Cumulus and its Role in the Atmosphere over the Tibetan Plateau

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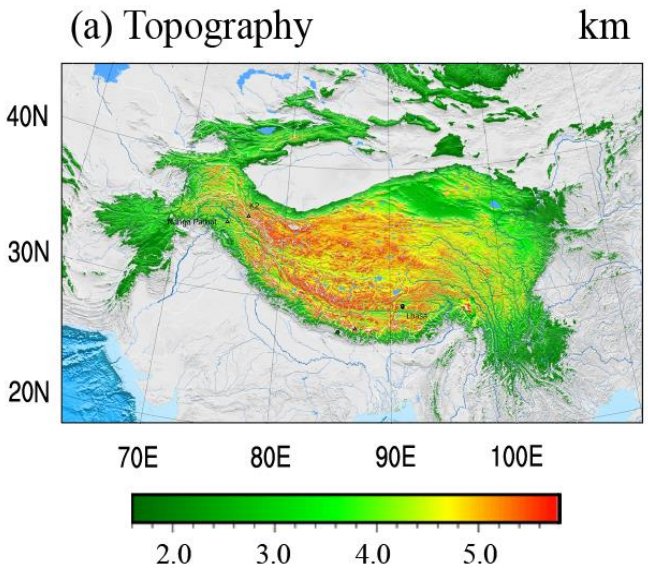
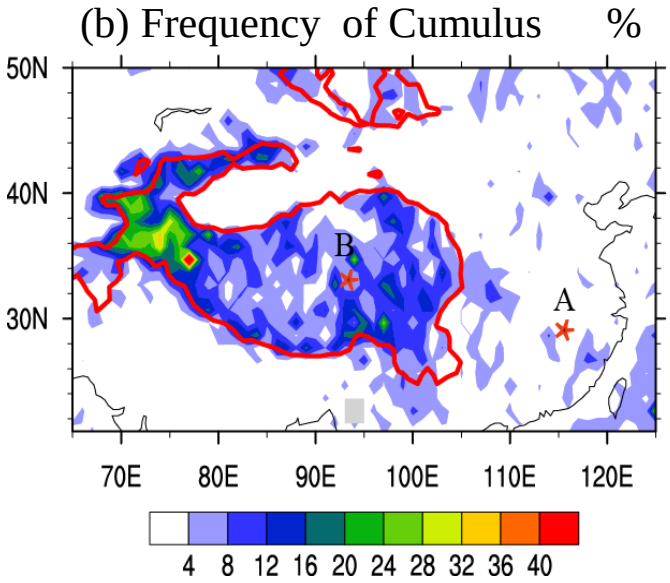
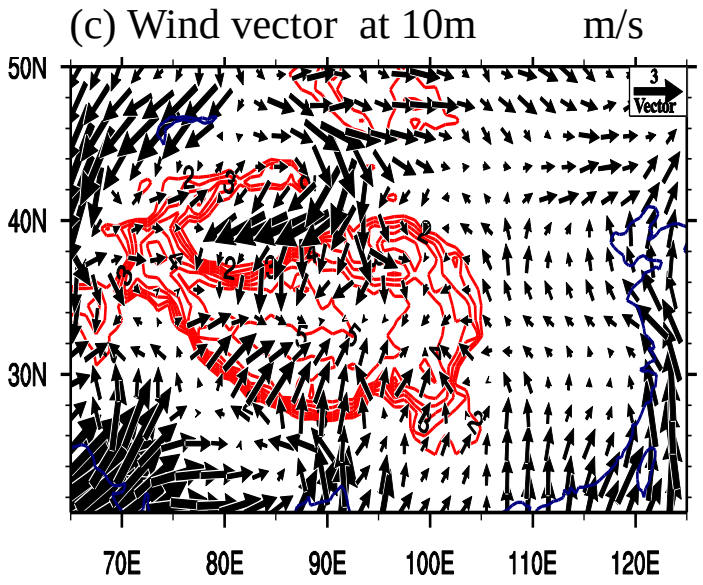
Outline

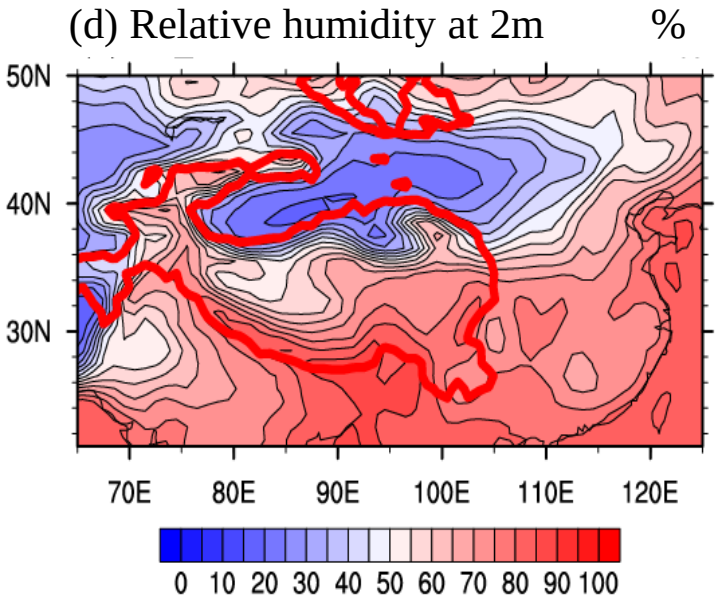
- **The formation of Cumulus over the TP**
- **The role of Cumulus in the atmosphere over the TP**





