

Multiple hazards under UK Climate Projections

The future of UK agriculture

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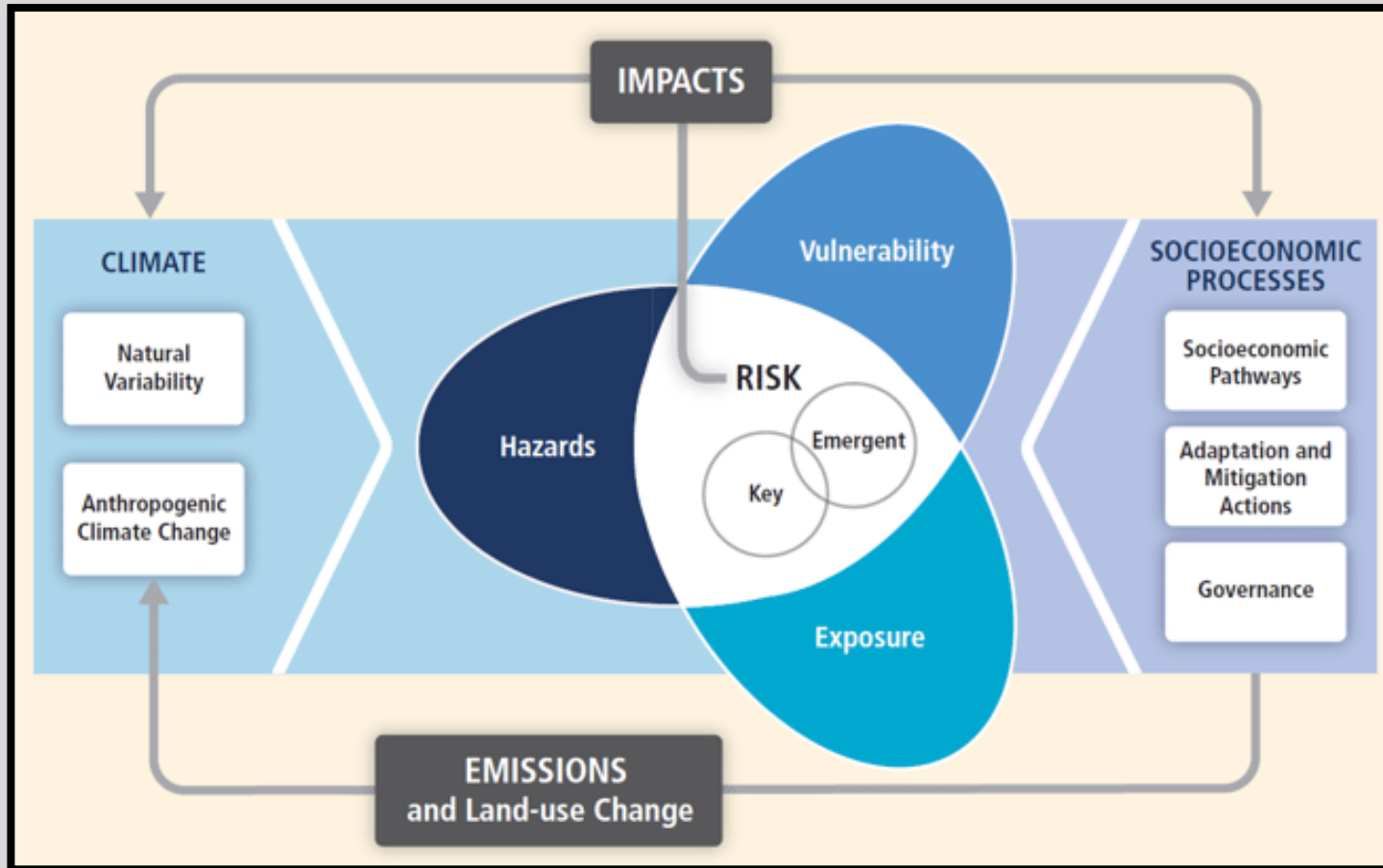
10 June 2020



UK Research
and Innovation



Hazard to Risk → Decision Making



Aim: development of approaches to combine hazard with exposure and vulnerability to produce projections of future climate risk

Probabilities of localised climate hazard

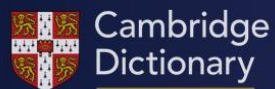
+

Measure of vulnerability from experienced stakeholders interested in a climate impact

+

Exposure information (demographics)

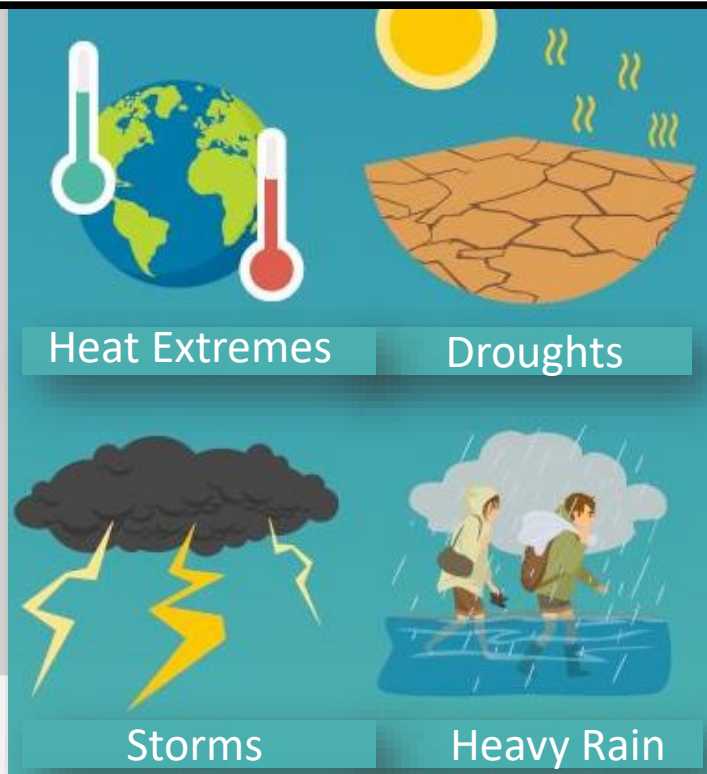
What is a hazard?



hazard

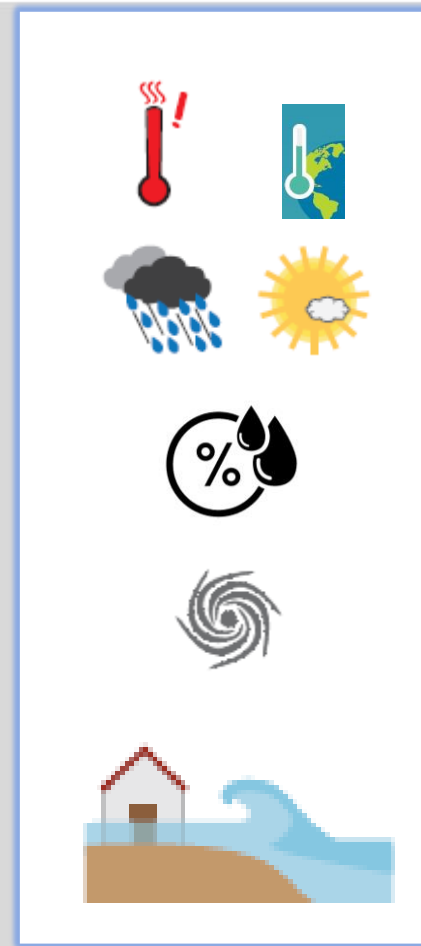
something that is dangerous and likely to cause damage:

- a health/fire hazard
- The busy traffic entrance was a hazard **to** pedestrians.

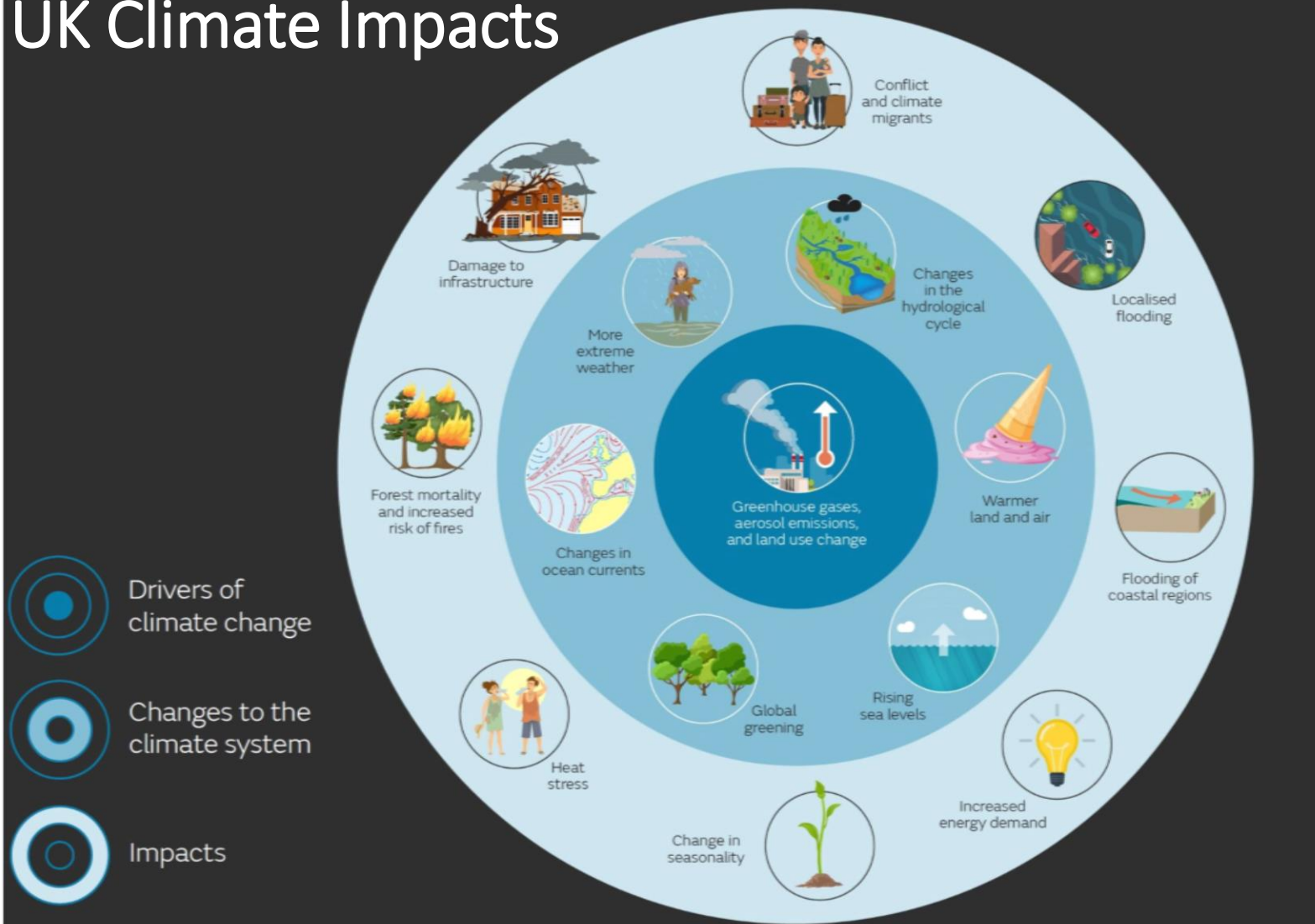


Climate metric associated with a hazard 'Climate Hazard' e.g.,

- Temperature
- Precipitation
- Relative Humidity
- High winds
- Sea level rise
- Storm surges



