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Review of the global models used within phase 1 of the Chemistry–Climate Model Initiative (CCMI)

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Abbreviations used below are as in the CCMVal-2 report, chapter 2 (SPARC CCMVal (2010), SPARC Report on the evaluation of chemistry-climate models, SPARC report no. 5, WCRP-132)

Table S1: Main structure of CCMs (description of submodules used in model setup if applicable). The ocean and sea ice set-up refers to the REF-C2 and SEN-C2 simulations.

Model name	Atmosphere	Ocean	Land	Sea ice	Comments
ACCESS CCM	HadGEM3 Global Atmosphere 2.0	prescribed HadGEM2-ES (r1p1i1 CMIP5)	MOSES2	prescribed HadGEM2-ES (r1p1i1 CMIP5)	Stone et al. (2015)
CCSRNIES MIROC3.2	MIROC3.2	prescribed	MIROC3.2	prescribed	SST and SIC from MIROC for IPCC-AR5
CESM1 CAM4-chem CESM1 WACCM	CAM4	POP2	CLM4	CICE4	Neale et al. (2013)
CHASER (MIROC-ESM)	MIROC 4.8 (CCSR/NIES AGCM)	COCO4	MATSIRO	calculated in MIROC	Watanabe et al (2011)
CMAM	CCCma AGCM3	prescribed from CanCM4 CMIP 5 simulations	CLASS 2.7	prescribed from CanCM4 CMIP5 simulations	
CNRM-CM5-3	ARPEGE-Climat v6.04	HadISST1 (prescribed)		HadISST1 (prescribed)	
EMAC	ECHAM5.3.02	prescribed HadGEM2-ES (Collins et al., 2011)	ECHAM5	prescribed HadGEM2-ES (Collins et al., 2011)	one REF-C2 simulation with interactive ocean model (MPIOM 1.3.0)
GEOSCCM	GEOS-5	prescribed CESM1	CLSM	prescribed CESM1	
GFDL-AM3	AM3	prescribed HadlSST2	LM3	prescribed HadlSST2	Donner et al. (2011) Lin et al. (2012a, 2012b, 2014, 2015a, 2015b)
GFDL-CM3	AM3	interactive (Griffies et al. (2011)	LM3	Interactive (Griffies et al., 2011)	Donner et al. (2011), Griffies et al. (2011)
HadGEM3-ES	Global Atmosphere 4.0 configuration of HadGEM3	NEMO vn3.4	Global Land 4.0 configuration of JULES	CICE vn4.1	Walters et al. (2014), Madec et al. (2008), Hunke et al. (2008), Morgenstern et al. (2009), O'Connor et al. (2014), Best et al. (2011)
LMDz-REPROBUS	L39 : LMDZ5 L79 : LMDZ6	L39 : N/A L79 : NEMO	L39 : N/A L79 : ORCHIDEE	L39 : N/A L79 : LIM	Dufresnes et al. (2013)
MRI-ESM1r1	MRI-AGCM3	MRI.COM3	HAL	MRI.COM3	Yukimoto et al. (2011)
NIWA-UKCA	HadGEM3 GA2	NEMO	MOSES2	CICE 4.0	Hewitt et al. (2011); Morgenstern et al. (2014)
SOCOL	ECHAM5.4.00	prescribed	ECHAM5	prescribed	Roeckner et al. (2003, 2006)
ULAQ CCM	ULAQ CCM	prescribed HadlSST1	N/A	prescribed HadlSST1	SST&SIC from: HadlSST1 (1960-2010) CCSM4.CAM(2011-2100)
UMSLIMCAT	UM4.5	prescribed	NA	presecribed	SST&SIC from: HadGEM2-ES
UMUKCA-UCAM	MetUM vn7.3 HadGEM3-A r2.0	Prescribed	MOSES2	Prescribed	SST & SIC from HadGEM2-ES RCP6.0 r2i1p1 ensemble member

Table S2: Vertical resolution (numbers of levels) in different pressure ranges

Model name	>850 hPa	850 – 300 hPa	300 – 100 hPa	100 – 1 hPa	Above 1 hPa	Comments
ACCESS CCM NIWA-UKCA UMUKCA-UCAM	8	13	7	22	10	US standard atmosphere
CCSRNIES MIROC3.2	4	5	6	13	6	
CESM1 CAM4-chem	4	7	7	8	0	
CESM1 WACCM	4	7	7	21	27	
CHASER (MIROC-ESM)	5	9	11	24	1	
CMAM	10	12	7	20	22	
CNRM-CM5-3	12	15	8	21	4	In the case of 60 level simulations
EMAC	5 (6)	11 (13)	11 (7)	48 (15)	15 (6)	L90MA (L47MA); (ha+hb*101325)/100
GEOSCCM	10	18	7	23	14	
GFDL-CM3/AM3	9	10	5	16	9	Donner et al. (2011).
HadGEM3-ES	12	23	13	28	9	Geometric height grid.
LMDz-REPROBUS	L39 : 7 L79 : 21	L39 : 7 L79 :14	L39 :14 L79 :23	L39 :6 L79 :12	L36 : 5 L79 :9	
MRI-ESM1r1	12	15	14	30	9	
MOCAGE	8	13	9	17	0	
SOCOL	5	6	5	15	8	
ULAQ CCM	3	12	14	57	40	568m resolution (pressure altitude)
UMSLIMCAT	4	13	9	24	14	

Table S3: Transport and chemistry schemes. SL = semi-Lagrangian. FFSL = flux-form semi-Lagrangian. FFEE = flux-form Euler Equations, PRM = Piecewise Rational Method. FV = finite-volume.

Model name	Transport model for meteorologically active constituents	Transport model for chemically active constituents	Chemistry scheme
ACCESS CCM NIWA-UKCA	SL	SL	Morgenstern et al. (2013); Isoprene: Pöschl et al. (2000)
CCSRNIES MIROC3.2	FFSL	FFSL	Akiyoshi (1997) Akiyoshi (2000) Akiyoshi et al. (2009)
CESM1 CAM4-chem	FV	FV (Lin and Rood, 1996; Lin, 2005)	Kinnison et al. (2007), Solomon et al. (2015), Tilmes et al. (2016)
CESM1 WACCM	FV	FV (Lin and Rood, 1996; Lin, 2005)	Kinnison et al. (2007), Solomon et al. (2015)
CHASER (MIROC-ESM)	MIROC (2nd order van Leer)	MIROC (2nd order van Leer)	Sudo et al. (2002,2007); Isoprene: Pöschl et al. (2000)
CMAM	spectral advection of ‘hybrid’ moisture (Merryfield et al., 2003)	spectral advection with ‘hybrid’ transformation used for certain species with strong horizontal gradients	Mechanism largely as in Jonsson et al. (2004), but solved throughout model domain
CNRM-CM5-3	Semi-lagrangian with cubic interpolation Déqué (2007)	Semi-lagrangian with cubic interpolation Déqué (2007)	REPROBUS (Lefèvre, 1994)
EMAC	FFSL (Lin and Rood, 1996)	FFSL (Lin and Rood, 1996)	MECCA (Sander et al. 2011a)
GEOSCCM	GEOS-5	GEOS-5	GMI (Strahan et al., 2007; Duncan et al., 2007)
GFDL-CM3/AM3	Putman and Lin (2007)	Putman and Lin (2007)	Naik et al. (2013); Austin et al. (2013). Isoprene: Horowitz et al. (2007)
HadGEM3-ES	GA4.0 HadGEM3	GA4.0 HadGEM3	Combined stratosphere chemistry from Morgenstern et al. (2009) and the TropIsop chemistry from O’Connor et al. (2014) called StratTrop (UKCA)
LMDz-REPROBUS	LMDz	LMDz	Hourdin et al. (2006)
MRI-ESM1r1	Hybrid SL quintic and PRM (Yukimoto et al., 2011)	Hybrid SL quintic and PRM (Yukimoto et al., 2011)	Deushi and Shibata (2011)
MOCAGE	None (CTM)	SL (Williamson and Rasch, 1989)	Stockwell et al (1997) Lefevre et al (1994)
SOCOL	FFSL (Lin and Rood (1996))	FFSL (Lin and Rood (1996))	Stenke et al. (2013) Isoprene: Pöschl et al. (2000)
ULAQ CCM	FFEE	FFEE	Sovde et al. (2014)
UMUKCA-UCAM	SL	SL	Morgenstern et al. (2009), Bednarz. et al (2016)

Table S4: Transport scheme, by tracer. FV = finite volume. FFSL = flux-form semi-Lagrangian. SL = semi-Lagrangian. FFEE = flux-form Eulerian explicit. (table 2.4 of SPARC CCMVal, 2010)

Model name	Physical tracers	Water vapour	Other chemical tracers	References
ACCESS CCM HadGEM3-ES NIWA-UKCA UMUKCA-UCAM	SL, quasi-cubic	SL. Hor.: Quasi-cubic. Vert.: quintic	As water vapour	Priestley (1993)
CCSRNIES MIROC3.2 CHASER (MIROC-ESM)	FFSL	FFSL	FFSL	Hasumi and Emori (2004)
EMAC GEOSCCM SOCOL	FFSL	FFSL	FFSL	Lin and Rood (1996)
GFDL-CM3/AM3	FFSL	FFSL	FFSL	Lin and Rood (1996, 1997)
LMDz-REPROBUS	FV	FV	FV	Hourdin and Armengaud (1999), Hourdin et al. (2006)
MRI-ESM1r1	Hybrid SL quintic and PRM	Hybrid SL quintic and PRM	Hybrid SL quintic and PRM	Yukimoto et al. (2011)
MOCAGE	SL,tricubic	SL,tricubic	SL,tricubic	Williamson and Rasch (1998)
ULAQ CCM	FFEE	FFEE	FFEE	

Table S5: Additional horizontal grids in CCMs. Models not listed do not have any additional grid. Cf table 2.3 of SPARC CCMVal (2010).

Model name	Grid	Comments
CCSRNIES MIROC3.2	Quadratic Gaussian (T42, 2.8°)	Physics and chemistry
EMAC	Quadratic Gaussian (T42, 2.8°)	Physics and chemistry
GEOSCCM	Catchment	*Koster et al. (2000)*
MRI-ESM1r1	Gaussian (TL159 (1.125°), TL95 (1.875°), and T42 (2.8°))	Physics (TL159), aerosol (TL95), chemistry (T42)
SOCOL	T42 (2.8°) Gaussian	Physics, chemistry, radiation

Table S6: Time stepping and calendar used. 360d = 360-day calendar. 365d = 365-day calendar.

