Climate Systems

National Environmental Science Program

Strengthening climate change attribution for decision makers

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The Climate Systems Hub acknowledges the Traditional Custodians of the land across Australia where this work occurred. We pay our respects to Elders past, presents and future and recognise the important role traditional knowledge plays in understanding Australia's climate.

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Executive summary

Decision makers must draw on the cutting-edge science of climate extremes to prepare for and reduce the impacts of future disasters.

The emerging field of extreme event attribution (EEA) allows scientists to establish the causes of extreme weather and the role of climate change in altering the likelihood, magnitude or intensity of specific extreme weather and climate events. This involves using climate model results to assess the changing probability or magnitude of an extreme weather event with, and without, human-driven climate change.

The Climate Systems Hub is investigating ways to strengthen extreme event attribution. Following a co-design approach to understand user needs, the researchers interviewed government decision makers across Australia and tested scientists' and communicators' abilities to meet these needs. This research revealed how extreme event attribution can inform and support climate risk understanding and climate risk decisions.

Key findings included:

- Almost 80% of decision makers were familiar with extreme event attribution or at least the concept. Despite high familiarity, only 18% were using the science to make decisions in their roles.
- The 5 most common ways decision makers thought attribution science and communication could be strengthened were by enhancing:
    1. language
    2. methodology explanations
    3. impact linkages
    4. action oriented messaging
    5. scientific comprehension (see table 1).
- Decision makers thought extreme event attribution could be more consistently used to inform and support climate risk understanding and climate risk decisions, if these areas of improvement were addressed.

The findings were then tested with scientists, climate service providers, knowledge brokers and communicators, who identified pathways forward including:

- ongoing collaboration and co-design with decision makers across research and engagement
- establishing communities of practice
- accompanying the science with clear visuals and language and creating extreme event attribution information kits
- connecting the science with tailored statements to link the science to observed impacts of weather extremes.

This report and its underpinning research sets out an ongoing need for the continued expansion of attribution science and for a collaborative approach to enhance its utility. Pursuing these efforts will enable extreme event attribution to continue to develop in a way that supports effective and equitable climate adaptation in Australia.

Climate Systems Hub Extreme Events Explained research

Researchers in the hub's Extreme Events Explained project study past extreme events that have impacted the environment, society and infrastructure.

The project aims to:

- provide context and understanding around extremes on a range of time scales
- develop confidence in understanding future climate extremes including why and how they are changing
- understand how contextualising extreme weather and climate events, including using extreme event attribution, can inform climate and future risk-related decisions
- improve and refine approaches to attributing climate change and the role of natural climate variability and how to effectively communicate it.

2023 Attribution for decision makers workshop. Photo credit: Pandora Hope

Introduction – about extreme event attribution

Decision-making, attribution science and the changing nature of climate extremes

Extreme heat and extreme rainfall are projected to increase in frequency and/or intensity in the face of anthropogenic climate change, posing increasing risks to communities and assets. Decision makers must now account for these changing conditions to manage climate and disaster risks both now and in the future.

Flooding across Brisbane, 2022

All levels of government are under increasing pressure to design and implement appropriate mitigation and adaptation strategies to reduce risk and manage damage and loss. In the face of extreme events, co-designing and co-producing climate research with decision makers is essential.

To understand, communicate and act in response to changing climate extremes, there is a wide range of information that decision makers can draw on. Through techniques known as extreme event attribution, scientists can establish the causes of extreme weather events.

What is extreme event attribution?

EEA findings can be transformed into statements and communicated to contribute to our understanding of changing climate risks. By better understanding if these causes link to climate change, attribution findings can guide impact reduction approaches.

Extreme Event Attribution (EEA) science is an emerging field of climate research, which involves quantifying the influence of climate change on the frequency, magnitude, and intensity of extreme events.

There are plans to establish an operational attribution service to inform policy development and climate risk management in Australia. However, targeted research about policy and decision maker needs, as well as scientists' and communicators' abilities to meet these needs, as described in this report, must first be understood to establish a seamless, effective and informative service.

How can science attribute the influence of climate change?