Data: CloudSat





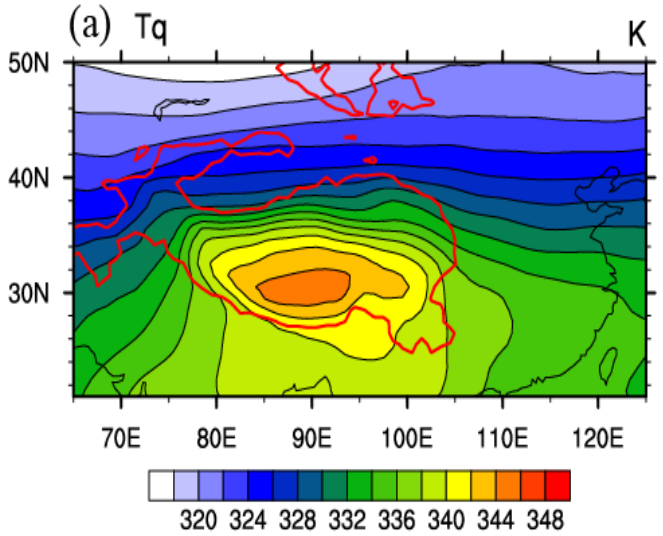
Data: ERA-40

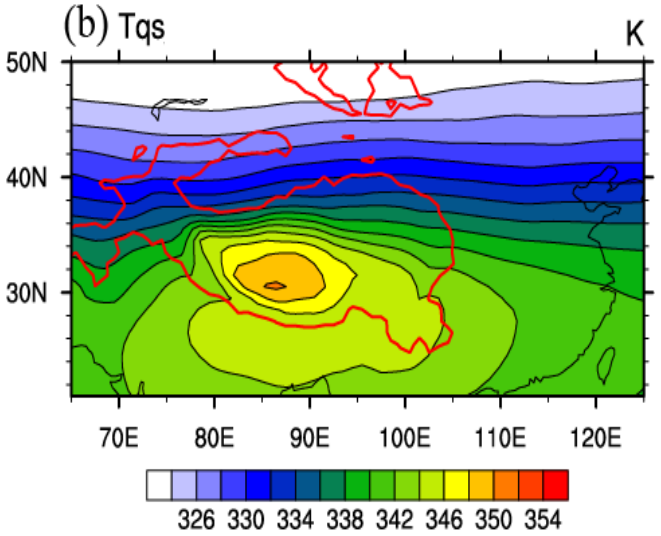
moist static energy at 500hPa

$$T_q = T + \frac{g}{C_p} z + \frac{Lq}{C_p}$$

saturated moist static energy at 500hPa

$$T_{qs} = T + \frac{g}{C_p} z + \frac{Lq_s}{C_p}$$





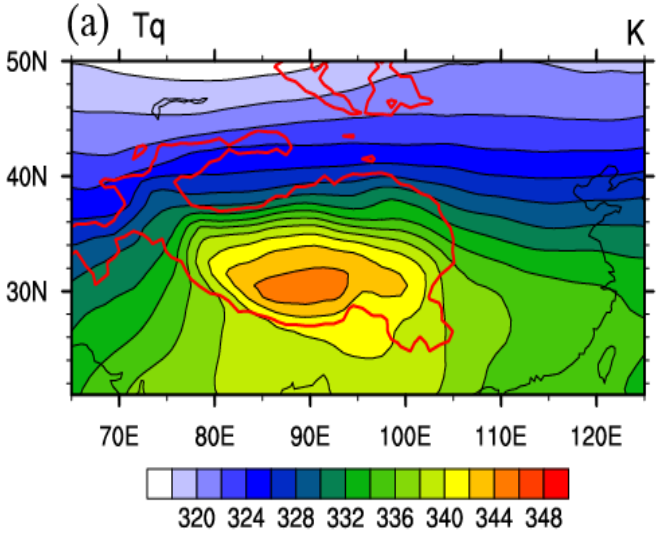
- Cumulus occurrence frequency over the Tibetan Plateau is 54%

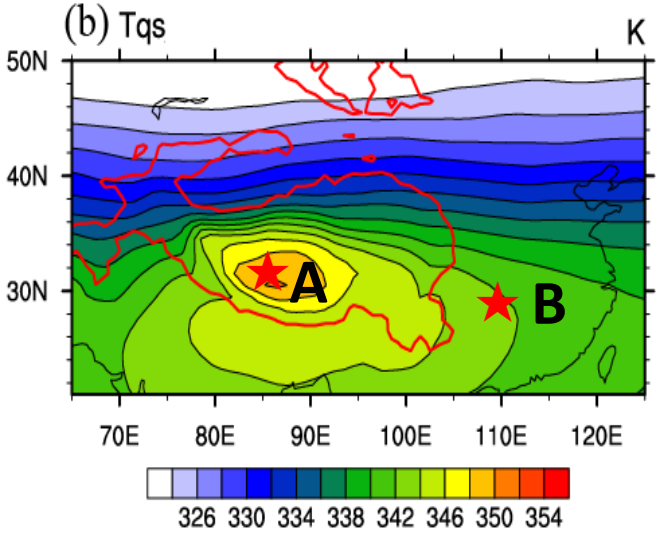
- Deep convection occurrence frequency over the Tibetan Plateau is 5%

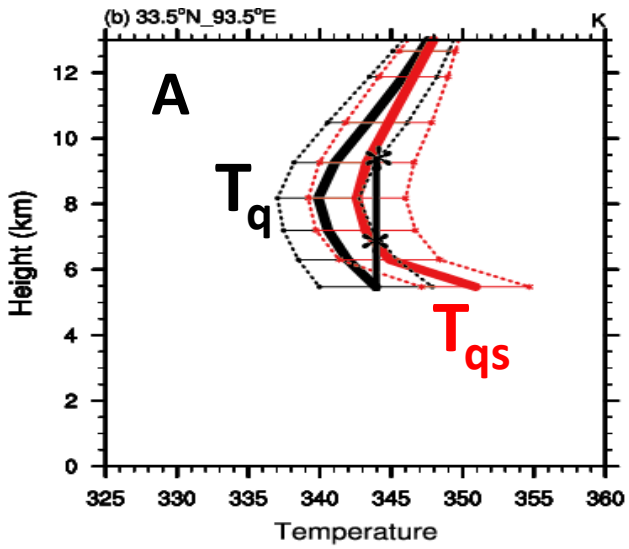
Why?

