

第一届中国同位素水文学论坛

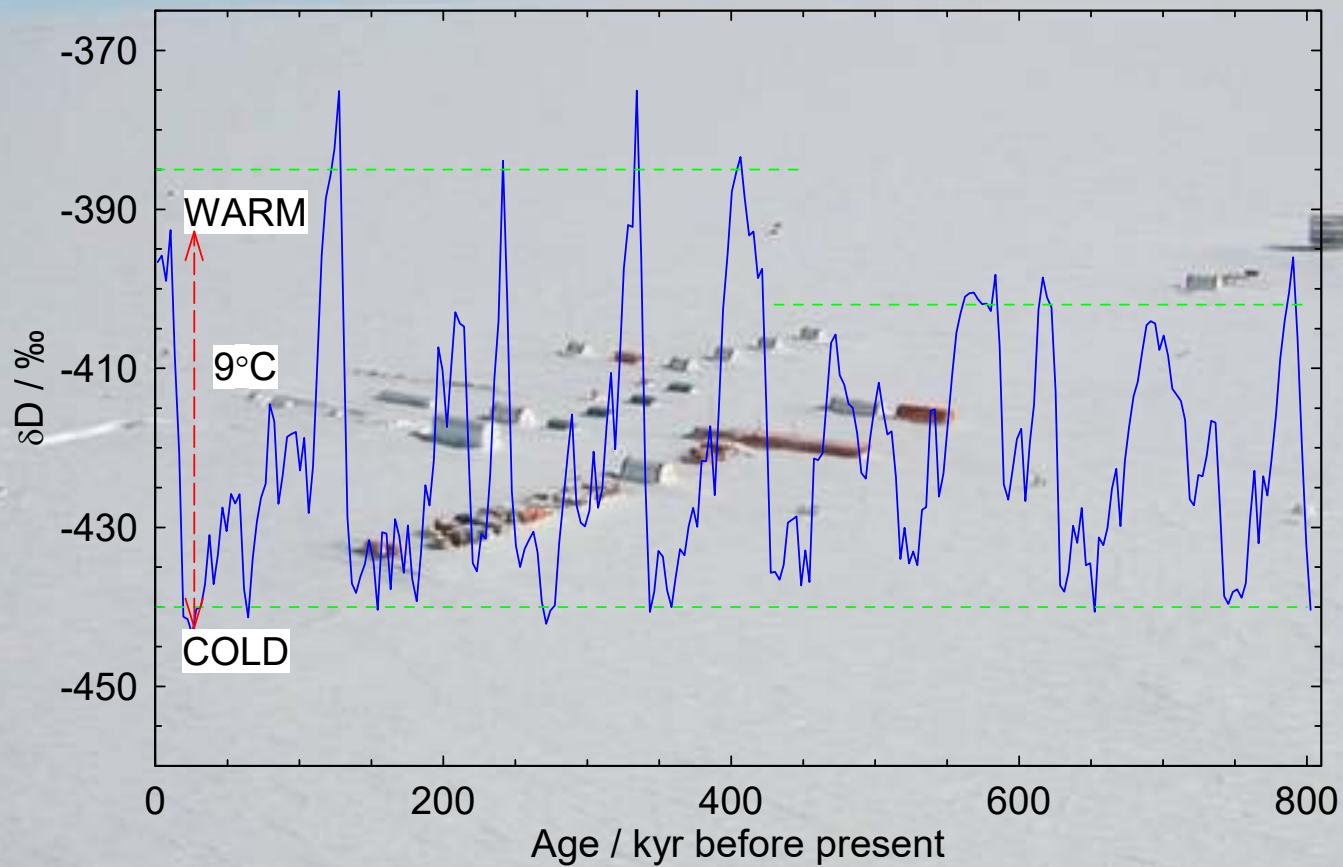
亚洲季风区降水稳定同位素现代 过程与古气候意义

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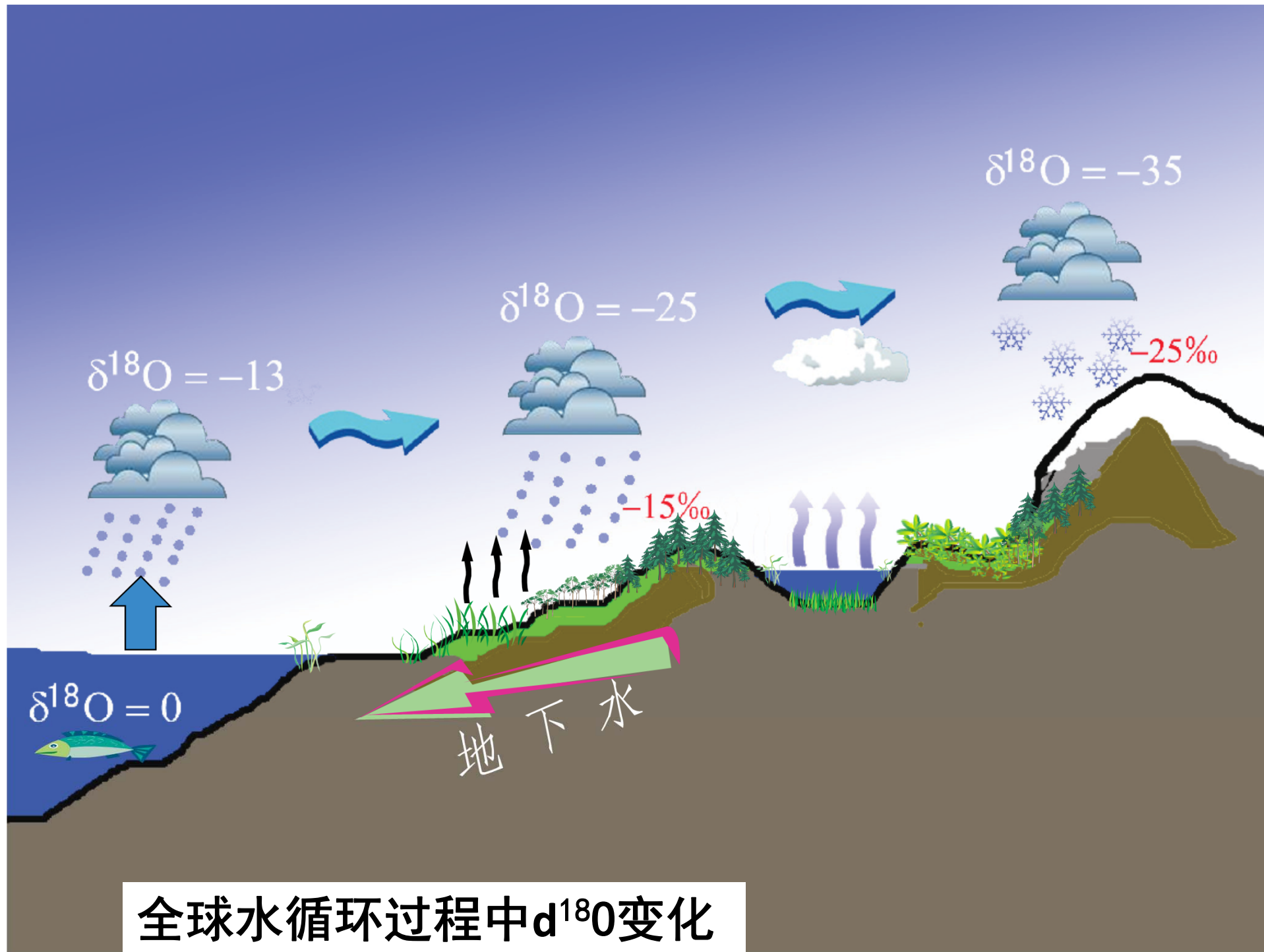
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Dome C冰芯揭示的过去80万年以来的气温变化序列



EPICA Community Members, *Nature*, 429, 623-628, 2004.

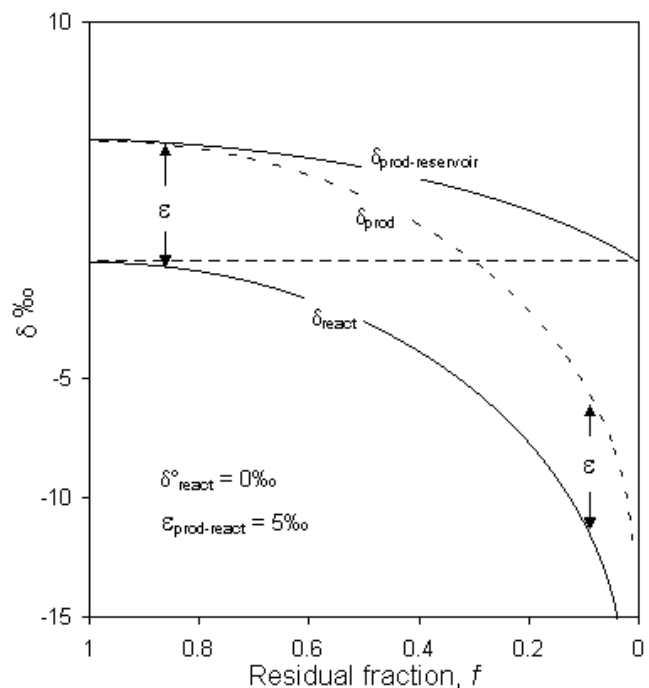


全球水循环过程中 $\delta^{18}\text{O}$ 变化

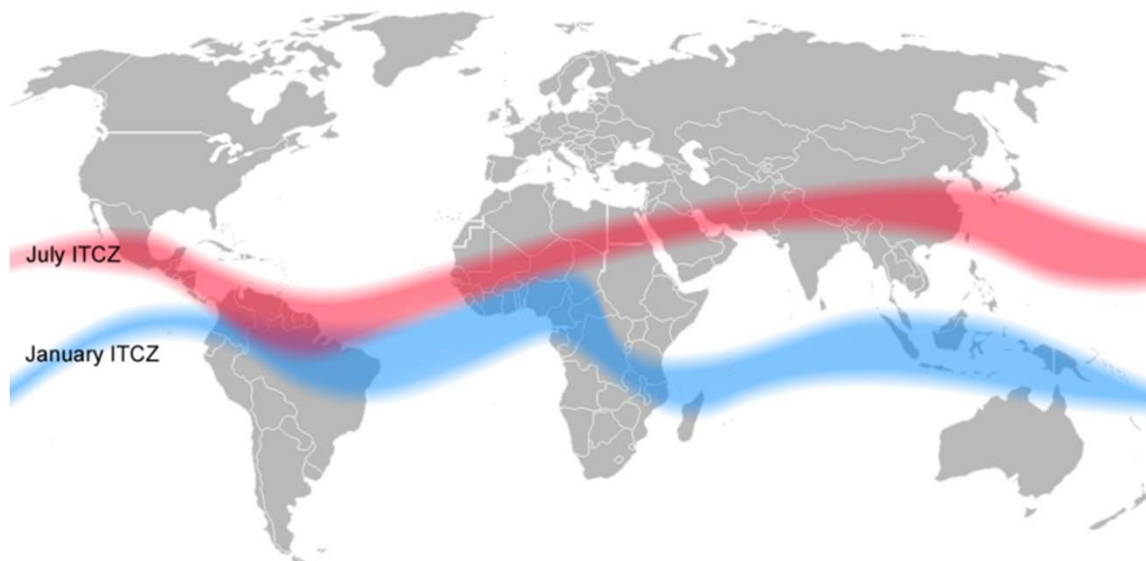
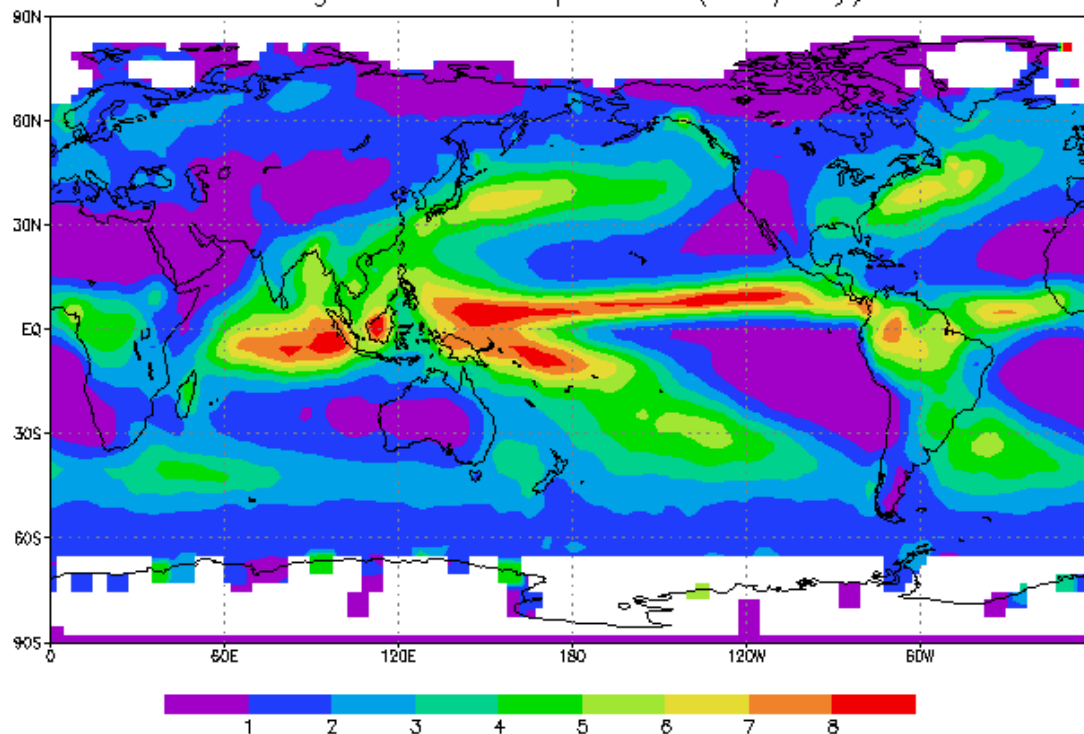
水循环的影响

