Supplementary Material for ”Estimates of ozone return dates from Chemistry-Climate Model Initiative Simulations”

Sandip S. Dhomse[1], Douglas Kinnison[2], Martyn P. Chipperfield[1], Irene Cionni[3], Michaela Hegglin[4], N. Luke Abraham[5,6], Hideharu Akiyoshi[7], Alex T. Archibald[5,6], Ewa M. Bednarz[5], Slimane Bekki[8], Peter Braesicke[9], Neal Butchart[10], Martin Dameris[11], Makoto Deushi[12], Stacy Frith[13], Steven C. Hardiman[10], Birgit Hassler[11], Larry W. Horowitz[14], Rong-Ming Hu[8], Partick Joeckel[11], Beatrice Josse[15], Oliver Kirner[16], Stefanie Kremser[17], Ulrike Langematz[18], Jared Lewis[17], Marion Marchand[8], Meiyun Lin[14,19], Eva Mancini[20], Virginie Marecal[15], Martin Michou[15], Olaf Morgenstern[21], Fiona M. OĆonnor[10], Luke Oman[13], Giovanni Pitari[22], David A. Plummer[23], John A. Pyle[5,6], Laura E. Revell[24,25], Eugene Rozanov[25,26], Robyn Schofield[27,28], Andrea Stenke[25], Kane Stone[27,28,*], Kengo Sudo[29,30], Simone Tilmes[2], Daniele Visioni[20], Yousuke Yamashita[7,30], and Guang Zeng[21]

[1]School of Earth and Environment, University of Leeds, Leeds, LS2 9JT, U.K.
[2]National Center for Atmospheric Research (NCAR), Boulder, Colorado, USA.
[3]Agenzia Nazionale per le Nuove Tecnologie, lenergia e lo Sviluppo Economica Sostenible (ENEA), Bologna, Italy.
[4]Department of Meteorology, University of Reading, Reading, U.K.
[5]Department of Chemistry, University of Cambridge, Lensfield Road, Cambridge, CB2 1EW, U.K.
[6]National Centre for Atmospheric Science, U.K.
[7]National Institute for Environmental Studies (NIES), Tsukuba, 305-8506 Japan.
[8]IPSL/CNRS, 75252 Paris, France.
[9]IMK-ASF, KIT, Karlsruhe, Germany.
[10]Met Office Hadley Centre, Exeter, U.K.
[11]Deutsches Zentrum fur Luft- und Raumfahrt (DLR), Institut fur Physik der Atmosphare, Oberpfaffenhofen, Germany.
[12]Meteorological Research Institute (MRI), Tsukuba, Japan.
[13]NASA/GSFC, USA.
[14]NOAA Geophysical Fluid Dynamics Laboratory, Princeton, NJ 08540, USA.
[15]Meteo-France, Toulouse, France.
[16]Steinbuch Centre for Computing (SCC), Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany.
[17]Bodeker Scientific, Alexandra 9320, New Zealand.
[18]Institut für Meteorologie, Freie Universitat Berlin, Berlin, Germany.
[19]Atmospheric and Oceanic Sciences, Princeton University, Princeton, NJ 08540, USA.
[20]Dept. of Physical and Chemical Sciences and Center of Excellence CETEMPS, Universita del lÁquila, Italy.
[21]NIWA, New Zealand.
[22]Department of Physical and Chemical Sciences, Universitat dell’Aquila, Italy.
[23]Climate Research Division, Environment and Climate Change Canada, Montreal, Canada.
[24]Bodeker Scientific, Alexandra, New Zealand.
[25]ETH Zurich, Institute for Atmospheric and Climate Science, Zurich, Switzerland.
[26]Physikalisch-Meteorologisches Observatorium Davos World Radiation Centre, Davos Dorf, Switzerland.
[27]School of Earth Sciences, University of Melbourne, Melbourne, Australia.
[28]ARC Centre of Excellence for Climate System Science, Sydney, Australia.
[29]Graduate School of Environmental Studies, Nagoya University, Nagoya, Japan.
[30]Japan Agency for Marine-Earth Science and Technology (JAMSTEC), Yokohama, 236-0001 Japan.

*Now at Massachusetts Institute of Technology (MIT), Boston, Massachusetts, USA

Correspondence: Sandip Dhomse, Douglas Kinnison, Martyn Chipperfield
(s.s.dhomse@leeds.ac.uk, dkin@acd.ucar.edu, m.chipperfield@leeds.ac.uk)

This document contains additional figures to support those presented in the main document. For discussion of the figures and references see the main text.

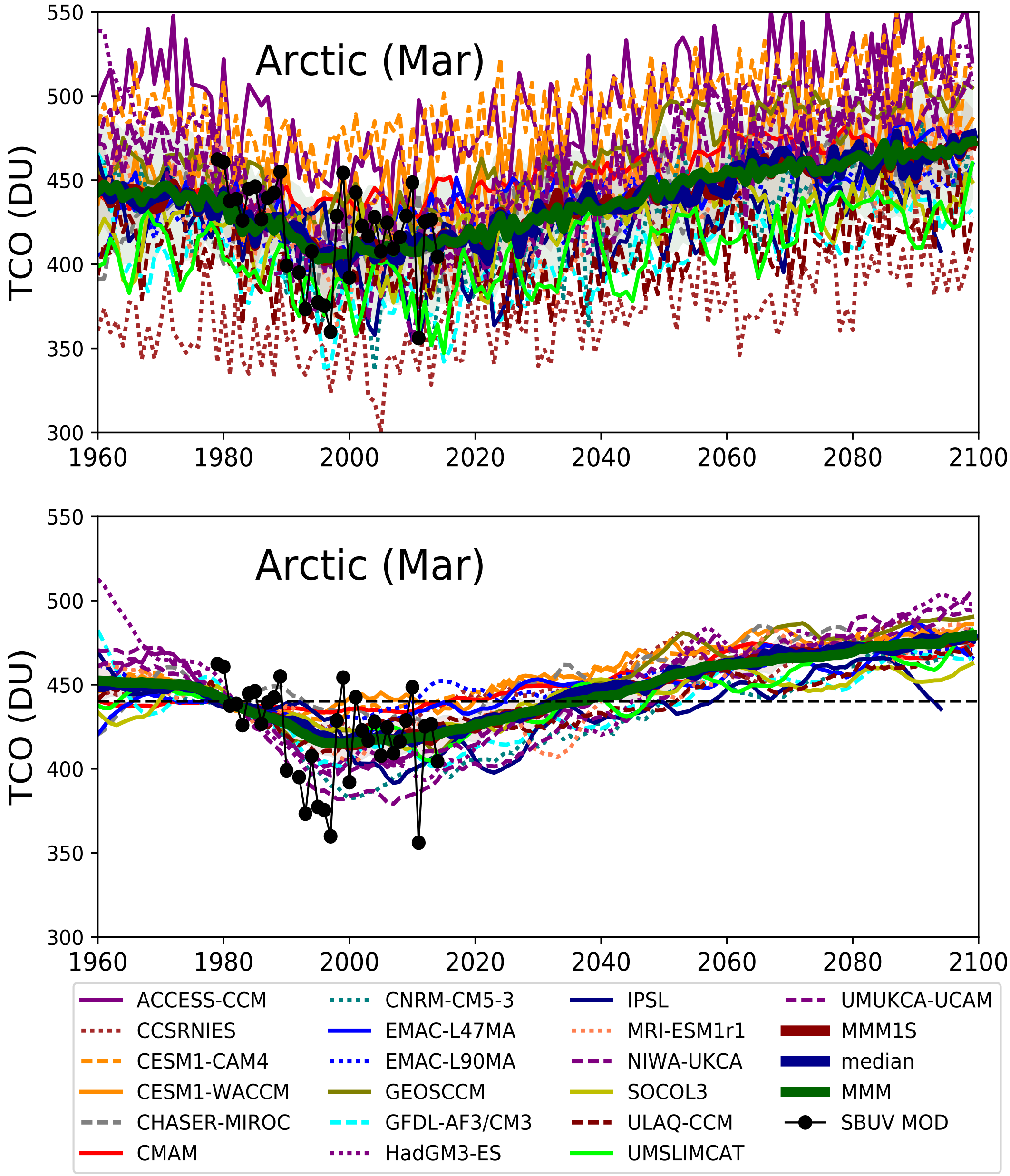

Figure S1. (a) Total column ozone time series (DU) for Arctic in March from 19 individual CCMs for March for the REF-C2 simulations along with observations from the SBUV merged ozone dataset. The MMM, median (MedM) and MMM1S are shown with thick green, blue and red lines, respectively. Light blue shaded region indicates 10th and 90th percentile range. Light green and red regions show 1-σ variability w.r.t. MMM and MMM1S mean lines. (b) Same as (a) but adjusted total ozone time series w.r.t. mean 1980-1984 observations. The dashed black line indicates 1980 reference value.

