Analysis of precipitation changes with ECHAM6 in radiative-convective equilibrium (RCE) mode

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CFMIP/EUCLIPSE meeting, Hamburg

11.06.2013

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How does precipitation change in a warming climate?

- The Atmospheric Balance Perspective -

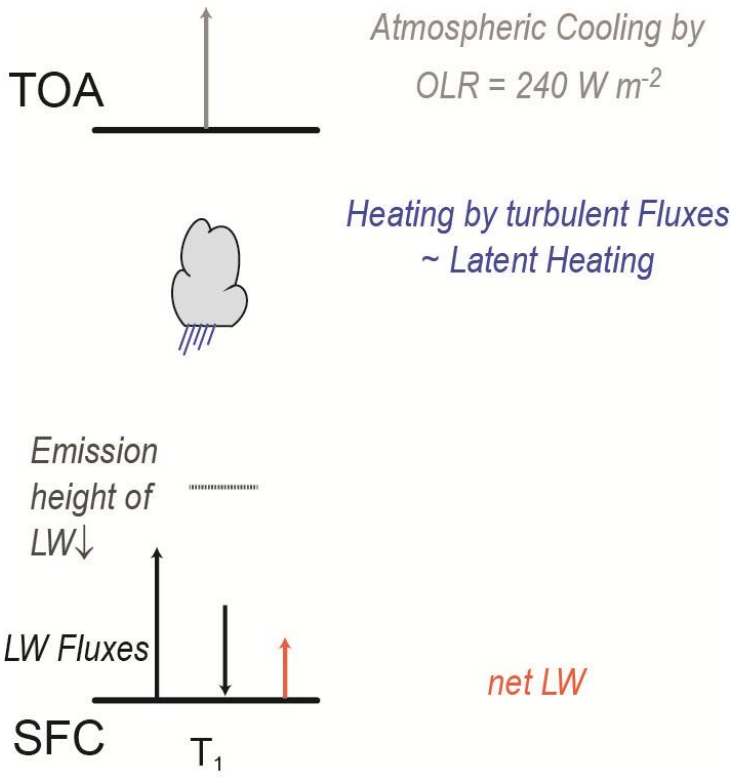
Atmospheric Cooling

=

Heating by turbulent Fluxes

+

Heating by Surface Net LW



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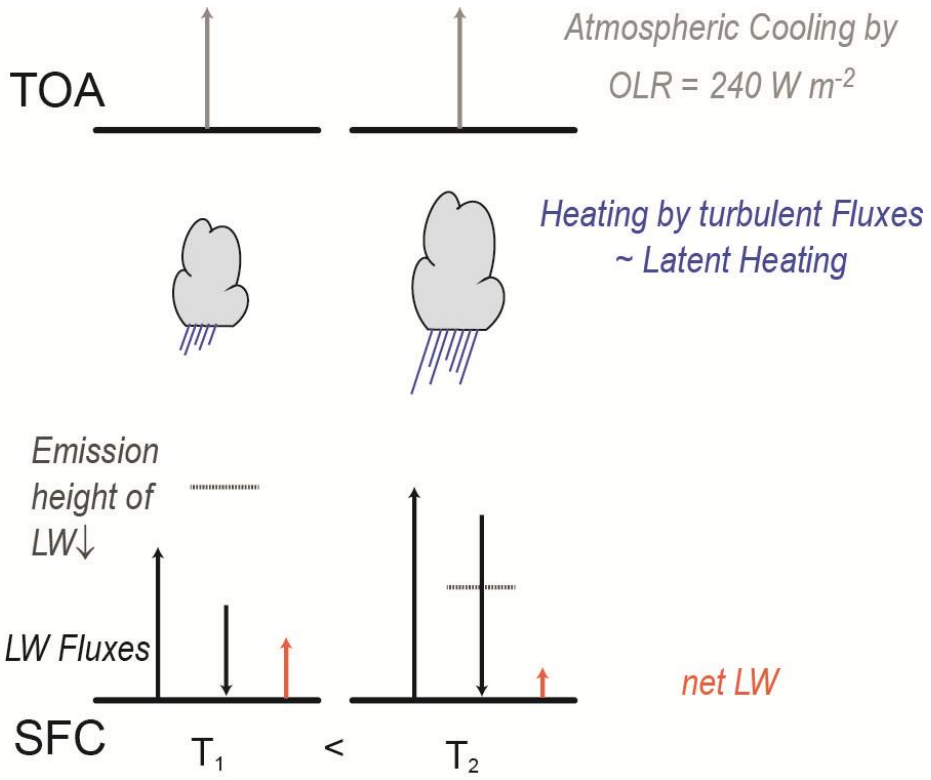

