Supplemental Material

Limitations on model simulations of CO2 transport due to the use of imperfect atmospheric analyses

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Figure S1. sp105_mn100_mn105_sp105_zonal_diffCO2.avi

Figure S1 shows an animation of the impact of changing Kain-Fritsch parameters (left) versus that of adding convective transport of tracers (right) during 2009. Zonal mean values are computed once per day at 0 UTC. Units are ppm.

Figure S2. sp105_mn100_mn105_sp105_XCO2_diff.avi

Figure S2 shows an animation of the impact of changing Kain-Fritsch parameters (top) versus that of adding convective transport of tracers (bottom) during 2009. Column mean values are computed once per day at 0 UTC. Units are ppm.
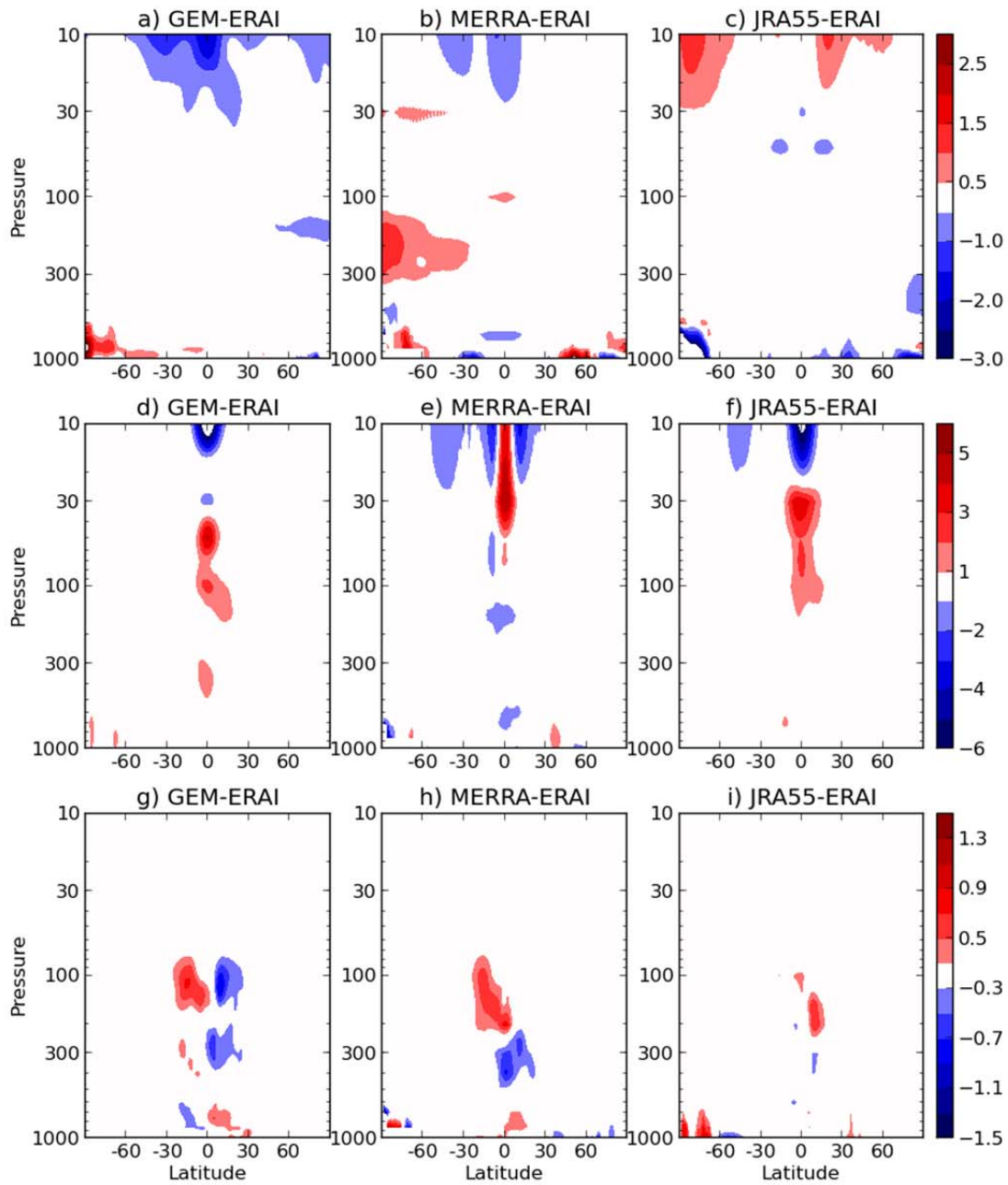
