

1           Supplementary information for: Revisiting the  
2 reanalysis-model discrepancy in Southern Hemisphere  
3           winter storm track trends

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Table S1: Summary of unprocessed time frequency and spatial grids of the datasets used in the study. The models that are only included in the CMIP6 and AMIP6 multi model ensemble are superscripted in *c* or *a*, respectively.

Dataset	Time frequency	Number of pressure levels (highest pressure level)	Horizontal resolution [longitude×latitude]
Reanalysis			
CFSR/CFSv2	Six-hourly	37 (1 hPa)	$0.5^{\circ} \times 0.5^{\circ}$
ERA-Interim	Six-hourly	37 (1 hPa)	$1.5^{\circ} \times 1.5^{\circ}$
ERA5	Six-hourly	37 (1 hPa)	$0.25^{\circ} \times 0.25^{\circ}$
JRA-3Q	Six-hourly	45 (0.01 hPa)	$0.375^{\circ} \times 0.375^{\circ}$
JRA-55	Six-hourly	37 (1 hPa)	$1.25^{\circ} \times 1.25^{\circ}$
MERRA1	Six-hourly	42 (0.1 hPa)	$0.67^{\circ} \times 0.5^{\circ}$
MERRA2	Six-hourly	42 (0.1 hPa)	$0.625^{\circ} \times 0.5^{\circ}$
NCEP2	Six-hourly	17 (10 hPa)	$2.5^{\circ} \times 2.5^{\circ}$
CMIP6 and AMIP6 models			
ACCESS-CM2	Daily-mean	8 (10 hPa)	$1.875^{\circ} \times 1.25^{\circ}$
ACCESS-ESM1-5	Daily-mean	8 (10 hPa)	$1.875^{\circ} \times 1.25^{\circ}$
BCC-CSM2-MR	Daily-mean	8 (10 hPa)	$1.125^{\circ} \times 1.125^{\circ}$
CAMS-CSM1-0 <sup>a</sup>	Daily-mean	8 (10 hPa)	$1.125^{\circ} \times 1.125^{\circ}$
CESM2 <sup>a</sup>	Daily-mean	8 (10 hPa)	$1.25^{\circ} \times 0.938^{\circ}$
CESM2-FV2 <sup>a</sup>	Daily-mean	8 (10 hPa)	$2.5^{\circ} \times 1.875^{\circ}$
CESM2-WACCM	Daily-mean	8 (10 hPa)	$1.25^{\circ} \times 0.938^{\circ}$
CESM2-WACCM-FV2 <sup>a</sup>	Daily-mean	8 (10 hPa)	$2.5^{\circ} \times 1.875^{\circ}$
CMCC-CM2-HR4 <sup>a</sup>	Daily-mean	8 (10 hPa)	$1.25^{\circ} \times 0.938^{\circ}$
CMCC-CM2-SR5	Daily-mean	8 (10 hPa)	$1.25^{\circ} \times 0.938^{\circ}$
CMCC-ESM2 <sup>c</sup>	Daily-mean	8 (10 hPa)	$1.25^{\circ} \times 0.938^{\circ}$
CanESM5	Daily-mean	8 (10 hPa)	$2.812^{\circ} \times 2.812^{\circ}$
EC-Earth3	Daily-mean	8 (10 hPa)	$0.703^{\circ} \times 0.703^{\circ}$
EC-Earth3-CC	Daily-mean	8 (10 hPa)	$0.703^{\circ} \times 0.703^{\circ}$
EC-Earth3-AerChem <sup>a</sup>	Daily-mean	8 (10 hPa)	$0.703^{\circ} \times 0.703^{\circ}$
EC-Earth3-Veg	Daily-mean	8 (10 hPa)	$0.703^{\circ} \times 0.703^{\circ}$
EC-Earth3-Veg-LR	Daily-mean	8 (10 hPa)	$1.125^{\circ} \times 1.125^{\circ}$
FGOALS-f3-L <sup>a</sup>	Daily-mean	8 (10 hPa)	$1.25^{\circ} \times 1.0^{\circ}$
FGOALS-g3	Daily-mean	8 (10 hPa)	$2.0^{\circ} \times 2.25^{\circ}$
GFDL-CM4	Daily-mean	8 (10 hPa)	$2.5^{\circ} \times 2.0^{\circ}$
IITM-ESM	Daily-mean	8 (10 hPa)	$1.875^{\circ} \times 1.915^{\circ}$
INM-CM4-8	Daily-mean	8 (10 hPa)	$2.0^{\circ} \times 1.5^{\circ}$
INM-CM5-0	Daily-mean	8 (10 hPa)	$2.0^{\circ} \times 1.5^{\circ}$
IPSL-CM6A-LR	Daily-mean	8 (10 hPa)	$2.5^{\circ} \times 1.268^{\circ}$
KACE-1-0-G <sup>c</sup>	Daily-mean	8 (10 hPa)	$1.875^{\circ} \times 1.25^{\circ}$
MIROC6	Daily-mean	8 (10 hPa)	$1.406^{\circ} \times 1.406^{\circ}$
MPI-ESM1-2-HAM <sup>a</sup>	Daily-mean	8 (10 hPa)	$1.875^{\circ} \times 1.875^{\circ}$
MPI-ESM1-2-HR	Daily-mean	8 (10 hPa)	$0.938^{\circ} \times 0.938^{\circ}$
MPI-ESM1-2-LR	Daily-mean	8 (10 hPa)	$1.875^{\circ} \times 1.875^{\circ}$
MRI-ESM2-0	Daily-mean	8 (10 hPa)	$1.125^{\circ} \times 1.125^{\circ}$
NESM3	Daily-mean	8 (10 hPa)	$1.875^{\circ} \times 1.875^{\circ}$
NorESM2-LM	Daily-mean	8 (10 hPa)	$2.5^{\circ} \times 1.875^{\circ}$
NorESM2-MM <sup>c</sup>	Daily-mean	8 (10 hPa)	$1.25^{\circ} \times 0.938^{\circ}$
SAM0-UNICON <sup>a</sup>	Daily-mean	8 (10 hPa)	$1.25^{\circ} \times 0.938^{\circ}$
TaiESM1	Daily-mean	8 (10 hPa)	$1.25^{\circ} \times 0.938^{\circ}$

