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How can Denmark support wind mapping in Africa ?

Hansen, Jens Carsten; Hahmann, Andrea N.; Mortensen, Niels Gylling; Badger, Jake

Publication date:
2011

Document Version
Publisher's PDF, also known as Version of record

Third Wind Energy Seminar & WindTalks Africa

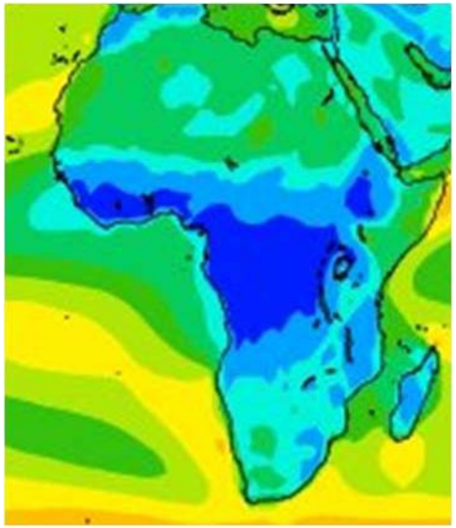
South Africa as a hub and model for wind energy in Africa

How can Denmark support wind mapping in Africa ?

Jens Carsten Hansen, Andrea Hahmann, Niels G. Mortensen and Jake Badger

DTU Wind Energy

Technical University of Denmark



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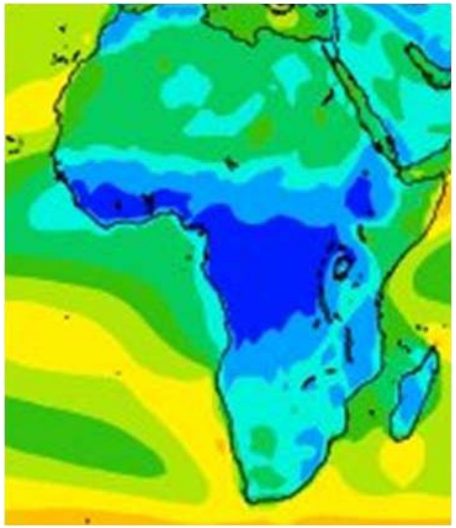
Outline

- Wind mapping – the facts
- Wind Atlas for South Africa (WASA) – the case
- Africa – challenges and opportunities



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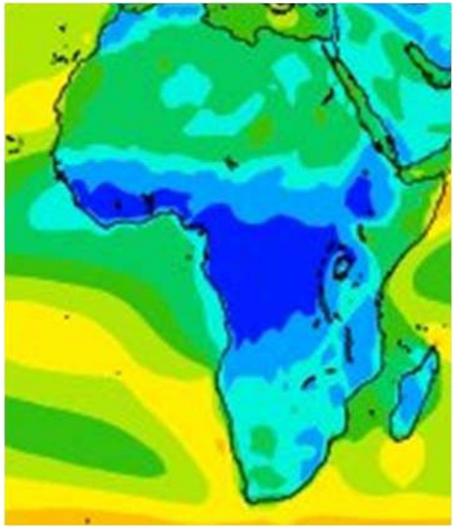
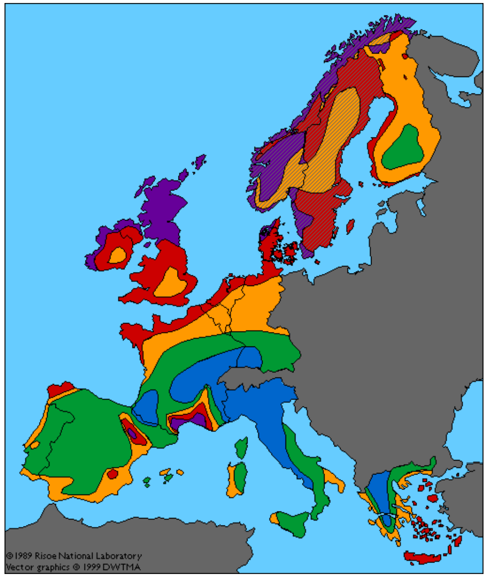
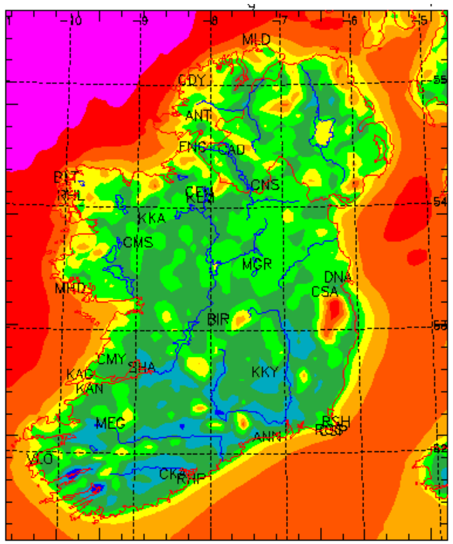


The Wind Atlas Method



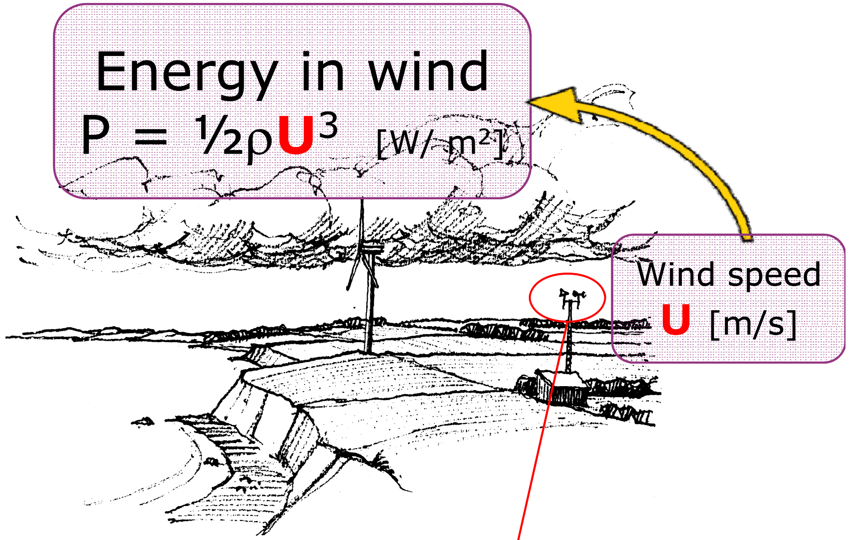
the *observational wind atlas* method and the microscale flow model, WAsP, were conceived in the 80's for the European Wind Atlas

the *numerical wind atlas and* mesoscale model techniques for larger domains, mesoscale effects and long-term wind climates came in the 90's



state-of-the-art wind resource assessment and planning is a combination of microscale and mesoscale modelling verified against measurements

Why Wind Atlas ?

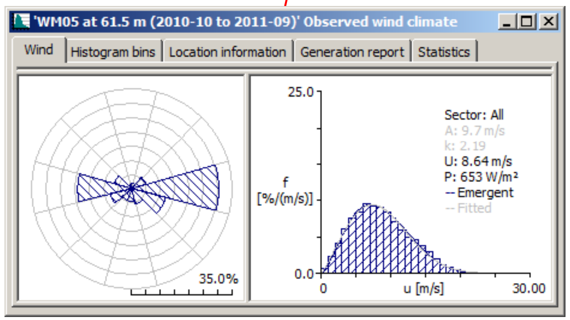


Wind power economics

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

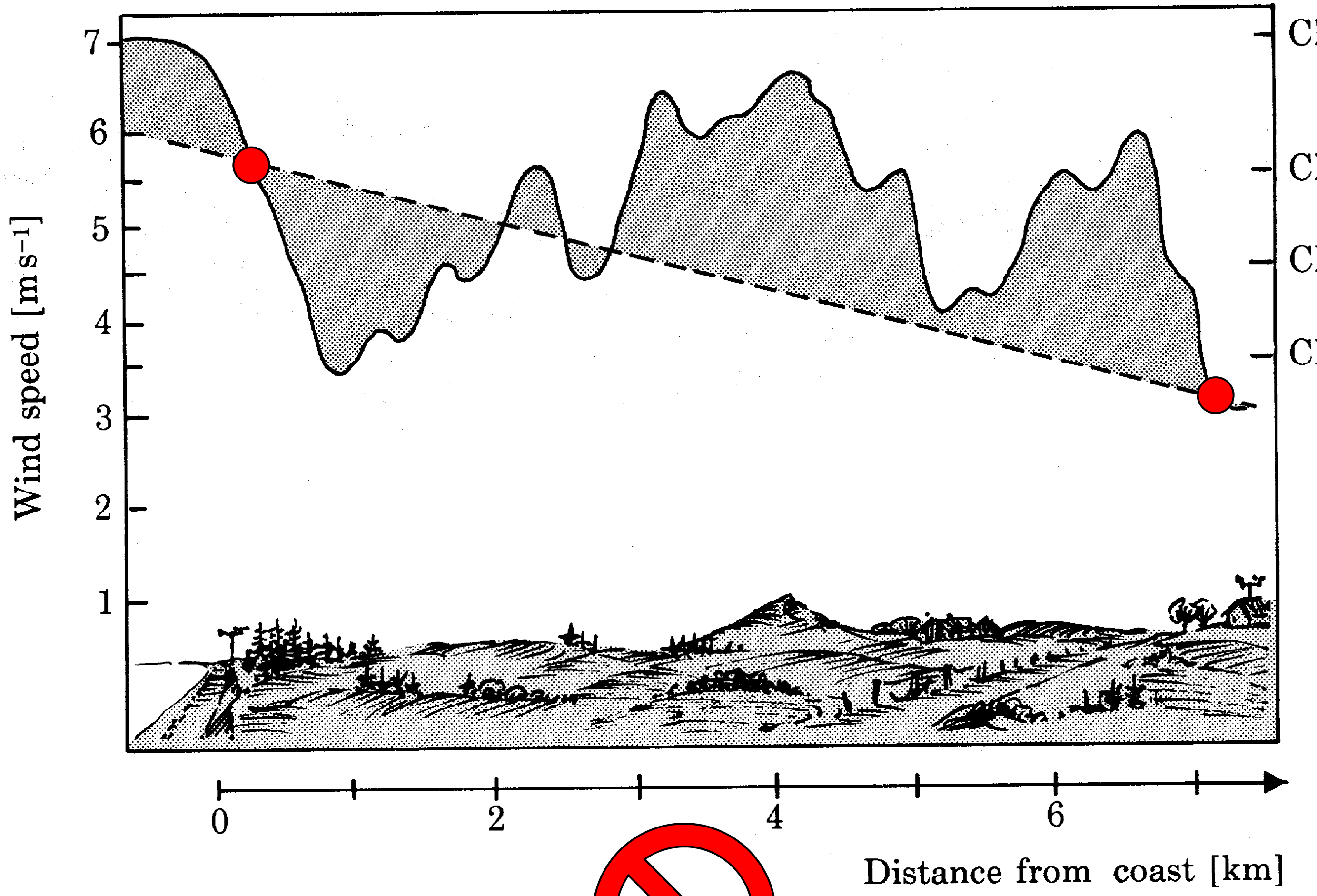
Wind provides the income in cost-benefit

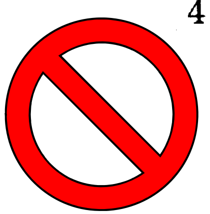
Wind measurements are in one point in space
Wind varies significantly across the terrain
Spatial distribution needed for planning and projects
Accuracy is essential (ΔU of 5% → ΔP of 15%)



Modelling is necessary and challenging

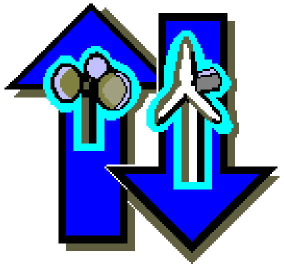
Measurements and Linear interpolation - NO



