How does internal variability influence the ability of CMIP5 models to reproduce the recent trend in Southern Ocean sea ice extent?

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SUPPLEMENTARY MATERIAL

Model Name	Atmospheric component	Oceanic component	Sea ice component	References
BCC-CSM1.1	BCC_AGCM2.1; 26 vertical layers, T42	MOM4_L40; 40 vertical layers, tripolar grid $1^\circ\times$ (1-1/3)$^\circ$	SIS; tripolar grid $1^\circ\times$ (1-1/3)$^\circ$	`http://www.lasg.ac.cn/C20C/UserFiles/File/C20C-xin.pdf`
CanESM2	CanAM4; 35 vertical layers, T63	CanOM4; 40 vertical layers, $\sim 1.4^\circ \times 0.9^\circ$	CanSIM1; T63 Gaussian Grid	`http://www.cccma.ec.gc.ca/models`
CCSM4	CAM4; 26 vertical layers, $1.25^\circ \times 0.9^\circ$	POP2; 60 vertical layers, $1.11^\circ \times (0.27 - 0.54)^\circ$	CICE4; $1.11^\circ \times (0.27 - 0.54)^\circ$	Gent et al. (2011)
CNRM-CM5	ARPEGE-CLIMAT v5.2; 31 vertical layers, T127	NEMO v3.2; 42 vertical layers, ORCA-1°	GELATO v5; ORCA-1°	Voldoire et al. (2012)
CSIRO-Mk3.6.0	Mk3.6 atmospheric component; 18 vertical layers, T63	Mk3.6 ocean component; 31 vertical layers, $\sim 1.875^\circ \times 0.9375^\circ$	Sea ice sub-component of Mk3.6 (part of the AGCM); T63	Rotstayn et al. (2010)
EC-EARTH	IFS; 62 vertical layers, T159	NEMO v2; 42 vertical layers, ORCA-1°	LIM2; ORCA-1°	Hazeleger et al. (2011)
FGOALS-g2	GAMIL2; 26 vertical layers, $\sim 2.8^\circ \times 3^\circ$	LICOM2; 30 vertical layers, $\sim 1^\circ \times 1^\circ$	CICE; $\sim 1^\circ \times 1^\circ$	Zhang and Yu (2011)
FGOALS-s2	SAMIL2; 26 vertical layers, R42	LICOM2; 30 vertical layers, (0.5-1)$^\circ\times$(0.5-1)$^\circ$	CSIM5; (0.5-1)$^\circ\times$(0.5-1)$^\circ$	Bao et al. (submitted)
GFDL-CM3	AM3p9; 48 vertical layers, C48	MOM4p1; 50 vertical layers, tripolar grid $\sim 1^\circ \times 1^\circ$	SISp2; tripolar grid, $\sim 1^\circ \times 1^\circ$	Griffies et al. (2011)
GFDL-ESM2M	AM2p14; 24 vertical layers, M45	MOM4p1; 50 vertical layers; tripolar grid $\sim 1^\circ \times 1^\circ$	SISp2; tripolar grid $\sim 1^\circ \times 1^\circ$	Dunne et al. (2012)
GISS-E2-R	ModelE; 40 vertical layers, $2^\circ\times2.5^\circ$	Russell; 32 vertical layers, $1^\circ\times$ 1.25°	Russel; $1^\circ\times$ 1.25°	`http://data.giss.nasa.gov/modelE/ar5/`
HadCM3	HadAM3; 19 vertical layers, $3.75^\circ\times2.5^\circ$	HadOM3; 20 vertical layers, $1.25^\circ\times1.25^\circ$	Sea ice component of HadOM3; $1.25^\circ\times1.25^\circ$	Collins et al. (2001)
HadGEM2-CC	HadGAM2; 60 vertical layers, N96	HadGOM2; 40 vertical layers, (1-0.3)$^\circ\times1^\circ$	Inspired from CICE	Martin et al. (2011)
HadGEM2-ES	HadGAM2; 38 vertical layers, N96	HadGOM2; 40 vertical layers, (1-0.3)$^\circ\times1^\circ$	Inspired from CICE	Martin et al. (2011)
INM-CM4	INM-CM4 atmospheric component, 21 vertical layers, $2^\circ\times1.5^\circ$	INM-CM4 ocean component; 40 vertical layers, $1^\circ\times0.5^\circ$	INM-CM4 ocean component; $1^\circ\times0.5^\circ$	Volodin et al. (2010)
IPSL-CM5A-LR	LMDZ4 v5; 39 vertical layers, $\sim 2^\circ \times 4^\circ$	NEMO v2.3; 31 vertical layers, ORCA-2°	LIM2; ORCA-2°	`http://icmc.ipsl.fr/`
IPSL-CM5A-MR	LMDZ4 v5; 39 vertical layers, $\sim 1.25^\circ \times 2.5^\circ$	NEMO v2.3; 31 vertical layers, ORCA-2°	LIM2; ORCA-2°	`http://icmc.ipsl.fr/`
MIROC4h	CCSR/NIES/FRCGC AGCM v5.7; 56 vertical layers, T213	COCO v3.4; 48 vertical layers, rotated pole, $0.28^\circ\times$ 0.19°	COCOv3.4; rotated pole, $0.28^\circ\times$ 0.19°	Sakamoto et al. (2012)
MROC5	CCSR/NIES/FRCGC AGCM; 40 vertical layers, T85	COCO v4.5; 49 vertical layers, $1.4^\circ\times$(0.5-1.4)$^\circ$	COCO v4.5; $1.4^\circ\times$(0.5-1.4)$^\circ$	Watanabe et al. (2010)
MIROC-ESM	CCSR/NIES/FRCGC AGCM; 80 vertical layers, T42	COCO v3.4; 44 vertical layers, $\sim 1.4^\circ \times 1^\circ$	COCO v3.4; $\sim 1.4^\circ \times 1^\circ$	Watanabe et al. (2011)
MIROC-ESM-CHEM	CCSR/NIES/FRCGC AGCM; 80 vertical layers, T42	COCO v3.4; 44 vertical layers; $\sim 1.4^\circ \times 1^\circ$	COCO v3.4; $\sim 1.4^\circ \times 1^\circ$	Watanabe et al. (2011)
MPI-ESM-LR	ECHAM6; 47 vertical layers, T63	MPI-OM; 40 vertical layers, $\sim 1.5^\circ\times1.5^\circ$	Sea ice component of MPI-OM; $\sim 1.5^\circ\times1.5^\circ$	Raddatz et al. (2007)
MRI-CGCM3	GSMUV; 48 vertical layers, TL159	MRI.COM3; 51 vertical layers, $1^\circ\times0.5^\circ$	MRI.COM3; $1^\circ\times0.5^\circ$	Yukimoto et al. (2011)
NorESM1-M	26 vertical layers, F19	53 vertical layers	No information available to us.	No information available to us.