Model name	Time step of dynamical core [s]	Time step(s) of physical processes [s]	Time step(s) of radiation [s]	Time step(s) of transport scheme(s) [s]	Time step of chemistry scheme [s]	Time step for coupling of chemistry and dynamics [s]	Calendar
ACCESS CCM NIWA-UKCA UMUKCA-UCAM	1200	1200	10800	1200	3600	1200	360d
CCSRNIES MIROC3.2	< 2400, (variable)	10800	10800	< 2400, (variable)	360	N/A	Gregorian
CESM1 CAM4-chem CESM1 WACCM	1800	1800	1800	225	1800		365d. SD: Gregorian
CMAM	450	450	450 solar 21600 terrestrial	450	450	450	365d
CHASER (MIROC-ESM)	1200	1200	10800	1200	600	1200	Gregorian
CNRM-CM5-3	1200 (900 for SD simulations)	1200 (900 for SD simulations)	10800s	1200 (900 for SD simulations)		N/A	Gregorian
EMAC	720 (L90MA); 600 (L47MA)	720 (L90MA); 600 (L47MA)	2160 (L90MA); 1800 (L47MA)	720 (L90MA); 600 (L47MA)	720 (L90MA); 600 (L47MA) with automatic sub-stepping	720 (L90MA); 600 (L47MA)	Gregorian
GEOSCCM	300	1800	1800	300	1800	1800	Gregorian
GFDL-CM3/AM3	225	1800	10800	225	1800	1800	Gregorian
HadGEM3-ES	1200	1200	10800	1200	3600	1200	360d. SD: Gregorian
LMDz-REPROBUS	180	900	10800	900	900	900	365d
MRI-ESM1r1	1800	1800	3600 (SW) 10800(LW)	1800	900	1800	Gregorian
MOCAGE	NA	900	NA	3600	900	NA	Gregorian
SOCOL	900	900	7200	900	7200	7200	Gregorian
TOMCAT	NA	1800	NA	1800	1800	NA	Gregorian
ULAQ CCM	1800	1800	1800	1800	1800	1800	360d
UMSLIMCAT	1800	1800	1800	1800	1800	1800	360d

Table S7: Horizontal diffusion (cf. table 2.7 of SPARC CCMVal, 2010)

Model name	Order of diffusion scheme	Linear	Damping time scale of smallest scales (h)	Treatment at model top	Reference	Comment
ACCESS CCM NIWA-UKCA UMUKCA-UCAM	N/A	N/A	N/A	Sponge	McCalpin (1988)	No explicit diffusion in lower 54 levels (except over the poles)
CCSRNIES MIROC3.2	4	Yes	18	Sponge	Numaguti et al. (1997)	
CHASER (MIROC-ESM	4	N/A	16	Sponge	Numaguti et al. (1997)	
CESM1 CAM4-chem CESM1 WACCM	4			Sponge	Lauritzen et al. Neale et al. (2010) Neale et al. (2013)	
CMAM			13.9		Koshyk and Boer (1995)	Modified Leith diffusion
CNRM-CM5-3	6	Yes			Yessad (2001)	
EMAC	10	No	9	Sponge	Roeckner et al. (2003)	
GEOSCCM	N/A	N/A	N/A	Sponge		No explicit diffusion
GFDL-CM3/AM3						Donner et al. (2011)
HadGEM3-ES	N/A	N/A	N/A	No sponge	McCalpin (1988)	No explicit diffusion except: 1. There is targeted local 1st order diffusion of water vapour where vertical velocity above a certain threshold. 2. A 1-2-1 filter in E-W direction is applied to potential temperature and horizontal winds at high latitudes. As the poles are approached the filter is applied multiple times to try and retain the same physical scale length in the fields, removing the variations at very small scales as the meridians converge.
LMDz-REPROBUS	NA	NA	NA	Sponge	Lott et al. (2005) ; Dufresnes et al. (2013)	
MRI-ESM1r1	4	Yes	3.2 (p>150 hPa) 60 (p<100 hPa)	No sponge		
MOCAGE	N/A	N/A	N/A			no explicit diffusion
SOCOL	10	No	9	sponge	Roeckner et al. (2003)	
ULAQ CCM	2	Yes	10	sponge		

Table S8: Usage of QBO nudging in CCMI simulations: model name; experiments run with QBO nudging (other than the specified-dynamics simulations). Models not listed here do not use QBO nudging. CF table 2.8 of SPARC CCMVal (2010).

Model name	Experiments including QBO nudging	Nudged variable	Timescale [day]	Latitude range [°]	Height range [hPa] or [km]	Comments
CCSRNIES MIROC3.2	All	<u>	5	Gaussian function from the equator with a half-width of 10 degrees	Gaussian function from 30km with a half-width of 8km	Akiyoshi et al. (2009)
CESM1 CAM4-chem CESM1 WACCM	All	U	10	Gaussian function from the equator with a half-width of 10 degrees	90 - 3 hPa	Giorgetta (1996)
CHASER (MIROC-ESM)	REF-C1SD	U	1.0	<10°	20-50 km	
EMAC	All	U	58 (L90MA) 10 (L47MA)	12.6°S - 12.6°N with full nudging at latitudes from 7 S–7 N	10–90 hPa, with full nudging weights (i.e., 1.0) from 20–50 hPa, levelling off to 0.3 (0.2) at the upper (lower) edge of the nudging region	Giorgetta and Bengtsson (1999)
SOCOL	All	U	7	10°S - 10°N (full) 20°S - 10°S, 10°N - 20°N (tapered)	90 - 3 hPa	Giorgetta (1996)
ULAQ CCM	All	U	10	10°S - 10°N	90 - 3 hPa	Giorgetta (1996)

Table S9: Orographic and non-orographic gravity wave drag (table 2.9 of SPARC CCMVal, 2010)

Model name	Reference for orographic GWD	Sources for nonorographic GWG	Launch level for prescribed gravity waves	Latitude range for parameterized gravity waves	Reference for nonorographic GWD
ACCESS CCM NIWA-UKCA UMUKCA-UCAM	Webster et al. (2003)	Prescribed	Parameterized	90S-90N	Scaife et al. (2002)
CCSRNIES MIROC3.2	McFarlane(1987)	Parameterized	Parameterized	90S-90N	Hines (1997)
CESM1 CAM4-chem	McFarlane (1987); Tilmes et al. (2016).	Parameterized	Parameterized	90S-90N	Beres et al. (2005); Richter et al. (2010).
CESM1 WACCM	McFarlane (1987); Garcia et al. (2016).	Parameterized	Parameterized	90S-90N	Beres et al. (2005); Richter et al. (2010).
CHASER (MIROC-ESM)	McFarlane (1987)	Parameterised			Hines (1997a,b)
CMAM	Scinocca and McFarlane (2000)	Specified generalised Desaubies	100 hPa for non-orographic	90S-90N	Scinocca (2003)
CNRM-CM 5-3	Lott (1997)	stochastic parameterization of non-orographic gravity waves triggered by convection (Lott et al., 2013)	N/A	90S-90N	Lott et al. (2013)
EMAC	Lott and Miller (1997), Lott (1999)	Parameterized	640 hPa	90S-90N	Hines (1997a,b)
GEOSCCM	McFarlane (1987)	Parameterized	100 hPa	90S-90N	Garcia and Boville (1994)
GFDL-CM3/AM3	Anderson et al. (2004), Donner et al. (2011).				Alexander and Dunkerton (1999)
HadGEM3-ES	Walters et al. (2014)	Prescribed	Prescribed	90S-90N	Walters et al. (2014)
LMDz-REPROBUS	Lott et al. (2005)	Parameterized	Parameterized	90S-90N	Lott et al. (2015)
MRI-ESM1r1	Iwasaki et al. (1989)	Parameterised	Lowest level	90S-90N, Uniform + tropical enhancement	Hines (1997b)
SOCOL	Lott and Miller (1997), Lott (1999)	Parameterized	~700 hPa	90S-90N	Hines (1997a,b)
ULAQ CCM	no OGWD	parameterized (Raleigh friction)			

Table S10: References for physical parameterizations

Model name	Turbulent vertical fluxes, dry convection	Moist convection	Cloud microphysics
ACCESS CCM NIWA-UKCA UMUKCA-UCAM	Hewitt et al. (2011)	Hewitt et al. (2011)	Hewitt et al. (2011)
CCSRNIES MIROC3.2	Noh and Kim (1999)	Arakawa and Schubert (1974) + cloud base mass flux by Pan and Randall (1998)	A simple microphysics scheme, Hasumi and Emori (2004)
CESM1 CAM4-chem CESM1 WACCM		Hack (shallow) and Zhang and MacFarlane (1995) deep	Rasch and Kristjannson (1998)
CHASER (MIROC-ESM)	Mellor & Yamada (1974) lev.2	Arakawa and Schubert (1974) + cloud base mass flux by Pan and Randall (1998)	Watanabe et al. (2011) Takemura et al. (2005,2012)
CMAM	Abdella and McFarlane (1996) for surface fluxes Scinocca et al. (2008) for mixing	Zhang and McFarlane (1995)	
CNRM-CM 5-3	Turbulent: Ricard and Royer (1993) - dry convection Bougeault (1985)	Bougeault (1985)	Ricard and Royer (1993)
EMAC	Roeckner et al. (2006)	Tiedtke (1989); Nordeng (1994)	Lohmann and Roeckner (1996)
GEOSCCM	Lock (2000), and Richardson-number scheme of Louis and Geleyn (1982)	Moorthi and Suarez (1992), Bacmeister et al. (2006)	Bacmeister et al. (2006)
GFDL-CM3/AM3	Donner et al. (2011)	Donner et al. (2011)	Donner et al. (2011)
HadGEM3-ES	Walters et al. (2014)	Walters et al. (2014)	Walters et al. (2014)
LMDz-REPROBUS	Dufresnes et al. (2013)	Dufresnes et al. (2013)	Dufresnes et al. (2013)
MRI-ESM1r1	Yukimoto et al. (2011)	Yoshimura et al. (2015)	Yukimoto et al. (2011)
MOCAGE	Louis et al. (1979)	Bechtold et al. (2001)	
SOCOL	Roeckner et al. (2006)	Nordeng (1994)	Lohmann and Roeckner (1996)
ULAQ CCM	Vertical diffusion	Grewe et al. (2001)	Kärcher and Lohmann (2002) [cirrus ice clouds]

