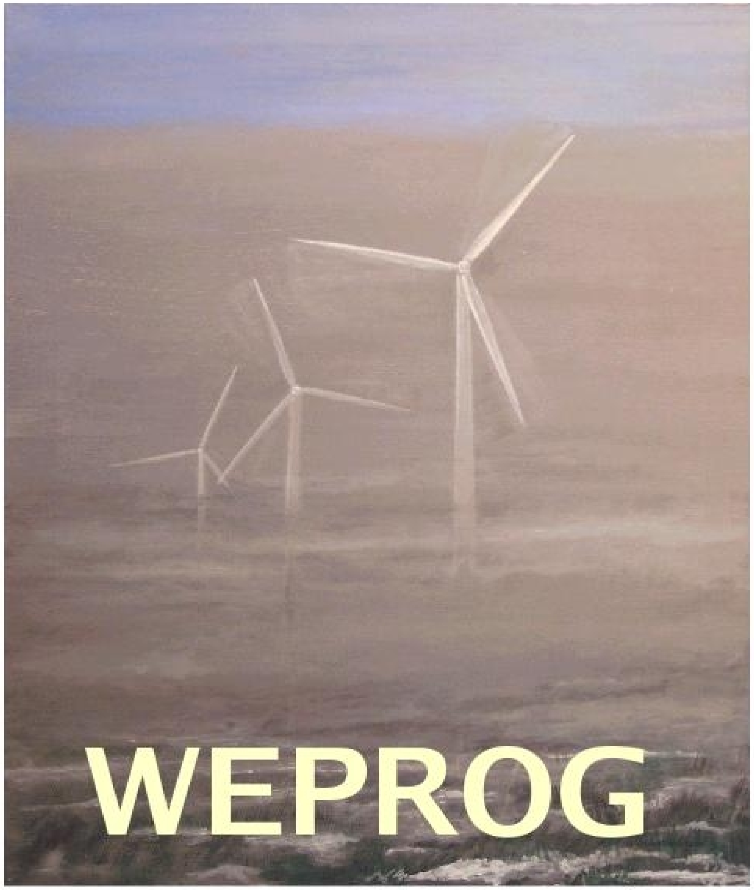
AESO Wind Power Forecasting Pilot Project Industry Workshop

Calgary, 11th/12th June 2008



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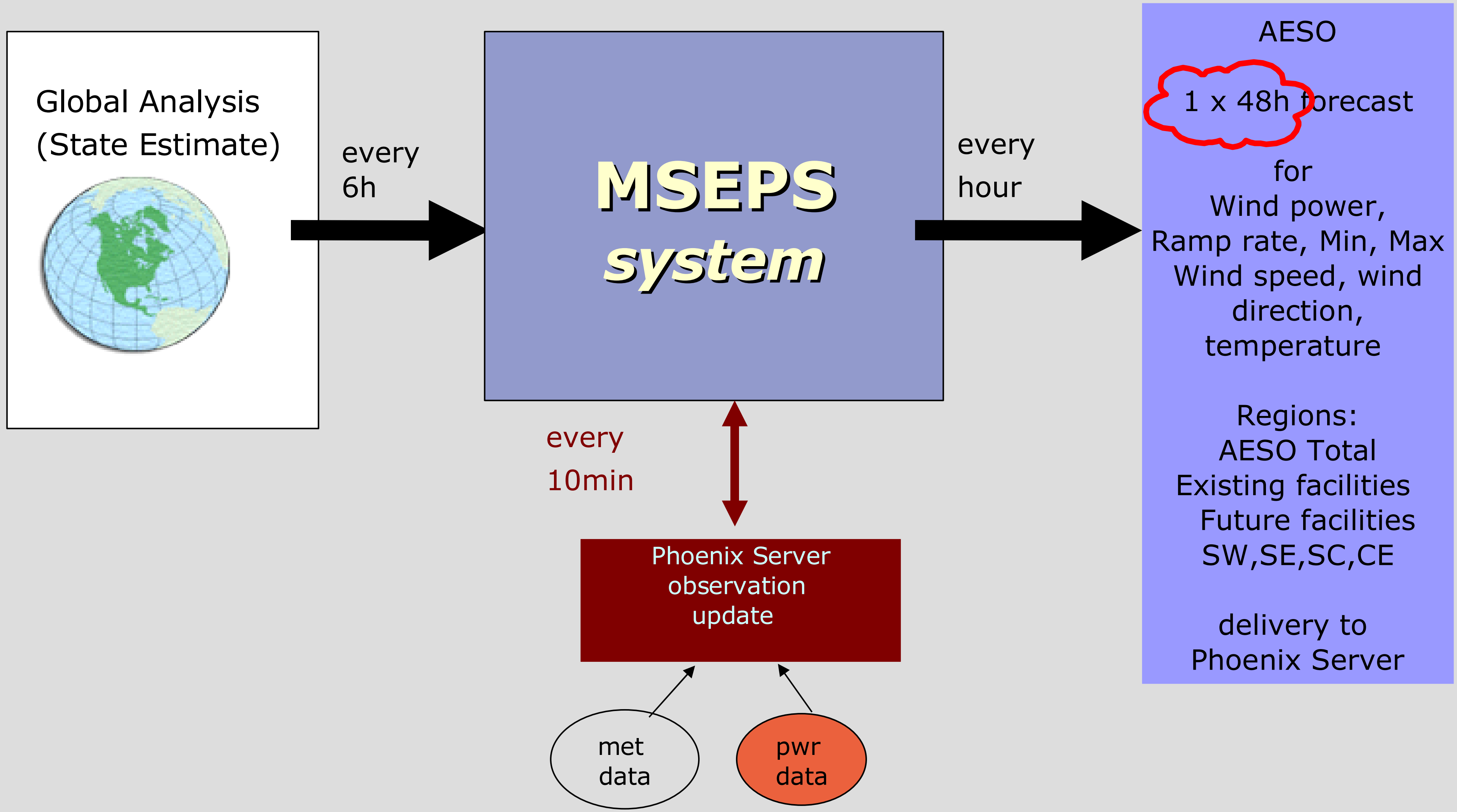
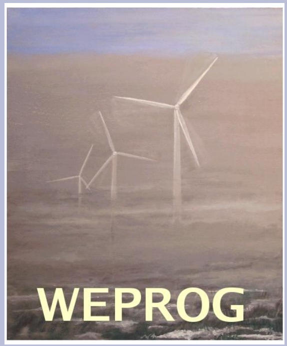
Brief Project Overview

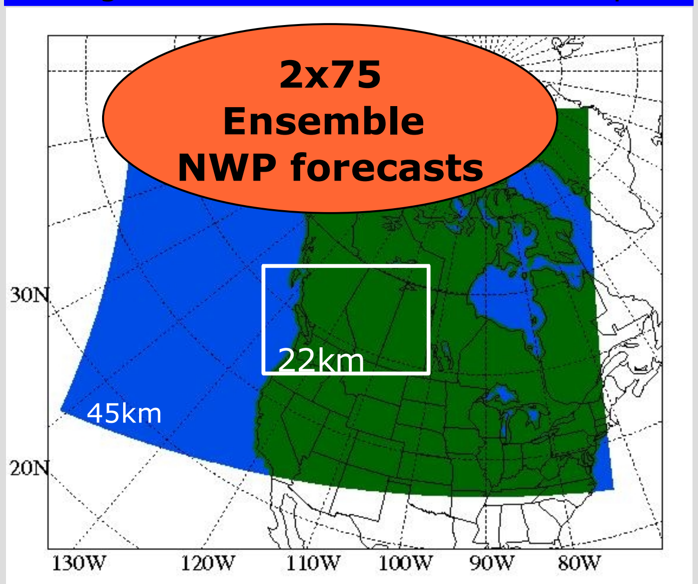
Setup of WEPROG's Multi-Scheme Ensemble Prediction System





What was in the MSEPS system box

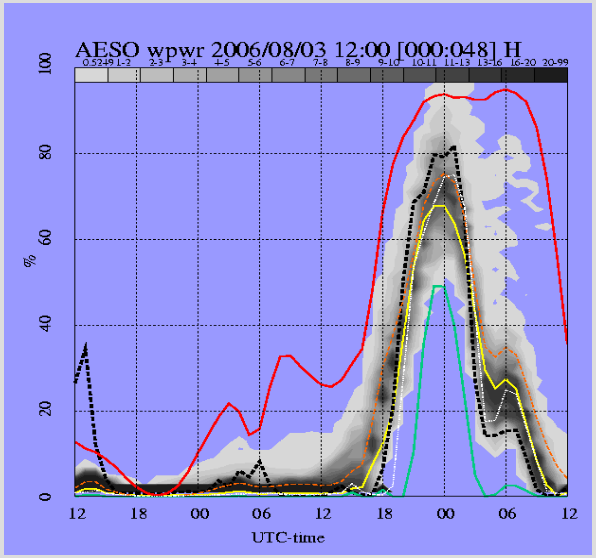
Large-scale and nested MSEPS setup

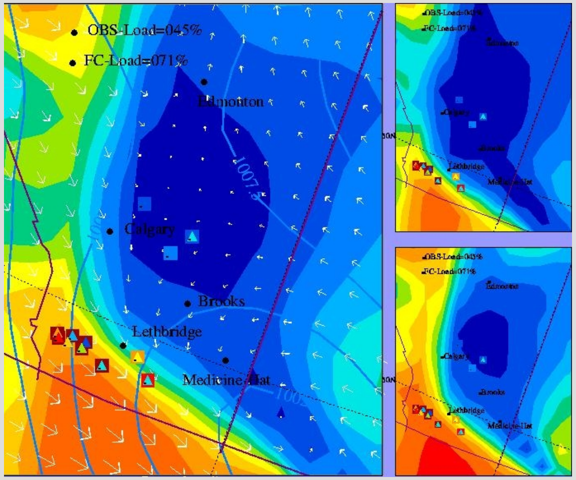


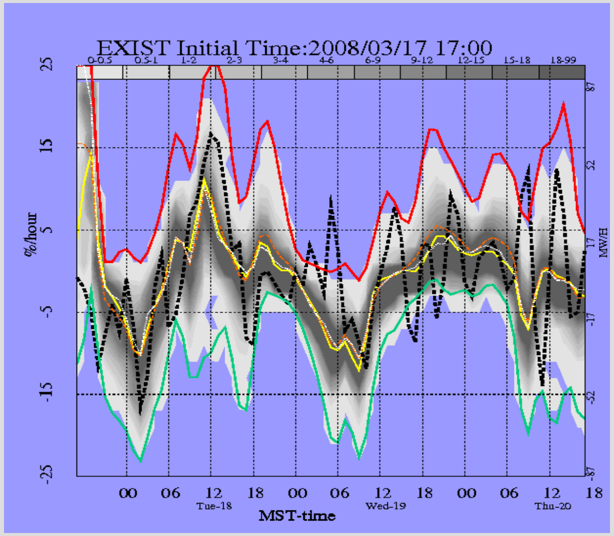
MSEPS 45km		MSEPS 22km		
1	-->	1		
2	-->	2		
3	-->	3		
4	-->	4		
5	-->	5		Min
.	-->	.	<-->	Max
.	-->	.		Optimal
.	-->	.		Mean
.	-->	.		
73	-->	73		
74	-->	74		
75	-->	75		

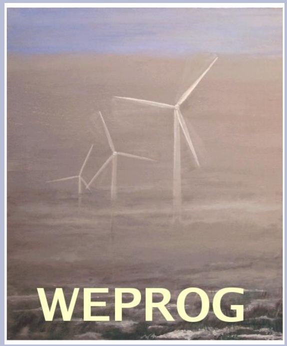
graphics production

- Probability wind power
- Probability ramp rate
- Min/Max/Mean horizontal maps + observations for wind power and met variables









Project Strategy

- **The scope was to test a defined methodology, thus maintain the setup and change only unintended bugs**

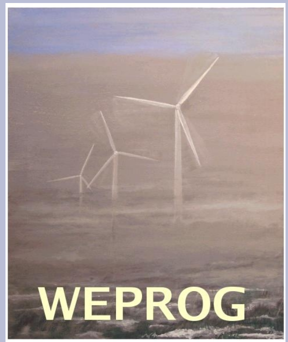
- **Study events**

- **Perform sensitivity tests for selected period**

- **Write a final report**

This was the optimistic plan, but the project went somewhat different ...

We misjudged the problem, because the training year (2006) was much easier to predict than 2007-2008 and the training error much lower. We thought we were on track and this project would be a walk over....



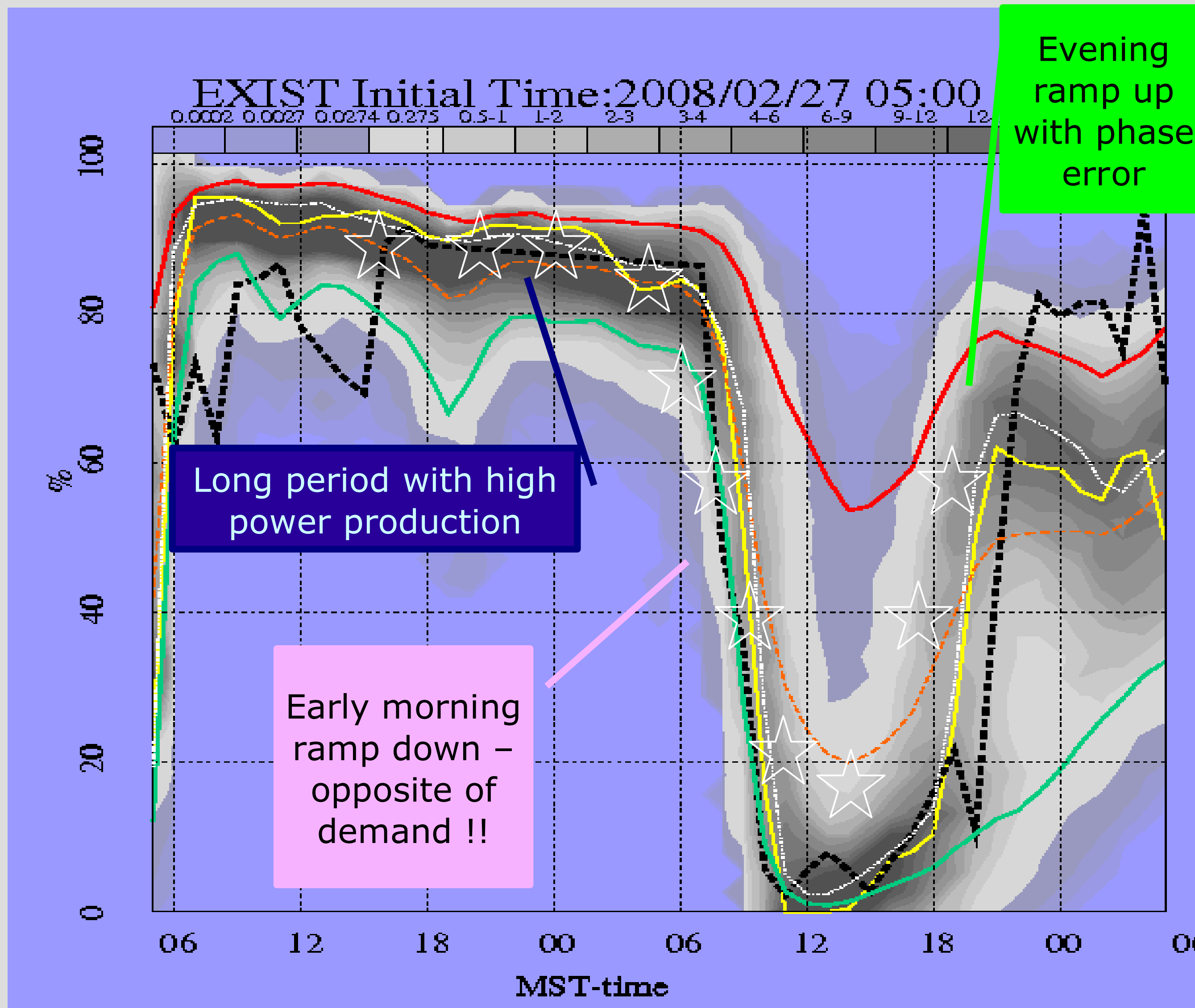
Why is forecasting in Alberta so difficult ?

The challenge of wind power forecasting in Alberta

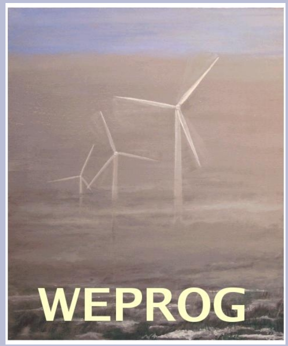
Example Forecast from the “Super-EPS” with 675 weather forecasts and 2625 power forecasts

A <u>critical</u> day in a <u>typical</u> situation:

“strong westerly flow followed by a low moving south/eastward” causing very strong down ramp in the hours, where the demand ramps up in the morning and a strong up ramp at the end of the day



☆ The following slides show horiz. plots at times indicated with the stars



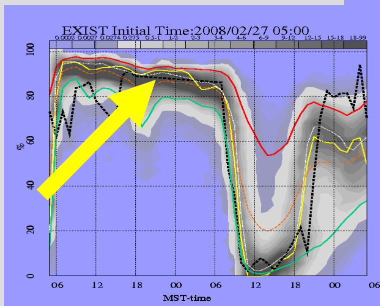
The High Certainty period with 6 sites >= 98.5% of peak

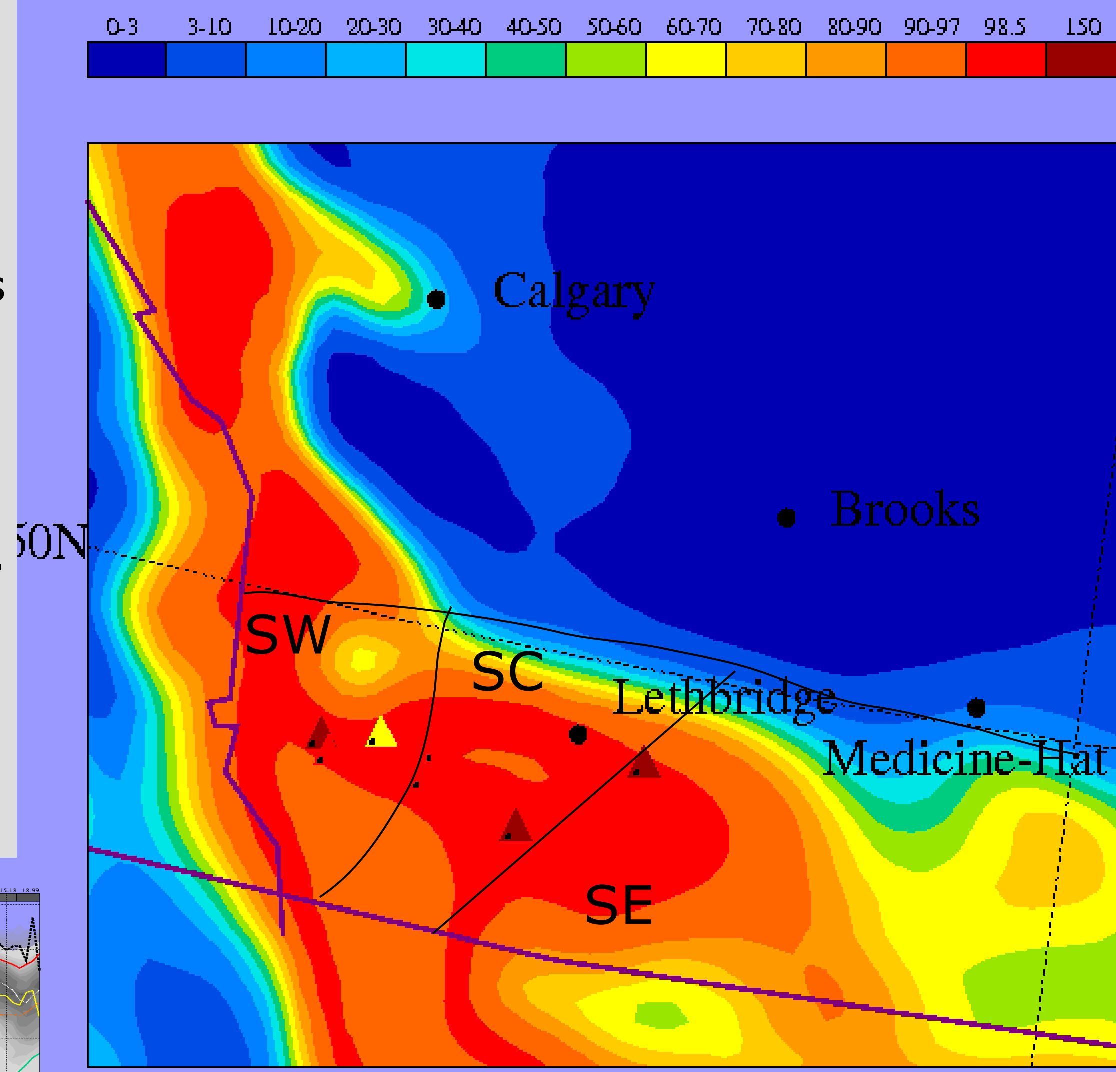
Horizontal map over the wind farm areas with potential wind power as background colour from the high resolution ensemble in 6km.

