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Strategies for optimising operational decisions using ensemble marine forecasts

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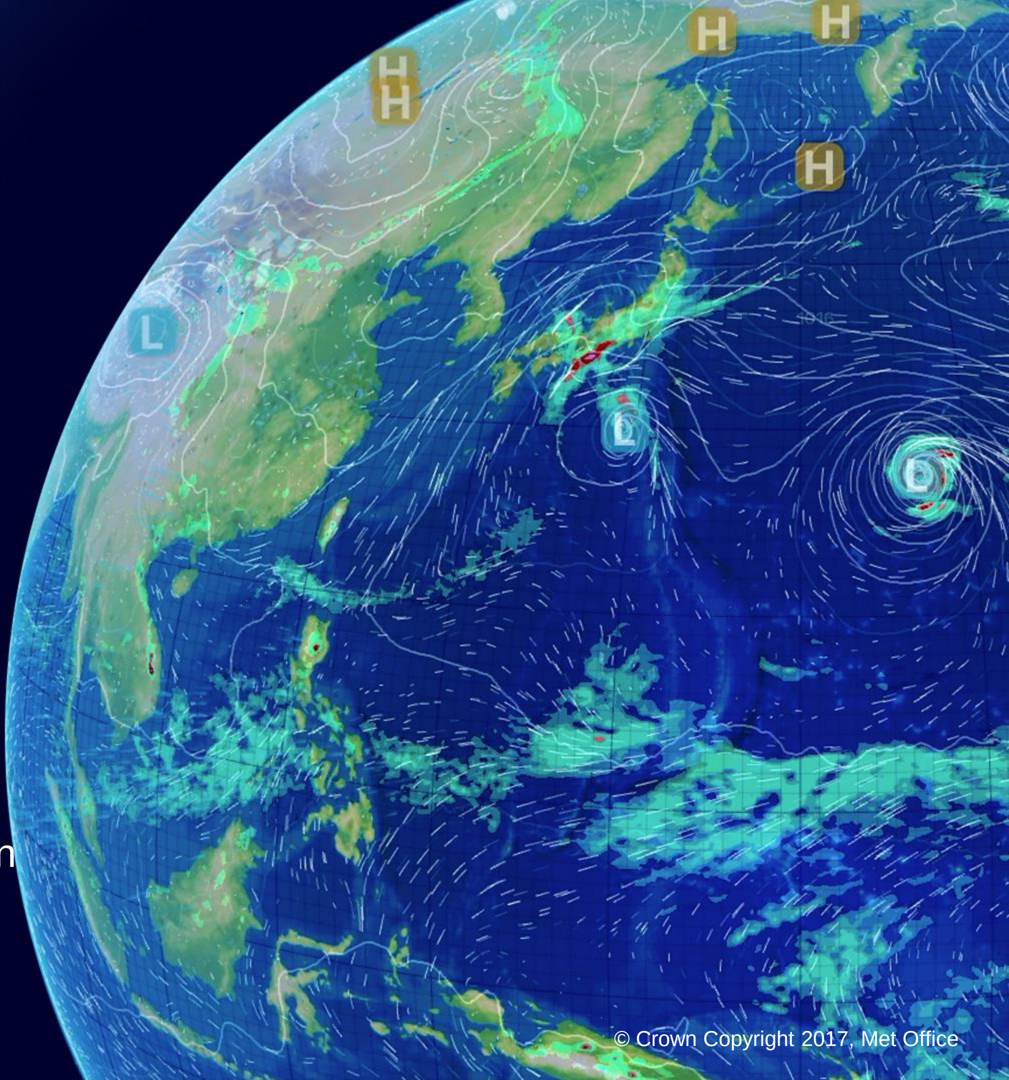

Background

Correct identification of calm weather windows can save many thousands of dollars per day in unplanned downtime, allowing large savings if decisions are made as early as possible, but only when the science is employed to best effect…

