Climate change with an iris-effect

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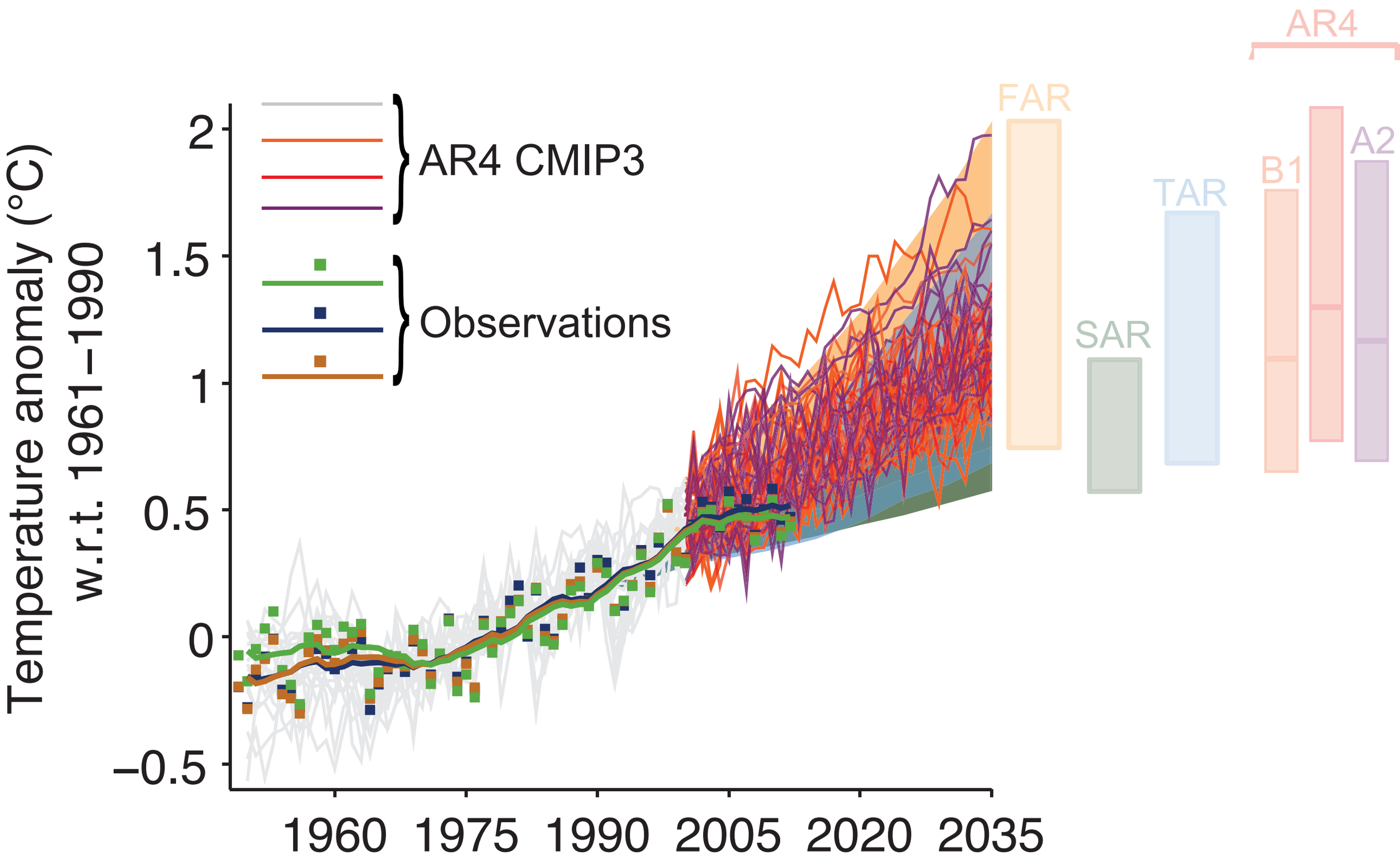
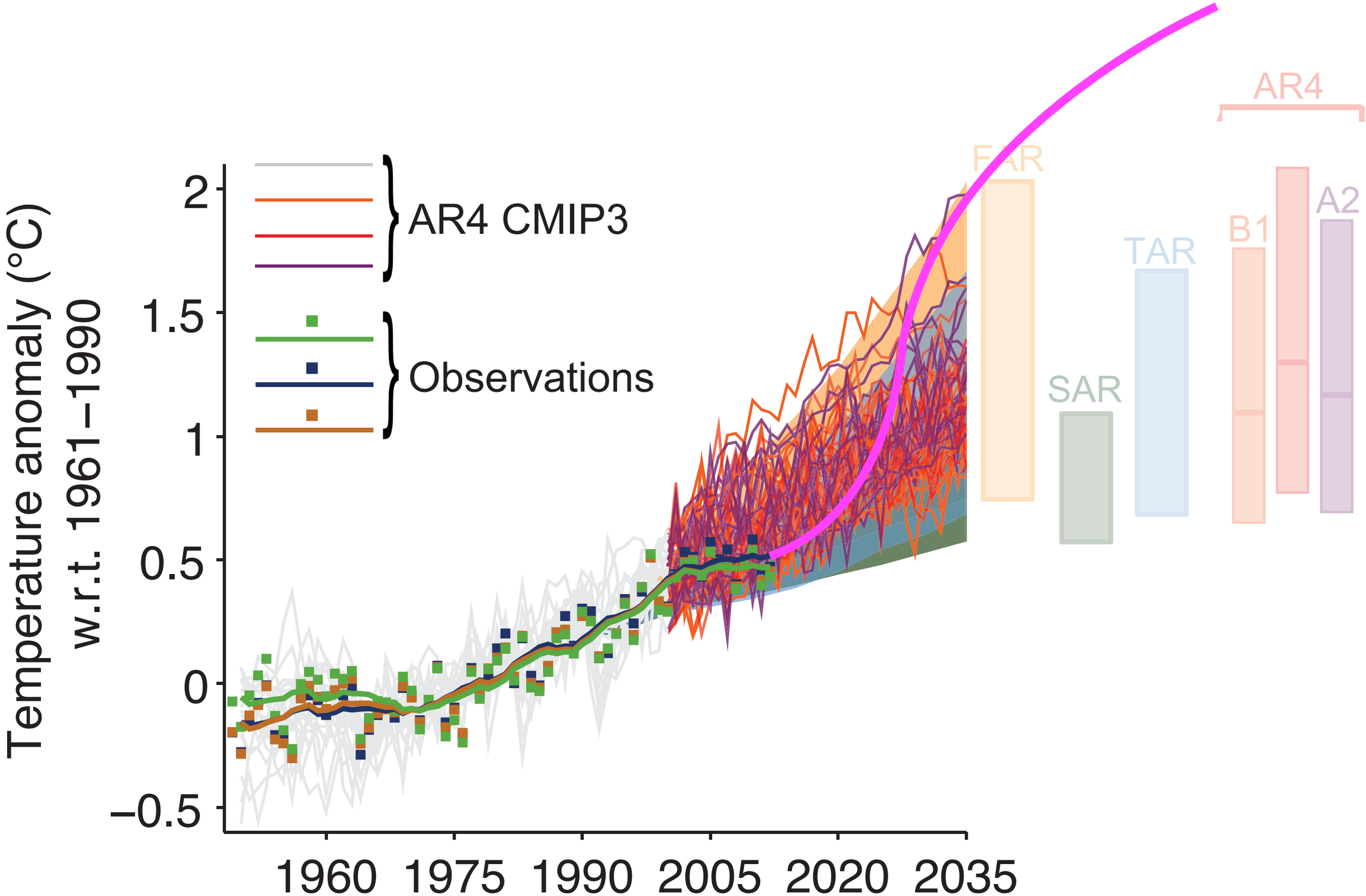

