S1 Evaluation of CanESM5 climatology

We reproduce here the figures in Section 6 in which we evaluate CanAM5 but instead of using CanAM4 and CanAM5 simulations with prescribed observed sea-surface temperatures (SSTs) and sea-ice we use coupled simulations in which SSTs and sea-ice evolves. In place of CanAM5 we use the first ensemble member of CanESM5 (r1i1p2f1) and in place of CanAM4 we use CanESM2 (r1i1p1) which, respectively, use CanAM5 and CanAM4 for their atmospheric model component.

Unlike the CanAM4 AMIP simulations which end in 2009, the CanESM2 historical simulations end in 2005. For some of the figures shown below, the time period to compute the means has been modified to end in 2005. This has little qualitative effect on the evaluations with observations nor the changes between CanESM2 and CanESM5.
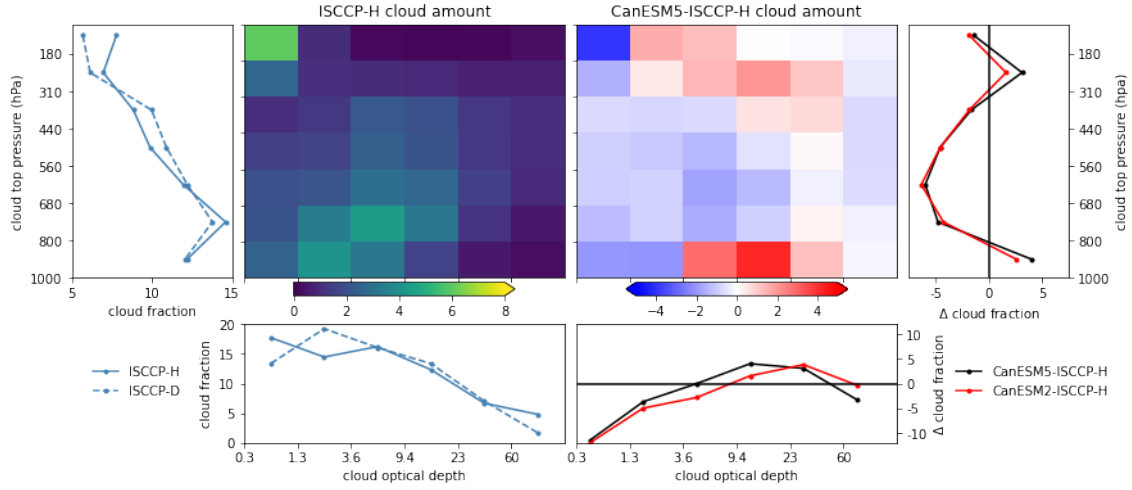
Figure S1. Mean histograms of the cloud fraction equatorward of 60° as a function of the cloud top pressure and cloud visible optical thickness from ISCCP-H and the biases in CanESM5 (middle panels in the upper row). To the side of each histogram is the mean cloud fraction, or cloud fraction bias, as a function of cloud top pressure, while below each histogram is shown the cloud fraction, or cloud fraction bias, as a function of cloud optical thickness. Means are averages over 1987-2005.
