Wind Power Africa 2010

Cape Town, 13th May 2010

Wind Atlas for South Africa (WASA)

Project overview and status

Presented by:

Steve Szewczuk CSIR

Chris Lennard - UCT

Acknowledgements

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

- the UNDP-GEF through the South African Wind Energy Programme (SAWEP), and
- the 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.

Outline

- The problem
- Wind Atlas history
- Large-scale wind regime in South Africa
- WASA project objectives and project overview
- Project status by Work Package
  - WP1: Meso-scale modelling
  - WP2: Wind measurements
  - WP3: Micro-scale modelling
  - WP4: Application for wind resource assessment
  - WP5: Extreme winds
  - WP6: Documentation and dissemination

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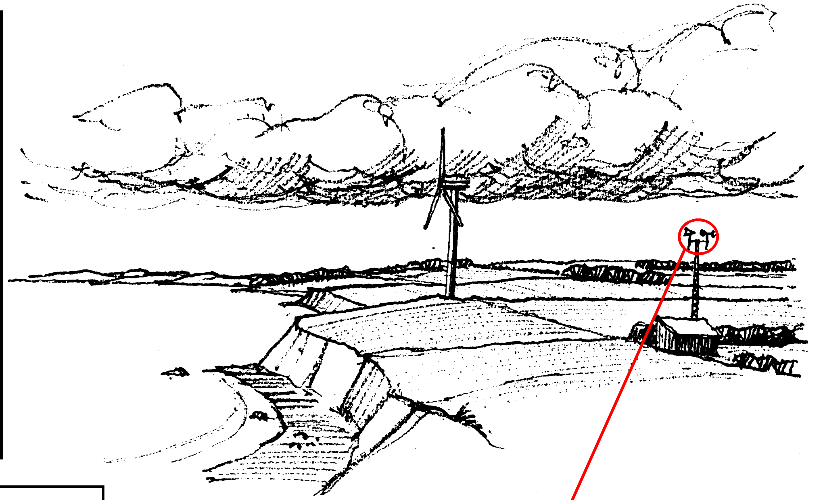
Wind resources - the problem

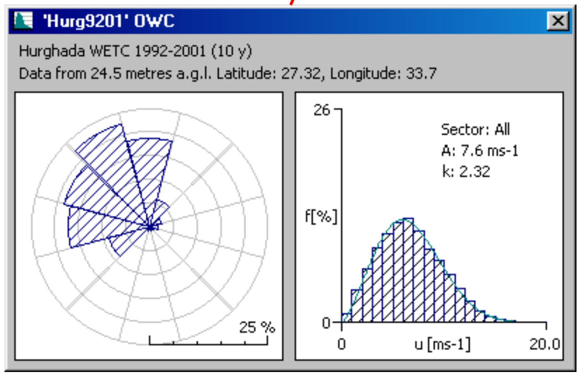
Determining the wind resources accurately is important and difficult

Main parameters governing wind power economics:

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



- Wind speed, U [m/s]
- Kinetic Energy flux, $P = \frac{1}{2}\rho U^3$ [W/ m^2]
- ΔU of 5% (e.g. U=10.0+0.5m/s) ⟹ ΔP of 15%



- Wind resources are in fact more P than U
- Both U and P are statistical distributions
- We measure U (and D) in one point in space, but need it in the entire atmospheric boundary layer, so Modelling is necessary

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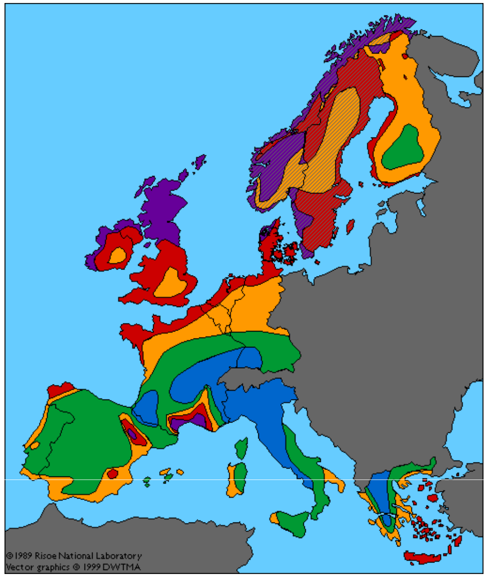
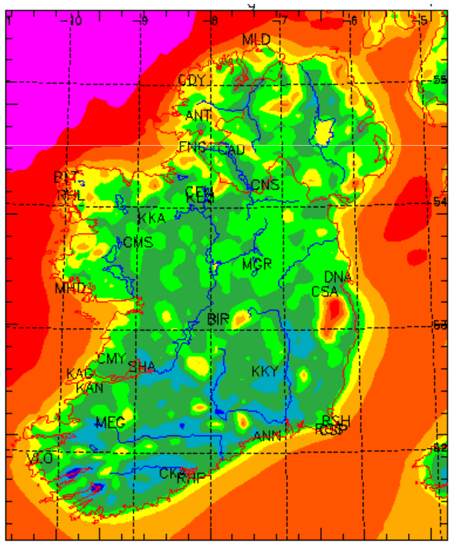
The Wind Atlas Method



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

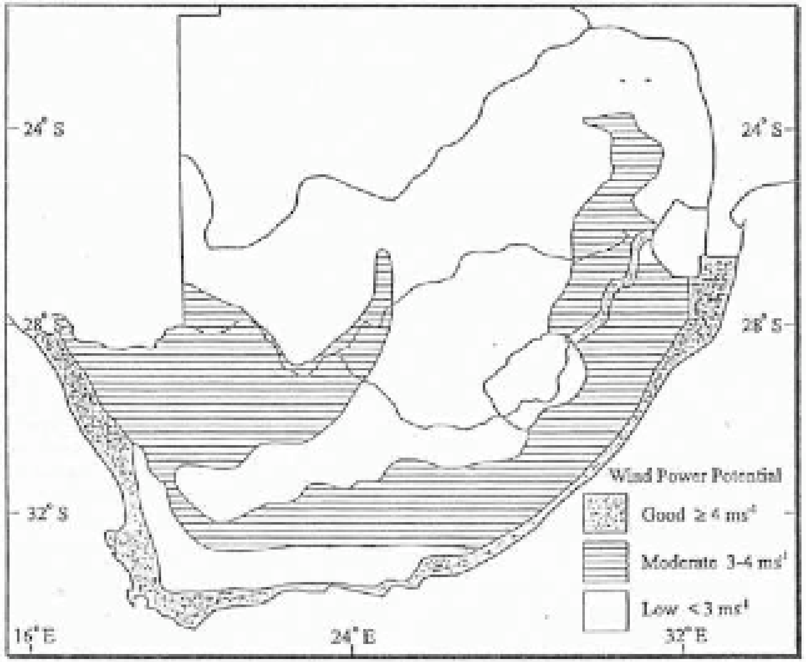
the *numerical wind atlas* and mesoscale modelling techniques for larger domains, mesoscale effects and long-term wind climates came in the 90’s



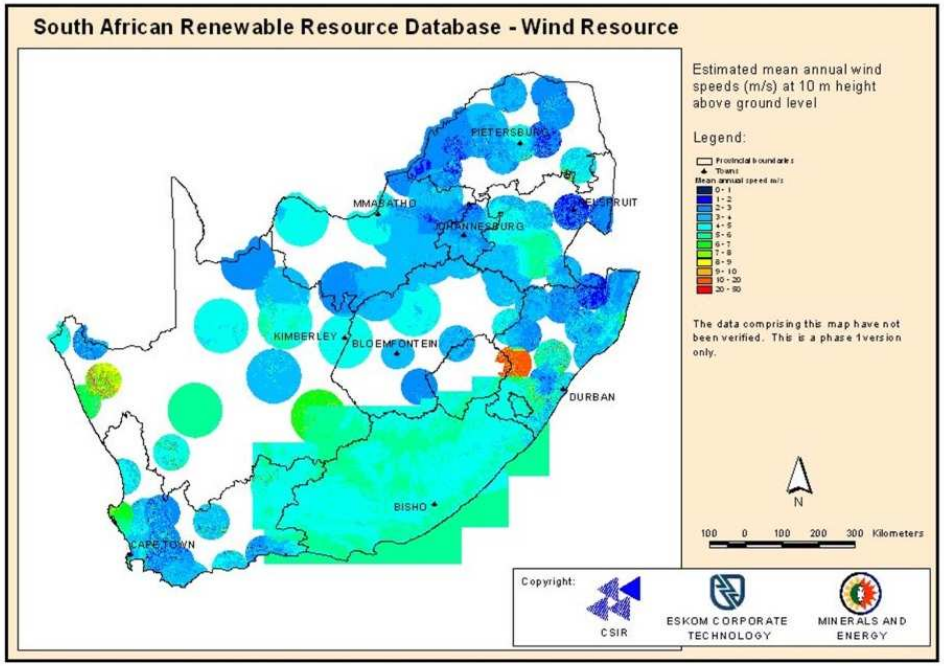
state-of-the-art wind resource assessment and planning is a combination of microscale and mesoscale modelling with verification against measurements

