Tracing hydrological processes at catchment scales

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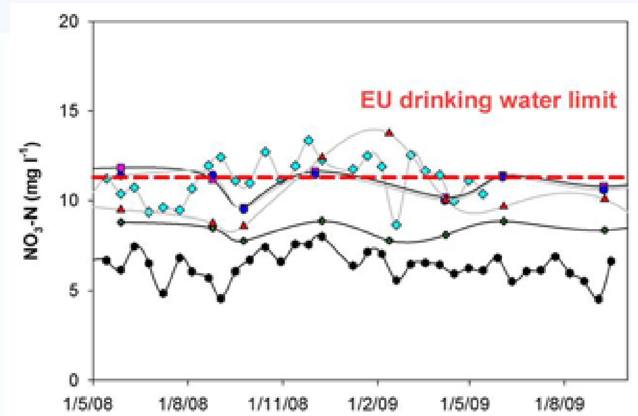
Hydrological extremes are likely to intensify = greater flood and drought risk

Need to reduce predictive uncertainty of hydrological models

Nutrient application to agricultural land – nitrate vulnerable zones potential for surface water (short-term) and groundwater (long-term) contamination

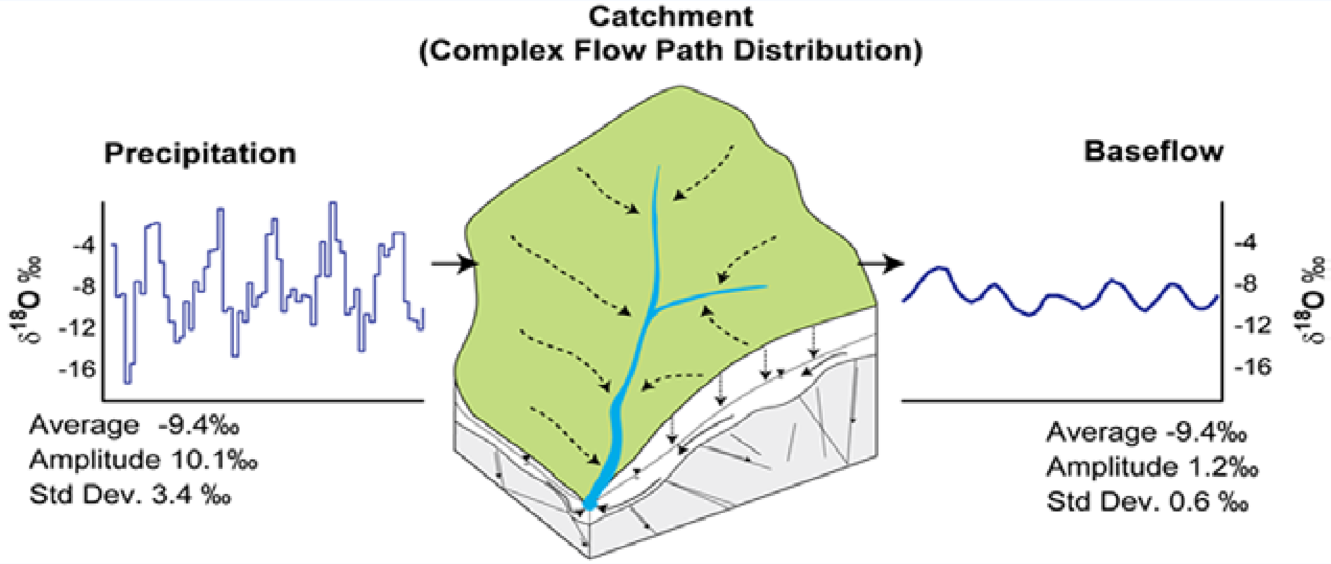


Need to understand transport over event to decadal time periods

Background

Tracers integrate hydrological response over catchment scales:

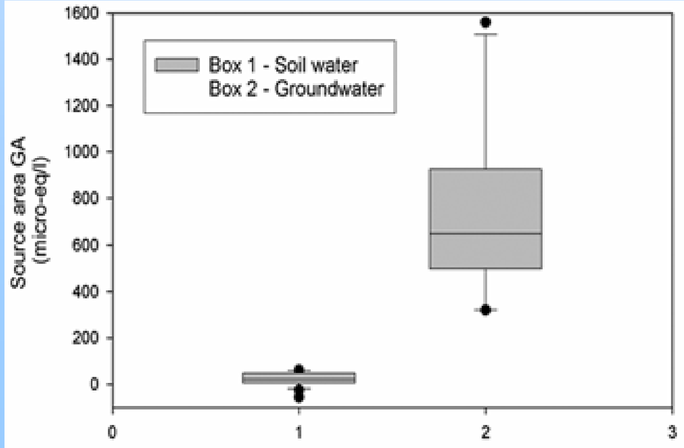
- Isotope tracers are a tool to study water age (time-domain)



McGuire & McDonnell (2005)

- Geochemical tracers are a tool to study water source (spatial-domain)

Soil water alkalinity



Groundwater alkalinity

Background

- New methods (e.g. automatic samplers and laser spectroscopy) make higher-resolution sampling inexpensive and feasible

Objectives:

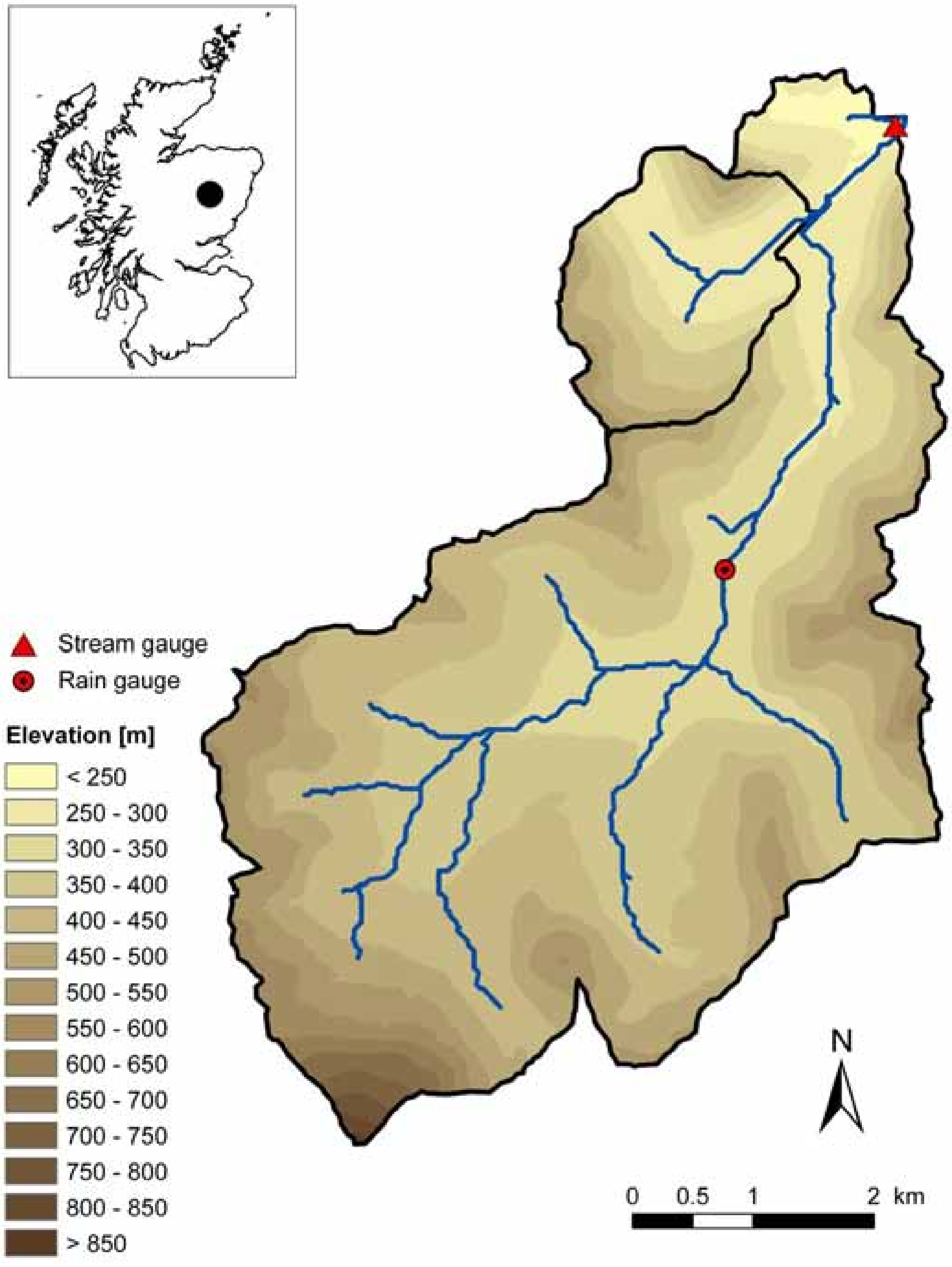
1. To use high-resolution tracer data and field observations to capture process dynamics at different spatial scales