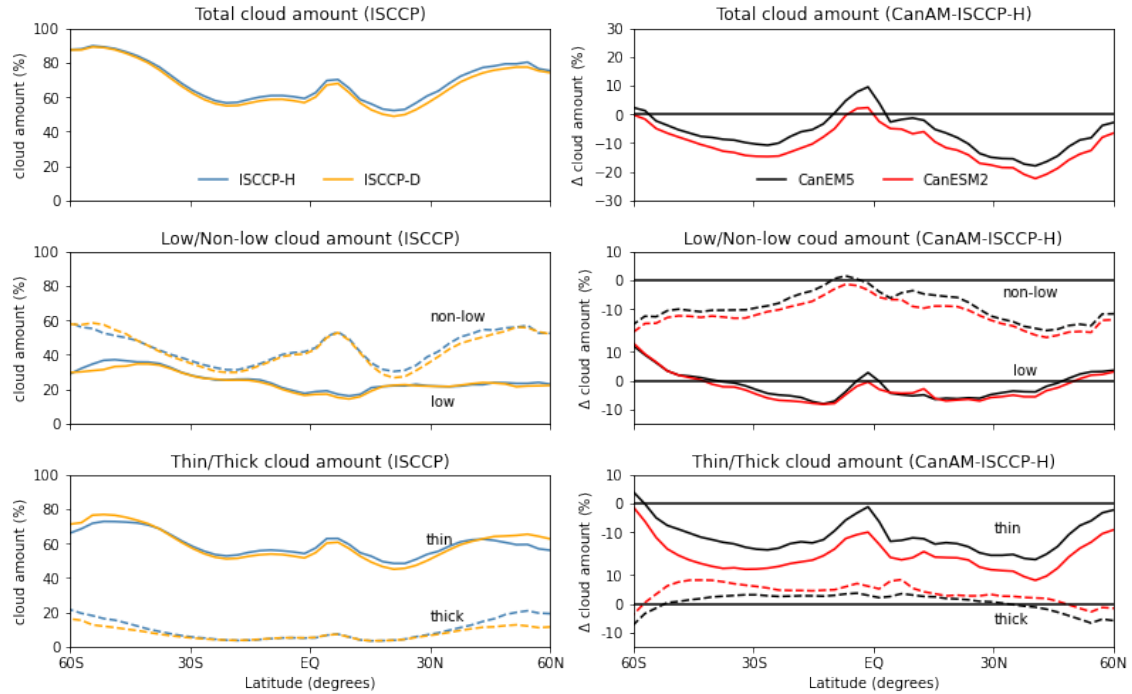
Figure S2. Zonal mean cloud fraction for the total cloud amount (upper row), cloud amount for low (cloud top pressure > 680 hPa) and non-low (cloud top pressure < 680 hPa) in the middle row and cloud amount for thin (cloud visible τ between 0.3 and 23) and thick (cloud visible τ > 23) in the bottom row. All CanAM and ISCCP cloud amounts only consider clouds with τ > 0.3. Observations for ISCCP-H and ISCCP-D are