Geophysical Research Letters

Supporting Information for

Local and remote impacts of atmospheric cloud radiative effects onto the eddy-driven jet

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S1. Latitude-dependent clouds-on experiments

In order to investigate the separate effects of tropical and extratropical clouds onto the eddy-driven jet, experiments additional to the standard COOKIE procedure are performed in which cloud radiative effects are turned on/off in only certain latitude bands, or for only LW versus SW. A weighting function that depends on latitude is constructed to smoothly interpolate between total radiative fluxes and heating rates, which include cloud radiative effects, and clear-sky fluxes and heating rates, which don't. Specifically, the weighting function is defined as

$$w(\phi, \phi_{ET}, \Delta\phi) = \begin{cases} 1, & |\phi| \geq \phi_{ET} + \Delta\phi/2 \\ 0, & |\phi| < \phi_{ET} - \Delta\phi/2 \\ 0.5\left(1 - \sin\left[\frac{\pi}{\Delta\phi}(\phi - \phi_{ET})\right]\right), & \phi_{ET} - \frac{\Delta\phi}{2} < \phi < \phi_{ET} + \frac{\Delta\phi}{2} \\ 0.5\left(1 + \sin\left[\frac{\pi}{\Delta\phi}(\phi + \phi_{ET})\right]\right), & -\phi_{ET} - \frac{\Delta\phi}{2} < \phi < -\phi_{ET} + \frac{\Delta\phi}{2} \end{cases} \qquad \text{(S1)}$$

where ϕ_{ET} is the boundary between clouds-on and clouds-off regions and $\Delta\phi$ is the width of the smoothing region between clouds off and clouds on. The weighting function w is plotted in Fig. S1 using the parameters $\phi_{ET} = 30°$ and $\Delta\phi = 10°$. Four experiments are performed with the GFDL-AM2.1 model in which cloud radiative effects are only included in certain latitude bands. These are: deep tropics (equatorward of 15°), tropics (equatorward of 30°), subtropics (between 15° and 30°) and extratropics (poleward of 30°). For the NCAR-CAM5.3 model, only the tropics and extratropics experiments are performed. Given some heating rate or radiative flux Q, which is computed by the radiative transfer scheme for both total (Q_{total}) and clear-sky ($Q_{clearsky}$) conditions, the actual heating rate or flux imposed in each of these simulations is given by:

$$Q_{extratrop\ on} = Q_{total} \cdot (1 - w(\phi_{ET} = 30°, \Delta\phi = 10°)) + Q_{clearsky} \cdot w(\phi_{ET} = 30°, \Delta\phi = 10°) \qquad \text{(S2)}$$

$$Q_{tropical\ on} = Q_{total} \cdot w(\phi_{ET} = 30°, \Delta\phi = 10°) + Q_{clearsky} \cdot (1 - w(\phi_{ET} = 30°, \Delta\phi = 10°)) \quad \text{(S3)}$$

$$Q_{deep\ trop\ on} = Q_{total} \cdot w(\phi_{ET} = 15°, \Delta\phi = 5°) + Q_{clearsky} \cdot (1 - w(\phi_{ET} = 15°, \Delta\phi = 5°)) \quad \text{(S4)}$$

$$Q_{subtrop\ on} = Q_{total} \cdot [w(\phi_{ET} = 30°, \Delta\phi = 5°) - w(\phi_{ET} = 15°, \Delta\phi = 5°)] + Q_{clearsky} \cdot [1 - w(\phi_{ET} = 30°, \Delta\phi = 5°) + w(\phi_{ET} = 15°, \Delta\phi = 5°)] \quad \text{(S5)}$$

In addition to the above-described experiments, two simulations are performed with the GFDL-AM2.1 model in which cloud radiative effects are included only for the longwave or shortwave bands separately.

Tables

Table S1: The values of the eddy-driven jet latitude in the clouds-off simulation, and its shift ($\Delta\phi$), the Hadley cell strength in the clouds-off simulation, and its shift ($\Delta\psi$) and ACRE_GRAD_diff for each supplemental experiment in which cloud radiative effects are only imposed in certain latitude bands, or for only the LW or SW bands. The length of each simulation is also shown.

