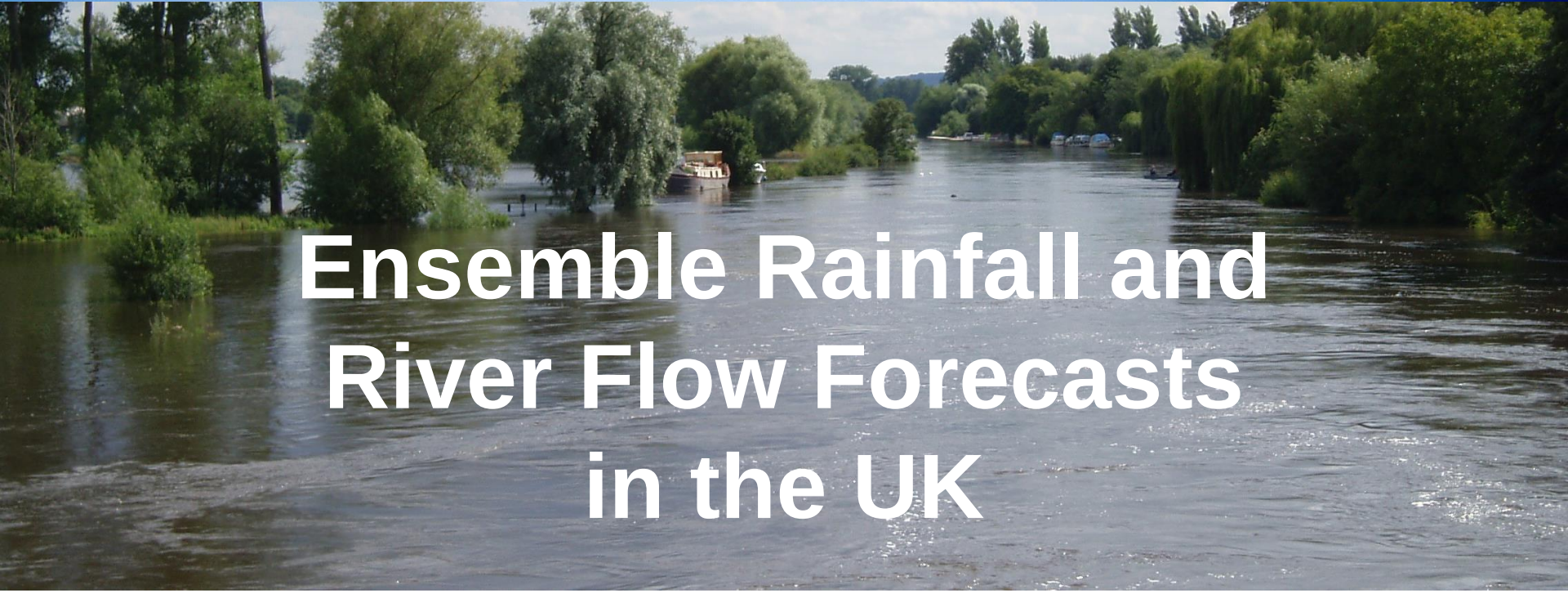


Ensemble Rainfall and River Flow Forecasts in the UK

Steven Cole, Robert Moore,
Steven Wells, Seonaid Anderson

Workshop on Use of Products from Ensemble Prediction Systems BHS
NCMRWF, India, 20-22 January 2021

UK Centre for
Ecology & Hydrology

scole@ceh.ac.uk

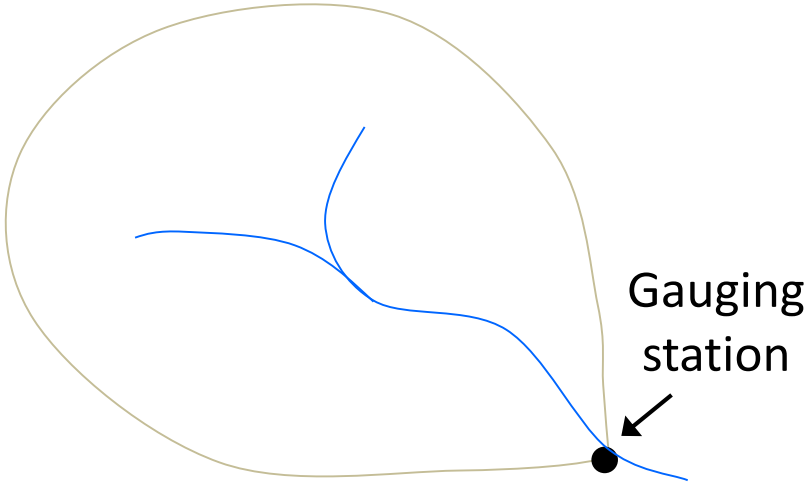
Overview

- Ensemble rainfall and flood forecasting
  - Needed to acknowledge and account for uncertainty
  - Supports risk-based decision making
  - See previous talks for further justification!

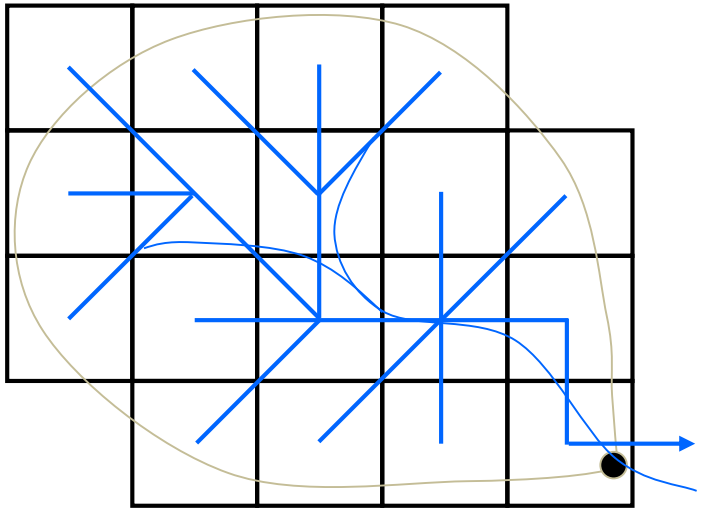
- Some UK experience
  - National scale hydrological modelling
  - Ensemble rainfall and flood products
  - Forecast performance assessment and ensemble verification
  - Impact-based Forecasting – Surface Water Flooding in the UK and prototype applications in India

Distributed hydrological modelling

Lumped Model
Traditional approach



Distributed Model
Recent development



- One model for each gauging station ⟺ One model for large regions (UK)
- Many calibrated parameters ⟺ Few parameters, use spatial datasets
- Flow estimates for one location only ⟺ Flow estimates in each grid (1km^2)
- Uses catchment average rainfall ⟺ Uses gridded rainfall estimates

