Newcastle University

Downscaling and Uncertainty

Hayley Fowler, Newcastle University, UK
Linda O. Mearns, NCAR

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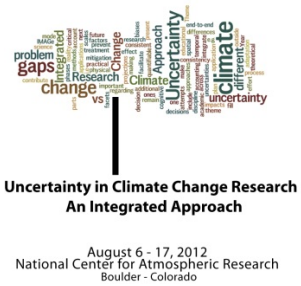
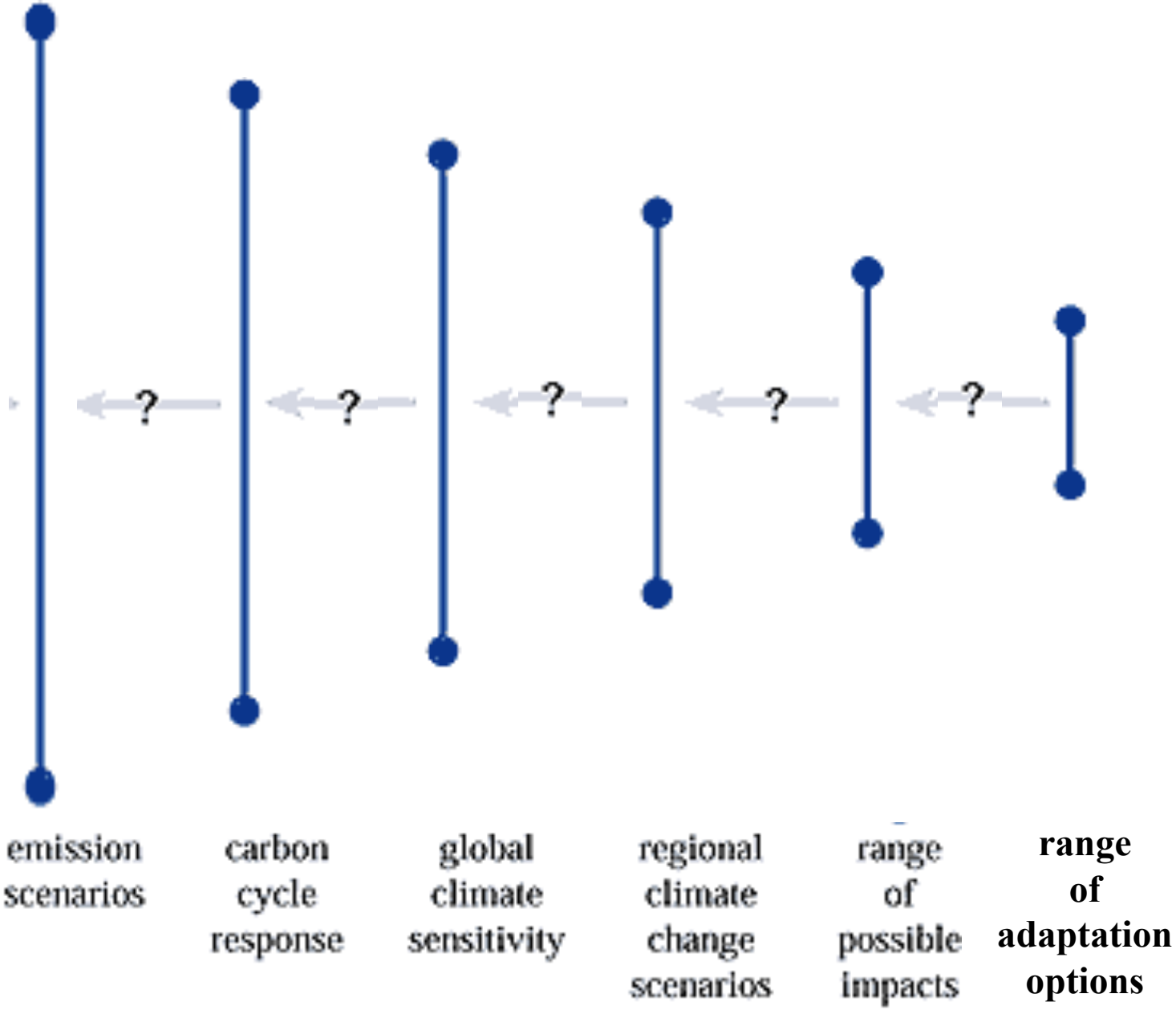
Overview

- What is downscaling?
- Different methods that are used – advantages/ disadvantages
- Comparisons
- Uncertainties
- How (not) to choose a downscaling method? Example applications
- UKCP09 weather generator



A New Uncertainty Cascade

Adapted from IPCC AR4 WG2 2007 (modified after Jones, 2000, and "cascading pyramid of uncertainties " in Schneider, 1983)



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Downscaling

There is a gap between climate model resolution and that of local-scale processes.

