

Supporting Information for “Testing latitudinally-dependent explanations of the circulation response to increased CO₂ using aquaplanet models”

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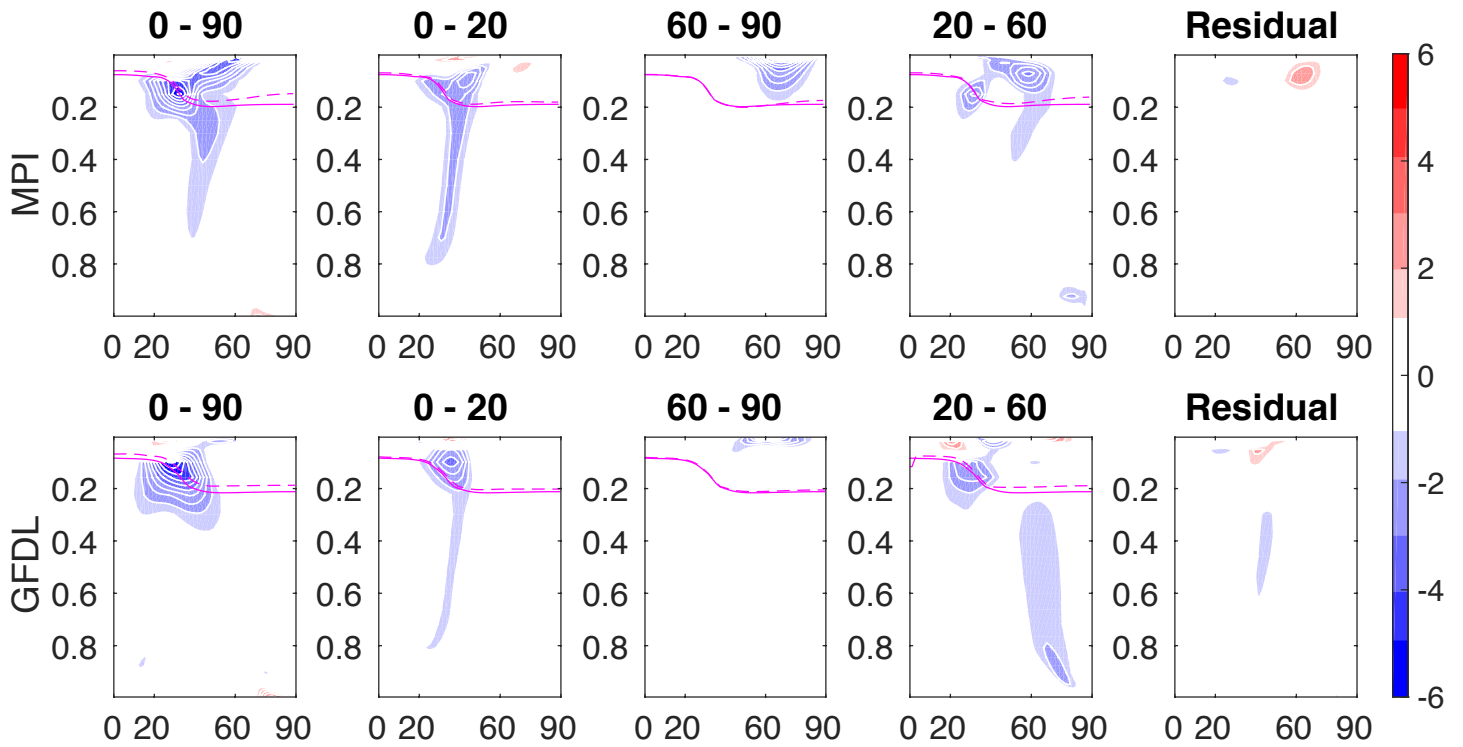


Figure 1. Response of zonal-mean meridional temperature gradient (shading, contour interval $1 \times 10^{-6} \text{ Km}^{-1}$) as a function of sigma level (pressure normalized by surface pressure) to latitudinally-dependent $4 \times \text{CO}_2$. WMO tropopause for climatology and changed climate indicated by solid and dashed magenta lines, respectively.

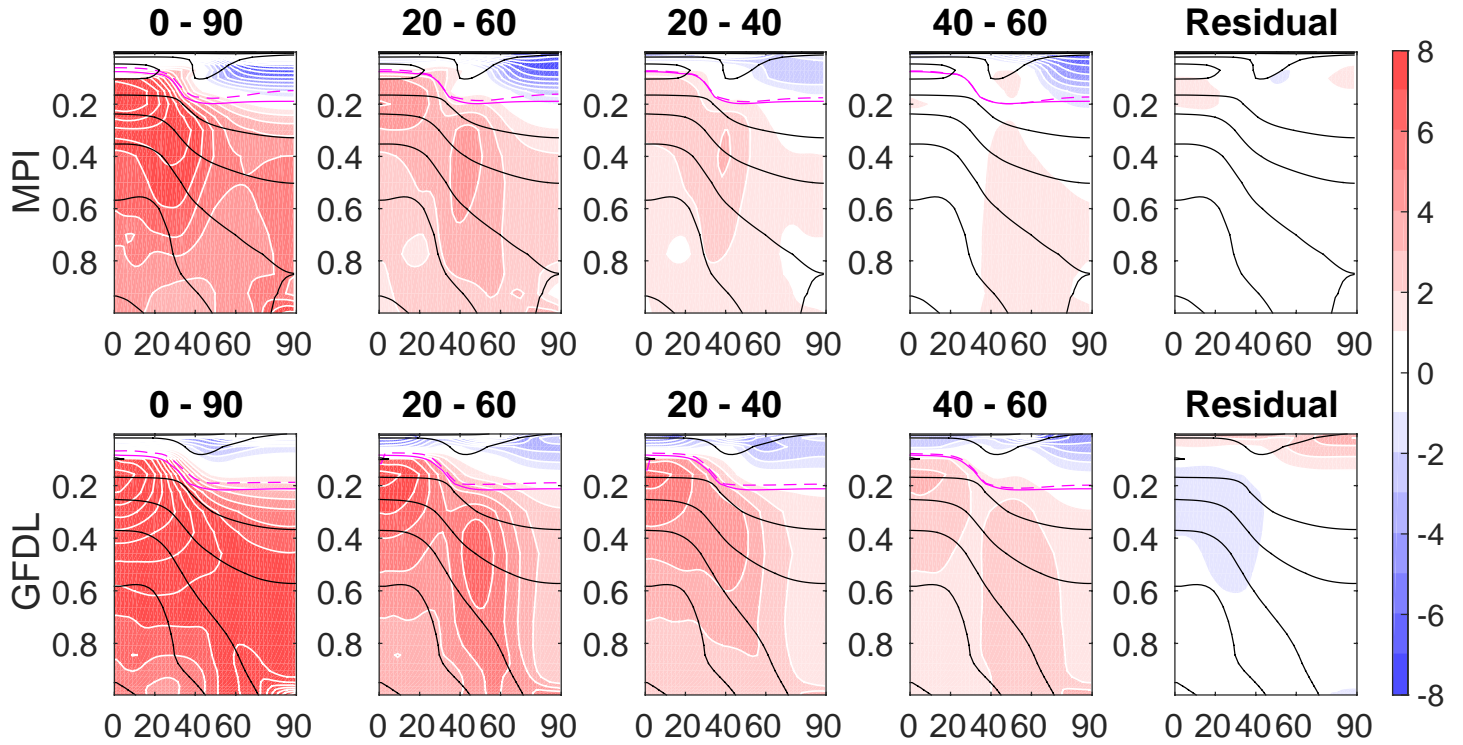


Figure 2. Response of time-mean, zonal-mean temperature (shading, contour interval 1 K) as a function of sigma level (pressure normalized by surface pressure) to latitudinally-dependent $4\times\text{CO}_2$. Climatology indicated by black contours (contour interval 20 K, up to 300 K). WMO tropopause for climatology and changed climate indicated by solid and dashed magenta lines, respectively. Residual is the sum of response to $20^\circ - 40^\circ$ and $40^\circ - 60^\circ$ minus $20^\circ - 60^\circ$.

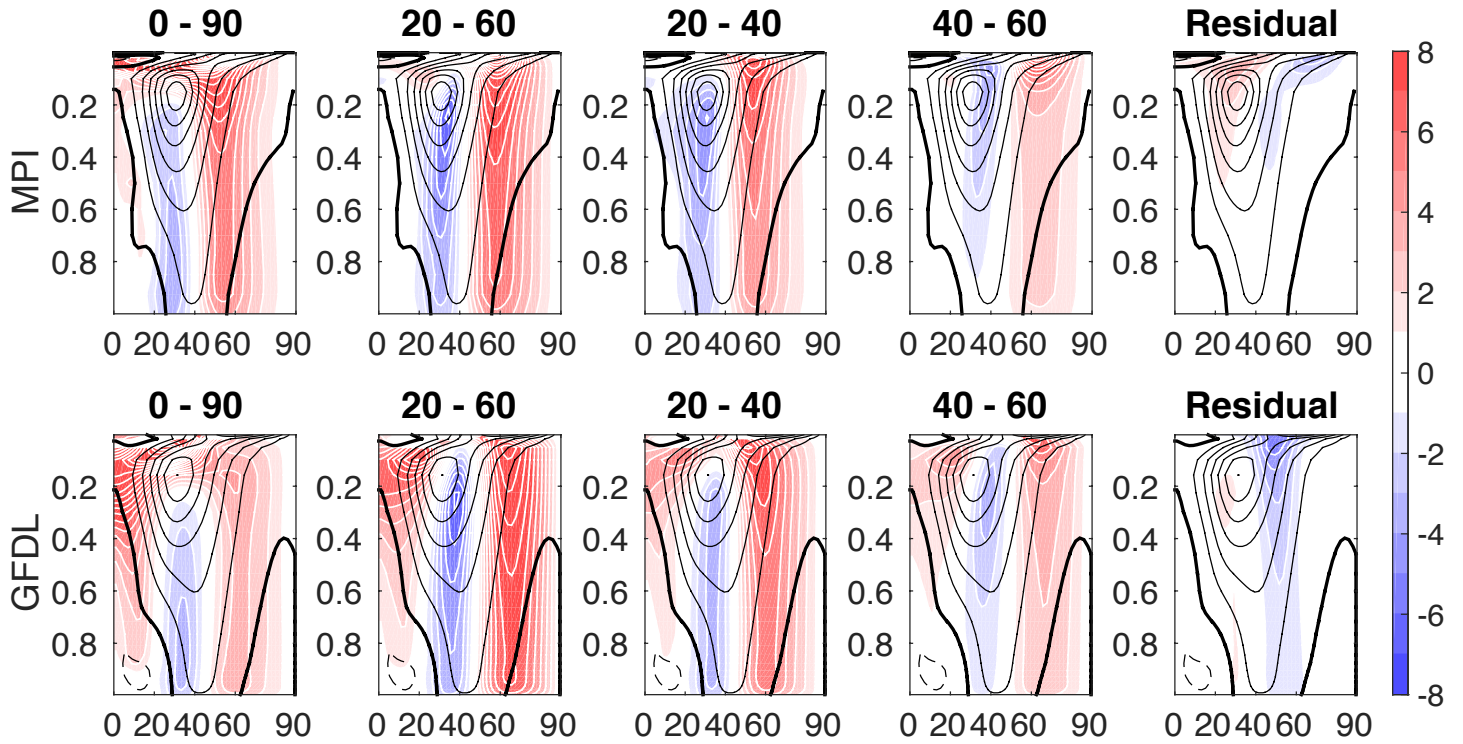


Figure 3. As in Figure 2 but for the response of time-mean, zonal-mean zonal wind (shading, contour interval 1 ms⁻¹, black contour interval 10 ms⁻¹, negative contours dashed).

