降水同位素演化与水汽源

孔彦龙
中国科学院地质与地球物理研究所
ylkong@mail.iggcas.ac.cn

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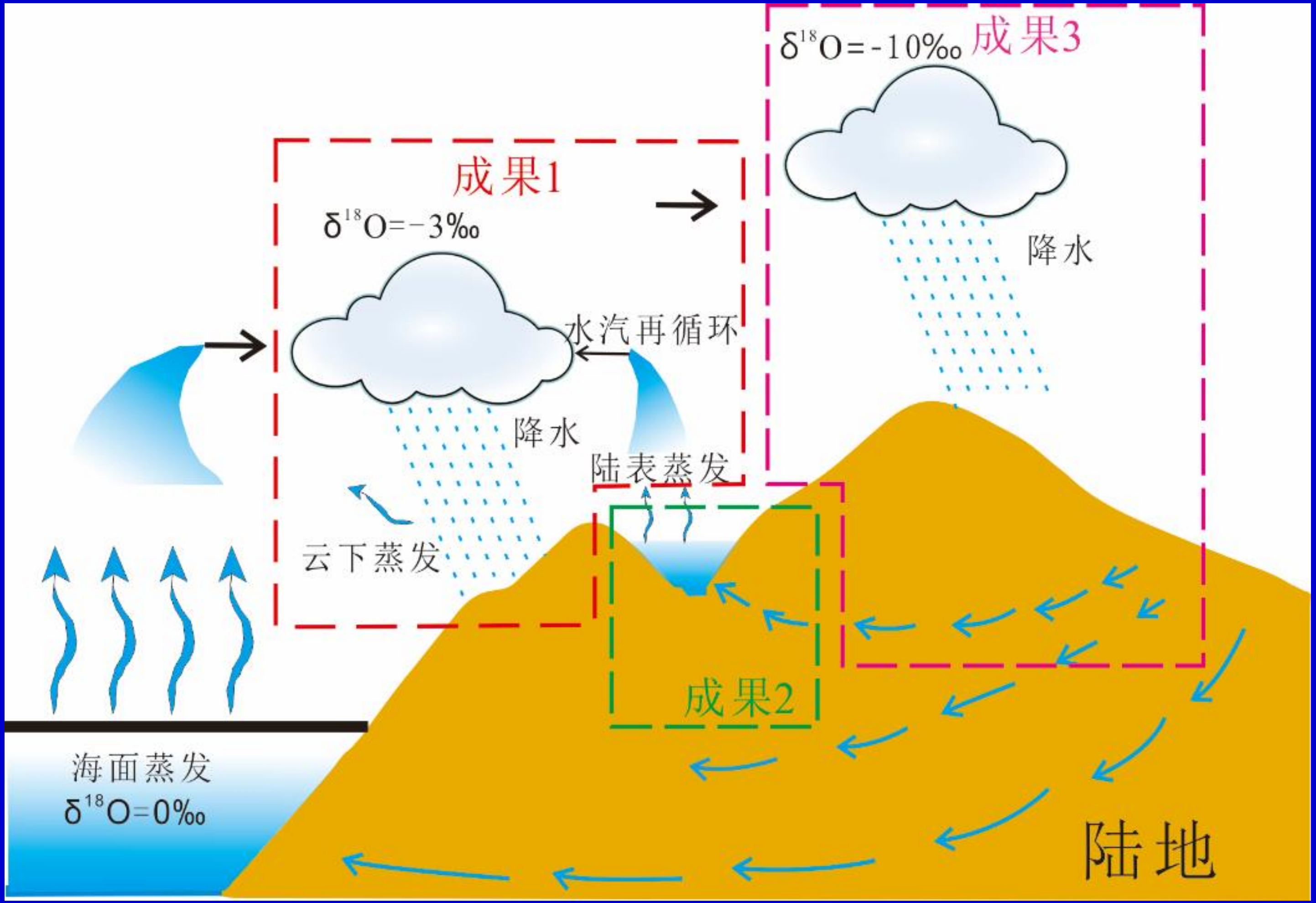
研究方向：同位素水文地质



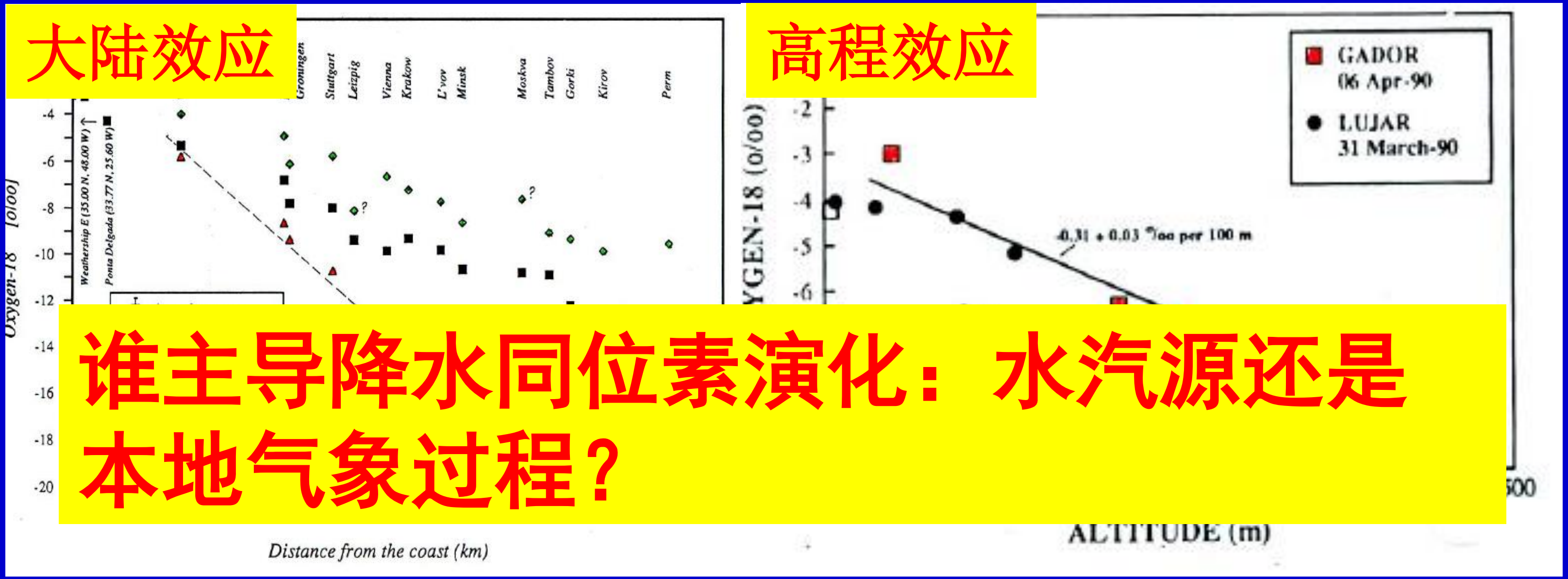
气候变化与人类活动背景下的地下水系统响应是地下水资源开发利用与地下水生态环境效应的关键科学问题。