Figure S3: Comparison of GEM-MACH-GHG meteorological analyses with other reanalyses for December 2009. Monthly and zonal means of differences with ERA-Interim fields of GEM-MACH-GHG (left column), MERRA (middle column) and JRA55 (right column) are shown for temperature in K (top row), zonal wind in m/s (middle row) and meridional wind in m/s (bottom row).
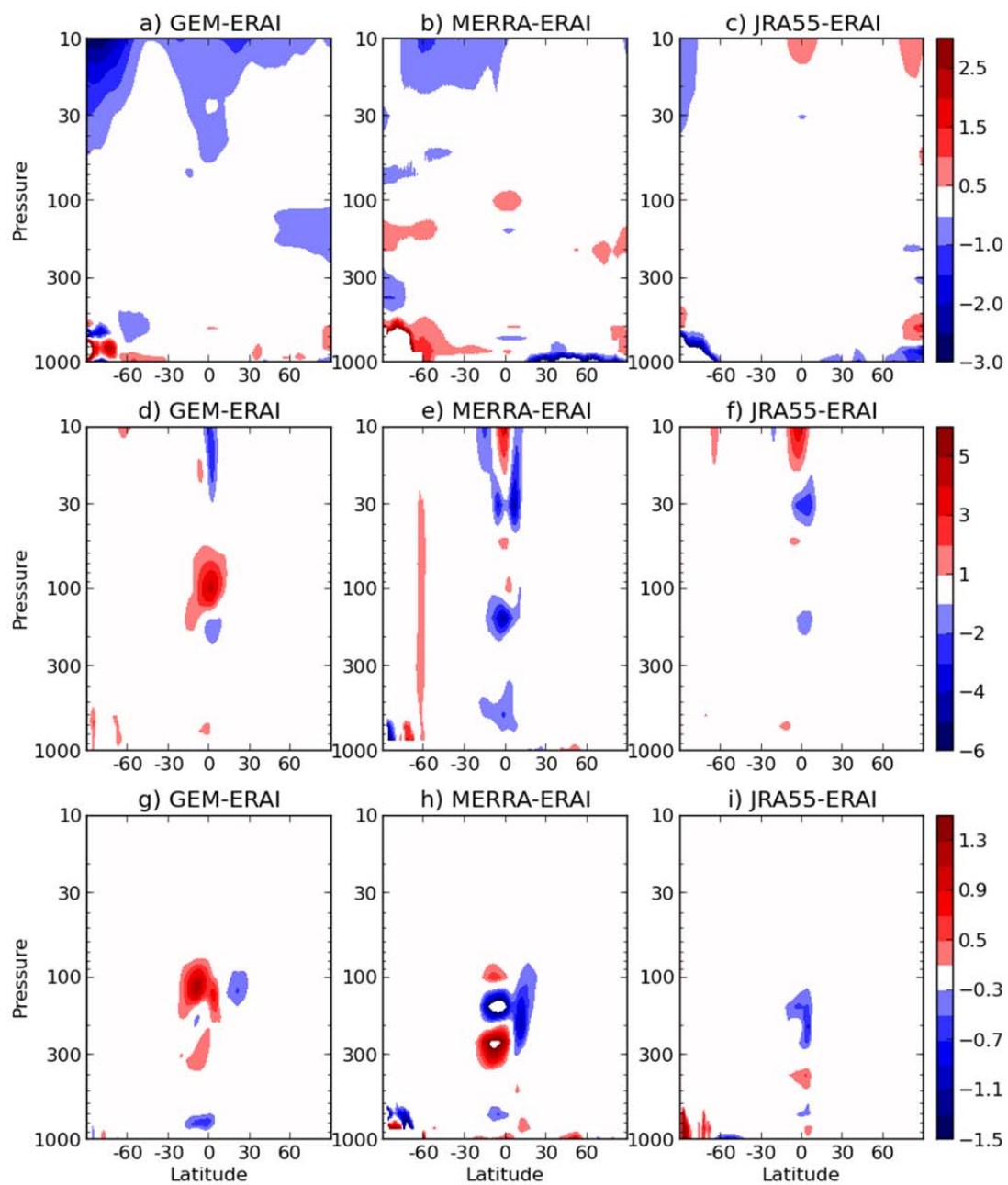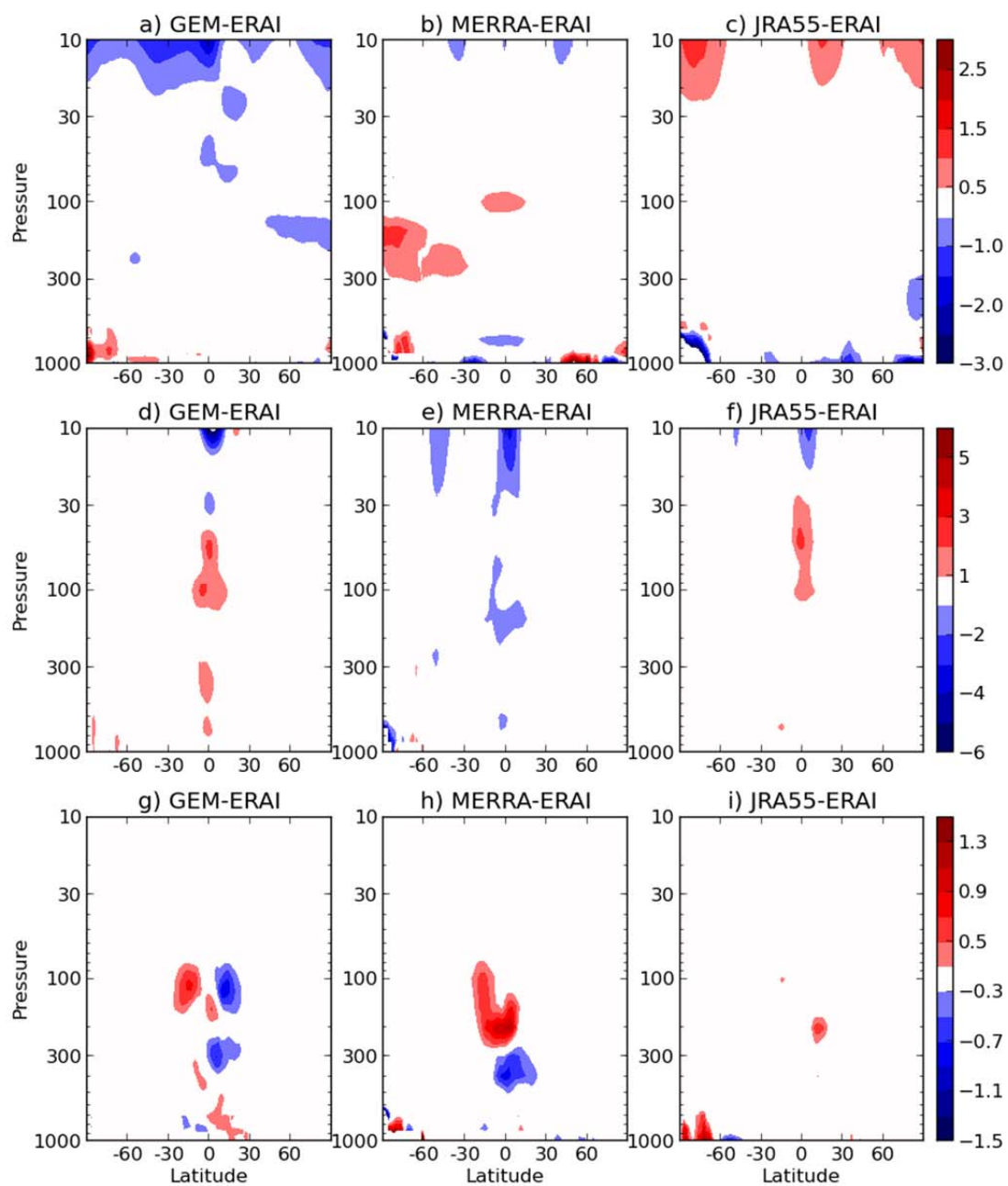
Figure S4: As in Figure S3 but for July 2010.

