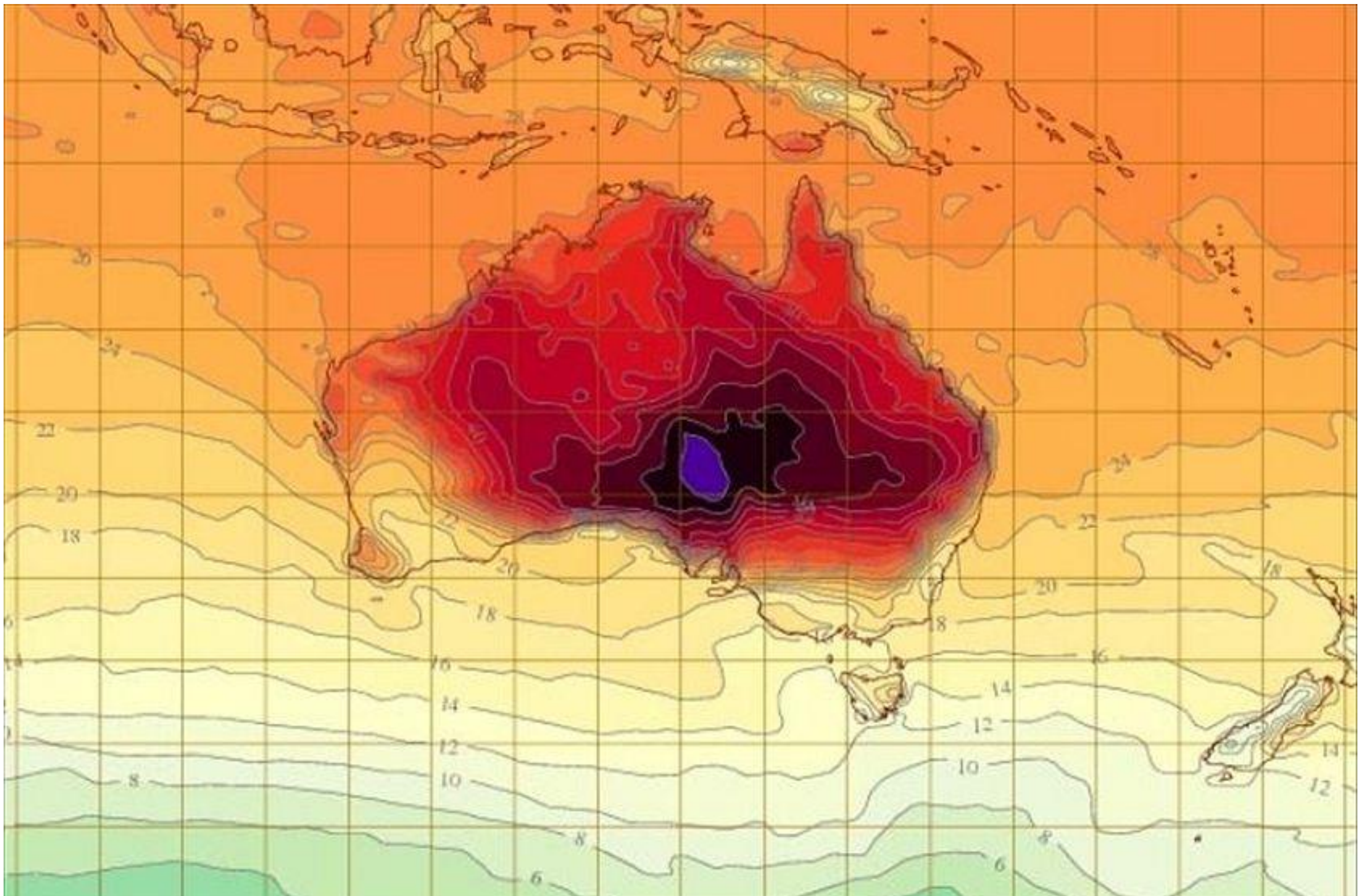
Detection and Attribution of Climate Change: From global mean warming to climate extremes and high impact weather

Dr Peter Stott, Met Office Hadley Centre

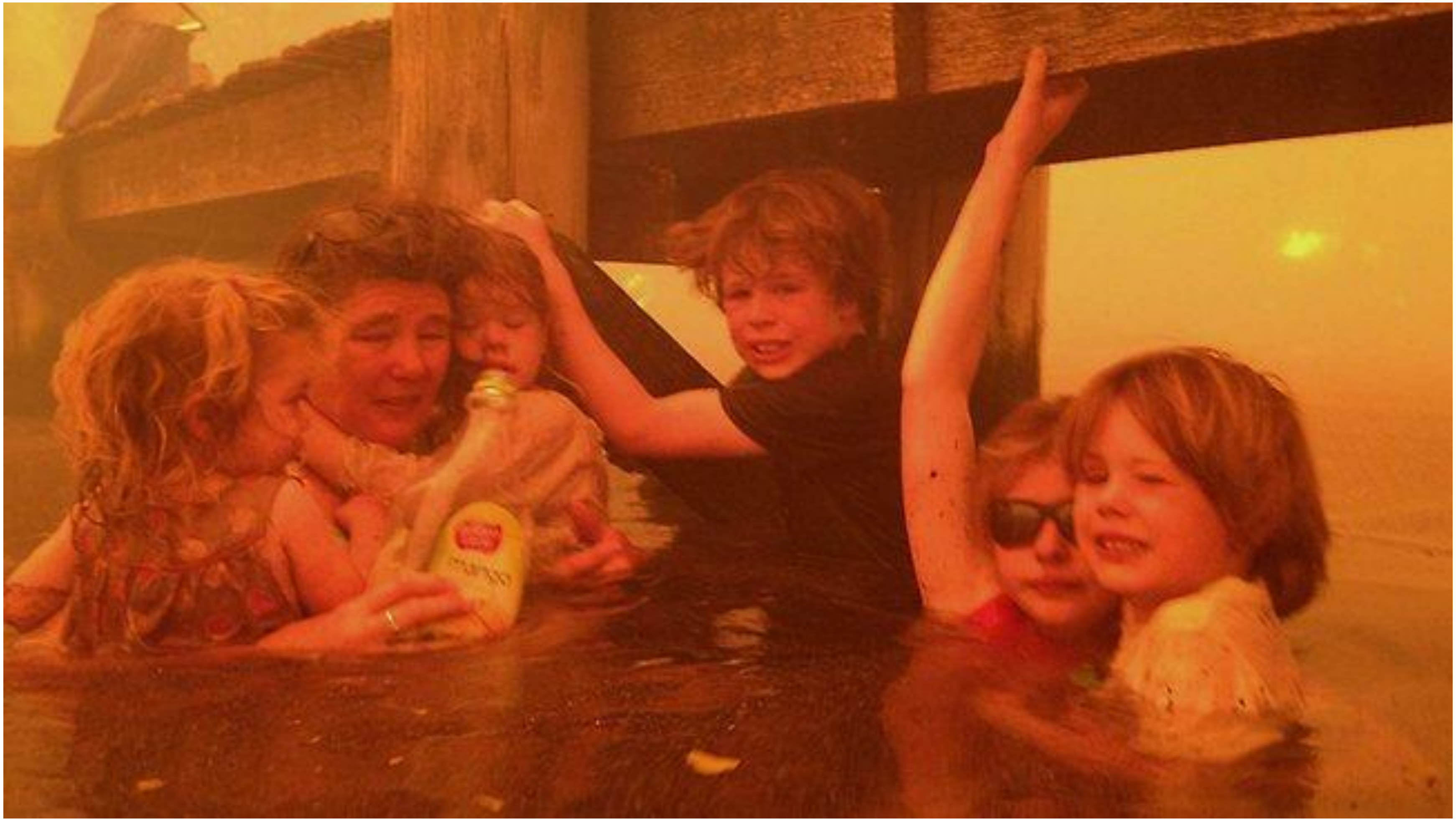
Australia
January 2013



Hobart, Tasmania, 4th January 2013

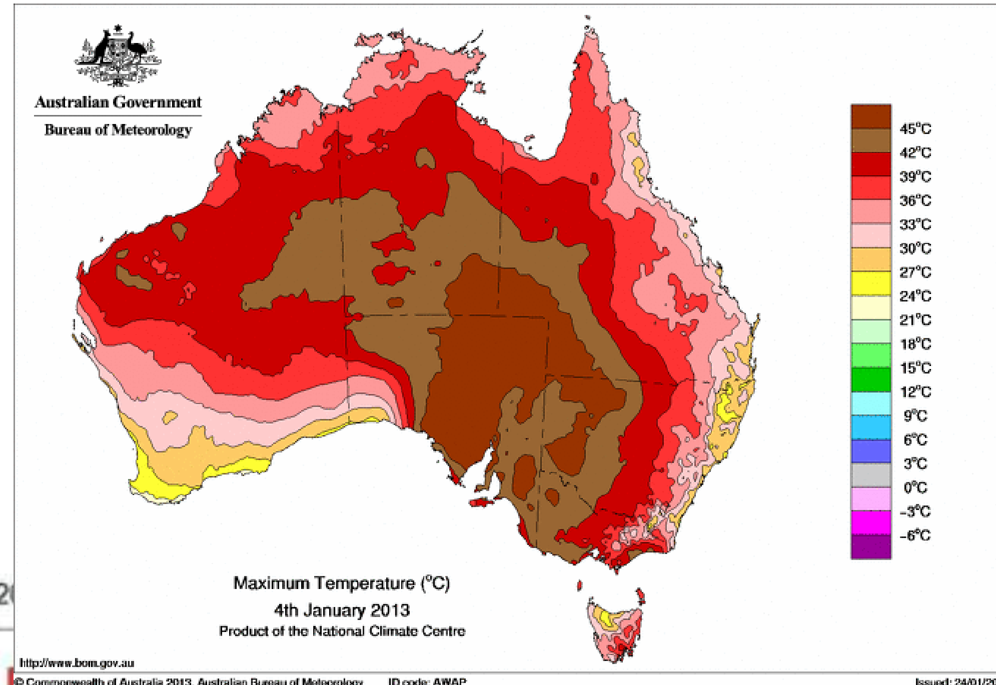
Met Office
Hadley Centre

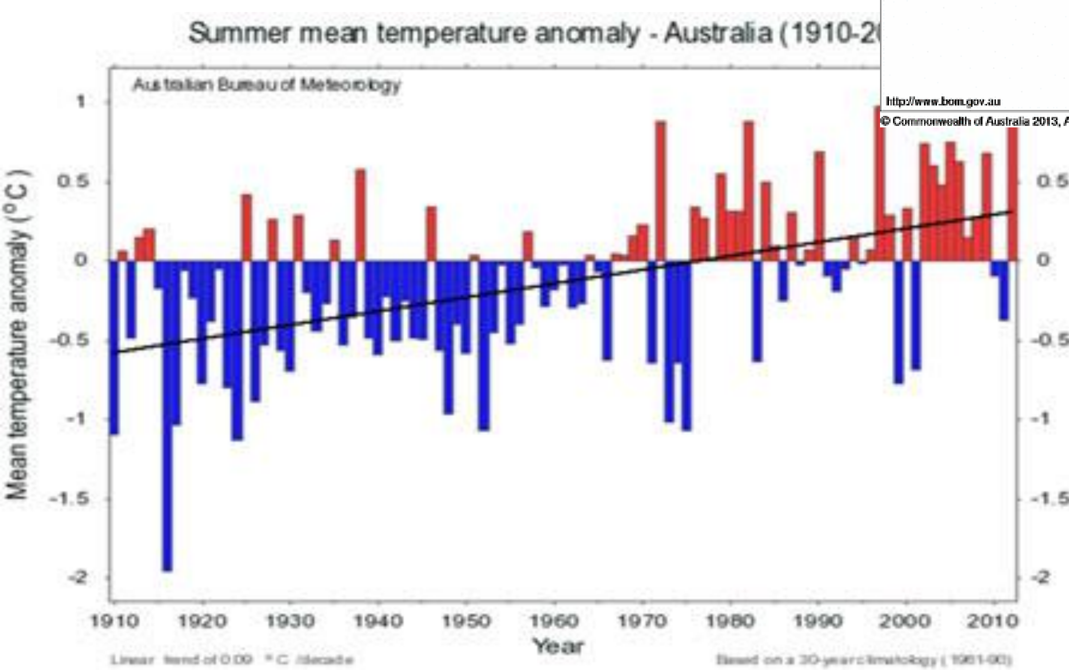
Dunalley, 4th January 2013



Dunalley, 4th January 2013

Australia's "angry summer"

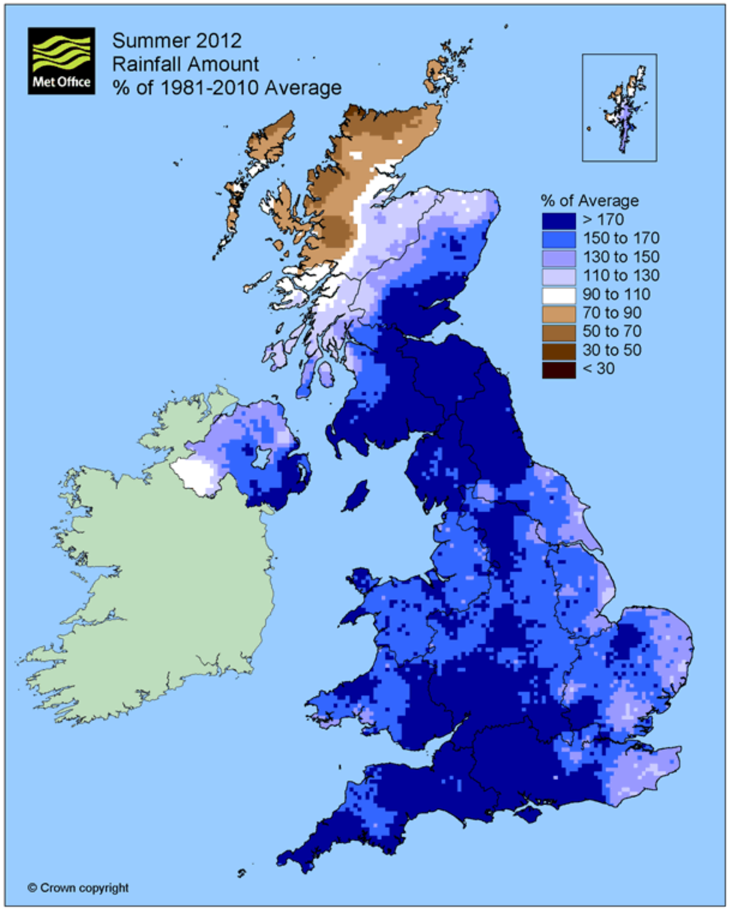




Britain’s washout Summer : 2012

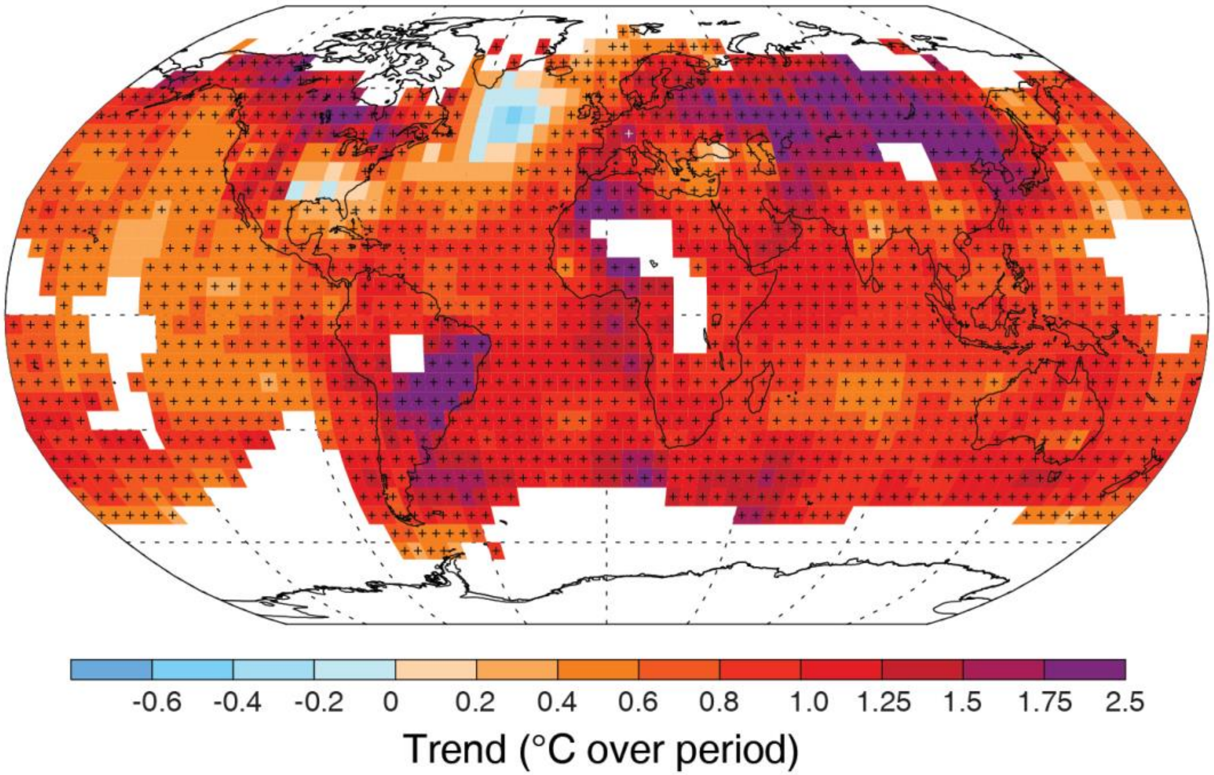
Diamond Jubilee, 3rd June, Reading

Wettest since 1912



- Why is climate changing ?
- How are climate extremes changing ?
- Is it possible to link recent climate extremes and high impact weather - like the Australian heat wave or the wet British summer - to climate change ?

