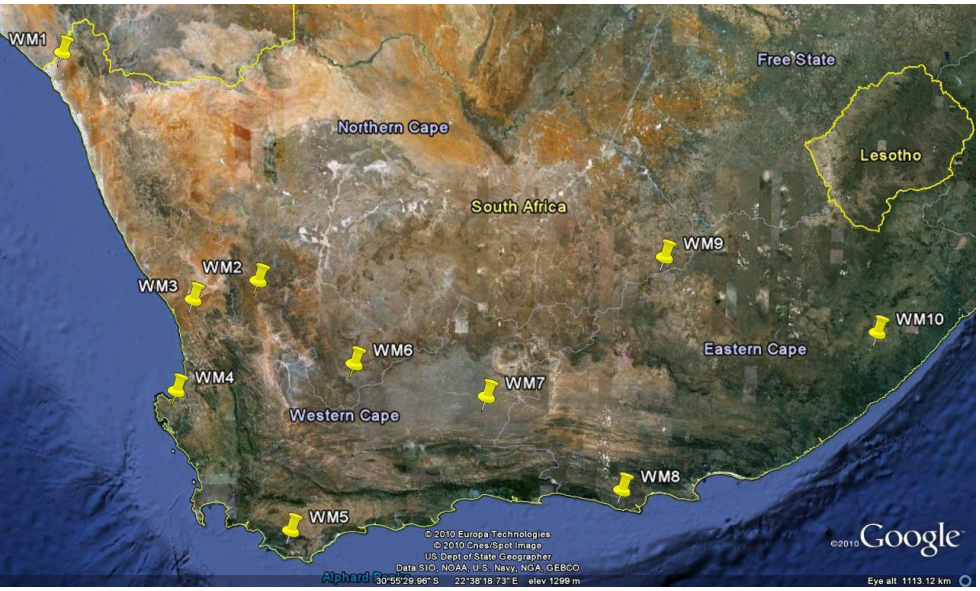
wind farm

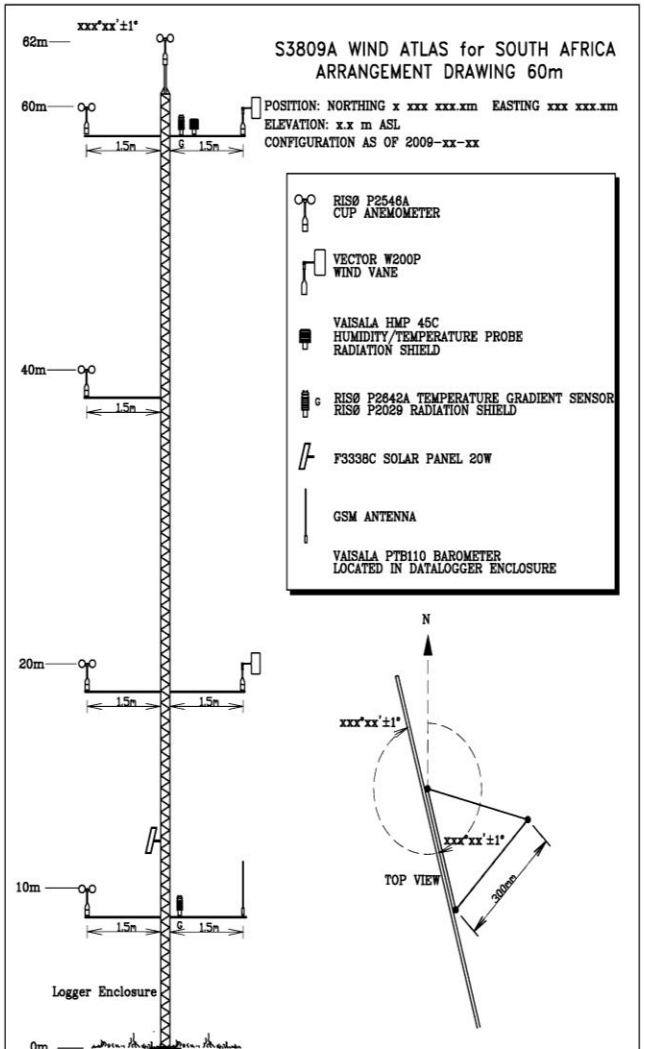
Regional wind climate

Local wind

Wind Atlas for South Africa – 10 WASA masts

10 minutes data and graphs available online on the project web site at CSIR:
http://www.wasa.csir.co.za





Measurements progress and status

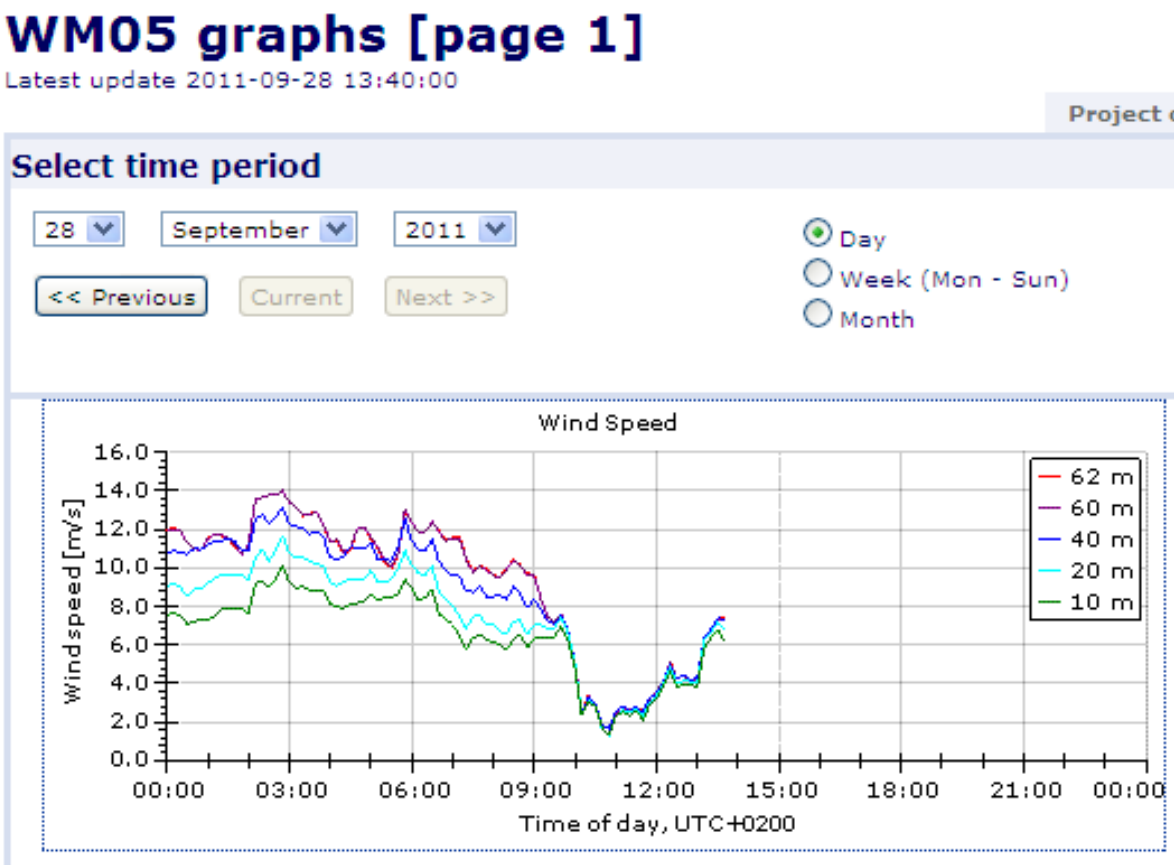
- First full year of measurements from the 10 WASA masts
- Station and site inspections carried out and report soon on data site
- Very good data recovery rate
  - theft of solar panel and cables at WM10,
  - collapse of WM09 mast
- One full year of validated data from 10 sites for the period Sep2010-Aug2011 (WM09 has 11 months, WM06 has 11½ months)