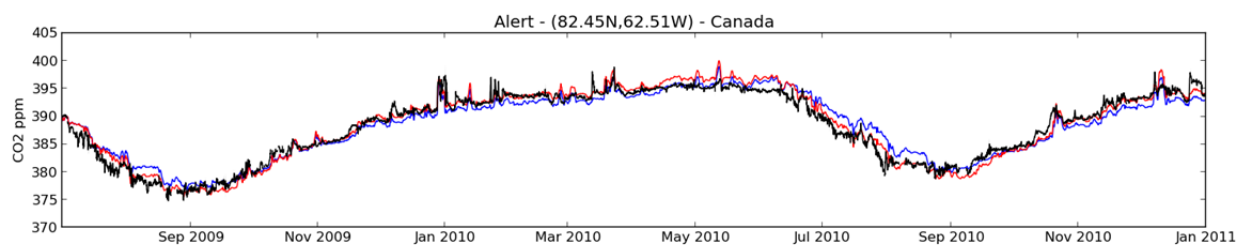**Figure S5**: As in Figure S3 and S4 but for December 2010.

Figure S6: Comparison of time series at Alert from continuous measurements (black) and from GEM-MACH-GHG with GEOS-Chem posterior fluxes obtained with GOSAT observations as in Deng et al. 2016 (red) and with surface observations only (blue). The over-estimation of CO_2 at Alert with GEOS-Chem fluxes in the spring was attributed to the model deficiencies in boundary layer mixing (see Deng et al. 2016). Note the agreement with observations in autumn for both model simulations.
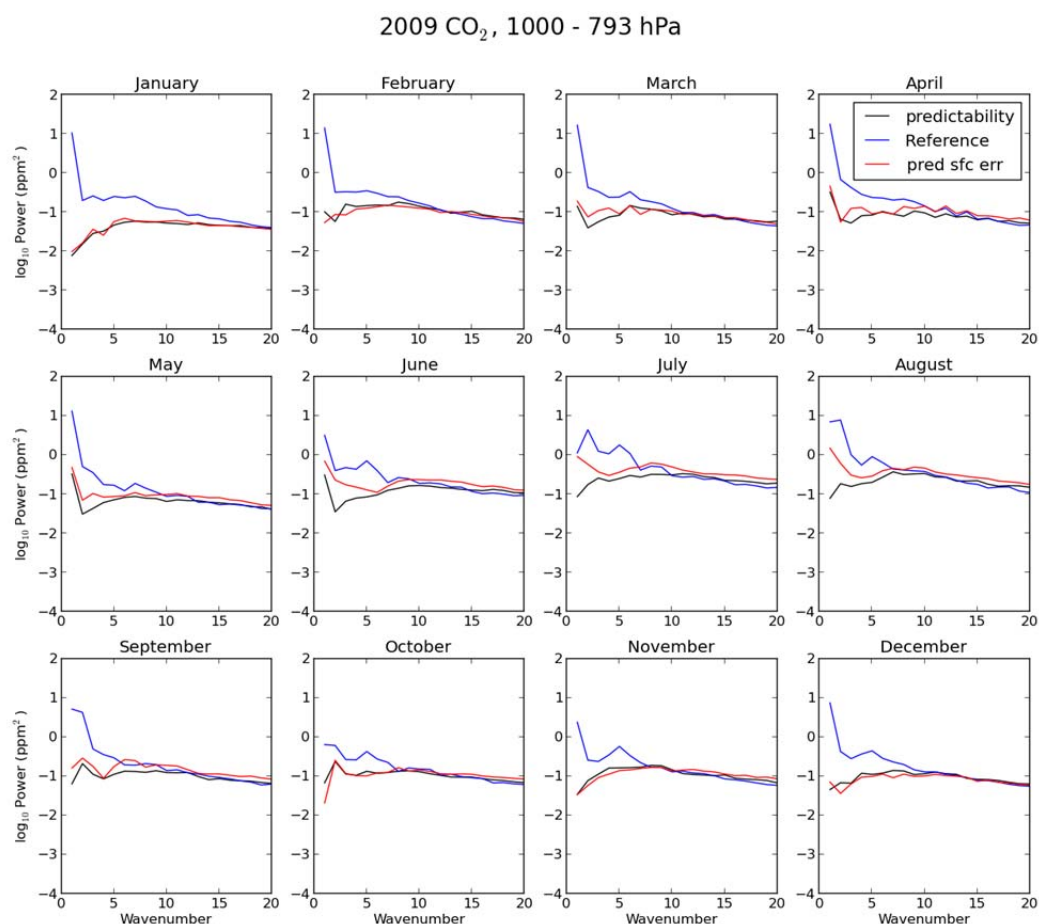
2009 CO_2, 1000 - 793 hPa

