The Hadley Centre System for Attribution of Extreme Events: Development, Applications and Future Directions

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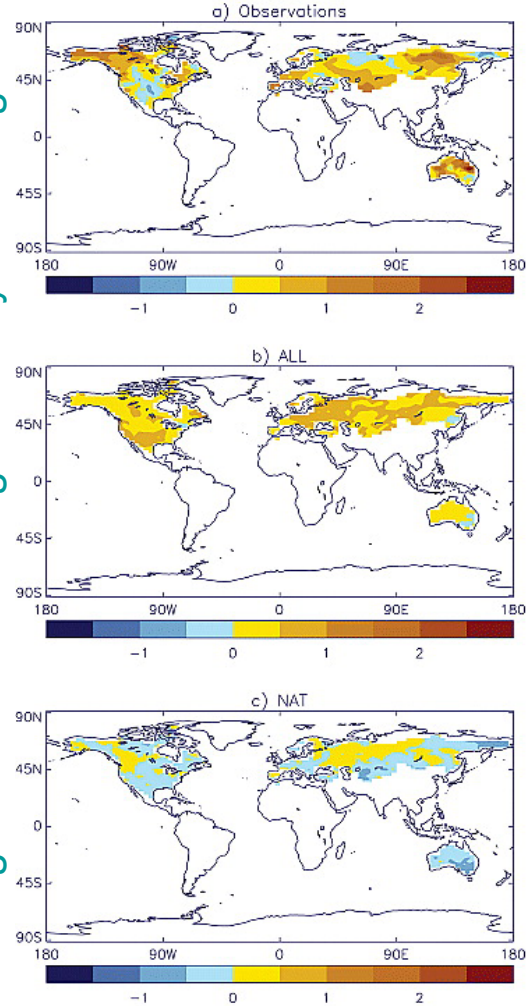
CLIVAR C20C Project 6th Workshop, Melbourne, 26 June 2013

From “Moderate” Extremes to High-Impact Extreme Events

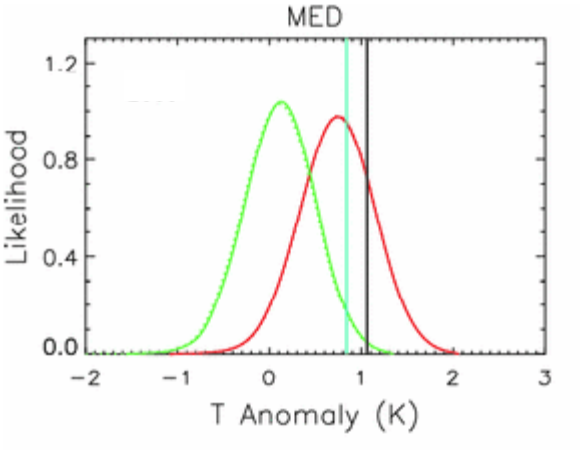
Met Office Hadley Centre

Quasi-Global

Change in the warmest night of the year during 1950-99

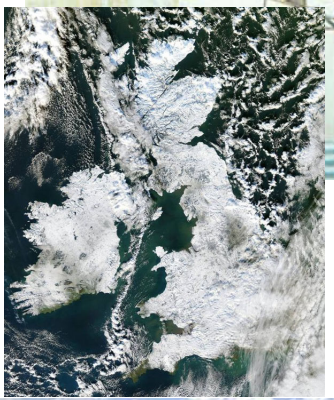


Regional



Change in the probability of having a warm year/season in a sub-continental region

Specific Events



Talk Outline

- Why do attribution of extreme events?
- Development of the Hadley Centre ACE system

  (ACE: Attribution of Climate-related Events)
- Examples of ACE studies
- What next?

What is the link between recent extreme weather events and climate change ?
Can we blame human-induced greenhouse gas emissions?
Do we need to adapt to a greater frequency of such events in future – or not ?

Pakistan flooding, 2010

Moscow heatwave, 2010

- It is possible to make attribution statements about individual events
- By calculating the odds of such events and the change in odds attributable to particular factors
- Mis-attribution, e.g. by blaming every extreme weather event on climate change, could lead to poor adaptation decisions

Australian floods, Jan 2011, Mar 2012

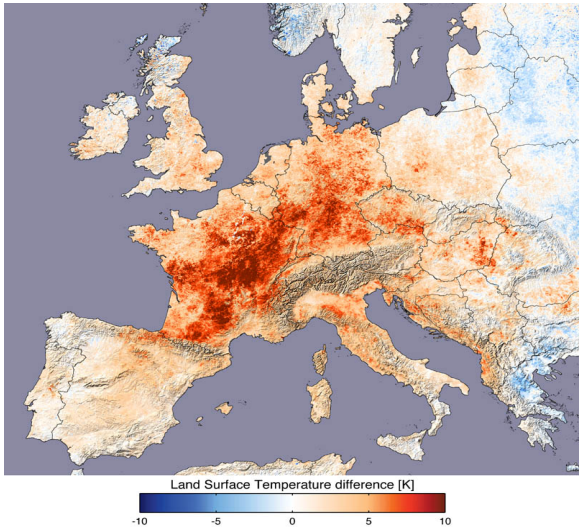
Cold winters, UK, 2009, 2010

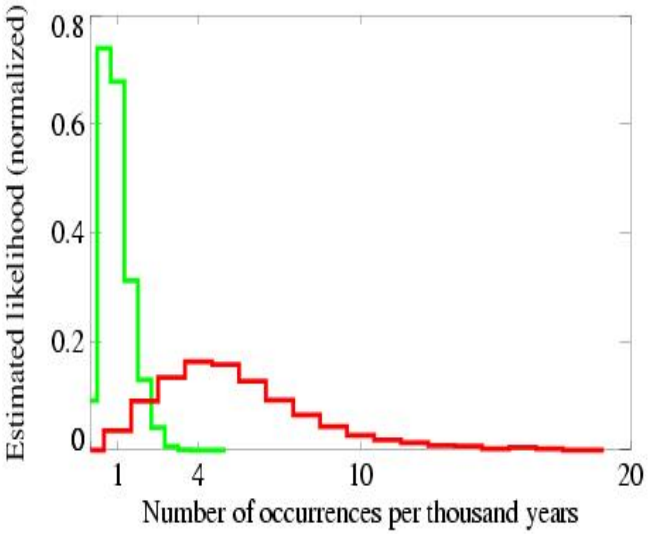
East African drought, 2011

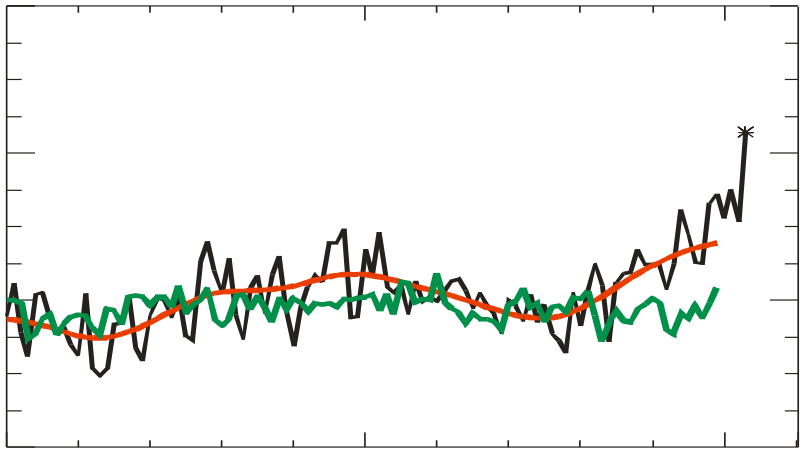
European Heatwave 2003: The first formal detection and attribution study that estimated the change in the frequency of a specific extreme event

