



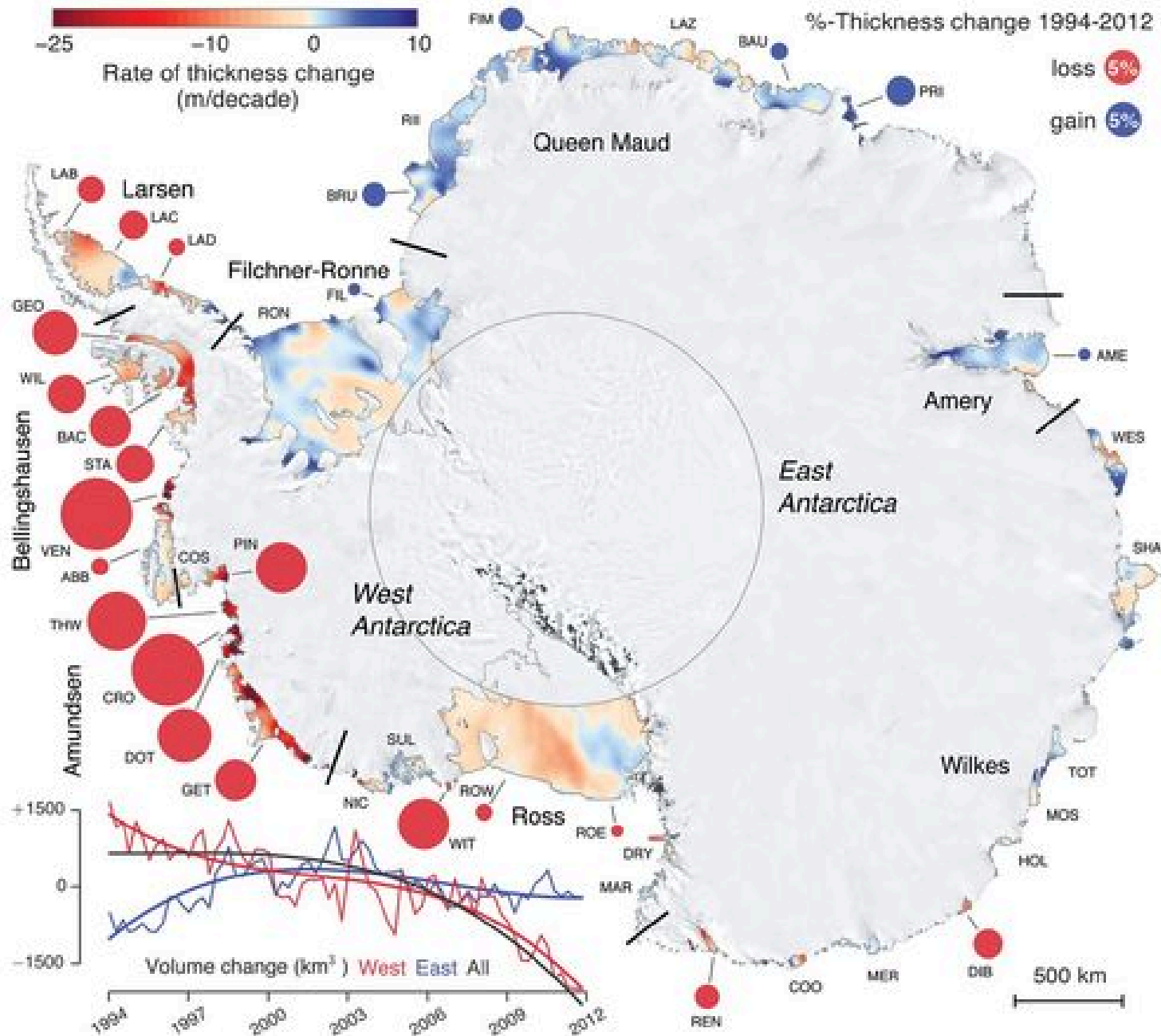
**PolarRES**  
Exploring future polar climates

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# Characteristics of surface “melt potential” over Antarctic ice shelves

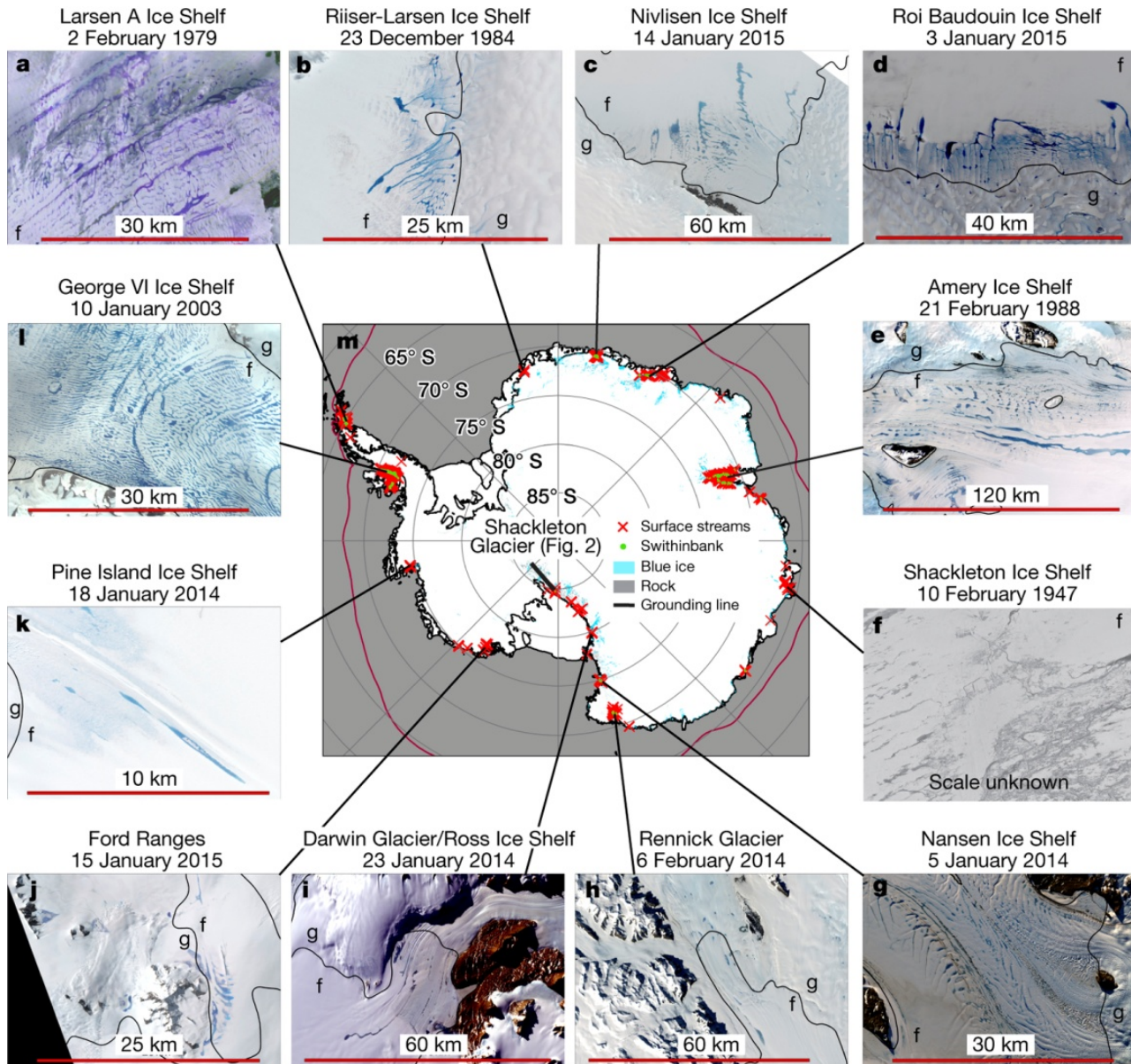
A. Orr, P. Deb, K. Clem, E. Gilbert, D. Bromwich, F. Boberg, S. Colwell, N. Hansen, M. Lazzara, P. Mooney, R. Mottram, M. Niwano, T. Phillips, D. Pishniak, C. Reijmer, W. J. van de Berg, S. Webster, and Z. Zou.

