



第五章:

大气环流中的纬向环流系统

5.2 Monsoon Circulation (II)

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2022. 12. 08



Observed features



- Summary:
 - A monsoon climate is characterized by the obvious **seasonal reversal** of wind, precipitation and atmospheric circulation.
 - From **a global view**: south asian monsoon is associated with the seasonal migration of ITCZ and Hadley circulation, which also plays an important role in the global meridional moisture and latent energy transport.
 - South asian monsoon exhibits obvious **sudden onset**, with the low-level winds and the whole monsoonal circulation built in two weeks.
 - **Intra-seasonal variation**: show periods in 4-5 days, 10-20 days and 40-50 days.
 - **Inter-annual variation**: Relatively weaker precipitation occurs during El Nino years.



Outline



- Introduction
- Features of monsoonal circulation:
an Indian monsoon example
- Monsoon dynamics
 - The land-sea contrast
 - The role of Orography, Tibet Plateau
 - Some GCM results
- On the east asian monsoon



Monsoon dynamics:

-land-sea contrast



- Thermal contrast: different (equivalent) heat capacity
- Moisture advection: provide source of precipitable water



Monsoon dynamics:

-land-sea contrast



■ Thermal contrast :

$$\boxed{\rho_g C_{pg} H_{sur}} \frac{\partial T_g}{\partial t} = F_{sur} + Q_{fx}$$

Determine the response time scale to surface heating

For ocean surface:

$$\rho_g C_{pg} \sim 4 \times 10^6 \text{ Jm}^{-3} \text{K}^{-1}$$

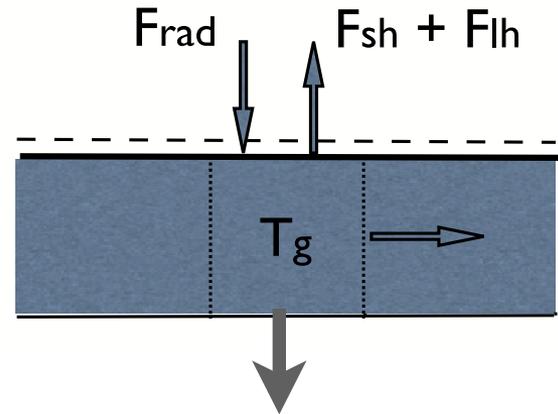
$$H_{sur} \sim \text{O}(10\text{m}) \text{ to } \text{O}(100\text{m})$$

For land surface:

$$\rho_g C_{pg} \sim 1 \times 10^6 \text{ Jm}^{-3} \text{K}^{-1}$$

$$H_{sur} \sim \text{O}(1\text{m})$$

Atmosphere

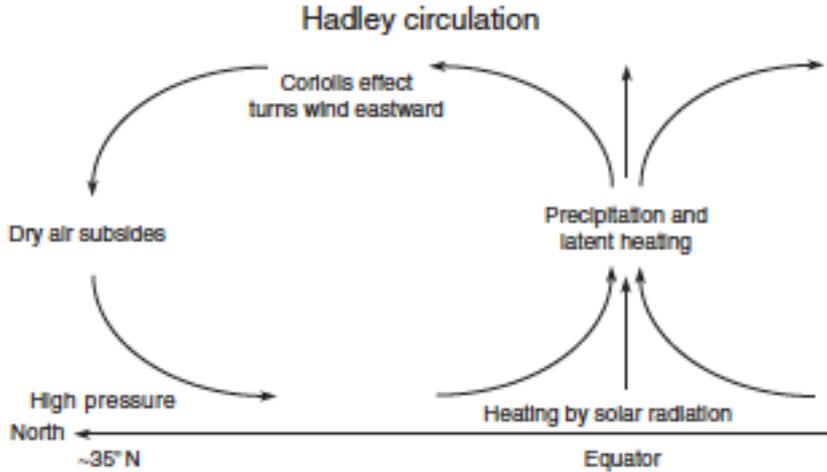


fast response time scale

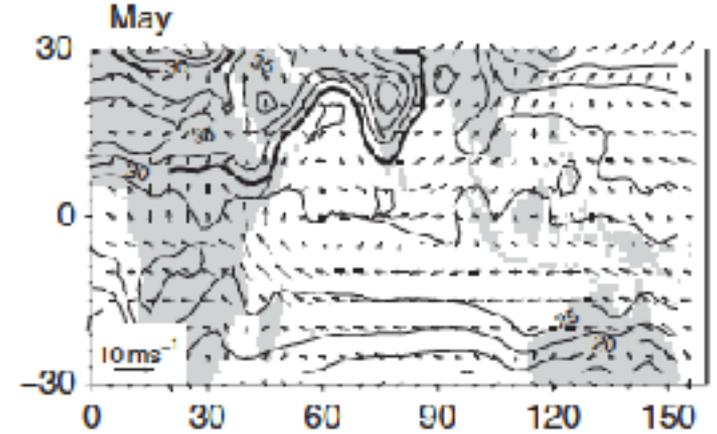


Monsoon dynamics:

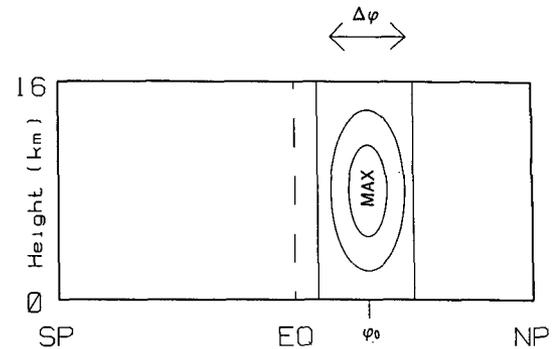
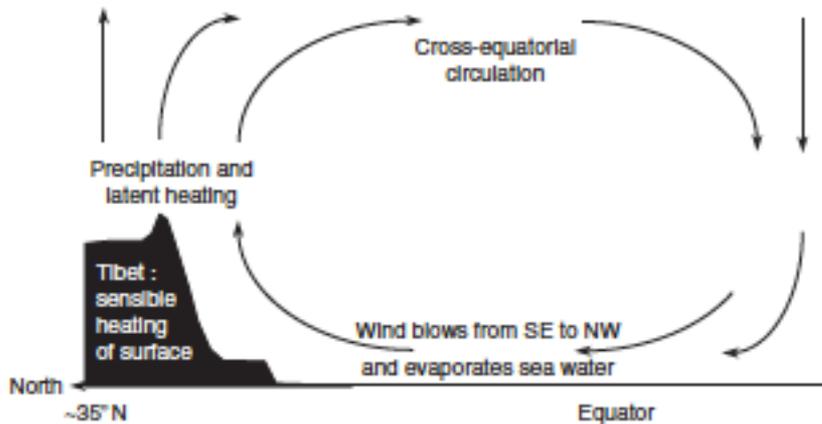
-land-sea contrast