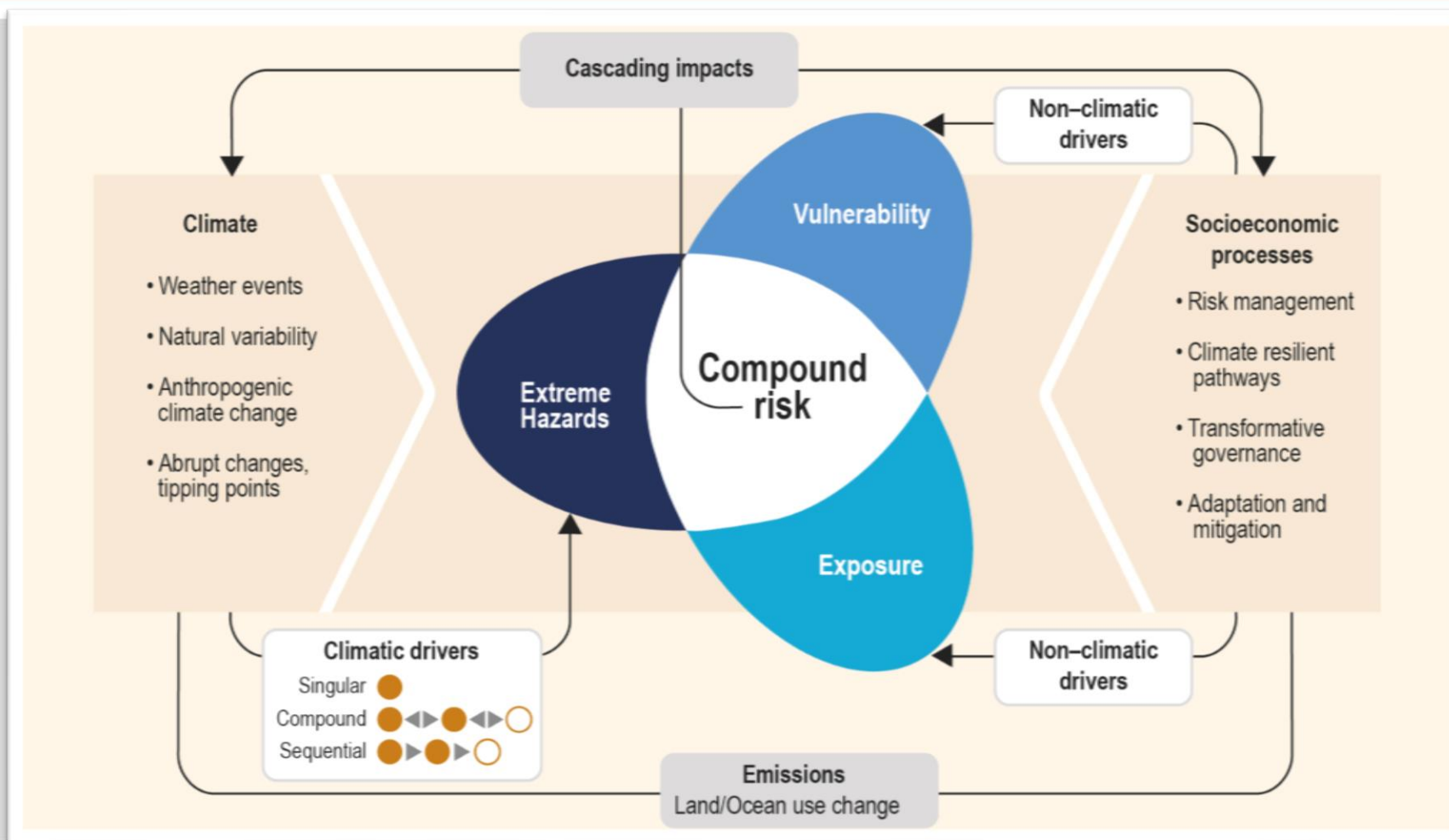
UK Climate Impacts



Which of these impacts might be caused by multiple hazards or might be involved in a compound event?

ALL! Some impacts are caused by more than one hazard inherently, but multiple impacts occurring simultaneously or in close succession can also constitute a compound event.

Compound Risk



Current compound events



- Non-climatic factors such as COVID-19 will determine whether and how climate events trigger impacts, and their severity.
- Human factors and feedbacks are rarely considered in physical science based approaches – key that we move toward a multi-disciplinary approach. How can we do this better?

Webinar by Alex Randell at: climateoutreach.org/resources/covid-19-climate-change-and-migration/

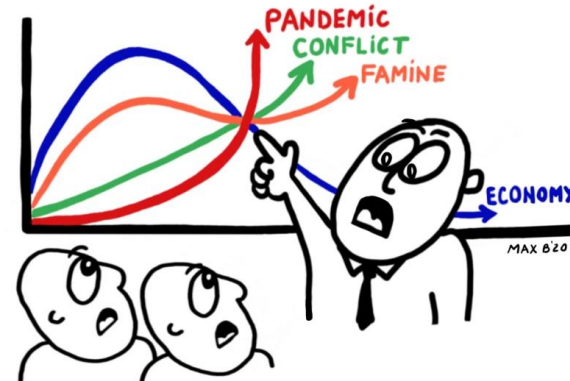


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Covid-19, climate change and migration

April 9, 2020



- The disasters are collaborating better than we are!

Cyclone Harold: relief for Vanuatu delayed by coronavirus contamination fears **theguardian.com 14 April 2020**

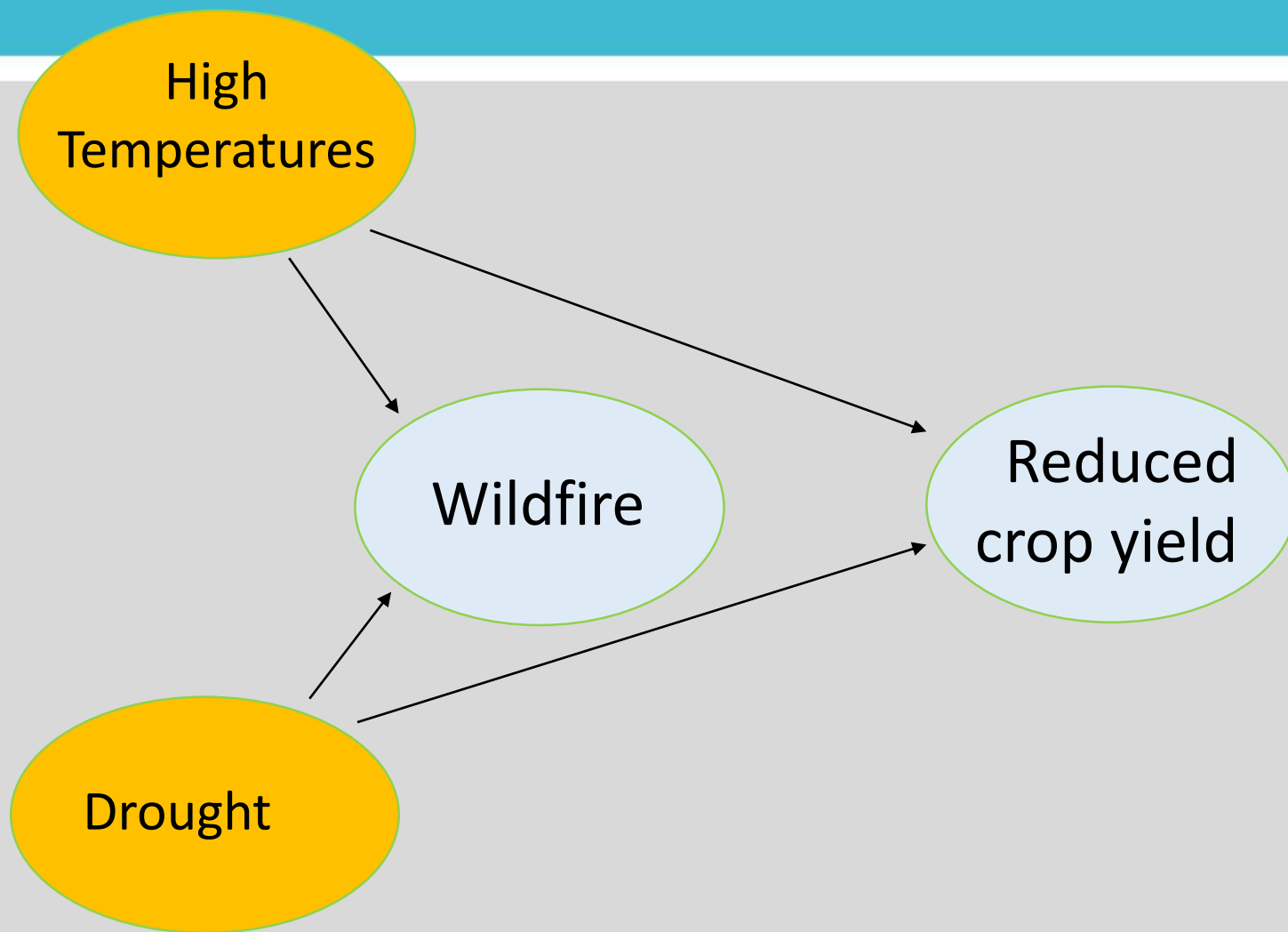
Humanitarian supplies flown in by Australian government can't be touched for three days due to strict quarantine rules



