Institute and Faculty of Actuaries

Life Conference 2022

23–25 November, ACC Liverpool

#LifeConf

Institute and Faculty of Actuaries

4most ANALYTICS CONSULTING

A Looming Threat? Understanding the Human Cost of Rising Temperatures

Daniel Gill
Alex Harding

Aims and Objectives

- Research and understand the relationship between mortality and future climate (temperature) change
- Build a temperature model to forecast future temperature increases up to 2090. Use publicly available temperature and death data to inform an investigation
- Design a mortality model to predict the impact of different hot/cold temperature events on mortality. Identify threshold hot/cold temperatures and lag effects
- Integrate predicted future temperatures with a mortality model to quantify the likely future impact of temperature change on UK mortality rates, under different scenarios
- Assess the suitability of existing mortality models for incorporating the impacts of future temperature change. For example, improvements in the CMI model

Our Journey

Research

- Gather research on climate change investigations
- Consult academic studies, (e.g. Hajat and Vardoulakis) to aid investigation.

Temperature Projection

- Simulate future climate scenarios and resulting temperatures
- Use historical data to project UK future daily temperatures.

Mortality Model

- Construct a mortality model in Python
- Explore the relationship between temperature and mortality in the UK.

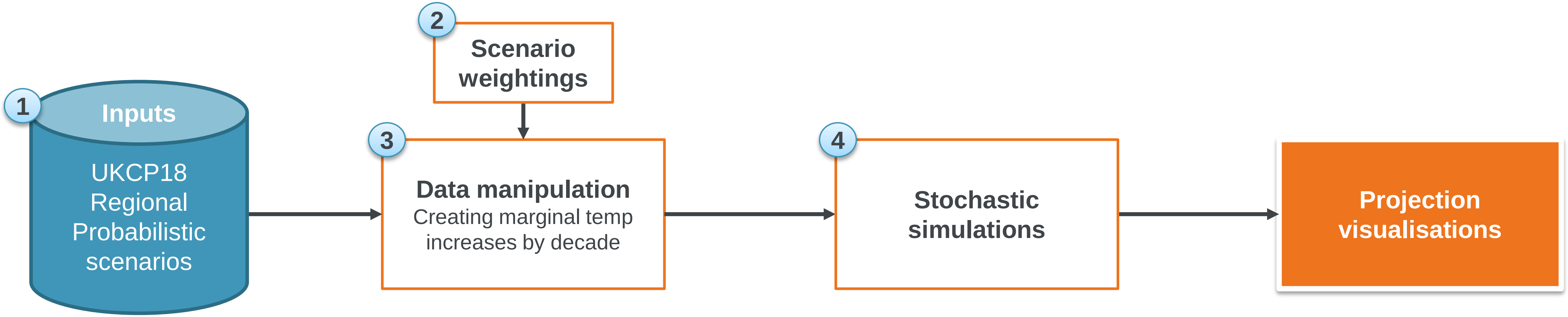
Analysis of Results

- Analyse outputs of the model under different scenarios
- Present and scrutinise findings against real-world events.

