Timescale and the role of land-sea contrast in the tropospheric adjustment

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Outline of this talk

Toward a process-based understanding of tropospheric adjustment (cloud, radiation, etc) …

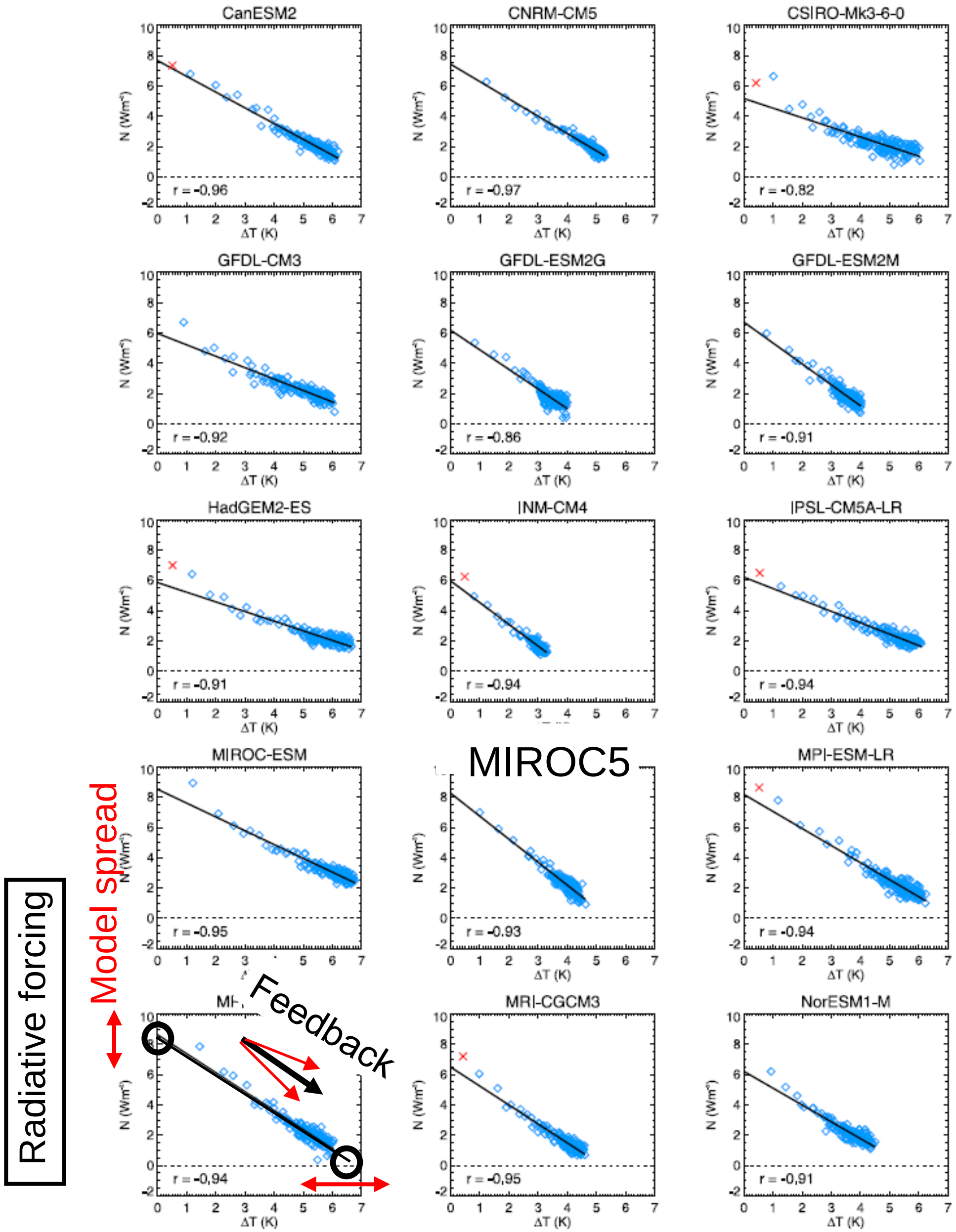
1. **Fast tropos adjustment over the ocean**

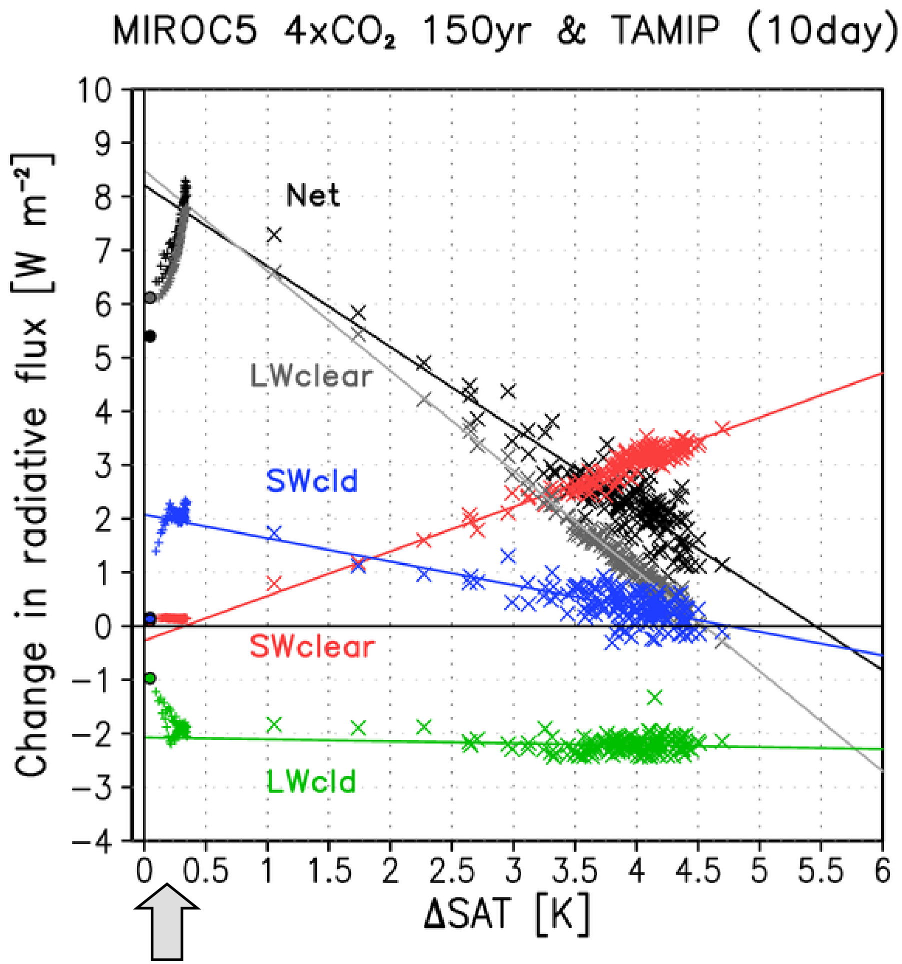
   ✓ 64 member ensemble of transpose-AMIP experiments

2. **Land effect on tropos adjustment**

   ✓ Aqua-planet + rectangular continent experiments

CMIP5 $4xCO_2$ (Andrews et al. 2012)





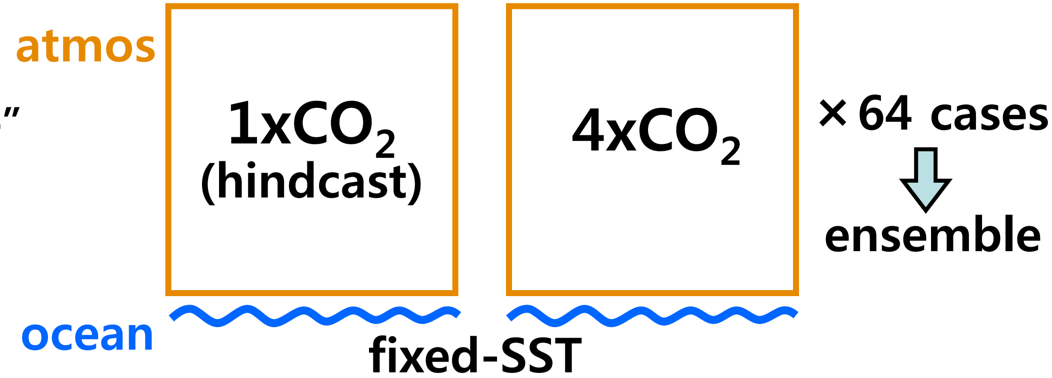
Fill the blank!

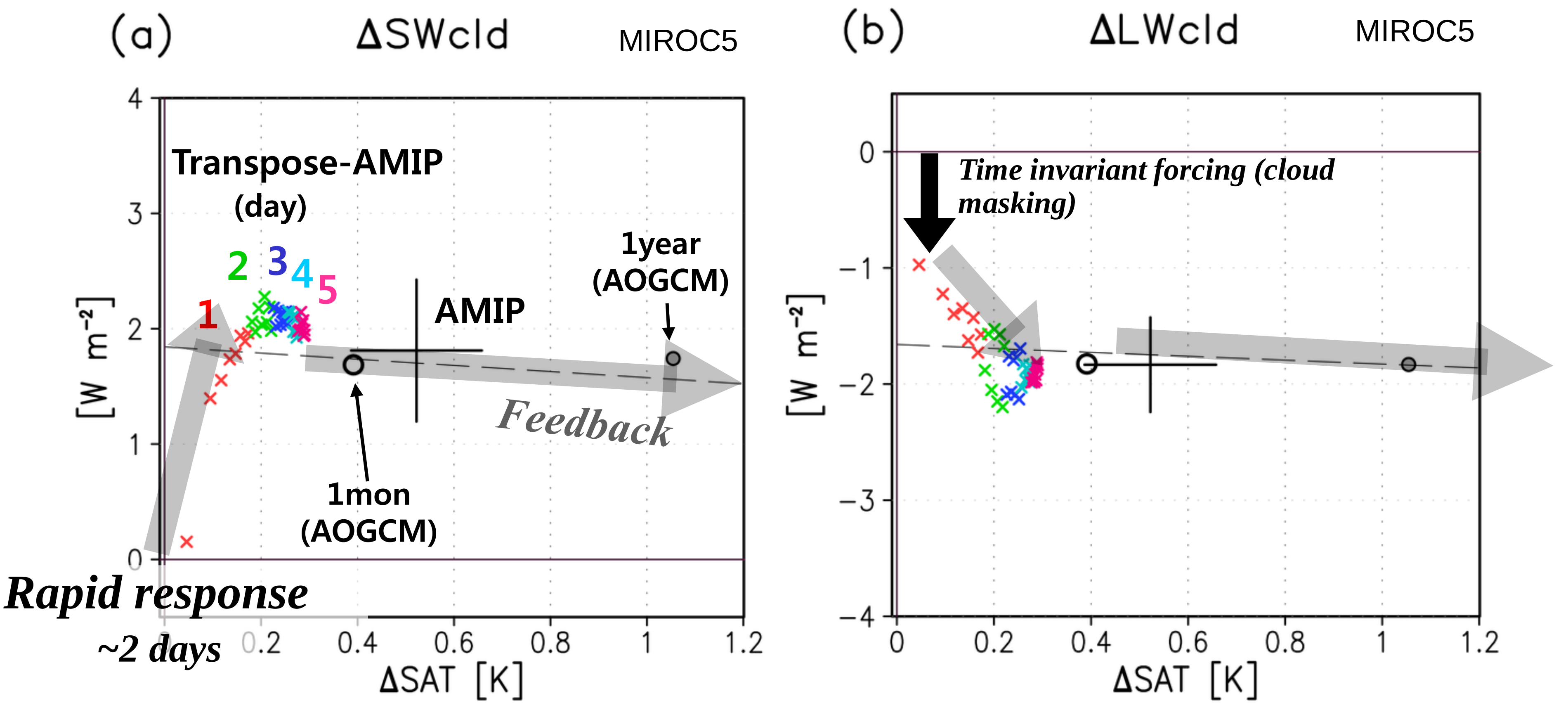
Phillips et al. (2004)

