Values in Models and Attribution methods
for Climate Change in Extreme Events
Events

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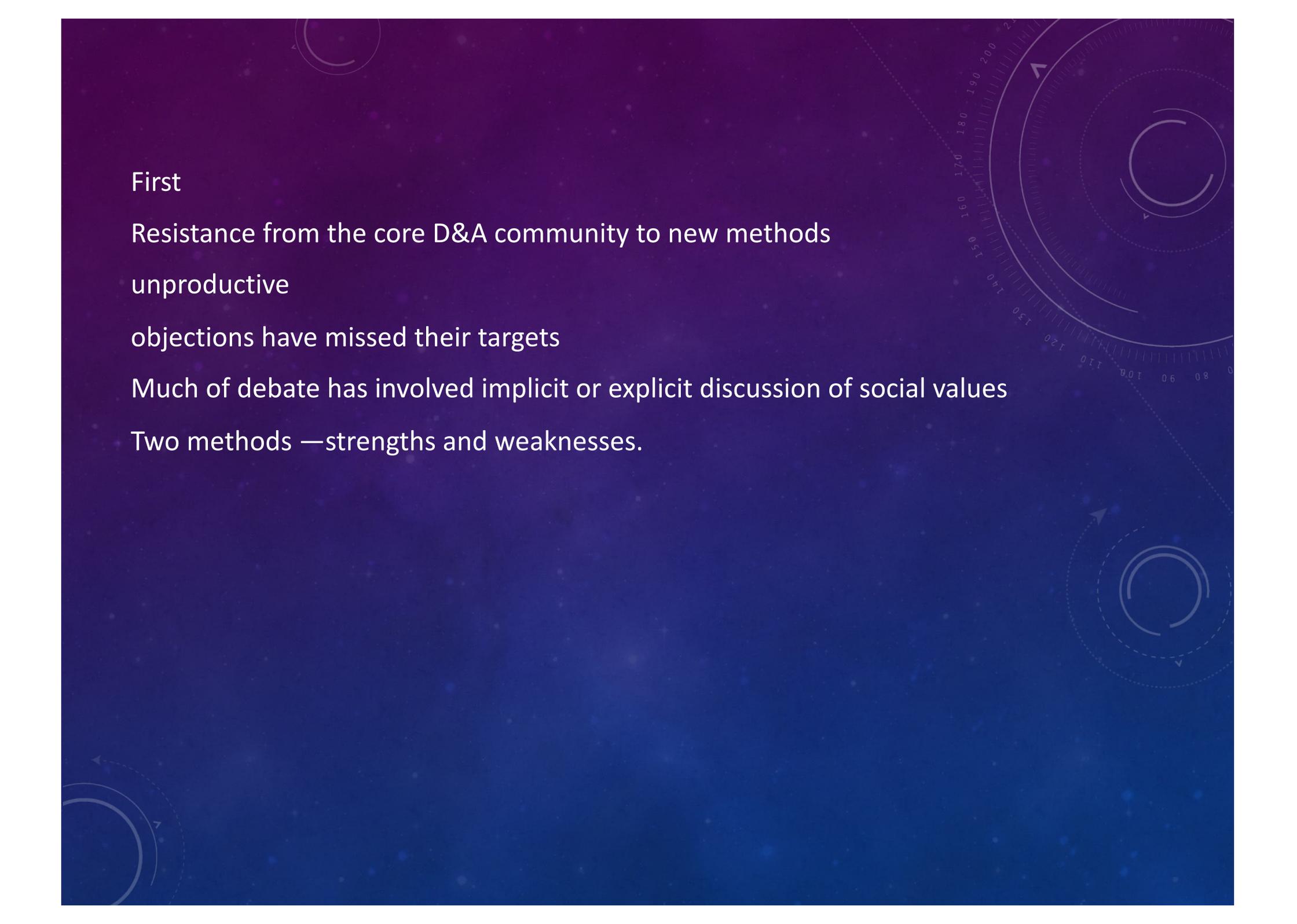
First

Resistance from the core D&A community to new methods

unproductive

objections have missed their targets

Much of debate has involved implicit or explicit discussion of social values

Two methods —strengths and weaknesses.
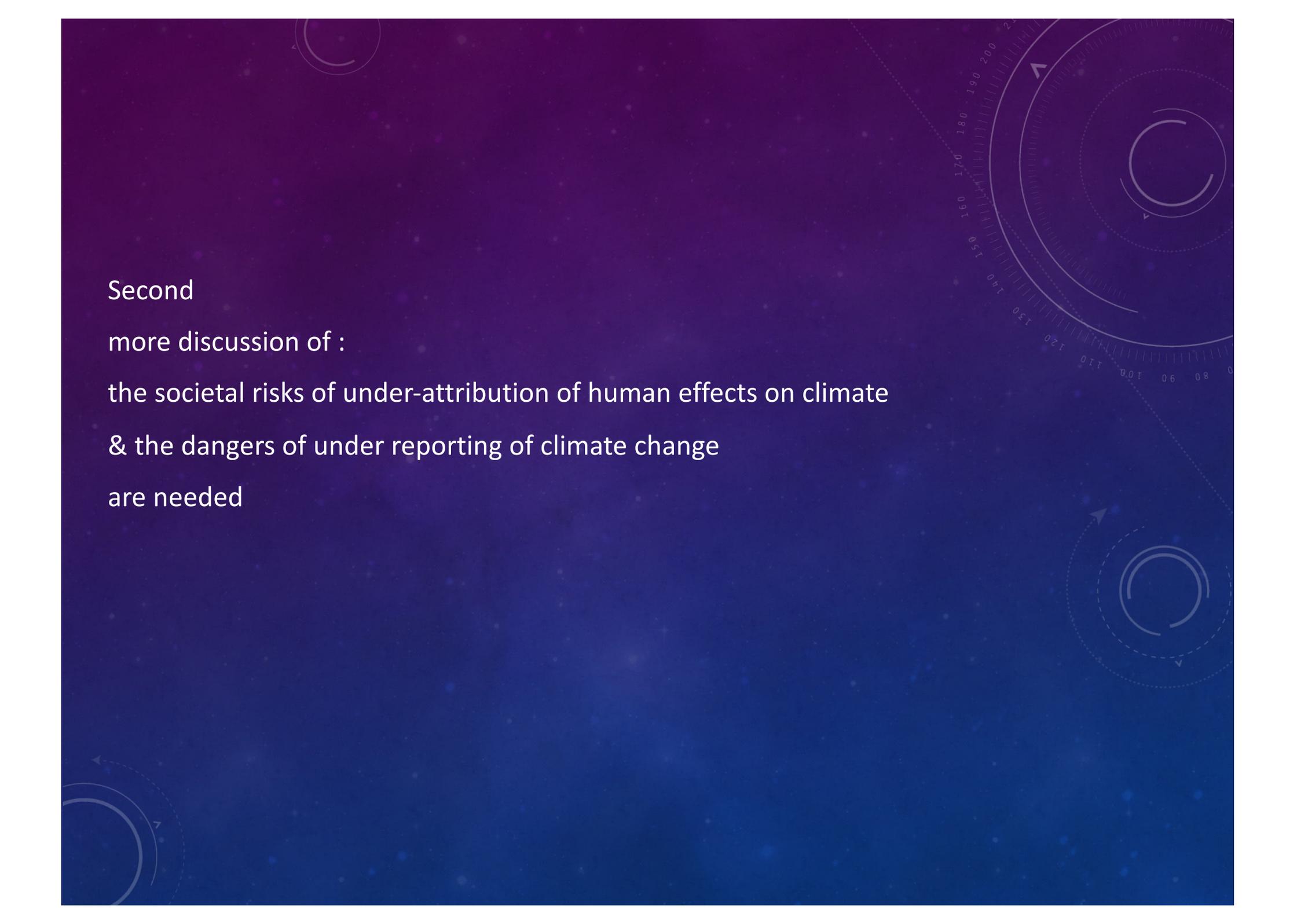
Second

more discussion of :

the societal risks of under-attribution of human effects on climate

& the dangers of under reporting of climate change

are needed

Third

Examining the role of storyline attribution methods in legal reasoning. . .

clarifies the fundamental value of its causal approach

Will show using an example from US recent legal matters

Fourth

Contrasts between two methods:

Risk-based approach: capable of giving probabilities of risk and combinations

but *not causal accounts* or *well-founded future projections or predictions*

Storyline approach: can give informative, causal, individual accounts

but *not quantitative accounts or probabilities*

although <u>can give well-founded predictions</u> using their causal analyses

unlike the risk-based account
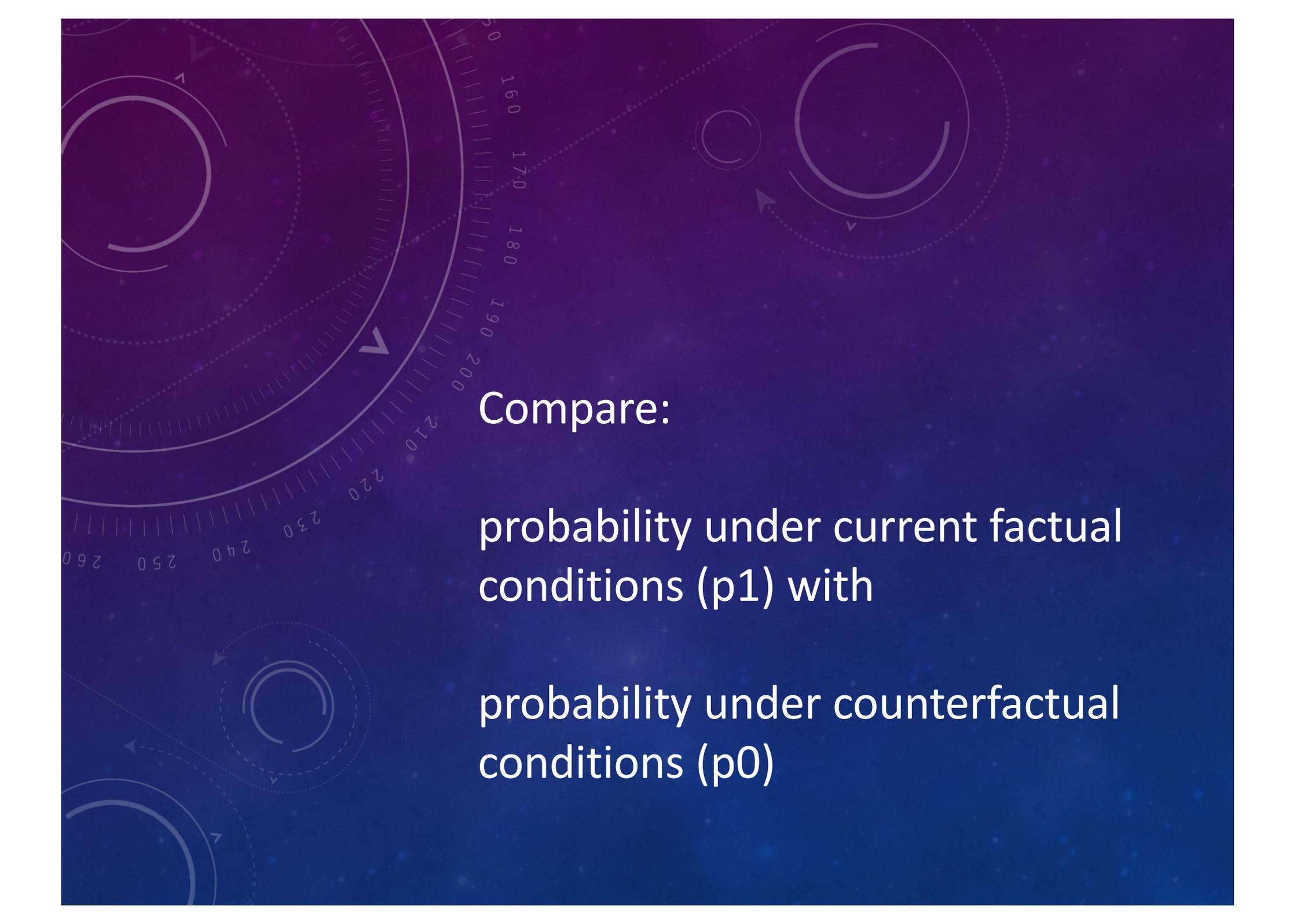
Compare:

probability under current factual conditions (p1) with

probability under counterfactual conditions (p0)

Probabilities and related diagnostics:

Fraction of Attributable Risk
(FAR = $1 - p_0/p_1$)

Risk Ratio (RR = p_1/p_0)
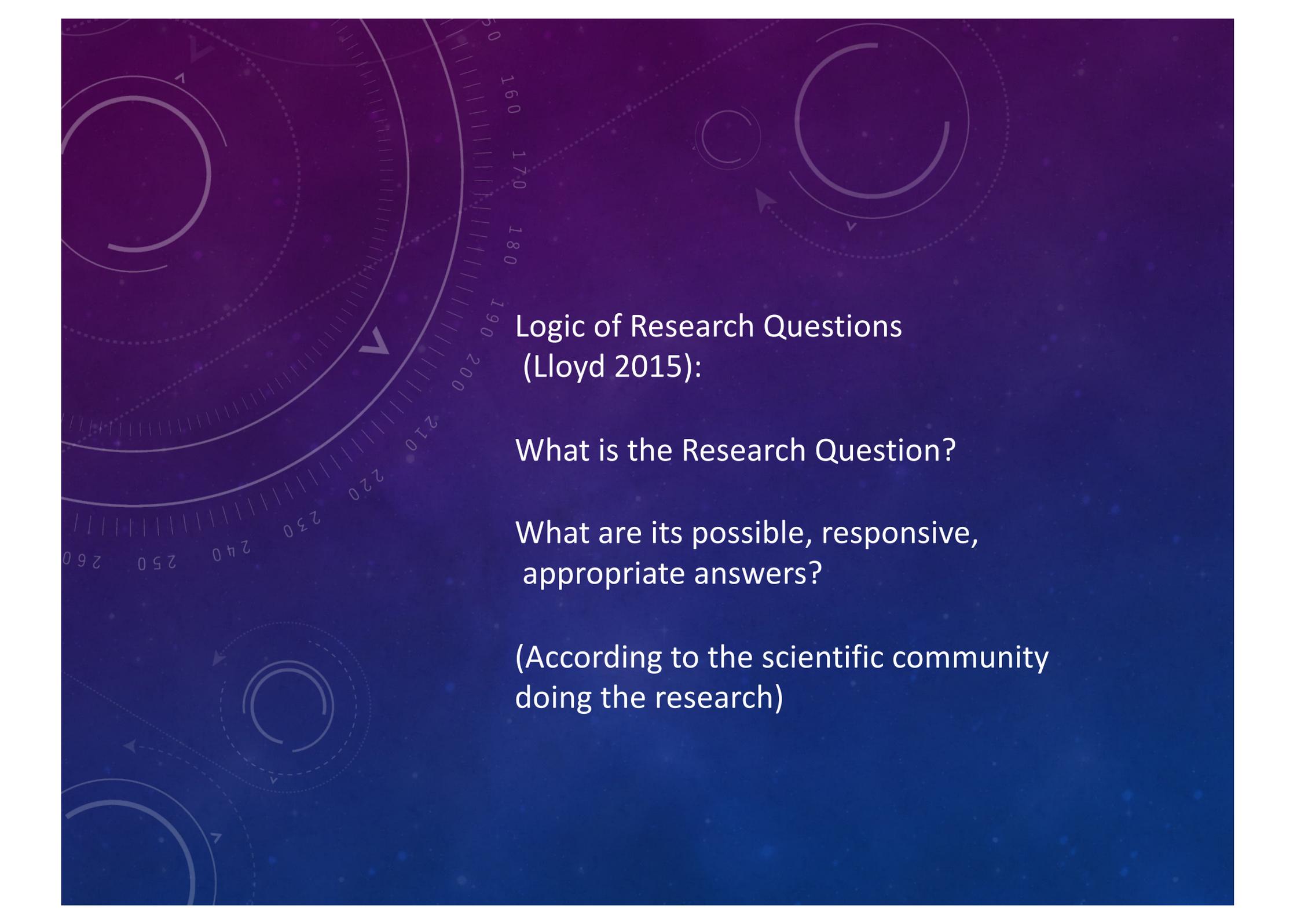
Logic of Research Questions
(Lloyd 2015):

What is the Research Question?

What are its possible, responsive,
appropriate answers?

(According to the scientific community
doing the research)

Research Question (risk-based):

"What is the **probability or risk**
of a specific class of weather event,
given our world **with** global climate change,
relative to a world **without** such change?"

Research Question (risk-based):

"What is the **probability or risk** of a specific class of weather event, given our world **with** global climate change, relative to a world **without** such change?"

Possible and Responsive answers
A: the risk of this type/class of extreme events
   will **increase** because of climate change

A: the risk of this type of extreme event
   will **decrease** because of climate change

A: the risk of this type of extreme event
   is **unaffected** by climate change
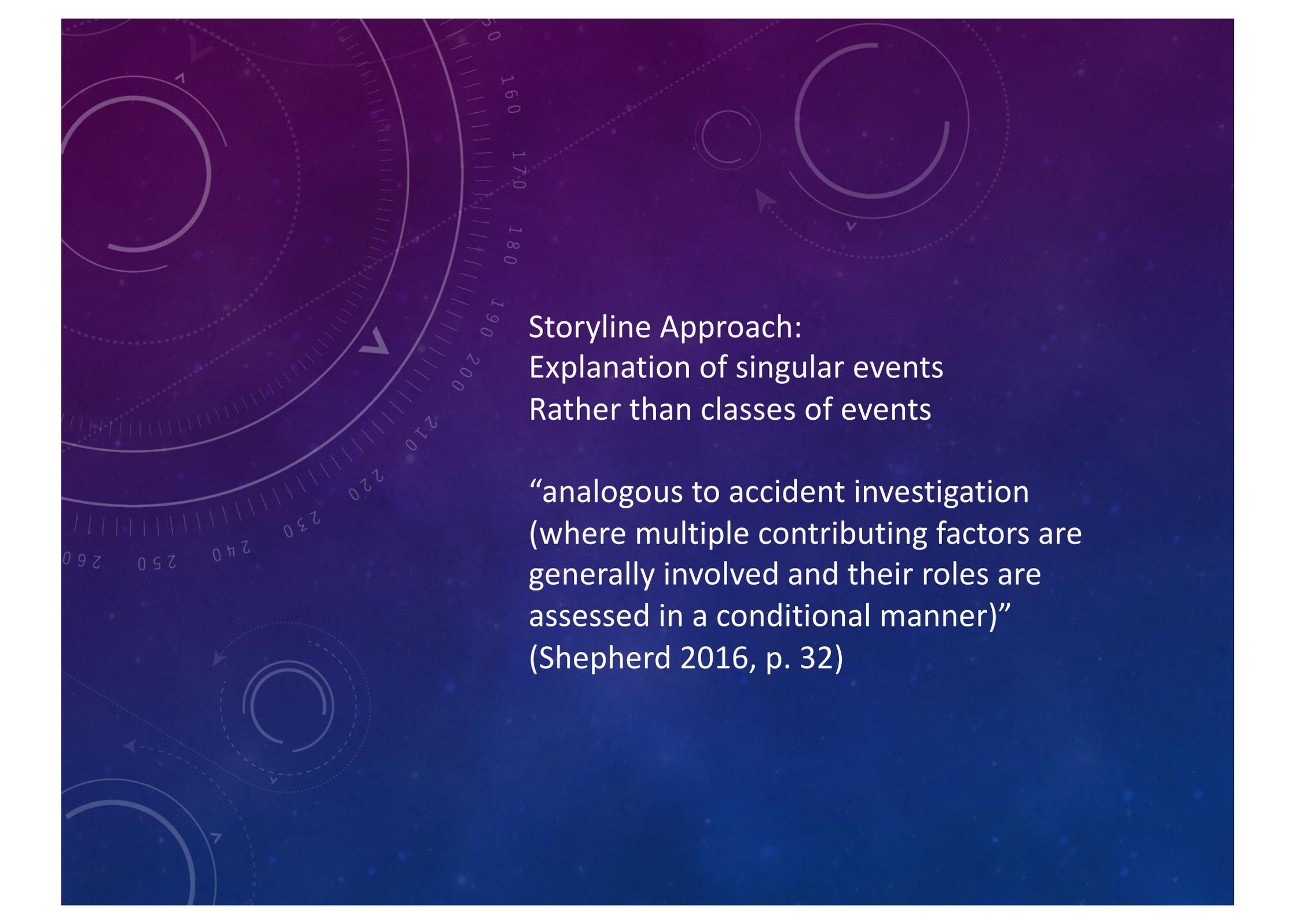
Storyline Approach:
Explanation of singular events
Rather than classes of events

"analogous to accident investigation
(where multiple contributing factors are
generally involved and their roles are
assessed in a conditional manner)"
(Shepherd 2016, p. 32)

From the IPCC AR6 Glossary (subject to editing) 2021:

Storyline   A way of making sense of a situation or a series of events through the construction of a set of explanatory elements. Usually it is built on logical or causal reasoning. In *climate* research, the term storyline is used both in connection to *scenarios* as related to a future trajectory of the climate and human systems or to a weather or climate event. In this context, storylines can be used to describe plural, conditional possible futures or explanations of a current situation, in contrast to single, definitive futures or explanations.