Intertropical Convergence Zone

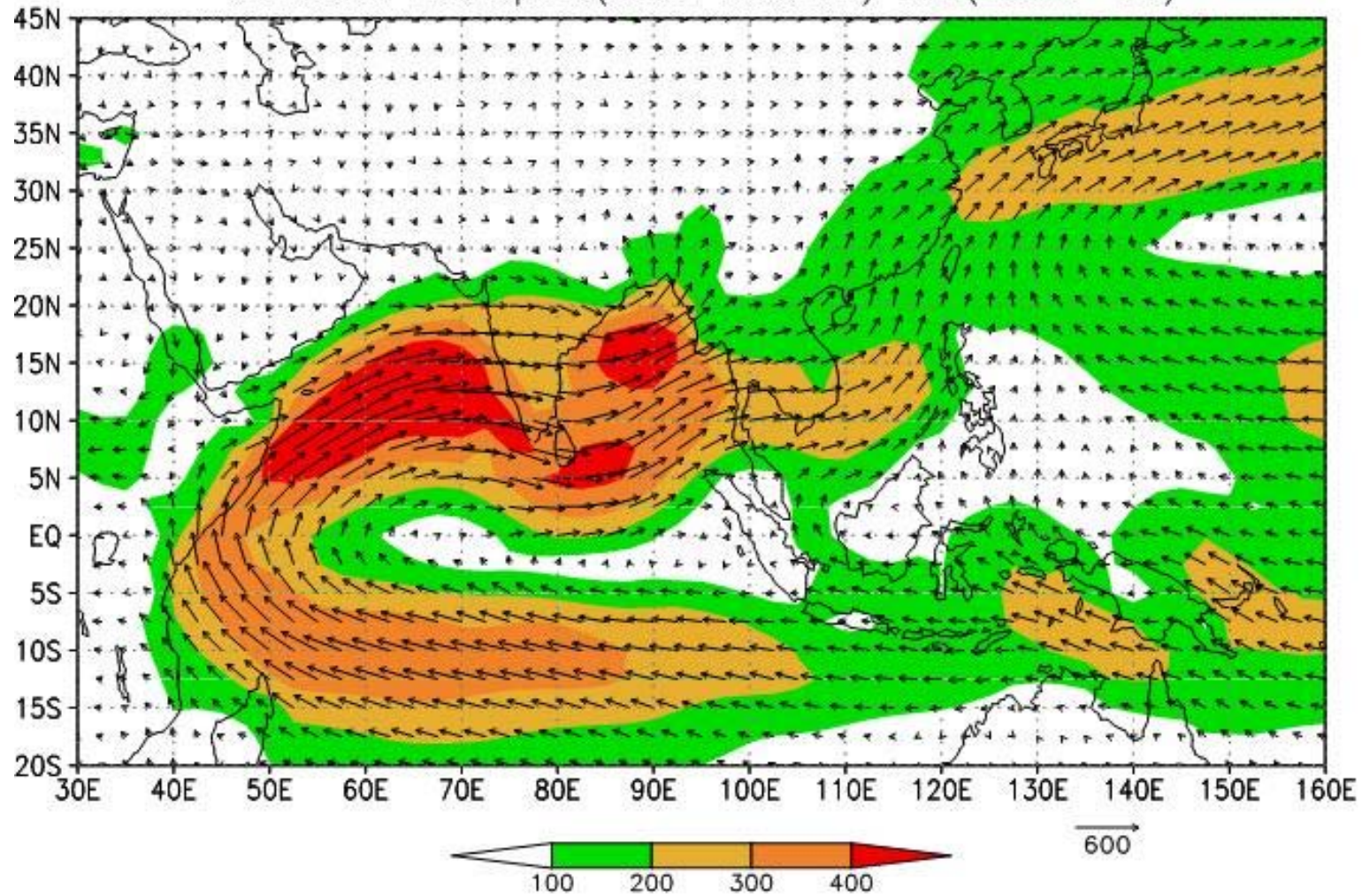
热带辐合带



Annual Average GPCP Precipitation (mm/day): 1988–96

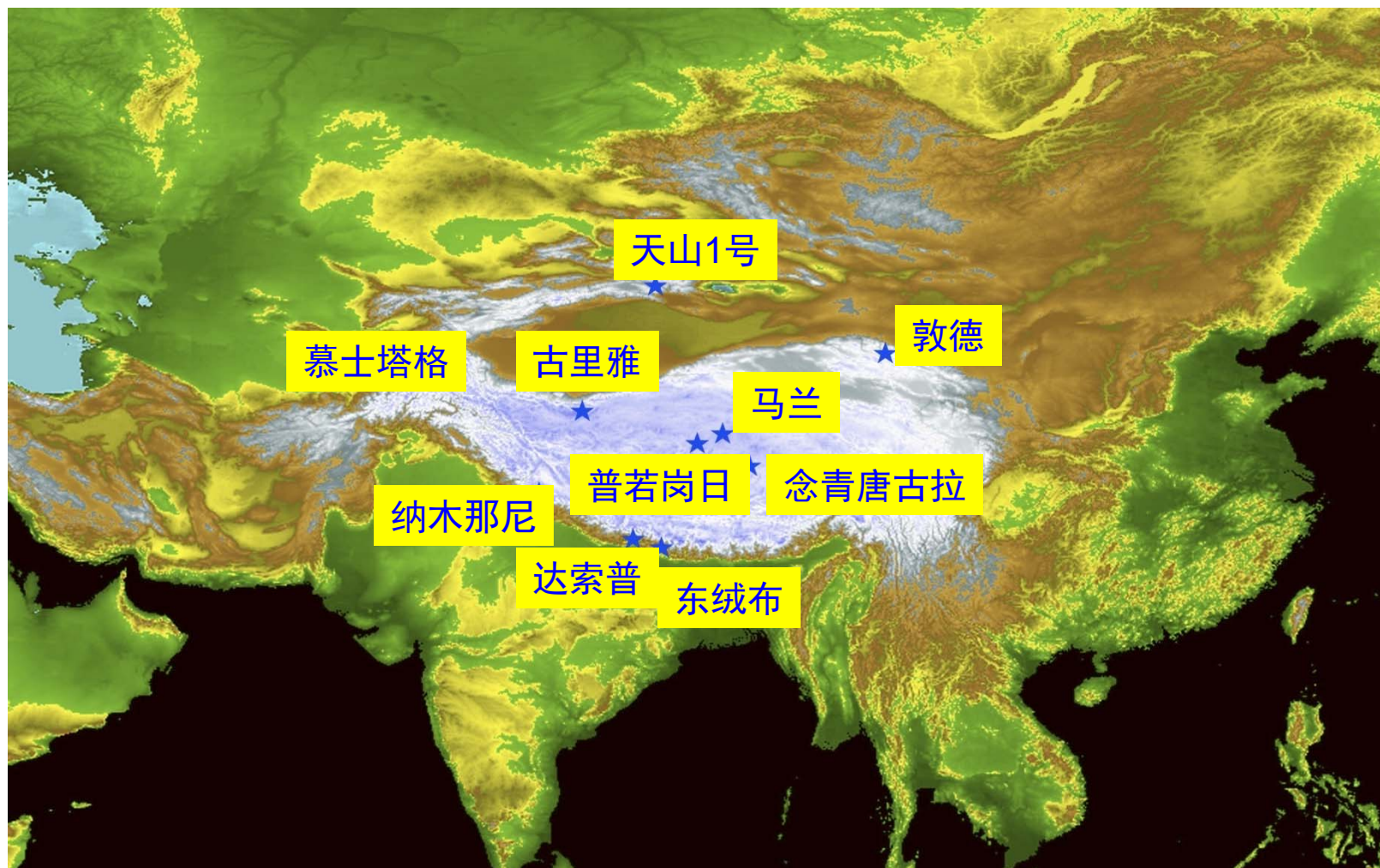


Moisture Transport(total column) JJA(1990-99)



From Ding Yihui

青藏高原冰芯钻取点

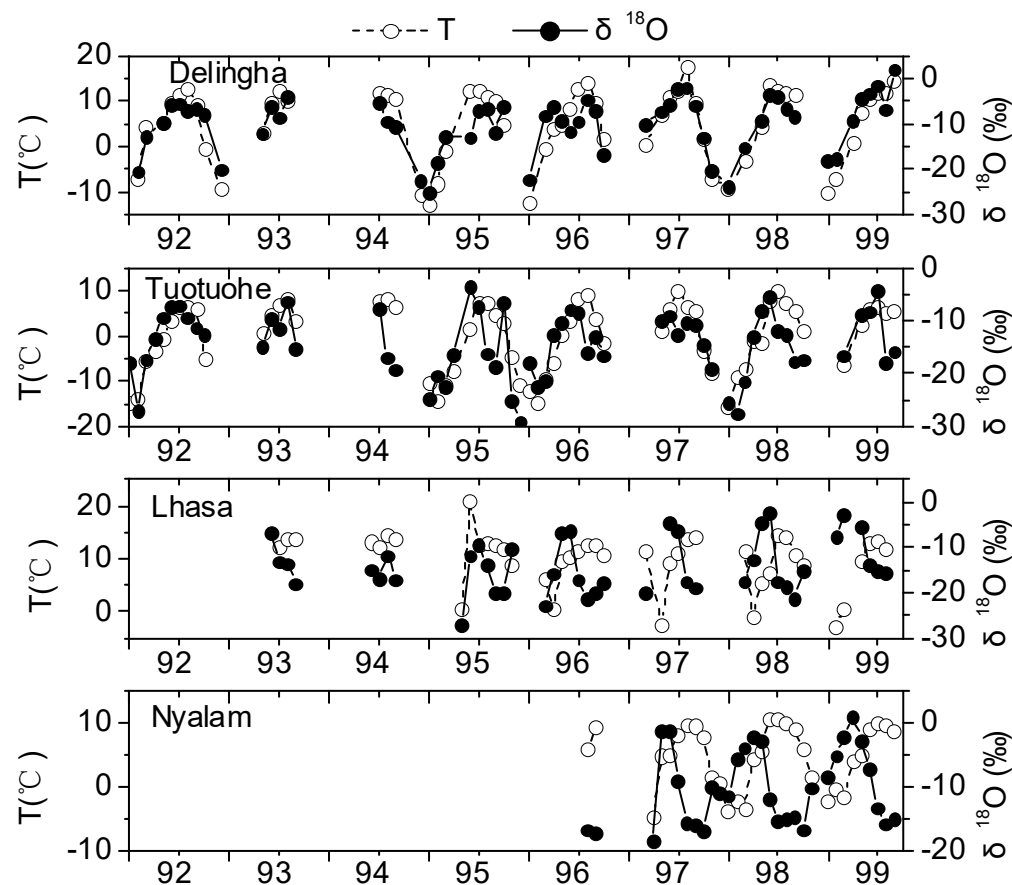






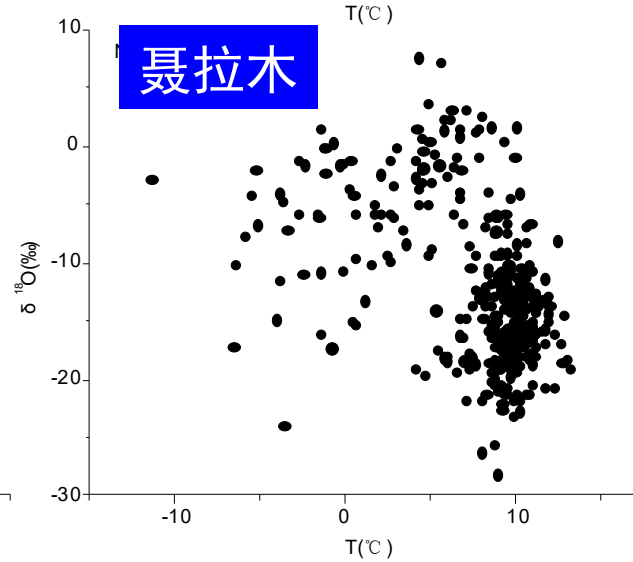
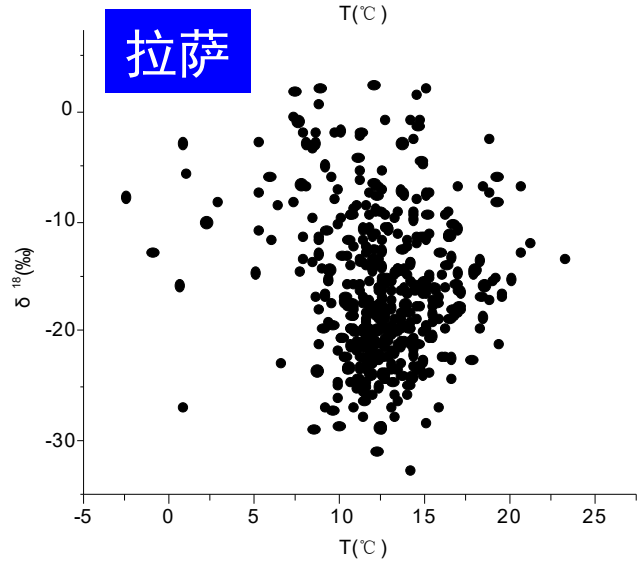
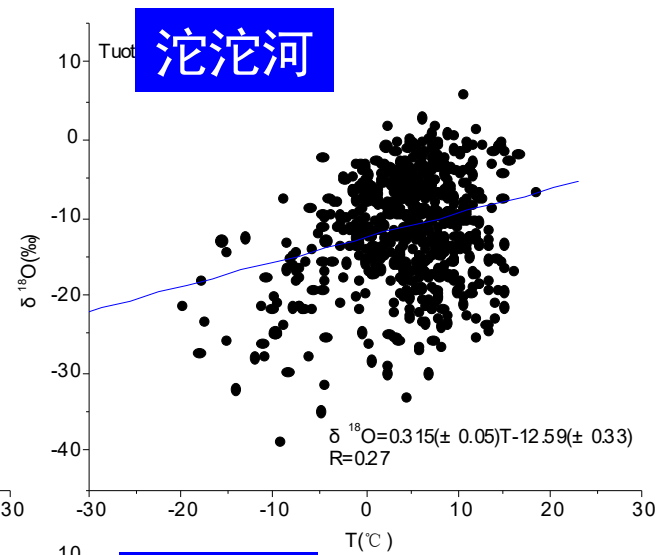
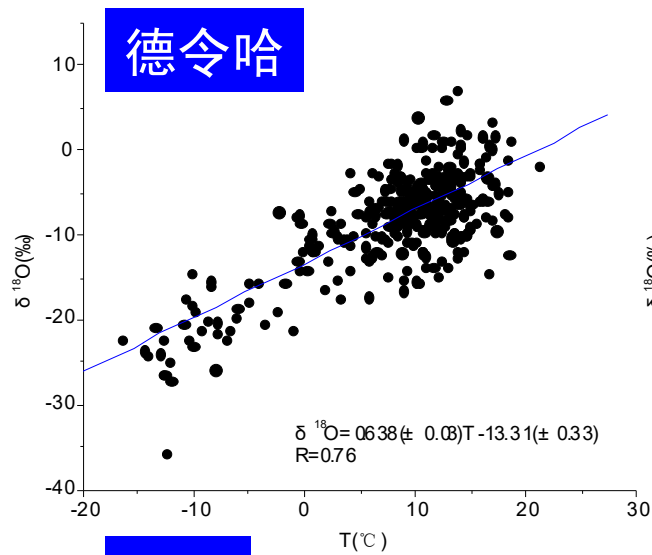
青藏高原降水同位素北部是“温度信号”，南部是“季风信号”