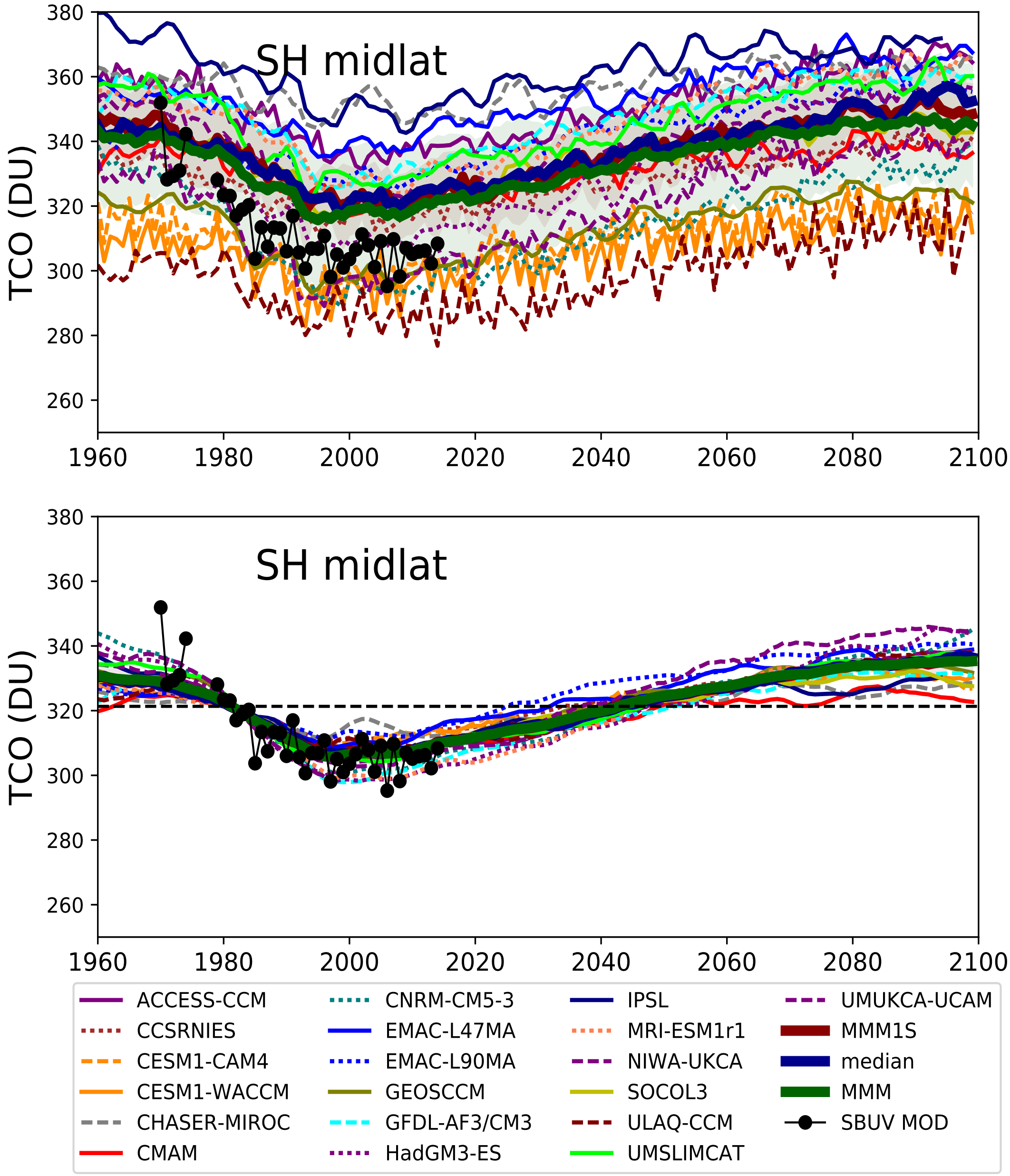

Figure S2. As Figure S1 but for annual mean total column ozone for SH mid-latitudes.

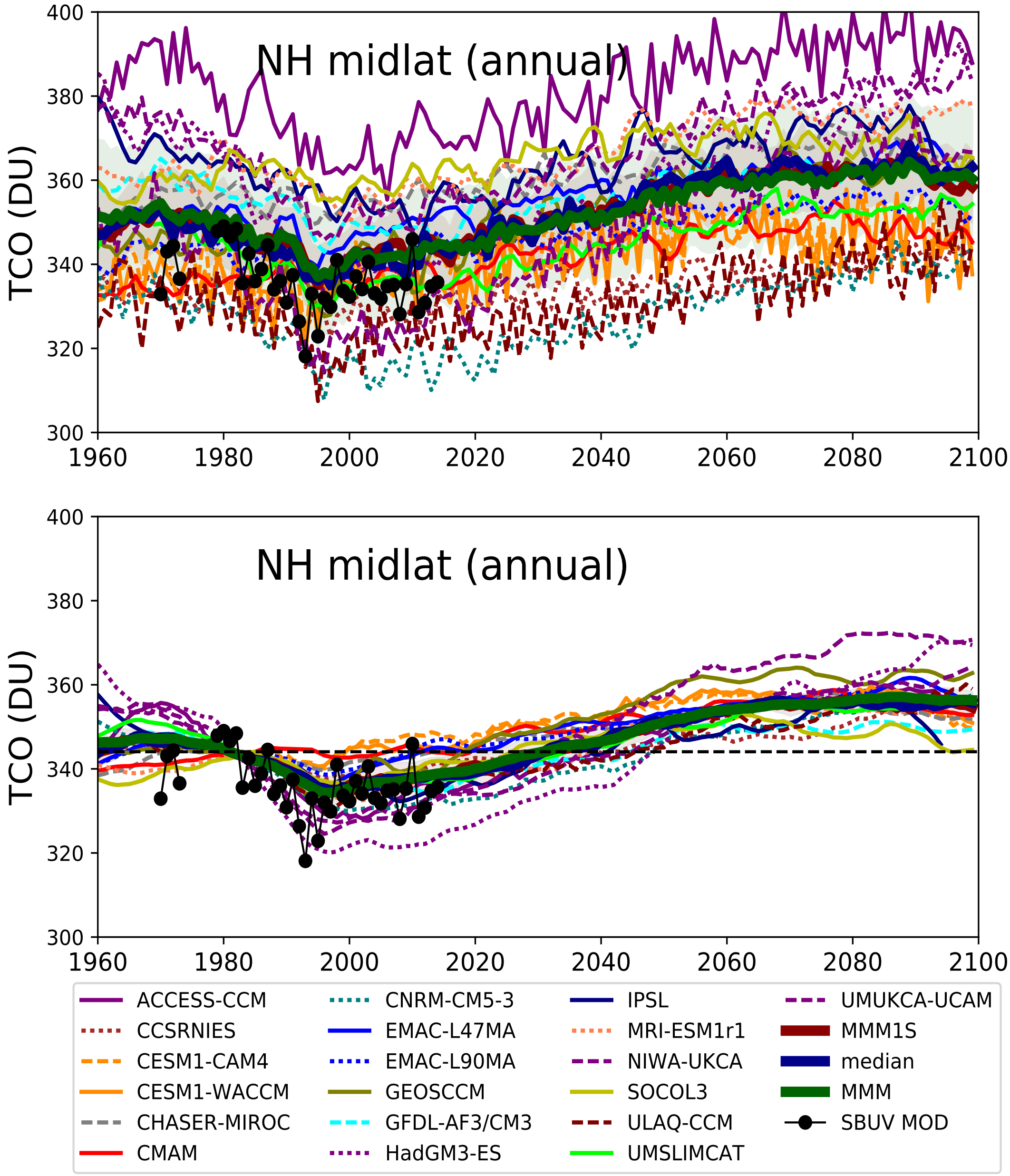

Figure S3. As Figure S1 but for annual mean total column ozone for NH mid-latitudes.

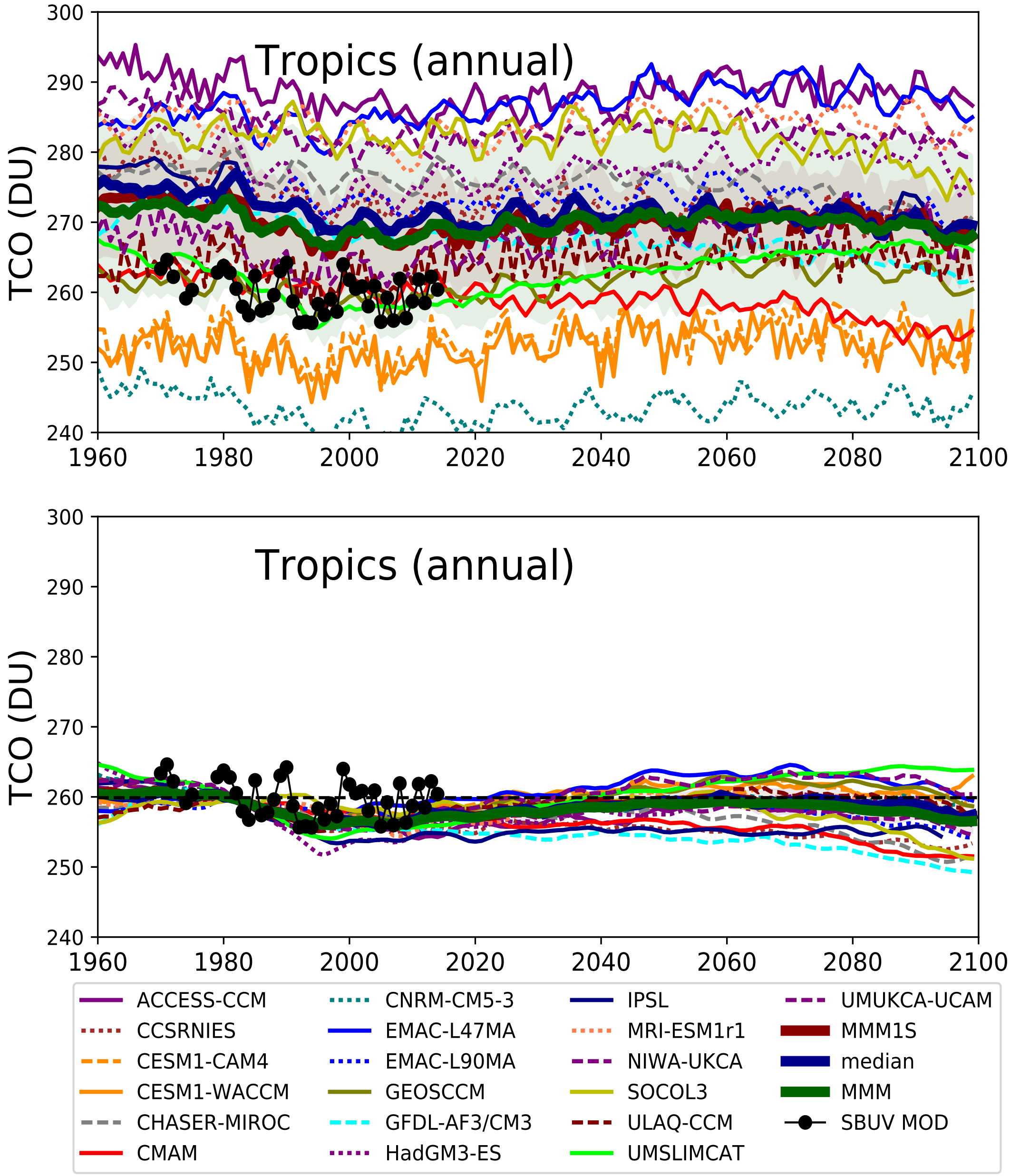

Figure S4. As Figure S1 but for annual mean total column ozone for the tropics (20S-20N).