Physical climate storyline   A self-consistent and plausible unfolding of a physical trajectory of the *climate system*, or a weather or climate event, on timescales from hours to multiple decades (Shepherd et al., 2018). Through this, storylines explore, illustrate and communicate uncertainties in the *climate system* response to *forcing* and in *internal variability*.

- Bottom line: Physical climate storylines represent uncertainty, where traditional probabilistic approaches (which are necessarily highly aggregated and simplified, and typically univariate) are limited or inappropriate
  - They are especially useful for representing correlated or compound risk

Research Question (storyline) (conditional)

Given the conditional state of the extreme event, how did climate change alter its **impacts**?

Research Question (storyline)

"**Given** an extreme event, how did climate change alter its **impacts**?

Possible and responsive answers
A: climate change made the event <u>more severe</u>

A: it made the storm or extreme event <u>less</u> <u>severe</u>

A: there was <u>no effec</u>t of climate change on
     the severity of the event
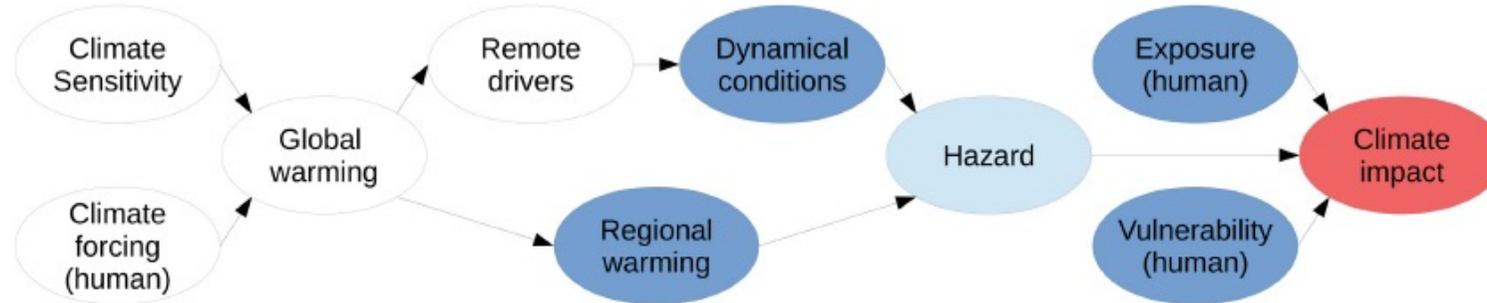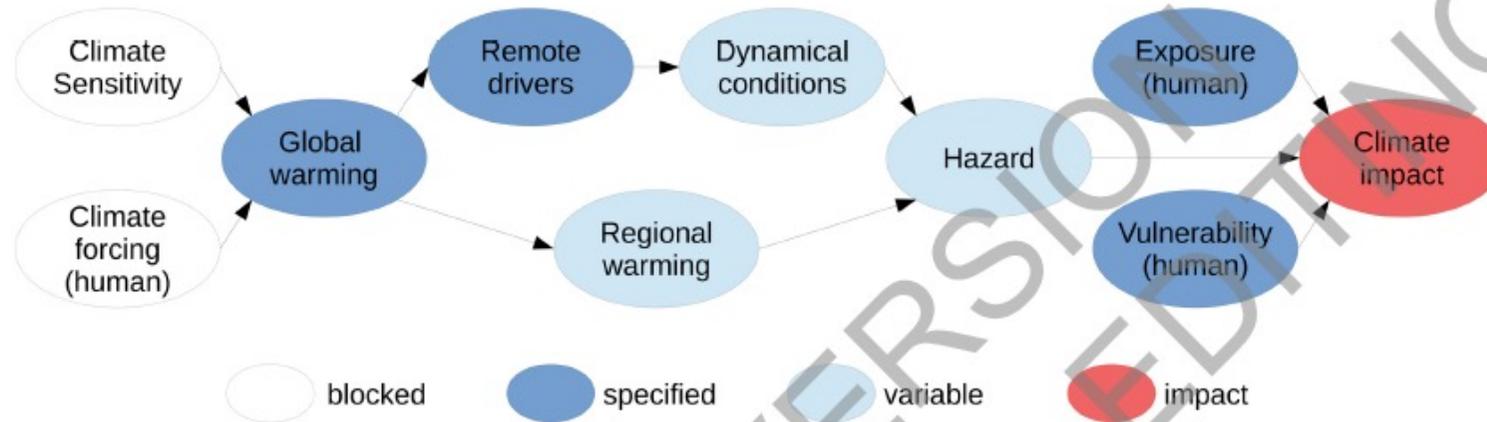
IPCC AR6 WGI Chapter 10, Box 10.2, Figure 1 (subject to editing); after Shepherd (2019 PRSA); See application to arctic case in Lloyd and Shepherd (2020 Annals NY Acad Scis)
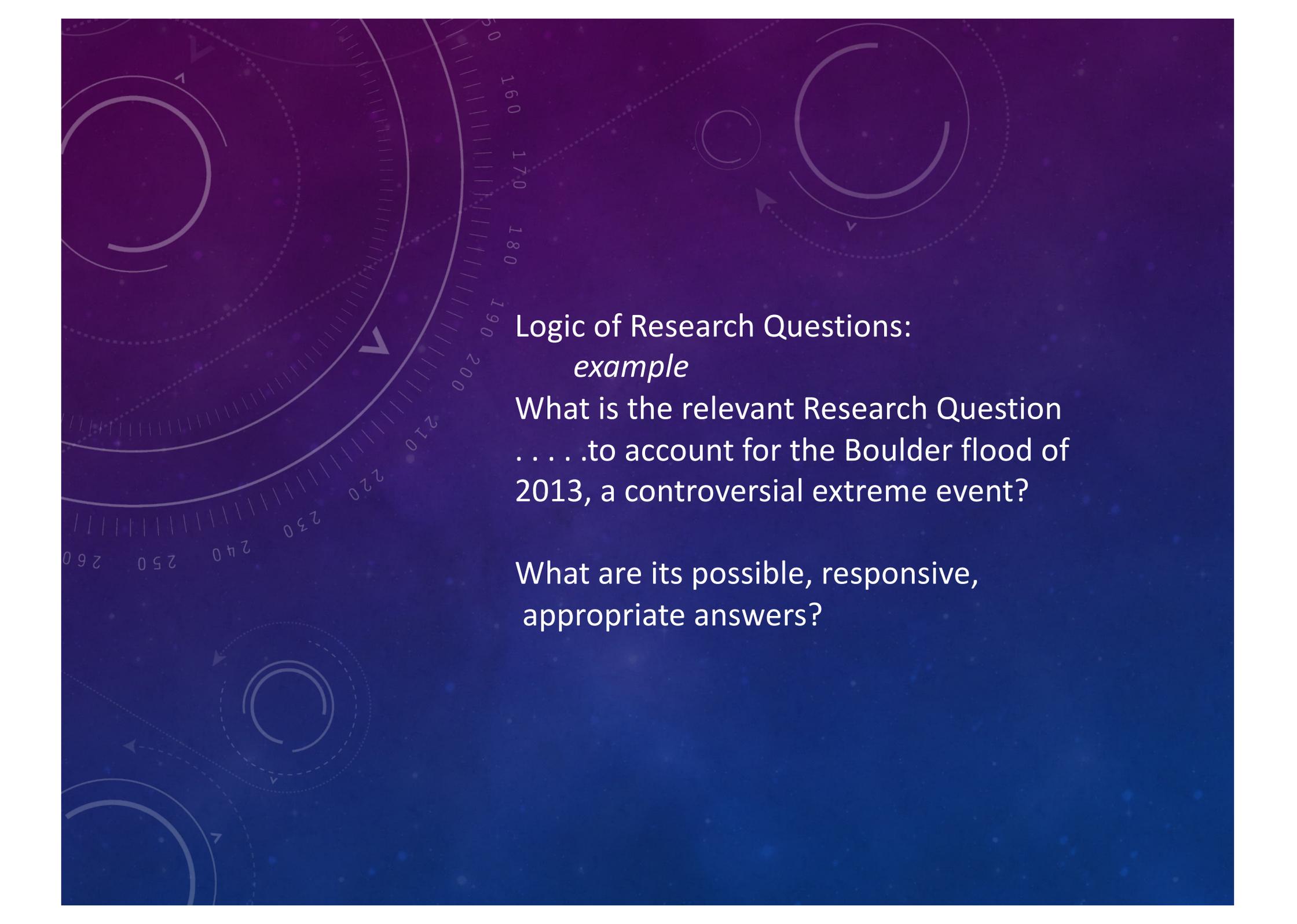
Logic of Research Questions:
   example
What is the relevant Research Question
. . . . .to account for the Boulder flood of
2013, a controversial extreme event?

What are its possible, responsive,
 appropriate answers?

Research Question (storyline)

"**Given** the Boulder, CO flood of 2013,
How did climate change affect the **severity** of the flood,
all other things being equal?"

Possible answers
A: it made more water available to the storm,
    e.g., through the Clausius/Clapyron relation,
    making the flooding more severe

A: it made the storm less severe

A: there was no effect of climate change on
    the severity of the storm
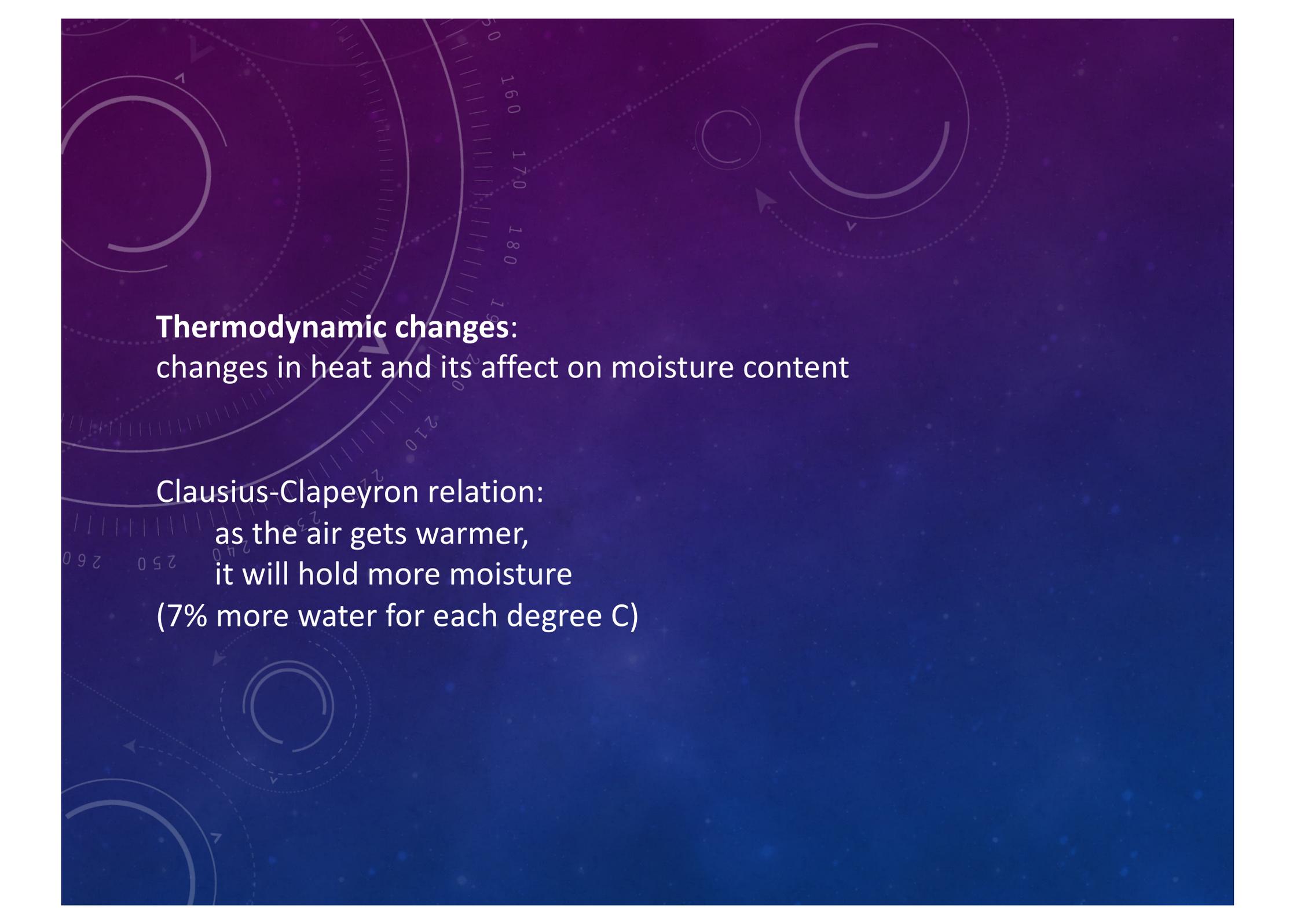
Thermodynamic changes:
changes in heat and its affect on moisture content

Clausius-Clapeyron relation:
    as the air gets warmer,
    it will hold more moisture
(7% more water for each degree C)

Research Question (storyline—Trenberth, Fusillo, Shepherd 2015)

"**Given** the Boulder flood of 2013,
How did climate change affect the **severity** of the flood,
all other things being equal?"

Possible answers
A: it made **more water available to the storm**,
   through the Clausius/Clapyron relation,
   making the flooding more severe
   (Trenberth et al. 2015)

A: it made the storm less severe

A: there was no effect of climate change on
    the severity of the storm

Type of Scientific Error this method makes?
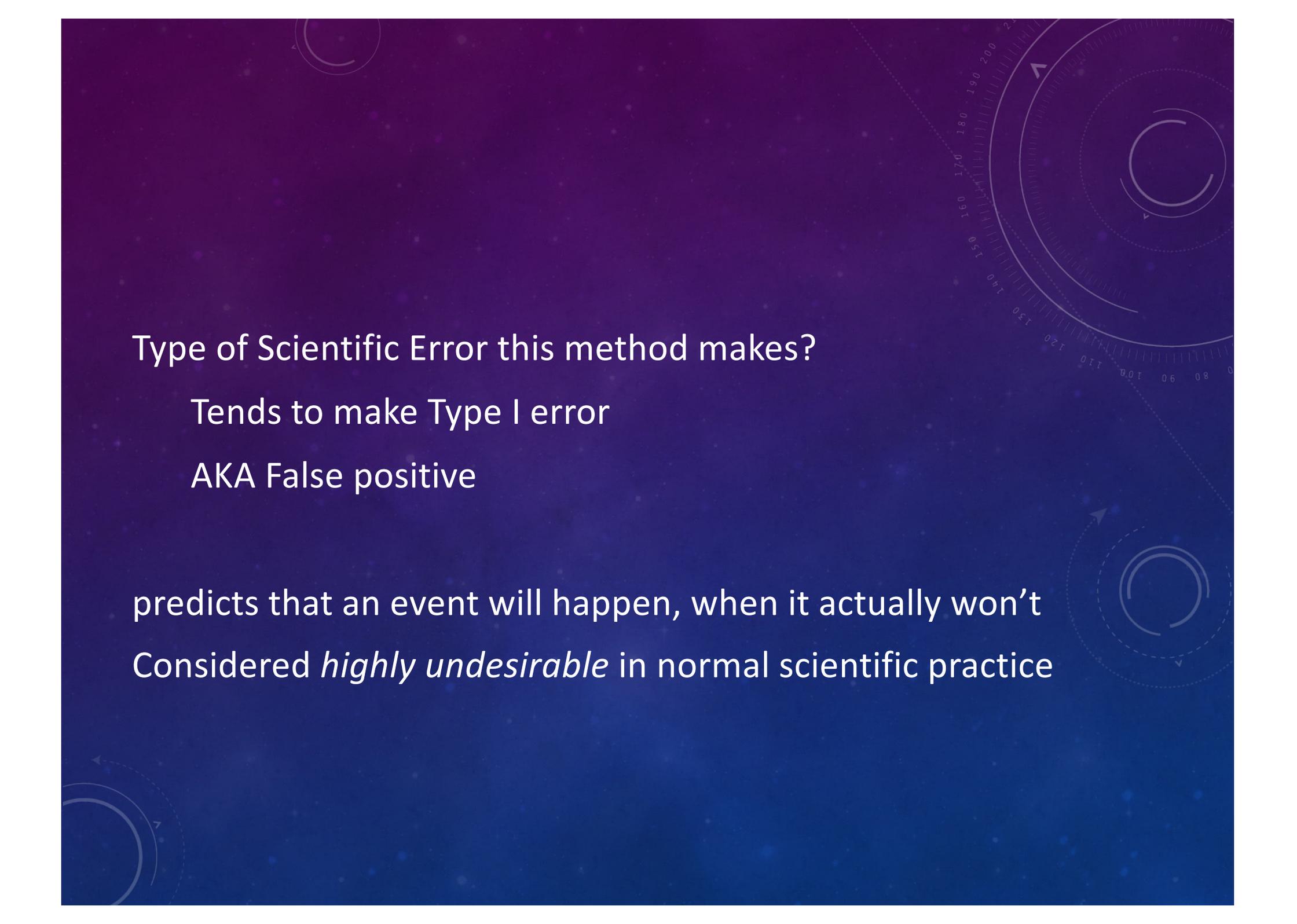
Tends to make Type I error

AKA False positive

predicts that an event will happen, when it actually won't

Considered *highly undesirable* in normal scientific practice

Research Question (risk-based):
"What is the **probability or risk** of a specific <u>class</u> of weather
Event like the Boulder 2013 flood, given our world **with** global climate change,
relative to a world **without** such change?"

Possible answers
A: the risk of this type/class of extreme events
   will increase because of climate change

A: **the risk of this type of extreme event
   (Boulder excess rain and flooding) will <u>decrease</u> because
   of climate change (Hoerling et al. 2014)**
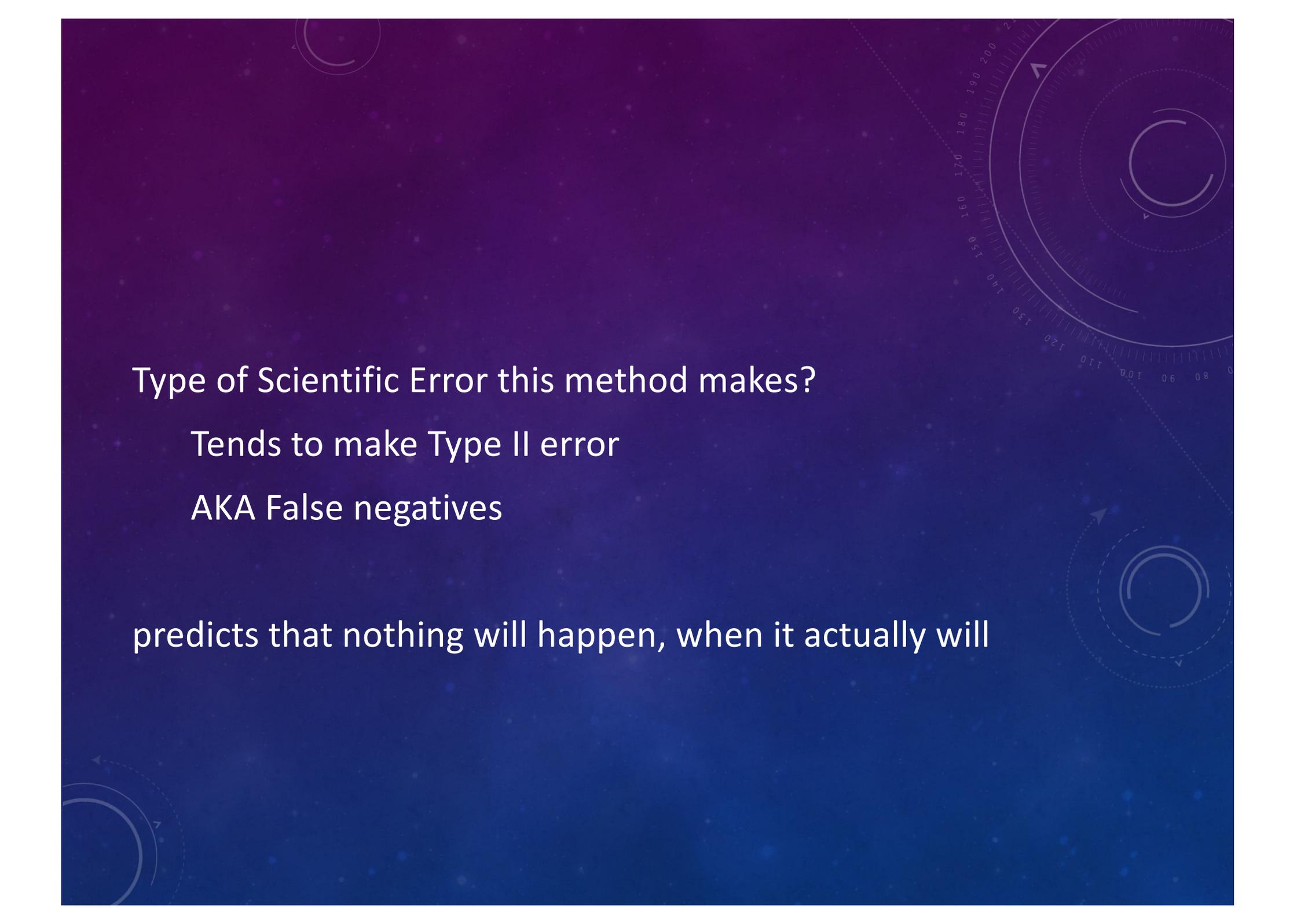
A: the risk of this type of extreme event
    is unaffected by climate change

Type of Scientific Error this method makes?