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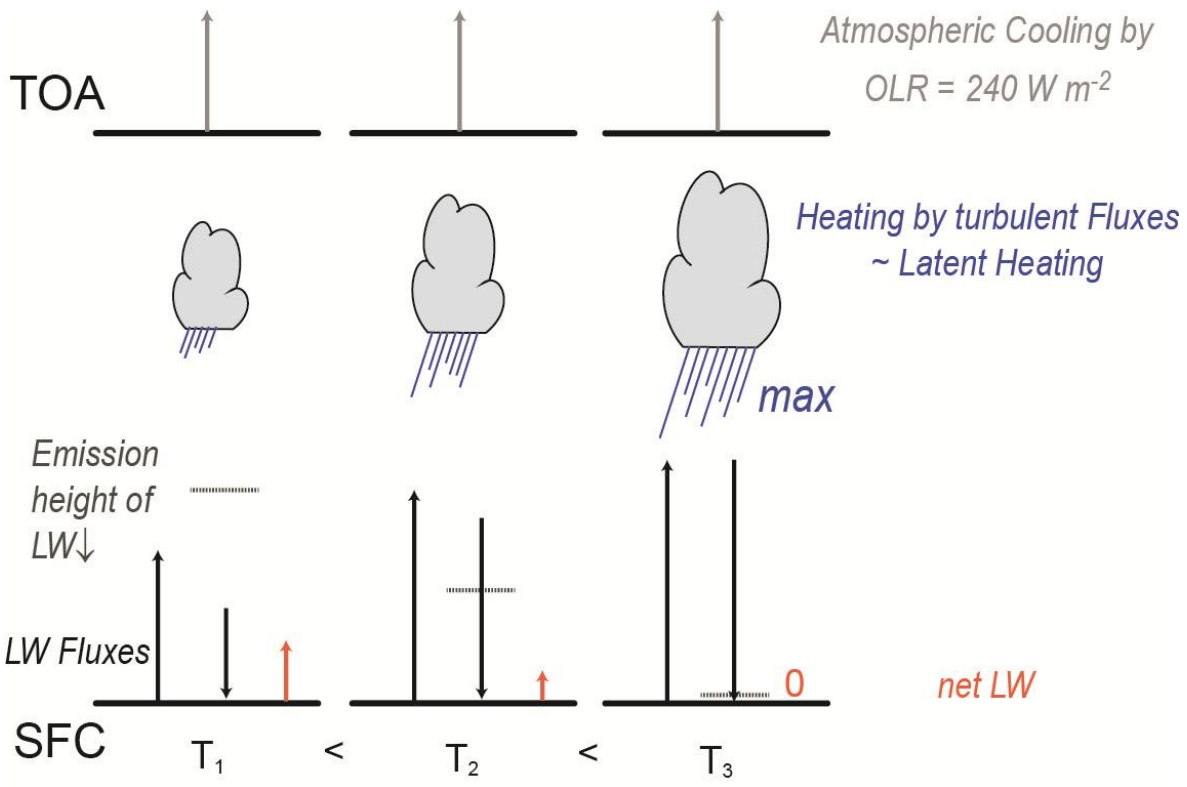
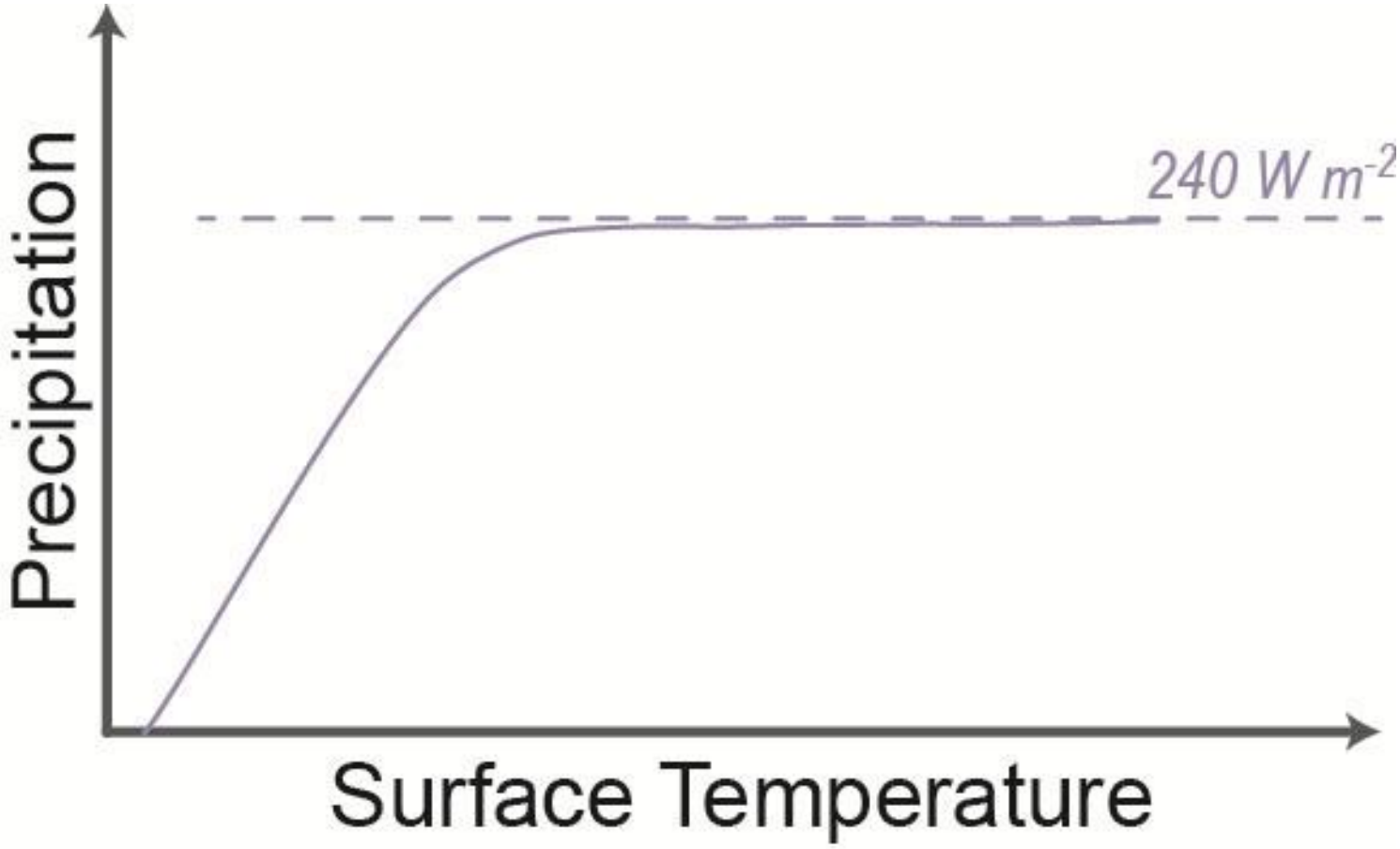


Maximum precipitation rate decreases in a warmer climate



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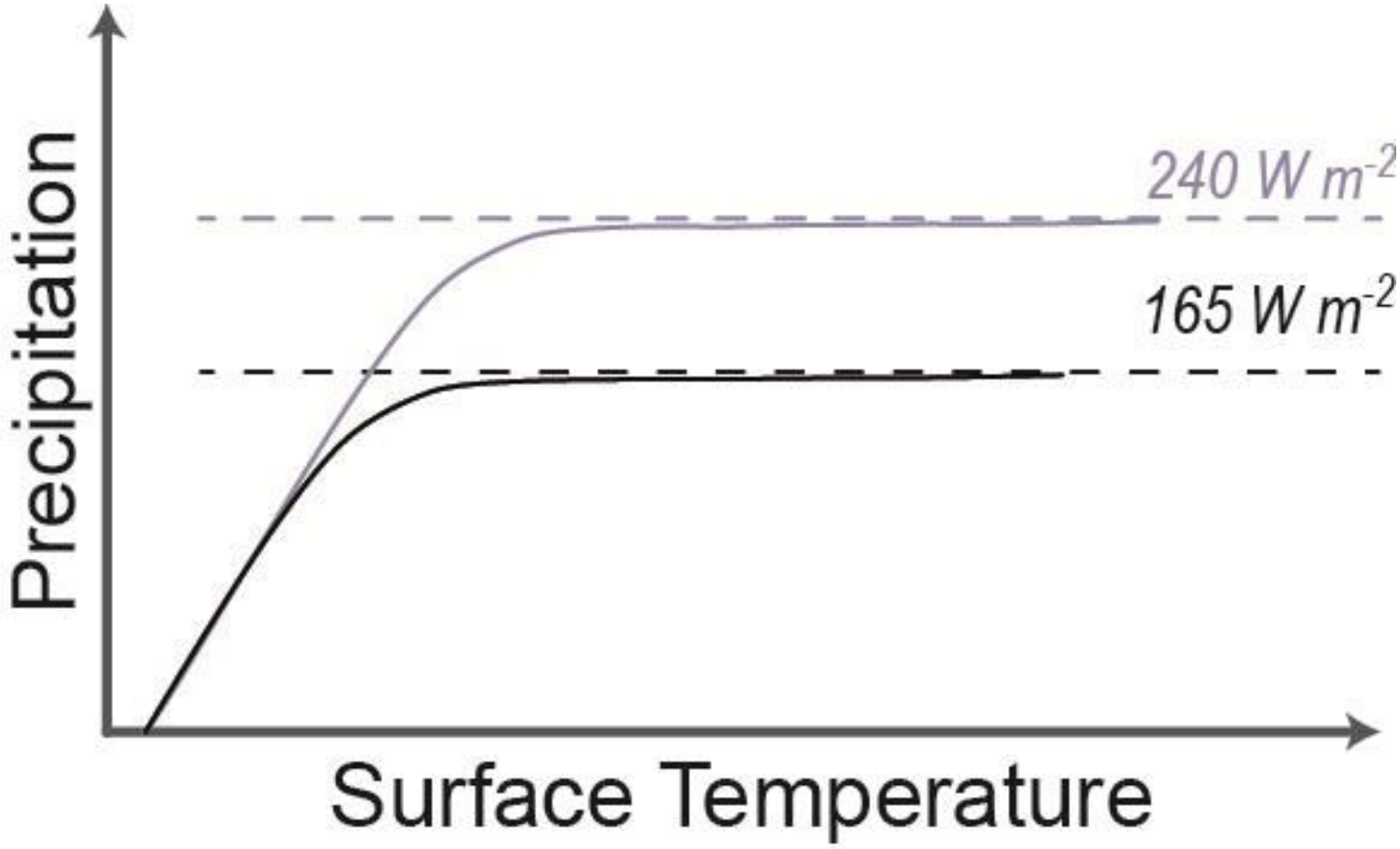

