On the magnitude of the stratospheric radiative feedback in global warming

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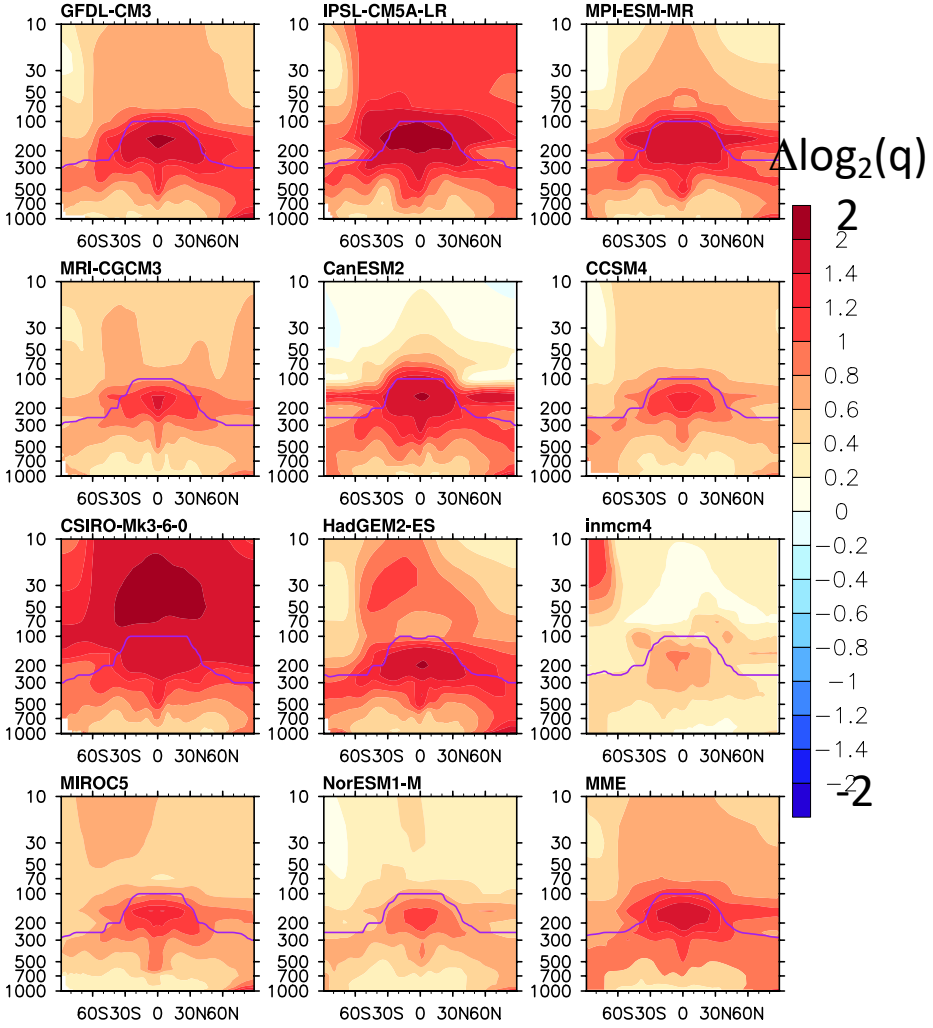
Stratospheric radiative feedback

- Feedback response: those driven by surface warming, e.g., abrupt4xCO2-sst4xCO2
- Significant stratospheric radiative feedback?
  - Significant moistening -> SWV feedback [Forster & Shine 2002, Solomon et al. 2010, Dessler et al. 2013, Banerjee et al. 2019…]: FDH method estimates 0.2-0.3 W m^{-2} K^{-1}
  - Small overall stratospheric radiative feedback: SWV radiative forcing + Strato. Temperature change induced radiative flux change ~ O(0.01 W m^{-2} K^{-1}) [Huang et al. 2016]

SWV: Stratospheric Water Vapor

FDH: Stratospheric radiative equilibrium and TOA flux change simulated under Fixed Dynamical Heating.



