



*Supplement of*

## **Role of precipitation and extreme precipitation events on the variability of ice core surface mass balances in Dronning Maud Land: insights from RACMO2.3 and statistical downscaling**

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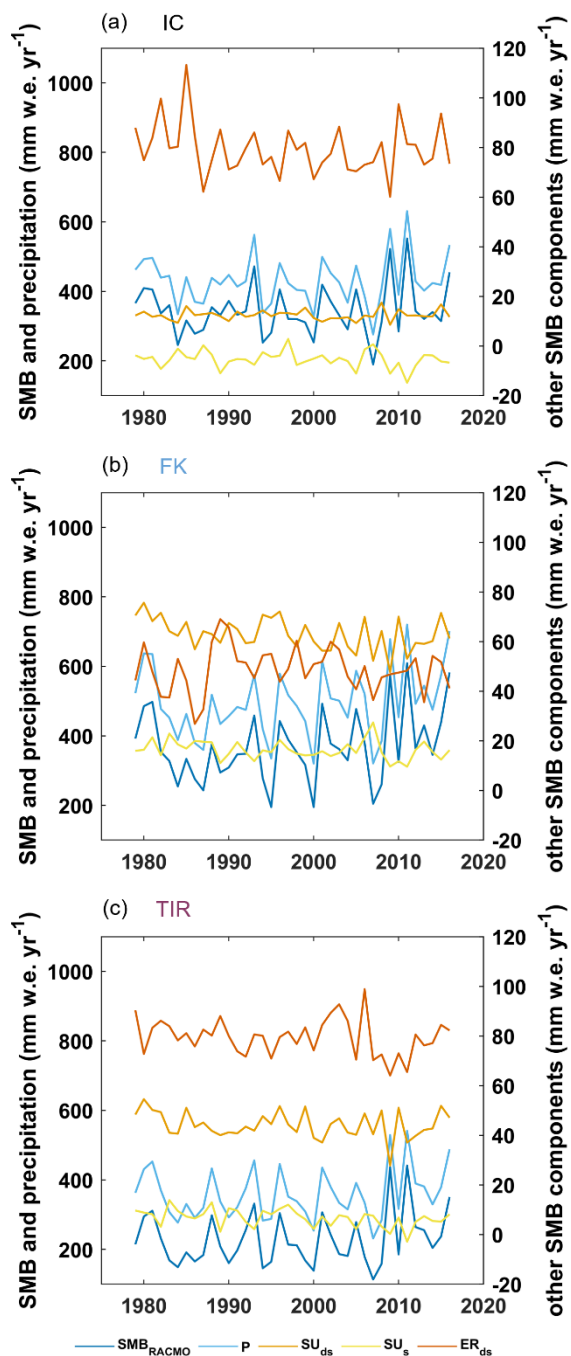


Figure S1: Temporal evolution of the SMB components and SMB derived from RACMO2.3 between 1979 and 2016 at (a) IC, (b) FK, and (c) TIR, expressed in  $mm\ w.e.\ yr^{-1}$ . Precipitation and SMB are represented on the left axis while sublimations and erosion are represented on the right axis.

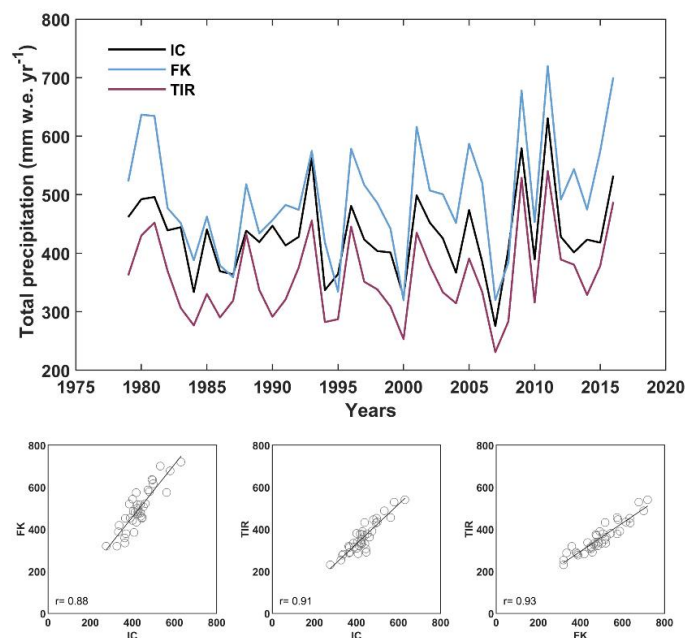
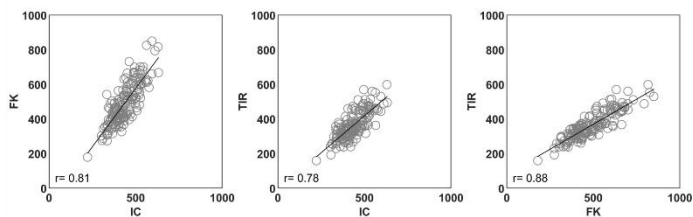
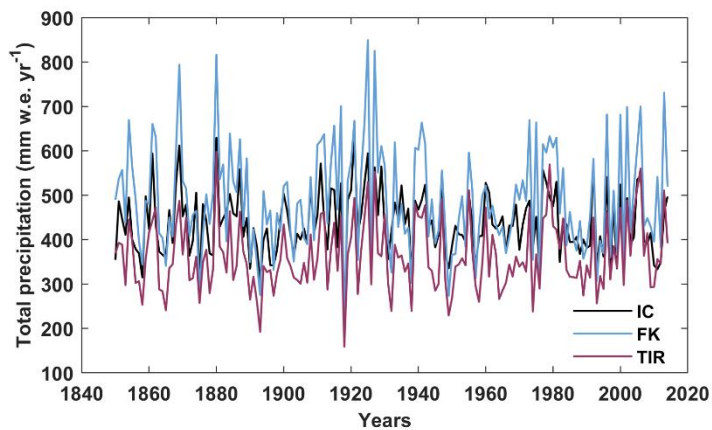


