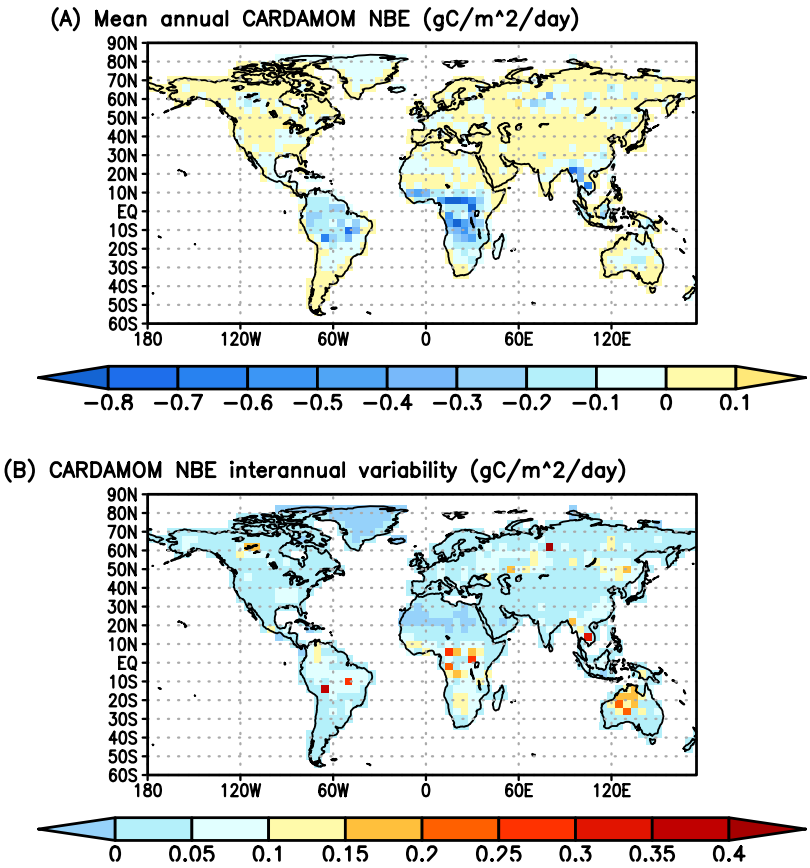

Figure S1 Annual mean net biosphere exchanges from CARDAMOM (A) and its interannual variability between 2010 and 2017 (B).