2. To develop conceptual models to simulate high-resolution tracer and process dynamics

3. To examine if model uncertainty can be reduced

headwater ↔ **downstream**

Study site: Girnock, Cairngorms NE Scotland



- Annual precipitation: ~1000 mm

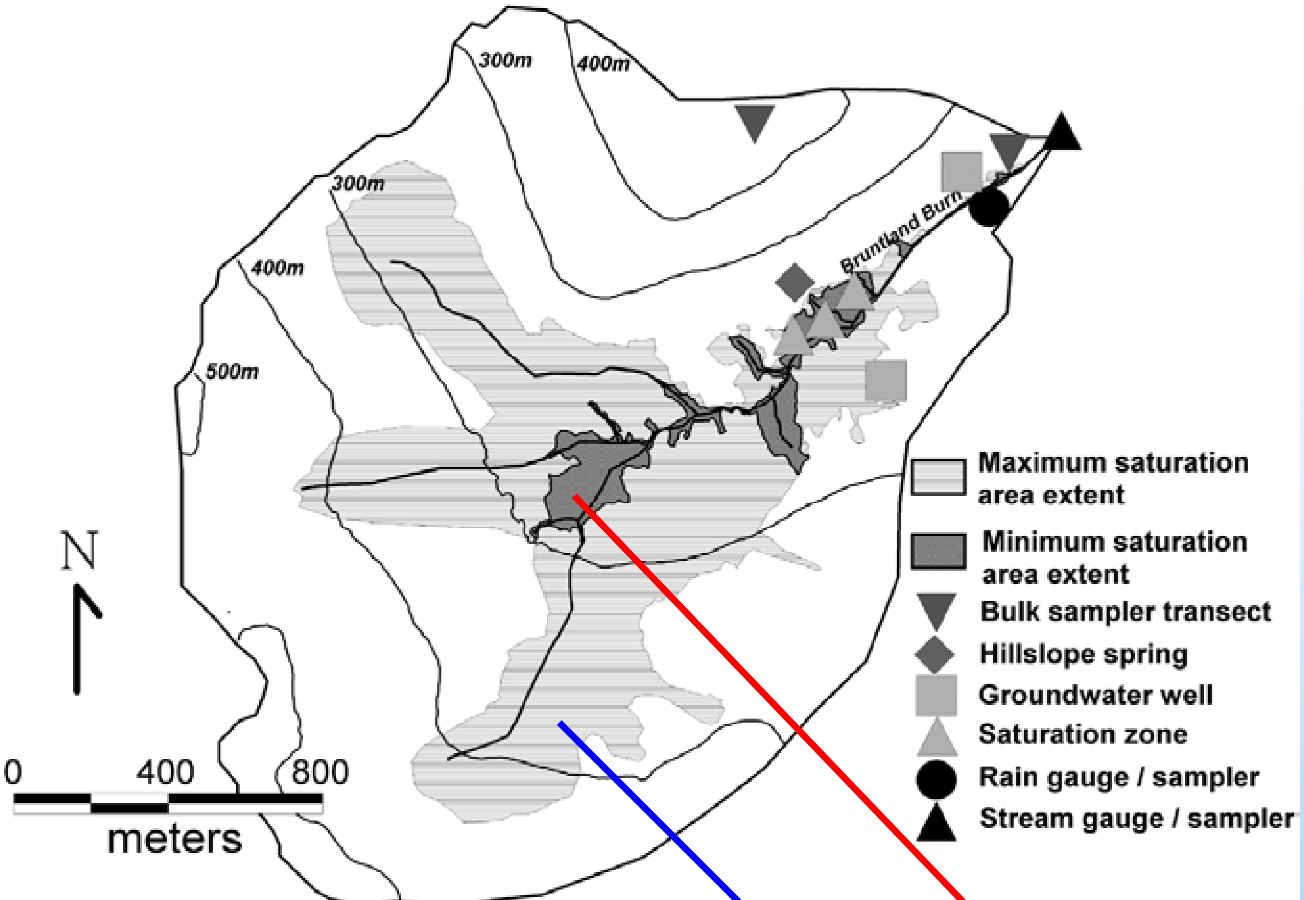
- Annual runoff: ~600 mm, ET ca. 400 mm

- Soils are important control on hydrological response

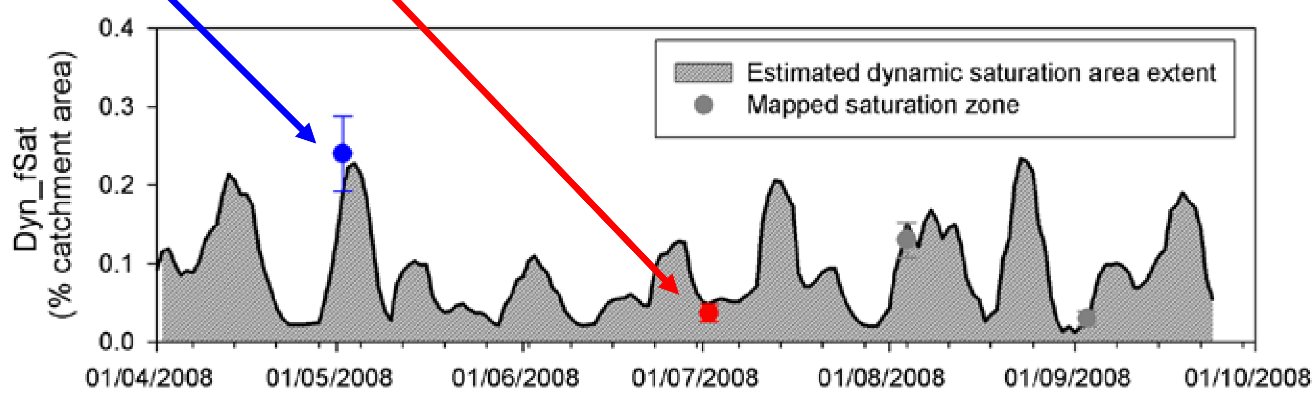
Dynamic conceptualisation of dominant processes

$$process = f(x)???$$

Dynamic conceptualisation of dominant processes

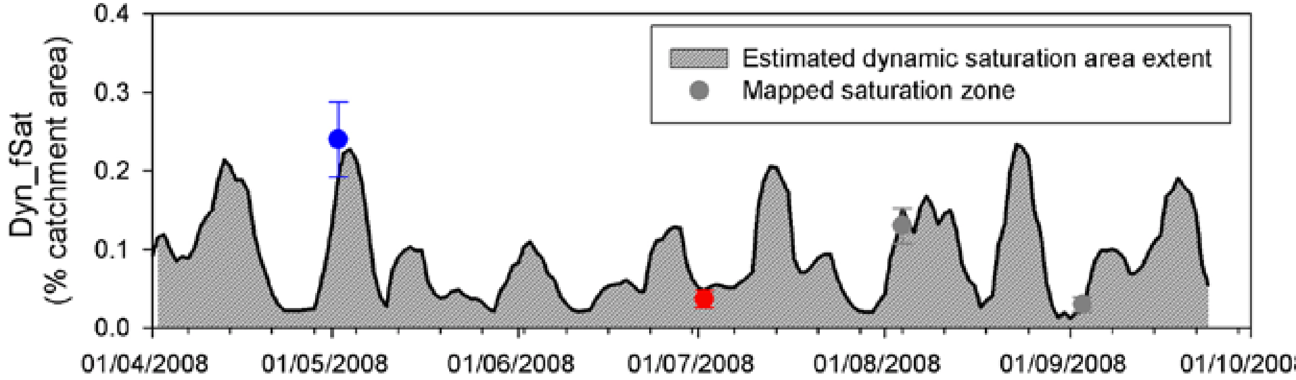


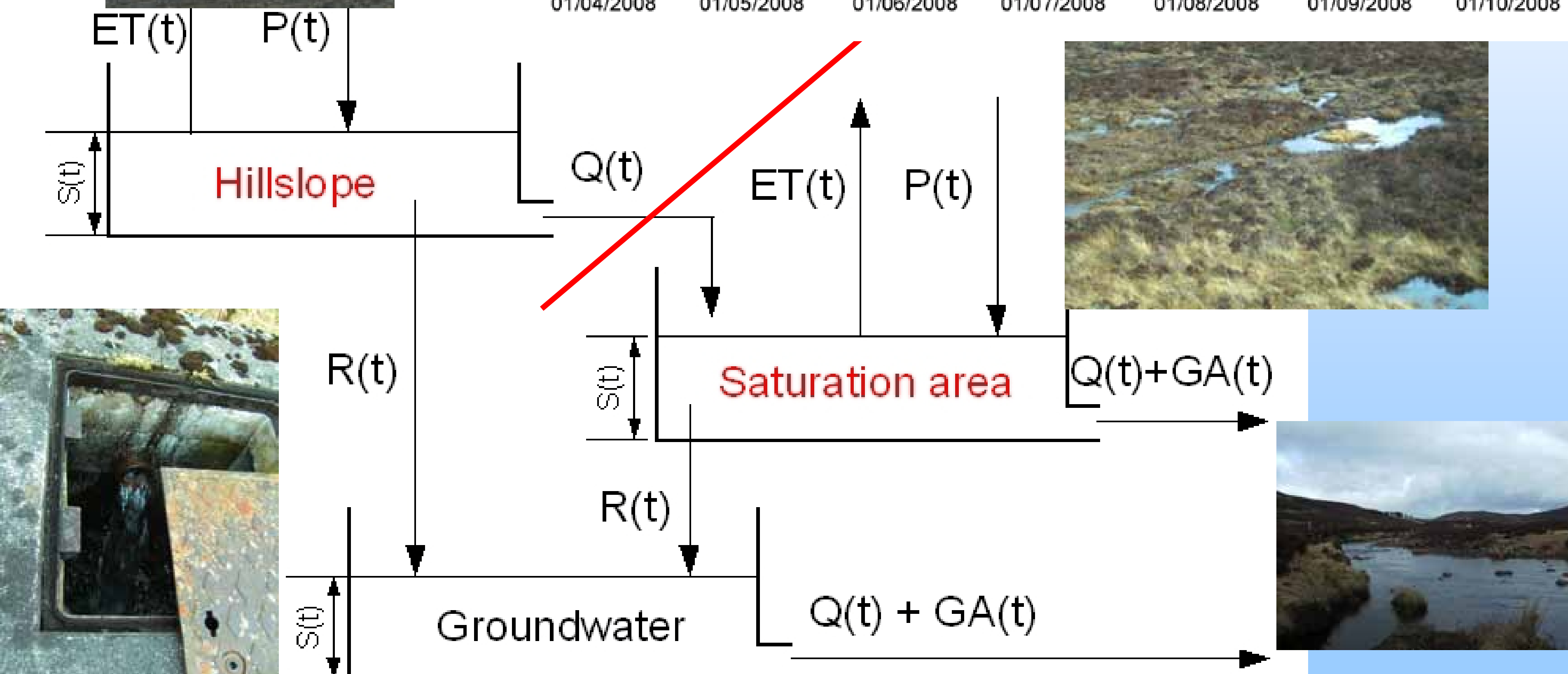
Mapped saturation area dynamics =
f (P, ET, Soils)