Met Office Hadley Centre

“ Human influence has very likely at least doubled the risk of European summer temperatures as hot as 2003”
Stott et al, Nature, 2004

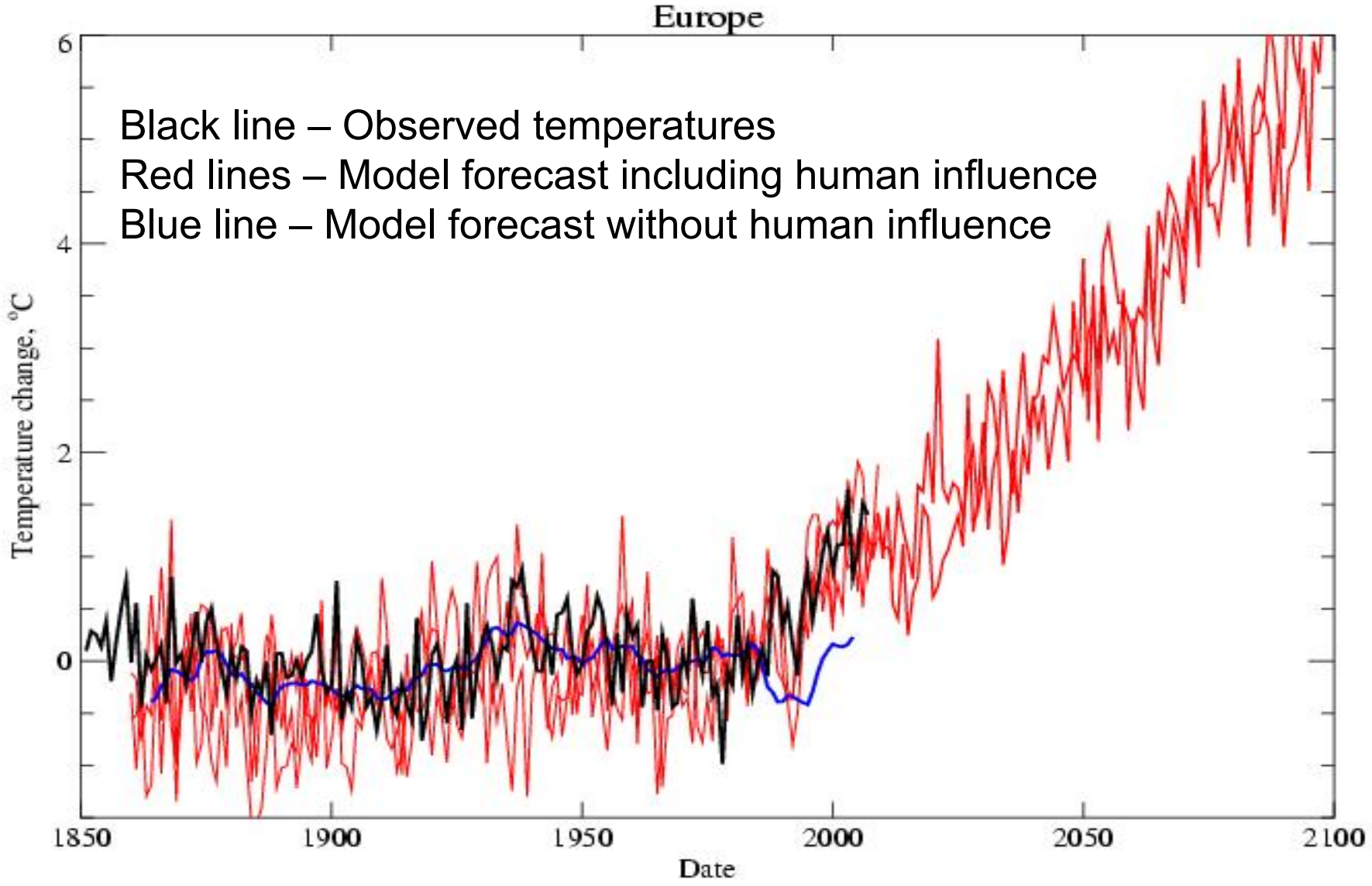






The estimated range of frequency of such a hot summer now is shown in red and compared with the frequency of such a hot summer in the world we would have had without human-induced climate change in green.

The European summers of 2003 and 2006 could be normal by 2040 and cool by 2060



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

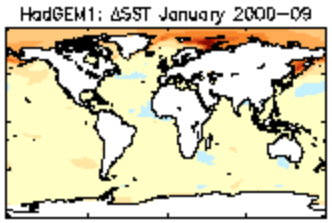
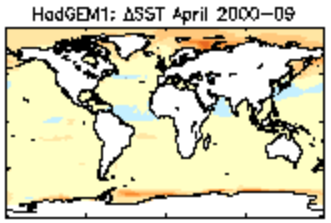
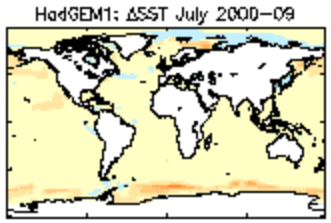
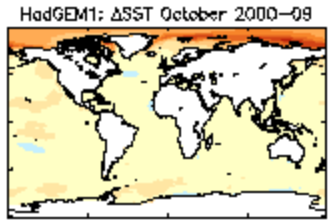
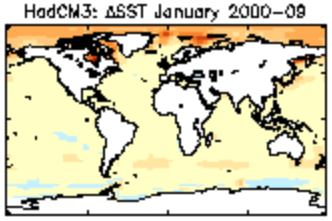
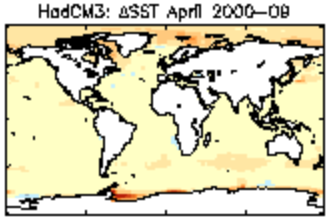
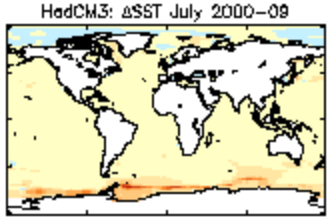
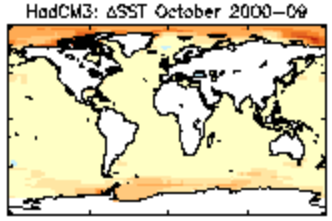
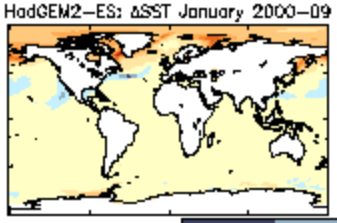
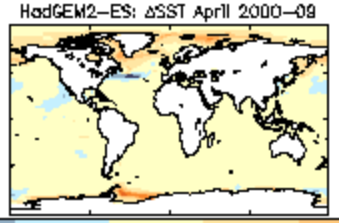
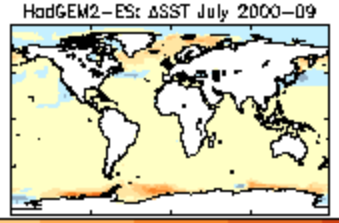
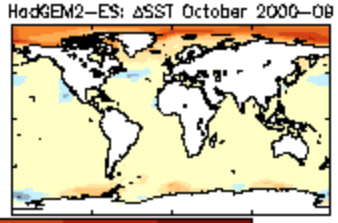
given certain modes of internal variability

