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Wind Energy Resource and Forecasting

Nicholas Cutler, 9th August, 2006

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Talk outline

- Wind Resource Assessment
  - Measuring the Wind Speed
  - Wind Atlases
- Wind Energy Forecasting
  - Traditional Methods
    - Power curve modelling
    - Numerical Weather Prediction
  - The Danish “Wind Power Prediction Tool”
  - CEEM research

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Measuring the wind speed

- Cup Anemometer
  - Point measurement
  - Overspeeding issue
  - Angular response
  - Icing

Risø cup anemometer
www.cupanemometer.com

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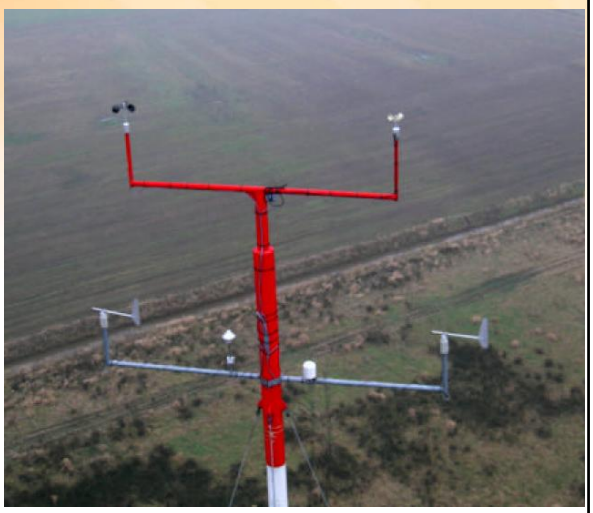
Measuring the wind speed

- Cup Anemometers
- Wind vanes - direction
- Watch for boom interference



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Measuring the wind speed

- Sonic Anemometer
  - 4 ultrasonic transformers act as acoustics emitters and receivers
  - Wind speeds up/slows down the acoustic signal
  - Calculates horizontal wind speed and direction from resolving the vectors
  - Sensors heated to avoid ice, snow or rainfall problems

Thies Ultra sonic anemometer
http://www.thiesclima.com/usanemo_e.htm

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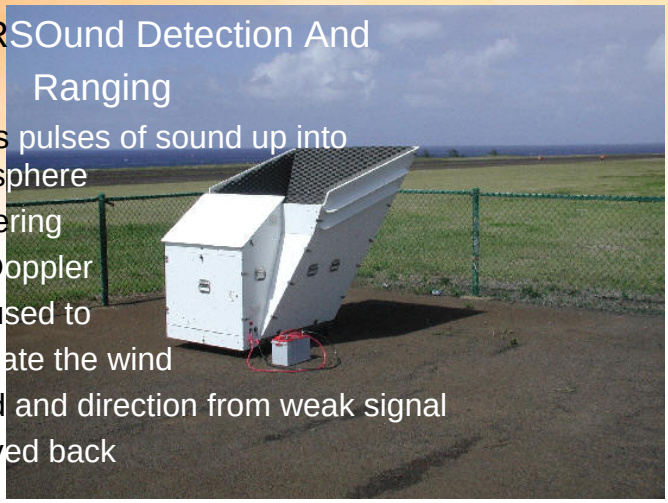
Measuring the wind speed

- SODAR SOund Detection And Ranging
  - Sends pulses of sound up into atmosphere
  - Scattering and Doppler shift used to calculate the wind speed and direction from weak signal received back



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Measuring the wind speed

- SODAR attributes
  - Measures wind speed average over a volume of air – could be useful to compare for wind turbine energy output
- SODAR issues
  - Calibration tricky
  - Must be kept flat
  - Rain interferes
  - Nearby obstacles can give "fixed echoes"