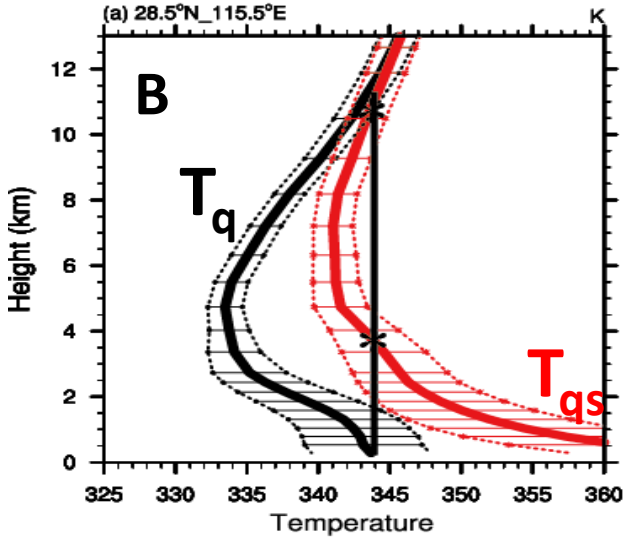
$$T_q = T + \frac{g}{C_p} z + \frac{Lq}{C_p}$$

$$T_{qs} = T + \frac{g}{C_p} z + \frac{Lq_s}{C_p}$$









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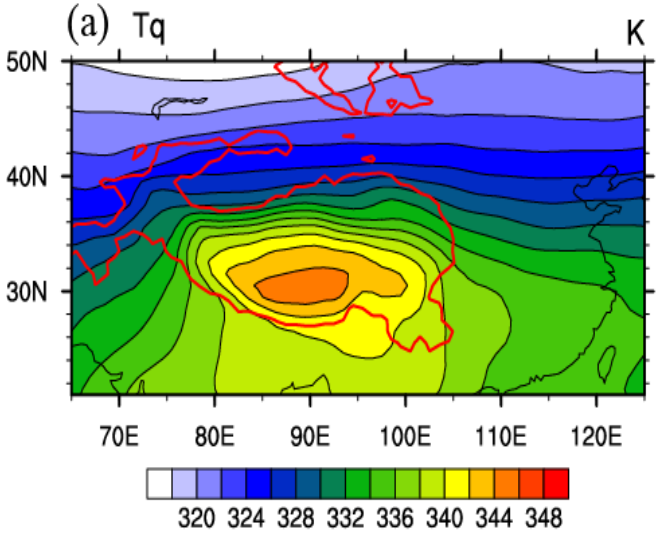

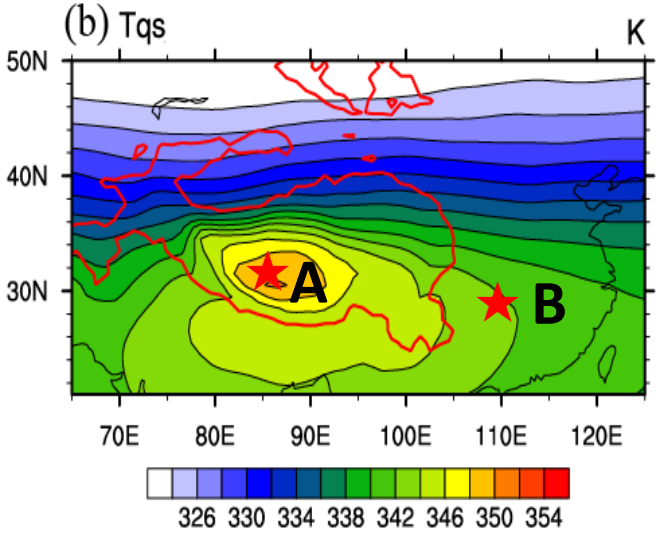

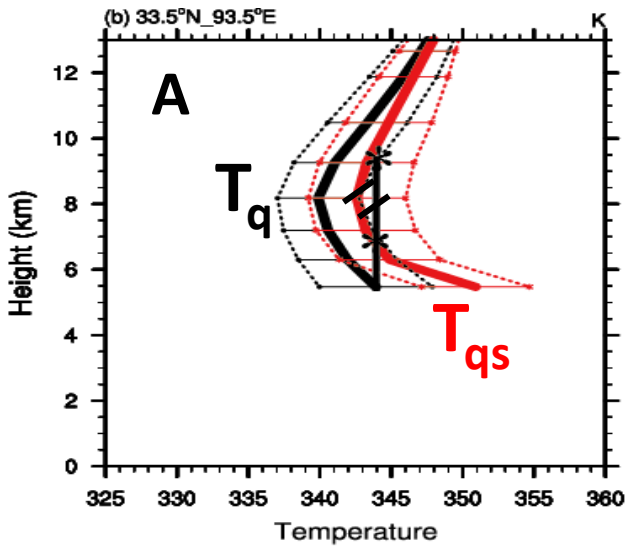

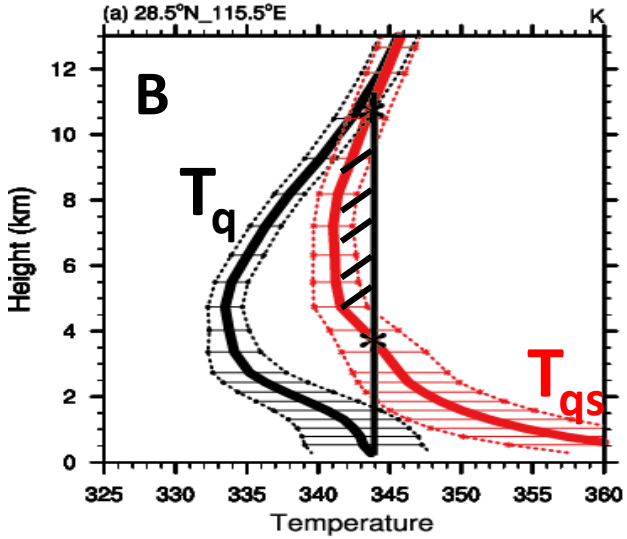

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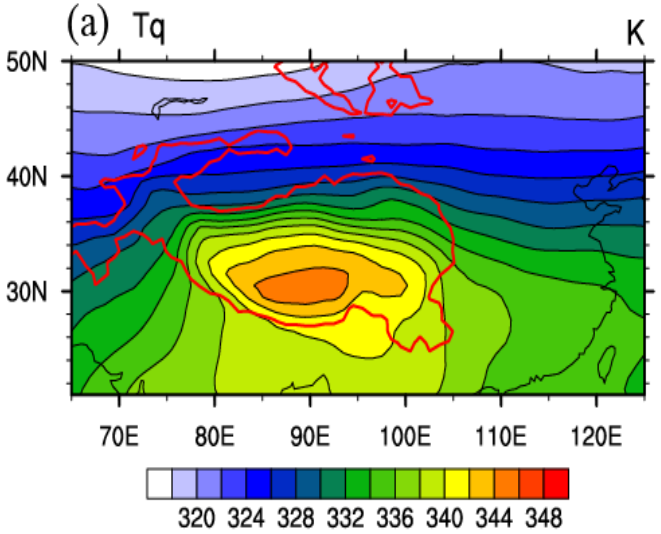