Observational wind atlases for South Africa

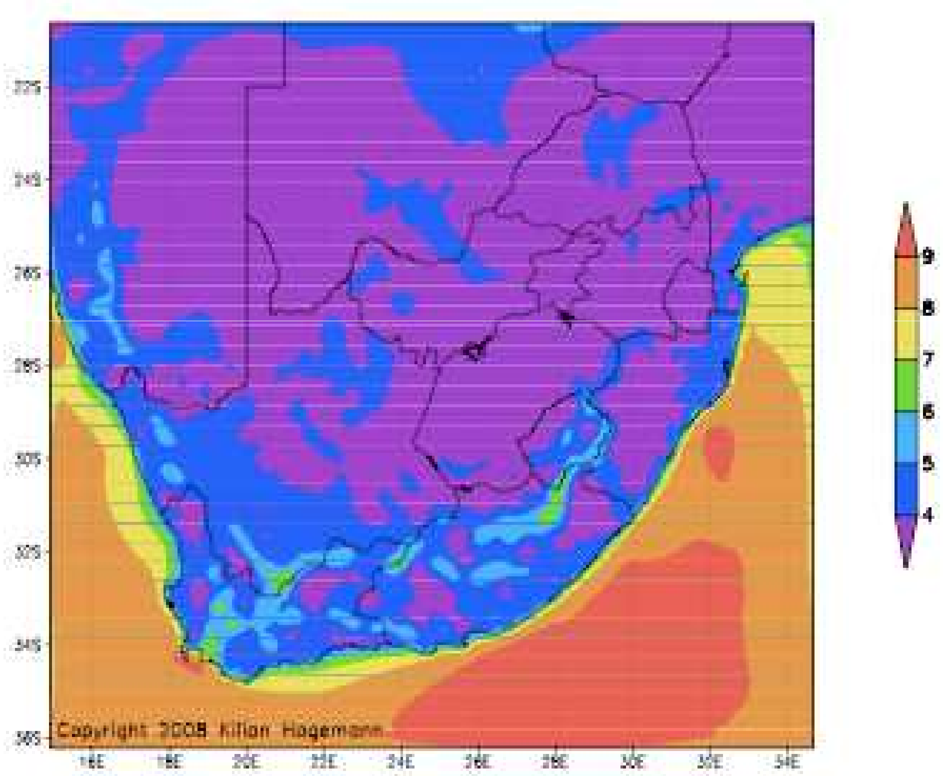
DME; R. Diab 1995



DoE, ESKOM, CSIR 2001

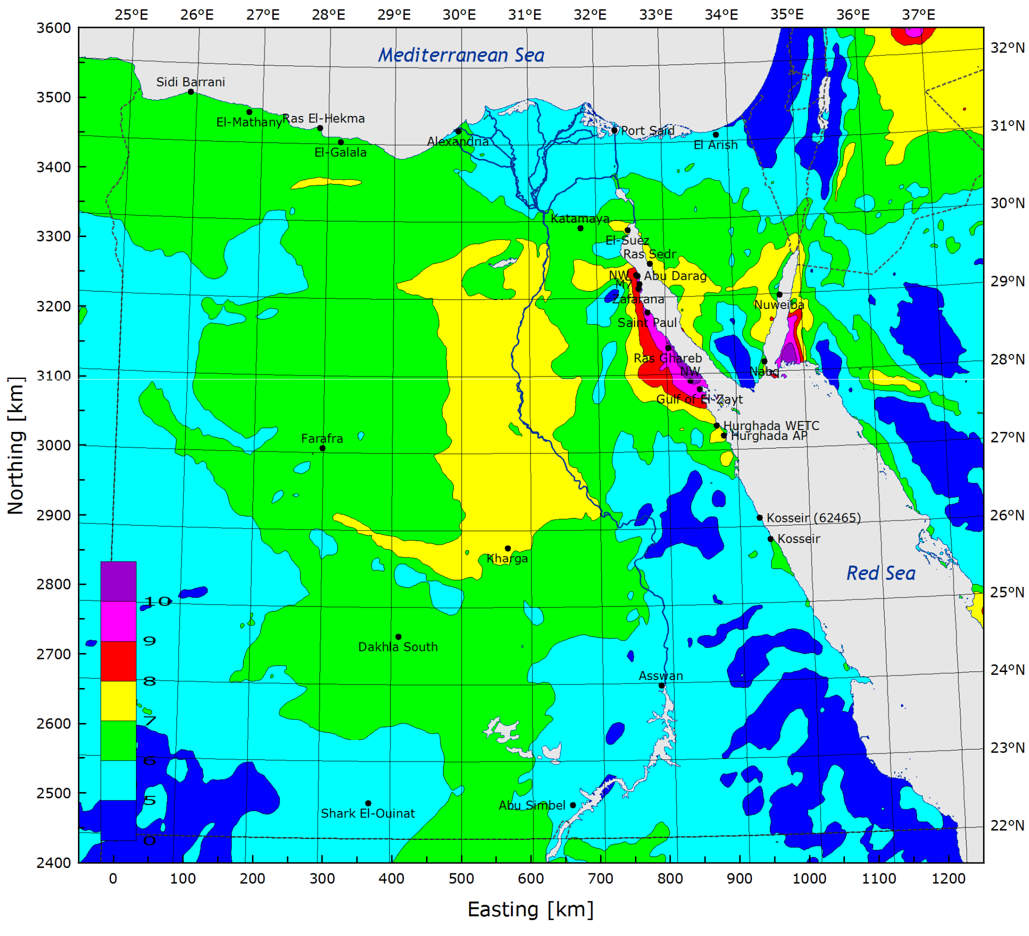


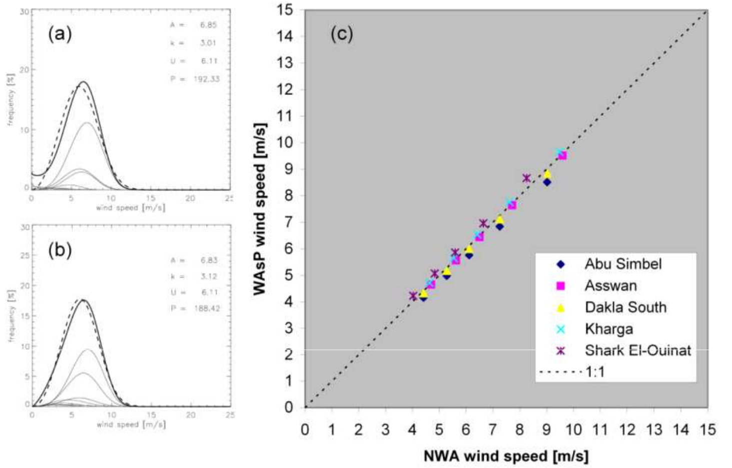
Statistical/dynamical downscaling using self organizing maps and Penn State/NCAR meso-scale model (MM5)



Average annual wind speed at 10 m above ground (m/s)
Kilian Hagemann, University of Cape Town (2008)

Numerical Wind Atlas for Egypt 2001-2005





Verification at selected met masts

- Comparison of generalized wind speed distributions a) mesoscale NWA modelled and b) measured, as well as comparison of c) generalized mean wind speeds at selected sites in Egypt
- Typical mean absolute error on the wind speed: 5-10 %

The numerical wind atlas method - summary

Mesoscale	**Pre-processing** Wind classes Terrain elevation Terrain roughness Input specifications Model setup	**Modelling** KAMM WRF MC2 MM5 etc.	**Post-processing** Predicted wind climate Regional wind climate Predicted wind resource for selected terrain site coordinates	**Numerical WA** Mesoscale maps Database WAsP *.LIB files Uncertainties Parameters
Measurements	**Met. stations** Siting Design Construction Installation Operation	**Wind data** Data collection Quality control Wind database Wind statistics Observed wind climate	**Verification** Meso - and microscale results vs. measured data Adjust model and model parameters to fit data Satellite imagery (offshore sites only)	**Applications** Best practices Courses and training Microscale flow model Wind farm wake model ⇒ **Wind farm AEP**
Microscale	**Pre-processing** Wind speed distributions Wind direction distribution Terrain elevation Terrain roughness Sheltering obstacles	**Modelling** WAsP MS-Micro CFD-models etc.	**Post-processing** Regional wind climate Predicted wind climate Predicted wind resource for selected terrain site coordinates	**Observational WA** Microscale maps Database WAsP *.LIB files Uncertainties Parameters