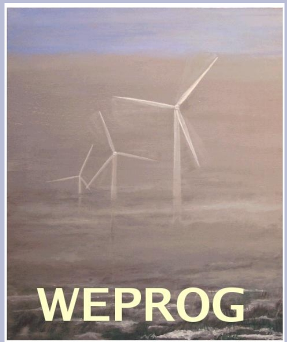
The triangles are the measurements at existing wind farms from AESO's web page.

The plot shows the high and certain power generation for all wind farms.

The <u>power is computed with a reference power curve in each model grid point</u> (without statistical training), it seems to give a ver reliable estimate and is easy to interpret





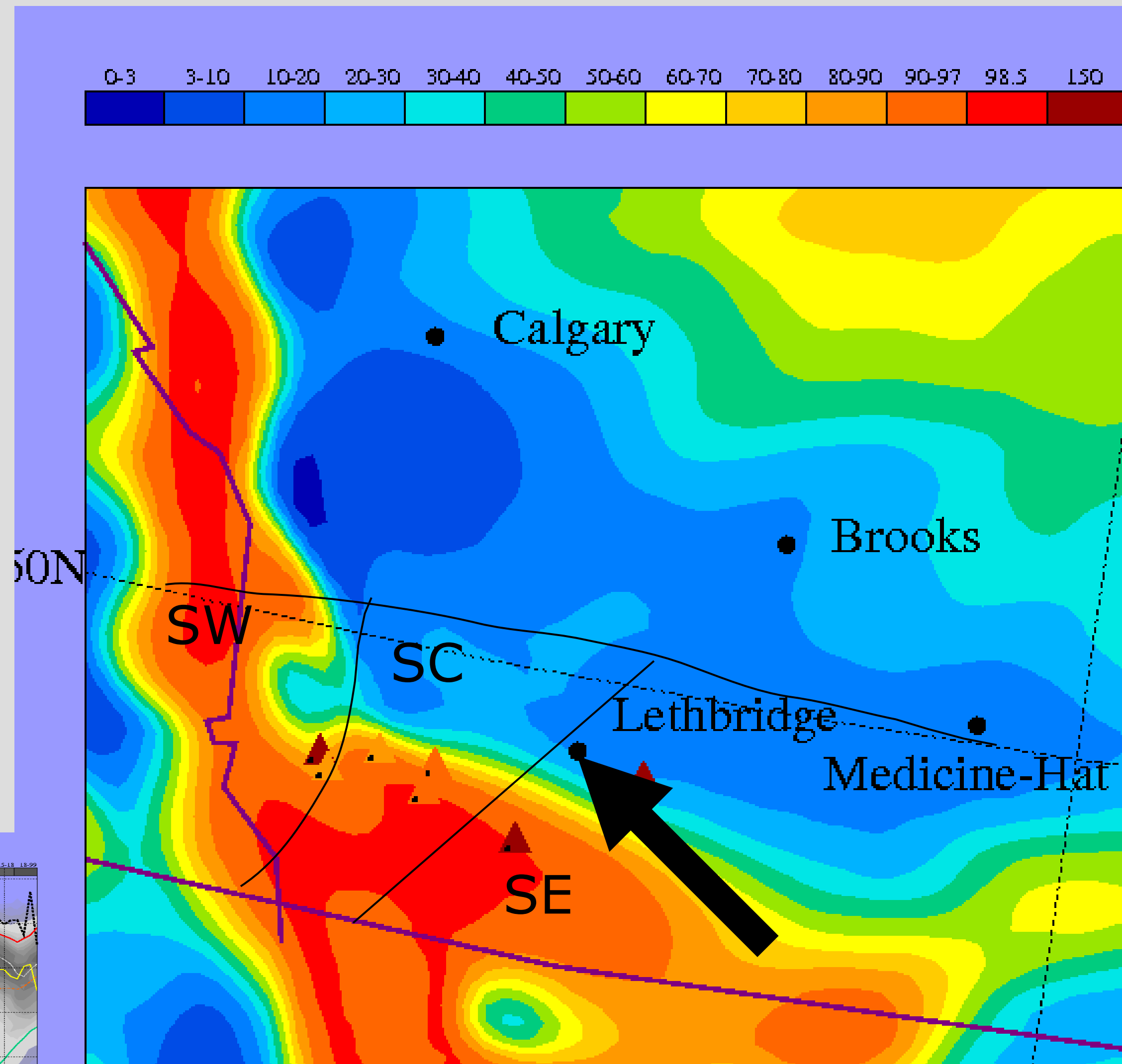


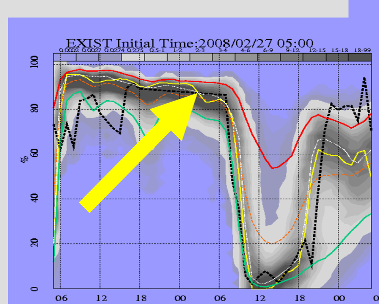
The High Certainty period about to end

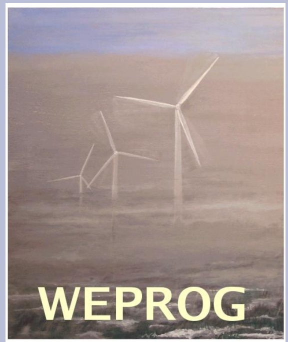
Even the ensemble mean has a very strong gradient in the wind power field in SW and SC perpendicular to the wind.

=>The uncertainty in SE is higher because the gradient is weaker

=> <u>the downdraft is too far south in the SE region –</u> <u>*the model wind is too strong and the Coriolis Force drives the downdraft southward*</u>





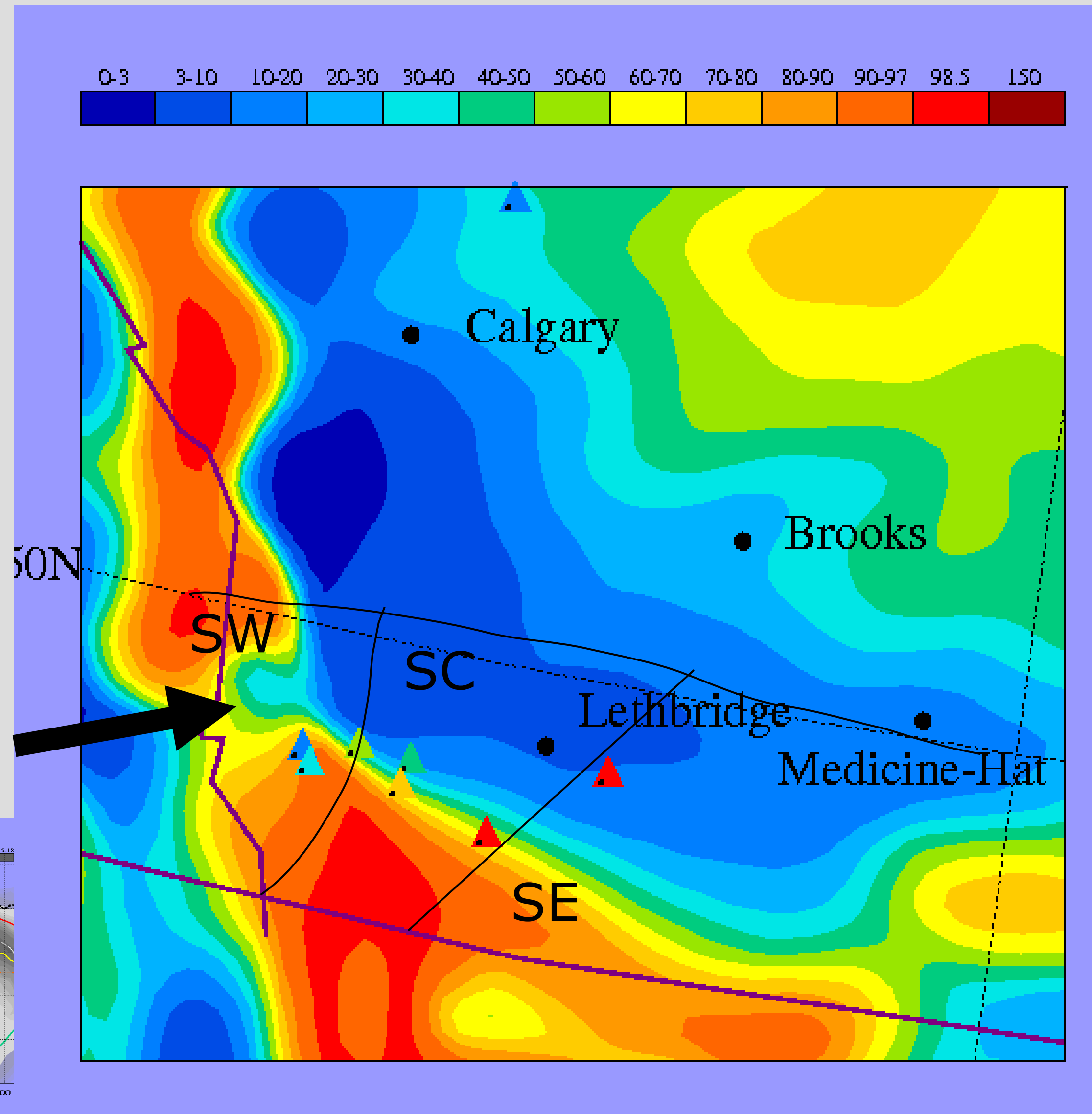


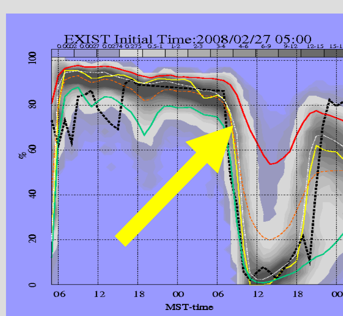
The Ramp Down

The downdraft region should move southwards in the SW region, but moves instead too fast southwards in the SE region.
The North-South gradient is still extremely sharp

The SW area have gone down in production to ~30% while SE is still up at full production

=> <u>the problem in the SW region seems to be related to wrong orography. The minimum is there but located wrong</u>

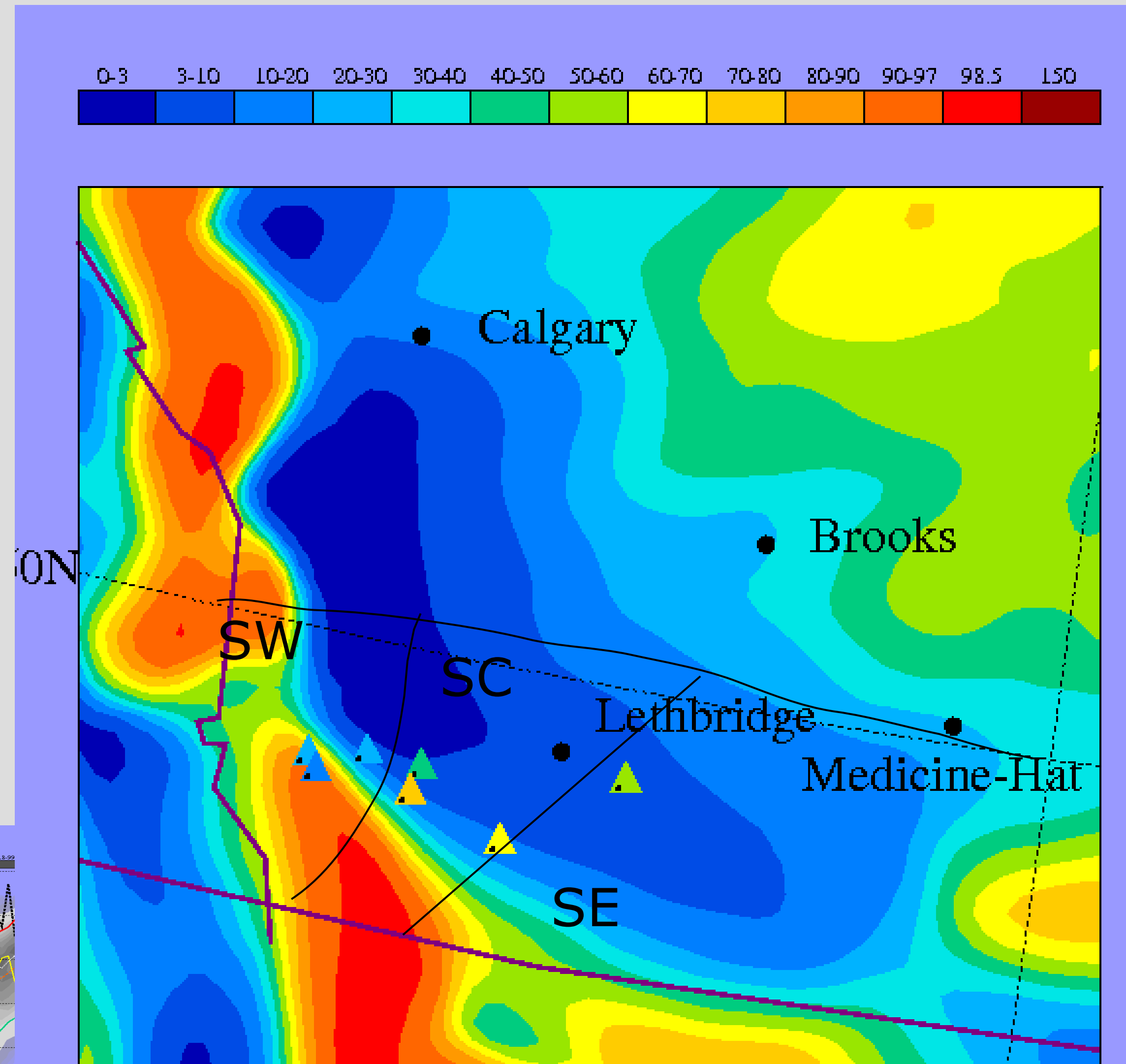


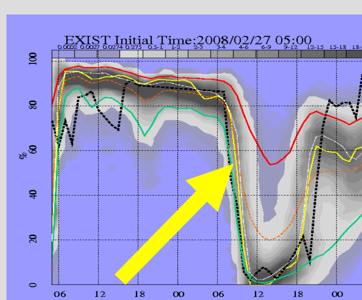


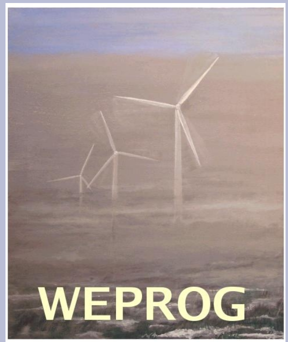
The Ramp Down

The model wind has dropped off in SC and SE too early and does no longer produce more than 10-20% of power.

The model still over-predicts the SW region.



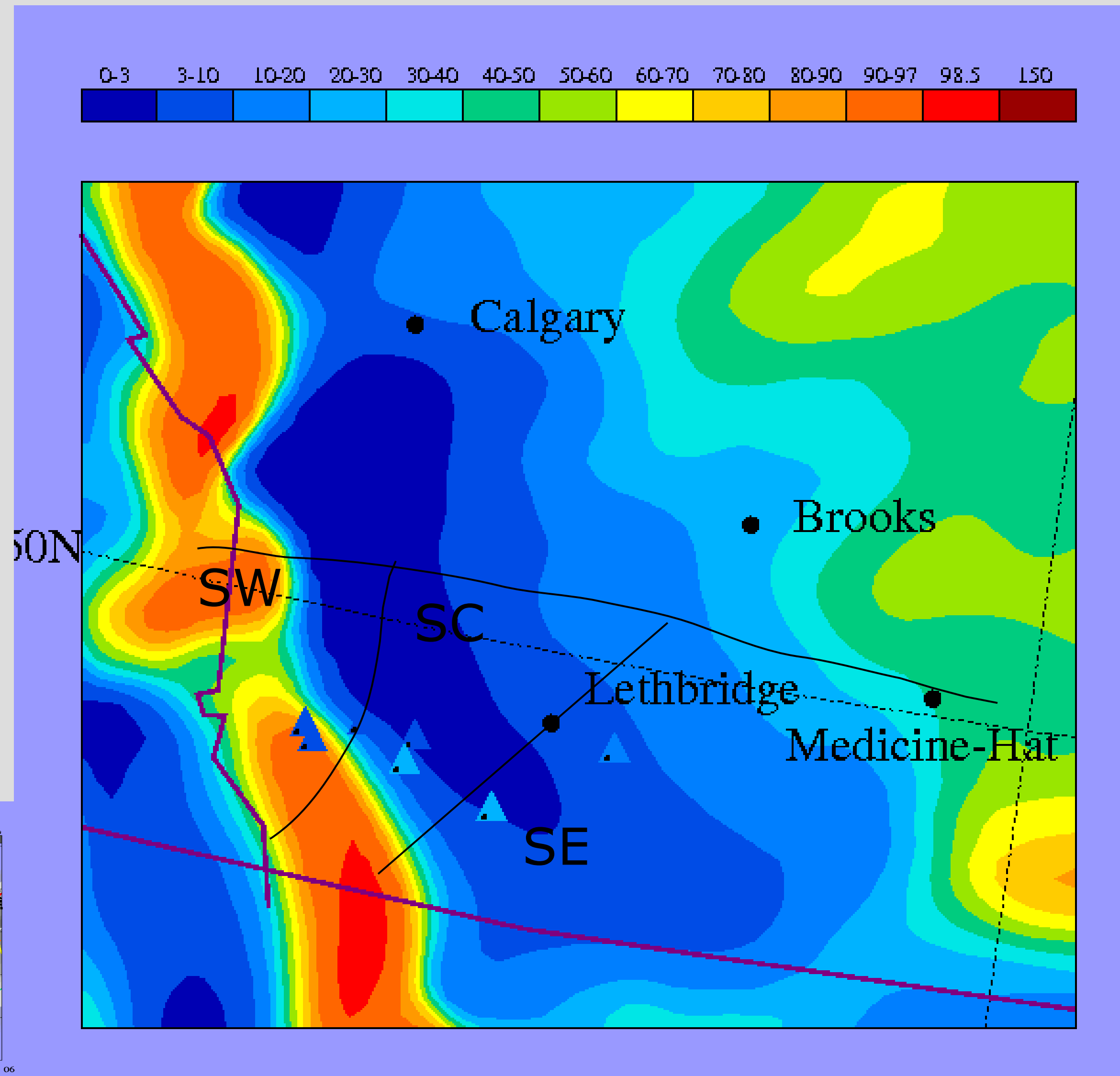


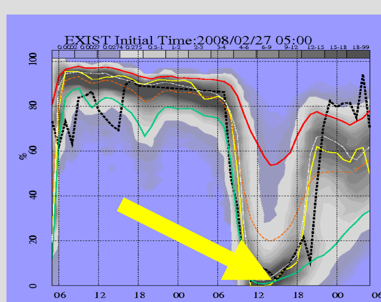


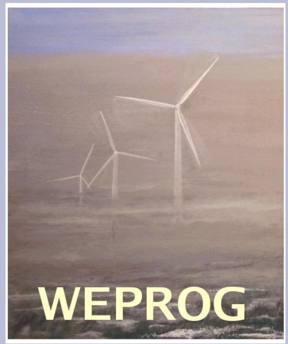
No Generation while the demand is Highest

The “real” wind has now also dropped off in SE and SC and the model's production is correct again.

