# Attribution of Extreme Events with the HadGEM3-A model

Nikos Christidis, Peter A Stott, Andrew Ciavarella, Gareth S Jones, Fraser Lott

Attribution of Weather and Climate Extremes Workshop, NOAA, Boulder CO, 11 September 2014

# Talk Outline

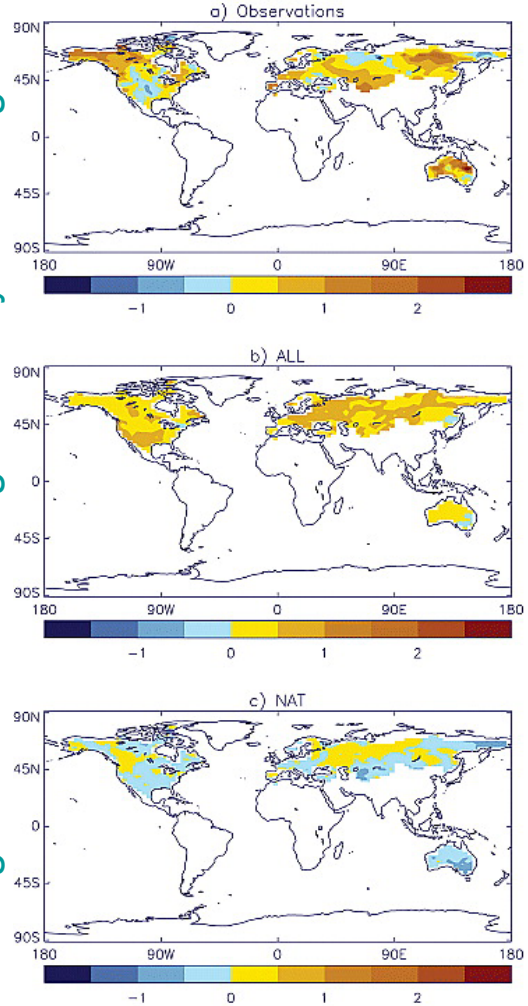
- The HadGEM3-A system for attribution of extremes
  - Description of the system
  - Model evaluation
  - ACE studies
  - Sensitivity to boundary conditions
- EUCLEIA
- ACE work with CMIP5 models
- Final points

# From “Moderate” Extremes to High-Impact Extreme Events

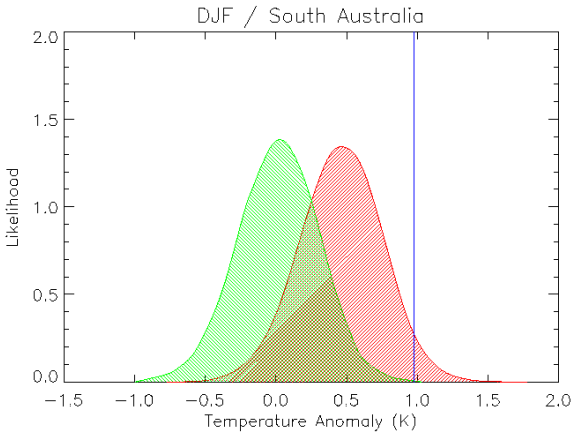
Met Office Hadley Centre

## 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

# 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 ?

Moscow heatwave, July 2010

Central Europe floods, June 2013

- 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

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

## AGCM 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.

## Hadley Centre near-real time attribution system

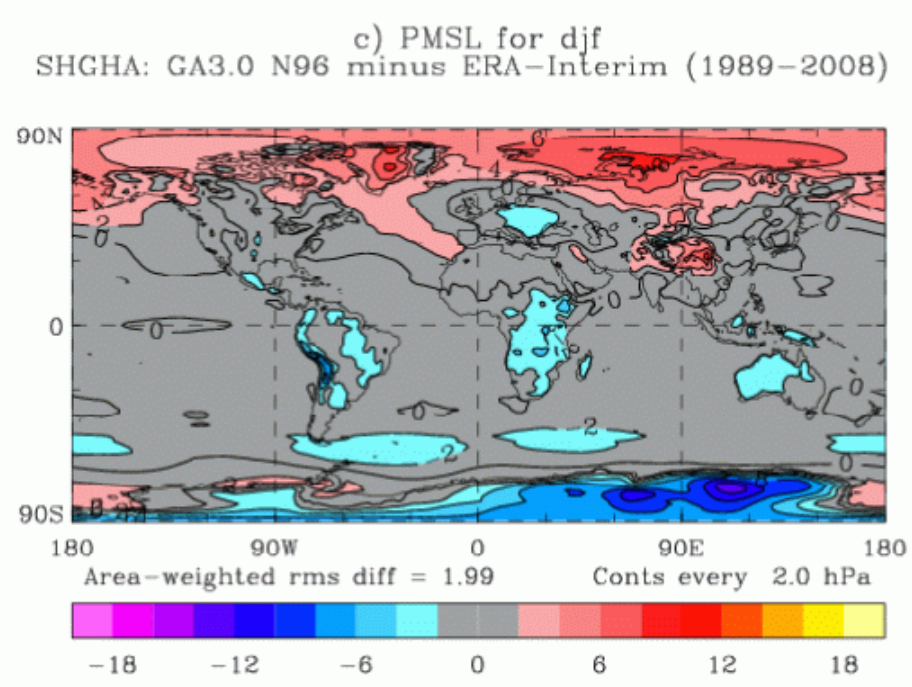
HadGEM3-A, N96 L38, N216 L85 (high res) ~135km ⇨ ~60km

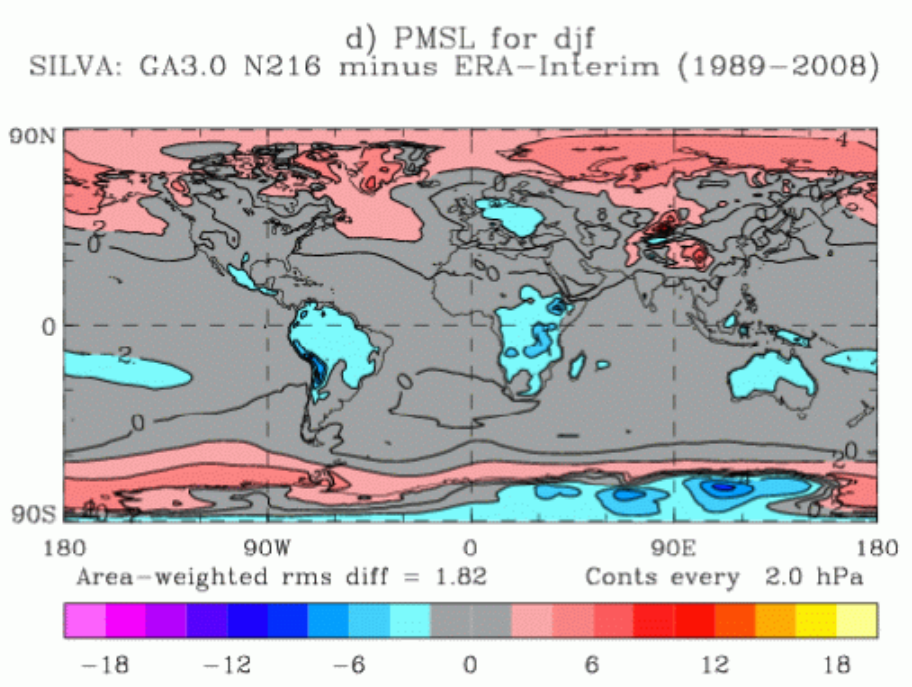
```
HadGEM3-A version 8.5:

ENDGame dynamical core and GA6.0 / GC2 compatibility

JULES land-surface package
```

# The HadGEM3-A system

**Hadley Centre near-real time attribution system**

**High resolution:** HadGEM3-A, N216 L85 (~60 km)




(Plot by Dan Copsey)

# Model evaluation

## Is the model fit for purpose?

Long HadGEM3-A simulations for model evaluation

**N96L38:** 5 runs with ALL forcings (1960-2010)
**N216L85:** 15 runs with ALL forcings (1960-2014)
15 runs with NAT forcings (1960-2014)

- Processes & mechanisms. Synoptic patterns.
- Reliability diagrams.
- Statistics of extremes.