Transpose AMIP

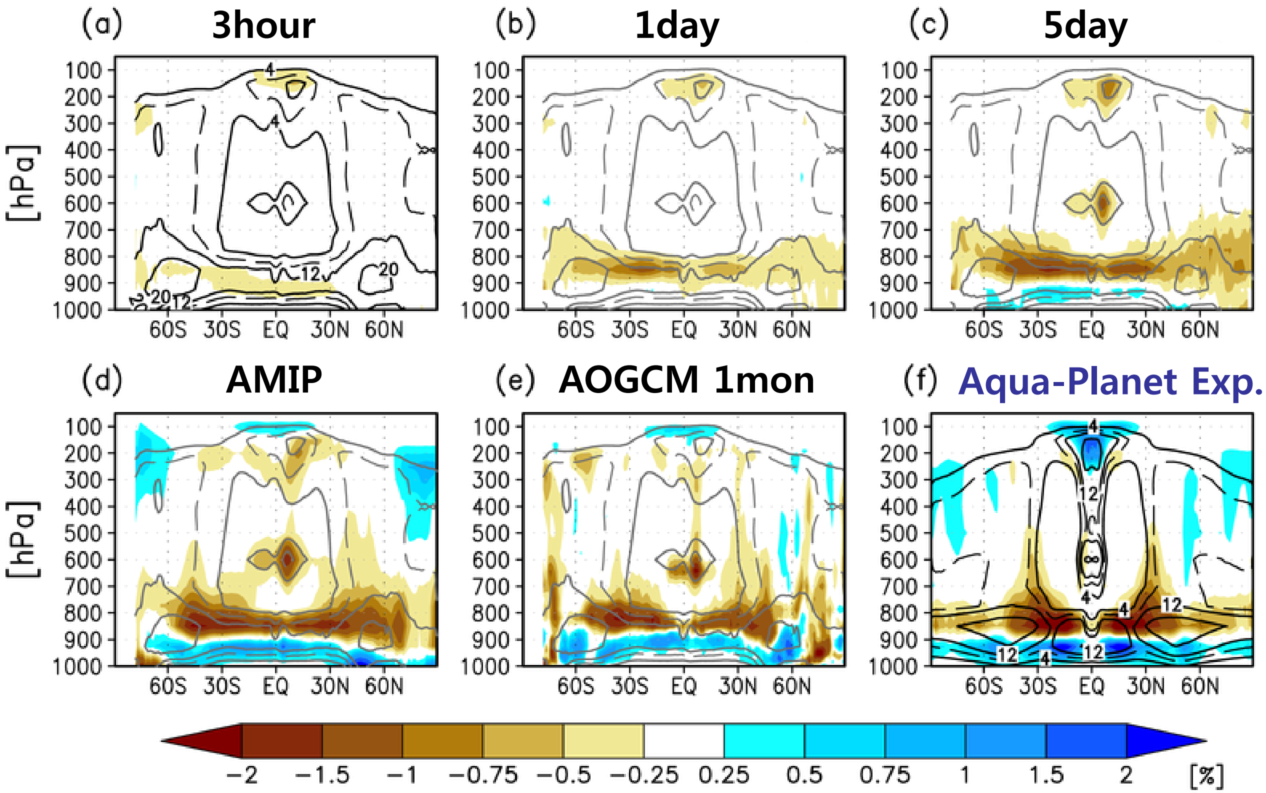
run GCMs in "weather forecasts mode"

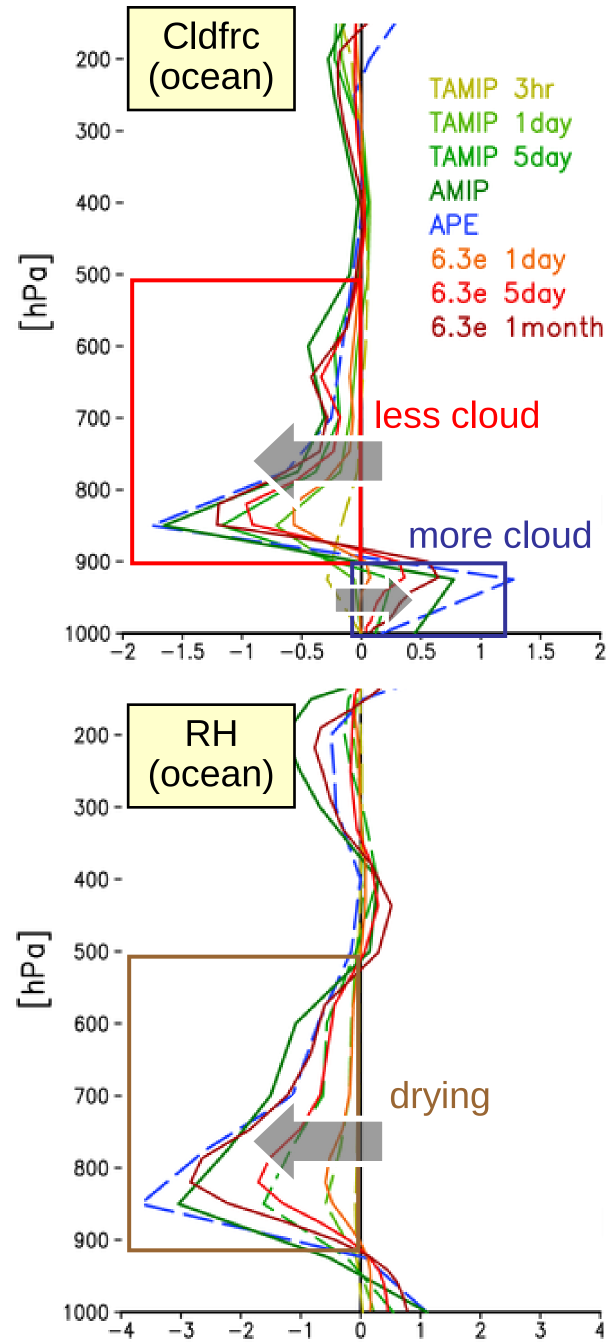
- ✓ ECMWF YOTC initialized
- ✓ 5 days integration
- ✓ Saved data: 3 hourly





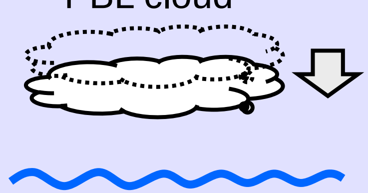
Cloud fraction (ocean)