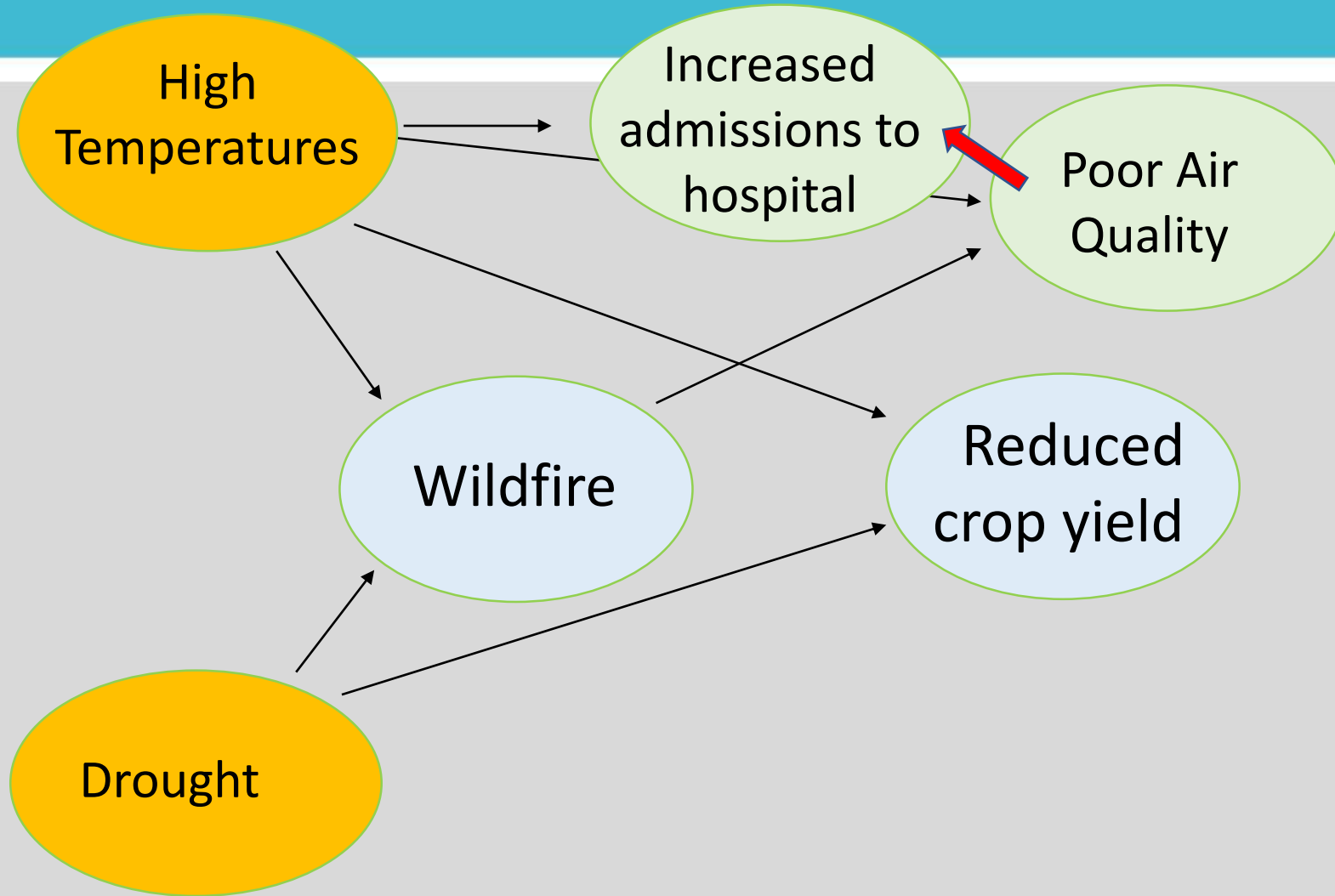
▲ A home destroyed in Wusi village, Espiritu Santo Island after category-five Cyclone Harold ripped through Vanuatu. Much-needed supplies to the Pacific island nation have been delayed due to fears over coronavirus contamination. Photograph: Christopher Y. Bartlett/The Guardian



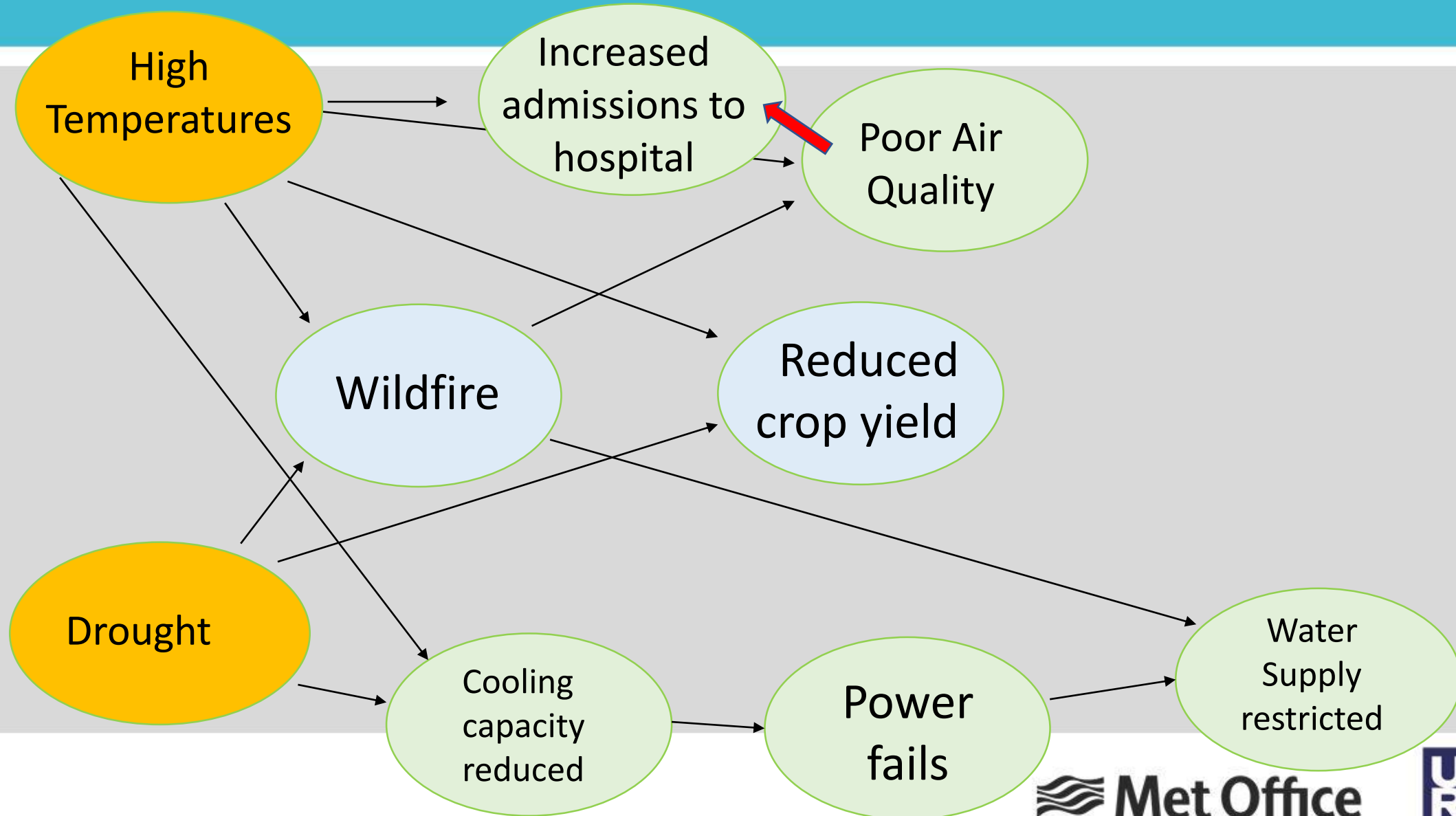
Cascading multi-sector impacts: an example



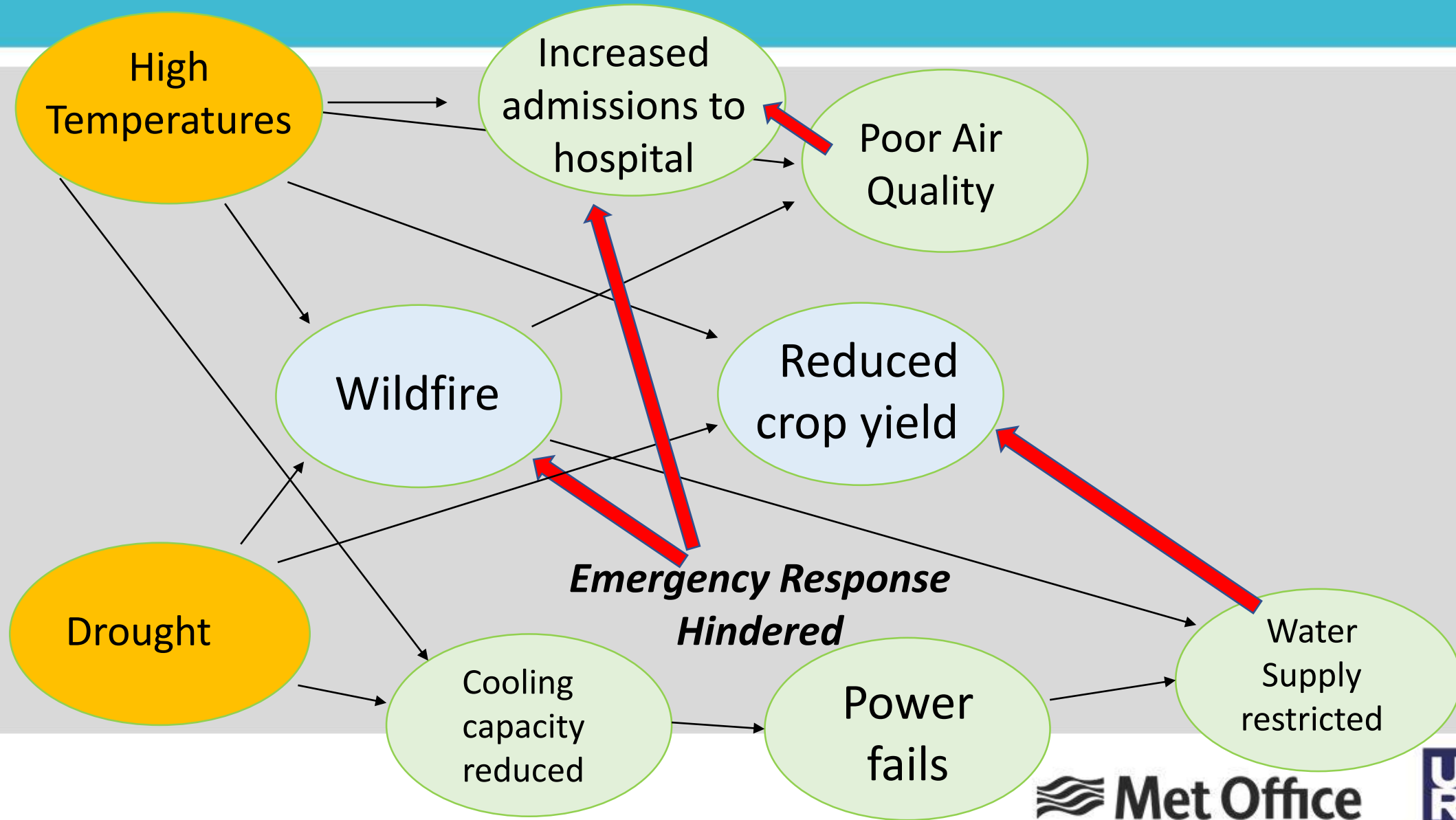
Cascading multi-sector impacts: an example