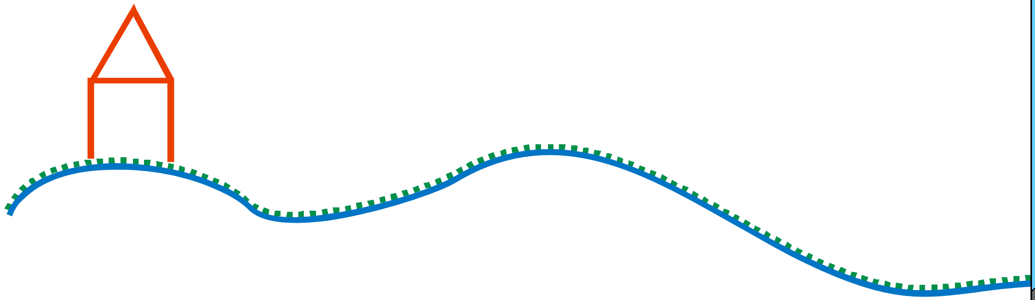


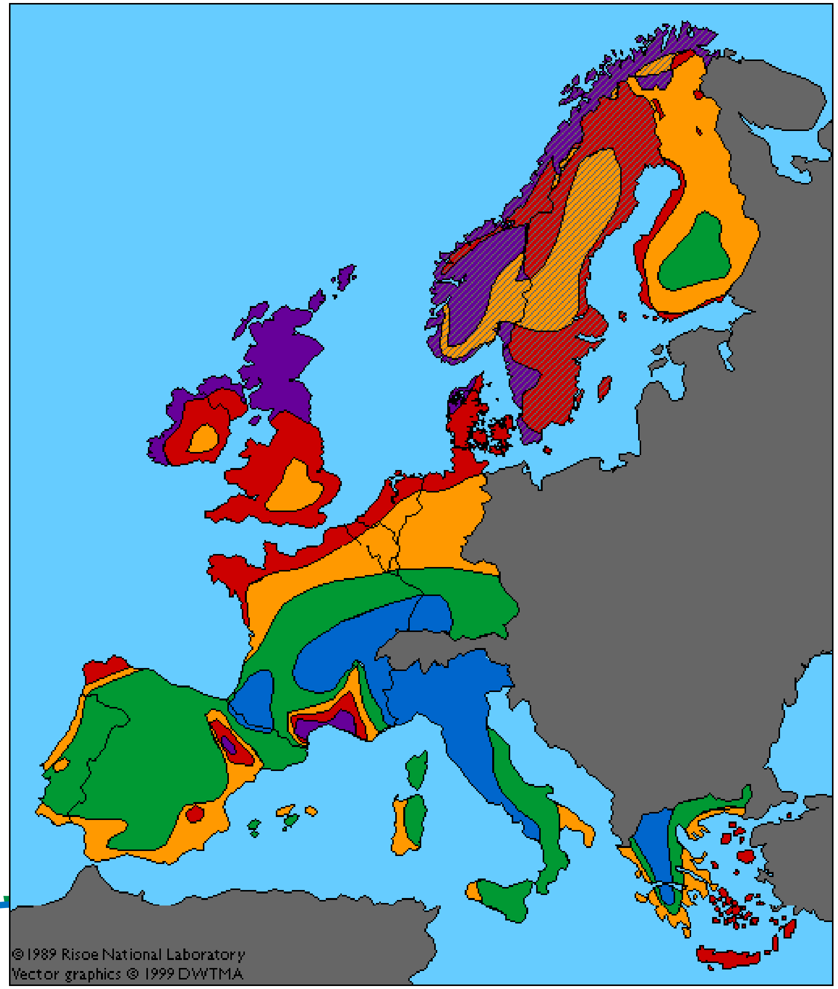
Microscale modelling, e.g. WAsP

assuming constant wind climate over modelling domain

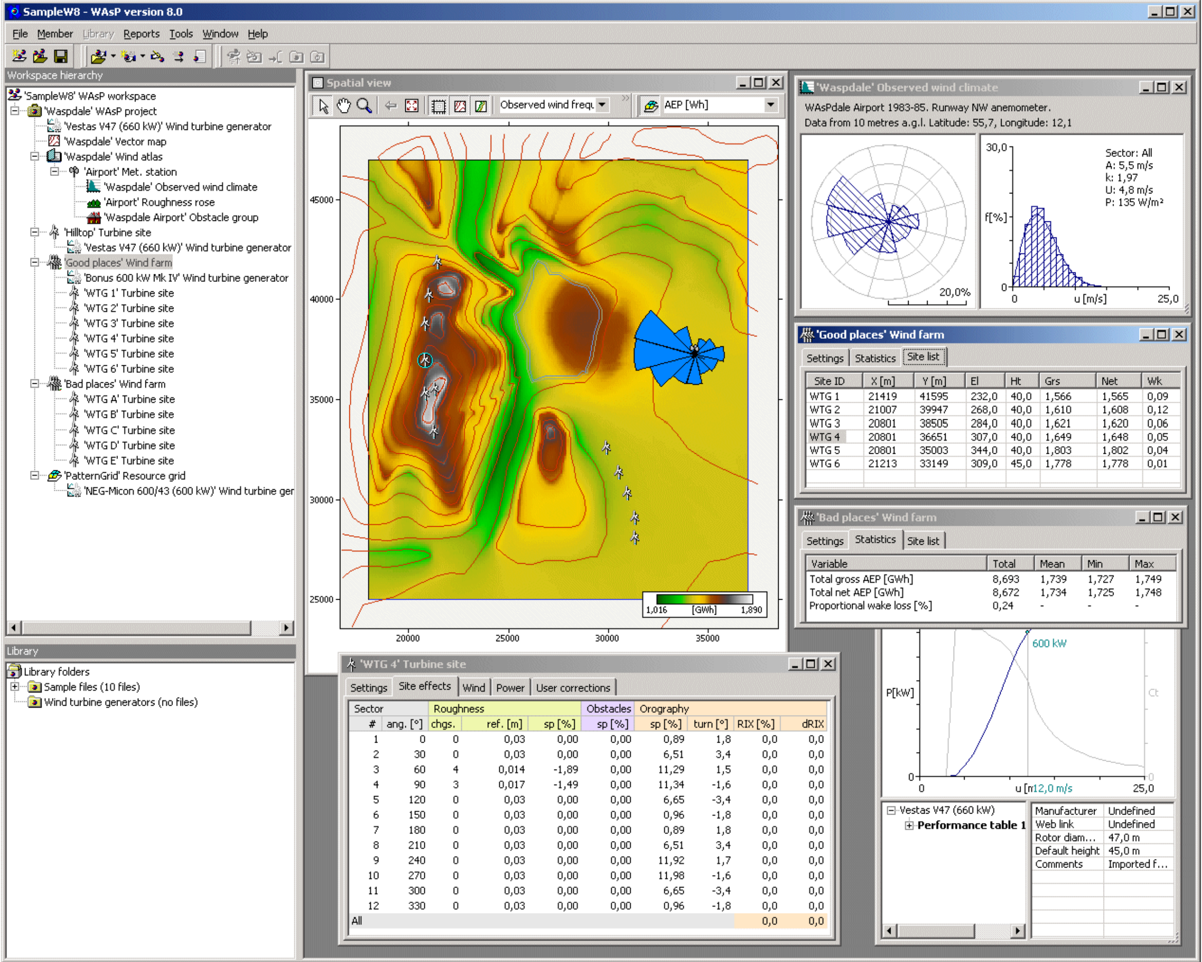


WAsP = ROU + ORO + OBST





WAsP - wind resources, energy production estimation and siting

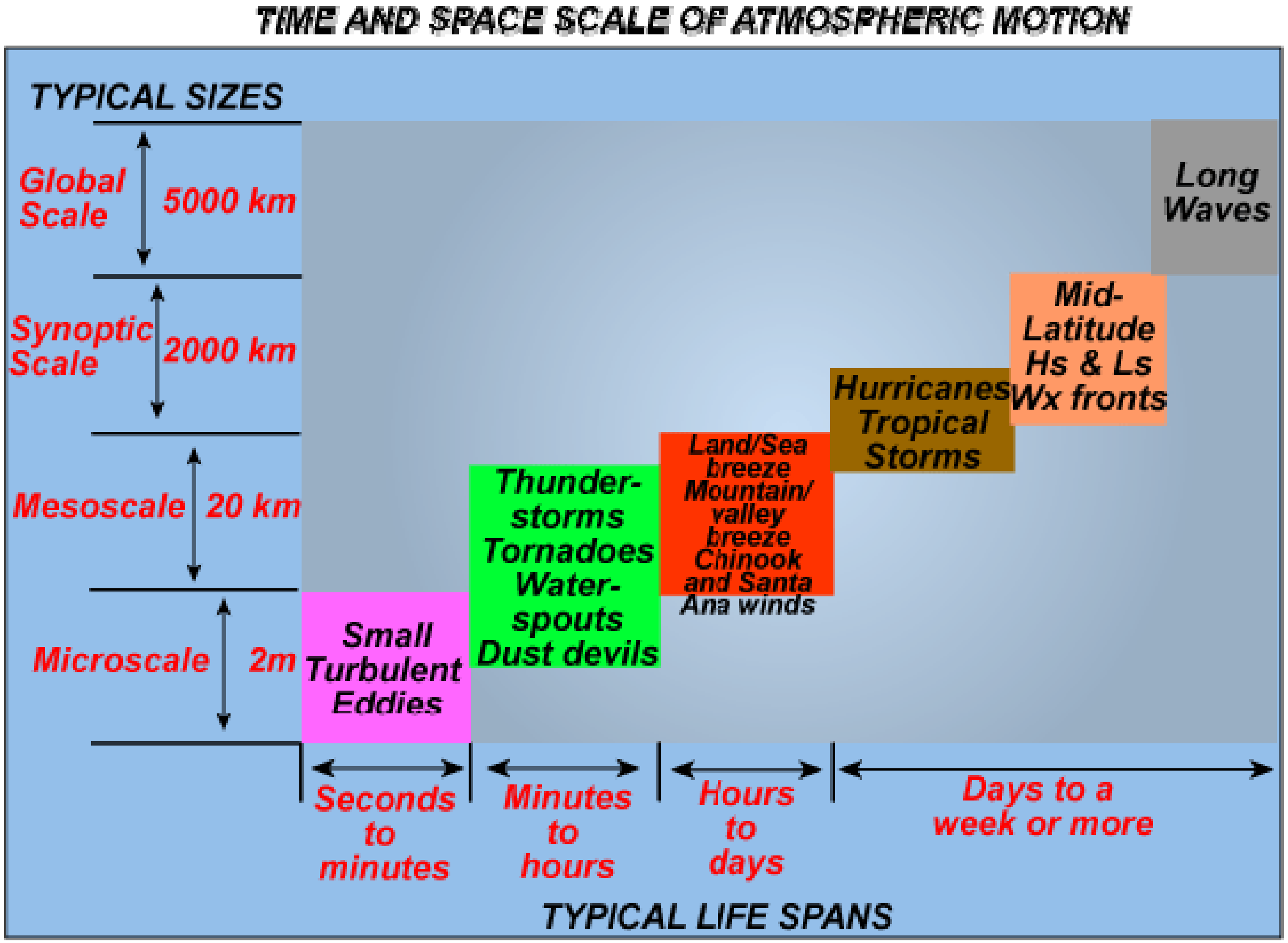


The industry-standard Wind Atlas Analysis and Application Program

More than 3600 users in over 110 countries use WAsP for:

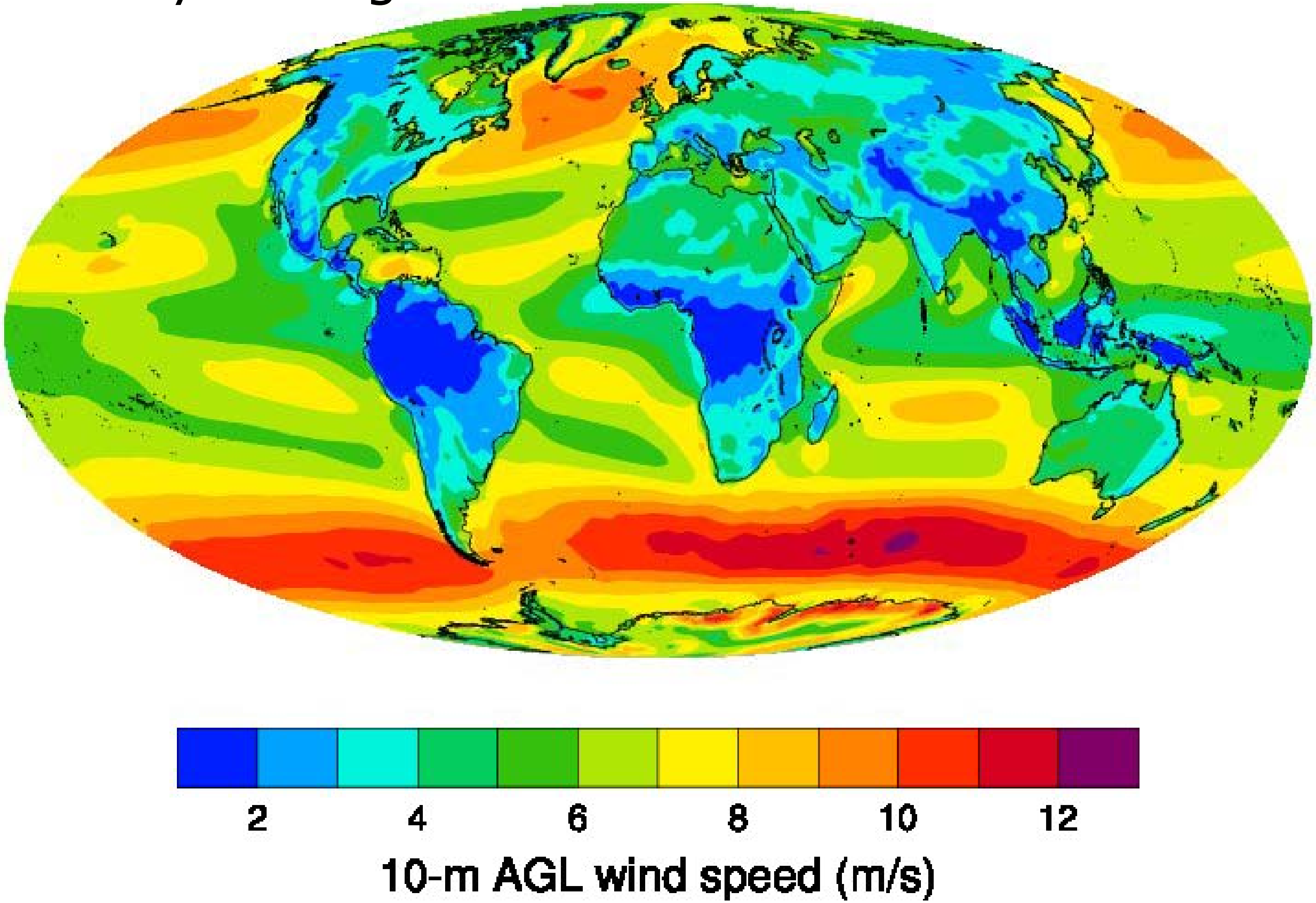
- Wind data analysis
- Map digitisation & editing
- Wind atlas generation
- Wind climate estimation
- Energy production of WTG's
- Micro-siting of wind turbines
- Wind farm production
- Wind farm efficiency
- Wind resource mapping

However, what about other scales of atmospheric motion ?



Global Circulation Models (GCMs)

Annually averaged winds across the world



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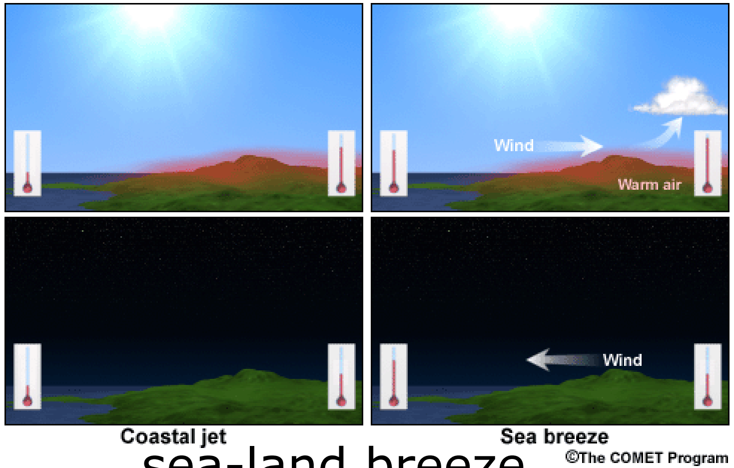
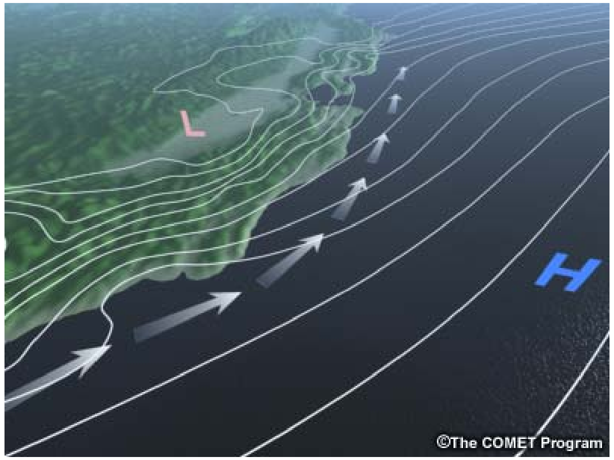
Source: European Center for Medium Range Weather Forecasting (ECMWF) - ERA Interim reanalysis

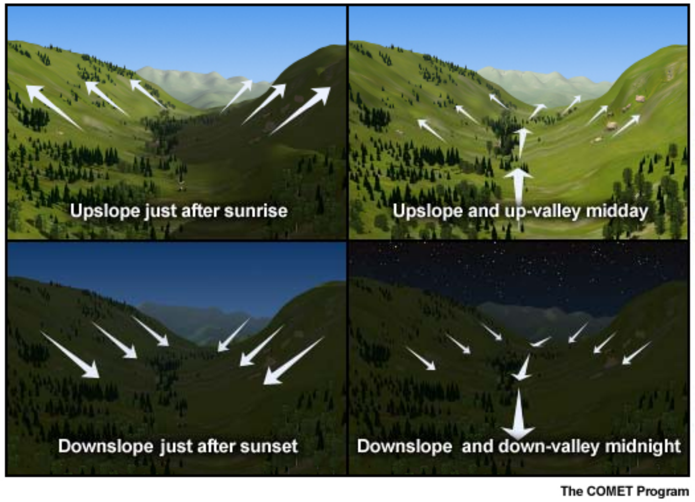
Mesoscale processes generate and / or modify regional circulation systems



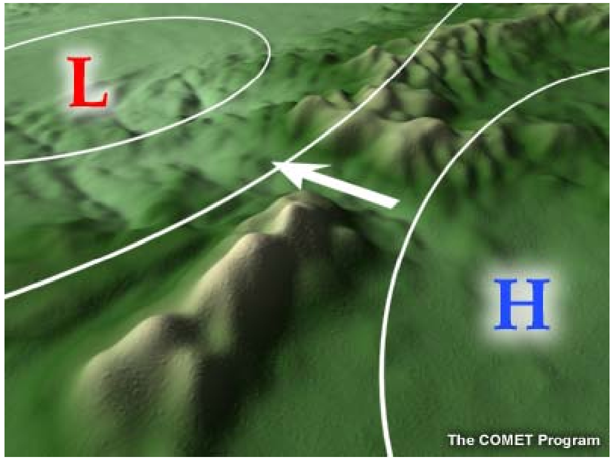
sea-land breeze



coastal jet



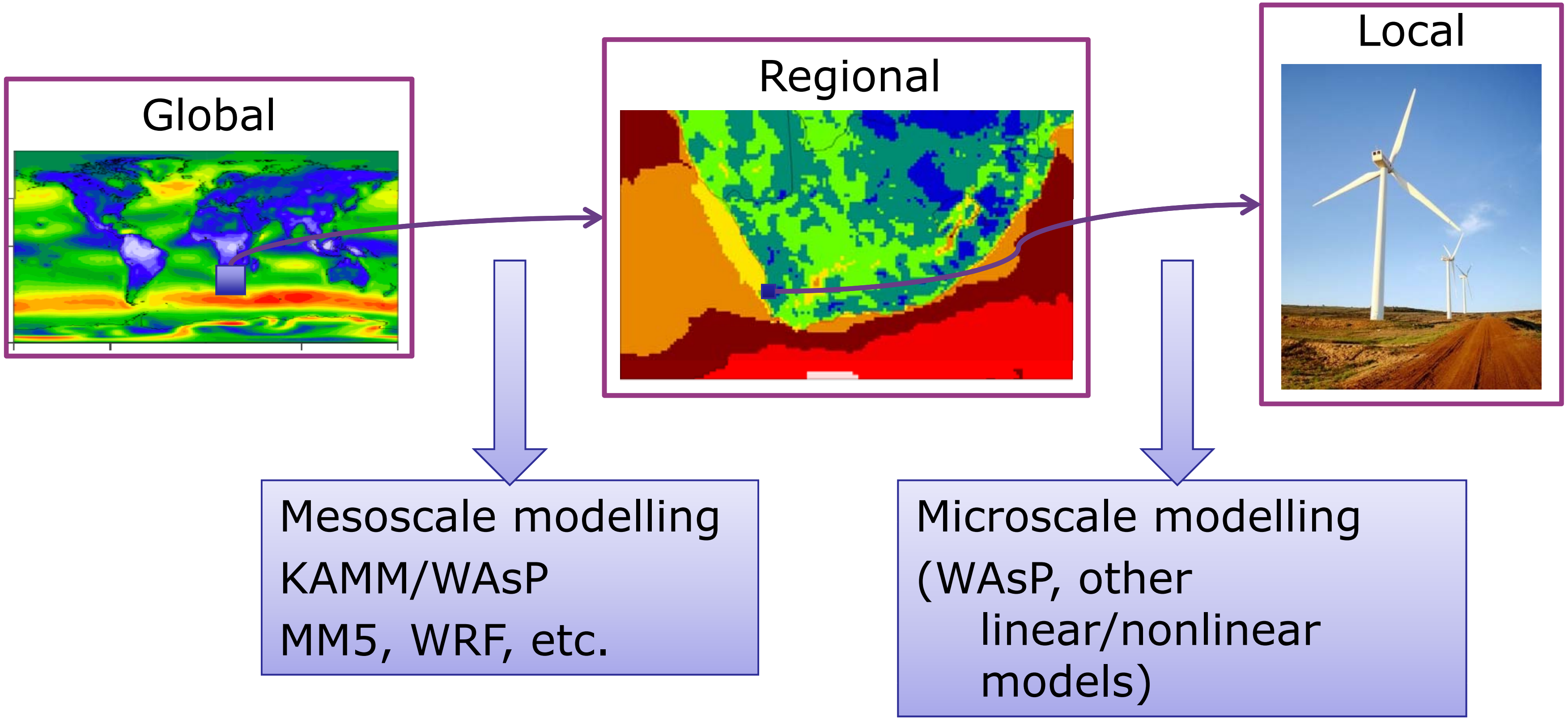
mountain-valley breeze



gap flow

Numerical Wind Atlas

Downscaling from global reanalysis data



KAMM: Karlsruhe Atmospheric Mesoscale Model
WAsP: Wind Atlas Analysis and Application microscale model

