Event attribution

Peter Stott

What do we mean by attribution?

- **Attribution** requires estimates of the expected changes in climate due to different factors (eg increased greenhouse gas concentrations or changing solar output) : the “fingerprints”.
- An observed change is **attributed** to a particular factor if observed changes are consistent with expected changes that include the relevant fingerprint and inconsistent with expected changes that exclude that fingerprint.
- **Attribution** is defined as the process of evaluating the relative contributions of multiple causal factors to a change or event with an assignment of statistical confidence.
- **Attribution** combines statistical analysis with physical understanding.
- [IPCC Good Practice Guidance Paper, 2010]

Observed warming consistent with that expected from anthropogenic factors and inconsistent with that expected from natural factors

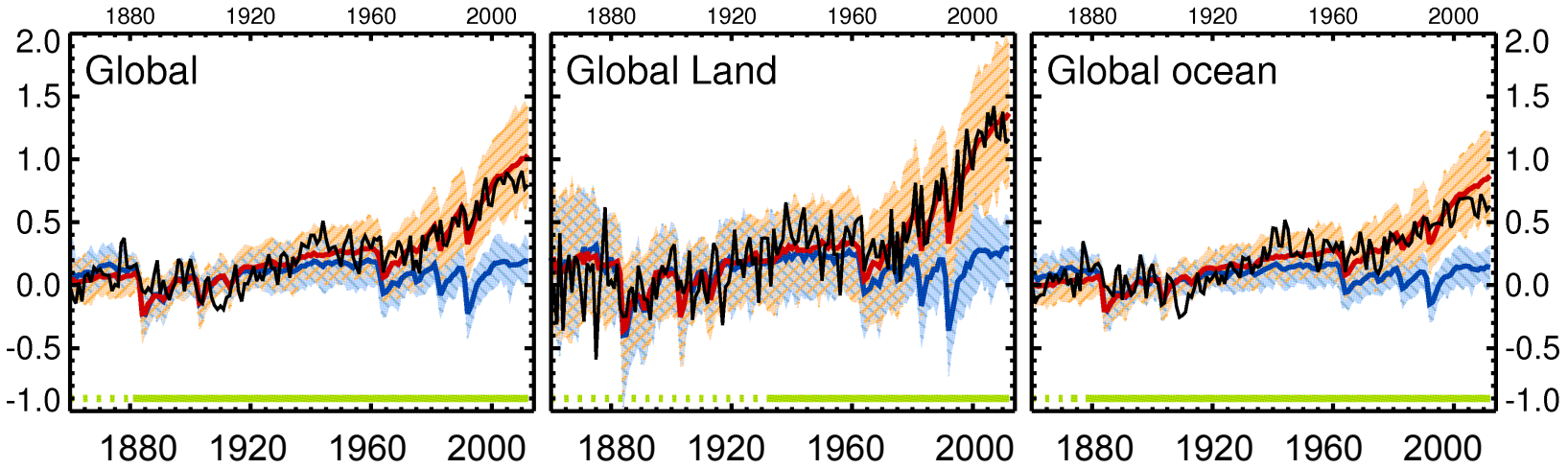
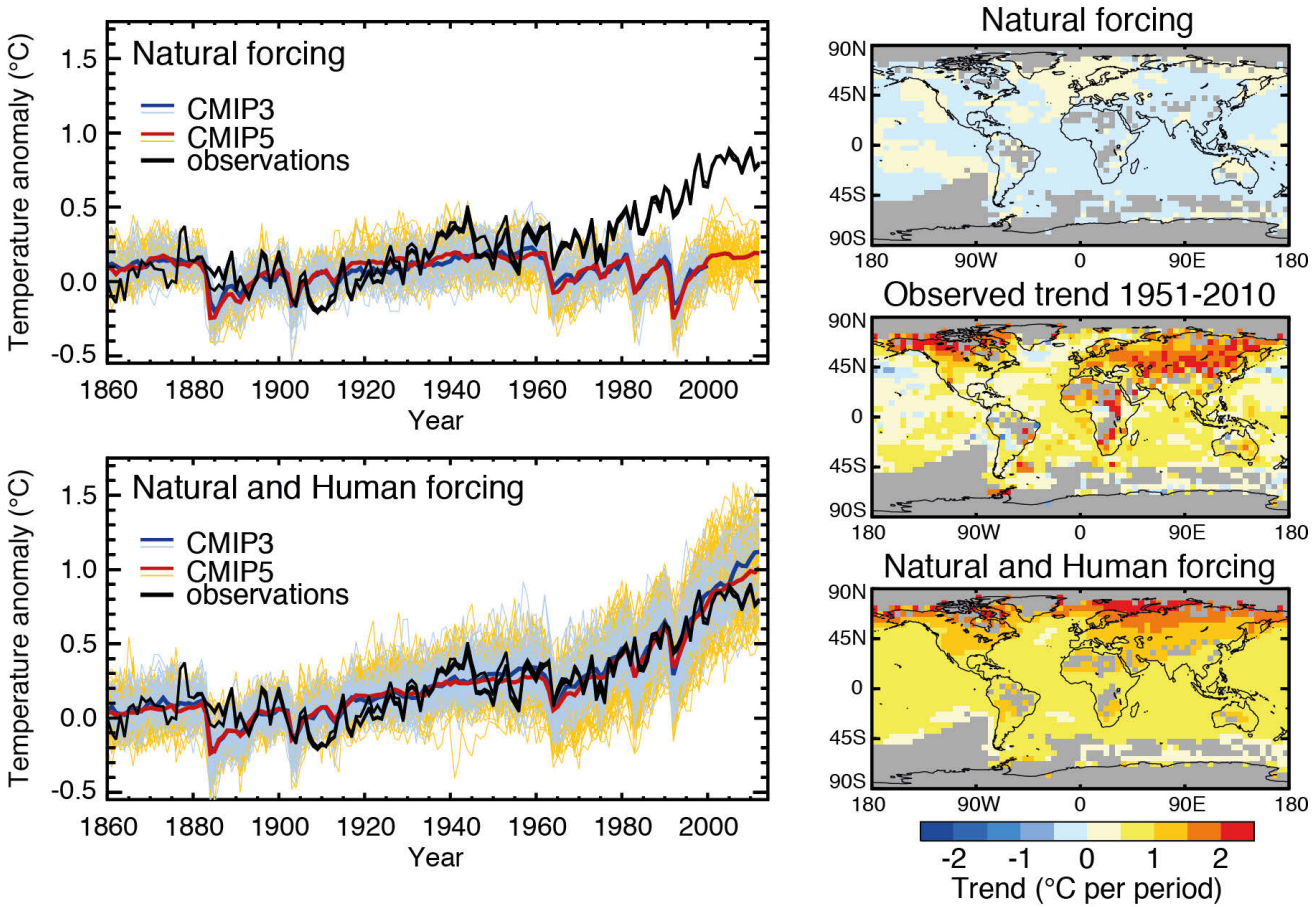


Fig 10.7

The first decade of the 21st century was the warmest on record.

Fingerprint studies quantify the contributions of anthropgenic and natural forcings to observed warming



FAQ 10.1
Fig 1

It is *extremely likely* that human influence has been the dominant cause of the observed warming since the mid-20th century.

Attribution studies based on different methodologies, a new generation of climate models and observations to 2010.
The best estimate of the human-induced contribution to warming is similar to the observed warming.

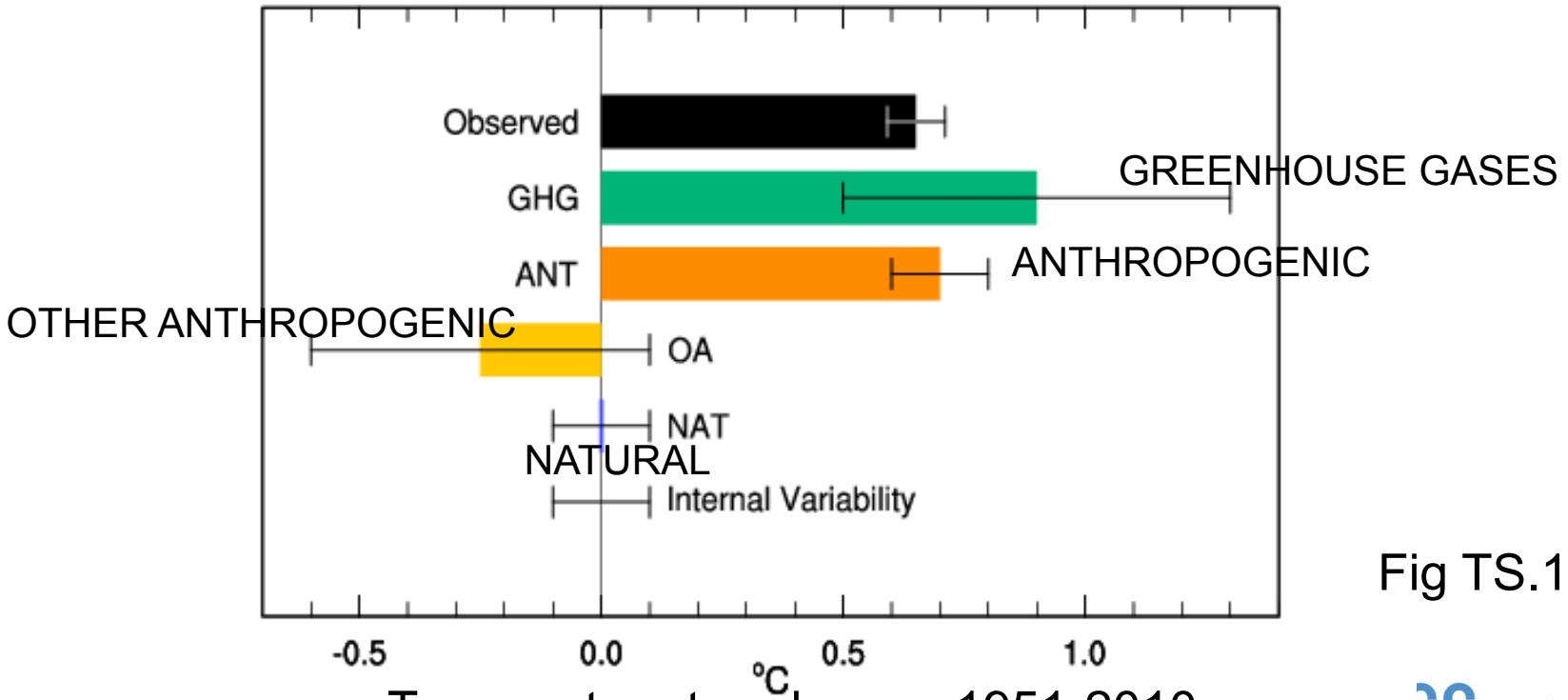
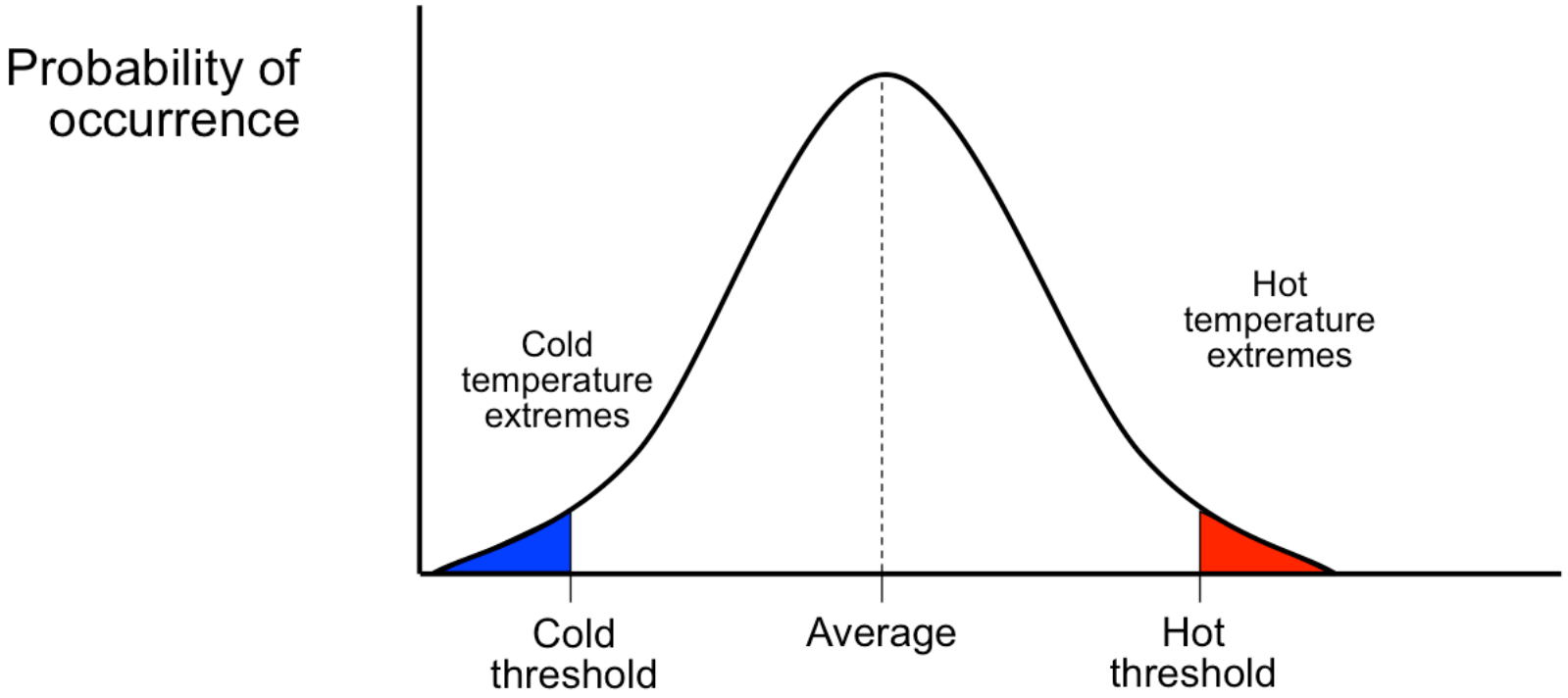


Fig TS.10

Temperature trends over 1951-2010

Change in temperature extremes in warming climate

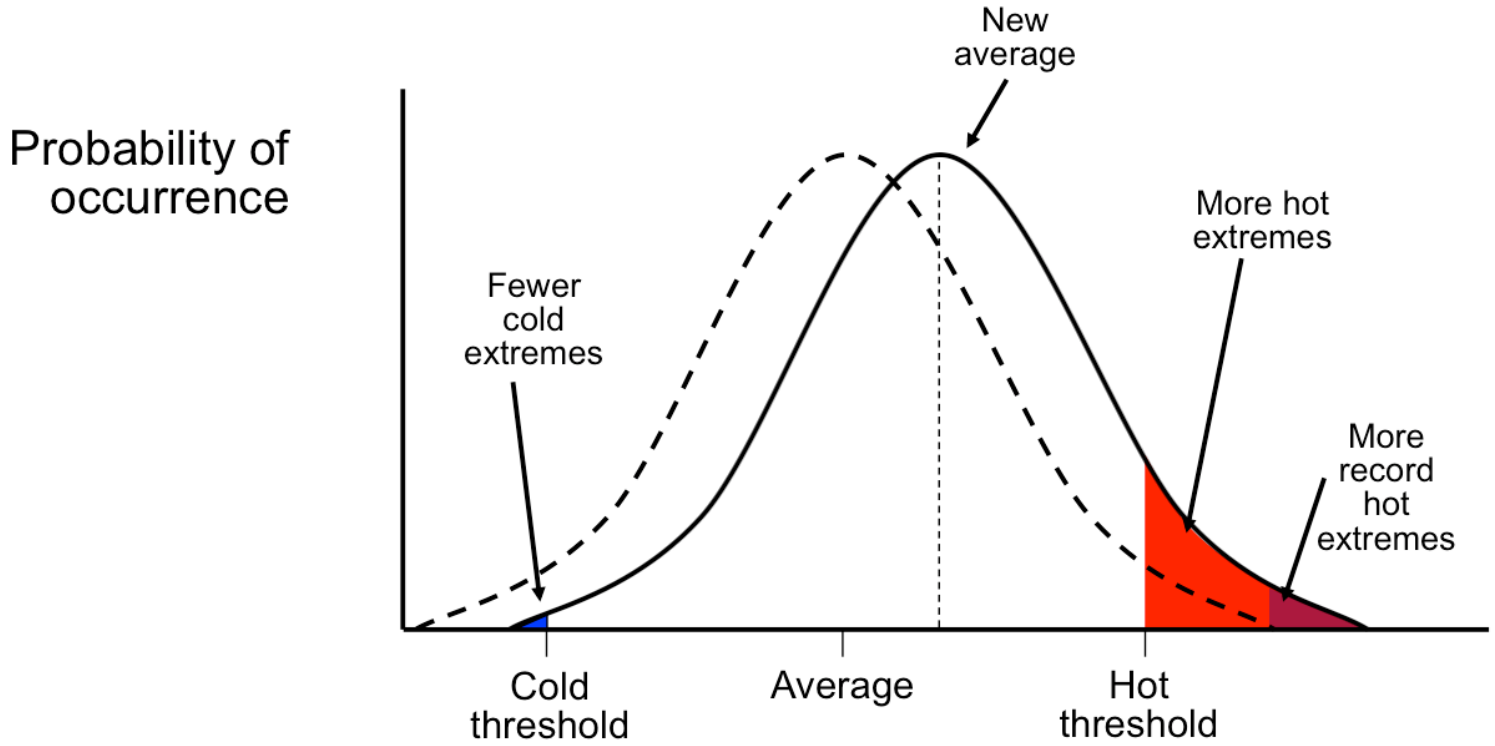
- Temperature now



E. Palin

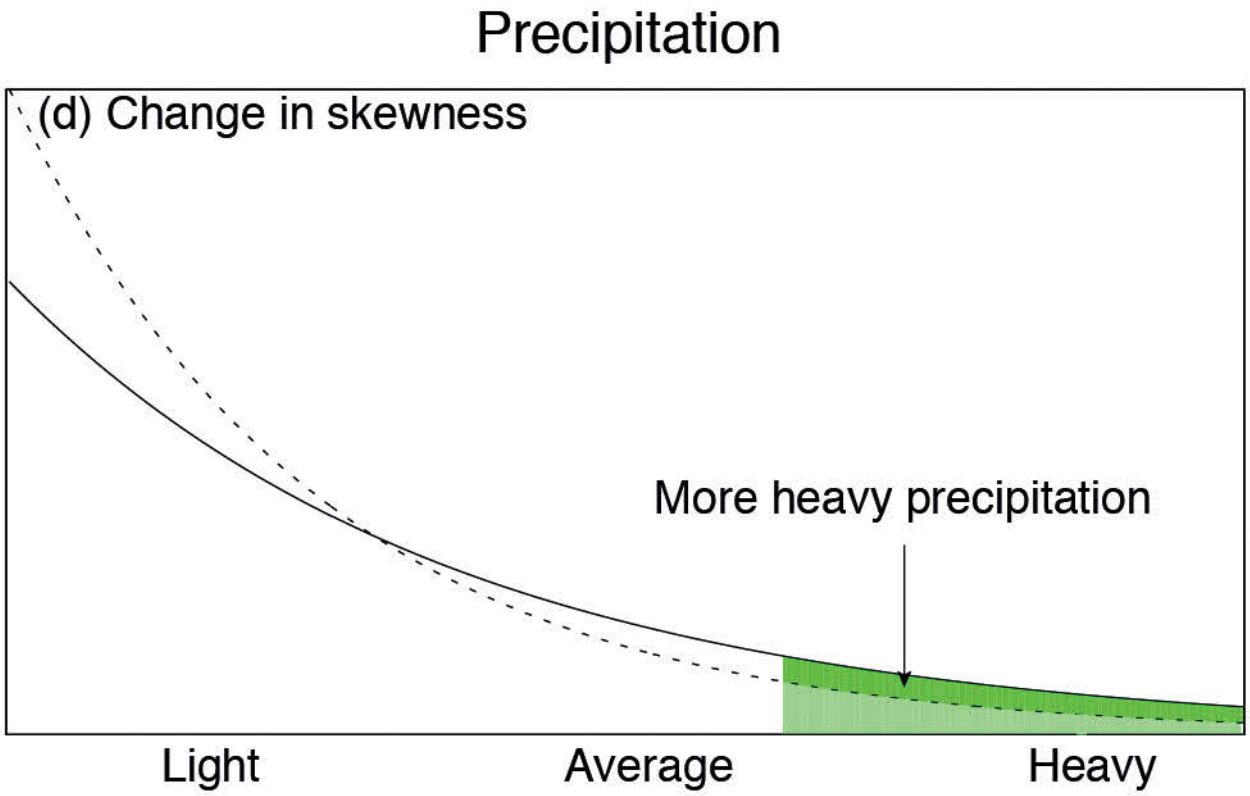
Change in temperature extremes in warming climate

