第四届全国稳定同位素生态学学术研讨会暨中国生态学会稳定同位素生态学专业委员会2017年学术年会

氘盈余在干旱区水文学中的应用

Deuterium excess in arid zone hydrology

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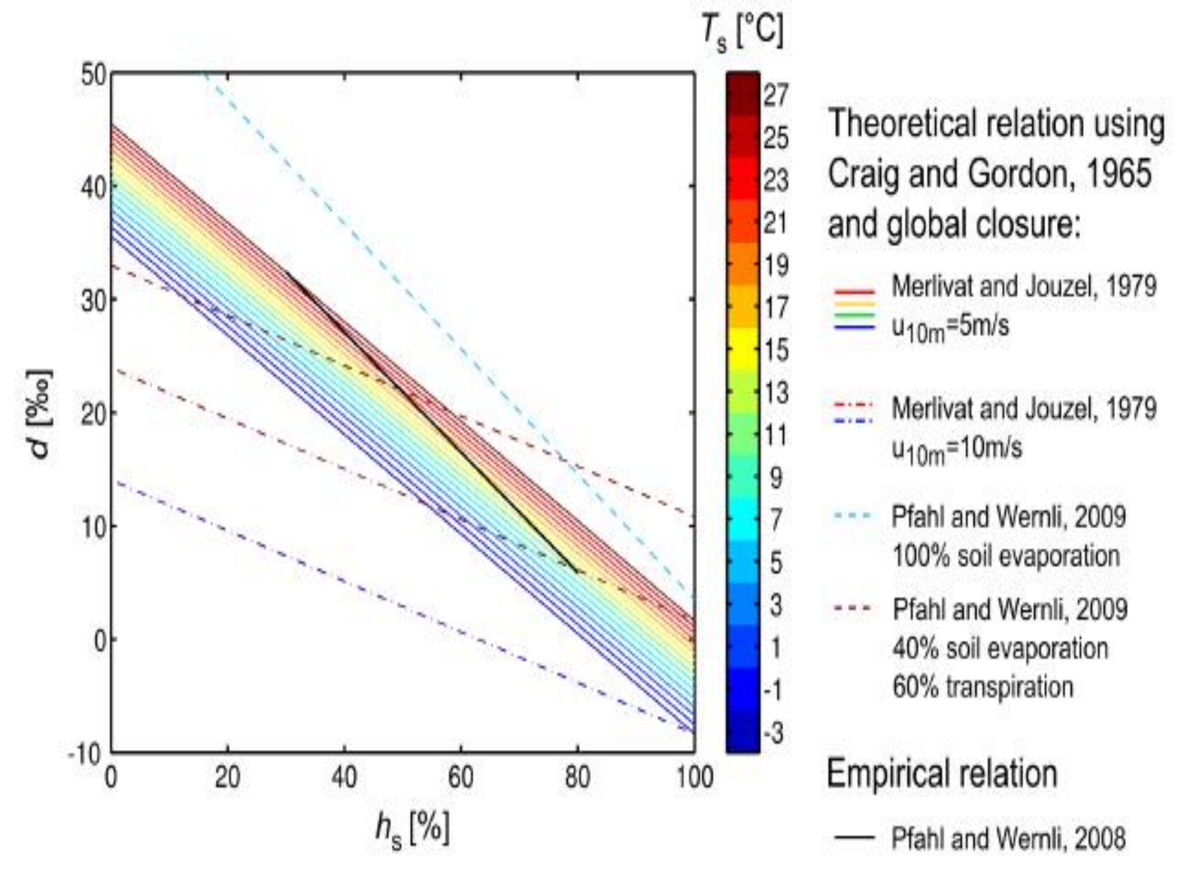
Contents 提纲

- Monitoring and modeling 观测与模拟
- Identification of moisture sources 水气源识别
- Quantification of recycled moisture in precipitation 再循环水汽比例确定
- Distinguishing salinization mechanisms 水体盐化机理
- Conclusions 结论

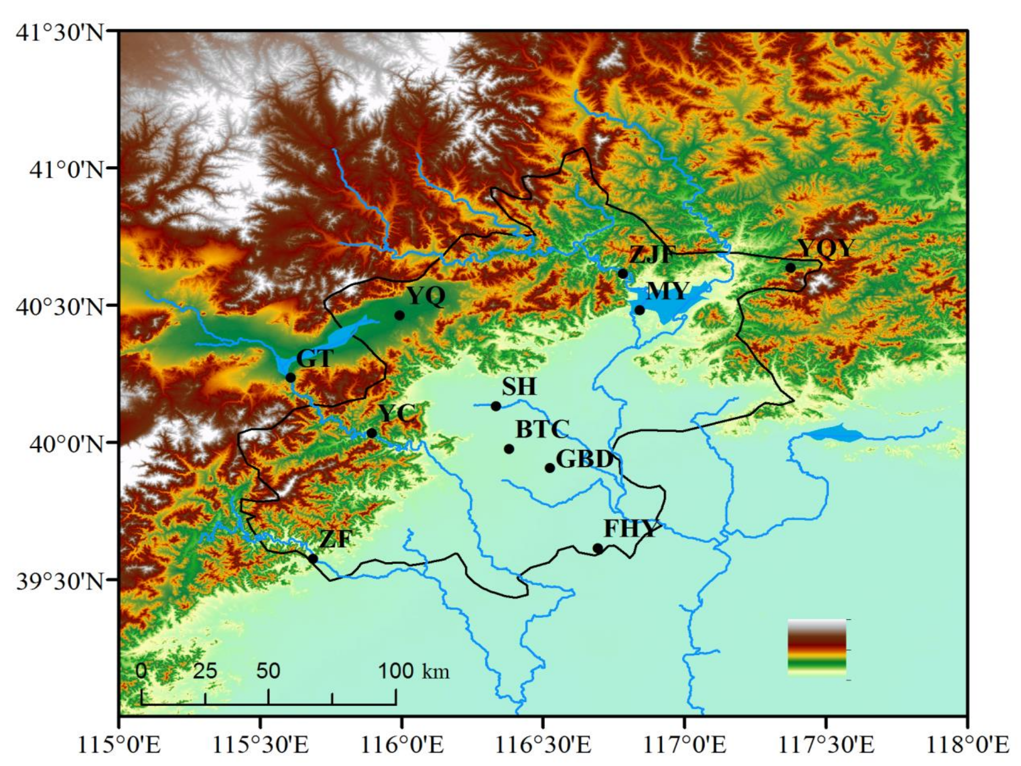
Monitoring and modeling

- **Definition:** d=$\delta^2H-8\delta^{18}O$ （Dansgaard,1964)
- **Affecting factors:** vapour source, relative humidity, SST, wind speed

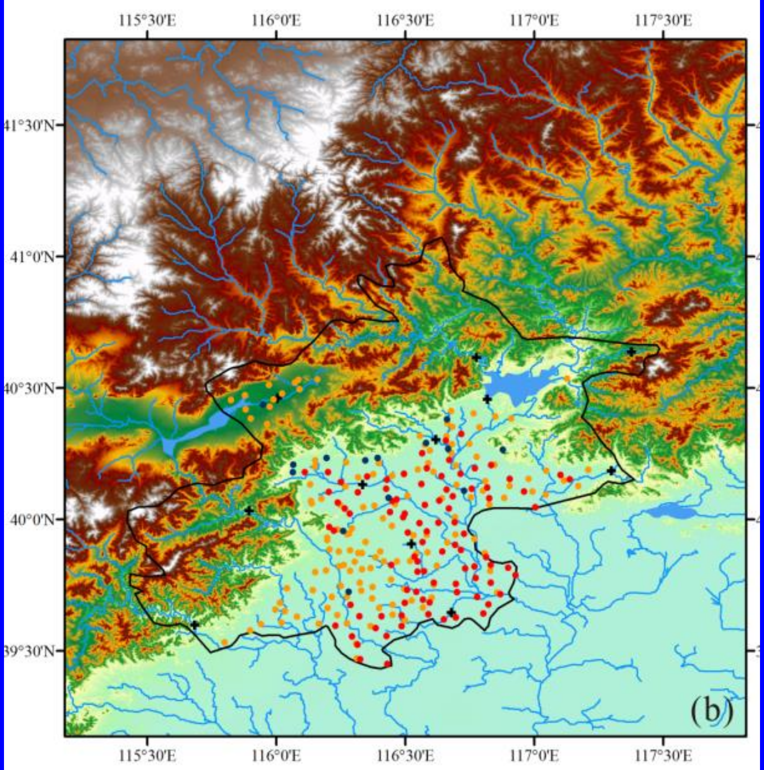


（Aemisegger, 2014)

BNIW: Beijing Network of Isotopes in Waters



Precipitation



Groundwater

- **Precipitation:** event-based, in operation since 2014
- **Groundwater:** sampling in the wet season (September) and in the dry season (April)

Precipitation stations and instruments

ZJF station

MY Station

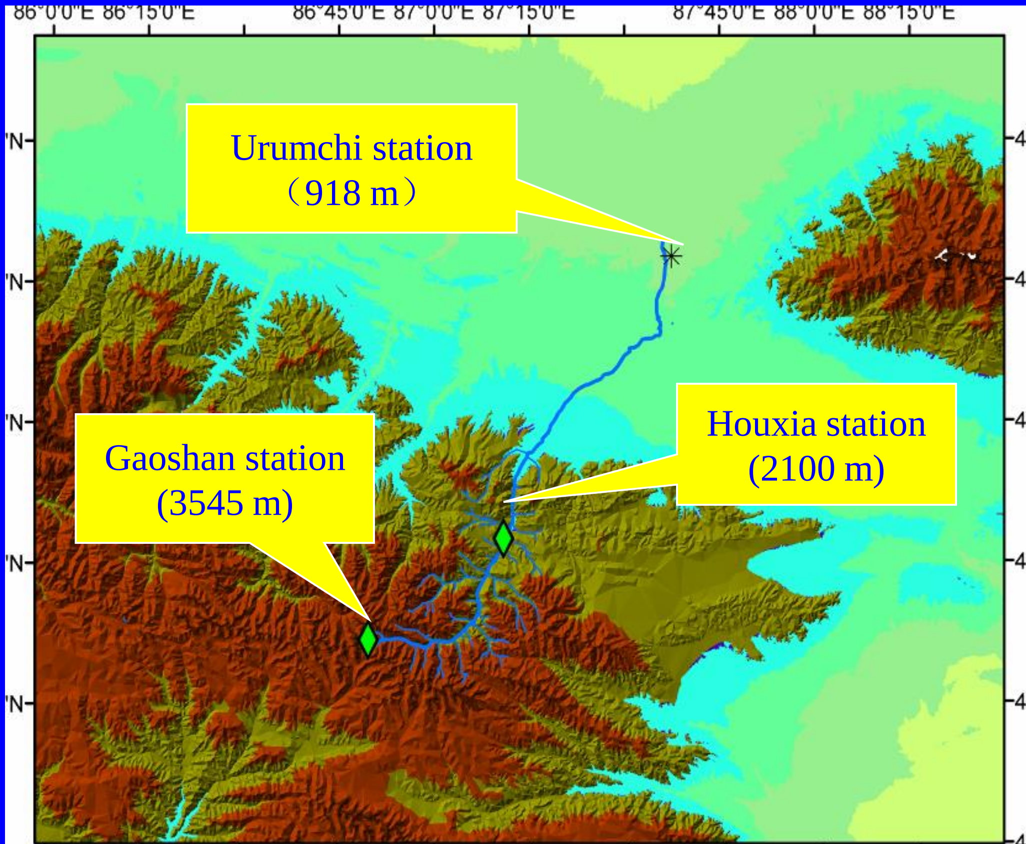
The amount of precipitation (*P*, mm), temperature (*T*, ºC), relative humidity (*RH*, %), and so on are measured at each observation station.

