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Using NWP forecasts at multiple grid points to assist power system operators to predict large rapid changes in wind power

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NZ WIND ENERGY CONFERENCE 2008

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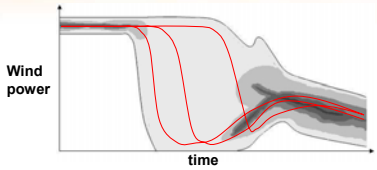
The Forecasting Challenge

- **A single value forecast will never be perfect**
- **Ideally we would like:**
  - Uncertainty band with complete probability distribution
  - The expected variation within the band



Or…

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The Forecasting Challenge

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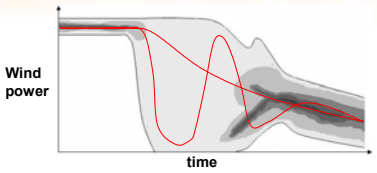

Or…

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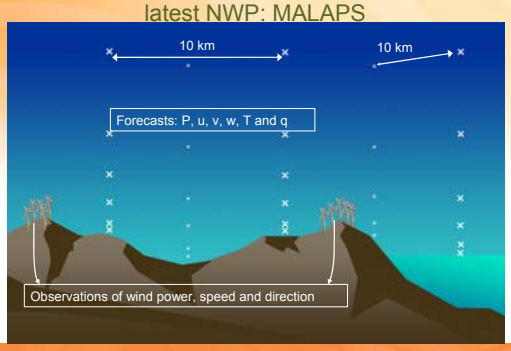
Introducing the Australian Bureau of Meteorology's latest NWP: MALAPS



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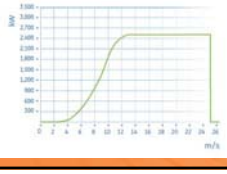
Traditional Wind Energy Forecasting (for prediction horizons of 6-36 hours)

- NWP forecast wind speed, usually at 10m height at nearest grid point to farm
- Make systematic corrections learning from past observations
- Convert corrected wind speed to power



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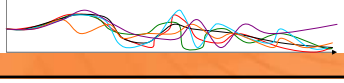
Traditional Wind Energy Forecasting (for prediction horizons of 6-36 hours)

- NWP forecast wind speed, usually at 10m height at nearest grid point to farm
- Make systematic corrections learning from past observations
- Convert corrected wind speed to power
- Add wind farm power predictions together
- For uncertainty, use wind speed ensemble from one NWP or several independent NWPs



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NWP strengths and weaknesses

- Good at predicting:
  - The broad synoptic weather out to 48 hours ahead
- Not so good at predicting:
  - The precise (< ≈50km) position and fine-scale structure of any weather system or associated features

This implies that for predicting the wind at a specific location, NWP forecast at a single grid point are OK for slow moving wind features with gradual spatial variation ***(eg. in high pressure systems)***

But for the fast moving/high variation features ***(Cold fronts, low pressure systems)*** *the forecast error at a single grid point can be large*

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More information from multiple grid points

- Using the forecast at just one grid point may be missing useful information in the NWP forecast
- Concept: displaying the wind forecast at multiple grid points at hub height in the region of the farm
- First problem: local model terrain affects the wind speeds differently at each of these grid points. Eg. Wind speed over the sea is typically higher than over land.

⇨ Need wind field with "normalised terrain"

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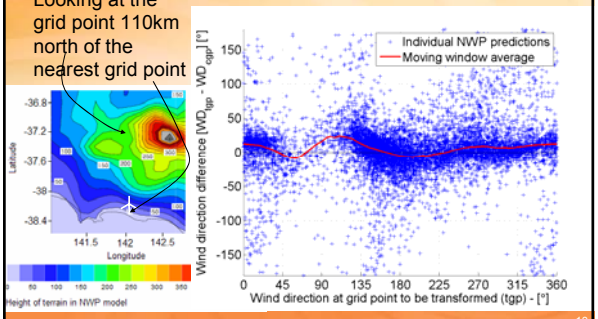
Terrain normalisation examples: wind direction

Looking at the grid point 110km north of the nearest grid point



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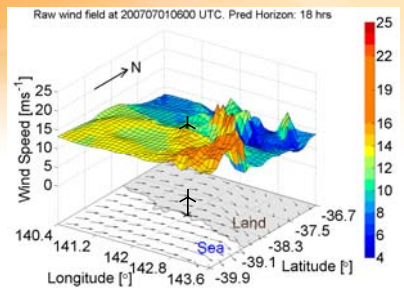
Example of terrain-normalising transformation

- Raw wind field



Snapshot of NWP 0.995σ wind speed forecast.