Table S11: Physical processes continued

Model name	Aerosol microphysics	Cloud cover
ACCESS CCM NIWA-UKCA UMUKCA-UCAM	Hewitt et al. (2011)	Hewitt et al. (2011)
CCSRNIES MIROC3.2	None	Le Treut and Li (1991)
CESM1 CAM4-chem CESM1 WACCM	Tie (2005)	Zhang et al. (2003)
CHASER (MIROC-ESM)	Takemura et al. (2005,2012)	Le Treut and Li (1991)
CMAM	N/A	Prognostic cloud cover based on relative humidity (Scinocca et al., 2008)
CNRM-CM5-3	Aerosols climatology in these simulation	Cloud cover Strati: Ricard and Royer (1993). Conv: Bougeault (1985)
EMAC	N/A	Sundqvist (1978)
GEOSCCM	Colarco et al. (2010)	Bacmeister et al. (2006)
GFDL-CM3/AM3	Donner et al. (2011)	Donner et al. (2011)
HadGEM3-ES	Walters et al. (2014)	Walters et al. (2014)
MRI-ESM1r1	Yukimoto et al. (2011)	Yukimoto et al. (2011)
LMDz-REPROBUS	Szopa et al. (2013)	Dufresnes et al. (2013)
SOCOL	N/A	Tompkins (2002)
ULAQ CCM	Pitari et al. (2014, 2015a, 2015b)	MERRA climatology

Table S12: Cloud information

Model name	Reference for cloud microphysics
ACCESS CCM NIWA-UKCA UMUKCA-UCAM	Wilson et al. (2008)
CCSRNIES MIROC3.2	Watanabe et al. (2010), Hasumi and Emori (2004)
CESM1 CAM4-chem CESM1 WACCM	Rasch and Kristjannson (1998)
CHASER (MIROC-ESM)	Watanabe et al. (2010), Hasumi and Emori (2004)
CMAM	Scinocca et al. (2008)
CNRM-CM 5-3	Ricard and Royer (1993)
EMAC	Lohmann and Roeckner (1996)
GEOSCCM	Bacmeister et al. (2006)
GFDL-CM3/AM3	Golaz et al. (2013)
HadGEM3-ES	Walters et al. (2014)
LMDz-REPROBUS	Dufresnes et al., 2013
MRI-ESM1r1	Yukimoto et al. (2011)
SOCOL	Lohmann and Roeckner (1996)
ULAQ CCM	Kärcher and Lohmann (2002), Pitari et al. (2015a) [cirrus ice clouds]

Table S13: Chlorine, bromine, and NMHC source gases, type of chemical scheme, origin of kinetic and photolysis data, handling of methane (PS == prescribed at surface, BP == prescribed in bulk; HA = hemispheric asymmetry consistent with observed asymmetries). See table 2.12 of SPARC CCMVal (2010). F10 = CCl_4. F11 = $CFCl_3$. F12 = CF_2Cl_2. F113 = $CF_2ClCFCl_2$. F114 = $(CF_2Cl)_2$. F115 = C_2F_5Cl. H21 = $CHFCl_2$. H22 = CHF_2Cl. H123 = $CHCl_2CF_3$. MCF = CH_3CCl_3. H141b = CH_3CFCl_2. H142b = CH_3CF_2Cl. H1211 = CF_2ClBr. H1301 = CF_3Br. H1202 = CF_2Br_2. H2402 = $(CF_2Br)_2$. MEK = $CH_3C(O)CH_2CH_3$. OTHC = "other carbon". BIGALK = "big alkanes". BIGENE = "big alkenes".

Model name	Cl source gases	Br source gases	NMHC source gases	Chemical scheme	Origin of kinetics and photolysis data	Handling of methane
ACCESS CCM HadGEM3-ES NIWA-UKCA	F11, F12 (scaled)	CH_3Br (scaled), CH_2Br_2, $CHBr_3$	HCHO, C_2H_6, CH_3CHO, C_3H_8, C_5H_8, $(CH_3)_2CO$	NMVOC-CH_4-CO-NO_x-ClO_x-BrO_x non-families	various	PS
CCSRNIES MIROC3.2	F11, F12, F113, H22, CH_3Cl, MCF	H1211, H1301, CH_3Br, CH_2Br_2, $CHBr_3$	None	N_2O-CH_4-CO-H_2O-O_x-HO_x-NO_x-CHO_x-ClO_x-BrO_x	JPL (2011)	PS
CESM1 CAM4-chem	F11, F12, F113, F114, F115, H22, H141b, H142b, MCF, CH_3Cl, F10	H1211, H1301, H1202, H2402, CH_3Br, CH_2Br_2, $CHBr_3$	HCHO, Benzene, Xylene, BIGALK, BIGENE, C_2H_2, C_2H_6, C_2H_4, C_3H_8, C_3H_6, CH_3CHO, C_2H_4OH, CH_3CHO, CH_3OH, MEK, Toluene, CH_3CCH_3, CH_3COOH, HCOOH	NMVOC-CH_4-CO-NO_x-ClO_x-BrO_x non-families Het chemistry (STS, NAT, ICE) 17 reactions	Mainly JPL (2011)	PS
CESM1 WACCM	F11, F12, F113, F114, F115, H22, H141b, H142b, MCF, CH_3Cl, F10	H1211, H1301, H1202, H2402, CH_3Br, CH_2Br_2, $CHBr_3$	HCHO, Benzene, Xylene, BIGALK, BIGENE, C_2H_2, C_2H_6, C_2H_4, C_3H_8, C_3H_6, CH_3CHO, C_2H_4OH, CH_3CHO, CH_3OH, MEK, Toluene, CH_3CCH_3, CH_3COOH, HCOOH	NMVOC-CH_4-CO-NO_x-ClO_x-BrO_x non-families Het chemistry (STS, NAT, ICE) 17 reactions; Ion-neutral chemistry in MLT region	Mainly JPL (2011)	PS
CHASER (MIROC-ESM)	F11, F12, F113, H22, MCF, CH_3Cl	CH_3Br, $CHBr_3$	HCHO, CH_3OH, C_2H_6, C_2H_4, C_3H_8, C_3H_6, CH_3CHO, C_5H_8, terpenes, $(CH_3)_2CO$, & a lumped species	NMVOC-CH_4-CO-NO_x-ClO_x-BrO_x	various	Prognostic ally calculated
CMAM	F11, F12, F10, MCF, H22, CH_3Cl	CH_3Br, CH_3Br_2 $CHBr_3$	N/A	CH_4-CO-NO_x-ClO_x-BrO_x	JPL (2011)	PS
CNRM-CM5-3	F10, F11, F12, F113, MCF, CH_3Cl, H22	CH_3Br, H1211, H1301	N/A	REPROBUS Lefèvre (1994)	JPL (2011)	PS
EMAC	F11, F12, MCF, F10, CH_3Cl, sea salt aerosol	$CHCl_2Br$, $CHClBr_2$, CH_2ClBr, CH_2Br_2, $CHBr_3$, CH_3Br, H1211, H1301, sea salt aerosol	C_2H_4; C_2H_6; C_3H_6; C_3H_8; C_5H_8; C_4H_{10}; CH_3CHO; $(CH_3)_2CO$; CH_3CO_2H; CH_3OH; HCHO; HCOOH; MEK	O_3; CH_4; NO_x; alkanes and alkenes up to C4; Br; Cl; NMHCs; C_5H_8; heterogeneous reactions of N_2O_5, halogen nitrates ($ClNO_3$, $BrNO_3$) and hypohalous acids (HOCl, HOBr)	JPL (2011) for kinetics and photolysis	HA with seasonal cycle
GEOSCCM	F10, F11, F12, F113, MCF, CH_3Cl, H22, H142b, H141b	CH_3Br, H1301, H1211, H2402	C_2H_6, C_3H_6 + $\geq$ C_3 alkenes, CH_3CHO, $\geq$ C_4 alkanes, $CH_3C(O)CH_3$, C_3H_8, CH_2O, C_5H_8, CH_3OH,	NMVOC-CH_4-CO-NO_x-ClO_x-BrO_x non-families	JPL (2011) for kinetics and photolysis	PS

			C_2H_5OH, RC(O)R (> C_3 ketones)			
GFDL-AM3	F11, F12, CH_3Cl, F10, MCF, H22	CH_3Br, H1211, H1301	C_2H_4, C_2H_6, C_3H_6, C_3H_8, CH_3OH, HCHO, $(CH_3)_2CO$, C_2H_5OH, C_4H_{10}, C_5H_8, $C_{10}H_{16}$	NMVOC-CH_4-CO-NO_x-ClO_x-BrO_x	Sander et al. (2006)	PS
LMDz-REPROBUS	F11, F12, F113, F10, MCF, CH_3Cl, H22	CH_3Br, H1211, H1301	None	CH_4-CO-NO_x-ClO_x-BrO_x	Latest JPL recommendations	PS
MRI-ESM1r1	F10, F11, F12, CH_3Cl	CH_3Br, H1211, H1301	C_2H_4, C_2H_6, C_3H_6, C_3H_8, HCHO, C_5H_8, $(CH_3)_2CO$, CH3CHO, C_4H_{10}, $C_{10}H_{16}$	N_2O-NMVOC-CH_4-CO-H_2O-O_x-HO_x-NO_x-ClO_x-BrO_x-SO_x	kinetics: JPL (2011) Atkinson et al. (2004, 2006) photolysis: Sander et al. (2006)	PS
MOCAGE	F11, F12, F113, H22, F10, MCF, CH_3Cl	CH_3Br, H1211, H1301	HCHO, C_2H_4, C_2H_6, C_3H_6, C_3H_8, butanes and higher alkanes, butene and higher alkenes, benzene, toluene, xylene, ketones, acids, alcohols, C_5H_8	N_2O-NMVOC-CH_4-CO-H_2O-O_x-HO_x-NO_x-ClO_x-BrO_x-SO_x	kinetics : JPL (2011), photolysis: tabulation from	PS
SOCOL	F11, F12, F113, F114, F115, F10, MCF, H22, H141B, H142B, CH_3Cl, H21, H123	$CHBr_3$, CH_2Br_2, CH_3Br, H1211, H1301, H2402	HCHO, C_5H_8	C_5H_8-CH_4-CO-NO_x-ClO_x-BrO_x (MEZON/MIM1)	kinetics: JPL (2011) photolysis: JPL (2011)	PS
TOMCAT	CH_3Cl, F11, F12, F113, F114, F115, F10, MCF, H22, H141b, H142b	CH_3Br, H1211, H1301, $CHBr_3$, CH_2Br_2		O_x-ClO_x-BrO_x-NO_x-HO_x-CHO_x Families	JPL(2011)	PS
ULAQ CCM	CH_3Cl, F11, F12, F113, F114, F115, F10, MCF, H22, H141b, H142b	CH_3Br, H1211, H1301, H2402	C_2H_6, C_2H_4, C_3H_6, C_5H_8, $C_{10}H_{16}$, OTHC	O_x-ClO_x-BrO_x-NO_x-SO_x-HO_x-CHO_x families	JPL (2011)	HA, no seasonal cycle
UMSLIMCAT	F11,F12 (scaled)	CH_3Br (scaled)		O_x-ClO_x-BrO_x-NO_x-SO_x-HO_x-CHO_x families	JPL(2011)	PS
UMUKCA-UCAM	F11, F12, F113, F10, MCF, CH_3Cl, H22	CH_3Br, H1211, H1301, CH_2Br_2, $CHBr_3$	HCHO	CH_4-CO-NO_x-ClO_x-BrO_x non-families	various	PS

Table S14: Interactive biogenic emissions by species, with reference for interactive emissions. NI = non-interactive. Please add columns as required for other species. Models not listed here do not represent any interactive biogenic emissions.

