On the seasonal variation of stable isotopic composition of precipitation over Asian monsoon region

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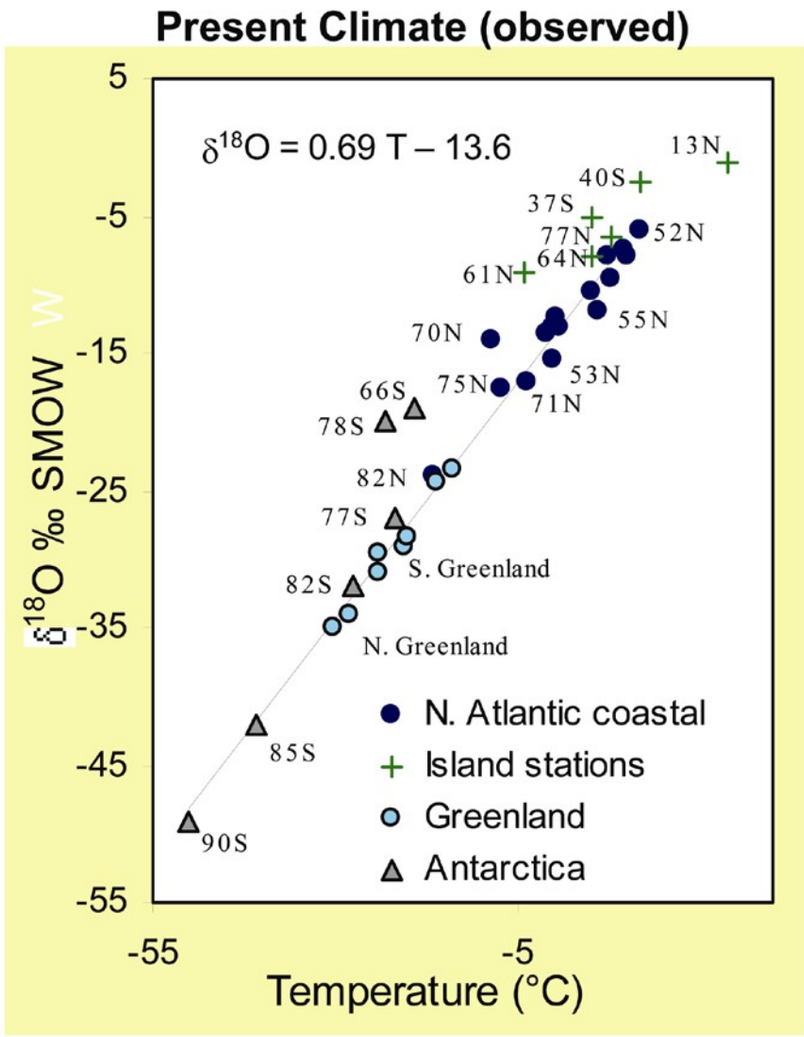
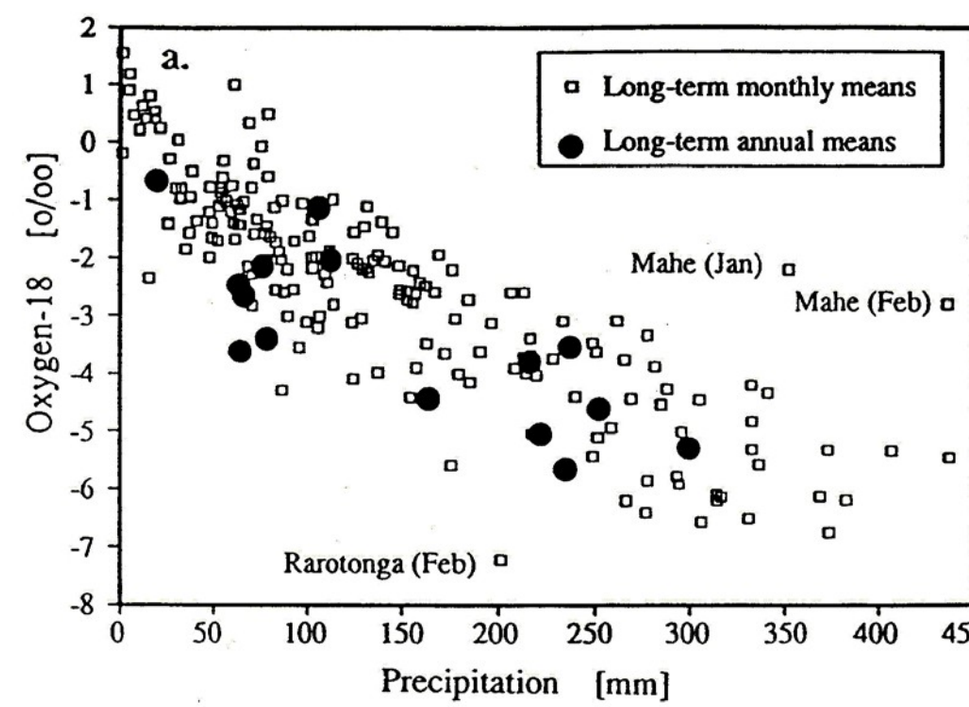
$\delta^{18}O_p$ Background

- Equilibrium Fractionation: rain enriched relative to vapor
- Rayleigh distillation: precipitatio depletion away from source
- Dansgaard relationship: 7 permil /K
- Amount effect: tropical islan $\delta^{18}O$ decreases with increas

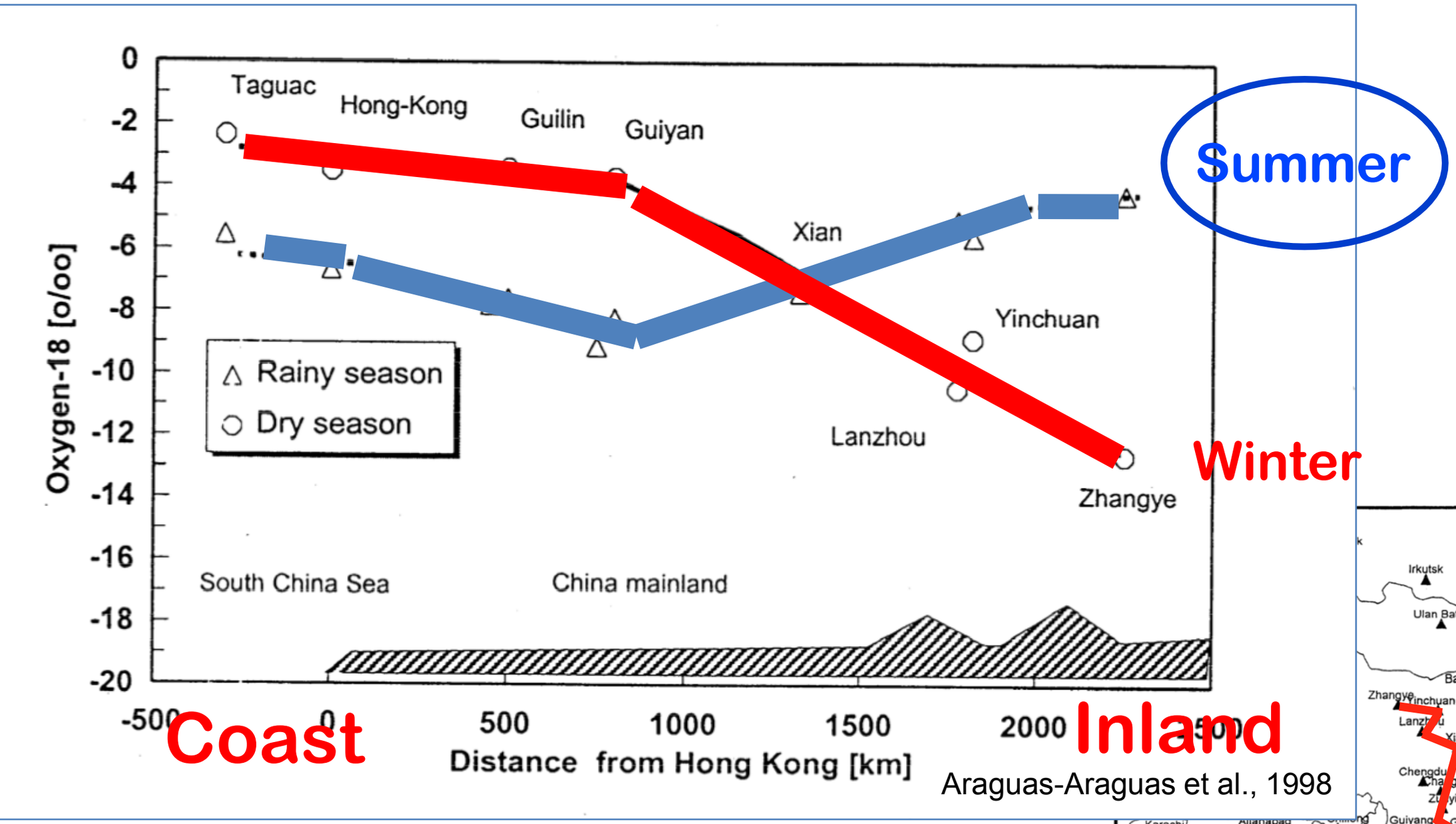


Dansgaard, [1964]

