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Factors controlling shortwave cloud feedbacks in Multi-Parameter Multi-Physics Ensemble (MPMPE)

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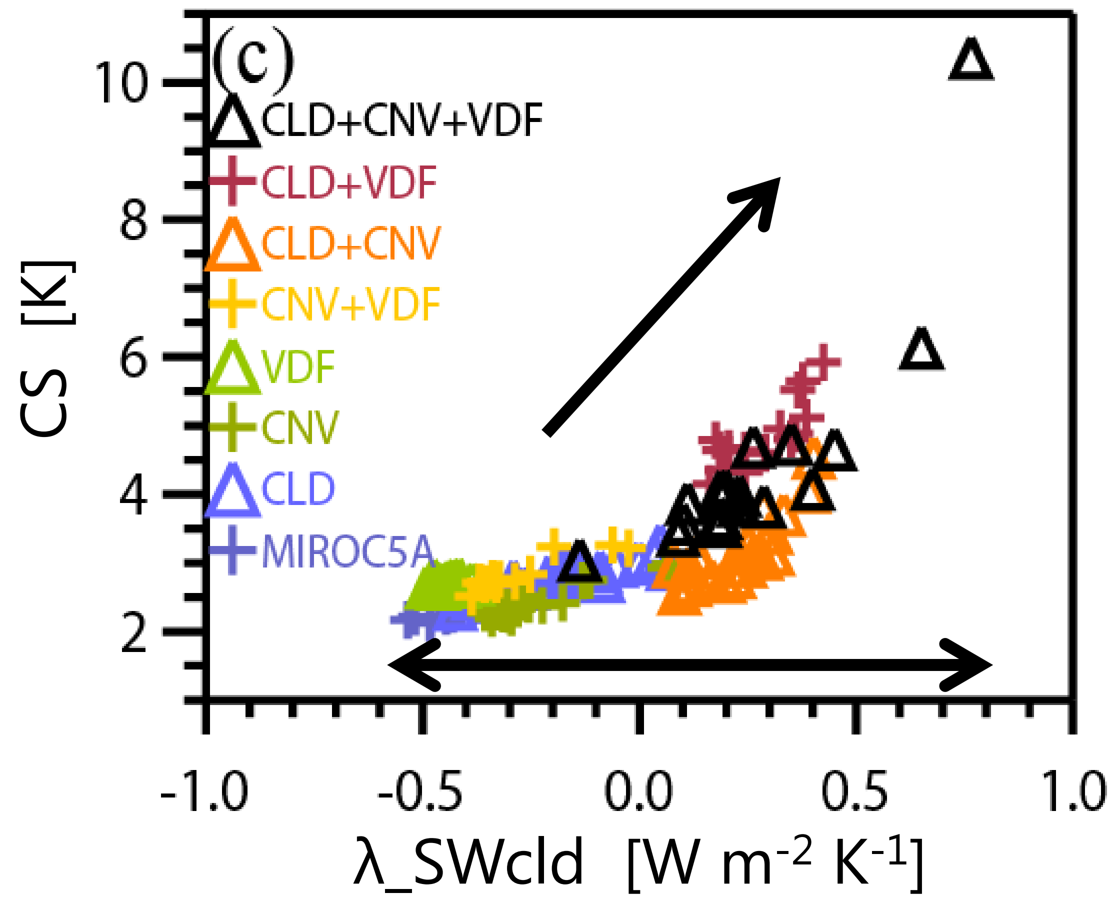
MPMPE (Multi-Parameter Multi-Physics Ensemble)

A new approach to explore both the parametric and structural uncertainties of CS

✓ Wide range of CS (2.2~10.4 K) results from a large spread in λ_SWcld



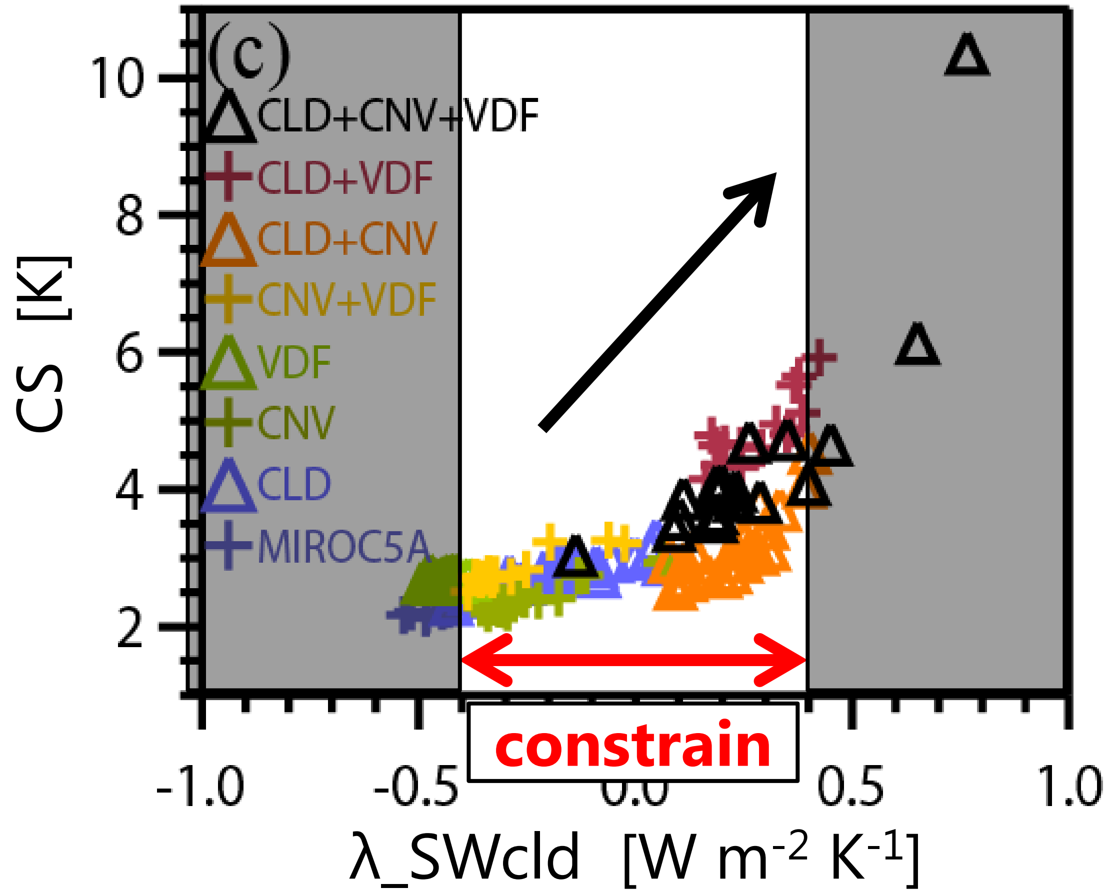
MPMPE (Multi-Parameter Multi-Physics Ensemble)

A new approach to explore both the parametric and structural uncertainties of CS

✓ Wide range of CS (2.2~10.4 K) results from a large spread in λ_SWcld

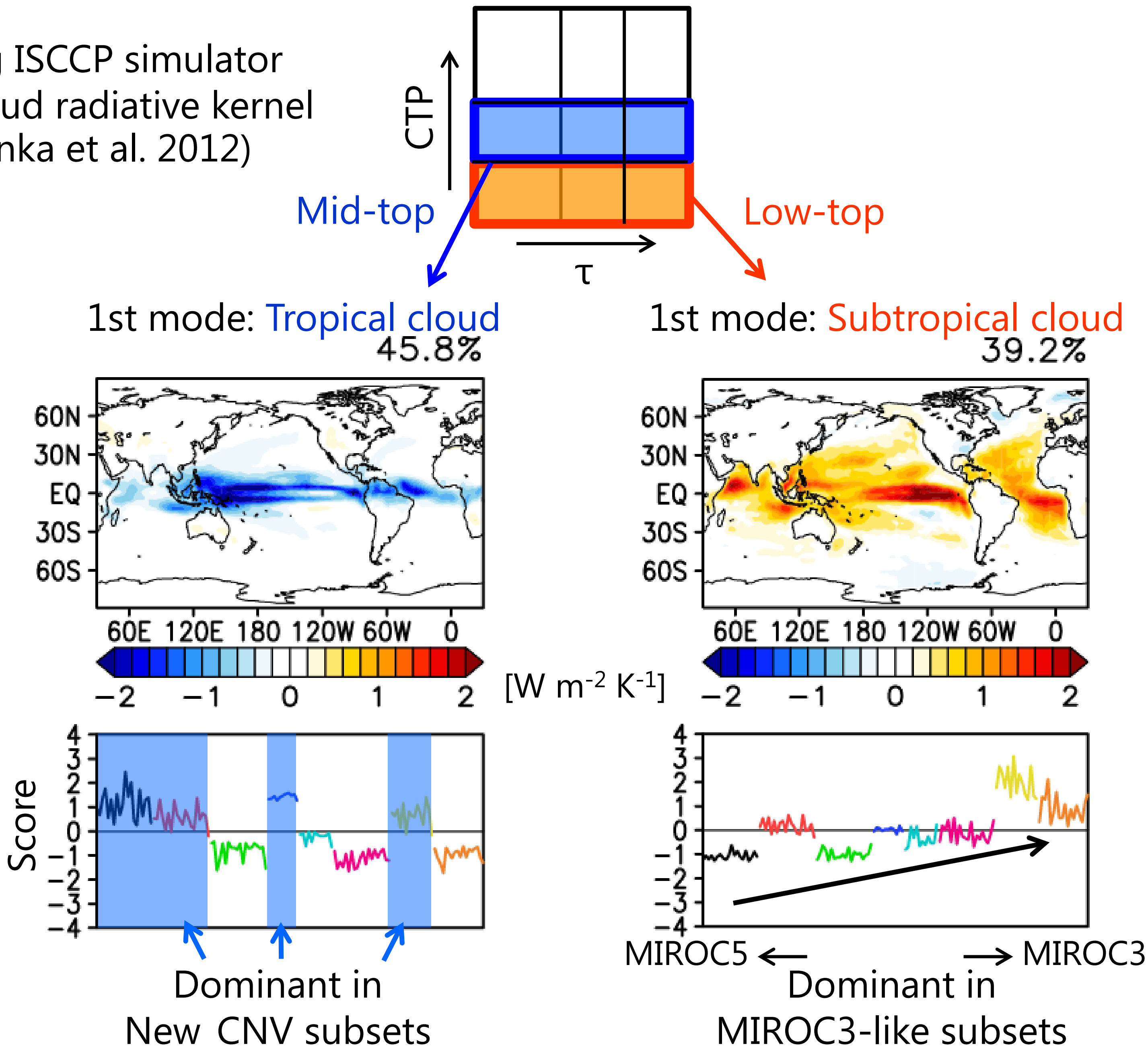
In my talk:

- ✓ We try to constrain λ_SWcld by using observation-based metrics (cloud fraction, LTMI)
- ✓ Lower and higher bounds of CS are constrained
- ✓ Two key feedbacks :
  1. Low-level cloud
  2. Mid-level cloud

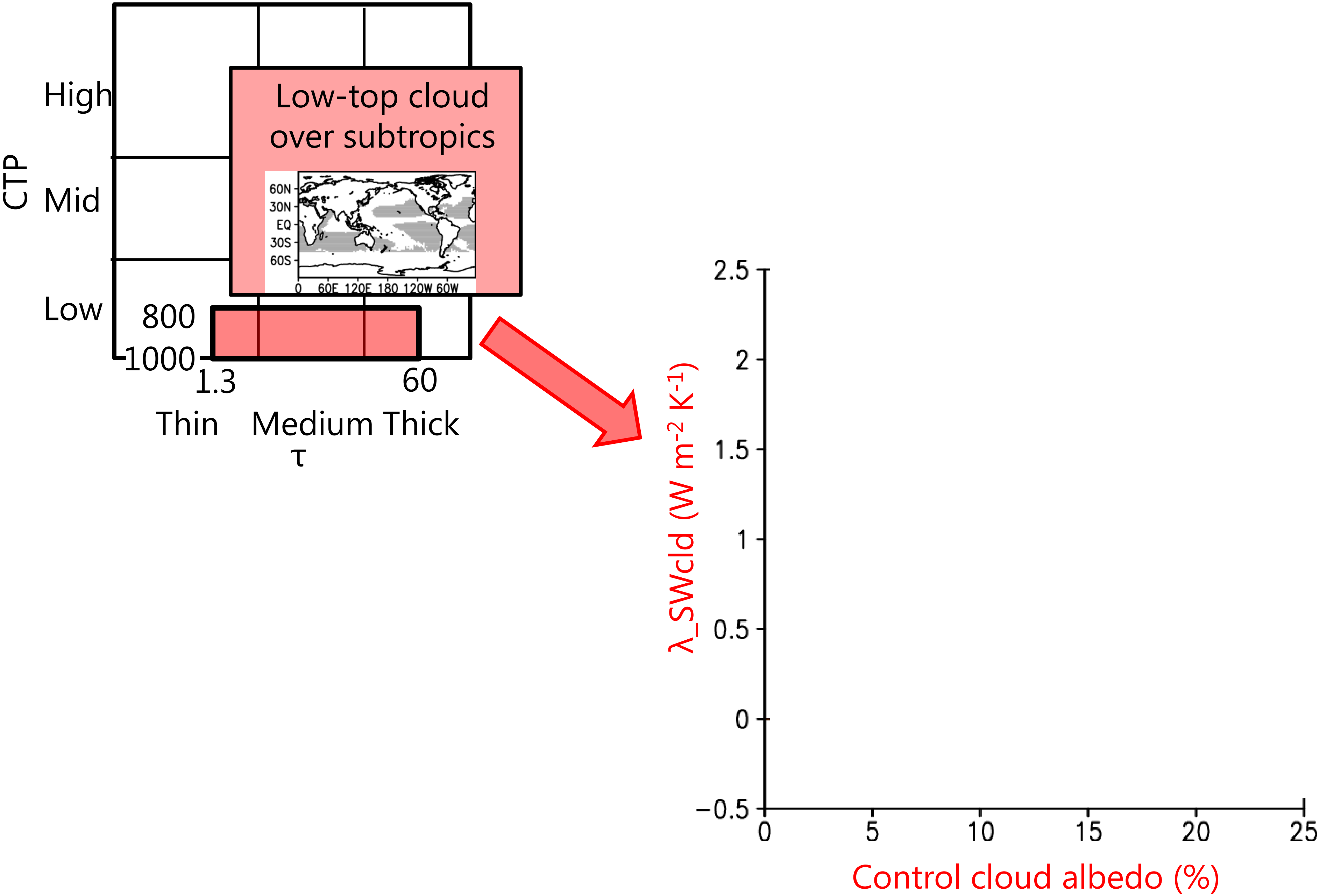


Dominant factors for λ_SWcld variance

Using ISCCP simulator
and cloud radiative kernel
(Zelinka et al. 2012)



1. Low-cloud feedback



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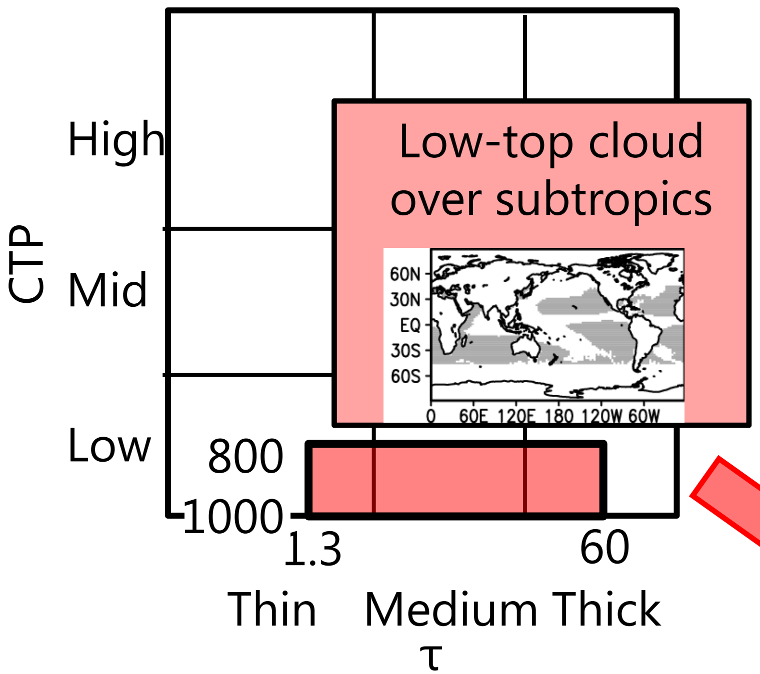
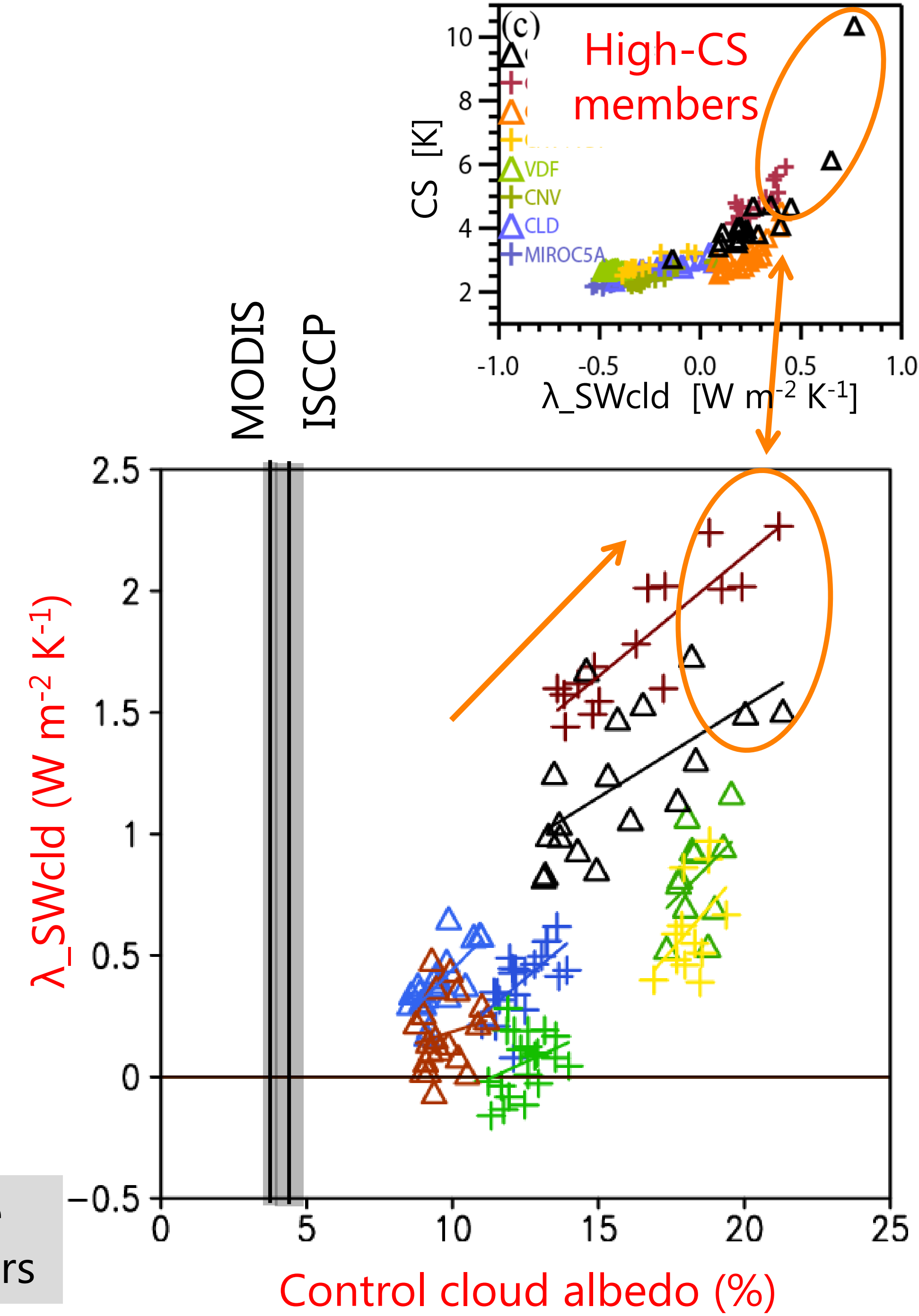


