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Modelling Climate-related Catastrophe Risk

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Agenda

1. How is global climate likely to change in future?
2. How do we know this?
3. Limits on our predictive capabilities
4. How do regulatory timelines compare with these limitations?
5. What do these limitations mean for catastrophe risk modelling?
6. What sort of catastrophe risk adjustments are proposed for future climates?
7. Implementation options 1 & 2
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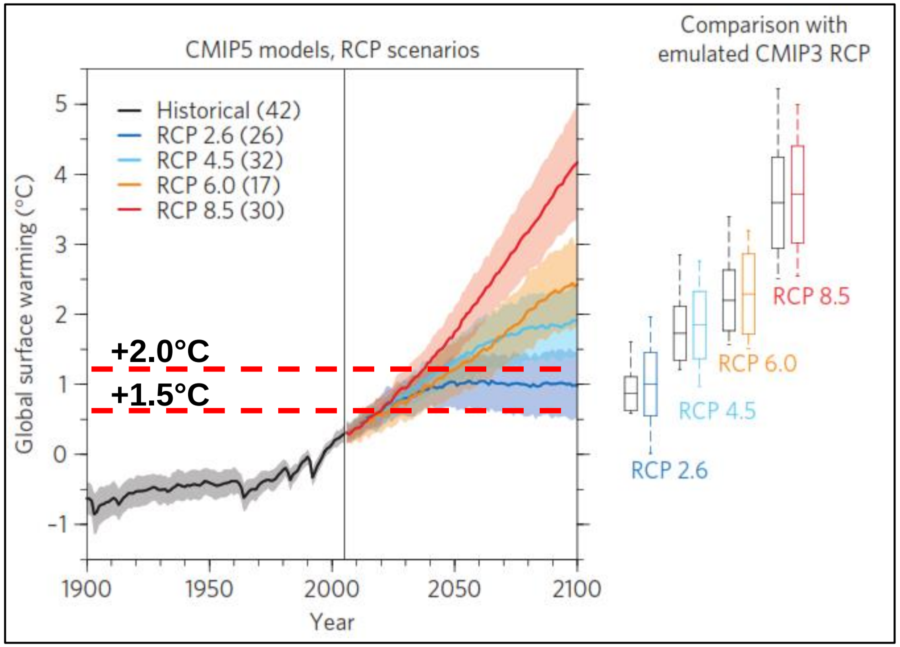
How is global climate expected to change in future?

- At COP21 in December 2015, 195 nations adopted the Paris Agreement to hold the increase in the global mean surface temperature to below 2°C above pre-industrial levels, and as far as possible to go further, by limiting the rise to 1.5°C if possible.

- Chart shows global mean surface temperature change from 1900 to 2005, and projections to 2100. [1900 is the end of the pre-industrial era]. Projections vary due to uncertainty in greenhouse gas concentration pathways known as **Representative Concentration Pathways (RCPs**). We do not know which will be the case in future, nor exactly how climate will respond.

- Each RCP can be arrived at from different trajectories of population growth, economic development and Government attitudes to emissions reduction. These variables become more uncertain over time; hence each RCP is represented as a cone of uncertainty that progressively increases in size over time.