Problematic when assessing the impacts of climate change *e.g.* hydrology, ecosystems, agriculture.

Downscaling refers to a range of techniques that aim to bridge this gap.

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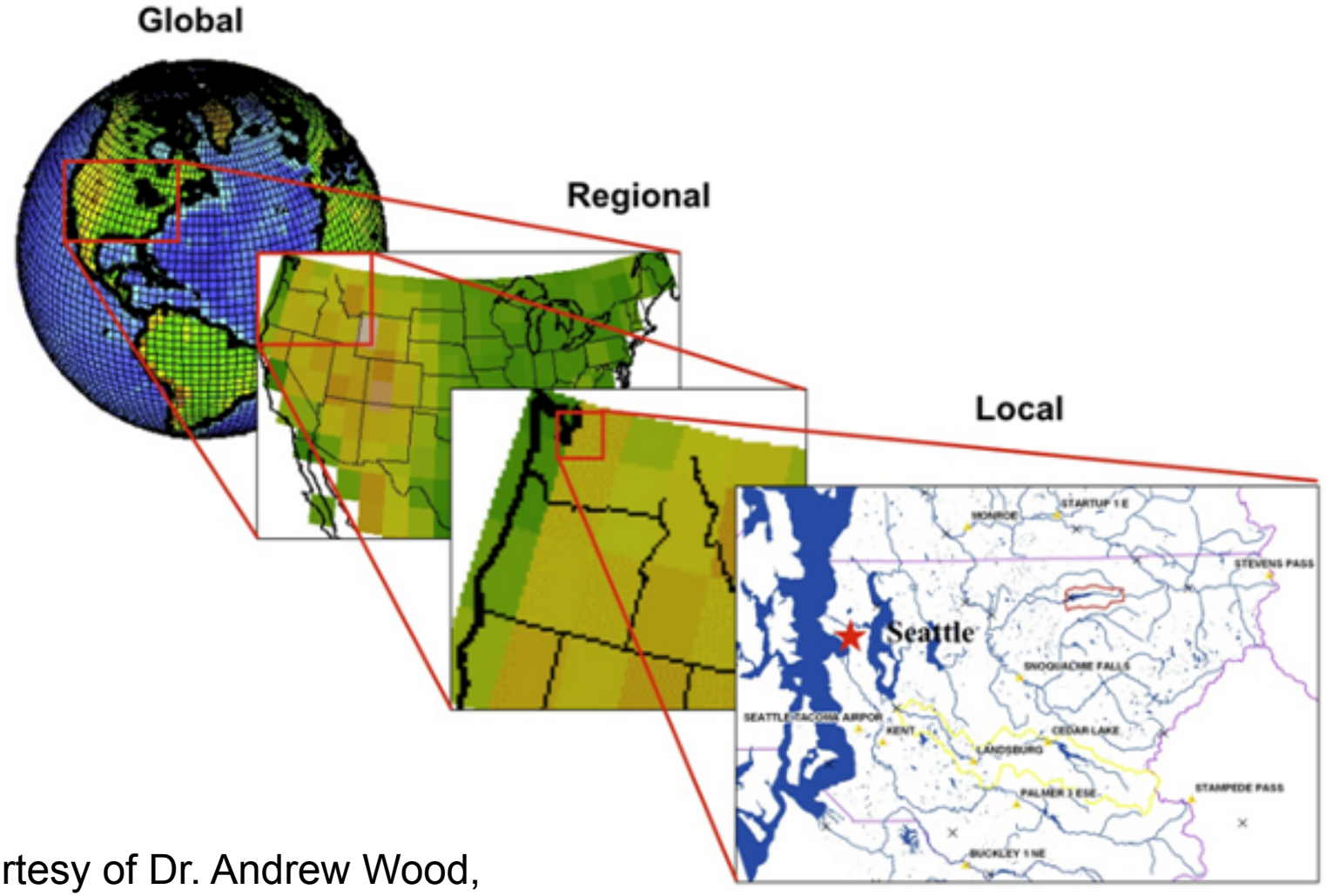