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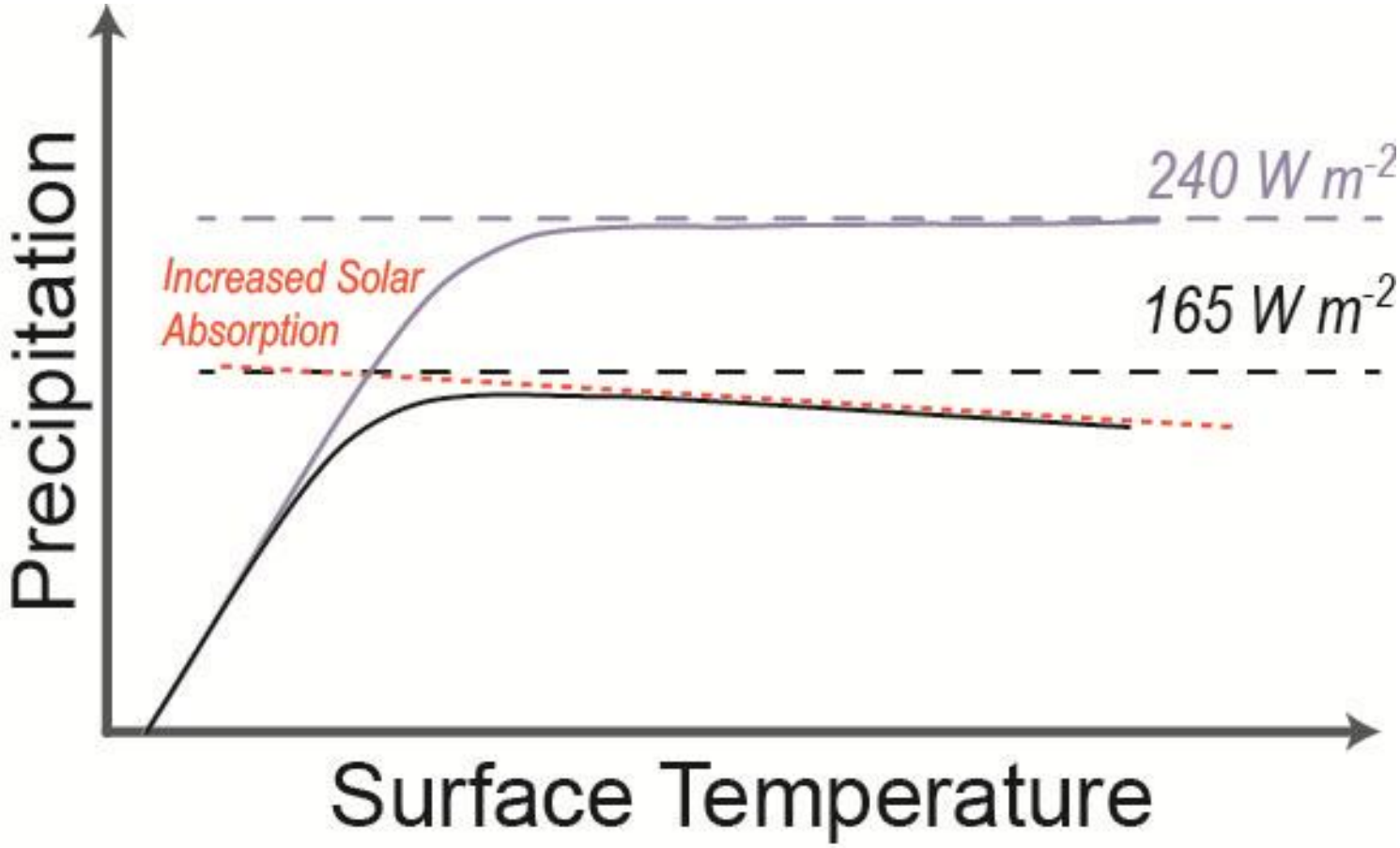

