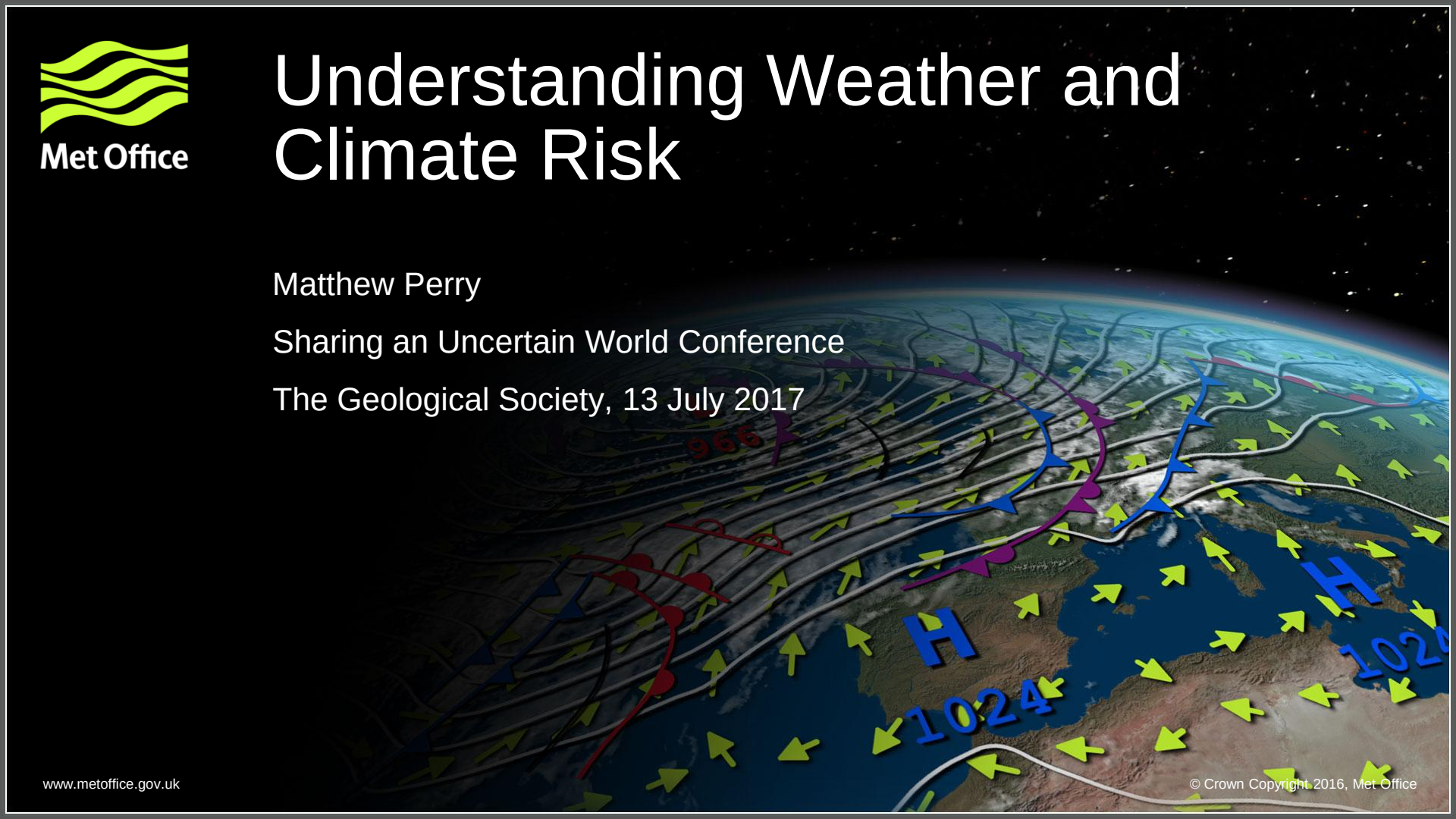
Understanding Weather and Climate Risk

Matthew Perry

Sharing an Uncertain World Conference

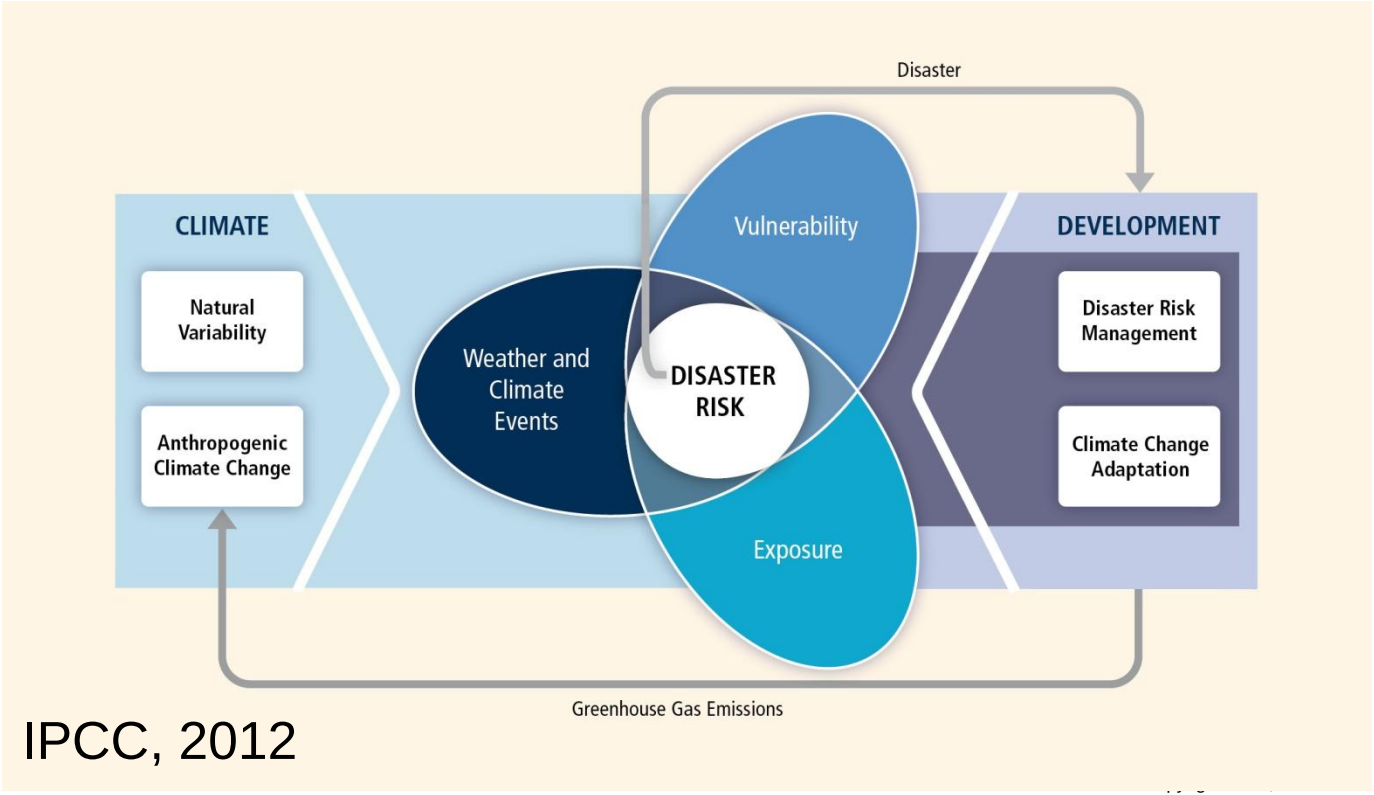
The Geological Society, 13 July 2017



What is risk in a weather and climate context?

- Hazard: something with the potential to cause harm (e.g. extreme weather and climate events)
- Exposure: the density of people, infrastructure, ecosystems or other economic or societal assets
- Vulnerability: the propensity to be adversely affected by a hazard (a lack of resilience)
- Hazard + exposure + vulnerability → risk of impacts / disaster

What is risk in a weather and climate context?