- Temperature **in future**

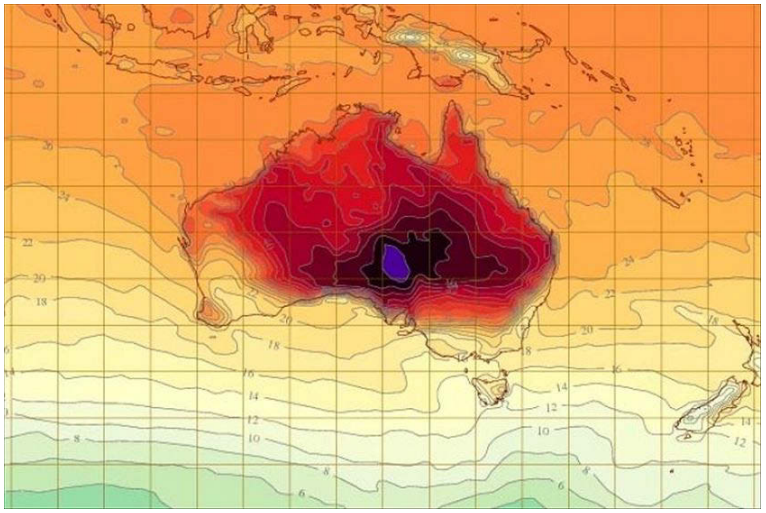


E. Palin

Change in precipitation extremes in warming climate



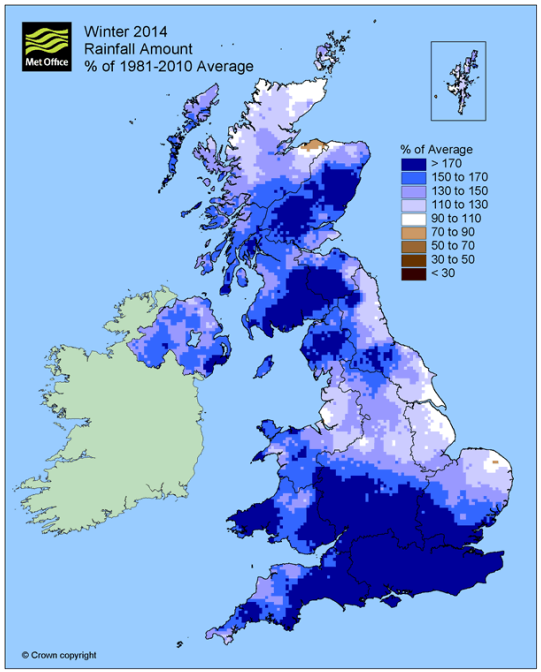
What can we say about individual climate-related events?

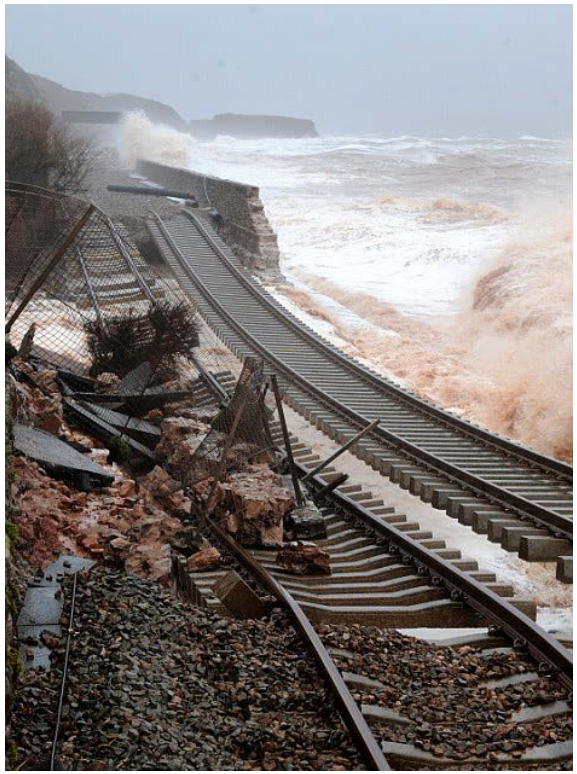


Australia's angry summer of 2013

What can we say about individual climate-related events?

Wettest winter in England and Wales since 1766



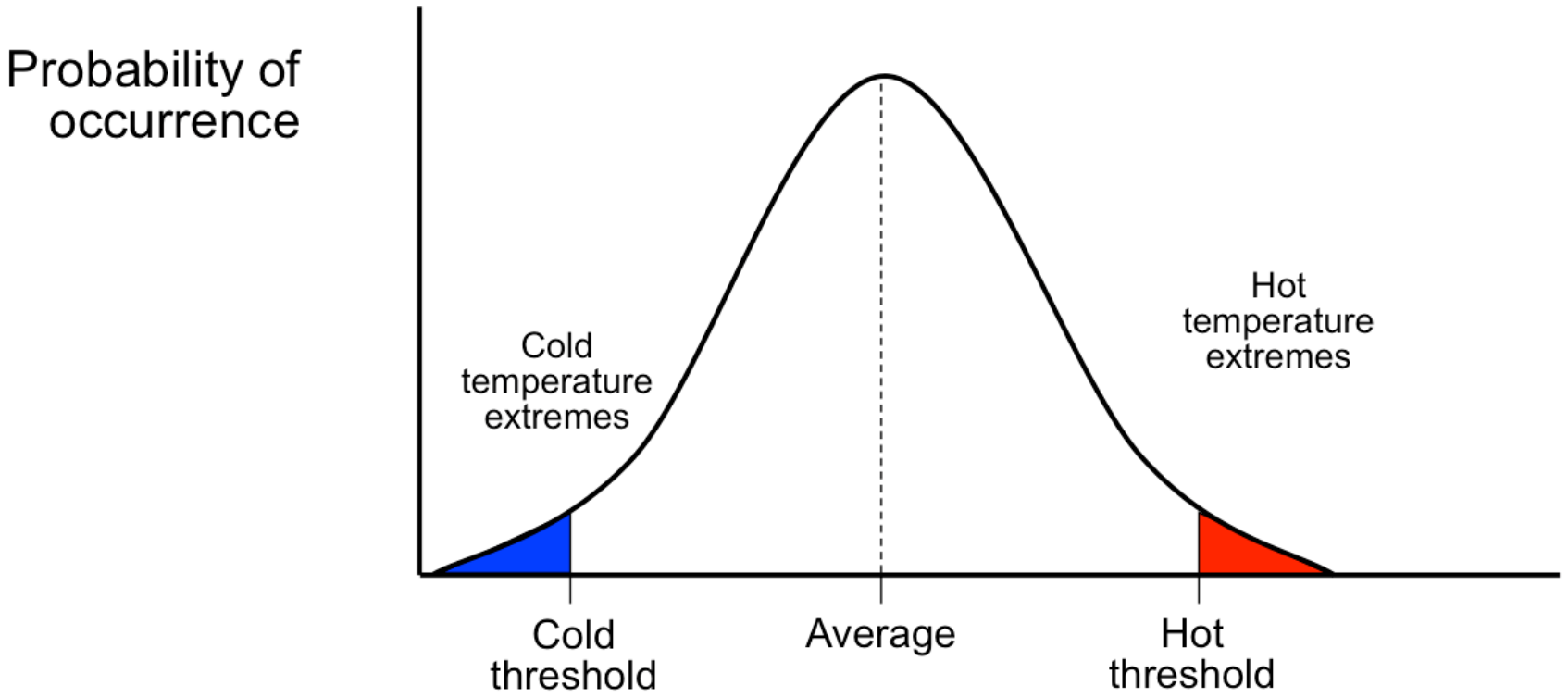


Two seminal papers (1)

Allen, Liability for Climate Change, Nature, 2003

Change in temperature extremes in warming climate

- Temperature now



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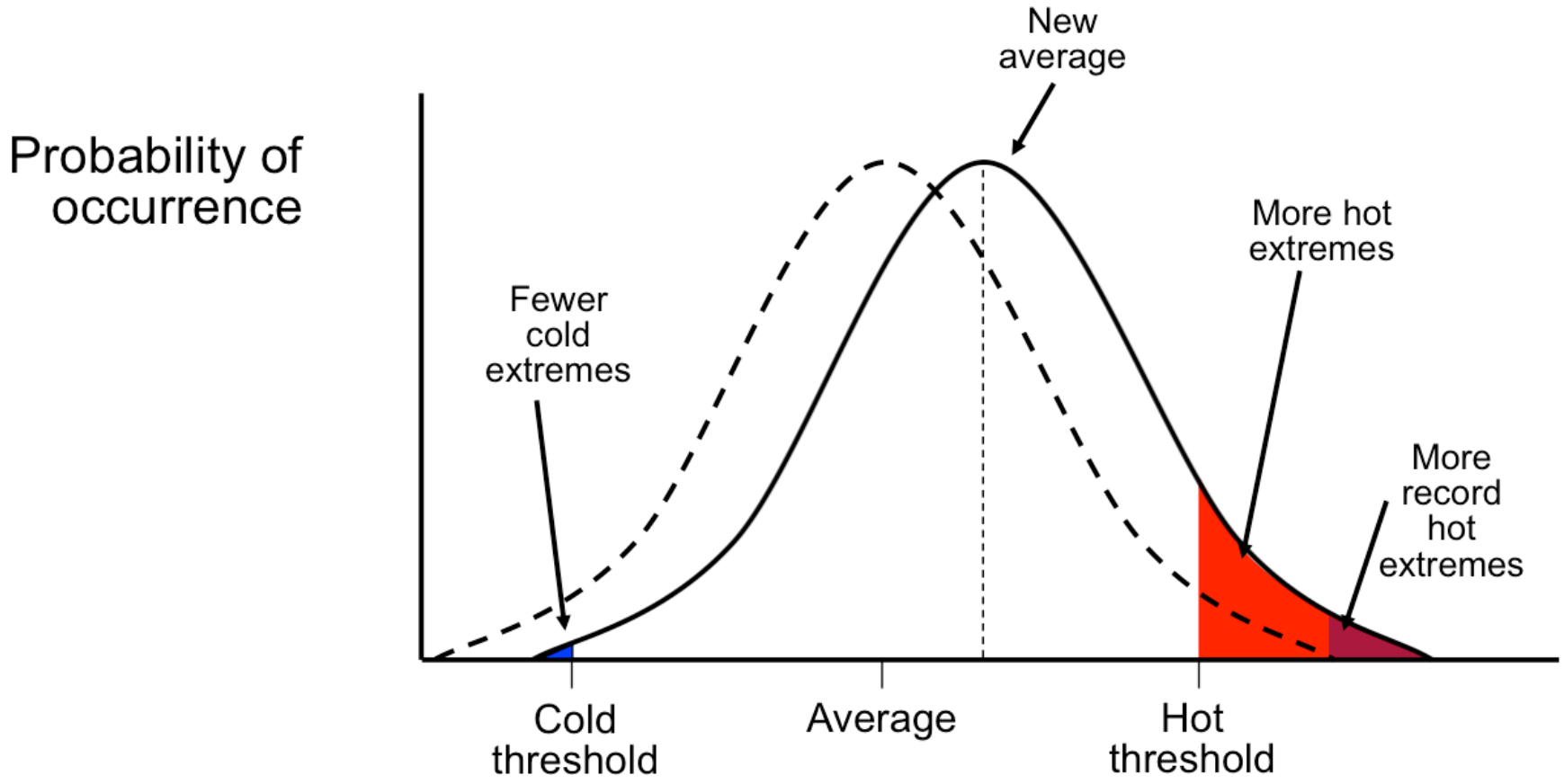
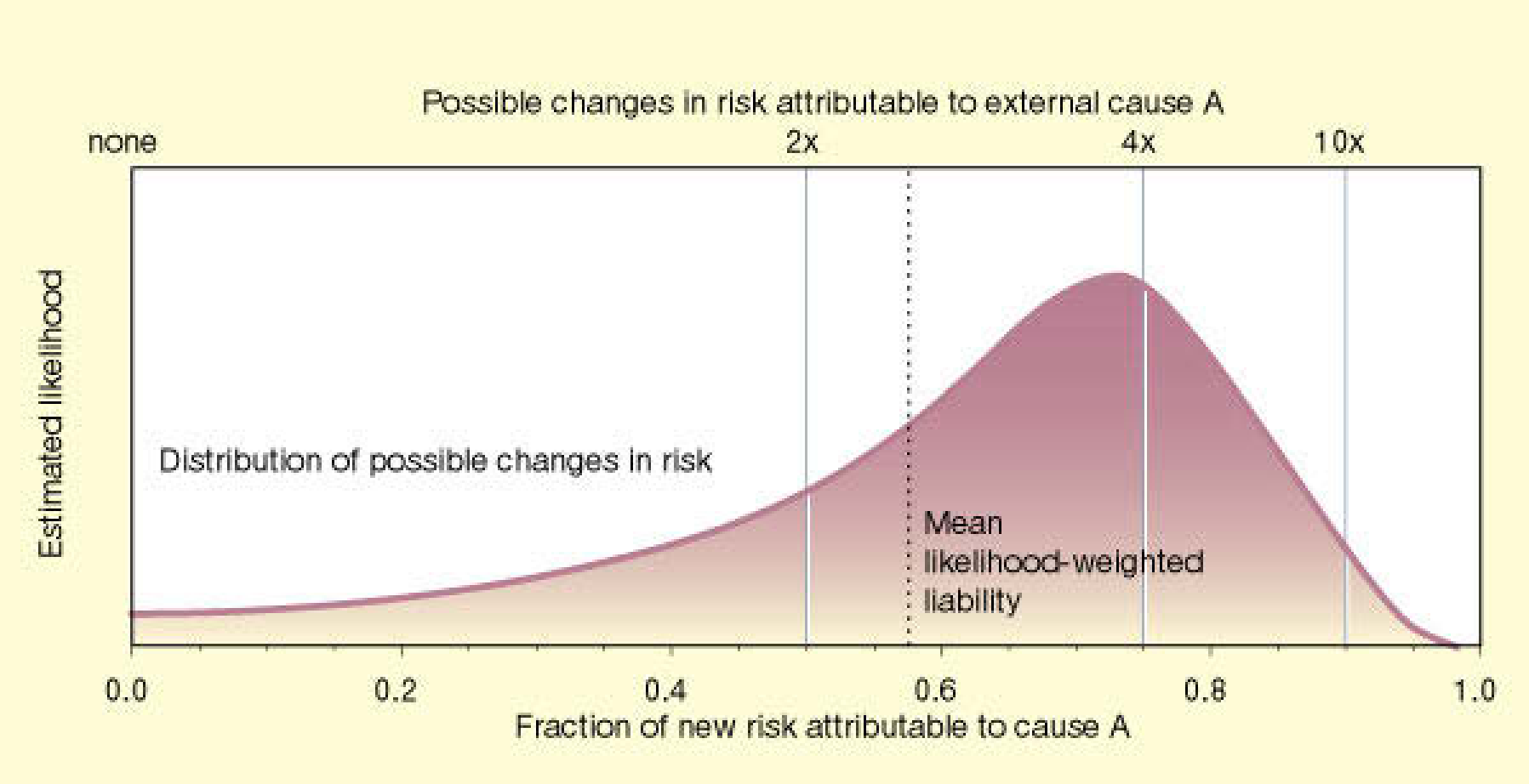
Change in temperature extremes in warming climate