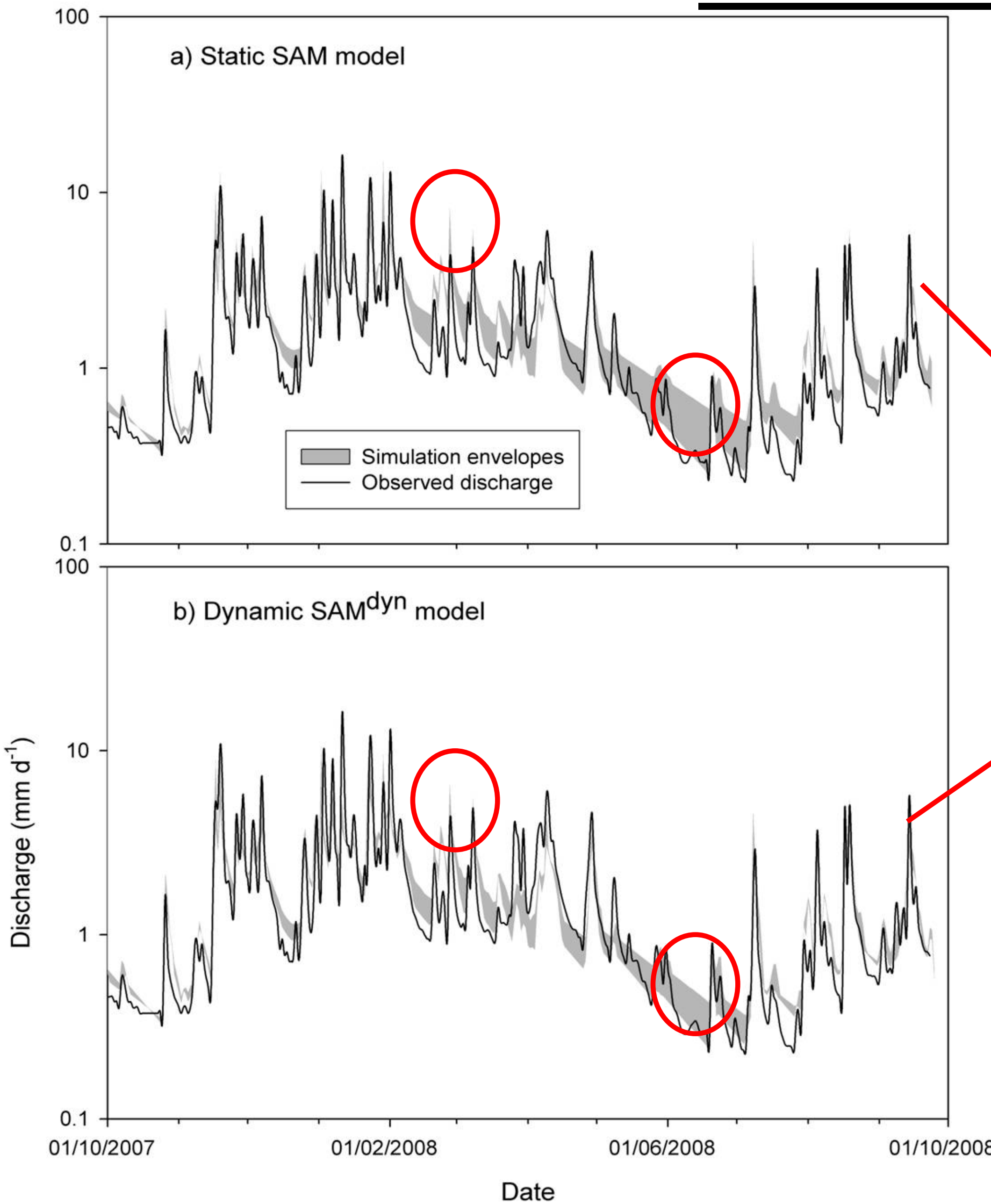
Model approach

Dynamic distribution of storage volumes:

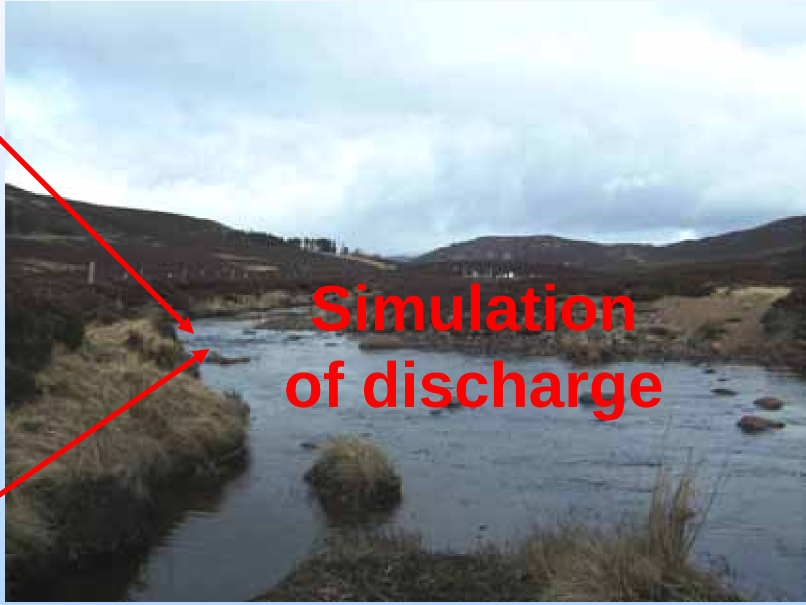




Does a better process representation help to reduce uncertainty?