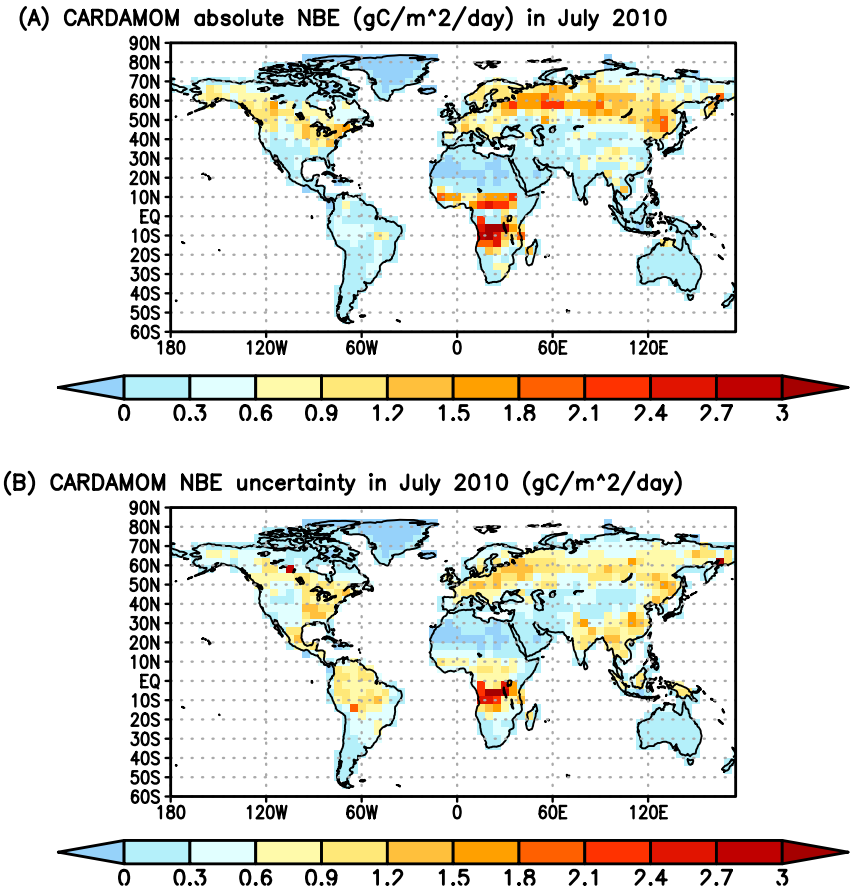

Figure S2 An example of absolute mean NBE (A) and its uncertainty (B) simulated by CARDAMOM. This is for July 2010.

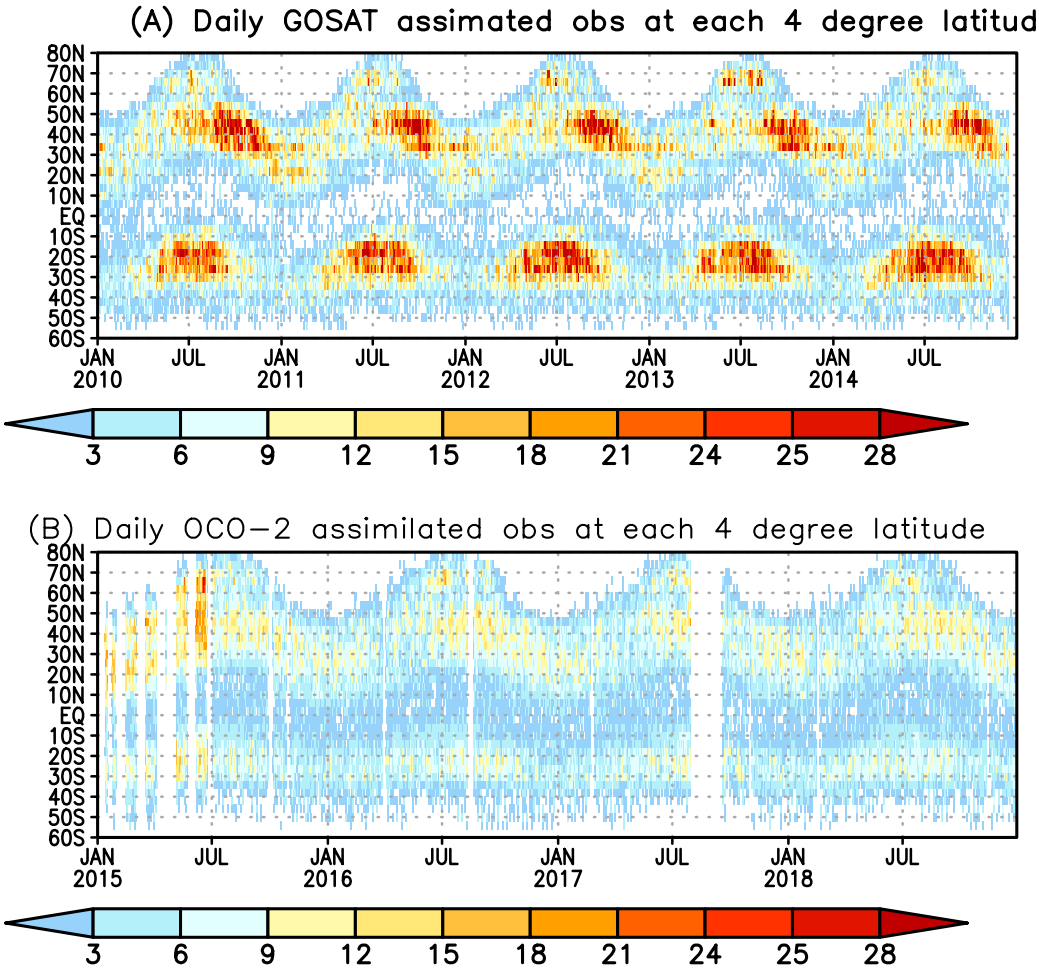

Figure S3 Daily number of ACOS-GOSAT b7.3 (A) and OCO-2 super observations (B) assimilated in the top-down inversions.

