Linking baseflow signatures to hydrological processes and catchment attributes

Sebastian Gnann[1], Hilary McMillan[2], Nicholas Howden[1], and Ross Woods[1]

[1]Department of Civil Engineering, University of Bristol, Bristol, UK

[2]Department of Geography, San Diego State University, San Diego, US

Why do many large scale studies struggle to identify controls on streamflow signatures other than climate[1,2] despite extensive field evidence that non-climatic catchment characteristics influence the streamflow response?

Focus of this presentation

We pose three general hypotheses:

1) ***Input data* are of too coarse resolution or relevant input data are missing**
2) *Hydrological signatures* aren‘t well connected to hydrological processes
3) *Models* can‘t translate input data into streamflow signatures

Hypothesis 1): Input data are of too coarse resolution or relevant input data are missing

- In large sample data sets such as CAMELS[3], geology is often only divided into a few general lithological units (which are then assigned representative permeability and porosity values[4])
- These attributes might be too general and might not contain the hydrologically relevant information that controls the hydrological response at the catchment scale
- We present a few case studies where more detailed local knowledge reveals how the subsurface controls baseflow signatures such as the baseflow index (BFI) and the normalised 5% streamflow percentile (Q_5)

Example 1: Ozarks in Missouri

- The Ozarks Plateau is mostly underlain by carbonate rock, yet catchments in the region differ widely in their BFI
- CAMELS data do not distinguish between the different carbonate strata (indicated by their age in Fig.2), which vary in their degree of karstification
- We can use sinkhole or age data as a proxy for karstification to better predict the BFI in this region (see Fig.1)

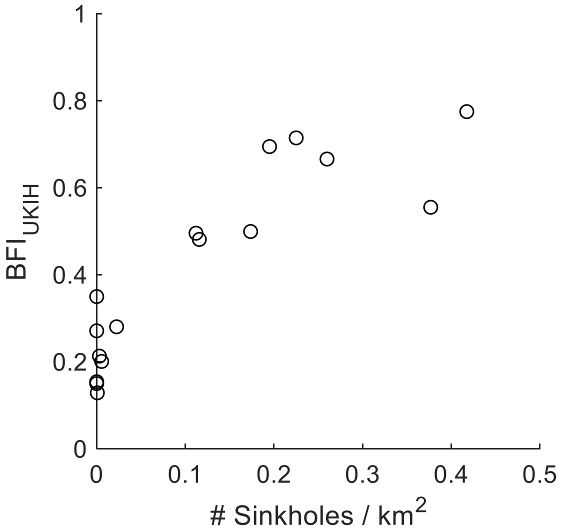

Fig.1
Sinkhole density[5] is a good descriptor of karstification and thus BFI (rank correlation 0.87)