Model name	NO	DMS	$(CH_3)_2CO$	C_5H_8	C_2H_6	(other species)
ACCESS CCM HadGEM3-ES NIWA-UKCA UMUKCA-UCAM	NI	Wanninkhof (1992)	NI	NI	NI	
CESM1 CAM4-chem CESM1 WACCM	NI	NI	MEGAN2.1	n.a.	MEGAN2.1	Isoprene, $C_{10}H_{16}$, CH_3OH, C_2H_5OH, CH_2O, CH_3CHO, CH_3COOH, HCOOH, HCN, CO, C_2H_4, C_2H_8, C_3H_6, BIGALK, BIGENE, MEK, TOLUENE
EMAC	Yienger and Levy (1995)	Pozzer et al. (2006); Wanninkhof (1992)	None	ocean: similar to DMS; land: Kerkweg et al. (2006b); Guenther et al. (1995)	None	CH_3OH (similar to DMS)
GEOSCCM	Yienger and Levy (1995)	NI	NI	MEGAN Guenther et al. (1999)	NI	C_3H_6: scaled from isoprene; CO: from monoterpenes and methanol
GFDL-AM3	NI	Chin et al. (2002)	NI	MEGAN2.1	NI	
GFDL-CM3	NI	Chin et al. (2002)	NI	NI	NI	
MRI-ESM1r1	NI	Yukimoto et al. (2011)	NI	NI	NI	
ULAQ CCM	NI	NI	N/A	NI	NI	$C_{10}H_{16}$ (NI)

Table S15: Details of lumping, usage of emissions beyond the recommendation (e.g. natural, coupled emissions, e.g. ocean CO, ocean DMS).

Model name	Lumping	Coupled emissions	Comments
ACCESS CCM NIWA-UKCA	NMVOC emissions are distributed across NMHC source gases.	DMS: SS concentrations prescribed No other coupled emissions..	O'Connor et al. (2014)
CESM1 CAM4-chem CESM1 WACCM	Alkenes and alkanes are lumped for C>3 (BIGENE and BIGALK) , some VOCs are lumped (MEK), others are explicit: CH_2O, CH_3CHO, $(CH_3)_2CO$, CH_3OH, C_2H_5OH	SeaSalt, Dust, Biogenic emissions	
CHASER (MIROC-ESM)	NMVOCs emissions are distributed across NMHC source gases.	BVOCs emissions are off-line coupled with the VISIT model	Ito (2013)
CMAM			Additional 250 Tg-CO/year emissions to account for isoprene oxidation, distributed as Guenther et al. (1995) isoprene emissions. Additional 160 Tg-CO/year from soils.
EMAC	NMVOC emissions are distributed among NMHC source gases	see on-line emissions (DMS, CH_3OH, C_5H_8 from ocean; Br and Cl from sea salt); volcanic SO_2; terrestrial DMS; NH_3;	
GEOSCCM	NMVOC emissions: MEK + >C3 ketones, propene + >= C3 alkenes, C_2H_6, C_3H_8, >= C4 alkanes, CH_2O, acetaldehyde	Dust, Sea Salt	
HadGEM3-ES	C_2H_2 and C_2H_4 lumped with C_2H_6 ems. C_3H_6 lumped with C_3H_8 ems. Ocean CO, HCHO, and CH_3CHO ems included.	DMS: SS concentrations prescribed No other coupled emissions. Ocean DMS included (see Kettle et al., 1999, and Wanninkhof, 1992)	O'Connor et al. (2014), Wanninkhof (1992), Kettle et al. (1999).
MRI-ESM1r1	NMVOC emissions are distributed across NMHC source gases.	Dust, SSALT, DMS	Yukimoto et al. (2011) Deushi and Shibata (2011)
MOCAGE	non lumped species: C_2H_6, C_2H_4, C_3H_6, C_5H_8, C_7H_8, C_8H_{10}, α-pinene Other NMVOC emissions are distributed across NMHC source gases.		
SOCOL	N/A	N/A	N/A
ULAQ CCM	NMVOC lumped species for VOCs other than C_2H_6, C_2H_4, C_3H_6, C_5H_8, $C_{10}H_{16}$	N/A	Müller and Brasseur (1995)

Table S16: Species with aircraft emissions, lightning NO_x reference, species with wet and dry deposition. Cf table 2.13 of SPARC CCMVal (2010). BC = black carbon. For other species' definitions the readers are referred to the corresponding individual model descriptions.

Model name	Aircraft emission	Lightning NO_x	Wet deposition	Dry Deposition	Comments
ACCESS CCM NIWA-UKCA	NO	Price and Rind (1992)	NO_3, N_2O_5, HO_2NO_2, HNO_3, HO_2, H_2O_2, HCHO, CH_3O_2, CH_3OOH, HONO, C_2H_5OOH, n-C_3H_7OOH, i-C_3H_7OOH, CH_3COCH_2OOH, ISOOH, ISON, MACROOH, HACET, MGLY, HCOOH, CH_3CO_3H, CH_3CO_2H, CH_3OH	O_3, NO, NO_3, NO_2, N_2O_5, HNO_4, HNO_3, H_2O, CO, HCHO, CH_3OOH, HONO, C_2H_5OOH, CH_3CHO, PAN, n-C_3H_7OOH, i-C_3H_7OOH, C_2H_5CHO, CH_3COCH_2OOH, PPAN, ISOOH, ISON, MACR, MACROOH, MPAN, HACET, MGLY, NALD, HCOOH, CH_3CO_3H, CH_3CO_2H, CH_3OH	
CCSRNIES MIROC3.2	None	None	HNO_3, HCl, HBr	O_3, H_2O_2, NO, NO_2, HNO_3, HNO_4, N_2O_5, HCl	
CESM1 CAM4-chem CESM1 WACCM	BC, NO, SO_2	Price and Rind (1992)	ALKOOH, $BrONO_2$, C_2H_5OH, C_2H_5OOH, C_3H_7OOH, CH_2O, CH_3CHO, CH_3CN, CH_3COCHO, CH_3COOH, CH_3COOOH, CH_3OH, CH_3OOH, $CLONO_2$, EOOH, GLYALD, H_2O_2, HBr, HCl, HCN, HCOOH, HNO_3, HO_2NO_2, HOBr, HOCl, HYAC, HYDRALD, $ISOPNO_3$, ISOPOOH, MACR, MACROOH, MEKOOH, MVK, NH_3, NH_50W, ONIT, ONITR, POOH, ROOH, SO_2, SO_2t, SOAG, TERPOOH, TOLOOH, XOOH, BC, Dust, NH_4, NH_4NO_3, OC, SO4, SOA, SeaSalt	ALKOOH, C_2H_5OH, C_2H_5OOH, C_3H_7OOH, BC, CH_2O, CH_3CHO, CH_3CN, $(CH_3)_2CO$, CH_3COCHO, CH_3COOH, CH_3COOOH, CH_3OH, CH_3OOH, CO, EOOH, GLYALD, H_2O_2, HCN, HCOOH, HNO_3, HO_2NO_2, HYAC, HYDRALD, ISOPOOH, MACROOH, MEKOOH, MPAN, NH_3, NH_4, NH_4NO_3, NO, NO_2, O_3, OC, ONIT, ONITR, PAN, POOH, ROOH, SO_2, SO_4, SOA, SOAG, TERPOOH, TOLOOH, XOOH	
CHASER (MIROC-ESM)	NO, SO_2, BC	Price and Rind (1992)	N_2O_5, HO_2NO_2, HNO_3, H_2O_2, HCHO, CH_3CHO, CH_3OOH, C_2H_5OOH, C_3H_7OOH, CH_3COOOH, ISOOH, ISON, MACROOH, HACET, MGLY, CH_3OH, SO_2, SO_4, NH_3, NH_4, $ClONO_2$, HCl, $BrONO_2$, HOBr, HBr, BC/OC, dust	O_3, NO, NO_2, NO_3, N_2O_5, HNO_3, HNO_4, H_2O_2, CO, C_2H_6, C_3H_8, C_2H_4, C_3H_6, ONMV, C_5H_8, $C_{10}H_{16}$, CH_3COCH_3, CH_2O, CH_3CHO, CH_3OH, NALD, MGLY, HACET, MACR, PAN, MPAN, ISON, CH_3OOH, C_2H_5OOH, C_3H_7OOH, ISOOH, HOROOH, CH_3COOOH, MACROOH, O_xS, SO_2, DMS, SO_4, NH_3, NH_4, OCS, ClO_x, $ClONO_2$, BrO_x, $BrONO_2$, HOBr, HBr, BrCl, BC/OC, dust	
CMAM	NO	based on updraft mass flux scheme of Allen and	HNO_3, HNO_4, H_2O_2, HCHO, CH_3OOH, HCl, HBr	O_3, NO_2, HNO_3, H_2O_2, HCHO, CH_3OOH	