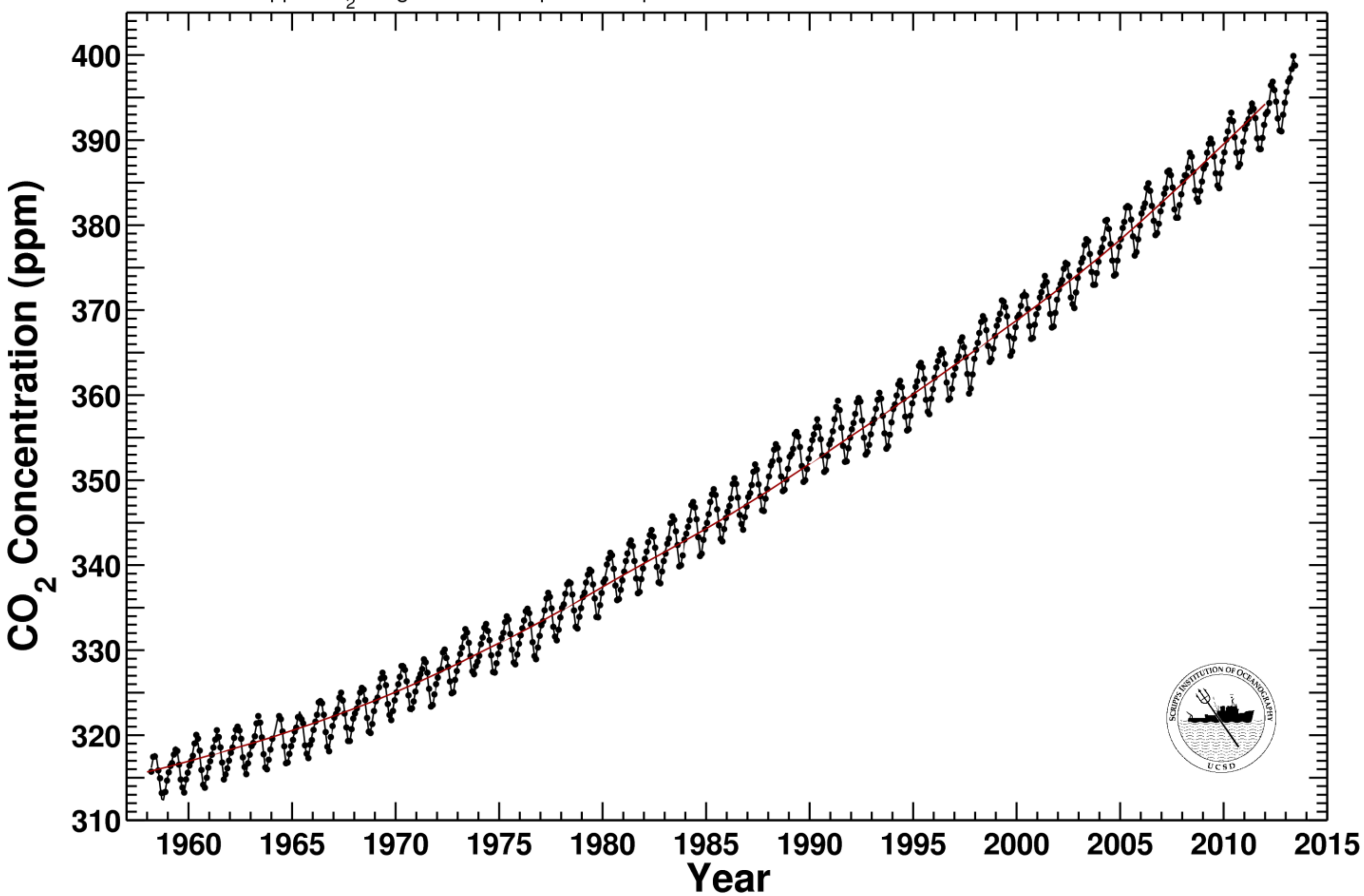
The climate is warming



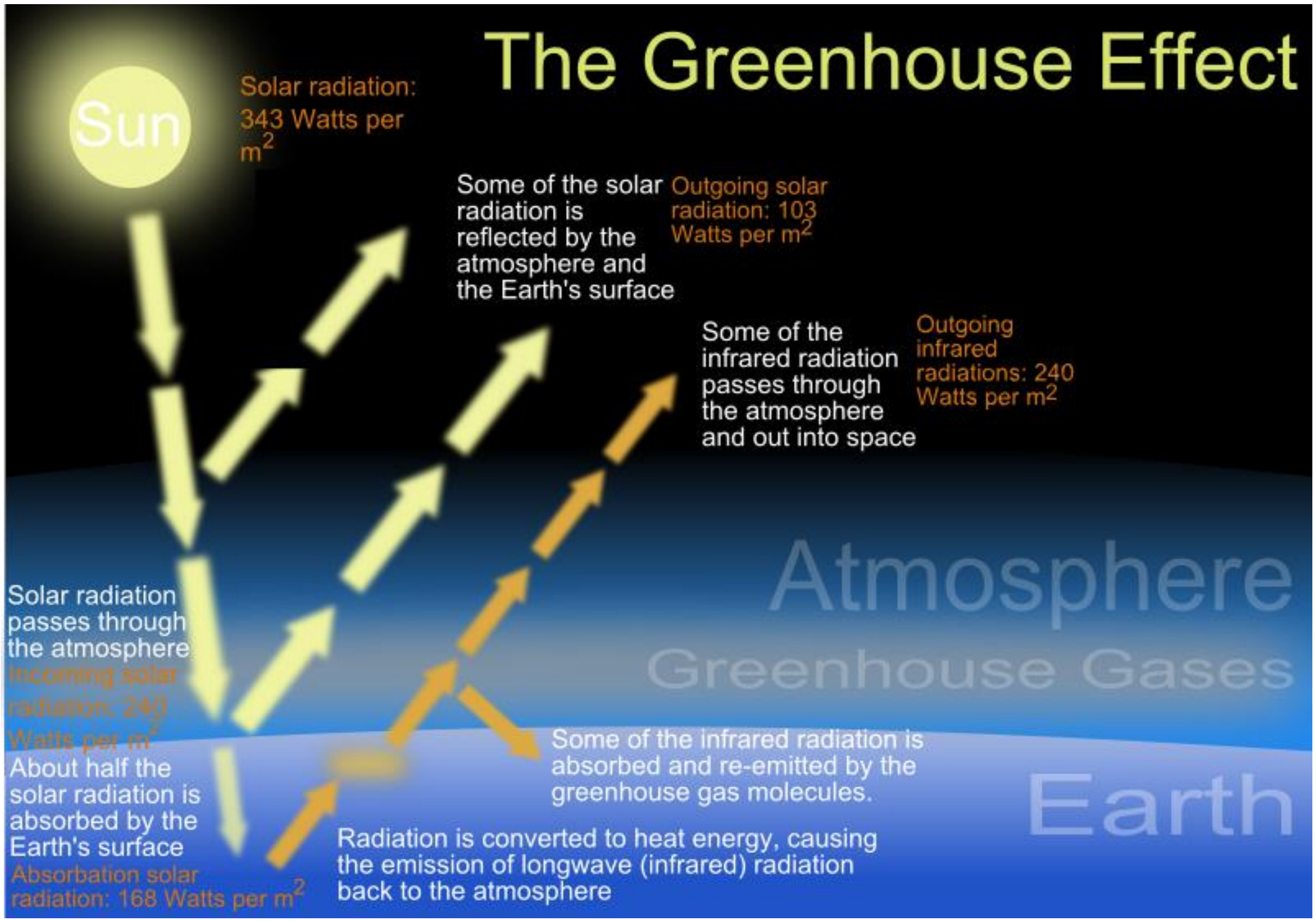
Annual mean temperature (1901-2012)

Concentrations of carbon dioxide and other greenhouse gases are increasing

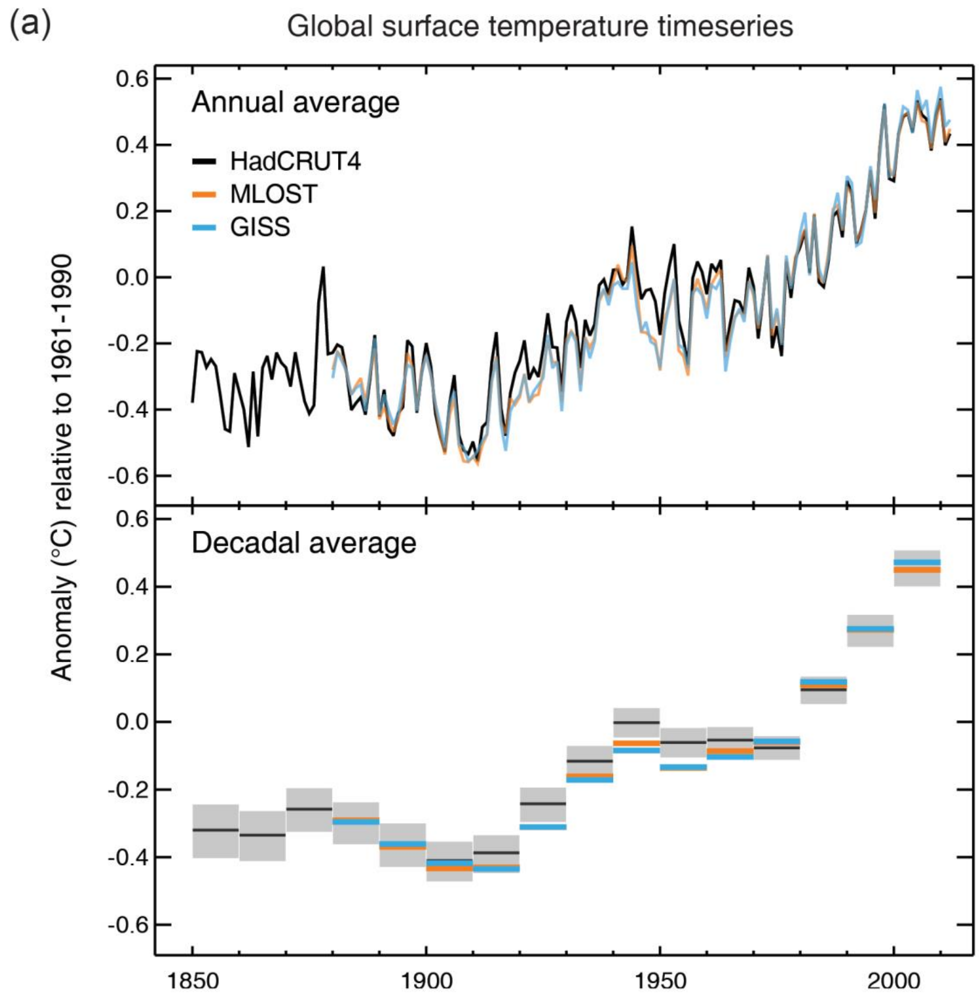
Mauna Loa Observatory, Hawaii
Monthly Average Carbon Dioxide Concentration
Mauna Loa Record and Fossil Fuel Trend
Data from Scripps CO_2 Program   Last updated September 2013



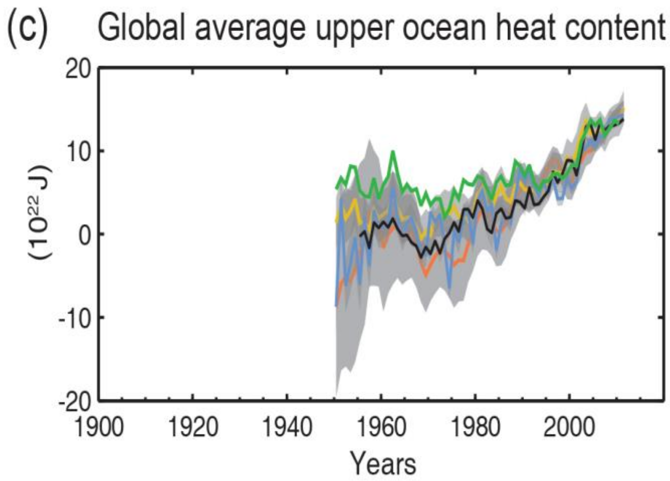
The greenhouse effect

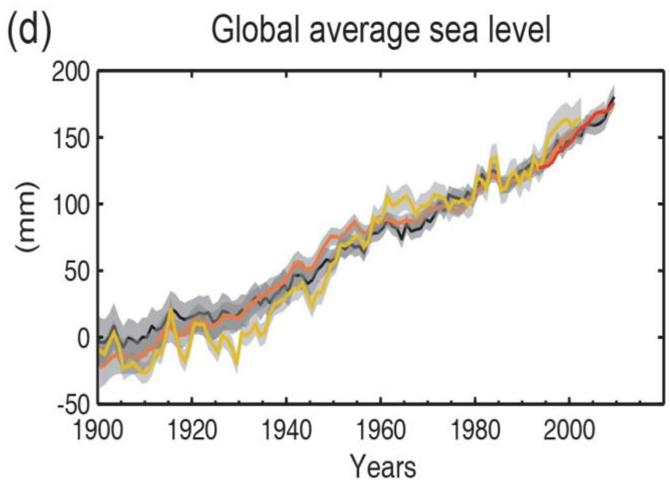


Global surface temperatures have increased.

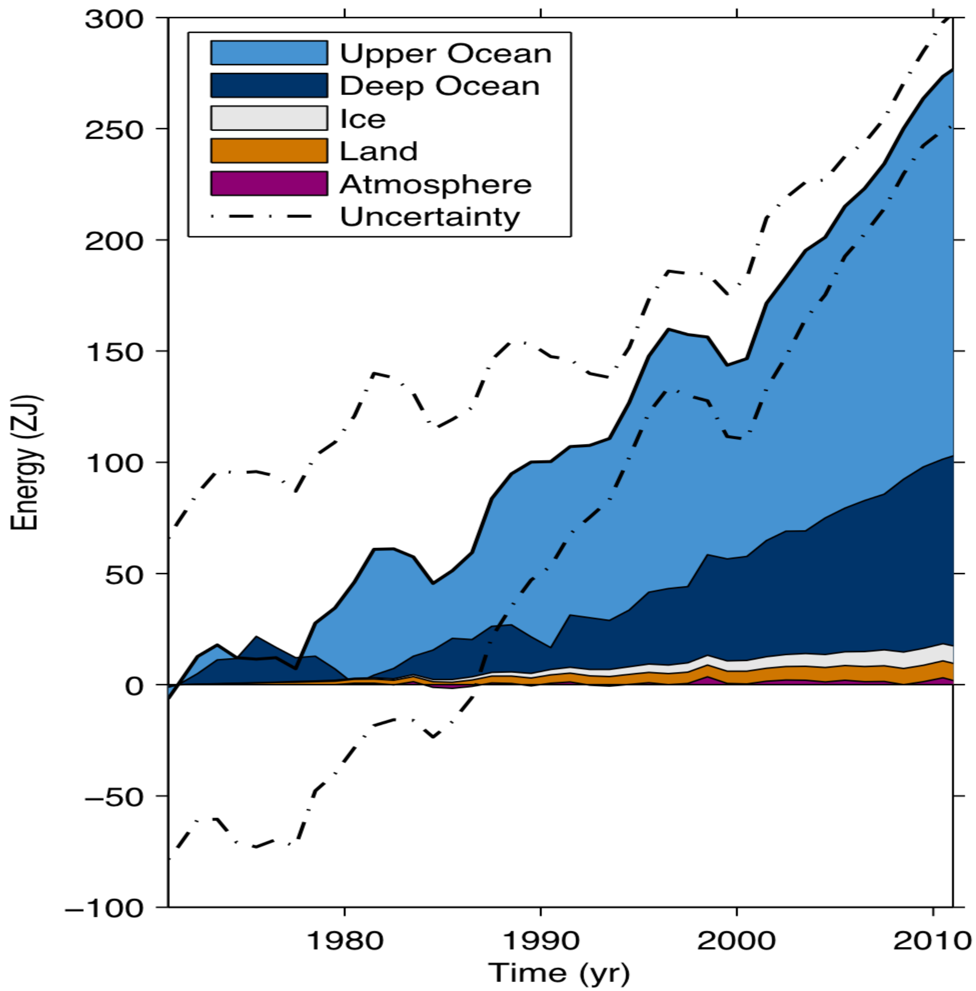


The oceans have warmed and sea level has risen.





The climate system has continued to accumulate energy during the last 15 years



Box 3.1 Fig 1

Observed decadal mean warming

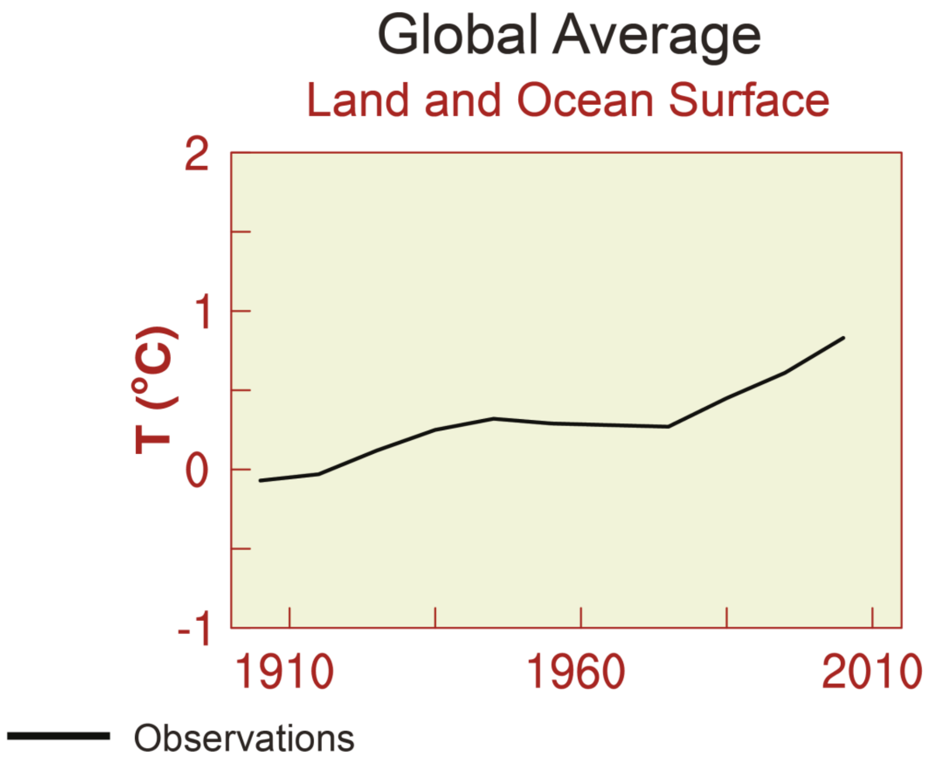
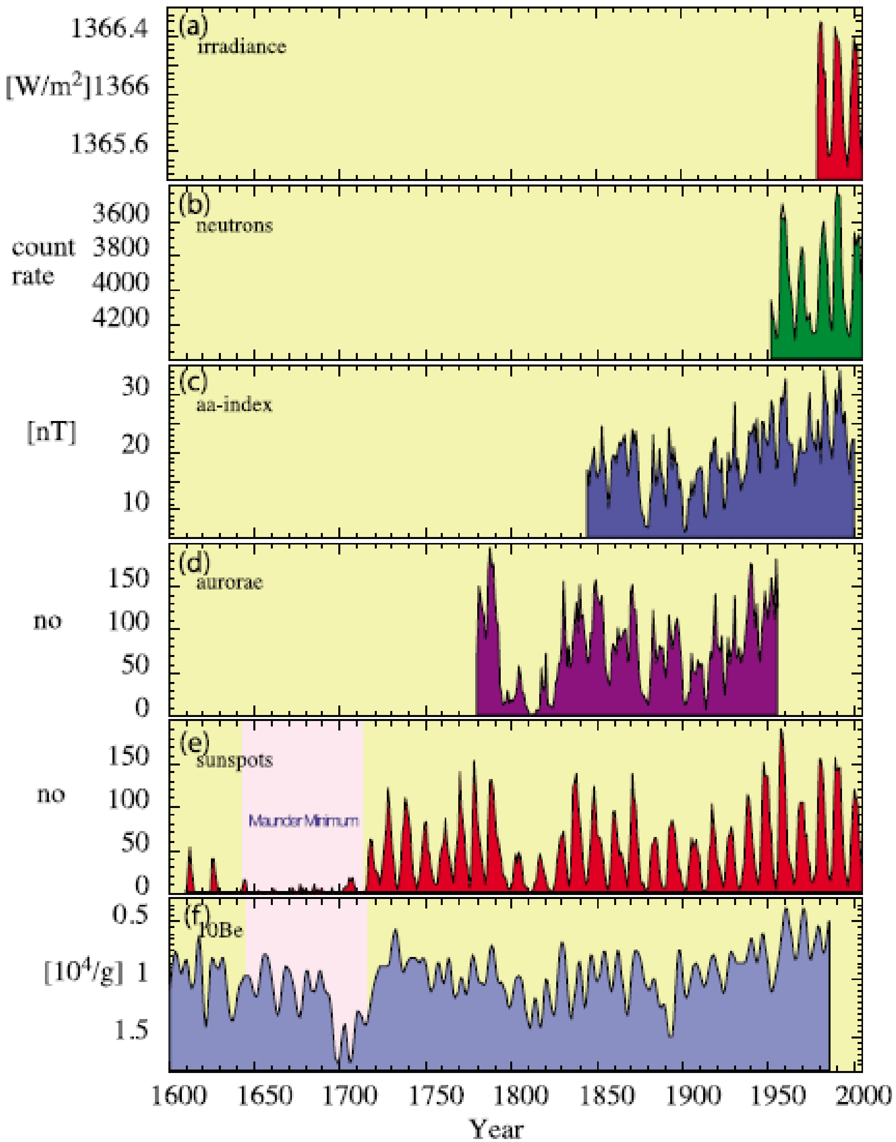
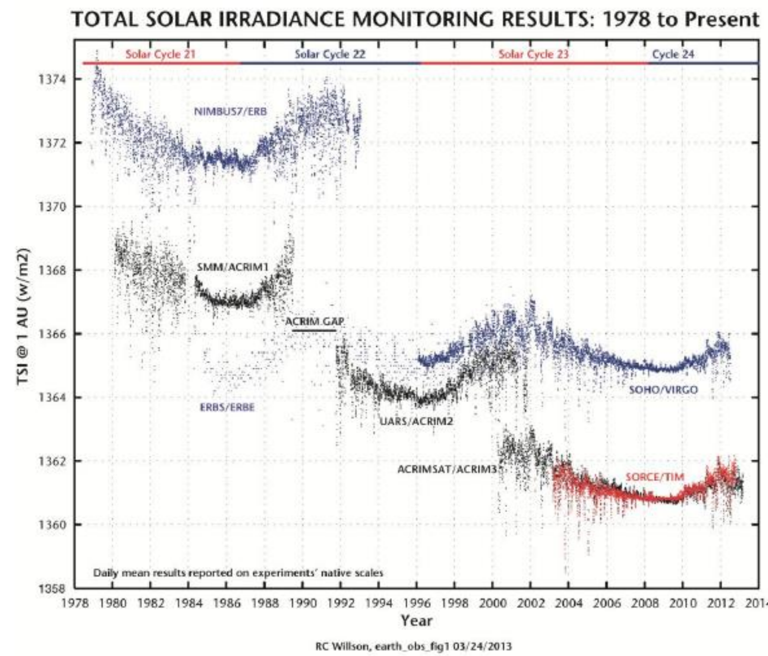