    Tends to make Type II error

    AKA False negatives

predicts that nothing will happen, when it actually will

Research Question (Robust Event Analysis (REA):
combo storyline & risk-based, Pall et al. 2017):

"**Given** the Boulder flood of 2013 and its mechanisms,
how did climate change affect the **severity** of the flood,
all other things being equal?"

Possible answers
A: **the magnitude of this type/class of extreme events,
based on mechanisms, will increase
about 30% because of climate change
(Pall et al. 2017) using <u>both storyline/risk methods (REA)</u>**

A: it made the storm less severe

A: there was no effect of climate change on
the severity of the storm

Type of Scientific Error this "Robust Event Attribution," REA, method makes?

Tends to make Type I error AND Type II error

Tend to balance out one another

- (Donhauser, Lloyd, and Pall 2022 BAMS invited)

"…whether the simulated change in the likelihood or severity of such conditions *is credible. . .*

And if plausible uncertainties are placed on those changes, then the result is likely to be 'no effect detected'. . .

But absence of evidence is not evidence of absence."

- (Shepherd 2016, p. 32)
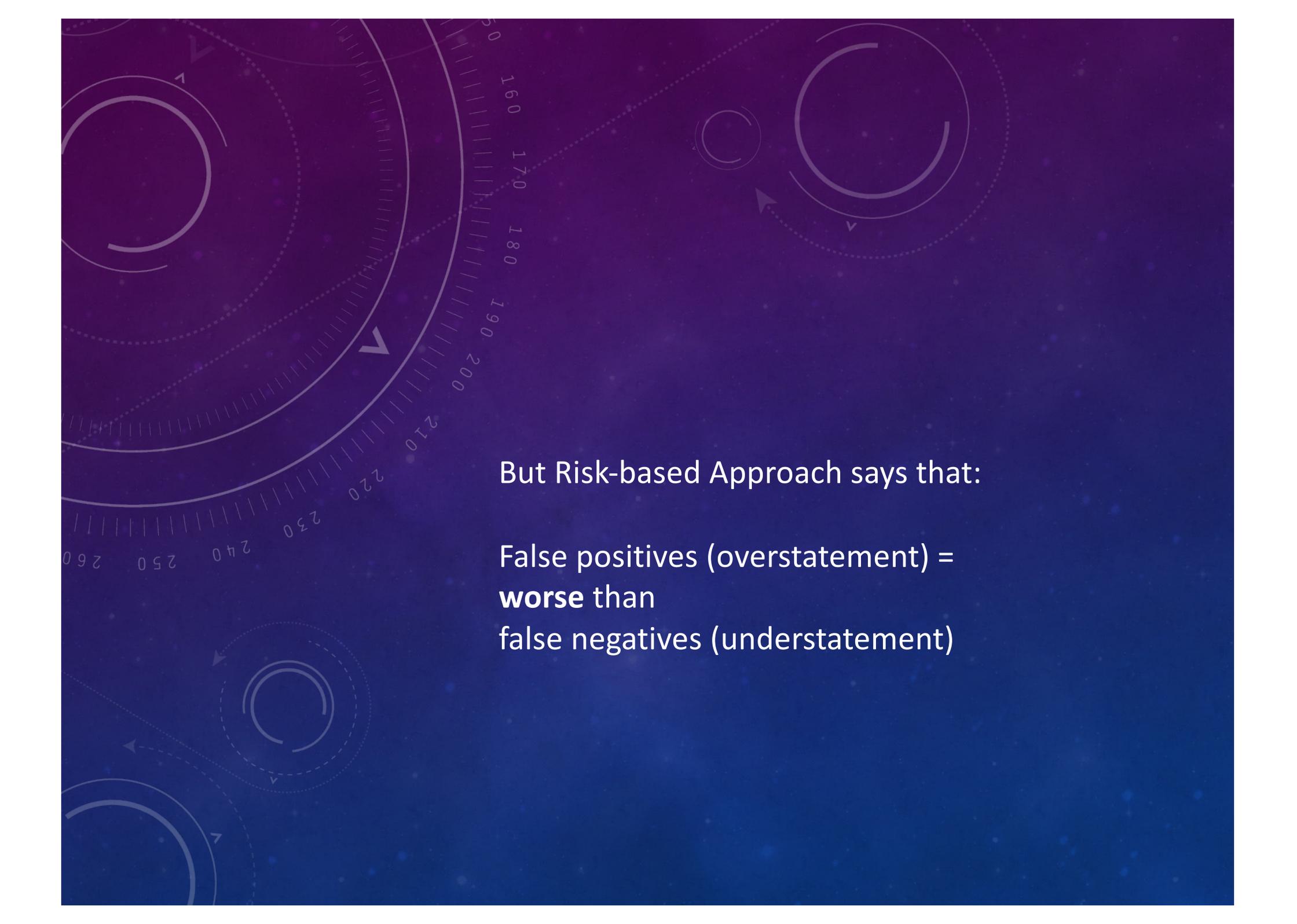
But Risk-based Approach says that:

False positives (overstatement) =
**worse** than
false negatives (understatement)
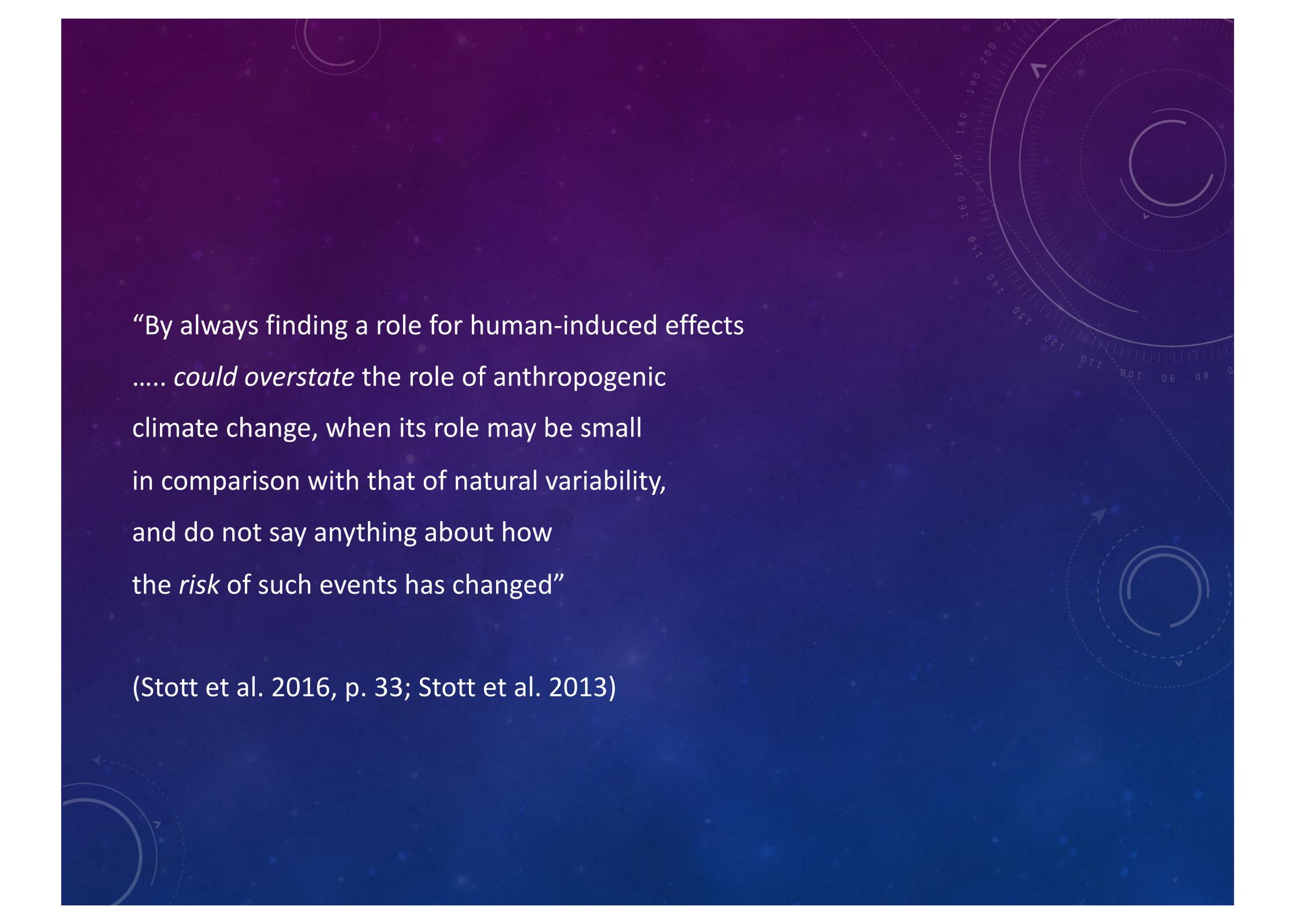
"By always finding a role for human-induced effects

….. *could overstate* the role of anthropogenic

climate change, when its role may be small

in comparison with that of natural variability,

and do not say anything about how

the *risk* of such events has changed"

(Stott et al. 2016, p. 33; Stott et al. 2013)
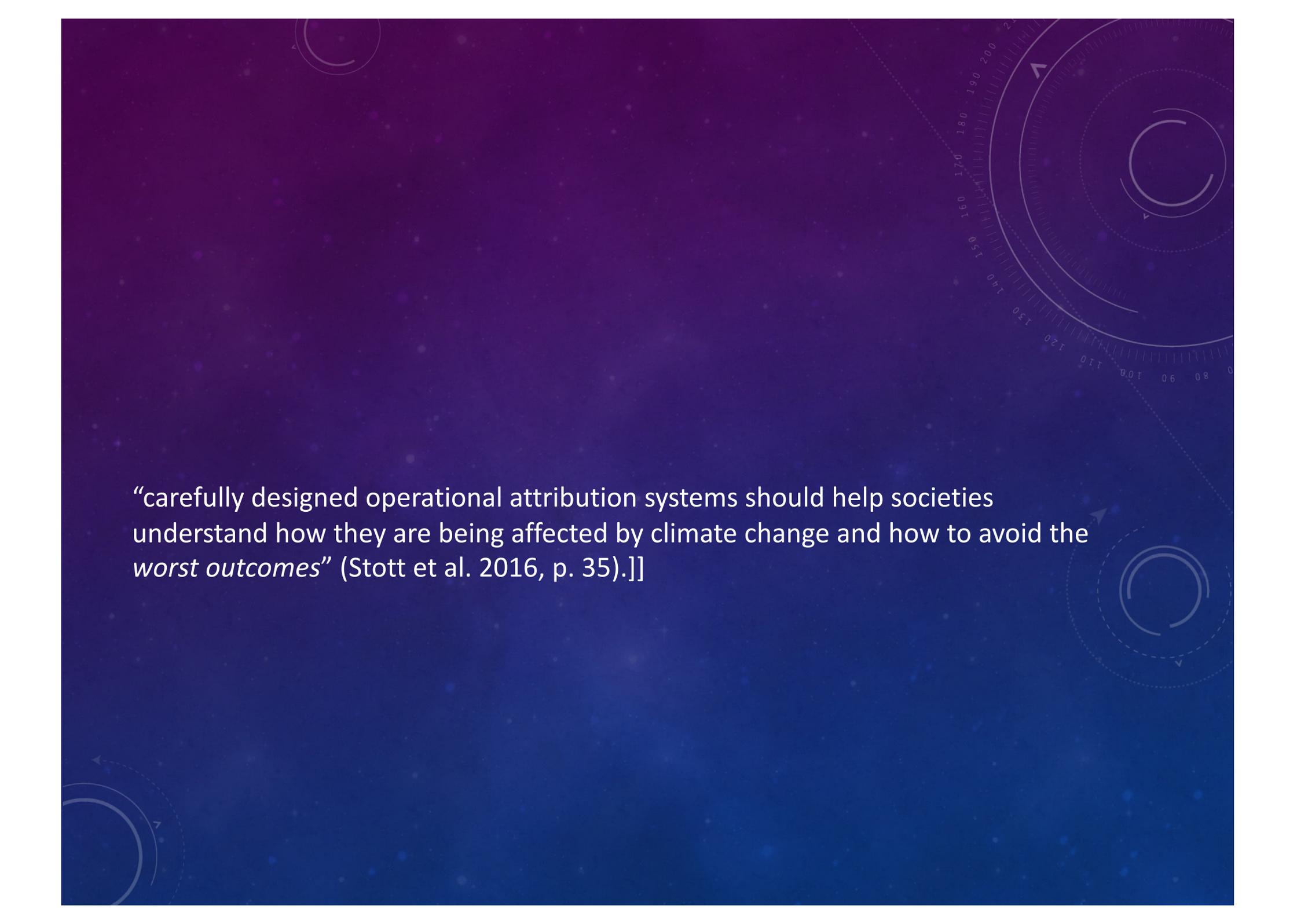
"carefully designed operational attribution systems should help societies understand how they are being affected by climate change and how to avoid the *worst outcomes*" (Stott et al. 2016, p. 35).]]
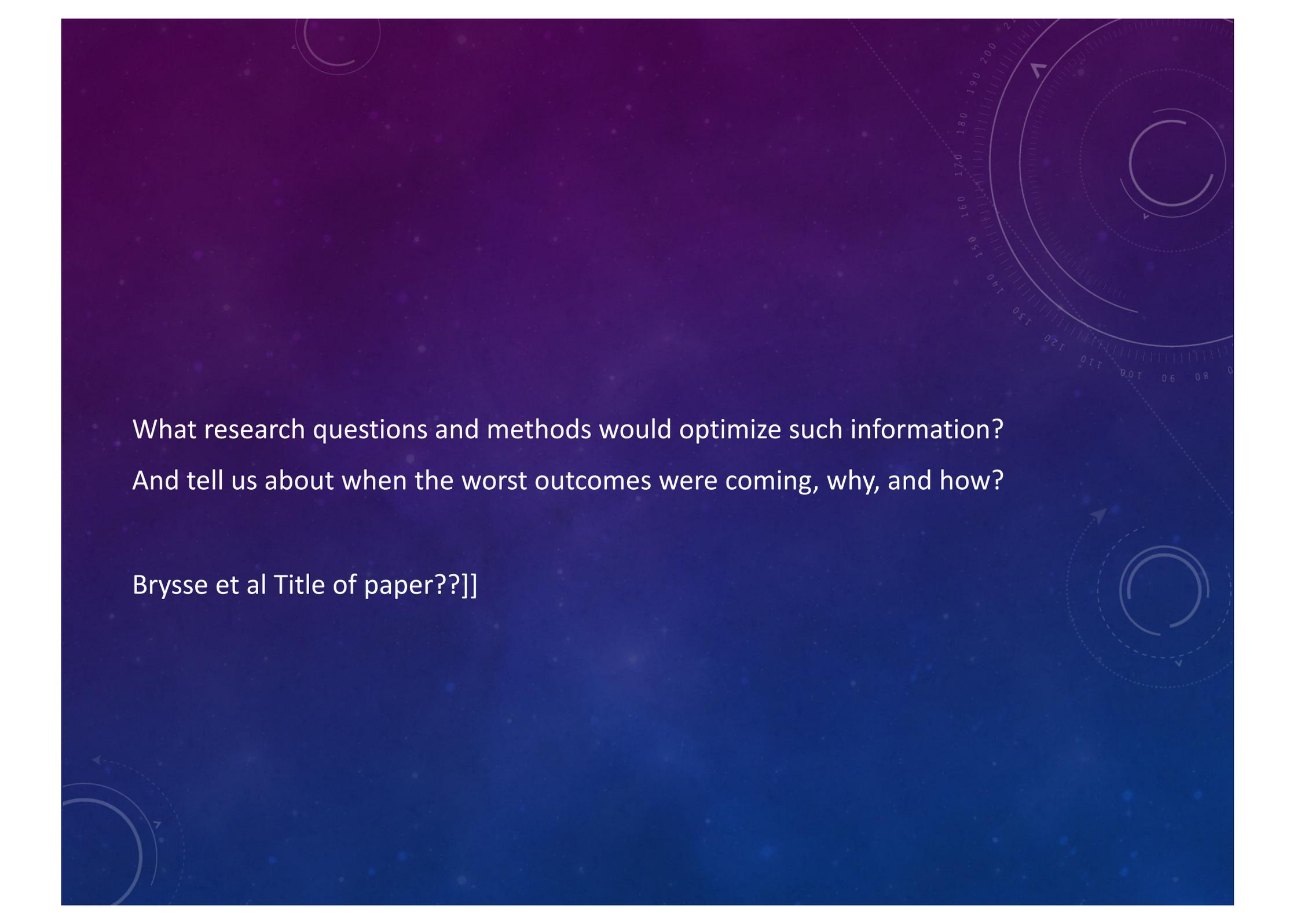
What research questions and methods would optimize such information?

And tell us about when the worst outcomes were coming, why, and how?

