

Positive low cloud feedback primarily caused by increasing longwave radiation from the sea surface in a climate model MIROC6

Tomoo Ogura¹ and Mark J. Webb²

1.National Institute for Environmental Studies

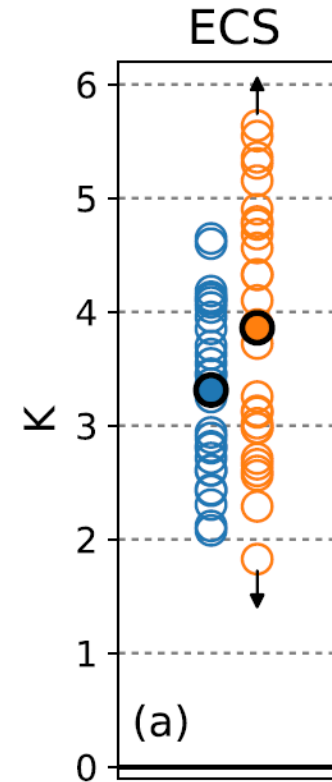
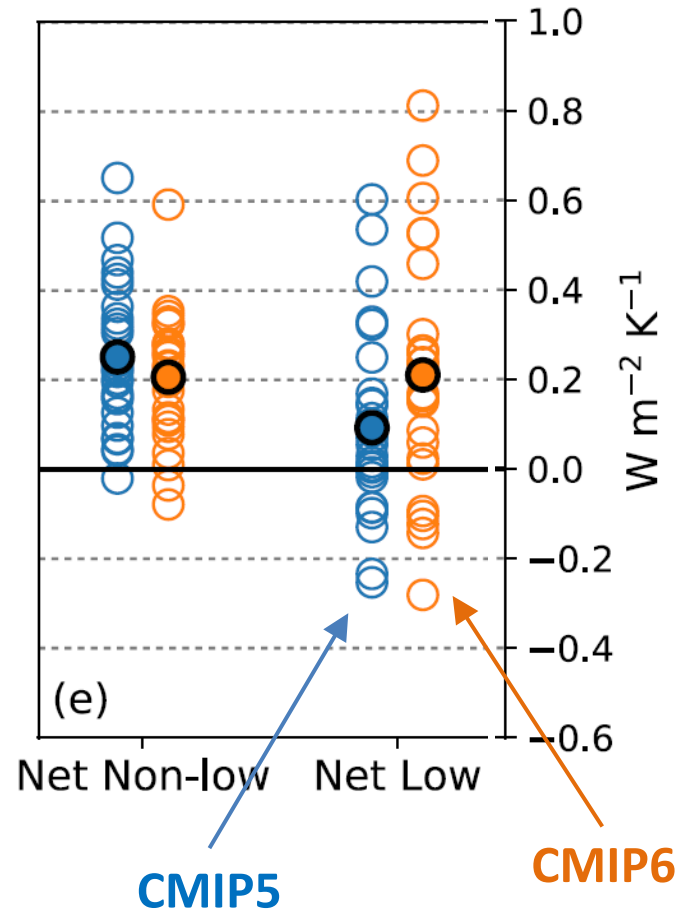
2.Met Office Hadley Centre



National
Institute for
Environmental
Studies, Japan

Motivation : positive low cloud feedback in CMIP5 & 6

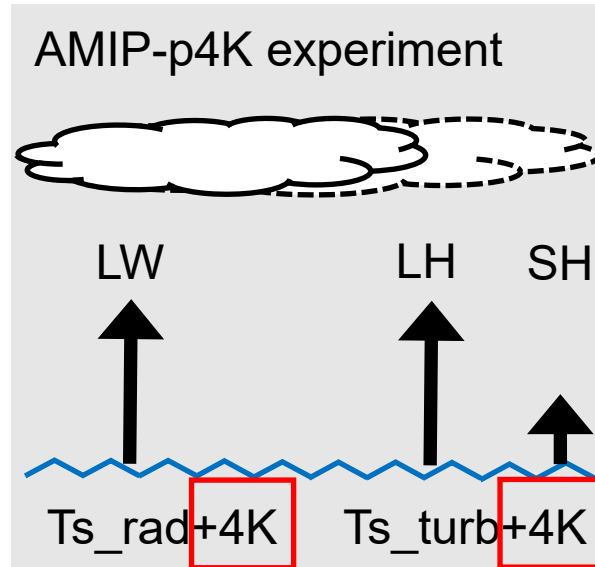
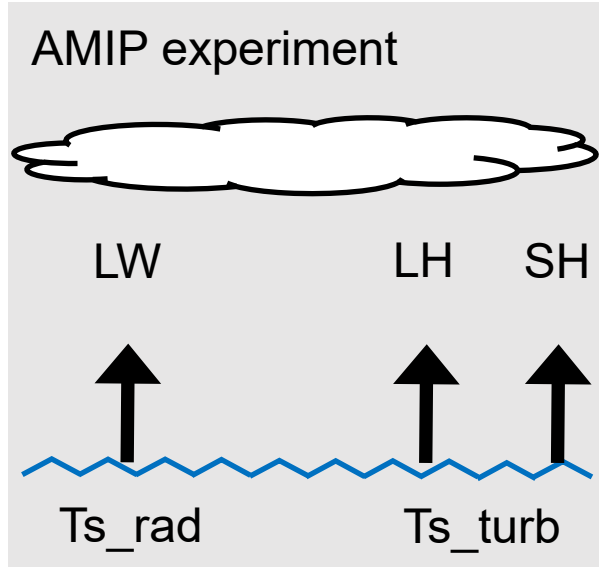
Global-Mean Cloud Feedbacks
(abrupt-4xCO₂ runs)



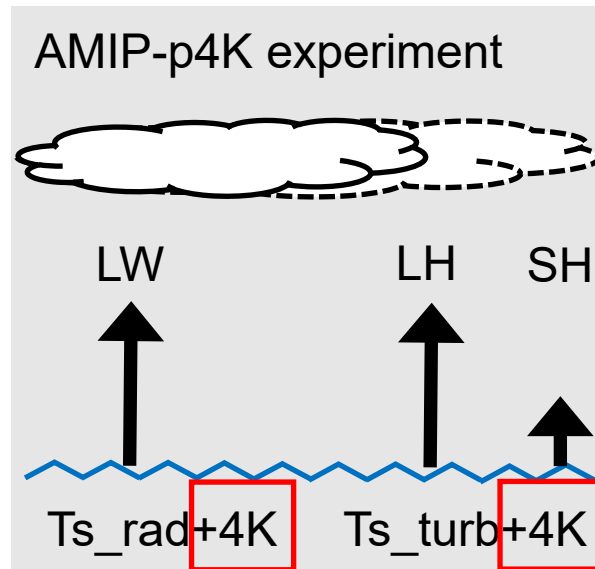
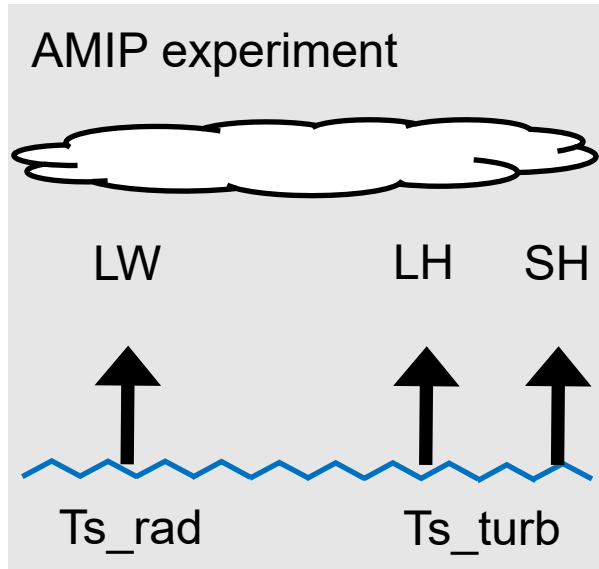
Adapted from Zelinka et al. (2020)

Low cloud feedback mostly positive in CMIP5 & CMIP6 GCMs. Why are they positive?