- Temperature **in future**



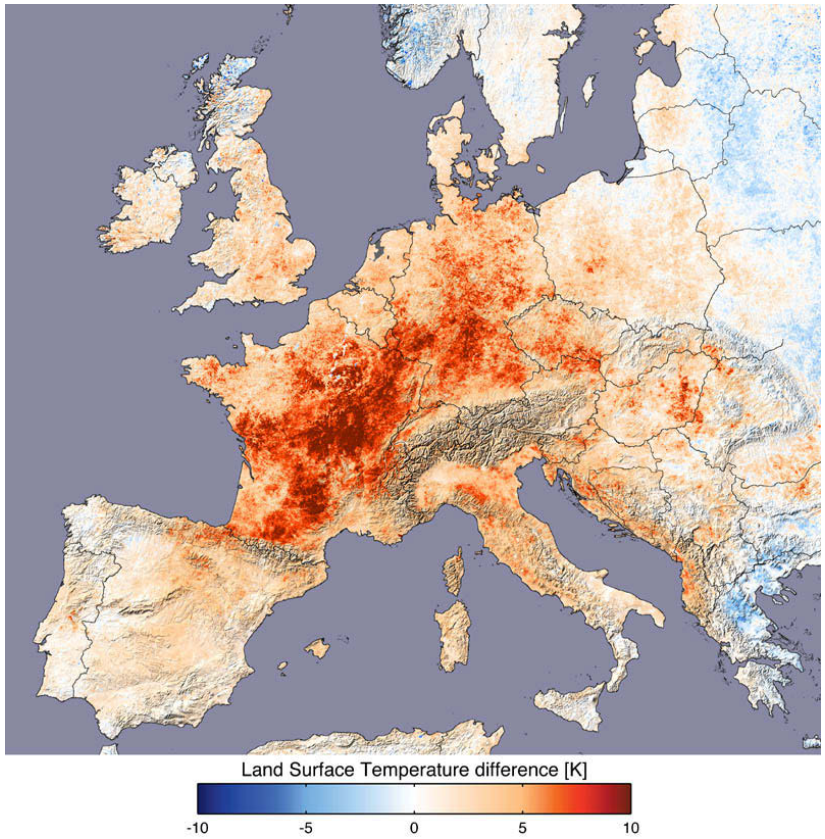
E. Palin

Allen, Liability for Climate Change, Nature, 2003

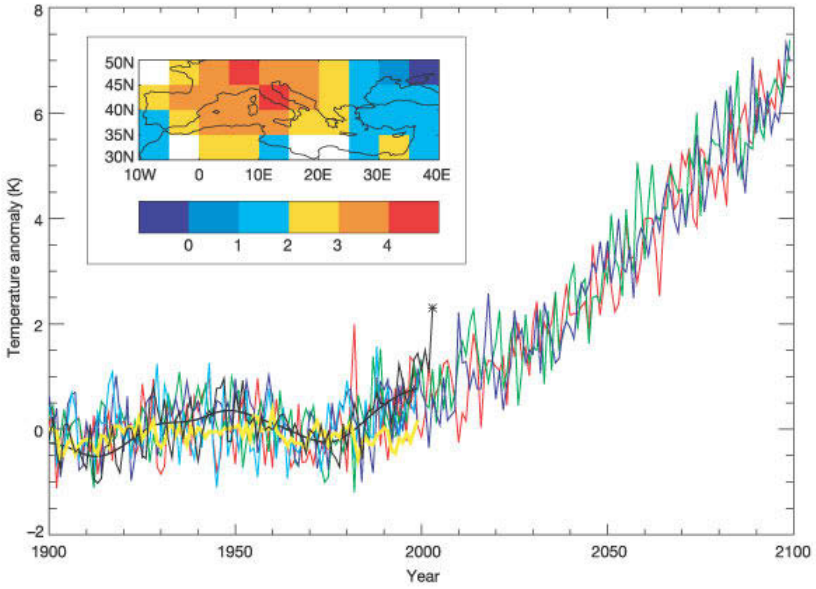


Two seminal papers (2)

Stott, Stone, Allen, Human contribution to the European heatwave of 2003, Nature, 2004.



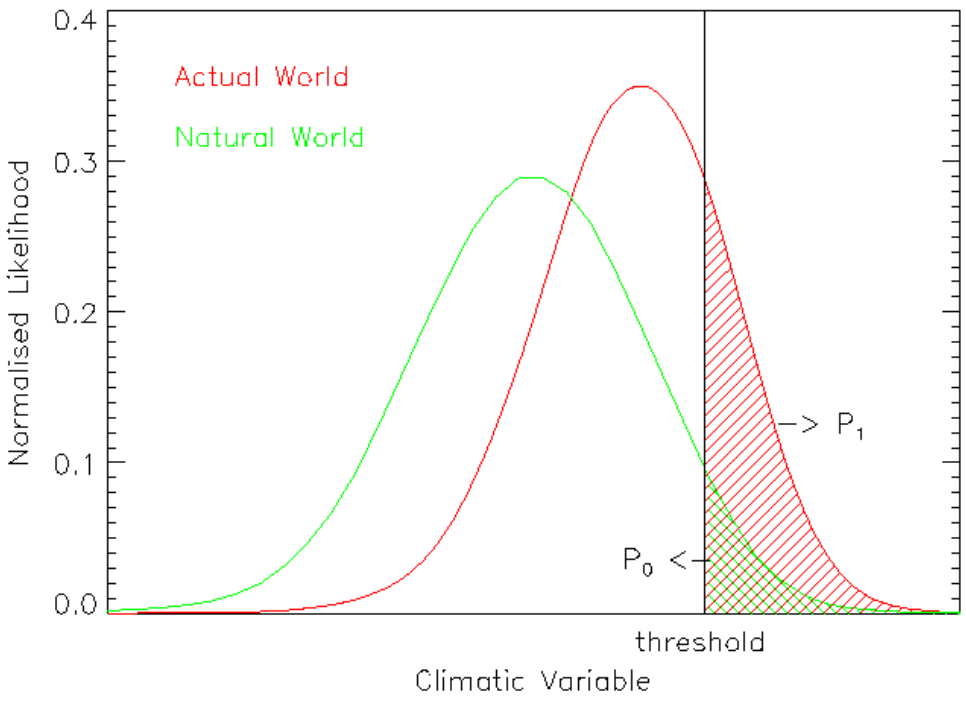
Methodology (1)



- Analyse JJA mean temperatures over a previously defined region that includes Central Europe
- Select an extreme temperature threshold just above the previous warmest year
- Determine mean temperature in “world that is” and compare to mean temperature in “world that might have been”
- By analysing the year to year variability around the mean climate in the two worlds calculate the probabilities P1, P0 of exceeding the threshold in the two worlds

Fraction of Attributable Risk

Fractional change in the likelihood of exceeding a temperature threshold as a result of the anthropogenic influences



P_0: Probability of exceeding a threshold in "world that might have been" (no anthropogenic forcings).

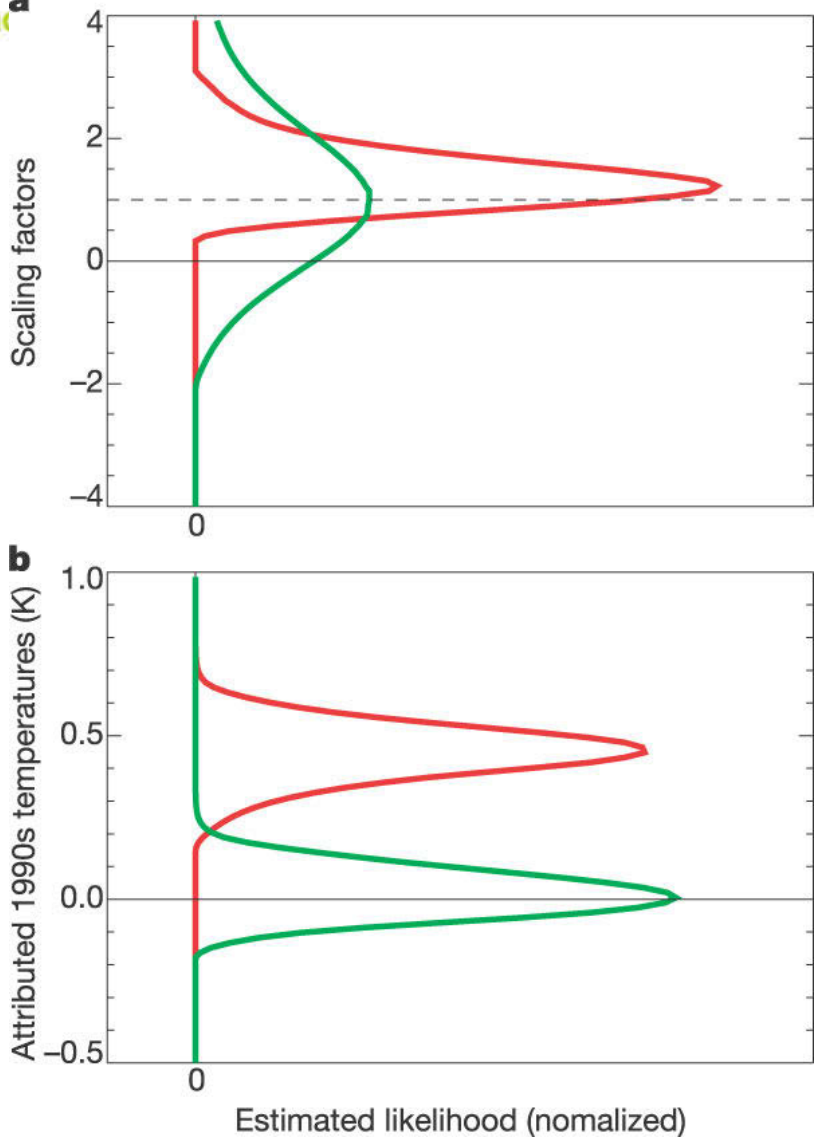
P_1: Probability of exceeding a threshold in "world that is".

$$FAR = 1 - (P_0 / P_1)$$

FAR ~ 1 Threshold exceeded only in the actual world

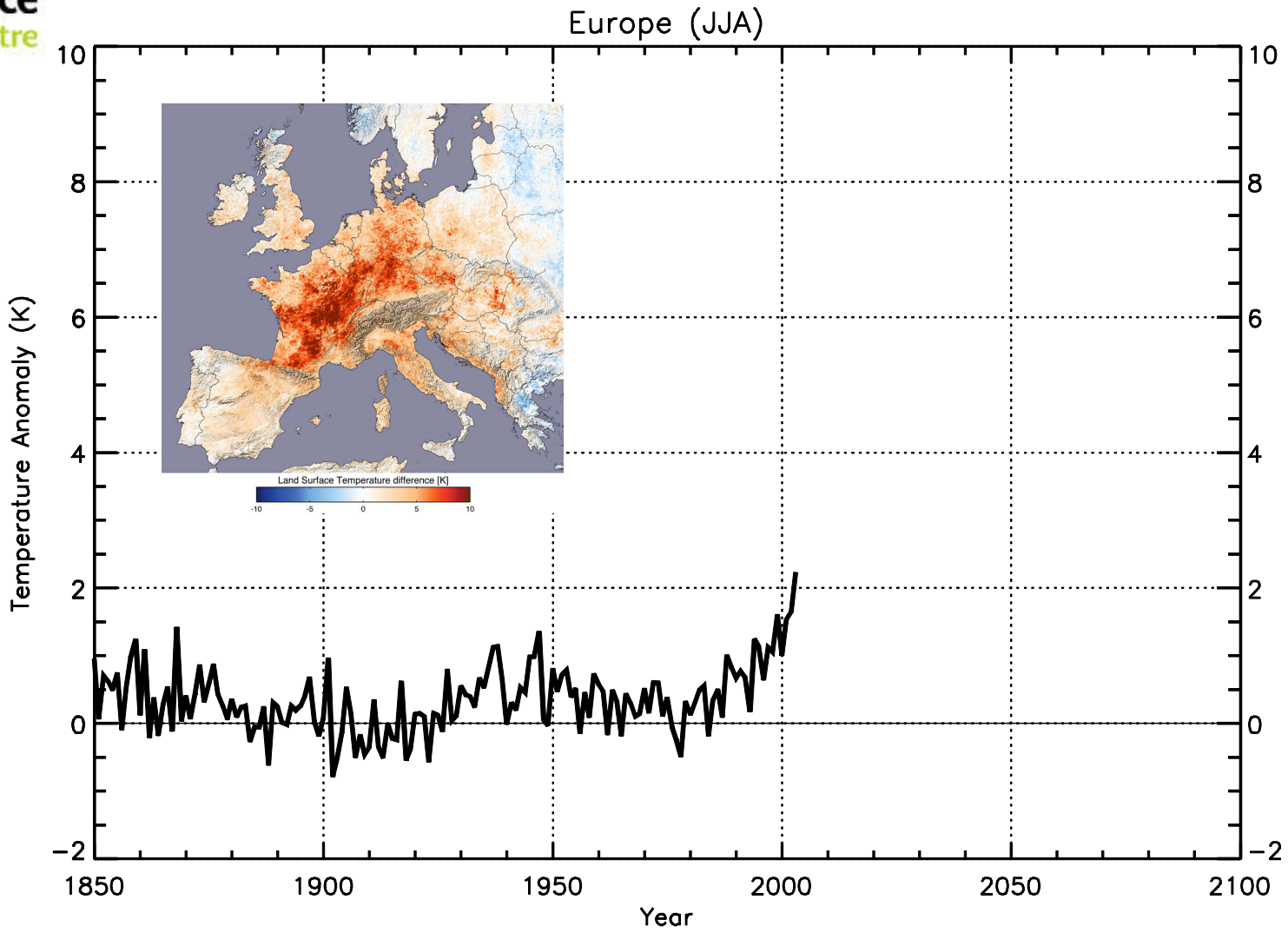
FAR < 0 More likely to exceed the threshold in the natural world

Methodology (2)



- Carry out an optimal detection analysis on European seasonal mean temperatures
- Acertain the scaling factors on anthropogenic and natural fingerprints
- Thus obtain the observationally calibrated temperatures in the 1990s in the “world that is” and the “world that might have been”.
- From this then calculate the probabilities P1, P0 of exceeding extreme temperature threshold in each world

European heatwave 2003



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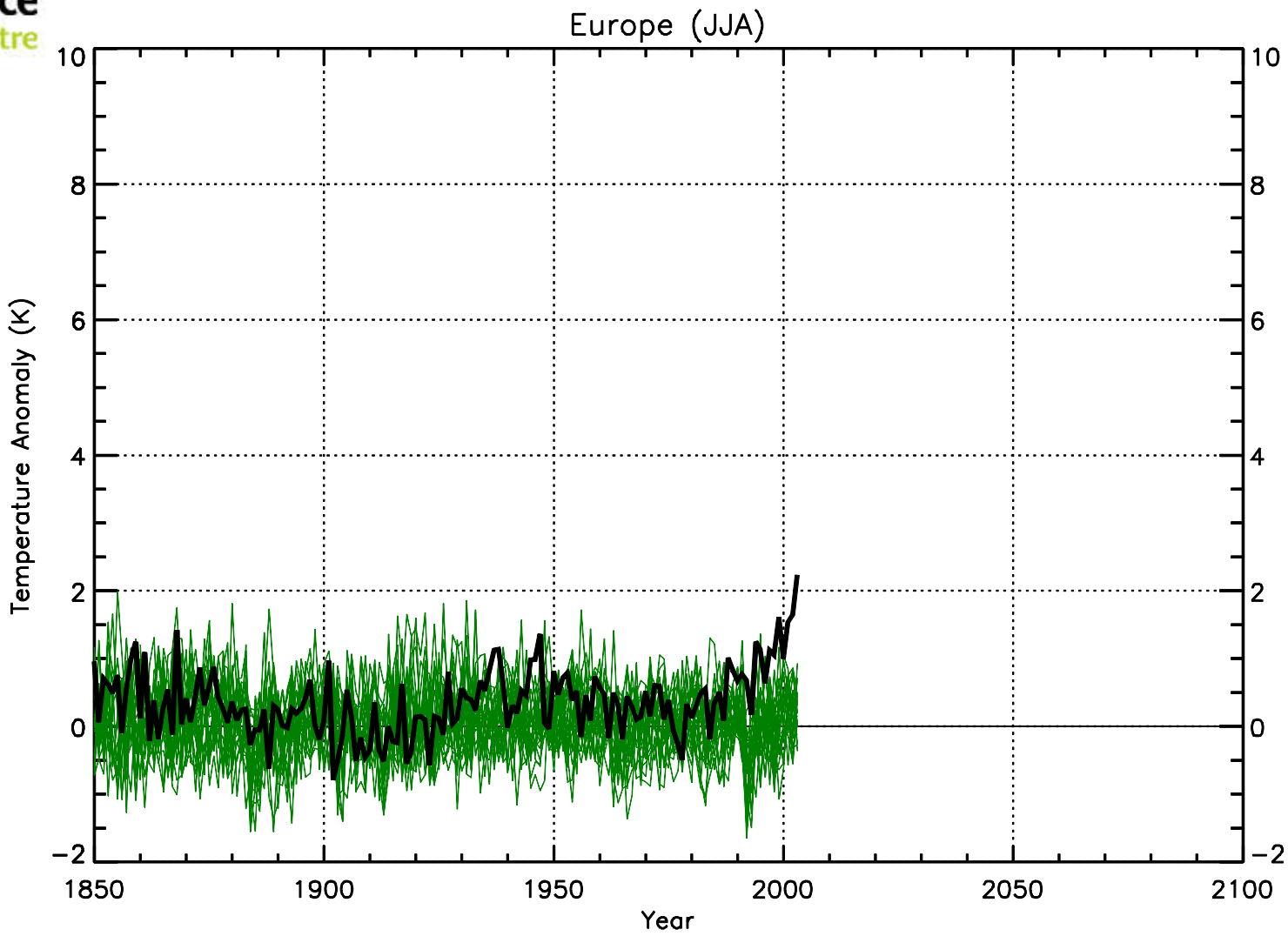
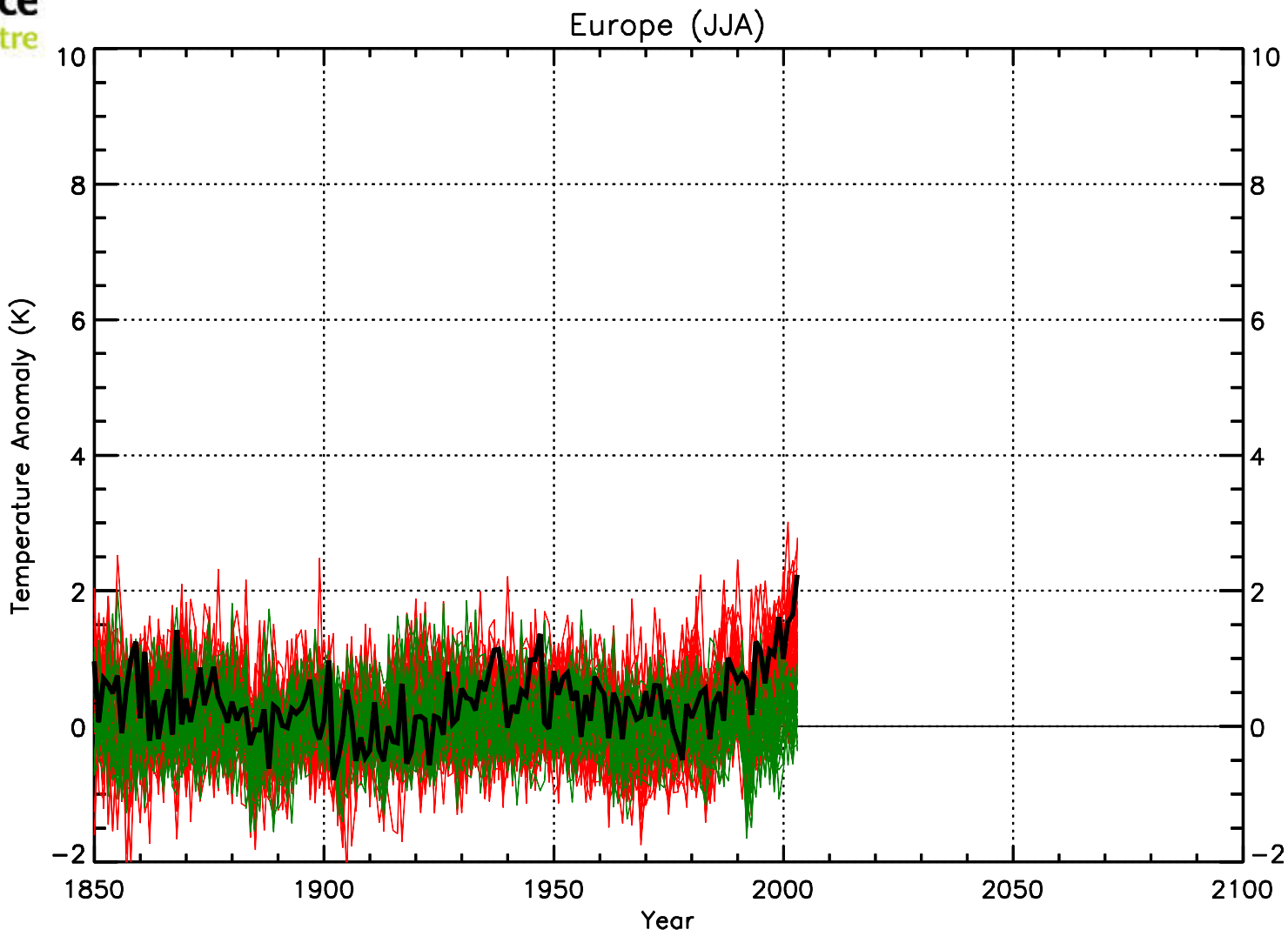
Hadley Centre



