A General Perspective of Discharge-Area Relationship during Recession

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Introduction:

- Major challenge in Hydrology - To predict discharge without any historical data
- One of the Solutions – Understanding how drainage basins function

Linking: Basin response ⟺ Physiological characteristics

- Focus so far: Understanding linkage between **Peak discharge** and **Area of basin**

$$Q_p \propto A^\theta \quad (1)$$

where, the exponent θ takes values between 0.5 to 1

- Most famous argument (Rigon et al., 2010)- Flood peak is controlled by basin Width Function W(x)

(W(x) is the probability distribution of distances, x, between any point in a basin and the outlet measured along stream channel)

Aim and Theoretical background:

We extended the Discharge-Area analysis to **Recession** domain

Aim: To analyse variation of exponent (θ) in equation (1) during recession

Hypothesis: Discharge becomes linearly related to the basin area as recession progresses

Theoretical background:

- Rainwater may follow different flow paths to reach the basin outlet
- We assumed two dominant flow processes to exist in natural basins

  Pure Surface Flow (PSF): Raindrops following quick path to reach nearby stream

  Mixed Surface Sub-surface Flow (MSSF): Raindrops entering the sub-surface and following local or regional path to reach the streams

- Dominant flow process during recession - **MSSF**

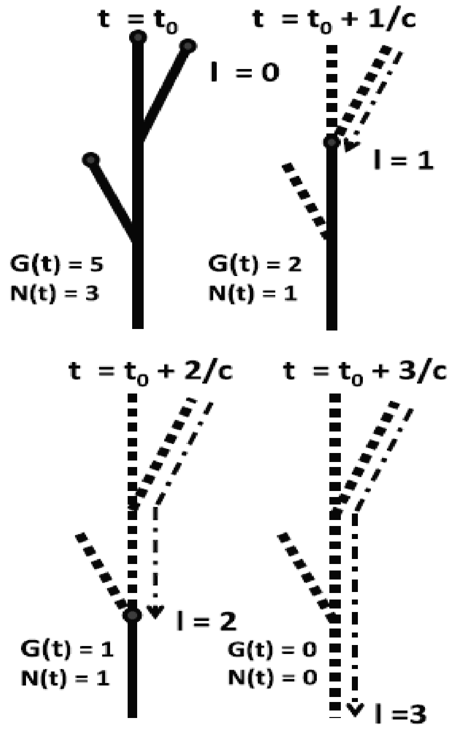
Mixed Surface Sub-surface Flow (MSSF):

- During recession, discharge (MSSF) at the outlet $Q(t) =$ Aquifer storage drained by the channel networks intersecting it

$$Q(t) = q.G(t) \qquad (2)$$

Where, $G(t)$ is total length of the saturated stream network or active drainage network (ADN) at t,

q is the discharge per unit length drained by ADN



Biswal and Marani,2010

- Channelled flow path will desaturate progressively in the downstream direction
- A stream link will contribute discharge at the outlet as long as its upstream links are saturated
- Assumptions- q and the rate (c=dI/dt) at which source links recede remains constant in space and time

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- Integration of eq. (2) gives:

$$\frac{dQ}{dt} = q.\frac{dG}{dt} = -qcN(t) \quad (3)$$

where, $N(t)$ = the number of channel sources in the ADN at time t

- As, $c = d\text{l}/dt$ is constant for a basin, we can rewrite eq. (2) as

$$Q(t) = q.G[(\text{l}(t)] \quad (4)$$

$$dQ/dt = -q.c.N[\text{l}(t)] \quad (5)$$

where, G(l) - total length of the ADN at a distance greater or equal to l downstream of the sources of the initial ADN configuration and

N(l) - number of sites located at a distance l from the sources of the initial ADN configuration