Assessing the extent to which climate change or natural variability plays a role in extreme events can be done using many approaches (Hope et al. 2022). One method uses large numbers of climate model experiments called ensembles (Lewis et al. 2014). One ensemble will include all observed human influences on the climate, the other won't, and each ensemble will contain multiple possible versions of the Earth's climate. Of the many possible 'worlds' represented by each experiment, researchers quantify the probability of the event occurring in the 'world as is' (with human influences on climate) and 'the world that might have been' (without human influences on climate).

Detection and attribution are conducted by first defining an event (for example the area affected, time period, temperature characteristic, temperature threshold (record: detection of change)), then estimating the frequency of the event in a counterfactual climate, with natural forcings but without human influence. Comparing that result to the frequency of the event in a factual climate, with natural forcings *and* human influence, shows the increased or decreased probability of an extreme event due to climate change. An attribution statement can then be made. This is illustrated in Figure 1 – how frequently temperature records are broken in climate model experiments with climates affected by human forcings, such as greenhouse gas emissions, compared to our climate without these forcings.

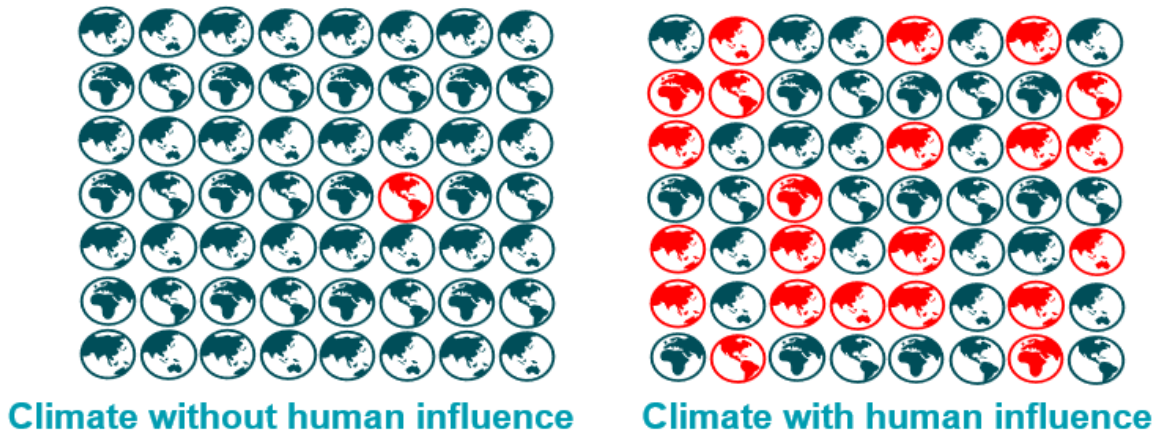

Figure 1: Schematic showing how frequently temperature records may be broken in climates with and without human influence. Red icons indicate record-breaking heat in that model experiment.

How is attribution science used in decision-making?

Attribution science can inform and motivate decisions about changing climate risks. At a global level, extreme event attribution findings are considered in justifying resource-allocation to climate mitigation and adaptation strategies (Schwab et al., 2017), and enabling insurance to regions vulnerable to loss and damages from extreme events (UNCDF, 2022). This presents opportunities for the science to be used more systematically to address climate risks in Australia.

Figure 2: Diagram showing how extreme event attribution findings can benefit climate risk decisions

Research design

Hub research into attribution science has spanned many years. It is an emerging and growing field of climate science and Australia is leading the way with a range of published research already available (Abhik et al., 2023, King 2018, Hope et al., 2016, Black et al., 2015).

The hub's Extreme Events Explained project and the Bureau of Meteorology collaborated with Monash University's Science Advanced Global Challenges Program who led research to strengthen the delivery of extreme event attribution information to decision makers, by:

- understanding decision maker needs, use and potential use of EEA science, including a comparison of how they vary across geographic regions and government scales (Bourbon et al. 2024).
- identifying the current capabilities, barriers, enablers and pathways forward for scientists and communicators to deliver these needs (Machin et al. 2024).

The research aims were achieved through a multi-phased, year-long co-designed project, creating an information flow value chain to link scientists to decision makers and back again.

