



Supplement of

Seamless seasonal to multi-annual predictions of temperature and Standardized Precipitation Index by constraining transient climate model simulations

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Model	Institution	Reference	Members	Number of members	DOI
ACCESS-CM2	CSIRO-ARCCSS	Bi et al. (2020)	r[1-3]ilp1f1	3	https://doi.org/10.1071/ES19040
ACCESS-ESM1-5	CSIRO	Ziehn et al. (2020)	r[4-6,8-10]ilp1f1	6	https://doi.org/10.1071/ES19035
CanESM5	CCCma	Swart et al. (2019)	r[1-25]ilp2f1	25	https://doi.org/10.5194/gmd-12-4823-2019
CMCC-ESM2	CMCC	Lovato et al. (2022)	rlilp1f1	1	https://doi.org/10.1029/2021MS002814
CNRM-CM6-1	CNRM-CERFACS	Voldoire et al. (2019)	rlilp1f2	1	https://doi.org/10.1029/2019MS001683
CNRM-ESM2-1	CNRM-CERFACS	Séférián et al. (2019)	rlilp1f2	1	https://doi.org/10.1029/2019MS001791
EC-Earth3	EC-Earth Consortium	Döscher et al. (2022)	r[2,7,10,14,16-24]ilp1f1	13	https://doi.org/10.5194/gmd-15-2973-2022
FGOALS-g3	CAS	Pu et al. (2020)	r[1,3]ilp1f1	2	https://doi.org/10.1007/s00376-020-2032-0
HadGEM3-GC31-LL	MOHC	Andrews et al. (2020)	rlilp1f3	1	https://doi.org/10.1029/2019MS001995
INM-CM5-0	INM	Volodin et al. (2017)	rlilp1f1	1	https://doi.org/10.1007/s00382-017-3539-7
IPSL-CM6A-LR	IPSL	Boucher et al. (2020)	r[1-6,10,11,14,22,25]ilp1f1	11	https://doi.org/10.1029/2019MS002010
MIROC6	MIROC	Tatebe et al. (2019)	r[1-3,21-50]ilp1f1	33	https://doi.org/10.5194/gmd-12-2727-2019
MIROC-ES2L	MIROC	Hajima et al. (2020)	r[1-30]ilp1f2	30	https://doi.org/10.5194/gmd-13-2197-2020
MPI-ESM1-2-LR	MPI-M	Mauritsen et al. (2019)	r[1-10]ilp1f1	10	https://doi.org/10.1029/2018MS001400
MRI-ESM2-0	MRI	Yukimoto et al. (2019)	rlilp1f1	1	https://doi.org/10.2151/jmsj.2019-051
NESM3	NUIST	Cao et al. (2018)	rlilp1f1	1	https://doi.org/10.5194/gmd-11-2975-2018
NorESM2-LM	NCC	Seland et al. (2020)	r[1-3]ilp1f1	3	https://doi.org/10.5194/gmd-13-6165-2020
NorESM2-MM	NCC	Seland et al. (2020)	rlilp1f1	1	https://doi.org/10.5194/gmd-13-6165-2020
UKESM1-0-LL	NIMS-KMA	Sellar et al. (2019)	r[1-4,8]ilp1f2	5	https://doi.org/10.1029/2019MS001946

Table S1: CMIP6 models and members used in this study.