GCM-projected moistening in global warming [Huang et al. 2016]

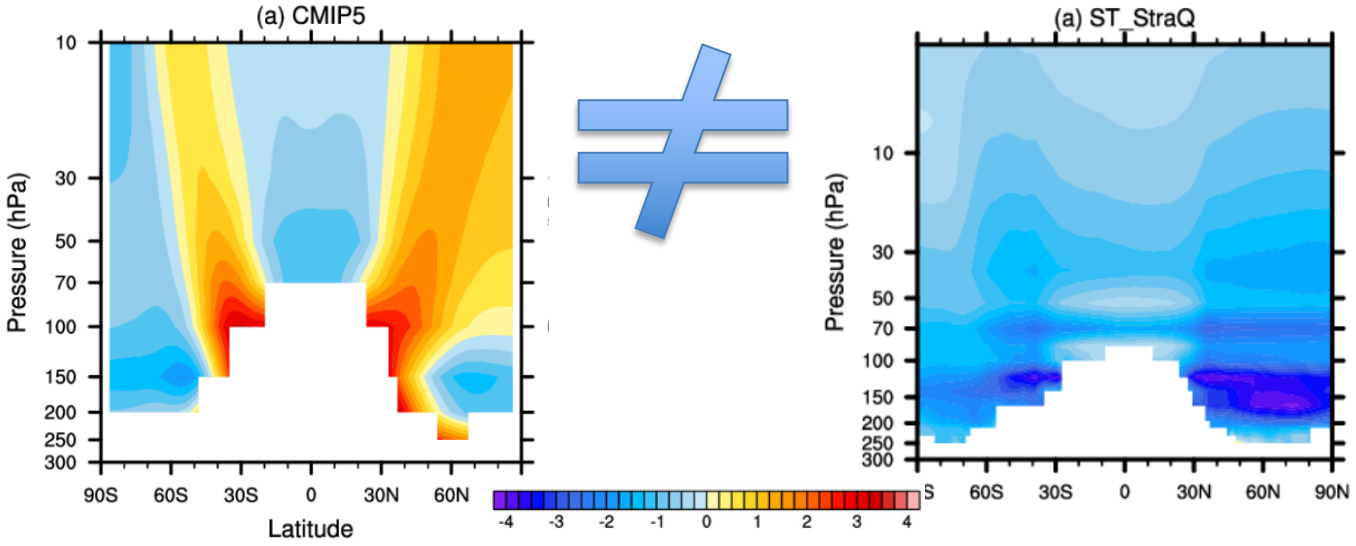
Agreements and disagreements

- TOA radiation budget perspective
- SWV radiative effect = $F_{direct} + F_{indirect}$

  F_{direct} : SWV direct forcing (greenhouse effect: trapping of OLR)

  $F_{indirect}$: SWV indirect forcing via cooling strat. temperature and reducing OLR
- Agreed
  - F_{direct} : small, O(0.1 W m^{-2}) [Huang et al. 2016; Banerjee et al. 2019]
  - $F_{indirect}$(Strat. Temp.) via FDH: large, O(1.0 W m^{-2}) [Banerjee et al. 2019, …]
- Disagreed
  - Is feedback temperature response in stratosphere dominated by SWV?