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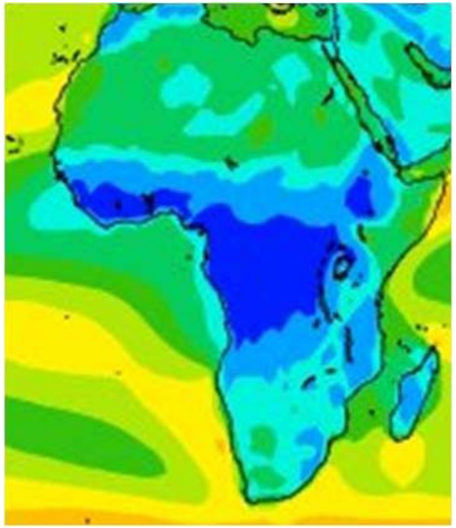
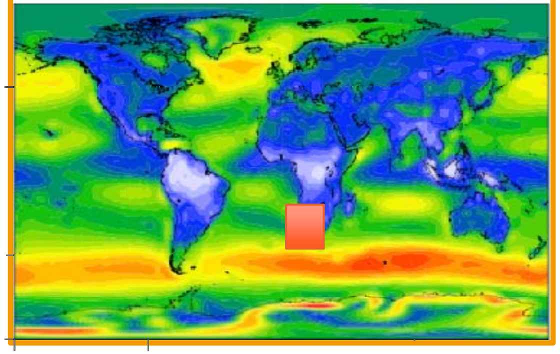
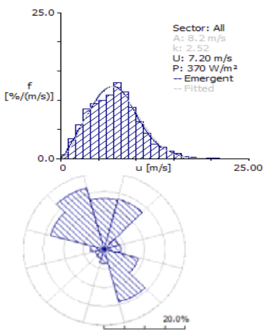


Wind Atlas for South Africa (WASA) project overview

Global



Measurements

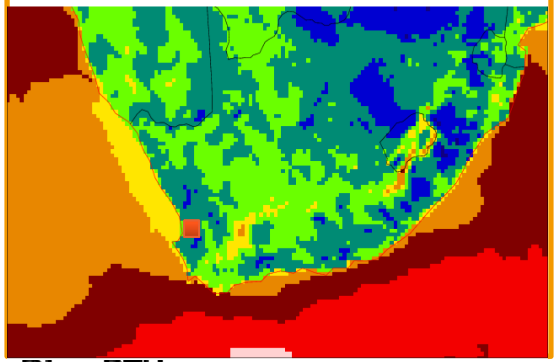


wind farm

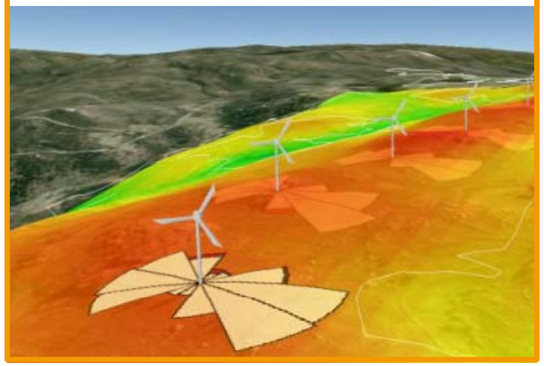
Mesoscale modeling

Microscale modeling

Regional wind climate

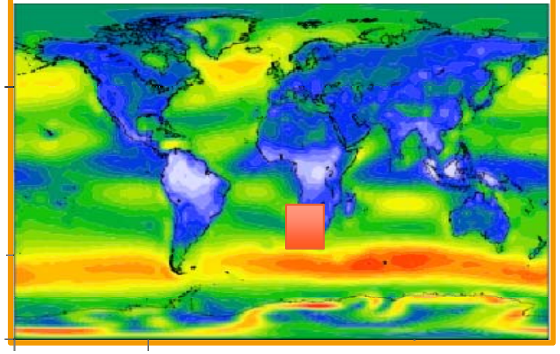


Local wind

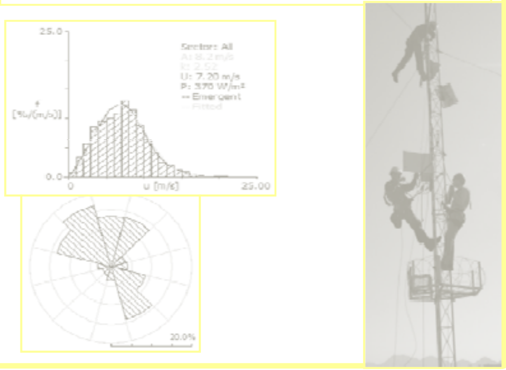


Wind Atlas for South Africa (WASA)

Global



Measurements



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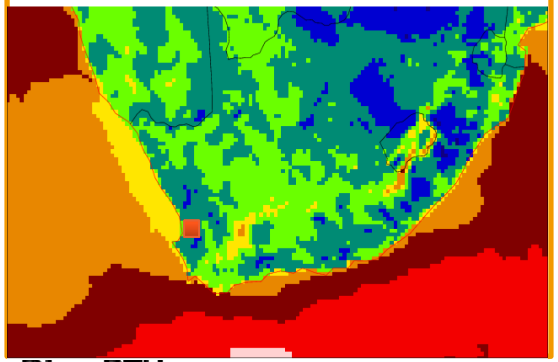
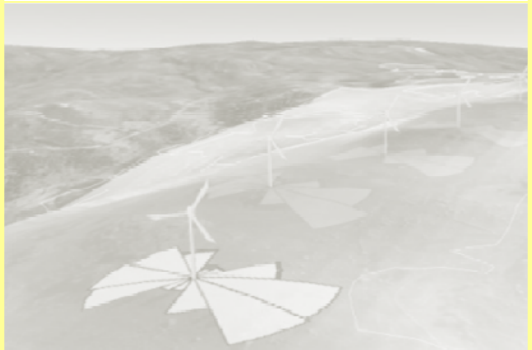
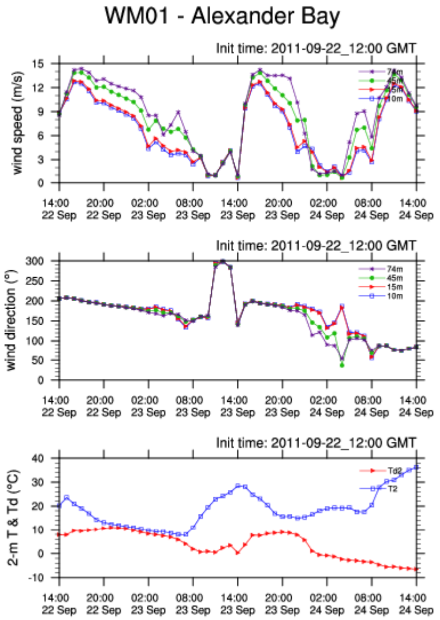


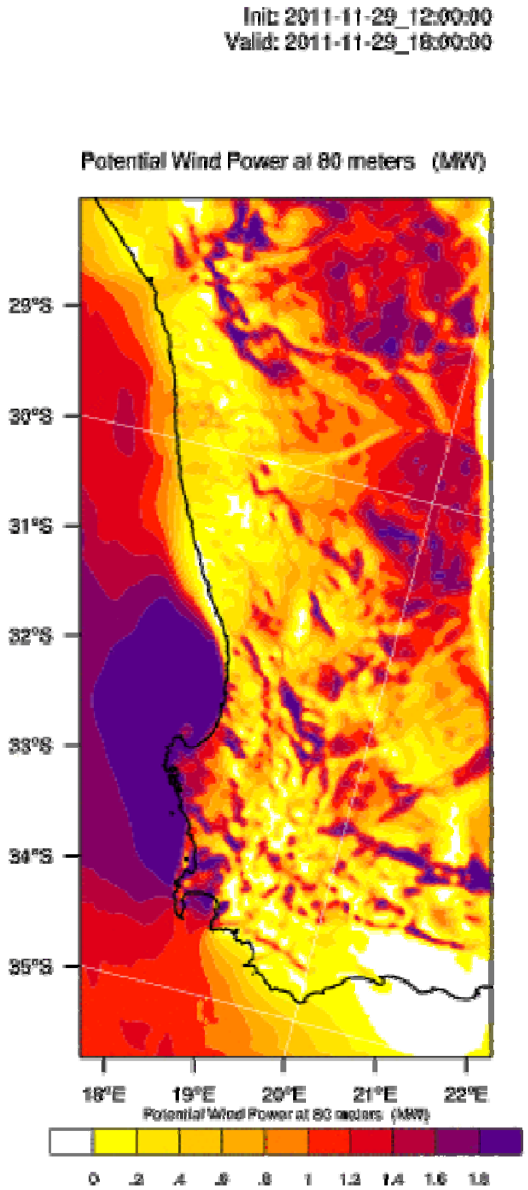
Local wind



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





First KAMM Mesoscale Modelling
30-year mean mesoscale wind speed at 100 m

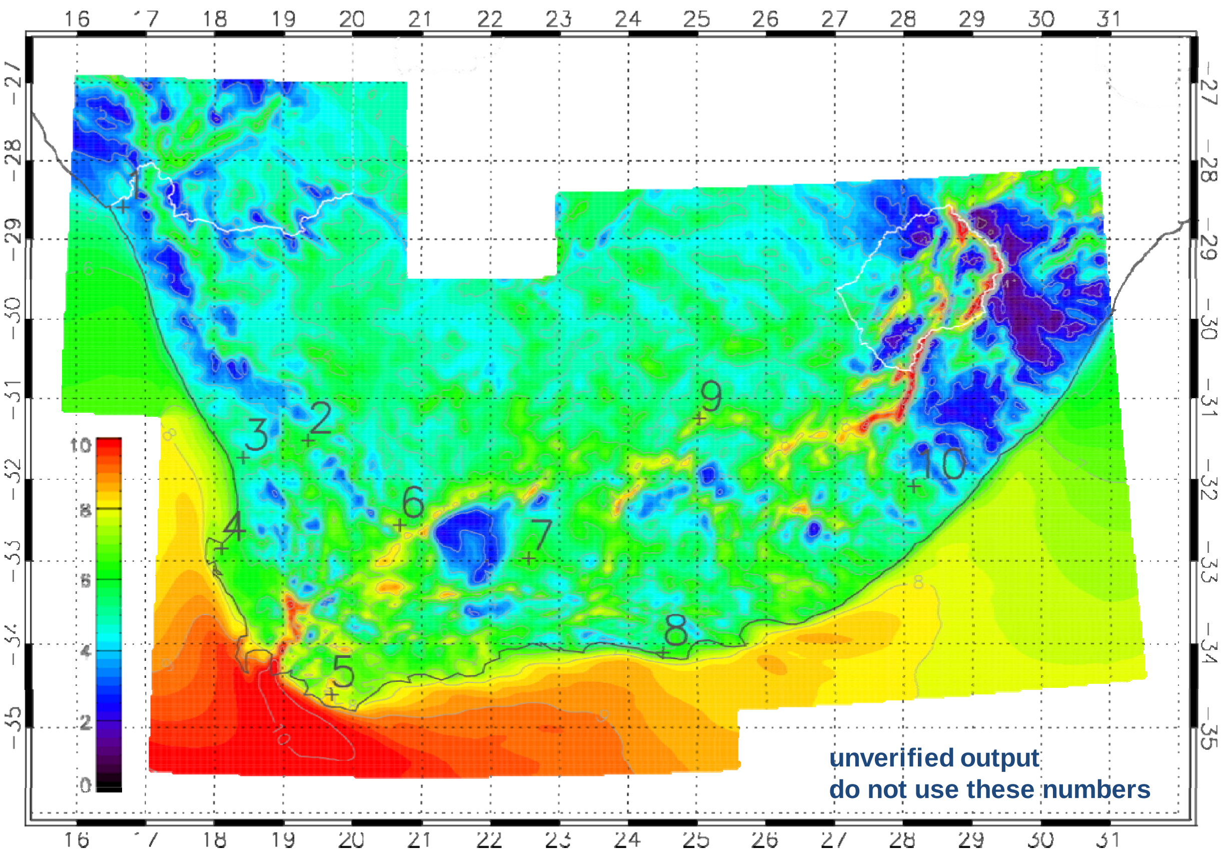
3 calculation domains

3 sets of wind classes determined by NCEP-DOE Reanalysis 2 for 1980-2009

5 km grid spacing

Elevation – SRTM30

Roughness – Land use from GLCC USGS

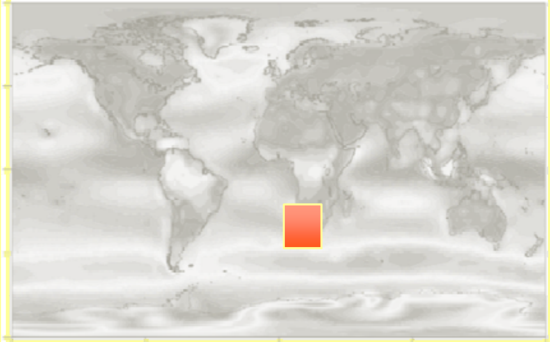


Preliminary comparisons with WASA data shows challenges, e.g. near WM01 and WM03

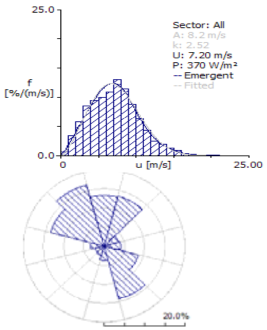
Ongoing work: Verification, improvements and recommendations for use