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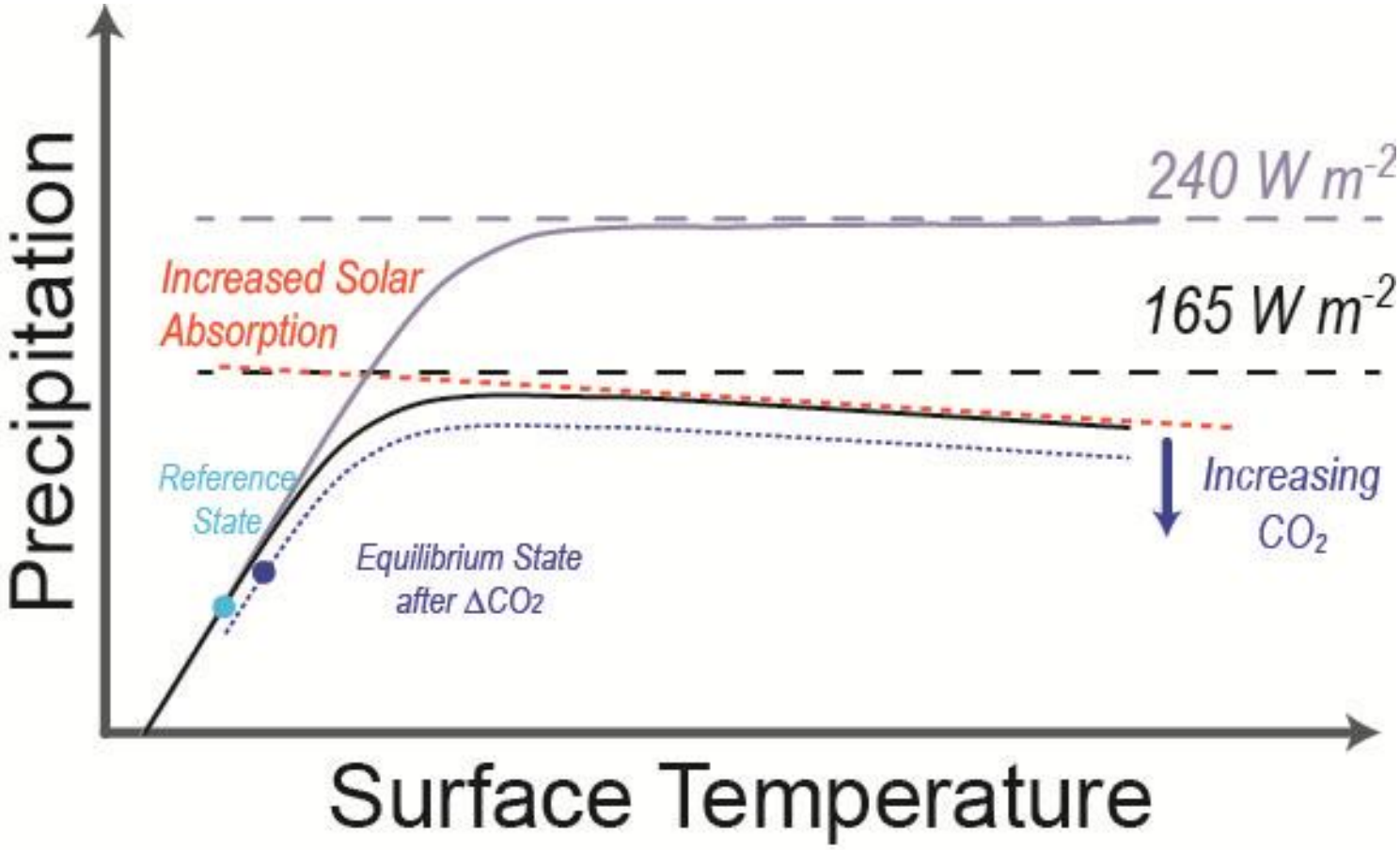

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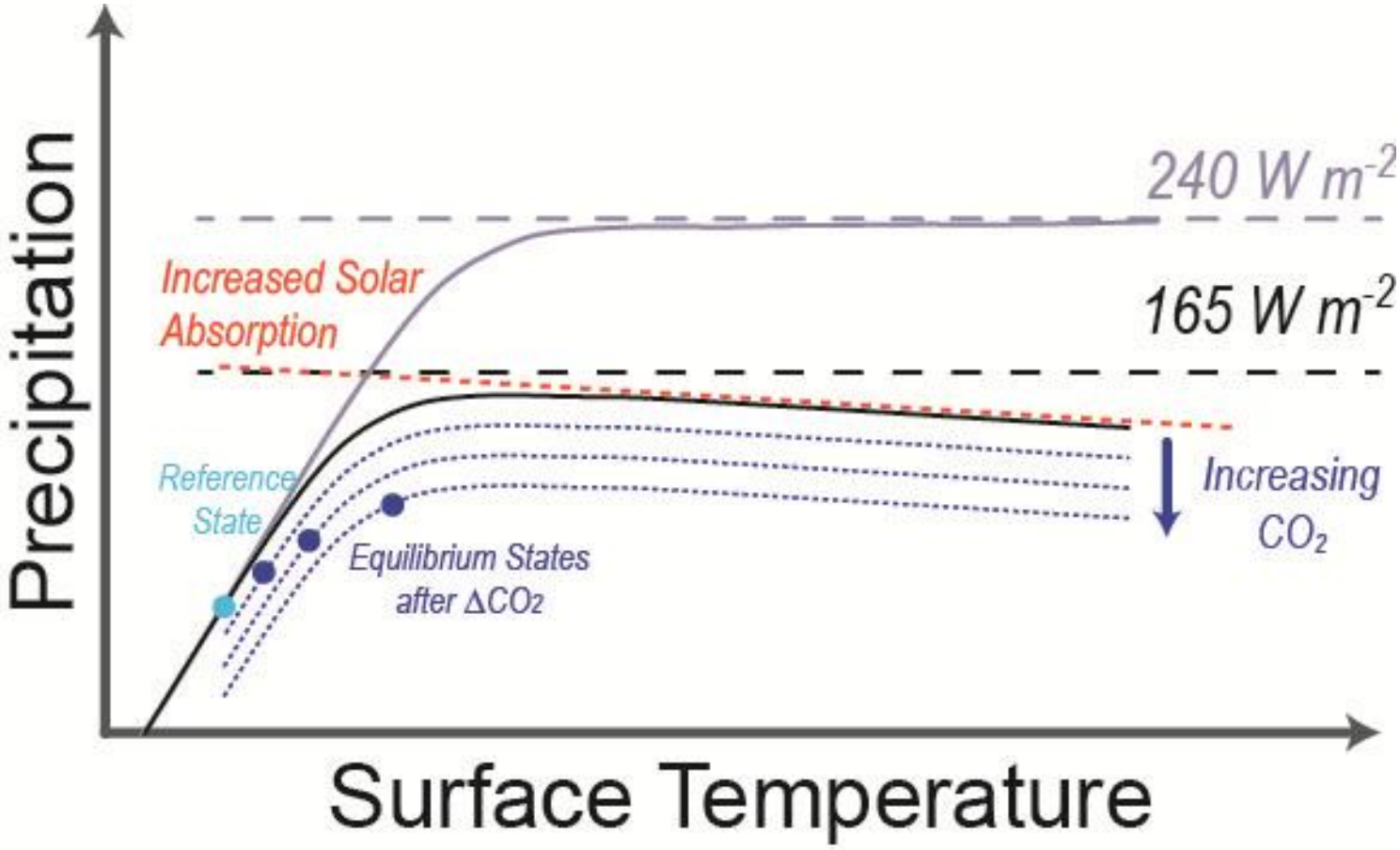