WASA	Data recovery Sep10-Aug11 (%)	U_{mean} @ 61.5m (m/s)
WM01	100.0	5.80
WM02	100.0	6.26
WM03	100.0	7.04
WM04	100.0	6.61
WM05	95.8	8.59
WM06	95.5	7.13
WM07	100.0	6.85
WM08	100.0	7.28
WM09	89.6	7.66
WM10	92.4	6.64

WASA data – user statistics
http://www.wasa.csir.co.za

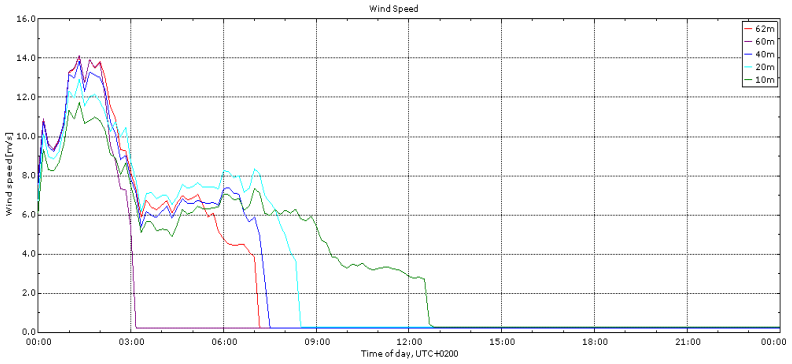
- 361 users registered
- 300+ users downloaded data
- 29 Countries

– Australia	– Lesotho
– Belgium	– Mozambique
– Brazil	– Namibia
– Canada	– Netherlands
– China	– Norway
– Denmark	– Pakistan
– Finland	– Portugal
– France	– South Africa
– Germany	– Spain
– Greece	– Sudan
– Hong Kong	– Sweden
– India	– Switzerland
– Ireland	– UK
– Italy	– USA
– Korea, South	



Data loss at WM09, NOUPOORT

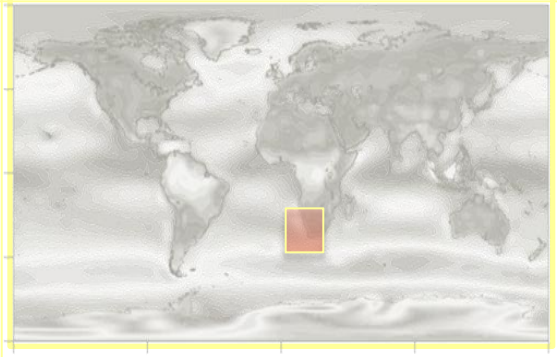
- Anemometers stopped working 25 July
- Data communication terminated 26 July
- Heaviest snowfalls in the region for 30y (photos taken at 1400m a.s.l.; wind mast is at 1800m a.s.l.)
- Site visit only possible 16 August
- Top section of mast collapsed, damaging most instruments
- Assessment ongoing and conclusion not yet available
- New mast expected before end of year



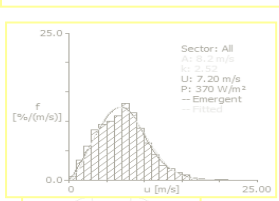
Snow photos: S. Erasmus

Wind Atlas for South Africa (WASA)