Figure S2: Total annual precipitation time-series at our three sites (upper panel) and correlation between the sites (down panel) according to RACMO2.3.

Supplement S3: Distribution of precipitation days and annual time-series from the downscaling dataset

	Number of events (%)				Quantity (%)			
	all sites	site only	+ site 1	+ site 2	all sites	site only	+ site 1	+ site 2
IC	77.2	2.6	10.3 (IC)	9.9 (TIR)	96.1	0.3	2.2 (FK)	1.4 (TIR)
	± 0.2	± 0.2	± 0.1	± 0.1	± 0.2	± 0.02	± 0.2	± 0.1
FK	78.9	2.3	10.5 (IC)	8.3 (TIR)	98.1	0.1	1.1 (IC)	0.7 (TIR)
	± 0.2	± 0.1	± 0.1	± 0.1	± 0.2	± 0.01	± 0.2	± 0.1
TIR	79.2	2.4	10.1 (IC)	8.3 (FK)	97.5	0.2	1.3 (IC)	1.0 (FK)
	± 0.2	± 0.1	± 0.1	± 0.2	± 0.3	± 0.02	± 0.2	± 0.1

25 Table S1: Distribution of precipitation days at the three sites using the downscaling dataset. An event occurring at one site is  
categorized differently if it affects all three sites, the considered site only or the considered site and one of the two other sites (in  
this case, the name in parenthesis indicates which site is the second site impacted). The “number of events” represents the fraction  
of the total number of events in the category. Quantity represents the percentage of total precipitation that fell at one site based on  
the event category. The average of the 10 members at each site is presented and the ± standard deviation values represent the  
30 internal variability of the ensemble.



**Figure S3: Total annual precipitation time-series at the three sites (upper panel) and correlation between the sites (down panel) from the downscaling dataset. The third member of each ensemble is shown here, as the correlation coefficients of this member are closest to the ensemble average.**

