Uncertainty in hydrological models

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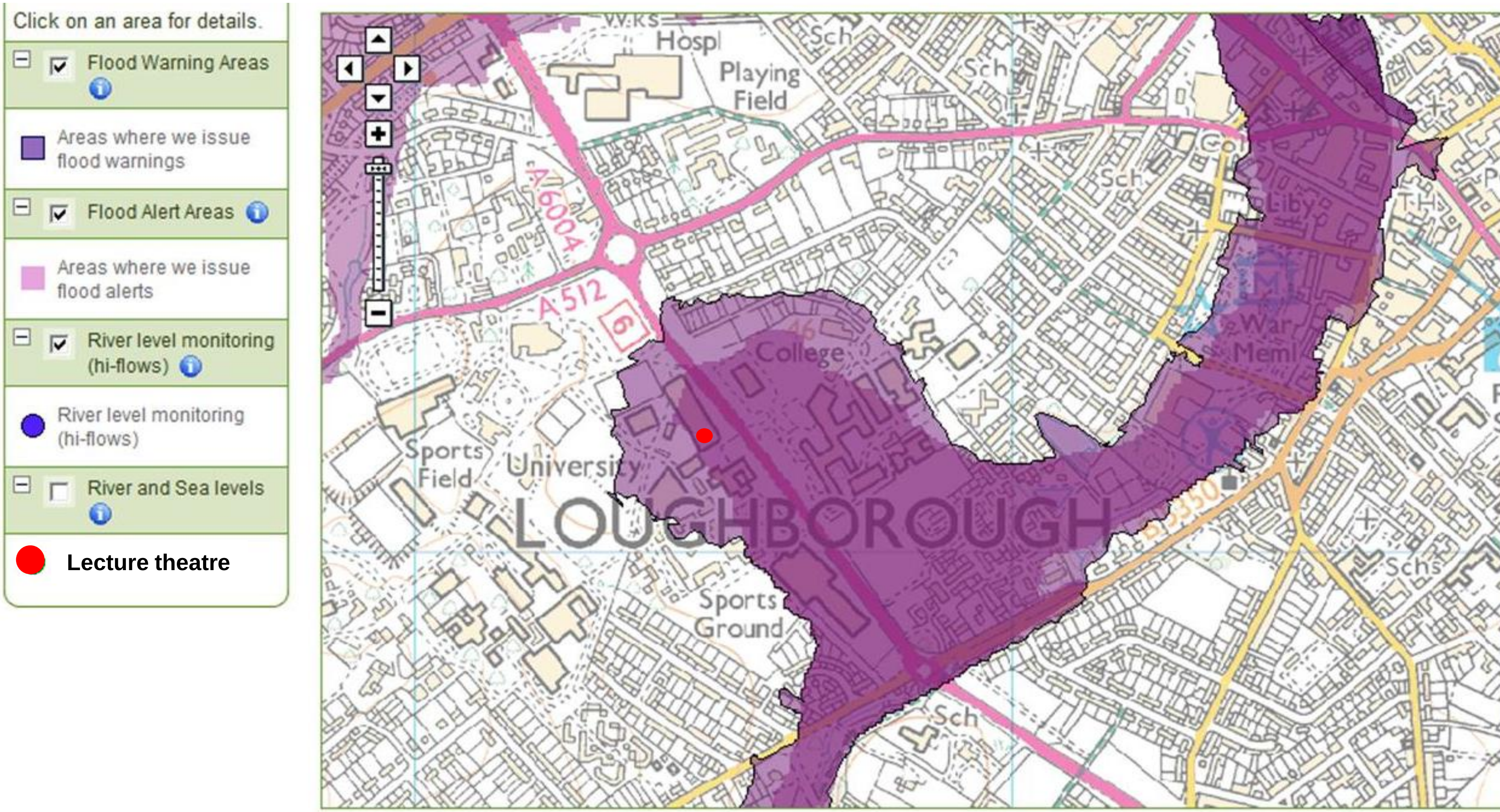
Loughborough University campus flash flood 28 June 2012

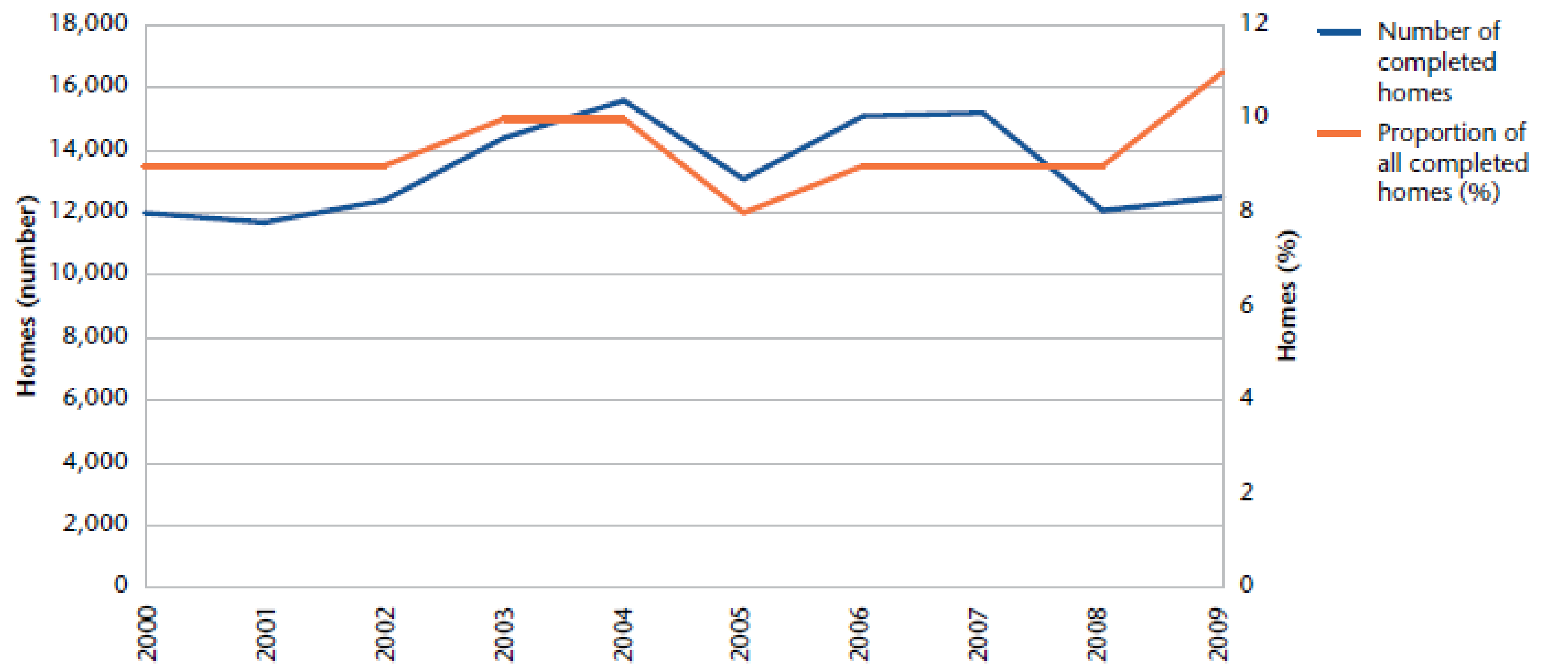
Certainty (flood risk)



Source: Environment Agency

Certainty (flood risk)

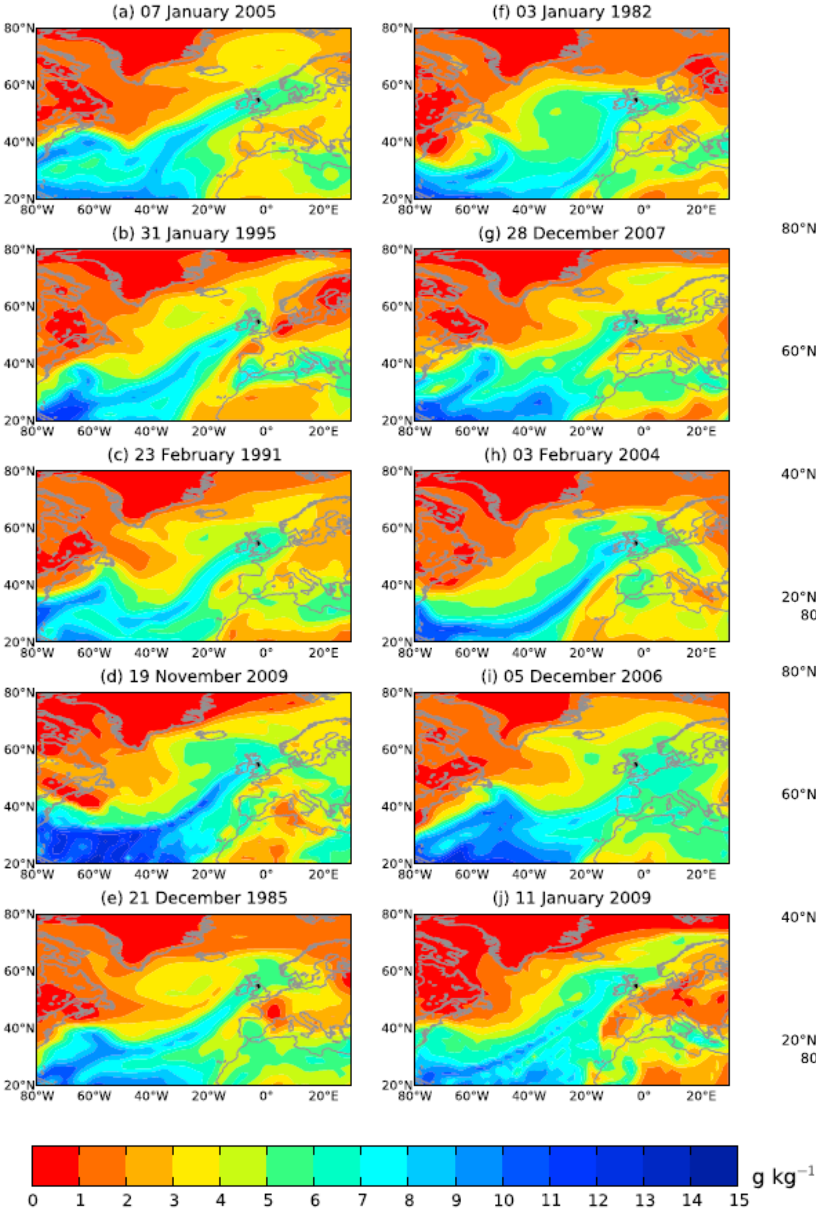
Figure 3.2: Number of new homes and % of all new homes built within areas of high flood risk in England (2000-2009)