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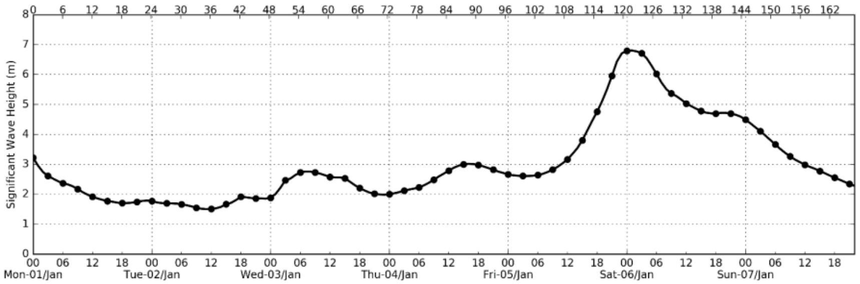
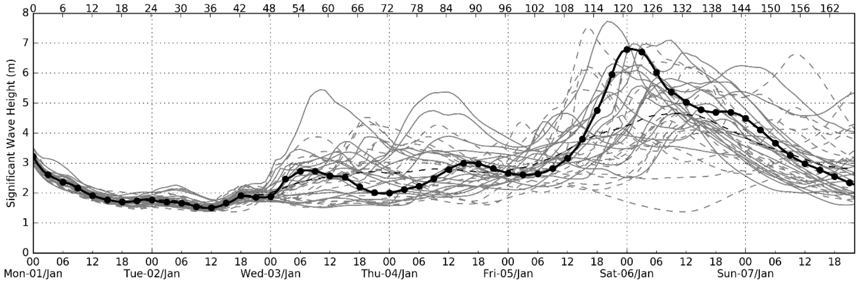
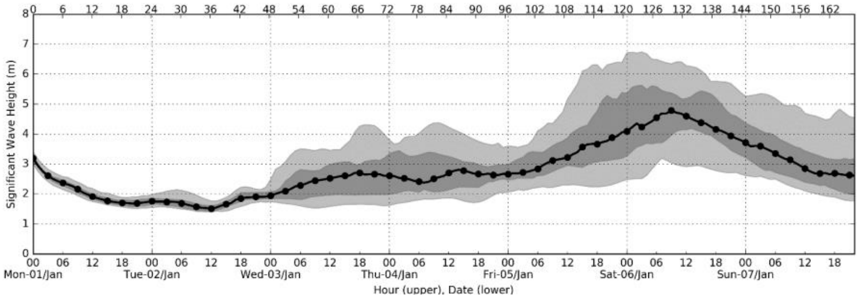
At present, most offshore industry decisions based on deterministic forecasts…



Probabilistic forecasts aim to quantify uncertainty dynamically and are more suitable for maximising the opportunity for planning…



…but due to perceived complexity, products are often (over) simplified, masking the actual values on which to make an objective decision.



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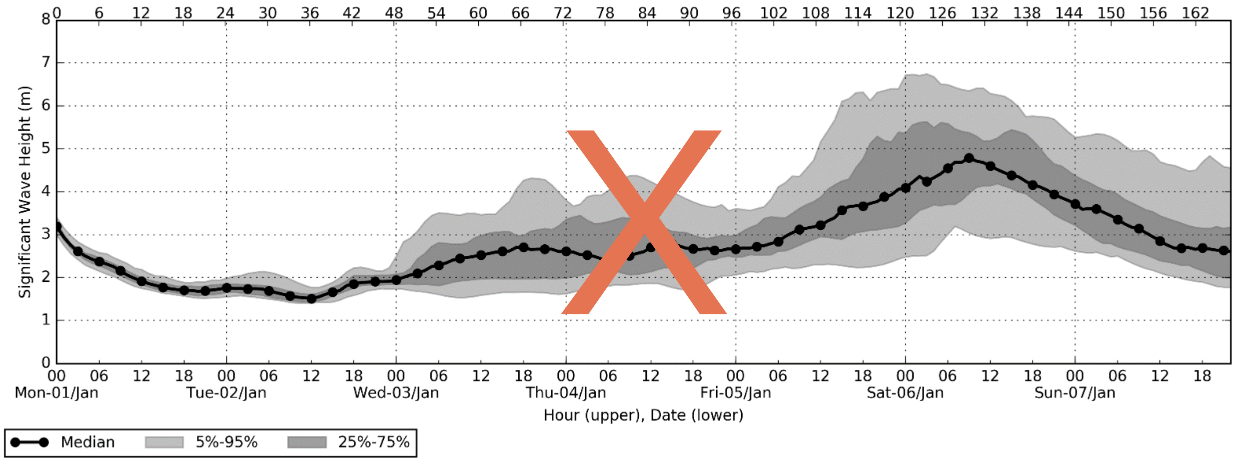
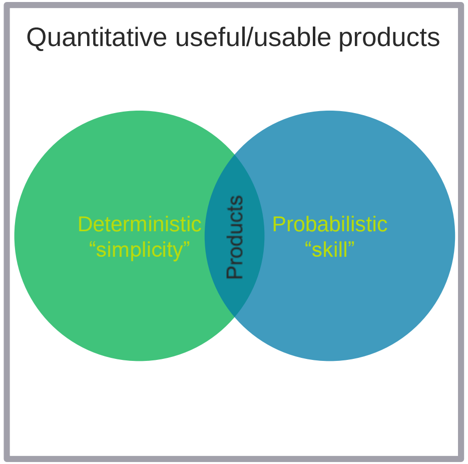
Leveraging as much science as possible (without the user even realising it!)

