Control of ITCZ width by low-level radiative heating from upper-level clouds

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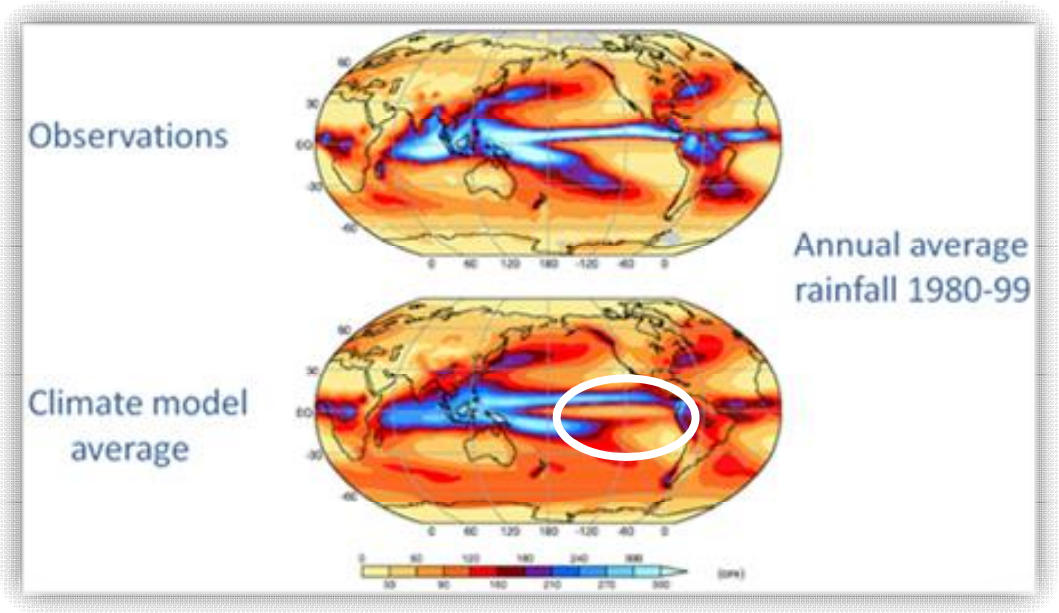
Double ITCZ syndrome

Double ITCZ syndrome *(Hubert et al. 1969; Mechoso et al.,1995)*



Sensitive to :

- Surface T pattern, ocean-atmosphere coupling *(Lin, 2007; Dahms et al. 2011; Oueslati et Bellon, 2012)*
- Convective parameterizations, e.g. *entrainment* *(Numaguti and Hayashi 1991; Liu et al. 2010; Möbis and Stevens 2012; Oueslati et Bellon, 2013)*
- Cloud radiative effect CRE *(Harrop and Hartmann, 2016;* Fläschner, 2016; Popp and Silver, 2017*)*

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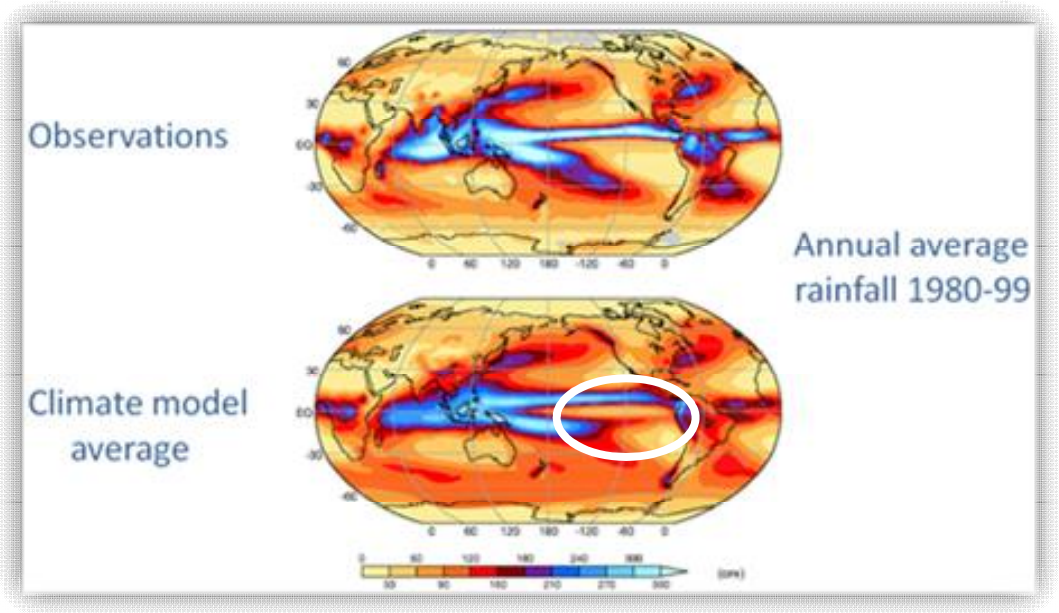

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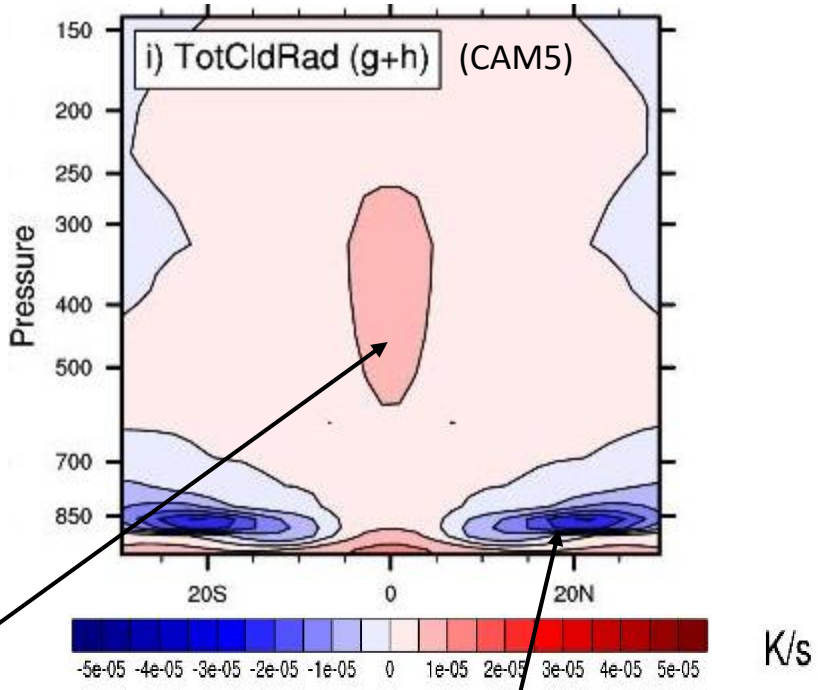
- **Cloud radiative effect CRE** *(Harrop and Hartmann, 2016;* Fläschner, 2016; Popp and Silver, 2017*)*