Why low cloud feedback positive in low latitudes ?

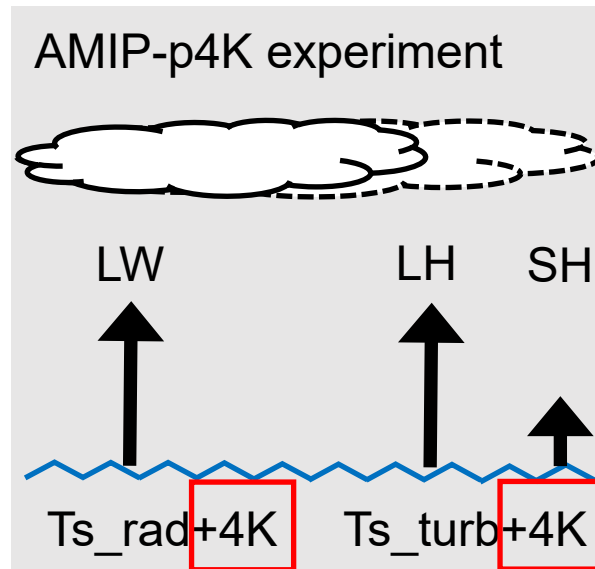
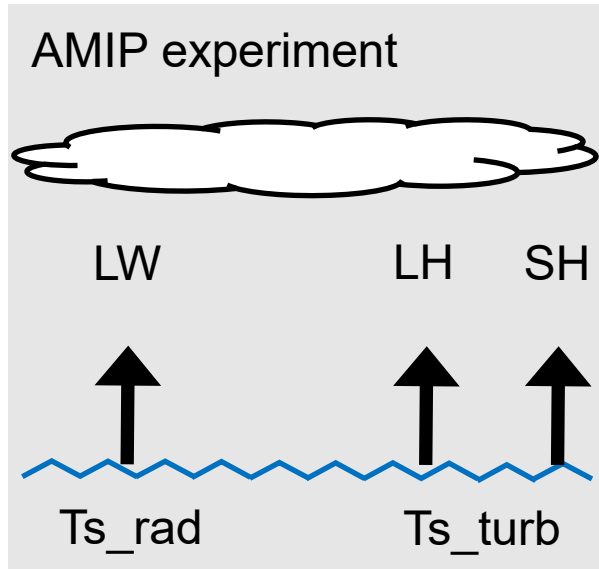


Why low cloud feedback positive in low latitudes ?



Latent heat flux increases.
Warmer & moister atmosphere

Why low cloud feedback positive in low latitudes ?



Negative feedback (cloud increase)

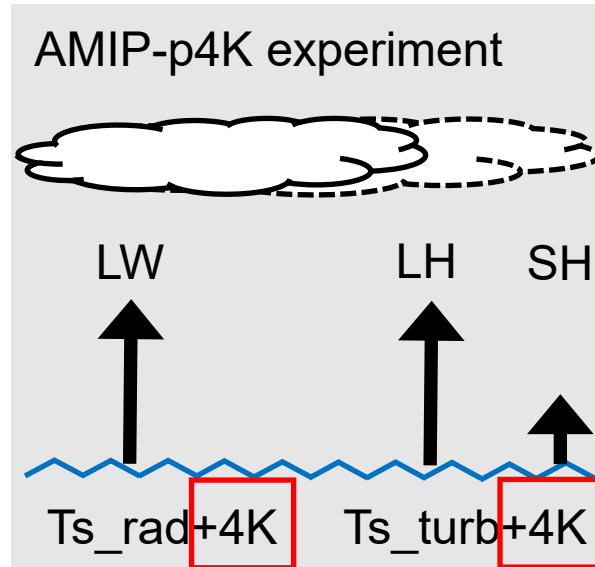
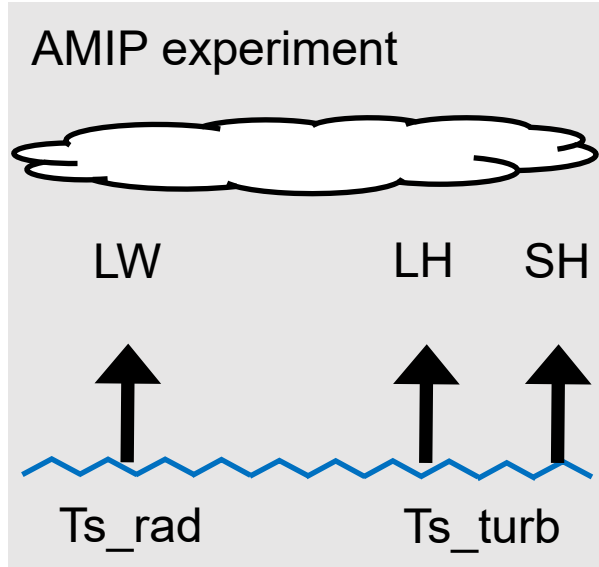
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Myers and Norris (2013)
- Inversion strengthens
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- LW cooling increases in B-Layer
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Positive feedback (cloud decrease)

- Cloud-top LW cooling weakens
Bretherton et al. (2013)
- MSE/moisture contrast increases
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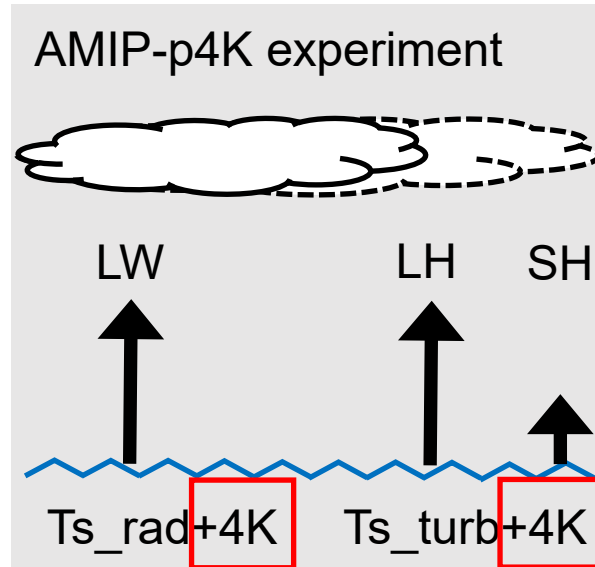
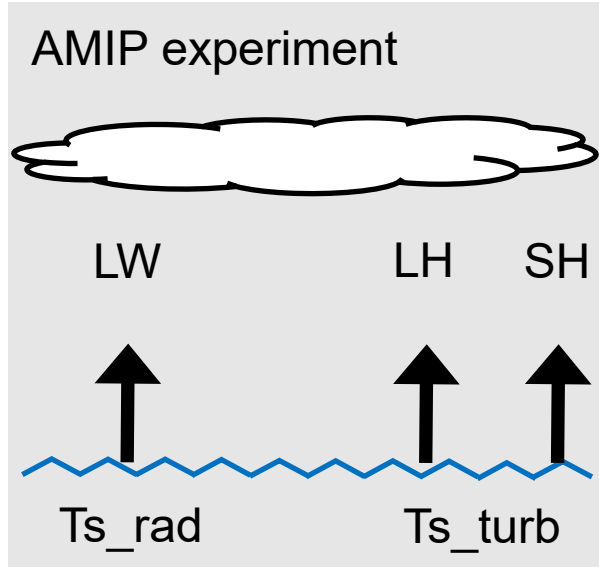
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Positive > **Negative** in LES.