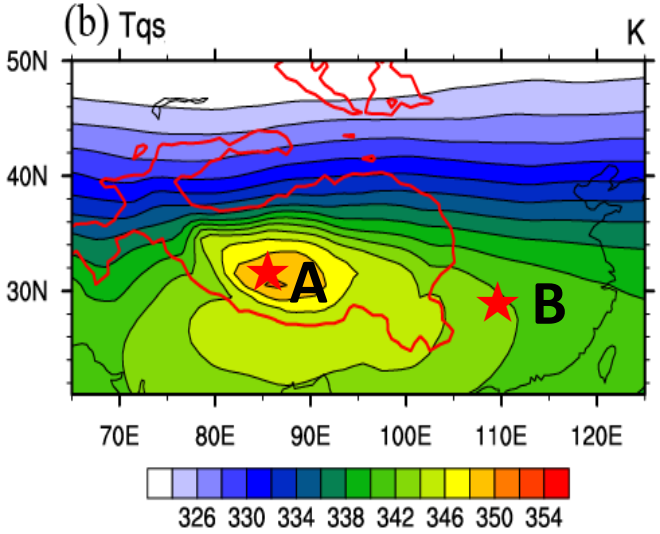

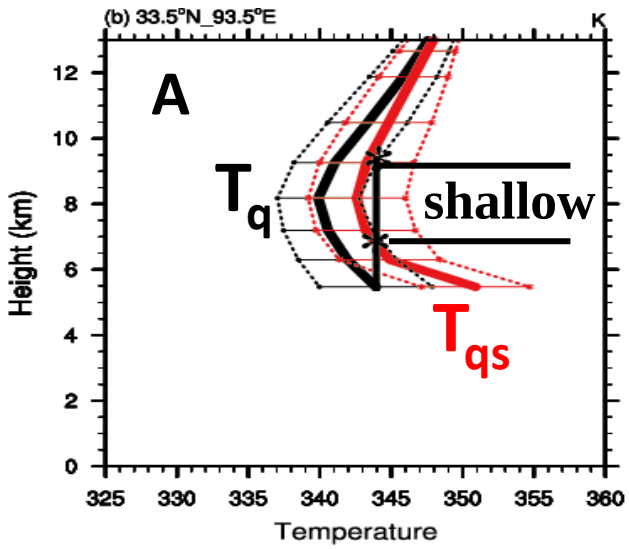

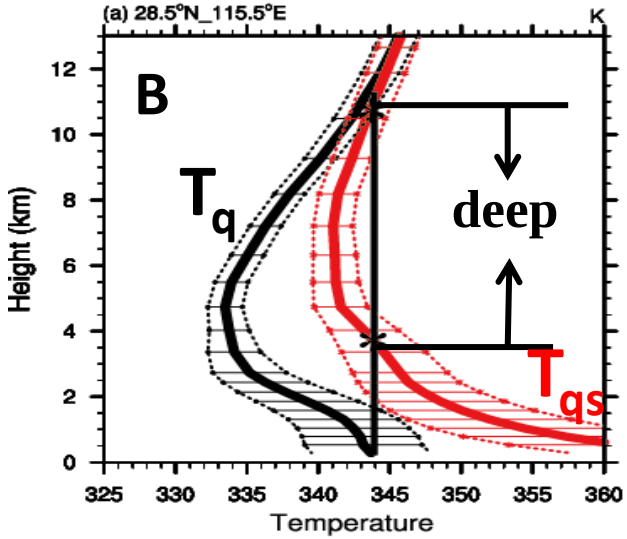

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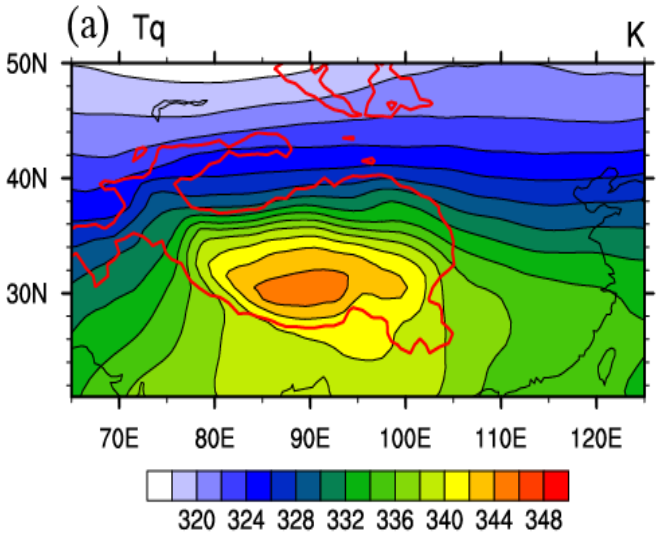