Supplement S4: Synoptic conditions during 98<sup>th</sup> percentile EPEs

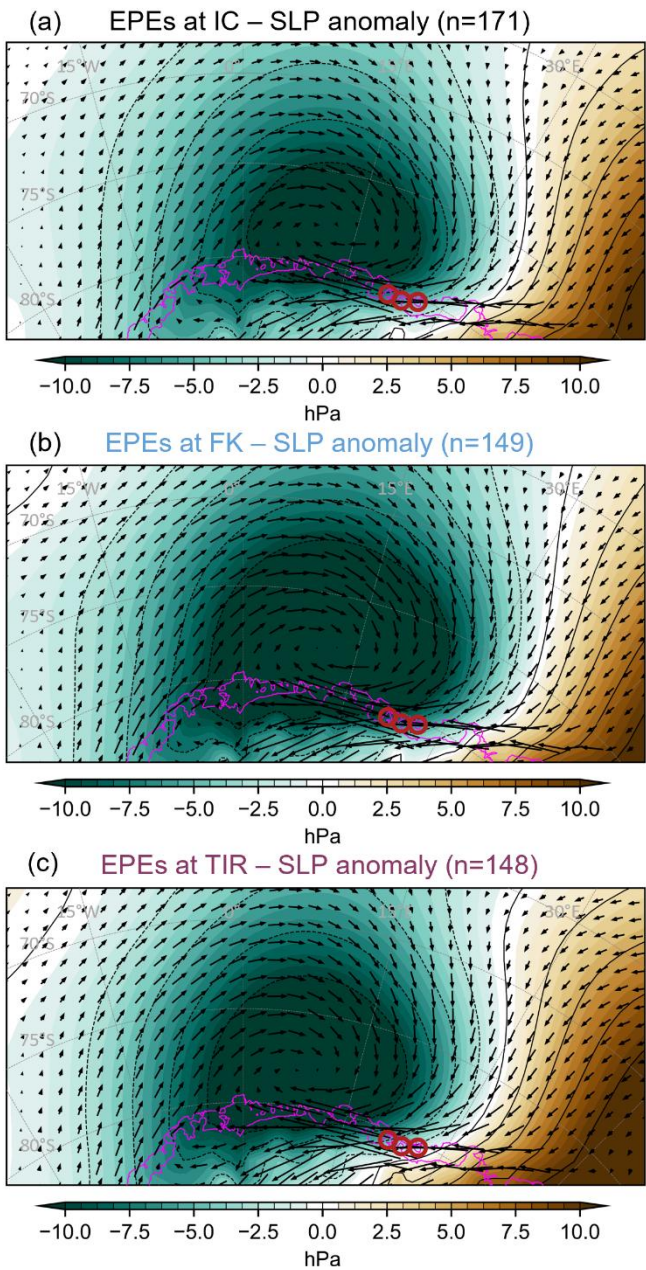
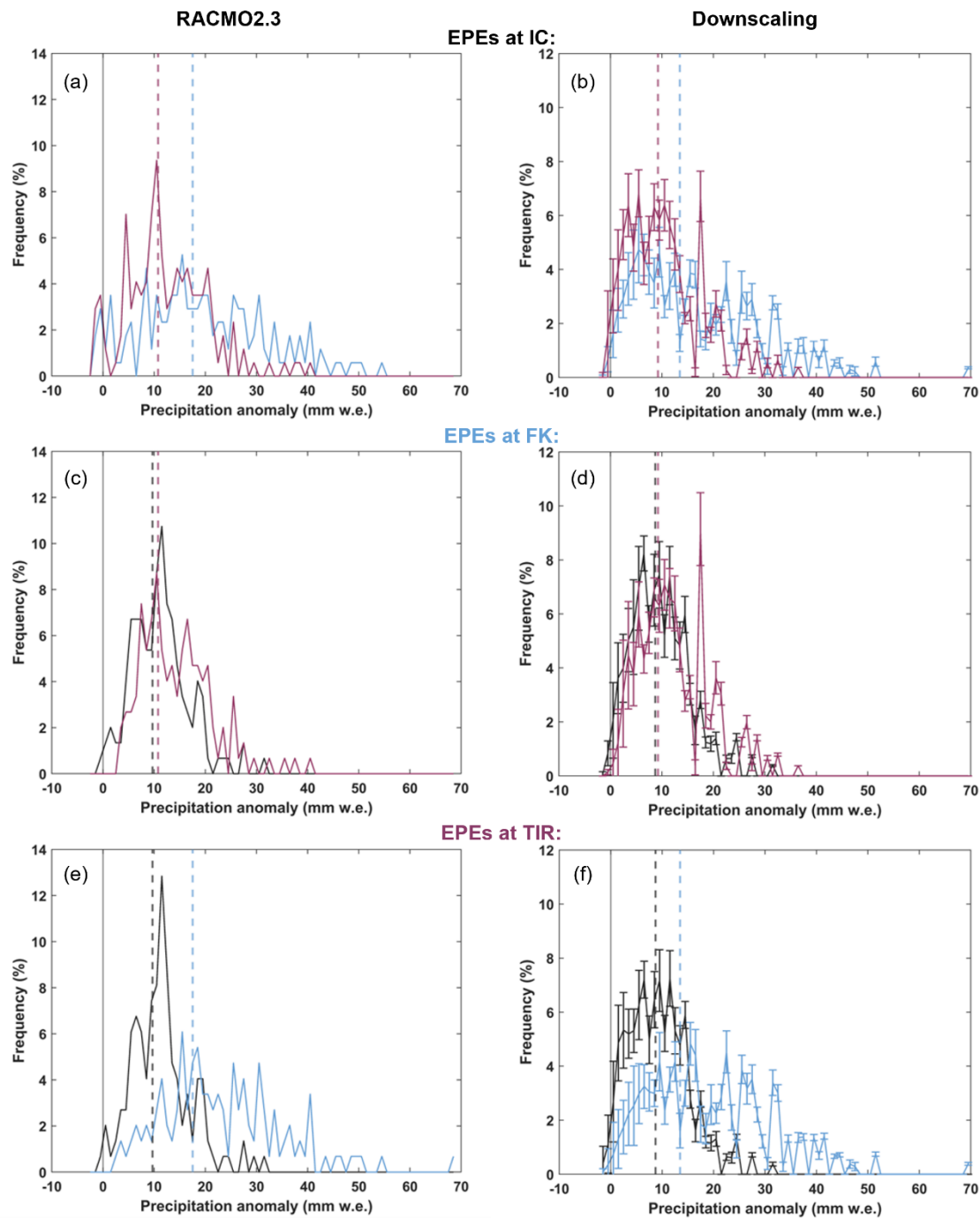