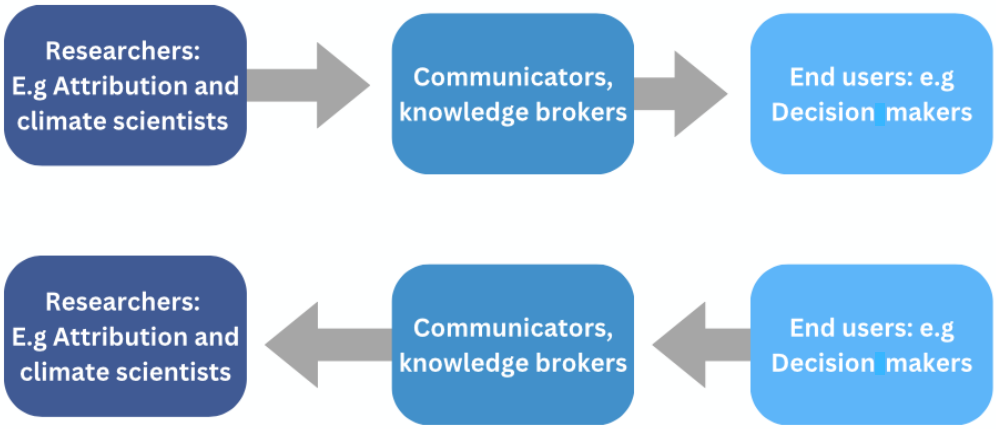

Figure 3: Diagram showing how through co-design end-users are able to shape attribution research with the reversal of the top chain value to start with end users

During this project, attribution statements were presented to decision makers, who identified areas for improvement. The statements came from climate science participants in a NESP-Australian Climate Service (ACS) Attribution Workshop held in 2022. Generally, attribution statements can be applied to a range of variables, for questions about changing event *frequency, magnitude* and *intensity*. For example, questions included: "How many more times would this heat event occur, and how much warmer was it in today's climate, relative to a world without climate change?"

or “How much more intense was this rainfall event in today’s climate, relative to an equally rare event occurring in a pre-industrial climate”? One simplified statement was presented to decision makers for each aspect.

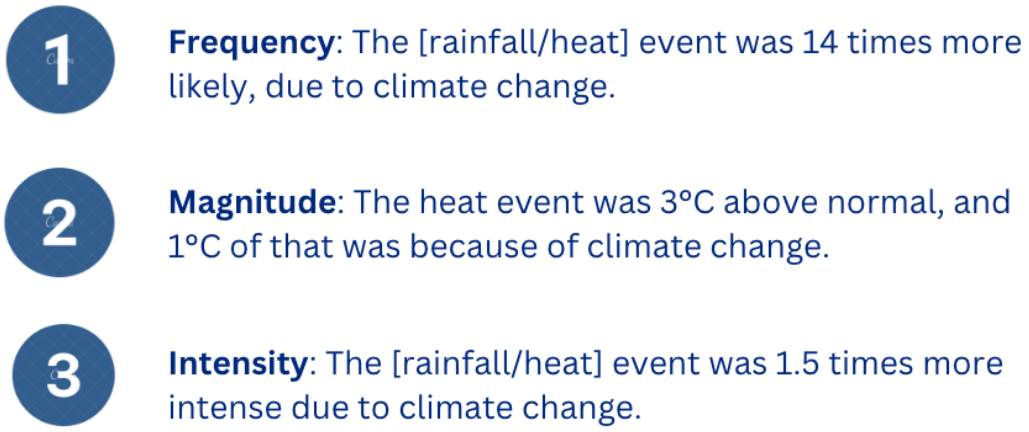

Figure 4: The three attribution statements tested in the research project

Phase 1 of the research identified the perceptions, uses and needs of decision makers in Australia’s northern tropical regions and south-eastern temperate regions regarding heat and rainfall extreme event attribution.

This distinction created the groundwork for Phase 2, completing a comparative national study to gain a broader understanding of EEA use by decision makers across Australia. These results set up Phase 3, where the capability of attribution scientists and communicators to meet decision maker needs was explored through a two-day international workshop.

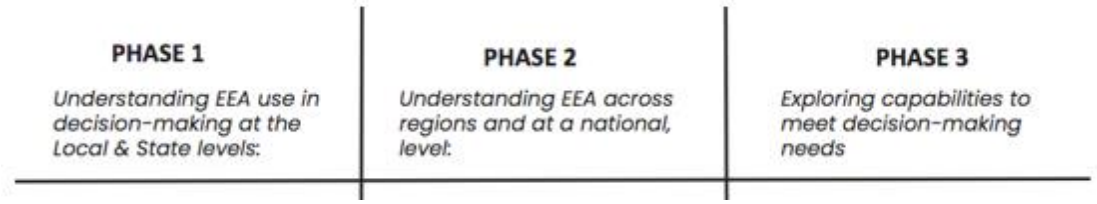

Figure 5: The 3 phases of the strengthening extreme event attribution research project

For the purpose of the project, the group communicators comprised knowledge brokers, advisors, as well as weather, climate services personnel and other communication-based roles. This group translate and communicate scientific information regarding climate risks to decision makers.