Does this explain
positive sign in GCMs?

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Warmer & moister atmosphere

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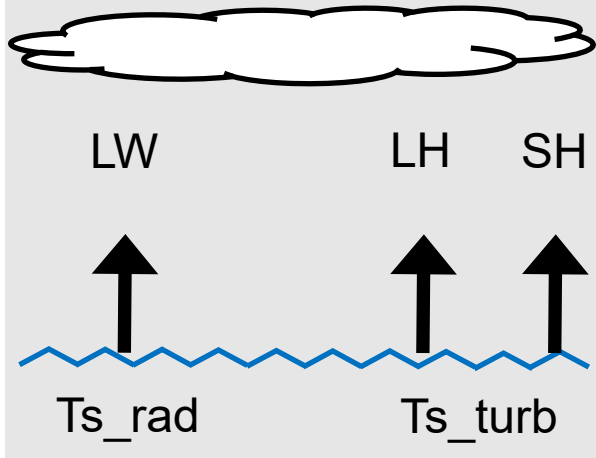
Here we have a gap in knowledge.

Positive > **Negative** in LES.

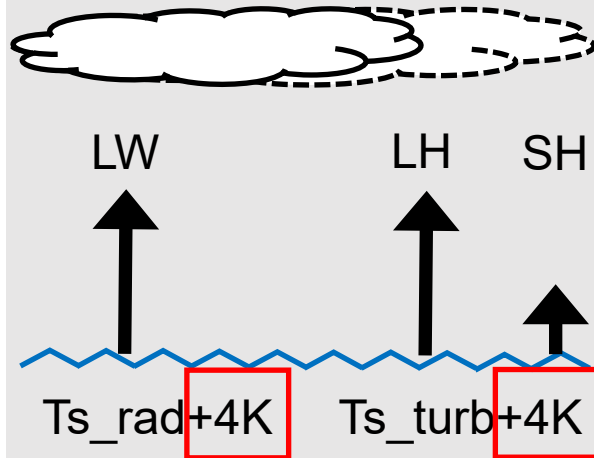
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Numerical experiments with MIROC6