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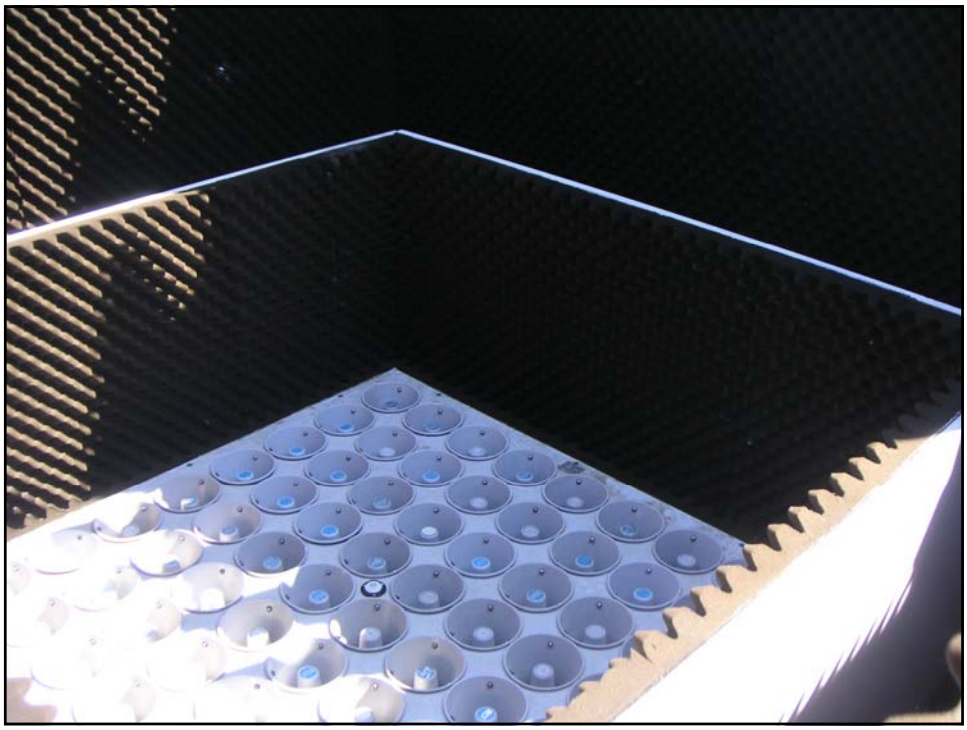

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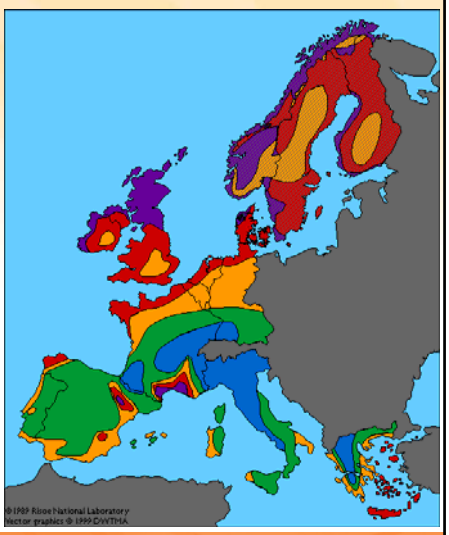
Wind Atlases

- Wind atlases describe how the average wind resource varies over a region
- European Wind Atlas
  - Made using over 200 met stations
  - Fluid dynamics model upscales these observations over an area



