



Centre for Energy and
Environmental Markets



UNSW
THE UNIVERSITY OF NEW SOUTH WALES
SYDNEY • AUSTRALIA



Forecasting scenarios of wind power generation for the next 48 hours to assist decision-making in the Australian National Electricity Market

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Talk outline

- **PART 1**

Overview on the wind power forecast spatial fields approach to wind power forecasting using NWP forecasts from multiple grid points

- **PART 2**

Preliminary results for the prototype wind power forecasting tool currently being developed for AEMO

Project background

- Australian Government funded CEEM to undertake research to facilitate the uptake of wind energy in the Australian National Electricity Market, including:
 - Nick Cutler’s wind forecasting PhD, completed in 2009
- Australian Energy Market Operator (AEMO) funding current project to further develop Nick’s PhD wind forecasting techniques into a prototype extreme events wind forecasting model.
- If successful, this could be an enhancement to AEMO’s Australian Wind Energy Forecasting System (AWEFS)

Value of wind forecasting

- Wind power generation has been shown in a previous study to have an effect on spot prices in SA*
- 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 can better plan their unit commitment

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



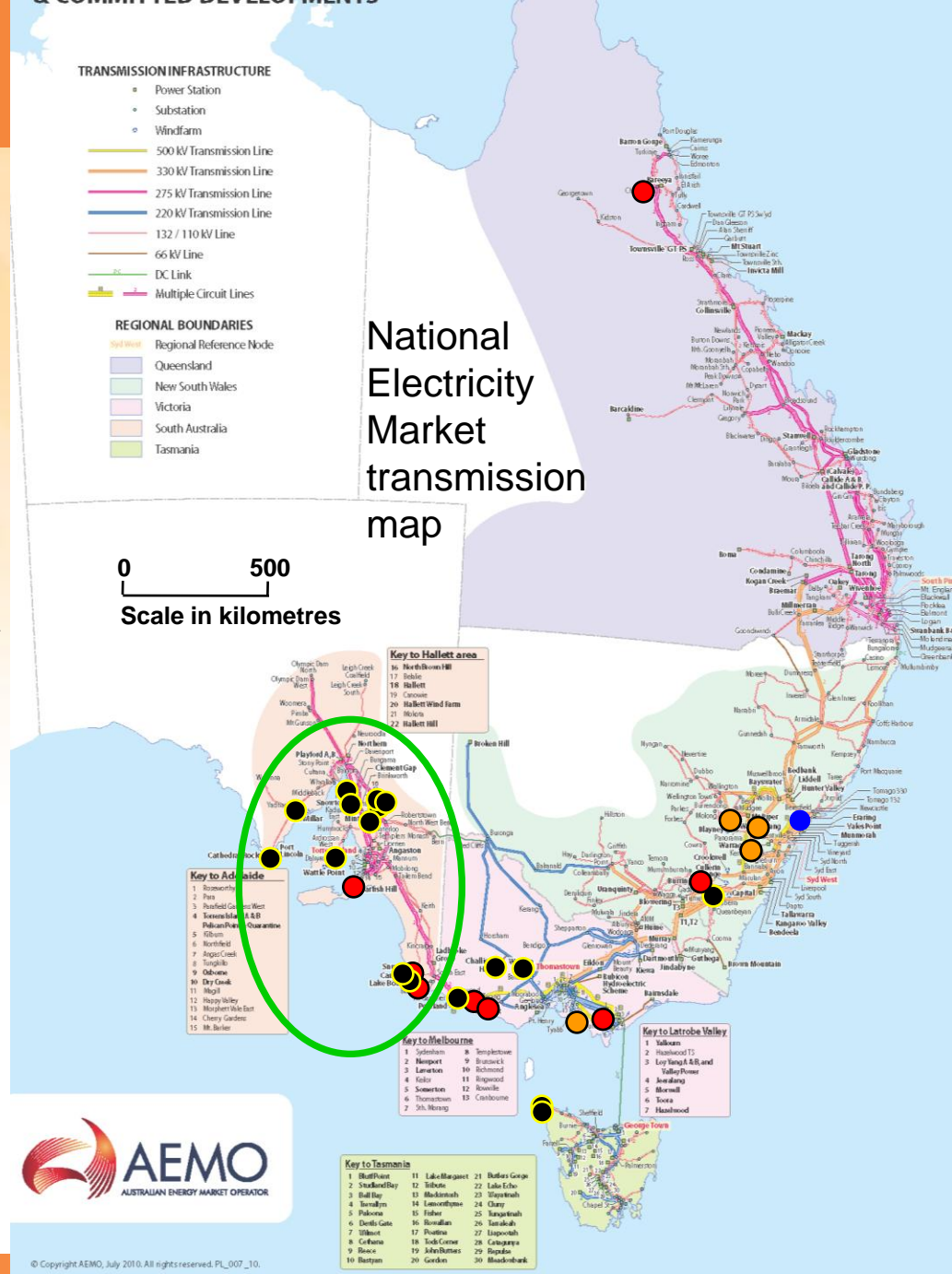
Wind Energy in Australia

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

Legend:

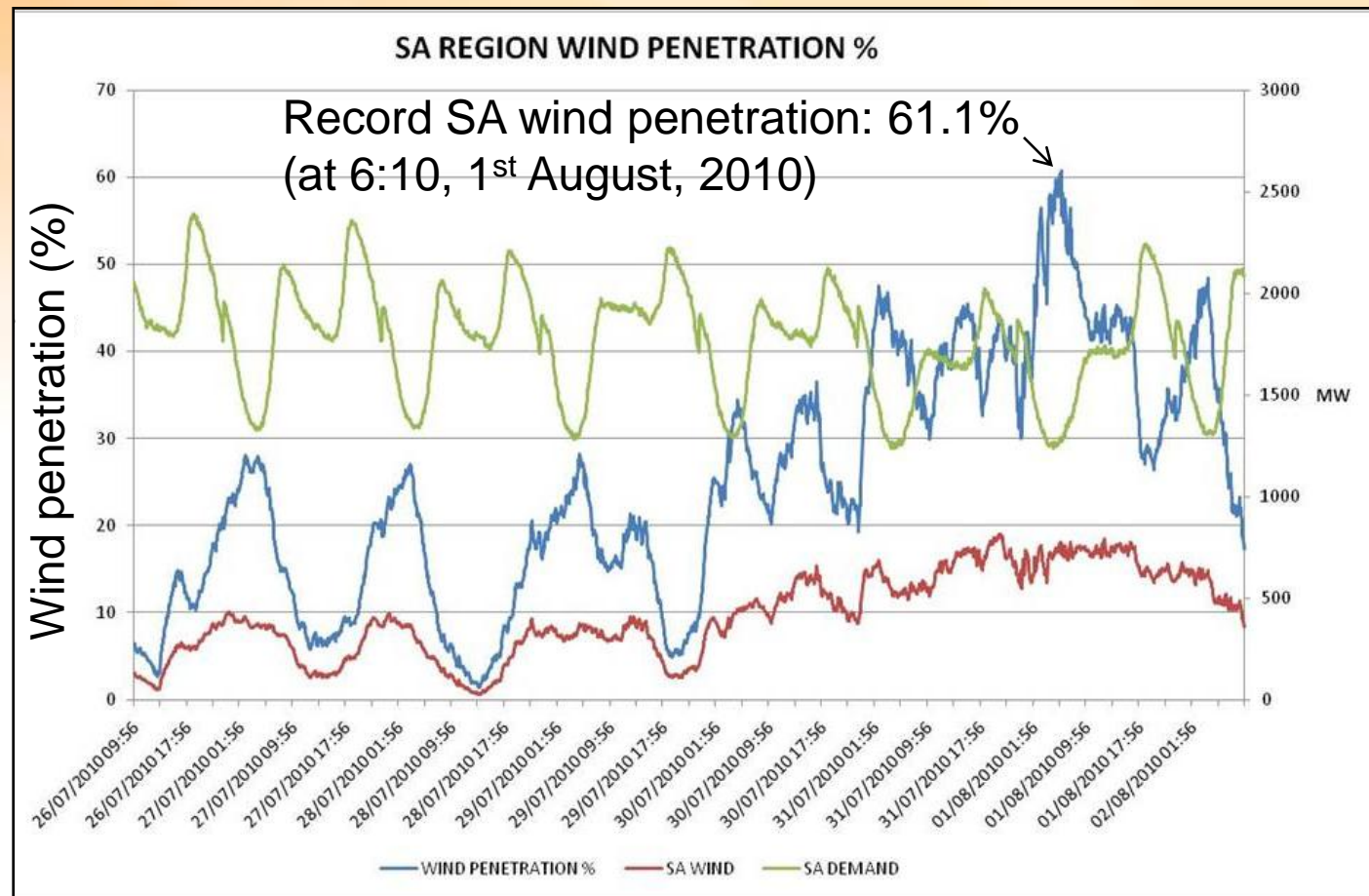
Wind farm size

- 0-1 MW
- 1-10 MW
- 10-50 MW
- > 50 MW



Growing wind penetration in the NEM

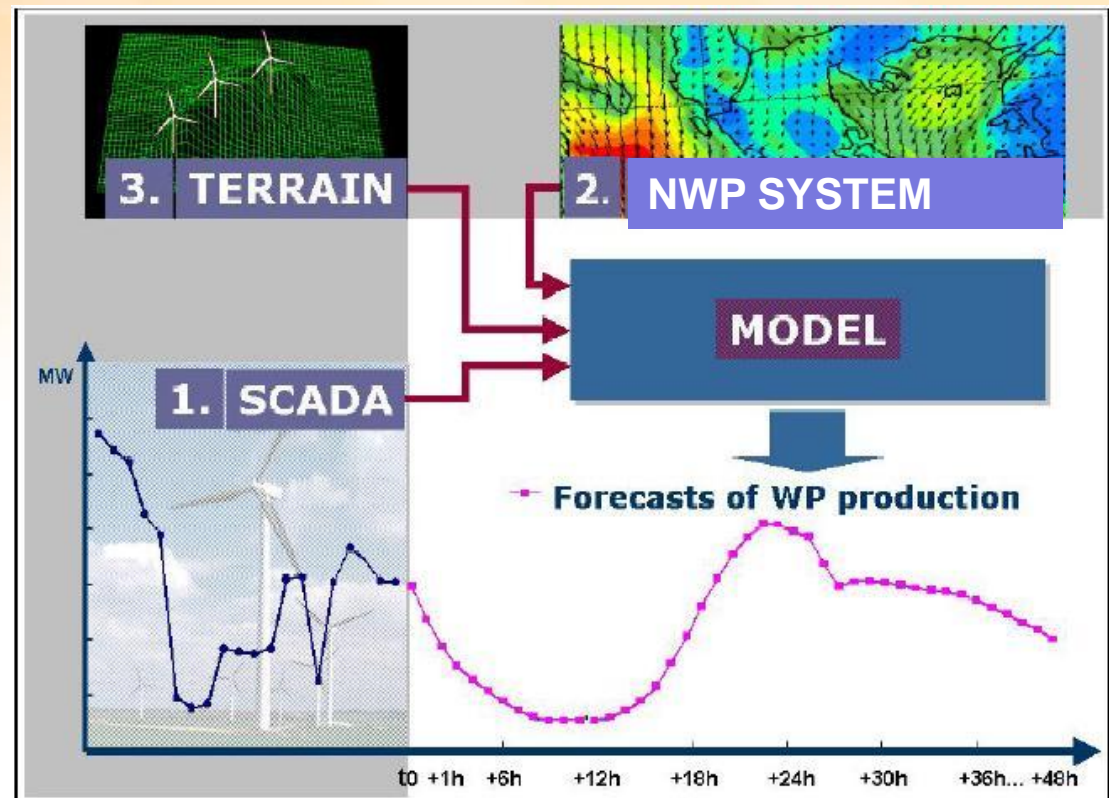
- Lead by South Australia:



(Peter Biddle, AEMO)