# Motivation and Methodology

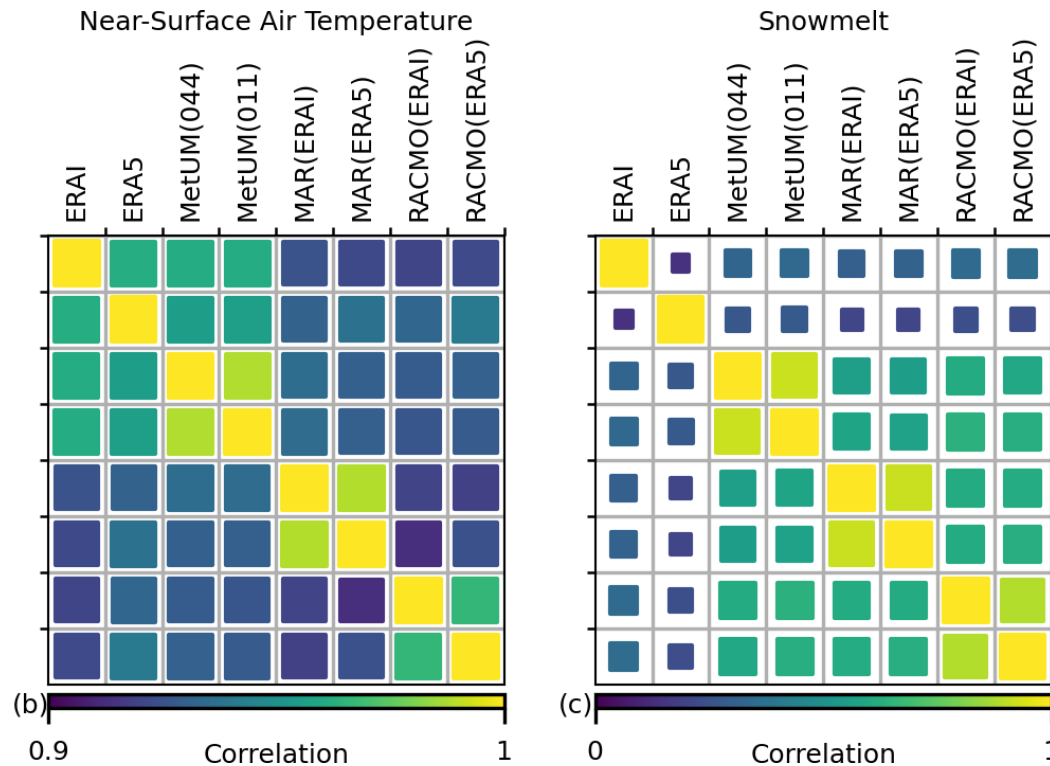


Change in ice shelf mass and volume from 1994 to 2012.

# Motivation and Methodology



Surface meltwater drainage around Antarctica



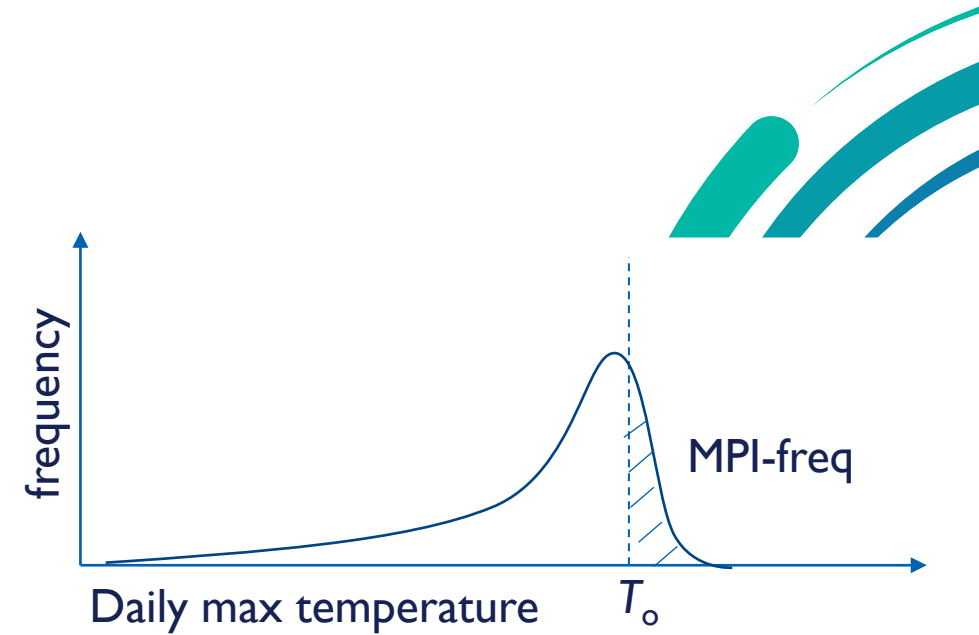
Correlation of near-surface temperature and surface melt between regional climate models (MetUM, MAR, RACMO) averaged over Antarctica

- Air temperature provides a simple and consistent indirect measure / proxy of melt
- Spatiotemporal understanding of summer temperatures over ice shelves is lacking
- Occurrence of temperature extremes is especially poorly quantified
- Address this knowledge deficit using near-surface temperature output from high-resolution (12 km) MetUM and HIRHAM5 regional climate simulations from summer 1979/80 to 2018/19

