Mechanism of tropical low-cloud response to surface warming using weather and climate simulations

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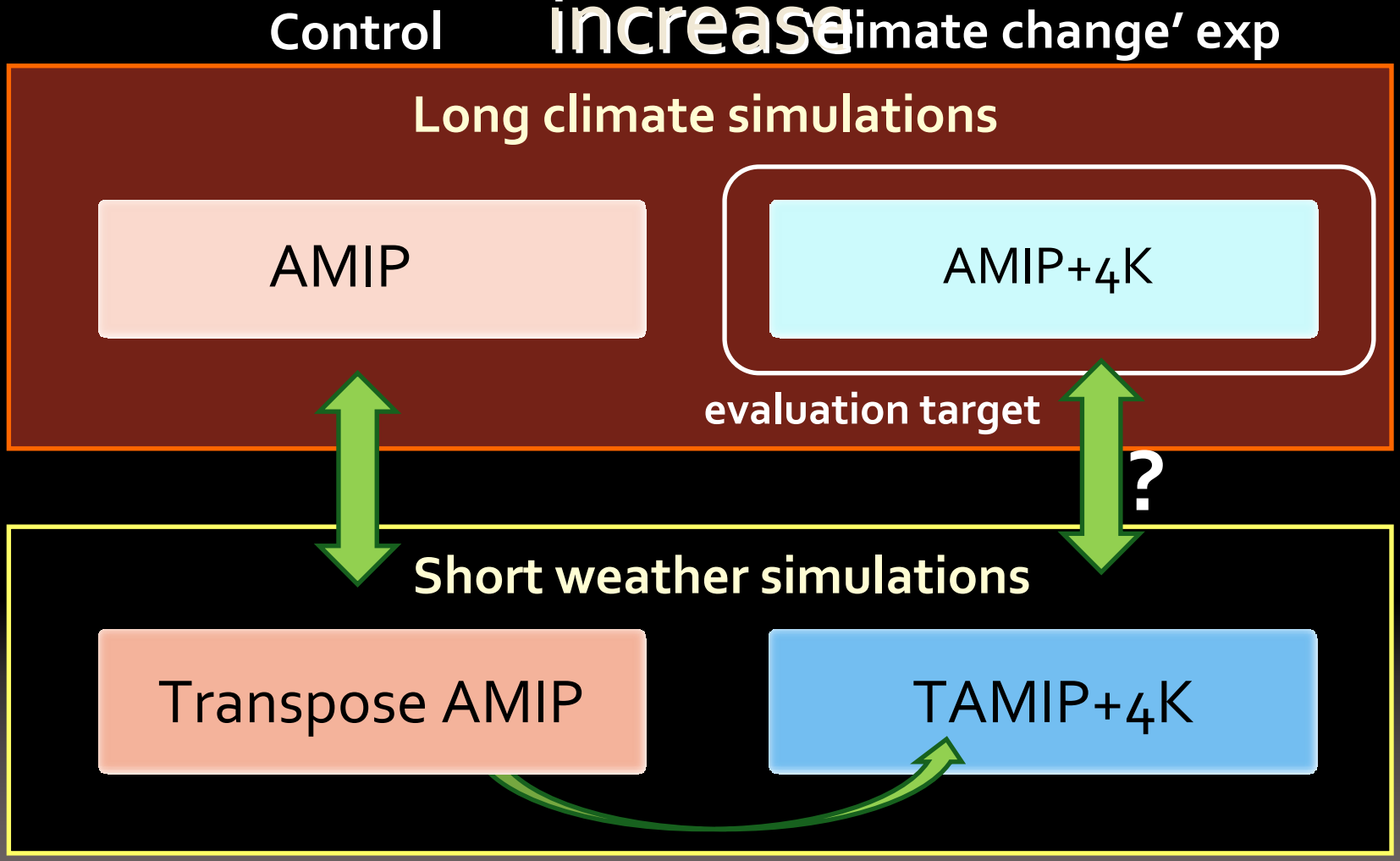
Assessing cloud response to SST increase

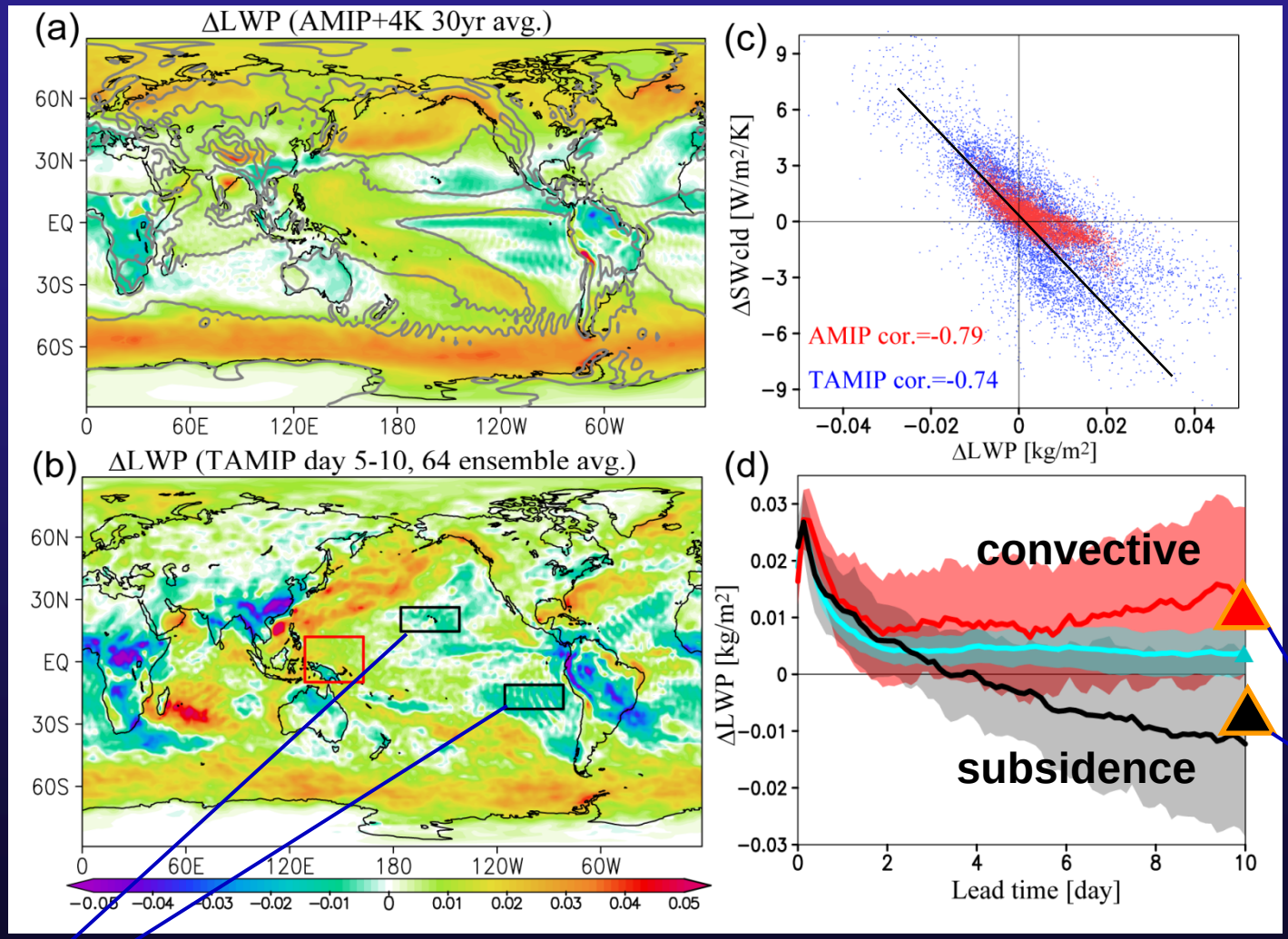


- ✓ Does TAMIP+4K reproduce cloud changes in AMIP+4K?
- ✓ If Yes, what is the mechanism of the fast physics?

Cloud response to SST+4K in MIROC5

ΔLWP (AMIP 30yr)

ΔLWP (TAMIP 5dy)

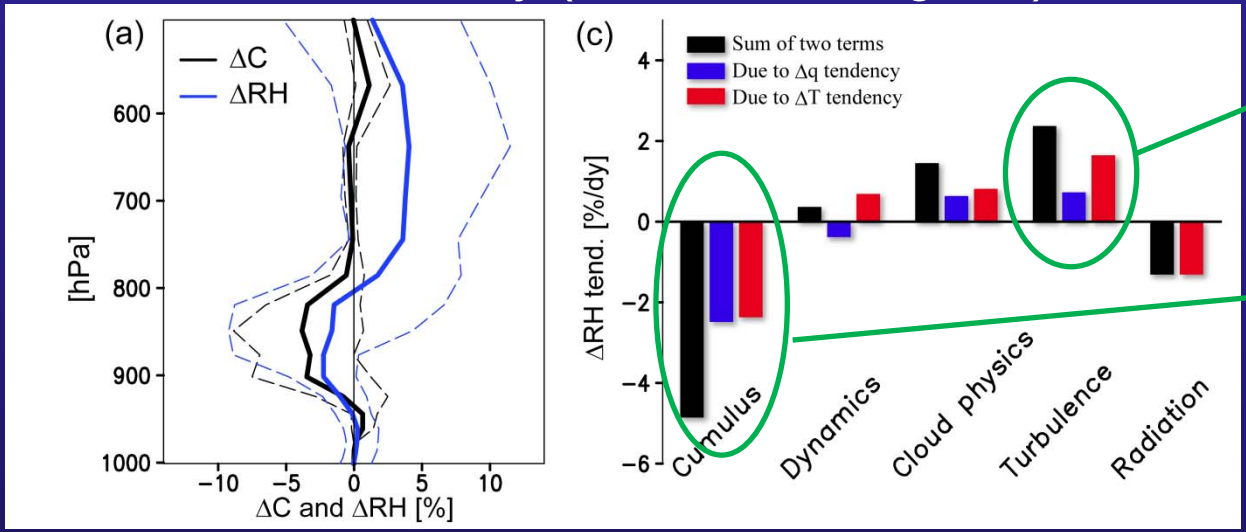


LWP decrease in subsidence regions

Demoto, Watanabe, and Kamae (2013, GRL)