Experiment	**Region/type of cloud radiative effects**	ϕ_{off} **[°N]**	$\Delta\phi$ **[° poleward]**	ψ_{off} **[10^9 kg/s]**	$\Delta\psi$ **[10^9 kg/s]**	**ACRE_GRAD_diff [10^{-6} W/m^3]**	**Length of run [years]**
GFDL-AM2.1, extratropical on	Imposed poleward of 30°, following Eq. S2	39.7	2.27	160.4	-0.6	-7.77	60
GFDL-AM2.1, tropical on	Imposed equatorward of 30°, following Eq. S3	39.7	-1.94	160.4	37.2	0.74	60
GFDL-AM2.1, deep tropical on	Imposed equatorward of 15°, following Eq. S4	39.7	-2.48	160.4	39.2	0.00	20
GFDL-AM2.1, subtropical on	Imposed between 15° and 30°, following Eq. S5	39.7	1.29	160.4	-3.0	-0.52	20
GFDL-AM2.1, LW on	Only longwave cloud radiative effects imposed	39.7	-0.91	160.4	71.0	-6.78	30
GFDL-AM2.1, SW on	Only shortwave cloud radiative effects imposed	39.7	1.17	160.4	-16.9	-2.08	30
NCAR-CAM5.3, extratropical on	Imposed poleward of 30°, following Eq. S2	42.3	2.57	135.6	2.06	-3.73	5
NCAR-CAM5.3, tropical on	Imposed equatorward of 30°, following Eq. S3	42.3	-3.04	135.6	34.4	-1.04	5

Figures

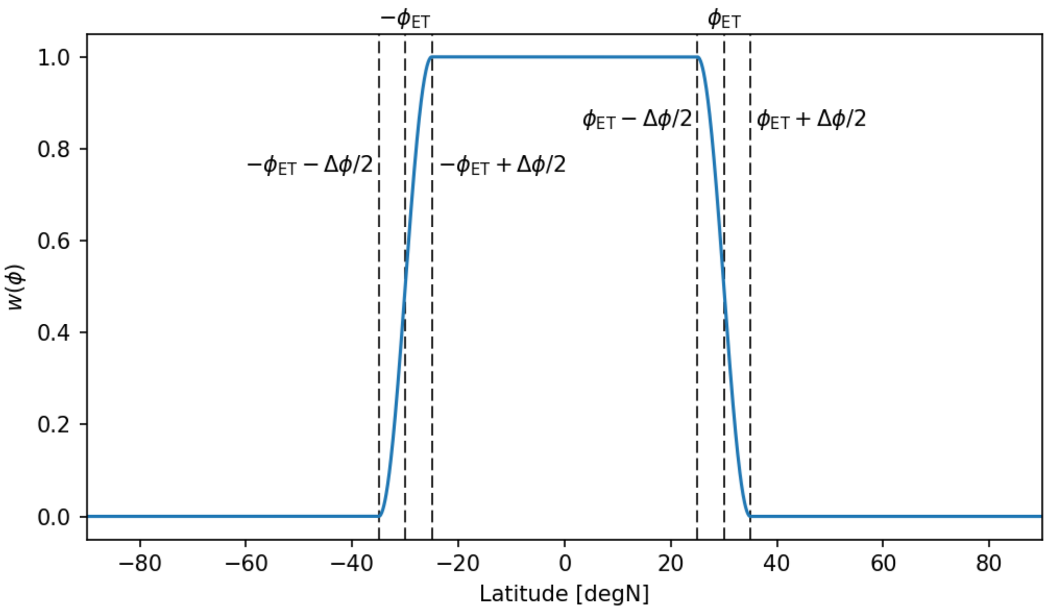

Figure S1: The weighting function $\boldsymbol{w}(\boldsymbol{\phi}, \boldsymbol{\phi_{ET}}, \Delta\boldsymbol{\phi})$ that is used to weight the total and clear-sky radiative fluxes and heating rates in order to include cloud radiative effects in only certain latitude bands. Here the weighting function is shown for the parameters $\boldsymbol{\phi_{ET}} = \mathbf{30}°$ and $\Delta\boldsymbol{\phi} = \mathbf{10}°$ (see Eq. S1).