		Pickering (2002)			
CNRM-CM 5-3	NI	NI	NI	NI	Relaxation up to 560 hPa to evolving ground values (tau=7 days)
EMAC	NO	Grewe et al. (2001)	CH_3CHO; CH_3CO_2H; $(CH_3)_2CO$; CH_3COO^-; CH_3O_2; CH_3OH; CH_3OOH; Cl^-; CO_2; ^{210}Pb; H_2O_2; HCHO; HCl; HCO_3^-; HCOOH; $HCOO^-$; HNO_3; HNO_4; HO_2; HONO; H^+; HSO_3^-; HSO_4^-; NH_3; NH_4^+; NO_2; NO_2^-; NO_3^-; NO_4^-; NO; O_3; OH; OH^-; PAN; SO_2; SO_3^{2-}; SO_4^{2-}	ACETOL; BIACET; Br_2; BrCl; $BrNO_3$; C_2H_5OOH; C_5H_8; CH_2Br_2; CH_2ClBr; CH_3Br; CH_3CHO; CH_3Cl; CH_3CO_2H; CH_3CO_3H; $(CH_3)_2CO$; CH_3OH; CH_3OOH; CH_3SO_3H; $CHBr_3$; $CHCl_2Br$; $CHClBr_2$; Cl_2; $ClNO_3$; DMSO; H_2O_2; H_2SO_4; HBr; HCHO; HCl; HCOOH; HNO_3; HNO_4; HOBr; HOCl; HONO; HYPERACET; i-C_3H_7OOH; ISON; ISOOH; l-C_4H_9OOH; l-MEKOOH; MEK; MGLYOX; MPAN; MVK; N_2O_5; NH_3; NH50W; NO; NO_2; NO_3; O_3; PAN; ^{210}Pb; SO_2; H^+(cs); NO_3^-(cs); SO_{4res}(cs); Cl^-_{res}(cs); $NH_4^+{}_{res}$(cs);	(cs)=coarse mode aerosol; res = residual;
GEOSCCM	NO	D. Allen - tied to model meteorology	CH_2O, HONO, HNO_3, HNO_4, HO_2, H_2O_2, MP, NO_2, NO_3, N_2O_5, O_x, Br, BrCl, $BrONO_2$, HBr, HOBr, ClO, $ClONO_2$, HCl, HOCL, PAN, PMN, PPN, R_4N_2, dust, sea salt, BC, OC, SO_2, SO_4	CH_2O, HONO, HNO_3, HNO_4, HO_2, H_2O_2, MP, NO_2, NO_3, N_2O_5, O_x, Br, BrCl, $BrONO_2$, HBr, HOBr, ClO, $ClONO_2$, HCl, HOCl, PAN, PMN, PPN, R_4N_2, dust, sea salt, BC, OC, SO_2, SO_4	
GFDL-CM3/AM3	NO BC OM	Tied to model meteorology	HNO_3, HO_2NO_2, CH_2O, H_2O_2, CH_3CHO, POOH, CH_3COOOH, ONIT, MVK, MACR, MACROOH, C_2H_5OOH, C_3H_7OOH, ROOH, CH_3OH, C_2H_5OH, GLYALD, HYAC, HYDRALD, $(CH_3)_2CO$, ONITR, XOOH, ISOPOOH, SO_2, SO_4, NH_3, NH_4NO_3, SOA, DUST, BC, OC, SSALT	O_3, NO, NO_2, HNO_3, HO_2NO_2, CH_4, CH_3OOH, CH_2O, CO, H_2O_2, CH_3CHO, CH_3COOOH, ONIT, MPAN, MVK, MACR, $MACRO_2$, MACROOH, C_2H_5OOH, C_3H_7OOH, ROOH, CH_3OH, PAN, $(CH_3)_2CO$, CH_3COCHO, C_2H_5OH, GLYALD, HYAC, ONITR, XOOH, ISOPOOH, SO_2, HCl, HBr, SO_4, NH_3, NH_4NO_3, SOA, DUST, BC, OC, DMS, SSALT	Naik et al. (2013) and updates to oxidized VOCs dry deposition based on Karl T. et al (2010)
HadGEM3-ES	NO	Price and Rind (1994) with some parameter updates	NO_3, N_2O_5, HO_2NO_2, $HONO_2$, H_2O_2, HCHO, CH_3OO, CH_3OOH, HO_2, $BrONO_2$, HCl, HOCl, HBr, HOBr, $ClONO_2$, HONO, EtOOH, n-PrOOH, i-PrOOH, CH_3COCH_2OOH,	O_3, NO, NO_3, NO_2, N_2O_5, HO_2NO_2, $HONO_2$, H_2O_2, CO, HCHO, CH_3OOH, HCl, HOCl, HBr, HOBr, HONO, EtOOH, CH_3CHO, PAN, n-PrOOH, i-PrOOH, EtCHO, CH_3COCH_2OOH, PPAN, ISOOH, ISON,	

			ISOOH, ISON, MACROOH, HACET, MGLY, HCOOH, CH_3CO_3H, CH_3CO_2H, CH_3OH	MACR, MACROOH, MPAN, HACET, MGLY, NALD, HCOOH, CH_3CO_3H, CH_3CO_2H, CH_3OH	
LMDz-REPROBUS	NA	NA	NA	NA	Climatological tropospheric composition is specified below 400 hPa
MRI-ESM1r1	NO, BC	Price and Rind (1992)	HNO_3, H_2O_2, HO_2NO_2, HCl, HBr, COF_2, HF, CH_2O, CH_3OOH, C_2H_5OOH, CH_3CO_3H, C_3H_7OOH, HACET, MGLY, GLYALD, $GCOO_2H$, POOH, ISON, ISOPOOH, MACROOH, SO_2, SO_3, SO_4, OCS, DMS, MSA, BC, OC, SSALT, DUST	O_x, CH_4, HNO_3, CO, H_2O_2, NO_2, HO_2NO_2, CH_2O CH_3OOH, C_2H_5OOH, PAN, ACET, C_3H_7OOH, HACET, MGLY, GLYALD, GPAN, $GCOO_2H$, ONIT, POOH, MACR, ISON, ISOPOOH, MACROOH, MPAN, SO_2, SO_3, SO_4, OCS, DMS, MSA, BC, OC, SSALT, DUST	
MOCAGE	NO	Price and Rind (1992)	All species, depending on their solubility	O_x, H_2O_2, NO, NO_2, NO_3, N_2O_5, HONO, HCl, HNO_3, HNO_4, SO_2, CO, HO_2, CH_4, ETH, HC3, HC5, HC8, ETEOLT, OLI, DIEN, ISO, TOL, XYL, CSL, HCHO, ALD, KET, GLY, MGLY, DCB, MACR, UDD, HKET, ONIT, PAN, TPAN, OP1, OP2, PAA, MO_2, DMS, NH_3, DMSO, MSA, H_2S	
SOCOL	NO_x	Price and Rind (1992)	HNO_3	CO, NO, NO_2, O_3, HNO_3, H_2O_2, H_2	
ULAQ CCM	NO_x, H_2O, SO_2, SO_4, BC	Grewe et al. (2001) [5 Tg-N)/yr]	HNO_3, H_2O_2, HO_2NO_2, HCl, HBr, CH_2O, CH_3OOH, C_2H_5OOH, C_3H_6OHOOH, CH_3CO_3H, CH_3CHO, SO_2, SO_4, MSA, BC, OC, SSALT, DUST	O_3, NO, NO_2, PAN, HNO_3, CO, H_2O_2, HO_2NO_2, CH_2O, CH_3OOH, C_2H_5OOH, C_3H_6OHOOH, CH_3CO_3H, CH_3CHO, SO_2, SO_4, MSA, BC, OC, SSALT, DUST	Müller and Brasseur (1995)
UMUKCA-UCAM	NO	Price and Rind (1992)	NO_3, N_2O_5, HO_2NO_2, HNO_3, HO_2, H_2O_2, HCHO, CH_3O_2, CH_3OOH, HONO	O_3, NO, NO_3, NO_2, N_2O_5, HNO_4, HNO_3, H_2O, CO, HCHO, CH_3OOH, HONO	

Table S17: Heterogeneous reactions, tropospheric surface area density. L = liquid water. LSA: liquid stratospheric aerosol. LTA: liquid (sulfuric) tropospheric aerosol. N: NAT/PSC. I: ice. SO_4:
sulfate. SAD: Sulfuric acid dihydrate. STS: supercooled ternary (H_2SO_4 / HNO_3 / H_2O) solution. LA: liquid aerosol. LSA = liquid sulfate aerosol, D = mineral dust. SS = sea salt. Cf table 2.15 of SPARC CCMVal (2010).

Model name	$ClNO_3$+H_2O	$ClNO_3$+HCl	HOCl+HCl	N_2O_5+H_2O	N_2O_5+HCl	$BrNO_3$+H_2O	HOBr+HCl	$ClNO_3$+HBr	$BrNO_3$+HCl	HOBr+HCl	HOBr+HBr	HNO_3 + H_2O
ACCESS CCM HadGEM3-ES NIWA-UKCA UMUKCA-UCAM	N/I/SO_4	N/I	N/I/SO4	N/I/SO4	N/I							
CCSRNIES MIROC3.2	N/I/STS	N/I/STS	N/I/STS	N/I/STS	N/I	N/I/STS	N/I/STS	N/I	N/I	N/I/STS	N/I/STS	
CESM1 CAM4-chem CESM1 WACCM	N/I/STS	N/I/STS	N/I/STS	N/I/STS		N/I/STS	I/STS			I/STS		
CHASER (MIROC-ESM)	N/I/STS	N/I/STS	N/I/STS	N/I/STS	N/I	N/I/STS	N/I/STS	N/I	N/I	N/I/STS	N/I/STS	
CMAM	I/STS	I/STS	I/STS	LSA/I/STS + LTA		LSA/I/STS	I/STS		I	I/STS		
CNRM-CM5-3	N/I/LSA	N/I	N/I	N/I/LSA	N/I	N/I	N/I				N/I/LSA	
EMAC	N/I/LSA	N/I/LSA	N/I/LSA	N/I/LSA + LTA/D/SS	N/I/LSA	N/I/LSA	N/I/LSA	N/I/LSA	N/I/LSA	N/I/LSA	N/I/LSA	
GEOSCCM	I/N/LSA	I/N/LSA	I/N/LSA	LSA		I/N/LSA	I/N/LSA		I/N			
GFDL-CM3/AM3	N/I	STS	STS	STS	STS	STS	STS				STS	
LMDz-REPROBUS	N/I/STS	N/I/STS	N/I/STS	N/I/STS		N/I/STS	N/I/STS					

MRI-ESM1r1	N/I/SO4/SS	N/I	N/I	N/I/SO4/SS	N/I	SO4/SS	N/I			N/I		
MOCAGE	N/I/STS	N/I/STS	N/I/STS	N/I/STS	N/I/STS	N/I/STS	N/I/STS			N/I	N/I	
SOCOL	LSA/N/I	LSA/N/I	LSA/N/I	LSA/N/I		LSA/I	LSA/I					
ULAQ CCM	N/I/SO4	N/I/SO4	N/I/SO4	N/I/SO4	N/I	N/I/SO4	N/I/SO4		N/I	N/I/SO4		D/SS

Table S18: Details of tropospheric chemistry (incl. details on deposition schemes), heterogeneous chemistry. l = liquid water droplets; i: ice crystals; SO_4: sulphate aerosol. OC = organic carbon. NO_3: nitrate. SS = sea salt. $N_2O_5 + H_2O$ is listed under "heterogeneous reactions" in table S17.