More cloud in base state

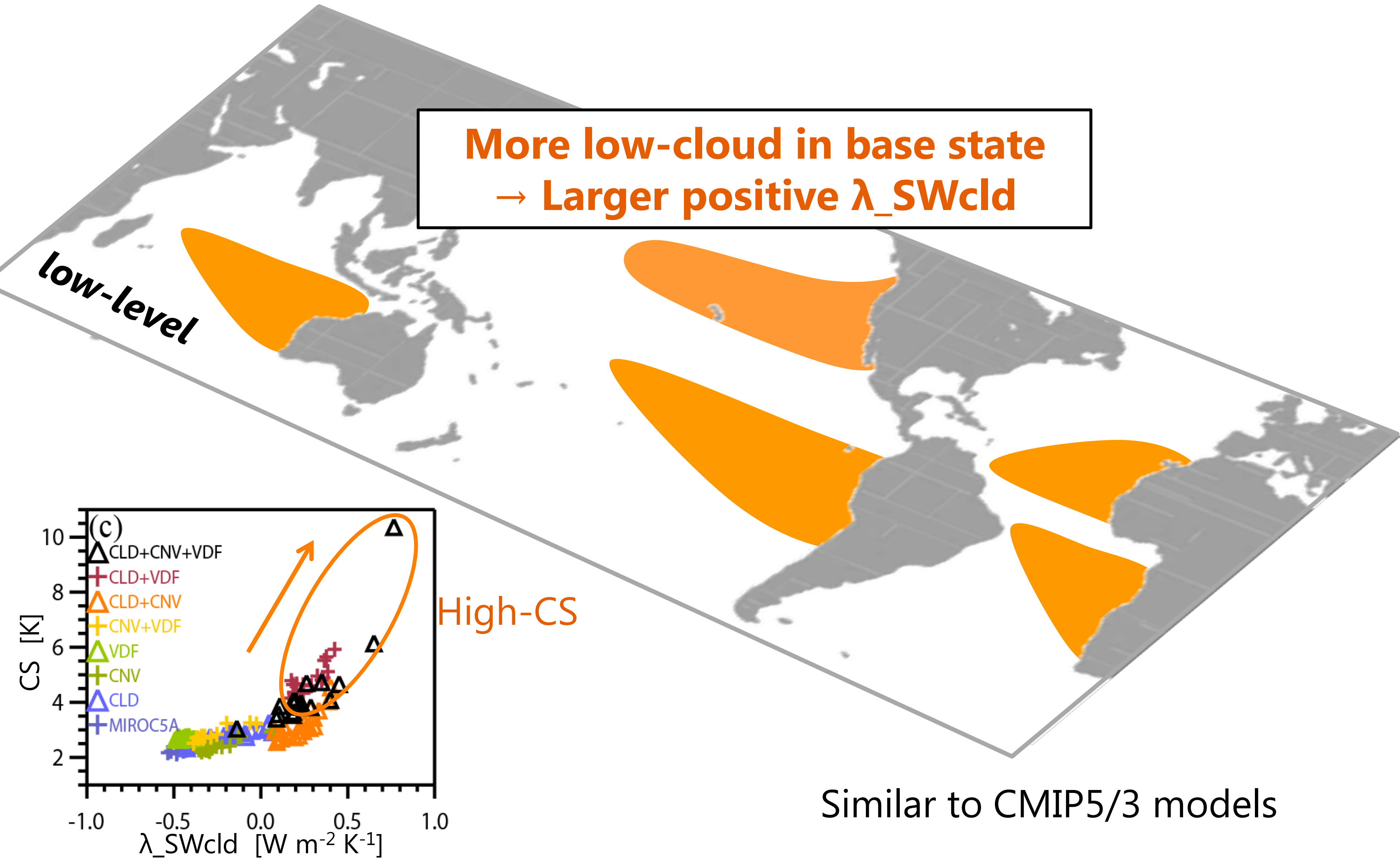
→ Larger positive λ_SWcld

→ Higher CS



Extremely large λ_SWcld (high CS) is more inconsistent with observation than the others