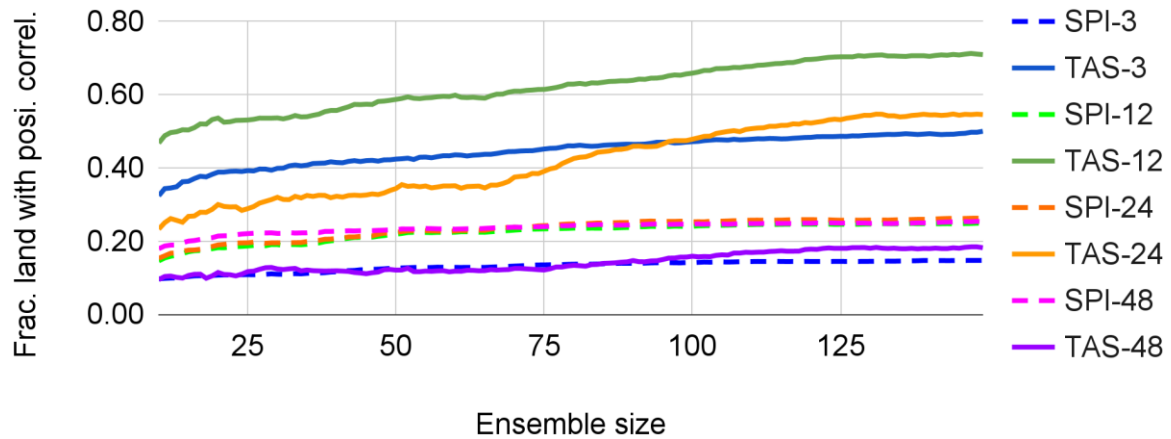


Figure S1: Fraction of land area with statistically significant positive correlation ($p < 0.10$) using a two-sided t-test for 3-, 12-, 24- and 48-monthly mean TAS, and SPI3, 12, 24 and 48, and the respective observations, as a function of ensemble size. The displayed values are based on residual correlations for TAS to remove the impact from the forced signal.

Forecast Period	TAS - 3 months		
	SST comparison length		
	1 month	3 months	Indo-Paci. SSTs 1 mon.
Dec-Feb+1	0.42	0.43	0.36
Jan-Mar	0.48	0.44	0.35
Feb-Apr	0.46	0.46	0.42
Mar-May	0.44	0.44	0.40
Apr-Jun	0.38	0.40	0.34
May-Jul	0.38	0.38	0.35
Jun-Aug	0.47	0.46	0.45
Jul-Sep	0.52	0.55	0.38
Aug-Oct	0.55	0.50	0.41
Sep-Nov	0.46	0.44	0.42
Oct-Dec	0.42	0.46	0.32
Nov-Jan+1	0.45	0.43	0.35
Mean	0.45	0.45	0.38

Table S2: Fraction of land area with statistically significant positive residual correlation ($p < 0.10$) using a two-sided t-test, between the 3-month TAS analog predictions and the respective observations for the 12 different 3-month periods throughout the year (rows) and different SST period of comparison for the analog selection (columns). The last column follows the methodology described in Ding et al. (2018). The darker the shading, the higher the residual correlation. All forecasts are initialized with a one-month lead time. The period of analysis is 1962-2018.

Forecast Period	SPI3		
	SST comparison length		
	1 month	3 months	Indo-Paci. SSTs 1 mon
Dec-Feb+1	0.16	0.16	0.16
Jan-Mar	0.15	0.16	0.15
Feb-Apr	0.15	0.16	0.14
Mar-May	0.13	0.14	0.14
Apr-Jun	0.12	0.12	0.11
May-Jul	0.11	0.11	0.11
Jun-Aug	0.10	0.09	0.10
Jul-Sep	0.13	0.10	0.12
Aug-Oct	0.17	0.12	0.15
Sep-Nov	0.16	0.16	0.16
Oct-Dec	0.18	0.19	0.17
Nov-Jan+1	0.16	0.18	0.18
Mean	0.14	0.14	0.14

Table S3: Fraction of land area with statistically significant positive correlation ($p < 0.10$) using a two-sided t-test, between the SPI3 analog predictions and the respective observations for the 12 different 3-month periods throughout the year (rows) and different SST period of comparison for the analog selection (columns). The last column follows the methodology described in Ding et al. (2018). The darker the shading, the higher the residual correlation. All forecasts are initialized with a one-month lead time. The period of analysis is 1962-2018.

Forecast Period	TAS - 12 months			
	SST comparison length			
	1 month	3 months	6 months	12 months
Jan-Dec	0.49	0.49	0.49	0.48
Feb-Jan+1	0.47	0.46	0.51	0.41
Mar-Feb+1	0.48	0.44	0.49	0.45
Apr-Mar+1	0.43	0.35	0.46	0.39
May-Apr+1	0.45	0.40	0.39	0.46
Jun-May+1	0.52	0.39	0.34	0.44
Jul-Jun+1	0.53	0.45	0.34	0.40
Aug-Jul+1	0.54	0.45	0.39	0.38
Sep-Aug+1	0.56	0.49	0.46	0.37
Oct-Sep+1	0.52	0.50	0.50	0.43
Nov-Oct+1	0.52	0.51	0.47	0.41
Dec-Nov+1	0.54	0.49	0.50	0.47
Mean	0.50	0.45	0.44	0.42

Table S4: Like Table S2 but for 12-month TAS predictions and for 4 different SST periods of comparison for the analog selection.