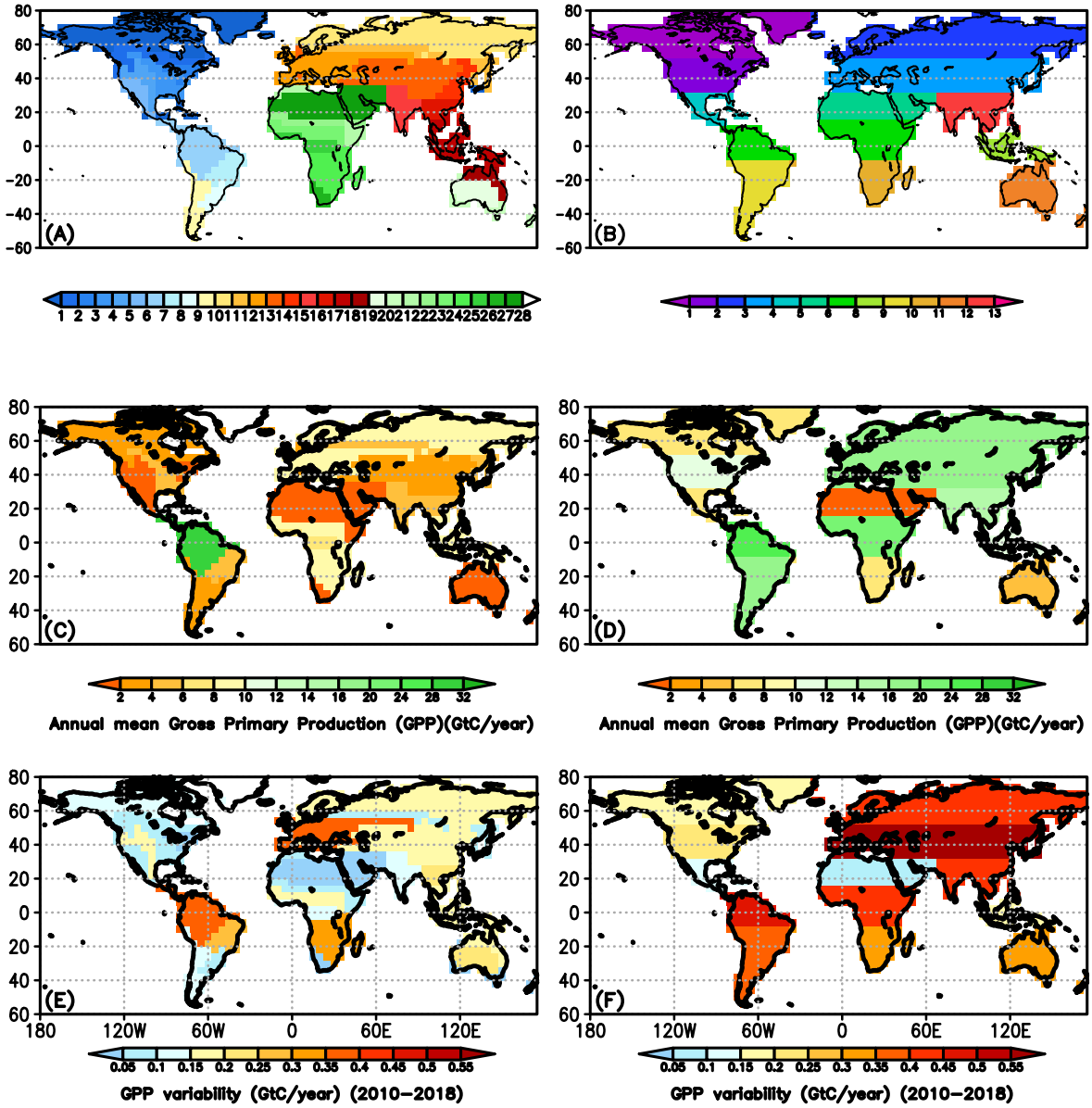

Figure S4 Regional mean GPP and its variability between 2010 –2018. (A and B) regional masks; (C and D) Regional mean GPP aggregated with two regional masks; (E and F) GPP variability between 2010 –2018.

