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The Cryosphere
Discussions

Interactive comment on "How does internal variability influence the ability of CMIP5 models to reproduce the recent trend in Southern Ocean sea ice extent?" *by* V. Zunz et al.

V. Zunz et al.

violette.zunz@uclouvain.be

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The authors warmly thank Anonymous Referee #3 for the relevant and encouraging comments on the manuscript. These suggestions helped us to improve our paper and to strengthen our conclusion.

The present answer gives a point-by-point response to the comments of Anonymous Referee #3. The referee's comments are in italic font and the author's response in upright font.

We also provide a new version of the manuscript (with changes highlighted in red) as a supplement to this comment.

Response to Anonymous Referee #3's comments

Overall, this paper is well written and its subject is relevant and timely. I just have some minor points:

1. *Why only use data 1979-2005? I understand that CMIP5 historical runs end in 2005, but you could probably use the 21st century scenarios that follow on. The evolution in observations since 2005 reinforces the upward trend. It'd be interesting to know if the few CMIP5 runs that do have a positive trend 1979-2005 maintain it to 2012.*

   Response: In order to properly investigate the internal variability of the models, we have used data over the historical period as defined by the CMIP5 protocol (until 2005) because there were more members available in the historical simulations than in the 21st century scenarios simulations (starting in 2006).

2. *I also miss a discussion of whether the degree of drift in the models after initialization affects the predictability results shown in figs 5 and 6. While there is overall little pre- dictability, it would be interesting to know how the magnitude of the initial shock, or drift, affects such predictability.*

   Response: Indeed, it would have been interesting to study how the magnitude of the initial shock impacts the predictability. However, to adress this issue, we would have needed, for a given model, simulations experiencing different kind and amplitude of initial shock (e.g. an initial shock on surface variables only, an initial shock affecting the 3D ocean, etc.) or simulations using different initialization methods. Consequently, it is not possible to properly investigate this question in the framework of an analysis of CMIP5 models.

3. *I find it a bit odd that nowhere in the paper you mention the levels of significance of your computed trends. This is a good way to account for how (internal) variability and the trend relate in a timeseries- e.g., in observations, not all seasonal trends have the same level of significance. Perhaps one suggestion would be for the figures showing trends to differentiate those trends that are significant (say above 95% level) from those that aren't. I suspect this might enforce your points on the influence of the effect of internal variability on the trend.*

   Action: We now discuss the level of significance of the computed trend in Sect. 3.2. We have added two tables in the supplementary material of the paper. These tables summarize the results of the models. In particular, we give the values of the trend computed for each member of all model ensembles. Significant trends at the 90% level appear in bold.

4. *I feel that the Summary and Conclusions section could do with some clearer language, particularly the last 3 paragraphs- they feel like they were written in a hurry, and inci- dentally have the highest frequency of typos in the paper.*

   Action: The Summary and conclusions section has been largely re-written to present more clearly the issues addressed in the paper and the answers provided by our analyses.

Please also note the supplement to this comment:
http://www.the-cryosphere-discuss.net/6/C2450/2012/tcd-6-C2450-2012-supplement.pdf

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Interactive comment on The Cryosphere Discuss., 6, 3539, 2012.

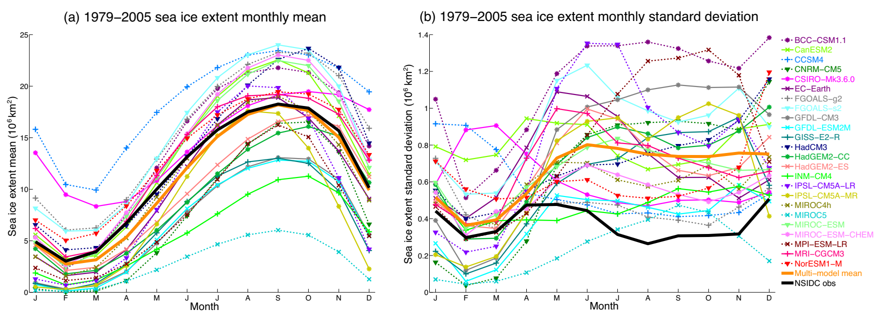

Fig. 2. **(a)** Monthly mean of Southern Ocean sea ice extent, computed over the period 1979–2005. **(b)** Standard deviation of detrended Southern Hemisphere sea ice extent, computed over the period 1979–2005 for each month of the year. Colors correspond to the ensemble mean of historical simulations from 24 different models. Dotted lines refer to models that provide both historical and hindcast simulations but here, results are only from historical simulations. Orange bold line is the multi-model mean. Black bold line refers to observations (Cavalieri and Parkinson, 2008).