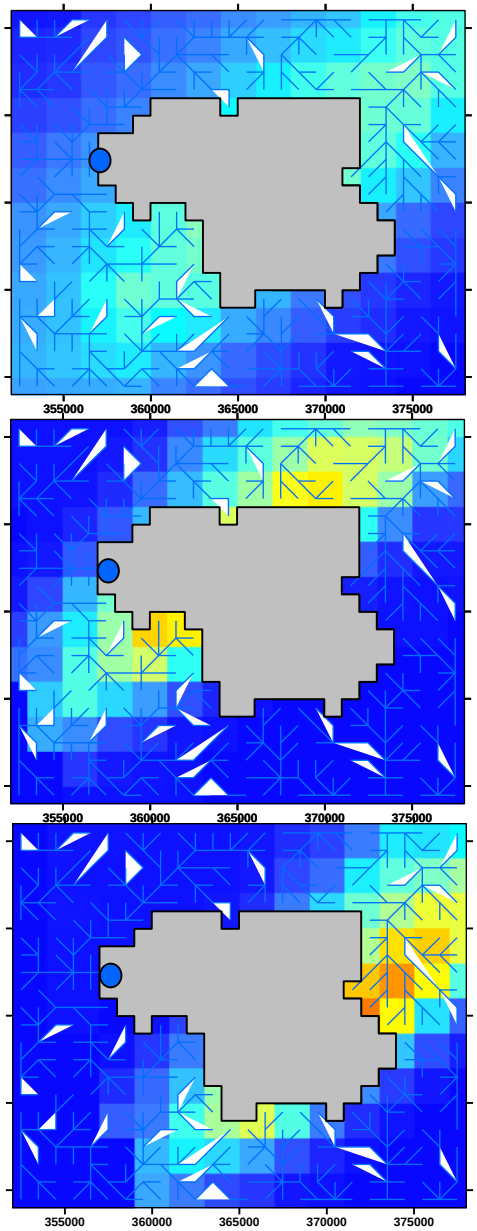
UK Centre for Ecology & Hydrology

Cole and Moore (2009), JoH

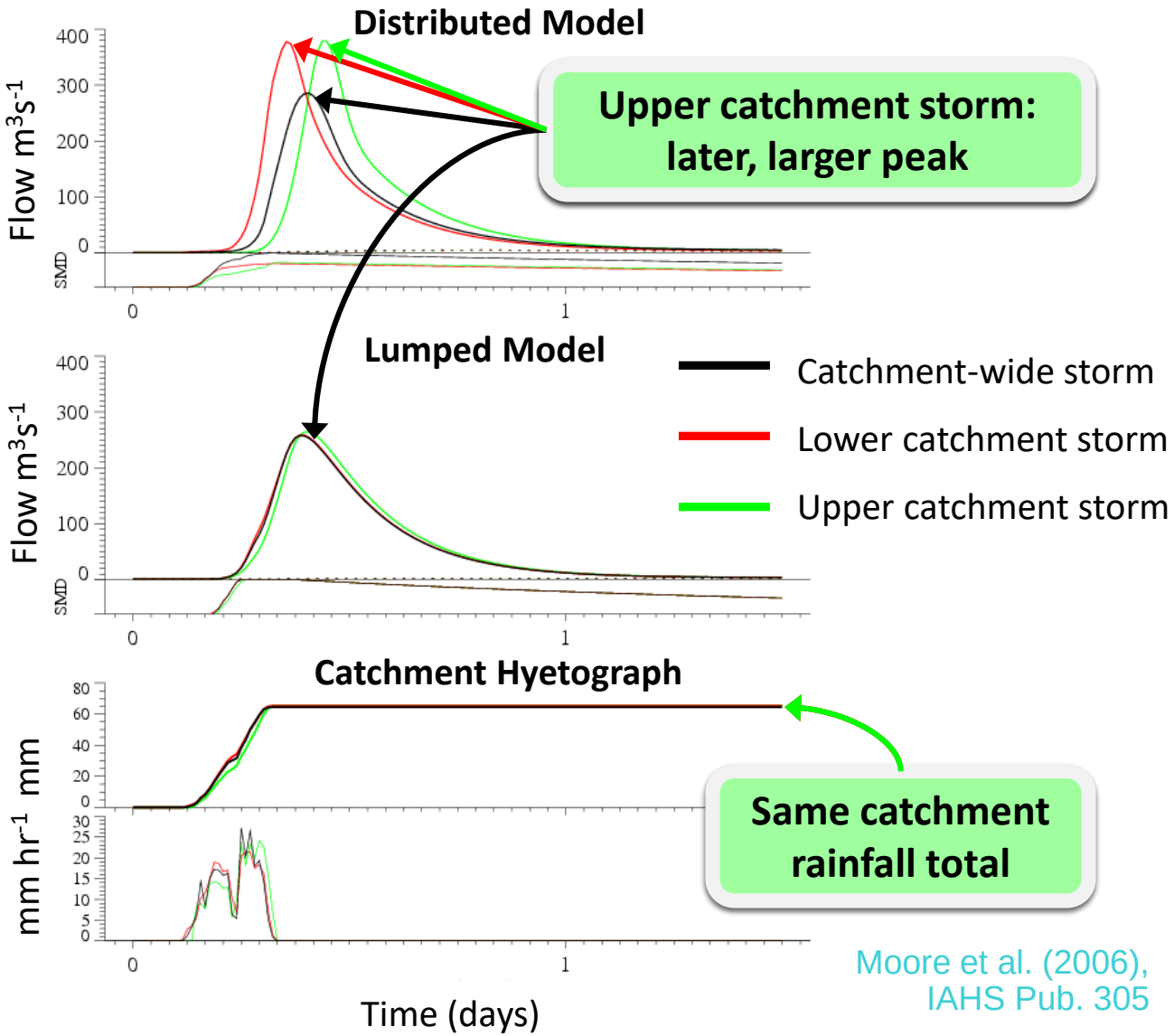
Potential for ungauged sites – forecasting everywhere!

Extreme Flood Response

Storm rainfall total

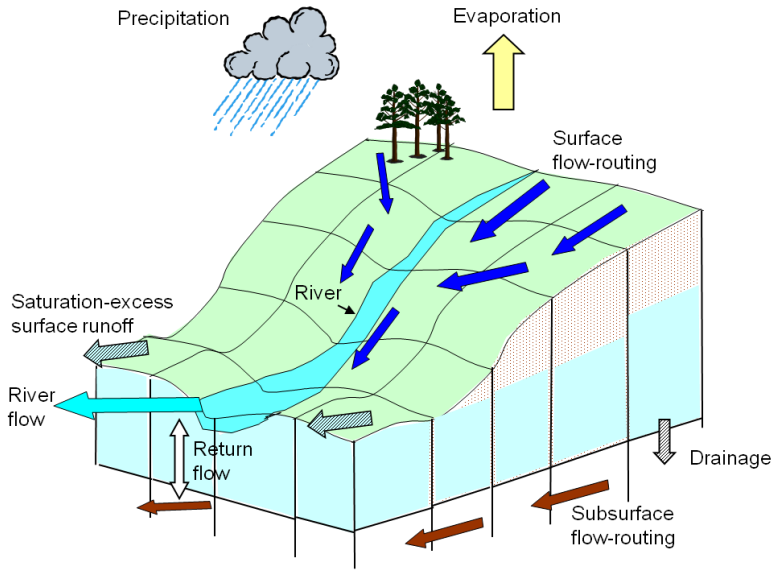


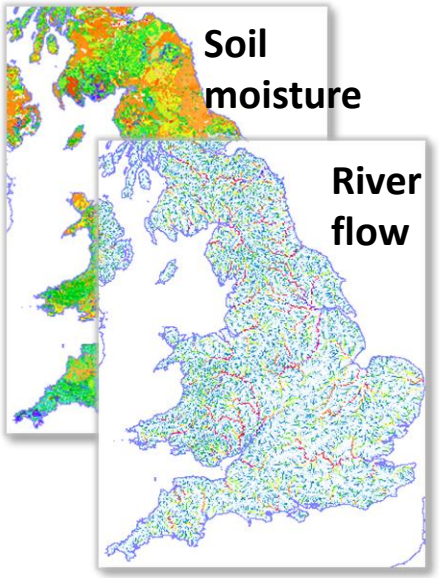
Impact of spatial extent and location of storm on flood response?