shown in the left column, biases for CanESM5 and CanESM2 relative to ISCCP-H in the right column.
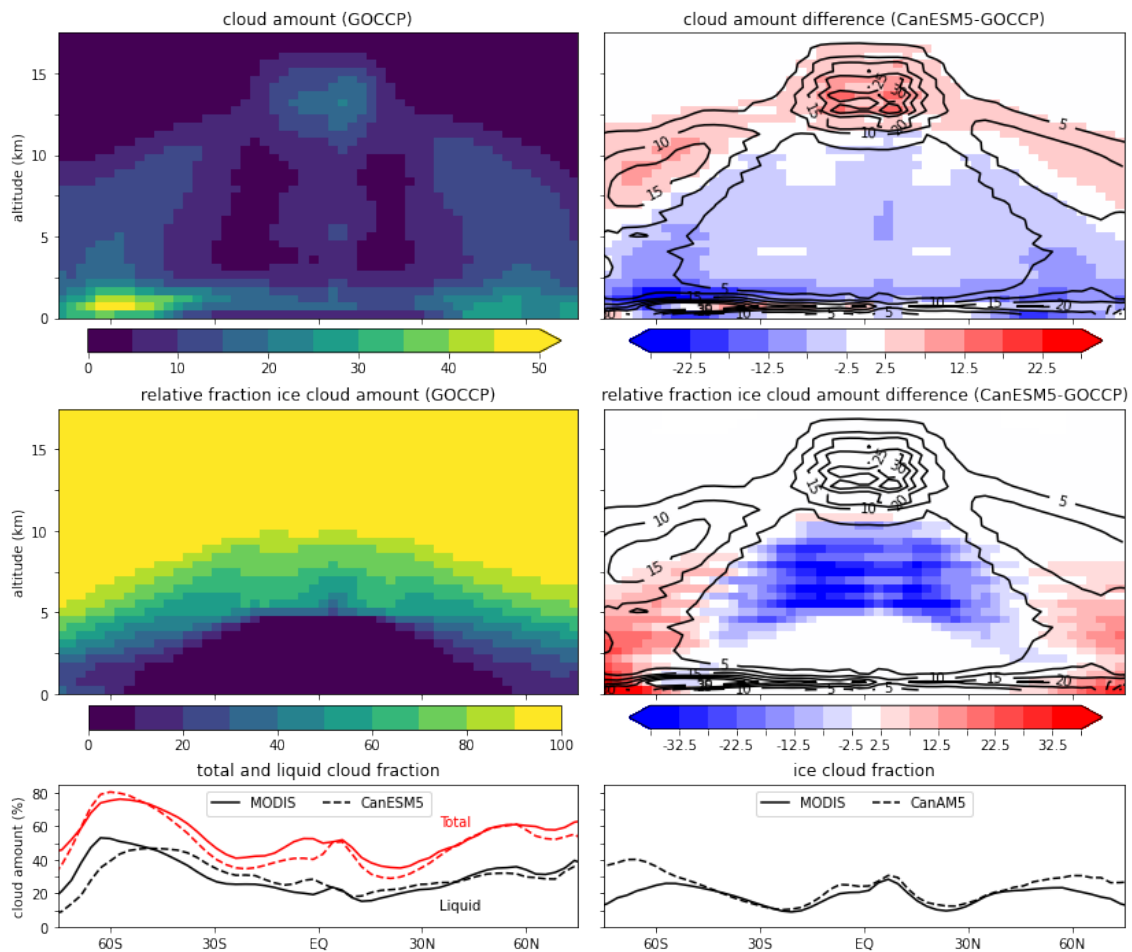
Figure S3. Zonal cloud fraction and cloud phase from CanESM5 compared with GOCCP and MODIS osbervations. Means are averages over 2000-2005.
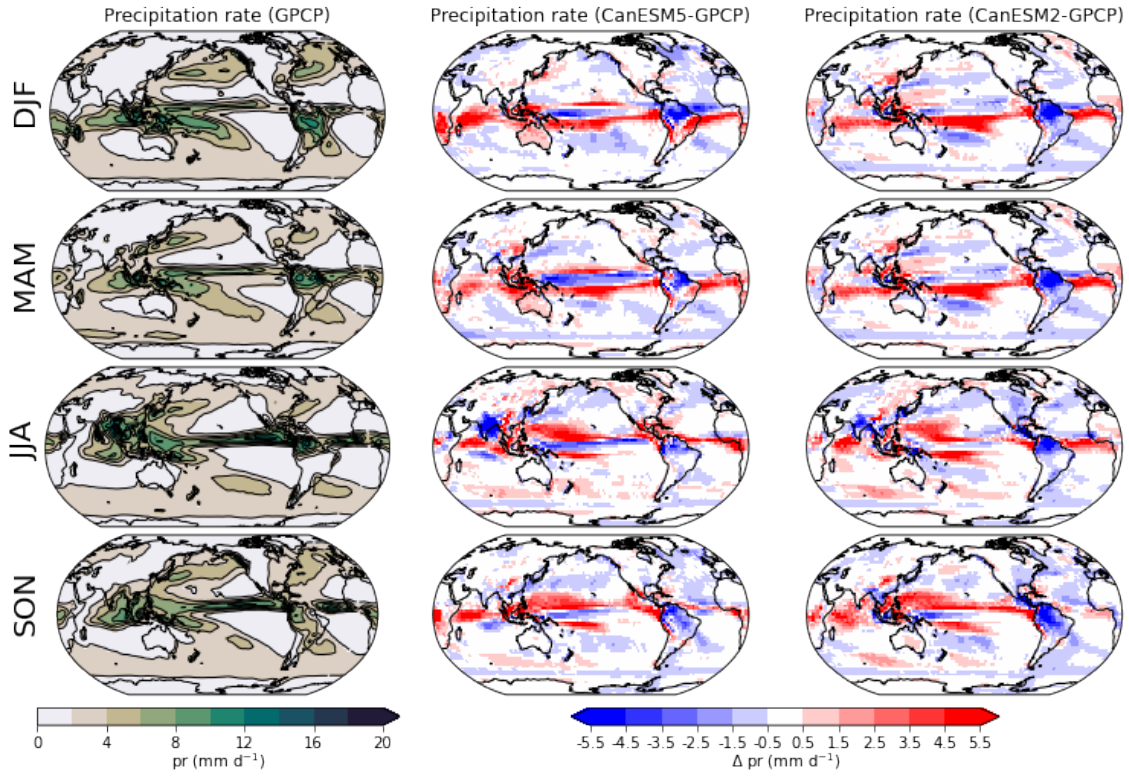
Figure S4. Seasonal mean precipitation rate from GPCP (left column), the bias of CanESM5 relative to GPCP (middle column) and the bias of