Brysse et al Title of paper??]]
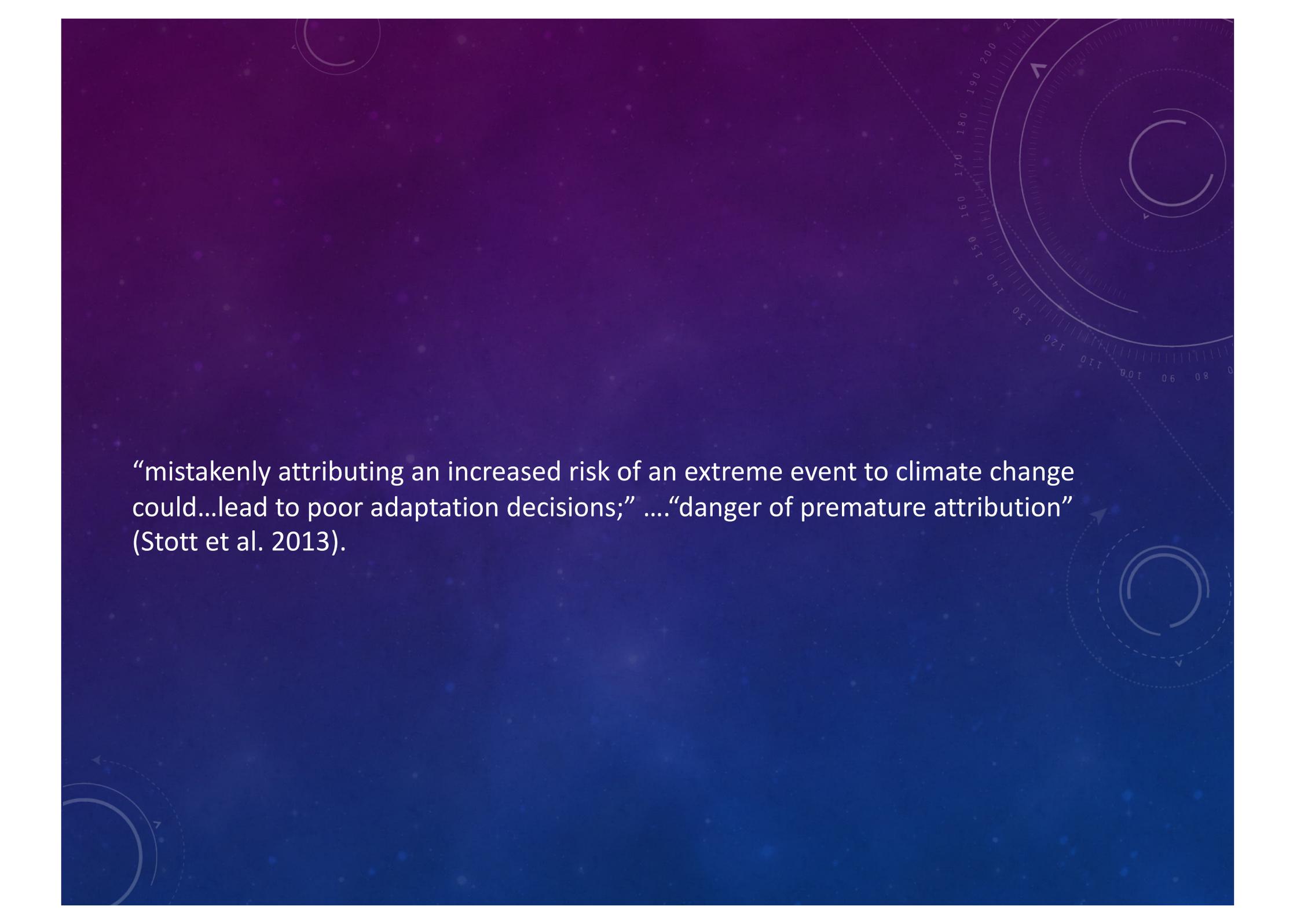
"mistakenly attributing an increased risk of an extreme event to climate change could…lead to poor adaptation decisions;" …."danger of premature attribution" (Stott et al. 2013).
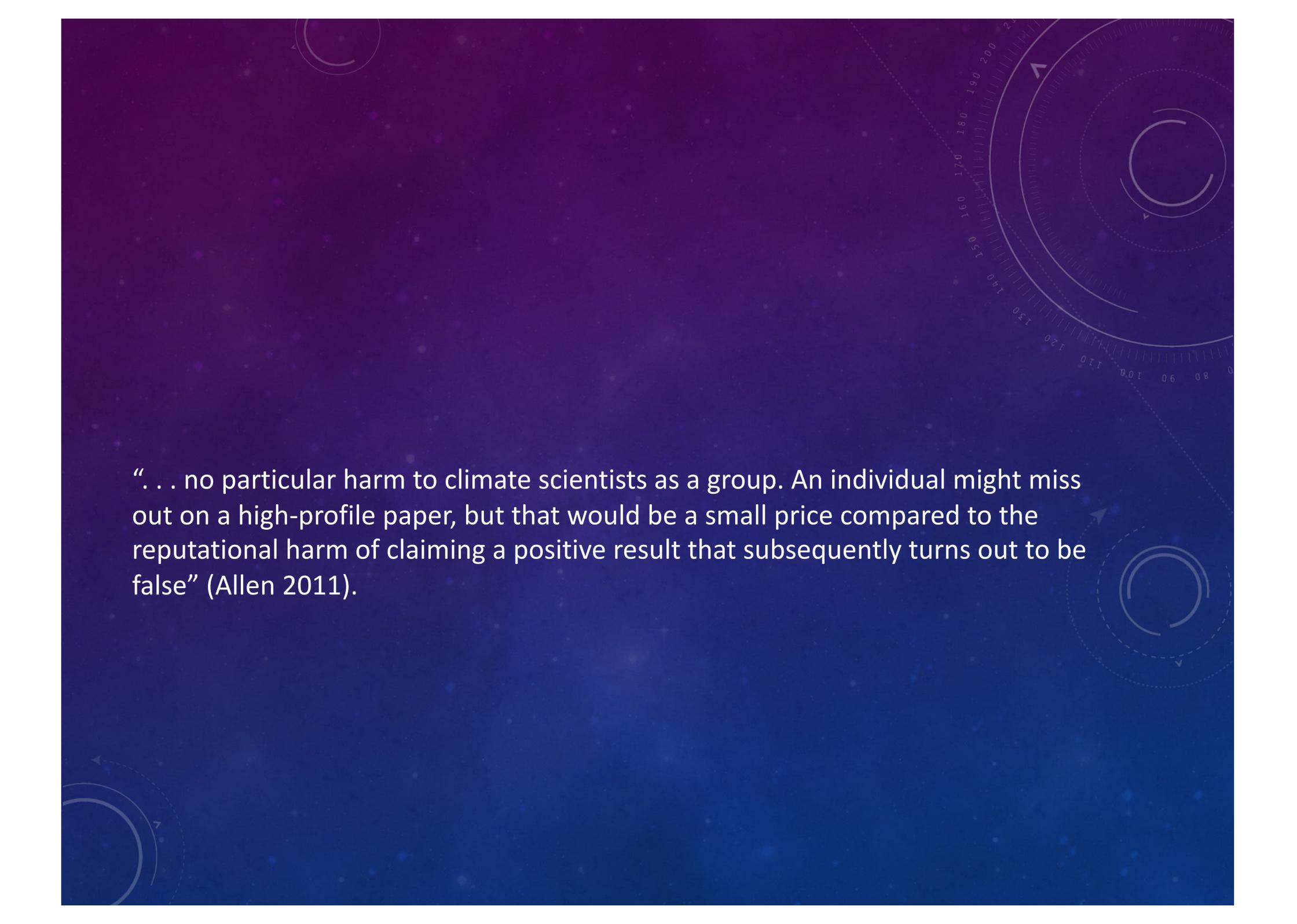
". . . no particular harm to climate scientists as a group. An individual might miss out on a high-profile paper, but that would be a small price compared to the reputational harm of claiming a positive result that subsequently turns out to be false" (Allen 2011).
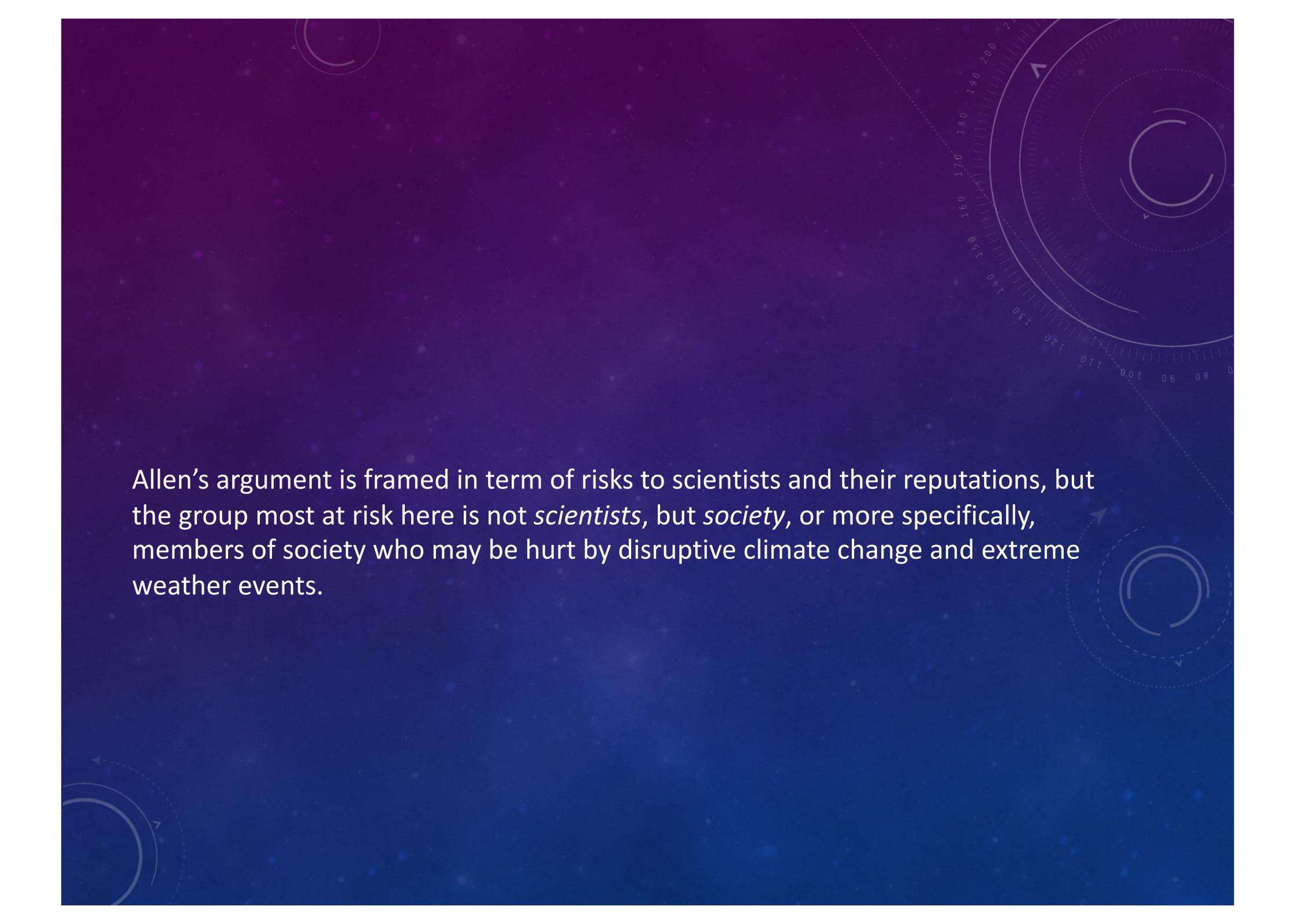
Allen's argument is framed in term of risks to scientists and their reputations, but the group most at risk here is not *scientists*, but *society*, or more specifically, members of society who may be hurt by disruptive climate change and extreme weather events.

". . . no particular harm to climate scientists as a group. An individual might <u>miss out on a high-profile paper</u>, but that would be a small price compared to the reputational harm of claiming a positive result that subsequently turns out to be false" (Allen 2011).

Significant reputational harms can accrue to experts who fail to predict important events (think Pearl Harbor and 9/11), or who fail to recognize and warn against adverse effects in a timely manner (e.g., Fukishima, Japan, L'Aquila, Italy, or Flint, Michigan; Oreskes 2015).
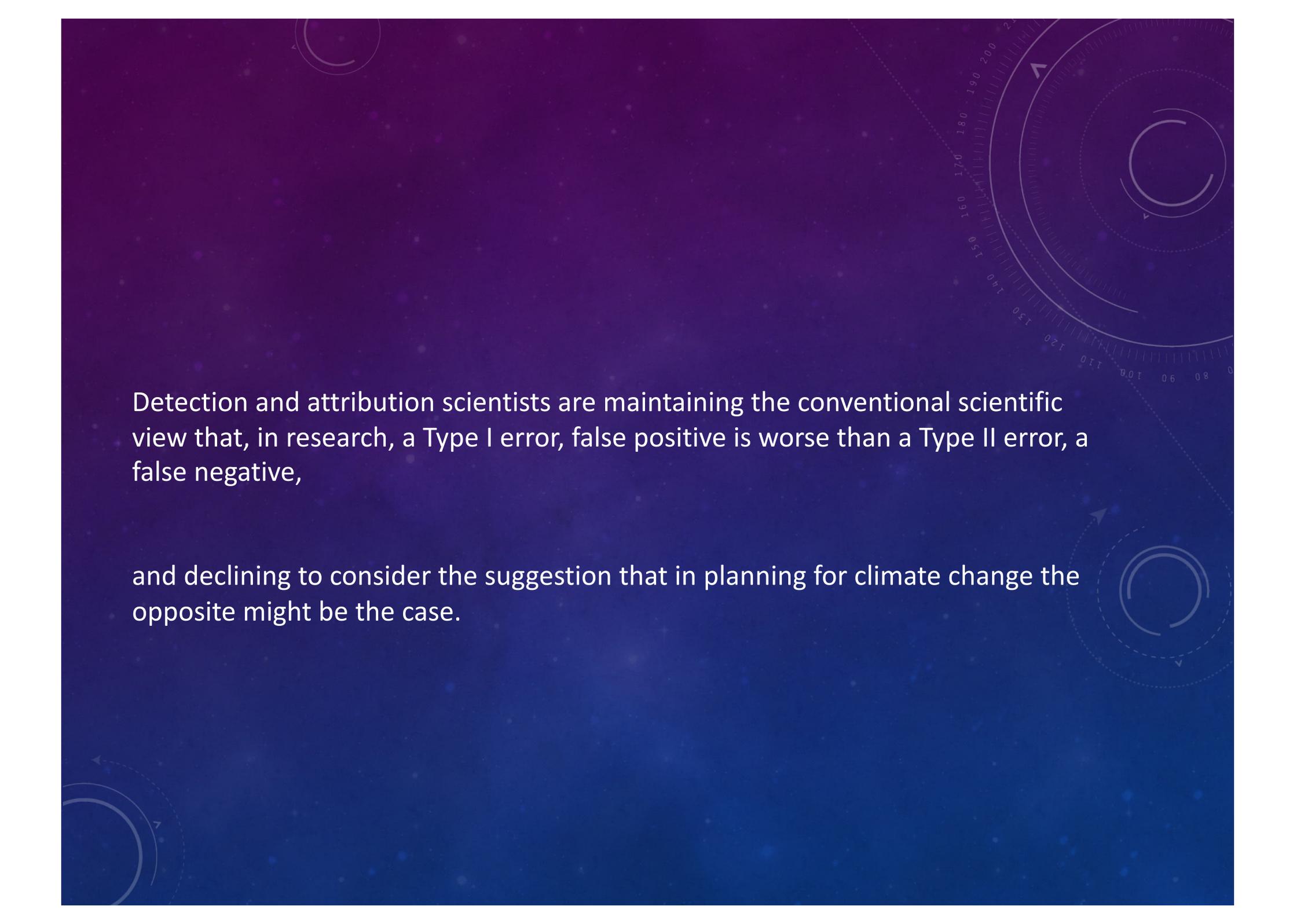
Detection and attribution scientists are maintaining the conventional scientific view that, in research, a Type I error, false positive is worse than a Type II error, a false negative,

and declining to consider the suggestion that in planning for climate change the opposite might be the case.

Scientists do not always assume a default of no effect.

To show new drug is effective, assume Null of no effect

BUT: To show a new drug is safe:

Null = adverse effect
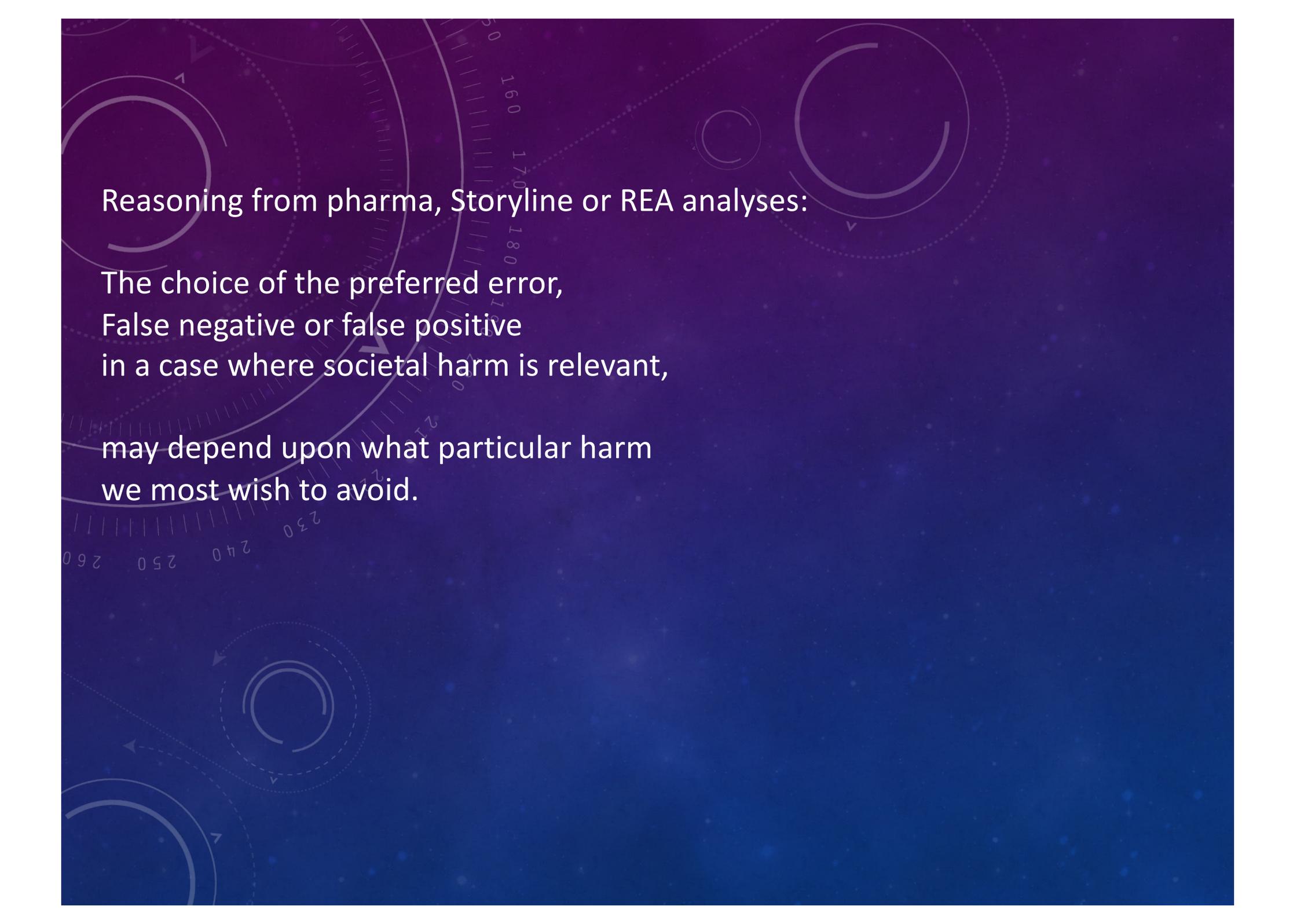
Reasoning from pharma, Storyline or REA analyses:

The choice of the preferred error,
False negative or false positive
in a case where societal harm is relevant,

may depend upon what particular harm
we most wish to avoid.
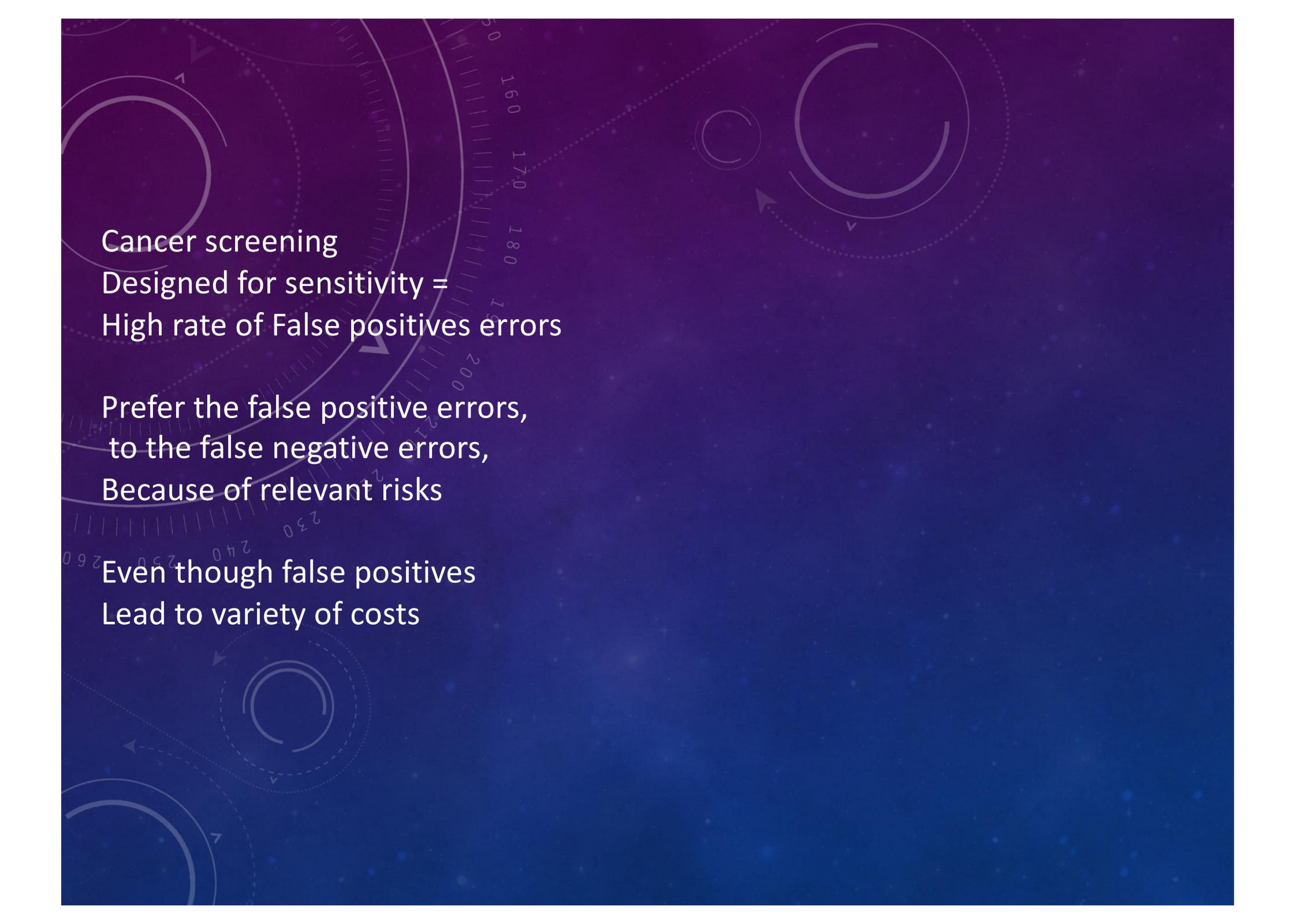
Cancer screening
Designed for sensitivity =
High rate of False positives errors