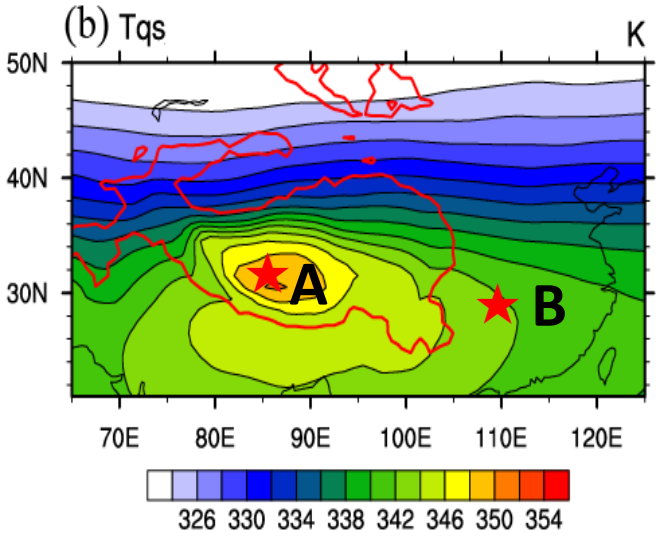

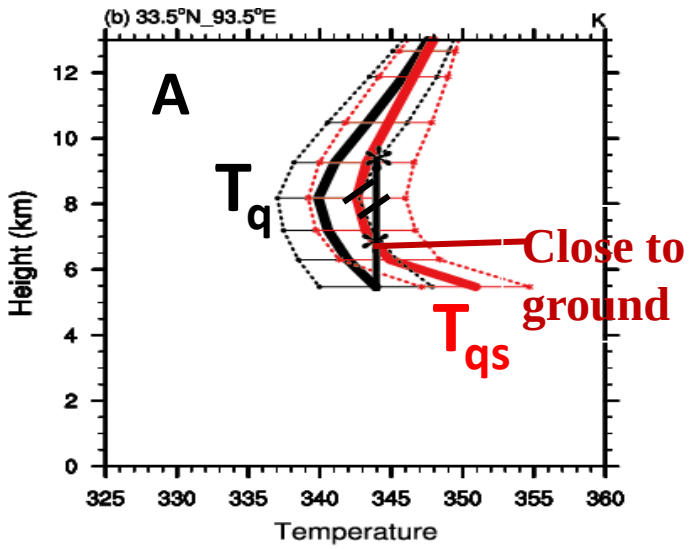

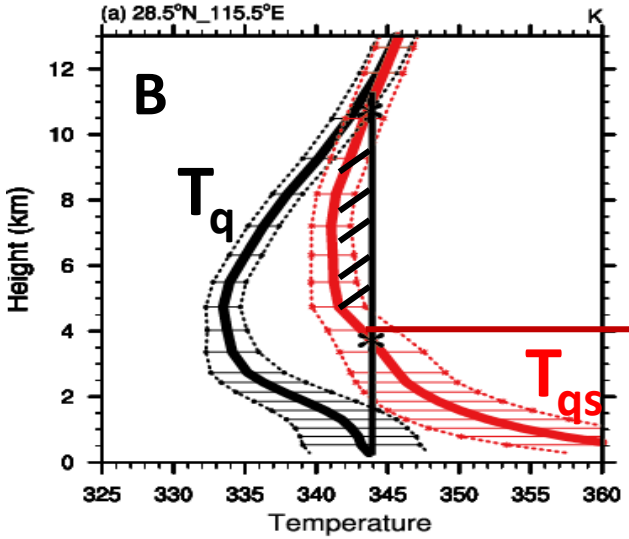

First Conclusion

- The unique Cumulus over the TP is caused by the higher air temperature and larger relative humidity above the TP surface than those in the surrounding regions at the same altitude.

- The conditions of weak instability, shallow layer of instability, and lower altitudes for the level of free convection are favorable for shallow convection but not deep convection.

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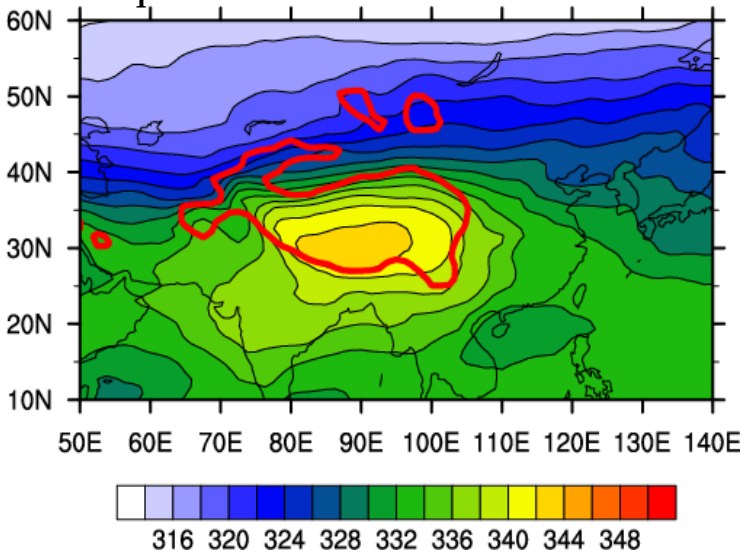
- **The role of Cumulus in the atmosphere over the TP**