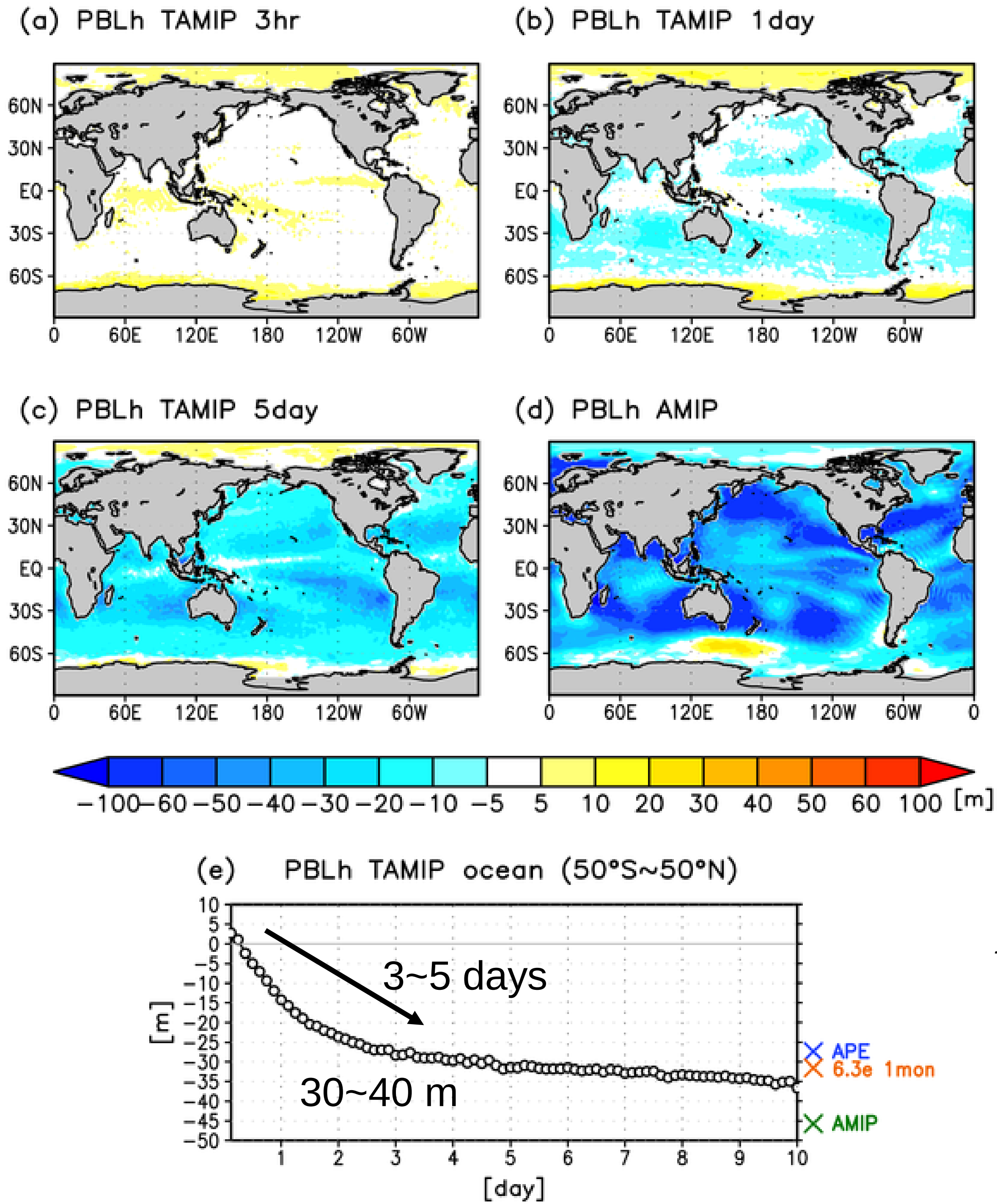


✓ Marine PBL shallowing

… can occur without land/sea contrast



✓ Cloud decreasing → Positive SWcld

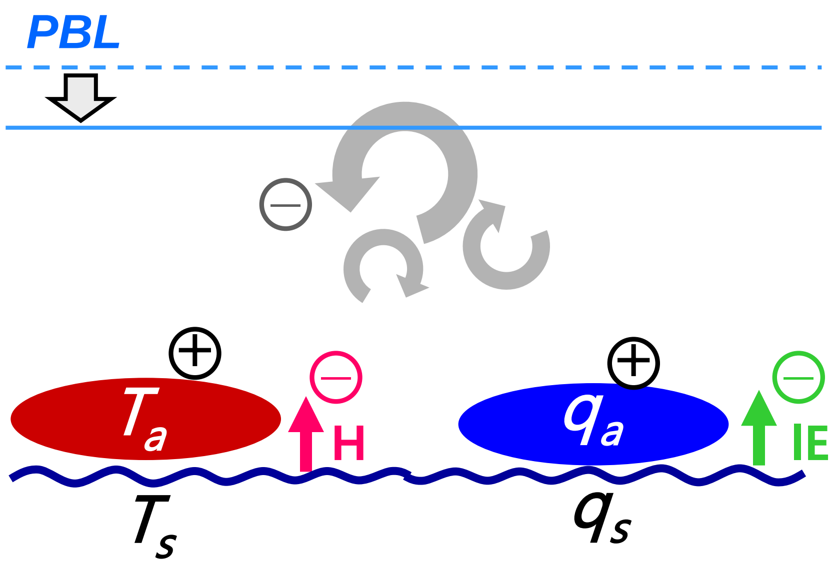


MPBL shallowing

Rapid response (daily-scale)

Mechanisms

I. Decreasing buoyancy flux



Ta, qa increase

⇩

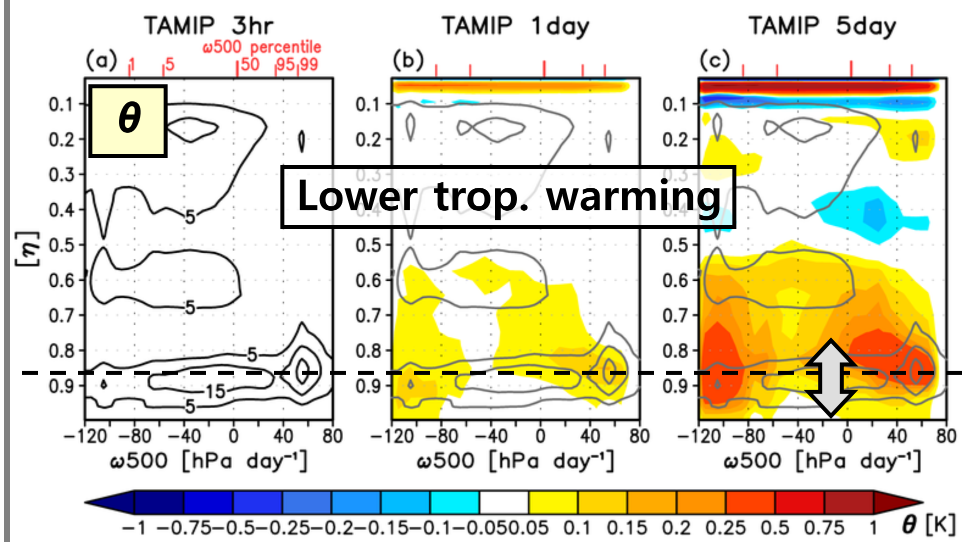
H & IE decrease

⇩

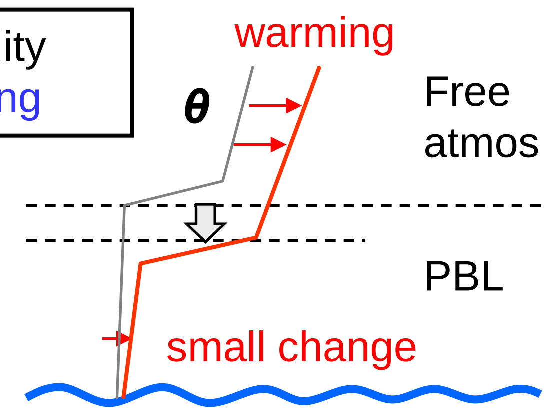
PBL shallowing

e.g. Watanabe et al. (2011)

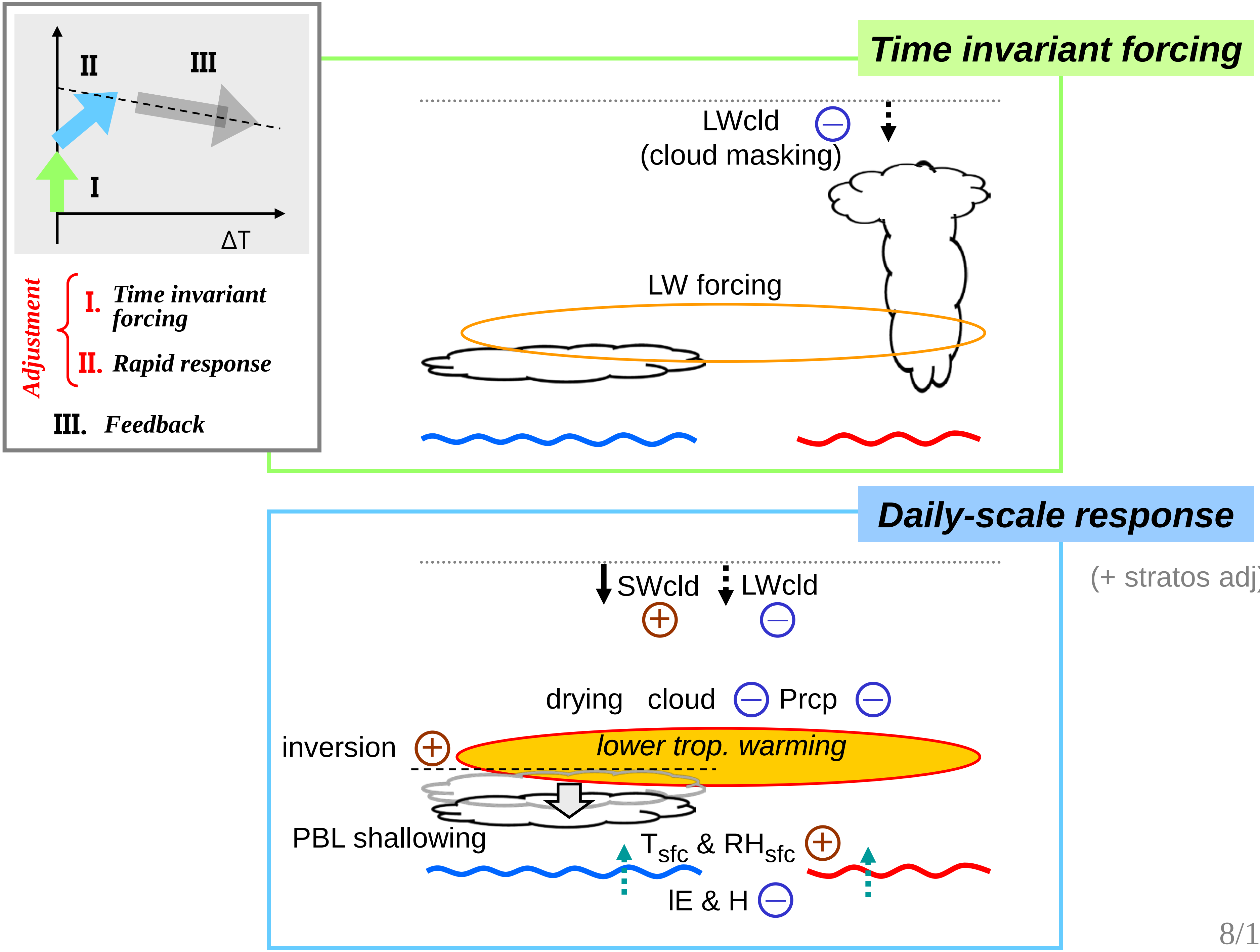
II. Strengthening of PBL inversion



increasing stability
→ PBL shallowing

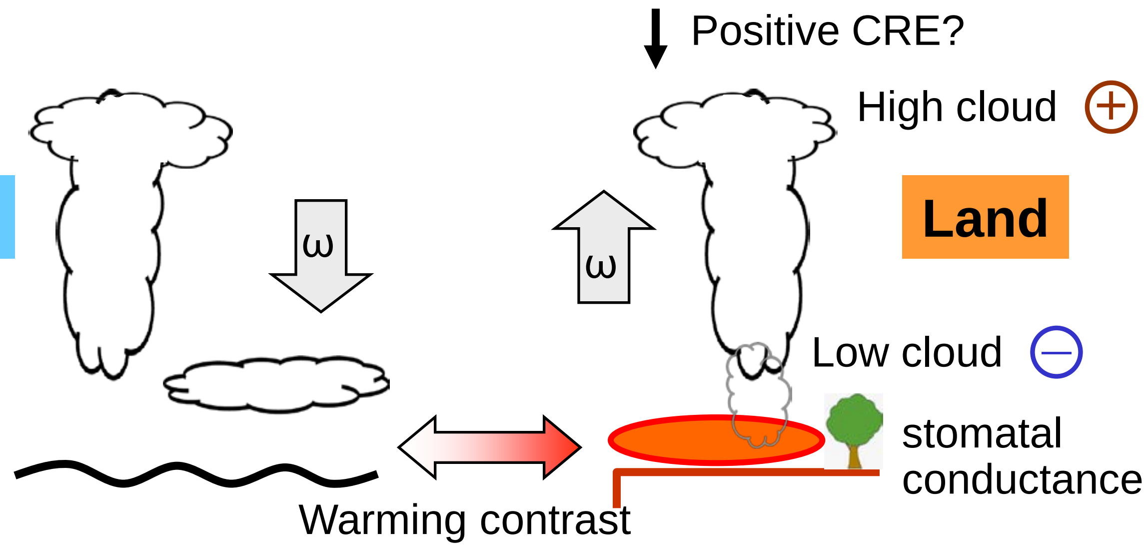


e.g. Wyant et al. (2012)



II
III
I
ΔT
Adjustment
I. Time invariant forcing
II. Rapid response
III. Feedback
Time invariant forcing
LWcld ⊖
(cloud masking)
LW forcing
Daily-scale response
(+ stratos adj)
SWcld ⊕
LWcld ⊖
drying
cloud ⊖
Prcp ⊖
inversion ⊕
lower trop. warming
PBL shallowing
Tsfc & RHsfc ⊕
lE & H ⊖