Figure S7: Power spectra versus total wavenumber of various errors and the reference CO_2 states. Spectra are averaged over one month and the 12 model levels nearest the surface (roughly 1000 to 831 hPa). The 12 panels correspond to each month of 2009 and only wavenumbers below 20 are shown. The mean spectra of the reference states (blue curves) are plotted along with the spectra of predictability errors (black curves) and the spectra of predictability errors from a cycle with seasonally shifted surface fields (red curves).
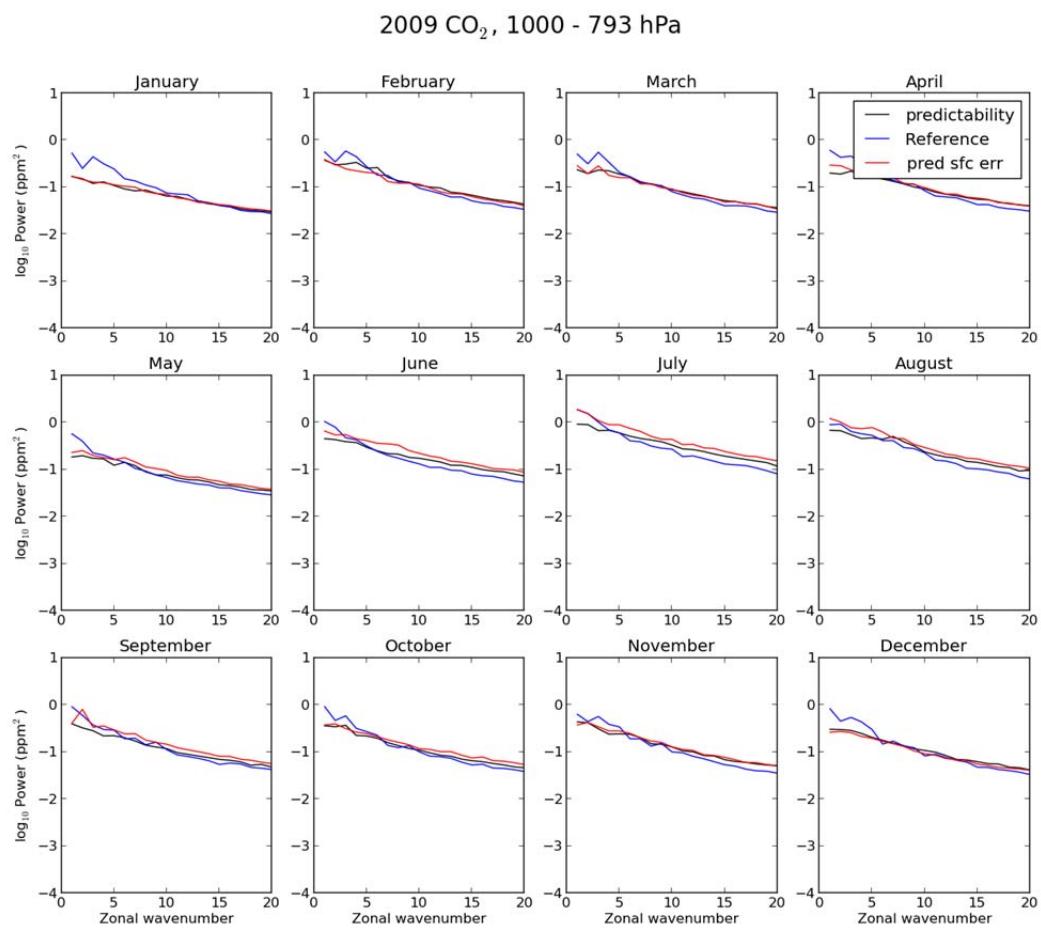
2009 CO_2, 1000 - 793 hPa

Figure S8: As in Figure S7 but for spectra plotted against zonal wavenumber.