# Model evaluation

## Reliability Diagrams

**HIGH TEMPERATURE FORECAST**

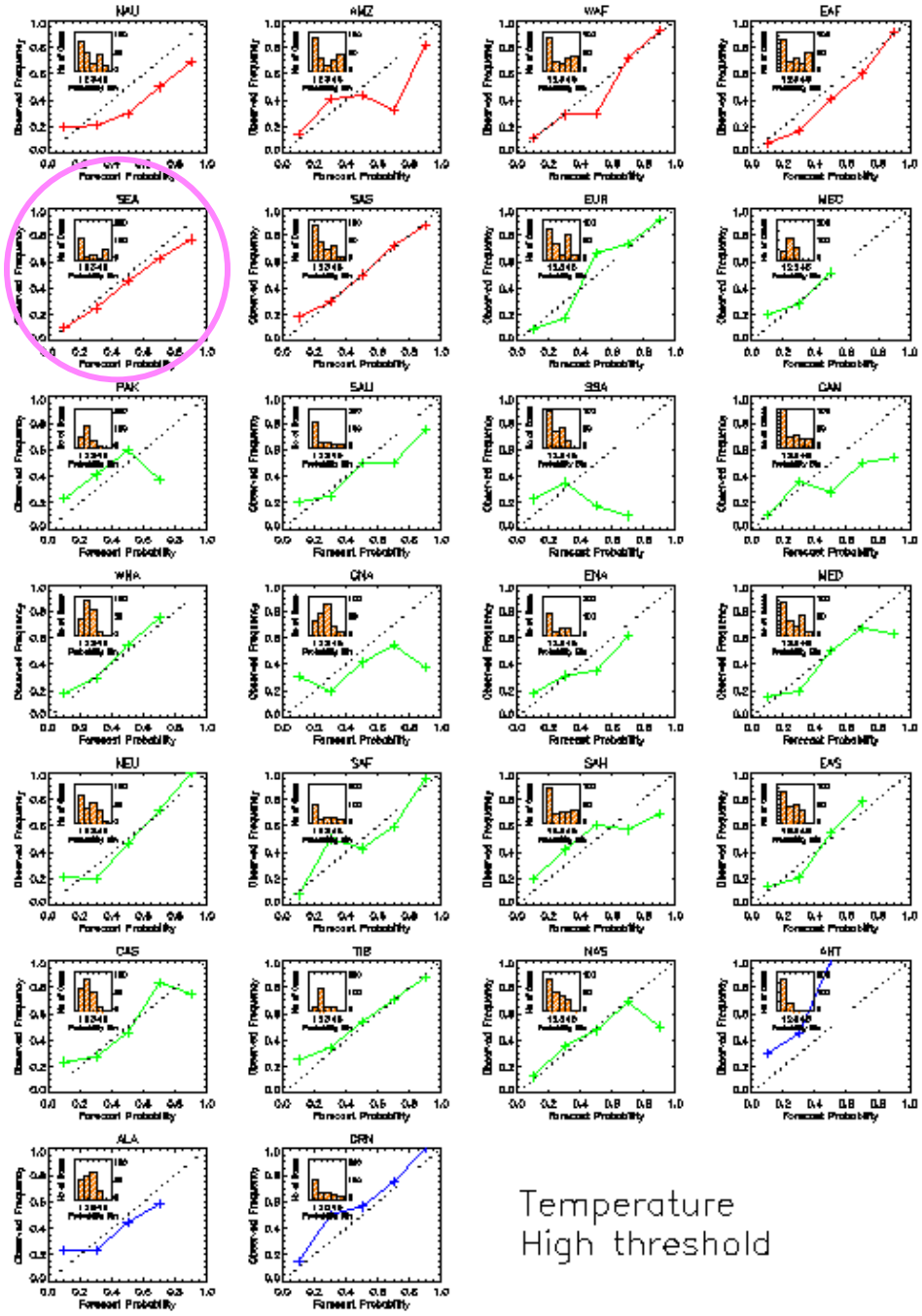
**Event: Seasonal Temperature greater than the 1971-2000 climatology upper tercile**