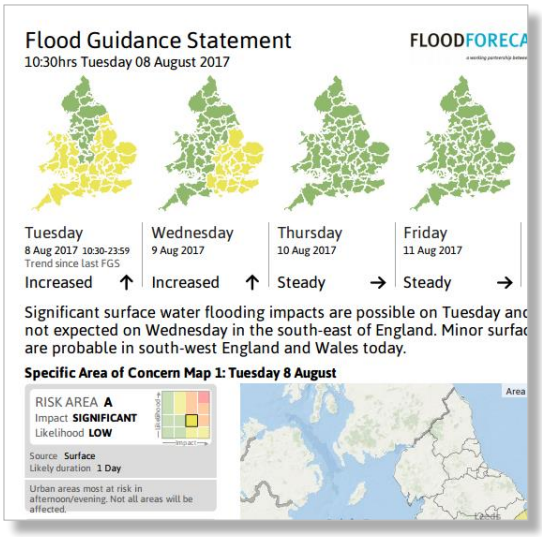


Moore et al. (2006), IAHS Pub. 305

Grid-to-Grid (G2G) Hydrological Model







FLOODFORECASTINGCENTRE
a working partnership between Environment Agency | Met Office

Met Office | SEPA Scottish Environment Protection Agency | Scottish Flood Forecasting Service
Working in partnership

- G2G used operationally across Britain at a 1km, 15 min resolution
- Uses spatial datasets on terrain, soil/geology, land-cover
- Responds to spatial variation of rainfall input
- Probabilistic forecasts inform Flood Guidance Statements

Moore *et al.*, IAHS Publ. 305 (2006)

Price *et al.*; Cranston & Tavendale, Water Management (2012)

Met Office Unified Model (PS43 2019)

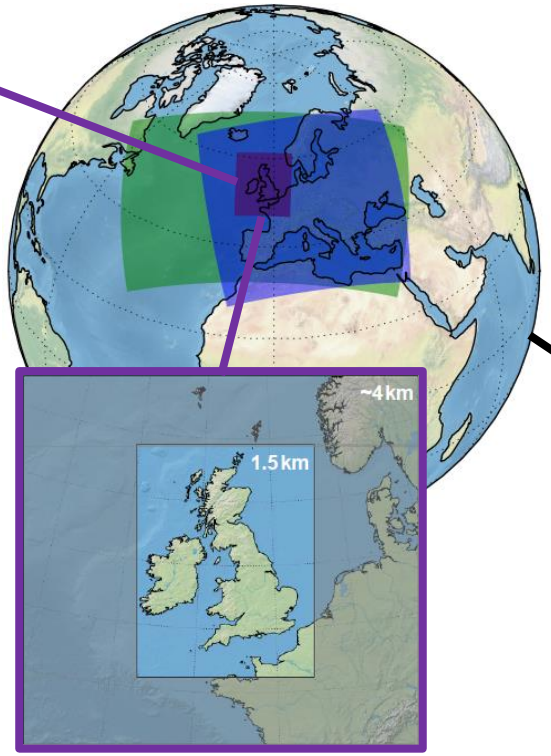
- Ensembles based on MOGREPS – Met Office Global and Regional Ensemble Prediction System (2.2km over UK)
- High-resolution deterministic configuration at 1.5km

UK

Deterministic:
1.5 km / 70 levels / hourly cycling
Lead-times 2x120h, 6x54h, 16x12h

Ensemble, MOGRESP-UK:
2.2 km / 70 levels / 5 days / hourly
3 members each hour
18 members when time lagging

Both nested in larger 4km domain



Global

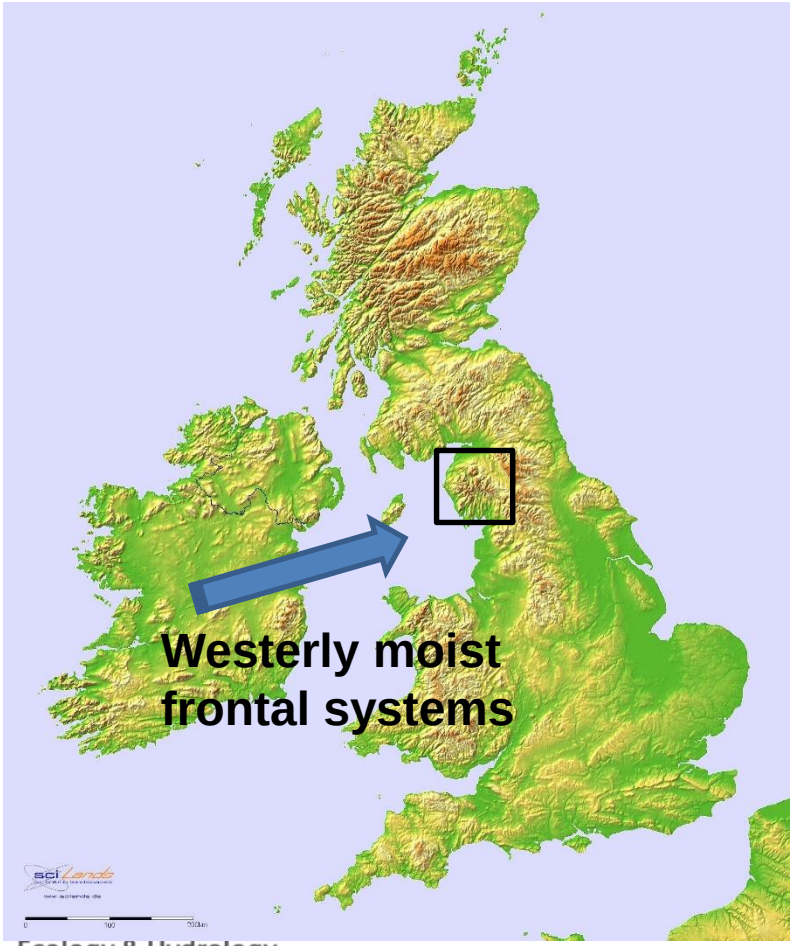
Deterministic:
10 km / 70 levels / 6 days / 4x daily

Ensemble:
20 km / 70 levels / 7 days / 4x daily
18 members
36 members when time lagging