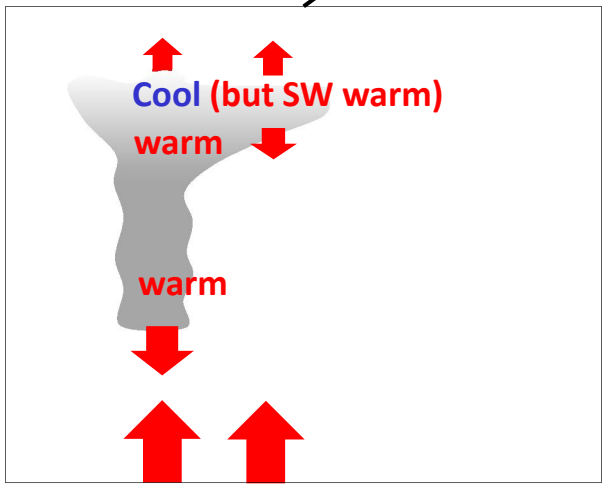
We focus on this one

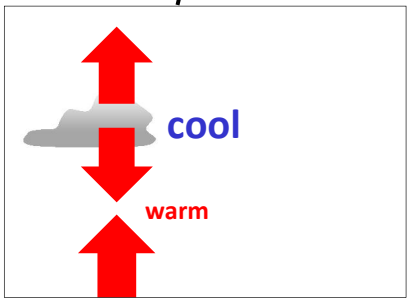
Structure of atmospheric Cloud Radiative Effect (ACRE)

ACRE =
Atmo. rad. heating rates
Cloudy sky minus clear sky



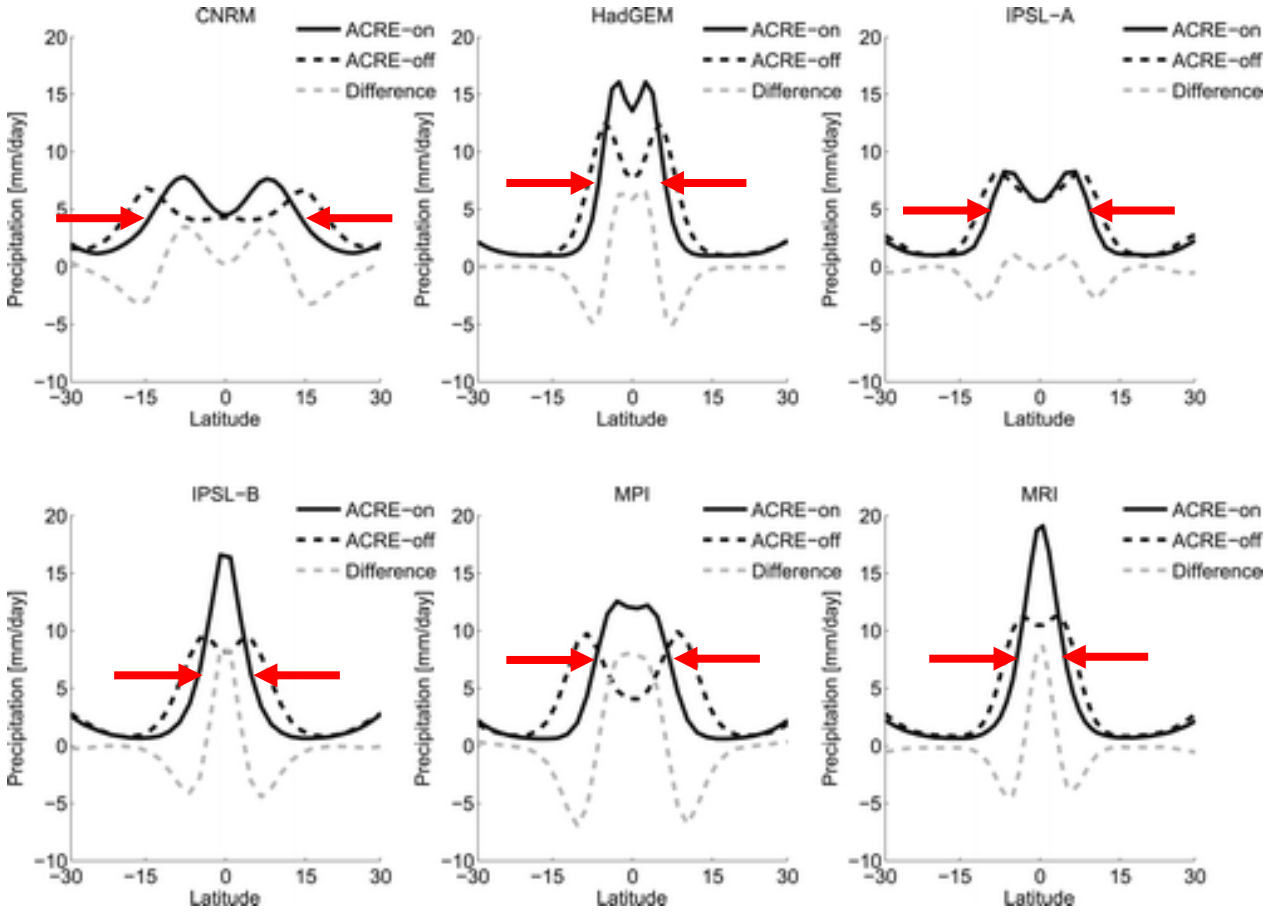
Mainly LW effects :





Fixed SST aquaplanet COOKIE experiments

*(**C**loud **O**n/**O**ff **K**lima **I**ntercomparison **E**xperiment)*



Atmospheric Cloud Radiative Effect (ACRE) On → contract ITCZ

(Harrop and Hartmann, 2016)

Coupling cloud radiative effects – circulation

Mechanisms for narrowing:

- *Harrop and Hartmann (2016)* : upper warming favor convection where low level MSE is maximum

  But not verified for all models

- *Popp and Silver (2017)* : increasing low level circulation lead to an increase in MSE gradient

  Role of the upper branches not discussed

- *Byrne and Schneider (2016)* : increasing GMS contributes to decreasing ITCZ width in increasing greenhouse effect experiments

Role of low clouds :

- Link 2xITCZ and ECS *(Tian et al., 2015)* - through low cloud LW effect ?

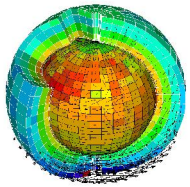
But no sensitivity of 2xITCZ to Low cloud CRE *(Fermepin and Bony, 2014)*

Here :

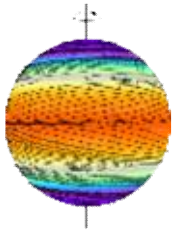
- Role of different cloud types / regions ?
- Possible mechanisms ?