Automatic temperature and humidity recorder

Artificial rain gauge

Microclimate instrument

Eventful monitoring of isotopes in precipitation in Tianshan Mountains



Monitoring stations at various elevation in the Tianshan Mt.

(Pang et al., 2011, Tellus B)

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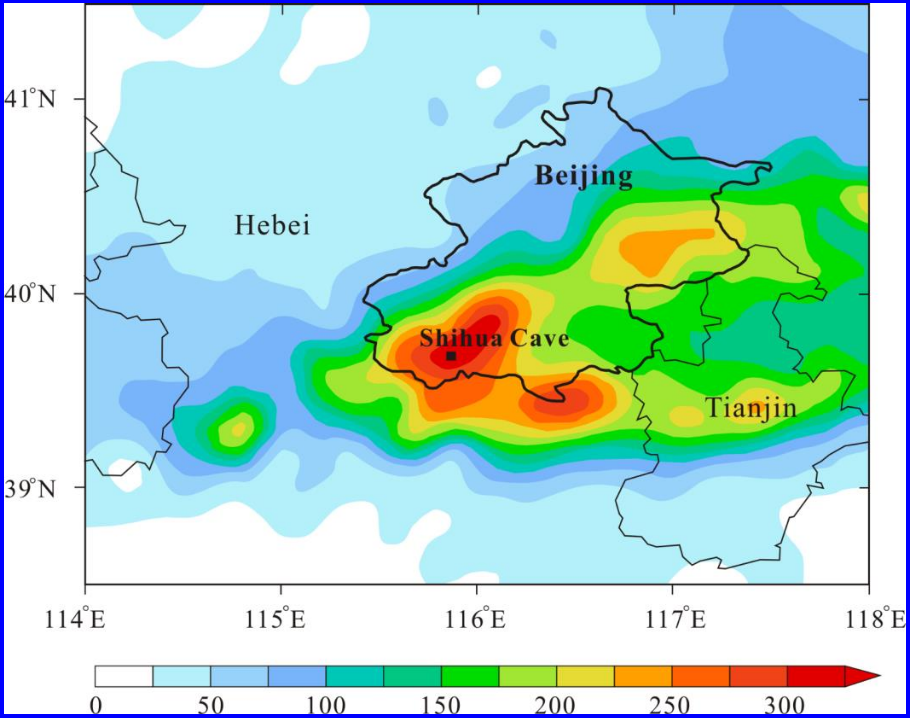
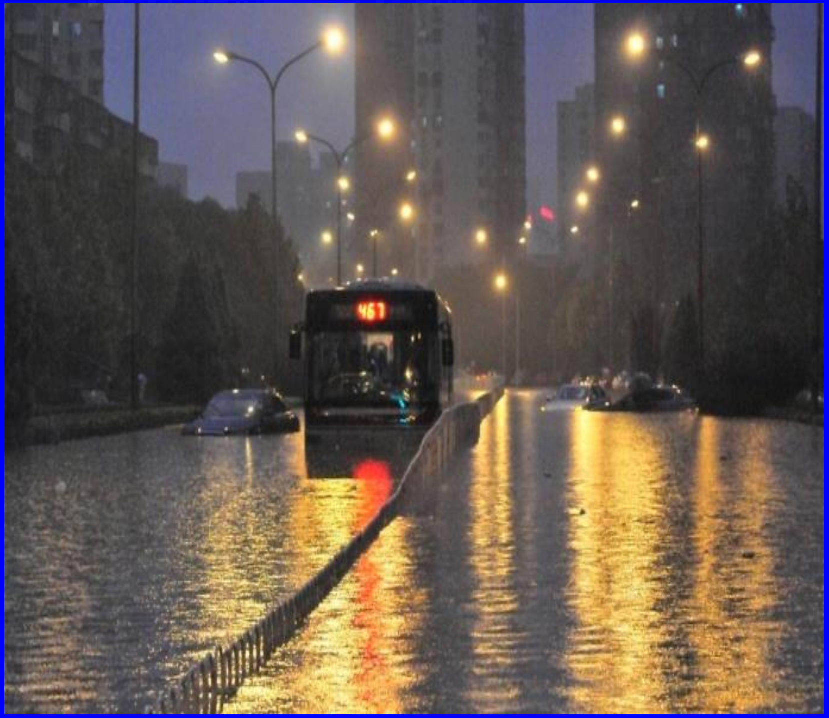
The extreme storm event in Beijing on 21 July 2012

The heaviest rainfall in 6 decades fell in Beijing on 21 July 2012 with a record-breaking amount of 460 mm in 18 h. Part of the city was heavily flooded, causing casualties and loss of properties.





Distribution of rainfall amount in 24 hours (21 -22 July） (Li et al., 2015)

The extreme storm event in Beijing on 21 July 2012

- **Our sampling at Shihua Cave (39.788N, 115.938E) is just located in the center of this extreme storm.**
- **Rain samples were collected for isotopic analyses during the entirety of the extreme storm event.**

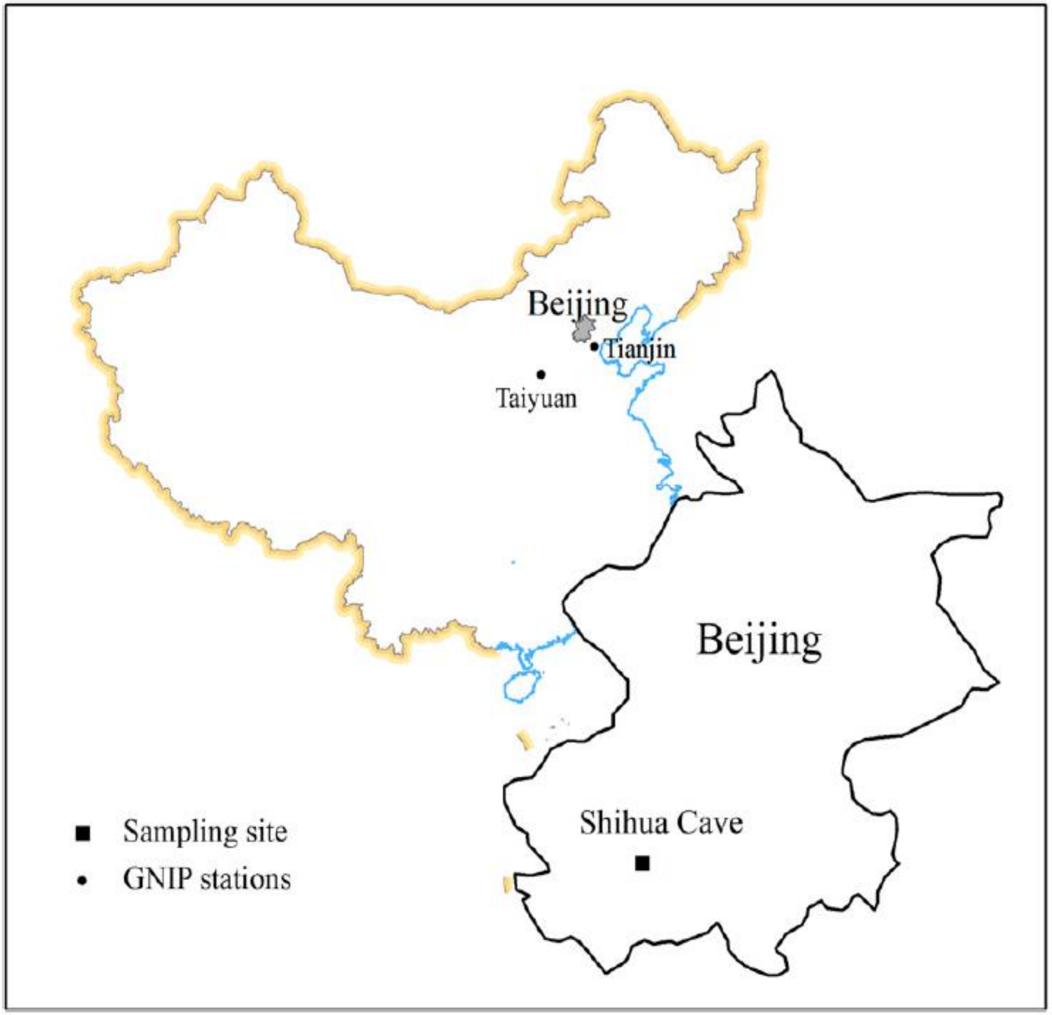
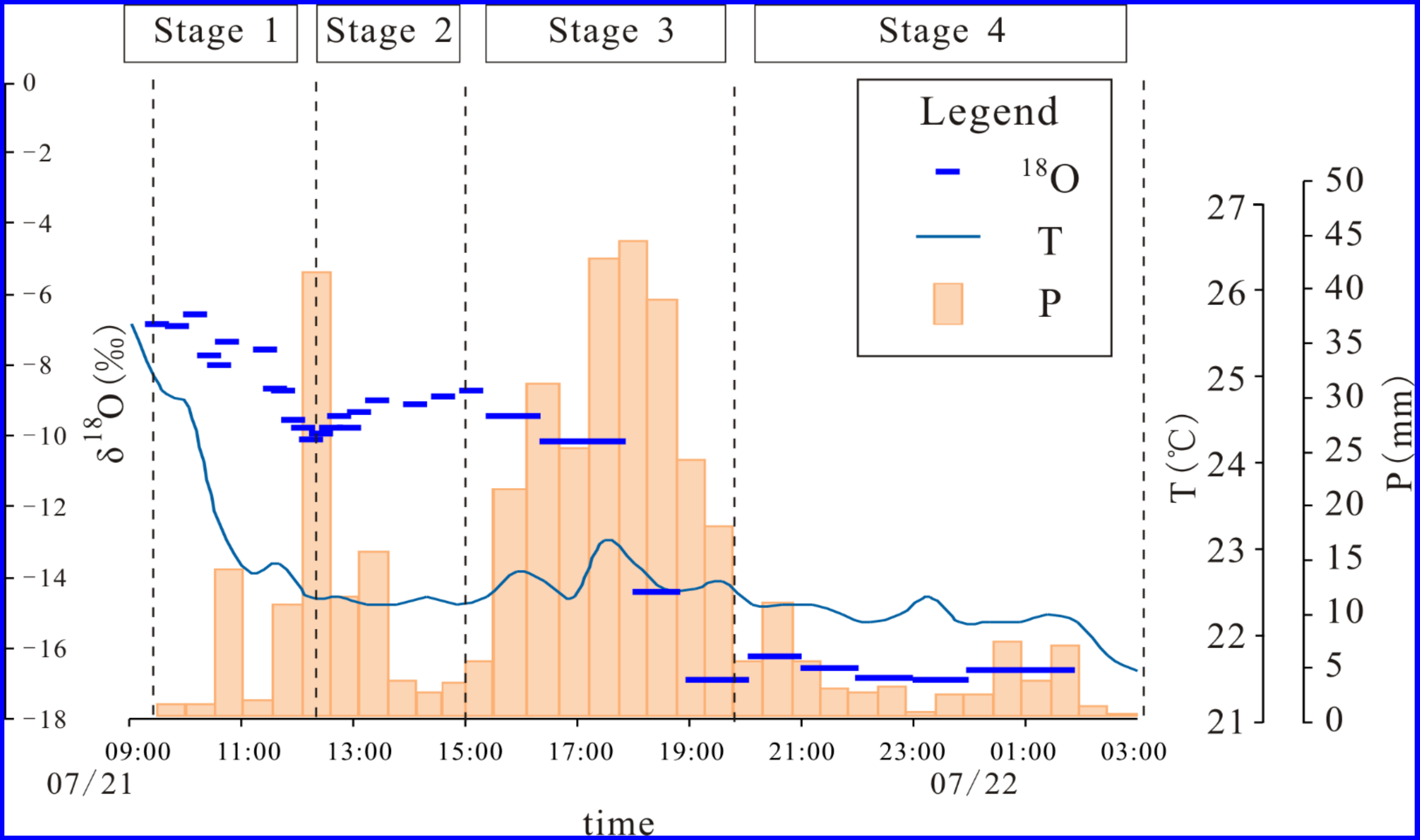


FIG. 1. Sketched map showing the sampling location and the adjacent GNIP stations.