Next Steps

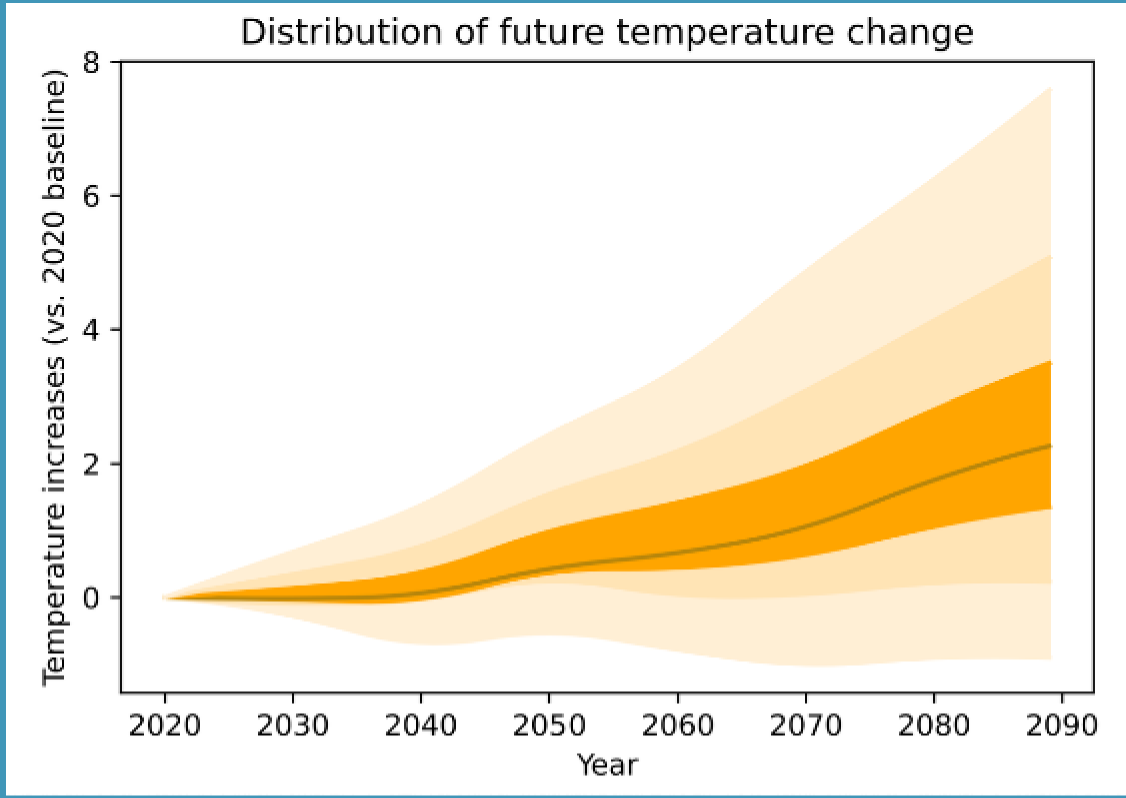
- Refine modelling approach and apply to practical analysis
- Enhance data to improve mortality risk factor insight.

Temperature Projection Model



1. **Inputs – UKCP18 scenarios:** We have used UKCP18 probabilistic scenarios to predict future temperature increases - these are provided as confidence intervals, split by decade
2. **Scenarios:** We use the industry standard RCPs ('Representative Concentration Pathways') as our baseline scenarios of future temperatures. The weightings between RCPs are set using expert judgment.
3. **Data manipulation:** Fits distributions using the UKCP18 scenarios and converts to marginal temperature increases