Table S1: Summary of the 24 models used in the analysis.

	1979-2005 sea ice extent ($10^6 km^2$)		1979-2005 trend in sea ice extent ($10^3 km^2$/decade)		
	Ensemble mean of seasonal means	Ensemble mean of seasonal standard deviations	Individual members	Ensemble mean	Ensemble standard deviation
BCC-CSM1-1	3.89	0.70	**-902.03** -132.44 -50.97	-361.81	469.61
CanESM2	4.13	0.71	**-880.51** **-728.81** -671.28 **-634.06** -110.28	-604.99	292.07
CCSM4	12.06	0.69	**-967.65** **-819.56** **-685.12** **-478.24** -195.45 8.56	-522.91	375.18
CNRM-CM5	0.16	0.08	-120.24 **-111.03** **-80.98** **-73.90** **-73.72** -54.79 -40.41 -36.38 -26.56 -0.19	-61.82	37.54
CSIRO-Mk3.6.0	10.45	0.70	-557.15 **-514.10** -325.14 -240.38 -183.97 -45.54 -23.27 -2.12 13.01 **371.72**	-150.69	276.07
EC-Earth	2.35	0.43	-32.41	-32.41	–
FGOALS-g2	7.15	0.46	0.83	0.83	–
FGOALS-s2	6.71	0.57	-465.78 -369.16 -343.86	-392.93	64.34
GFDL-CM3	0.63	0.22	-126.66 -31.00 27.83 134.95 142.06	29.44	113.84
GFDL-ESM2M	0.44	0.13	**-116.49**	-116.49	–
GISS-E2-R	0.66	0.14	-39.52 -25.73 10.50 14.65 59.69	3.92	38.84
HadCM3	5.00	0.39	**-411.58** **-252.60** **-229.59** **-229.57** -207.29 -179.35 -132.36 -79.55 -19.43 20.64	-172.07	125.76
HadGEM2-CC	2.72	0.35	-114.61	-114.61	–
HadGEM2-ES	3.04	0.37	**-326.27**	-326.27	–
INM-CM4	1.27	0.41	**-268.62**	-268.62	–
IPSL-CM5A-LR	1.04	0.24	**-289.85** **-158.40** -132.87 -98.51	-169.91	83.64
IPSL-CM5A-MR	0.50	0.17	-89.76	-89.76	–
MIROC4h	2.48	0.36	**-500.60** **-343.58** -330.13	-391.43	94.78
MIROC5	0.19	0.05	-10.94	-10.94	–
MIROC-ESM	3.70	0.42	-469.10 **-450.42** **-418.50**	-446.01	25.59
MIROC-ESM-CHEM	4.02	0.39	**-240.84**	-240.84	–
MPI-ESM-LR	1.64	0.34	-208.42 -83.99 -67.01	-119.81	77.21
MRI-CGCM3	4.55	0.37	**-643.00** -203.22 132.63	-237.86	388.98
NorESM1-M	5.93	0.54	-139.58 -135.12 -86.09	-120.27	29.68
Observations	3.96	0.32	148.69	–	–