image courtesy of Dr. Andrew Wood,
NOAA/NWS NWRFC

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Downscaling Types

General Circulation Models (GCMs)

e.g. HadAM3H, ECHAM4

Statistical / Empirical Downscaling

Change Factors

Regression methods

Weather/circulation classification

Stochastic weather generators

Dynamical Downscaling

Regional Climate Models (RCMs)

e.g. HIRHAM, RCAO

Downscaled climate outputs

Simple downscaling methods: Analogues

Analogues make use of observed data

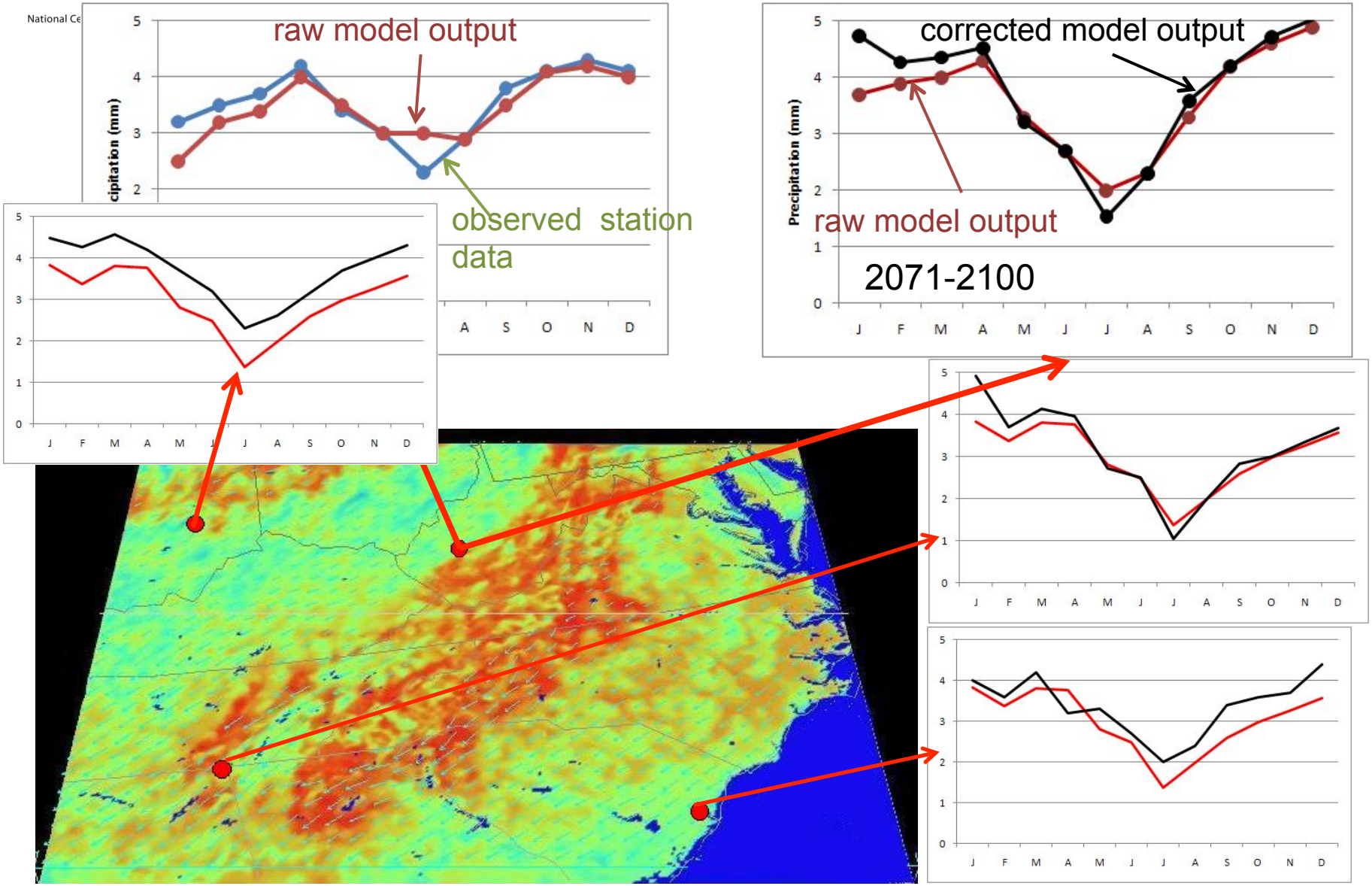
– **Spatial analogue**

- Select area with climate similar to that predicted
- Simple but inflexible: limited by availability