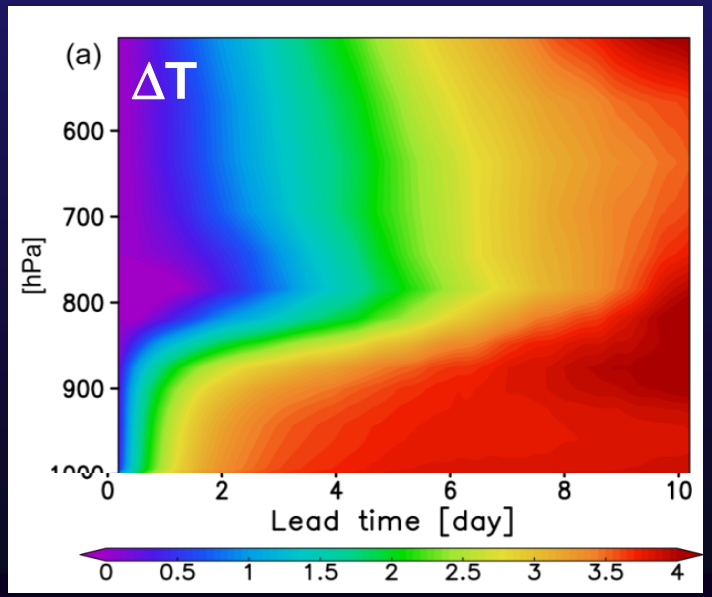
Why low clouds (⟷ LWP) have to decline?

ΔRH and its tendency (subsidence regions) in TAMIP

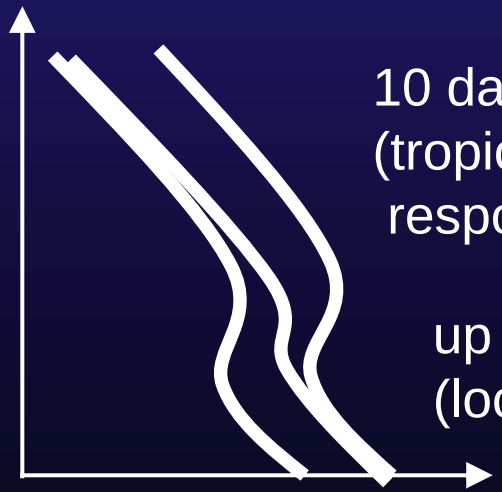


Positive ΔRH due to turbulence

Negative ΔRH due to convection



Two timescales in the response



10 days and more (tropical tropospheric response)

up to 5 days (local PBL response)

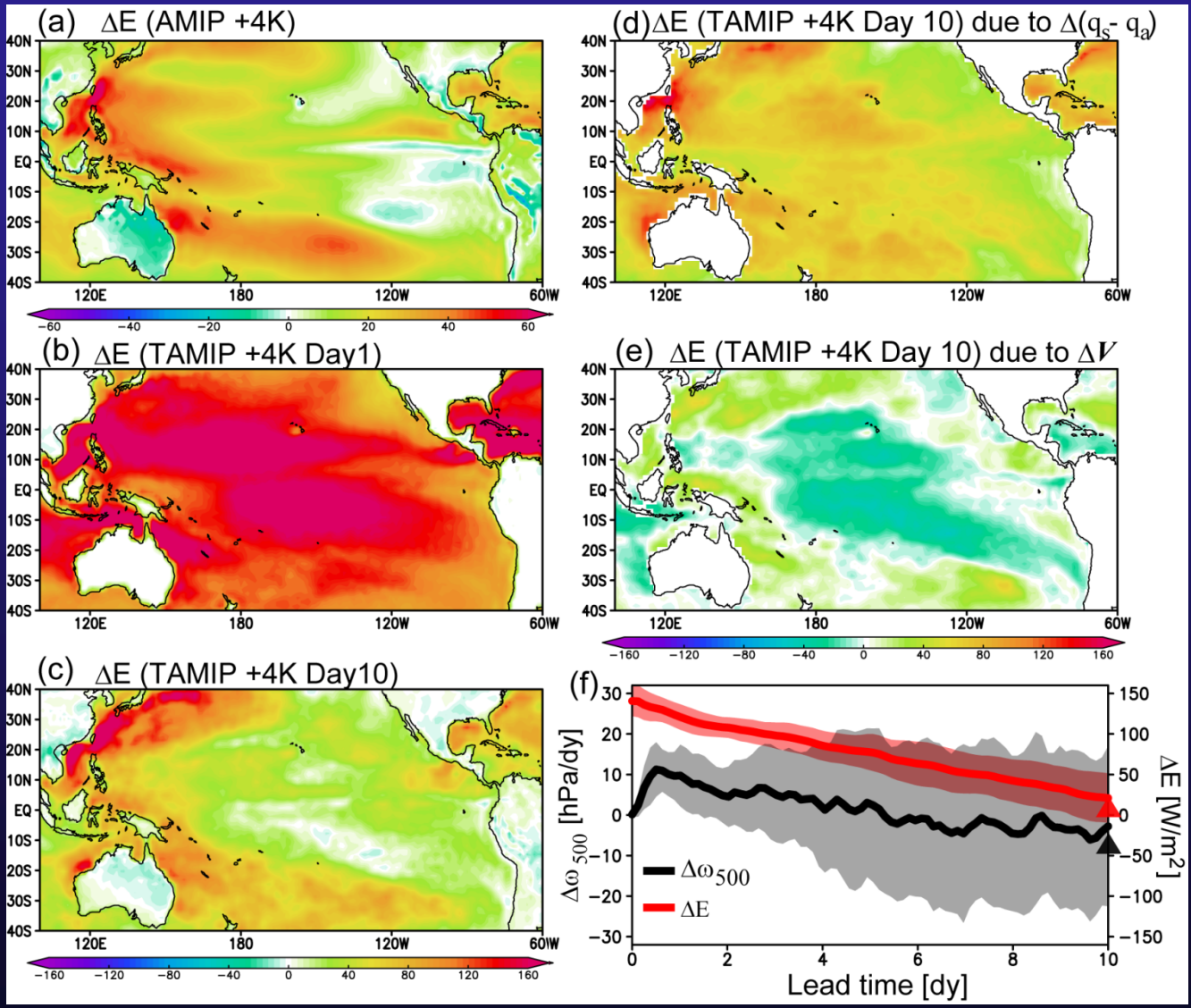
Demoto, Watanabe, and Kamae (2013, GRL)

Surface flux response

ΔE (AMIP 30yr)

ΔE (TAMIP day 1)

ΔE (TAMIP day 10)



ΔE (TAMIP day 10) due to Δq

ΔE (TAMIP day 10) due to ΔV_s

Suppress ΔE <=> Slowdown of circulation

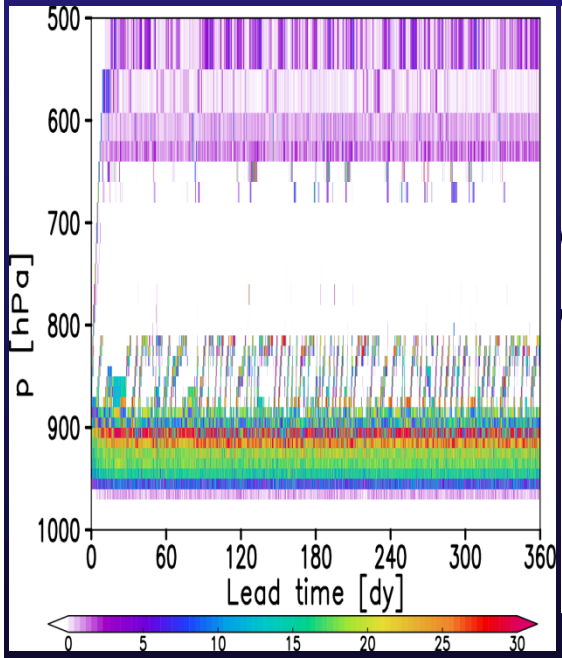
More evap in the west, less in the east

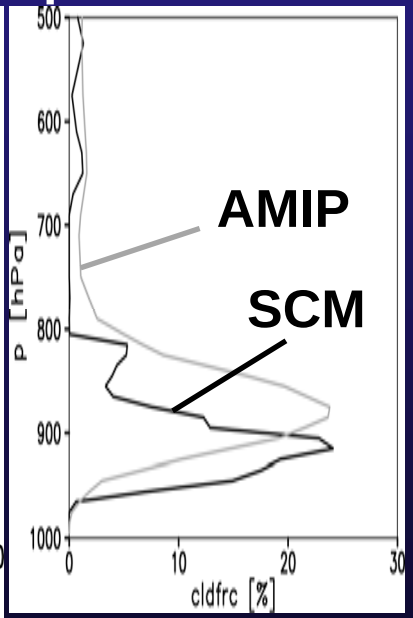
Demoto, Watanabe, and Kamae (2013, GRL)

SCM experiments

- ✓ Identical physics package as MIROC5-AGCM
- ✓ CGILS S6 external conditions, CTL & SST+2K
- ✓ Vertical advection & adiabatic heating internally calculated

