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Climate science needs to take risk assessment much more seriously

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Refs: Sutton, R, 2019, BAMS early online release; and 2018, Earth Syst. Dynam., 9

Climate change is an <u>*urgent*</u> problem

"We can't solve a crisis without treating it as a crisis"

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Climate change is an *urgent* problem

- Climate science is essential to informing prudent decisions
- But are we focussing on the right priorities to meet urgent societal needs?
- After 31 years, is there a need for changes to the IPCC?

The centrality of risk assessment

- From the perspective of decision makers, climate change is a problem in **risk assessment** and **risk management**, e.g. Met Office Hadley Centre Government questions:

  1. Present weather and climate risks
  2. Future weather and climate risks under different emissions scenarios
  3. Mitigation strategies and the case for early action
  4. Impacts and opportunities of mitigation and adaptation

- What are the consequences for priorities in:

  1. Research in physical (WG1) climate science?
  2. Climate modelling?
  3. Climate assessments?

"WGI" = The community of physical climate scientists

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Is there a problem with current priorities?

Why didn't IPCC do this work a long time ago?

Information requirements for risk assessment

1. What events are possible?
2. How likely are they?
3. What could the impacts and consequences be?

- **Risk = likelihood x impact**
- A central concern is the *plausible worst case*:
    - How bad could things be?
    - What is it we must avoid?

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IPCC Risk Assessment Framework

- **Risk = likelihood x impact**

  ~~WGI~~ ~~WGII~~

- Impact =
  f(hazard, vulnerability, exposure)

- No single "best" measure of impact / risk

- *WGI is required to assess likelihood and the physical hazard component of impact, i.e. to assess risk in terms of physical climate variables.*

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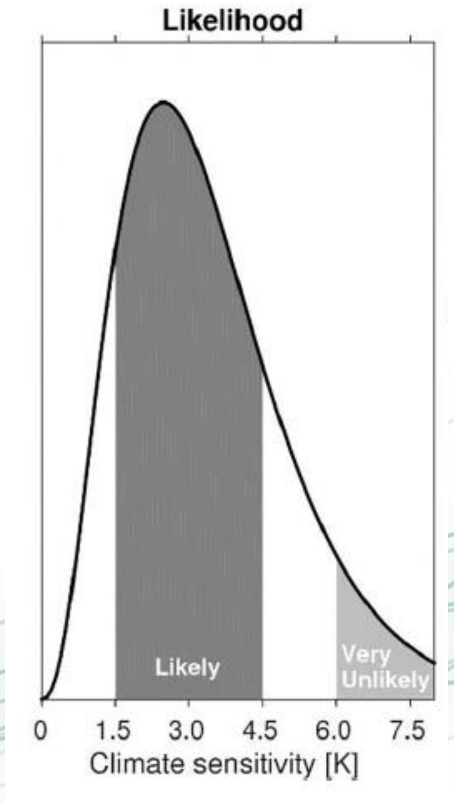
Siloed science is a problem for risk assessment

IPCC WGI has focussed on likelihood, and primarily on assessment of the "*likely*" range for key parameters



~~1. What events are possible?~~
~~2. How likely are they?~~
~~3. What could the impacts and consequences be?~~

What events are *likely*?

Figure by Ed Hawkins from Sutton, ESD 2018

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Siloed science is a problem for risk assessment