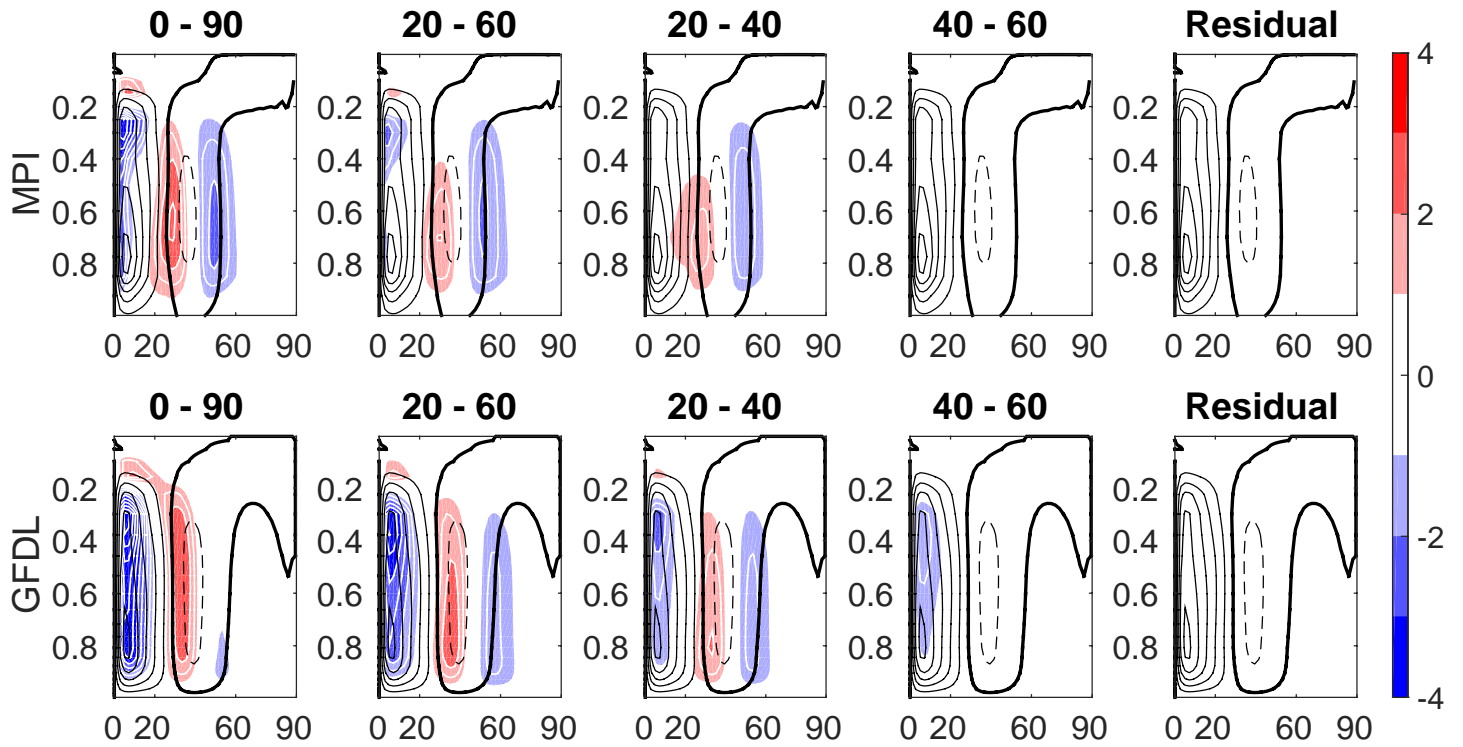


Figure 4. As in Figure 2 but for the response of time-mean, zonal-mean Eulerian streamfunction (shading, contour interval $0.5 \times 10^{10} \text{ kgs}^{-1}$, black contour interval $5 \times 10^{10} \text{ kgs}^{-1}$, negative contours dashed).

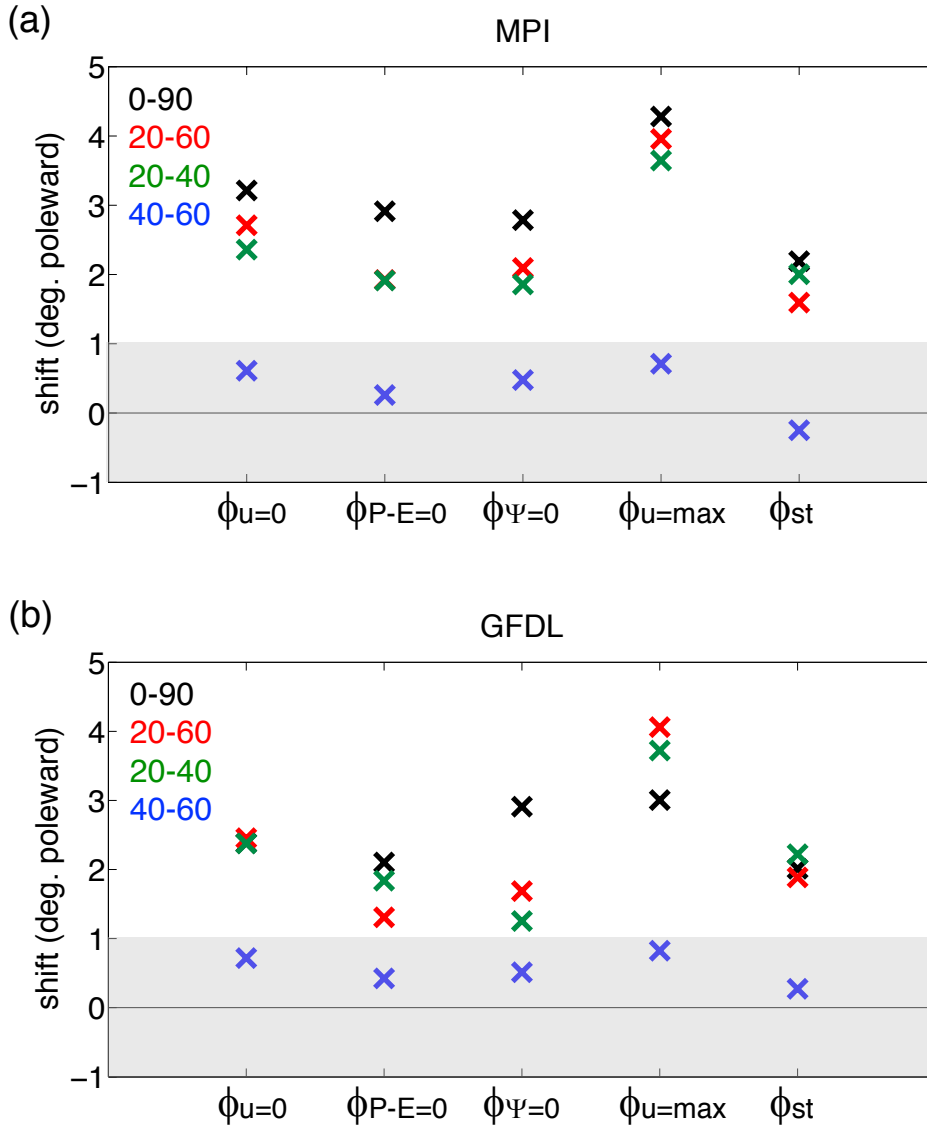


Figure 5. Circulation shift in response to latitudinally-dependent 4xCO₂ (see section 2 for more information). Gray shading indicates shifts whose absolute value is $\leq 1^\circ$. In panel (a) the red cross for $\phi_{P-E=0}$ is behind the green cross. In panel (b) the black cross for $\phi_{u=0}$ is behind the red cross.

