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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2. How might storms respond to climate change?

3. Future research
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

The high-frequency model output required to track cyclones in multiple climate models wasn’t available in 2008.
CMIP5 model biases

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

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

Zappa et al. 2013a, J. Climate
CMIP5 model biases

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

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

Zappa et al. 2013a, J. Climate
CMIP5 models with smallest biases

djf track density

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

Zappa et al. 2013a, J. Climate
What impact will climate change have on extratropical storms?

Why do we have storms anyhow?
Climate change and storms

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

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

Fewer Scandinavian and Mediterranean cyclones

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

Zappa et al. 2013b, J. Climate
CMIP5 response to climate change

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

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

Zappa et al. 2013b, J. Climate
Future Research

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)
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
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

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Courtesy of Ed Hawkins
Global climate change

Changes in global average surface temperatures and Arctic sea ice extent projected from the CMIP5 climate models for the RPC2.6 (blue) and RPC8.5 (red) scenarios. Historical simulations are in black. Source: IPCC AR5
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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

Harvey et al. 2014, Clim Dyn.