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

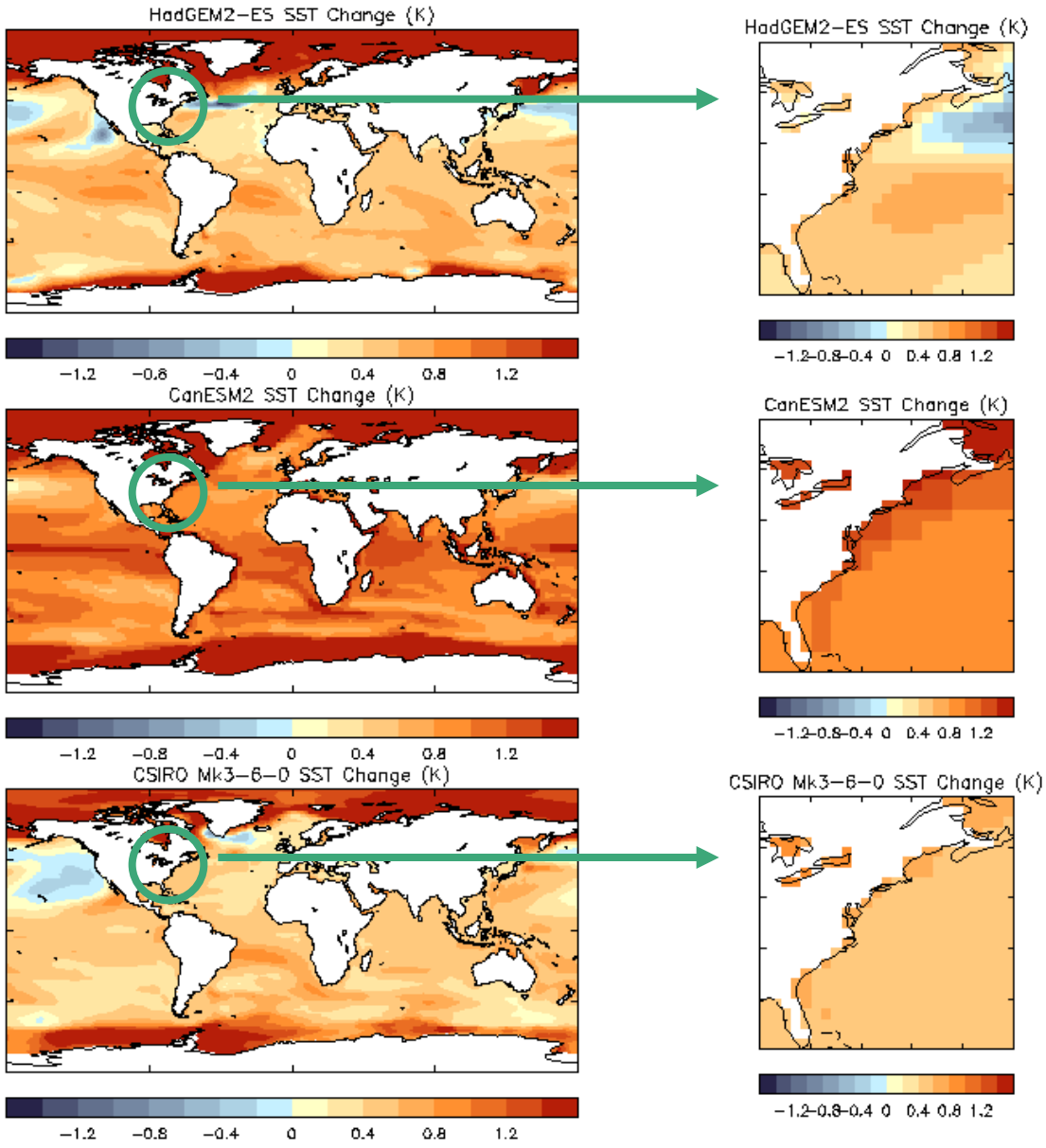
	January	April	July	October
HadGEM1				
HadCM3				
HadGEM2-ES				

Patterns of the change in the SST

HadGEM2-ES

CanESM2

CSIRO Mk3-6-0



Validation

1) Reliability Diagrams

HIGH TEMPERATURE FORECAST

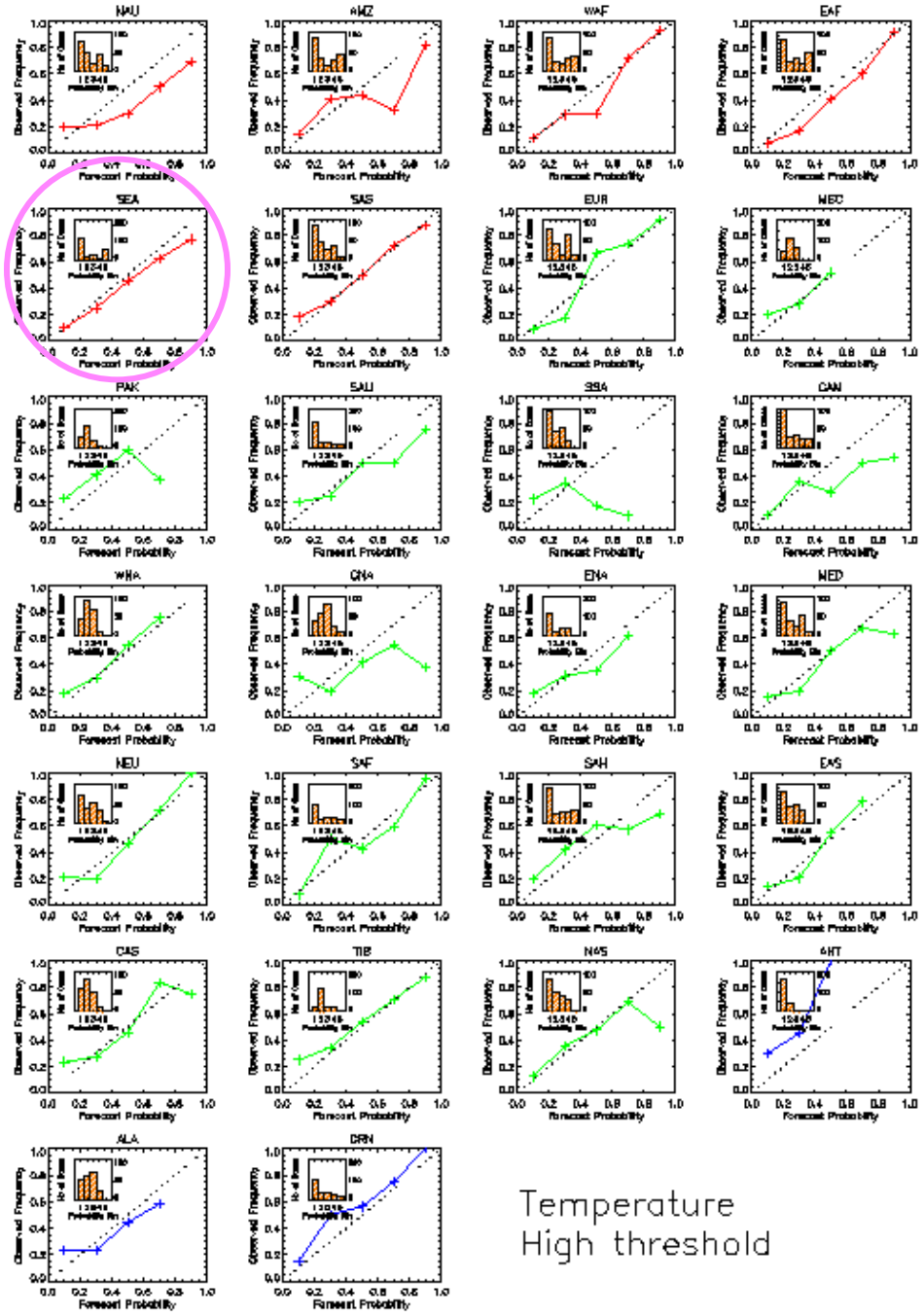
Event: Seasonal Temperature greater than the 1971-2000 climatology upper tercile