AMIP experiment

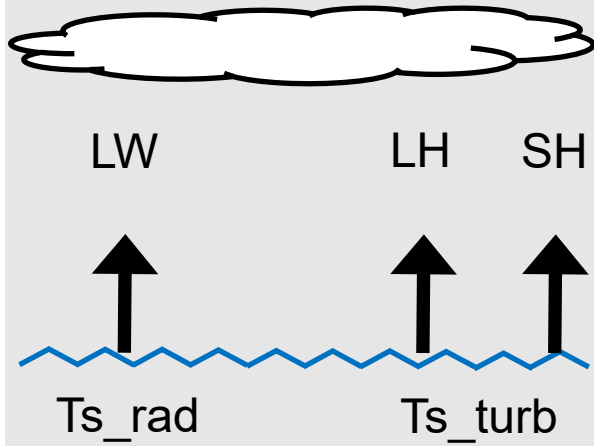


AMIP-p4K experiment

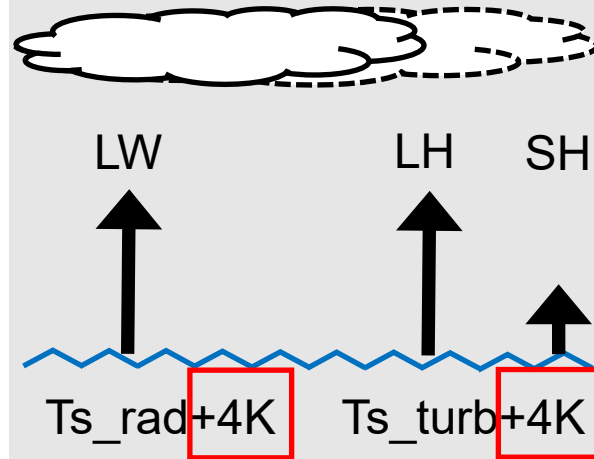


Numerical experiments with MIROC6

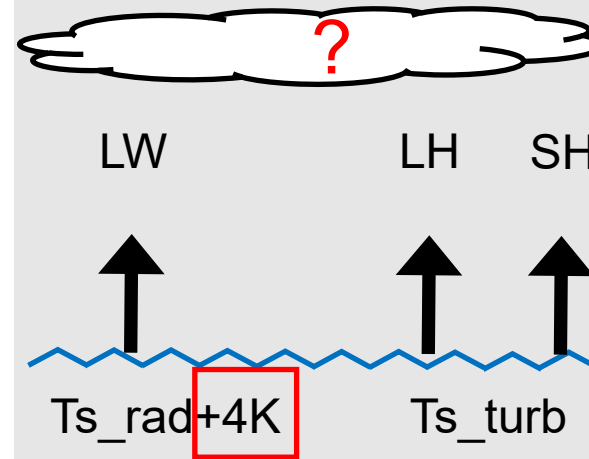
AMIP experiment



AMIP-p4K experiment

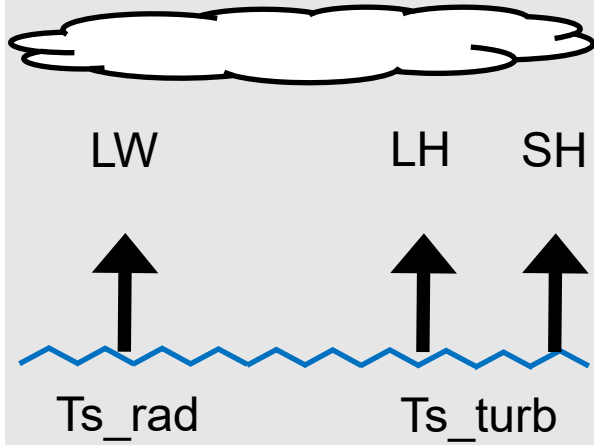


AMIP-p4Krad experiment

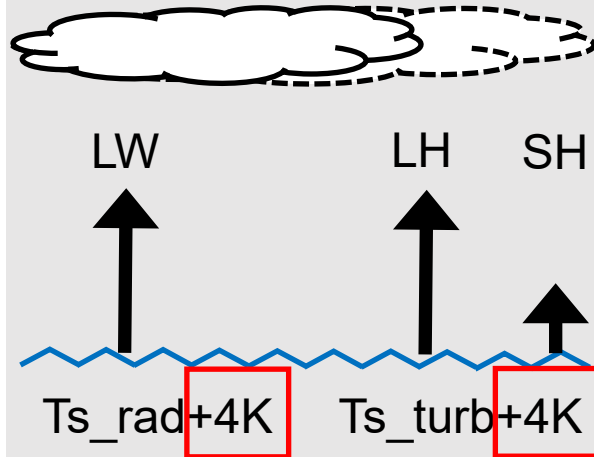


Numerical experiments with MIROC6

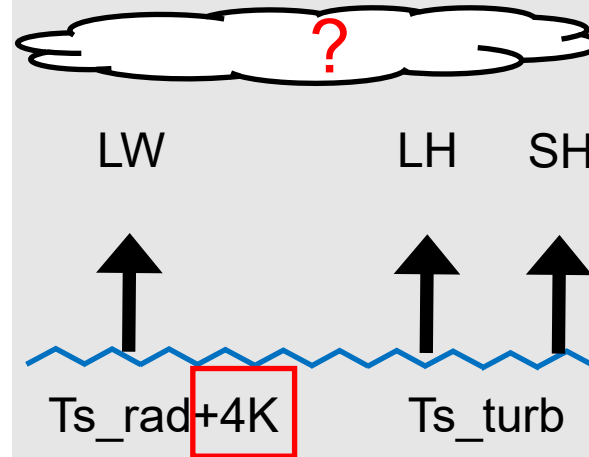
AMIP experiment



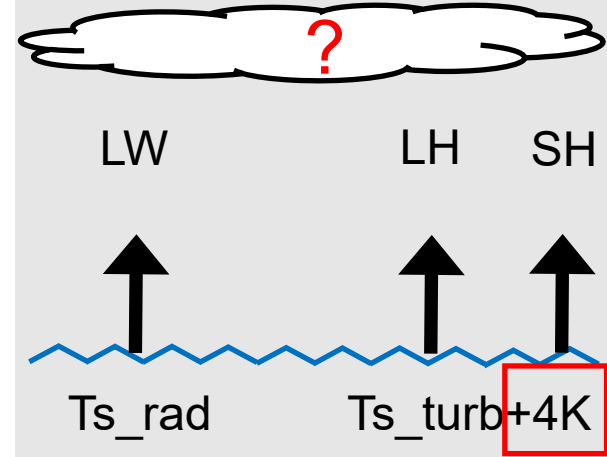
AMIP-p4K experiment



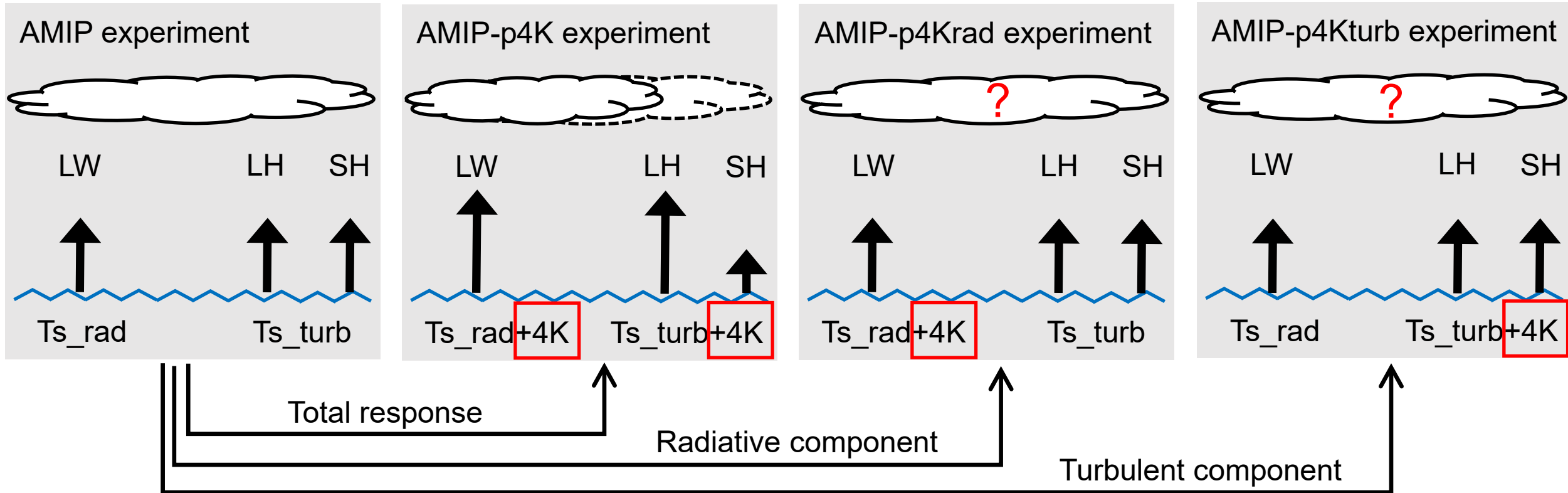
AMIP-p4Krad experiment



AMIP-p4Kturb experiment



Numerical experiments with MIROC6



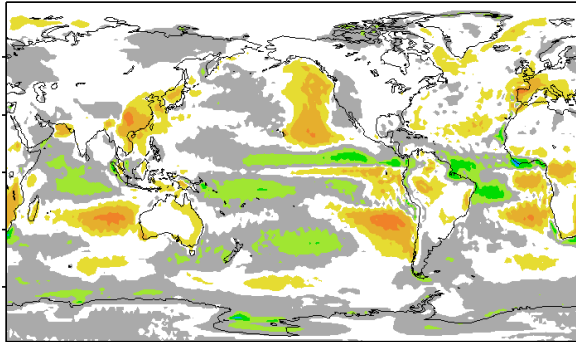
$$\boxed{\text{Total response (e.g., low cloud feedback)}} = \boxed{\text{Radiative component}} + \boxed{\text{Turbulent component}} + \boxed{\text{Residual}}$$

Which term makes the low cloud feedback positive ?

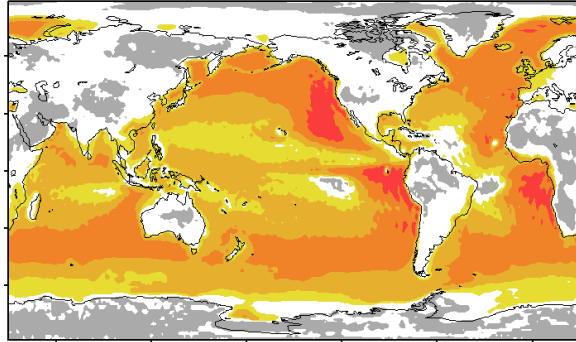
Which term makes the low cloud feedback positive?

Low cloud feedback induced by 4K increase in SST

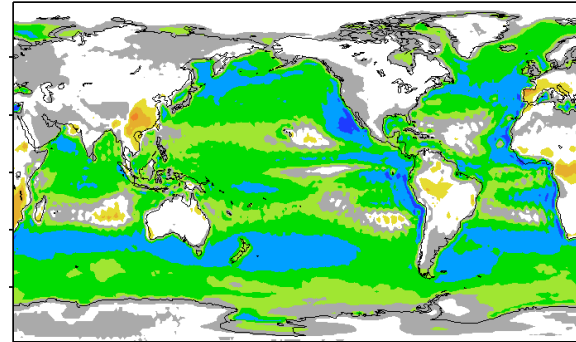
Total response



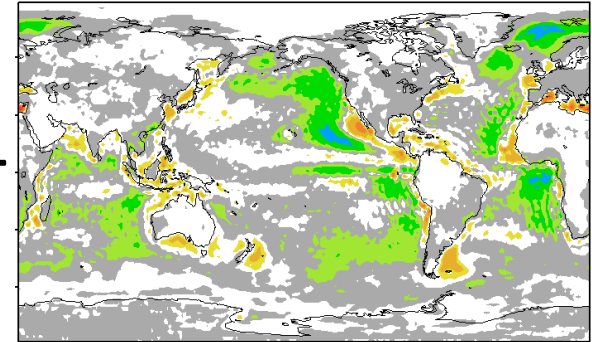
Radiative component



Turbulent component



Synergy (residual)

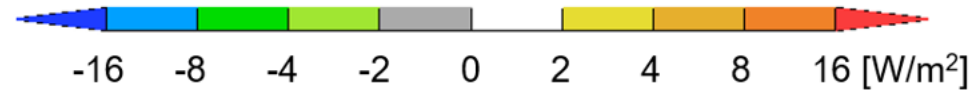
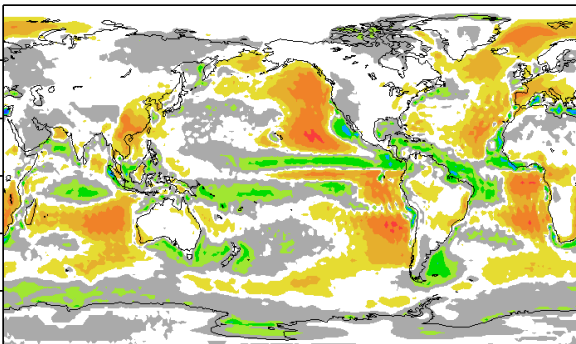


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Radiative + Turbulent



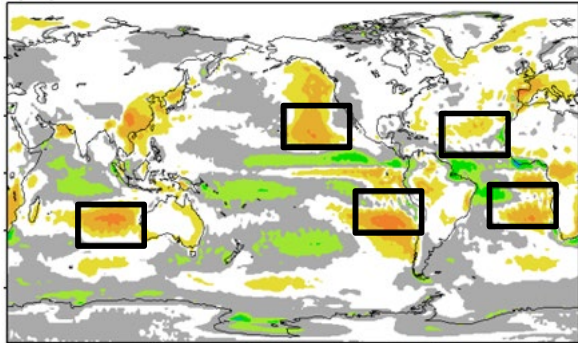
Pattern correlation
0.81

Radiative component makes the feedback positive. But how?