Table S2: Percentile rank of individual reanalysis in the multi-model or large ensemble simulations.

Lower ranks correspond to larger trends.

Rank (%)	CFSR	ERA1	ERA5	JRA3Q	JRA55	MERRA1	MERRA2	NCEP2
Zonal mean								
CMIP6	23.1	3.8	3.8	3.8	0.0	96.2	34.6	0.0
AMIP6	53.1	25.0	18.8	6.2	0.0	93.8	68.8	0.0
South Pacific								
CMIP6	50.0	3.8	3.8	3.8	0.0	11.5	11.5	0.0
AMIP6	87.5	62.5	50.0	46.9	21.9	68.8	71.9	0.0
CESM2 zonal mean								
CESM2-LE	58.0	2.0	0.0	0.0	0.0	76.0	56.0	0.0
GOGA	80.0	20.0	10.0	10.0	0.0	100.0	80.0	0.0
SOPACE	76.2	14.3	9.5	0.0	0.0	90.5	71.4	0.0
PacPACE	60.0	10.0	10.0	0.0	0.0	80.0	60.0	0.0
SUM	86.0	20.0	14.0	8.0	0.0	94.0	86.0	0.0
CESM2 South Pacific								
CESM2-LE	64.0	8.0	6.0	6.0	2.0	20.0	32.0	0.0
GOGA	100.0	60.0	40.0	40.0	10.0	80.0	90.0	0.0
SOPACE	90.5	4.8	0.0	0.0	0.0	19.0	28.6	0.0
PacPACE	90.0	40.0	30.0	20.0	0.0	60.0	80.0	0.0
SUM	94.0	46.0	34.0	34.0	16.0	56.0	68.0	0.0