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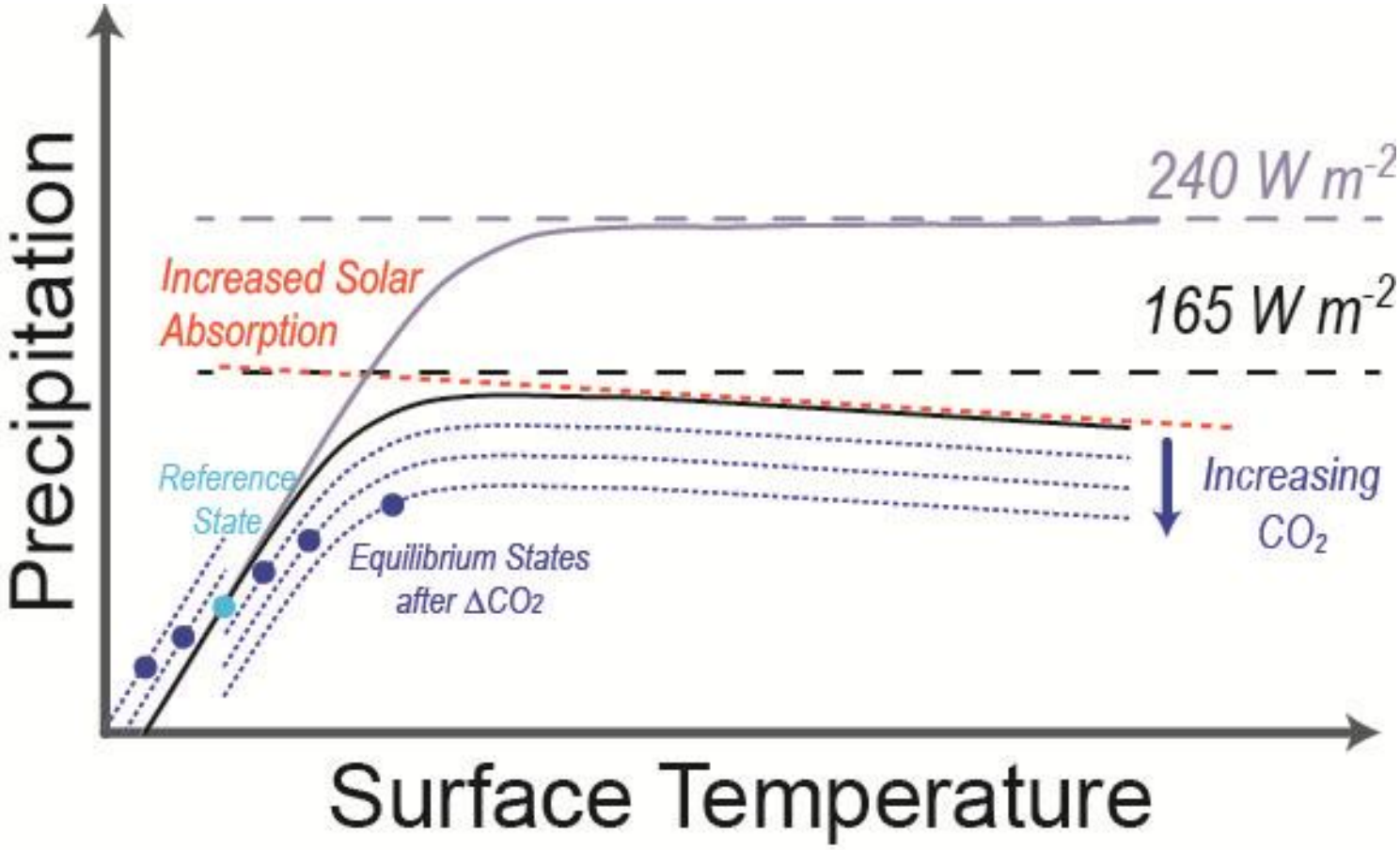
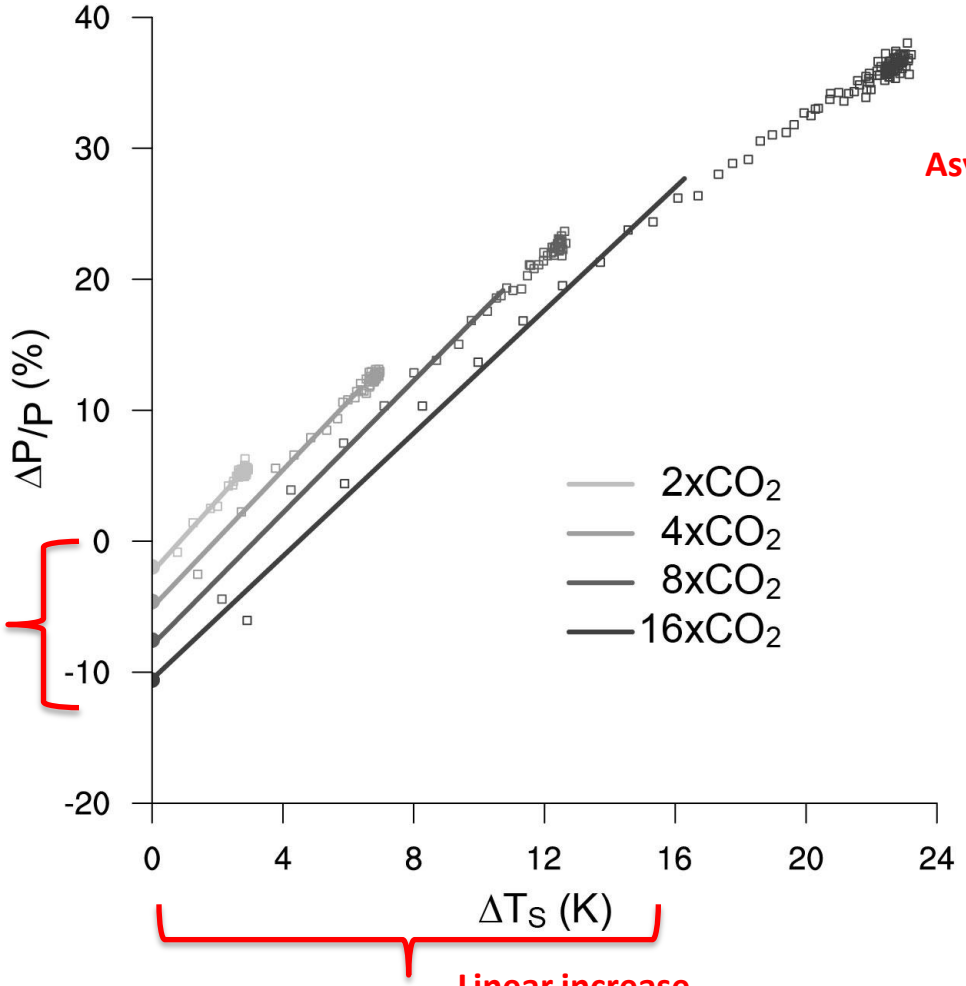