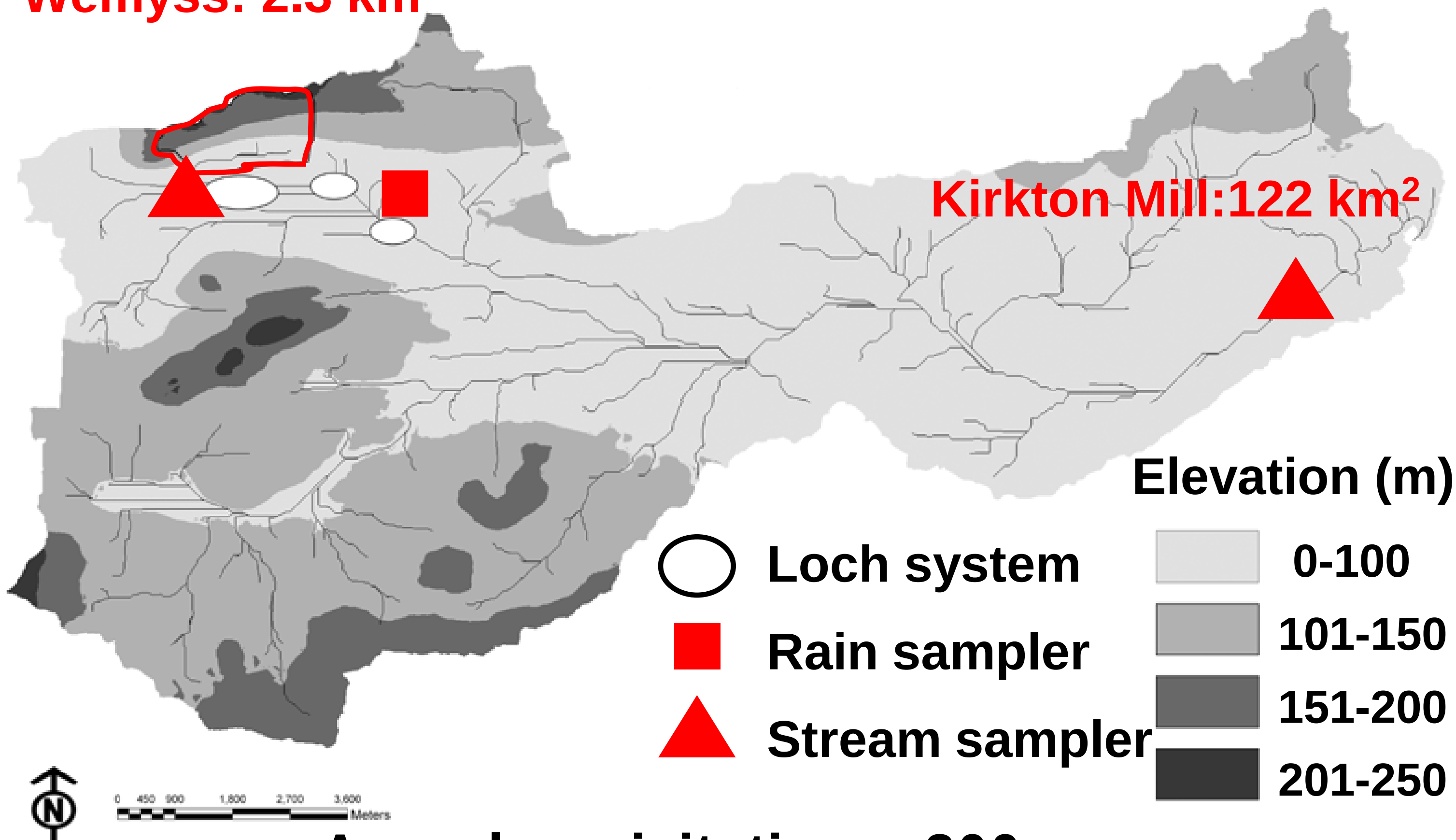


STATIC



DYNAMIC

Study site: Lunan, E Scotland



- Annual precipitation: ~800 mm

- Annual runoff: ~400 mm, ET ca. 400 mm

- Loch system in upper catchment (~25%)

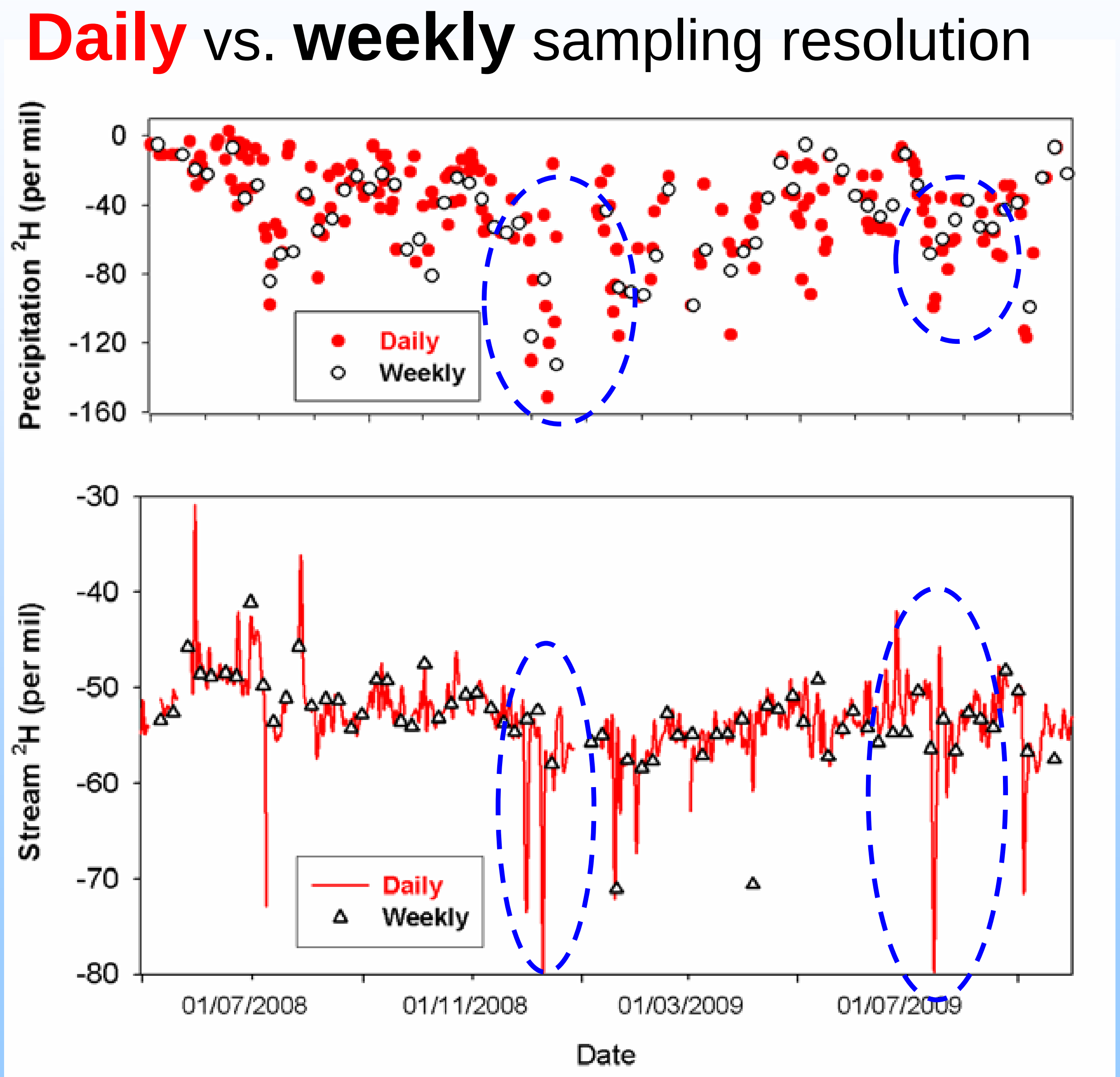
- Intensive agriculture (~80%)

