Met Office

CEH Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

Catchment-based precipitation ensemble forecast skill in the presence of observation uncertainty

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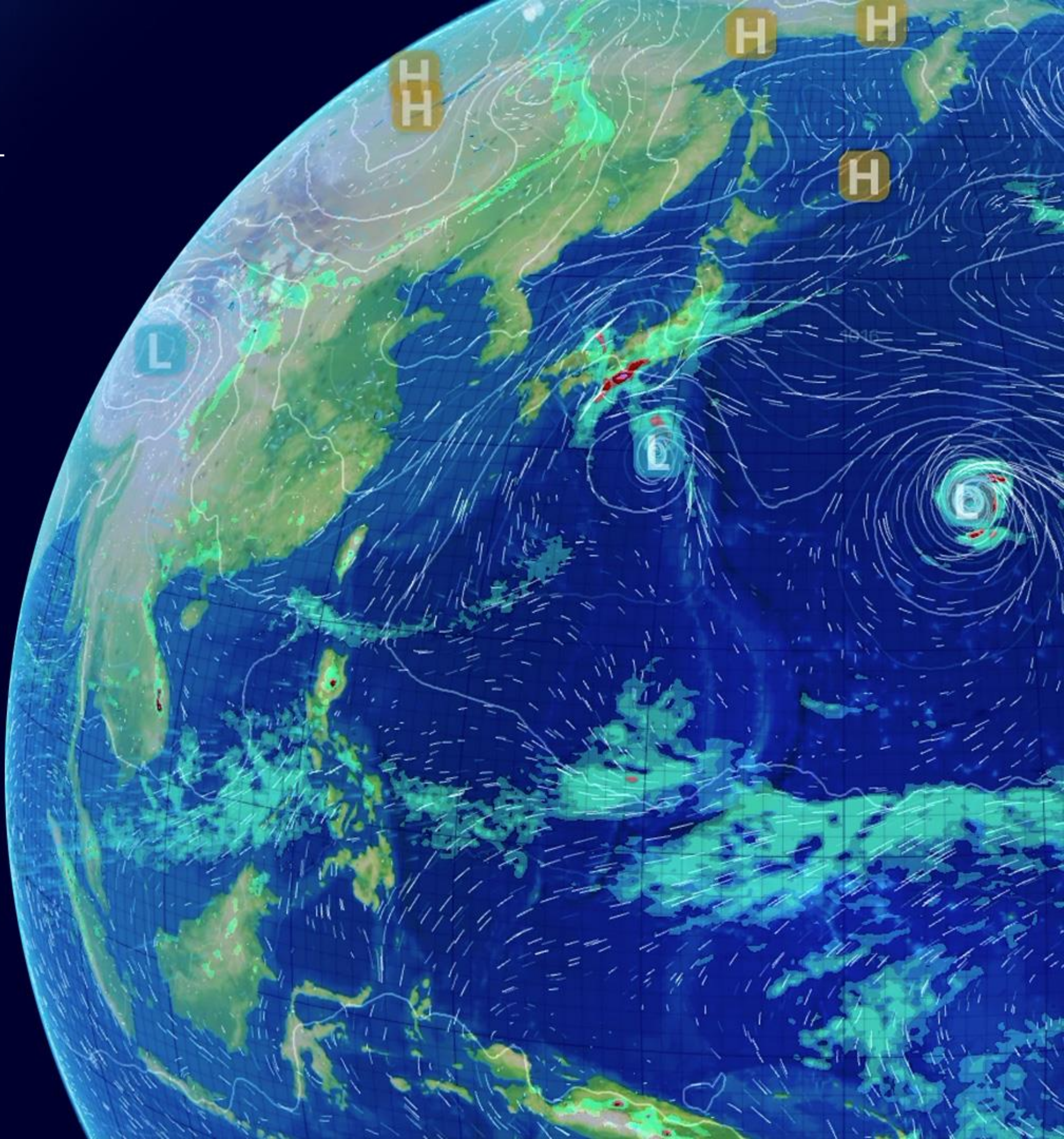

Outline

- Introduction of the project task
- Observation error
    - Mathematical background
    - Observation error estimation
    - Using the estimated observation error in the verification
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"Rainfall and River Flow Ensemble Verification" project

- Commissioned by the **Flood Forecasting Centre** on behalf of the **Scottish Environment Agency**, **Environment Agency** and **Natural Resources Wales**
- Carried out jointly between **Centre for Ecology & Hydrology** (CEH) and the **Met Office**

- **Aim:** Develop a joint verification framework for catchment-scale precipitation and river flow ensembles

- **Using:** deterministic (e.g. ME. MAE, RMSE) and probabilistic (e.g. BS(S), CRPS(S), ROCSS, REV, Reliability & ROC diagram) verification measures

Forecast chain

STEPS Nowcast
(2km, t+7h)

MOGREPS-UK
(2.2km,~t+48h)

MOGREPS-G
(32km, ~t+144h)

uses STEPS to combine nowcast, MOGREPS-UK and MOGREPS-G data together with stochastic noise

“Best medium-range blended ensemble”
Res: 2km & 15 min

Grid-to-grid (G2G) hydrological model
Res: 1km & 15 min
developed by Centre for Ecology & Hydrology (CEH)

INTERPRETATION + FLOOD FORECAST

Verification against:

Radar rainfall

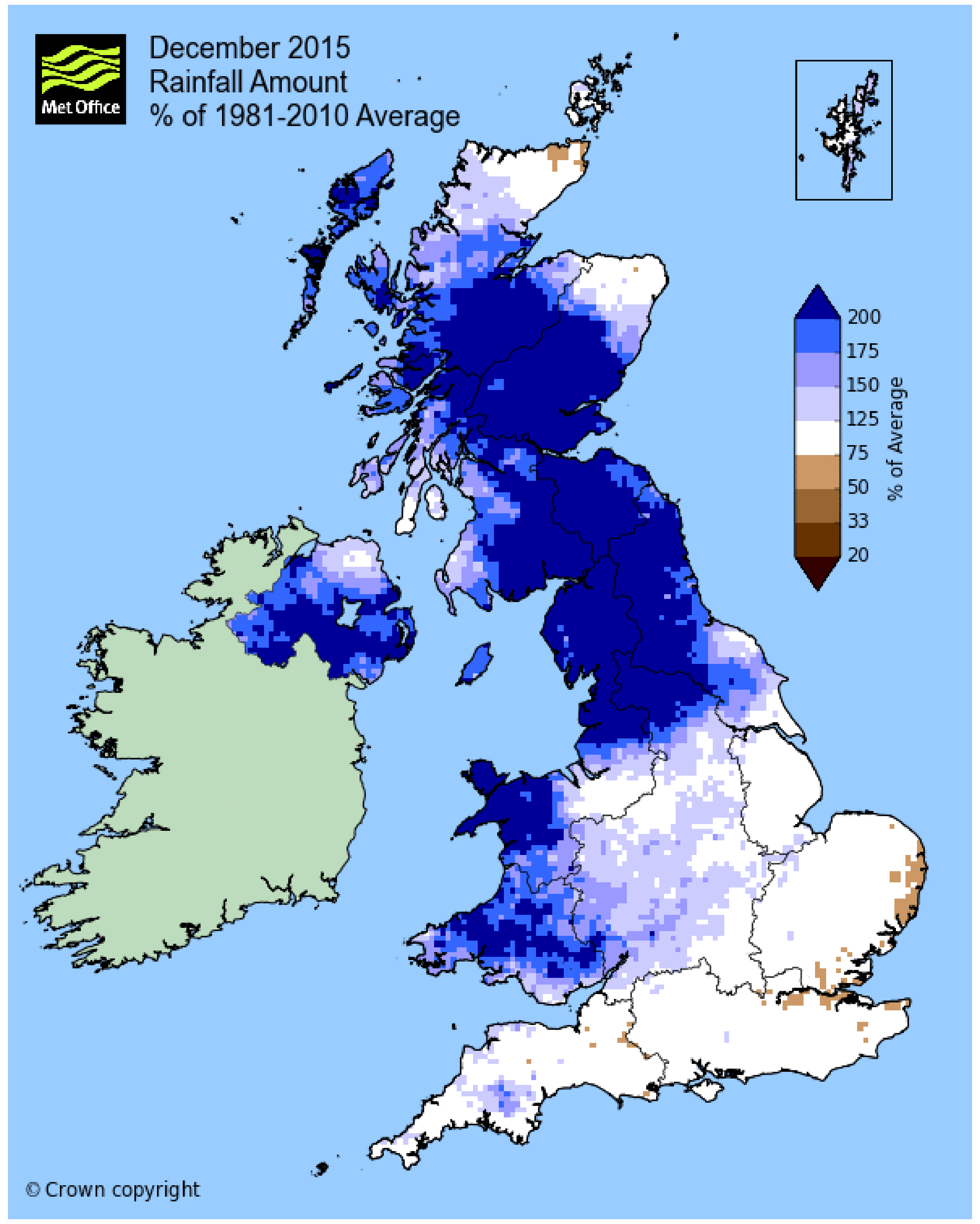
Gridded rain-gauge

River flow observation

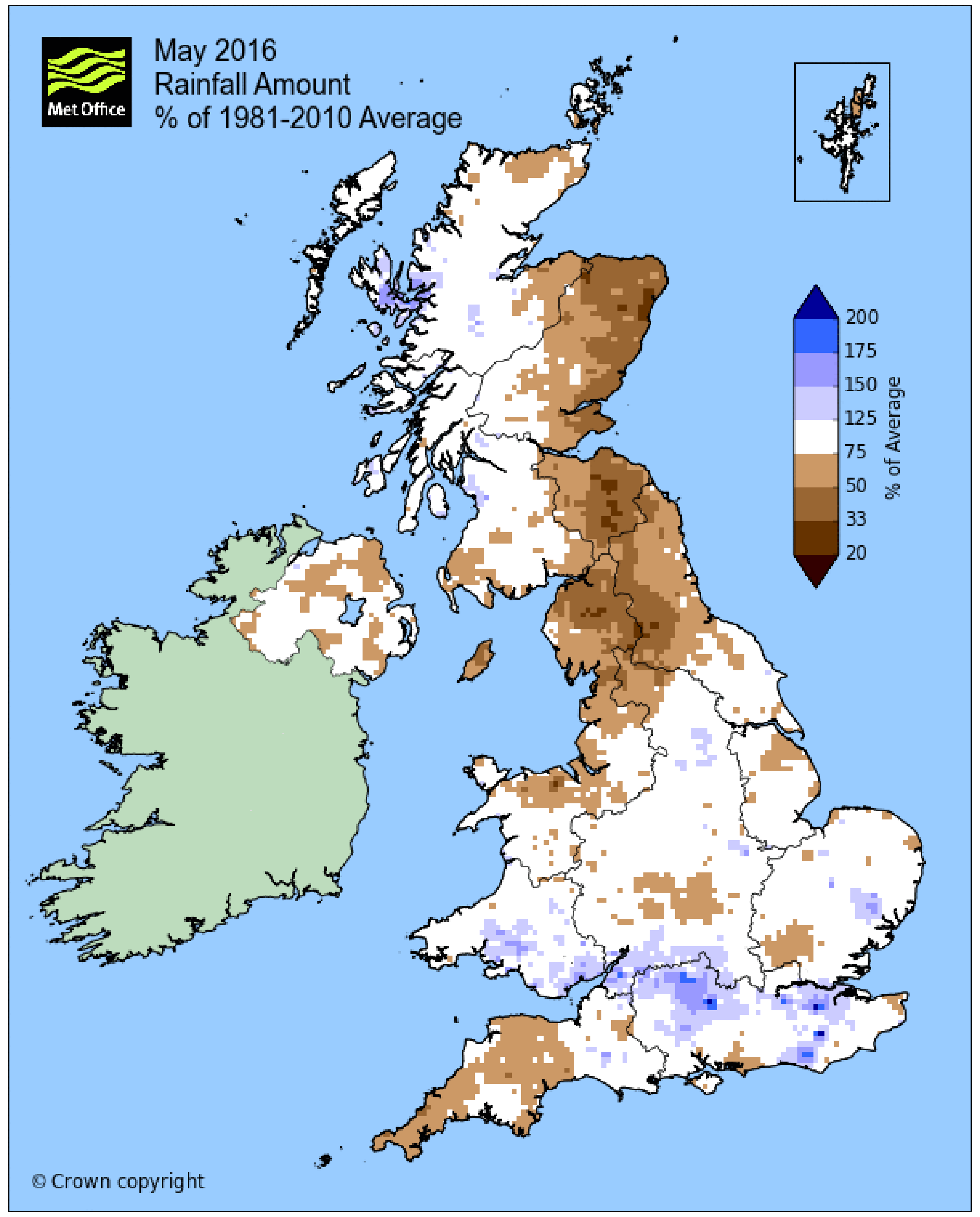
Time periods

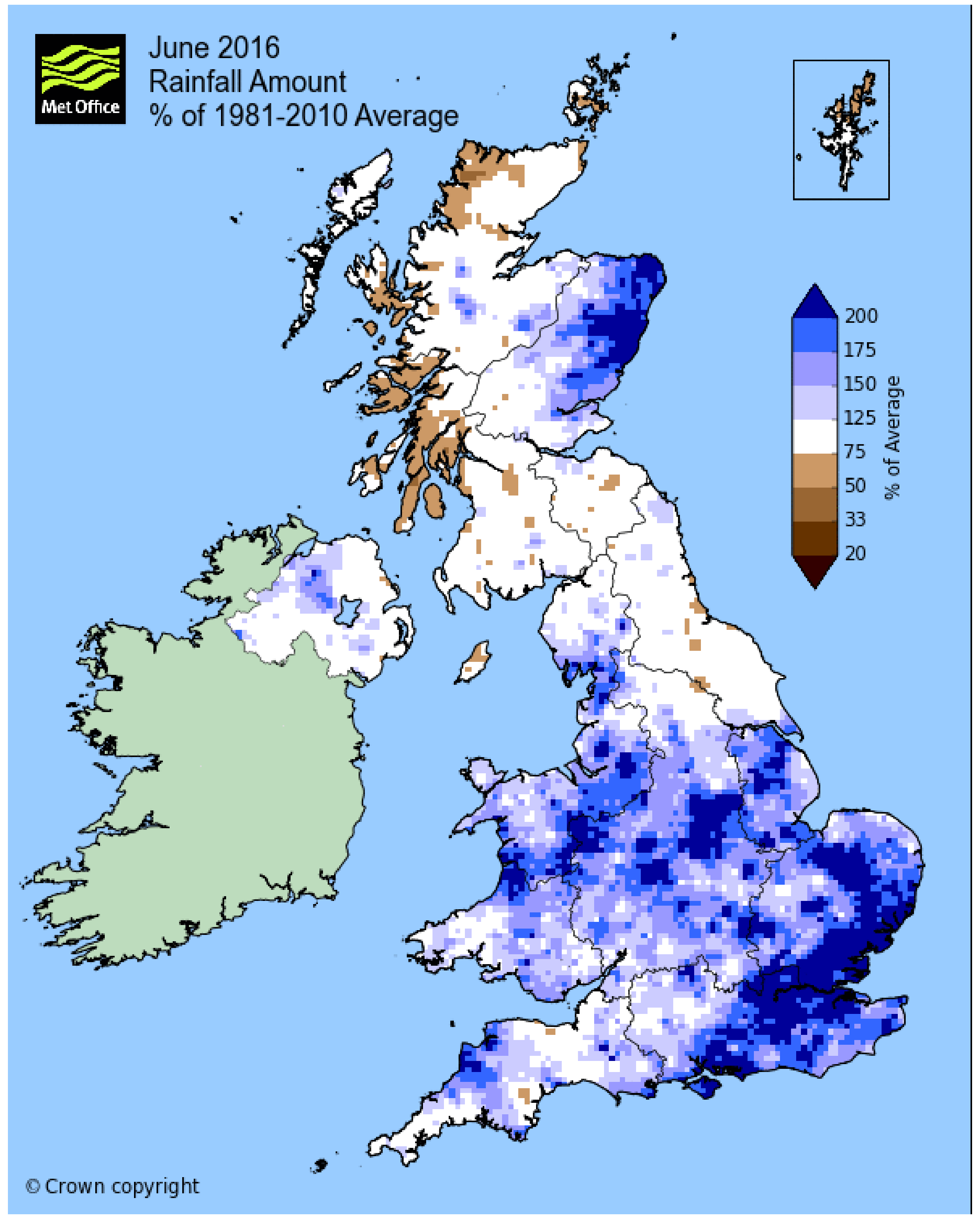
Winter: 25/11/2015 – 26/12/2015

Summer: 15/05/2016 – 15/06/2016



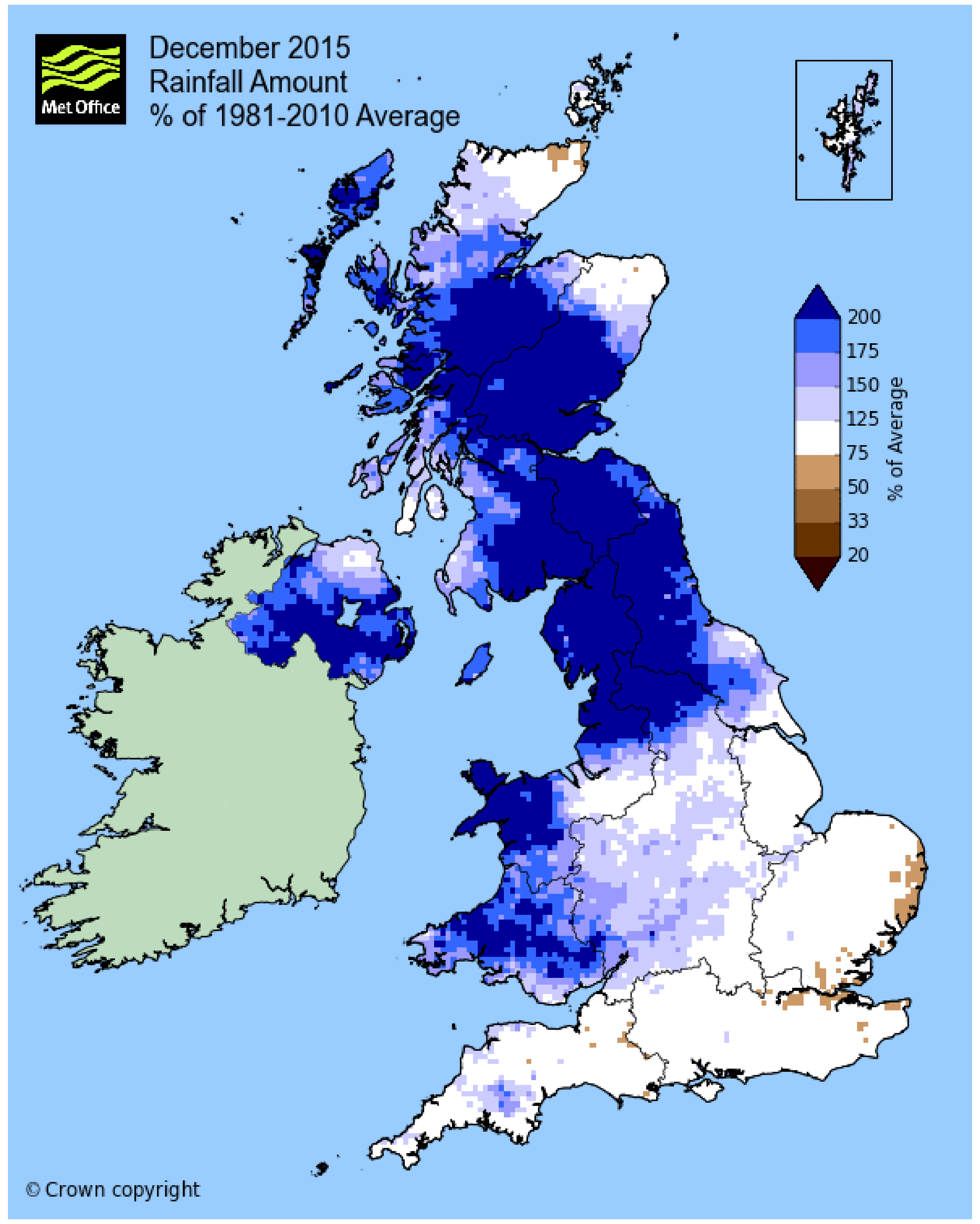
Anomaly Rainfall maps



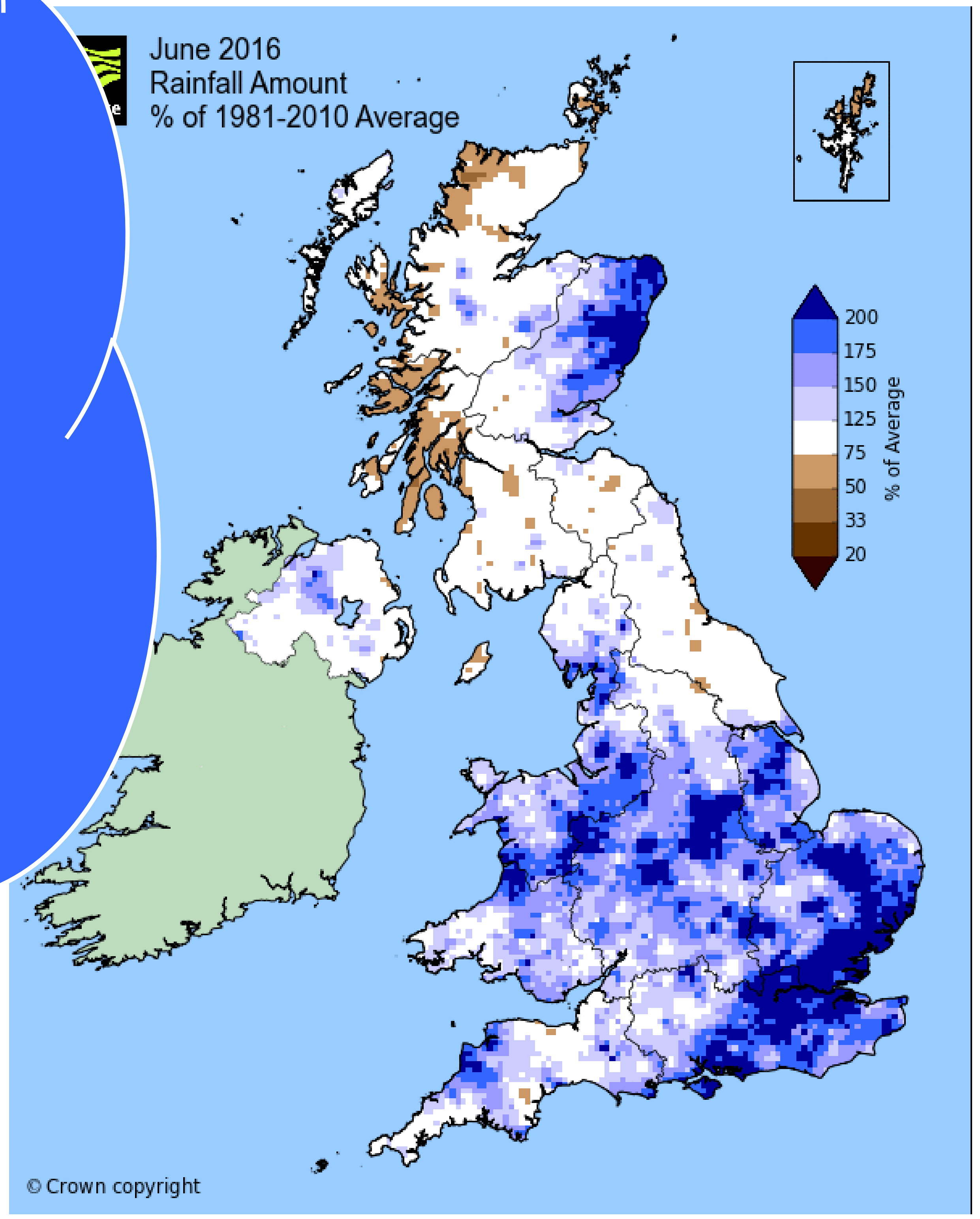


Time periods

Winter: 25/11/2015 – 26/12/2015



Sum 1 /2016 – 15/06/2016