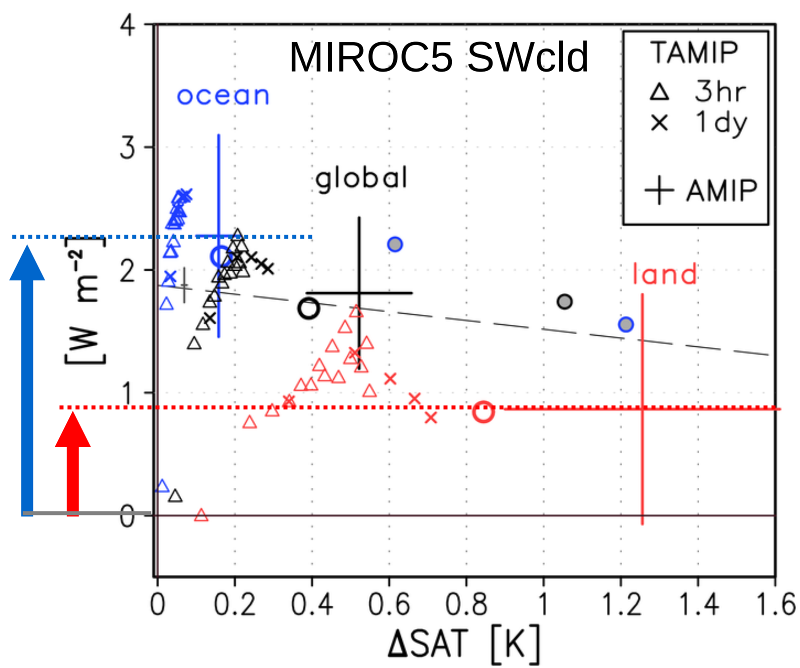
The land-sea contrast is not essential ??



Doutriaux-Boucher et al. (2009)
Dong et al. (2009)
Andrews et al. (2011)
Lambert et al. (2011)
Wyant et al. (2012)

Adjustment

Ocean > Land

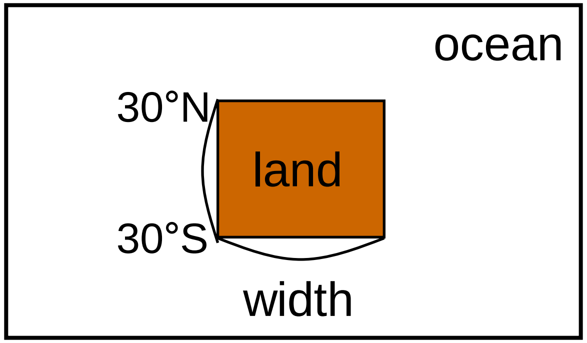


Existence / Size of continent

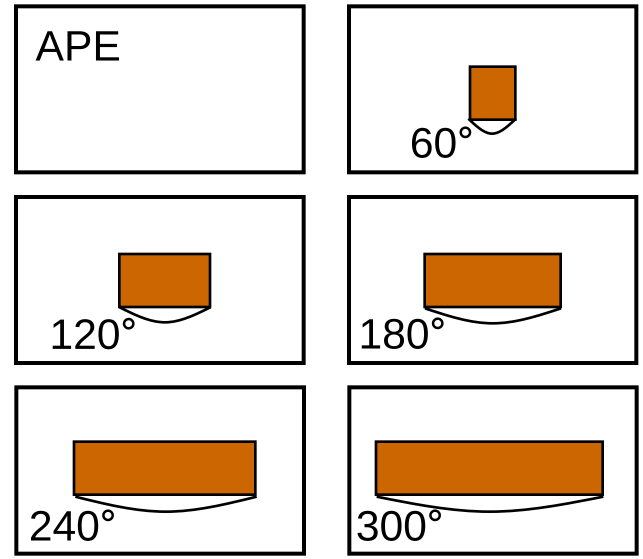
??

Total adjustment

Aqua-planet + rectangular continent experiment



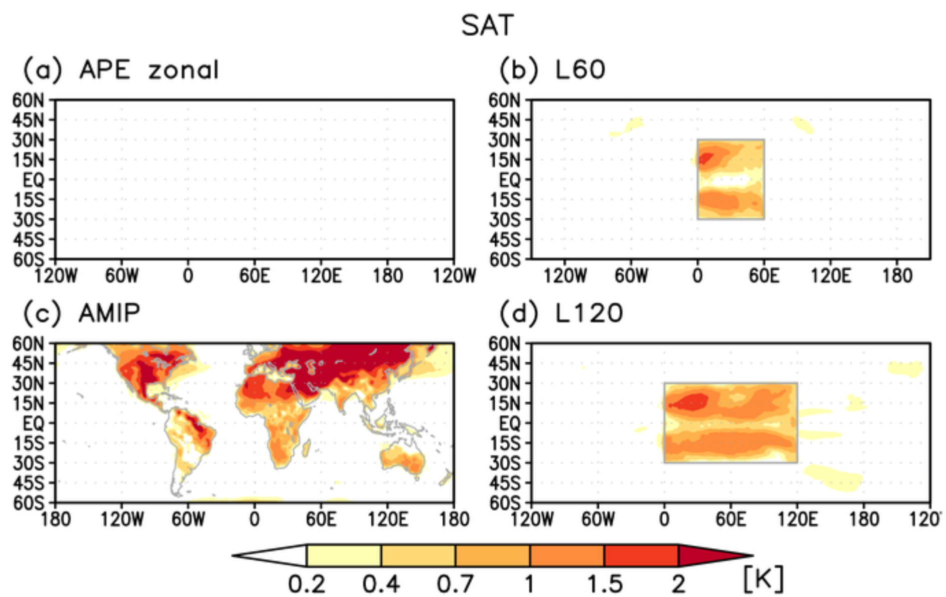
✓ *6 types config*

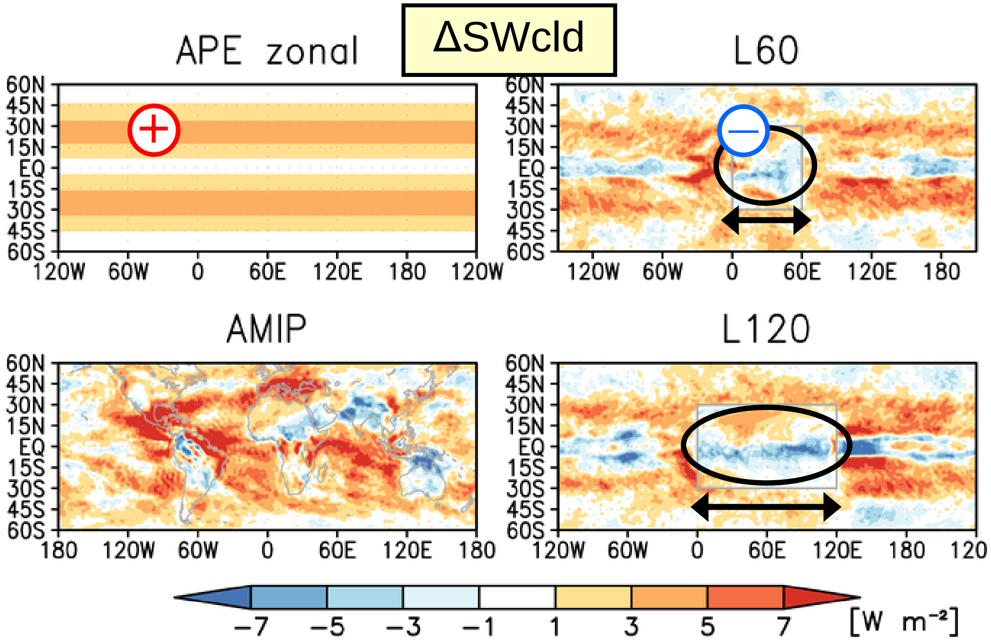


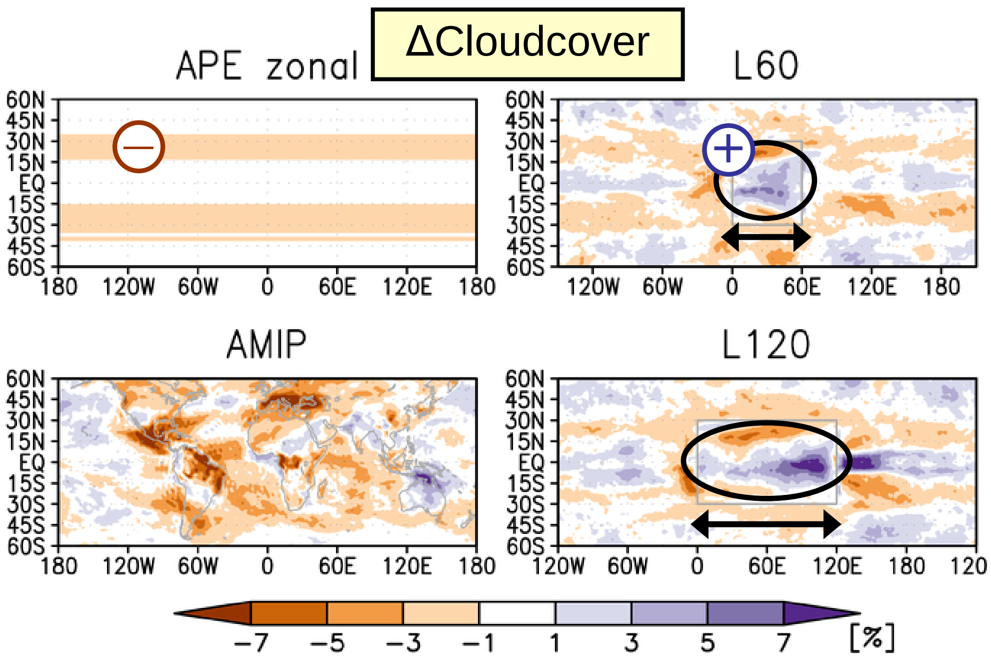
- ✓ SST, sea ice : fixed
- ✓ Land cover: the most dominant type in each lati.
- ✓ $1xCO_2$ & $4xCO_2$ experiments
- ✓ 6 years integration