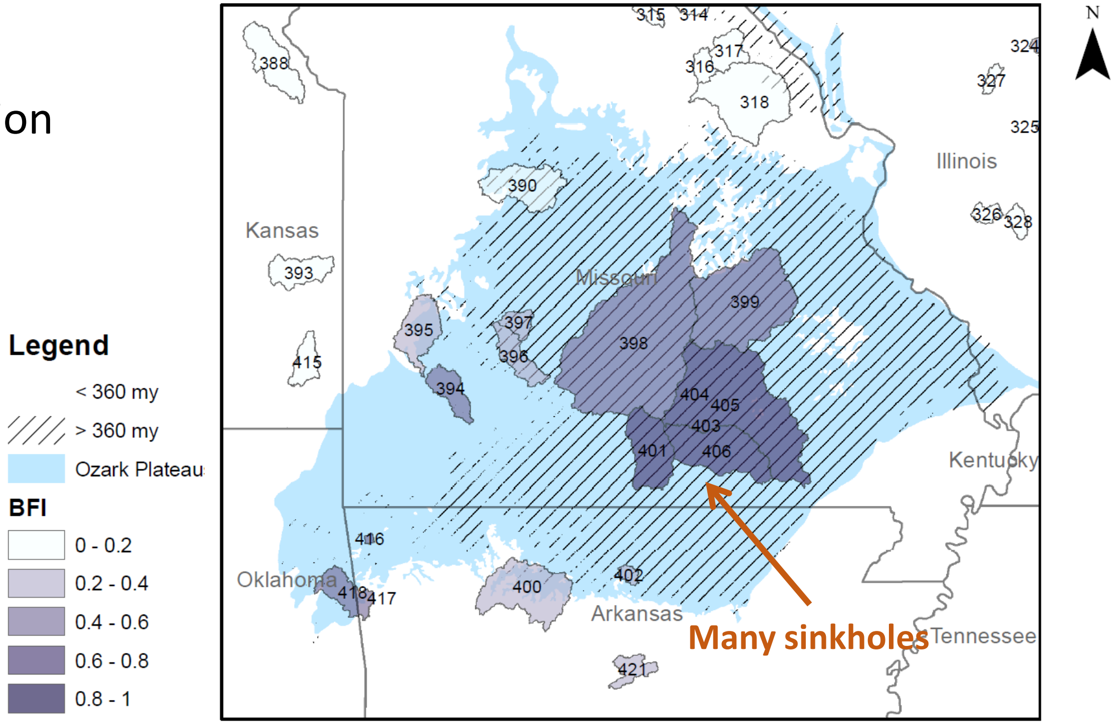

Fig.2 Ozarks Plateaus aquifer system[6,7]

Example 2: Edwards-Trinity Aquifer System in Texas

- The Edwards-Trinity aquifer system can be divided into the Edwards-Trinity aquifer, the Trinity aquifer and the Balcones Fault Zone (see Fig.4)
- CAMELS data do not distinguish between the different aquifers, which lead to a different hydrological response
- We can distinguish between the different aquifers and account for groundwater losses to better predict Q_5 (Fig.3)

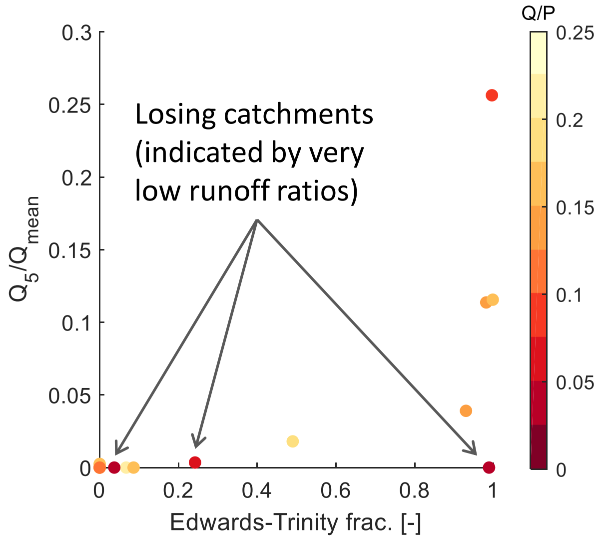

Fig.3 Edwards-Trinity aquifer fraction is a good predictor of Q_5 (rank correlation 0.72), but we need to account for losing catchments

Catchments in the Balcones Fault Zone (BFZ) lose water to the underlying aquifer, distorting the relationship between geology and hydrological signatures