But the most important risks are rarely associated with the *likely* range

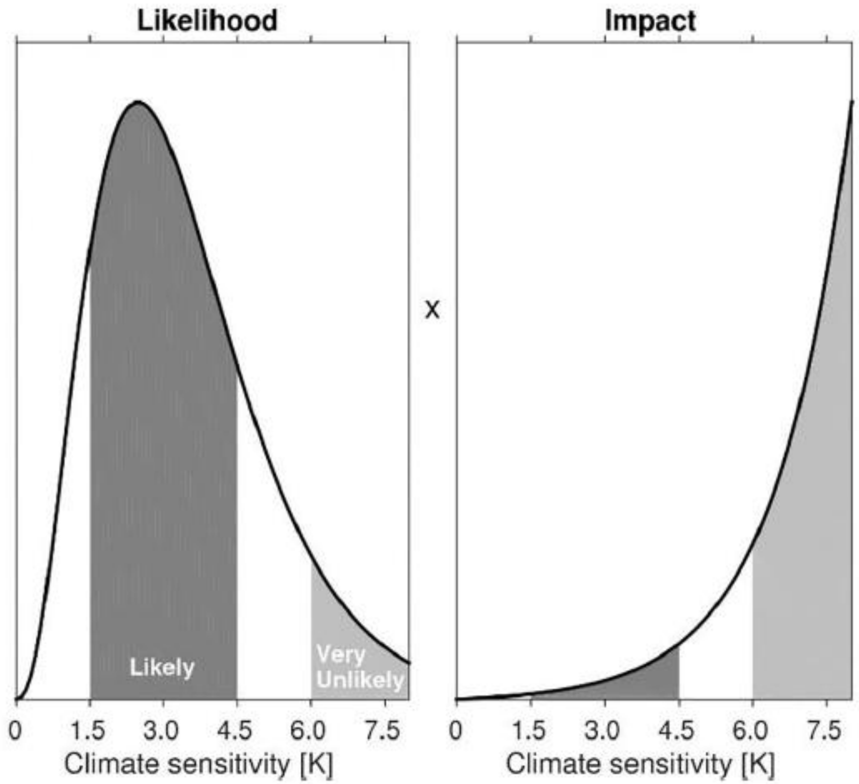

Figure by Ed Hawkins from Sutton, ESD 2018

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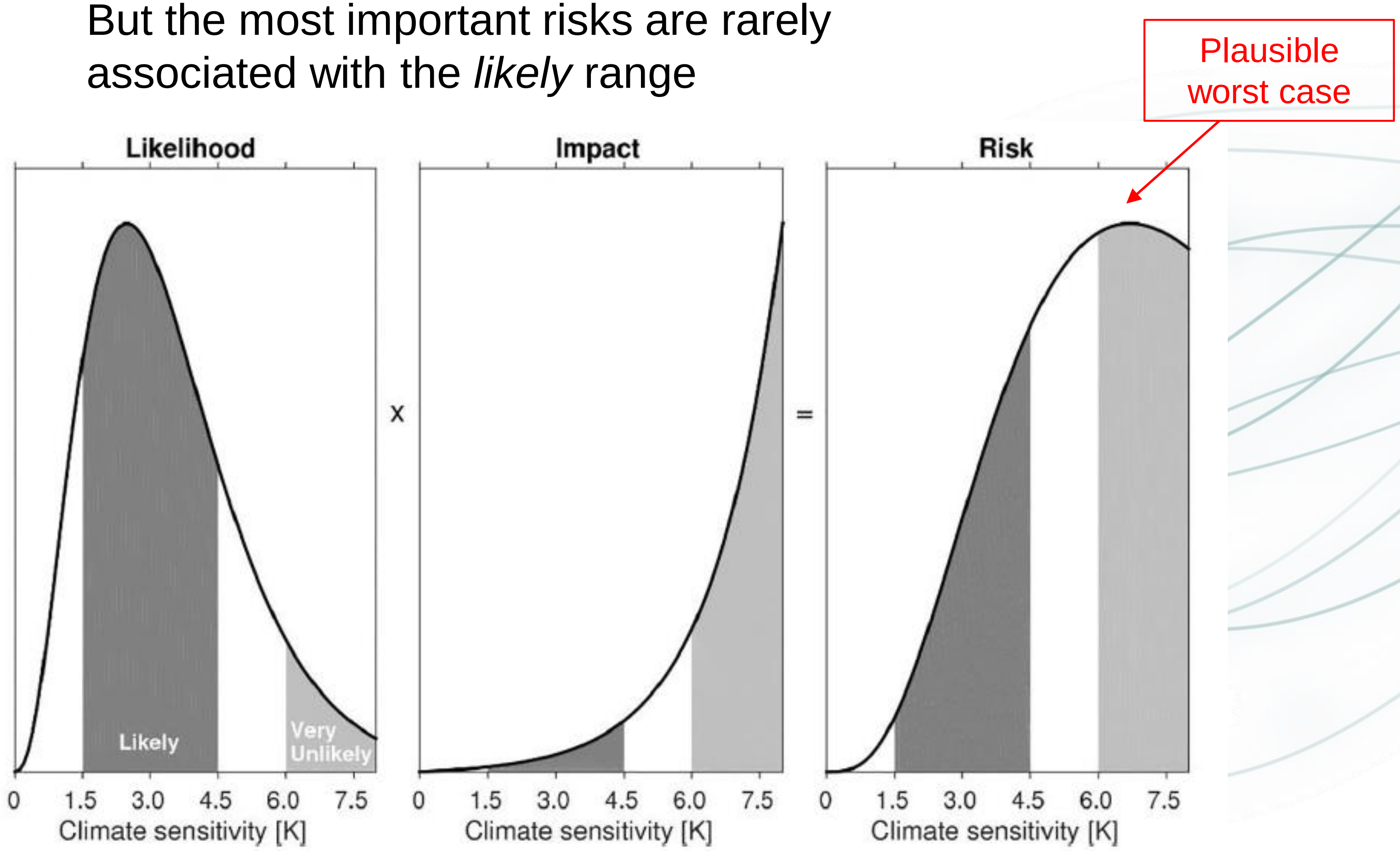