– **Temporal analogue**

- Select time period with desired climate
- Simple but inflexible: may not have period with predicted properties

Simple downscaling methods: Bias correction



Simple downscaling methods: Change Factors (Delta method)

- Very widely used
- Most commonly used method in UK water industry assessments (up to 2009!)
- Take change factor between control and future simulations of climate models (GCM or RCM) and apply to observed climate series (e.g. monthly rainfall totals)
- More sophisticated use of change factors is with stochastic methods such as weather generators – more later….

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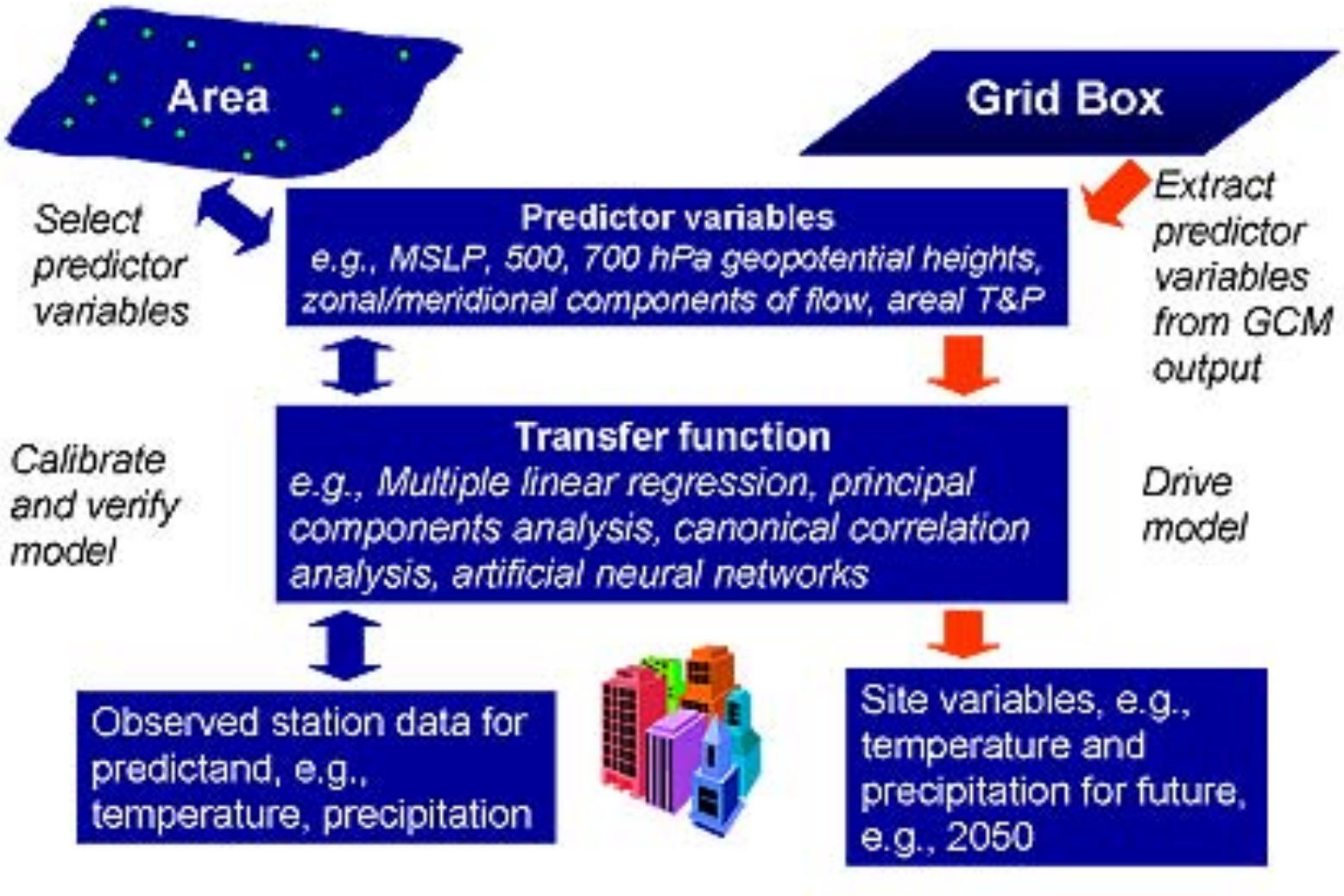
Statistical downscaling methods