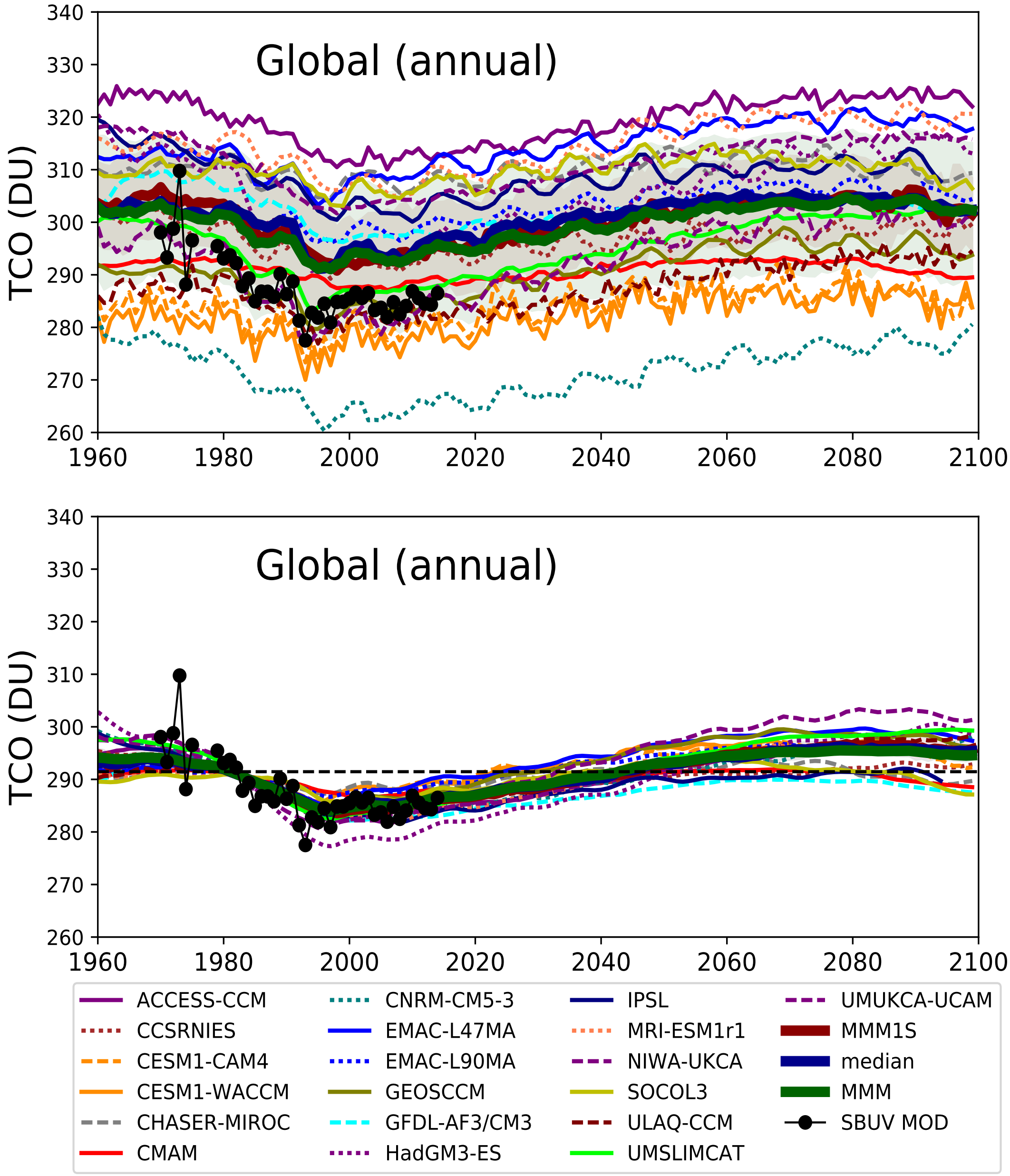

Figure S5. As Figure S1 but for annual mean near global mean (60S-60N) total column ozone.

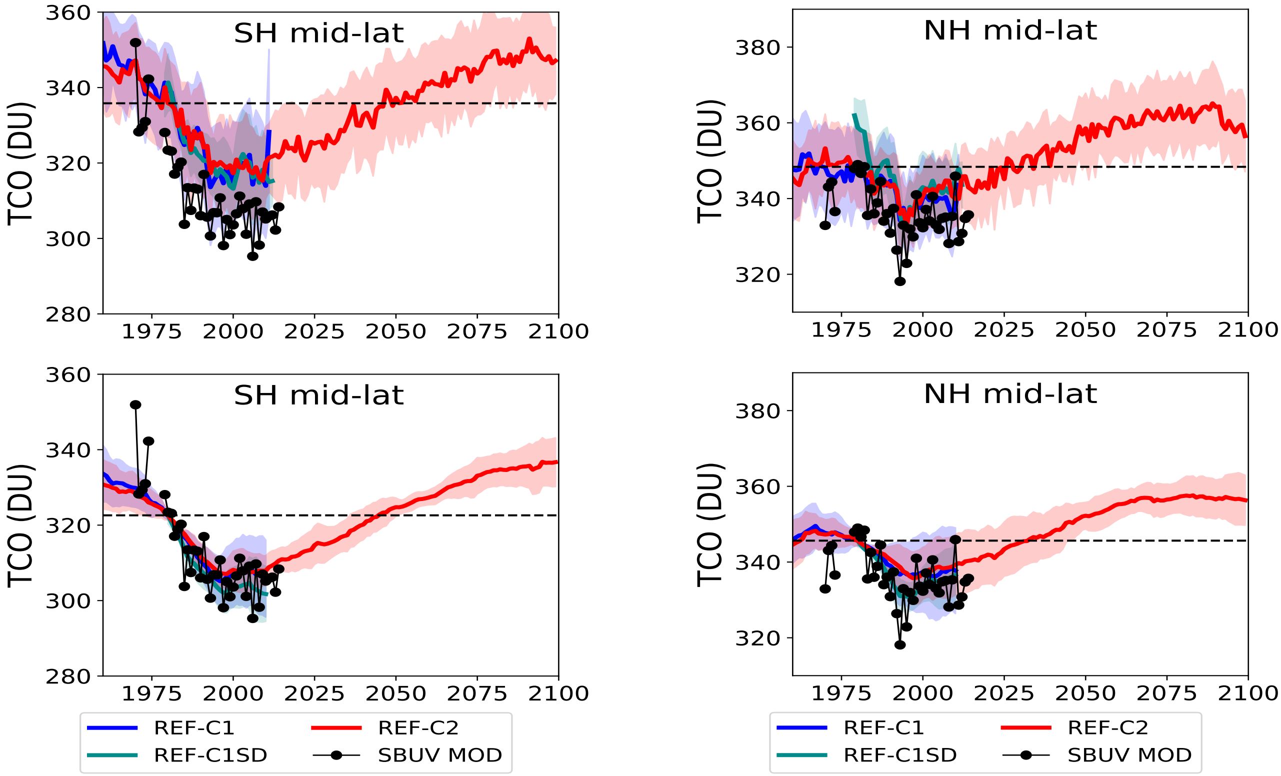

Figure S6. MMM1S total column ozone time series (DU) from REF-C1 (blue), REF-C1SD (dark cyan) and REF-C2 (red) simulations for (left) SH mid-latitudes and (right) NH mid-latitudes. Dashed black lines show 1980 reference value for a given zonal latitude band. The top row shows the unadjusted modelled values and the bottom row shows the time series adjusted w.r.t. mean 1980-1984 observations. Also shown are merged SBUV observations.