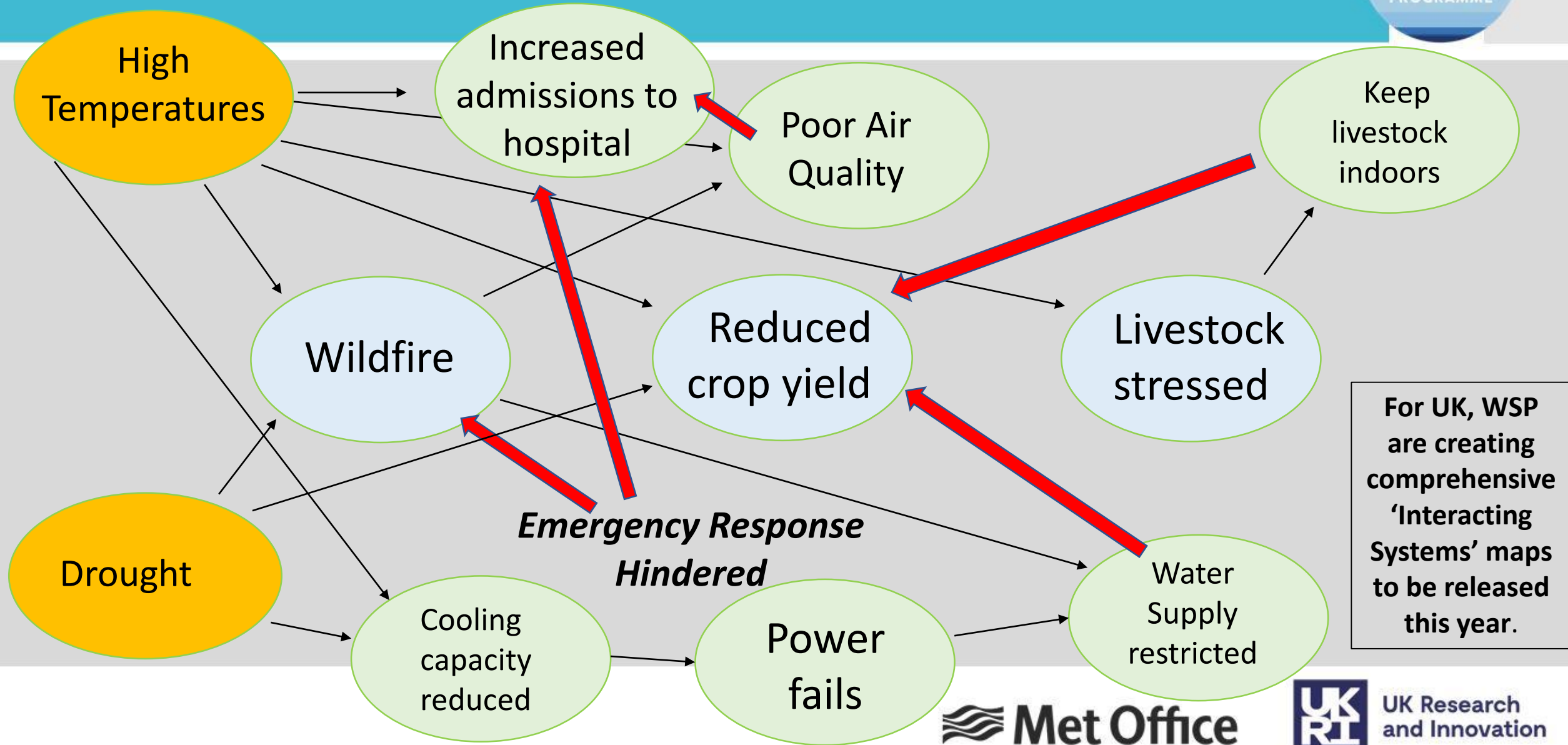
Cascading multi-sector impacts: an example



Cascading multi-sector impacts: an example



Cascading multi-sector impacts: an example



Complexity of compound events



Compound events may happen over **different timescales**:

- Extreme short events (timescales of days)
- Prolonged events (timescales of months +)
- Changes in conditions (over days or months +)



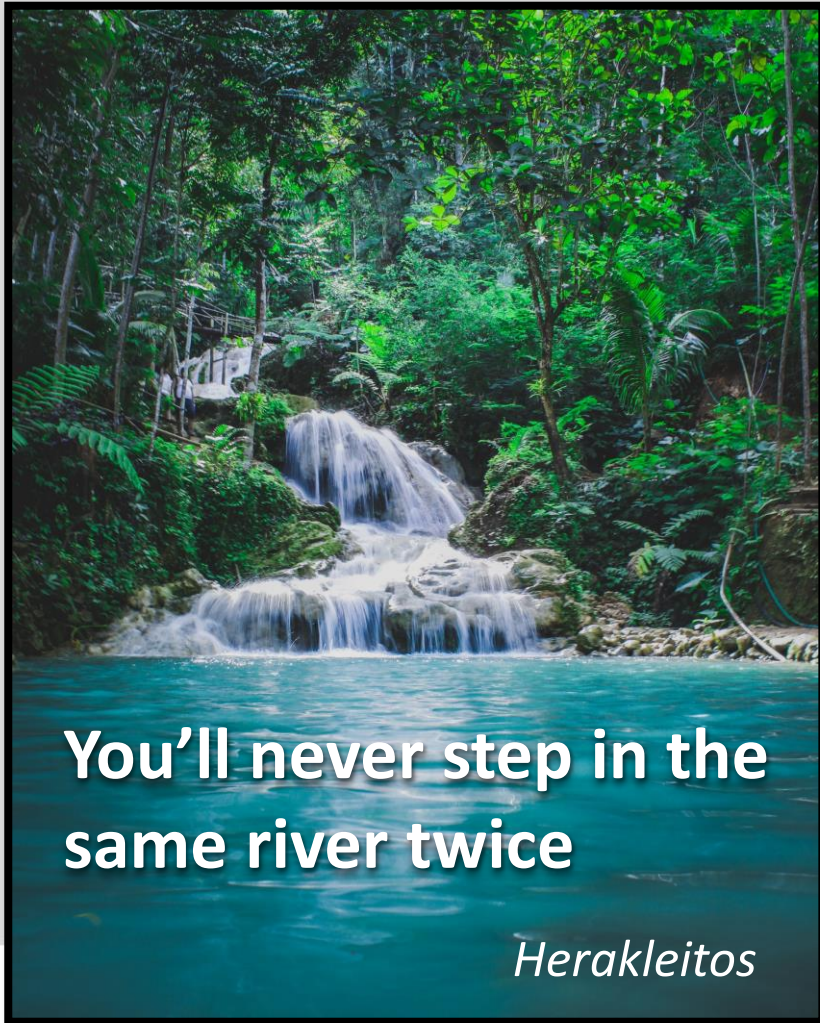
Compound events may affect **multiple UK sectors** simultaneously.

Impacts of compound events in one sector may **trigger** impacts in other sectors (cascading events), or **amplify** them.



Compound events **external to the UK** may impact UK sectors.

Understanding future risk



**You'll never step in the
same river twice**

Herakleitos

- Compound events are often unique, and impacts local
- Global or large area assessments of risk may not help local planners much
- A regional focus, considering local impacts and hazards may be more useful for decision making
- However, case studies can be very specific
- We start with a case study approach, but aim to build methodologies that can be applied elsewhere
- We can think about different types of compound events, and create methodologies applicable for each type

Thoughts on stakeholder & science-user interface




- Everyone we speak to in the user community agrees compound hazards are important to think about.
- However, emerging field of research which often relies on a high level statistical understanding, and many stakeholders do not consider it quantitatively.
- We are trying to identify key areas in which additional research perspective is useful – initial focus on UK agriculture.
- We are trying to work with stakeholders to co-develop products that will be useful and useable, and inform decision making.
- Making connections and building relationships with stakeholders takes time.

Agriculture in the UK



- A survey suggests 75% of farmers say extreme weather costs them around £10,000 per year, on average (Farmers Weekly/Macleod Research 2020).
- 90,000 square kilometres of utilised agricultural land, just under half of which is used for crops, mostly cereals (wheat/barley) & oilseed crops.
- Around 5 million cattle, 4 million pigs, 15 million sheep, 33 million chickens.
- Beef and pork are the biggest agricultural exports from the UK.
- Over 300,000 people work on agricultural holdings in England.

£10.7 billion 
the contribution from
agriculture and fishing
to the economy (2014)

Figures from the Department of Environmental Farming and Rural Affairs, June 2019

Impact information to understand current risk



How have we learnt about UK agriculture and impacts?