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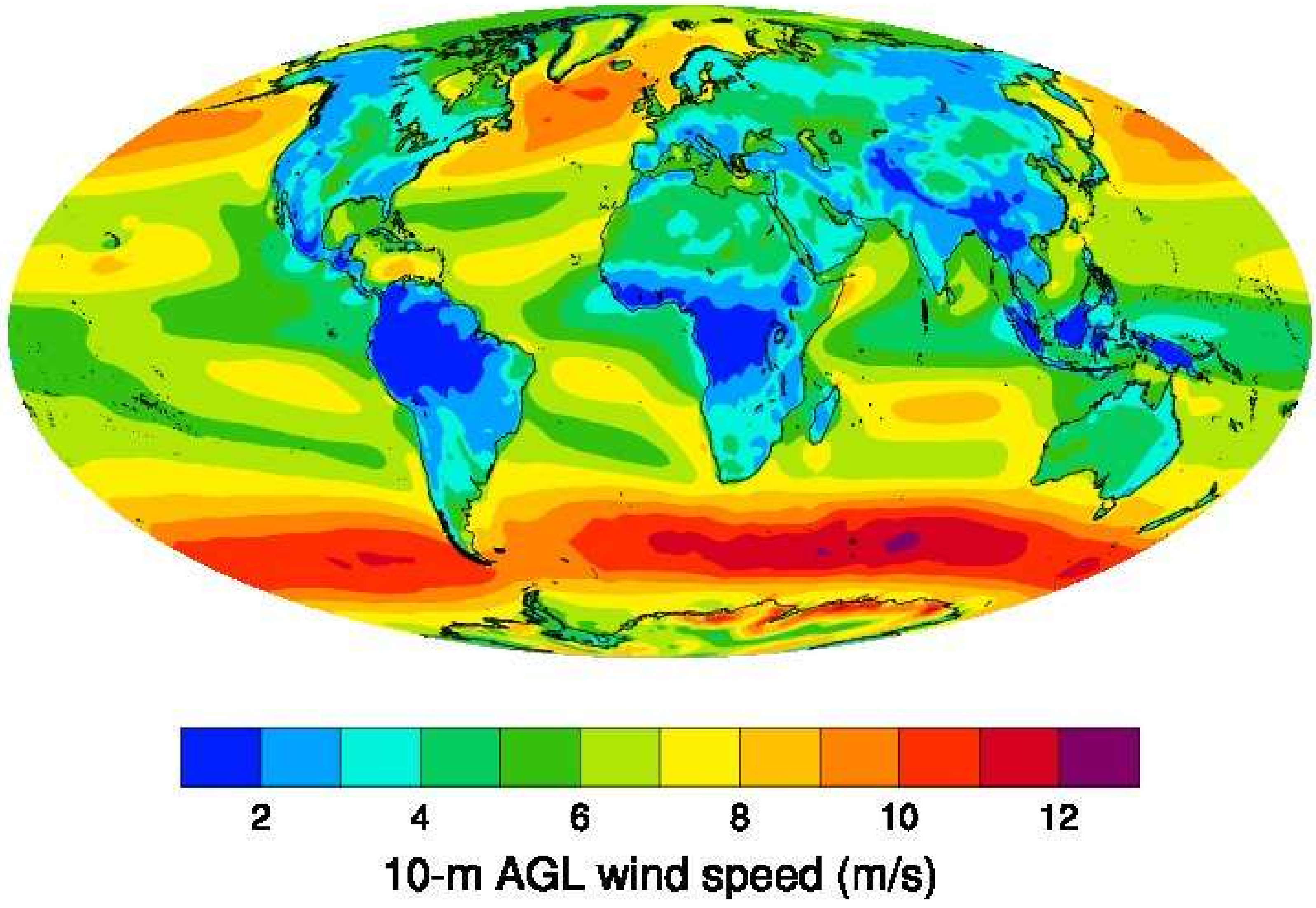
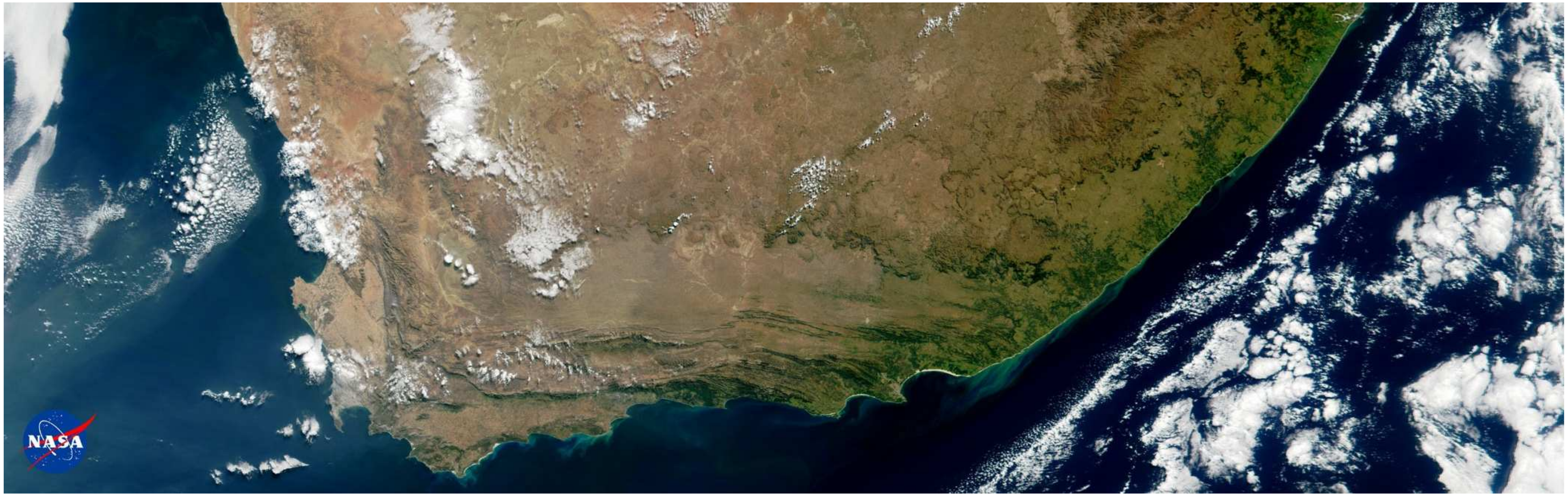
Annual average 10-m winds across the world



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

South Africa weather systems

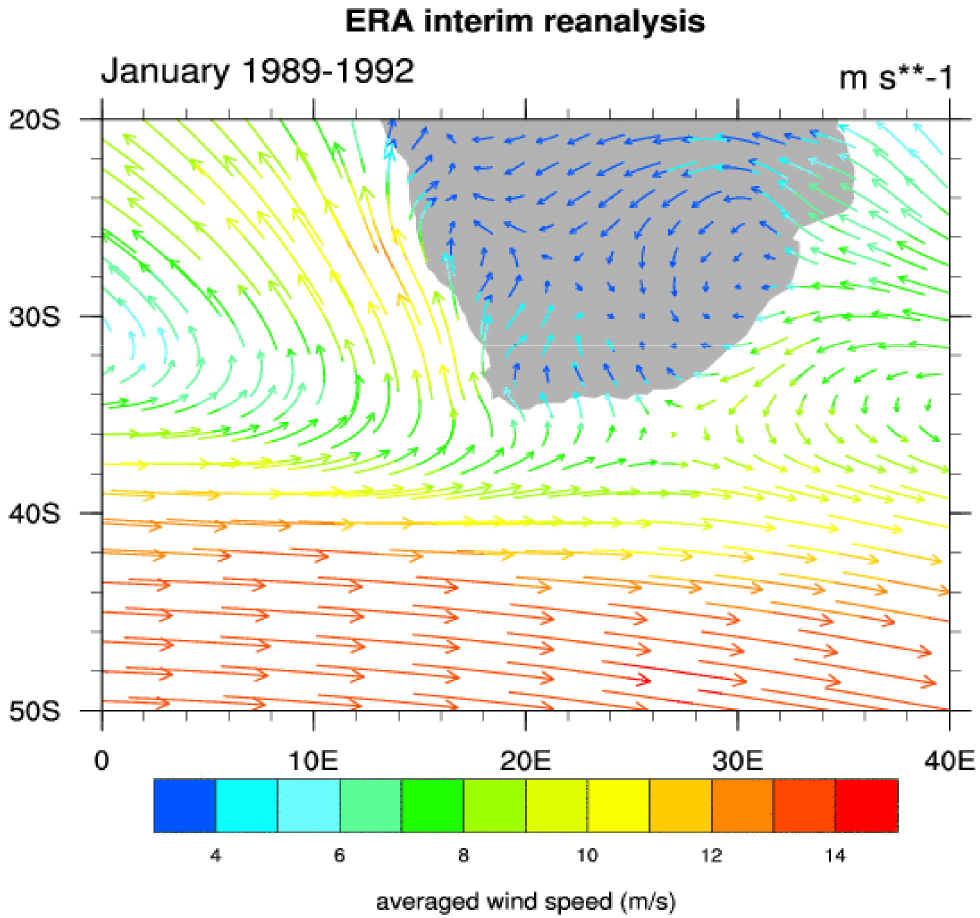
- South Africa has a very diverse climate, and this diversity applies to the wind climate as well
- Different prevailing weather systems dominate the wind climate over different regions of South Africa
- The influence of these weather systems tend to change in their strengths and spheres of influence during the course of a typical year



Seasonal and annual cycle

- The seasonal differences in the circulation features of the atmosphere, near the surface of southern Africa and the surrounding oceans, are mainly the result of the northward displacement of the subtropical high pressure belt by almost five degrees latitude from summer to winter.
- Usually these lower-level anticyclones on land are interrupted once to twice per week by cold-front troughs.

Annual cycle of the 10-meter winds
(one picture per month)