■ Thermal contrast :



Indian summer monsoon



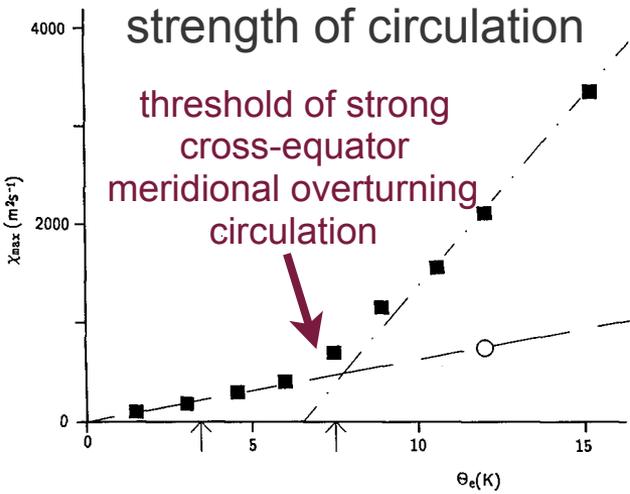
Plumb and Hou (1992)



Monsoon dynamics:

-land-se

Thermal contrast:

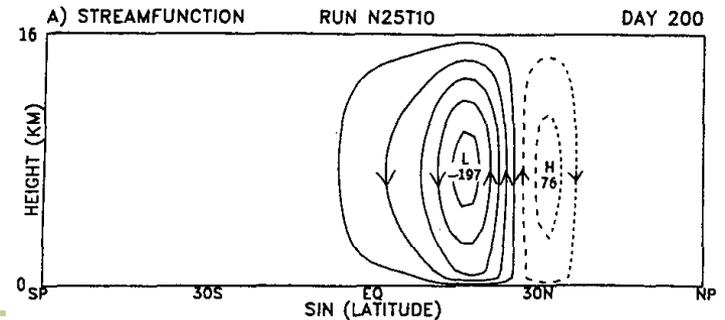
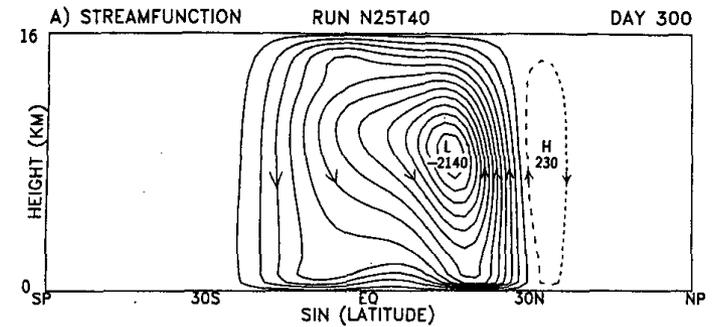
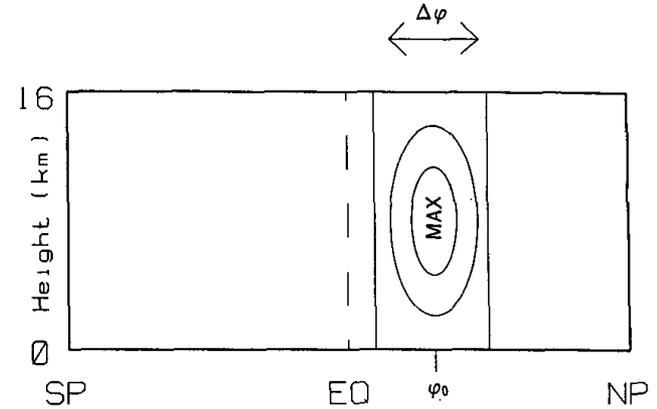


Plumb and Hou (1992)

Numerical results for **axisymmetric** flow

strong heating:

weak heating:



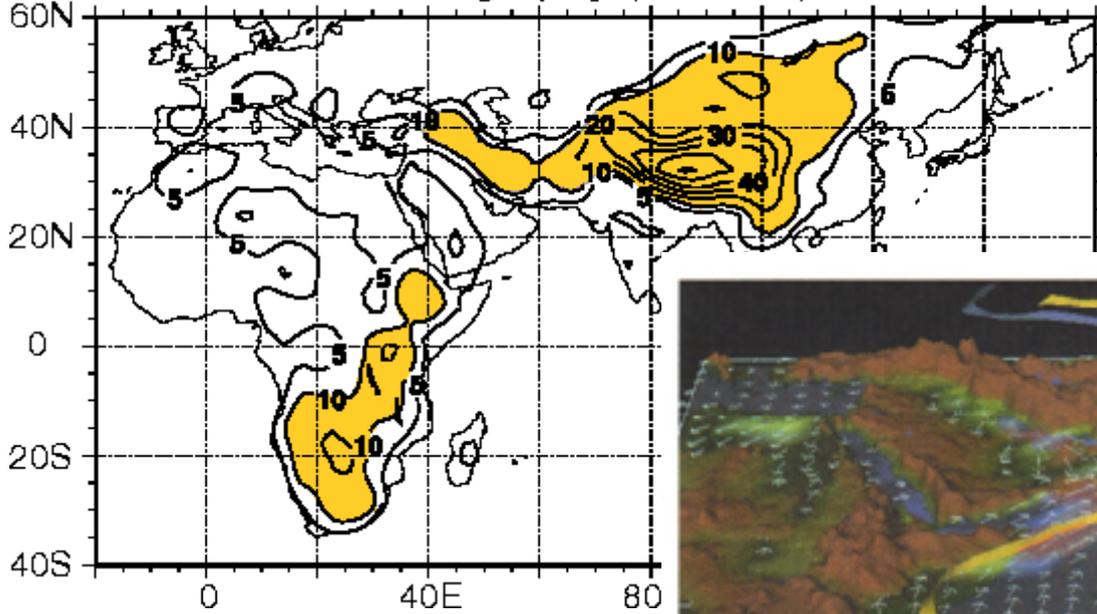


Monsoon dynamics:

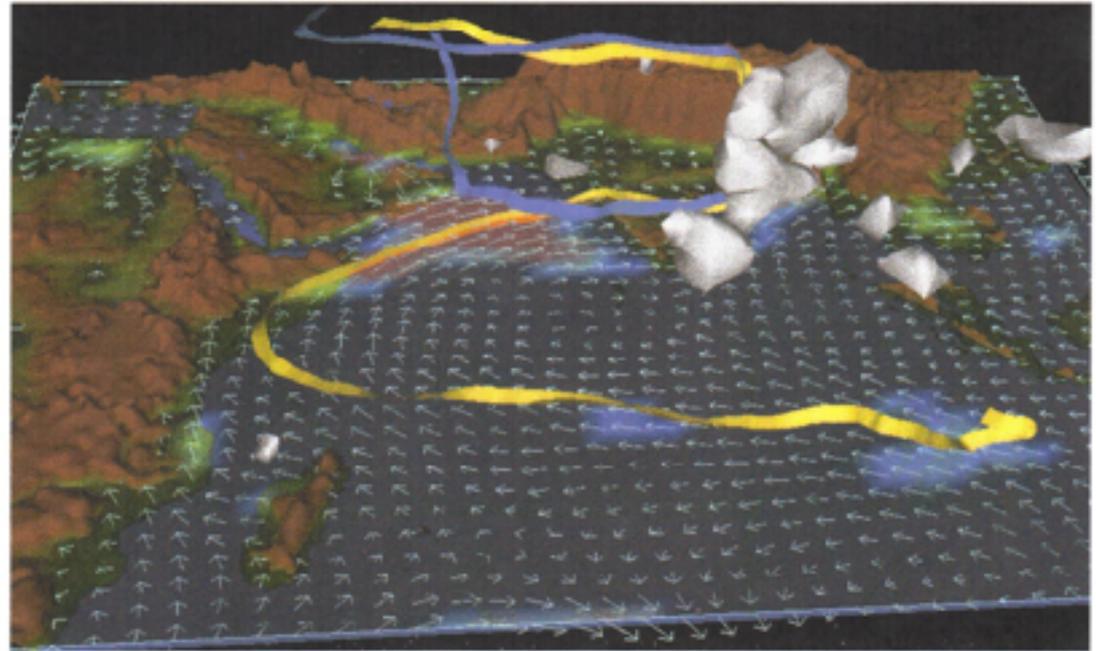
- Orography, Tibet Plateau



Orography (10^{**2} m)



(from Webster 1998)



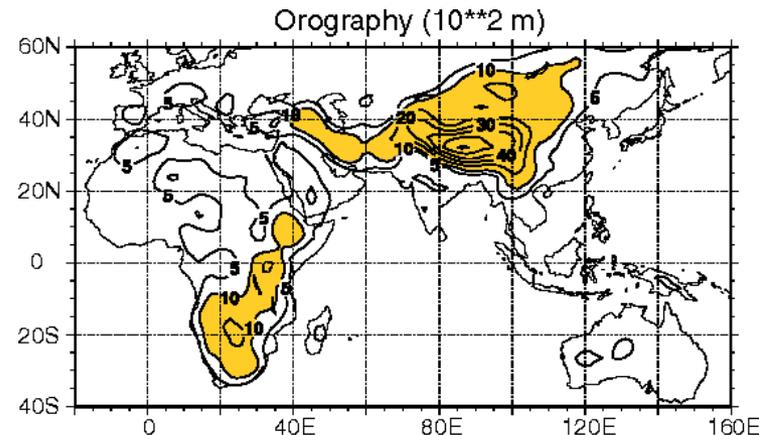


Monsoon dynamics:

- Orography, Tibet Plateau



- Thermal heating: behaves as a heat source of the upper level flow;
- Mechanical forcing:
 - a local impact on precipitation through induced uplift;
 - a more spread impact by shielding the monsoon region from the cold dry air from higher latitude.