Temperature anomaly (°C)
w.r.t. 1961–1990
2
1.5
1
0.5
0
−0.5
1960
1975
1990
2005
2020
2035
AR4 CMIP3
Observations
AR4
FAR
SAR
TAR
B1
A2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1960
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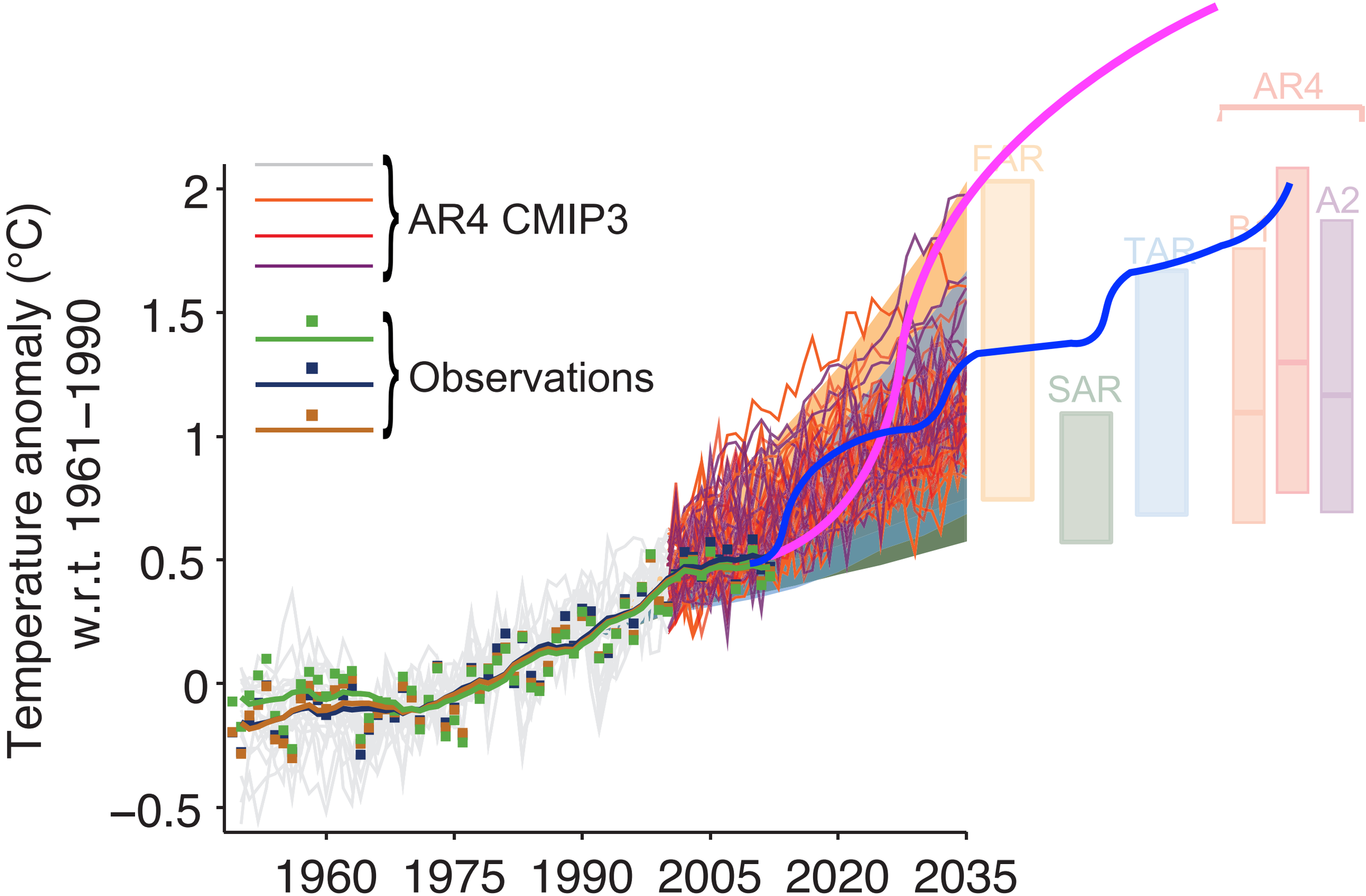
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1
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SAR
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B1
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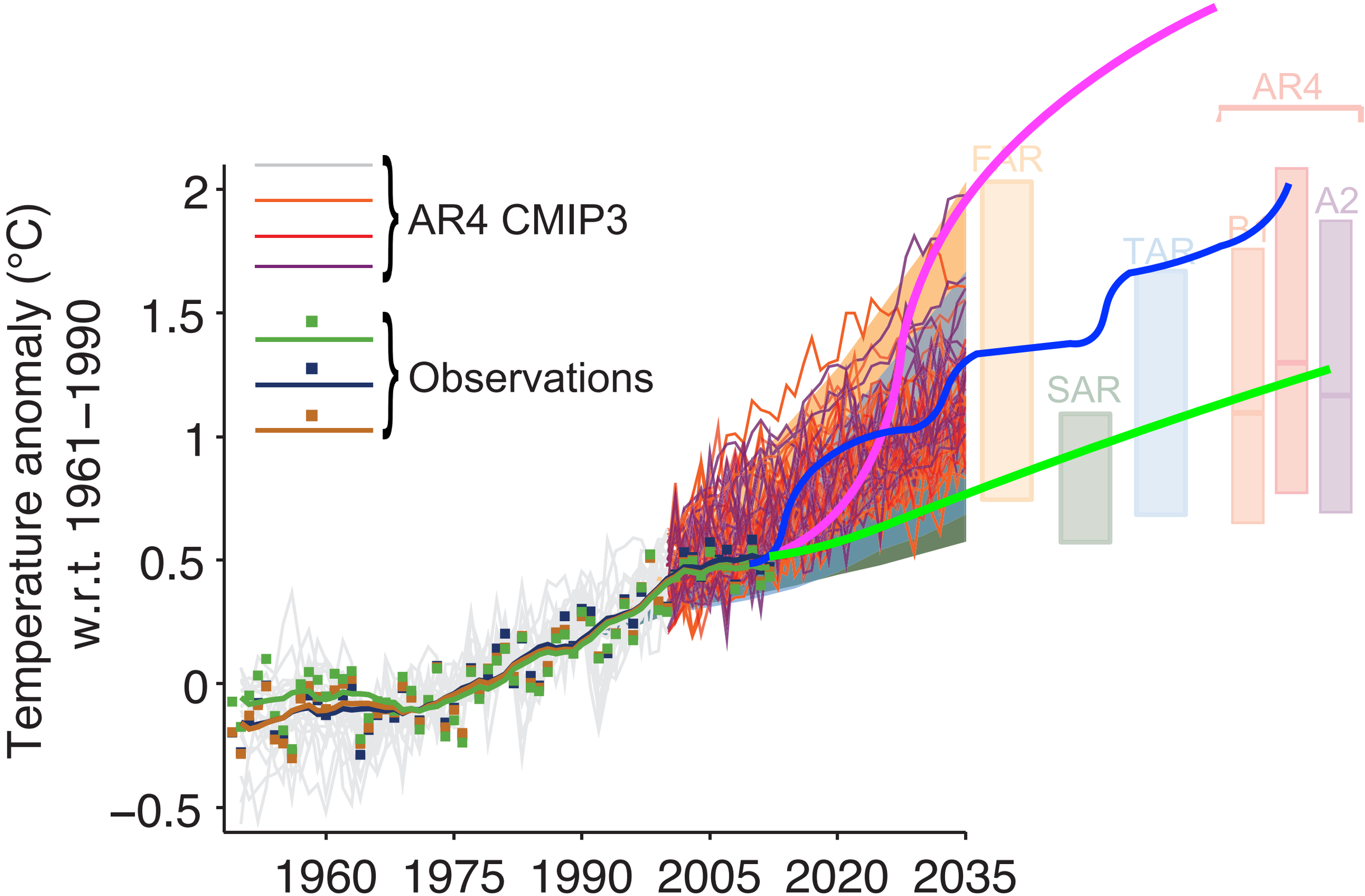
AR4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SAR
TAR
B1
A2

Climate sensitivity:

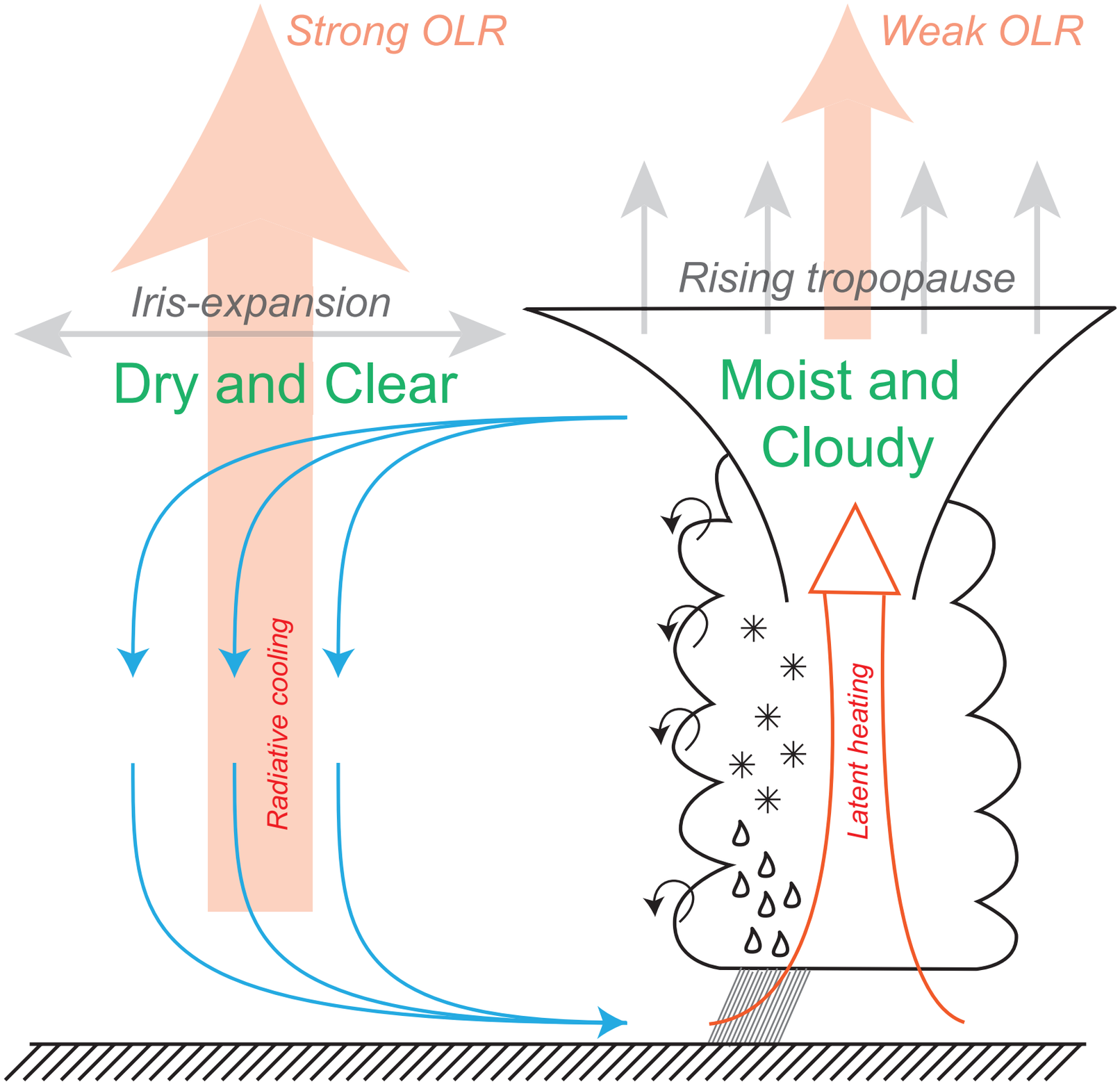
Recent warming (~2K)
(e.g. Otto et al. 2013)
vs.
Model-based (3-5K)
(Clement et al. 2009, Fasullo and Trenberth 2012, Sherwood et al. 2014)

Hydrological sensitivity:

Models underestimate by about a factor 2
(Zhang et al. 2007, Wentz et al. 2007, Durack et al. 2012, Ren et al. 2013)