^{18}O variations

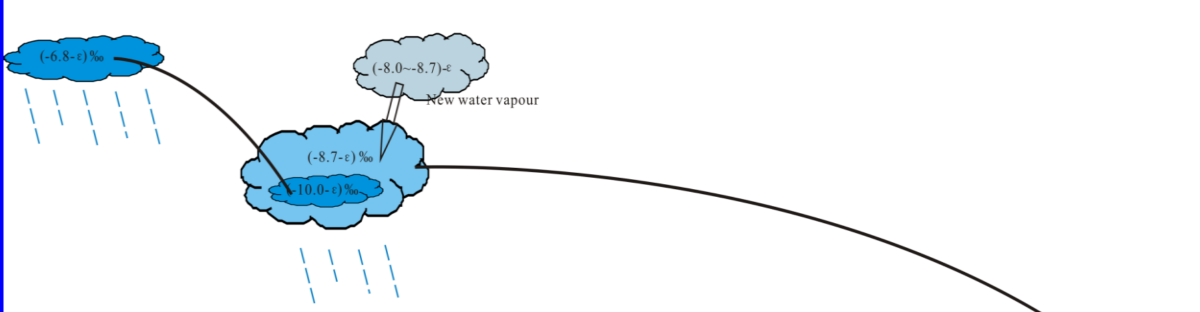


Three rainfall processes are indicated :

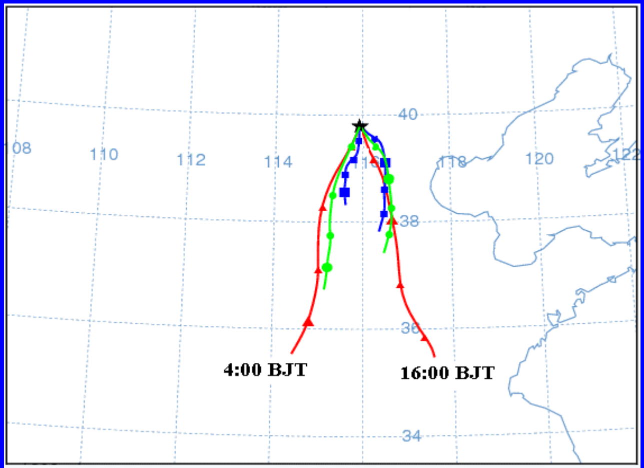
- **single-vapor source rainfall (stage 1)**
- **mixing of two vapor sources (stage 2)**
- **double-vapor source rainfall with strong rainout effects (stages 3 and 4)**

(Li et al., 2015)

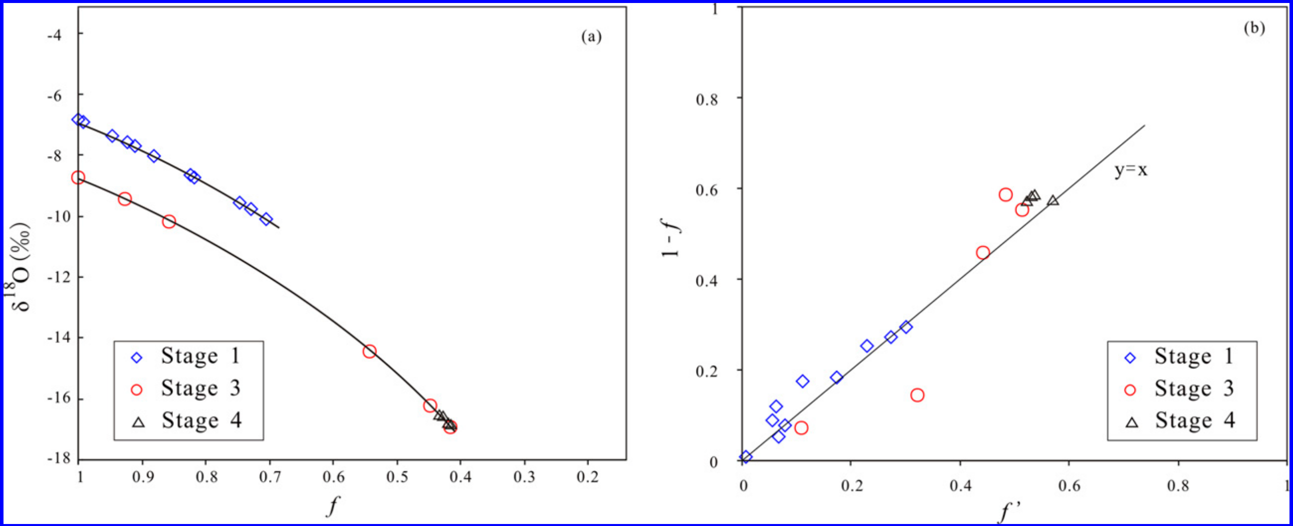
Identification of moisture sources



29% of the initial moisture was precipitated in stage 1, and 56% of moisture was precipitated in stages 3 and 4.

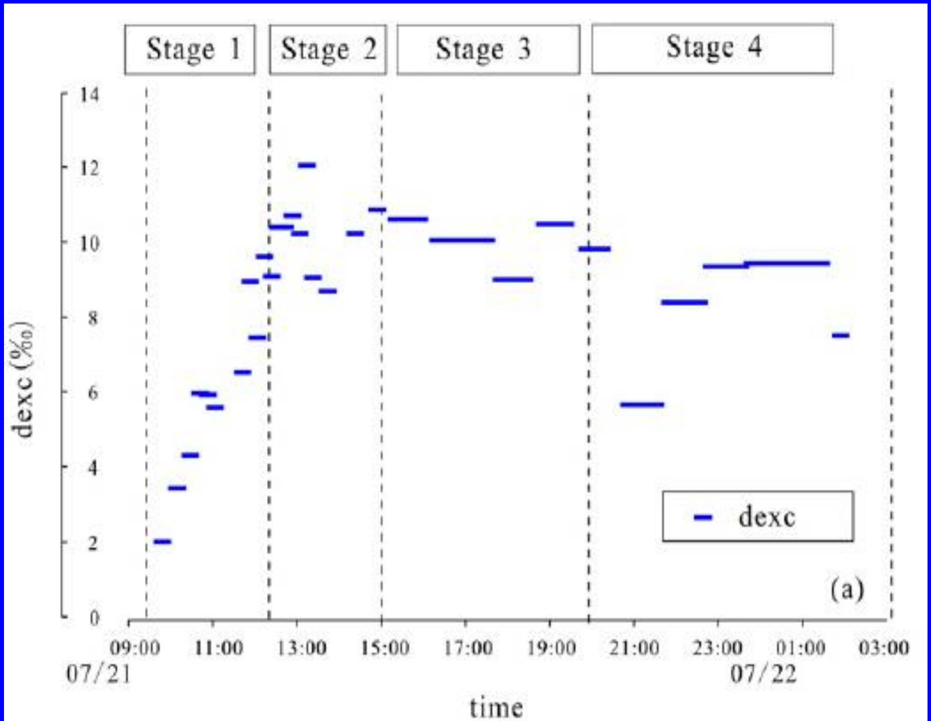


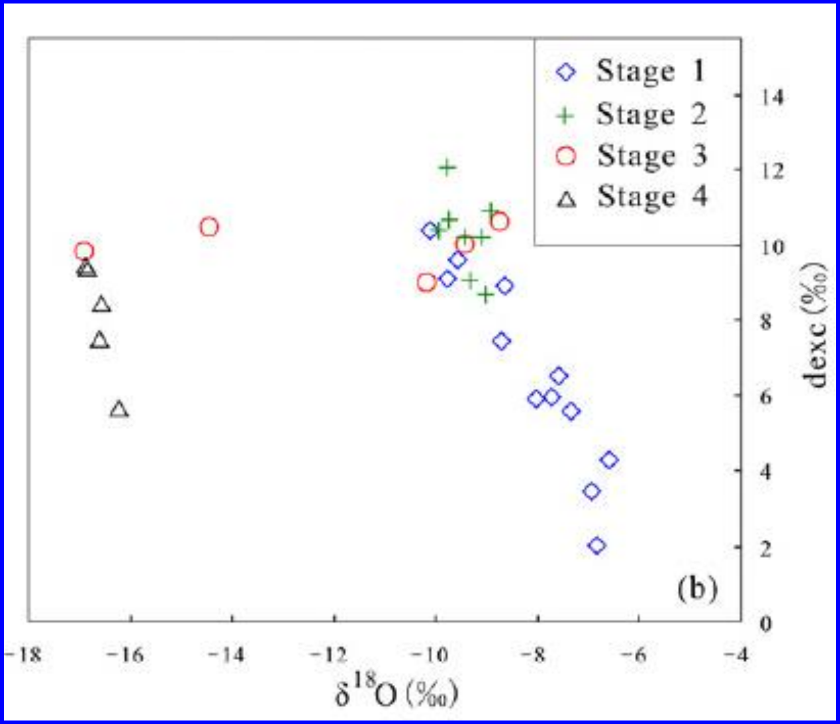
Two different moisture trajectories obtained from HYSPLIT at 0400 and 1600 LT 21 Jul 2012.



The isotopic composition was reconstructed using the Rayleigh depletion model, which demonstrates that the rainout effect is the dominant process during the rainfall event, except during stage 2.

D-excess and moisture sources in the 721 storm event





- During stage 2, deuterium excess remains around 10, suggesting back-building as the source of warm moist air, which was probably extended from offshore areas westward over Beijing.
- Two moisture sources were identified for the storm event, comprising a southwest trajectory and a southeast trajectory.

(Li et al., JHM, 2015)