Fig SPM.5

Solar influences on climate





Gray et al, 2010. Solar influences on climate, Reviews in Geophysics, 48, RG4001.

INTERGOVERNMENTAL PANEL ON climate change

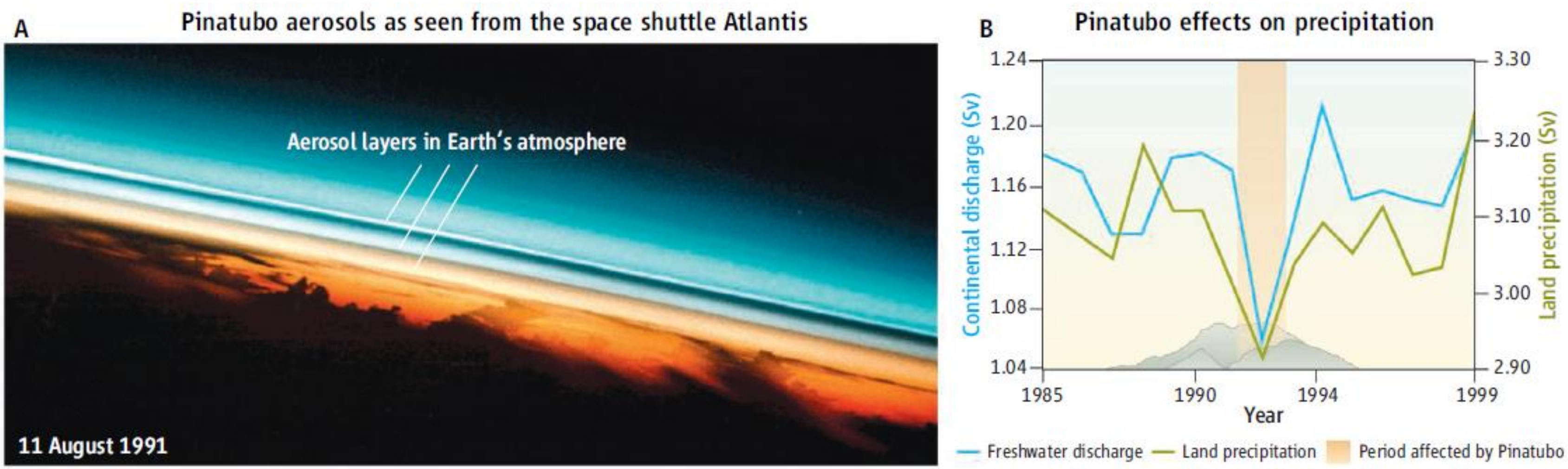
WMO UNEP

Volcanic influences on climate

Pinatubo, 1991

Krakatau, 1883

Volcanic eruptions cause short term cooling – and reduced global temperature and precipitation



Observed warming inconsistent with that expected from natural factors

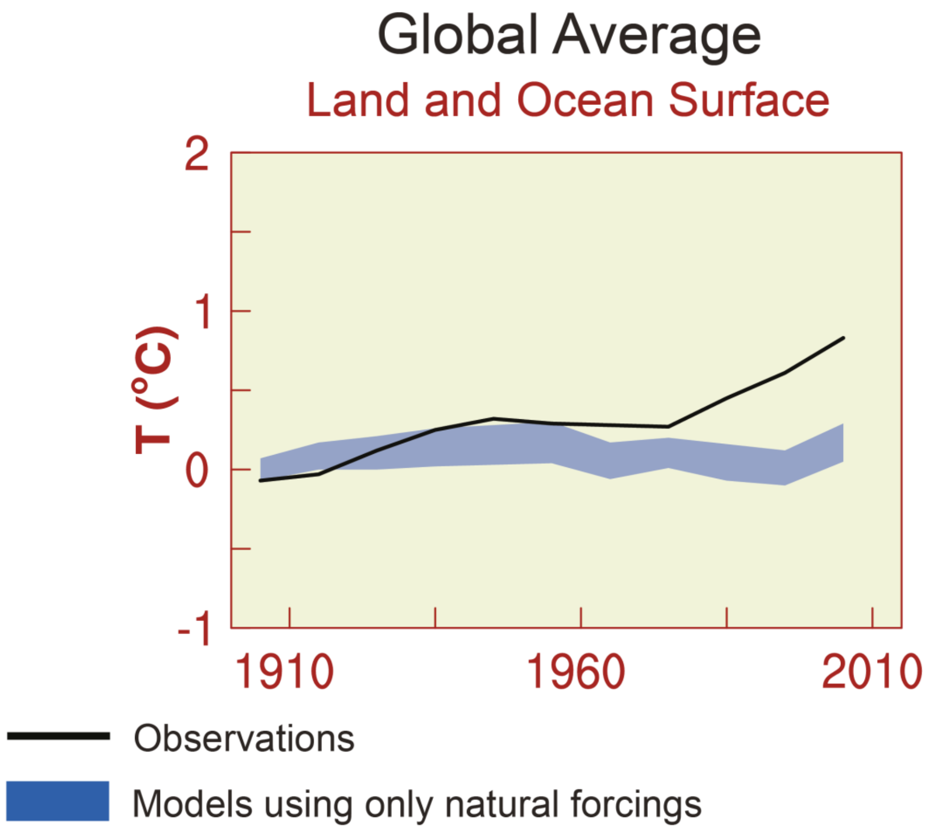


Fig SPM.5

Observed warming consistent with simulations that include anthropogenic factors

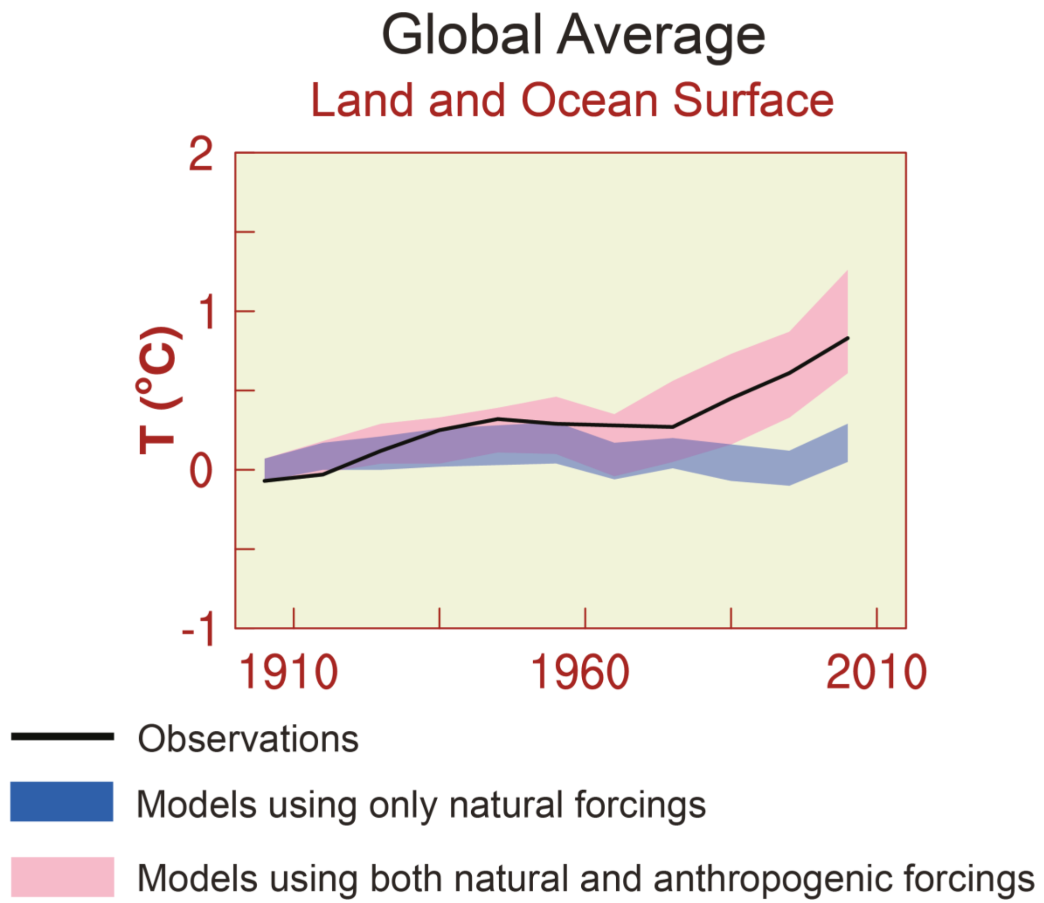
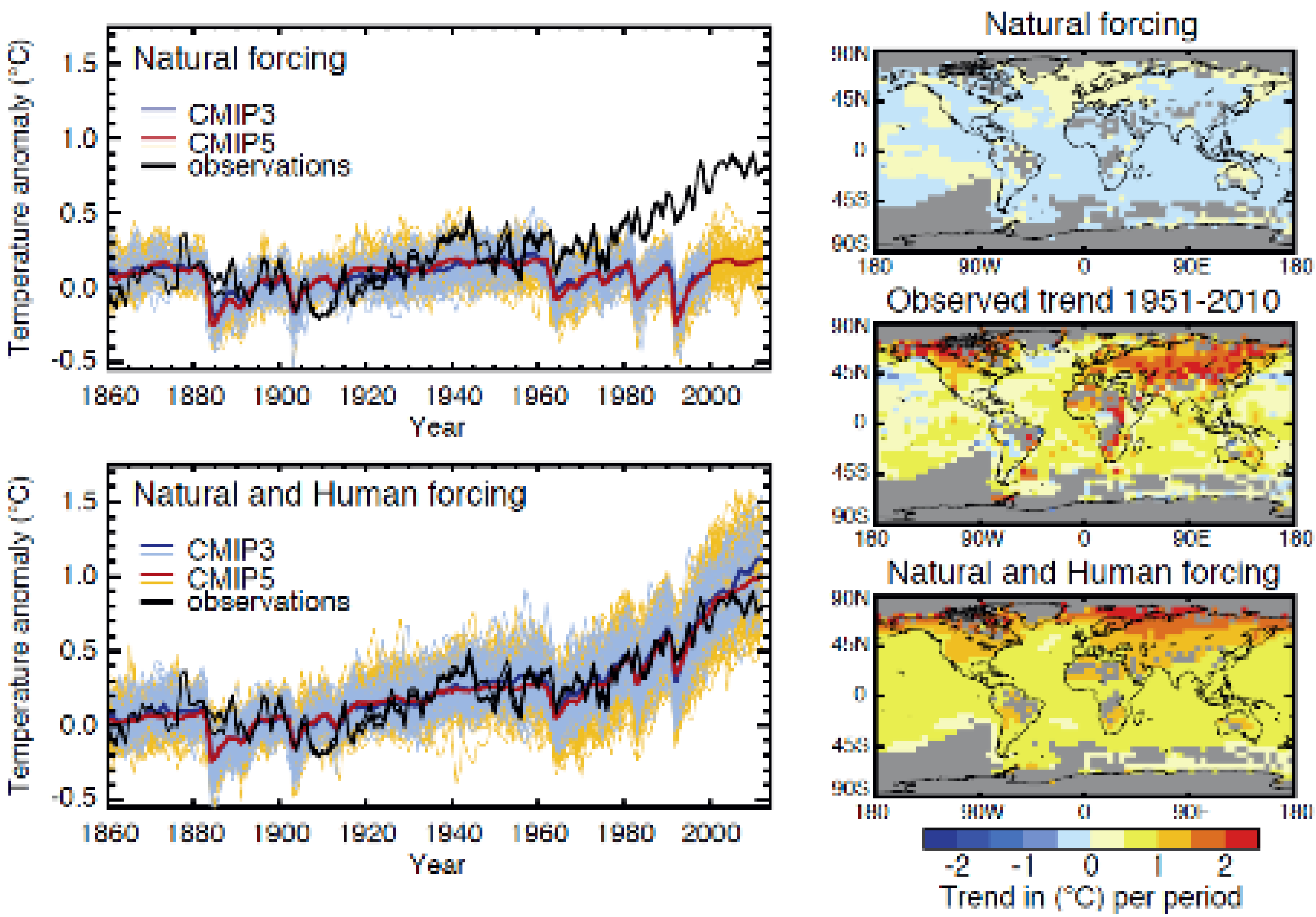


Fig SPM.5

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



FAQ 10.1
Fig 1

Optimal Fingerprinting

Are model response patterns (fingerprints) detected in the observations?

Generalised multivariate regression

$\mathbf{y}$: Observations

$\mathbf{x}$: Model Fingerprint (ensemble mean)

sampling noise

climate noise in the obs

$$\mathbf{y} = \sum_{i=1}^{m} (\mathbf{x}_i - \upsilon_i)\, \beta_i + \upsilon_0$$

• If β consistent with zero: no detection
• If β consistent with one (and small uncertainty range): good model simulation

Allen and Tett, 1999; Allen and Stott, 2002

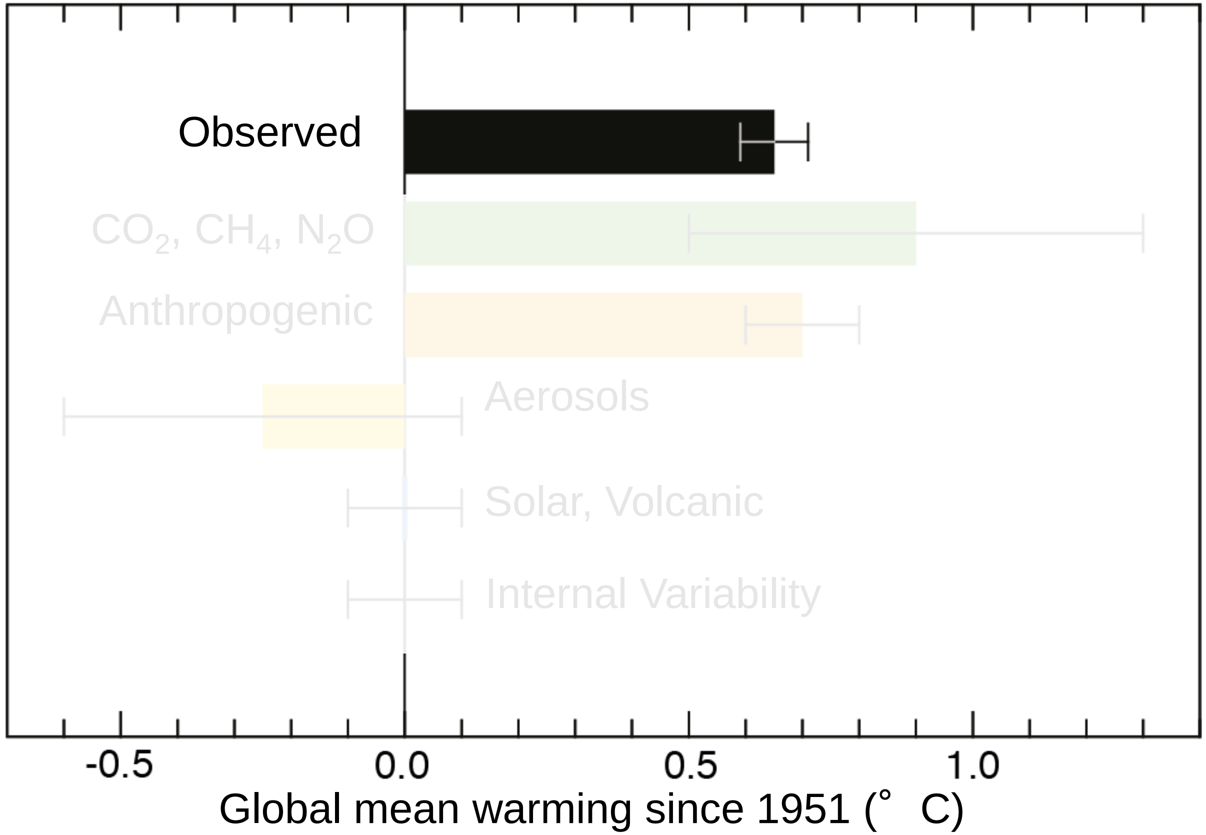
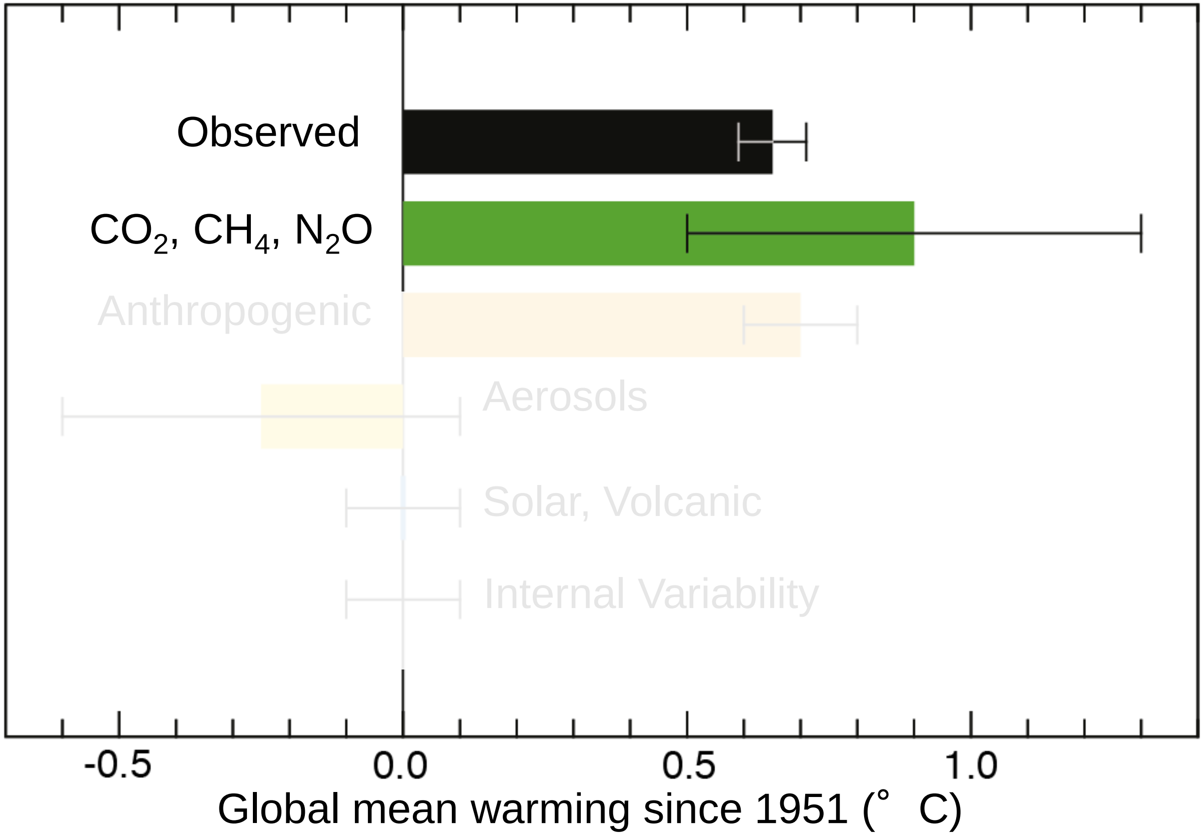