However, the model still over-predicts the SW region because of the incorrect orography





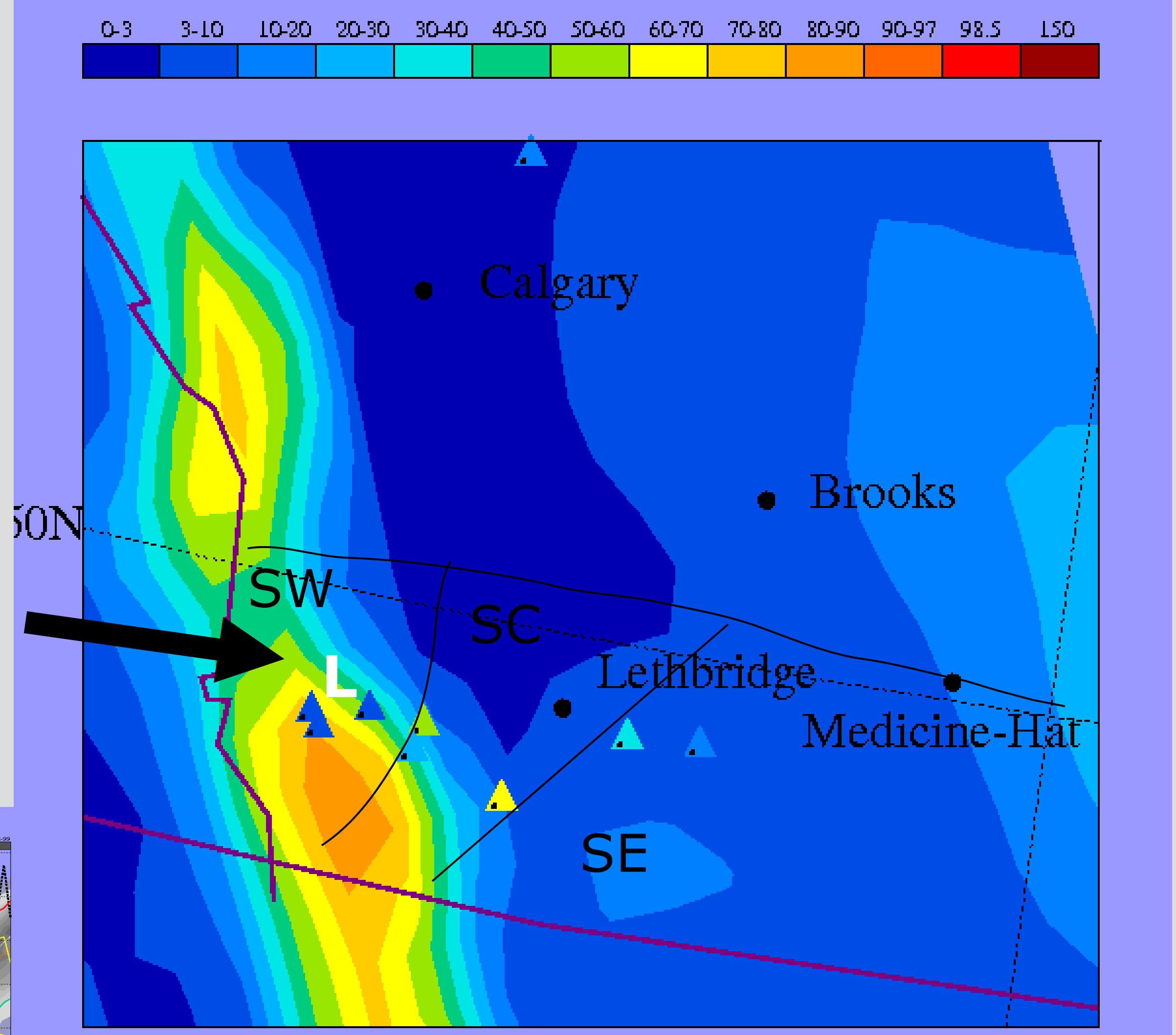


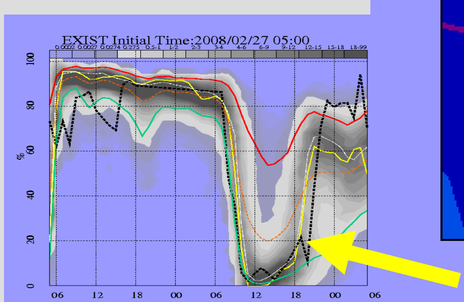
The Challenge of wind power forecasting in Alberta

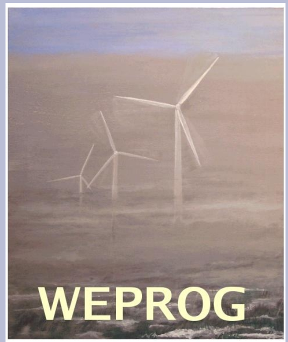
Forecast from the 22.5km model 4 hours later:

The wind power field is less sharp and fully off track. What is ongoing is a birth of a low pressure system in SW.

The model produces almost correct power, but for the wrong reason!!!
Can an operator trust this ?



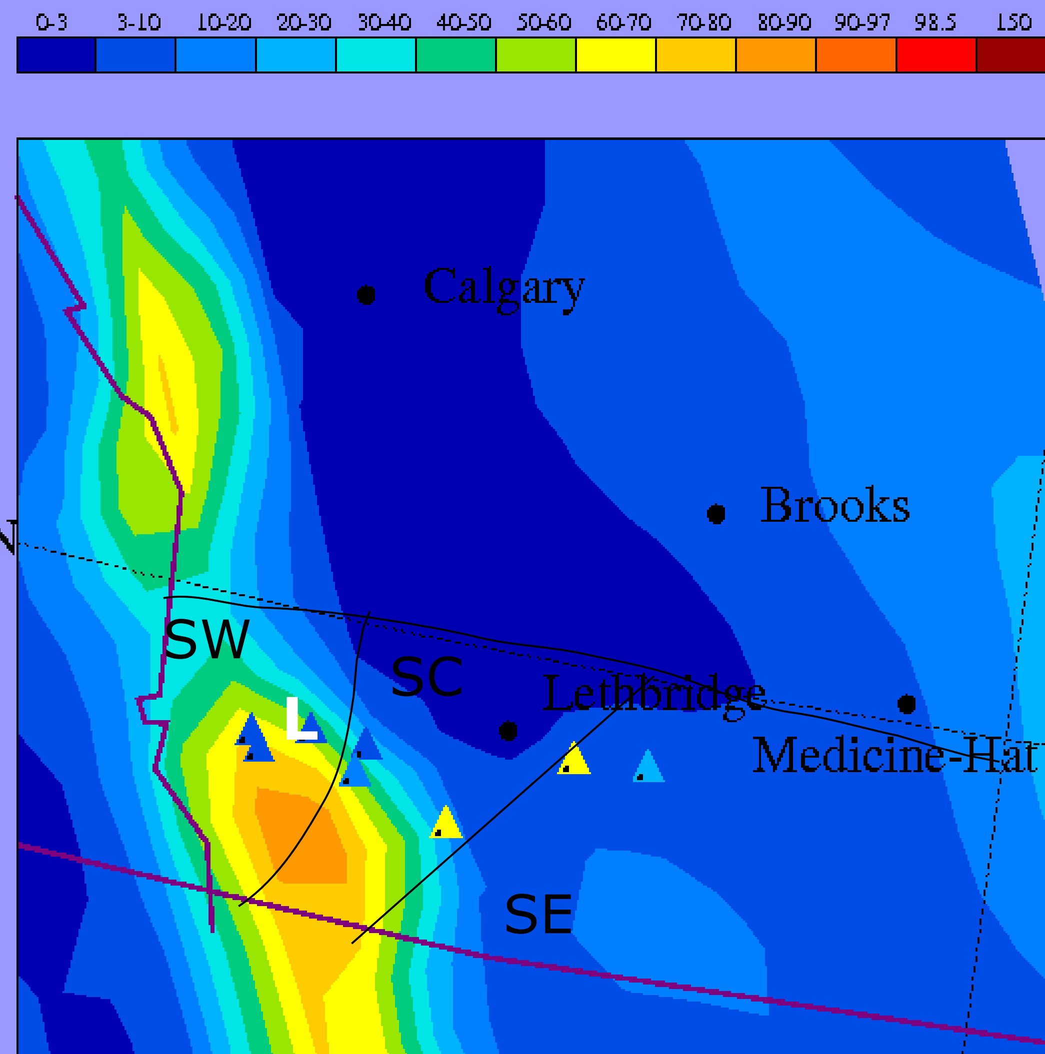


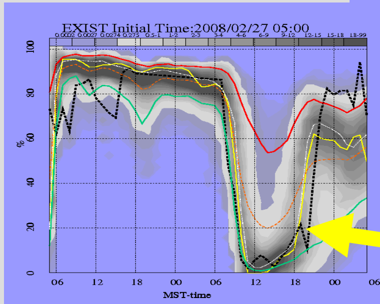


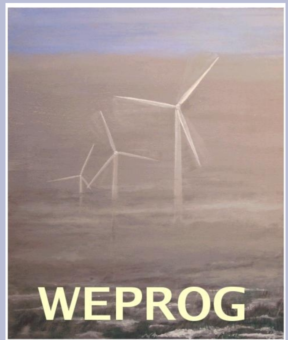
The Low moves Eastward

The model is still off track.

The problem is that it can not develop motion on that scale. It has the low too far north, too strong wind on the backside from Northwest and too weak wind in the warm sector.



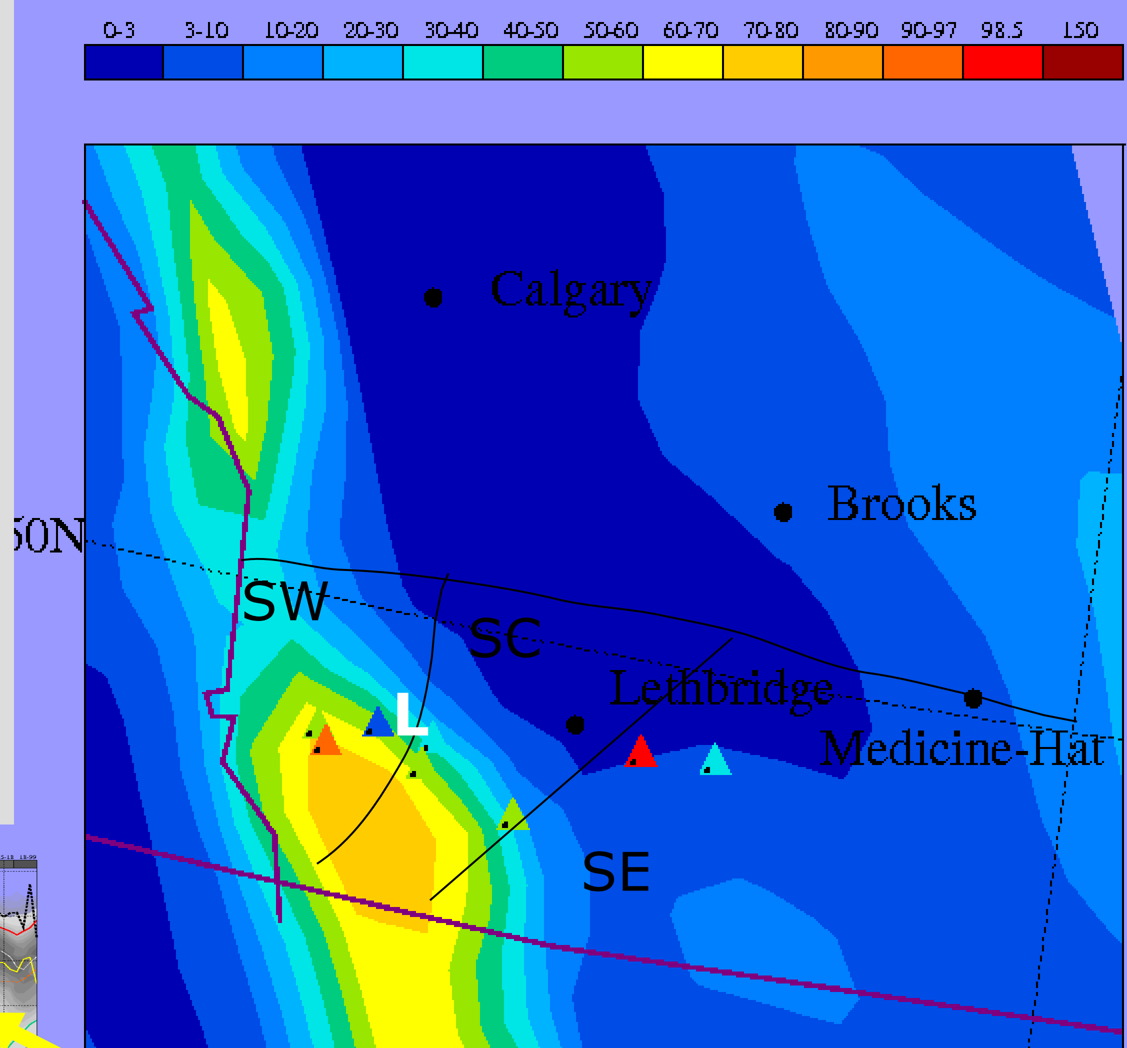


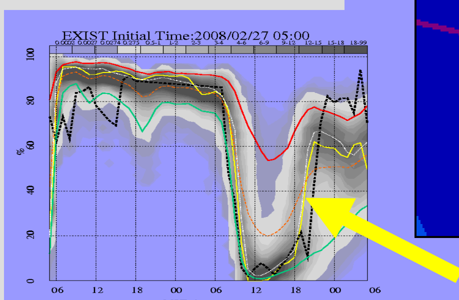


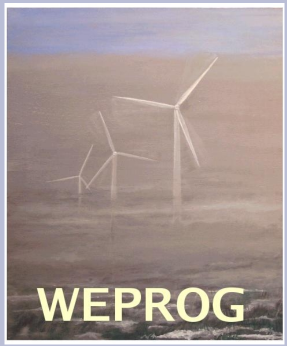
The Challenge of wind power forecasting in Alberta

We can now finally see the cold front in SW (it is not really cold though).
There is a shift in the wind direction, so it takes a while before the last SW triangle changes colour.

The pattern is still the same – almost correct power, but now we can trust that the model is on the way to be ”on track”.

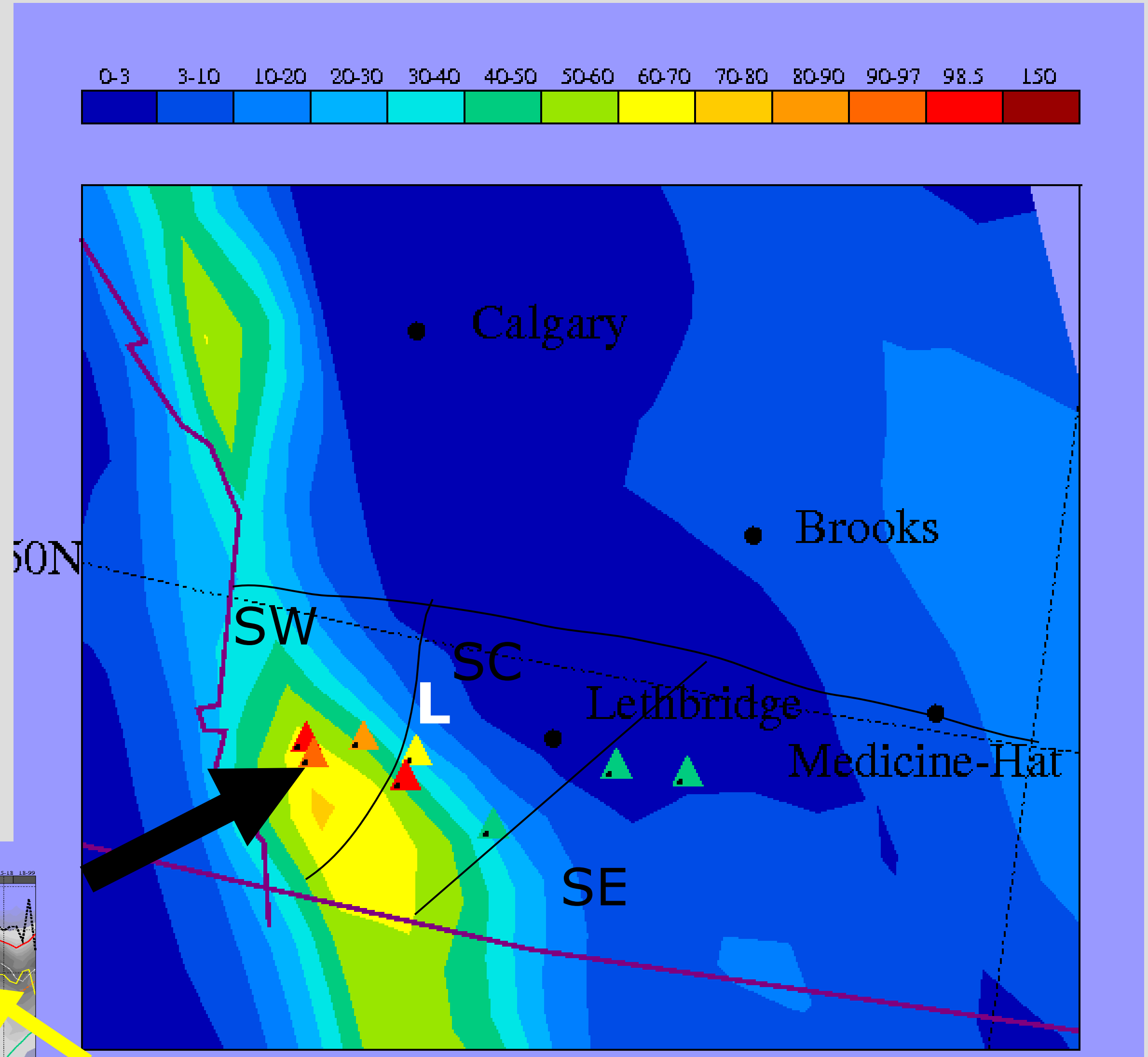


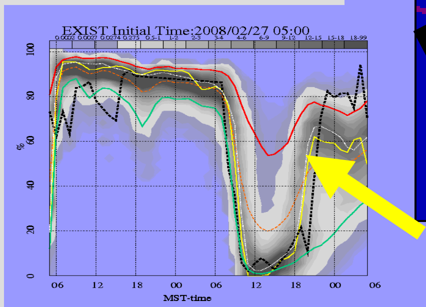


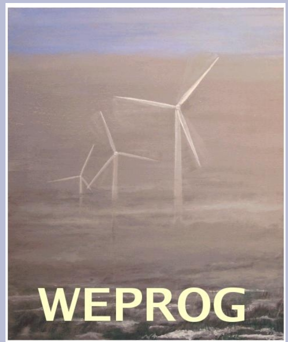


The model result is correct again!

The low is now lying in the northern part of SC and we have again a stable flow, which may still develop further.