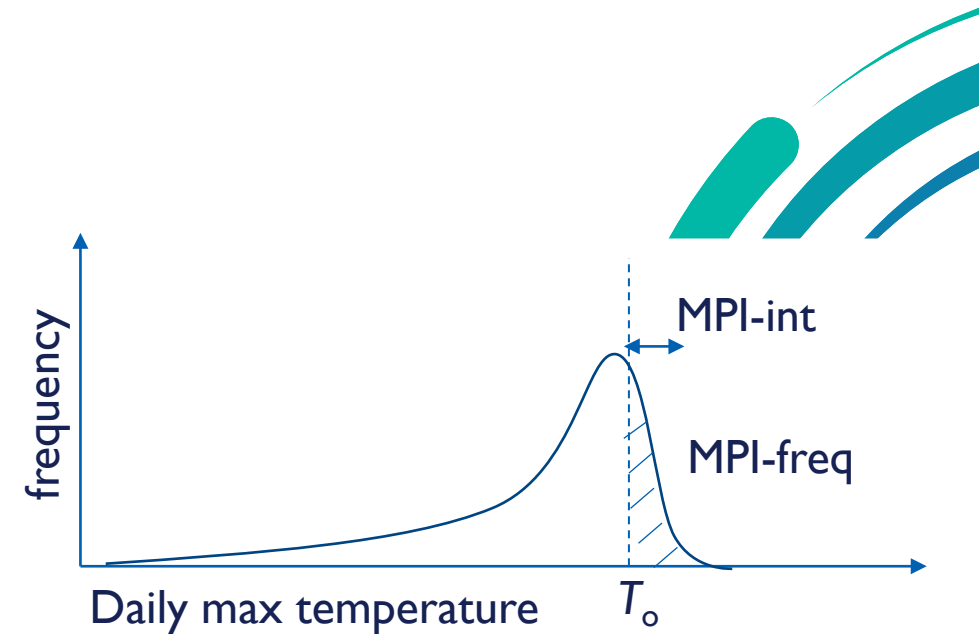
- 3-hourly near-surface temperature output from MetUM and HIRHAM5 simulations from 40 summer (DJF) seasons
- Use to create a probability distribution frequency (PDF) of summer daily maximum temperatures at each grid point over an Antarctic ice shelf.
- Two components measuring the frequency and intensity of daily maximum temperatures exceeding a temperature/melt threshold value  $T_0 = 273.15 \text{ K}$  ( $0^\circ\text{C}$ ).
- Refer to as the “melt potential” index (MPI).



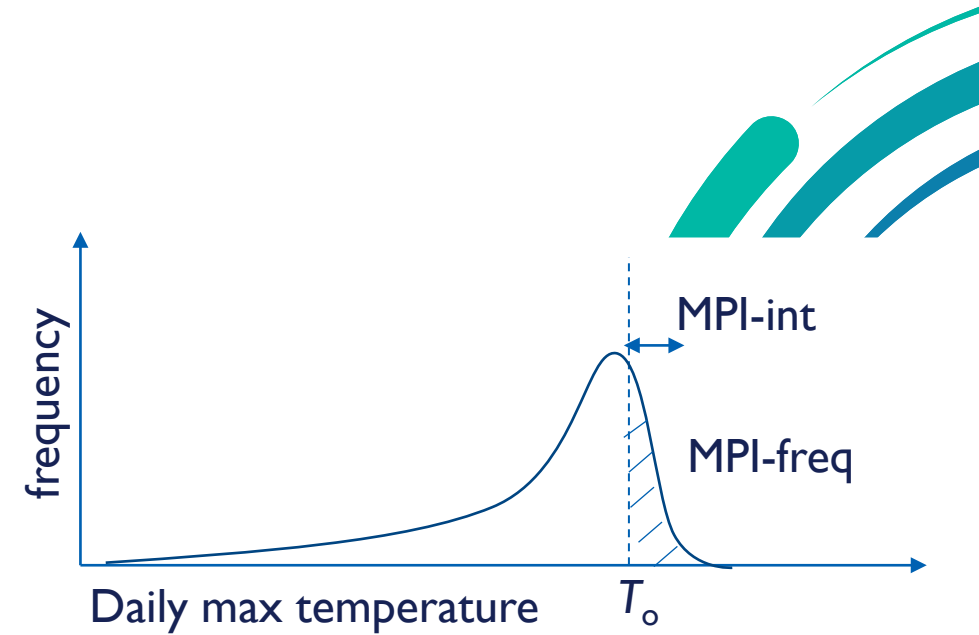
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- **MPI-freq: Frequency of daily maximum temperatures exceeding  $T_0$**



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- **MPI-freq: Frequency of daily maximum temperatures exceeding  $T_0$**
- **MPI-int: Difference between the 95<sup>th</sup> percentile of the distribution of summer daily maximum temperatures and  $T_0$ .**

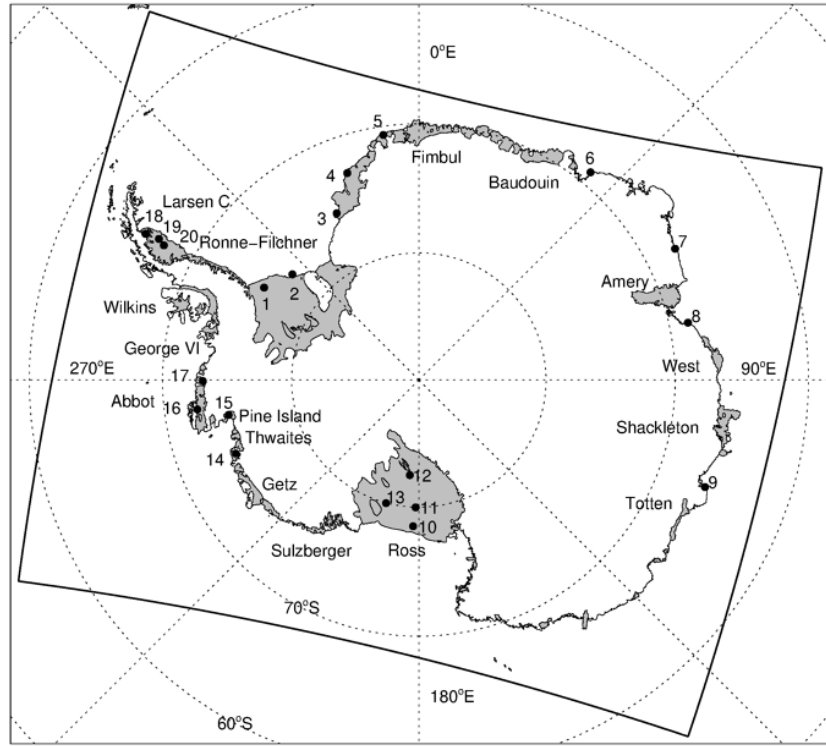


- 3-hourly near-surface temperature output from MetUM and HIRHAM5 simulations from 40 summer (DJF) seasons
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- **MPI-int: Difference between the 95<sup>th</sup> percentile of the distribution of summer daily maximum temperatures and  $T_0$ .**
- Hotspots of MPI
- Variability and trends in timeseries for selected ice shelves
- Correlate with other tropical/remote and local fields
- Correlate with other climate indices for ENSO and SAM