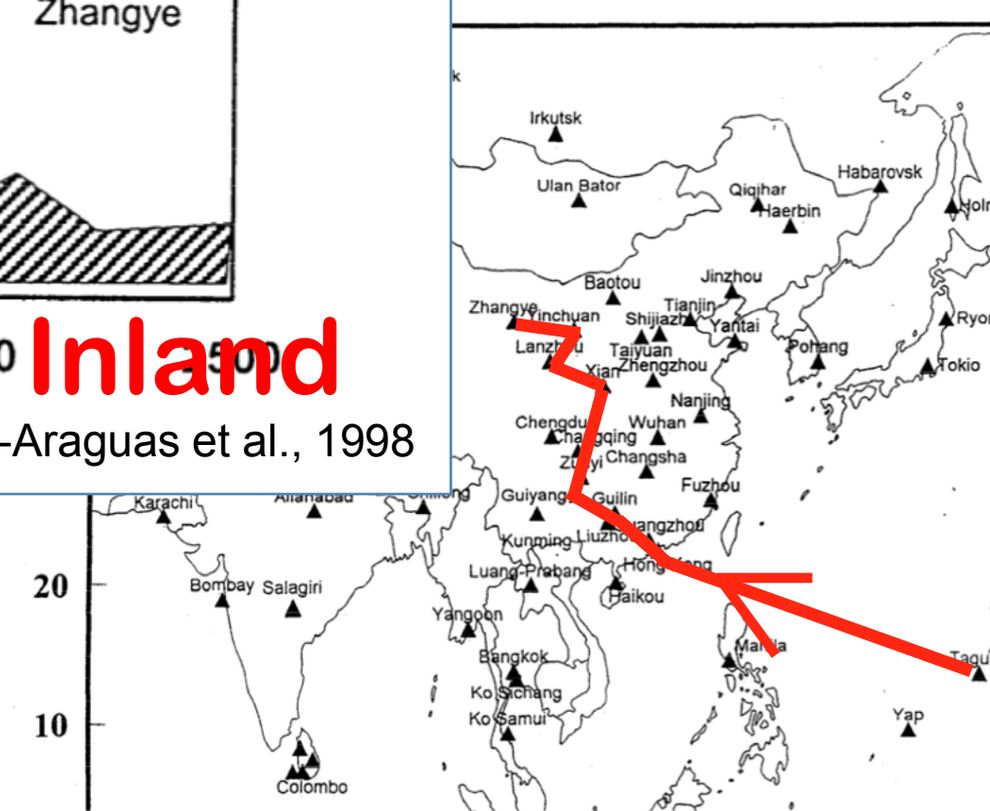


Long-term monthly and annual mean $\delta^{18}O$ val

GNIP: $\delta^{18}O_p$ increases inland to the northwest in summer



Araguas-Araguas et al., 1998

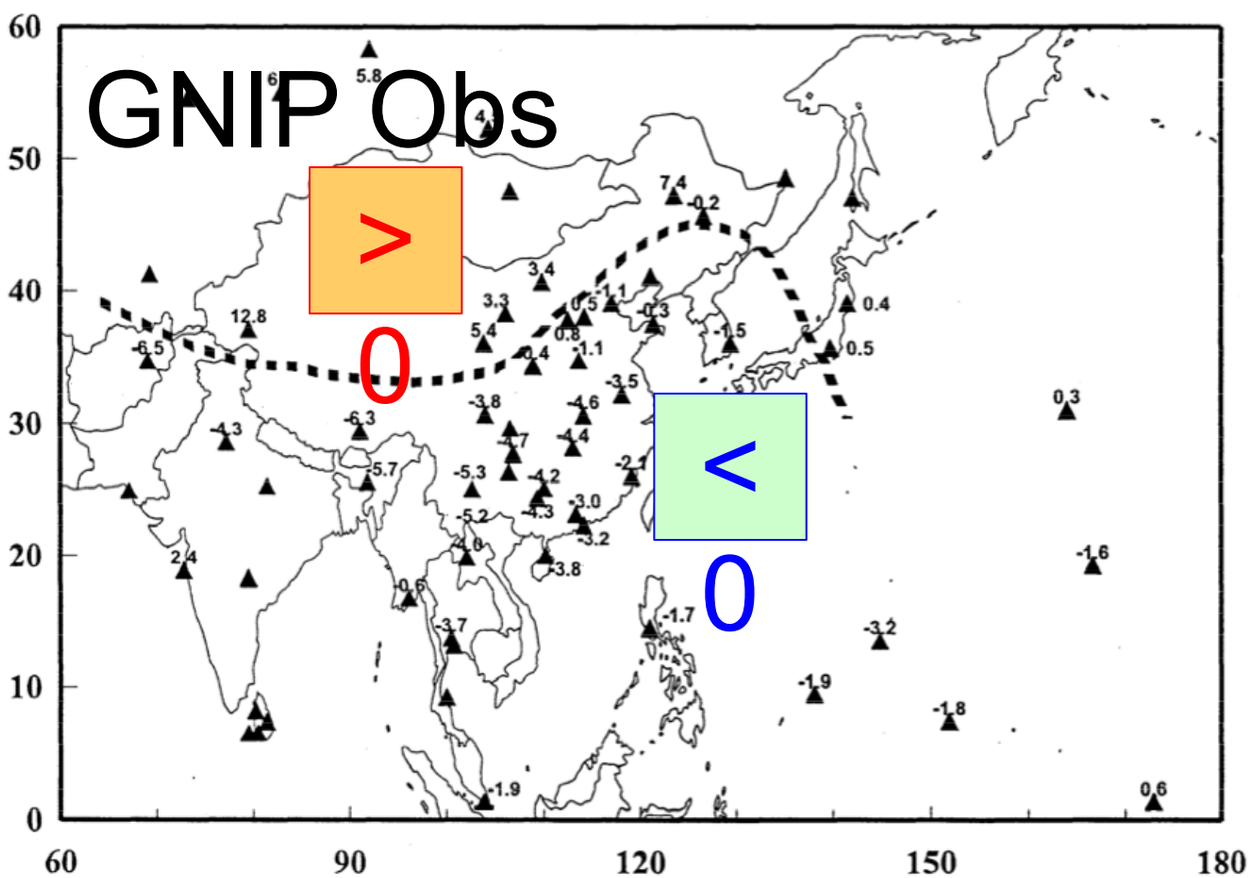


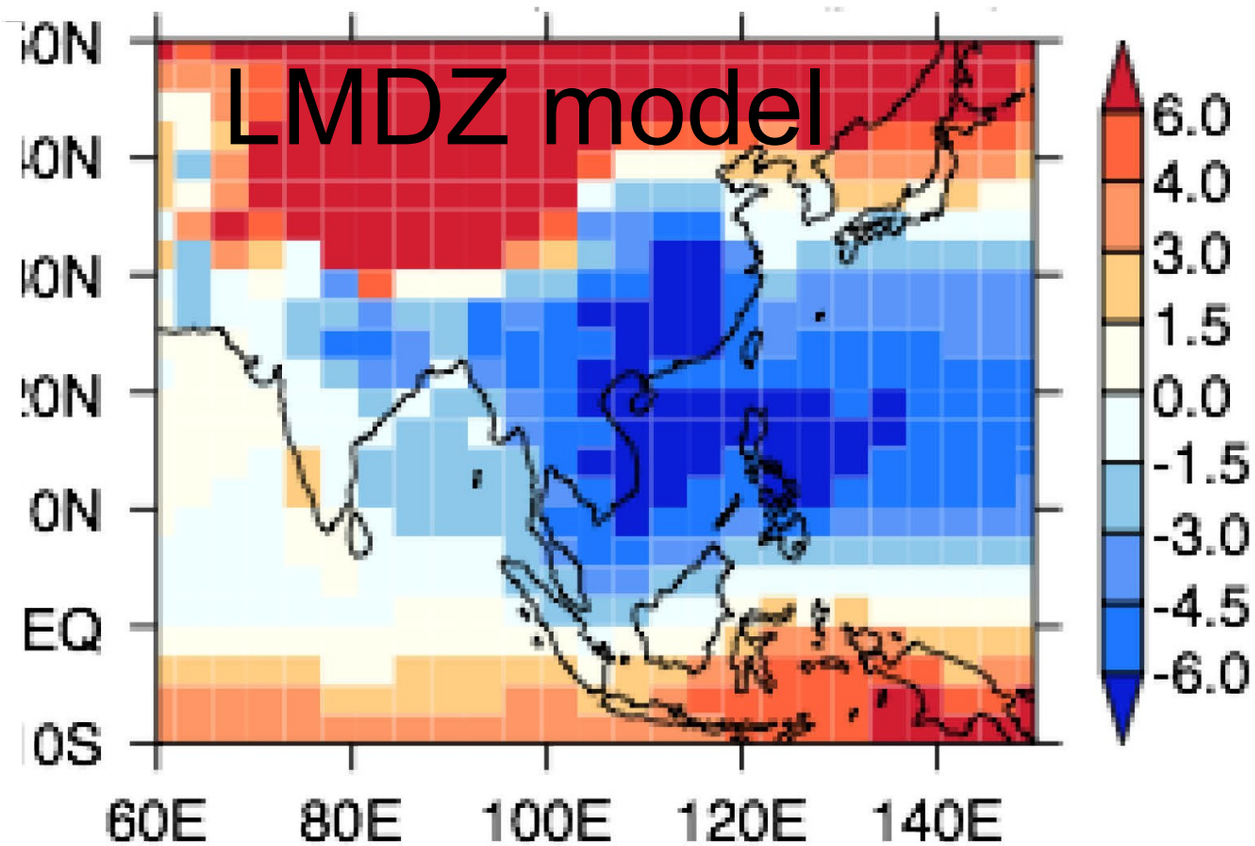
Our tools (I):

Isotope-enabled LMDZ Climate Model: Risi et al., 2010

•Nudged with ECMWF wind – reasonable simulation of precipitation; Water tracers; 2.5° × 3.75°