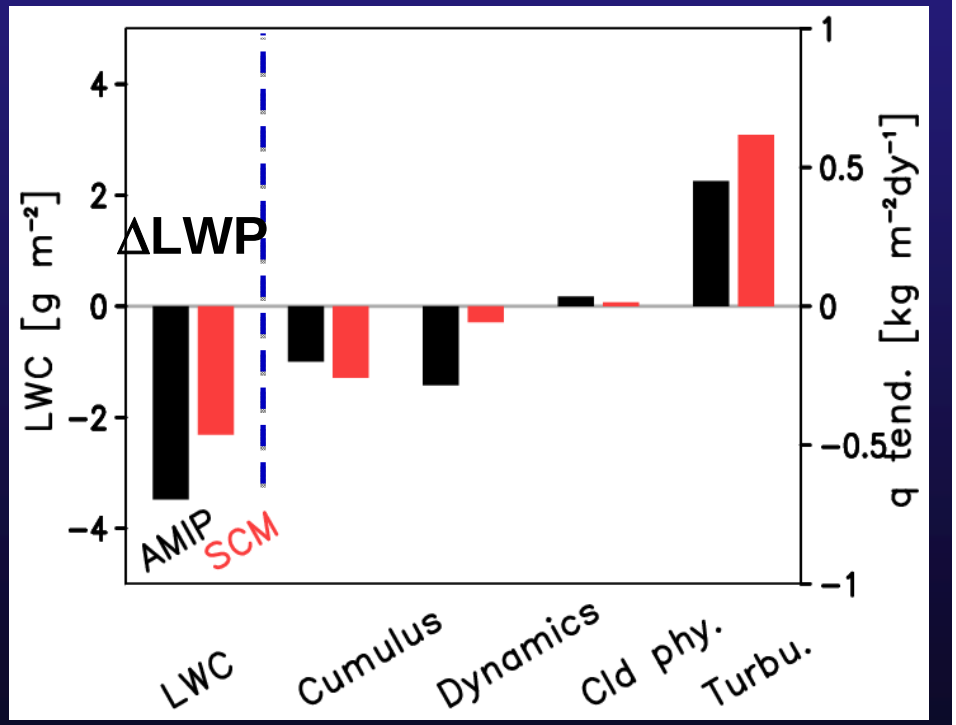
Time evolution and equilibrium in CTL





Cloud fraction

Changes in q-tendency terms

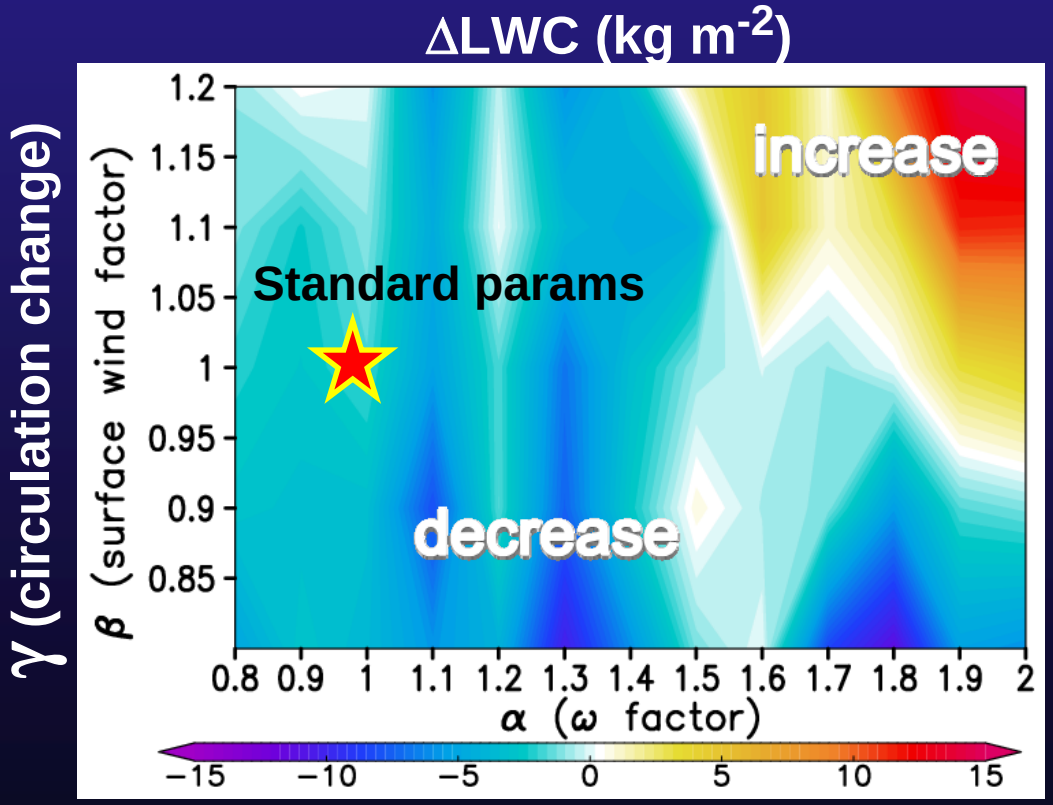


Qualitatively good ability to reproduce AMIP mean cloud & its change

Parameter dependence in SCM

✓ How ΔLWP depends on mean state & sfc flux response?

Parameter	Definition	Range
α	Factor for ω in CTL run ($\Delta\omega$=const.)	0.8-2.0
γ	Factor for sfc wind speed change in SST+2K run	0.8-1.2

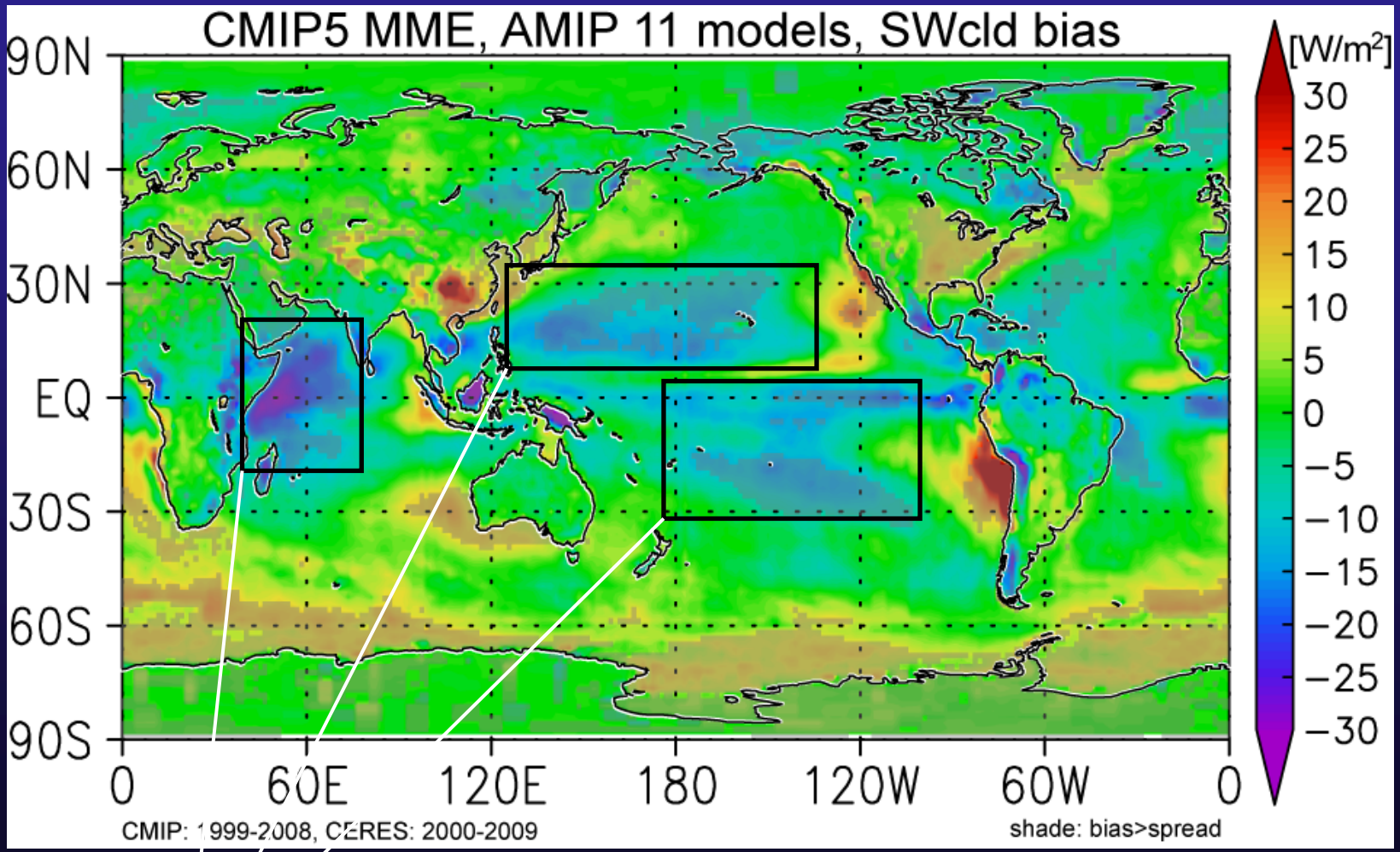


With stronger mean inversion layer, cumulus convections cannot be active in drying the boundary layer

➡ low-cloud increase due to enhanced evaporation

Model errors in SWcld

Excessive tropical cooling in GCMs



Owing to 'too bright' low clouds

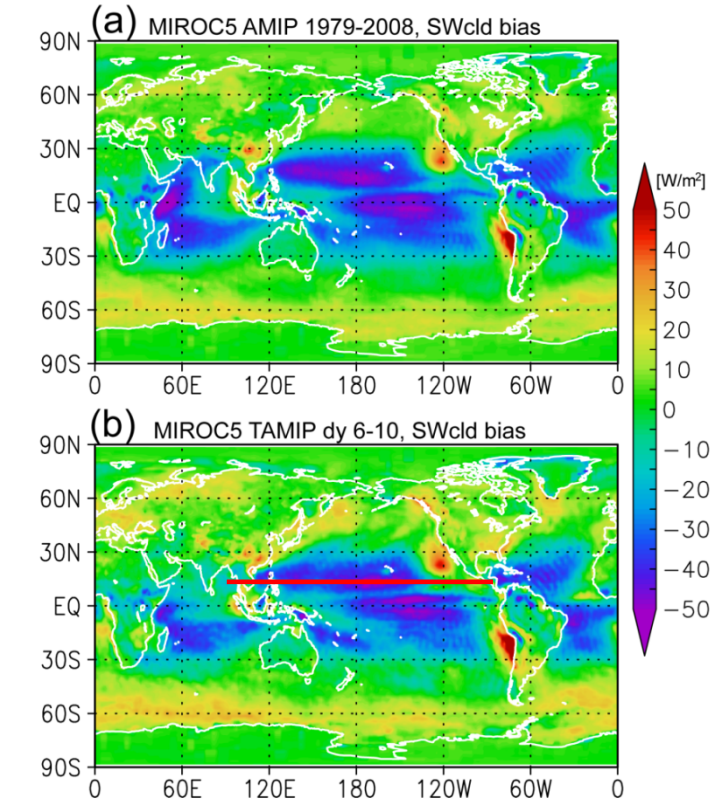
Watanabe and Jiang (2013, in prep)