Met Office
Hadley Centre



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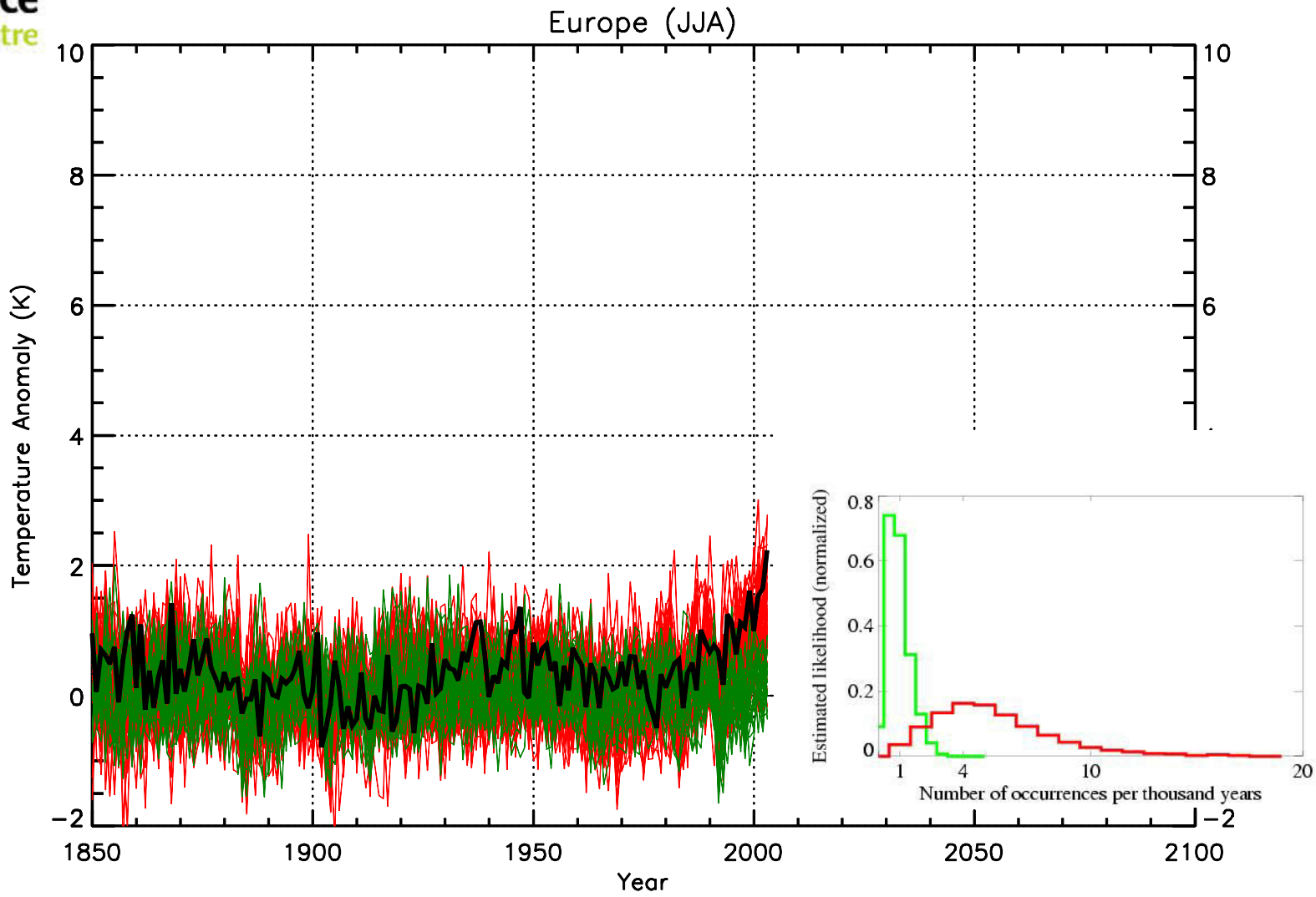
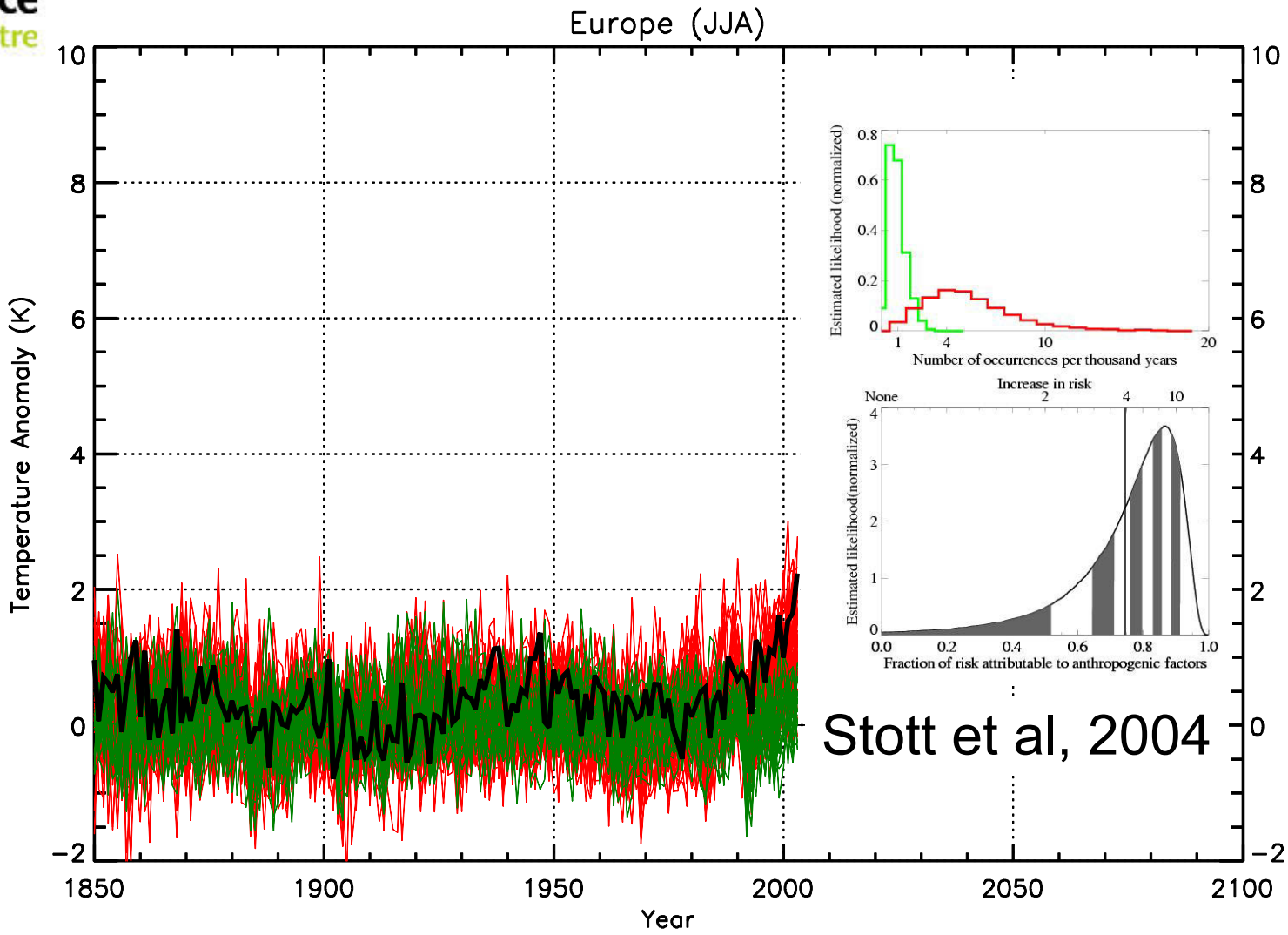
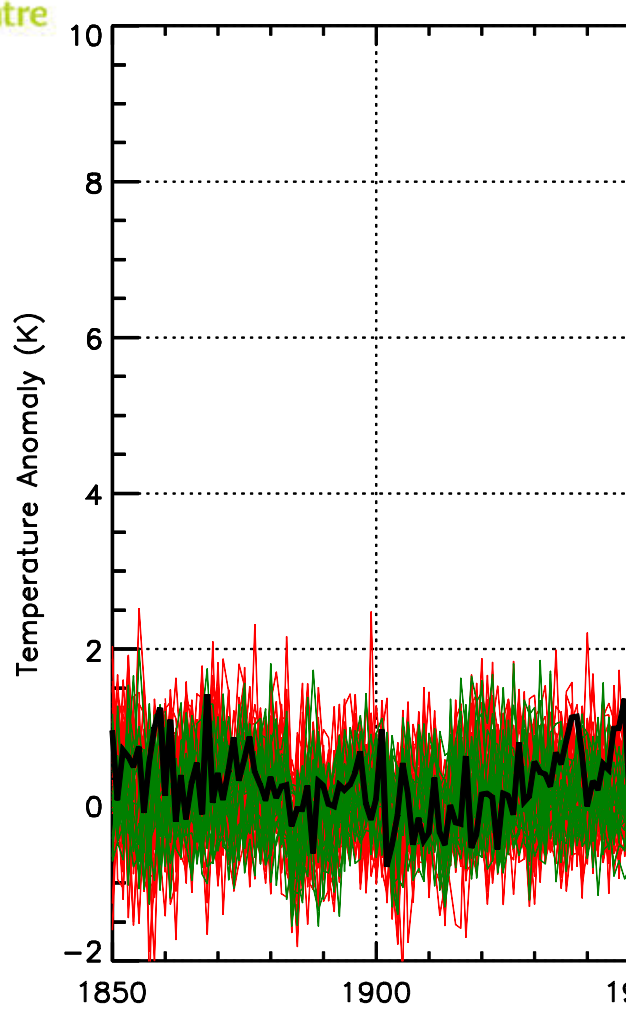
Hadley Centre

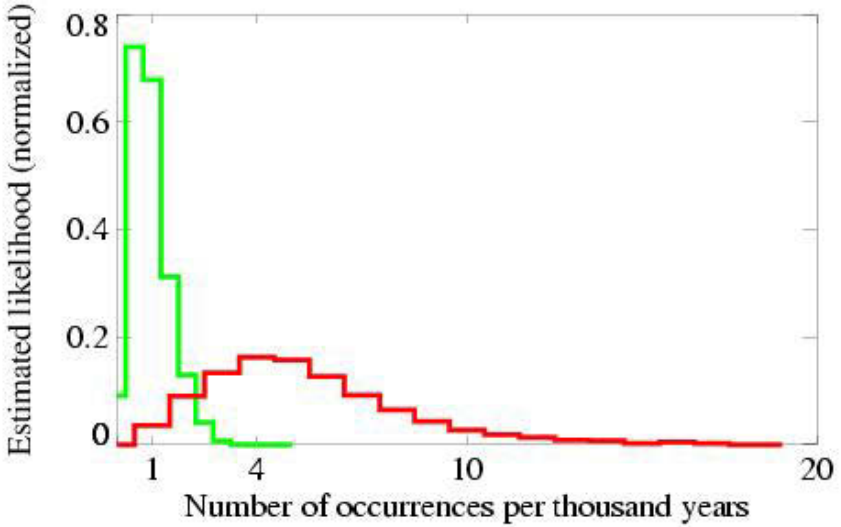


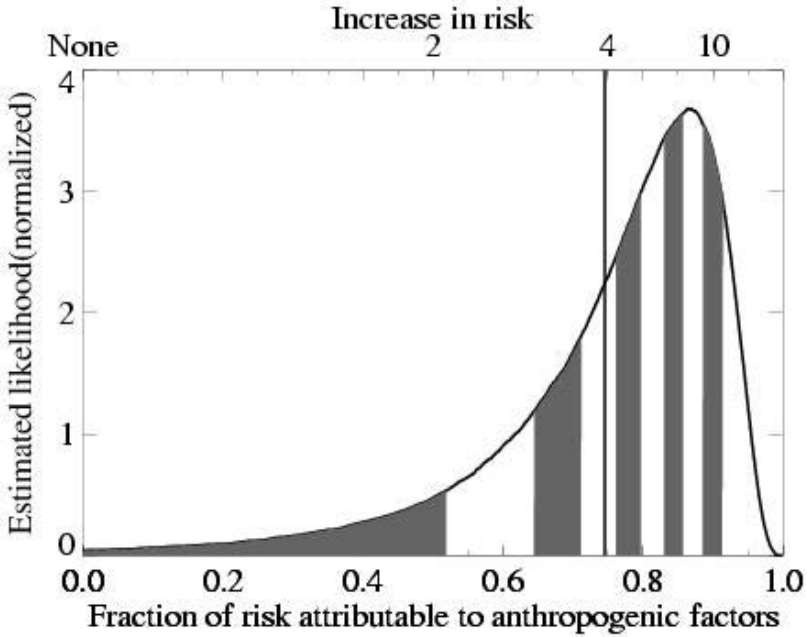
Met Office
Hadley Centre



Met Office
Hadley Centre







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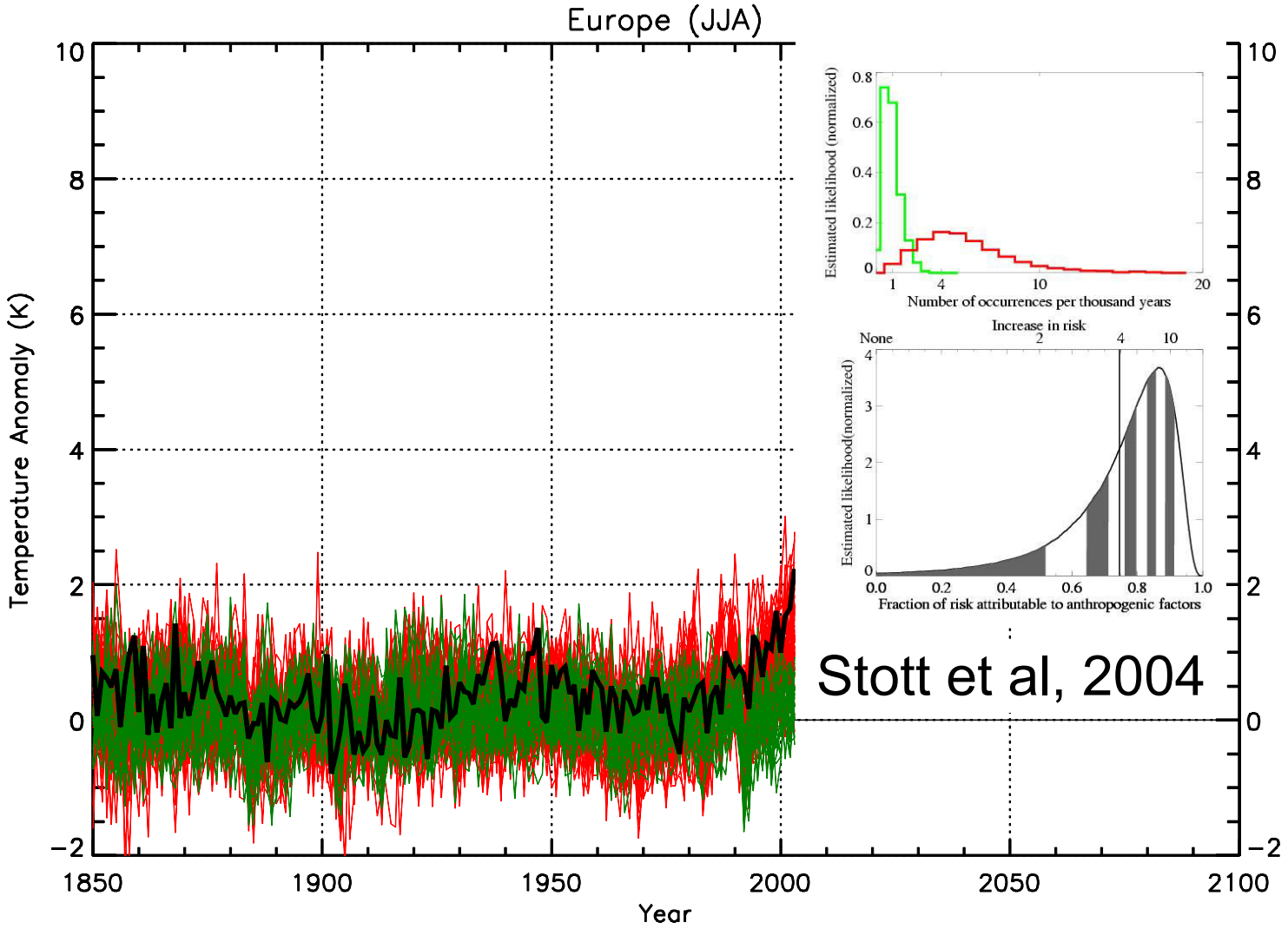
"Using a threshold for mean summer temperature that was exceeded in 2003, but in no other year since the start of the instrumental record in 1851, we estimate it is very likely (confidence level >90%) that human influence has at least doubled the risk of a heatwave exceeding this threshold magnitude"