Statistical downscaling

- **Advantages**
- Not computationally intensive
- Applicable to GCM and RCM output
- Provide station/point values

- **Disadvantages**
- Lack of long/reliable observed series
- Affected by biases in the GCM/RCM
- Not physically based e.g. climate feedbacks
- Under-estimate variability and extremes
- Assume stationary relationships in time

Comparison of downscaling methods

- We know theoretical strengths and weaknesses of downscaling methods, where systematic inter-comparisons have been made, e.g. STARDEX, no single best downscaling method is identifiable
  - temperature can be downscaled with more skill than precipitation
  - winter climate can be downscaled with more skill than summer due to stronger relationships with large-scale circulation
  - wetter climates can be downscaled with more skill than drier climates
- Direct comparison of skill of different methods difficult due to the range of climate statistics assessed in the literature, the large range of predictors used, and the different ways of assessing model performance

Largest uncertainties

- Choice of downscaling method
- Choice of predictor variables (statistical methods)
- Lack of predictability (tropics, convective processes dominate)
- Driving GCM boundary conditions (dynamical downscaling), parameterisations, structural assumptions, initial conditions etc.

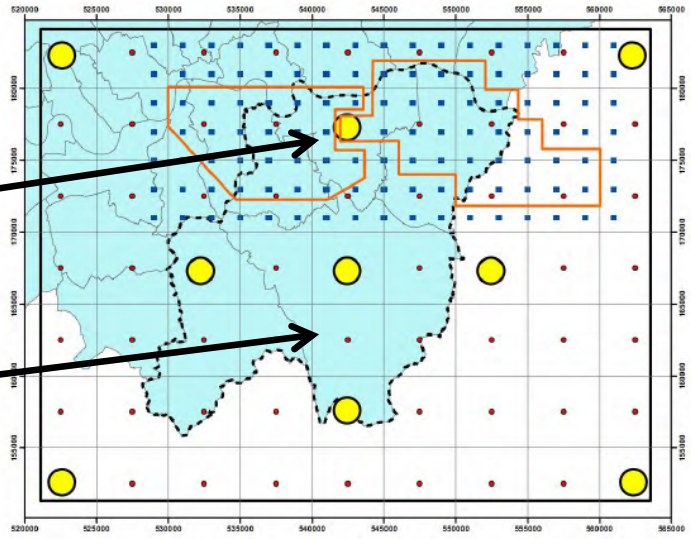
How to choose a downscaling method?

- Additional comparison studies are not needed
- Need to define the climatic variables that it is necessary to accurately downscale for each different impact application
- Little consideration given to the most appropriate downscaling method to use for a particular application
- Different climates, different seasons and different climatic variables may be more accurately downscaled by using more appropriate downscaling methods