Experiments

Model & configuration :



CAM5 (NCAR)



Aquaplanet, (zonally symmetric, fixed SST)

Experiments :

- **Cloud On-Off COOKIE**

Clouds transparent

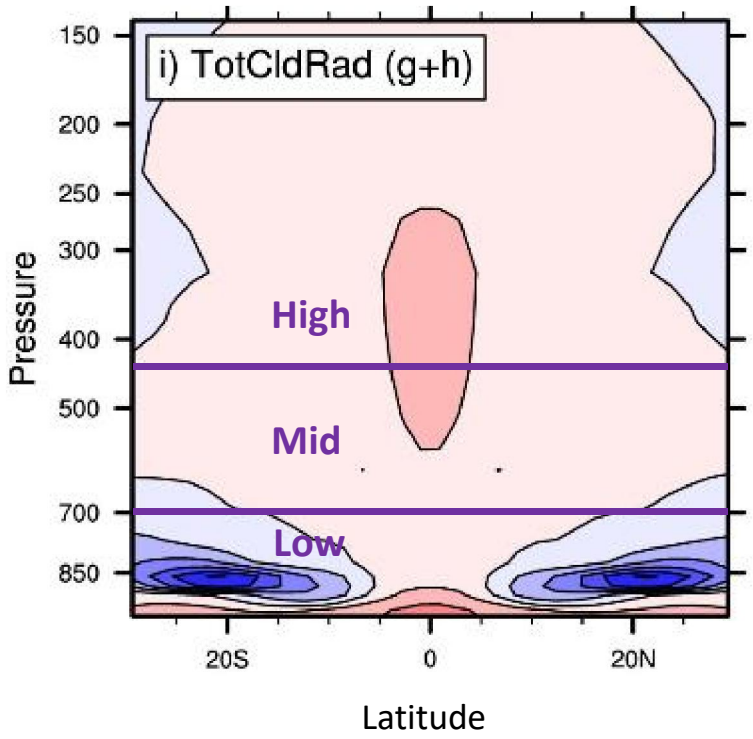
- **Cloud heating rate On-Off CHOOKIE**

Radiative heating rates set to 0

- where ?

→ Global (CHOOKIE = COOKIE)

→ per **level** / per **latitudinal band** (CHOOKIE ≠ COOKIE)



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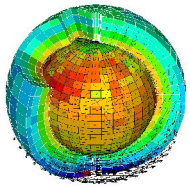

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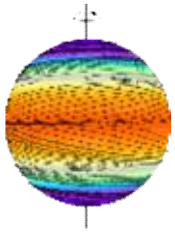

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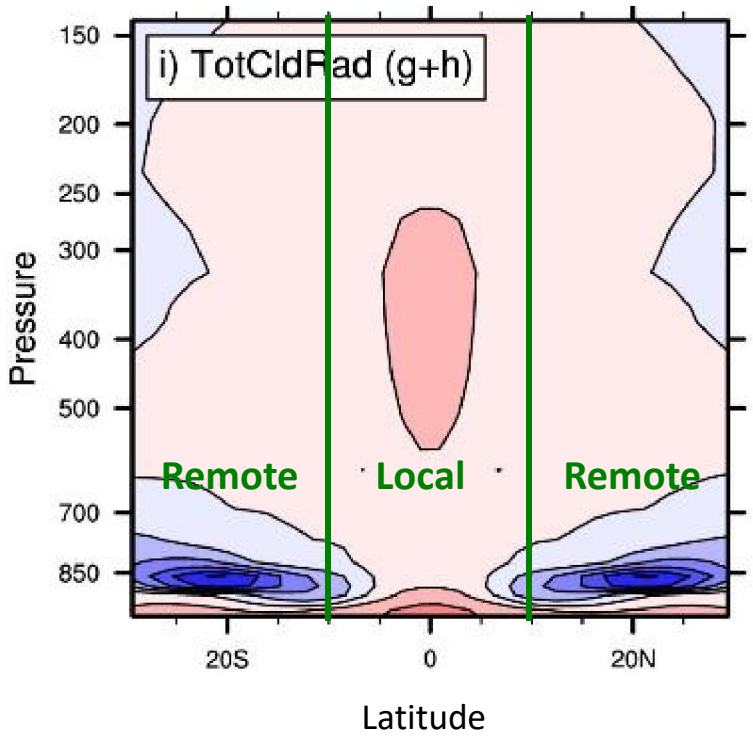
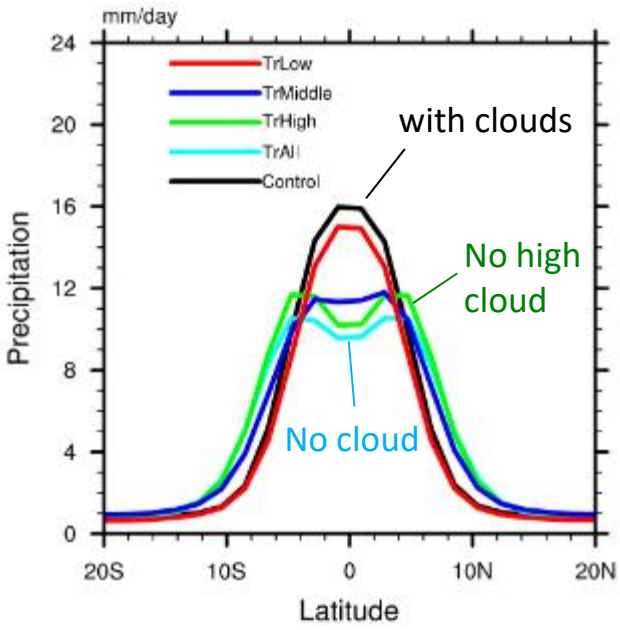
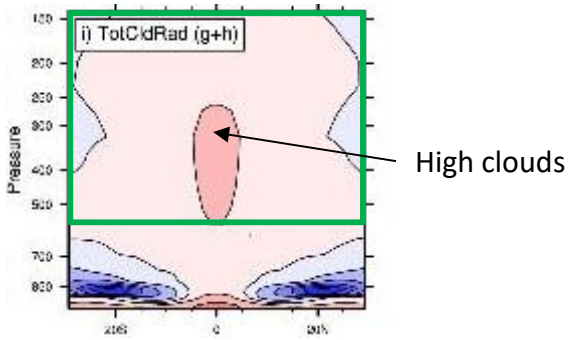


Precipitation response to Cloud On/Off

Cloud transparent (COOKIE)



Which clouds ?