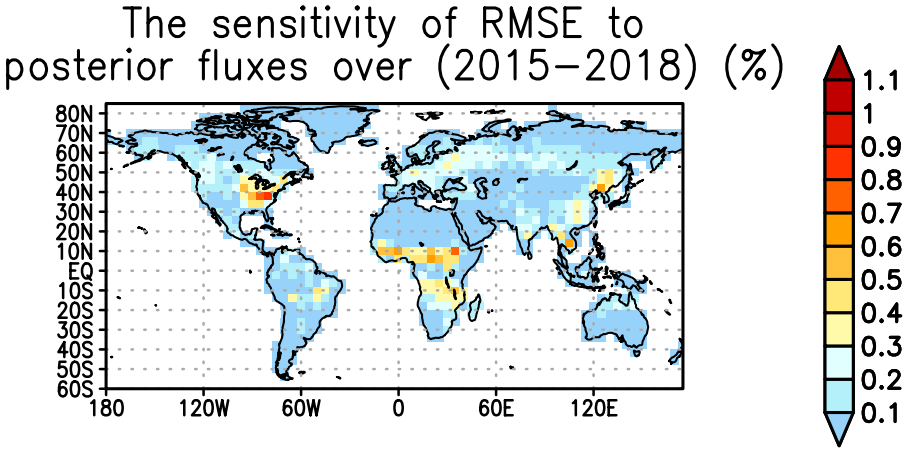

Figure S5 The relative sensitivity of root mean square errors (RMSE) of posterior CO_2 to surface fluxes at every grid point. The adjoint model is carried over Sep 2014–Dec 2018.