Figure S4: Maps of the sea level pressure anomaly (SLP) overlaid by mean surface wind vectors, retrieved from ERA5, during 98<sup>th</sup> percentile EPEs at the three sites: (a) IC, (b) FK, and (c) TIR. The number in parentheses corresponds to the number of EPE days. Blue colors indicate negative anomaly (i.e., low pressure) and brown colors indicate positive anomaly (i.e., high pressure).



45 **Figure S5: Frequency distributions of precipitation anomalies (calculated as the precipitation – the average value of precipitation series) at the two other sites corresponding to the dates of 98<sup>th</sup> percentile EPEs at (a-b) IC, (c-d) FK, and (e-f) TIR, using the RACMO2.3 data series (left panels) and the downscaling data series (right panels).**

These results are summarized in Table S2:

<b>RACMO2.3</b> (%)	EPEs at IC		EPEs at FK		EPEs at TIR	
	FK	TIR	IC	TIR	IC	FK
Above EPE thr	52.0	53.8	59.7	63.8	62.2	64.2
Neg. anom.	4.7	6.4	0.7	0	0.7	0
<b>Downscaling</b> (%)	EPEs at IC		EPEs at FK		EPEs at TIR	
	FK	TIR	IC	TIR	IC	FK
Above EPE thr	52 ± 5	51 ± 4	53 ± 5	63 ± 7	52 ± 4	63 ± 7
Neg. anom.	0.7 ± 0.5	2 ± 2	0.9 ± 0.5	0.1 ± 0.1	1.5 ± 1.7	0.4 ± 0.7

**Table S2: Distribution of the precipitation anomalies at two sites when there is a 98<sup>th</sup> percentile EPE at the third site, in %, for both the RACMO2.3 and downscaling datasets. For the downscaling, the average of the 10 members is shown, as well as the standard deviation to highlight the variability between members. See text for more explanations on the “Above EPE thr” and “Neg. anom.” categories.**

**Supplement S6: Scatter plots of precipitation anomalies – spatial variability**

Another way to investigate the spatial variability of precipitation and extreme precipitation events in depth is to use scatter plots of normalized precipitation anomalies for pair of sites categorized into four groups: (1) all precipitation anomalies, (2) precipitation anomalies corresponding to EPEs at the first site (with the corresponding values at the second site), (3) precipitation anomalies corresponding to EPEs at the second site (with the corresponding values at the first site), and (4) precipitation anomalies corresponding to EPEs at both sites. This means that certain values can appear in two or more categories.

Normalized precipitation anomalies are expressed as a ratio of precipitation anomaly to the average precipitation day and are calculated as:

$$\text{normalized precipitation anomaly} = \frac{\text{precipitation} - \text{average precipitation day}}{\text{average precipitation day}} \tag{S1}$$

Note that non-precipitation days (with less than 0.02 mm per day) are assigned a value of 0, so their ratio is -1. Dividing by the average of all precipitation days removes the mean state (which differs for each site) from the variability, making it possible to compare sites without the influence of the amount of precipitation.

This analysis is performed on both datasets and for both percentiles. An interesting feature to compare is the slope of the best-fit line for each category. If the slope is equal to one, it means that both sites receive the same relative quantities. Another interesting feature for studying spatial variability is the explained variance ( $R^2$ ).

70 When comparing all precipitation anomalies and EPE precipitation anomalies for RACMO2.3 (Fig. S6), it appears that the slopes are generally more different from the 1:1 slope for the EPEs (with the exception of EPE at IC in IC-TIR plots) than for all precipitations. This indicates that the unequal distribution of the precipitation quantities is more marked during EPEs. The explained variance ( $R^2$ ) is significantly lower during EPEs, and generally even lower when EPEs occur at both sites. This confirms the previous observations that EPEs induce a larger spatial variability compared to the average conditions, mostly due to more localized effects. This is further supported by the lower values of  $R^2$  and slopes for the 98<sup>th</sup> percentile than for the  
75 95<sup>th</sup> percentile (Fig. S7): more extreme events lead to more localized impacts.