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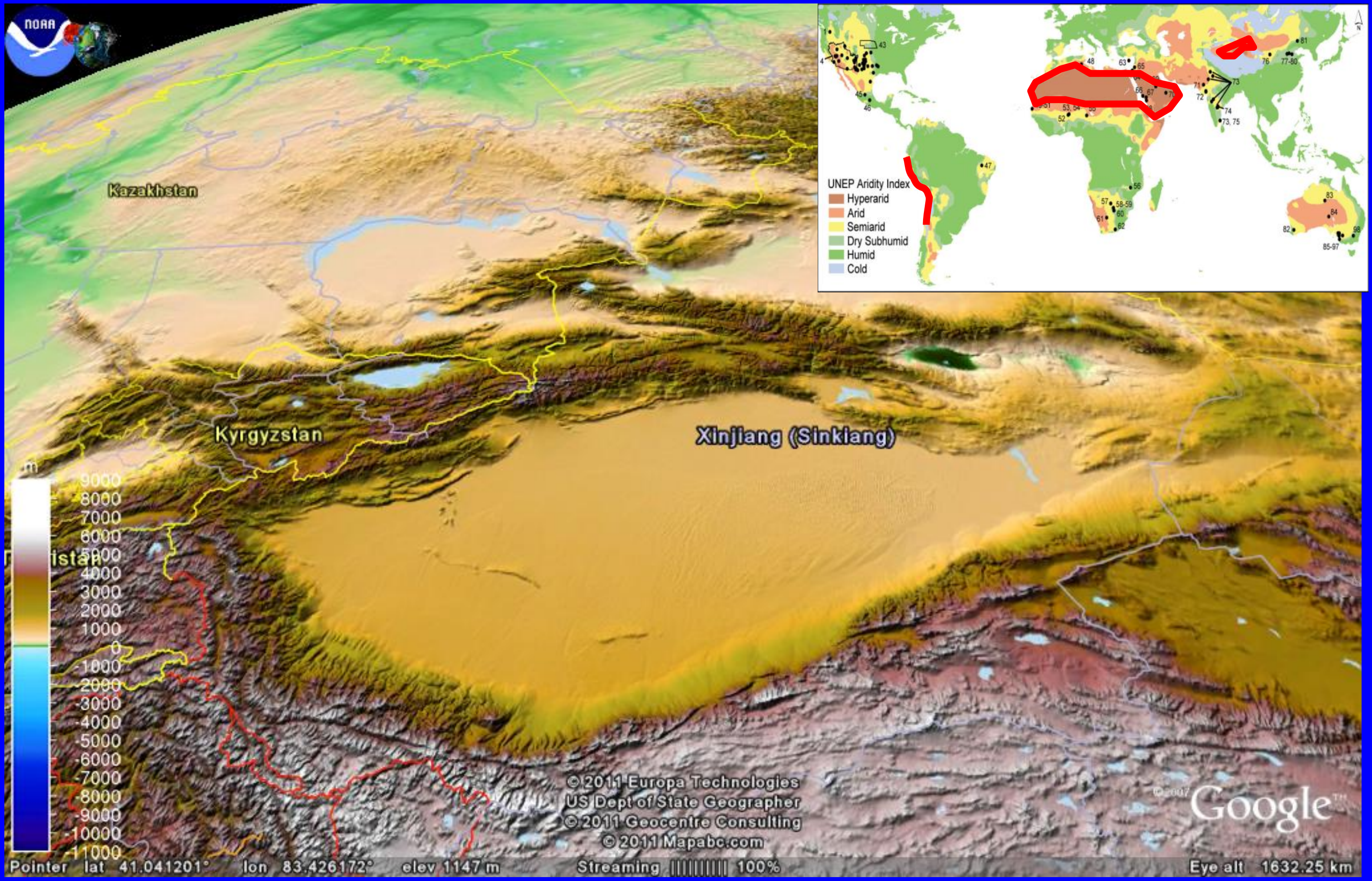
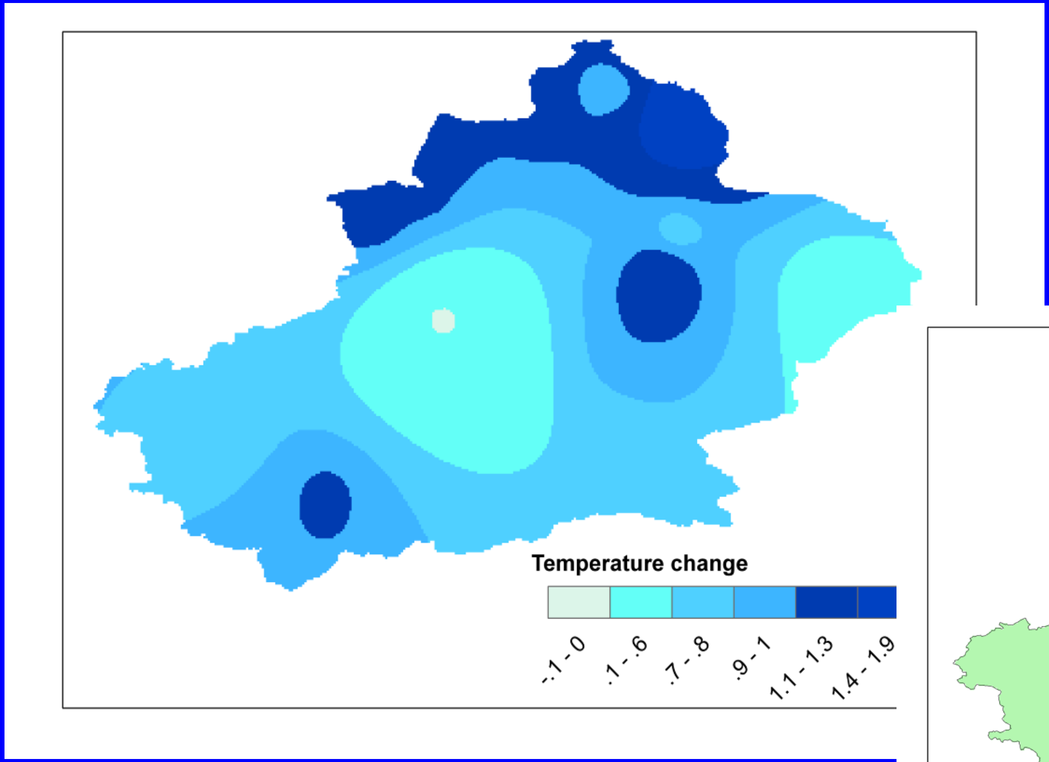
Tarim Basin in Xinjiang Uygur Autonomous region is one of the driest regions in the world

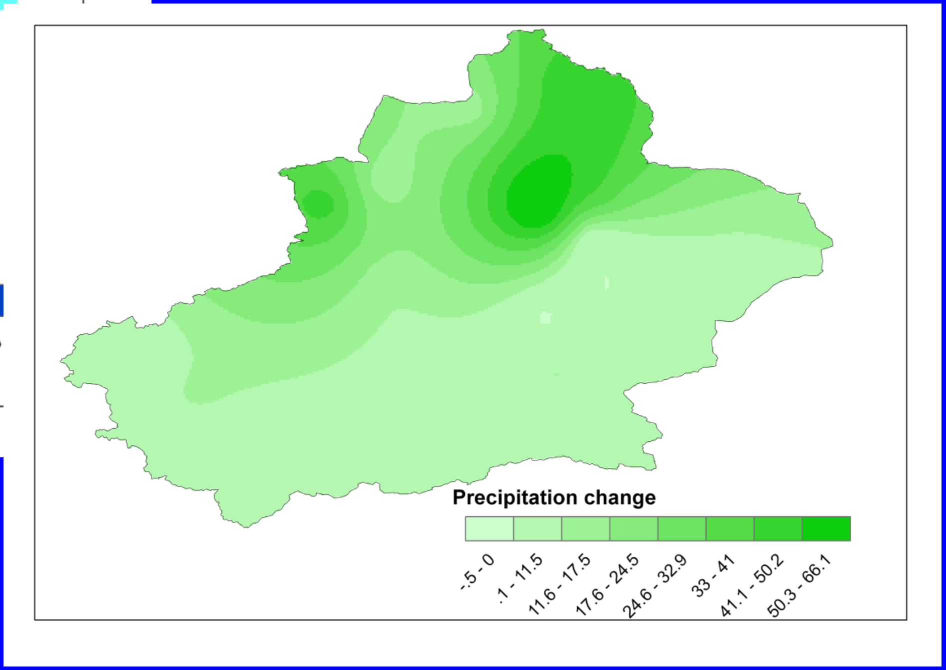


Climate change in Xinjiang is strong-causing glaciers to be quickly reduced...

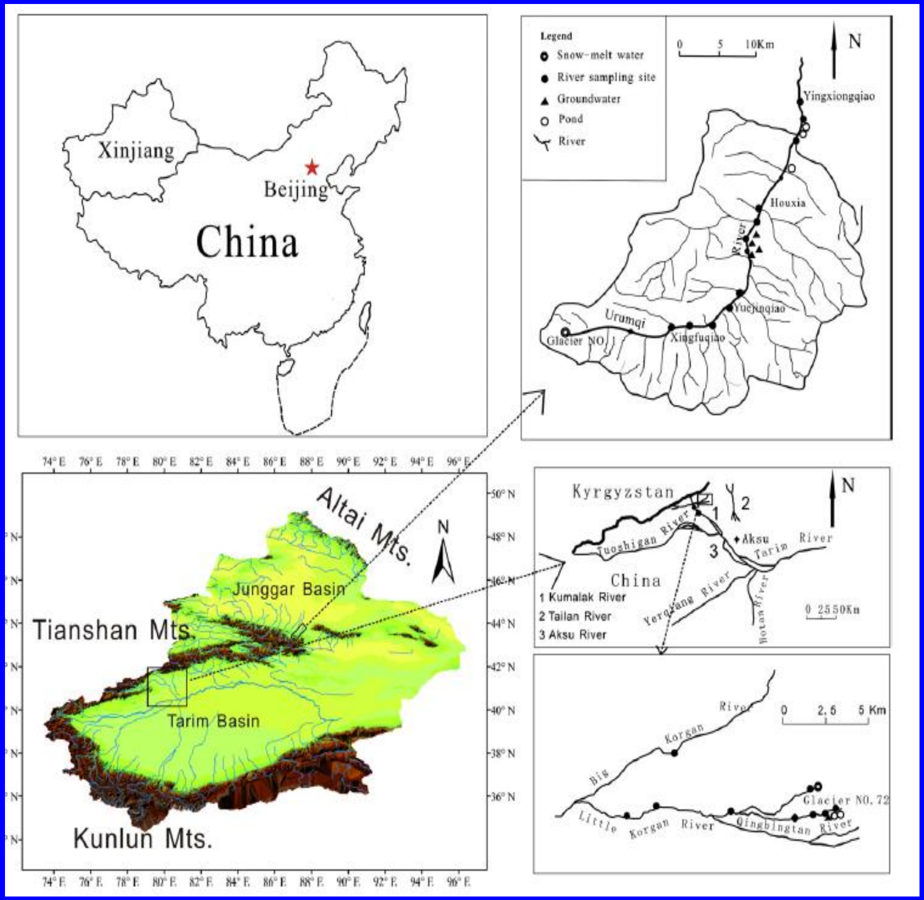


Rising in temperature

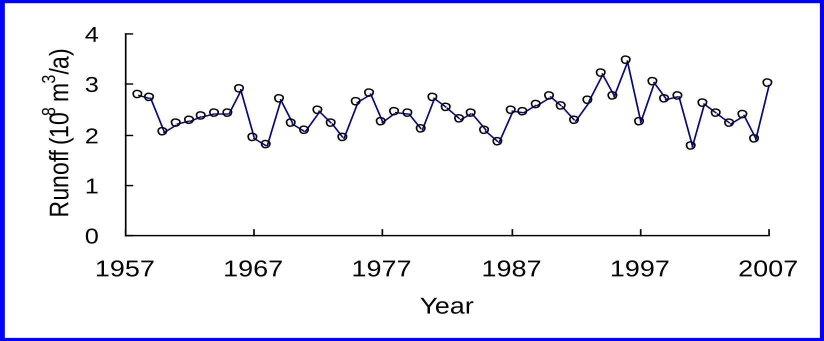
Rising in precipitation



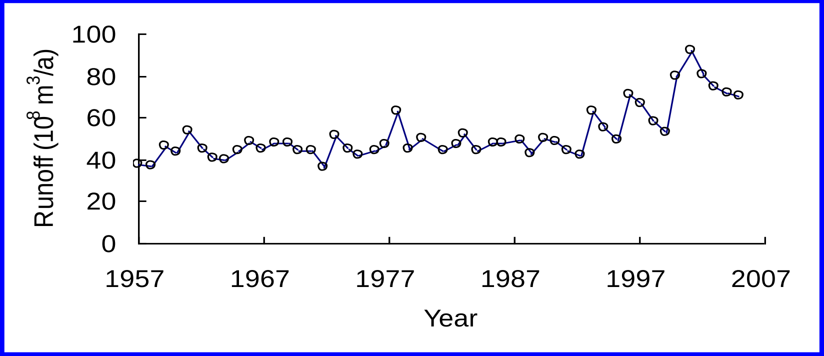
The region is sensitive to climate change, which has been recorded in rivers in the north and south regions, respectively, and heavy floods take place some times during the summer.



Urumqi and Kumalak Rivers in north and Sourth Xinjiang, respectively.