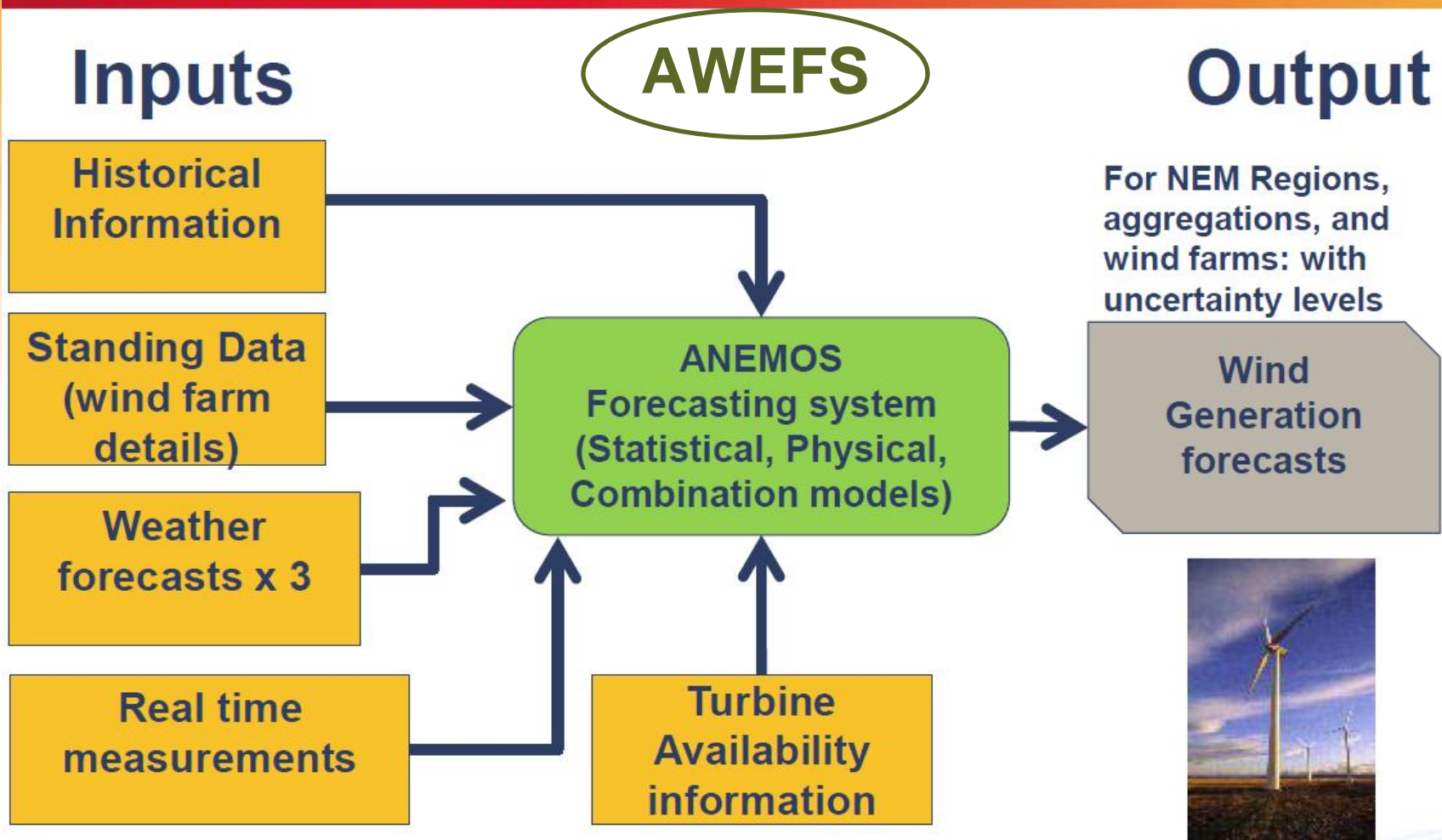
Wind Energy Forecasting Conventional Approach

- SCADA: recent observations
- “NWP “ is Numerical Weather Prediction
- “Model” usually contains:
 - “Power curve”
 - Other statistical transformations



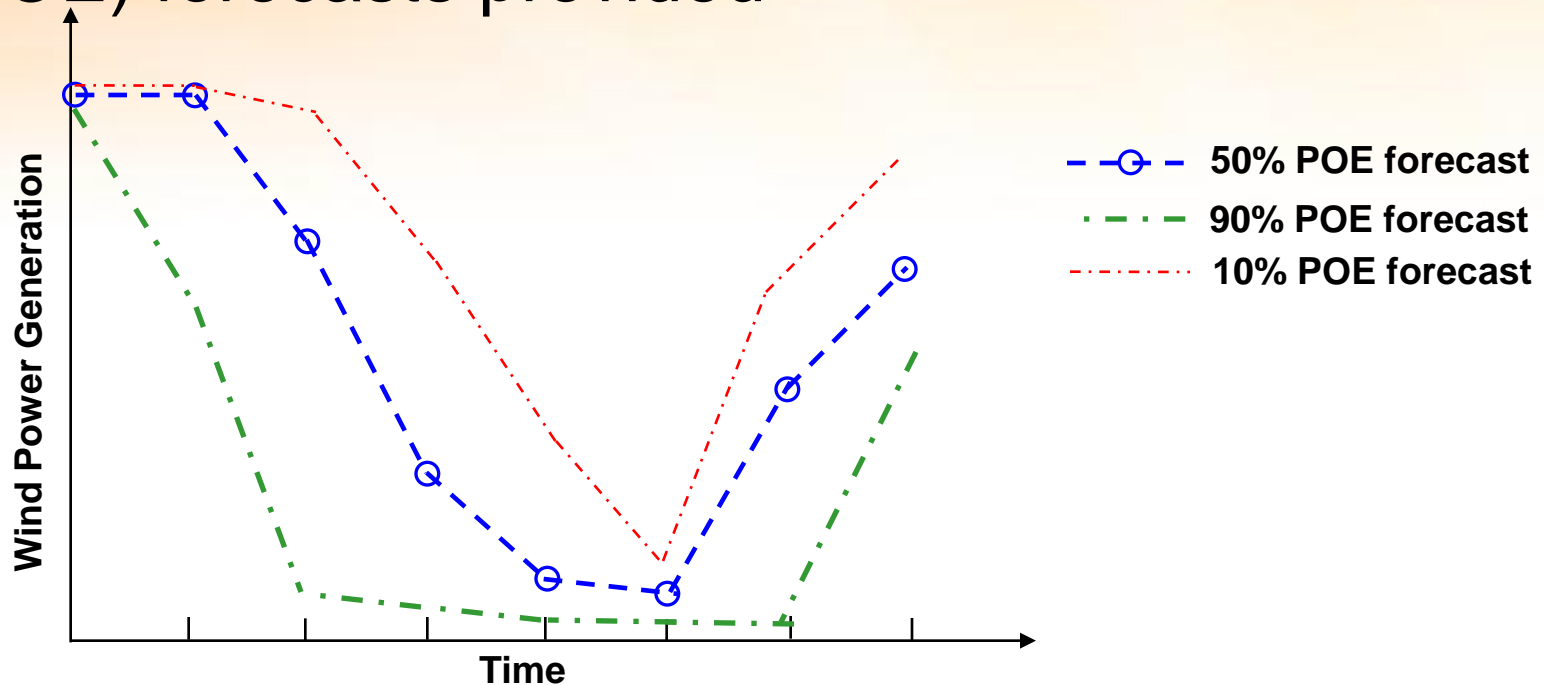
(Giebel G, 2003)

HOW DO WE FORECAST WIND GENERATION ? ANEMOS DATA FLOWS



AWEFS – special features

- Forecasts every 5 mins up to 2 hours, then every 30 mins to 6 days, then daily up to 2 years
- 10%, 50% and 90% Probability Of Exceedance (POE) forecasts provided

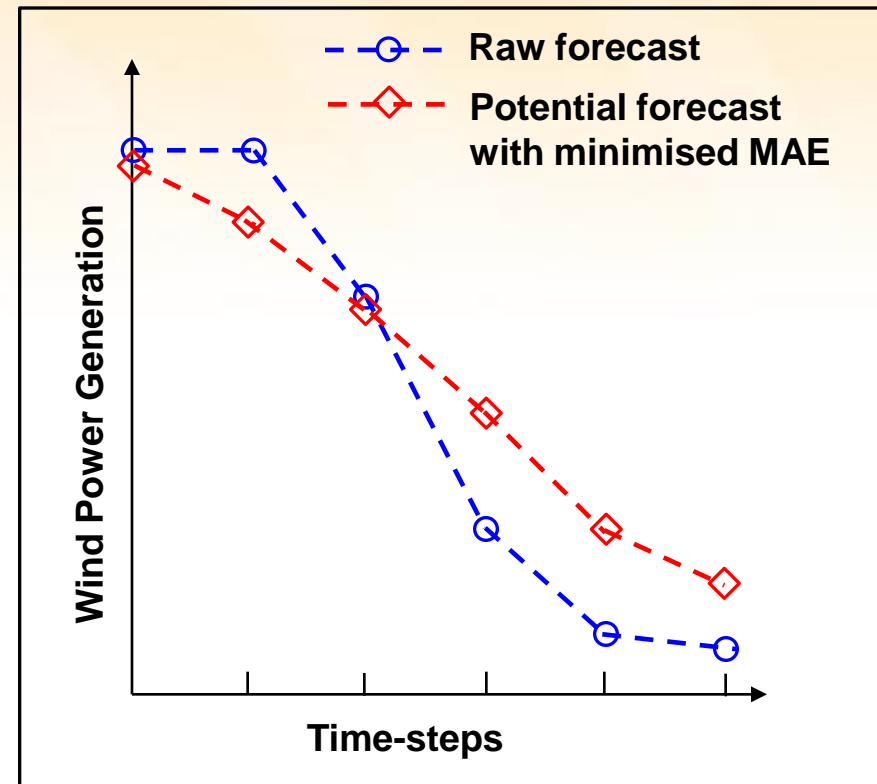


AWEFS – special features

- Forecasts every 5 mins up to 2 hours, then every 30 mins to 6 days, then daily up to 2 years
- 10%, 50% and 90% POEs provided
- An extensive wind farm power observation SCADA data set, including wind turbine availability
- Researcher access server
 - And researcher wind farm data access agreements with wind farm data owners
 - Scope for enhancements including beyond Phase B of the AWEFS project

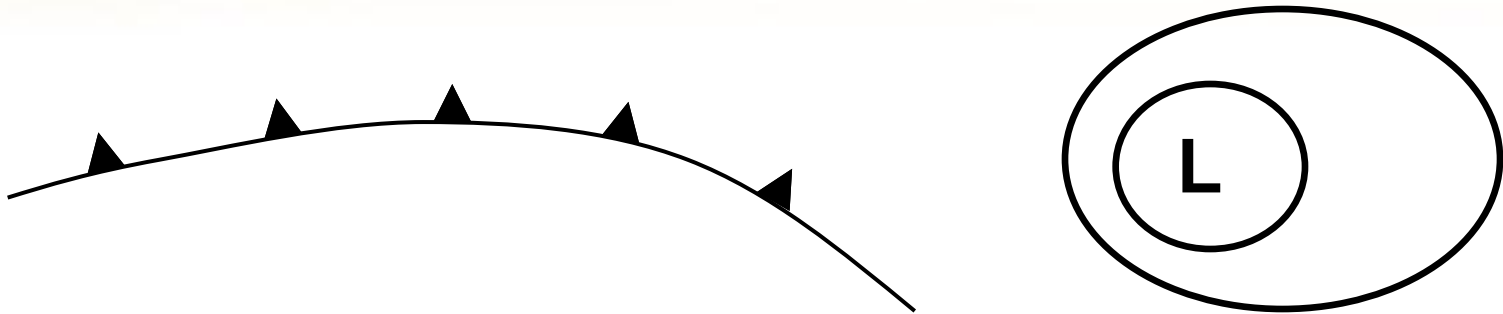
Wind Forecast Performance Assessment

- Systems often designed to minimise average amplitude error, such as mean absolute error (MAE)
- Two potential issues:
 - Temporal sampling and temporal averaging of data
 - Treats forecast errors as independent
 - Large rapid changes with timing uncertainty could be smoothed out



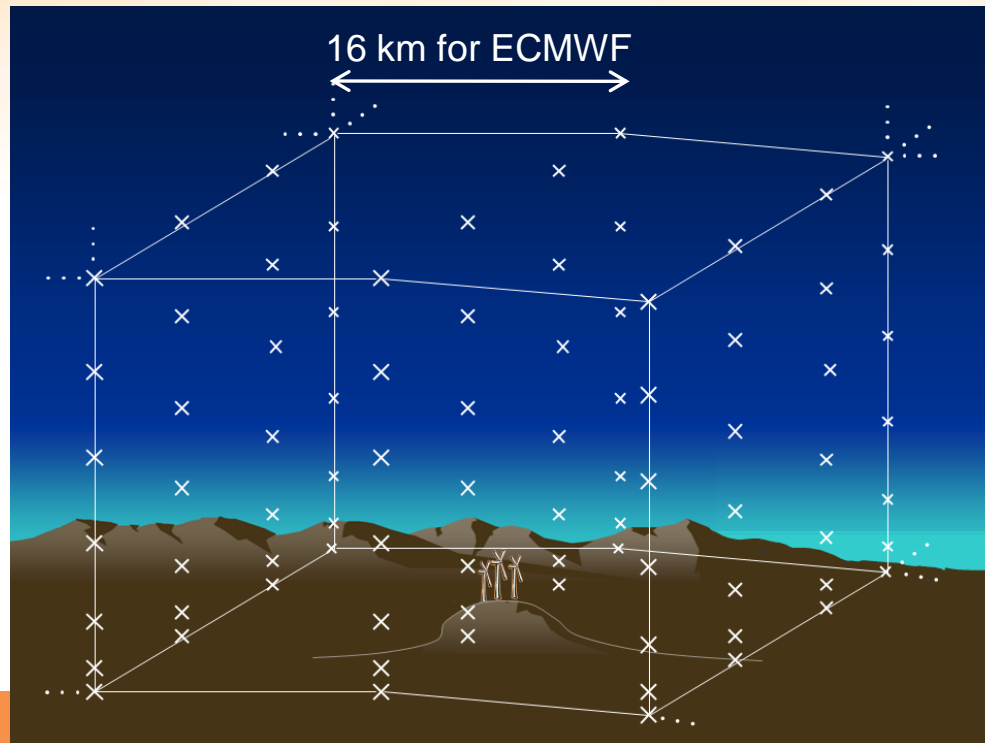
What causes large rapid changes in wind power?