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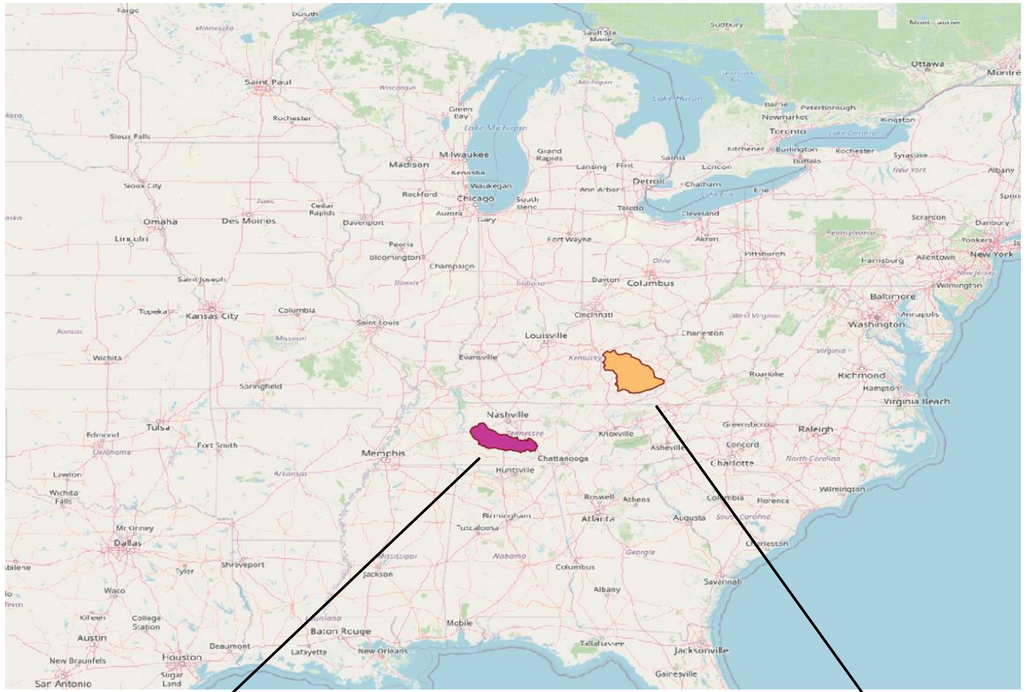
- From eq. (3) and Eq. (4), we can write