Mixed-layer ocean (MLO) experiments show expected behavior



Asymptotes with warming

CO_2 direct effect

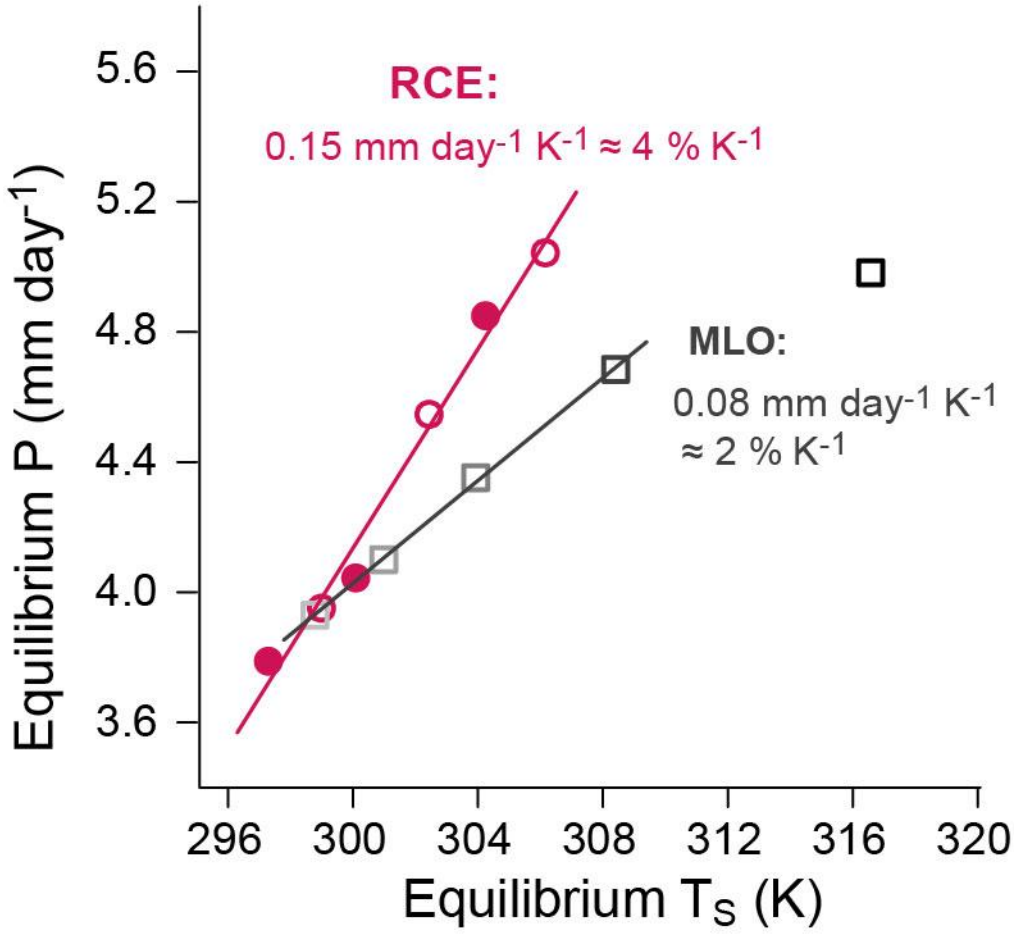
Linear increase

- ECHAM, global: 2.3-2.8 % K^{-1}
- Lambert & Webb, 2008: 1.4-3.4 % K^{-1}

Lambert & Webb, 2008; Bony et al., 2013; O'Gorman & Schneider, 2008; Andrews et al.,2009

Estimated hydrological sensitivity from equilibrium states

- Twice as large in radiative-convective eq. (RCE) as in MLO tropics -



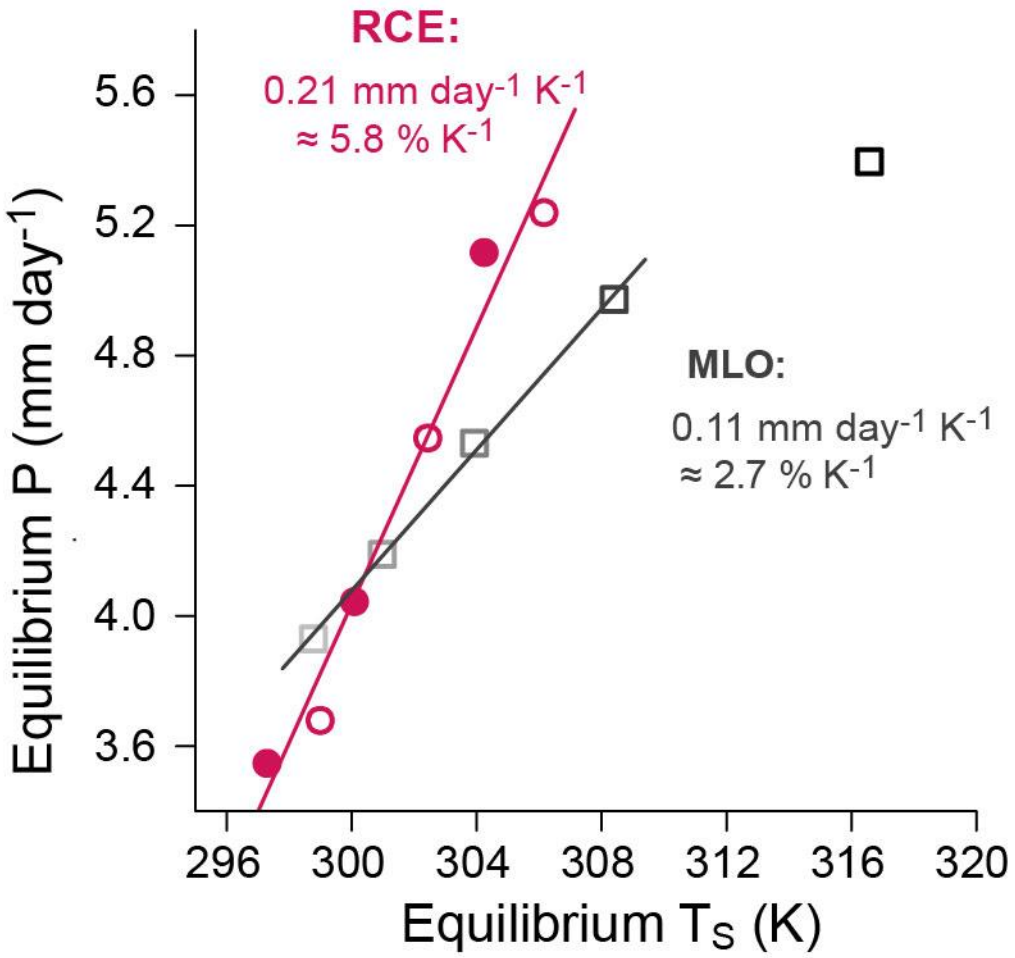
Held & Soden, 2006:
„For reasons that are unclear, some one-dimensional radiative-convective models predict sensitivites of global hydrological cycle as large as 4 % K^{-1}“

Analysis misses CO_2 direct effect

- underestimation of hydrological sensitivity

Estimated hydrological sensitivity from equilibrium states, corrected for CO_2 direct effect