- For the Australian wind farms we have studied, large, rapid changes in wind power are largely caused by horizontally propagating synoptic weather phenomena:
 - Eg. Cold fronts and low pressure systems



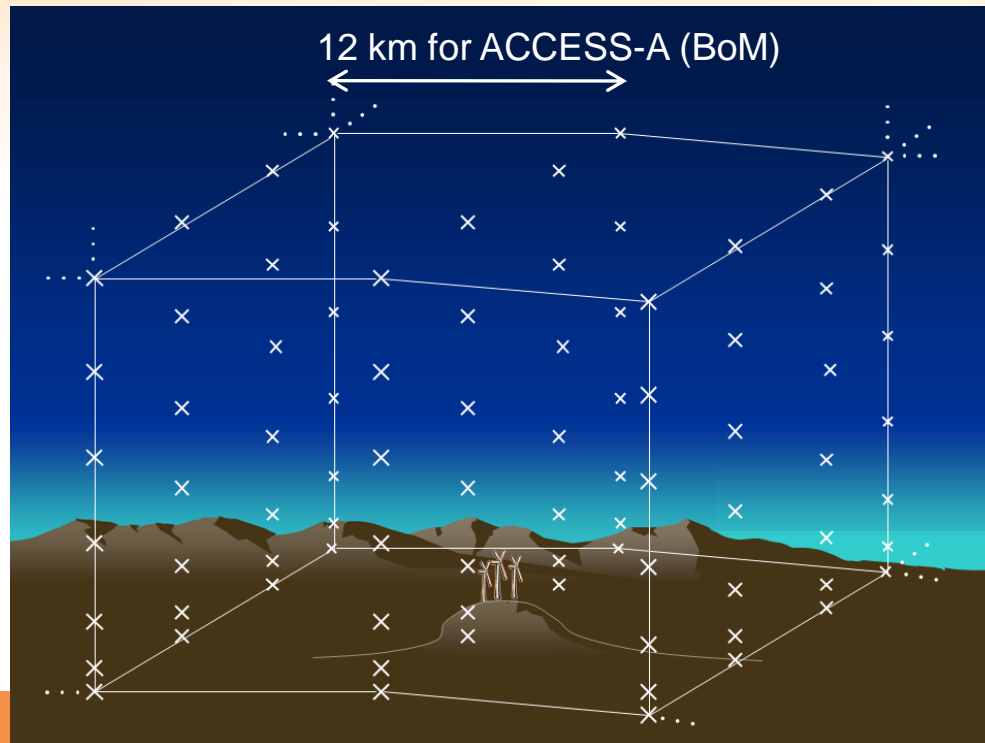
NWP systems (1)

- Represent the atmosphere on a relatively coarse horizontal grid
 - ECMWF global model horizontal resolution is 16 km (increased from 25 km this year) with 91 vertical levels



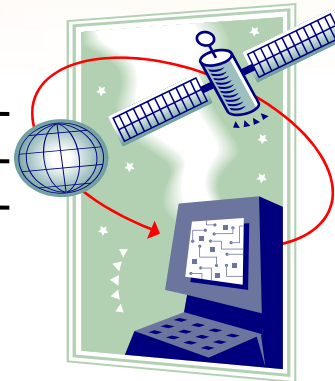
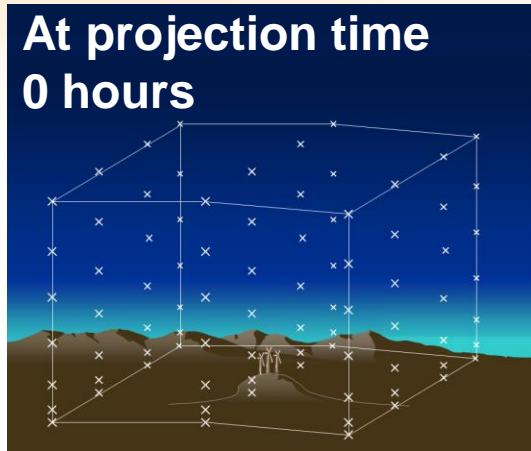
NWP systems (2)

- Represent the atmosphere on a relatively coarse horizontal grid
 - The new local NWP model from the Australian Bureau of Meteorology has 11 km resolution with 50 vertical levels



NWP systems (3)

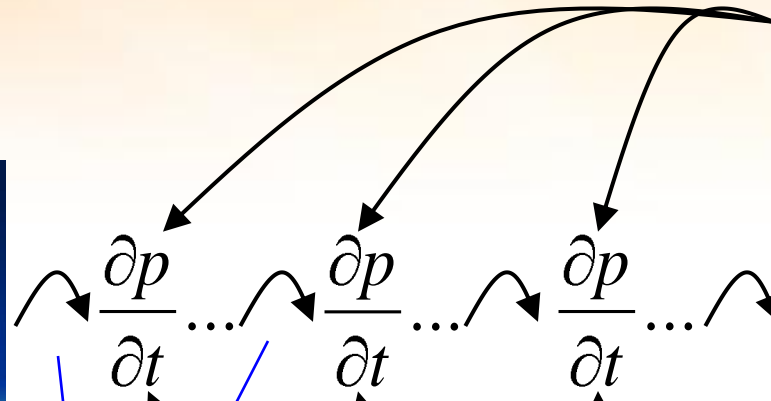
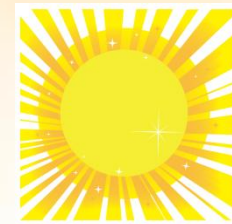
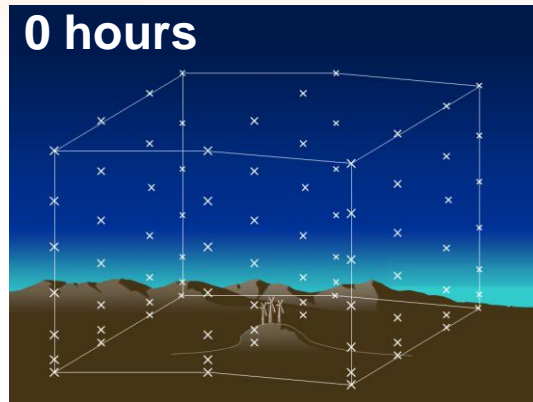
- Forecast is produced in two steps:
 - 1. **Estimate initial state** of the atmosphere (wind, pressure, temperature and humidity) on the model grid using all available observations



Ground
observations

NWP systems (4)

- Forecast is produced in two steps:
 - 2. **Run model forward** in time, solving simplified equations of motion in response to known disturbances
 - eg. sun's heating, Coriolis Force



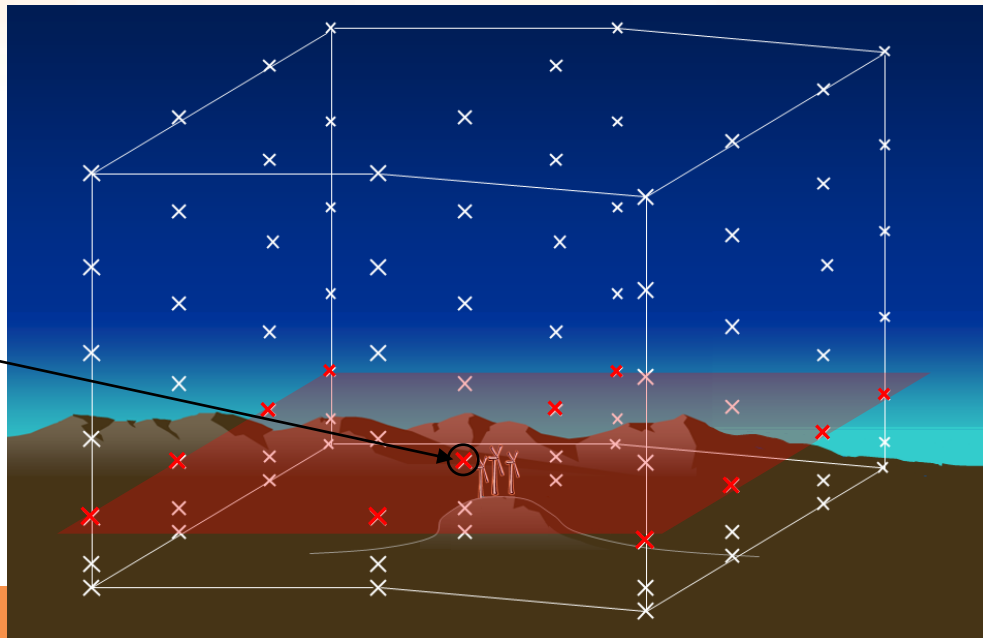
Time-steps

NWP systems (5)

- Conventional use of NWP information: take forecast at a single grid point (or interpolation of grid points) near location of interest at each time step
- Alternatively, could utilise multiple grid points

Single grid point near wind farm

Multiple grid points



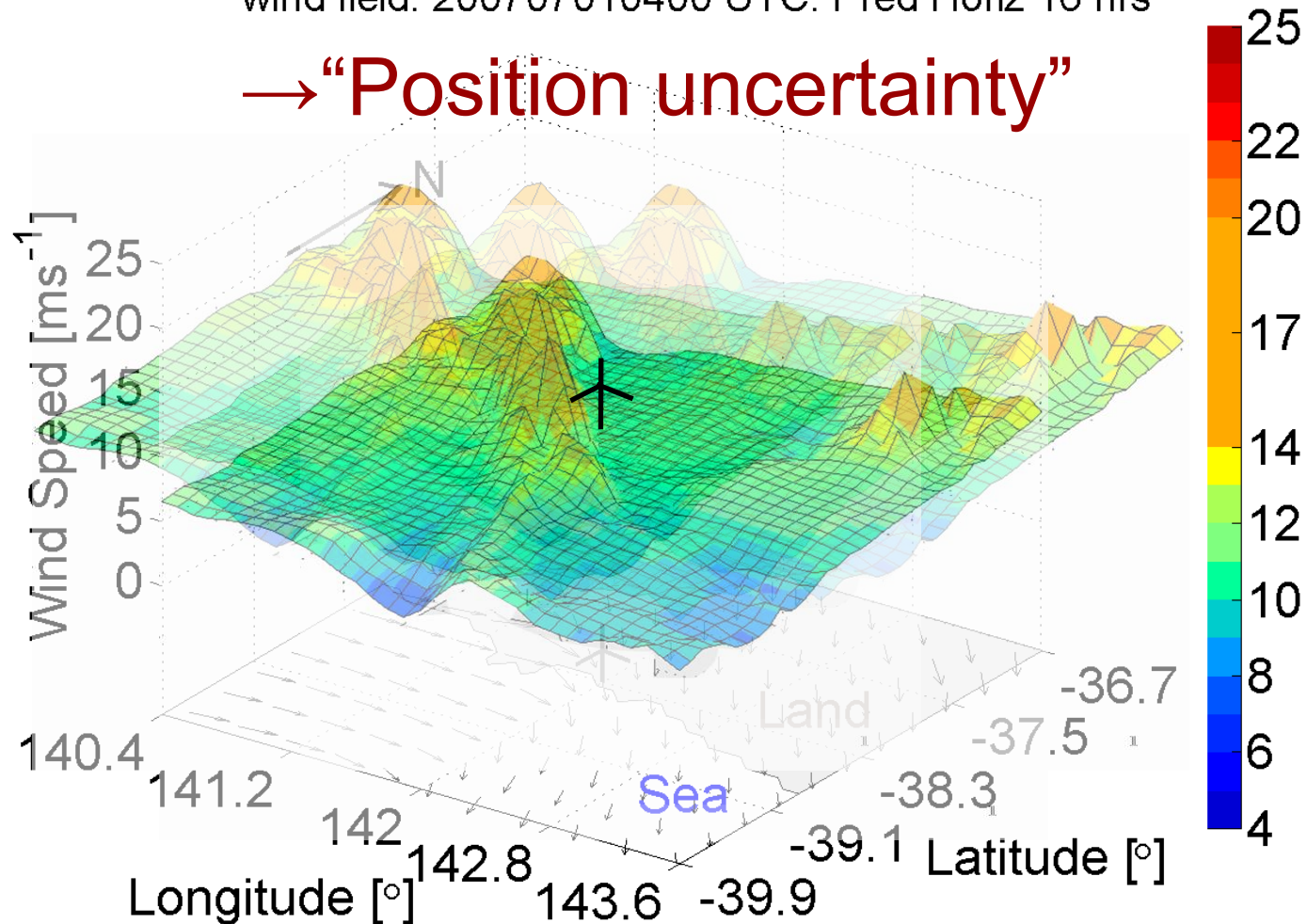
Strengths and weaknesses of NWP systems for wind power forecasting

- Cannot directly model fine-scale detailed topographic effects on the wind due to coarse resolution
 - Fortunately, large aggregated changes in wind power are not likely to be caused by these effects
- 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 as they propagate in time
- Uncertain in forecast broad region-wide wind speed (or more generally the broad kinetic energy levels)

Outcomes from PhD thesis

wind field. 200707010400 UTC. Pred Horiz 16 hrs

→ “Position uncertainty”