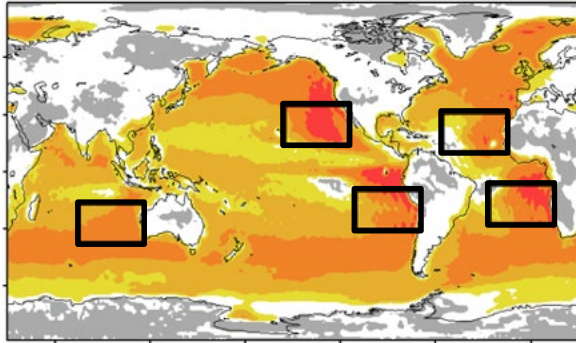
Which term makes the low cloud feedback positive?

Low cloud feedback induced by 4K increase in SST

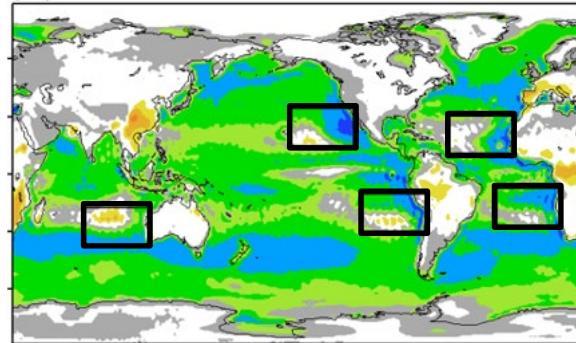
Total response



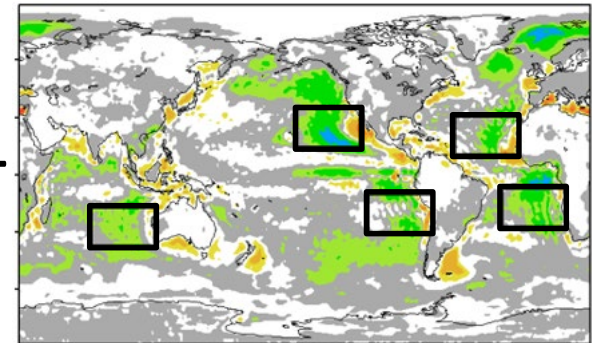
Radiative component



Turbulent component



Synergy (residual)

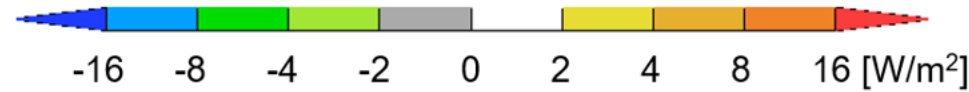
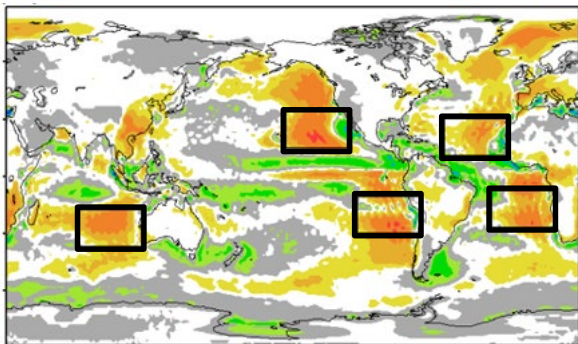


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Radiative + Turbulent

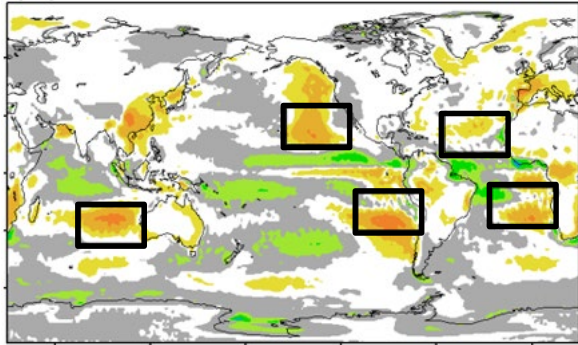


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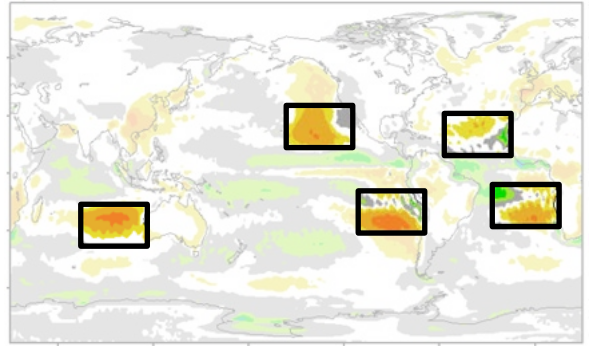
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Total response



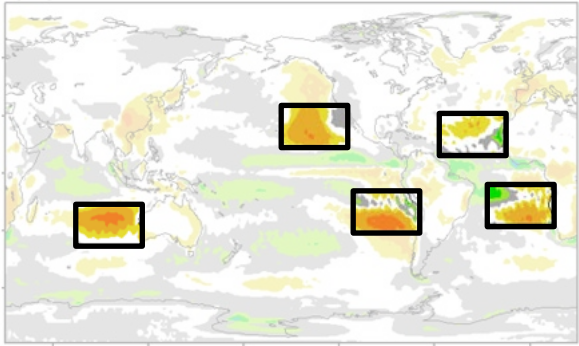
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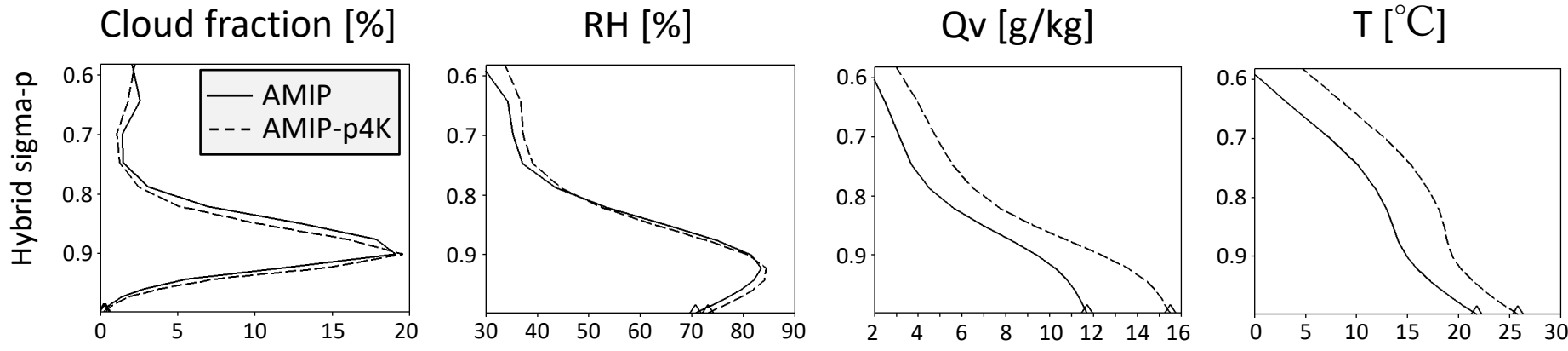