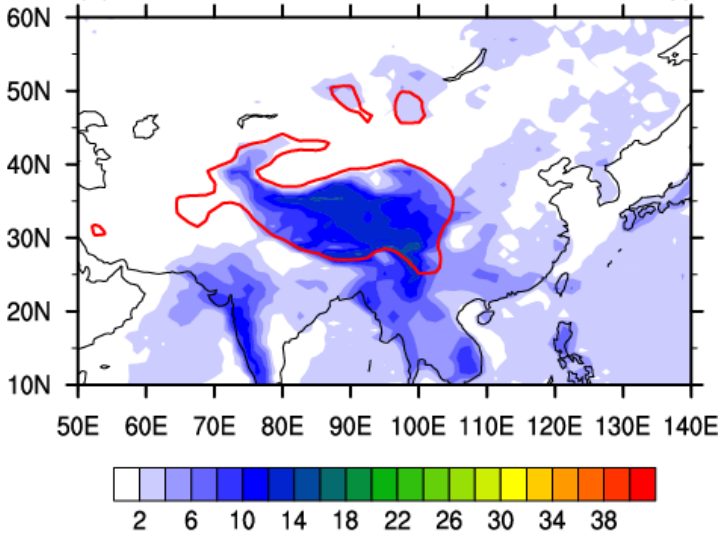
Tq at 500hPa

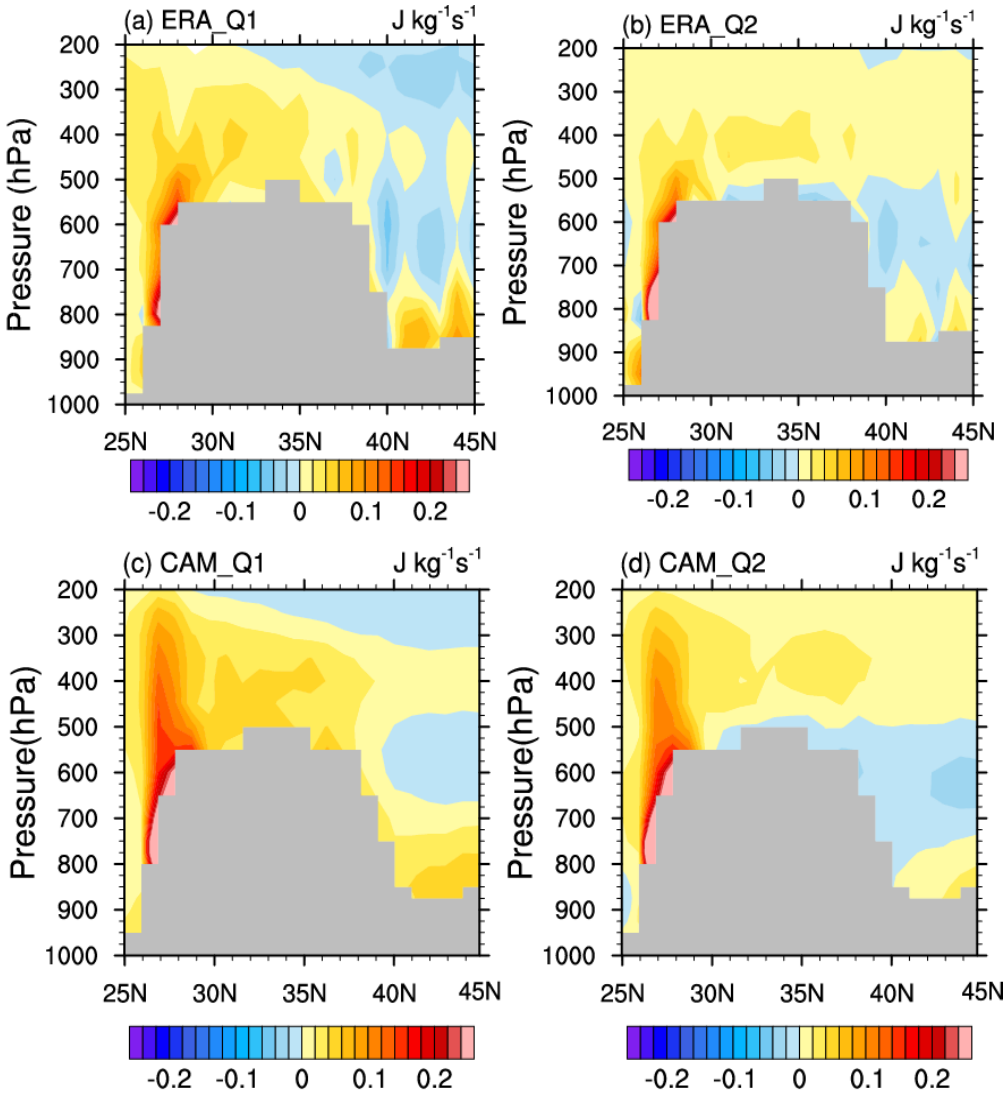


apparent heat $Q_1 = C_p[\frac{\partial T}{\partial t} + \vec{V} \bullet \nabla T + (\frac{p}{p_0})^k \omega \frac{\partial \theta}{\partial p}]$

apparent moisture $Q_2 = -L[\frac{\partial q}{\partial t} + \vec{V} \bullet \nabla q + \omega \frac{\partial q}{\partial p}]$

Distribution of shallow convection





CAM 5 model

apparent heat Q_1

moist physics

solar radiative heating

longwave radiative cooling

vertical transport

$$Q_1 = \left(\frac{\partial T}{\partial t}\right)_{DTCOND} + \left(\frac{\partial T}{\partial t}\right)_{QRS} + \left(\frac{\partial T}{\partial t}\right)_{QRL} + \left(\frac{\partial T}{\partial t}\right)_{DTV}$$

$$\left(\frac{\partial T}{\partial t}\right)_{DTCOND} \approx \left(\frac{\partial T}{\partial t}\right)_{ZMDT} + \left(\frac{\partial T}{\partial t}\right)_{CMFDT} + \left(\frac{\partial T}{\partial t}\right)_{MPDT} + \left(\frac{\partial T}{\partial t}\right)_{MACPDT}$$