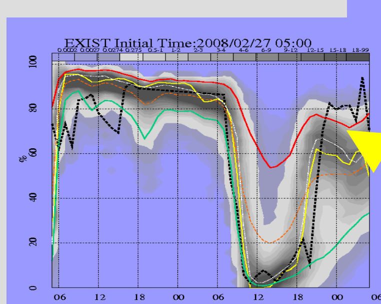


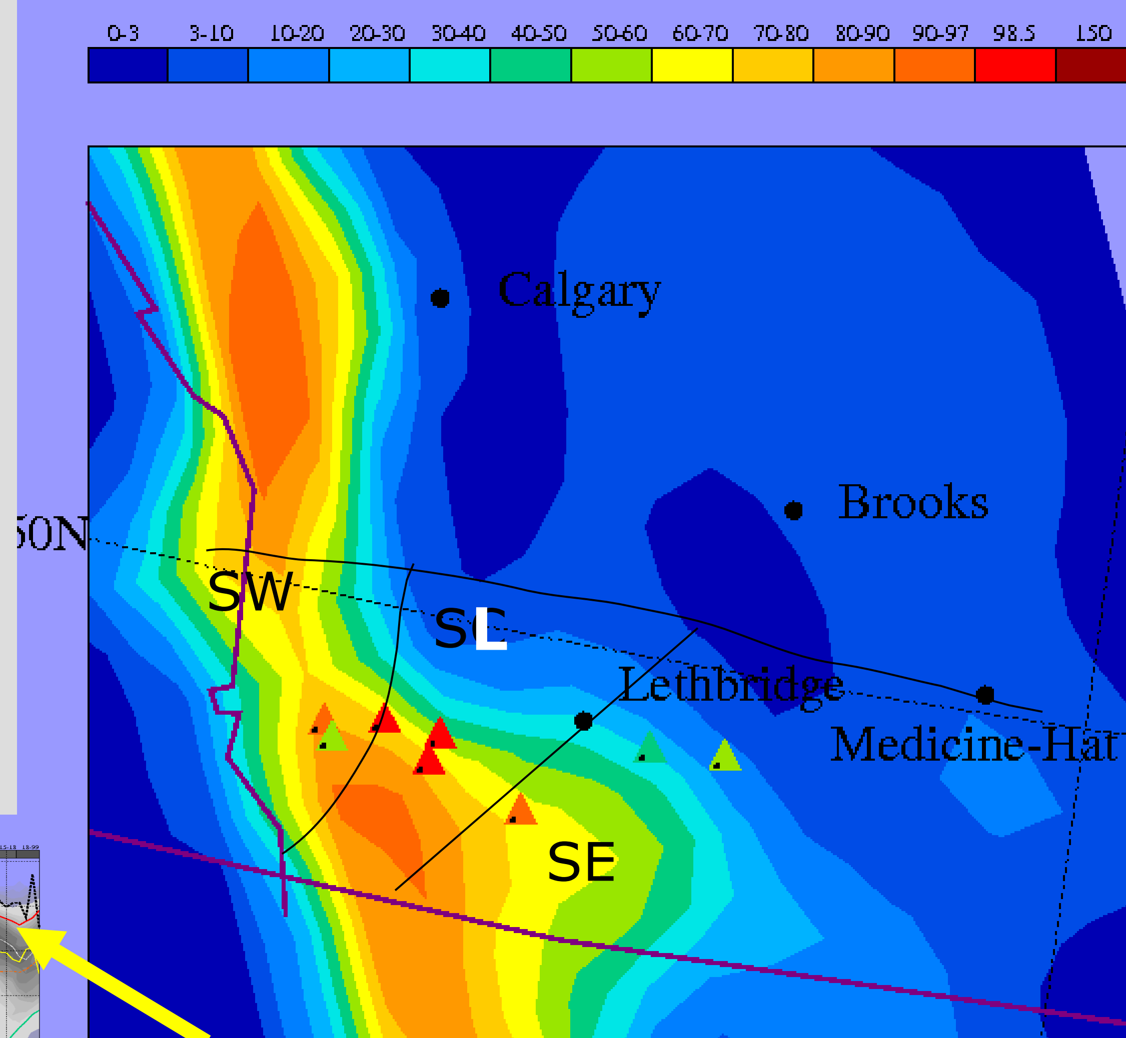
A typical flow

We have now a flow from Northwest and it is essentially a regular low pressure system, but the dynamics is not the same as a traditional low. The "cold air" on the backside of the low (cold front) is warm in the local environment, so it may rise again with the cyclonic motion.

It is not possible to simulate this flow in 20km resolution. If a model gives reasonable scores then the reason may be wrong. One can see that although our forecast were ok (probability power plot), due to the dispersion of wind farms.

But, there were phases where the model is really off track.





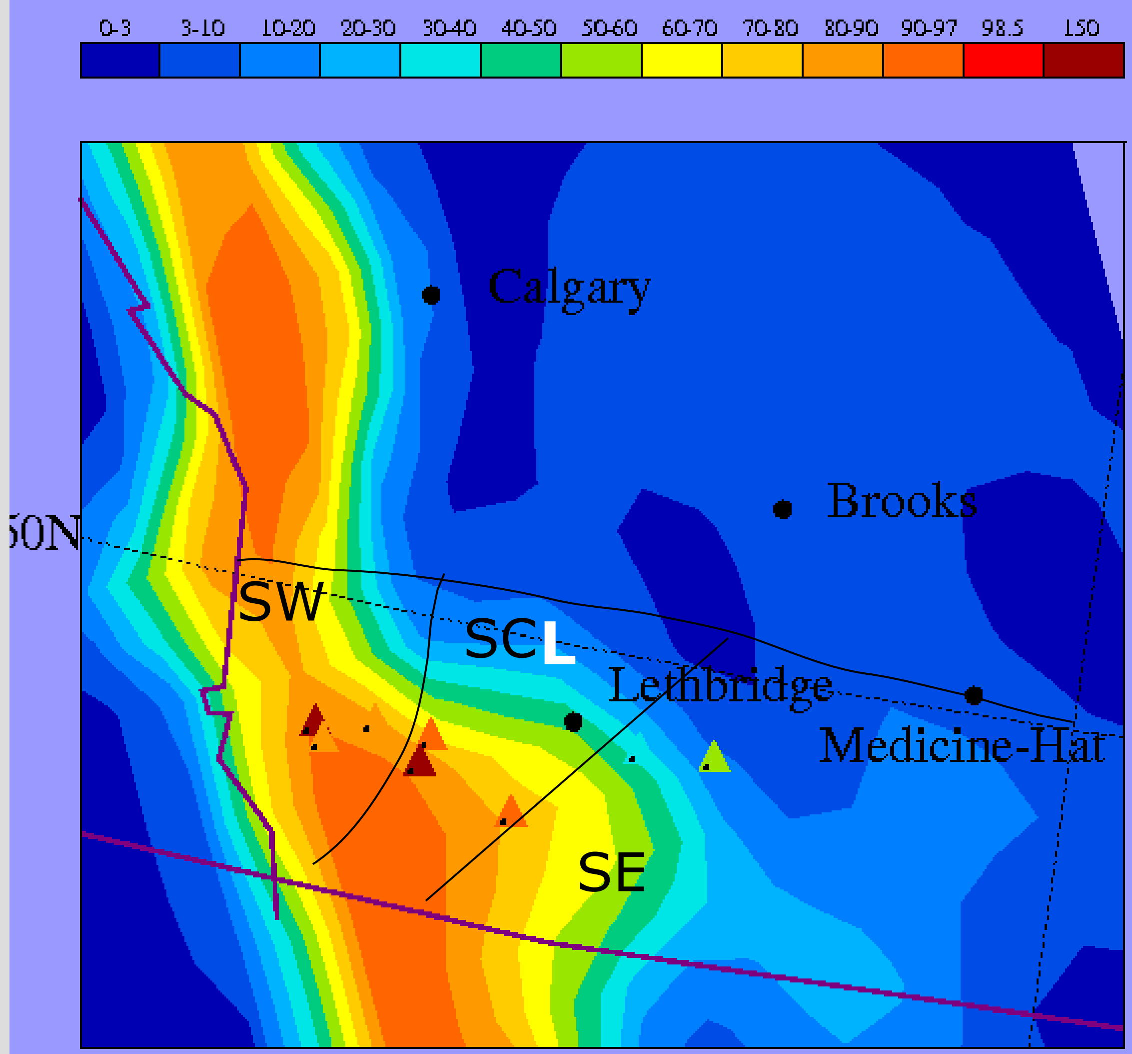
WEPROG

Why do the Forecasts Fail ?

The accuracy of the orography and the roughness is not suffient

Only very high resolution NWP models can resolve the flow correct

Phase errors are predominant, because the inherent uncertainty in the initial conditions is equivalent to the time scale of one ramp

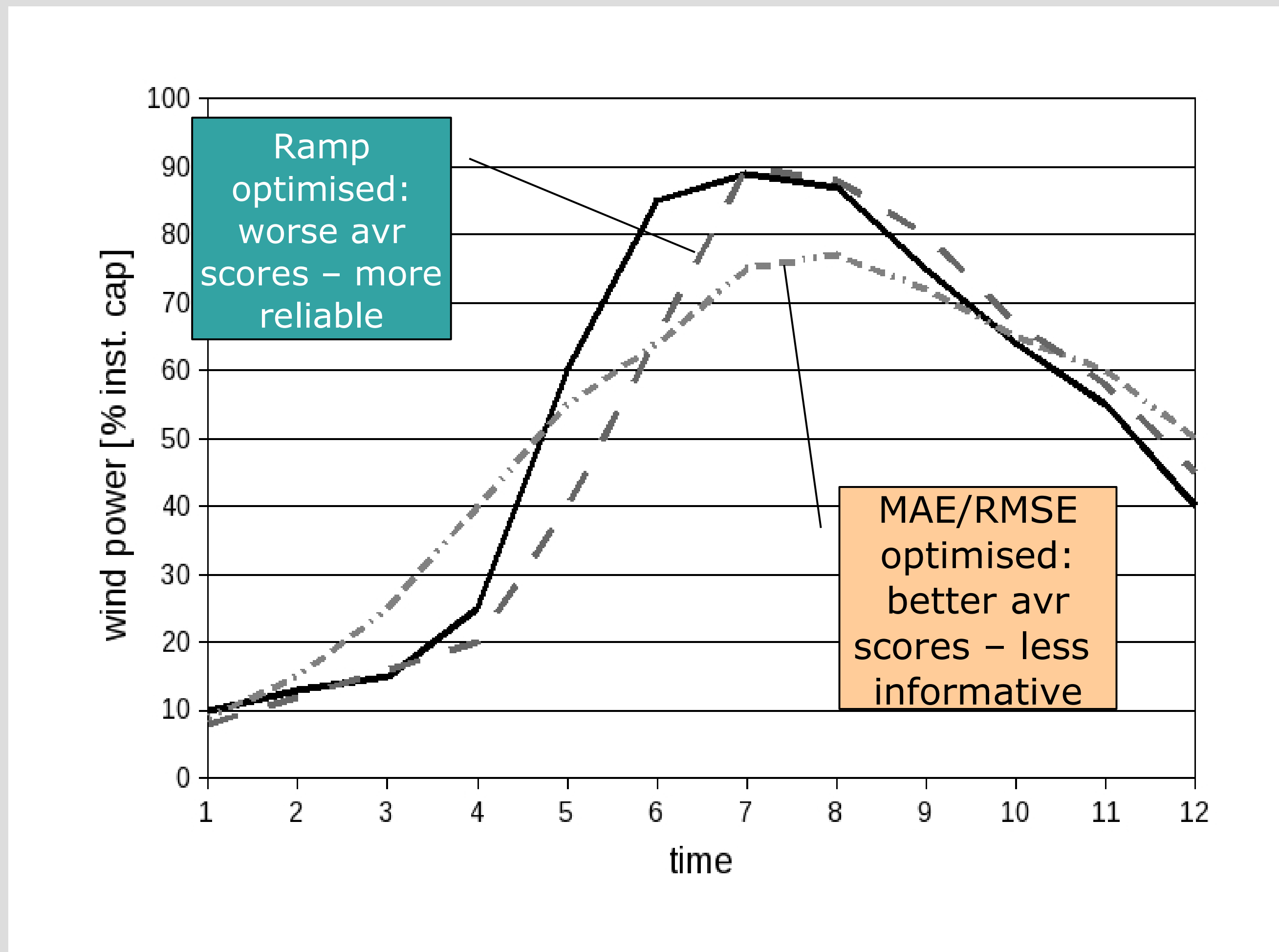


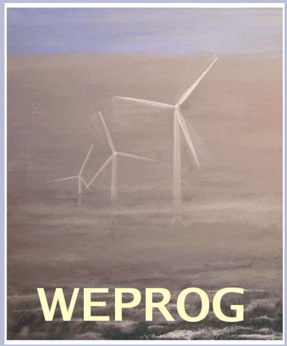
Lessons Learned in the Pilot Project
– example of 2 different optimising approaches -

"Ramp optimised" versus least square "MAE/RMSE optimised" tuning of the wind power forecasts:

-tuning on the frequency distribution of the forecasted power generation.

- the forecast should produce the correct amount of hours with no generation and full generation.



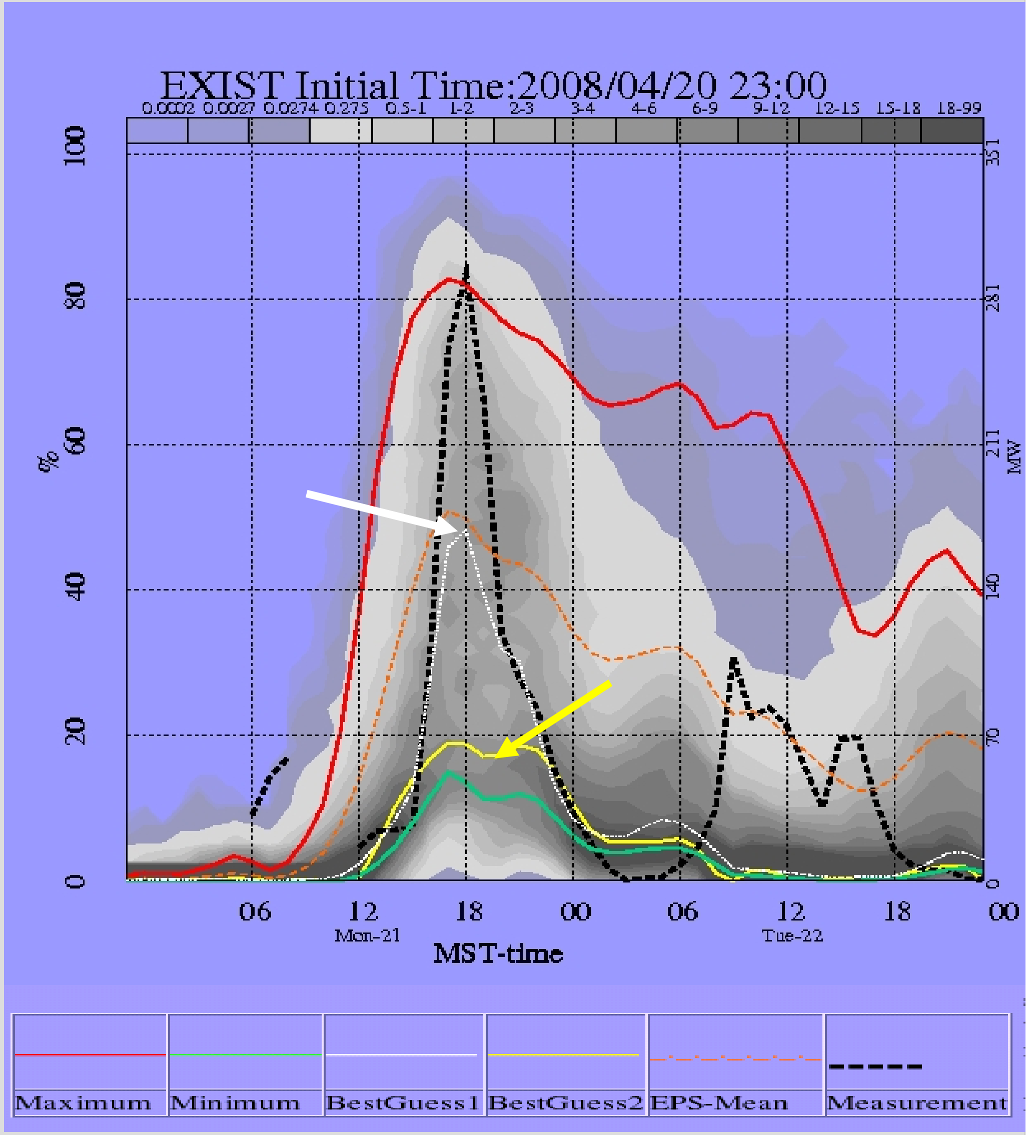


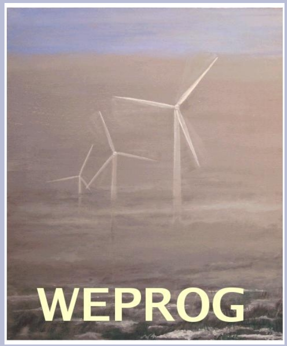
Lessons learned
- key findings on "best" forecast -

The **ensemble spread** is an important measure for the **uncertainty of amplitude and phase** of **steep ramps**.

Statistical processing suppresses the model signal in extreme events.

The effect is strong in Alberta, because there are considerable phase errors in the training. These ***phase errors cause the statistical corrections to dampen the forecast signal*** and most important ramps (see white/yellow arrow)





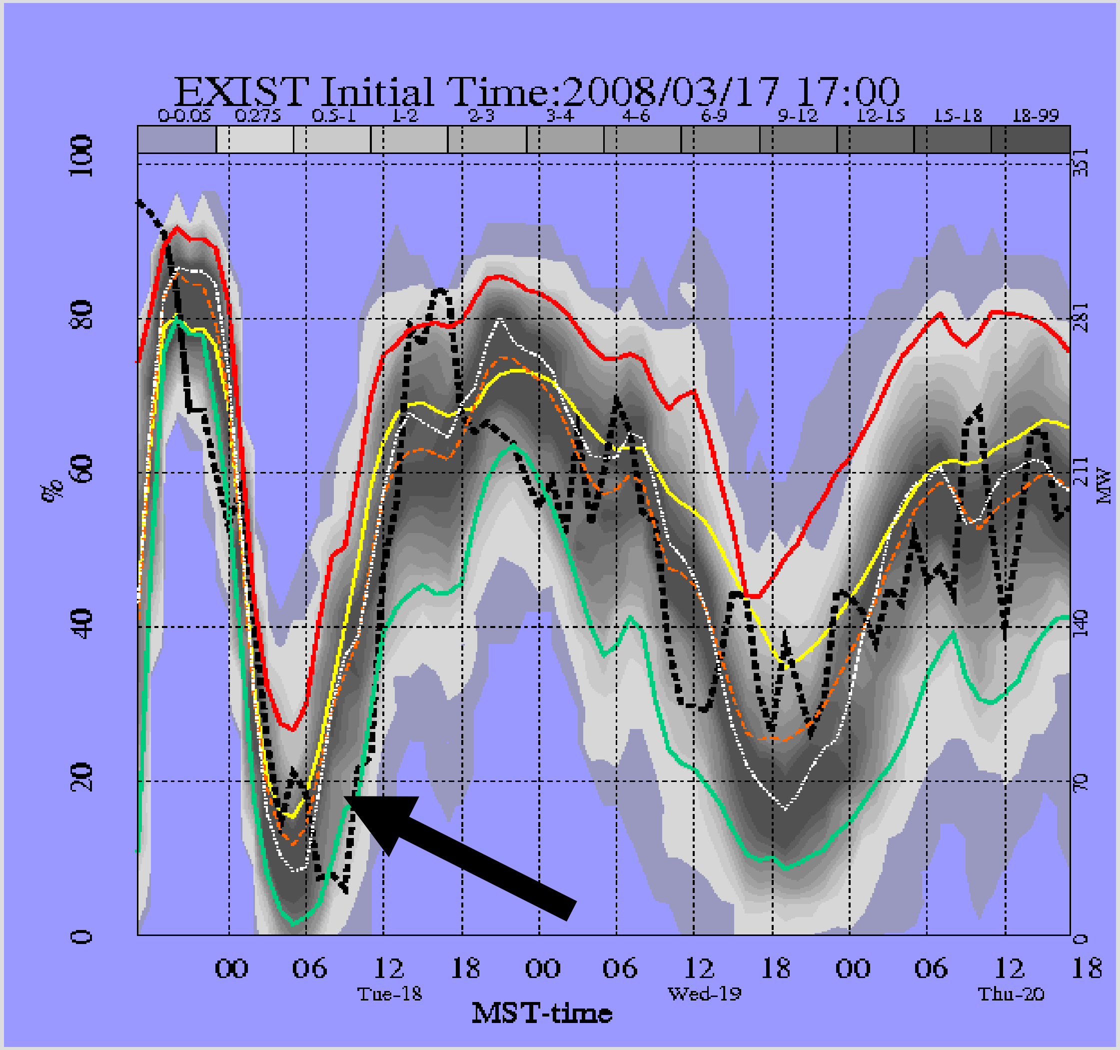
Lessons learned
- key findings on phase errors -

Minimisation of phase errors should in theory be possible by giving **weight to** the ensemble **members with the lowest dispersion term**

Alberta Test from 2006-2008 showed:

=> there is ***no systematic pattern*** in which forecasts have a positive or a negative **phase error**.