SWcld errors in MIROC5

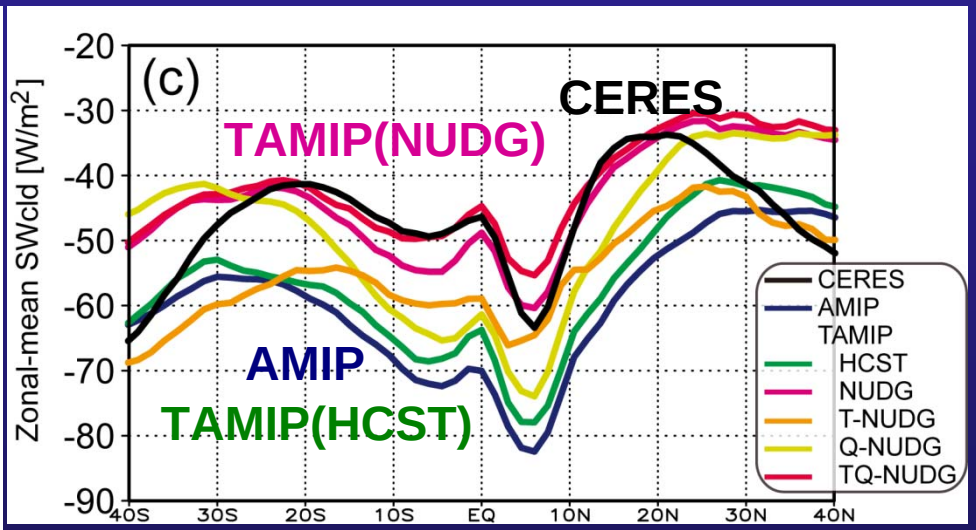
Errors wrt CERES

AMIP 30yrs

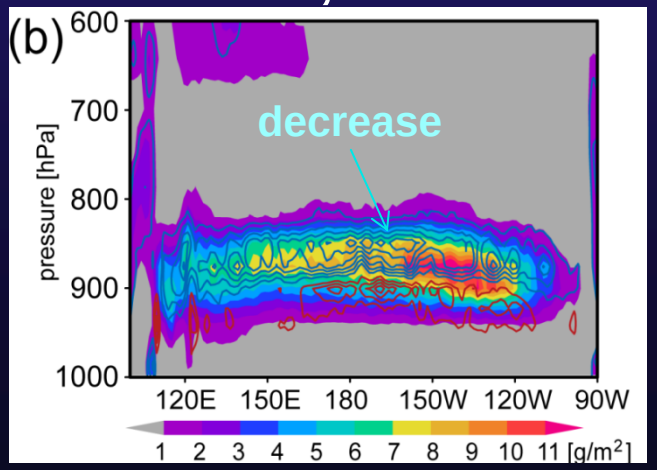
TAMIP 6-10dy



Zonal-mean SWcld



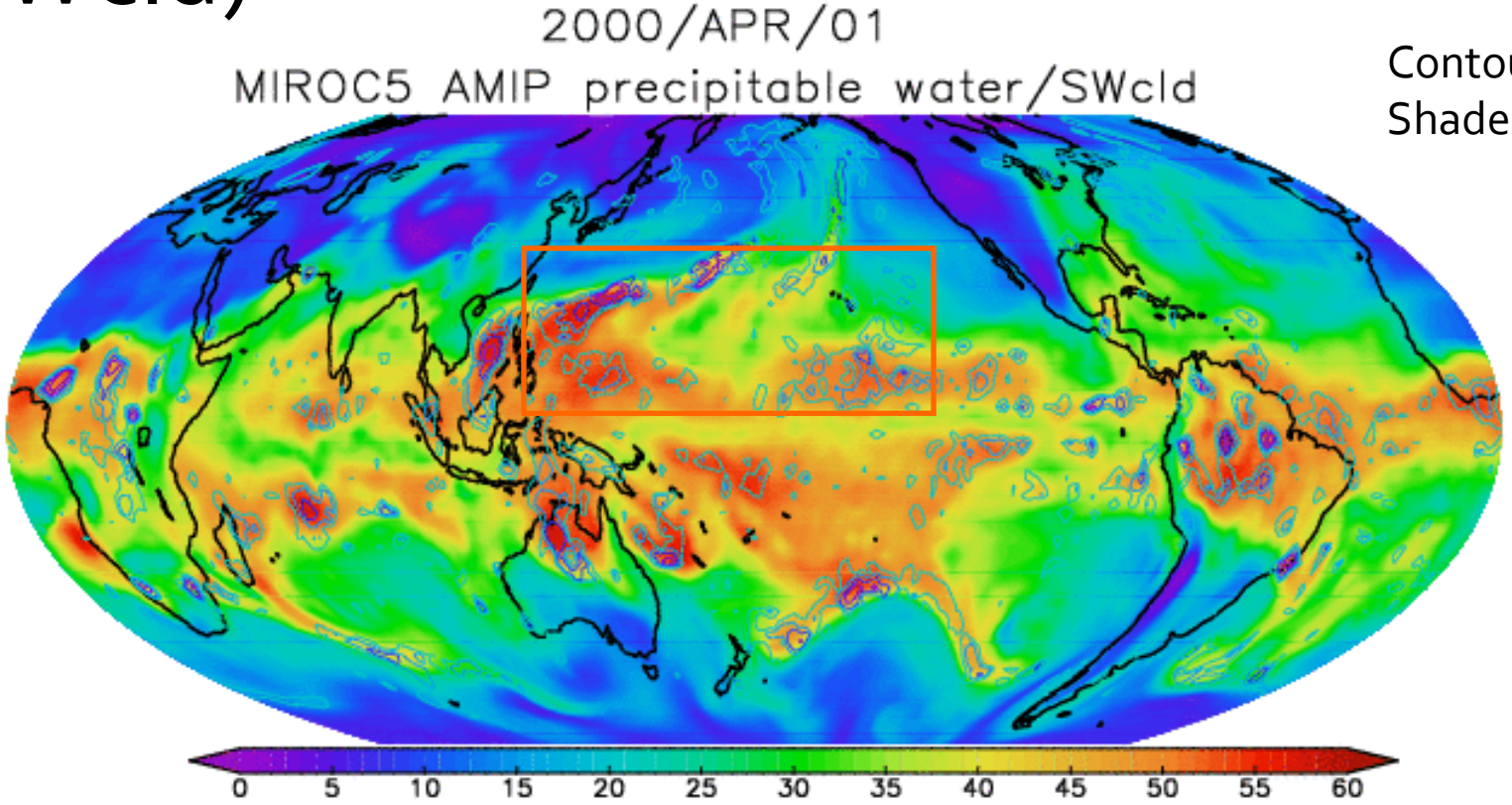
Cloud water, NUDG-HCST



- Error in TAMIP similar to bias in AMIP
- SWcld error greatly reduced when T & q are 'correct'
- Low clouds should be thinner and lower

Watanabe and Jiang (2013, in prep)

AMIP snapshots (precip water & SWcld)



Contour: SWcld
Shade: PW

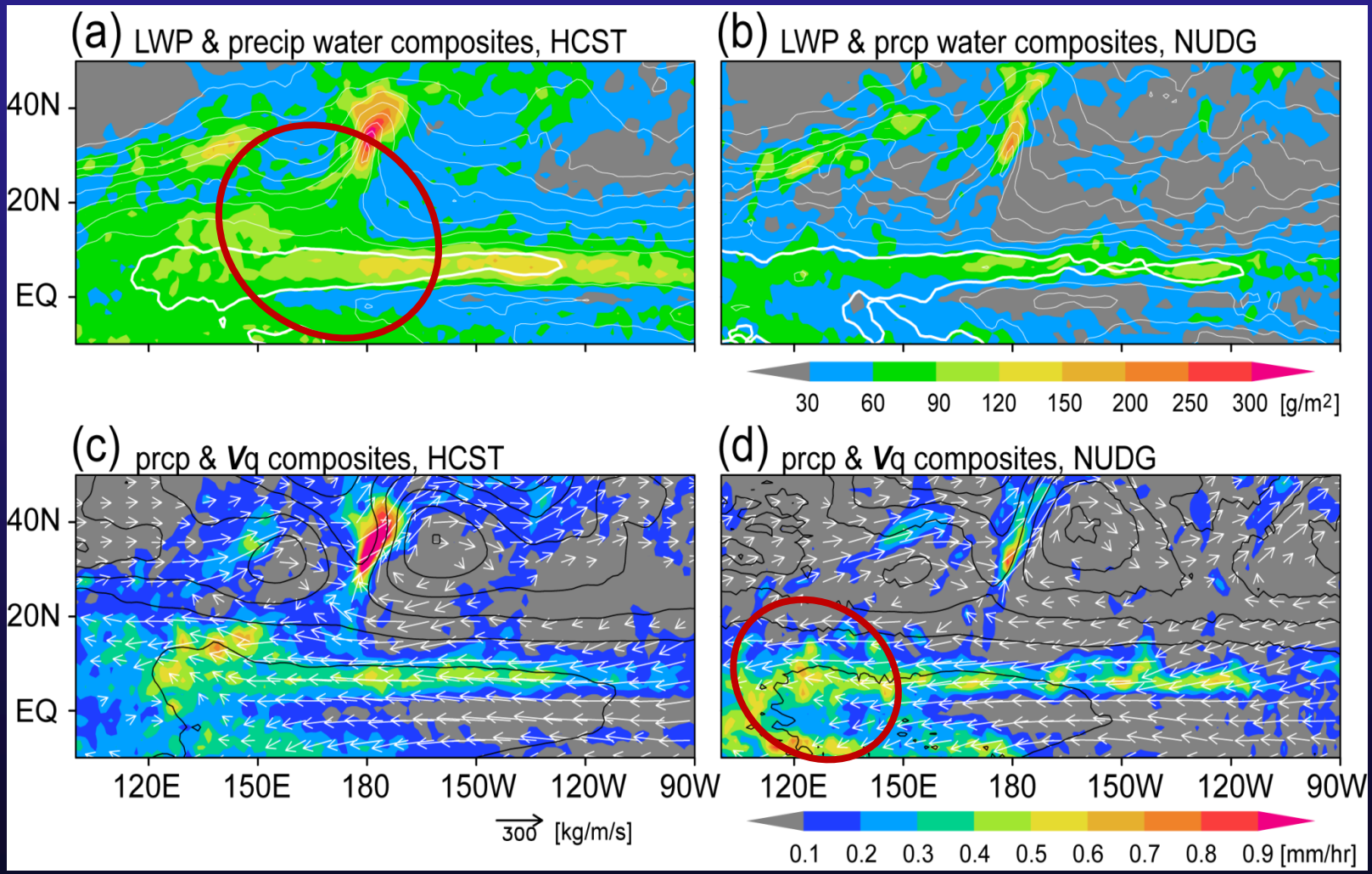
- **Cooling due to SWcld occurs at the edge of waves**
- **Are errors in mean SWcld synoptic origin?**