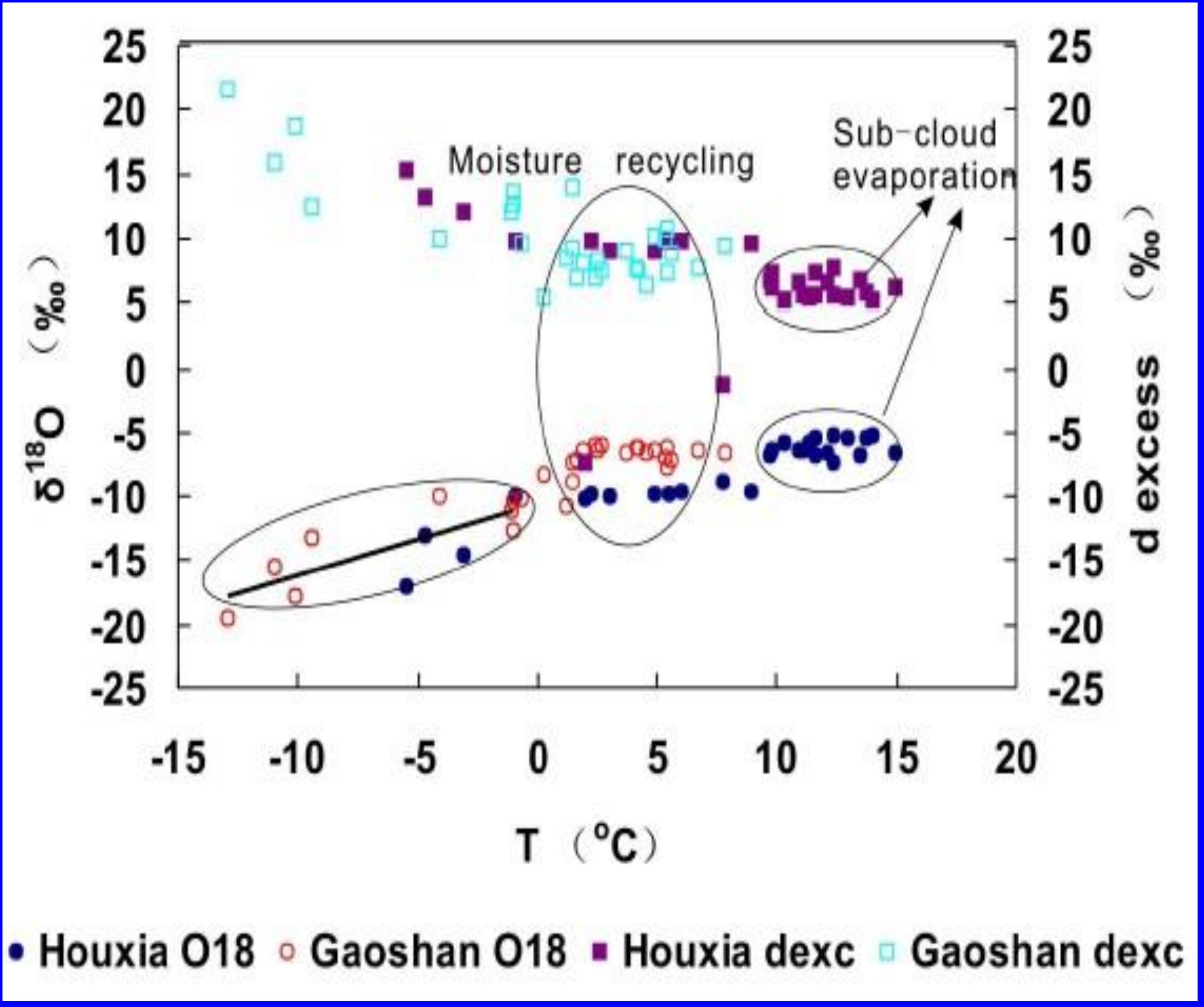
Urumqi River in Northern Xinjiang increases by 10%



Kumalak River in Sourthern Xinjiang increases by 38.7%

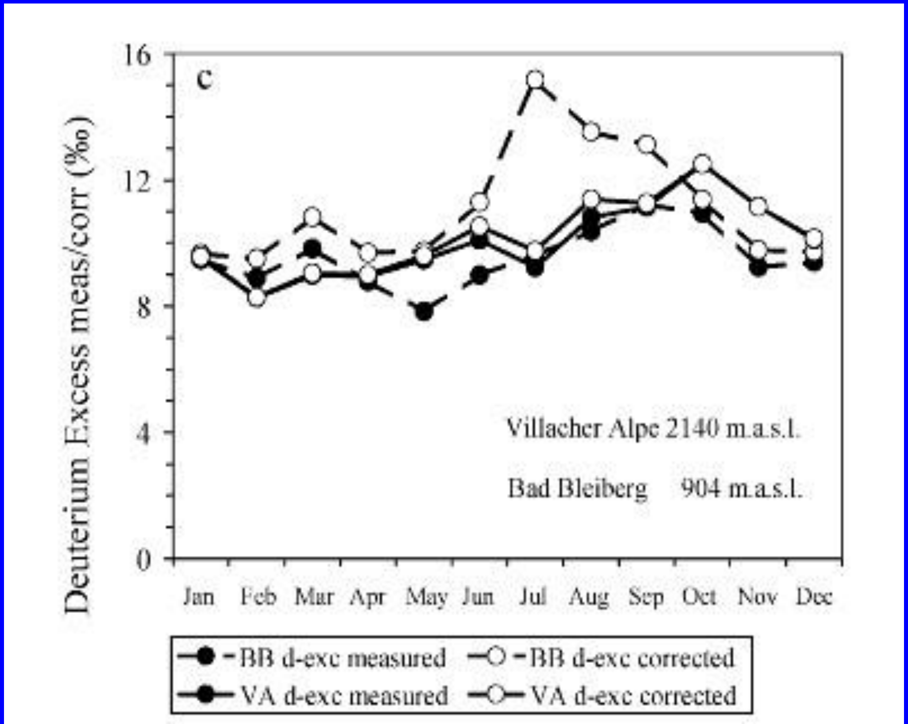
Precipitation isotopes affected by local processes

Through the comparison between O-18 and d-excess, three processes can be identified, namely adibiotic cooling, moisture recycling and sub-cloud evaporation in shaping precipitation isotopes in Tianshan mountains.



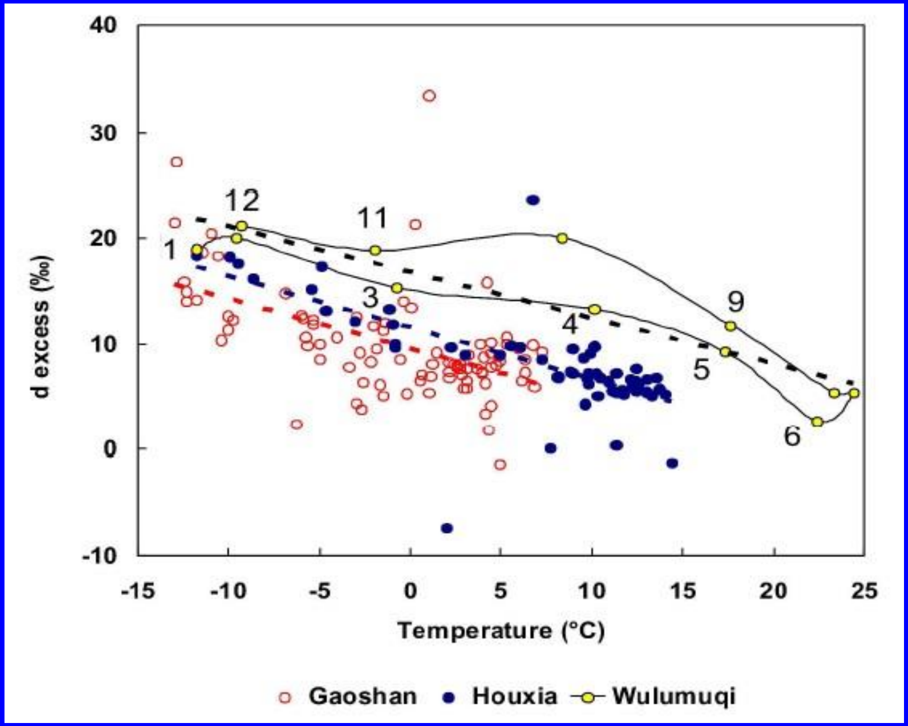
(Pang et al., 2011, Tellus B)

The inverse altitude effect of deuterium excess



deuterium excess in the humid region

(Froehlich et al, 2008)

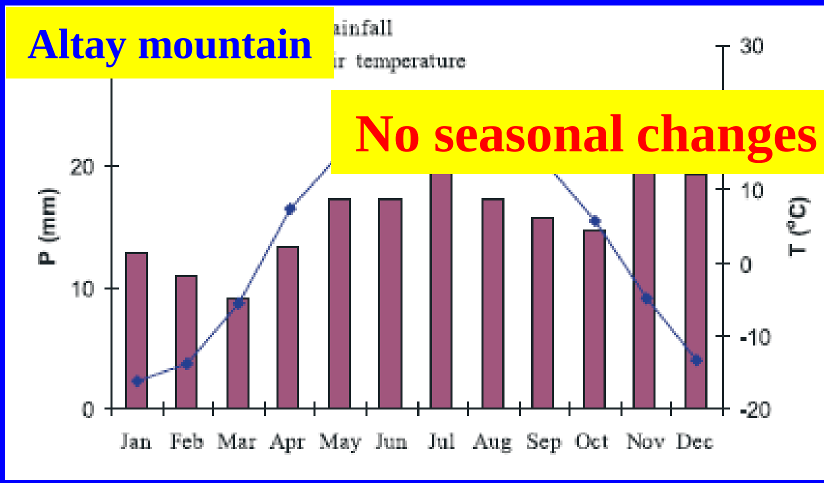


Deuterium excess in the arid region-Xinjiang Uygur

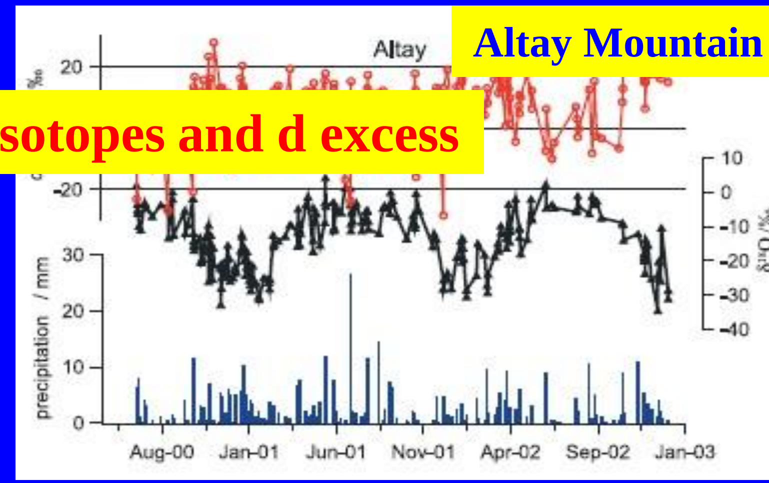
(Pang et al., 2011)