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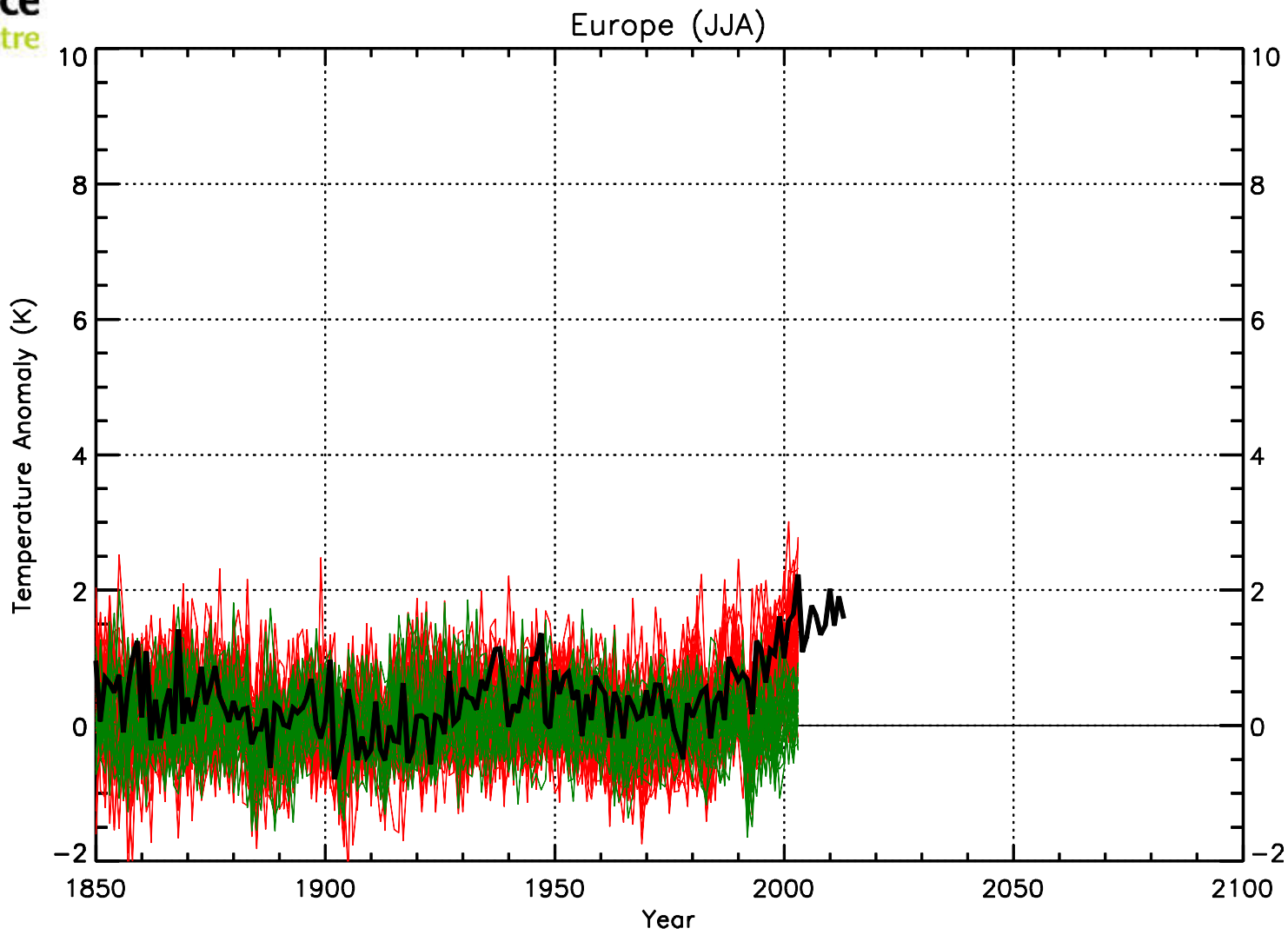

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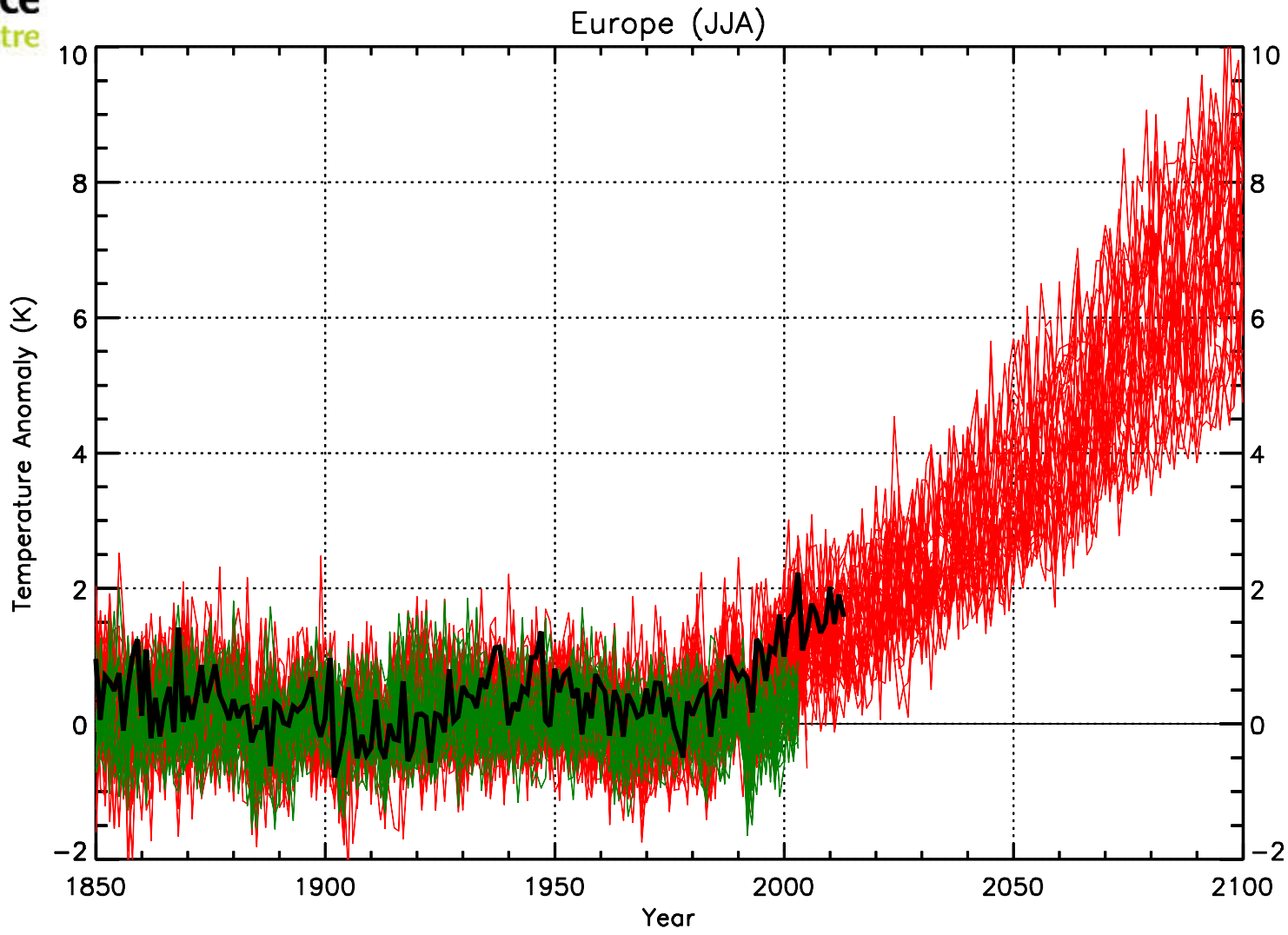
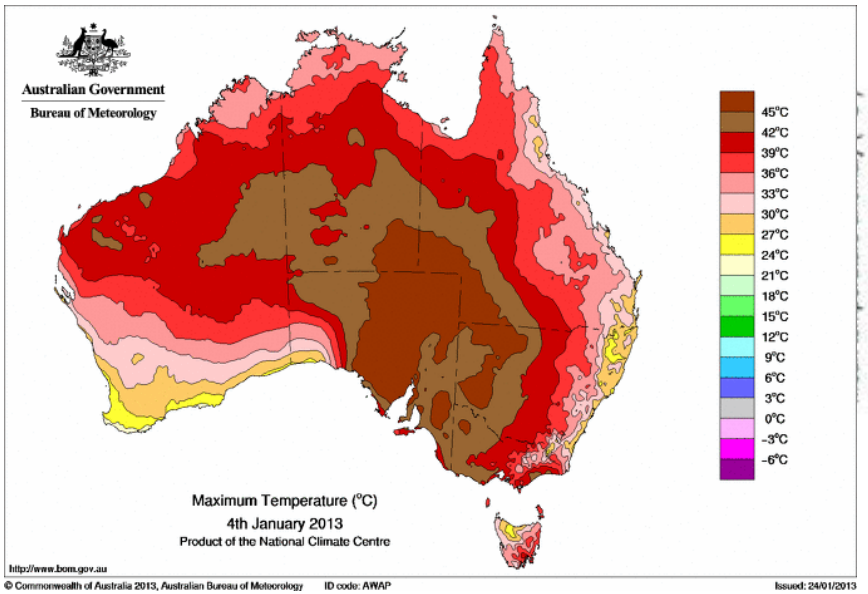
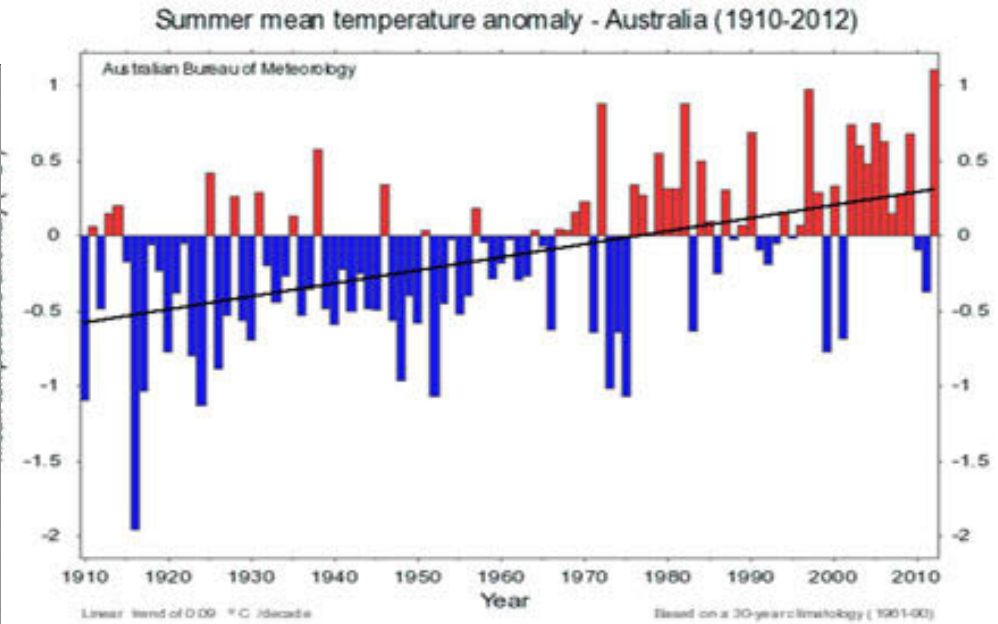
European summer temperatures on track for 2003 to become the norm by 2030s



This has also now been done for the Australian summer of 2012/13.





Such extreme summer temperatures as 2013 *very likely* at least 2.5 times more probable due to human influence. Lewis et al, GRL, 2013.

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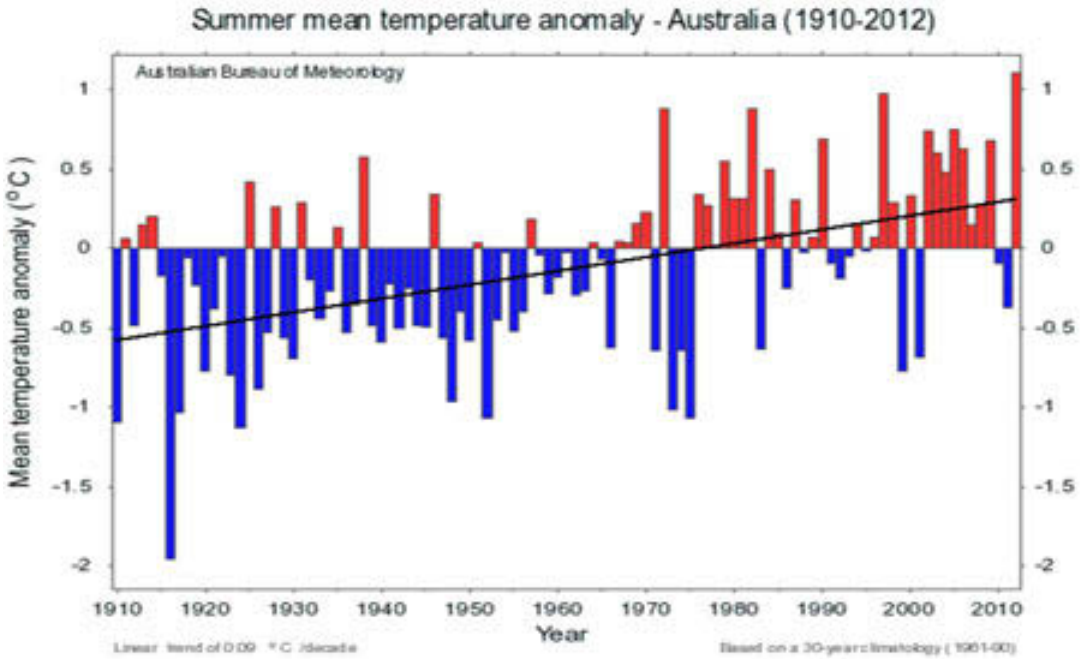
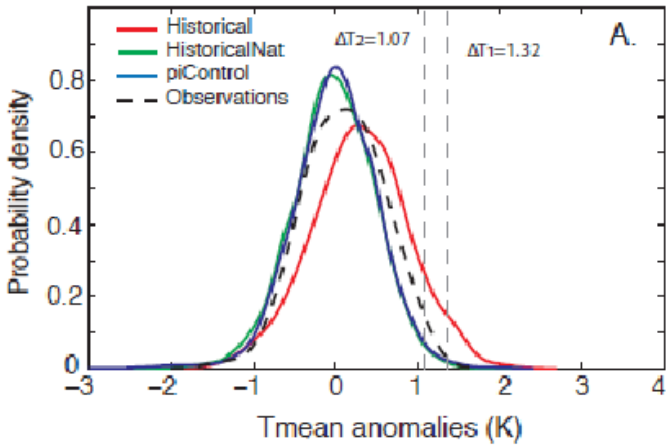
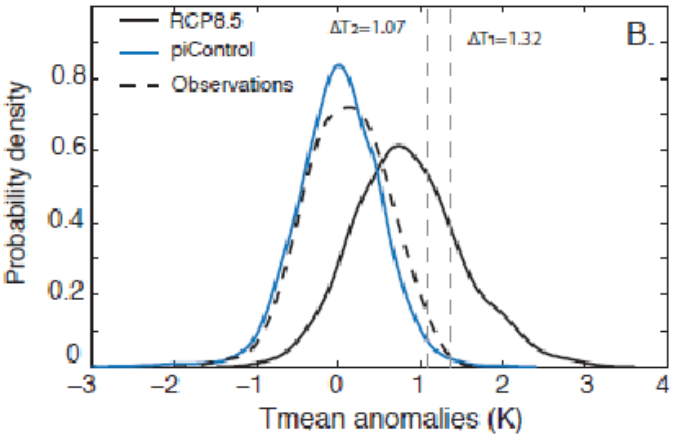
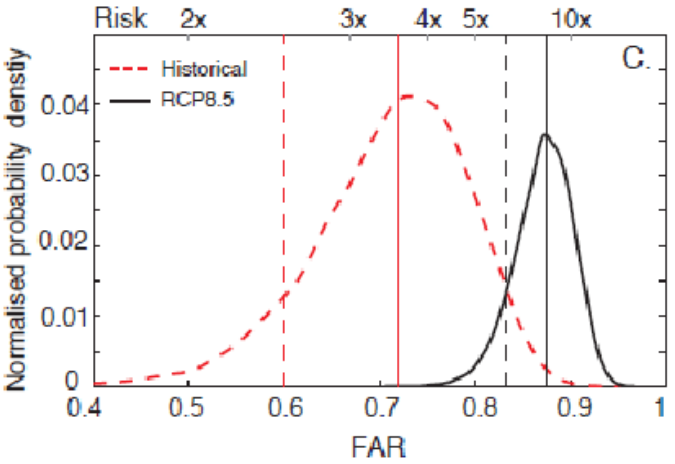
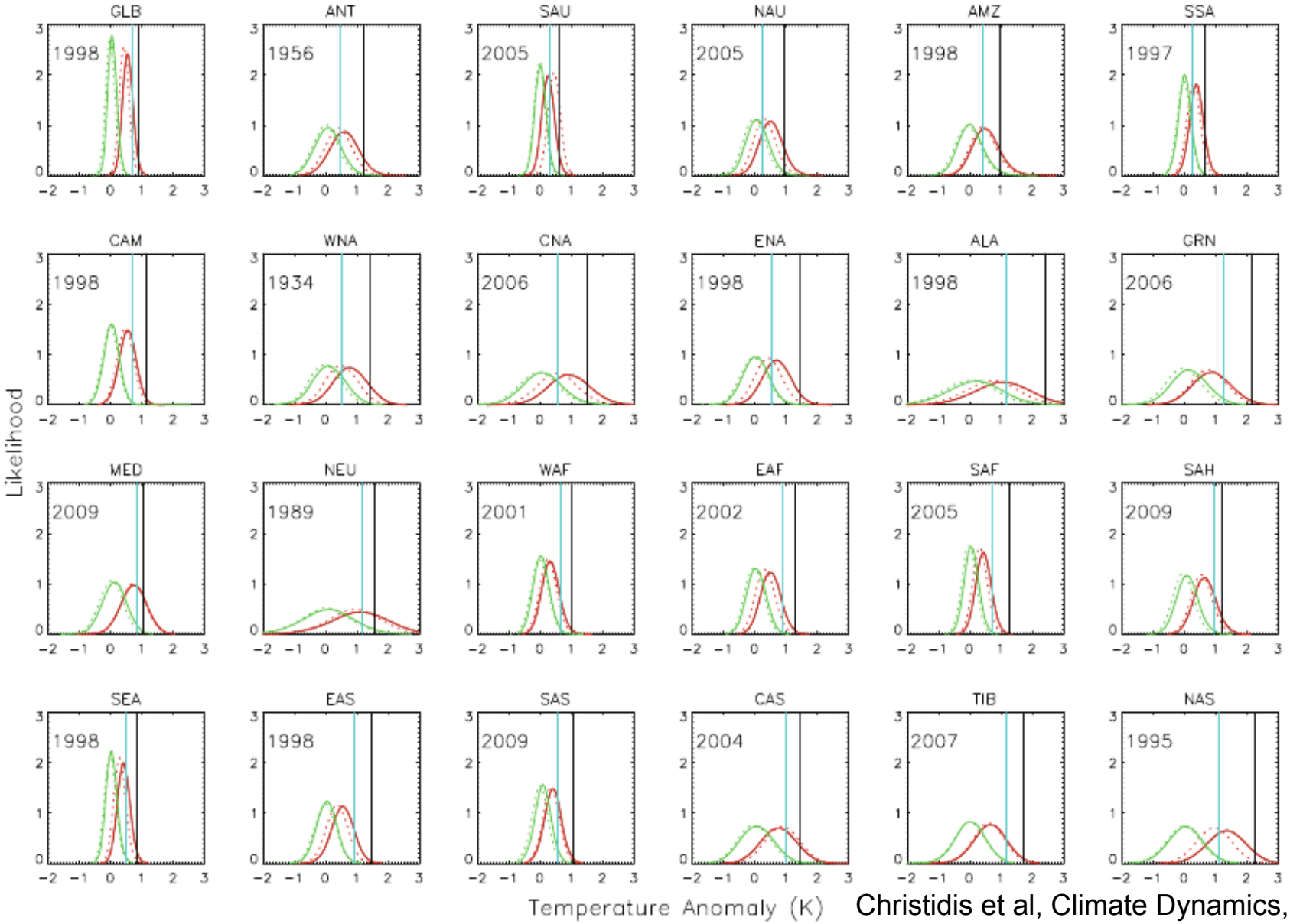