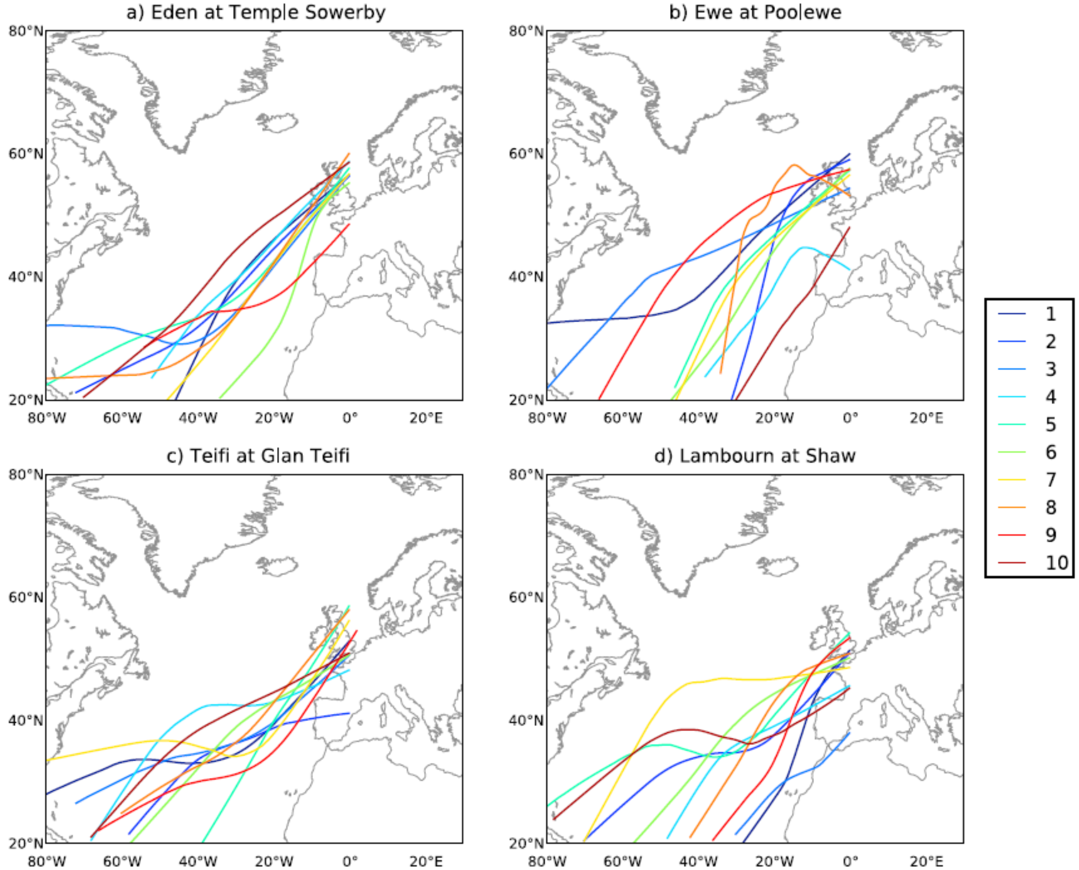


Source: Department for Communities and Local Government Land Use Change Statistics (2010b).
Note: High flood risk areas defined as Flood Risk Zone 3, which does not account for flood defences. Figures on percentage of new dwellings located in flood risk zone 3 from DCLG Land Use Change Statisitics. Figures on number of dwellings calculated by applying the annual proportion of new dwellings in high flood risk areas to the total number of completed dwellings obtained from DCLG Housing & Planning Statisitics (2010a).

Source: Adaptation Sub Committee (2011)

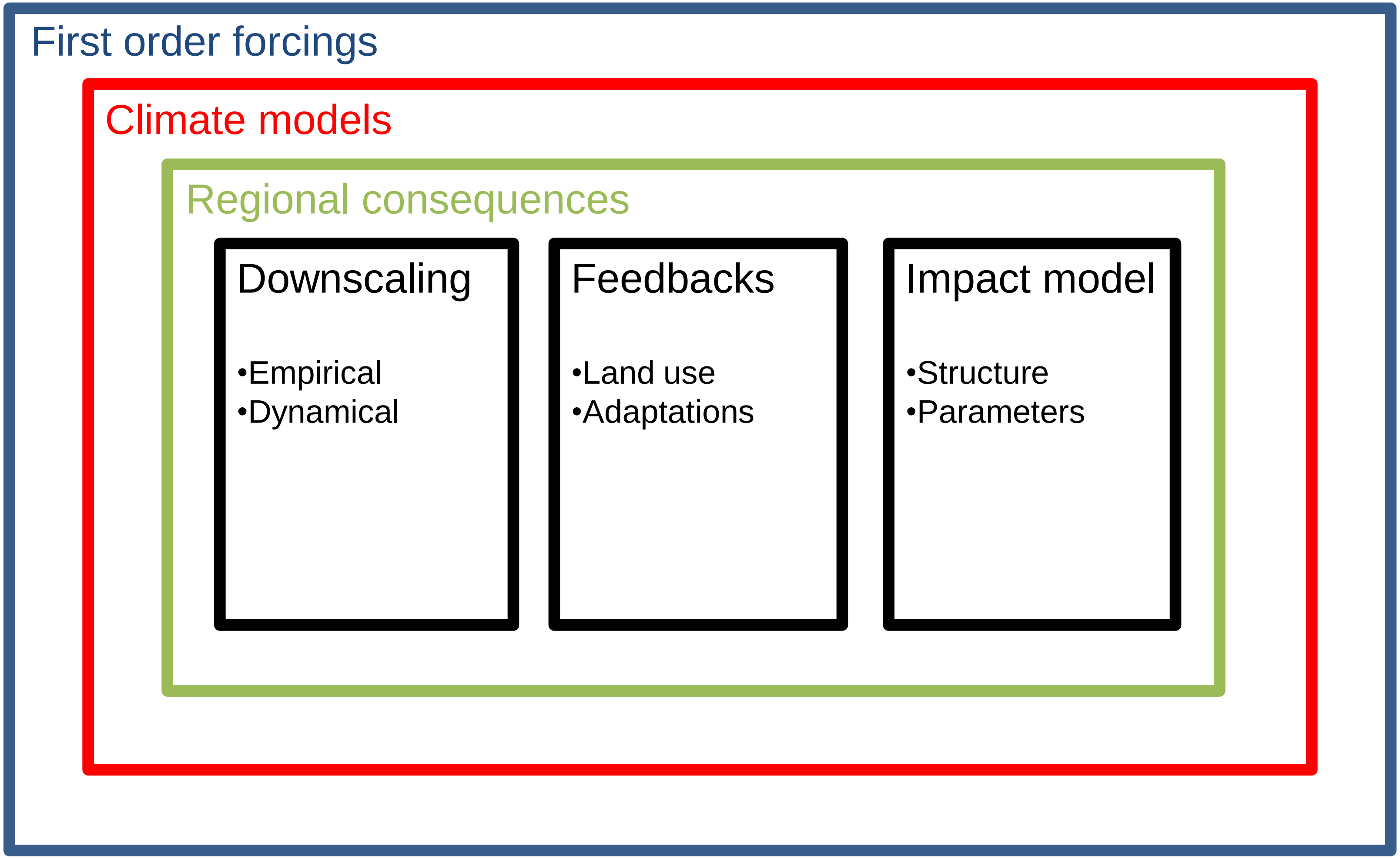
Certainty (atmospheric rivers)





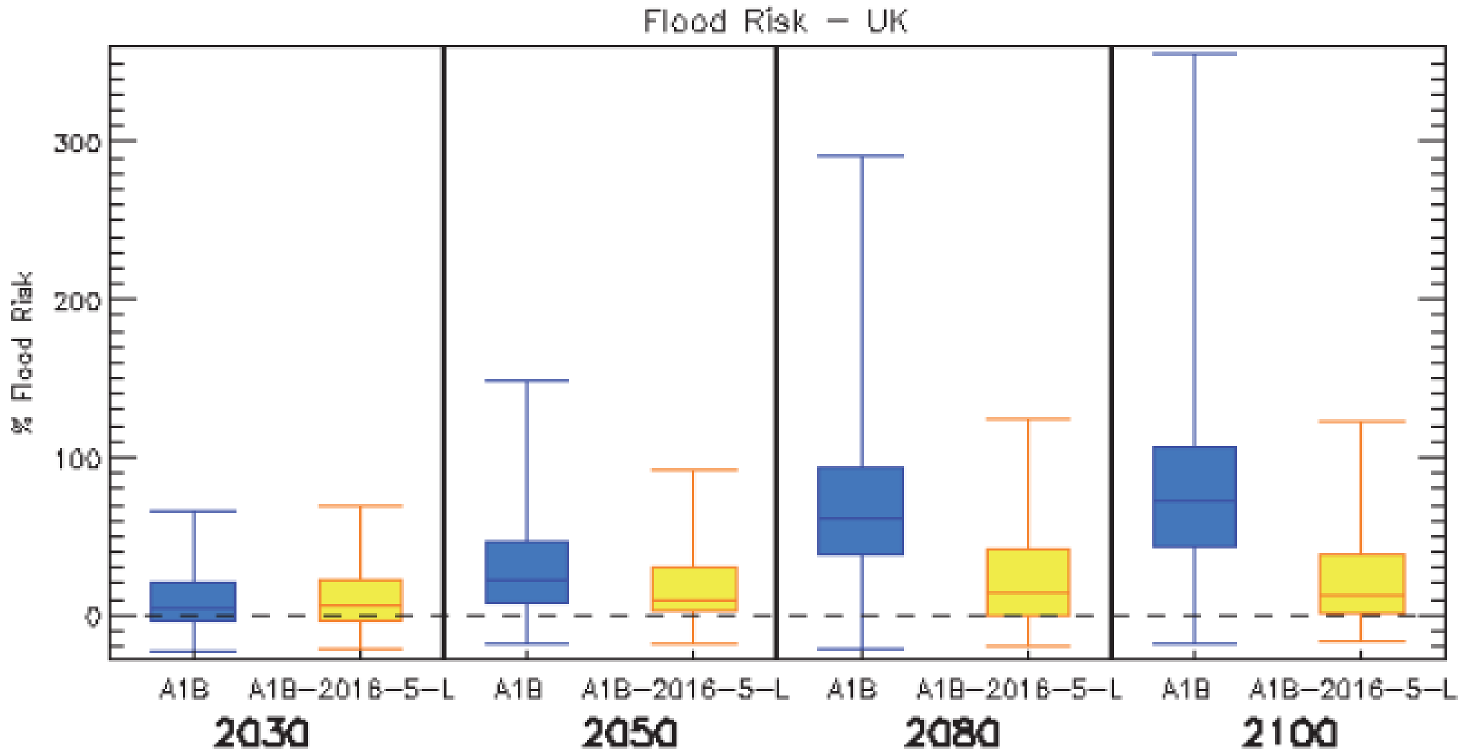
The 900 hPa specific humidity fields at 0600 UTC for the top 10 winter flood events on the River Eden at Temple Sowerby (left) and AR location for top 10 winter floods in selected catchments. Source: Lavers et al. (2011)

Uncertainty “hierarchy” (future risks)



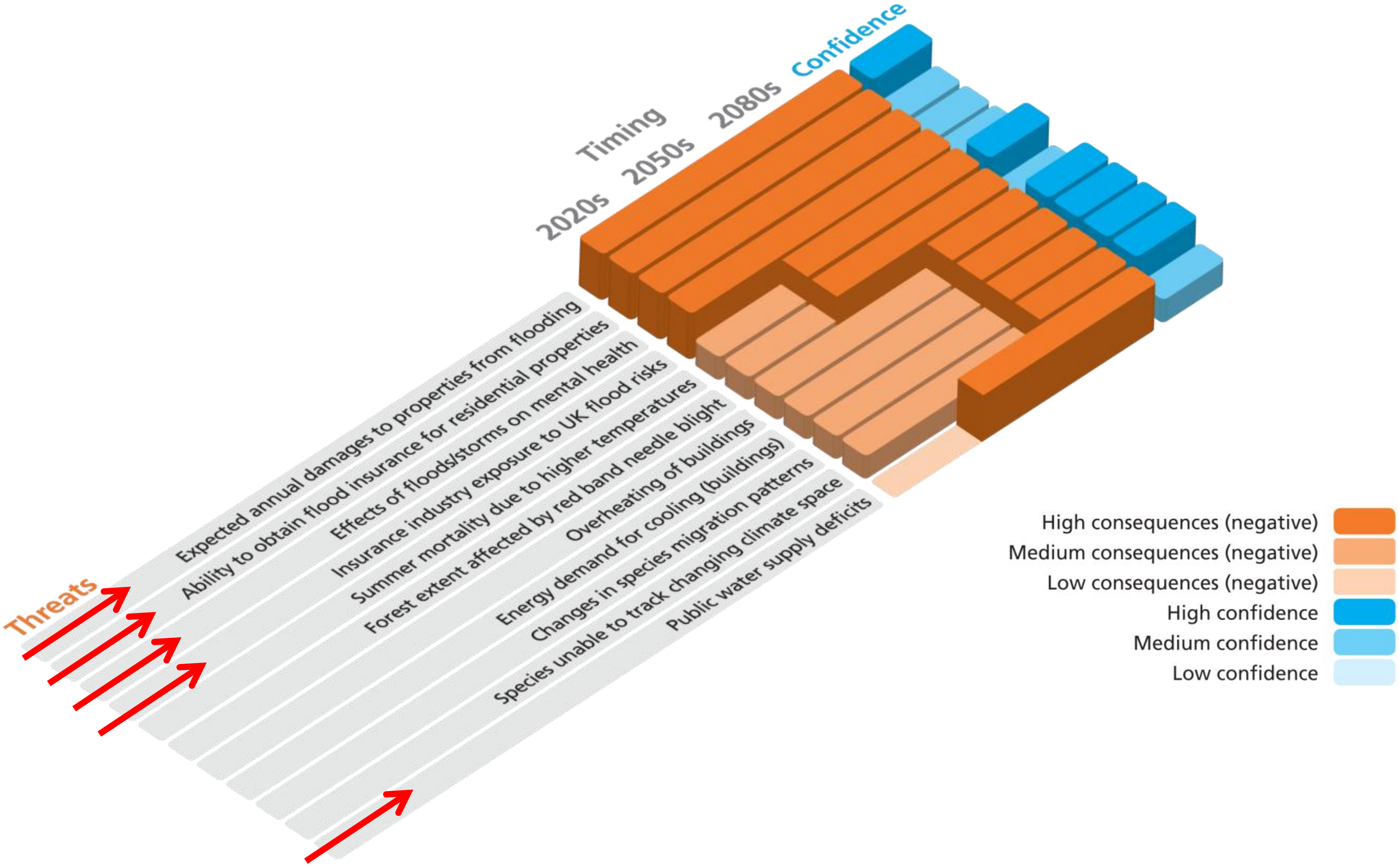
Typical finding of assessments:

"much greater tendency for increasing flood risk"



GCMs under two emissions scenarios (A1B and A1B-2016-5-L), at four time horizons. The plots show the 25th, 50th, and 75th percentiles (represented by the boxes), and the maximum and minimum values (shown by the extent of the whiskers).
Source: Warren et al. (2010) from AVOID programme

National CCRA headline threats



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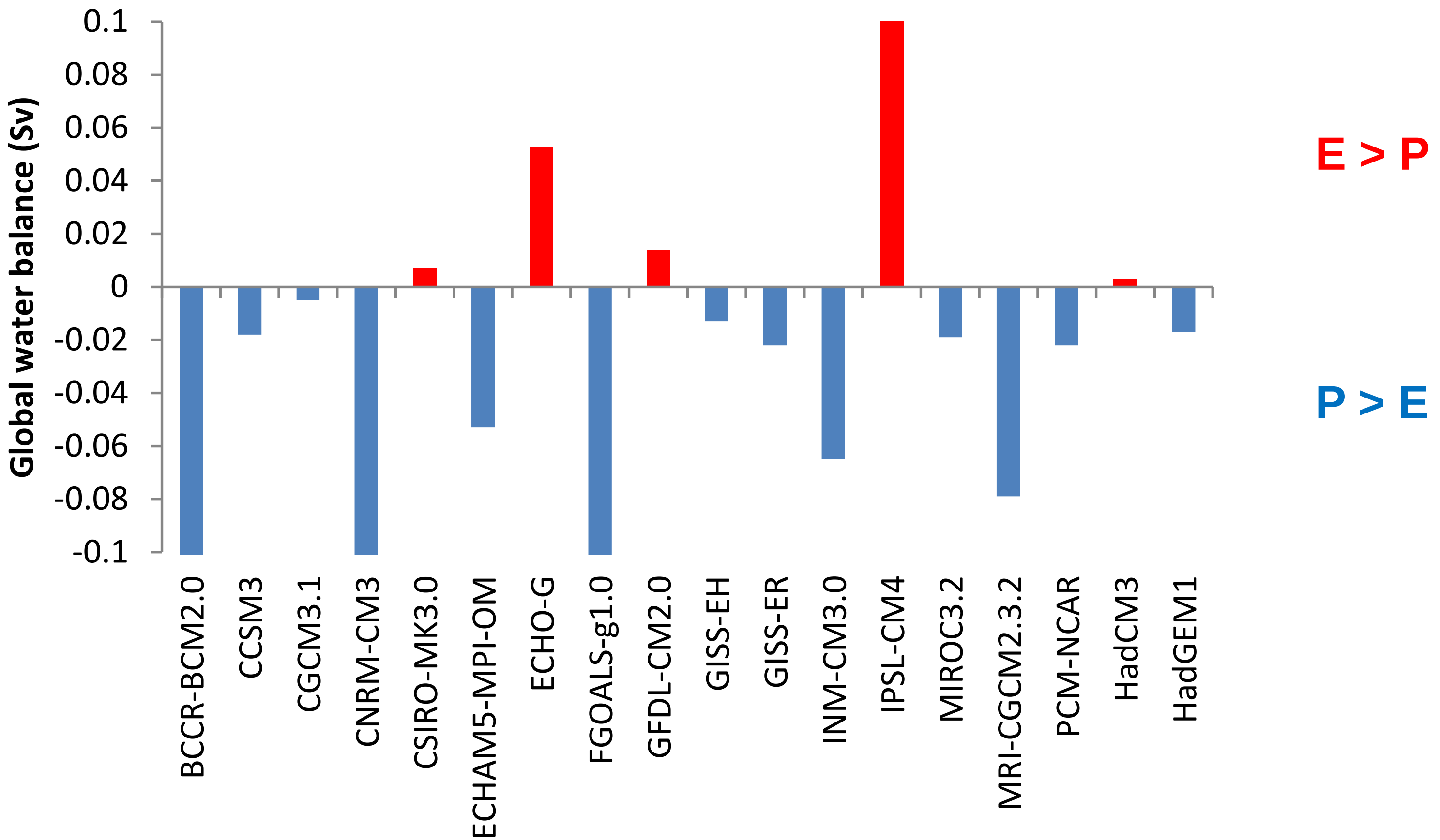
Hydrological model uncertainty in perspective

Input uncertainty (GCMs)



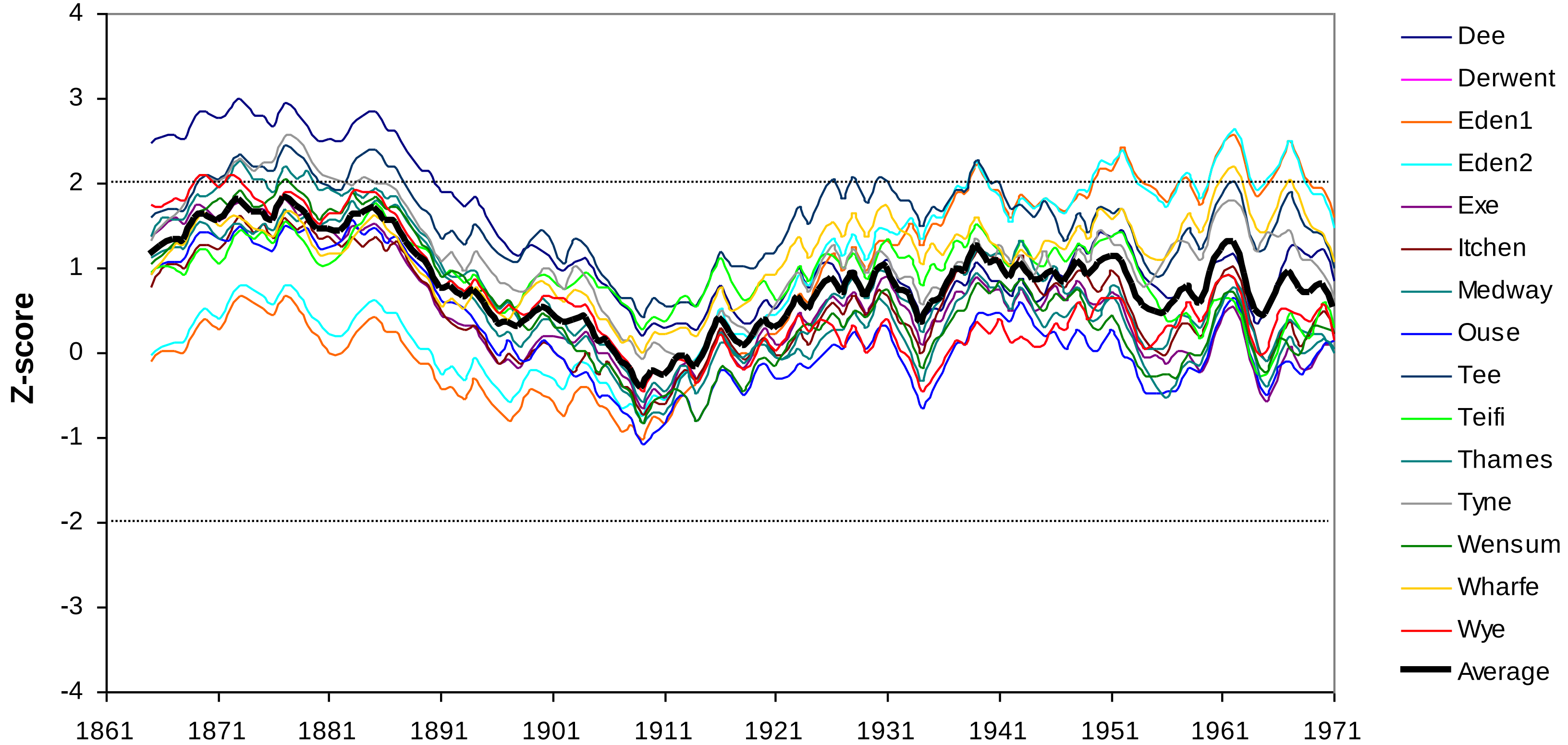
'Ghost' moisture sources: Global annual mean residual of the atmospheric water balance (E – P – dw/dt) for CMIP3 climate models. One Sverdrup (Sv) is 10^6 m^3s^{-1} or 31,600 km^3 yr^{-1}. Note that four climate models have residuals > 0.1 Sv. For comparison, observed atmospheric moisture transport from ocean to land is estimated to be 1.2 Sv. Data from Liepert and Previdi (2012).