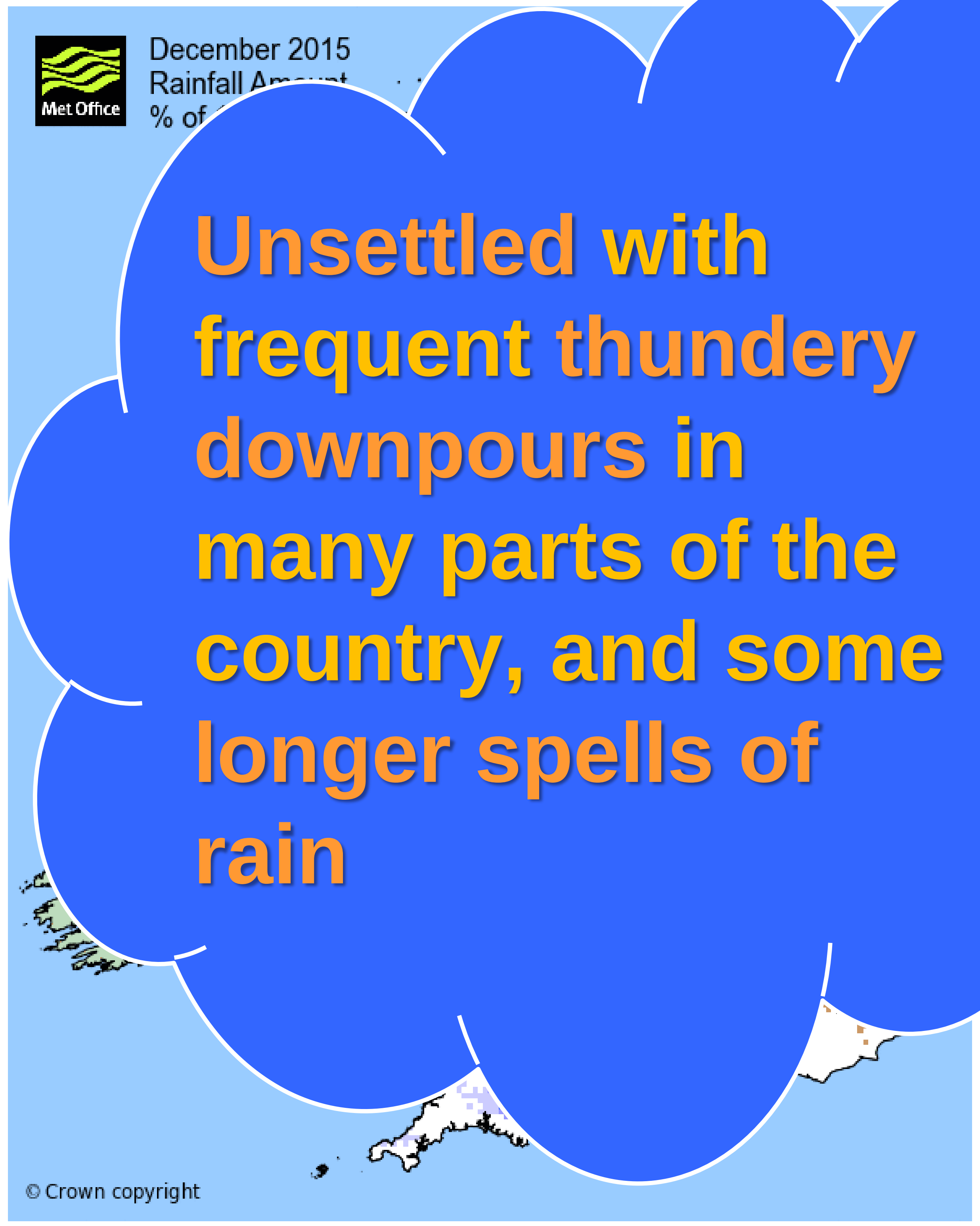


Exceptionally wet and often windy

Storms: **Desmond, Eva and Frank** – with record-breaking rainfall over much of Scotland, Wales and northern England

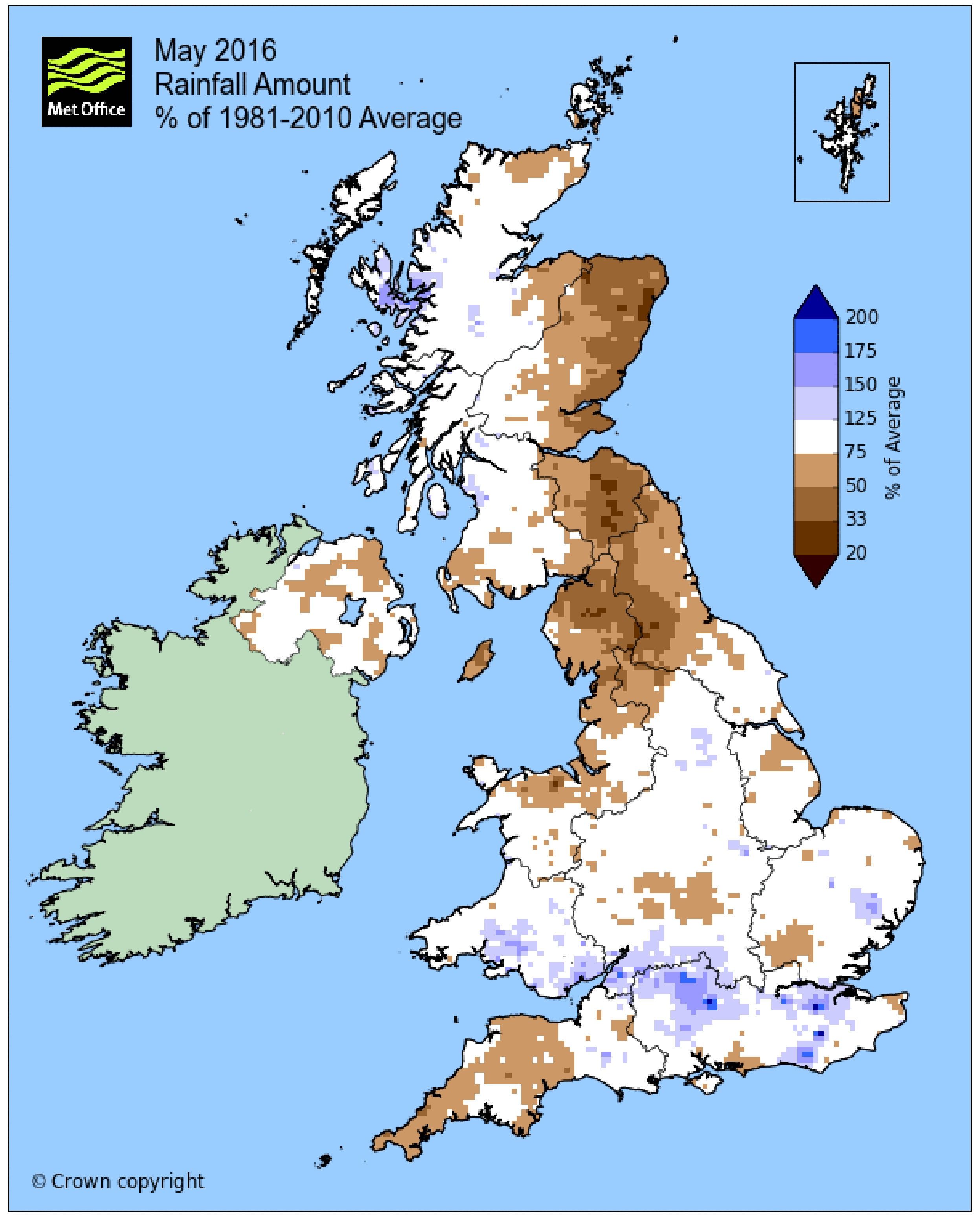
Time periods

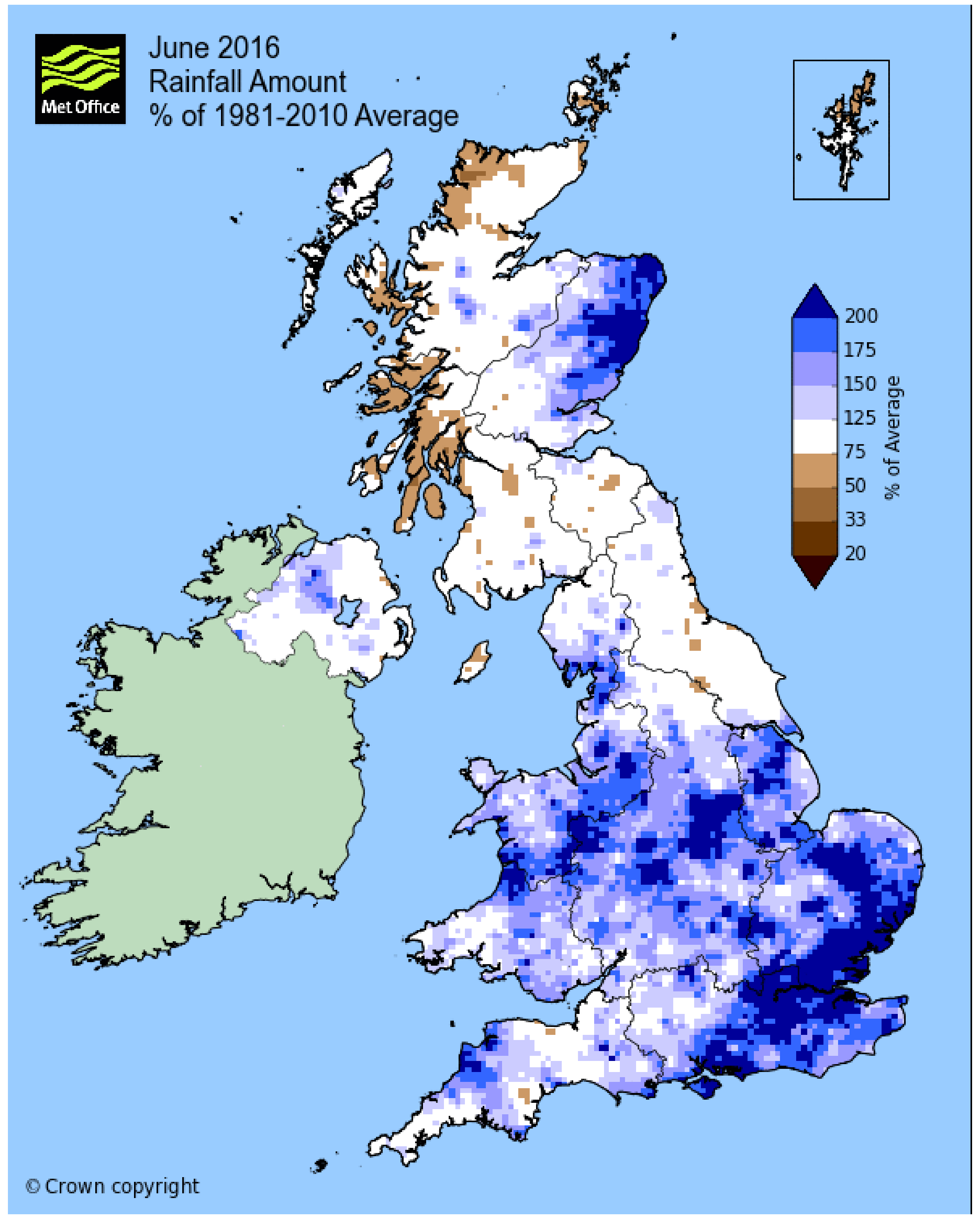
Winter: 25/11/2015 – 26/12/2015



Unsettled with frequent thundery downpours in many parts of the country, and some longer spells of rain