Model name	Deposition scheme	$SO_2 \rightarrow SO_3$	Further reactions	Surface types for these reactions	Reference
ACCESS CCM NIWA-UKCA UMUKCA-UCAM	Zeng and Pyle (2003)	L			
CESM1 CAM4-chem CESM1 WACCM	Wesely (1995)		N_2O_5 ->2 HNO_3 NO_3 ->HNO_3 NO_2 ->0.5 (OH + NO + HNO_3) HO_2 -> 0.5 H_2O_2		Lamarque et al. (2012)
CHASER (MIROC-ESM)	Wesely (1995)	1	$HO_2 \rightarrow H_2O_2$, $RO_2 \rightarrow$ ROOH $CH_3OH \rightarrow$ HCHO	1,i,SO_4,OC,NO_3	
EMAC	D(ry)DEP (Kerkweg et al., 2006a); SCAV (Tost et al., 2006a)	1	see references and supplement of Jöckel et al. (2015)		Jöckel et al. (2016)
GEOSCCM	Dry dep based on Wang et al. (1998)	1			
GFDL-CM3/AM3	Naik et al. (2013)	l			Tie et al. (2005)
HadGEM3-ES	O'Connor et al. (2014)	1			
MRI-ESM1r1	Yukimoto et al. (2011); Deushi and Shibata (2011)	l			
MOCAGE	dry dep base on Wesely (1989)	l			
SOCOL	Deposition velocities: Hauglustaine et al. (2004)	N/A	N/A		
ULAQ CCM	Deposition velocities; Müller and Brasseur (1995)	l/i	$HNO_3 + H_2O \rightarrow NO_3^-$	dust, SS	

Table S19: Microphysics of polar stratospheric clouds (table 2.16 of SPARC CCMVal, 2010). EQ = thermodynamic equilibrium. HY = hysteresis. NAT = nitric acid trihydrate.

Model name	Sedimentation velocity (mm/s)	Thermodynamics	Transported PSC tracers	Reference
ACCESS CCM HadGEM3-ES NIWA-UKCA UMUKCA-UCAM	NAT: 0.46 NAT/ice: 17.3	EQ	none	Morgenstern et al. (2009)
CCSRNIES MIROC3.2 CHASER (MIROC ESM)	Interactive	EQ	none	Akiyoshi et al. (2009)
CESM1 CAM4-chem CESM1 WACCM	Interactive	EQ	none	Solomon et al. (2015).
CMAM	No sedimentation	EQ	none	
CNRM-CM 5-3	NAT/ice : recalculated (mean value around 17.3)	EQ	none	Lefèvre (1994)
EMAC	Interactive (Kerkweg et al., 2006a)	NAT: HY; ice: EQ	HNO_3_nat and 9 corresponding size bins	Kirner et al.. (2011)
GEOSCCM	Interactive	non-EQ	HNO_3, H_2O	Considine et al. (2000)
GFDL-CM3/AM3	Interactive	EQ	none	Austin et al. (2013)
LMDz-REPROBUS	NAT: NAT/ice	EQ	none	Lefevre et al. (1998)
MRI-ESM1r1	NAT: 0.17, ice: 17.4	EQ	none	Shibata et al. (2005)
MOCAGE	Interactive		HNO_3, H_2O	Carslaw et al. (1995)
SOCOL	Schraner et al. (2008)	EQ	none	Carslaw et al. (1995)
ULAQ CCM	Interactive	non-EQ	HNO_3, H_2O	Butchart et al. (2010)

Table S20: Tropospheric aerosol (categories, bulk/sectional/modal). SS = sea salt. OC = organic carbon. BC = black carbon, SO_4 = sulfate. AOD = aerosol optical depth. DD = dry dust. OM = organic matter

Model name	Type of scheme	No. of dust tracers	No. of SS tracers	No. of OC tracers	No. of BC tracers	No. of SO_4 tracers	Reference
ACCESS CCM NIWA-UKCA UMUKCA-UCAM	Bulk	6	0	3	3	3	Martin et al. (2006)
CHASER (MIROC-ESM)	Bulk	6	4	2	2	1	Watanabe et al. (2011)
CESM1 CAM4-chem CESM1 WACCM	Bulk	4	4	2	2	1	Tie 2005
CNRM-CM 5-3	monthly AODs of DD, SS, OM, BC and SO_4						Szopa et al. (2012)
EMAC	prescribed aerosol surface area concentration						Righi et al. (2013) LOW_AIR simulation
GEOSCCM	Bulk	5	5	2	2	1	Colarco et al. (2010)
GFDL-CM3/AM3	Bulk	5	5	2	2	1	Levy et al. (2013), Liu et al. (2011)
HadGEM3-ES	Bulk	6	0	3	3	3	Bellouin et al. (2011); Walters et al. (2014)
MRI-ESM1r1	sectional for dust and SS; bulk for other species	10	10	3	2	1	Yukimoto et al. (2011)
SOCOL	Prescribed aerosol mixing ratios taken from CAM3.5 with bulk aerosol model	2	2	2	2	1	
ULAQ CCM	sectional; modal for nitrates	6	6	6	6	15	Pitari et al. (2014, 2015a, 2015b, 2015c)

Table S21: Implementation of volcanic effects in REF-C1 (including info on data provider). “CCMI” is the CCMI recommended data set. SAD = surface area density. SPARC = the SPARC dataset as used for CCMVal-2.

Model name	SADs for heterogeneous chemistry	Direct radiative effects	Comment / reference
ACCESS CCM NIWA-UKCA	CCMI	Not implemented	
CCSRNIES MIROC3.2	CCMI	Calculated online	
CESM1 CAM4-chem CESM1 WACCM	CCMI	Calculated online using CCMI effective radius	
CHASER (MIROC-ESM)	CCMI	Calculated online	
CMAM	CCMI*	Calculated online	extinction at 1020 nm calculated from SAD following Thomason et al (1997).
CNRM-CM5-3	CCMI	for the direct radiative effects the climatology of volcanic AODs is that of Ammann et al. 2007	
EMAC	CCMI	Calculated online	Jöckel et al. (2016)
GEOSCCM	CCMI	Calculated online	Aquila et al. (2012)
GFDL-AM3/CM3	Austin et al. (2013).	Imposed aerosol extinction	Austin et al. (2013); Lin et al. (2015a)
HadGEM3-ES	CCMI	Calculated online	Hardiman et al. (2016)
LMDz-REPROBUS	CCMI	L39 : not implemented	
MRI ESM1r1	CCMI	Calculated online	Yukimoto et al. (2011)
SOCOL	CCMI	Calculated online	
TOMCAT	CCMI	Not implemented	Dhomse et al. (2015)
ULAQ CCM	CCMI	Calculated online	Pitari et al. (2016a); Pitari et al. (2016b); Pitari et al. (2016c)
UMSLIMCAT	CCMI	Not implemented	Tian and Chipperfield (2005)
UMUKCA-UCAM	SPARC	Calculated online	SPARC (2006)

Table S22: Photolysis (table 2.14 of SPARC CCMVal, 2010). SZA = solar zenith angle. OC = ozone column. T = temperature. P = pressure.

Model name	Reference for scheme	Reference for cross sec.	Online	Spectral range (nm)	Average resolution (nm)	Max SZA (degrees)	Temperature range (K)	Interpolation parameters
ACCESS CCM HadGEM 3-ES NIWA-UKCA UMUKCA-UCAM	FAST-JX: Telford et al. (2013) Neu et al. (2007) Lary and Pyle (1991)	Various	Yes (below 60 km); No (above 60 km)	117-850 nm	variable	95/96	200-300	T, p, SZA, OC (above 60 km)
CCSRNIES MIROC3.2	Minschwaner et al. (1993); Kurokawa et al. (2005); Akiyoshi et al. (2016)	JPL (2011)	Yes	177.5-690 nm, Lyman-α	0.90-2.35 (S-R bands), 9.96-100.0 (>200 nm)	96	195-300	
CESM1 CAM4-chem CESM1 WACCM	TUV4.3, Kinnison et al (2007).	JPL(2011)	Yes	EUV, 121nm-750nm	Variable, 33 bins from 121-200nm; 67 bins from 200-750nm.	97	150-350	T, p, SZA, Albedo, OC
CHASER (MIROC-ESM)	Sudo et al. (2002)	JPL (2011)	Yes	185-800	variable	90	200-300	
CMAM	TUV5 (Madronich and Flocke, 1998)	JPL(2011) plus others	No (on-line cloud correction)	120-735	generally 3 to 4 nm, except 1 nm around 300nm	100	single profile using US standard atmosphere	p, SZA, OC, albedo
CNRM-CM5-3	TUV 4.1a (Madronich and Flocke, 1998)	JPL (2011)	No	116-850	0.01 (S-R bands); 0.1 (L-alpha); 1 (elsewhere)	94	187-288	p, SZA, OC
EMAC	JVAL (Sander et al. 2014)	JPL (2011)	Yes	175- - 683 nm (8 bands), Lyman-α	1-5 for precalculation of coeficients; 8 - 260 for bands (with scattering)	94.5	Variable	
GEOSCCM	Bian and Prather (2002)	JPL (2002)	Yes	171-850 nm	variable	98	Variable	
GFDL-AM3	Fast-JX							

GFDL-CM3	TUV4.4							
LMDz-REPROBUS	TUV 4.1a (Madronich and Flocke, 1998); Marchand et al. (2012)	JPL (2011)	No	116-850 nm	Variable: 1 nm but enhanced resolution in the 300 nm region	94	variable	p, SZA, OC. No explicit chemistry below 400 hPa, just climatologies
MRI-ESM1r1	Deushi and Shibata (2011)	JPL (2006)	No (online cloud correction)	116.3-735; 171 bands	0.7-5.0	96	253-293	T, p, SZA, OC
MOCAGE	TUV		No (online cloud correction)		variable	95		T, p, SZA, OC
SOCOL	Rozanov et al. (1999)	JPL (2011)	Yes (LUTs)	121-750, 73 bands	1-160; median: 5nm	98	Variable	
ULAQ CCM	Minschwaner et al. (1993)	JPL (2011)	Yes	119.5-850; 150 bands	1-10	96	200-300	

Table S23: Shortwave radiation. 2-s = Two-stream (cf table 2.10 of SPARC CCMVal, 2010). 2-s = two-stream. UV-Vis = ultra-violet to visible wavelength region. NIR = near infrared.