CanESM2 relative to GPCP (right column). Means are computed from the years 1980-2005.
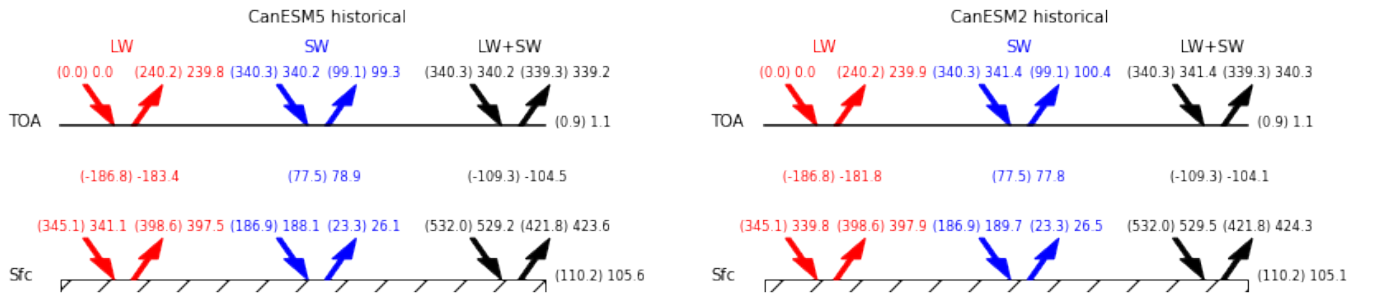
Figure S5. Global and time mean radiative fluxes at the top of atmosphere (TOA) and surface, as well as the net flux divergence for the atmosphere, from AMIP simulations by CanESM5 and CanESM2 compared with CERES EBAF. For each pair of numbers, the left is CERES and the right is CanESM5 or CanESM2. Means are averages over 2000-2005.