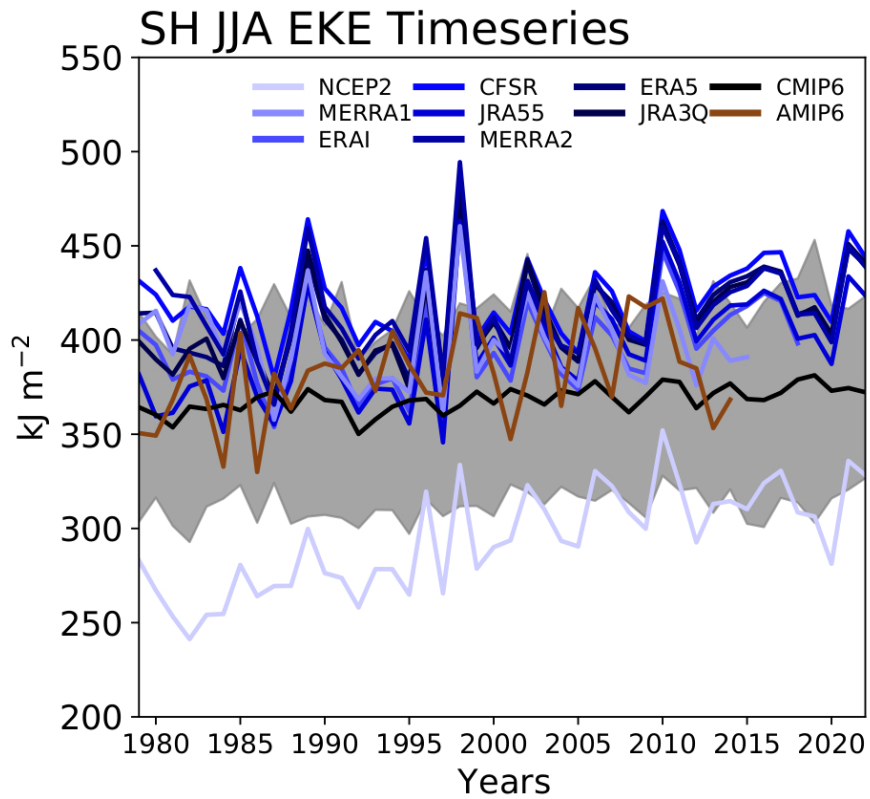


Figure S1: **Time evolution of SH winter storminess across reanalyses and models.** a Time series of SH JJA EKE ( $40\text{--}75^\circ\text{S}$ ) in 8 reanalysis datasets (blue colors) and in CMIP6 (black) and AMIP6 (brown) multi-model-mean. The gray shading indicates 10–90% range of CMIP6 ensemble storminess distribution.