Central black box: closest grid point to Yambuk

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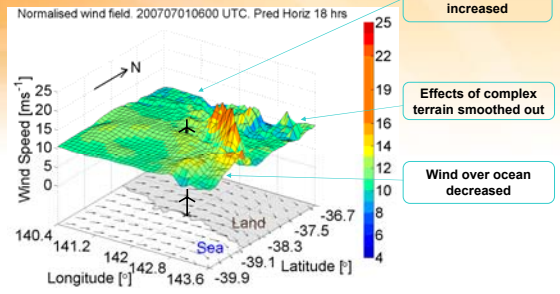
Example of terrain-normalising transformation

- Transformed wind field



Wind further inland increased

Effects of complex terrain smoothed out

Wind over ocean decreased

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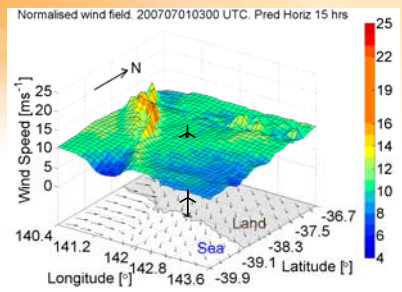
Example of terrain-normalising transformation

- Transformed wind field



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Example of terrain-normalising transformation

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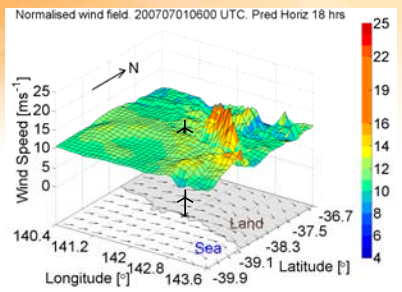

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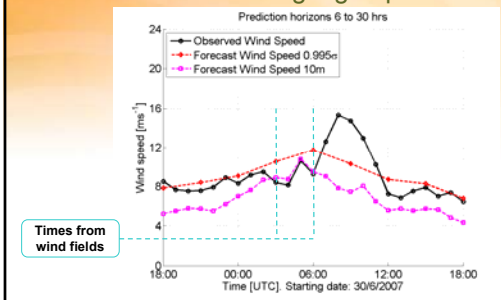
1st July event: cold front
Observations and single grid point forecasts



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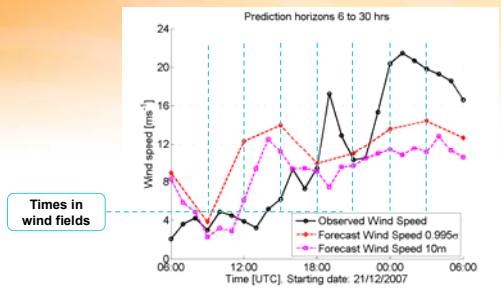
21st December event: low pressure system
Observations and single grid point forecasts



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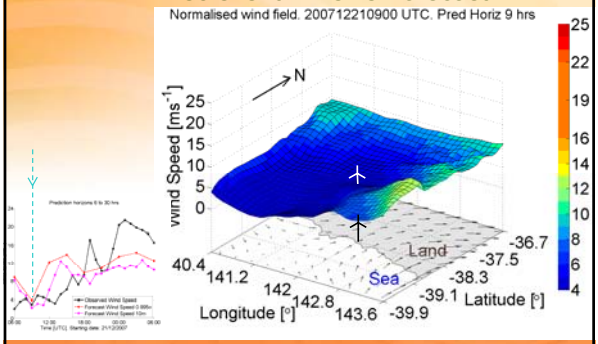
21st Dec event: - Newer forecast



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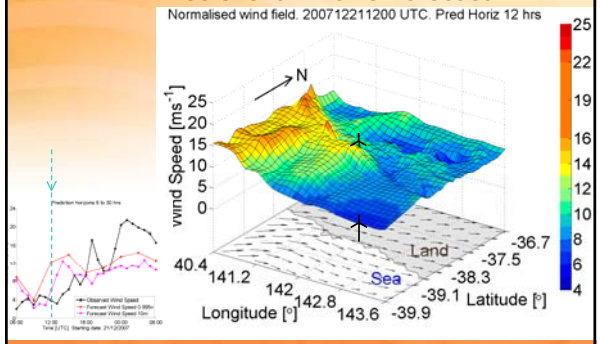
21st Dec event: - Newer forecast