Synoptic origin of LWP errors

Composite in HCST **Composite in NUDG**

LWP

precip



More cloud water, less precip

Watanabe and Jiang (2013, in prep)

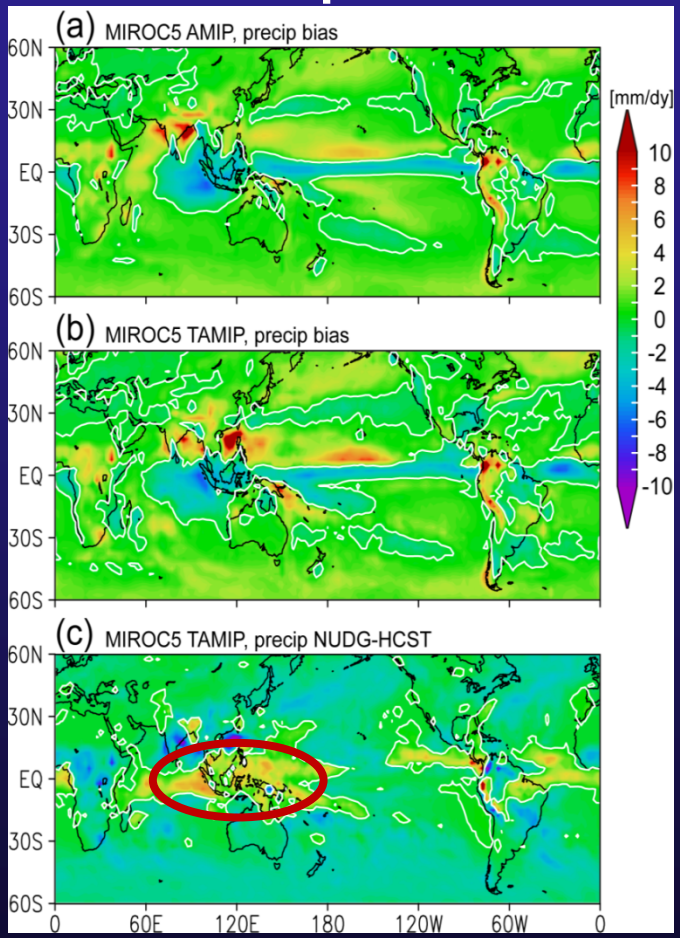
Error compensation?

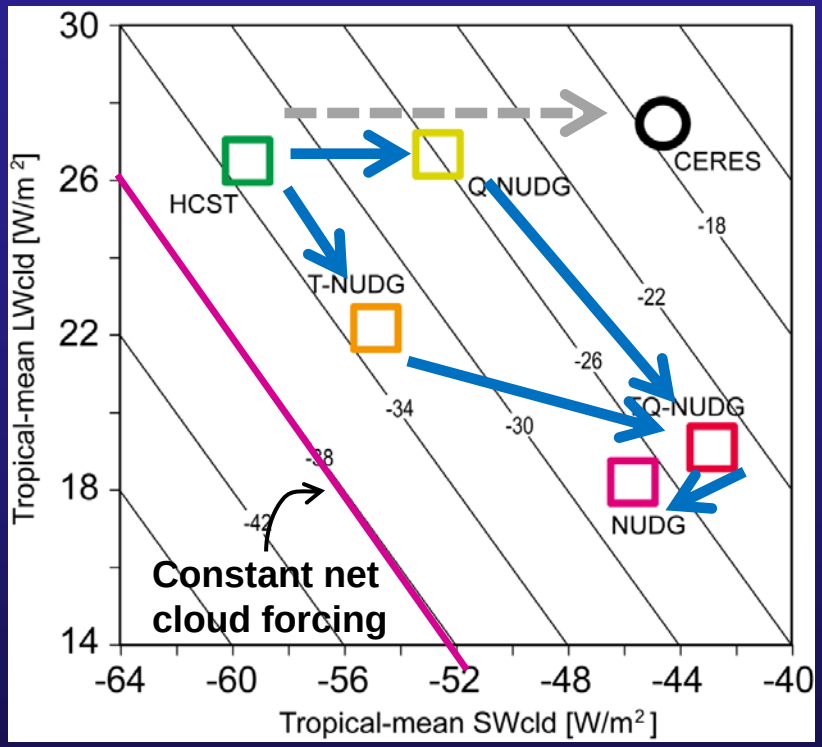
Precip bias

AMIP

TAMIP (HCST)

NUDG -HCST





Coupling of errors in subtropical low cloud & precip over the western eq. Pacific

Errors DO compensate

- ✓**Reducing SWcld bias amplifies LWcld bias**
- ✓**Need to fix the problem for each**

Watanabe and Jiang (2013, in prep)

Summary

Mechanisms of SWcld 'feedback' in a GCM

✓Subtropical low-cloud decrease to uniform SST rise found both in MIROC5 AMIP & TAMIP

-> fast cloud response in about 10 days

✓Competition between convective drying (*local*) and turbulent moistening (*non-local*) the boundary layer, the latter eventually ineffective due to slow-down of the tropical circulation (cf. Webb & Lock 2012)

Disentangling causes of subtropical SWcld bias

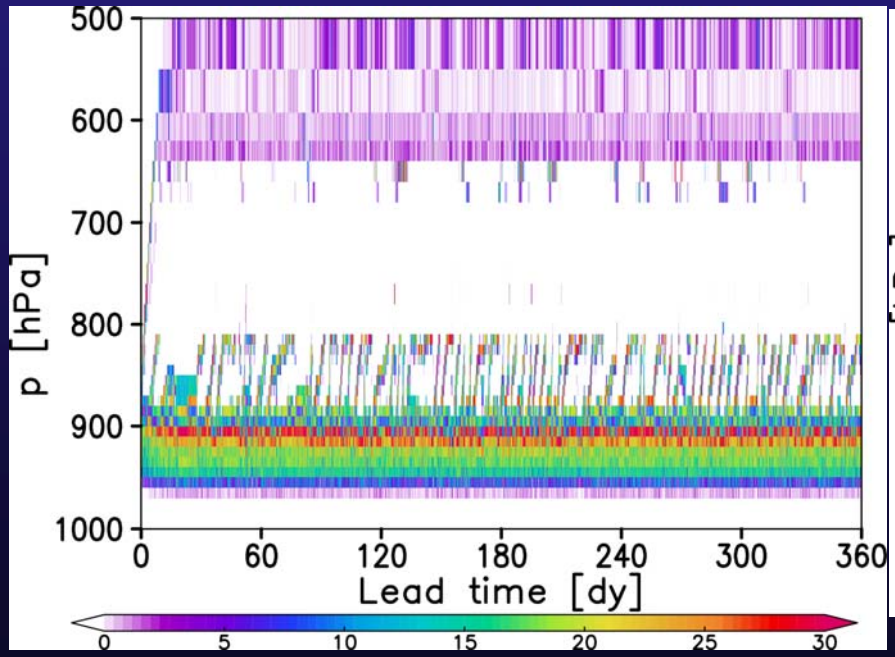
✓Common GCM bias of 'too-bright' low clouds may have synoptic origin, and coupled with errors deep-convective regime (maritime cont.)

backup

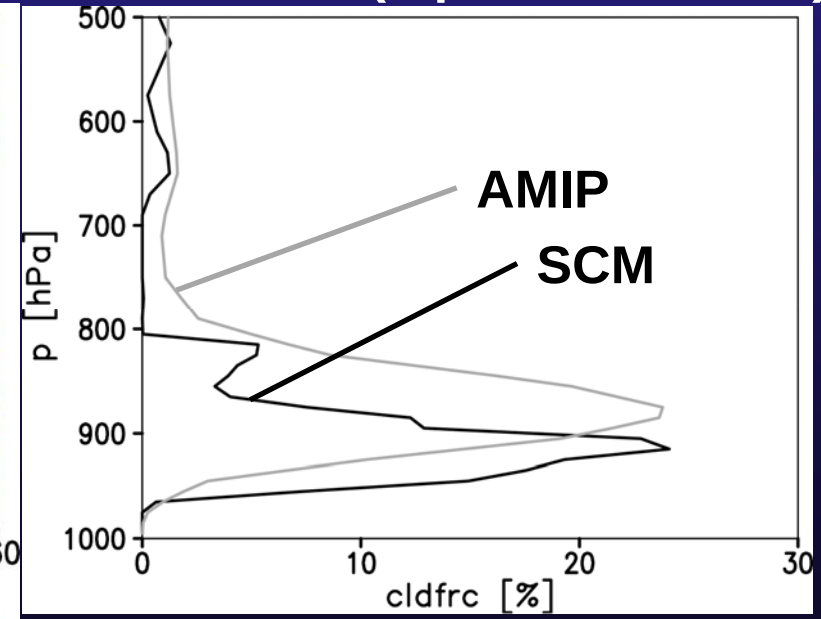
SCM experiments

- ✓ Identical physics package as MIROC5-AGCM
- ✓ CGILS S6 external conditions, CTL & SST+2K
- ✓ Vertical advection & adiabatic heating internally calculated

Cloud fraction



Cloud fraction (equilibrium state)