- Dominated by high clouds radiative effect
- Low clouds : small effect

agreement with Fermepin and Bony (2014)

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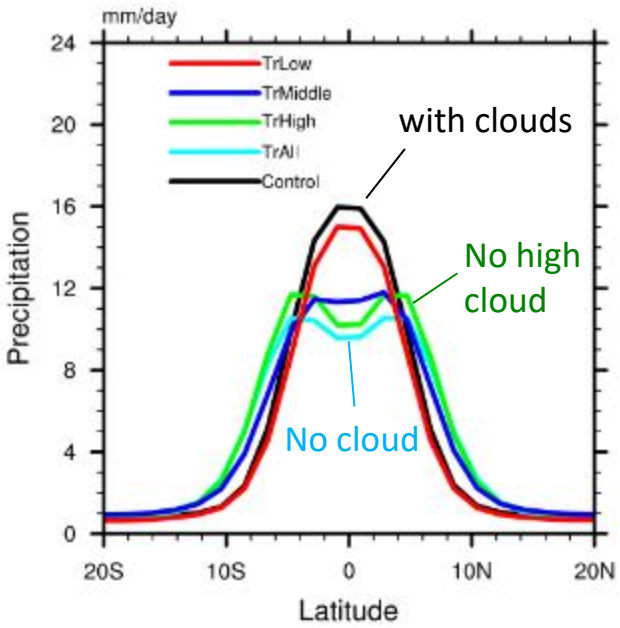

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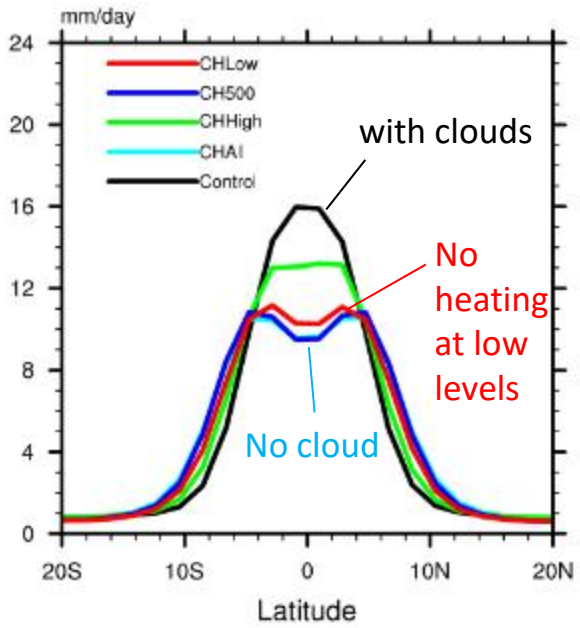

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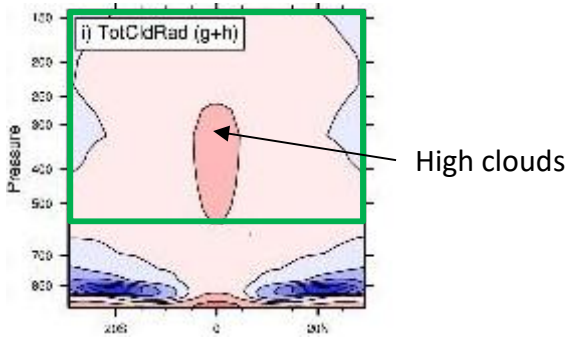
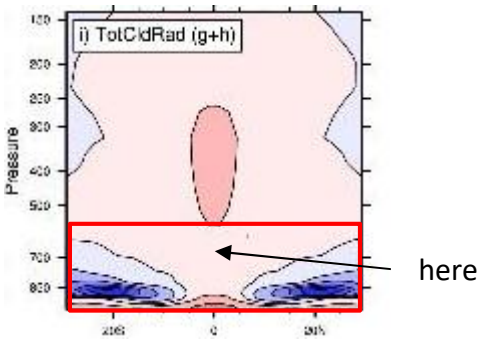


Location of the heating with the largest impact?



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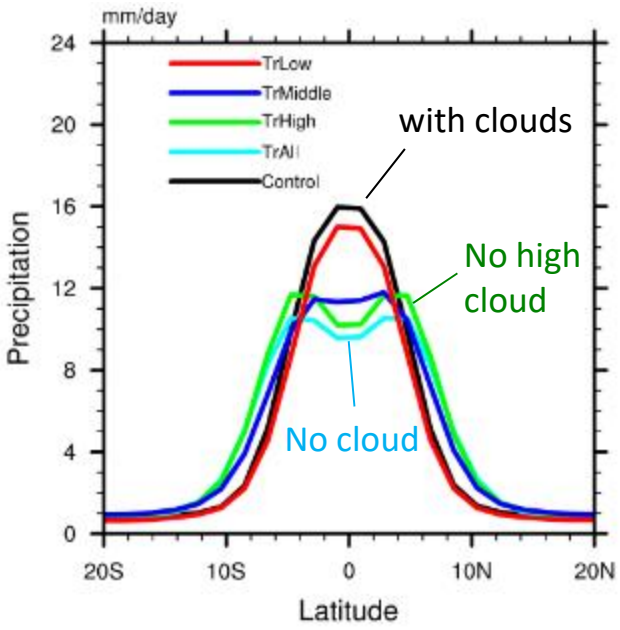

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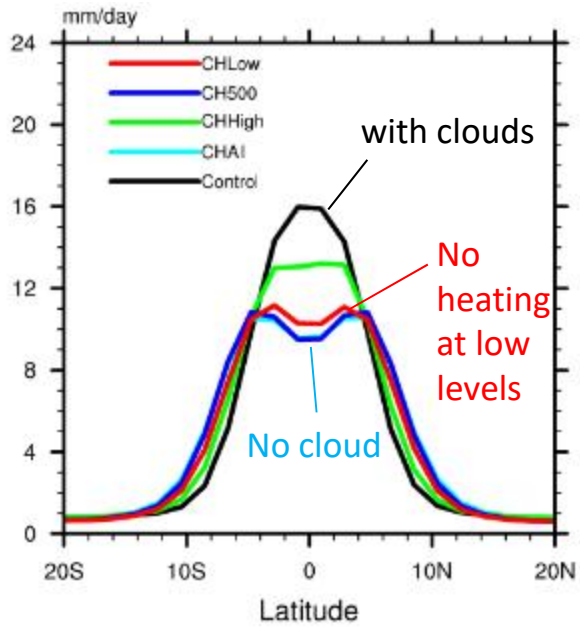

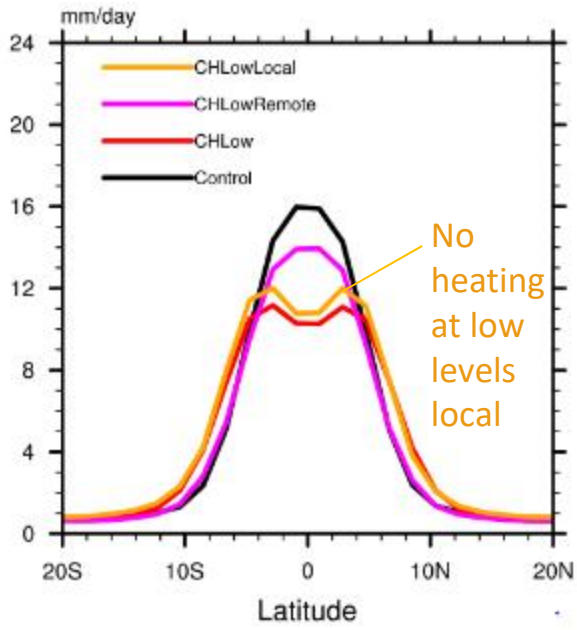

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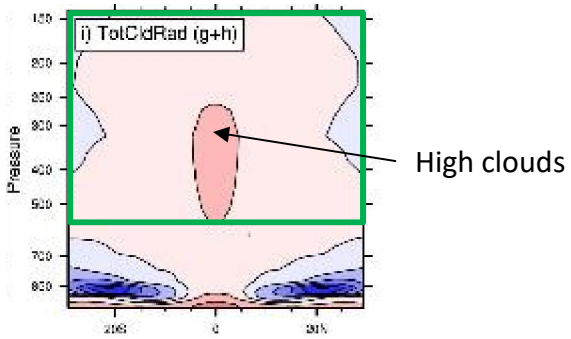

