

How might extratropical storms change in the future?

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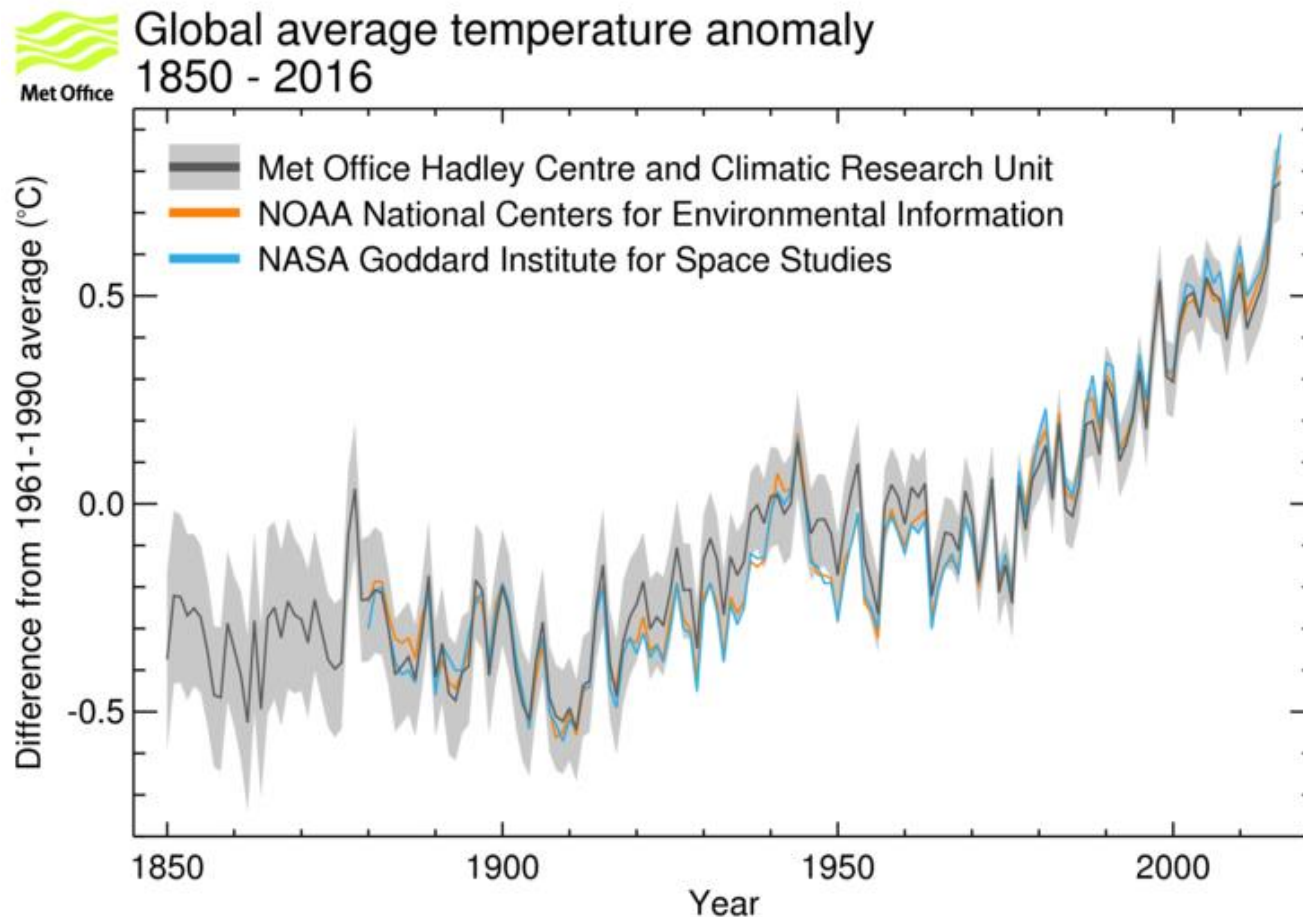


- Extratropical storms
 - Strong winds, extreme waves, storm surge, heavy rainfall,...
 - Wind, wave and flood damage; evacuating platforms; disruption to operations, etc...



1. Have we observed any changes in extratropical storms?
2. How might storms respond to climate change?
3. Future research

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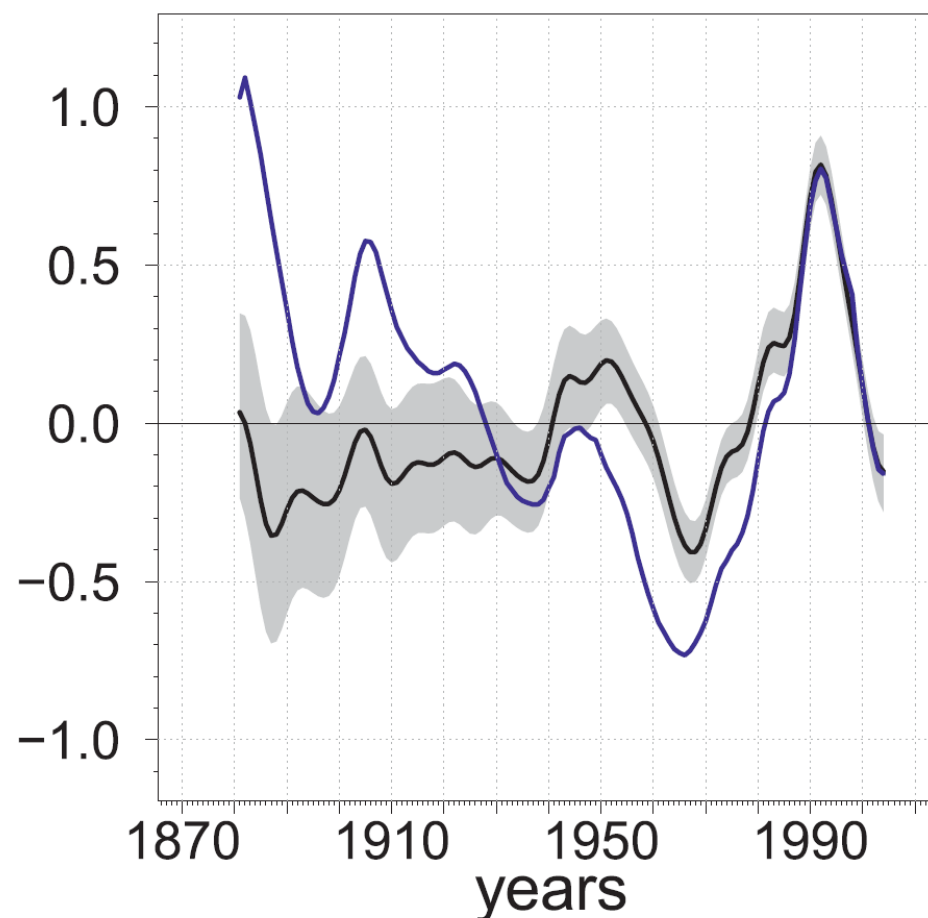


Global average temperature anomalies (1850-2016)
Source: Met Office www.hadobs.org