Fig. TS.10

The observed warming 1951− 2010 is approximately 0.6° C to 0.7° C.



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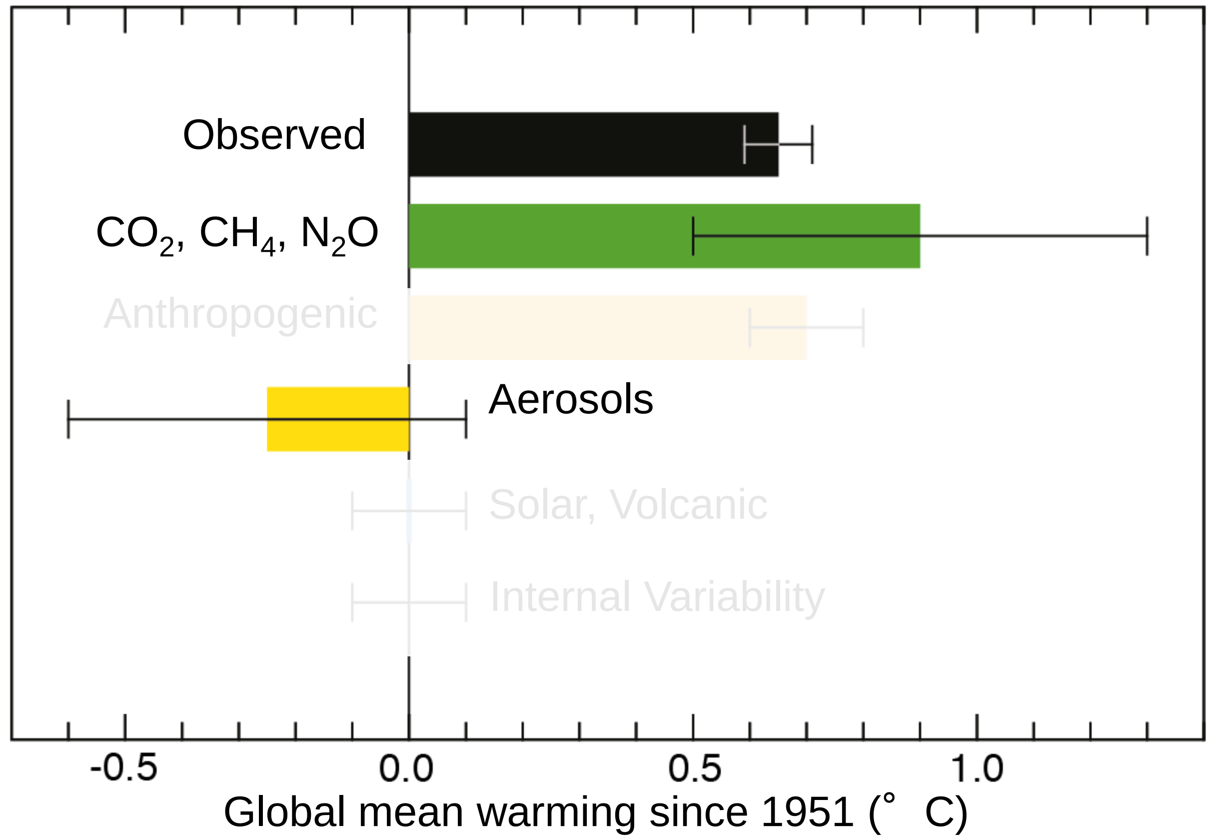

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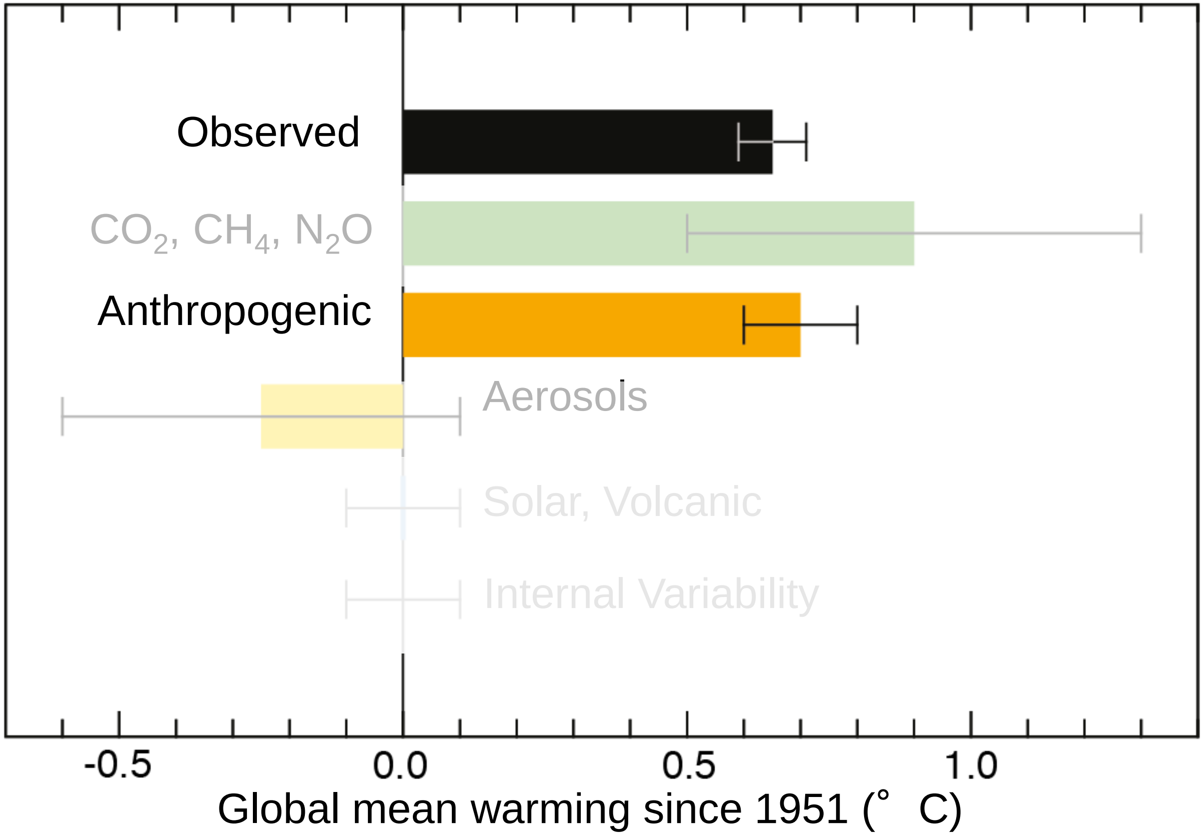
INTERGOVERNMENTAL PANEL ON climate change



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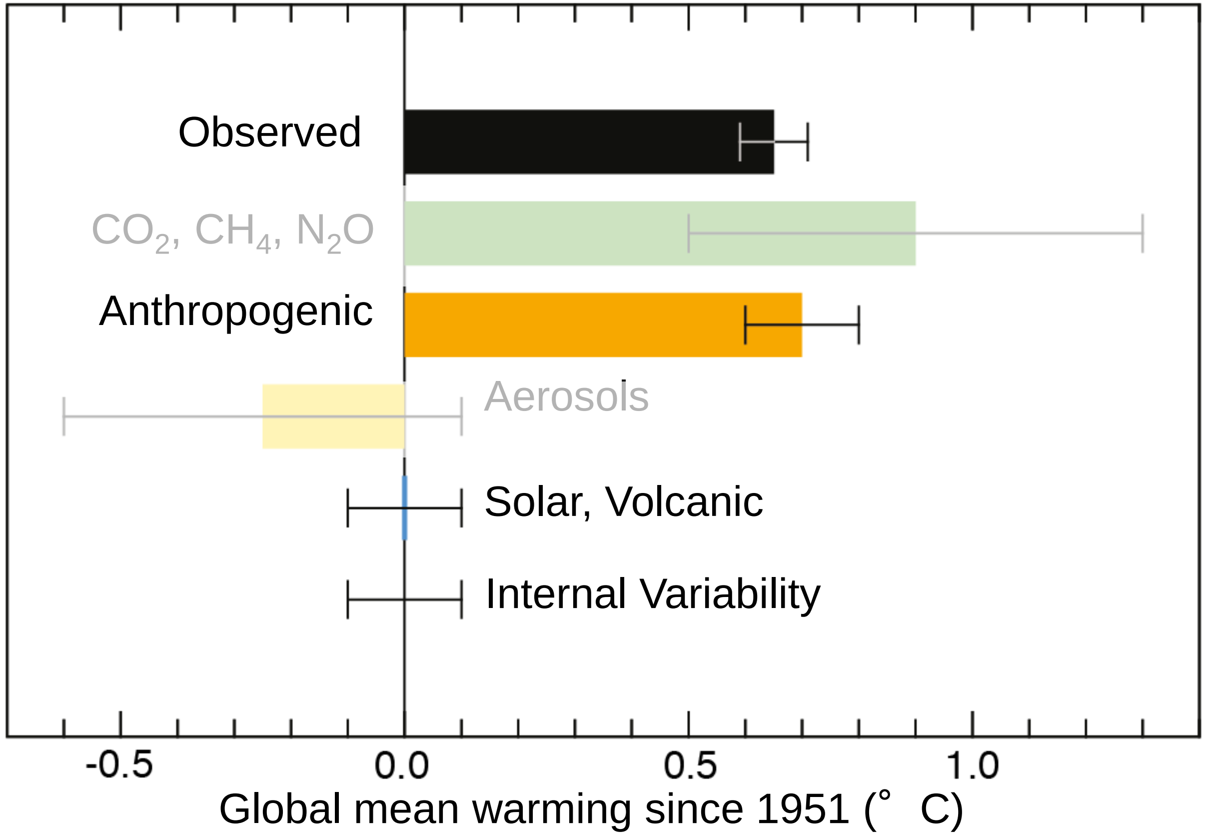

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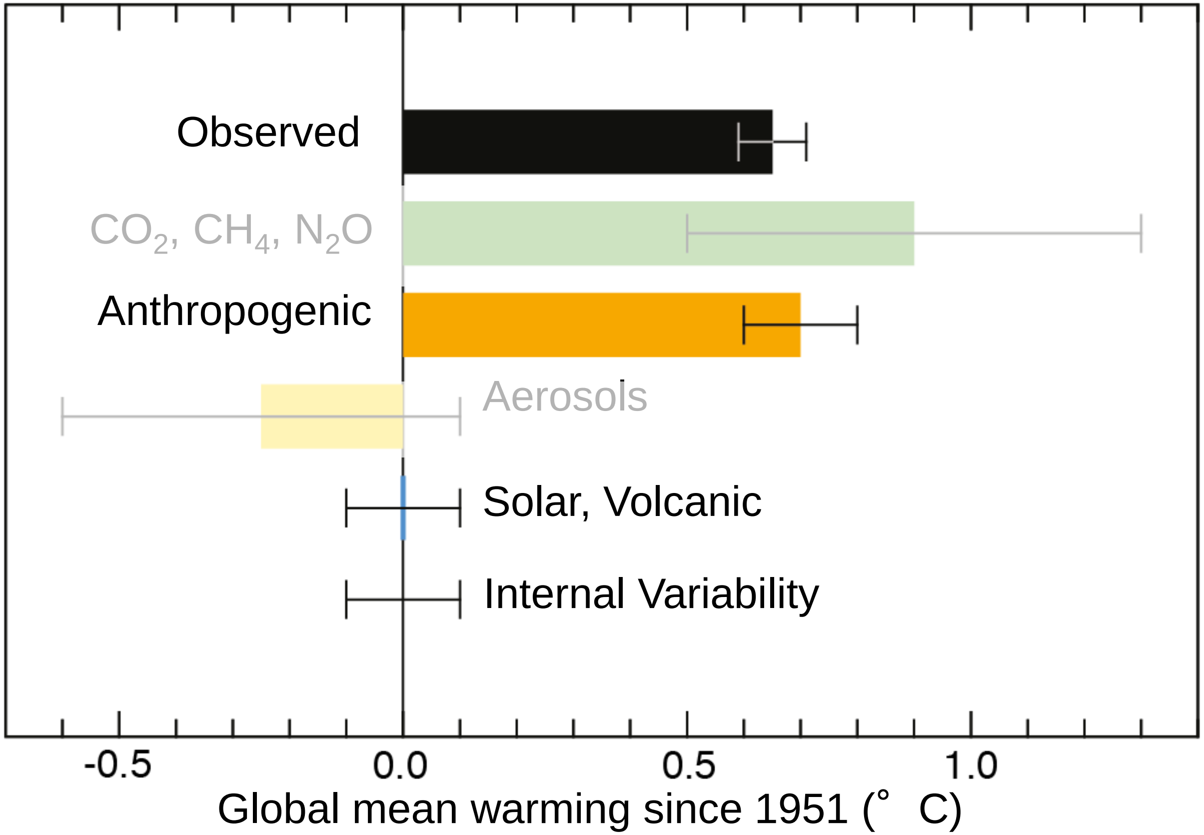


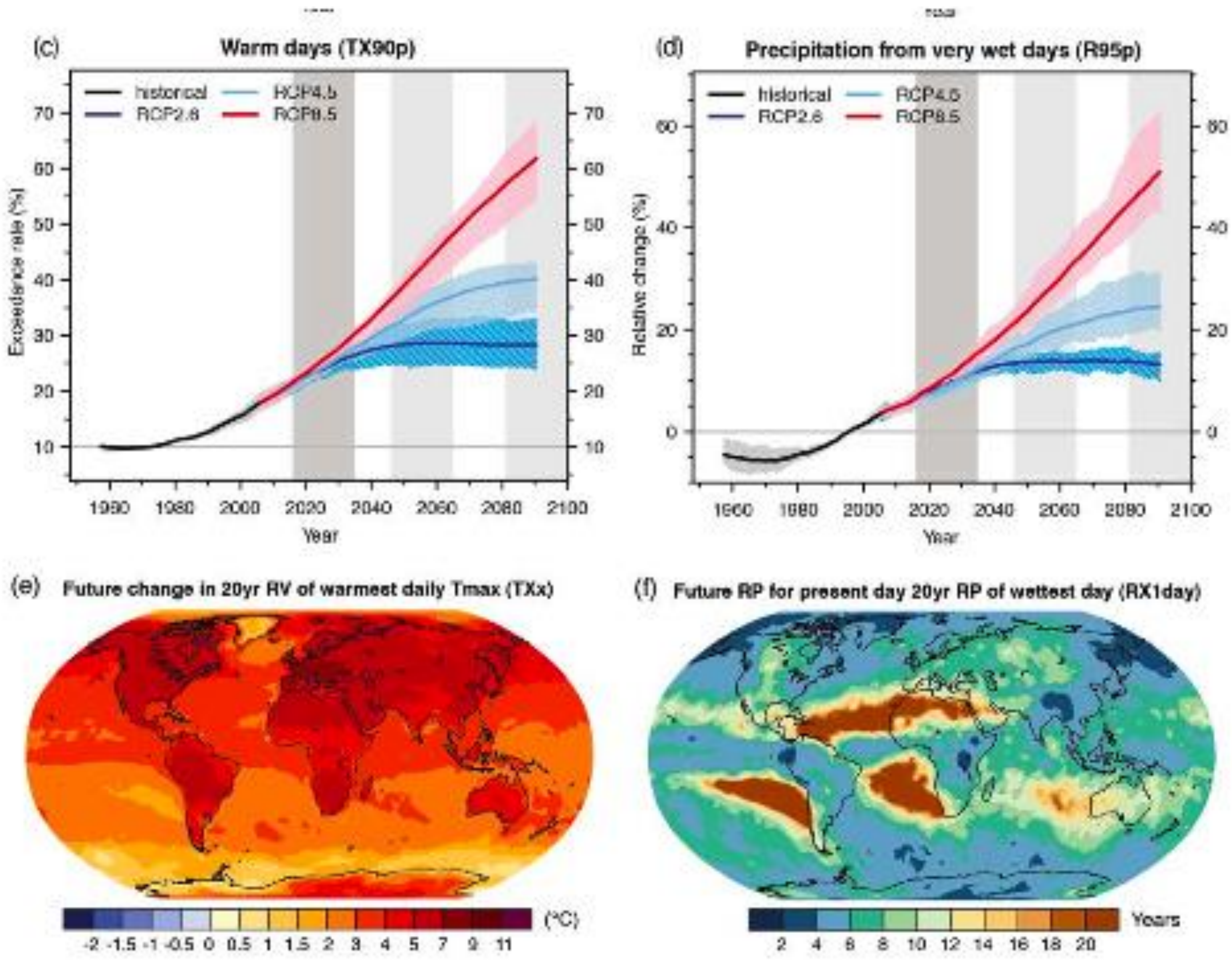
Fig. TS.10

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

IPCC Summary for Policy Makers agreed line by line in Stockholm, September 2013, by 110 governments

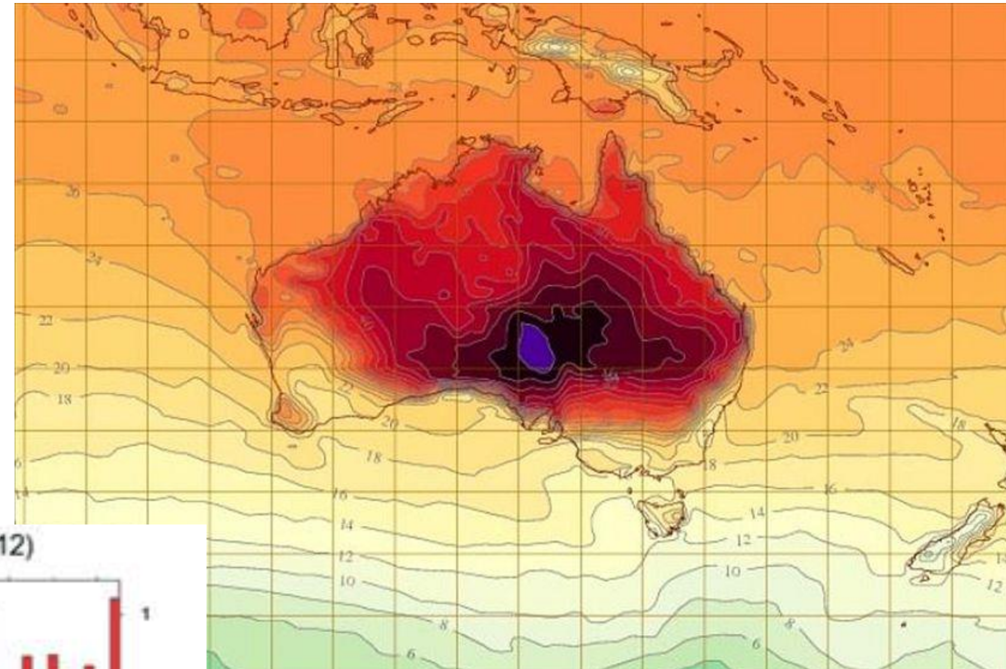
- Why is climate changing ?
- How are climate extremes changing ?
- Is it possible to link recent climate extremes and high impact weather - like the Australian heat wave or the wet British summer - to climate change ?