Doing the same analysis for the downscaling dataset, some similarities arise with RACMO2.3 (Fig. S8). The slopes are more different from the 1:1 slope for the EPEs than for all precipitations. The explained variances are significantly higher for all precipitations than for the EPEs. For most members, the  $R^2$  values are lower when EPEs occur at both sites. The 10-members average values of  $R^2$  and slopes are also lower for the 98<sup>th</sup> percentile than for the 95<sup>th</sup> percentile (Fig. S9). One notable feature  
80 of the downscaling dataset is that the FK-TIR pair is significantly more correlated than the other pairs for all four categories.



(1) All precipitation anomalies

(2) EPEs at site x

(3) EPEs at site y

(4) EPEs at both sites

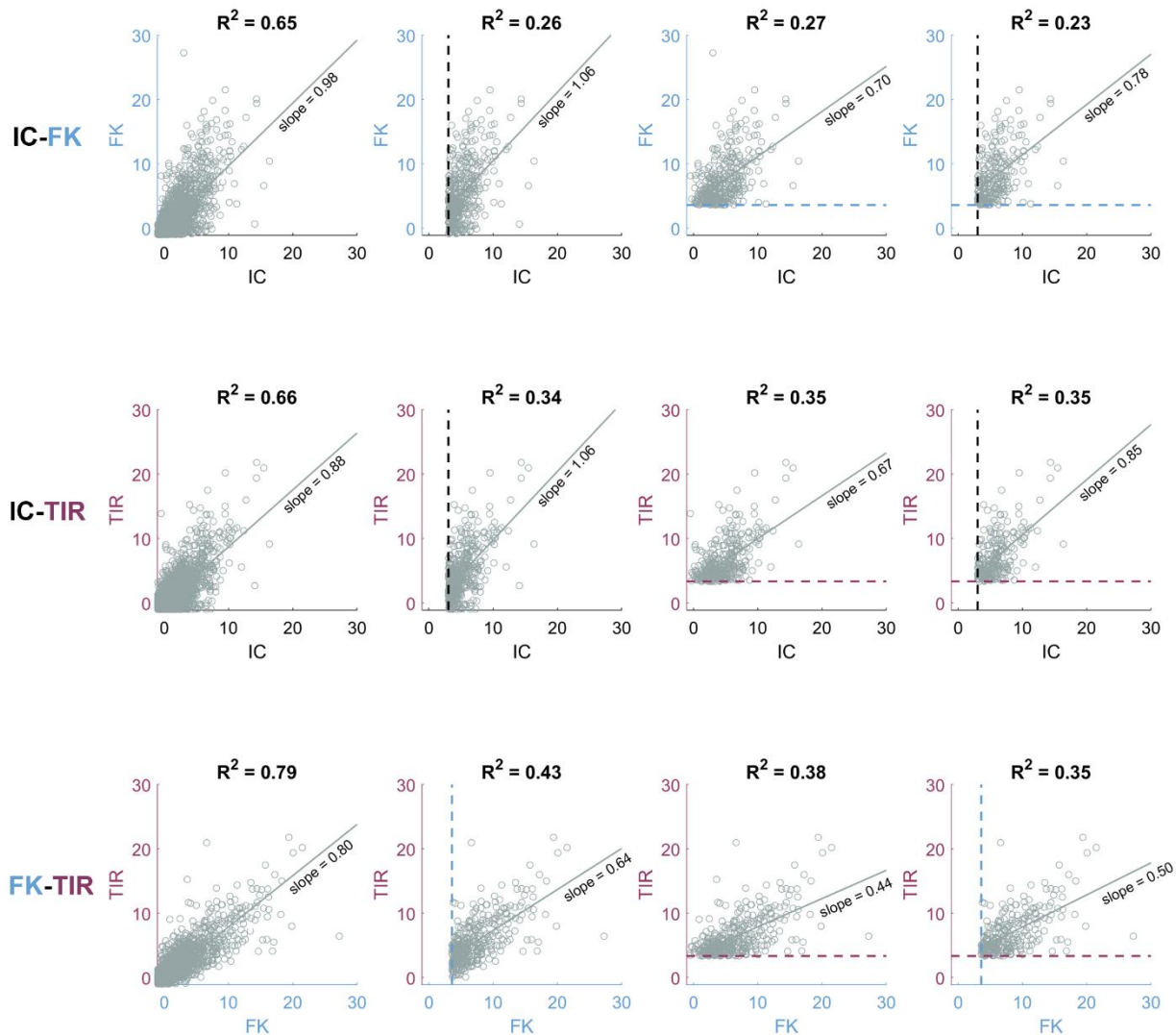


Figure S6: Scatter plots of normalized precipitation anomalies per pair of sites for the 95<sup>th</sup> percentile of RACMO2.3: IC-FK (upper panels), IC-TIR (middle panels), and FK-TIR (lower panels). There are 4 categories: (1) all normalized precipitation anomalies, (2) EPEs at site of x-axis and corresponding anomalies at site of y-axis, (3) EPEs at site of y-axis and corresponding anomalies at site of x-axis, and (4) EPEs at both sites.