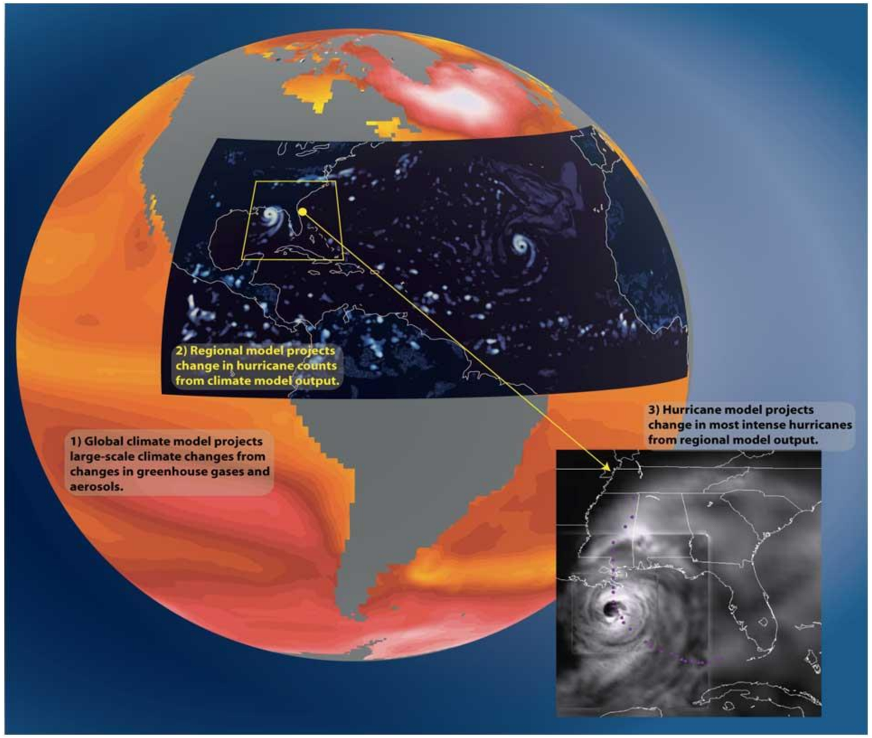


Global temperature change and uncertainty (mean and one standard deviation as shading) relative to 1986-2005. The number of GCM models is shown in parentheses. Figure 1 from Knutti & Sedlácek (2012).

- Difficult for climate models to resolve RCPs from each other and from natural climate variability on a less than 20-year timescale between 2000 and 2050 due to heavy uncertainty blur. Even by 2070 it is not realistic to resolve RCP 6.0 and RCP 4.5 – both cause similar global warming at that point in time.

How do we know this?

- Climate projections are based on ensembles of climate model projections – using different models, starting points, and parameters within each run.
- Two types - **General Circulation Models** (**GCMs**) and **Regional Climate Models** (**RCMs**). Both are good at simulating large-scale atmospheric and oceanographic features, and can be run over many decades into the future (e.g. to 2100).
- GCMs use a 50 - 100 km horizontal grid covering the entire globe. Coupled ocean, land and atmosphere. Too coarse to accurately represent large scale perils (hurricanes, ETCs*) in any degree of detail.
- **Dynamical downscaling:** RCMs can be nested within GCMs to provide higher resolution (10-30 km) for specific regions to model hurricanes and ETCs. Very high resolution (1 to 10 km grid) Numerical Weather Prediction (NWP) models can be nested within an RCM to more accurately represent hurricanes, ETCs, regional precipitation, over short periods of time. Cannot run from 2023 to 2030 –computationally prohibitive!

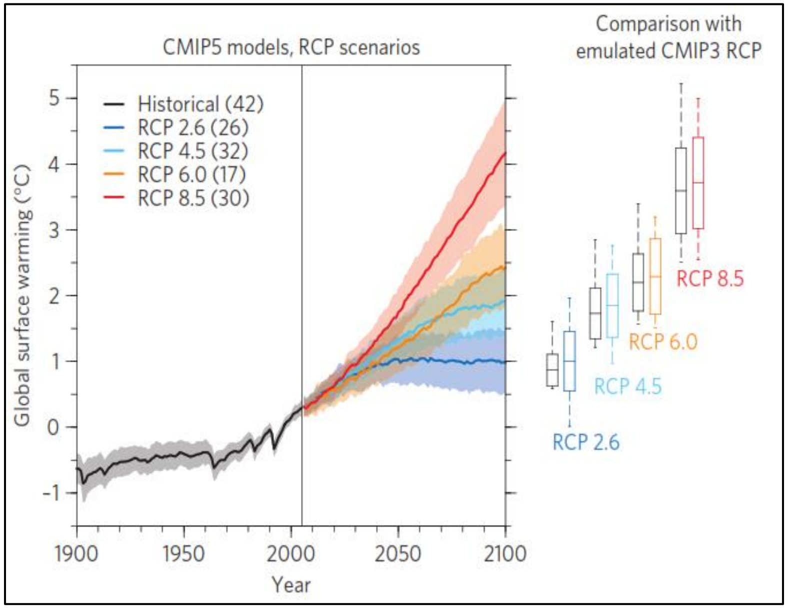


Downscaling to understand the impacts of global climate change on hurricane frequency, intensity and associated rainfall in the North Atlantic. Fig 1 in GFDL (2022).