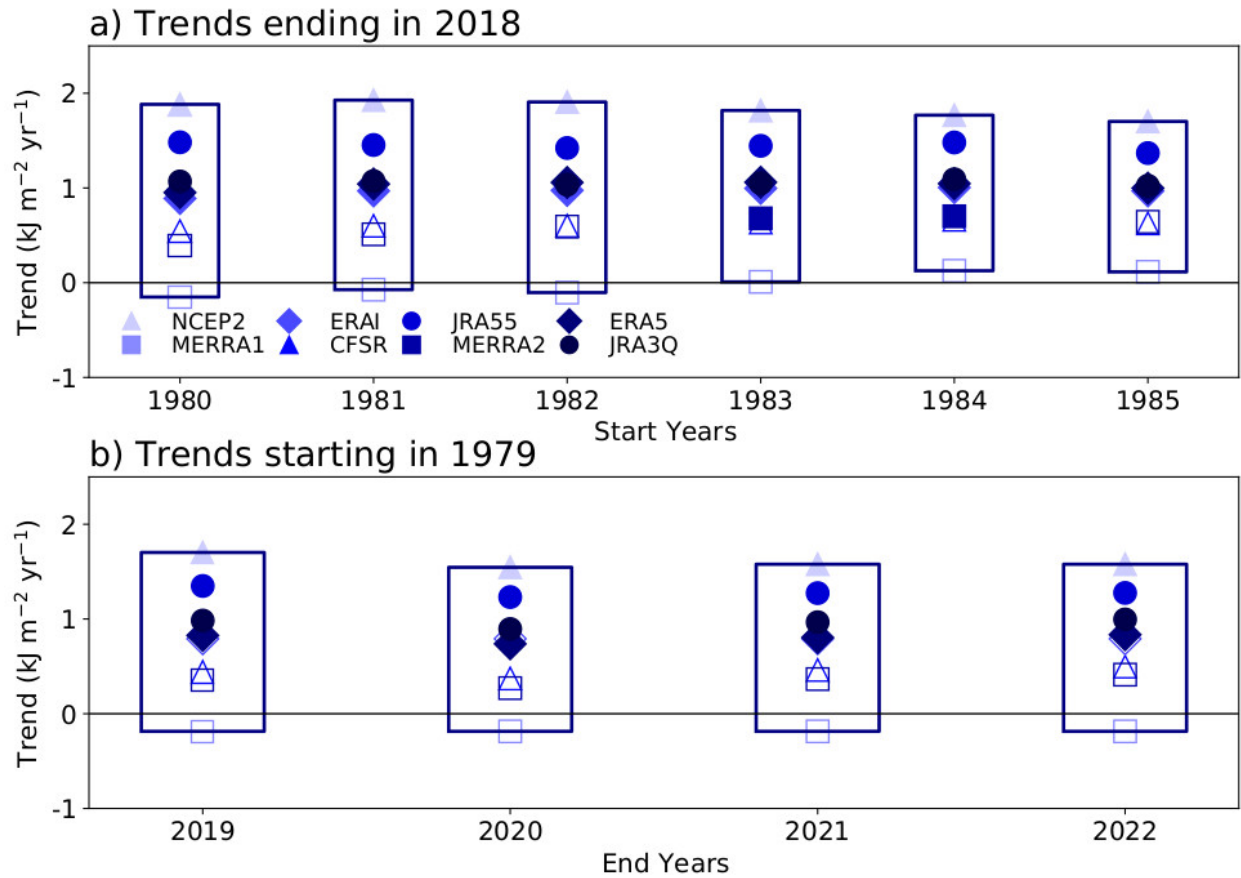


Figure S2: **Reanalysis uncertainty for trends calculated from different start years to different end years.** **a** Linear trends of SH JJA EKE ( $40\text{--}75^\circ\text{S}$ ) in 8 reanalysis datasets (blue colors) from different start years to 2018 (or the last available year). **b** Same as **a**, but for trends starting from 1979 to different end years (or the last available year). The box represents the full spread of reanalysis trends

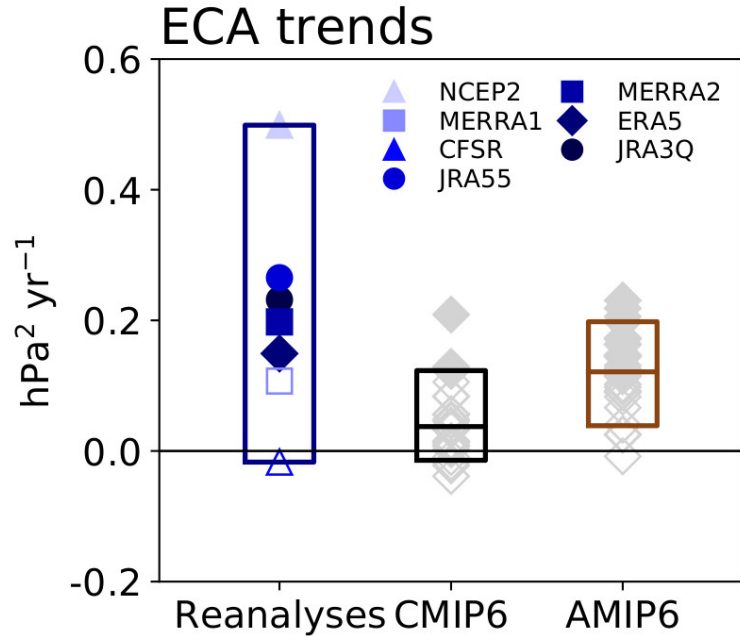


Figure S3: **Storminess trends quantified by sea-level pressure variance.** Same as Fig. 1a, but storminess is quantified using 24-hour sea-level pressure (SLP) variance:  $ECA = \frac{(\overline{SLP(t+24)} - \overline{SLP(t)})^2}{\overline{SLP(t+24)} - \overline{SLP(t)}}$ . SLP from ERAI was unavailable at the time of writing.

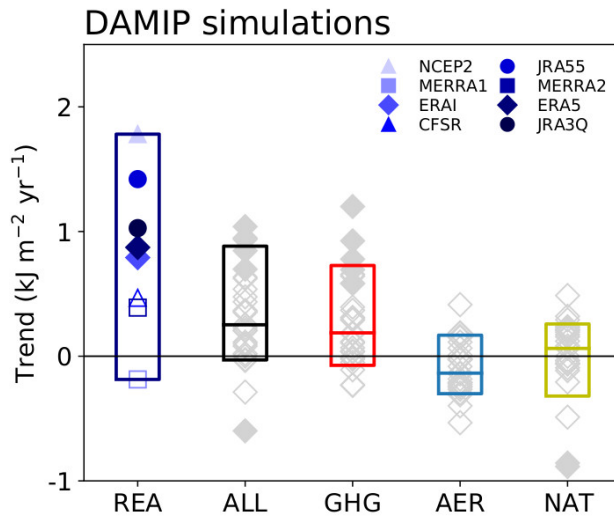


Figure S4: **Attribution of SH winter storminess trends.** Similar results to Fig. 1a, but for the DAMIP simulations. ALL, GHG, AER, and NAT refer to all forcing (historical and SSP2-4.5), greenhouse gas forcing (hist-GHG), anthropogenic aerosol forcing (hist-aer), and natural forcing (hist-nat). Storminess trends from ACCESS-ESM1-5 (3), CanESM5 (9), FGOALS-g3 (1), IPSL-CM6A-LR (6), MIROC6 (3), MRI-ESM2-0 (5) models are used where the numbers in parenthesis indicate the number of ensemble members used.