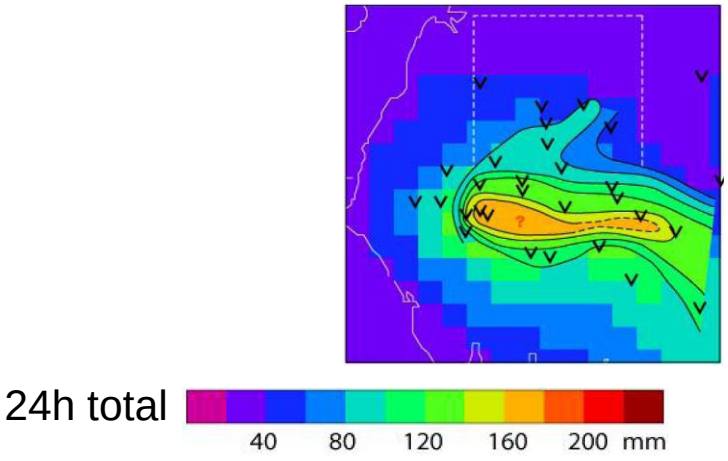
UK Centre for Ecology & Hydrology

Carlisle 2005 floods – high-res NWP

Orographically enhanced rainfall over Lake District, record floods



Raingauge



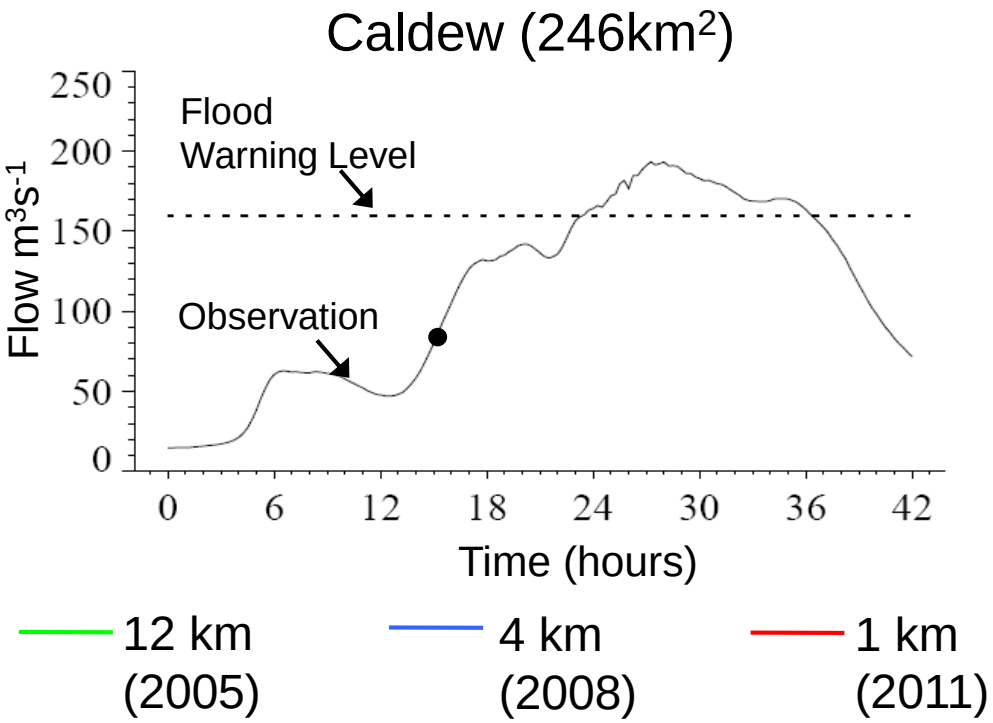
Roberts, Cole *et al.*, 2009, Met. Apps

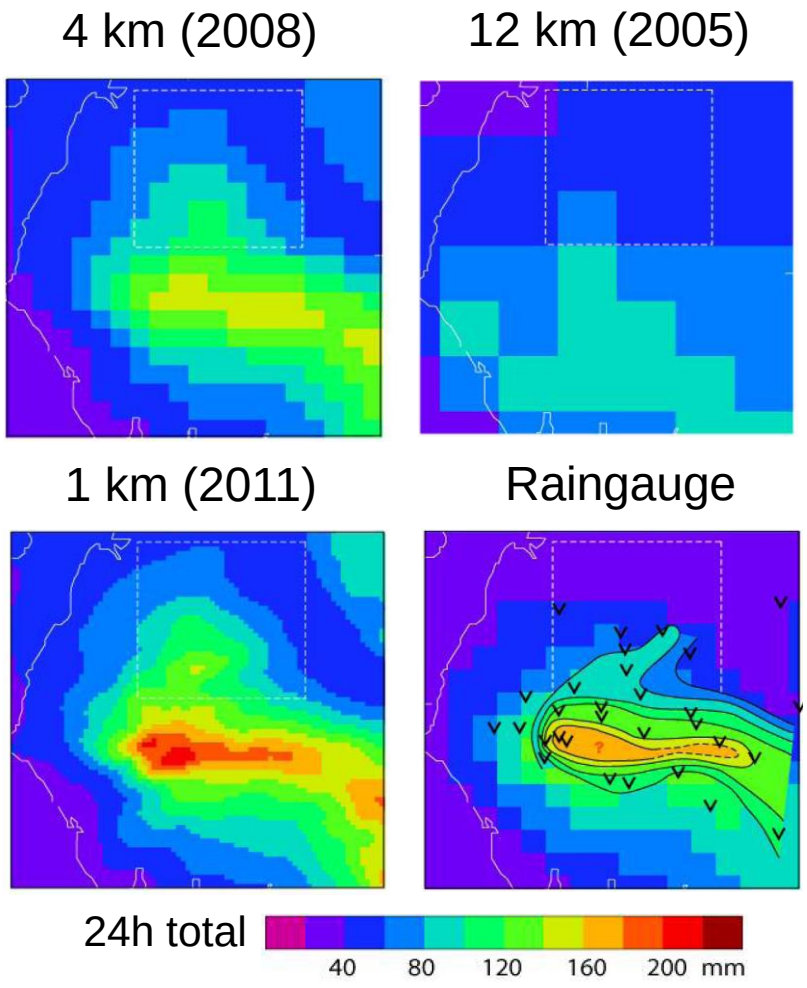
Ecology & Hydrology

Carlisle 2005 floods – high-res NWP

Orographically enhanced rainfall over Lake District, record floods

High-resolution NWP provides benefits for flood forecasting and warning





Roberts, Cole *et al.*, 2009, Met. Apps

Rapid Response Catchments

- Rapid Response Catchments are typically small & ungauged
- Challenge to develop forecast/warning capability
- Needs rainfall forecast ensembles (~2km, 24h, 12 members)
- Case study experience (6-7 July 2012)

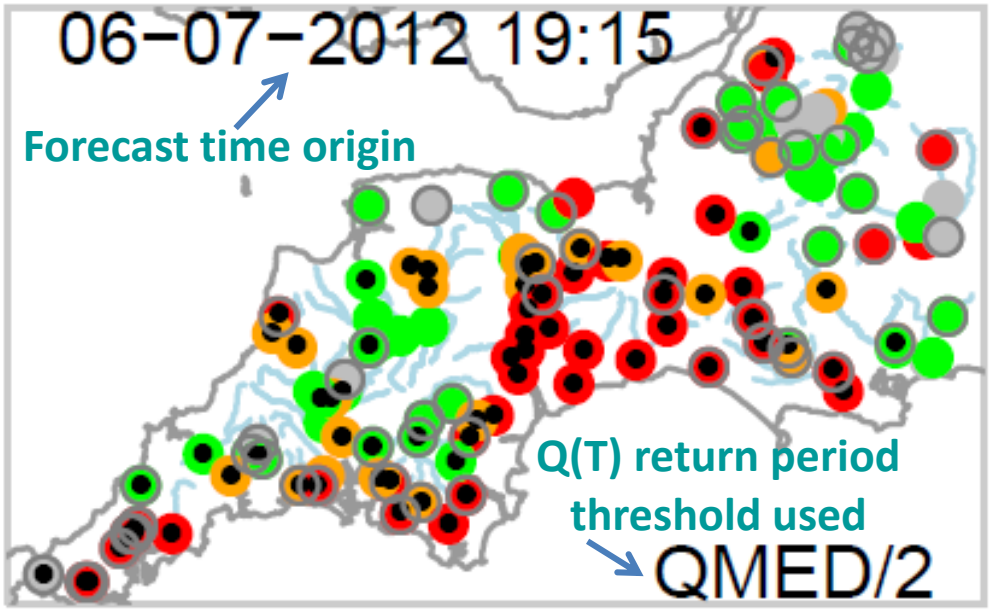
Met Office

Circles denote gauging stations

- ○ Solid outline: area <50km^2
- ● Observed flow exceeds threshold during forecast

Percentage of ensembles that exceeded the Q(T) threshold at some point during forecast

0 | 0-33% | 34-66% | >67%



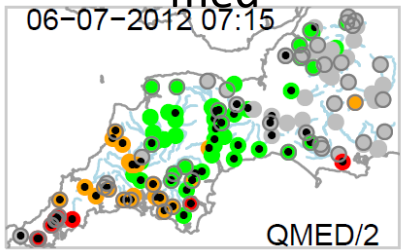
Case study: 6-7 July 2012

Threshold

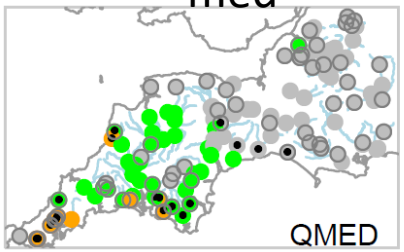
Forecast Origin

06-07-2012 07:15

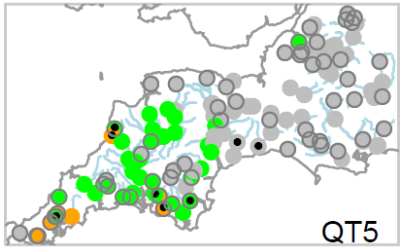
$Q_{med}/2$



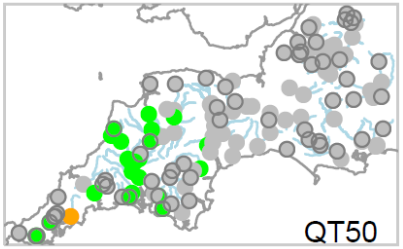
Q_{med}



Q(5)