Prefer the false positive errors,
 to the false negative errors,
Because of relevant risks

Even though false positives
Lead to variety of costs

Cancer screening
Designed for sensitivity =
High rate of False positives errors

Prefer the false positive errors,
 to the false negative errors,
Because of relevant risks

Climate: **Current risk-based D&A**
Insensitive: Low rate of False positives,
Low over-reacting
High risks to society of under-reporting
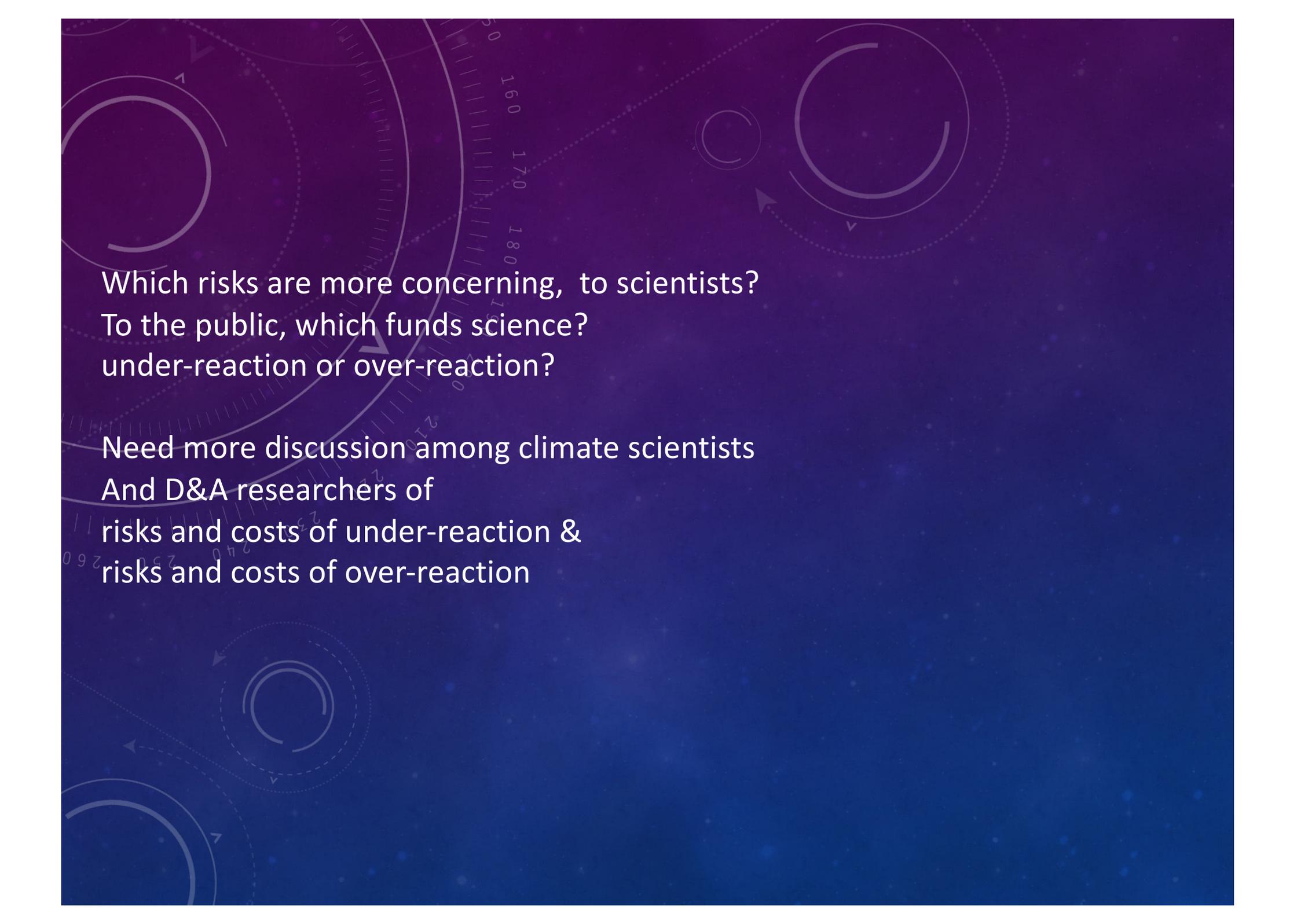
Which risks are more concerning, to scientists?
To the public, which funds science?
under-reaction or over-reaction?

Need more discussion among climate scientists
And D&A researchers of
risks and costs of under-reaction &
risks and costs of over-reaction
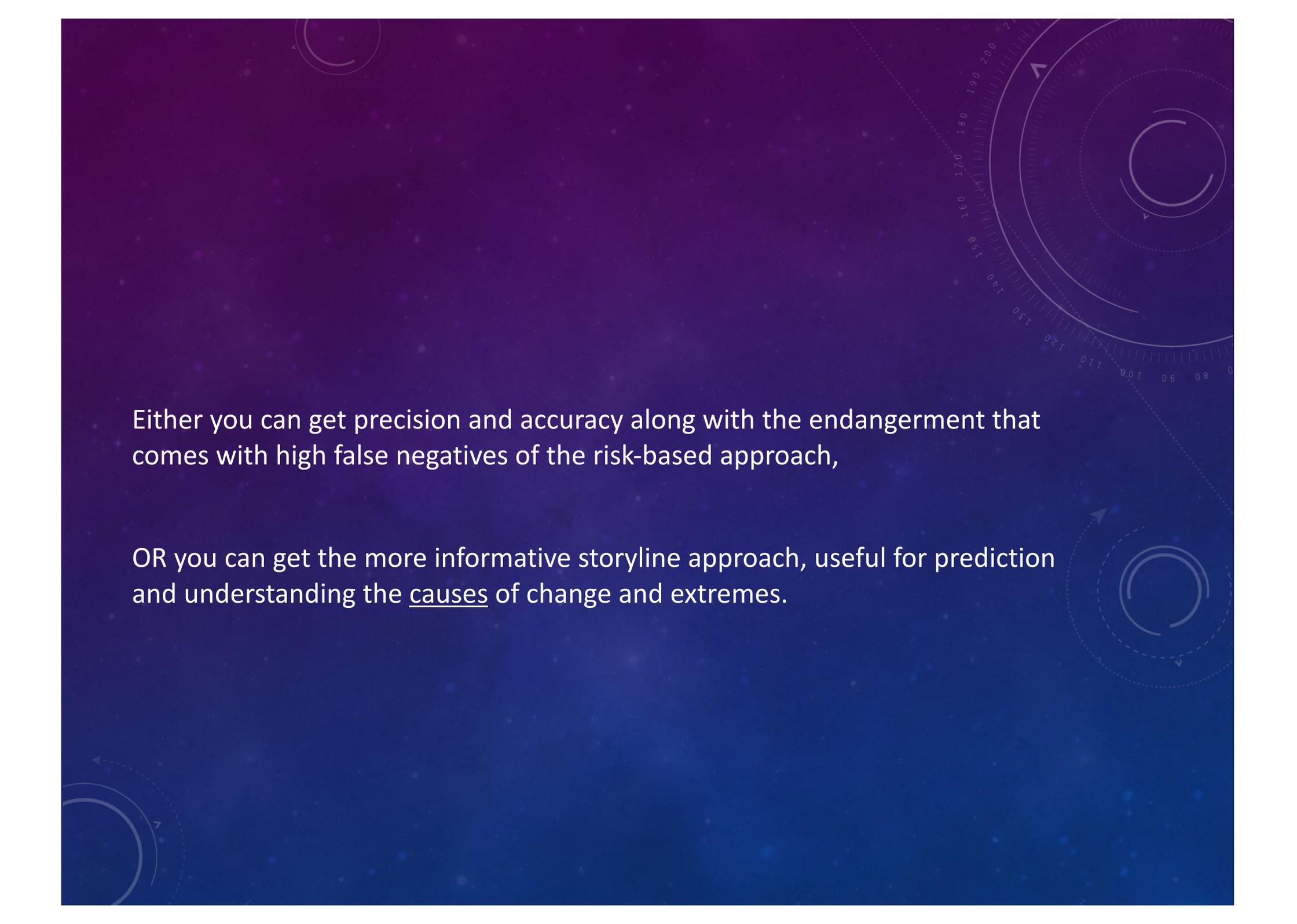
Either you can get precision and accuracy along with the endangerment that comes with high false negatives of the risk-based approach,

OR you can get the more informative storyline approach, useful for prediction and understanding the _causes_ of change and extremes.

risk-based approach *cannot*, technically, give you *causal account*s , given the probability tools they are using, which do not entitle them to such singular causal claims

Risk-based approaches, as *counterfactual claim*s about _classes _of events, can give us _neither causal_ accounts of individual events, _nor predictions_ of future events .

Stone, D. A., & Allen, M. R. (2005). The end-to-end attribution problem: From emissions to impacts. *Climatic Change*, *71*(3), 303-318.

Donhauser, Justin. "The Value of Weather Event Science for Pending UN Climate Policy Decisions." *Ethics, Policy and Environment*, no. 3 (2017): 263–78.

Justin Donhauser, Elisabeth A. Lloyd, Pardeep Pall (2022) "Robust Weather Event Attribution: a more complete approach." (Invited, Under review at BAMS, Bulletin of the American Meteorological Society).

Cancer screening
Designed for sensitivity =
High rate of False positives errors

Prefer the false positive errors,
 to the false negative errors,
Because of relevant risks

Climate: **Proposed Storyline D&A**
Sensitive: Higher rate of False positives, Type I error
Higher over-reacting
Low Type II error, lower risks to society of under-reporting

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Tropical Cyclones and Climate Change Assessment: Part I: Detection and Attribution

KNUTSON ET AL. HURRICANES

"As discussed by Lloyd and Oreskes . . . . for future planning and risk assessment, one may want to reduce Type II errors [false negatives] in particular. For example, **planners for infrastructure development in coastal regions** may want to consider emerging detection/attribution findings--even if not at the 0.05 significance level-- in their planning and decision-making."

(BAMS 2019)

KNUTSON ET AL. ON LLOYD AND ORESKES

power and utility of having an alternative account operating under *different*, but *equally scientific*, statistical standards.

SHEPHERD, ORESKES, MANN, DONHAUSER, PALL, AND LLOYD

REA: Robust Event Attribution: Donhauser, Lloyd, and Pall

Using model robustness analysis to combine all available methods of attribution of extreme events, including risk-based, storyline, and other conditional approaches.
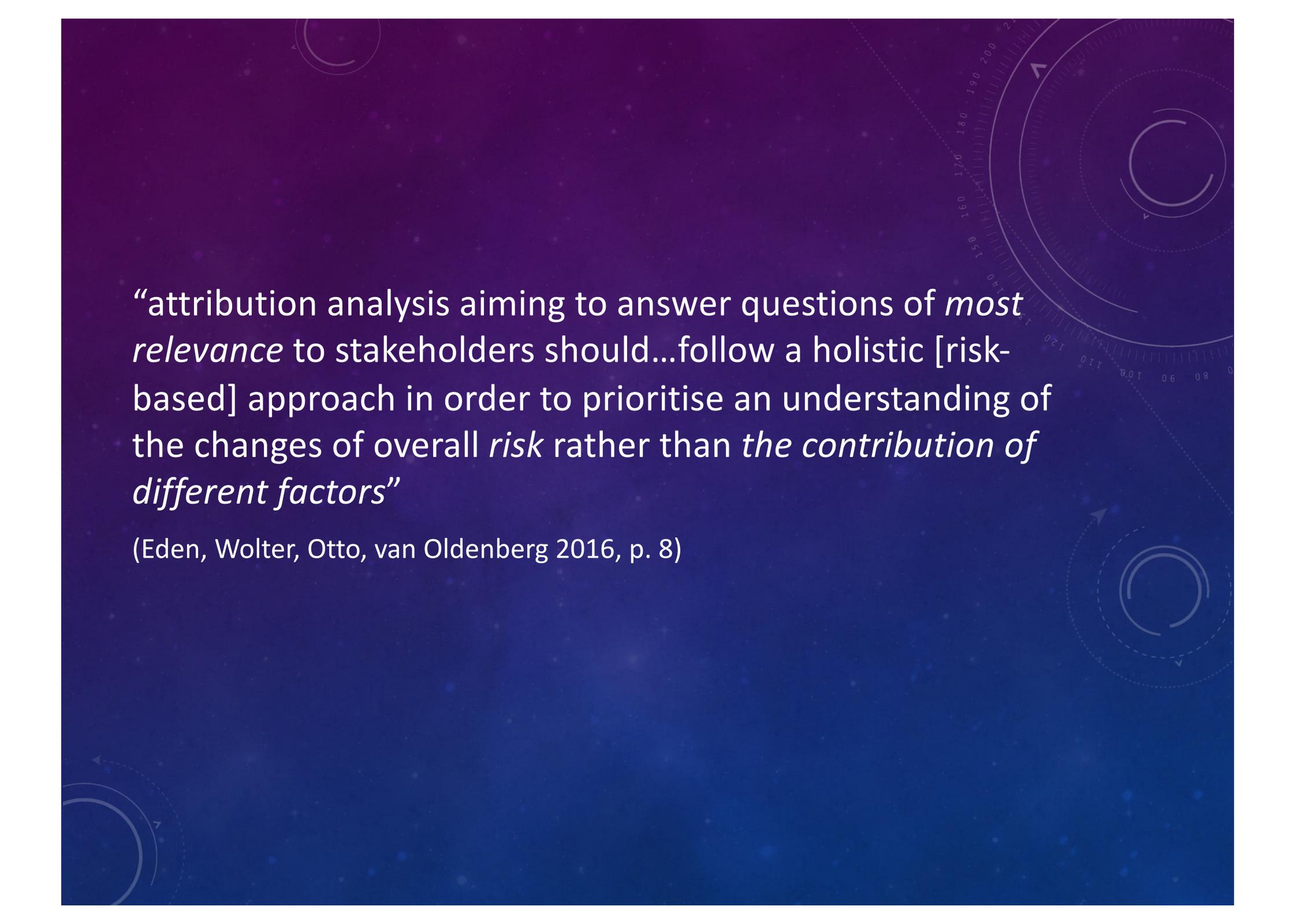
"attribution analysis aiming to answer questions of *most relevance* to stakeholders should...follow a holistic [risk-based] approach in order to prioritise an understanding of the changes of overall *risk* rather than *the contribution of different factors*"

(Eden, Wolter, Otto, van Oldenberg 2016, p. 8)

PLAINTIFF'S CLAIMS

Juliana et al. v. United States

- plaintiffs claimed constitutional violations via the specific harms undergone via damages from GHG global warming

- (US government deemed partly responsible),

- having aggravated particular kinds of extreme weather and climate events in the US.

(see e.g., Burger et al. 2020, section III.C.3.b.i),

Climate change attribution and legal contexts: evidence and the role of storylines

Elisabeth A. Lloyd[1] • Theodore G. Shepherd[2]

Question: How well does the storyline approach to extreme event attribution align with the requirements of evidence in the context of legal liability for harm?

"The question is", said Alice, "whether you can make words mean different things."
"The question is", said Humpty Dumpty, "which is to be master — that's all."
(Lewis Carroll, Alice's Adventures in Wonderland)

ROLE OF STORYLINE METHOD IN CASE

Event attribution question at the heart of the case.

Trenberth gave testimony using causal, conditional, 'storyline' attribution method supporting plaintiffs.

Trenberth took certain factors as contingent and assessed the role of climate change conditional on those factors.

US Government used integrated assessment modeler John Weyant to rebut Trenberth's analyses.

Climate lawyers Burger et al. (2020) explain why the Juliana case is so significant:

"*Juliana* illustrates some of the challenges plaintiffs may face in establishing a causal connection to individual injuries…

the plaintiffs dedicated a large portion of their briefs and expert testimony to defining that causal nexus between climate change and specific injuries, and if the case had gone to trial, this would have been one of *the key factual disputes*."

Burger et al. (2020 Columbia J. Environ. Law)

- Burger et al. note:

  "One critical question . . .is to what extent observational evidence of local impacts (e.g., loss of snowpack at ski resorts) can be used to support claims of injury *in the absence of an attribution study of a matching geographic and temporal scope* showing that the observed impact was caused by anthropogenic influence on climate change." [emphasis added]

- Such a detailed attribution study **would be essentially impossible to perform**

  Excluding evidence from being admissible is a classic technique in such cases

- The question then is whether it is nevertheless possible to **reason from the general to the specific**, taking account of the specificity in a contingent, conditional manner

- Is it possible to reason from the general to the specific in these cases of climate change attribution?

- Because *Juliana* has been dismissed on unrelated (standing and justiciability) grounds this specific climate question has yet to be tested in court.

- Can review principles of reasoning offered in this case, for possible future applications.

(see Burger et al. 2020, section III.C.1.b.vi),

WEYANT'S TESTIMONY

"Reports of Plaintiff's Experts Trenberth [and Running] do not and cannot reliably tie global climate change due to the Defendants' conduct at issue to the claimed injuries. . . because: These climate and climate impact models generally cannot determine the regional effects of global climate change to the <u>degree of specificity necessary to causally link to specific weather events</u>, let alone to individuals and any claimed injuries."

WEYANT'S TESTIMONY

"The current set of climate and climate impact models

cannot separate the[various causal] factors with <u>*sufficient certainty to disentangle the effect of regional climate changes*</u> from the effect of other region-specific <u>*confounding factors."*</u> (emphasis added)

"C. Unsupported Logical Leap of Dr. Trenberth's Analysis"

". . . but all [Trenberth's] conclusions of the injuries to Plaintiffs suffer from the _same failure to_ _connect his conditional approach conclusions to_ _Plaintiffs' local circumstances_." (emphasis added)

TAKING AN INSTANCE

- this "unsupported logical leap" = standard logical inference of *taking an instance from a generalization*:

- Trenberth taking a general statement, generalizing over many individual cases or members of a group, about a phenomenon applying to an area of the world, or a season, members of a group, or a pattern of the physical world, and then picking out *one* of those cases as an example or instance of that phenomenon,

......which Weyant describes as an illegitimate "leap" of logic.

WEYANT'S "LOGICAL ARGUMENT"

"e. Dr. Trenberth states:

'Plaintiff Nathan has experienced thawing permafrost and wildfires around his home in Fairbanks, Alaska, especially in 2015. Thawing permafrost is uneven and more likely on sunlight [sic] slopes, and has led to tilted and broken buildings and frost heaves in roads. Wildfires were widespread in Alaska in the summer of 2015. These harms are made worse by human-induced climate change.'"