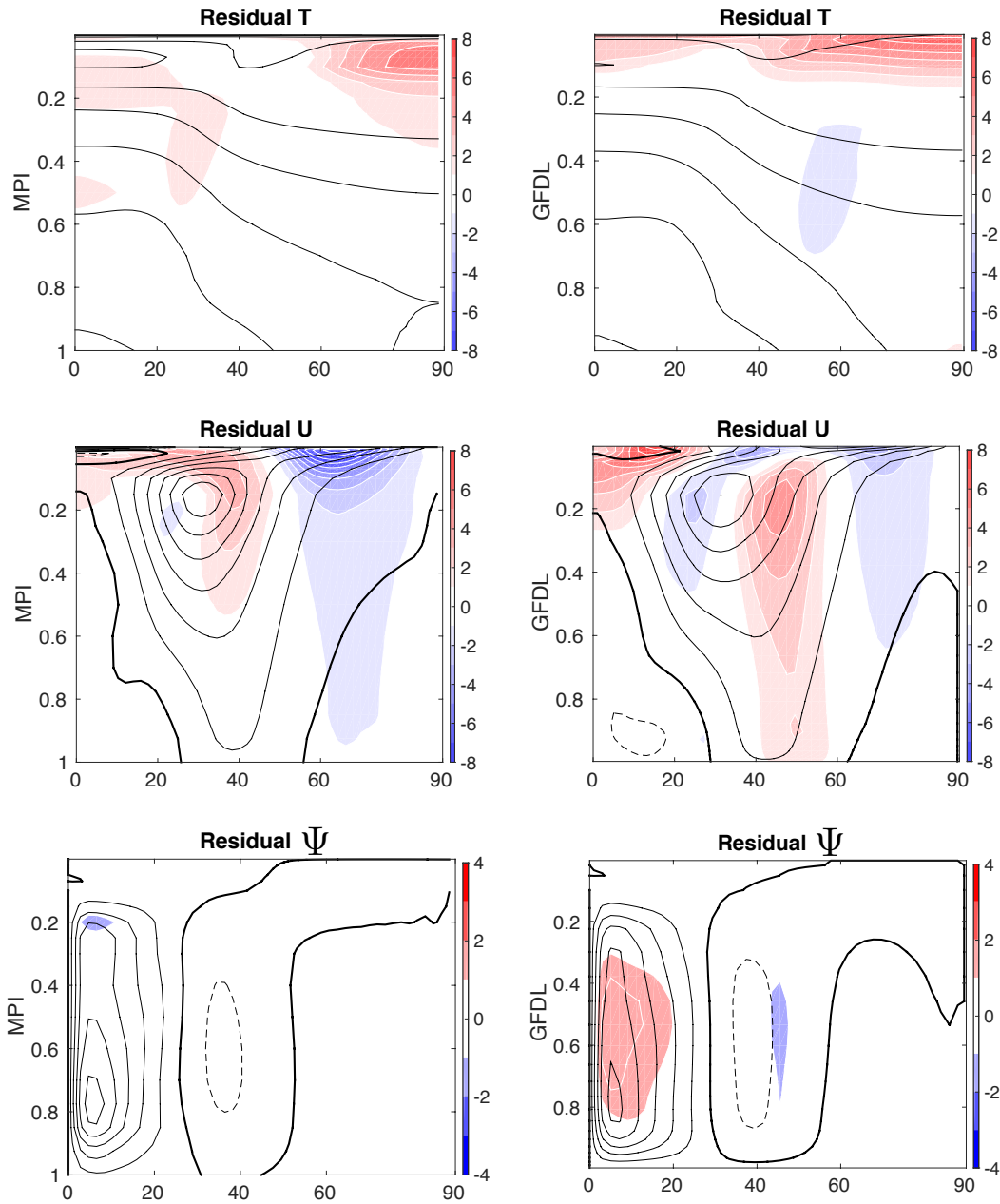


Figure 6. Residual (sum of response to $4xCO_2$ from $0^\circ - 20^\circ$, $60^\circ - 90^\circ$ and $20^\circ - 60^\circ$ minus $0^\circ - 90^\circ$). Contour interval is 1 K (top), 1ms^{-1} (middle) and $0.5 \times 10^{10} \text{ kgs}^{-1}$ (bottom).

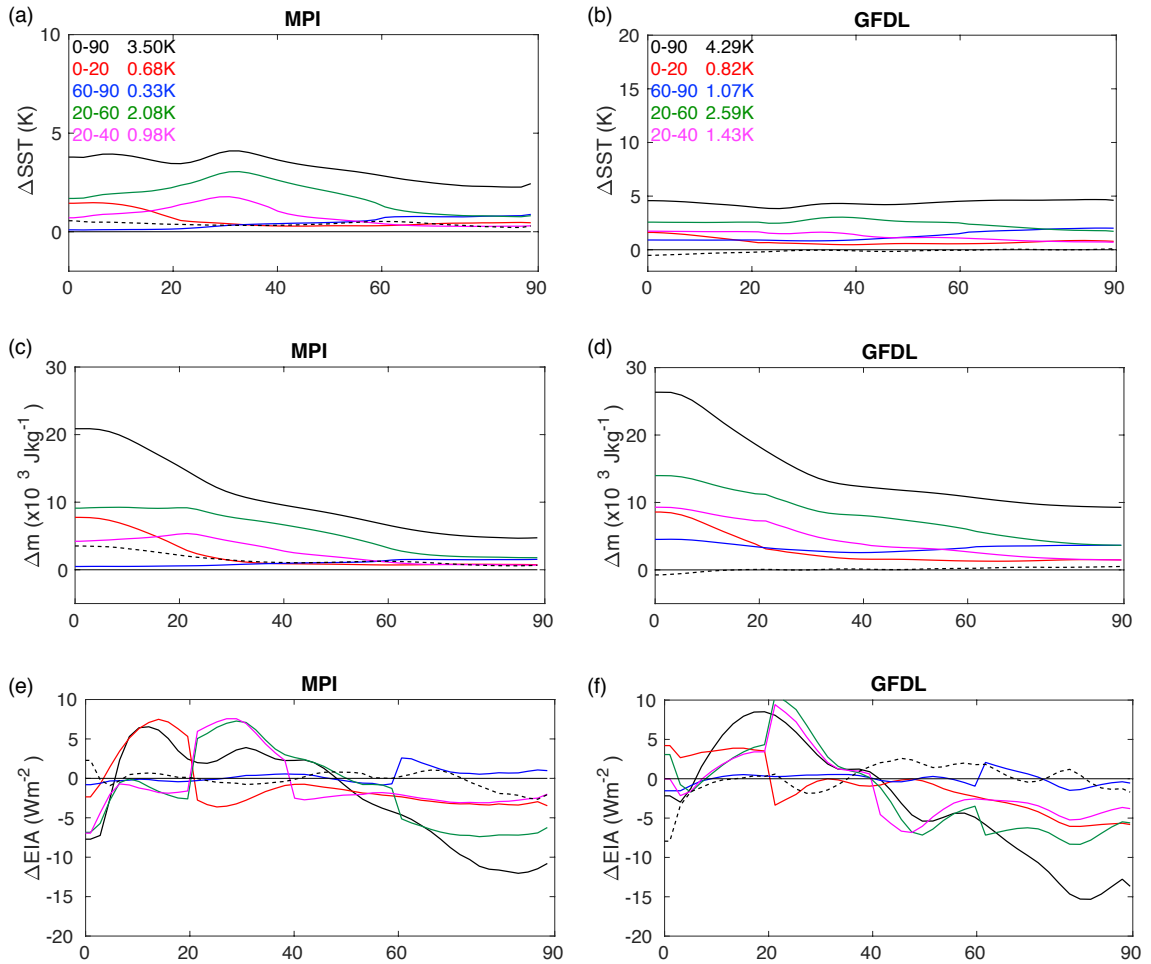


Figure 7. Response of time-mean, zonal-mean (a,b) sea-surface temperature (SST), (c,d) near-surface MSE and (e,f) energy input to the atmosphere to increased CO₂ in the presence of a seasonal cycle. Dashed black lines indicate the residual (sum of response to 0° - 20°, 60° - 90° and 20° - 60° minus 0° - 90°). Global mean SST response shown in top-left of panels (a) and (b).

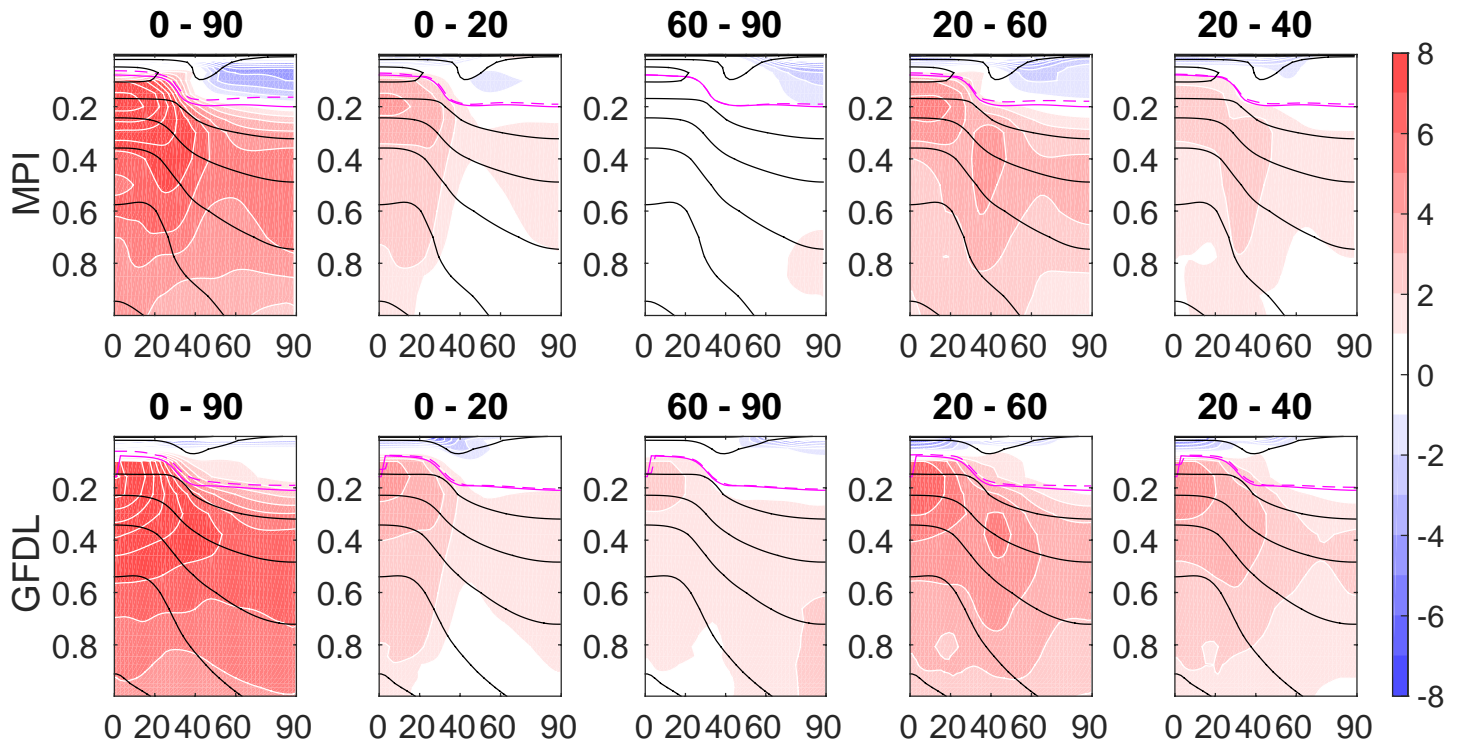


Figure 8. Response of annual-mean, zonal-mean temperature (shading, contour interval 1 ms^{-1}) as a function of sigma level to increased CO₂ in the presence of a seasonal cycle. Climatology indicated by black contours (contour interval 20 K, up to 300 K). WMO tropopause for climatology and changed climate indicated by solid and dashed magenta lines, respectively.