http://www.windatlas.dk/Europe/EuropeanWindResource.html

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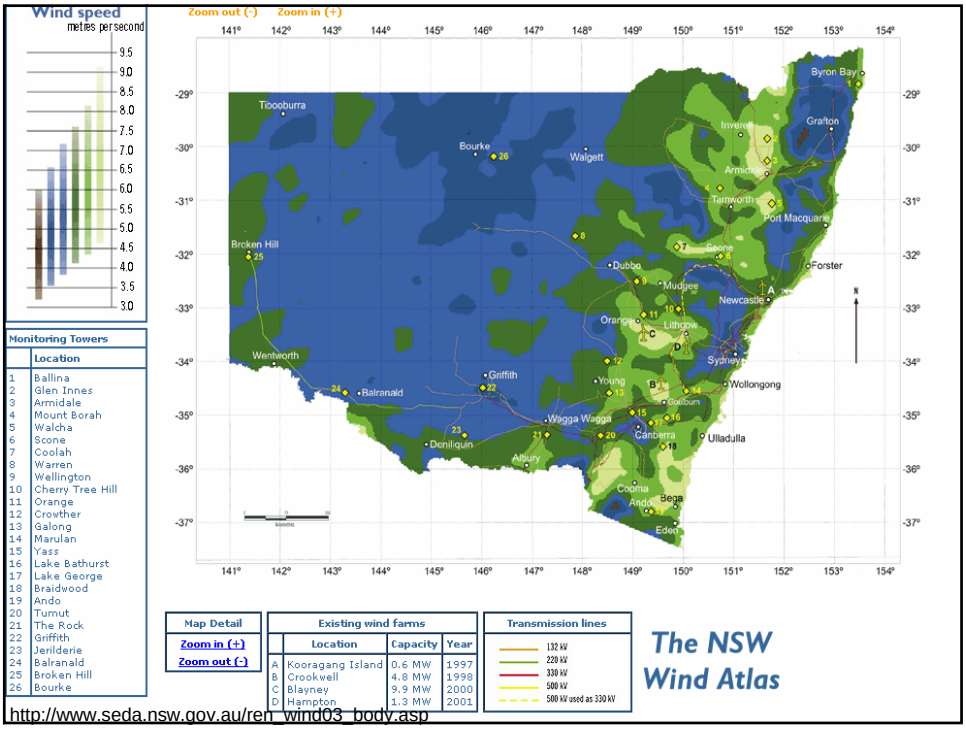

http://www.seda.nsw.gov.au/ren_wind03_body.asp

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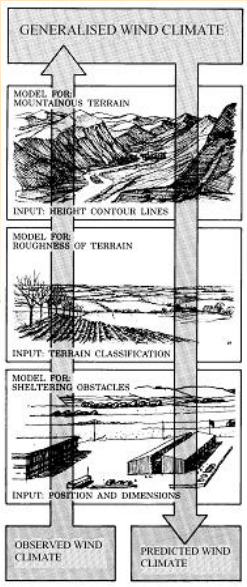
WAsP

- WAsP – the Wind Atlas Analysis and Application Program
  - predicts wind climates and annual power productions for wind farms
  - Includes:
    - complex terrain flow model,
    - a roughness change model and
    - a model for sheltering obstacles
  - www.wasp.dk

Terrain

Roughness

Obstacles



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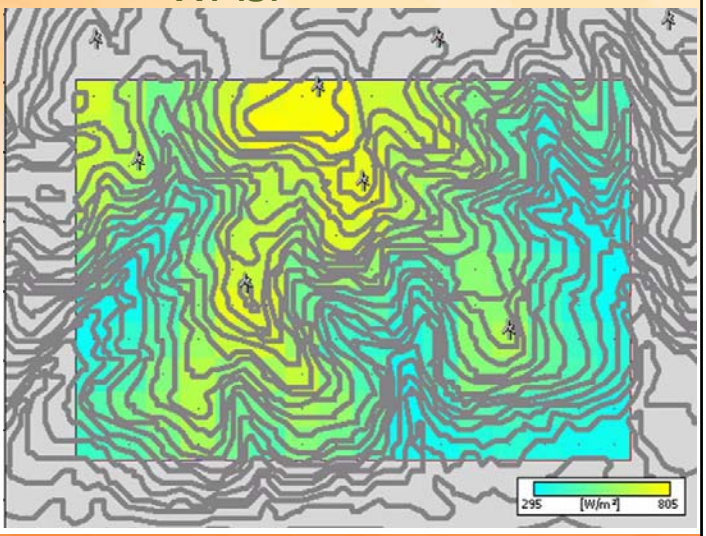
WAsP

- Resource Grid



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Wind Energy Forecasting

- Why Forecast?
  - Wind energy is considered as negative demand
- Two main groups benefit from it in Australia
  - Grid Operator – NEMMCO
    - They traditionally forecast energy demand to manage security of supply and dispatch commands
    - Particularly interested in forecasting rapid swings in power output – it's like forecasting a generator failure
  - Energy Traders
    - Traditionally forecast the energy demand
    - Optimise their bids to NEMMCO