Limit of artic moisture : North Xinjiang but not south

Altay mountain



Altay Mountain

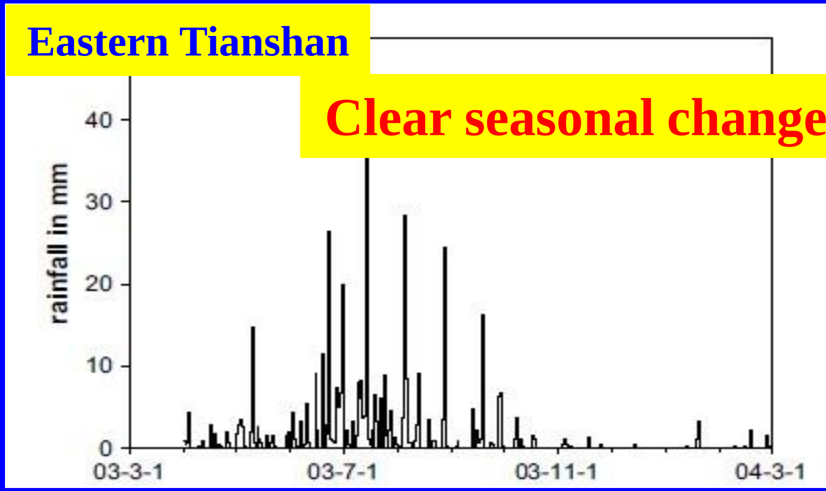


No seasonal changes of isotopes and d excess

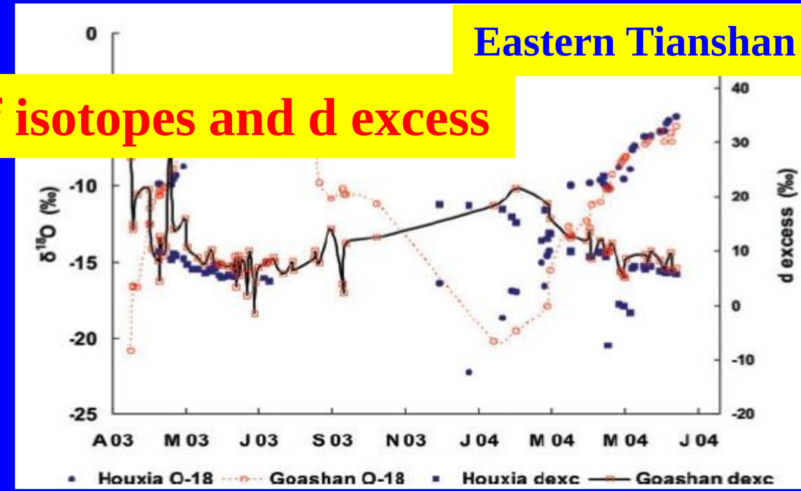
(Tian et al., 2007)

(Tian et al., 2007)

Eastern Tianshan



Eastern Tianshan



Clear seasonal changes of isotopes and d excess

(Zhao et al., 2008)

(Pang et al., 2011)

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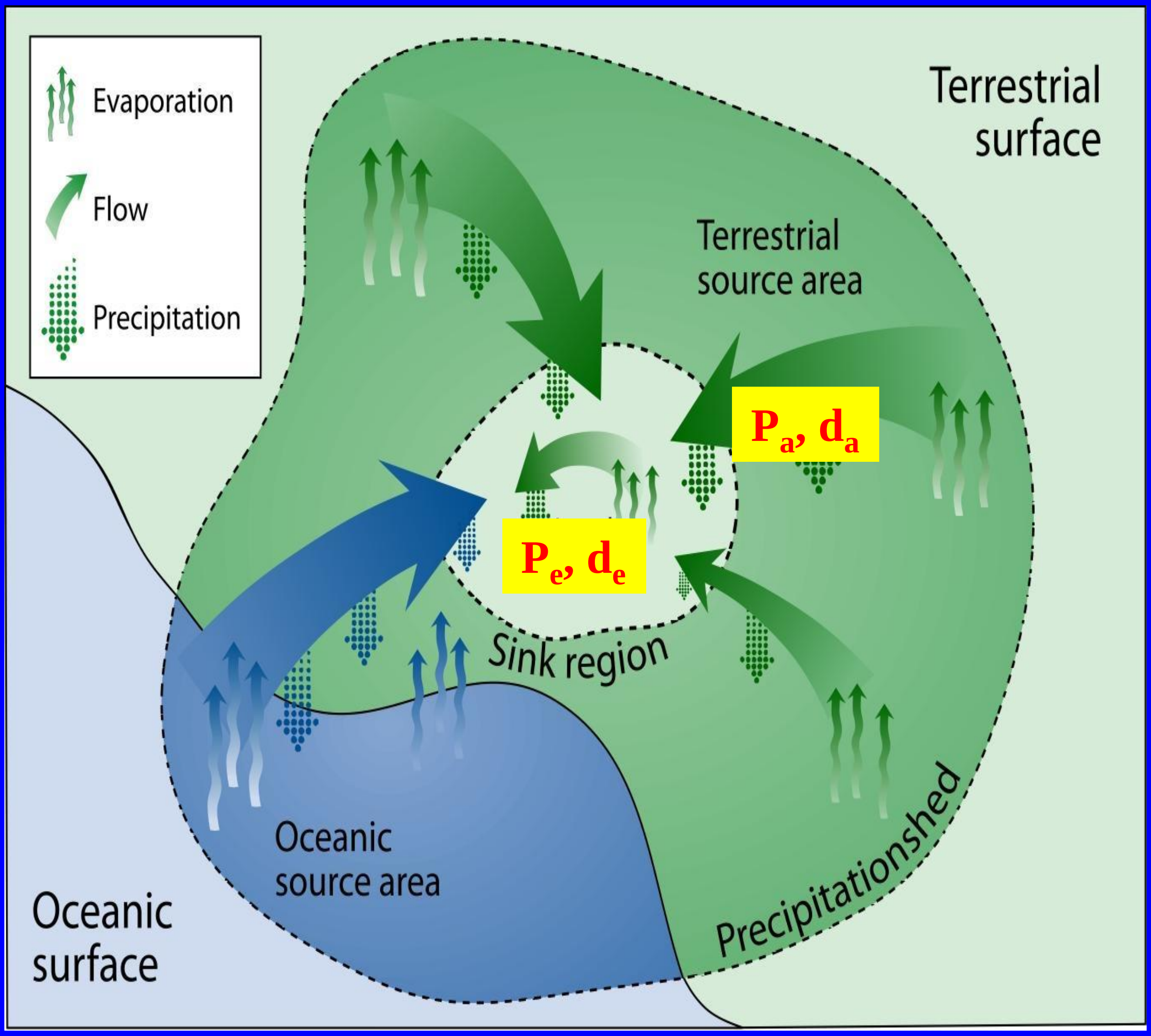
Using d-excess to quantify recycled moisture



$$P = P_e + P_a$$

$$d = d_e f_e + d_a(1-f_e)$$

$$f_e = \frac{d - d_a}{d_e - d_a}$$

P: precipitation

d: d-excess

P_e: precipitation from local moisture

d_e: d-excess of P_e

P_a: precipitation from external moisture

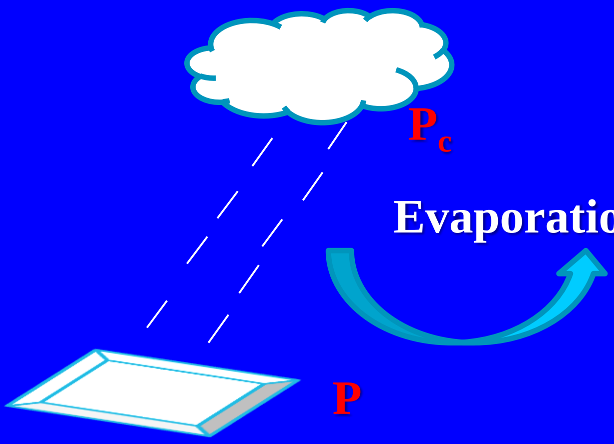
d_a: d-excess of P_a

(Pang et al., 2005)

The calculation of "f" factor

$$f = \frac{P}{P + V_{evap}t}$$

$$V_{evap} = 4\pi rD\left(1 + \frac{Er}{s'}\right)(\rho_a - \rho_b)$$



$P_c = P + V_{evap}t$

Evaporation loss: $V_{evap}t$

where, P is precipitation amount; V_{evap} is evaporated velocity of precipitation ; t is falling time of water droplet, which depends on average falling rate of droplet(V) and falling elevation(H):

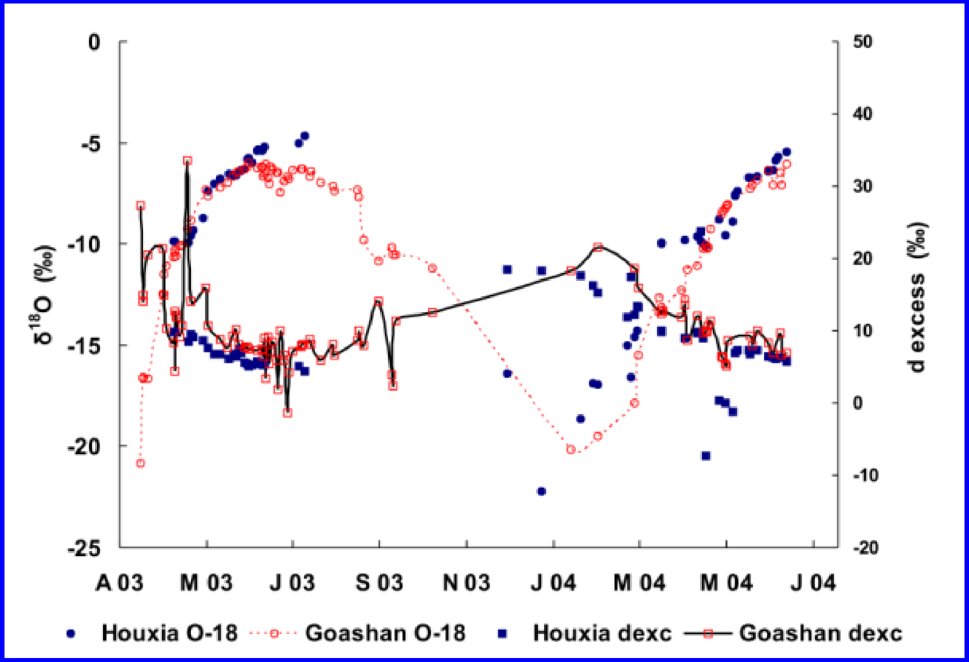
t = H/V

$$V = 9.58\left\{1 - \exp\left[-\left(\frac{r}{0.885}\right)^{1.147}\right]\right\}$$

where, r is the radius of water droplet **(Kong et al., 2013)**

The calculation of d_a

There is almost no sub-cloud evaporation and mositure recycling for precipitation below 0℃!