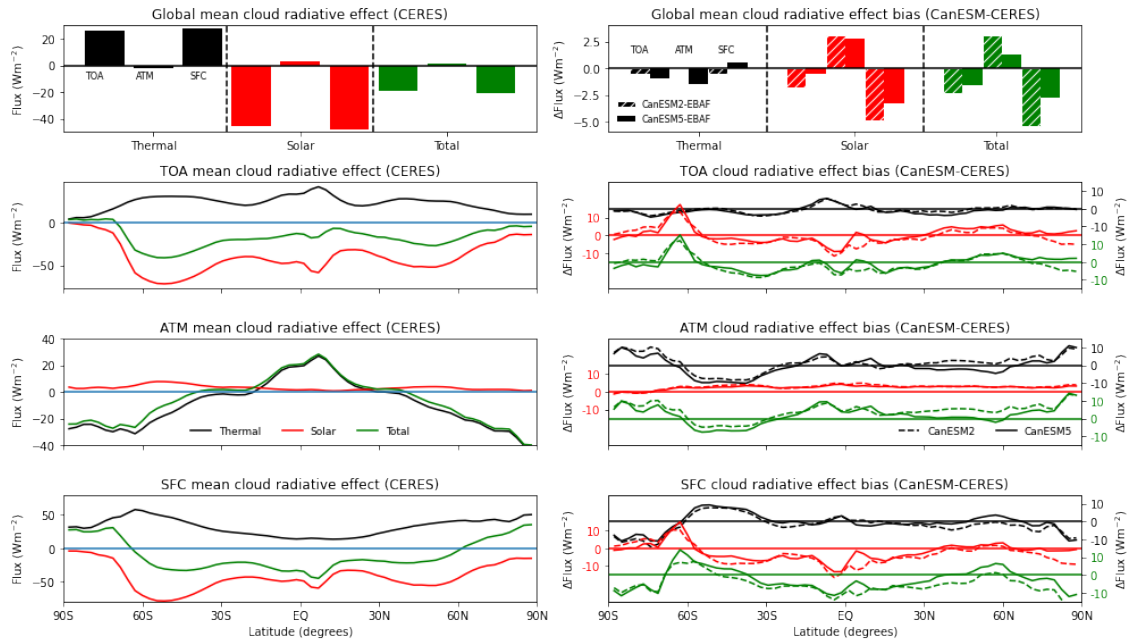
Figure S6. Annual global and zonal mean cloud radiative effects at the top of atmosphere, surface and atmosphere, from CERES EBAF observation (left column) and from CanESM5 and CanESM2 historical simulations (right column). Means are averages over 2000-2005.
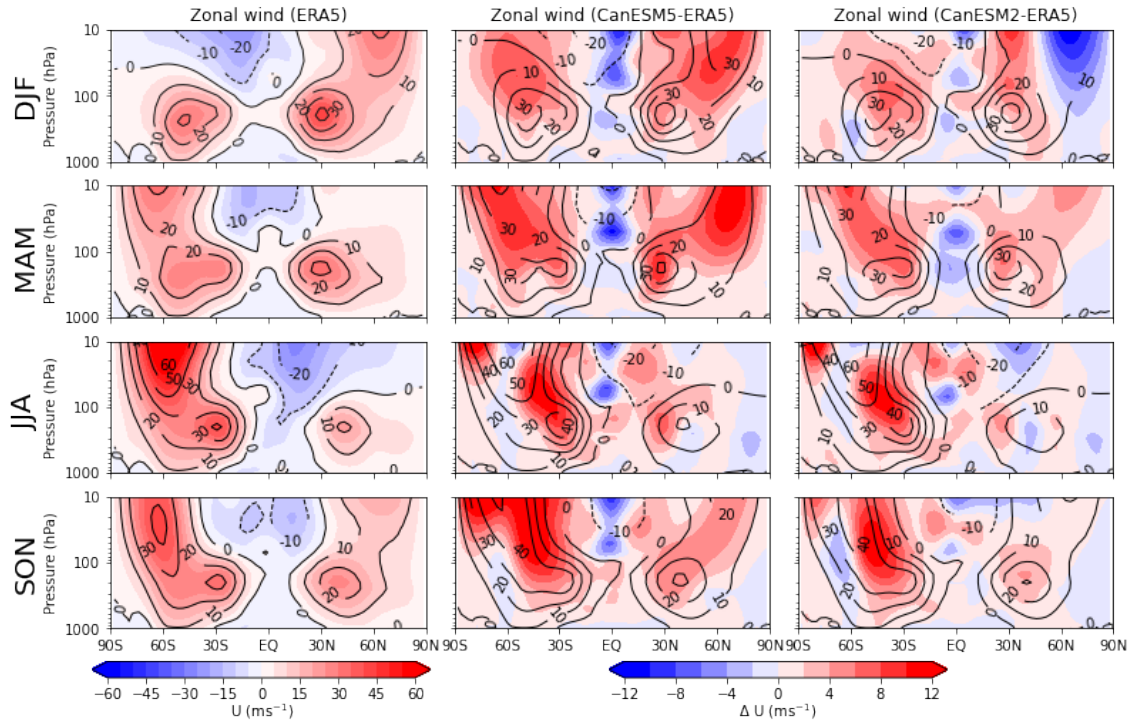
Figure S7. Seasonal mean latitude-pressure plots of zonal wind from ERA5 (left column), the bias of CanESM5 relative to ERA5 (middle column) and the bias of CanESM2 relative to ERA5 (right column). For all plots, contours are the mean. For the ERA5 plot, shading is the mean, in other plots the shading is the bias relative to ERA5. All plots use data from years 1980-2005.