4. **Stochastic simulator:** The process which drives the Monte Carlo simulations of future temperature projections

Future Temperature Change



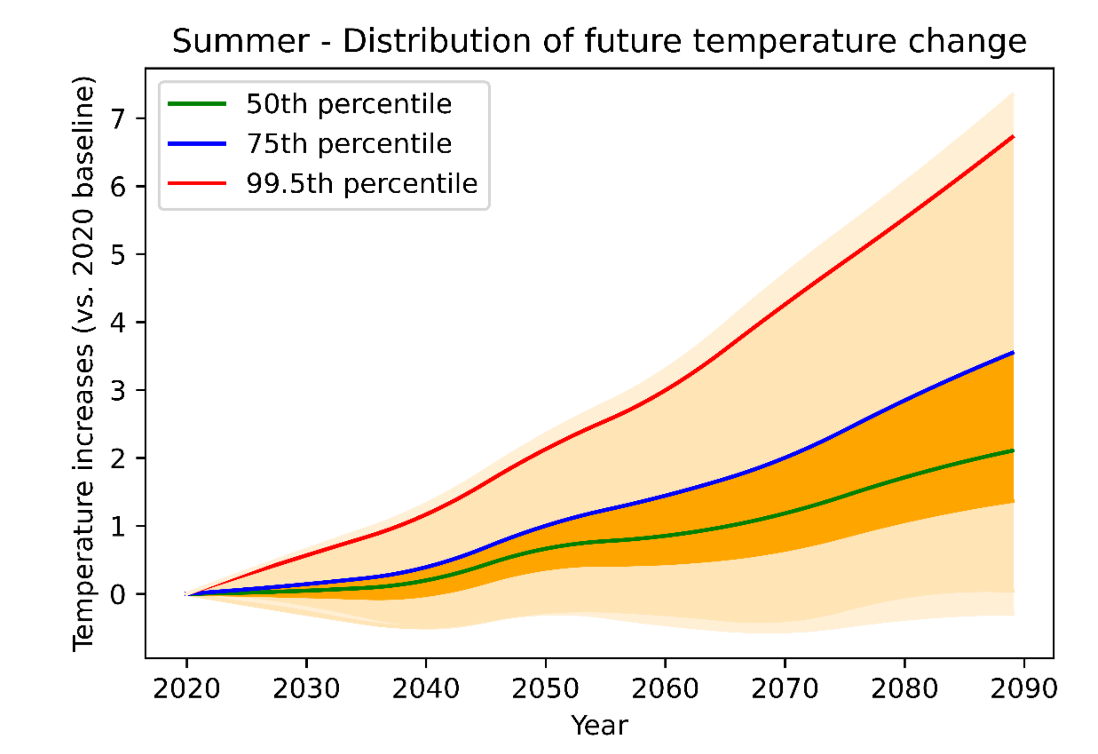
- To create the simulations, we take a random simulation from the normal distribution for each RCP scenario
- We then select a simulation based on the relative weightings for each scenario
- The pathway is then interpolated to give an annual temperature increase for the simulation (rather than by decade)
- The Monte Carlo simulations produce the temperature projections for 1000 simulations. The graphs below illustrates the resulting distributions