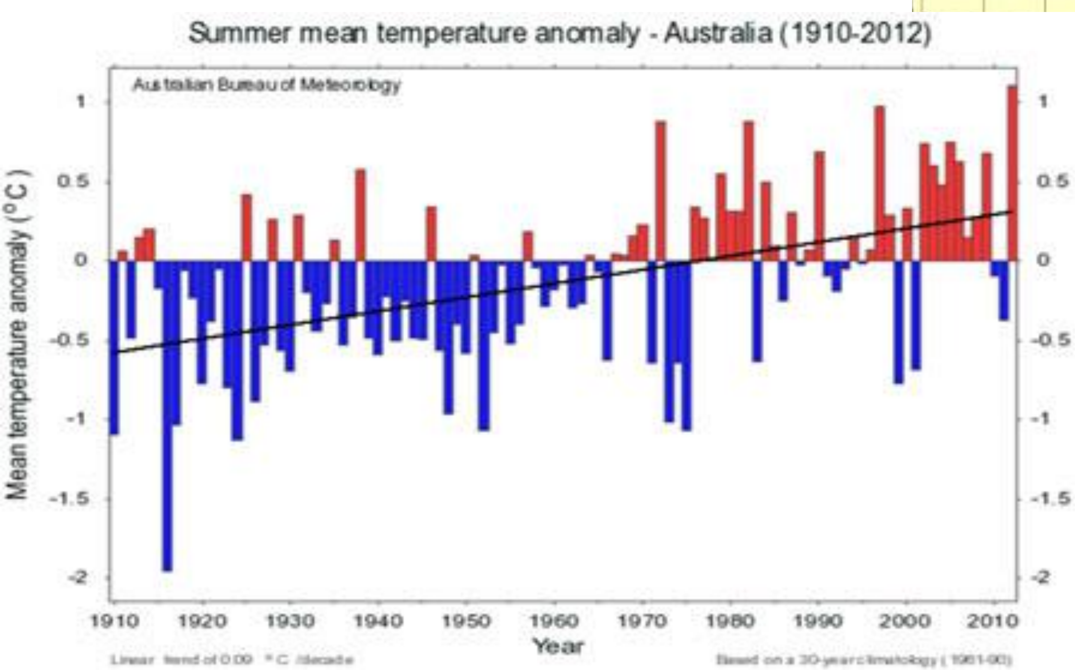
Changing temperature and precipitation extremes



- Why is climate changing ?
- How are climate extremes changing ?
- Is it possible to link recent climate extremes and high impact weather - like the Australian heat wave or the wet British summer - to climate change ?

Was Australia's "angry summer" due to anthropogenic climate change ?





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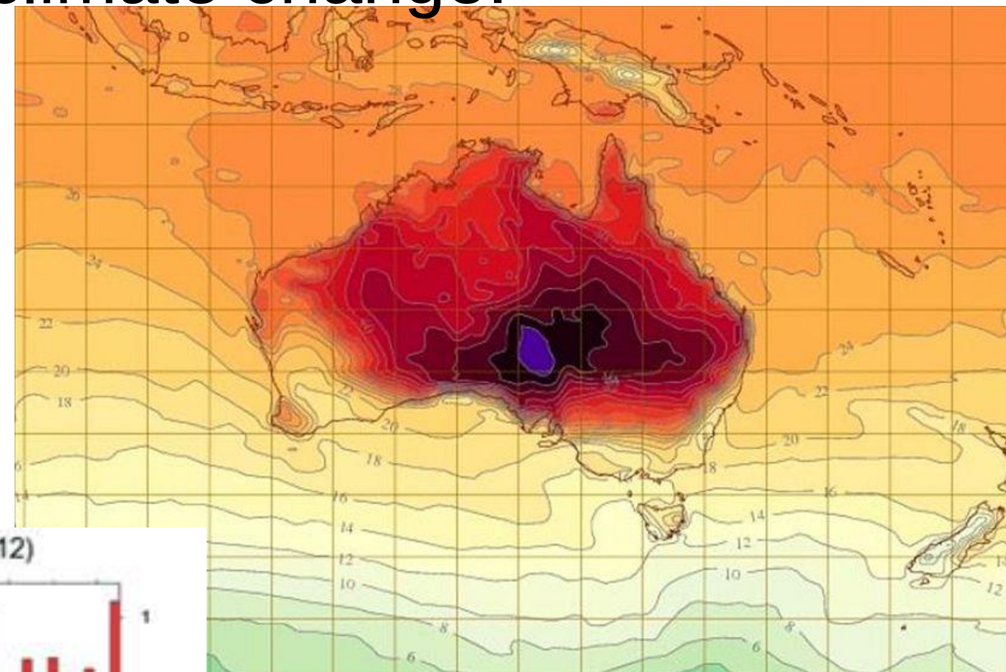
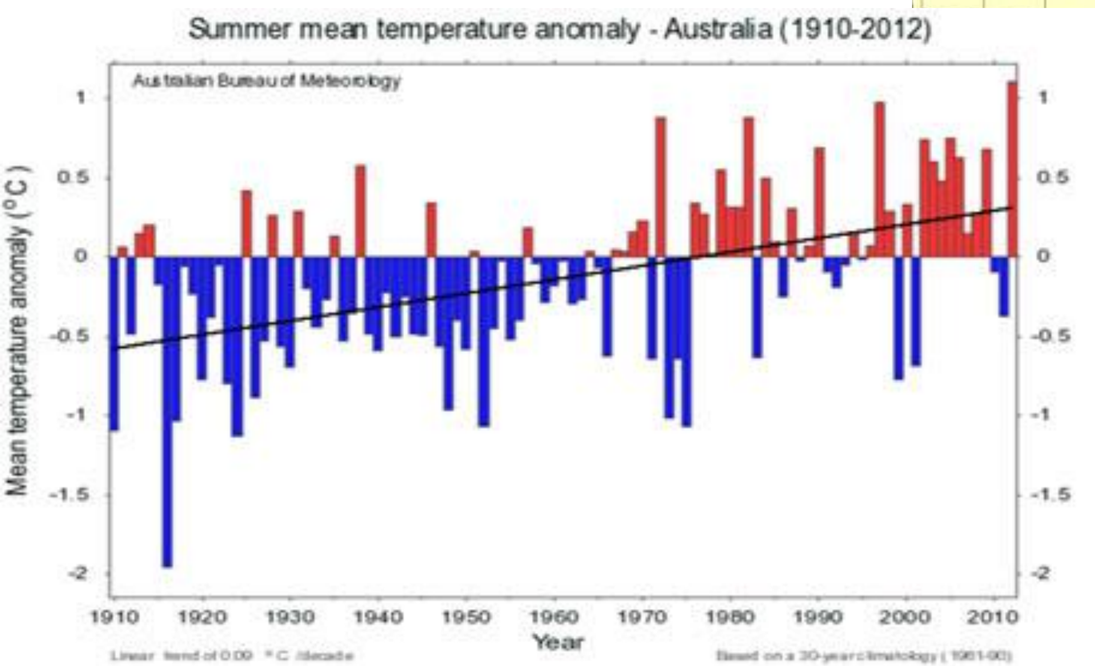
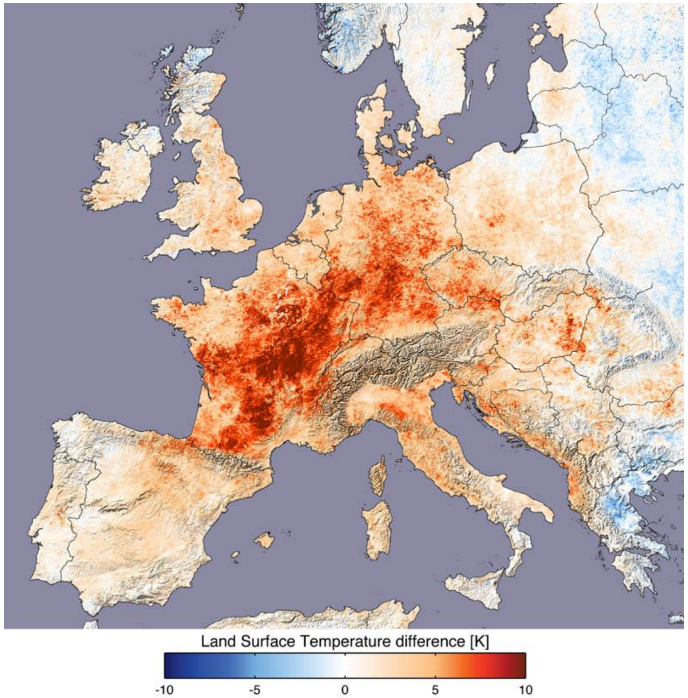
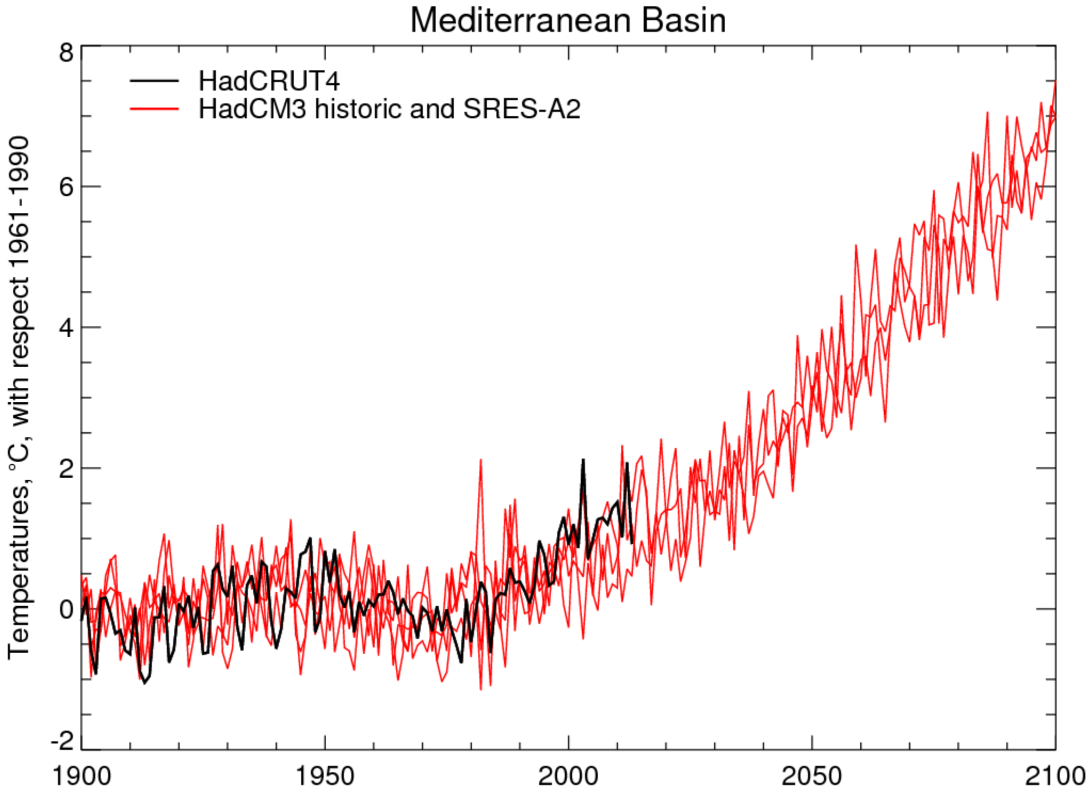
It isn’t possible to say a particular extreme season was or was not due to anthropogenic climate change.



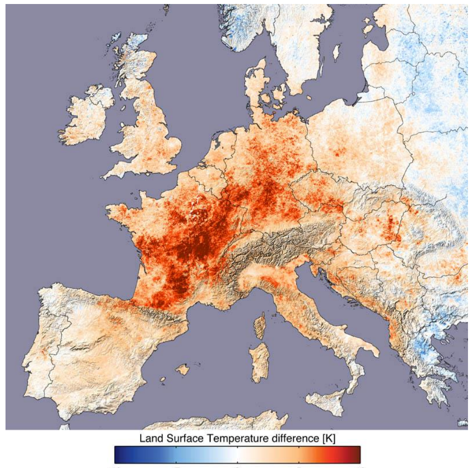


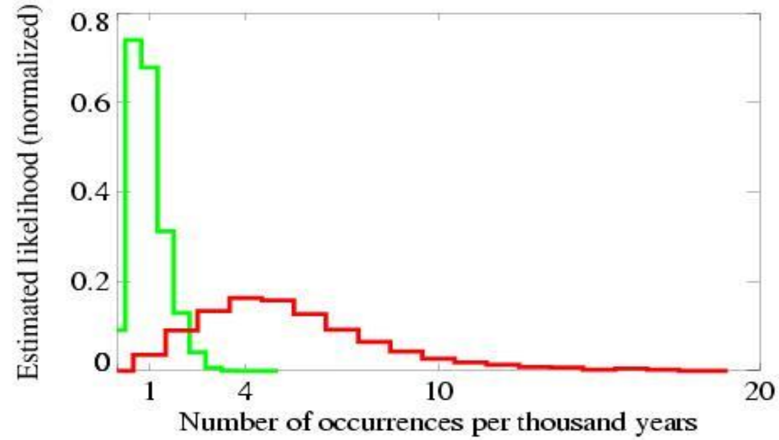
But it is possible to evaluate how the odds of such an event have changed.

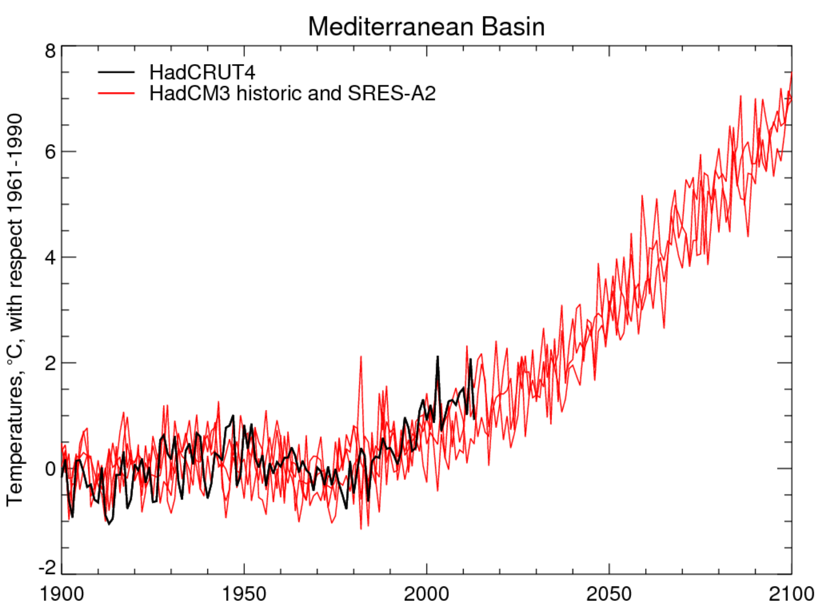


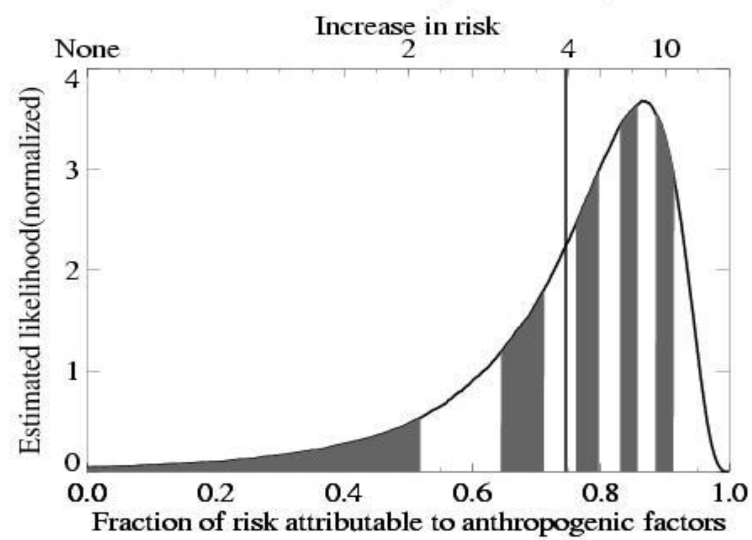


Human influence has *very likely* at least doubled the probability of European summer temperatures as hot as 2003. Stott et al, Nature, 2004.