Examples:

- Using relative economic value of forecasts to determine when to take action upon it;
- Using weather pattern typology to identify calm weather windows for local operations;

Combining customer insights with ensembles





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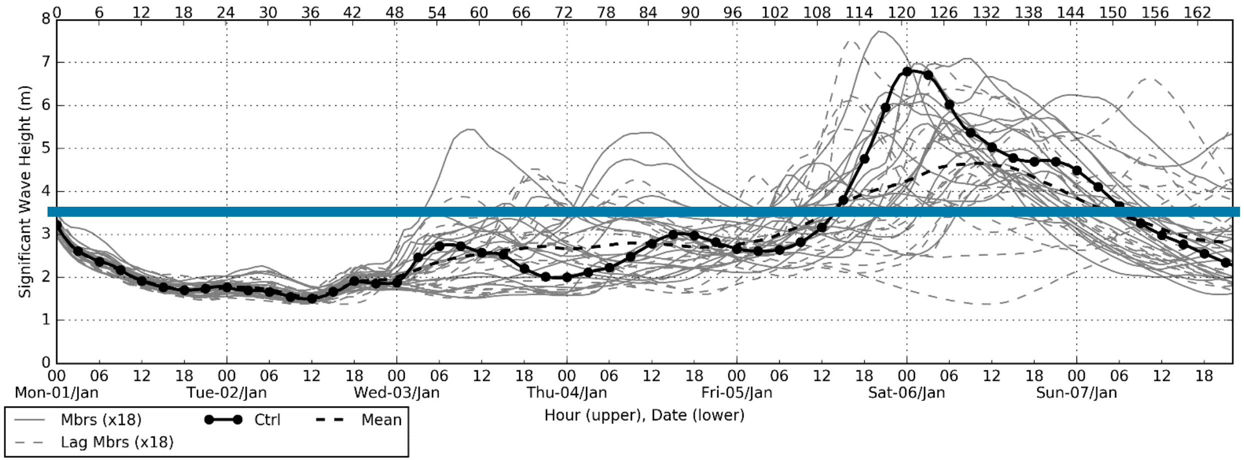
Combining customer insights with ensembles – relative economic value



Continuous forecasts can be turned into binary forecasts by applying a user-relevant threshold.

With binary forecasts, action is clear:

Event forecast – take action

Event not forecast – take no action

With ensemble forecasts a decision must be made on which probability value to act on.

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Combining customer insights with ensembles – relative economic value

$$V = \frac{E_c - Ef}{E_c - Ep}$$

Where:

$$Ec = \min\left(C, L\frac{(a+c)}{n}\right); \quad Ep = C\frac{(a+c)}{n}; \quad Ef = C\frac{a}{n} + C\frac{b}{n} + L\frac{c}{n}$$

2x2 contingency table:

Observed (columns), Forecast (rows)

	Yes	No
Yes	a	b
No	c	d

Cost-loss assignments:

Observed (columns), Forecast (rows)

	Yes	No
Yes	C	C
No	L	0

The Relative Economic Value allows impact of an adverse weather event to be estimated in industry-relevant (economic) terms:

- Cost incurred whenever decision made to protect (irrespective of occurrence);
- Loss incurred whenever the event occurs and the decision made not to protect;

Value compared to climatological baseline (V=0) and expressed as fraction of the maximum obtained from using a perfect forecast (V=1).

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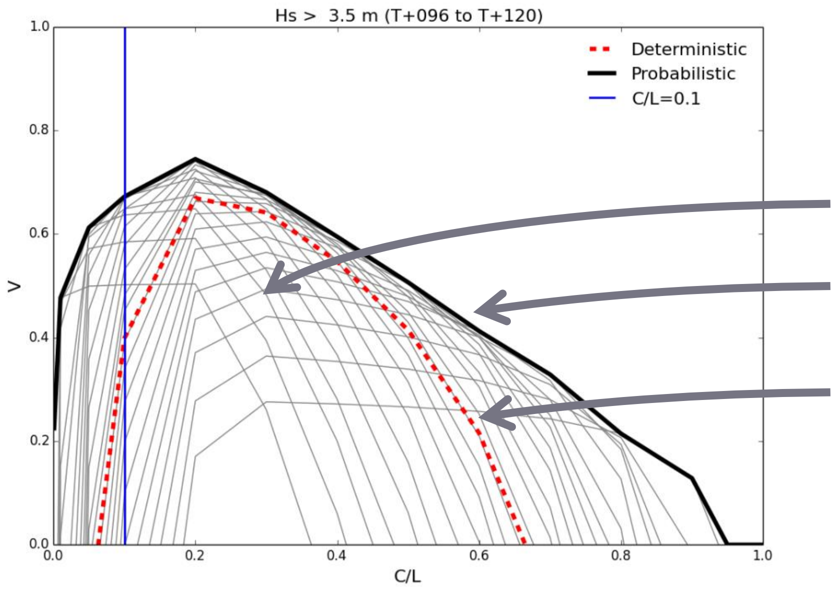
Combining customer insights with ensembles – relative economic value



Thin black lines = individual probability thresholds

Thick black line = optimum probability threshold (maximizes V at each C/L)

Dashed red line = result from deterministic forecast

The Relative Economic Value as a function of C/L, calculated from forecasts made 3 days ahead for 10 locations over 1 year (adverse event: Hs > 3.5m in 24 hours).