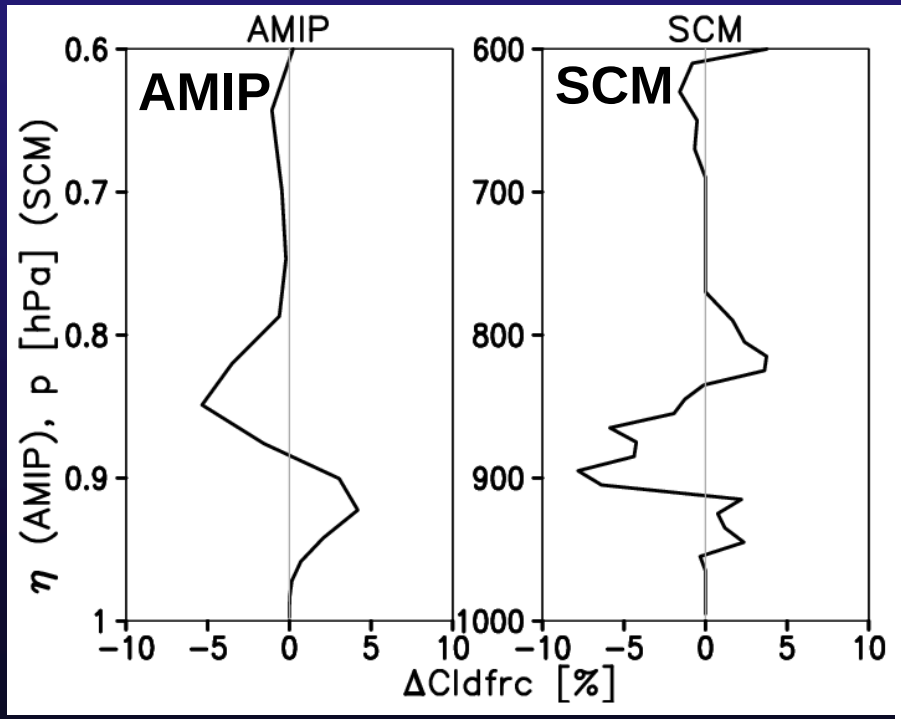


Qualitatively good ability to reproduce AMIP mean cloud

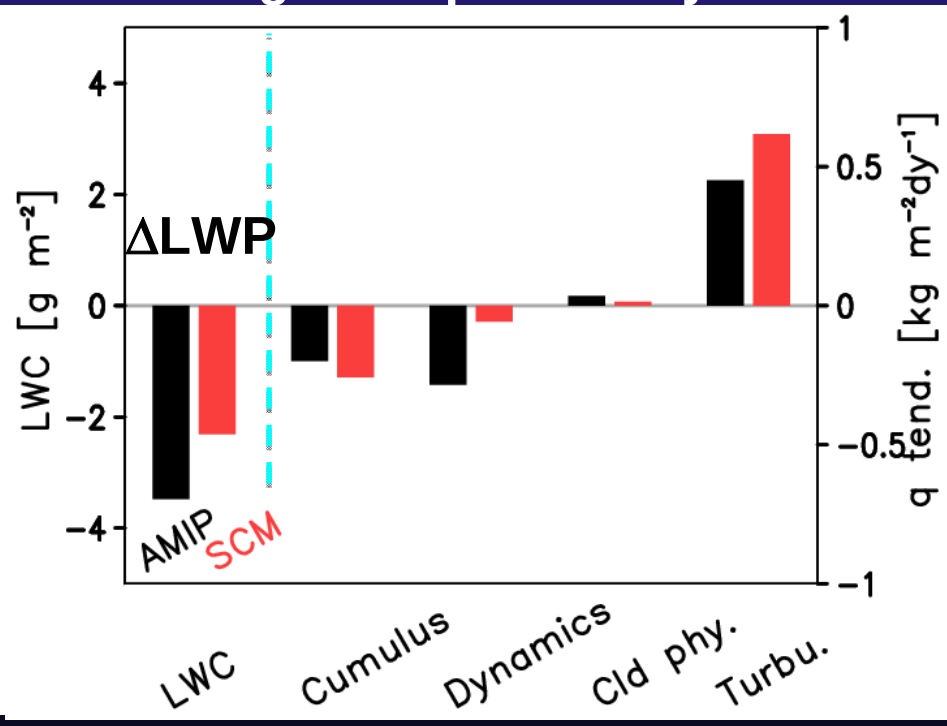
SCM experiments

- ✓ SST+2K run (cf. CGILS)
- ✓ SCM reproduces low cloud reduction as well as changes in individual tendency terms