Table S2: Summer (JFM) sea ice extent: 1979-2005 seasonal mean and trend, computed from the historical simulations. The ensemble mean of seasonal means is the average over all the JFM extents of the individual members of one model historical simulation. The ensemble mean of seasonal standard deviations is the mean of all the seasonal standard deviations of the individual members. The ensemble mean of the trends is the mean of all the trends of the individual members and the ensemble standard deviation of the trend is the standard deviation of the trend between members. Trends that are significant at the 95% level are in bold. The autocorrelation of the residuals has been taken into account in both the standard deviation of each trend and in the number of degrees of freedom used to to determine the significance threshold (see for instance Santer et al., 2000; Stroeve et al., 2012). Details about the observations are given in Cavalieri and Parkinson (2008).

	1979-2005 sea ice extent (10^6km^2)		1979-2005 trend in sea ice extent (10^3km^2/decade)		
	Ensemble mean of seasonal means	Ensemble mean of seasonal standard deviations	Individual members	Ensemble mean	Ensemble standard deviation
BCC-CSM1-1	20.94	1.32	-2522.87 422.24 434.57	-555.35	1703.93
CanESM2	21.02	0.64	**-904.52** **-878.38** **-826.56** -819.50 -67.45	-699.28	354.99
CCSM4	22.76	0.40	**-767.07** **-741.68** **-649.03** **-559.13** -551.02 -122.50	-565.07	234.58
CNRM-CM5	13.95	0.90	**-2172.40** **-1245.13** **-1019.92** -827.53 **-646.85** -580.44 -506.43 -445.84 -262.46 -165.47	-787.25	587.27
CSIRO-Mk3.6.0	17.81	0.46	**-617.24** **-494.90** **-427.46** -323.45 **-285.16** -201.11 -196.83 -58.77 -3.14 56.81	-255.13	218.47
EC-Earth	17.93	0.72	-147.14	-147.14	–
FGOALS-g2	21.78	0.41	-205.75	-205.75	–
FGOALS-s2	22.62	0.96	-967.45 -917.19 -775.29	-886.64	99.66
GFDL-CM3	11.86	1.07	**-1116.57** -288.07 472.70 766.19 1299.64	226.78	945.00
GFDL-ESM2M	11.76	0.45	-178.78	-178.78	–
GISS-E2-R	12.31	0.78	-607.23 -373.34 -282.37 -179.70 -88.96	-306.32	199.30
HadCM3	19.84	0.71	**-682.10** -654.18 **-647.19** **-521.33** **-424.63** **-414.32** **-377.90** -317.35 -222.93 -4.44	-426.64	213.14
HadGEM2-CC	13.61	0.83	-72.26	-72.26	–
HadGEM2-ES	14.60	0.78	-412.92	-412.92	–
INM-CM4	9.35	0.46	**-459.18**	-459.18	–
IPSL-CM5A-LR	19.12	1.00	-768.83 -573.81 -553.79 325.71	-392.68	488.65
IPSL-CM5A-MR	16.72	0.85	338.90	338.90	–
MIROC4h	17.89	0.54	**-1107.68** **-740.15** **-542.24**	-796.69	286.93
MIROC5	5.42	0.38	-135.04	-135.04	–
MIROC-ESM	20.75	0.76	**-735.34** -575.80 **-519.86**	-610.33	111.82
MIROC-ESM-CHEM	21.33	0.57	-237.01	-237.01	–
MPI-ESM-LR	13.87	1.14	-509.02 -53.14 208.48	-117.89	363.11
MRI-CGCM3	18.75	0.73	**-726.16** -330.31 127.28	-309.73	427.09
NorESM1-M	18.48	0.50	-409.14 -166.62 -50.12	-208.63	183.16
Observations	17.17	0.25	85.57	–	–

Table S3: Winter (JAS) sea ice extent: 1979-2005 seasonal mean and trend, computed from the historical simulations. The ensemble mean of seasonal means is the average over all the JAS extents of the individual members of one model historical simulation. The ensemble mean of seasonal standard deviations is the mean of all the seasonal standard deviations of the individual members. The ensemble mean of the trends is the mean of all the trends of the individual members and the ensemble standard deviation of the trend is the standard deviation of the trend between members. Trends that are significant at the 95% level are in bold. The autocorrelation of the residuals has been taken into account in both the standard deviation of each trend and in the number of degrees of freedom used to determine the significance threshold (see for instance Santer et al., 2000; Stroeve et al., 2012). Details about the observations are given in Cavalieri and Parkinson (2008).

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