Evaluating ‘fitness’ for hydrological tasks

Principles for climate model evaluation
1. *Quantify the uncertainty in the observed data used for model evaluation (homogeneity, confidence intervals, outliers)*
2. *Compare like with like (grid to grid, scale to scale)*
3. *Select indicators of performance relevant to the intended hydrological applications (extremes, low-frequency variability)*
4. *Evaluate climate models relative to other components of hydrological uncertainty (impact model, weighting)*
5. *Test combined climate, downscaling and hydrological model skill using near-term applications (seasonal forecasts)*

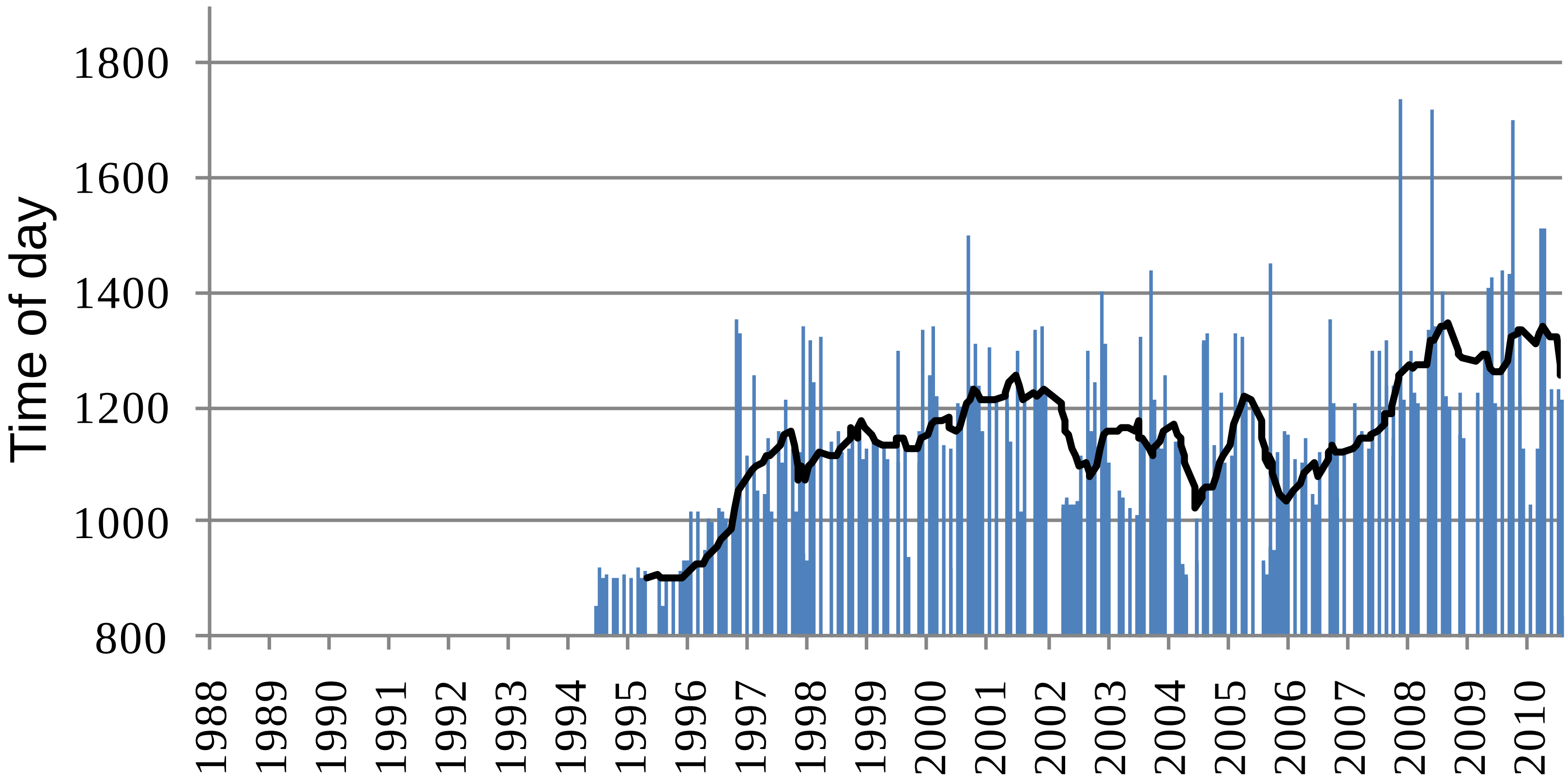
Indicators for evaluation of climate model outputs from the perspective of hydrological applications. Source: Wilby (2010)

Trends consistent with GCMs?



Mann-Kendall test for significant trends (Z_s) in area-average winter rainfall for 15 river basins in England and Wales. Source: Wilby (2006)

Confounding factors (observer practices)



Environment Agency water temperature measurement times at Glutton on the River Dove. The black line shows the moving average of 12 samples. A shift in sampling time of 2 hours between 1990s and 2000s equates to a warming of ~0.7°C. Source: Toone et al. (2011)

Confounding factors (river regulation)

Confounding factors (known unknowns)

$$Q = (A.P.k) + (G.\Delta T) - (A.E) \pm S \pm D$$

Q is the discharge (km^3),

A is the basin area (km^2),

P is the annual precipitation (km),

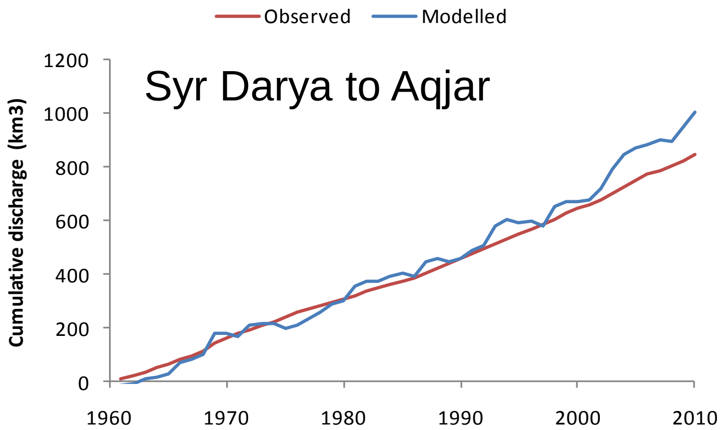
k is a scaling factor,

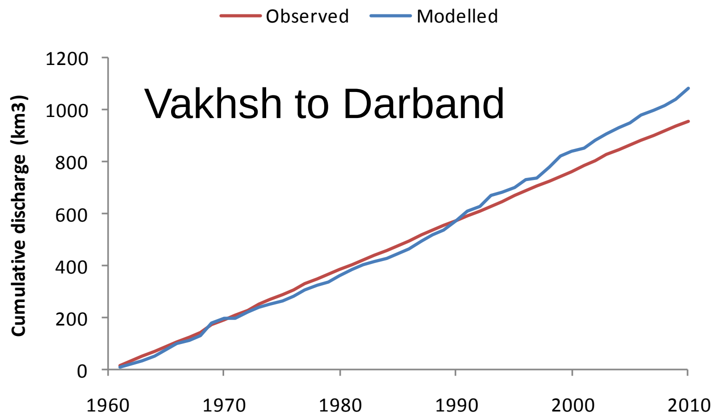
G is the total snow and glacier melt per year ΔT degree temperature change (km^3/yr/°C),

E is the annual evaporation total (km),

S is upstream storage change (km^3),

D is diversions for irrigation or effluent (km^3).





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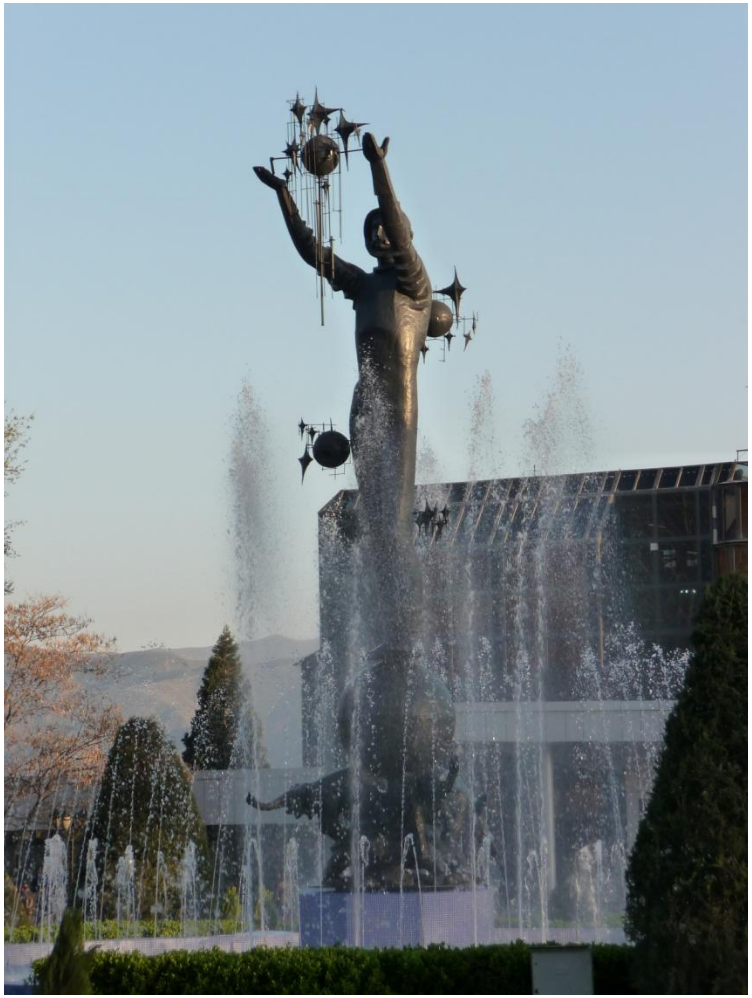
Confounding factors (known unknowns)

Hydrological models



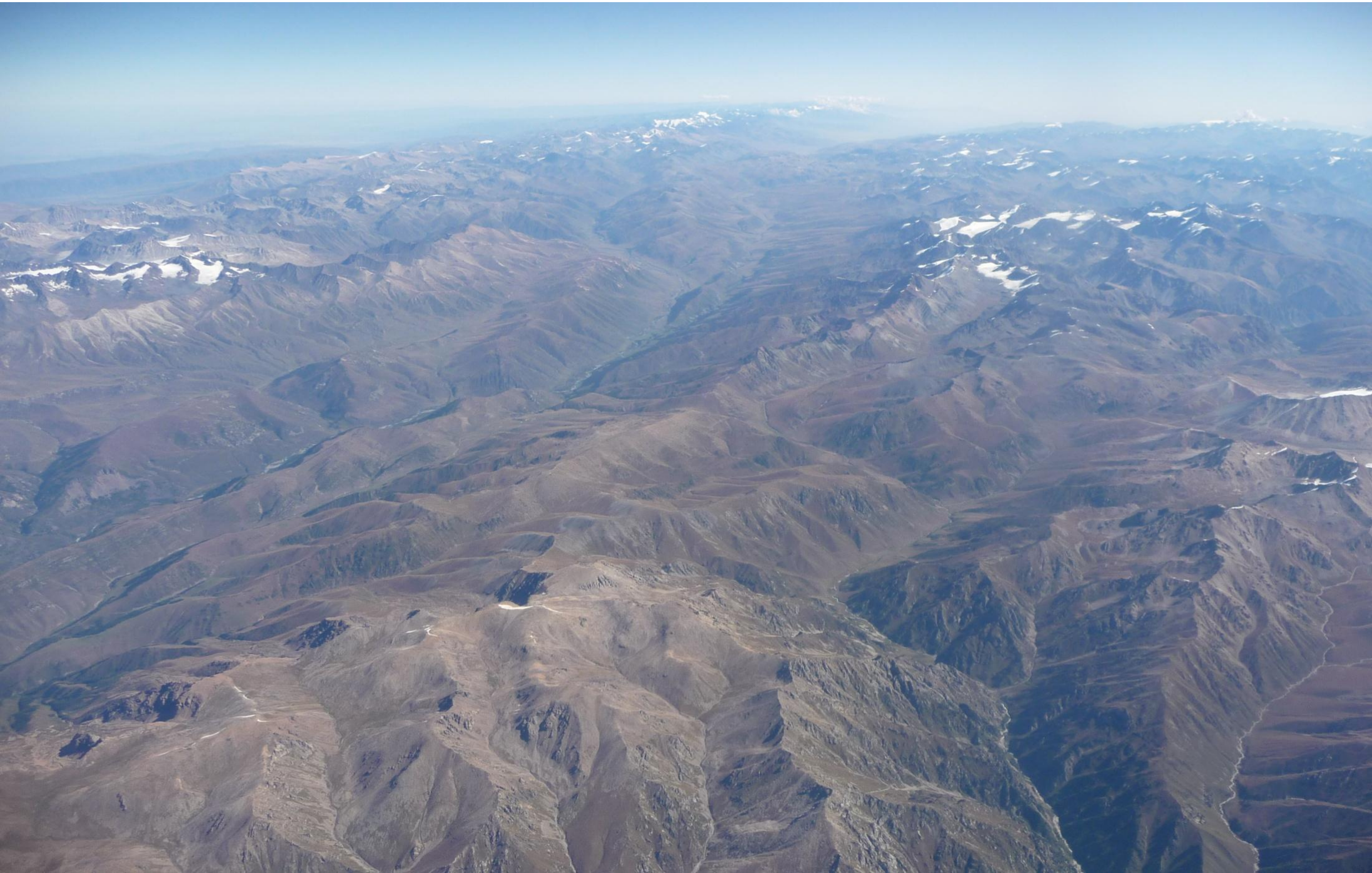
Input uncertainty

Structure uncertainty

1. Empirical/statistical
2. Water balance
3. Conceptual
4. Physically based

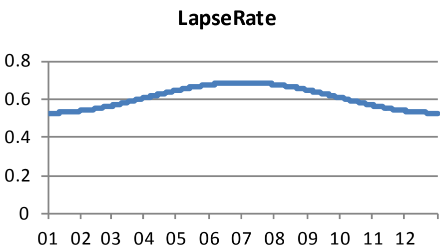
Parameter uncertainty

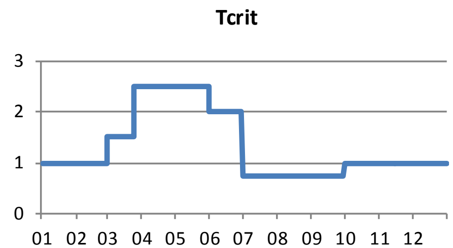
Input uncertainty

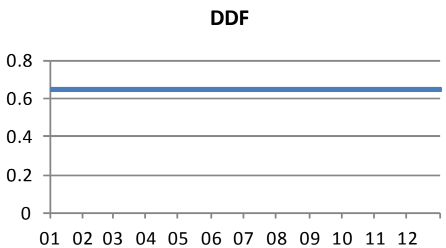


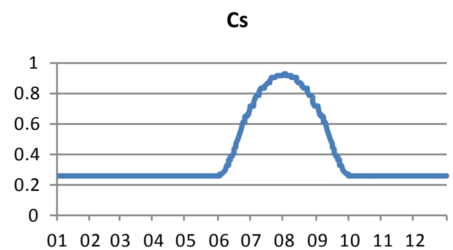
Snowmelt Runoff Model (SRM)