Forecast Period	SPI12			
	SST comparison length			
	1 month	3 months	6 months	12 months
Jan-Dec	0.13	0.13	0.12	0.13
Feb-Jan+1	0.13	0.14	0.12	0.12
Mar-Feb+1	0.14	0.12	0.13	0.12
Apr-Mar+1	0.13	0.13	0.12	0.12
May-Apr+1	0.14	0.14	0.13	0.13
Jun-May+1	0.16	0.15	0.13	0.14
Jul-Jun+1	0.17	0.17	0.14	0.14
Aug-Jul+1	0.18	0.17	0.16	0.15
Sep-Aug+1	0.18	0.18	0.16	0.15
Oct-Sep+1	0.16	0.18	0.17	0.16
Nov-Oct+1	0.14	0.15	0.16	0.14
Dec-Nov+1	0.15	0.15	0.15	0.14
Mean	0.15	0.15	0.14	0.14

Table S5: Like Table S3 but for SPI12 predictions and for 4 different SST periods of comparison for the analog selection.

Forecast Period	TAS - 24 months					
	SST comparison length					
	1 month	3 months	6 months	8 months	12 months	24 months
Jan-Dec+1	0.38	0.39	0.45	0.50	0.38	0.33
Feb-Jan+2	0.40	0.34	0.35	0.41	0.36	0.33
Mar-Feb+2	0.38	0.38	0.35	0.40	0.40	0.26
Apr-Mar+2	0.35	0.35	0.33	0.42	0.33	0.29
May-Apr+2	0.40	0.39	0.32	0.38	0.43	0.33
Jun-May+2	0.41	0.42	0.36	0.36	0.39	0.32
Jul-Jun+2	0.48	0.43	0.36	0.36	0.35	0.33
Aug-Jul+2	0.50	0.46	0.40	0.34	0.35	0.30
Sep-Aug+2	0.54	0.50	0.39	0.35	0.33	0.30
Oct-Sep+2	0.48	0.53	0.43	0.41	0.34	0.30
Nov-Oct+2	0.46	0.52	0.51	0.41	0.34	0.32
Dec-Nov+2	0.43	0.48	0.47	0.44	0.40	0.32
Mean	0.43	0.43	0.39	0.40	0.37	0.31

Table S6: Like Table S2 but for 24-month TAS predictions and for 6 different SST periods of comparison for the analog selection.

Forecast Period	SPI24					
	SST comparison length					
	1 month	3 months	6 months	8 months	12 months	24 months
Jan-Dec+1	0.16	0.17	0.18	0.17	0.15	0.16
Feb-Jan+2	0.17	0.16	0.17	0.14	0.17	0.15
Mar-Feb+2	0.15	0.15	0.17	0.15	0.19	0.15
Apr-Mar+2	0.15	0.16	0.17	0.14	0.18	0.15
May-Apr+2	0.15	0.15	0.16	0.14	0.17	0.16
Jun-May+2	0.17	0.16	0.16	0.15	0.17	0.17
Jul-Jun+2	0.18	0.16	0.16	0.18	0.17	0.17
Aug-Jul+2	0.19	0.18	0.17	0.20	0.16	0.16
Sep-Aug+2	0.20	0.20	0.16	0.19	0.17	0.18
Oct-Sep+2	0.20	0.20	0.18	0.22	0.17	0.16
Nov-Oct+2	0.18	0.18	0.19	0.19	0.17	0.16
Dec-Nov+2	0.17	0.19	0.18	0.18	0.15	0.15
Mean	0.17	0.17	0.17	0.17	0.17	0.16

Table S7: Like Table S3 but for SPI24 predictions and for 6 different SST periods of comparison for the analog selection.

Forecast Period	TAS - 3 months							
	Method 1		Method 2		Method 3		Method 4	
	1 analog	5 analogs	1 analog	5 analogs	1 analog	5 analogs	1 analog	5 analogs
Dec-Feb+1	0.43	0.42	0.38	0.43	0.38	0.43	0.42	0.42
Jan-Mar	0.49	0.41	0.40	0.41	0.44	0.40	0.48	0.42
Feb-Apr	0.45	0.48	0.38	0.44	0.46	0.48	0.46	0.47
Mar-May	0.44	0.41	0.40	0.41	0.44	0.42	0.44	0.42
Apr-Jun	0.37	0.39	0.34	0.38	0.35	0.37	0.38	0.38
May-Jul	0.38	0.34	0.37	0.35	0.39	0.34	0.38	0.34
Jun-Aug	0.47	0.46	0.42	0.50	0.48	0.49	0.47	0.47
Jul-Sep	0.48	0.48	0.46	0.52	0.52	0.48	0.52	0.51
Aug-Oct	0.52	0.47	0.51	0.54	0.52	0.50	0.55	0.48
Sep-Nov	0.47	0.45	0.41	0.47	0.44	0.45	0.46	0.46
Oct-Dec	0.46	0.40	0.51	0.43	0.45	0.43	0.42	0.40
Nov-Jan+1	0.42	0.41	0.40	0.42	0.44	0.41	0.45	0.41
Mean	0.14	0.15	0.13	0.15	0.13	0.14	0.14	0.15

Table S8: Fraction of land area with statistically significant positive residual correlation ($p < 0.10$) using a two-sided t-test, between the 3-month TAS analog predictions and the respective observations for the 12 different 3-month periods throughout the year (rows) and for the different methods tested (columns). The darker the shading, the higher the residual correlation. All forecasts are initialized with a one-month lead time. The period of analysis is 1962-2018.