Highest value from ensemble: user gains some benefit over best-estimate forecast and climatology.

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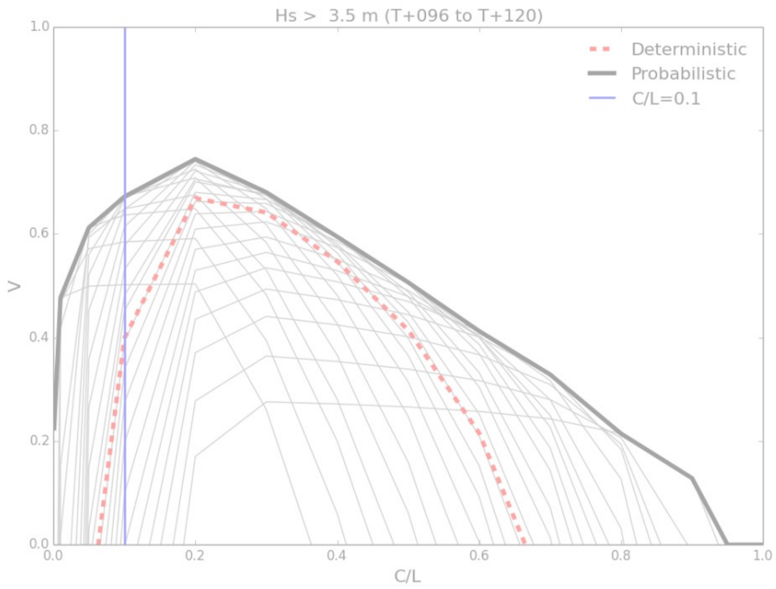
Combining customer insights with ensembles – relative economic value



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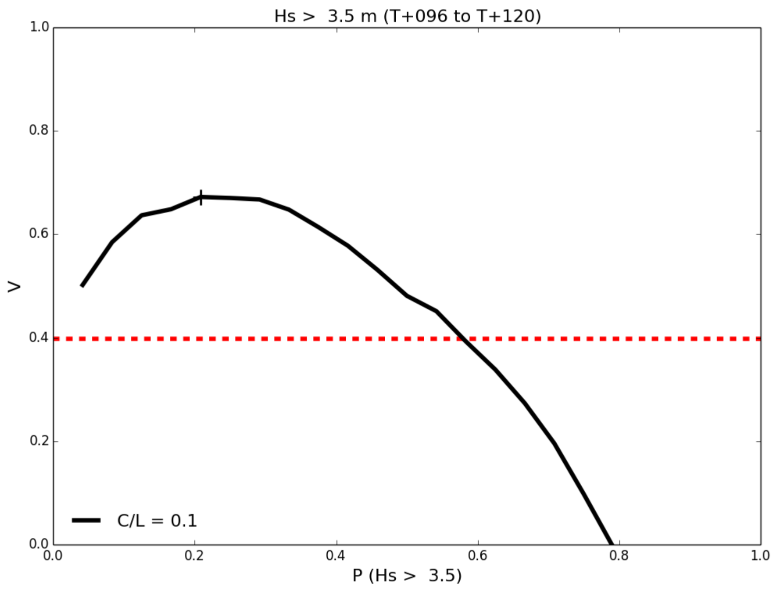


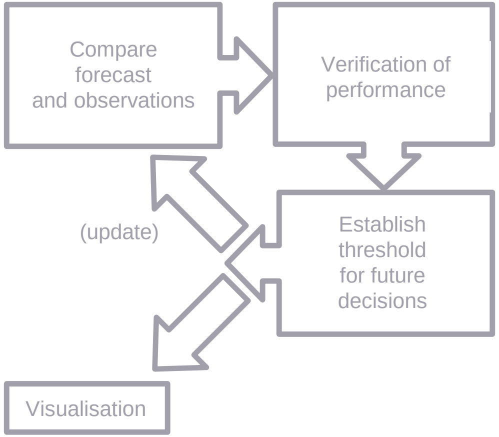
The Relative Economic Value as a function of probability (fixed C/L = 0.1 (typical of offshore operations).