(1) All precipitation anomalies

(2) EPEs at site x

(3) EPEs at site y

(4) EPEs at both sites

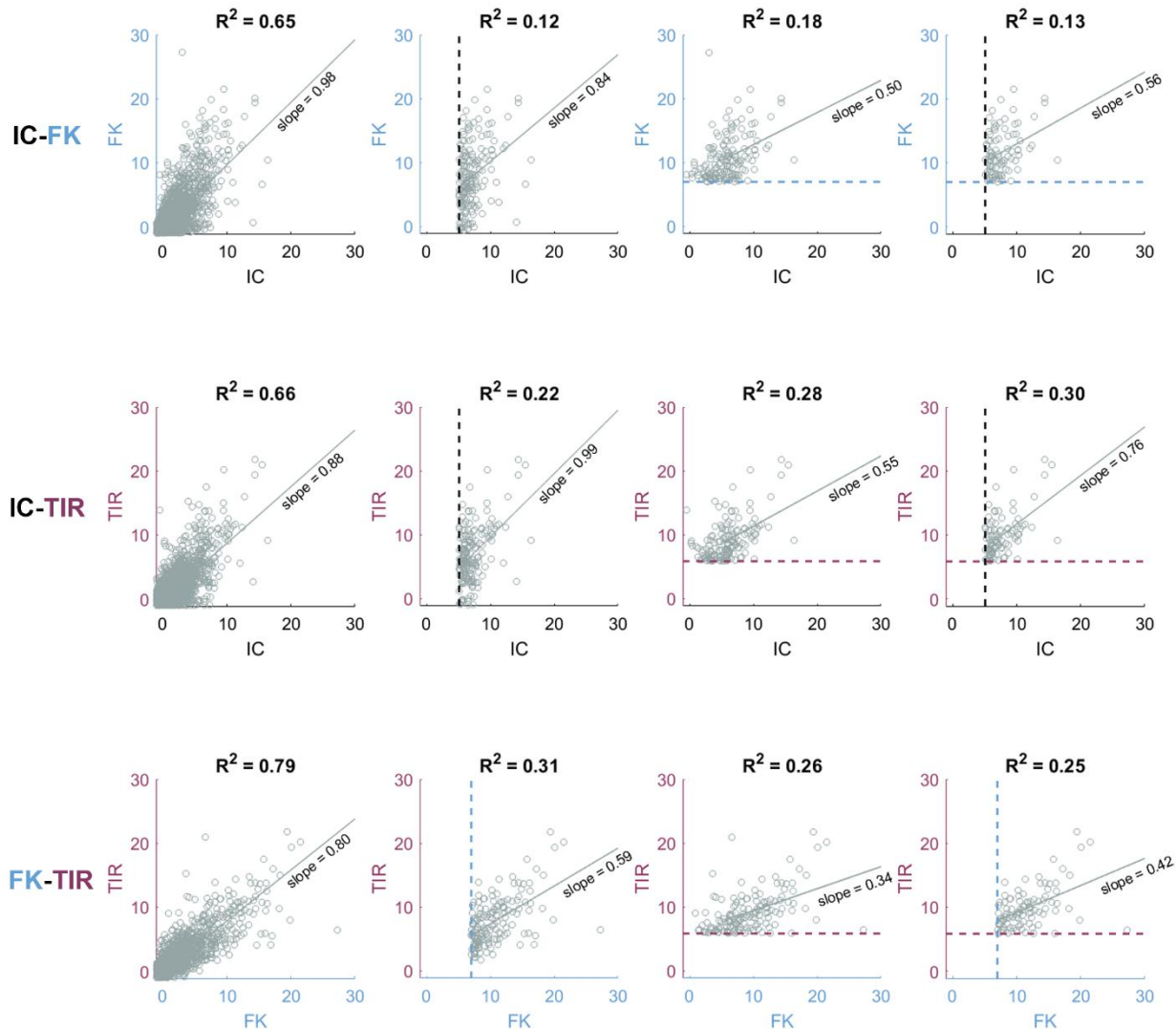


Figure S7: Scatter plots of normalized precipitation anomalies per pair of sites for the 98<sup>th</sup> percentile of RACMO2.3: IC-FK (upper panels), IC-TIR (middle panels), and FK-TIR (lower panels). There are 4 categories: (1) all normalized precipitation anomalies, (2) EPEs at site of x-axis and corresponding anomalies at site of y-axis, (3) EPEs at site of y-axis and corresponding anomalies at site of x-axis, and (4) EPEs at both sites.