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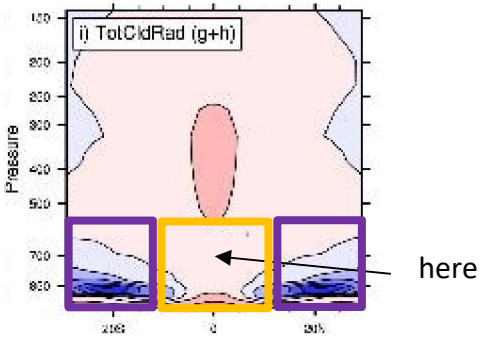
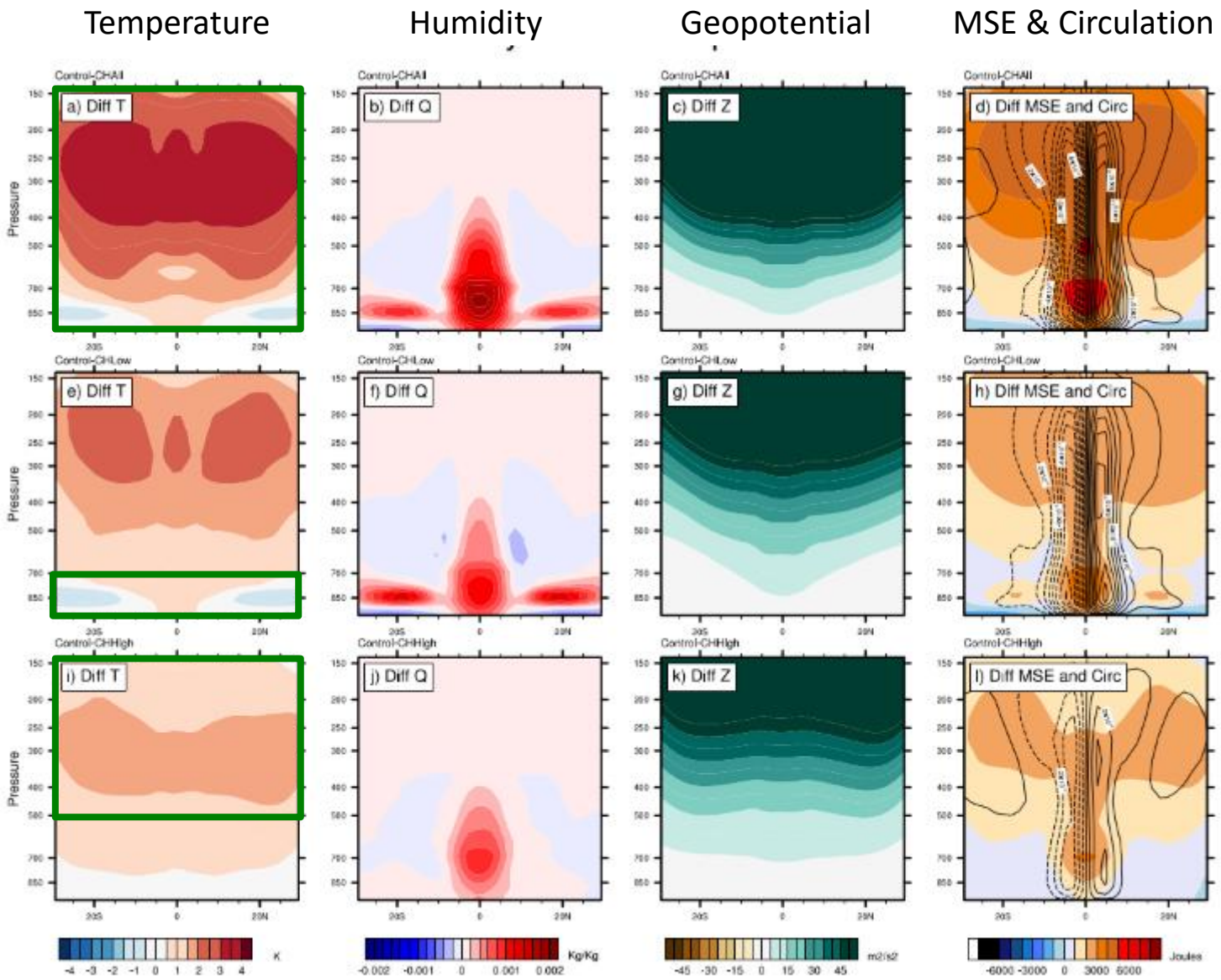


Cloud radiative heating : On minus Off

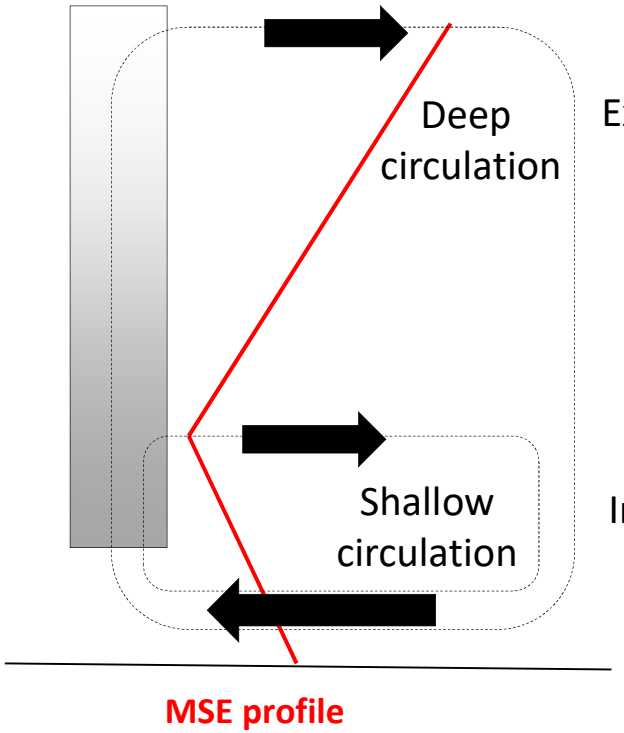
On minus Off at all level

On minus Off at low level only

On minus Off at high level only



MSE and circulation response



Stronger deep circulation → GMS ↑ (negative feedback)