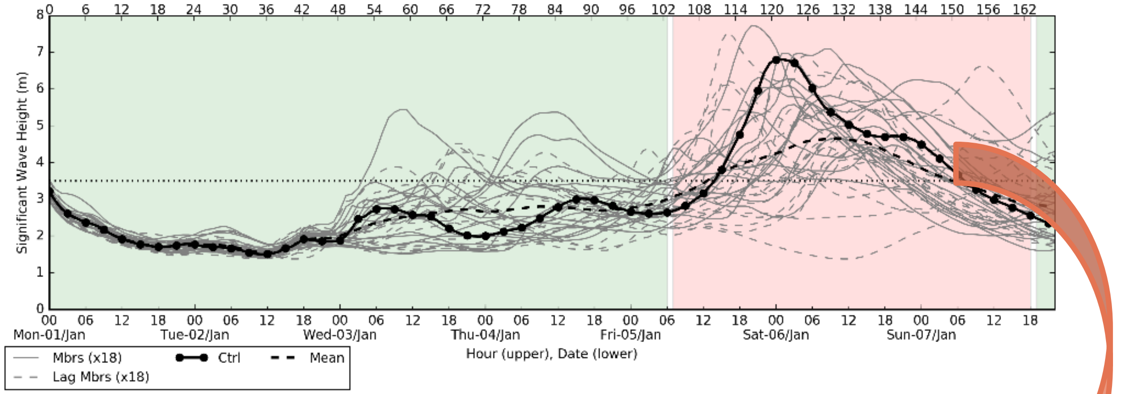
Value is maximum when P = 0.2: user gains maximum benefit by postponing operations when more than 5 of 24 ensemble members predict the adverse event or vice versa.

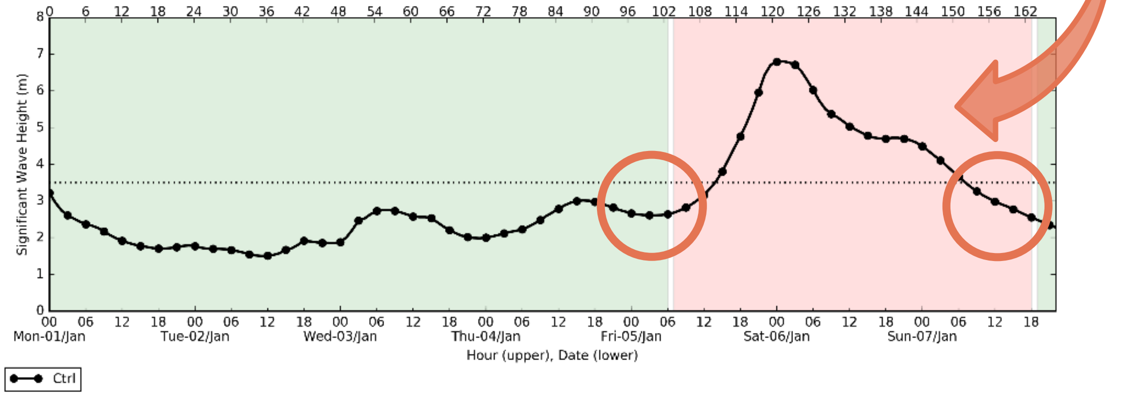
Combining customer insights with ensembles – relative economic value

Proceed

Protect







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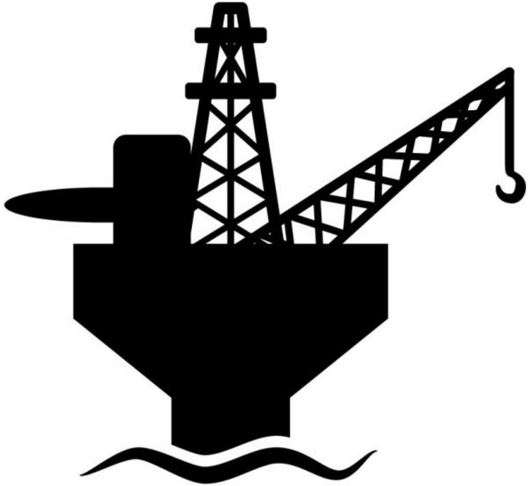
Benefits to offshore asset managers



Actual decision-making often more complex than a simple yes/no, but the C/L framework offers a sensible basis for handling probabilities.

Greater reliability of probabilistic forecasts over deterministic forecasts days to weeks ahead offers the opportunity for more timely decision-making.

Useful in coordinating interrelated components of operations (e.g. vessels / supplies) or starting installation shut-down preparations (cancelling activities / removing non-essential personnel) early.

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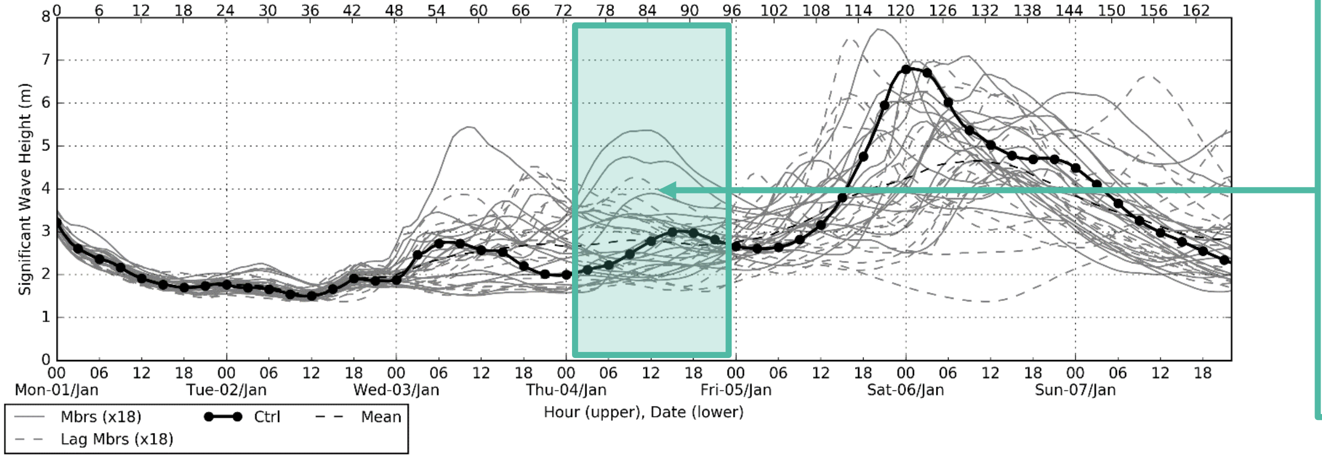
Importance of particular weather windows