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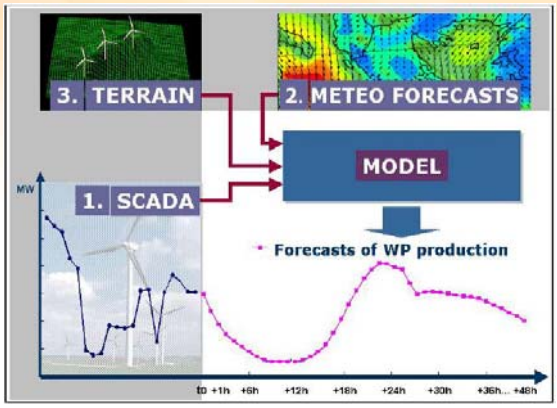
Wind Energy Forecasting

- Traditional Methods
- Meteo Forecasts:
  - Numerical Weather Prediction (NWP)
- "Model" usually contains:
  - Power curve
  - Statistics



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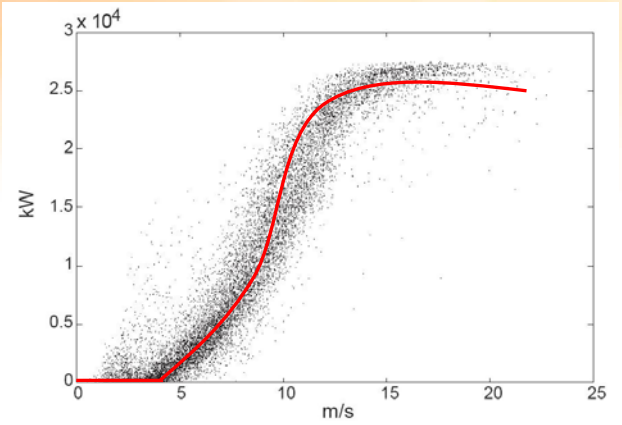
Wind Energy Forecasting

- Power Curve



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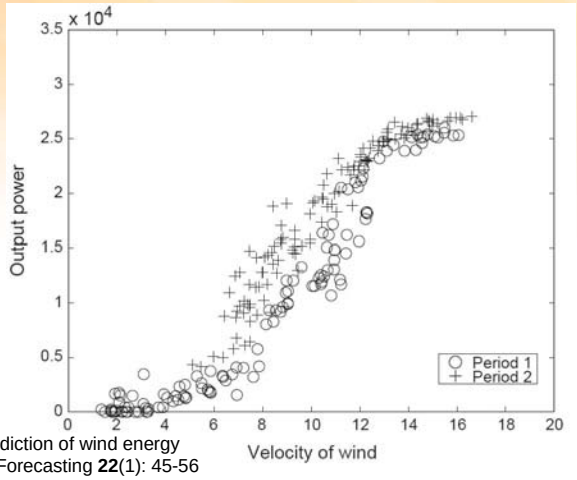
Wind Energy Forecasting

- But power curve varies
  - With season (mostly due to vegetation)



Source: Sanchez, I. (2006). "Short-term prediction of wind energy production." International Journal of Forecasting **22**(1): 45-56

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Wind Energy Forecasting

- But power curve varies
  - With season (mostly due to vegetation)
  - With direction

Hydro Tasmania's wind farm at Woolnorth, NW Tasmania

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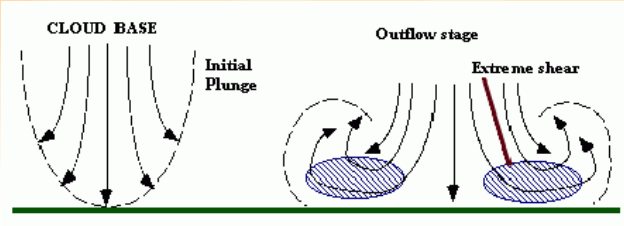
Wind Energy Forecasting

- But power curve varies
  - With season (mostly due to vegetation)
  - With direction
  - With turbulence – cup response different to turbine



Aviation Microscale Meterology website:
http://www.auf.asn.au/groundschool/umodule21.html

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Wind Energy Forecasting

- But power curve varies
  - With season (mostly due to vegetation)
  - With direction
  - With turbulence
  - With conditions on blades