=> Attempts to subjectively correct for phase errors are therefore rather likely to fail 50%



Probabilistic versus deterministic forecasting

The pilot project has demonstrated that:

- An operator cannot expect sustained high accuracy of one forecast

- A security margin will always have to be added and the cost of these securities are significant

- The ensemble forecast methodology provides more possibilities in the optimisation process, also for extreme ramps

- The ensemble forecast methodology provides more possibilities in risk evaluation

=> there is reason to use an objective quantification of the security requirement

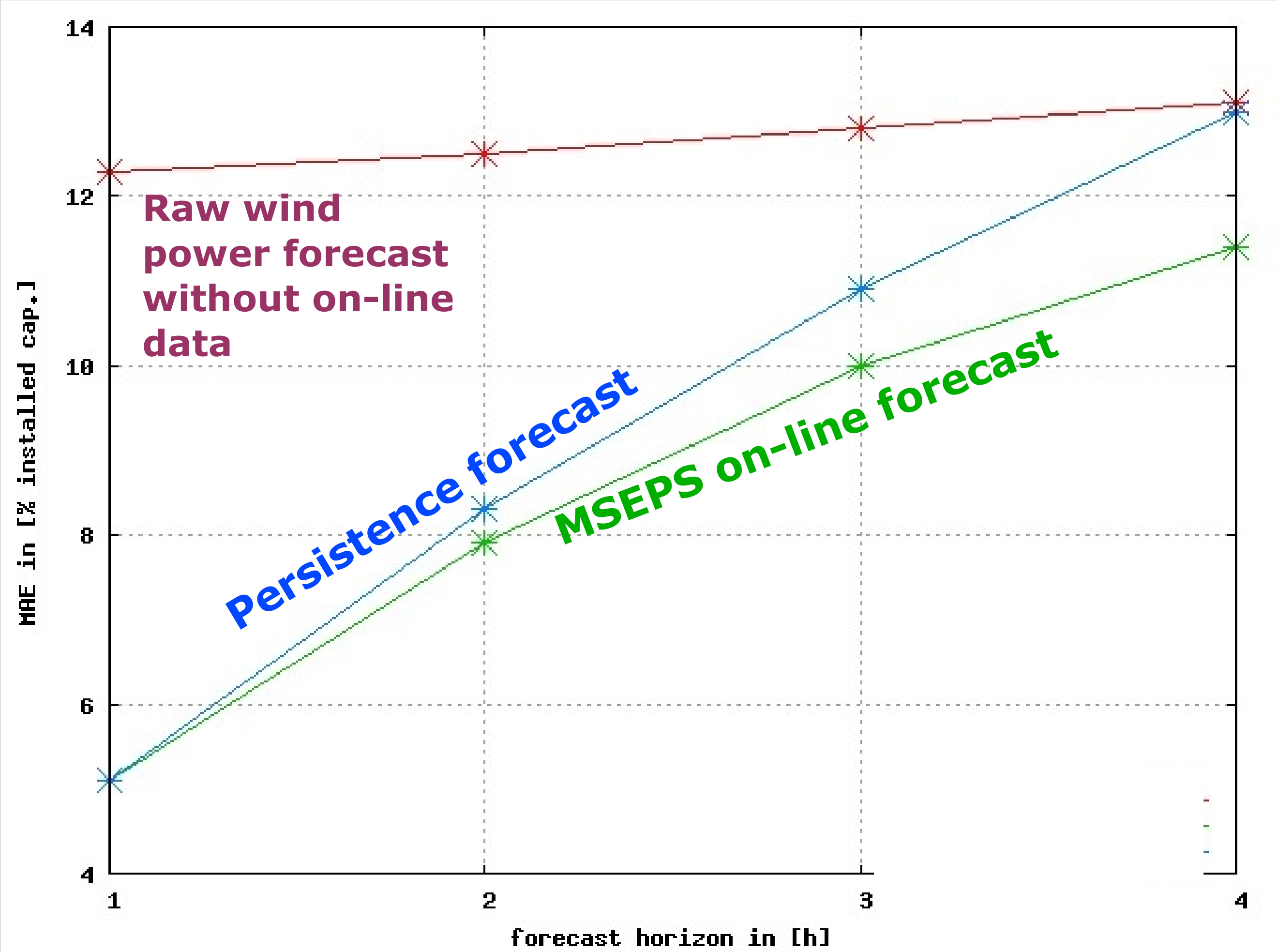
Lessons learned in the Pilot Project

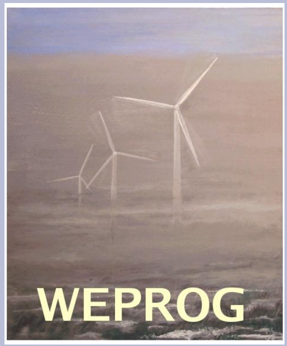
Forecast performance:

the good news: short-term forecasts

Application of the WEPROG MSEPS ensemble algorithm for short-term forecasting using two basic assumptions:

- Quasi linear decay in 5hours of the initial error
- Ensemble spread proportional to the error.





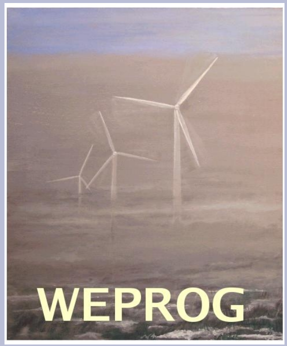
Extreme Ramp Event Analysis

simple fail/success rate statistics of ramps > +/- 80MW/h

Events observed : 69 — Positive : 41 — Negative 28
Avr Ramp: 89MW/h — Max: 154MW/h — Min: -124MW/h

ID	allowed Phase error	% of 80MW/h	Fail rate [#/69]	Fail rate %	Success rate [#/69]	Success rate %
1	+/-0h	95%	25	36%	44	74%
2	+/-1h	95%	13	19%	56	81%
3	+/-2h	95%	9	13%	60	87%
4	+/-3h	95%	7	10%	62	90%
5	+/-4h	95%	7	10%	62	90%

There is a threshold at 3h phase error allowance:
if the forecasts did not capture the event within 3 hours, the event was not predicted as "extreme event" at all



Lessons learned in the Pilot Project

Forecast Performance:

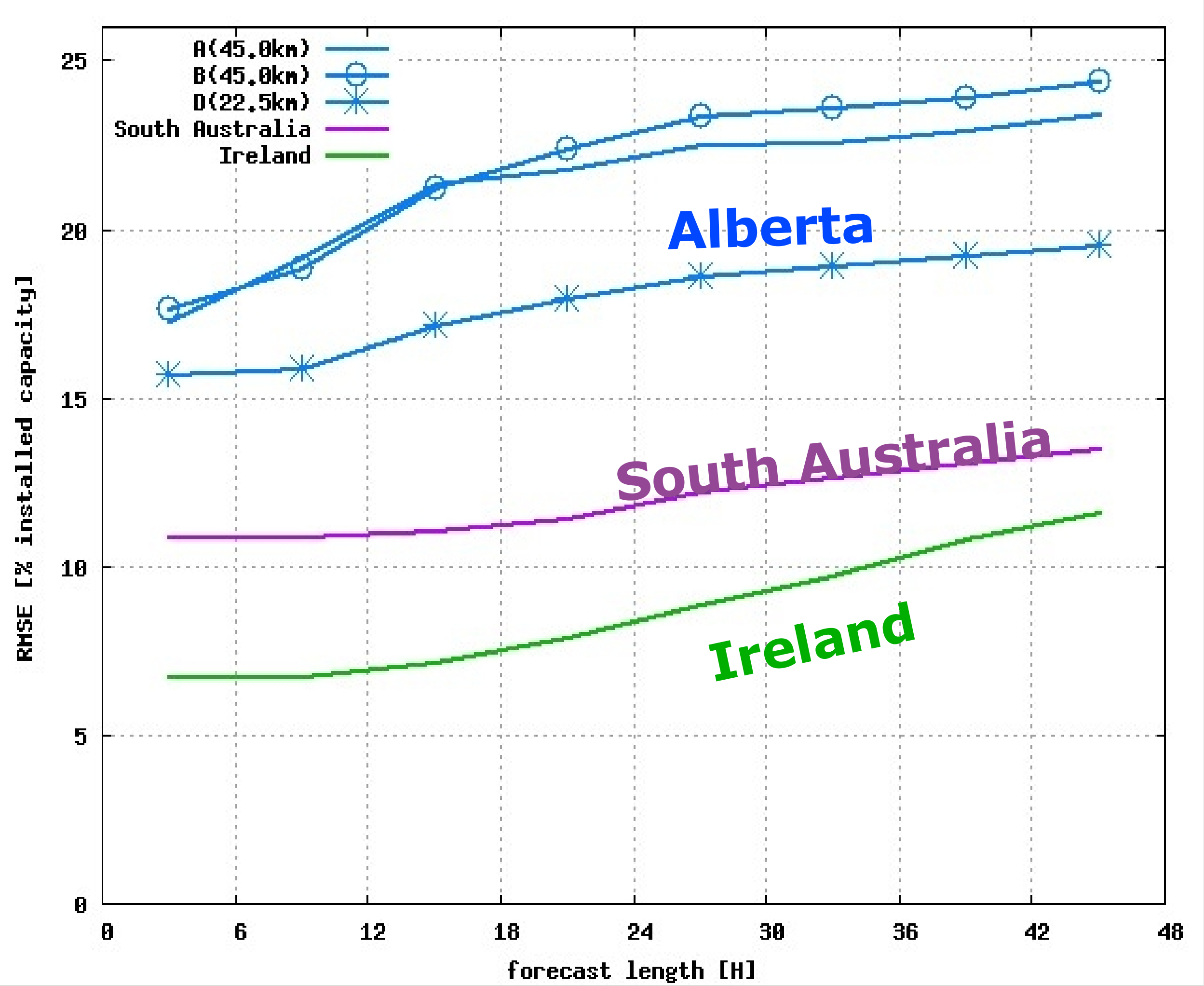
the bad news: day-ahead forecast

The figure shows <u>least square (MAE) optimised power forecasts for 3 areas.</u>

Note, this is not the power forecast delivered to the project, but the wind forecasts with a LS power conversion to ensure consistency of comparison, as we delivered ramp optimised forecasts to the project, which are higher on MAE/RMSE.

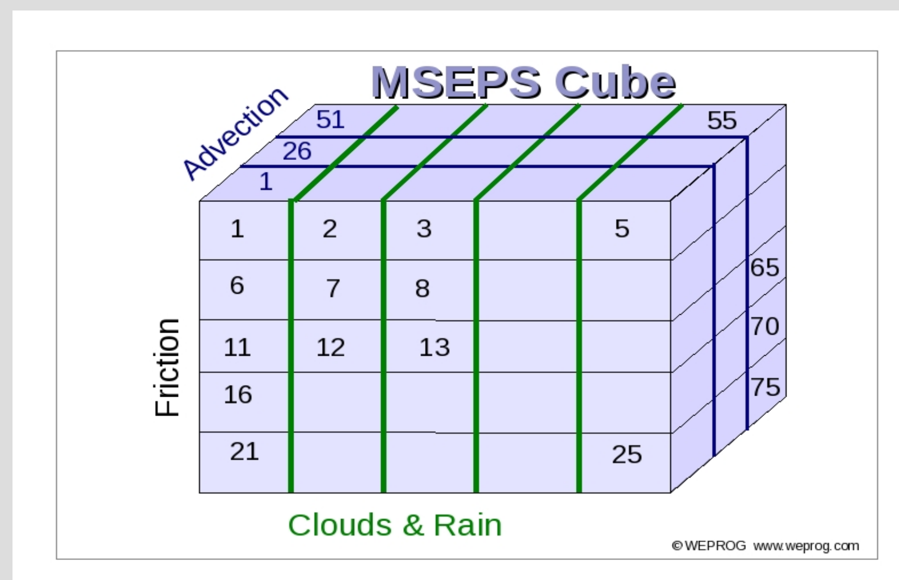
The error in Alberta is far above the other 2 areas. Note, in <u>South Australia the number of wind farms is the same as in Alberta</u> and <u>all 3 areas have a similar capacity factor</u>.

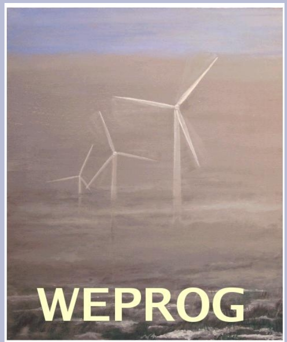
Note also the difference between 45km and 22km resolution models for Alberta, but also that the error growth is quite similar in all areas.



The AESO Forecasting Test-bed - Procedure -

- Acquisition of new hardware, suitable for the task: a HP blade system
- Installation of operating system and cluster maintenance software
- Installation of the MSEPS software and first test runs
- Migration into a hosting centre
- Final set-up and testing of the ``AESO forecasting Test-bed''
- Setting the new system into real time operation





The AESO Forecasting Test-bed

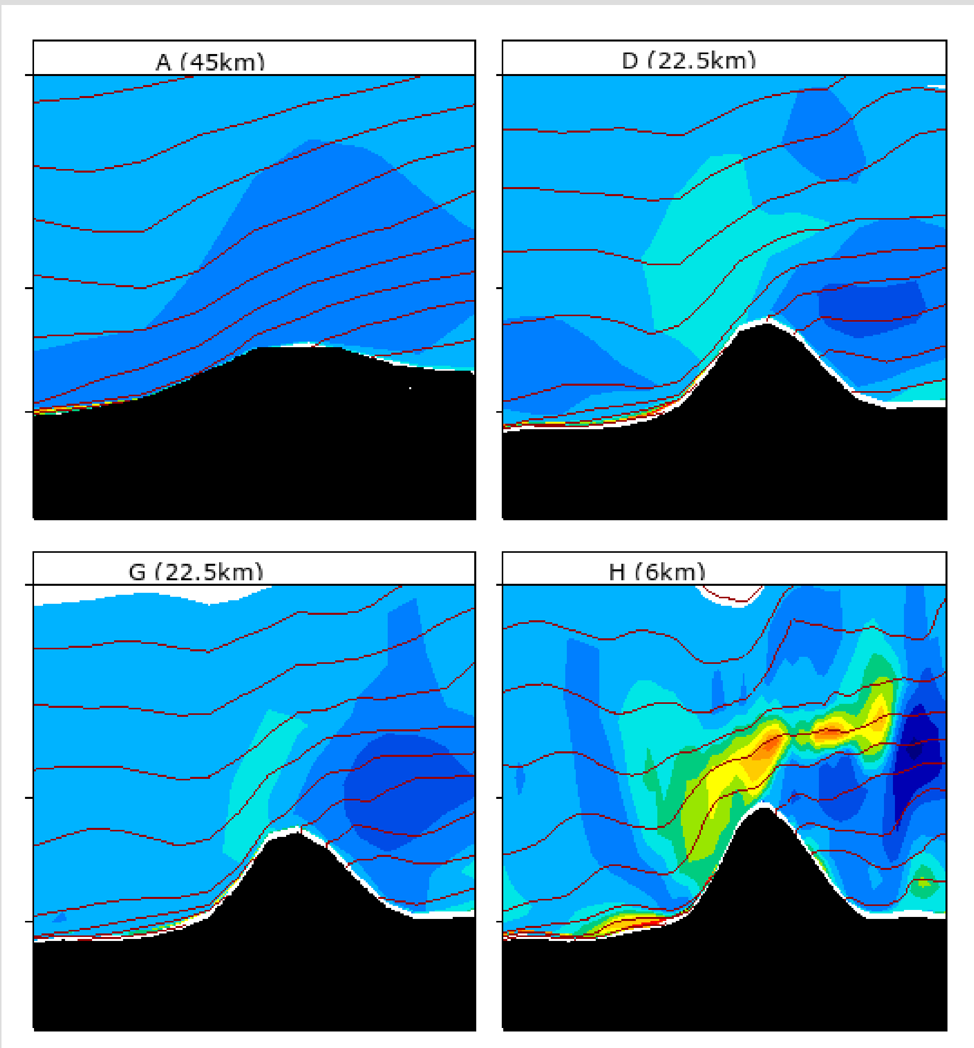
ID	Hor. Model Resol. [deg]	# of members	Resol. lat. Bnd [deg]	# of lat. Bnd	Analysis	Analysis Resolution	Orography	FC Horizon
A	0.45	75	1.0		NCEP	1	envelope	72
B	0.45	75	1.0	1	NCEP	1	mean	72
C*	0.45	75	1.0	1	NCEP	1	mean	72
D	0.22	75	0.45	75	NCEP	1	envelope	72
E*	0.22	75	0.45	75	NCEP	1	envelope	72
F	0.22	75	0.45	8	NCEP	1	envelope	72
G	0.22	75	0.23	8	NCEP	1	envelope	72
H	0.06	75	0.23	8	NCEP	1	envelope	48
I	0.22	75	0.23	8	CMC	0.6	envelope	72
J	-	675	-	-	-	-		-
K	0.6	75	1.0	1	NCEP	1	mean	42

=> 750 weather forecasts every 6 hours for 3 months

=> 2100 NWP model years -> enough to give robust error statistics

* C=B & E=D in weather, but differed in power prediction.

