Towards a unified theory of runoff generation in montane watersheds: using process-based maps of soil hydrology to identify first order controls

1. INTRODUCTION

- Constraints in developing unifying theories in hydrology are well known
  - Different spatial scales – different hydrological processes
  - “Uniqueness of place”: specific combinations of landscape controls that are characterized by heterogeneity at all scales

- Need to develop tools that translate process understanding in multi-scale manner

2. OBJECTIVES

- Identification of catchment-scale controls (using USGS) on hydrological sources and mean residence times
- Use of tracers & hydrometrics to understand hydrological functioning of mesoscale catchments
- Extrapolation to range of mesoscale catchments to identify first order controls on landscape hydrology

3. METHODOLOGY

- Use of long-term data collected from 3 individual mesoscale (30-230 km²) catchments in the uplands of northern Scotland
- 25 individual basins at scales ranging from 0.9 – 233 km²
- Use of geochemical and isotopic tracers to carry out chemical hydrograph separations to quantify the relative contribution of different hydrological sources to annual runoff and estimate mean residence times in each catchment
- GIS analysis to assess the nature of landscape controls on hydrological sources and residence times
- Application of HOST (Hydrology Of Soil Types) – digital UK data base soil maps based on hydrological properties

4. RESULTS

- Soils could be divided between:
  1) hydrologically “responsive” montane soils (e.g. peats, rankers, peaty gleys), which mainly generate storm runoff by saturation-overland flow and shallow sub-surface storm flow (Figure 3)
  2) “freely-draining” soils (e.g. brown soils and humus-iron podzols), which mainly facilitate groundwater recharge (Figure 4)

- Hydrograph separation (tracer-based): mean annual groundwater contributions: 23 – 62% of annual runoff.
- Residence times estimated from δ¹⁸O variations (Figure 5): mean residence times: 83 days – 840 days

- Use of long-term data collected from 3 individual mesoscale (30-230 km²) catchments in the uplands of northern Scotland
- Digital HOST database found to be effective “carriers” of process-information, soils integrate the effects of heterogeneities in catchment topography, geology, climate and vegetation
- Effective characterisation of catchment hydrology by combining tracers and GIS
- Landscape organisation – especially soil distribution – much more important than scale in controlling hydrology
- Potential application in catchment characterization, further upscaling, constraining models and assessing ungaged basins
- Need for theoretical advances to be rooted in experimental knowledge