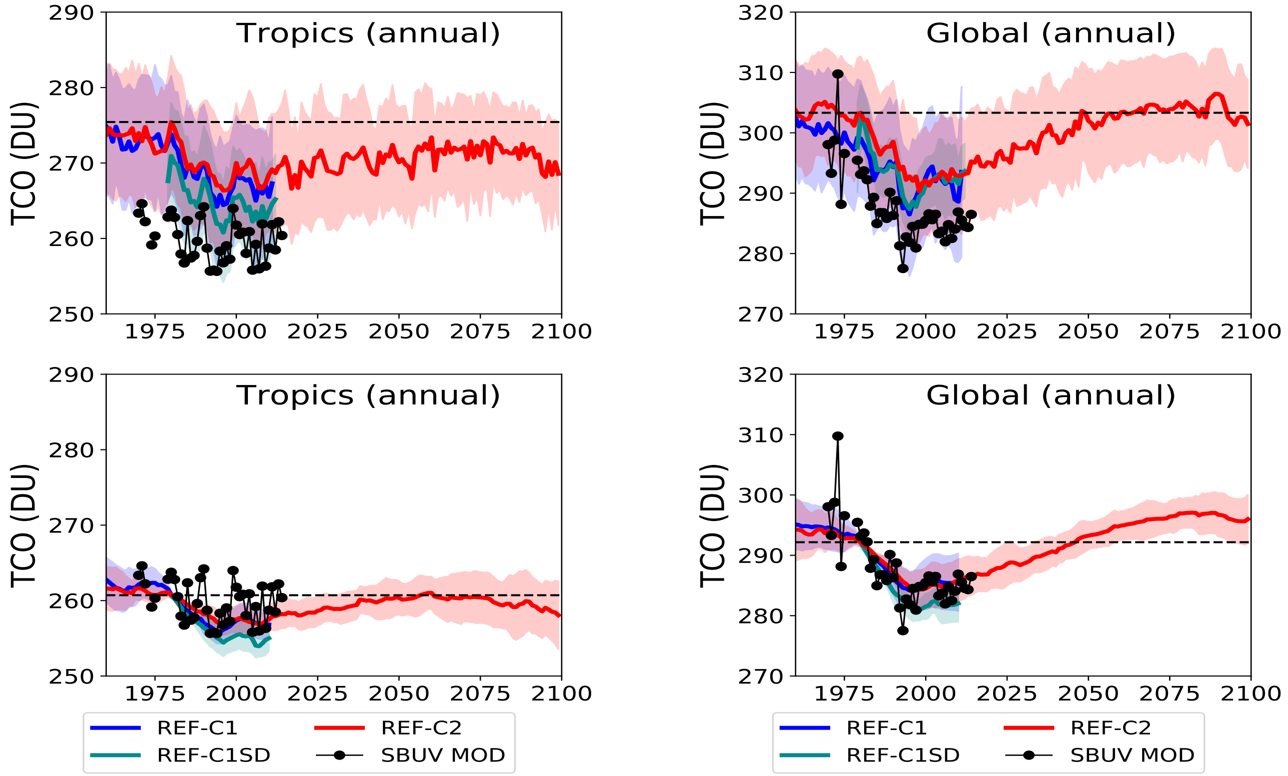

Figure S7. As Figure S6 but for the tropics (20S-20N) and near global average (60S-60N).

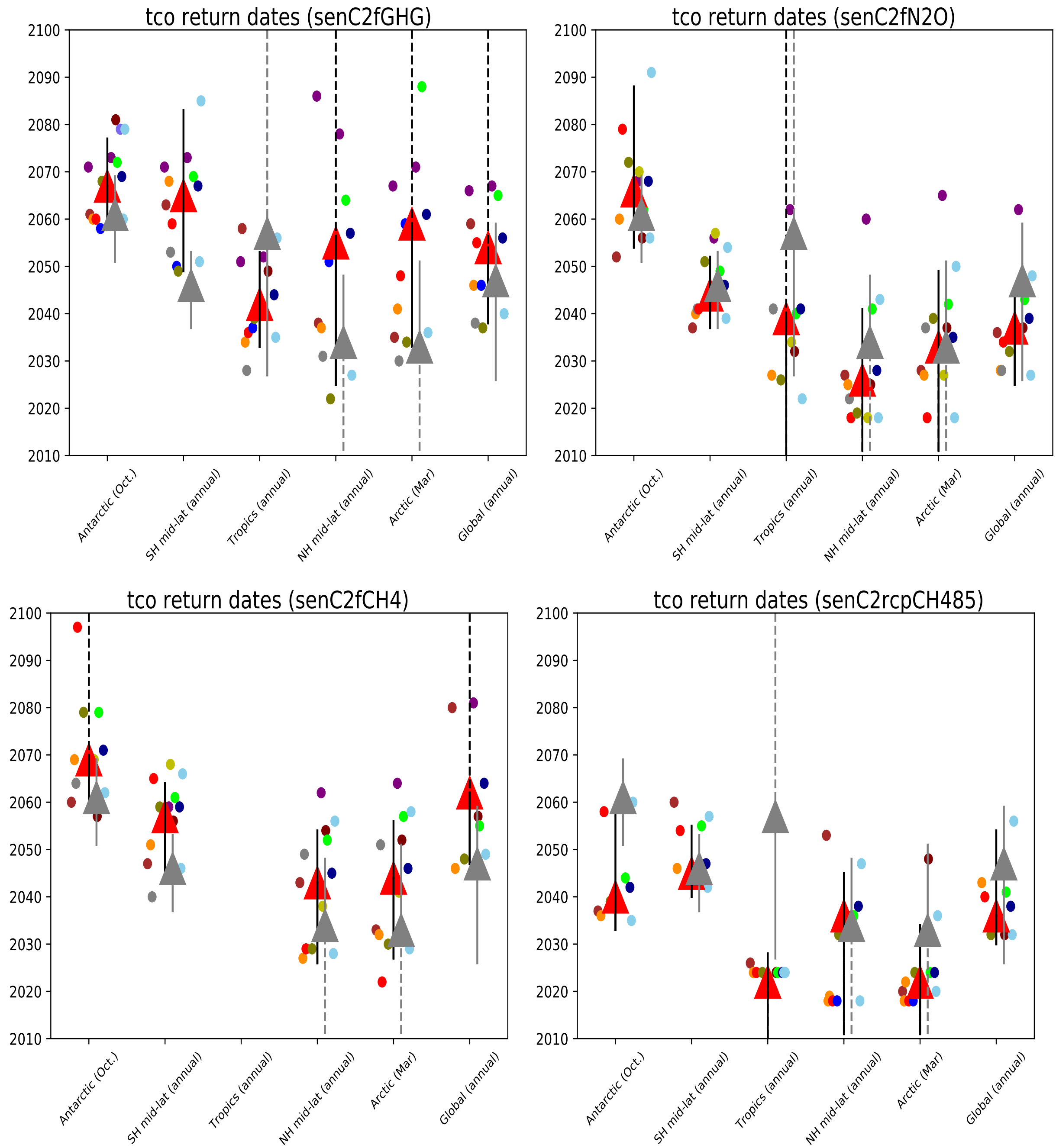

Figure S8. Estimated MMM1S return dates (red triangles) of total column ozone from the SEN-C2-fGHG, SEN-C2-fN2O, SEN-C2-fCH4 and SEN-C2-CH4RCP85 simulations for different latitude bands. The estimated 1-σ uncertainties are shown with vertical black lines. Estimates for individual models are shown with coloured dots. Some individual models do not predict a return of column ozone in the tropics. Return dates from REF-C2 (see Figure 4 in main paper) are shown with grey triangles.

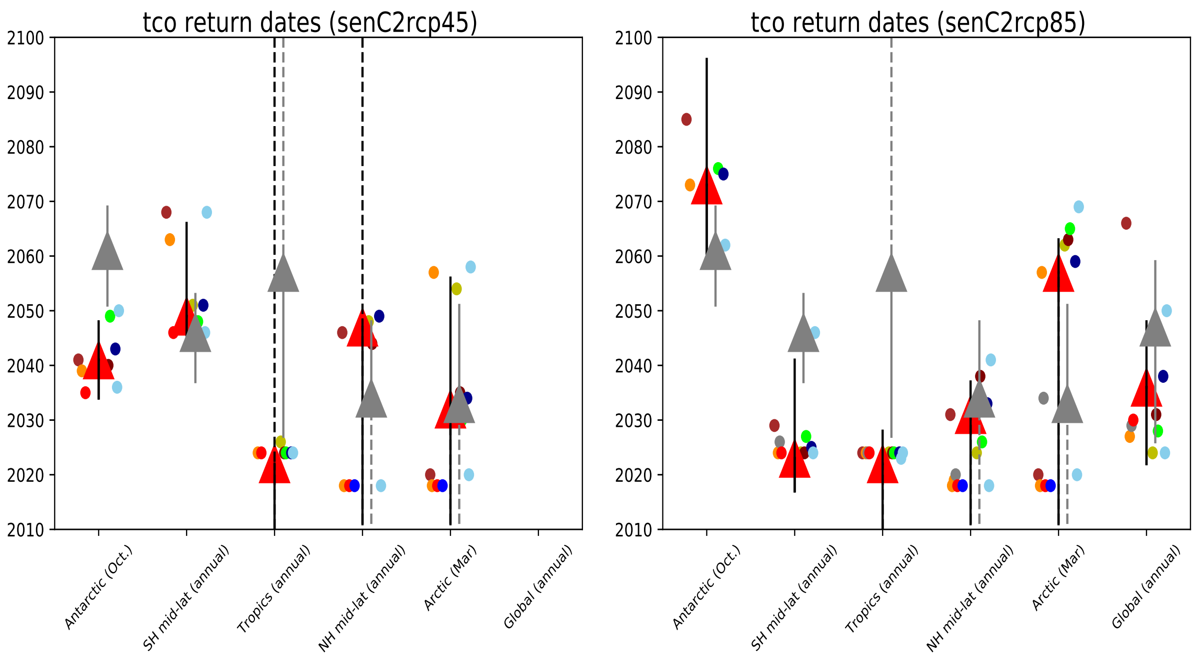

Figure S9. As Figure S8 but for the SEN-C2-RCP45 and SEN-C2-RCP85 simulations.