Figure by Ed Hawkins from Sutton, ESD 2018

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Impacts in WGI

Risk = likelihood x impact

- **Quantification of impacts is fundamental to judging whether a particular risk is important**
- WGI has assumed that assessment of *impacts* and *risk* are tasks for WGII, and that the primary task of physical climate science is to provide *projections* with a focus on *likelihood* (*e.g.:* "Quantifying the Uncertainty in Climate Projections")
- Quantification of impacts has been systematically neglected, e.g. AR5:
    - "Extreme precipitation events will … *very likely* become more intense and more frequent"
    - "It is *very unlikely* that the AMOC will undergo an abrupt transition or collapse in the 21st century for the scenarios considered"
- **No quantification of impact => no value for risk assessment**

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Impacts in WGI

Risk = likelihood x impact

- Quantification of impacts cannot be left to WGII
- There is no single "best" measure of impact. Whilst issues of vulnerability and exposure are outside WGI expertise, WGI is the appropriate community to assess and quantify impacts in terms of physical climate variables (e.g. temperatures, precipitation, carbon budgets etc)
- Essential to assess impacts for unlikely as well as for likely scenarios

1. What events are possible?
2. How likely are they?
3. What could the impacts and consequences be?

Recommendation 1: WGI should pay systematic attention to quantifying the impacts of future climate change in terms of physical climate variables

Likelihood

Risk = likelihood x impact

- In many risk assessment problems it is *not possible* to quantify likelihoods precisely – e.g. terrorist attack; economic crisis
- This is true for projections of future climate change (*unlike NWP*), e.g.:
  - "Structural uncertainty" - the role of processes that are not included in any climate models
  - What is climate sensitivity of the real world?
- In such cases it is standard practice to develop ***scenarios*** to stress test resilience and explore management options
- Scenarios are not associated with a specific quantified likelihood
- Nevertheless, detailed quantitative information about impacts can be developed for each scenario, and is very useful for decision making

Likelihood in WGI

Risk = likelihood x impact

- WGI has focused too much attention on efforts to better quantify likelihoods - whilst neglecting impacts - even though many such efforts are ill-posed and the results have little value for risk assessment.

Recommendation 2: WGI should develop discrete sets of risk-informed global and regional climate scenarios that span the uncertainty in the climate response to anthropogenic forcing