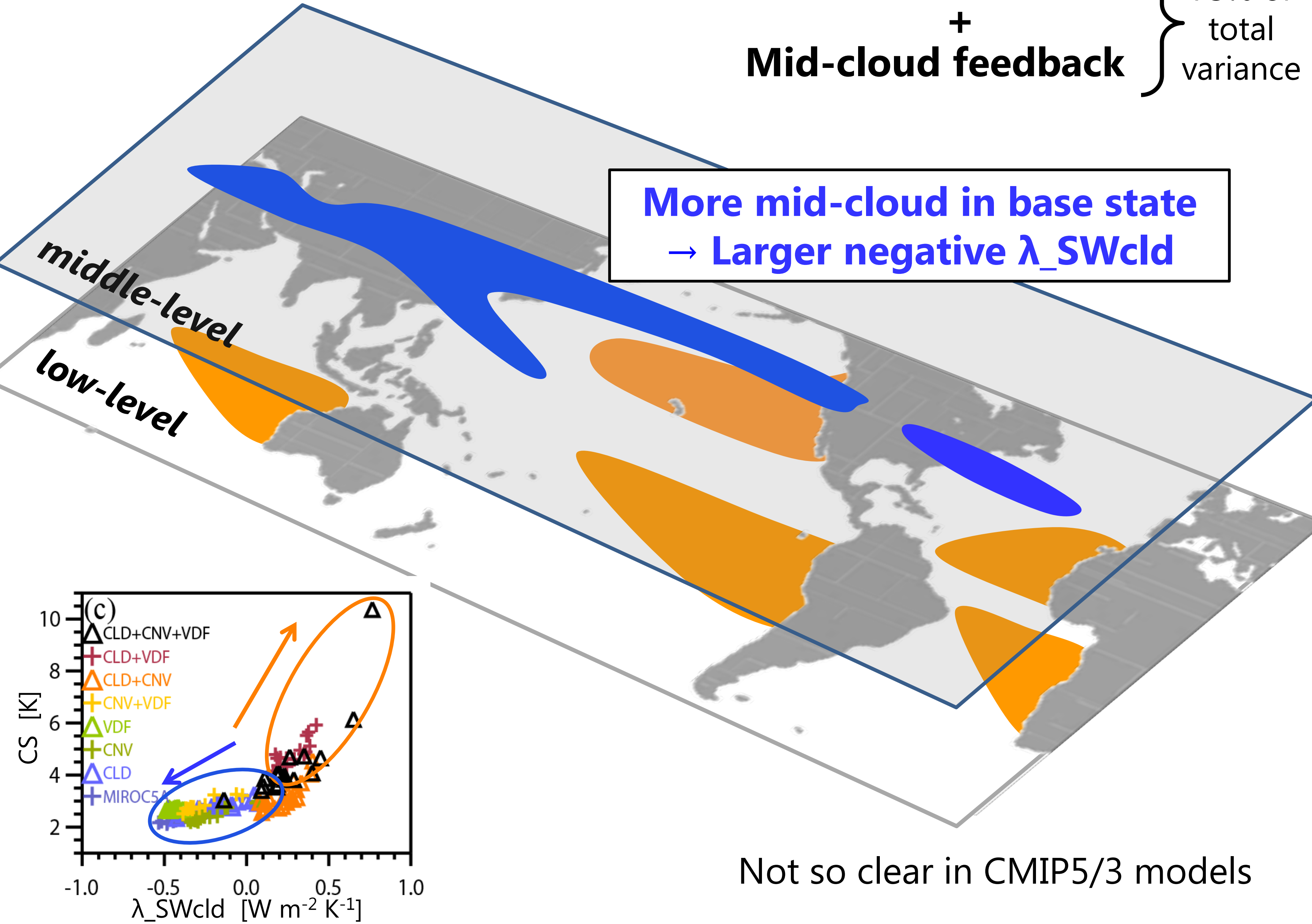
1. Low-cloud feedback



Similar to CMIP5/3 models

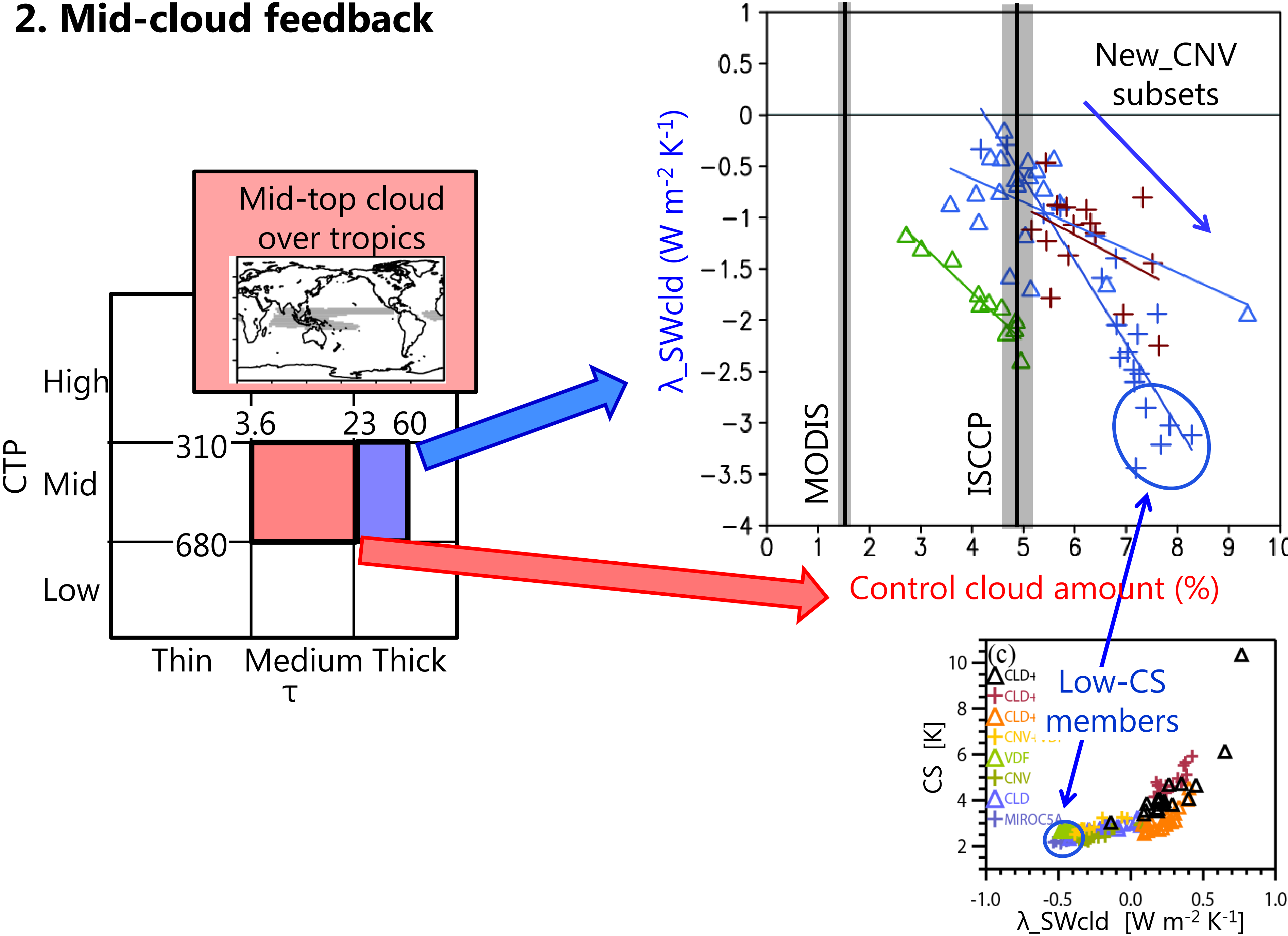
2. Mid-cloud feedback

Low-cloud feedback
+
Mid-cloud feedback
} 75% of total variance



Not so clear in CMIP5/3 models

2. Mid-cloud feedback



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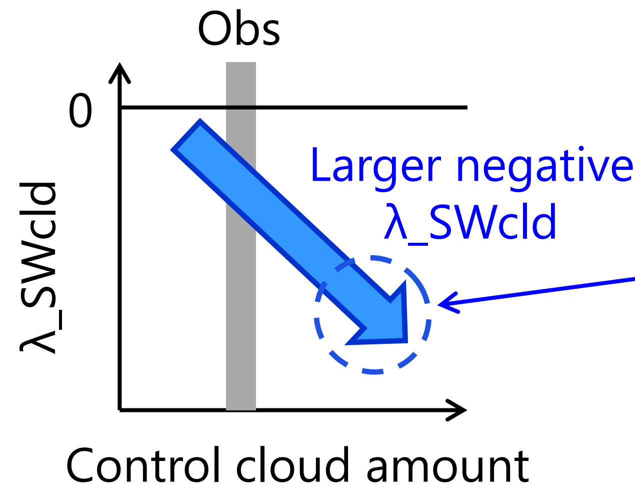
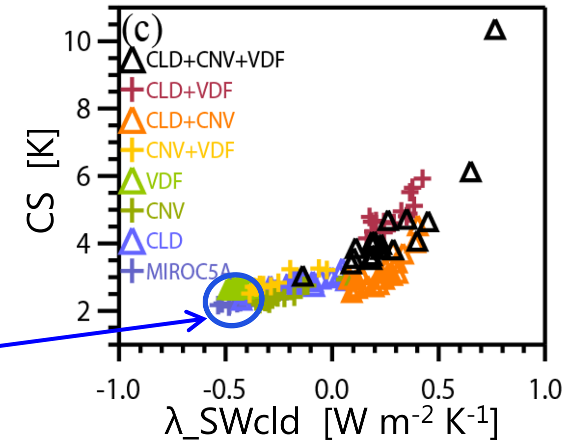
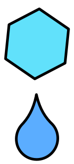


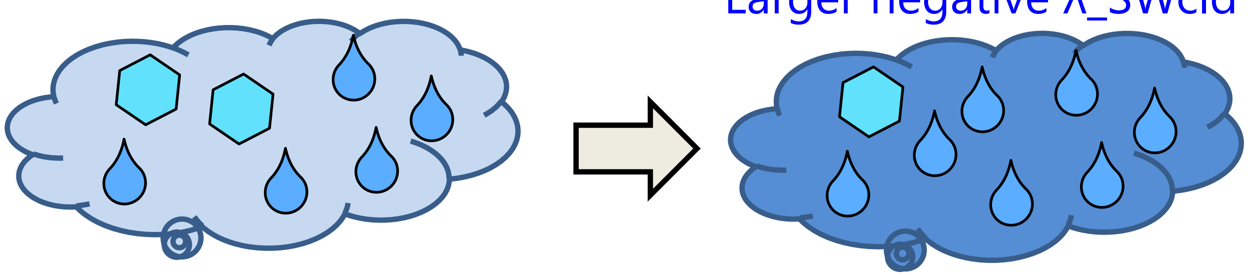




More med-τ cloud

More optically-thicker cloud

Larger negative λ_SWcld



Control climate

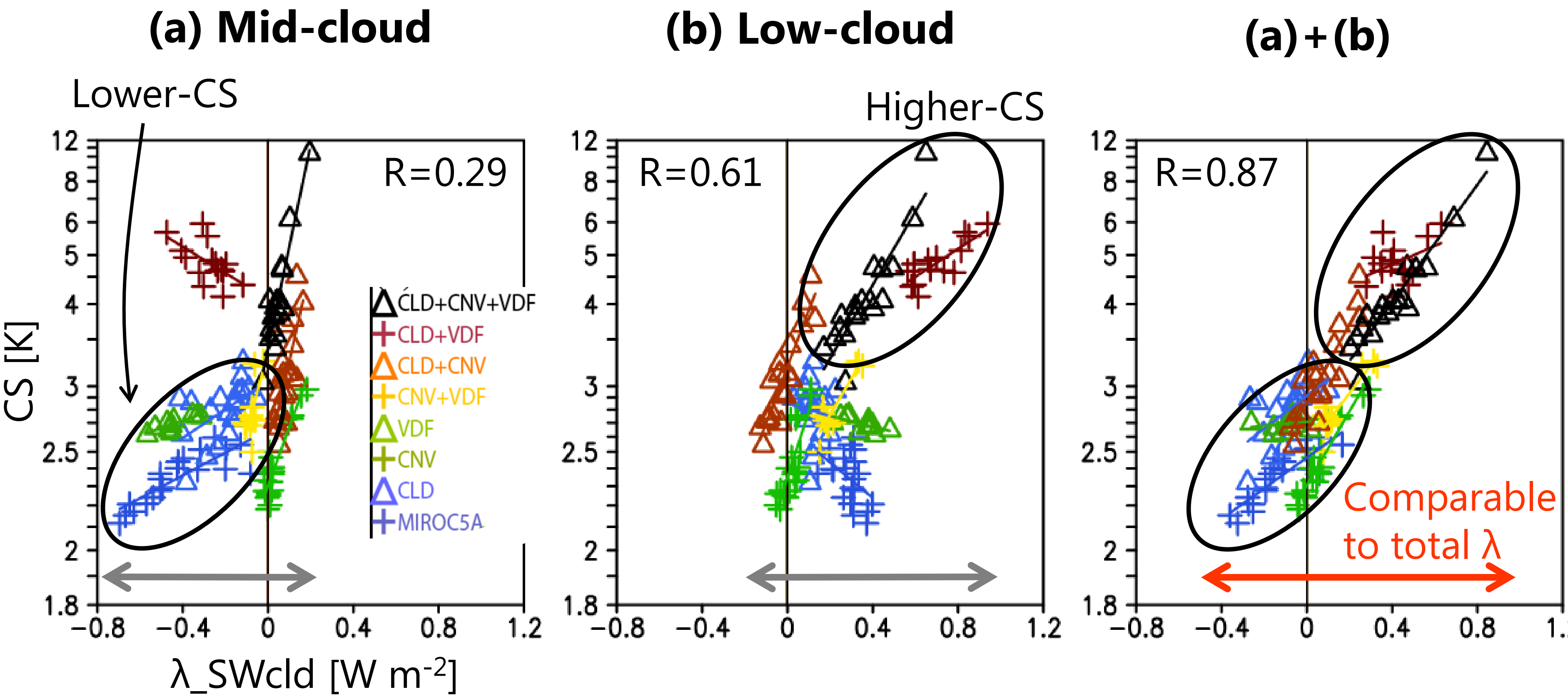
Warmed climate

✓cloud ice decreases

✓cloud liquid increases

Extremely large negative λ_SWcld (low CS)
is not supported by observations

Low-cloud feedback + Mid-cloud feedback

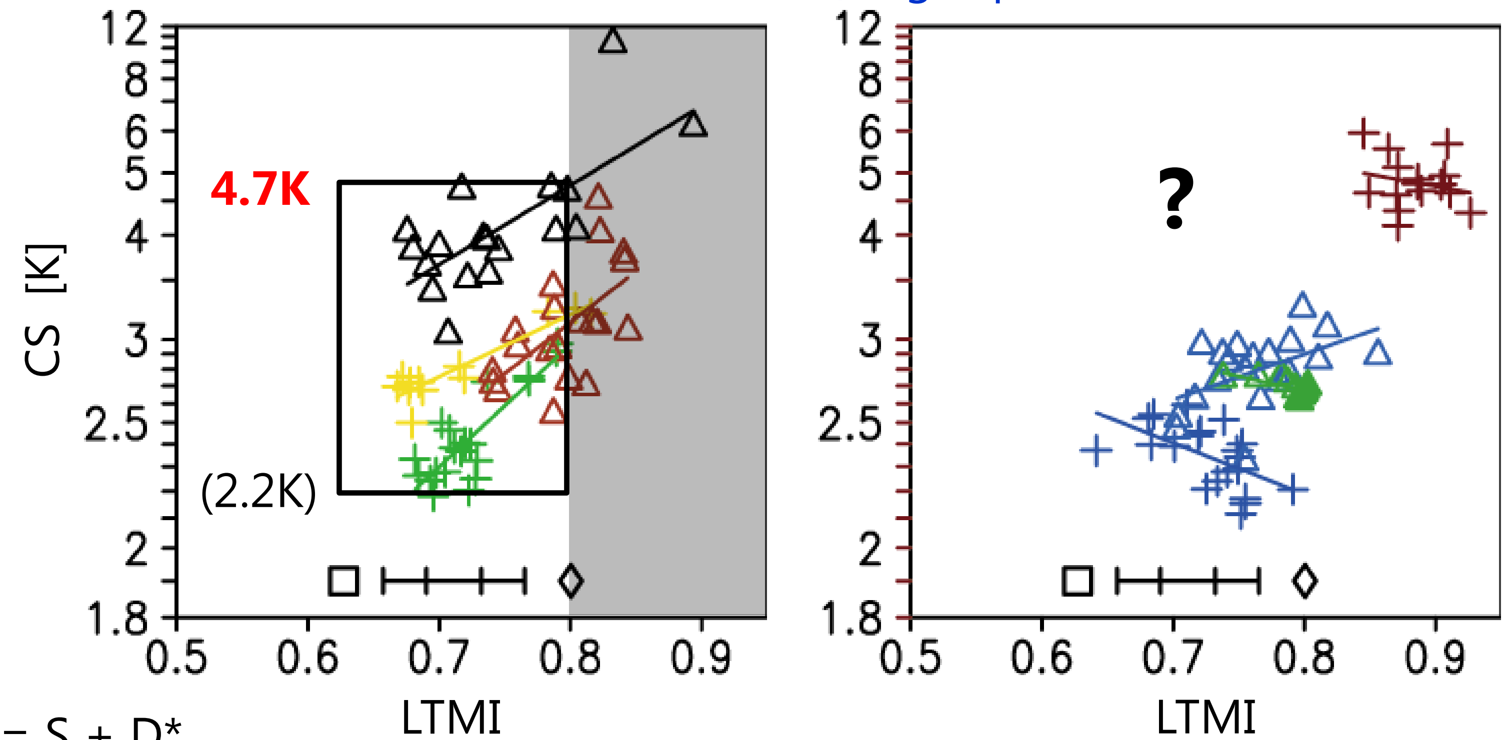


Sum of the two components explain 75% of total variance in CS

LTMI (Sherwood et al. 2014) vs CS in MPMPE

Old_CNV subsets

New_CNV subsets
(Large spread in mid-level λ_SWcld)