Global



Measurements

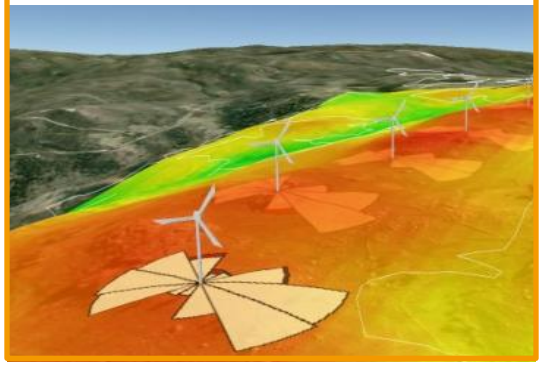


Mesoscale modeling

Microscale modeling

Regional wind climate

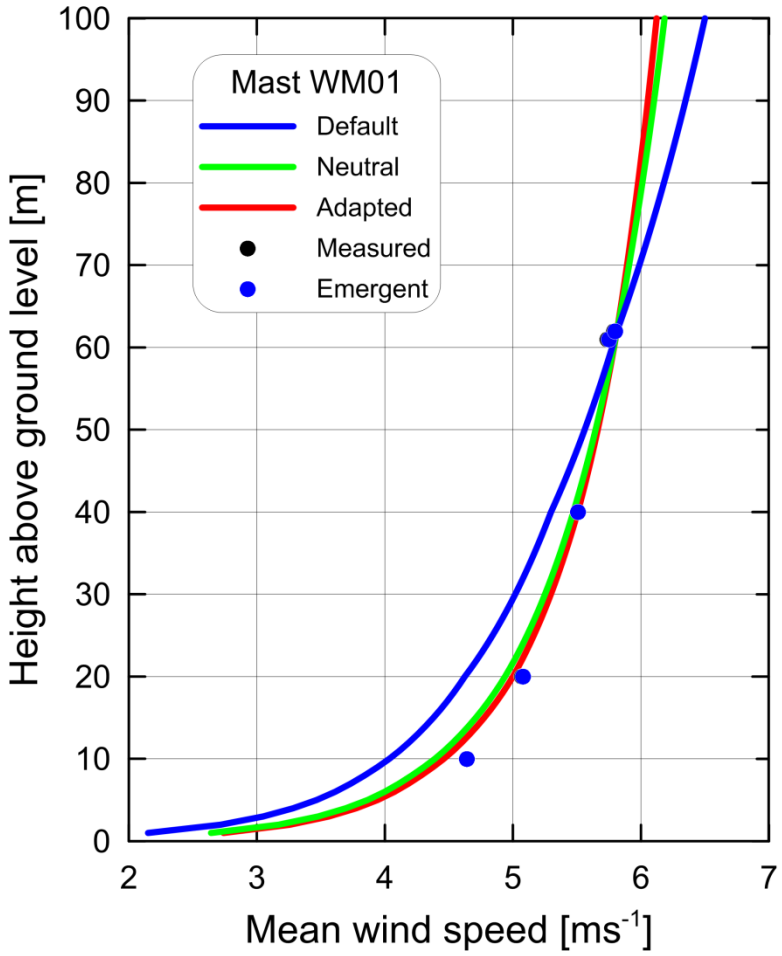
Local wind



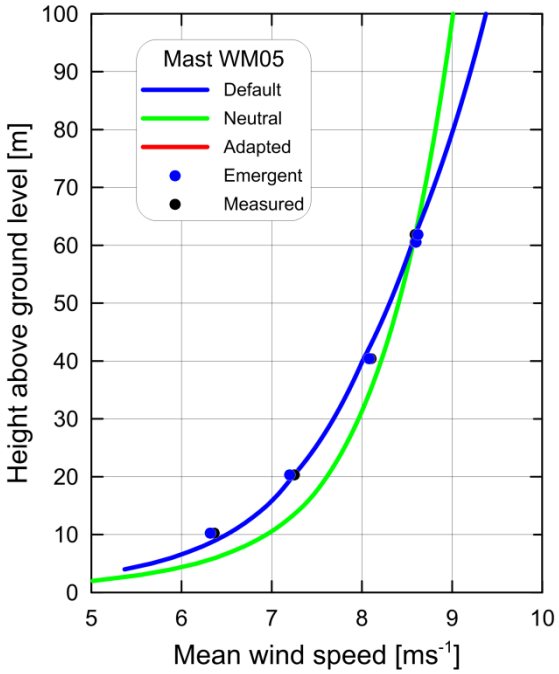
wind farm

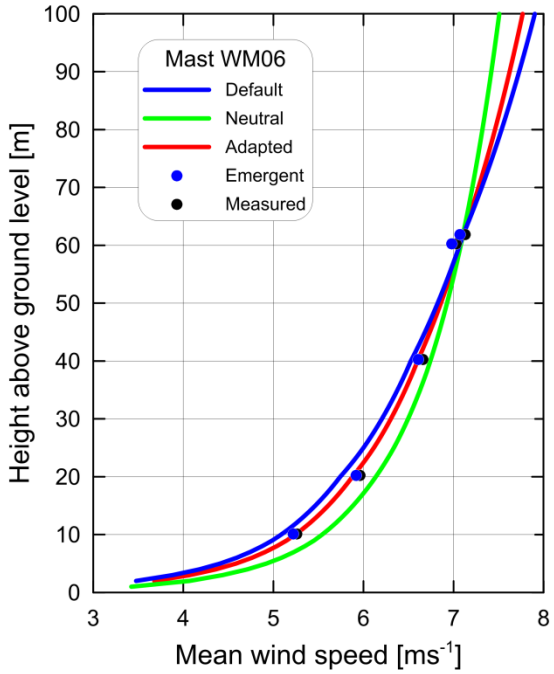
Microscale modelling at the 10 WASA masts

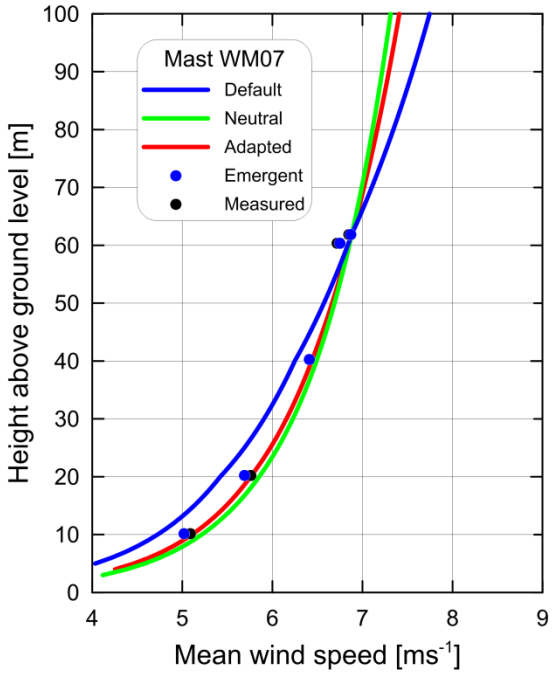
- Wind-climatological inputs
  - One-years-worth of wind data
  - Five levels of anemometry
- Topographical inputs
  - Elevation maps (SRTM 3 data)
  - Simple land cover maps (SWBD + Google Earth); water + land
- Preliminary results
  - Microscale modelling verification
    - Site and station inspection
    - Simple land cover classification
    - Adapted heat flux values
  - Wind atlas data sets from 10 sites



