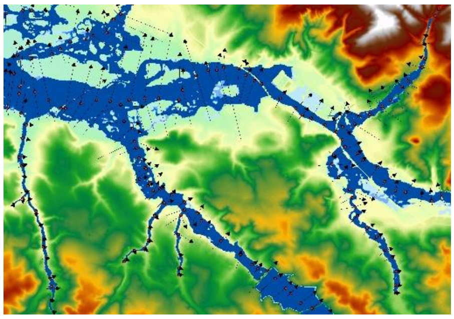
Non-stationarity and flooding: from statistical models to flood risk management

Workshop report

19 September 2018, held at The Bond Co, Birmingham



Background

Many important decisions about planning for and mitigating the risk of flooding rely on statistical assessments of risk. These assessments usually involve looking at historical data sets. With increasing evidence of changes and variability in climate, and other drivers of flood risk, there is now a growing concern that the past may no longer be a reliable guide to the future. Many types of change (or non-stationarity) can be included in statistical models, but these types of model have not been routinely applied in flood risk analysis.

This one-day workshop enabled communication and discussion between academics and practitioners on the technical, practical, scientific and risk management implications of applying non-stationary statistical models to flood event data.

Objectives

- To hear presentations about state-of-the-art alternatives within non-stationary statistical modelling
- To exchange views about:
    a) the applicability of statistical models, and their representation of the physical processes which can be fed-back into model development
    b) how to make statistical models more accessible to hydrological/FRM professionals and researchers
- To discuss the presentation and communication of risk in a non-stationary world

Seminar and panel discussion – key points raised by speakers

Framing the risk analysis for a non-stationary world

1. There is a need to assess and communicate risk at times other than during and immediately following flood events.

2. Parallel problems and science issues exist for drought risk.

3. How useful is return period or annual exceedance probability as a measure of risk when dealing with non-stationarity? Are other measures more informative? Is it credible to adopt a single measure that is treated as unchanging over time?

4. Non-stationarity may prompt us towards more realistic statements about risk that are conditional (different, but coherent, statements over specified time frames, geographical limits, conditional on e.g. prevailing seasonal situation). We may need to re-think our descriptions and communications of risk to account for a changing world, e.g. integrating over specific time frames and use of relative risk measures. A recurring issue is to ensure that such communications enhance credibility, which poses new challenges if time-varying risk measures were to be introduced.

5. It is not yet clear how big a problem non-stationarity is relative to, say, having bigger and better data sets. Proportionality is important to ensure resources are used effectively.

Methodological issues

6. There are many possible models for non-stationary processes and data. The primary strategies are either to introduce covariates through a regression approach, or a time-varying random effects.

   The key challenges (for both strategies) are:
   a. They are more complicated to fit than stationary models
   b. They may require a different approach to interpretation
   c. Both raise similar questions about how to project forward to examine future risk (Will trends continue? Will patterns of random effects persist?)

   However, there are methods and statistical tools that can be applied to address these issues and could be further developed/refined to be more accessible for flood risk management professionals.

   Other analytical approaches that could be considered include smoothing (local-likelihood, quantile regression), time-varying moments, and non-stationary regional frequency analysis.

7. Reliance on annual maximum data alone limits our analysis of non-stationarity

8. Spatial homogeneity may help in learning more about temporal non-stationarity, perhaps using Bayesian Hierarchical models, with questions to be resolved about sensitivity to the choice of region, and assumptions about the independence of observations at different sites regardless of proximity.

Prediction and attribution

9. Time is not the only, or necessarily the best, explanatory variable to account for change. Care is needed if physical covariates are to be used to predict into the future.

10. Trend analysis is risky – it is very sensitive to the choice of start and end dates (although the analysis of "stopping rule bias" may help ameliorate this)

11. Attribution and estimation of non-stationarity are related issues that should ideally be linked to gain a more robust understanding of change.

Breakout discussions

The programme included a workshop session themed around three topics, which are summarised below.