需要从地球系统论的角度，开展大气水-地表水-地下水（“三水”）协同研究。边界是系统论的基本概念，“三水”界面关键水文过程的量化识别，是回答上述科学问题的基础

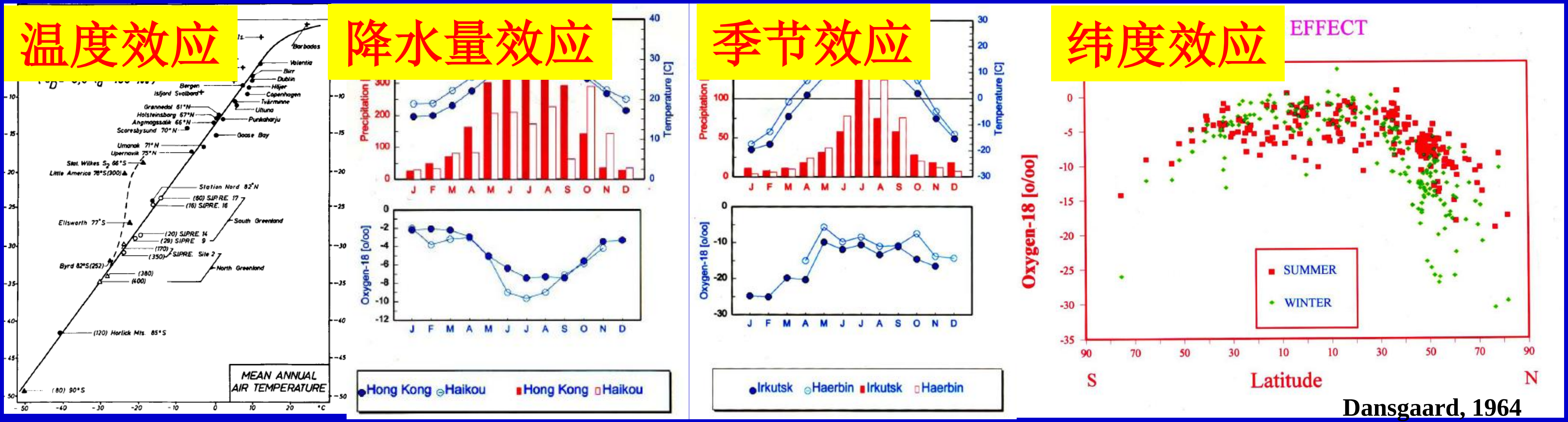
主要内容

- 降水同位素演化与时空变化
- 降水同位素分馏的控制机理
- 实际应用
- 主要结论

降水同位素地理效应

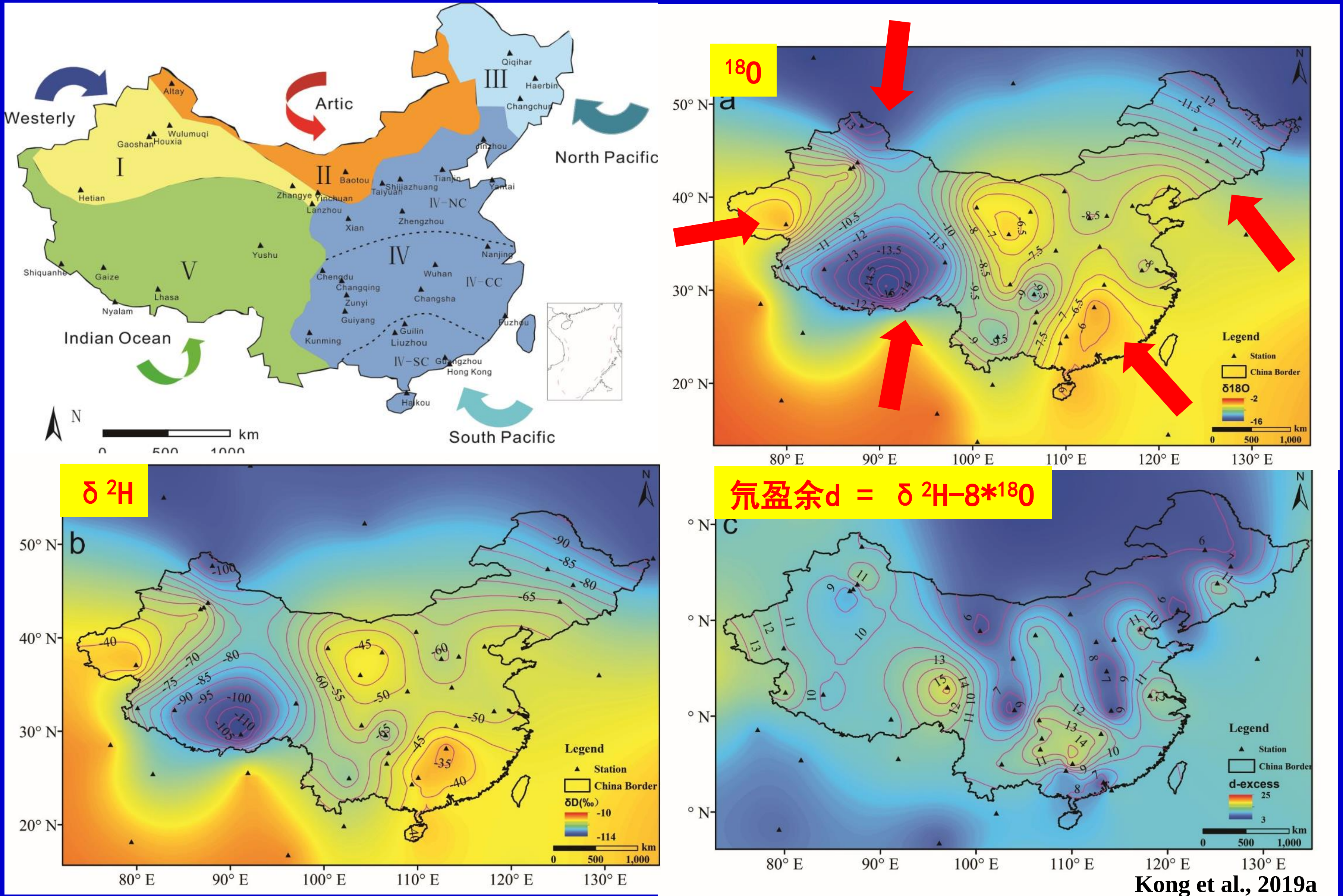


谁主导降水同位素演化：水汽源还是本地气象过程？



Dansgaard, 1964

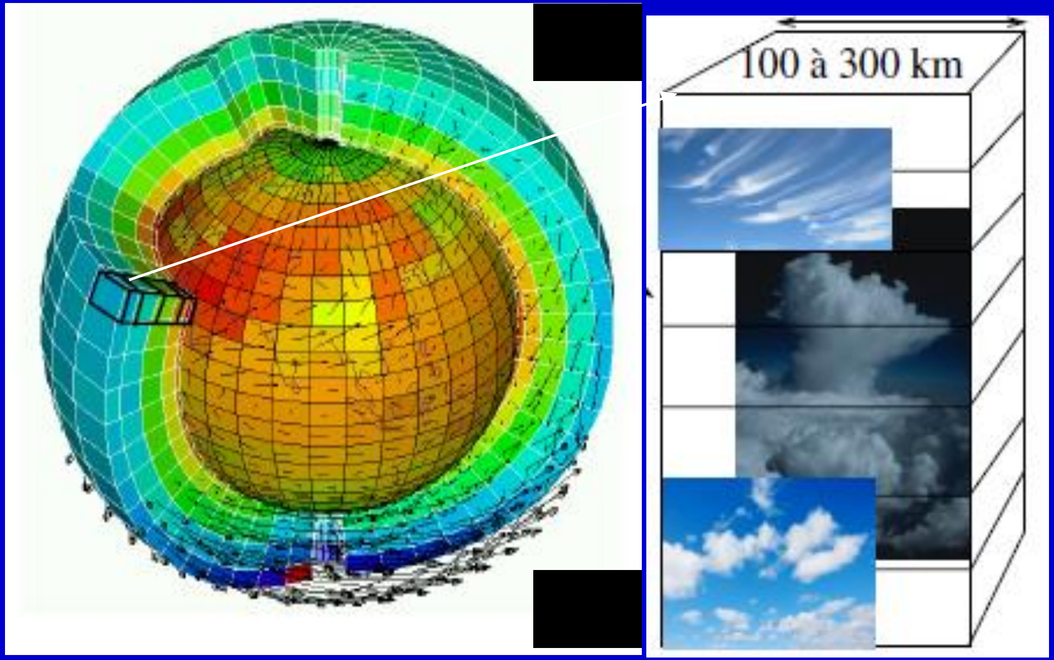
水汽源区与同位素空间变化高度一致



Kong et al., 2019a

降水同位素演化的时间尺度解构

Atmospheric 3D model



Resolution: 96x72x19

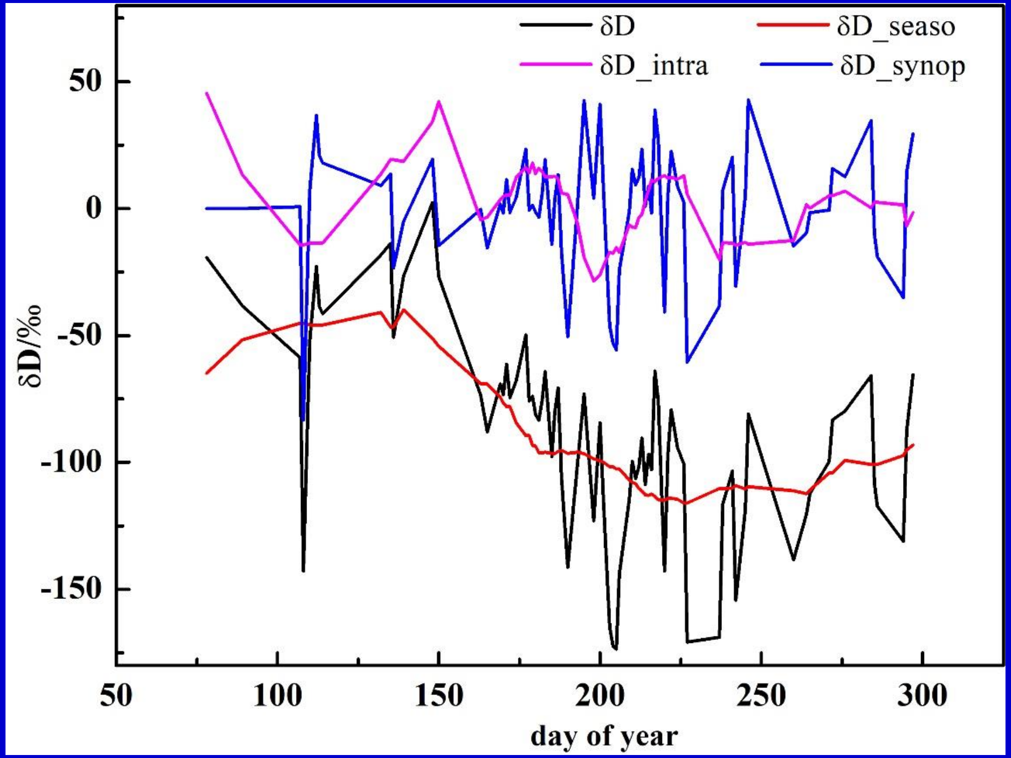
- **SWING2** (9 models)
  (Stable Water Isotope
  Inter-comparison Group,
  Phase 2)
  Monthly data (2001-2003)

- **LMDZ**
  (Laboratoire de Météorologie
  Dynamique zoomed)
  Daily data (2017)

Shi et al., 2020, JGR

降水同位素演化的时间尺度解构

$$\delta D = \delta D_{seaso} + \delta D_{intra} + \delta D_{synop}$$



Three different time scales:

δD_{seaso} is the seasonal signal

$$\delta D_{seaso} = \boxed{\delta D_{30}}$$

δD_{intra} is the intra-seasonal signal

$$\delta D_{intra} = \boxed{\delta D_{10} - \delta D_{30}}$$

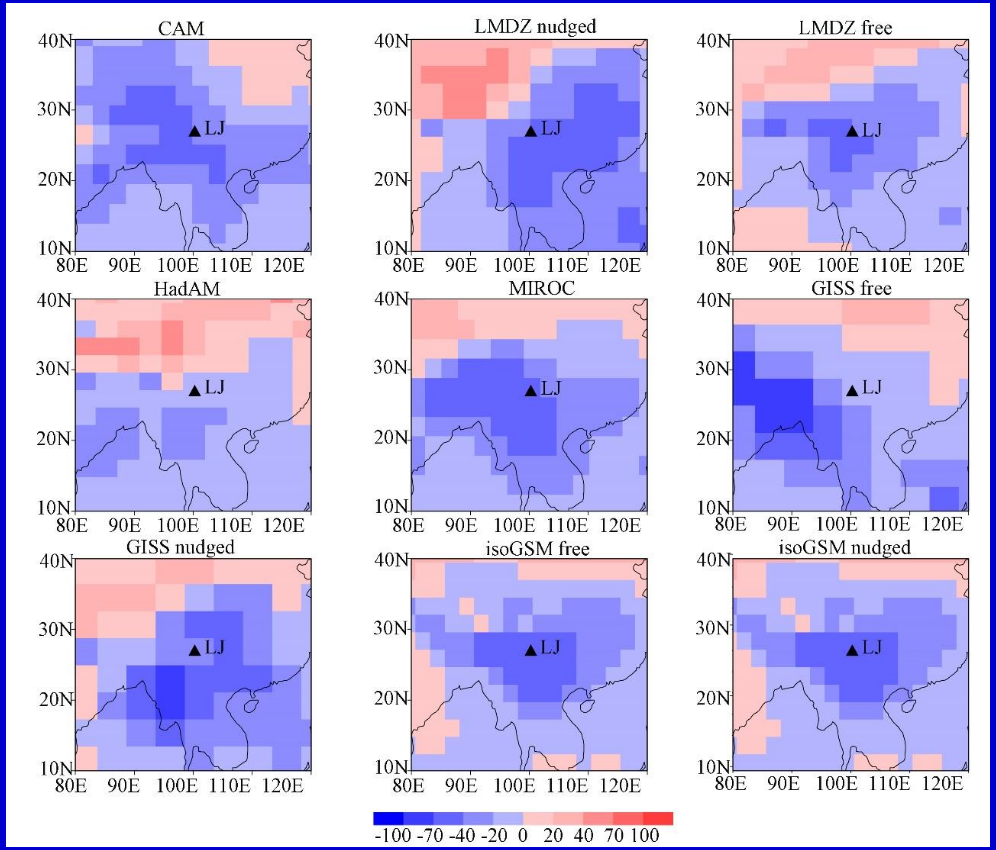
δD_{synop} is the synoptic signal

$$\delta D_{synop} = \boxed{\delta D - \delta D_{10}}$$