Measured and modelled wind profiles







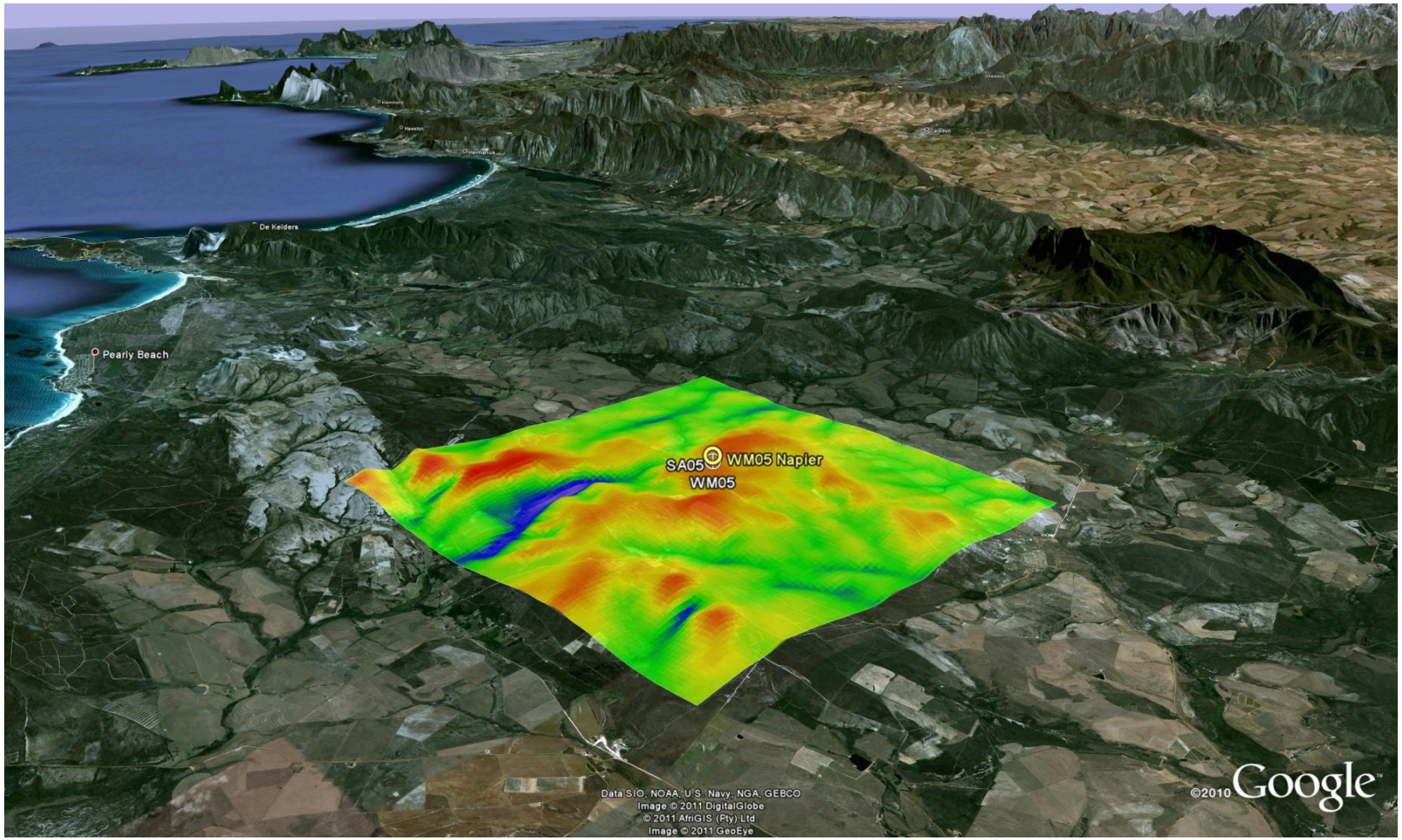
WM05 Napier
Elevation: 288 m
MAPE: 1.0%

WM06 Sutherland
Elevation: 1581 m
MAPE: 0.6%

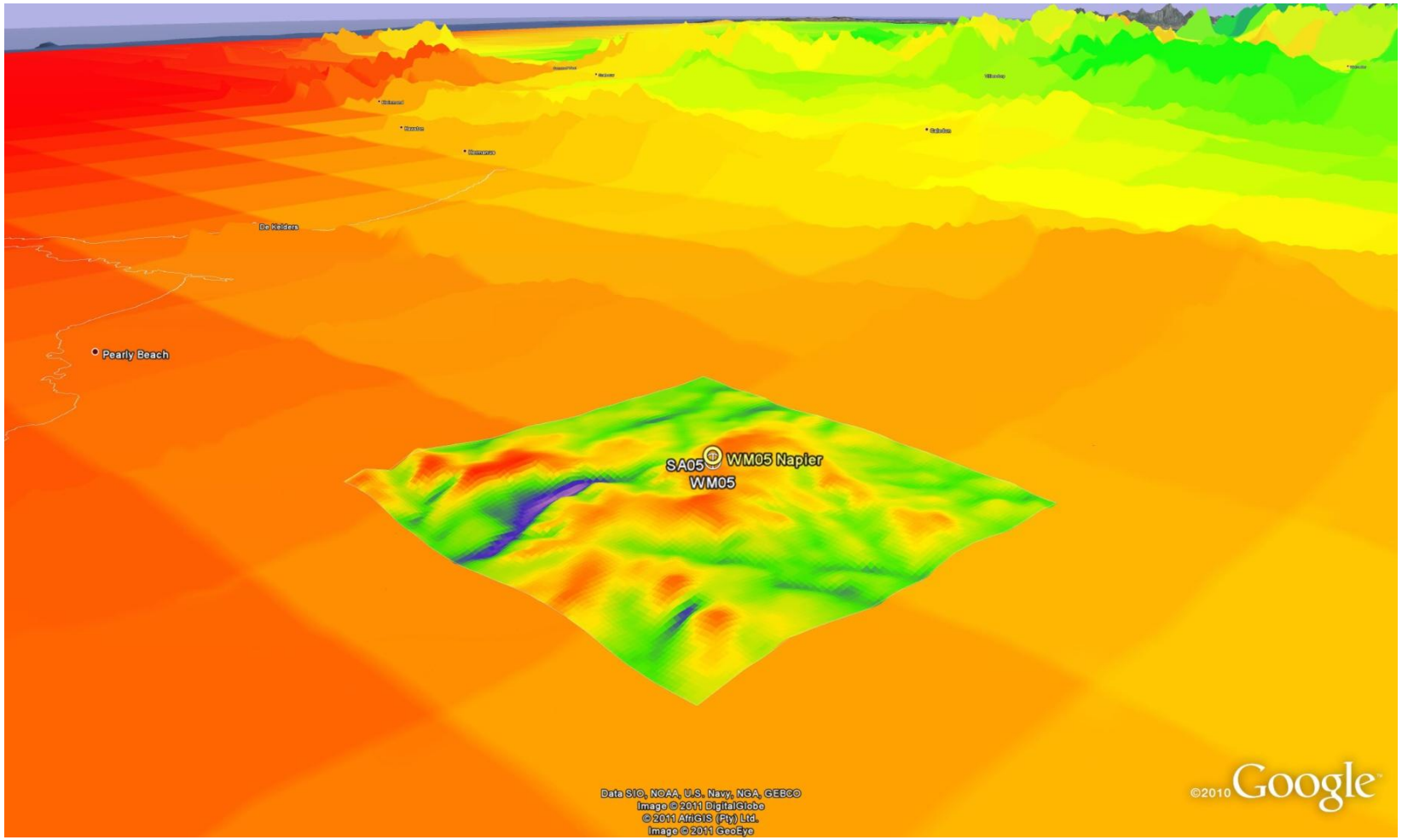
WM07 Beaufort W
Elevation: 1047 m
MAPE: 1.0%