Summer: 15/05/2016 – 15/06/2016

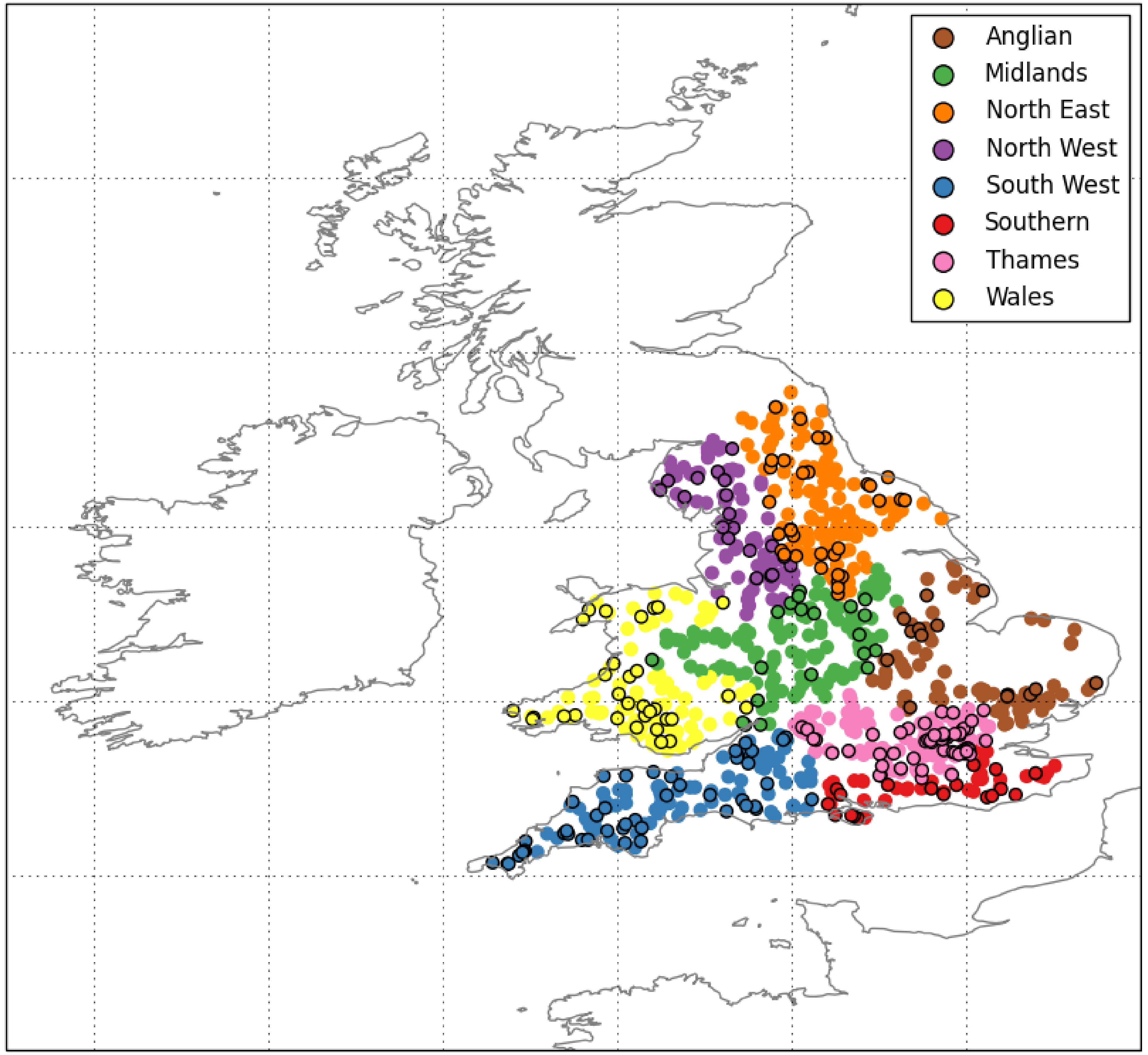




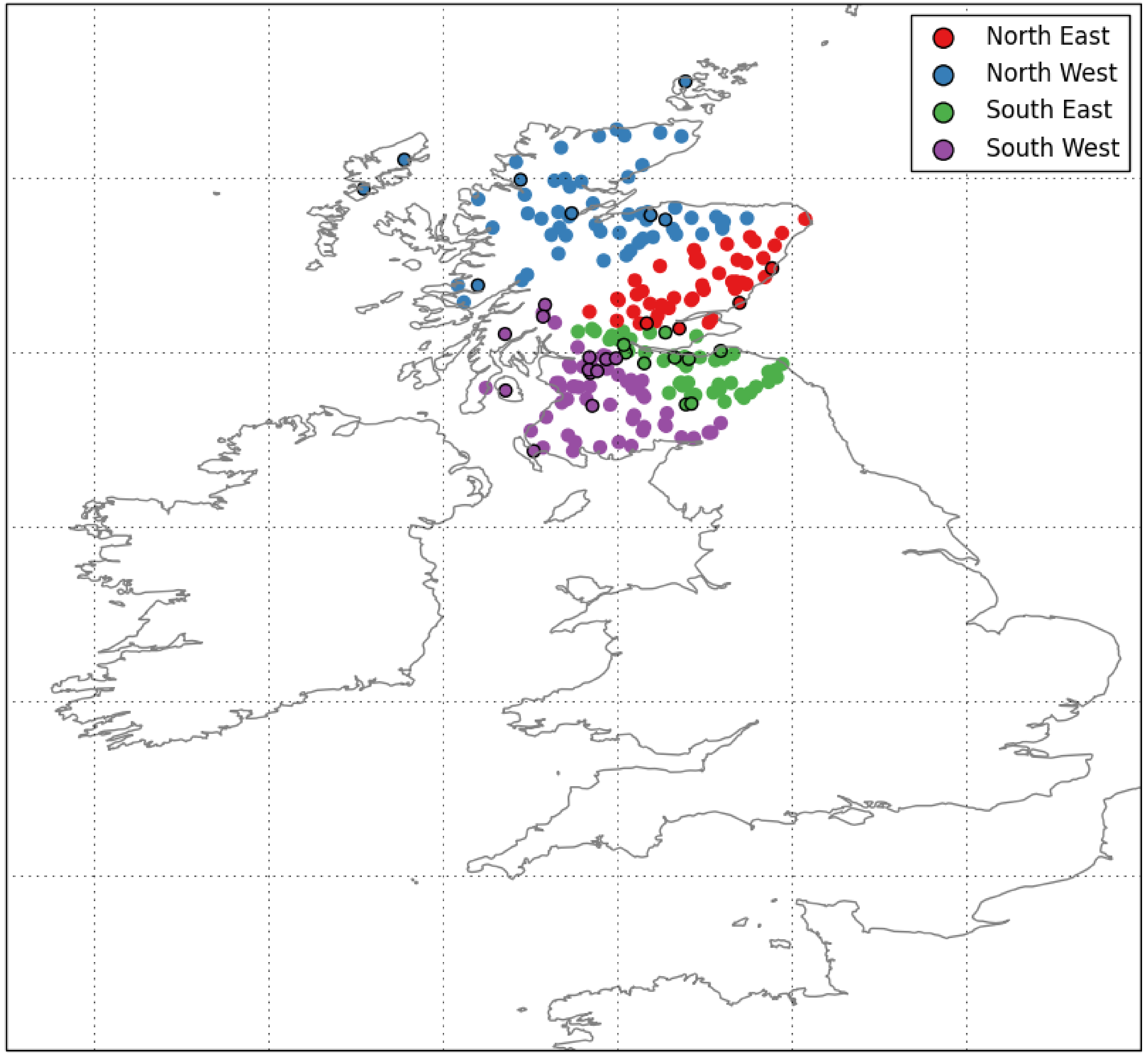
Catchments, Regions and Countries

Used the *catchment averages* as the forecast and observation dataset

England & Wales (E&W)



Scotland



Examined parameters in different attributes in the project work and in the **observation error** calculations

- **Countries: England&Wales and** Scotland
- **Time resolutions:** daily, **hourly**, 15-min
- **Time periods: winter and** summer
- **Observation types: radar and gauge**
- **Aggregating lead times: Day1**, Day2-3, Day4-6

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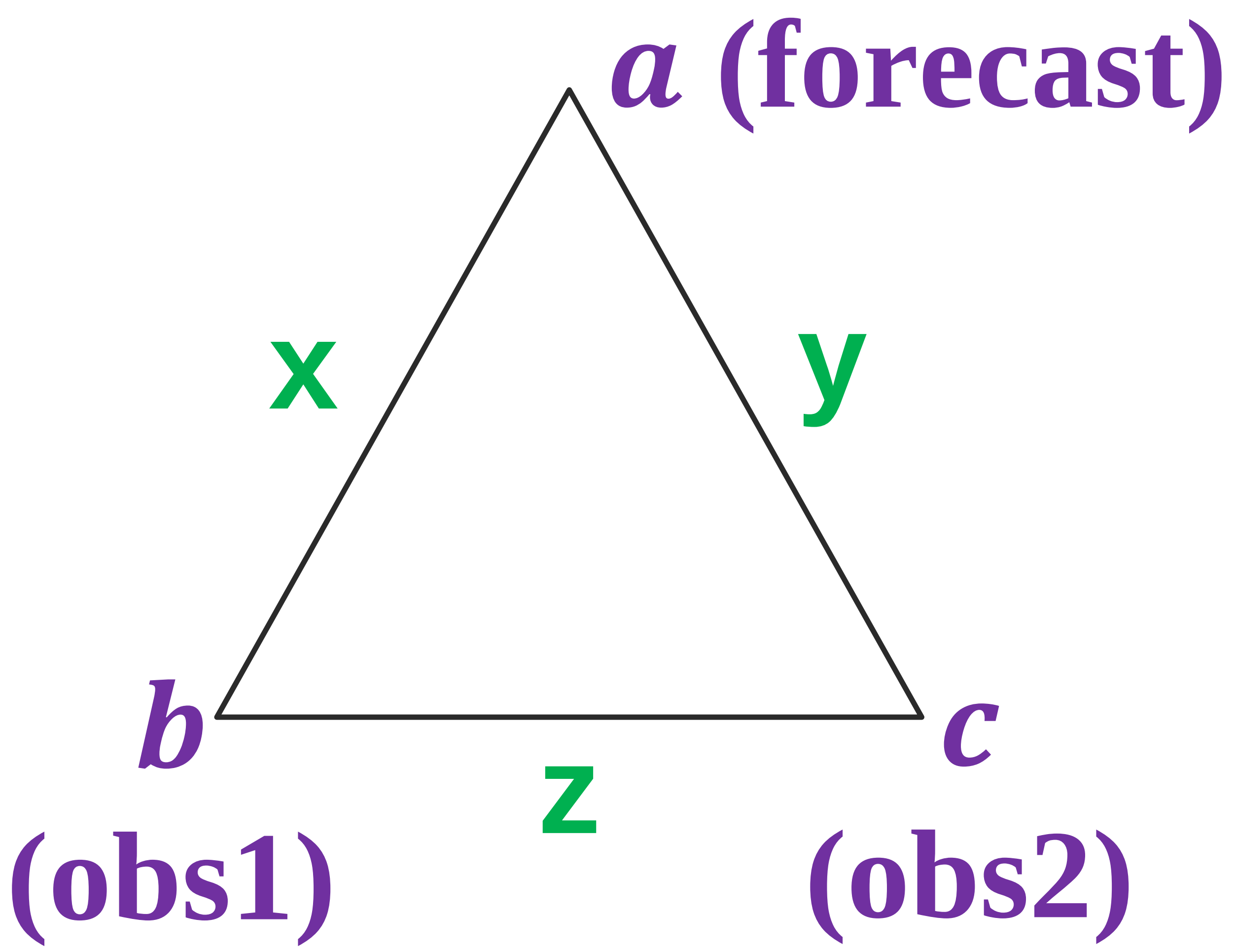

f_a : actual values of forecast

f_b : actual values of obs1

f_c : actual values of obs2

t : true values

x: MSE of the forecast & obs1

y: MSE of the forecast & obs2

z: MSE of the obs1 & obs2

$$x = E(f_a - f_b)^2 = E[(f_a - t) - (f_b - t)]^2 = E(\delta_a^2) + E(\delta_b^2) \cancel{- 2E(\delta_a \delta_b)}$$

Assumption:
the two errors are <u>not</u> correlated

$$E(f_a - f_b)^2 = x = E(\delta_a^2) + E(\delta_b^2)$$

$$E(f_a - f_c)^2 = y = E(\delta_a^2) + E(\delta_c^2)$$

$$E(f_b - f_c)^2 = z = E(\delta_b^2) + E(\delta_c^2)$$

$$E(\delta_a^2) = \frac{x+y-z}{2}$$ **forecast error**

$$E(\delta_b^2) = \frac{x-y+z}{2}$$ **obs1 error**

$$E(\delta_c^2) = \frac{-x+y+z}{2}$$ **obs2 error**

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Observation error estimation

- Determined an adjacent bin series:

  BIN1: **[0,0.1)**
  BIN2: **[0.1,1)**
  BIN3: **[1, 2)**
  BIN4: **[2, 4)**
  BIN5: **[4, ∞)**

The distribution of the forecast (ensemble mean & control) and the observations based on the bins

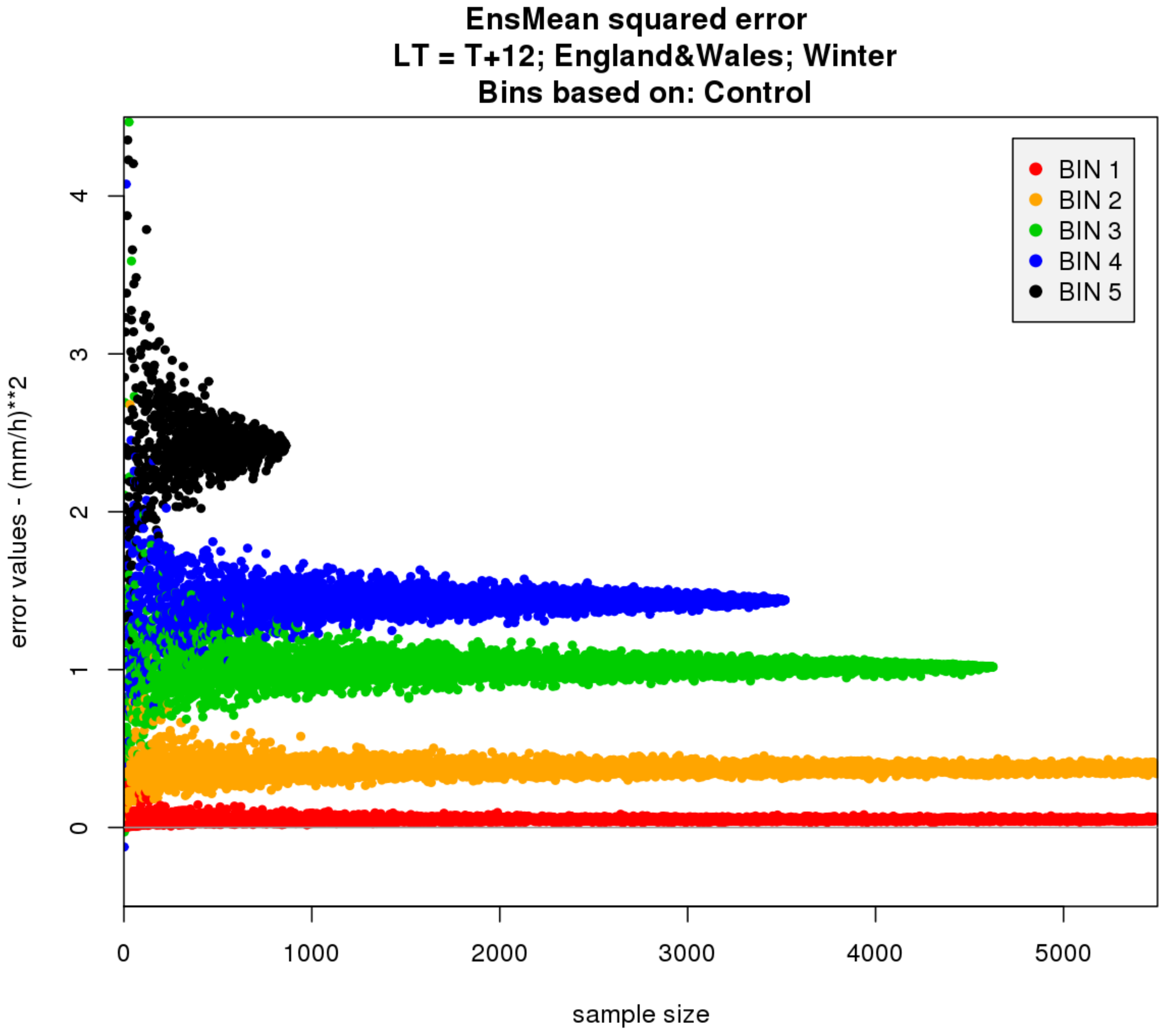
%	BIN 1	BIN 2	BIN 3	BIN 4	BIN 5
Ensemble mean	59.4	31.4	6.3	2.7	0.2
Radar	74.5	17.8	4.3	2.6	0.8
Gauge	71.1	21.4	4.3	2.5	0.7
Control forecast	72.1	17.7	5.5	3.7	1.0