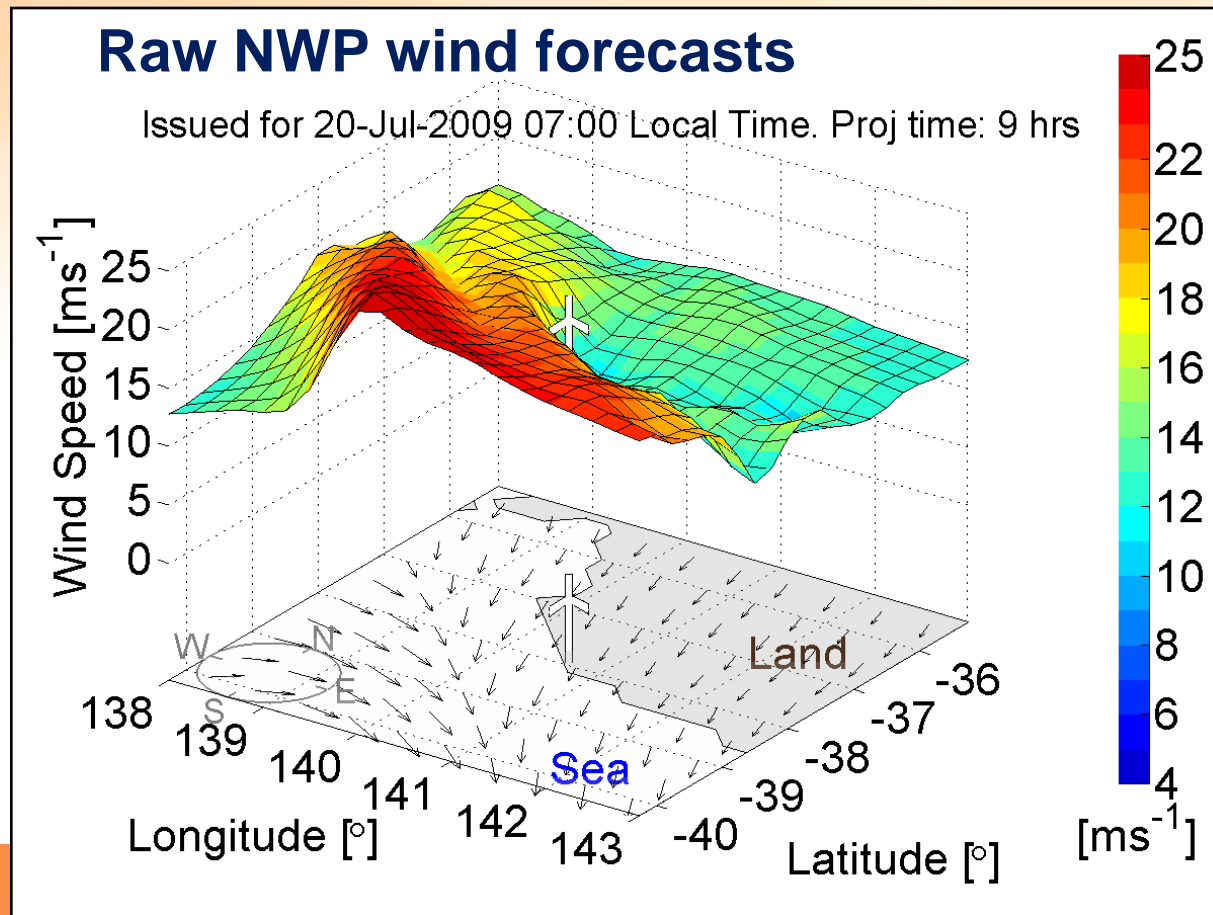


Outcomes from PhD thesis

- Identified that conventional time-series forecast derived from a single grid point may be missing useful information in NWP system
 - Position uncertainty during large rapid changes could imply significantly different plausible scenarios to single grid point forecast
- Developed technique to display multiple grid point information from NWP systems to characterise wind forecast uncertainty due to position uncertainty
 - Problem: the wind at each grid point is influenced by the local topography →

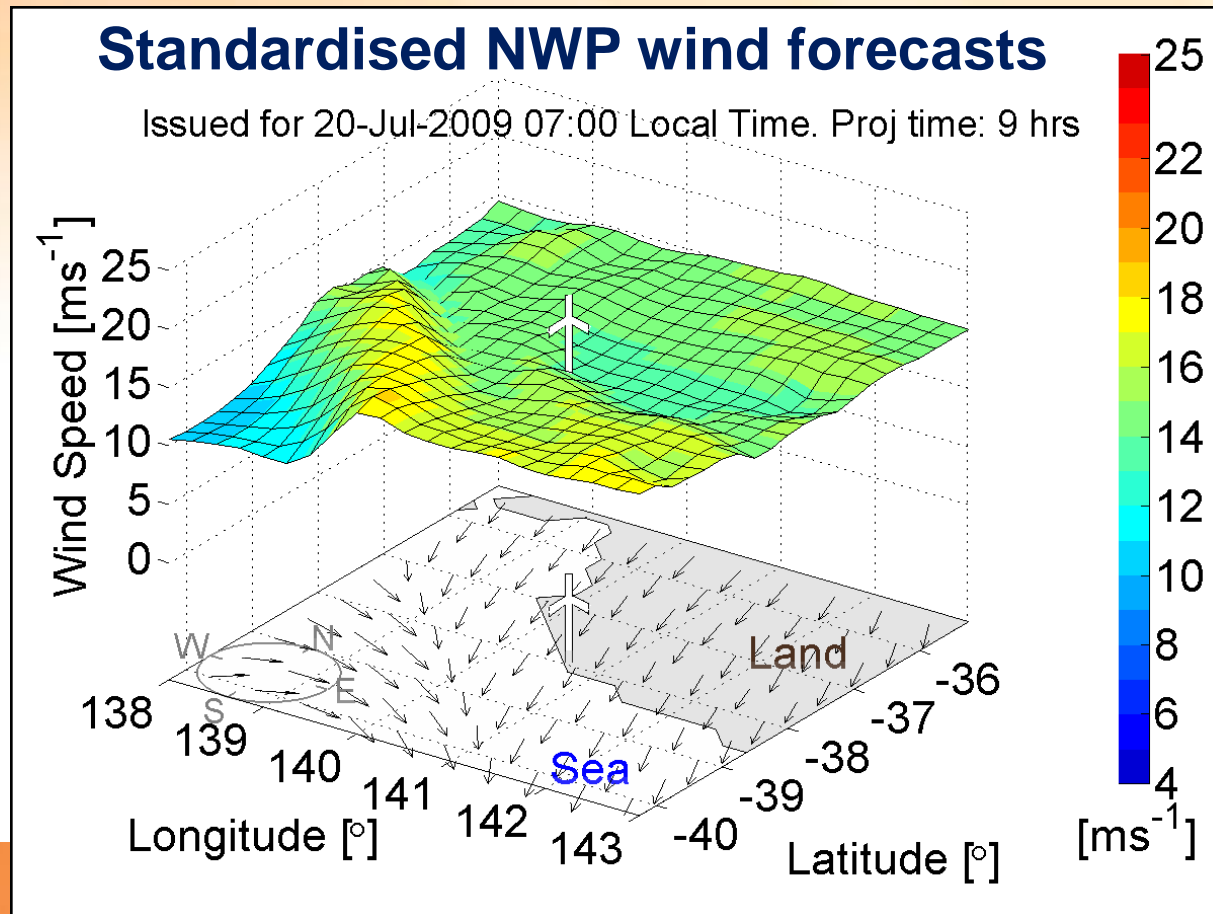
PhD outcomes: Terrain standardisation method

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



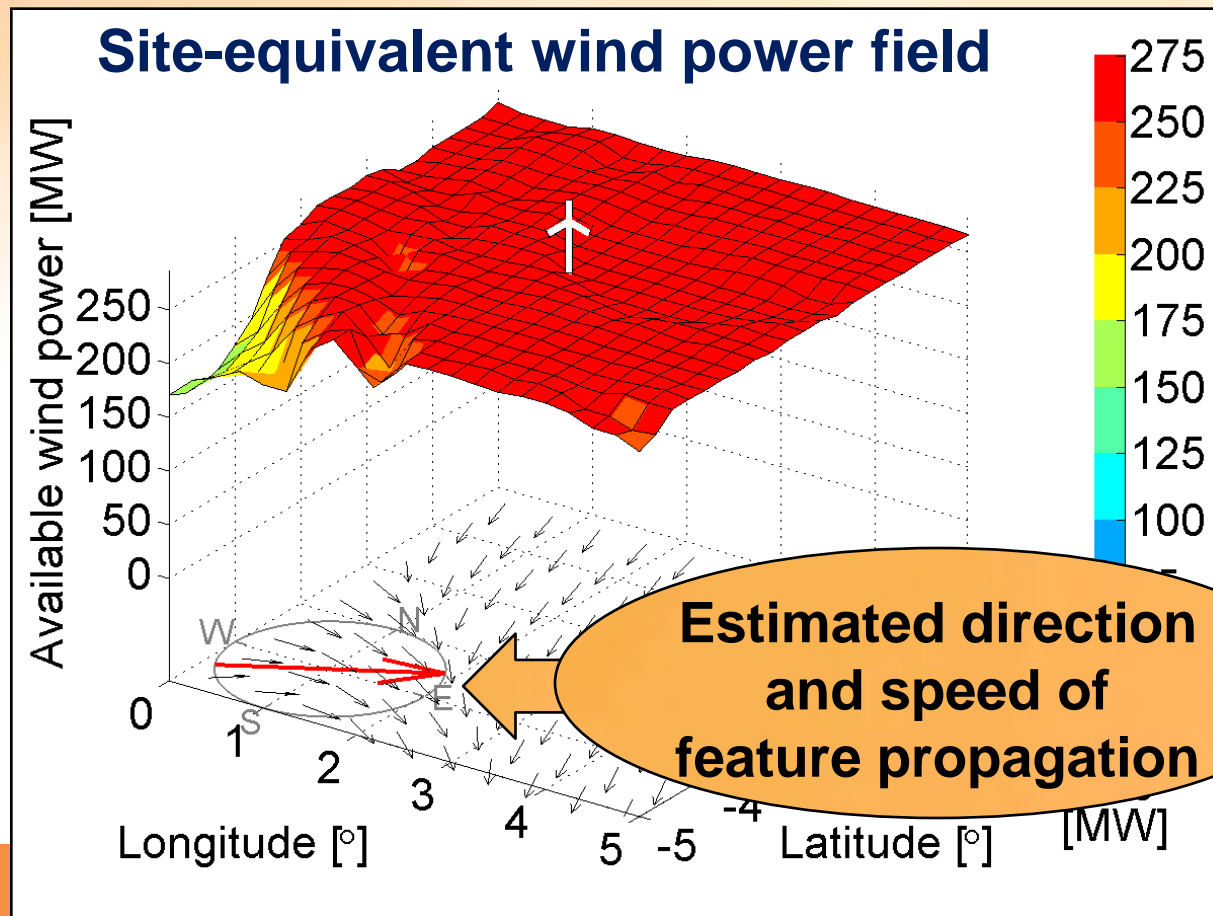
PhD outcomes: Terrain standardisation method

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



PhD outcomes: Convert wind field to wind power

- Develops relationships between historical forecasts and observations to create:





PART 2

The prototype forecasting tool for AEMO

- The prototype tool is specified to provide information in two steps:
 - Raise **alerts** when there is the possibility of a large rapid change occurring within a forecast horizon of 48 hours
 - For each alert, **presentations of** the available **forecast information** is to be provided highlighting plausible multiple scenarios for wind power generation, in 2 forms:
 - An animation of successive wind power spatial fields,
 - A time-series plot showing multiple scenarios, with an indication of their associated probability.
 - These presentations would only be assessed by the operators if they deem the alert to occur at a critical time (eg. other constraints in the network)