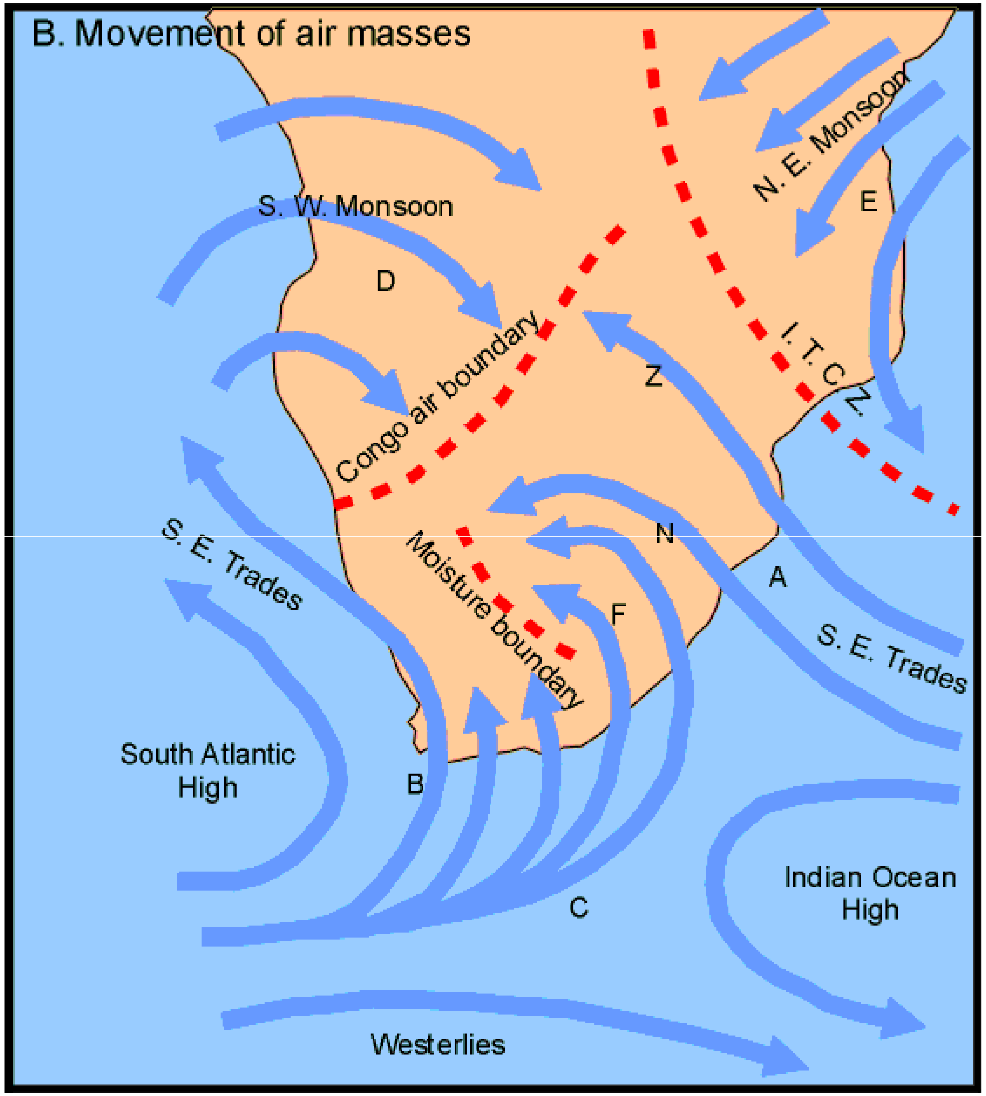
Summer winds

The “westerlies” are situated well to the south of the continent.

The south-eastern Trades (A) influence the north-eastern part of the region. These winds can be strong, curving sometimes from Limpopo Province (N) into the Free State (F), or moving over far northern areas, such as Zimbabwe and Zambia (Z).

In the west, the S. E. Trades (B) caused by ridging of South Atlantic High, are often strong and persistent.

The strong westerlies are only able to influence the western, southern and south-eastern coastal areas and adjacent interior.



Winter winds

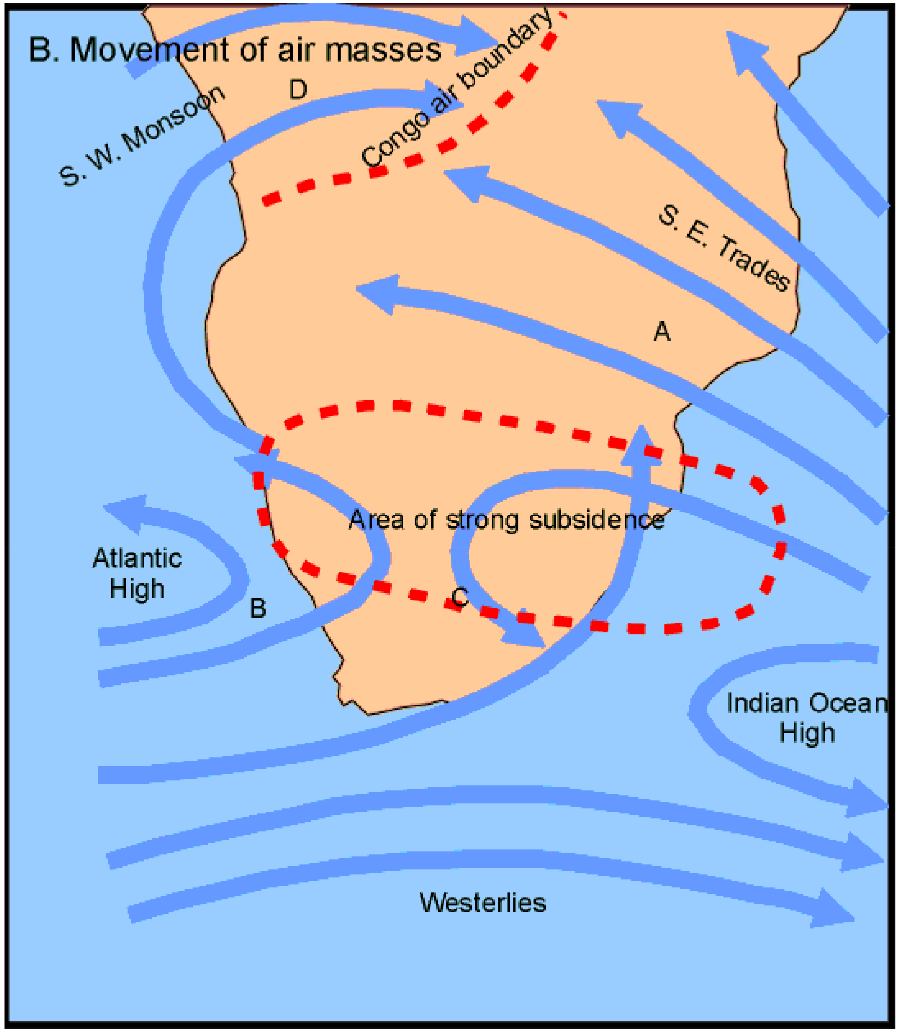
All circulation features are situated more to the north than in summer.

Strong winds and gusts during winter are usually caused by strong cold fronts, moving mostly over the southern half of South Africa, and also by the ridging of the high pressure systems behind the fronts.

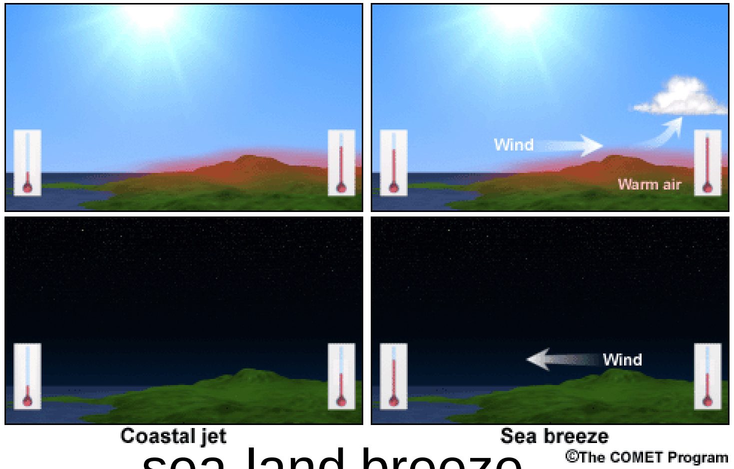
The "westerlies" influence the weather of the southern and central parts of the subcontinent to a large degree. Cold fronts often move over these areas and may reach far to the north.

The strong westerlies are only able to influence the western, southern and south-eastern coastal areas and adjacent interior.

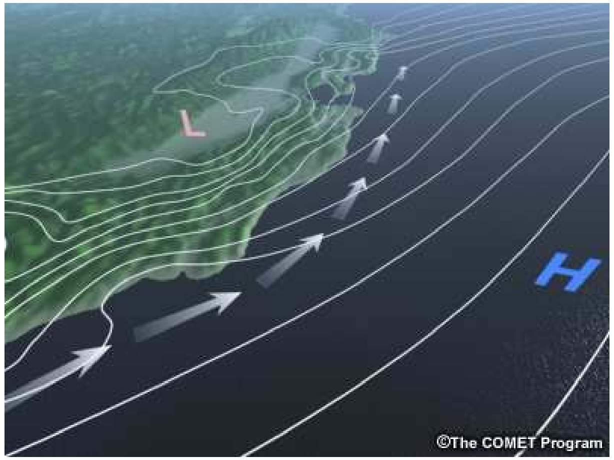
When the Atlantic high pressure system moves more eastwards and stays strong, gale force winds can spread to the KwaZulu-Natal coast as far north as the Mozambique Channel.



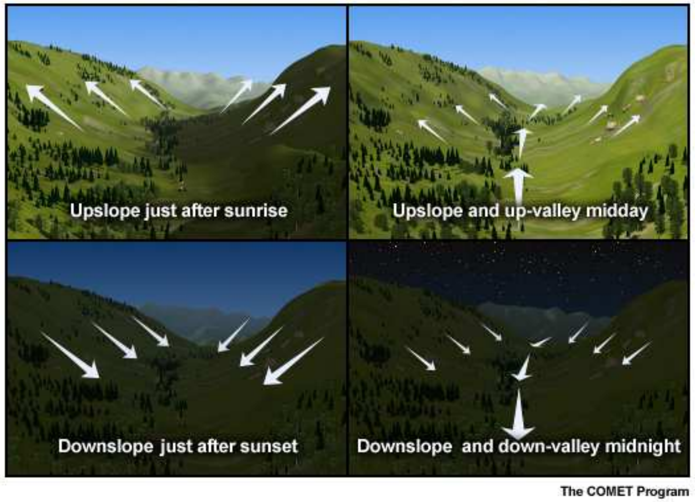
Meso-scale processes generate regional circulation systems and/or modify these general patterns