Summer minus Winter $\delta^{18}O_p$

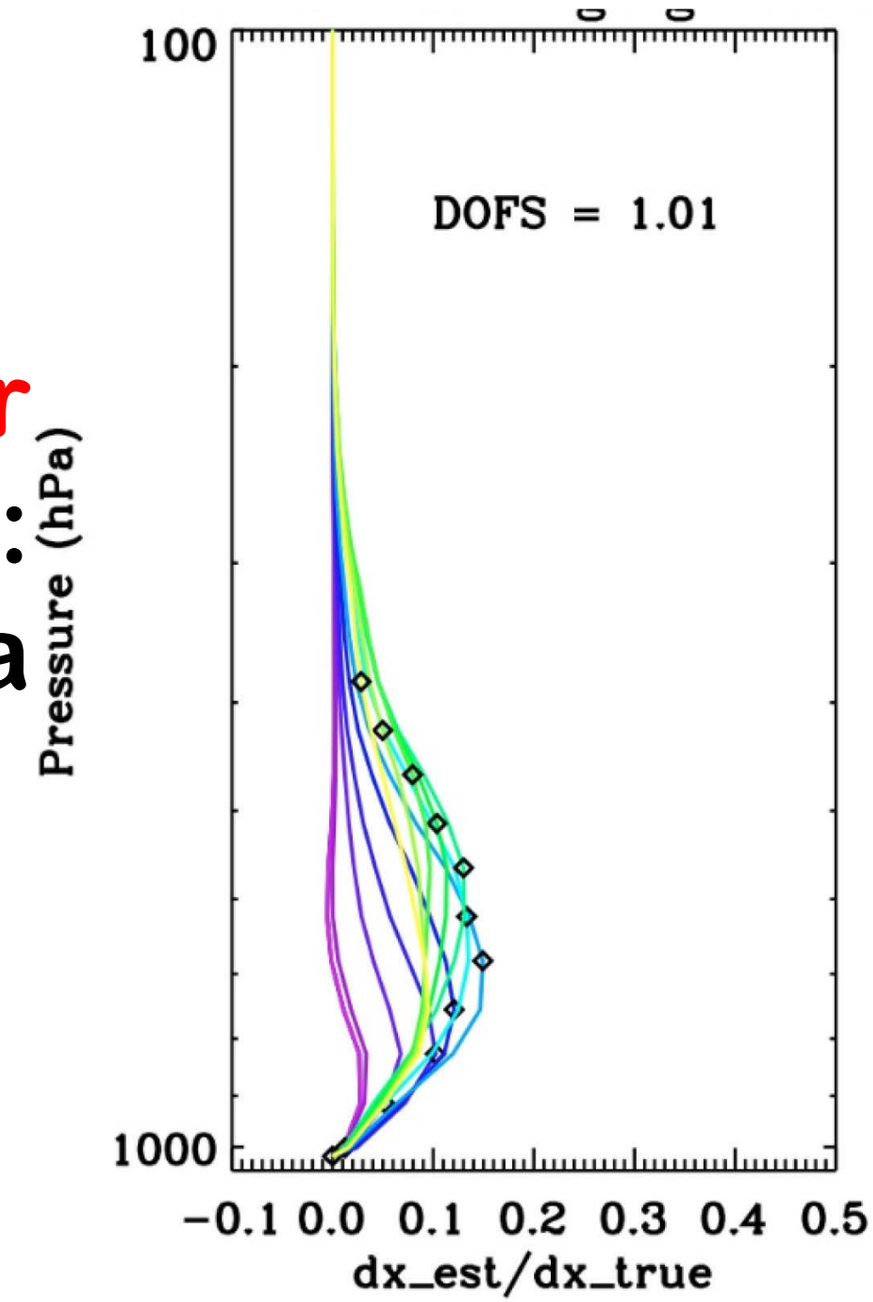




Our tools (II): Satellite Obs of HDO in vapor

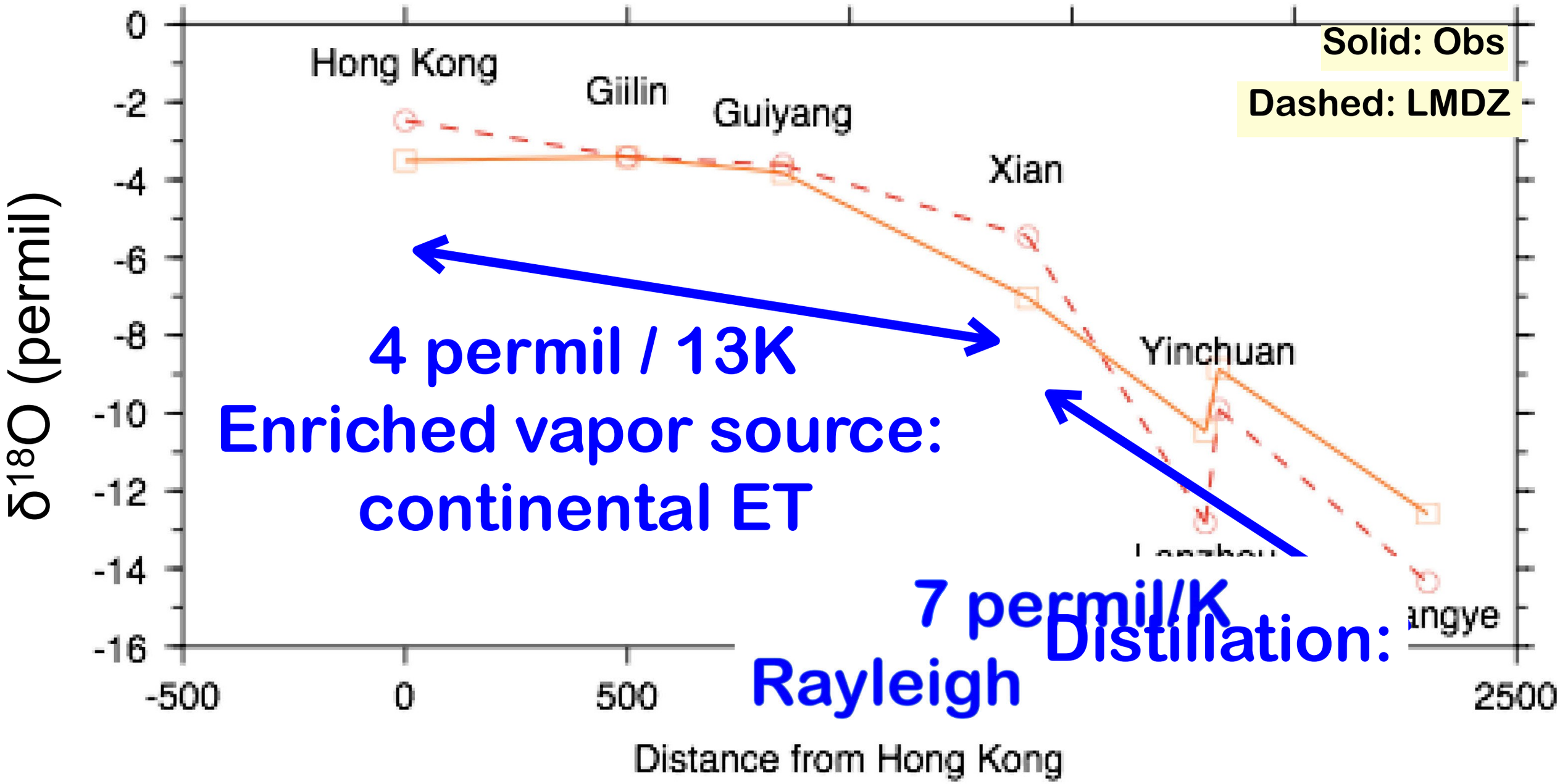
Thermal Emission Spectrometer (TES):

Averaging kernal peak ~ 600 hPa



SCIAMACHY: no vertical variations in averaging kernal. Column HDO dominated by lower tropospheric

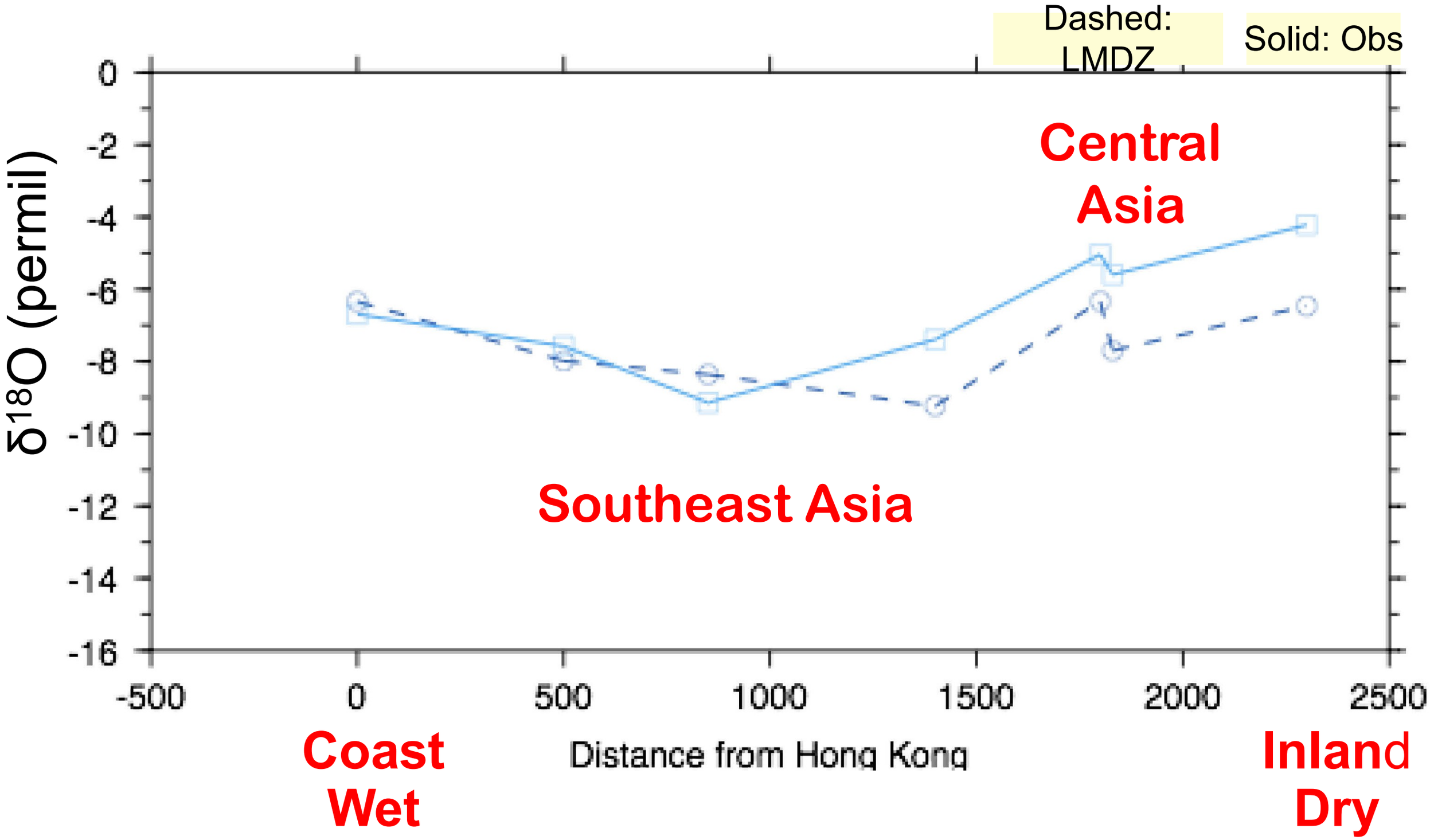
Winter: Off-shore winds



Coast
Warm

Inland
Cold

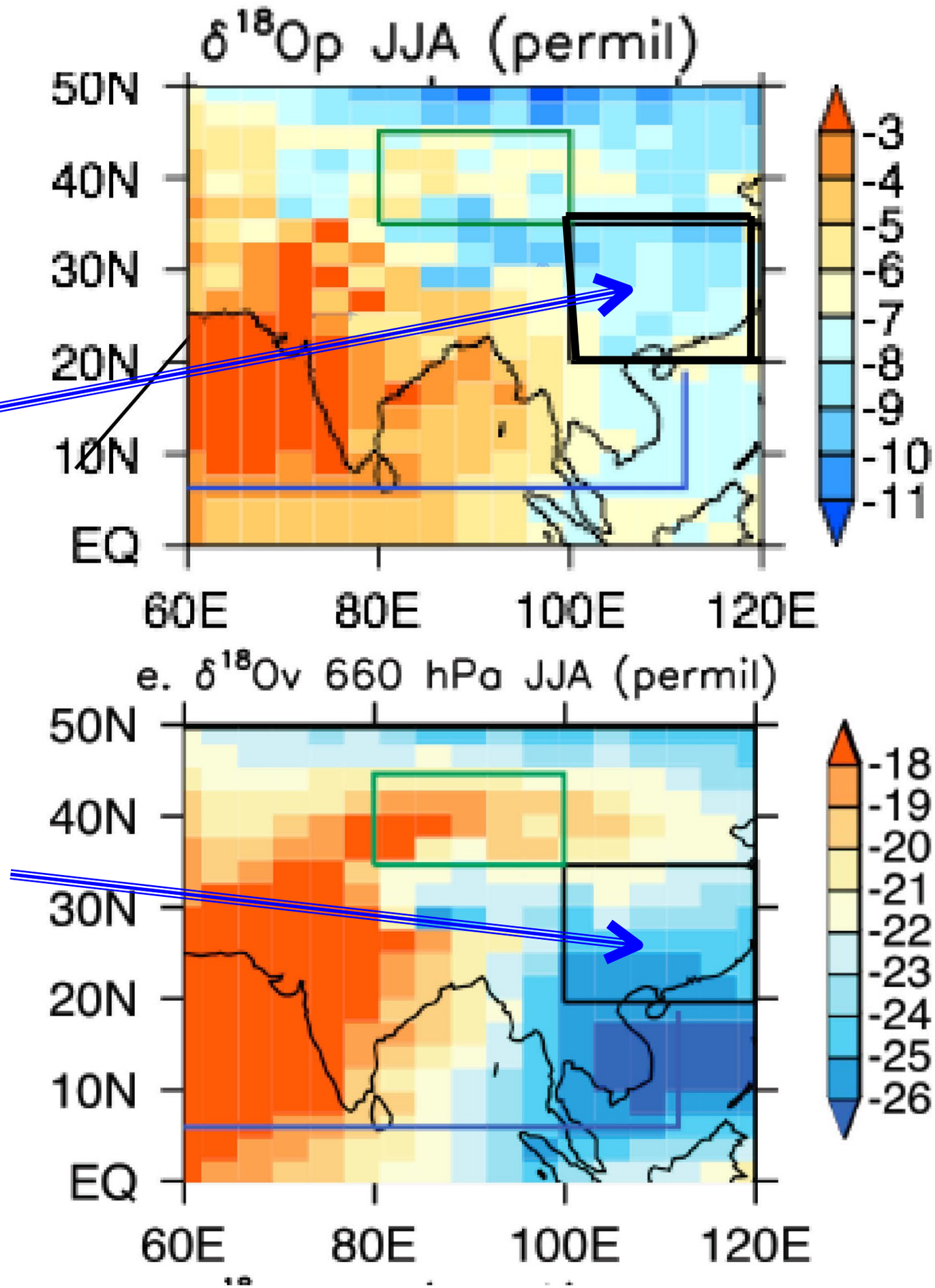
Summer: $\delta^{18}O_p$ increases from coast towards NW