Research findings

Decision maker needs

Familiarity and use of the science

In Phases 1 and 2, detailed interviews were conducted with over 40 decision makers across all levels of government in northern and southern Australia and at a national level.

Decision makers were largely policy development and climate risk management experts. The researchers took advantage of the hub's knowledge broker networks to identify participants who were surveyed, then interviewed in facilitated one-to-one discussions. Further information can be found in Bourbon et al. (2024) and the researchers' theses.

Almost 80% of decision makers were familiar with extreme event attribution or at least the concept. Despite high familiarity, only 18% overall were using the science to make decisions in their roles (Figure 6).

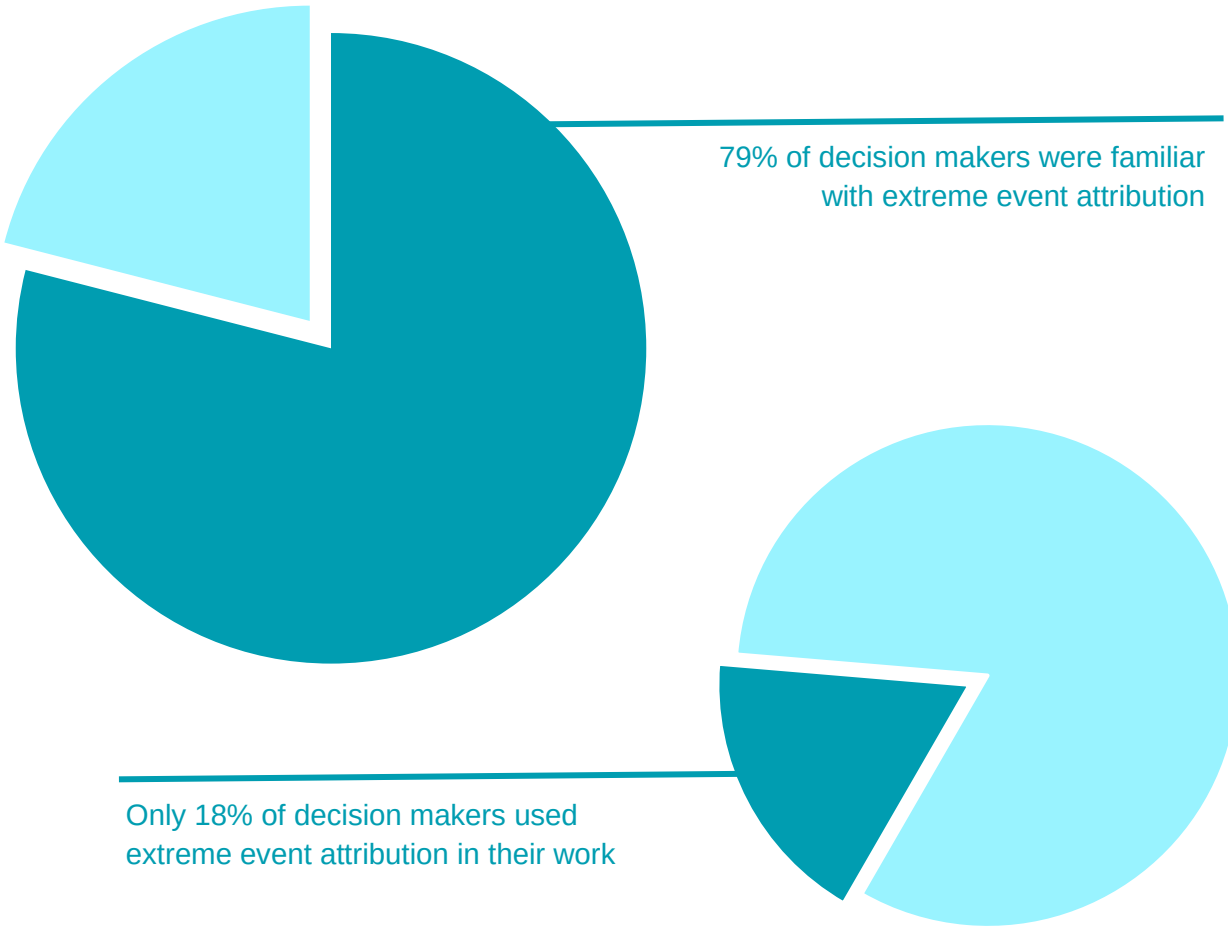

Figure 6: Diagram showing the extent of familiarity and use of extreme event attribution by decision makers across all levels of Government in Australia

Use was mainly for educational purposes such as increasing climate risk, but could also be used to inform and uplift decisions, as well as supporting resource allocation (Figure 7).

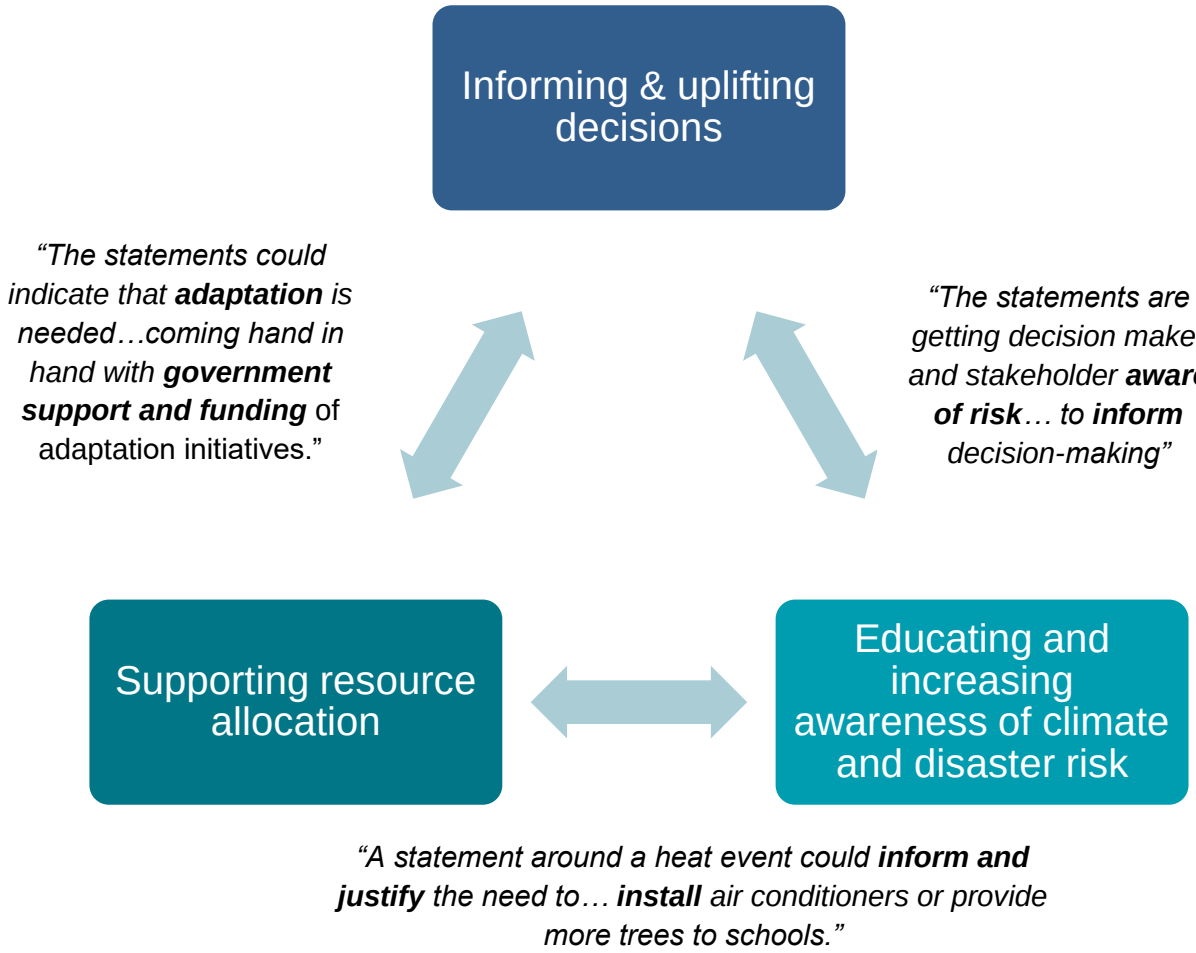

Figure 7: Diagram showing how extreme event attribution could inform and support decision maker actions

Areas of improvement for attribution science and communication

Almost all decision makers shared that EEA could be used more systematically to inform and support climate risk understanding and climate risk decisions, if areas of improvement were addressed.