Red Lines: Tropical Regions

Green Lines: Extra-tropical Regions

Blue Lines: Polar Regions

Reliability diagrams based on 5 runs (1960-2010) with ALL forcings

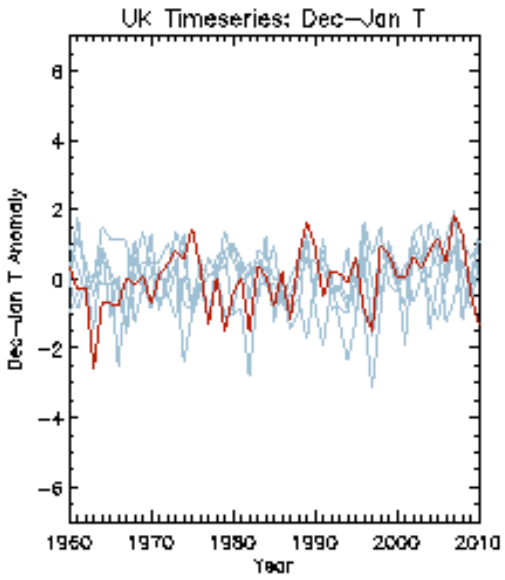


Temperature
High threshold

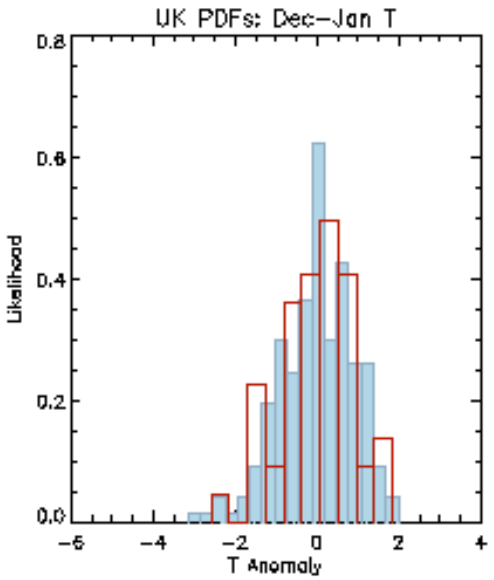
Validation

Dec-Jan UK Temperature

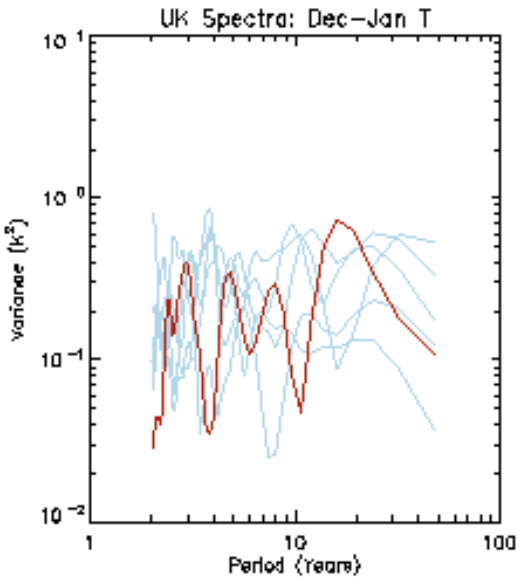
1960-2010 Timeseries



Distributions



Power Spectrum



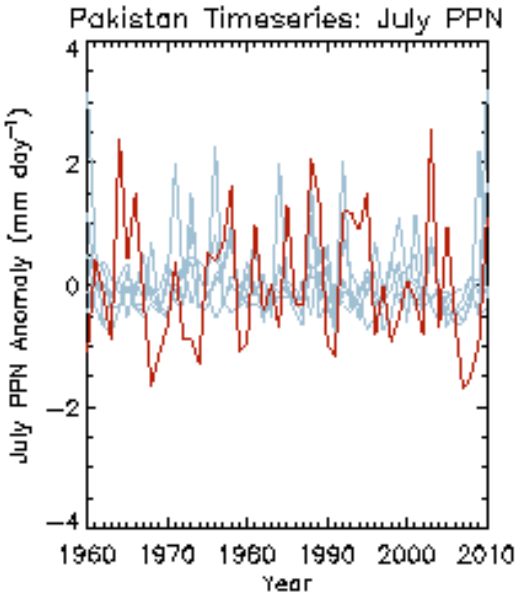
Red Lines: NCEP/NCAR Reanalysis

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

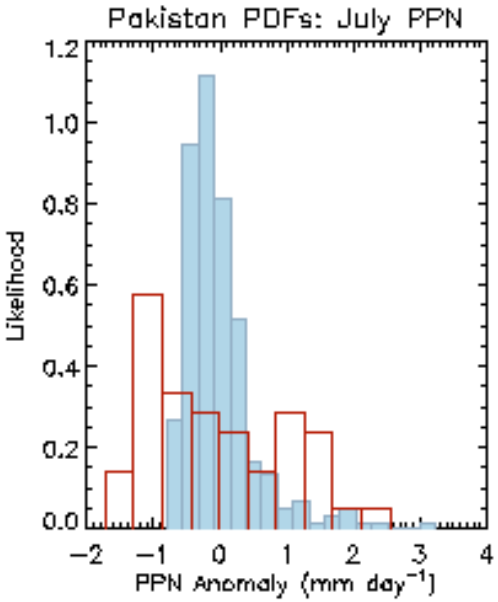
Validation

July Rainfall in Pakistan

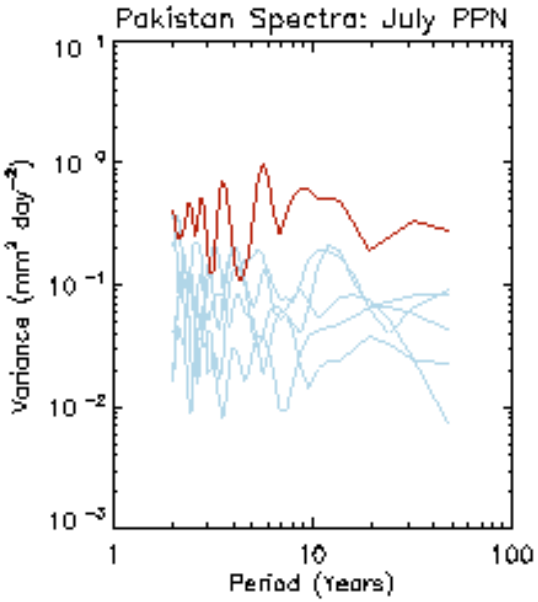
1960-2010 Timeseries



Distributions



Power Spectrum



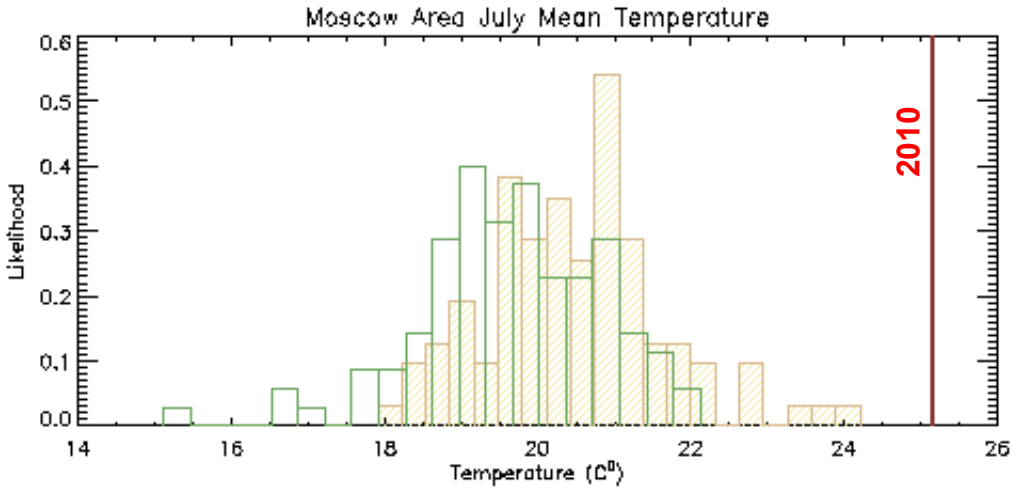
Red Lines: NCEP/NCAR Reanalysis