Lessons learned
- Is high-resolution feasible ? -

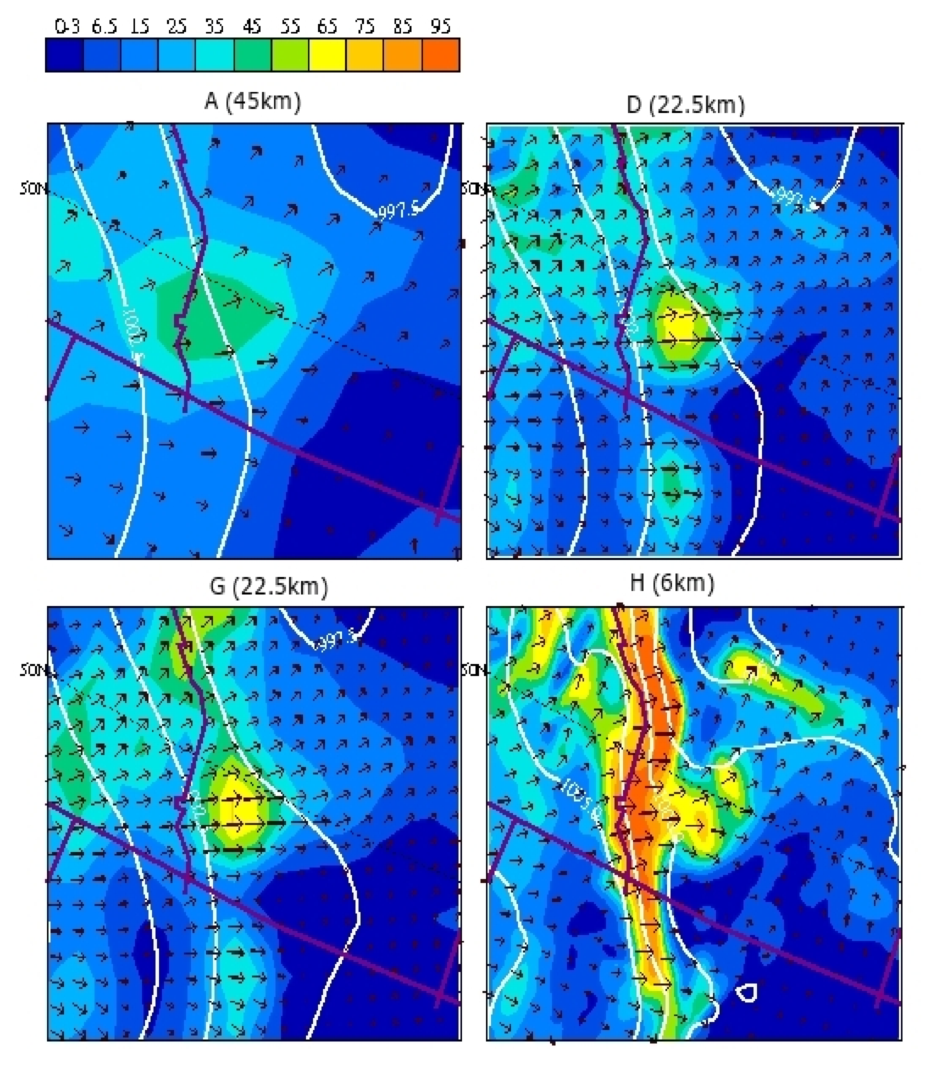


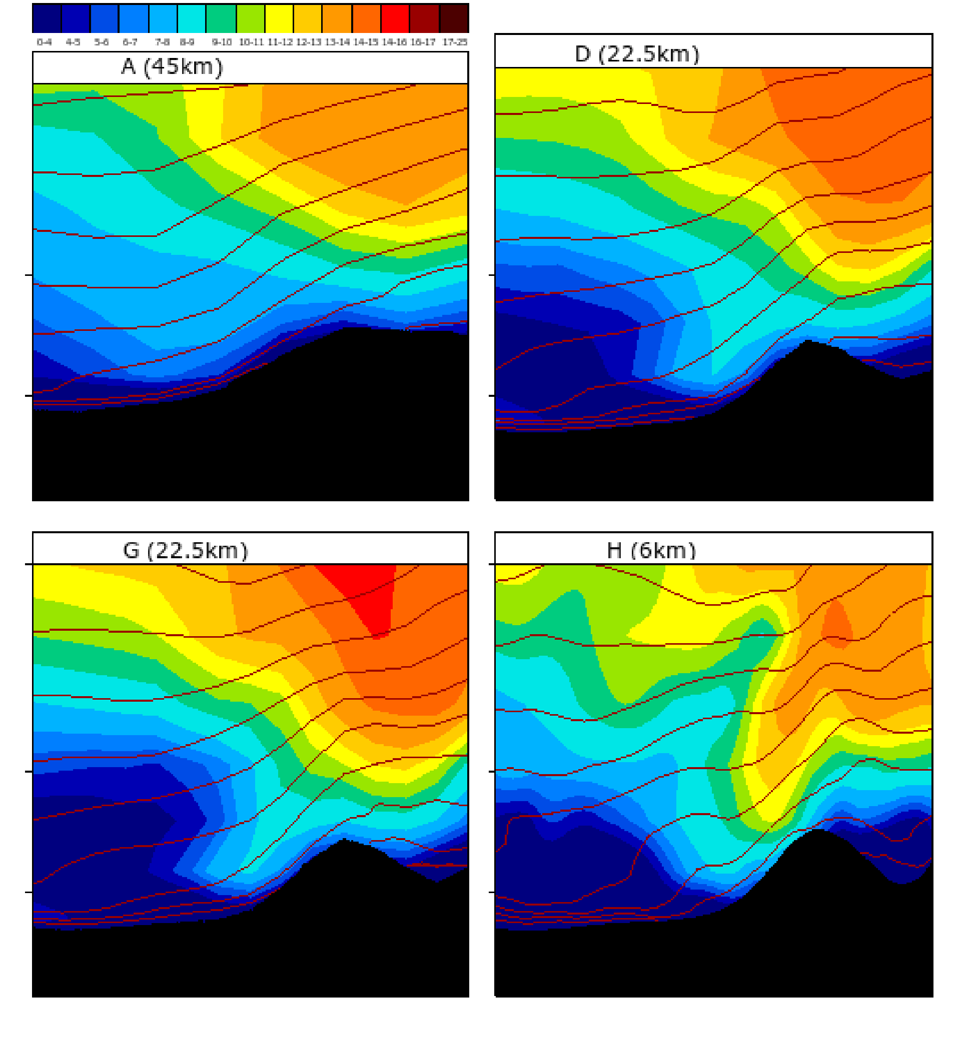
The Question was:
Can a high resolution model (3km-6km) run stable in real-time with nearly 4000m high mountains between BC & AL.

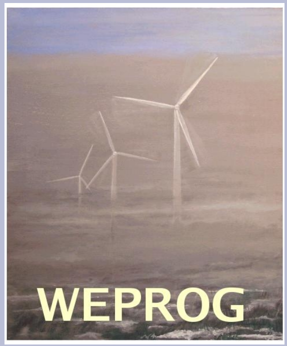
The figure shows the orographic differences and the sensitivity of the potential vorticity of the 45km, 22.5km and the 6km resolution models B,D,G and H in the same hour just before a ramp on the 25th of April.

High resolution wind speeds look fundamentally different

=>less statistical training & adjustments required





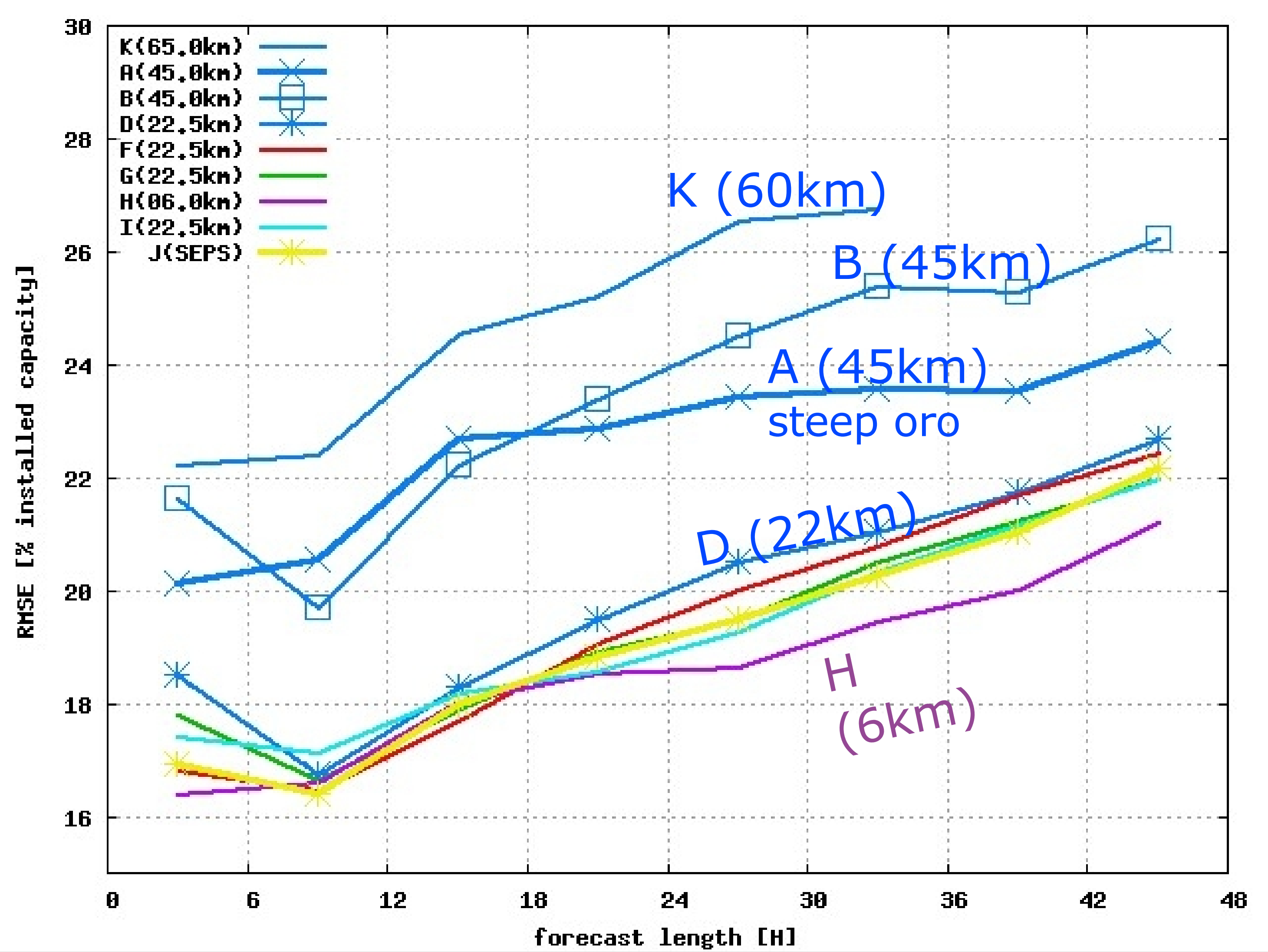


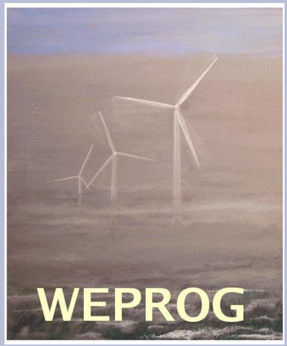
Lessons learned

- Q4 RMSE statistics of the 9 model set-ups in the forecasting Test-bed -

Forecast accuracy is very **sensitive** to:

- Spatial resolution
- Type of orography
- Initial conditions
- Lat. boundary data





Lessons learned

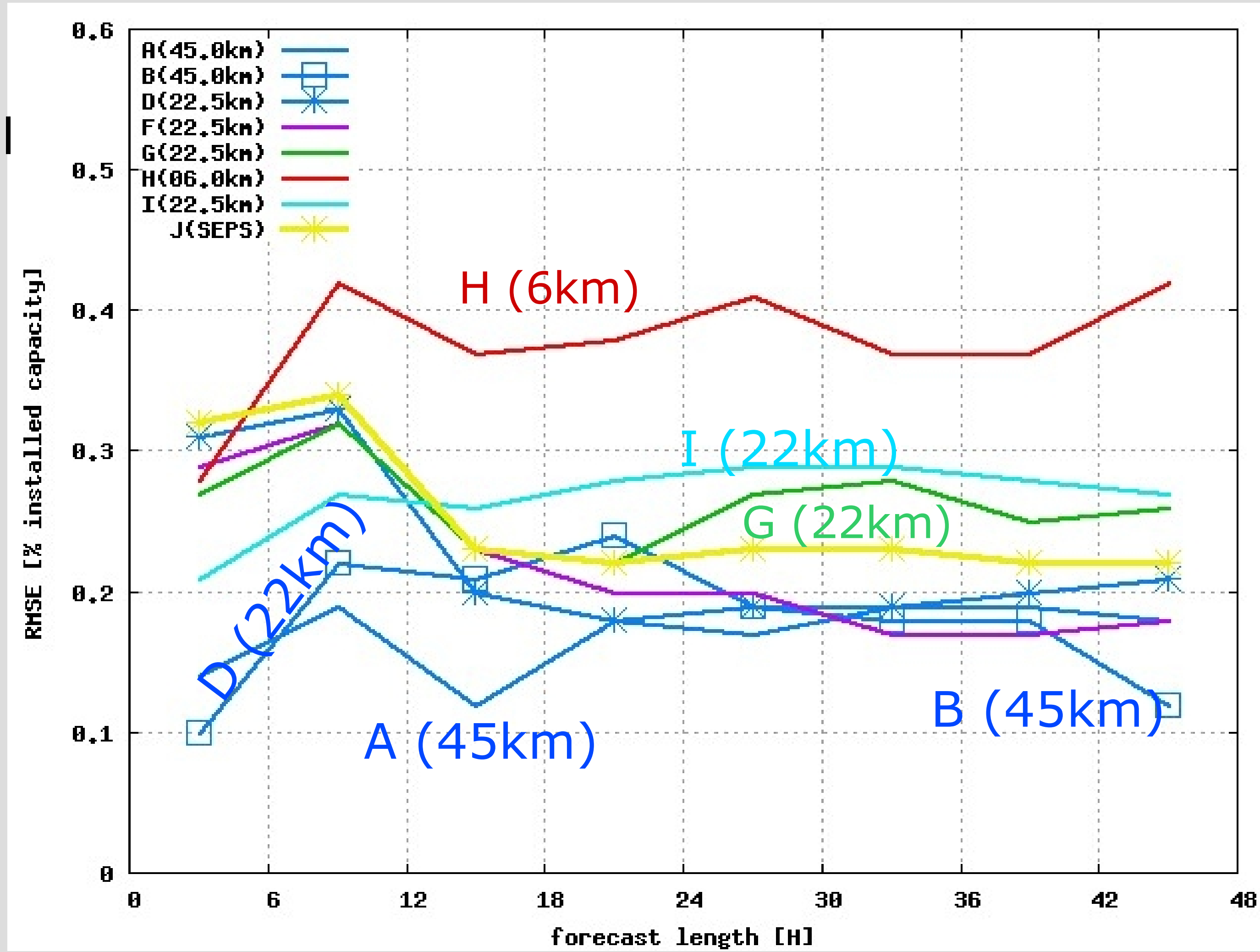
- Q4 Statistics of ability to predict the forecast error -

=> correlation between forecast spread and the actual error of the forecast

Our results show that the correlation between spread and actual error:

- **increases with spatial resolution**

- does **not reduce with increased forecast horizon**



Summary of Lessons learned

- key findings from the Test-bed experiments -

- The **initial conditions** are an important and essential factor for the forecast quality in Alberta (compare I <=> G).

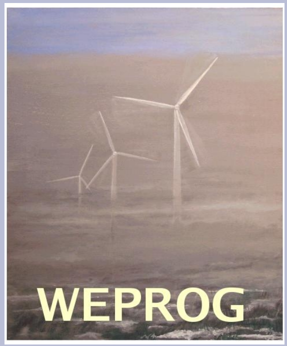
- The **lateral boundary conditions** need to be provided from a high resolution model (<=22km), because system G, H and I are better than D and F.

- The **60/45km ensemble is unsuitable** for Alberta, as it cannot resolve the mountains and the details in the facility regions sufficient well

- The **steeper orography** helps on the score on all parameters and the error growth (compare A <-> B).

- The 6km ensemble is **highly limited by the initial conditions** – only forecasts horizons longer than 27 hours have high quality – those are the hours where the lateral boundaries I=G => thus the large scale 22km boundaries count

- The **correlation** between **spread and actual error** increases with spatial resolution and does not reduce with increased forecast horizon.



Wrap-up of lessons learned

The good news:

we understand what causes the error and where we can improve, but

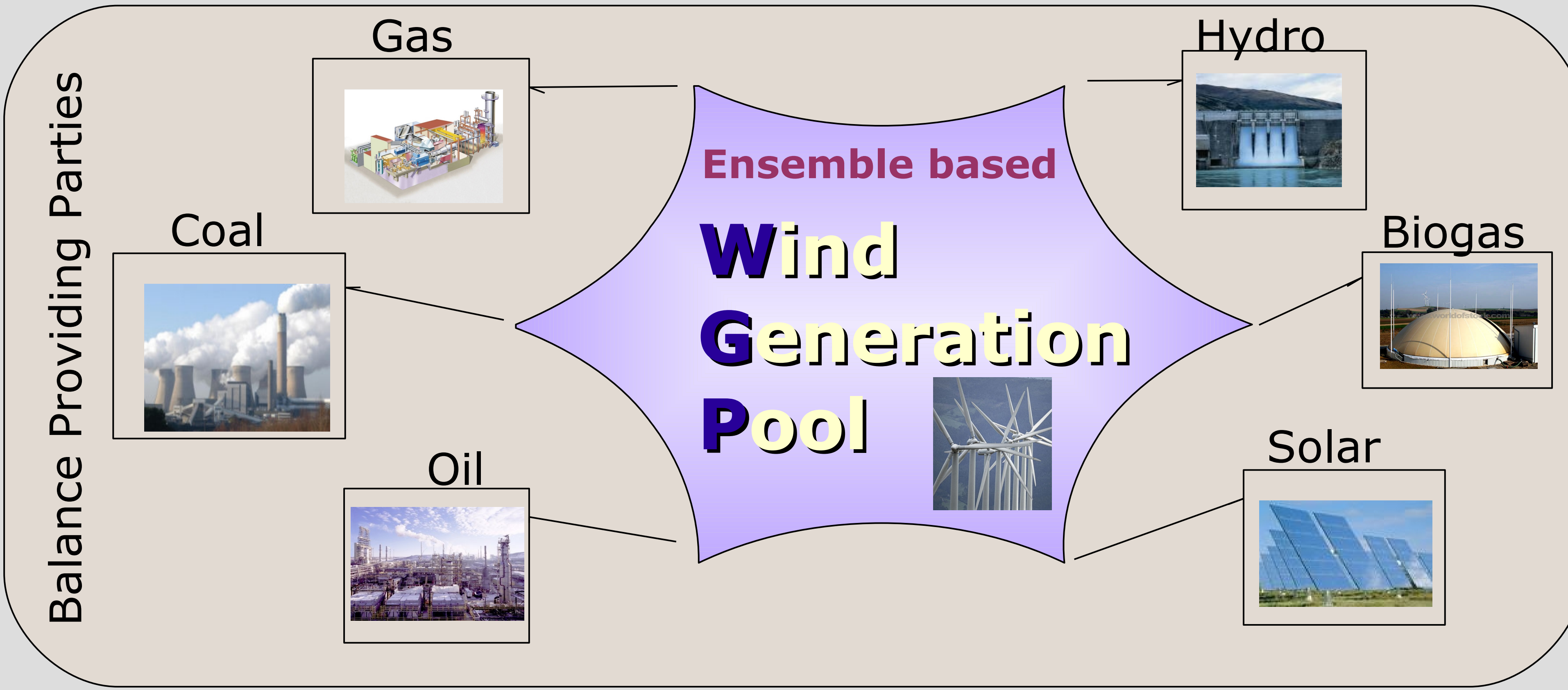
The disappointing news:

we must expect high error on the day-ahead forecast and a highly variable forecast uncertainty. This error will grow in MW with increase installed capacity and cause price volatility at levels higher than elsewhere.

Is there a solution to the problem ?

Yes, by using forecasting in a new way !