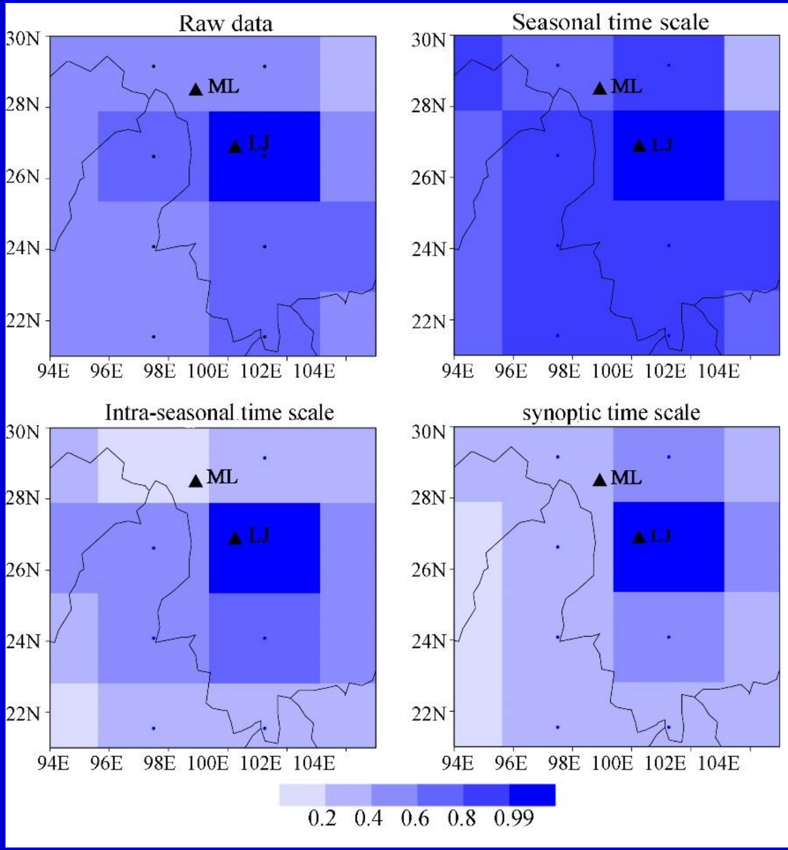
将δD 信号转变为季节、季内及场景三种时间尺度

Shi et al., 2020, JGR

水汽源区控制同位素季节尺度变化



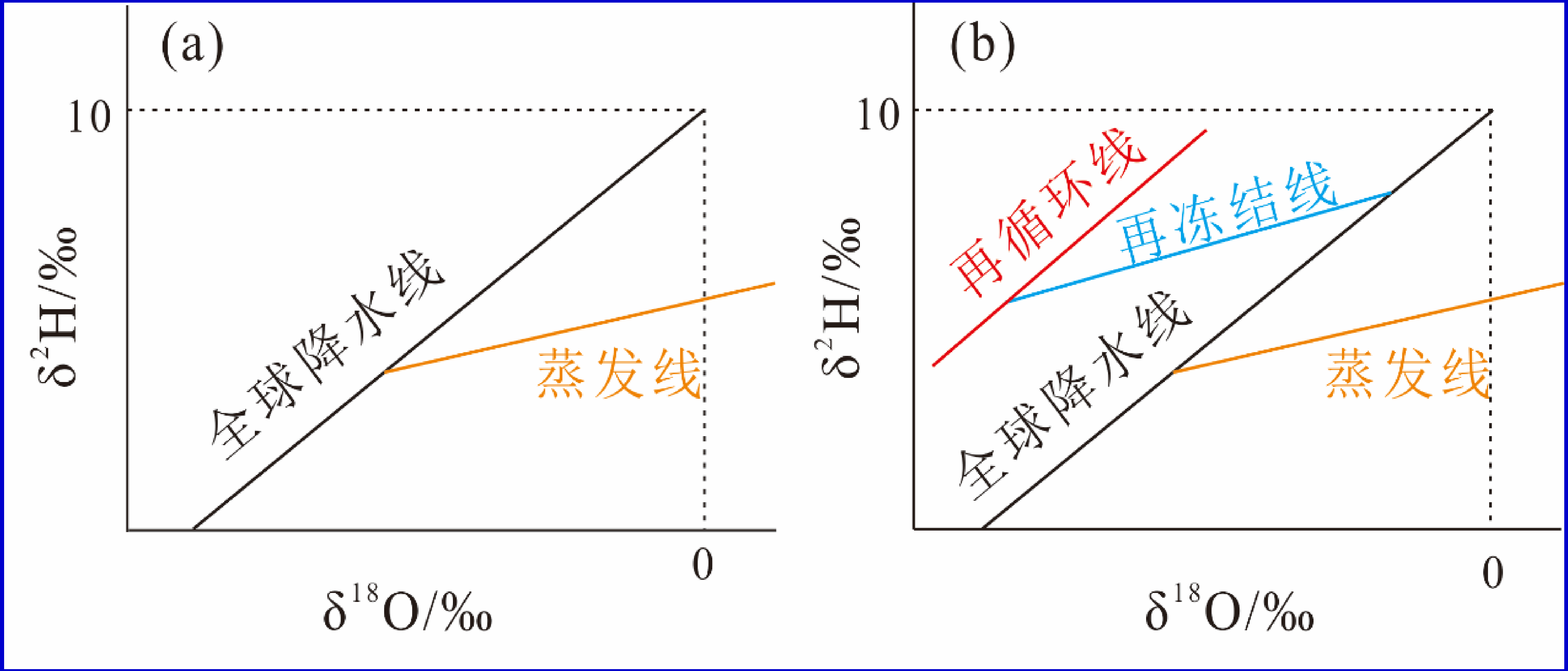
模型拟合的同位素值



与观测值的相关性

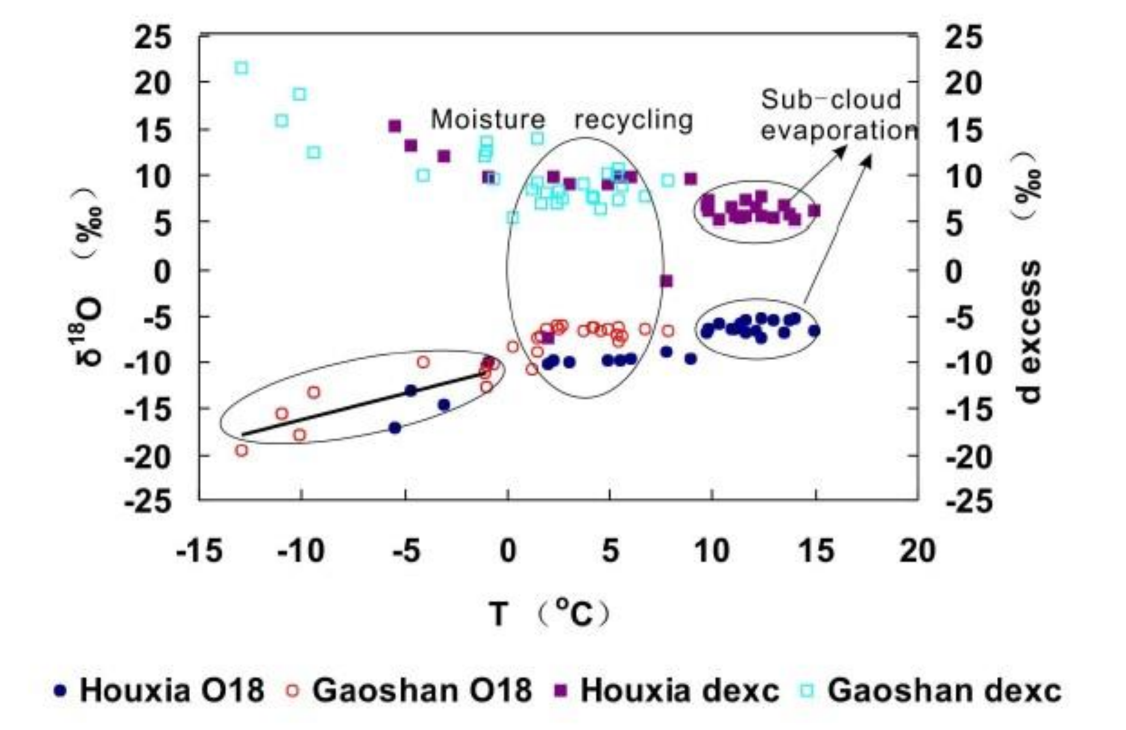
Shi et al., 2020, JGR

降水同位素的演化过程

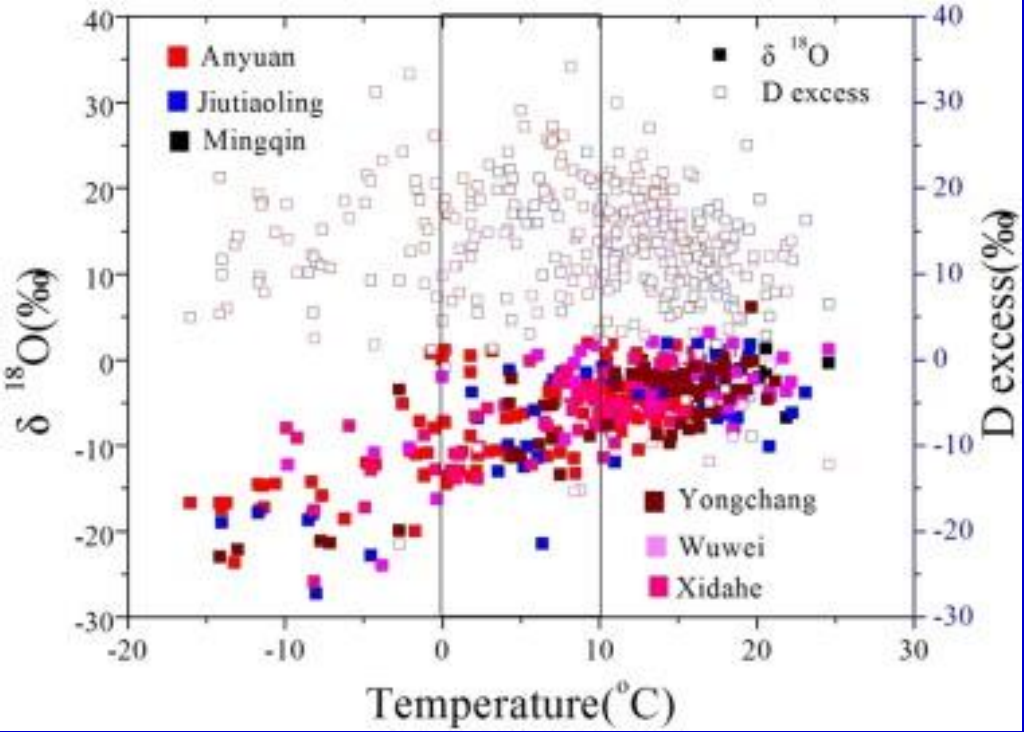


水汽再循环影响下的水同位素温度效应

水汽再循环导致水同位素温度效应“消失”