Wind Atlas for South Africa (WASA)

Global



Measurements

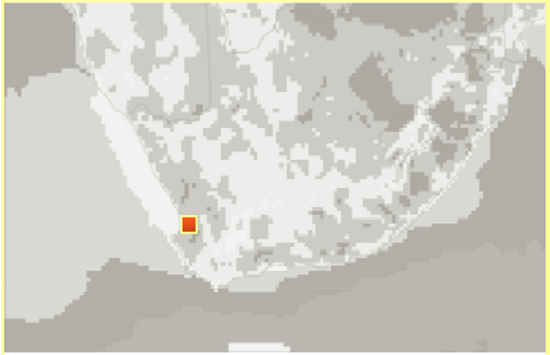


wind farm

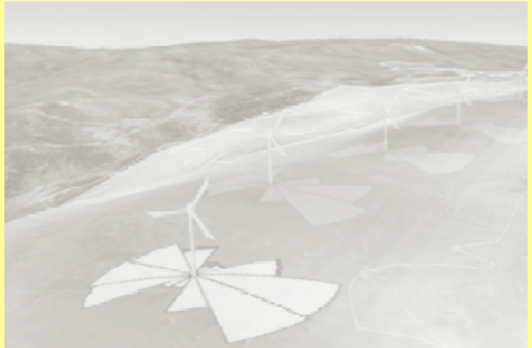
Mesoscale modeling

Microscale modeling

Regional wind climate

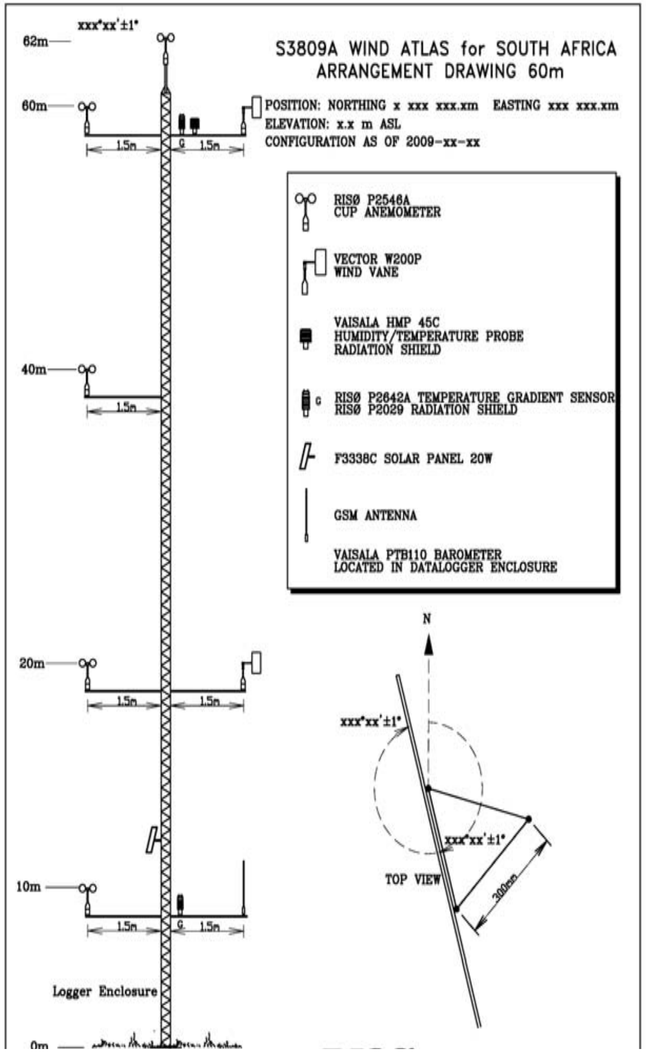


Local wind



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



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Measurement progress

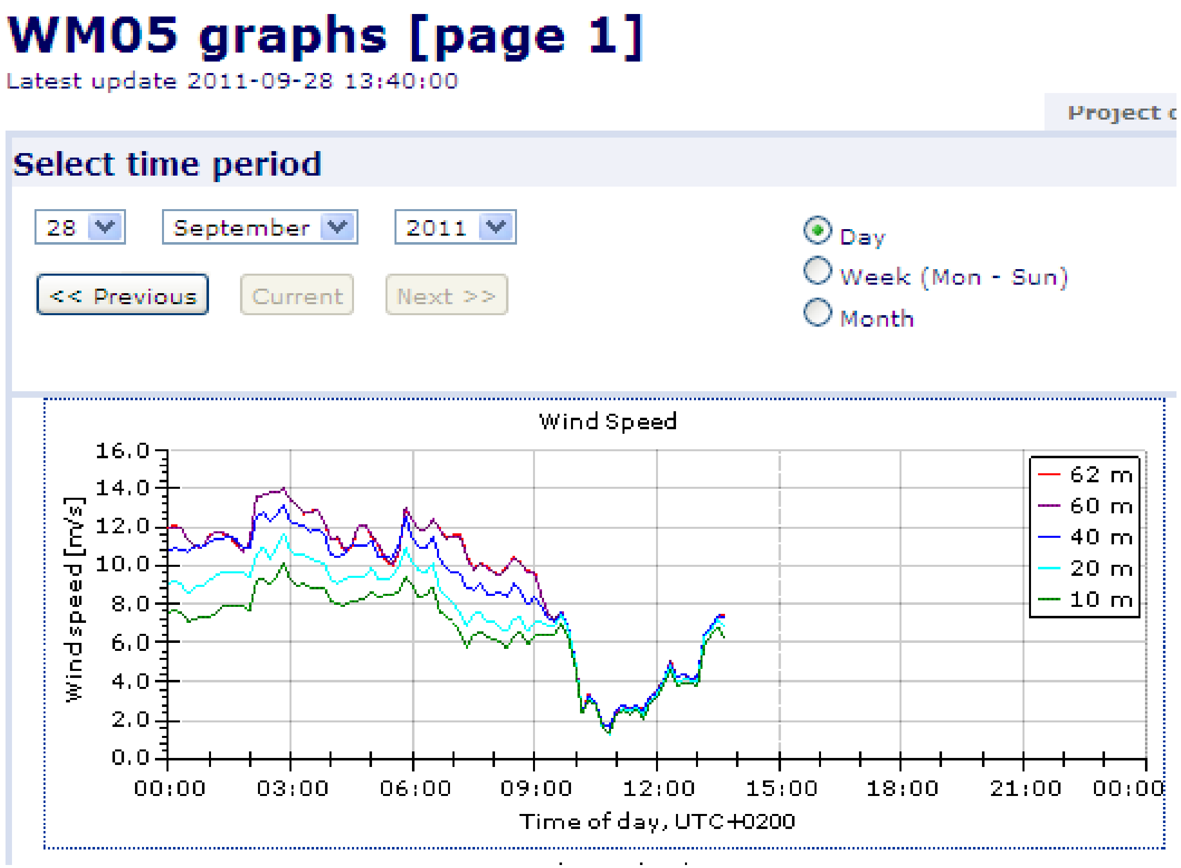
- First full year of data
  October 2010 – September 2011
- Station and site descriptions
- Very good data recovery
- Lessons learned will be collected

WASA	Data recovery (%)	U_{mean} @ 61.5m (m/s)
WM01	100.0	5.83
WM02	100.0	6.19
WM03	100.0	7.13
WM04	100.0	6.68
WM05	95.8	8.58
WM06	100.0	7.00
WM07	100.0	6.95
WM08	100.0	7.36
WM09	89.6	7.55
WM10	92.4	6.52

WASA data – user statistics

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

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



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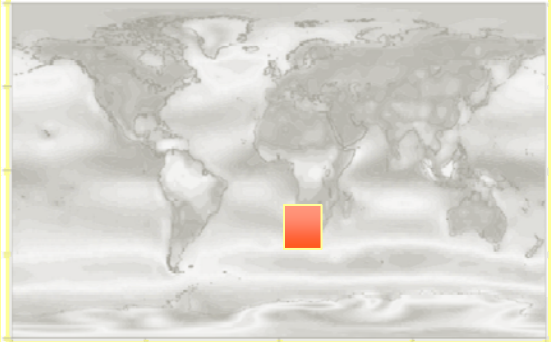
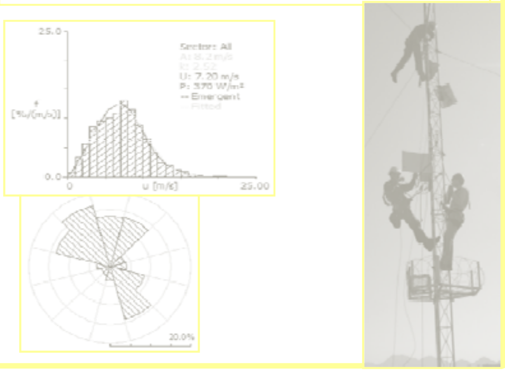


Measurements



wind farm

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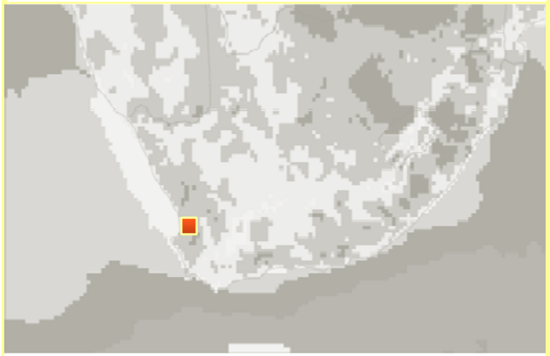
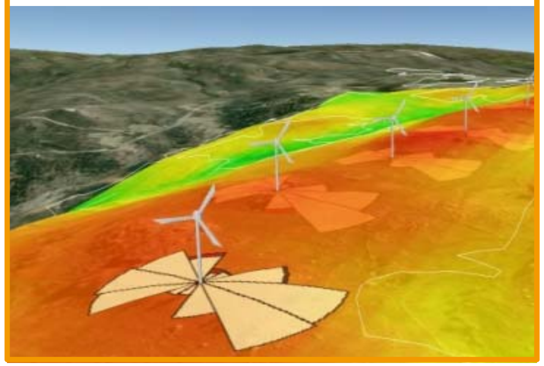
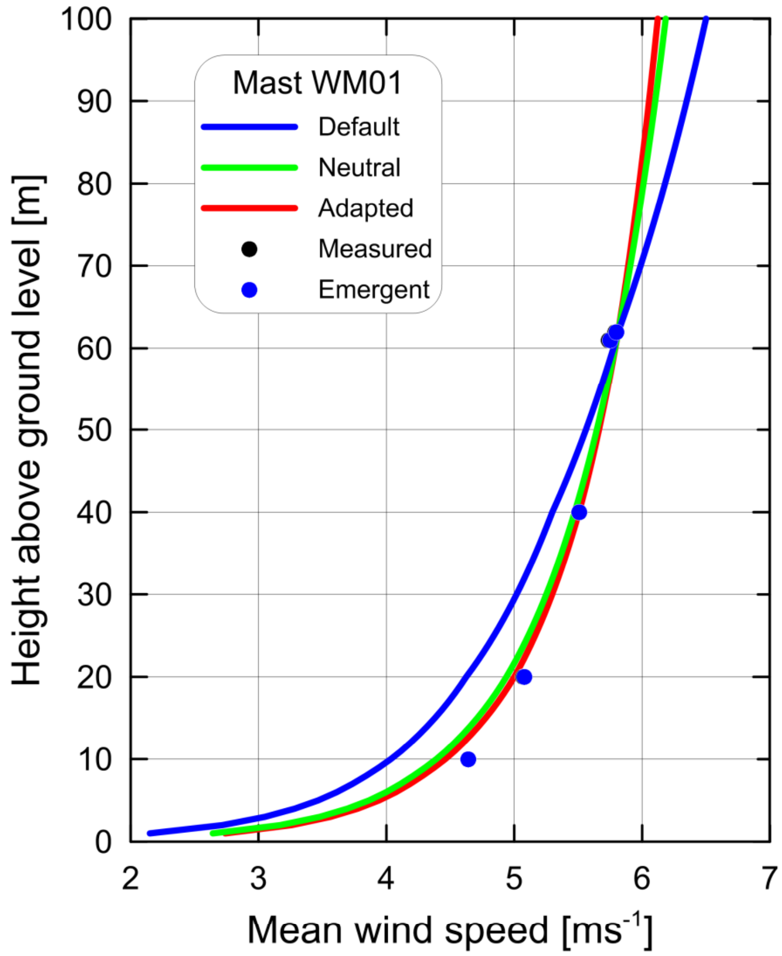