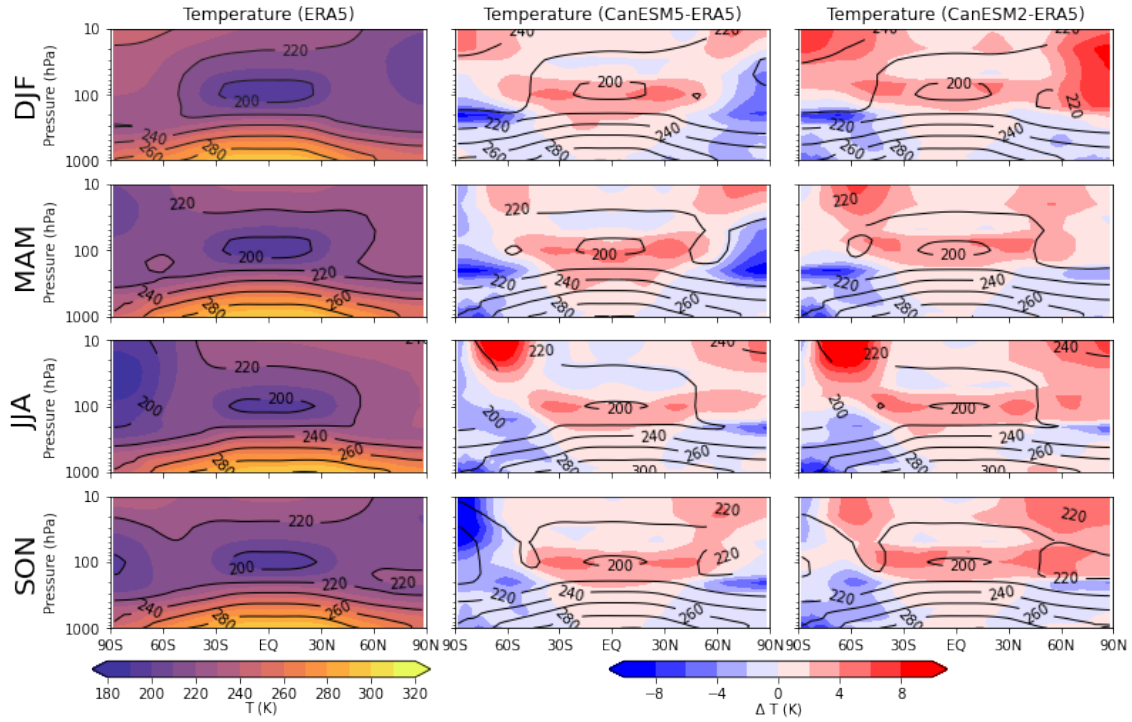
Figure S8. Seasonal mean latitude-pressure plots of temperature from ERA5 (left column), the bias of CanESM5 relative to ERA5 (middle column), and the bias of CanESM2 relative to ERA5 (right column). For all plots, contours are the mean. For the ERA5 plot, shading is the mean, in other plots the shading is the bias relative to ERA5. All plots use data from years 1980-2005.
