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Forecasting scenarios of wind power generation for the next 48 hours to assist decision-making in the operation of the power system

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7th June, 2010

www.ceem.unsw.edu.au

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Project background

- PhD at CEEM was funded by the Australian Government to develop wind forecasting techniques for Australian conditions
- Completed PhD in 2009
- Current project is funded by Australian Energy Market Operator (AEMO) to further develop the PhD wind forecasting techniques into a prototype extreme events wind forecasting model. If successful, this could be incorporated as an enhancement to AEMO's Australian Wind Energy Forecasting System (AWEFS)

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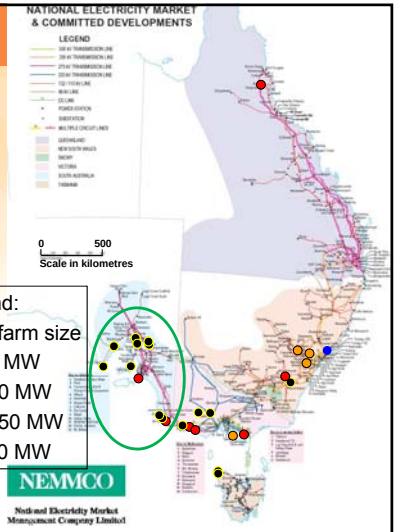
Wind Energy in Australia

- National Electricity Market (NEM) →
- Wind Farms currently installed in the grid →
- 1600 MW of wind in Australia (July 2009)
- More than half in SA (868 MW)



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Value of wind forecasting

- Wind power generation has been shown in a previous study to have an effect on spot prices in SA*
  - For more information see presentation at 14:00 tomorrow
- Wind forecasts (0-24 hours lead time) can allow better spot price forecasts, and in turn allow:
  - Generators to optimise their bidding strategies
  - Demand-side response groups to better capitalise on price spikes
- Power system operators can use wind power forecasts to plan for potential large disturbances
- Slow-start generators to plan unit commitment

*See http://www.crawford.anu.edu.au/research_units/eerh/pdf/EERH_RR38.pdf

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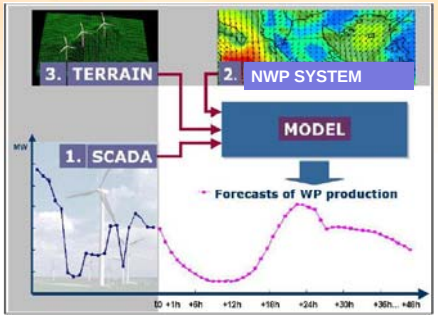
Wind Energy Forecasting Conventional Approach

- SCADA: recent observations
- Numerical Weather Prediction (NWP) system forecasts:
- "Model" usually contains:
  - "Power curve"
  - Other statistical transformations



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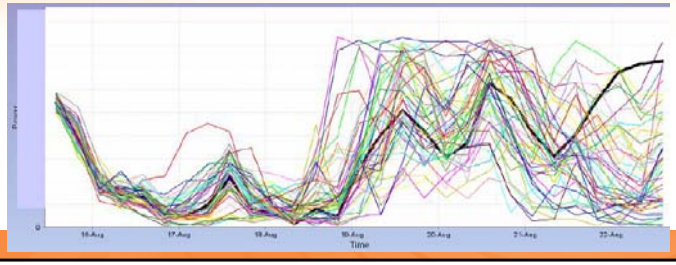
Wind Energy Forecasting Conventional Approach

- Prediction of NWP system uncertainty can be useful:
  - NWP Ensemble Forecasting
    - Take forecasts from different NWP systems or the same system with different initial conditions/different physical assumptions
    - Uncertainty based on the spread of the ensemble members