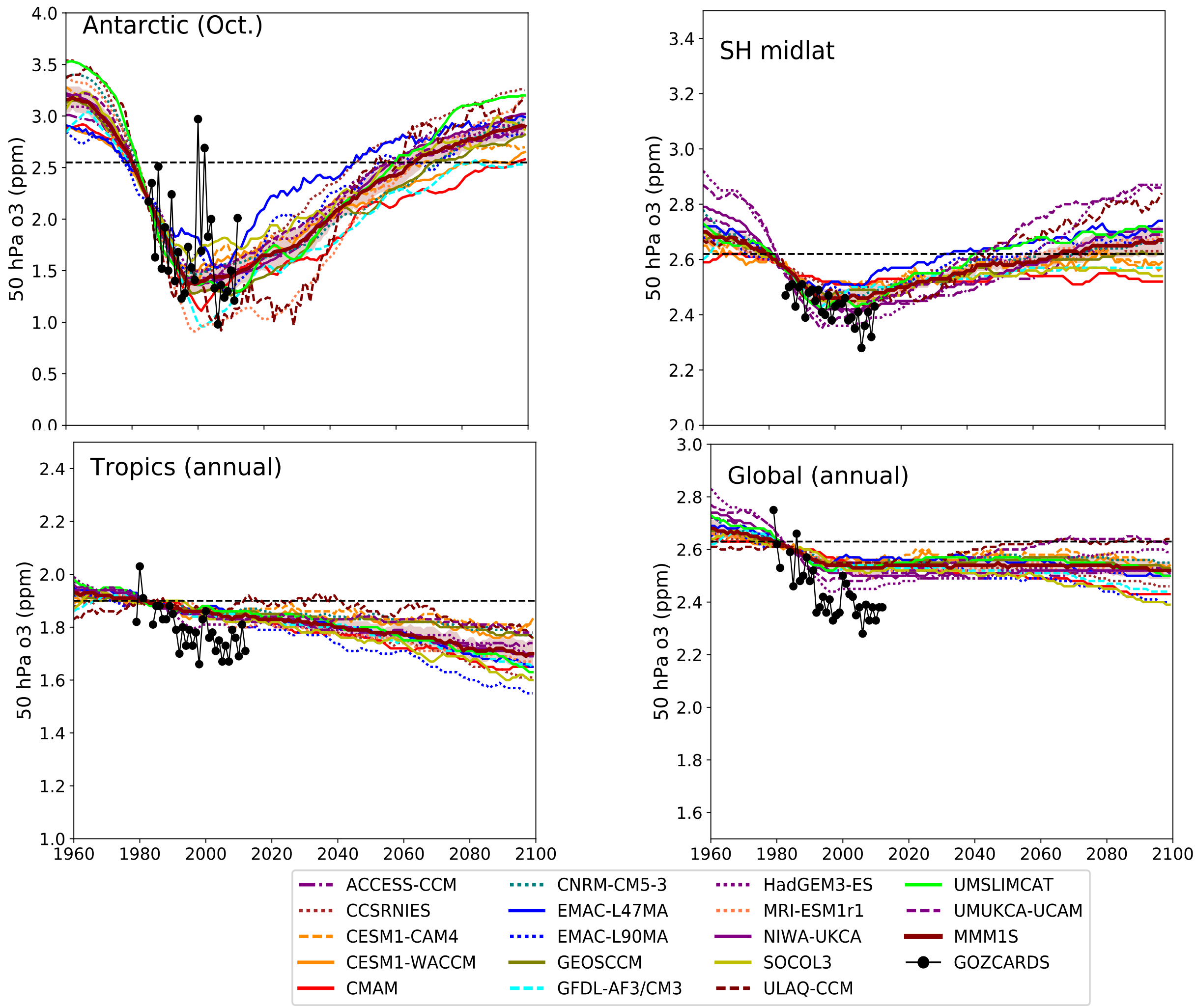

Figure S10. Time series of adjusted ozone at 50 hPa from the REF-C2 simulations for Antarctic, SH midlatitudes, tropics and global mean. The dark red line shows the MMM1S and the shaded region indicates corresponding 1-σ standard deviation. The reference value for year 1980 is shown with dashed black line. Also shown are observations from the GOZCARDS merged dataset.

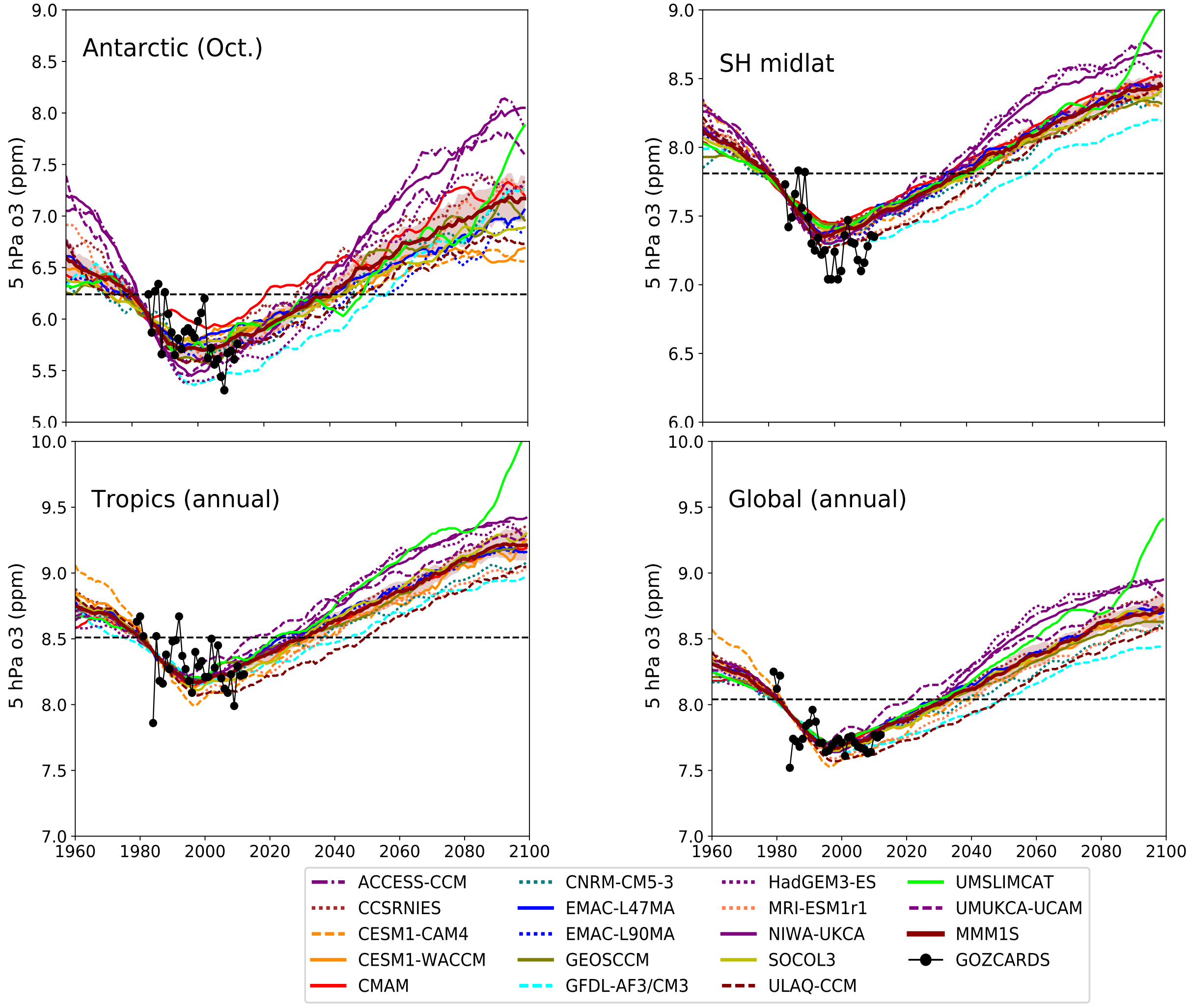

Figure S11. As Figure S10 but for 5 hPa.

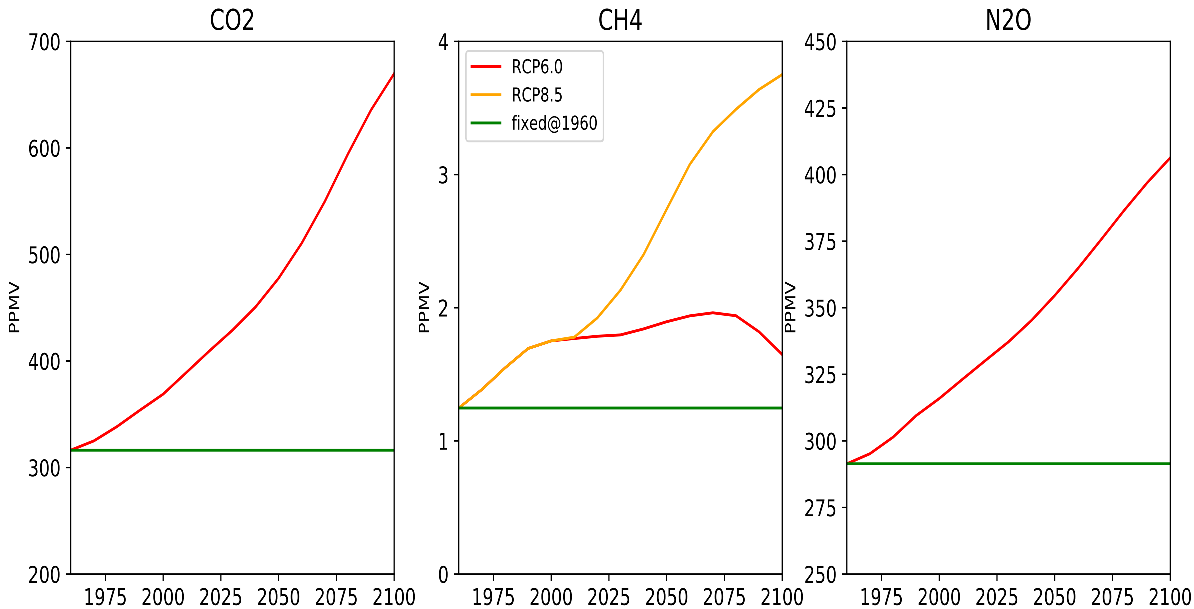

Figure S12. Volume mixing ratios (vmrs) of CO_2, CH_4 and N_2O used in the REF-C2 (RCP6.0) scenario (red lines). The values for reference year 1960 are shown with green lines and the CH_4 vmr used in the SEN-C2-CH4RCP85 simulation is shown with an orange line.