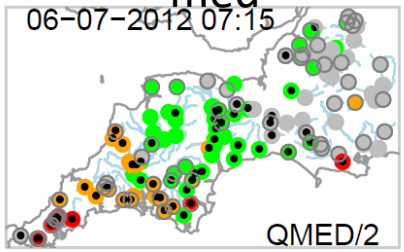
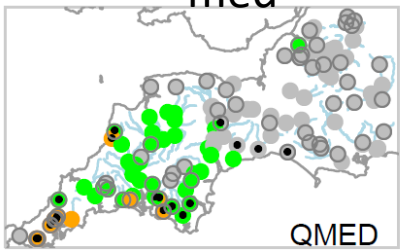
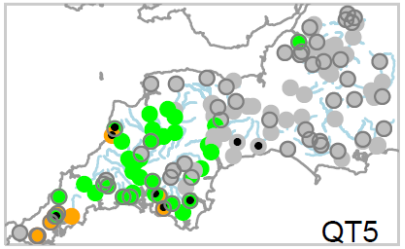
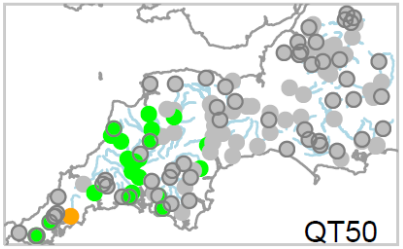
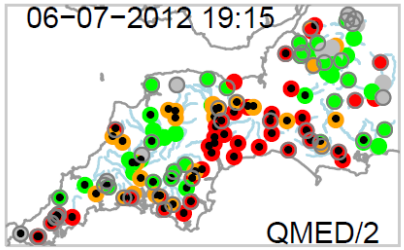
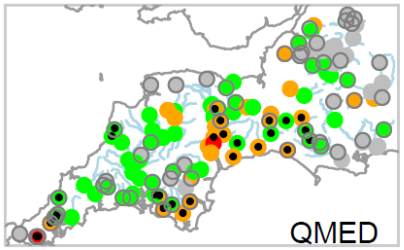
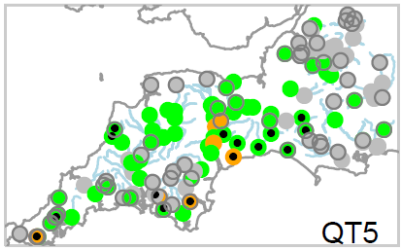
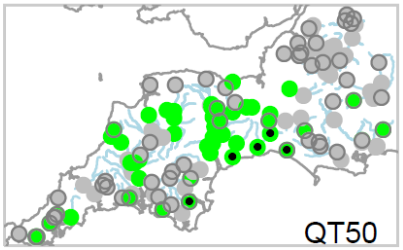
Q(50)



Case study: 6-7 July 2012

Threshold

Forecast Origin

	$Q_{med}/2$	Q_{med}	Q(5)	Q(50)
06-07-2012 07:15				
06-07-2012 19:15				

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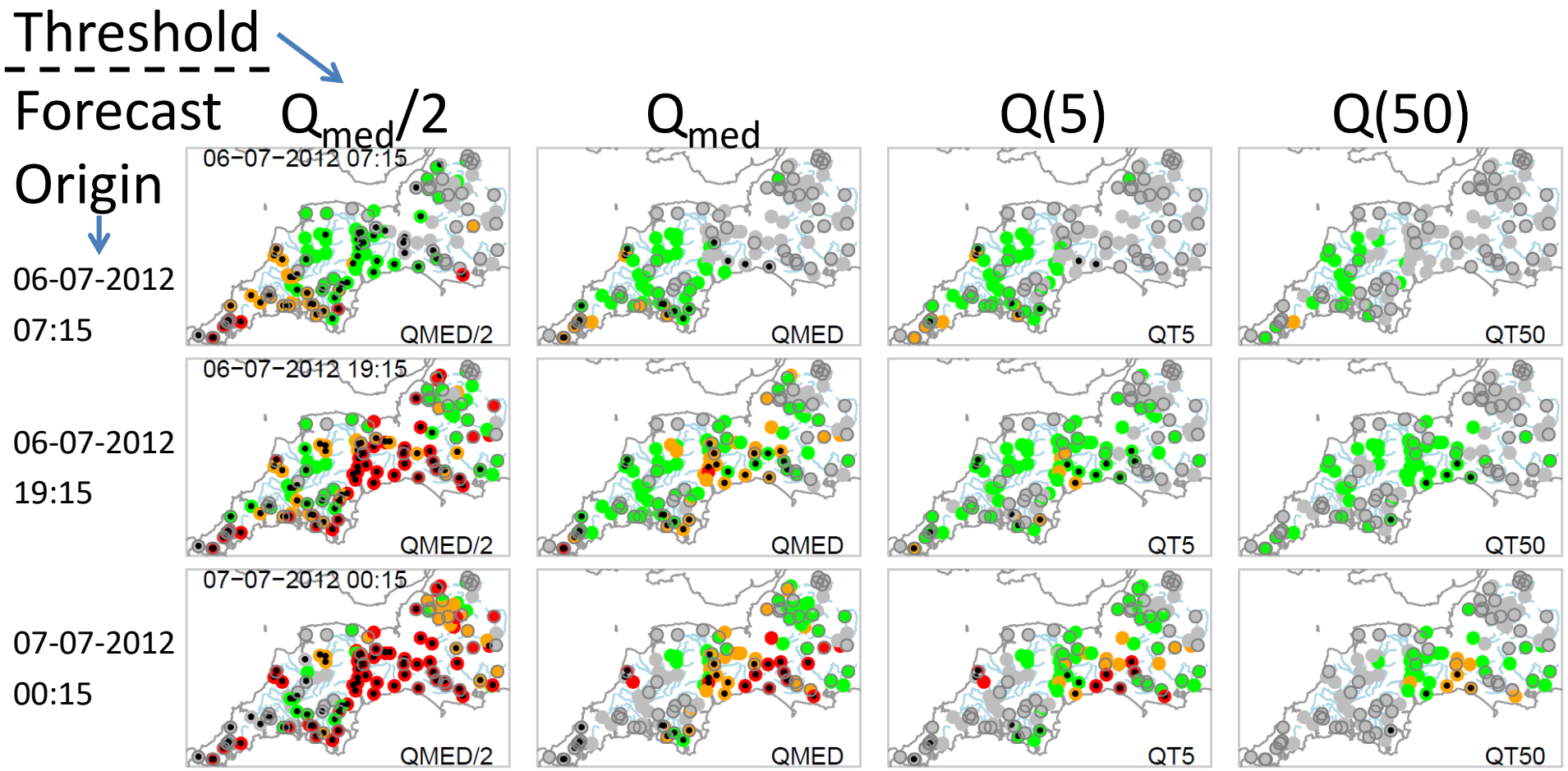