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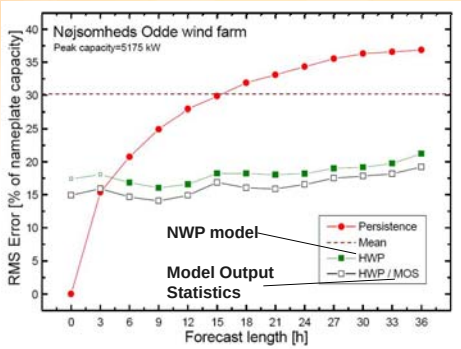
Wind Energy Forecasting Conventional Approach

- Forecast Performance Assessment
- Systems designed to minimise overall mean error score such as root mean square error (RMSE)



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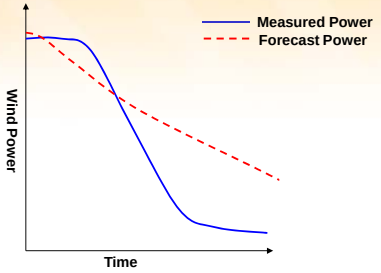
Wind Energy Forecasting Conventional Approach

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



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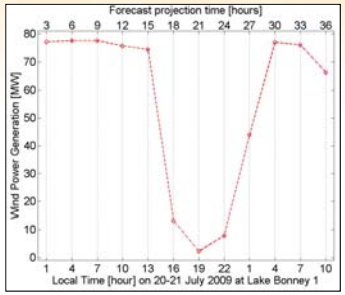
Wind power forecasting methods of use

- Wind power forecasting can be used in two ways:
  - Best guess generation used automatically for commercial optimisation (eg. in electricity markets)



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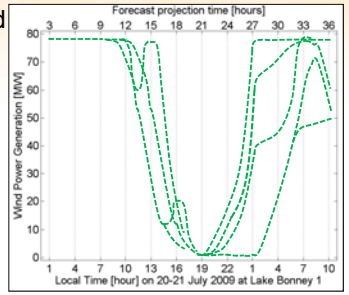
Wind power forecasting methods of use

- Wind power forecasting can be used in two ways:
  - Best guess generation used automatically for commercial optimisation (eg. in electricity markets)
  - Multiple scenarios provided for visual interpretation to characterise forecast uncertainty and assist decision-making in critical situations (eg. Managing power system security and large rapid changes in aggregated wind power)



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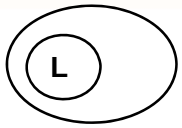
Outcomes from the PhD thesis (1)

- Large, rapid changes in wind power in Australia are largely caused by horizontally propagating synoptic weather phenomena:
  - Eg. Cold fronts and low pressure systems



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Outcomes from the PhD thesis (2)

- Large, rapid changes in wind power in Australia are largely caused by horizontally propagating synoptic weather phenomena:
  - Eg. Cold fronts and low pressure systems
- By their nature, statistical forecasting methods based on past observations will struggle to provide useful information on large rapid changes
- Numerical Weather Prediction (NWP) systems are the best tool available to forecast significant changes in the weather

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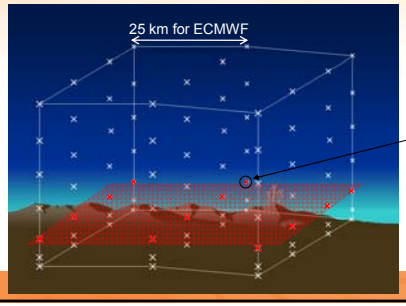
NWP systems

- Represent the atmosphere on a coarse horizontal grid (25 km for global ECMWF system) and cannot directly model local, fine-scale detail topographic effects on the wind



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NWP systems

- Represent the atmosphere on a coarse horizontal grid (25 km for global ECMWF system) and cannot directly model local, fine-scale detail topographic effects on the wind
- Good at forecasting broad synoptic weather phenomena (such as cold fronts and low pressure systems) and how they affect near-surface winds out to around 48 hours ahead
- Uncertain in the timing, or more generally the precise position of such synoptic weather phenomena