IPCC, 2012

Hazardous extreme weather events

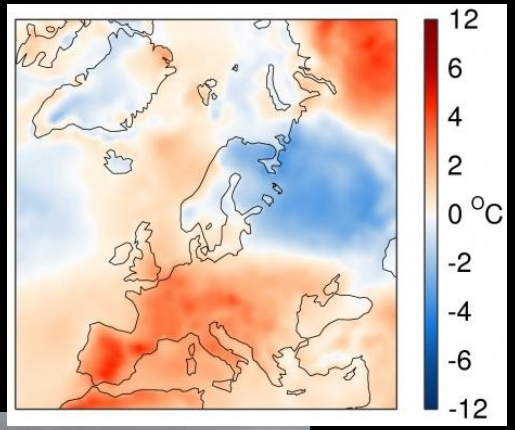
Heavy Precipitation and Flooding Storm Frank, Dec 2015, NI

Northeastern USA snowstorm, March 2017

Drought in Kenya, 2017

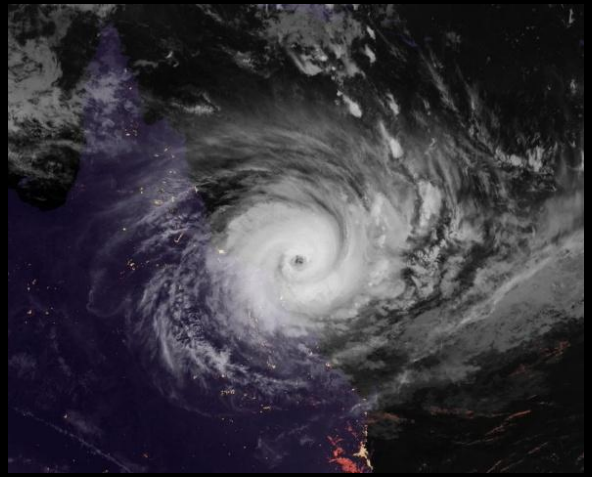
Hazardous extreme weather events

European Heatwave, June 2017



Wildfire in Portugal

Tropical Cyclone Debbie, March 2017



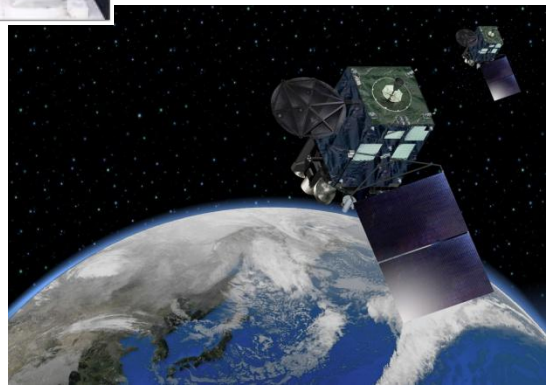
Earth Observation

Provides data to help us monitor and understand the climate

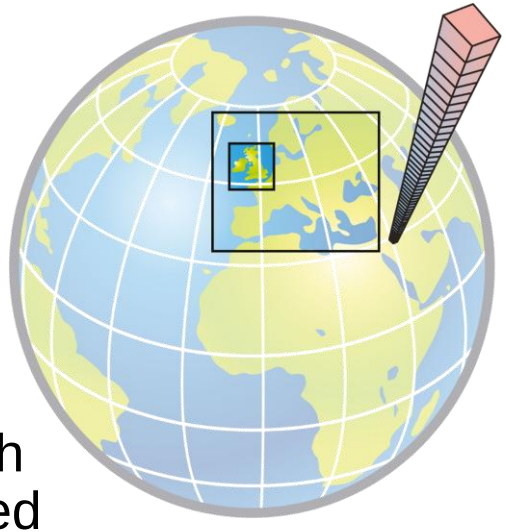
- Land stations
- Marine – buoys, ships
- Weather satellites
- RADAR and LiDAR
- Weather balloons – radiosondes
- Aircraft

Figure 4. Stevenson screen.

Figure 5. View inside the screen.



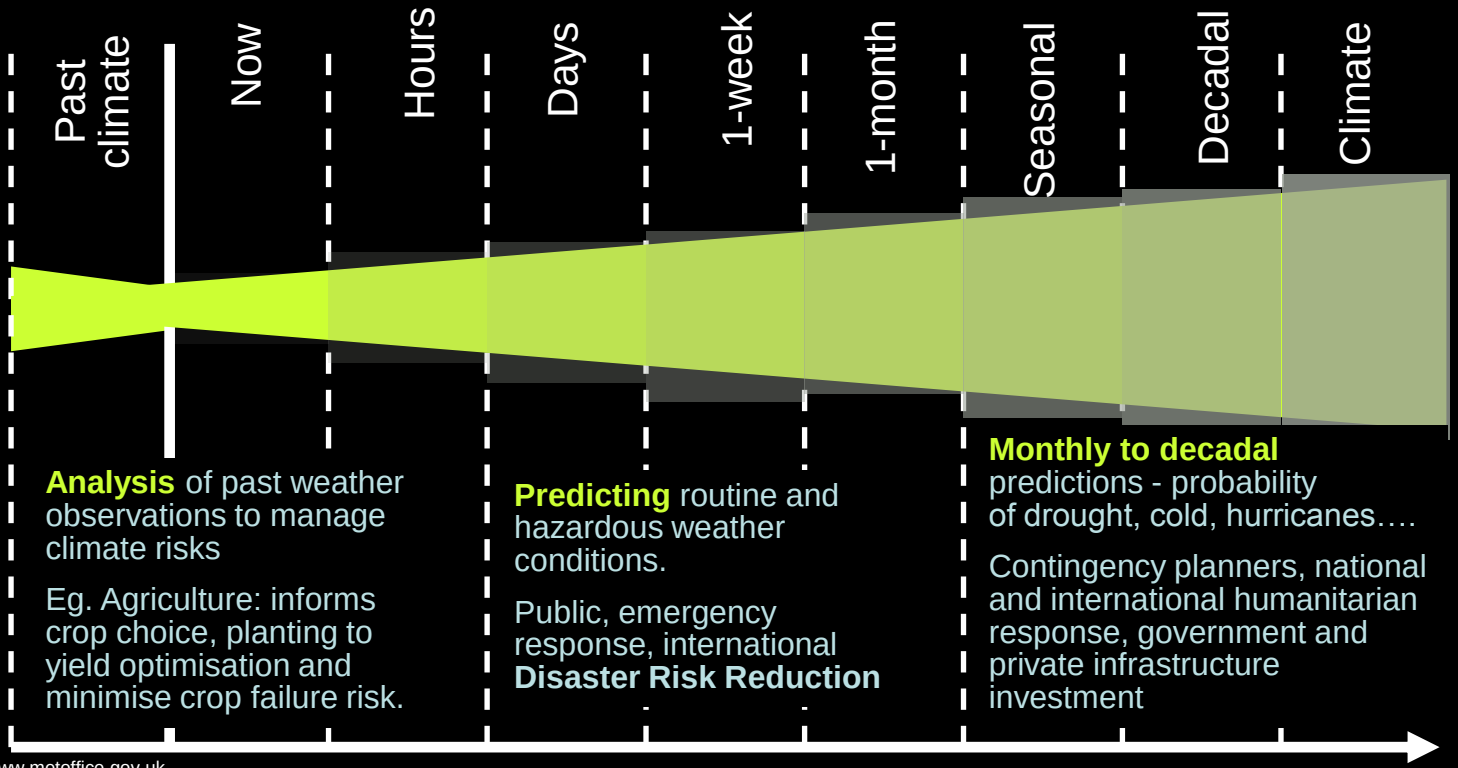
Numerical Modelling



- Start from a snapshot of current atmospheric conditions, at points on a three-dimensional grid
- Atmospheric variables are stored for each grid box, and a set of equations are solved to predict the values a short time later
- The process of generating a forecast is repeated, stepping further into the future to produce a weather forecast for the next few days or a climate prediction for the coming 100 years
- The Met Office Unified Model is run operationally in a number of global and regional configurations at different spatial resolutions and timescales

Predictions across all timescales

Global coupled modelling on all timescales



Analysis of past weather observations to manage climate risks

Eg. Agriculture: informs crop choice, planting to yield optimisation and minimise crop failure risk.

Predicting routine and hazardous weather conditions.

Public, emergency response, international **Disaster Risk Reduction**

Monthly to decadal predictions - probability of drought, cold, hurricanes….

Contingency planners, national and international humanitarian response, government and private infrastructure investment

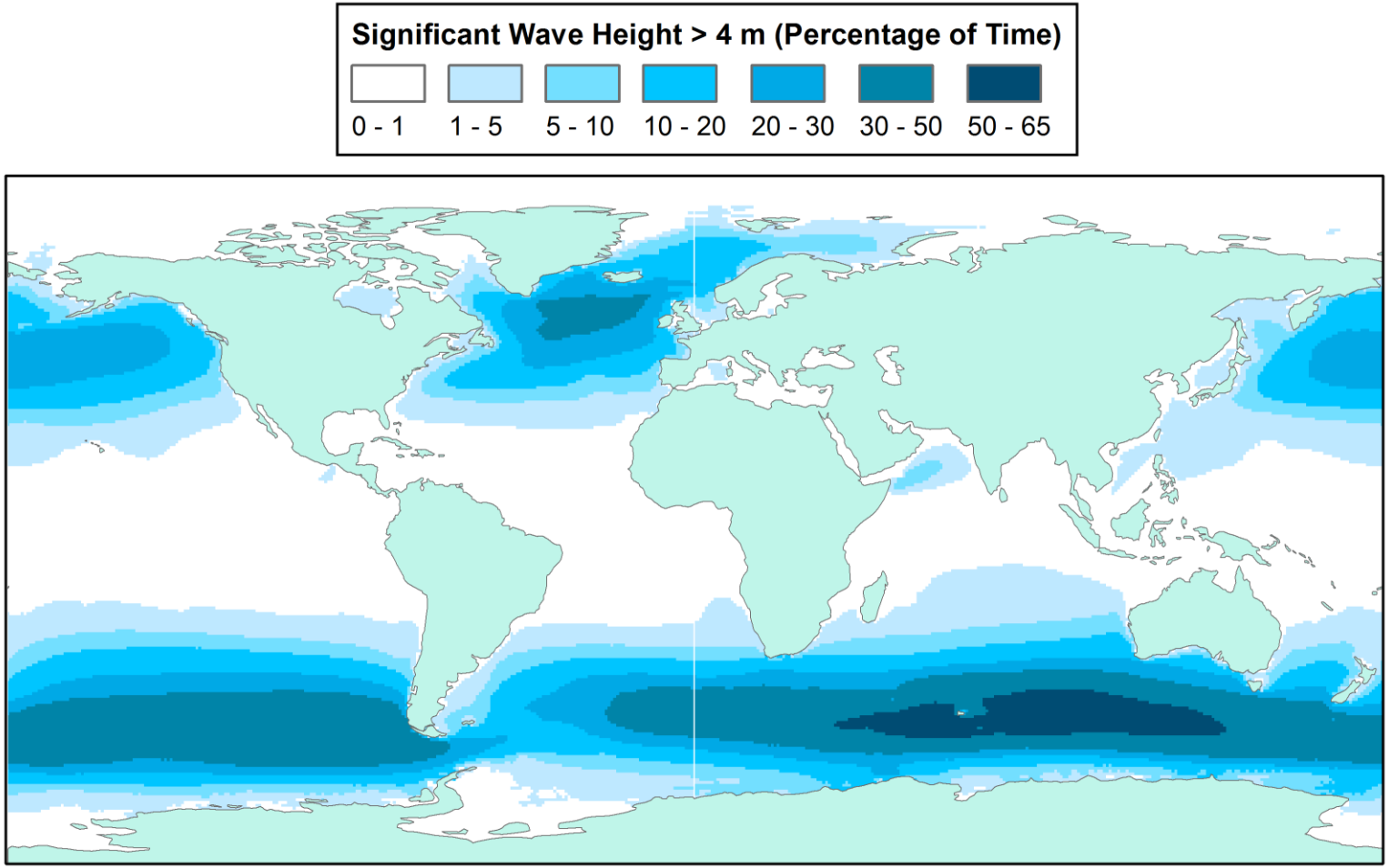
Global and regional climate predictions.