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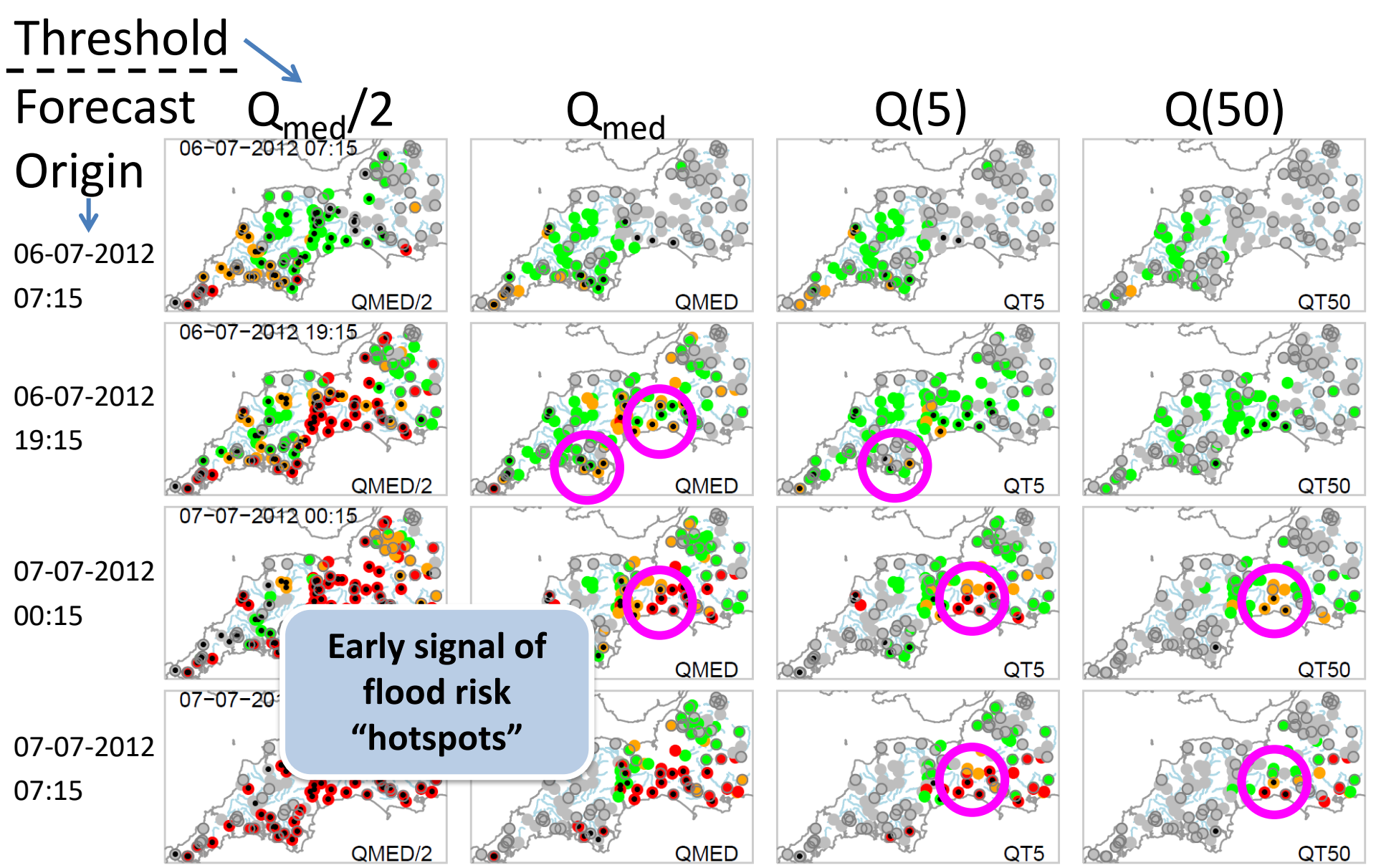
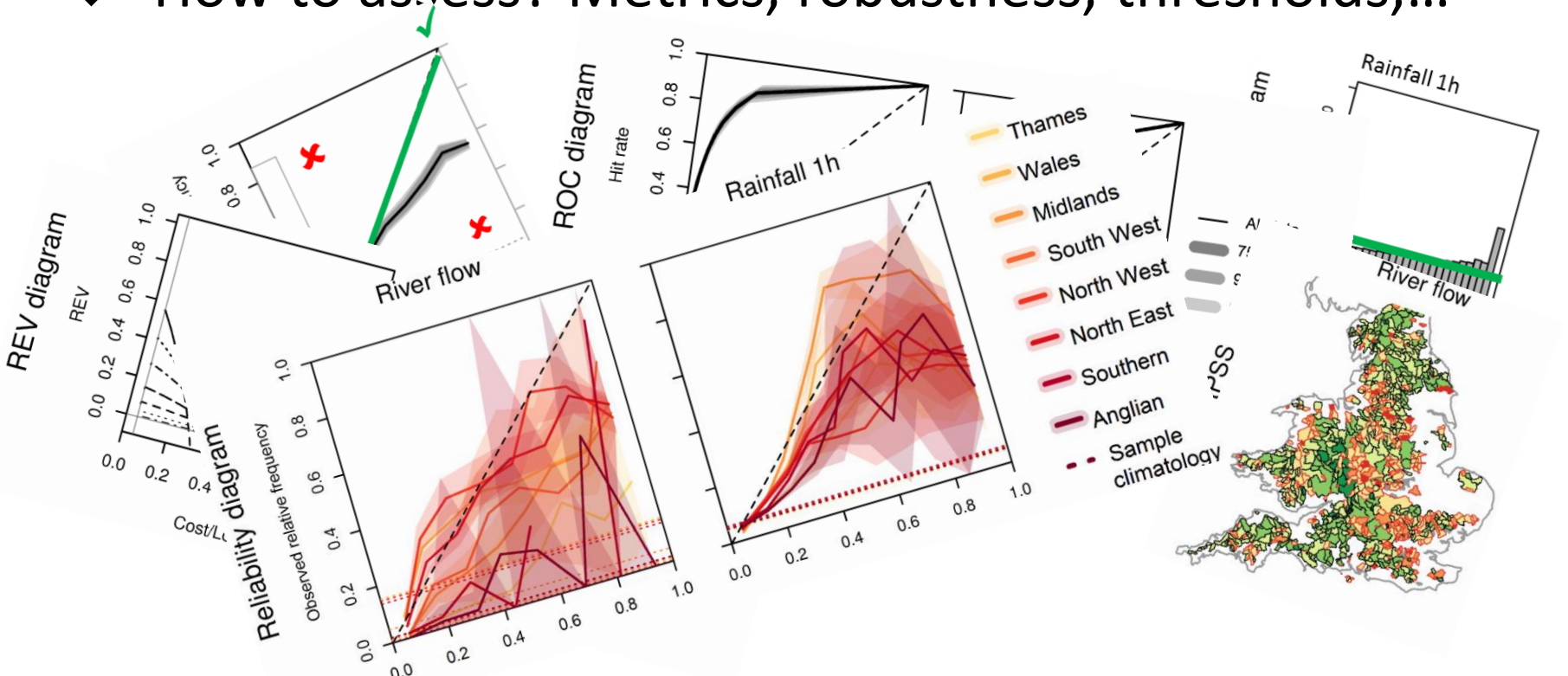


Rainfall & River flow Ensemble Verification

- Generally accepted that probabilistic rainfall and flood forecasts are needed BUT…
  - How well do forecasts perform? (ensemble verification)
  - How to assess? Metrics, robustness, thresholds,…



Anderson et al., JoH, (2019)

Rainfall & River flow Ensemble Verification

- Generally accepted that probabilistic rainfall and flood forecasts are needed BUT…
  - How well do forecasts perform? (ensemble verification)
  - How to assess? Metrics, robustness, thresholds,…
- Key is to be stakeholder and user focused:
  - Flood-producing events of interest.
  - What does this mean for *today's* forecast?
- UKCEH/Met-Office project for Flood Forecasting Centre, Scottish Flood Forecasting Service, EA, SEPA

Anderson et al., JoH, (2019)

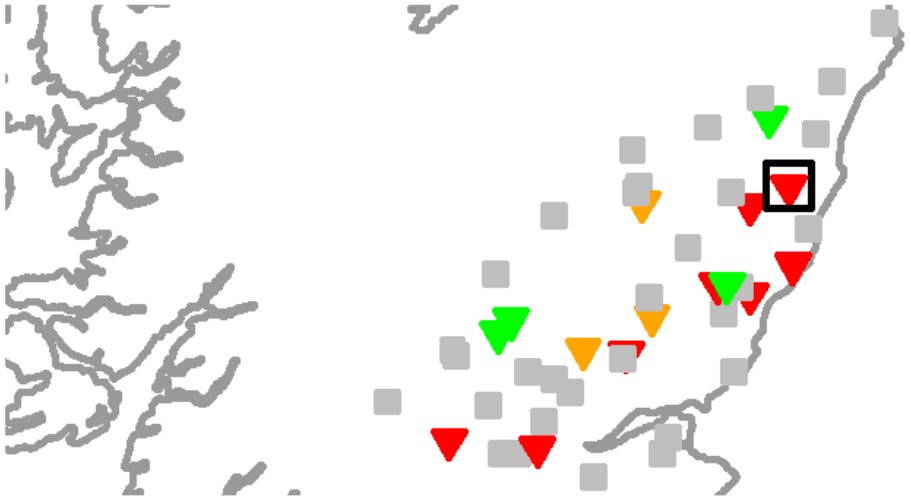
HEPEX blog: https://hepex.inrae.fr/verification-detail-matters/

Rainfall & River flow Ensemble Verification

What does this mean for today's forecast?