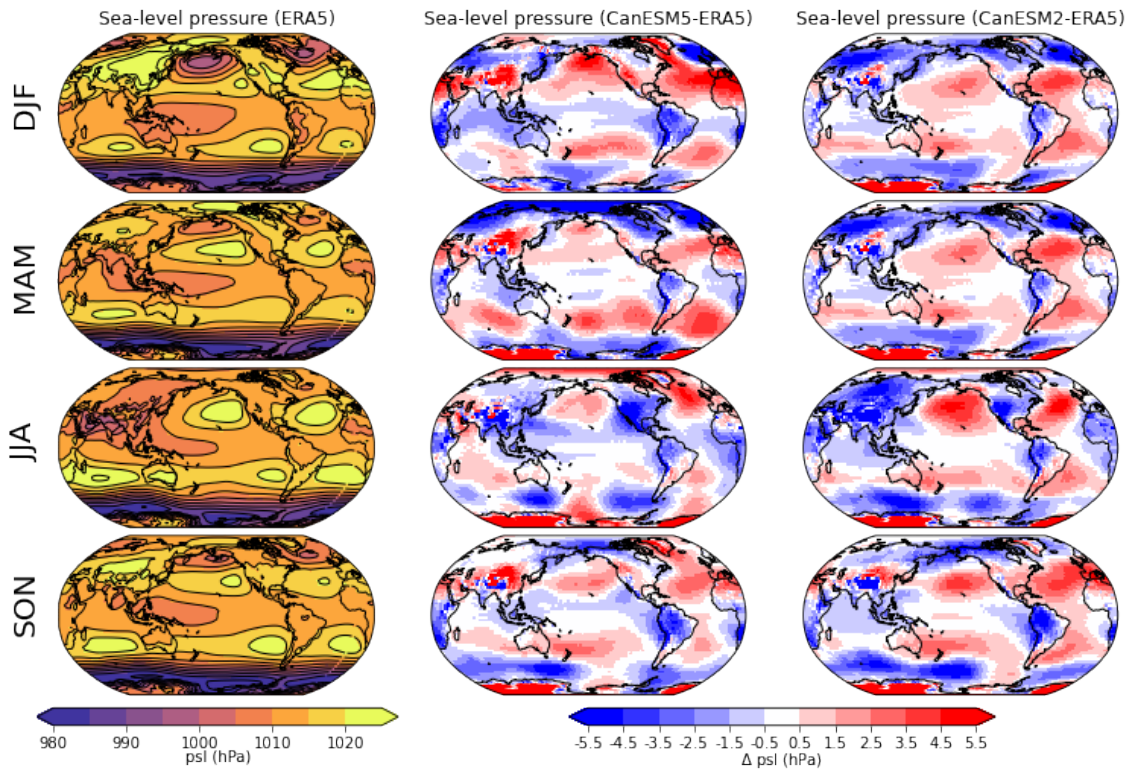
Figure S9. Seasonal mean sea-level pressure from ERA5 (left column), the bias of CanESM5 relative to ERA5 (middle column), and the bias of CanESM2 relative to ERA5 (right column). All plots use data from years 1980-2005.