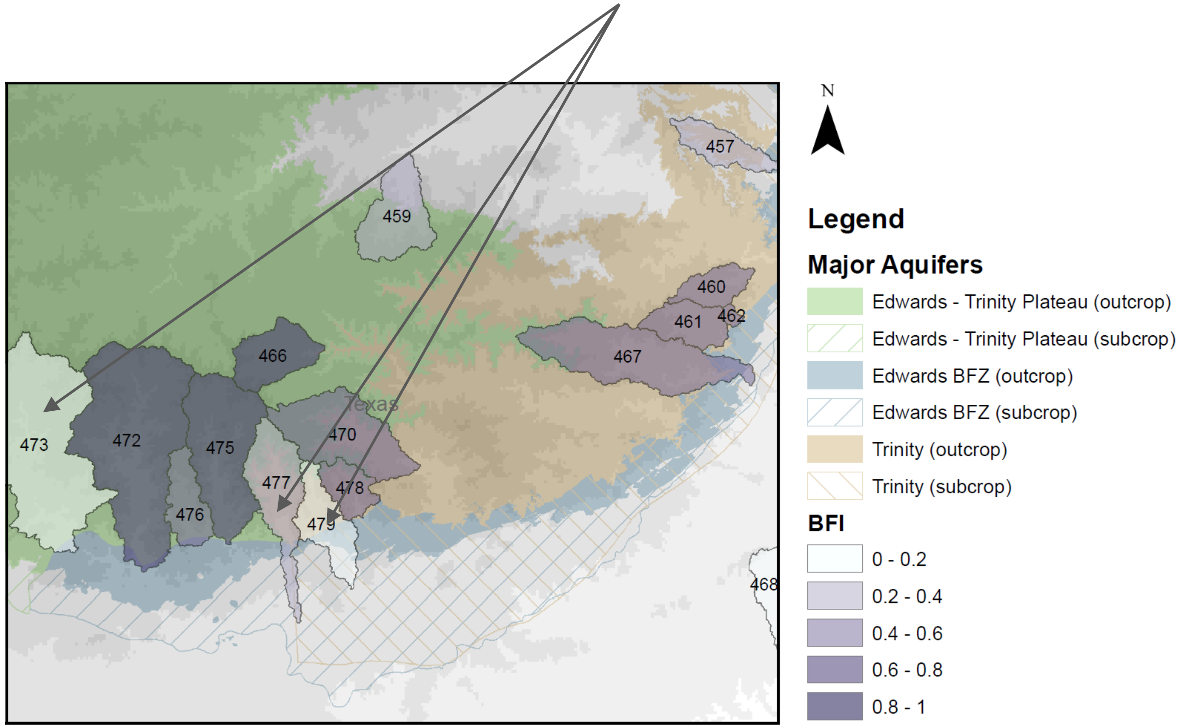

Fig.4 Edwards-Trinity aquifer system[8]

Example 3: Bedrock covered by glacial deposits

- Huge parts of North America are overlain by glacial deposits from one or several glaciations
- These deposits effectively mask the underlying bedrock (e.g. carbonate rock in Michigan or Indiana)
- Areas covered by thick sediment layers require a proper description of the hydrological properties of the sediments rather than the bedrock

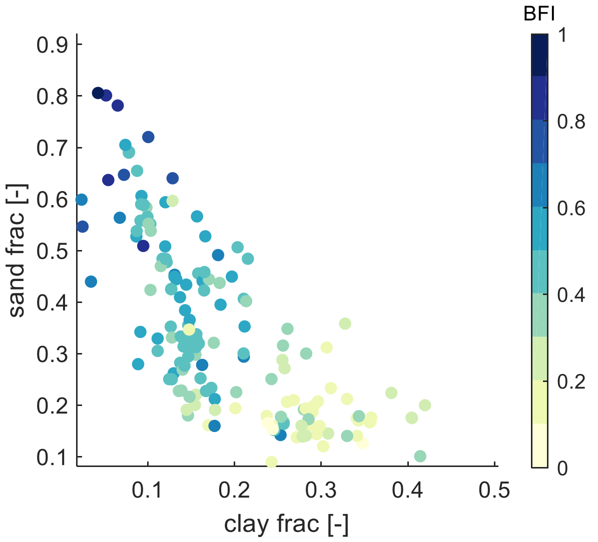

Fig.5 Soil texture strongly controls the BFI in areas covered by **glacial** desposits (rather than bedrock properties)