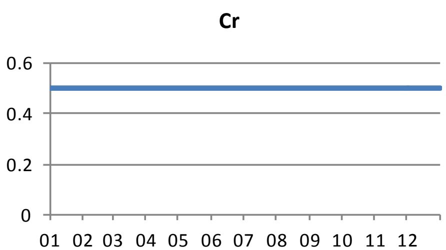
$$Q_{n+1} = [C_{Sn} \cdot \alpha_n (T_n + \Delta T_n) S_n + C_R \cdot P_n] A \cdot v (1 - k_{n-1}) + [Q_n \cdot r_{n+1}]$$

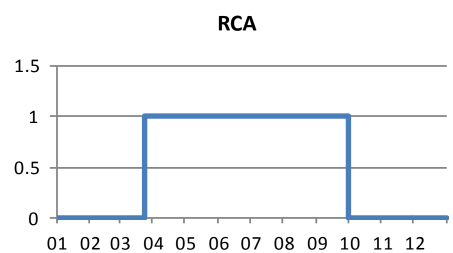


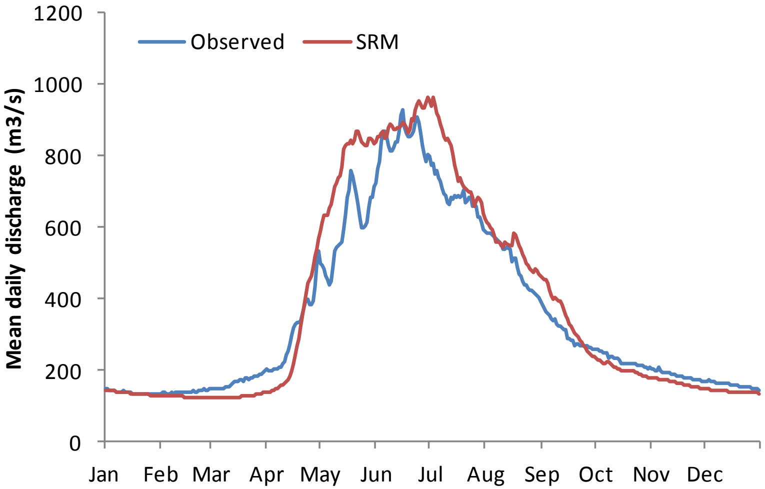












Daily mean composite of observed and SRM discharges at Darband 2001-2010

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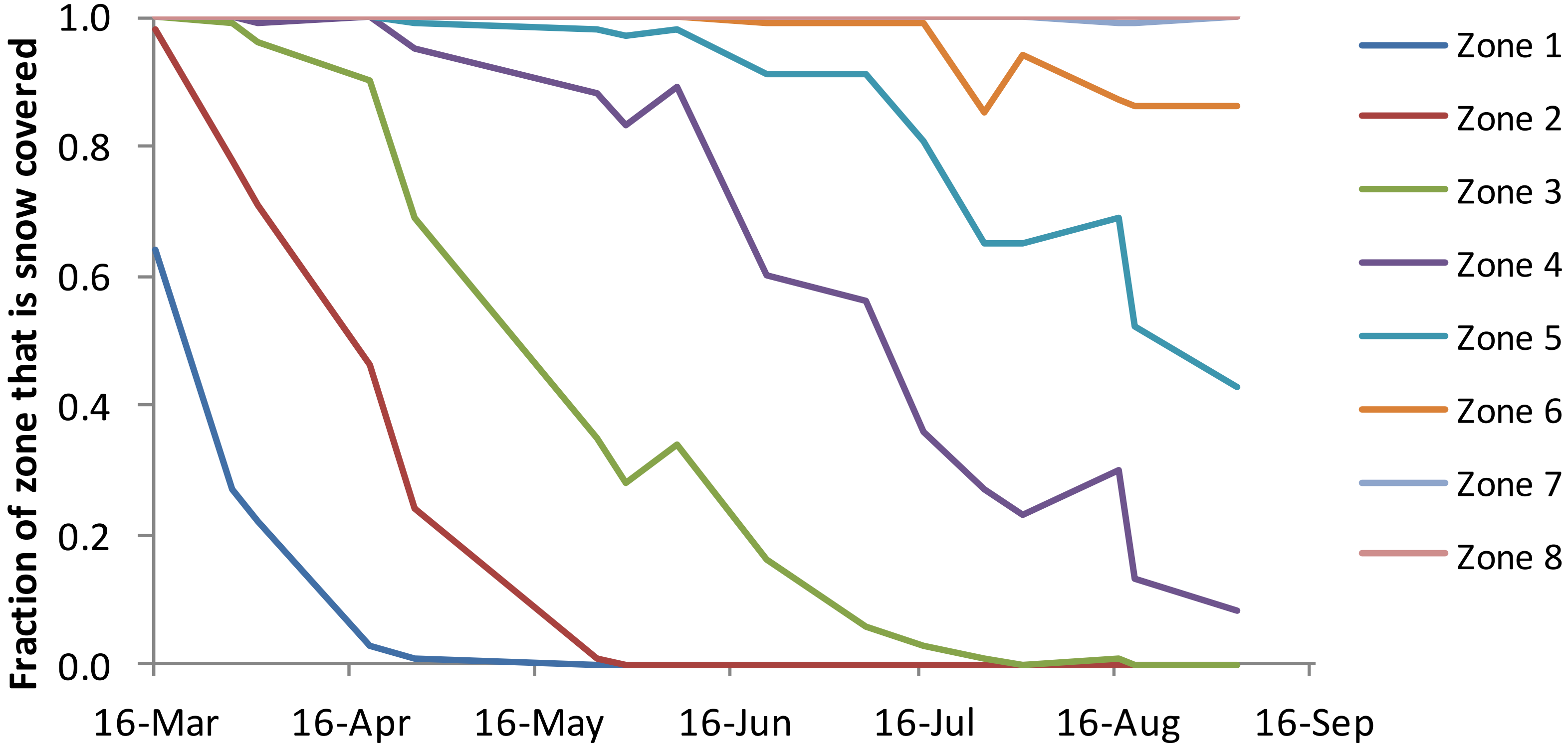
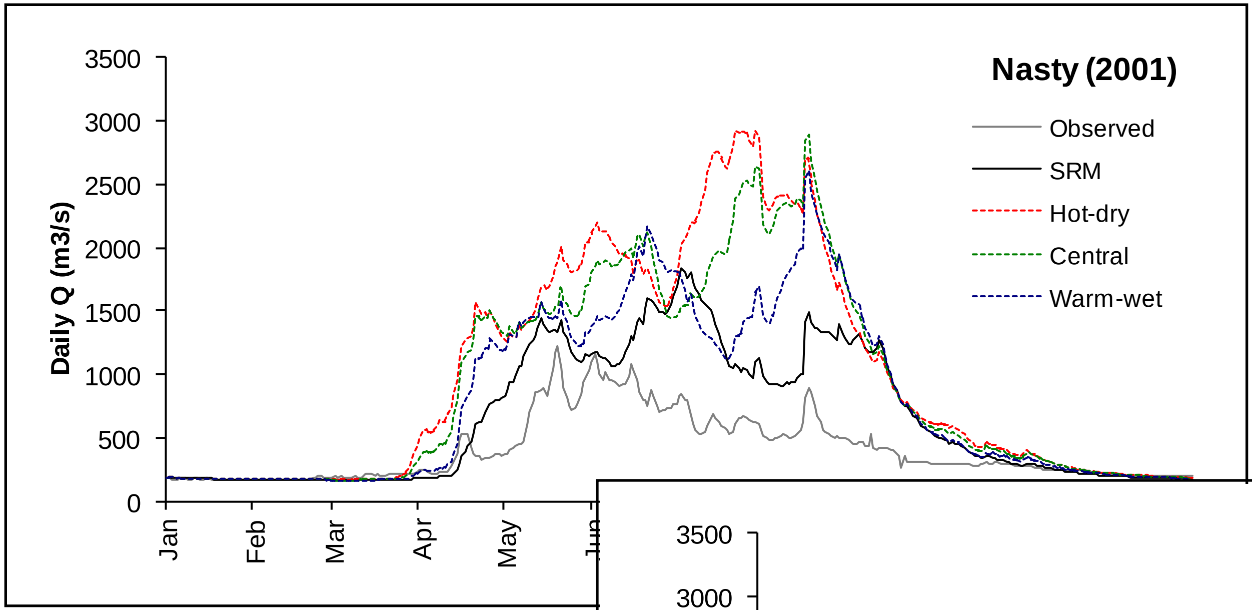
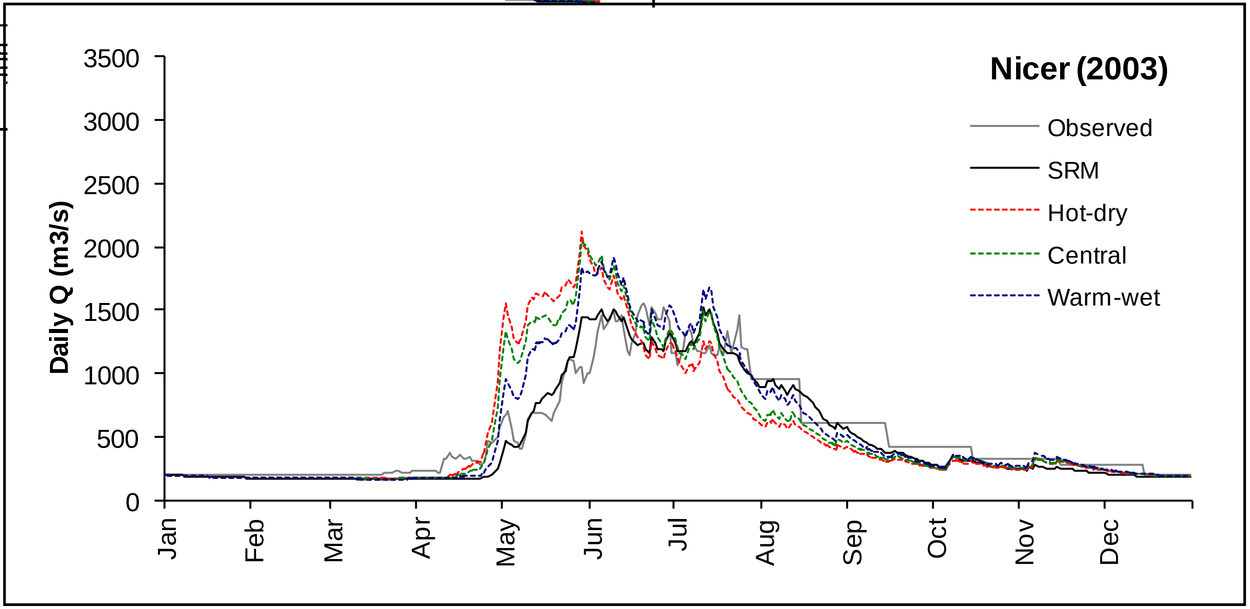
Input uncertainty (snow cover)