高原北部



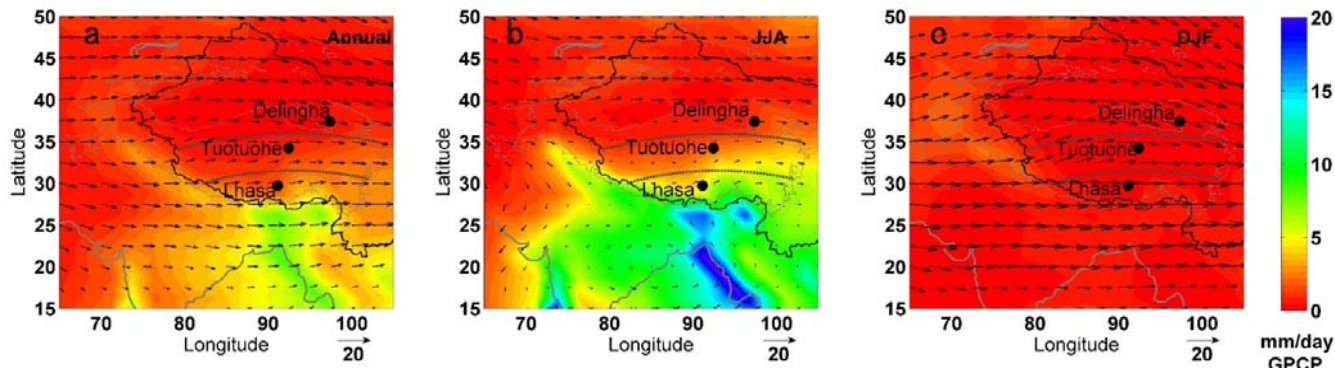
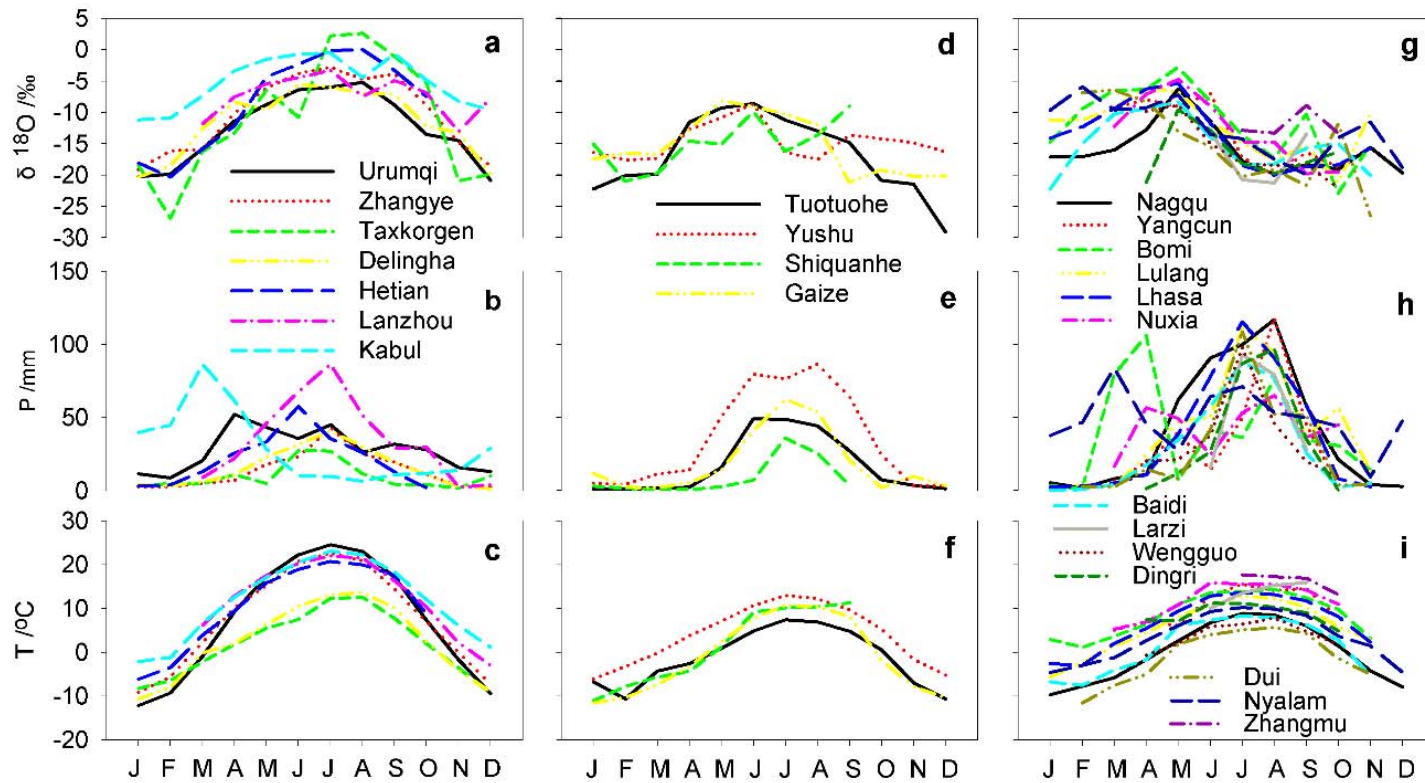
高原南部

青藏高原北部（德令哈与沱沱河）多年降水中 $\delta^{18}\text{O}$ 显示“温度效应”，而南部（拉萨与聂拉木）受季风影响降水显著， $\delta^{18}\text{O}$ 变化与气温无关。



青藏高原4个站点降水中 $\delta^{18}\text{O}$ 与气温关系

降水稳定同位素三种模态



(Gao et al., 2013)

古里雅冰芯稳定同位素变化

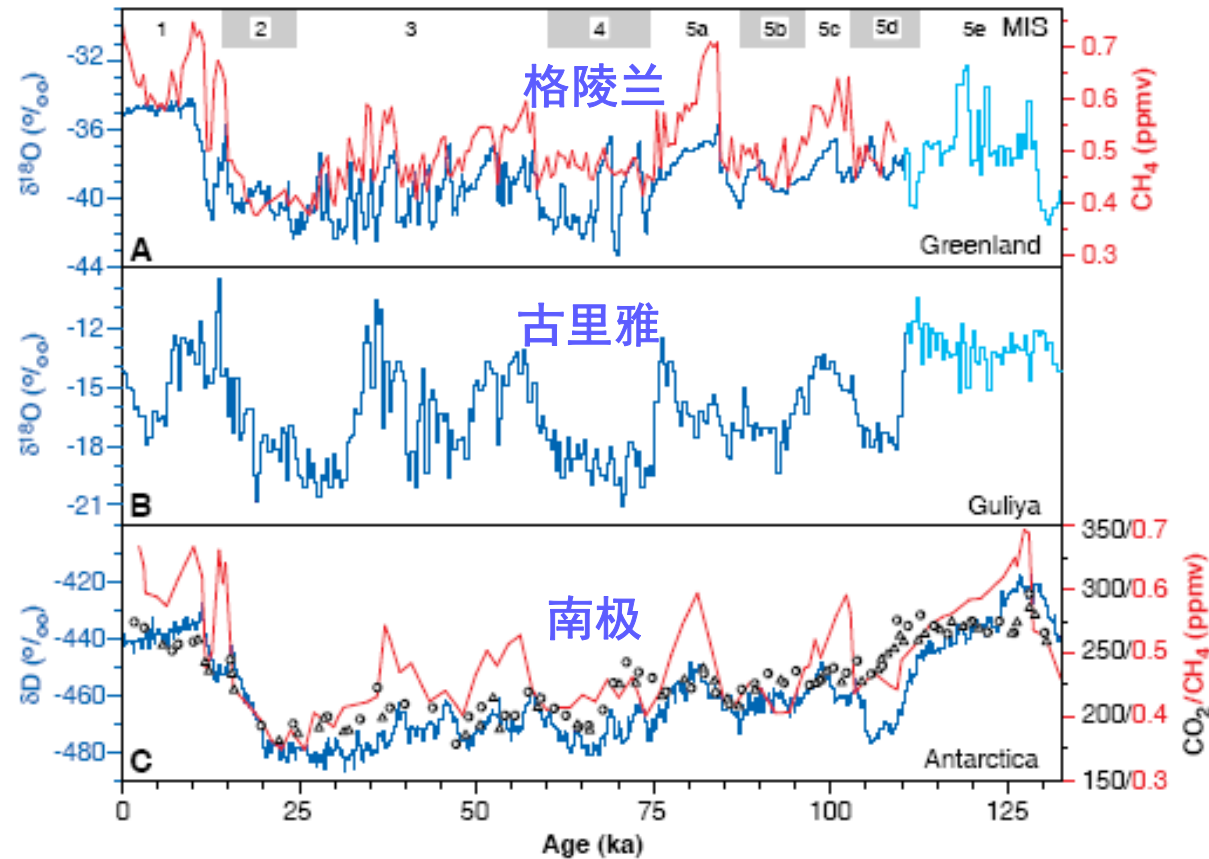


Fig. 3. (A) The GISP2 $\delta^{18}\text{O}$ (blue) and CH_4 records (red) are shown with time for the past 132 ka (11). The record is compromised by ice deformation below 110 ka, as shown by the light blue dotted line. The Guliya $\delta^{18}\text{O}$ record over the past 110 ka (B) is matched to the GISP2 CH_4 record over the past 110 ka. The Guliya record is also compared to the Vostok δD (blue), CH_4 (red) and CO_2 (black) [(13); circles, 1987 data; triangles, 1991 data] records (C), which display temporal continuity below isotope Stage 5d.

达索普冰芯稳定同位素与北半球气温变化趋势一致，而与冰川积累量关系不明显。

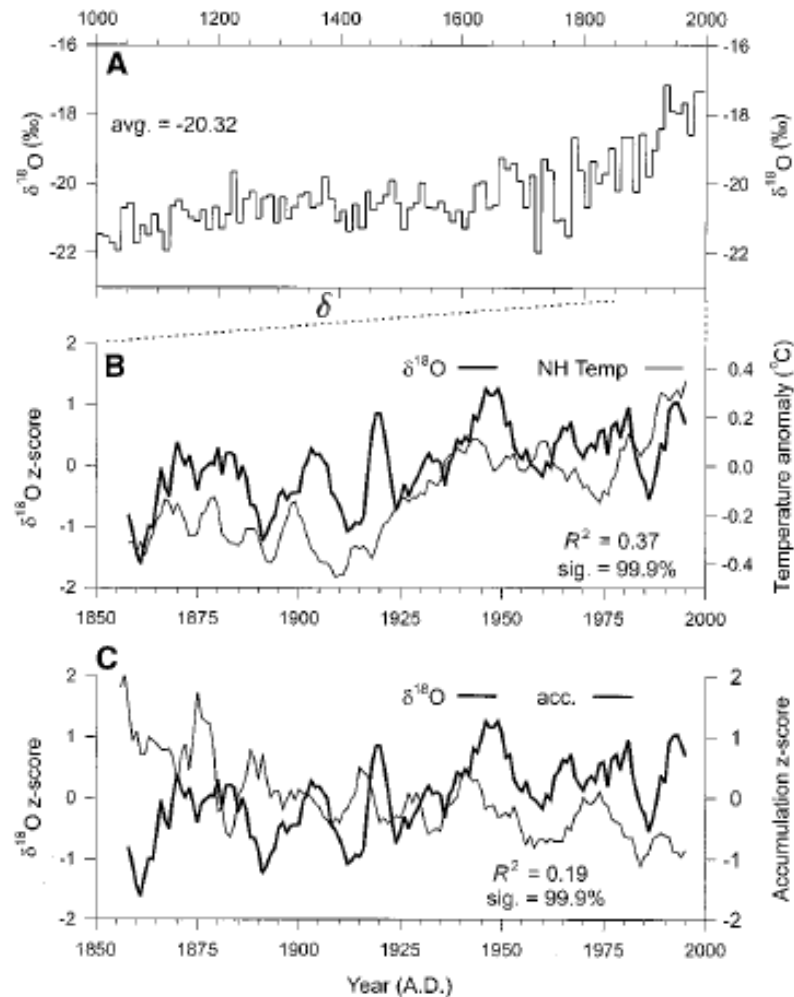
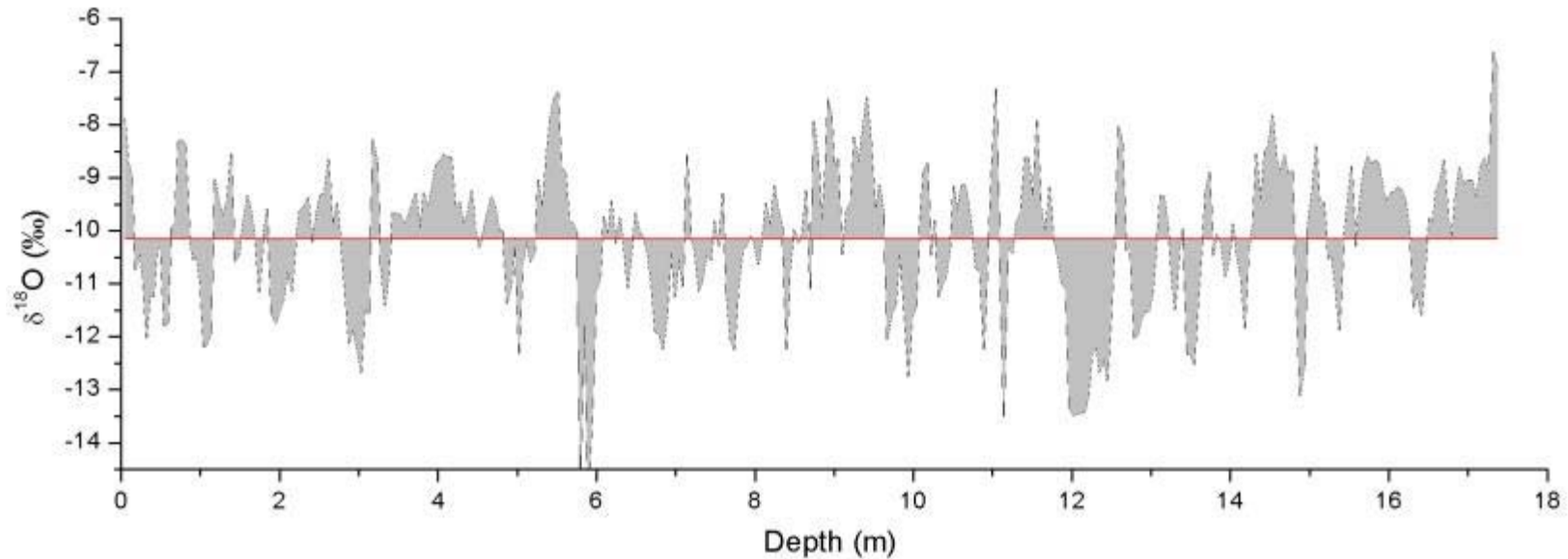


Fig. 6 (right). (A) Decadal averages of $\delta^{18}\text{O}$ for the last 1000 years on Dasuopu reveal the isotopic enrichment beginning in the 19th century and intensifying in the 20th century. (B) Five-year running means of $\delta^{18}\text{O}$ from Dasuopu are significantly correlated with NH temperature anomalies since 1860. (C) Five-year running means of $\delta^{18}\text{O}$ and accumulation from Dasuopu are weakly correlated. Z scores for the Dasuopu $\delta^{18}\text{O}$ and accumulation data were calculated using respective means of -18.63‰ and 1104.4 mm and respective σ of 1.92‰ and 423.7 mm.