Informs **mitigation** policy and **adaptation** choices. Impacts on water resources, heat stress, crops, infrastructure.

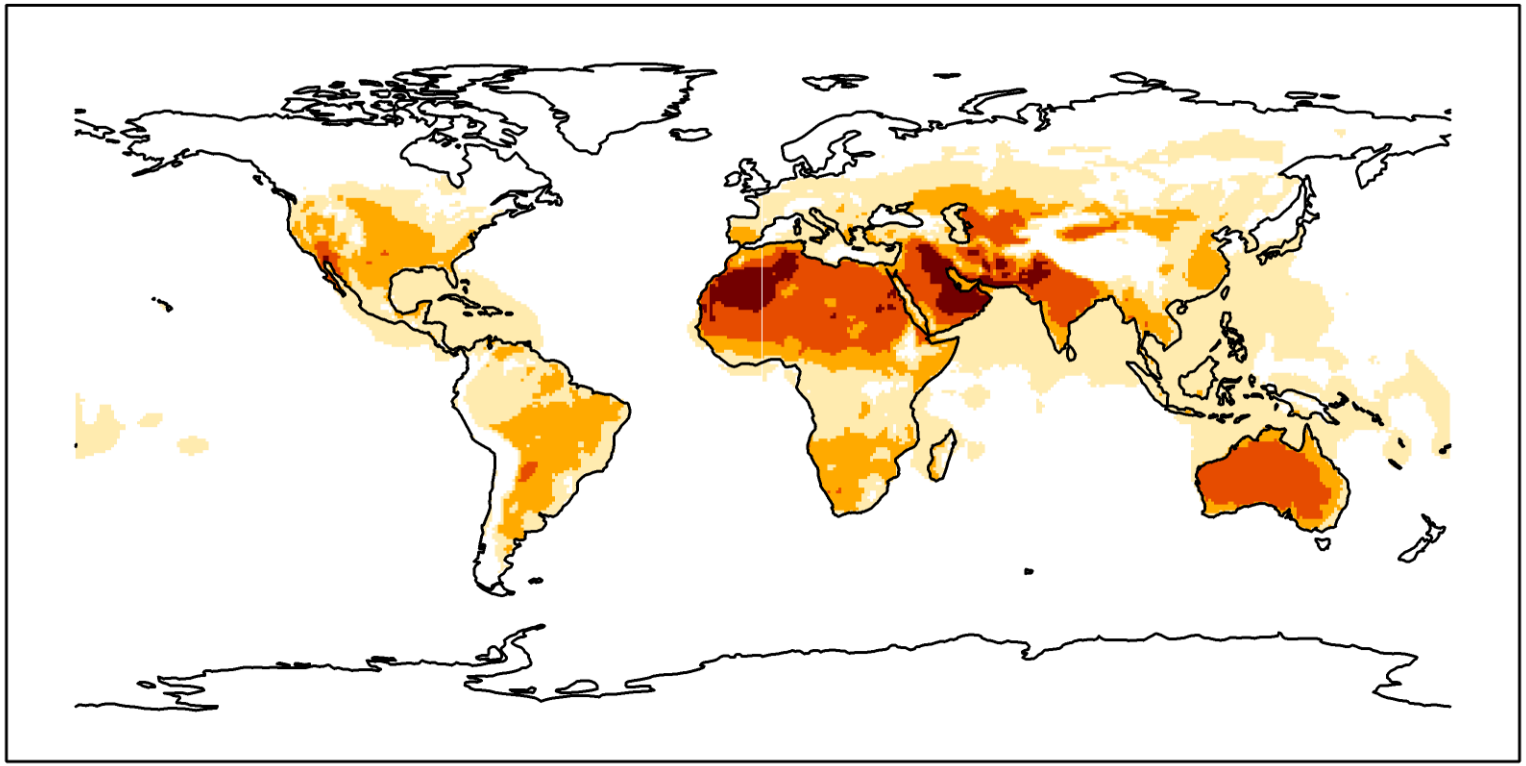
Spatial mapping of climatological hazard

- Understanding hazards and their spatial distribution can help with preparedness
  - Testing of equipment, design of infrastructure, disaster planning
- Thresholds above which operations are impacted can be considered
- 30 years of past data are often used to obtain robust climatological statistics

Met Office


Significant Wave Height > 4 m (Percentage of Time)
0 - 1
1 - 5
5 - 10
10 - 20
20 - 30
30 - 50
50 - 65

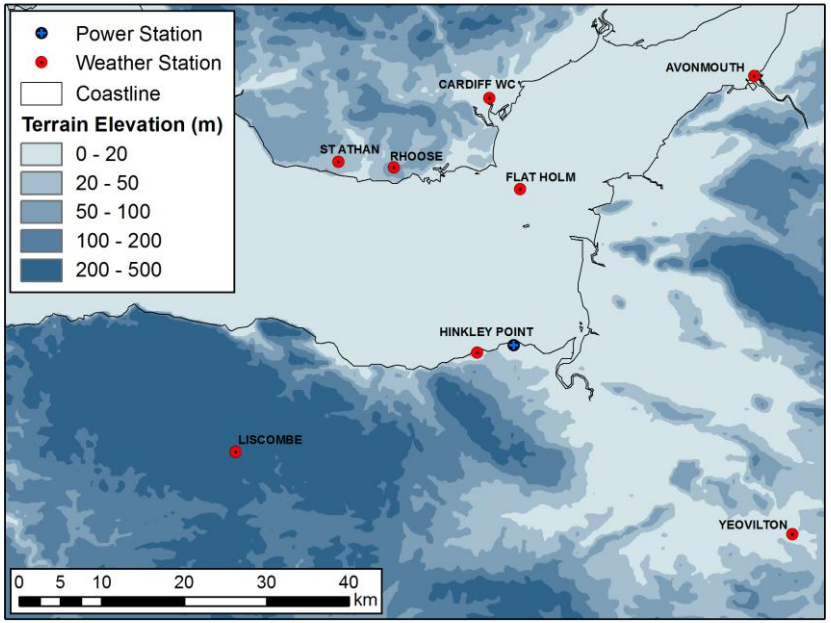
Met Office



for the hottest month of the year

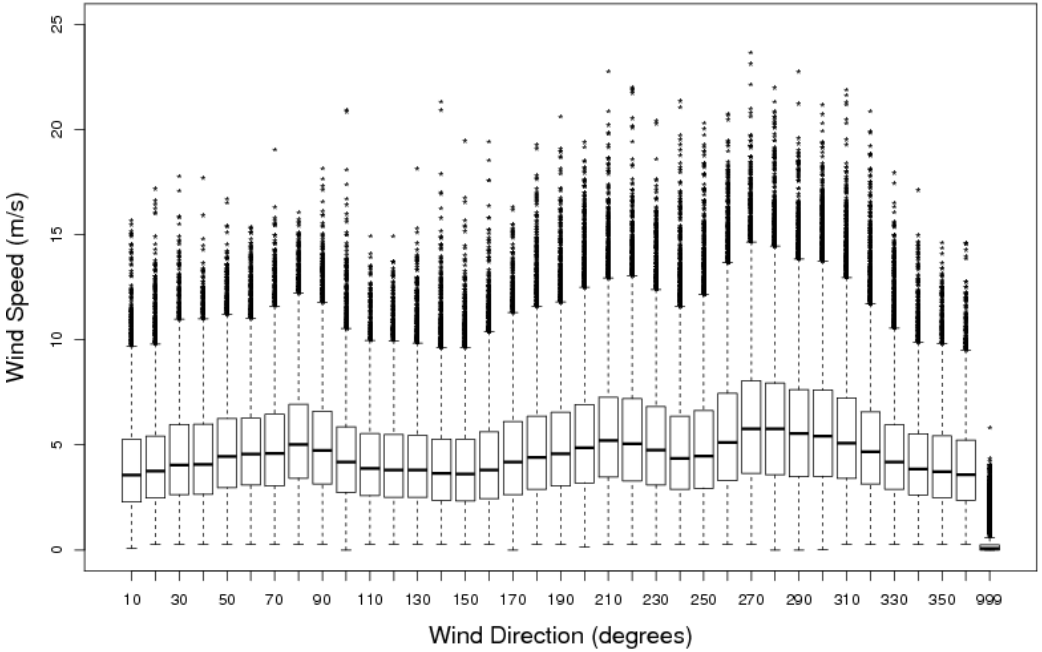
Understanding Risk of Extreme Events using Extreme Value Analysis