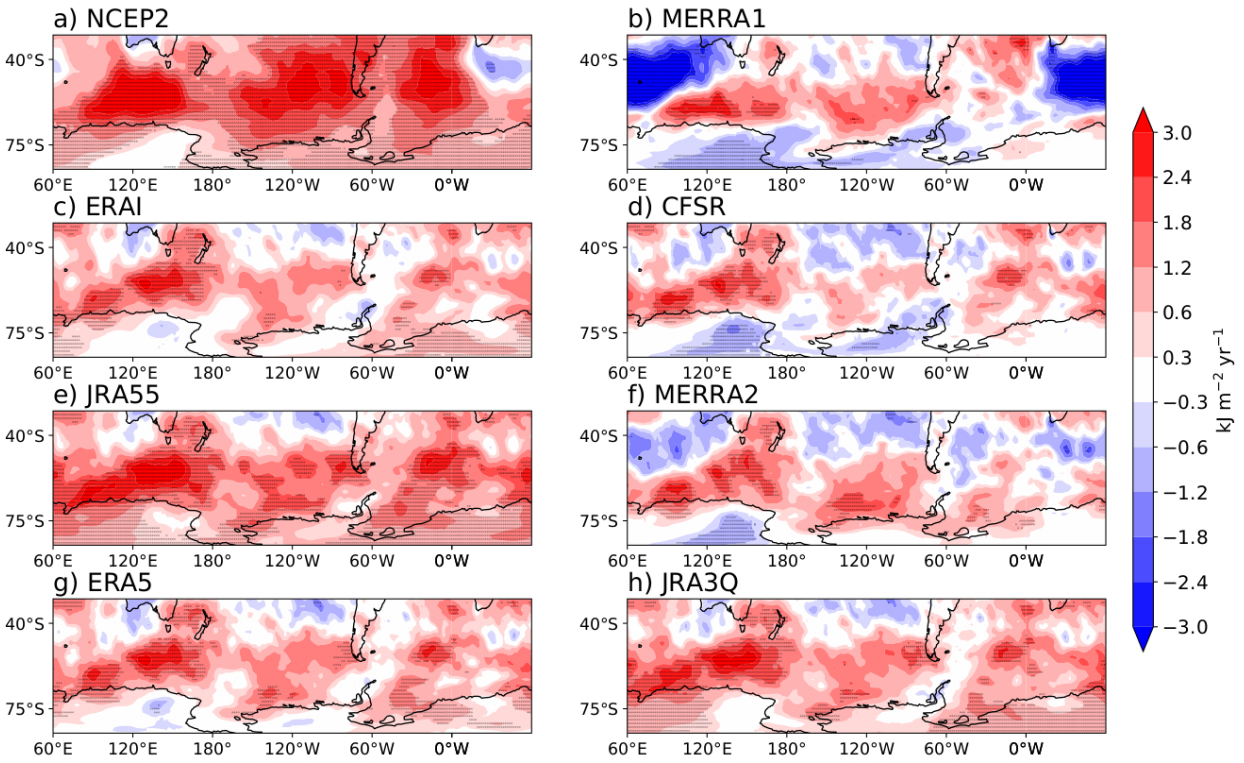


Figure S5: **Spatial pattern of storminess trends in individual reanalysis.** Spatial pattern of JJA storminess trends from 1979 to 2018 for **a** NCEP2, **b** MERRA1, **c** ERAI, **d** CFSR, **e** JRA55, **f** MERRA2, **g** ERA5, and **h** JRA3Q. Stipples indicate trends that are significant at the 95% confidence level.