Overall, 5 common themes emerged as opportunities for improvement (Table 1). Other needs were also identified and were important to specific climate regions and government scales but were not as common overall.

Table 1: Top 5 most commonly identified areas of improvement for extreme event attribution communication

Improvement opportunities	Advice for communication	What we heard	Pathways forward
1. Language	Define terms including 'normal', 'event' and 'intensity' to make language clearer and to provide context about what the statements are being compared to. Translate EEA findings to be more broadly understood.	**"'Normal' for who and where?"** (Health, QLD)	Create standardised definitions for words and define the words within findings.
2. Methodology explanations	Explain how the attribution statement is derived including methods and approaches used and baselines for comparison. Vary explanation levels to cater to different audience needs.	**"What does [the statement] actually mean if there's no baseline to compare it to?"** (Environment and Science, WA)	Clearly define baselines and methods used. The level of detail provided should be appropriate for the audience.
3. Impact linkages	Link EEA findings to impacts that are relevant to decision-makers. For example, include information about how the event may affect assets, livelihoods, infrastructure, or health.	"**The statements need to have a 'so what' factor, like 'This is having a significant impact on the economy/ demand for emergency services**." (Climate Governance, VIC)	Pair EEA findings with simple impact statements (as in quote).

4. Action-oriented messaging	Pair EEA information with actionable recommendations to support decision-making.	**"Something that has to come after the statement is: what can someone do to change the influence of climate change?"** (Climate Governance, VIC)	Recommend adaptation or mitigation actions to reduce climate risks and accompany EEA findings. For example, installing air conditioners or planting trees in areas experiencing more intense extreme heat.
5. Scientific comprehension	Supplement EEA wording to facilitate understanding and enable decision makers to conceptualise and visualise the EEA findings	**"'1.5 times' [in Statement 2] is easier to comprehend. '14 times' [in Statement 1] is too hard to understand, visualise, or feel."** (Climate Governance, VIC)	Pair the statements with visuals and graphs.

By addressing these 5 key needs, statements will be more clear, meaningful and valuable for decision makers, allowing EEA science to be used for various purposes.

Different needs across Australia

Governments at all levels are responsible for the management of climate and weather-related risks, however, individual roles and responsibilities differ across the 3 tiers of government: Local, State and Territory, and Commonwealth (COAG, 2012). Decision maker needs also vary by location with differences apparent through this research between the northern tropical regions and south-eastern temperate regions of Australia.

The importance of language for northern Australia

Language needs were identified as critical in the north of the country, particularly for some communities where English is a third or fourth language. In these cases, translation of the science into local languages to make the statements clearer was recommended (Figure 8).

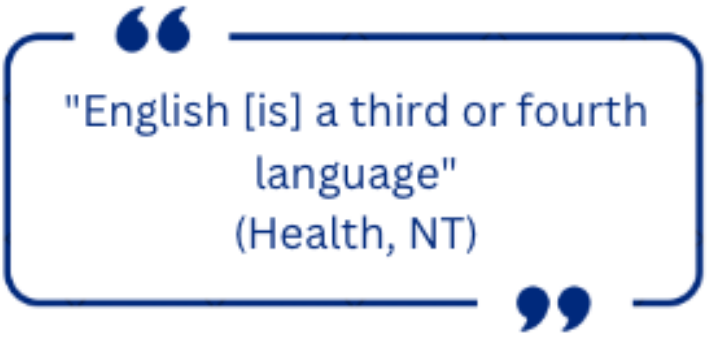

Figure 8: A part of the northern Australian decision maker context

Supplement wording to build science literacy

Scientific comprehension needs were more prominent in the south-east of the country. Decision makers are familiar with other sorts of climate science information where key findings are often communicated via visual means alongside written explanations (for example, future climate projections via AdaptNSW and Victoria's Climate Science Report). Decision makers expressed interest in having visual or diagrammatic information to supplement EEA statements to facilitate understanding.

