Verification challenges in developing TC response procedures based on ensemble guidance

Grant Elliott
Senior Metocean Meteorologist

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woodside

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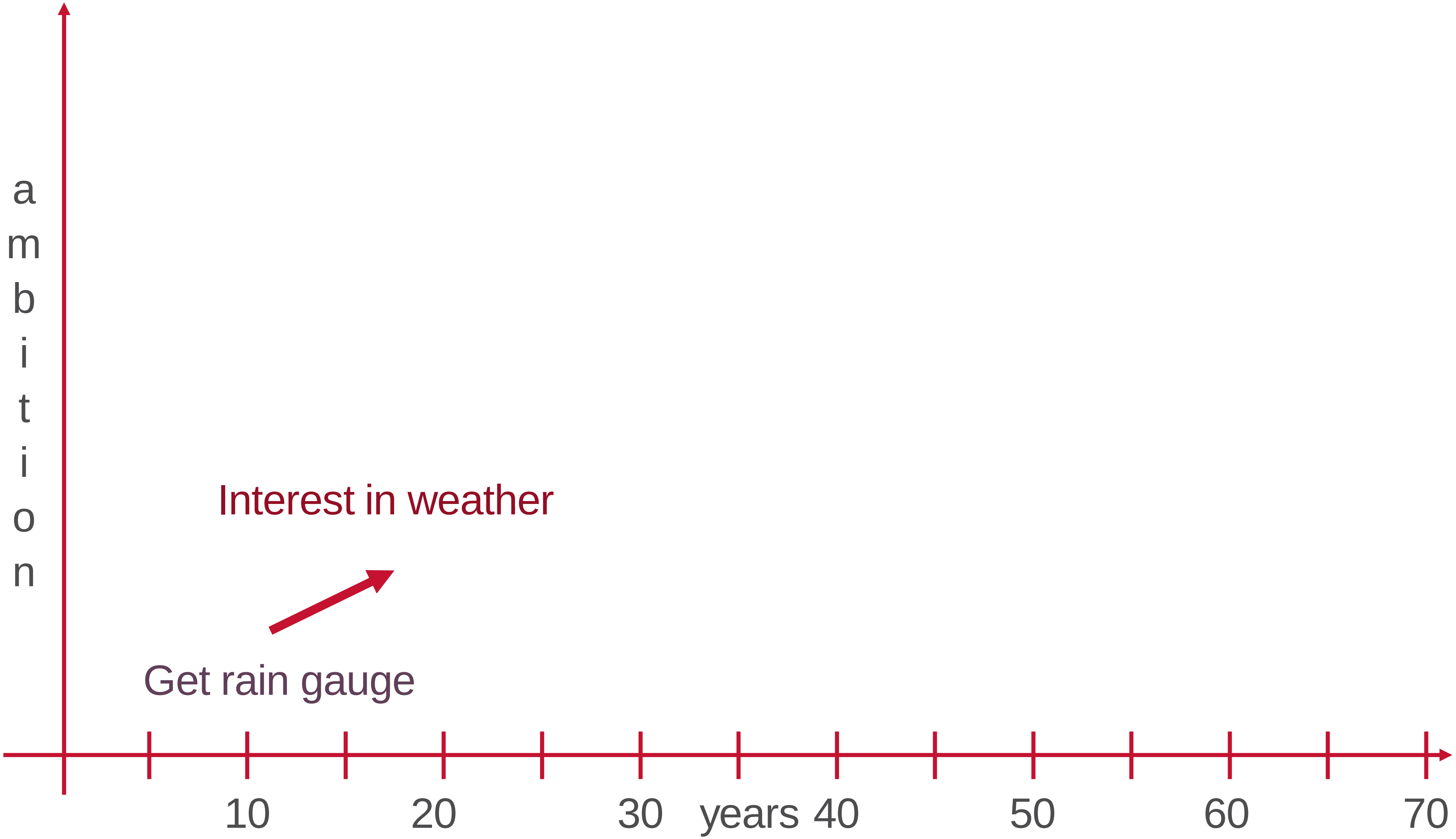
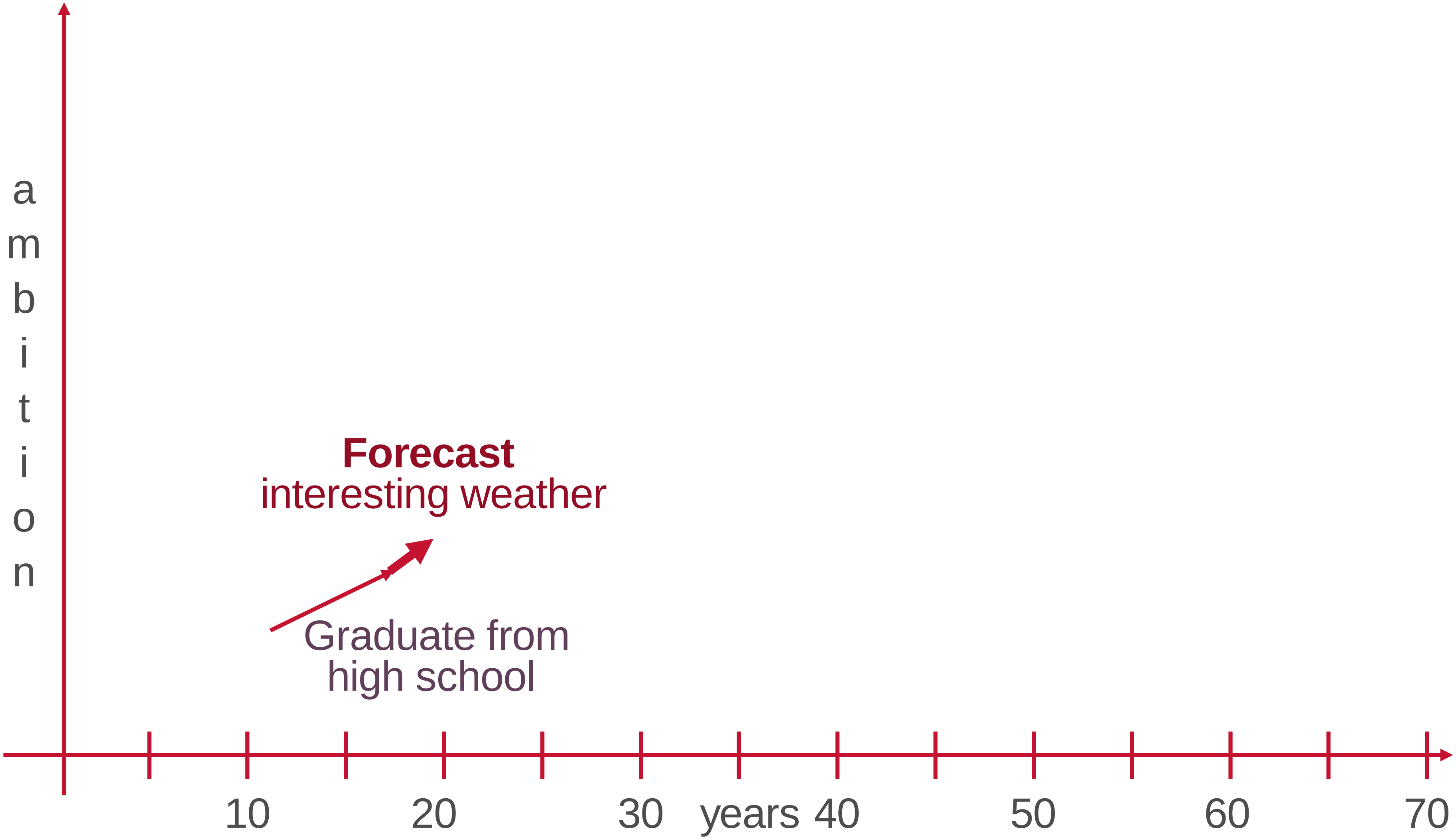
All references to dollars, cents or $ in this presentation are to US currency, unless otherwise stated.

References to “Woodside” may be references to Woodside Petroleum Ltd. or its applicable subsidiaries.

.. Career pathway .. as explained by Hewson / Sharpe / Rodwell .. in terms in of data assimilation .. determinism and ensemble jumps ..