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Wind Energy Forecasting

- But power curve varies
  - With season (mostly due to vegetation)
  - With direction
  - With turbulence
  - With conditions on blades
  - With turbine fatigue

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The Domains of the Operational Suite of

Numerical Weather Analysis and Prediction Systems

GASP

Global Analysis and Prediction System

- 1,236 (smallest half wavelength resolved : 83 km)
- 20 levels
- Prediction to 8 days

LAPS

Limited Area Prediction System
Australian Region

- 0.375° horizontal grid spacing
- 29 levels
- Prediction to 72 hours

TLAPS

Tropical Limited Area Prediction System

- 0.375° horizontal grid spacing
- 29 levels
- Special features for tropical analysis
- Prediction to 48 hours

MESO-LAPS

Smaller scale versions of LAPS

- 0.05°–0.125° horizontal grid spacing
- 29 levels
- Prediction to 36 hours
- Special version for tropical cyclone prediction

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Wind Energy Forecasting

- Numerical Weather Prediction (NWP) Models
  - Represent the physics of the atmosphere (with assumptions) with equations
  - Requires initial state of atmosphere – data assimilation
  - Fast computers use the physics to model how the current state will evolve in the future
- Problems for Wind Energy Forecasting
  - Bureaus have not traditionally been concerned with forecasting wind speeds of 1 ms^{-1} accuracy
  - Model resolutions (5 to 40 km) are not high enough to model local winds affecting wind farms

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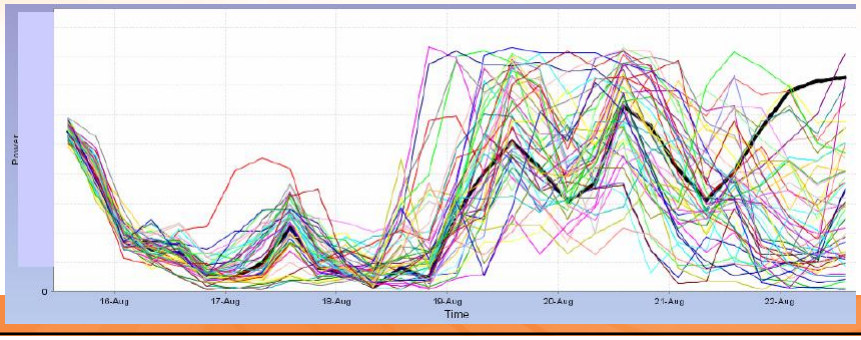
Wind Energy Forecasting

- Prediction of model uncertainty useful:
  - Ensemble Forecasting
    - Take forecasts from different models/different initial conditions/different assumptions in physics
    - Uncertainty based on the spread of the forecasts



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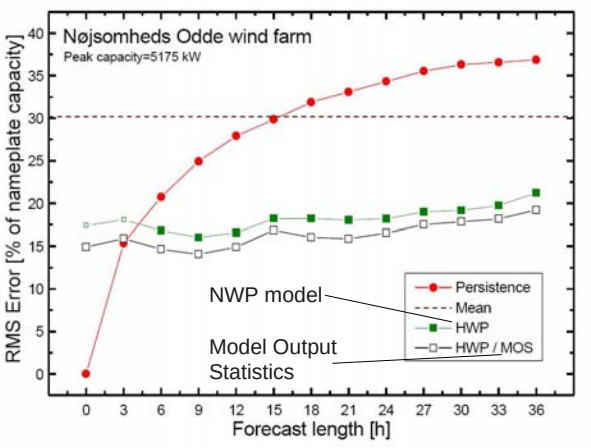
Wind Energy Forecasting

- Forecast Performance Assessment
- Systems designed to minimise overall mean error



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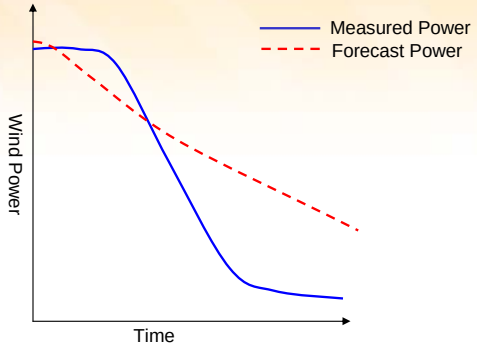
Wind Energy Forecasting