Δcloud fraction



Changes in q-tendency terms

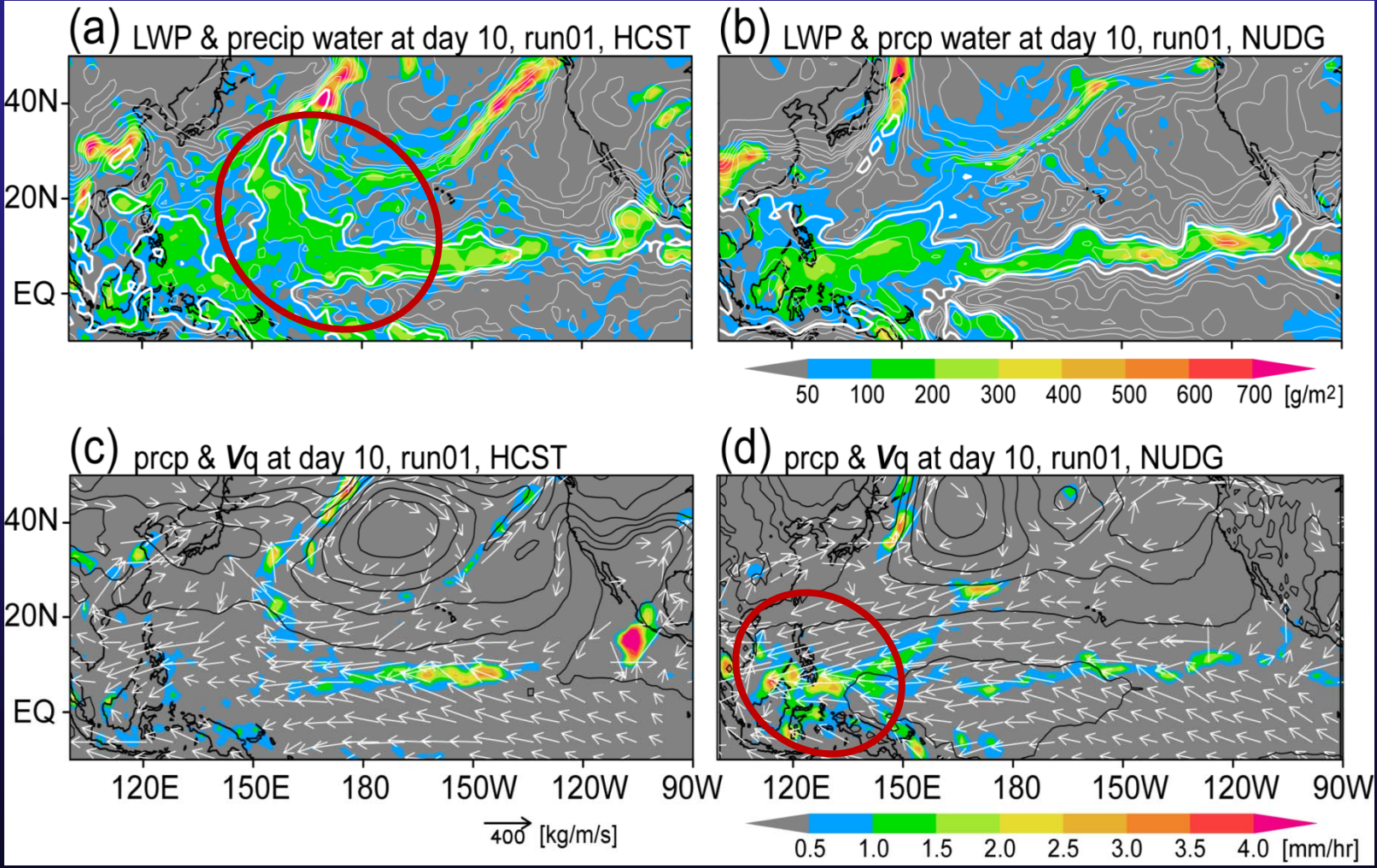


Synoptic origin of LWP errors

Day 10, run01 in HCST **Day 10, run01 in NUDG**

LWP

precip

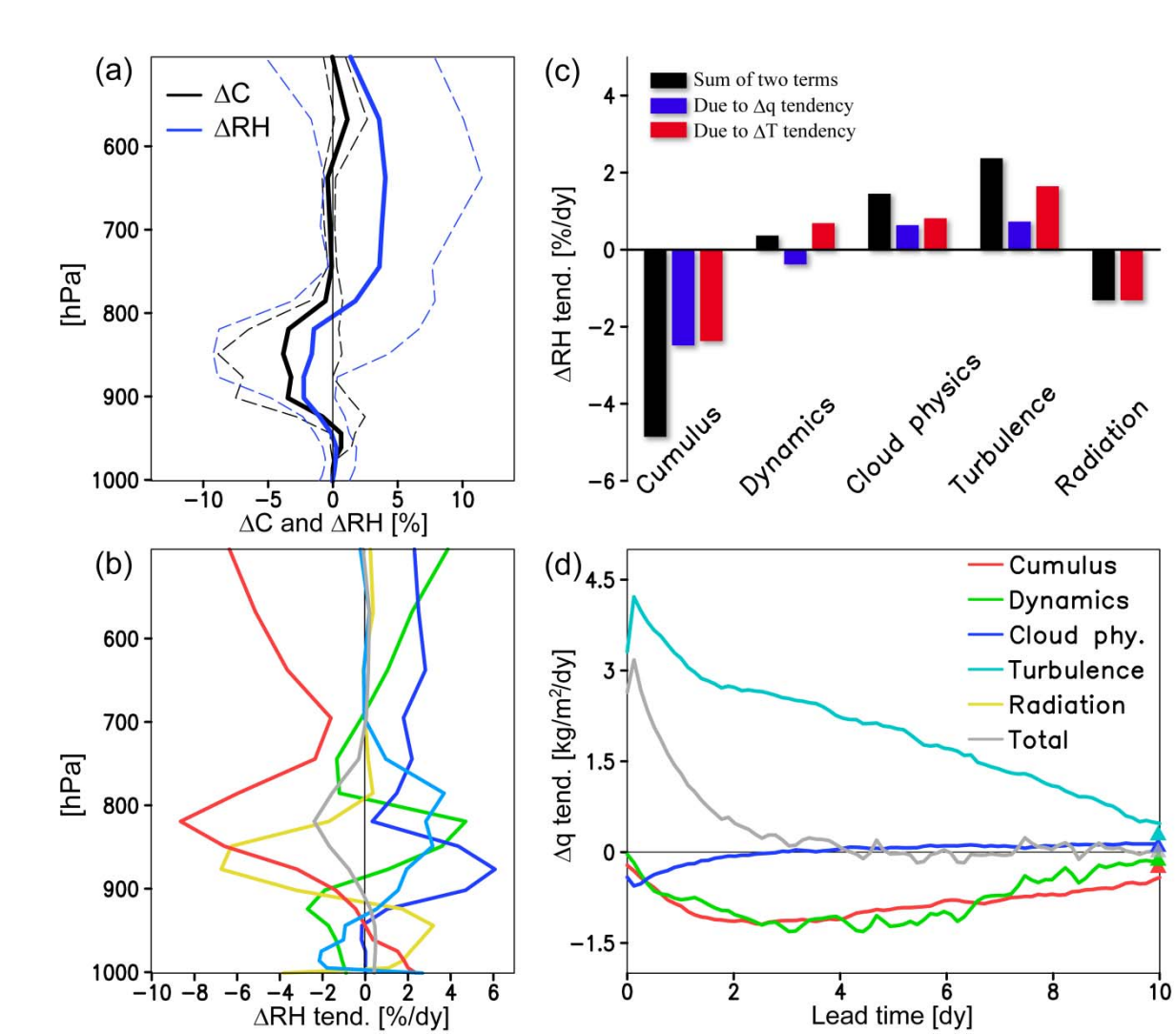


More cloud water, less precip

Watanabe and Jiang (2013, in prep)

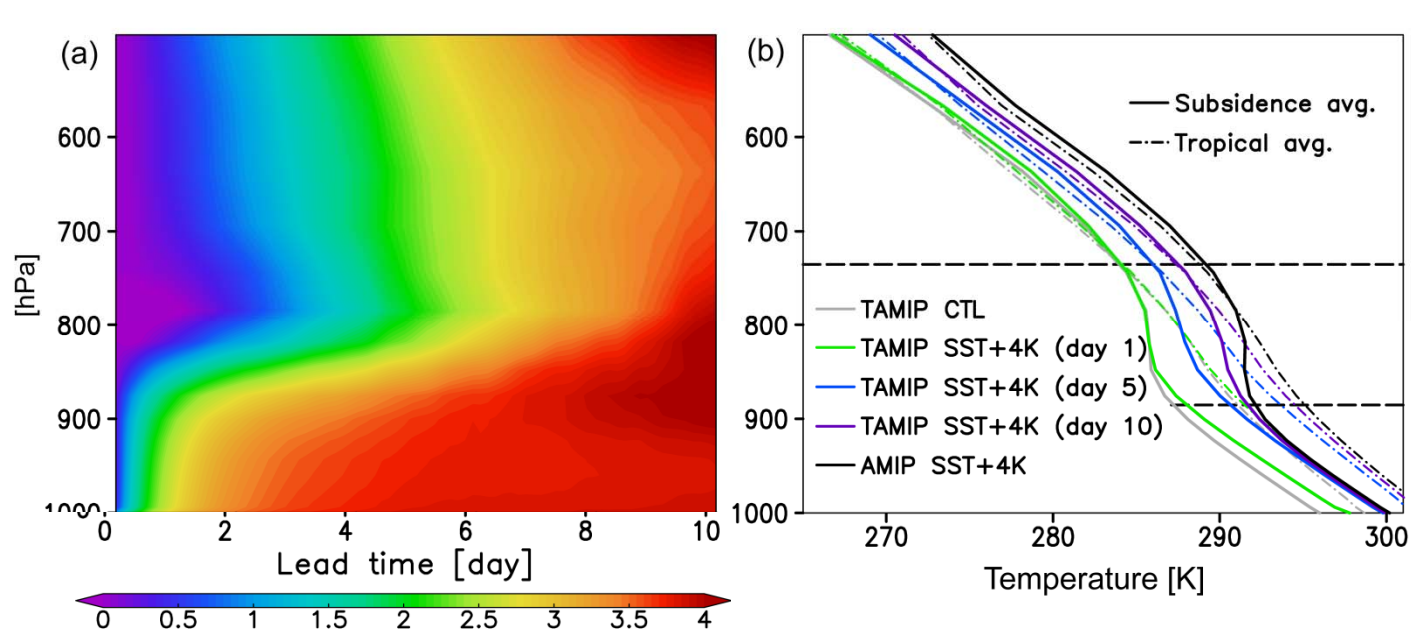
Tendency analysis

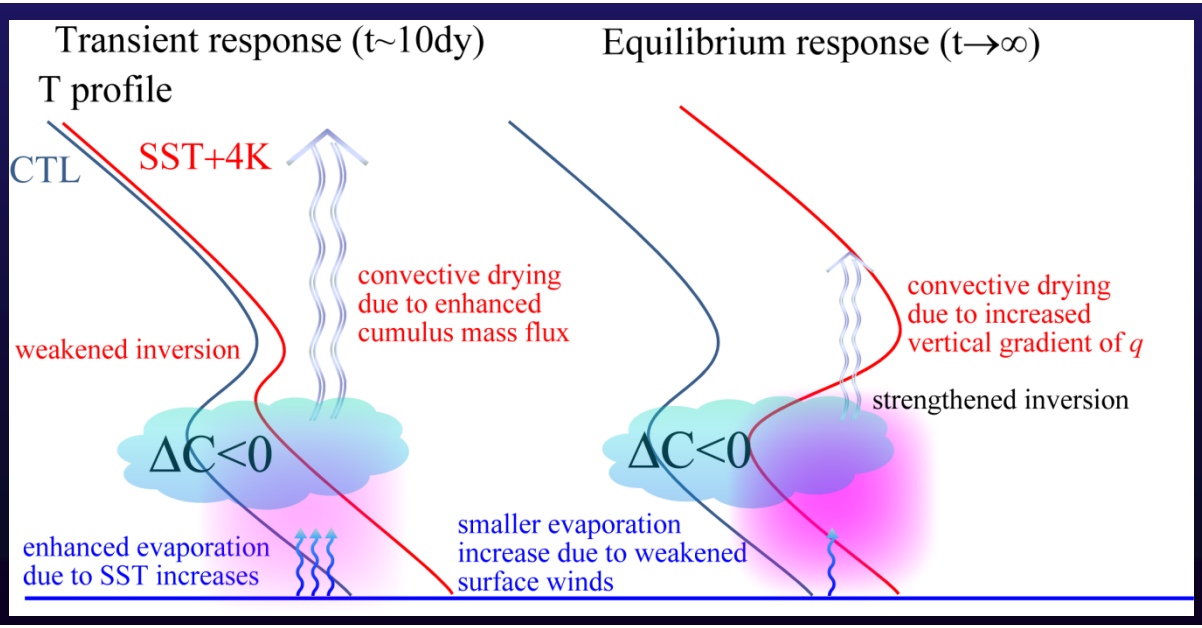
Why low clouds (<=> LWP) have to decline over the subsidence regions ?



Demoto, Watanabe, and Kamae (2013, GRL)