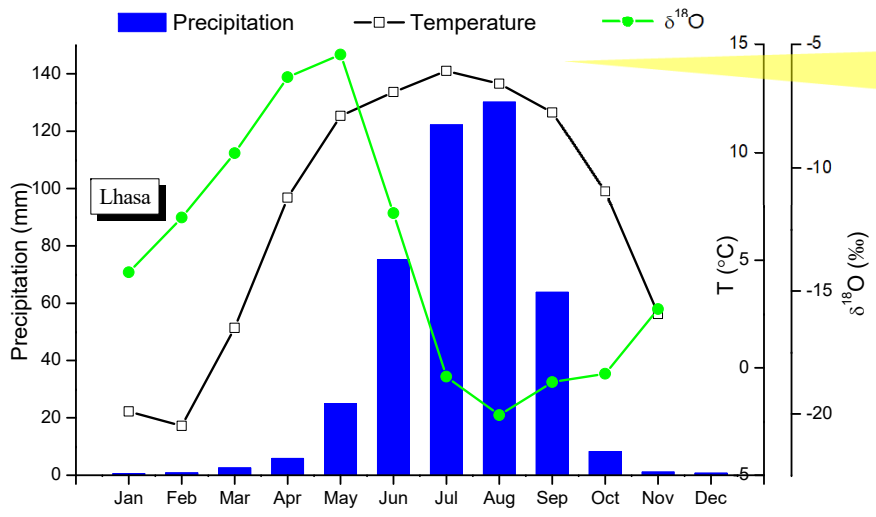
Thompson et al. 2000. A high-resolution millennial record of the South Asian Monsoon from Himalayan ice cores. *Science*, 289, 1916-1919.

青藏高原冰芯研究的挑战

为什么过去几十年青藏高原升温明显，但冰芯同位素没有相应的升高？

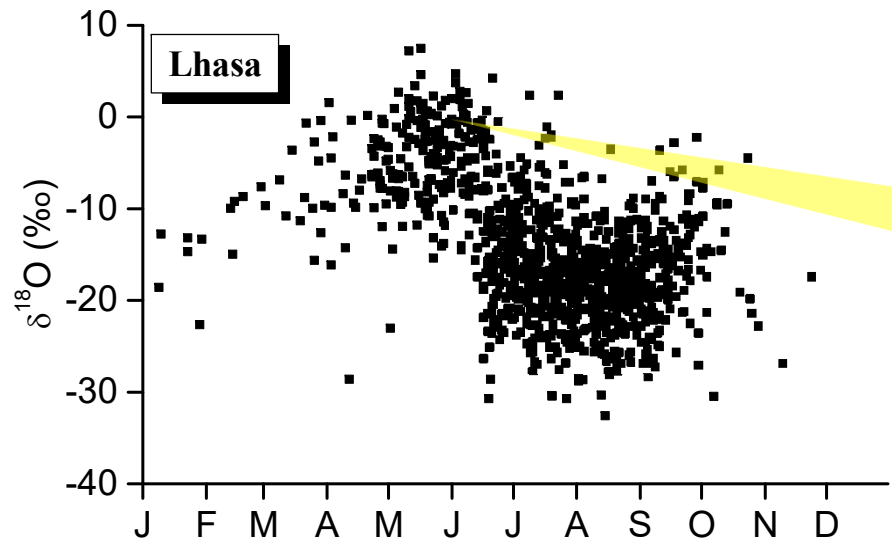


Ice core isotope record did not rise up in recent years



“降水量效应”
的机制

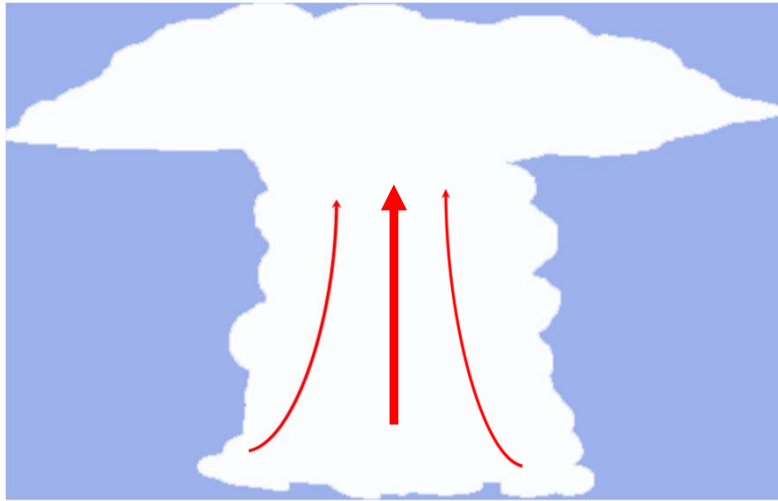
拉萨降水同位素 δ¹⁸O, 降水量与气温的季节变化



水汽来源变化?

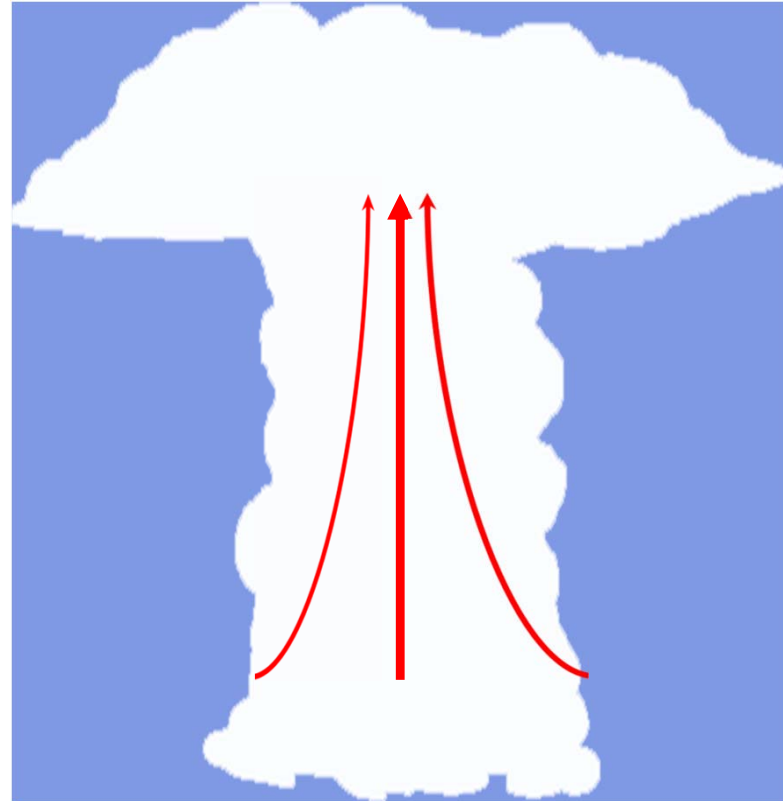
拉萨降水事件尺度 δ¹⁸O 季节变化

Higher air pressure
Higher temperature



季风弱

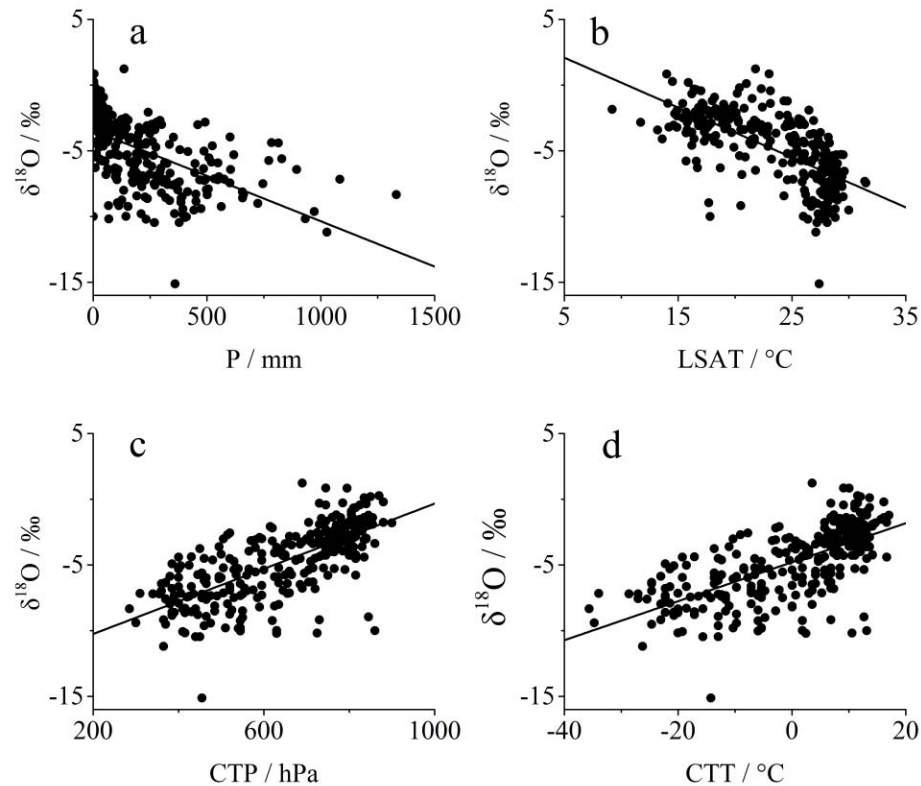
Lower air pressure
Lower temperature



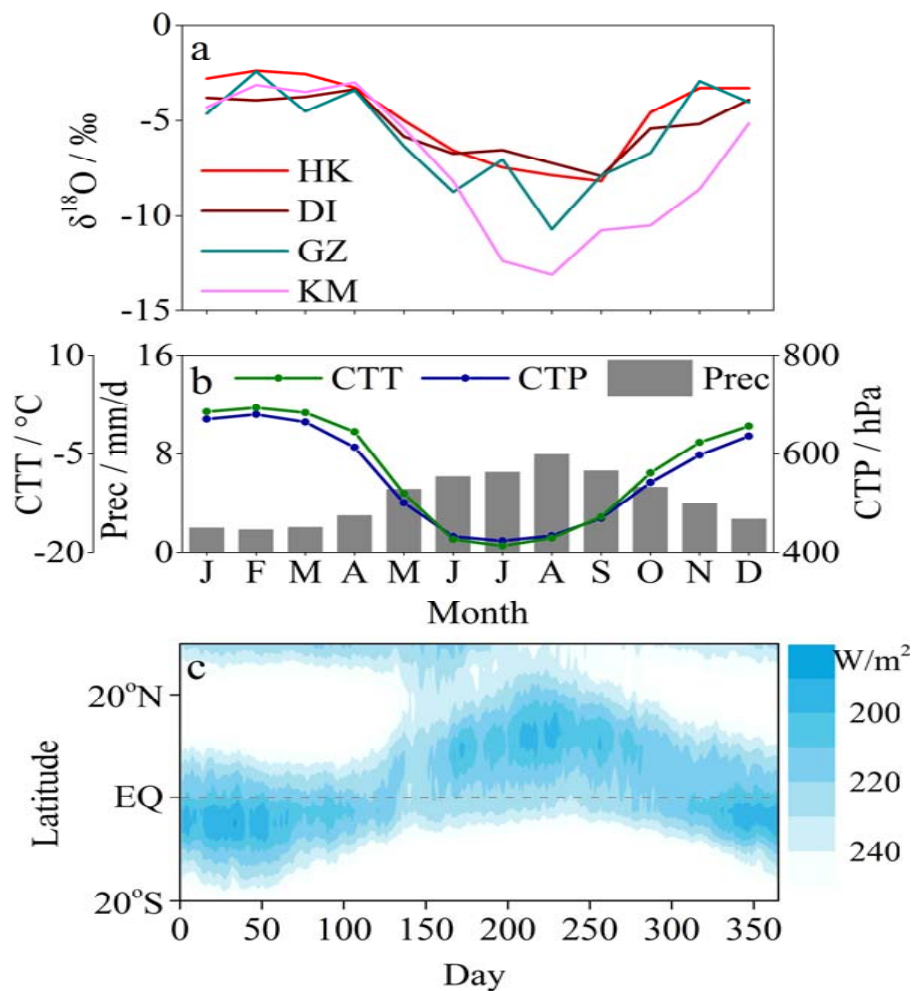
季风强



International Satellite Cloud Climatology Project (ISCCP) (1983-2009)



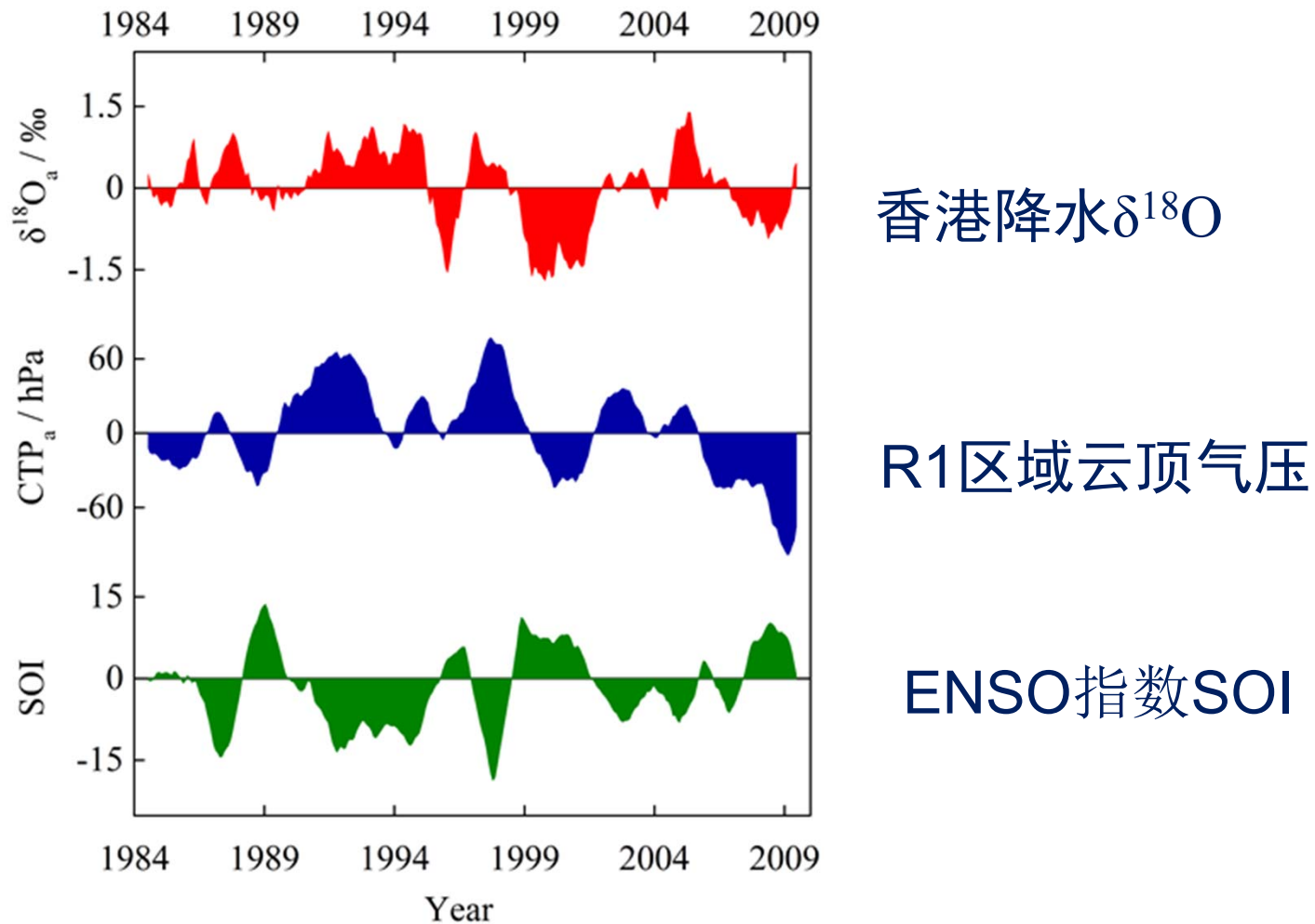
Relation between monthly $\delta^{18}\text{O}$ in Hong Kong precipitation and local precipitation amount (a); local land surface air temperatures (LSAT) (b); CTP in the $2.5^\circ \times 2.5^\circ$ Hong Kong grid box (c); and CTT in the $2.5^\circ \times 2.5^\circ$ Hong Kong grid box (d). Black lines indicate linear regression lines.