Forecast Period	SPI3							
	Method 1		Method 2		Method 3		Method 4	
	1 analog	5 analogs	1 analog	5 analogs	1 analog	5 analogs	1 analog	5 analogs
Dec-Feb+1	0.15	0.16	0.14	0.16	0.14	0.16	0.16	0.17
Jan-Mar	0.14	0.17	0.12	0.17	0.13	0.17	0.15	0.17
Feb-Apr	0.15	0.16	0.15	0.16	0.13	0.15	0.15	0.17
Mar-May	0.13	0.15	0.11	0.14	0.12	0.13	0.13	0.15
Apr-Jun	0.12	0.12	0.12	0.13	0.11	0.12	0.12	0.11
May-Jul	0.11	0.12	0.10	0.11	0.10	0.11	0.11	0.12
Jun-Aug	0.10	0.11	0.09	0.11	0.09	0.11	0.10	0.11
Jul-Sep	0.13	0.12	0.10	0.11	0.11	0.12	0.13	0.12
Aug-Oct	0.14	0.14	0.13	0.14	0.14	0.14	0.14	0.14
Sep-Nov	0.16	0.17	0.14	0.17	0.14	0.17	0.16	0.17
Oct-Dec	0.18	0.19	0.16	0.19	0.16	0.19	0.18	0.19
Nov-Jan+1	0.16	0.18	0.15	0.18	0.16	0.17	0.16	0.18
Mean	0.14	0.15	0.13	0.15	0.13	0.14	0.14	0.15

Table S9: Fraction of land area with statistically significant positive correlation ($p < 0.10$) using a two-sided t-test, between the SPI3 analog predictions and the respective observations for the 12 different 3-month periods throughout the year (rows) and for the different methods tested (columns). The darker the shading, the higher the correlation. All forecasts are initialized with a one-month lead time. The period of analysis is 1962-2018.

Forecast Period	TAS - 12 months							
	Method 1		Method 2		Method 3		Method 4	
	1 analog	5 analogs	1 analog	5 analogs	1 analog	5 analogs	1 analog	5 analogs
Jan-Dec	0.47	0.47	0.42	0.46	0.41	0.42	0.49	0.44
Feb-Jan+1	0.45	0.41	0.40	0.38	0.45	0.33	0.46	0.38
Mar-Feb+1	0.43	0.45	0.45	0.42	0.47	0.43	0.44	0.45
Apr-Mar+1	0.34	0.41	0.38	0.45	0.37	0.47	0.35	0.41
May-Apr+1	0.39	0.40	0.32	0.43	0.39	0.44	0.40	0.40
Jun-May+1	0.37	0.36	0.39	0.42	0.36	0.37	0.39	0.36
Jul-Jun+1	0.47	0.43	0.45	0.44	0.43	0.44	0.45	0.43
Aug-Jul+1	0.43	0.45	0.45	0.44	0.45	0.48	0.45	0.44
Sep-Aug+1	0.49	0.47	0.49	0.47	0.47	0.52	0.49	0.47
Oct-Sep+1	0.49	0.49	0.48	0.51	0.50	0.55	0.50	0.51
Nov-Oct+1	0.50	0.49	0.48	0.51	0.55	0.56	0.51	0.54
Dec-Nov+1	0.46	0.46	0.45	0.52	0.50	0.54	0.49	0.48
Mean	0.44	0.44	0.43	0.45	0.45	0.46	0.45	0.44

Table S10: Like Table S8 but for 12-month TAS predictions.