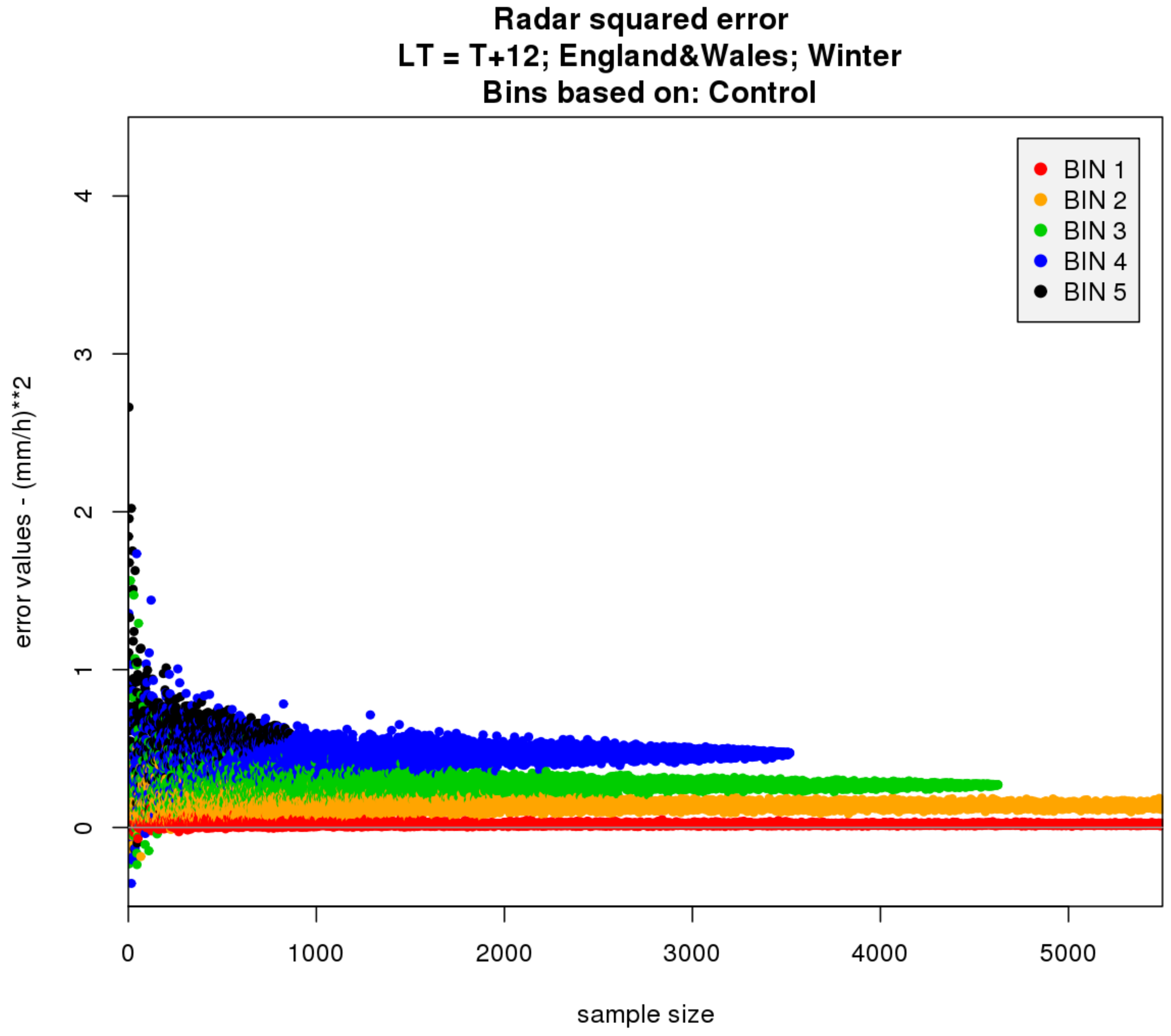
Other binning strategy gave similar results

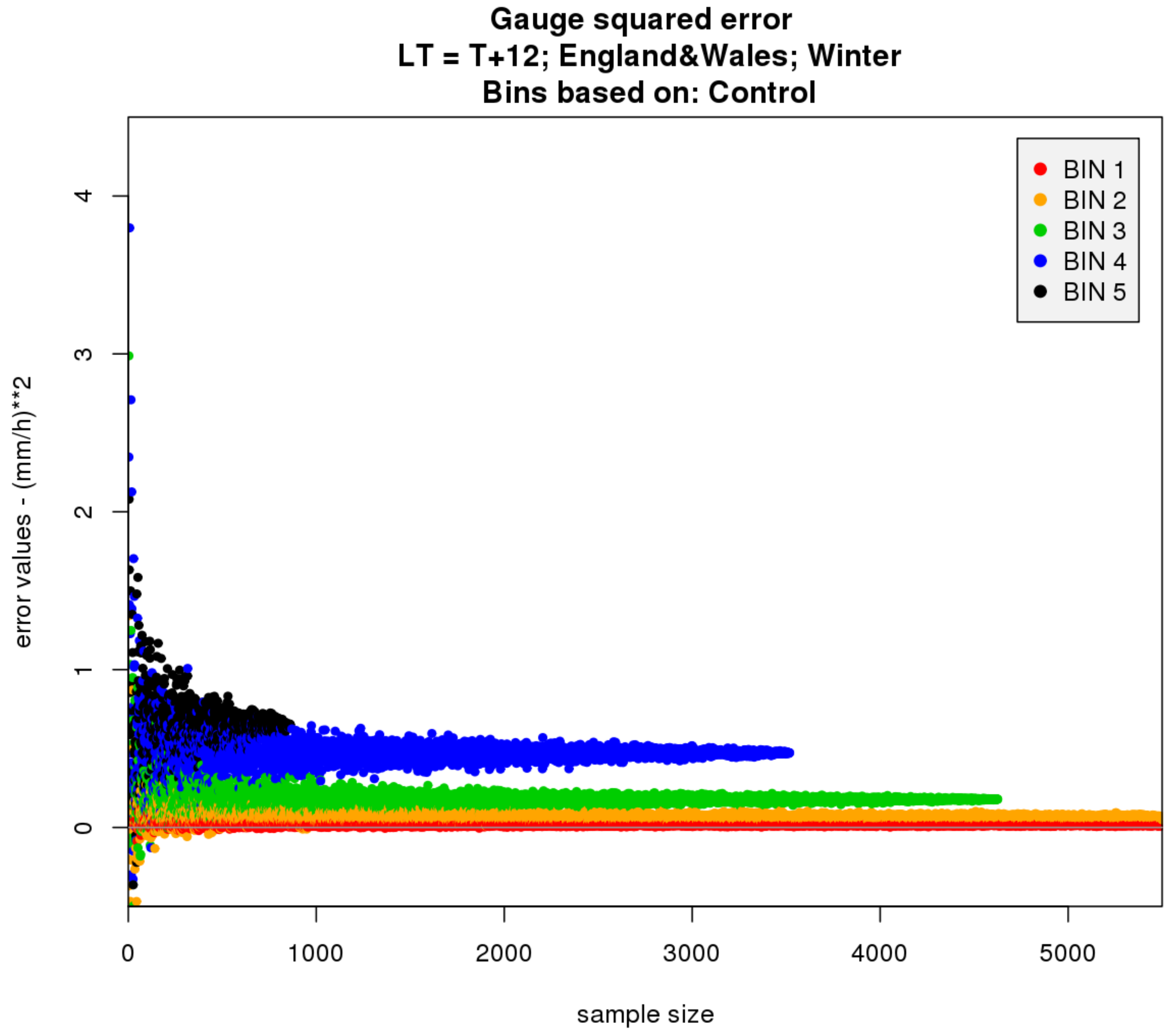
Observation error estimation

Squared error plots as a function of the sample size

- Binning based on the **Control**
- Forecast error were calculated from **Ensemble mean**