Overall $\Delta T_{stratos}$

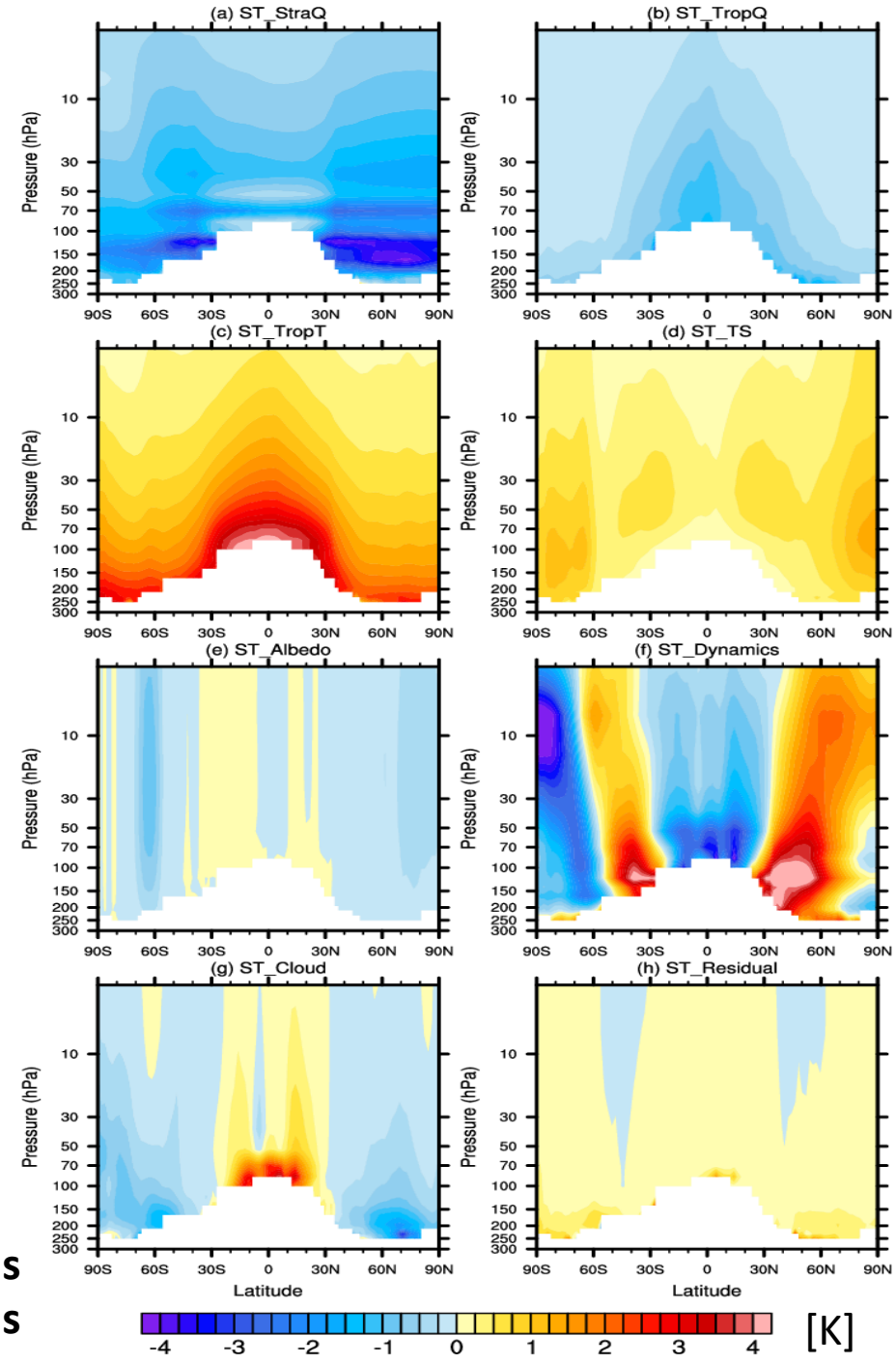


Hypothetical (FDH-based) SWV-caused $\Delta T_{stratos}$

Full decomposition of $\Delta T_{stratos}$

- $\Delta T_{stratos}$ is NOT dominated by SWV
- Other radiative effects, esp. those from troposphere, offset SWV radiative cooling of stratosphere!

Stratos WV	Tropos WV
Tropos Temp	Surf Temp
Surf. Albedo	Strato Dynamics
Clouds	Residual



$\Delta T_{stratos}$ change driven by different perturbations obtained via radiative equilibrium simulations

Radiative feedback of $\Delta T_{stratos}$

- $\Delta T_{stratos}$ is NOT dominated by SWV
- Other radiative effects, esp. those from troposphere, offset SWV radiative cooling of stratosphere and thus neutralize the SWV warming effect!

ΔR change driven by different perturbations

	SWV	ΔT StraQ	ΔT TropQ	ΔT TropT	ΔT TS	ΔT Albedo	ΔT Dyn	ΔT Cloud
Flux Changes at TOA (W m^{-2})	0.23	0.53	0.19	-0.56	-0.18	0.03	-0.21	0.17
Feedbacks (W m^{-2} K^{-1})	0.05	0.12	0.04	-0.12	-0.04	0.01	-0.05	0.04

Accounted by FDH

NOT accounted

Surface warming effect of SWV?

- How to determine the surface warming effect of SWV?

  - RTM: Instantaneous forcing [Huang et al. 2016]

  - FDH: Stratosphere-adjusted forcing [Banerjee et al. 2019; Dessler et al. 2013; Solomon et al. 2020; …]

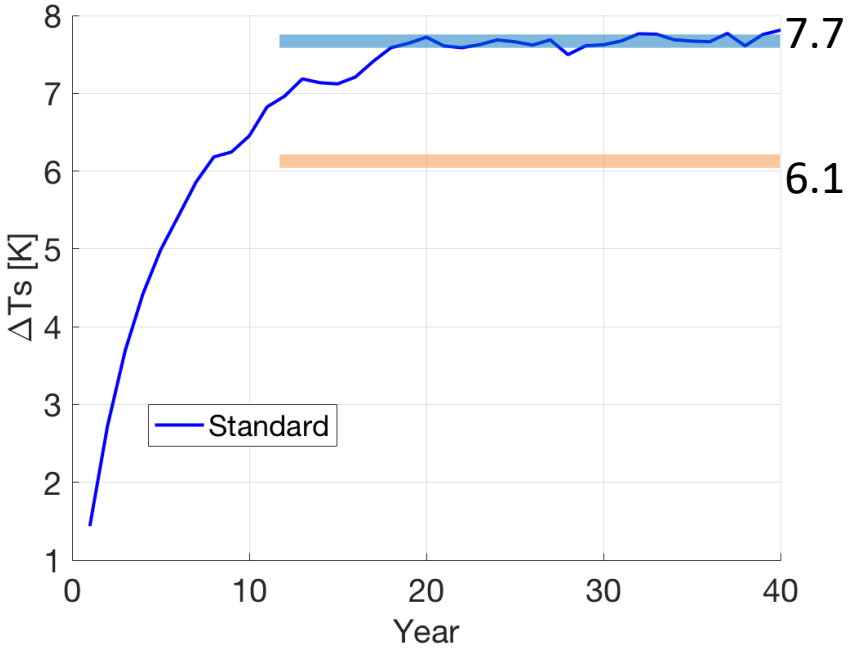
  - **Mechanism denial experiment: SWV-locking**