季风及ITCZ的季节进退导致了降水同位素的季节变化；这并不支持水汽来源的解释，非季风期降水可能也是海洋性水汽来源。

东亚季风区3个站点降水 $\delta^{18}\text{O}$ 季节变化(a), 研究区域长期平均的云顶温度 (CTT)、云顶气压 (CTP) 与降水量 (Prec) 的季节变化 (b) ; 100oE-150oE区域平均OLR的季节变化, 显示了ITCZ在两半球的波动 (c)

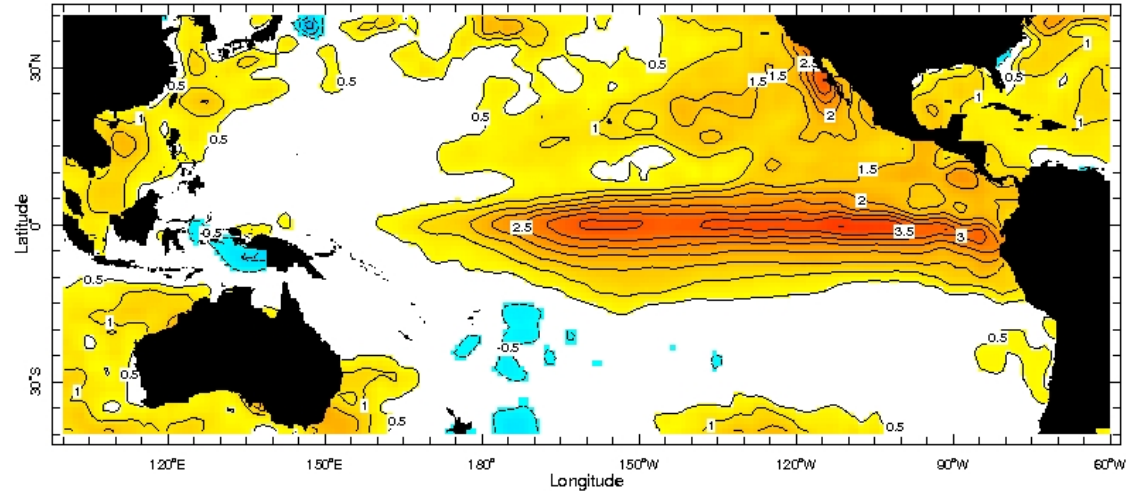
季风区降水同位素在年际尺度上的波动与 ENSO 相关，受大尺度大气环流过程的影响



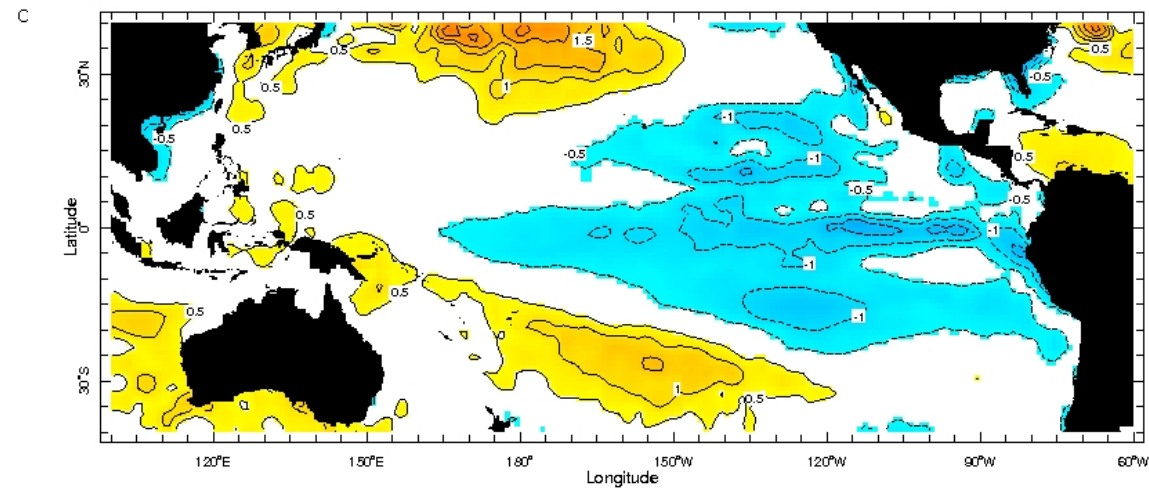
(Cai and Tian, J Climate. 2016)

ENSO drivers the interannual monsoon precipitation isotopes and ice core record

El Niño



La Niña

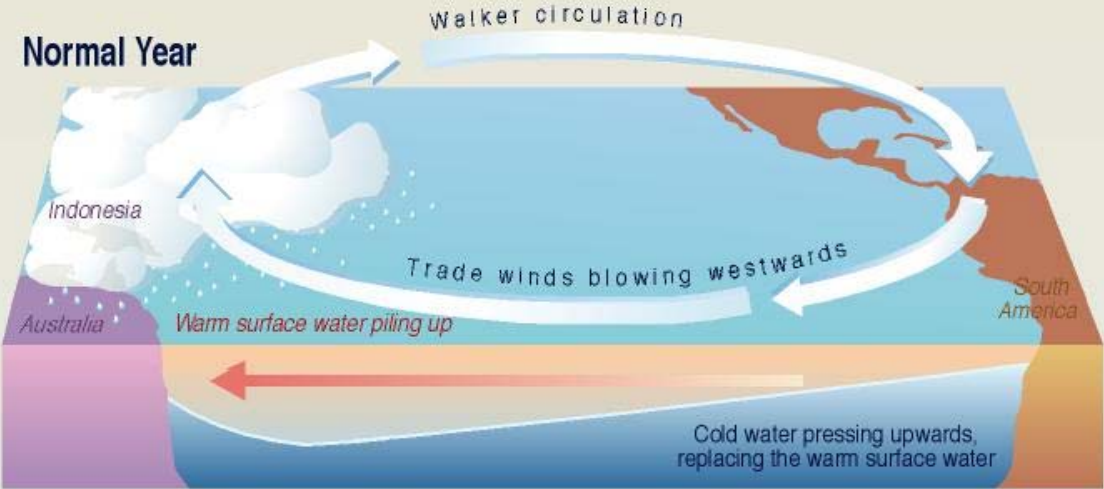


Oct-Dec 2011

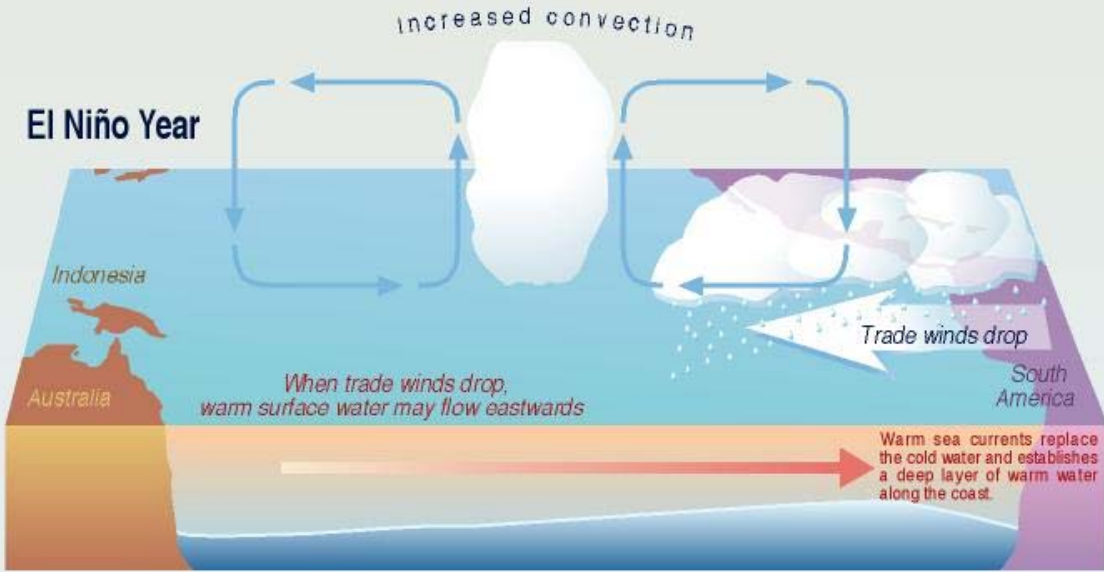
Sea surface temperature analogy during El Niño/La Niña

El Niño Phenomenon (ENSO)