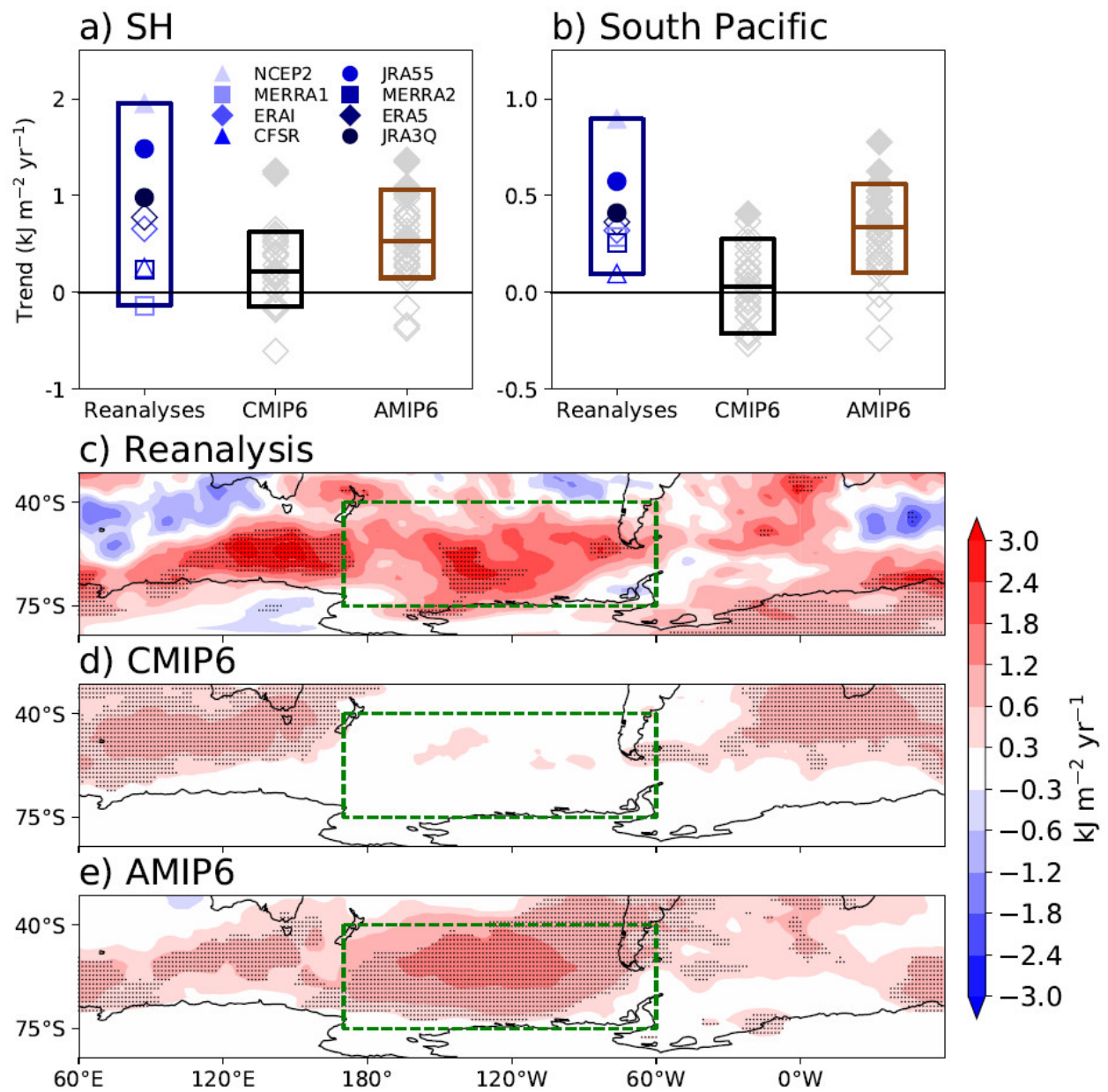


Figure S6: **Robustness to time period.** Same as Fig. 1, but trends from 1979 to 2013 as in Fig. 2.