LTMI = S + D*
(D* is derived from
all longitude)

Large spread mid-level λ_SWcld in New_CNV PPEs
→ unclear relationship between LTMI & CS

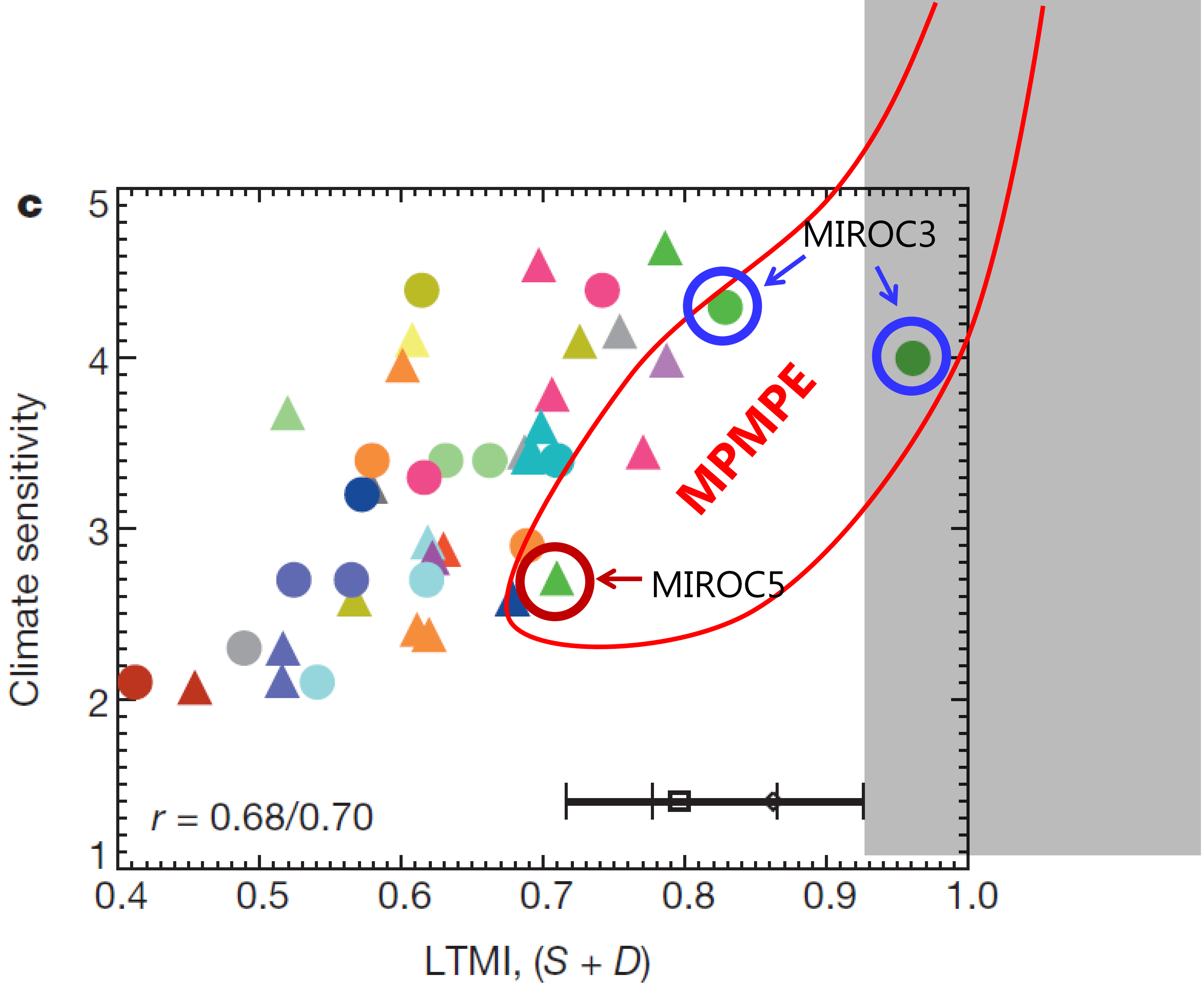
Extremely high CS (>4.7K) are
not supported by observed LTMI

Major result

Some MIROC3-like ensembles have extremely large CS (due to large low-level λ_SWcld), but they are not supported by observation

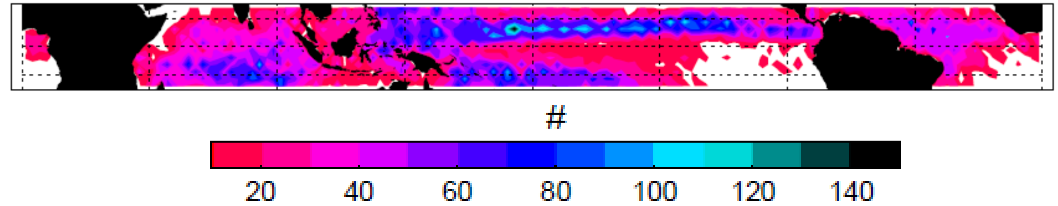
Broad implications

LTMI is applicable to some PPEs, but…
Mid-level cloud feedback also contributes to divergence in CS in some model PPEs
⟶ Single indices like LTMI are not effective to constrain the total range of CS in such ensembles



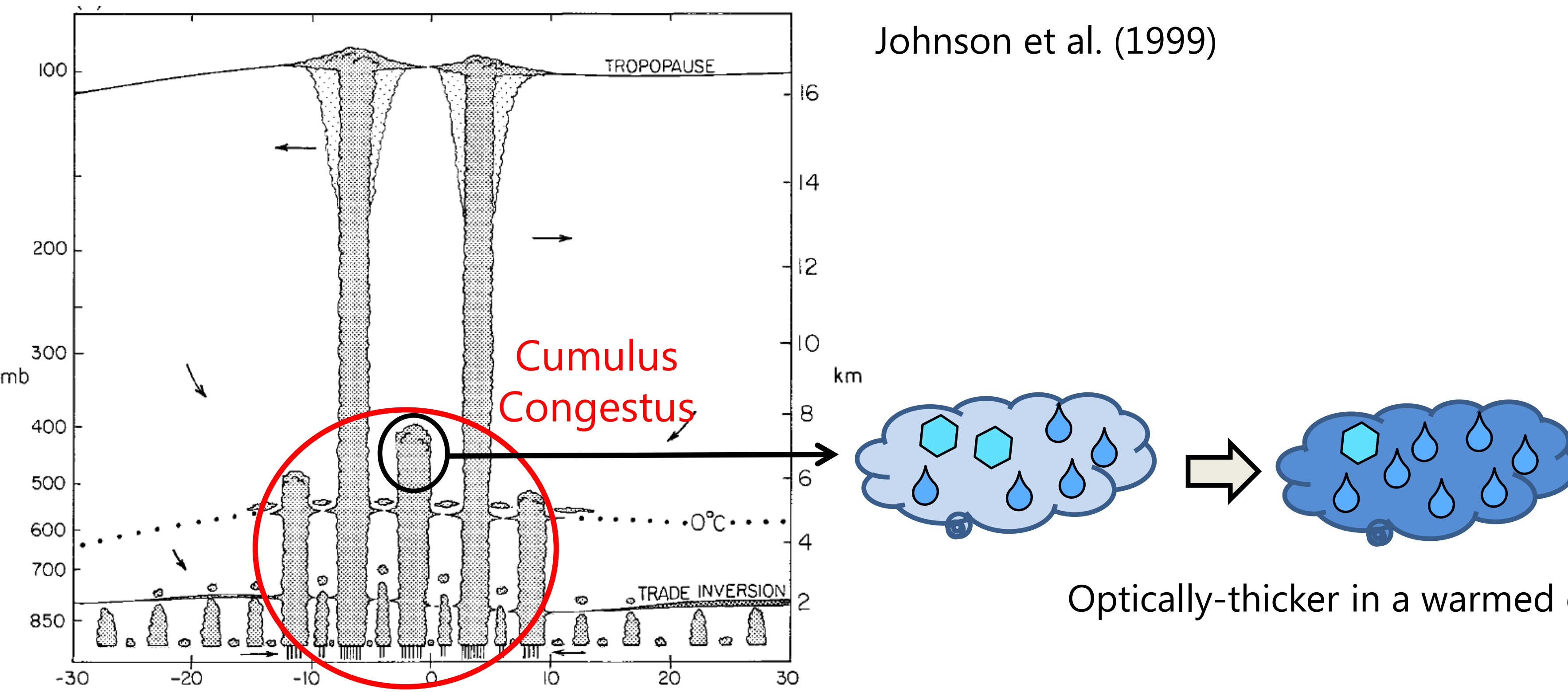
Sherwood et al. (2014)

Cumulus Congestus
3~9km cloud-top height
A-train 2008 (full year)