WEYANT'S "LOGICAL ARGUMENT"

But Weyant responds to Trenberth's analysis that climate change made the thawing permafrost and wildfires worse around Nathan with:

"As with his other examples, Dr. Trenberth does not address any *confounding factors* that might have contributed to the specific weather outcomes in Alaska in 2015, *the analysis of which is essential to reach a scientifically valid conclusion about <u>any causal role</u> played by human-induced climate change on Plaintiff Nathan.*" (p. 27, emphasis added)
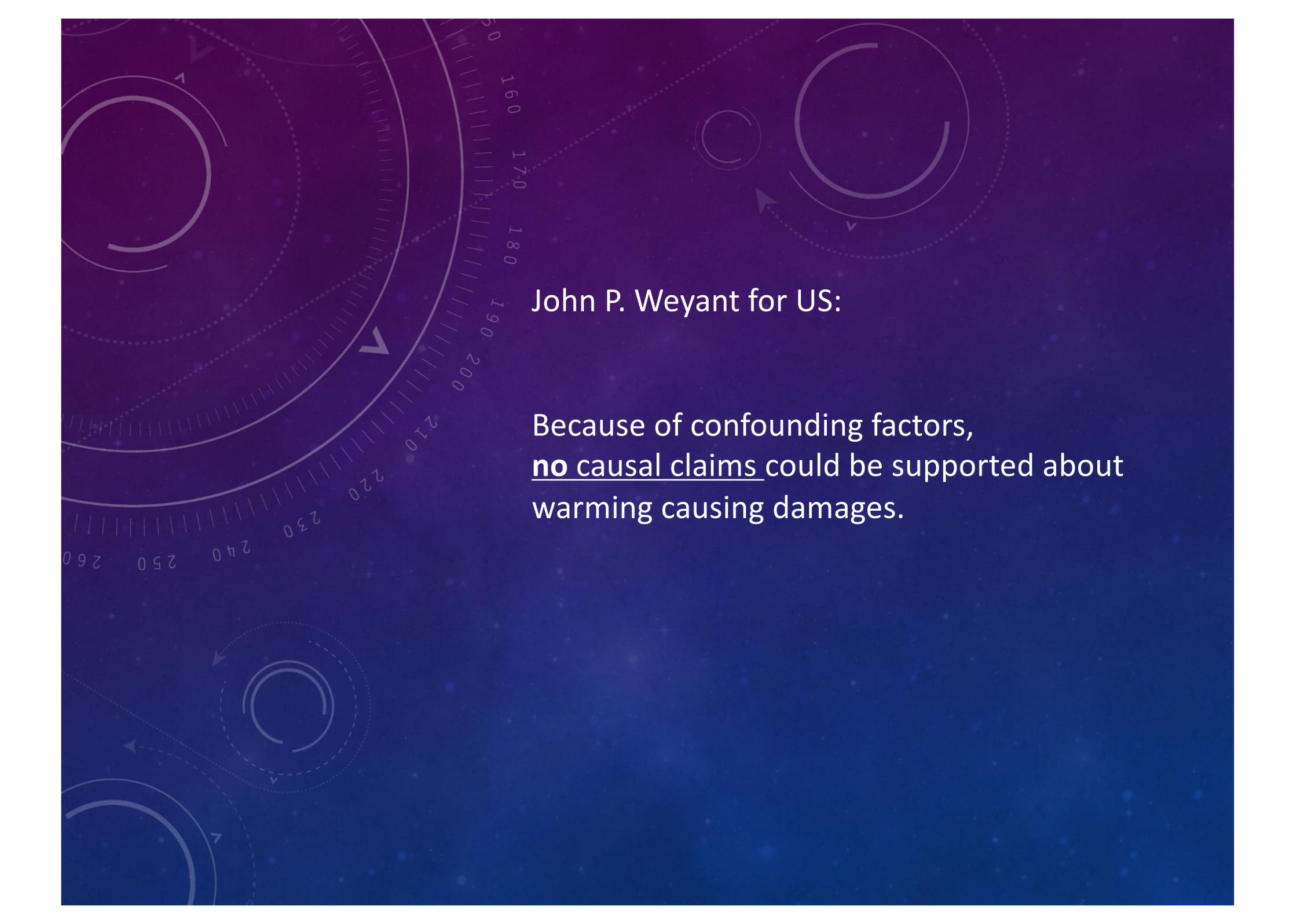
John P. Weyant for US:

Because of confounding factors,
no causal claims could be supported about
warming causing damages.

Causality in law

According to Cranor (2005 Law Philos.), there are five steps involved (paraphrased here)

1) A plausible causal chain must be articulated, connecting the action of the responsible party to the bad outcome, which is reflected in what actually happened. E.g., Can be considered a **scientific hypothesis**; expressible in a **causal network, from climate science.**

2) We also need **the** articulation of possible alternative explanations for the bad outcome.

3) We need tests that could discriminate between these possible alternative explanations, and their results

4) We need to show the collection of all relevant information, whichever hypothesis it supports.

5) And also we need to show the bad outcome being more probable with the specified cause than without it, considering chance, and mediating, confounding, or contributing factors.

CONFOUNDS
# VS. CONTRIBUTING OR MEDIATING CAUSES

- A confounding factor is something that influences both the alleged *cause* and the alleged *effect*, introducing *a spurious association that is not the causal one being alleged*. That is not the case here, so "confounding factors" is not a relevant concept.

- We are, rather, talking about a mediating or contributing factor.

- And we expect that the extent of impacts from climate change will depend on mediating factors such as vulnerability and exposure.
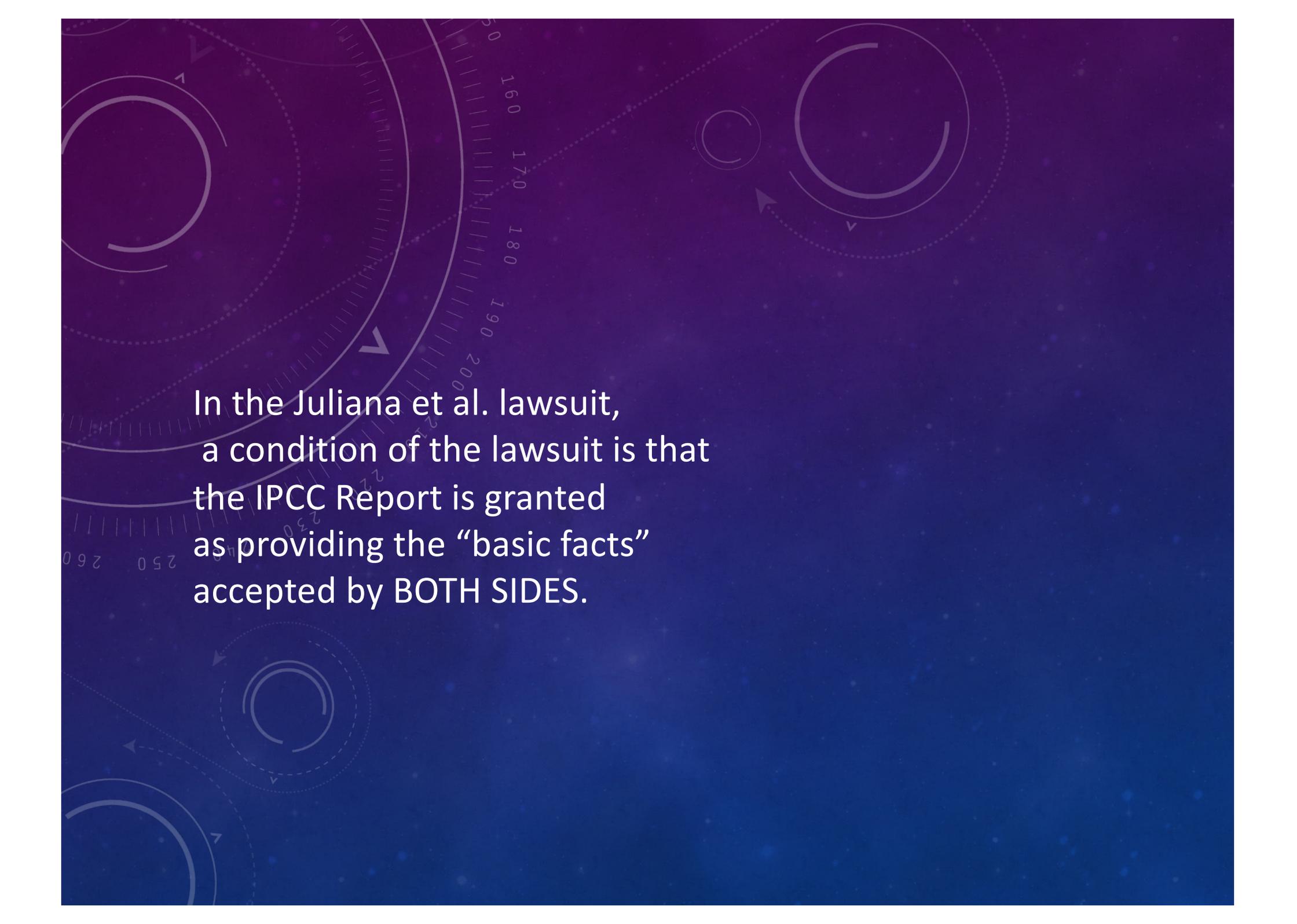
In the Juliana et al. lawsuit,
 a condition of the lawsuit is that
the IPCC Report is granted
as providing the "basic facts"
accepted by BOTH SIDES.
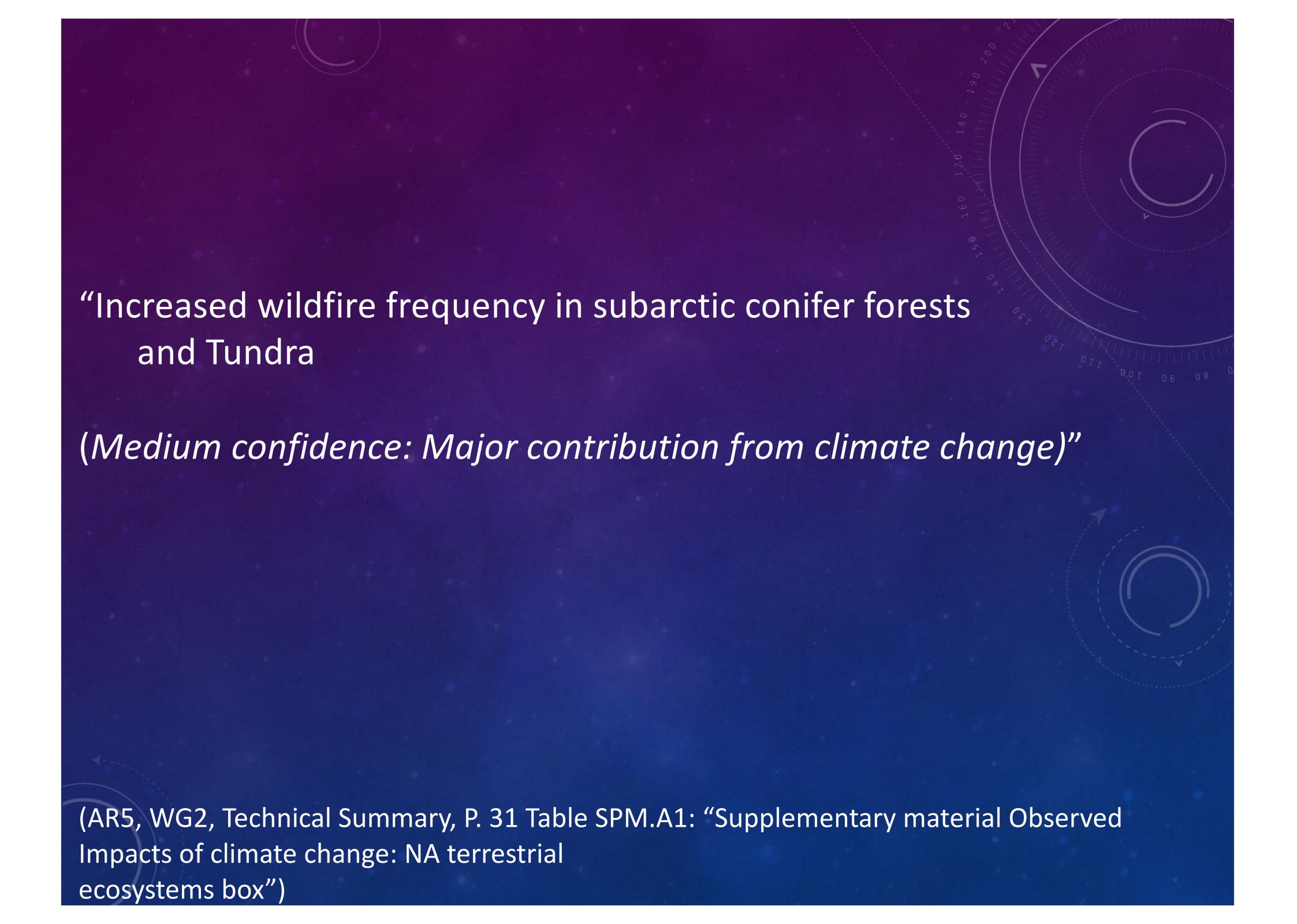
"Increased wildfire frequency in subarctic conifer forests and Tundra

(Medium confidence: Major contribution from climate change)"

Also:

"Widespread permafrost degradation,
    esp. in the Southern Arctic

(*High confidence: Major contribution from climate change*)"

(AR5, WG2, Technical Summary, P. 31 Table SPM.A1: "Supplementary material Observed Impacts
of climate change: NA terrestrial
ecosystems box"),

"<u>Given</u> that the permafrost damage occurred, we ask how much worse did climate change make that damage or impact?"

 And we know the answer to that from the IPCC....

"(*High confidence: Major contribution from climate change*)"

So it is scientifically **incorrect** to say that we cannot reach a "scientifically valid conclusion about <u>any causal role </u>played by human-induced climate change" on this Plaintiff.

Mistaken on the science of attribution.
Moved the goalposts. To have '**sufficient evidence**'
Mistaken on the logic of this case.

IN CLIMATIC CHANGE (2021):

Lloyd, Elisabeth A, Naomi Oreskes, Sonia I Seneviratne, Edward J Larson,

"Climate Scientists Set the Bar of Proof too High." 165:5

https://doi.org/10.1007/s10584-021-03061-9.

Elisabeth A. Lloyd and Theodore G. Shepherd (2021)

"Climate change attribution and legal contexts: evidence and the role of storylines." (July 2021) 167:28
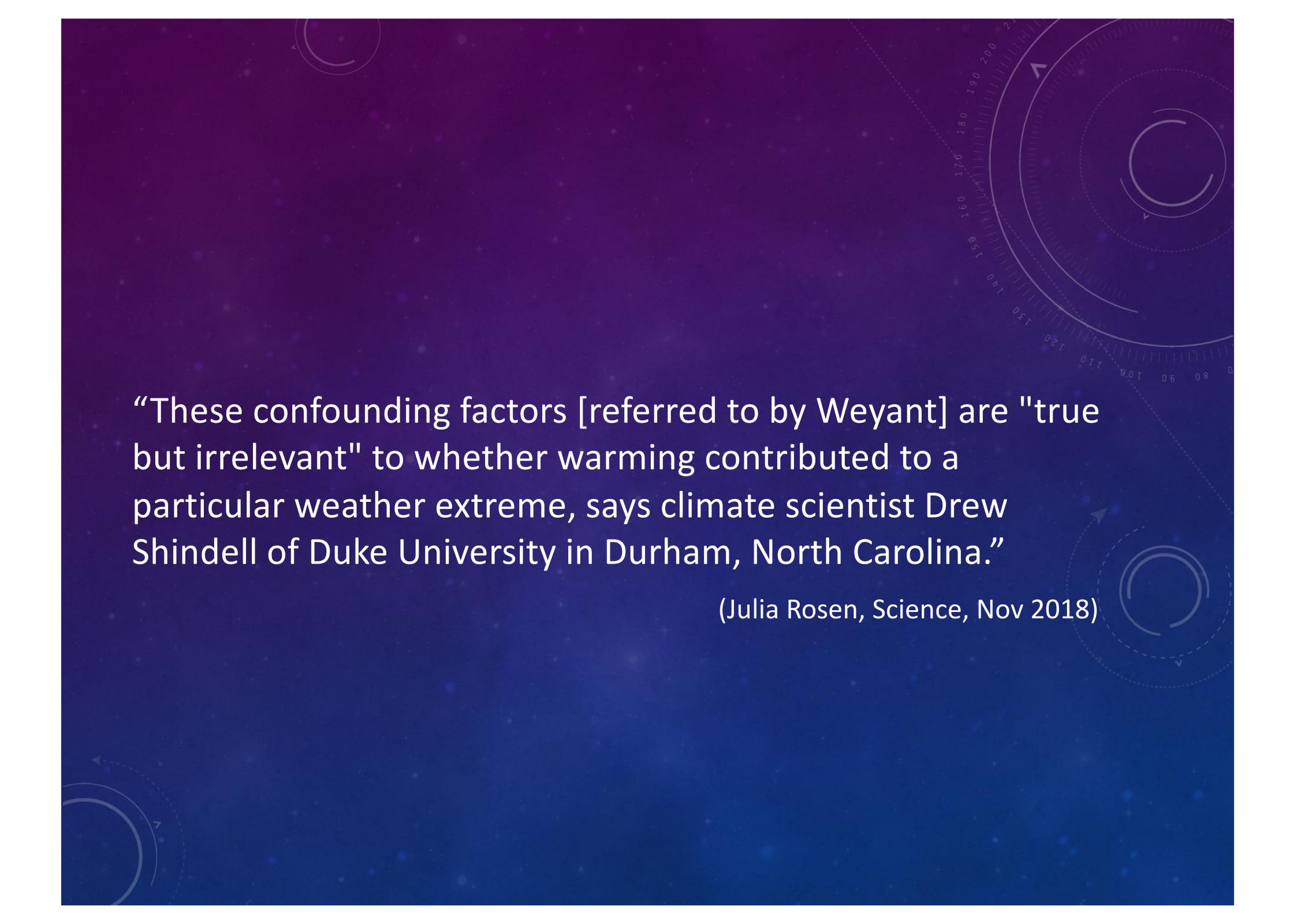
https://doi.org/10.1007/s10584-021-03177-y

"These confounding factors [referred to by Weyant] are "true but irrelevant" to whether warming contributed to a particular weather extreme, says climate scientist Drew Shindell of Duke University in Durham, North Carolina."

(Julia Rosen, Science, Nov 2018)
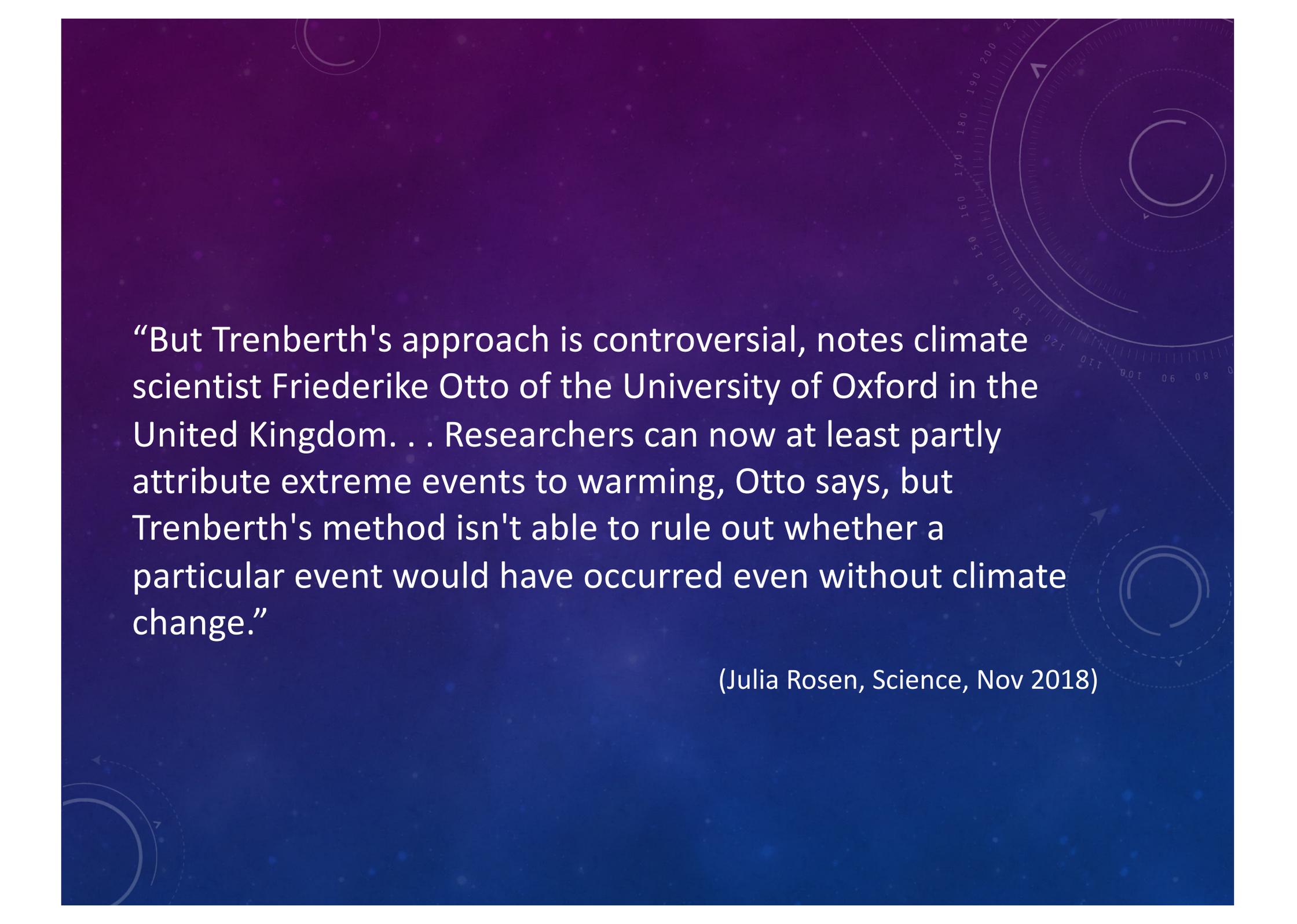
"But Trenberth's approach is controversial, notes climate scientist Friederike Otto of the University of Oxford in the United Kingdom. . . Researchers can now at least partly attribute extreme events to warming, Otto says, but Trenberth's method isn't able to rule out whether a particular event would have occurred even without climate change."