Research priorities

These discussions aimed to identify research topics to prioritise in the future and the reasons why these topics are so important for flood risk management.

a. Attribution of flood risk is needed for accurate predictions, but a better general understanding is needed of the factors driving flooding.
b. Approaches for linking climate-based indicators to flooding could be improved by bringing climate models and observations together.
c. Further evidence is needed with regard to the importance of accounting for non-stationarity in flood risk modelling given the extra uncertainty associated with trend estimation.
d. Understanding how best to distinguish between long-term trends and short-term clusters.
e. Distinguishing between the different types of non-stationarity arising from effects relating to climate, catchment area and data collection.
f. How to use non-stationary models for inference in data-poor locations.
g. Exploring how non-stationary models reflect processes that are spatially coherent.
h. Reconciling non-stationary models with regional approaches (e.g. FEH).
i. Explore different metrics/accumulations which may lead to identified trends on different scales.
j. More inter-disciplinary collaboration between statisticians, hydrologists and atmospheric scientists to continue discussions and feed off mutual expertise to attempt to answer these questions.

What tools and/or guidance are needed from a flood risk management perspective?

What do end-users need to know before non-stationary models are put in practice?

a. An initial review outlining the current state of research, our knowledge of non-stationary processes and models to capture this, and crucially, the gaps in this knowledge requiring further thought and research.
b. Convergence of ideas among academics and users towards a common framework for addressing non-stationarity.
c. Access to previous studies relating to non-stationarity.
d. Knowledge of how uncertainty around extremes changes as we move forward.
e. Guidance on how to use climate change correction factors in combination with non-stationary models.
f. Guidance on how to determine when non-stationarity is an important factor to consider in a flood risk analysis.
g. Clarity on the uncertainties involved in trend estimation enabling improved communication for practitioners.
h. How to account for observational bias after a large event occurs.

i. Guidance on whether more robust designs are needed to account for non-stationary processes.
j. How should historical data be used in a potentially non-stationary flood frequency analysis?
k. Guidance on how to describe and communicate risk in a changing world
l. Guidance or tools to help determine quickly whether a non-stationary analysis is needed/justified in a particular study – when does it really matter?

Implications of non-stationarity for flood risk management and decision-making

a. Benefits of improved and more robust flood risk assessments.
b. Increased complexity of analysis is a challenge for communication of flood risk to the public, flood risk managers and decision-makers and also in the guidance of policy.
c. Changes to methodology for design flows and decision analysis that will feed into the cost-benefit trade-off.
d. Relative risk approach may lead to changes in how flood forecasting systems are used – potential for change in how ensemble forecasts are interpreted and communicated.
e. Potential changes to insurance models.
f. Encouraging the use of managed adaptive approaches among decision-makers.
g. More careful thinking required on how to handle allowances for climate change in non-stationary models.
h. Possible deflection of funds away from other research and investments.
i. Standardisation of approaches to assessment may lead to a wider acceptance of outcomes for decision-making.

Other discussion topics

Further points that were raised during breakout group discussions.

1. How best do we exploit spatial structure about trends – do we rely on pre-defined hydrometric areas or do a further analysis related to gauge homogeneity?
2. Is it important in non-stationary models to distinguish between floods caused by different drivers, e.g. summer flash floods and winter storm-related floods?
3. Record length is important when determining whether a series is non-stationarity. Apparent trends may actually be multi-decadal climate variability. How do we distinguish between these?
4. Clustering of independent events means that the probability of extreme events may actually be higher than what the return period suggests. Can use a relative risk measure to assess this.

Annexe A: Breakout group flipcharts

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(A) Research priorities (and why!)

RED!

(more multi-disciplinary approach)

Understand what drives flooding

- ATTRIBUTION!
- BRINGING CLIMATE MODELLING + OBSERVATIONS TOGETHER

Needed for predicting in the future: need to protect people

✓ - HOW IMPORTANT IS NON-STAT RELATIVE TO ~~UNC~~ UNCERTAINTY V. TRENDS

(Does ~~it~~ inc. seasonality, intensity,)

(precipitation + flow data)

(issue of scale climate model vs catchment)

✓ - CLIMATE V. CATCHMENT V. DATA EFFECTS
- DISTINGUISH BETWEEN LONG-TERM TRENDS + SHORT-TERM CLUSTERS
- Communication with client, etc.
- SPATIAL COHERENCE + SCALE
- How to apply the method in data poor locations.
- Better measurement of high flows
- Avoid modelling chain: stage → Flow → Level (ie no gauge flow data)
- Reconciling this, with regional approaches
  - → non-stationarity
- Use more of the rainfall records: non-stationarity there?
- Use ~~other~~ metrics other than peak flow (volume, rate of rise, ...)