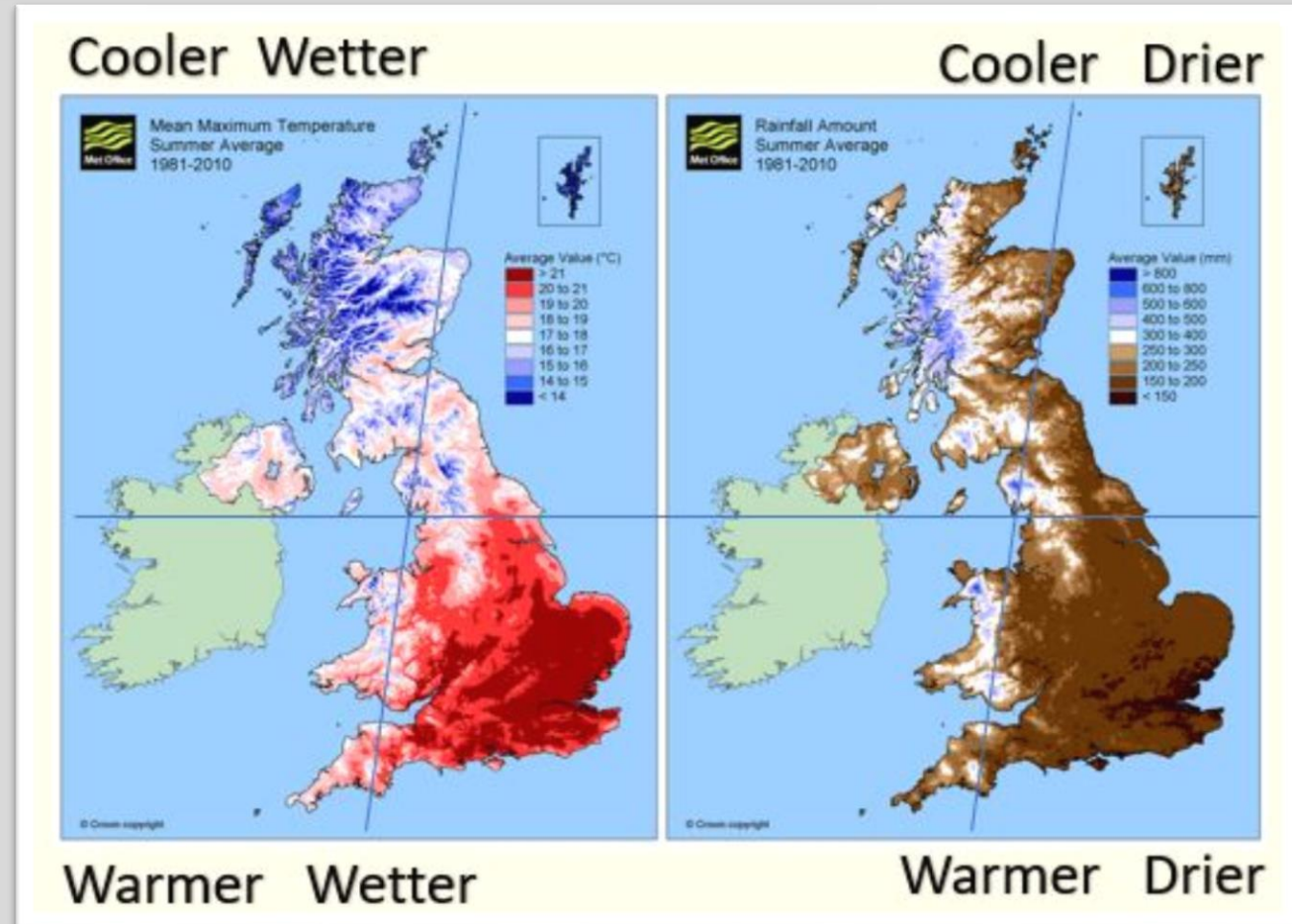
- Peer review literature
- Colleagues already working on agriculture questions at Met Office
- Conversations with Agricultural and Horticulture Development Board
- Communications from Department of Agriculture, Environment & Rural Affairs (Northern Ireland)
- Reading Farmers Weekly articles and other UK news
- Conversations with Department for Environment, Food and Rural Affairs (DEFRA).
DEFRA are a link to the development of agricultural adaptation policy and planning, which is a proxy for direct integration with the agriculture sector.



Our approach



- Initial focus on specific impacts as case studies for UK agriculture
- Develop methodologies that can be applied to other case studies
- Consider different type of compound events, affecting different areas of the UK
- Use established thresholds for an impact and apply them to future climate projections to assess changes in risk
- Generate own thresholds for impact from previous compound events with known impacts, and assess changes in risk of similar events



UK Climate Projections

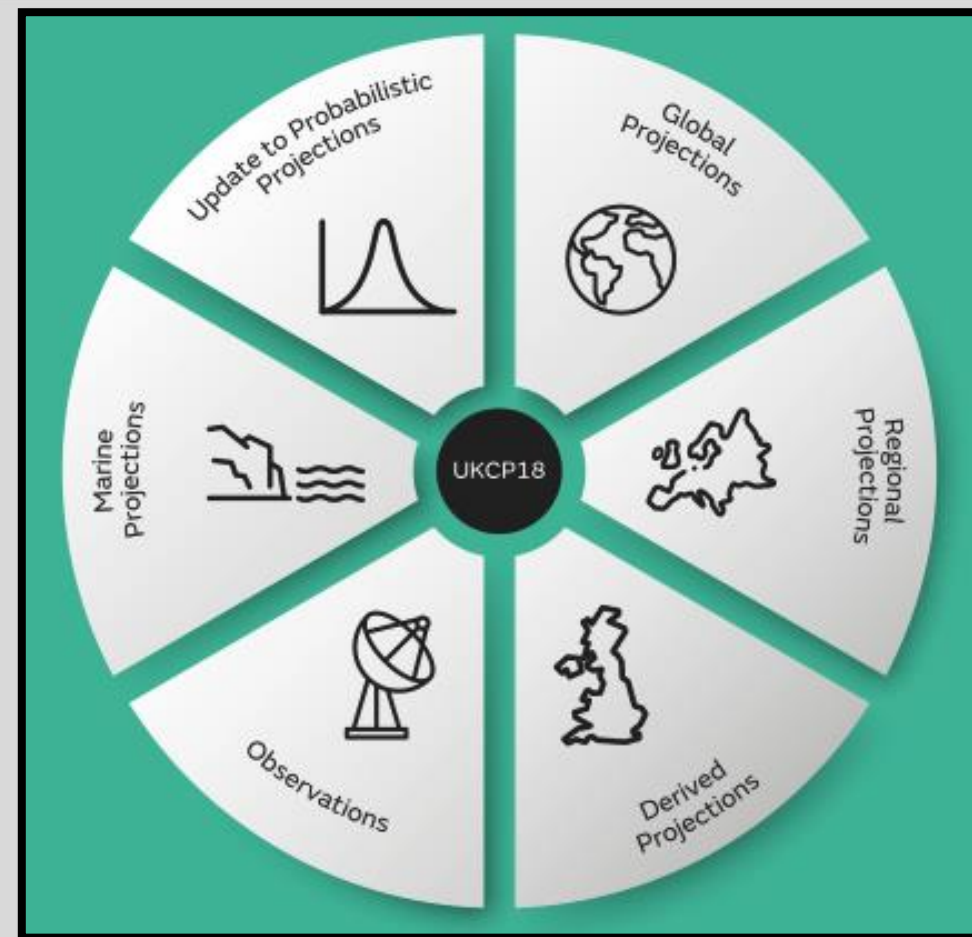


Now able to answer questions about:

- ✓ changing risks of extremes
- ✓ plausible sets of realistic future weather
- ✓ sea-level rise variations around the UK coastline
- ✓ Paris agreement targets

Headline result:

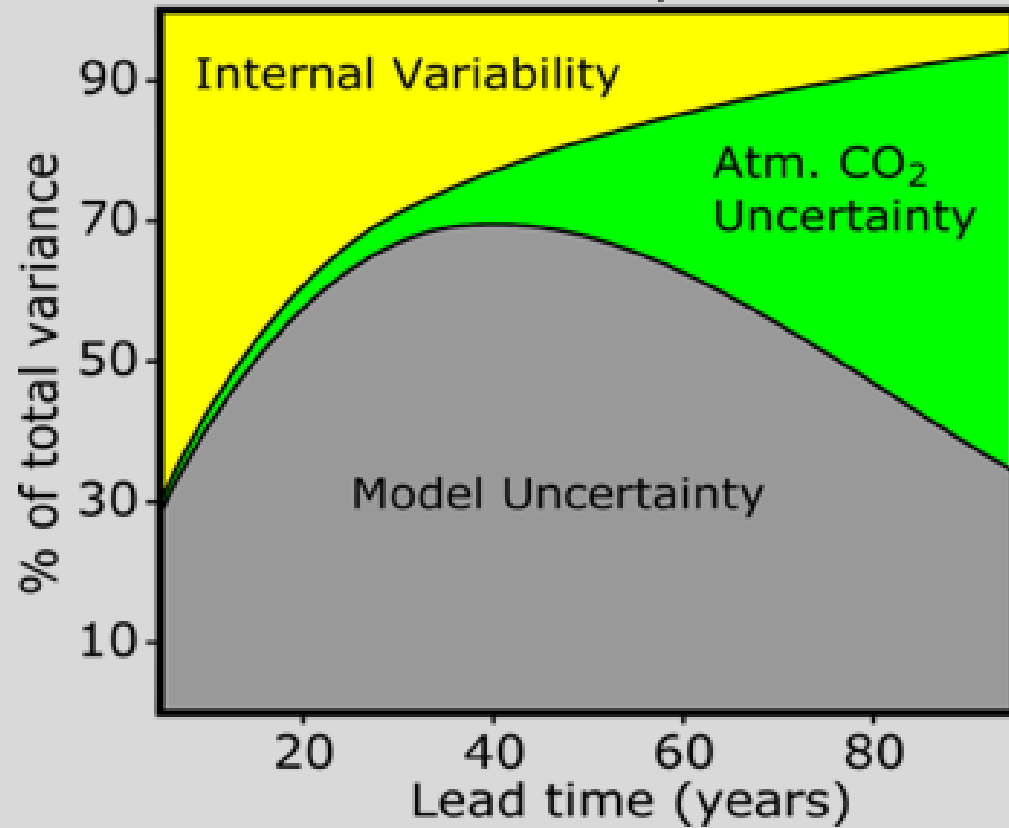
“a greater chance of warmer, wetter winters and hotter, drier summers”