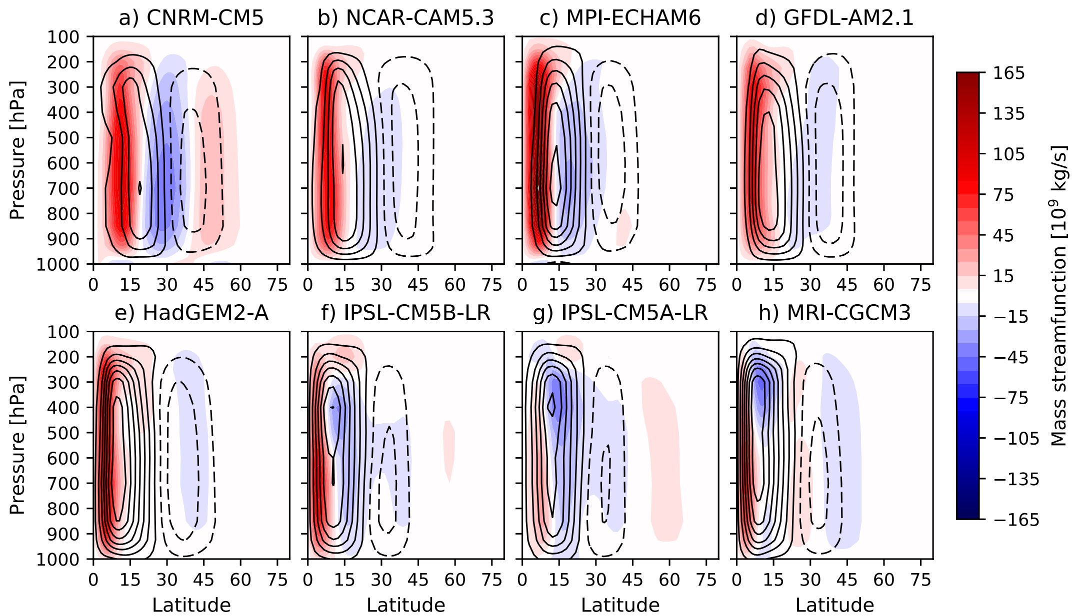

Figure S2: The mass streamfunction in the clouds off experiment (black contours, $30*10^9$ kg/s intervals) and the difference in mass streamfunction between the clouds on and clouds off experiment (shaded contours) for each model in the COOKIE ensemble. Positive (solid) contours indicate a clockwise circulation and negative (dashed) contours indicate a counter-clockwise circulation.