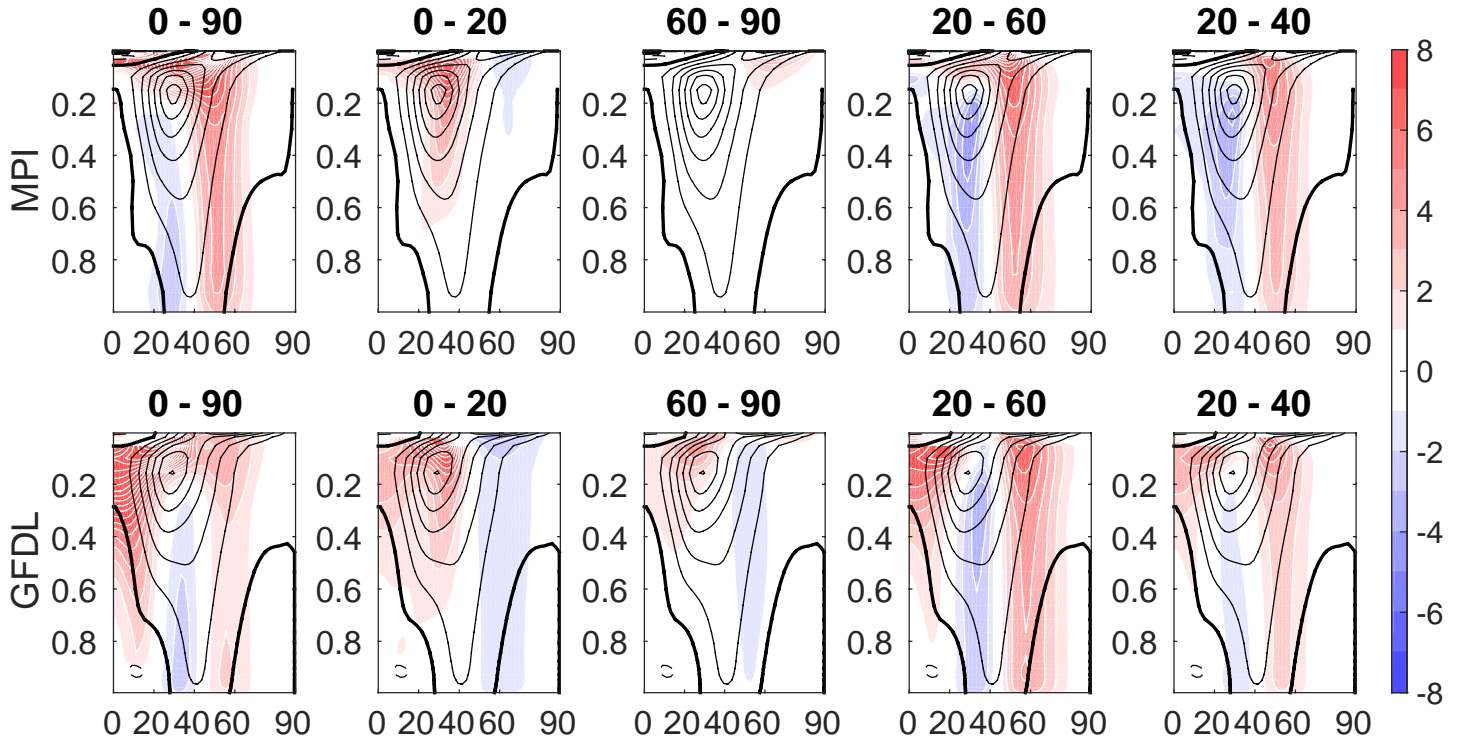


Figure 9. As in Figure 8 but for the response of annual-mean, zonal-mean zonal wind (shading, contour interval 1 ms⁻¹, black contour interval 10 ms⁻¹, negative contours dashed).

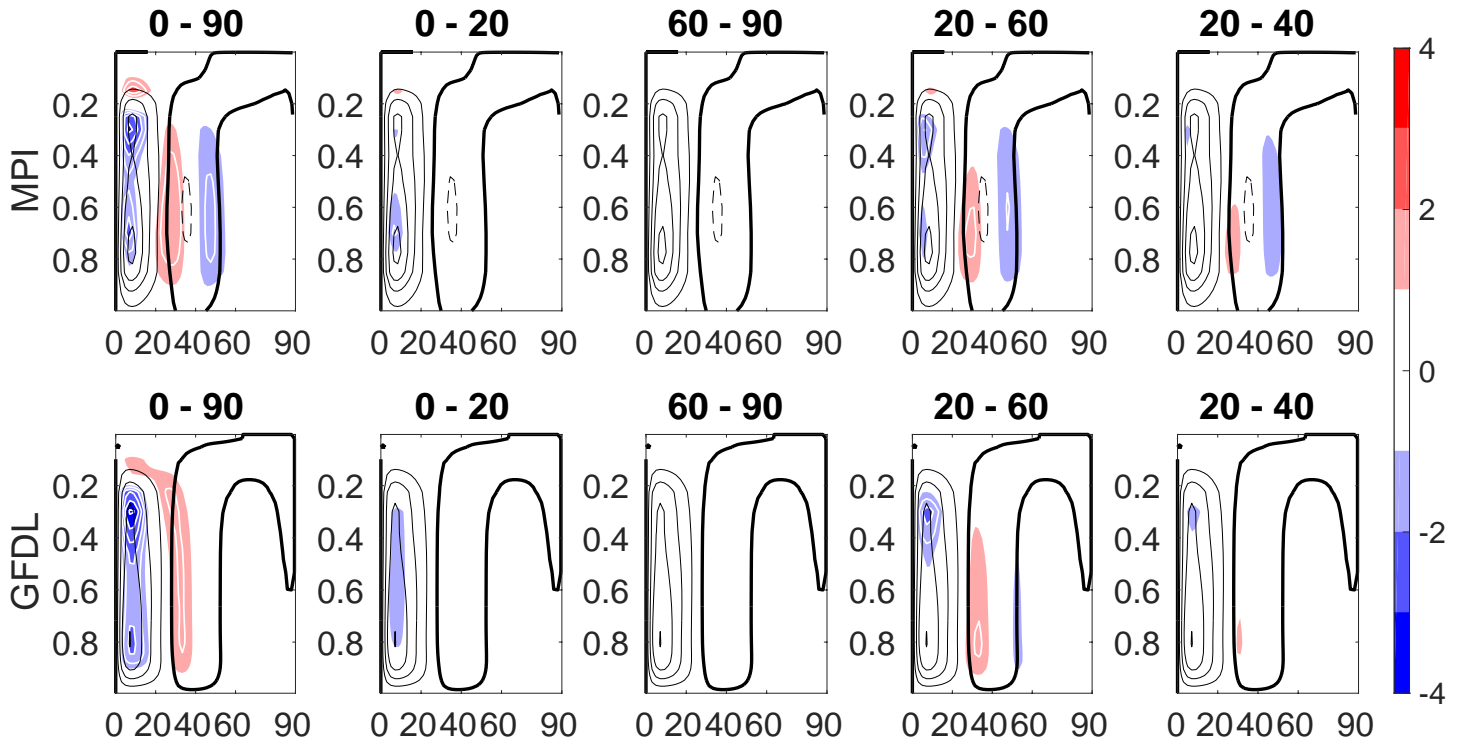


Figure 10. As in Figure 8 but for the response of annual-mean, zonal-mean Eulerian streamfunction (shading, contour interval $0.5 \times 10^{10} \text{ kgs}^{-1}$, black contour interval $5 \times 10^{10} \text{ kgs}^{-1}$, negative contours dashed).