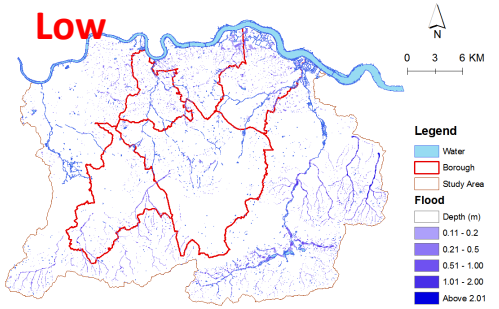
Flooding

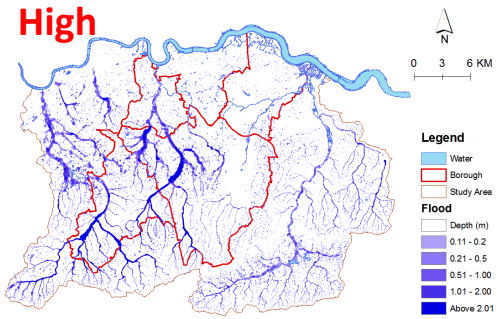
15minute, 2km

Hourly, 5km



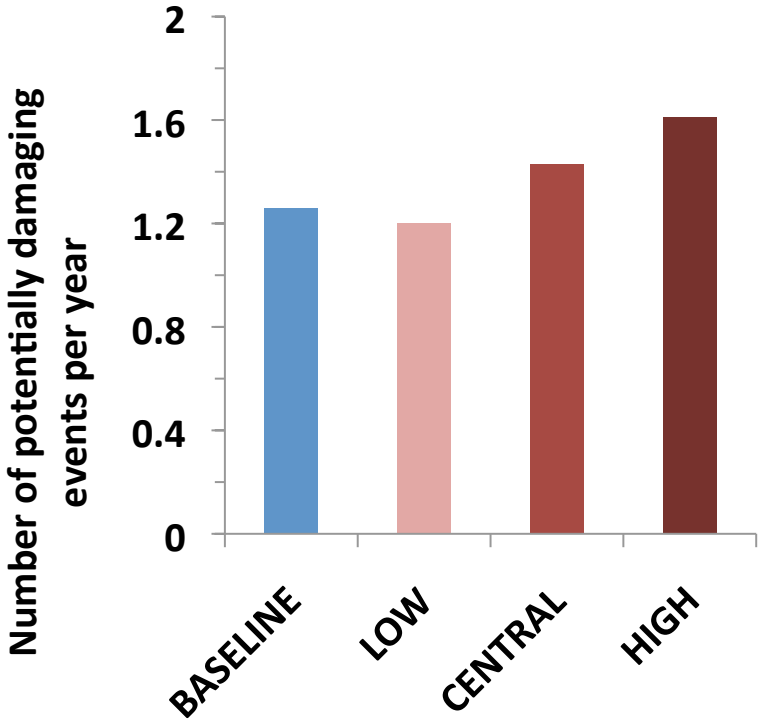
UKCP09 sample applied to rainfall model and Urban Inundation Model





EPSRC Engineering and Physical Sciences Research Council

Damaging winds



Baseline

'Low' climate projection

'Central estimate' climate projection

'High' climate projection

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The UKCP Weather Generator (WG)

A WG is a statistical model producing synthetic time series of weather variables with realistic properties

A combination of:

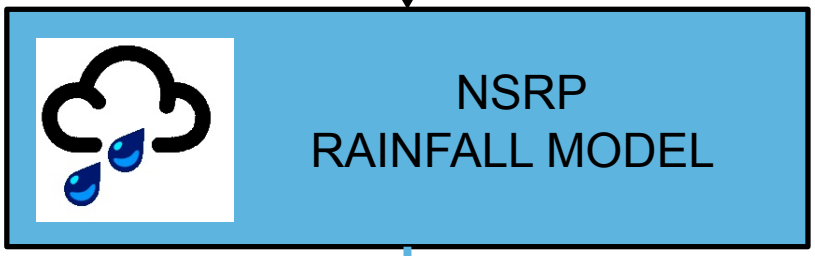
- Stochastic rainfall model (NSRP)
- Regression models for other variables

Features:

- daily and hourly time resolution
- 5km grid coverage of UK
- realistic properties of extremes
- extensively validated against observed data

The "Kilsby et al. (2007)" Weather Generator

Observed rainfall data
(+ RCM change factors)

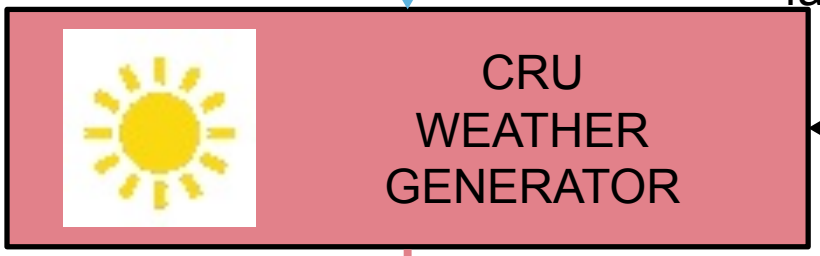


(1) Primary variable:
Precipitation (mm)

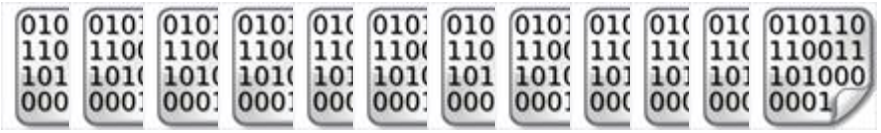
(2) Secondary variables:
Mean temperature (°C)
Daily temperature range (°C)
Vapour pressure (hPa)
Wind speed (ms^{-1})
Sunshine duration (hours)