Model name	Reference	Description	Clouds	Spectral interval boundaries (nm)	Gas. abs.
ACCESS CCM NIWA-UKCA UMUKCA-UCAM	Edwards and Slingo (1996) Zdunkowski et al. (1980)	2-s.	Maximum to random overlap	[200,320], [320,690], [320,690], [690,1190], [1190,2380], [2380,10000]	O_2, O_3, CO_2, H_2O
CCSRNIES MIROC3.2	Nakajima and Tanaka (1986); Nakajima et al. (2000)	2-s.	Maximum random overlap (Geleyn and Hollingsworth, 1979)	[200,217], [217,230], [230,278], [278,290], [290,303], [303,317], [317,330], [330,340], [340,355], [355,400], [400,500], [500,600], [600,690], [690,800], [800,1099], [1099,1250], [1250,1667], [1667,2128], [2128,2778], [2778,4000]	O_2, O_3, CO_2, H_2O
CHASER (MIROC-ESM)	Nakajima and Tanaka (1986); Nakajima et al. (2000)	2-s	Maximum random overlap (Geleyn and Hollingsworth, 1979)	[185.185,200], [200,217.4], [217.4,230], [230,277.8], [277.8,289.9], [289.9,303], [303,317.5], [317.5,330], [330,340], [340,355], [355,400], [400,500], [500,600], [600,678], [678,754], [754,784], [784,1000], [1000,1666], [1666,1923], [1923,2127], [2127,2631], [2631,3030], [3030,4000], [4000,5000], [5000,7173], [7173,7547], [7547,8163], [8163,8510], [8510,10204]	O_2, O_3, CO_2, H_2O
CMAM	Fouquart and Bonnel (1980) and Fomichev et al. (2004)	Δ-Eddington 2-s	maximum random overlap	[250, 690], [690, 1190], [1190, 2380], [2380, 4000]	O_2, O_3, H_2O, CO_2
CNRM-CM5-3	Morcrette (1991)	2-s	maximum random overlap	[185,250], [250,440], [440,690], [690,1190], [1190-2380], [2380,4000]	O_3, H_2O, O_2, CO_2, CH_4, N_2O
EMAC	Dietmüller et al. (2016); Kunze et al.. (2014); Roeckner et al. (2003); Fouquart and Bonnel (1980)	Δ-Eddington 2-s	Maximum random overlap	[250, 690], [690,1190], [1190, 2380], [2380, 4000]; < 70 hPa: 55 intervals [121.5,690]	O_2, O_3, CO_2, H_2O
GEOSCCM	Chou and Suarez (1999); Sud et al. (1993); Chou et al. (1997)	Δ-Eddington 2-s	Maximum random overlap	[175-225], [225-245], [245-260], [260-280], [280-295], [295-310], [310-320], [320-400], [400-700], [700-1220], [1220-2270], [2270-10000]	O_2, O_3, CO_2, H_2O
GFDL-CM3/AM3	Donner et al. (2011)	2-s	Donner et al. (2011)	Donner et al. (2011)	Donner et al. (2011)
HadGEM3-ES	Walters et al. (2014)	2-s.	Maximum to random overlap	[200,320], [320,690], [320,690], [690,1190], [1190,2380], [2380,10000]	O_2, O_3, CO_2, H_2O
LMDz-REPROBUS	Dufresnes et al. (2013)	2-s.	Parameterized (including overlapping)	L39: [250,680], [680,4000] L79: [185,250], [250,440], [440,690], [690,1190], [1190,2380], [2380,4000]	O_2, O_3, CH_4, CO_2, H_2O, N_2O

MRI-ESM1r1	Yukimoto et al. (2011)	2-s. (⊿-Eddington)	Maximum random overlap	[174,231], [231,250], [250,274], [274,283], [283,290], [290,296], [296,303], [303,313], [313,333], [333,364], [364,407], [407,448], [448,500], [500,599], [599,685], 7 intervals [700-5000]	O_2, O_3, CO_2, H_2O
SOCOL	Fouquart and Bonnel (1980); Cagnazzo et al. (2007)	Δ-Eddington 2-s.	Maximum random overlap	[185,250], [250,440], [440,690], [690,1190], [1190,2380], [2380,4000]	O_3, H_2O, CO_2, N_2O, CO, CH_4, O_2
ULAQ CCM	Randles et al., (2013); Pitari et al. (2014, 2015a, 2015b, 2015c)	2-s	Maximum random overlap	150 UV-VIS bands, 100 NIR bands covering [119.5, 7000]	O_2, O_3, NO_2, CO_2, H_2O, SO_2

Table S24: Longwave radiation (table 2.11 of SPARC CCMVal, 2010)

Model name	Reference	Description	Spectral interval boundaries (μm)	Gas abs.	Chem. heating	Non-LTE
ACCESS CCM NIWA-UKCA	Edwards and Slingo (1996), Zdunkowski et al. (1980)	2-s.	[25,10000], [18.2,25], [12.5,18.2], [13.3,16.9], [8.33,12.5], [8.93,10.1], [7.52,8.33], [6.67,7.52], [3.34,6.67]	H_2O, CO_2, O_3, CH_4, N_2O, F11 (rescaled), F12 (rescaled)	NO	NO
CCSRNIES MIROC3.2	Nakajima et al. (2000)	2-s.	[4.00,5.00], [5.00,7.14], [7.14,8.51], [8.51,10.2], [10.2,12.2], [12.2,13.3], [13.3,14.9], [14.9,16.4], [16.4,18.9], [18.9,40.0], [40.0,1000.]	H_2O, CO_2, O_3, CH_4, N_2O, CFCs	NO	NO
CHASER (MIROC-ESM)	Nakajima et al. (2000)	2-s	[12.2,13.3], [13.3,14.9], [14.9,16.4], [16.4,18.9], [18.9,25], [25,40], [40,1000]	H_2O, CO_2, O_3, CH_4, N_2O, CFCs/HFCs	NO	NO
CMAM	Morcrette (1991); Fomichev et al. (2004)	2-s up to 39 hPa transitioning to Matrix param. above 6.7 hPa	2-s: [6.9, 8.0 : 3.5, 5.3], [9.0, 10.3], [10.3, 12.5 : 8.0, 9.0], [12.5, 20.0], [20.0, 28.6], [28.6, 10000 : 5.3, 6.9] Matrix param: 15 μm CO_2; 9.6 μm O_3; rotational H_2O bands	2-s: H_2O, CO_2, O_3, CH_4, N_2O, F11, F12 Matrix param: H_2O, CO_2, O_3	Yes	Yes
CNRM-CM 5-	Morcrette 2001	2-s	Spectral interval boundaries (cm-1) 16 [10,250], [250,500], [500,630], [630,700], [700,820], [820,980], [980,1080], [1080,1180], [1180,1390], [1390,1480], [1480,1800], [1800,2080], [2080,2250], [2250,2380], [2380,2600], [2600,3000]	H_2O, CO_2, O_3, CH_4, N_2O, F11, F12	NO	NO
EMAC SOCOL	Mlawer et al. (1997)	k-correlated method, RRTM	[40,1000], [20,40], [15.87,20], [14.29,15.87], [12.2,14.29], [10.2,12.2], [9.26,10.2], [8.47,9.26], [7.19,8.47], [6.76,7.19], [5.56,6.76], [4.81,5.56], [4.44,4.81], [4.2,4.44], [3.85,4.2], [3.33,3.85]	H_2O, CO_2, O_3, CH_4, N_2O, F12, F11	NO	NO
GEOSCCM	Chou et al. (2001)	k-distribution and table look-up	[29.4,10000], [18.5,29.4], [16.1,18.5], [13.9,16.1], [12.5,13.9], [10.2,12.5], [9.09,10.2], [8.23,9.09], [7.25,8.23], [5.26,7.25], [3.33,5.26]	H_2O, CO_2, O_3, CH_4, N_2O, F11, F12, H22	No	No
GFDL-CM3/AM3	Donner et al. (2011)	Donner et al. (2011)	Donner et al. (2011)	Donner et al. (2011)	Donner et al. (2011)	Donner et al. (2011)
HadGEM3-ES	Walters et al. (2014)	2-s.	[25,10000], [18.2,25], [12.5,18.2], [13.3,16.9], [8.33,12.5], [8.93,10.1], [7.52,8.33], [6.67,7.52], [3.34,6.67]	H_2O, CO_2, O_3, CH_4, N_2O, F11(rescaled), F12 (rescaled), H134a (rescaled)	NO	NO
LMDz-REPROBUS	Dufresnes et al., 2013	2-s.	[3.55,8], [8,10.31], [10.31,12.5], [12.5,20], [20,28.57], [28.57,1000] wavenumbers 0 to 2.82×10^5 m^{-1}	O_3, CH_4, CO_2, H_2O, N_2O, F11, F12	NO	NO
MRI-ESM1r1	Yukimoto et al. (2011)	2-s. k-distribution and table look-up	[3.33,5.26], [5.26,7.25], [7.25,8.23], [8.23,9.09], [9.09, 10.2], [10.2, 12.5], [12.5,13.9], [13.9,16.1], [16.1,18.5], [18.5, 29.4], [29.4, 1000.]; wave numbers 0 to 3000 cm-1	H_2O, CO_2, O_3, CH_4, N_2O, F11, F12, H22	No	No
ULAQ CCM	Chou et al. (2001); Pitari et al. (2014, 2015a, 2015c)	2-s. k-correlated method	[3.3,5.3], [5.3,7.2], [7.2,8.2], [8.2,9.1], [9.1, 10.2], [10.2, 12.5], [12.5,16.1], [16.1,18.5], [18.5, 29.4], [29.4, 1000.]	H2O, CO2, O3, CH4, N2O, F11, F12, H22	No	No

UMUKCA-UCAM	Edwards and Slingo (1996), Zdunkowski et al. (1980)	2-s.	[25,10000], [18.2,25], [12.5,18.2], [13.3,16.9], [8.33,12.5], [8.93,10.1], [7.52,8.33], [6.67,7.52], [3.34,6.67]	H_2O, CO_2, O_3, CH_4, N_2O, F11, F12, F113, H22	No	No

Table S25: Specify the solar/galactic forcing used in the simulations except SEN-C1-SSI. SWR = short-wave radiation. TSI = total solar irradiance.

Model name	Spectrally resolved irradiance data	Proton ionization	Galactic cosmic ray forcing	Consistency between SWR and photolysis	Consistency between TSI and SSI data	Solar forcing in all sims	Comments
ACCESS CCM NIWA-UKCA	Y	N	N	N	N	N	No solar variability
GEOS CCM	Y	N	N	N	N	N	
CCSR NIES MIROC3.2	Lean et al. (2005)	N	N	N	Y	Y	
CESM1 CAM4-chem	Lean et al. (2005)	N	N	N	Y	Y	
CESM1 WACCM	Lean et al. (2005)	Y	Y	N	Y	Y	
CHASER (MIROC-ESM)	Lean et al. (2005)	N	N	N	Y	Y	
EMAC	Lean et al. (2005)	N	N	Y	Y	Y	
HadGEM3-ES	Solanki and Krivova (2003)	N	N	Y	Y	Y	
LMDz-REPROBUS	Lean et al. (2005)	N	N	N	Y	Y	Monthly mean data calculated from the original daily data are used.
MRI-ESM1r1	Y	Y	N	Y	Y	Y	Monthly mean data calculated from the original daily data is used.
SOCOL	Sukhodolov et al. (2014)	Rozanov et al. (2012)	N	Y	Y	Y	

TOMCAT	Y	N	N	N	Y	Y	Dhomse et al. (2011, 2013)
ULAQ CCM	Y	N	N	Y	Y	Y	Monthly mean data calculated from the original daily data
UMSLIMCAT	Y	N	N	N	Y	Y	Dhomse et al. (2011)
UMUKCA-UCAM	Y	N	N	N	N	Y	

Table S26: Same as above, but for the SEN-C1-SSI simulations.