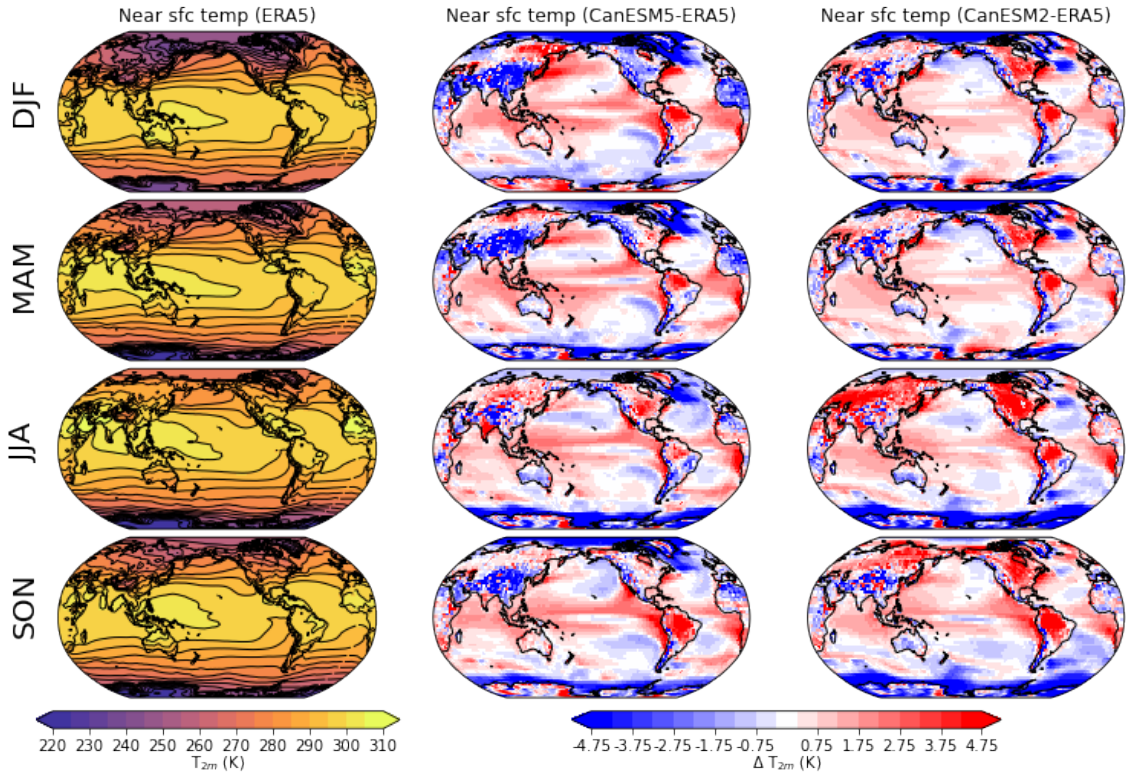
Figure S10. Seasonal mean near surface temperature from ERA5 (left column), the bias of CanESM5 relative to ERA5 (middle column) and the bias of CanESM2 relative to ERA5 (right column). All plots use data from years 1980-2005.
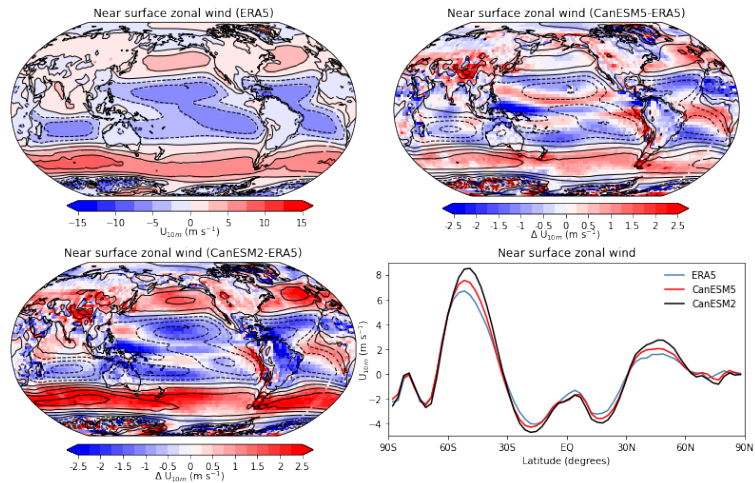
Figure S11. Annual mean near surface zonal wind, nominally at 10 m above the surface from ERA5 (upper left) and CanESM5 and CanESM2 biases. For all plots, contours are the mean, while for the ERA5 plot shading are also the mean but in the other plots the shading is the bias relative to ERA5. All plots use data from years 1980-2005.