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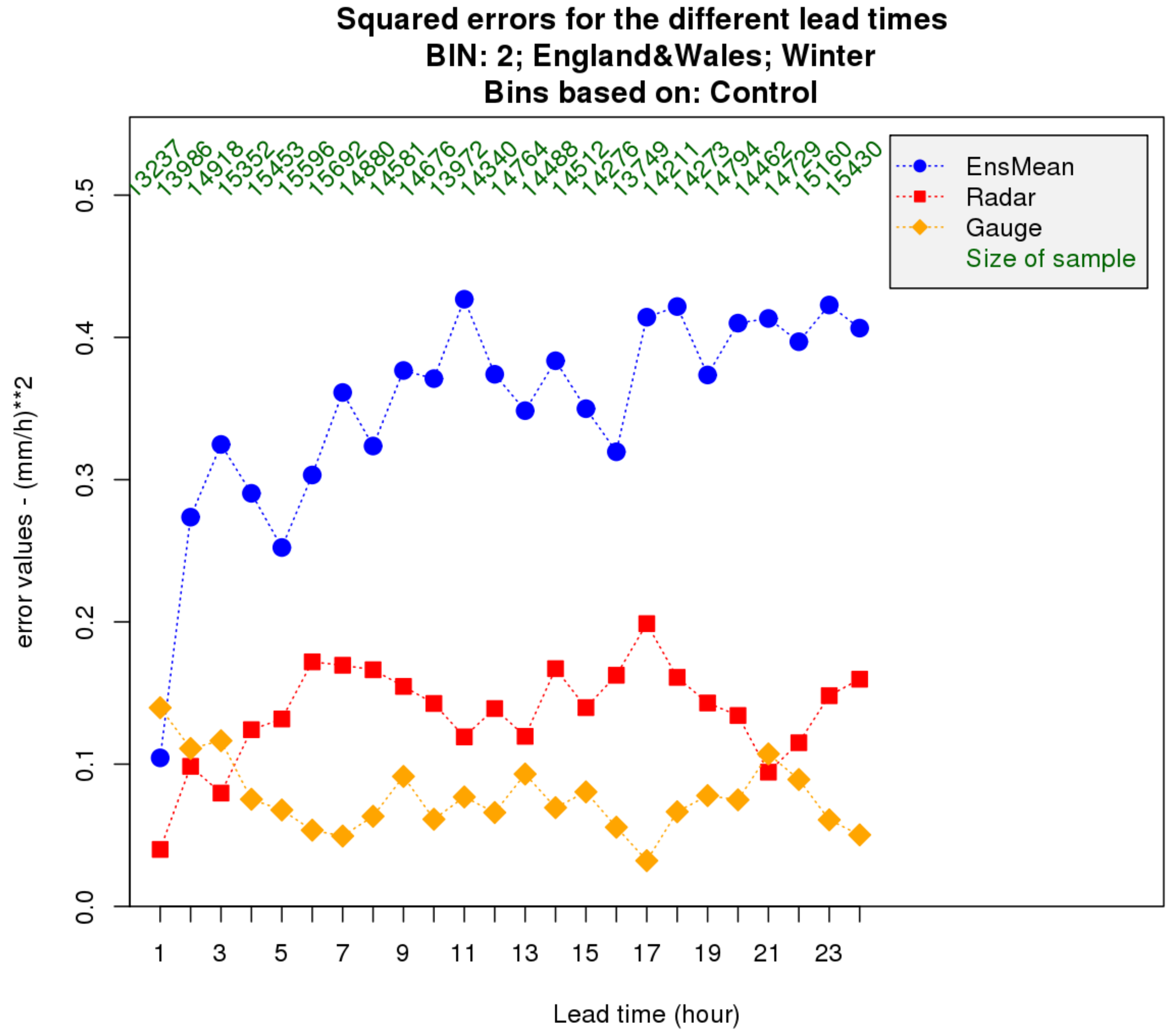
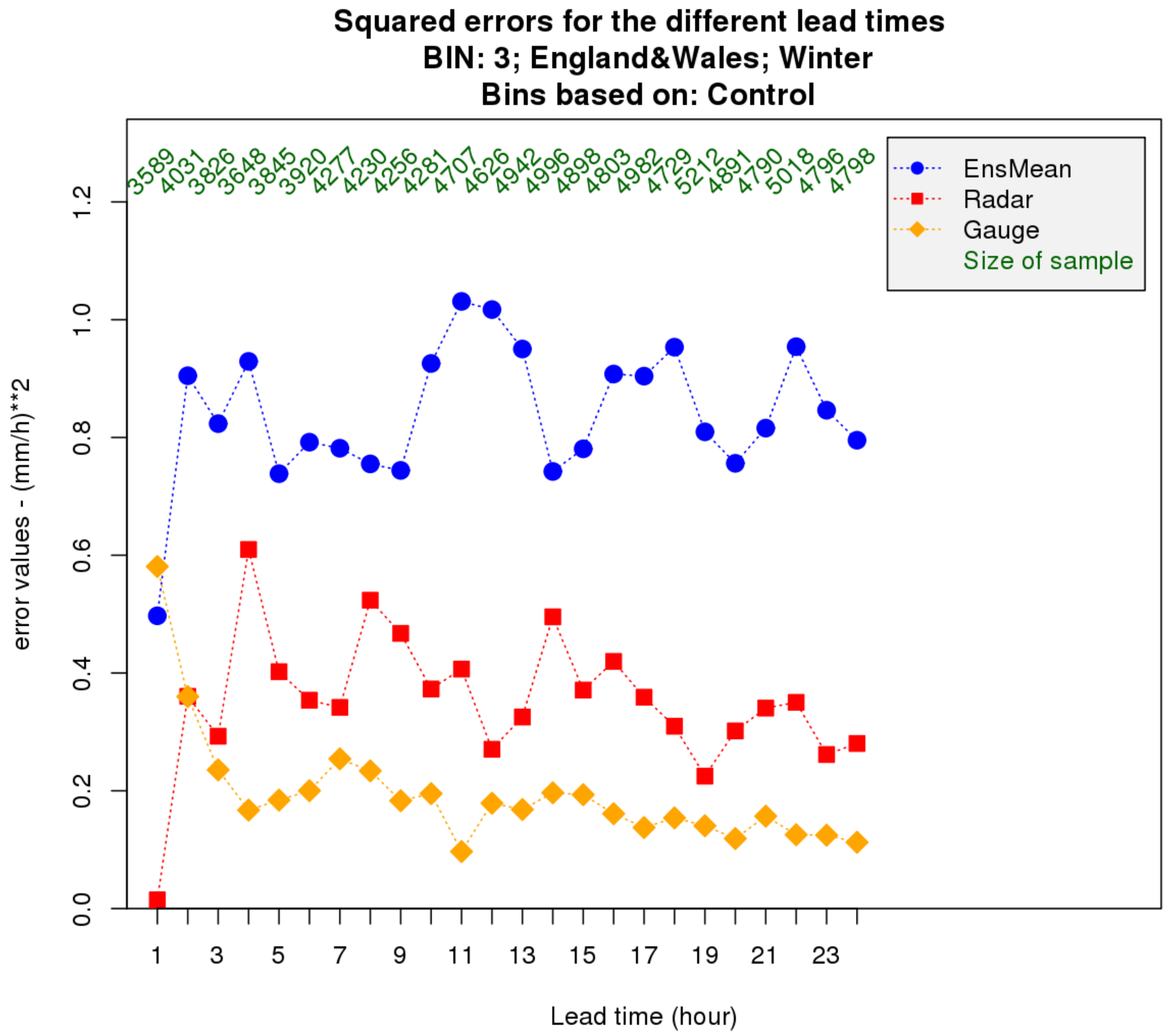
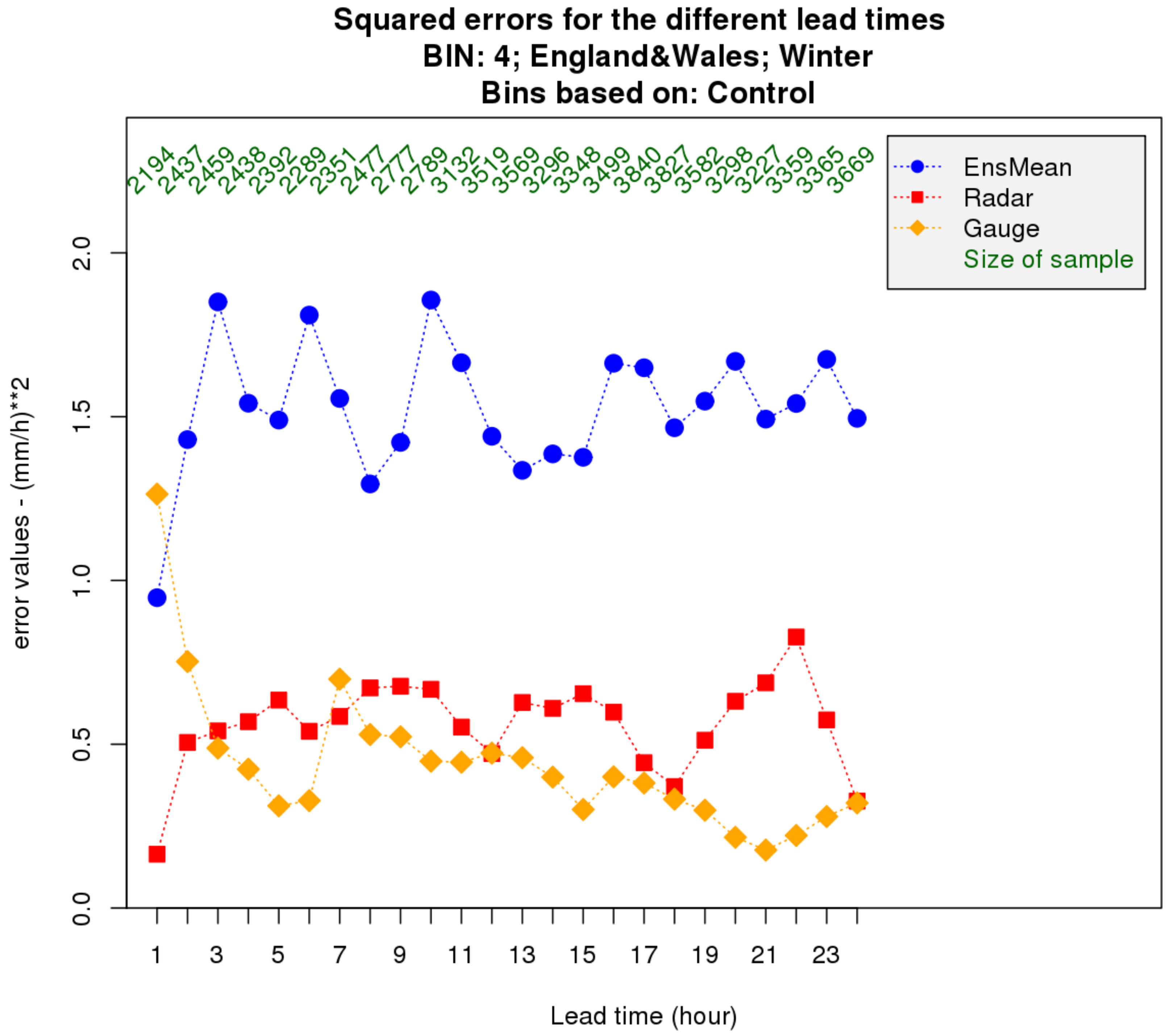
Observation error estimation

Squared error plots as a function of the lead time

- Observation errors are **not changing** with the lead time
- The forecast error is **increasing** with the lead time