4most ANALYTICS CONSULTING

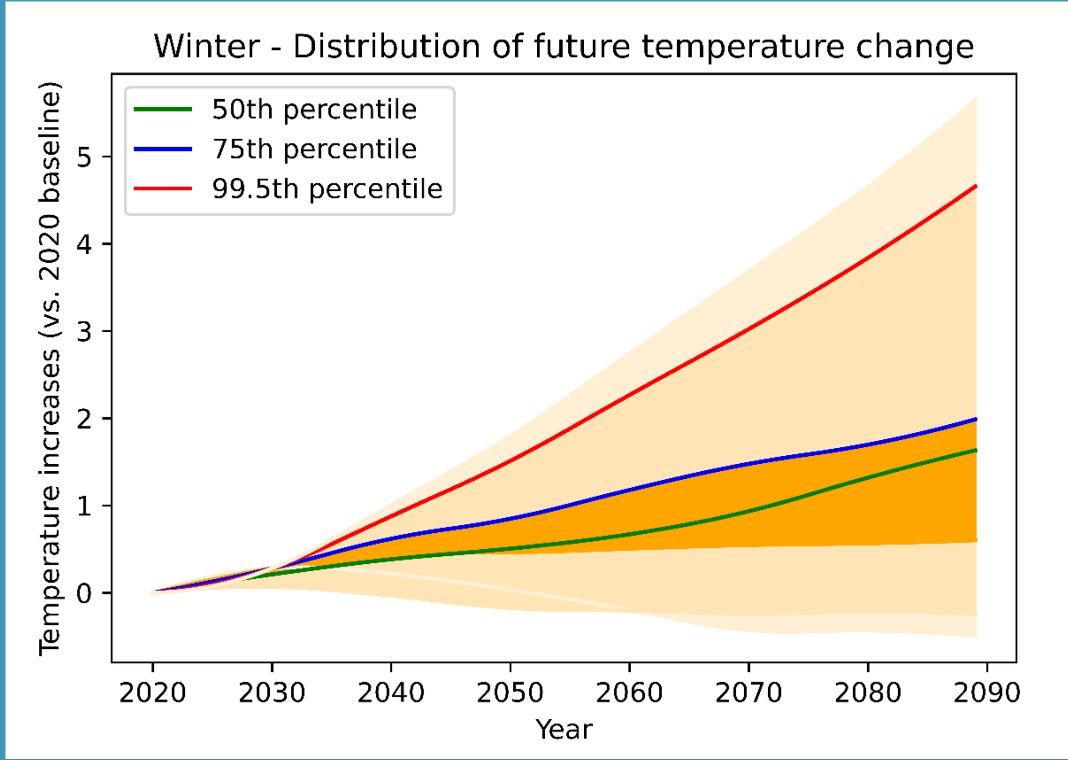
Institute and Faculty of Actuaries

Summer vs Winter

Summer



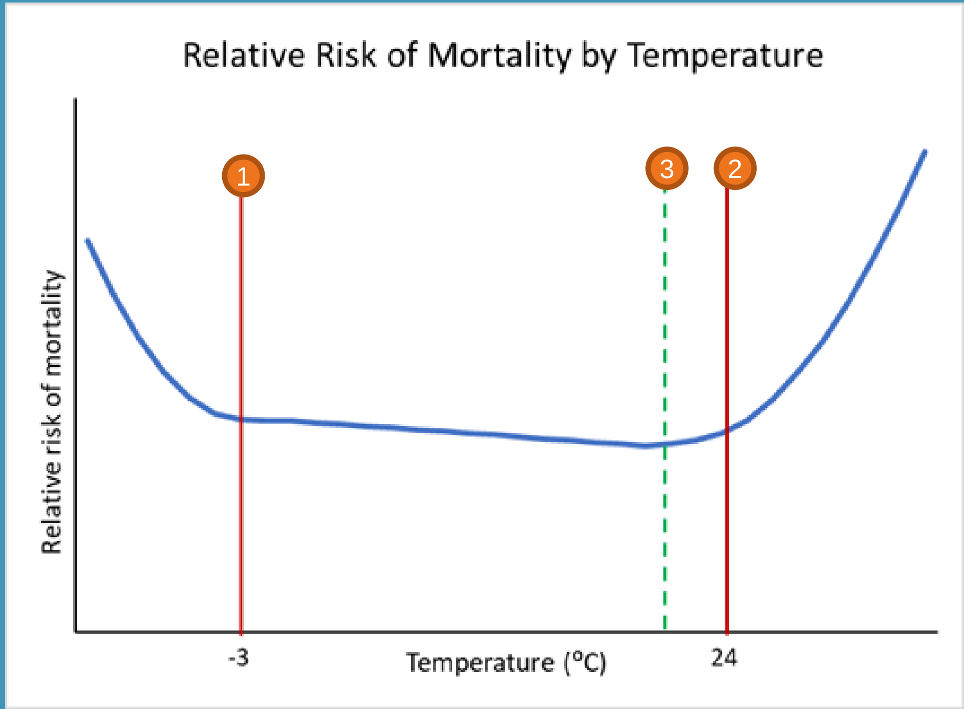
Winter



4most ANALYTICS CONSULTING

Institute and Faculty of Actuaries

Mortality Model - Research



The 'U-shaped' relationship between temperature and mortality, highlights the pinch-point temperatures (1&2) and point of lowest mortality (3).

- Temperature and mortality relationship model, based on scientific research (Gasparrini)
- Introduces 3 key temperature points:
  1. **Cold-event temperature** (beyond which relative risk of mortality increases, giving rise to more 'excess cold' deaths)
  2. **Hot-event temperature** (beyond which relative risk of mortality increases, giving rise to more 'excess hot' deaths)
  3. **Optimum daily temperature** (at which the relative risk of mortality is lowest)