东天山观测的降水同位素-温度关系



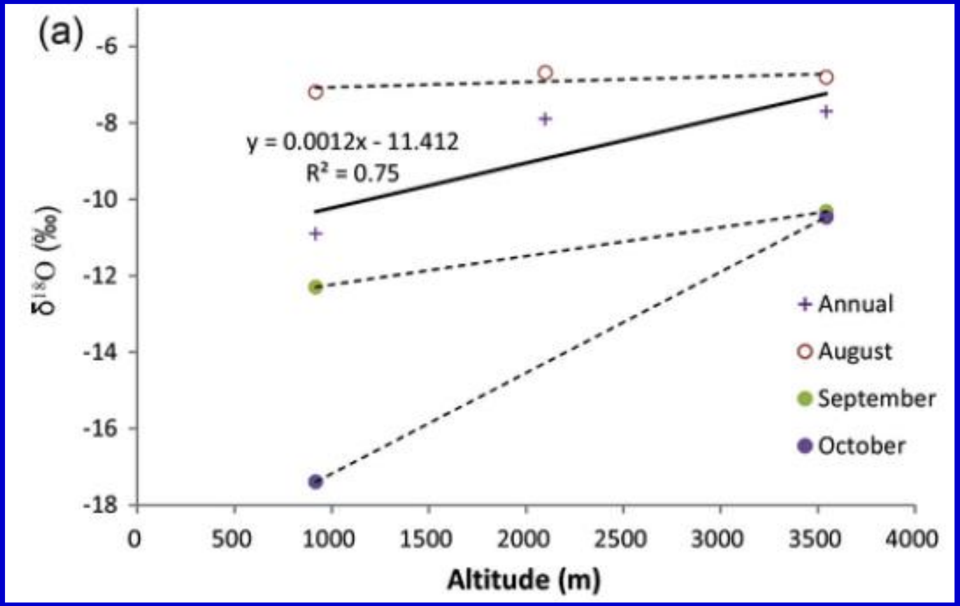
石羊河观测的降水同位素-温度关系

Pang et al., 2011; Li et al., 2013

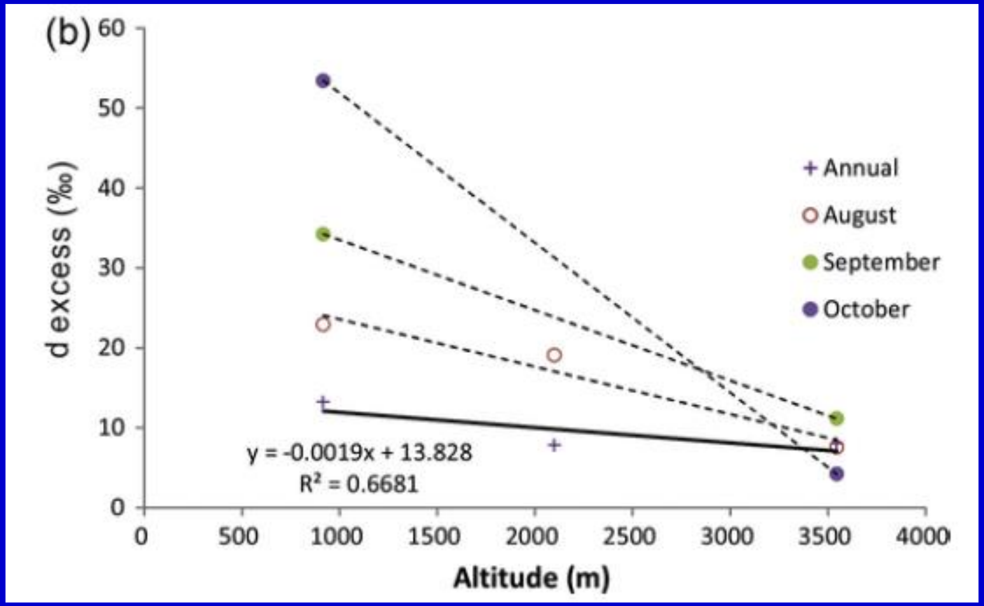
反高程梯度

降水梯度值：**0.12 ‰/100m**
全球平均值：**-0.28 ‰/100m；范围： -0.1~-0.5 ‰/100m**

氘盈余d = $\delta^2H - 8*\delta^{18}O$ （Dansgaard，1964)