deep convection

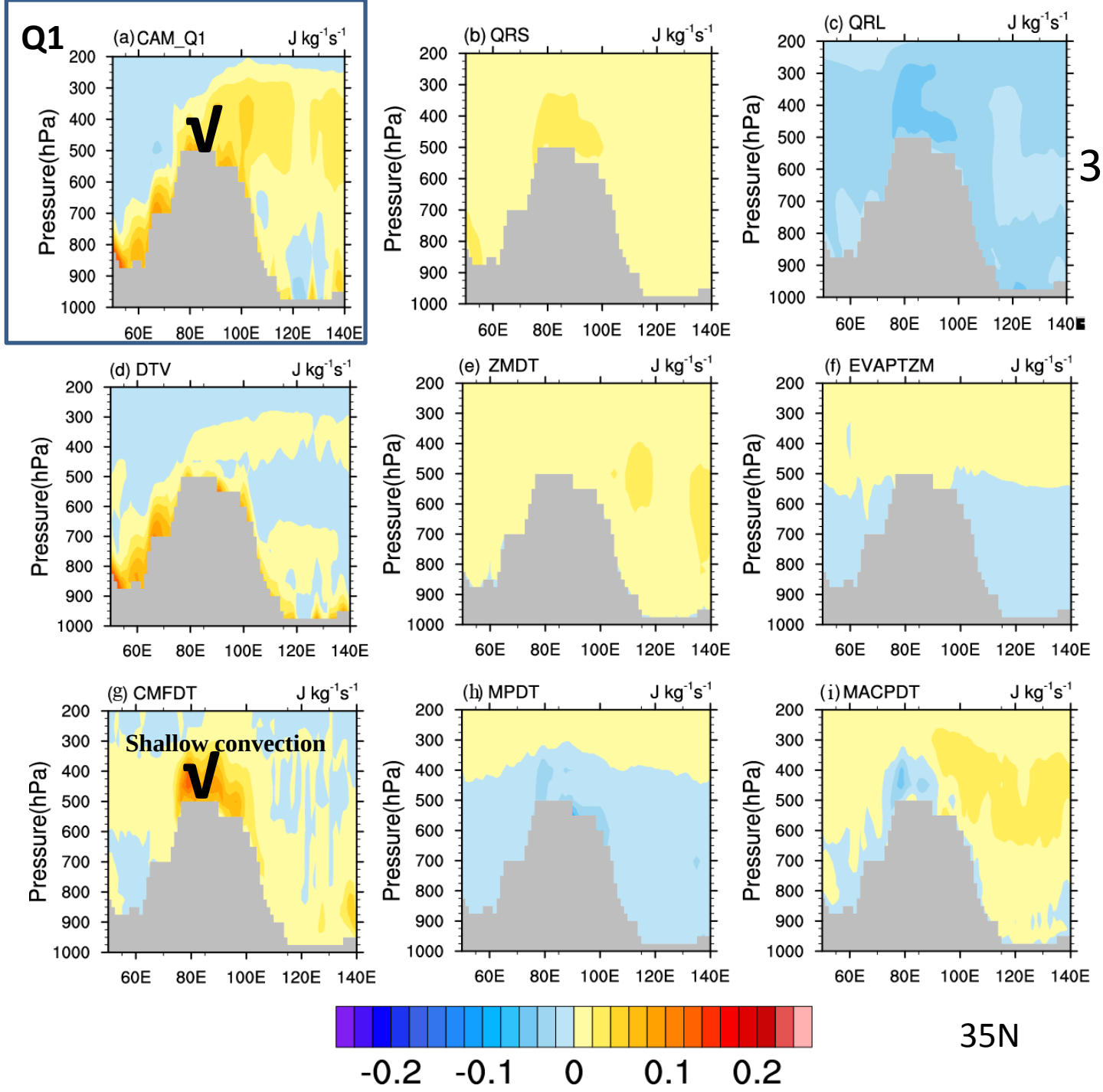
shallow convection

stratiform micro-physical processes

stratiform macro-physical processes

Temperature increase

Role: heating the atmosphere



35^{0}N

35N

apparent moisture Q_2

moist physics

vertical transport

$$Q_2 = \left[-L\left(\frac{\partial q}{\partial t}\right)\right]_{DQCOND} + \left[-L\left(\frac{\partial q}{\partial t}\right)\right]_{DQV}$$

$$\left(\frac{\partial q}{\partial t}\right)_{DQCOND} \approx \left(\frac{\partial q}{\partial t}\right)_{ZMDQ} + \left(\frac{\partial q}{\partial t}\right)_{CMFDQ} + \left(\frac{\partial q}{\partial t}\right)_{MPDQ} + \left(\frac{\partial q}{\partial t}\right)_{MACPDQ}$$

deep convection

shallow convection

stratiform micro-physical processes

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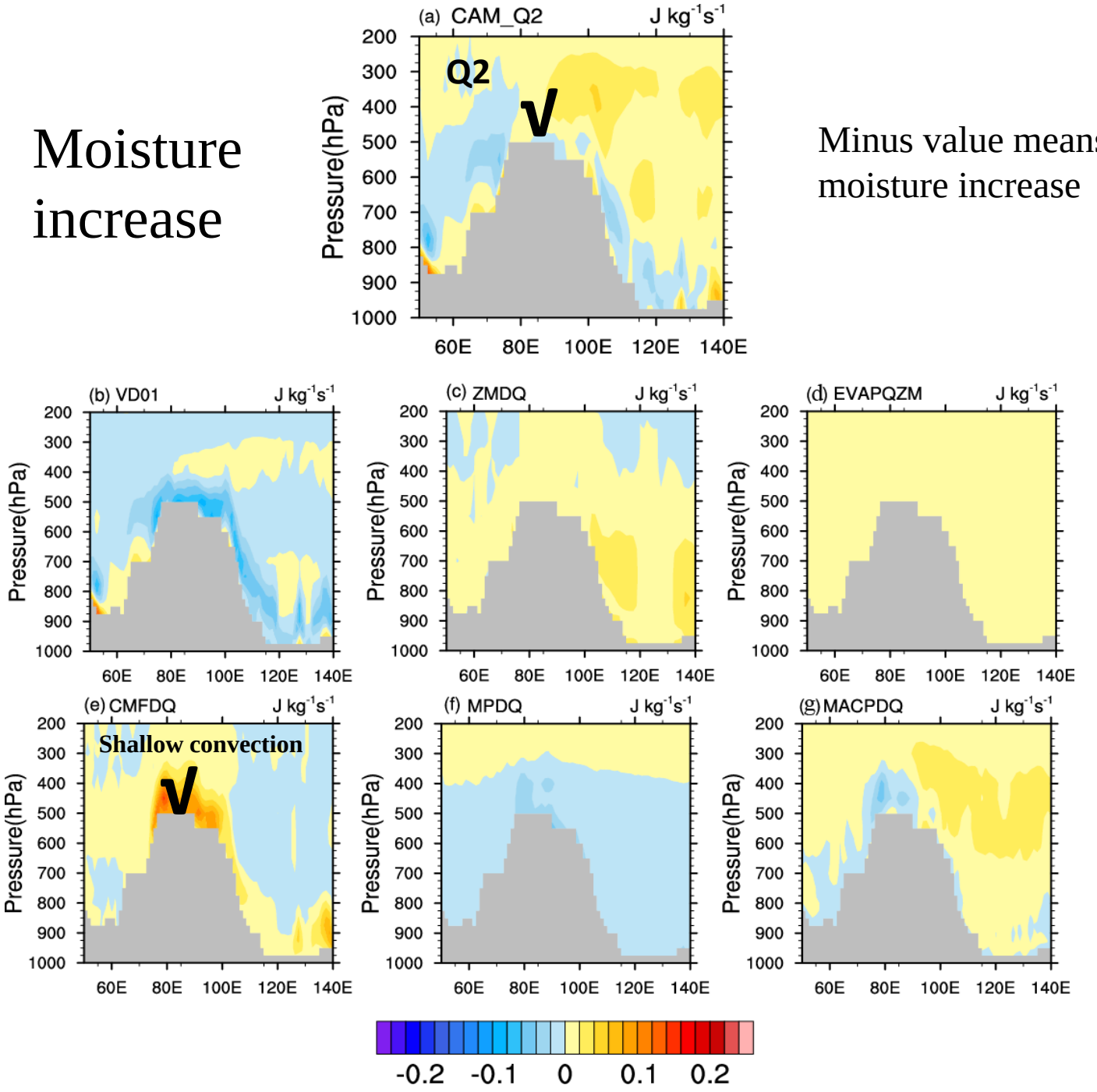
Moisture increase