MAPE - Mean Absolute Percentage Error

WM05 Napier resource grid

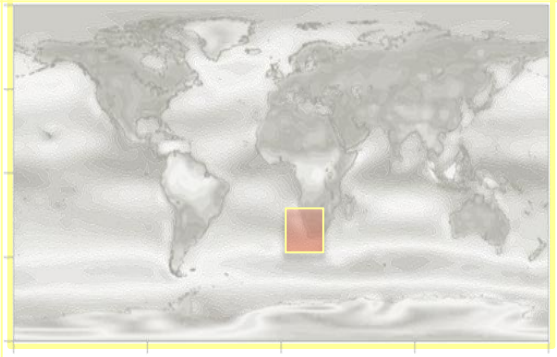


WM05 Napier resource grid

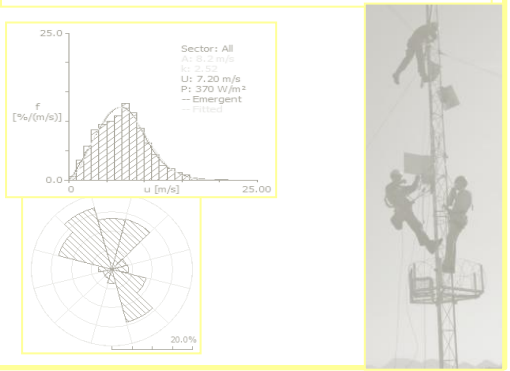


Wind Atlas for South Africa (WASA)

Global



Measurements



Mesoscale modeling

Microscale modeling

Regional wind climate

Local wind

wind farm

Preliminary assessment of SA's wind resource

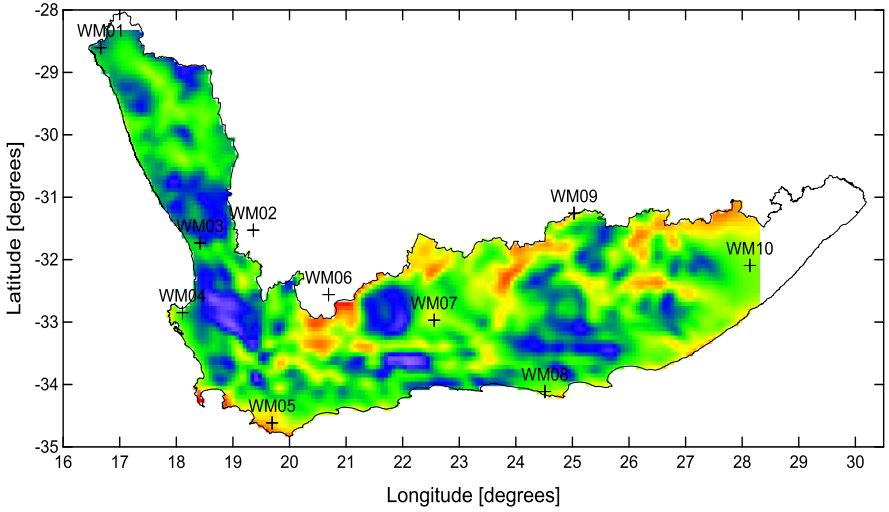
- SA's wind resource compared to other countries?
- What capacity factors should be possible?
- Large-scale wind energy developments?

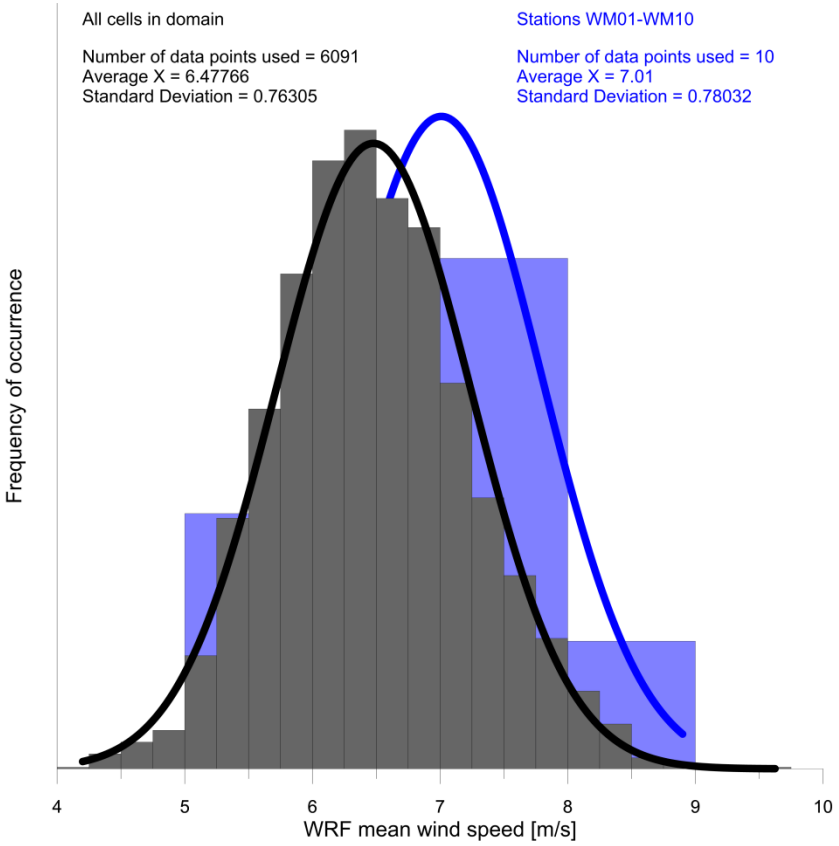
Comparisons and discussion of

- Representativeness of data
- Capacity factors (and some thoughts re. cost of energy)
- South Africa compared to other countries

How well do the mast sites represent SA?