乌鲁木齐河流域降水同位素随高程的变化



乌鲁木齐河流域降水氘盈余随高程的变化

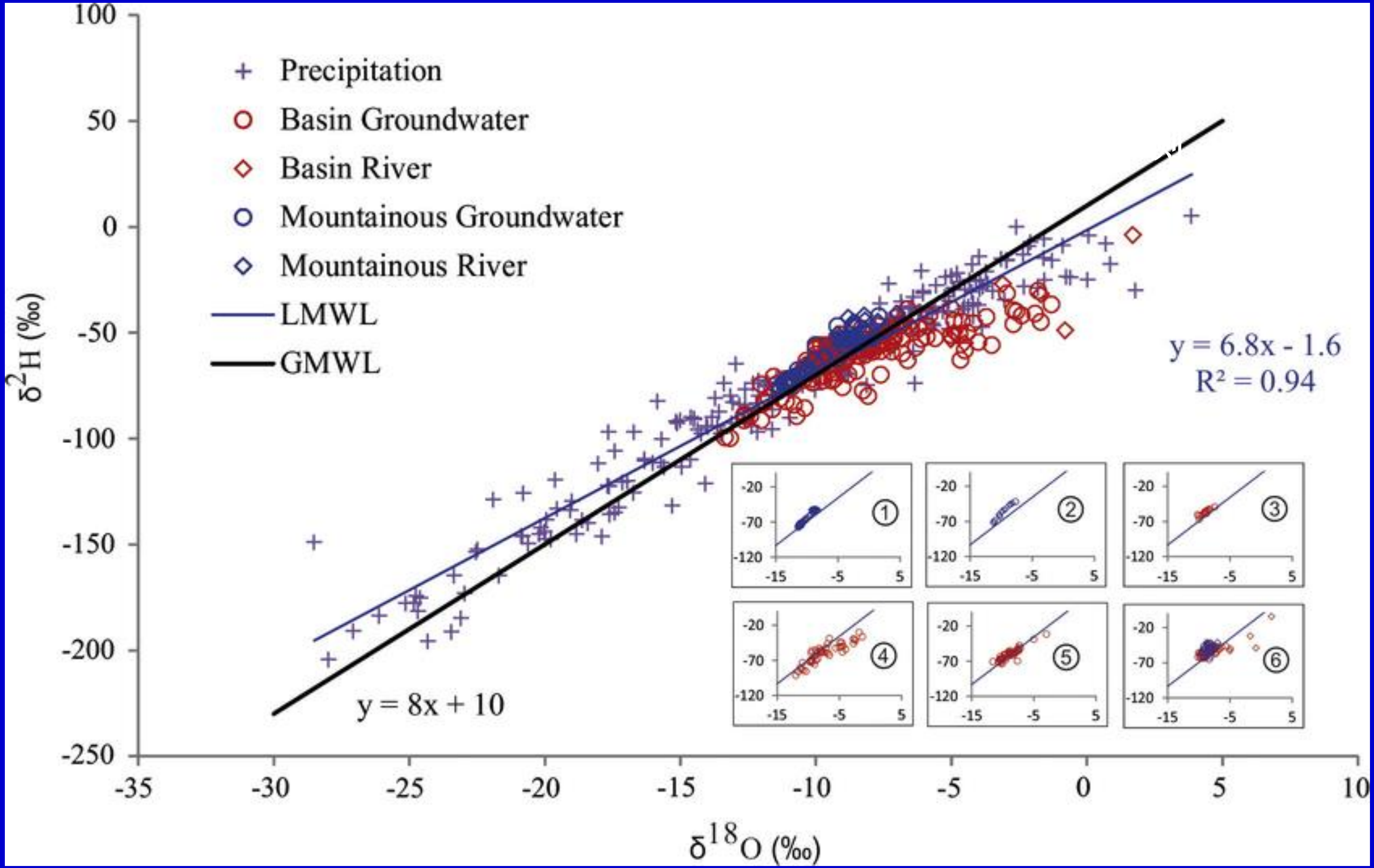
Kong and Pang, 2016, *JH*

西北水同位素研究

收集了西北地区不同流域的地表水和地下水同位素数据

准格尔盆地(Kong and Pang, 2012; Li et al., 2015)；
塔里木河流域 (Pang et al., 2010; Kong et al.,2014),；
酒泉盆地(He et al., 2012);
巴丹吉林流域 (Gates et al., 2008);
民勤盆地(Edmunds et al., 2006)；
黑河流域(Chen et al., 2006; Qin et al., 2011)

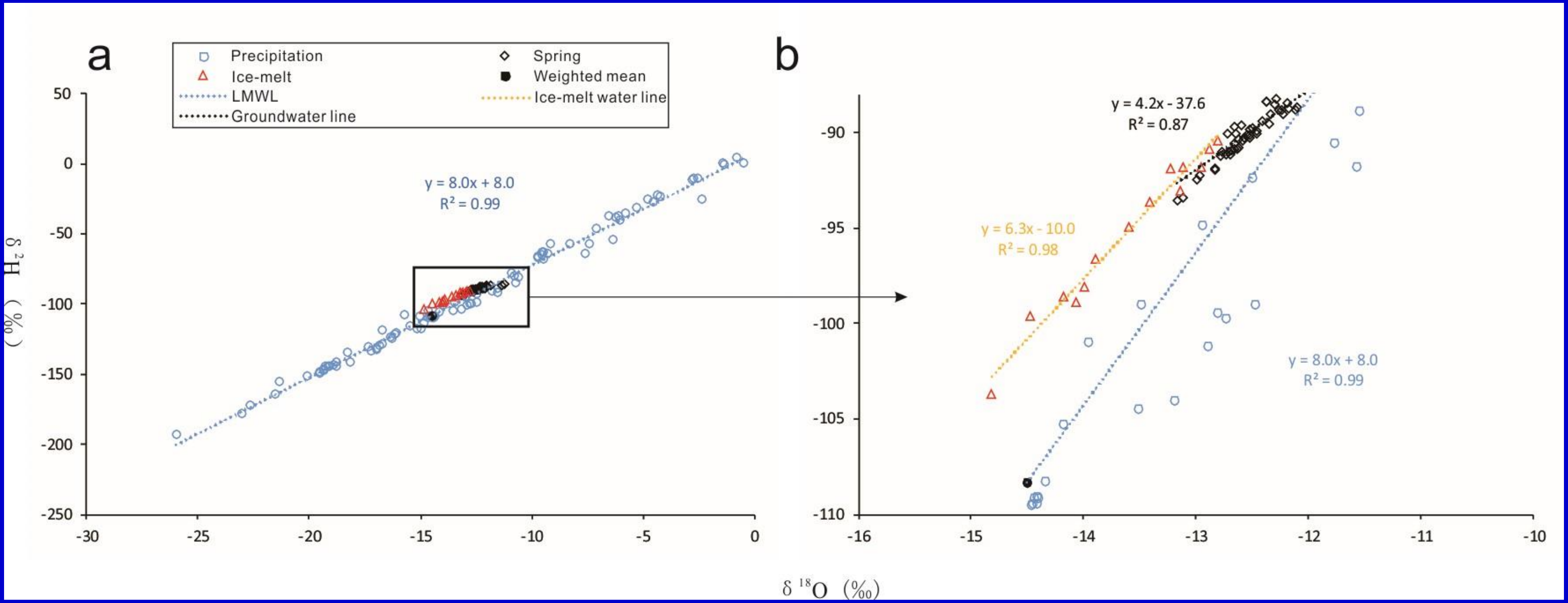
西北水同位素分布：受再循环和蒸发的影响



Kong and Pang, 2016, *JH*

梅里雪山明永冰川区的水同位素分布

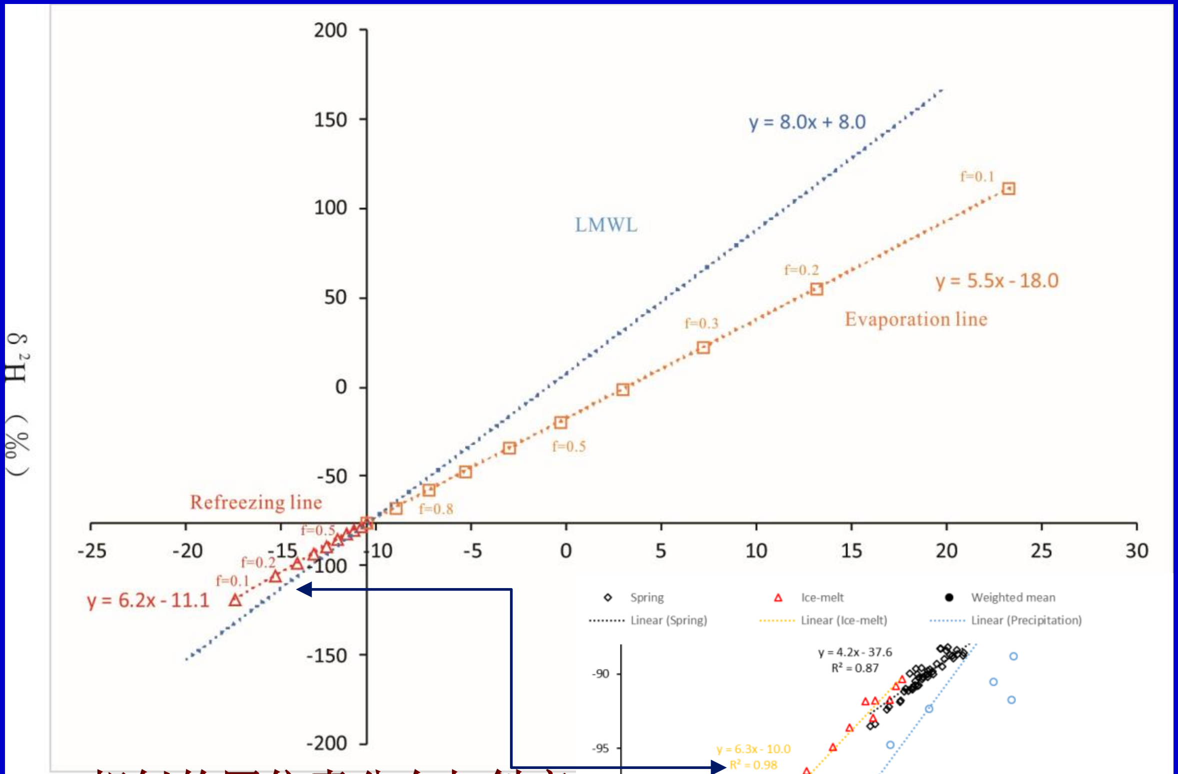
(1) 地下水和冰川融水的点都分布在雨水线左上侧;
(2) 地下水线和冰川融水线的斜率都小于雨水线;
(3) 地下水和冰川融水的平均值均显著高于降水加权均值.