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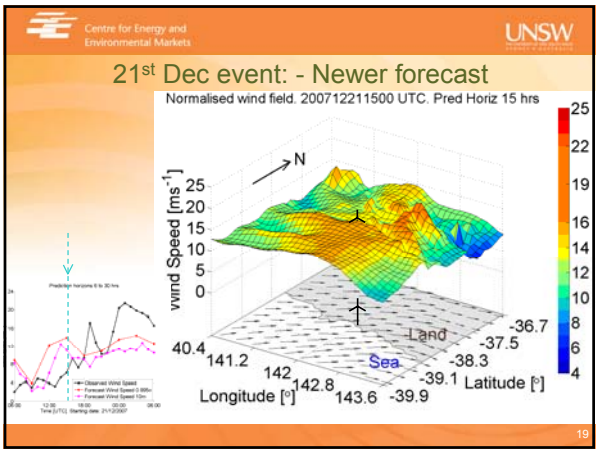
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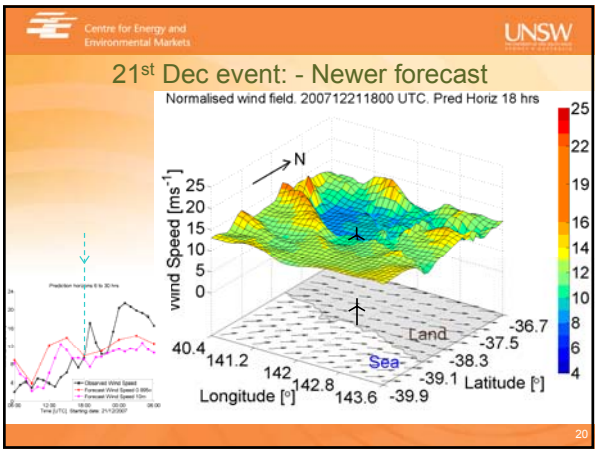
21st Dec event: - Newer forecast
Normalised wind field. 200712211500 UTC. Pred Horiz 15 hrs
vvind Speed [ms-1]
N
Land
Sea
Longitude [°]
Latitude [°]
19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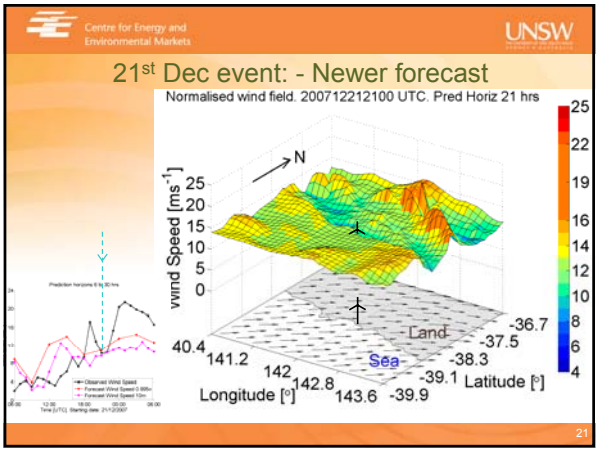
Land
Sea
Longitude [°]
Latitude [°]
20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21st Dec event: - Newer forecast
Normalised wind field. 200712212100 UTC. Pred Horiz 21 hrs
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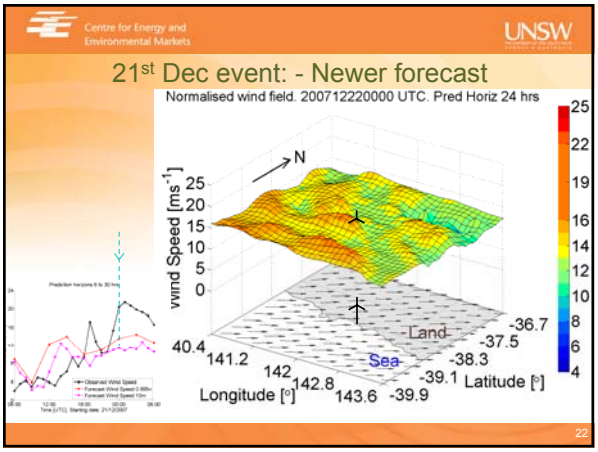
N
Land
Sea
Longitude [°]
Latitude [°]
21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21st Dec event: - Newer forecast
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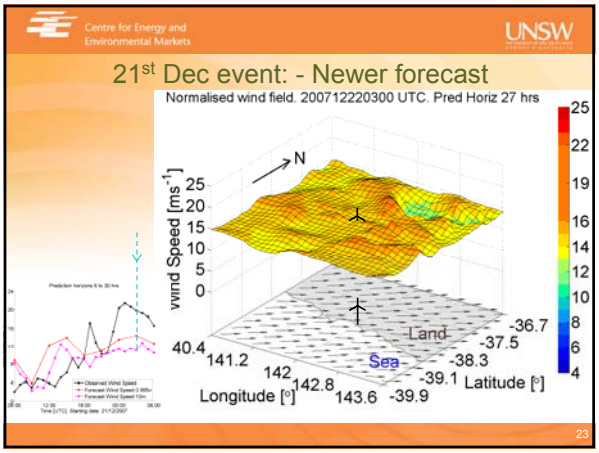
N
Land
Sea
Longitude [°]
Latitude [°]
22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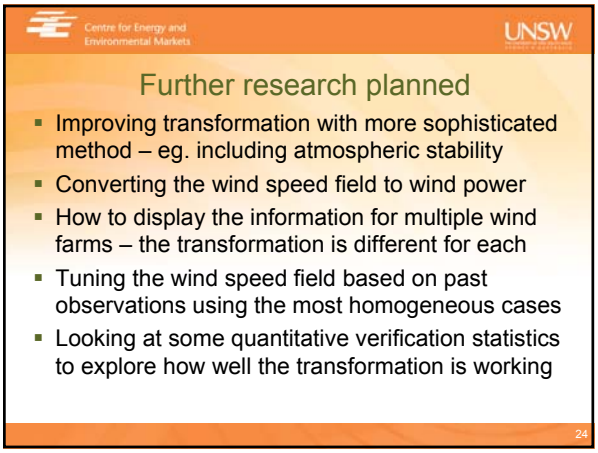
N
Land
Sea
Longitude [°]
Latitude [°]
23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Further research planned
Improving transformation with more sophisticated method – eg. including atmospheric stability
Converting the wind speed field to wind power
How to display the information for multiple wind farms – the transformation is different for each
Tuning the wind speed field based on past observations using the most homogeneous cases
Looking at some quantitative verification statistics to explore how well the transformation is working
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Summary