- Estimating the severity of events associated with a low probability of occurrance
- Long wind speed and direction data series generated by combining records from weather stations near to the location of interest



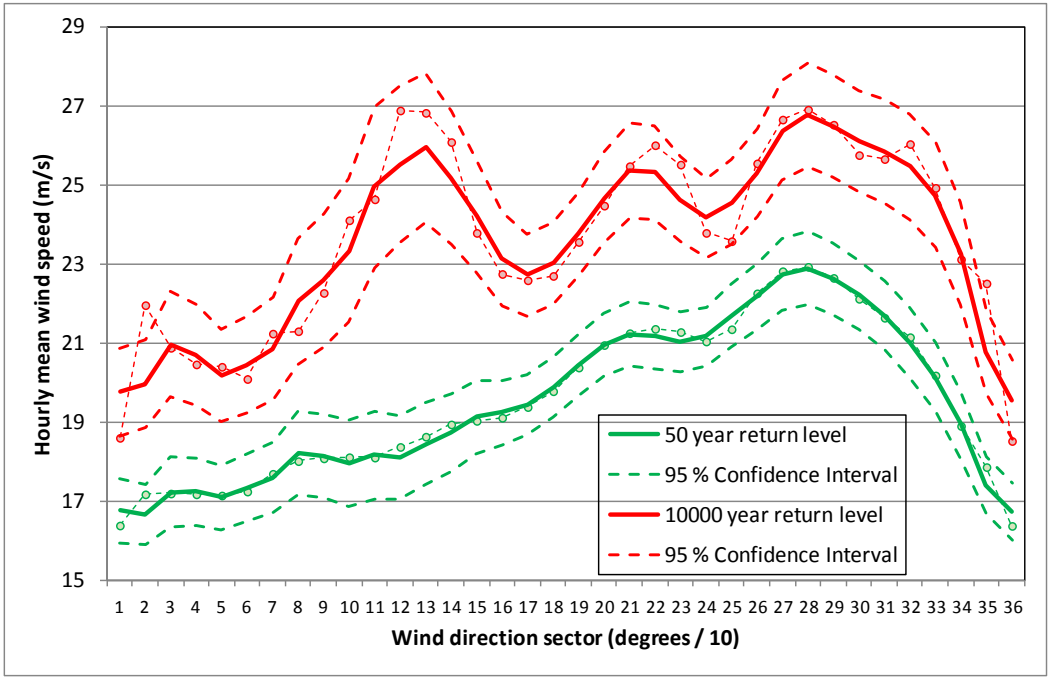
Understanding Risk of Extreme Events using Extreme Value Analysis

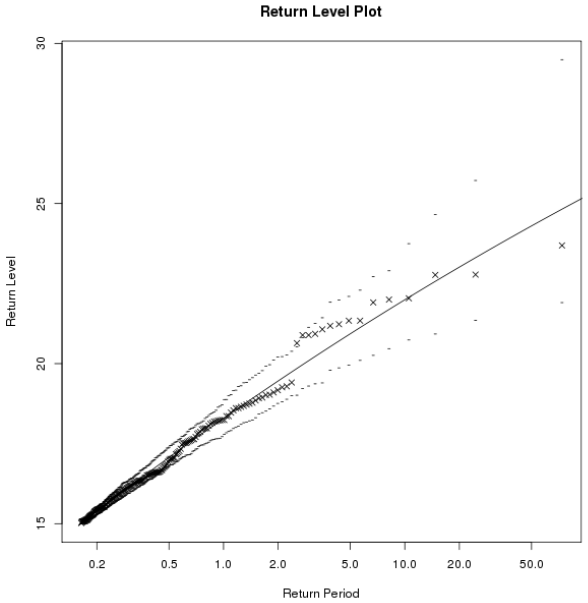
- Statistical model fitted to data above a threshold, using the Generalised Pareto Distribution
- Directional analysis: variable threshold, smoothing of model parameters



Understanding Risk

Extreme Value Analysis





- Model allows us to estimate wind speeds associated with return periods
- Considerable uncertainty extrapolating to 1:10,000 year return period

Forecasting: Global Hazard Map

- Provides a global summary of hazardous weather forecast for the next 7 days
- Uses a multi-model ensemble of global forecast data: ECMWF ENS and MOGREPS-G
- GIS web map service used by Met Office forecasters – users can overlay different layers
- Aims to combine hazards with exposures and vulnerabilities to give information on likely impact

How are the forecast layers produced?

Tropical cyclones

ECMWF ENS and MOGREPS-G forecast data

→ Identify and track TCs in MOTCTracker (existing and forming storms)

Calculate probability of a TC passing within 120km in each 24-hour period in ECMWF ENS, MOGREPS-G and multi-model ensemble

Precipitation
Wind gust
Snowfall

ECMWF ENS and MOGREPS-G forecast data

ECMWF model climatology (M-Climate)

→ Calculate probabilities (ECMWF-ENS, MOGREPS-G, multi-model ensemble):
- 24-hour precip accumulation > 99th centile in M-Climate
- 24-hour maximum wind gust > 99th centile in M-Climate
- 24-hour total snowfall > 99th centile in M-Climate

Mask out precipitation and snowfall over sea and areas of very low precip / winds

Heatwave
Coldwave

ECMWF ENS forecast data

ERA-Interim climatology

→ Calculate Excess Heat Factor (EHF) and Excess Cold Factor (ECF) in each member

Calculate probability of a severe heatwave / severe coldwave

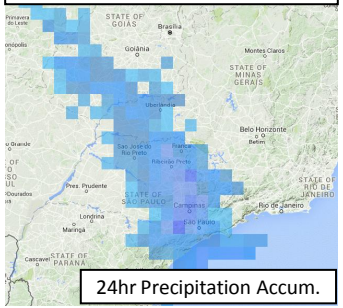
GHM forecast layers: Creation of summary map

Met Office

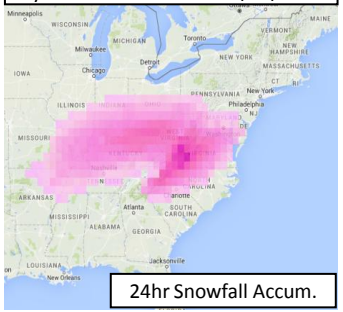
ECMWF ENS; MOGREPS-G; Multi-model ensemble