**Red Lines: Tropical Regions**

**Green Lines: Extra-tropical Regions**

**Blue Lines: Polar Regions**

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

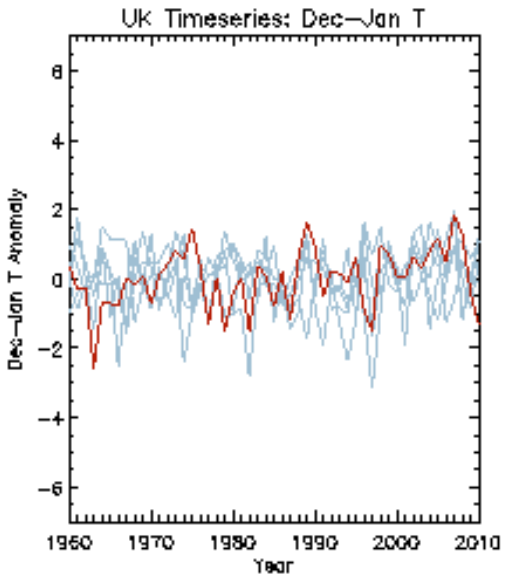



Temperature
High threshold

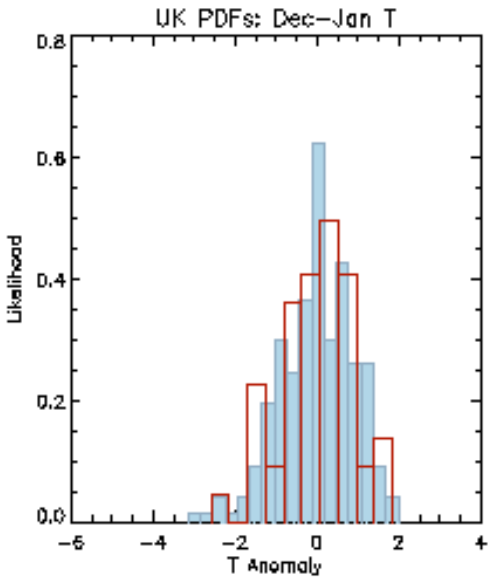
# Model evaluation

## Dec-Jan UK Temperature

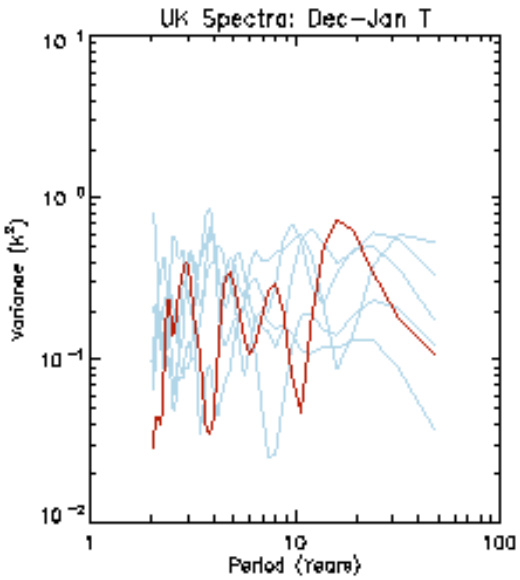
### 1960-2010 Timeseries




### Distributions




### Power Spectrum



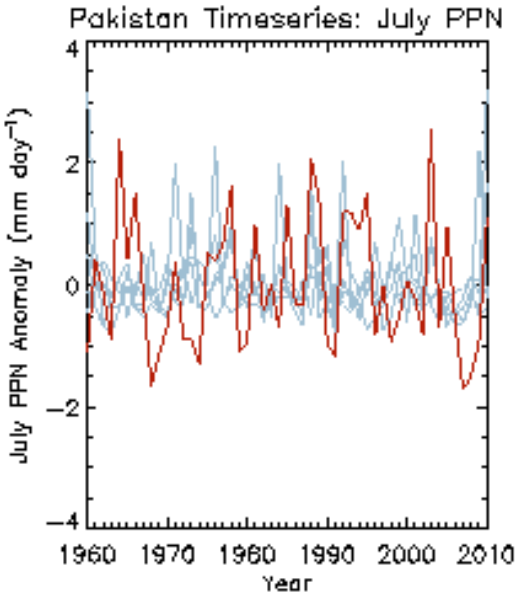

Red Lines: NCEP/NCAR Reanalysis

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

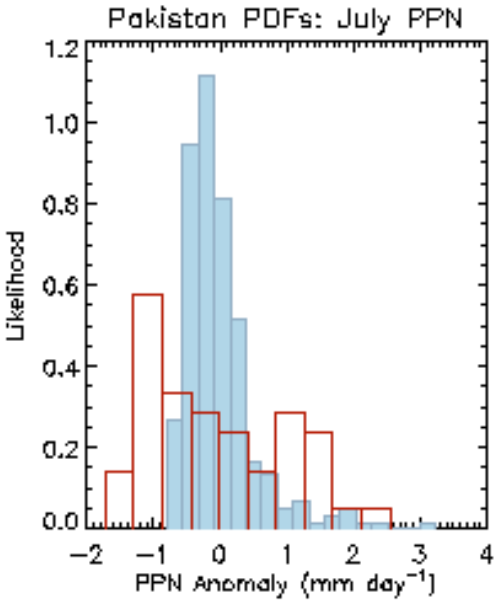
# Validation

## July Rainfall in Pakistan

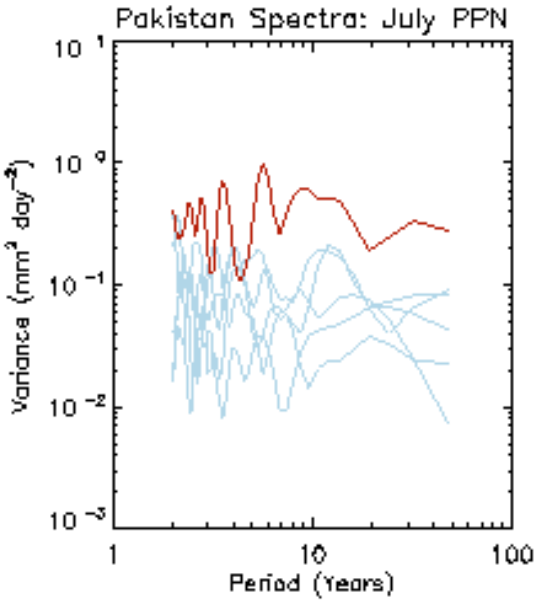
### 1960-2010 Timeseries




### Distributions




### Power Spectrum




Red Lines: NCEP/NCAR Reanalysis

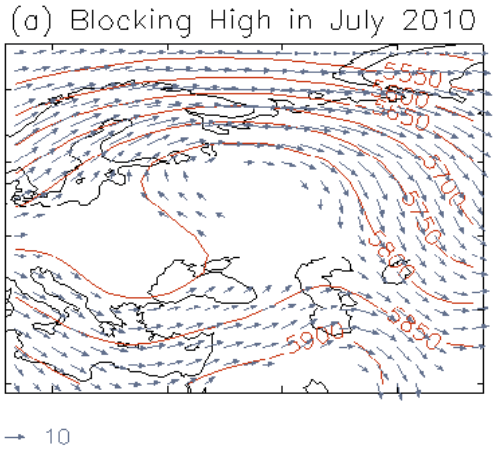
Black Lines: 5 Model runs with ALL forcings and observed SSTs & SI

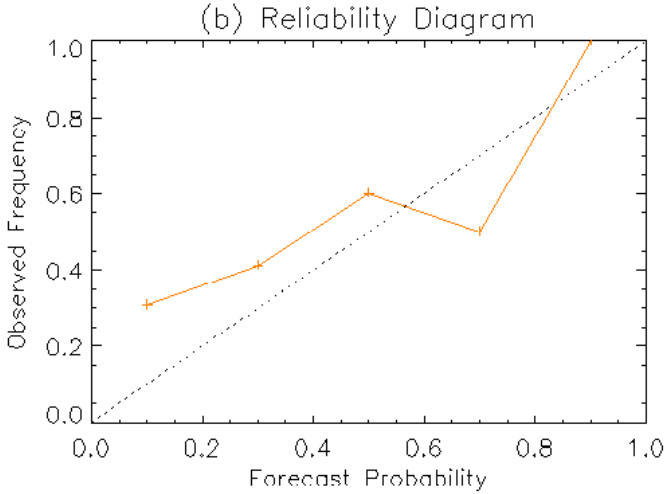
# An ACE Study of the Hot July in Moscow in Year 2010