Summer: SE Asia

- Precip very depleted ~ −8 permil
- Onshore winds

- Source vapor very depleted ~ −20 permil

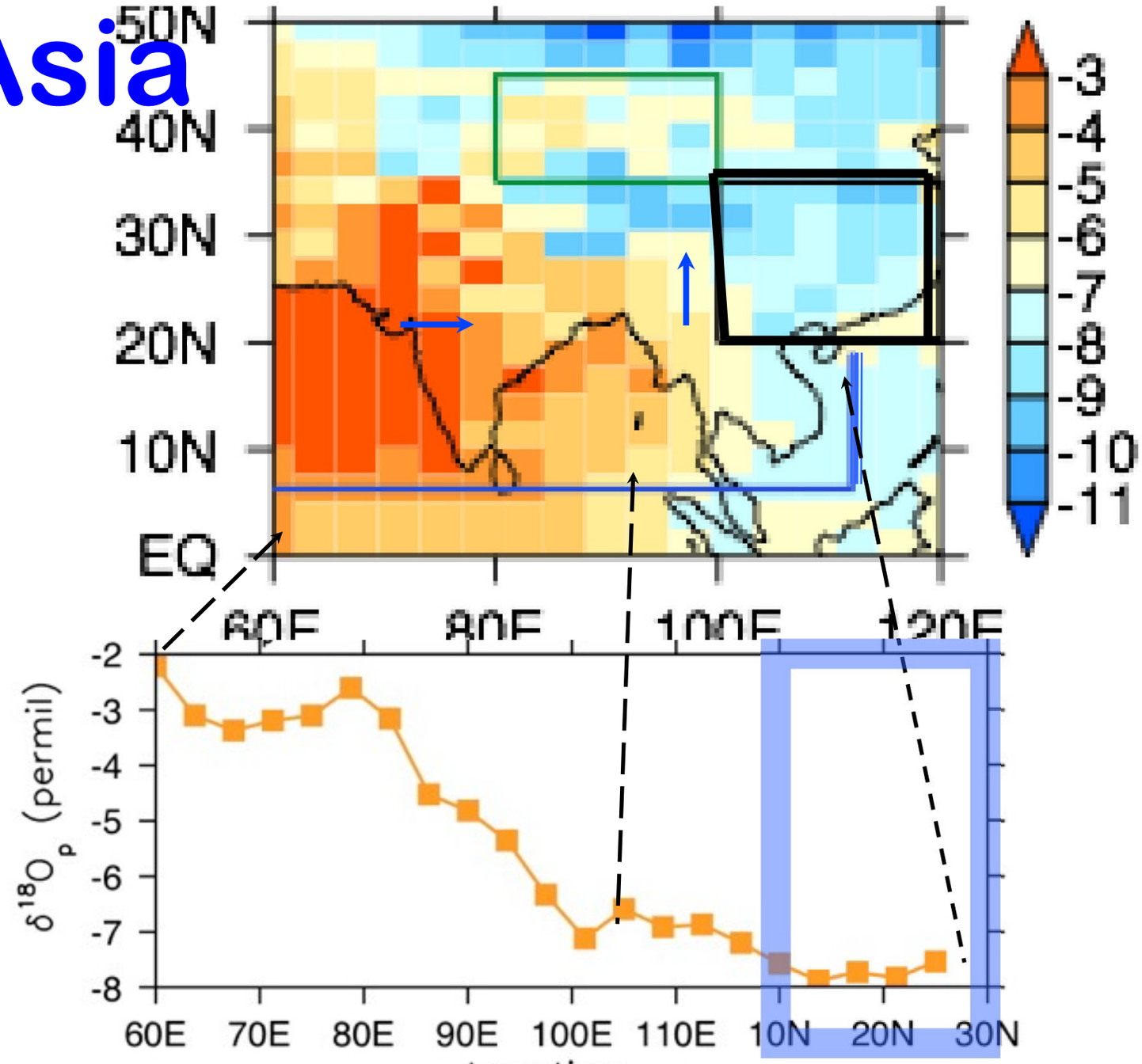


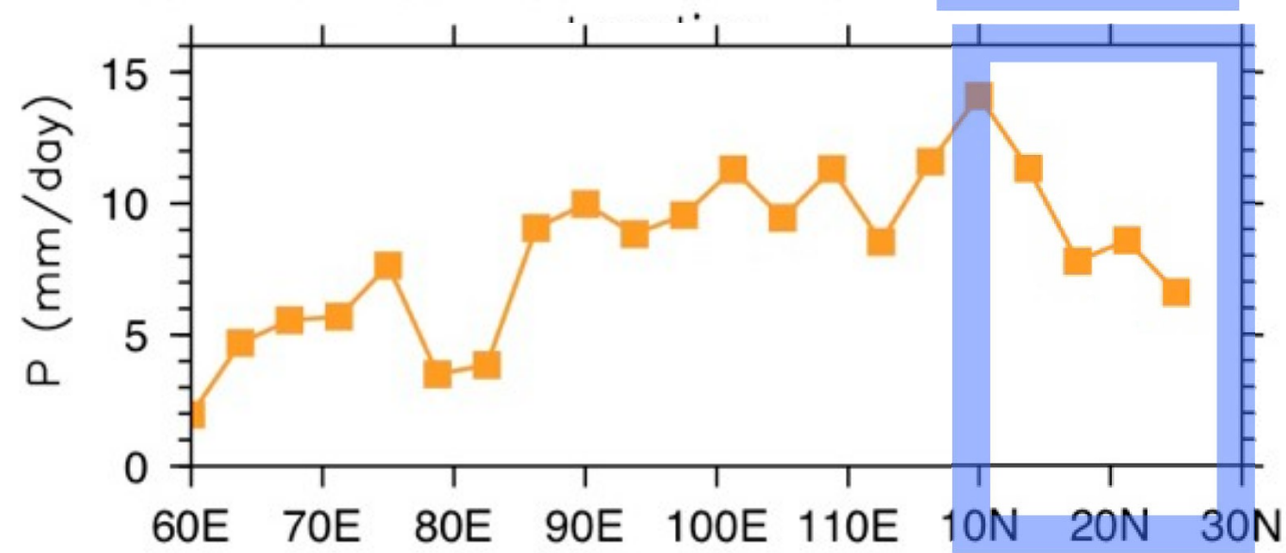
Summer: SE Asia

- Onshore winds
- Source vapor: depleted

$\delta^{18}O_p$ decreases as the airmass moves from the Indian Ocean to the upstream regions of Southeast Asia

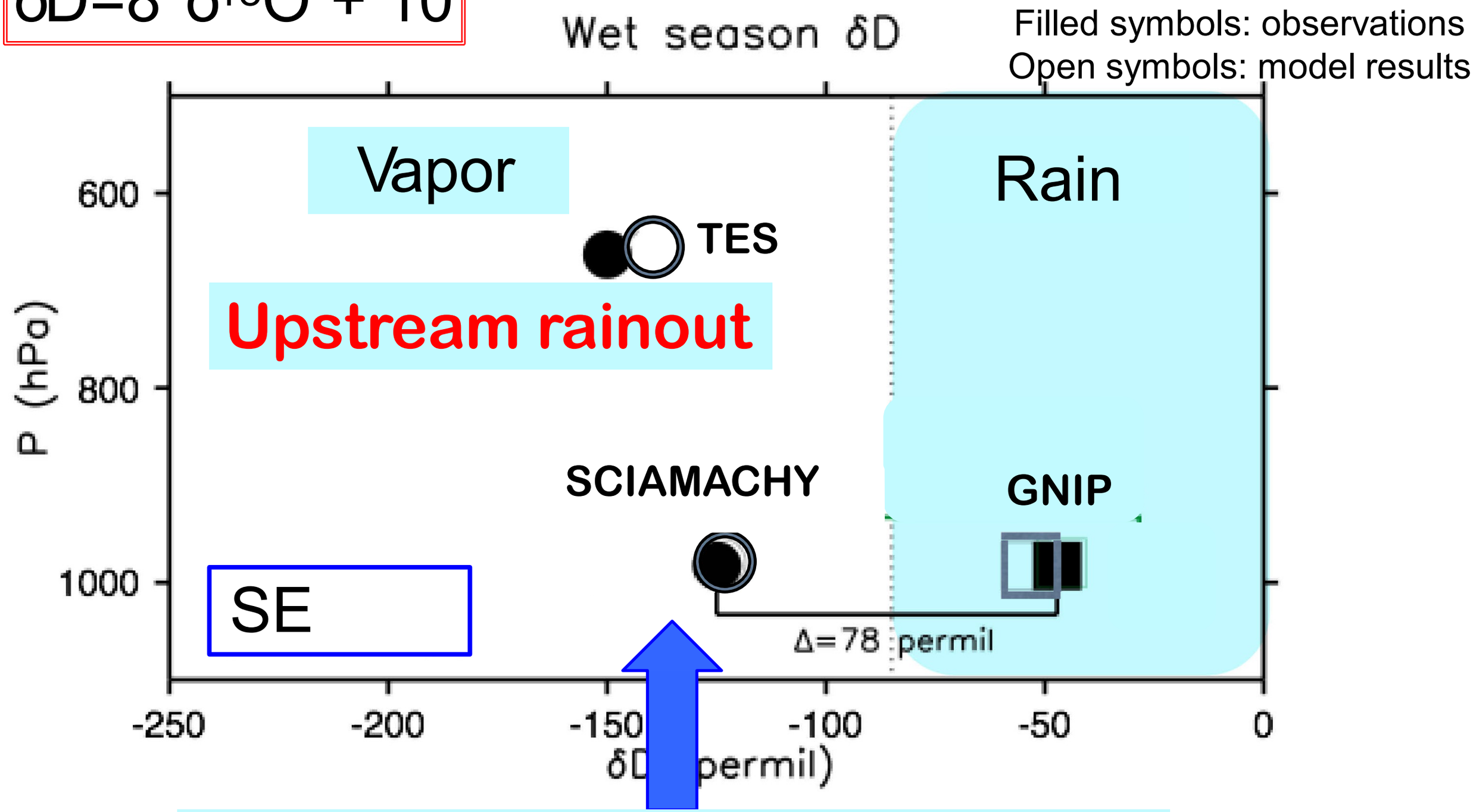
Convergence of low $\delta^{18}O_v$ decreases $\delta^{18}O_p$ over Southeast Asia