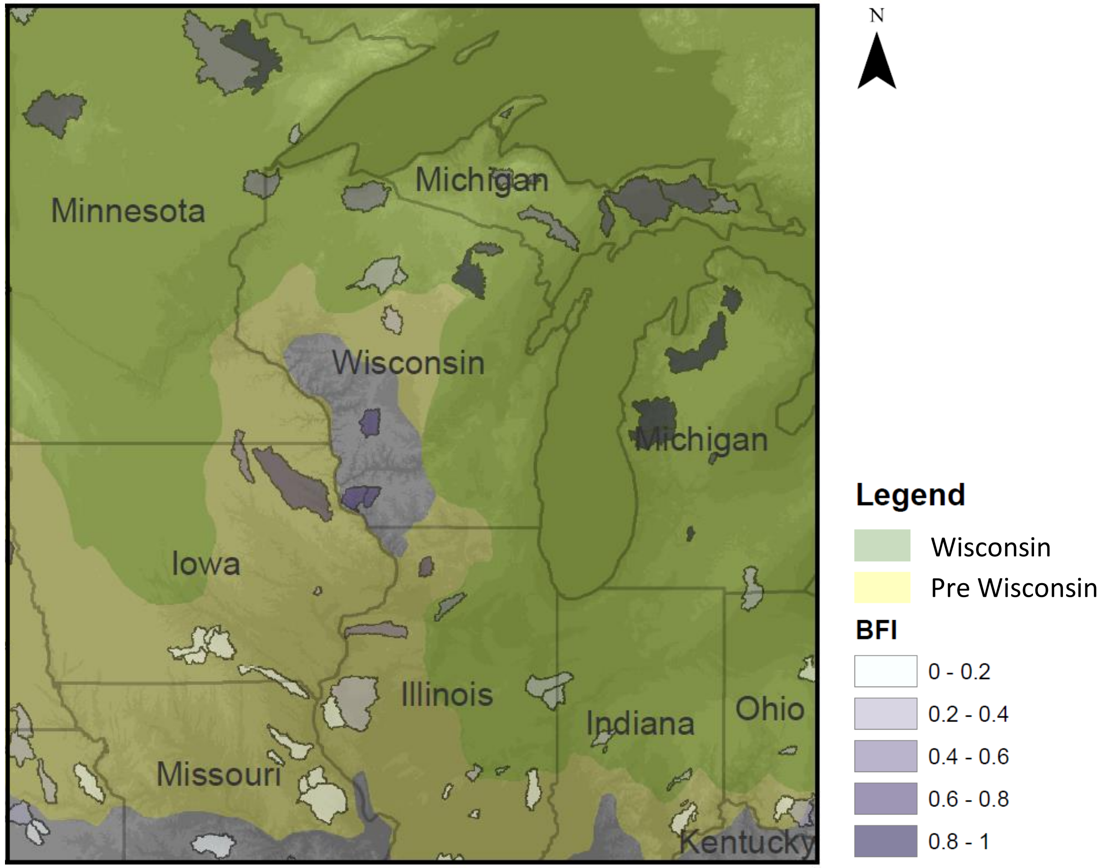

Fig.6 Formerly glaciated areas during the Winsconsin or previous glaciations[10]

Preliminary conclusions and next steps

- **Geology and other catchment attributes matter**. But sometimes we need to look closer or find additional data to better characterise the subsurface (such data often exists!)
- We will extend this analysis to other regions and more signatures (e.g. recession parameters). Eventually, our aim is to **include local knowledge into a global framework** ("balance depth with breadth"[10])
- Standardised **perceptual models** will enable us to organise our knowledge across different places

References and Data Sources

[1] Beck, H.E., De Roo, A. and van Dijk, A.I., 2015. Global maps of streamflow characteristics based on observations from several thousand catchments. Journal of Hydrometeorology, 16(4), pp.1478-1501.

[2] Addor, N., Nearing, G., Prieto, C., Newman, A.J., Le Vine, N. and Clark, M.P., 2018. A ranking of hydrological signatures based on their predictability in space. Water Resources Research, 54(11), pp.8792-8812.

[3] Addor, N., Newman, A.J., Mizukami, N. and Clark, M.P., 2017. The CAMELS data set: catchment attributes and meteorology for large-sample studies. Hydrology and Earth System Sciences (HESS), 21(10), pp.5293-5313.

[4] Gleeson, T., Moosdorf, N., Hartmann, J. and Van Beek, L.P.H., 2014. A glimpse beneath Earth's surface: GLobal HYdrogeology MaPS (GLHYMPS) of permeability and porosity. Geophysical Research Letters, 41(11), pp.3891-3898.

[5] https://apps5.mo.gov/geostrat/

[6] https://pubs.er.usgs.gov/publication/ds1052

[7] https://water.usgs.gov/ogw/aquifer/map.html

[8] http://www.twdb.texas.gov/mapping/gisdata.asp

[9] https://purl.stanford.edu/vz874sc7648

[10] Gupta, H. V., Perrin, C., Blöschl, G., Montanari, A., Kumar, R., Clark, M., and Andréassian, V.: Large-sample hydrology: a need to balance depth with breadth, Hydrol. Earth Syst. Sci., 18, 463–477, https://doi.org/10.5194/hess-18-463-2014, 2014.