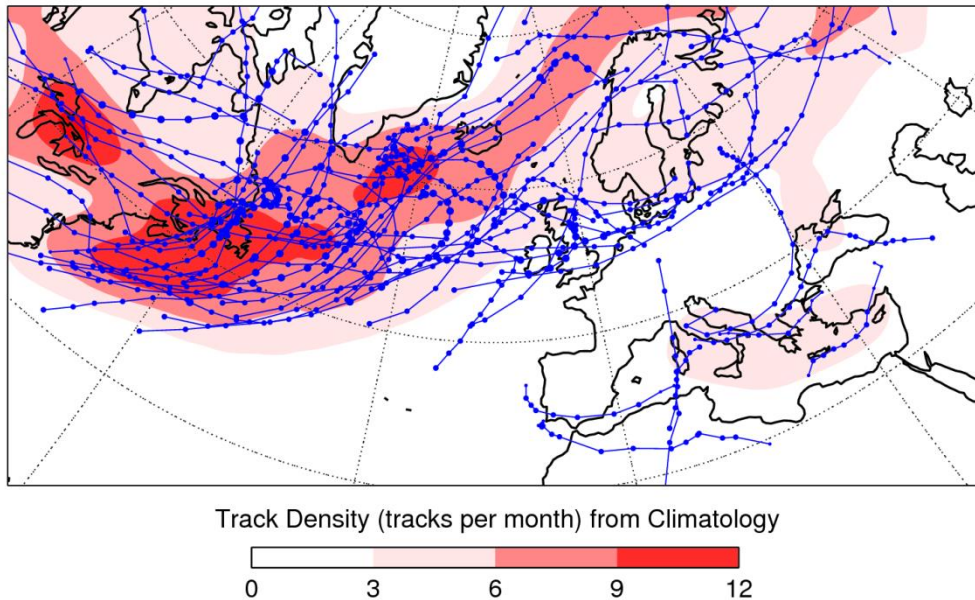
Early 20th century and 1980s -1990s were stormy periods in Europe

Some datasets show an increase in winter storminess in NW Europe since 1900 but trends are small compared to variability

Krueger et al. (2013): Low-pass filtered timeseries of 95th percentile European geostrophic winds from station data (blue) and 20CR reanalysis (black)



1. Have we observed any changes in extratropical storms?
2. How might storms respond to climate change?
 - Are climate models fit for purpose?
 - If so, what do they say about the climate change?
3. Future research

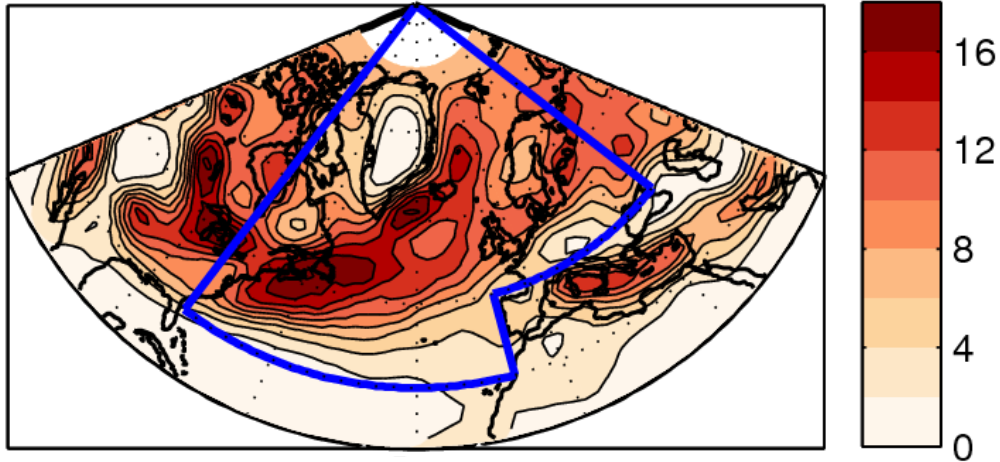


Hodges (1995) cyclone tracking algorithm using 6-hourly 850hPa vorticity

Courtesy of Tim Woollings

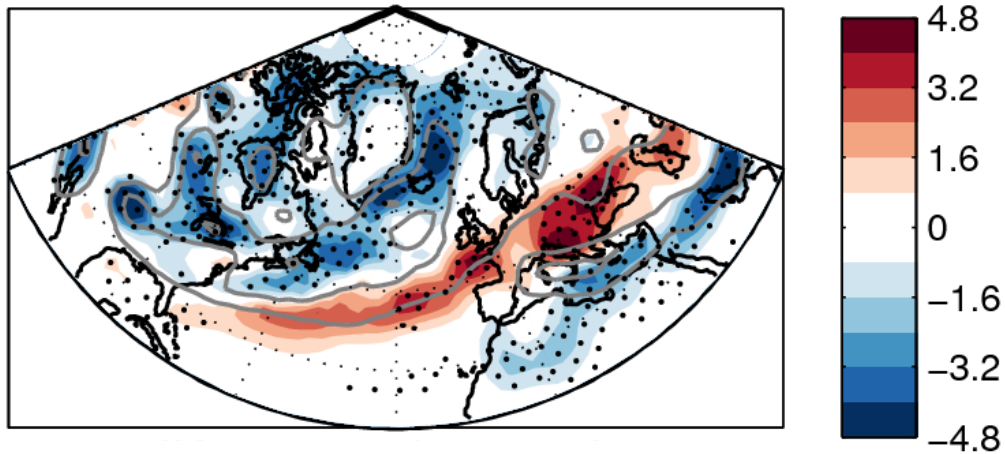
The high-frequency model output required to track cyclones in multiple climate models wasn't available in 2008

djf track density



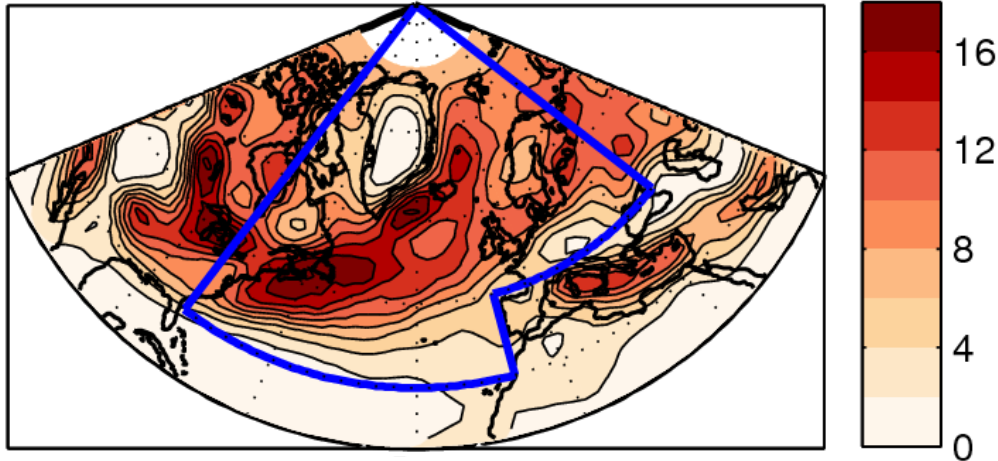
DJF ERA-Interim wintertime
cyclone track density (1990-2009)
(Tracks per month in a 5° radius)