# Downscaling – 95<sup>th</sup> percentile

(1) All precipitation anomalies

(2) EPEs at site x

(3) EPEs at site y

(4) EPEs at both sites

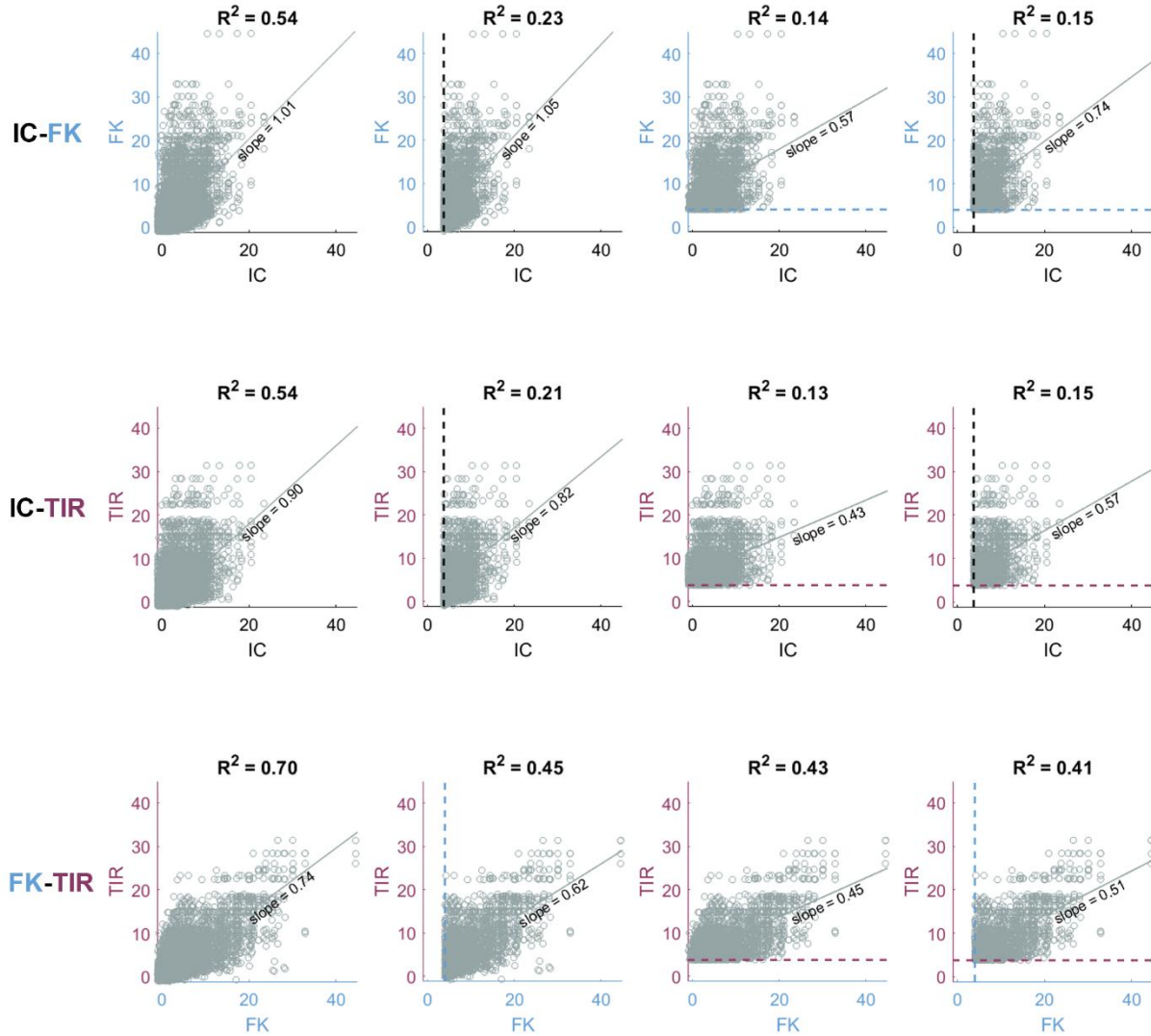


Figure S8: Scatter plots of normalized precipitation anomalies per pair of sites for the 95<sup>th</sup> percentile of downscaling: IC-FK (upper panels), IC-TIR (middle panels), and FK-TIR (lower panels). There are 4 categories: (1) all normalized precipitation anomalies, (2) EPEs at site of x-axis and corresponding anomalies at site of y-axis, (3) EPEs at site of y-axis and corresponding anomalies at site of x-axis, and (4) EPEs at both sites. Member 3 is represented, as it is close to the average of the 10 members.