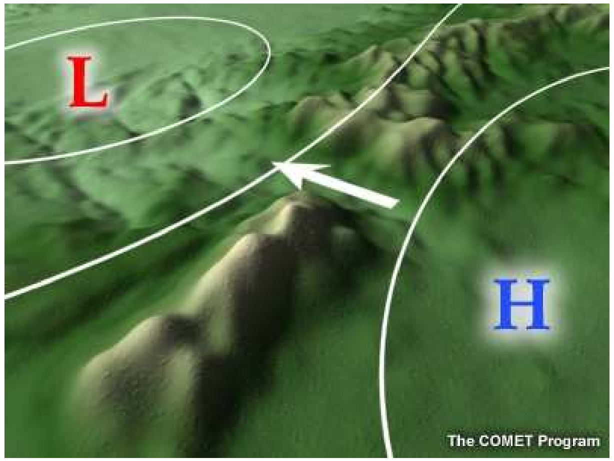
sea-land breeze



coastal jet

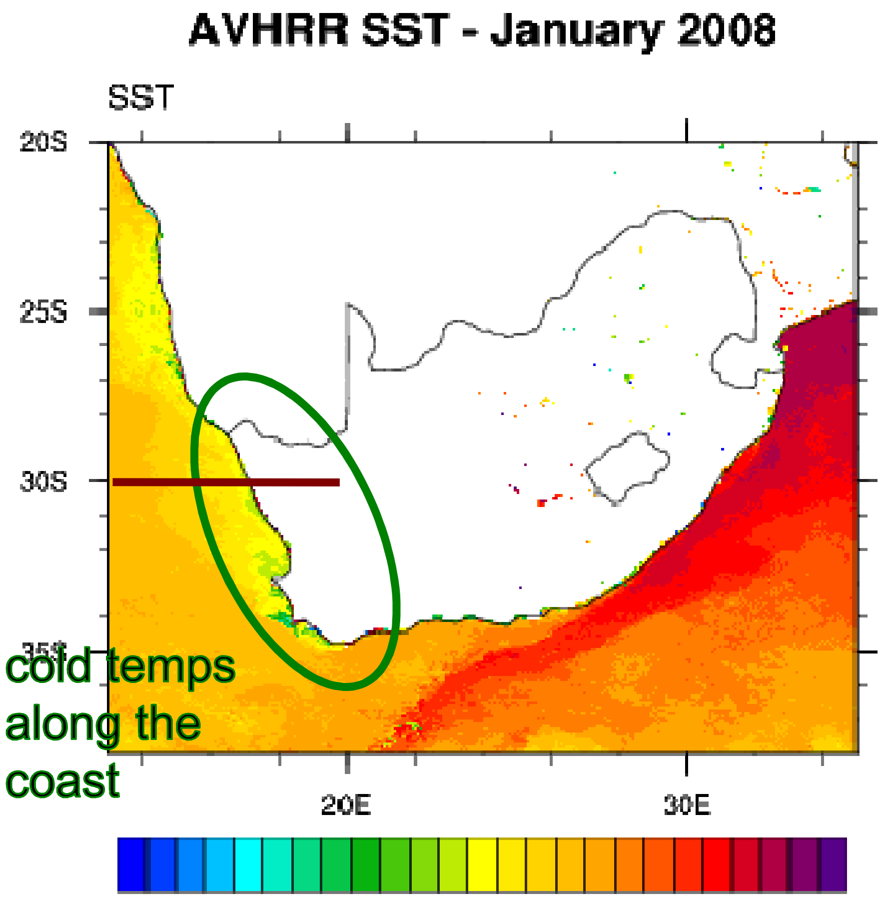


mountain-valley breeze

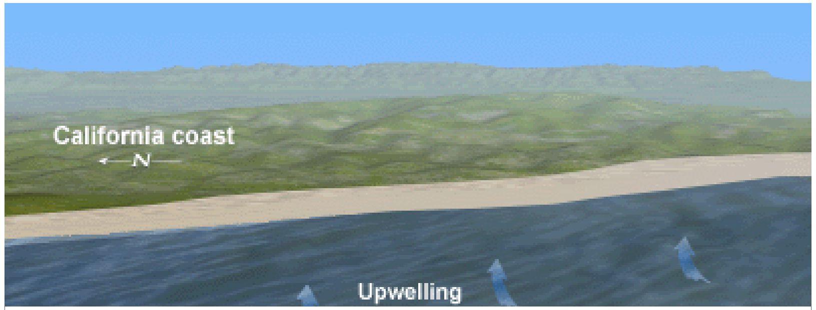


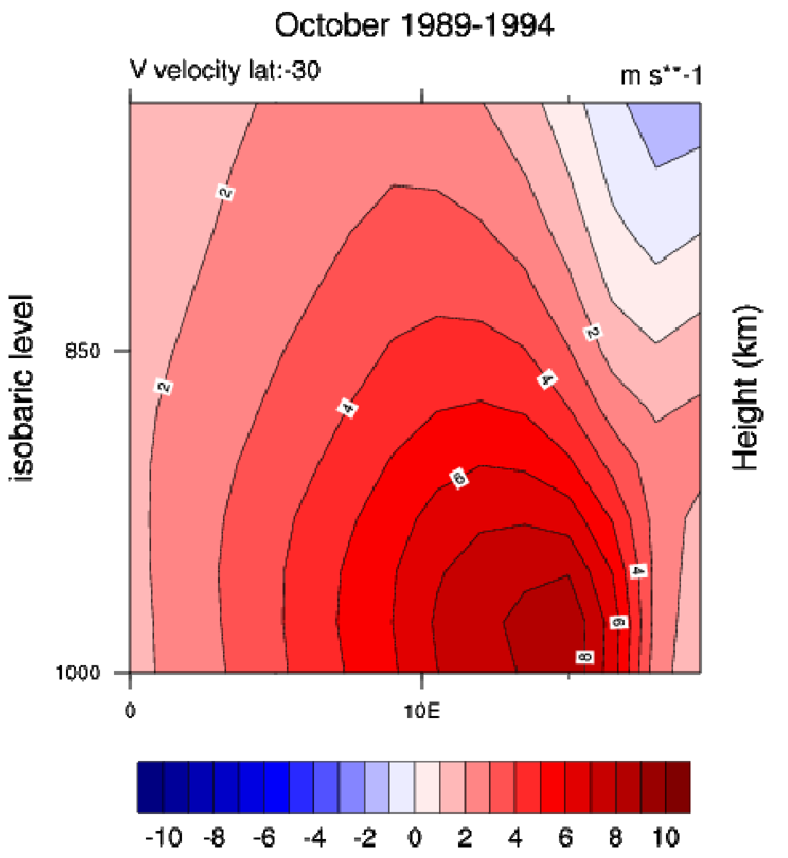
gap flow

SA meso-scale example: Coastal jet along the west coast



sea-surface temperatures





Source: ERA Interim reanalysis

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

The overall objectives according to the grant agreement are to:

- Improve conditions for realization of national goals for development of wind energy
- Reduce cost of electricity from wind energy

The objective tree of the Project Description Document specifies the objectives as:

Development objectives

Improve incentive for investments in wind energy	Improve efficiency of planning for wind energy	Improve benefit and reduce uncertainty of investments in wind energy

Immediate objectives

Improve knowledge & quality of wind resource assessment methods & tools as well as to ensure availability of tools / data for planning / application for wind farm developments, off grid electrification & extreme wind studies

WASA project – Work Packages

WP1 – Mesoscale wind modelling (Chris Lennard UCT, Andrea Hahmann RISØ)

- KAMM /WRF/WAsP statistical/dynamical downscaling
- WRF – dynamical downscaling

WP2 – Wind measurements (Eric Prinsloo CSIR, Poul Hummelshøj RISØ)

- 10 high quality met stations (60m) for verification
- Database of measured data

WP3 – Micro scale wind modelling (Steve Szewczuk CSIR, Hans E. Jørgensen RISØ)

- Creation of Observational Wind Atlas for selected measurement sites in South Africa

WP4 – Application for wind resource assessment (S Szewczuk CSIR, Jens Carsten Hansen RISØ)

- Mid-term Workshops for invited stakeholders from e.g. authorities, planners, developers, banks, scientists, etc.
- Develop tools - guidelines and training materials
- Micro-scale resource map for 30-50% of the modelled areas in the three provinces, incl. integration as GIS layer
- Final Workshops and training of trainers for invited stakeholders, incl. opportunities for application in determination of extreme wind climate; seasonal forecasting; and other than wind energy.

WP5 – Extreme winds (Andries Krüger SAWS, Hans E. Jørgensen RISØ)

- Application of mesoscale modelling results to the estimation of an extreme wind climate of South Africa

WP6 – Documentation and dissemination (Thembakezi Mali SANERI, Jens Carsten Hansen RISØ)

- Prepare and disseminate research publications, incl. final book and homepage publication
- Prepare national wind seminars
- Establish and document research cooperation between South African and international wind research partners.