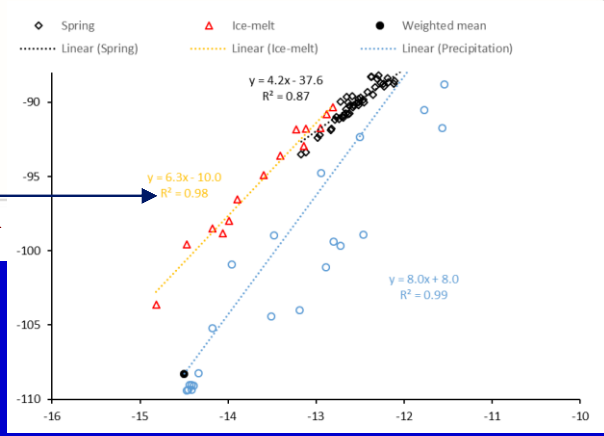
Kong et al., 2019, JGR

再冻结过程的定量模拟

再冻结过程遵循瑞利分馏过程，模型获得的同位素分布和融水线斜率与观测结果一致；地下水是冰川融水和降水混合的结果，各占46±22% 和54±22%。



相似的同位素分布与斜率



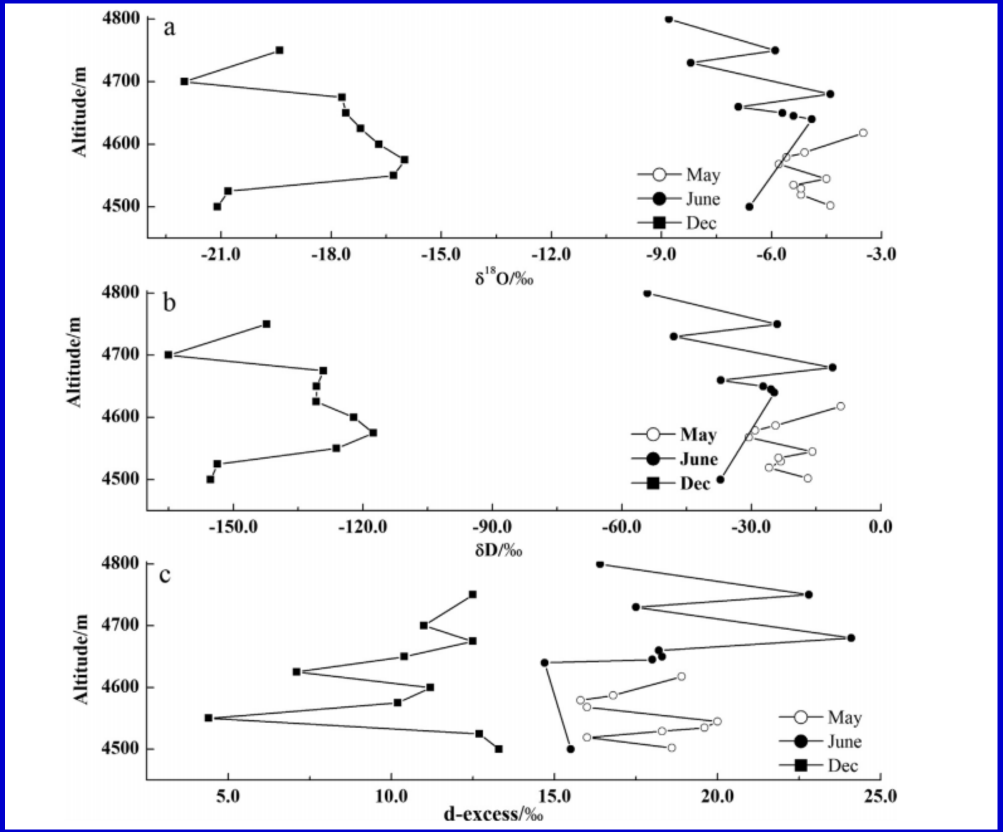
$$R = R_0 f^{(\alpha-1)}$$

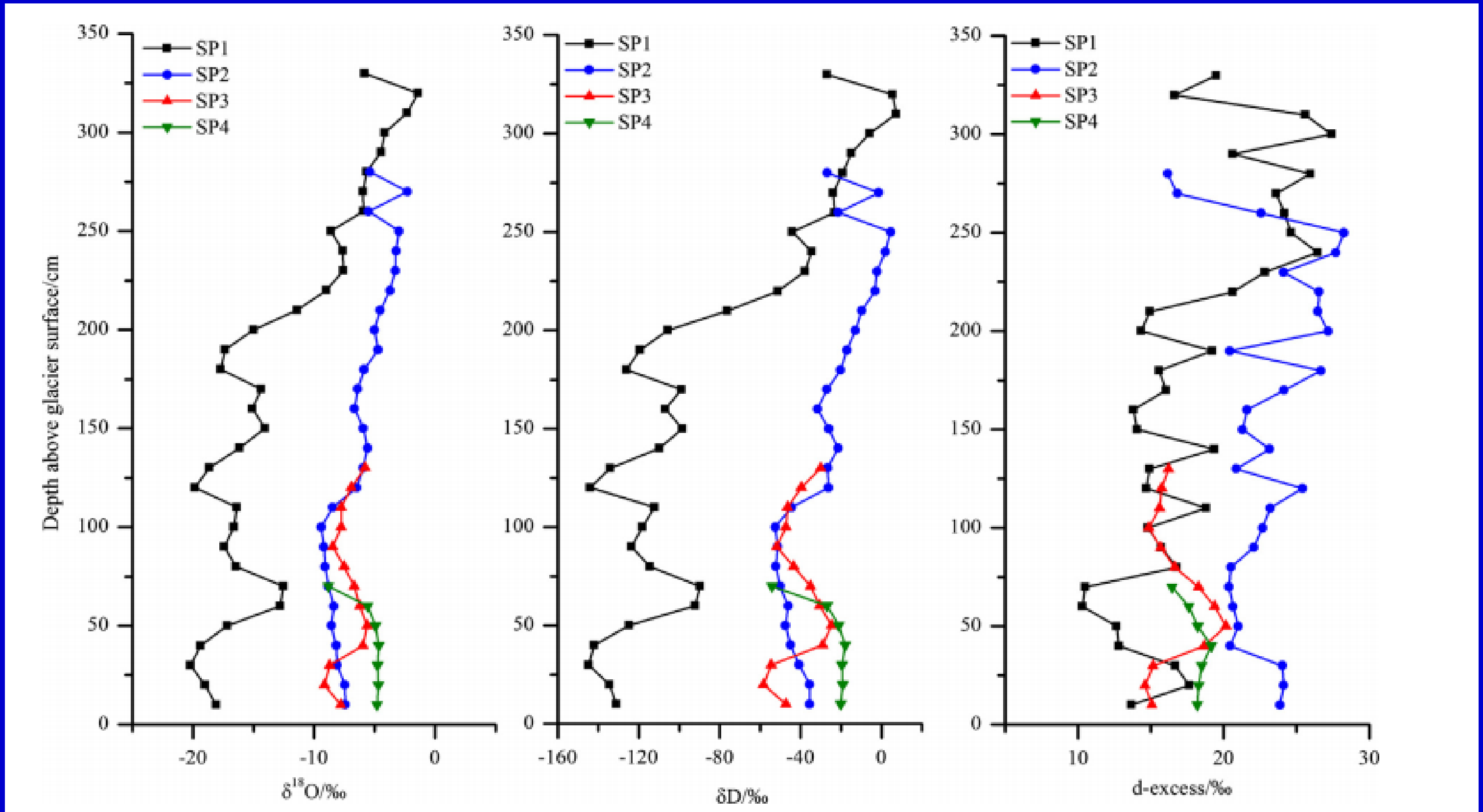
$$\delta^2 H_r \approx \frac{\alpha^2 H - 1}{\alpha^{18} O - 1}\delta^{18} O_r \delta_0{}^2 H_r - \frac{\alpha^2 H - 1}{\alpha^{18} O - 1}\delta_0{}^{18} O_r$$

$$F_i = \frac{\delta^{18} O_s - \delta^{18} O_p}{\delta^{18} O_i - \delta^{18} O_p}$$