$$f_e = \frac{d - d_a}{d_e - d_a}$$

d_a = -0.52T + 11.6

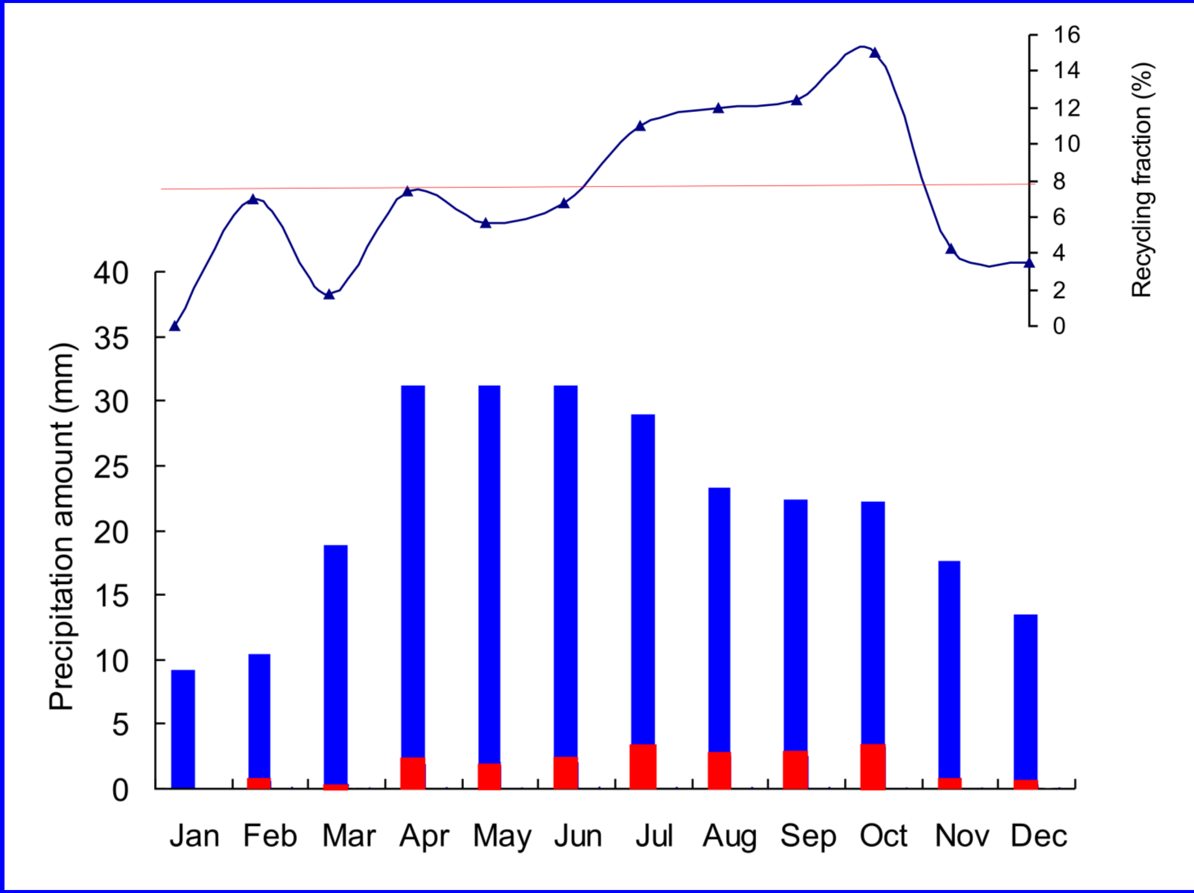
where T is average temperature

(Kong et al., 2013)

Recycled fraction in Precipitation

The precision of the d excess method computed by Monte-Carlo simulation is less than 1%.

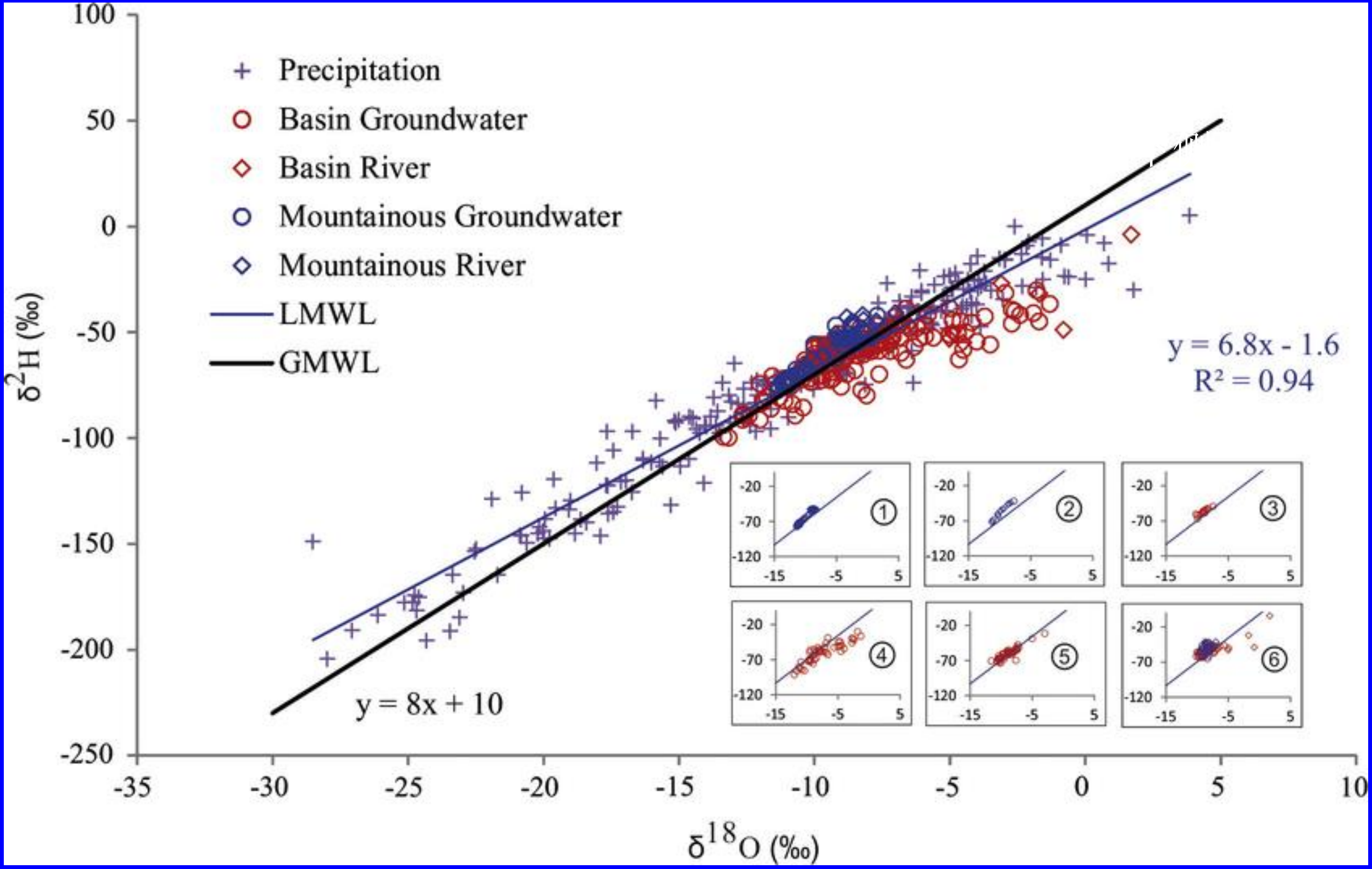
8% is less than the global average.



Ratio of recycled moisture in precipitation

(Kong et al., 2013)

Data points of water isotopes plot over the GMWL in the Northwest China affected by moisture recycling



(Kong and Pang, 2016, *JH)*

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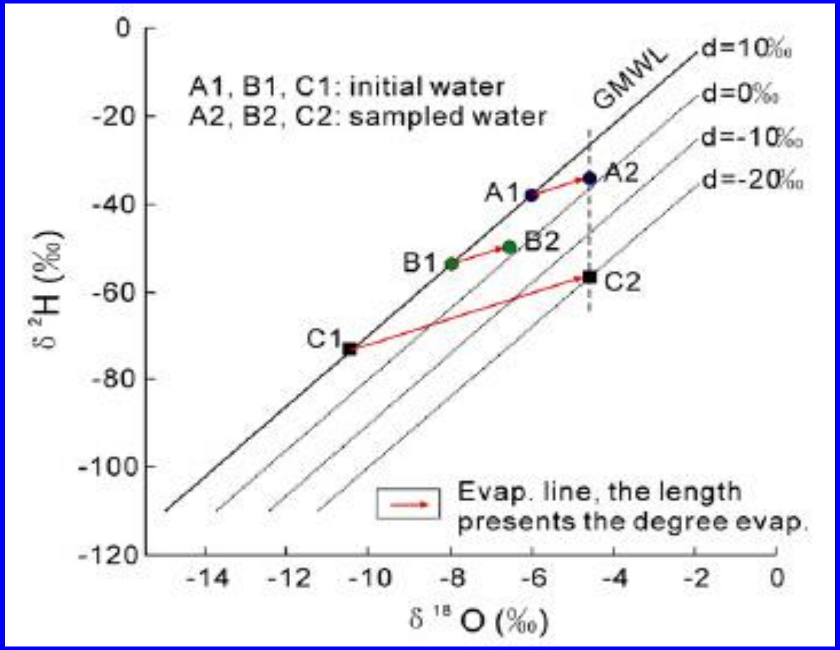
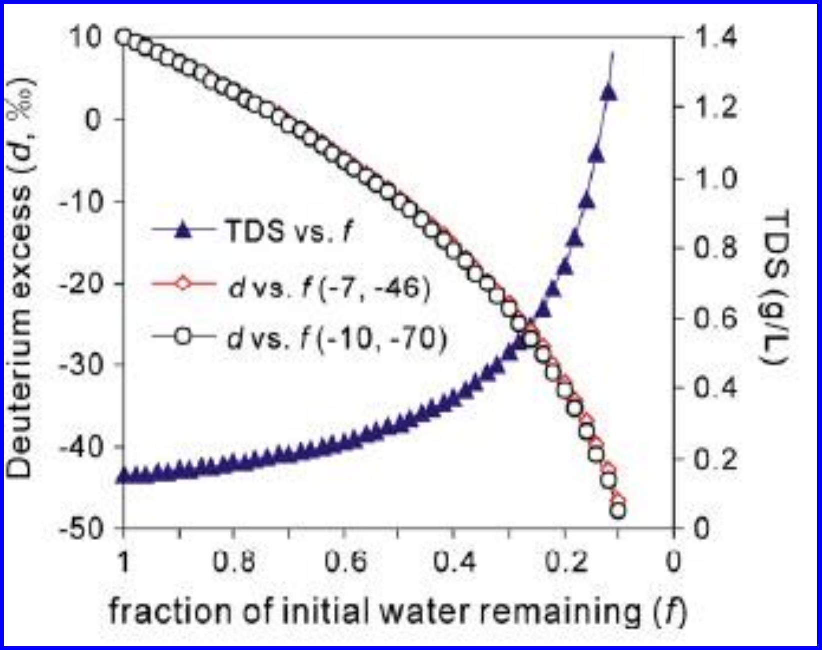
D-excess in determining sources of water salinisation

- **Previous study:** $\delta^{18}O(\delta^{2}H)$-TDS only works for the condition of same isotope composition in original water, not including watersheds scale
- d-TDS has less to do with original isotope composition





(Huang and Pang, 2012)