WASA project – main outputs

- The project will produce the following main results:
  - Measurement program for verification for a total period of 3-years
  - First wind atlas according to standard proven and tested method after 1 year of measurements
  - Researched wind atlas after 3 years of measurements

- All results in public domain

- UCT to be national competence center for mesoscale modelling
- CSIR-Stellenbosch to be national competence center for high-quality measurements
- CSIR-Pretoria to be national competence center for microscale modelling
- SAWS to be national competence center for extreme wind assessment
- SANERI responsible for coordination and dissemination
- A PSC has been established, currently comprising of: DoE (chair) DST, UNDP, RDE, SAWEP,SANERI. Meets approx twice a year in synch & after PIU meetings

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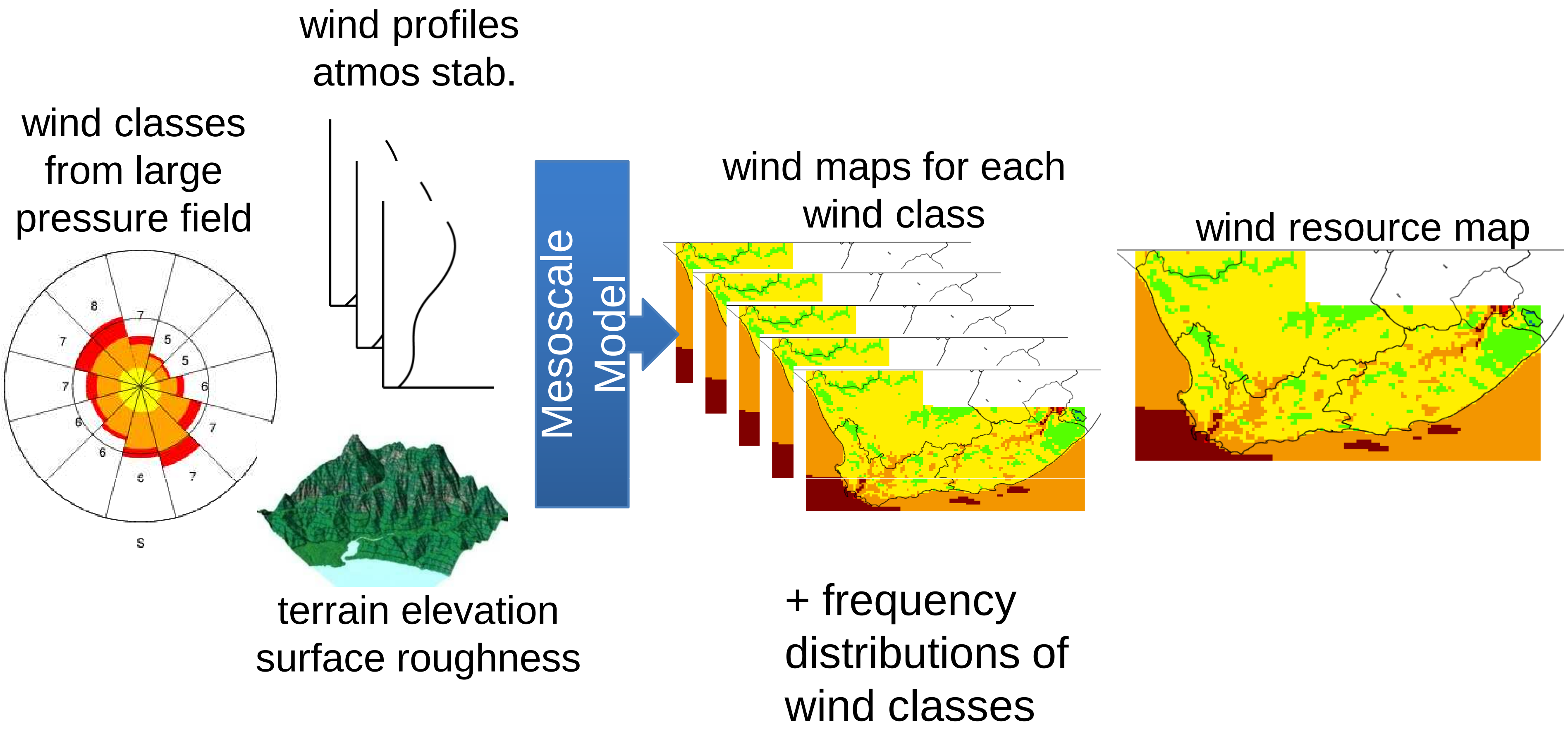
WASA project
main milestones according to present work plan

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 2010	10 WASA measurement stations in operation
September 2010	Wind data publishing monthly on web-site activated
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 • Research wind resource atlas • Extreme wind atlas

WASA project status
WP1 – Meso-scale modelling

- KAMM /WAsP statistical downscaling – ongoing and
- WRF – dynamical downscaling – planning and familiarisation (weather forecast for SA running)
- Awaiting WP2-data for verification

WP1 methods overview

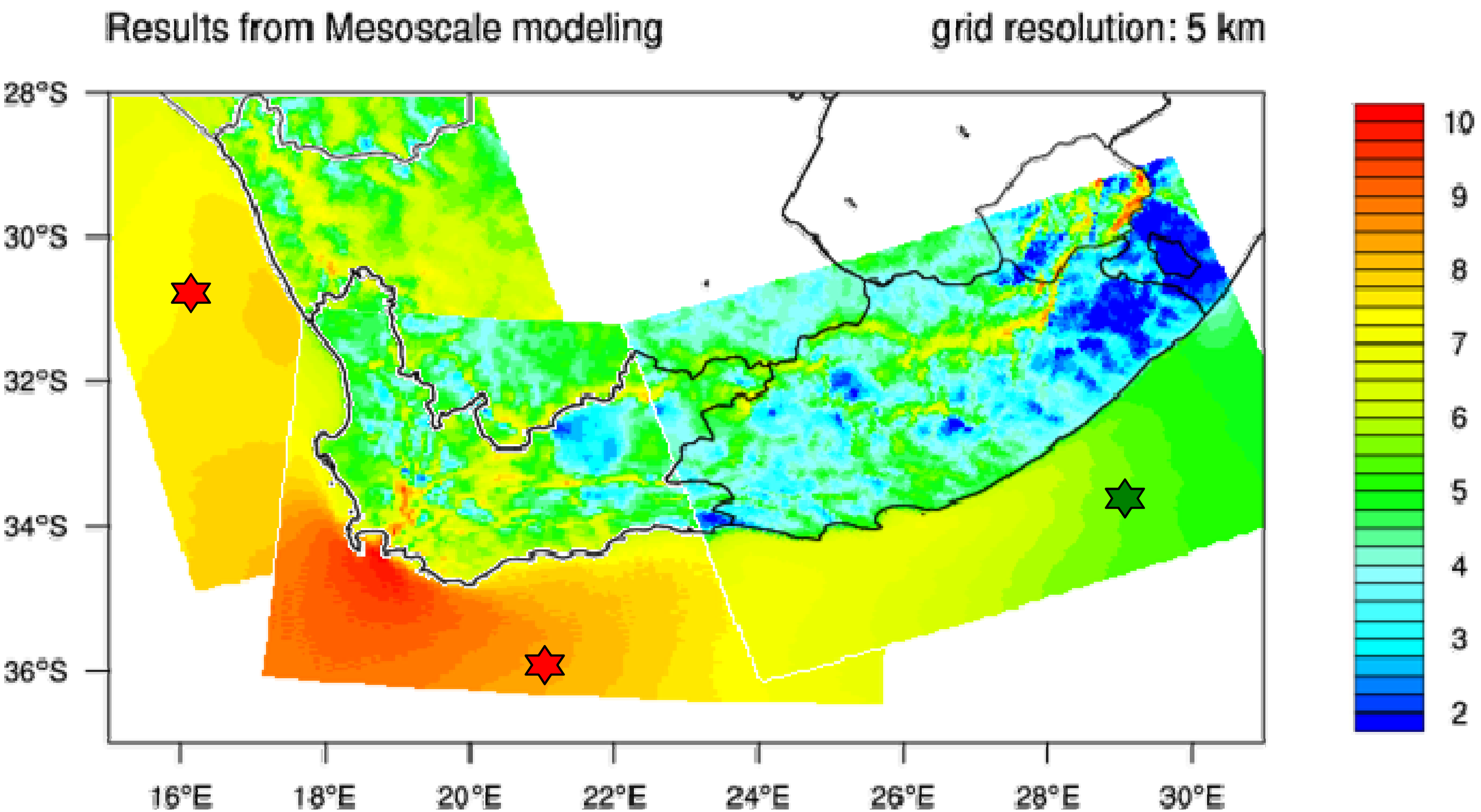


Simple/Fast/Cheap → Complex/Slow/Expensive

Interpolation | Risø Wind Atlas | Statistical-dynamical | Fully dynamical

WP1 Preliminary calculations for SA

Mean wind speed (m/s) at 50 m – KAMM/WAsP, 3 domains



unverified output, do not use these numbers

WASA project status
WP2 – Wind measurements

- Site selection criteria developed
- Site selection, site visits, land owner interaction and agreements completed
- Masts designed, procured and manufactured
- Measurement equipment designed and delivered
- Data acquisition system delivered, installed and training completed
- EIA - Basic assessment procedure negotiated, application document submitted
- Environmental approvals obtained
- Site preparations and foundation construction completed

- Activities ongoing
  - Mast transport to site and erection
  - Instrumentation
- Data acquisition from all masts expected to start July 2010
- RODEO, web and data availability for public access expected to start September 2010

WP2 method overview

Wind measurements for verification

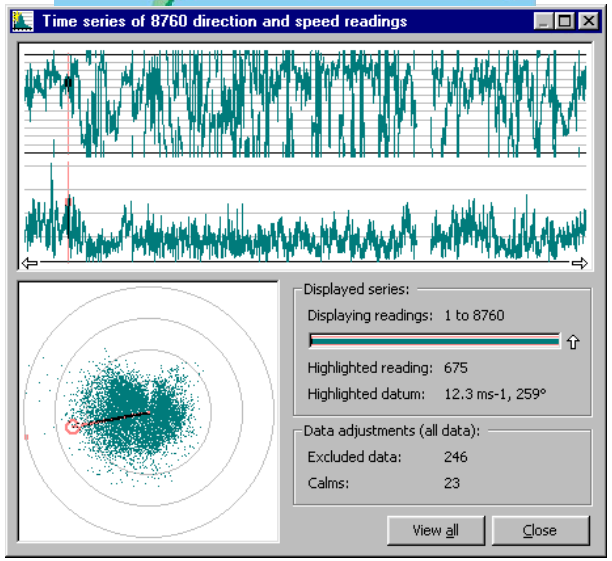
The wind data must be

- accurate
- representative
- reliable

10 good sites were identified representative terrain types, suitable for meso-scale modelling, and geographically spread over the project area