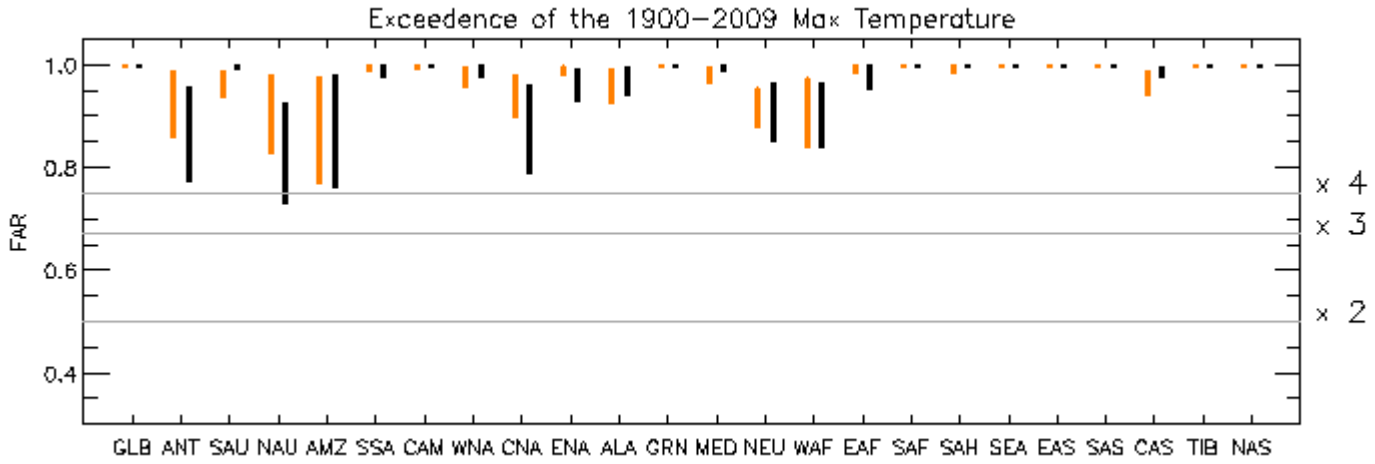


Sub-continental regions



Christidis et al, Climate Dynamics, 2011

Sub-continental regions



Estimates of the FAR in different regions

How much have anthropogenic forcings increased the likelihood of exceeding the warmest year in CRUTEM3 during recent years?

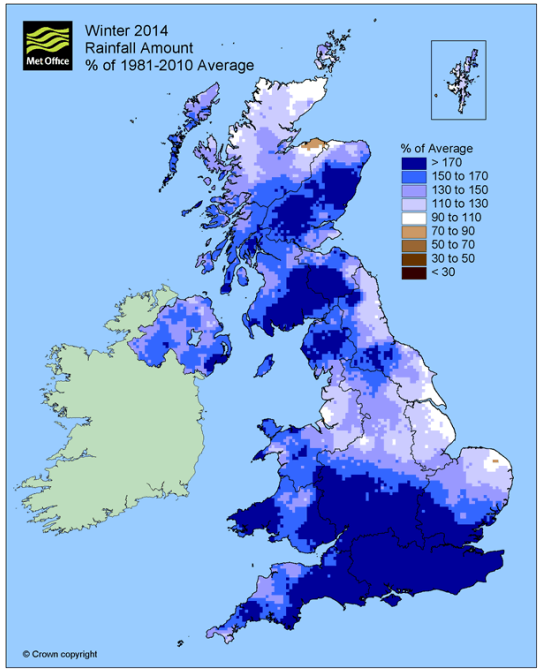
Red bars: HadGEM1

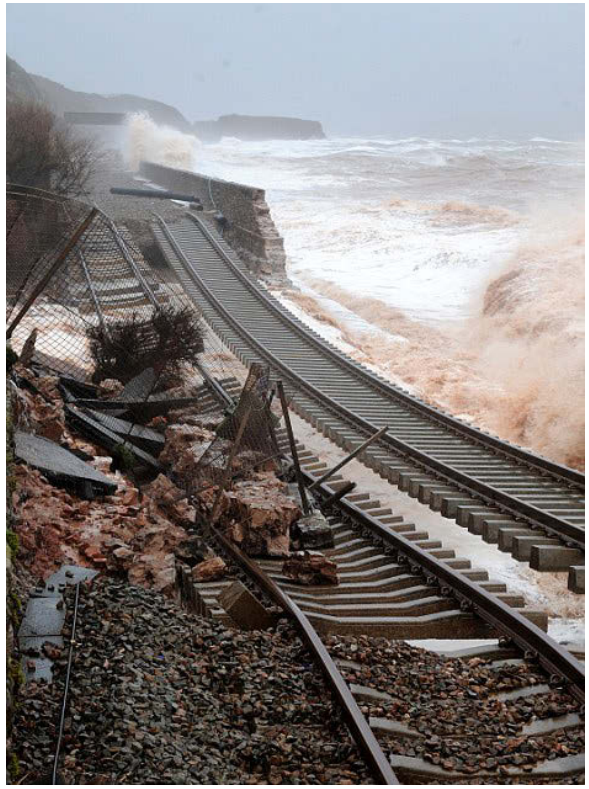
Black bars: MIROC

In 23 out of 24 regions the likelihood has at least quadrupled

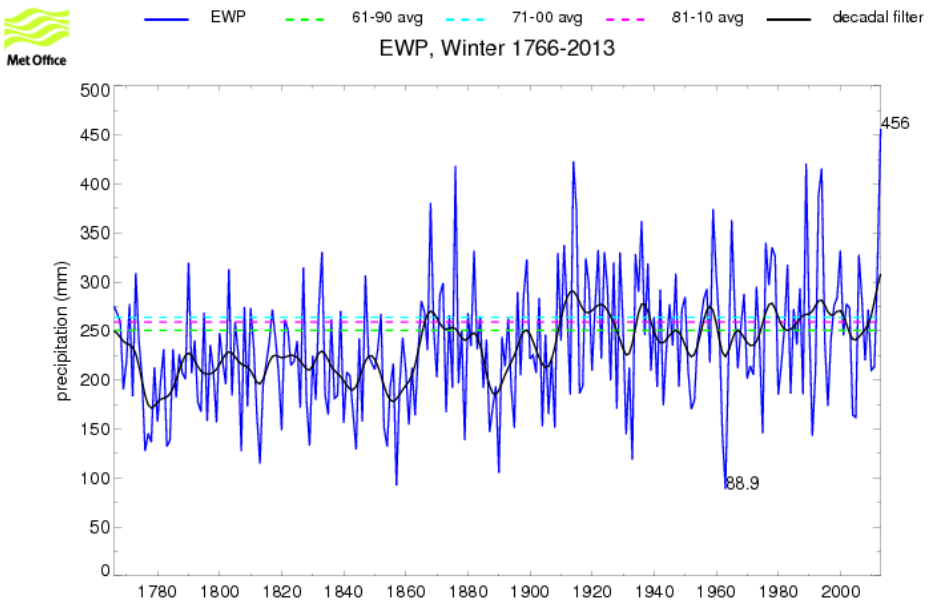
Extreme rainfall events

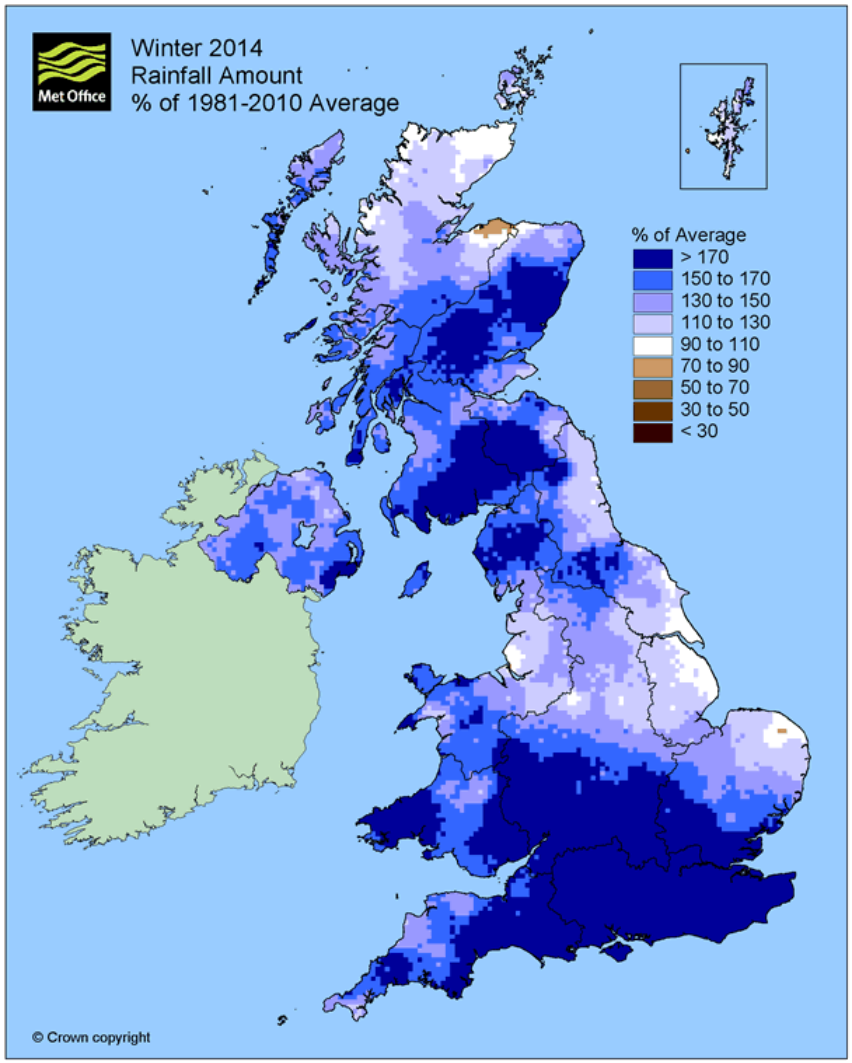
Wettest winter in England and Wales since 1766