- Forecast Performance Assessment
- Systems designed to minimise overall mean error
- Hence rapid changes with timing uncertainty are smoothed out



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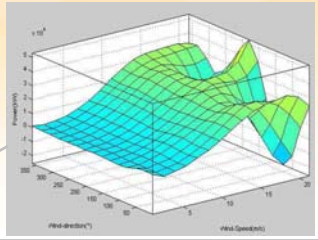
The Wind Power Prediction Tool (WPPT)

- How does WPPT work
  - Statistically combines recent wind power measurements and future wind speed forecasts to make a wind power prediction
  - At time *k*:



power curve

$$\hat{P}_{k+1} = \theta_1 P_k + \theta_2 P_{k-1} + \theta_3 \hat{f}_{pc}(wspd_{k+1}, wdir_{k+1}) + \theta_4[\cos, \sin \text{ of time}] + \theta_5$$

  - Updates parameters θ, and power curve to minimise errors as each new power measurement is obtained
  - Naturally there are different optimum values for θ for different prediction horizons: weighting for P_k and P_{k-1} decreases as horizon increases.

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Current situation in Australia

- NEMMCO have purchased a high resolution ensemble NWP model with embedded power curve model
  - 2-year interim wind forecasts for 6 wind farms in SA and one in Tas
- The Australian Greenhouse Office (AGO) have a $14 million project to purchase a longer term wind power forecasting system to be hosted at NEMMCO.
  - Some funding for local researchers (eg. CEEM) to hopefully contribute/compliment to this system

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Research Question

- How might we define high-risk scenarios in wind energy output?
- Who's risk?
  - Grid operators for power system security
  - Energy traders for optimising energy bids
- Define grid operators' high-risk scenario for wind power prediction:
  - A situation where a misleading wind energy forecast will have significant consequences for power system security.
  - This is an aggregation of wind farms effect – not just one wind farm

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Research Question

- How might we predict high-risk scenarios in wind energy output?
- Looking at weather events that cause the high-risk scenario
- Looking at predicting the occurrence of these scenario a day or two ahead
- Interested in the rapid swings in power output in the broad sense, not the high frequency detail

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Predicting Large-swings / High-Risk Scenarios

- Higher resolution/tailored NWP models
  - Eg. WindyLAPS – Bureau research
- Weather types/Analogues
  - Australian Bureau has only automated “Synoptic Typer” used operationally to assist NWP forecasts in the world
  - Analogue forecasting better at extreme events than NWP
- Statistical methods correcting NWP output to wind farm swings using other observations
  - Data example: Sea-surface wind field from satellites (QuickSat)
  - Statistical method example: Bayesian Hierarchical models
- Note: Weather systems are changing due to Climate Change

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Next Talk

- Wednesday 30th August
- The First Australian Installation of WPPT
- WPPT and Bureau performance at Woolnorth wind farm in Tasmania
- Analysis of rapid swings in power output at Woolnorth and what weather systems are causing them
- To be presented again at the Global Wind Energy Conference in Adelaide, September 18-21

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- Thank you
- Questions?

Many of our publications are available at:
www.ceem.unsw.edu.au

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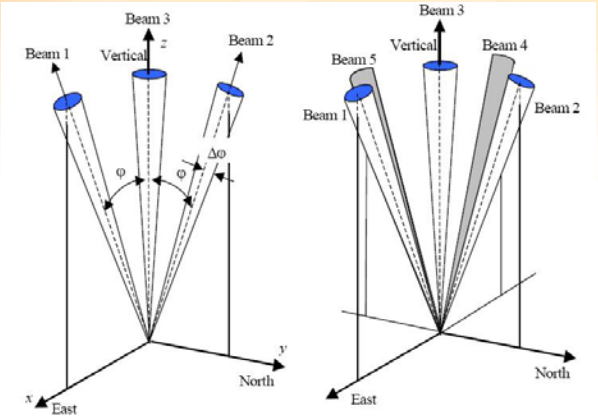
Measuring the wind speed

- 3-beam and 5-beam SODAR designs



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