Fig. 1. New version of Fig. 2

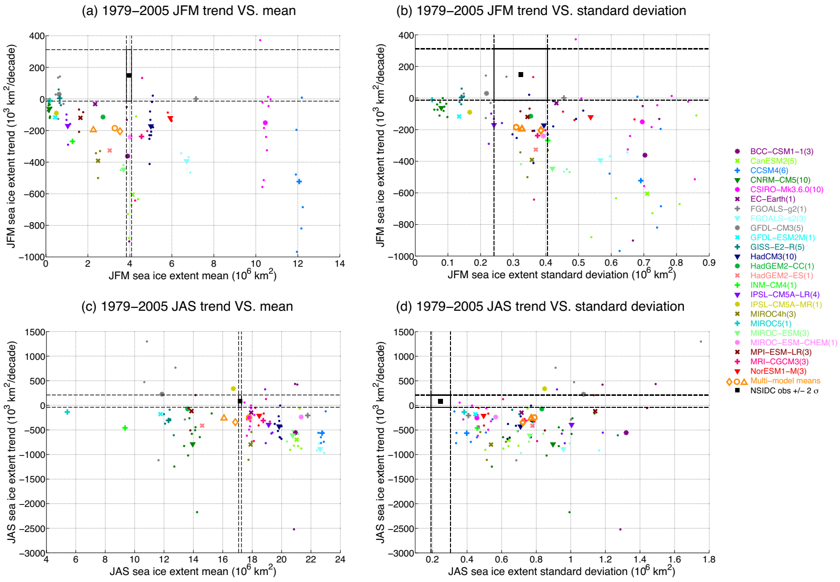

Fig. 3. Sea ice extent trend for the period 1979–2005 over the whole Southern Ocean vs. mean **(a, c)** and standard deviation **(b, d)**. The first row corresponds to summer (JFM), the second to winter (JAS). The different colors correspond to the historical simulations from 24 different models. For each color, the small dots refer to model individual members and the symbol specified in the legend is for the model ensemble mean. The number of members in each model is indicated in brackets in the legend. Orange refers to multi-model means: diamond sign is for the average over all the models, circle sign is for the mean of models with interactive chemistry (in bold in Table 2) and triangle sign is for the mean of models with 35 atmospheric levels or more on the vertical. Black square is for the observations (Cavalieri and Parkinson, 2008), surrounded by 2 standard deviations (black dashed lines).

Fig. 2. New version of Fig. 3

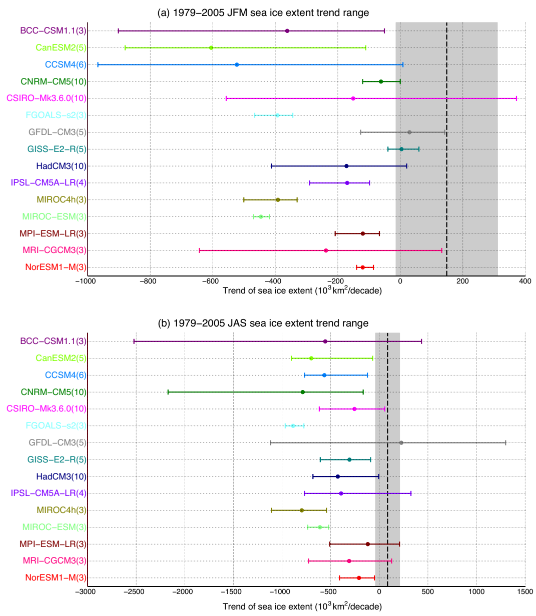

Fig. 4. Ensemble mean, minimum and maximum value of the sea ice extent trend for the period 1979–2005 over the whole Southern Ocean for summer **(a)** and winter **(b)**. The different colors correspond to the historical simulations from the 15 models that have at least 3 members in their ensemble. Dots refer to the ensemble means of the trends. Horizontal bars show the minimum and the maximum value of the trend reached by the members of one model ensemble. Black dashed line is for the trend of the observations (Cavalieri and Parkinson, 2008) surrounded by 2 standard deviations (grey shade).

Fig. 3. New figure

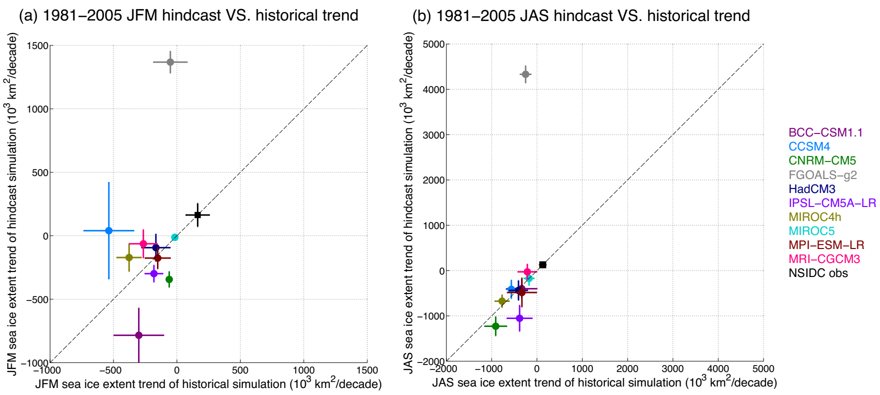

Fig. 5. Hindcast vs. historical Southern Ocean sea ice extent trend for summer **(a)** and winter **(b)**, computed over the period 1981–2005. The different colors refer to the different models. For each model, the dot refers to the ensemble mean of the trends and the horizontal (vertical) bar shows the ensemble mean of the standard deviations of the trends in the historical (hindcast) simulations. Black square is for the trend of the observations (Cavalieri and Parkinson, 2008). The vertical and the horizontal black bars are for the standard deviation of the observed trend. Dashed line represents the line $y(x) = x$.

Fig. 4. New version of Fig. 4 (now Fig. 5)

	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 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	3.7	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** **-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 a 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 90% level are in bold. Details about the observations are given in in Cavalieri and Parkinson (2008).

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Fig. 5. New table in the supplementary material

	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	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	199.3
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	338.9	338.90	–
0 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 a 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 90% level are in bold. Details about the observations are given in in Cavalieri and Parkinson (2008).

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Fig. 6. New table in the supplementary material