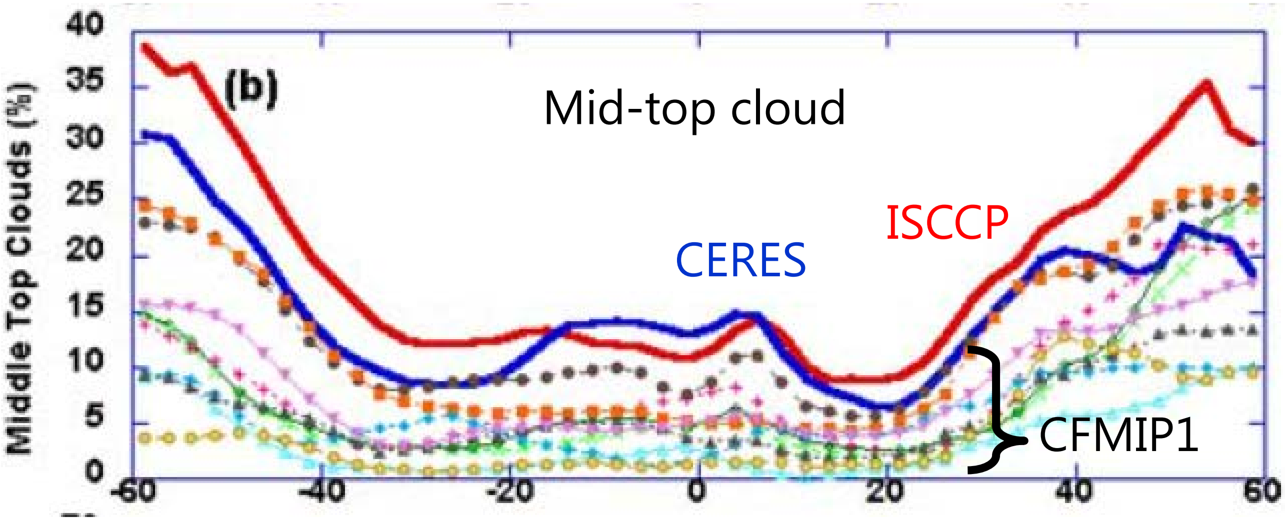


Casey et al. (2012)

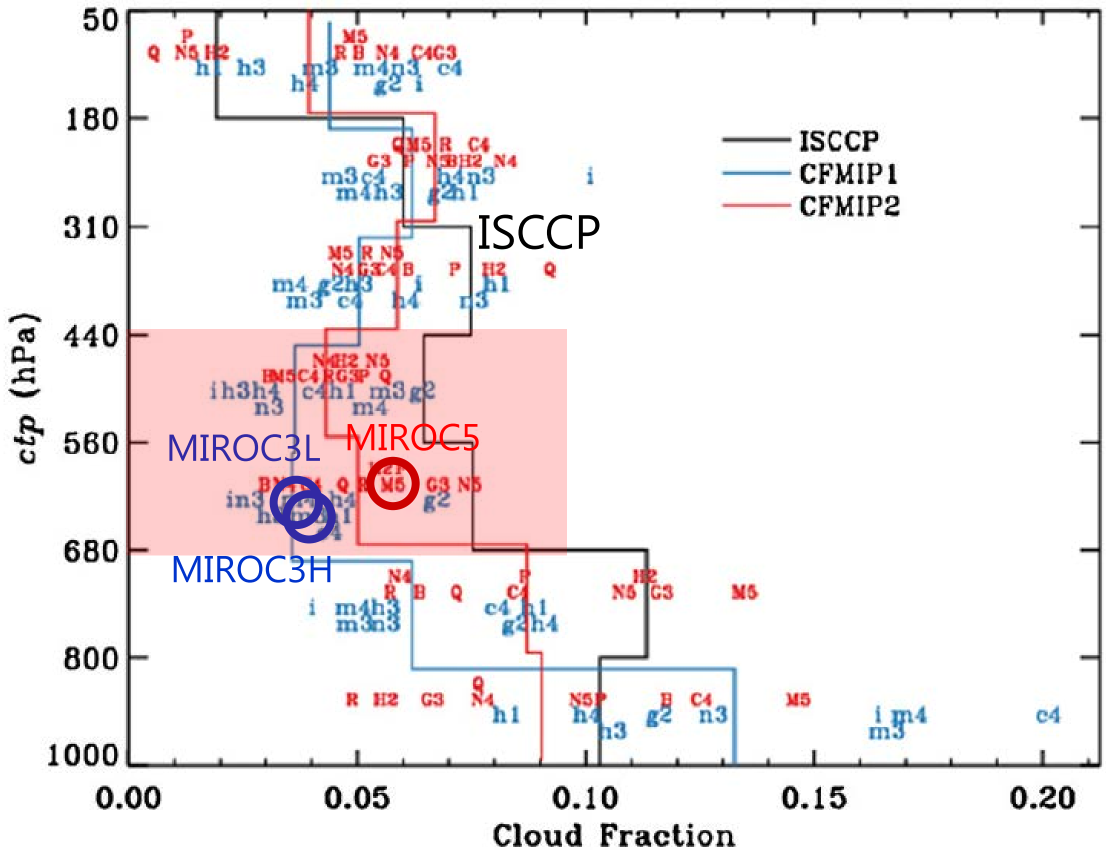
Johnson et al. (1999)



Optically-thicker in a warmed climate



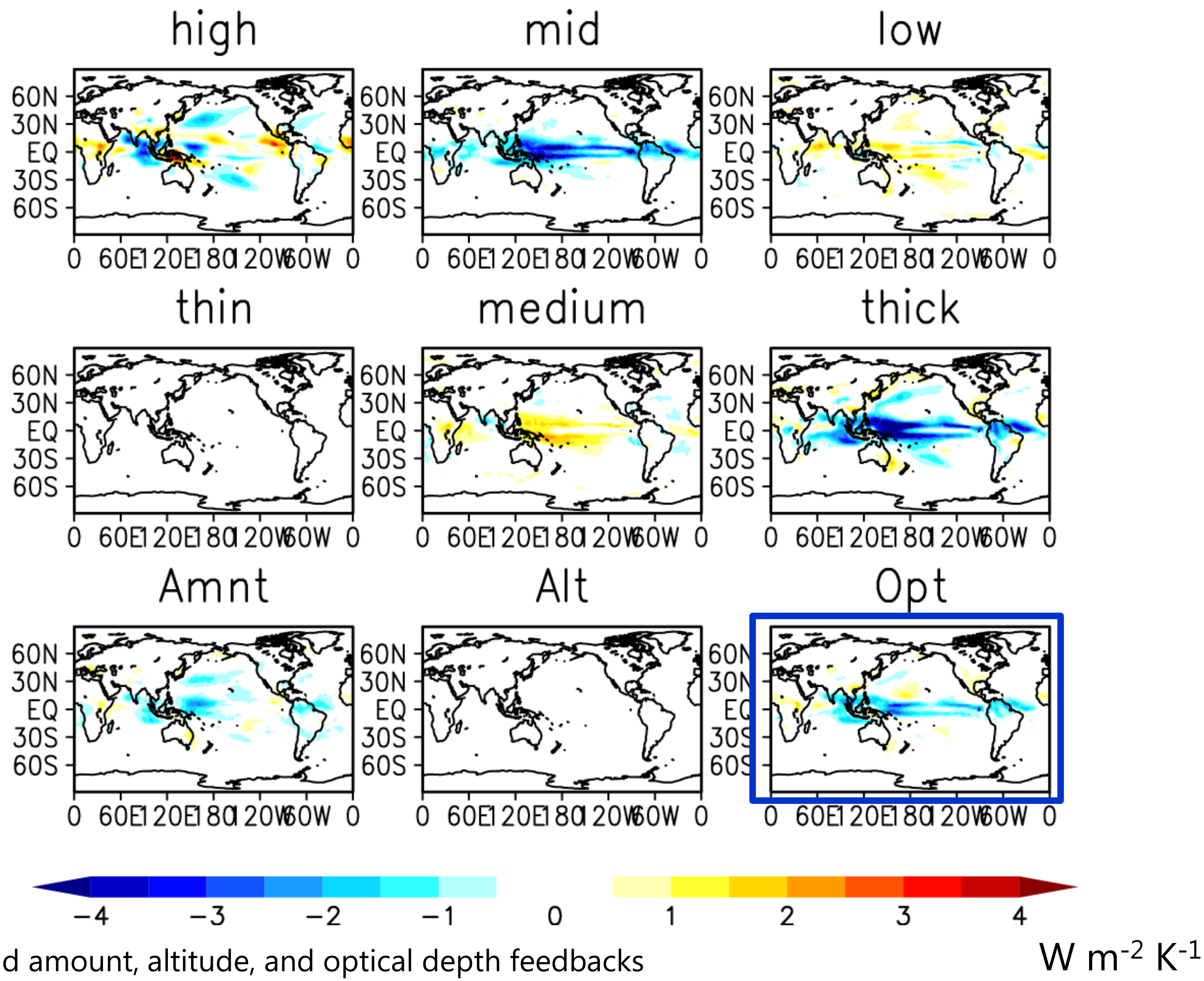
Zhang et al. (2005)