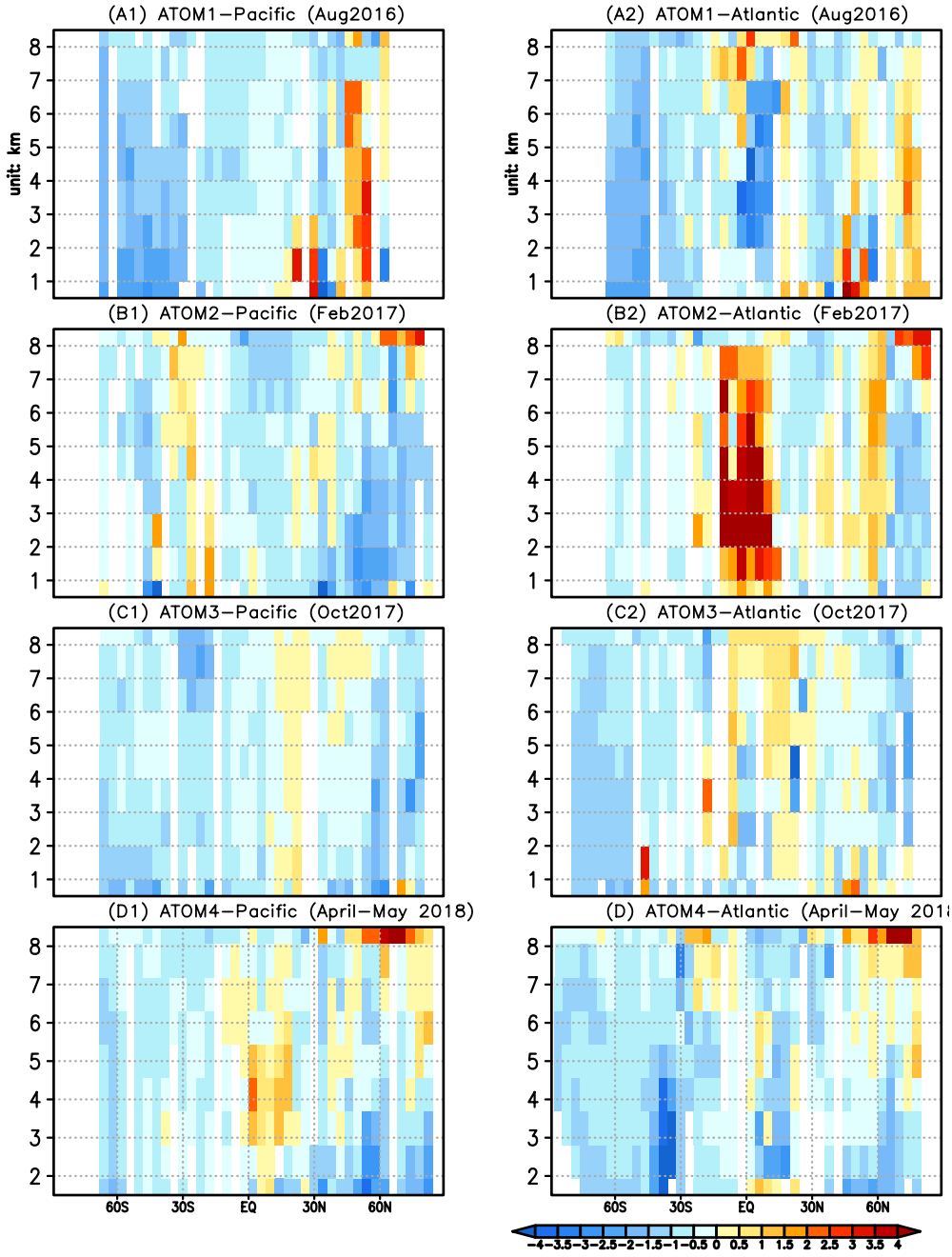

Figure S6 Differences between posterior CO_2 and ATOM 1-4 aircraft CO_2 observations over Pacific (A1-D1) and Atlantic Ocean (A2-D2) as a function of latitude and altitude (unit: km). Unit: ppm.

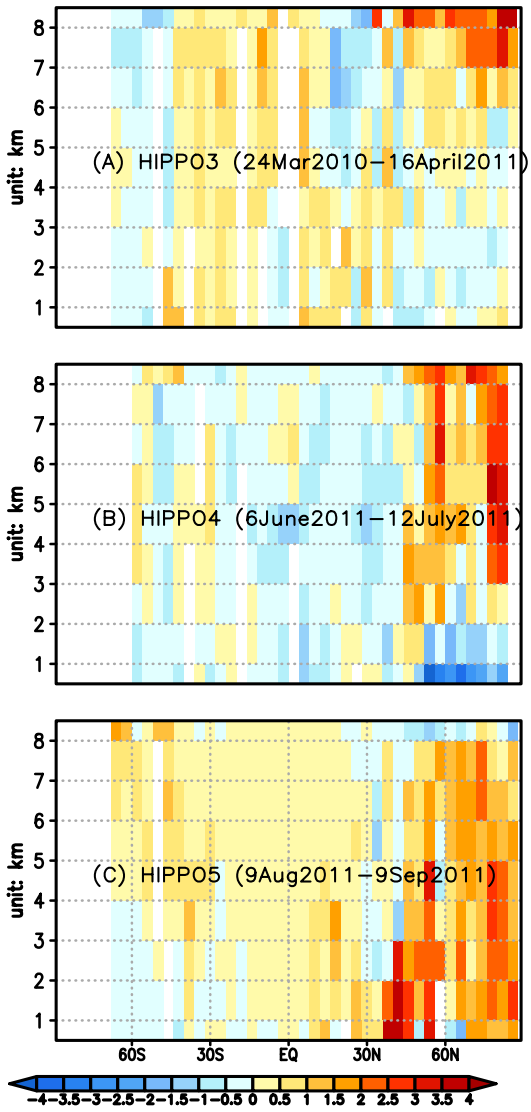

Figure S7 Differences between posterior CO_2 and HIPPO 3-5 aircraft CO_2 observations over Pacific (A-C) as a function of latitude and altitude. Unit: ppm.