djf track density



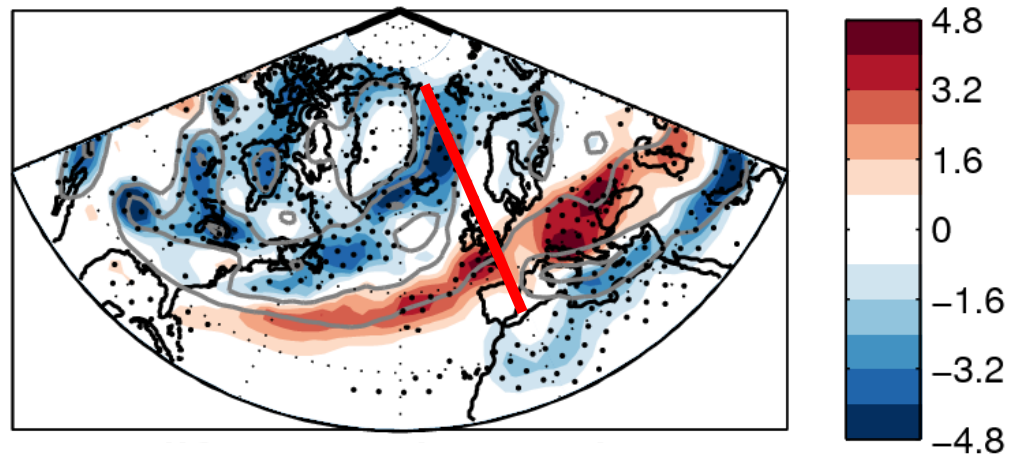
DJF CMIP5 historical model
mean biases against ERA-
Interim from 22 CMIP5 models

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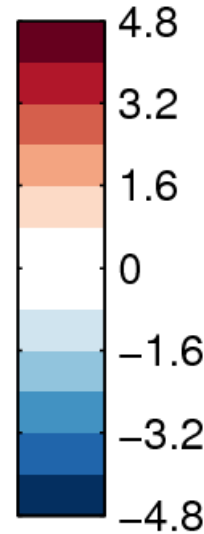
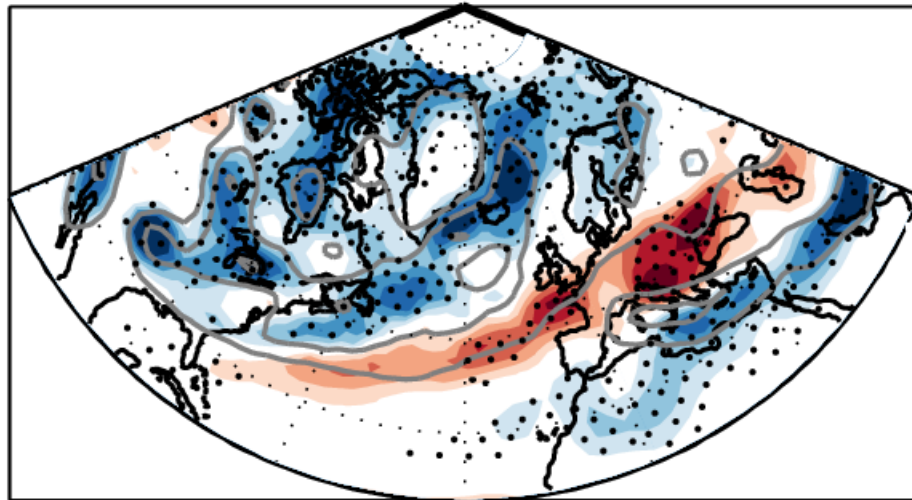
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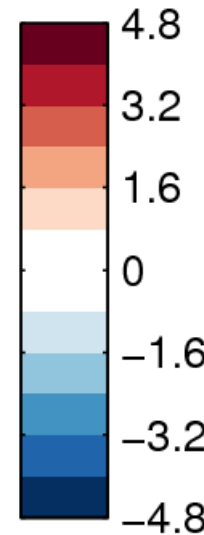
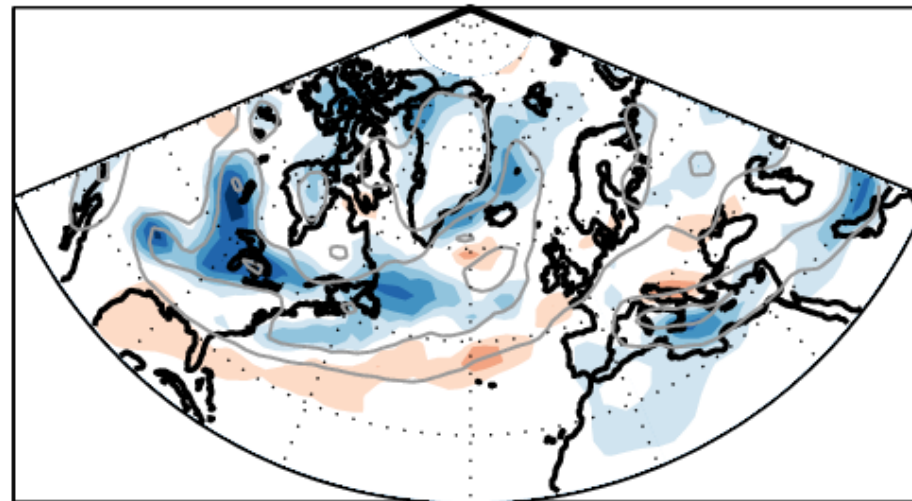
The latitude of the North
Atlantic storm track agreed
with ERA-Interim in 4 models

djf track density



DJF CMIP5 present day model biases
against ERA-Interim: Cyclone Track
density

tden Small errors



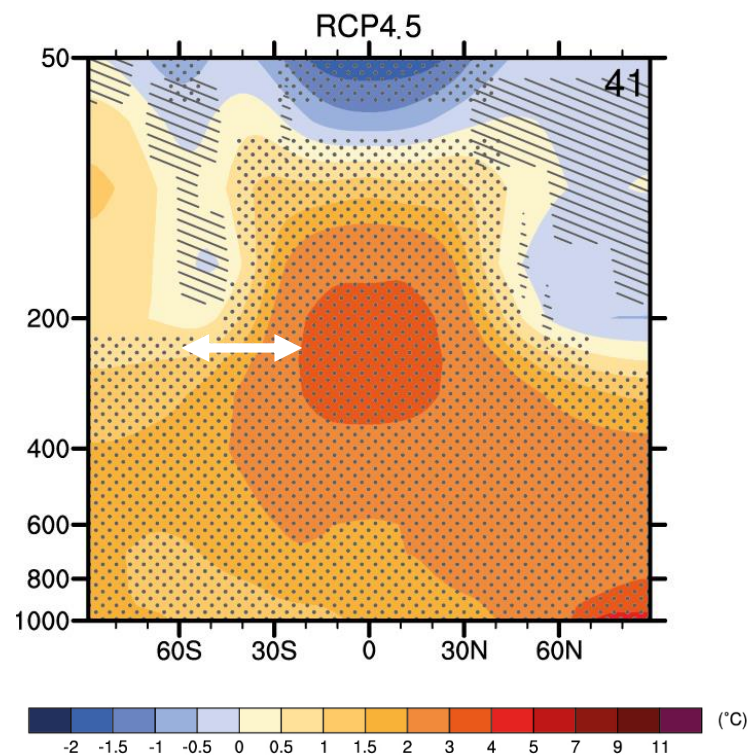
DJF CMIP5 present day model biases
against ERA-Interim for 4 models with
smallest biases

What impact will climate change have on extratropical storms?