Multiple Simulated
Rainfall Series

Observed daily weather data
(+ RCM temperature change
factors)



Multiple series of simulated weather variables + PET + direct and diffuse radiation



Change Factor Perturbation Method

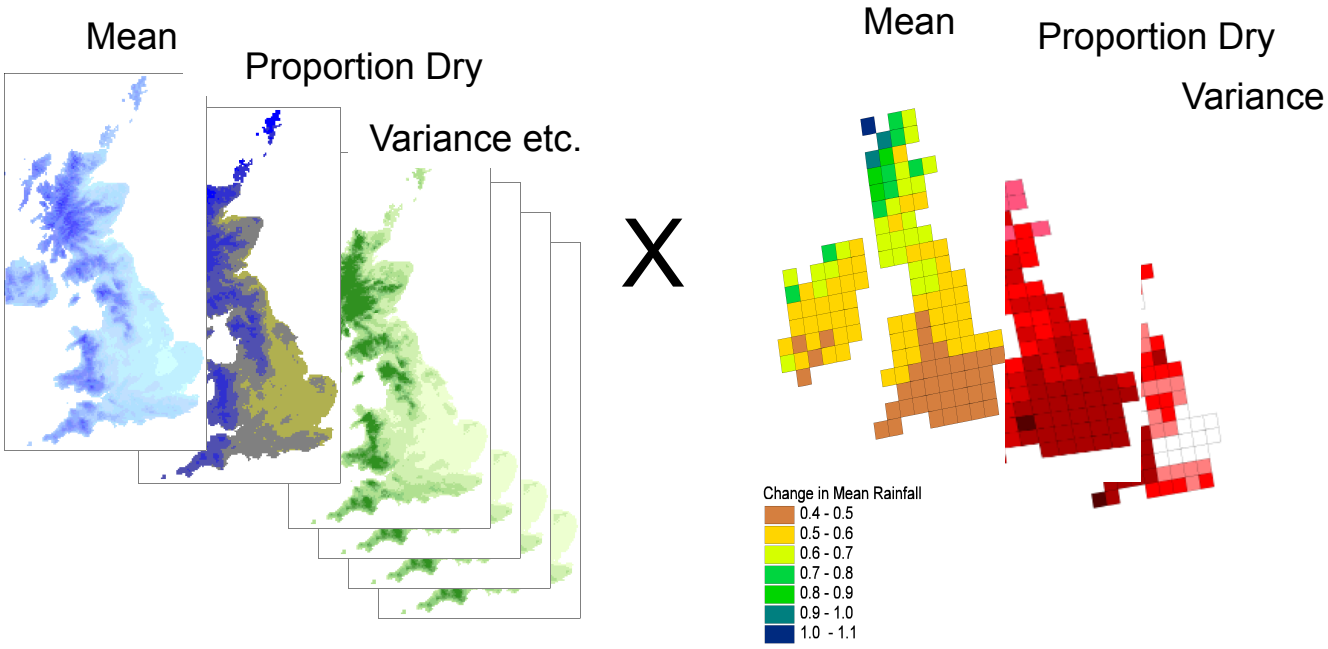
Factors are multiplicative (except for mean temperature)

Hourly stats derived using observed regression relations (fixed for future)