Snow-cover duration curves (CDCs) for the upper Vakhsh basin in 2010

Input uncertainty (outcome)



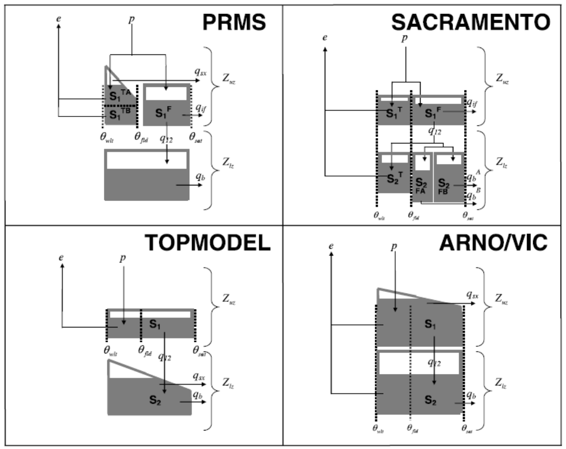


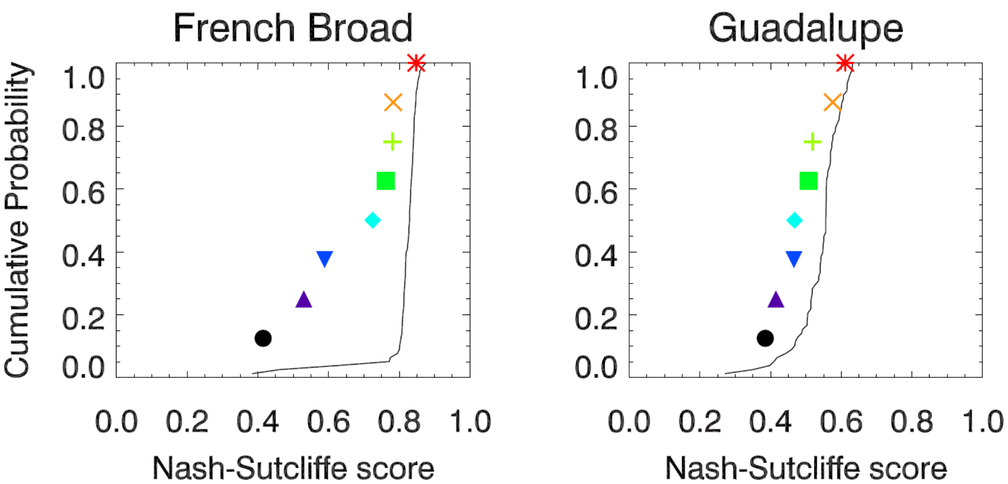
Observed and SRM estimates of daily discharge in the Naryn under present and changed climate for the 2050s (hot-dry, central, and warm-wet).

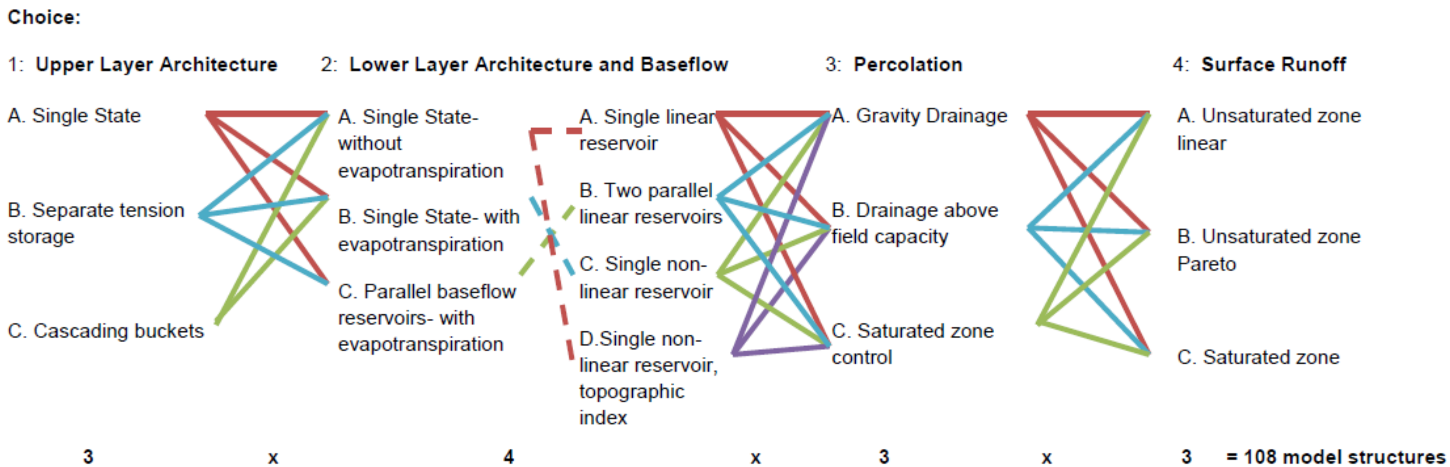
Source: EBRD (2011)

Framework for Understanding Structural Errors (FUSE)

Source: Clark et al. (2008)

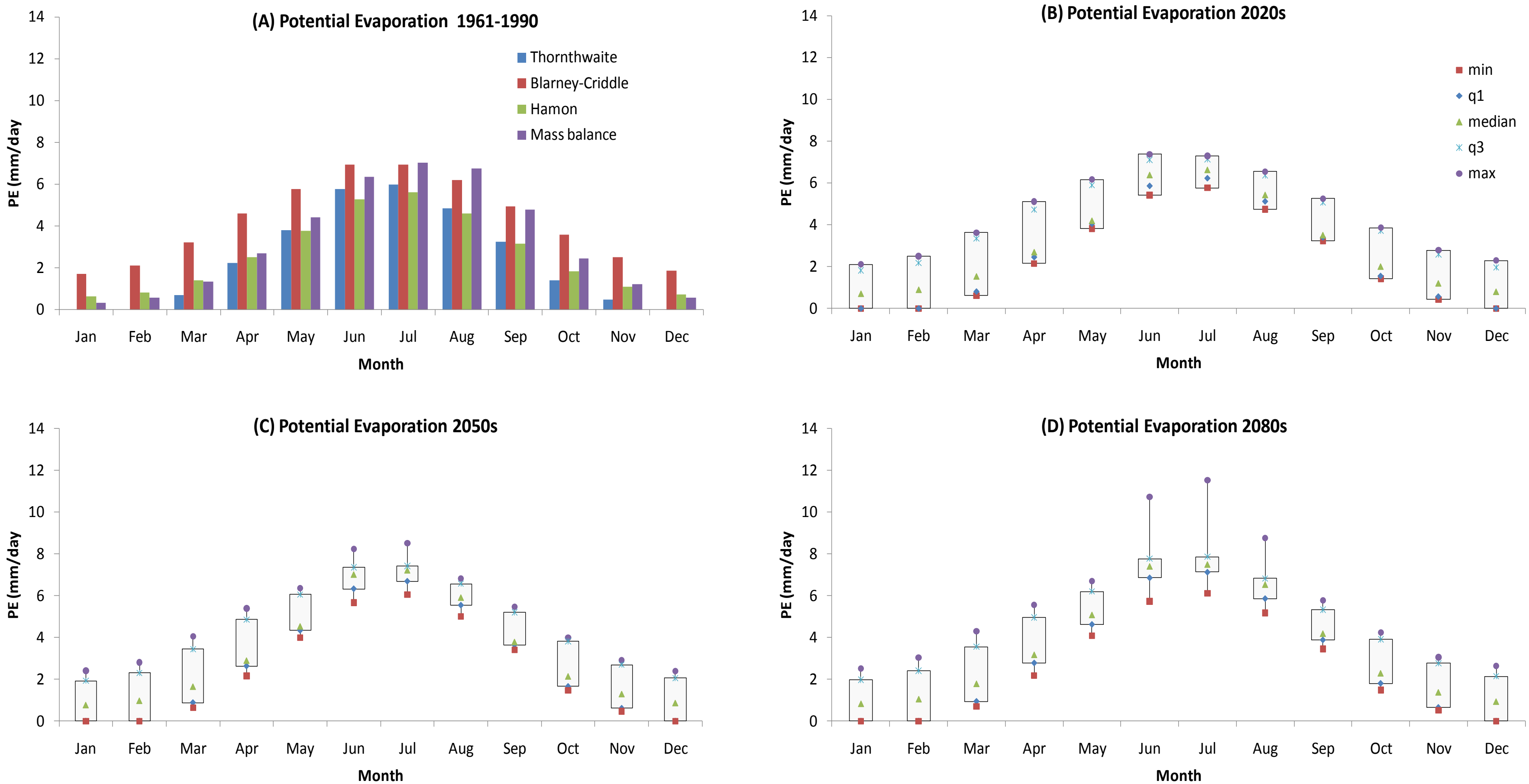






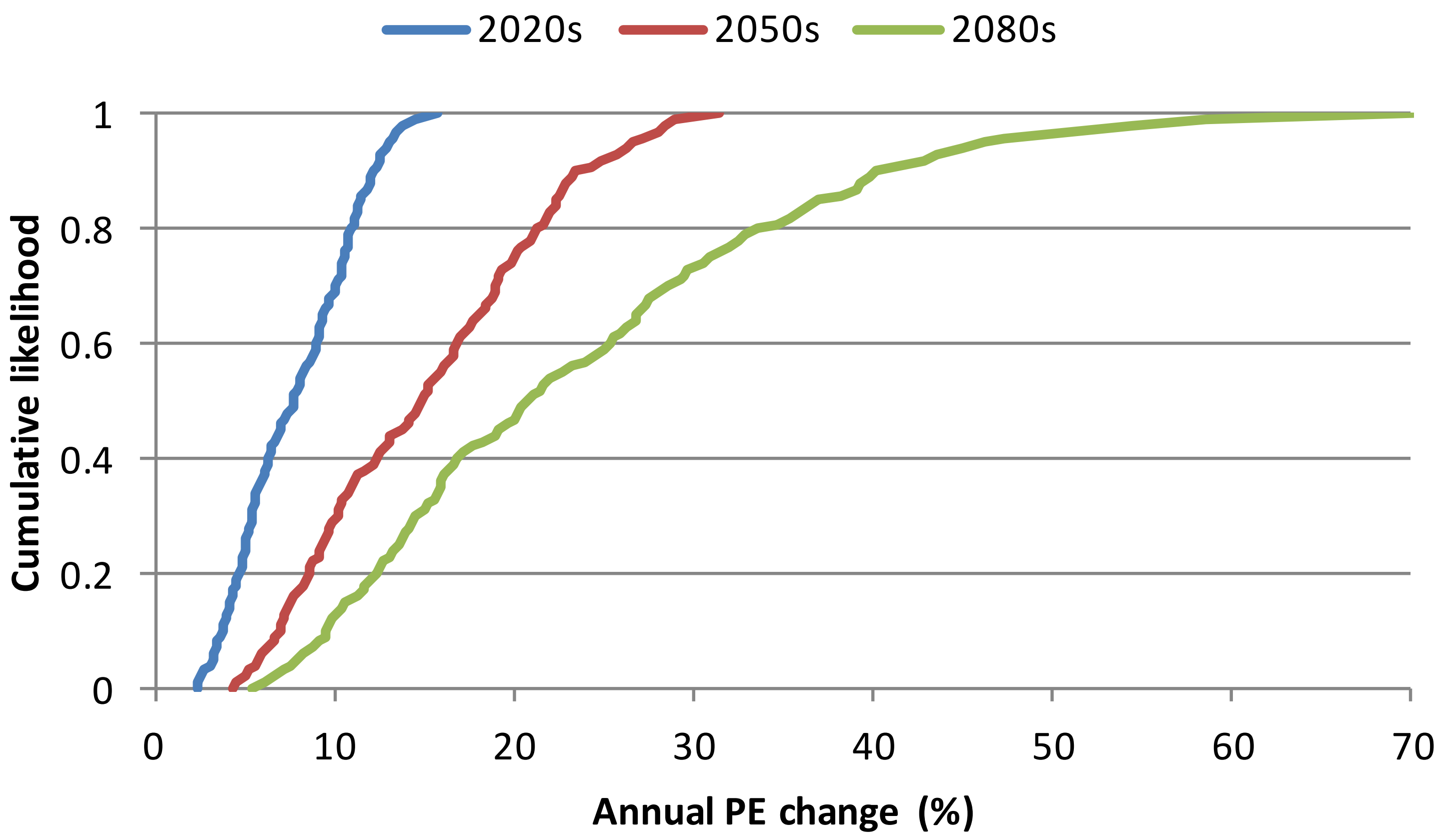
Source: Freer et al. (2012)