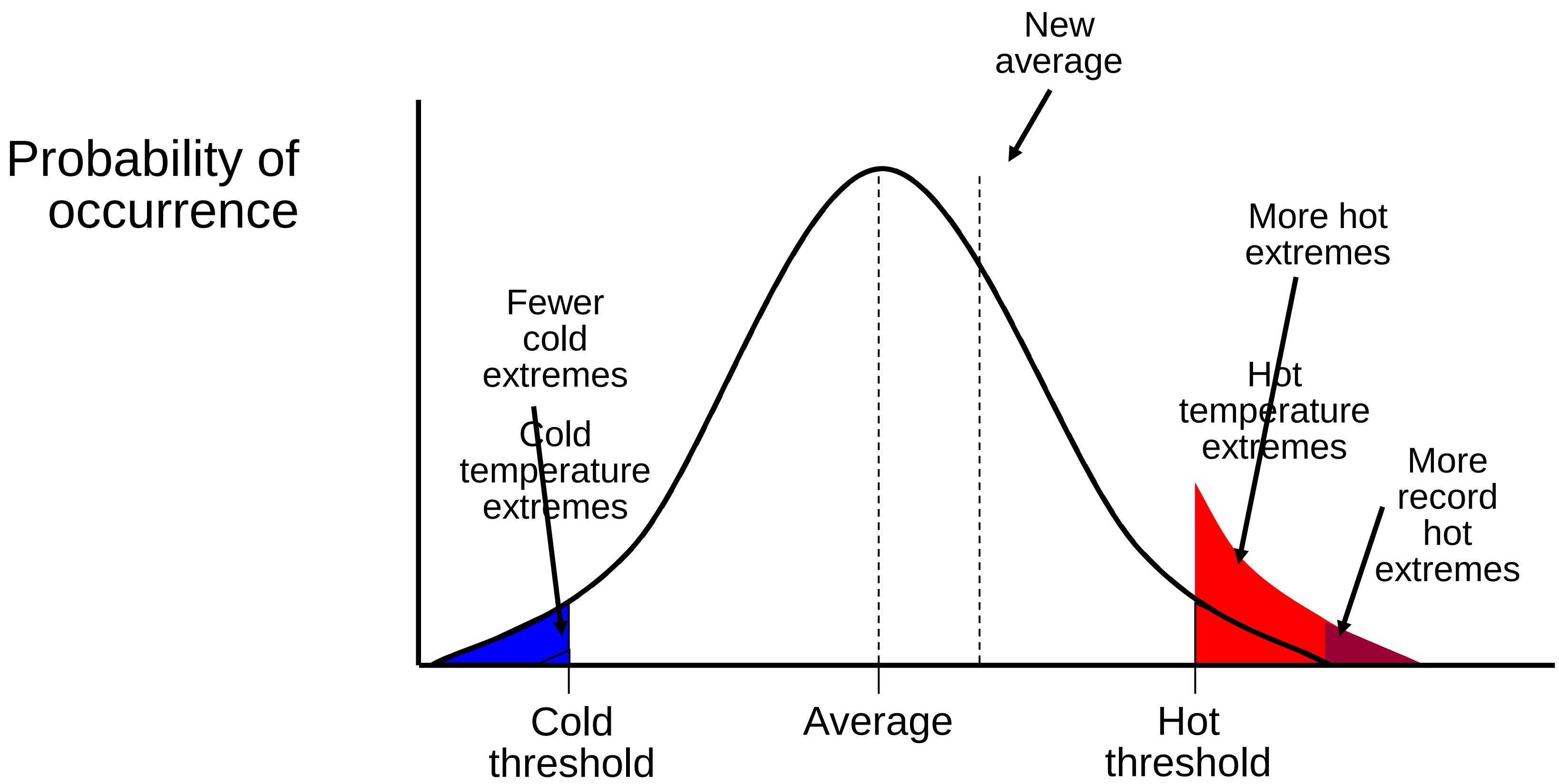




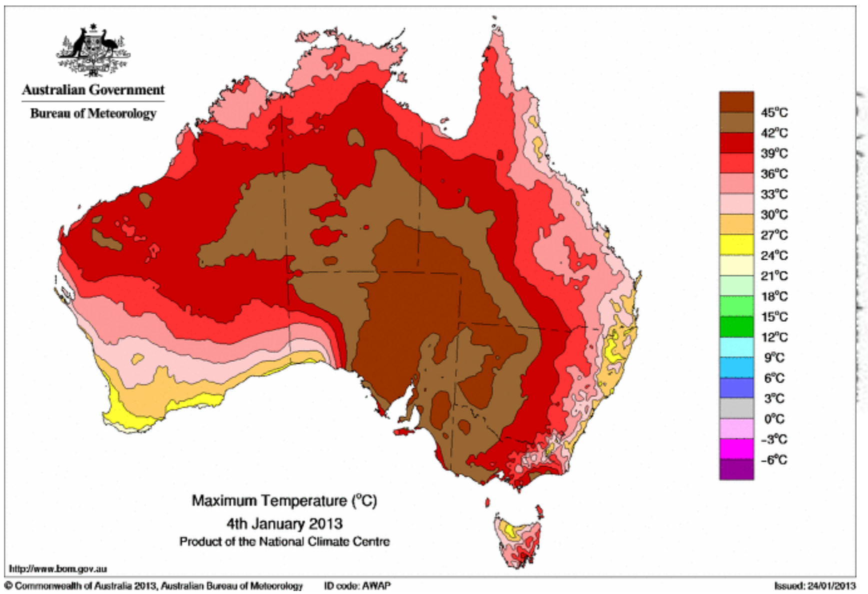
Stott, Stone, Allen, Nature 2004

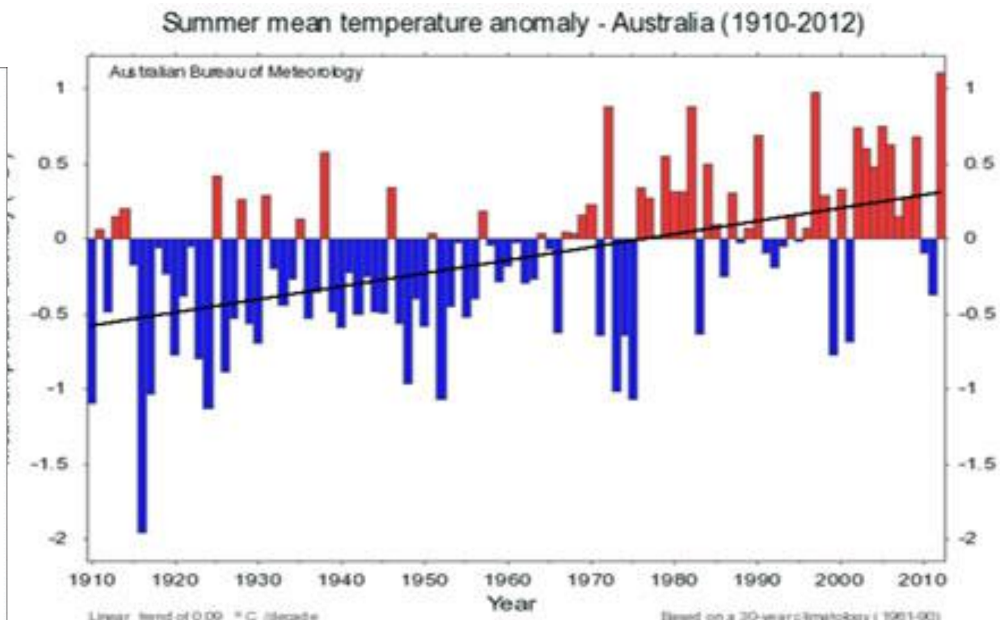
Change in Extremes in warming climate

- Temperature now
- Temperature in future



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.

But what about that wet summer ?

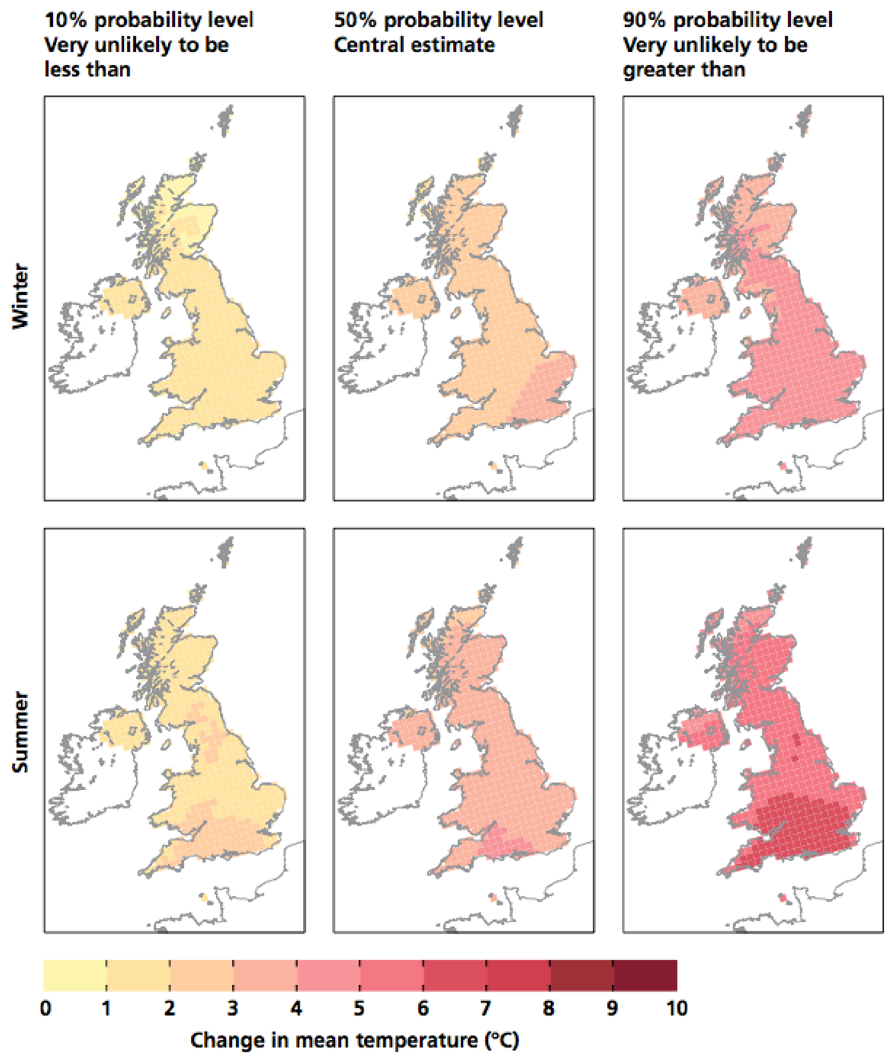


Figure 4.4: 10, 50 and 90% probability levels of changes to the average daily mean temperature (°C) of the winter (upper) and summer (lower) by the 2080s, under Medium emissions scenario. (Note that individual maps are from the User Interface, but this does not allow maps to be grouped as shown here).

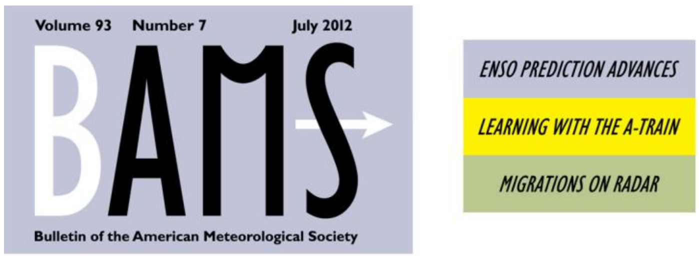
Headlines:

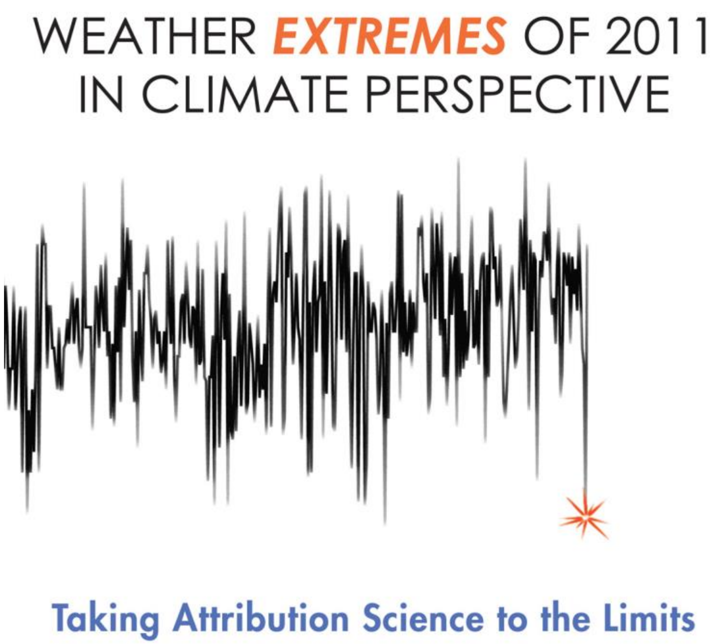
Hotter drier summers

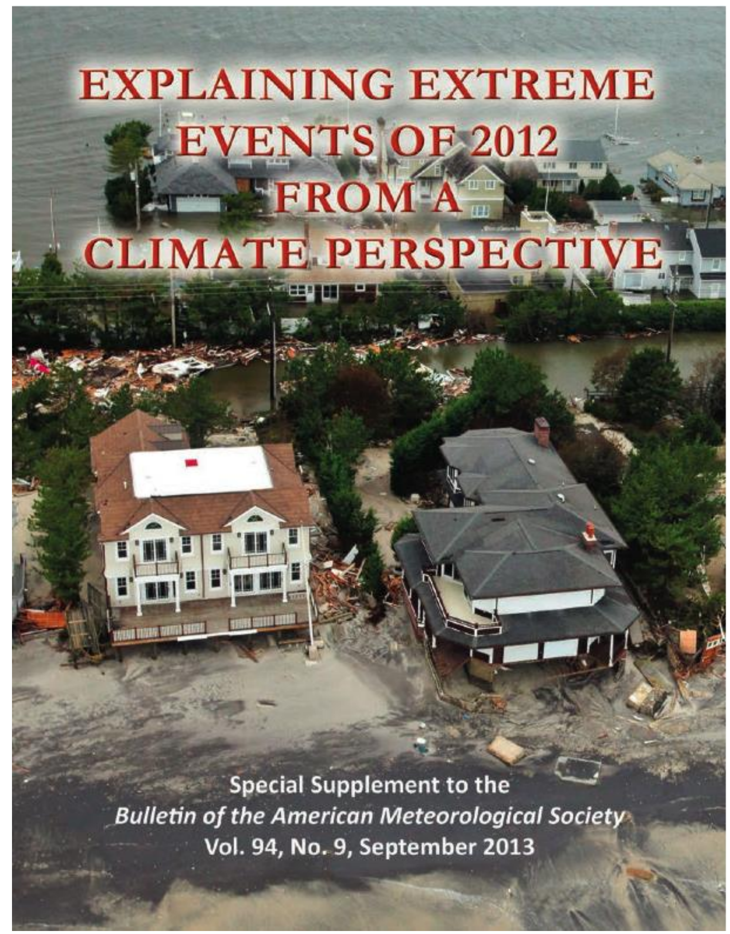
Warmer wetter winters

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

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



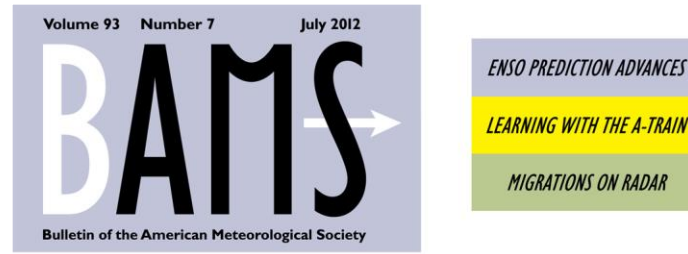




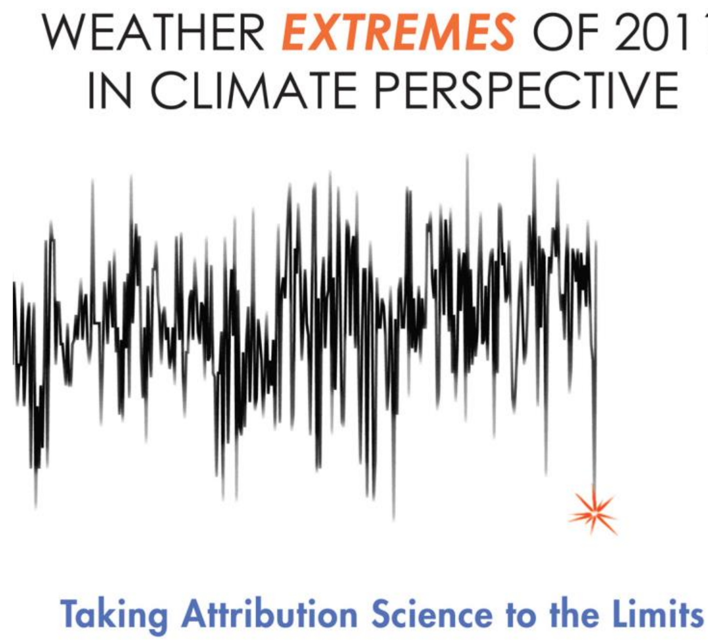
Explaining extreme events of the previous year from a climate perspective

Tom Peterson, Peter Stott, Stephanie Herring (Editors)

BAMS attribution supplement on Explaining Extreme Events of 2011 quickly became the most read paper on the BAMS website

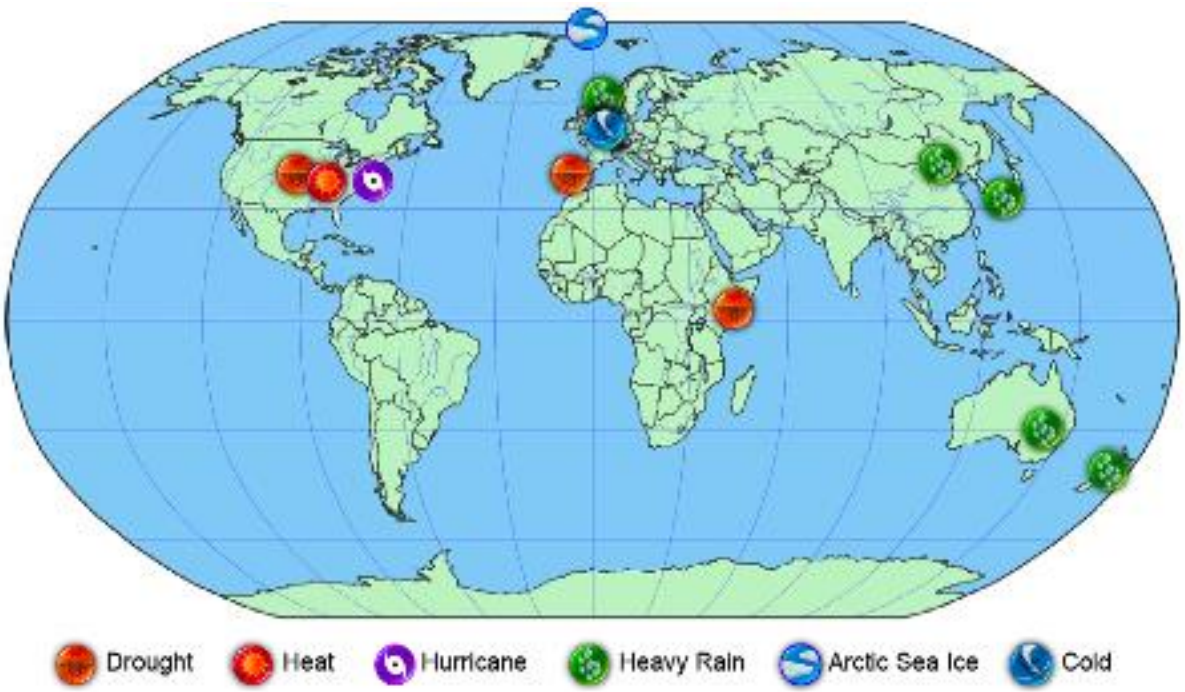


- Determining the causes of extreme events is difficult
- A goal of this paper is to foster the growth of the science
- Cannot say a particular event was or was not caused by climate change
- Can explain how the odds of such events have changed in response to global warming