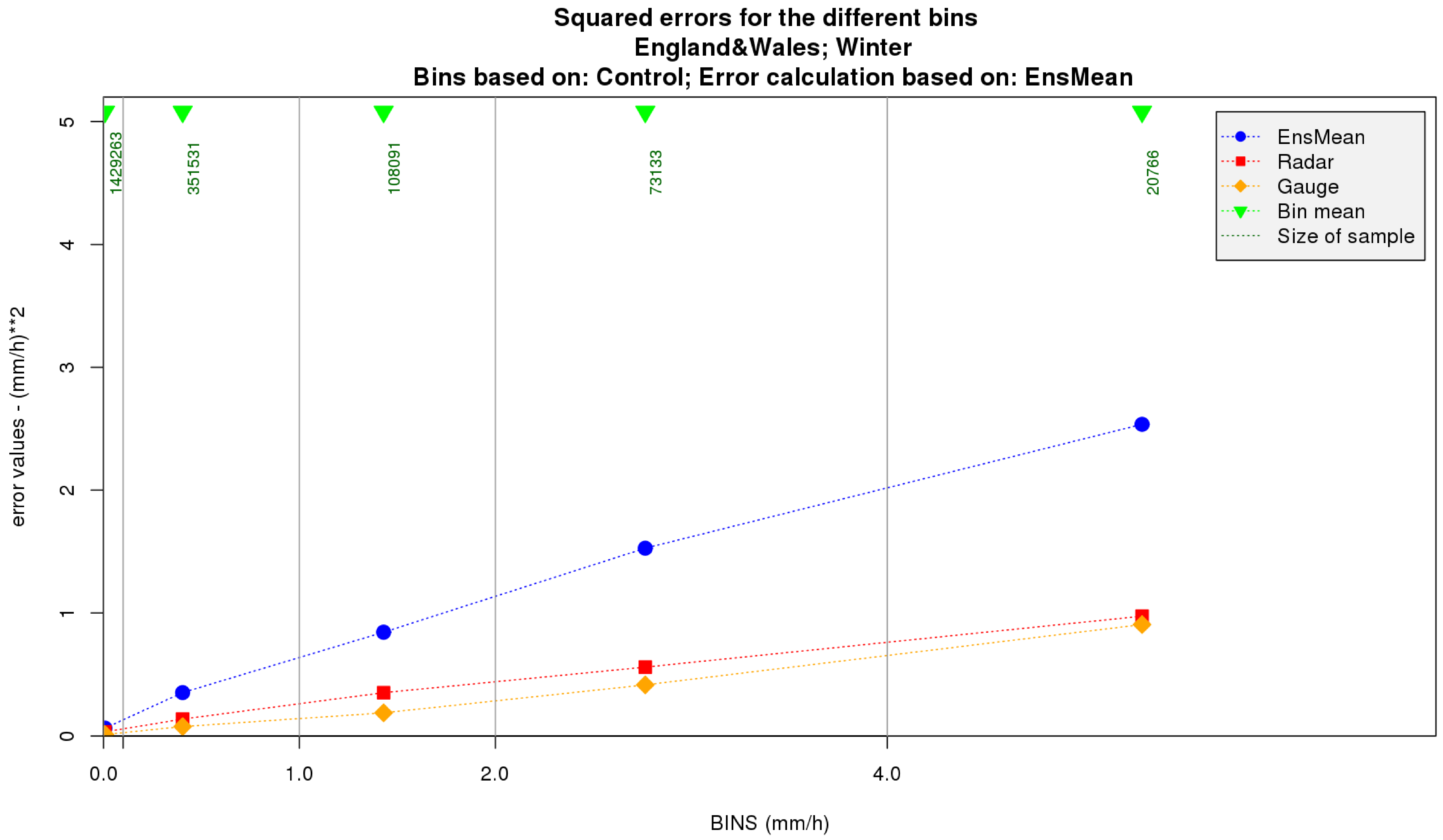






Observation error estimation

Squared error values as a function of the bin-mean values of the forecast



The functions are roughly log linear

=>

Can fit linear models to them

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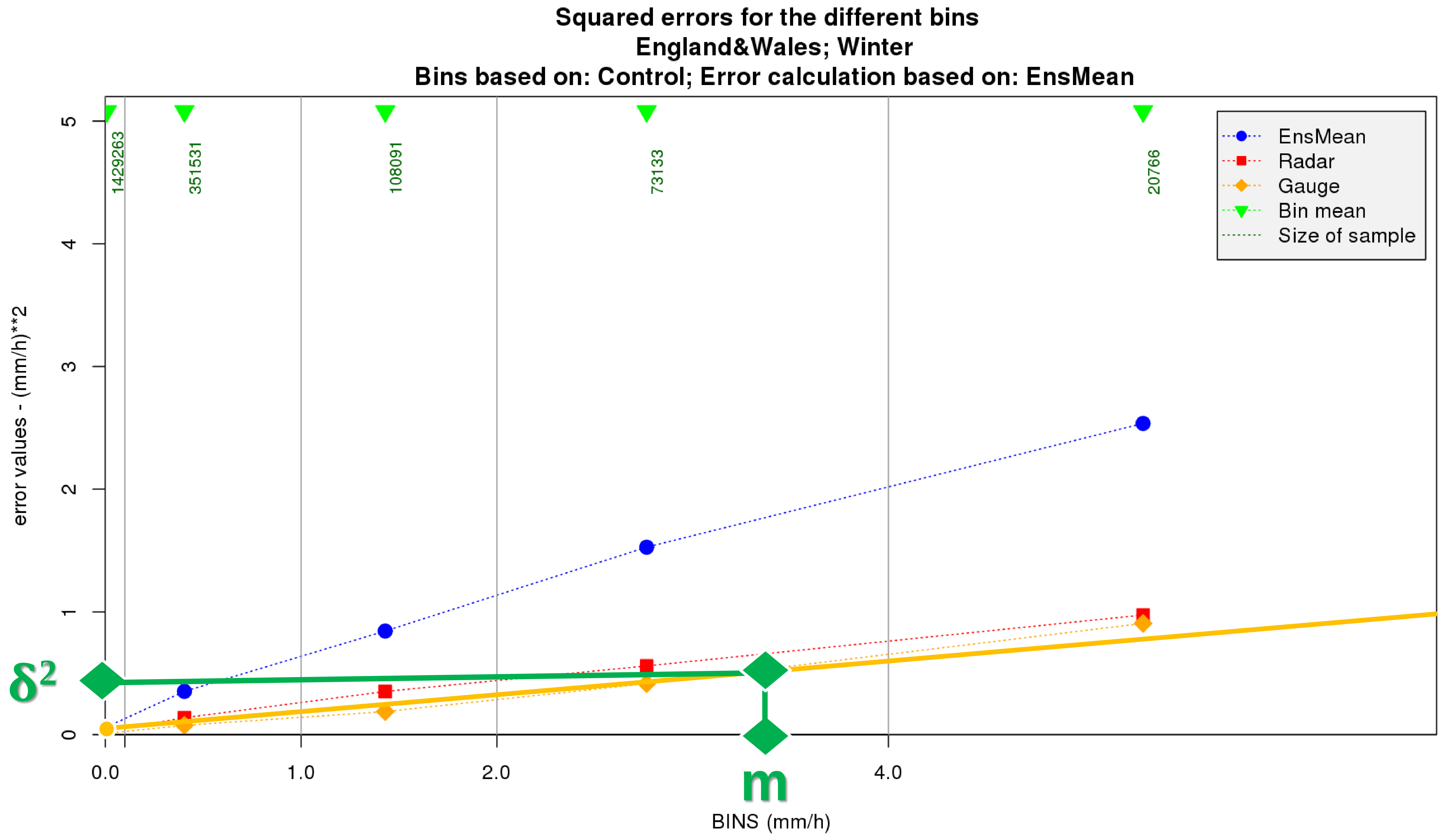
Using the estimated observation error in the verification

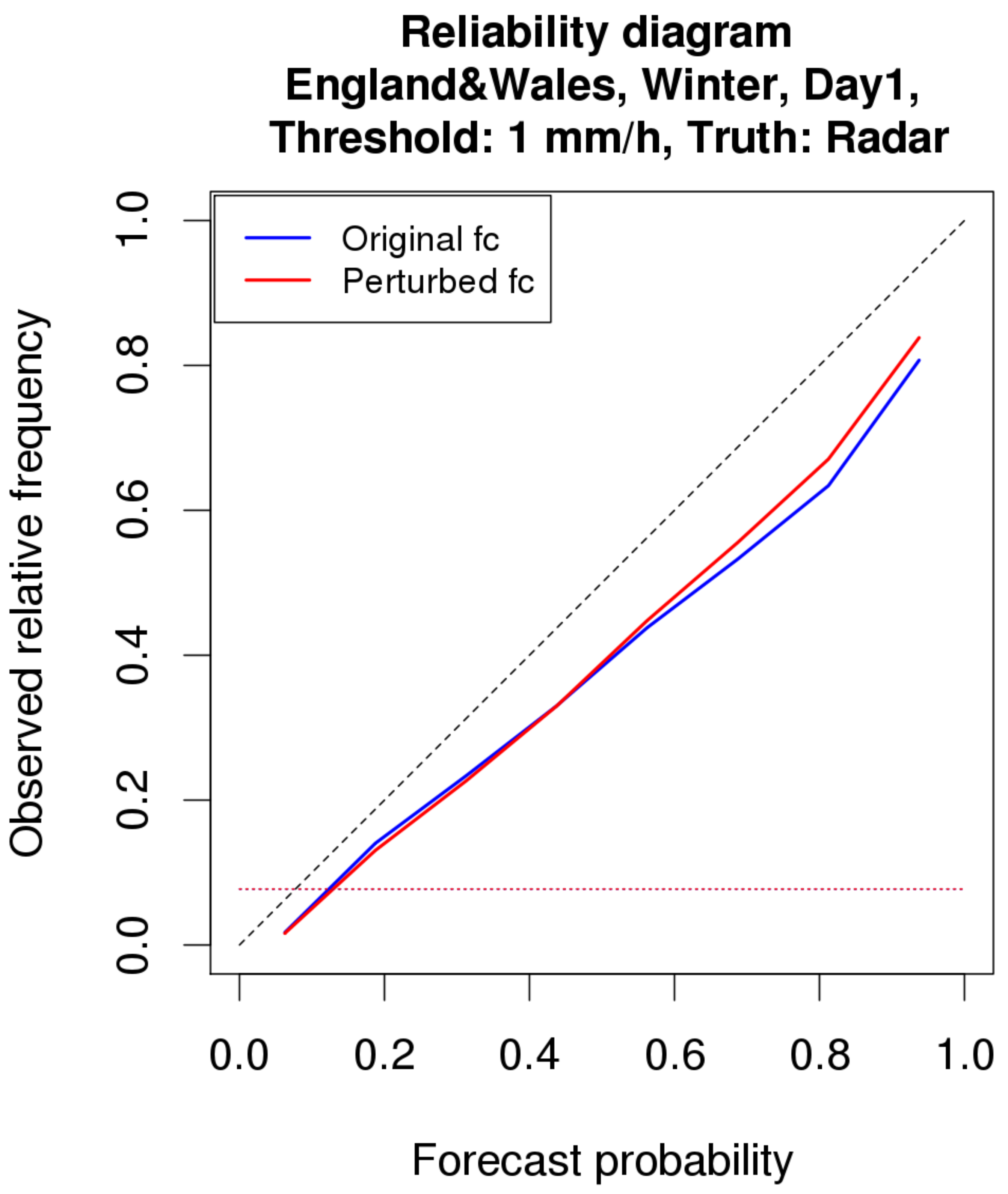


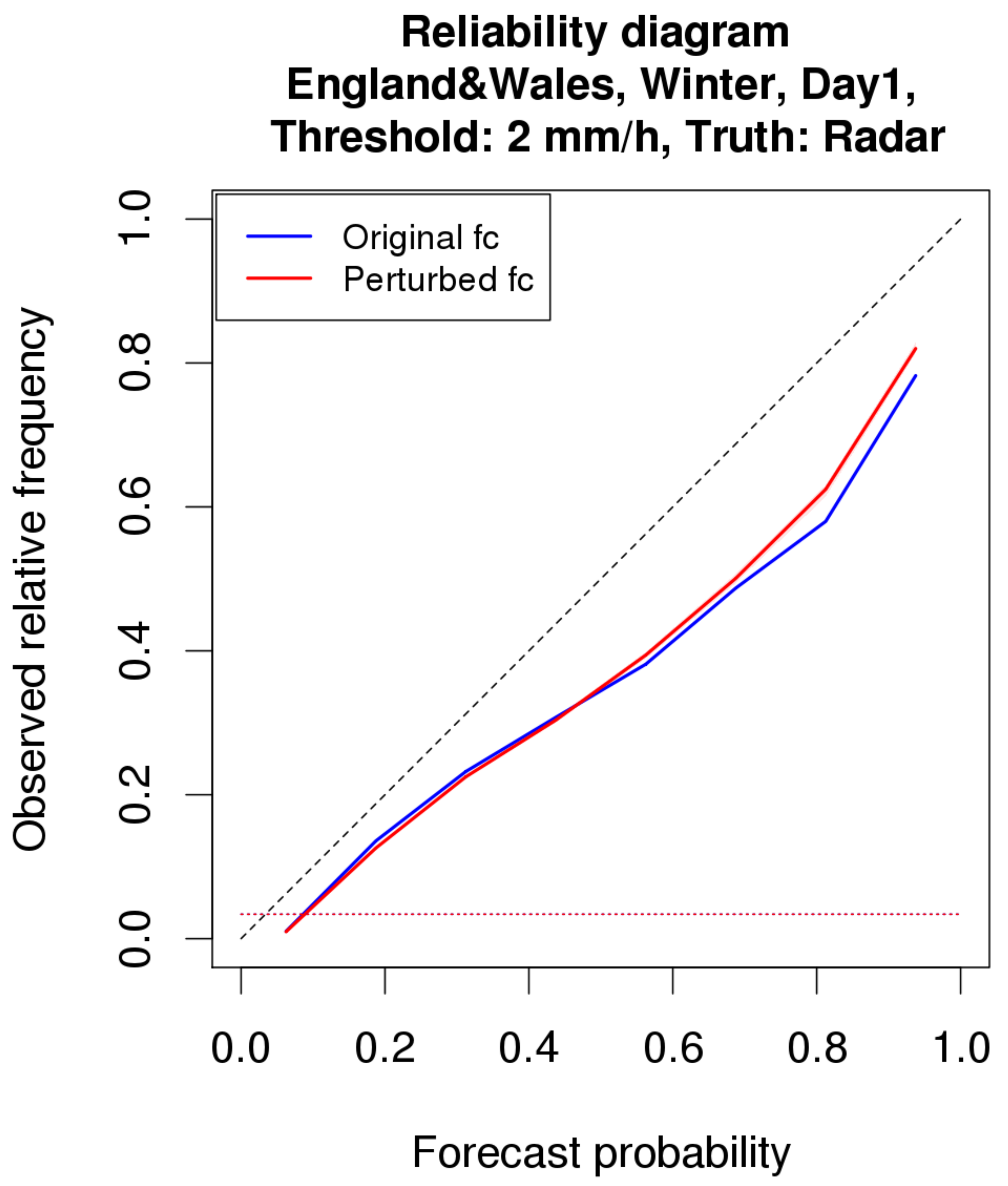
For each forecast case:

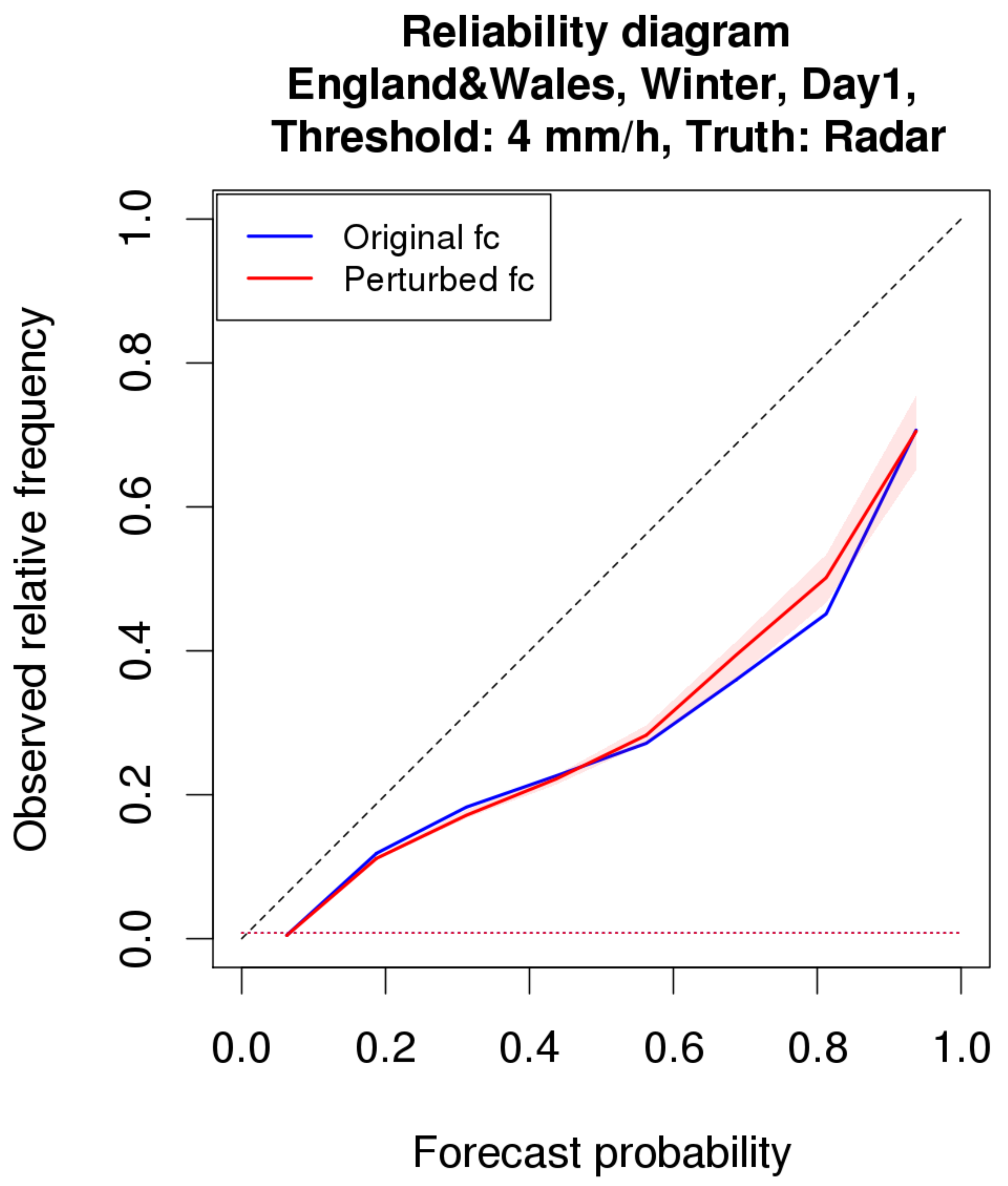
1. Based on the forecast magnitude (m) and the linear model => estimate the observation error (δ)
2. Random sample from $N(0, \delta^2)$
3. Add the random sample to given forecast case magnitude