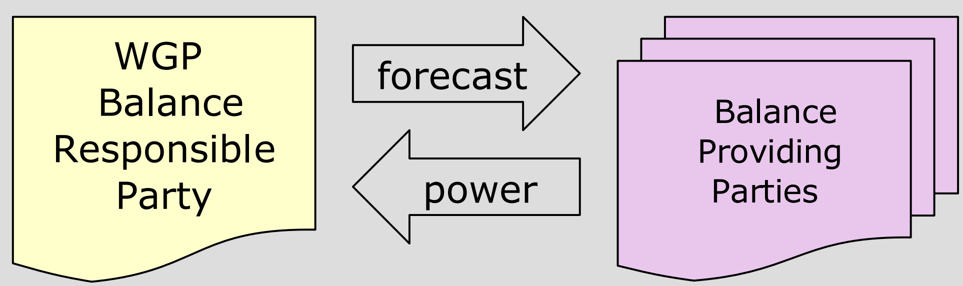
A possible future Wind Power Management



Dynamic Primary Power

ensures:

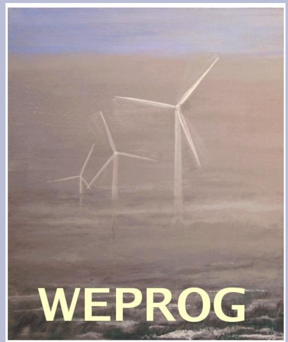
- minor price volatility
- high security



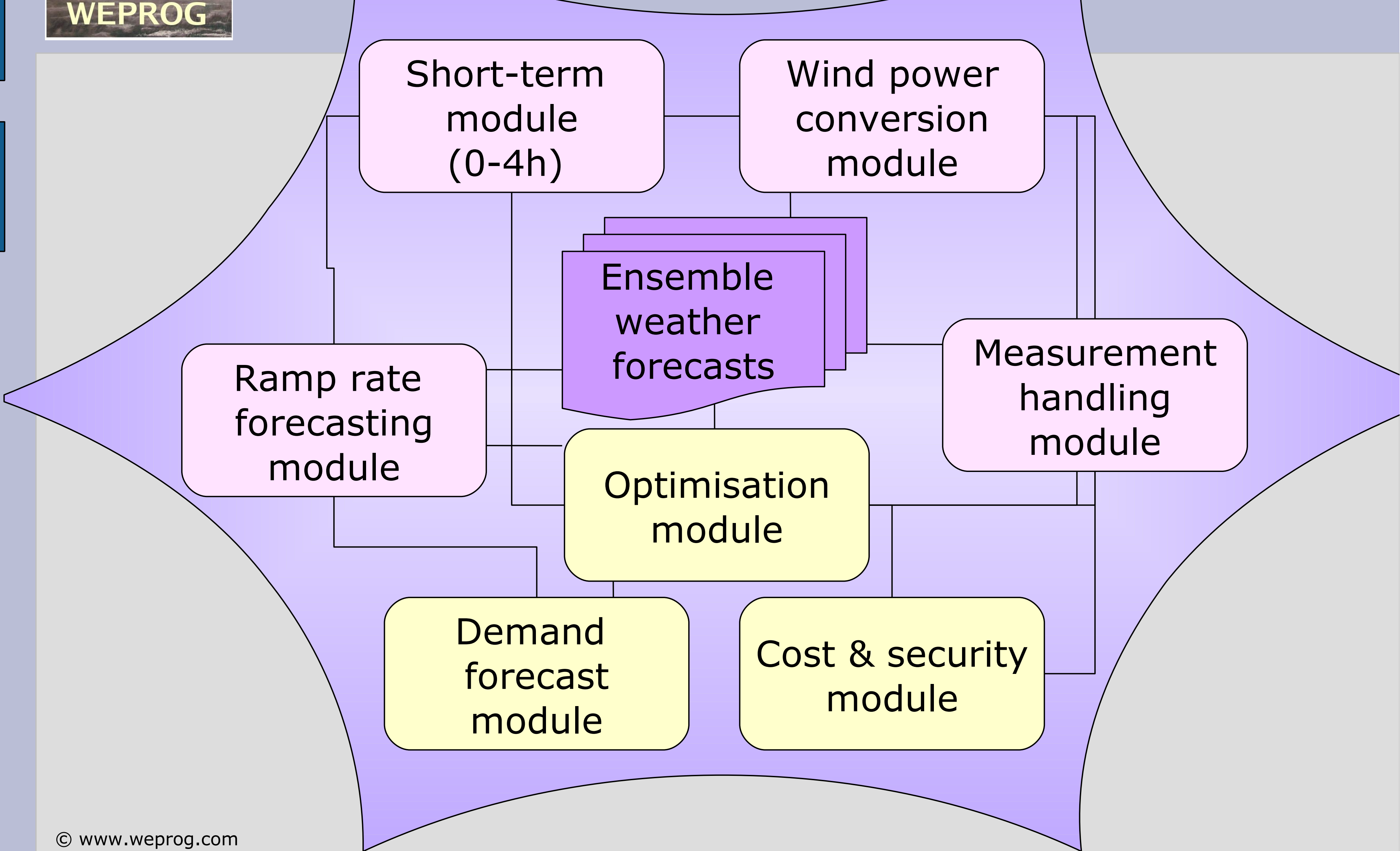
Wind Generation Pool - Purpose -

<u>The purpose of the WGP is to:</u>

- bid into the market with a smooth generation profile of the pool
- prevent that the market can predict WGP's bid on the market from weather forecasts
- maximise the reliability of the WGP power generation
- keep the balance costs at a minimum using pre-purchased “balance”



"Wind Generation Pool's" Inside - 8 modules -



Wind Generation Pool - bidding structure -

Bid: "optimised" EPSmax

BPP shall be prepared to deliver:

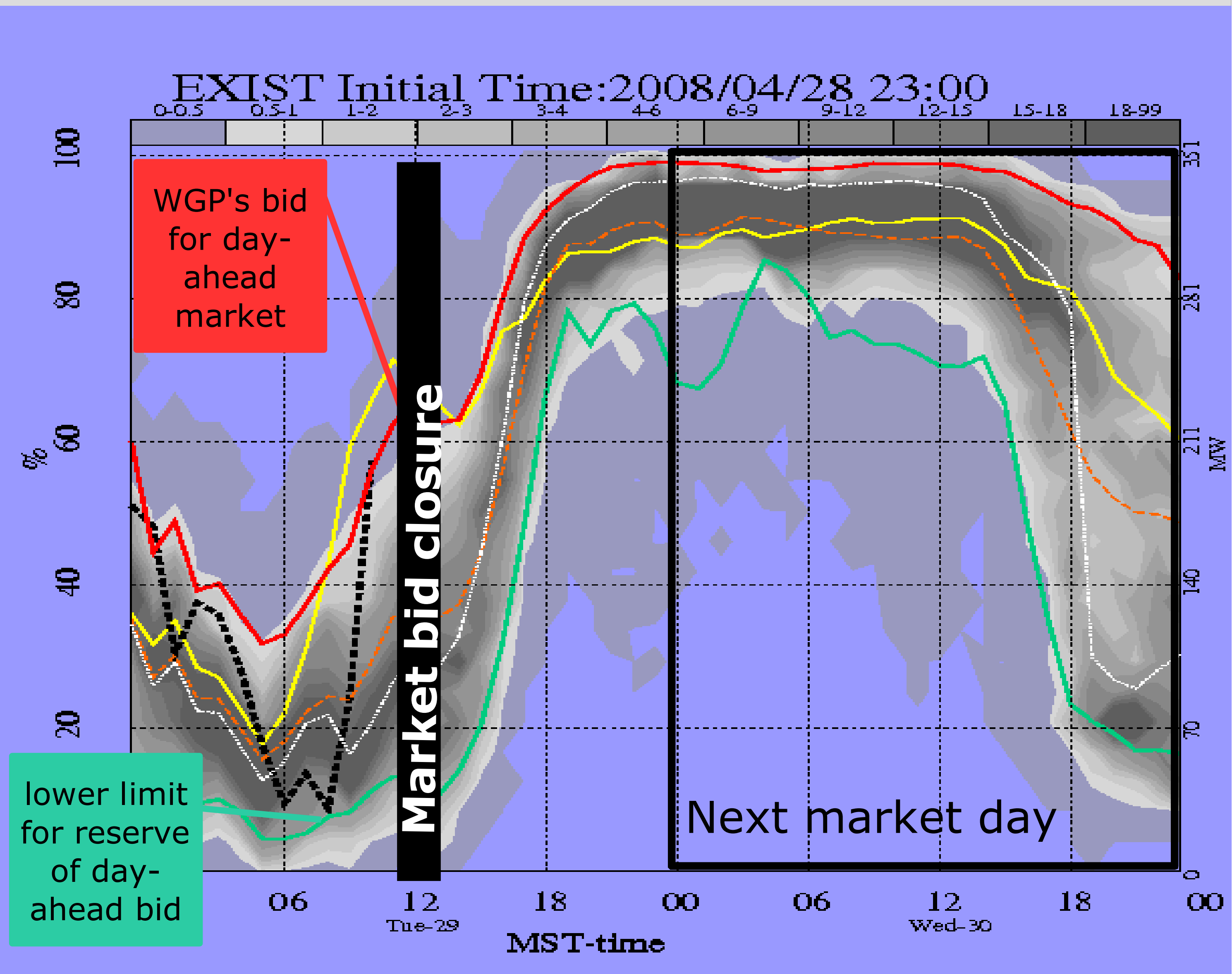
$\Delta = EPS_{max} - EPS_{min}$

or

$EPS_{min} + R_{max}$

if the max. ramp rate is > BPP ramp capacity.

BPP=balance providing party



Summary and Conclusions

Alberta is a special area:

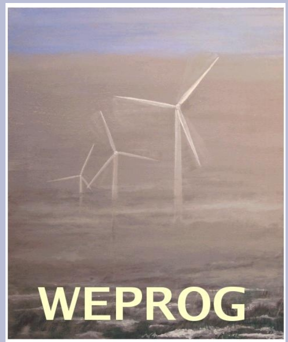
- high wind resource
- relatively low interconnection
- low dispersion of wind farms
- high forecast error on the day-ahead
- every improvement is marginal

New thinking is required:

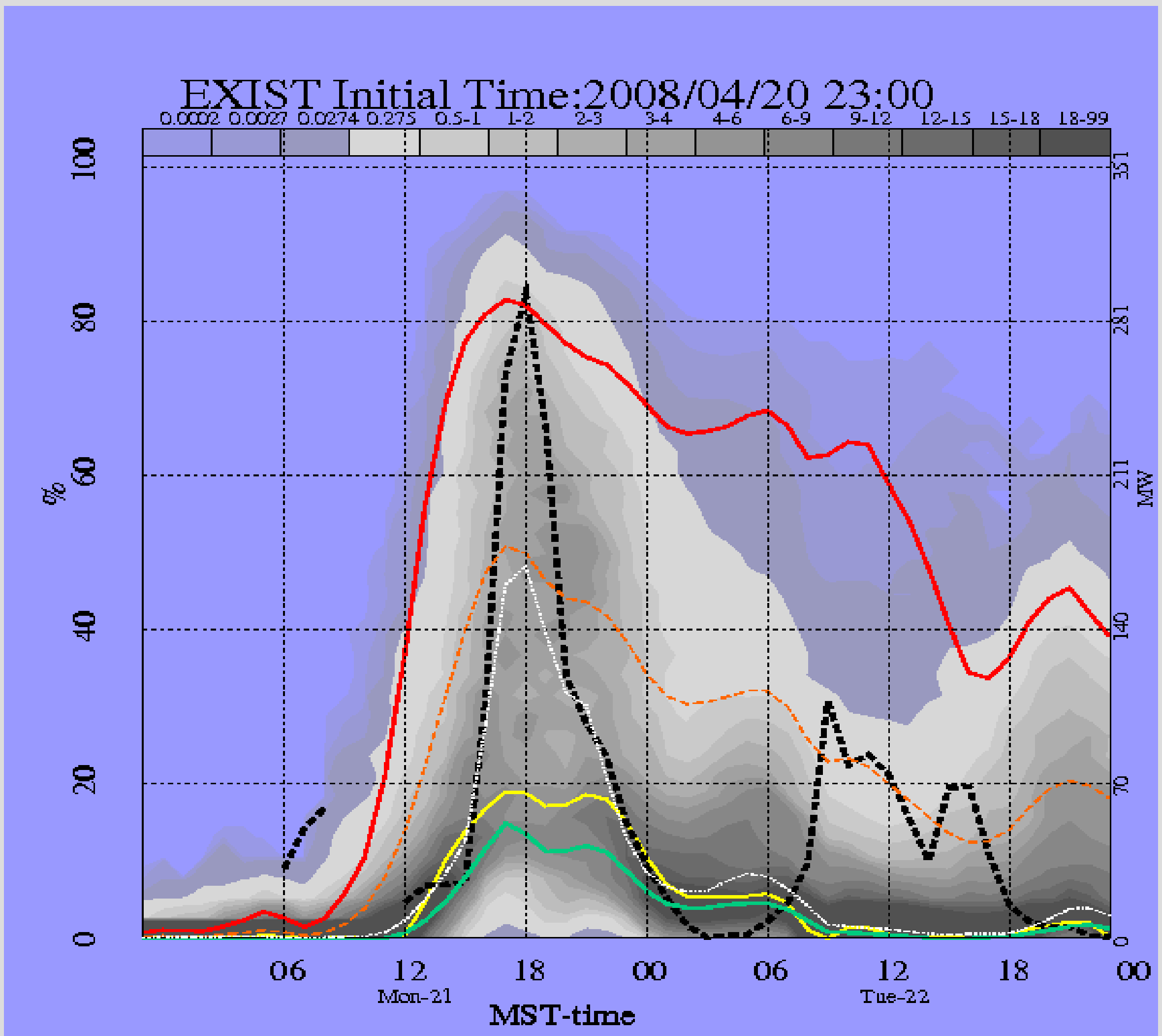
Forecasting has to become a ***Value Added Service*** to optimise the operation and scheduling of wind power into the market and hence enable continued feasibility and development.

A traditional single forecast will be to the disadvantage of wind developers, the consumers and the environment, but to the benefit of the scheduled generation.

The ***Wind Generation Pool*** concept will be able to assist in achieving high penetration without compromising on security and economic feasibility of wind power !



Questions ?



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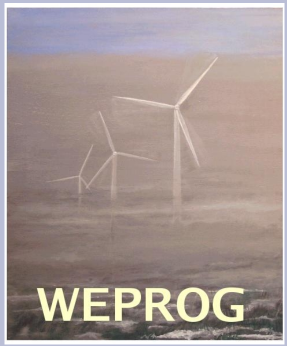
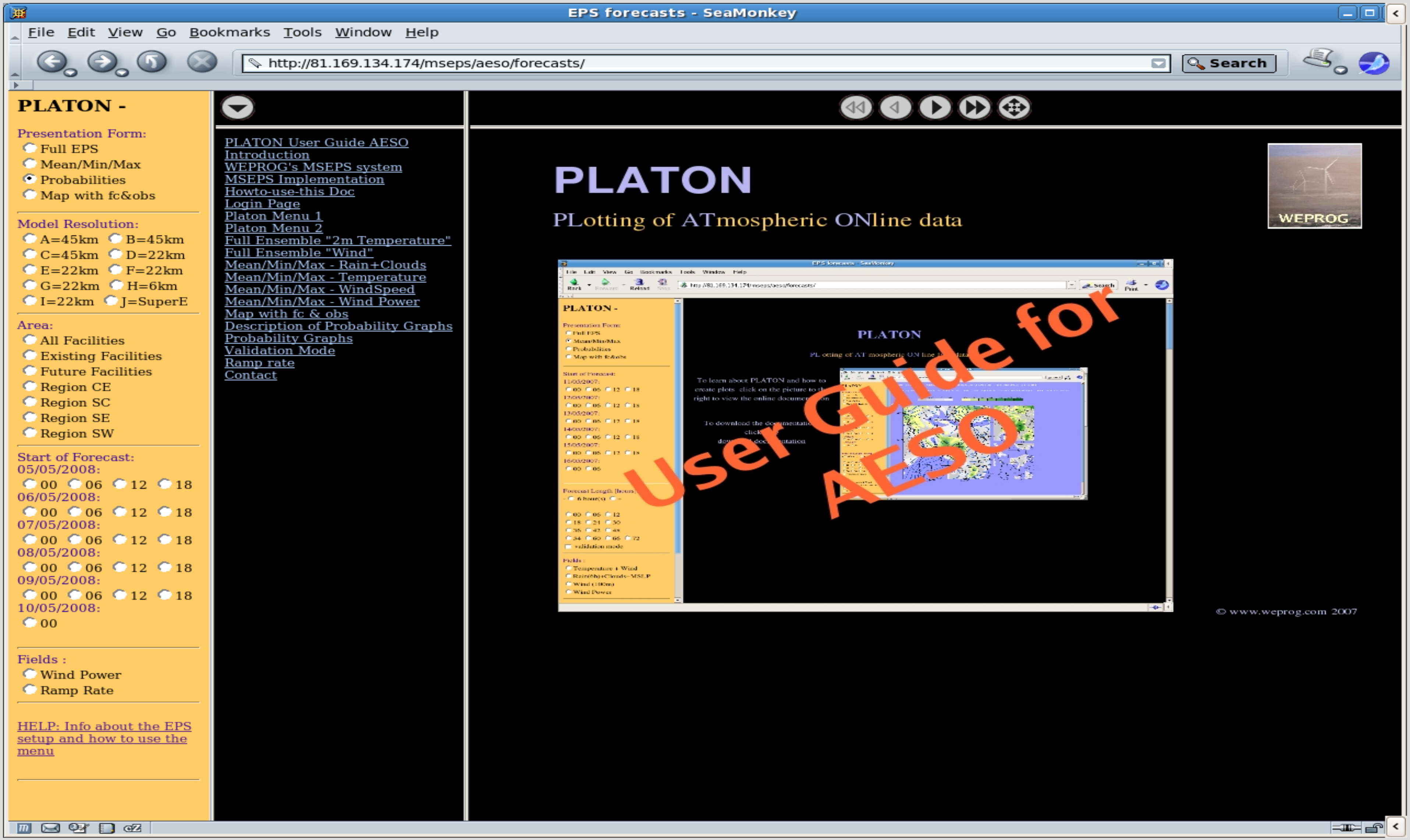
PLATON Graphical Interface for Real-time forecasts

The following pages provide some samples of the Graphical User Interface PLATON - PLotting of ATmospheric ONline Ensemble Data – provided to the AESO in the wind forecasting pilot project

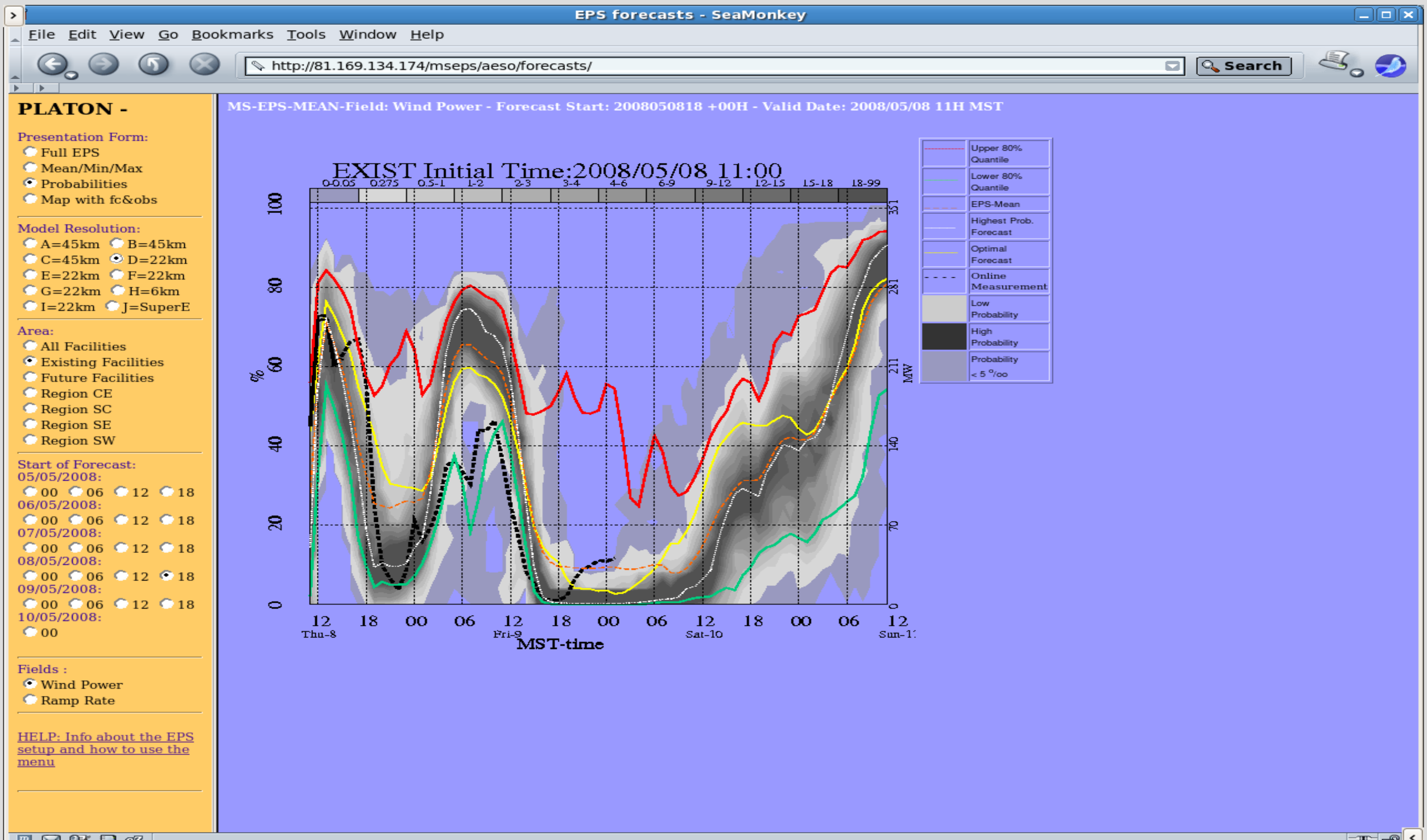


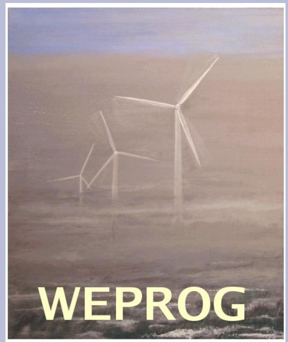
PLATON Graphical Interface for Real-time forecasts