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(B) What tools/guidance are needed? (FRM/engineering)

Yellow!

A * Guidance on when it matters, when to account for it.

* need convergence first.

+ guide/review (A)

What we are now
what we know/don't know.

→ context & gauging records

* need to put it in context of other uncertainties (+ our ability to reduce the others) A

* access to previous studies on non-stationarity

* should moderate arguments based on bias introduced by analysis after a big event

A Clarity of the uncertainty to improve communication and guidance for practitioners

* how uncertainty around extremes changes as we look forward

* how to use climate change uplift values + non-stationarity

(A) MORE ROBUST DESIGNS?

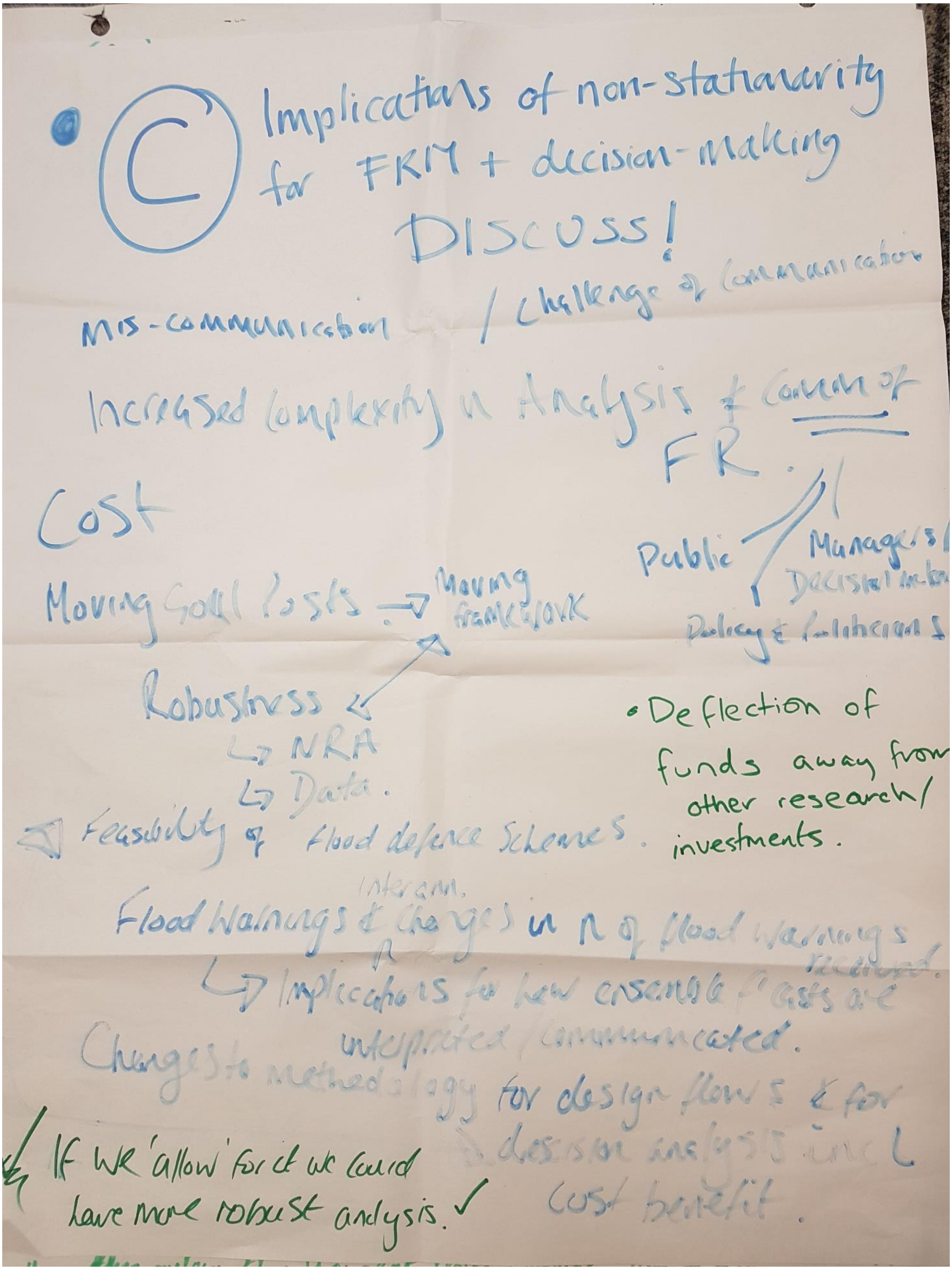
FEH local R&D
– using historic data
how to include this?