- Displaying successive normalised wind fields has the potential to compliment more traditional wind power forecasts by:
  - Considering misplacement of wind features
  - Identify potential aliasing errors due to hourly snapshot
  - Allowing for assessment of the likelihood of coincident events at multiple wind farms
  - Could be used to assess the uncertainty in the forecast without using NWP ensembles

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Thank you

- NZWEA for this opportunity
- Co-authors Merlinde Kay, Hugh Outhred, Iain MacGill (UNSW) and Jeff Kepert (BMRC)
- Data providers:
  - BMRC - MALAPS
  - Pacific Hydro Pty Ltd (wind farm developer)

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PacificHydro BMRC Bureau of Meteorology Research Centre

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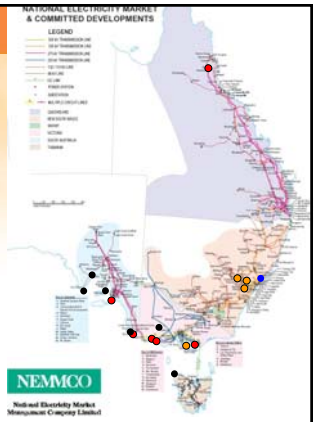
Wind Energy in Australia

- National Electricity Market (NEM) →
- Wind Farms currently installed in the grid →

Legend:
Wind farm size
- 0-1 MW
- 1-10 MW
- 10-50 MW
- > 50 MW



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Terrain normalisation method used:

- Transform the wind speed at nearby grid points at sigma level 0.995 (≈44m) as if they were displaced at the nearest grid point (*ngp*) to the wind farm.
  - Take all NWP predictions where WS_{ngp} > 5 m/s
  - For each nearby grid point to transform (*tgp*):
  1. Make rolling average (30° window) for WD_{tgp} vs direction difference using trimmed mean (including only middle 70% of data to remove outliers)
  2. Transform wind direction at *tgp* making the rolling average the same as the *ngp*

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Terrain normalisation method used:

- Transform the wind speed at nearby grid points as if they were displaced at the nearest grid point
  3. Where the difference between the *ngp* wind direction and the transformed wind direction at *tgp* < 20° make rolling average (trimmed mean again) of wind speed ratio versus WD_{tgp}
  4. Transform all wind speeds at the *tgp* based on this rolling average ratio which is dependent on the *tgp* wind direction and wind speed bin

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