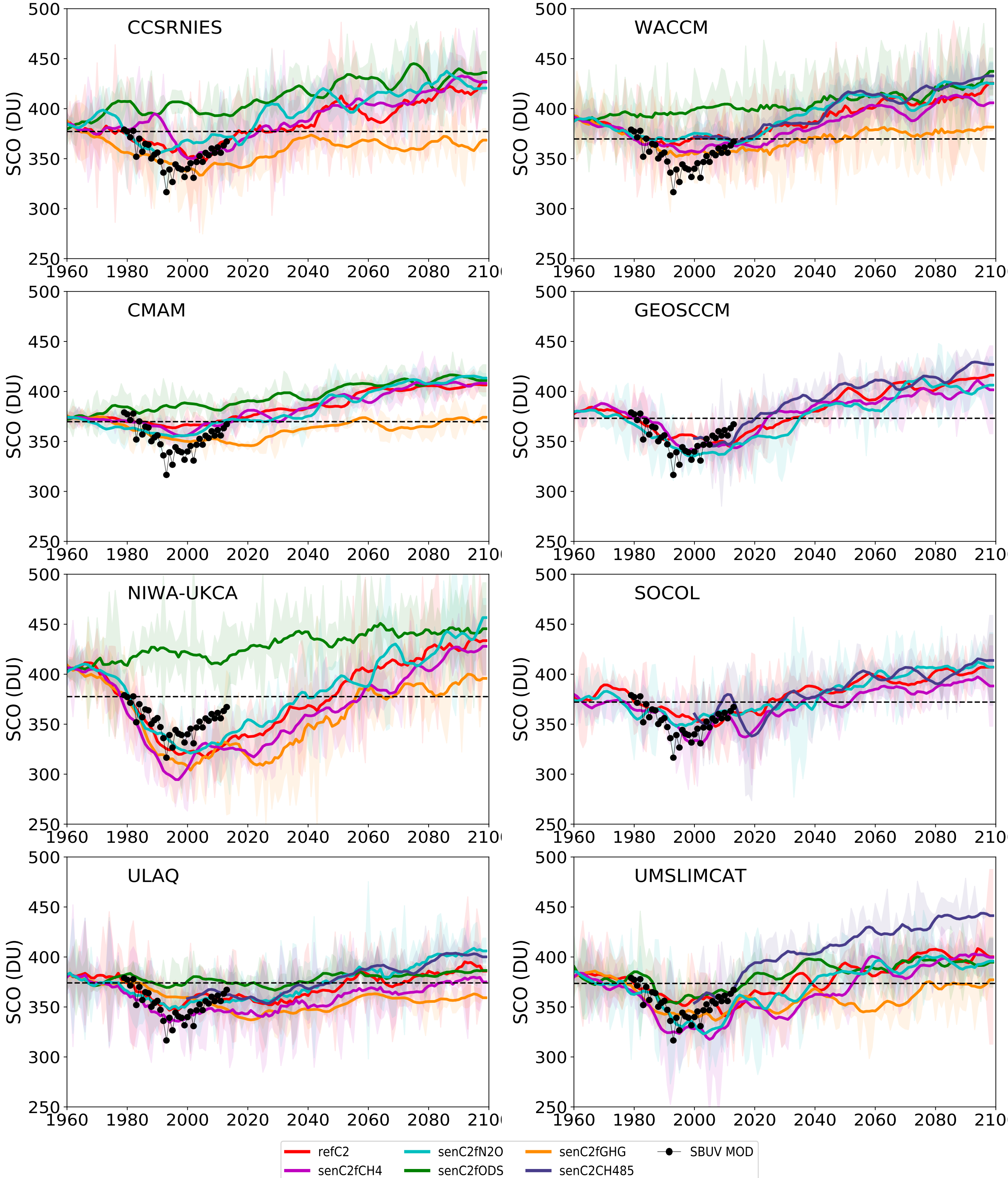

Figure S13. Evolution of Arctic (March) stratospheric ozone columns (DU) from selected models for REF-C2, SEN-C2-fCH4, SEN-C2-fN2O and SEN-C2-CH4RCP85 simulations. Also shown are observations from the merged SBUV dataset.

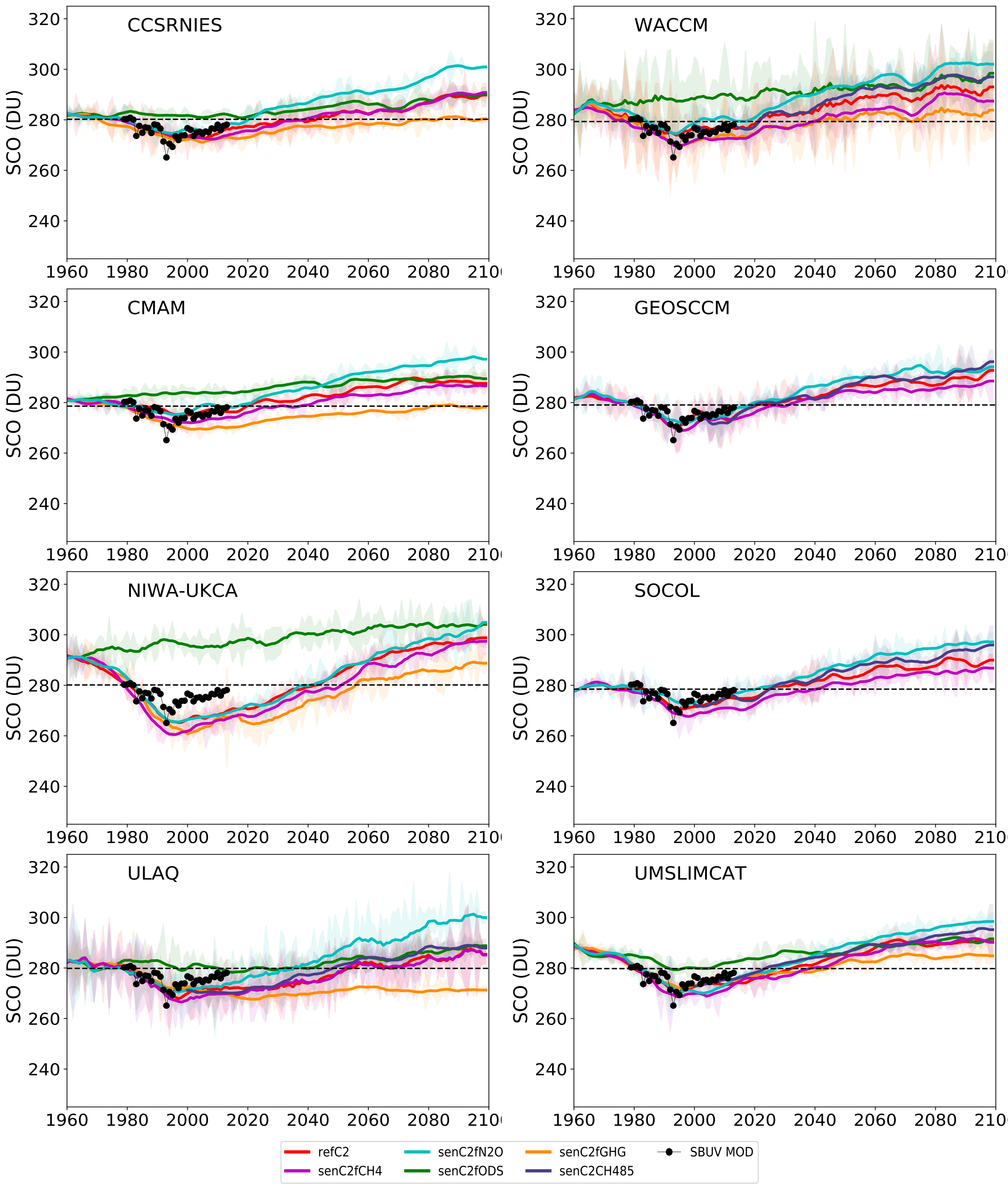

Figure S14. As Figure S13 but for NH mid-latitudes.