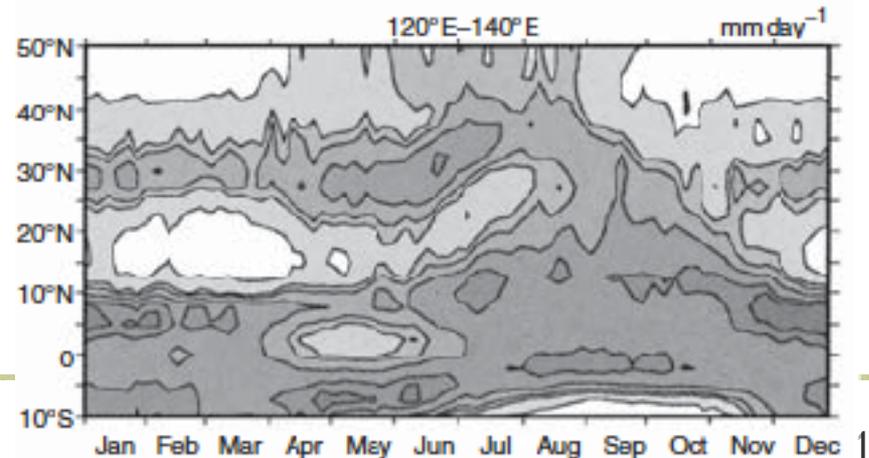
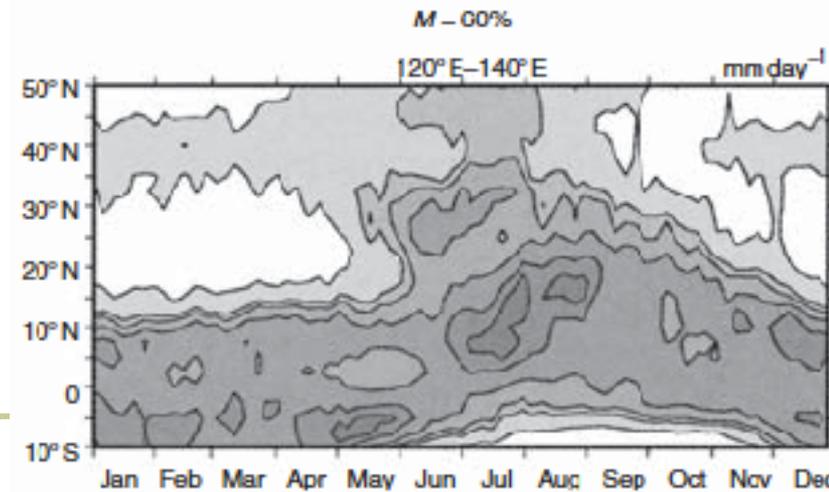
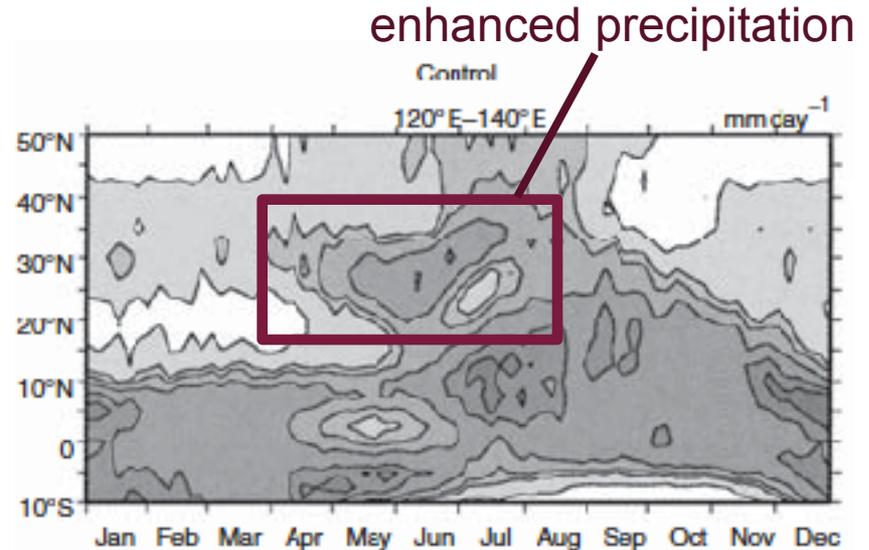
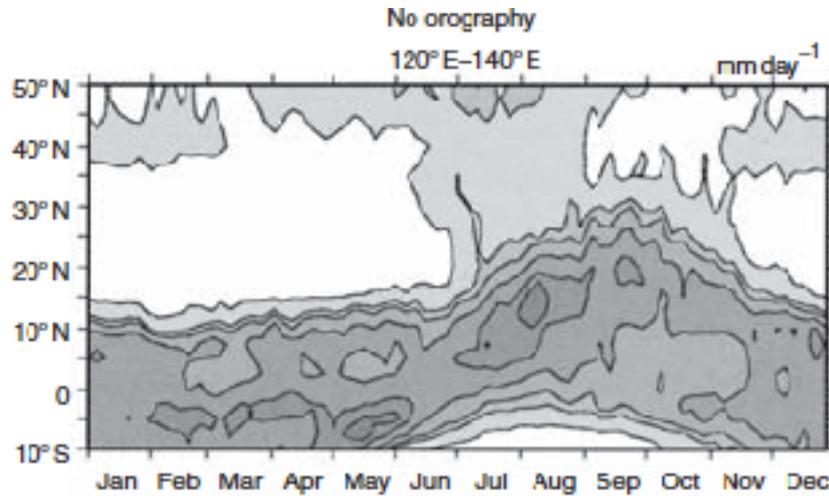


Monsoon dynamics:

- Orography, Tibet Plateau



- Sensitivity to mountain height



(from Kitoh, 2004, JC)



Monsoon dynamics:

- An idealized GCM results



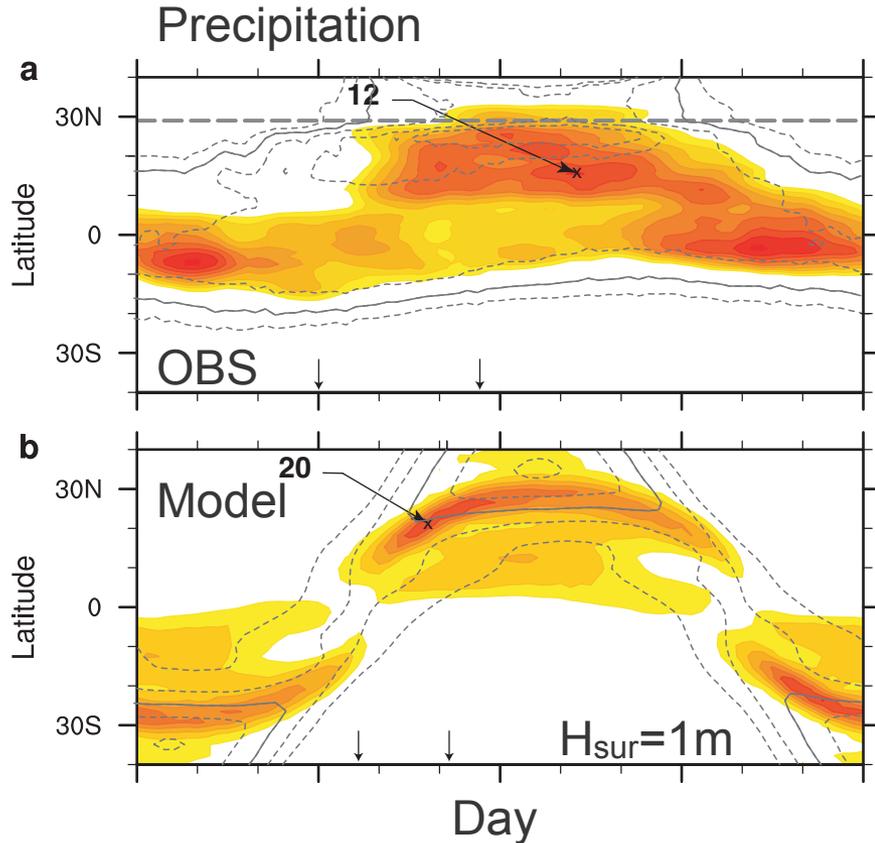
Numerical results from idealized aqua-planet model:

- ocean surface all the globe
- no orography
- only vary depth of the ocean mixed layer



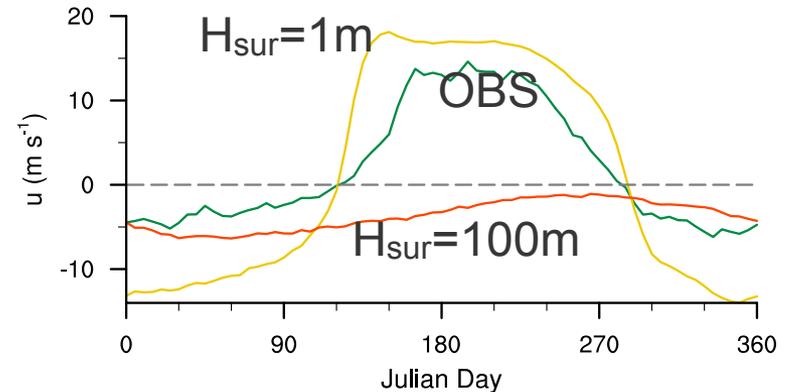
Monsoon dynamics:

- An idealized GCM results



Numerical results from idealized aqua-planet model:

- ocean surface all the globe
- no orography
- only vary depth of the ocean mixed layer



A monsoonal circulation can be observed only when the surface heat capacity is small enough.

(Bordoni and Schneider, 2008, nature-geosci.)



Monsoon dynamics:

- GCM results on Orography



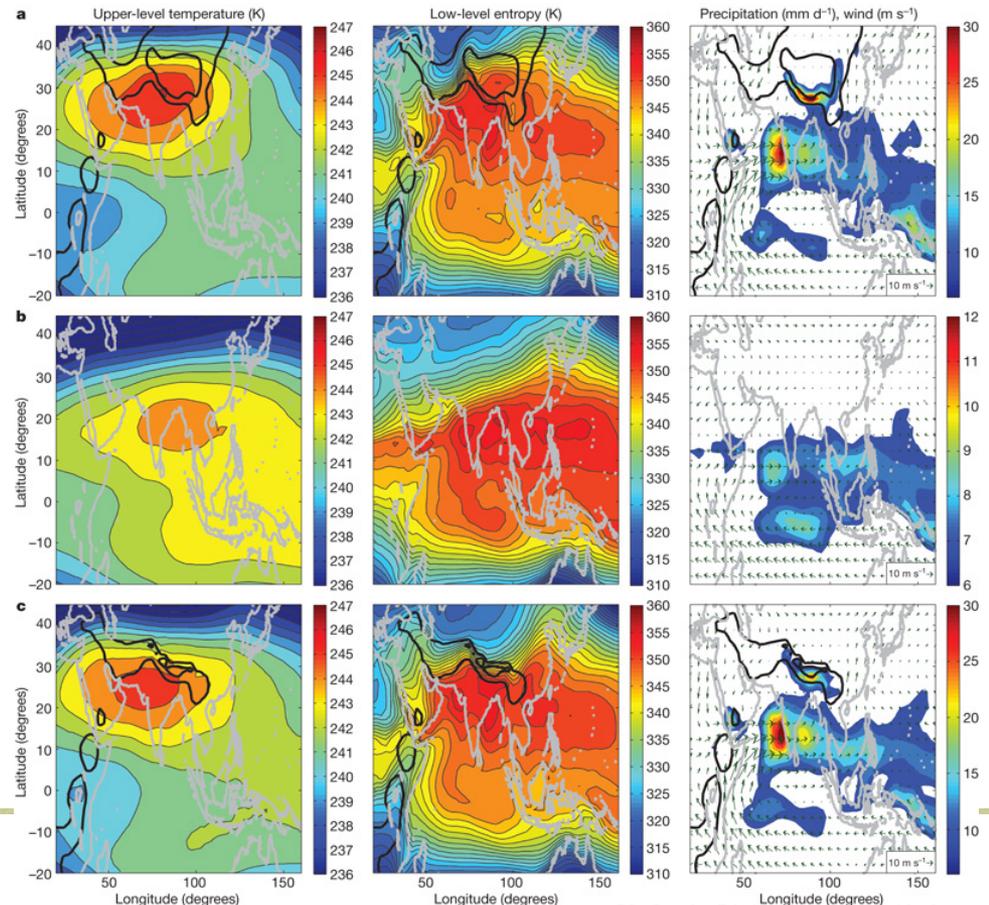
■ Thermal heating vs. Mechanical forcing (I)

Upper level T, lower level entropy, precipitation

Standard Orography

No Orography

Surface elevations north of Himalayas set to zero



(from Boos et al, 2010, nature)



Monsoon dynamics:

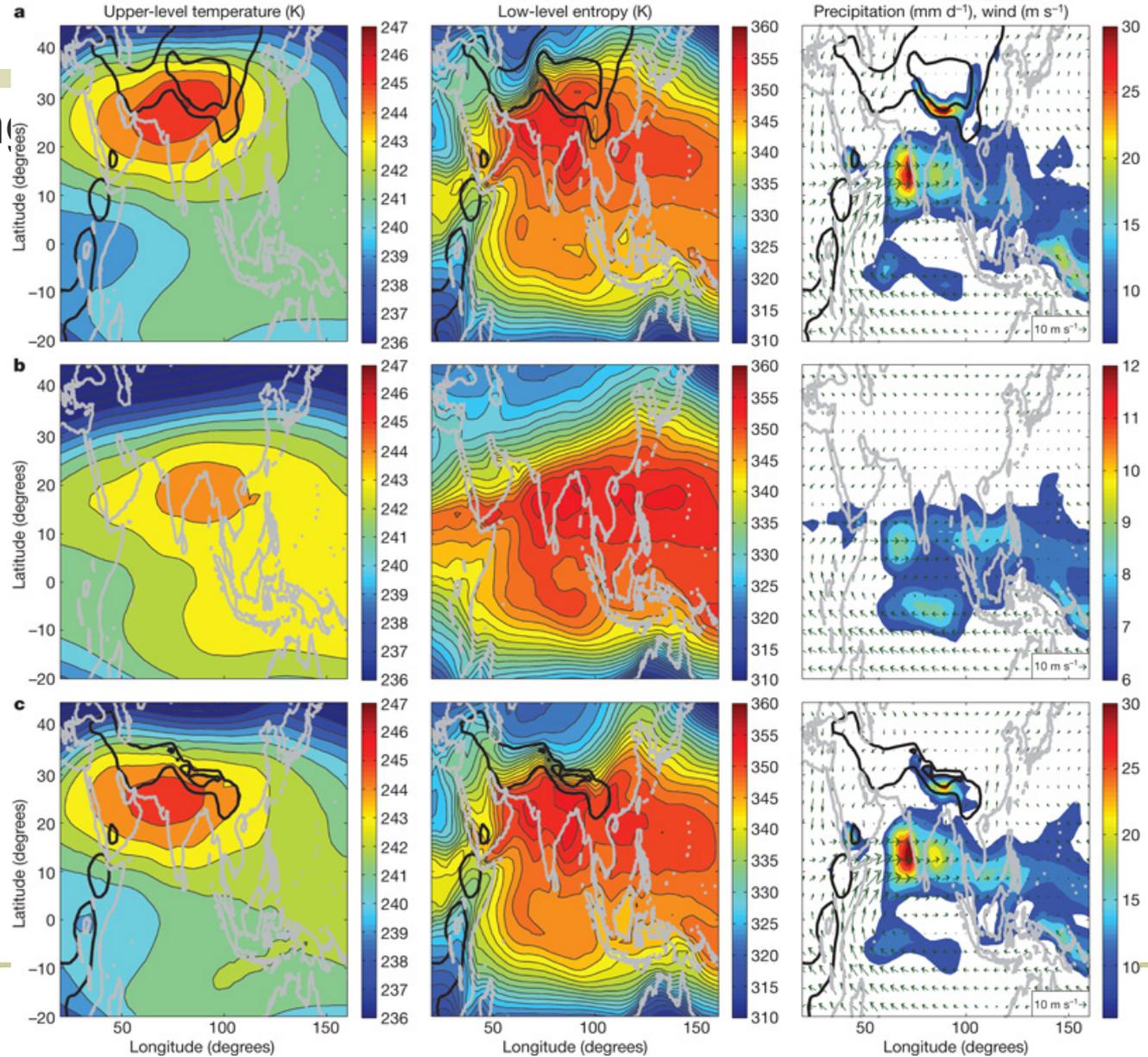
■ Thermal heating

Standard Orography

No Orography

Surface elevations north of Himalayas set to zero

(from Boos et al, 2010, nature)





Monsoon dynamics:

- GCM results on Orography



■ Thermal heating vs. Mechanical forcing (II)

Artificially separate the thermal and mechanical forcings of Tibet Plateau

Experiment design:

- prescribed, seasonally varying SST and sea ice
- orographic setting - changing prescribed surface elevations
- no-sensible heat experiment - the surface energy balance was kept unchanged, but the surface sensible heat released at the elevation above 500m was not allowed to heat the atmosphere.



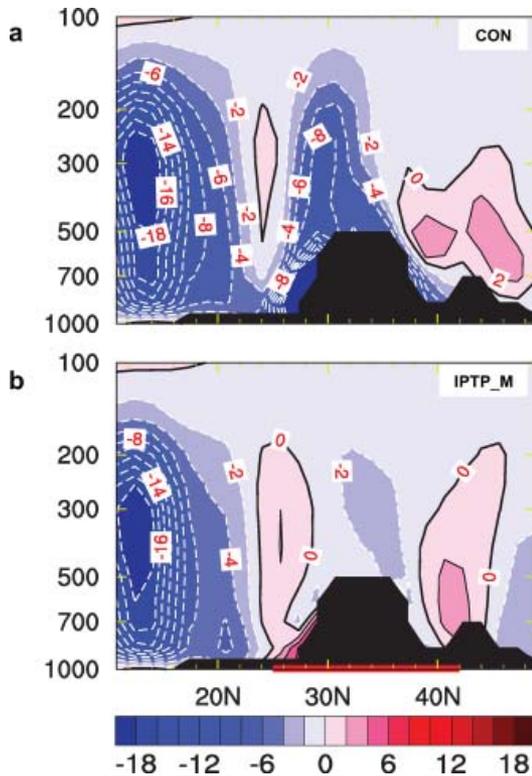
Monsoon dynamics:

- GCM results on Orography



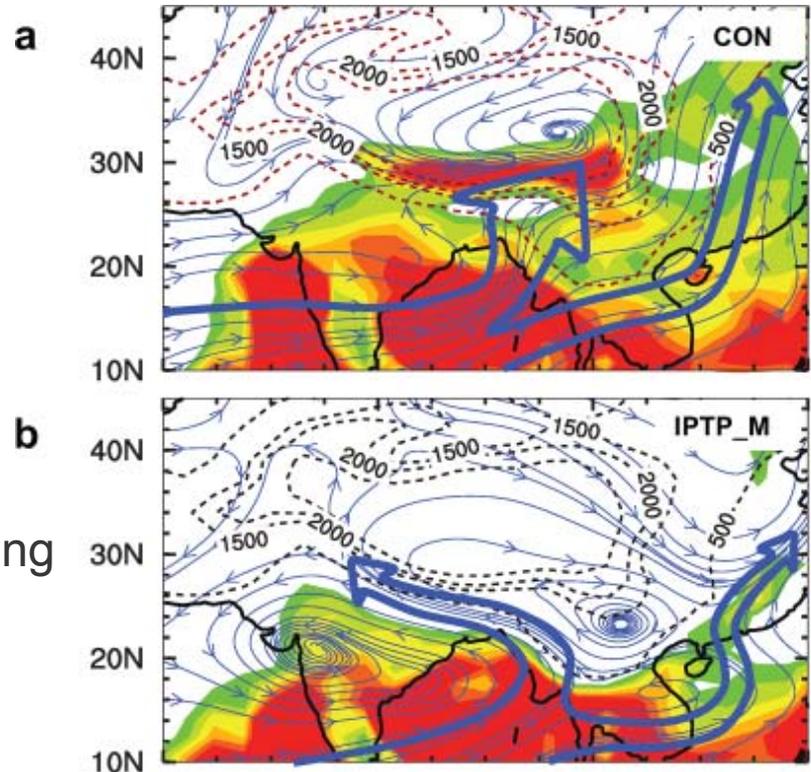
■ Thermal heating vs. Mechanical forcing (II)