Why do we have storms anyhow?

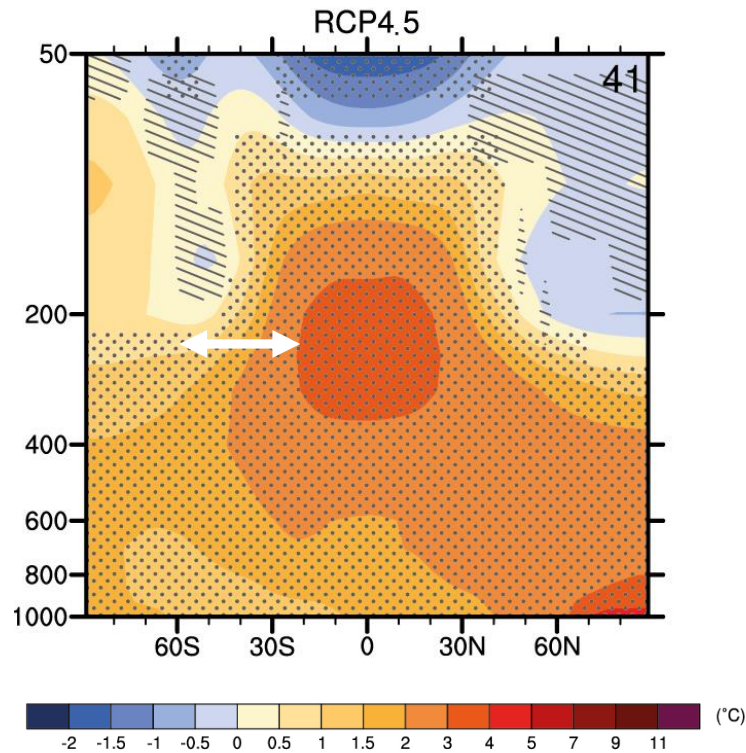


The Fourth IPCC Assessment Report focused on the **poleward shift** in the zonal mean jetstreams and storminess

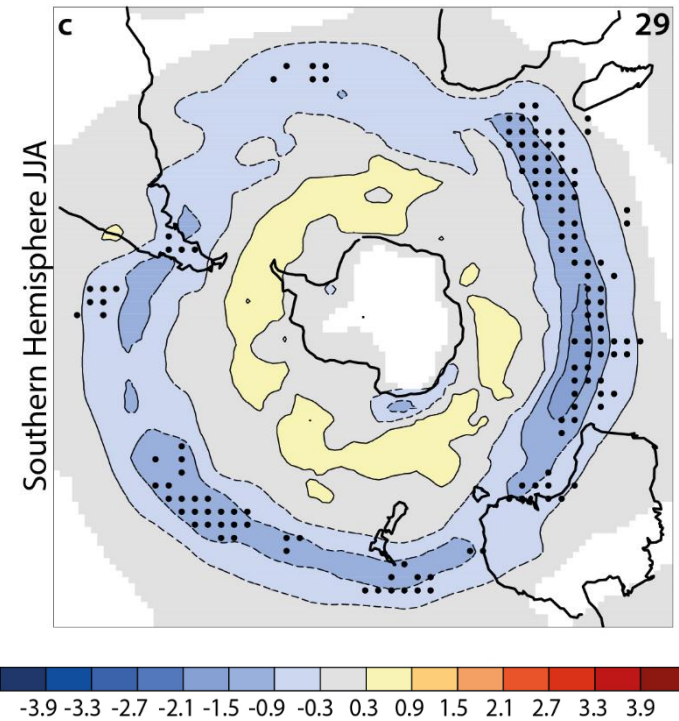


Zonal and annual mean temperature differences for 2080-2099 minus 1980-2005 from the CMIP5 models (IPCC AR5, 2013)

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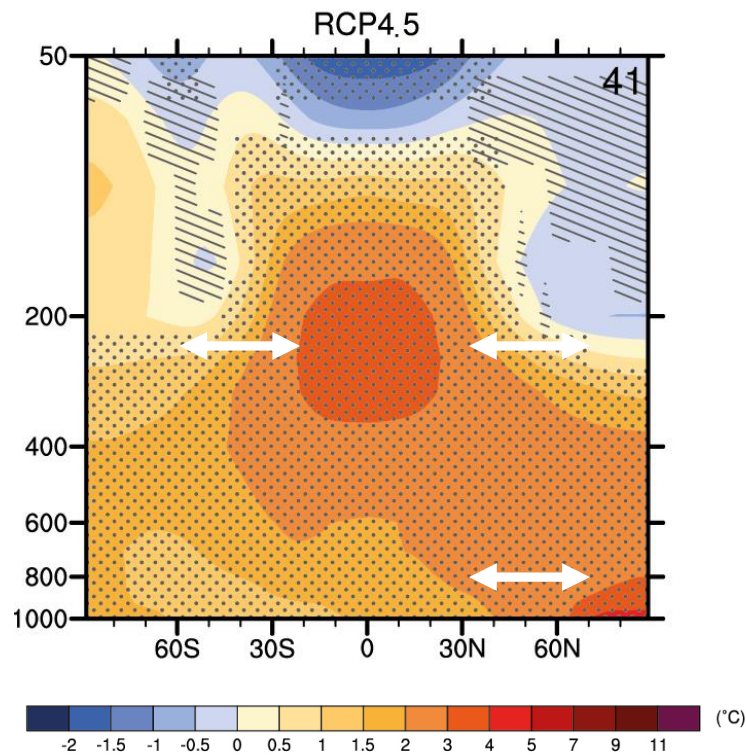


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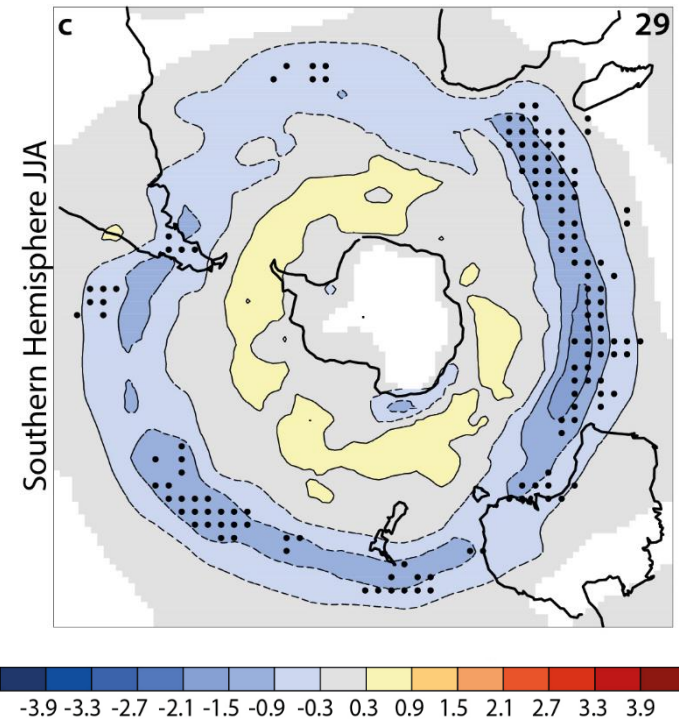