- Currently no way to explicitly project the modelling of very-small-scale perils (convective storms, small wildfires and localised flash flooding) decades ahead – as would require a sub-km scale grid and short model timesteps < 10 mins.

Limits on our predictive capabilities

- Fiedler et al. (2021) highlight that GCMs and RCMs have definite limitations – these are not widely known outside the climate modelling community:
  1. **Time horizons** – Natural climate variability swamps the climate change signal in climate models at projection leads of less than several decades. Climate projections at < 20 years lead are therefore unlikely to be robust.
  2. **Geographic scales** – Climate models are suitable for use at **sub-continental** (tropical North Atlantic, West North Pacific) to **global scale**. At smaller scales we need to downscale the projections, however this obviously introduces an additional layer of uncertainty. That increases with increasing projection lead time.
  3. **Extreme (catastrophe) events**
     1. Large scale perils – hurricanes, ETC – can robustly forecast but not pick out detail – may lead to understatement of frequency of the most severe hurricanes
     2. Very small-scale perils – cannot explicitly model or project, must rely on historic statistical associations and empiric relationships to project changes in frequency/ severity of these perils.



Global temperature change and uncertainty (mean and one standard deviation as shading) relative to 1986-2005. The number of GCM models is shown in parentheses. Figure 1 from Knutti & Sedlácek (2012). Fair use / fair dealing.

How do regulatory timescales compare with these limitations?

ENTITY	TEST	SHORT TERM	MEDIUM TERM	LONG TERM
Taskforce on Climate-related Financial Disclosures (TCFD)	General guidance (2020)	5 years	10 years	20 years
UK Prudential Regulation Authority (PRA)	General guidance (2019)	1-5 years	5-10 years	10+ years
	2021 CBES			30 years (2051)
Monetary Authority of Singapore (MAS)	2022 IWST			30 years (2052)
European Central Bank	2022 Supervisory climate stress test	1 year		30 years
US Federal Reserve	2022 stress test scenarios	3 years		

- Most regulators enforce financial disclosure on timescales shorter than the capability of climate models to differentiate between the signal of climate change and the noise of natural climate variability. Some of these also employ longer timeframes (20 years+), often for stress testing of capital requirements.

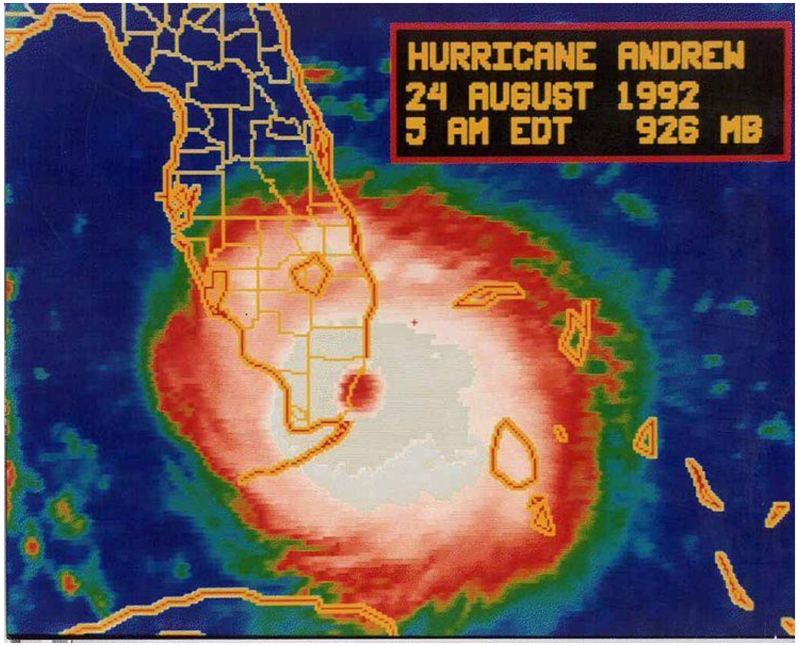
- A mismatch clearly exists between short and medium term regulatory expectations and the capabilities of climate models. This raises the possibility of mis-statement of risk in climate-related financial disclosures over these time frames (Fielder et al. 2021) – consequences of which potentially include the holding of inappropriate levels of capital; and the taking of inappropriate climate risk mitigation/ adaption activities (e.g. affecting underwriting and/ or investment decisions).