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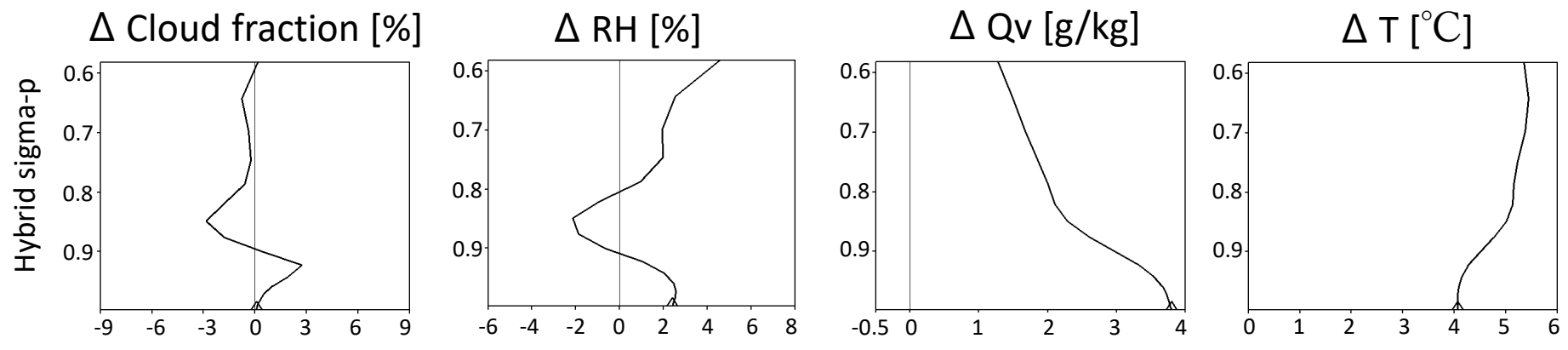
Total response



AMIP & AMIP-p4K experiments

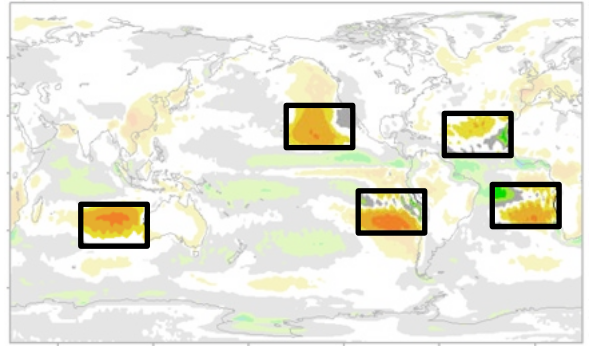


Total response (AMIP-p4K minus AMIP)

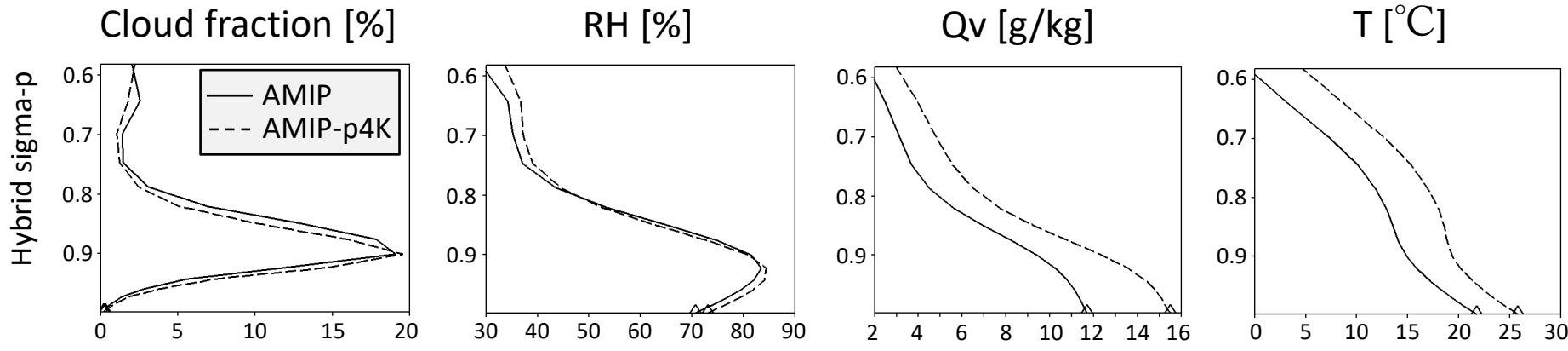


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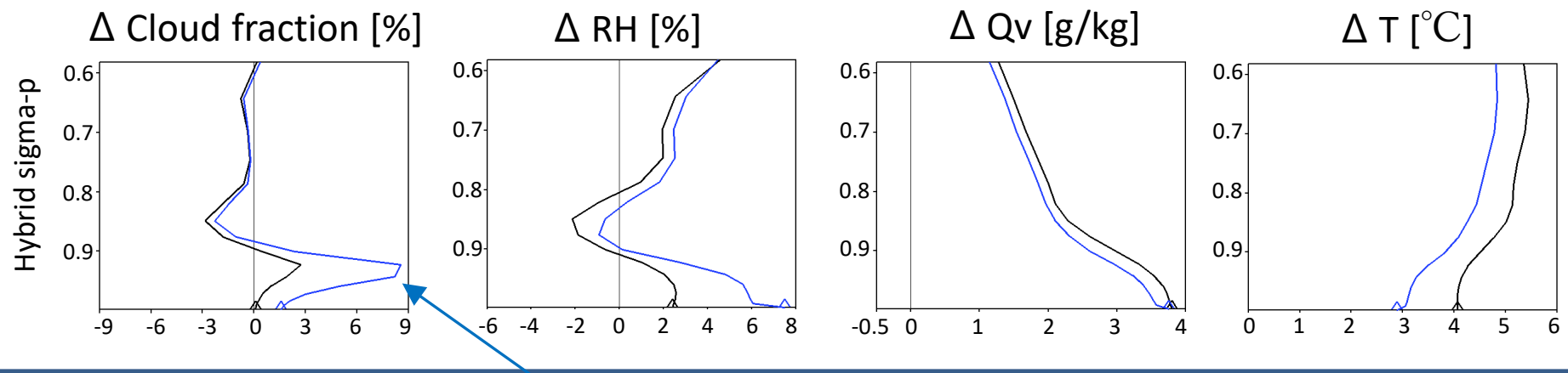
Total response