Uncertainty in future projections



Regional (UK) decadal mean surface air temperature

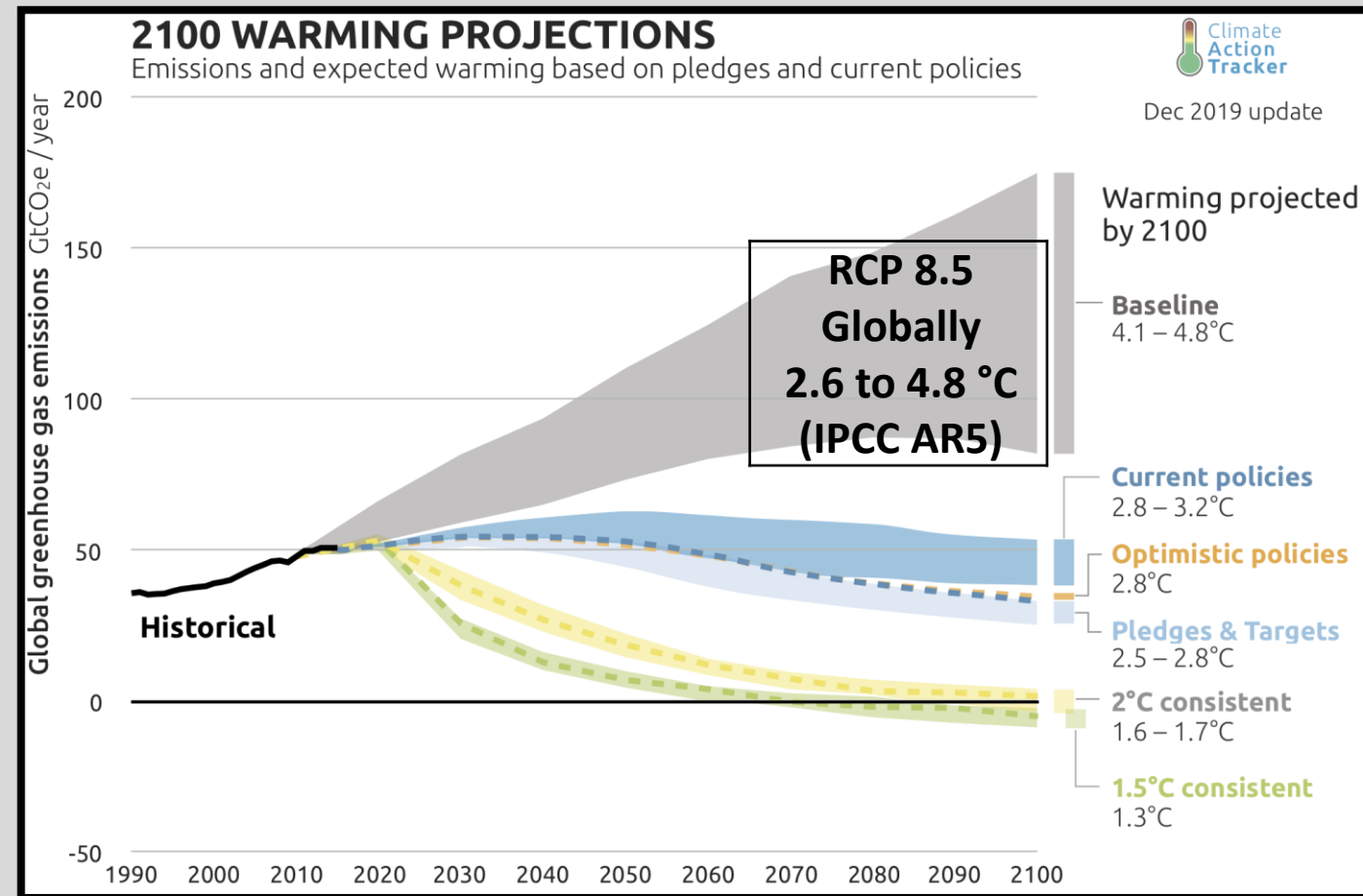


- For near term projection, internal variability dominates.
TOOL: Large ensemble (usually of same model) using different initial conditions.
- For prediction out to multiple decades, model uncertainty increases:
TOOL: Multi-model ensembles and/or Perturbed parameter ensembles

Uncertainty in future projections



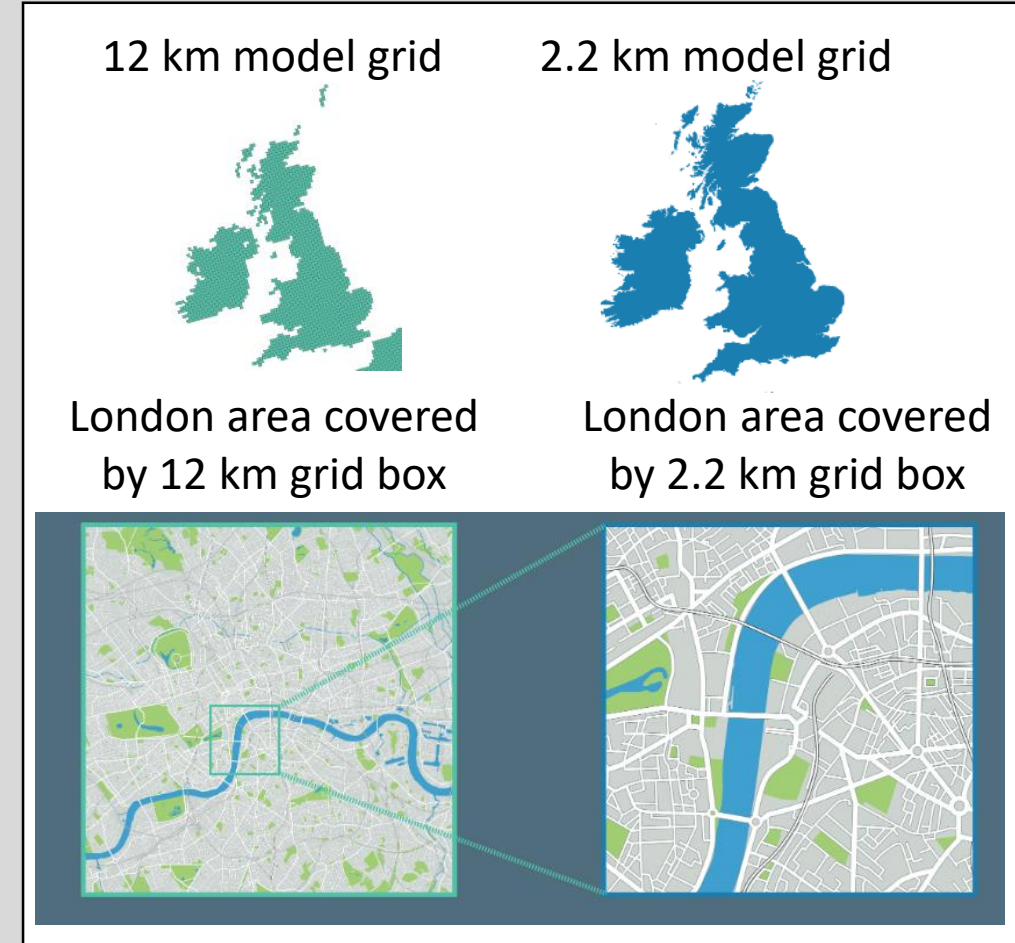
- By the end of the century, the greenhouse gas emissions determines a large fraction of uncertainty.
- Strongly dependent on socio-economic choices made over future years.
- Climate response dependent on the path as well as final outcome.
- RCP 8.5 was initially intended as a high-end baseline scenario, but has been portrayed as a business-as-usual scenario (for some years we tracked it closely, Peters et al. 2013)



Tool: Regional UK Climate Projections (1980 - 2080)



- Very high spatial resolution over UK.
- Perturbed parameter ensemble - 12 future projections of each model, assuming different but plausible climate behaviour over spatial scales below the model resolution (here 12km and 2.2km).
- Same emissions forcing in each projection (RCP 8.5 'business as usual', but emissions forcing doesn't affect projections much until you go beyond 2050).
- Other models are likely to project different magnitudes of trends to any of the simulations here (all 12 projections are using the same model).



Types of compound event



Framework proposed by Zscheischler et al (to appear in Nature Reviews Earth and Environment)

- **1. Multi-variate events**

Hot and humid weather

– risk of thermal heat stress on livestock

- **2. Preconditioning**

Cold spring followed by a warm/dry summer

– risk of food shortages for livestock

- **3. Temporally compound**

Storm surges that caused the collapse of Dawlish sea wall

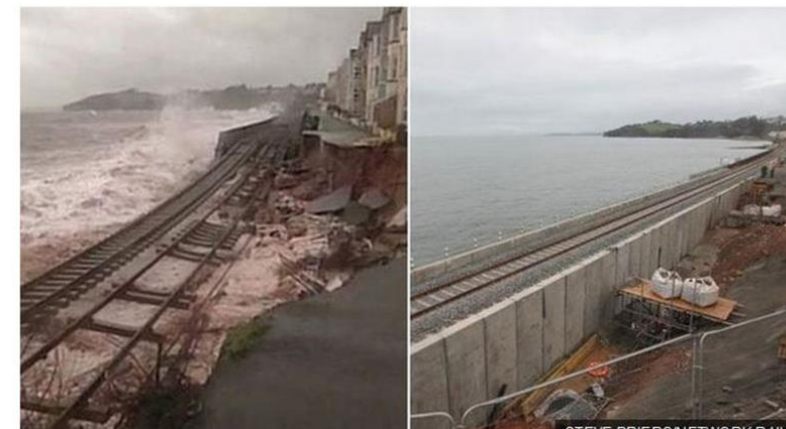
- **4. Spatially compound**

Widespread cold spring and warm dry summer – risk of food shortages for livestock

Dawlish rail line: Closure 'costs economy up to £1.2bn'

5 February 2015

f t e Share



Here we focus on compound events driven by weather and climate variables (atmosphere and ocean) but climate hazards may combine with natural hazards (e.g. volcanoes or disease).

Compound events impacting UK agriculture



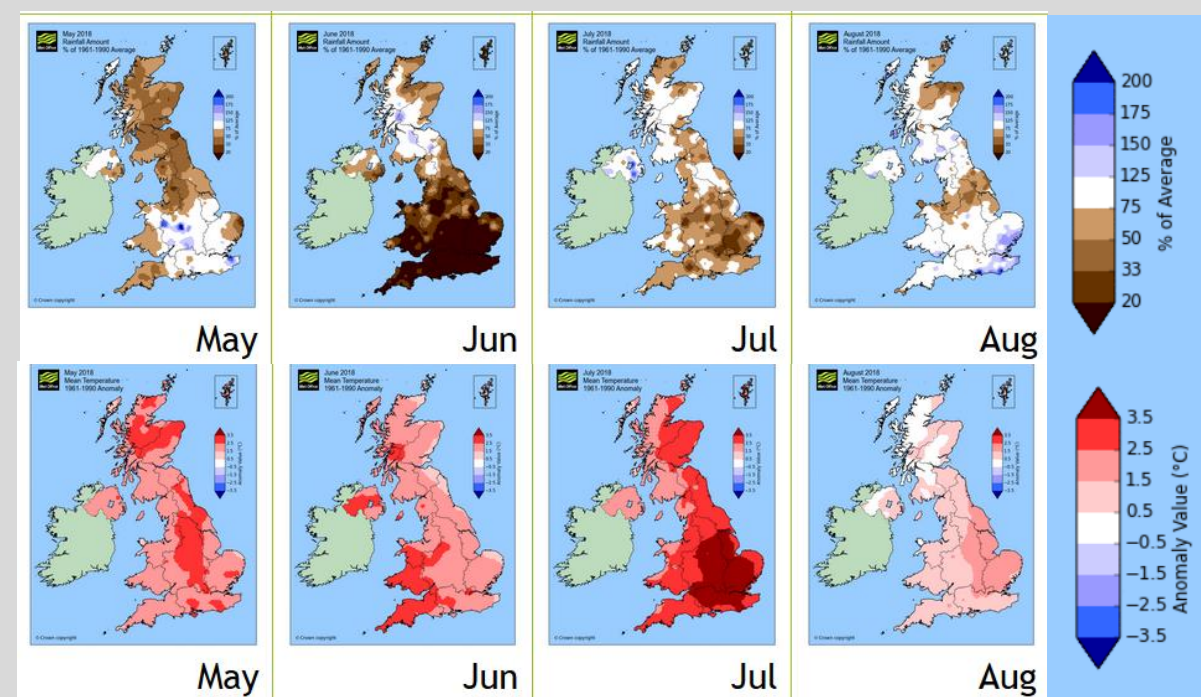
Multivariate event

Hot dry weather in 2018 led to wheat yields being 6% down on the 5 year average (as reported in Farmers Weekly).