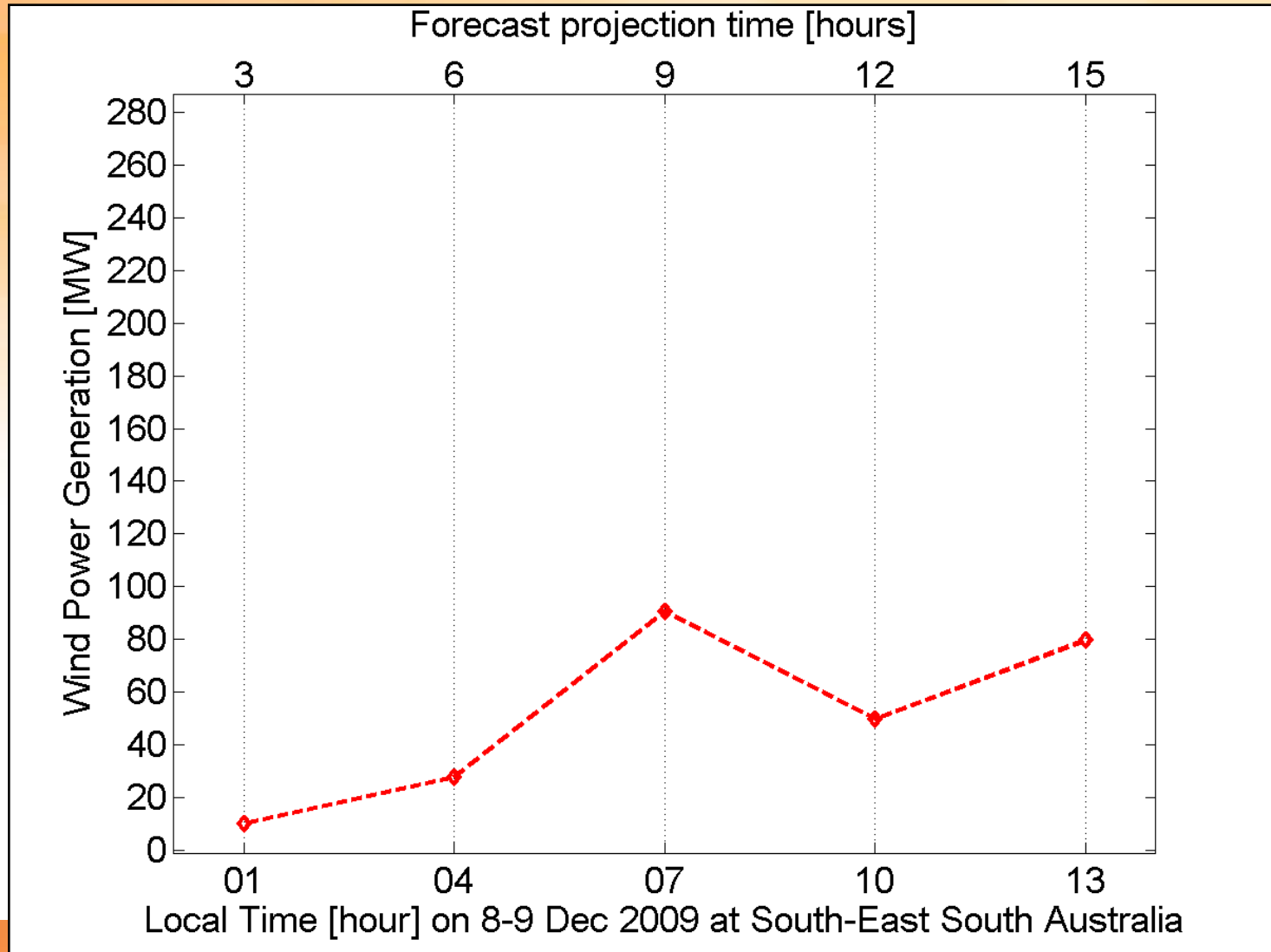


SESA changes by 150 MW in 30min

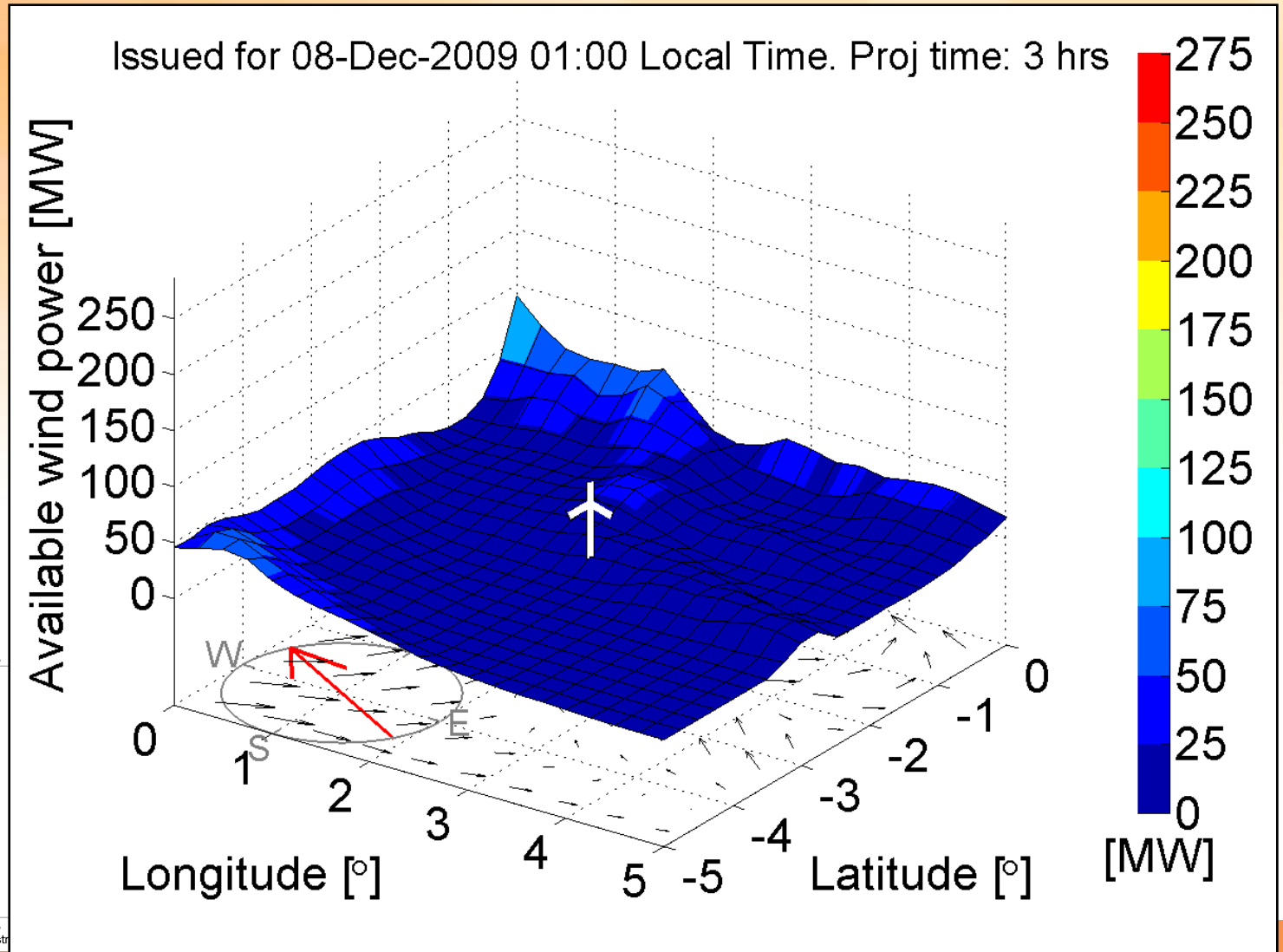
- 1.5 years of data: 548 days
- Two types of events
 - Rapid change in wind speed
 - High wind speed cut-out

Statistic	Change in wind speed	High wind speed cut-out
Number of events alerted	187	61
Number of events occurred	23	10
Number of missed events	7/23	1/10

Example event, the single grid point forecast



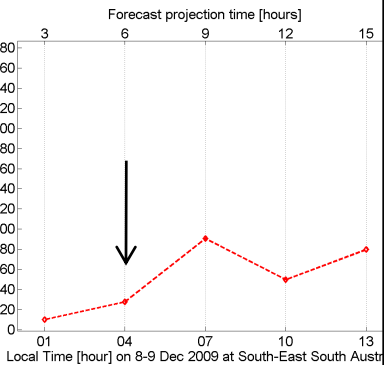
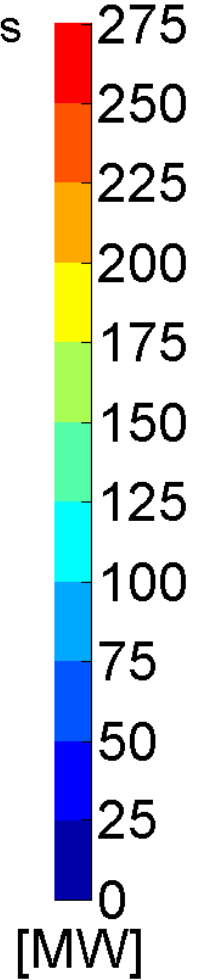
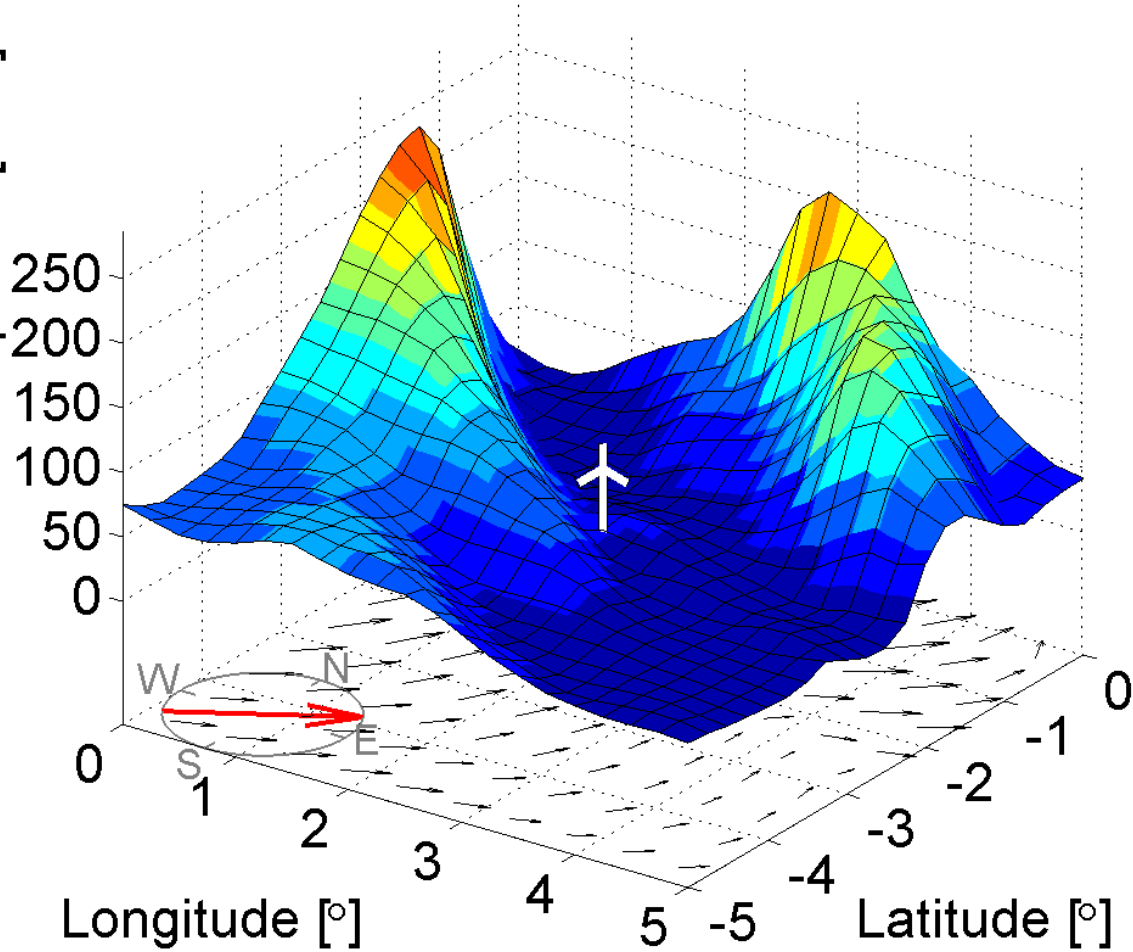
Animation of wind power forecast fields example



Animation of wind power forecast fields example

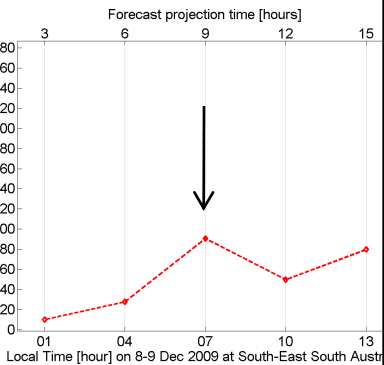
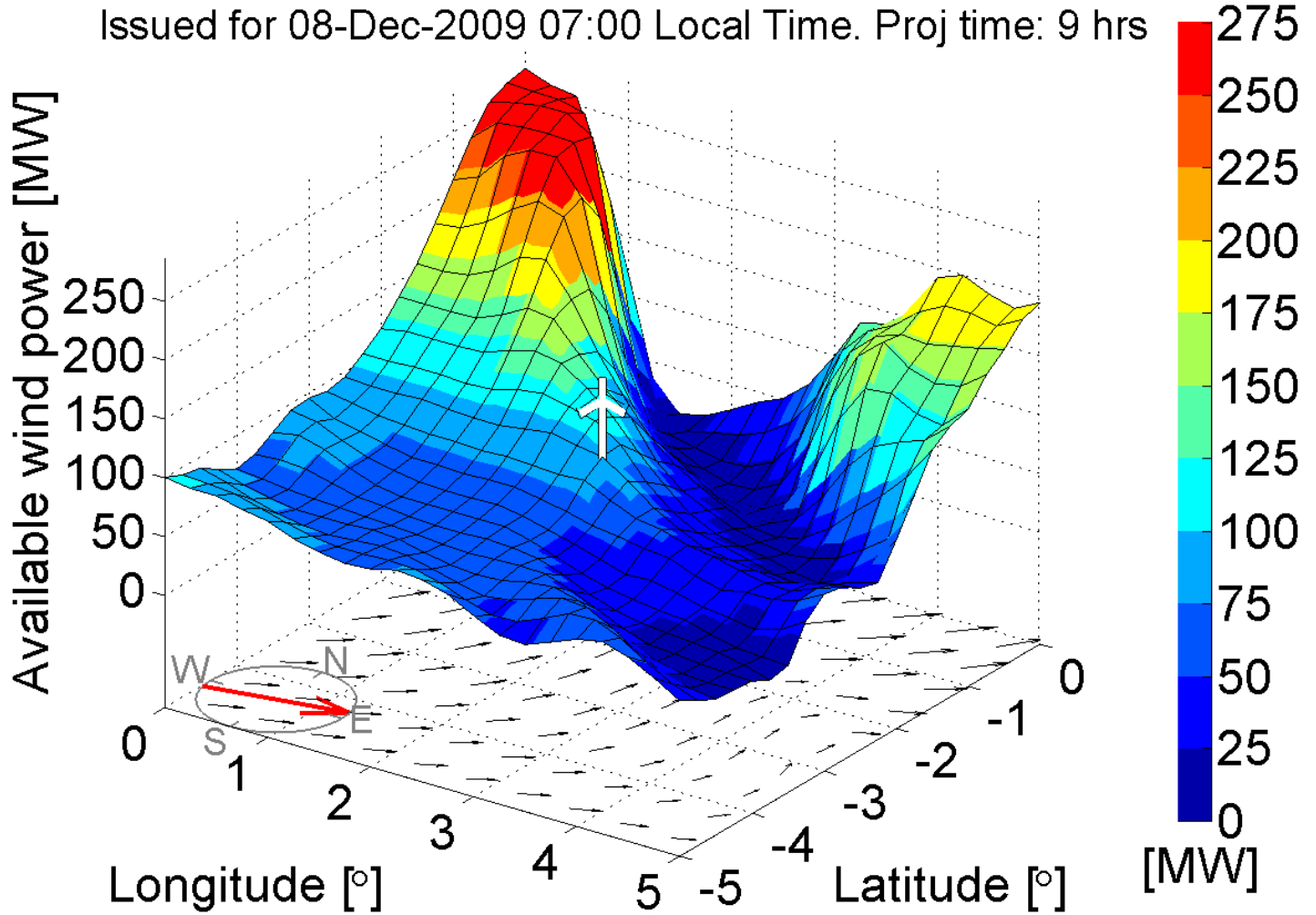
Issued for 08-Dec-2009 04:00 Local Time. Proj time: 6 hrs

Available wind power [MW]