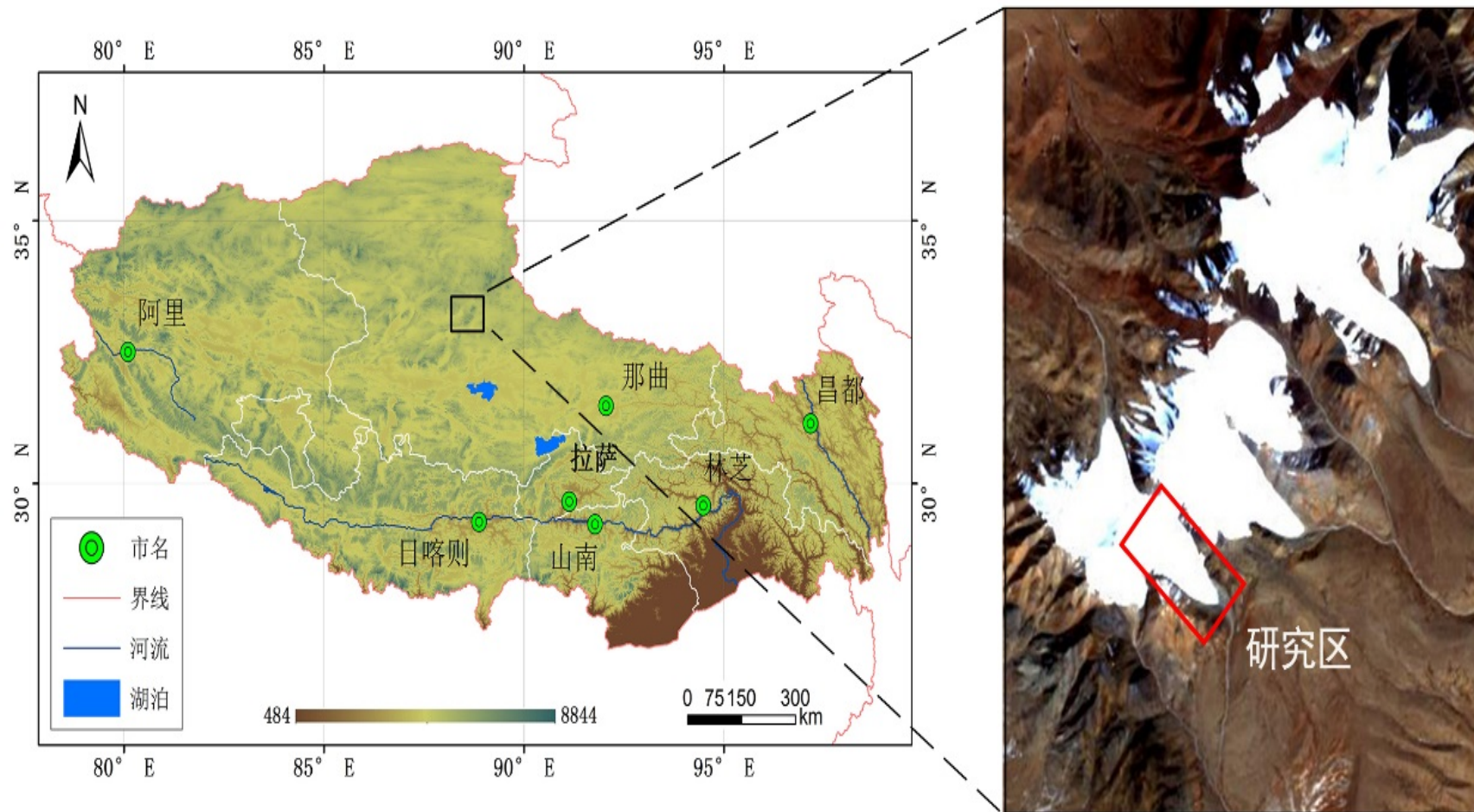
Normal Year

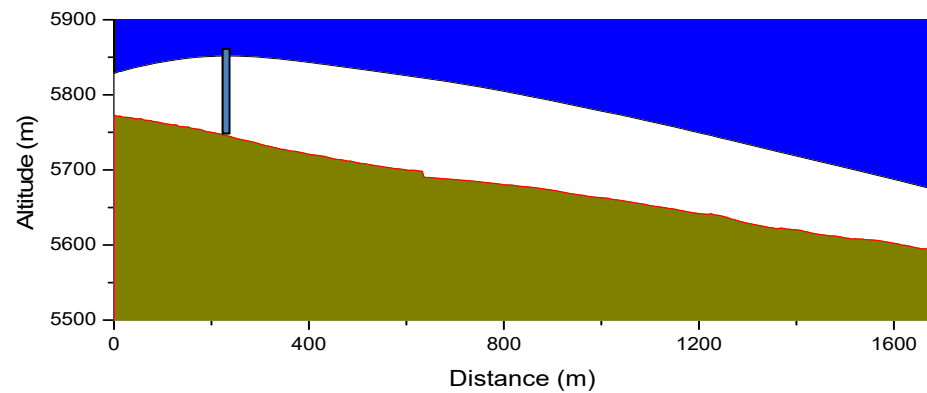


El Niño Year

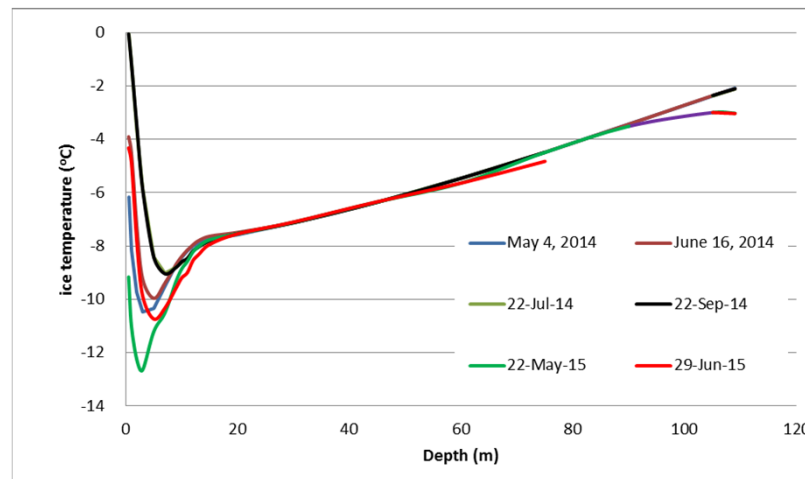


双湖“羌塘1号冰川”冰芯记录



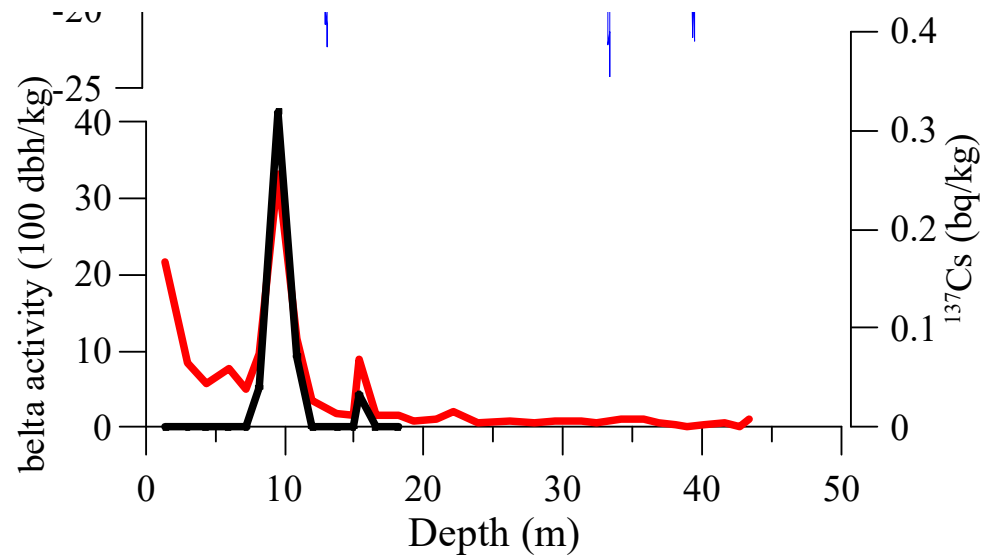


冰川纵剖面雷达测厚

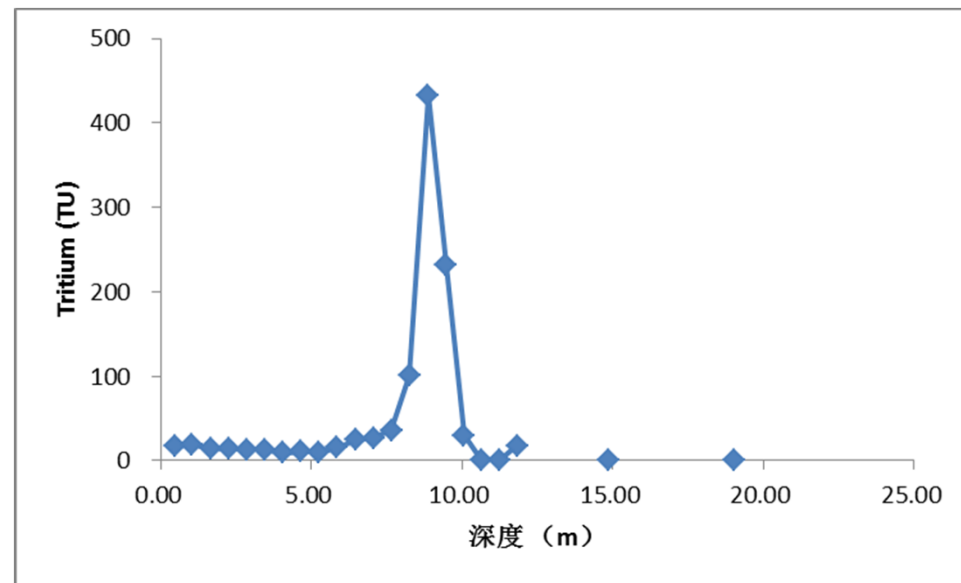


冰孔温度

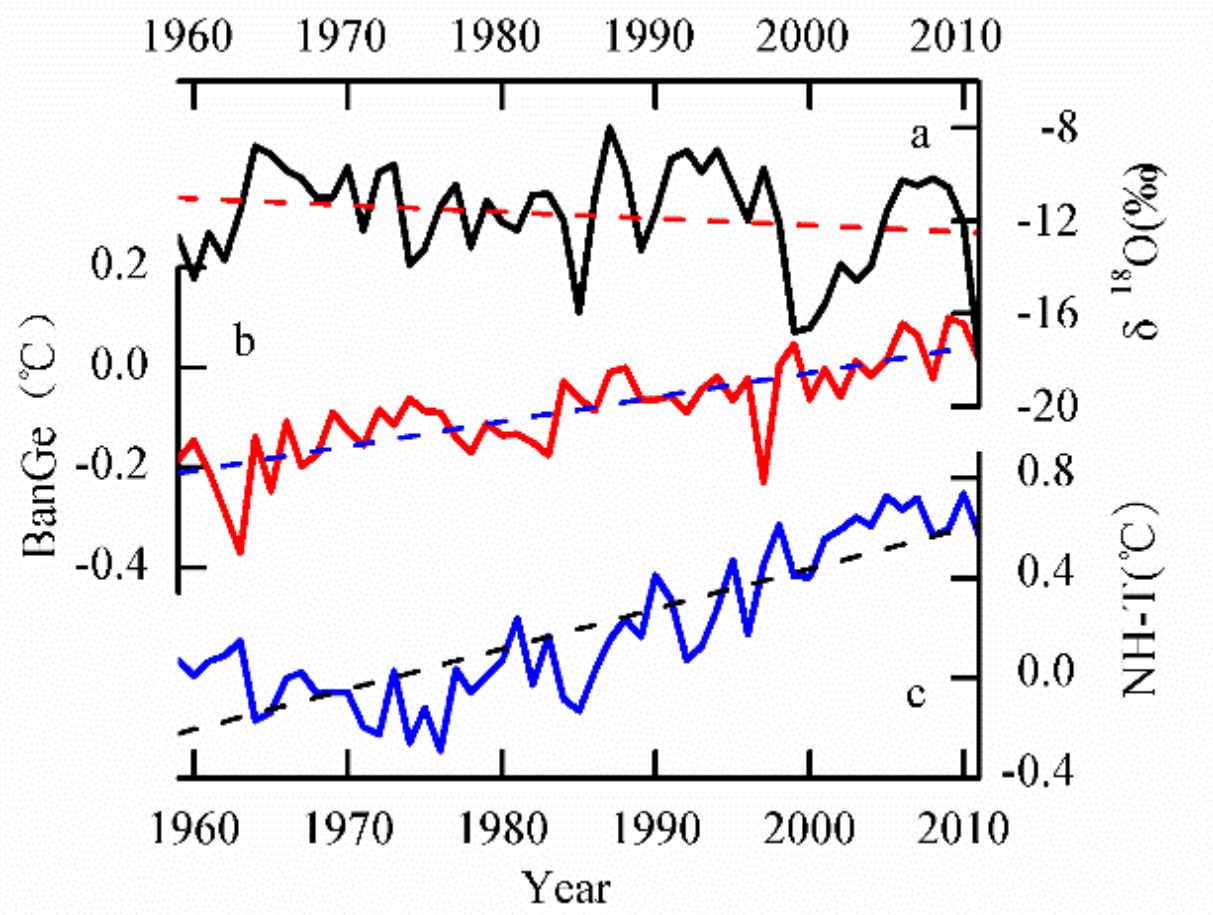




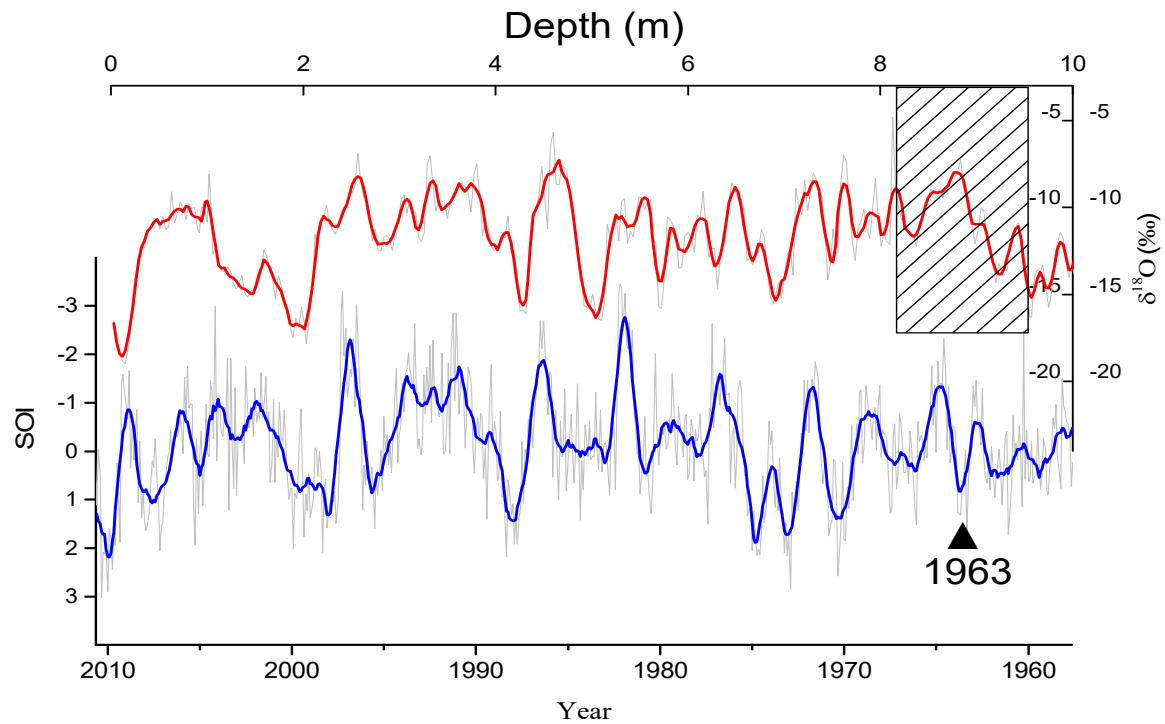
冰芯中的Beta 活动度与 ^{137}Ce 放射性年层



冰芯中 ^3H 浓度随深度变化

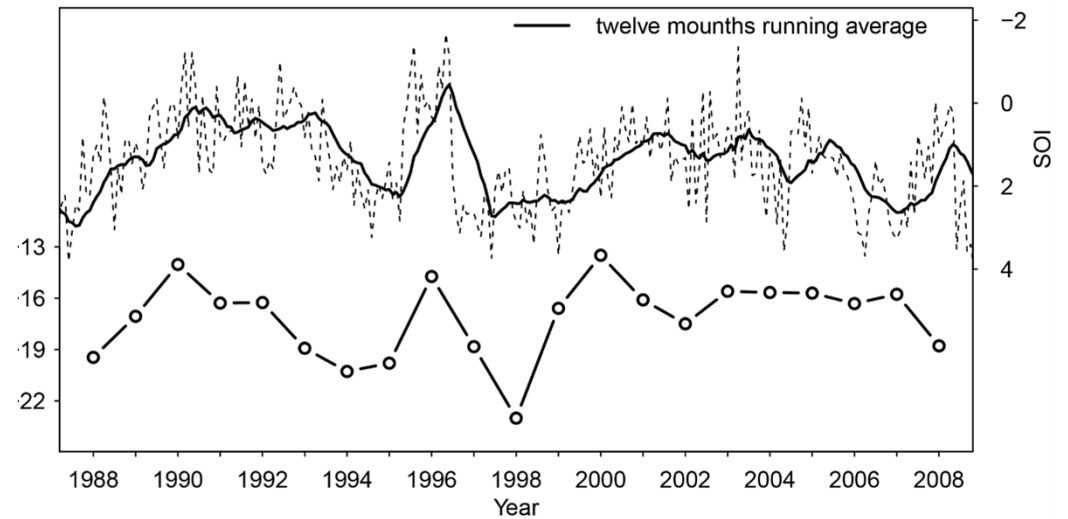
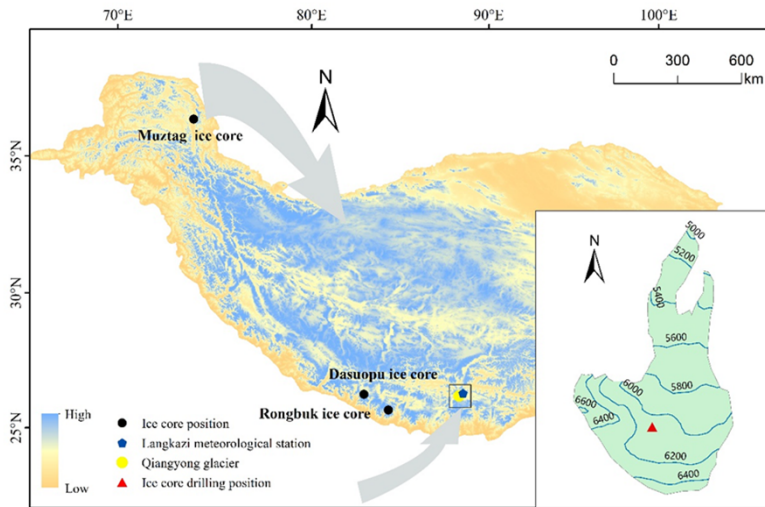