Structural uncertainty (PE)



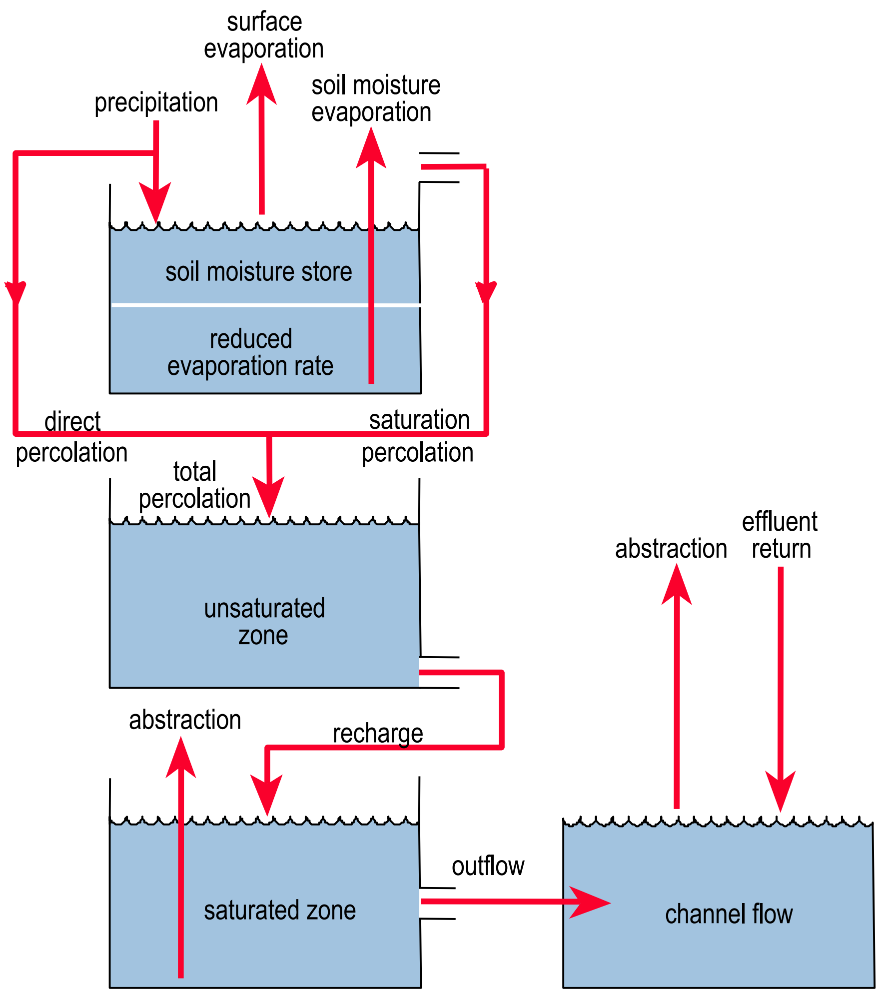
Estimated *PE* for 1961-1990 based on the Thornthwaite, Blaney-Criddle and Hamon methods and observed temperatures. Mass balance estimates were calculated from reservoir (Kairakkum) inflows and outflows. Source: EBRD (2012)

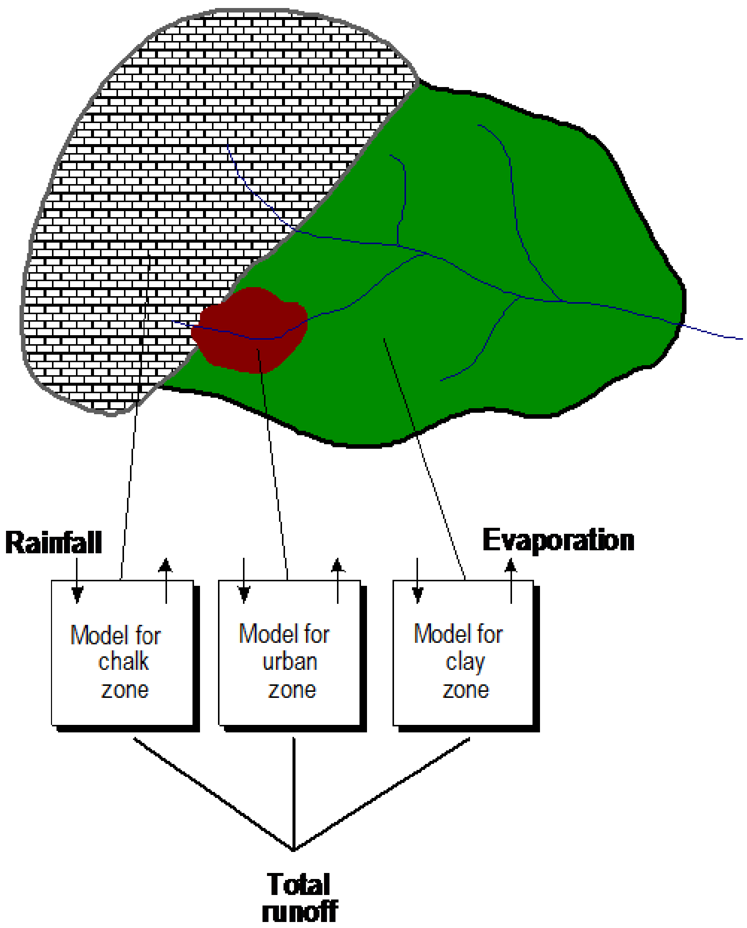
Structural uncertainty (PE, GCM, emissions)



Cumulative likelihood distributions of annual PE increases (% change with respect to the 1961-1990 baseline) projected by ensembles of PE estimation method, emission scenario, and GCM output (for the closest grid-points to the Kairakkum reservoir).

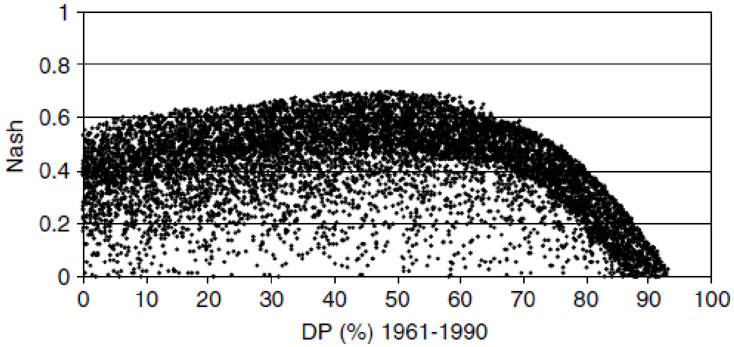
Parameter uncertainty



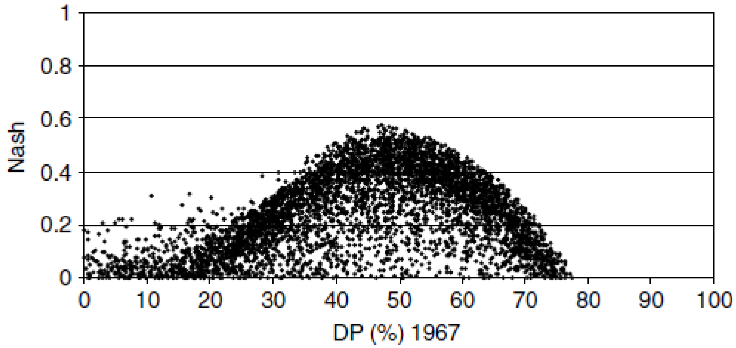


CATCHMOD lumped conceptual model

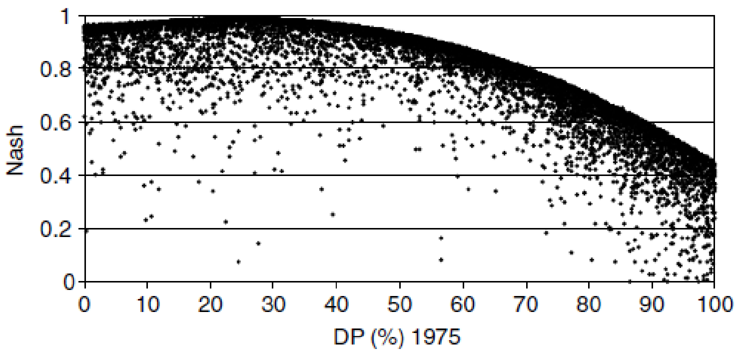
Parameter uncertainty (high identifiability)



All data (1961-1990)



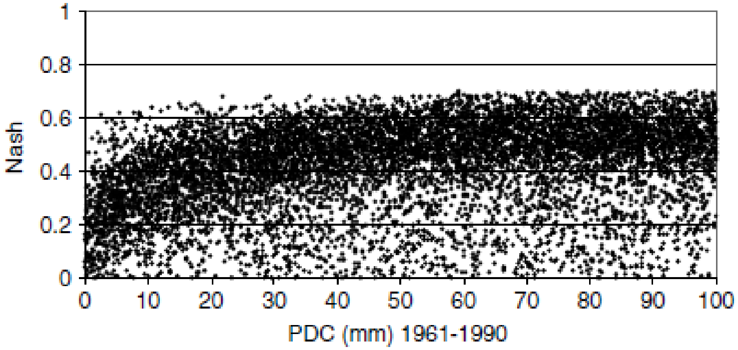
Wettest year (1967/68)



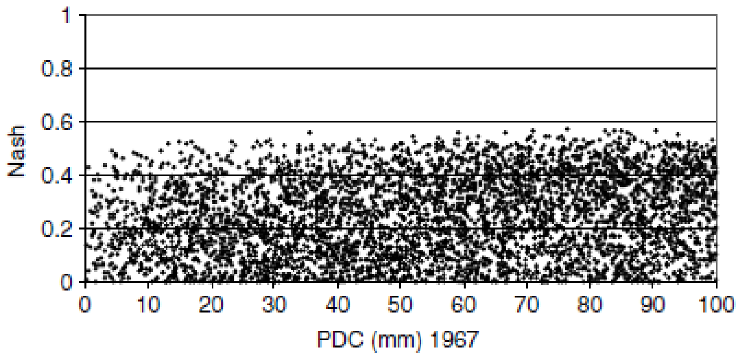
Driest year (1975/76)

CATCHMOD direct percolation (DP) parameter for Thames basin. Source: Wilby (2005)