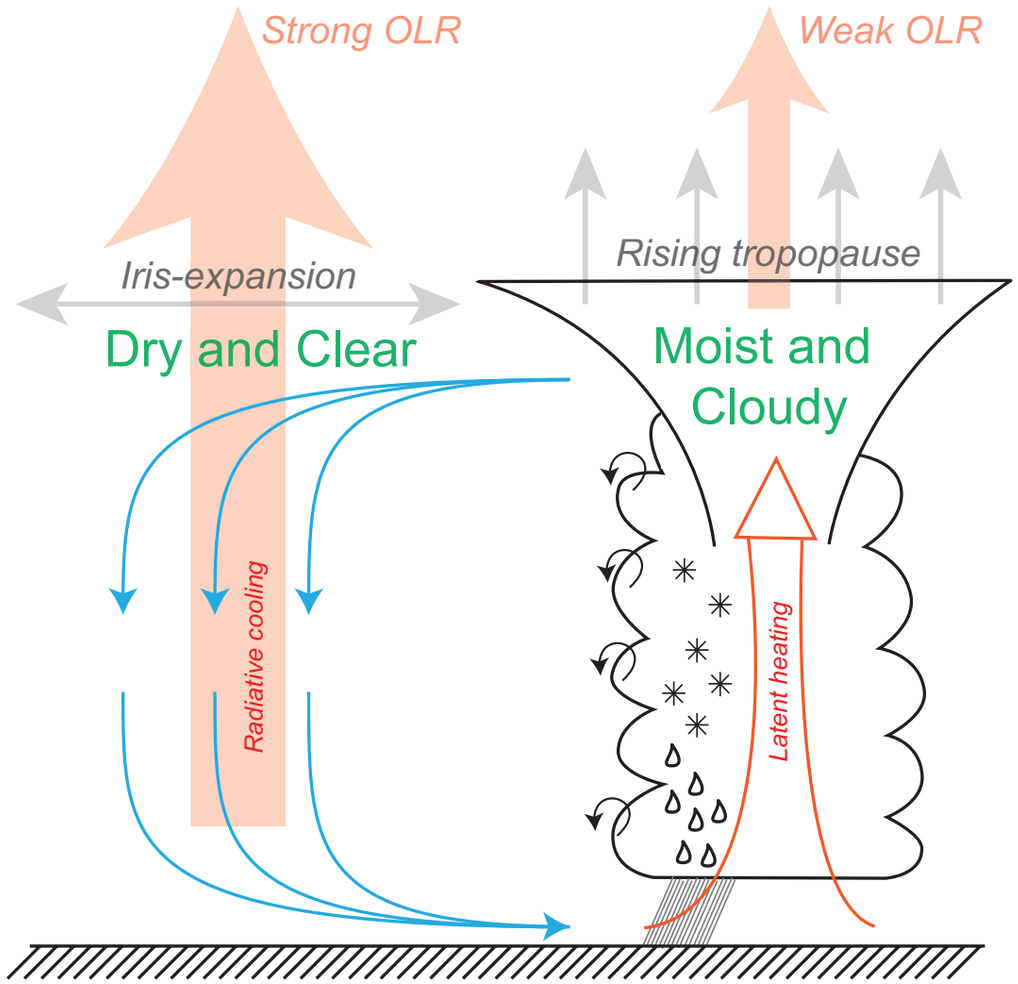
Tropospheric warming:

Models warm too much in upper troposphere
(Thorne et al. 2011, Po-Chedley and Fu 2012)


Strong OLR
Weak OLR
Iris-expansion
Rising tropopause
Dry and Clear
Moist and
Cloudy
Radiative cooling
Latent heating

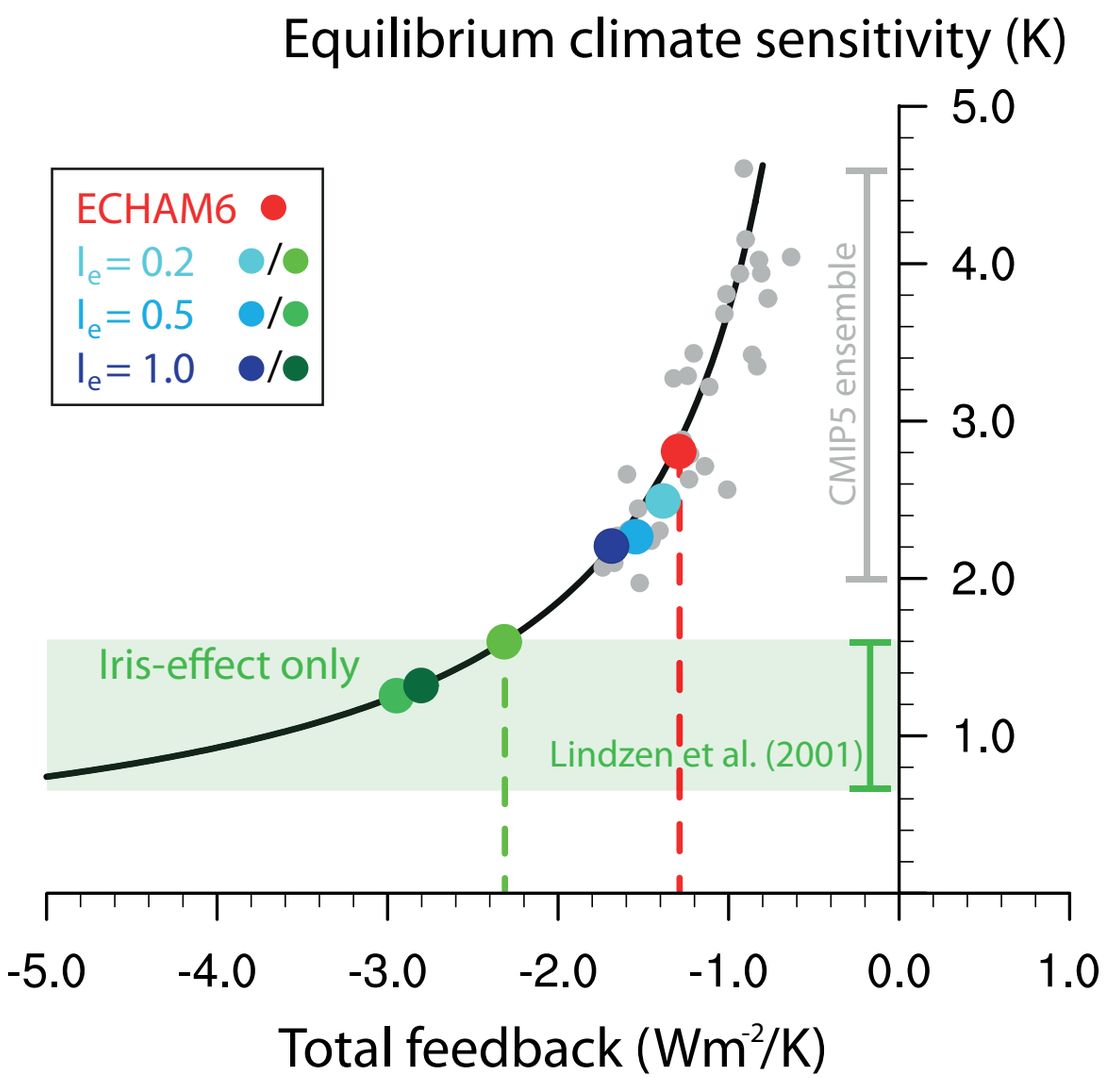
An Iris-effect:

$$C_p(T_s) = C_o \cdot (1 + I_e)^{T_s - T_o}$$

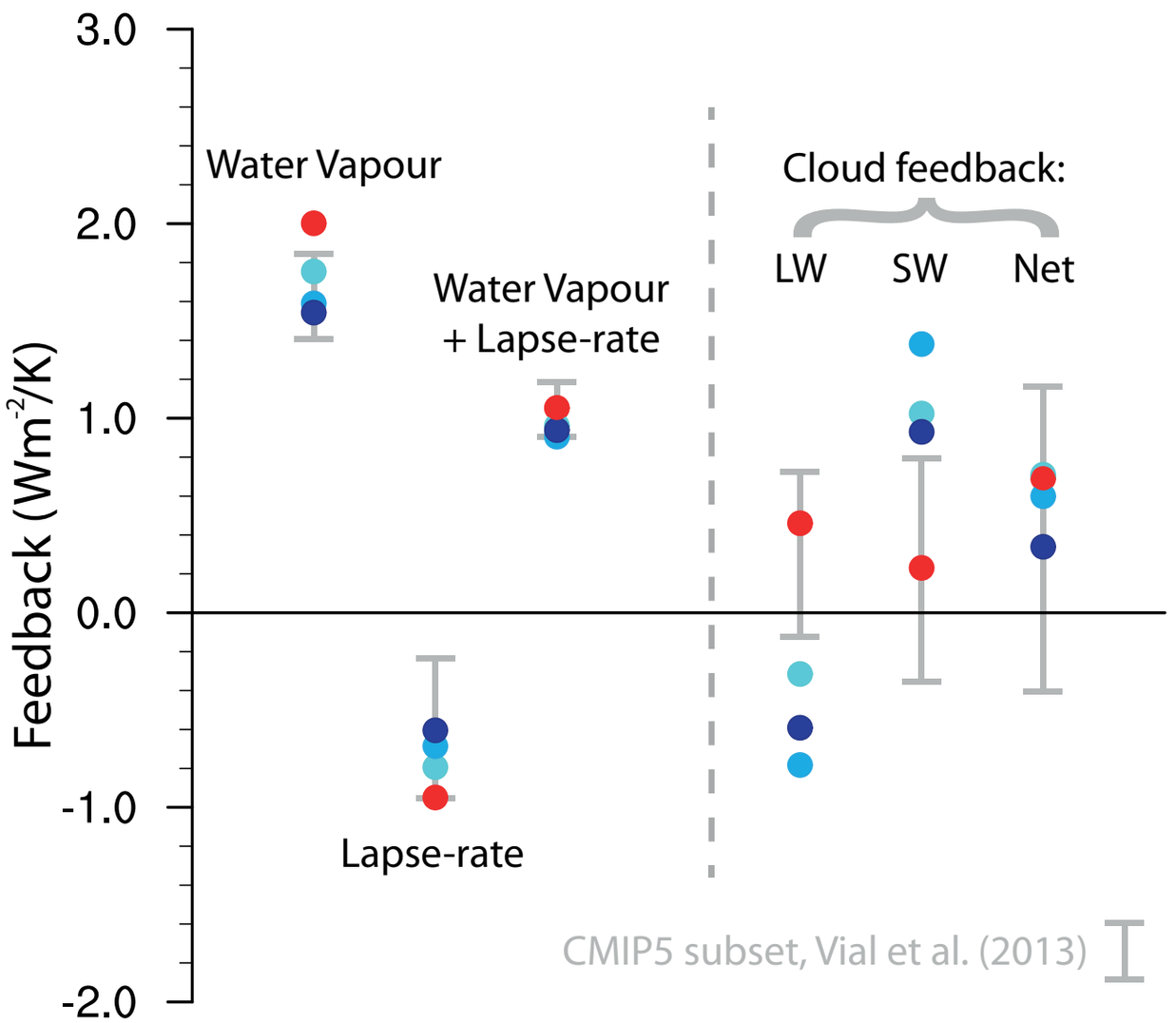


ECHAM6, T63L47
Coupled to mixed-layer ocean
2xCO2 forcing
Partial radiative perturbations (PRP) feedback analysis