The wind measurement stations were designed with a view to

- Meeting IEC standards and MEASNET guidelines
- Proven sensors of high quality and individually calibrated
- Instrumentation arranged to minimise errors and uncertainties due to flow distortion



- Daily data transfer via GSM
- Acquisition, QA, calibration and database organisation and web publishing by RODEO at CSIR
- Web www.wasa.csir.co.za
  - Graphs daily
  - Data files monthly

Locations of wind measurement masts

Met. Masts installed - layout

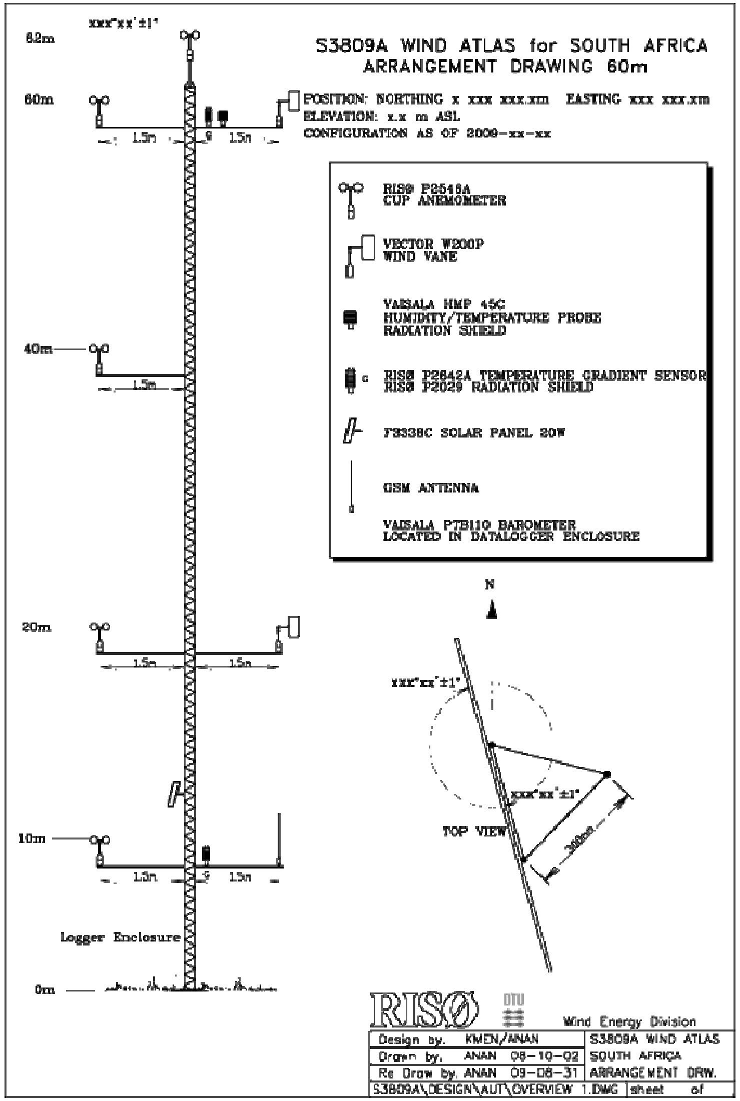
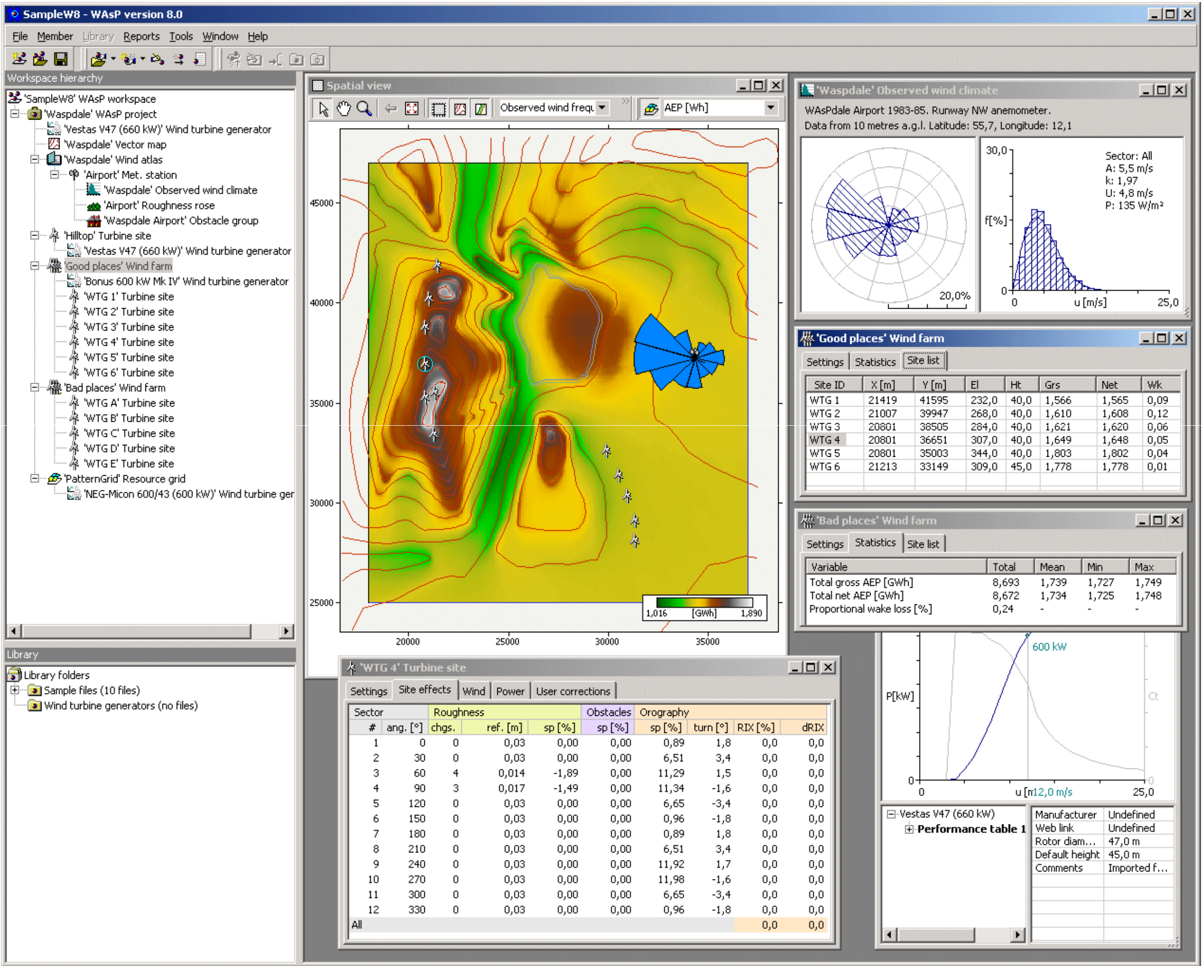


Photo of WM4: Vredenburg - 60-m lattice masts

WASA project status
WP3 – Micro-scale modelling

- Micro-scale workshop for all partners held November 2009
- Land-use data extracted from CSIR GIS systems for use in both WP1 and WP3
- Awaiting WP2-data

WP3 method overview



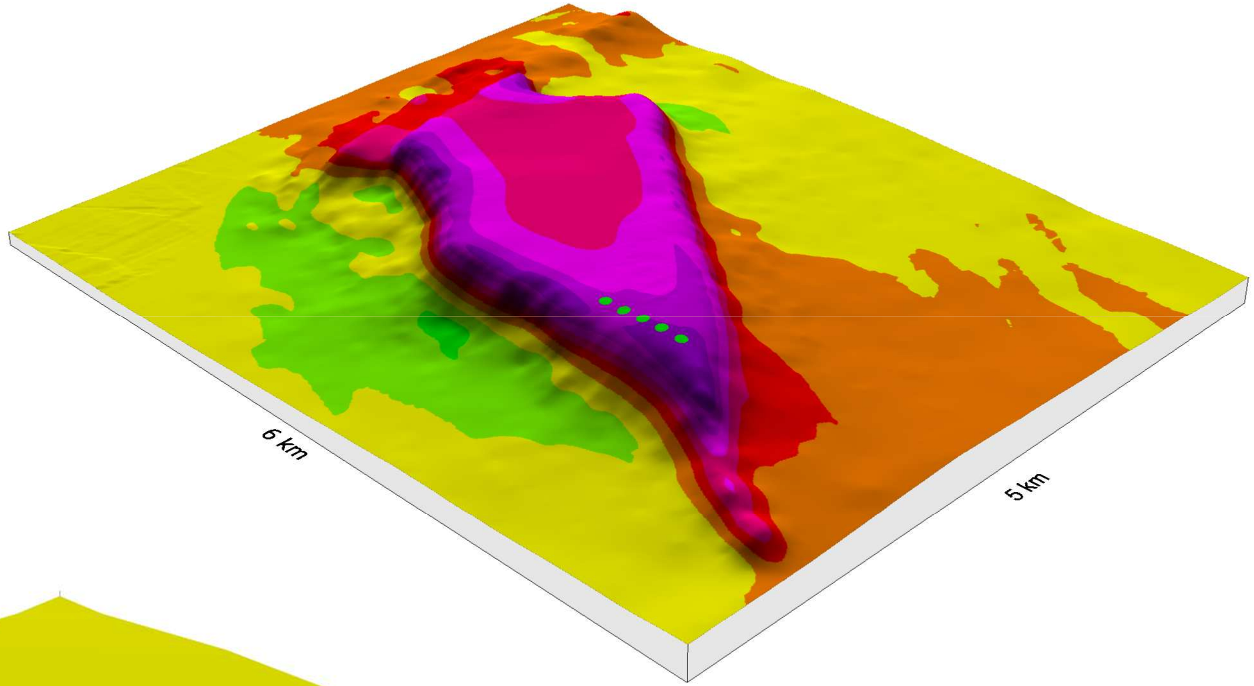
WAsP (Wind Atlas Analysis and Application Program) is the industry standard micro-scale modelling software tool that will be used throughout the WASA project.