Using the estimated observation error in the verification
Reliability diagrams

Radar
Thresholds: 1, 2, 4 mm/h



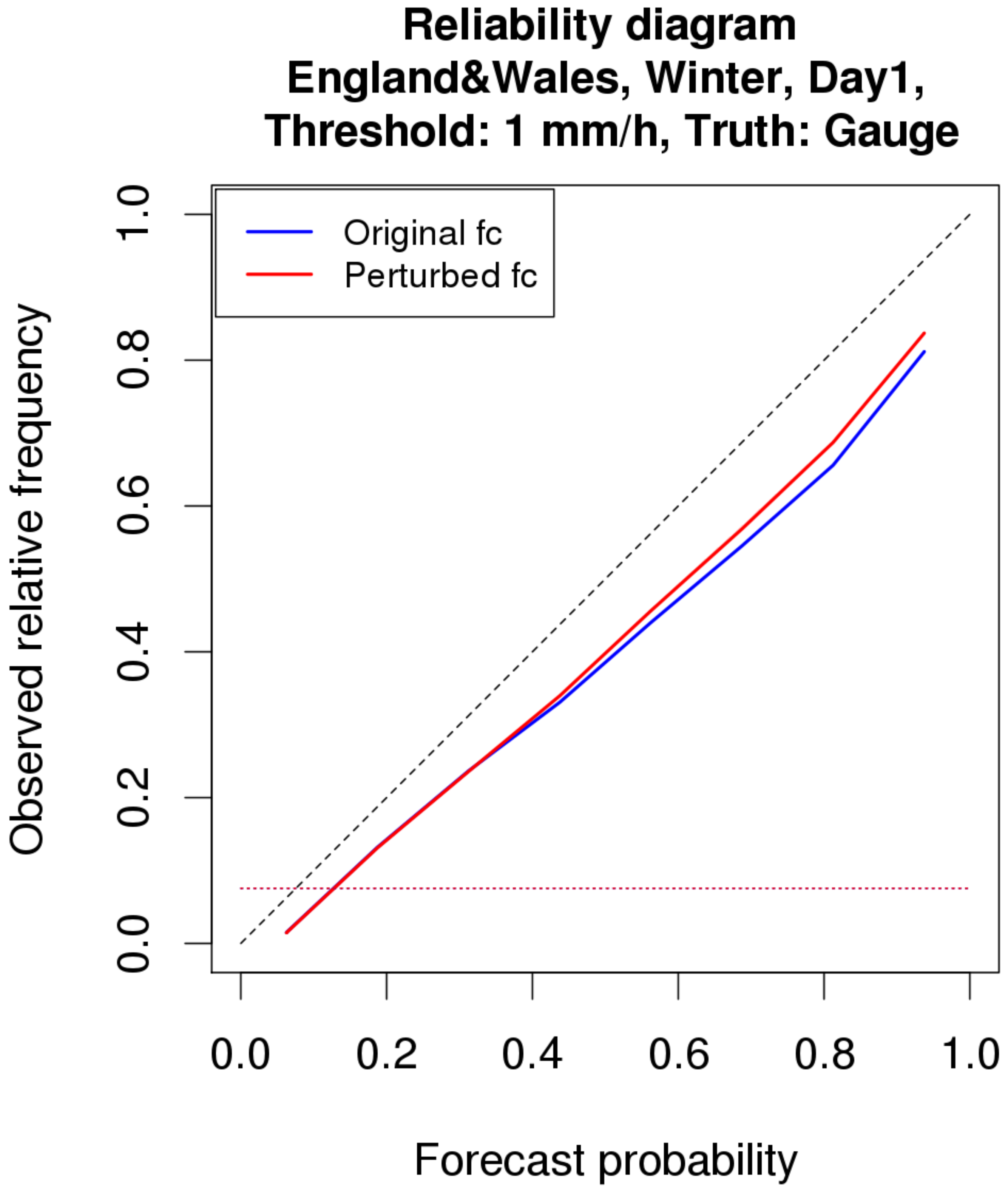


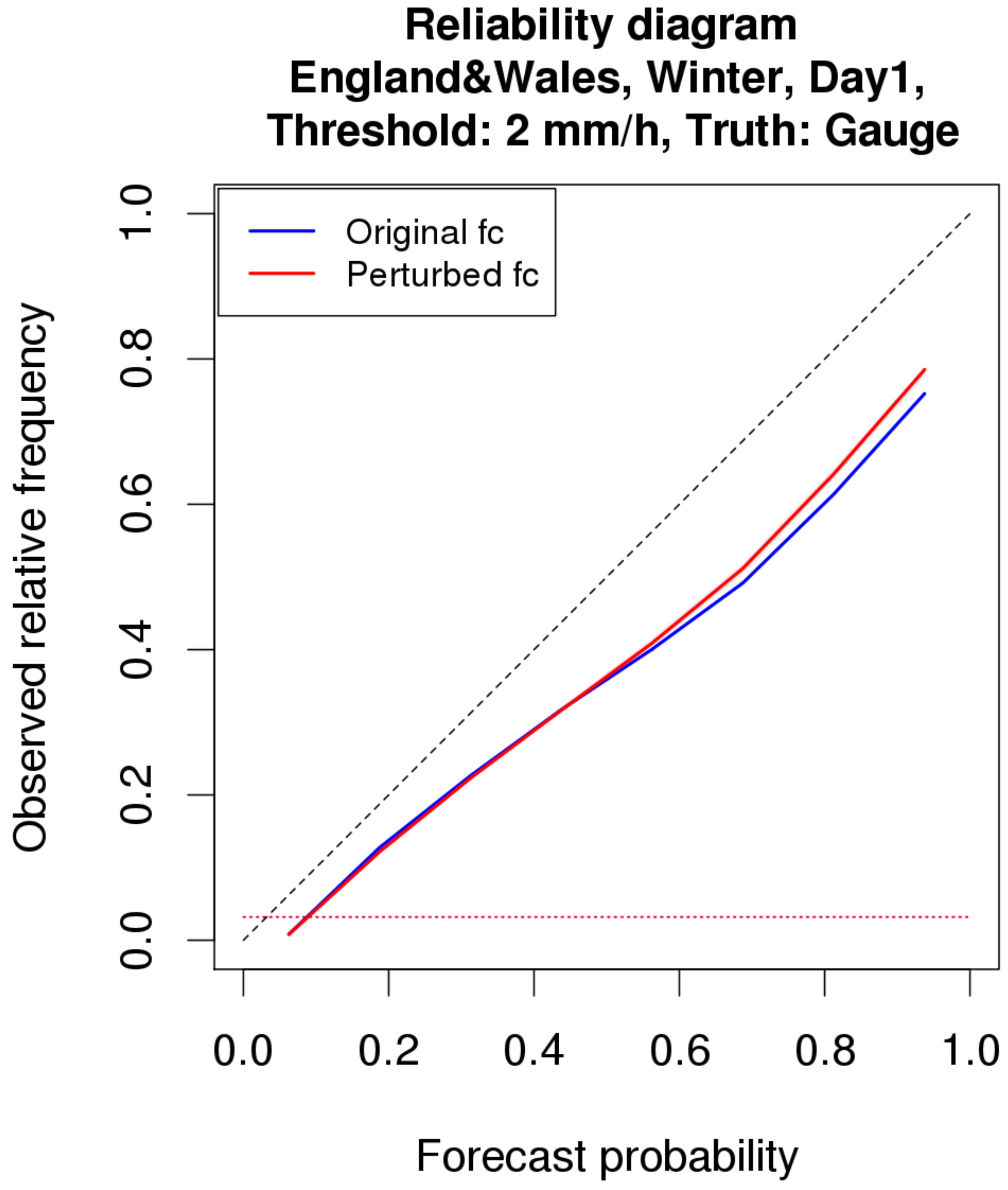


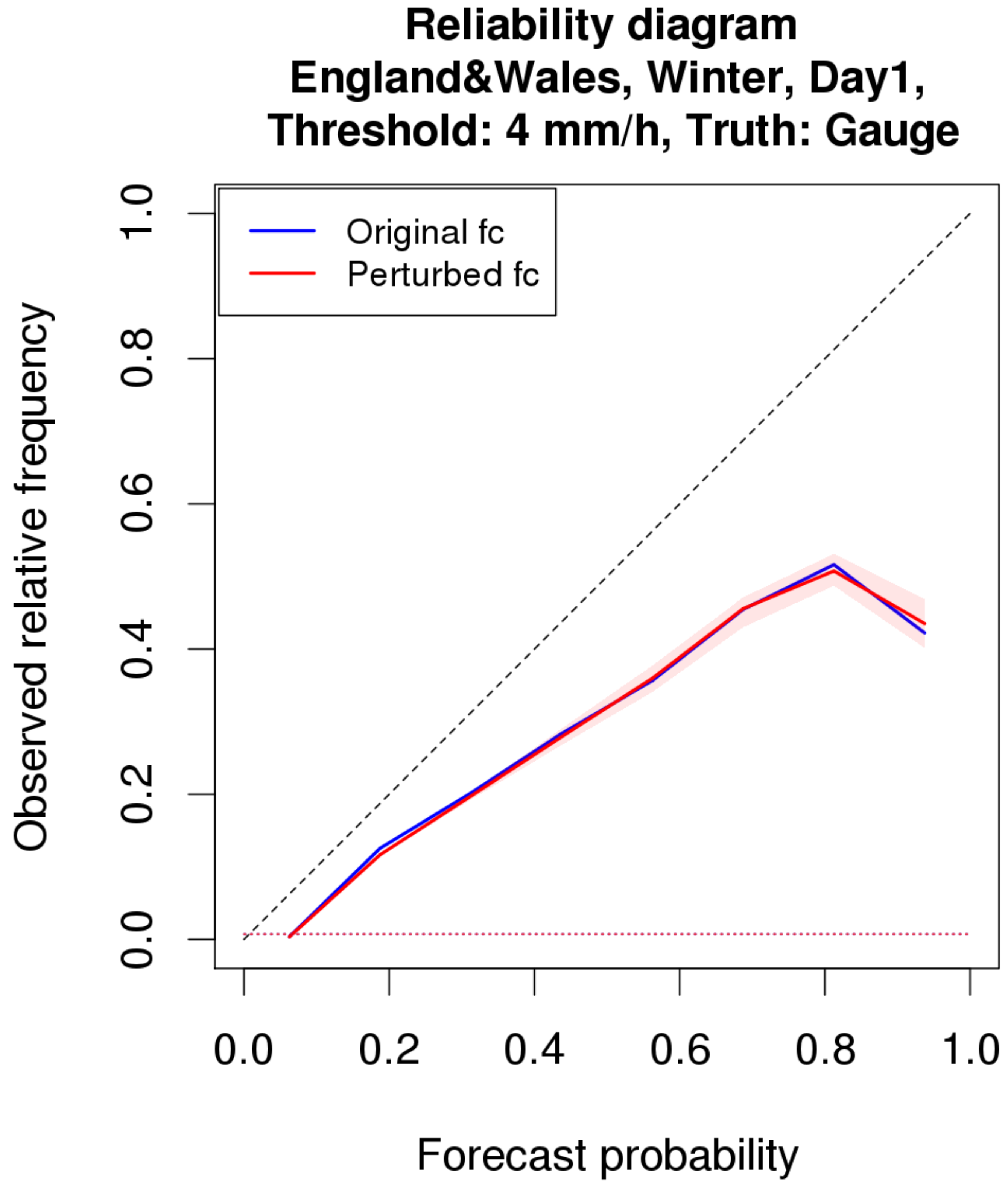
Using the estimated observation error in the verification

Reliability diagrams

Rain gauges
Thresholds: 1, 2, 4 mm/h







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Summary

- Need to count with observation- and representativity errors
- Two different kinds of observation style =>

  - errors have been estimated

  - perturbed the ensemble forecast with estimated error values
- The preliminary results are encouraging

Cumbria, Dec, 2015

Budapest, June, 2013

Thank you for your attention!

Questions?

A special thank you to **Jonathan Flowerdew (Met Office)** for helping in the mathematical aspects of the observation error handling.