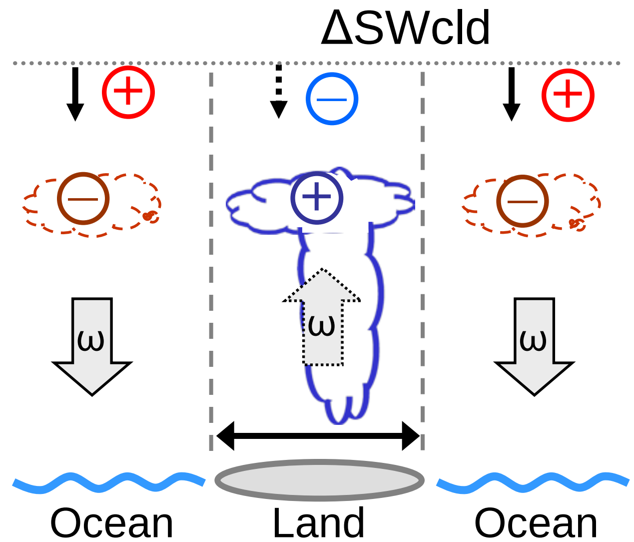
ΔSAT

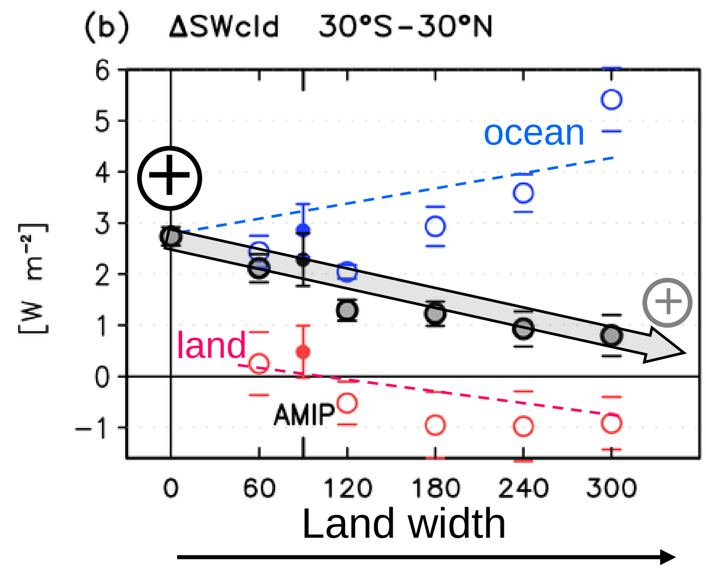
$4xCO_2 – 1xCO_2$











As land becomes larger,
the land effect becomes more prominent

Summary

Over theového ocean …

✓ **Reduction of mid & low cloud** due to **LW forcing**
→ **Positive/negative adjustment in SWcld/LWcld**

✓ **PBL shallowing** corresponds with **decrease of buoyancy fluxes** and **strengthening of PBL inversion**

Daily-scale responses to **Time-invariant forcings**

The land-sea contrast …

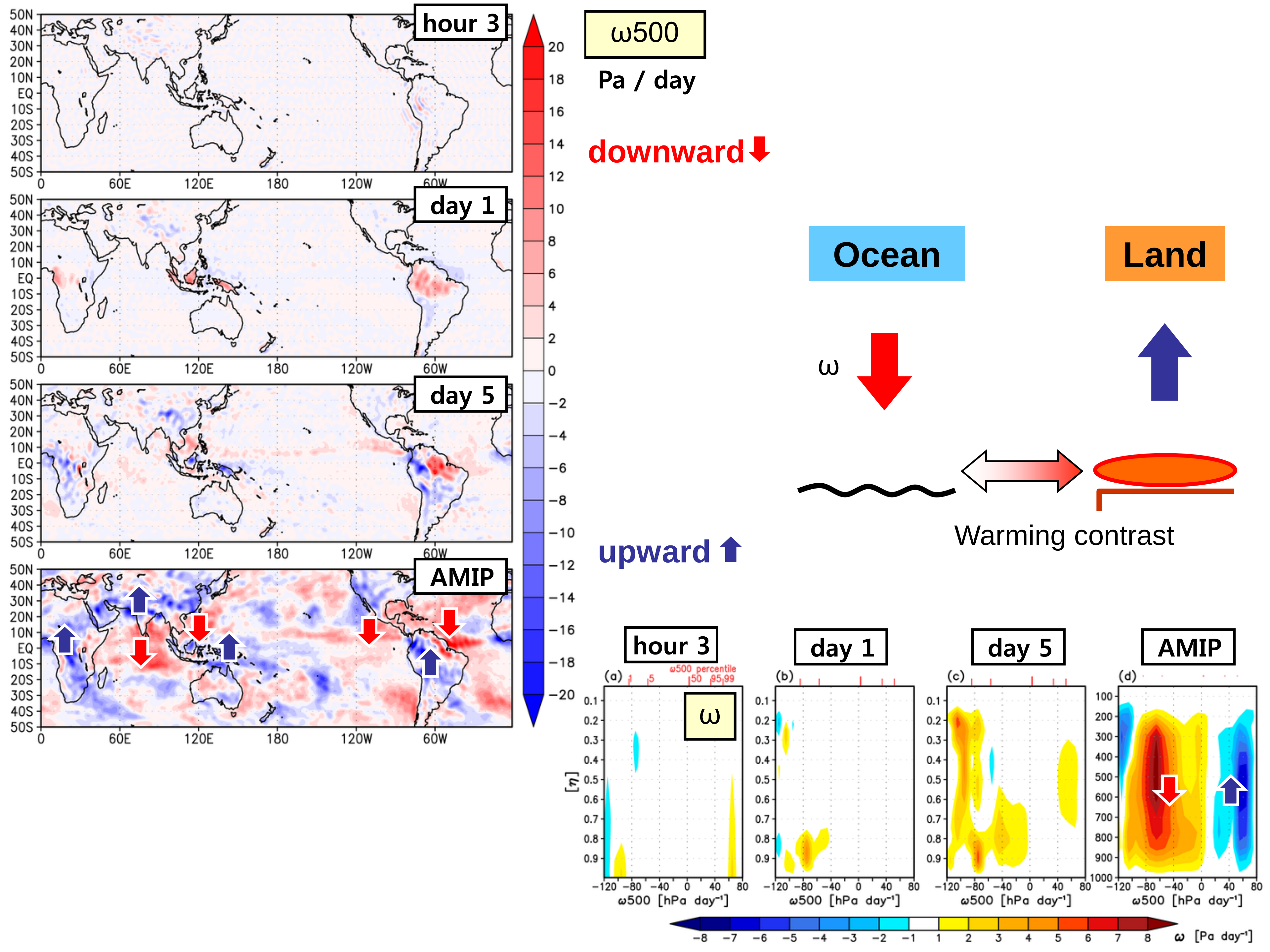
regulates the tropos adjustment quantitatively
But it is not essential

Further questions / implications

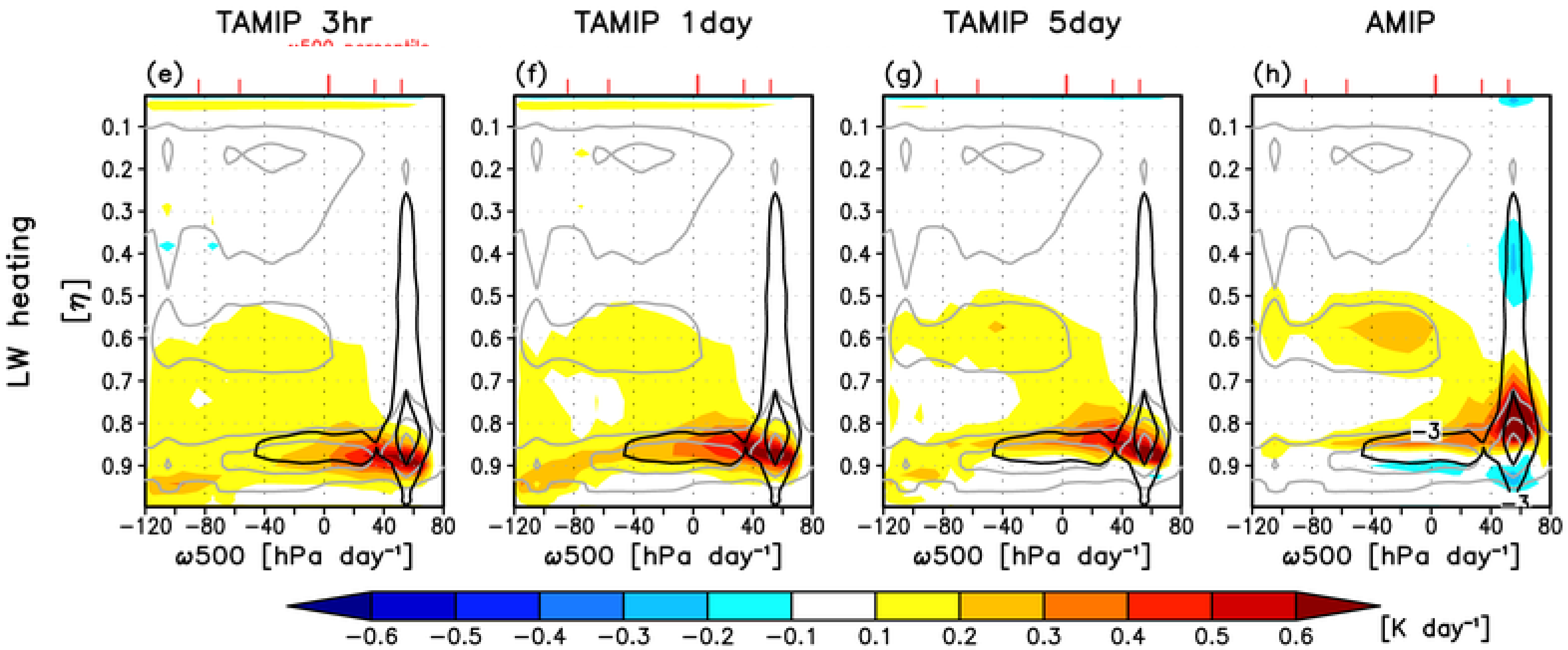
✓ Robustness of daily responses and role of land-sea contrasts among CFMIP/CMIP5 multi-models

✓ What determines the timescale of rapid responses? Radiation? Circulation?

✓ Any relations with slower climate responses?