Mesoscale mean wind speed @ 80 m. WRF model for 2010 @ 7.5 km grid resolution.





Capacity factors – worldwide averages

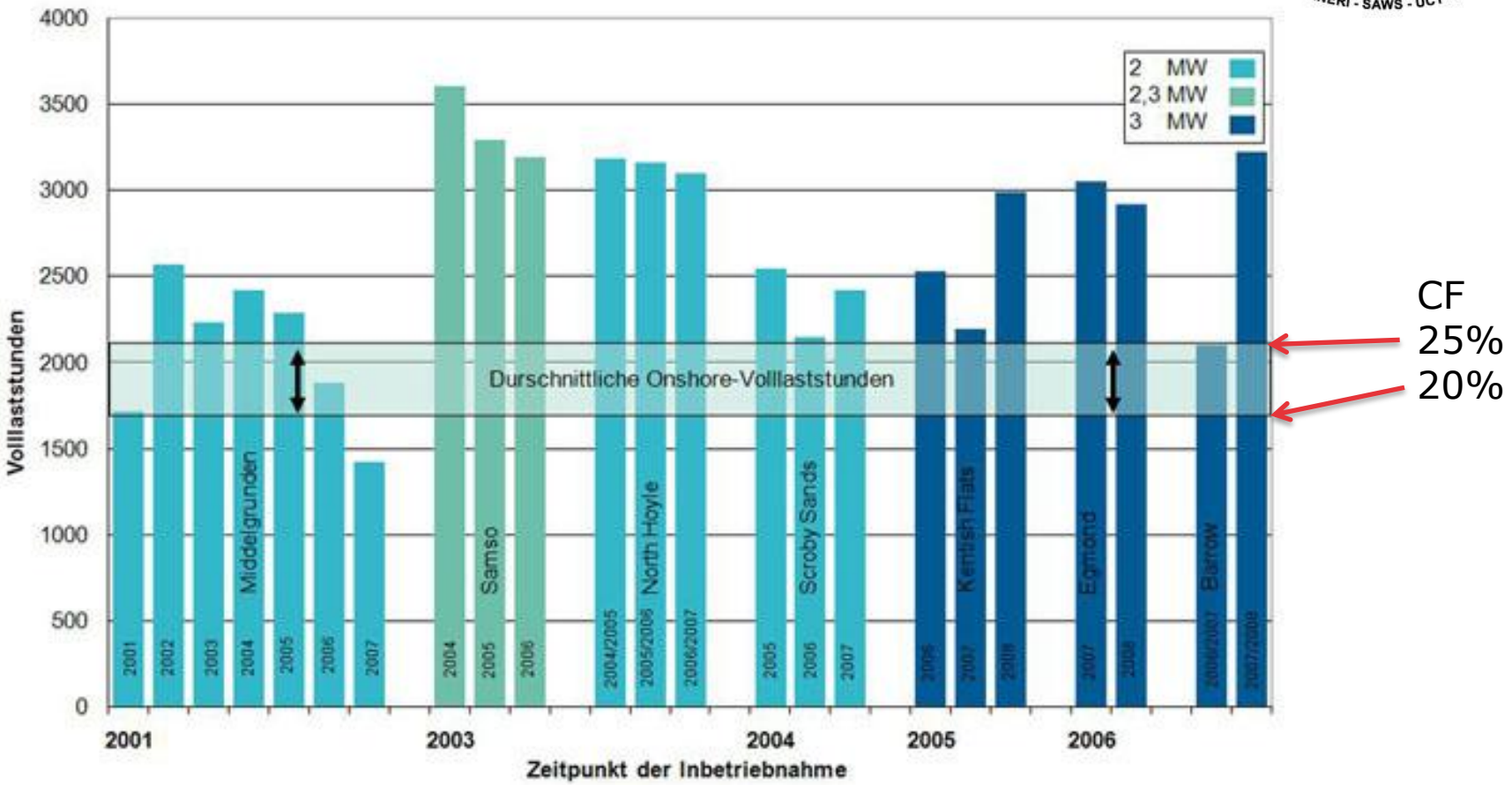
Electricity from Wind Power (BTM Consult)

Country/Region	Cumulative MW - end 2010	Est. average full load hours	Est. average capacity factor	Est. electricity production in 2010 TWh
USA	40,274	2,300	26.3%	92.63
Germany	27,364	1,813	20.7%	49.61
Spain	20,300	2,200	25.1%	44.66
P.R. China[1)]	44,781	1,800	20.5%	80.61
India	12,966	1,800	20.5%	23.34
Italy	5,793	2,000	22.8%	11.59
France	5,961	2,100	24.0%	12.52
United Kingdom	5,862	2,628	30.0%	15.40
Denmark	3,805	2,250	25.7%	8.56
Portugal	3,837	2,200	25.1%	8.44
Canada	4,011	2,278	26.0%	9.14
The Netherlands	2,241	2,100	24.0%	4.71
Japan	2,429	2,100	24.0%	5.10
Australia	2,084	2,500	28.5%	5.21
Greece	1,482	2,500	28.5%	3.70
Sweden	2,141	2,100	24.0%	4.50
Austria	1,013	1,794	20.5%	1.82
Rest of World	14,190	2,000	22.8%	28.38
Total	**199,520**	**(avg. 2,054)**	**(avg. 23.5%)**	**409.91**

Source: BTM Consult - A Part of Navigant Consulting - March 2011

Energy unit: 1 Tera Watt Hour (TWh) = 1 Billion kWh

Capacity Factors onshore vs offshore



The average onshore full load hours (~Capacity Factors 20-25%) are measured for all old and new wind farms in North Germany from the coast to the Mittelgebirge