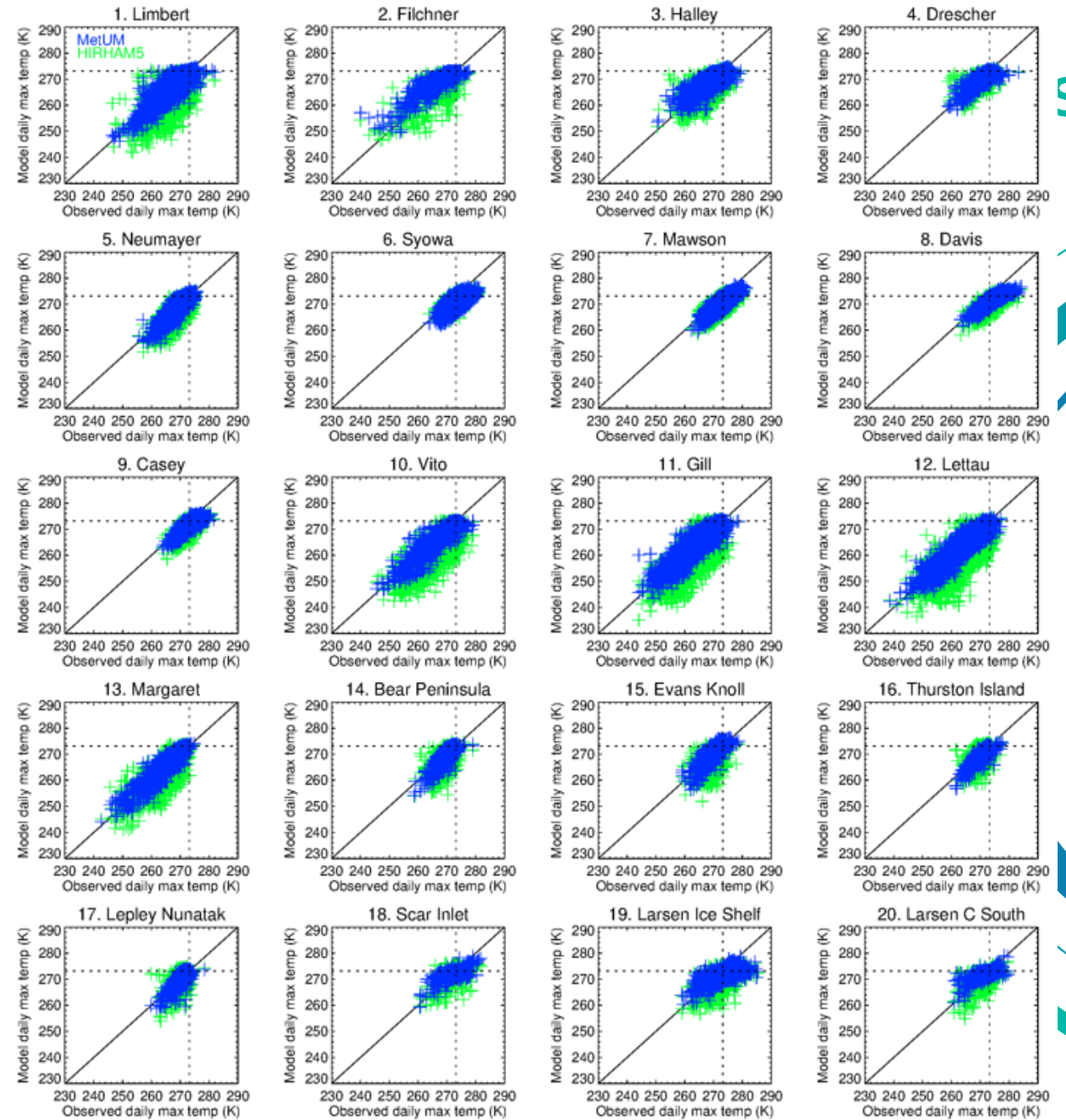


# Comparison of modelled and observed summer daily maximum temperatures



(Above) Map showing the sixteen ice shelves examined, as well as the locations of the 20 weather stations used (labelled 1 to 20). The solid box shows the domain used by the MetUM and HIRHAM5 simulations.

(Right) Scatterplots comparing the observed daily summer maximum temperature and MetUM (blue) and HIRHAM5 (green) model daily maximum temperature at each of the 20 weather stations.



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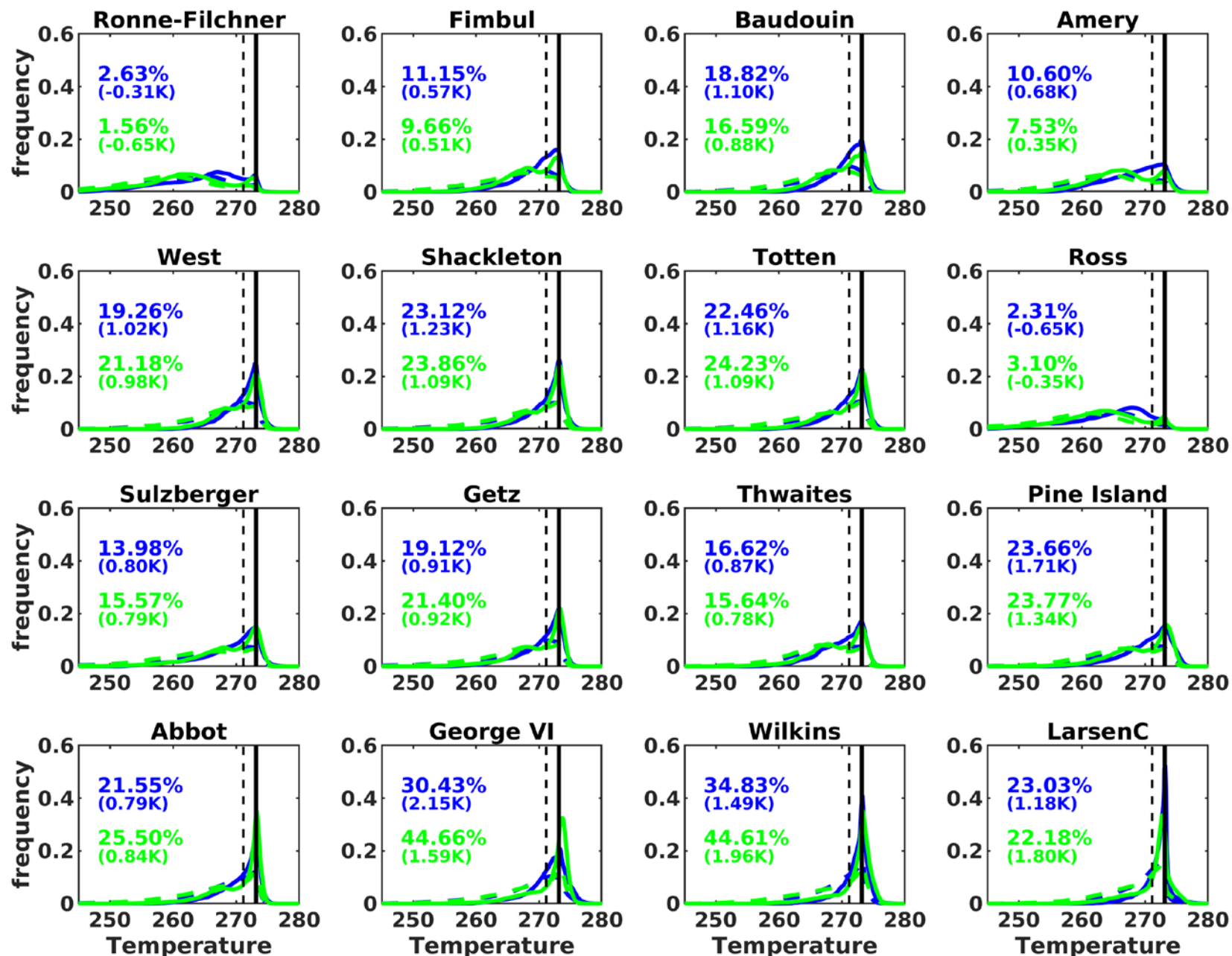
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## Hotspots of “melt potential” index