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Forecast
interesting weather
Graduate from
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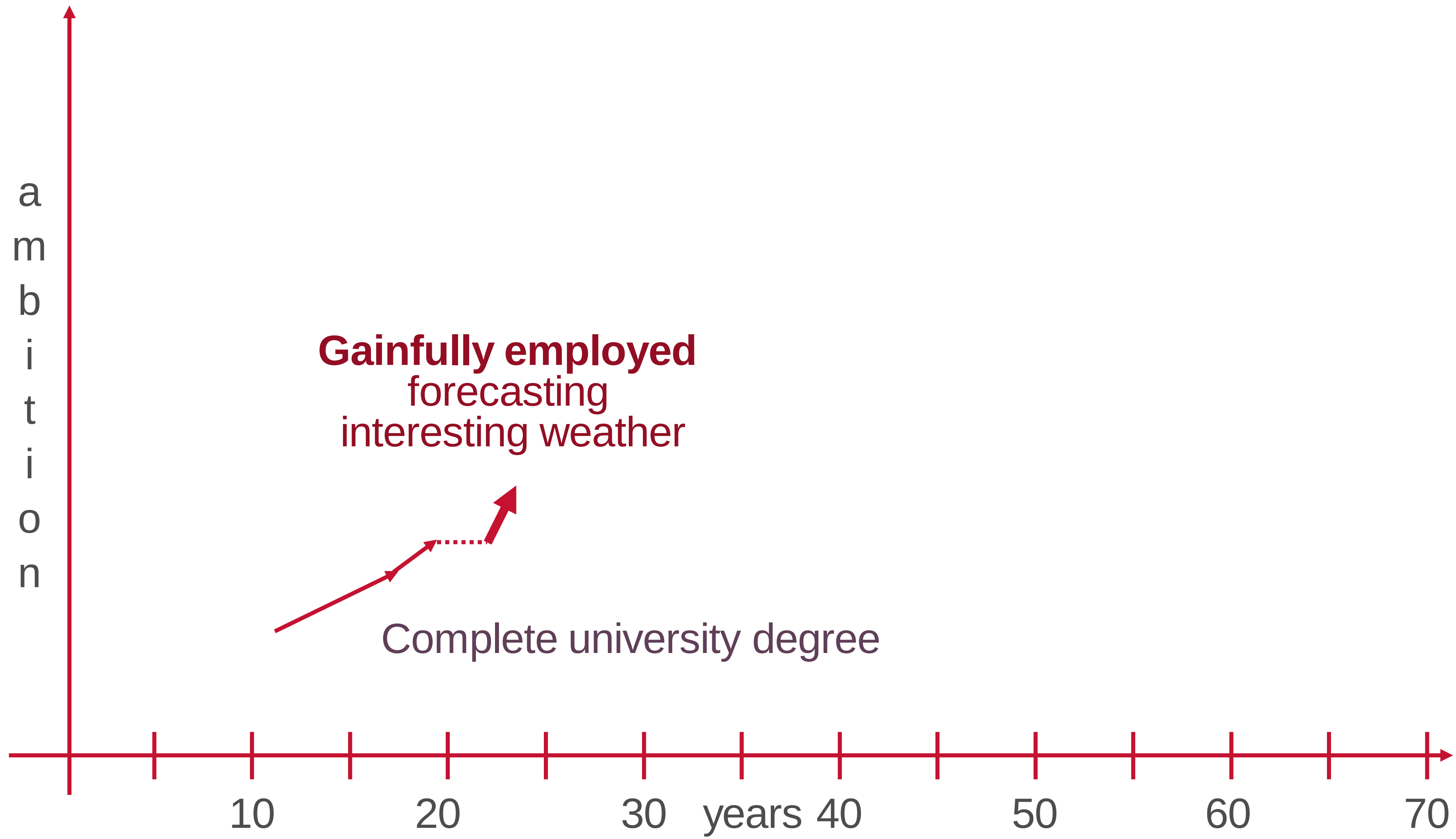
ambition
Gainfully employed
forecasting
interesting weather
Complete university degree
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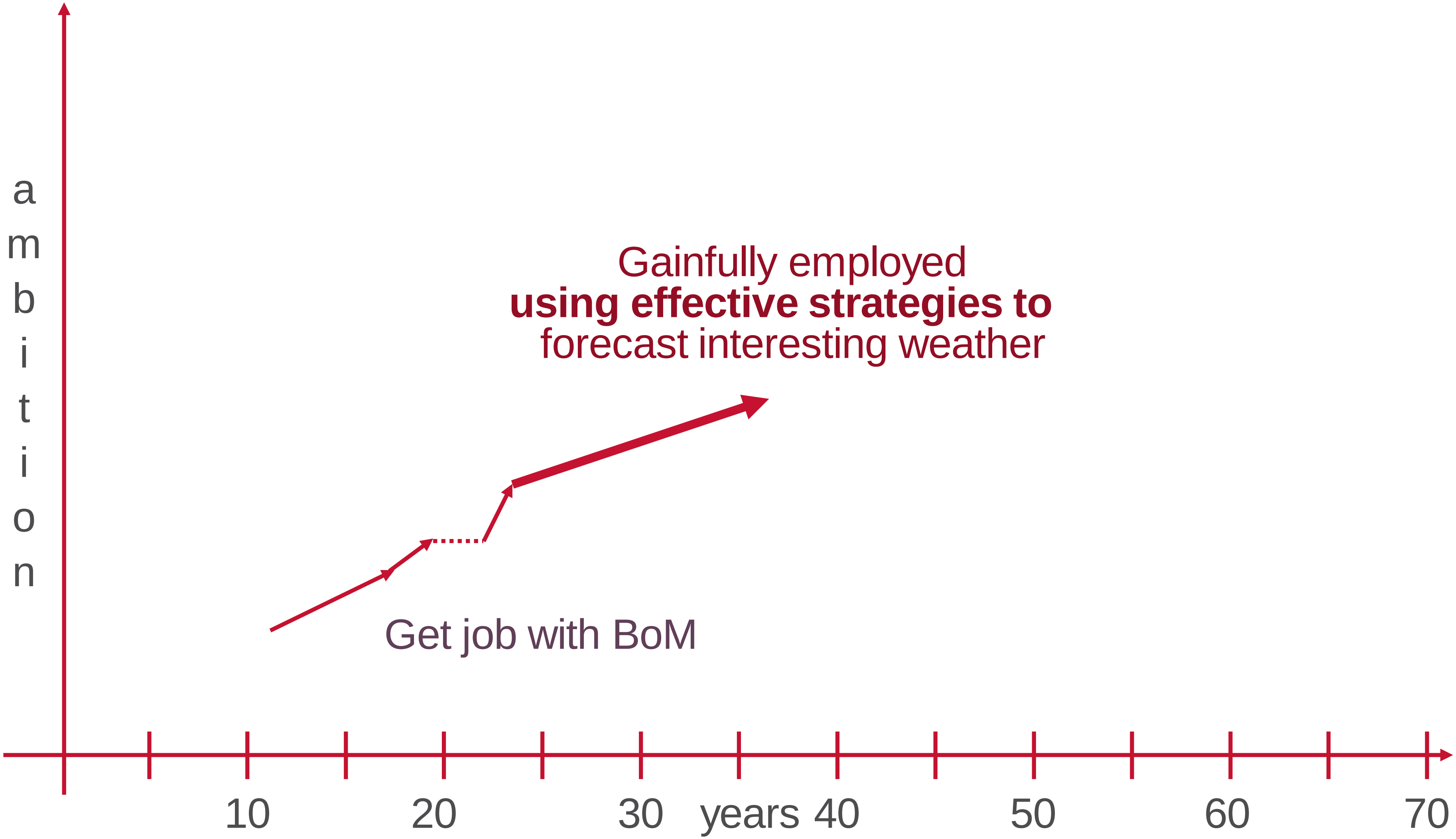

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Gainfully employed
using effective strategies to
forecast interesting weather
Get job with BoM
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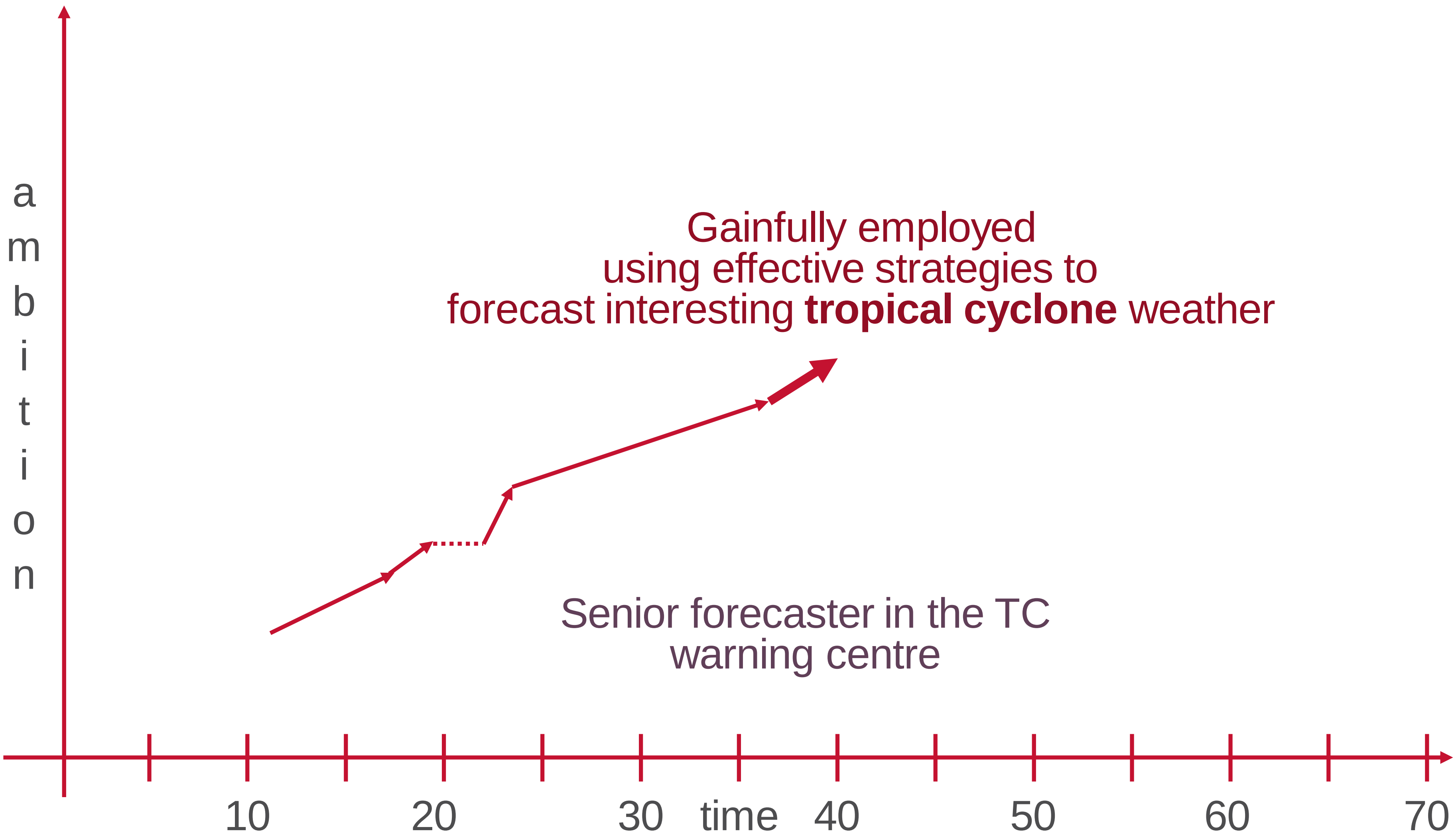
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Gainfully employed
using effective strategies to
forecast interesting **tropical cyclone** weather
Senior forecaster in the TC
warning centre
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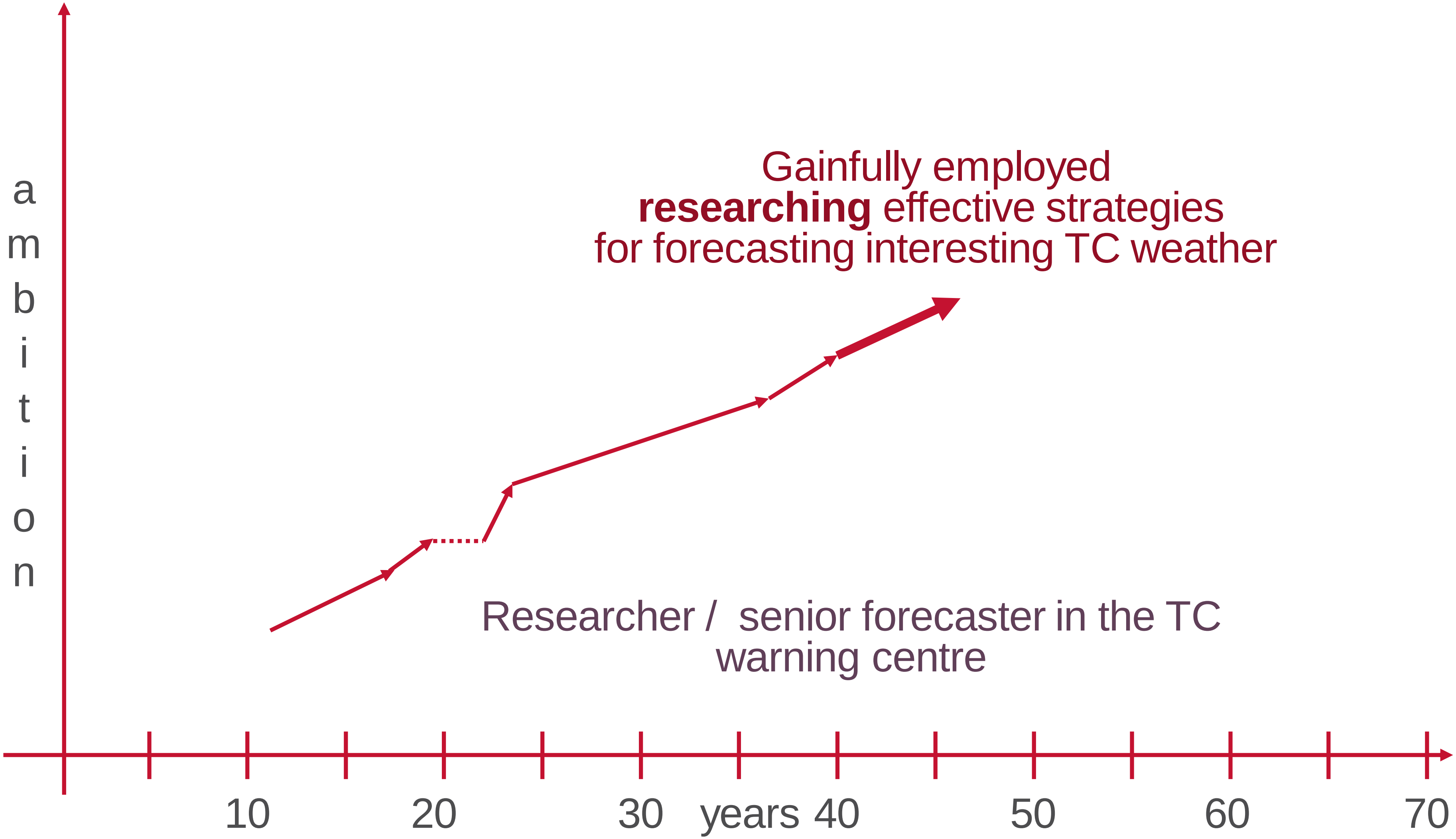
Gainfully employed
researching effective strategies
for forecasting interesting TC weather
Researcher / senior forecaster in the TC
warning centre
ambition
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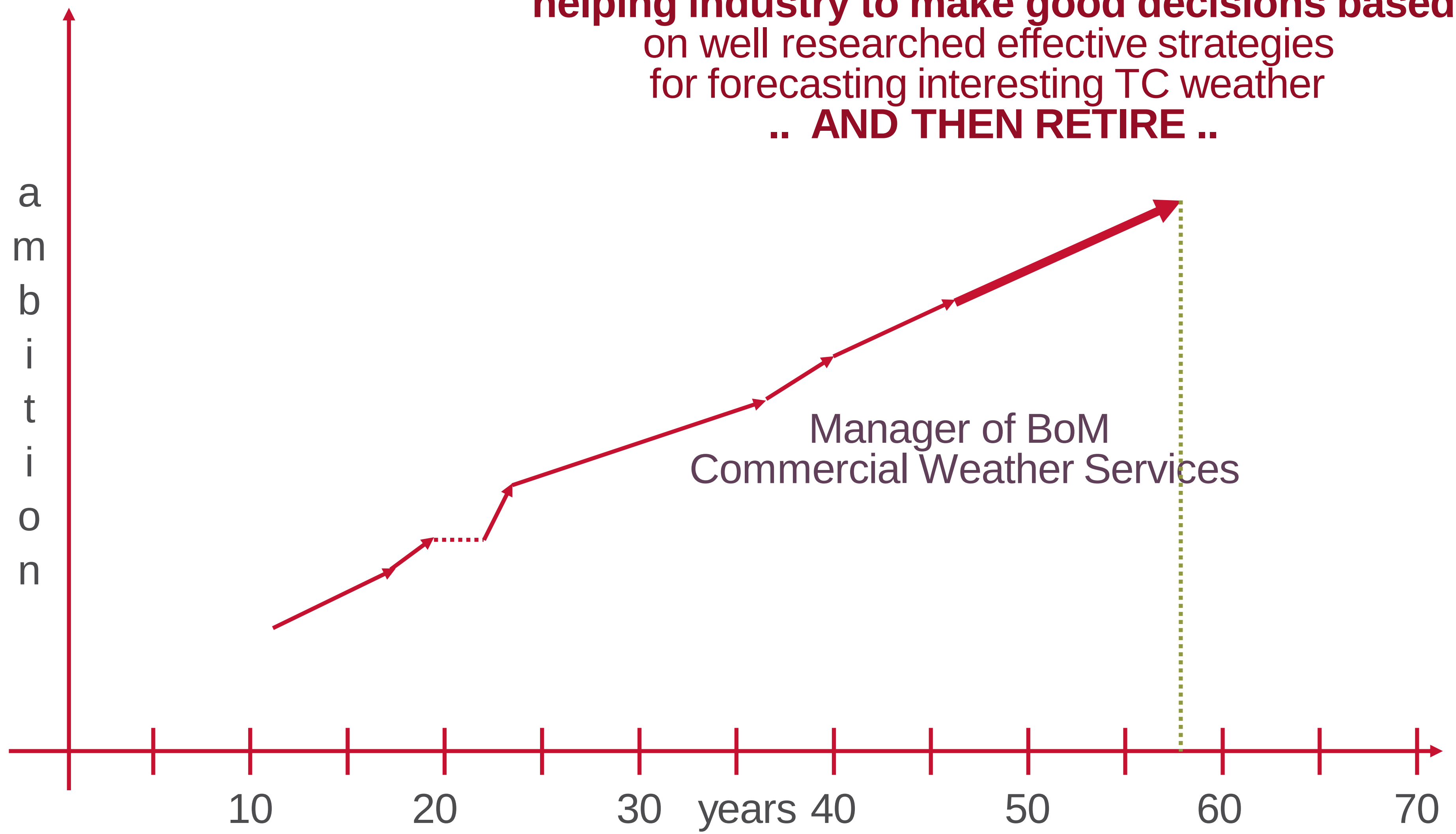
Gainfully employed
helping industry to make good decisions based
on well researched effective strategies
for forecasting interesting TC weather
.. AND THEN RETIRE ..