ECMWF ENS only

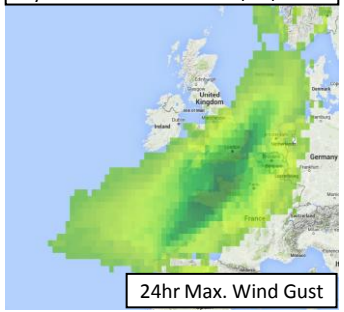
Day 3 forecast from 00Z 09/03/2016



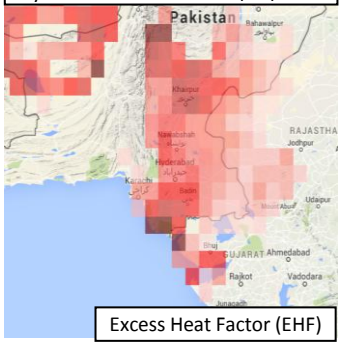
Day 4 forecast from 00Z 19/01/2016



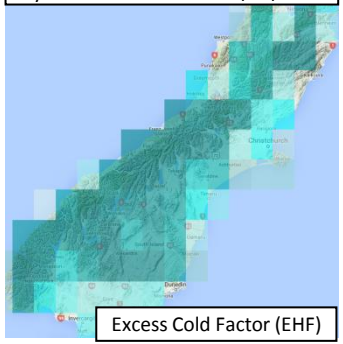
Day 4 forecast from 00Z 25/03/2016



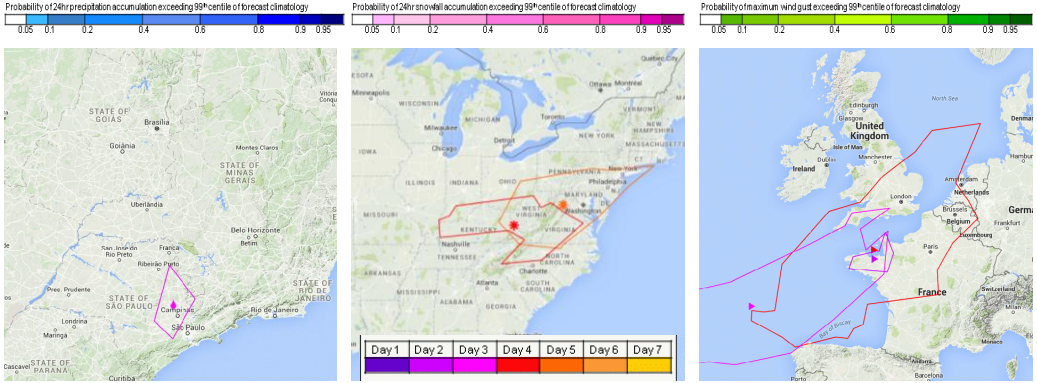
Day 5 forecast from 12Z 15/06/2015

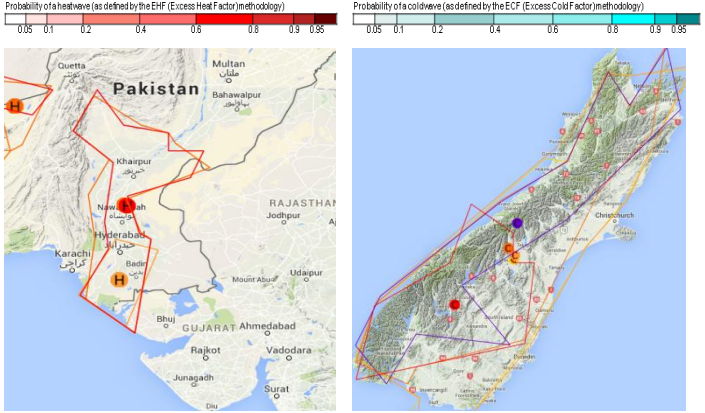


Day 6 forecast from 00Z 15/06/2015

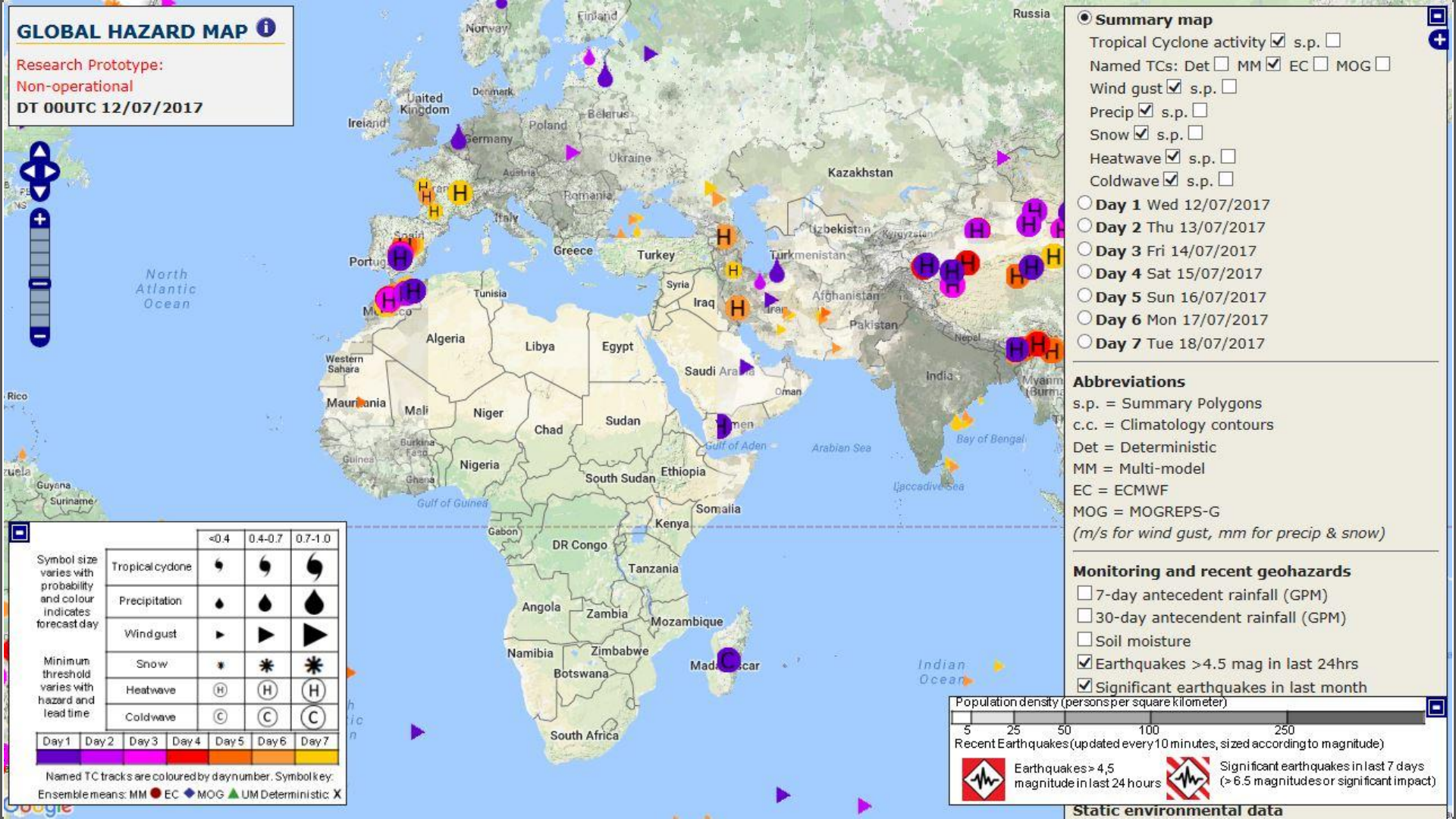


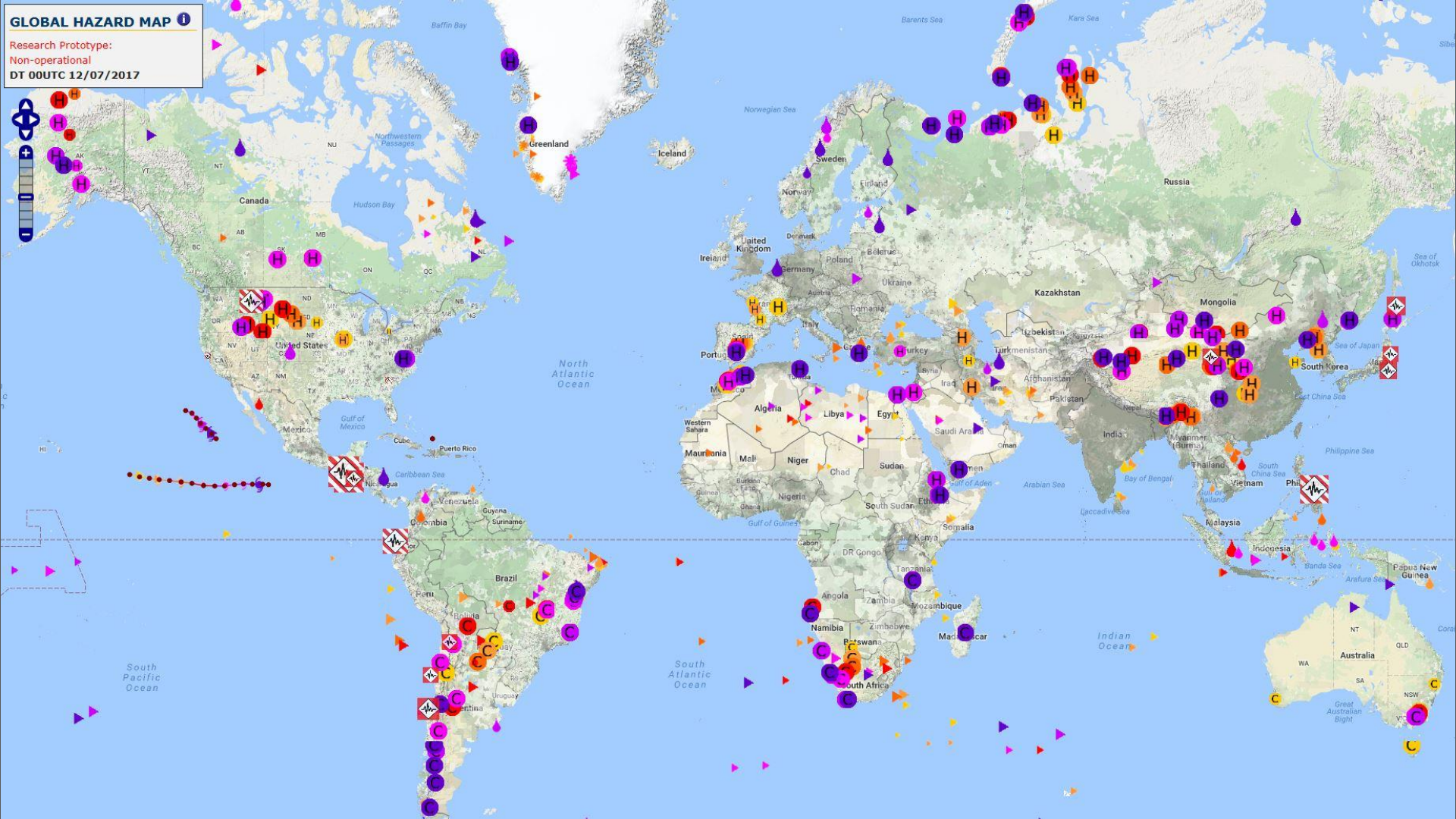
For each of these it shows the probability of exceeding the 99th centile of forecast climatology