JJA SH cyclone track density differences for 2080-2099 minus 1980-2005 from the CMIP5 models (IPCC AR5, 2013)

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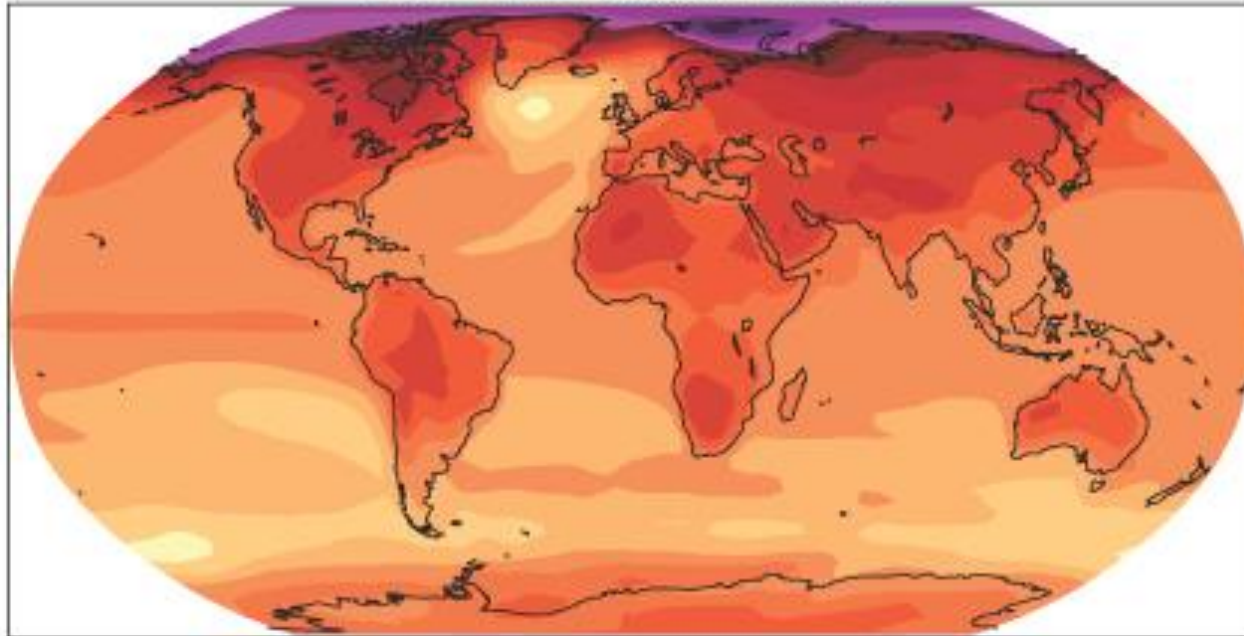


Zonal and annual mean temperature differences for 2080-2099 minus 1980-2005 from the CMIP5 models (IPCC AR5, 2013)



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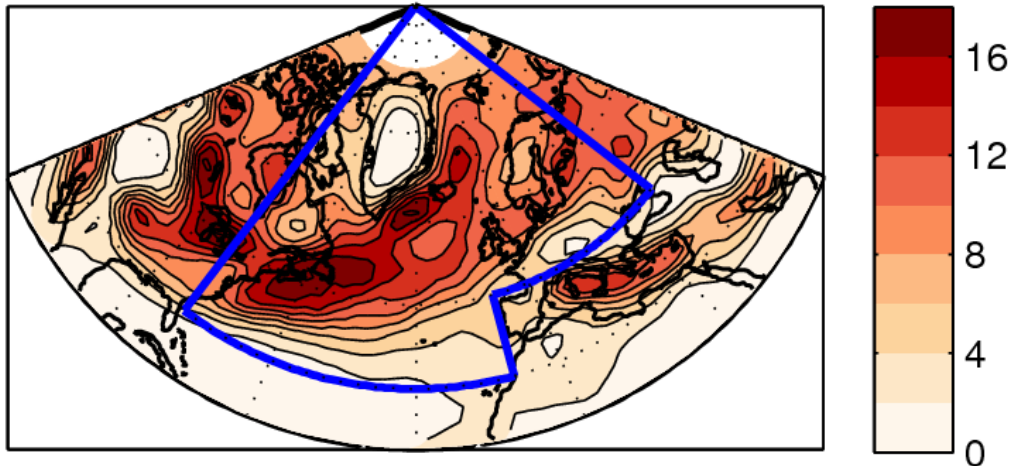
A1B: 2080-2099



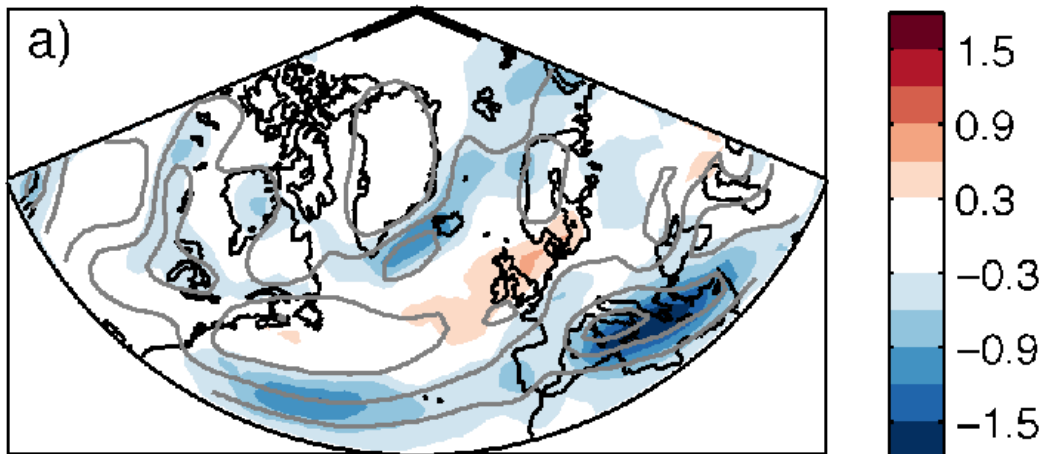
Annual mean surface temperature differences for 2080-2099
minus 1980-1999 from the CMIP3 models(IPCC AR4, 2007)