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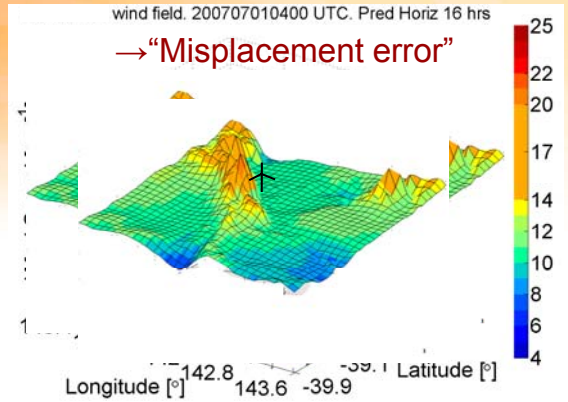
Outcomes from PhD thesis



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Outcomes from PhD thesis

- Identified that conventional single grid point extraction and corresponding time-series forecast may be missing useful information in NWP system
  - Misplacement errors during large rapid changes in wind can cause large differences in single grid point forecast
- Developed technique to display multiple grid point information from NWP systems to characterise wind power forecast uncertainty due to misplacement errors
  - Problem: the wind at each grid point is influenced by the local topography →

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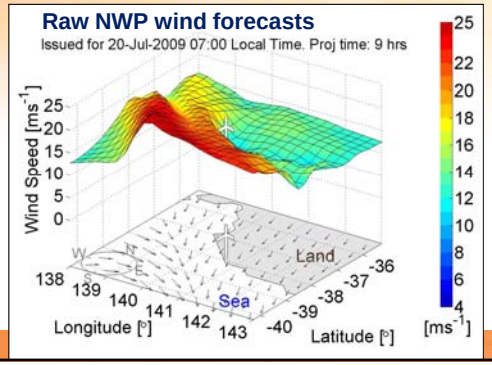
PhD outcomes: Terrain standardisation method

- Develops relationships between grid points based on historical data to standardise effects of topography



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PhD outcomes: Terrain standardisation method

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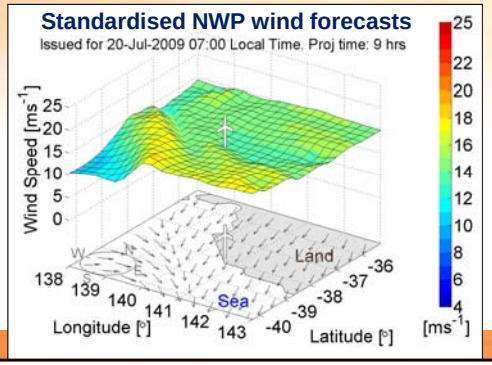

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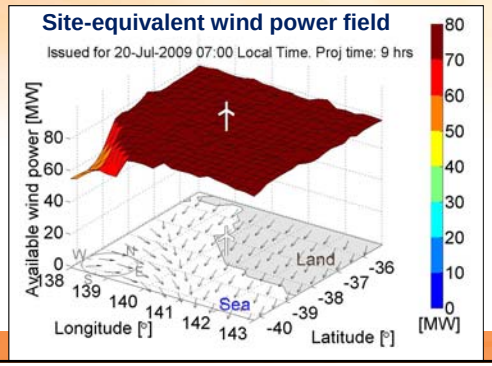
PhD outcomes: Convert wind field to wind power

- Develops relationships between historical forecasts and observations to create:



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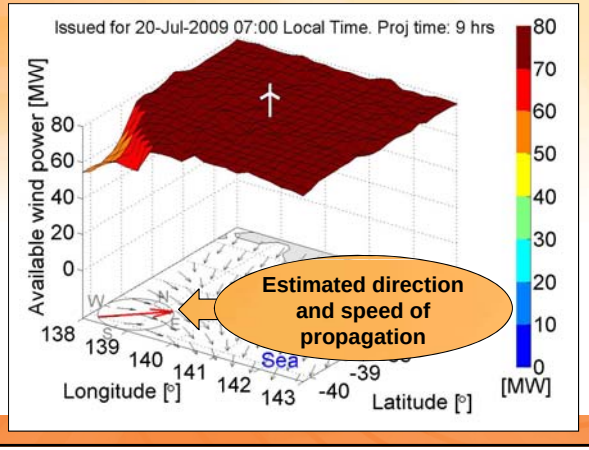
PhD outcomes: Animation of wind power forecast fields



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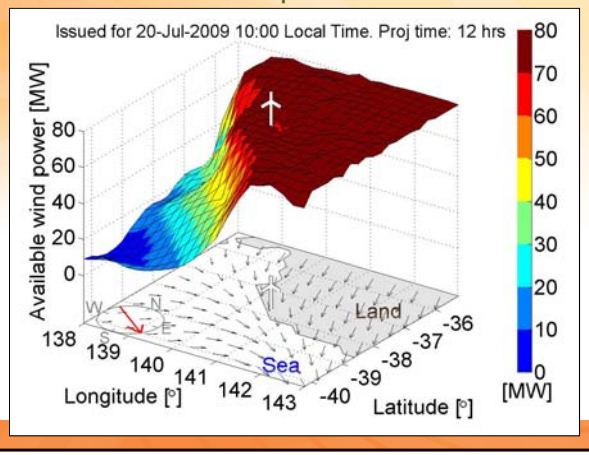
Animation of wind power forecast fields



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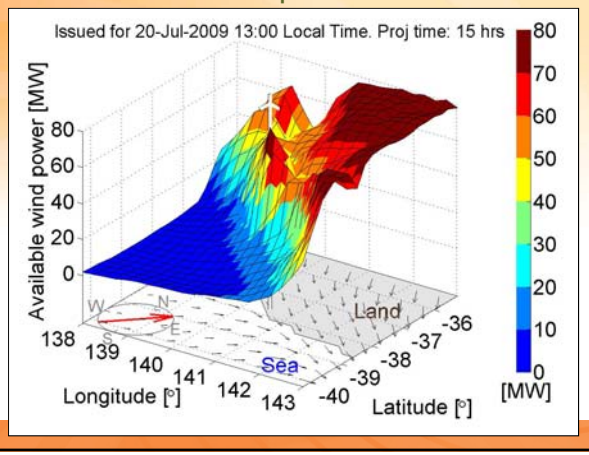
Animation of wind power forecast fields



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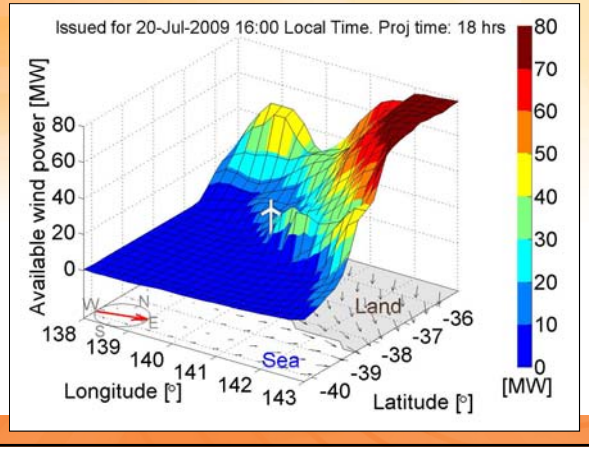
Animation of wind power forecast fields