But stronger shallow circulation → GMS ↓ (positive feedback)

Larger surface MSE gradient

Gross moist stability **GMS** :
ratio of the MSE flux to the outgoing mass flux
(both vertically integrated)

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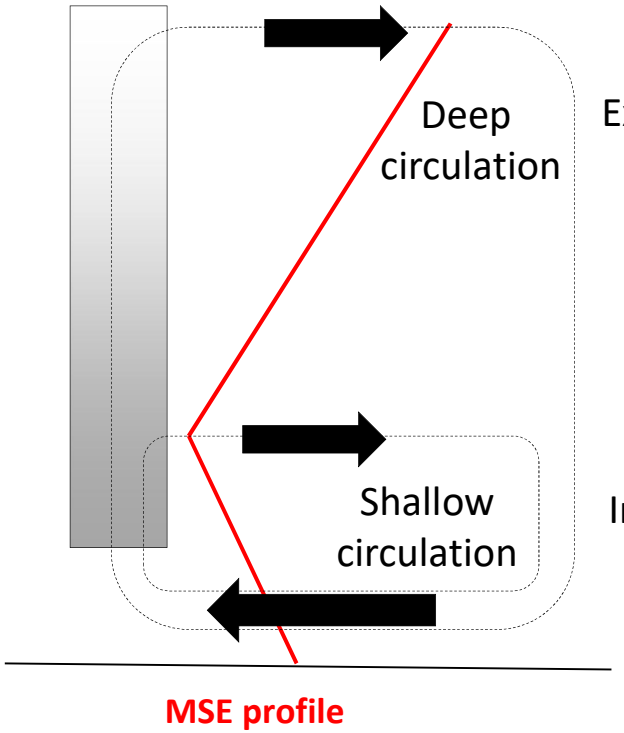

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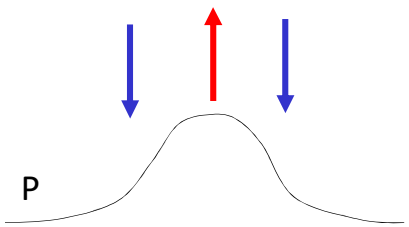
Larger surface MSE gradient

→ precipitation ↑ in ITCZ core

Gross moist stability **GMS** : ratio of the MSE flux to the outgoing mass flux (both vertically integrated)

Assuming radiative cooling invariant
→ P ↓ on the edge



Conclusion

- No contribution of low level clouds (agreement with previous studies)

→ suggest potential relationship with ECS does not involve low cloud LW cooling

- Anvil / cirrus amount may contribute in shaping ITCZ width

(could contribute to a link between double ITCZ syndrome and ECS through FAT ?)

- Tight coupling between ITCZ width and circulation response :

Likely key role of a feedback associated with the shallow circulation response :
strenghtening → decrease of GMS in ITCZ core (more energetically unstable)
→ increase of precipitation in the core / decrease at the margin

Precipitation response to Cloud Heating On/Off

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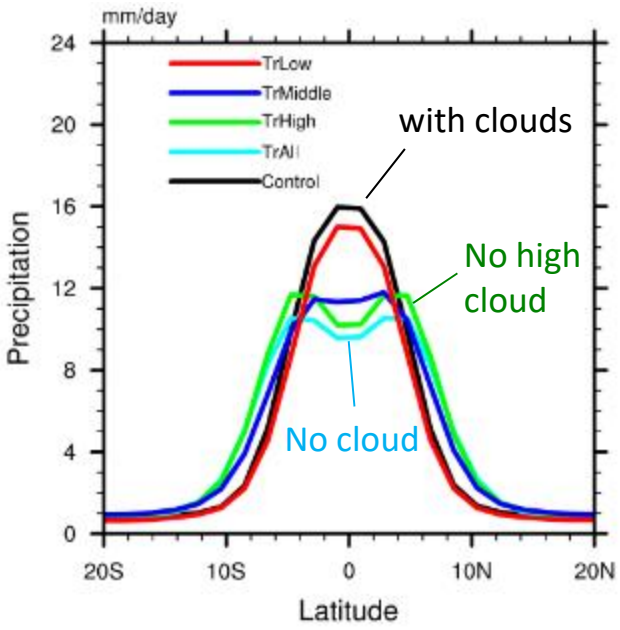

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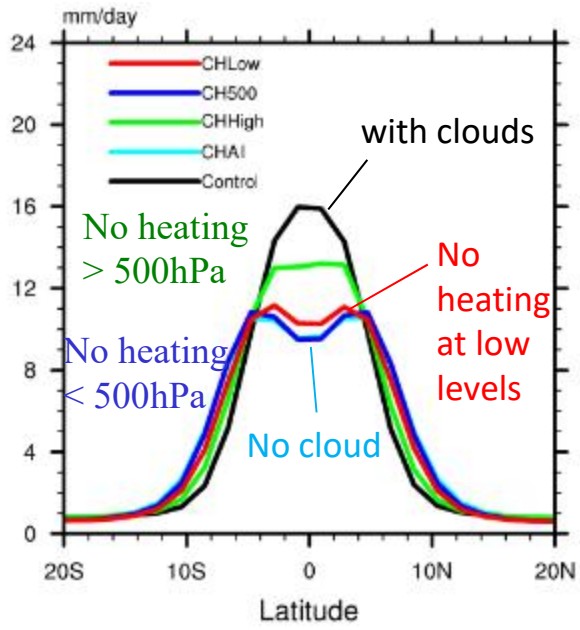

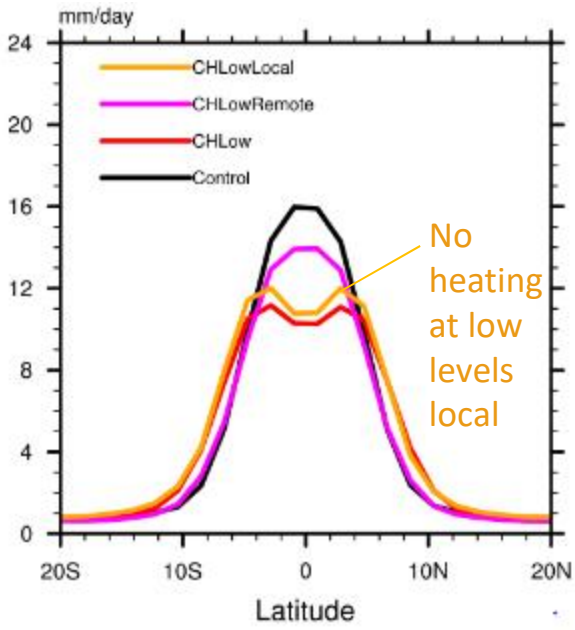

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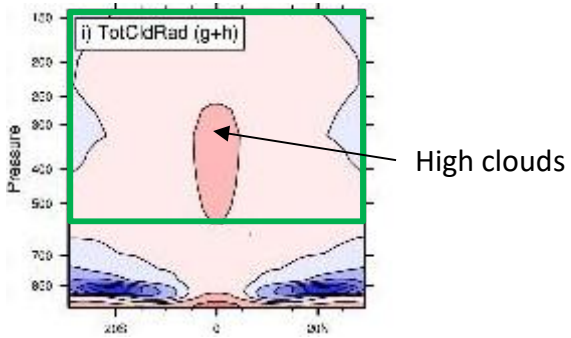