Kong et al., 2019, JGR

降雪同位素演化与水汽源



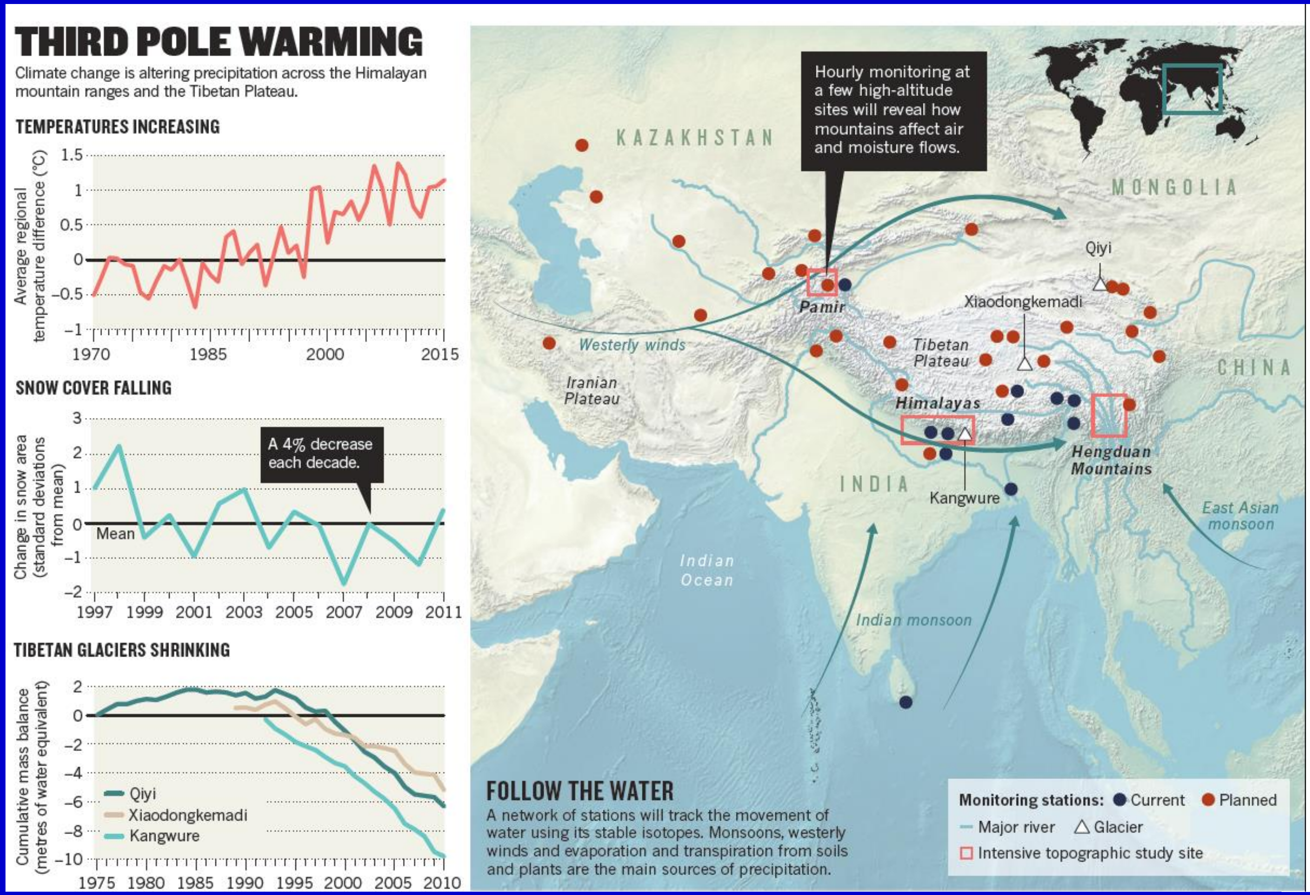


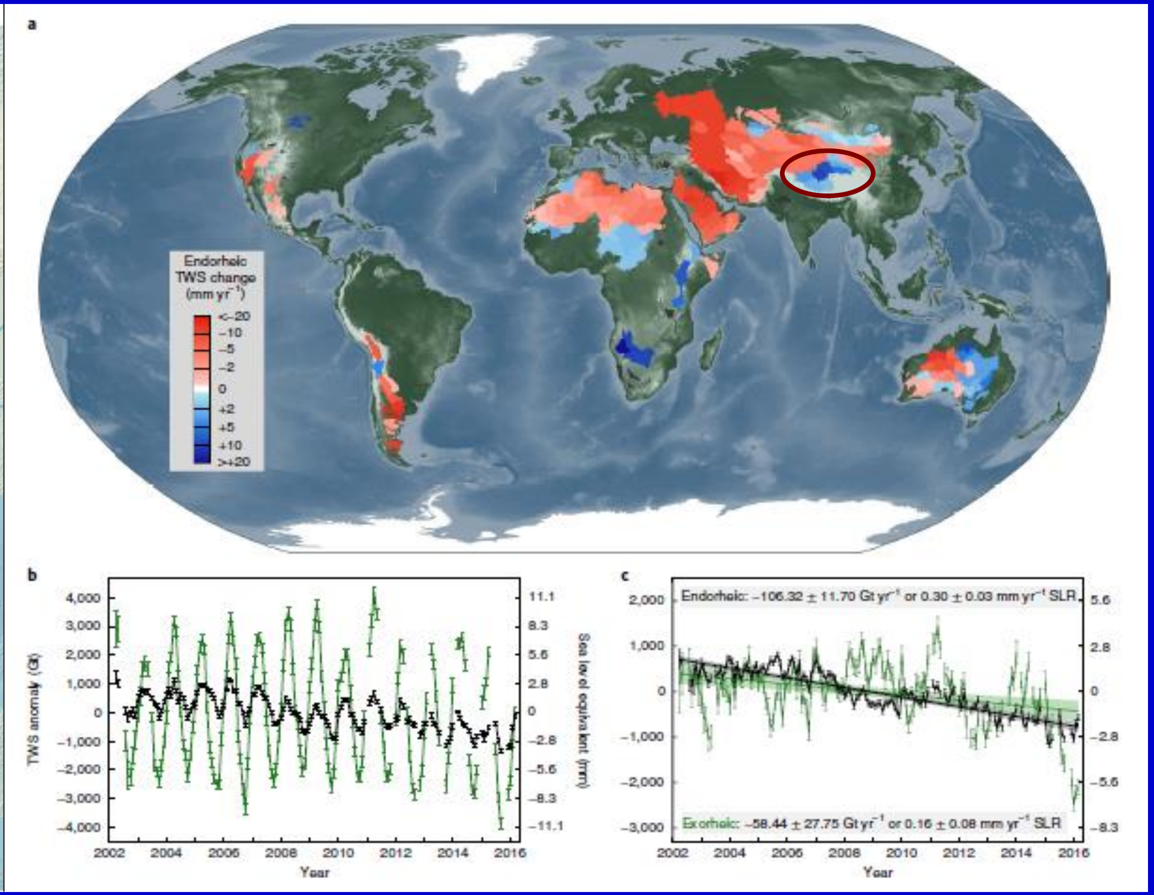
玉龙雪山表层雪同位素变化

玉龙雪山雪坑同位素变化

Pu et al., 2020, JH；WRR

大量融化的冰川是否入渗补给了地下水?





Gao et al., 2019, Nature **Wang et al., 2018, Nature-Geoscience**

主要结论

1. 水汽源是降水同位素演化的主控因素；
2. 雨水线之上的水同位素受控于水汽再循环和再冻结等过程；
3. 水同位素可用于定量评估水汽再循环、再冻结和地下水补给等过程。

更多信息……

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