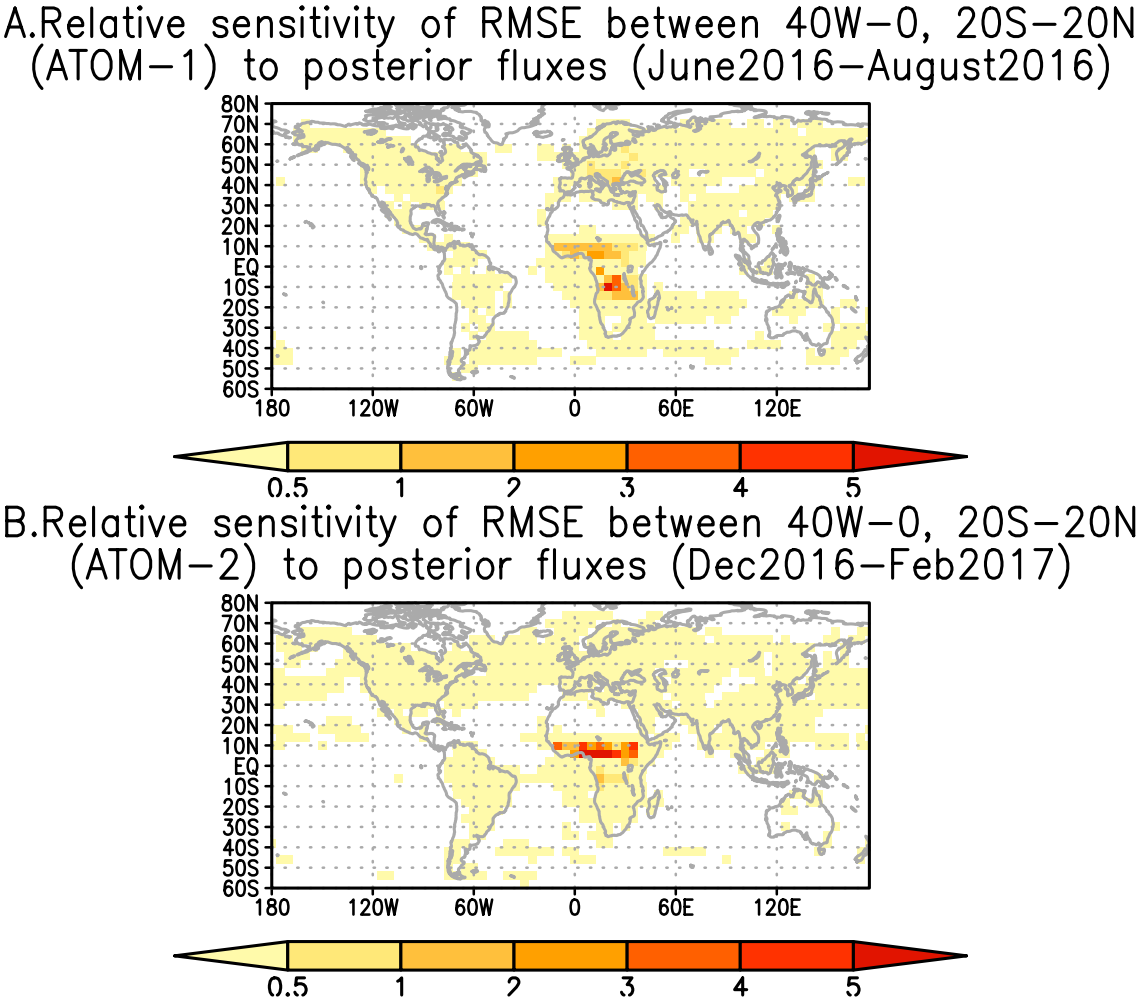

Figure S8 The relative sensitivity of root mean square errors (RMSE) of posterior CO_2 to surface fluxes at every grid point. The RMSE is calculated against aircraft CO_2 observations from ATom-1 (A) and ATom-2 (B) between 40°W-0°, 20°S-20°N. The adjoint model is carried over June – August 2016 (A) and Dec 2016 – Feb 2017 (B). Unit: %.