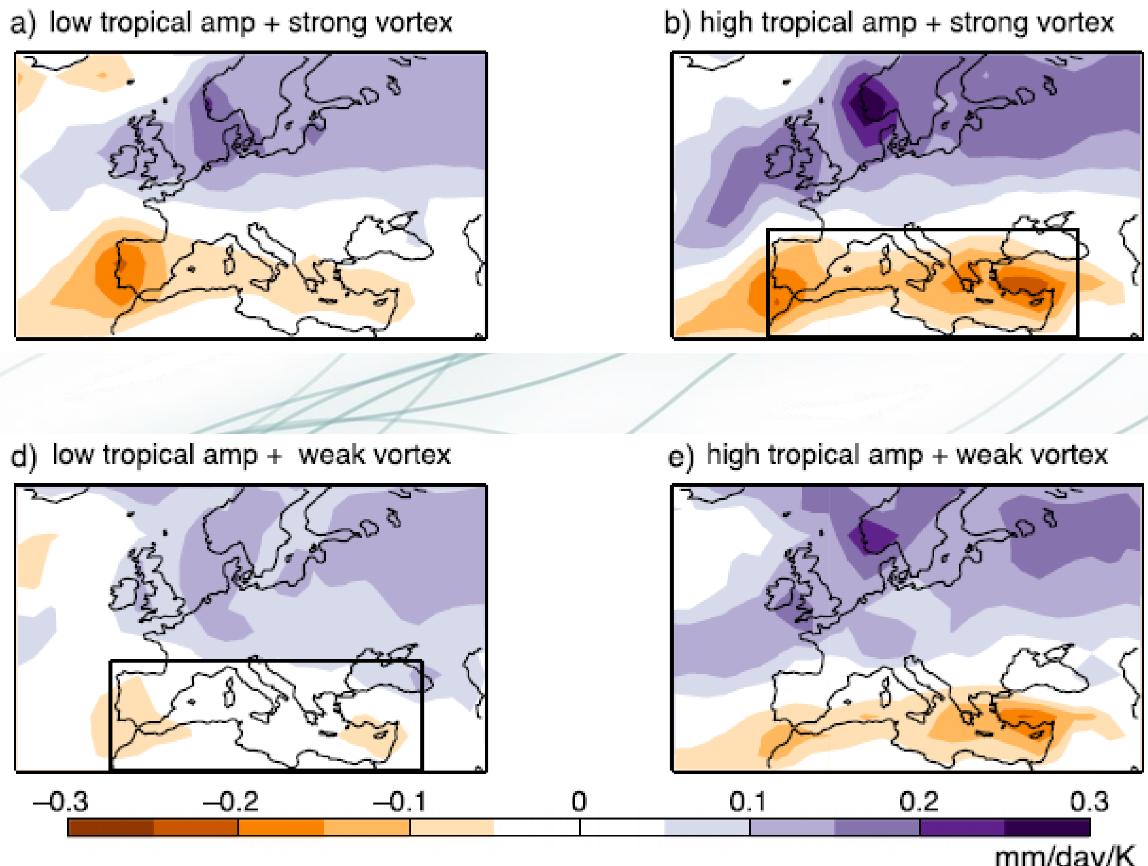
- Many national climate scenarios of this type exist[1] but global and regional climate scenarios have never been systematically developed. (CMIP / ScenarioMIP do not do this.)
- ***Storyline approaches*** (Zappa & Shepherd 2017; Shepherd et al, 2018 & 2019) offer a powerful approach to span the uncertainty in climate responses in a way that is relevant to risk assessment *and* consistent with physical understanding and constraints.

[1] e.g. www.climatescenarios.nl

Storylines of Atmospheric Circulation Change for European Regional Climate Impact Assessment,

Zappa and Shepherd, J. Climate, 2017

Some possible scenarios for future changes in European winter precipitation, which span specific *physically-based* uncertainties in the climate response to greenhouse gas forcing



mm/day per degree of global warming

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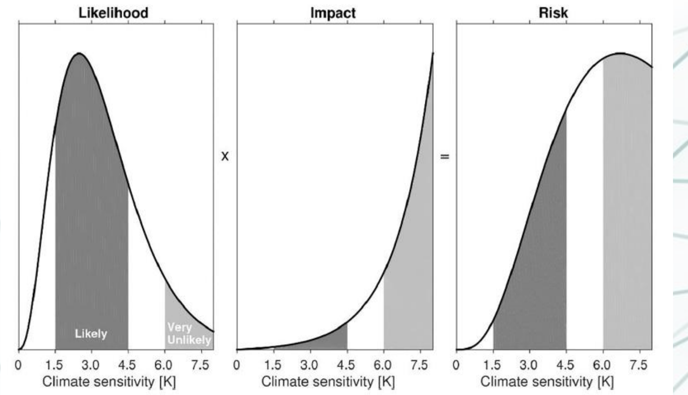
Physically Plausible High Impact Scenarios (PPHIS)