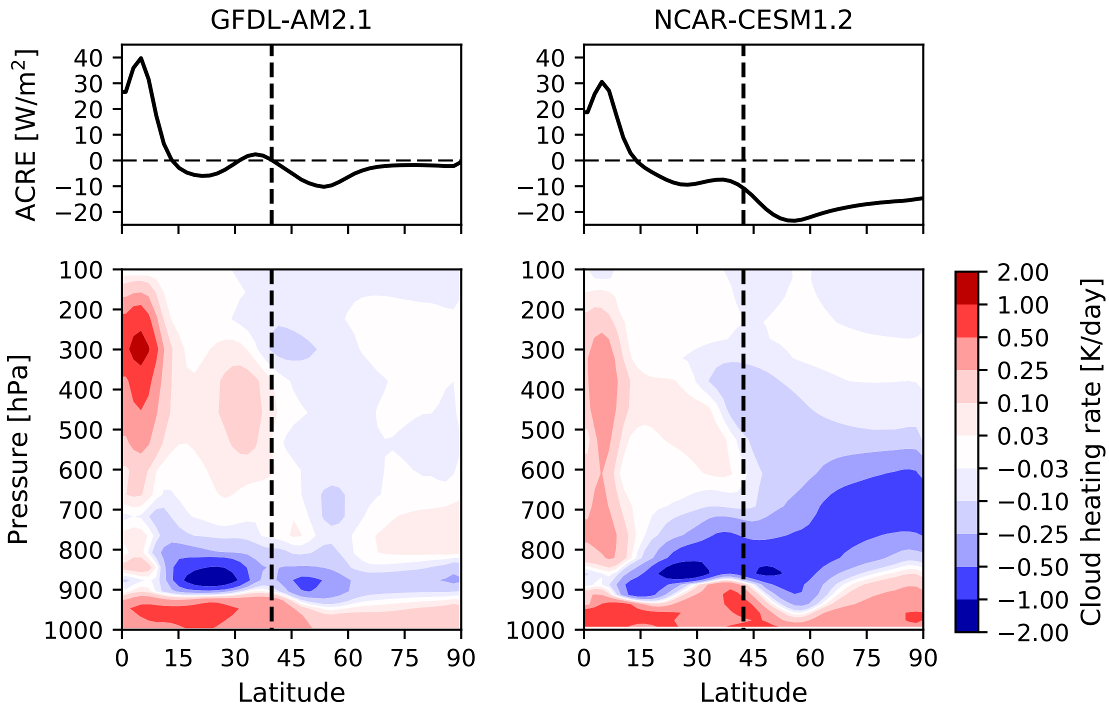

Figure S3: The ACRE (top row) and cloud heating rate (bottom row) for the GFDL-AM2.1 model (left column) and the NCAR-CESM1.2 model (right column), both for the clouds-on experiment. The cloud heating rate is taken as the difference between the total and clear-sky heating rates, summed over both the longwave and shortwave bands. The ACRE can be computed as the vertical integral of the cloud heating rate: $\boldsymbol{ACRE = \frac{c_p}{g}\int_0^{p_s} Q_{cld}(p)dp}$. The vertical dashed lines mark the latitude of the eddy-driven in the clouds-off simulation ($\boldsymbol{\phi_{off}}$).

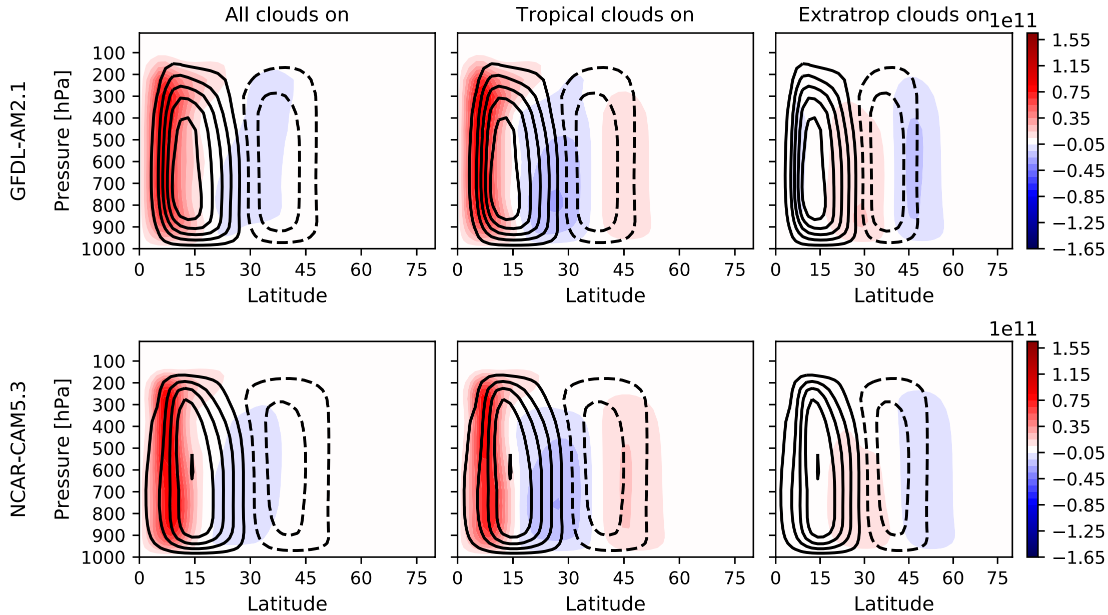

Figure S4: The mass streamfunction in the GFDL-AM2.1 (top row) and NCAR-CAM5.3 (bottom row) clouds off experiment (black contours, $30*10^9$ kg/s intervals) and, in the shading, the difference in mass streamfunction ($10*10^9$ kg/s interval) between the (a) all clouds on, (b) tropical clouds on and (c) extratropical clouds on and clouds off experiments with the GFDL AM2.1 model. Positive (solid) contours indicate a clockwise circulation and negative (dashed) contours indicate a counter-clockwise circulation.