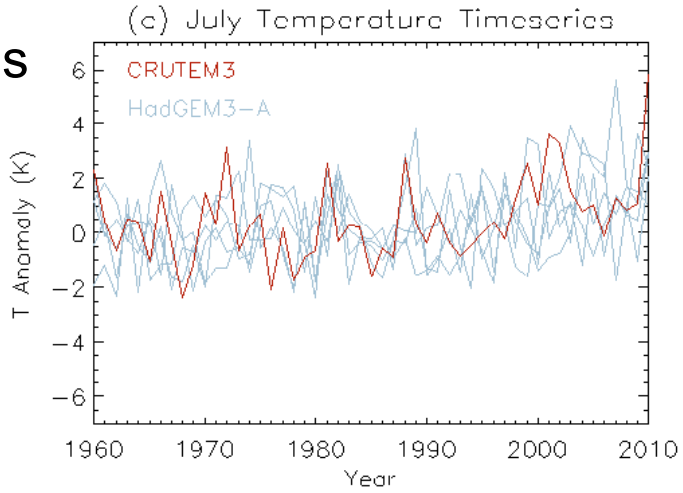
**ACE Ensembles**

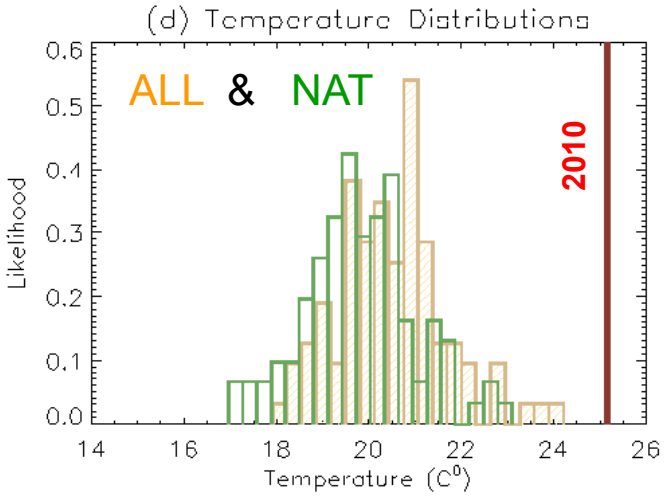
**ALL**:
100 simulations

**NAT**:
100 simulations





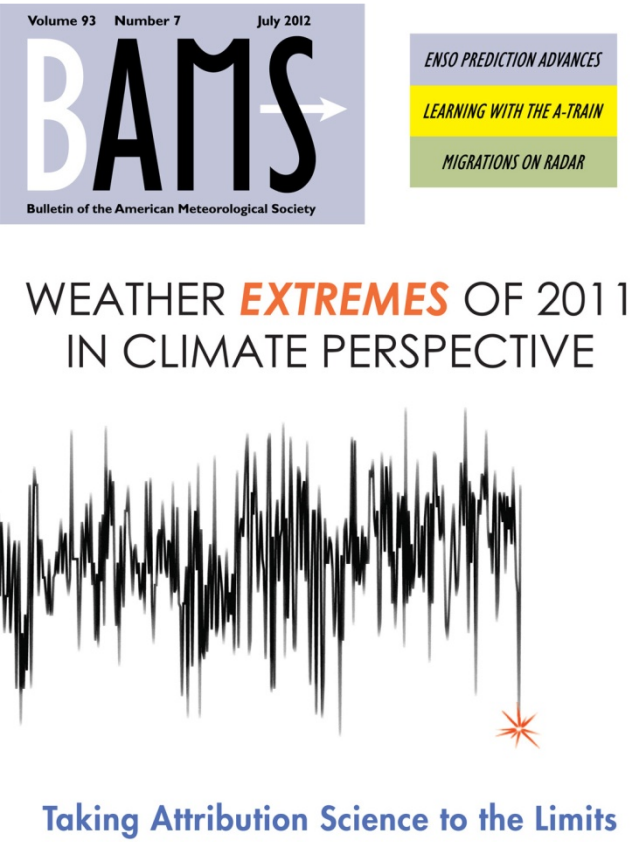

Christidis et al., 2013, *J. Climate*

# ACE studies with the HadGEM3-A system

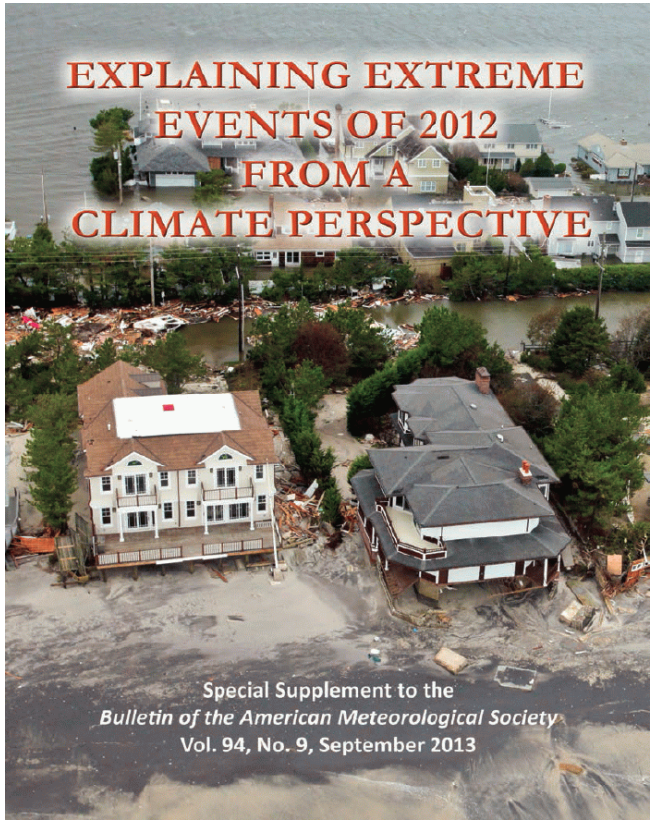
| Event | Anthropogenic Influence | Reference |
|---|---|---|
| Cold UK Dec 2009 – Jan 2010 | Chances decrease 2-90 times | Christidis et al., 2013 (J Clim) |
| Moscow heatwave 2010 | Unlikely without human effect | Christidis et al. 2013 (J Clim) |
| Cold UK Dec 2010 – Jan 2011 | Chances decrease 1.2-4 times | BAMS report, 2012 |
| East African drought 2011 | Long rain season rainfall decrease (FAR > 0.2) | Lott et al., 2013 |
| Eastern Australia floods 2012 | Chances of heavy rainfall increase by 4-25% | BAMS report, 2013 |
| Cold UK spring 2013 | Odds of a cold spring decrease by 30-50 times | BAMS report , 2014 |

# Explaining extreme events from a climate perspective

The 1st BAMS attribution supplement was the most read paper on the BAMS website




The editors of the 2nd BAMS report were selected as Leading Global Thinkers by *Foreign Policy*