Sutton, ESD, 2018

- Essential to pay systematic attention to high impact scenarios even if their likelihood is considered low
- ***PPHIS****: An assessed physically-based storyline for specific aspects of future climate change, which is consistent with all available evidence and would result in impacts substantially greater than those implied by the relevant likely range*
- Scenarios for "abrupt" change are only a subset of PPHIS
- Research and assessment must quantify the impacts of specific PPHIS



<u>Recommendation 3</u>: WGI should pay *systematic* attention to identifying and characterising Physically Plausible High Impact Scenarios

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Examples adapted from AR5 WG1 SPM

- **ECS:** It is *very unlikely* that ECS is greater than 6C (medium confidence) but this value may be considered a physically plausible high-impact scenario (PPHIS). If realised, such a value for ECS would very likely result in an increase in global mean temperature by 2100 well above 2C relative to 1850–1900 under all RCP scenarios except RCP2.6 (high confidence).

- **AMOC:** It is *very unlikely* that the AMOC will undergo an abrupt transition or collapse in the 21st century for the scenarios considered (medium confidence). However, if it did occur such a transition would have very large (<u>quantified</u>) rapid (decadal timescale) impacts on the regional climate of the North Atlantic and surrounding continents (high confidence) and substantial impacts (<u>quantified</u>) on the climate of regions further afield (medium confidence).

- **Precipitation:** Extreme precipitation events will … *very likely* become more intense and more frequent. Quantitative increases in intensity ….

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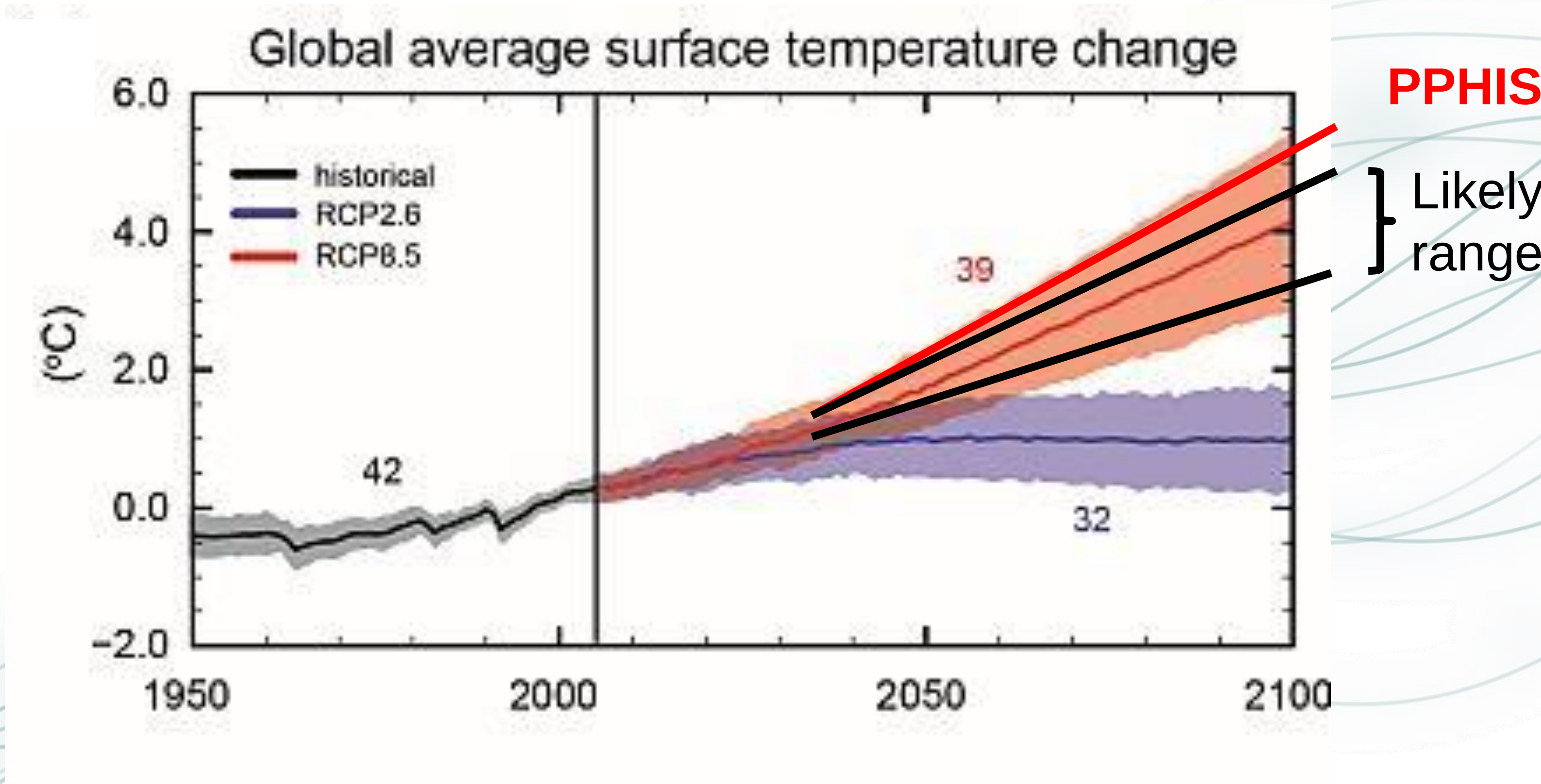
Example scenarios for global mean temperature