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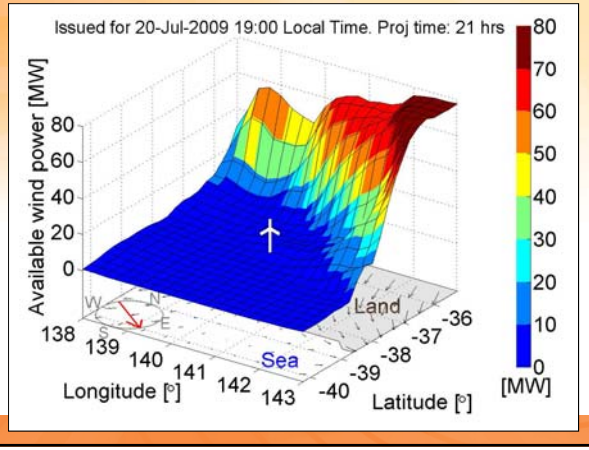
Animation of wind power forecast fields



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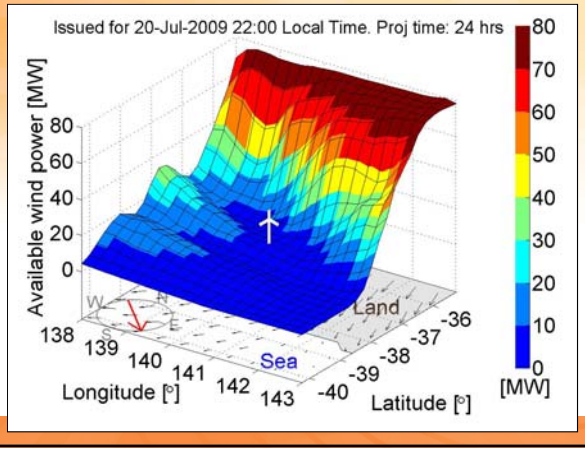
Animation of wind power forecast fields



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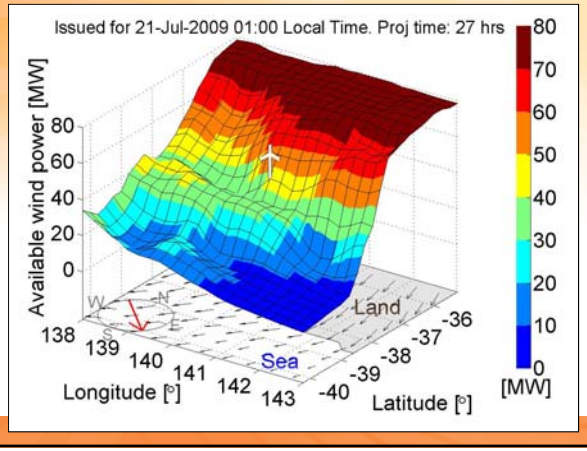
Animation of wind power forecast fields



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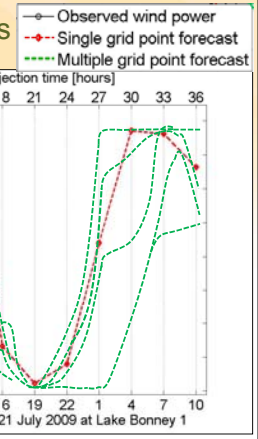
Interpreting wind power forecast fields



- Projection time 6 hours
  - High probability of full power generation

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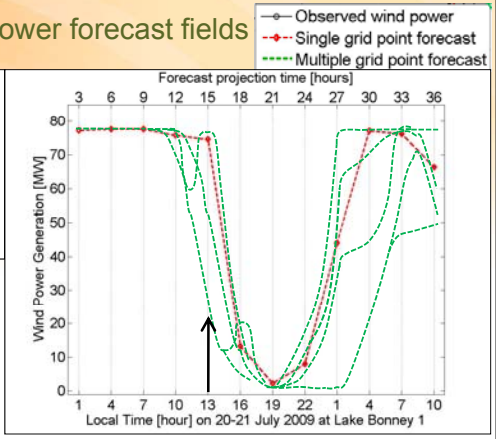
Interpreting wind power forecast fields



- Projection time 15 hours
  - Low probability of single grid point forecast value