Day 1

Derive using >1 year of 5 day forecasts made 4 times a day



QT(2)/2

Colours give probability of threshold crossing

Red: 16 to 24 of members

Orange: 8 to 16 of members

Green: 1 to 8 of members

Symbols give suggested tendency from verification

△ Upwards triangle: possible underestimation

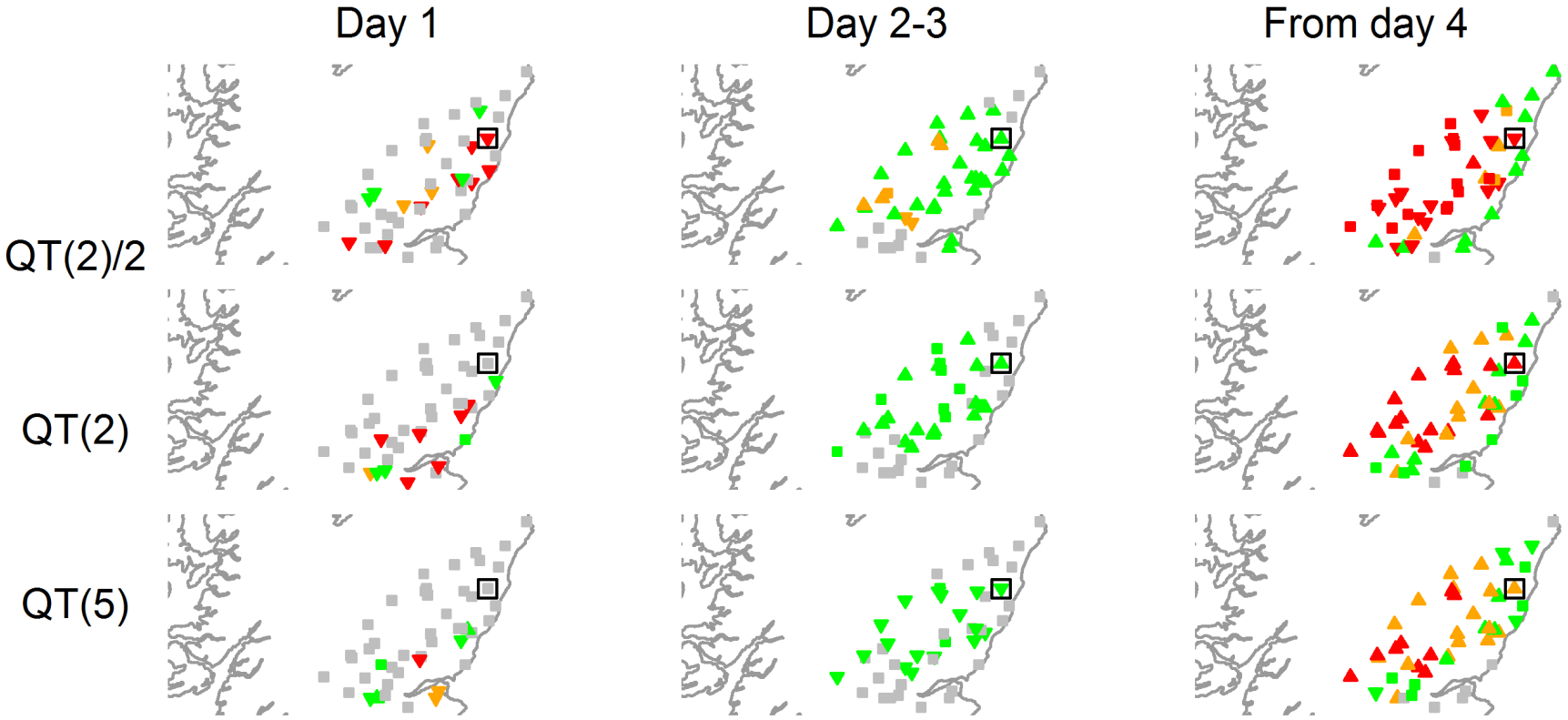
▽ Downwards triangle: possible overestimation

□ Square: no suggested trend

◆ Diamond: not enough data for a trend

Rainfall & River flow Ensemble Verification

What does this mean for today's forecast?



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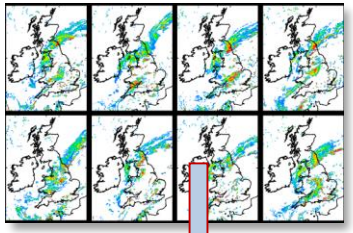
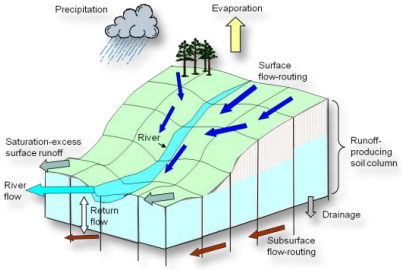
Impact-based Forecasting (IbF)

- Surface Water Flooding Hazard Impact Model (SWF HIM) developed by the Natural Hazards Partnership
- Builds on existing models & tools
- Operated by Flood Forecasting Centre over England & Wales

Rainfall ensembles (MOGREPS-UK)



Grid-to-Grid Hydrology

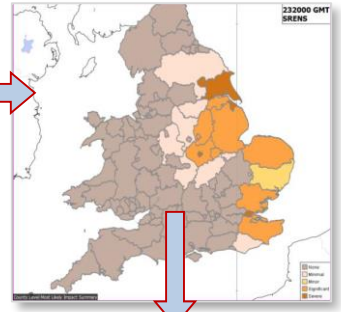


SWF Hazard Footprint

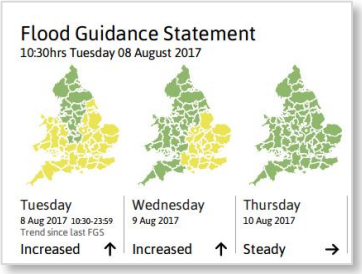
SWF HIM

Real-time SWF risk outputs

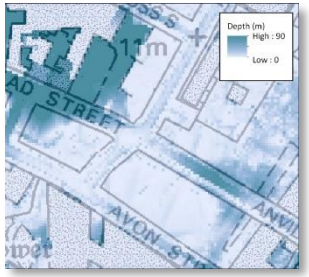
Visualisation



Dissemination

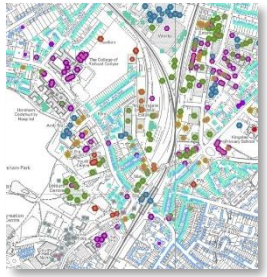


Impact Library



Updated Flood Map for Surface Water

National Receptor Database (NRD)