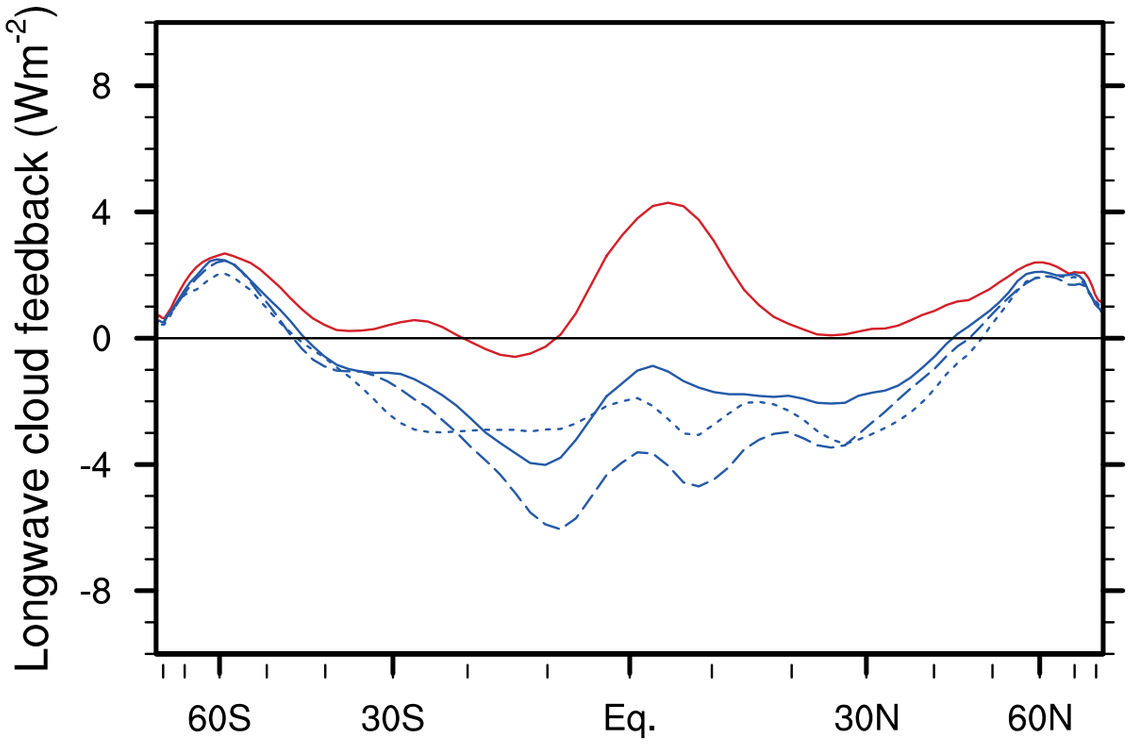
a)


Equilibrium climate sensitivity (K)
ECHAM6
I_e = 0.2 /
I_e = 0.5 /
I_e = 1.0 /
CMIP5 ensemble
Iris-effect only
Lindzen et al. (2001)
5.0
4.0
3.0
2.0
1.0
-5.0
-4.0
-3.0
-2.0
-1.0
0.0
1.0
Total feedback (Wm^{-2}/K)

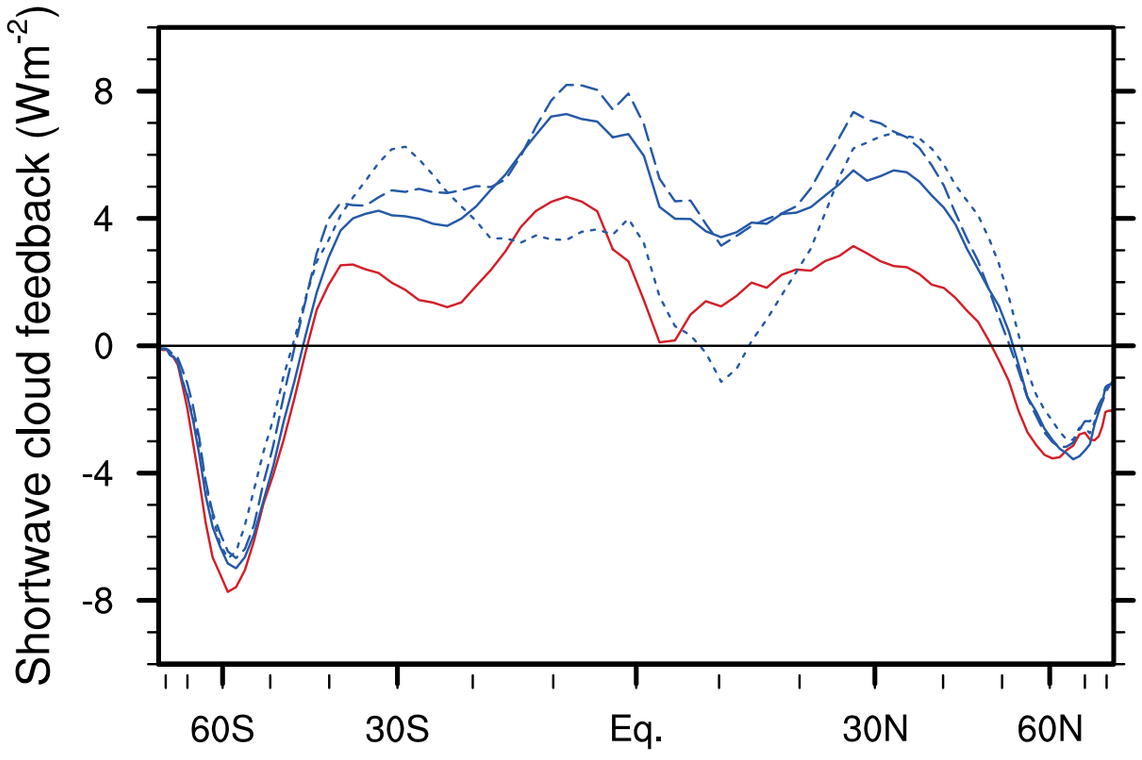
b)


Water Vapour
Water Vapour
+ Lapse-rate
Lapse-rate
Cloud feedback:
LW
SW
Net
CMIP5 subset, Vial et al. (2013)
Feedback (Wm^{-2}/K)
3.0
2.0
1.0
0.0
-1.0
-2.0

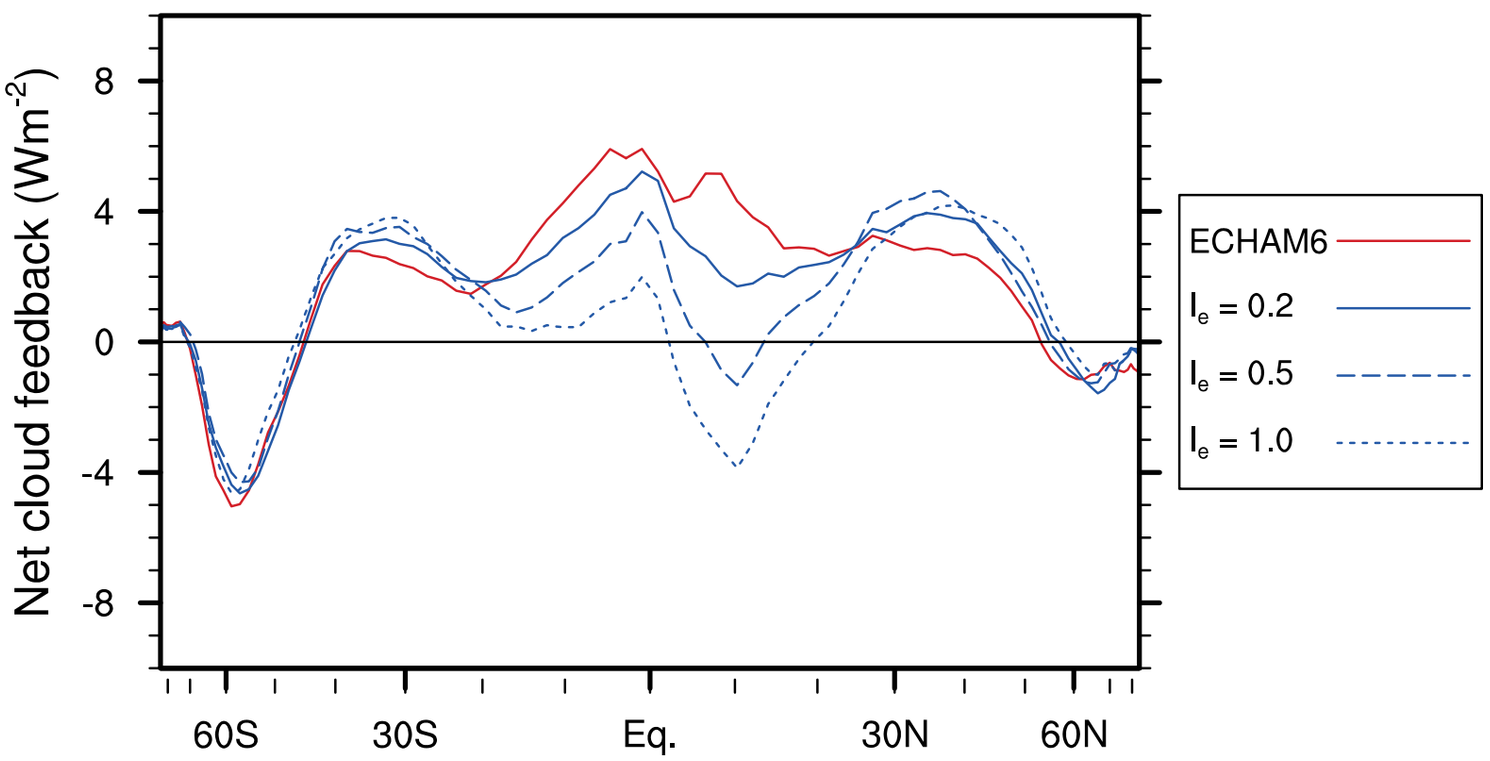
Longwave cloud feedback:



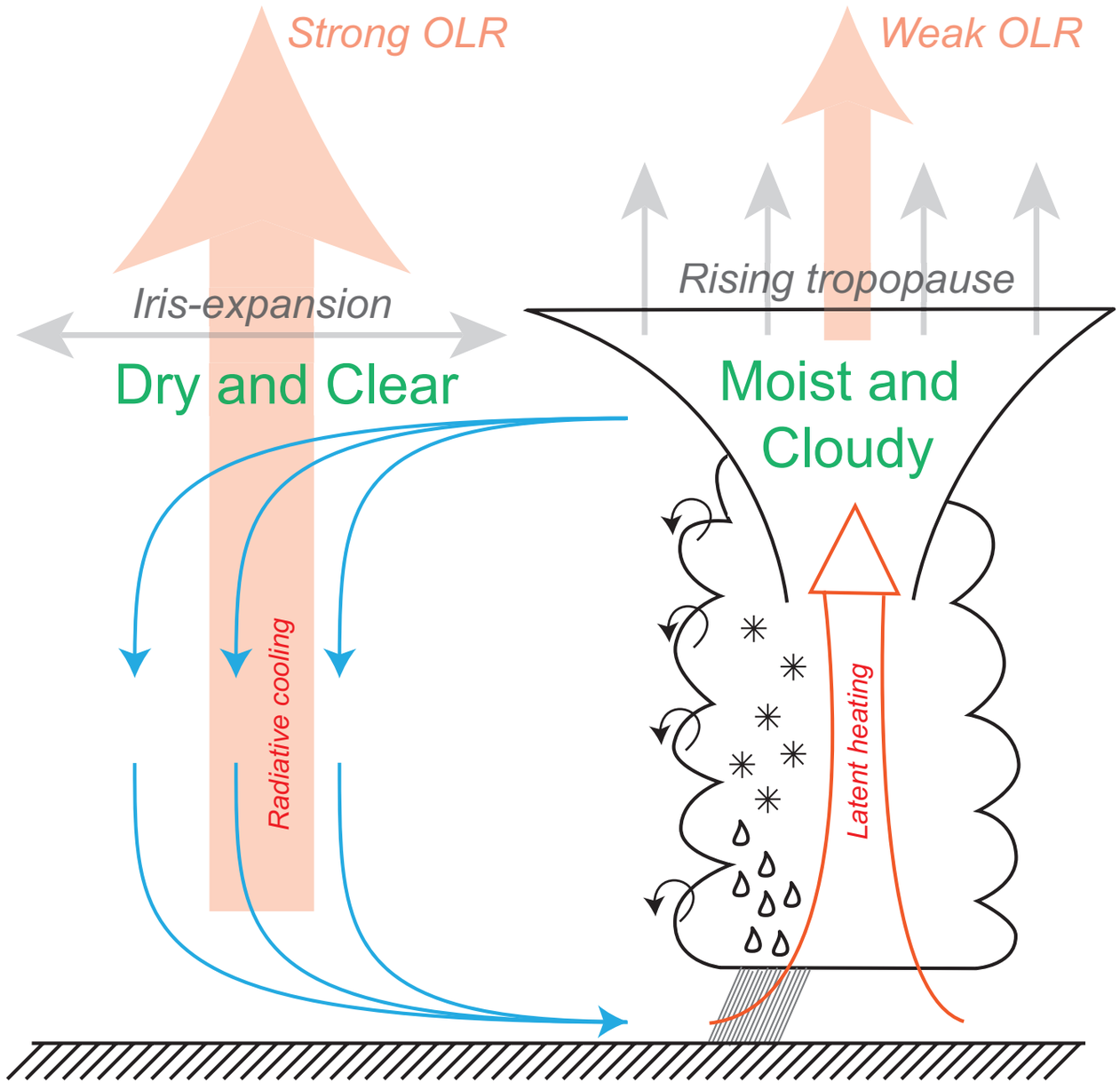
Shortwave cloud feedback:



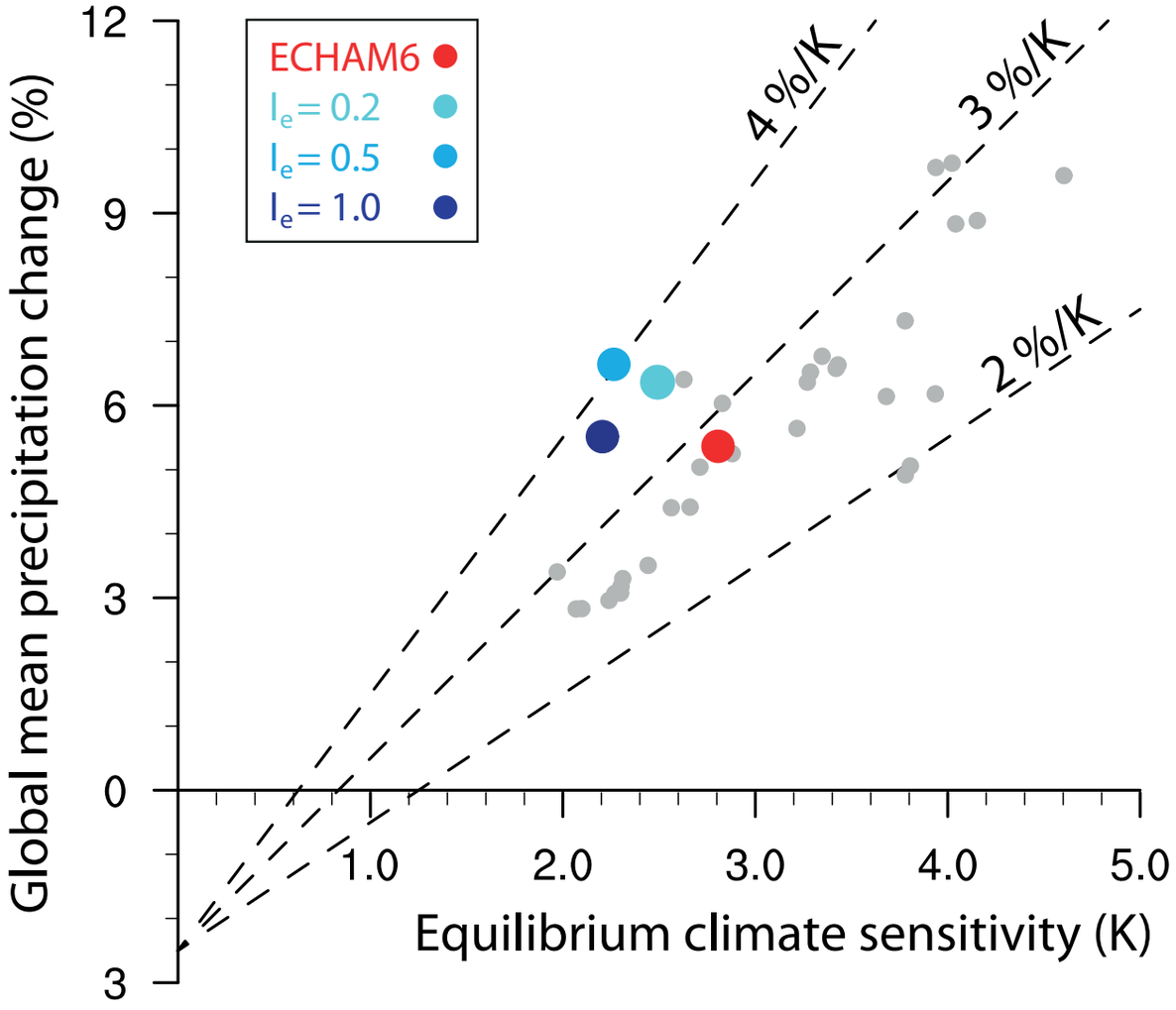
Net cloud feedback:



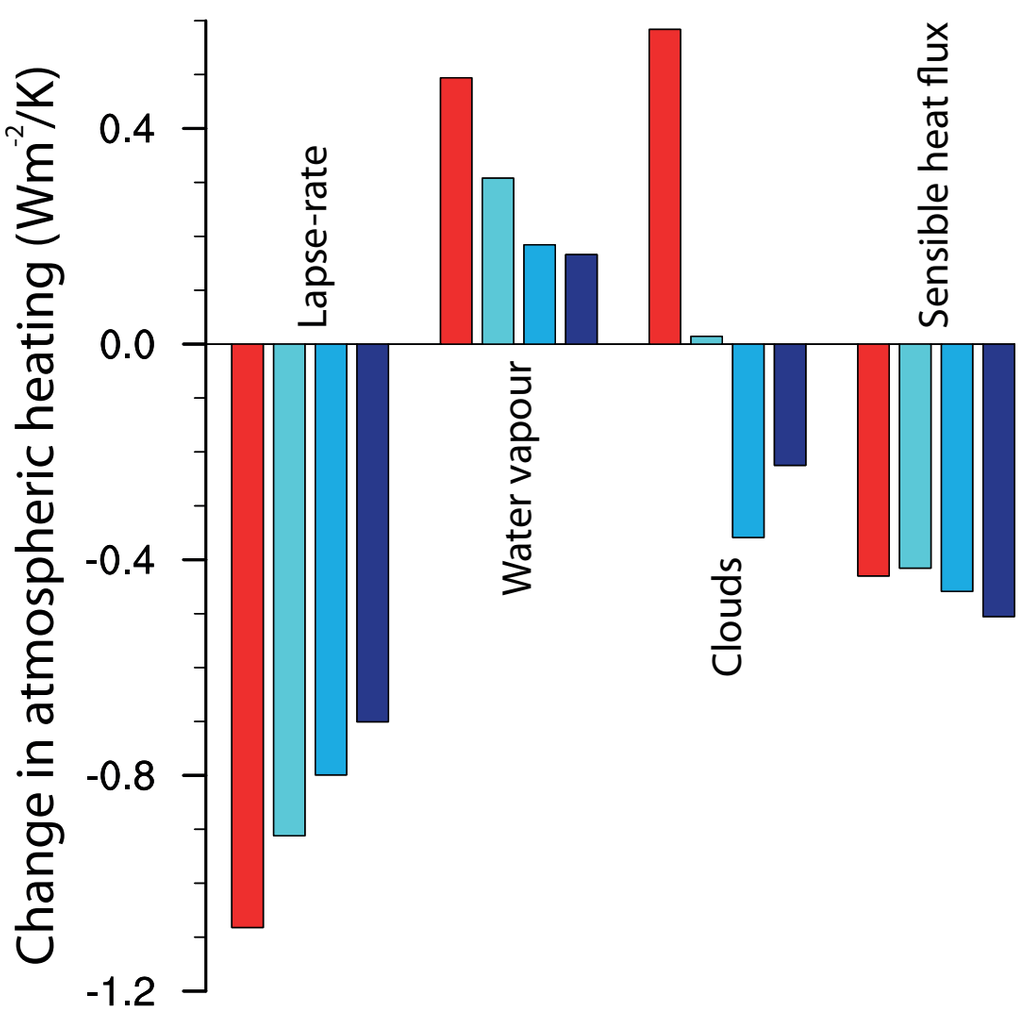
Hydrological sensitivity is controlled by atmospheric energy budget:

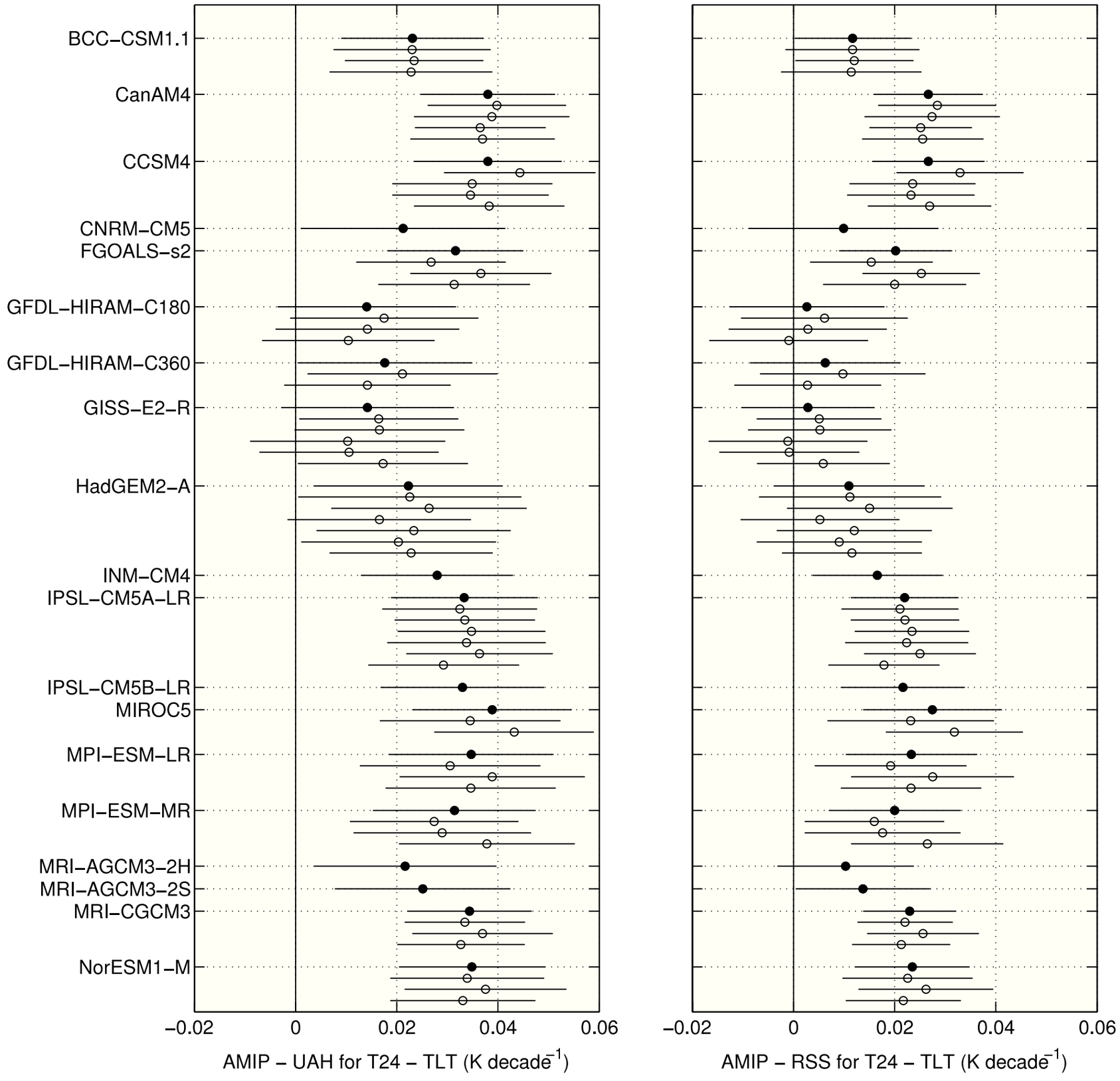


a)

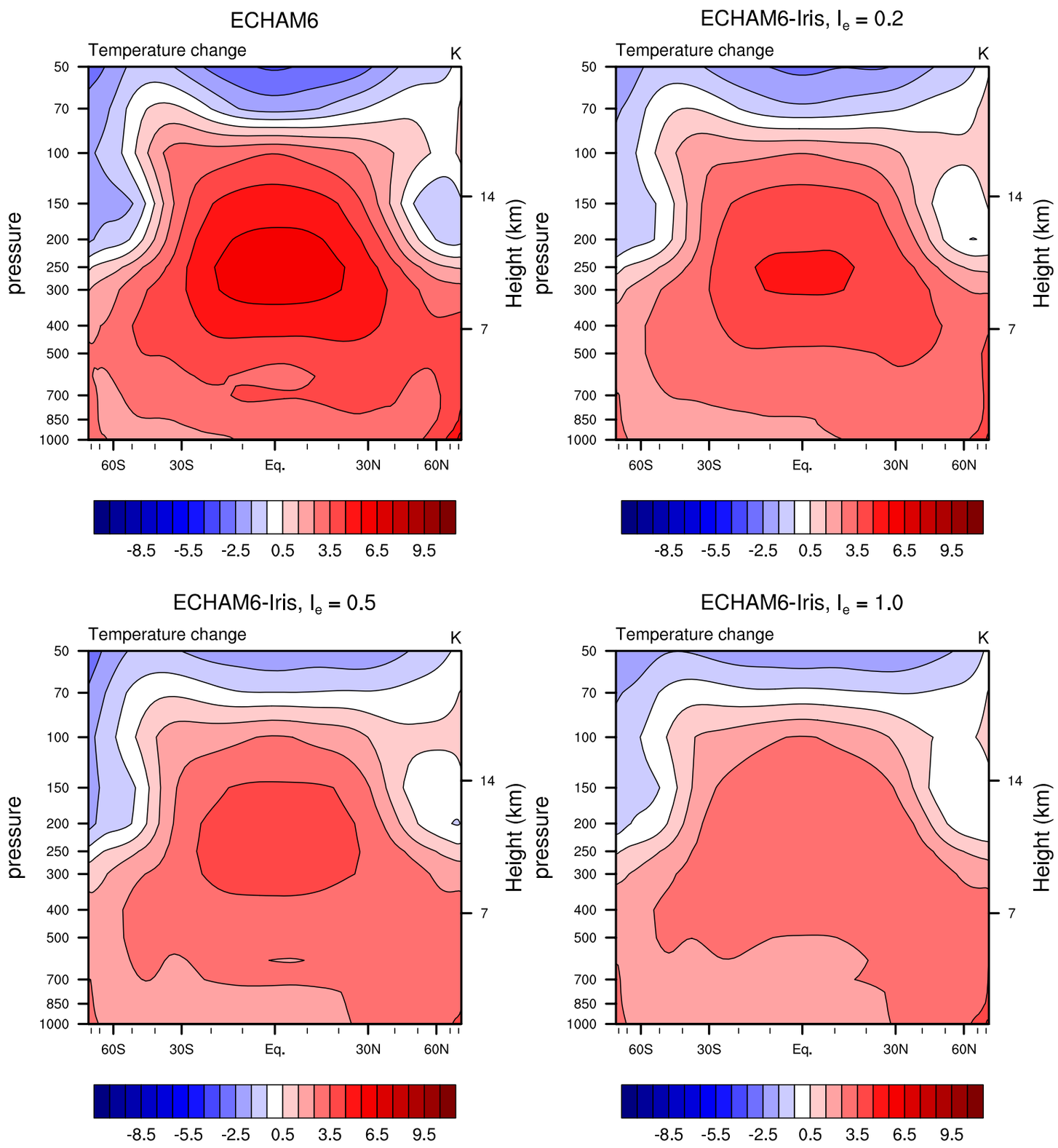

ECHAM6
I_e = 0.2
I_e = 0.5
I_e = 1.0
4 %/K
3 %/K
2 %/K
Global mean precipitation change (%)
12
9
6
3
0
3
1.0
2.0
3.0
4.0
5.0
Equilibrium climate sensitivity (K)

b)

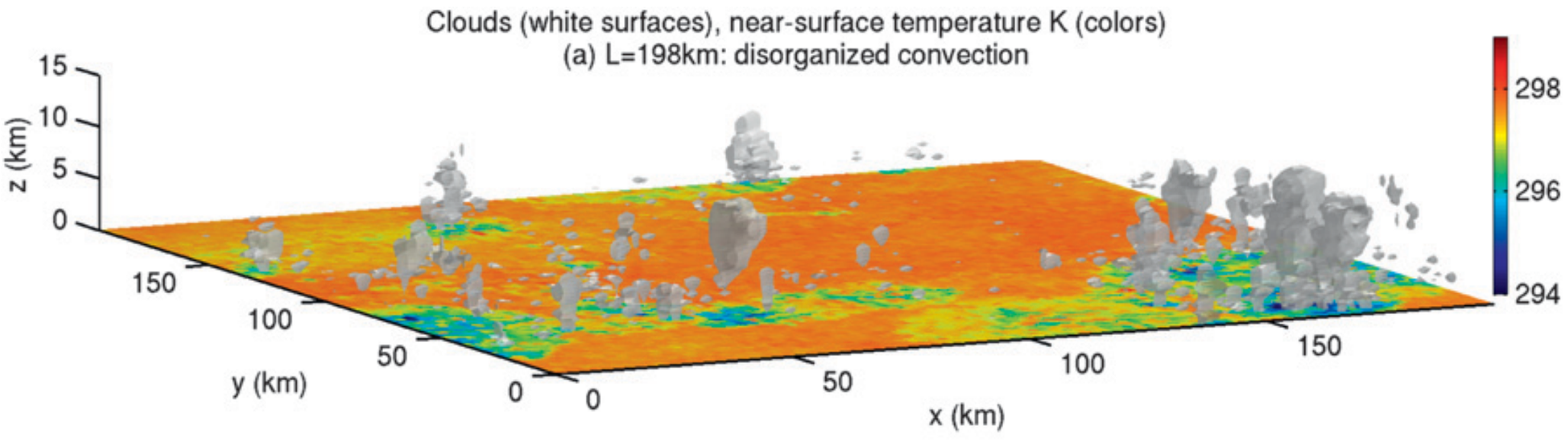

Change in atmospheric heating (Wm^{-2}/K)
0.4
0.0
-0.4
-0.8
-1.2
Lapse-rate
Water vapour
Clouds
Sensible heat flux