NH Reduced Equator to Pole temperature difference –
less storms

Reduced warming in the North Atlantic Ocean



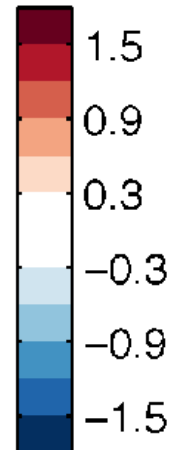
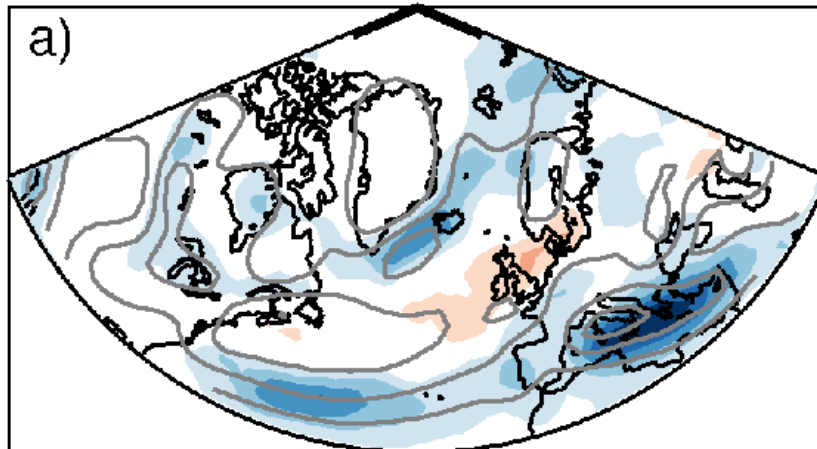
ERA-Interim DJF cyclone track density.
Units: Number of storms per month
per 5° radial cap



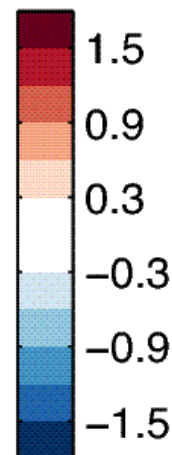
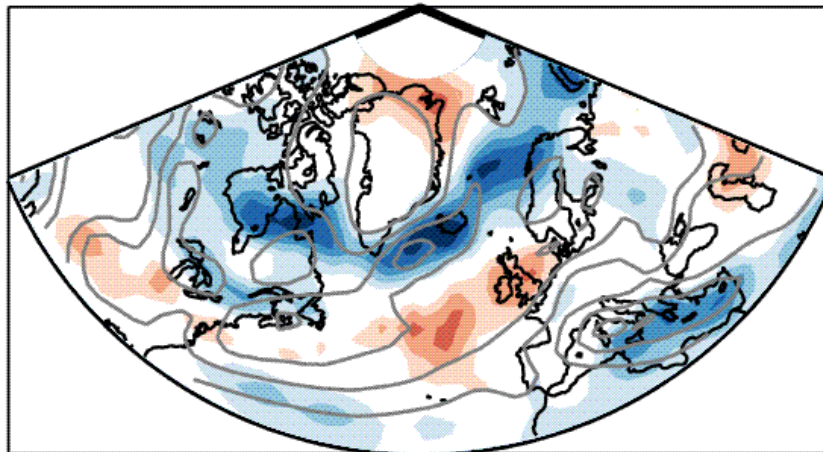
CMIP5 cyclone track density: RCP4.5
Scenario (2070-2100) minus Historical
(1980-2005)

Fewer Scandinavian and
Mediterranean cyclones

track density

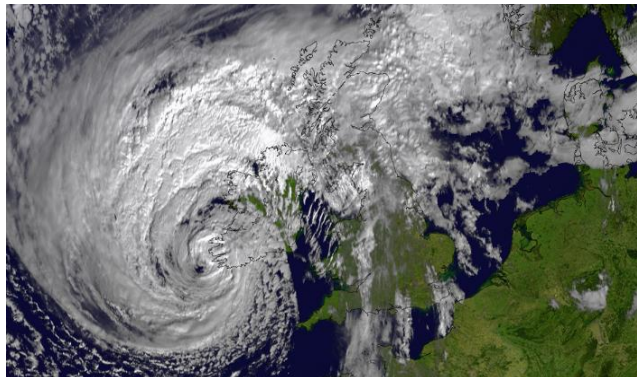


CMIP5 cyclone track density: RCP4.5
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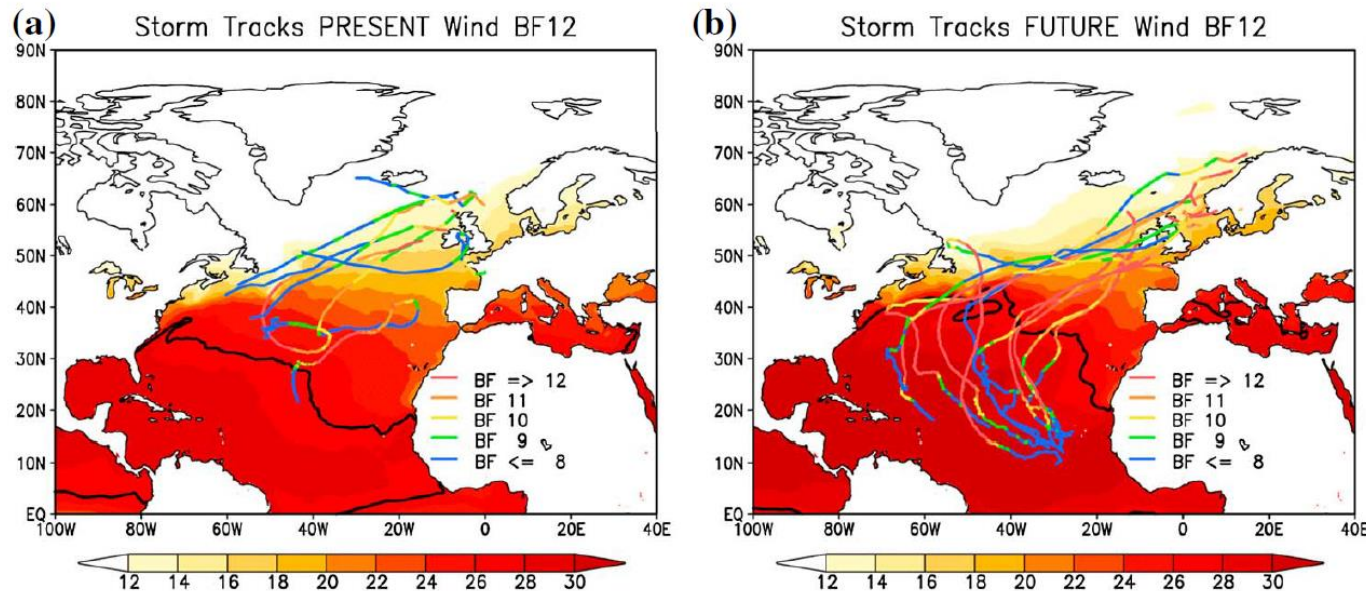
CMIP5 cyclone track density: RCP4.5
Scenario (2070-2100) minus
Historical (1980-2005) for the Small
Biases climate models

- i. Better understanding drivers of change e.g. Arctic Amplification, North Atlantic ocean circulation,...
- ii. Will storms get stronger? Competing effects of increased moisture and temperature gradient
- iii. CMIP6 and higher resolution climate model projections (e.g. HiResMIP)



Tropical-extratropical transitions

Climate models typically have resolutions of approx. 100km and can't resolve Tropical Cyclones. However, computing power is increasing all the time...