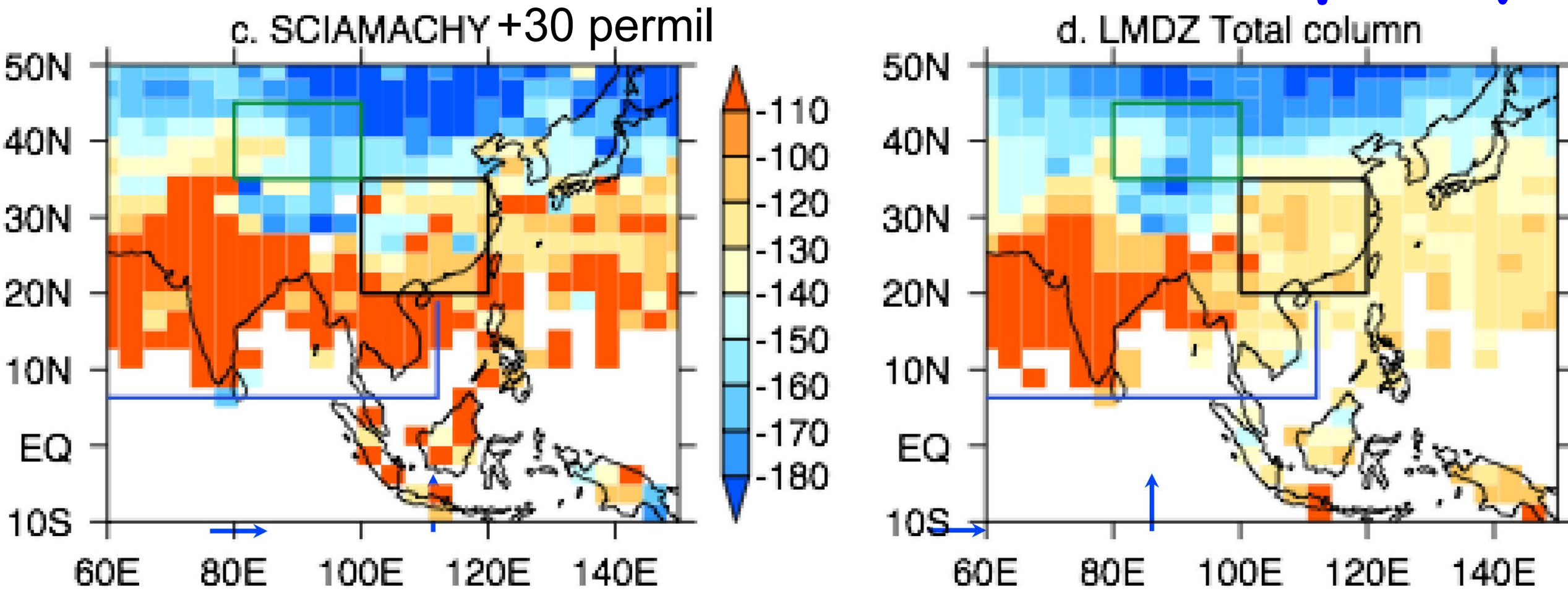
Summer: SE Asia, HDO vapor

$\delta D = 8 * \delta^{18}O + 10$



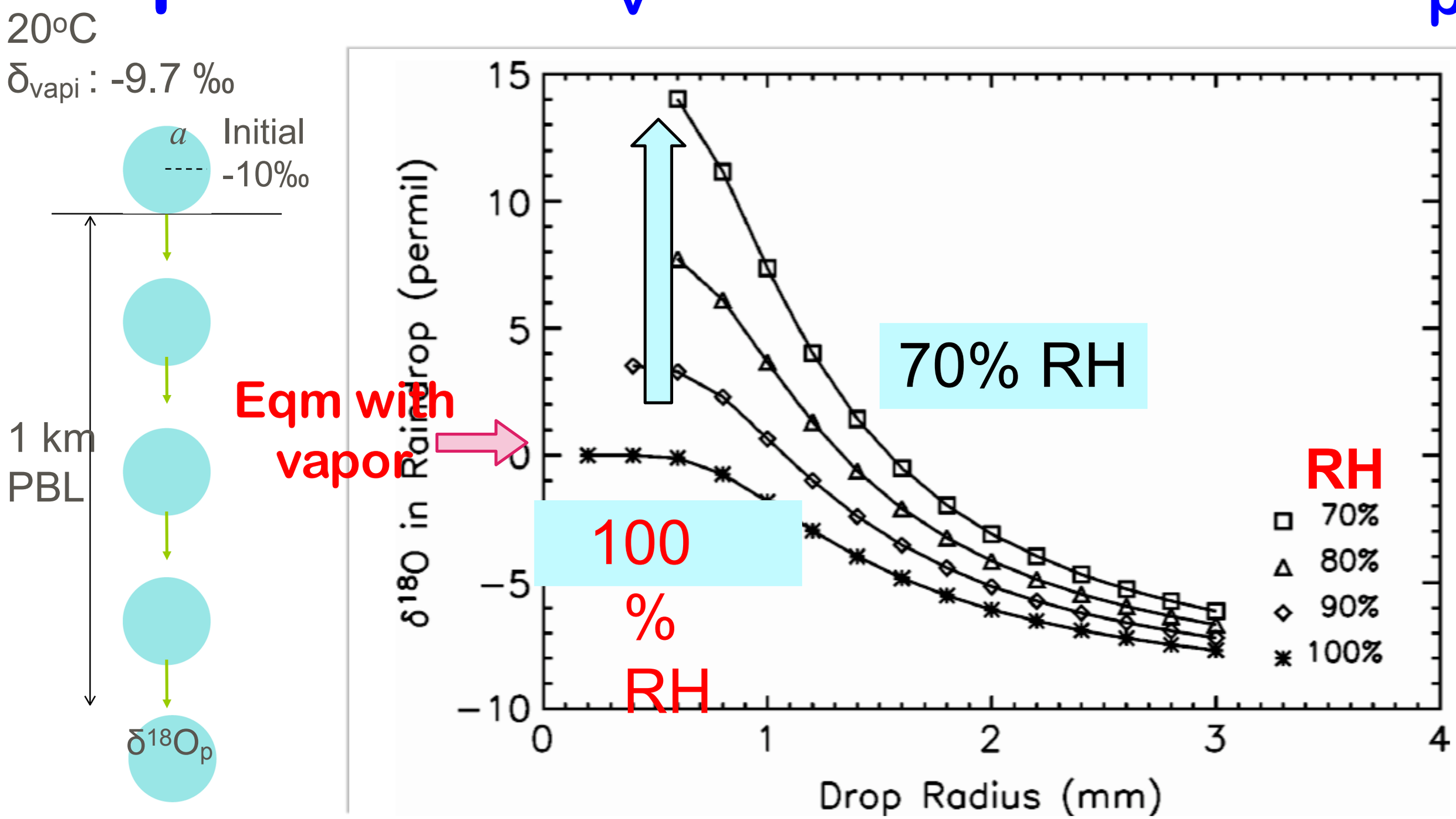
ET enriches near-surface vapor

Summer Central Asia: lower trop δD_v

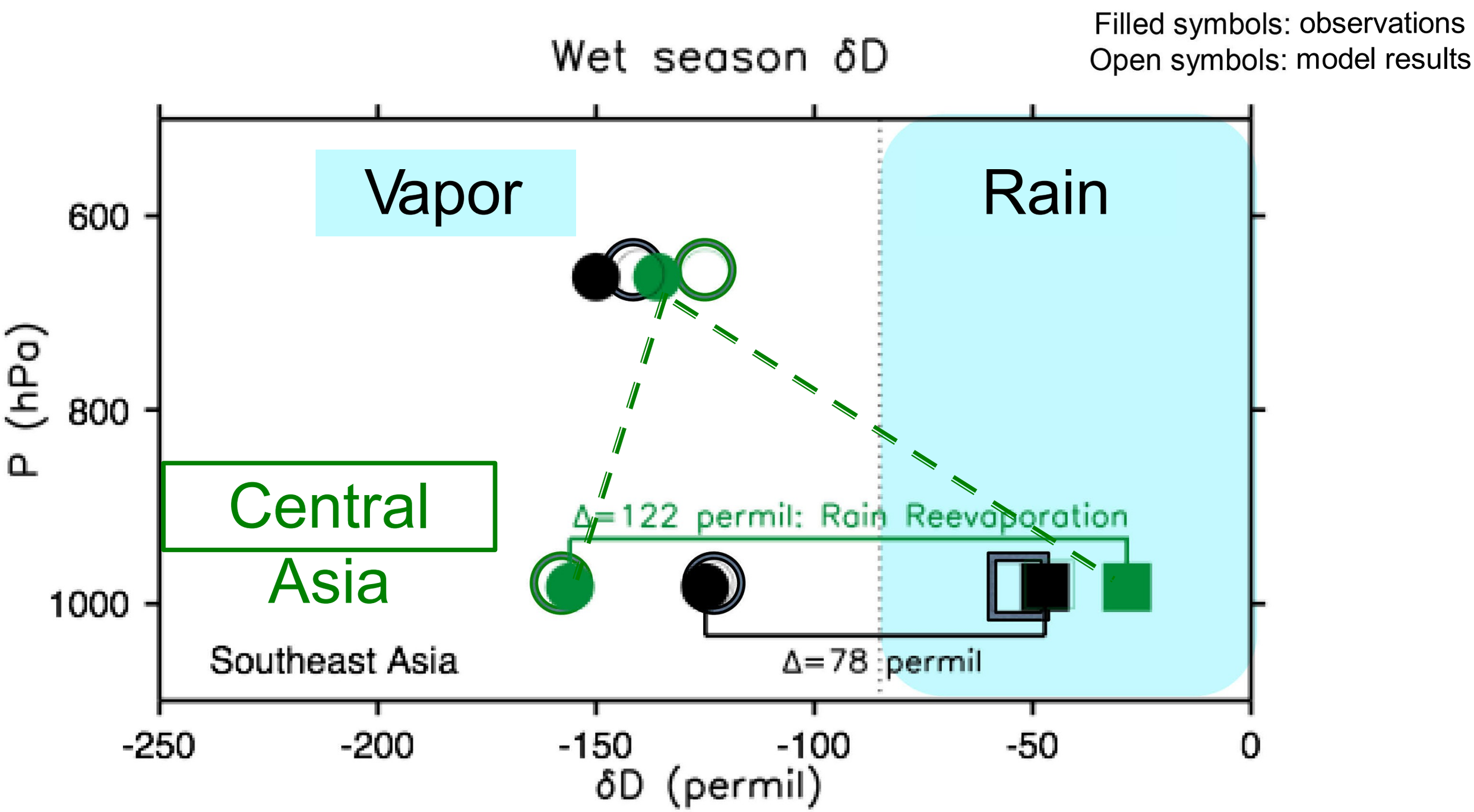


- Vapor more depleted over Central Asia than SE Asia
- Central Asia
  - Air mass from west: little upstream rainout ✖
  - Dry soils: ET small role ✖

Evap of raindrop during descent depletes $\delta^{18}O_v$ and enriches $\delta^{18}O_p$

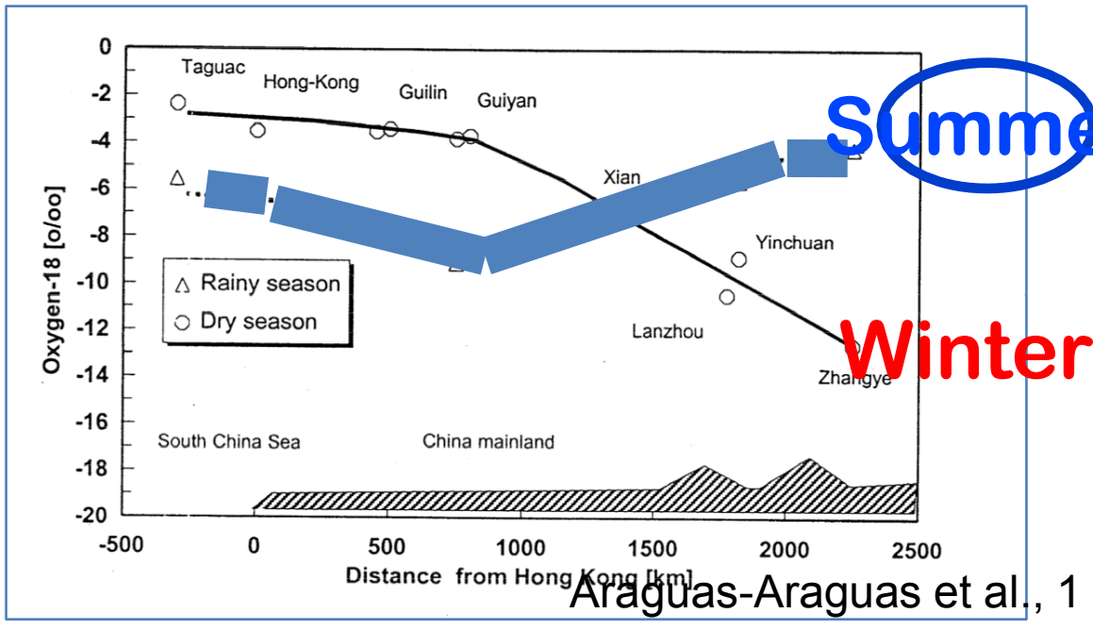


Lee and Fung, HP, 2008



- Evaporation of raindrops during descent:
  - Depletes vapor, enriches raindrops

Summary: Case Study



Araguas-Araguas et al., 1

SE Asia:

- **Winter: continental ET → enriched vapor**
- **Summer: strong convergence of depleted vapor from ocean → $\delta^{18}O_p$ more depleted than in winter**

