Implications of using Large Ensembles of Climate Data for Management of River Ecology

Fai Fung, Ana Lopez, Mark New
Purpose of Talk

• Demonstrate the usability of probabilistic-like climate information for decision-making

• To show the steps in a classic “top-down approach” of climate change impacts assessment

• How prepared are the Environment Agency for looking at climate change impacts on river ecology?
The Case Study Area
Chalk Stream: River Itchen
Ecology

Macro-invertebrates
From climate models to impacts

Increasing uncertainty →

Emission scenarios → Climate model → Downscaling → Impact models

Multiple story lines
Ensembles of climate models
Dynamic or stochastic
Same as GCMs
• Explore model uncertainty by varying settings of poorly constrained model parameters.

• Distributed computing experiment:
  – GCM: Hadley Centre model
  – ~5000 model runs up to date
  – 26 parameters varied
  – 1920-2000 historic forcing
  – 2000-2080 scenarios
Climate prediction experiments:

- Explore model uncertainty by varying settings of poorly constrained model parameters.
- Distributed computing experiment:
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  - ~5000 model runs up to date
  - 26 parameters varied
  - 1920-2000 historic forcing
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Climateprediction.net: BBC experiment (I)

- HADCM3L model: standard atmosphere and low resolution ocean.
- 26 perturbed parameters (radiation, large scale cloud formation, ocean circulation, sulphate cycle, sea ice formation and energy convection) and initial conditions ensembles.
- Each simulation involves 160 years control and transient runs.
- Transient runs:
  - 1920-2000 forced with historical CO2, solar and volcanic forcing.
  - 2000-2080 forced with different possible scenarios.
Climateprediction.net: BBC experiment (II)

• Global, regional (Giorgi) and UK grid boxes monthly mean time series of:
  – Convective cloud amount
  – Ground surface temperature
  – Surface air temperature (1.5m)
  – Relative humidity (1.5m)
  – Total precipitation rate
  – Mean sea-level pressure

• Ensemble analysed here: 246 transient model runs, identical future forcing (SRES A1B). This is just a subset of ~ 5000 model runs now available
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Why Downscaling?

- GCMs generate climate variables at 2.5 x 3.75 spatial resolution.

- Typical river runoff model needs daily time series of precipitation and potential evaporation at a location.
Precipitation

- Need to
  - Downscale to daily time series
  - Correct biases

- Observed daily time series: 1961-1990

- USE Gamma transform method on a monthly basis: preserves monthly precipitation distribution and provides a reasonable way to downscale to daily precipitation
Potential Evaporation

- Penman-Monteith formulation: PET is a function of
  - Temperature (use surface air temperature from model runs)
  - Sunshine (use cloud cover from model runs)
  - Vapour pressure (use relative humidity and temperature from model runs)
  - Wind velocity (assume constant and equal to observed values)

- Observed daily time series: 1961-1990
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Hydrological Modelling

CATCHMOD (water balance model) parameterised for Itchen ran for 246 combinations of bias-corrected precipitation and potential evaporation time series.
CC Impacts on Hydrology

**Standard Model**

- 5th Percentile
- 25th Percentile
- 50th Percentile
- 75th Percentile
- 95th Percentile

**Year**

- 2000
- 2020
- 2040
- 2060

**Tyndall Centre**
for Climate Change Research
CC Impacts on Hydrology
• Dominant factors determining distribution and survival for macroinvertebrates:
  – Water temperature
  – Substratum characteristics (composition and stability)
  – River flow
**Target 1** The long-term average summer Q95 flow should be above 262Ml/day

**Target 2** River flow should not fall below 198Ml/day

**Target 3** The annual summer Q95 should not fall below 237Ml/day more frequently than recorded in the gauged flow record, i.e. 1 in 6 years
Target 1: Long term Q95

The diagram shows the distribution of summer Q95 (Ml/day) from 1990 to 2080, with percentiles indicated for 5th, 25th, 50th, 75th, and 95th. The standard target is represented by a green line, while the target 1 is marked in red. The graph indicates a decreasing trend for both the standard and target 1 over the years.
Target 2: Daily Flow

- Flow threshold 1
- Flow threshold 2
- Flow threshold 3

Healthy
Changing
High risk of Damage
Timing of Low Flows

![Graph showing the timing of low flows with data points for different months and years.](image-url)
Target 3: Low Flow Frequency
Using Existing Tools

- Reduces analysis to a set of only three values (target thresholds)
- Based on statistical relationships derived from short observed dataset
- What happens during multi-year droughts?
<table>
<thead>
<tr>
<th></th>
<th>1 year only</th>
<th>2-4 consecutive years</th>
<th>&gt; 5 consecutive years</th>
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</thead>
<tbody>
<tr>
<td><strong>Upper flow warning band</strong></td>
<td>No adverse impacts on invertebrates and overall ecology of river River remains healthy</td>
<td>Some risk of invertebrate community being harmed but can recover</td>
<td>High risk of community changing with some chance of recovery</td>
</tr>
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<td>(198 - 262 ML/day)</td>
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<td>Invertebrate community harmed and some risk that it can’t recover</td>
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<td>Permanent highly modified community more typical of arid environments capable of adapting to extended periods of drought</td>
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<td>and RAM threshold</td>
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<td>(&lt; 157 ML/day)</td>
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<td>Ecological Impacts Matrix</td>
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| **Lower flow warning band (157 - 198Ml/day)** |
| Invertebrate community being harmed but can recover | Invertebrate community changing but with high chance of recovery | High risk of community changing with some species remaining |

| **Below flow warning band and RAM threshold (< 157Ml/day)** |
| Invertebrate community harmed and some risk that it can’t recover | High risk of invertebrate community changing permanently to slow flow-type communities | Permanent highly modified community more typical of arid environments capable of adapting to extended periods of drought |

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Ecological Impacts Matrix

2020s

2030s

2040s

2050s

2060s

2070s

Extent

Duration

Models

> 0%

50%

25%

10%

5%

> 0%
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Discussion

• Uncertainty in hydrological and ecological models
• Lack of long observed ecological datasets
• Reliance on expert opinion
• Further work
  – Water temperature
  – Water quality
  – Habitat modification
Conclusions

• Climate change impacts assessment
  – Using 246 member climate ensemble
  – Hydrological impacts
  – Addressing ecological impacts through existing means and developing new impacts matrix approach

• Communication
  – Translating data from large-ensembles for a multi-disciplinary audience
  – Richer picture
  – Decision-relevant results
Thank you