AMIP & AMIP-p4K experiments

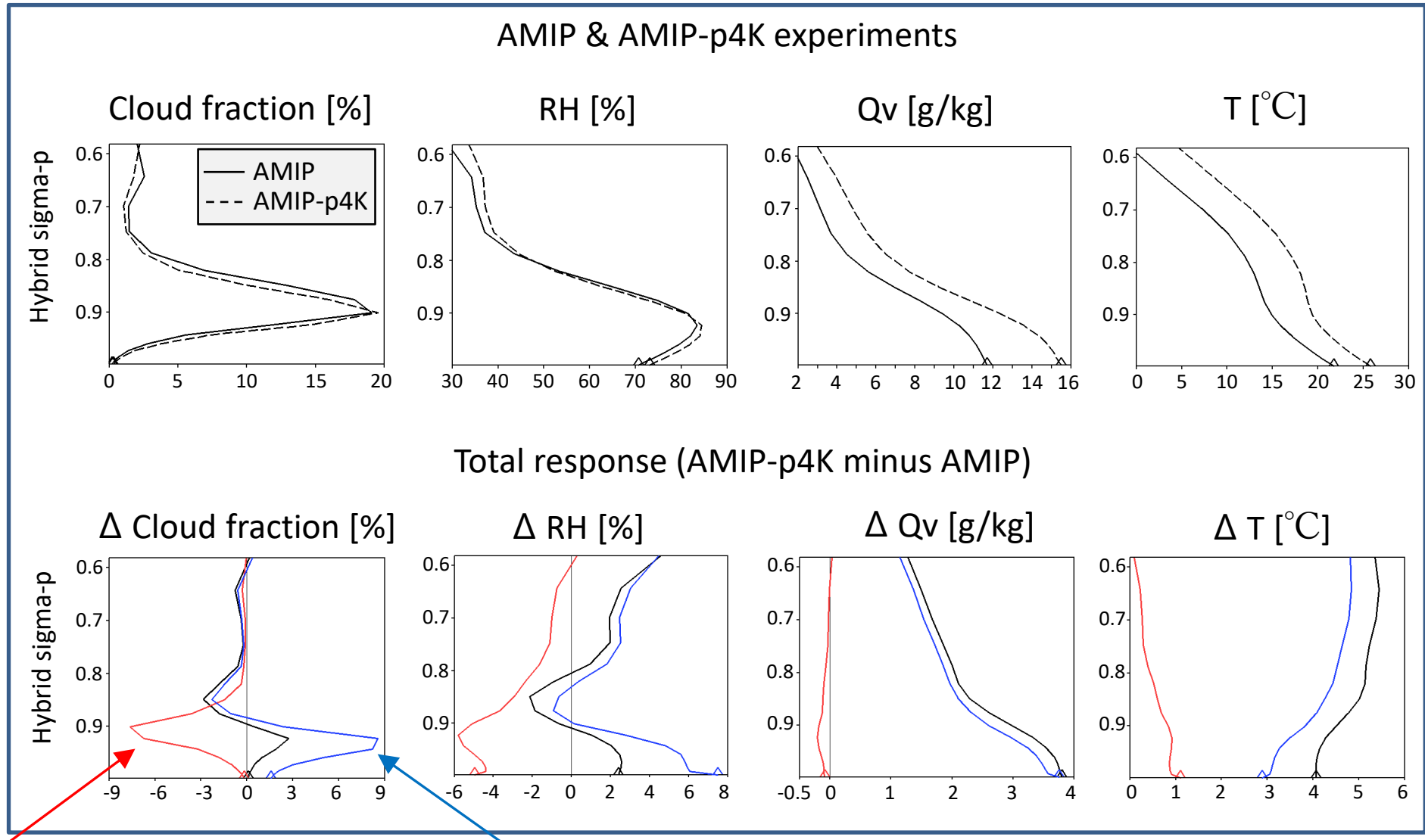
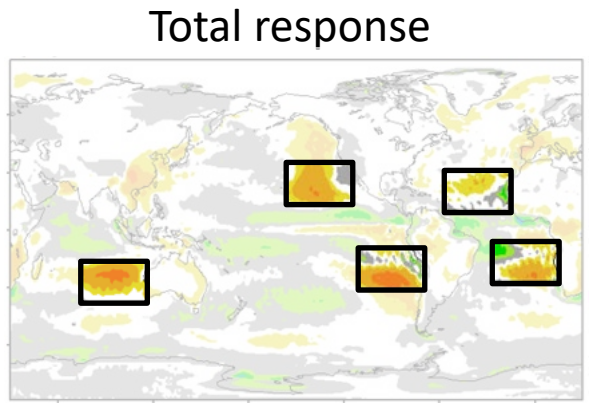


Total response (AMIP-p4K minus AMIP)



Turbulent

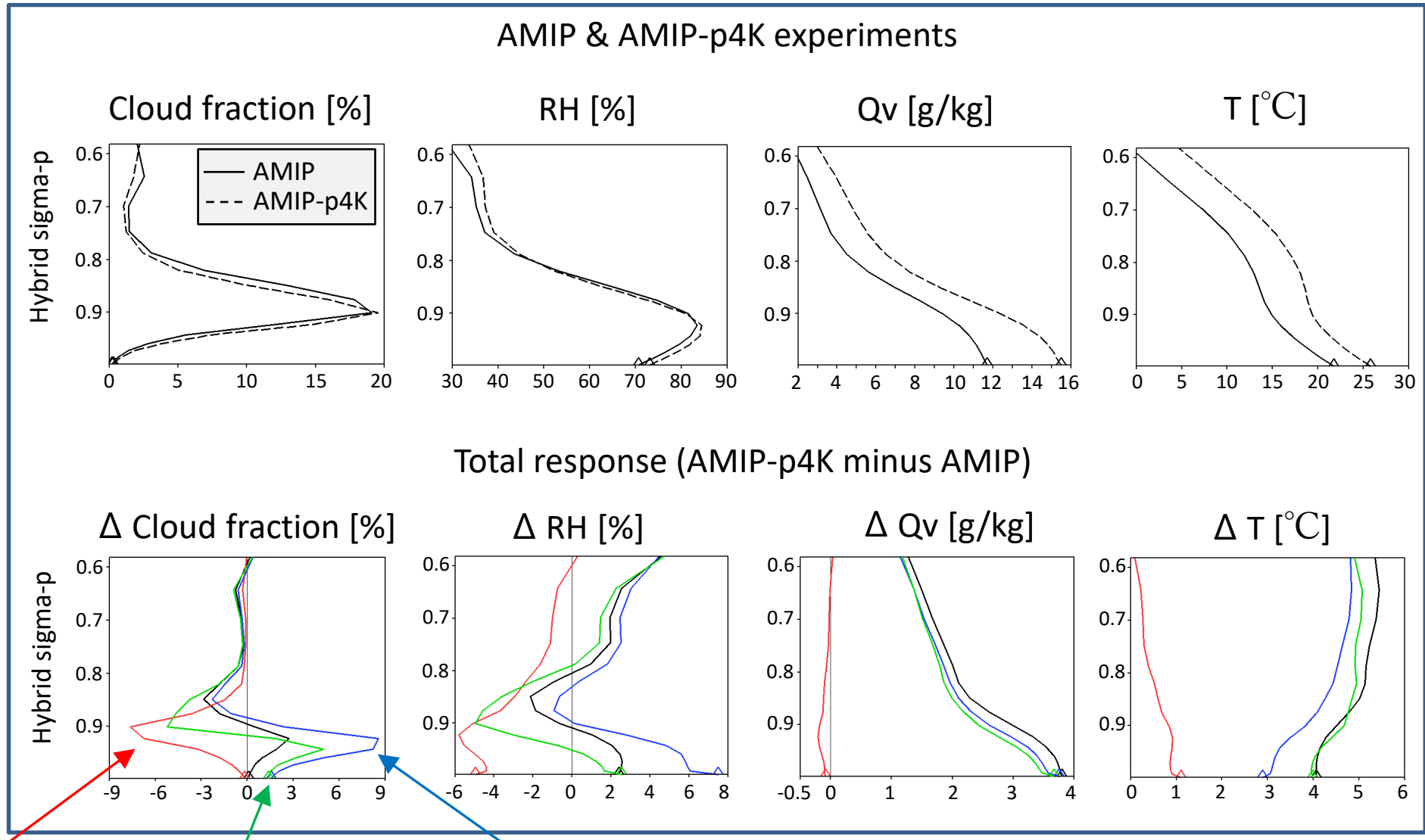
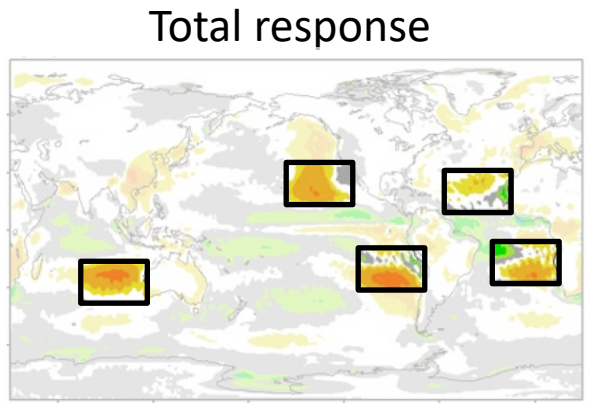
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Radiative