PPHIS mechanisms:

- High climate sensitivity
- Declining terrestrial carbon uptake
- Rapid permafrost melt

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Another neglected issue: current weather and climate risks

- What is the *current* likelihood of high impact weather and climate events?
- Huge issue for government, businesses and society, but largely ignored by WGI

- Observations are totally inadequate: records are too short and the climate is non-stationary

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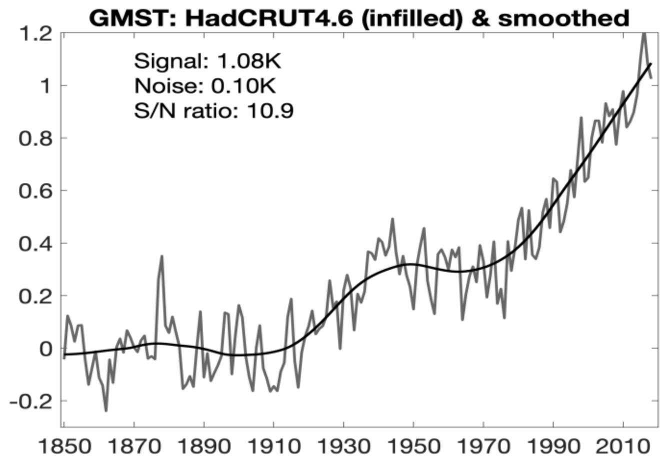
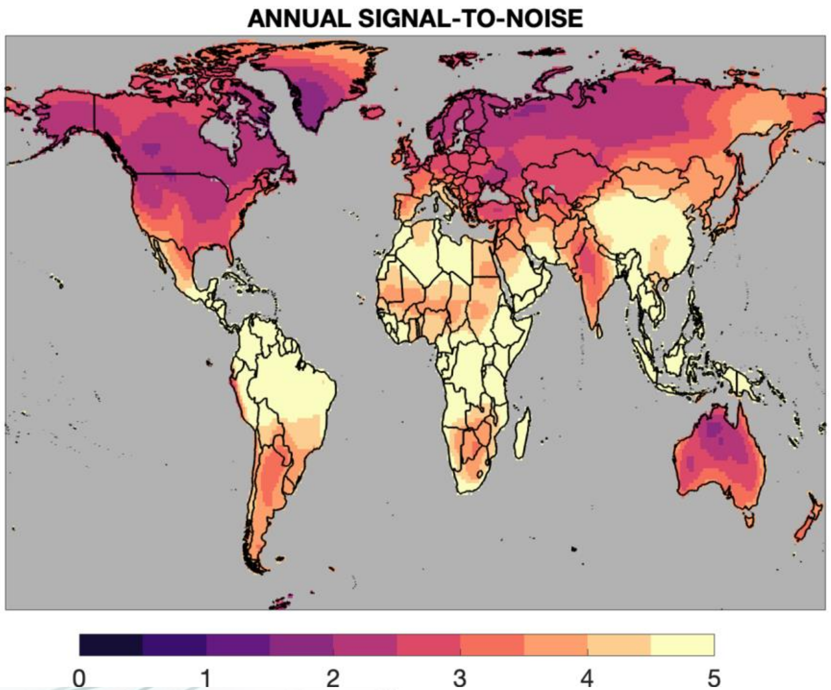
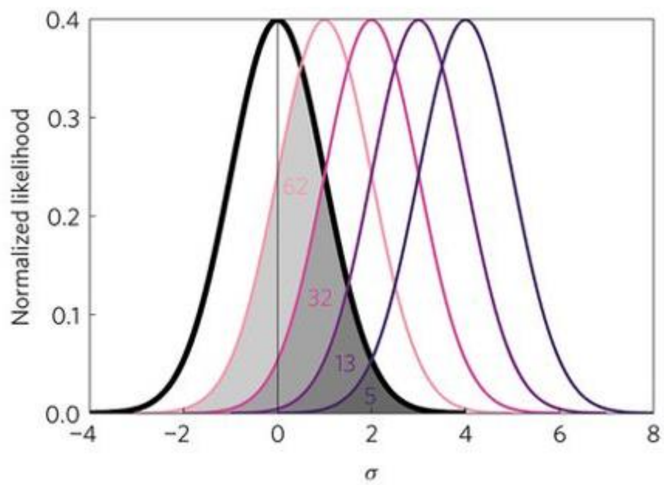
Climate has already changed dramatically