Change industry best practice
Demonstrate safety case
Develop fit for purpose
guidance metrics and products
Train decision makers
Build new procedures
Develop training material
Changed jobs and joined
Woodside Energy (an oil and gas company)
a m b i t i o n
10
20
30
years
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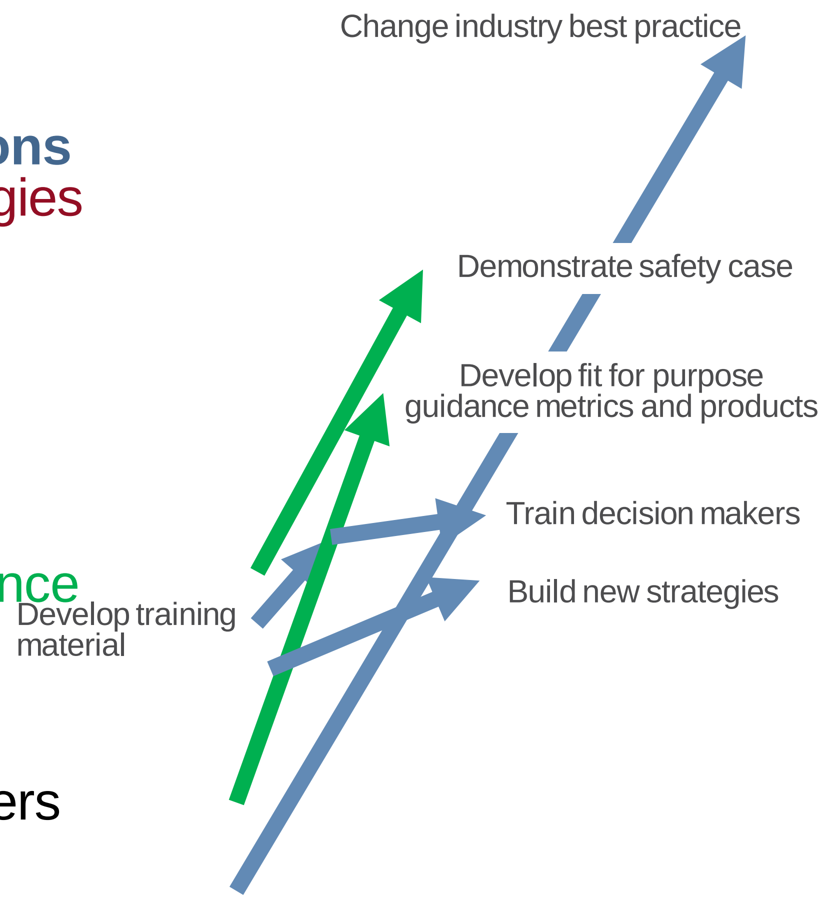
.. so want went wrong ..

Gainfully employed
helping industry to make good decisions
based on well researched effective strategies
for forecasting interesting TC weather

VISION / AMBITION

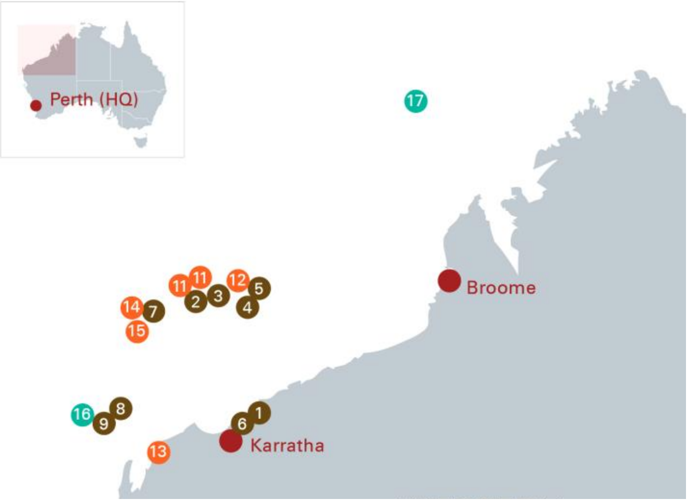
- Effective response strategies
- That maintain a safe workplace
- Based on fit for purpose well verified guidance inputs
- Provided in easy to consume products
- Implemented by well trained decision makers
- Who have practiced on effective use of the products
- And understand the strengths and weaknesses of the strategies



Talk Outline

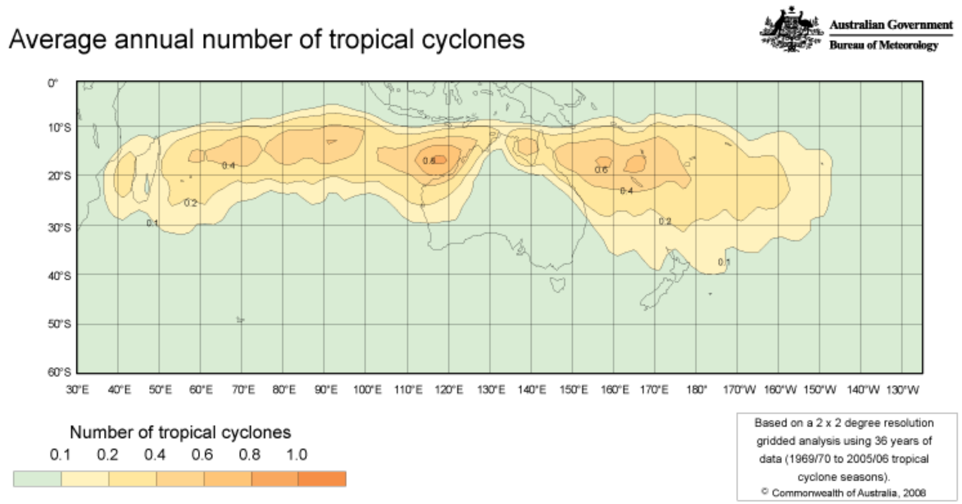
- Outline briefly when and why Woodside respond to TC threats
- Identify how response strategies might change based on probability of TC impact guidance
- Discuss research work that the Australian Bureau of Meteorology (BoM) have done to develop calibrated ensemble based probability guidance
- Describe (verification) challenges in incorporating this TC impact guidance into new response procedures
- How ECMWF may be able to assist ..