What do these limitations mean for catastrophe risk modelling?

- Catastrophe ('Cat') models are the basis for acute physical climate risk disclosures to regulators, calculating expected loss and PML at a snapshot in time to a portfolio of insured locations from a wide range of extreme events.

- Cat models are intended to represent the current long term climatology – not a future point in time. We need to adjust the frequencies and/ or severities of the stochastic events in order to represent future climate states.

- These frequency/ severity projections are based on climate model simulations, which as we have just seen, have definite limitations. We should therefore use robust projections targeting risk horizons of 20+ years ahead, at sub-continental scale and above. Such data exists for large scale perils.



Infrared image of Andrew over Dade county at 0900 UTC August 24, 1992. NOAA. Public domain. https://www.nhc.noaa.gov/1992andrew.html

- One argument routinely levelled at Cat models is that we are not confident of extreme event rates today, how then can we project them into the future with confidence?

- Answer is that yes this is the case with upper tail loss events (1:100 and beyond) – we are not confident of their rates today due to very small or absent sample sizes. Projecting them into an uncertain future will only increase this uncertainty, and even more so for very small-scale perils that cannot be robustly projected.

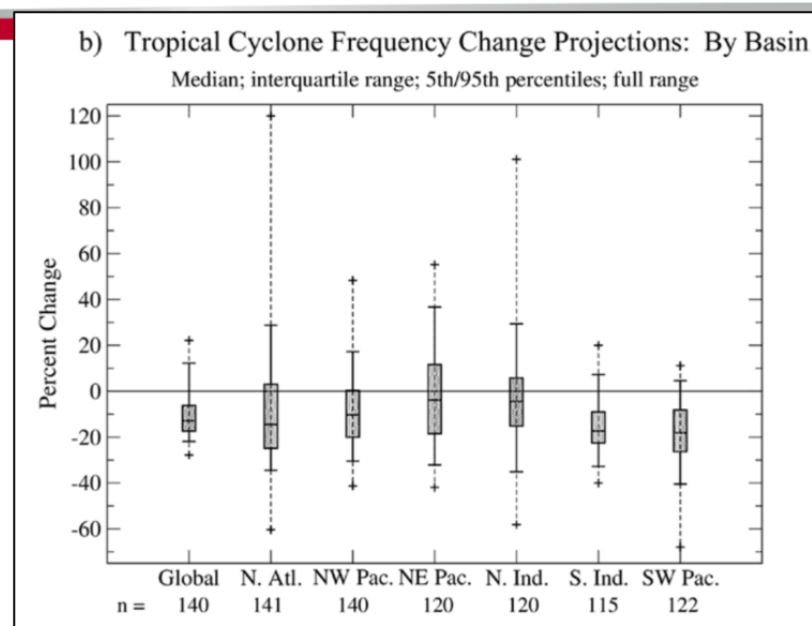
What sort of Cat risk adjustments are proposed for future climates?

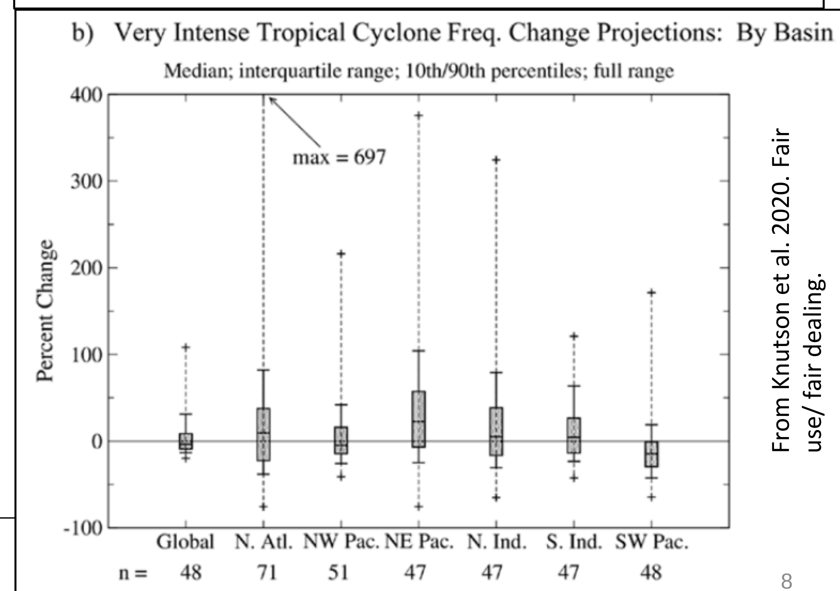
- Knutson et al. (2020) compiled >100 climate model tropical cyclone projection studies and divides them by parameter (frequency, sustained windspeed and precipitation rate), ocean basin and storm intensity (SSHWS* Category 0-5 and Category 3-5) for a 2°C increase in global warming. [*Whiskers in both charts show the wide range, horizontal line shows the median*].