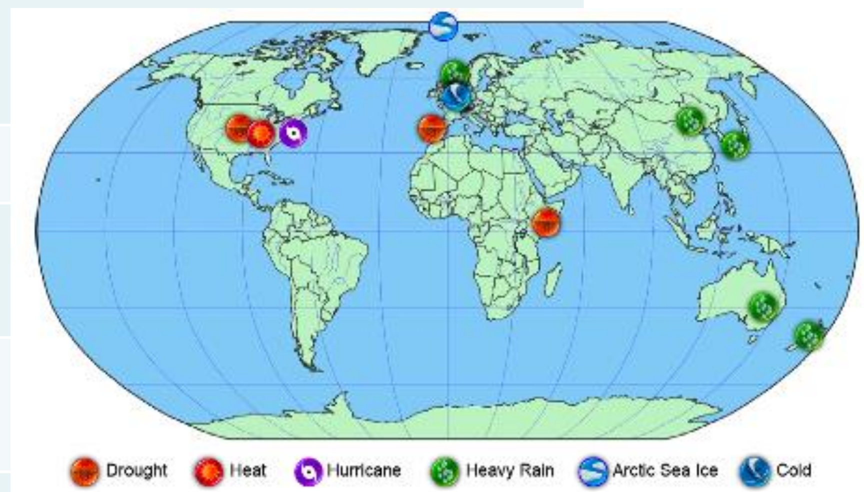
Explaining extreme events of 2012 from a climate perspective

Tom Peterson, Martin Hoerling, Peter Stott, Stephanie Herring (Editors)



- Increase from 6 contributions last year to 19 this
- 18 different research groups
- 12 extreme events
- Some events have multiple different groups looking at them

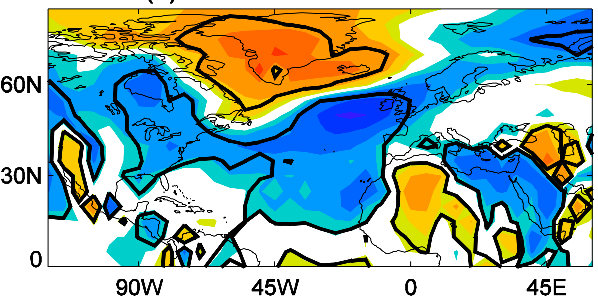
Extreme event	Evidence for anthropogenic influence ?
US heatwave	YES
Hurricane Sandy storm surge	YES
September Arctic sea ice minimum	YES
February European cold spell	NO
Wet UK summer	NO
Iberian winter drought	YES
Rainfall deficitits in Eastern Kenya and Southern Somaliia	NO
North China floods, July	NO
Heavy rainfall in Southwestern Japan, July	NO
Extreme rainfall over Eastern Australia, March	YES
Extreme rainfall, Goldan Bay, New Zealand, December 2011	YES
US drought	NO



Wet summer 2012

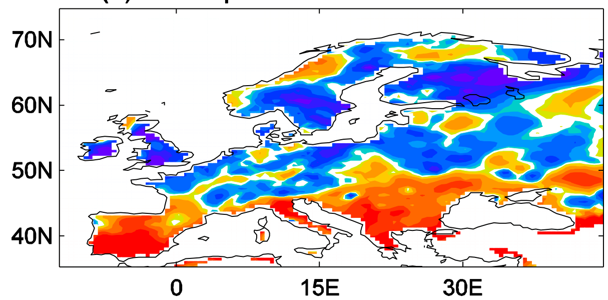
Sea level pressure 2012

(a) SLP anomalies in 2012



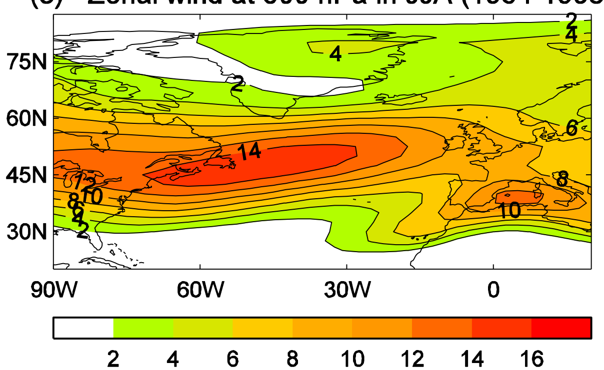
Precipitation 2012

(b) Precipitation anomalies in 2012



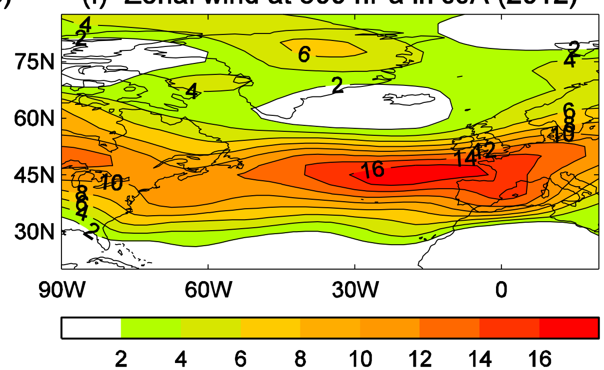
Zonal wind (climatology)

(e) Zonal wind at 500 hPa in JJA (1964-1993)



Zonal wind (2012)

(f) Zonal wind at 500 hPa in JJA (2012)

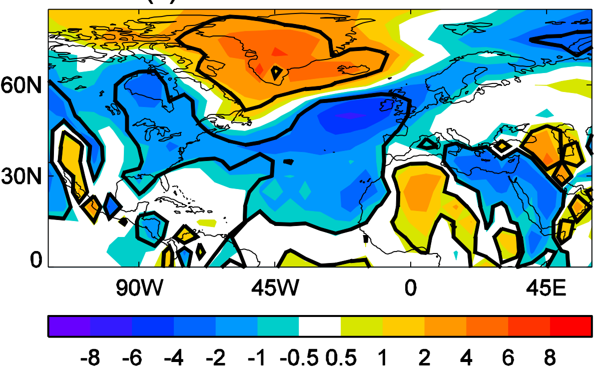


Dong et al, 2013

Wet summer 2012

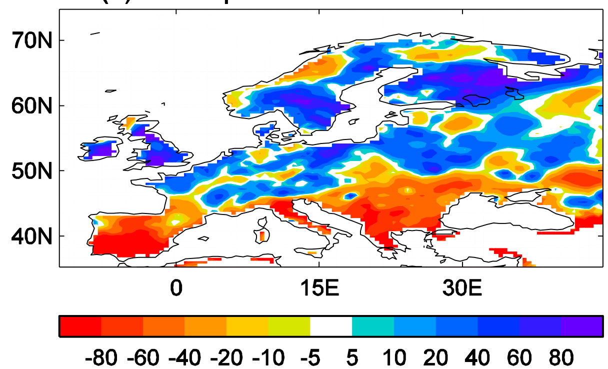
Sea level pressure 2012

(a) SLP anomalies in 2012



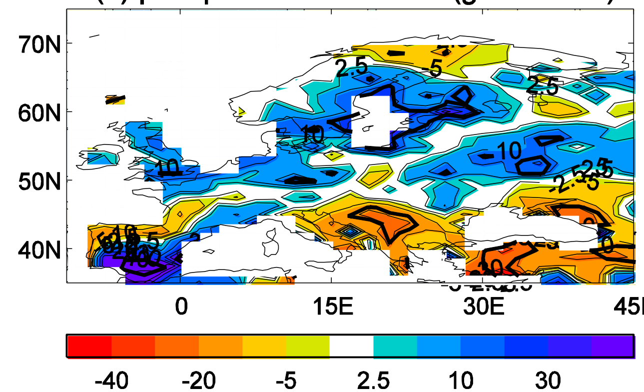
Precipitation 2012

(b) Precipitation anomalies in 2012



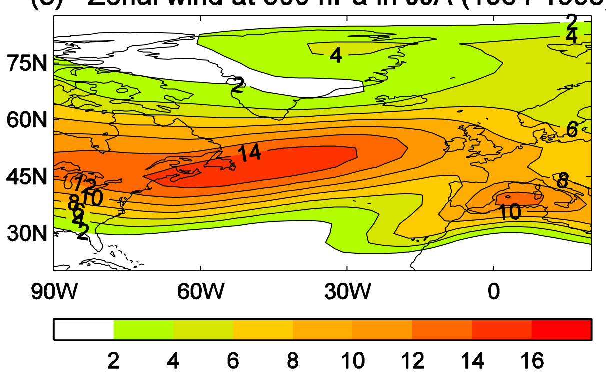
Simulated Precipitation

(d) precipitation anomalies (global SST)



Zonal wind (climatology)

(e) Zonal wind at 500 hPa in JJA (1964-1993)



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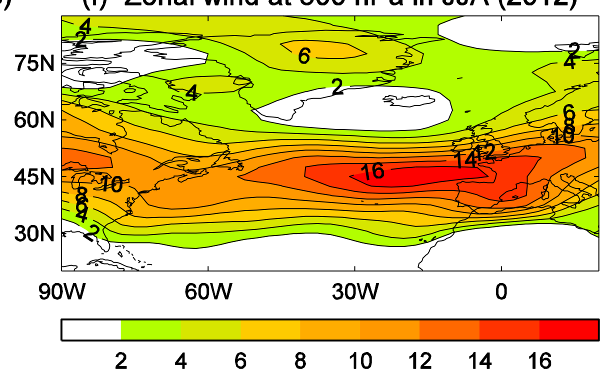
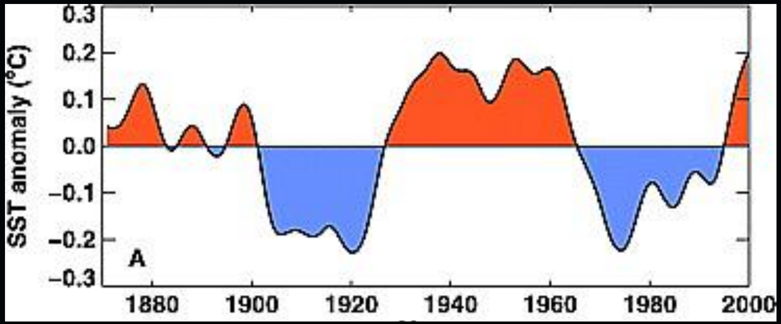
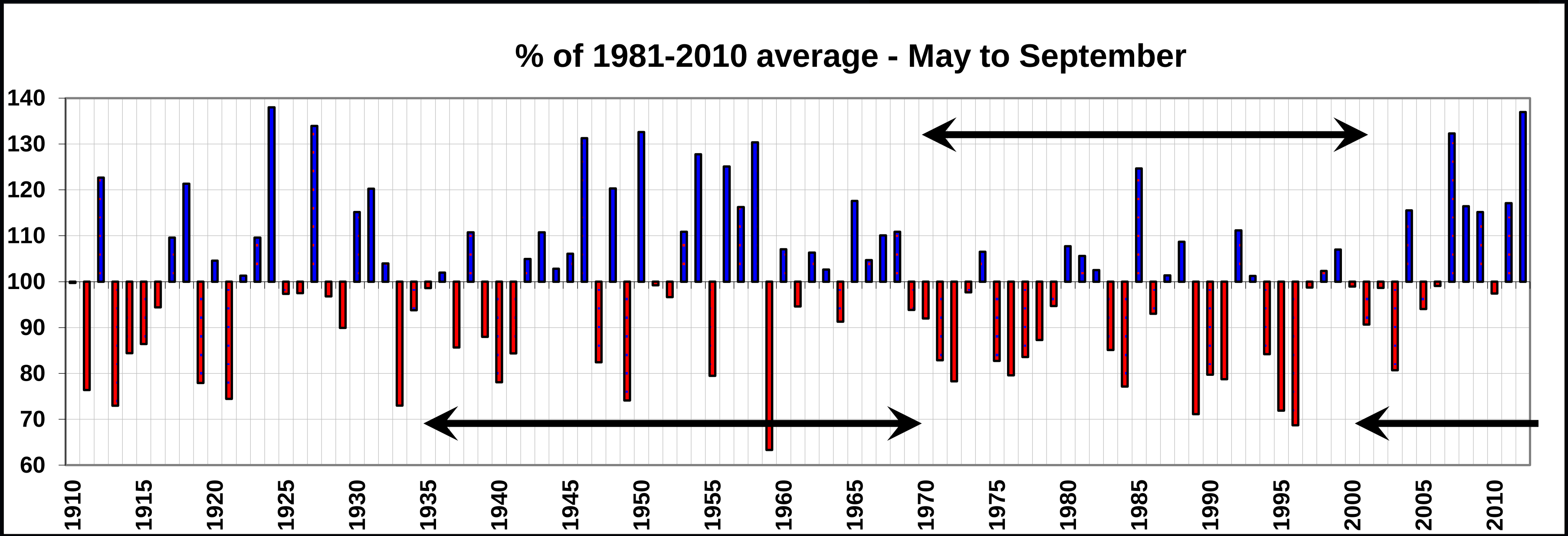


Dong et al, 2013

Summer 2012

- Long term natural cycle
  - Atlantic sea surface temperature
  - Shifts jet stream





Met Office
Hadley Centre

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

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

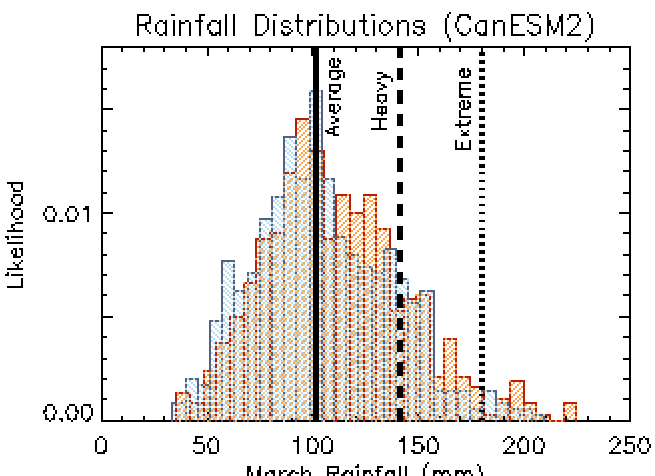
Calculate changed probability of occurrence of such an extreme rainfall total.

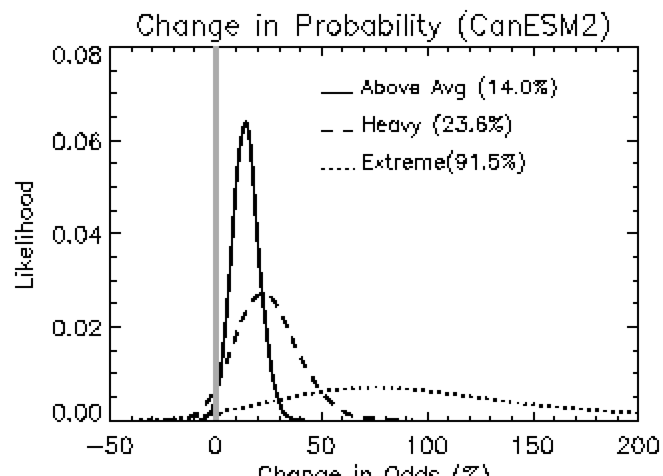
Strong La Nina contribution with some evidence for effect of anthropogenic warming increasing the odds.