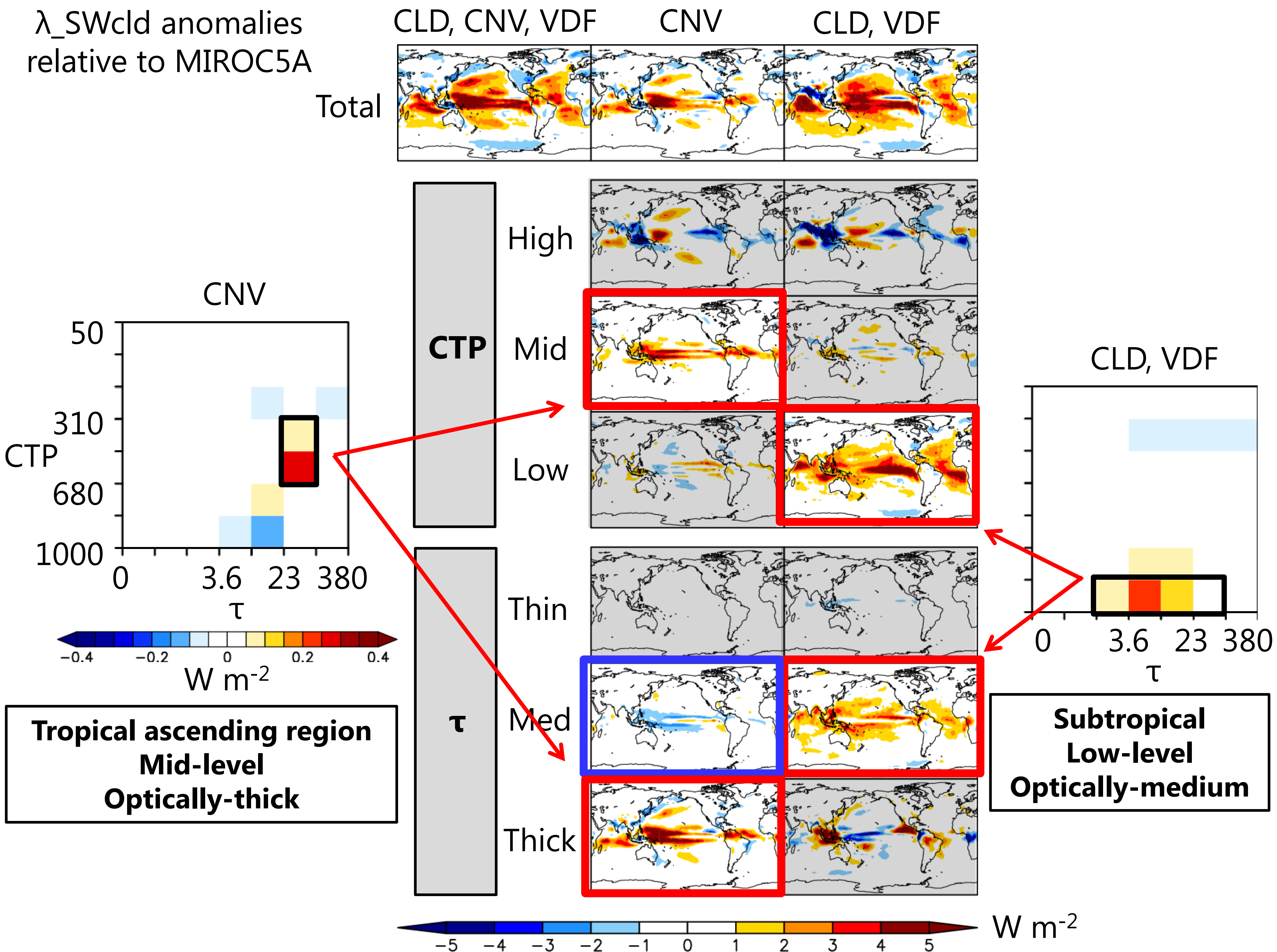
Klein et al. (2013)

CFMIP1/2 models tend to underestimate the middle-top cloud fraction

Mid-cloud feedback (New_CNV minus Old_CNV)

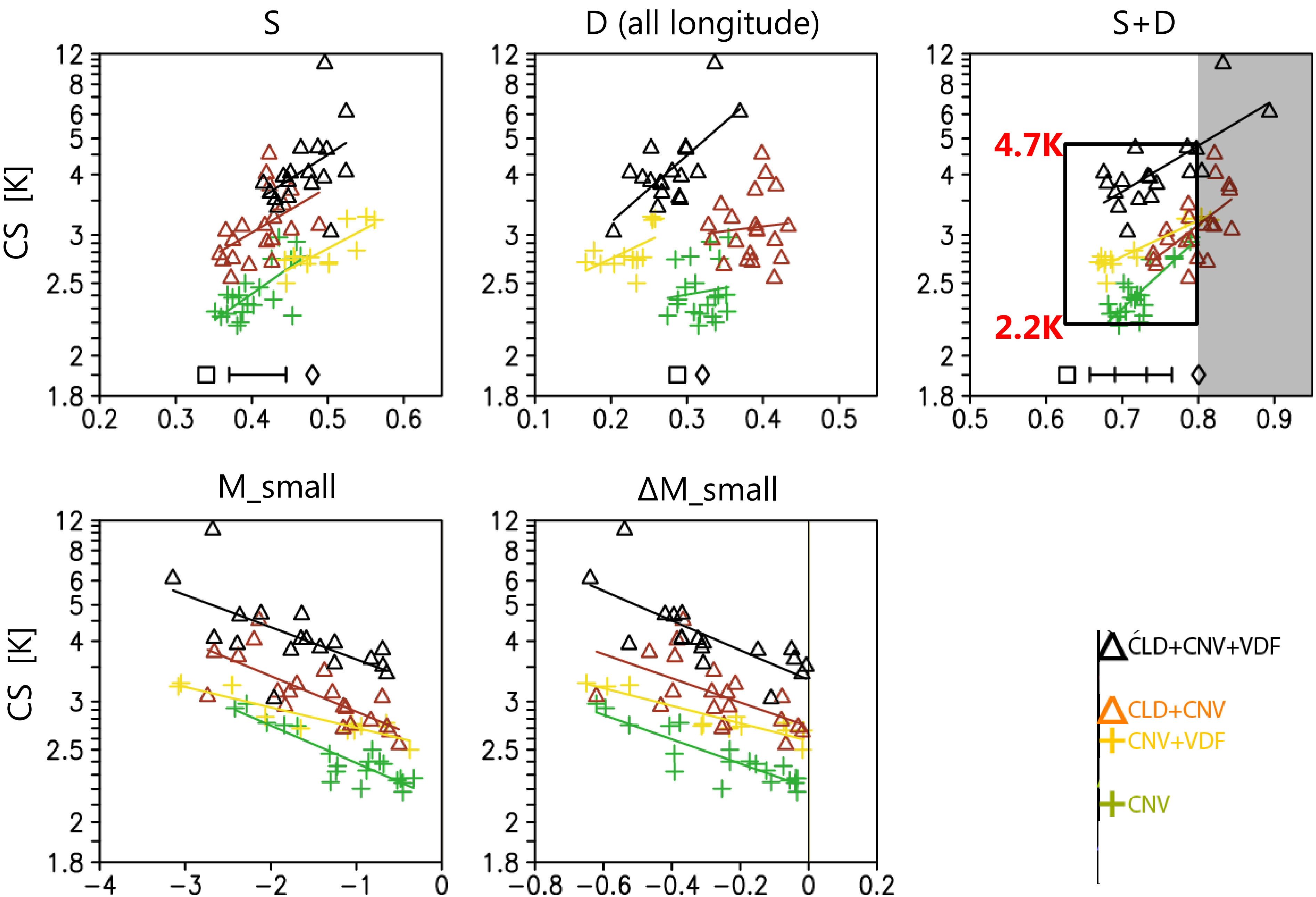


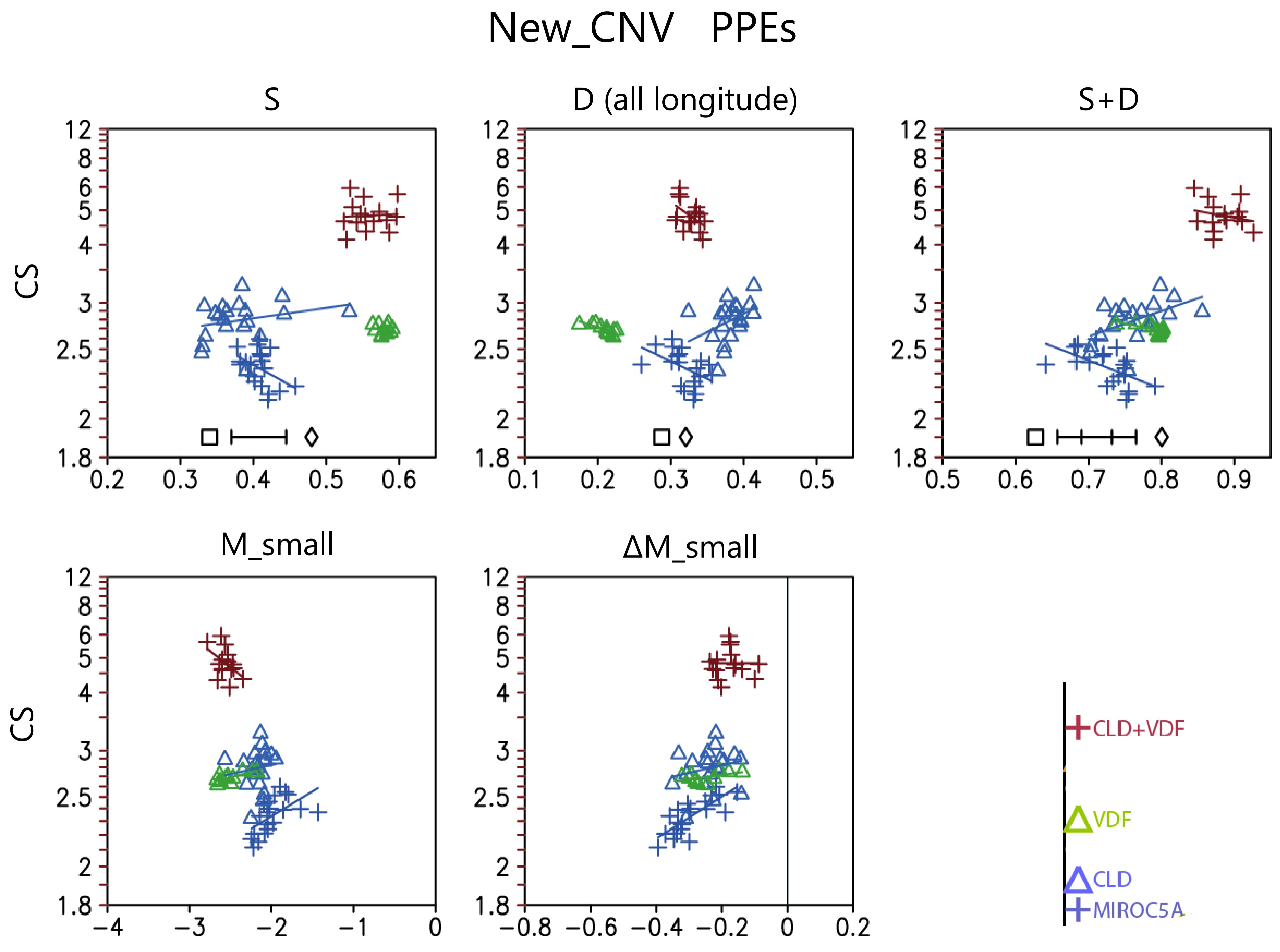
Decomposing cloud amount, altitude, and optical depth feedbacks
Zelinka et al. (2012b, 2013)



λ_SWcld anomalies
relative to MIROC5A
CLD, CNV, VDF
CNV
CLD, VDF
Total
CTP
High
Mid
Low
τ
Thin
Med
Thick
CNV
50
310
680
1000
CTP
0
3.6
23
380
τ
−0.4
−0.2
0
0.2
0.4
W m-2
Tropical ascending region
Mid-level
Optically-thick
CLD, VDF
0
3.6
23
380
τ
Subtropical
Low-level
Optically-medium
−5
−4
−3
−2
−1
0
1
2
3
4
5
W m-2