Central Asia:

- **Winter: Rayleigh distillation**
- **Summer: Higher rain reev aporation increases $\delta^{18}O_p$**

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Precipitation is the excess water the atm cannot hold

$\delta^{18}O_p$ records the life history of water:

- ET source of vapor
- variations of $\delta^{18}O_v$ during transport
- T and $\delta^{18}O_v$ at condensation
- post-condensation exchange with vapor

Models relatively mature to aid interpretation of paleoclimate proxies

Supported by NSF, NASA

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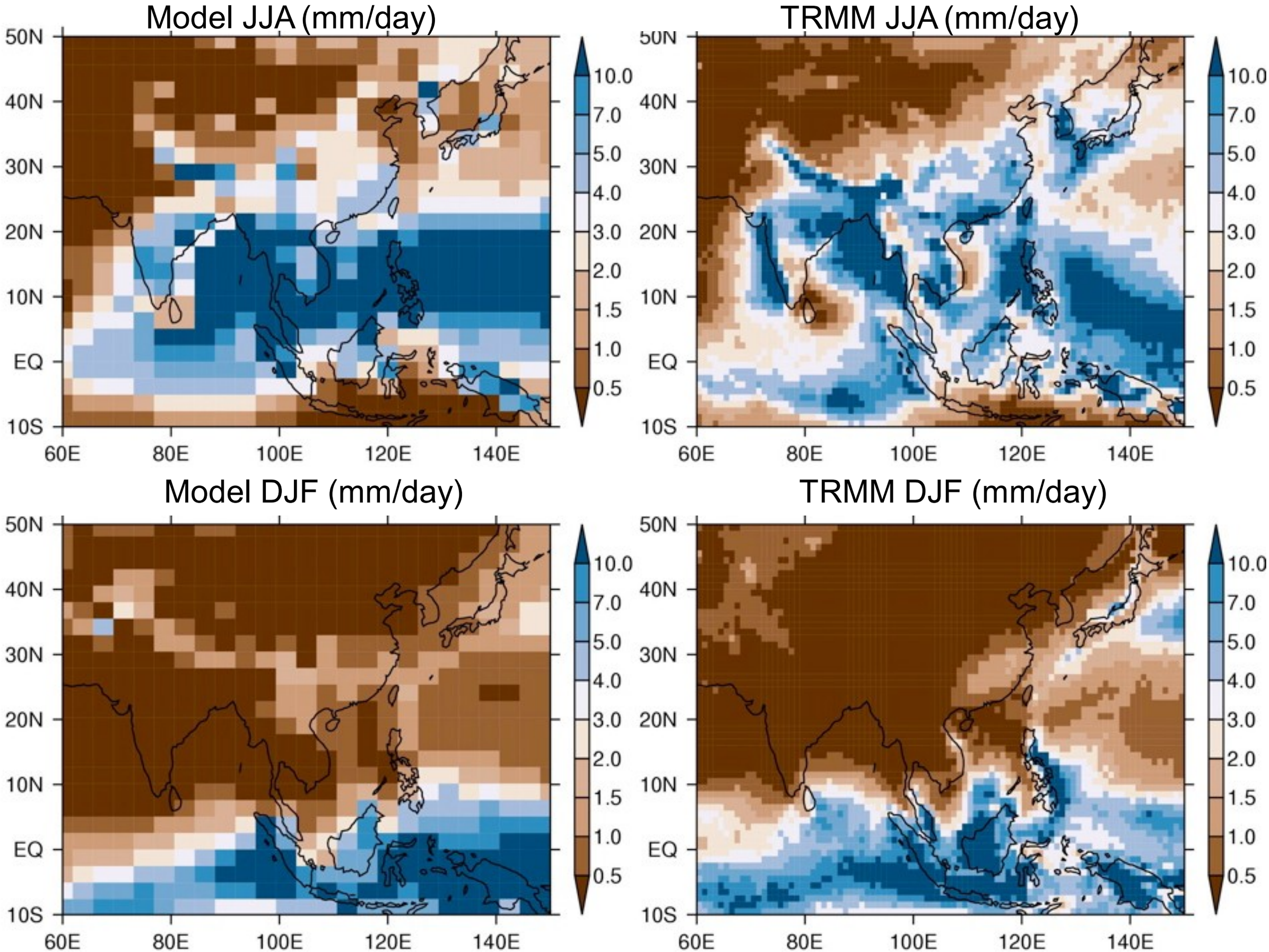
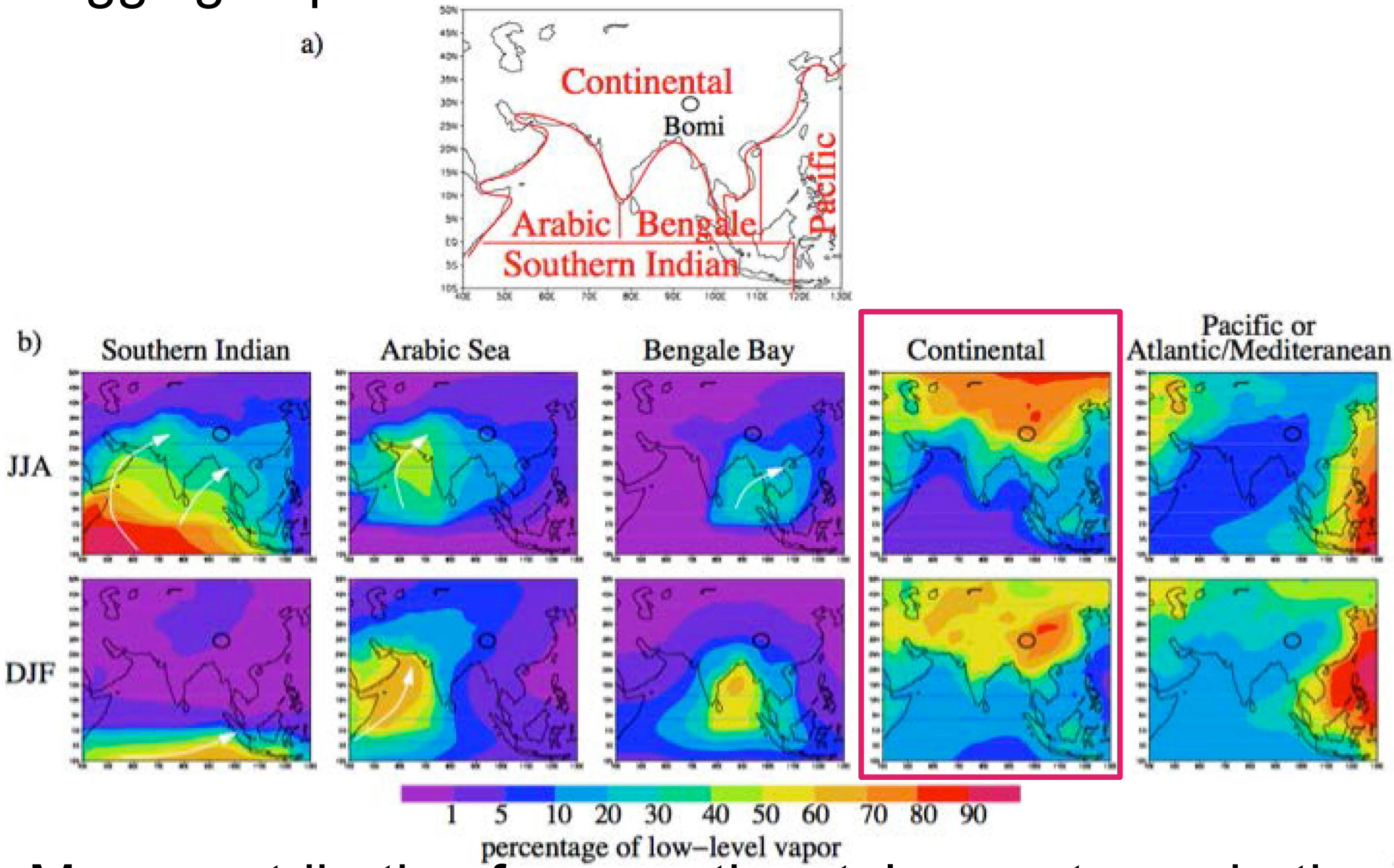
Reasonable simulation of precipitation

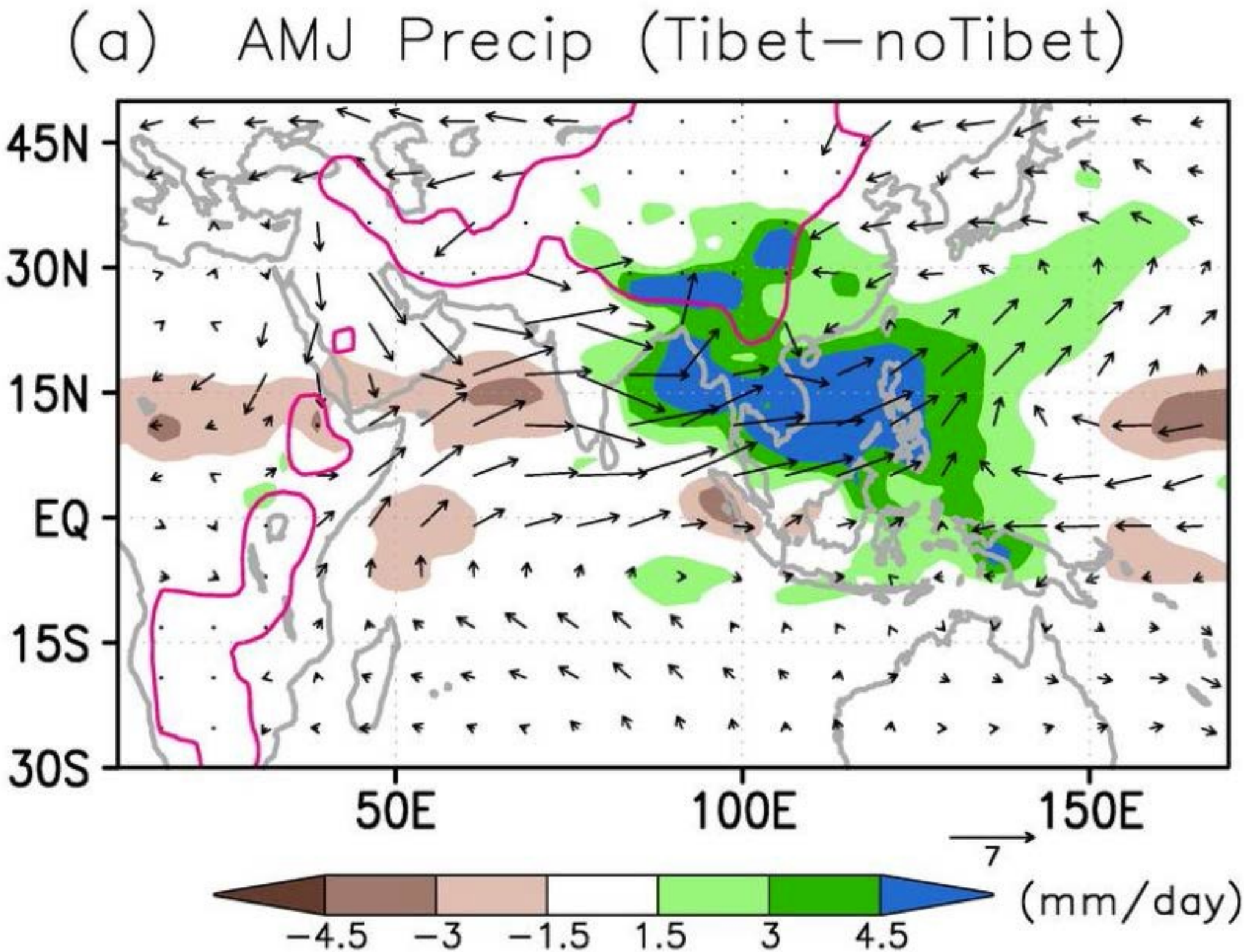


Tagging experiment



More contribution from continental evapotranspiration over Central Asia, but...