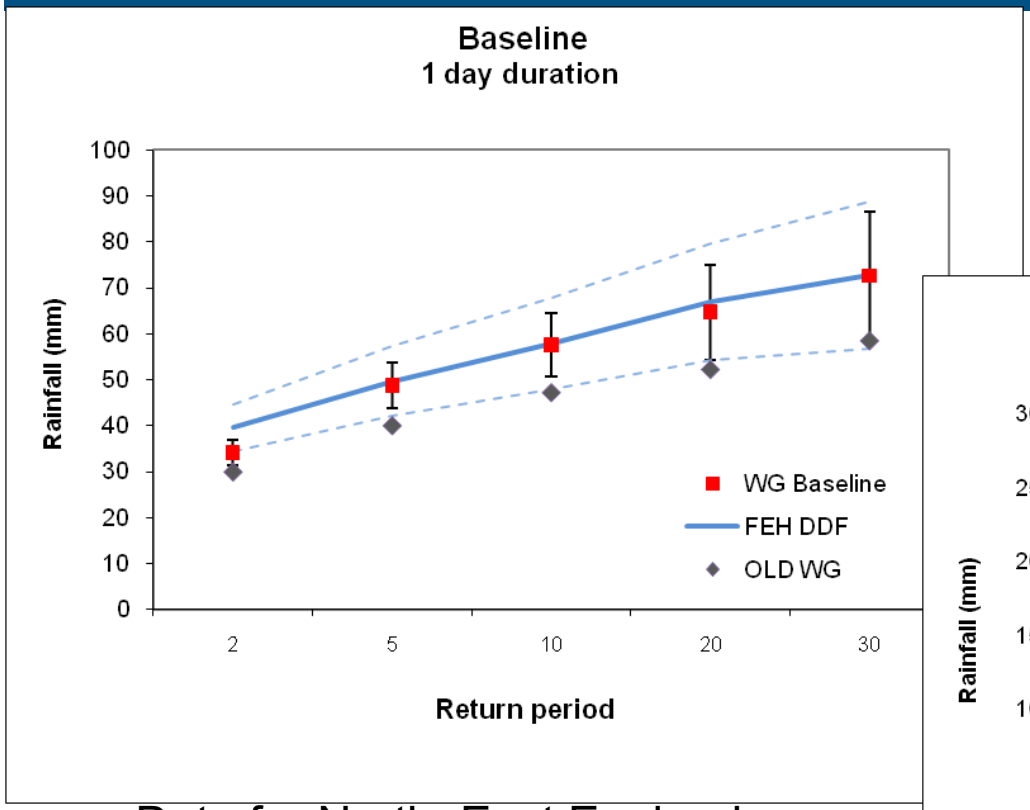
Inter-variable relationships also fixed for future

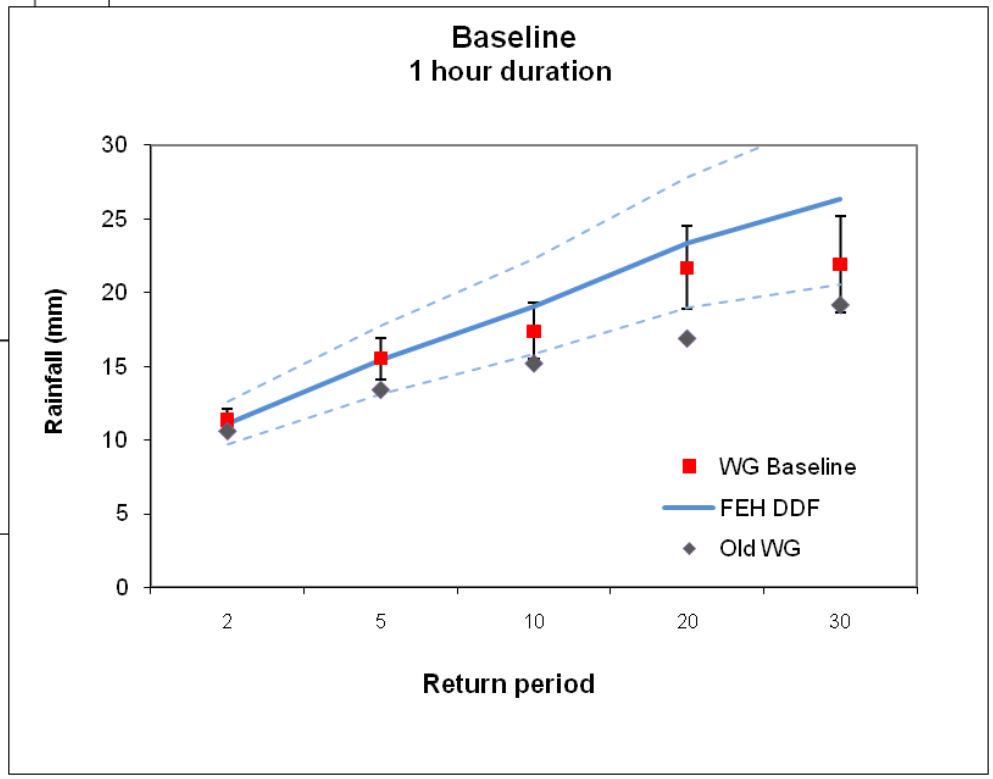
So, no change information included at higher than daily resolution

Observed statistics X RCM change factors



Testing the WG: Extremes in rainfall model





Data for North East England
-1000 year simulations
- baseline climate 1961-1990
- single site

Published studies on downscaling