PDFs of summer daily maximum near-surface temperature for the sixteen ice shelves (solid lines) based on MetUM (blue) and HIRHAM5 (green) output.

The numbers show climatological values of MPI-freq (%) and MPI-int (K; shown in brackets). Values of MPI-freq and MPI-int are shown for both MetUM (blue) and HIRHAM5 (green).

The solid line shows the temperature/melt threshold value  $T_0 = 273.15$  K ( $0^\circ\text{C}$ ). The dashed line shows a threshold value of  $271.15$  K ( $-2^\circ\text{C}$ ) used in a sensitivity test.



**MetUM**

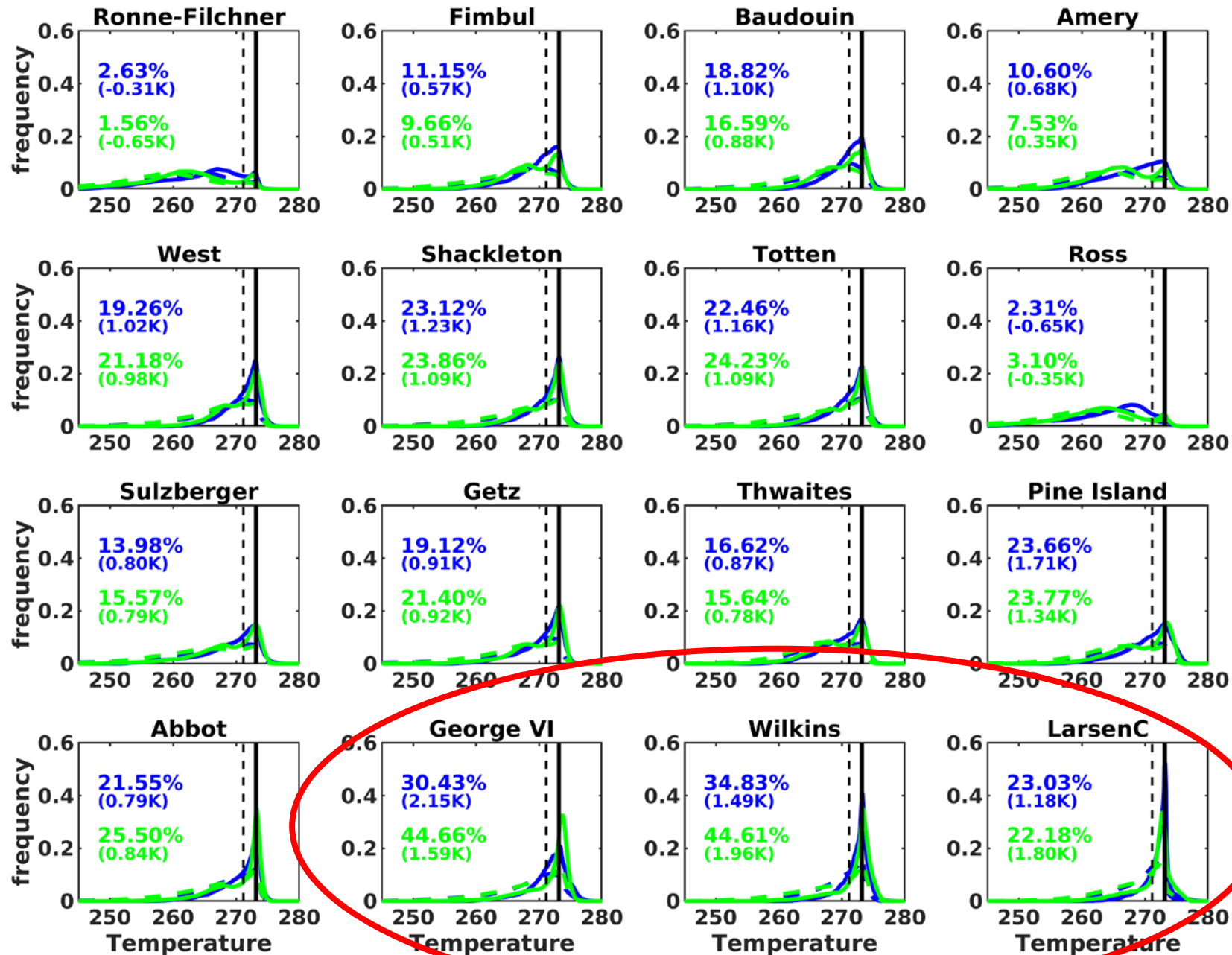
**HIRHAM5**

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**Highest for Antarctic Peninsula ice shelves (MPI-freq 23-35%, MPI-int 1.2-2.1 K)**