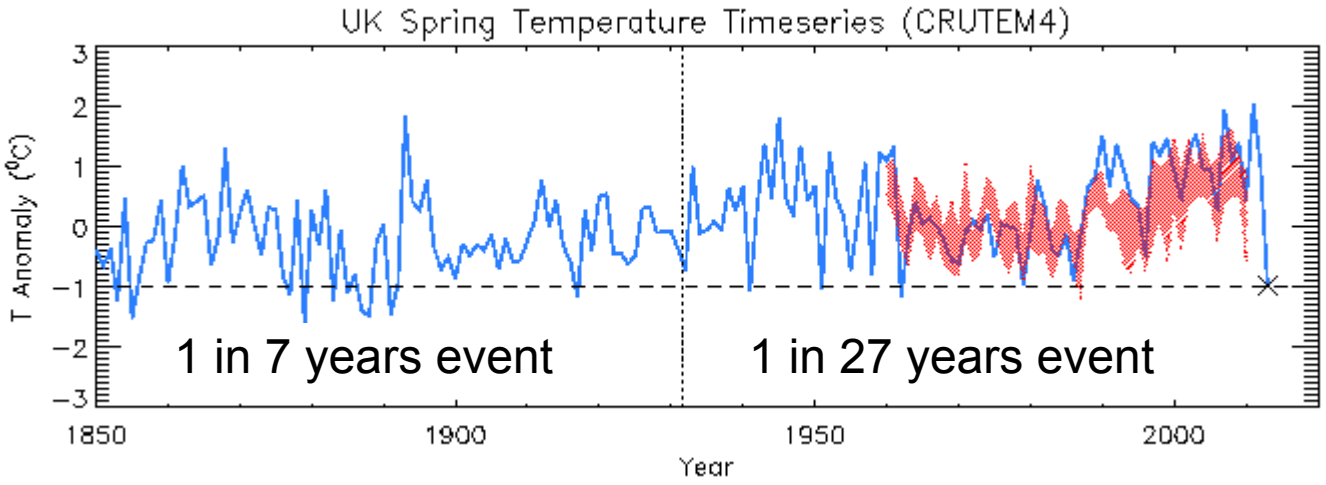

A goal of this paper is to foster the growth of the science

- 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

# The cold spring of 2013 in the UK




## IMPACTS:

- Newborn lambs killed in snowdrifts

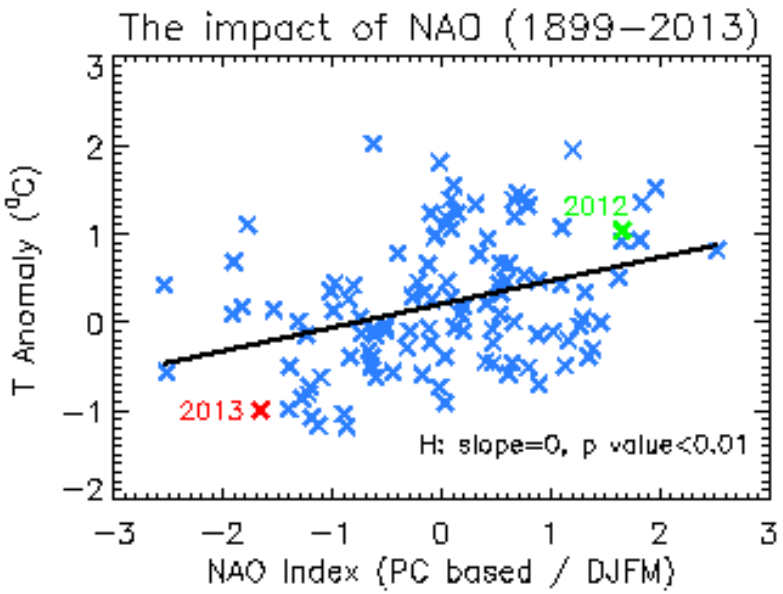
  UK Government paid £250,000 in reimbursements
- Frozen soil stunted the growth of crops
- Damage of the power and electricity network infrastructure



