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Comparison of hydrological control in streamwater residence times across headwater catchments

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Introduction

Questions about Mean Residence (or Transit) Times (MRTs or MTTs)…

- ✓ What are the meaning of MRTs…?
- ✓ How to estimate the correct MRTs. All tracer can show the same estimates?
- ✓ How the estimated value can be applied to other related studies?
- ✓ How the MRTs decided in each catchment?? ⇐ *Main topic of this study*

Objective

To compare / consider the controlling factors of streamwater mean residence time across the catchments

⇒ Inter-catchment comparison from various regions in 29 headwater catchments from 9 sites across Japan.

To find key parameters need to consider for future detailed works

Conclusions

- ✓ Recharge process is dominant at (some of) smaller catchments; Much water infiltrate into the deep, bedrock layer, and does not contribute to the stream within the concerned catchment.
- ✓ Discharge process will be dominant at larger catchments; The water passed through bedrock layer will contribute to stream
- ✓ Hydrological processes will be related with MRTs.
- ✓ Simple parameters, water budget and annual runoff ratio, are useful for the catchment classification and future comparative studies

Sites & Samples

$\delta^{18}O$ of Rain & Stream water from

9 sites, 29 catchments, 0.086 - 49.7 ha

- Chiba: 2 catchments, 0.802-1.1ha
- Tanzawa: 3 catchments, 5-47ha
- Surumi: 1 catchment, 10.4 ha
- Kiryu: 5 catchments, 0.086-5.99 ha
- Fudoji: 3 catchments, 1.9-49.7 ha
- Ashiu: 4 catchments, 7.95-16.1 ha
- Aburahi: 1 catchment, 3.34 ha
- Gomadan: 9 catchments, 3.15-23.92 ha
- Hiruzen: 1 catchment, 5.93 ha

Approach

Catchment inverse transit time proxies (ITTPs)

Tetzlaff et al. (2009 HP)

ITTPs…? a simple metric of isotopic tracer damping

MRT estimation by stable isotope in water considers Damping of variation & Transmission of wave phase.

$$\text{ITTPs} = \frac{s.d.\ \text{of}\ \delta^{18}\text{O in Streamwater}}{s.d.\ \text{of}\ \delta^{18}\text{O in Rainwater}}$$

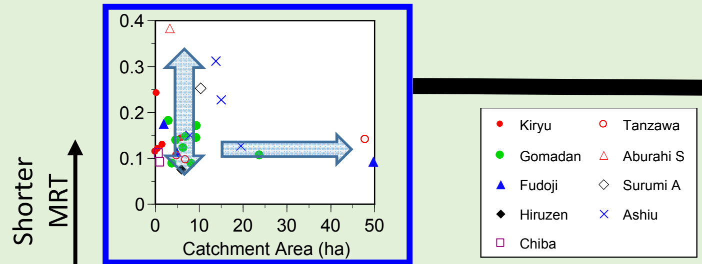
Larger ITTPs = less damping = shorter RTs

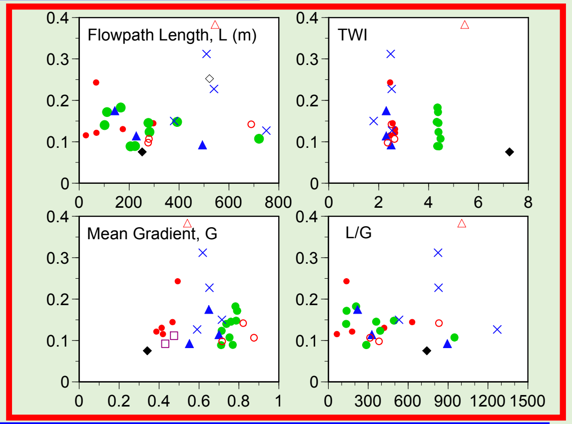
Smaller ITTPs = greater damping = longer RTs

ITTPs can be readily applied to different sites particularly within inter-catchment comparison (Tetzlaff et al., 2009)

Results & Discussions

Topographic control…?





Inter-Catchment variation

- ✓ Smaller catchments have variations of MRTs
- ✓ Larger catchments have longer MRTs

Intra-Catchment variation

- ✓ In each site, TWI and G are similar, and L, and consequently L/G, are large variation
- ✓ However, variations of ITTPs are small
- ✓ So, topographic control seems weak

Certainly, any parameters cannot explain uniformly for all catchments

Hydrologic Parameters – Water budget – Bedrock Infiltration

$P - Q = ET + B + \Delta S$

Annual Loss

Bedrock infiltration Fluctuate depending on annual *P*.

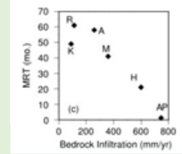
Evapotranspiration Roughly constant every year.

Small, mountainous, headwater = Recharge area, as well as Discharge area for perennial stream flow

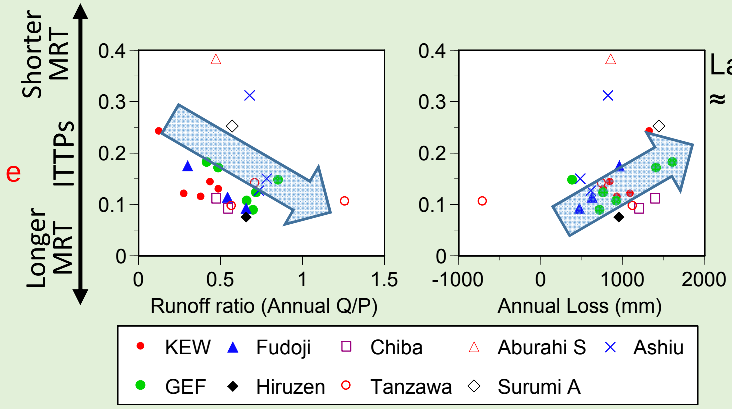
⇓

Recharge processes control MRT!

Subcatchments with shorter MRT had larger bedrock infiltlation in Kiryu catchment. (Katsuyama et al. 2010 HP)



Larger *Q/P* ‖ Discharge >> Recharge ‖ Longer MRT



Larger Annual Loss ≈ Larger Bedrock infilt. ‖ Shorter MRT

Smaller catchments (< 10 ha) … *Two types*

Recharge dominant catchments

Small *Q/P*, Large Loss (or large *B*) = Stream is mainly fed by Shallow Soil W. = Shorter MRT

Discharge dominant catchments

Large *Q/P*, Small Loss (or large *B*) = Stream is fed by both Shallow Soil W. & Deep GW = Longer MRT

Larger catchments (> 10 ha) … **Discharge dominant**

Large *Q/P*, Small Loss (or large *B*) = Stream is fed by both Shallow Soil W. & Deep GW = Longer MRT

Water budget can reveal the hydrologic control on MRT of stream