AESO wind forecasting pilot project industry workshop Calgary, 10th June 2008

PLATON Graphical Interface for Real-time forecasts





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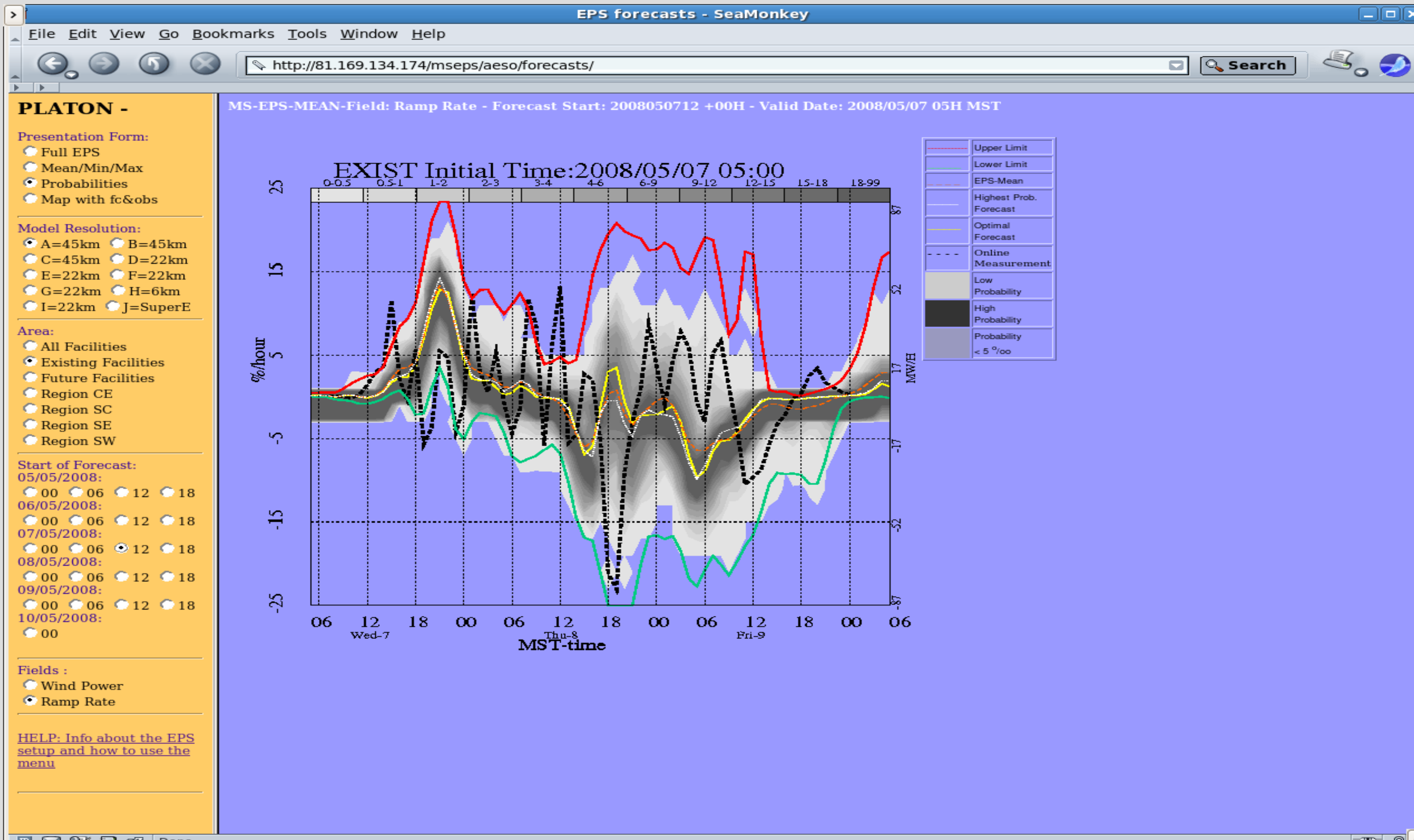

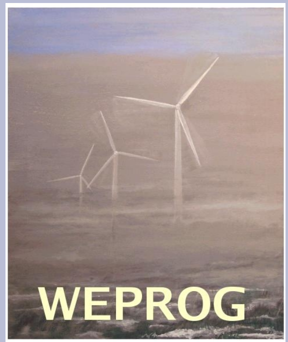

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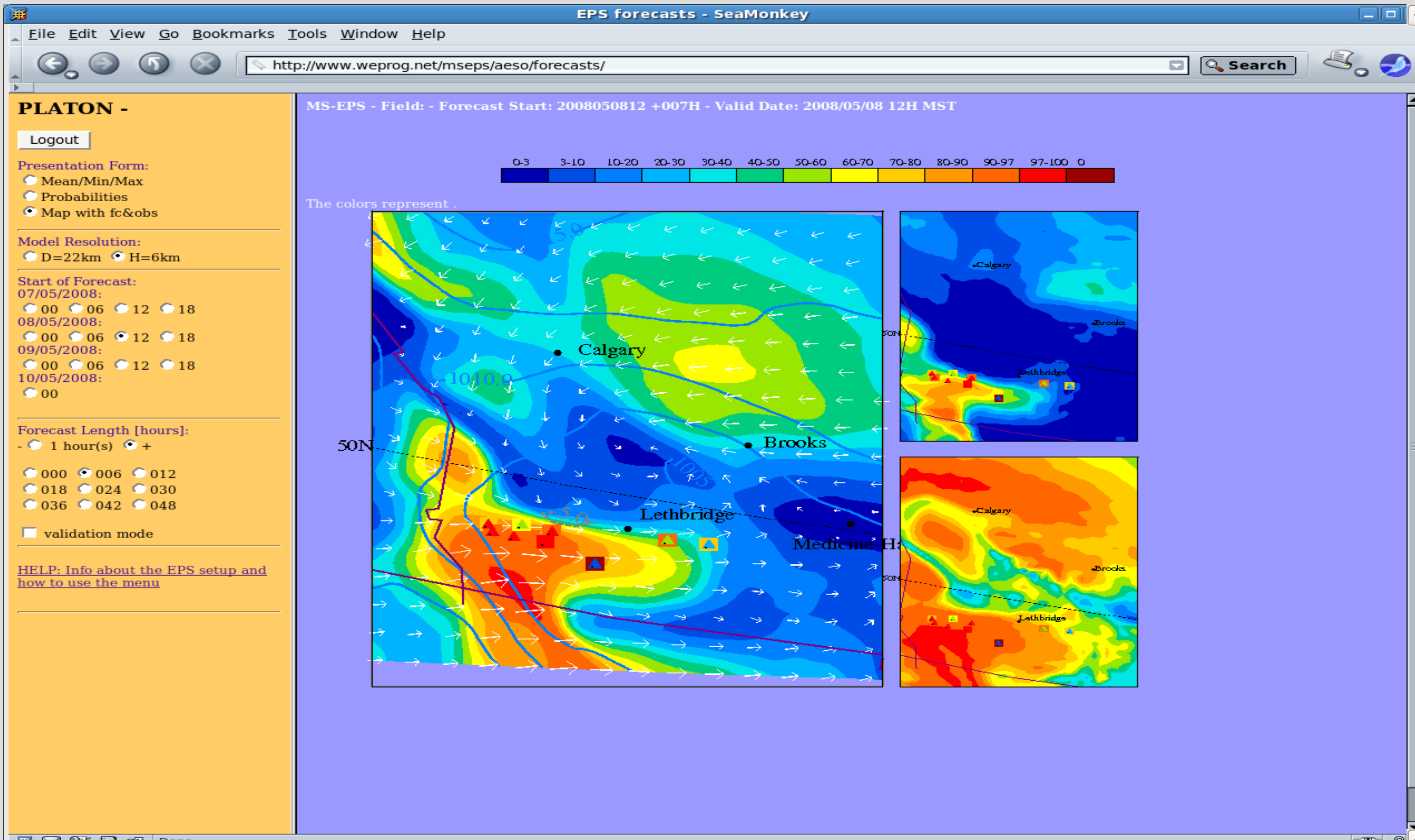

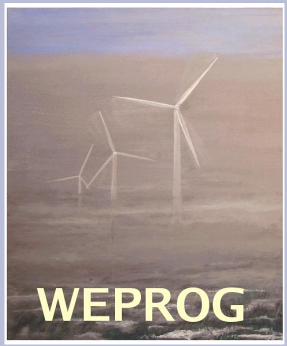

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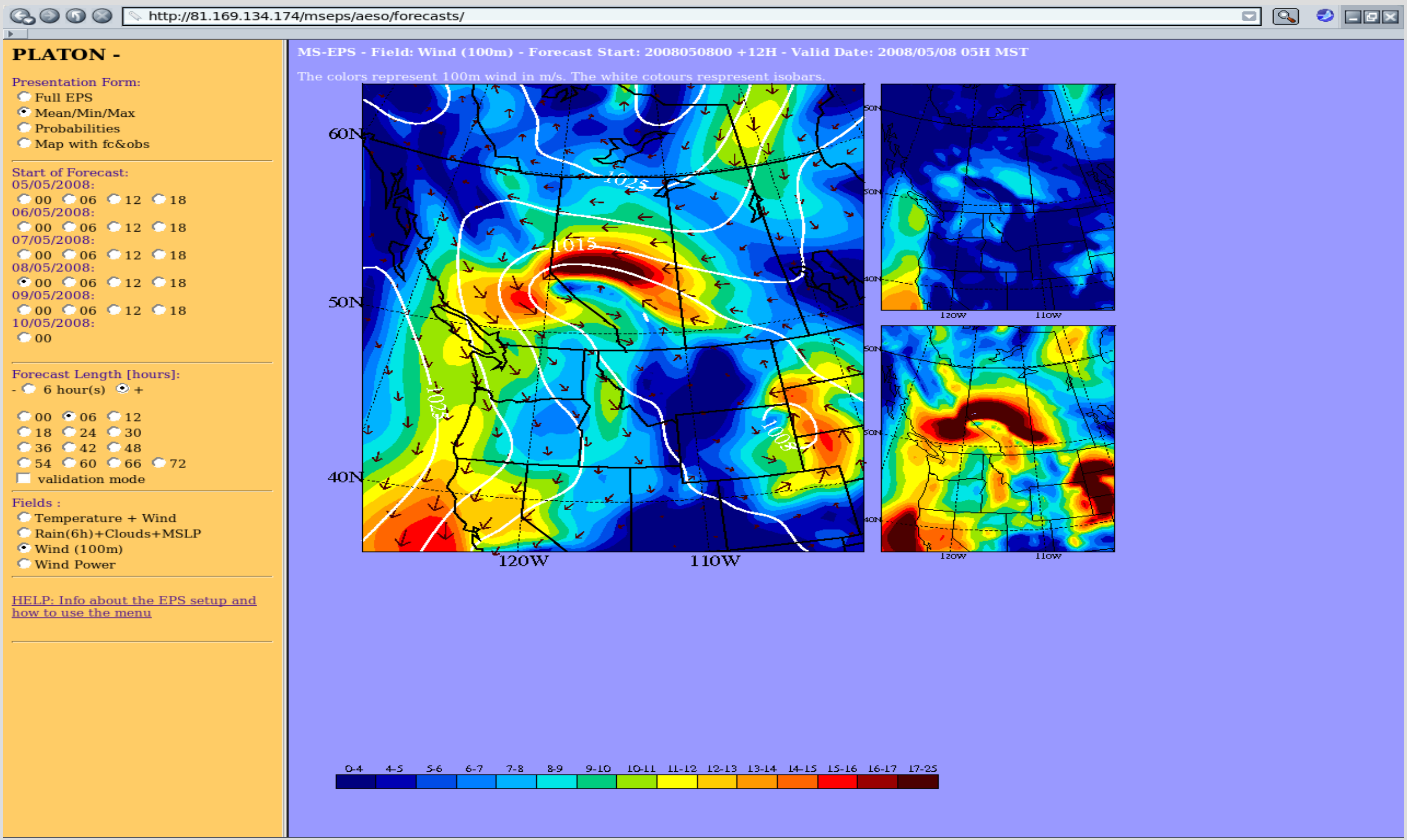

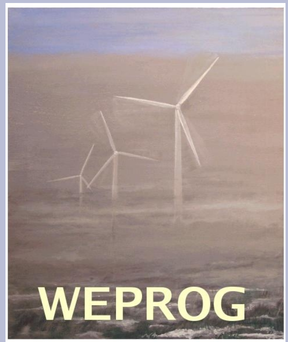

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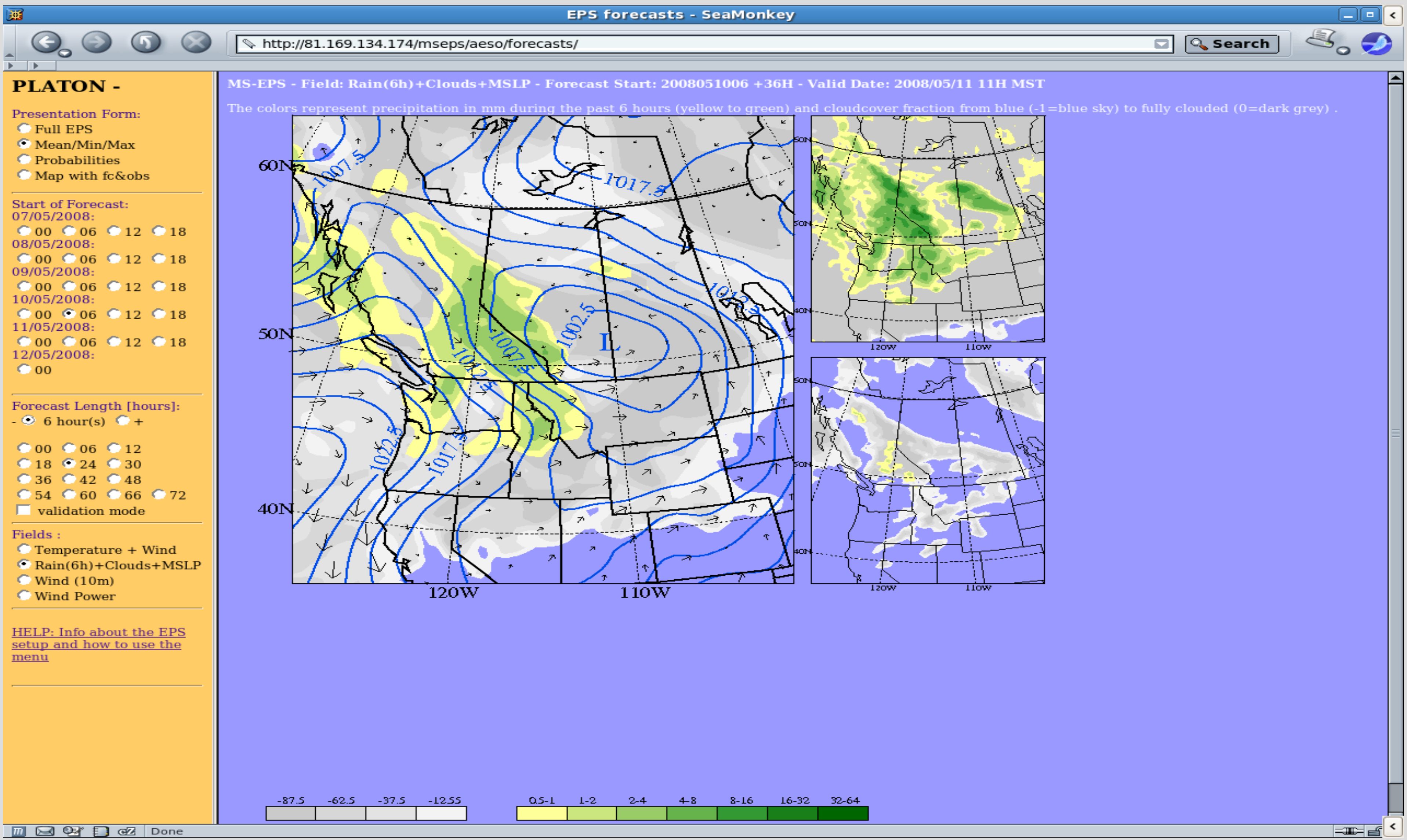

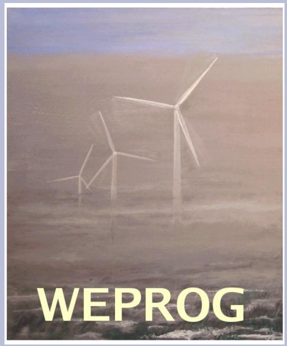

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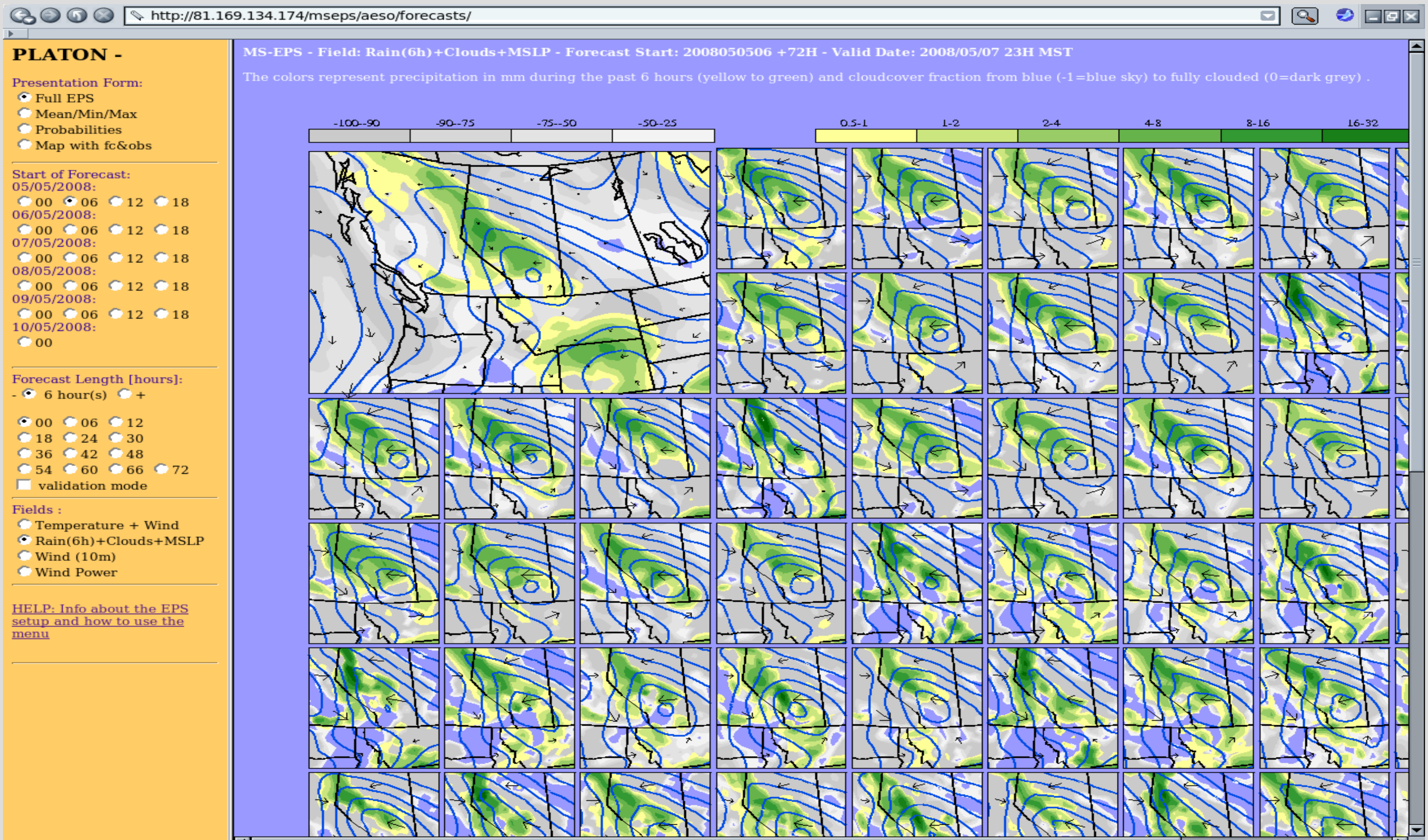

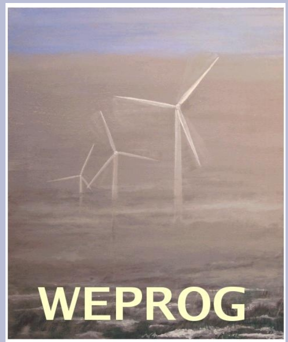

PLATON Graphical Interface for Real-time forecasts