4most ANALYTICS CONSULTING

Institute and Faculty of Actuaries

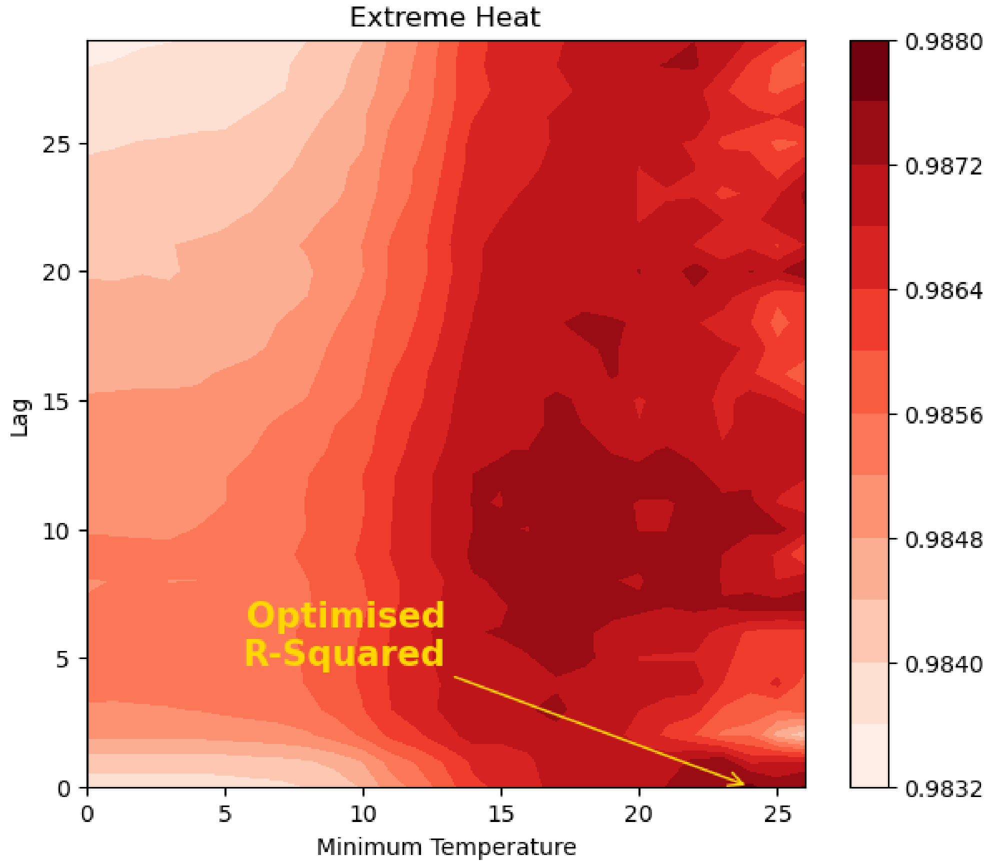
Approach

- **Focus on population above the age of 65**
  - To split into different age groups (65-69, 70-74, 75-79, 80-84, 85-89, 90+)
- **Define a minimum hot and maximum cold temperature**
  - To ensure we are looking at sufficiently extreme events
- **Parameterise lag effect**
  - For **hot events** there is no real lag; when it is hot, the impact is seen on the same day, e.g. heat stroke.
  - For **cold events** however, there is a lag present; if someone gets a cold on day 1 due to the low temperature, may not die due to the cold for up to two weeks
- **Build regression model**
  - We define a linear regression to establish where a clear link between temperature and mortality begins and ends
  - The regression model is then applied to a subset of data, where the observed maximum/minimum temperature on that day was above/below a defined threshold

Parameterisation

1. Minimum temperature for hot events
2. Lag time for hot events
3. Maximum temperature for cold events
4. Lag time for cold events