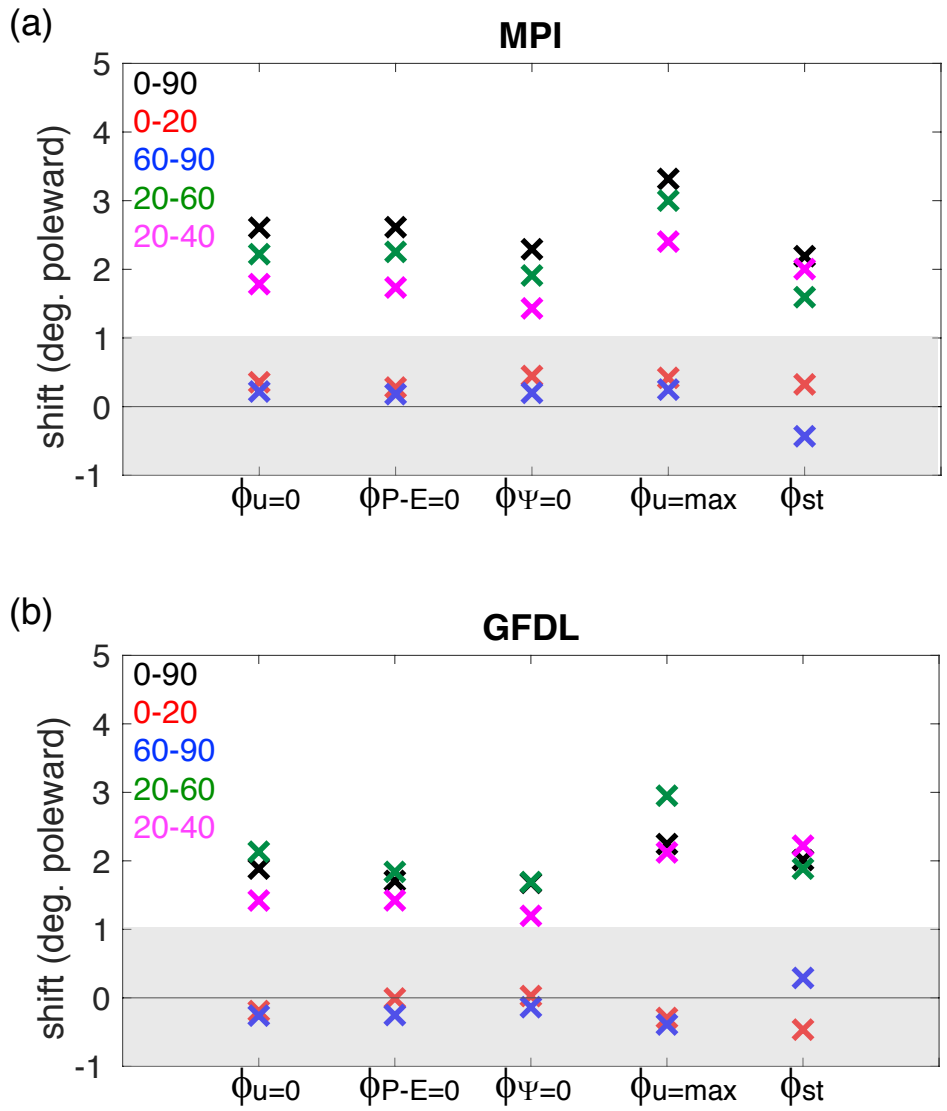


Figure 11. Circulation shift in response to latitudinally-dependent CO₂ increase in the presence of a seasonal cycle (see section 2 for more information). Gray shading indicates shifts whose absolute value is $\leq 1^\circ$.

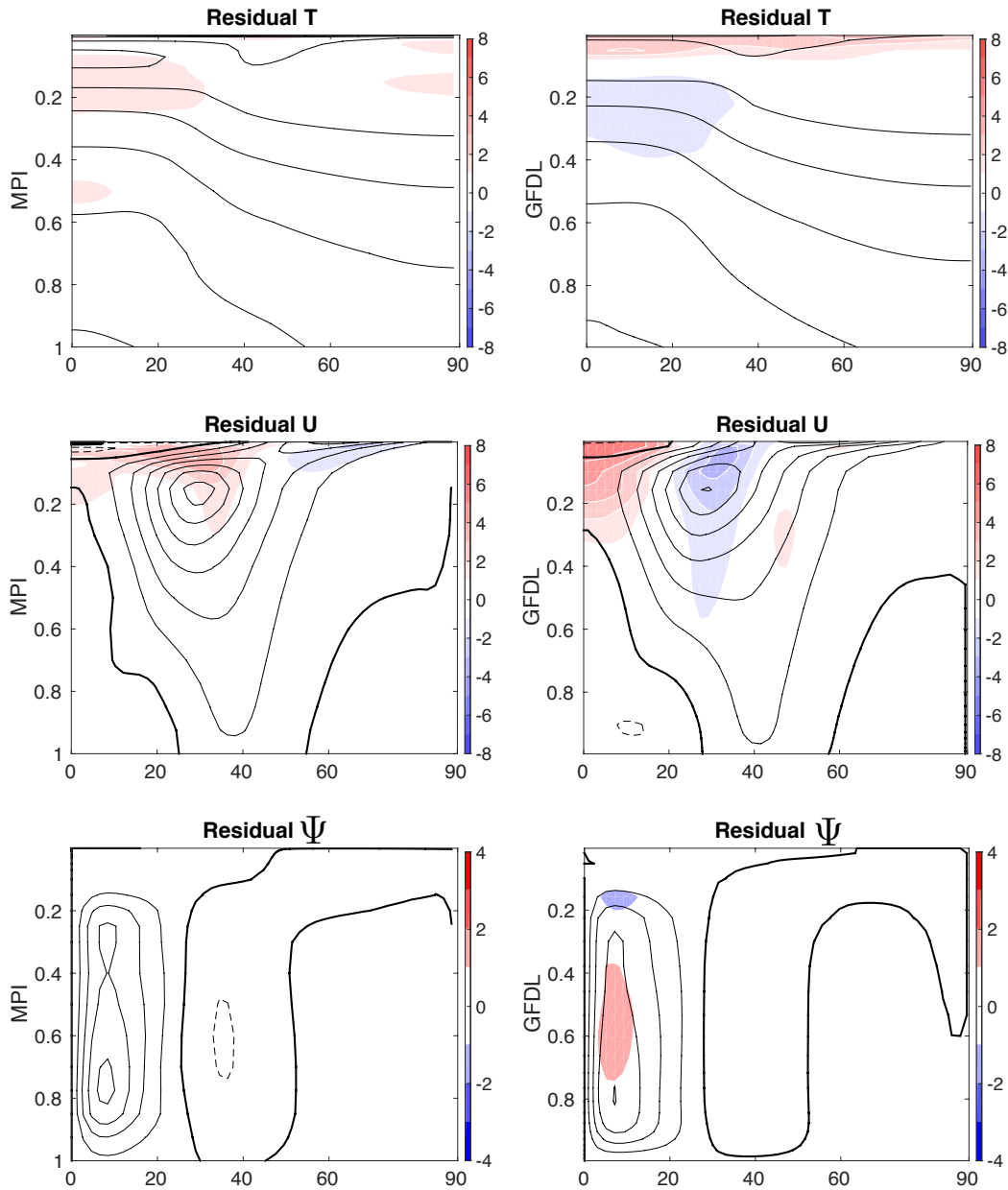


Figure 12. Residual (sum of response to 4xCO₂ from 0° - 20°, 60° - 90° and 20° - 60° minus 0° - 90°) in the presence of a seasonal cycle. Contour interval is 1 K (top), 1ms⁻¹ (middle) and 0.5x10¹⁰ kgs⁻¹ (bottom).

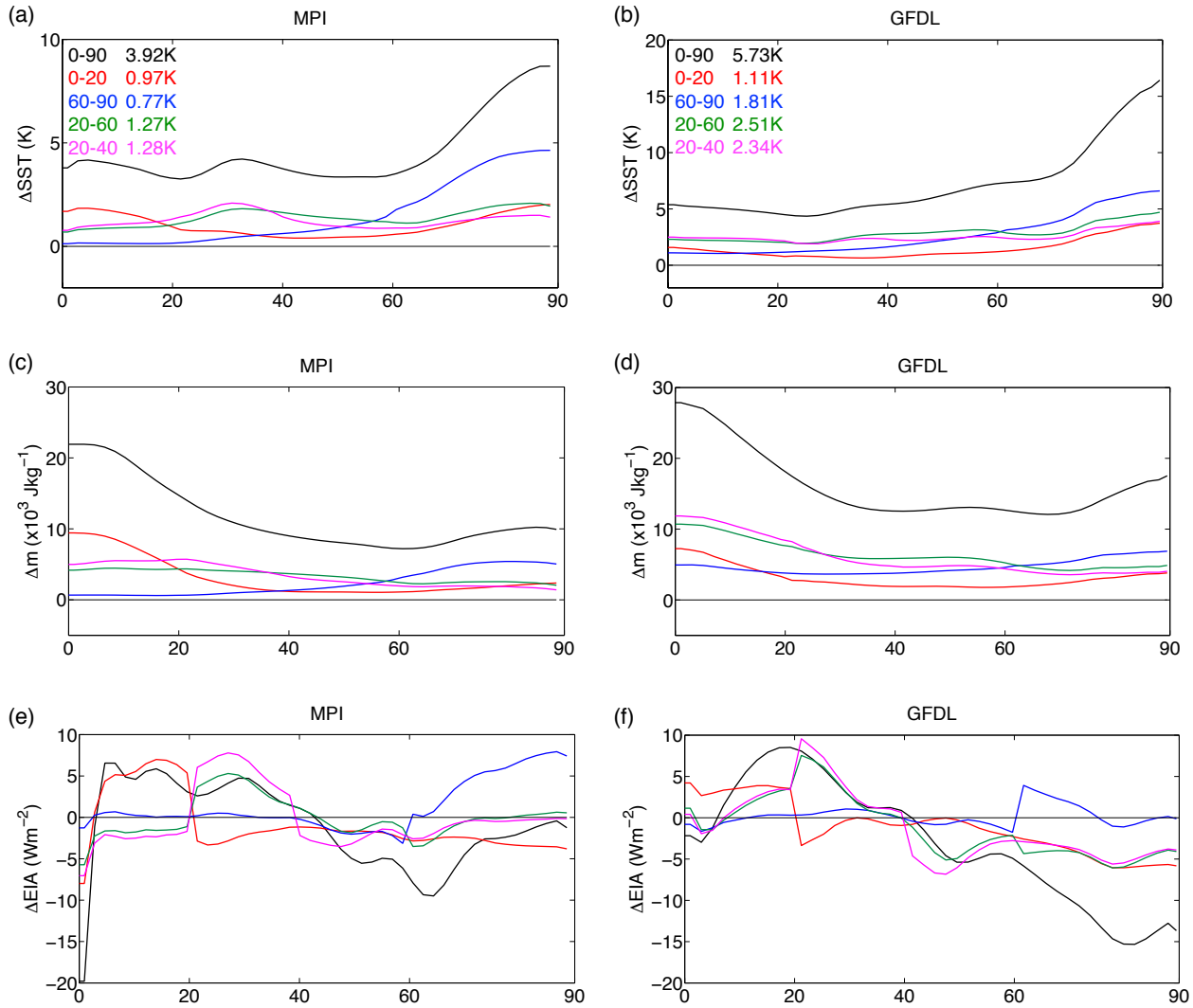


Figure 13. Response of time-mean, zonal-mean (a,b) sea-surface temperature (SST), (c,d) near-surface MSE and (e,f) energy input to the atmosphere to latitudinally-dependent CO₂ increase scale to account for area: $4x\text{CO}_2$ for $0^\circ - 90^\circ$ and $0^\circ - 20^\circ$, $9.94x\text{CO}_2$ for $60^\circ - 90^\circ$, $2.38x\text{CO}_2$ for $20^\circ - 60^\circ$, and $4.13x\text{CO}_2$ for $20^\circ - 40^\circ$. Global mean SST response shown in top-left of panels (a) and (b).