25km resolution climate model results suggest that tropical-extratropical transitions may become more frequent under climate change, Haarsma et al. (2013)

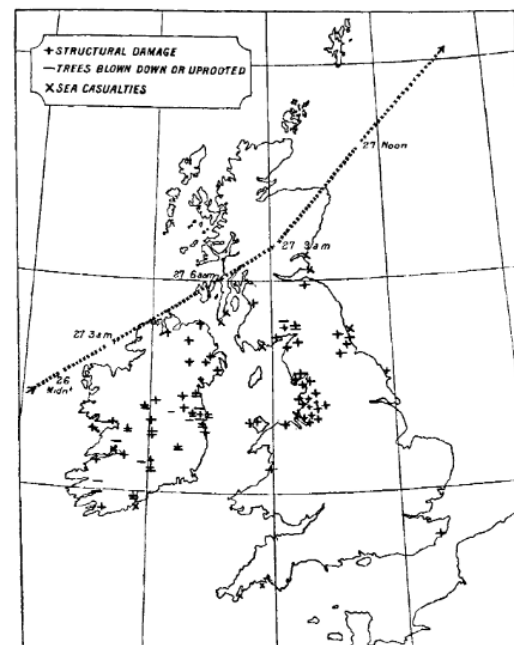
1. Have we observed any changes in extratropical storms?
Some datasets show an increase in storminess in NW Europe since 1900 but trends are small compared to the variability
2. How might storms respond to climate change?
SH: Poleward shift of the storminess
NH: Reduction of storminess over the Northern Hemisphere, but an increase over North Western Europe
3. Future research
 - i. Will storms get stronger? Competing effects of increased moisture and temperature gradient
 - ii. CMIP6 and higher resolution climate model projections

Ulysses storm 26 February 1903

Inspired a passage in Joyce's Ulysses;
3000 trees uprooted in Phoenix Park

Can we learn more about past storms?

Observatory at the summit of Ben
Nevis (1883-1904)



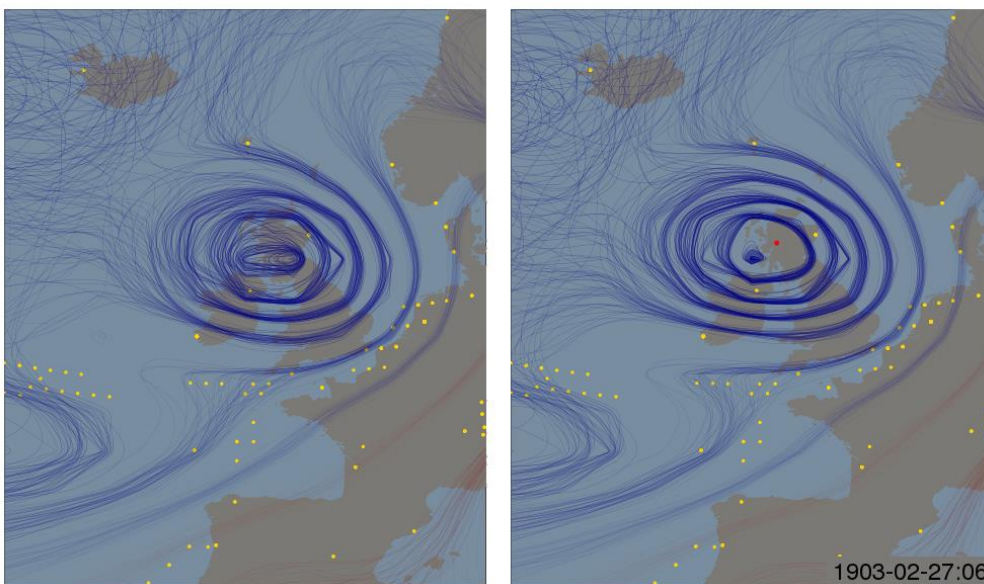
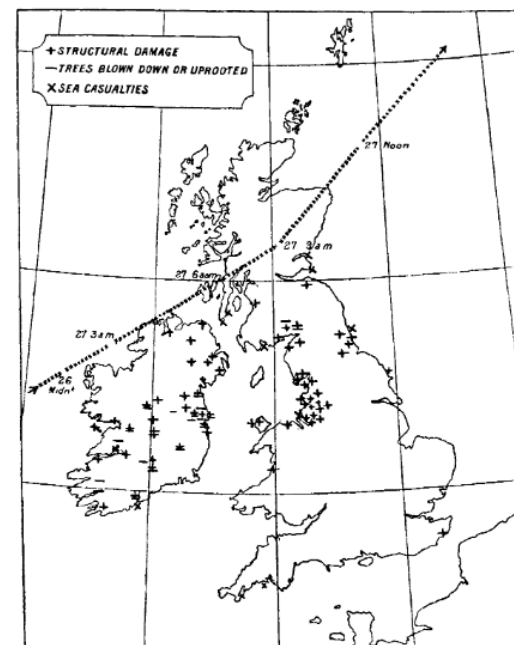
Ben Nevis observations
digitised as part of the
Operation Weather Rescue
citizen science project
www.weatherrescue.org