Min temp for hot events: 24ºC
Lag for hot events: 0 days



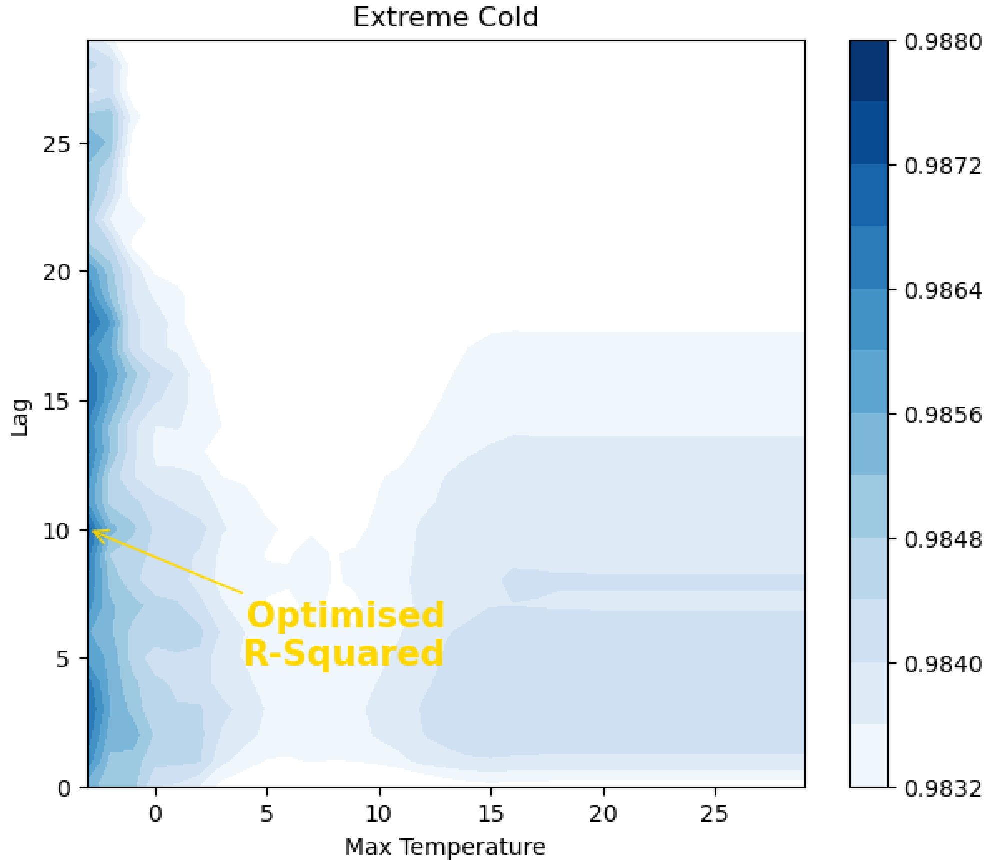
4most ANALYTICS CONSULTING

Institute and Faculty of Actuaries

Parameterisation

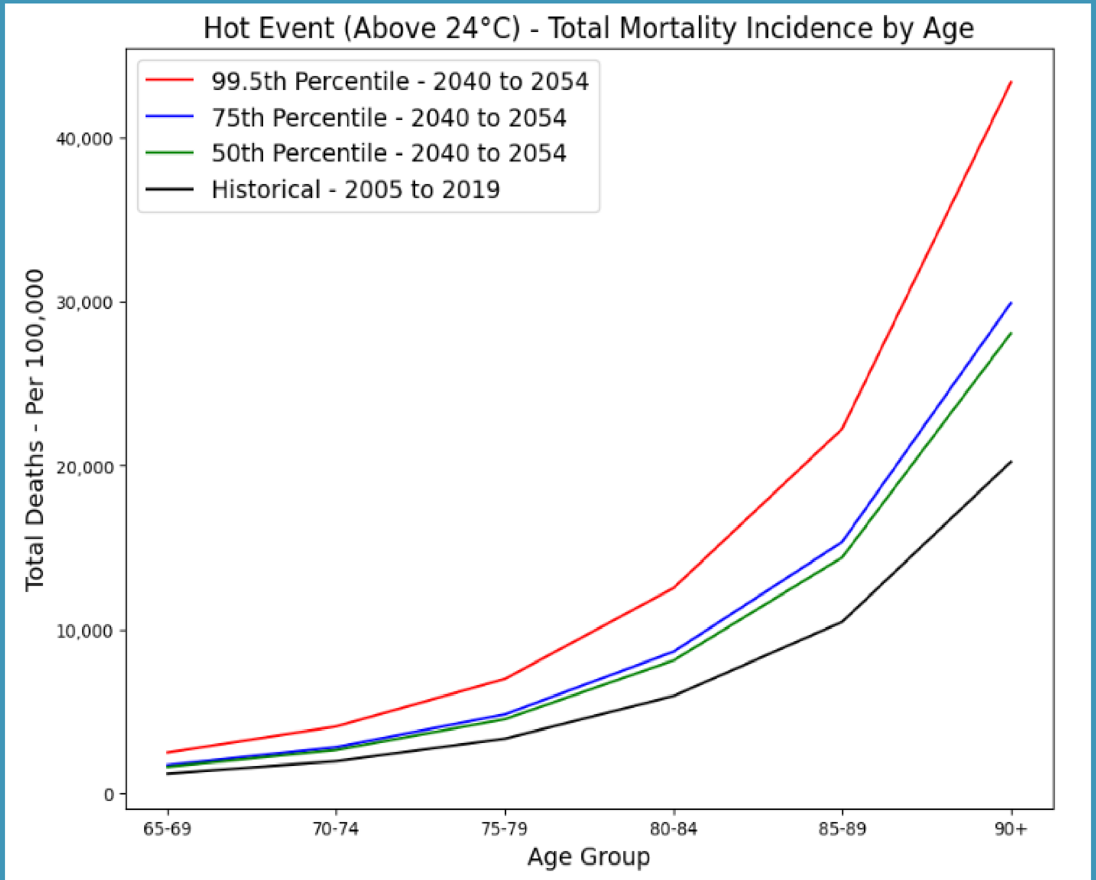
1. Minimum temperature for hot events
2. Lag time for hot events
3. Maximum temperature for cold events
4. Lag time for cold events