D-excess in determining sources of water salinization

- The relationship between f and d

$$d = \delta^2 H - 8^{18}O$$

Isotope abundance: $\delta = (R / R_{VSMOW} - 1) \times 1000$

Rayleigh fractionation: $R = R_0 f^{(\alpha_{v-l} - 1))}$

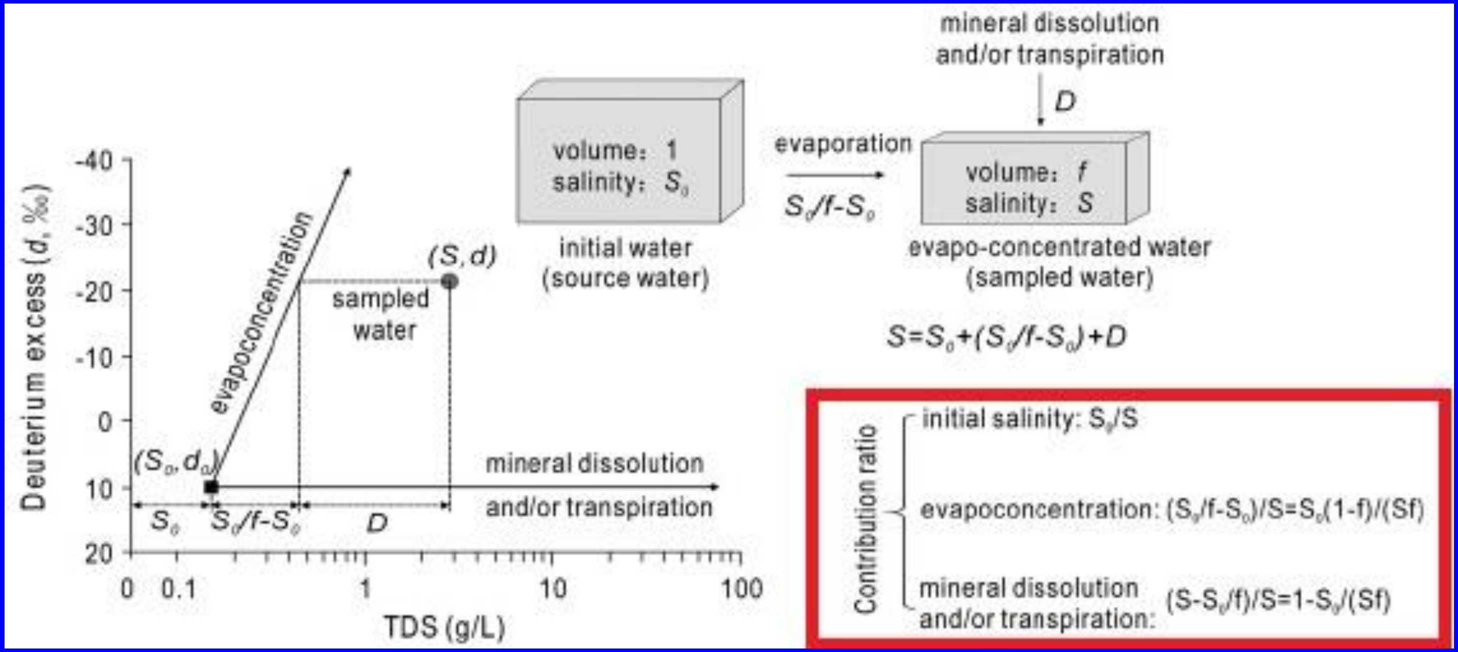
↓

$$d = (\delta_0{}^2H + 1000) f^{(\alpha^2H - 1)} - 8(\delta_0{}^{18}O + 1000) f^{(\alpha^{18}O - 1)} + 7000$$

（Huang and Pang, 2012)

D-excess in determining sources of water salinisation

- **The relationship beween f and TDS**

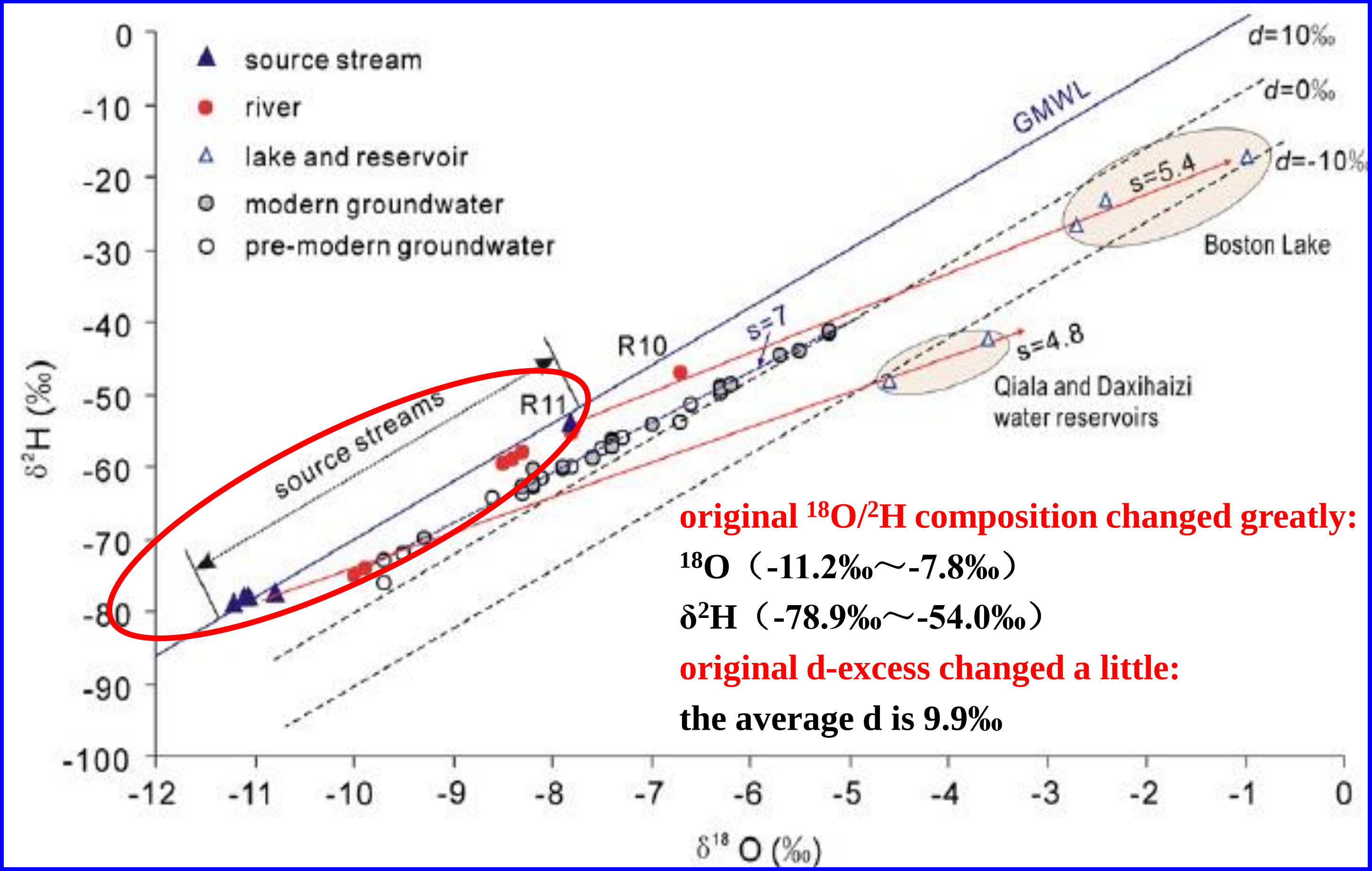


Evaporation and condensation : $(s_0 / f - s_0) / s = s_0(1 - f) / (s \cdot f)$

Dissolution (or transpiration): $(s - s_0 / f) / s = 1 - s_0 / (s \cdot f)$

(Huang and Pang, 2012)

The Tarim river salinization case study



original $^{18}O/^{2}H$ composition changed greatly:

^{18}O（-11.2‰～-7.8‰）

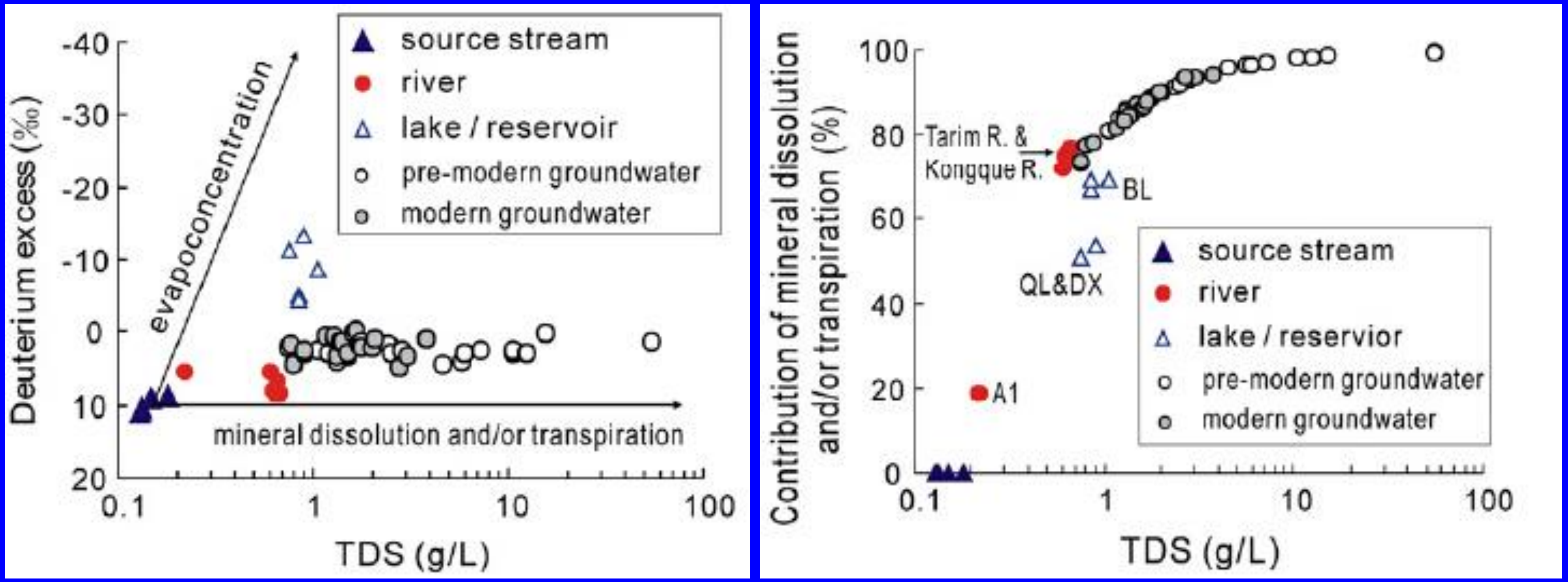
$\delta^{2}H$（-78.9‰～-54.0‰）

original d-excess changed a little:

the average d is 9.9‰

（Huang and Pang, 2012)

The Tarim river salinization case study

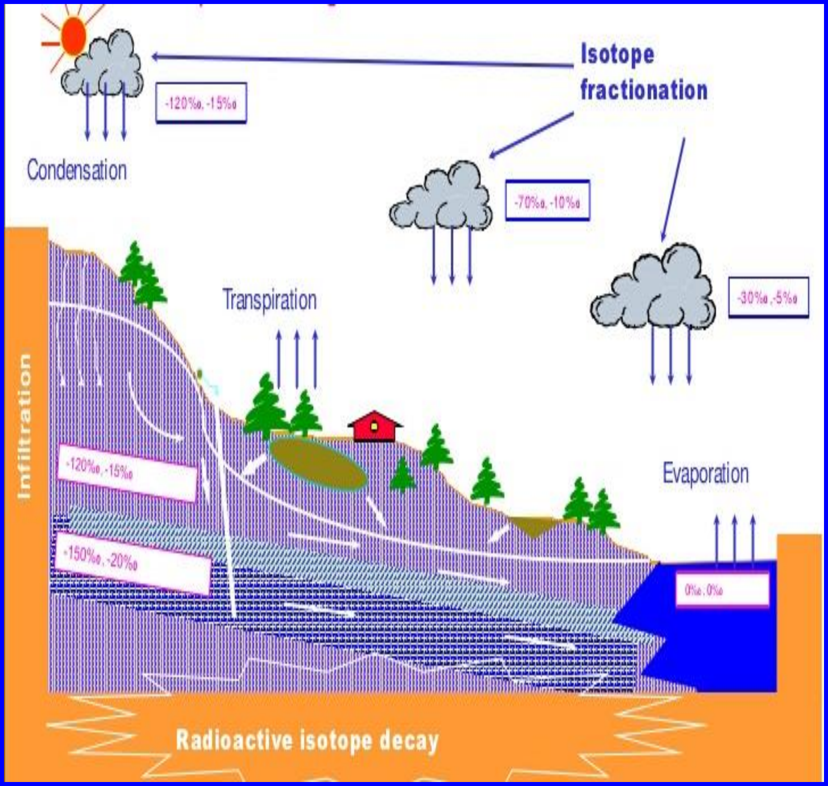


(Huang and Pang, 2012)

- The dissolution account for 67%～77% of the total salinisation

Conclusions

- High frequency eventful monitoring of precipitation isotopes in Beijing and Xinjiang has offered new insights into complicated processes in arid regions.
- D-excess has been found useful in: Identification of Different Moisture Sources; Quantifying recycled moisture fraction in precipitation; Determining the water salinisation mechanism



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