High-resolution data – *capturing process dynamics*

Example Wemyss 2.3 km²:

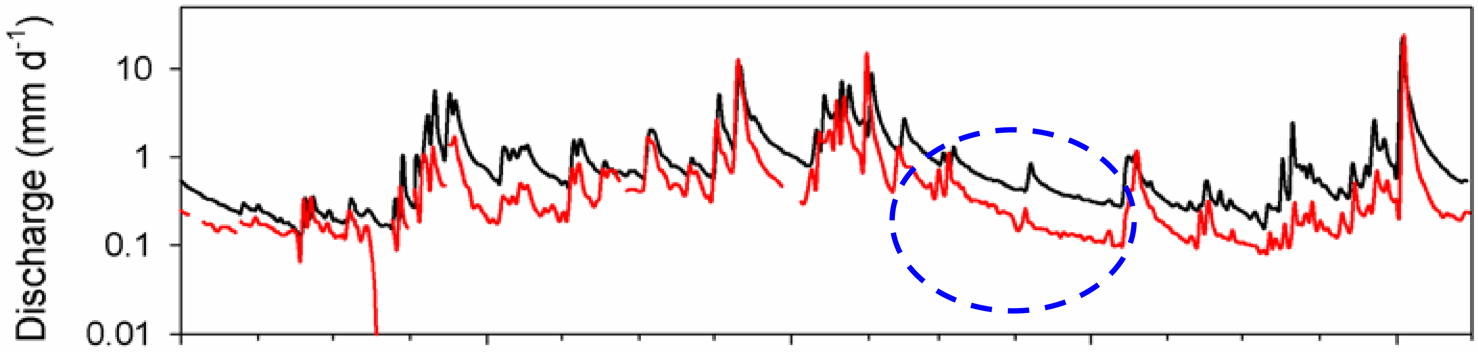
Input

Output

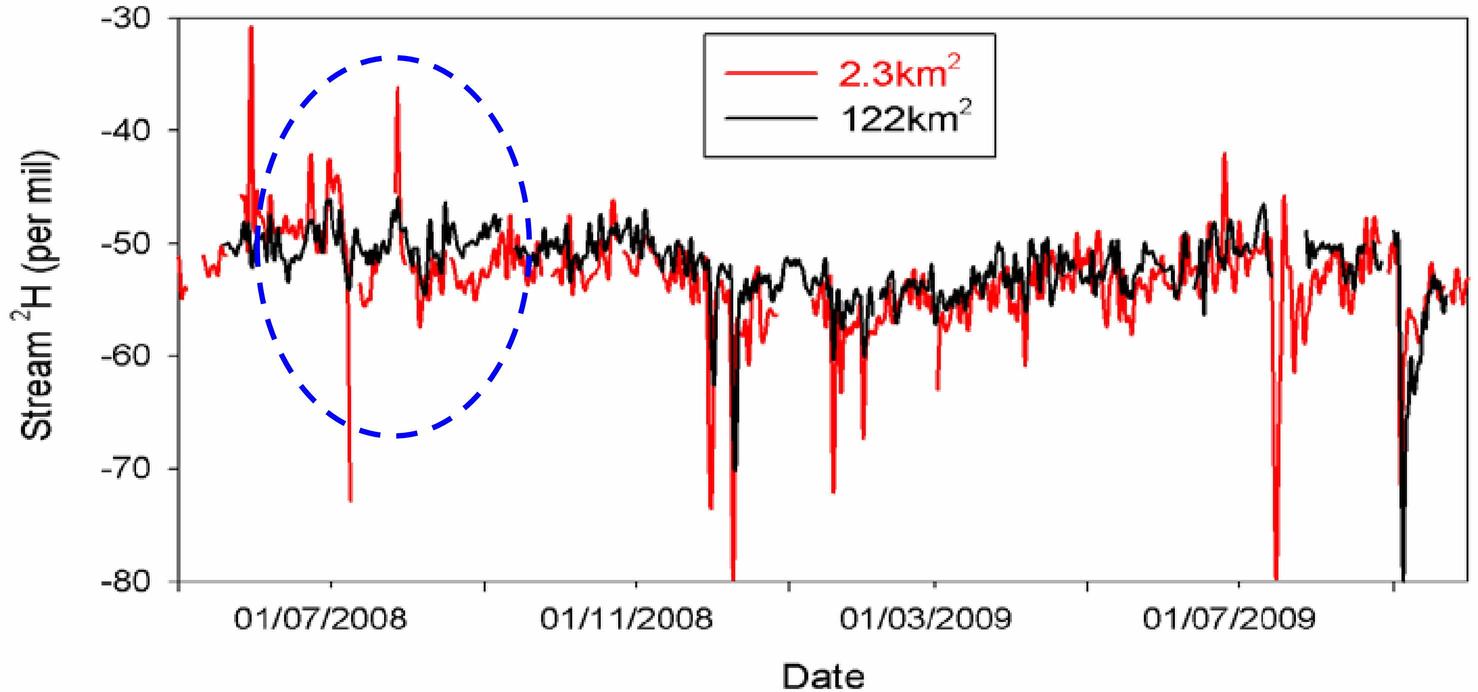


Response at different spatial scales