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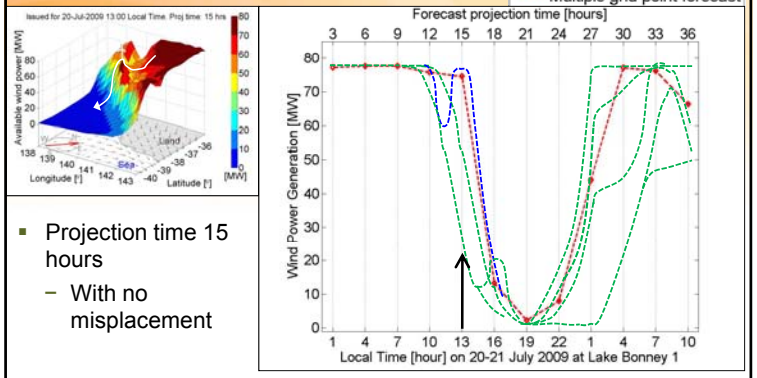
Interpreting wind power forecast fields



- Projection time 15 hours
  - With no misplacement

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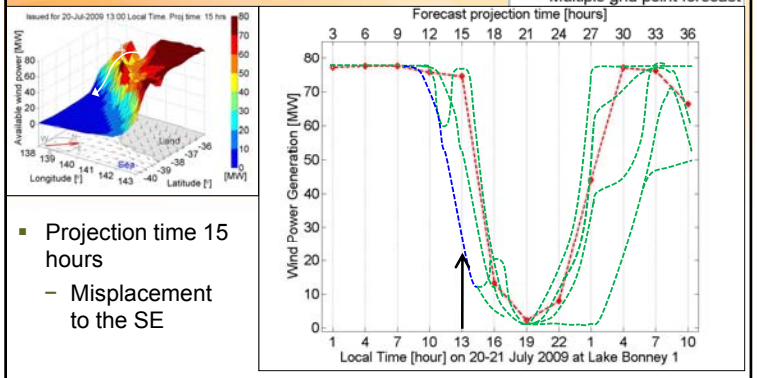
Interpreting wind power forecast fields



- Projection time 15 hours
  - Misplacement to the SE

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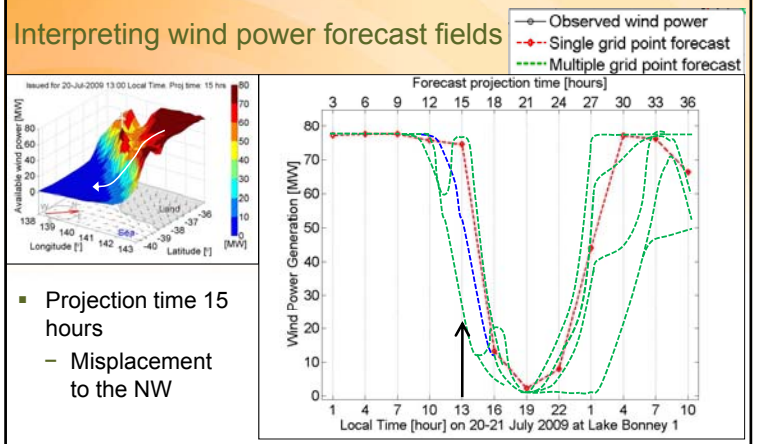
Interpreting wind power forecast fields