    Control: 1xCO2

    Standard: 4xCO2, CESM (CAM+SOM)

    Locking: 4xCO2, SWV replaced with Control values

Global mean ΔT_S, CESM 4xCO2



$R_{net} = F + \lambda \Delta T_S = 0$

F = 8.4 W m^{-2} (from fixed-SST 4xCO_2)

ΔT_S = 7.7 K

=> λ = -1.1 W m^{-2} K^{-1}

Had λ_{SWV}= 0.3 W m^{-2} K^{-1} been subtracted,

ΔT_S(no SWV feedback) = F/-(λ-λ_{SWV}) = 6.1 K

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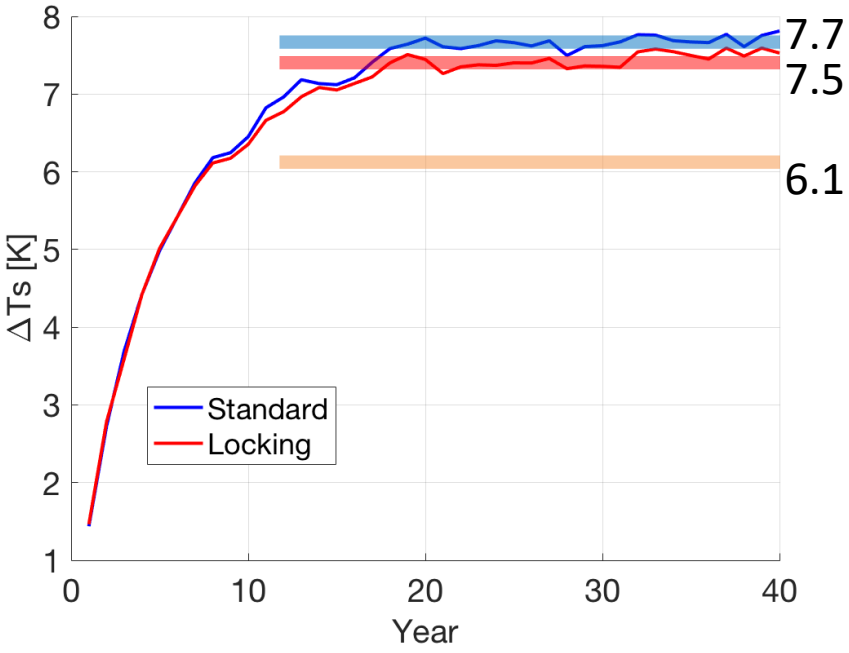
Insignificant (2%) warming enhancement by SWV!

Global mean ΔT_S, CESM 4xCO2



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However, from SWV-locking: ΔT_S= 7.5 K !