- Top chart shows Category 0-5 TCs, lower chart shows Category 4-5 TCs. On average, we expect TCs to become less frequent but stronger, with an increase in the frequency of Category 4-5 TCs balanced by a decrease in the frequency of Cat 0-2 TCs.

- No specific timeline is specified for when the 2°C trajectory begins – it is instead assumed that these changes will occur regardless of starting point. Jewson (2021) rebases the parameter changes to match the historic event catalogue from which the Cat model was built (e.g. 1900-2018).

- Question is how to apply this to the Cat model? Two main choices – DIY or license an adjusted vendor model?





From Knutson et al. 2020. Fair use/ fair dealing.

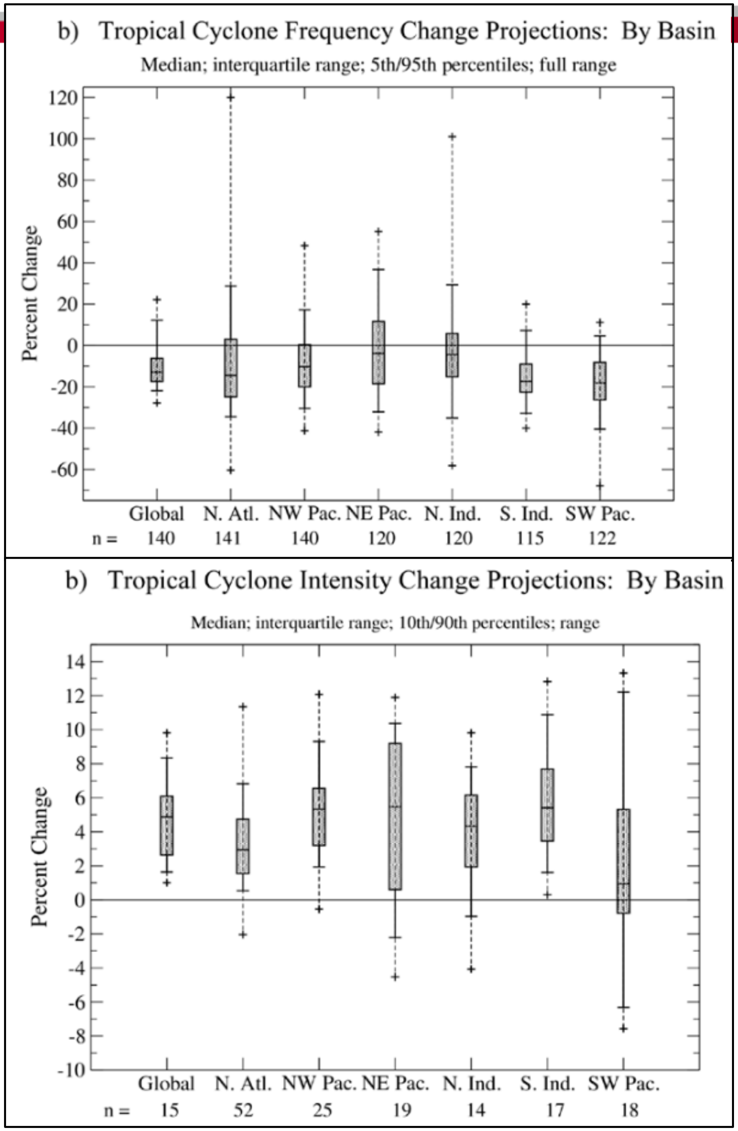
* SSHWS = Saffir Simpson Hurricane Wind Scale

Option 1: DIY

- This is the most widely used approach and is implemented by adjusting stochastic event rates and/ or loss severities. Both will shift the mean frequency of the loss distribution and may also change the variance.