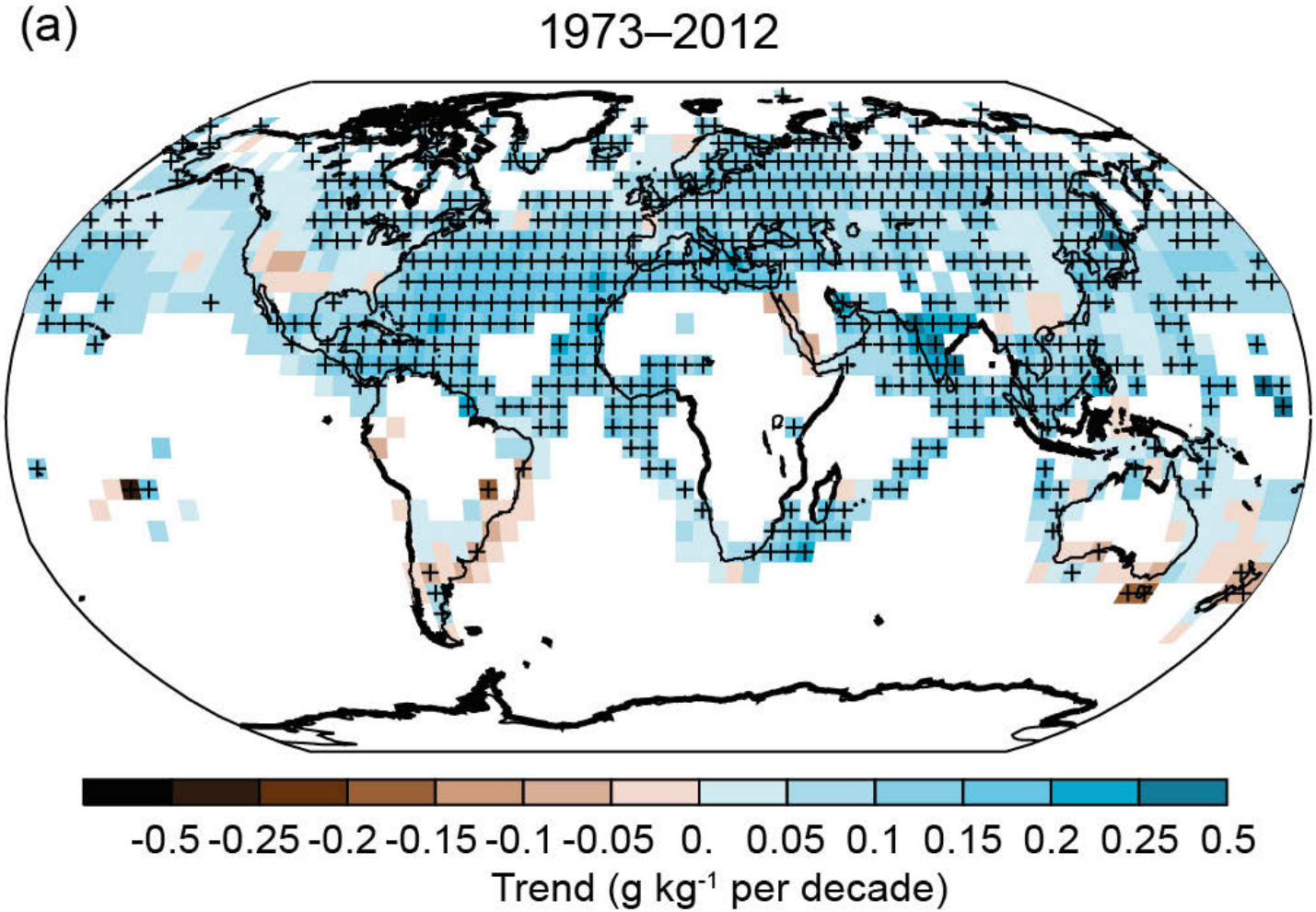


Wettest winter in England and Wales since 1766

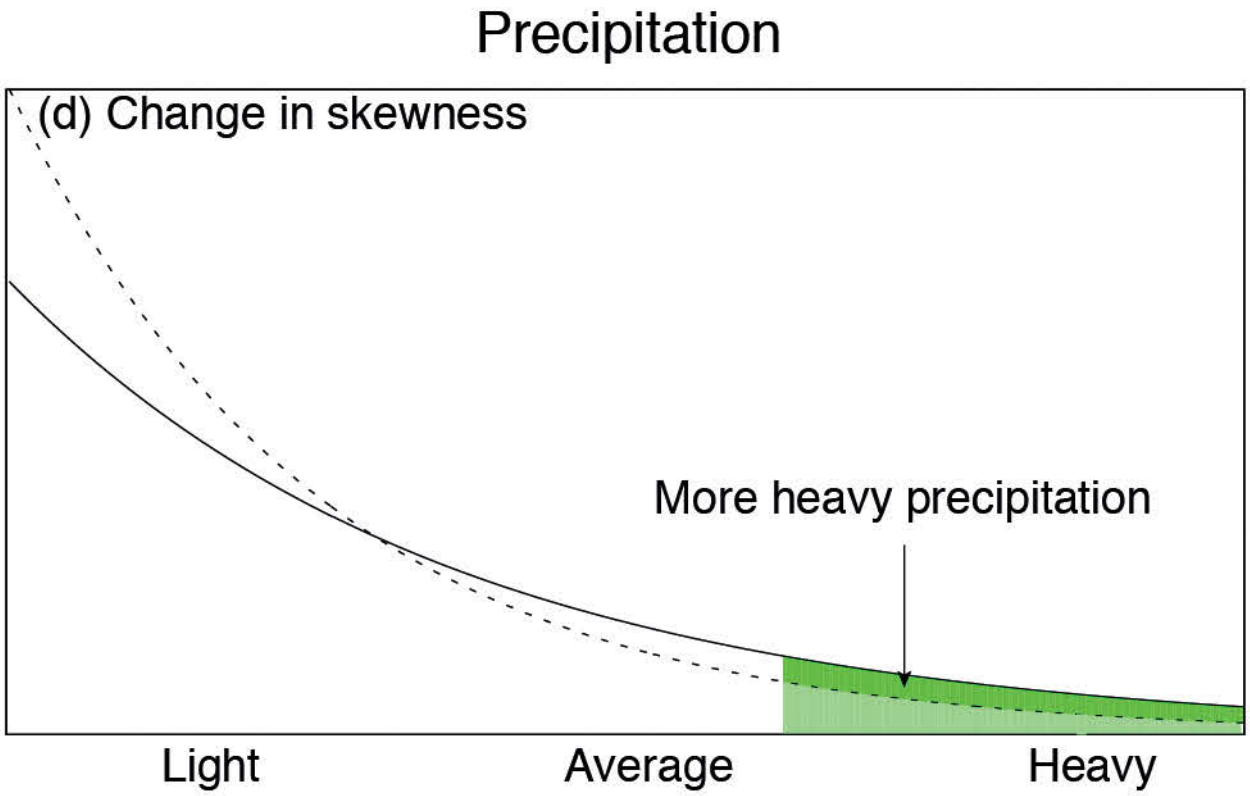




Atmosphere moisture has increased



Change in precipitation extremes in warming climate



The unusual jet stream

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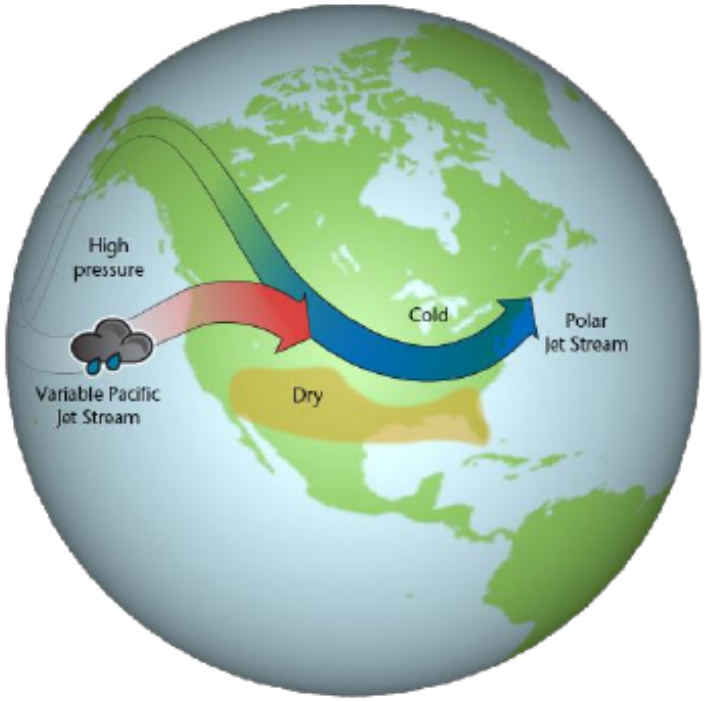


Met Office

CEH Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

The Recent Storms and Floods in the UK

February 2014

Attribution of Climate-related Events (ACE) Development of the Hadley Centre near-real time attribution system

ACE approach:

- Generate large ensembles (perturbing physics parameters), running our model with observed SSTs and external forcings.
- Generate a second ensemble without the human influence. An estimate of the anthropogenic change in the SSTs is subtracted from the observations. Only natural forcings are included.

Change in the likelihood of the event

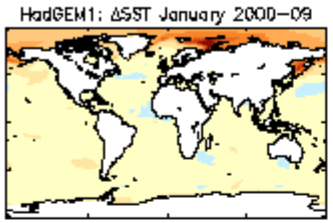
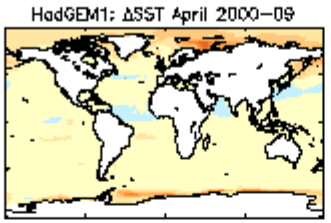
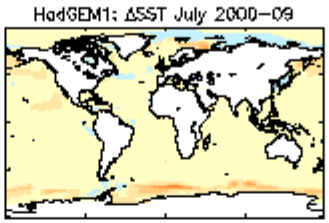
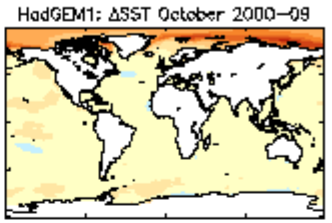
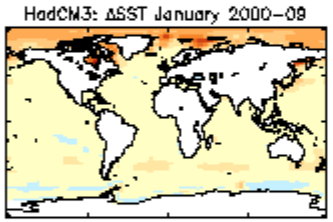
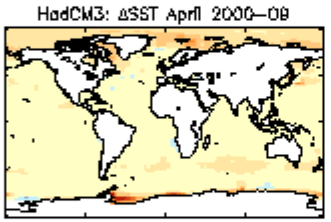
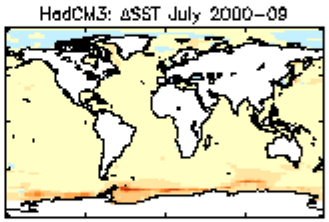
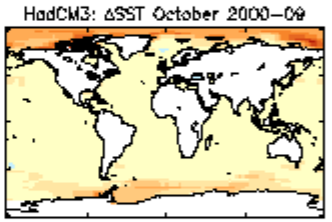
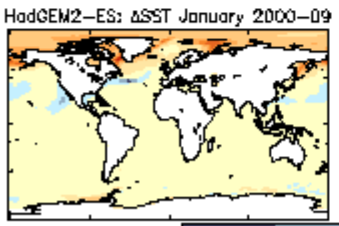
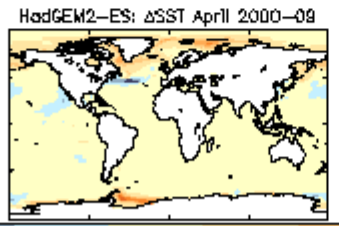
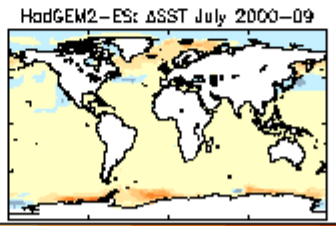
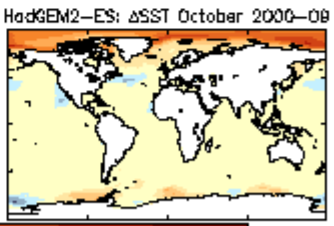
given certain modes of internal variability

Hadley Centre near-real time attribution system

HadGEM3-A, N96 L38. (Currently upgrading N216 L85)

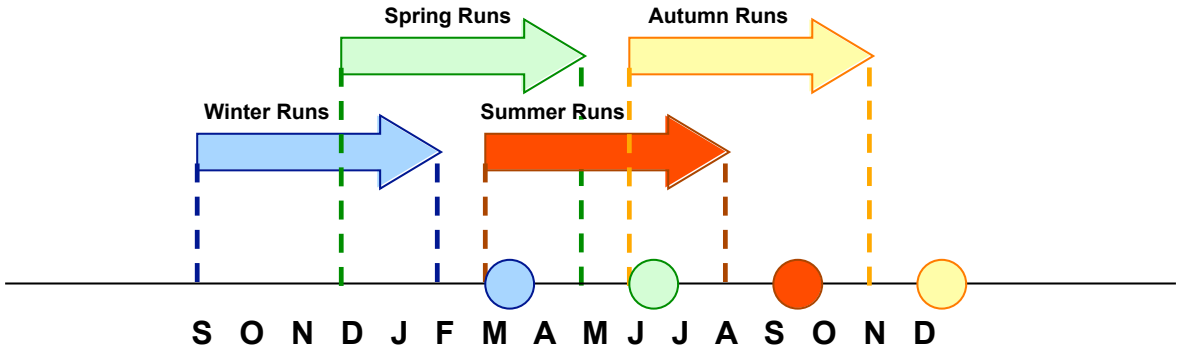
Patterns of the change in the SST

Met Office Hadley Centre

	January	April	July	October
HadGEM1				
HadCM3				
HadGEM2-ES				

Operational Attribution Systems

An example of an operational system: seasonal ACE runs



An illustration of the operational ACE runs for each season in the year. The arrows represent the period covered by the runs and the circles mark the point in real time when the runs will be carried out. The seasons are with reference to the Northern Hemisphere

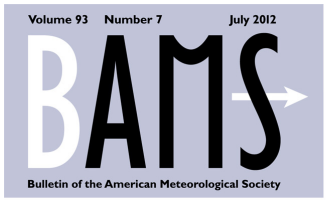
Christidis et al, J. Climate, 2012

Met Office Hadley Centre

Explaining extreme climate and weather events of the previous year from a climate perspective

Editors : Stephanie Herring, Martin Hoerling, Tom Peterson, Peter Stott.

NOAA

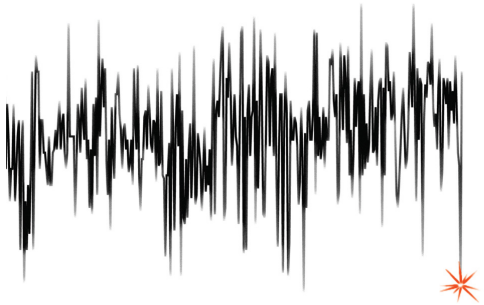


ENSO PREDICTION ADVANCES

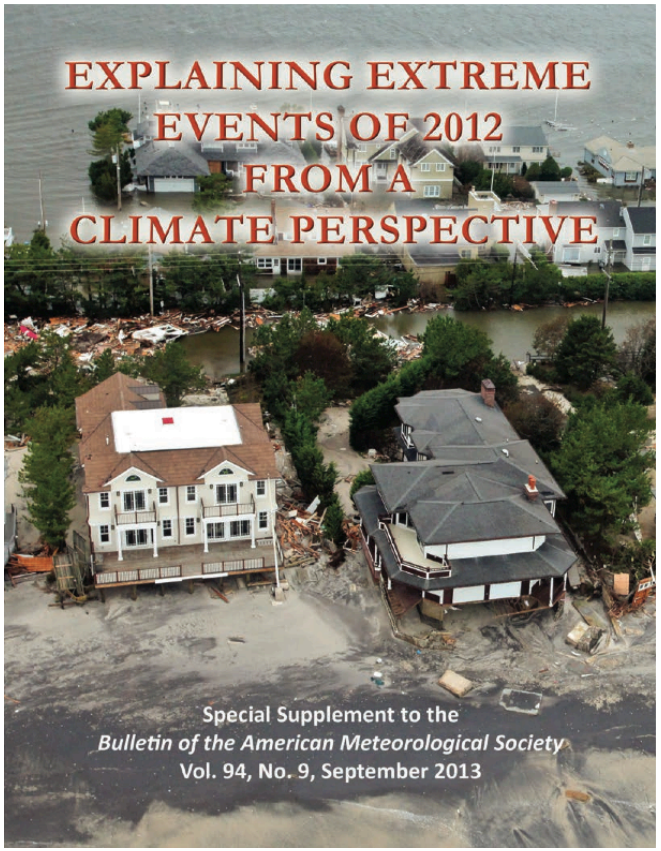
LEARNING WITH THE A-TRAIN

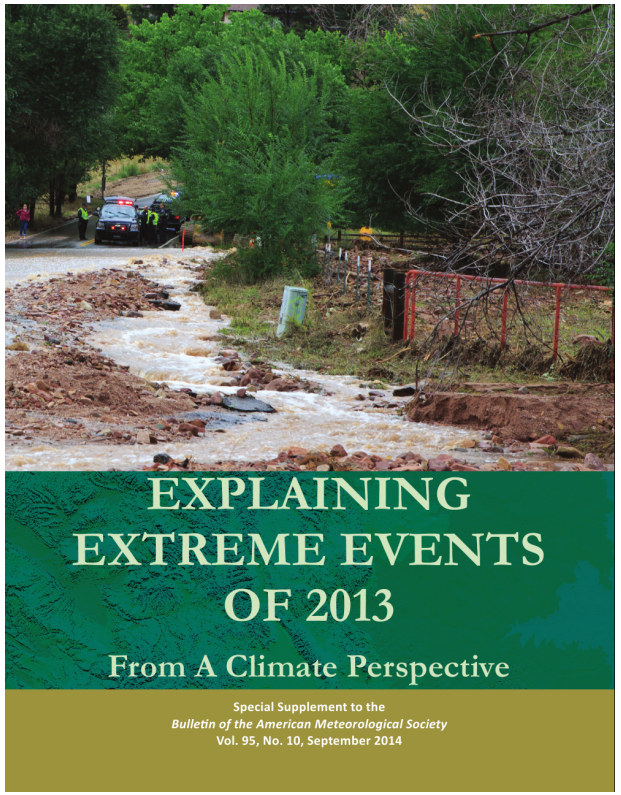
MIGRATIONS ON RADAR

WEATHER *EXTREMES* OF 2011 IN CLIMATE PERSPECTIVE

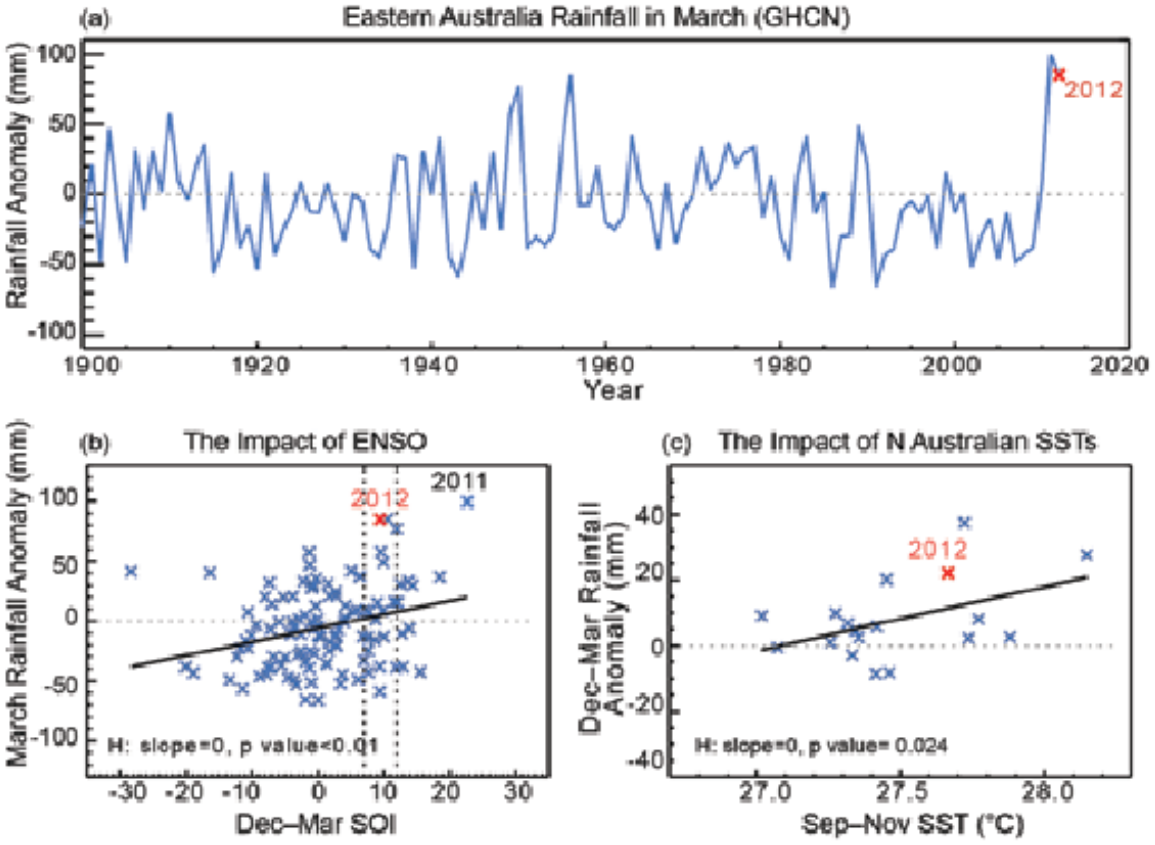


Taking Attribution Science to the Limits





Met Office attribution system applied to heavy Australian rainfall, March 2012



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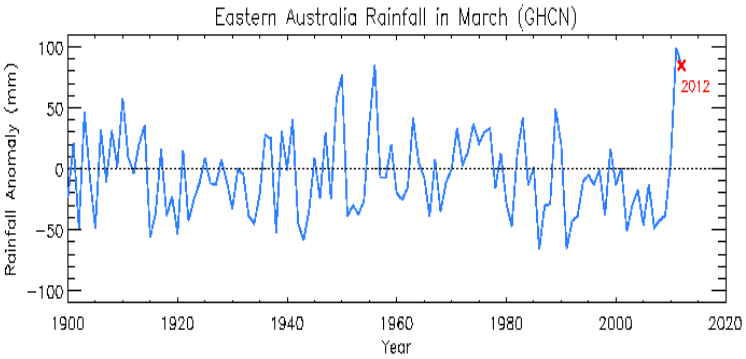


600 member ensembles with and without the effect of human influences.

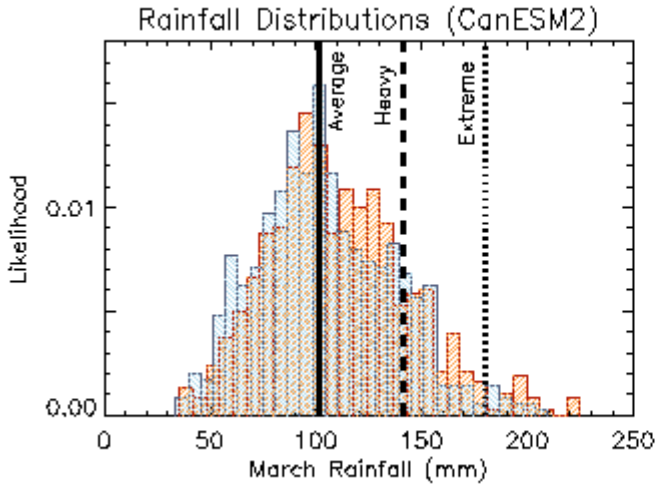
Calculate changed probability of occurrence of such an extreme rainfall total.