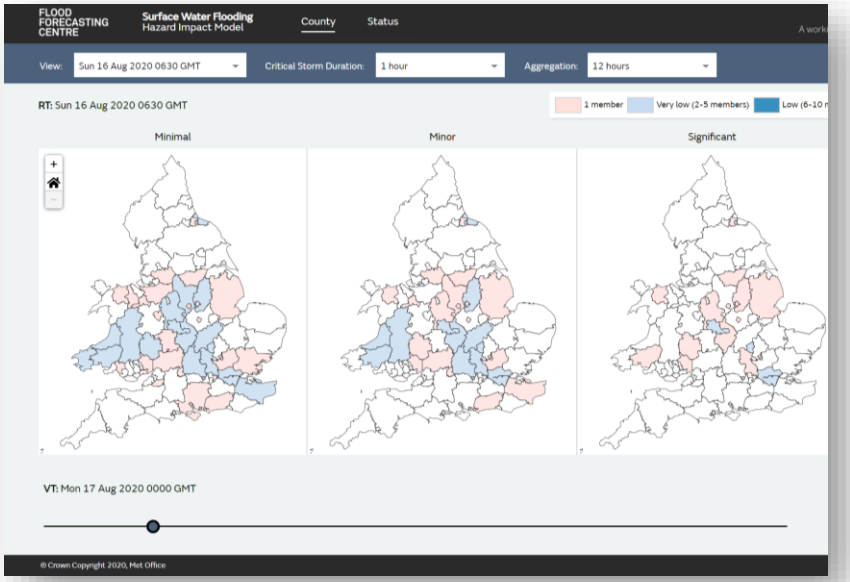


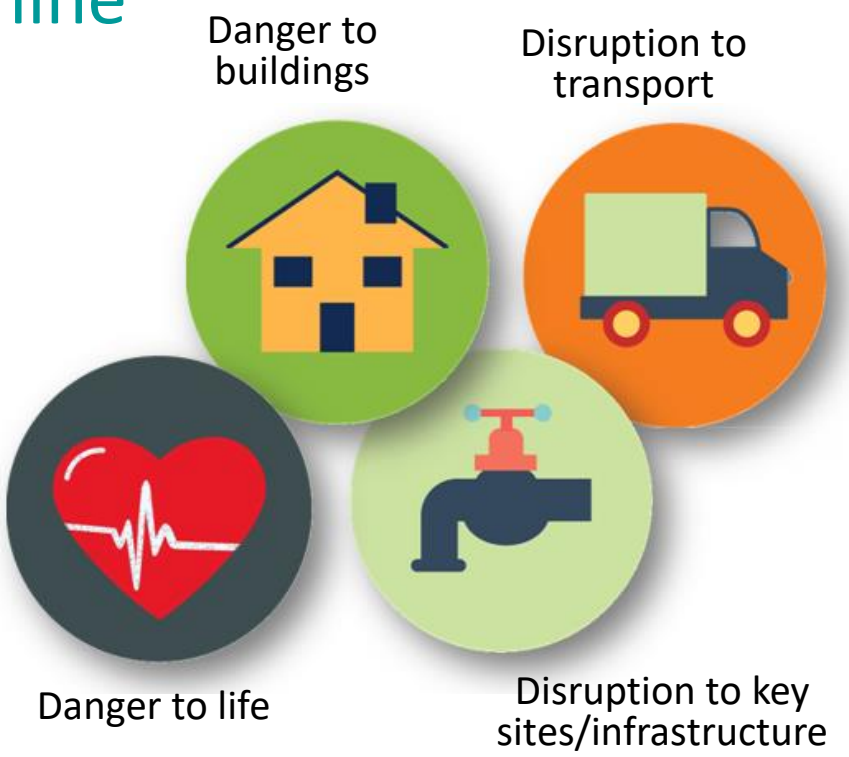
National Population Database (NPD)

FLOODFORECASTINGCENTRE
a working partnership between Environment Agency | Met Office

Impact Library and Visualisation

- Impact Library developed offline and accessed in real-time
- Four categories of disruption (impact criteria)
- Uses a Risk Matrix approach





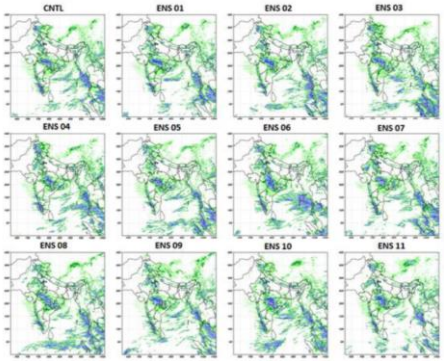
- Operational since April 2020

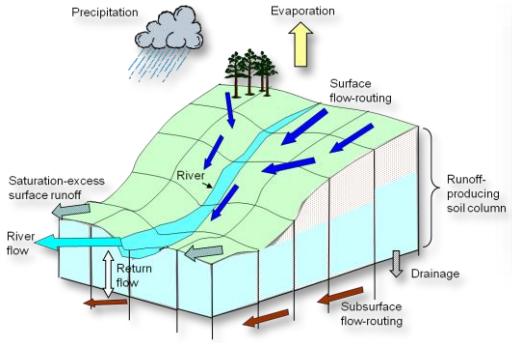
Cole et al., Aldridge et al., FLOODrisk2016
www.naturalhazardspartnership.org.uk

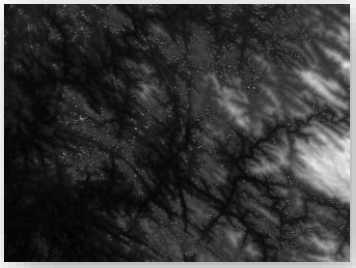
IbF prototype development in India

Ensemble Rainfall (NEPS-R) → **Ensemble Floods** (G2G) → **High-resolution Inundation** (HiPIMS) → **Automated IbF**

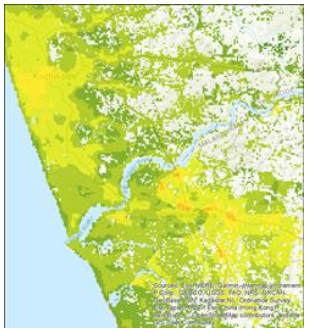
IbF components





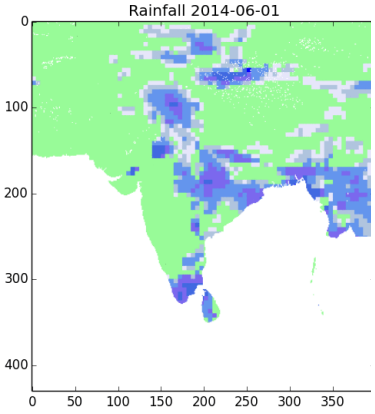


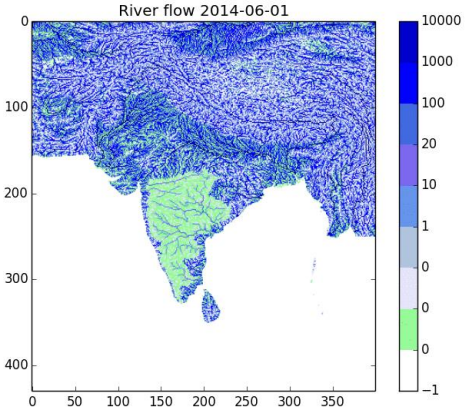
ALOS (12.5m)

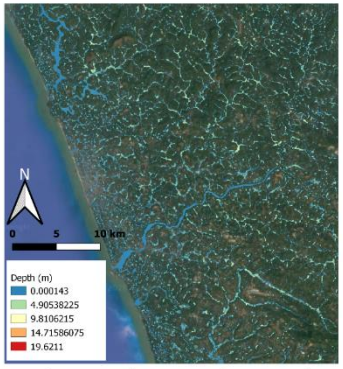


Population

Prototype outputs







Population at risk

UK Centre for Ecology & Hydrology · HSE · Loughborough University · NHP · Ministry of Earth Sciences · Met Office · WCSSP-India

Closing remarks

- Distributed Hydrological Models operational across Britain
  - G2G provides fluvial forecasts “everywhere” on a 1km grid
- Ensemble rainfall and flood forecasting
  - Enabled by high resolution (~2.2km, 5 day+) rainfall ensembles
- Flood model performance assessment and verification
  - Evidence for strategic and real-time decision making
- Real-time mapping of surface water flooding *impacts*
- Partnership working, India IbF prototype

Dr Steven Cole:
scole@ceh.ac.uk