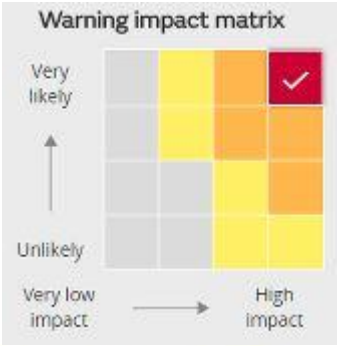
Summary polygons, coloured by lead time, show the areas where the probabilities are significant for that lead time and hazard

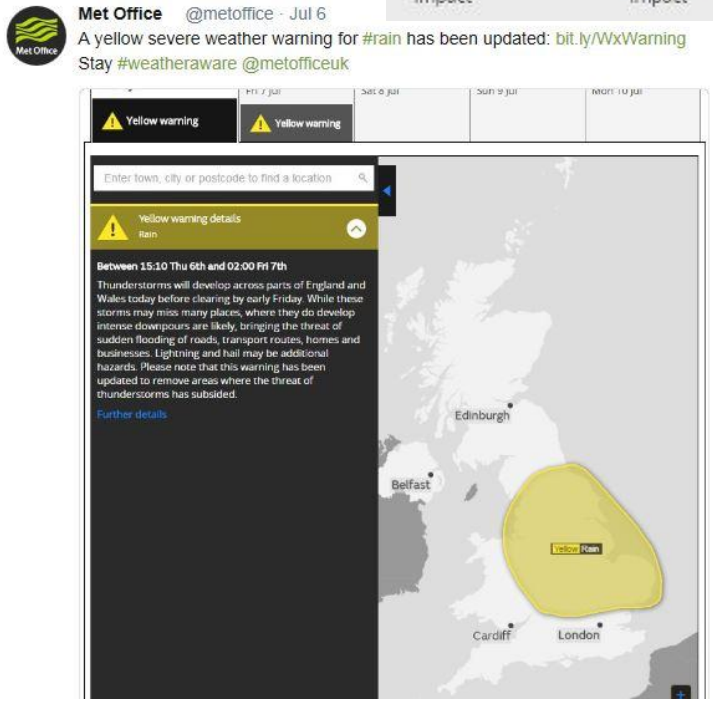

GLOBAL HAZARD MAP
Research Prototype:
Non-operational
DT 00UTC 12/07/2017
Summary map
Tropical Cyclone activity s.p.
Named TCs: Det MM EC MOG
Wind gust s.p.
Precip s.p.
Snow s.p.
Heatwave s.p.
Coldwave s.p.
Day 1 Wed 12/07/2017
Day 2 Thu 13/07/2017
Day 3 Fri 14/07/2017
Day 4 Sat 15/07/2017
Day 5 Sun 16/07/2017
Day 6 Mon 17/07/2017
Day 7 Tue 18/07/2017
Abbreviations
s.p. = Summary Polygons
c.c. = Climatology contours
Det = Deterministic
MM = Multi-model
EC = ECMWF
MOG = MOGREPS-G
(m/s for wind gust, mm for precip & snow)
Monitoring and recent geohazards
7-day antecedent rainfall (GPM)
30-day antecedent rainfall (GPM)
Soil moisture
Earthquakes >4.5 mag in last 24hrs
Significant earthquakes in last month
Symbol size varies with probability and colour indicates forecast day
Minimum threshold varies with hazard and lead time
<0.4
0.4-0.7
0.7-1.0
Tropical cyclone
Precipitation
Wind gust
Snow
Heatwave
Coldwave
Day 1
Day 2
Day 3
Day 4
Day 5
Day 6
Day 7
Named TC tracks are coloured by day number. Symbol key:
Ensemble means: MM EC MOG UM Deterministic X
Population density (persons per square kilometer)
5
25
50
100
250
Recent Earthquakes (updated every 10 minutes, sized according to magnitude)
Earthquakes > 4.5 magnitude in last 24 hours
Significant earthquakes in last 7 days (> 6.5 magnitudes or significant impact)
Static environmental data
North Atlantic Ocean
Indian Ocean
Arabian Sea
Bay of Bengal
Gulf of Aden
Gulf of Guinea
Laccadive Sea
Norway
Finland
Russia
United Kingdom
Ireland
Denmark
Germany
Poland
Belarus
Ukraine
Kazakhstan
Romania
Austria
Italy
Spain
Portugal
Greece
Turkey
Uzbekistan
Kyrgyzstan
Turkmenistan
Syria
Iraq
Iran
Afghanistan
Pakistan
Nepal
India
Tunisia
Algeria
Libya
Egypt
Western Sahara
Mauritania
Mali
Niger
Chad
Sudan
Saudi Arabia
Oman
Yemen
Nigeria
Burkina Faso
Guinea
Ghana
South Sudan
Ethiopia
Somalia
Kenya
Gabon
DR Congo
Tanzania
Angola
Zambia
Mozambique
Namibia
Zimbabwe
Botswana
South Africa
Madagascar
Guyana
Suriname
Rico


GLOBAL HAZARD MAP
Research Prototype:
Non-operational
DT 00UTC 12/07/2017
Baffin Bay
Greenland
Iceland
Barents Sea
Kara Sea
Norwegian Sea
Northwestern Passages
Hudson Bay
Canada
United States
Mexico
Gulf of Mexico
Caribbean Sea
Cuba
Puerto Rico
Venezuela
Guyana
Suriname
Colombia
Brazil
Peru
Bolivia
Paraguay
Uruguay
Argentina
Chile
South Pacific Ocean
North Atlantic Ocean
South Atlantic Ocean
Sweden
Norway
Finland
Russia
United Kingdom
Ireland
Denmark
Germany
Poland
Belarus
Ukraine
Austria
Romania
Italy
Spain
Portugal
Turkey
Kazakhstan
Mongolia
Uzbekistan
Turkmenistan
Afghanistan
Pakistan
Iraq
Syria
Saudi Arabia
Oman
Yemen
India
Myanmar (Burma)
Thailand
Vietnam
South Korea
Sea of Japan
East China Sea
South China Sea
Philippine Sea
Sea of Okhotsk
Bay of Bengal
Arabian Sea
Gulf of Aden
Malaysia
Indonesia
Banda Sea
Arafura Sea
Papua New Guinea
Australia
Great Australian Bight
Indian Ocean
Western Sahara
Mauritania
Mali
Niger
Algeria
Libya
Egypt
Chad
Sudan
Nigeria
Guinea
Burkina Faso
Ghana
Gulf of Guinea
South Sudan
Ethiopia
Somalia
Kenya
Uganda
DR Congo
Tanzania
Angola
Zambia
Mozambique
Zimbabwe
Namibia
Botswana
South Africa
Madagascar

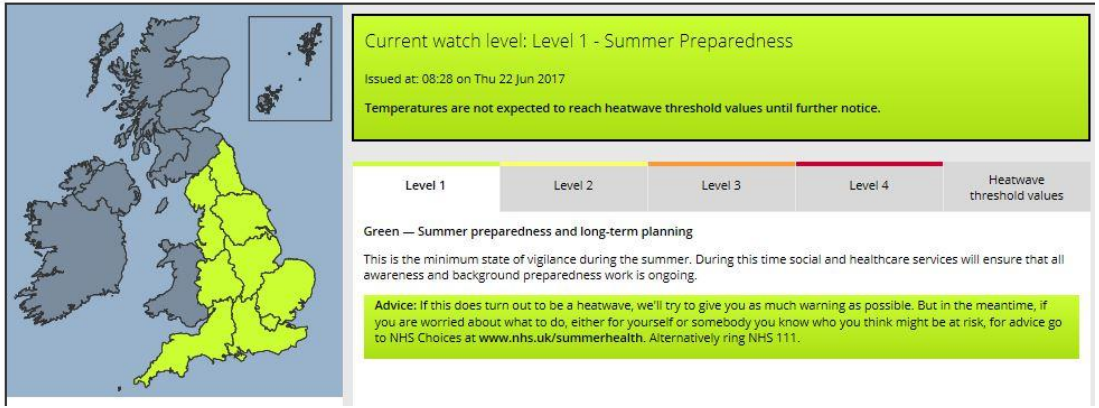
Forecasting: UK Severe Weather Warnings

- Rain, snow, wind, fog and ice
- Combination of likelihood and impact
- Heat-health Watch warning service