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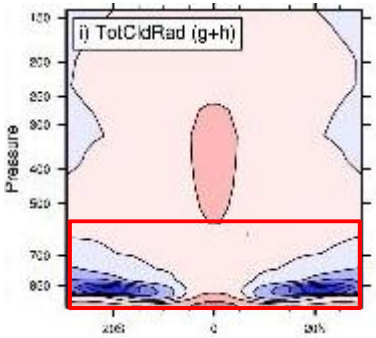
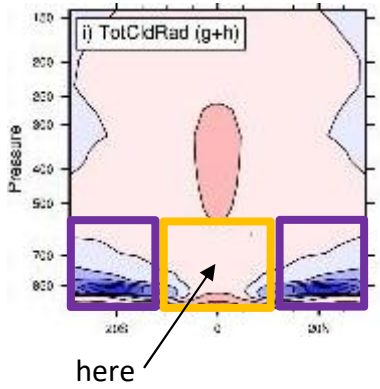
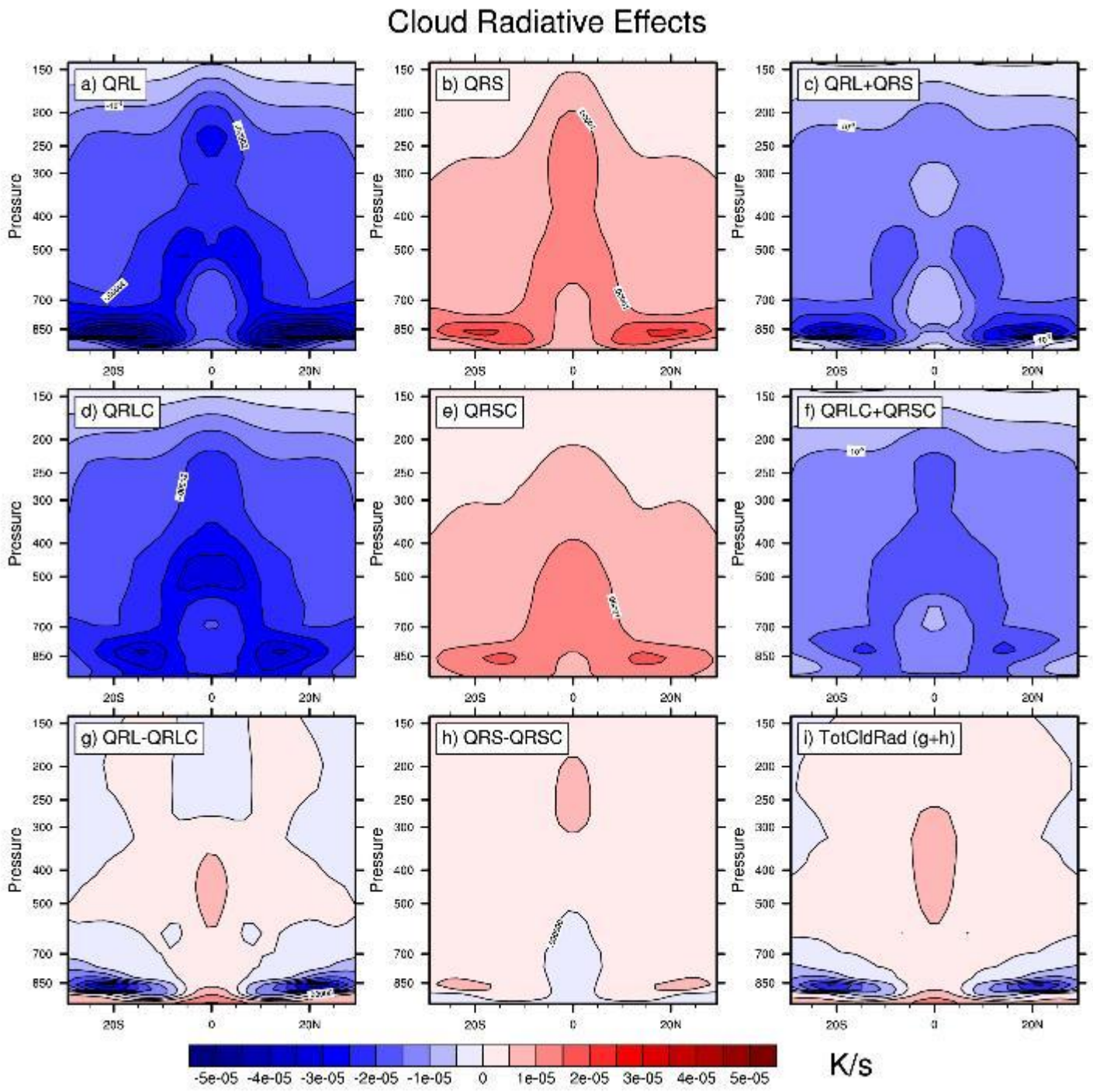
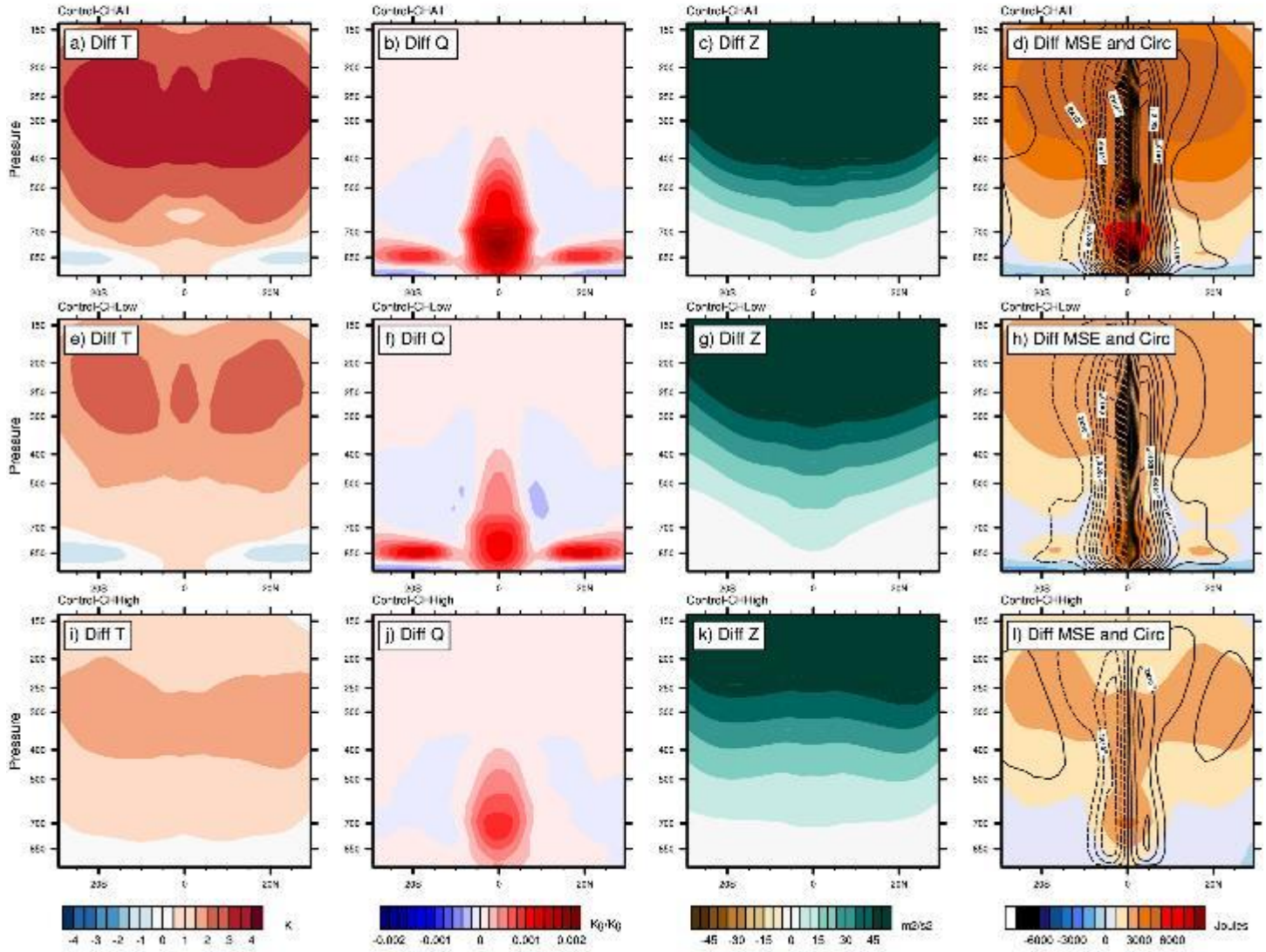