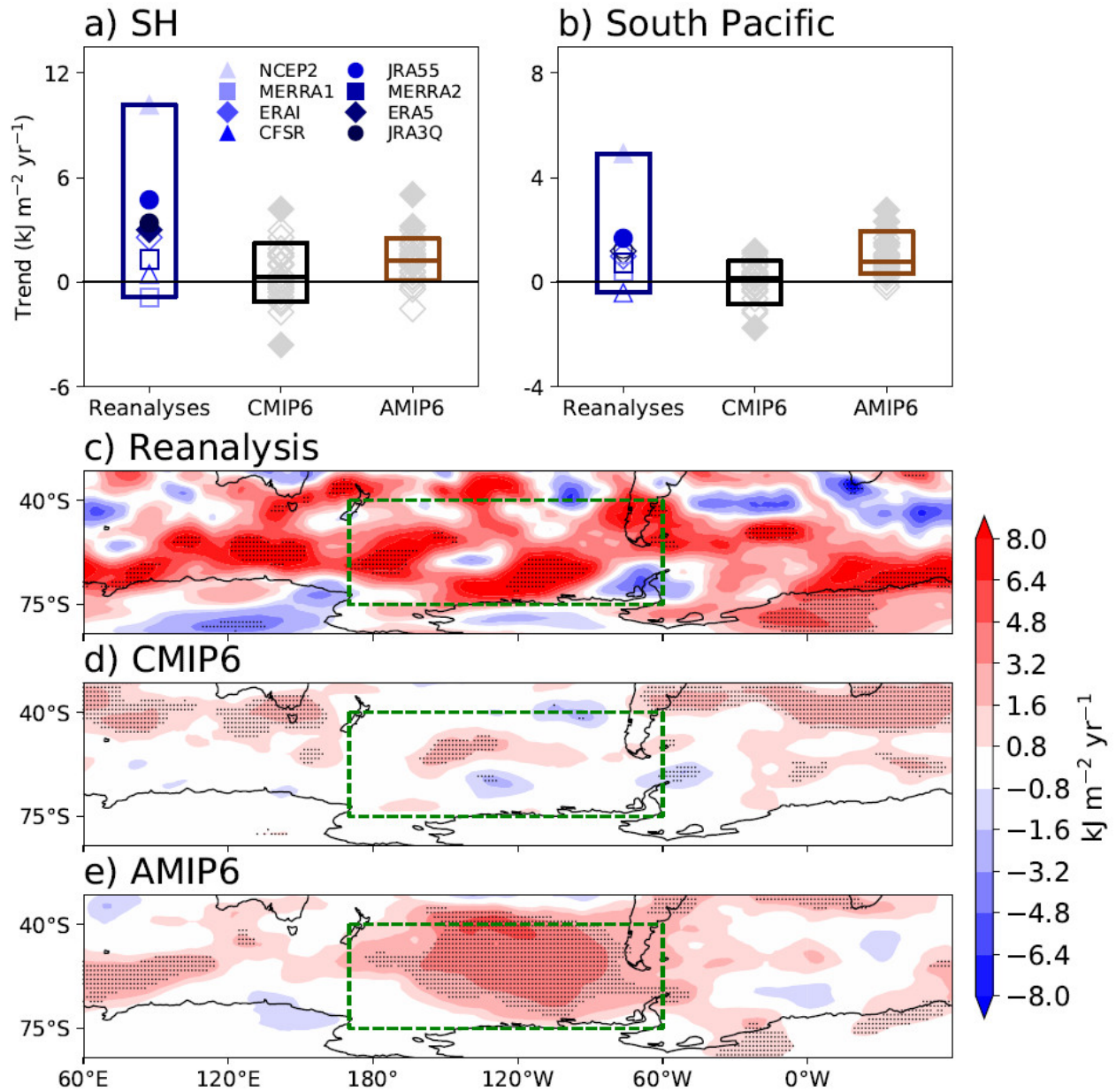


Figure S7: **Robustness to EKE definition.** Same as Fig. 1, but EKE is calculated from deviations from monthly mean. Trend is calculated from 1979 to 2013.

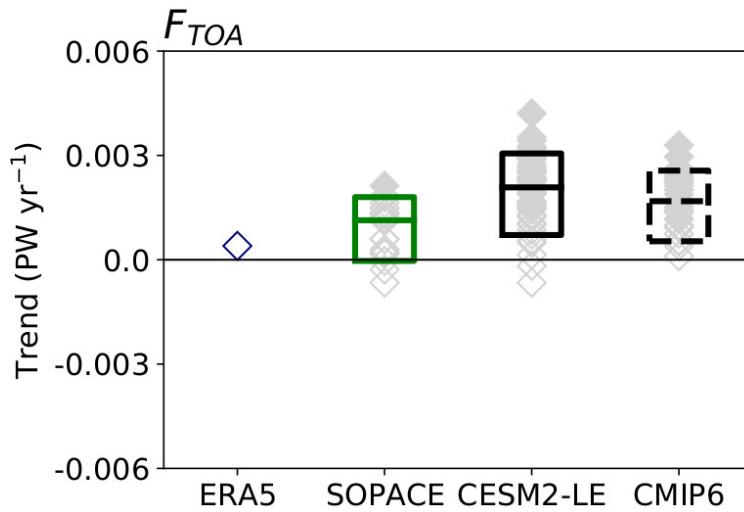


Figure S8: **Top-of-atmosphere radiation strengthens SH winter storminess.** Similar results to Fig. 5b, but for  $F_{TOA}$ .