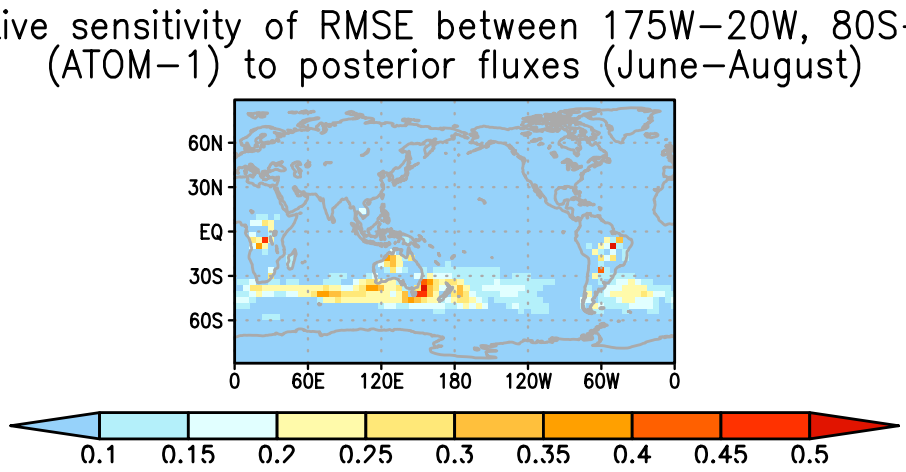

Figure S9 The relative sensitivity of root mean square errors (RMSE) of posterior to surface fluxes at every grid point. The RMSE is calculated against aircraft CO_2 observations from ATom-1 between 175°W-20°W, 80°S-30°S. The adjoint model is carried over June – August 2016. Unit: %.

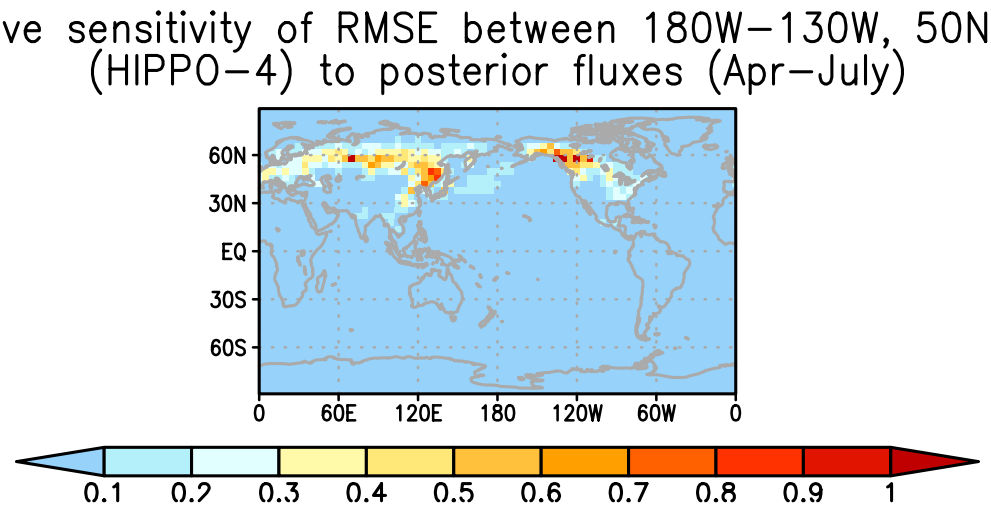

Figure S10 The relative sensitivity of root mean square errors (RMSE) of posterior to surface fluxes at every grid point. The RMSE is calculated against aircraft CO_2 observations from HIPPO-4 between 180°W-130°W, 50°N-90°N. The adjoint model is carried over April – July 2011. Unit: %.