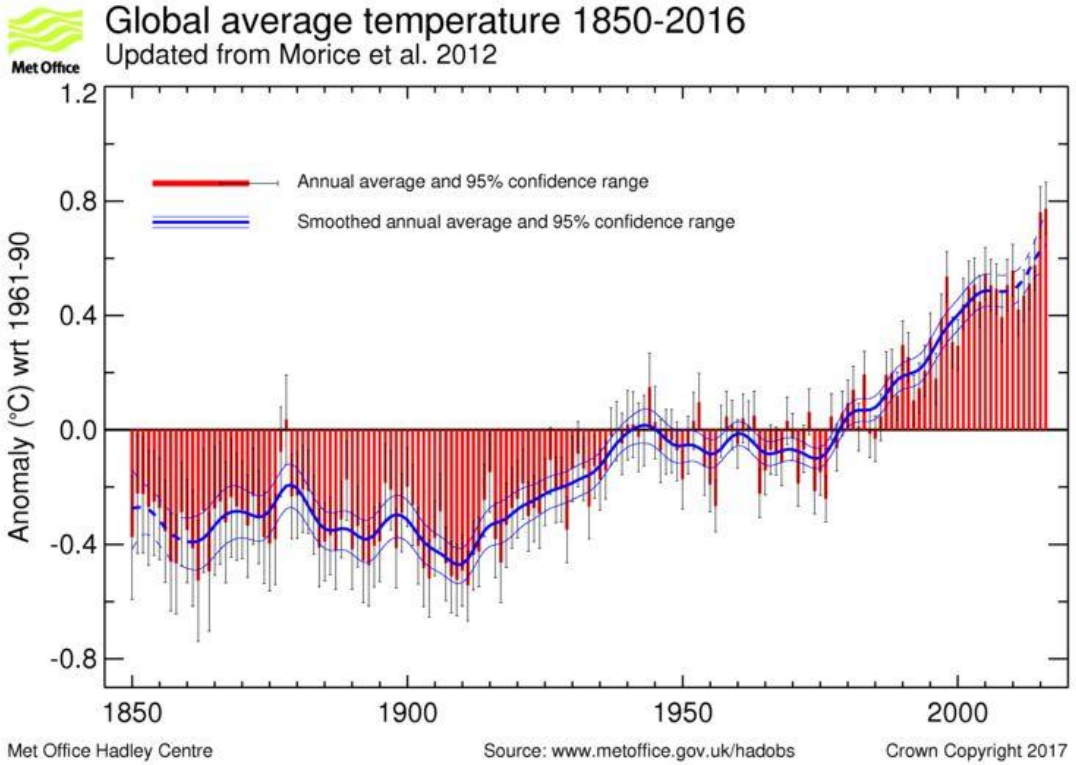
Heat-health watch



Climate Change

Setting the scene – our climate's recent history

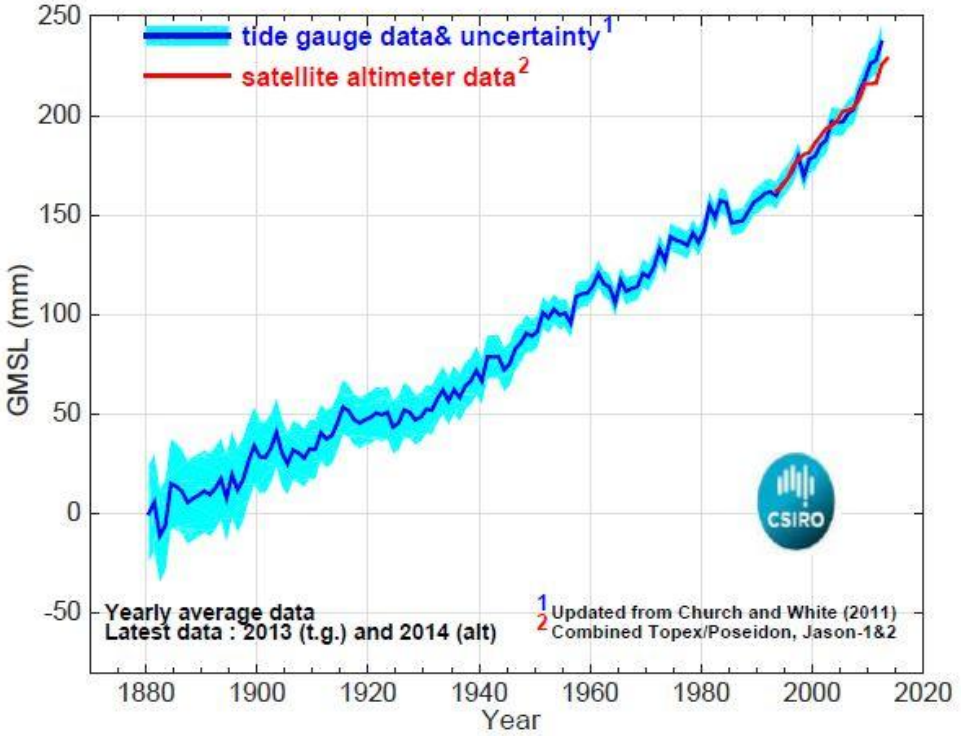
- Global average temperature has increased by about 1° C since 1880
- Spiral visualisation



Climate Change

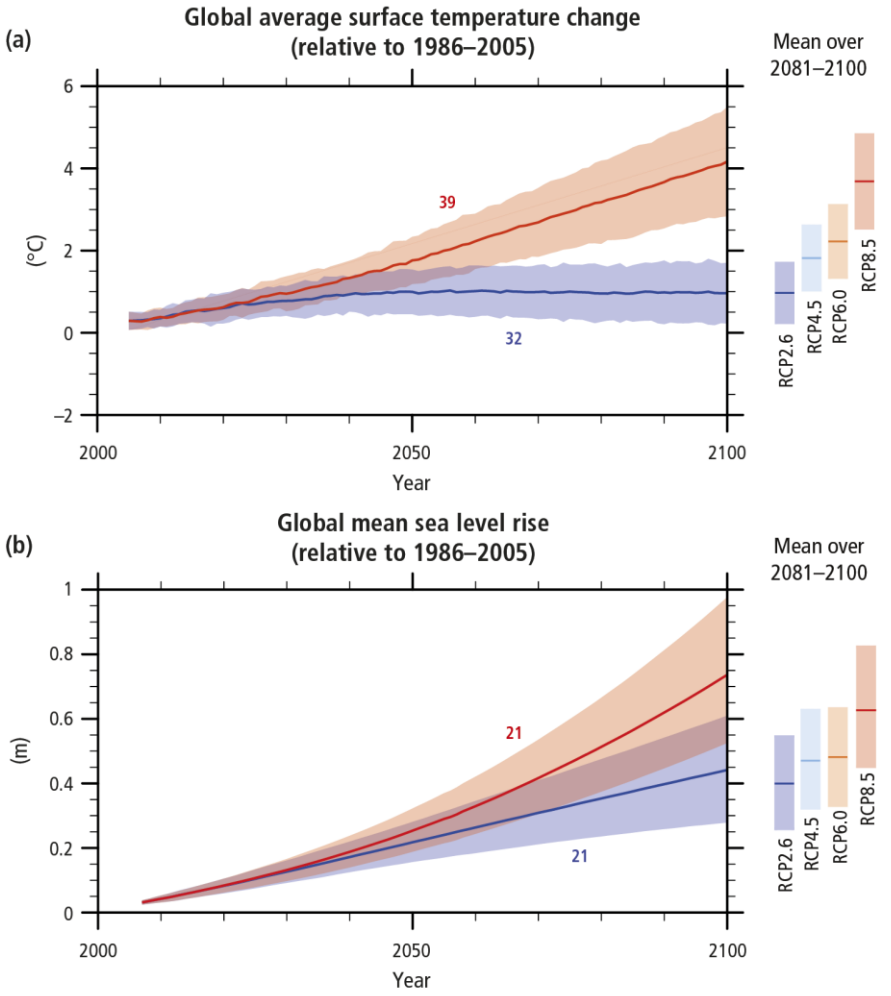
Setting the scene – our climate's recent history

- Global mean sea level has increased by about 20 cm in the last 100 years



Future Climate Change

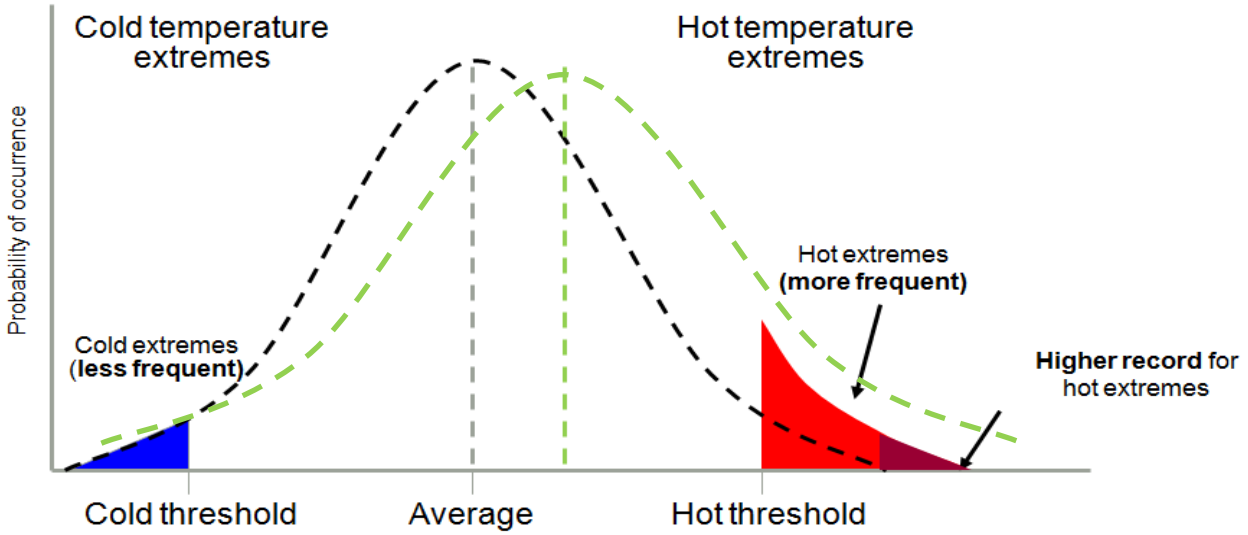
- Climate projections show that these changes are projected to increase into the future
- The rate of change is dependant on the emissions scenario – how well the world does at curbing emissions of Greenhouse gases
- Increases in mean temperature can also lead to changes in the likelihood of extreme weather events occurring