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

Moscow Hot July 2010

Distribution of the July Temperature in Moscow

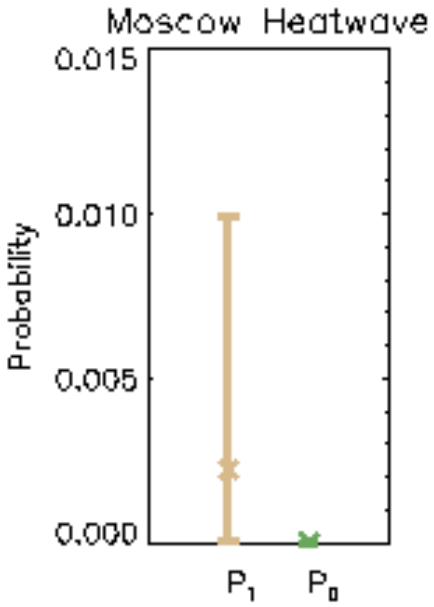
ALL & NAT



Probability of getting higher temperatures than observed in 2010

P_0: with NAT forcings

P_1: with ALL forcings



As $P_0 \longrightarrow 0$

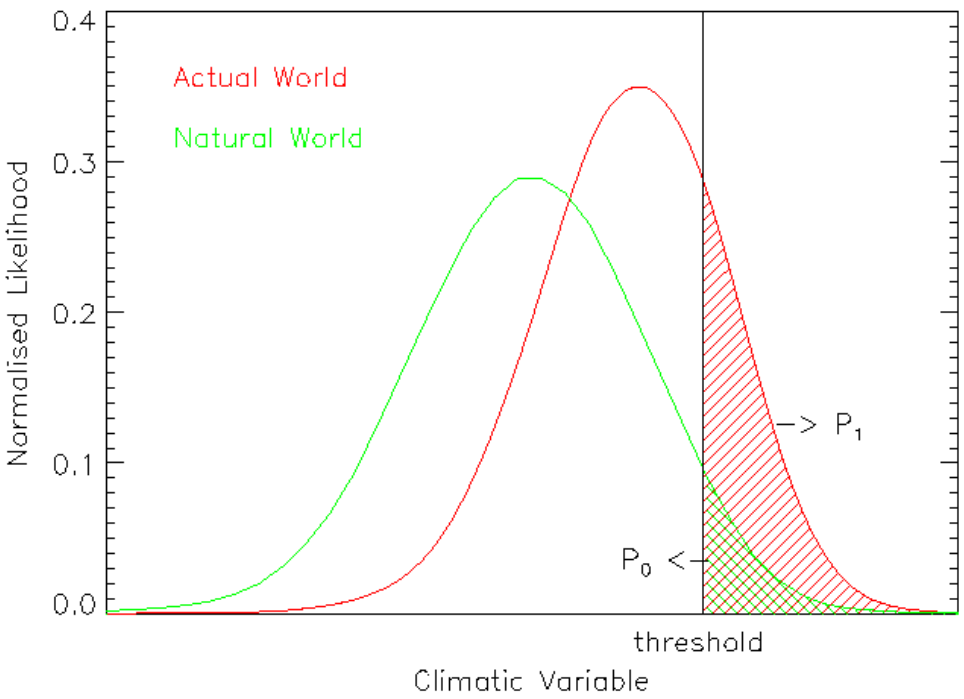
the FAR=1-P_0/P_1 saturates to 1

(i.e. the 2010 temperature is only exceeded in the climate with ALL forcings)

Christidis et al., 2013, *J. Climate*

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 a "natural world" (no anthropogenic forcings).

P_1: Probablity of exceeding a threshold in the real world.

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

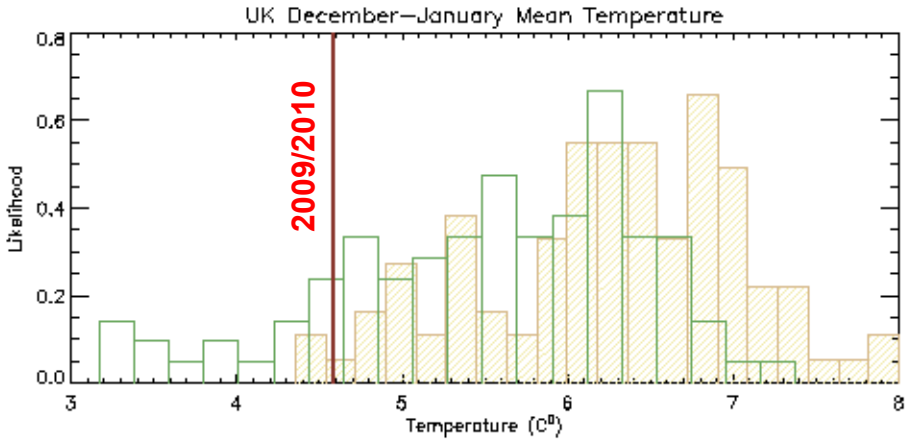
FAR ~ 1 Threshold exceeded only in the actual world