Artificially separate the thermal and mechanical forcings of Tibet Plateau



Control run

Turn off the thermal heating of TP,IP



(from Wu et al, 2012, Scientific Reports)



Monsoon dynamics



- Land-sea contrast
 - thermal contrast: strongest heating over subtropical land
 - moisture advection: provide precipitation water
- Orography
 - Thermal forcing as an upper level heat source
 - Mechanical forcing:
 - a local precipitation enhancement
 - a widespread barrier of cold, dry air
- GCM results
 - **strong seasonal heating** due to the small heat capacity of the underlying surface seems to be **crucial** to the formation of monsoonal circulation;
 - the special **topography** of south asian reinforces the monsoon, especially by protecting warm and moist tropical air from the cold and dry extratropics ;
 - thermal heating from the south slope of TP suggested strengthen the monsoon
- Monsoon variation in timescales as intra-seasonal, inter-annual scales needs further studies

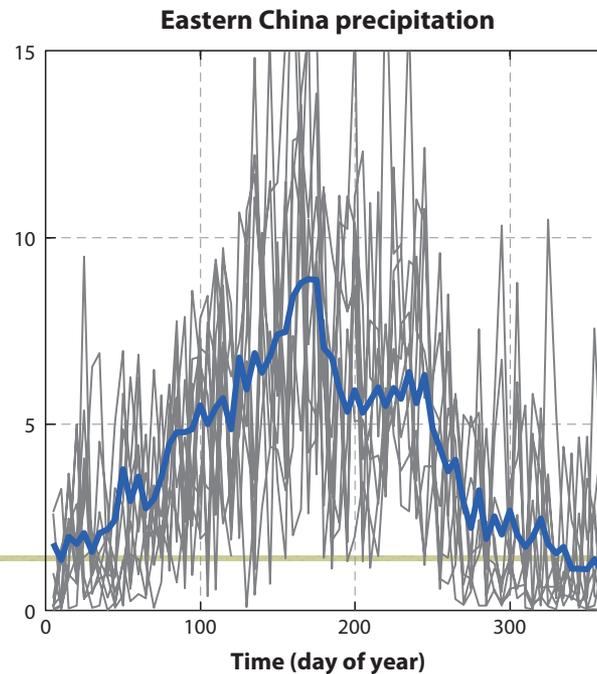
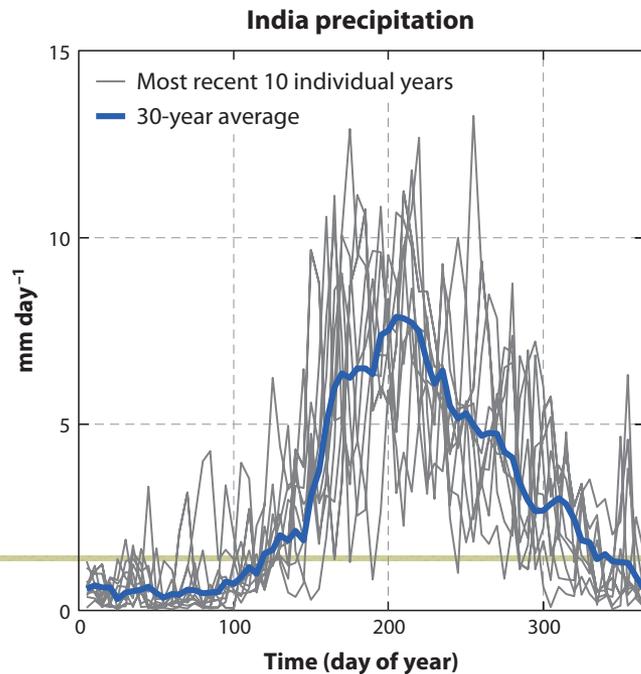


Features of monsoonal circulation: -the east asian monsoon



■ Difference in observed features

- no such obvious sudden onset
- precipitation in spring-summer is organized as the **Meiyu Front**
- evolution and migration of the fronts are closely associated with the **East Asian jet stream** and the **western pacific subtropical high**

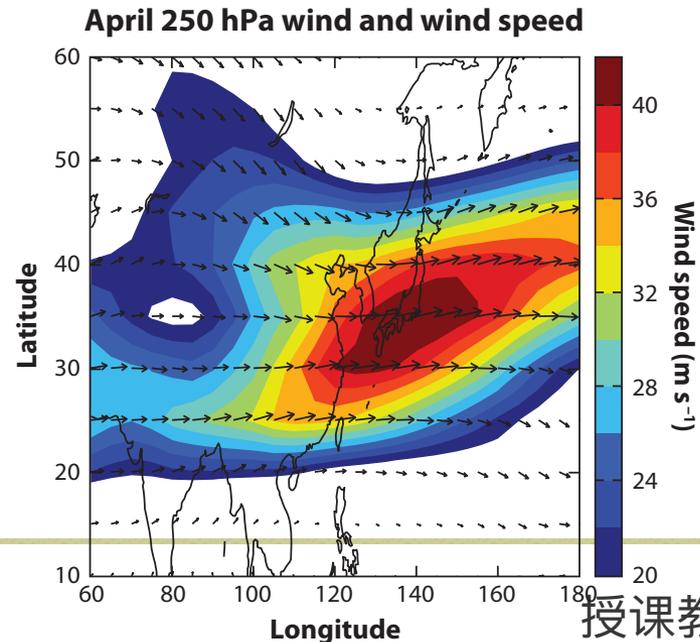
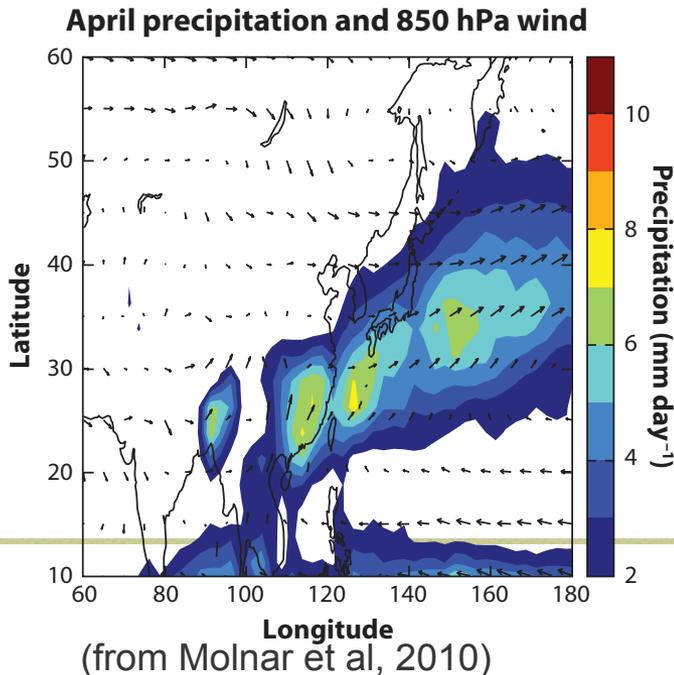