Woodside Australian operations / Tropical cyclone activity

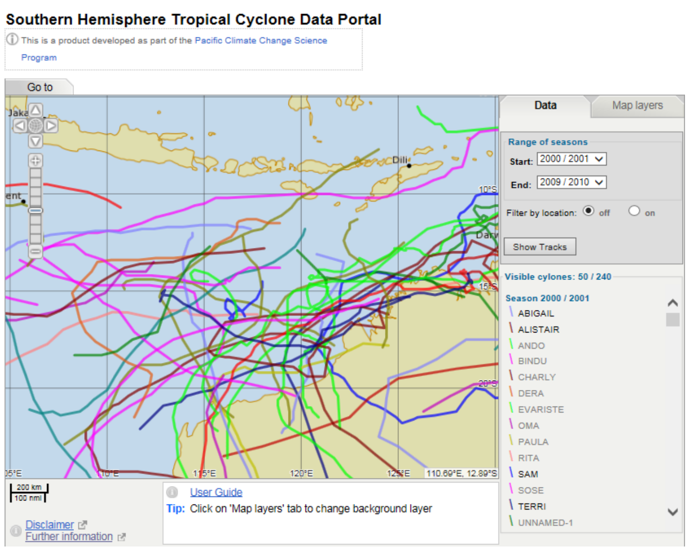


Producing Assets		
1	Karratha Gas Plant	North West Shelf
2	Goodwyn A platform	North West Shelf
3	North Rankin Complex	North West Shelf
4	Okha FPSO	North West Shelf oil
5	Angel platform	North West Shelf
6	Pluto LNG Plant	Pluto
7	Pluto LNG platform	Pluto
8	Ngujima-Yin FPSO	Vincent oil
9	Nganhurra FPSO	Enfield oil
Projects		
10	Greater Western Flank Phase 1	North West Shelf
11	Greater Western Flank Phase 2	North West Shelf
12	Persephone	North West Shelf
13	Wheatstone LNG Plant (non-operated)	Wheatstone
14	Wheatstone LNG platform (non-operated)	Wheatstone
15	Julimar	Julimar, Brunello
Developments		
16	Greater Enfield Oil	Enfield oil
17	Browse Development	Browse

Average annual number of tropical cyclones

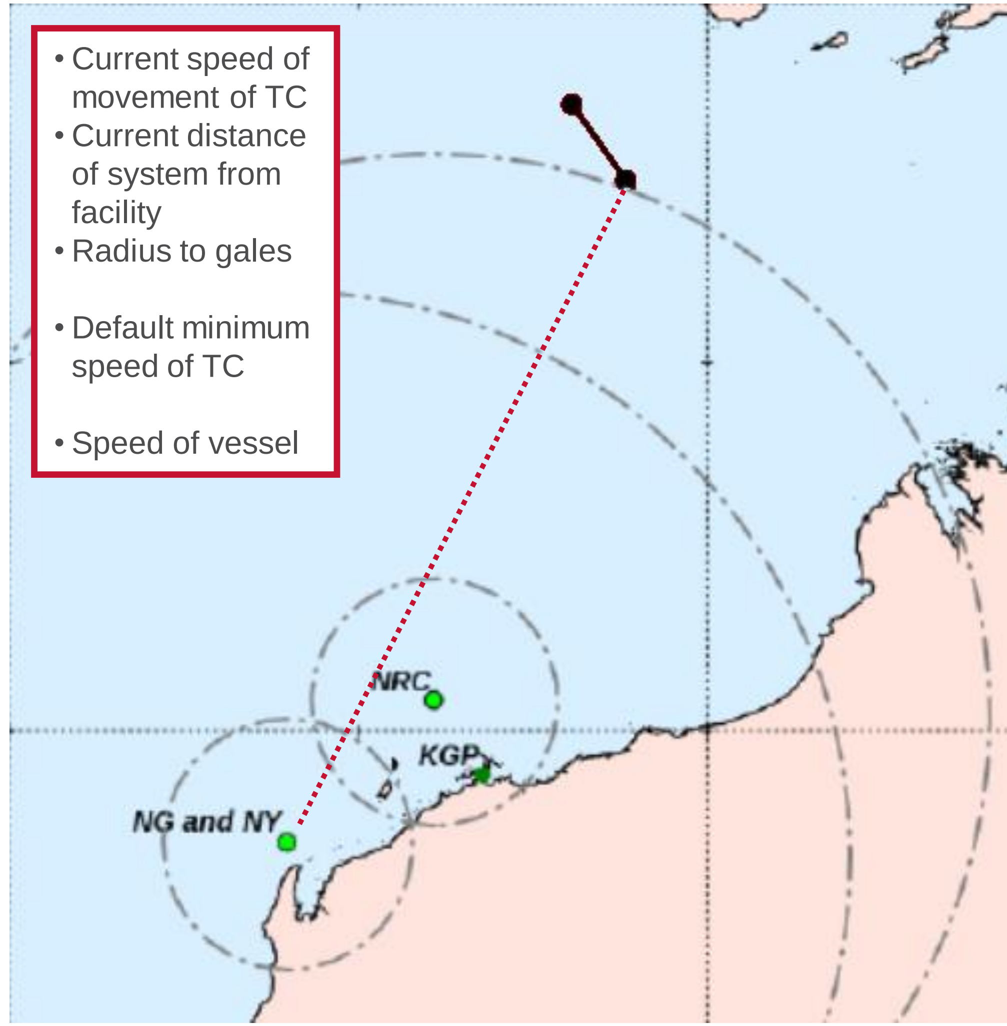


http://www.bom.gov.au/climate/maps/averages/tropical-cyclones/



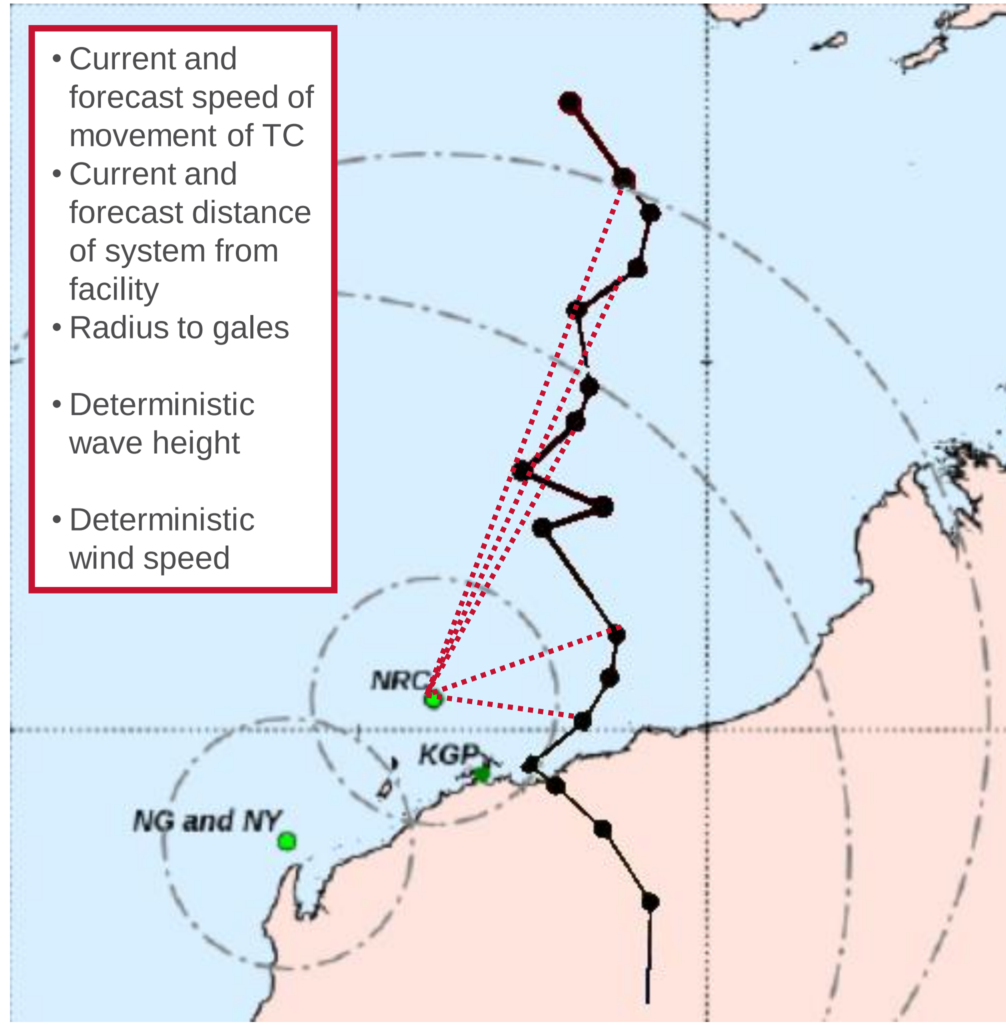
http://www.bom.gov.au/cyclone/history/tracks/index.shtml

Woodside Floating Production, Storage and Offloading vessels (FPSO)



- Decision to disconnect is made if excessive wave height (say 5 metres) is expected during a TC (takes between 10 to 40 hours to disconnect)
- Aim to disconnect 24 hours prior to the arrival of gales.
- Presently only use OBSERVED characteristics to determine when gales may arrive