- This method uses **loss** as a proxy for **hazard**, which is a major simplifying assumption (as loss is not linearly related to hazard, e.g. loss vs. windspeed). As model licensees, we only have loss results available to adjust.

- Implementation is via post-processing of model results, and depends on format of the model results:
  - For **ELT-based* models**, we directly adjust frequencies of storms falling within defined SSHWS intensity categories.
  - For **YELT-based* models**, we need to re-simulate the YELT to reproduce the desired frequencies of storms within each SSHWS category in each simulation year in turn.
  - Crucially, we need to be careful to avoid further loss severity adjustments if we have already shifted towards stronger (Cat 4-5) or weaker (Cat 0-2) storms.



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* ELT = event-loss-table, YELT = year-event-loss-table.

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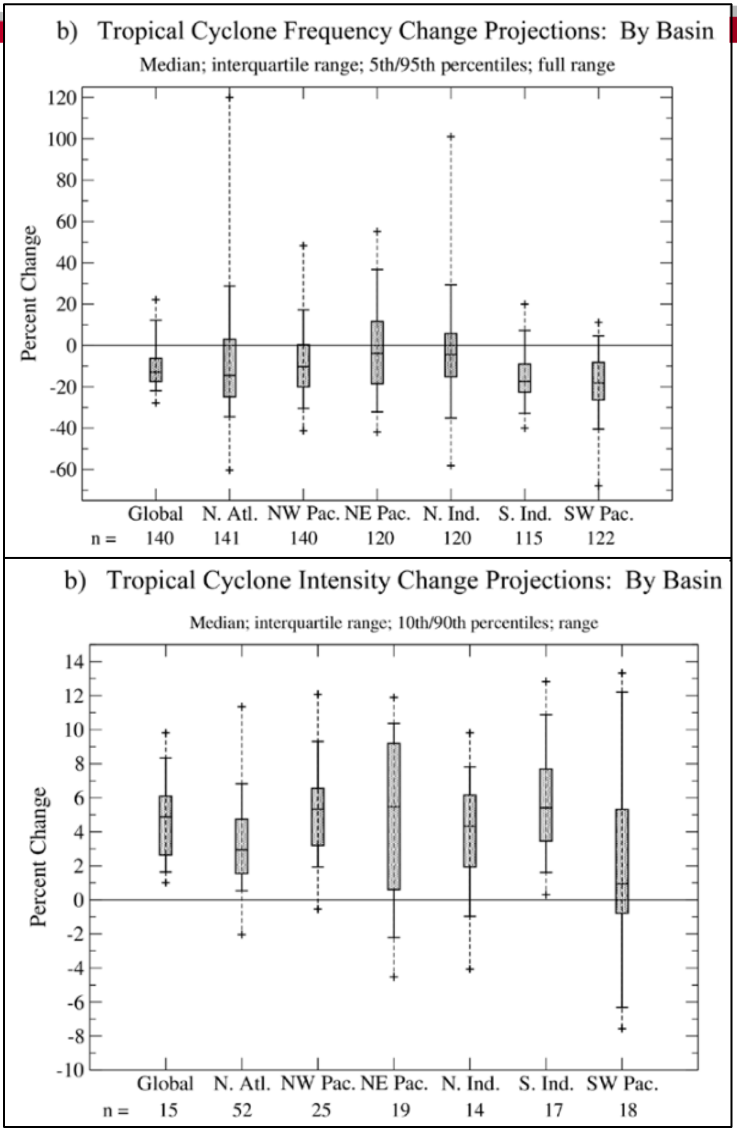
Option 2: Climate-conditioned vendor model

- Most major Cat model vendors now produce 'climate conditioned' stochastic catalogues representing the vendor's view of event frequency and severity at one or more future risk horizons, using rebased parameter projections, for a given RCP trajectory.