Also temporally and spatially compounded event, because it was so widespread.

Imported wheat largely from France and Germany, and they may experience similar conditions, so import prices could be high in future similar events.

Rainfall Amount
% of 1961-1990 Average



Mean temperature (°C)
1961 – 1990 Anomaly

Compound events impacting UK agriculture



Preconditioning

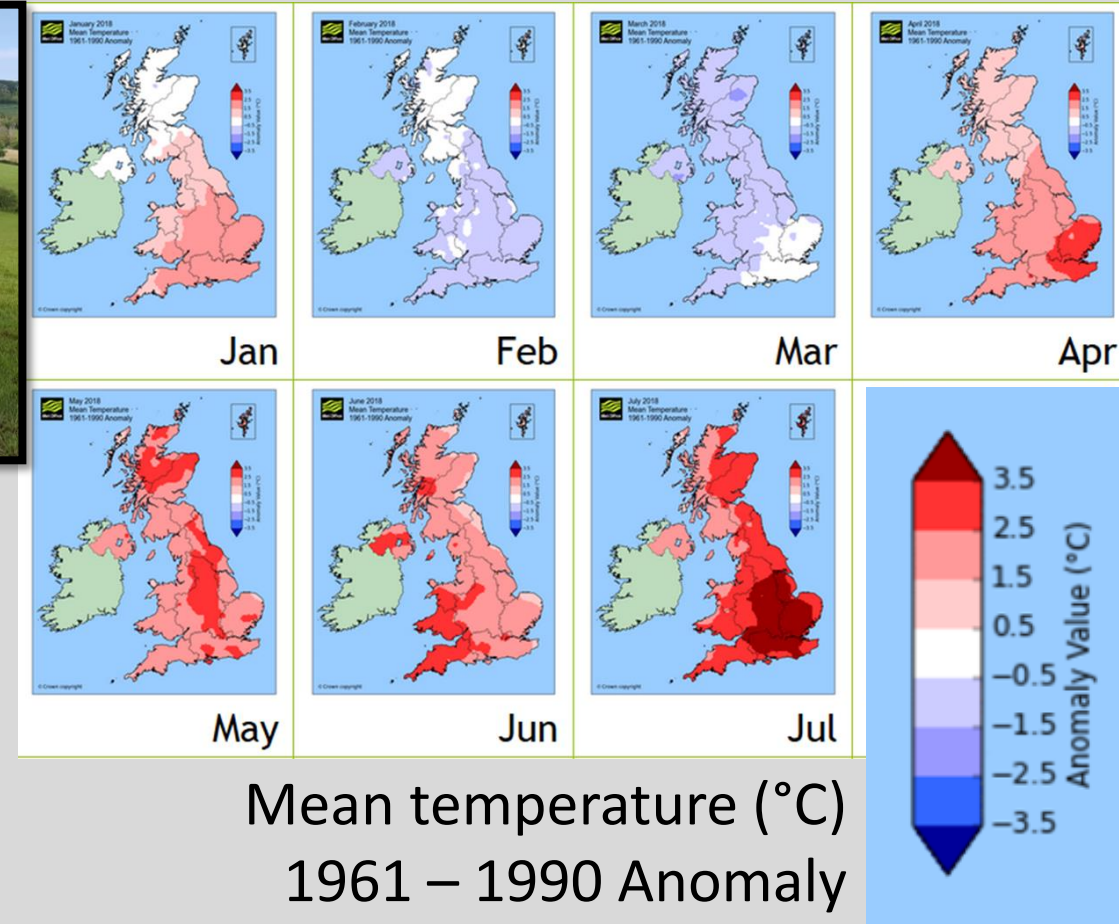
Hot dry summer in 2018 was preceded by a cold wet spring.



Impact

Cattle inside for much longer than normal

Livestock feed (hay and silage) was in short supply and became very expensive in parts of the country. It also exposed cattle to additional health risks.



Mean temperature (°C)
1961 – 1990 Anomaly

Instances of cold spring and warm summer



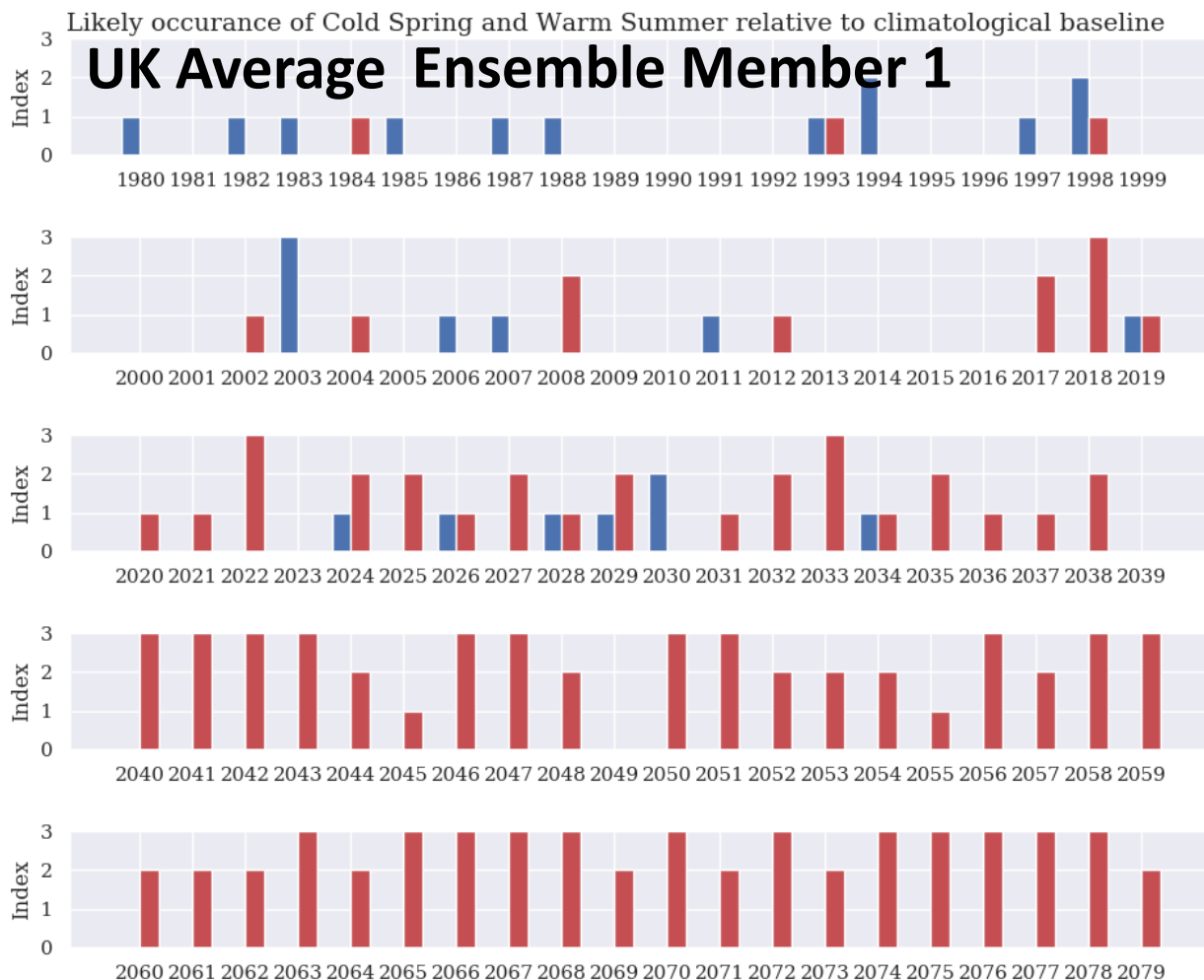
1980-
1999

2000-
2019

2020-
2039

2041-
2059

2060-
2079



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- How many (out of 3) months satisfy a threshold criteria from 1980 – 2080?

- Use threshold criteria based on 2018 conditions

Cold spring -1.7°C below climatology

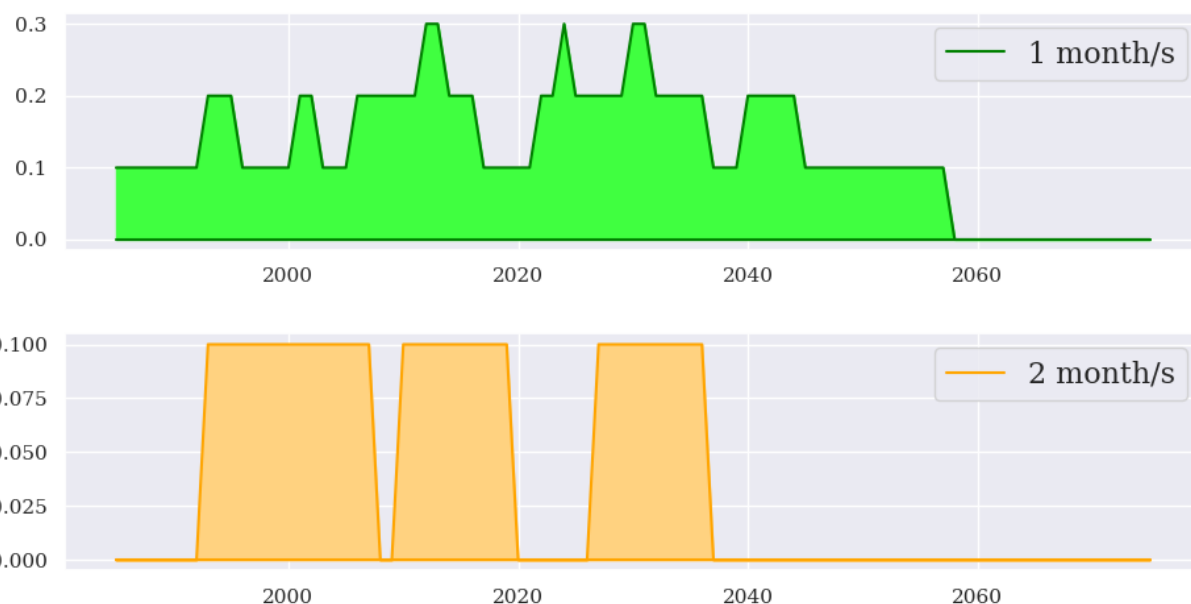
Hot summer $+2^{\circ}\text{C}$ above climatology

- Instances of cold spring months and warm summer months occur through 2020 – 2040 but less chance of occurring post 2040

Probabilities of cold spring & warm summer



Probabilities of Cold Spring and Warm Summer



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Probabilities of both cold spring month and warm summer month happening in same year (in 2018, there were 2 cold spring months and 3 warm summer months):

- 1 cold and 1 warm happens **up to 3 out of 10 years between 2020 and 2040.**
- Due to unlikely nature of cold spring after 2060 - not likely to experience both events.
- 2 cold and 2 warm happens up to **1 in 10 years between 2020 and 2040.**
- No 3 cold & 3 warm in same year.