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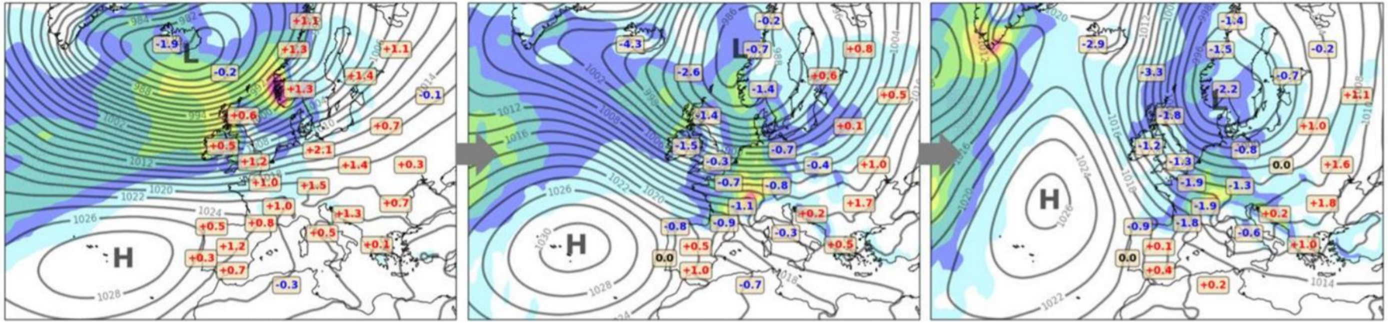
A weather pattern approach to assisting decision-making – "Decider"

Constraining an otherwise ambiguous set of ensemble members can be achieved by grouping these data according to some criteria, e.g. weather pattern.



Cyclonic westerly

(Mild, wet and windy conditions)

Cyclonic north-westerly

(Cool and showery conditions)

Cyclonic northerly

(Cold and showery conditions)

Weather pattern: "one of many broad-scale atmospheric circulation types over a particular area – that differs in characteristics from other weather pattern classifications over the same domain –and can vary on a daily basis".

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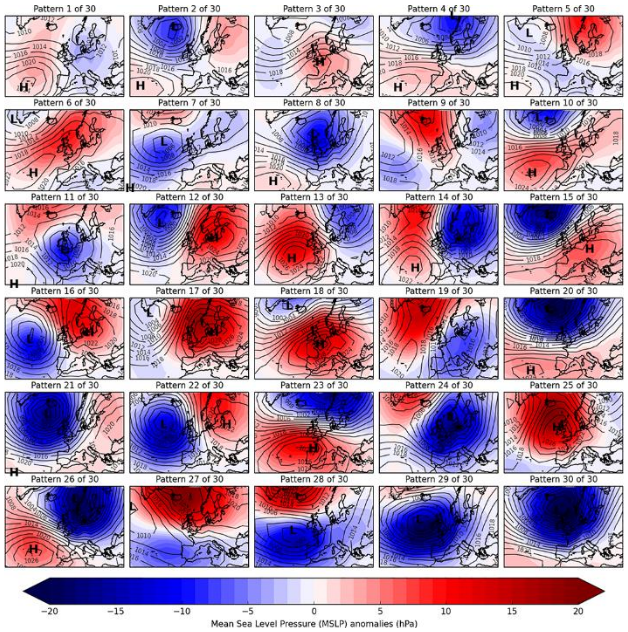
A weather pattern approach to assisting decision-making – “Decider”

The Met Office has established a set of 30 predefined weather pattern types by clustering 154-years of daily averaged Mean Sea Level Pressure Anomalies.

These are used for the examination of variability within large-scale circulation types up to several weeks ahead, and numbered by annual historic occurrence.



A weather pattern approach to assisting decision-making – “Decider”

Ensemble members are assigned to the closest of 30 weather pattern definitions, simplifying the data into a sequence of probabilities.

Occurrence of each weather pattern may be correlated with the viability of different types of offshore operations at a local scale.