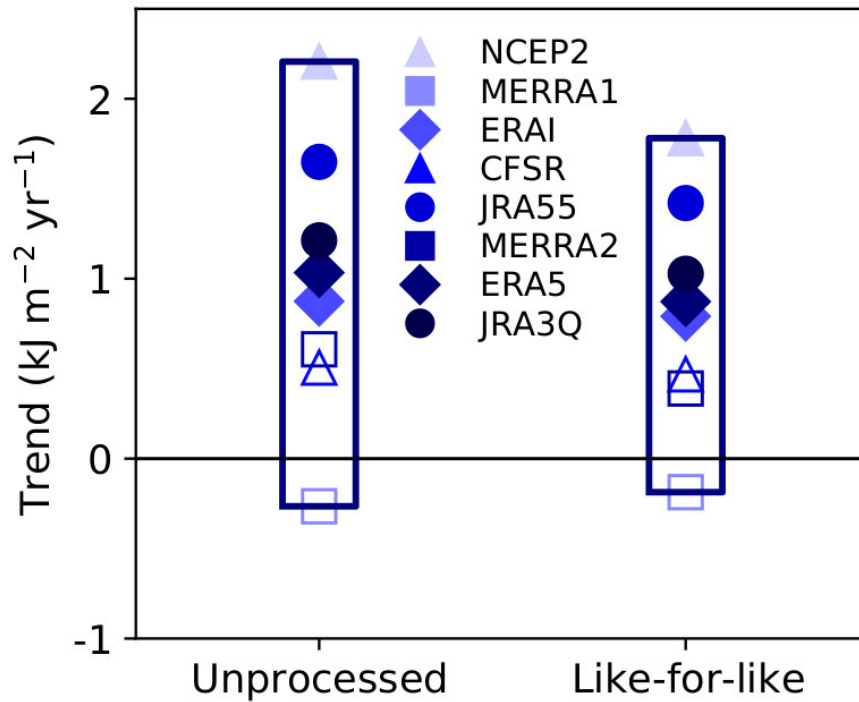


Figure S9: **Impact of like-for-like calculation.** Linear trends of SH JJA EKE (40–75°S) in 8 reanalysis datasets (blue colors, 1979–2018) calculated in unprocessed and like-for-like time and spatial grids. Statistically significant trends at the 95% confidence level are filled. The box represents the full spread of reanalysis trends.

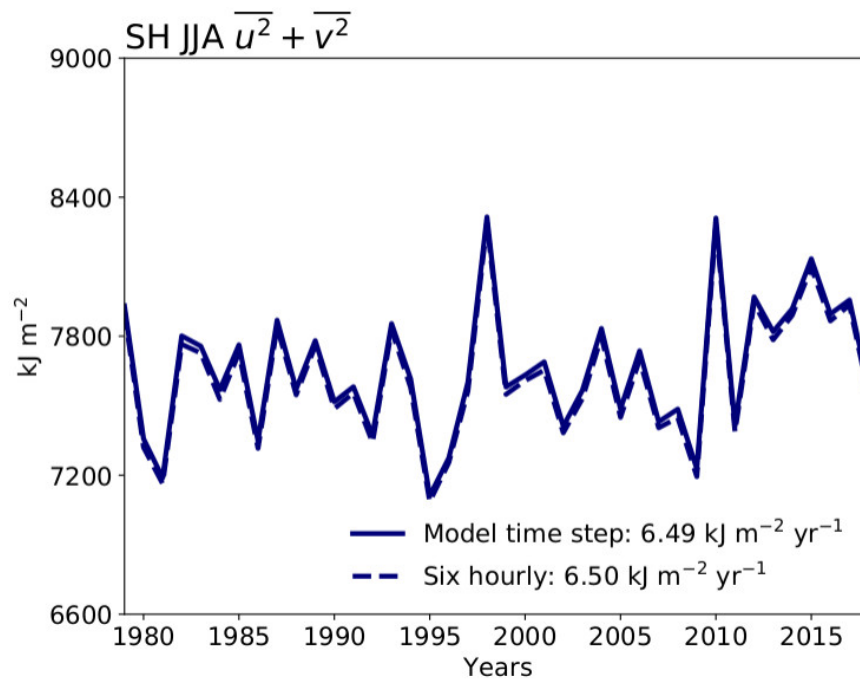


Figure S10: **SH kinetic energy in ERA5.** Timeseries of SH JJA (40–75°S) vertically integrated kinetic energy calculated from model time step (solid) and six-hourly time step (dashed) from ERA5. Linear trends from 1979 to 2018 are also denoted.