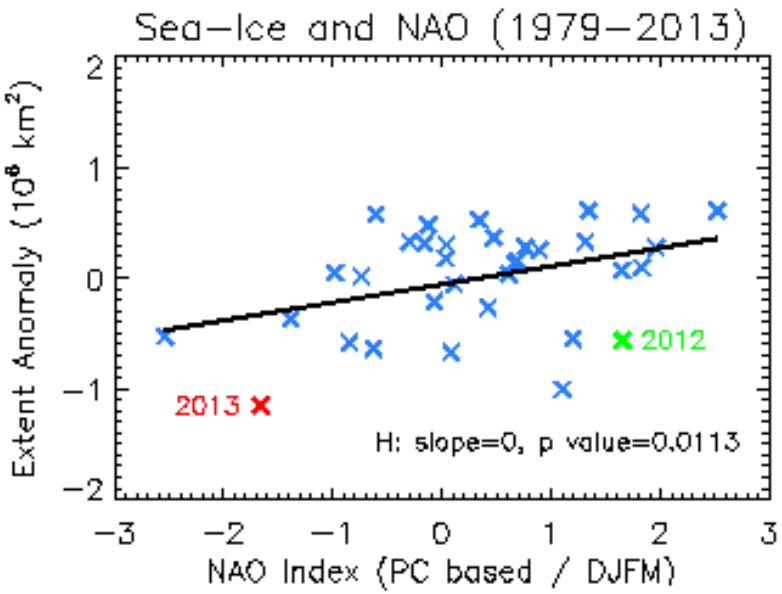
Christidis et al. 2014, *BAMS*

# The cold spring of 2013 in the UK

## North Atlantic Oscillation



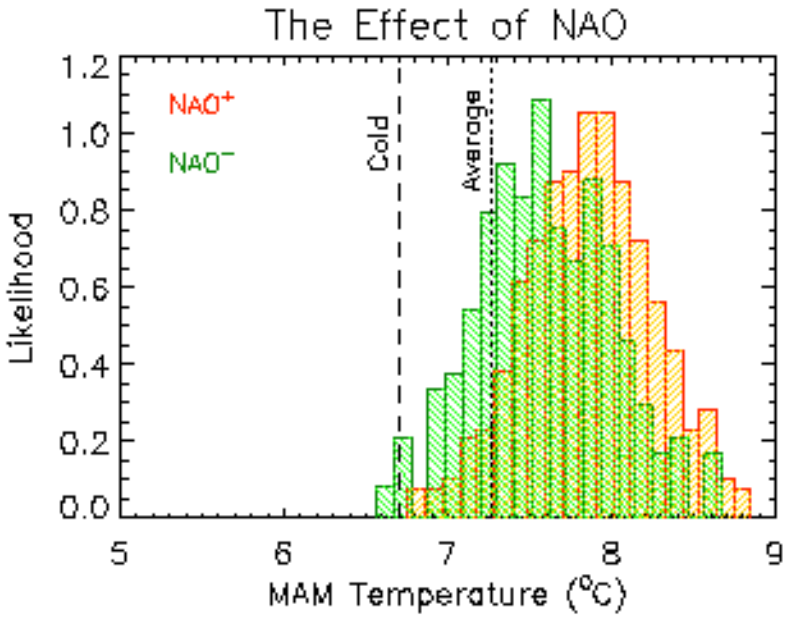

## Sea-Ice and NAO

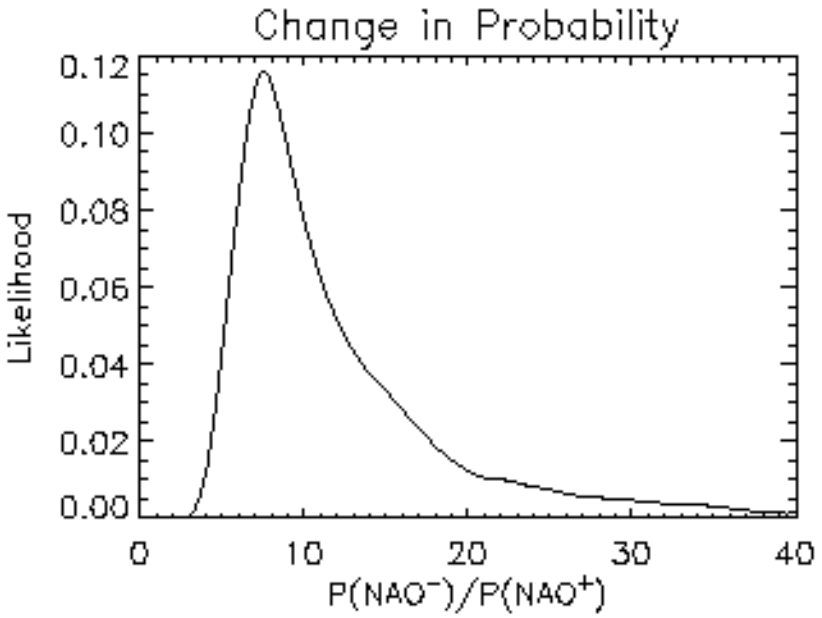





Christidis et al. 2014, *BAMS*

# The cold spring of 2013 in the UK



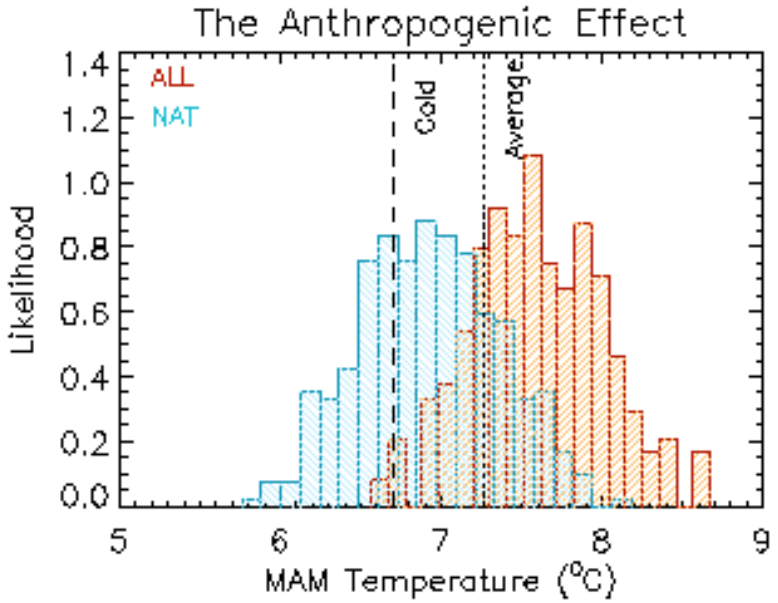

## ACE Analysis

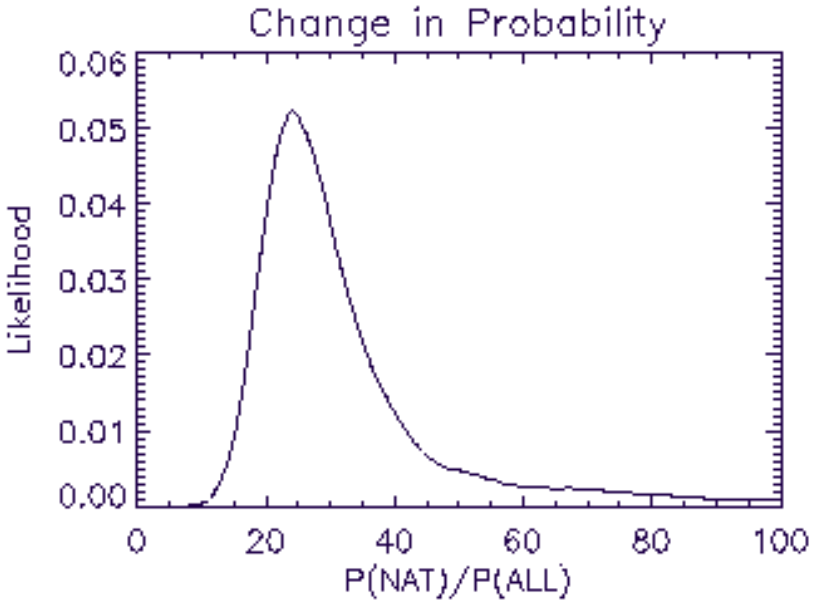
- 600 simulations with **ALL** forcings → positive NAO
- 600 simulations with **NAT** forcings → negative NAO



Christidis et al. 2014, *BAMS*

# The cold spring of 2013 in the UK




## ACE Analysis

- 600 simulations with **ALL** forcings → negative NAO
- 600 simulations with **NAT** forcings → negative NAO