	Thu 1 Jan	Fri 2 Jan	Sat 3 Jan	Sun 4 Jan	Mon 5 Jan	Tue 6 Jan	Wed 7 Jan	Thu 8 Jan	Fri 9 Jan	Sat 10 Jan	Sun 11 Jan	Mon 12 Jan	Tue 13 Jan	Wed 14 Jan	Thu 15 Jan
Pattern 1												2			4
Pattern 2											2		2		2
Pattern 3															
Pattern 4													2	2	2
Pattern 5															
Pattern 6															
Pattern 7															2
Pattern 8											4	4	2	4	6
Pattern 9															
Pattern 10								2	2					2	2
Pattern 11															
Pattern 12					4	6	2	2					4		2
Pattern 13				2						2			2		2
Pattern 14											4	4	2		12
Pattern 15					20	61	29	2		2		6	4	10	2
Pattern 16															
Pattern 17					2										
Pattern 18				98	73	16	2	2			2	4	2	6	2
Pattern 19															
Pattern 20						12	49	47	25	12	10	18	22	22	14
Pattern 21							10		2		4	2	10	8	2
Pattern 22														2	
Pattern 23	100	100	100		2	6		4	14	10	10	4	6	10	18
Pattern 24											6	2	6	4	
Pattern 25															
Pattern 26								10	39	63	41	20	16	18	27
Pattern 27															
Pattern 28															
Pattern 29												2			2
Pattern 30							8	31	18	12	18	33	22	14	

http://exvmogwebprod01/~regimes/decider/home.shtml

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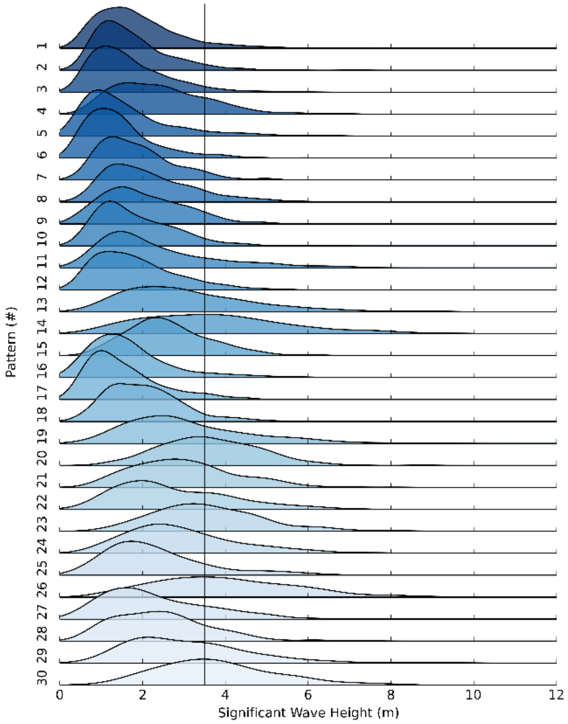
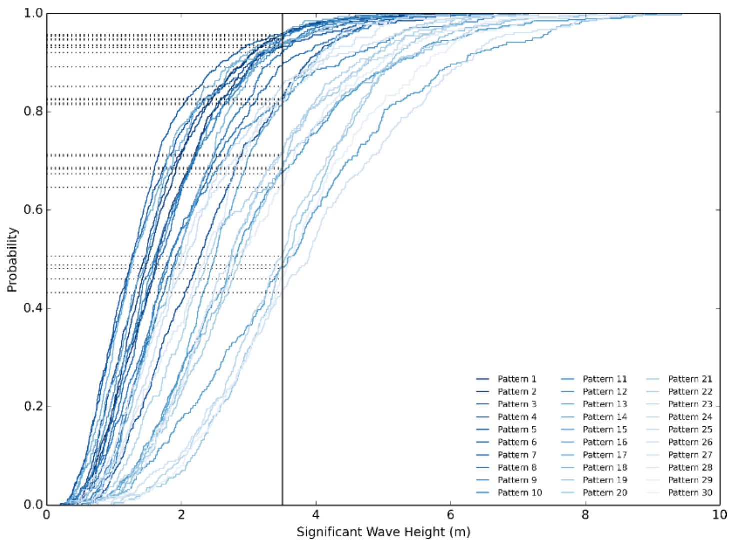
A weather pattern approach to assisting decision-making – “Decider”

Example set of KDEs of daily maximum significant wave height for each of the historical weather pattern classifications for the location of interest (Central North Sea).