Source: windmonitor.iwes.fraunhofer.de, September 2011

Capacity Factors in SA

Summary of site predictions @ 80 m
based on 1 year of data from the 10 WASA stations

WASA station	Wind speed	Power	2-MW Ø90	Capacity Factor	3-MW Ø90	Capacity Factor
	U [m/s]	P [W/m²]	AEP [GWh]	[%]	AEP [GWh]	[%]
WM01	6.2	323	5.221	30	5.955	23
WM02	6.7	304	5.658	32	6.230	24
WM03	7.5	409	7.413	42	8.373	32
WM04	7.0	364	6.715	38	7.555	29
WM05	9.0	724	9.564	55	11.661	44
WM06*	7.5	400	6.554	37	7.354	28
WM07	7.3	356	6.666	38	7.335	28
WM08	7.7	500	7.591	43	8.951	34
WM09*	8.1	441	7.271	42	8.189	31
WM10	7.0	360	5.957	34	6.668	25
Average				39		30

* Less than a year of data.

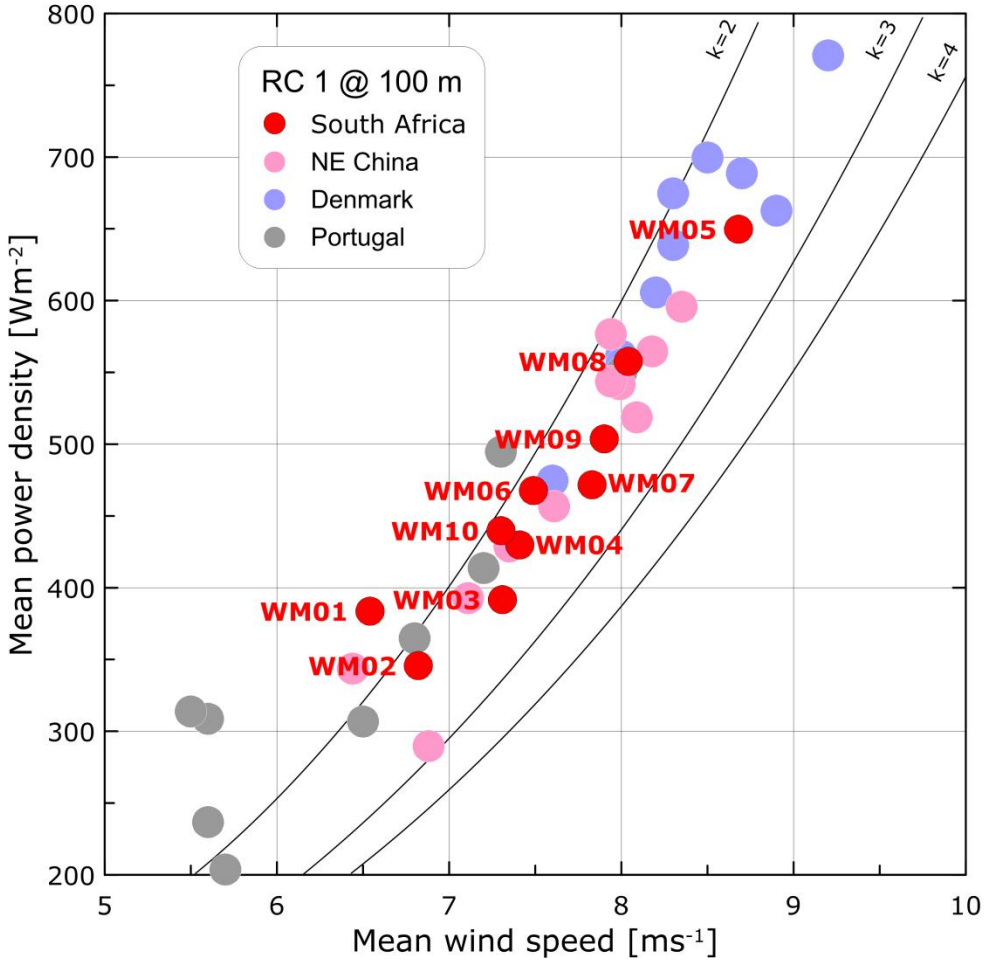
Wind farm Capacity Factors will be less than theoretical values above
- wake effects, WTG-availability, grid availability, grid losses, other losses

Some 10-25% reductions may be expected depending on
- site conditions, wind climate, wind turbine, wind farm size, layout, grid

Best sites should be developed first (WASA masts are not at best sites)
- note: WASA project may assist planning and identification of sites