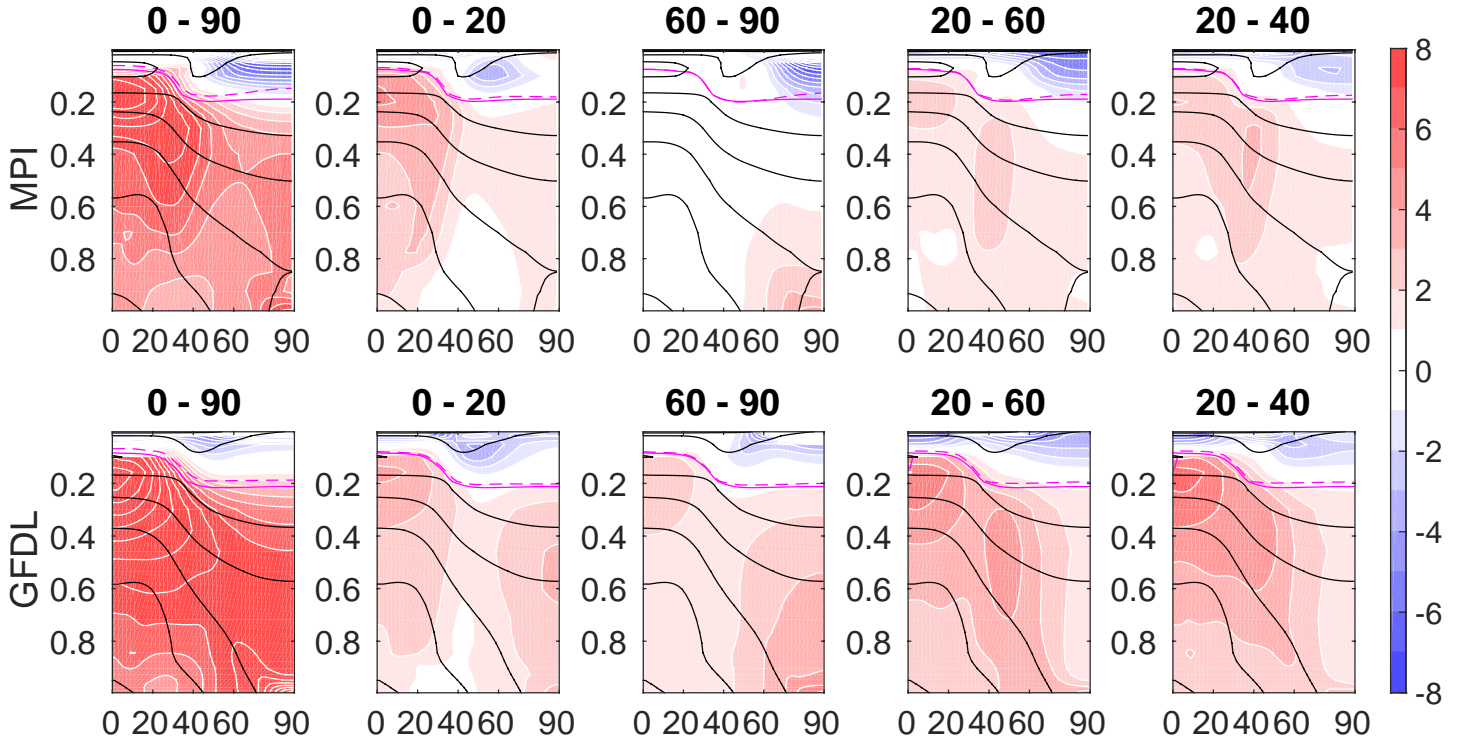


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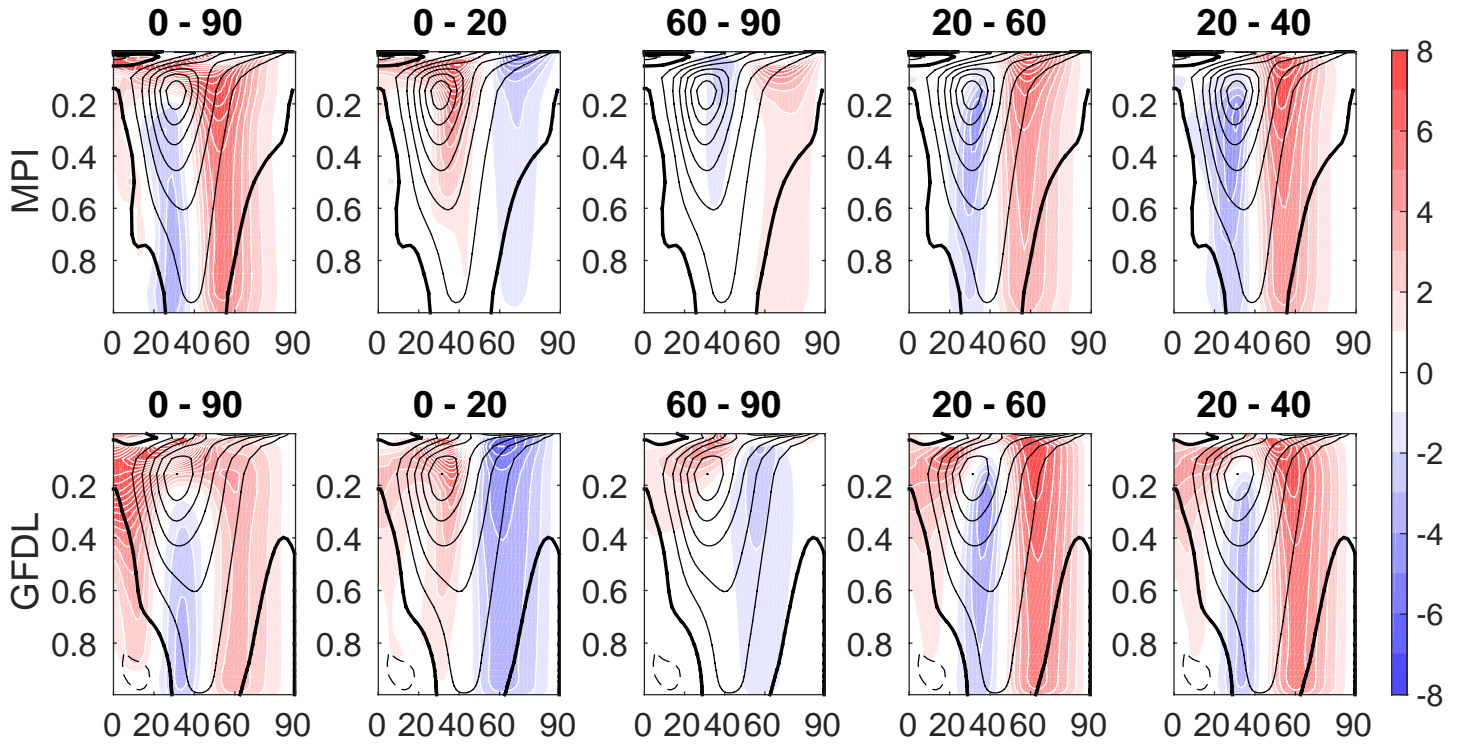


Figure 15. As in Figure 13 but for the response of time-mean, zonal-mean zonal wind (shading, contour interval 1 ms⁻¹, black contour interval 10 ms⁻¹, negative contours dashed).

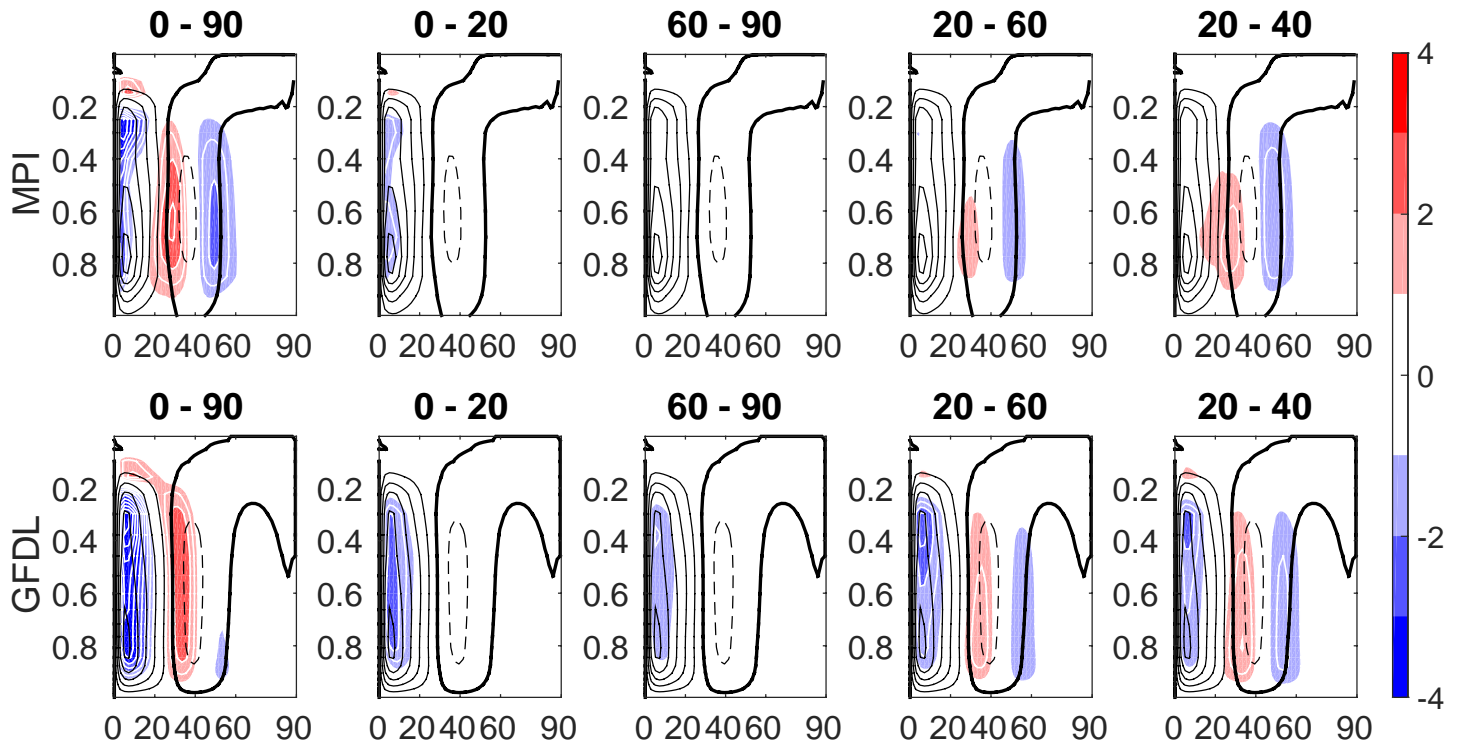


Figure 16. As in Figure 13 but for the response of time-mean, zonal-mean Eulerian streamfunction (shading, contour interval $0.5 \times 10^{10} \text{ kgs}^{-1}$, black contour interval $5 \times 10^{10} \text{ kgs}^{-1}$, negative contours dashed).