(Julia Rosen, Science, Nov 2018)

"Otto says, but Trenberth's method isn't able to rule out whether a particular event *would have* occurred even *without* climate change." (Rosen)

= risk-based research question (said to be a weakness of storyline method. . .)

In other words: storyline method does *not* answer particular risk-based research questions.

But it *does* answer the relevant legal questions about causation for tort law responsibility for loss and damages.

And Otto does admit: "Researchers can now at least partly attribute extreme events to warming, Otto says. . . " (Rosen)

That is, storyline researchers CAN answer their own, storyline AND legal questions.

Thank you!!

Whose research questions do we really want the answers to?
For example, is a singular extreme event partially attributable to warming?

Criticisms of the storyline method actually demonstrate *strengths* for use in legal settings

Methods are seen as more complementary nowadays: see more support for REA

Mismatch:

- What climate scientists set as a bar of proof for themselves for attribution: Lloyd et al. (2021) argue, they typically demand too much of themselves in terms of evidence to make attribution claims:

    (90%-100%) probability

- What Courts require [US, UK, nearly all common law countries] In comparison with the level of evidence expected in public policy, regulatory, or, more specifically, civil cases in US, UK, and virtually all common law countries: "More likely than not" (over 50%)

Table 1 Likelihood scale based on the uncertainty guidance from IPCC (Mastrandrea et al. 2010). Permission granted for public use by IPCC

Likelihood scale

Term*	Likelihood of the outcome
Virtually certain	99–100% probability
Very likely	90–100% probability
Likely	66–100% probability
About as likely as not	33 to 66% probability
Unlikely	0–33% probability
Very unlikely	0–10% probability
Exceptionally unlikely	0–1% probability

Additional terms that were used in limited circumstances in the AR4 (*extremely likely* 95–100% probability, *more likely than not* > 50–100% probability, and extremely *unlikely* 0–5% probability) may also be used in the AR5 when appropriate

Research Question: (Risk-based)
"what is the probability (risk) of a class of weather event,
given our world with global climate change,
relative to a world without?"

Problem raised for storyline method: "not able to rule out" whether an extreme
event would occur under counterfactual conditions (Otto)
= risk-based research question (said to be a weakness of storyline method. . .)

In other words: storyline method does not answer risk-based research questions.

Research Question: (Storyline)
"What is the detailed
"autopsy" of the extreme event and the causes of
Individual events? Under the present, given conditions,
what is the impact of anthropogenic
climate change?"

ROGER PIELKE

On Lloyd and Oreskes:

- Allow too much
- Wrongly motivated

ROGER PIELKE

The rise of individual "event attribution" studies coincides with frustration that the IPCC has not definitively concluded that many types of extreme weather had become more common. Elizabeth [sic] Lloyd, a philosopher of biology, and Naomi Oreskes, a science historian, expressed this frustration in a 2018 paper in the journal Reviews of Geophysics:

(Forbes, Jan 8, 2020)

Attribution science

Researchers have published more than 170 studies* examining the role of human-induced climate change in 190 extreme weather events.

Legend:
- More severe or more likely to occur
- Less severe or likely to occur
- No discernible human influence
- Insufficient data/ inconclusive

Chart — Number of extreme weather events (x-axis: 0 to 70), categories:
- Heat†
- Drought
- Rain/ flooding
- Oceans
- Cold/ice/ snow
- Storms
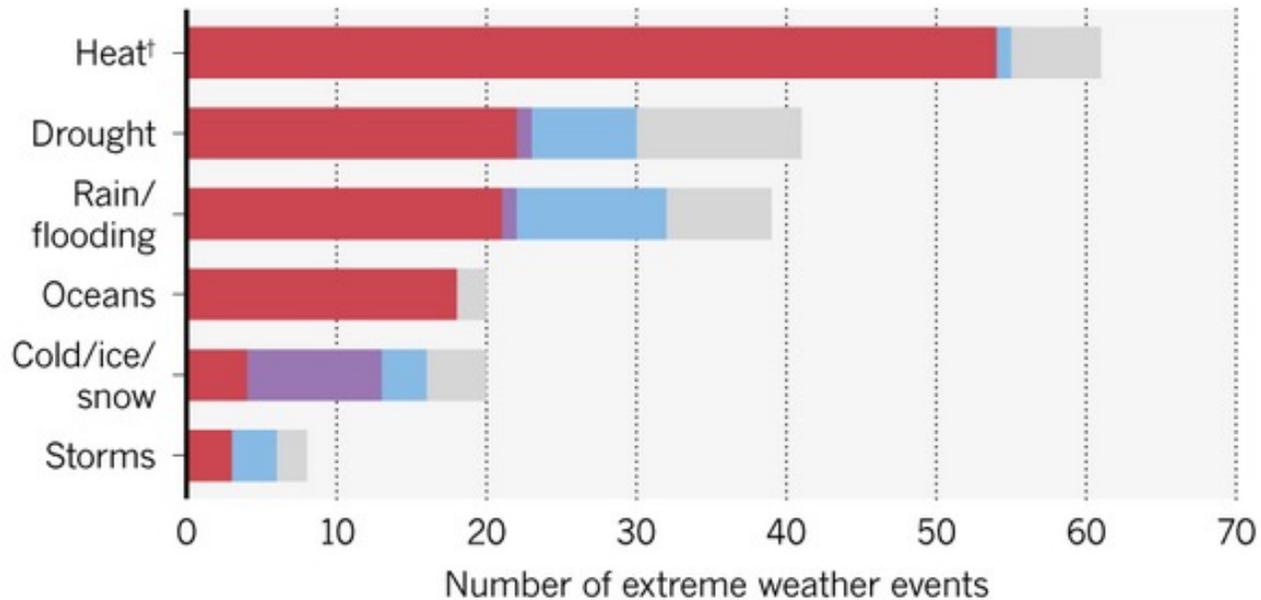
*Studies from 2004–18 collated by *Nature* and CarbonBrief. †Heat includes heatwaves and wildfires; Oceans includes studies on marine heat, coral bleaching and marine-ecosystem disruption.

©nature

ROGER PIELKE

"The rise of 'event attribution' studies offers comfort and support to **those focused on climate advocacy** by establishing the linkage (weasel word) of specific extreme events and climate change. It is not clear however that such studies offer much in the way of empirical rigor, particularly as compared to the conventional IPCC detection and attribution framework."

(Forbes, Jan 8, 2020; added emphasis)

Thomas Knutson
NOAA/Geophysical Fluid Dynamics Laboratory, Princeton, New Jersey

Suzana J. Camargo
Lamont-Doherty Earth Observatory, Columbia University, Palisades, New York

Johnny C. L. Chan
Guy Carpenter Asia-Pacific Climate Impact Centre, City University of Hong Kong, Hong Kong, China

Kerry Emanuel
Department of Earth, Atmospheric and Planetary Sciences, Massachusetts Institute of Technology, Cambridge, Massachusetts

Chang-Hoi Ho
School of Earth and Environmental Sciences, Seoul National University, Seoul, South Korea

James Kossin
Center for Weather and Climate, NOAA/National Centers for Environmental Information, Madison, Wisconsin

Mrutyunjay Mohapatra
India Meteorological Department, New Delhi, India

Masaki Satoh
Atmosphere and Ocean Research Institute, The University of Tokyo, Chiba, Japan

Masato Sugi
Meteorological Research Institute, Tsukuba, Japan

Kevin Walsh
School of Earth Sciences, University of Melbourne, Parkville, Victoria, Australia

Liguang Wu
Nanjing University of Information Science and Technology, Nanjing, Jiangsu, China

KNUTSON ET AL. HURRICANES

"As discussed by Lloyd and Oreskes . . . . for future planning and risk assessment, one may want to reduce Type II errors [false negatives] in particular. For example, **planners for infrastructure development in coastal regions** may want to consider emerging detection/attribution findings--even if not at the 0.05 significance level-- in their planning and decision-making."

(BAMS 2019)

"As discussed in the context of 'climate change attribution' by Lloyd and Oreskes (2018) and Knutson et al. (2019), the choice of significance levels depends on how one intends to interpret the results."

(Pante et al. 2021, p. 38)

In such a situation, choosing a large alpha [less strict statistical requirement] implies <u>reducing so-called "type II errors"</u> [false negatives] . ..

(Pante et al. p. 39, 2021 Atmos. Chem. Phys.)

Ultimately, it is the balance of all available evidence that does or does not suggest that an identified trend has other-than-natural causes (Knutson et al., 2019), and this is the philosophy we are following in this study.

We feel that such an approach is particularly justified in the given situation as a risk assessment for a potential local human influence on rainfall in [South West Africa] is urgently needed.

(Pante et al. p. 39, 2021 Atmos. Chem. Phys.)

Thank you!!

- **Trenberth (2011):** "Attribution of climate variations and trends to human influences and natural variability"

- **Trenberth, Fasullo, and Shepherd (2015):** "Attribution of climate extreme events"

- **Shepherd (2016):** "A common framework for approaches to extreme event attribution"

- **Shepherd et al. (2018):** "Storylines: an alternative approach to representing uncertainty in physical aspects of climate change"

- **Shepherd (2019):** "Storyline approach to the construction of regional climate change information"

- **Hannart et al. (2016a,b):** "Causal counterfactual theory for the attribution of weather and climate-related events" **and**

- "DADA: Data assimilation for the detection and attribution of weather and climate-related events."

Research Question (risk-based):
"What is the **probability or risk** of a specific class of weather event, given our world **with** global climate change, relative to a world **without** such change?"

Research Question (storyline)
"**Given** an extreme event, how did climate change alter its **impacts**?
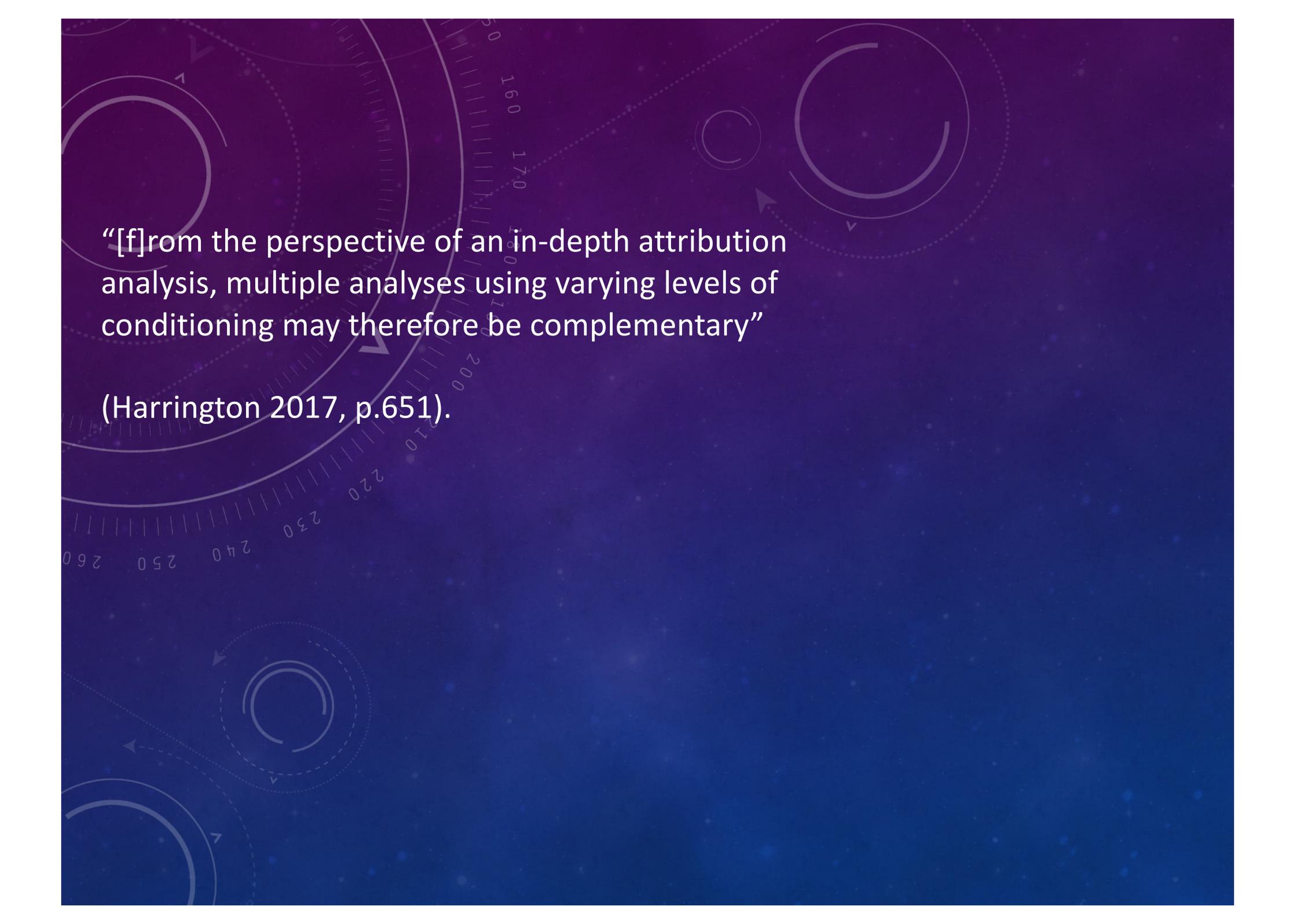
"[f]rom the perspective of an in-depth attribution analysis, multiple analyses using varying levels of conditioning may therefore be complementary"

(Harrington 2017, p.651).

- There are two fundamental principles of physics represented in climate models: the first law of thermodynamics, and dynamics. . .

- Every aspect of climate change in which there is strong confidence, including not only the surface-temperature-related quantities. . . but also certain global-scale patterns. . ., is based on thermodynamics. Circulation, on the other hand, is also governed by dynamics. ..

- there is relatively high confidence in the thermodynamic aspects of climate change, and relatively low confidence in the dynamic aspects.

- (Shepherd 2014, p. 703)
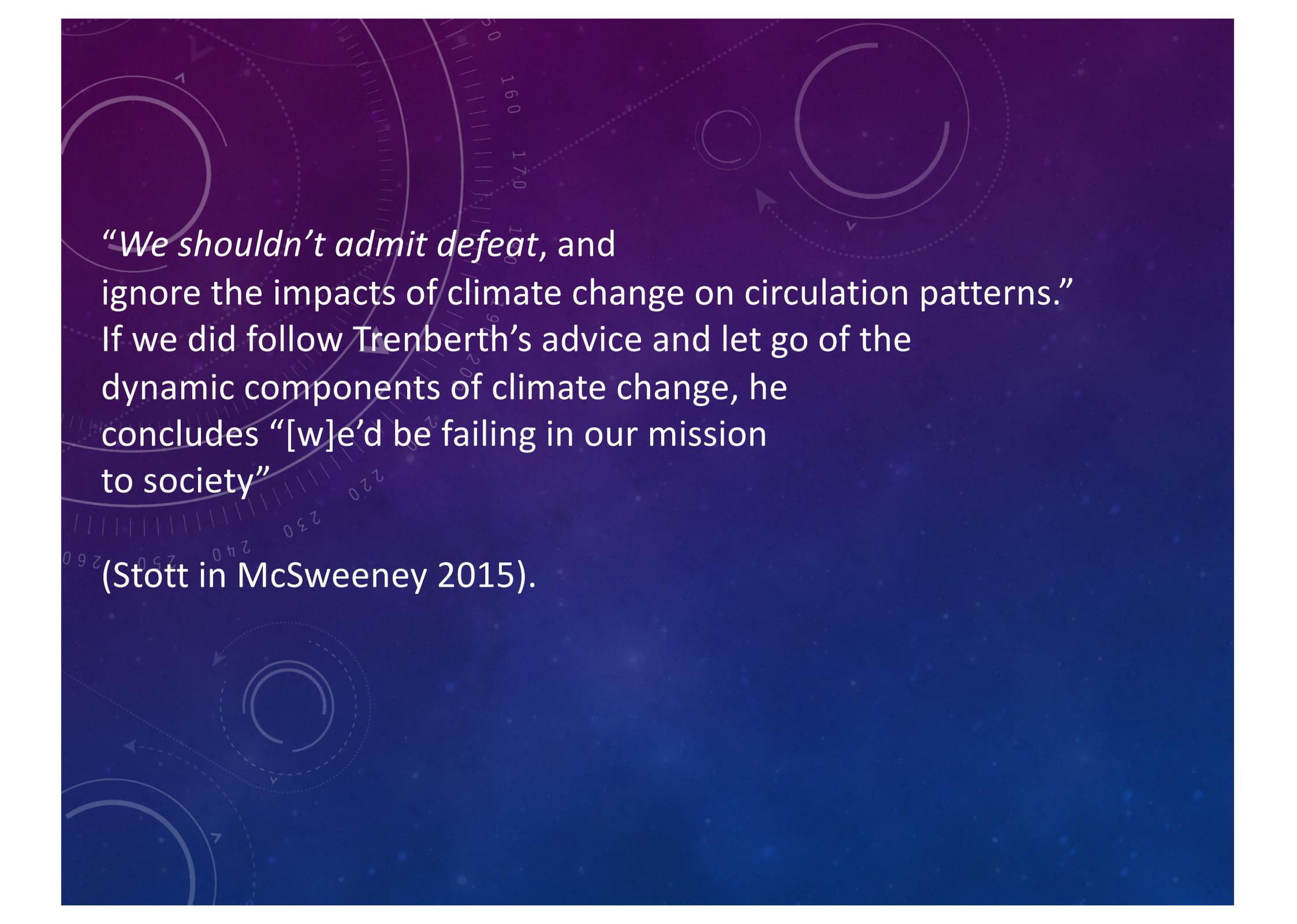
"*We shouldn't admit defeat*, and
ignore the impacts of climate change on circulation patterns."
If we did follow Trenberth's advice and let go of the
dynamic components of climate change, he
concludes "[w]e'd be failing in our mission
to society"