MetUM

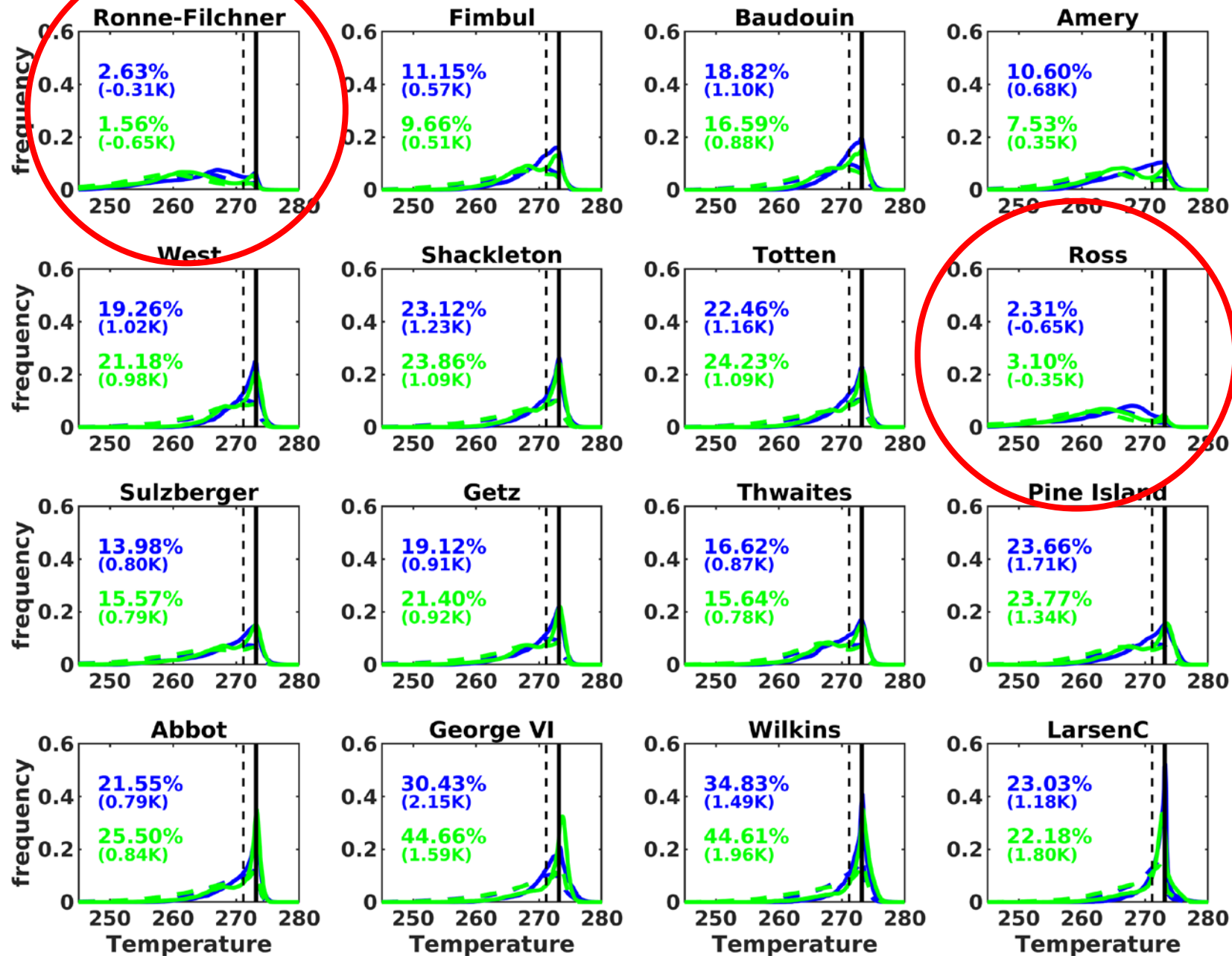
HIRHAM5

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- Highest for Antarctic Peninsula ice shelves (MPI-freq 23-35%, MPI-int 1.2-2.1 K)

- Lowest (2-3%, < 0 K) for Ronne-Filchner and Ross ice shelves

MetUM

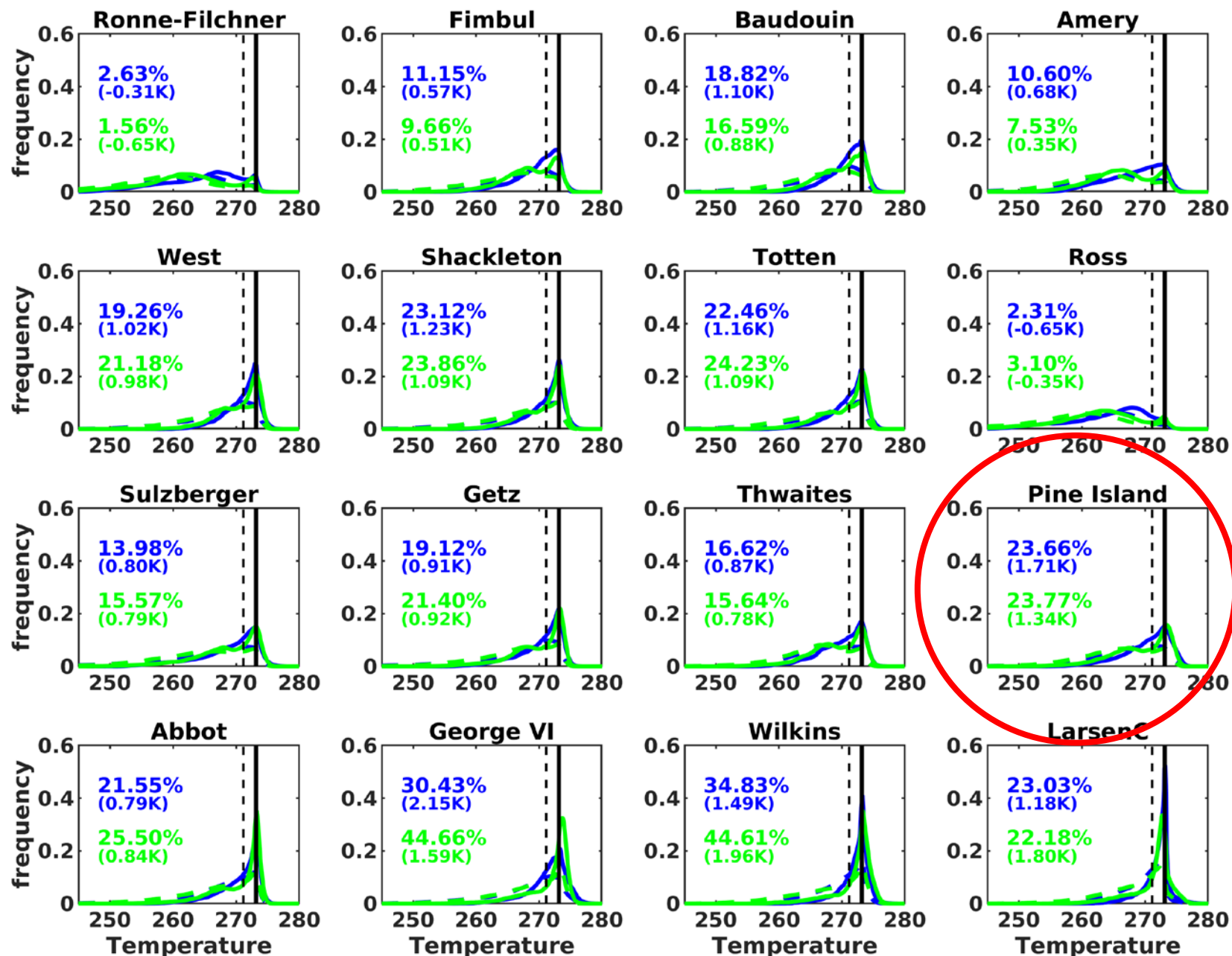
HIRHAM5

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- Highest for Antarctic Peninsula ice shelves (MPI-freq 23-35%, MPI-int 1.2-2.1 K)

- Lowest (2-3%, < 0 K) for Ronne-Filchner and Ross ice shelves

- Around 10-24% and 0.6-1.7 K for the other ice shelves.