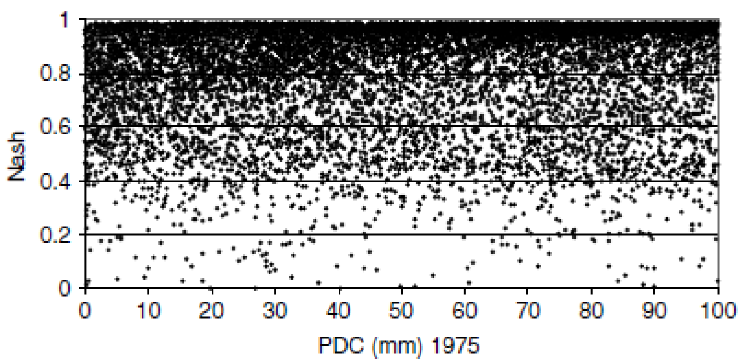
Parameter uncertainty (low identifiability)



All data (1961-1990)



Wettest year (1967/68)



Driest year (1975/76)

CATCHMOD potential drying constant (PDC) parameter for Thames basin. Source: Wilby (2005)

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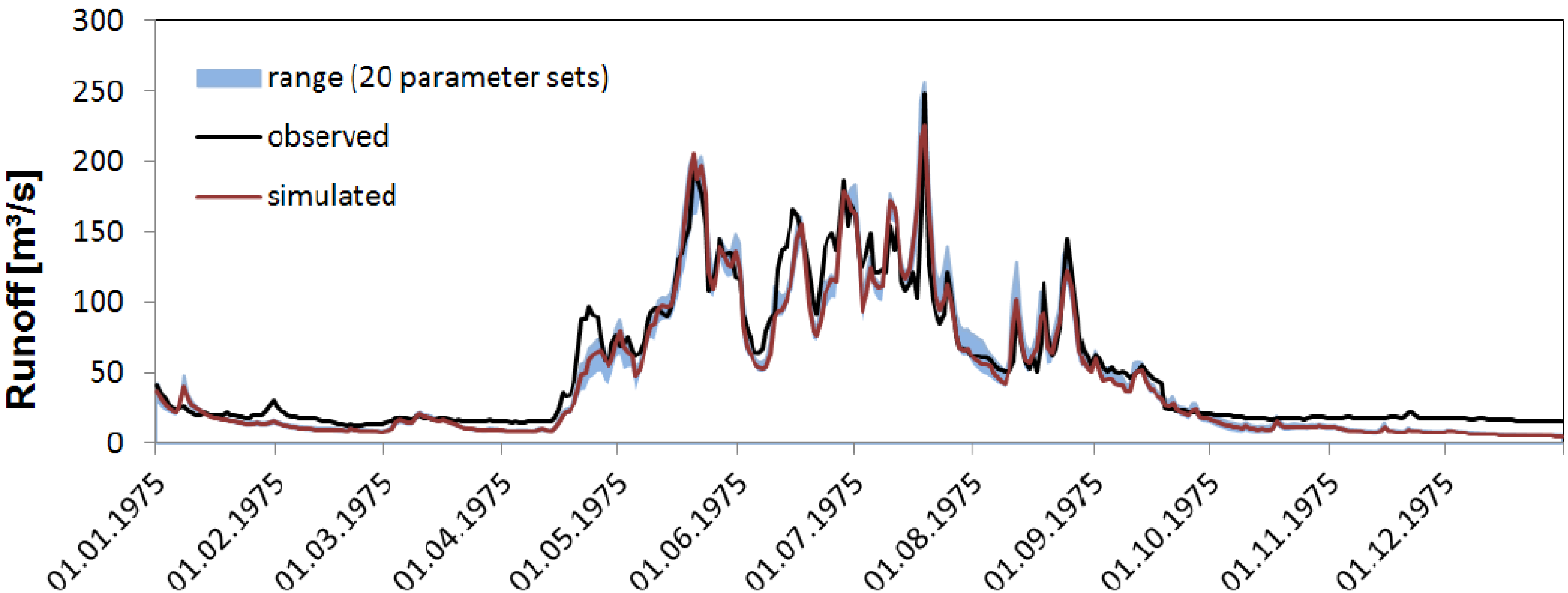
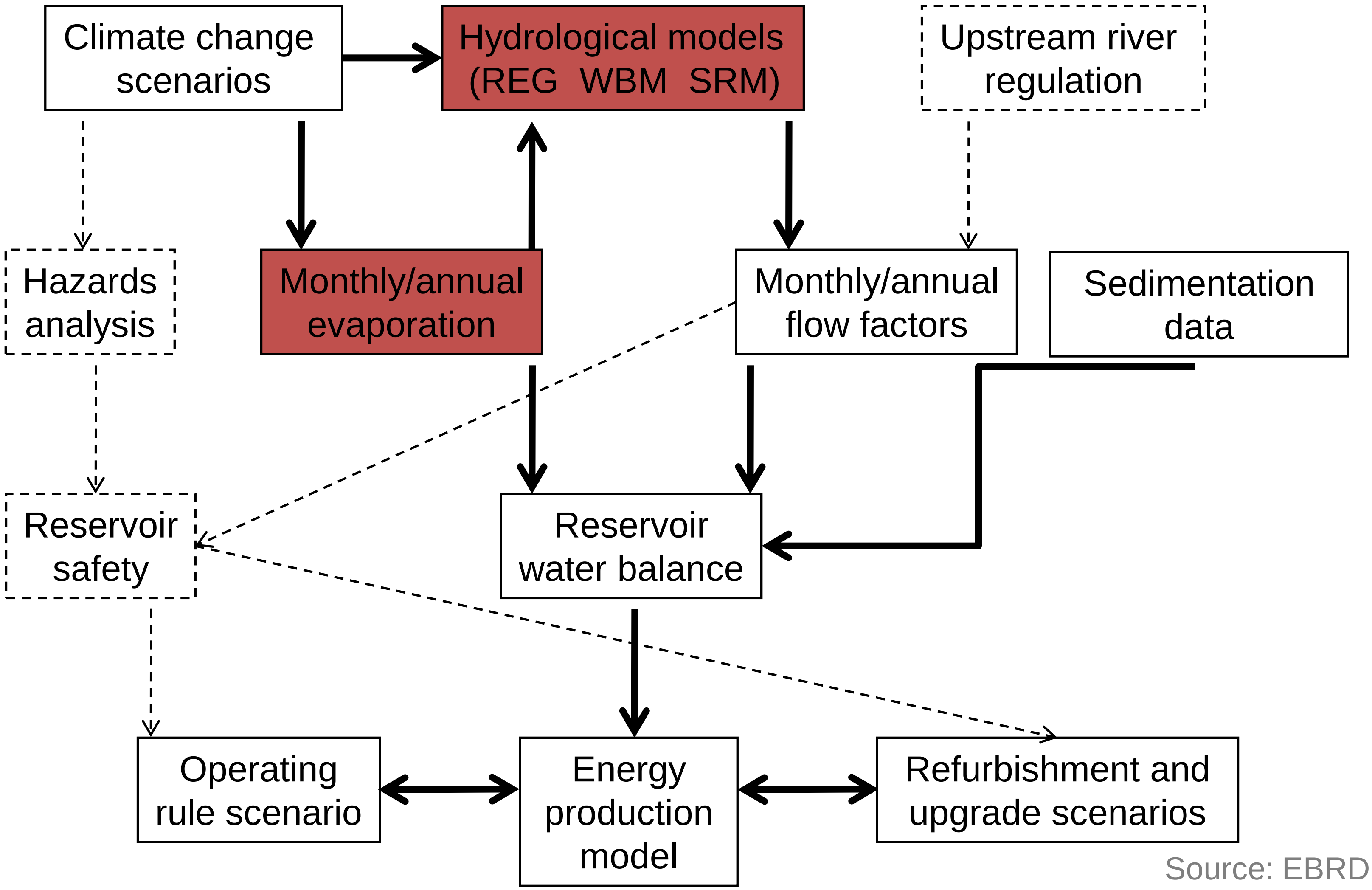
Parameter uncertainty (outcome)



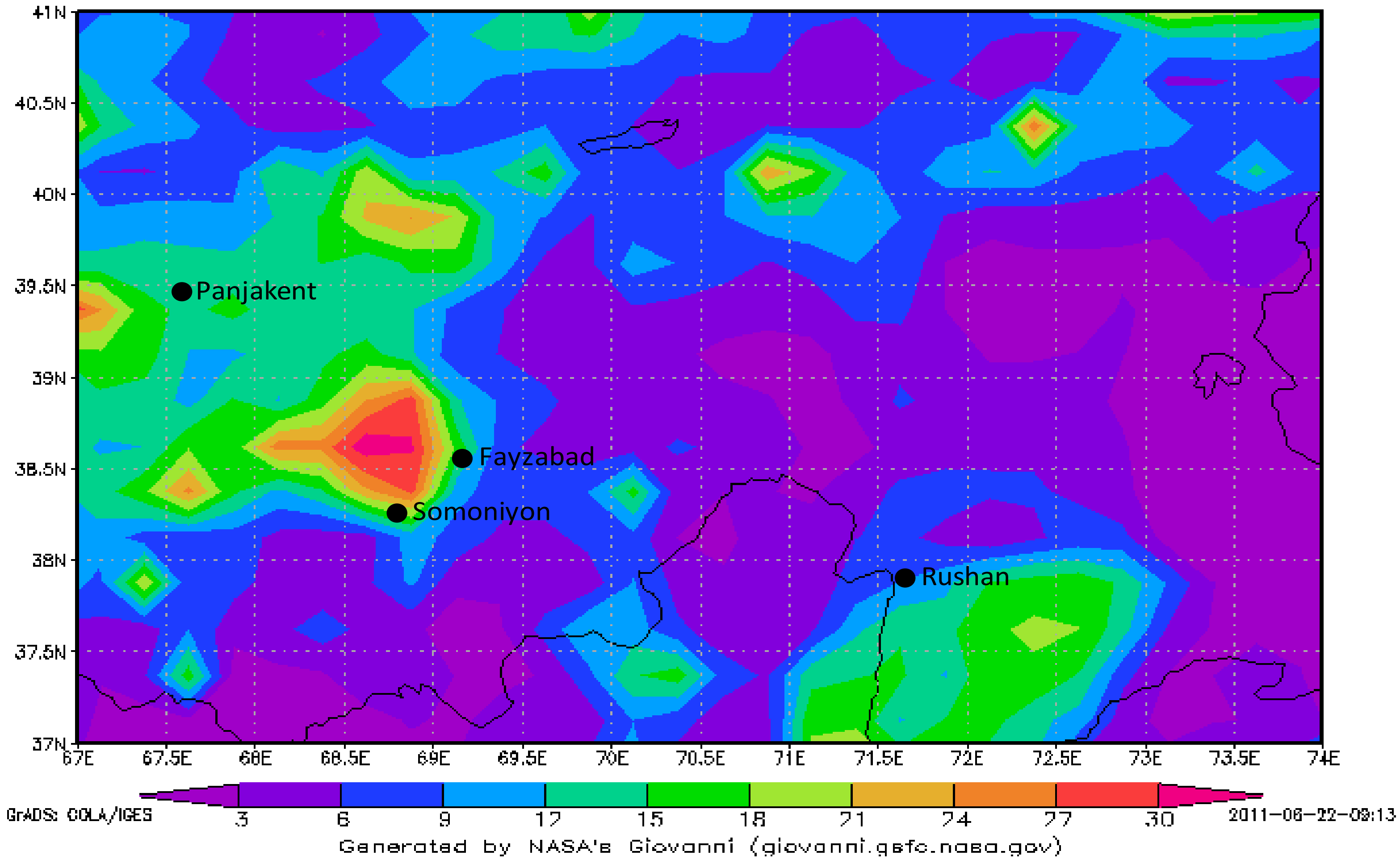
Observed and simulated runoff in the Lech basin, Austria for the year 1975. Blue shading indicates the range obtained from 20 different parameter sets. Source: Dobler et al. (submitted).

Overview: Hydrological uncertainties in perspective (hydropower)



Source: EBRD (2012)

Hydrological hazard forecasting
(scientifically tractable risk reduction measure)



Locations of mudflows and reported flooding 5 to 11 May 2011 compared with TRMM rainfall

Where the need is greatest