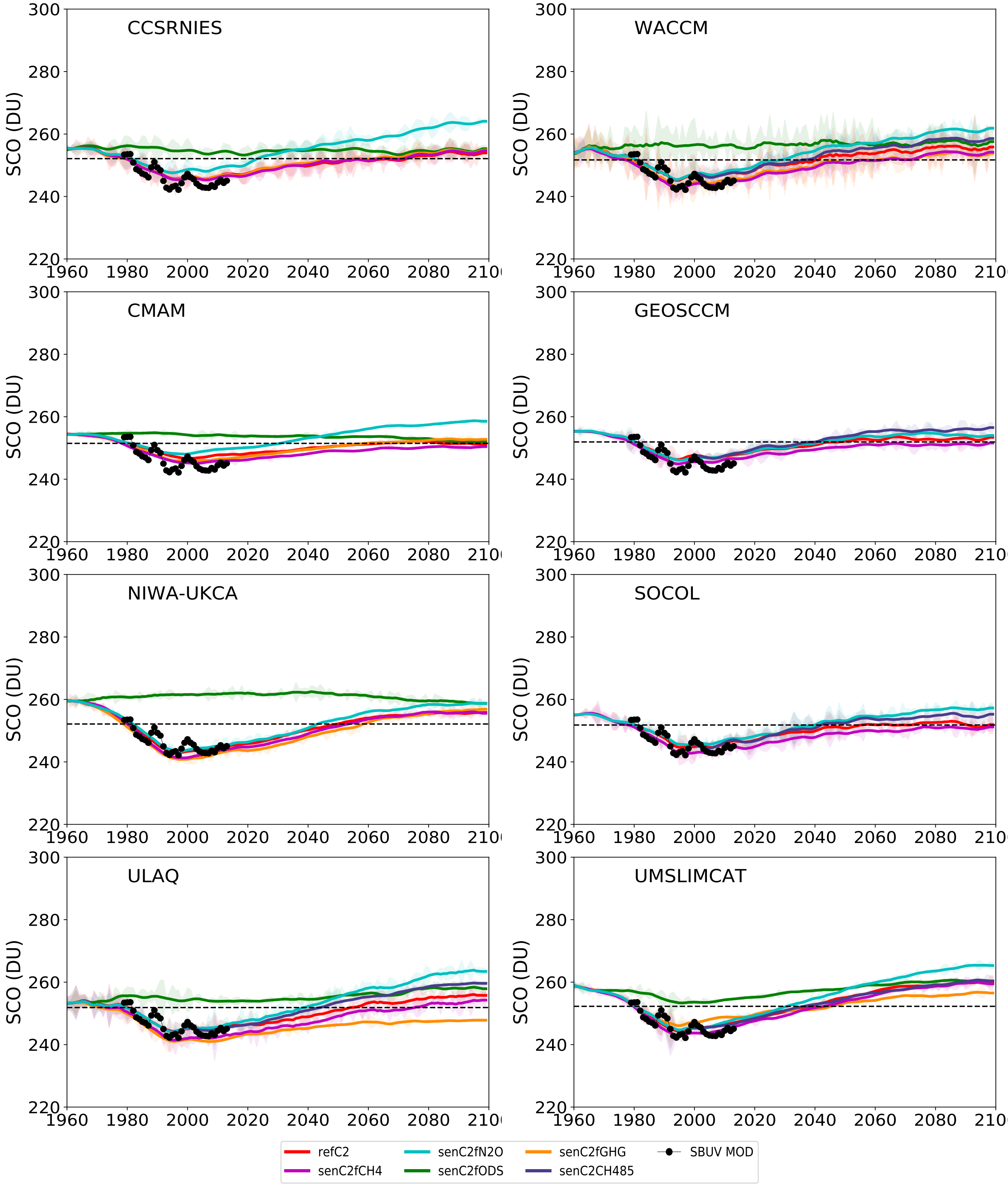

Figure S15. As Figure S13 but for near-global average (60S-60N).

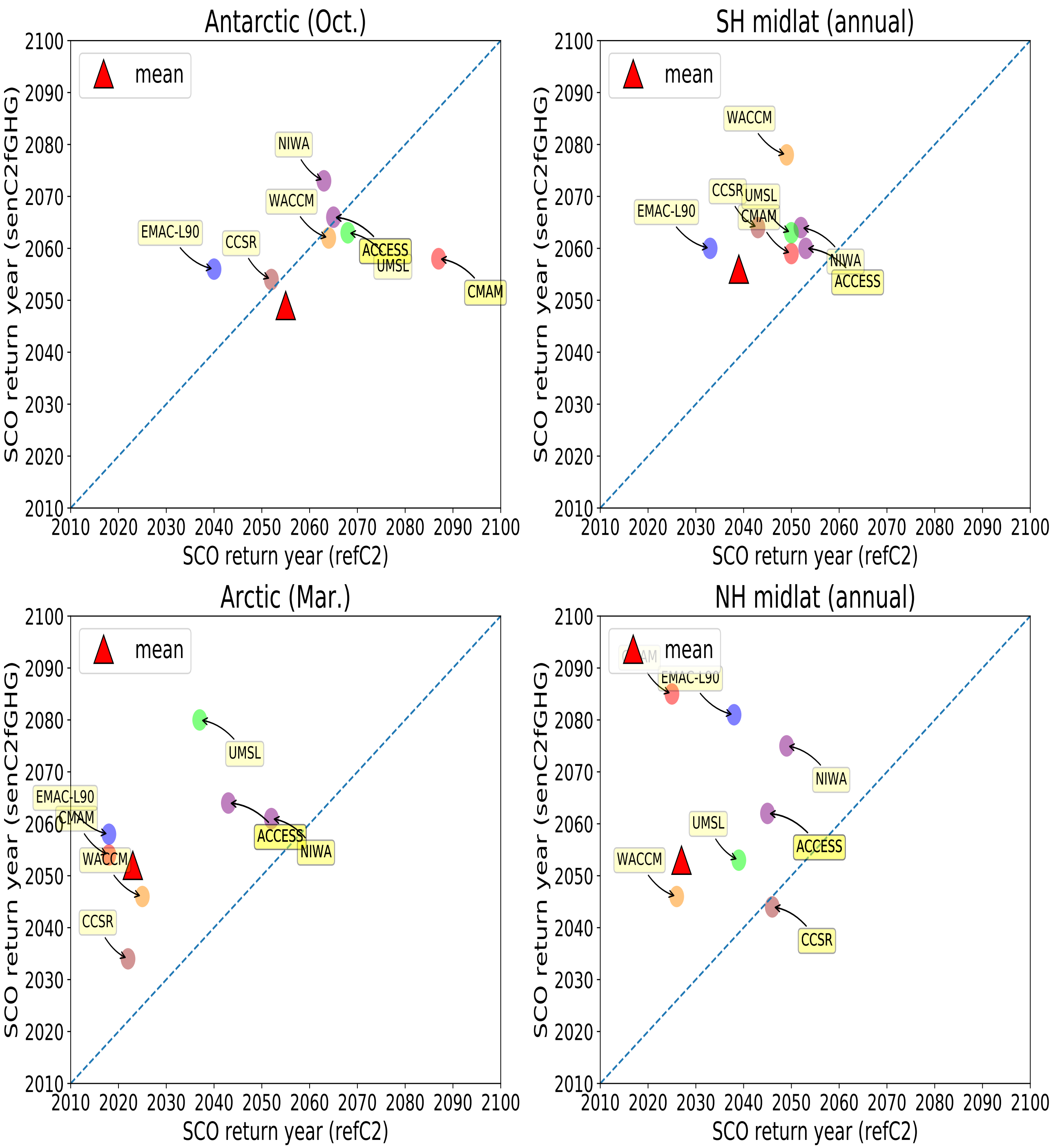

Figure S16. Correlation plots of stratospheric column ozone (SCO) return dates from the SEN-C2fGHG simulations against SCO return dates from REF-C2 simulations for individual models within four latitude bands.