# Downscaling – 98<sup>th</sup> percentile

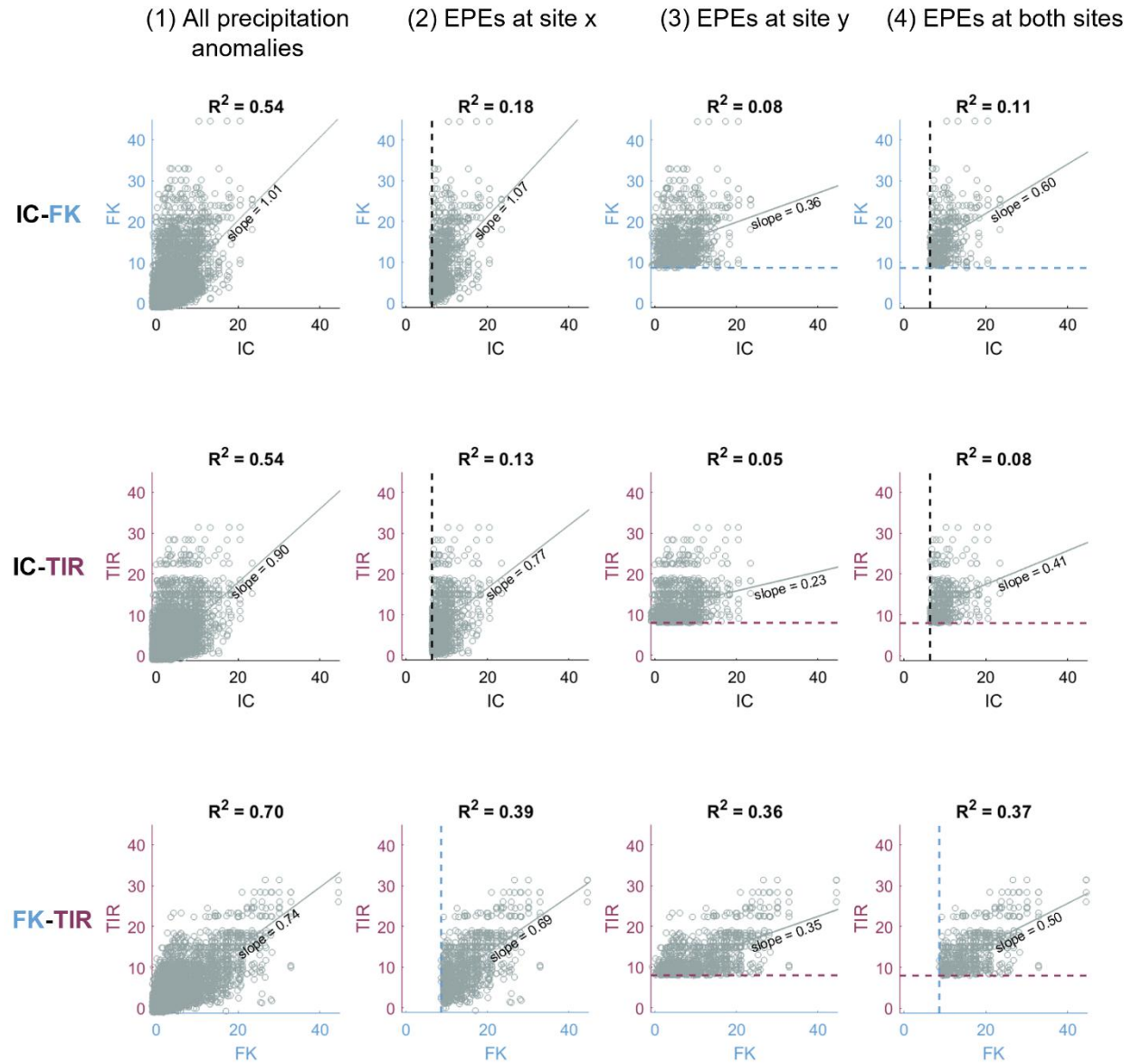


Figure S9: Scatter plots of normalized precipitation anomalies per pair of sites for the 98<sup>th</sup> percentile of downscaling: IC-FK (upper panels), IC-TIR (middle panels), and FK-TIR (lower panels). There are 4 categories: (1) all normalized precipitation anomalies, (2) EPEs at site of x-axis and corresponding anomalies at site of y-axis, (3) EPEs at site of y-axis and corresponding anomalies at site of x-axis, and (4) EPEs at both sites. Member 3 is represented, as it is close to the average of the 10 members.