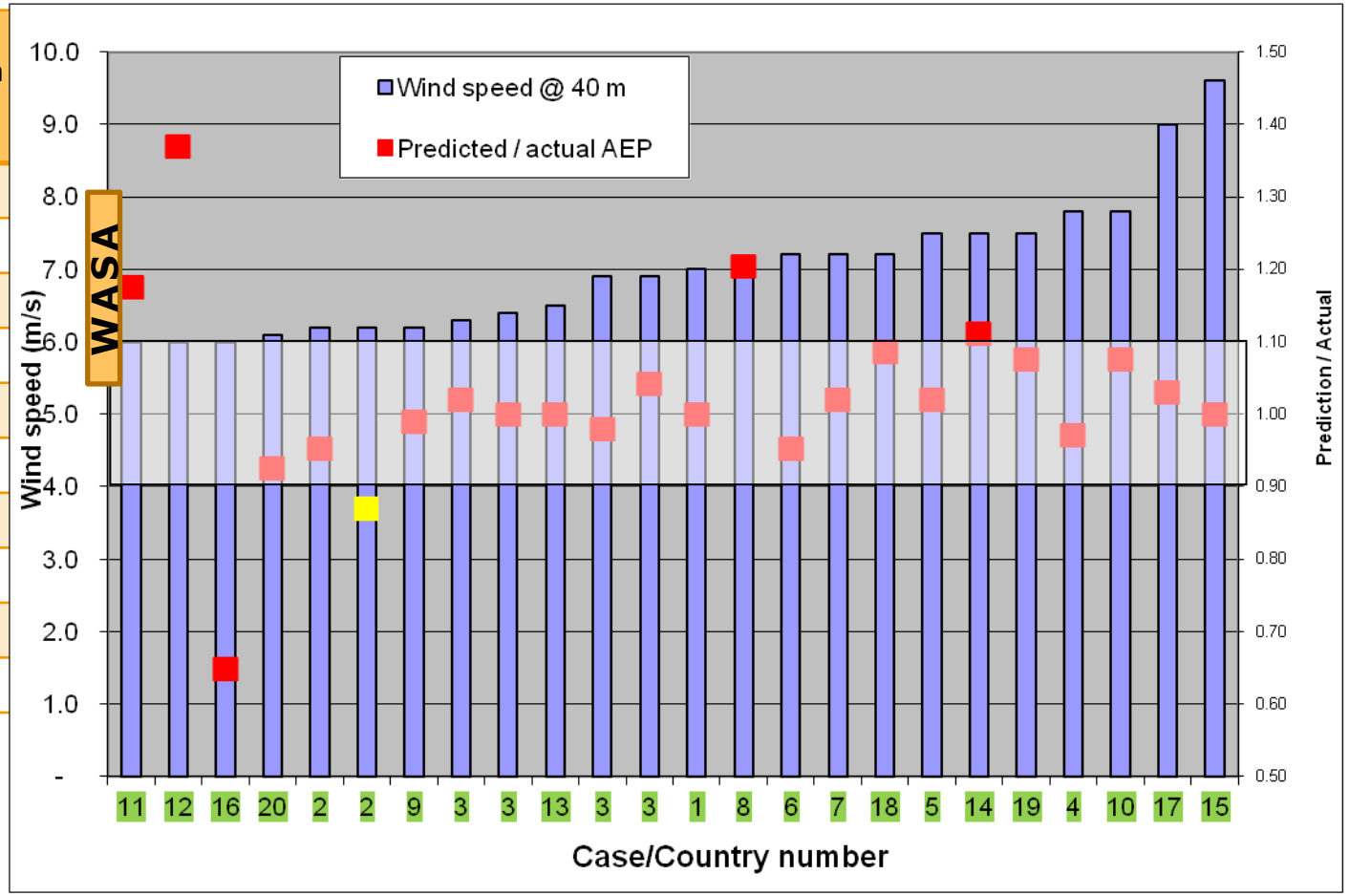
South Africa wind compared to other countries

Wind atlas values @ 100 m a.g.l. (z0 = 0.03 m)



WASA sites compared to 20 int. wind farm sites (from WAsP AEP prediction assessment study)

WASA Sep10-Aug11	U_{mean} @ 40m (m/s)
WM01	5.30
WM02	5.77
WM03	6.54
WM04	6.00
WM05	8.01
WM06	6.53
WM07	6.25
WM08	6.69
WM09	7.01
WM10	6.04

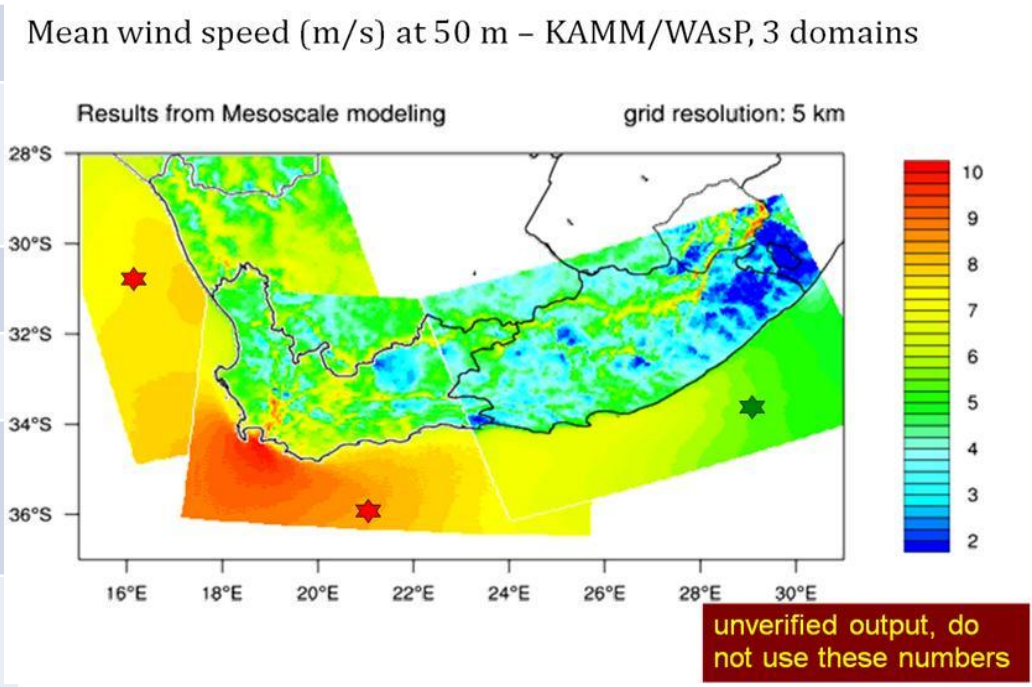


1	DK
2	DK
3	DK
4	DK
5	DK
6	DK
7	DK
8	SE
9	FIN
10	DE
11	DE
12	DE
13	NL
14	FR
15	EIRE
16	POR
17	GR
18	TR
19	AUS
20	USA

Source: http://www.emd.dk/Documentation/Introduction (2002)

Wind Atlas for South Africa – work plan

30 June 2009	Project Commencement at contract signature
March 2010	First public project workshop presenting • Project plans, methods and tools • First unverified wind atlas
July/Aug/Sep 2010	10 WASA measurement stations in operation
September 2010	Wind data publishing monthly on web-site activated
September 2011	1 year of data QA'ed. Site and station description reports for microscale modelling at the 10 WASA measurement stations.
February 2012	Midterm Workshop presenting • First wind atlas according to standard proven and tested method after 1 year of measurements
February 2014	Final Workshop and Wind Seminar presenting • Researched wind resource atlas • Extreme wind atlas



Presentations and links to information are available at the SANERI web site **http://www.saneri.org.za**

Concluding remarks

- SA's wind resource compares well to other countries with major wind energy developments
- Capacity factors of 25-35% should be possible – rough estimate based on 1 year of data and no correction to long-term average climate
- Large-scale wind energy developments should be possible with the land availability in SA

- The WASA project will have more geographical coverage by Feb2012 when the First Verified Wind Atlas will be presented at a WASA Workshop
- The WASA project runs another 2½ years

On behalf of the entire WASA project team

THANK YOU