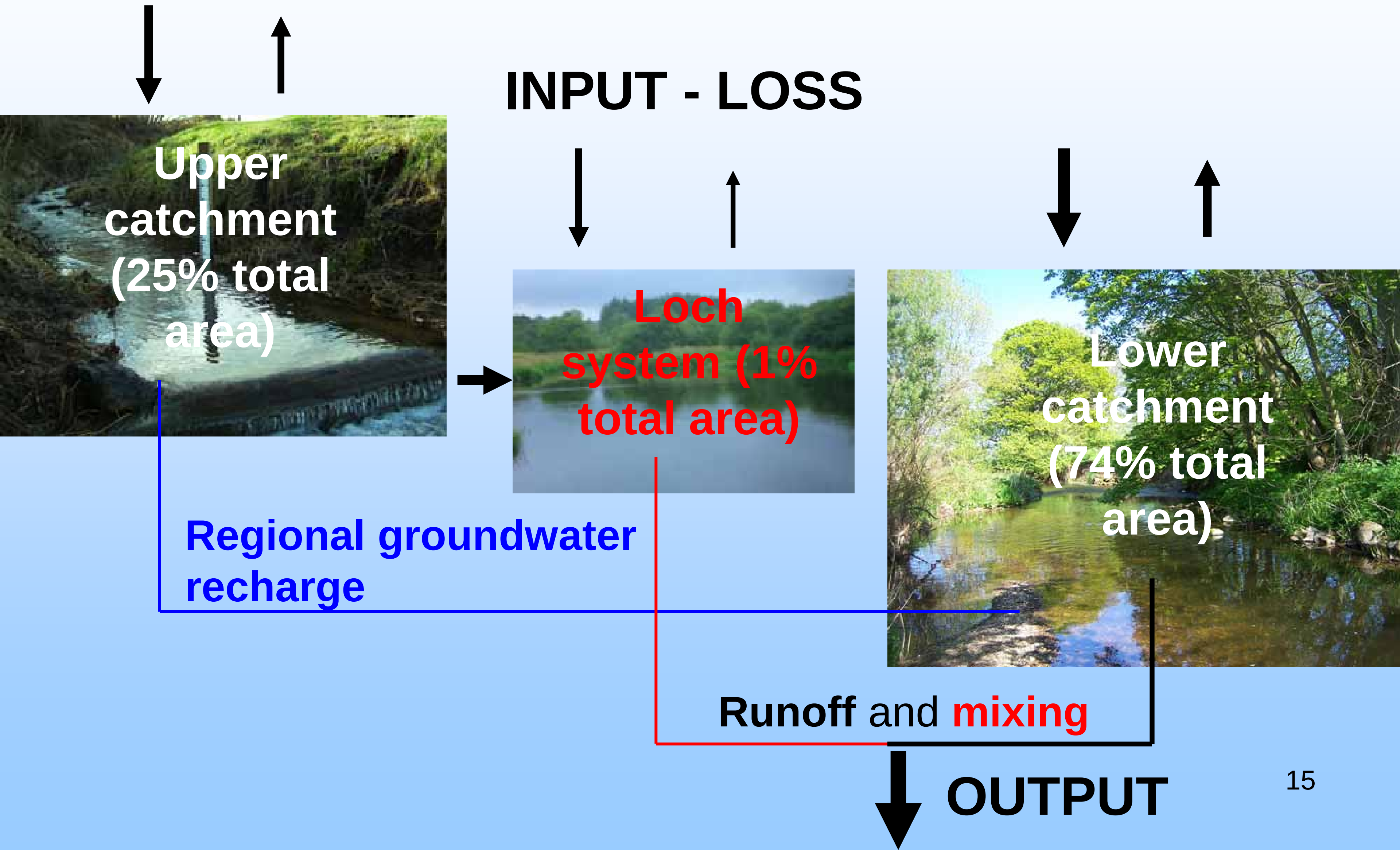
Hydrology: Difference in annual runoff > 100 mm a^{-1}



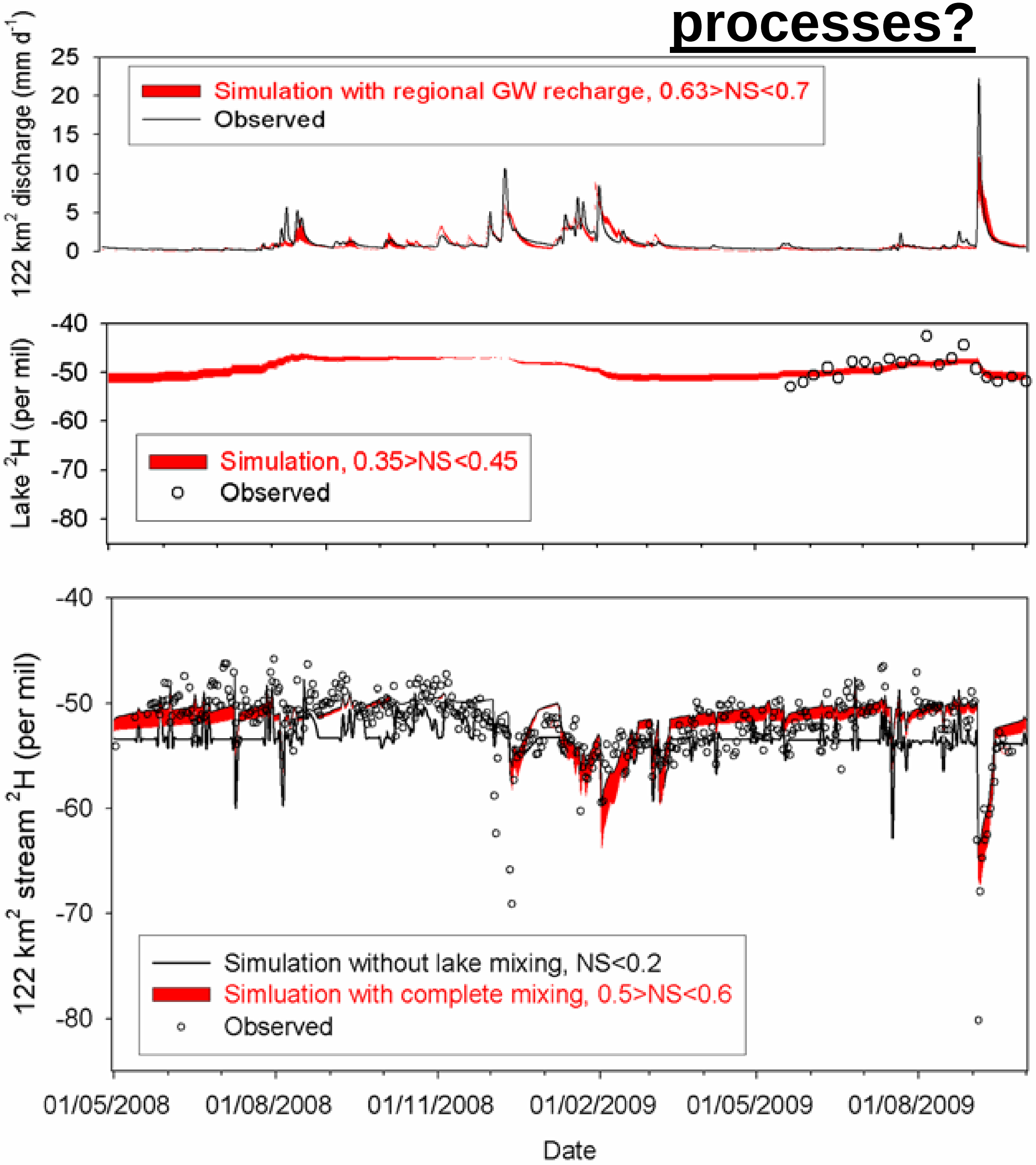
Isotopes: more damped and enriched at larger scale