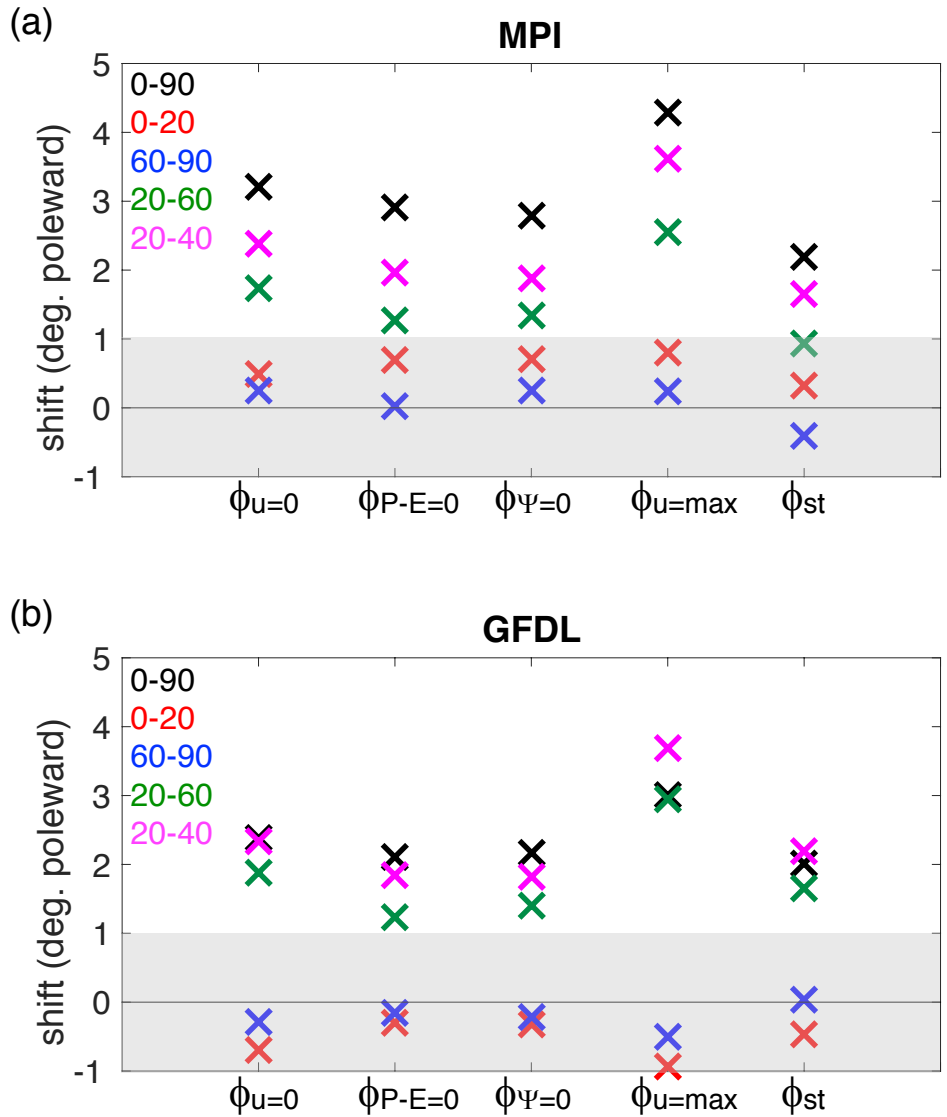


Figure 17. Circulation shift in response to latitudinally-dependent CO₂ increase scale to account for area: 4xCO₂ for 0° - 90° and 0° - 20°, 9.94xCO₂ for 60° - 90°, 2.38xCO₂ for 20° - 60°, and 4.13xCO₂ for 20° - 40°. Gray shading indicates shifts whose absolute value is $\leq 1^\circ$.

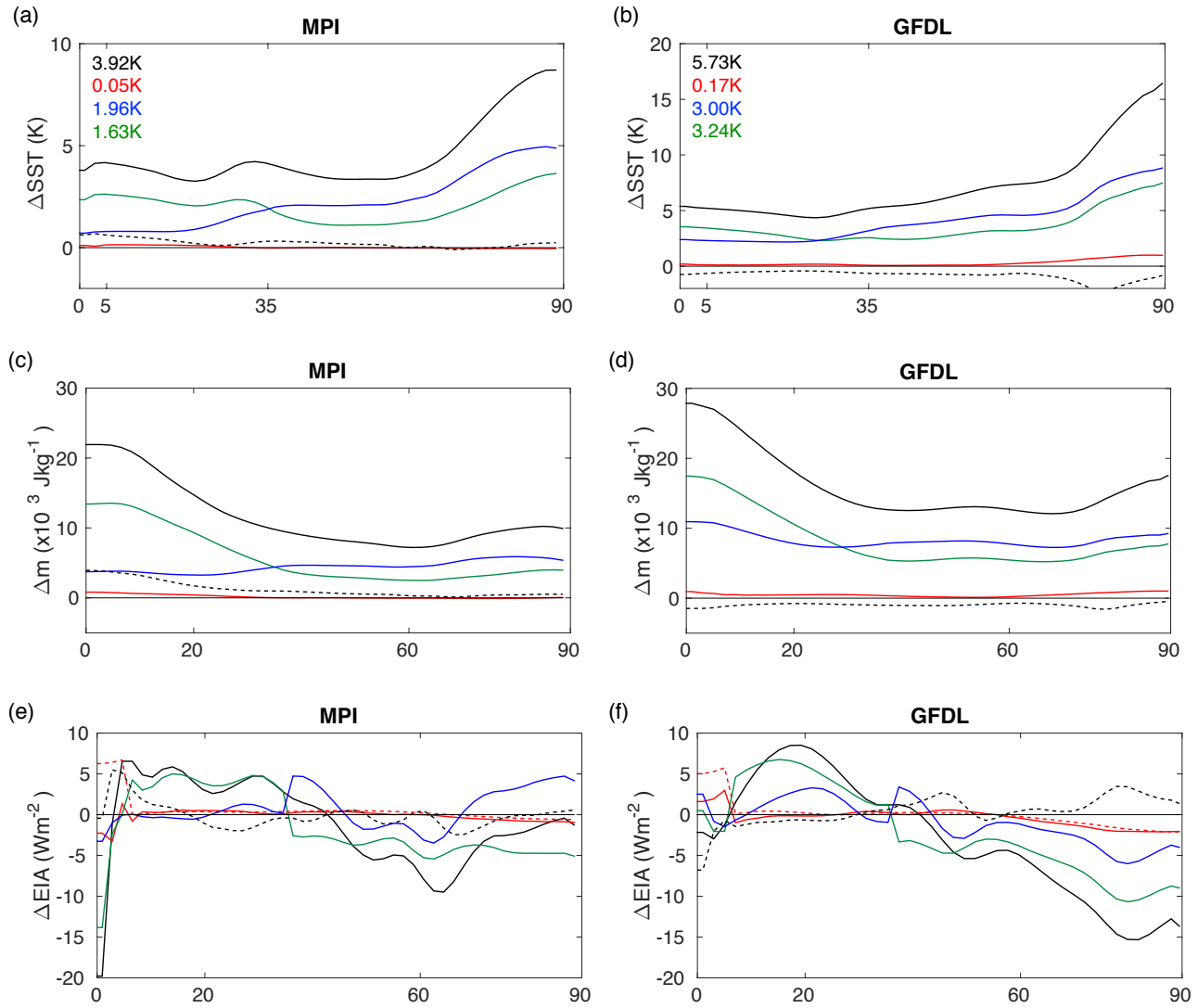


Figure 18. Response of time-mean, zonal-mean (a,b) sea-surface temperature (SST), (c,d) near-surface MSE and (e,f) energy input to the atmosphere to latitudinally-dependent $4\times\text{CO}_2$. Black, red, blue and green lines indicated response to increased CO_2 from $0^\circ - 90^\circ$, $0^\circ - 5^\circ$, $5^\circ - 35^\circ$ and $35^\circ - 90^\circ$, respectively. Dashed black lines indicate the residual (sum of response to $0^\circ - 5^\circ$, $5^\circ - 35^\circ$ and $35^\circ - 90^\circ$ minus $0^\circ - 90^\circ$). Red dashed line indicates clear-sky radiation. Global mean SST response shown in top-left of panels (a) and (b).