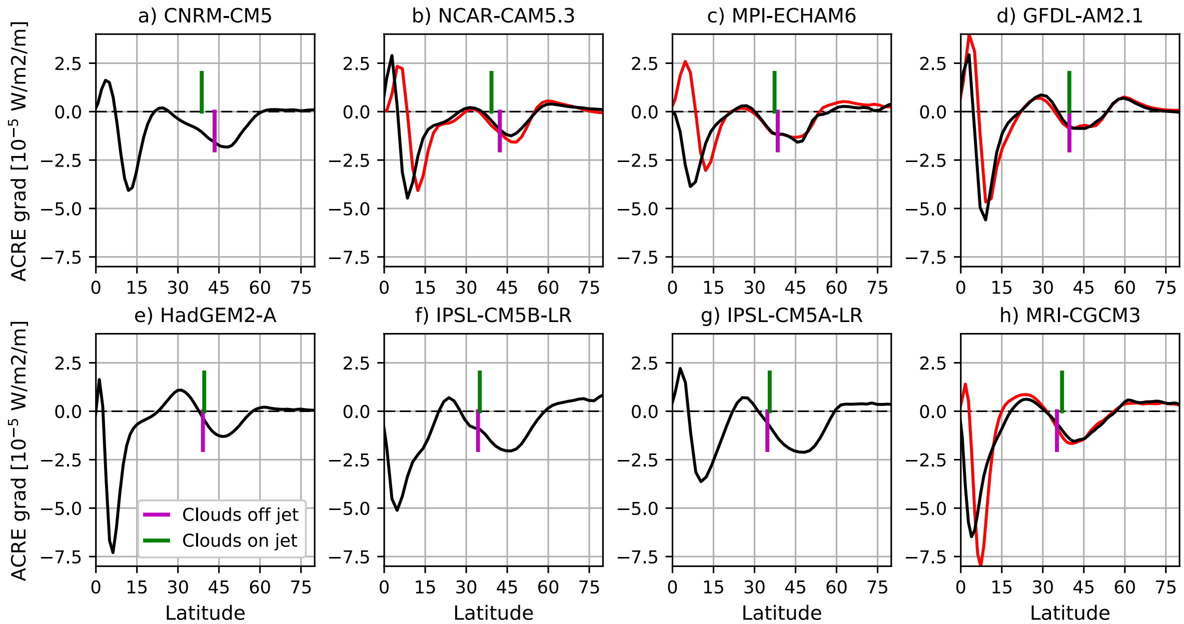

Figure S5: The meridional gradient of ACRE for the clouds-on simulations of each model (black) and the ACRE for the clouds-off simulation of each model, where available. The latitude of the eddy-driven jet in the clouds off and clouds on simulations marked by vertical magenta and green lines, respectively. In panel h), the height-dependent cloud heating rate for the GFDL-AM2.1 model.

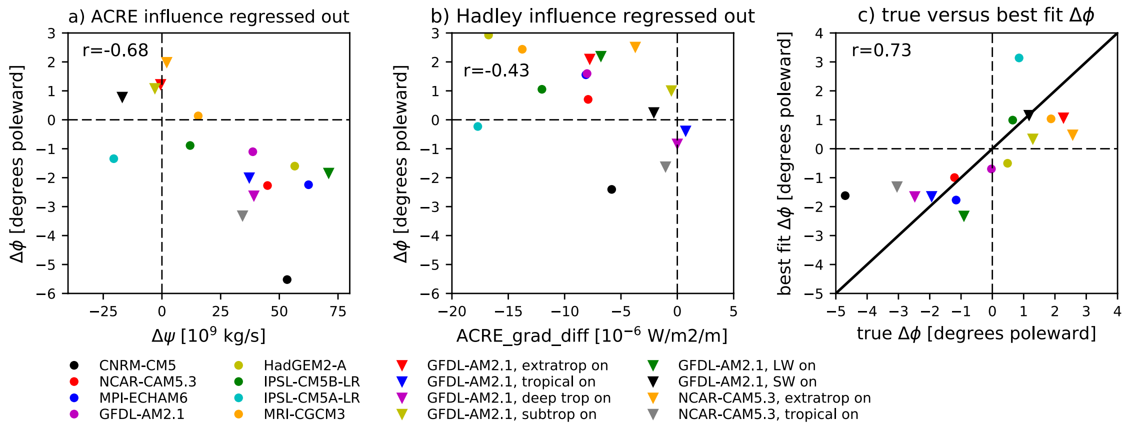

Figure S6: Scatter plots of a) $\Delta\psi$ versus $\Delta\phi$ after removing influence of ACRE_grad_diff, b) ACRE_GRAD_diff versus $\Delta\phi$ after removing influence of $\Delta\psi$, (see text for details) and c) the true $\Delta\phi$ versus the best fit $\Delta\phi$ computed using Eq. 3 for each experiment.