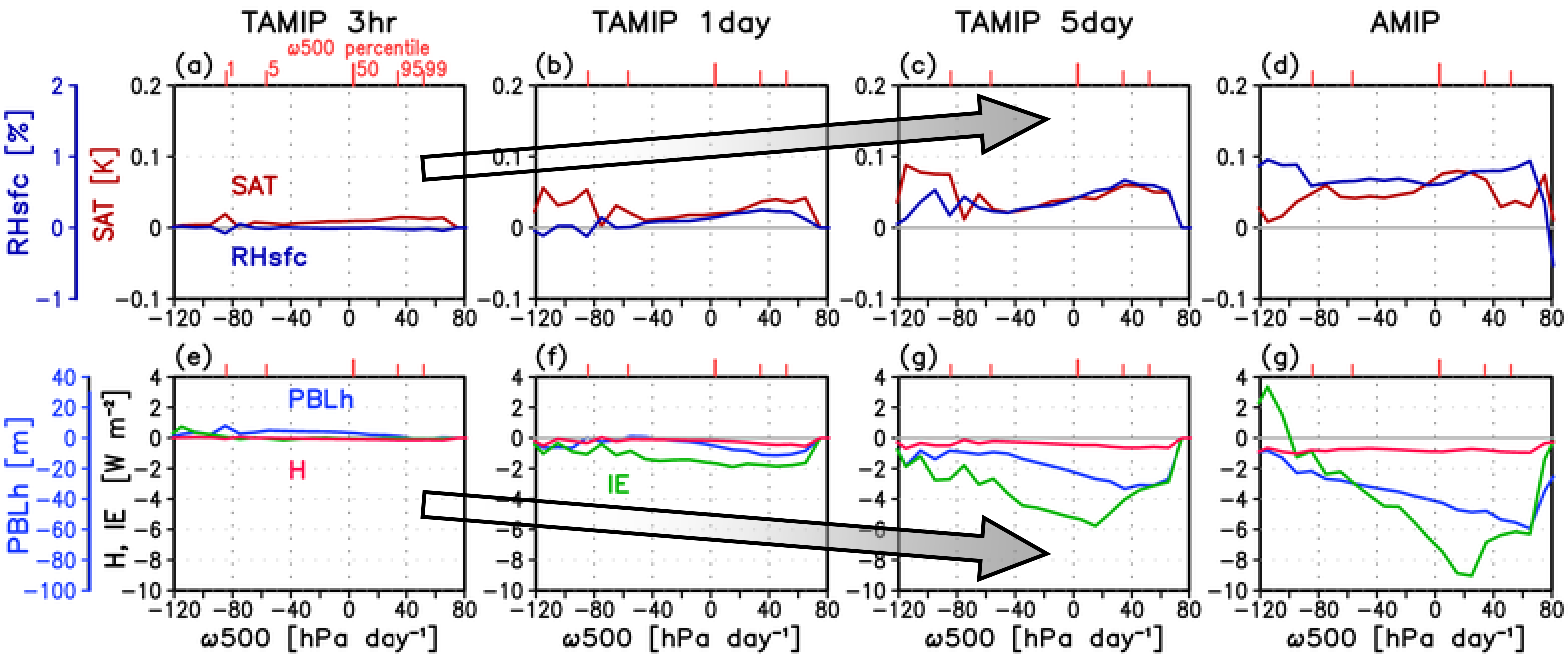
hour 3
day 1
day 5
AMIP
ω500
Pa / day
downward
upward
Ocean
Land
ω
Warming contrast
hour 3
day 1
day 5
AMIP
(a)
(b)
(c)
(d)
ω500 percentile
ω
[η]
ω500 [hPa day⁻¹]
ω [Pa day⁻¹]



TAMIP 3hr
TAMIP 1day
TAMIP 5day
AMIP
(e)
(f)
(g)
(h)
LW heating
[η]
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
−120
−80
−40
0
40
80
ω500 [hPa day⁻¹]
−3
−0.6
−0.5
−0.4
−0.3
−0.2
−0.1
0.1
0.2
0.3
0.4
0.5
0.6
[K day⁻¹]

Mechanism I.

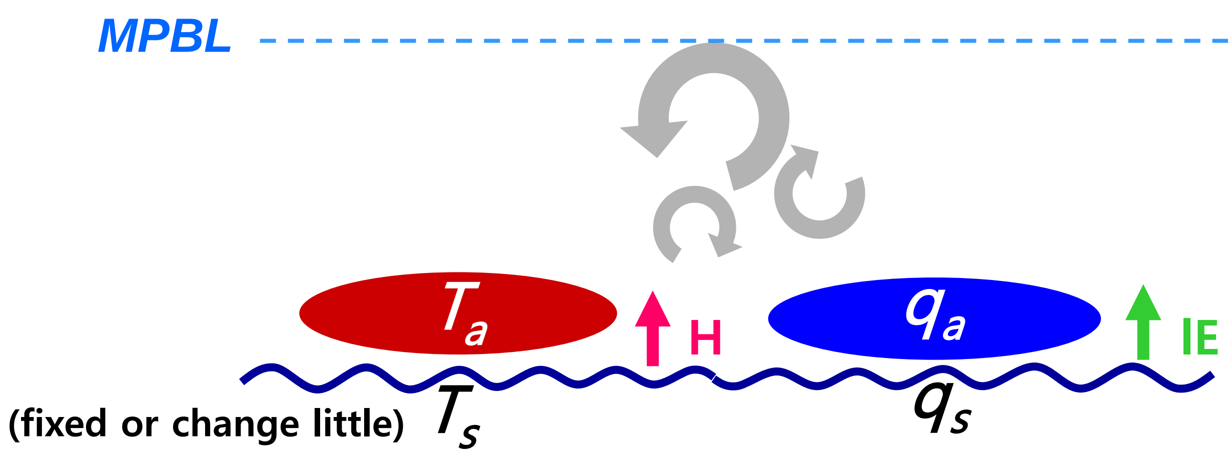
Decreasing of buoyancy flux



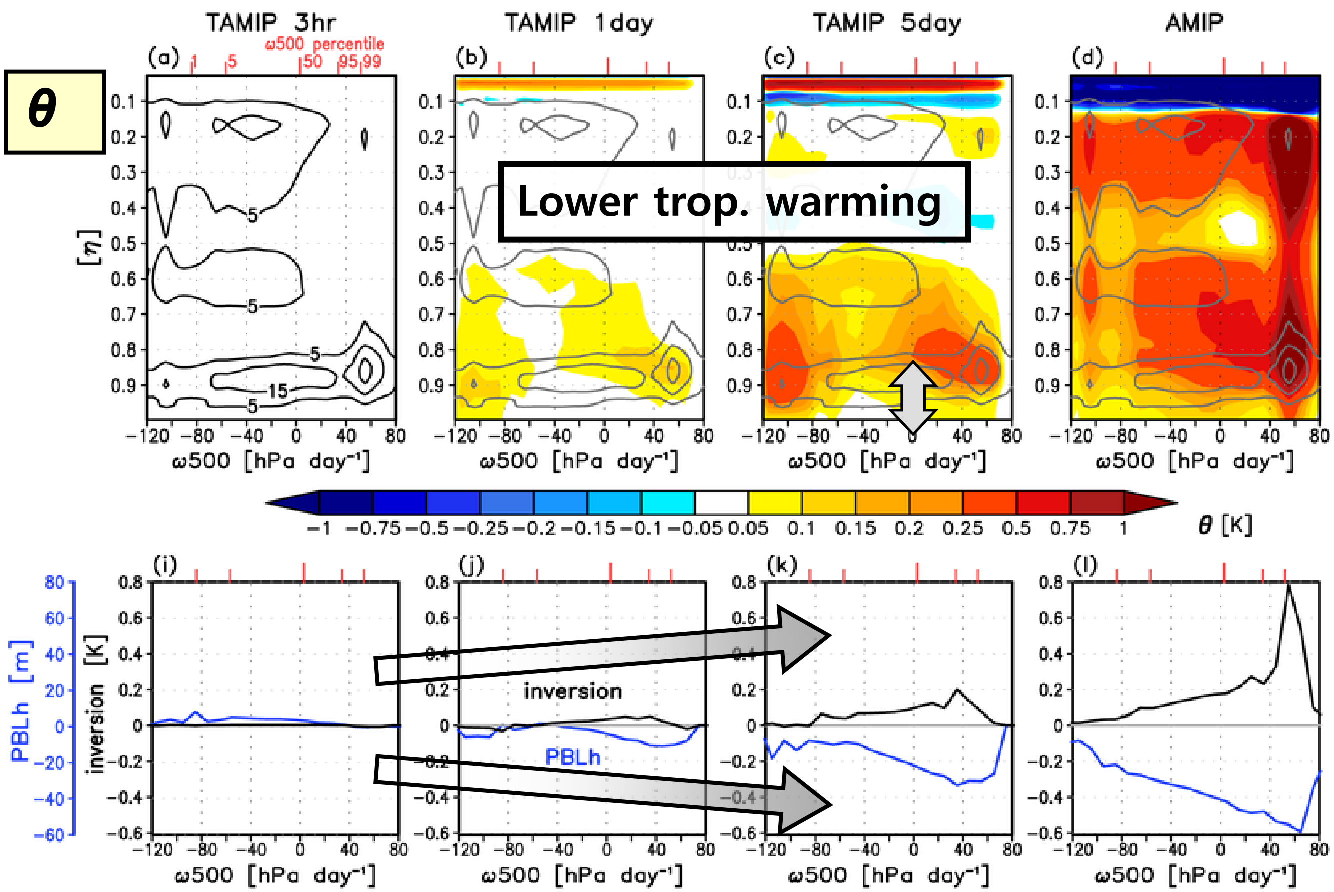
Ta, qa increase

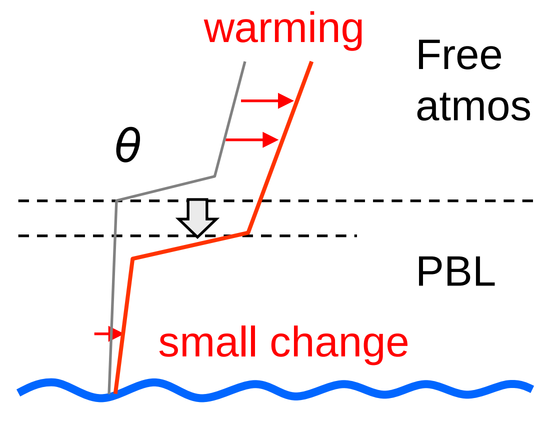
H & IE decrease

MPBL shallowing



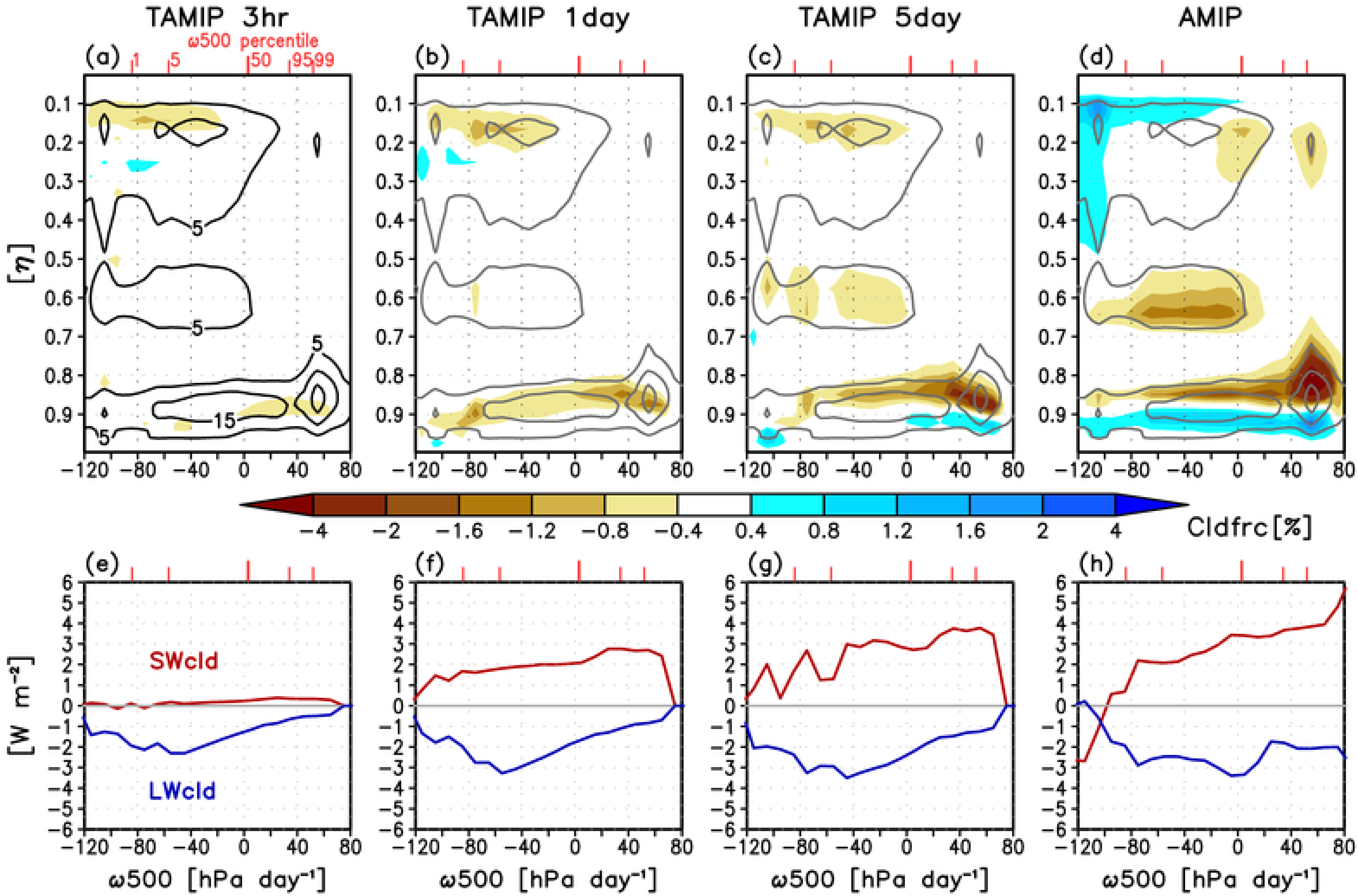
Mechanism II. Strengthening of PBL inversion