Christidis et al, 2013

March Rainfall Distribution

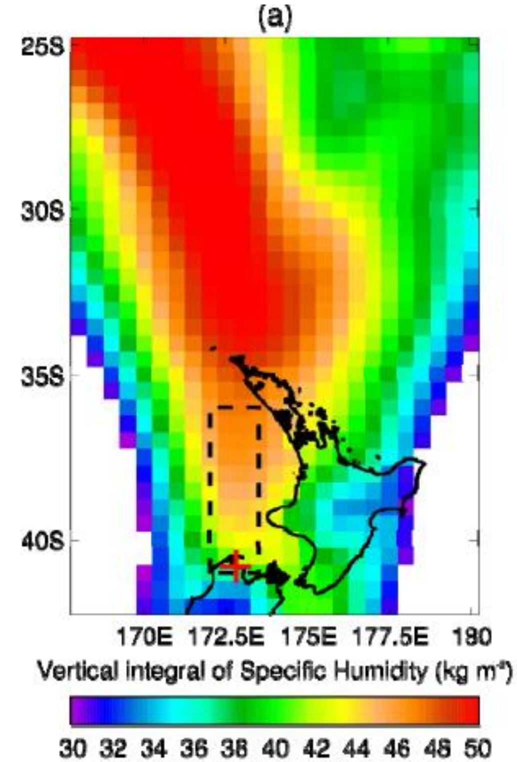
ALL & NAT





Golden Bay New Zealand Extreme rainfall event

Dean et al, 2013



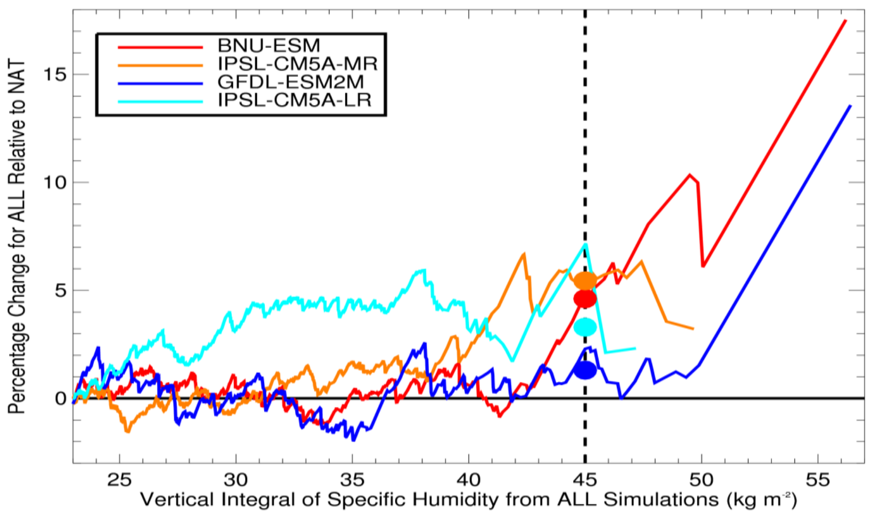
Very heavy rain and landslides, Golden Bay, New Zealand, 14th December, 2011

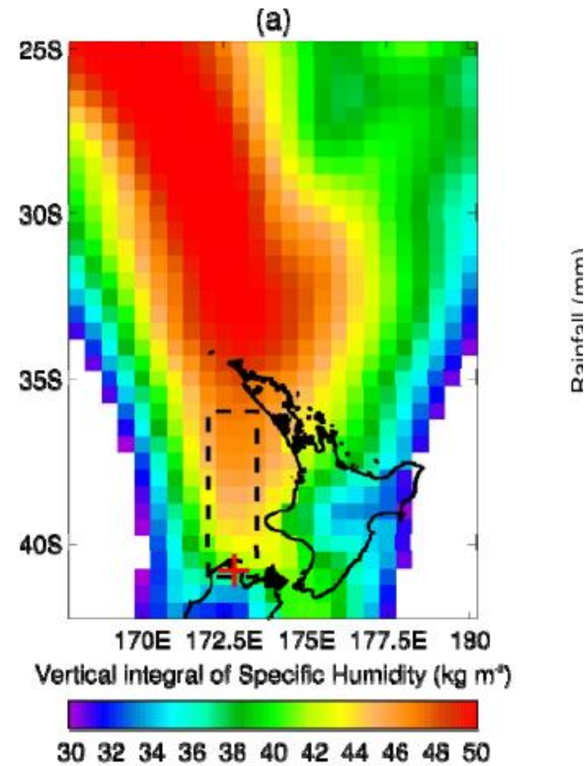
An example of an atmospheric river bringing very high levels of moisture and extreme rainfall to a mid latitude location

Met Office
Hadley Centre

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

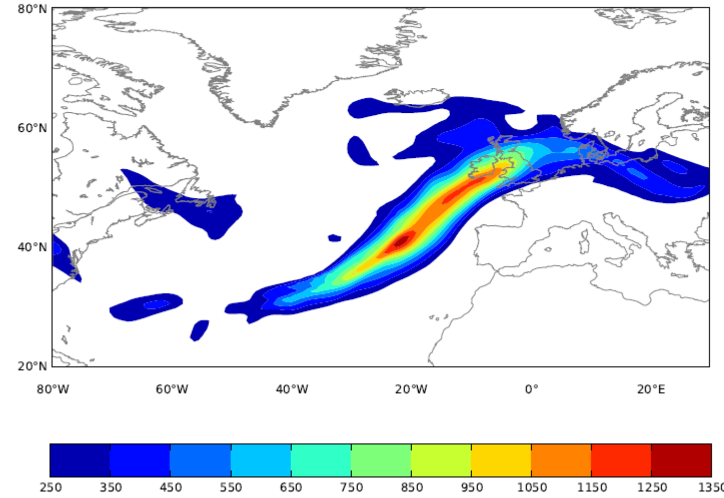
Narrow bands of intense moisture flux in the lower troposphere

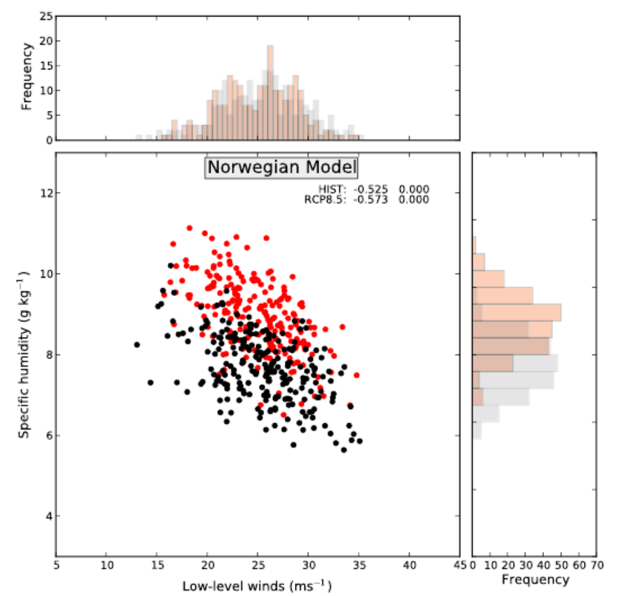
- Associated with periods of heavy rainfall and many of the largest floods in mid latitudes

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

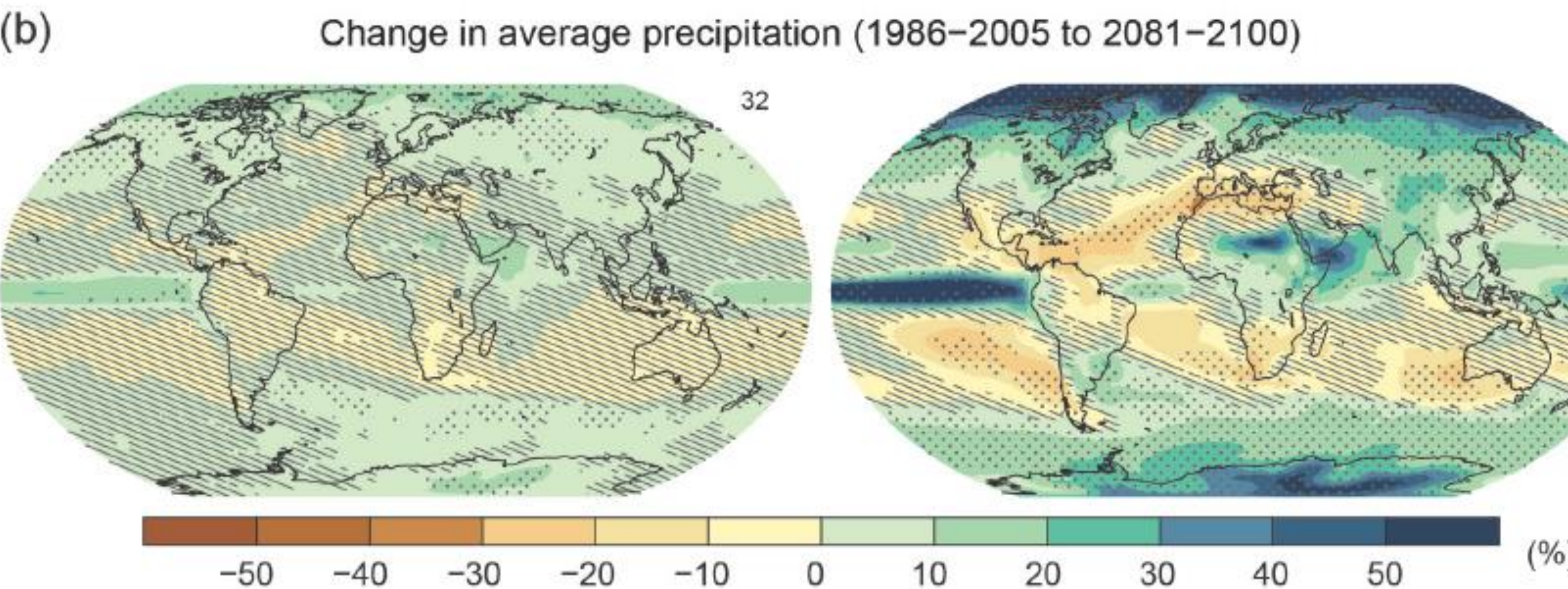
- This is predominantly a thermodynamic response to warming resulting from anthropogenic forcing

- Lavers et al, 2013. ERL, 8, 034010.

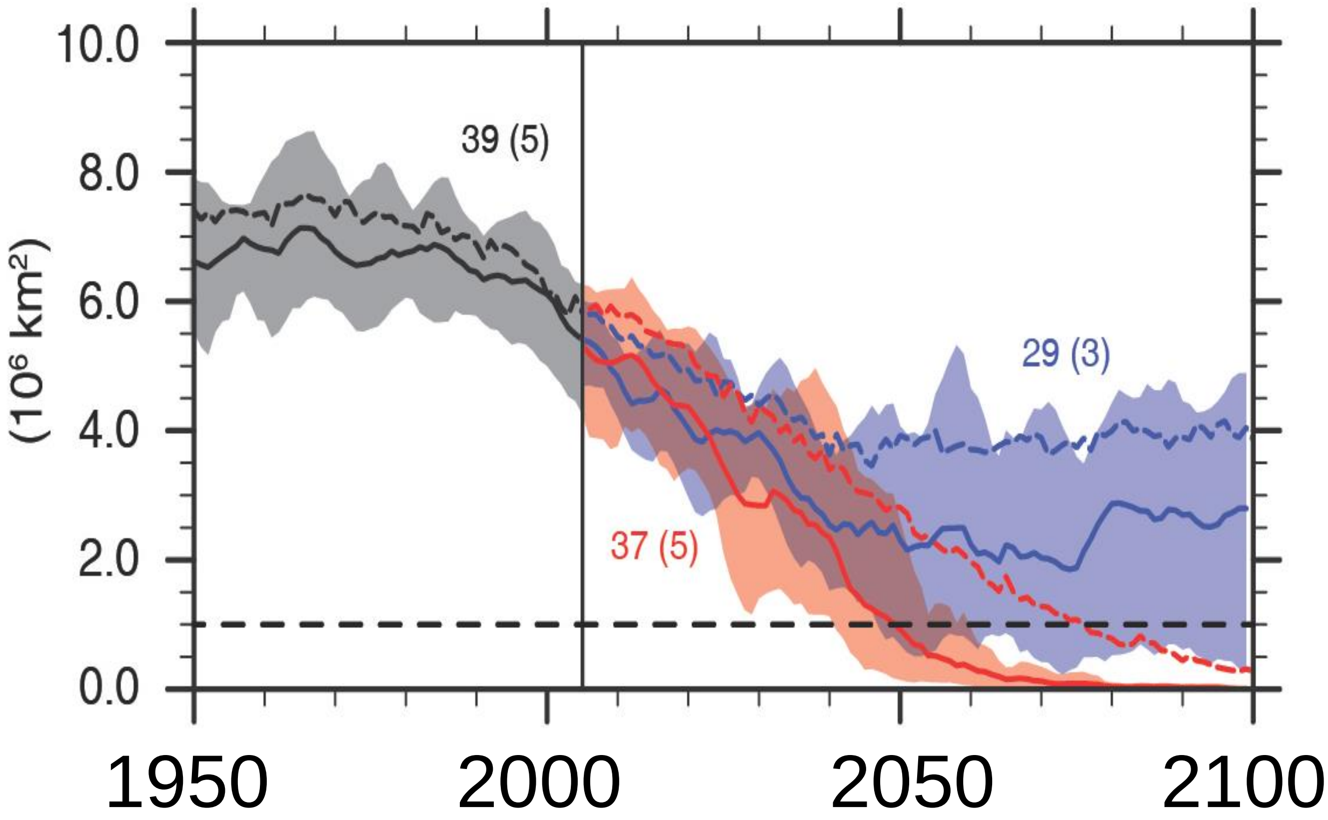




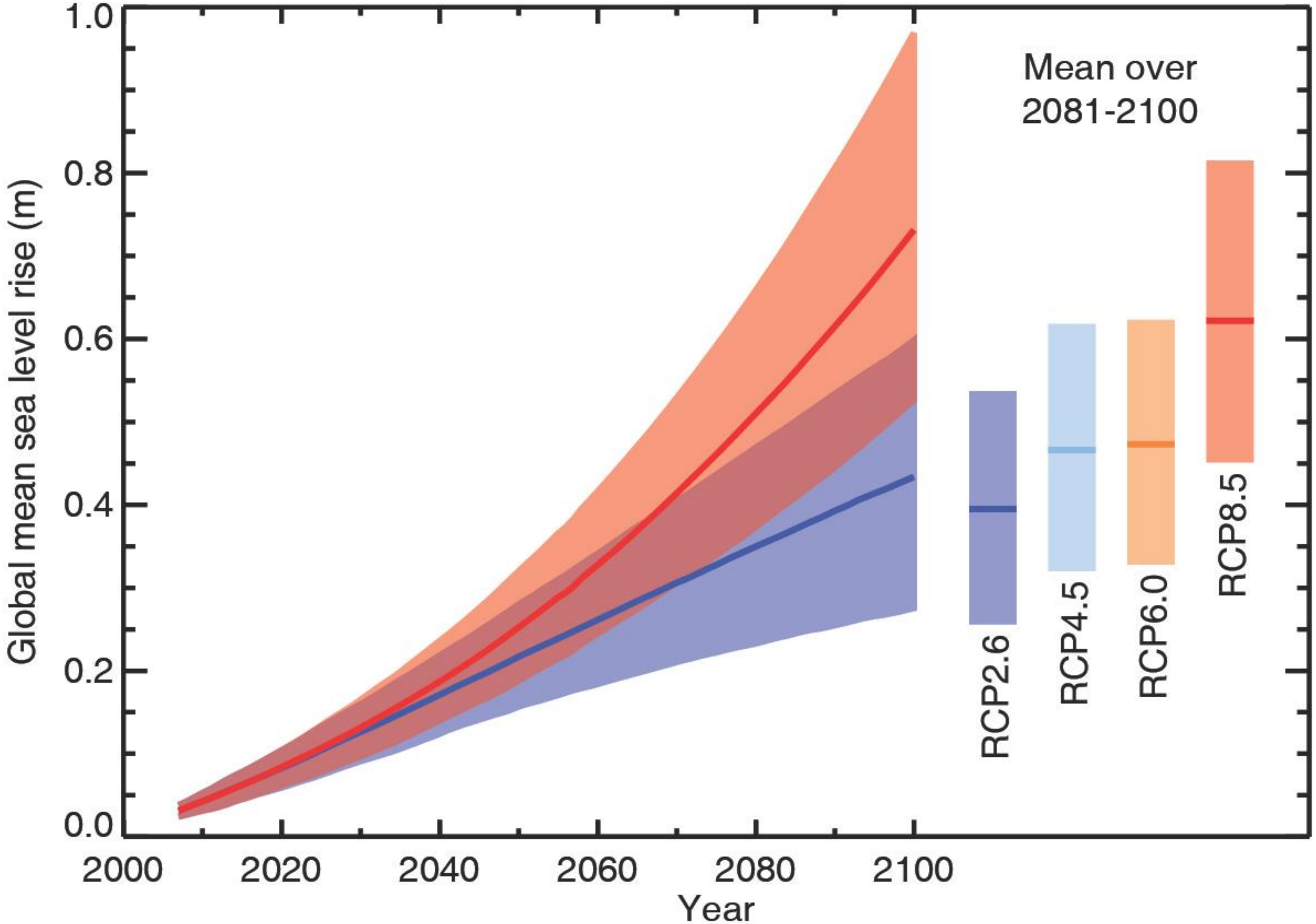
Rainfall patterns are projected to continue to change leading to more frequent droughts in some regions and more floods in others.



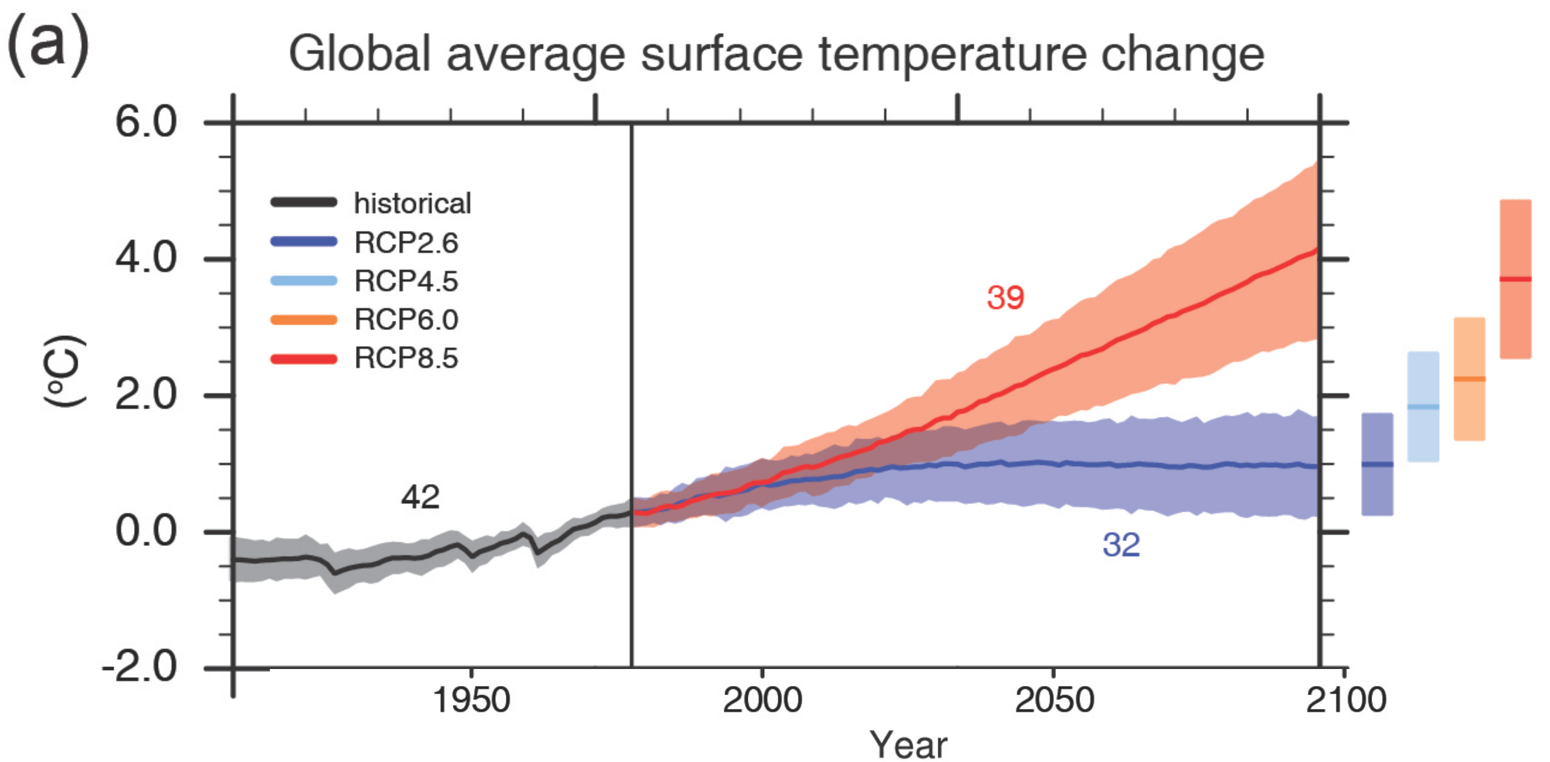
Arctic sea ice in September could be gone by 2050



Sea level rise will continue



But the extent of climate change depends on future greenhouse gas emissions



Human influence on the climate system is clear

- Better understanding of the changing risks of extreme weather will help people cope with the effects of anthropogenic climate change.
- Extreme weather and seasons result from the interplay of natural climate variability and anthropogenic climate change.
- At the Met Office we are developing an “operational attribution” system to assess the risks of such extremes on a regular basis.
- A new annual report provides puts extreme weather from last year in different regions of the world into the context of natural climate variability and anthropogenic climate change.