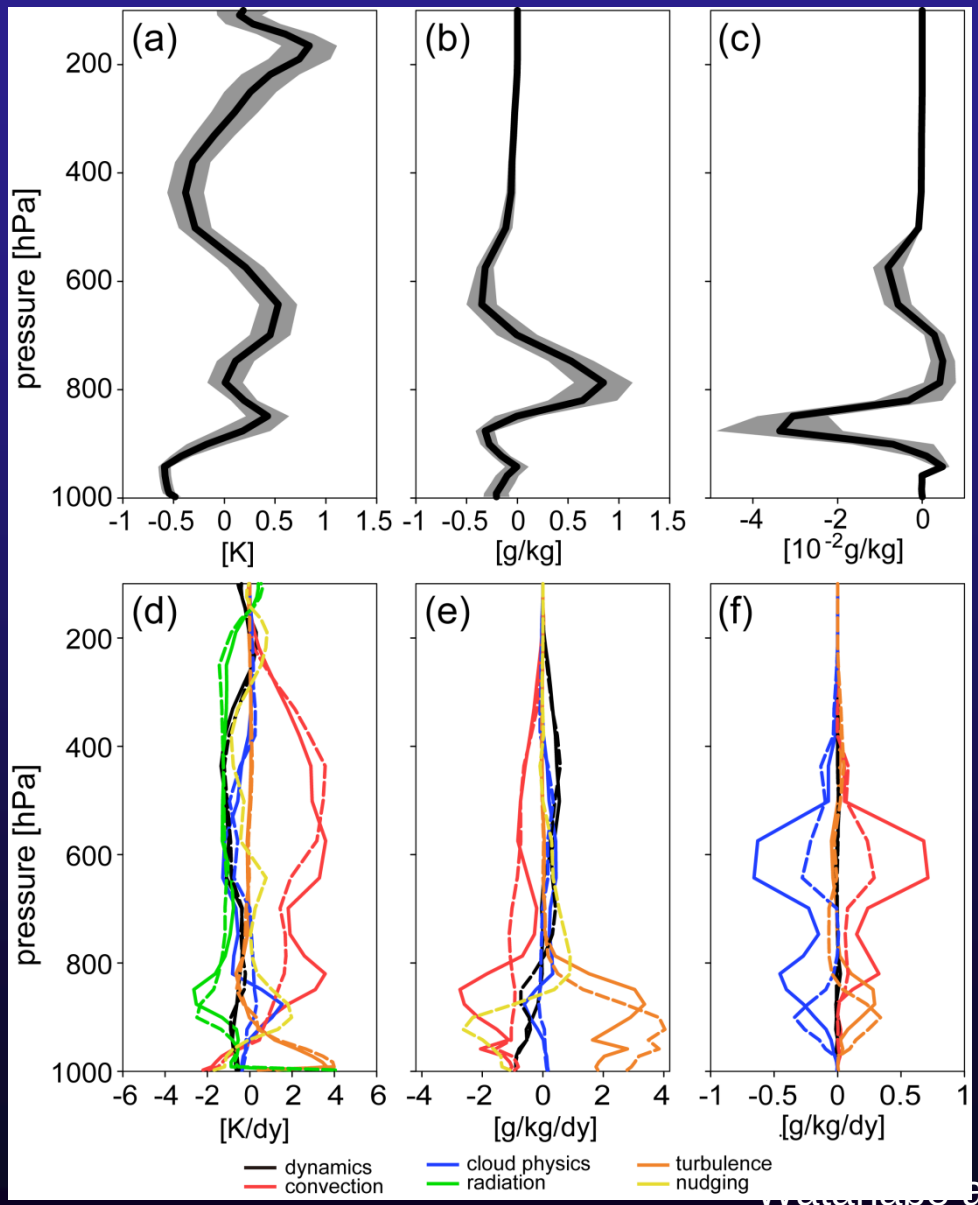
Two timescales in the response





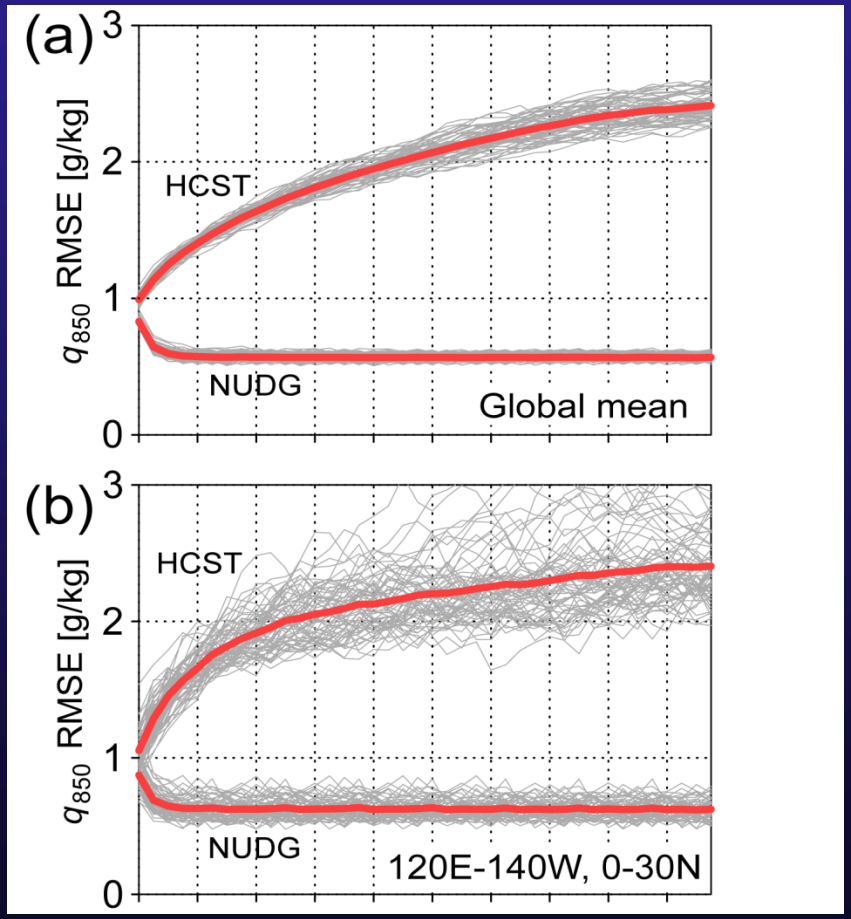
Kamae (2013, GRL)

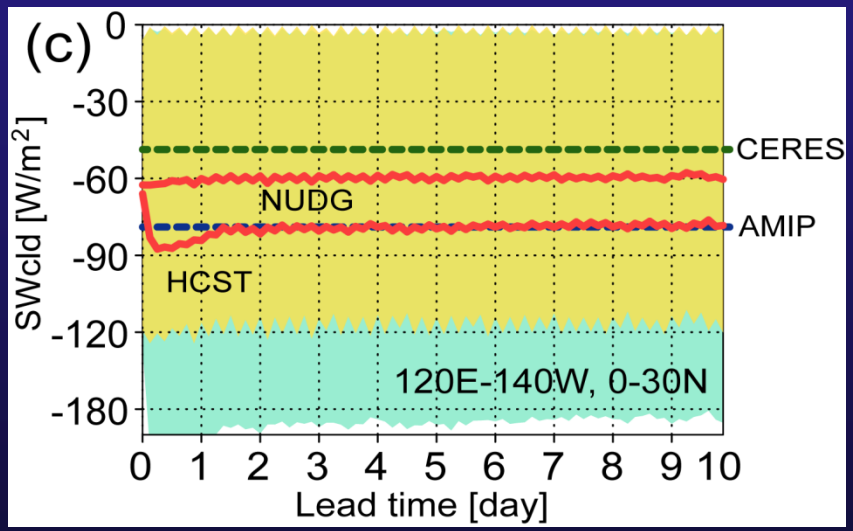
Cloud regimes



and Jiang (2013, in prep)

Cloud regimes





Watanabe and Jiang (2013, in prep)

議論

✓TAMIP実験の意義について

→ ハインドキャストが本質ではない。

短期間のアンサンブル実験を用いて速い応答プロセスを特定できることが重要。

✓‘initial adjustment’ には ECMWFの再解析を用いた初期値化によって生じうる初期ショックが含まれているのではないか

→AMIPコントロール実験の大気場で初期値化した追加実験（30日積分）を行った。

そのショックがここまでの議論に本質的でないことを確認した。

✓TAMIPの10日間の過渡応答が、AMIPの平衡応答をどの程度で説明できるのか

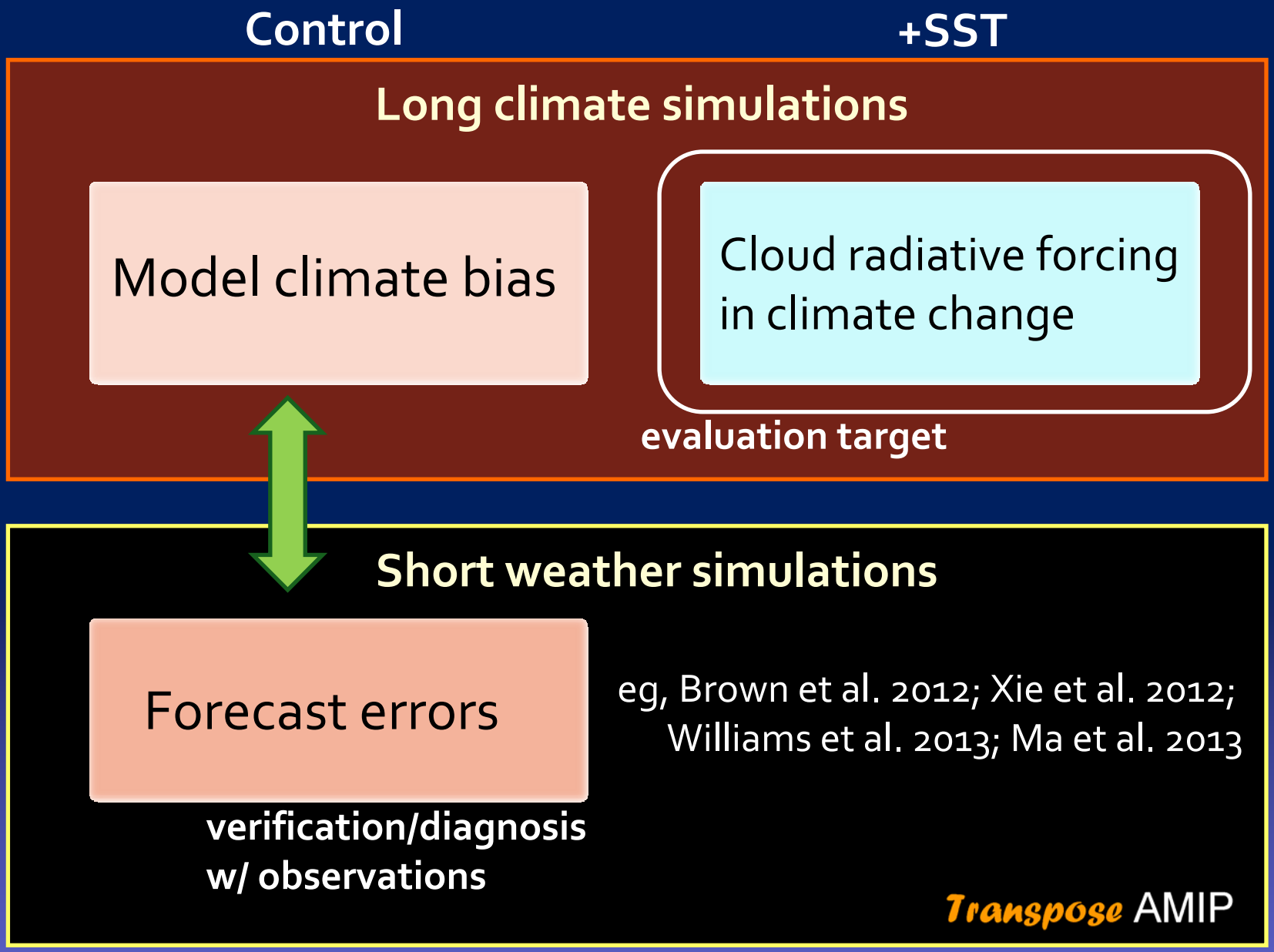
→積雲対流による乾燥化の働き方は変わる（30日積分の解析より）。

10日目以降の変化は下層雲応答を変えるほど大きくない。

✓今回ひとつのモデルしか用いていないが、解釈の妥当性をどう議論するか

→Single column model (SCM)を用いて、外部強制の変化に対する雲の応答の違いを検証する。

Seamless model evaluation



Seamless model evaluation