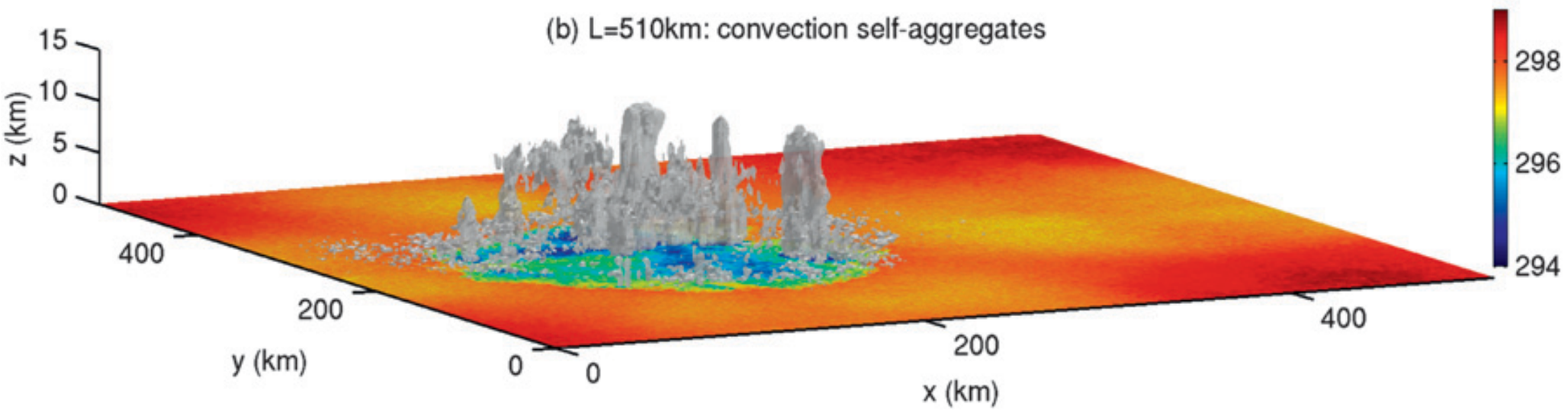


Po-Chedley and Fu (2012)

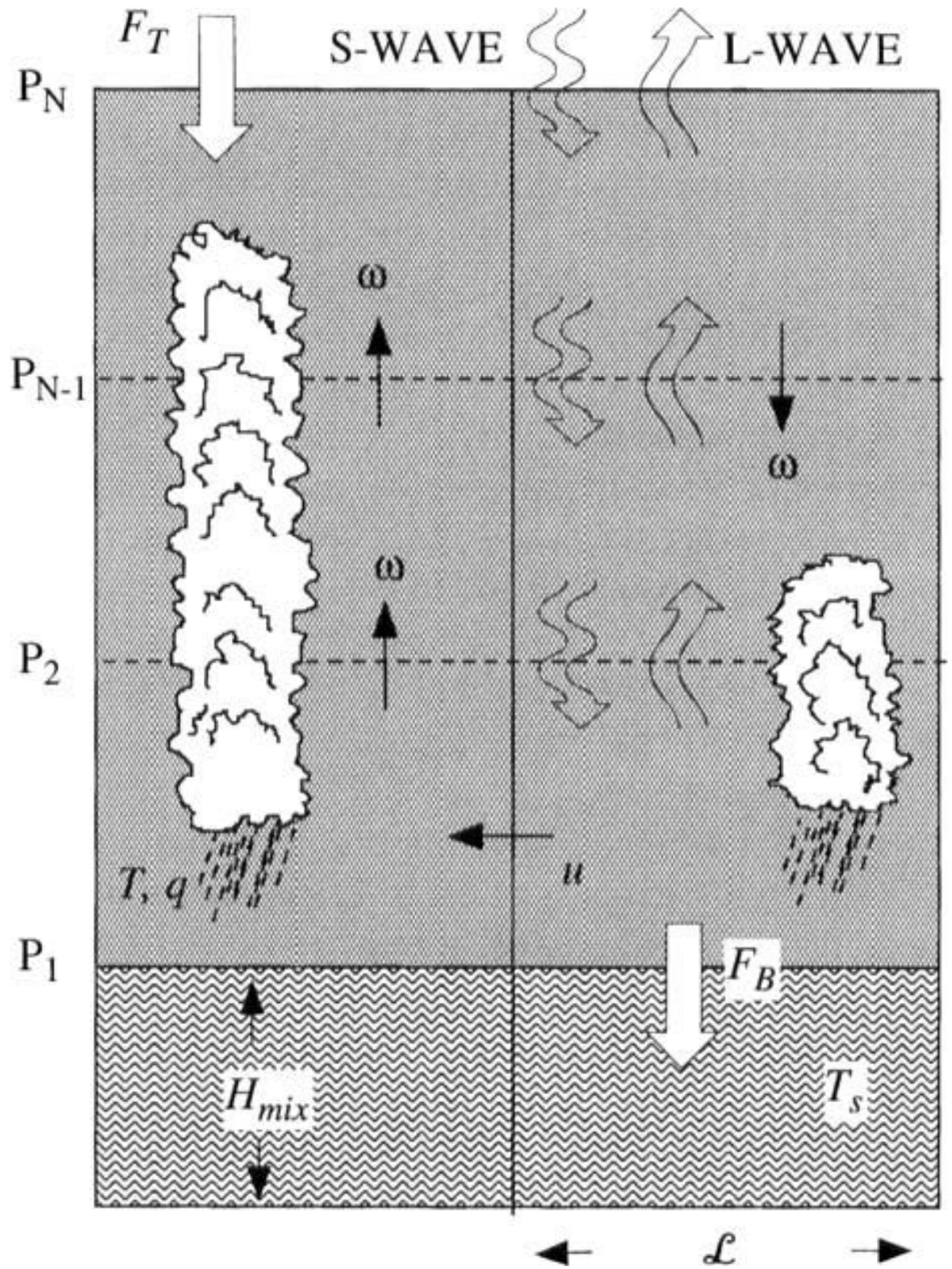

ECHAM6
Temperature change
K
pressure
50
70
100
150
200
250
300
400
500
700
850
1000
60S
30S
Eq.
30N
60N
14
7
Height (km)
-8.5
-5.5
-2.5
0.5
3.5
6.5
9.5
ECHAM6-Iris, I_e = 0.2
ECHAM6-Iris, I_e = 0.5
ECHAM6-Iris, I_e = 1.0

Mechanism?



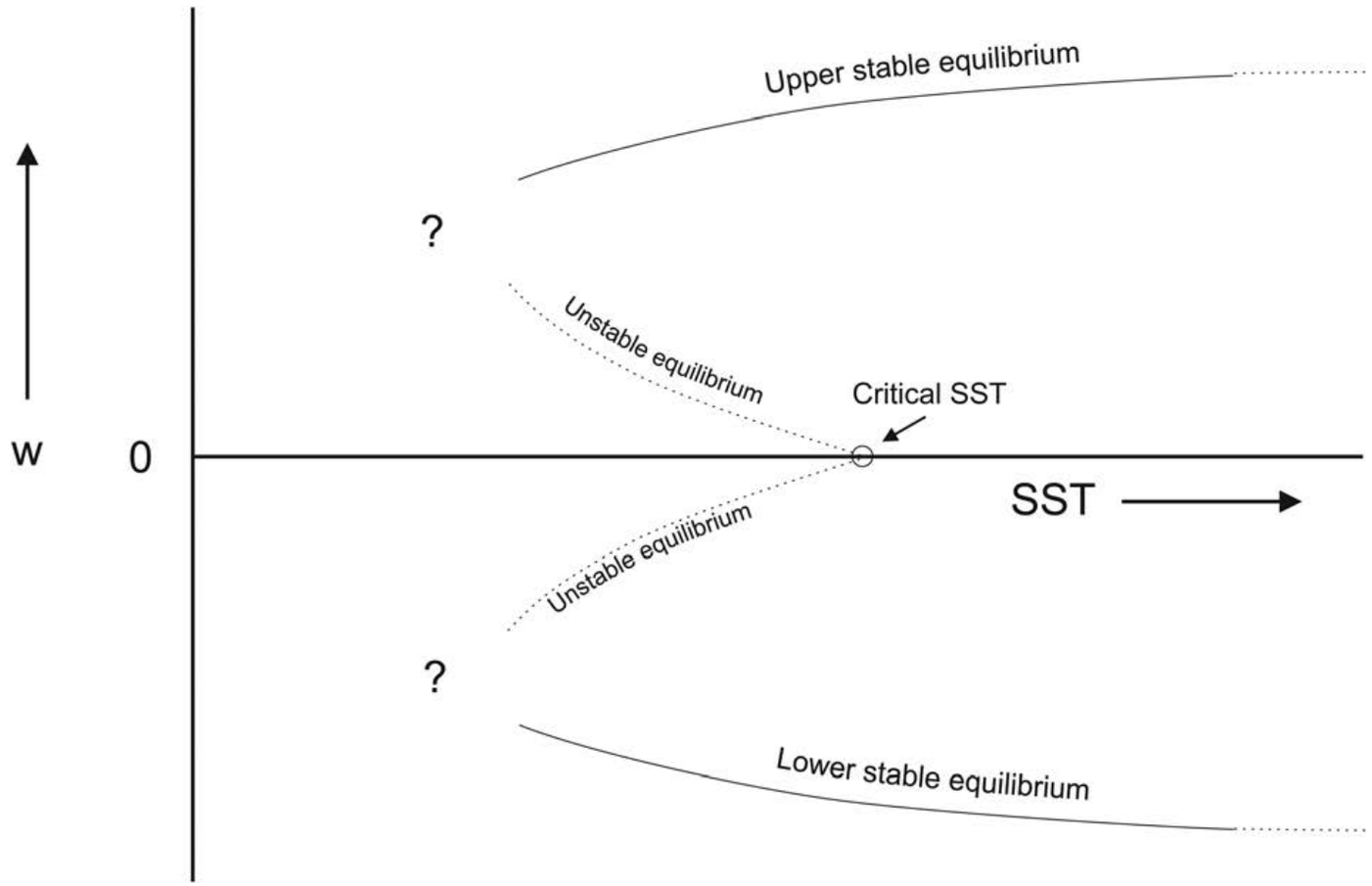


Muller and Held (2012)