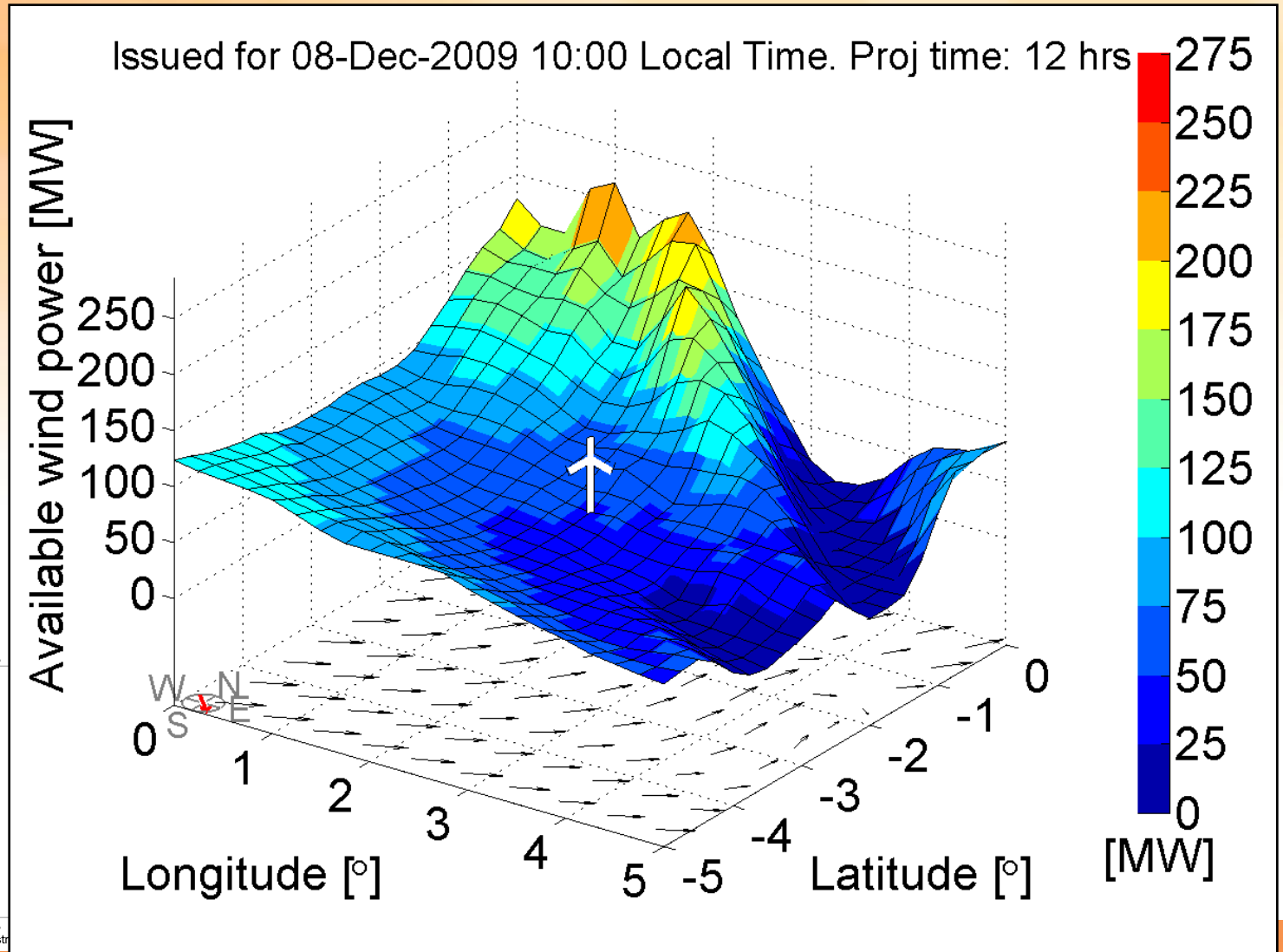


Animation of wind power forecast fields example

Issued for 08-Dec-2009 07:00 Local Time. Proj time: 9 hrs



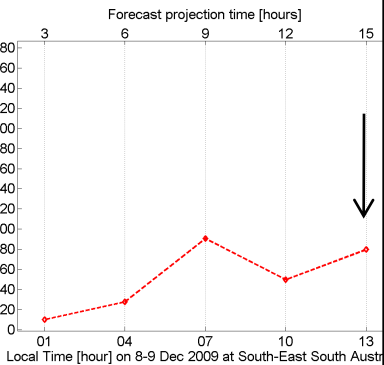
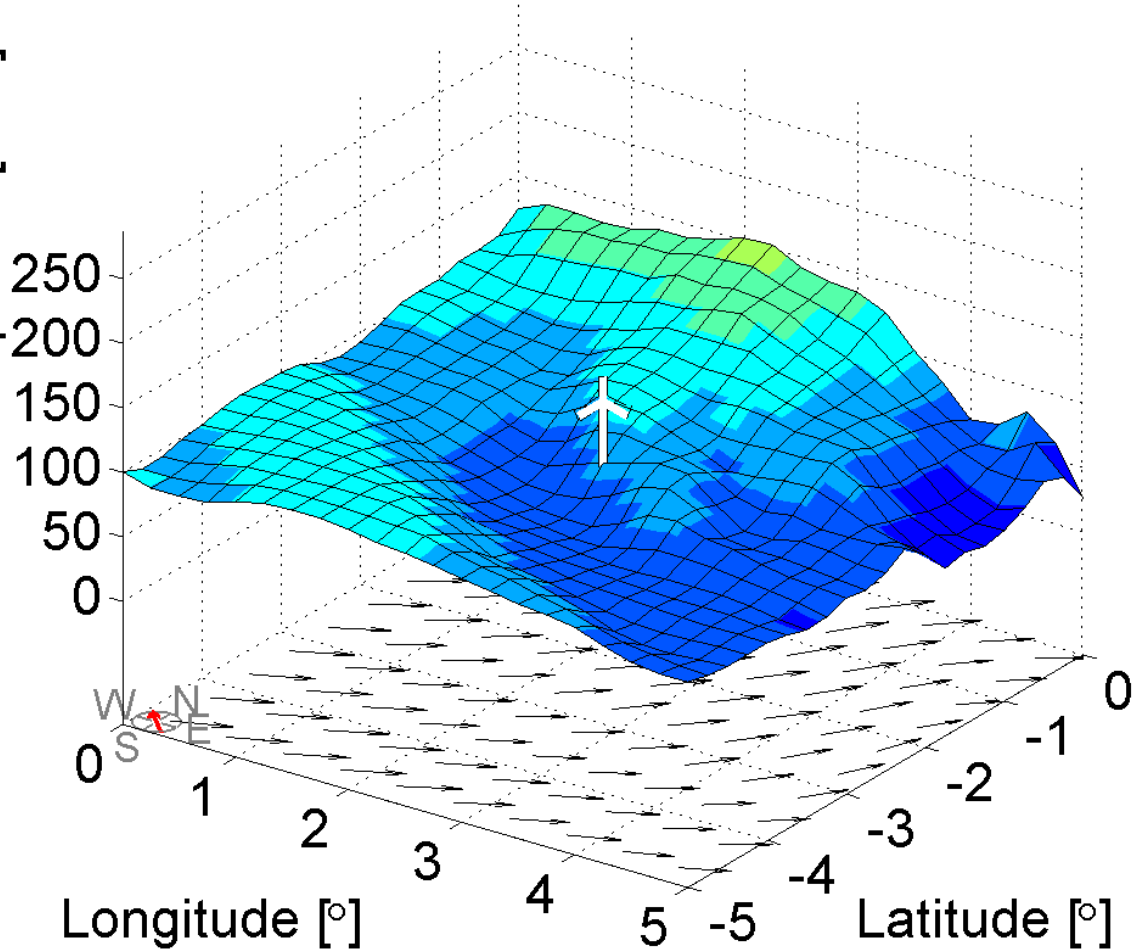
Animation of wind power forecast fields example



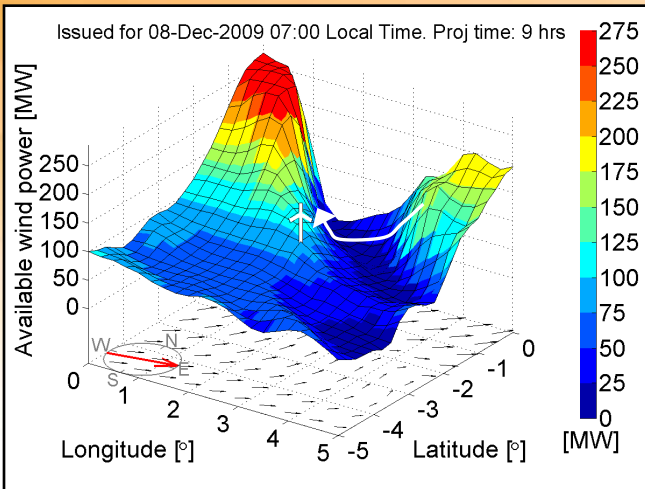
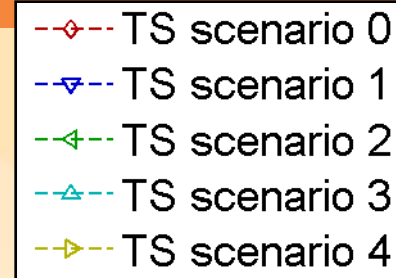
Animation of wind power forecast fields example

Issued for 08-Dec-2009 13:00 Local Time. Proj time: 15 hrs

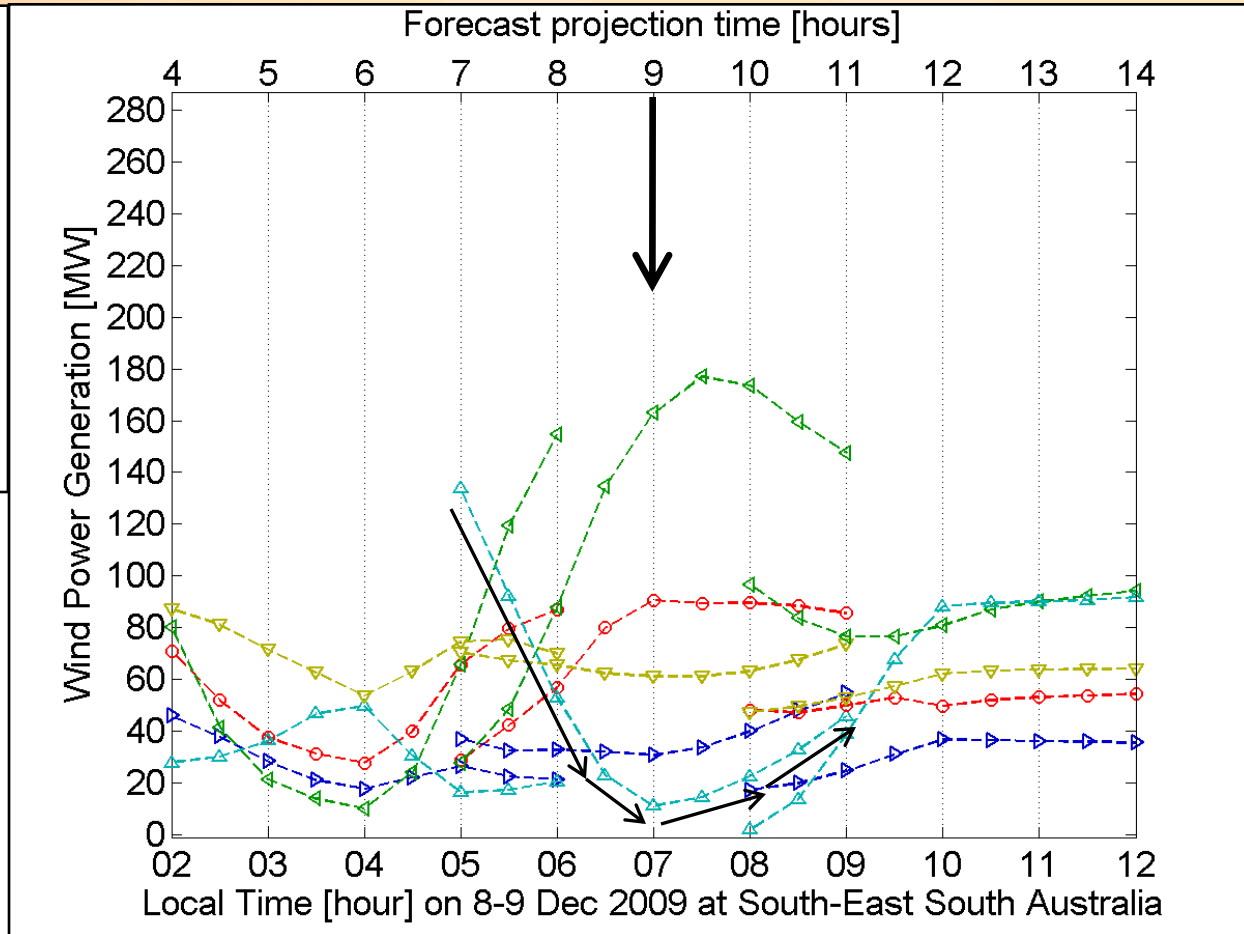
Available wind power [MW]