Turbulent

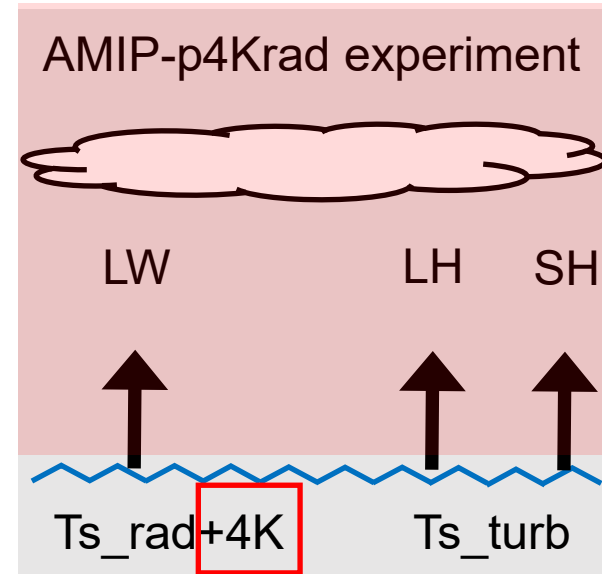
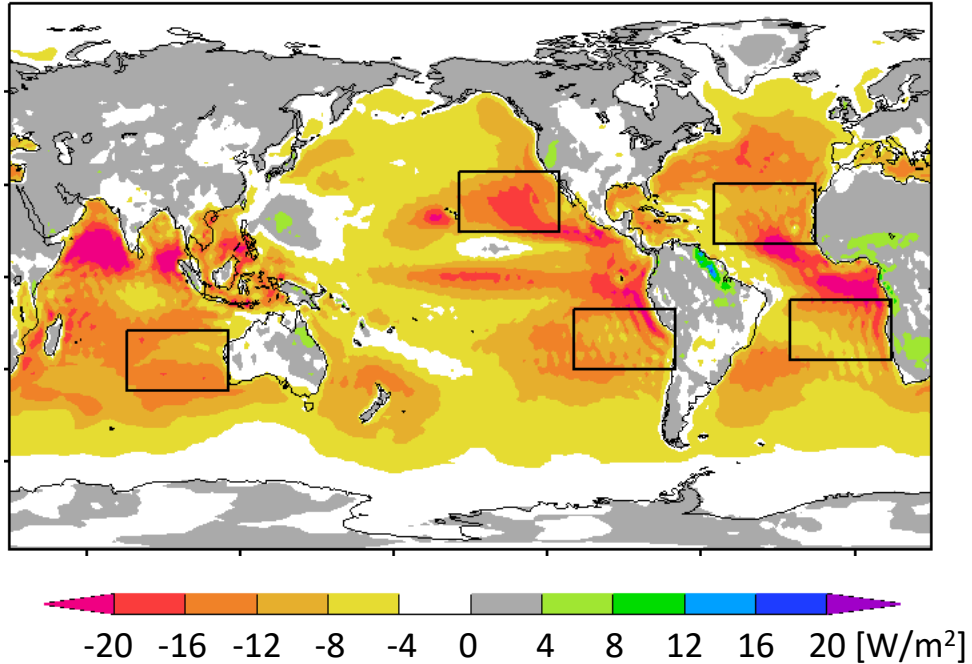
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Radiative **Turbulent+Radiative** **Turbulent**

Latent heat flux decreases in radiative component

Δ Latent heat flux
(AMIP-p4Krad minus AMIP)

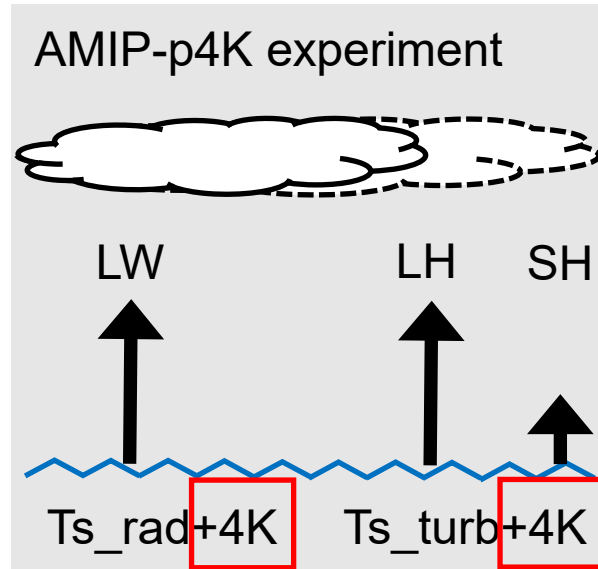
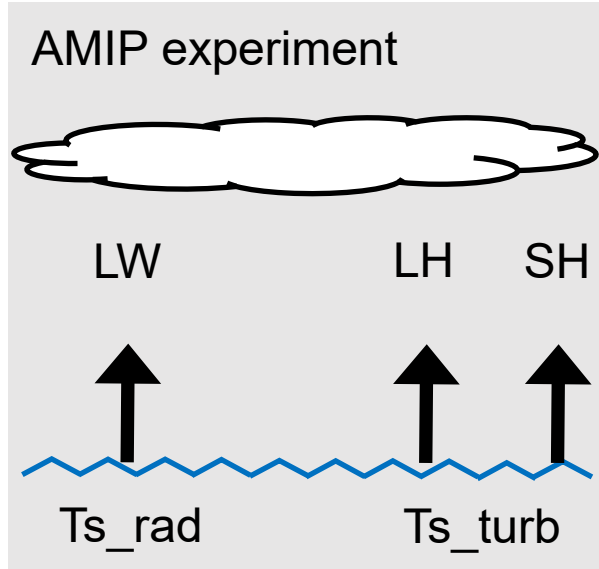


Surface air T warms up
 T_{s_turb} stays the same

Static stability increases at air-sea interface

Bulk coefficient decreases, LH decreases

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This study

Positive feedback (cloud decrease)

Increase in LW from sea surface

↓

Warming & drying ($\Delta Q_v < 0$) in B-Layer

↓

Decrease in low cloud

This study

Positive > Negative in LES.

Does this explain positive sign in GCMs?

Negative > Positive in MIROC6

Latent heat flux increases.
Warmer & moister atmosphere

Discussion & Summary

Positive feedback from LW heating work in other GCMs?

Yes & No.

Mark Webb is presenting multi-GCMs analysis (next talk).
Results of some GCMs consistent with the present study.

Positive feedback from LW heating work in LES?

Yes.

Adrian Lock presented LES experiments in CFMIP.
Radiative component consistent with MIROC6.
Turbulent component more complicated than MIROC6.

- Positive low cloud feedback primarily caused by increasing LW radiation from the sea surface in MIROC6.