Model name	Spectrally resolved irradiance data	Proton ionization	Galactic cosmic ray forcing	Consistency between SWR and photolysis	Consistency between TSI and SSI data	Solar forcing in all sims	Comments
TOMCAT	Y	N	N	N	Y	Y	Dhomse et al. (2011, 2013)
ULAQ CCM	Y	N	N	Y	Y	Y	Monthly mean data calculated from the original daily data
UMSLIMCAT	Y	N	N	N	Y	Y	Dhomse et al. (2011)

Table S27: Sea surface (SST) and sea ice data sets used for CCMI simulations. HadISST is the recommended SST/sea ice dataset for the REF-C1 and SEN-C1 simulations.

Model name	SST/sea ice for REF-C1, REF-C1SD SEN-C1 (all)	SST/sea ice for REF-C2, SEN-C2	Reference for SST/sea ice used in REF-C2
ACCESS CCM	HadISST	Prescribed	
CCSRNIES MIROC3.2	HadISST	Prescribed (MIROC/IPCC-AR5)	Watanabe et al. (2010)
CESM1 CAM4-chem CESM1 WACCM	HadISST	Interactive	Meehl et al. (2013)
CHASER (MIROC-ESM)	HadISST	HadICE	Hewitt et al. (2011)
CMAM	HadISST	Prescribed (CanCM4 RCP6.0)	
CNRM-CM 5-3	REF-C1: HadISST REF-C1SD: ERA-Interim Renalysis (Dee et al., 2011)	Prescribed (CNRM-CM5.1 RCP6.0)	Voldoire et al. (2012)
EMAC	REF-C1: HadISST REF-C1SD: ERA-Interim	Prescribed (HadGEM2-ES; one sim. interactive)	Collins et al. (2011)
GEOSCCM	HadISST	Prescribed (CESM1)	Meehl et al. (2013)
GFDL-CM3/AM3	HadISST	Interactive	Griffies et al. (2011)
HadGEM3-ES	HadISST	Interactive	Rayner et al. (2003)
LMDz-REPROBUS	AMIP	Prescribed (SRES A1B IPSL)	Dufresnes et al., (2013); Szopa et al. (2013)
MRI-ESM1r1	HadISST	Interactive	Yukimoto et al. (2012)
NIWA UKCA	HadISST	Interactive	Hewitt et al. (2011)
SOCOL	HadISST	Prescribed (CESM1-CAM5)	Meehl et al. (2013)
ULAQ CCM	HadISST	Prescribed (HadISST + various CCSM4.CAM sims.)	

Table S28: Details on ocean forcing/coupling.

Model name	Atmos. Module	Ocean module	Sea ice module	Coupling frequency	Fields passed to atmosphere	Fields passed to ocean	Fields passed to sea ice	Reference
CHASER (MIROC-ESM)	CCSR/NIES AGCM	CoCo v4	MIROC	< ~1day				Watanabe et al. (2011)
EMAC	ECHAM5.3.02	MPIOM 1.3.0	MPIOM 1.3.0	2 hr	sea surface temperature ice thickness ice compactness (fraction of ice) snow thickness zonal surface water velocity meridional surface water velocity	zonal wind stress over water; meridional wind stress over water; zonal wind stress over ice; meridional wind stress over ice; solid freshwater flux; liquid freshwater flux; residual heat flux over ice; conductive heat flux over ice; net heat flux over water; downward shortwave radiation; 10 meter wind velocity;		Pozzer et al. (2011)
HadGEM3-ES	GA4.0 (UM vn8.2)	NEMO vn3.4, ORCA 1	CICE vn4.1	3 hours	Ocean SST, Sea ice fraction, Sea ice depth, snow thickness, surface layer temperature of ice, surface layer conductivity of ice, ocean surface velocity	Surface wind stress, heat flux, total rainfall, total snowfall, evaporation, 10 meter wind speed, river runoff, top melt, bottom melt, Ocean-ice stress, Freshwater fluxes, solar radiation, heat flux, ice velocity, snow and ice thickness, top layer temperature and effective conductivity.	Wind stress, Surface downward latent heat flux, GBM conductive flux through ice, GBM surface heat flux, wind speed, Incoming SW, Incoming LW, Air temperature, Potential temperature, Air density, Specific Humidity, Atmos level height, snowfall, rainfall, freezing/melting potential, SST, SSS, Surface ocean	Walters et al. (2014), Madec et al. (2008)

							current, Sea surface slope.	
LMDz-REPROBUS	LMDZ	NEMO	LIM	< ~1day	sea ice fraction and albedo, sea ice temperature, sea surface temperature	Radiative fluxes, wind stress, runoff, ice sheet melting, fresh water flux, sea ice fraction	Radiative properties, water budget, solid precipitation, wind stress over sea ice, sea surface temperature, salinity, surface current	Marti et al. (2010); Dufresnes et al. (2013)
MRI-ESM1r1	MRI-AGCM3	MRI.COM3	MRI.COM3	1 hr	temperature, salinity, and velocity in the first level, fractional area of ice pack, ice/snow thickness, temperature at the ice/snow surface	precipitation, SLP, wind at 10m, wind stress, water flux, heat fluxes, LW/SW radiation, evaporation/condensation/ sublimation, surface skin temperature	precipitation, SLP, wind at 10m, wind stress, water flux, heat fluxes, LW/SW radiation, evaporation/condensation/sublimation, surface skin temperature	Yukimoto et al. (2011)
NIWA-UKCA	GA2 (UM 7.3) N48L60	NEMO ORCA2	CICE vn4.0	1 day	ice concs., snow thickness, eff. ice depth, surface u & v, SST	surface stress, freshwater flux, solar radiation, heat flux Runoff out of ocean, salt flux, ice conc.	wind stress snowfall, rainfall, freshwater flux, heat fluxes, freezing/ melt potential, salt flux. ice conc.	Hewitt et al. (2011)

Table S29: Surface, soil, and boundary layer scheme

Model name	Land surface scheme (reference)	Soil moisture (reference)	Planetary boundary layer scheme (reference)
ACCESS CCM NIWA-UKCA UMUKCA-UCAM	Hewitt et al. (2011)	Hewitt et al. (2011)	Hewitt et al. (2011)
CESM1 CAM4-chem CESM1 WACCM			Vertical fluxes scheme: Holtslag and Boville (1993)
CHASER (MIROC-ESM)	Takata et al. (2003)	Takata et al. (2003)	
CMAM	Verseghy (2000)	Verseghy (2000)	Scinocca et al. (2008)
CNRM-CM 5-3	Noilhan and Planton (1989) Douville et al. (2000)	Noilhan and Planton (1989) Douville et al. (2000)	Boundary layer based on Louis (1982) modified by Mascart et al. (1995)
EMAC	Roeckner et al. (2003)	Roeckner et al. (2003)	Roeckner et al. (2003)
GEOSCCM	Koster et al. (2000) coupled to snow model of Stieglitz (2001)	Koster et al. (2000) coupled to snow model of Stieglitz (2001)	estimate from combined Lock (2000) with Louis and Geleyn (1982)
GFDL-CM3/AM3	Donner et al. (2011)	Donner et al. (2011)	Donner et al. (2011)
HadGEM3-ES	Walters et al. (2014)	Walters et al. (2014)	Walters et al. (2014)
LMDz-REPROBUS	Dufresnes et al. (2013)	Dufresnes et al. (2013)	Dufresnes et al. (2013)
MRI-ESM1r1	Yukimoto et al. (2011)	Yukimoto et al. (2011)	Yukimoto et al. (2011)
SOCOL	Roeckner et al. (2003)	Roeckner et al. (2003)	Roeckner et al. (2003)

Table S30: Details of nudging in the specified-dynamics simulations. ERAI = ERA-Interim (http://www.ecmwf.int/en/research/climate-reanalysis/era-interim). CIRA = Cooperative Institute for Research in the Atmosphere (http://www.cloudsat.cira.colostate.edu). MERRA = Modern Era Retrospective ReAnalysis (https://disc.gsfc.nasa.gov/mdisc/overview). NCEP/NCAR = National Center for Environmental Prediction / National Center for Atmospheric Research (http://www.esrl.noaa.gov/psd/data/gridded/data.ncep.reanalysis.html). JRA-55 = Japanese 55-year ReAnalysis (http://jra.kishou.go.jp/JRA-55/index_en.html).

Model name	Pressure/height range of nudging	Newtonian relaxation timescale	Spectral nudging (Y/N)	Nudged variables	Source of nudging data	Reference
CCSRNIES MIROC3.2	1000-1 hPa 1-0.01 hPa	1 day 1 day	Y Y	u, v, T, zonal-mean u and T	ERAI CIRA	Akiyoshi et al. (2016)
CESM1 CAM4-chem	Surface - top	50 hours	N	u, v, T, ps, surface stress, latent, sensible heat flux	MERRA	Lamarque et al. (2012)
CESM1 WACCM	Surface - 50km (transition 40-50km)	50 hours	N	u, v, T, ps, surface stress, latent, sensible heat flux	MERRA	Lamarque et al. (2012)
CHASER (MIROC-ESM)	900-10 hPa	0.8 day for u/v, 7 days for T	N	u, v, T	ERAI	
CNRM-CM 5-3	Nudging is applied to the entire atmosphere and all model levels, with a transition zone from the surface over the last five model levels.	5-hour e-folding time.	N	u, v, T, q	ERAI	Douville (2009)
EMAC	The boundary layer and the stratosphere / middle atmosphere above 10 hPa are not nudged with transition layers of intermediate strengths inbetween.	48 h 6 h 24 h 24 h	Y	Divergence vorticity temperature (with and without wave 0), (logarithm of) surface pressure	ERAI	Jöckel et al. (2016)
GFDL-AM3	Surface to 10 hPa	6 h (surface) 60 h (100 hPa) 600 h (10 hPa)	N	u, v	NCEP/NCAR	Lin et al. (2012a; 2014; 2015a; 2015b).
HadGEM3-ES	2.6km-51.1km	1 day	N	u, v, T	ERAI with anomaly correction following McLandress et al. (2014)	McLandress et al. (2014)
LMDz-REPROBUS	Surface to 0.1 hPa	3 hrs for u and v 0.5 hrs for T	N	u, v, T	ERAI	Dufresnes et al., (2013)
MOCAGE	Surface to 5 hPa	Direct CTM	N	u, v, T, q	ERAI	
MRI-ESM1r1	870-1 hPa	24 h (870-40 hPa) 24-∞ h (40-1 hPa)	N	u, v, T	JRA-55	Deushi and Shibata (2011)
TOMCAT	Surface to 60 km	Direct CTM	N	u, v, T	ERAI	Chipperfield (2006)