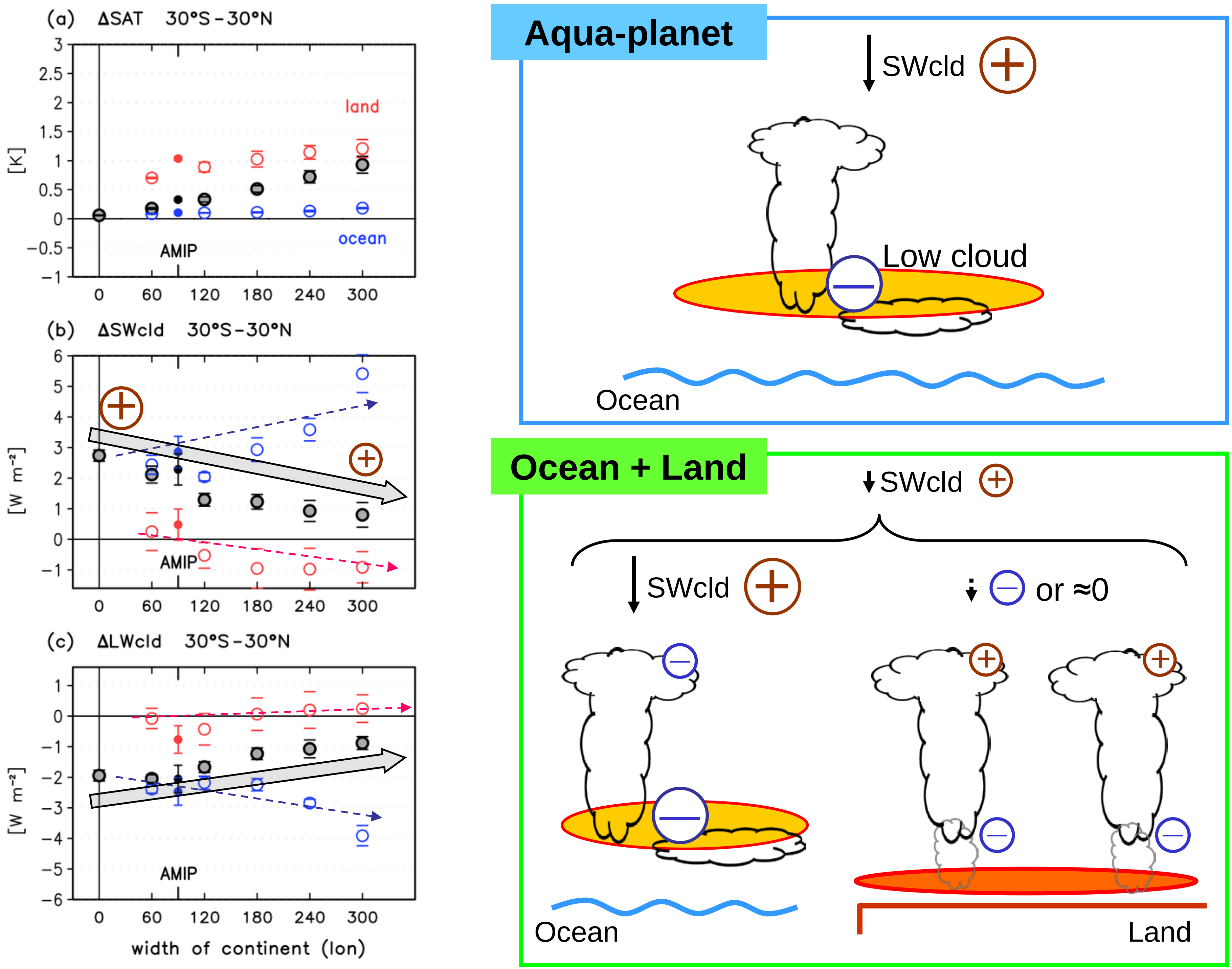


increasing stability
→ PBL shallowing

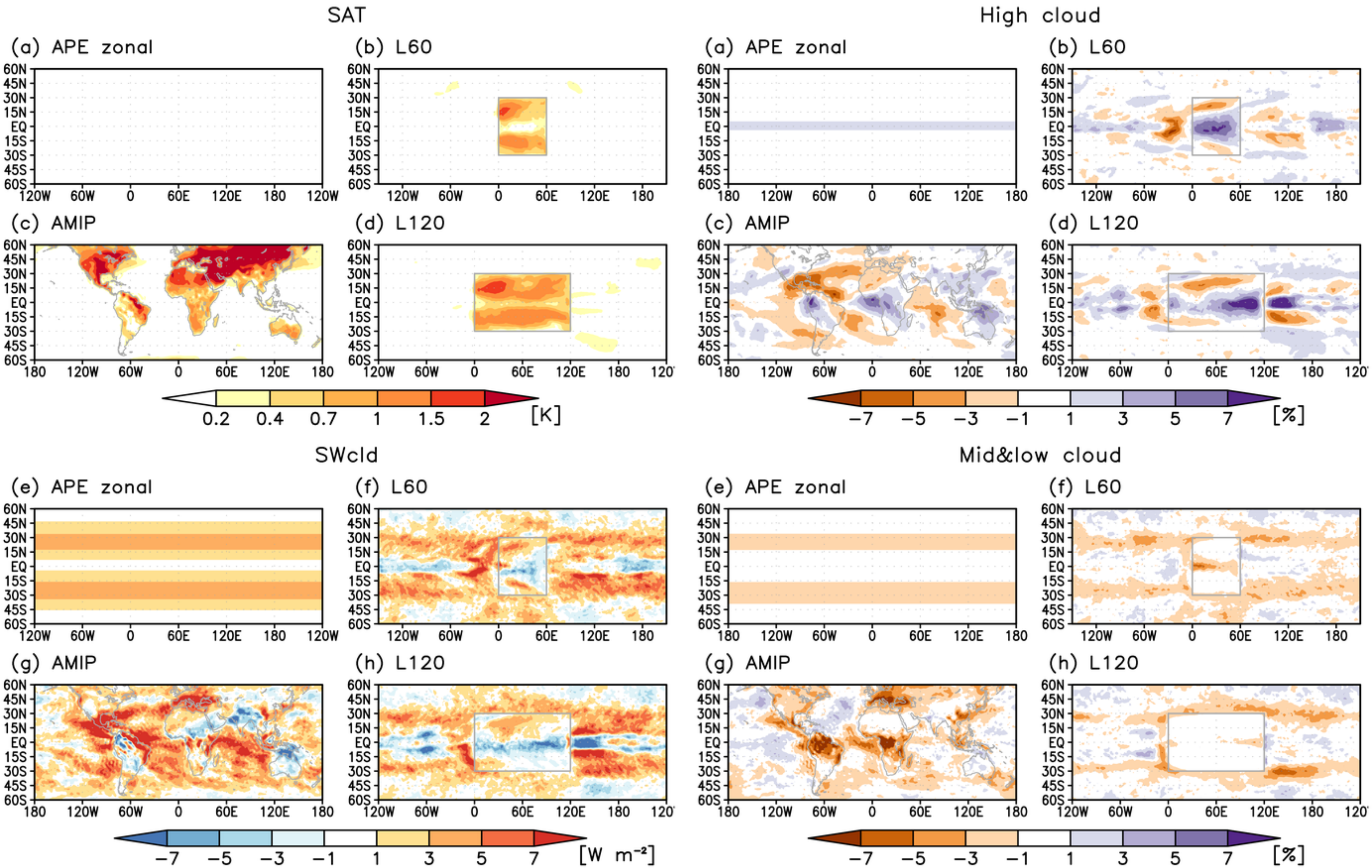
Free atmos warming due to LW heating
→ Strengthening of PBL inversion
→ PBL shallowing