Max temp for cold events: -3ºC
Lag for cold events: 10 days



4most ANALYTICS CONSULTING | Institute and Faculty of Actuaries

Findings and Conclusions



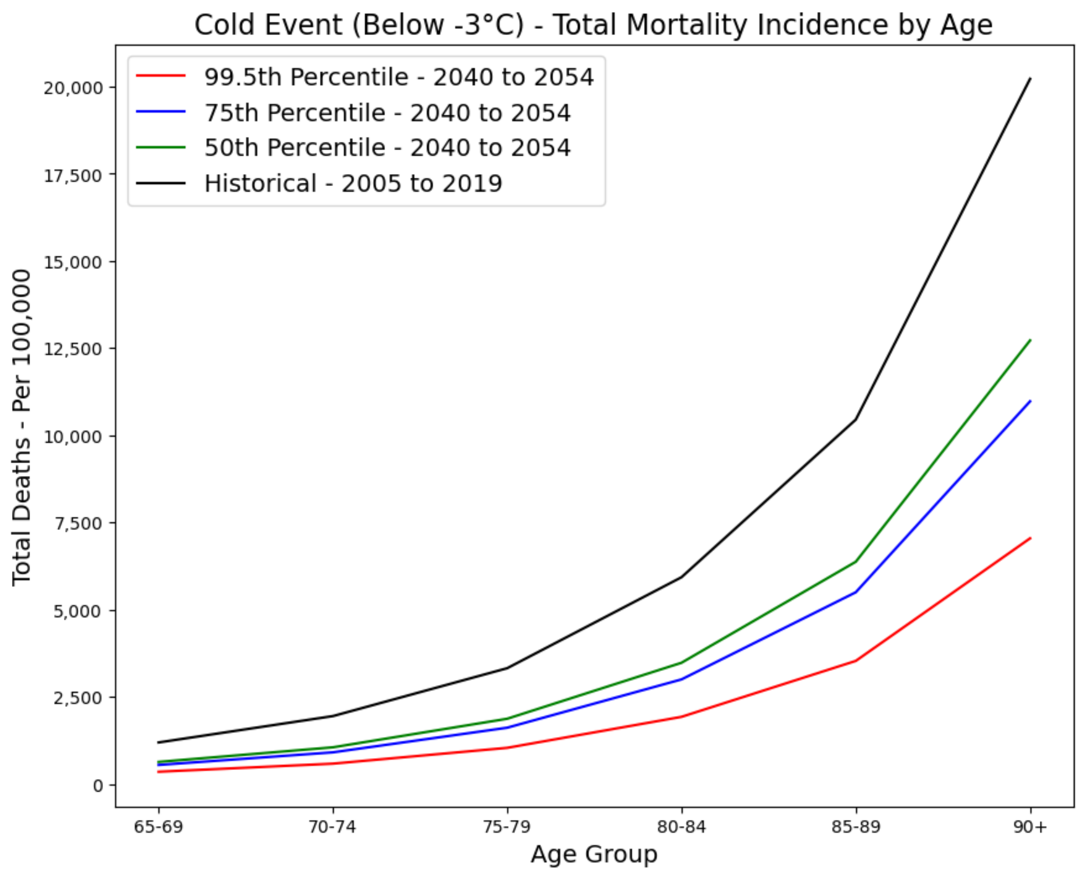
Hot Event Mortality

1.48% increase in mortality, per 1 degree increase in temperature above the 24°C threshold