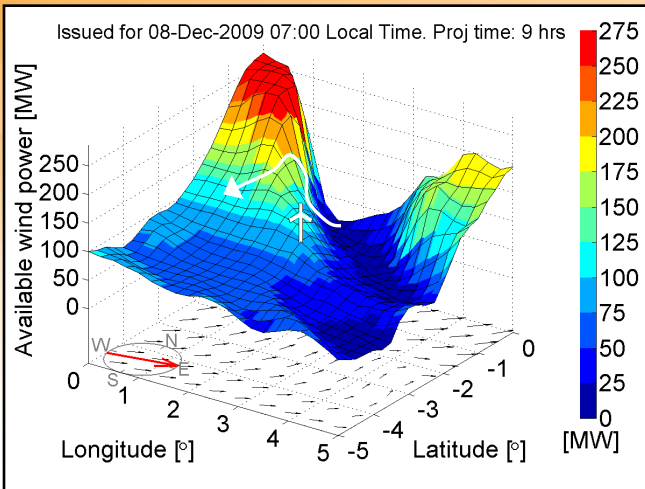
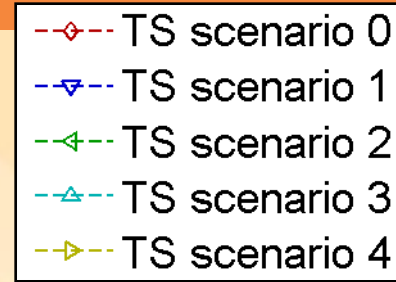
Interpreting wind power forecast fields



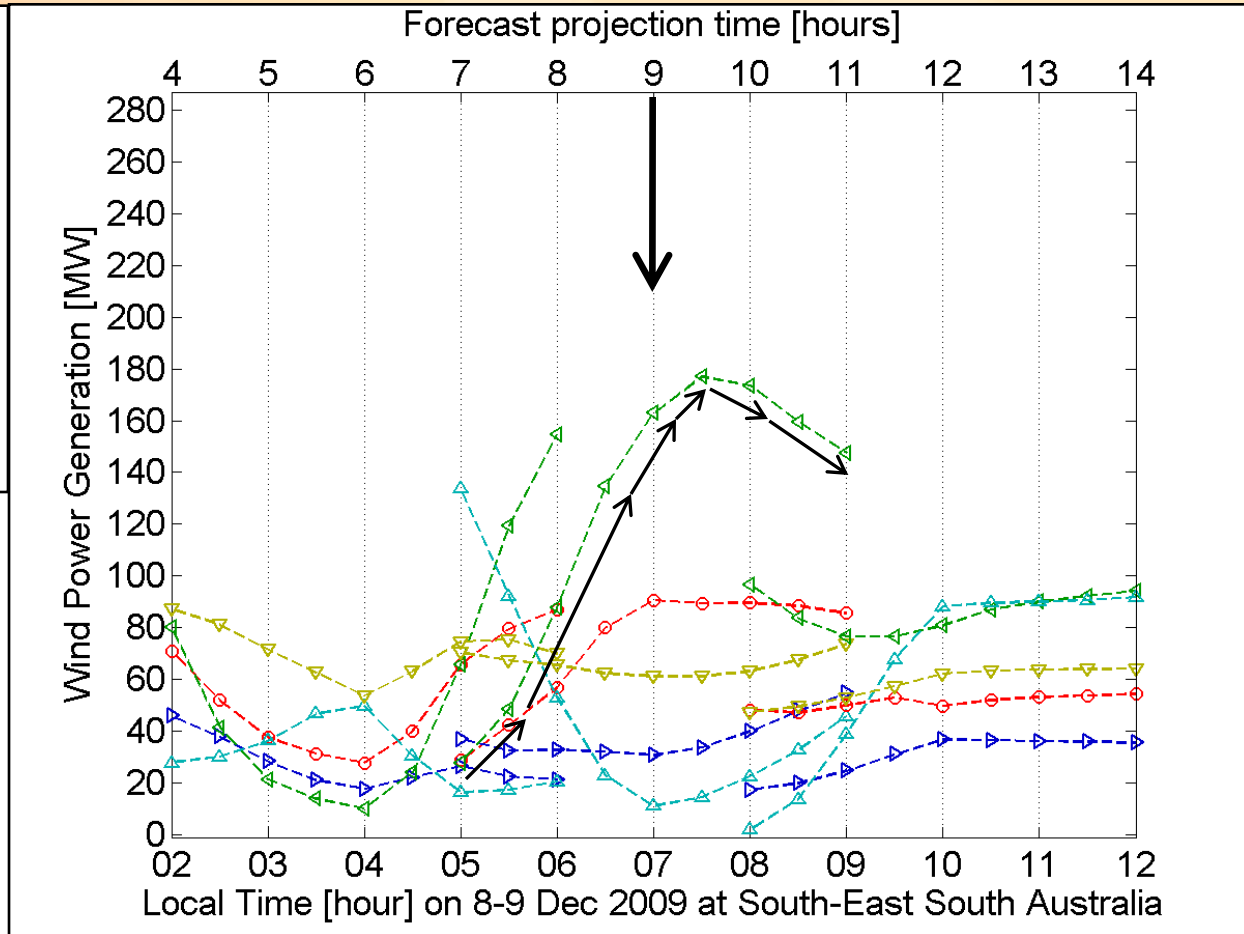
- Projection time 9 hours
- Potential large rapid change in wind power



Interpreting wind power forecast fields

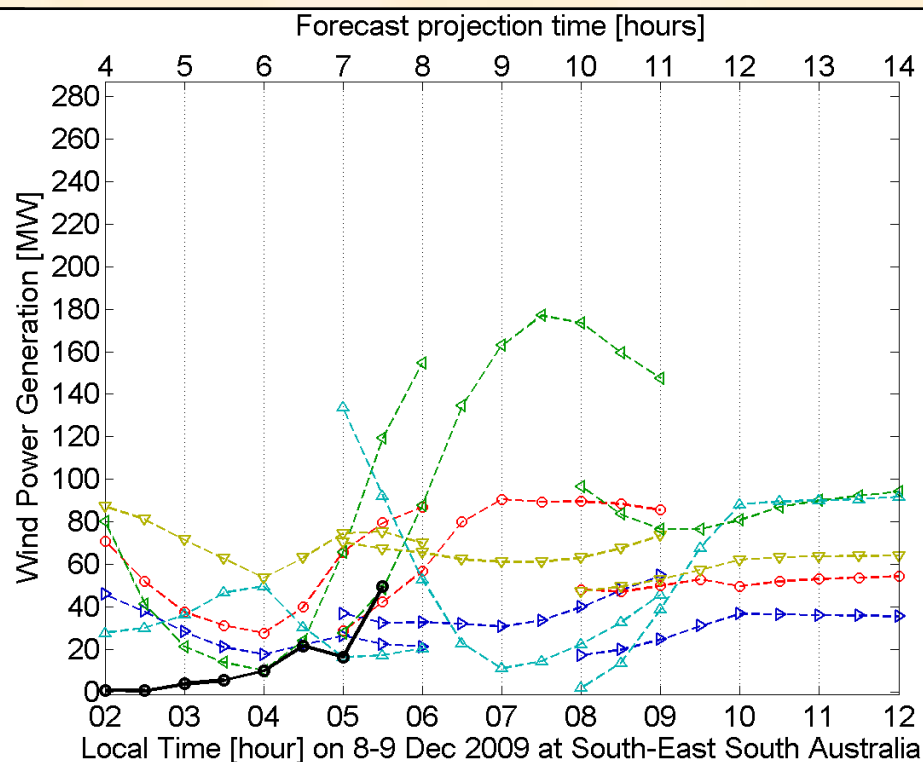
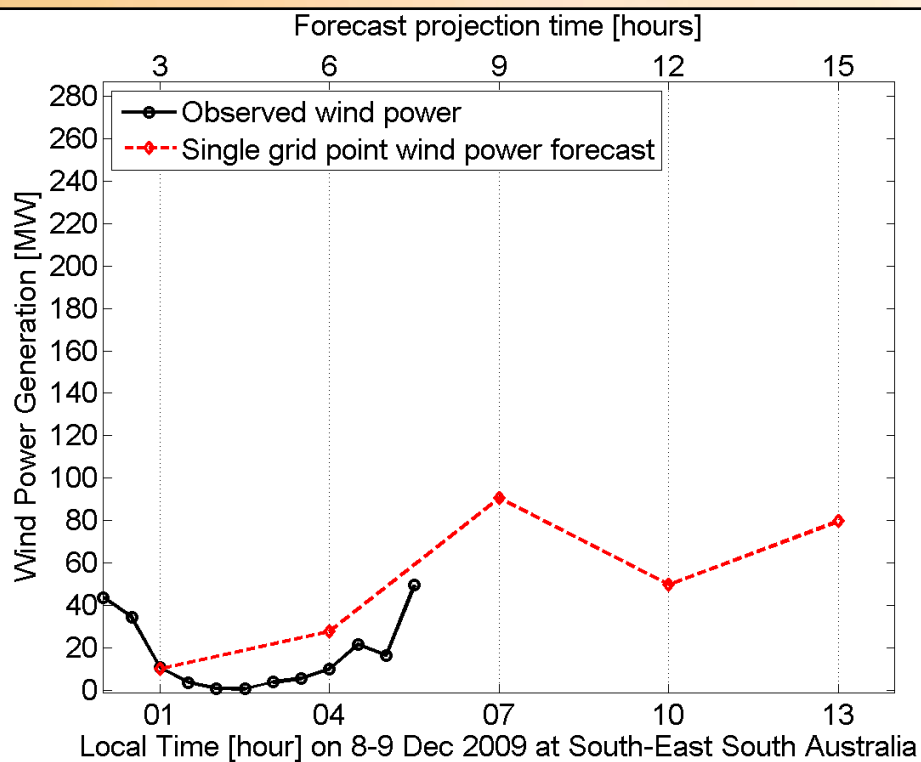
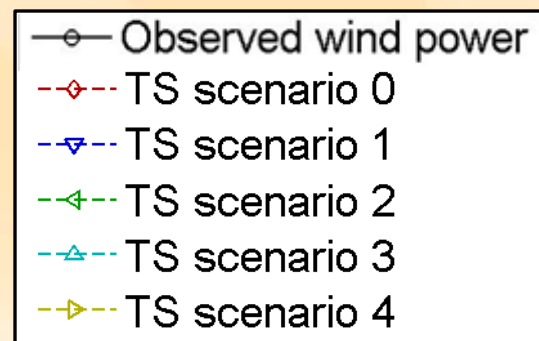


- Projection time 9 hours
- Potential large rapid change in wind power



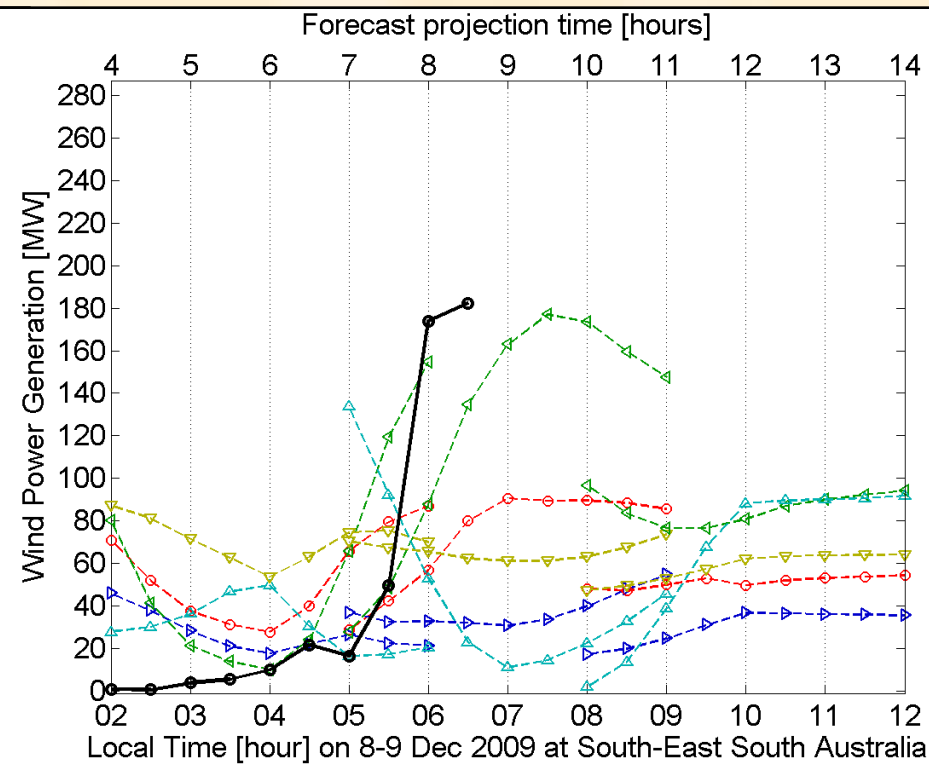
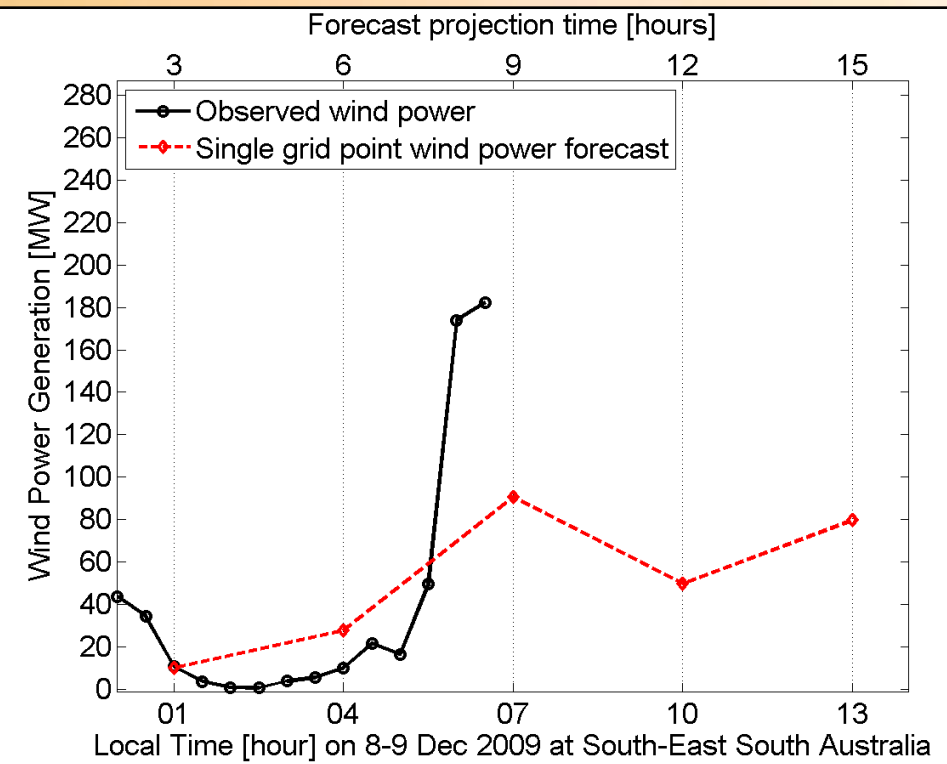
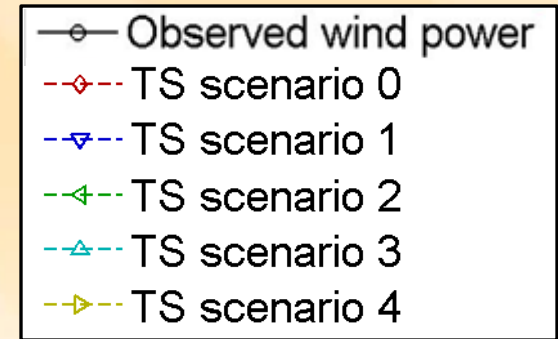
Interpreting wind power forecast fields