Features of monsoonal circulation: -the east asian monsoon

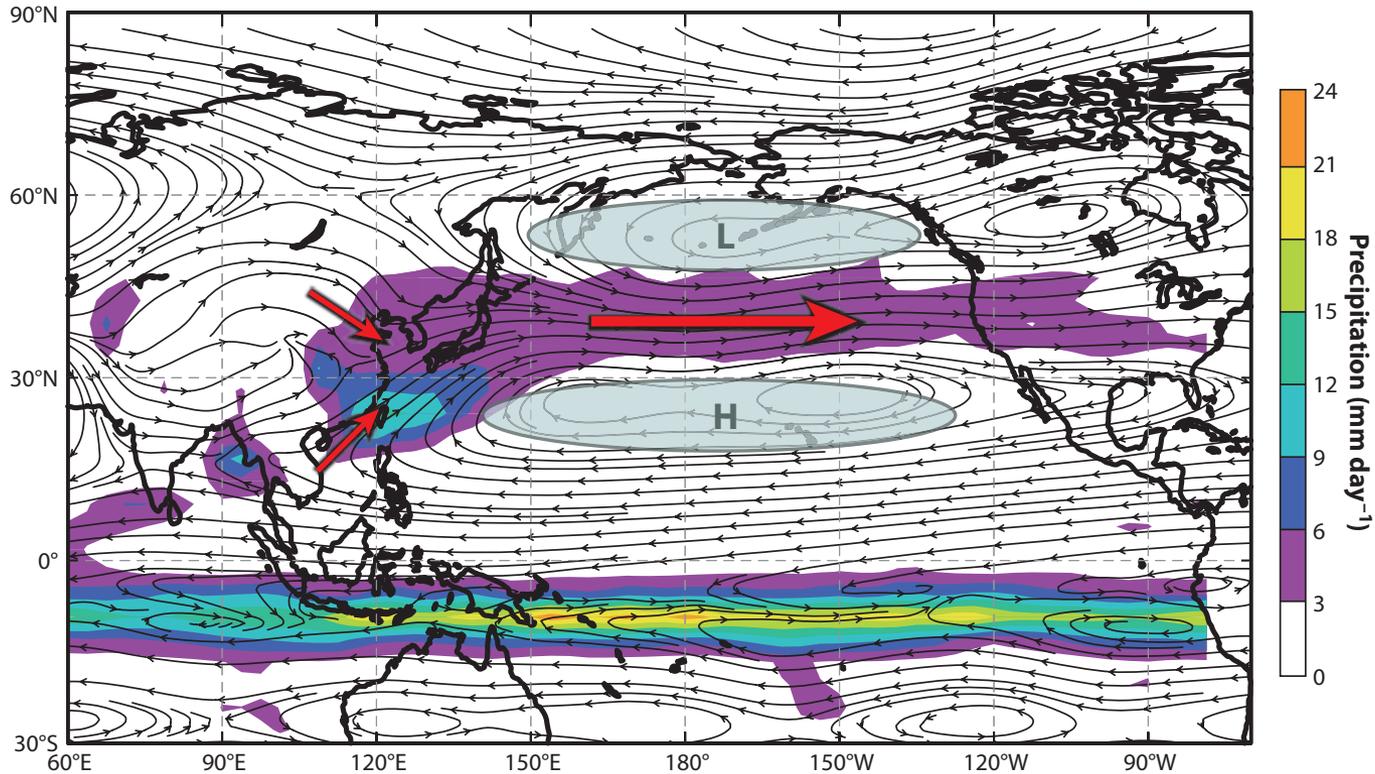


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Features of monsoonal circulation: -the east asian monsoon



Calculated precipitation rates (*in color*) and lower tropospheric (850 hPa) streamlines superimposed on a map of Earth. A general circulation model (GCM) was coupled to a slab ocean in calculations (an aquaplanet), and included only the high terrain equivalent to that of Tibet. Perpetual equinox insolation was used; all forcings except orography are also symmetric about the equator. East of the high terrain that mimics Tibet, focusing (*converging red arrows*) and intensification of the upper-level jet (*large red arrow across the central Pacific*) set up circulation with lower-level convergence and heavy precipitation colocated where southeastern China is located. (From unpublished work of K. Takahashi and D.S.B.)

(from Molnar et al, 2010)



Features of monsoonal circulation: -the east asian monsoon



- Difference in observed features
 - no such obvious sudden onset
 - precipitation in spring-summer is organized as the **Meiyu Front**
 - evolution and migration of the fronts are closely associated with the **East Asian jet stream** and the **western pacific subtropical high**
- Different systems in the summer/winter east asian “monsoon”, which is distinctly **extratropical** in nature
- The different role of Tibet Plateau in south/east asian monsoon
 - South Asian monsoon: acting as an **obstacle** the southward cool, dry air
 - East Asian monsoon: **lying in the path** of subtropical jet stream
 - The importance of thermal heating is under study



Reference



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