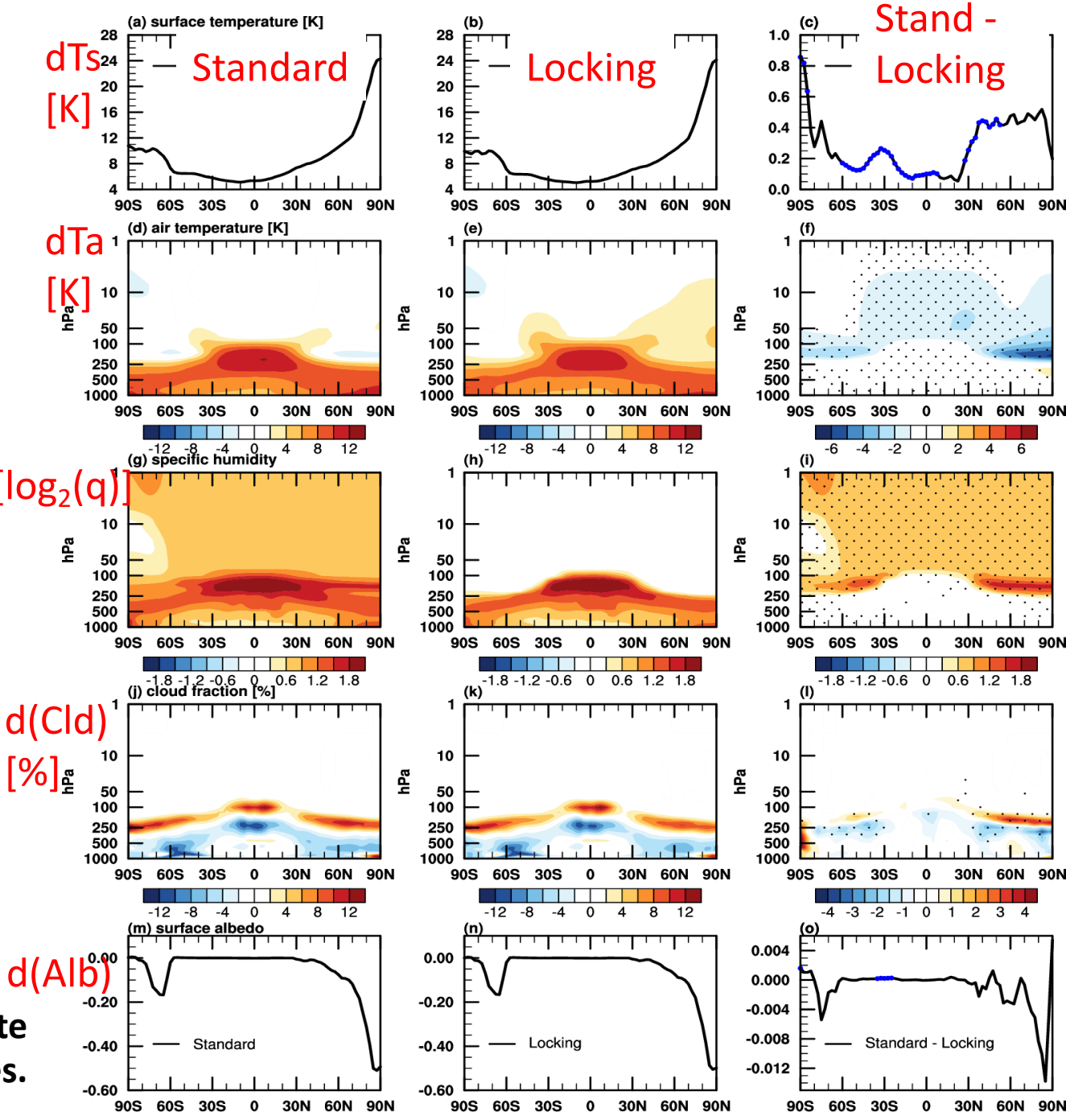
Small SWV warming: why?

- TOA budget perspective
- Stratospheric cooling
- Tropospheric warming
- Cloud (high)

SWV coupled with other feedbacks;

Compensation of these feedbacks neutralize the warming effect of SWV in (Stand-Locking) experiment.

Zonally averaged climate feedback responses.



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Compensation of these feedbacks neutralize the warming effect of SWV in (Stand-Locking) experiment.
FDH assessment may be misleading!

	ΔT_{sur} (K)	Forcing (W m^{-2})		ΔR_X cause by Feedback Variables (W m^{-2})							Total (W m^{-2})
		CO_2, ins.	CO_2, adj.	Wstr	Wtro	Tstr	Ttro	Tsur	ALB	CLD	
Standard	7.71	4.70	3.67	0.18	12.95	-0.23	-21.31	-4.91	2.09	2.69	0.02
Locking	7.53	4.70	3.67	0.00	12.77	-0.77	-20.58	-4.75	2.05	2.97	0.03
Difference	0.18	0.00	0.00	0.18	0.18	0.54	-0.73	-0.16	0.04	-0.28	-0.01

Global mean surface warming and TOA radiation flux changes, decomposed to forcing and feedback components using the kernel method.

Take-home messages

- Strong stratospheric cooling due to SWV hypothesized by FDH method: NOT observed because of compensating effects.
- Surface warming effect of SWV assessed by a mechanism-denial, SWV-locking experiment: small (2% warming enhancement).
- No evidence of a strong stratospheric radiative feedback in GCM.

References

- Huang, Y. and Y. Wang, (submitted), Stratospheric water vapor feedback disclosed by a locking experiment, Geophys. Res. Lett.
- Wang, Y. and Y. Huang, (submitted), Stratospheric radiative feedback limited by the tropospheric influence in global warming, Climate Dynamics.