- Projection time 15 hours
  - Misplacement to the NW

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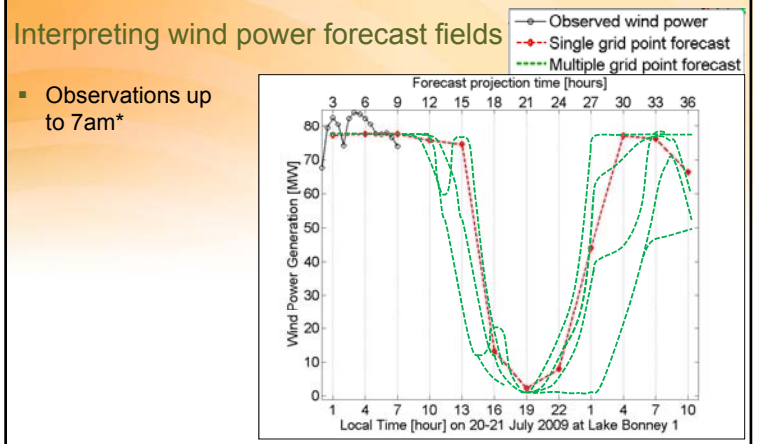
Interpreting wind power forecast fields



- Observations up to 7am*

* Note that all observations and forecasts have had a constant scaling factor applied to assume a level of availability of the wind turbines in the wind farm

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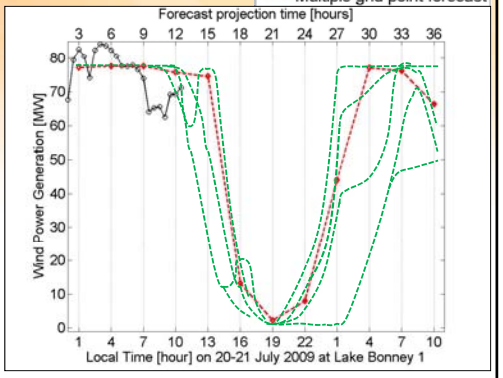
Interpreting wind power forecast fields

- Observations up to 10:30am



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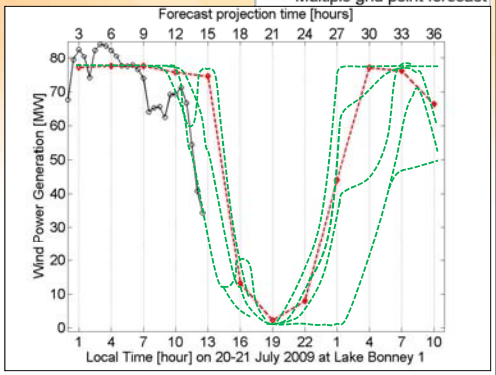
Interpreting wind power forecast fields

- Observations up to 12:30pm



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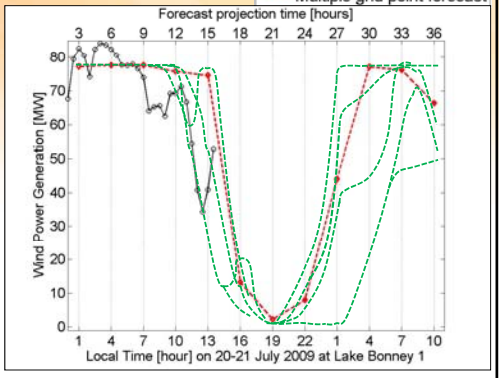
Interpreting wind power forecast fields

- Observations up to 1:30pm



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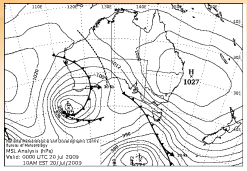
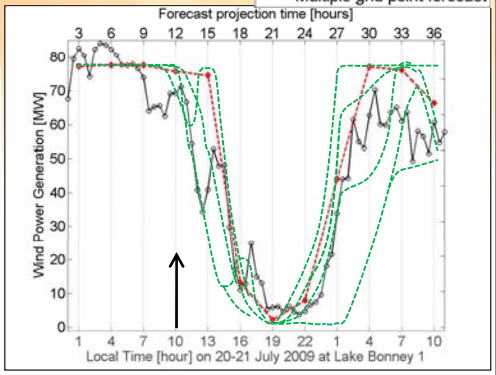
Interpreting wind power forecast fields