Local wind



Microscale modelling at the 10 WASA masts shows WASA data is high quality

- 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



Resource grids at 10 WASA masts

Possible at 10 sites

In public domain

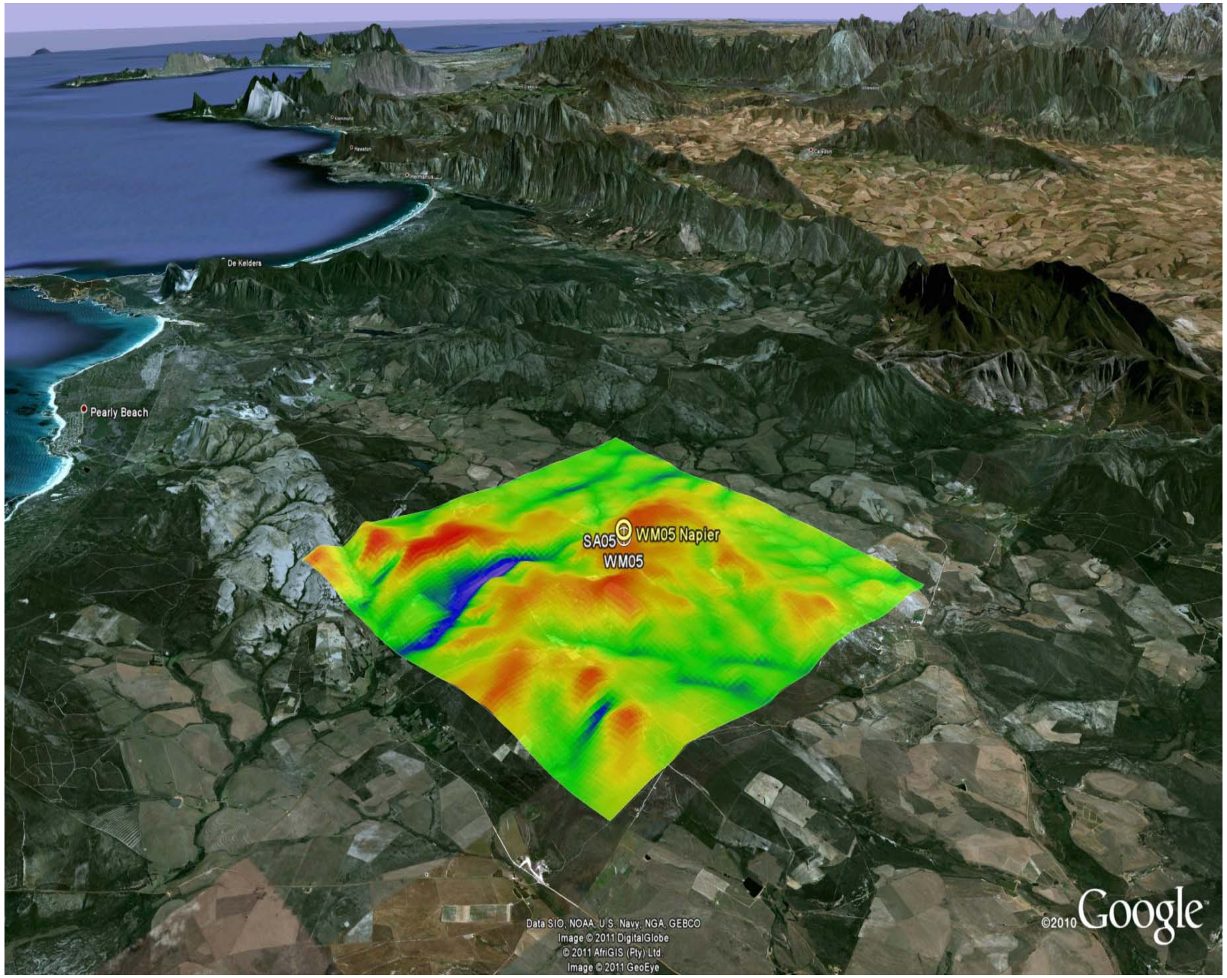
Example using WAsP at WM05

Inputs:

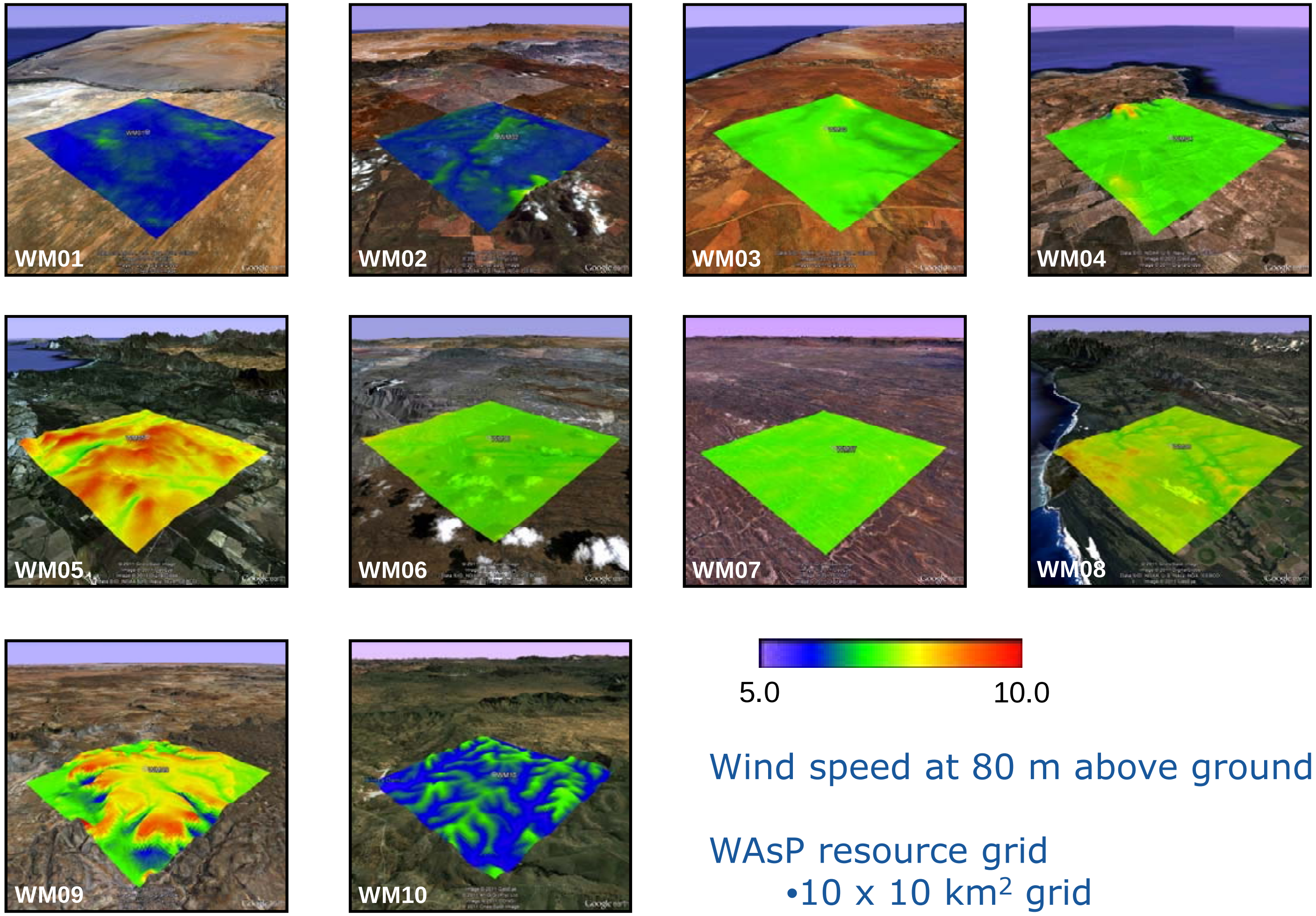
- 1-year WASA data
- WASA Station Description
- SRTM elevation map
- Google Earth roughness

Result:

- 10 km by 10 km area, 100 m grid resolution
- Annual Energy Production, AEP, of 2-MW/Ø90m wind turbine. Range: ▪5.5 GWh/y to ▪10.5 GWh/y



Microscale WAsP modelling at 10 WASA sites from the one year of WASA data



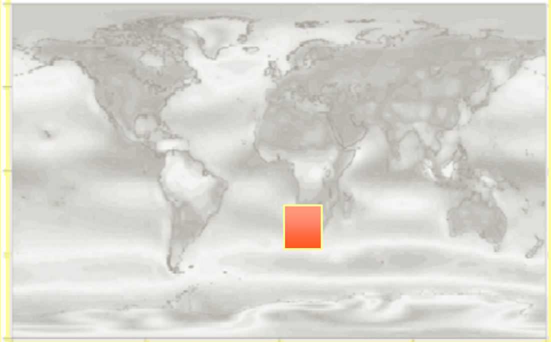
Wind speed at 80 m above ground level

WAsP resource grid

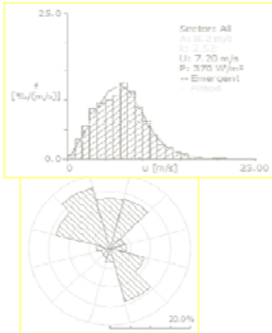
- 10 x 10 km^2 grid
- 100 meter grid spacing

Wind Atlas for South Africa (WASA)