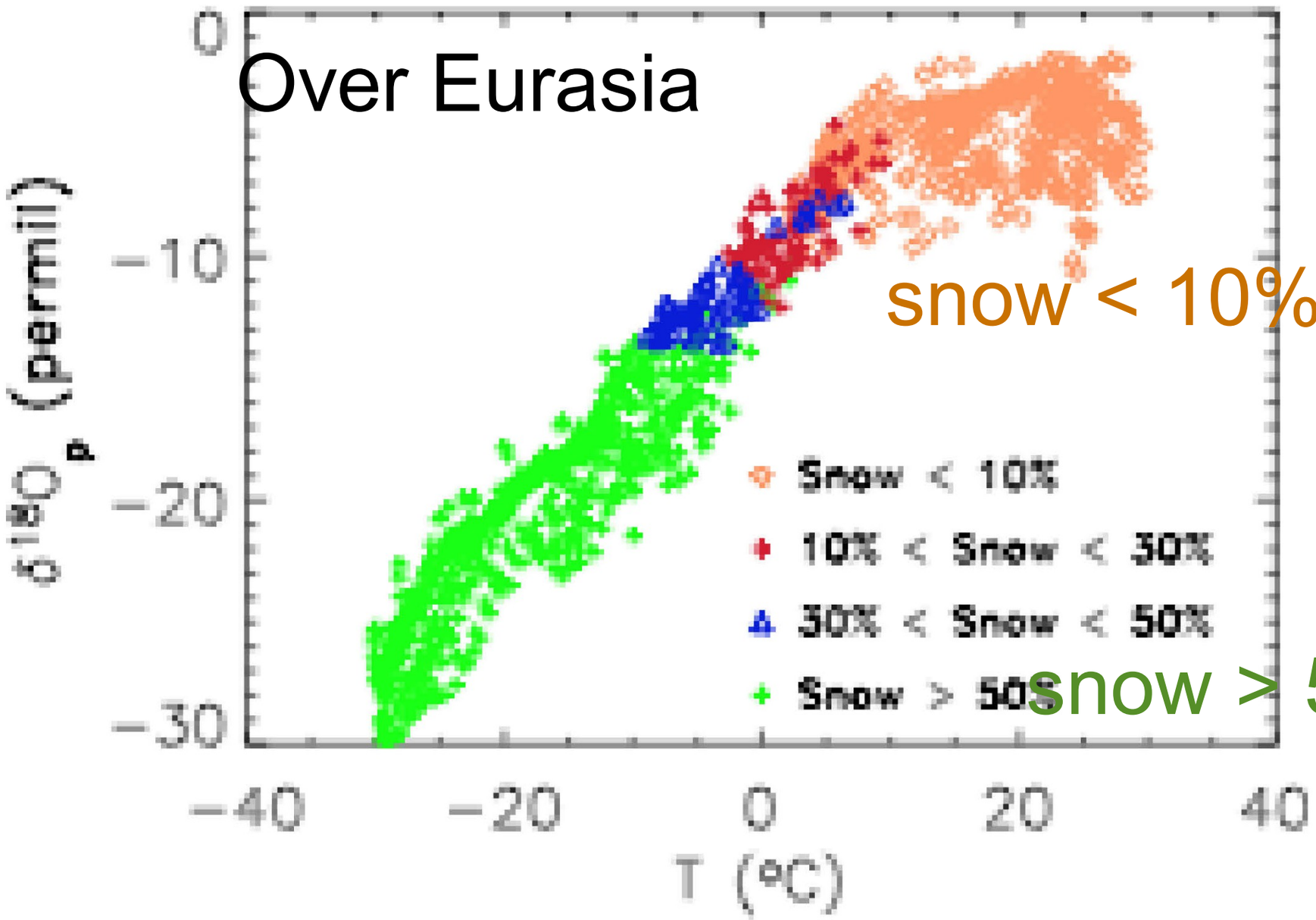
Low isotope values are probably related with strong convergence due to the existence of Tibet



Park et al., in review

Winter

But, the temperature effect is small if precipitation is in liquid form

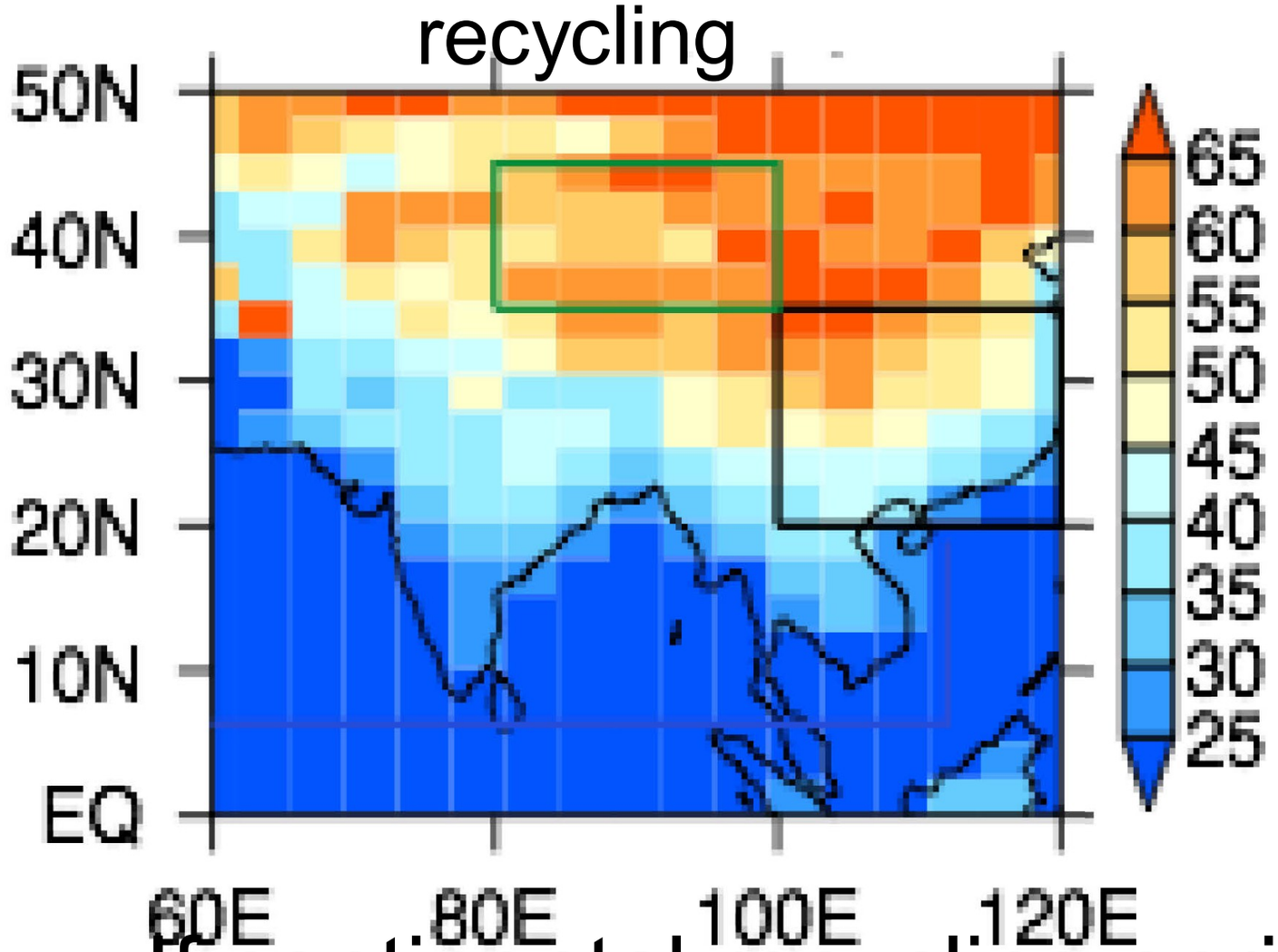


snow < 10%: r^2=0.13

snow > 50%: r^2=0.8

Summer: Central Asia

% of precip from continental recycling



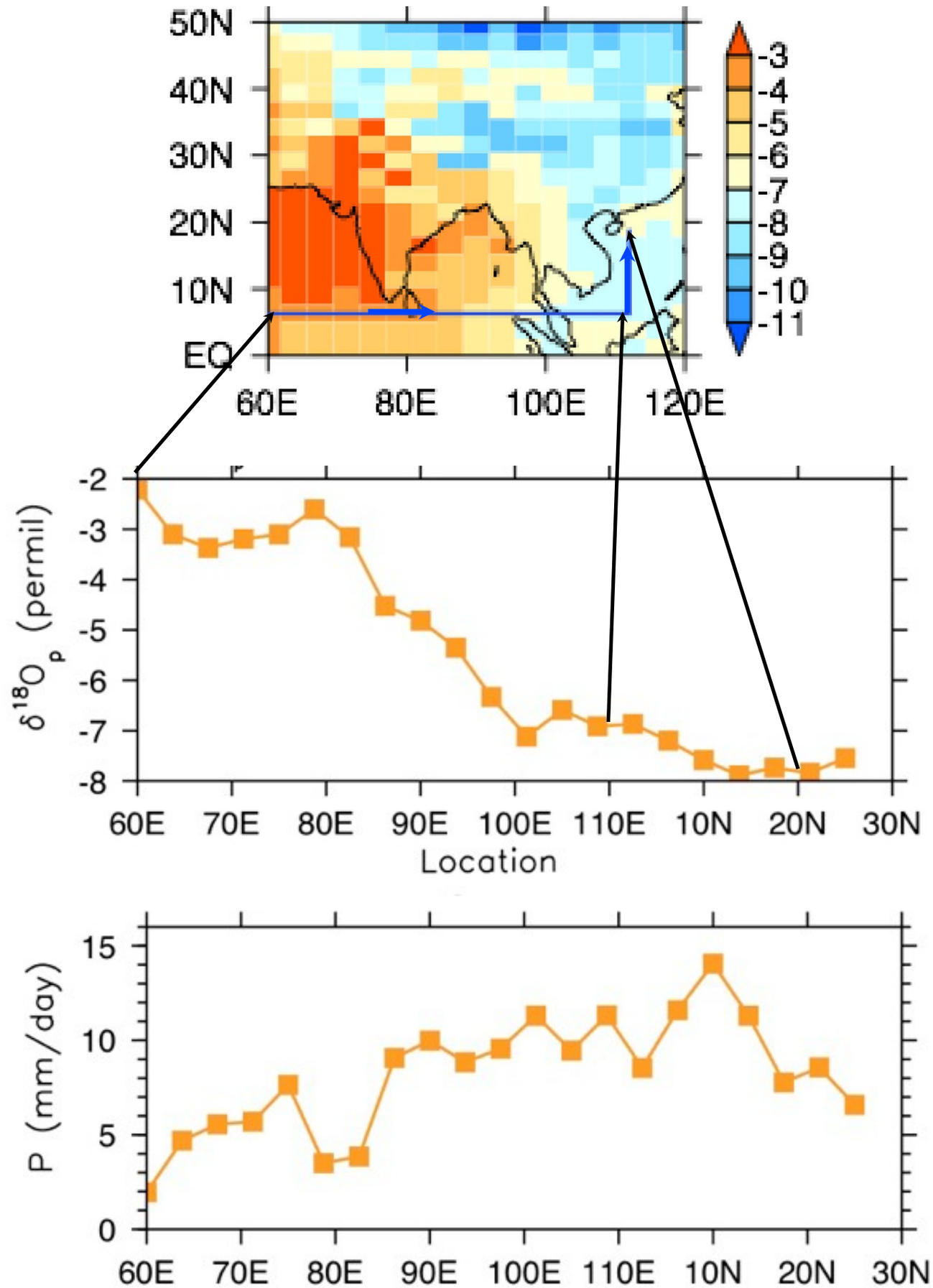
- **Air mass from west**
- **High regional recycling of water over Central Asia**

If continental recycling enriches surface vapor isotopically, $\delta^{18}O$ of near-surface vapor should be high.