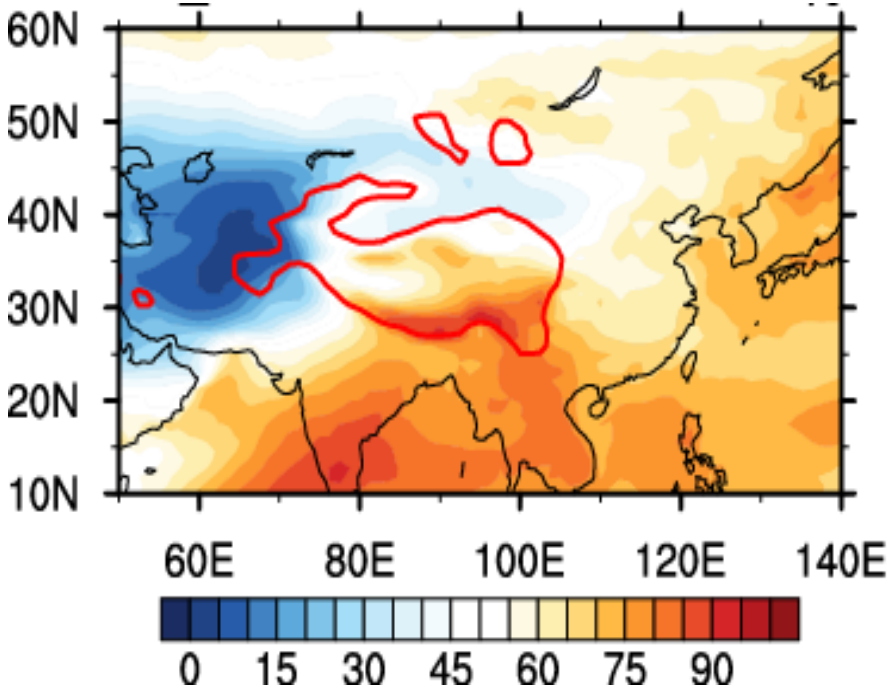


Minus value means moisture increase

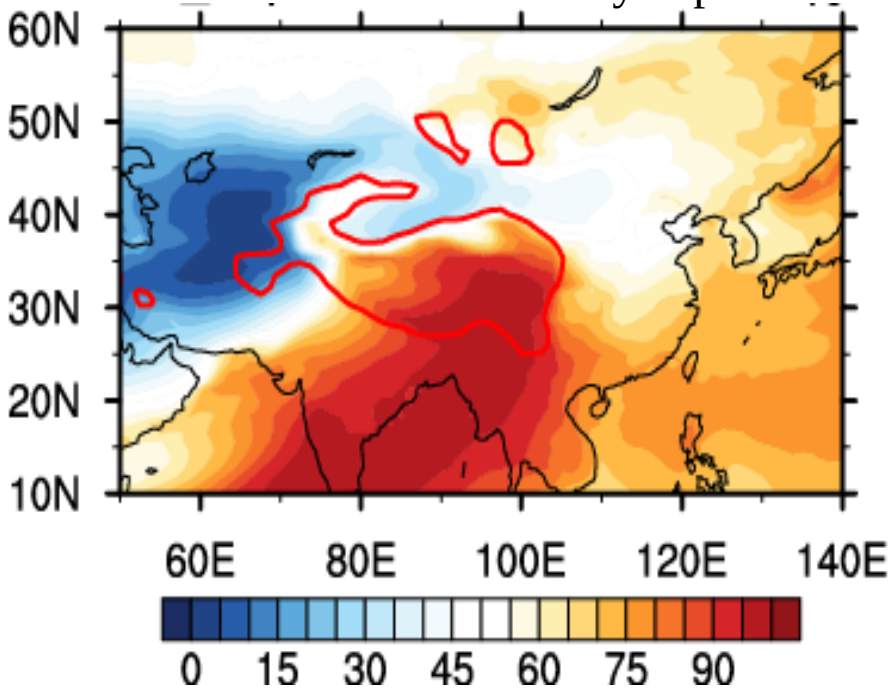
Role:
drying the atmosphere

Sensitivity Experiment:
remove shallow convection and its effect in the CAM5 model

Stratiform clouds in the control run



Stratiform clouds in sensitivity experiment



Reason: without the heating and drying effects of shallow convection, the temperature would decrease and the specific humidity would increase, this result in the increase of stratiform clouds.

Second Conclusion

- Cumulus has larger heating and dilution effects on the environment than any other cloud types over the TP.

- Without Cumulus, stratiform clouds increases by ways of increasing relative humidity under relatively cold and wet air.

Yunying Li and Minghua Zhang(2016).Cumulus over the Tibetan Plateau in the Summer Based on CloudSat–CALIPSO Data. ***Journal of Climate***, 29(3), 1219-1230.

Yunying Li and Minghua Zhang(2017). The Role of Shallow Convection over the Tibetan Plateau. ***Journal of Climate***, 30(15), 5791-5803