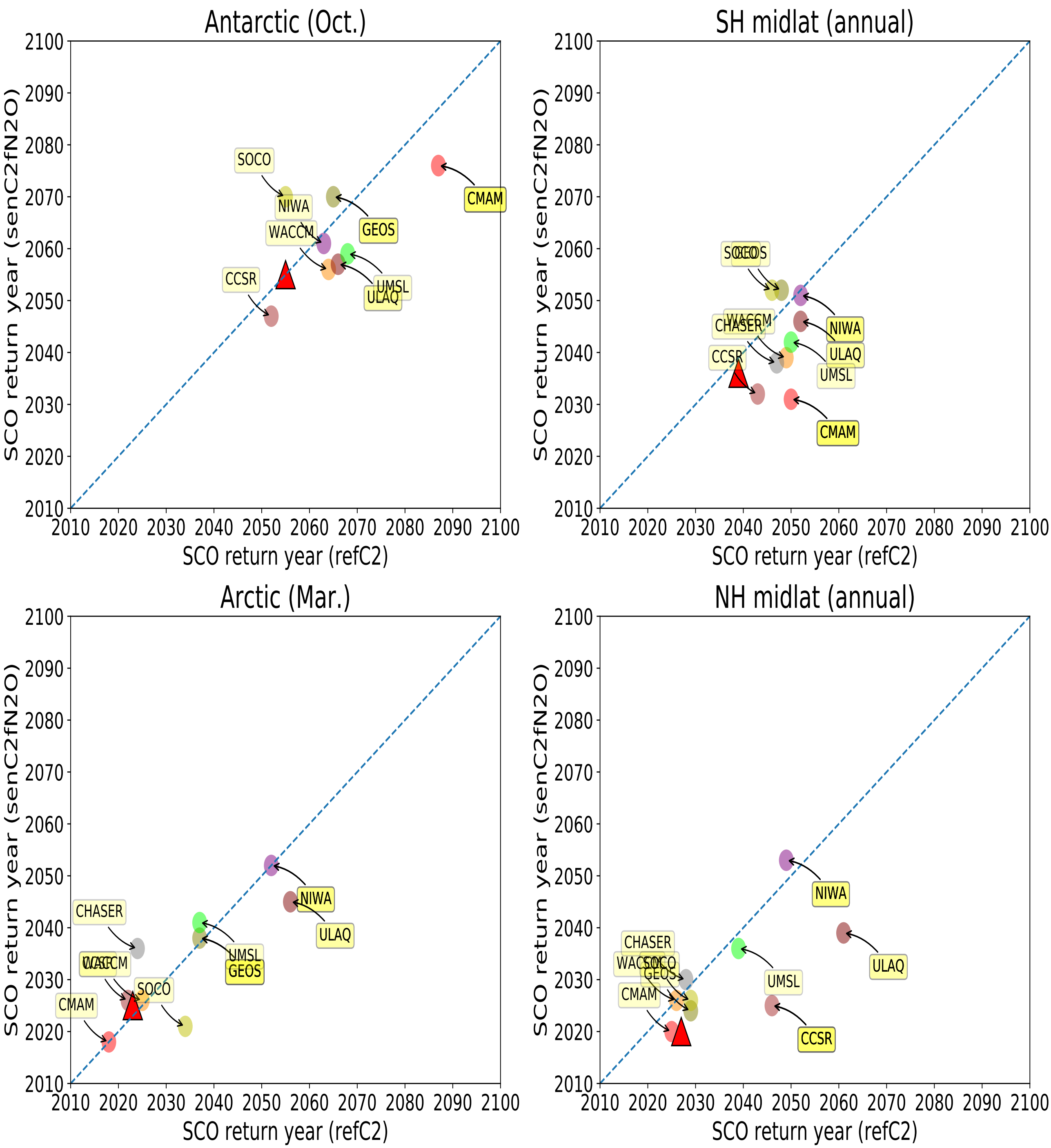

Figure S17. As Figure S16 but for simulation SEN-C2-fN2O.

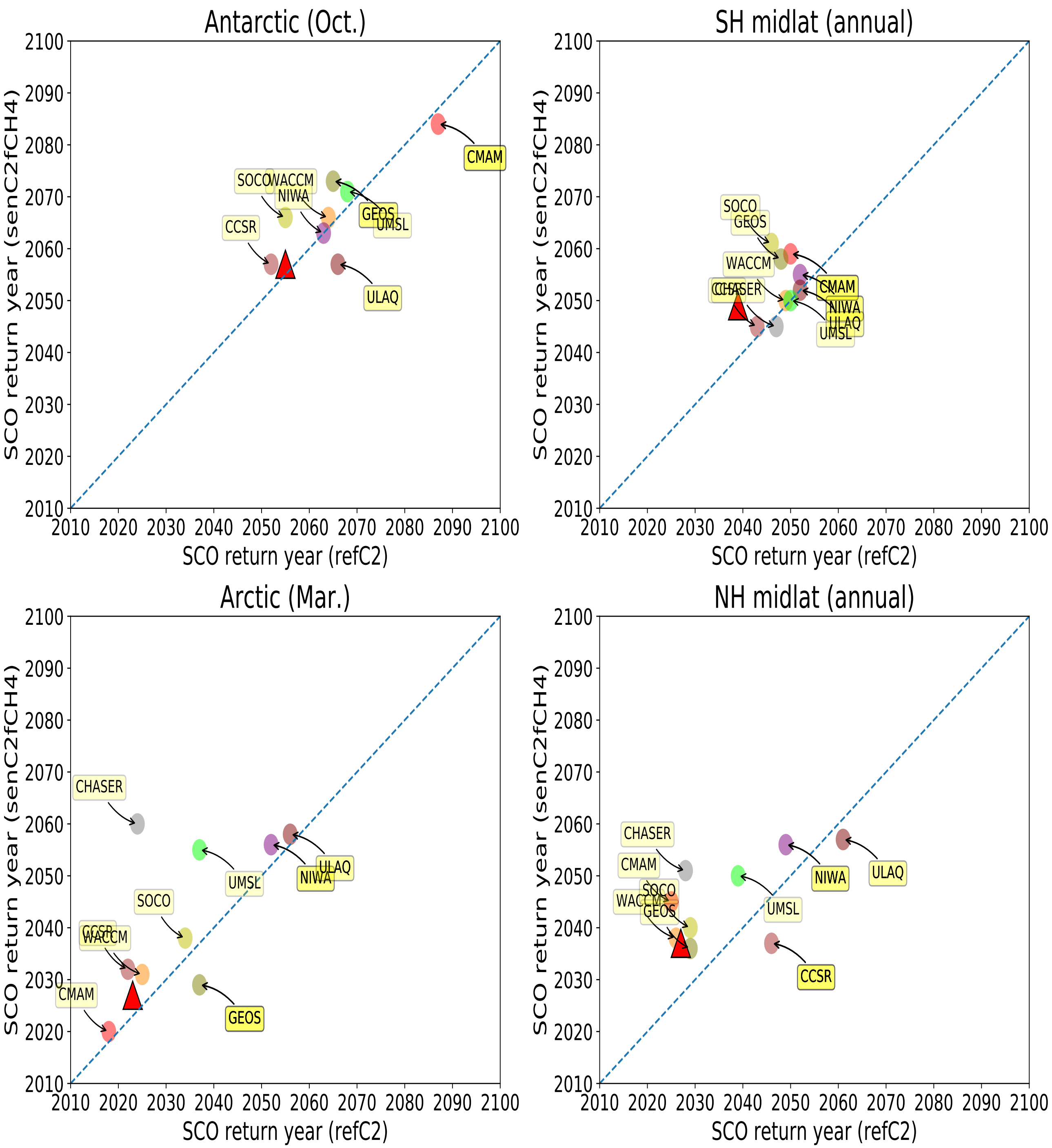

Figure S18. As Figure S16 but for simulation SEN-C2-fCH4.

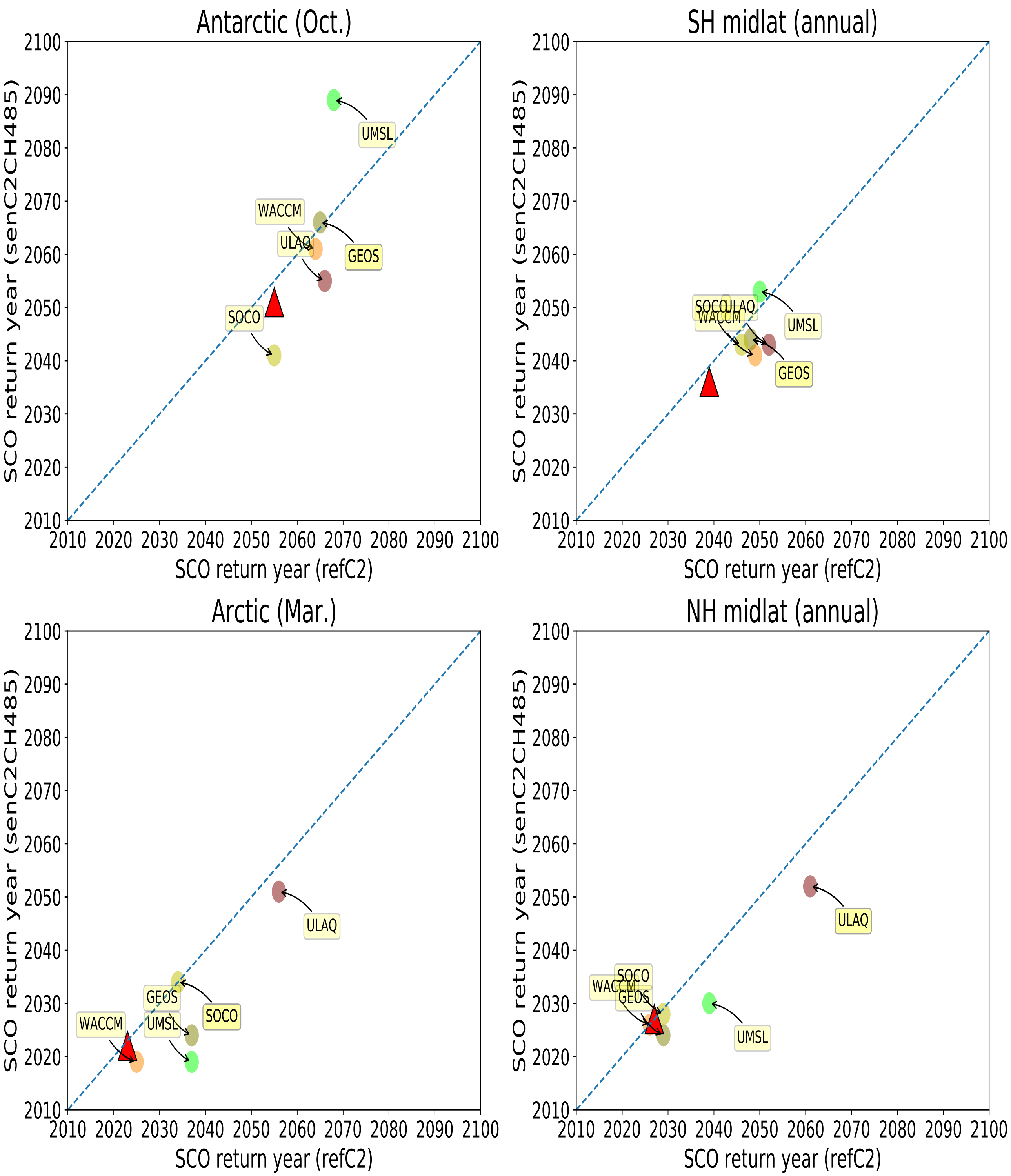

Figure S19. Same as S16 but for simulation SEN-C2-CH4RCP85.