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

UK Cold Dec 2009 - Jan 2010

Distribution of the UK Dec/Jan Temperature

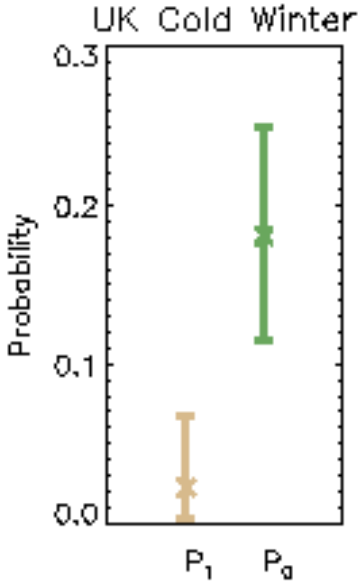
ALL & NAT



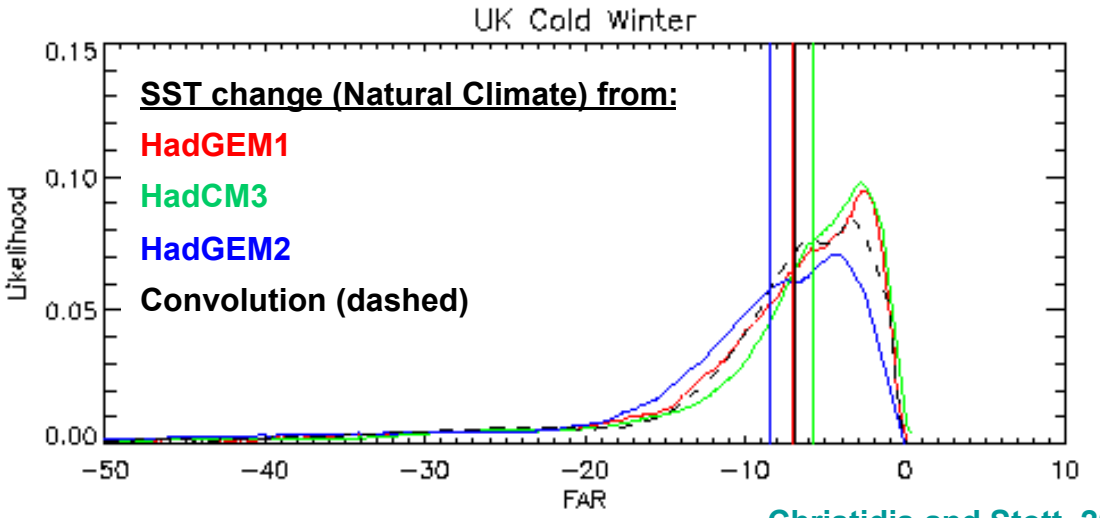
Probability of getting temperatures colder than observed in 2009/2010

P_0: with NAT forcings

P_1: with ALL forcings



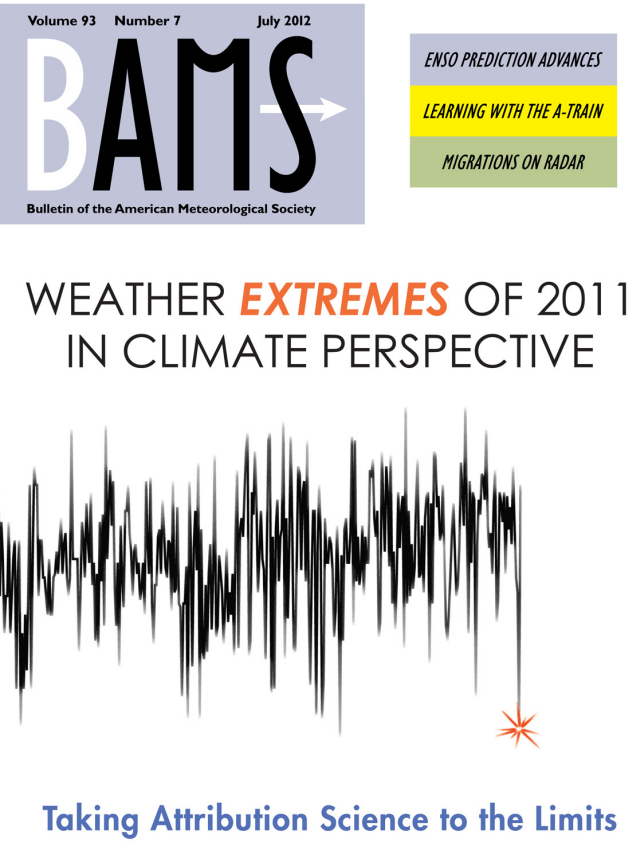
Distribution of the FAR, FAR = 1 - (P_0 / P_1)

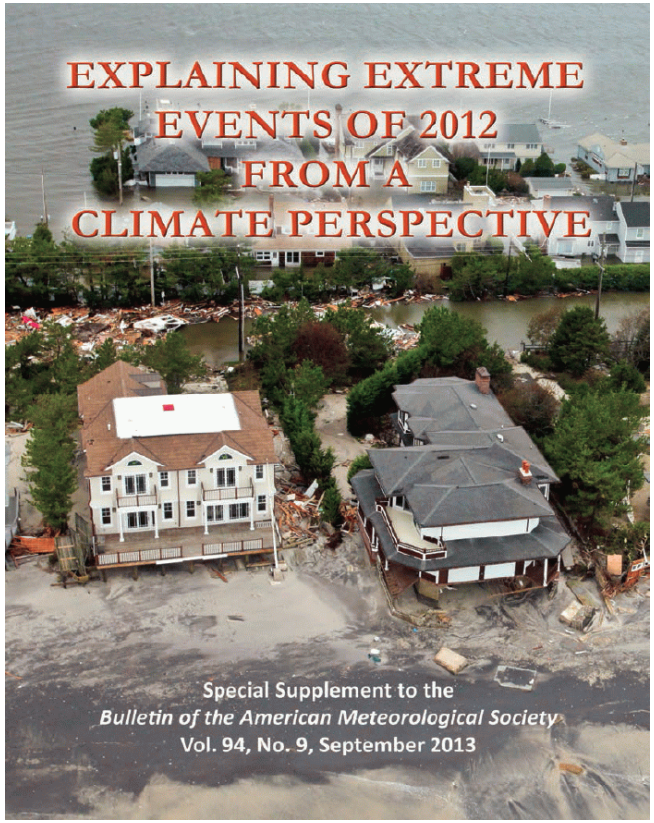


Christidis and Stott, 2012, *BAMS*

Explaining extreme events from a climate perspective

The 1st BAMS attribution supplement on Explaining Extreme Events of 2011 was the most read paper of the last year on the BAMS website





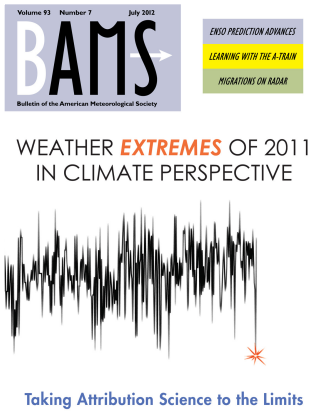
A goal of this paper is to foster the growth of the science

- Cannot say a particular event was or was not caused by climate change

but…

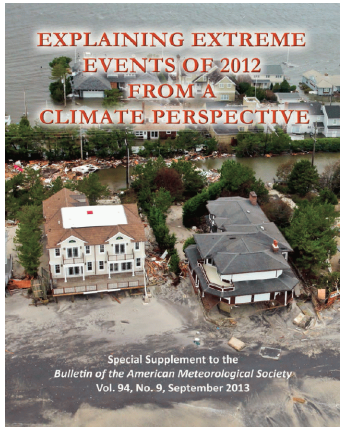
- Can explain how the odds of such events have changed in response to global warming