- All observations: 30 minutes





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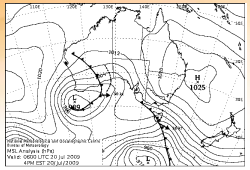
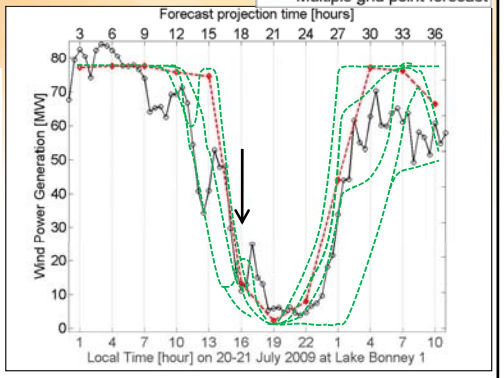
Interpreting wind power forecast fields

- All observations: 30 minutes





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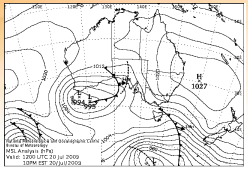
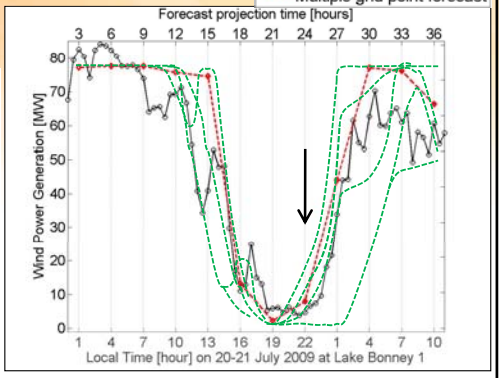
Interpreting wind power forecast fields

- All observations: 30 minutes





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Animated wind power field versus NWP ensembles

- Both show uncertainty information in wind forecast:
  - Wind power field uncertainty based on multiple grid points, and assuming potential misplacement errors. Field highlights potential chronological behaviour
  - Ensembles are based on different (perturbed) initial states of the atmosphere, or different physical assumptions
- Both reduce uncertainty when scenarios are similar
- Spatial resolution is usually compromised to run the NWP system multiple times for an NWP ensemble
- Wind power fields show chronological behaviour between the NWP system time-stamps, ensemble scenarios could suffer from sampling error

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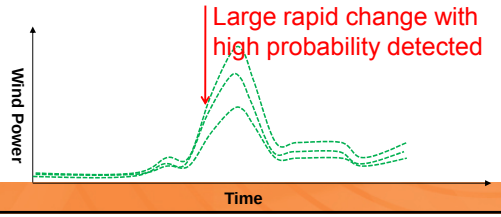
Future work

- To automate provision of time-series traces (potential scenarios) of wind power generation from wind power forecast fields
- The tool could also provide alarms for large rapid changes based on the information in the traces
- Combining the NWP ensembles and spatial fields



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Thank you & Questions

- AEMO for supporting this project
- Renewable Energy Research Conference
- Supervisors: Iain MacGill and Hugh Outhred
- Collaboration with Jeff Kepert (Australian Bureau of Meteorology)

AEMO Australian Government Bureau of Meteorology

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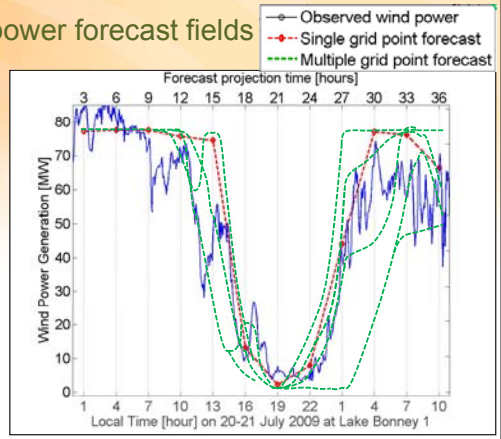
Interpreting wind power forecast fields

- All observations: 5 minutes



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