- Observations up to 5:30



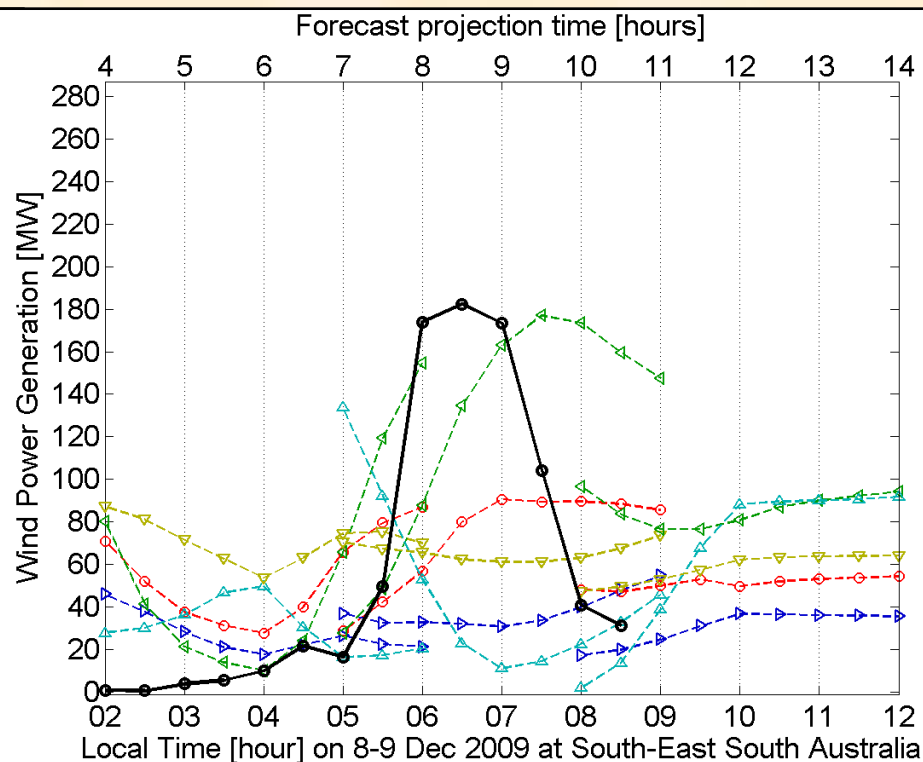
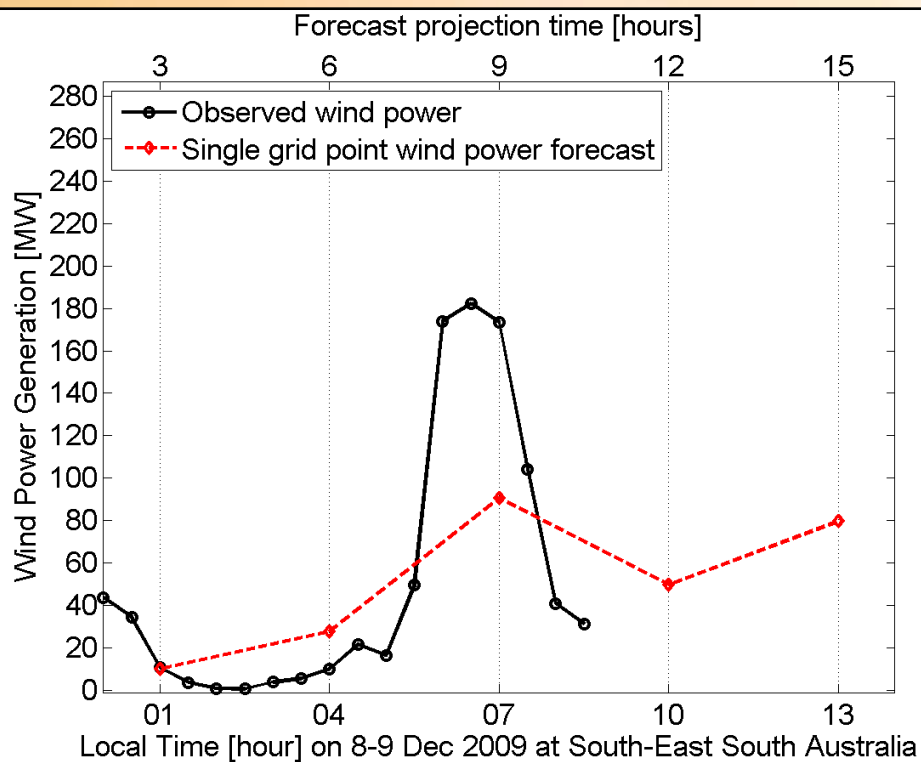
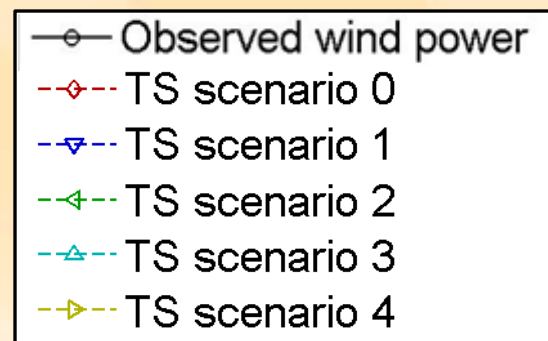
Interpreting wind power forecast fields

- Observations up to 6:30



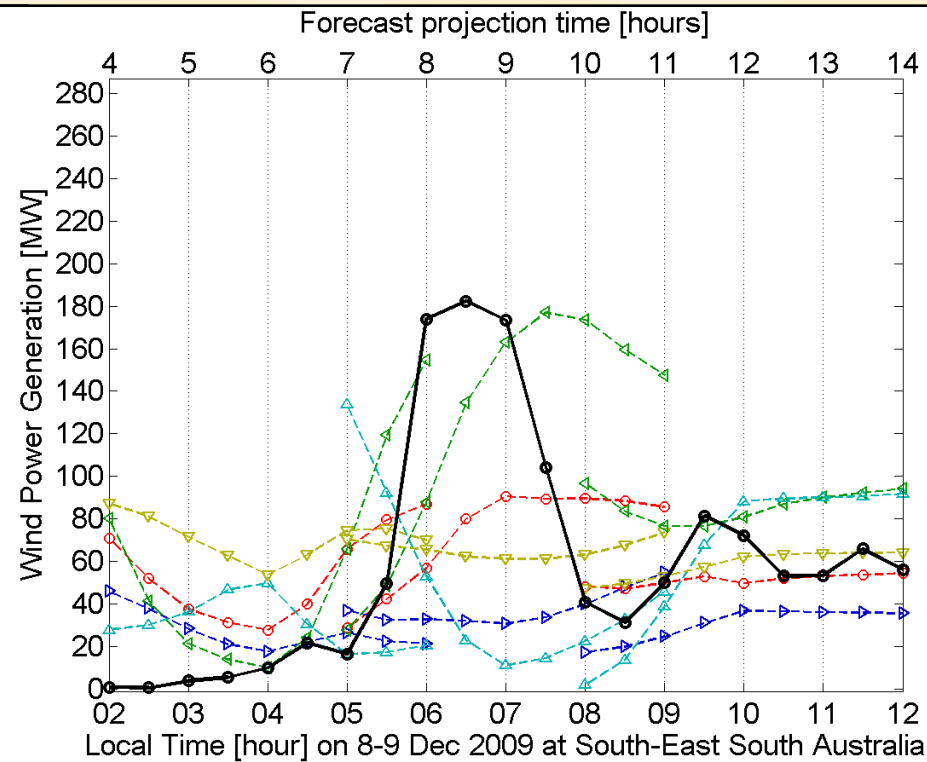
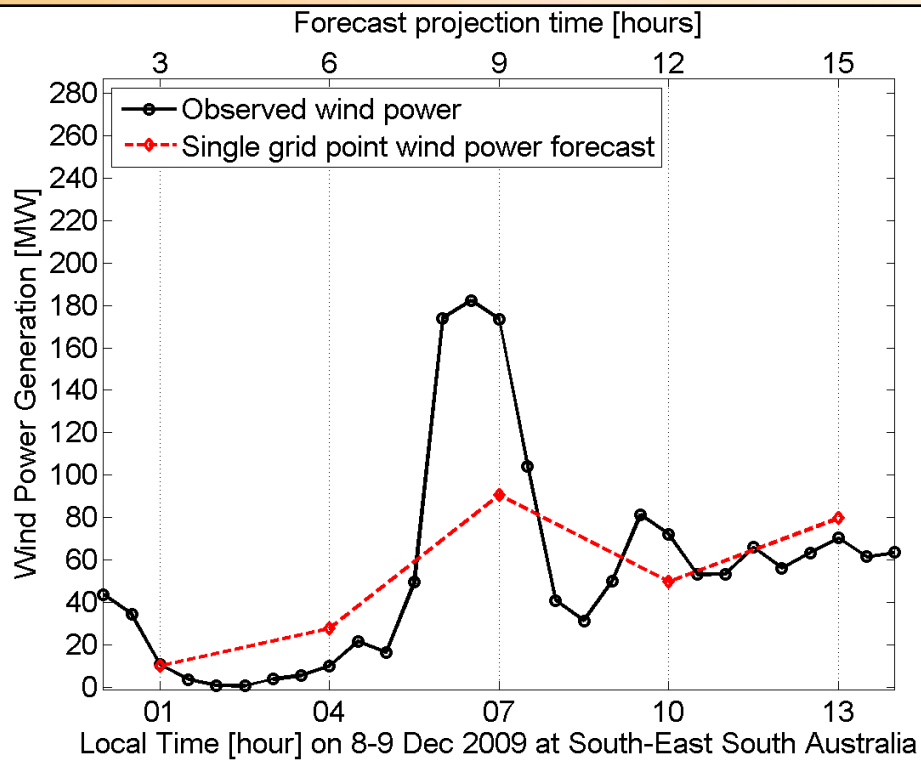
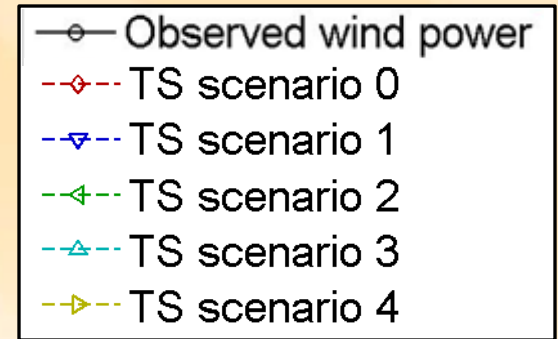
Interpreting wind power forecast fields

- Observations up to 8:30



Interpreting wind power forecast fields

- All observations



Conclusion and discussion

- We have developed a prototype tool to forecast large rapid changes in wind power.
- The tool:
 - Provides alerts for when potential large rapid changes might occur
 - Provides visual information from the NWP system to assist with decision-making during alerted periods
- Discussion:
 - Could a similar approach could be made to forecast large rapid changes in solar energy?
 - How might the problem differ for the case of solar?

Thank you & Questions

- Australian Solar Energy Society and AuSES
- AEMO for supporting this project



- UNSW colleagues: Iain MacGill and Hugh Outhred
- Collaboration with Jeff Kepert
(Australian Bureau of Meteorology)



Australian Government
Bureau of Meteorology



Animated wind power field versus NWP ensembles

Animated spatial fields	NWP Ensemble
Scenarios based on displacement errors from one plausible evolution of the atmosphere	Could characterise different evolutions of the atmosphere
Highlights behaviour relating to timing, rapidity and size of large rapid changes	If used for single grid point scenarios, they are subject to sampling error
Data currently exists in AWEFS	More expensive to purchase
Single NWP model typically has a higher spatial resolution	Typically has lower spatial resolution
Can show very different scenarios within a short forecast horizon, with more sensitivity during the events of interest: large rapid changes	May not provide very different scenarios in the first 24 hours because it can take some time for the ensemble members to differ