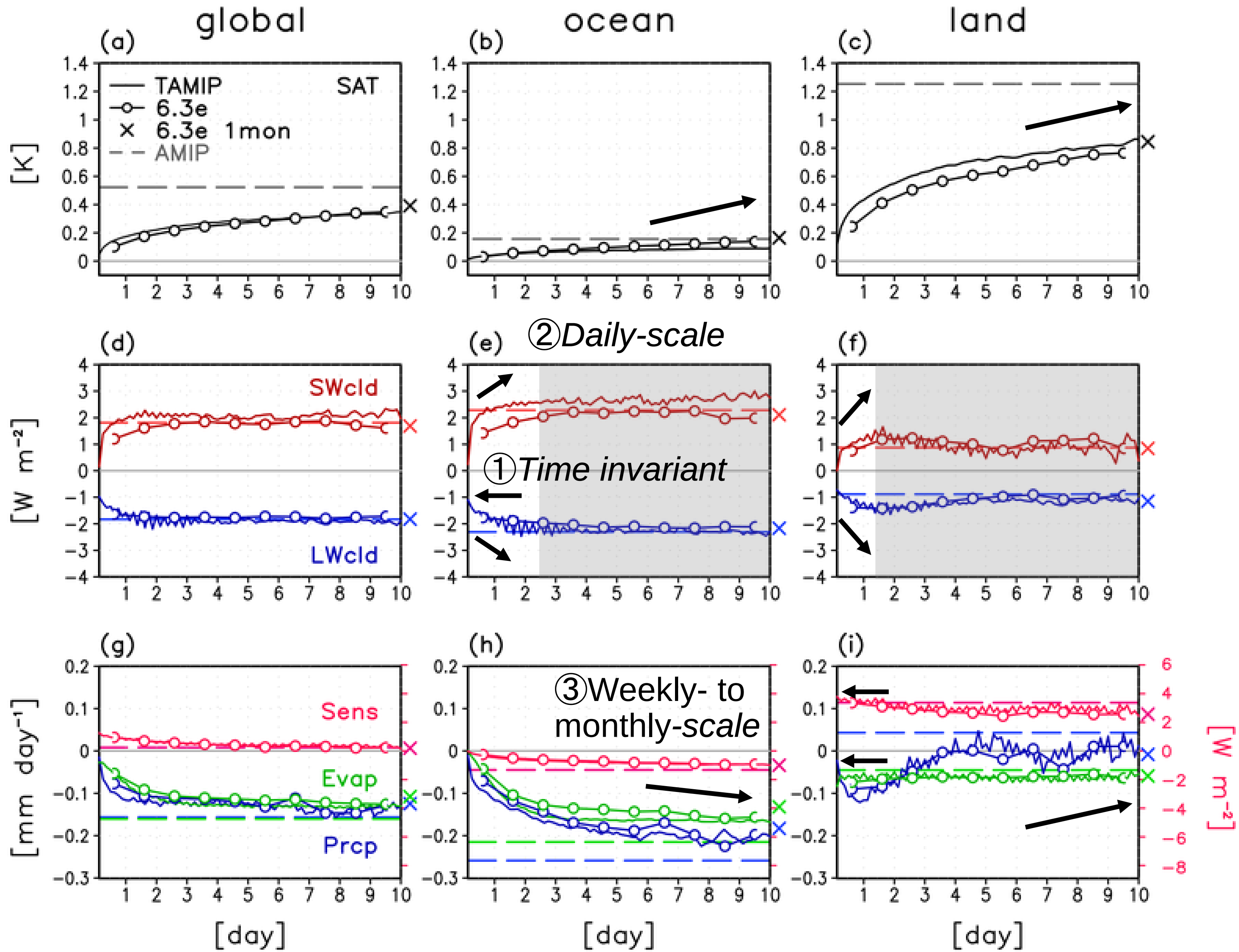
TAMIP 3hr
TAMIP 1day
TAMIP 5day
AMIP
ω500 percentile
1
5
50
95
99
(a)
(b)
(c)
(d)
(e)
(f)
(g)
(h)
[η]
Cldfrc[%]
SWcld
LWcld
[W m⁻²]
ω500 [hPa day⁻¹]



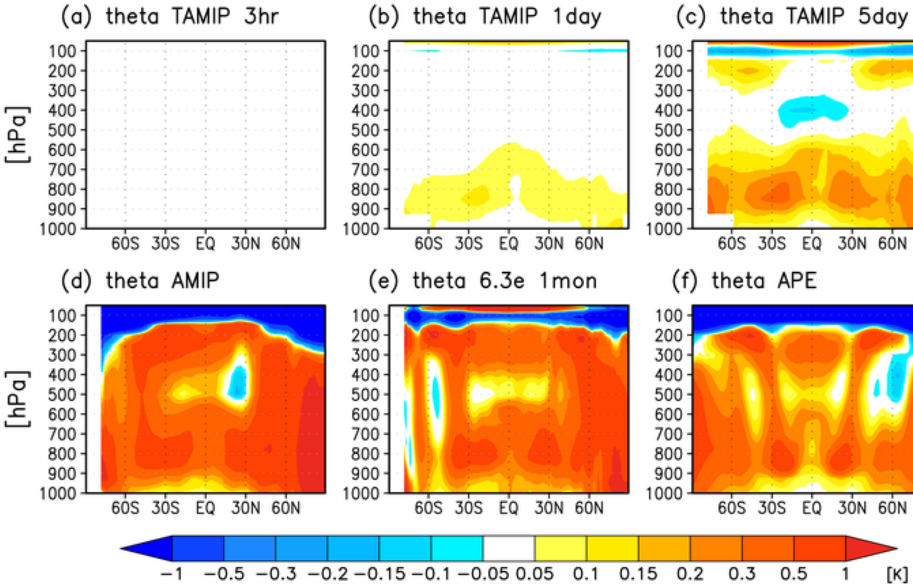
(a) ΔSAT 30°S-30°N
[K]
land
ocean
AMIP
(b) ΔSWcld 30°S-30°N
[W m⁻²]
AMIP
(c) ΔLWcld 30°S-30°N
[W m⁻²]
AMIP
width of continent (lon)
Aqua-planet
SWcld
Low cloud
Ocean
Ocean + Land
SWcld
SWcld
or ≈0
Ocean
Land

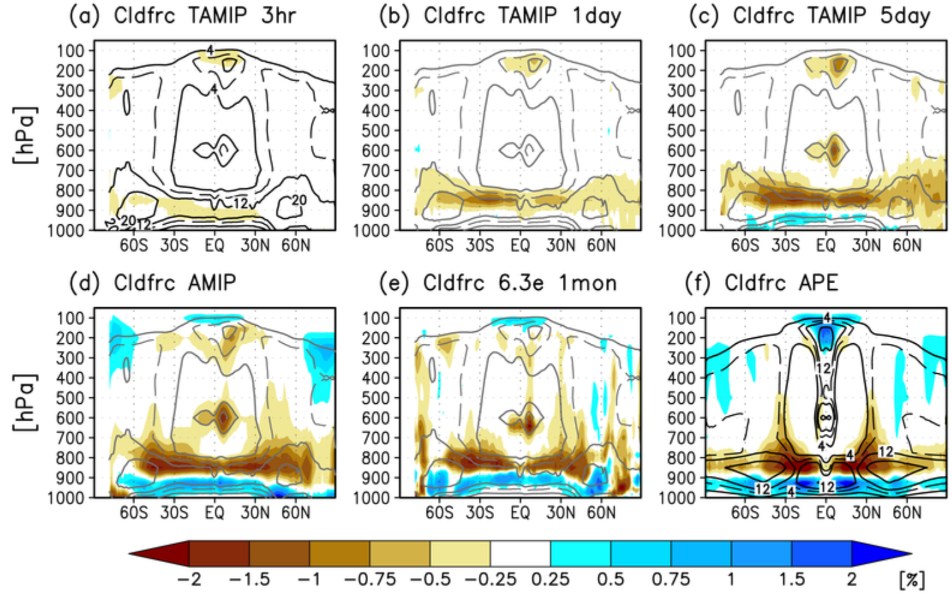


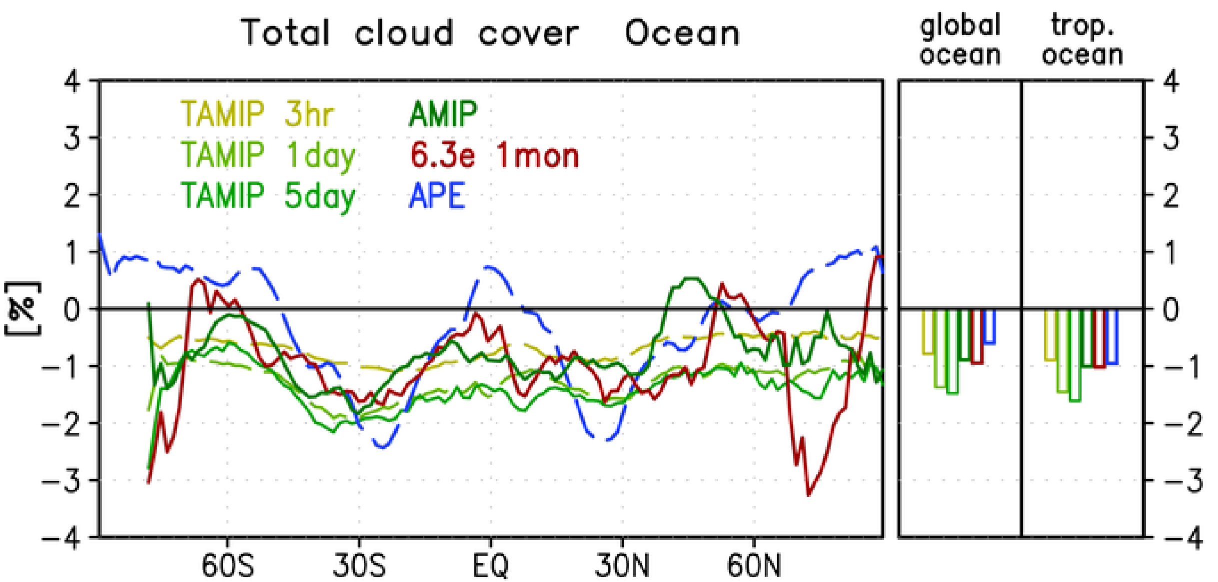
SAT
High cloud
(a) APE zonal
(b) L60
(c) AMIP
(d) L120
0.2 0.4 0.7 1 1.5 2 [K]
−7 −5 −3 −1 1 3 5 7 [%]
SWcld
Mid&low cloud
(e) APE zonal
(f) L60
(g) AMIP
(h) L120
−7 −5 −3 −1 1 3 5 7 [W m⁻²]
−7 −5 −3 −1 1 3 5 7 [%]



global
ocean
land
(a)
(b)
(c)
TAMIP
6.3e
6.3e 1mon
AMIP
SAT
[K]
(d)
(e)
(f)
②Daily-scale
SWcld
LWcld
①Time invariant
[W m⁻²]
(g)
(h)
(i)
Sens
Evap
Prcp
③Weekly- to monthly-scale
[mm day⁻¹]
[W m⁻²]
[day]


(a) theta TAMIP 3hr
(b) theta TAMIP 1day
(c) theta TAMIP 5day
(d) theta AMIP
(e) theta 6.3e 1mon
(f) theta APE
[hPa]
100 200 300 400 500 600 700 800 900 1000
60S 30S EQ 30N 60N
−1 −0.5 −0.3 −0.2 −0.15 −0.1 −0.05 0.05 0.1 0.15 0.2 0.3 0.5 1
[K]


(a) Cldfrc TAMIP 3hr
(b) Cldfrc TAMIP 1day
(c) Cldfrc TAMIP 5day
(d) Cldfrc AMIP
(e) Cldfrc 6.3e 1mon
(f) Cldfrc APE
[hPa]
100 200 300 400 500 600 700 800 900 1000
60S 30S EQ 30N 60N
−2 −1.5 −1 −0.75 −0.5 −0.25 0.25 0.5 0.75 1 1.5 2
[%]


Total cloud cover Ocean
global ocean
trop. ocean
TAMIP 3hr
TAMIP 1day
TAMIP 5day
AMIP
6.3e 1mon
APE
[%]
4 3 2 1 0 −1 −2 −3 −4
60S 30S EQ 30N 60N