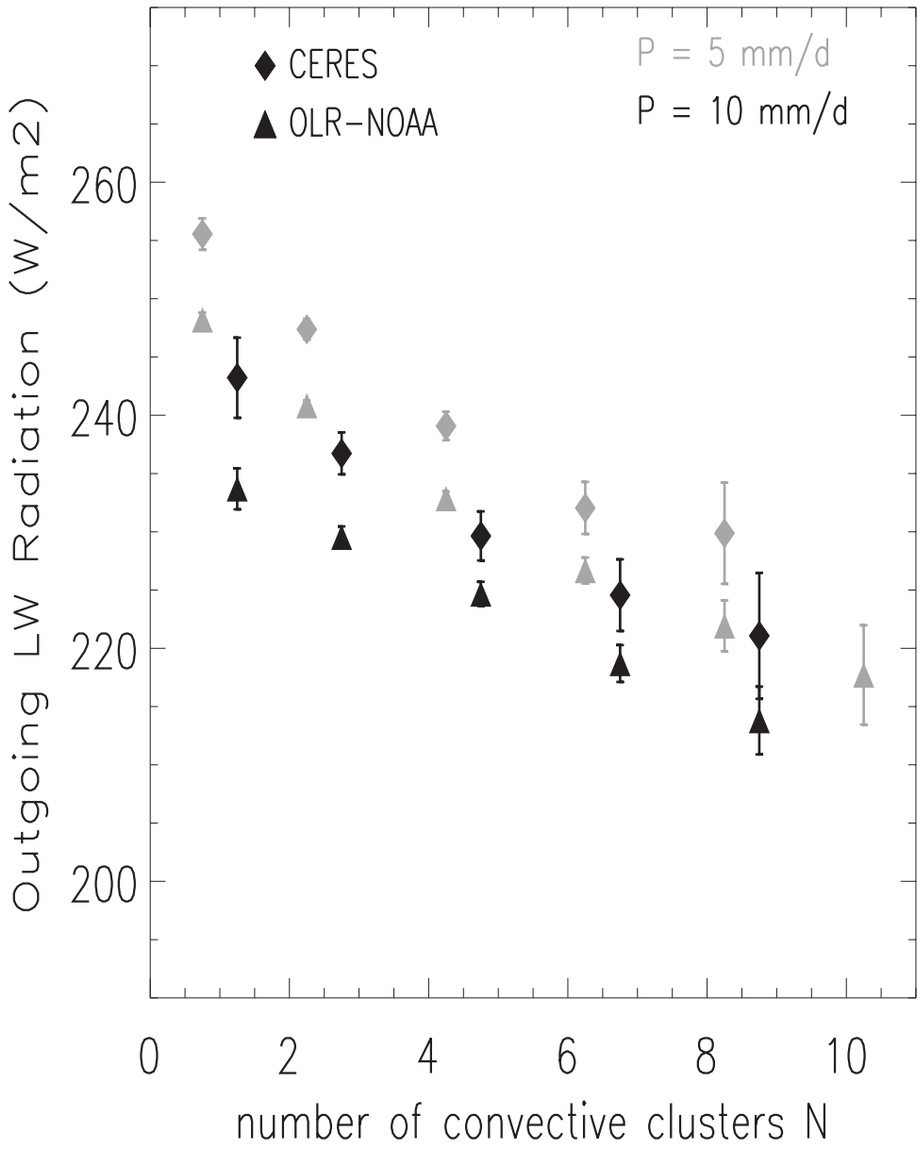


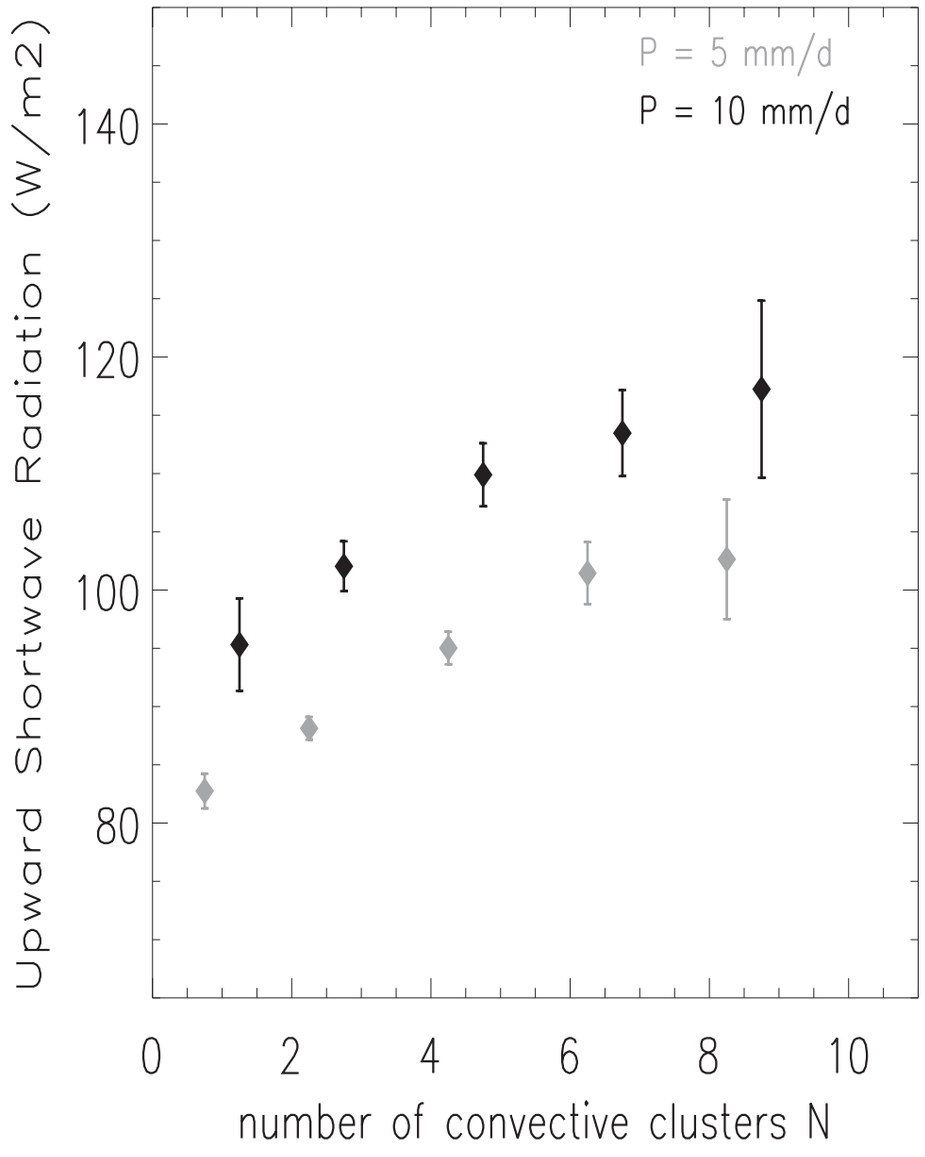
Nilsson and Emanuel (1999)

Warmer atmosphere is more prone to aggregate



Emanuel et al. (2013)

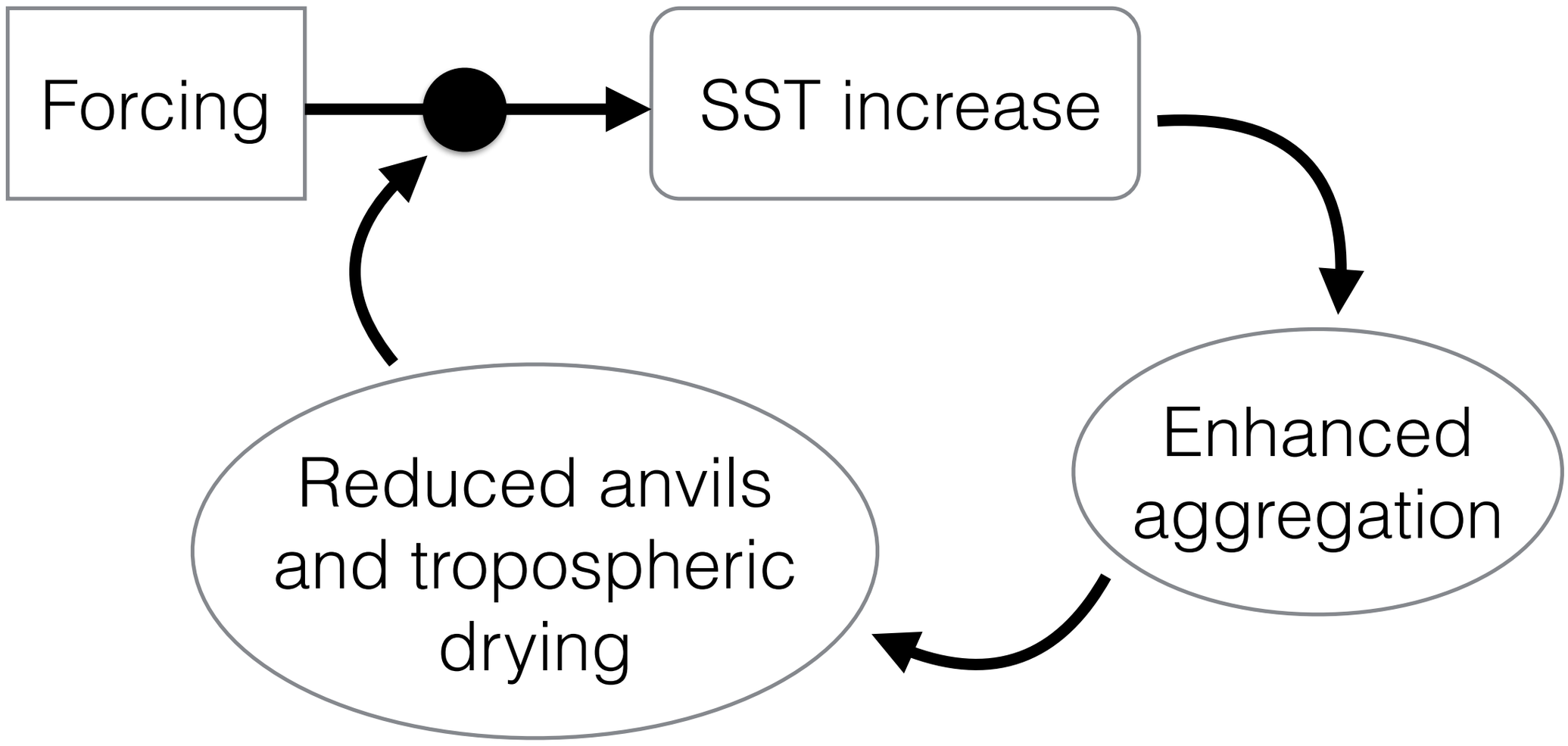




More aggregated

Tobin et al. (2012)

A negative feedback loop (longwave)



We have implemented a representation of an iris-effect in ECHAM6:

- Climate sensitivity is only lowered from 2.8 to 2.2-2.5 K – not to 1 K as suggested earlier – due to natural compensation from lapse-rate and shortwave cloud feedbacks

- Hydrological sensitivity increases, in order to sustain the enhanced atmospheric cooling, to values higher than that of any other model

- Troposphere warms less than a moist adiabat with an iris-effect

The results show that an iris-effect, for instance caused by unrepresented **convective aggregation**, could be a **missing link** between models and observations, thus deserving further attention

1. Forcing
2. Ocean heat uptake
3. Climate sensitivity