Global



Measurements

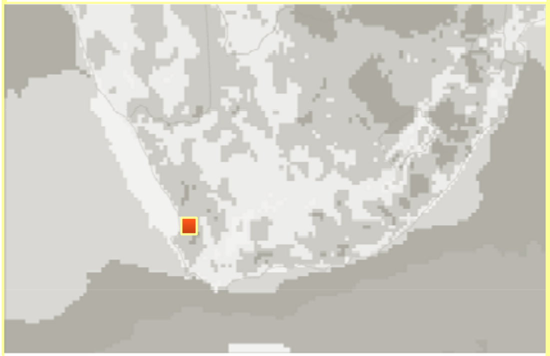


Mesoscale modeling

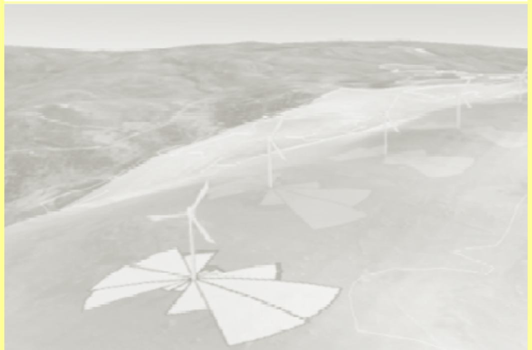
Microscale modeling

wind farm

Regional wind climate



Local wind



Wind resource assessment in SA

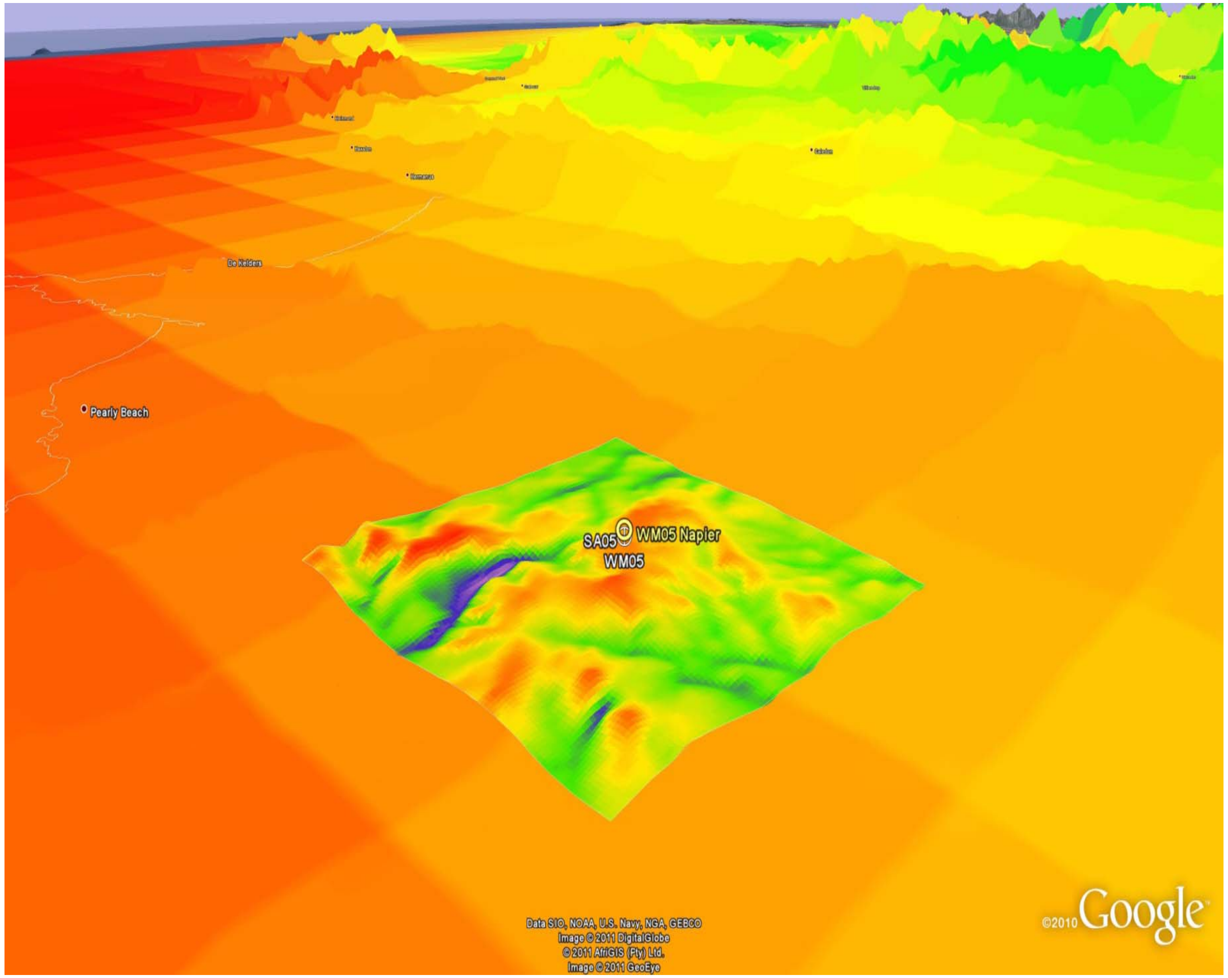
Apply the WASA mesoscale results within the project area even far from WASA masts (February 2012)

In public domain

Microscale modelling on grid of mesoscale climate provides actual wind resource, e.g. WAsP

- Input WASA wind atlas climatology
- Elevation (user defined)
- Roughness (user defined)
- Any size and resolution

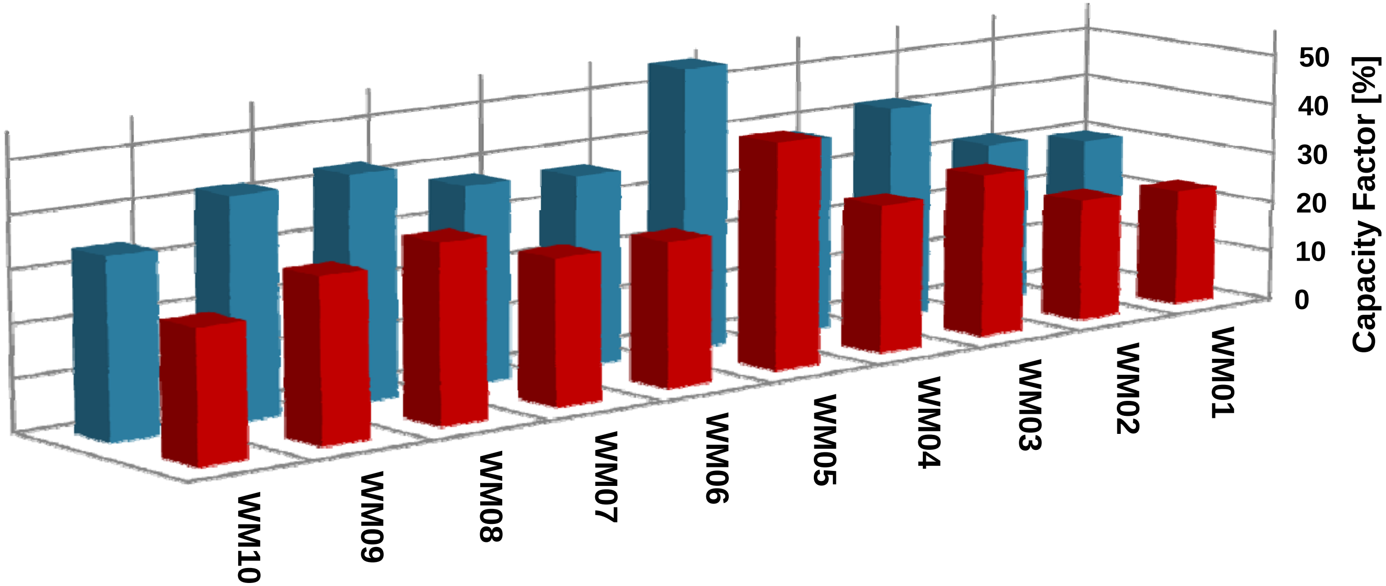
Uncertainties depend on location and terrain type



Capacity Factors in SA

WAsP predictions for 1 WTG on 10 WASA sites - 1 year of data

- Theoretical values, assuming 100% availability, no wakes, no losses
- Note that WASA masts are for model verification and not at windiest sites



	WM01	WM02	WM03	WM04	WM05	WM06	WM07	WM08	WM09	WM10
2-MW Ø90m	30	32	42	38	55	37	38	43	42	34
3-MW Ø90m	23	24	32	29	44	28	28	34	31	25

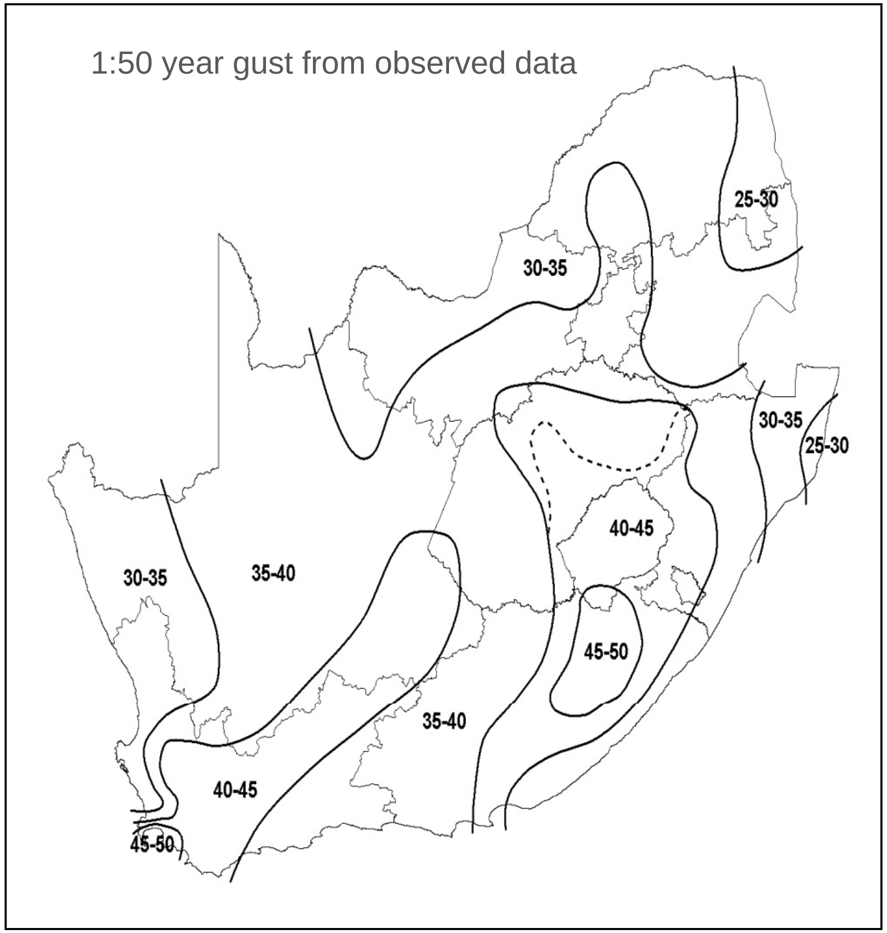
and WASA aims to improve knowledge about Extreme wind climate