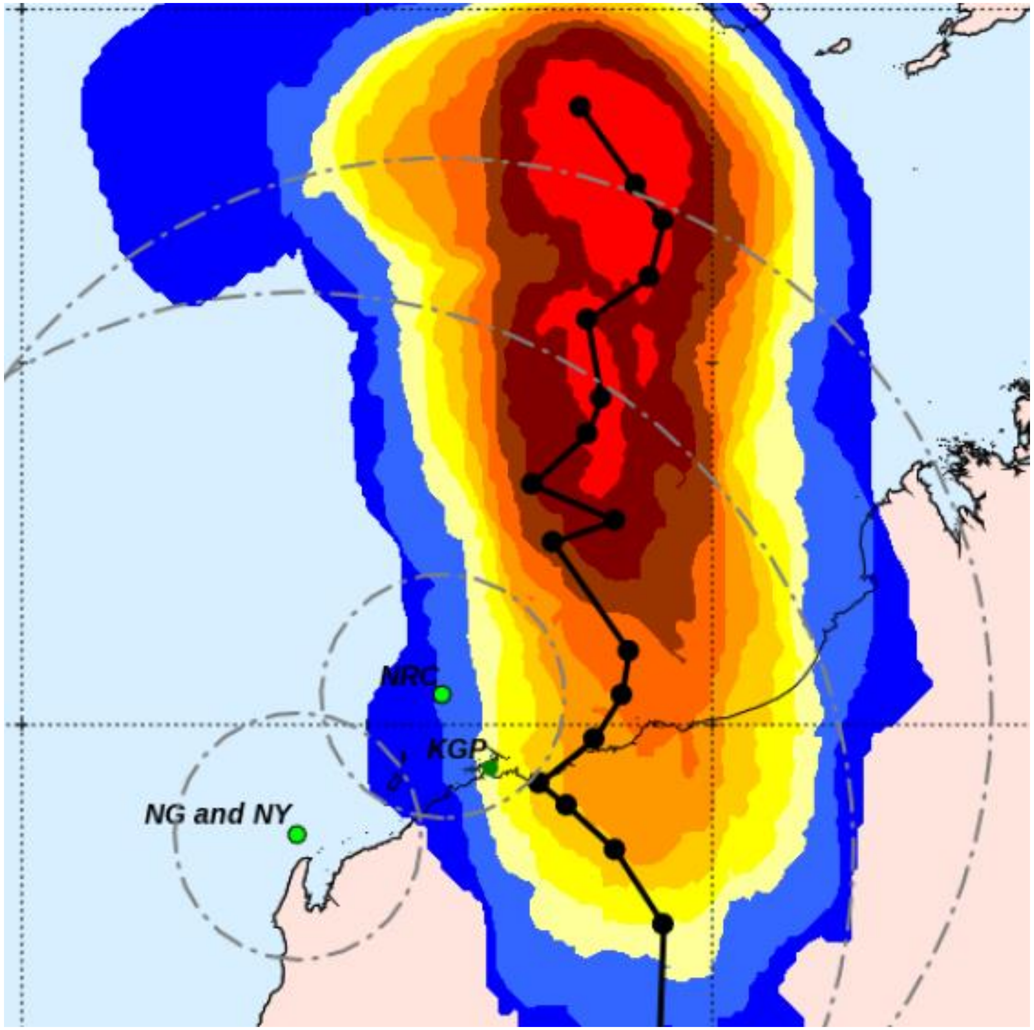
Woodside manned platforms



- Decision to deman is made if excessive wave height (say 15 metres) or Cat 4 winds are expected during a TC (takes between 12 to 24 hours to deman)
- Arrival time of gales is used as a proxy for time to complete demanning.
- Only use OBSERVED and DETERMINISTIC forecast characteristics to decide when to deman..

The proposed change - TC response procedures

- Current response strategies only refer to OBSERVED and DETERMINISTIC forecast characteristics.
- Would like to demonstrate efficacy of PROBABILITY BASED response strategies that support safe operations and improve efficiencies
- Requirement to demonstrate that using probabilities will maintain risk of failure below 1 in 10,000 year return period frequency – or As Low As Reasonably Practical (ALARP)
- Therefore there is a need for well calibrated well understood risk metrics



TC Stan - courtesy Australian Bureau of Meteorology

Joint Industry Project – Improvements to Tropical Cyclone Forecasting

Australian Bureau of Meteorology (BoM) were contracted by Chevron, INPEX, Shell Australia, and Woodside as part of a Joint Industry Project to develop the following research:

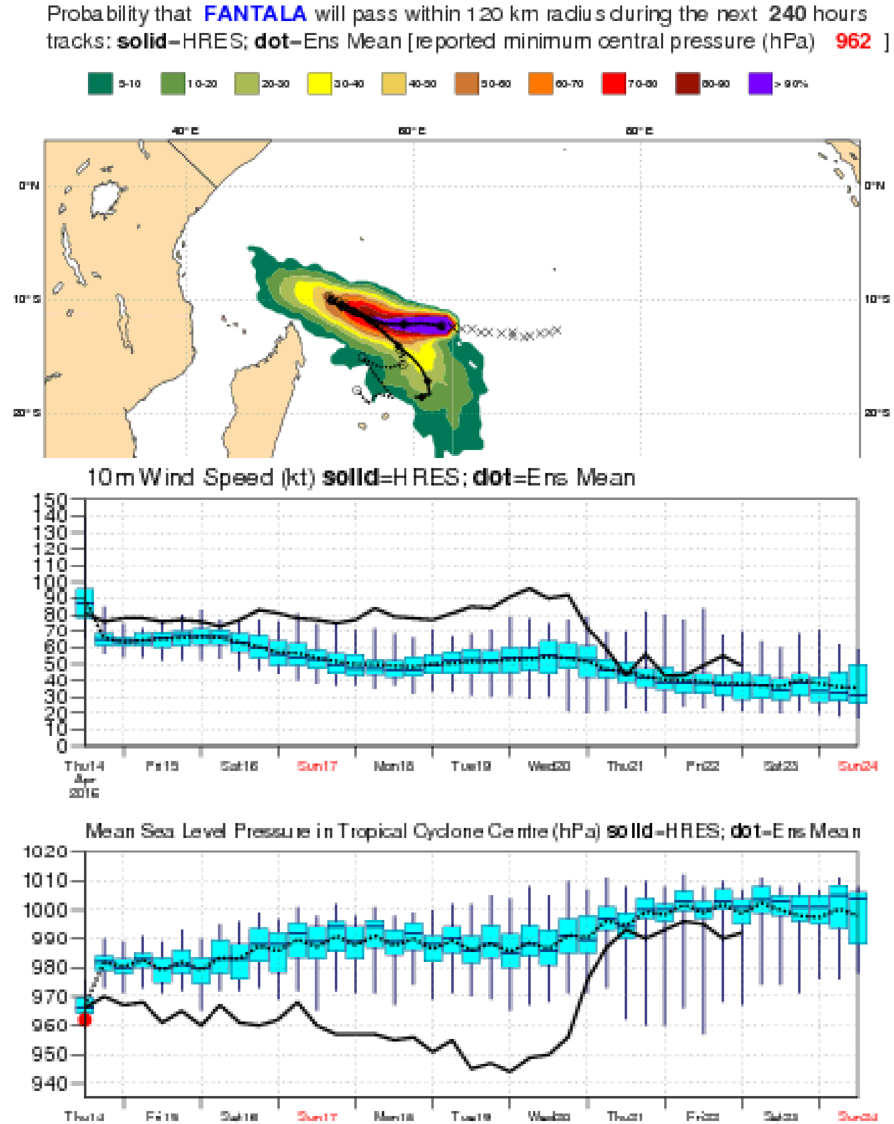
Post-processing of the ECMWF ensemble.

a. Comprehensive verification of ECMWF-EPS surface fields during tropical cyclones, including track, intensity, and size

b. **Bias correction of the EPS surface winds** for systematic errors in size and intensity

c. **Run the AUSWAVE wave model** forced by the ensemble wind fields developed in part b

d. **Comprehensive verification of the resulting fields**, including of probabilistic forecasts, ensemble spread and skill, and wave forecasts.



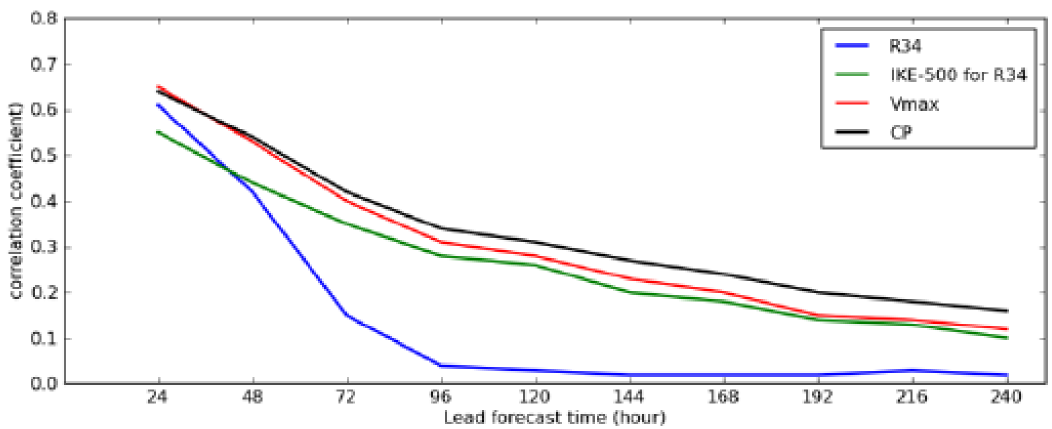
JIP research outcomes for *“Post-processing of the ECMWF ensemble”*

woodside

Bias correction using Principle Component Analysis …

… at +96 hours

- Central Pressure RMSE — 26 hPa -> 14 hPa
- Max Wind RMSE — 20 m/s -> 8 m/s
- Radius Max Wind RMSE — 113 km -> 16 km
- Radius 34 kn Wind RMSE — 68 km -> 50 km



courtesy Australian Bureau of Meteorology

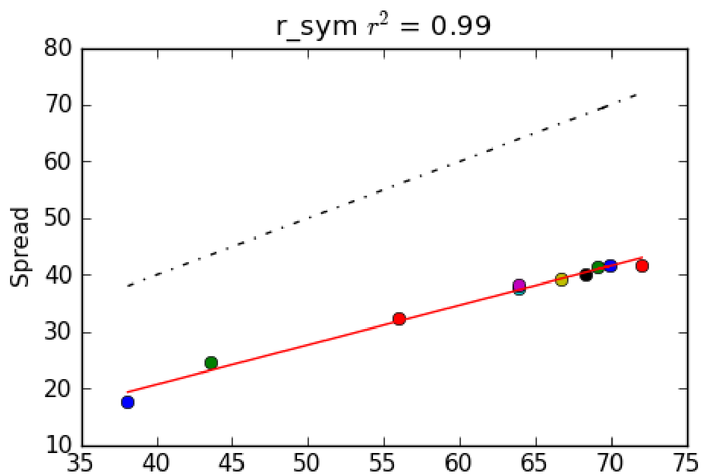
	Lead time (hour)	Uncorrected	Principal Component Analysis	Relative improvement from PCA	n
Pressure	24	21	12	43%	299
	48	22	13	41%	104
	72	24	14	42%	102
	96	26	14	46%	95
	120	26	14	46%	142
	144	28	14	50%	141
	168	28	14	50%	187
	192	29	15	48%	186
	216	30	16	47%	235
	240	30	17	43%	238
R34	24	55	32	42%	299
	48	58	39	33%	104
	72	65	42	35%	102
	96	68	50	26%	95
	120	67	49	27%	142
	144	69	55	20%	141
	168	70	60	14%	187
	192	71	65	8%	186
	216	71	65	8%	235
	240	74	69	7%	238
Speed	24	18	7	61%	299
	48	19	8	58%	104
	72	20	8	60%	102
	96	20	8	60%	95
	120	21	9	57%	142
	144	22	9	59%	141
	168	22	9	59%	187
	192	23	9	61%	186
	216	23	10	57%	235
	240	23	10	57%	238
Rmax	24	56	17	70%	299
	48	70	20	71%	104
	72	92	21	77%	102
	96	113	16	86%	95
	120	120	19	84%	142
	144	135	21	84%	141
	168	138	24	83%	187
	192	145	27	81%	186
	216	151	28	81%	235
	240	160	30	81%	238