Explaining extreme events from a climate perspective



Extremes of 2011

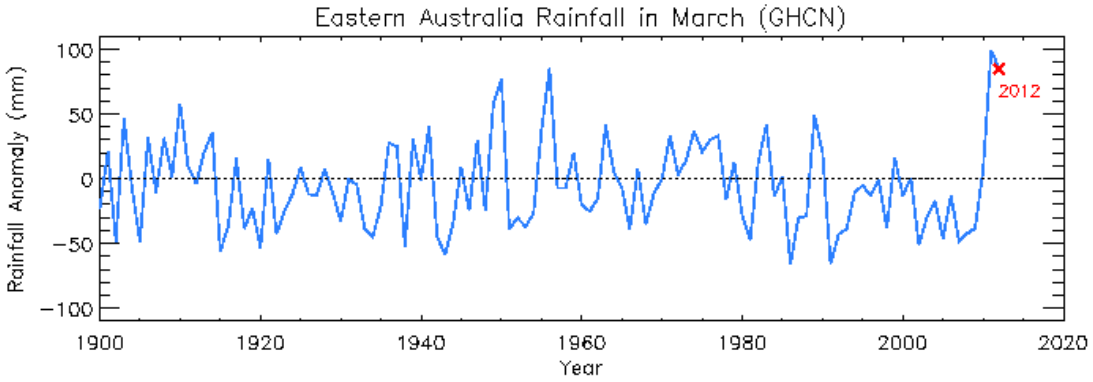
- 6 Analyses
- 6 Events
- 3 studies found evidence that anthropogenic climate change changes the odds of the event



Extremes of 2012

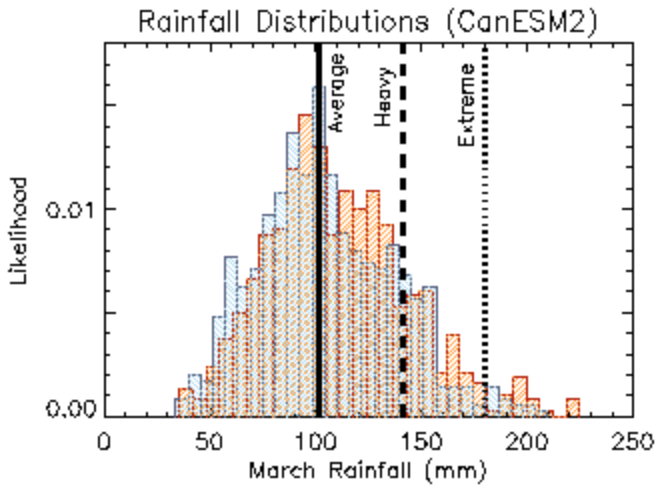
- 19 Analyses
- 12 Events
- 10 studies found evidence that anthropogenic climate change changes the odds of the event

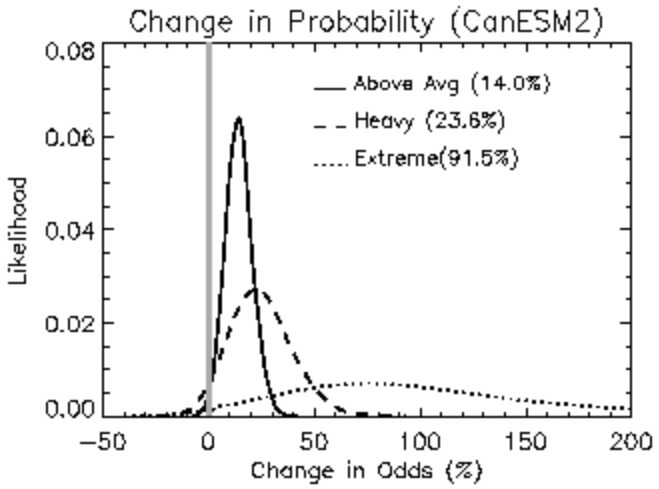
Heavy Rainfall over Eastern Australia in March 2012



March Rainfall Distribution

ALL & NAT





ACE Experiments:

600 member ensembles with and without the effect of human influences

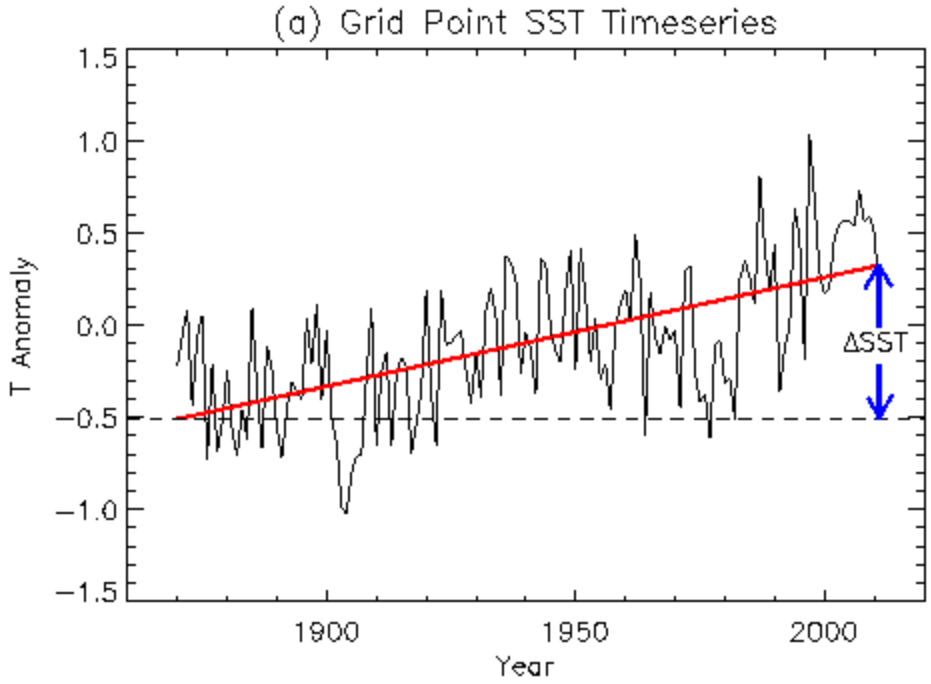
Christidis et al., 2013, *BAMS*

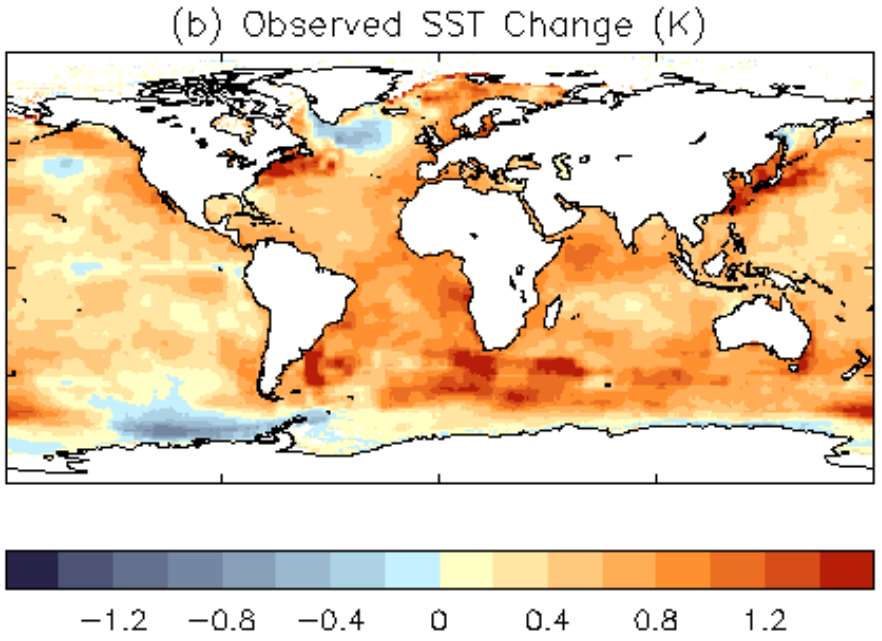
Patterns of the change in the SST

Estimate of the anthropogenic change in the SST

The effect of natural forcings and low frequency variability is assumed to be small