- Here also about twice as large in RCE as in MLO tropics -

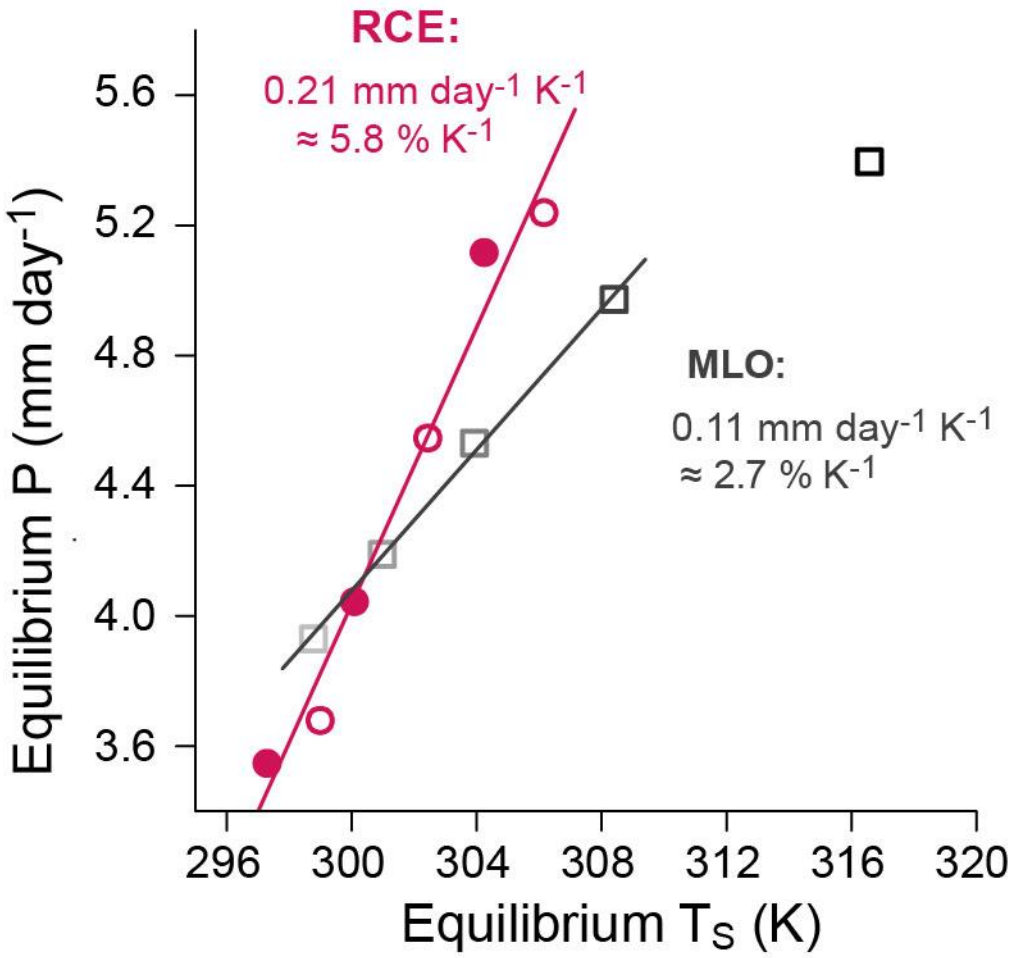


Correcting for CO_2 direct effect:

- Stronger hydrological sensitivity

Estimated hydrological sensitivity from equilibrium states, corrected for CO_2 direct effect

- Here also about twice as large in RCE as in MLO tropics -



Correcting for CO_2 direct effect:

- Stronger hydrological sensitivity

MLO: only tropics over ocean considered

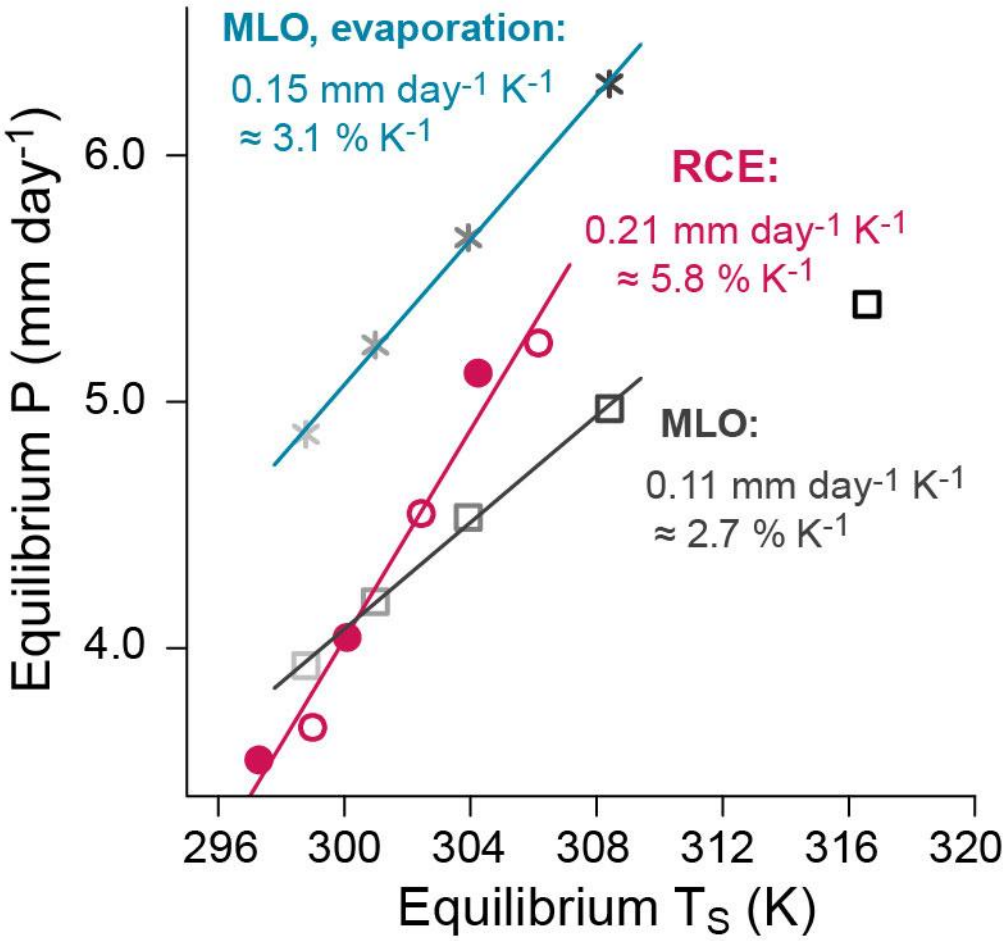
- moisture export may lead to lower hydrol. Sensitivity

Estimated hydrological sensitivity from equilibrium states, corrected for CO_2 direct effect & moisture export