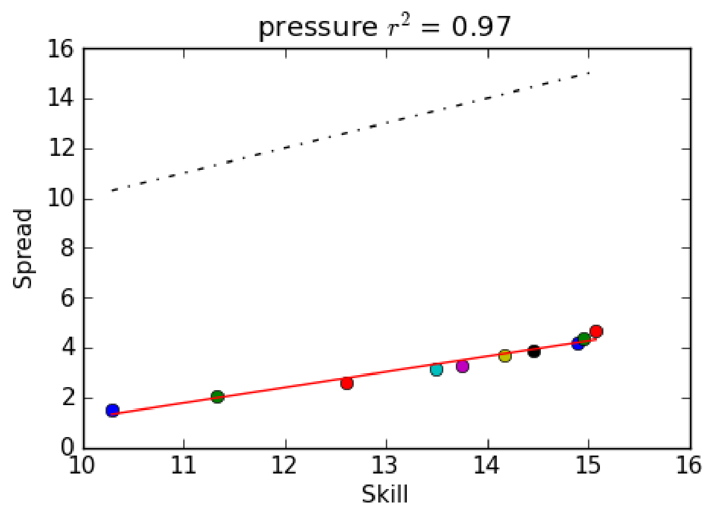
courtesy Australian Bureau of Meteorology

JIP research outcomes for *“Post-processing of the ECMWF ensemble”*

Spread-Skill relationship:

- Is being carefully evaluated
- Is improved by bias correcting the ensemble mean, rather than each ensemble member
- However ..





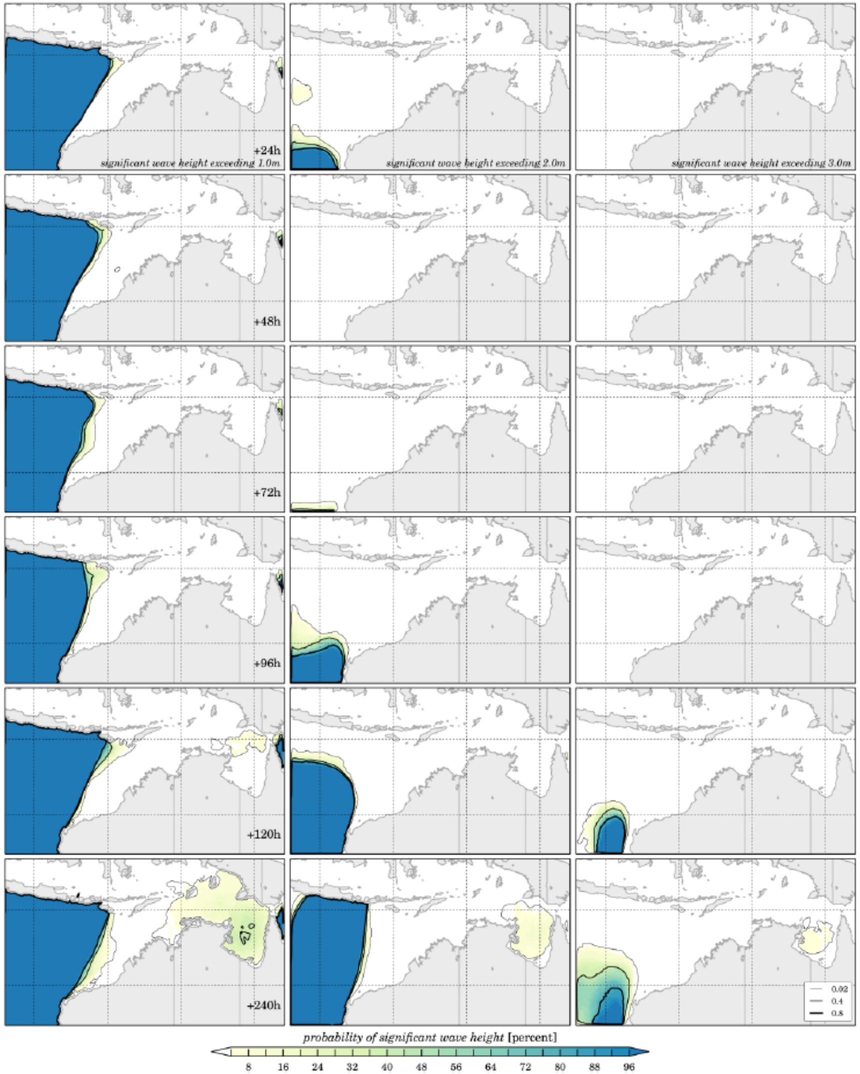
.. both Size and Intensity are significantly under-spread .. and care will be required in use of the outputs

courtesy Australian Bureau of Meteorology

JIP research outcomes for *“Post-processing of the ECMWF ensemble”*

Next steps:

- Bias corrected wind fields will be reinserted into the original ensemble forecast data, maintaining asymmetries
- A process will be developed to select initial conditions for the wave model
- AUSWAVE will then be re-run on the revised ensemble wind field to produce ensemble wave fields

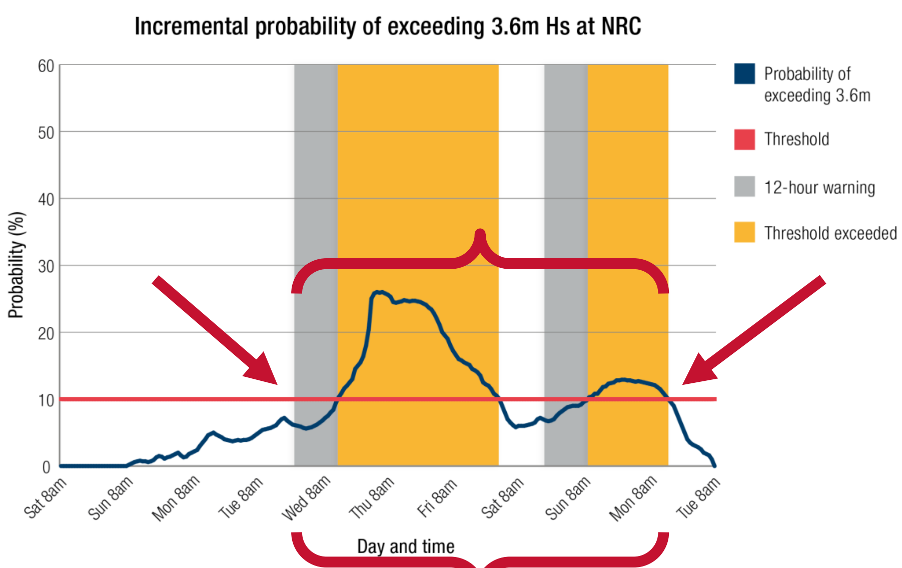


courtesy Australian Bureau of Meteorology

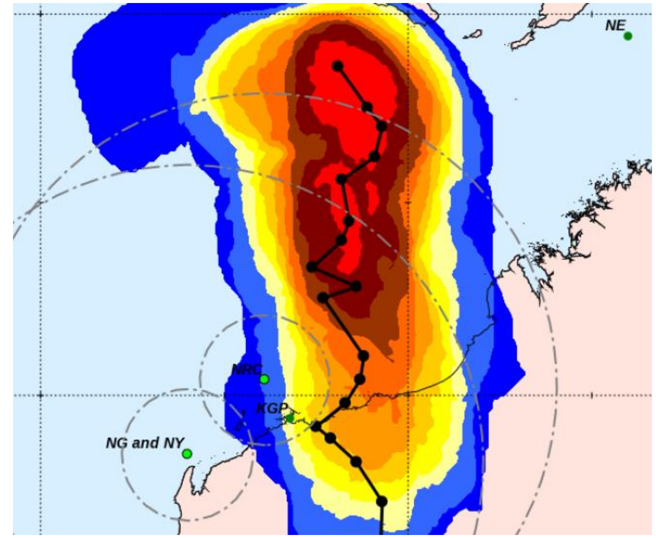
Consequential outcomes for Woodside after operationalisation

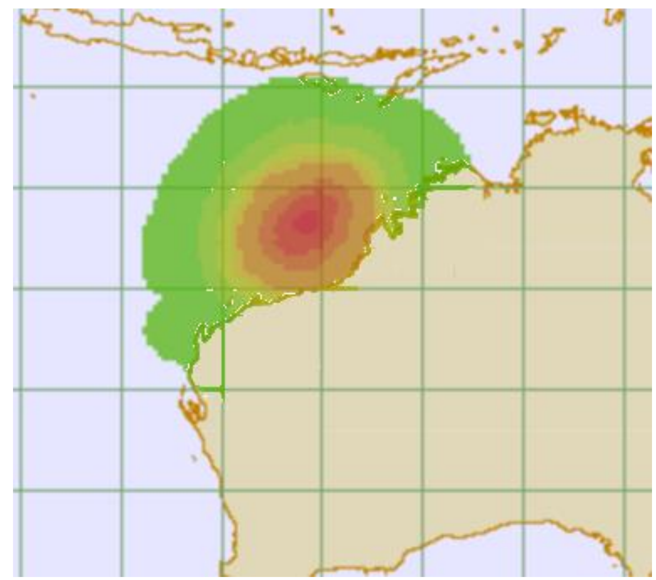
After operationalisation there will be well calibrated estimates of the risk of exceedance of critical thresholds through time and space for both wind and wave

Woodside would like to develop response procedures based on non-zero risk of exceedance of critical thresholds at assets.