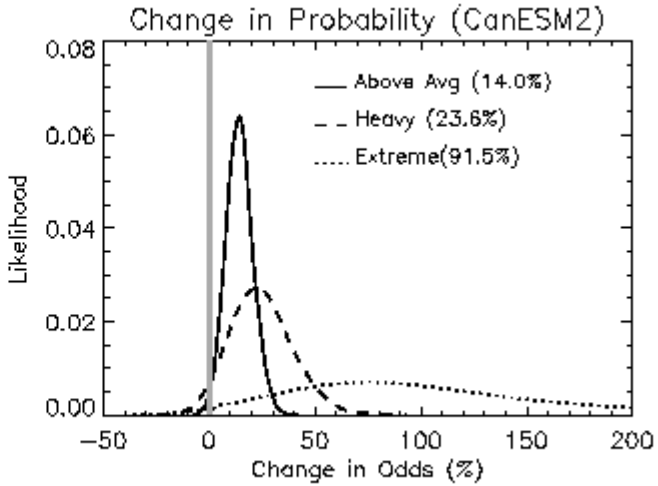
Strong La Nina contribution with some evidence for effect of anthropogenic warming increasing the odds.

Christidis et al, 2013

March Rainfall Distribution

ALL & NAT





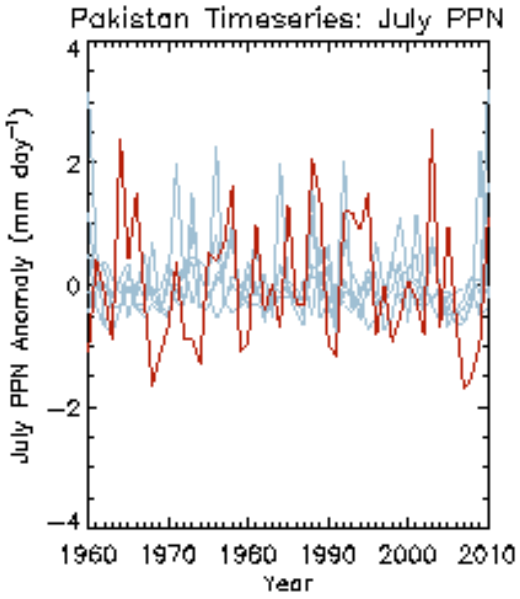
Met Office
Hadley Centre

Record breaking 10.8 inches of rain fell in Peshawar, Pakistan during 24 hours in July 2010

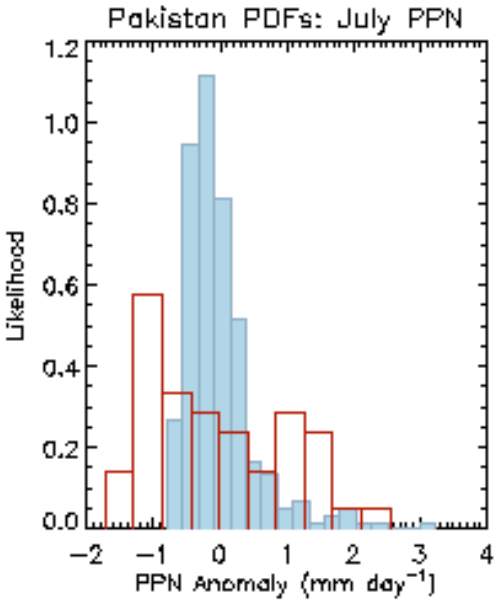
Verification

July Rainfall in Pakistan

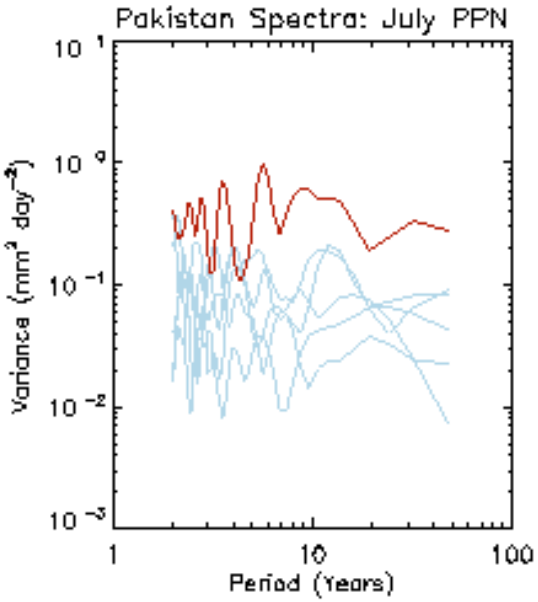
1960-2010 Timeseries



Distributions



Power Spectrum

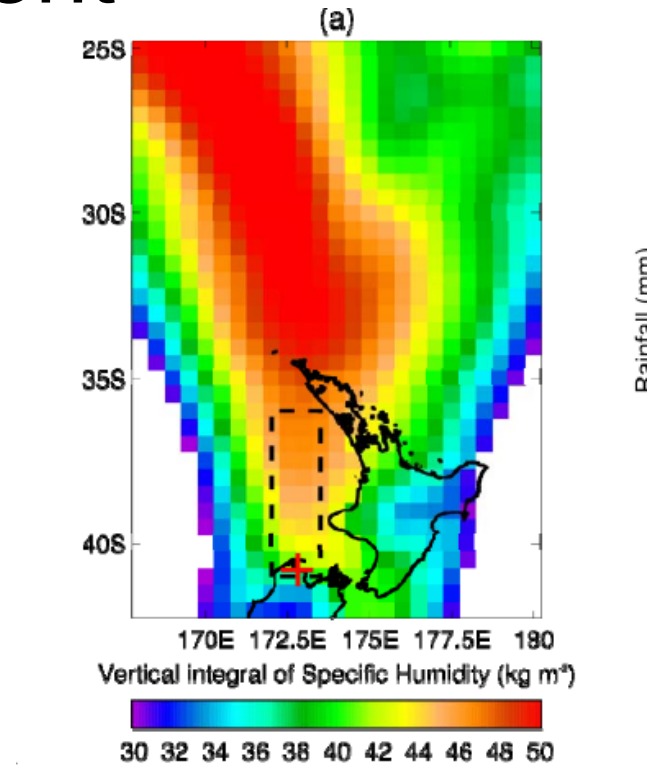


Red Lines: NCEP/NCAR Reanalysis

Black Lines: 5 Model runs with ALL forcings and observed SSTs & SI

Golden Bay New Zealand Extreme rainfall event

Dean et al, 2013

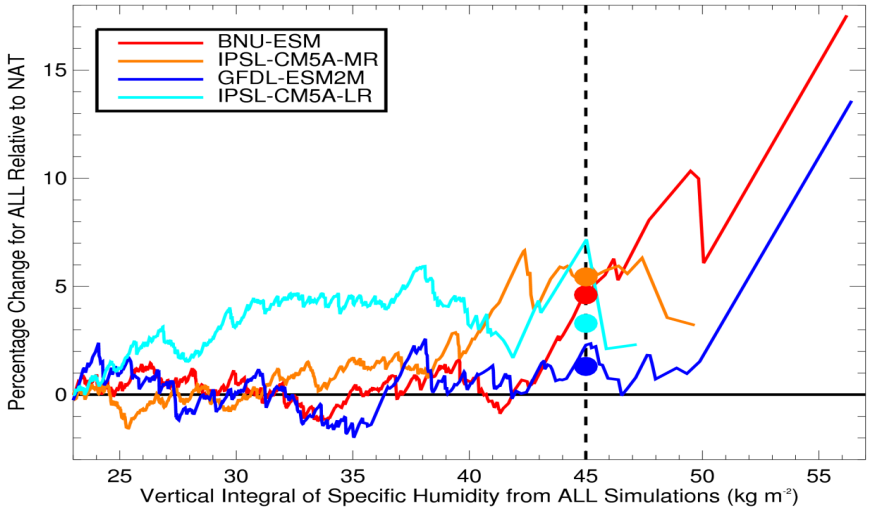


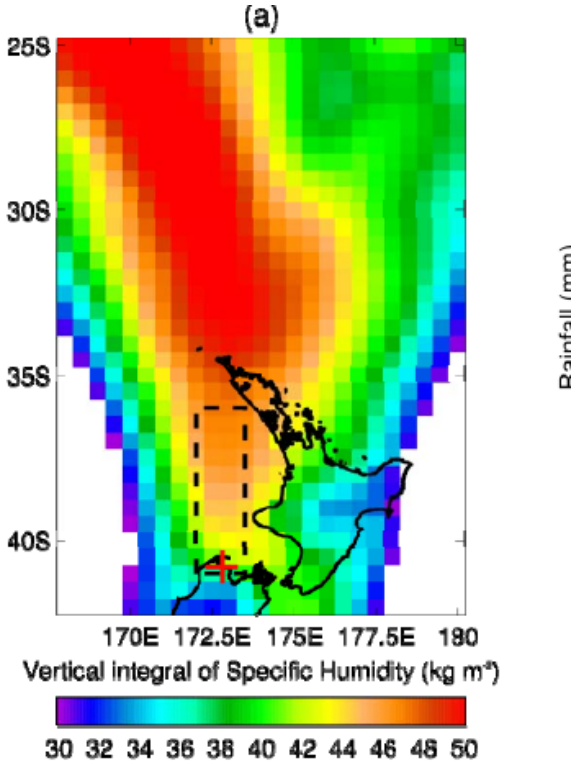
Very heavy rain and landslides, Golden Bay, New Zealand, 14th December, 2011

An example of an atmospheric river bringing very high levels of moisture and extreme rainfall to a mid latitude location

Golden Bay New Zealand Extreme rainfall event

Dean et al, 2013



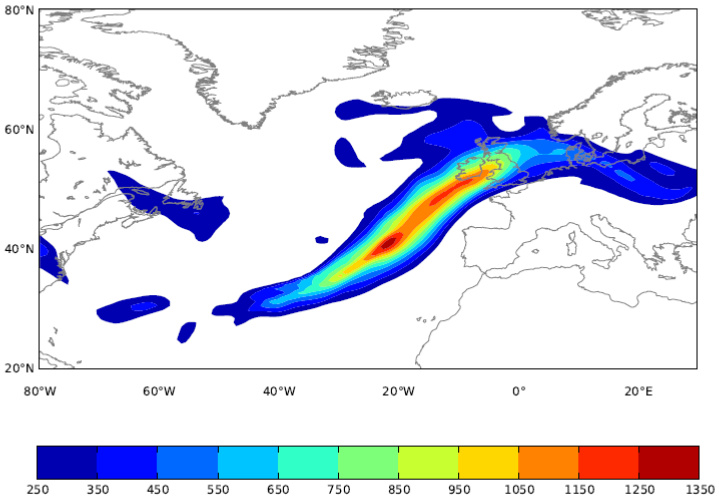


Total moisture available for precipitation in this event has increased by 1% to 5% as a result of the emission of greenhouse gases.

Models show an increase in the frequency of such events of between 8 and 32%.

Predominantly due to a thermodynamic response.

Atmospheric rivers

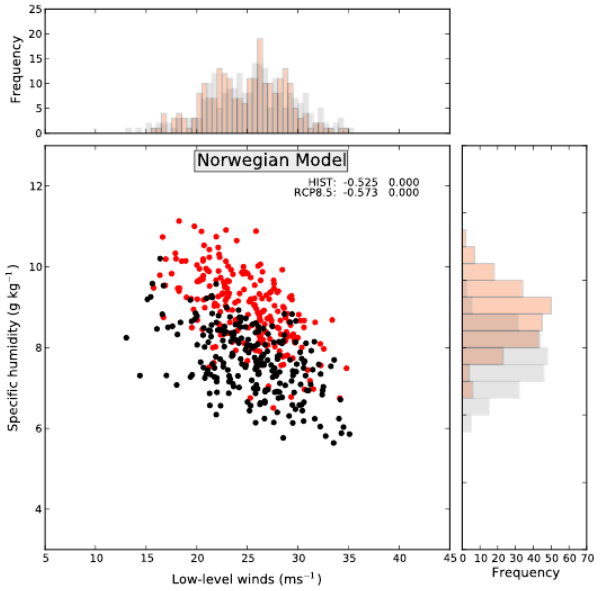


Narrow bands of intense moisture flux in the lower troposphere

• Associated with periods of heavy rainfall and many of the largest floods in mid latitudes

• In North Atlantic are projected to become stronger in future with increased water vapour transport

• This is predominantly a thermodynamic response to warming resulting from anthropogenic forcing



•Lavers et al, 2013. ERL, 8, 034010.

Met Office Hadley Centre

ACE Attribution of Climate-related Events group

EUCLEIA

EUropean **CL**imate and weather **E**vents: **I**nterpretation and **A**ttribution

ACE : International ad-hoc group of scientists interested in event attribution from US, Europe, Japan, China, Australia, New Zealand, etc

EUCLEIA: 3 year project under the FP7-SPACE Call, that brings together 11 European partners with an outstanding scientific profile in climate research:

The project aims to develop a quasi-operational attribution system, well calibrated on a set of test cases for European extreme weather, that will provide to targeted groups of users, well verified, well understood assessments on the extent to which certain weather-related risks have changed due to human influences on climate.

TEST CASES:

- Heat waves
- Cold spells
- Droughts
- Floods
- Storm surges

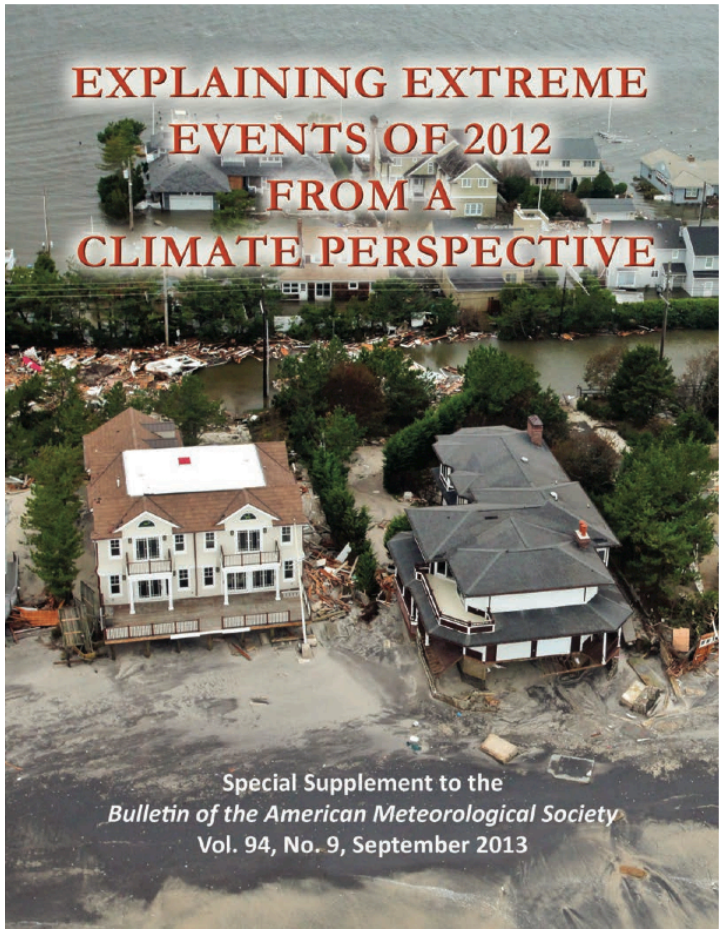
Explaining extreme climate and weather events of the previous year from a climate perspective

Tom Peterson, Peter Stott, Stephanie Herring.

- Report ground breaking in applying attribution science to recent extreme weather events.
- Climate change has made some events more likely, some less likely
- We do not see evidence for a strong human influence in all weather extremes. Natural variability also plays an important role
- Inaugural report quickly became “most read” article in BAMS

Explaining extreme climate and weather events of the previous year from a climate perspective

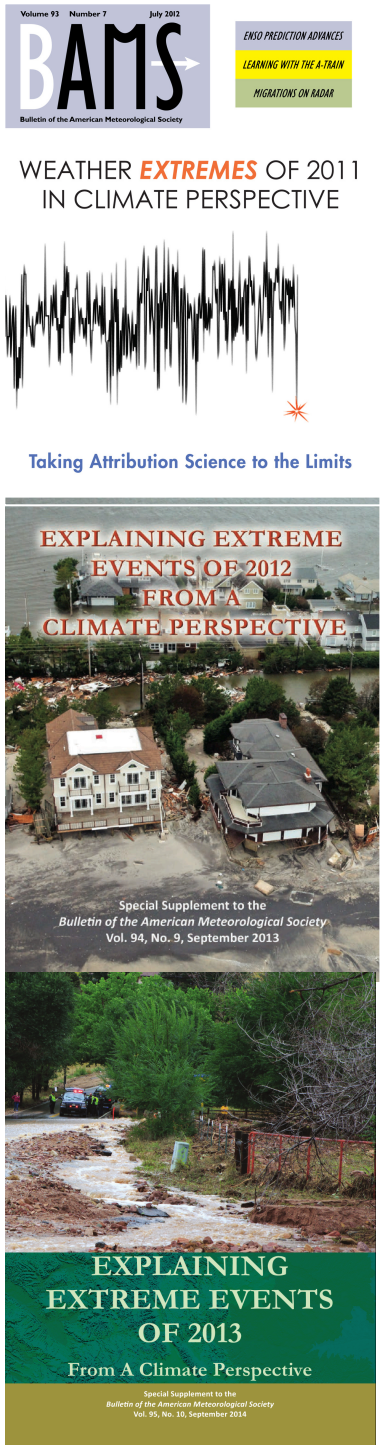
Tom Peterson, Martin Hoerling, Peter Stott, Stephanie Herring.



- Increase from 6 contributions last year to 19 this year
- 18 different research groups, 12 extreme events
- Some events have multiple different groups looking at them
- About half the analyses found some evidence that anthropogenic climate change was a contributing factor
- Natural climate variability a factor in all events

Event Attribution

- Compare probability of exceeding a threshold in the "world that is" (P1) and the "world that might have been" (P0)
- Climate models are needed to calculate P0 and P1
- Model verification is important
- For extreme temperature thresholds a robust signal of human influence is found for many regions
- For extreme precipitation thresholds there can be a complex interplay of dynamic and thermodynamic factors
- We need to understand both, and be confident models are correctly capturing their variability and changes



Human influence on the climate system is clear

- What is our vulnerability to extremes in a changing climate?
- Operational attribution systems can provide regular assessments of attributable risk of extreme events.
- Further development of models, observations and understanding is required.
- European project, EUCLEIA, aims to develop our ability to provide reliable attribution assessments for heatwaves, floods, droughts, cold spells and storm surges.
- International collaboration through the ACE (Attribution of Climate-related Events) group

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