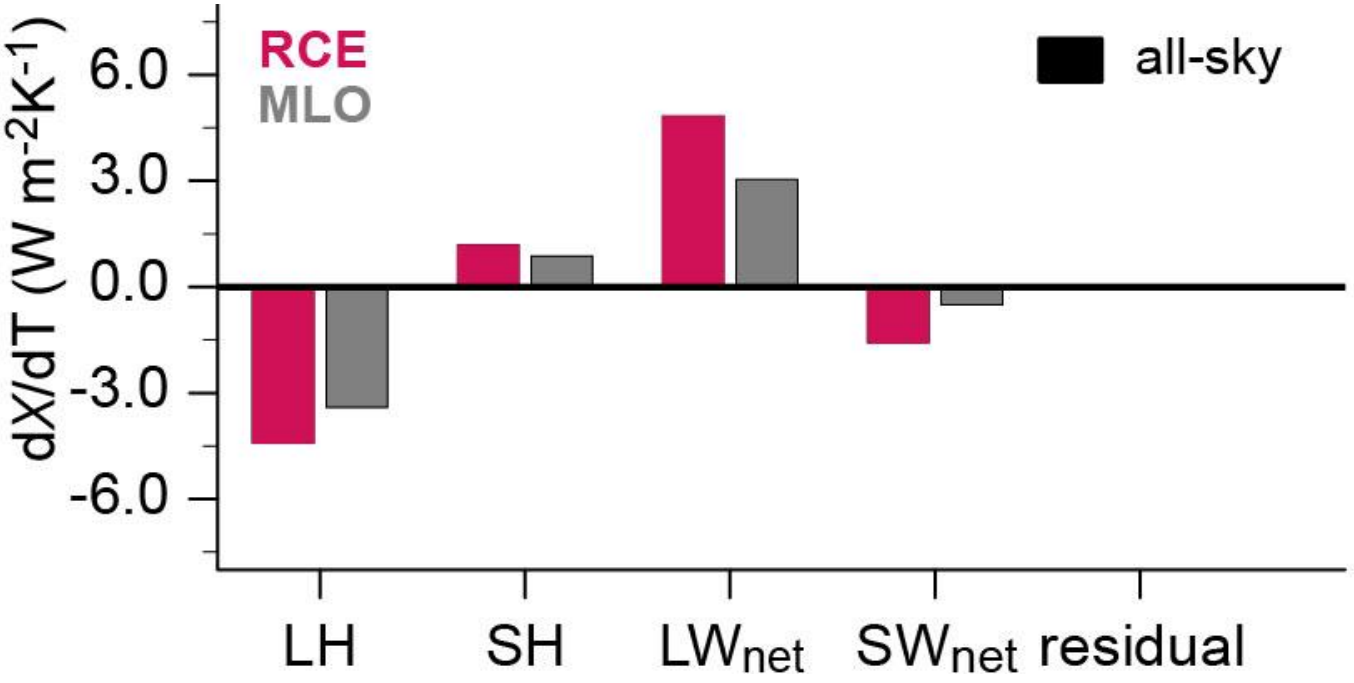
- Moisture export explains less than half of the difference between RCE & MLO -

MLO tropics: if E = P

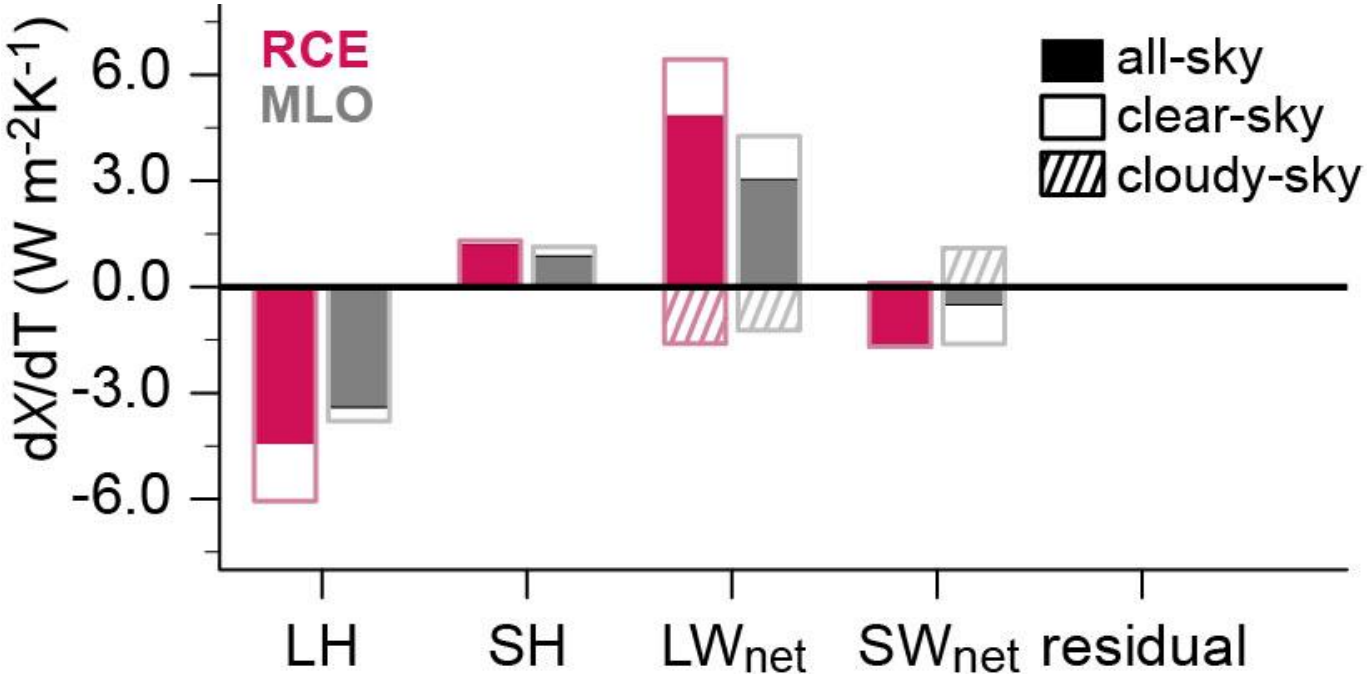
- stronger hydrol. Sensitivity
- but still not commensurate to that of RCE



Change of surface fluxes with temperature



Difference of LW_{net} clear-sky is cause for different hydrological sensitivity



Offline Radiation Calculations:

- similar flux changes estimated from mean temperature and humidity profiles
- stronger lower tropospheric temperature and relative humidity changes in RCE as in MLO explain difference in hydrological sensitivity

Conclusions

- Neglect of CO_2 direct effect leads to biased estimates of hydrological sensitivity
- Precipitation is twice as sensitive to temperature in RCE compared to MLO
- Moisture export from tropical regions in MLO explains less than half of the difference
- Remainder can be attributed to different behavior in surface clear-sky LW
  - We attribute this to changes in the thermal structure of the lower troposphere

Outlook

- Can the range of surface clear-sky LW explain the spread in hydrological sensitivity within the CMIP5 experiments?