4most ANALYTICS CONSULTING

Institute and Faculty of Actuaries

Findings and Conclusions



Cold Event Mortality

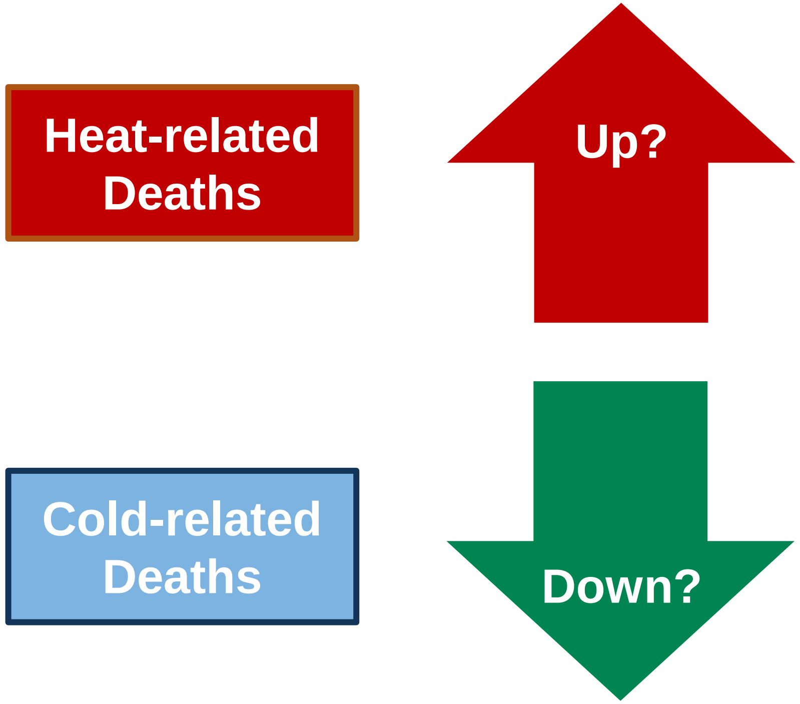
1.69% increase in mortality, per 1 degree decrease in temperature below the -3°C threshold.

4most ANALYTICS CONSULTING

Institute and Faculty of Actuaries

Findings and Conclusions

- Based on our projections, **deaths related to extreme heat will increase drastically by 2040**
  - This is predominantly driven by an increase in number of heat events
  - But also by the severity of these heat events
  - Even the median scenario shows a significant increase in death rates
- This effect would be offset by **fewer deaths related to extreme cold**
  - Increasing average temperatures could mean fewer winter deaths
  - However, this is dependant on stable temperature volatility and weather systems
  - It is possible to see a constant or even increased number of cold events, which could drive an increase in overall death rates.
- Further analysis on 'normal temperature' days required
  - It is possible that overall death rates are unaffected by temperature change, but the timing and distribution of deaths is affected.



4most ANALYTICS CONSULTING

Institute and Faculty of Actuaries

Assumptions and Limitations

Assumptions

- Variance of daily temperatures remain static
- Representative Concentration Pathways (RCP) scenario weightings
- The temperature parameters for defining extreme hot/cold events remain static
- The temperature model uses Met Office's average annual temperature increases to forecast future temperature changes
- The population of each age group stays constant throughout each year

Limitations

- Data availability
- Future mortality improvements
- The temperature increases by decade, interpolation is carried out to derive yearly increases
- The LTSM model used to project future temperatures has an approx. 30 minute run time, meaning that a large number of simulations cannot be made
- The model is not 'Trained', and so could be over fitting to the data
- The use of the regression model projections assumes that deaths are independent i.e. tomorrow's mortality rate is not dependent on today's mortality rate

Applications and Next Steps

Applications

Assumption Setting

- Understand the effect of temperature change on existing mortality assumptions
- Apply modelling to policyholder data to generate tailored assumptions for insured populations

Risk Management

- Ensure compliance with current and future regulatory stress testing, capital and disclosure requirements
- Understand climate-related financial risks for internal governance processes

Next Steps

Data Improvement

- Improve data granularity e.g. exact ages instead of age groups, cause of death, region/postcode analysis etc.
- Adaptation of existing or introduction of a new CMI model parameterisation

Wider impacts

- Consider lapse/morbidity impacts of climate change
- Consider non-temperature related climate change impacts

Questions

Comments

Expressions of individual views by members of the Institute and Faculty of Actuaries and its staff are encouraged.

The views expressed in this presentation are those of the presenter.

Institute and Faculty of Actuaries

Thank you

www.4-most.co.uk

#LifeConf