Livestock stress in South West England



Dairy cattle susceptible to heat stress due to **high temperature** and **relative humidity** (Johnson et al. 1963) leading to reduced weight gain, decreased fertility and milk yield.

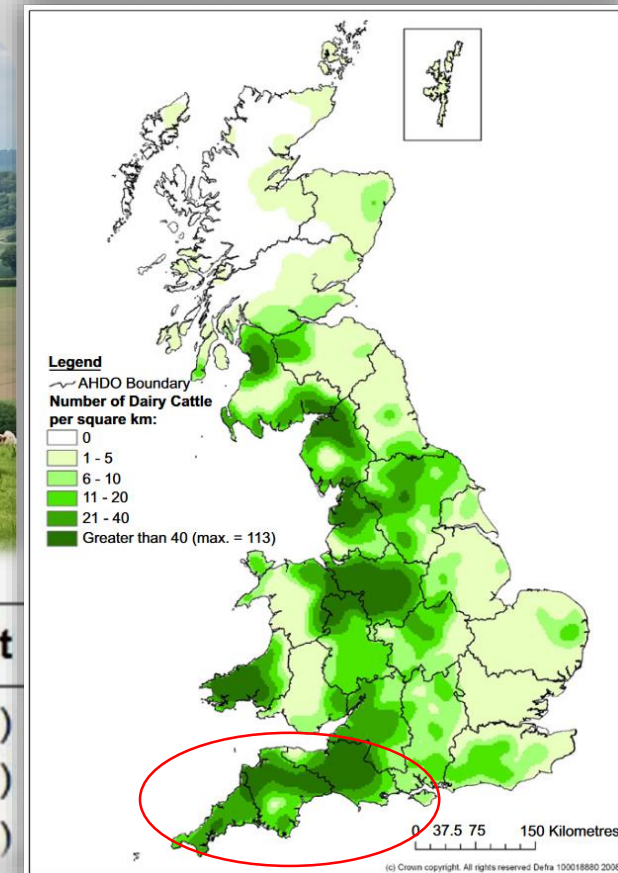
Follows work by Dunn et al. (2014), where thermal heat index is calculated using:

$$THI = (1.8T + 32) - (0.55 - 0.0055RH) \times (T - 26.8)$$

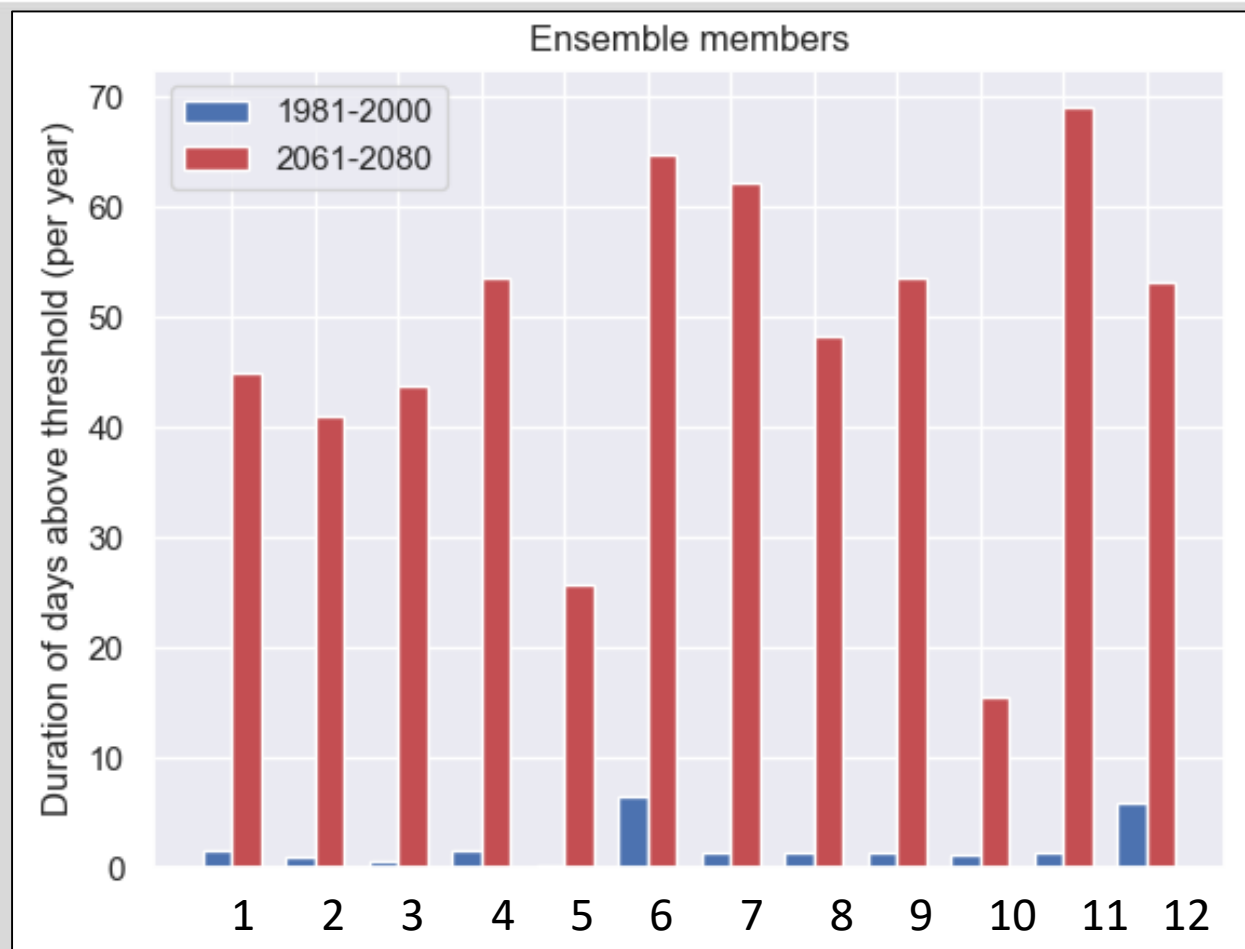


Livestock:

(Thousand head)	South West	
Cattle	1,736	(33%)
Dairy herd	432	(39%)
Beef herd	186	(27%)



Heat stressed cattle in South West England



We show duration (days/year) above the threshold of stress (70) for all the 12 km ensemble members.

Suggests that there are likely to be many more days where cattle are stressed during 2061-2080 than during 1981-2000 in South West England (as a regional average).

Ensemble mean 1981-2000: 2 days / year

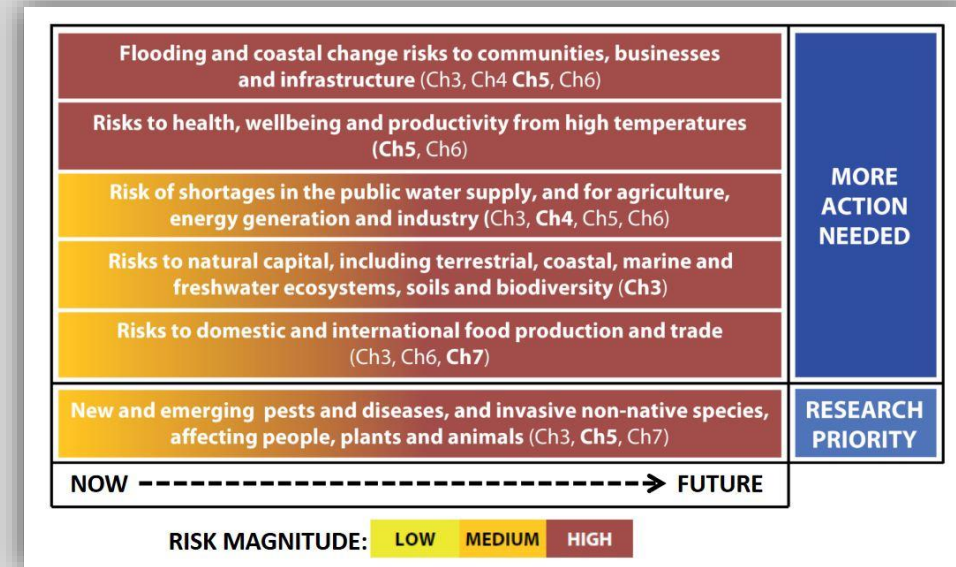
Ensemble mean 2061-2080: 49 days / year

Range of ensemble members reveals inherent uncertainty due to model parameters.

Future of our compound events work



- Extension of current case studies and comparison to other models where appropriate (e.g. using probabilistic projections)
- Additional user cases in other sectors
- Continue developing links across SPF UK Climate Resilience projects and the wider climate community to explore future collaborations related to compound events
- Further develop methodologies and the range of cases that our software will be able to process
- Making software tools available for others to use at the end of the project



ASC (2016) UK CCRA 2017 – Synthesis Report



Summary



- As well as characterising future changes to compound hazards, we aim to combine this information with exposure and vulnerability generate risk projections where possible.
- We are using a case study approach to study compound hazards.
- We show some straightforward examples here, but we also plan to use more advanced statistical methodologies for multiple hazards.
- We are trying to work with stakeholders as much as possible, to ensure our work is useful and useable.
- We hope that our projections will be used in decision making for UK climate adaptation.

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