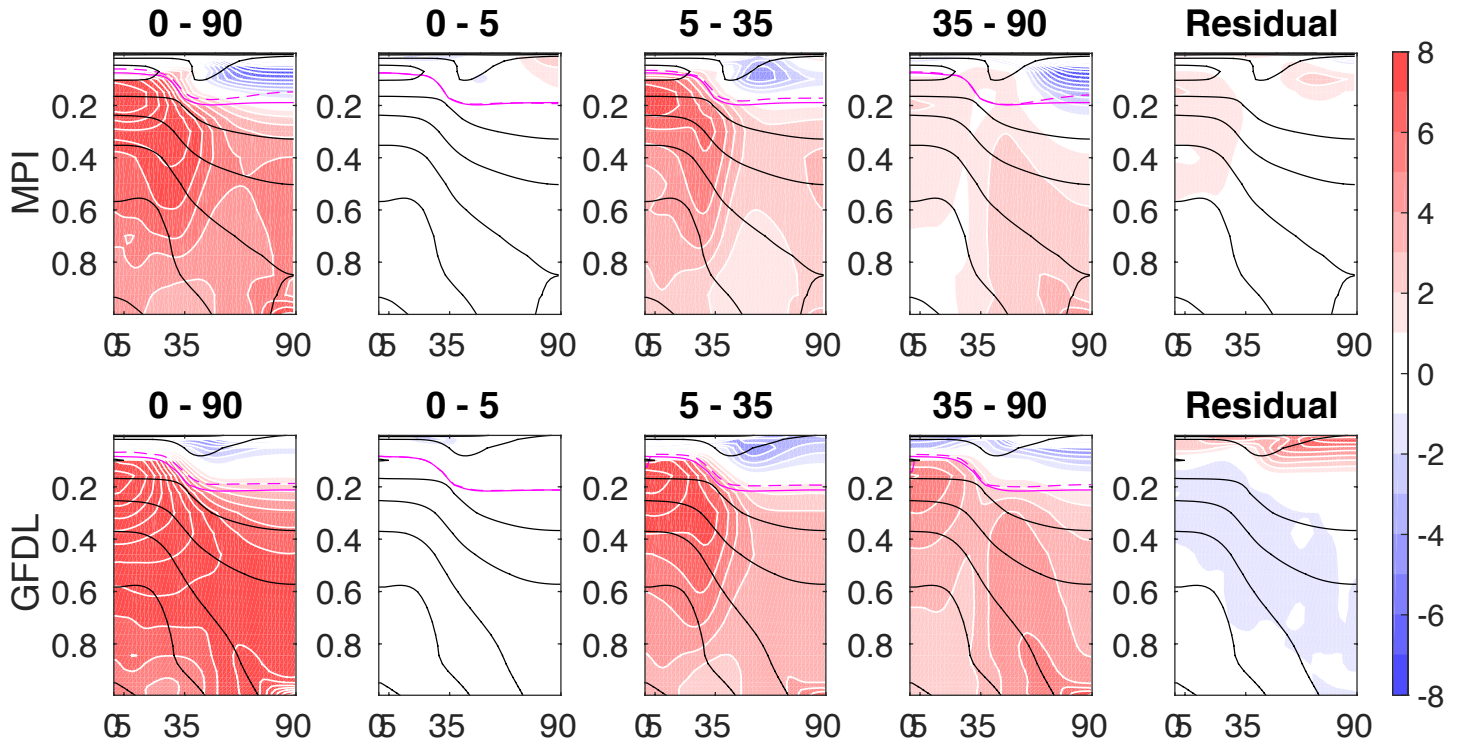


Figure 19. Response of time-mean, zonal-mean temperature (shading, contour interval 1 ms^{-1}) to increased CO₂. Climatology indicated by black contours (contour interval 10 ms^{-1} , negative contours dashed). Residual is the sum of response to $0^\circ - 5^\circ$, $5^\circ - 35^\circ$ and $35^\circ - 90^\circ$ minus $0^\circ - 90^\circ$.

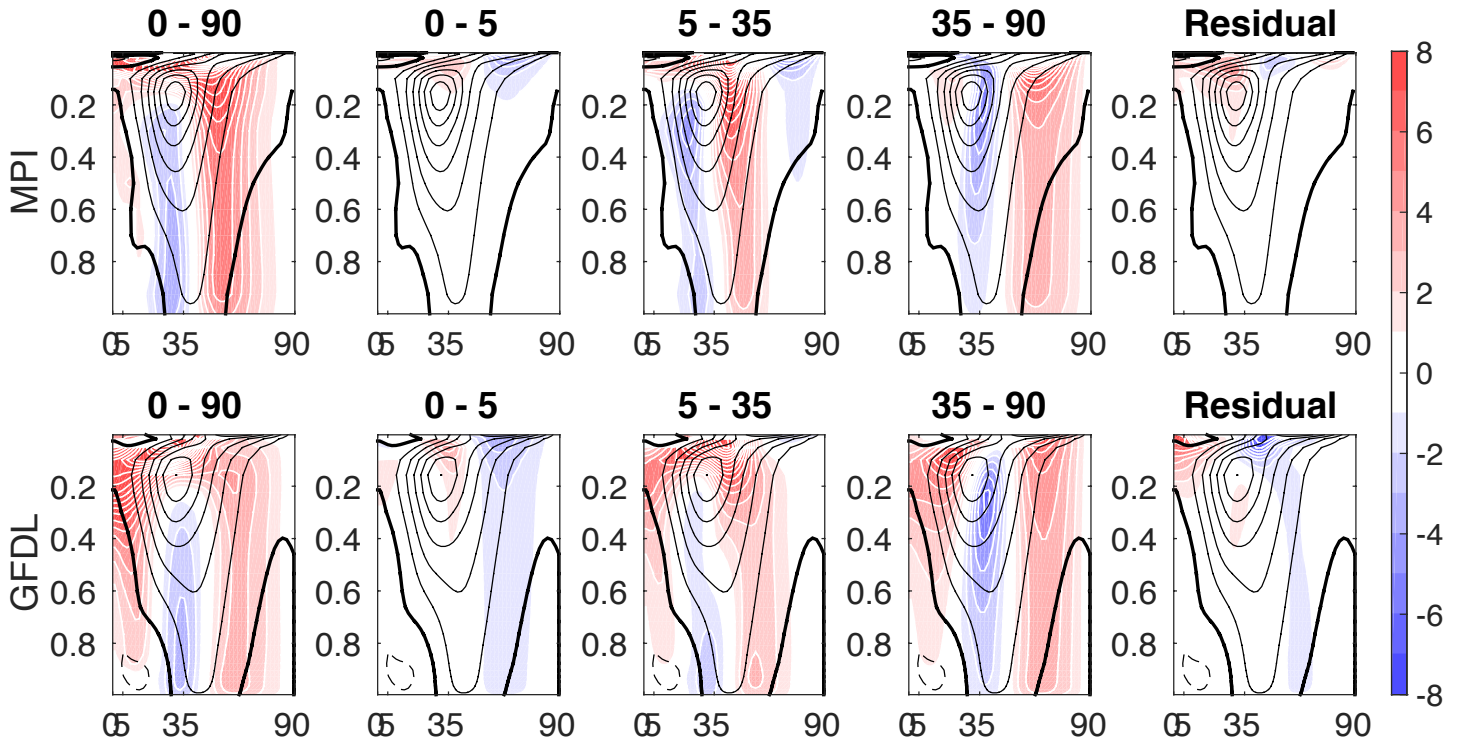


Figure 20. As in Figure 18 but for the response of time-mean, zonal-mean zonal wind (shading, contour interval 1 ms⁻¹, black contour interval 10 ms⁻¹, negative contours dashed).

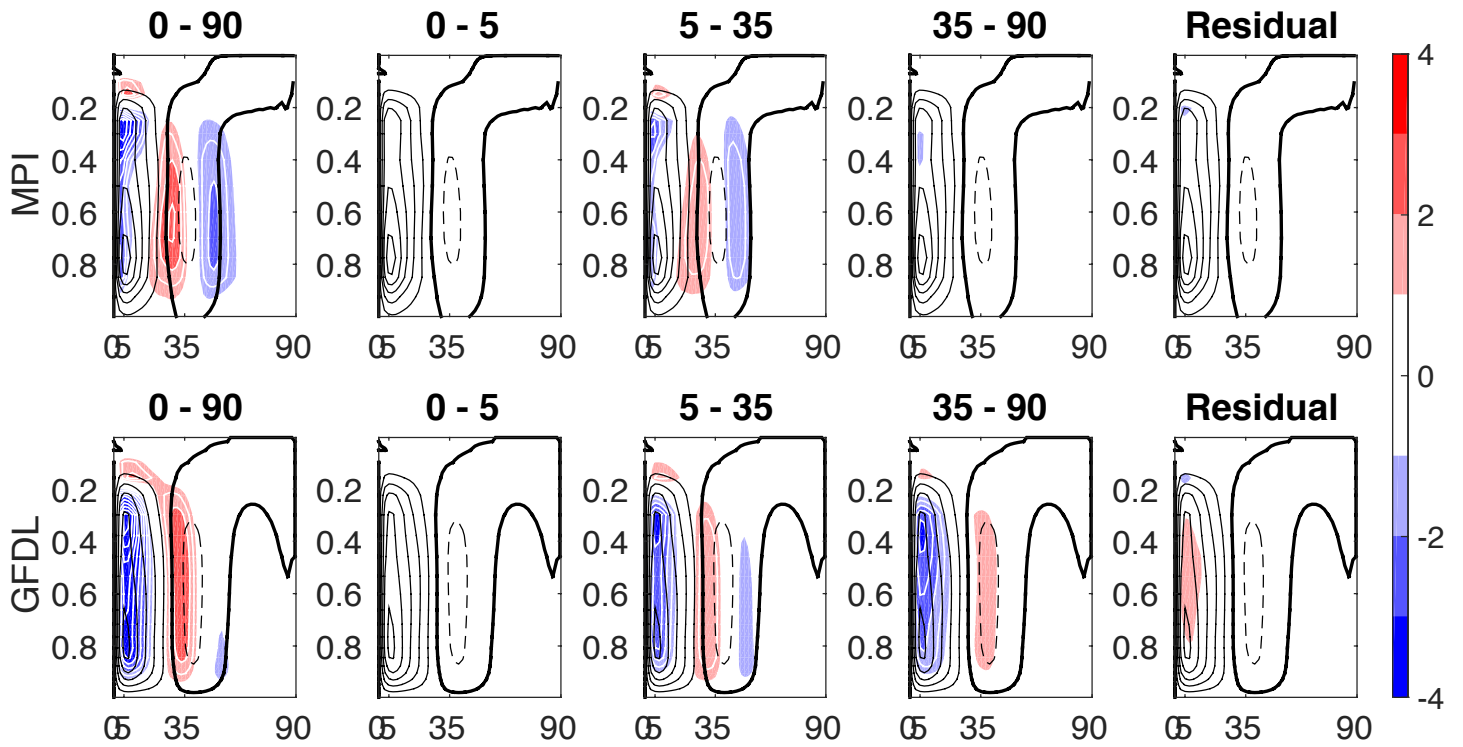


Figure 21. As in Figure 18 but for the response of time-mean, zonal-mean Eulerian streamfunction (shading, contour interval $0.5 \times 10^{10} \text{ kgs}^{-1}$, black contour interval $5 \times 10^{10} \text{ kgs}^{-1}$, negative contours dashed).