- **Pros**
  - Scientifically informed view
  - Quickly available off the shelf, usable out of the box
  - Removes need to employ climate scientists on-staff
  - **Changes are made to hazard (not loss) and automatically 'ripple through' to final losses – hence losses directly reflect the adjusted hazard**
- **Cons**
  - Additional licensing cost
  - **Lack of involvement means limited knowledge transfer from vendor to client. Regulators like model licensees to 'own' their view of risk, and not just import it wholesale from a model vendor.**

- Uptake of climate conditioned Cat models is thought to have been fairly limited to date – but this may change in future!



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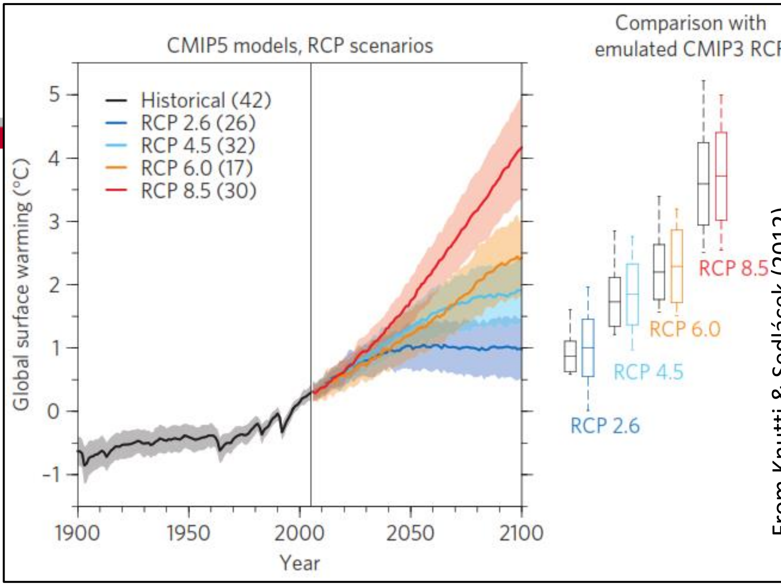
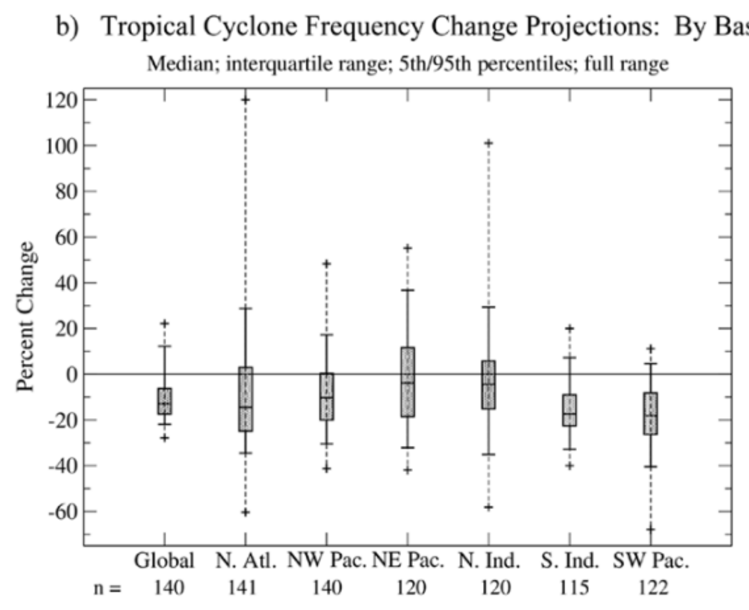
Recommendations for climate risk analysis

1. Familiarise ourselves with limitations of climate model outputs (Fiedler et al. 2021) so that we 'use the model right' – starting at several decades lead, at sub-continental scale.
2. Embed these limitations in regulatory frameworks – so that the two are consistent and not contradictory.
3. Accept that catastrophe risk analysis is an uncertain 'science', even more so when projected into the future.
4. Decide a robust future risk horizon (e.g. 2050) and seek projections showing how large-scale perils may change over large areas (sub-continental scale) between now and then under assumed future climate states.
5. Rebase these projection data to match the starting point of the historic catalogue used to build the Cat model, the future risk horizon, and the most likely RCP trajectory.
6. Decide and execute implementation option.
7. Keep abreast of climate science as will need to repeat these steps with updates and improvements on an annual basis for regulatory climate risk reporting!



From Knutti & Sedláček (2012)



From Knutson et al. 2020

Thank you for listening!

Please direct any further questions to
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