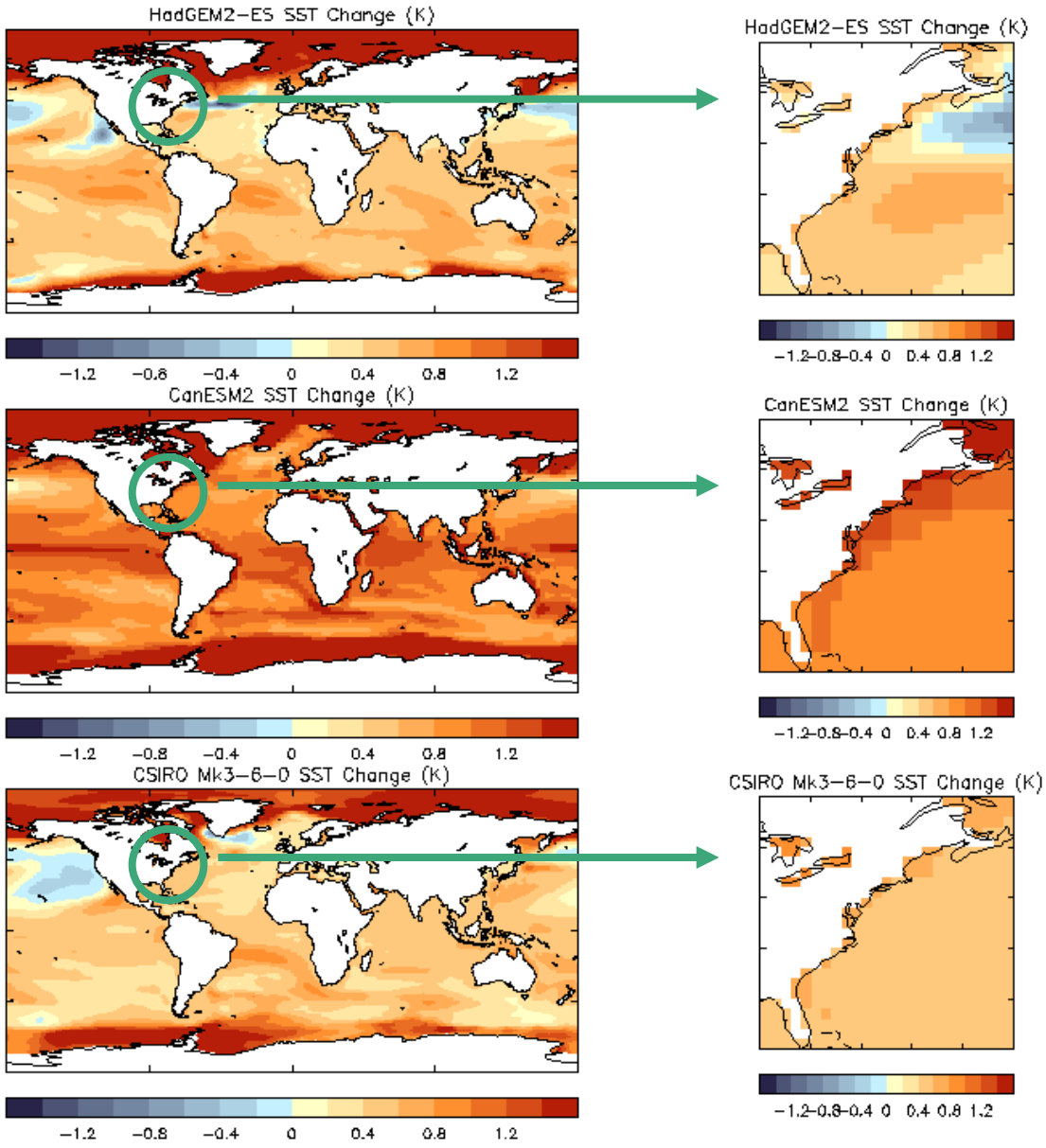
Christidis et al. 2014, *BAMS*

# Patterns of the change in the SST

**HadGEM2-ES**

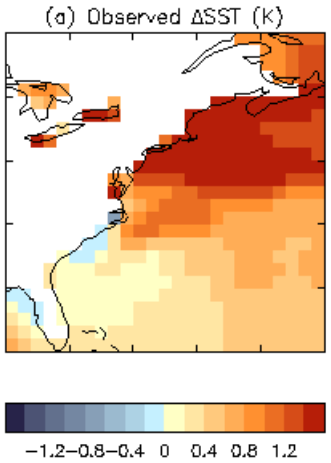
**CanESM2**

**CSIRO Mk3-6-0**

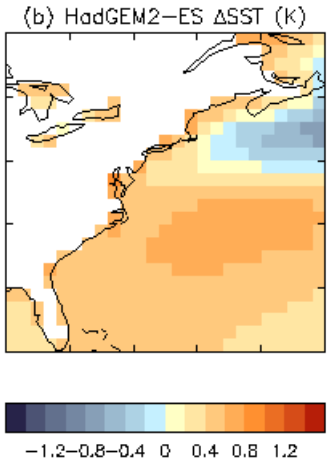


# Patterns of the change in the SST

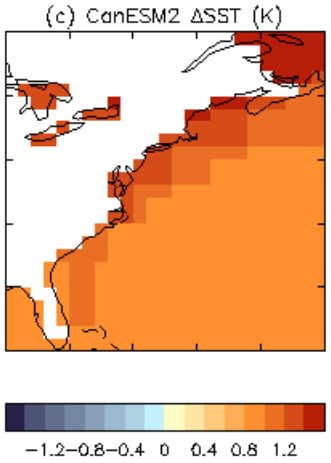
**HadISST**



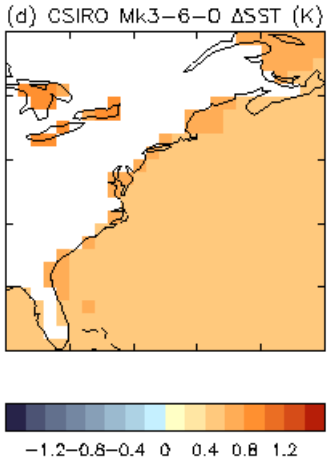

**HadGEM2-ES**

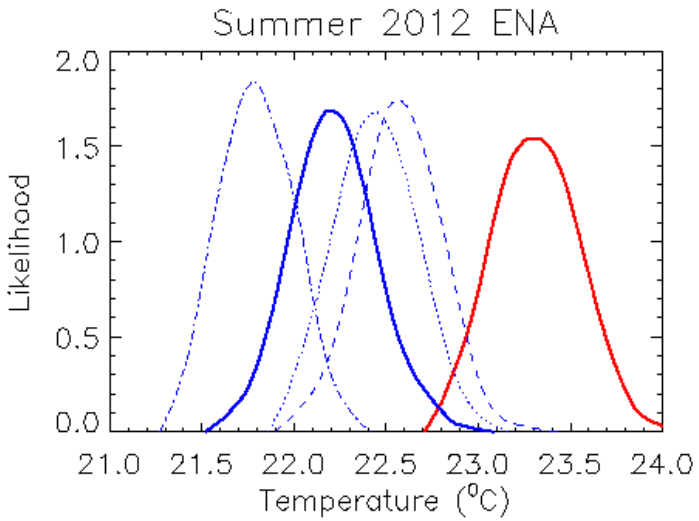


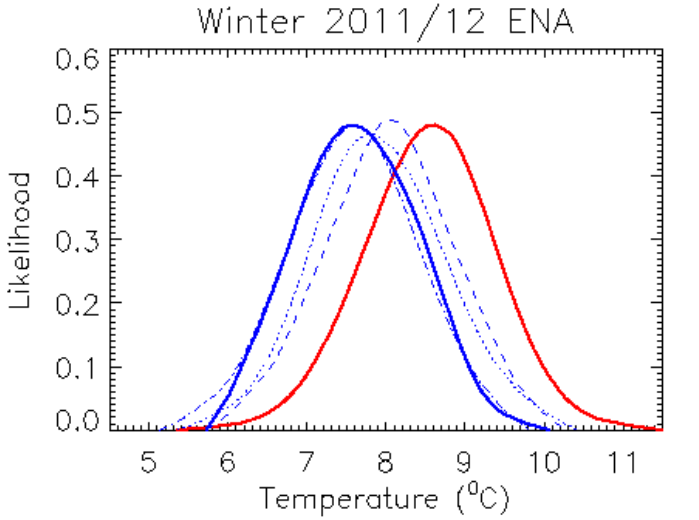

**CanESM2**




**CSIRO Mk3-6-0**






Christidis and Stott 2014, *J Climate*

# EUCLEIA

**EU**ropean **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

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

Met Office Hadley Centre

❖**WP4 (HZG)**
Stakeholder Engagement

❖**WP5 (Oxford)**
Methodologies / Framing Issues

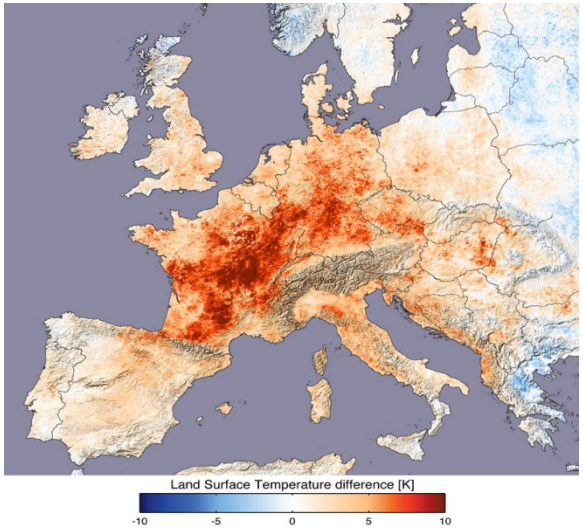
❖**WP6 (CNRS CEA)**
Evaluation & Diagnostics