courtesy Australian Bureau of Meteorology





courtesy Australian Bureau of Meteorology

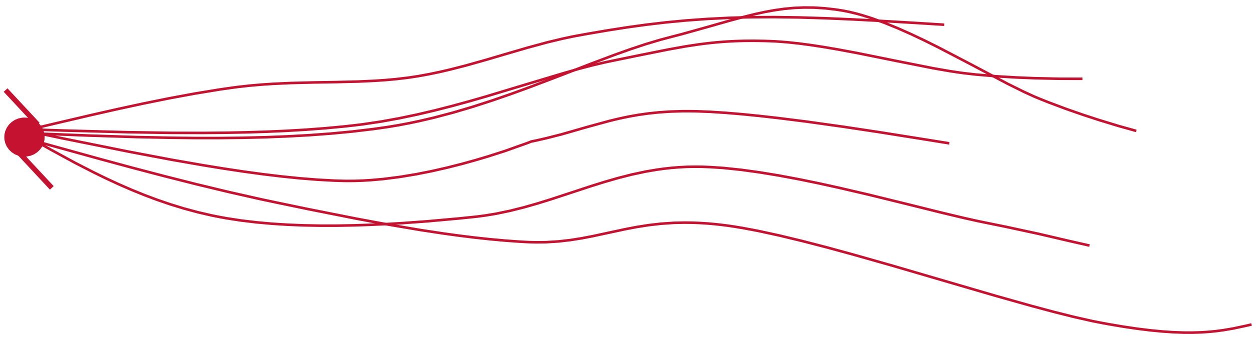
(Verification) Challenges in using probabilistic guidance

1. **Keeping Safe** .. New response procedures should keep our workforce safe .. at the same time as leading to more efficient outcomes

   - Procedures should have return periods of failure as low as 1 in 10,000 years.
   - So if ensemble location guidance is to be used it will be important to estimate return period LOCATION errors.
   - With only a limited number of forecast runs and a limited number of ensemble members to verify against, estimating the scale of potential errors in forecast TC LOCATION is challenging

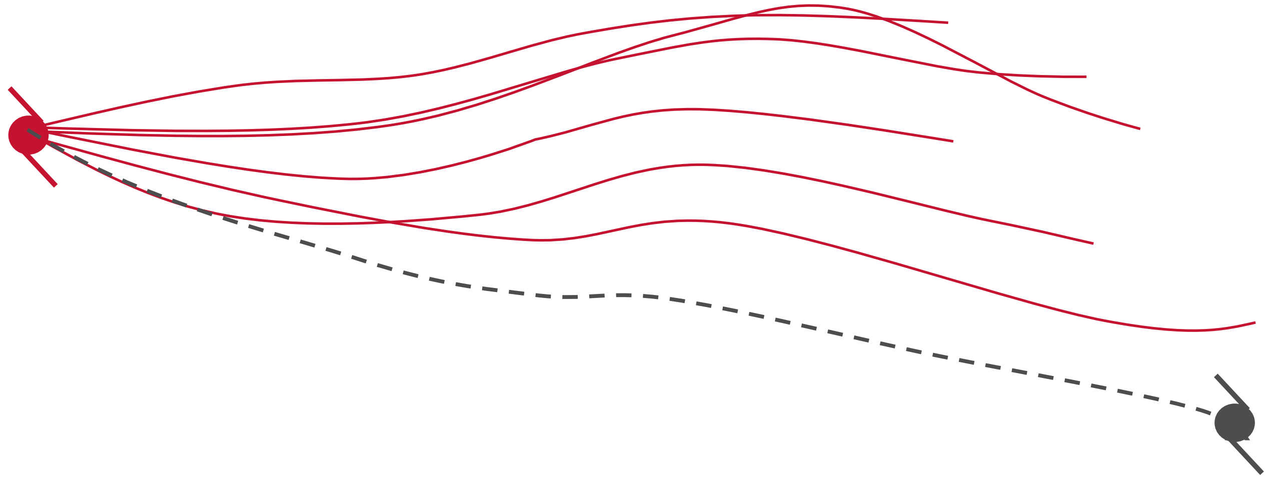
.. One possible approach ..

Using an historical dataset (say TIGGE), review the ensemble guidance TC forecast locations for a given forecast tau ..



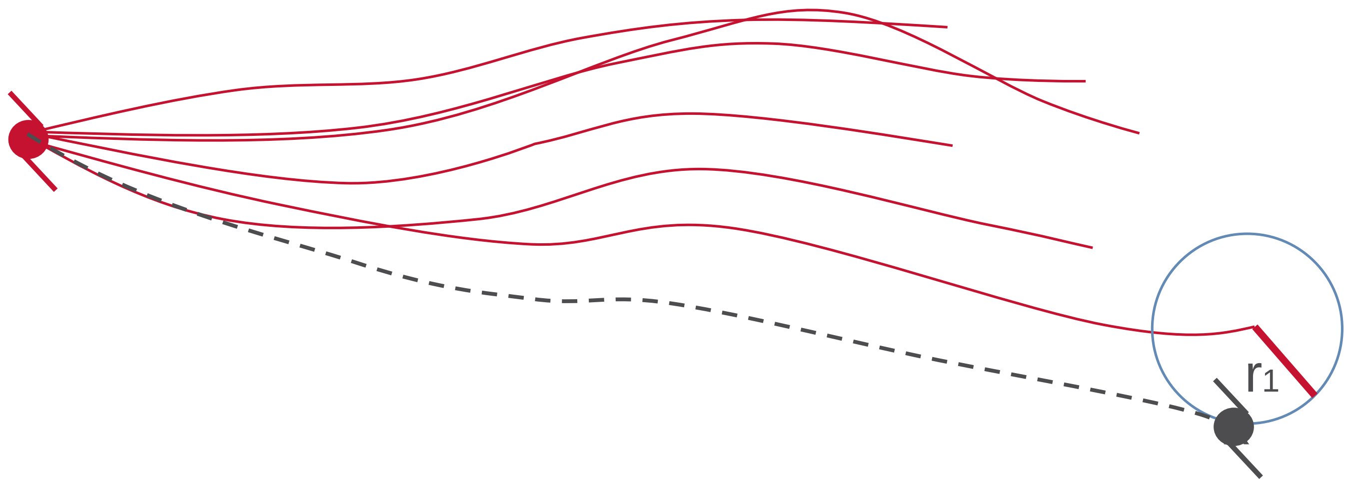
.. One possible approach ..

.. assess the best track observed location ..



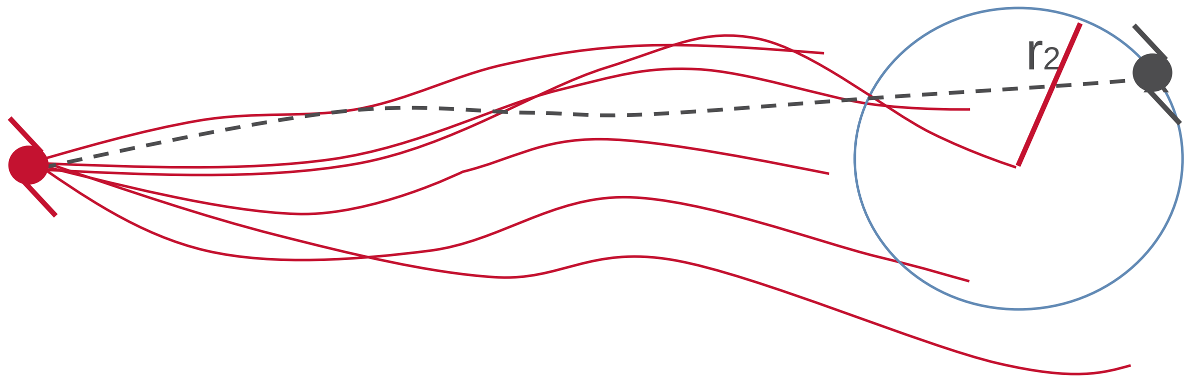
.. One possible approach ..

.. derive the smallest distance, r, to the closest ensemble member location ..



.. One possible approach ..

.. over the historical dataset ..



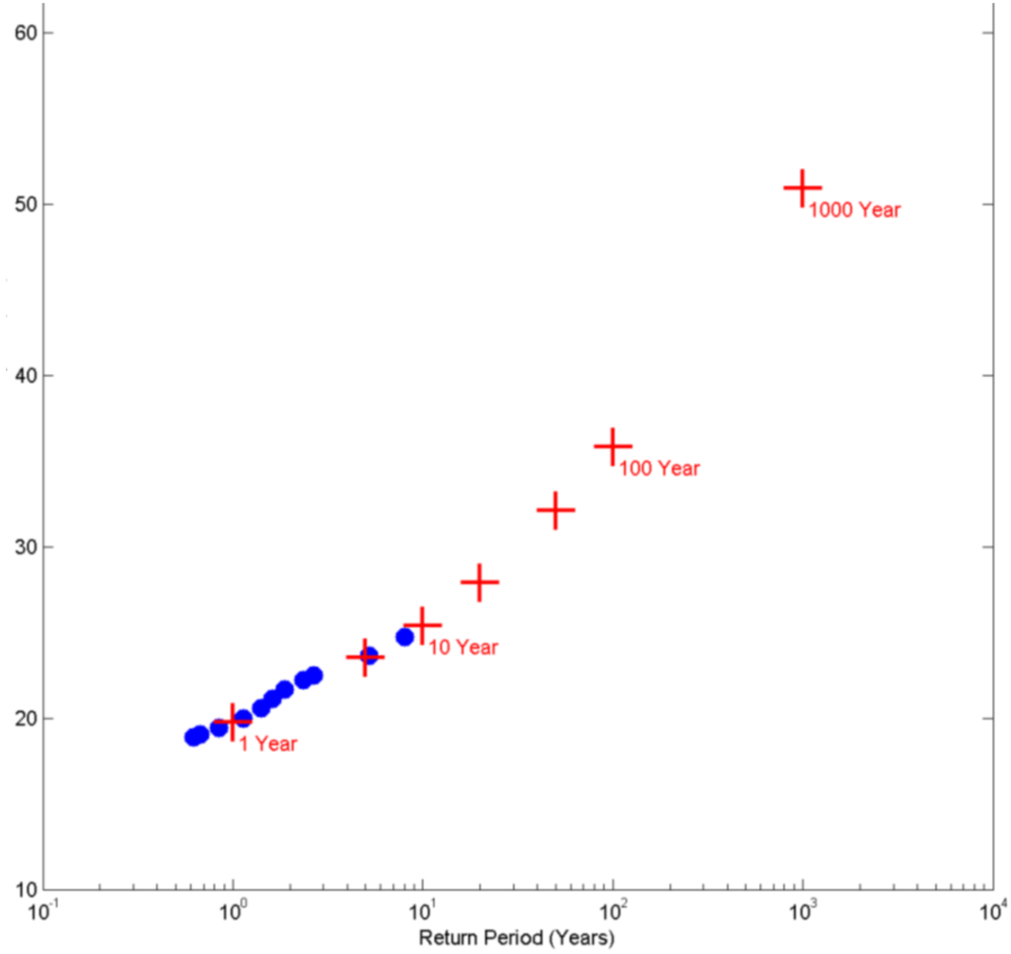
.. One possible approach ..

.. and then derive return period error estimates using an extreme value analysis approach.

These estimates could be refined by partitioning by intensity, latitude band, basin.