A weather pattern approach to assisting decision-making – "Decider"



$$P(H_s < \delta) = \sum_{i=1}^{30} P(H_s < \delta \mid Wi) \,.\, P(Wi)$$

	Thu 1 Jan	Fri 2 Jan	Sat 3 Jan	Sun 4 Jan	Mon 5 Jan	Tue 6 Jan	Wed 7 Jan	Thu 8 Jan	Fri 9 Jan	Sat 10 Jan	Sun 11 Jan	Mon 12 Jan	Tue 13 Jan	Wed 14 Jan	Thu 15 Jan
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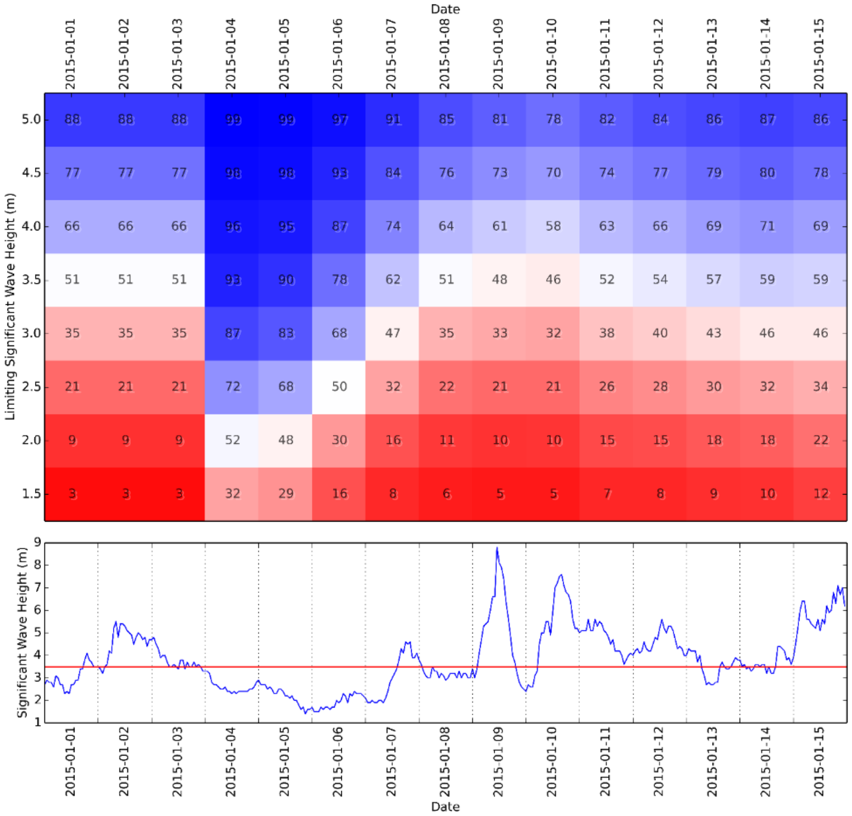
A weather pattern approach to assisting decision-making – “Decider”

Example forecast of the probability of the significant wave height being less than various maximum limits as a function of lead time.

Depending on operational limits, the user must reference that particular row of the table, with the decision to proceed with activity based on the probability of calm conditions exceeding their (pre-defined) confidence level.



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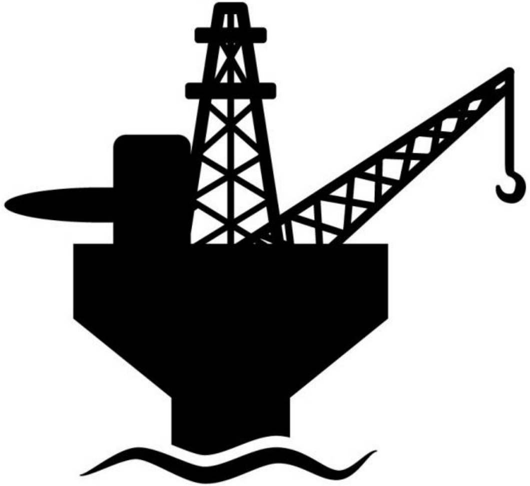

Weather pattern analysis offers the opportunity for contingencies to be established.

Useful in anticipating how long equipment / personnel will remain offshore if conditions are favourable at the outset but delays in preceding operation mean weather windows are misses, or when to plan for re-deployment following an installation shut down.

Knowing the odds of having a sustained period of limited flying will also allow asset managers to re-prioritise supplies / personnel changes.

Conclusion

- The key to effective customer application is synthesising the science.
- To enable users to assess weather risks, two established methods for the efficient interpretation of probabilistic data based on cost-loss and regime analysis are described and applied to ocean wave forecasting;
  - Cost-loss analysis offers an objective method of determining ensemble thresholds;
  - Regime analysis offers an intuitive approach to simplifying ensemble forecasts;
- Appropriate use of these methods will enable more timely decision-making and therefore help reduce operational costs for the offshore energy sector;
- Ultimately, planning will be best supported by the use of forecasts across all timescales;

Thank you for listening!

Dr Edward Steele

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Find out more in our recent publications:

- **Steele et al. (2017)** Making the most of probabilistic marine forecasts on timescales of days, weeks and months ahead. DOI: https://doi.org/10.4043/27708-MS.
- **Steele et al. (2018)** Using weather pattern typology to identify calm weather windows for local operations. DOI: https://doi.org/10.4043/28784-MS.