MetUM

HIRHAM5

## Hotspots of “melt potential” index

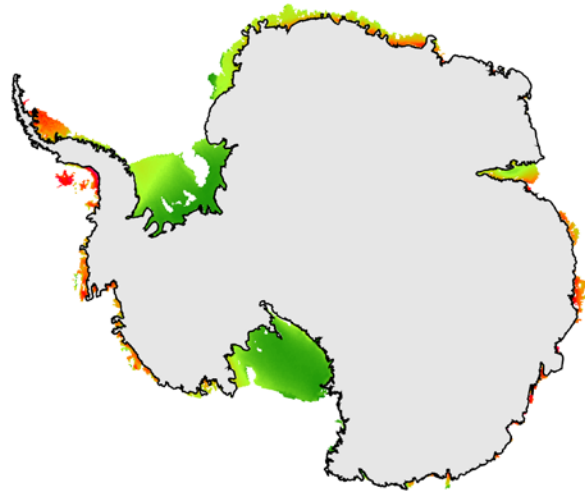


Maps of the climatological values of MPI-freq (top) based on MetUM (left) and HIRHAM5 (right) output.

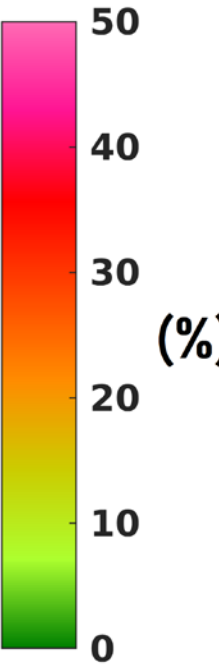
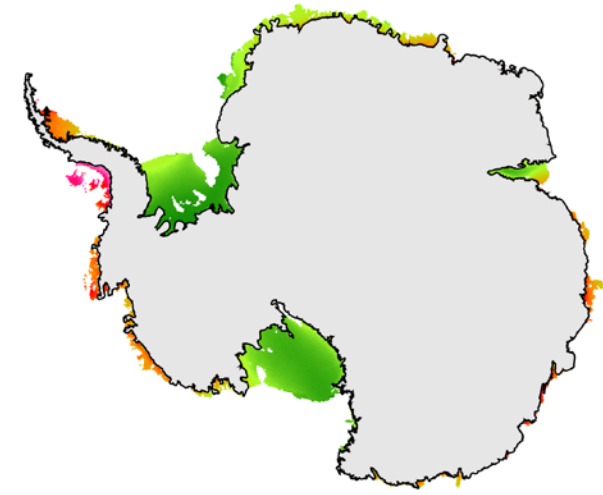
# Hotspots of “melt potential” index

Maps of the climatological values of MPI-freq (top) and MPI-int (bottom) based on MetUM (left) and HIRHAM5 (right) output.

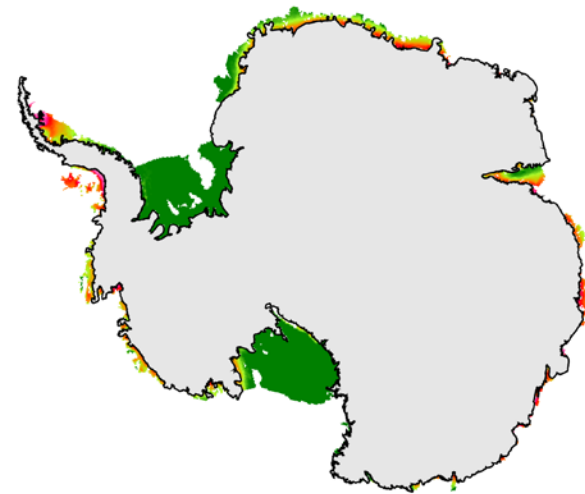
(a) MetUM



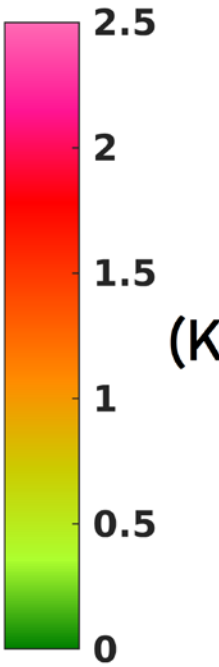
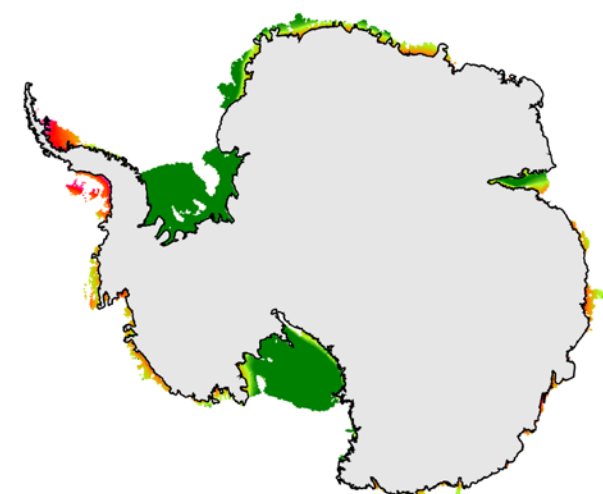
(b) HIRHAM5