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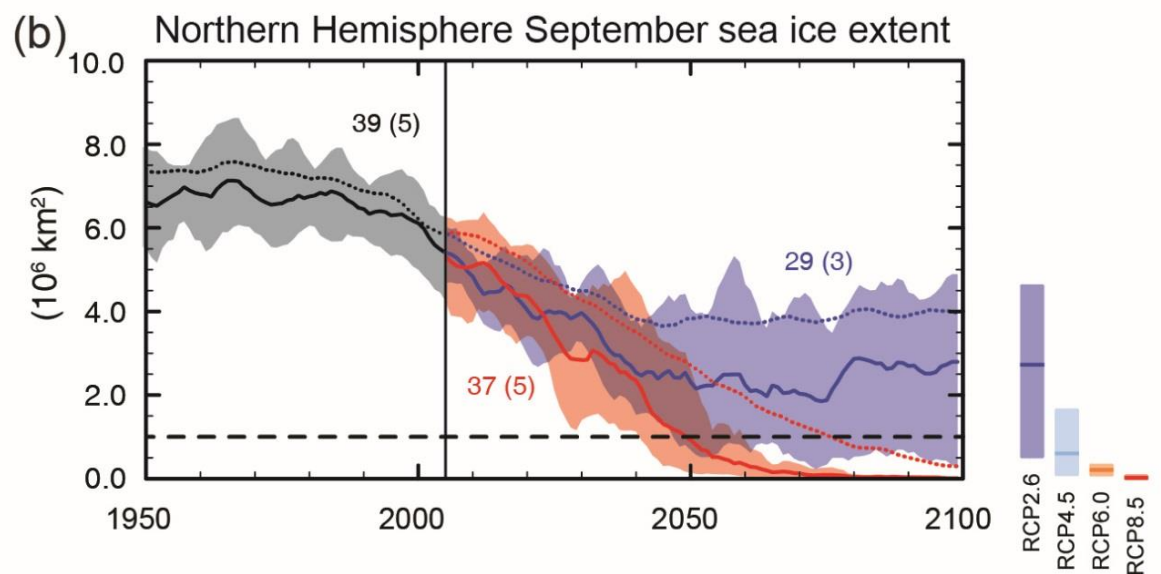
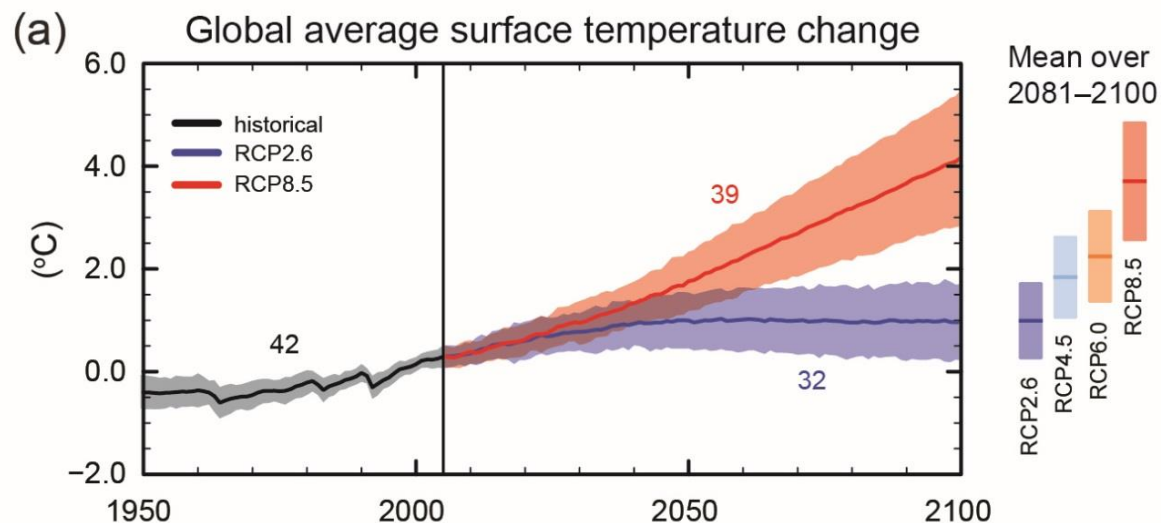
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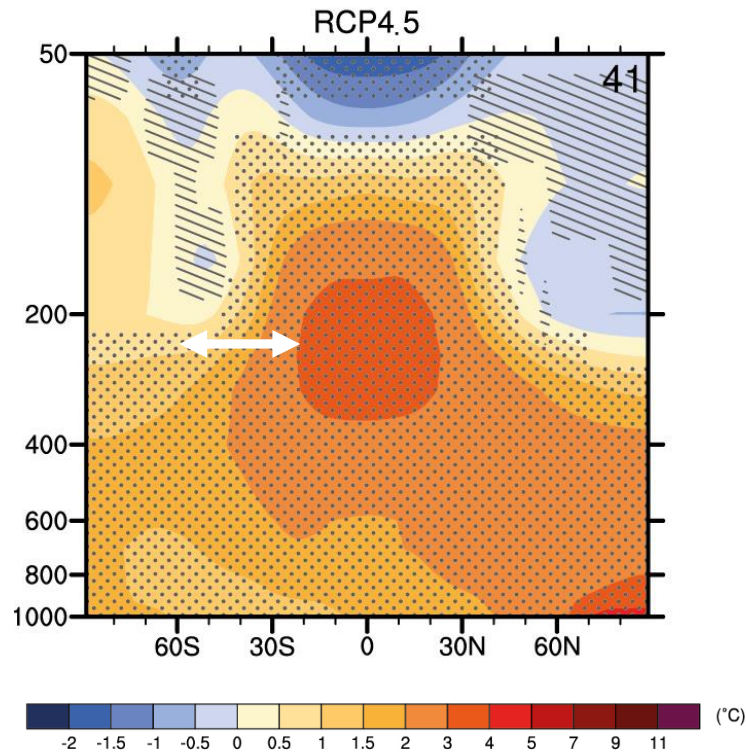
Courtesy of Ed Hawkins

Ben Nevis observations
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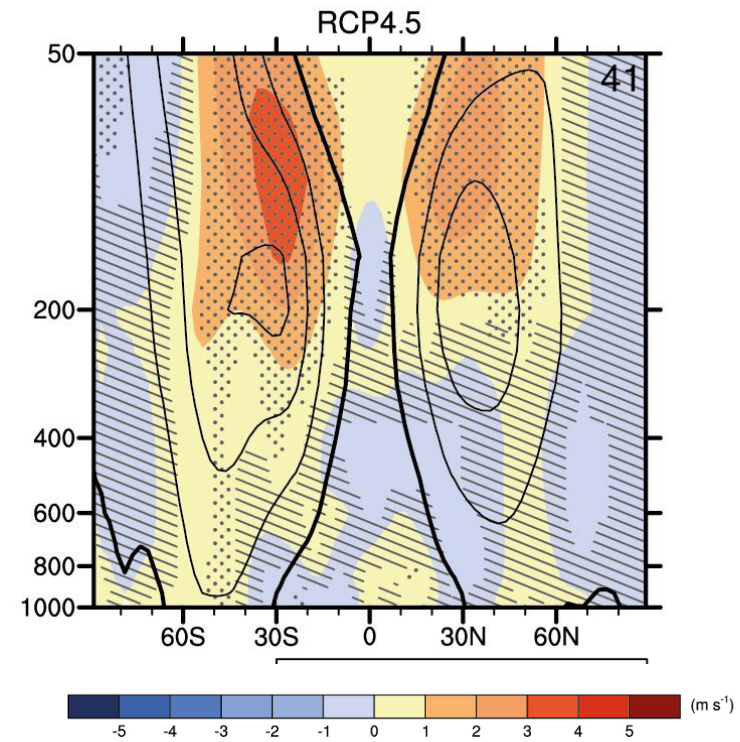


Changes in global average surface temperatures and Arctic sea ice extent projected from the CMIP5 climate models for the RCP2.6 (blue) and RCP8.5 (red) scenarios. Historical simulations are in black. Source: IPCC AR5

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Zonal and annual mean temperature differences for 2080-2099 minus 1980-2005 from the CMIP5 models (IPCC AR5, 2013)



Zonal and annual mean zonal wind differences for 2080-2099 minus 1980-2005 from the CMIP5 models (IPCC AR5, 2013)

- Relationship between climate change, Arctic Amplification, AMOC decline and changes in extratropical cyclones?
 - Decline of Arctic sea ice and Arctic amplification leads to weakening of equator-to-pole temperature and storminess (Harvey et al. 2014)

Spread in NH storm track responses associated with changes in equator-to-pole temperature difference, which is itself mostly governed by the spread of CMIP5 climate change response in the Arctic