(Stott in McSweeney 2015).
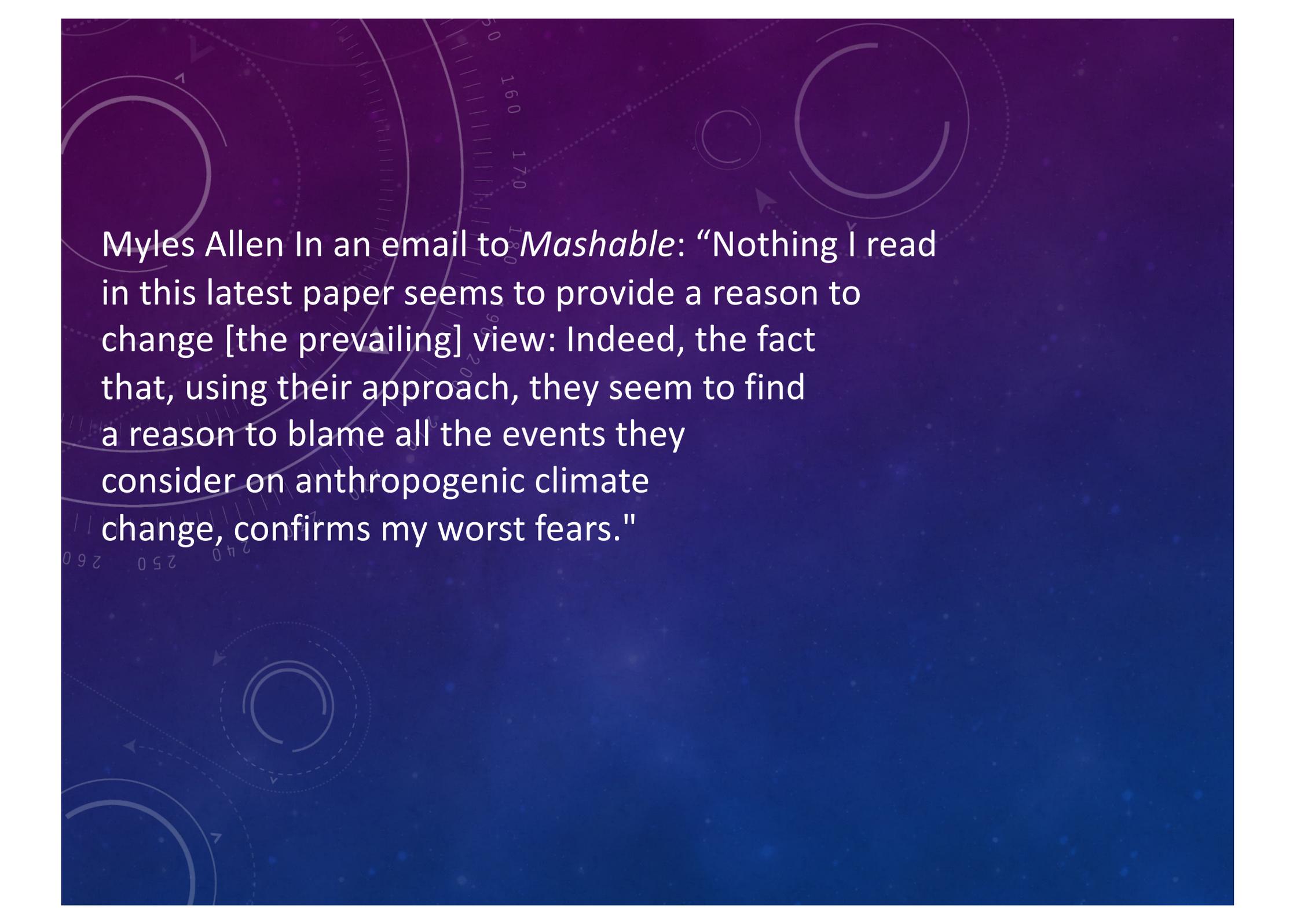
Myles Allen In an email to *Mashable*: "Nothing I read in this latest paper seems to provide a reason to change [the prevailing] view: Indeed, the fact that, using their approach, they seem to find a reason to blame all the events they consider on anthropogenic climate change, confirms my worst fears."
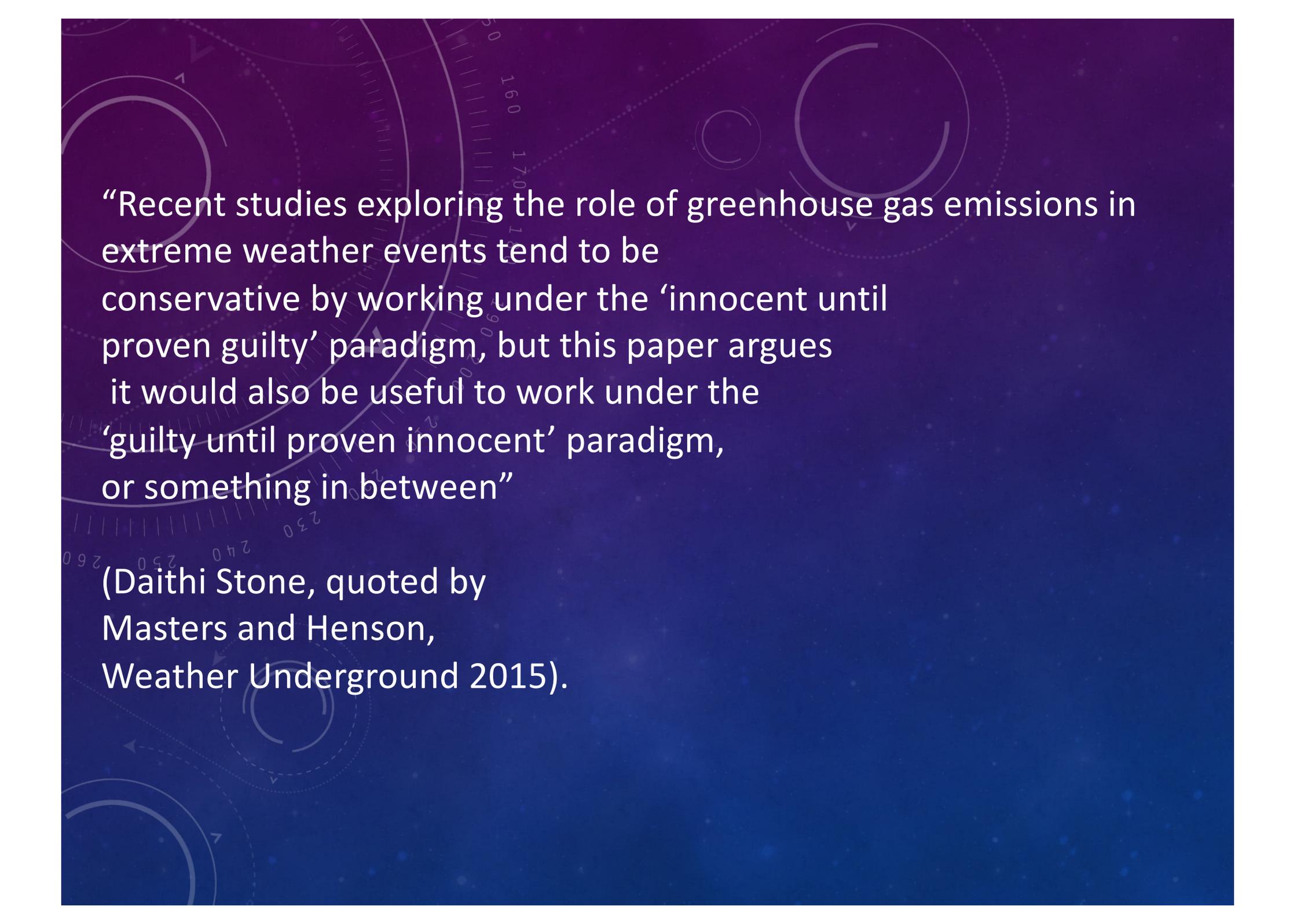
"Recent studies exploring the role of greenhouse gas emissions in extreme weather events tend to be conservative by working under the 'innocent until proven guilty' paradigm, but this paper argues it would also be useful to work under the 'guilty until proven innocent' paradigm, or something in between"

(Daithi Stone, quoted by Masters and Henson, Weather Underground 2015).
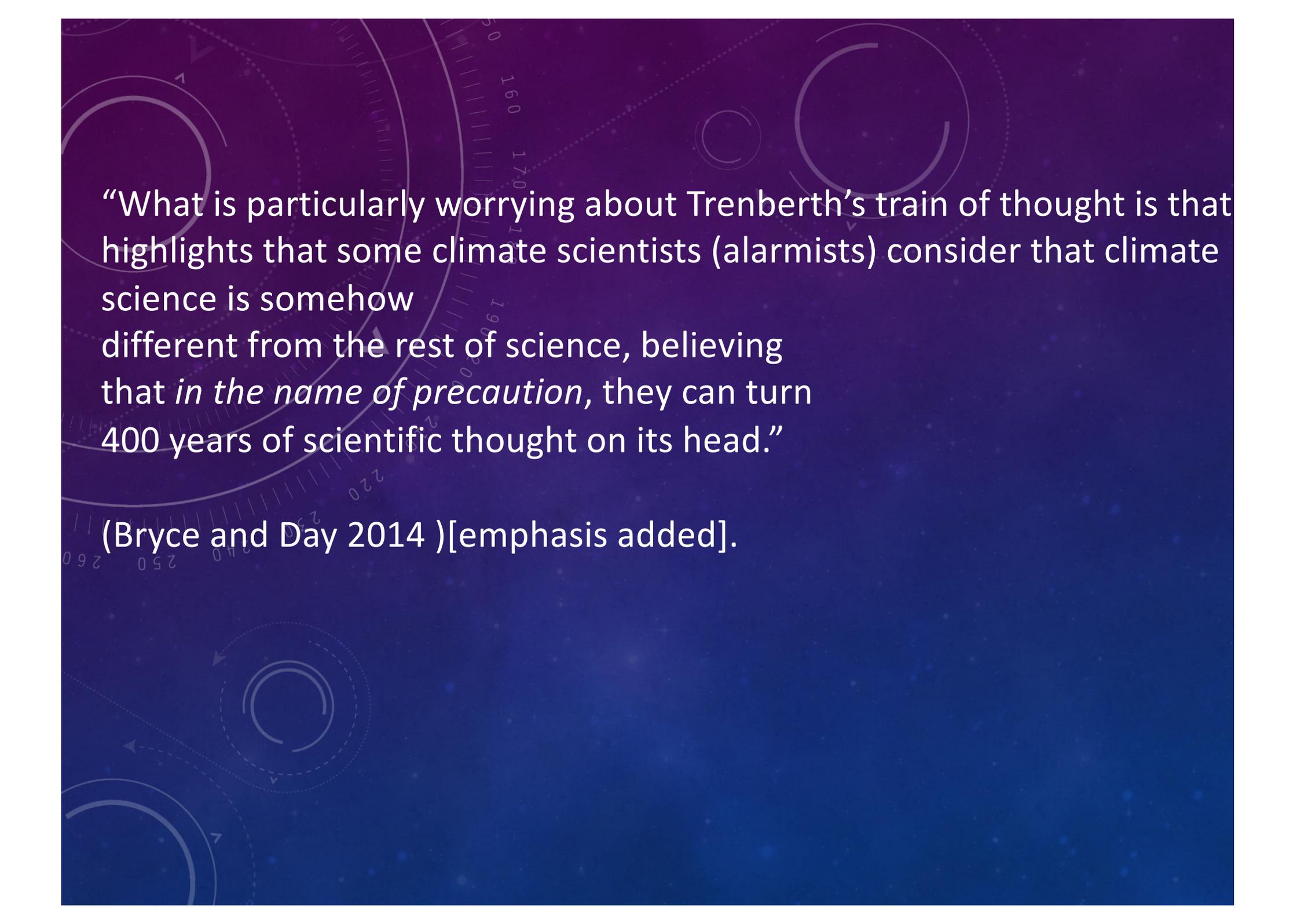
"What is particularly worrying about Trenberth's train of thought is that highlights that some climate scientists (alarmists) consider that climate science is somehow
different from the rest of science, believing
that *in the name of precaution*, they can turn
400 years of scientific thought on its head."

(Bryce and Day 2014)[emphasis added].
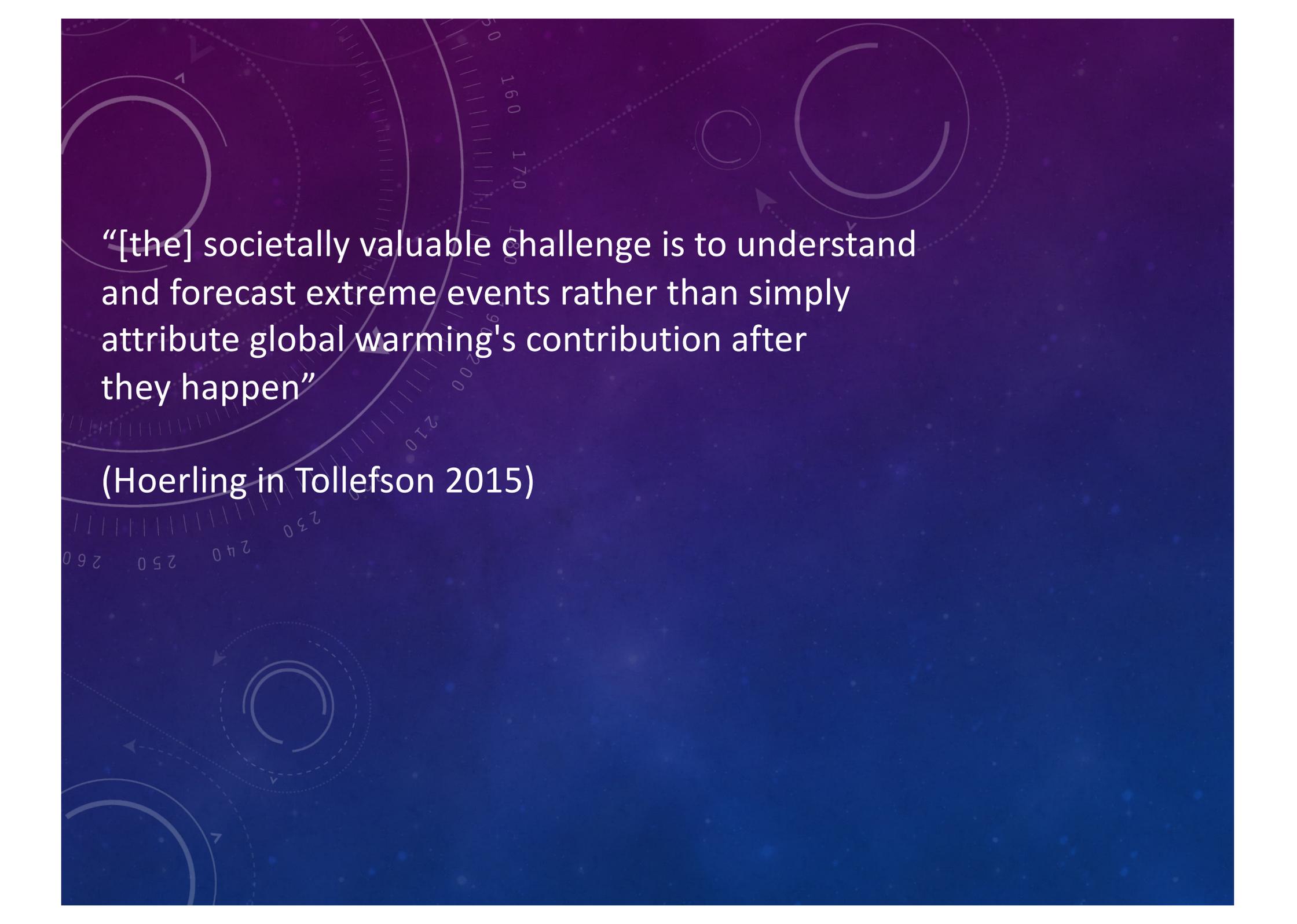
"[the] societally valuable challenge is to understand and forecast extreme events rather than simply attribute global warming's contribution after they happen"

(Hoerling in Tollefson 2015)
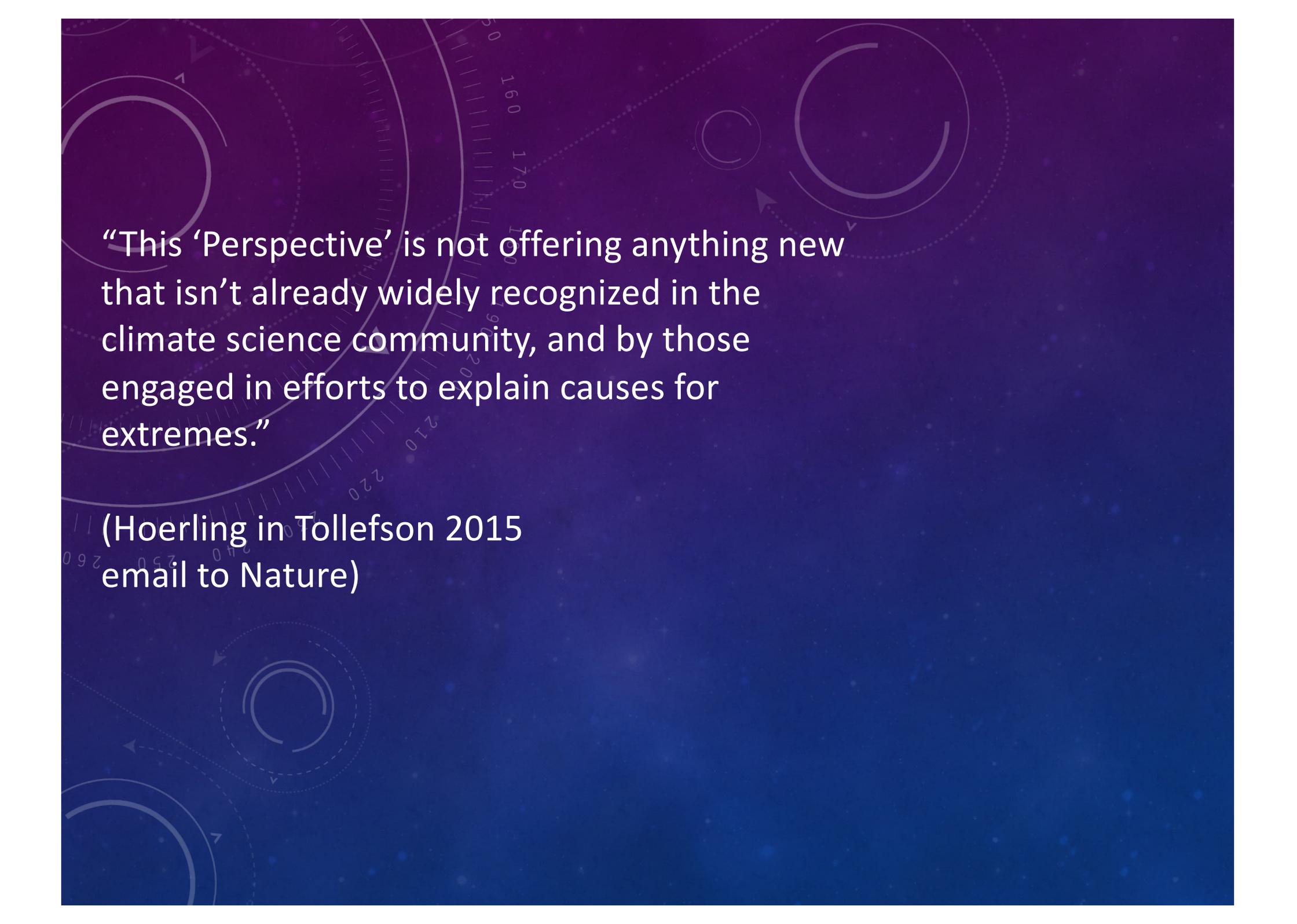
"This 'Perspective' is not offering anything new that isn't already widely recognized in the climate science community, and by those engaged in efforts to explain causes for extremes."

(Hoerling in Tollefson 2015 email to Nature)

- As Otto et al. (2016) note (while not crediting this to Trenberth or Shepherd, but rather to a different conditioned paper endorsed in Otto (2015)): "isolating specific drivers can still be invaluable in improving understanding and in turn our ability to simulate extreme events" (2016, p. 813).

In contradictory fashion:

- In the same paper, Otto et al. criticize the Trenberth et al. (2015) approach for being "intrinsically biased towards an outcome that may not be relevant to either the assignation of blame nor planning decisions in disaster recovery" (2016, p. 814).

Research Question (storyline)

"**Given** an extreme event, how did climate change alter its **impacts**?"
S1 "What were the relevant causal factors that led to the event?"
S2 "How might climate change have contributed to those causal factors?"
S3 "How might future climate change make a future such event
        even more impactful?"

Research Question (risk-based):

"What is the **probability or risk** of a specific class of weather event,
given our world **with** global climate change, relative to a world
without such change?"
R1 "How was the likelihood of the event affected by climate change?"
R2 "How was the magnitude of the event affected by climate change?"

In court now: *Juliana v US*
21 Plaintiffs suing for US carbon plan and protection of rights:
Suing to:

". . . Order Defendants to prepare and implement an enforceable
national remedial plan to phase out fossil fuel emissions and
draw down excess atmospheric CO2 so as to stabilize the climate
system and protect the vital resources on which Plaintiffs now
and will depend.''
(Juliana v US, p. 95)

Research Question (storyline)

"**Given** an extreme event, how did climate change alter its **impacts**?
OR:
S1 "What were the relevant causal factors that led to the event?"
S2 "How might climate change have contributed to those causal factors?
S3 "How might future climate change make a future such event
even more impactful?"