高原中部羌塘冰芯 $\delta^{18}\text{O}$ 记录与当进气温与北半球气温变化对比



羌塘冰芯 $\delta^{18}\text{O}$ 记录与南方涛动指数 (SOI) 对比

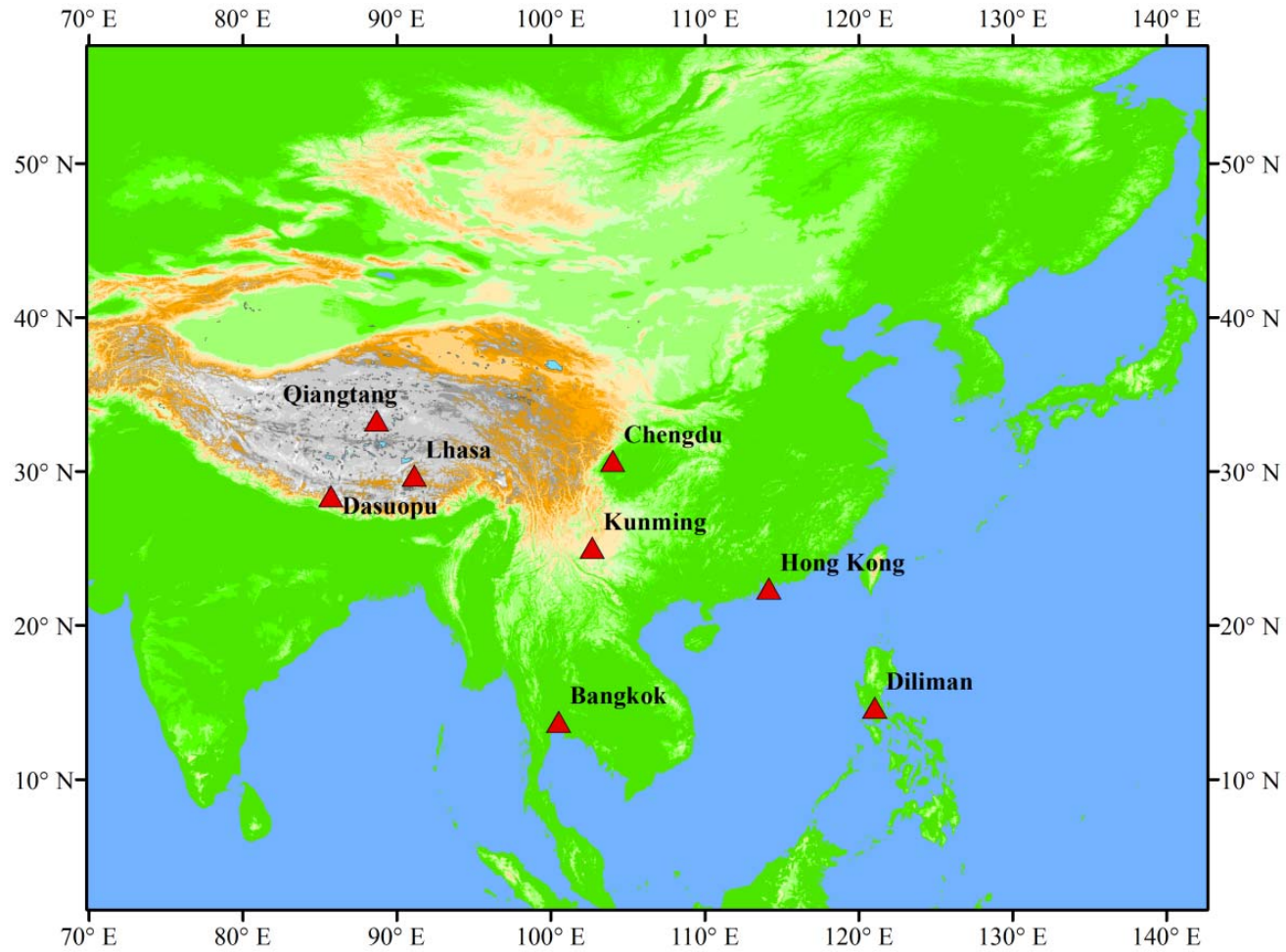
(Shao et al., Atmosphere Research, 2017)

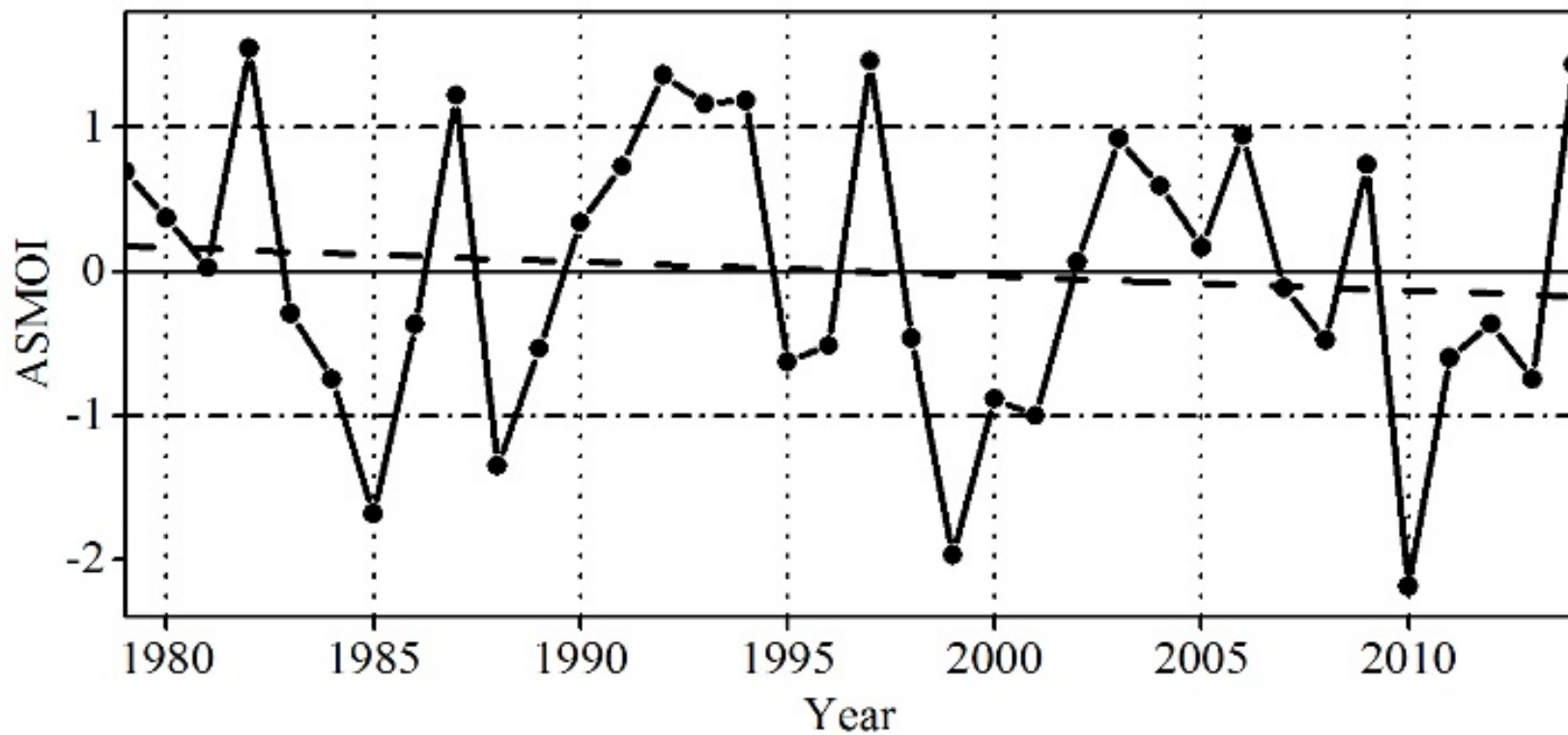


表藏高原南部枪勇冰芯同位素变化与月均南方涛动指数 SOI (dotted line) 变化一致

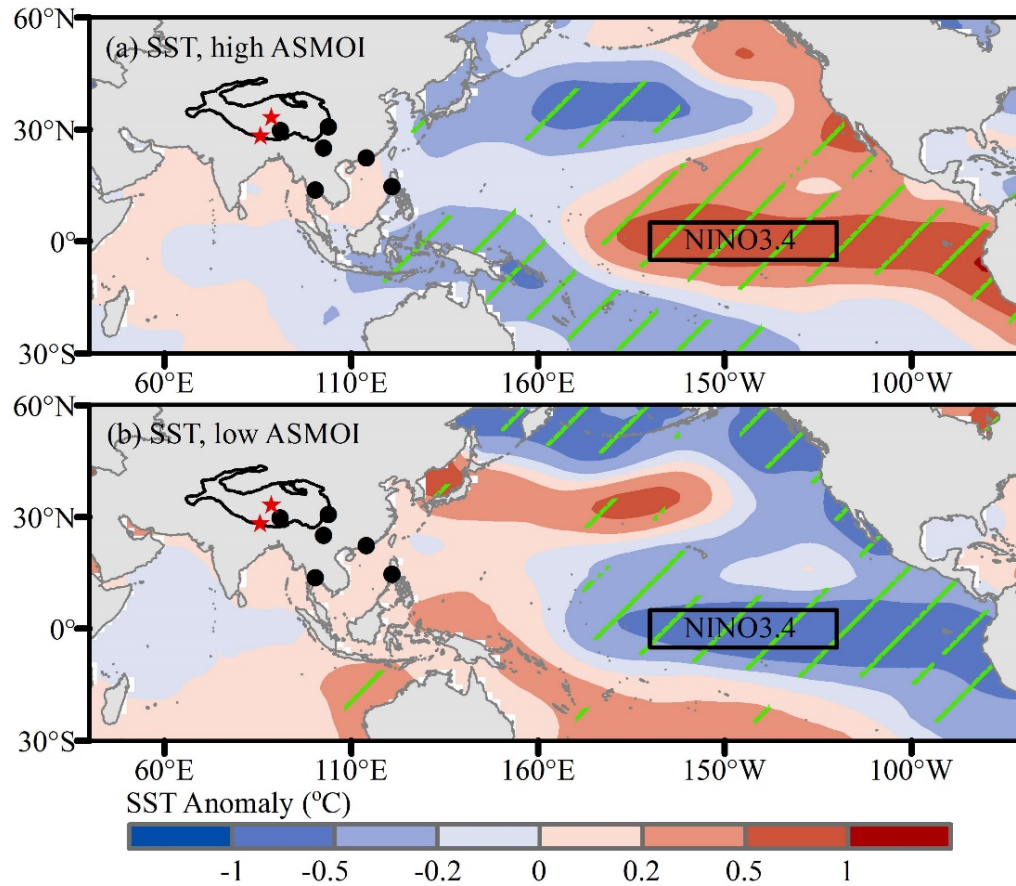
(Tian Ran and Tian Lide, 2018)

ASMOI –Asia Summer Monsoon Oxygen Isotope Index





亚洲夏季风降水 $\delta^{18}\text{O}$ 指数ASMOI时间序列

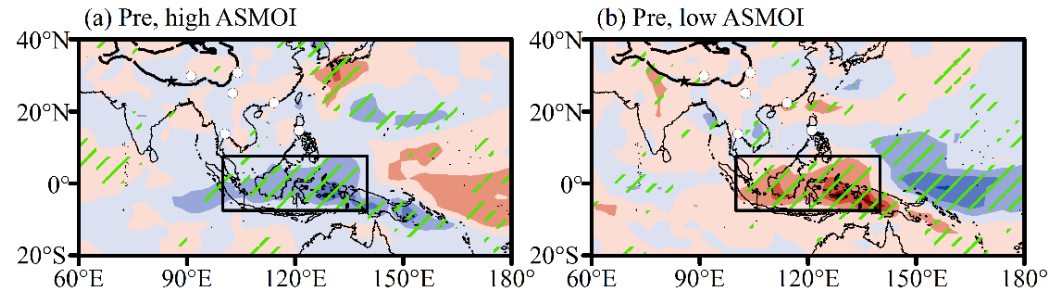


ASMOI高值年份海表
温度距平合成

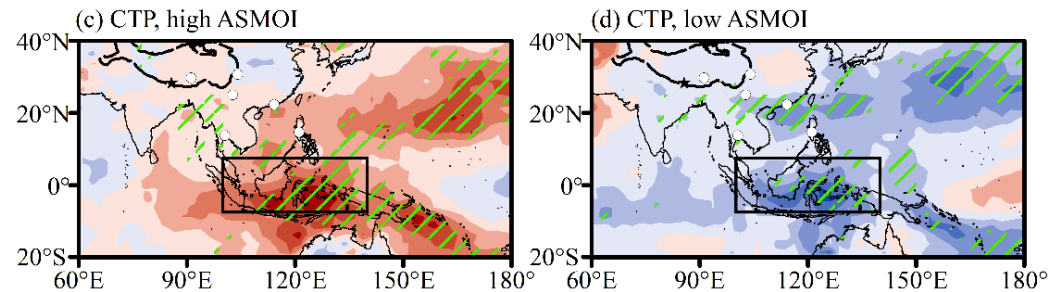
ASMOI低值年份海表
温度距平合成

(Cai et al., EPSL, 2017)