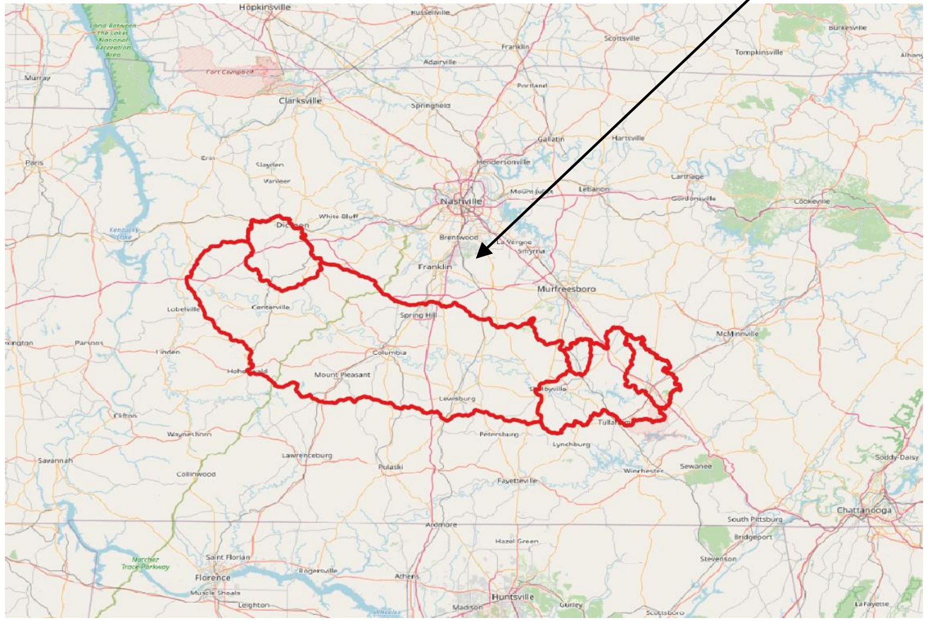
$$Q(t) \propto G(l) \text{ and}$$

$$\frac{dQ}{dt} \propto N(l)$$

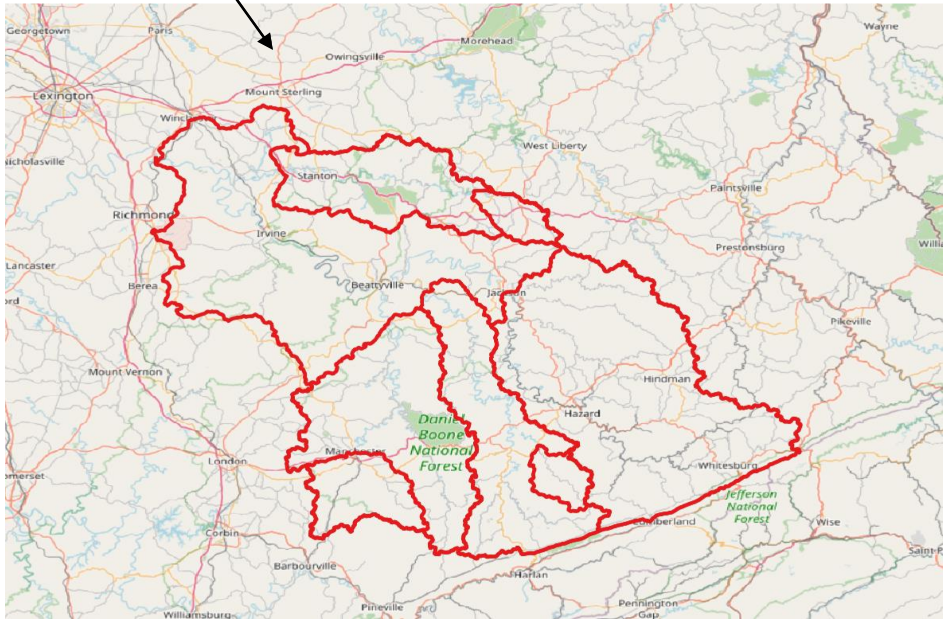
- $G(l)\ vs.\ N(l) \Longleftrightarrow Q(t)\ vs. \frac{dQ}{dt}$, Power-law relationship with similar values of the exponent -(Biswal and Marani, 2010)
- G(l) is linearly related to the basin area as a result of Smart (1972)'s constant drainage density assumption -(Biswal and Marani, 2014)
- Thus, Q is linearly related to the basin area during recession

Study Area:





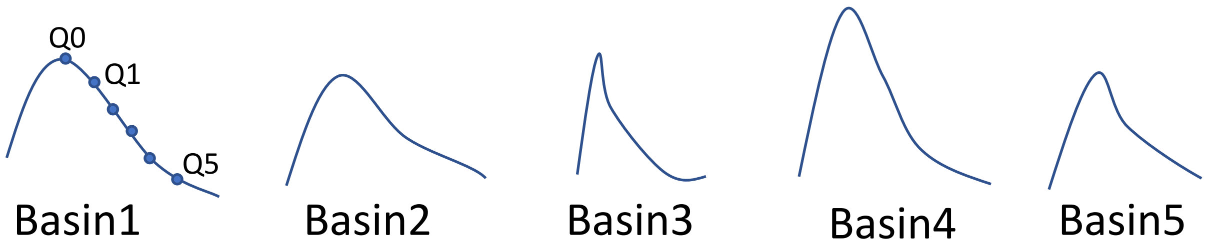
Duck Basin



Kentucky Basin

Methodology:

- Recession periods were identified for each study basin and its sub-basins
- Recession discharge values (Qn, n=day after the peak) in basin and its sub-basins are noted and regressed with their areas



- We used Budyko-GHRM model to support our assumed hypothesis of process 2 dominating during recession period
- Dynamic Budyko model (Biswal, 2016) - Effective rainfall (ER) estimation
- GHRM (Biswal and Singh, 2017) – Channel network morphology based routing of ER

Results:

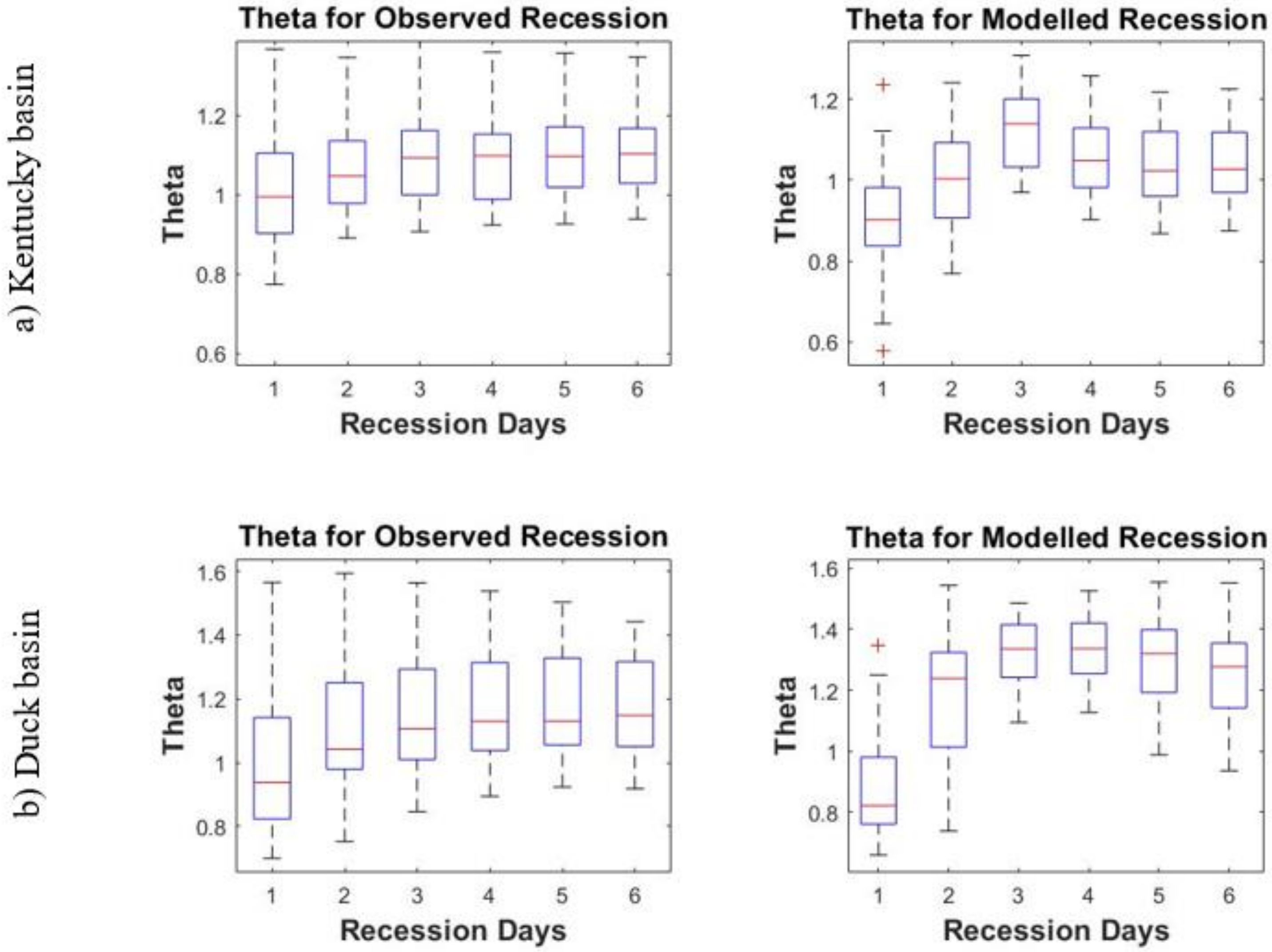


Fig.2 Variation of θ_n with n for observed recession discharge and modelled recession discharge for a) Kentucky basin and b) Duck basin