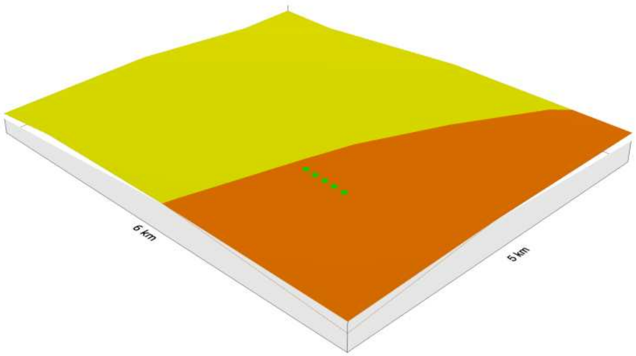
WAsP will be used for:

- Wind data analysis
- Map digitisation & editing
- Wind atlas generation
- Wind climate estimation
- Calculating power production in any cases studied
- Wind resource mapping

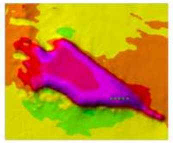
WP3 - no WASA results yet, but

this slide illustrates importance of resolution to overcome uncertainties





- meso-scale map only
- Grid cell size 5120 m
- Wind farm 5 x 2 MW
- AEP = 39 GWh



- KAMM/**WAsP** resource map
- Grid cell size 20 m
- Wind farm 5 x 2 MW
- AEP = 55 GWh

WASA project status
WP4 – Application for wind resource assessment

- Workshops for invited stakeholders held 4 March 2010
- http://www.saneri.org.za/wind_atlas.htm
  - SAWEP background
  - 1. Introduction - WASA project overview and purpose of workshop
  - 2. Wind Climate South Africa 2010
  - 3. Measurements and meteorological data
  - 4. WASA Rodeo
  - 5. Wind Atlas Introduction 2010
  - 6. Flow Modelling
  - 7. Resource mapping
  - 8. WAsP Engineering
  - 9. Wind farm calculations
  - 10. CSIR GIS

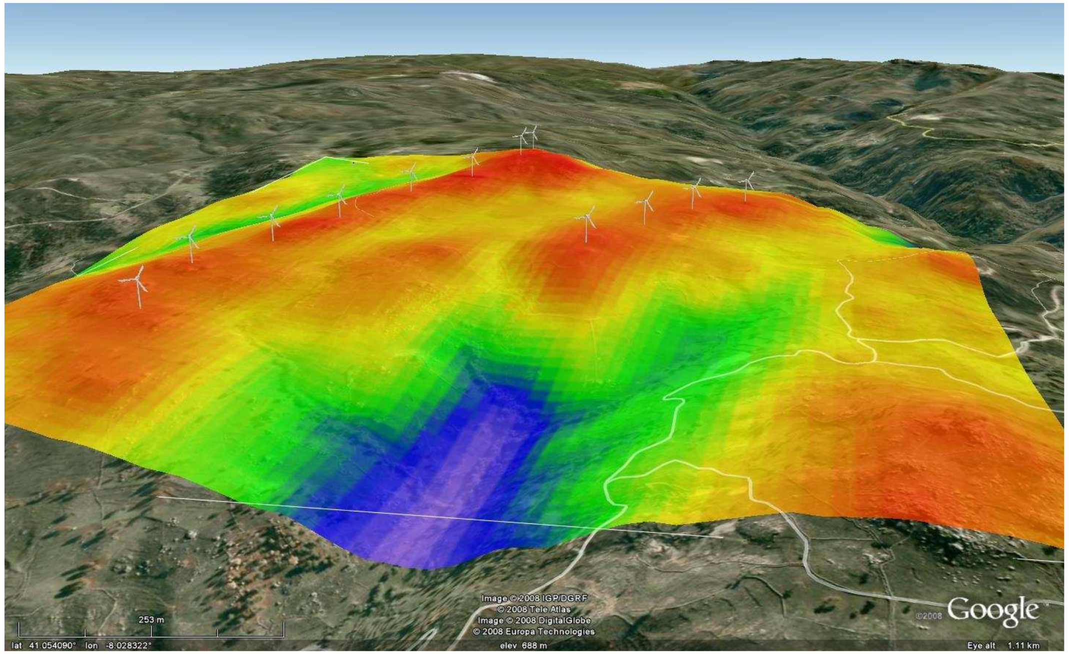
WP4 method overview

Courses on how to apply the Wind Atlas for South Africa will be developed and made available. Main applications considered are e.g.

- National, regional and local planning
- Wind resource assessment for project preparation
- Siting of wind farms and turbines
- Bankable projects – close to masts

Any software tools necessary for applying WAsP to the Wind Atlas for South Africa will be developed

Wind Atlas for South Africa Database availability will be ensured through www.wasa.csir.co.za and presented at Mid-term and Final Workshops



WASA project status
WP5 – Extreme winds

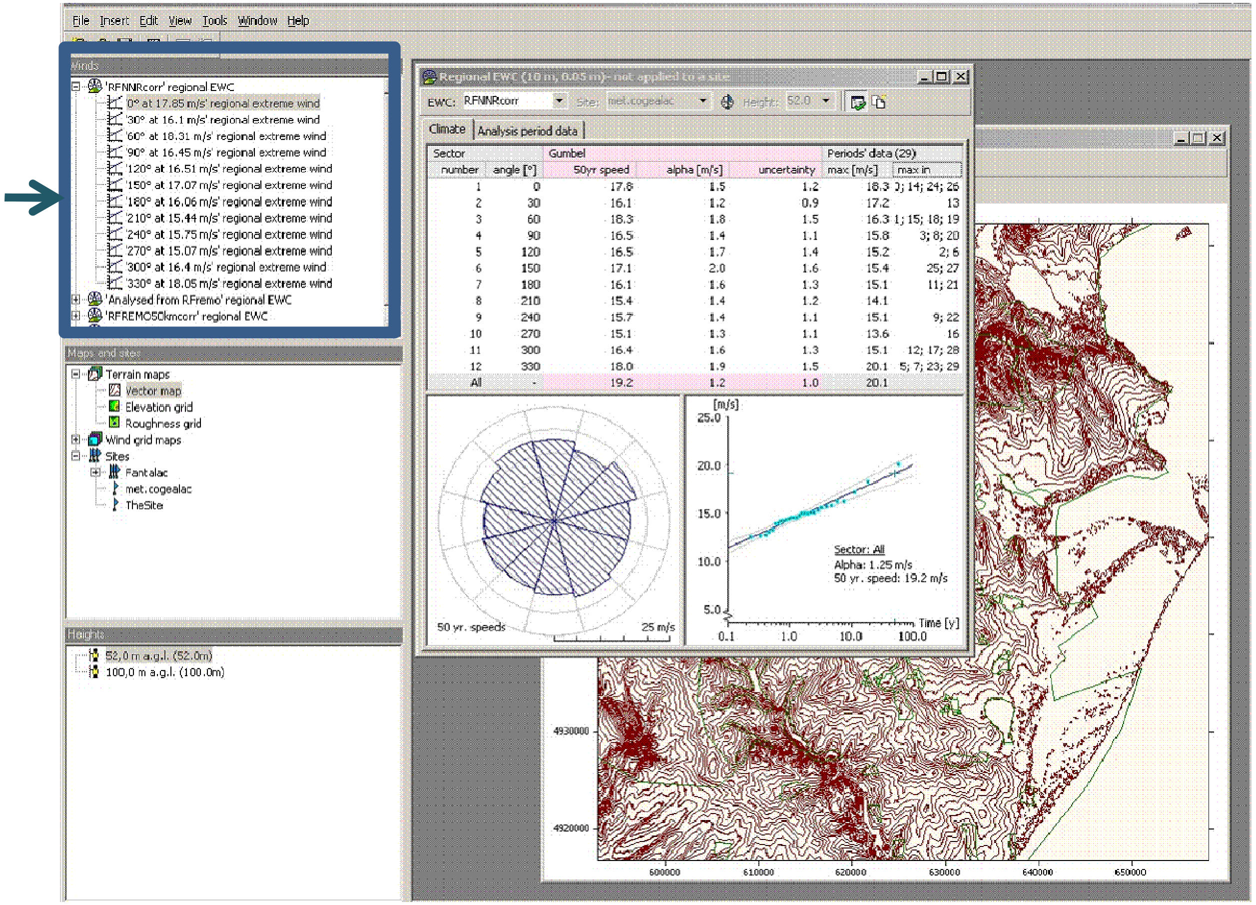
- WP done by SAWS – Basis of PhD for Andries Krüger
- Training in WAsP-Engineering in upgrading the estimation of the extreme wind climate of South Africa completed

WP5 method overview

Extreme wind estimation by WAsP Engineering

Regional extreme wind climate (EWC) obtained from:

- Observations
- Global reanalysis data
- Mesoscale simulations
  - Storm episodes method
  - Wind class method
  - Climate simulation



WP5 ”if any preliminary results” slide

WASA project status
WP6 – Documentation and dissemination

- Research publications
- Web-site publication
- Wind seminars and workshops
- Research cooperation

On behalf of the entire WASA project team

THANK YOU

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