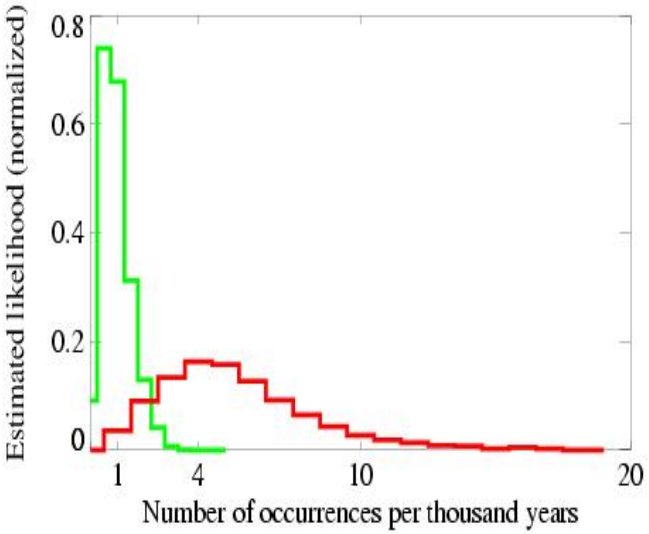
❖**WP7 (KNMI)**
Targeted Test Cases

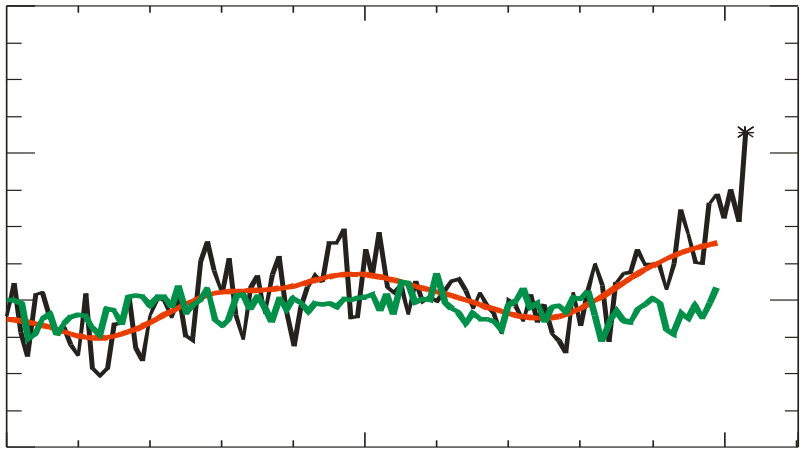
❖**WP8 (Metoffice)**
Near-real time attribution service

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

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



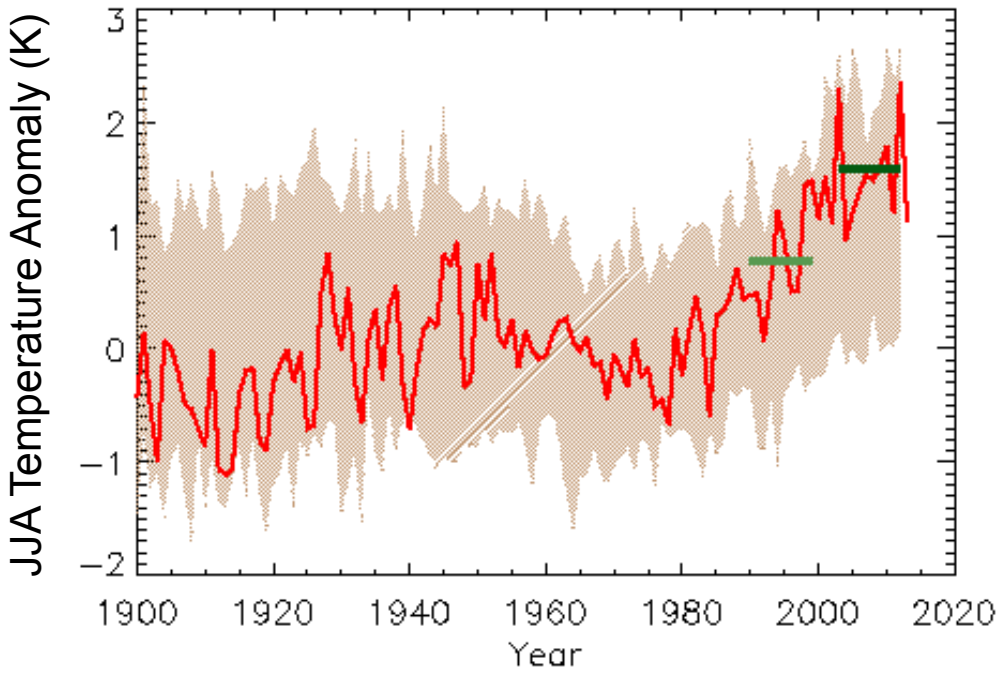



The estimated range of frequency of such a hot summer now is shown in red and compared with the frequency of such a hot summer in the world we would have had without human-induced climate change in green.

# The 2003 European heatwave

CRUTEM4 observations and the range from 7 CMIP5 models



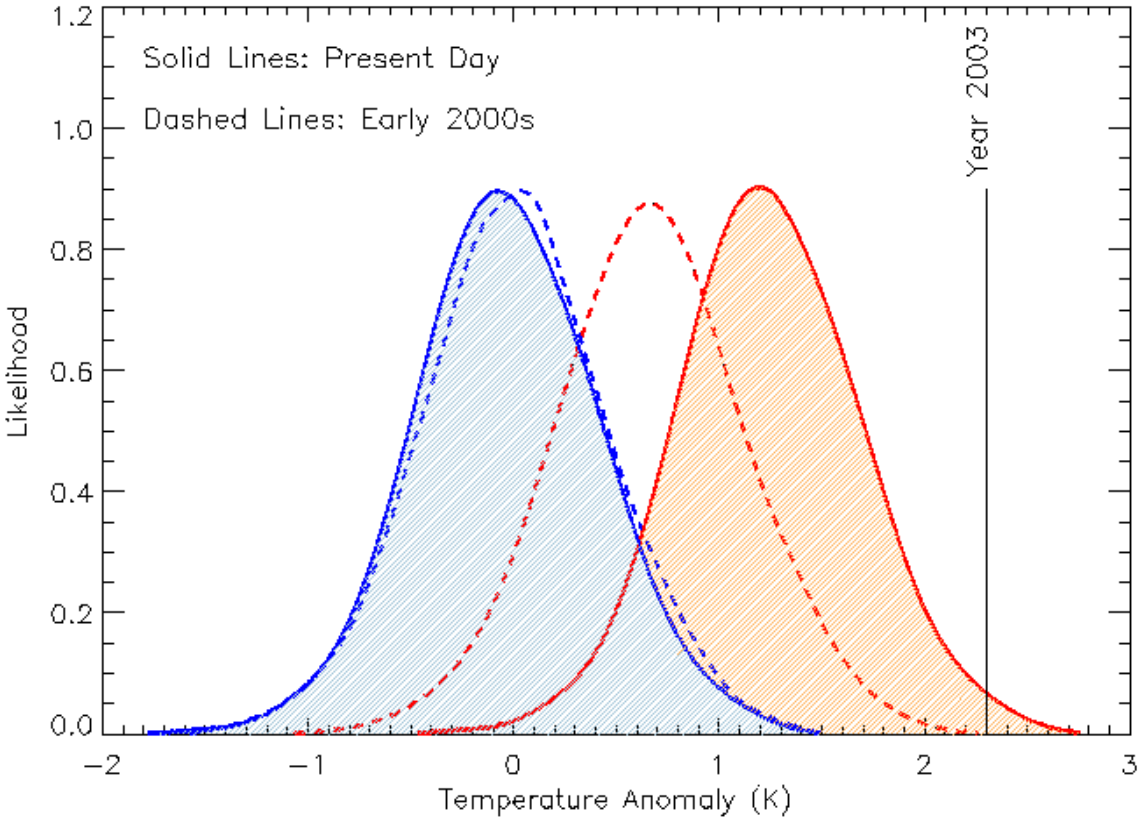

European summers have warmed by

**$0.81^0$ K** since 2003

# The 2003 European heatwave

Heatwaves that would be expected to occur twice a century in early 2000s are now expected to occur twice a decade

Return time of a heatwave like the one in 2003:
127 years
(1000s of years in the early 2000s)



# Final points…

- Attribution of extremes is an active area of research. A state-of-the art 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?