Development of a conceptual flow-isotope model



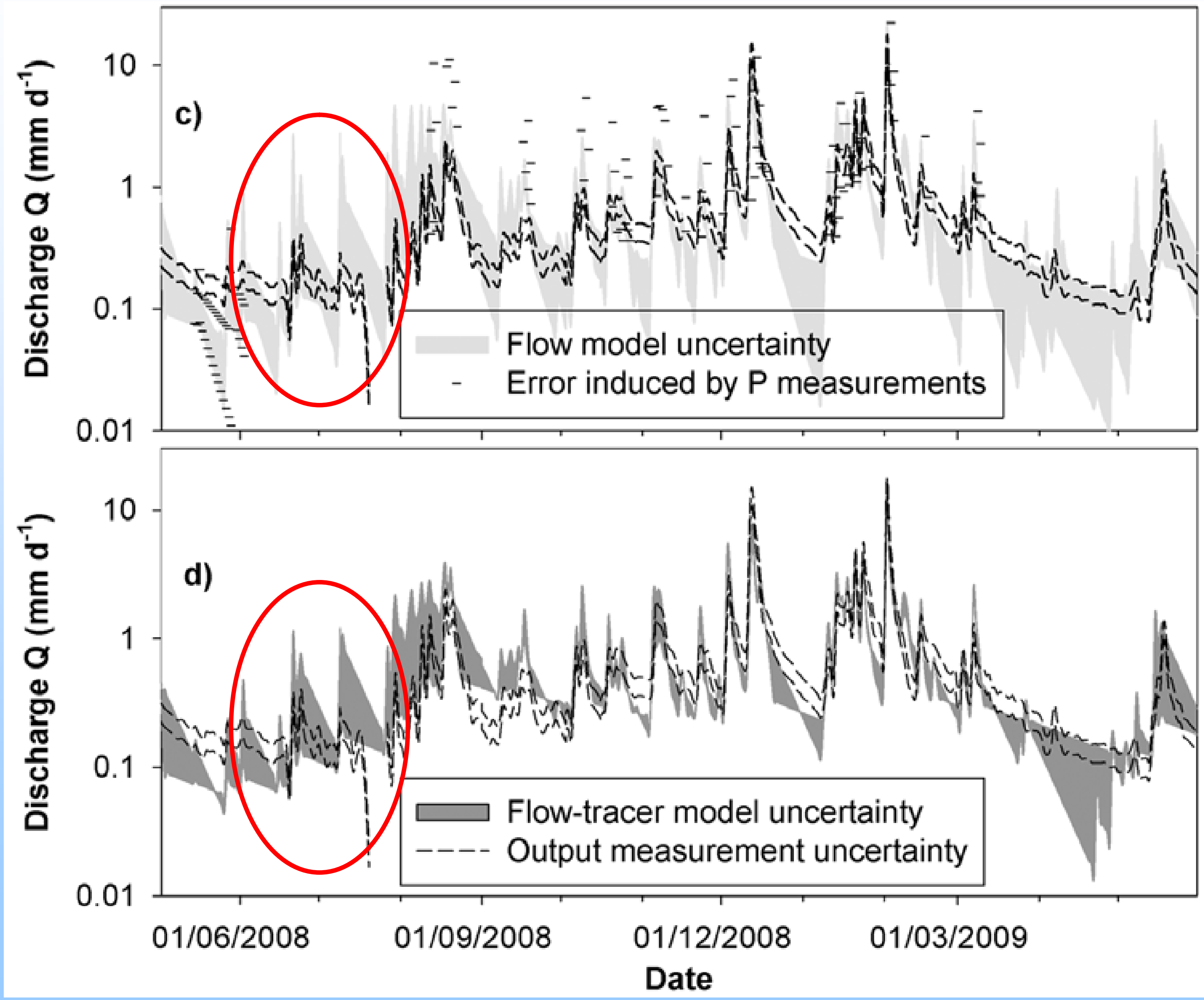
Does tracer data help better understand transport processes?



Regional groundwater recharge closes water balance at large scale

Mixing with loch water: improved downstream isotope simulation

Does the incorporation of tracer data into hydrological models help reduce uncertainty?



Isotope data constrains model simulations

Conclusions:

1. **Dynamic representation of hydrological processes improves simulations.**
2. **High-resolution isotope data captures dynamics and extremes better.**
3. **Uncertainty of conceptual models is reduced after incorporation of tracers and dynamic processes, but models are still too simple to be fully able to reproduce the variability in stream isotope dynamics.**

3. Tracers reveal scale-dependent transport mechanisms due to mixing of different water sources.

4. Tracer studies can help understand temporal dynamics of diffuse pollution.

Many thanks for your attention!