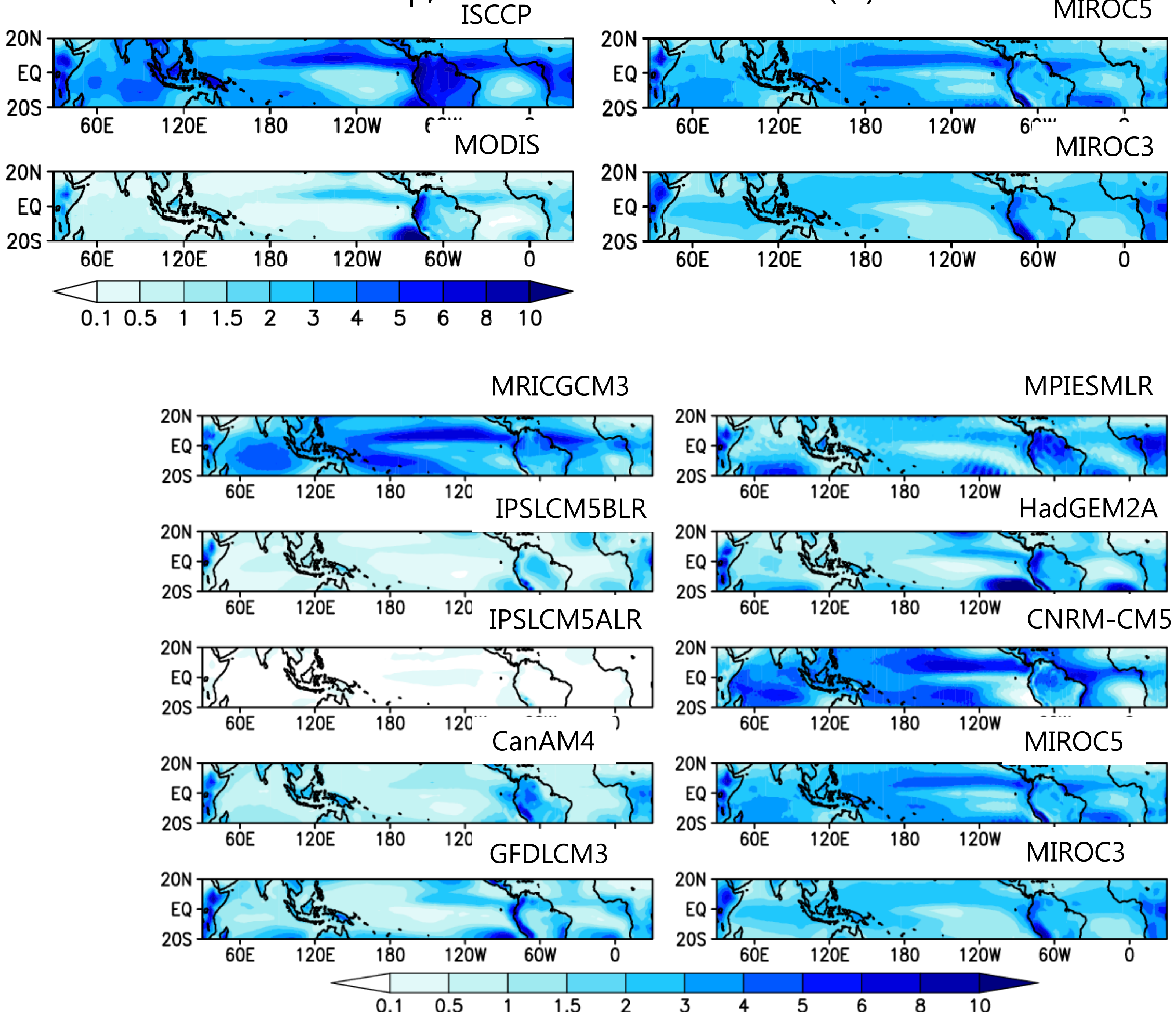
LTMI (Sherwood et al. 2014) vs CS in MPMPE (Old_CNV PPEs)



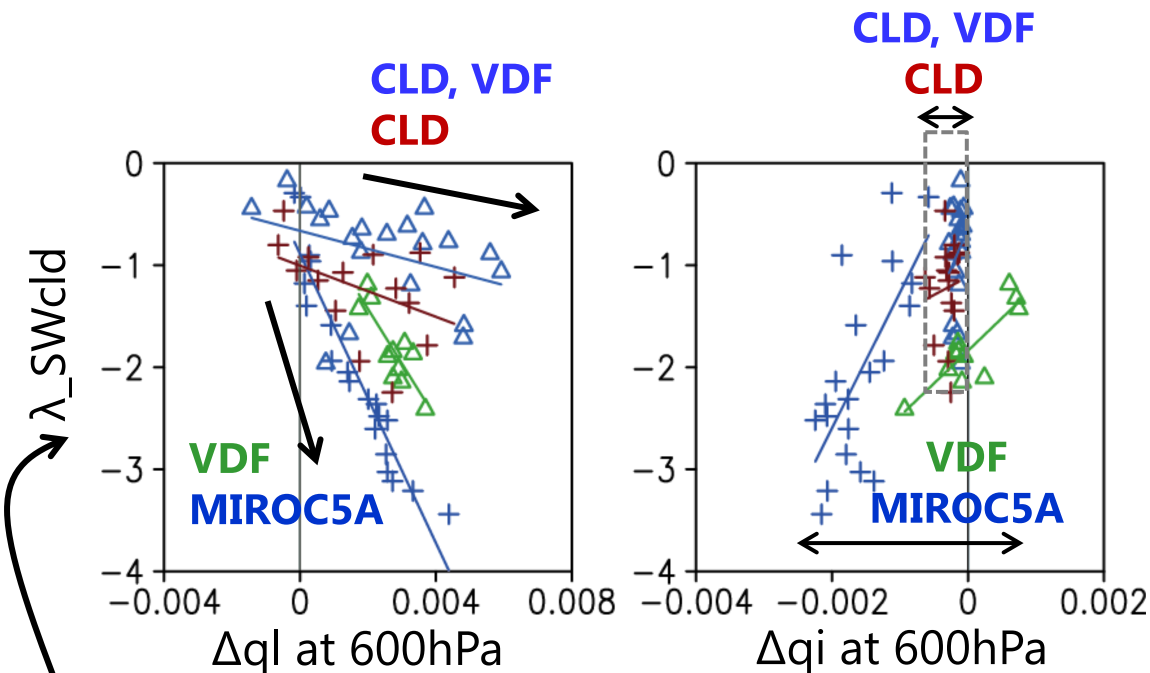


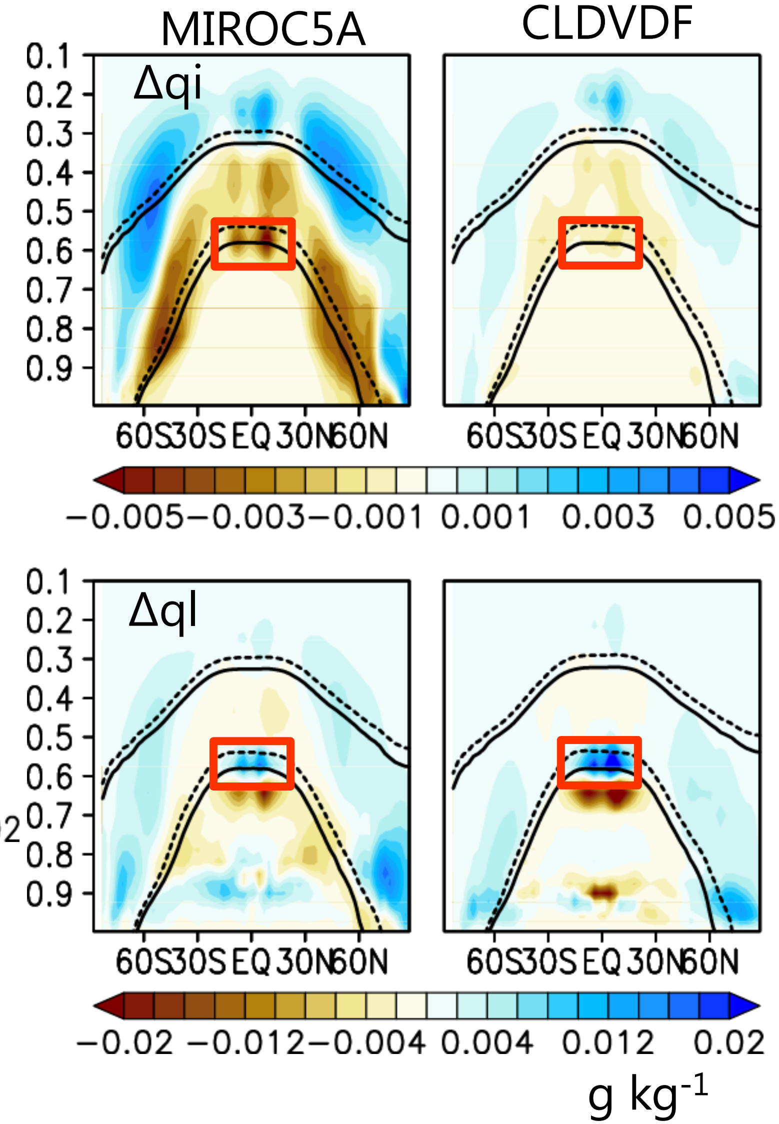
New_CNV PPEs
S
D (all longitude)
S+D
M_small
ΔM_small
CS
CS
CLD+VDF
VDF
CLD
MIROC5A

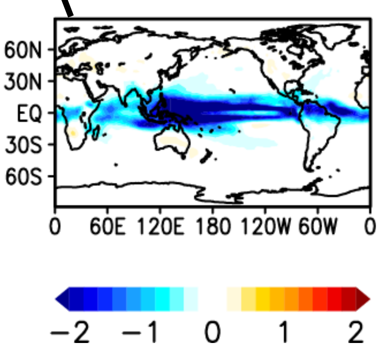
Mid-top, medium-τ cloud albedo (%)



Why does middle-level cloud become optically-thicker in New_CNV models?







Decreasing qi but increasing ql -> optically-thicker cloud

Old_CLD models have smaller qi in control run -> smaller λ_τ