Weather & Climate Extremes

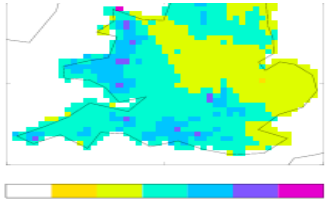
Case Study: Temperature

Increased temperatures → More frequent hot extremes e.g. Heat waves → Socio-economic impacts e.g. Higher mortality rates



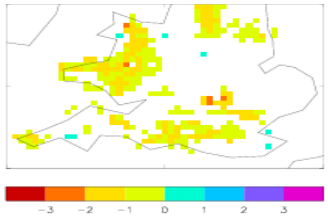
Future change in heavy rainfall at hourly timescale in winter

Observed heavy rain (radar)

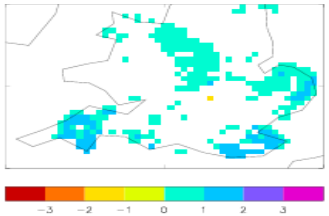


White = model biases and future changes not significant at the 1% level

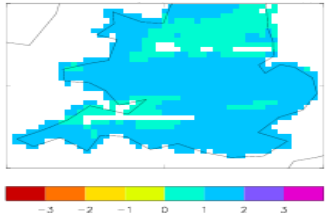
12km model - radar



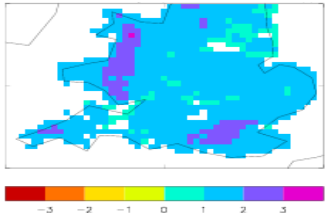
1.5km model - radar



12km model future change



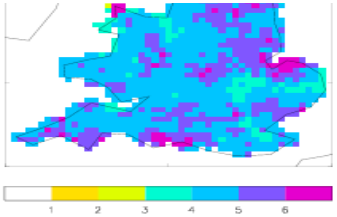
1.5km model future change



Kendon et al, 2014, Nature Clim. Change

Future change in heavy rainfall at hourly timescale in summer

Observed heavy rain (radar)



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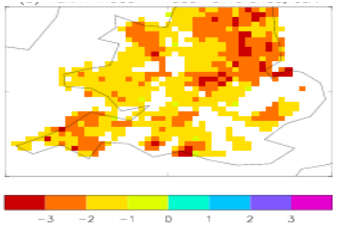

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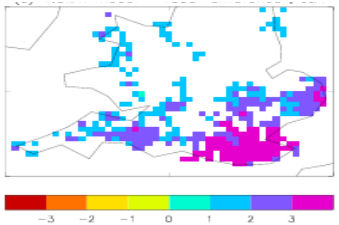
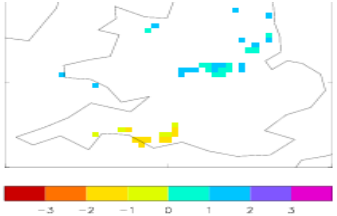


12km model future change



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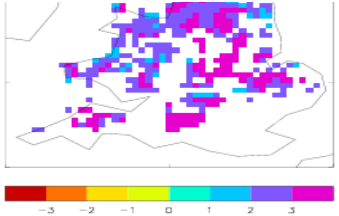


Kendon et al, 2014, Nature Clim. Change

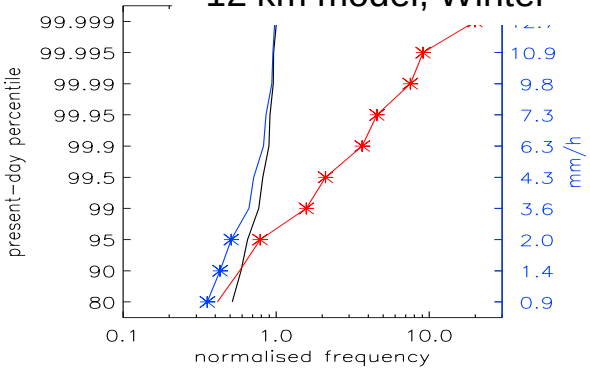
Frequency of exceeding high thresholds

Models show significant increases in peak rainfall intensity across all durations during winter

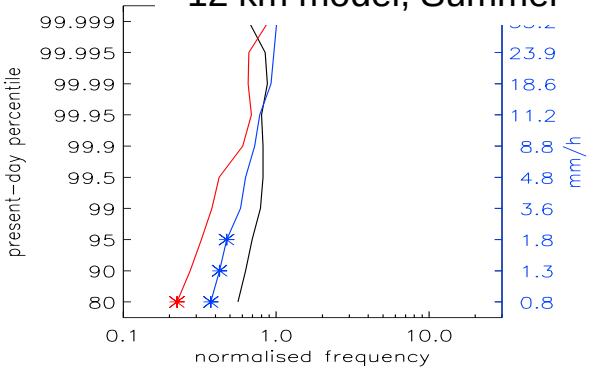
During summer, 1.5km model shows intensification of short-duration rainfall

radar
present-day
future
significant bias/change

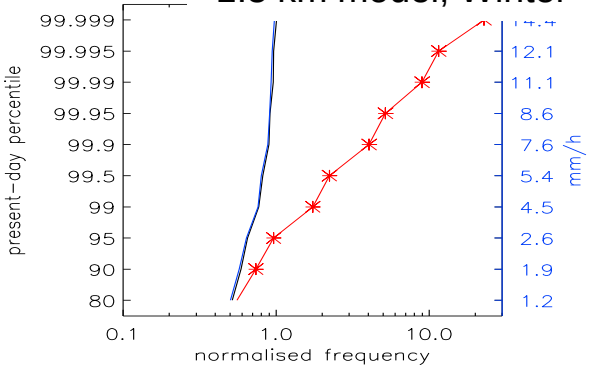
12 km model, Winter



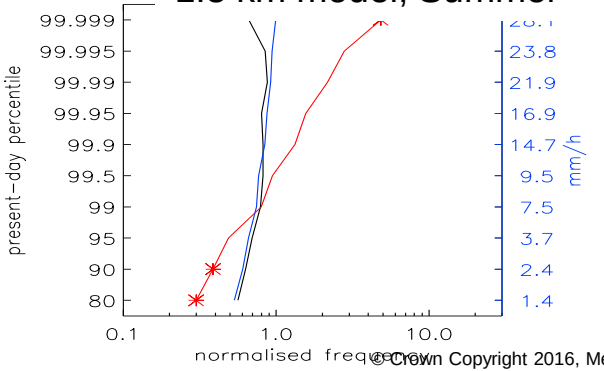
12 km model, Summer



1.5 km model, Winter



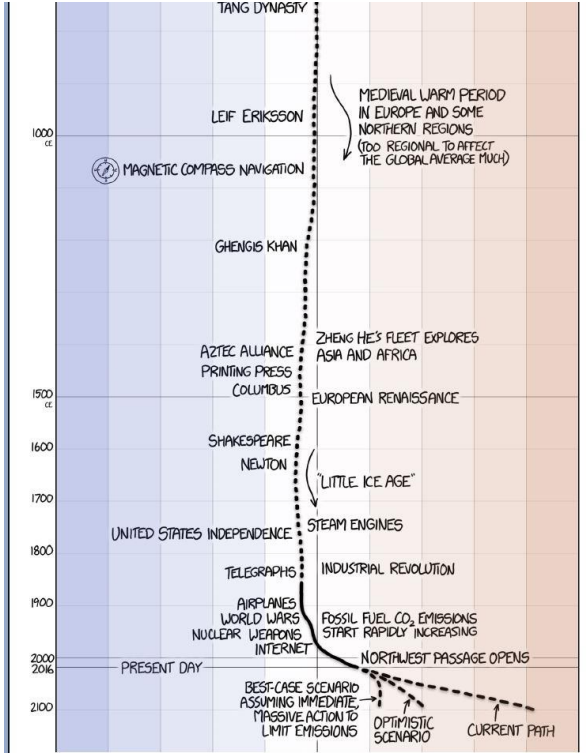
1.5 km model, Summer



Kendon et al, 2014, Nature Clim. Change

Summary

- Hazardous weather can lead to risk of impacts when combined with exposure and vulnerability
- Risk can be managed by increasing understanding through the use of datasets and models
  - Communication of risks needed to feed into planning decisions, warnings and adaptation



- Observed and future climate change leads to changes in the likelihood of hazardous weather events occurring

Any questions?