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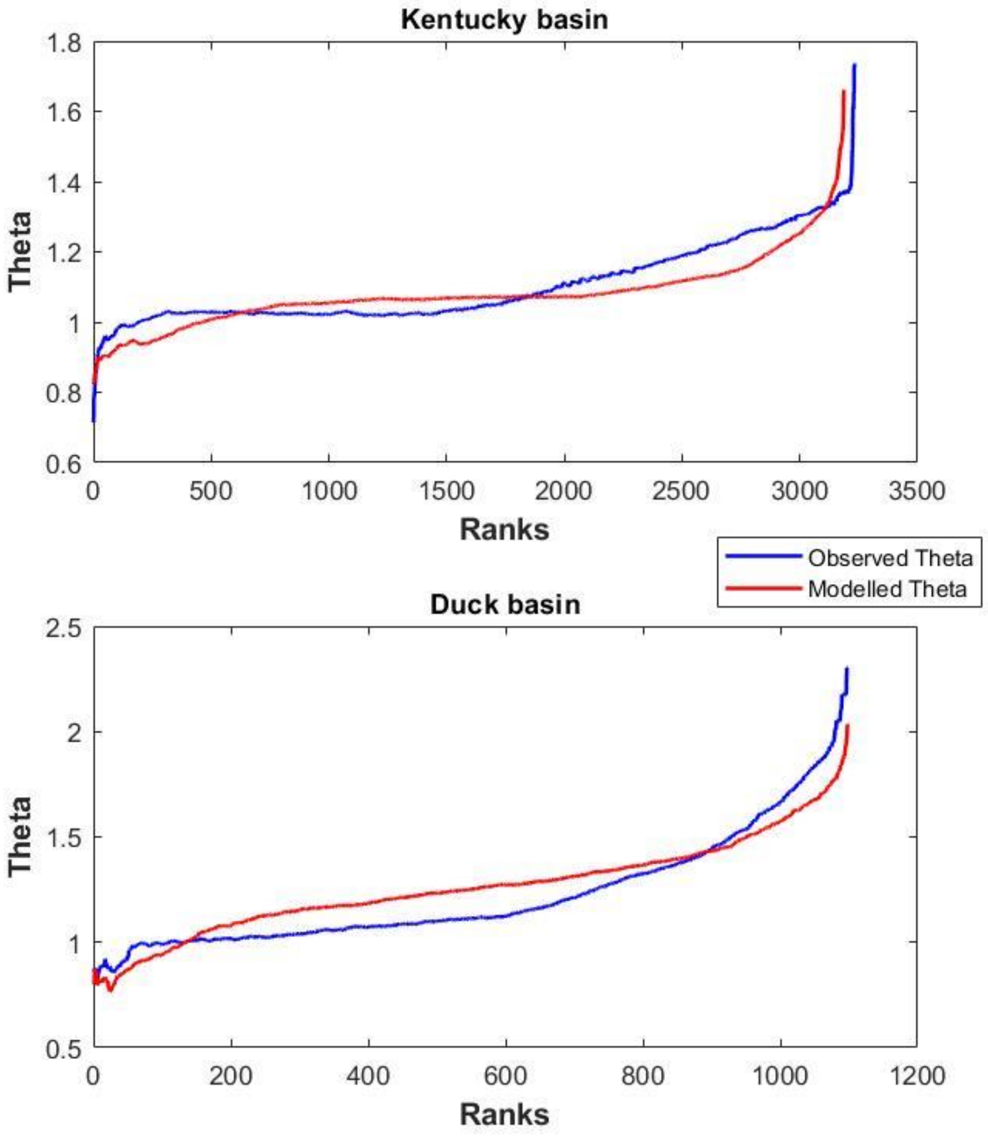

Fig.3 Variation of θi with rank for observed recession discharge and modelled recession discharge

Results and Discussion:

- θ_n was found to be increasing and approaching 1 with increasing n
- For both observed as well as modelled recession discharge θ_n shows increasing pattern in the beginning and then remains almost constant to a value close to 1
- θi initially increases to remains fairly constant till the scaling relationship breaks and then increases nearly exponentially for lower discharge values
- This supports the notion that MSSF dominates as n increases

Thank You