Summer
Southeast Asia

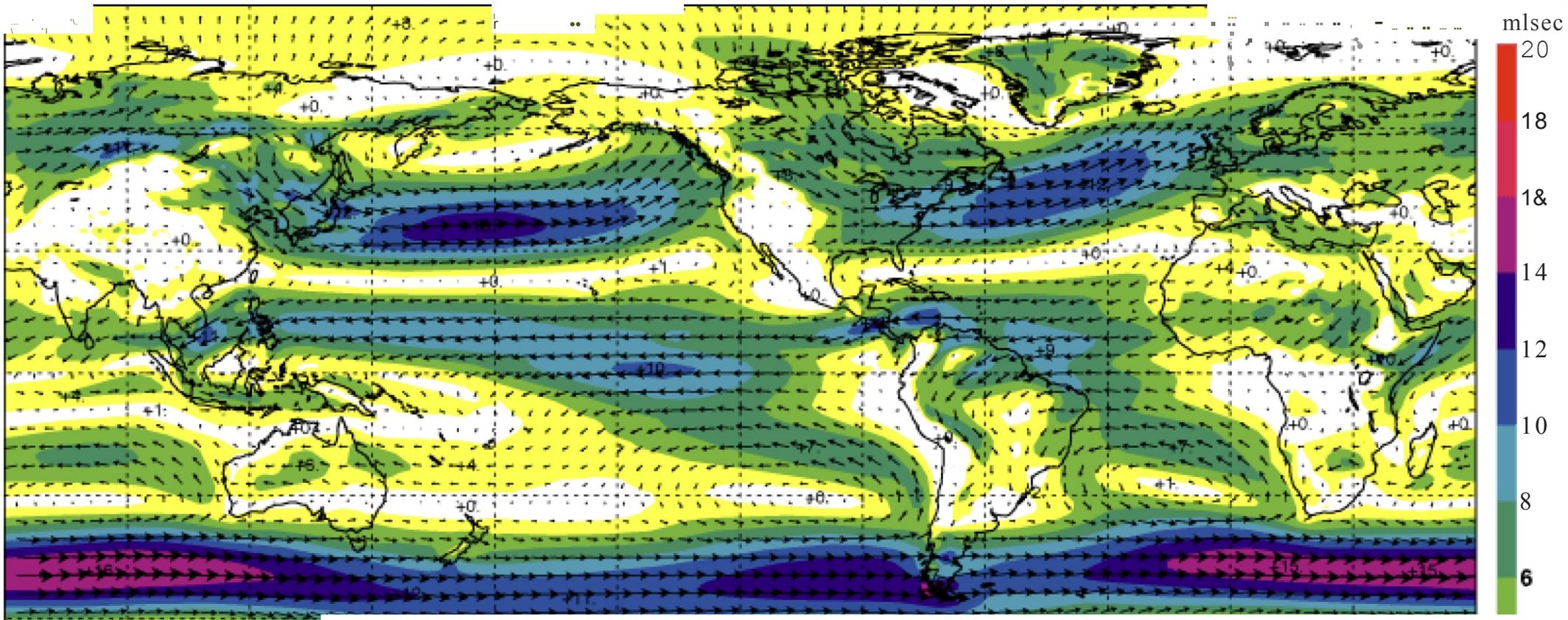
Minimum $\delta^{18}O$ is located over the downstream of highest precipitation area

$\delta^{18}O_p$ decreases as the airmass moves from the Indian Ocean to the upstream regions of Southeast Asia



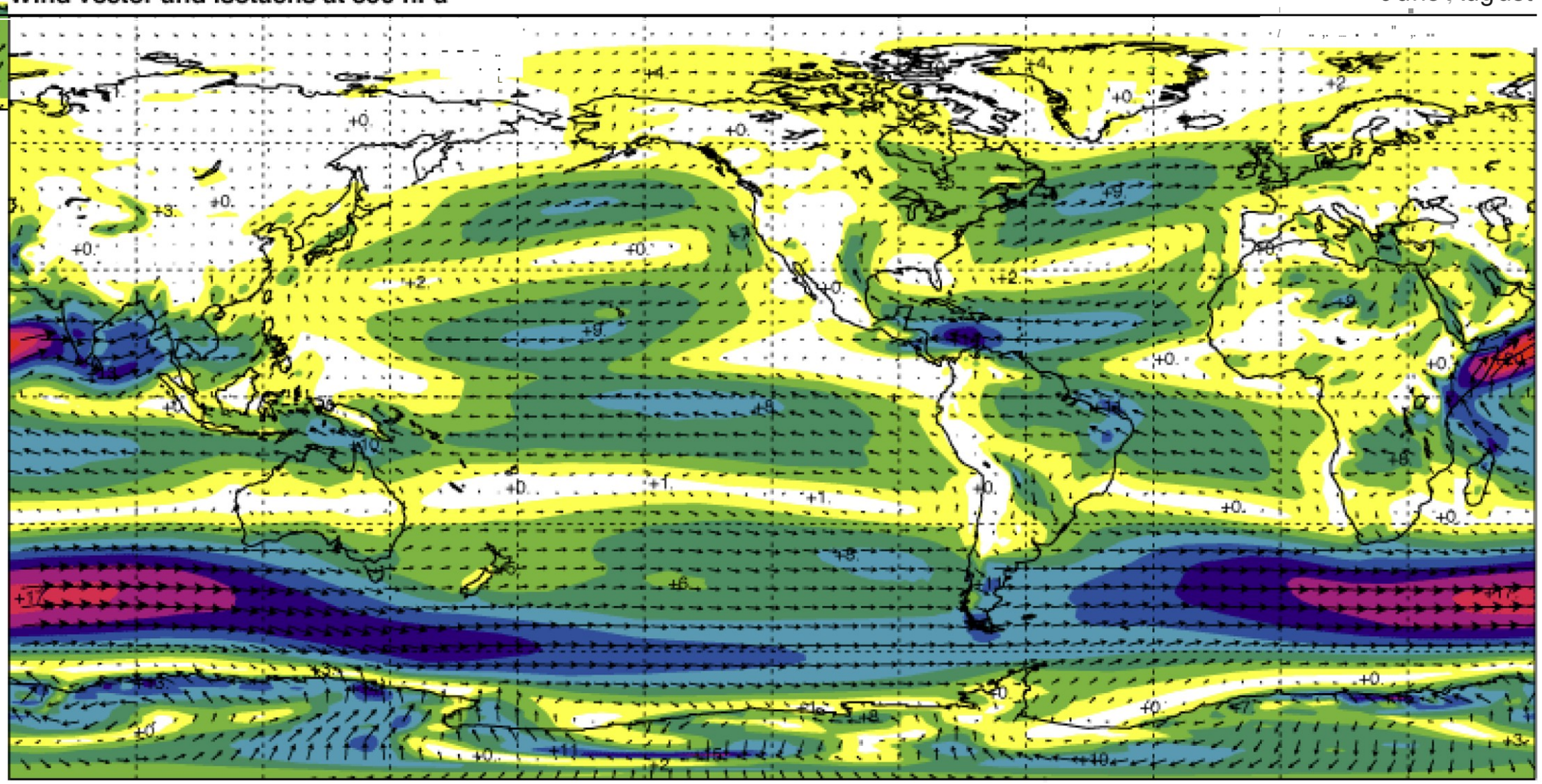
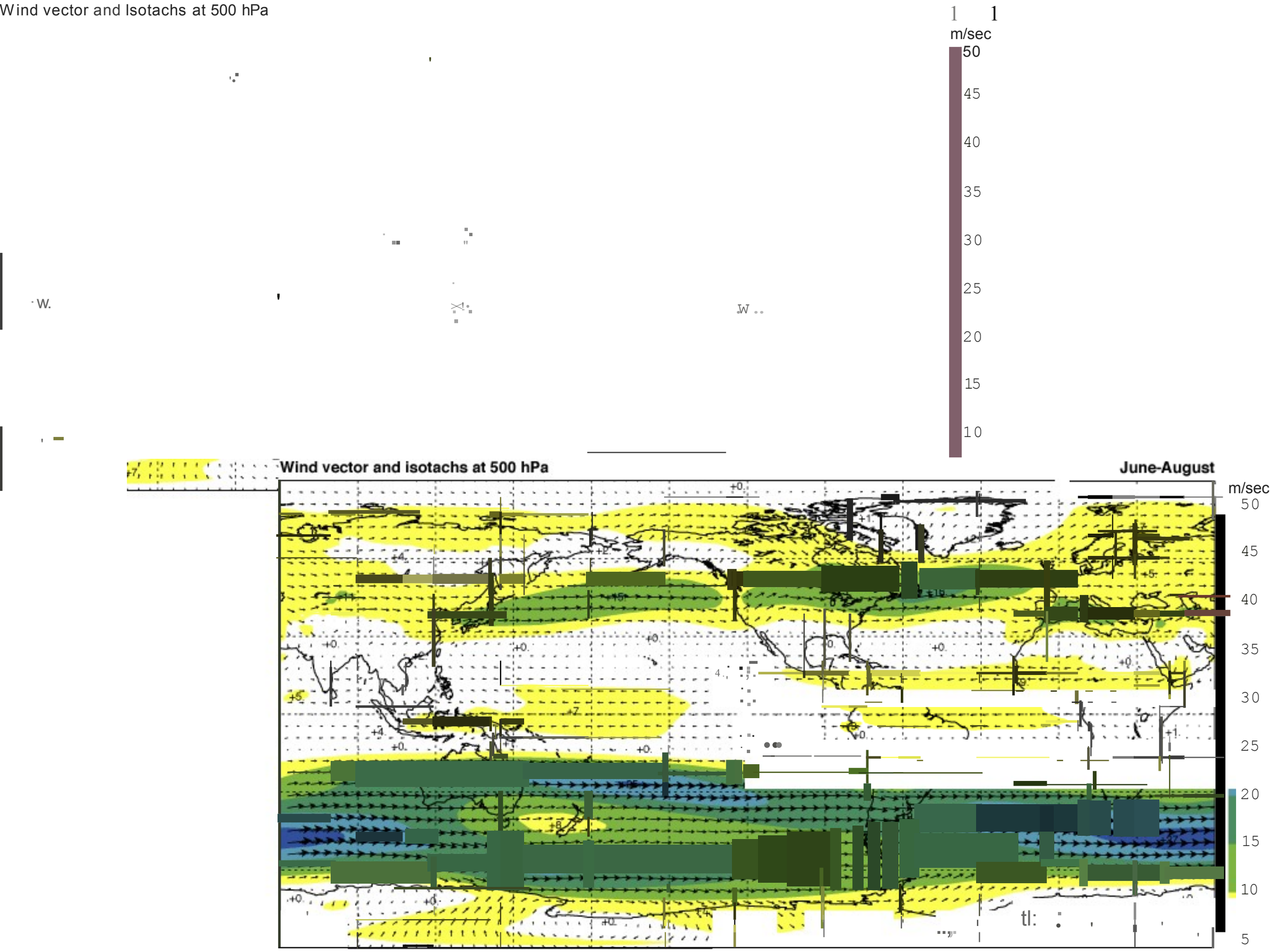
Wind vector and Isotachs. &1850 hPa

December-F-ebruary



Wind vector and isotachs at 850 hPa

June-August



Wind vector and Isotachs at 500 hPa