Varying needs across government levels

Despite its importance at the State level, enhancing scientific comprehension was not mentioned as an improvement need by decision makers at the Federal level.

Opportunities to write the statements with clearer language and provision of information about the methodology used to create the statements were more frequently raised at both State and Federal levels. For local government, impact attribution or wording to put the event in context was most important, as decision makers desired information about relevant, local effects to inform their decisions.

Local and State government decision makers, in particular, seek localised context. However, this may be scientifically challenging especially where climate data is not available at an extremely high spatial resolution.

Decision makers from all government levels mentioned that the credibility of the attribution statement and its source was important. For example, even if the science was not 100% certain, they might use EEA statements more confidently if provided by trusted and reputable organisation such as the Bureau of Meteorology or CSIRO.

Scientist and communicator capabilities to meet decision maker needs

Findings about whether scientists and communicators had capability to meet decision maker needs were collected in Phase 3 of the research, from an Attribution Workshop held in August 2023 supported by the Australian Climate Service. Workshop attendees included scientists, service providers, knowledge brokers and communicators from Australian Climate Service, the hub, the Bureau of Meteorology and Australia and New Zealand universities. Results are summarised in Machin et al. 2024.

Workshop participants were asked to assess, on behalf of their organisation, how they thought the science had progressed, and where challenges might lie, in being able to meet the top five needs decision makers identified to improve extreme event attribution. Table 2 shows that scientists and communicators are confident in their ability to deliver on some aspects, however, other components were more difficult to immediately achieve.

Table 2: Science and communicator capability to address decision maker needs

Improvement needed	Capability currently exists to enhance EEA statements and meet improvement need	Ongoing research and further enhancements will be beneficial	Challenges
Language	Yes	Yes	A general attribution statement may not be fit-for-purpose when decision-making needs can be very diverse
Methodology explanations	Yes	Yes	Doing this consistently and systematically across all extreme events
Impact linkages	No	Yes	Data and model limitations especially where data is not available at extremely high spatial resolution
Action oriented messaging	No	Yes	Lack of visibility of which decisions are affected hinders scientists from being able to tailor bespoke attribution statements and creates challenges in producing action-oriented messaging
Scientific comprehension	Yes	Yes	Further testing of improved explanations

Next steps

Attribution of extreme events research is ongoing in the Climate Systems Hub and this report highlights the appetite that decision makers have for usable and understandable EEA information.

Through this attribution research, decision makers, scientists and communicators identified opportunities to further develop and enhance extreme event attribution science.

Opportunities can be broadly grouped into 2 themes with ongoing cooperation a key feature in each:

1. collaboration to further enhance science application and communication
2. research collaboration to ensure momentum in advancing the science

Scientists' and communicators' ways forward had a focus on understanding decision makers' needs. Discussions to enhance how attribution statements are presented included:

- they expect to build relationships and enable ongoing co-design, establish communities of practice to shape statements and develop attribution information kits.
- they expect significant progress could be made within a 2-to-5-year timeframe, especially as new science emerges, and different techniques are applied.

Decision makers highlighted that attribution science could inform adaptation and mitigation decisions if the science is clear and impactful. To meet language, methodology and scientific comprehension needs the importance of expert communications inputs and having diverse formats for presenting the information were identified.

To further advance EEA science, communication and service delivery and advance the 5 most commonly identified decision maker needs, future research should consider the following:

- maintaining the positive feedback loop between scientists, communicators and decision makers to further extend the science and align to communication needs around impact attribution, action-oriented communication and scientific comprehension.
- working alongside decision makers and adaptation experts to understand which action-oriented recommendations should be paired with EEA statements.
- joining with sector-based experts to enhance impact attribution through the provision of an intermediary statement linking extreme event attribution findings to event impacts. This will add gravity to the statements, motivating decision makers to act. For example, 'The heat/rainfall event was X times more intense or likely due to climate change, and a total of Y hospital admissions were recorded.'
- further exploring visual communication options for EEA including using knowledge brokers to help interpret the science, as well as diagrams and graphs to make the science accessible and fit-for purpose.
- developing, conducting and assessing impact attribution research and EEA studies in northern tropical Australia.

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