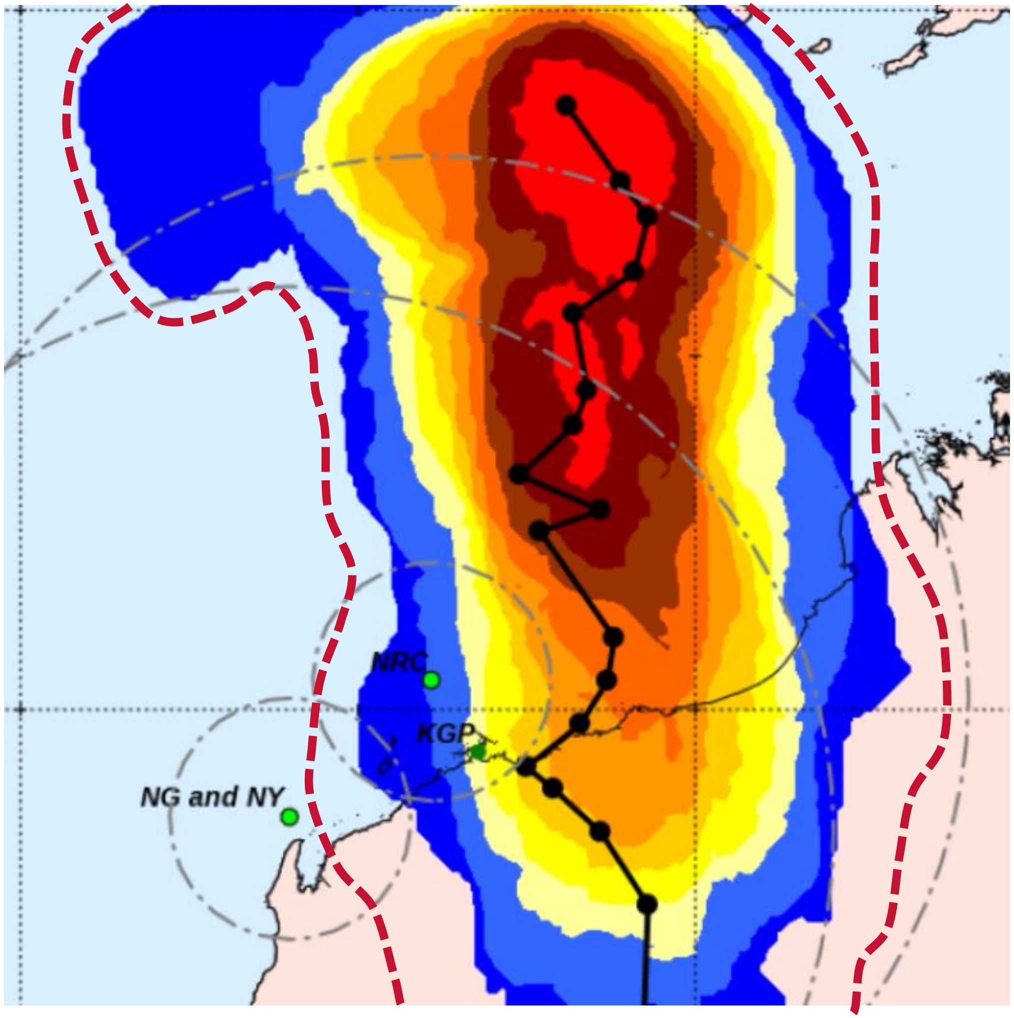
They could also be done on the n^{th} closest member to build up estimates of the value of 5%, 20%, 50%, (etc) risk metrics

r



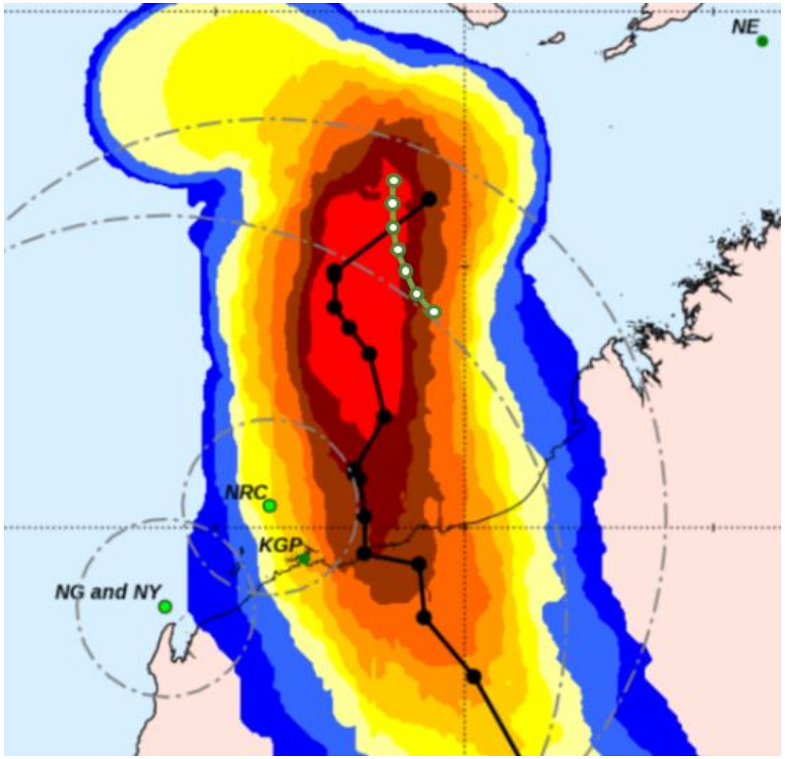
.. One possible approach ..

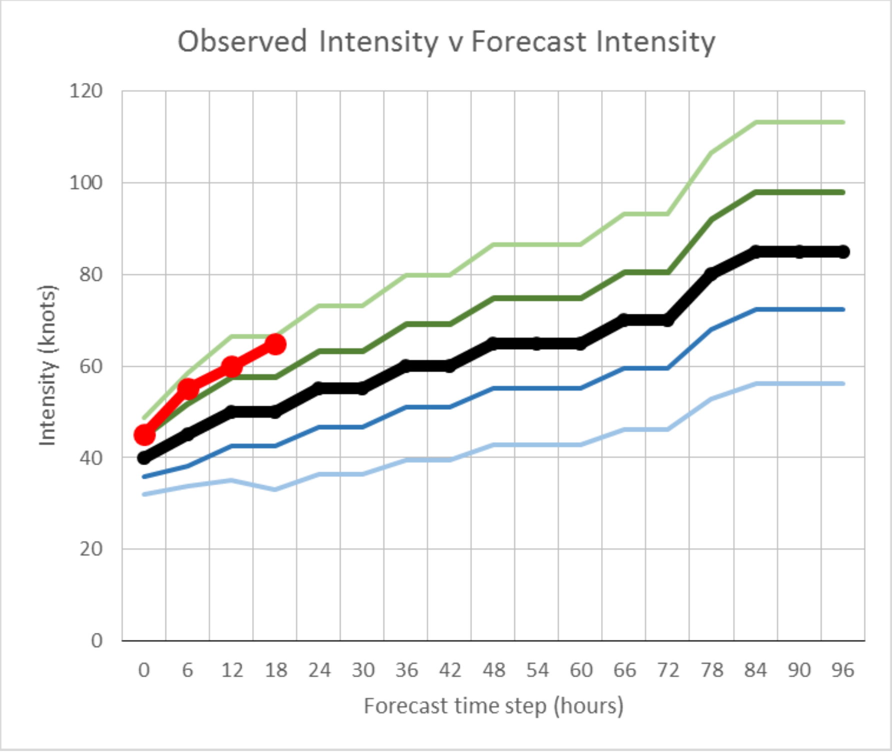
This could then inform a calibrated “cone of uncertainty” to apply to the ensemble location guidance



(Verification) Challenges in using probabilistic guidance

2. **Staying Informed ..** review the performance of the calibrated ensemble guidance against the observed TC characteristics on a 3 or 6 hourly basis.
   - An assessment should be made on a frequent basis to establish if the ensemble guidance is providing appropriate risk estimates into the short and medium term and thus whether the associated response strategies can still reliably be used.





..this could lead to a product, say ..

At 02:00 Wed 27 Jan for TC Stan

Is located 15.6S 119.2E, with 45% of ensemble members within 100 km. This is well below the norm of 75%, and therefore confidence is LOW for future location guidance.

Has moved in the last 6 hours at 11 knots, with 35% of ensemble members having speeds within 2 knots. This is well below the norm of 70%, therefore confidence is LOW for future speed of movement guidance.

Has a 10 minute maximum wind speed of 55 knots, with 60% of ensemble members having intensities within 8 knots. This is near the norm of 65%, therefore confidence is HIGH for future intensity estimates.

(Verification) Challenges in using probabilistic guidance

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3. **Maintaining Quality ..** reliable use of calibrated TC ensemble guidance is predicated on invariance in model TC climatology.

- When significant model upgrades occur a re-calibration action is needed prior to changeover.
- This consequentially means developing an understanding of how the model TC climatology has changed, and how to modify the calibration components.
- BoM did research the weekly 5 ensemble / 18 year hind cast for use in recalibration. Unfortunately the ECMWF hind cast TC climatology is different to the ensemble TC climatology (due to differences in data assimilation) therefore its use is problematic.

.. so this might be accomplished by ..

ECMWF being able to provide a weekly hind cast TC dataset with similar climatological characteristics to the ensemble (problematic due to DA challenges)

A clever comparison between TC hind casts of the older model version against the newer model version (problematic as it assumes that the delta between versions is the same in hind cast mode as in ensemble mode)

A moving average approach where the calibration is updated on a weekly or monthly basis (good but still suffers in the first phase of implementation)

ECMWF being able to provide grids or TC tracks for pre-operational model runs to enable calibration (good but the number of calibration events may be smaller than desired)

In summary ..

1. Bias correction is expected to add significant value to ensemble based probability guidance (wind AND rain) on potential TC impacts
2. **Keeping Safe ..** New procedures using probability guidance will require underpinning verification to demonstrate continued alignment with safe work outcomes
3. **Staying Informed ..** Short lead time verification will provide insight into the short and medium operational reliability of the guidance
4. **Maintaining Quality ..** Ongoing calibration of the bias corrections will be required when significant model upgrades occur

.. therefore ..

5. ECMWF may be able to assist by providing to service providers (BoM) the **grids or TC tracks** from pre-operational model runs to enable timely recalibration.
6. ECMWF may be able to assist by providing to service providers (BoM) example **high impact events** from pre-operational model runs for industry decision makers to practice on

Thank you

High Impact events - Slide for Tim Hewson / Dave Richardson

- [TC] Sig Wave Heights (difference between risk of 3m and risk of 5m) days 1-3
- TC Sig Wave Heights (difference between risk of 10m and risk of 15m) days 1-2
- TC 10m wind (difference between risk of Cat 4 and Cat 5 winds) days 1-2
- Risk of potential TC impact (days 3-6)
- Onset / Duration of potential TC impact (days 3-6)
- Very low risk of TC impact over a period of 5 to 10 days (days 1-15)
- Onset / cessation of TC season (2 to 4 months ahead)
- Likely seasonal count of TC impact days (2 to 8 months ahead)

Model Requests - 2025 - Slide for Erland

- Wind drag co-efficients on ocean waves in severe TCs
- Ocean currents