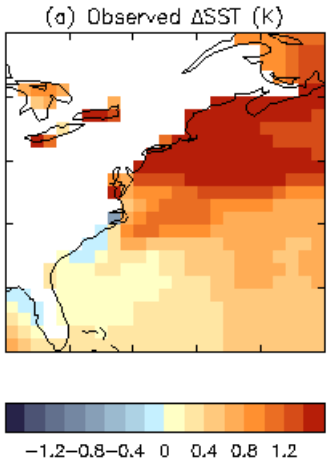
SST timeseries (HadISST data 1870-present day) for a grid-point in the tropical Atlantic



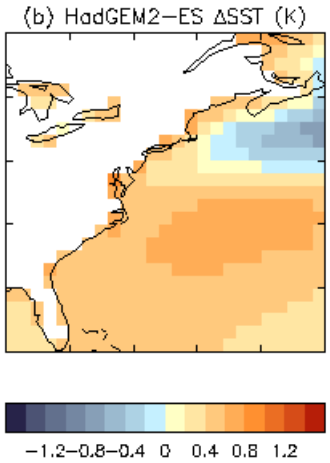


Patterns of the change in the SST

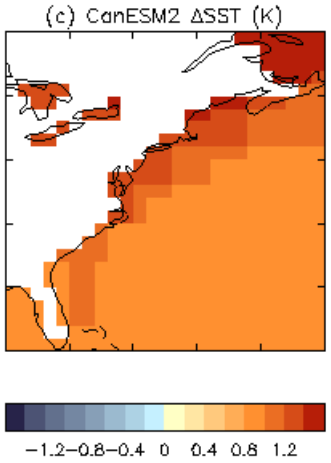
HadISST



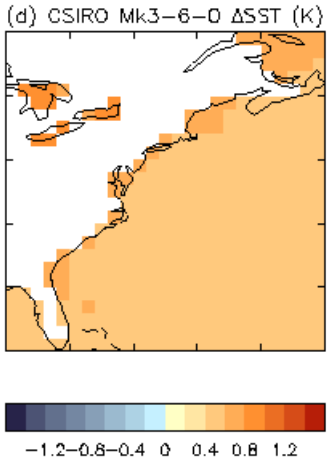
HadGEM2-ES

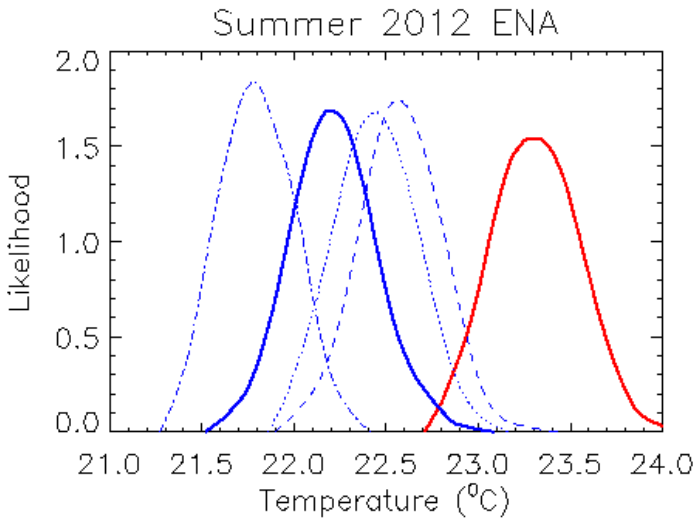


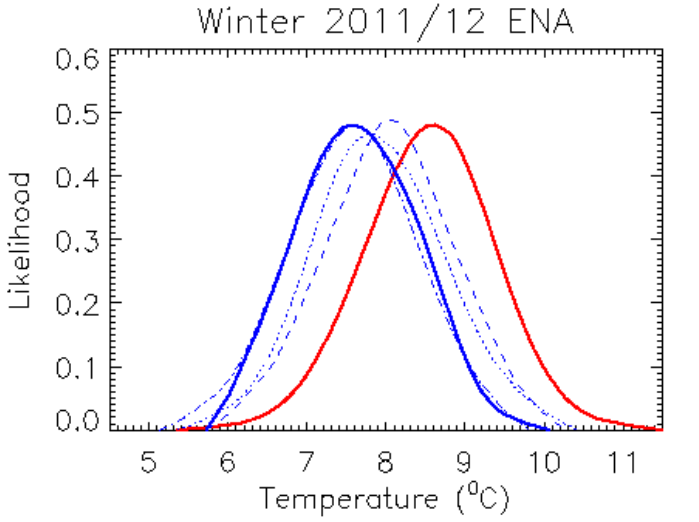
CanESM2



CSIRO Mk3-6-0







Further developments

- Upgrade of the Met Office ACE system. A paper introducing the system was published in J. Climate, 2012.
- Model Evaluation
- Continue to contribute to the BAMS attribution supplement on Explaining Extreme Events from a climate perspective
- ACE group
  - Has identified important science challenges
  - Identified stakeholder groups who are very interested
  - ACE activity now endorsed by World Climate Research Program (WCRP) under **Prediction and Attribution of Extreme Events : A WCRP Grand Science Challenge**
- C20C: Generate long simulations to look at events over a long period
- EUCLEIA bid to EU FP7 : “European Climate and weather Events: Interpretation and Attribution”

EUCLEIA

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

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

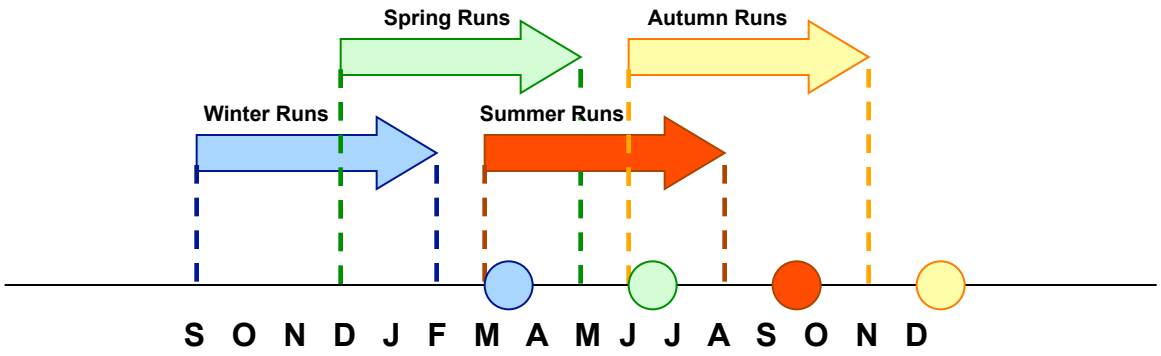
EUCLEIA

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

Met Office Hadley Centre

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

Summary

- Attribution of extremes is an active area of research. A new ACE system has been developed in the Hadley Centre and has already been used to study a number of high-impact events.
- Changes in the odds of extremes due to anthropogenic forcings have been identified in several cases. However, natural variability plays an important role.
- In the future ACE systems need to be integrated into an operational framework to provide timely assessments soon after an event occurs.

Met Office
Hadley Centre

Any questions?