Cloud Radiative Effects
a) QRL
b) QRS
c) QRL+QRS
d) QRLC
e) QRSC
f) QRLC+QRSC
g) QRL-QRLC
h) QRS-QRSC
i) TotCldRad (g+h)
Pressure
150
200
250
300
400
500
700
850
20S
0
20N
-5e-05 -4e-05 -3e-05 -2e-05 -1e-05 0 1e-05 2e-05 3e-05 4e-05 5e-05
K/s

Anomaly of MSE components



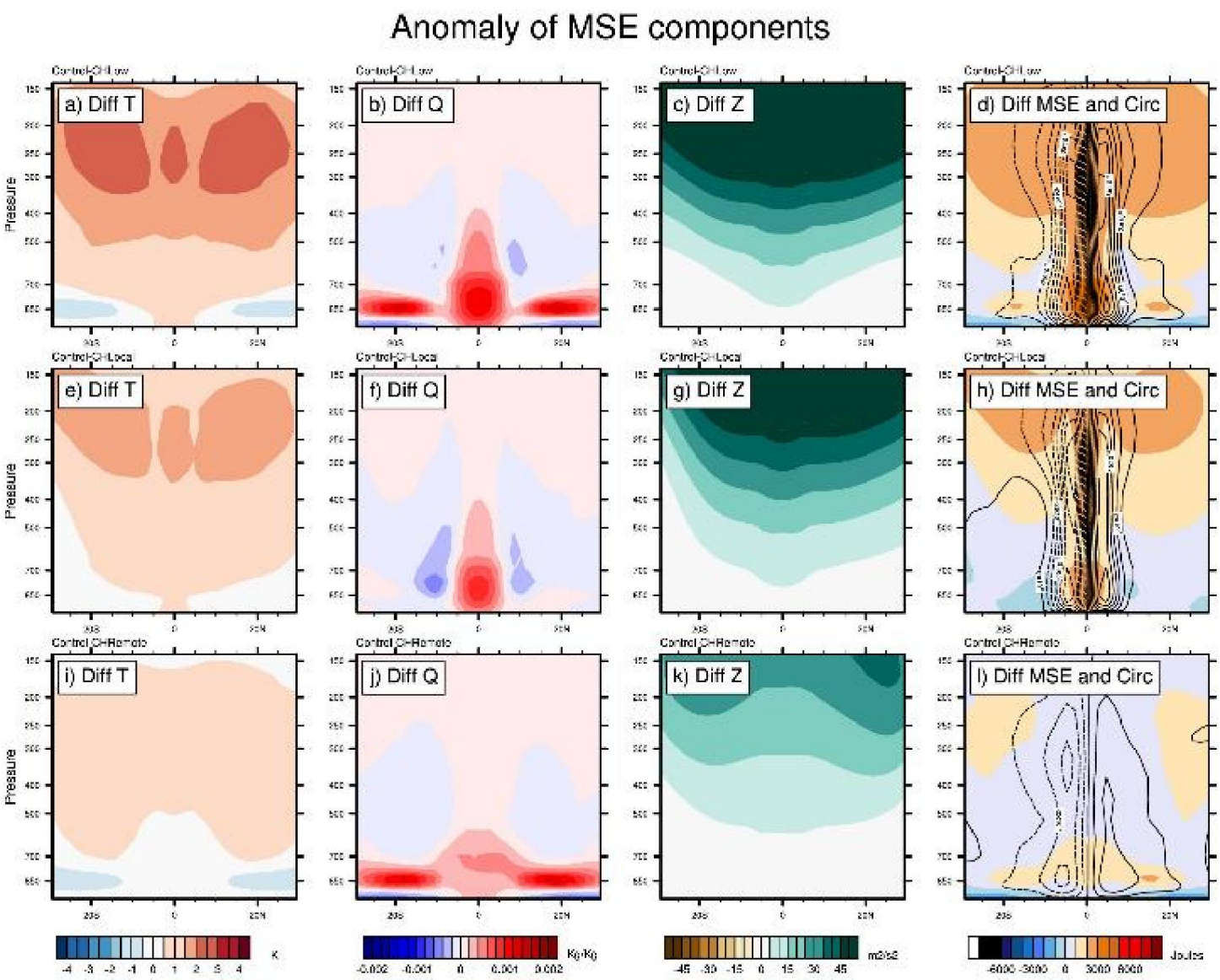
Low

Low

Local

Low

Remote



TrHigh

TrLow