Ed Hawkins and Frame et al, NCC, 2017





Change in annual mean temperature since early industrial period (1850-1900)



S/N>1: Unusual
S/N>2: Unfamiliar
S/N>3: Unknown

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Quantifying current weather and climate risks

- Global climate model simulations are essential, at a resolution sufficient to capture high impact weather phenomena with fidelity
- Sampling uncertainty is huge: large ensembles are essential
- These capabilities are just now becoming available e.g.:
    - d4PDF project (Mizuta et al, BAMS, 2017)
    - NCAS-Met Office programme in High Resolution Global Modelling (Leaders: Pier Luigi Vidale & Malcolm Roberts)
    - Movie by Benoit Vanniere, NCAS, for EU DYAMOND project HadGEM3-GA7.1_N2560_WesternPacific.mp4

Recommendation 4: There is an urgent need for large ensembles of high resolution global climate simulations to quantify current and future weather and climate risks

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Quantifying *future* weather and climate risks

- Future weather and climate risks should be quantified *conditioned on specific scenarios* designed to span the uncertainty in global and regional climate change
- PPHIS should sample uncertainties in the rate and/or level of global warming, and in high impact regional changes, e.g. associated with:
    - Changes in circulation (e.g. monsoons, AMOC)
    - Changes in extremes

- For simple events statistical methods may suffice; for complex events climate model simulations are essential

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Summary

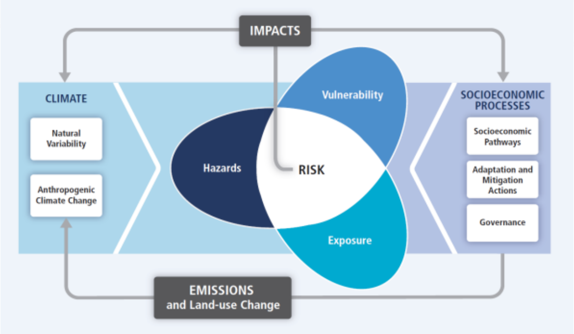
- Climate change is an urgent problem for society and for science
- For society and decision makers it is a problem in risk assessment and risk management. This fact has much greater implications for physical climate science than has generally been appreciated by the WGI/WCRP community.
- The contribution of physical climate science to risk assessment has been limited by an erroneous assumption that our task is to provide projections - with an excessive focus on quantifying likelihood and what is likely - rather than to inform risk assessments

- Climate science is essential to meeting societal needs, but we must focus on the right priorities, urgently

Recommendations for physical climate science:

1. Pay systematic attention to quantifying the impacts of future climate change in terms of physical climate variables
2. Develop discrete sets of risk-informed global and regional climate scenarios, which span the uncertainty in the climate response to anthropogenic forcing; quantify impacts for each scenario.
3. Pay systematic attention to identifying and characterising Physically Plausible High Impact Scenarios
4. A specific urgent need is for large ensembles of high resolution global climate simulations to quantify current and future weather and climate risks

5. Collaborate with WGs II & III to provide fully integrated risk assessments



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