Forecast Period	SPI12							
	Method 1		Method 2		Method 3		Method 4	
	1 analog	5 analogs	1 analog	5 analogs	1 analog	5 analogs	1 analog	5 analogs
Jan-Dec	0.15	0.15	0.13	0.13	0.12	0.13	0.15	0.15
Feb-Jan+1	0.12	0.14	0.12	0.12	0.12	0.12	0.13	0.13
Mar-Feb+1	0.12	0.13	0.11	0.13	0.11	0.12	0.13	0.13
Apr-Mar+1	0.13	0.13	0.13	0.13	0.13	0.13	0.14	0.13
May-Apr+1	0.12	0.13	0.12	0.13	0.13	0.13	0.13	0.12
Jun-May+1	0.14	0.15	0.13	0.14	0.14	0.17	0.14	0.15
Jul-Jun+1	0.16	0.17	0.13	0.17	0.14	0.17	0.16	0.18
Aug-Jul+1	0.17	0.17	0.15	0.17	0.16	0.17	0.17	0.17
Sep-Aug+1	0.17	0.18	0.17	0.18	0.17	0.18	0.18	0.19
Oct-Sep+1	0.17	0.18	0.16	0.18	0.16	0.18	0.18	0.19
Nov-Oct+1	0.15	0.17	0.14	0.16	0.15	0.17	0.16	0.17
Dec-Nov+1	0.14	0.15	0.13	0.14	0.13	0.14	0.14	0.16
Mean	0.15	0.15	0.13	0.15	0.14	0.15	0.15	0.16

Table S11: Like Table S9 but for SPI12 predictions.

Forecast Period	TAS - 24 months							
	Method 1		Method 2		Method 3		Method 4	
	1 analog	5 analogs	1 analog	5 analogs	1 analog	5 analogs	1 analog	5 analogs
Jan-Dec+1	0.47	0.39	0.44	0.42	0.48	0.41	0.50	0.41
Feb-Jan+2	0.37	0.37	0.35	0.34	0.33	0.33	0.41	0.38
Mar-Feb+2	0.39	0.40	0.36	0.35	0.34	0.32	0.40	0.38
Apr-Mar+2	0.39	0.43	0.37	0.38	0.34	0.37	0.42	0.42
May-Apr+2	0.40	0.43	0.31	0.41	0.29	0.40	0.38	0.43
Jun-May+2	0.33	0.34	0.33	0.37	0.36	0.43	0.36	0.36
Jul-Jun+2	0.34	0.34	0.38	0.35	0.32	0.41	0.36	0.36
Aug-Jul+2	0.32	0.33	0.35	0.34	0.34	0.38	0.34	0.34
Sep-Aug+2	0.35	0.35	0.36	0.34	0.32	0.37	0.35	0.36
Oct-Sep+2	0.38	0.40	0.37	0.40	0.38	0.40	0.41	0.40
Nov-Oct+2	0.40	0.47	0.40	0.47	0.40	0.45	0.41	0.43
Dec-Nov+2	0.42	0.48	0.40	0.46	0.46	0.46	0.44	0.47
Mean	0.38	0.39	0.37	0.39	0.36	0.39	0.40	0.39

Table S12: Like Table S8 but for 24-month TAS predictions.

Forecast Period	SPI24							
	Method 1		Method 2		Method 3		Method 4	
	1 analog	5 analogs	1 analog	5 analogs	1 analog	5 analogs	1 analog	5 analogs
Jan-Dec+1	0.19	0.19	0.17	0.19	0.18	0.18	0.17	0.19
Feb-Jan+2	0.18	0.17	0.16	0.16	0.17	0.16	0.14	0.17
Mar-Feb+2	0.18	0.16	0.15	0.15	0.16	0.16	0.15	0.17
Apr-Mar+2	0.16	0.16	0.14	0.16	0.16	0.16	0.14	0.16
May-Apr+2	0.17	0.17	0.16	0.17	0.16	0.17	0.14	0.17
Jun-May+2	0.18	0.18	0.17	0.18	0.16	0.17	0.15	0.17
Jul-Jun+2	0.20	0.20	0.18	0.19	0.18	0.19	0.18	0.19
Aug-Jul+2	0.20	0.20	0.19	0.20	0.19	0.19	0.20	0.20
Sep-Aug+2	0.20	0.21	0.18	0.20	0.18	0.20	0.19	0.21
Oct-Sep+2	0.23	0.23	0.20	0.22	0.19	0.21	0.22	0.22
Nov-Oct+2	0.21	0.22	0.19	0.21	0.19	0.20	0.19	0.22
Dec-Nov+2	0.19	0.21	0.18	0.20	0.18	0.20	0.18	0.21
Mean	0.19	0.19	0.17	0.19	0.18	0.18	0.17	0.19

Table S13: Like Table S9 but for SPI24 predictions.

References

Ding, H., Newman, M., Alexander, M. A., and Wittenberg, A. T. Skillful climate forecasts of the tropical Indo-Pacific Ocean using model-analogs. *Journal of Climate*, 31(14), 5437–5459. <https://doi.org/10.1175/JCLI-D-17-0661.1>, 2018.