Better understanding/guidance of what is required

(A) Observations / bias after event

(A) GUIDANCE
A FILTER of PRAGMATISM.

(A) HOW APPLY NON STAT & UNCERTAINTY FOR ENGINEERS. CAN WE REDUCE UN-ATTRIBUTABLE UNCERTAINTY


C
Implications of non-stationarity for FRM + decision-making
DISCUSS!
MIS-COMMUNICATION / Challenge of Communication
Increased complexity in Analysis & Comm of FR.
Public
Managers / Decision makers
Policy & Politicians
Cost
Moving Goal Posts → Moving framework
Robustness
→ NRA
→ Data.
Feasibility of flood defence schemes.
• Deflection of funds away from other research/ investments.
Flood Warnings & changes in n of flood warnings received.
→ Implications for how ensemble f'casts are interpreted / communicated.
Changes to methodology for design flows & for decision analysis incl cost benefit.
If we 'allow' for it we could have more robust analysis. ✓

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- BENEFITS OF IMPROVED in FF ASSESSMENT
- INCREASED UNCERTAINTY IN FLOWS → ↑ UNCERTAINTY IN DESIGN + CBA
- INSURANCE IMPLICATIONS
- NUDGING DECISION MAKERS TOWARDS MANAGED ADAPTIVE APPROACHES
- REL. BETWEEN NON-STAT IN HIST RECORD + FUTURE CLIMATE CHANGE ALLOWANCES.
- Standardisation of approaches to assessment → wider acceptance of outcomes for decision making.
- ~~NON STAT~~ COMPLEXITY OF NON STAT DOESN'T MEAN WE SHOULD IGNORE IT!
- better use of funds

Annexe B: Programme

10:00-10:40	Registration/coffee
10.40-10.45	Welcome and introductions: **Prof Rob Lamb**, Director of JBA Trust
10.45-11.00	Keynote: **Prof Doug Wilson**, Director of Research, Analysis and Evaluation, Environment Agency
Seminar talks from Academic Speakers	
11.00-11.30	**Dr Emma Eastoe and Prof Jonathan Tawn** (Mathematics and Statistics, Lancaster University)
11.30-11.45	Break
11.45-12.15	**Prof Ivan Haigh** (Ocean and Earth Science, University of Southampton)
12.15-12.45	**Dr Ilaria Prosdocimi** (Statistics, University of Bath)
12.45-13.30	Lunch
Panel talks from Industry Speakers	
13.30-13.40	**Dr Duncan Faulkner** (Head of Hydrology, JBA Consulting)
13.40-13.50	**Jamie Hannaford** (Lead, Hydrological Reporting Group, CEH)
13.50-14.00	**Dr Manuela Di Mauro** (Water Lead, National Infrastructure Commission)
14.00-14.10	**Stuart Homann** (Statistics Manager, Environment agency)
14.10-14.30	Panel discussion of short talks
14.30-14.45	Break
14.45-15.30	Break-out group discussions on a. Academic research priorities b. What tools/guidance is needed (from FRM/engineering perspective) c. Implications of non-stationarity for FRM and decision-making.
15.30-16.00	Group reports
16.00-16.00	Closing summary: **Prof Rob Lamb**
16:15	Finish

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