Extreme winds essential for design of wind turbines

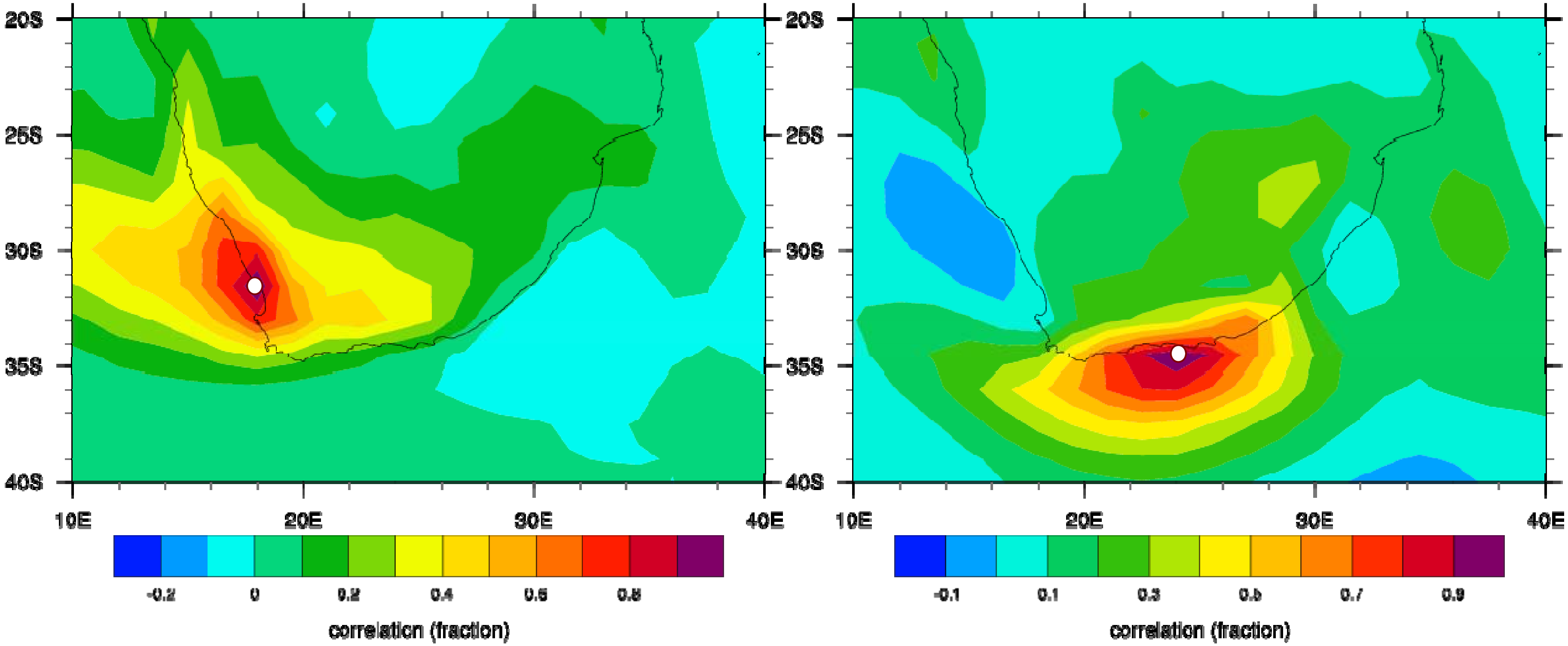
Estimations need long measuring periods and adequate density of measurements

Work in progress:

Use of WASA data and modelling



Spatial correlations (lag 0) between 6-hourly wind speed
ERA Interim Annual 1989



Wind-speed correlations in the large-scale flow.

Further research needed to drive down uncertaities
ex: The Bolund Experiment

Blind test of flow models vs measurements at escarpment

Most downloads in Sept 2011 in Boundary-Layer Meteorology

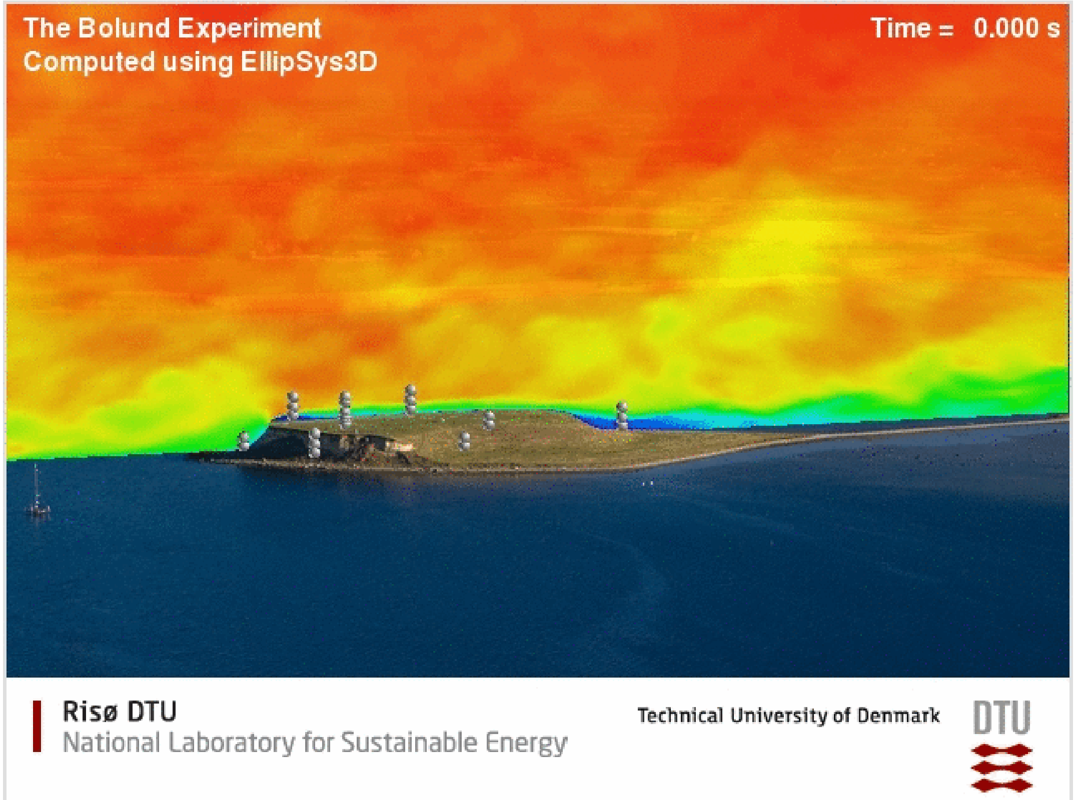
Conclusions

The Blind Comparison

1. Recommendation: RANS k-ε is today's main workhorse, LES has not matured yet.

2. 10% error on speed-up and 20% on TKE is what to expect in complex terrain?

3. 7 diff. CFD solvers in top 10: The user is more important than the solver.



The Bolund Experiment is thanks to

- Danish Energy Counsel
- Vestas Technology R&D
- and the 60 participating companies:

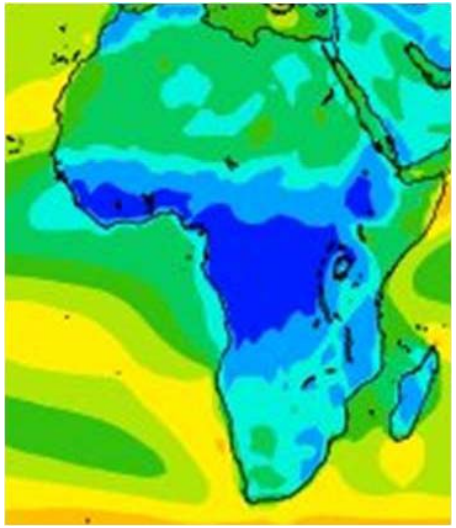
3Tier
ANSYS
Barlovento Recursos Naturales
CENER
CERC
CEsA Univ Porto
Chalmers Univ of Tech.
COWI
CRES
DMI Force
ECOFYS
École de Technologie Supérieure
EMD
ENERCON
EREDA
ETH Zürich
GAMESA
Garrad Hassan
GE Infrastructure
DNV
Geo-net
Germanischer Lloyd
Go Virtual Nordic AB
Kjeller Vindteknikk
Megajoule
Meridian Energy
Metacomp Technologies
Meteodyn
MS Micro
National Institute of Water & Atmospheric Research
Natural Power
NCAR
Nordex
Normawind
Numeca
RES
ReSoft ltd
RWE npower renewables
Siemens Wind Power a/s
Star-CD
Suzlon Wind Energy
Tokyo Institute of Technology
TUV Nord
Univ Maryland
Univ Berkeley
Univ Duke
Univ Edinburgh
Univ Johns Hopkins
Univ Madrid
Univ Nottingham
Univ Southampton
Univ Stanford
Univ York (Toronto)
Vattenfall
Vijayant Kumar
Von Karman institute
Wind Farm Grou
Windlab Systems
WindSim

WASA 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. Site and station description at the 10 WASA stations
February 2012	Midterm Workshop presenting • First wind atlas verified against 1 year of measurements
February 2014	Final Workshop and Wind Seminar presenting • Researched wind resource atlas • Extreme wind atlas

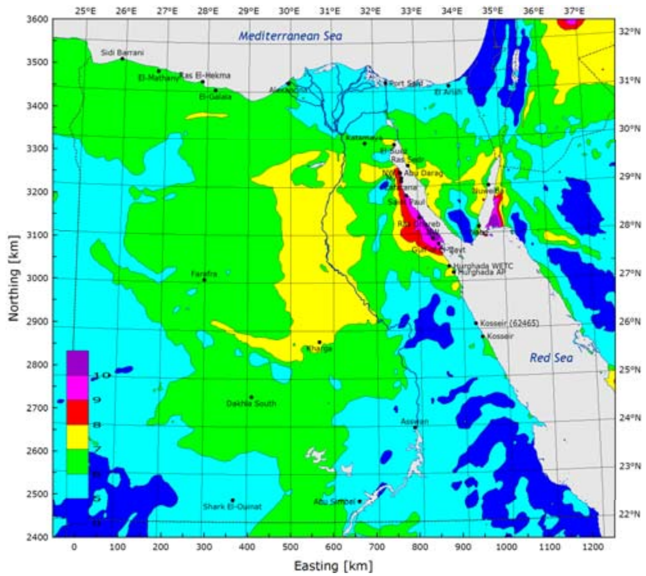
Outline

- Wind mapping – the facts
- Wind Atlas for South Africa (WASA) – the case
- Africa – challenges and opportunities



Some challenges and needs for wind resource assessment in Africa

- Energy, electricity and sustainable solutions needed
- Development of power systems are long term efforts
- Planning, implementation and operation of power systems need temporal and spatial wind power distributions
- Limited human and financial resources, therefore cost efficient solutions only
- Traditional climatology and global models do not provide the answer regarding wind resources – seen e.g. both in Egypt and South Africa
- Wind data availability is insufficient and quality inappropriate in most of Africa



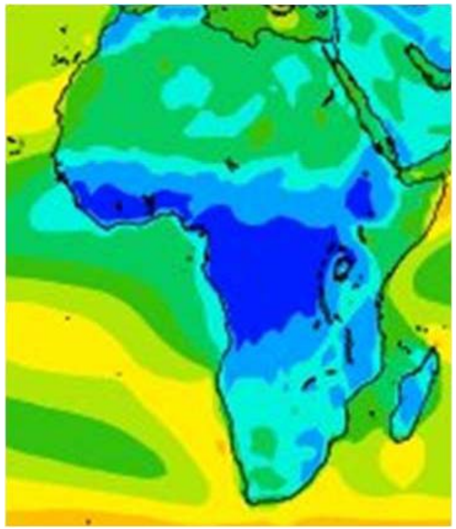
Global Wind Atlas for policy and planning

Clean Energy Ministerial Multilateral Working Group on Solar and Wind Technologies has taken an initiative regarding a Global Wind Atlas

- For the needs of policy makers, energy planners and the Integrated Assessment Modelling (IAM) community.
- The Global Wind Atlas will provide a unified, high resolution, and public-domain dataset of wind energy resources for the whole world by 2015
- Risø DTU has developed a framework methodology for the project
  - usíng microscale modelling to capture small scale wind speed variability (crucial for better estimates of total wind resource), but no mesoscale modelling
  - giving comprehensive uncertainty estimates
- Results to be published the methodology to ensure transparency (peer review)
- DK government funds Risø DTU providing Denmark’s contribution to the CEM Multilateral Working Group on Solar and Wind technologies implementation plan.
- Other partners at this stage:
  - International Renewable Energy Agency (IRENA)
  - CENER, Spain
  - DLR, Germany
  - NREL and NCAR, USA

Some concluding remarks

- The Wind Atlas Method can be applied in various forms for the needs of planning, policies and development
- The national wind atlas projects made e.g. in South Africa and Egypt show benefits for planning of the development of wind energy – new areas with promising resources, geographical coverage and temporal distributions
- The Global Wind Atlas can be used to identify regions that should be further explored, for Integrated Assessment Modelling and provide more accurate aggregated wind resource data then is available today
- The Global Wind Atlas needs national Numerical Wind Atlas for verification of its results in representative selected areas
- Numerical Wind Atlas should be made for detailed planning in all regions with possible wind energy potential
- Further research is needed in a global transparent collaboration



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

South African National Energy Research Institute (SANERI) is the Executing Partner coordinating and contracting contributions from the implementing partners:

CSIR, UCT, SAWS, and Risø DTU


Thank you