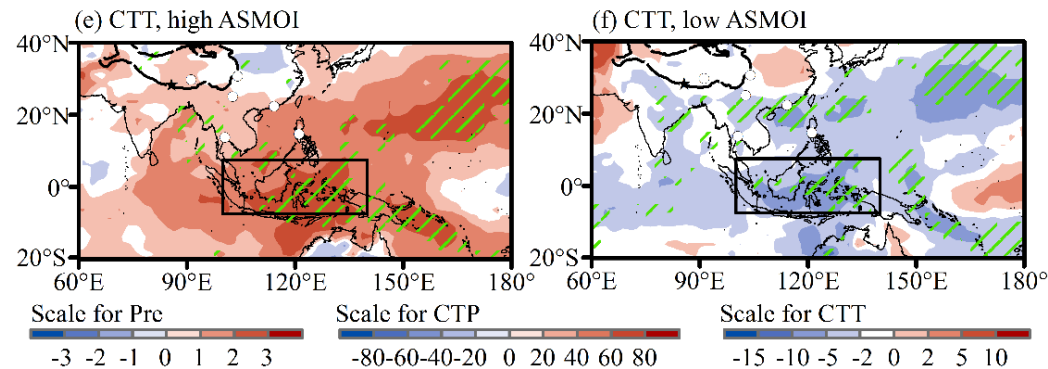
降水量



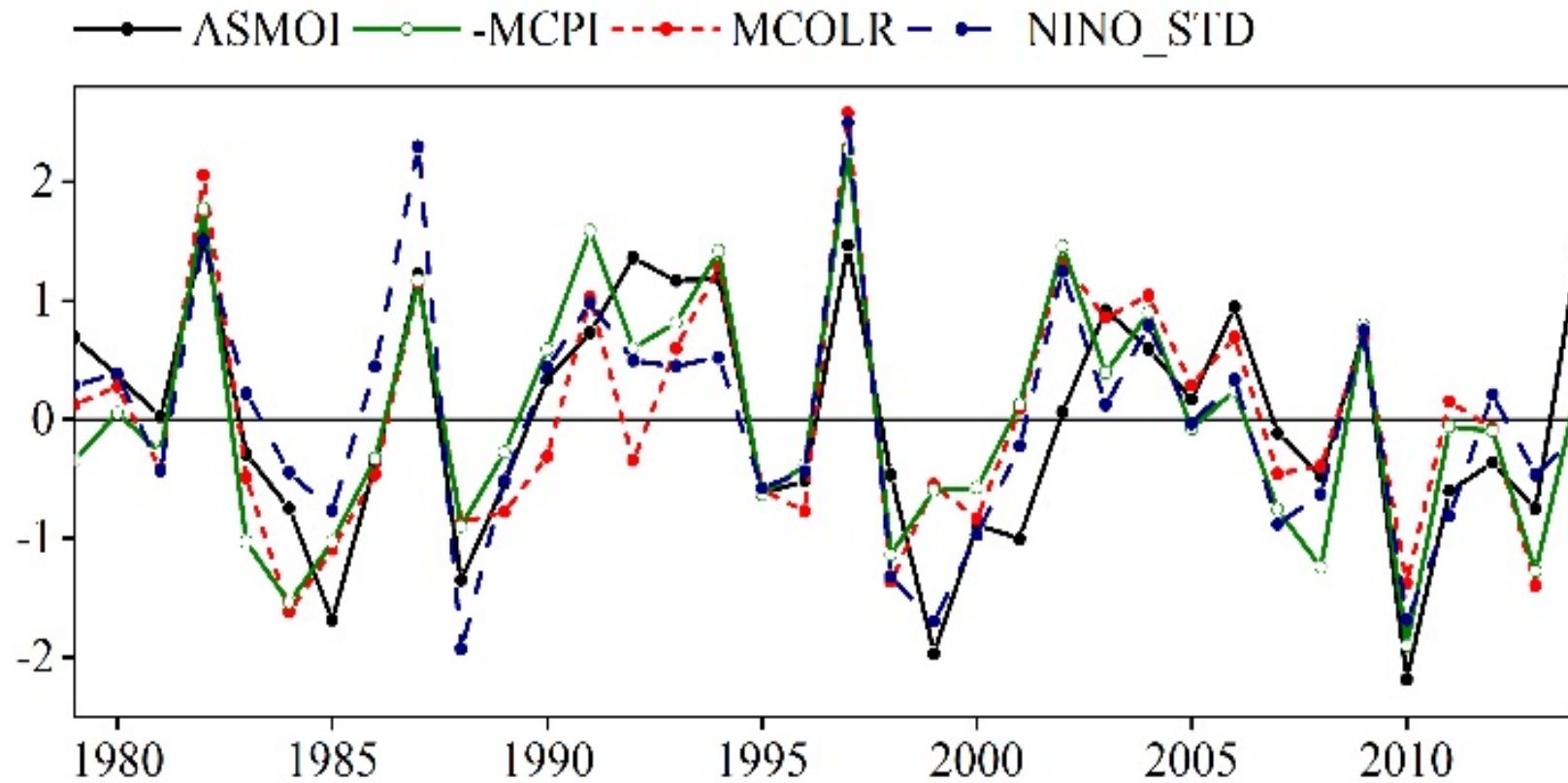
云顶气压



云顶温度

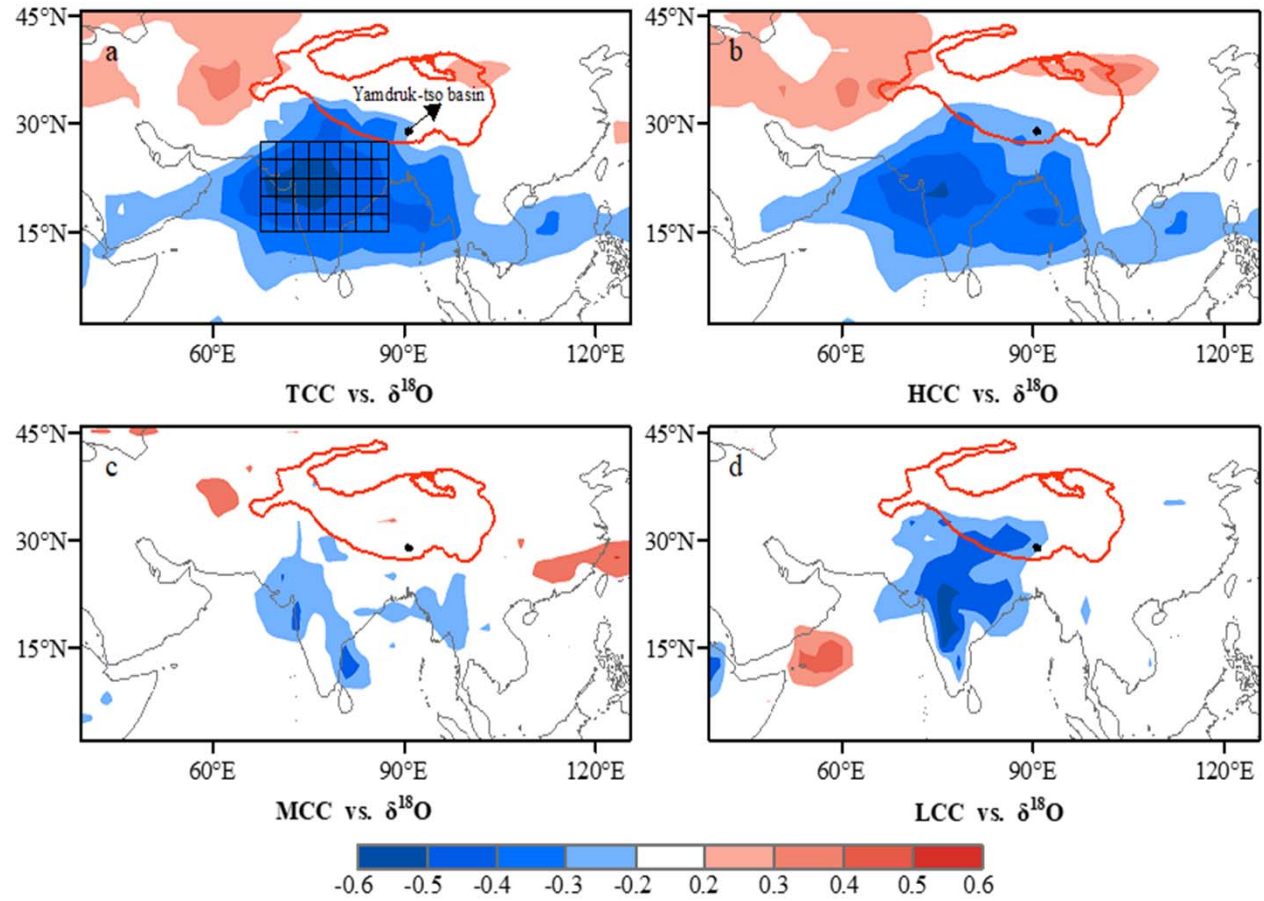
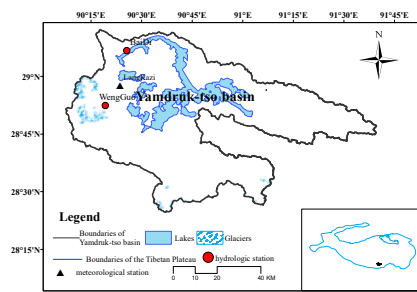


Composite anomalies of JJAS (a) precipitation, (c) CTP and (e) CTT for high ASMOI years, and for JJAS (b) precipitation, (d) CTP and (f) CTT for low ASMOI years. The rectangle denotes the area taken to be the Maritime Continent. Values exceeding the 90% confidence level are hatched.



亚洲夏季风同位素指数数据年际变化，与赤道海洋陆地区域夏季降水（负相关系数）、OLR，以及NINO34 区域温度。
东亚季风区与南亚季风区降水同位素变化控制机制一致。

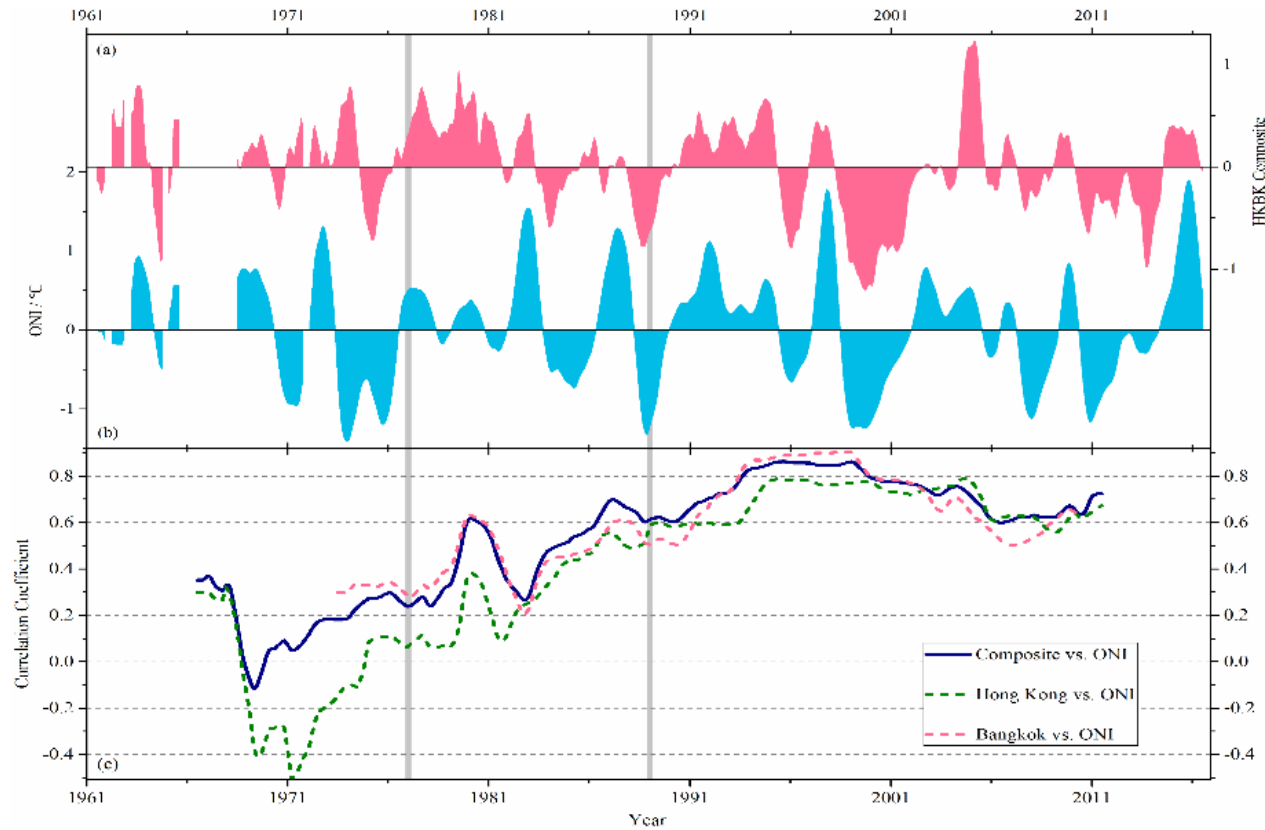
(Cai et al., EPSSL, 2017)



青藏高原南部降水 $\delta^{18}\text{O}$ 与大尺度总云量 (a)、高层云量 (b)、中层云量 (c)、低层云量的相关性分布

(Wang Di et al., EPSL. 2019)

发现ENSO- $\delta^{18}\text{O}$ 关系年际变化的波动与非季风季有关



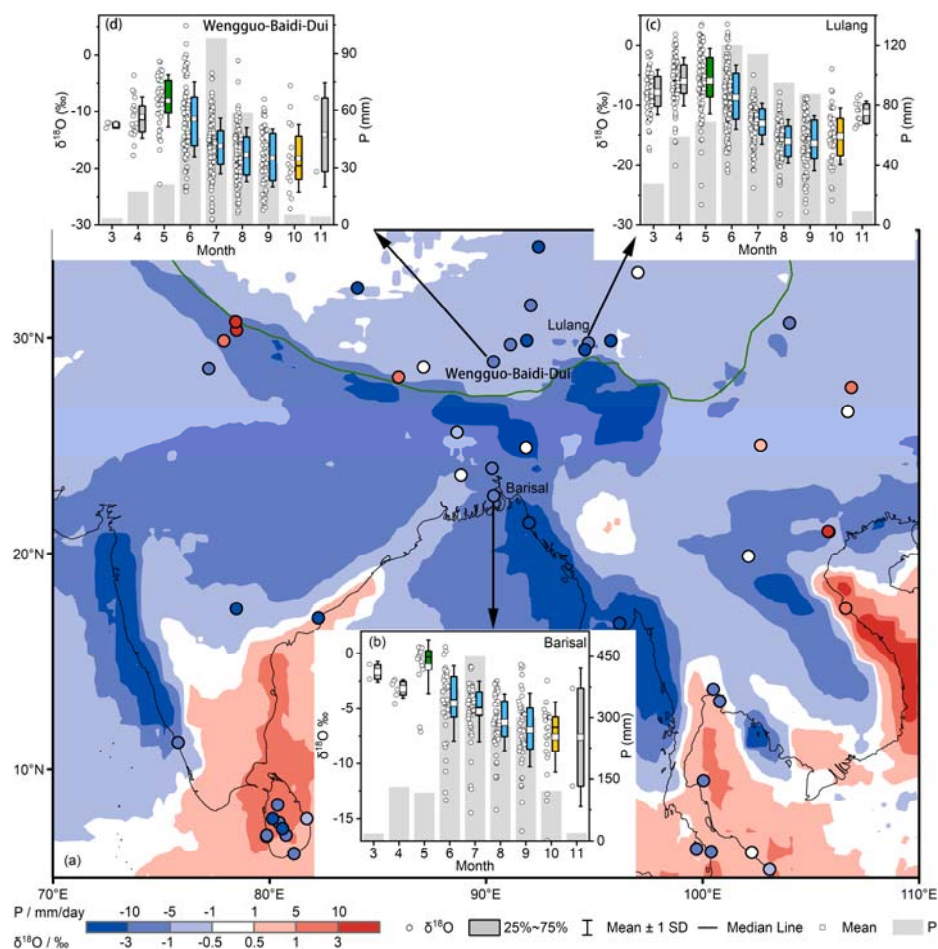
年际尺度上ENSO- $\delta^{18}\text{O}$ 变化与非季风期ENSO对对流影响
变弱有关

【Cai et al. 2019, *JGR-Atmosphere*】

新的认识

- 亚洲季风区同位素的变化，特别是年际年代际变化，主要不是受当地条件影响决定的，而是受由赤道地区的温度场—大气环流—赤道地区的降水决定的；
- 如果说亚洲季风区同位素是一个温度信号，它更应该是赤道中东太平洋的温度信号；
- 影响降水同位素的变化过程更主要是其水汽来源地上游的降水强度（对流降水）的变化，可能本地降水的影响小；
- 影响更长时间尺度降水同位素的变化信号还有待于进一步的深入研究；

1. 亚洲季风区天气尺度的现代过程研究



发出高原南部与孟加拉湾地区季风后期降水 $\delta^{18}\text{O}$ 仍然很低。
研究发现该季节变化与东风的水汽输送有关。

(Cai and Tian, GRL, 2020)

Thank You!