(c) MetUM



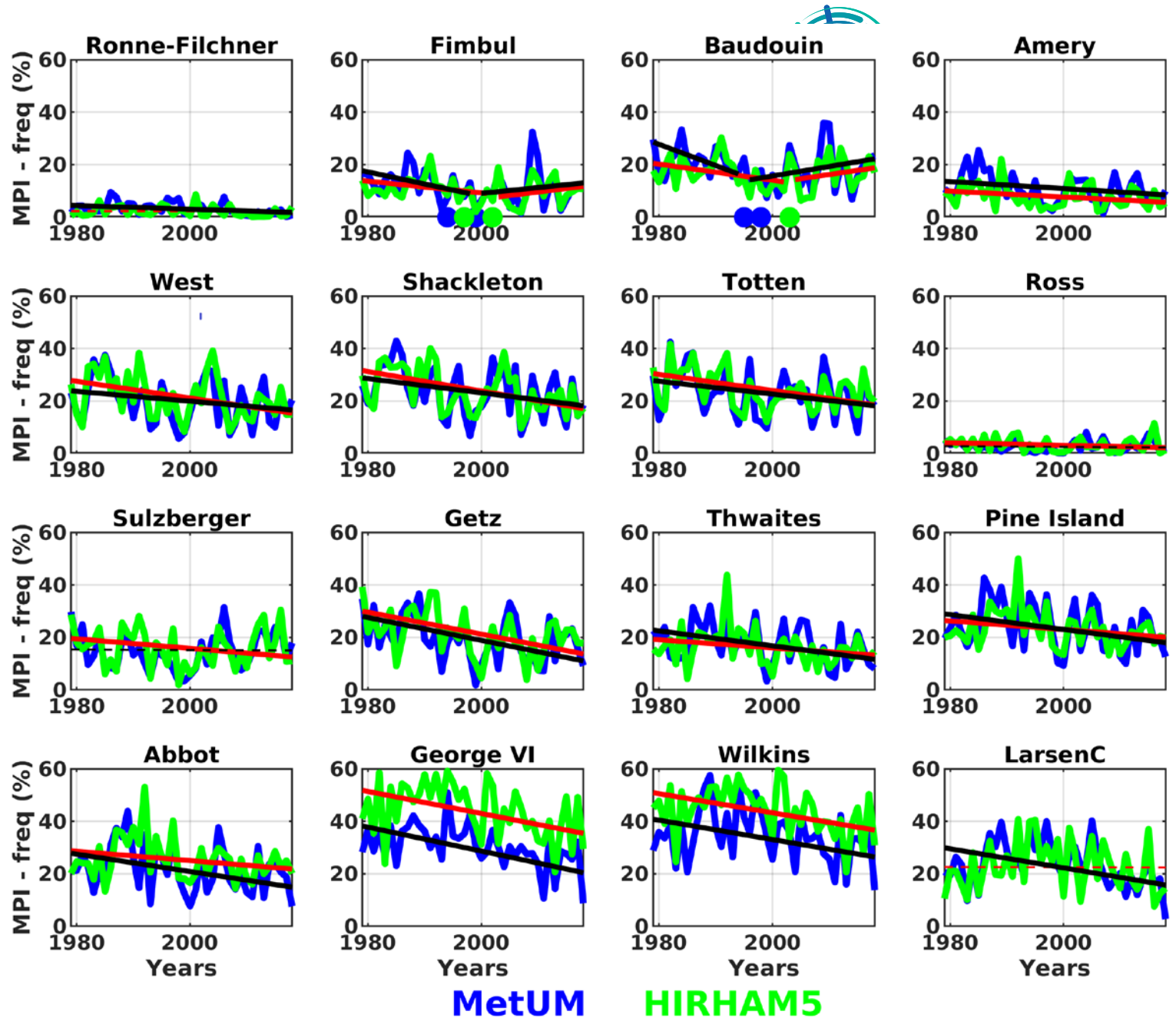
(d) HIRHAM5



# Trends and interannual variability of “melt potential” index

Timeseries of MPI-freq based on MetUM (blue) and HIRHAM5 (green) output.

The solid (dashed) lines show the statistically significant (insignificant) linear trends based on MetUM (black) and HIRHAM5 (red) output. The solid circle shows when a change-point occurred based on MetUM (blue) and HIRHAM5 (green) simulations.



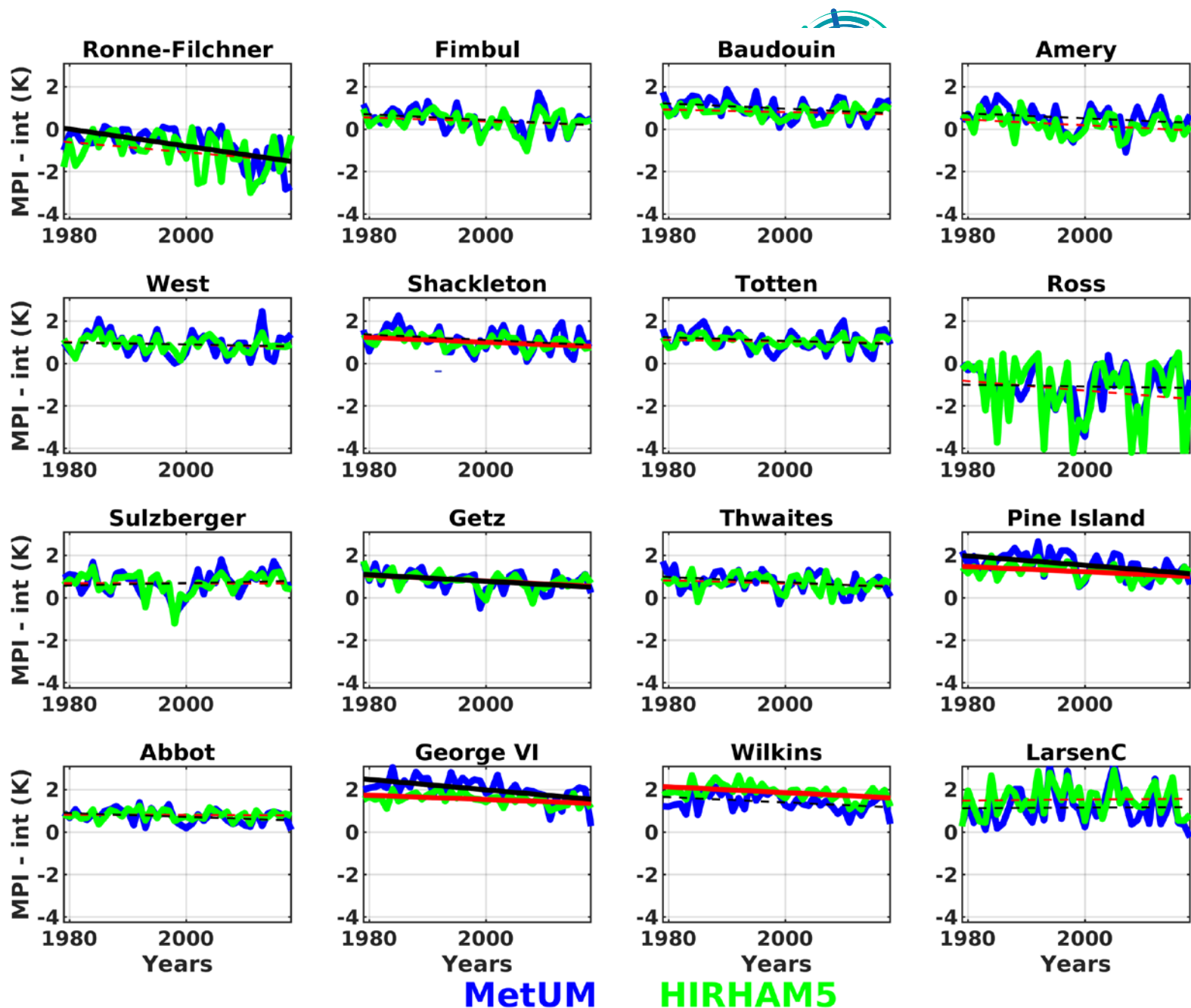
- Most ice shelves show significant decreasing trend in MPI-freq
- Fimbul and Baudouin show a change-point



# Trends and interannual variability of “melt potential” index

As previous slide but showing trend in MPI-int.

Only significant trends in MPI-int based on MetUM are negative for Ronne-Filchner, Getz, Pine Island and George VI



# Mechanisms responsible for interannual variability of “melt potential” index



Detrended correlation between MPI-freq for a temperature/melt threshold of  $T_0 = 273.15$  K and Niño 4, Southern Oscillation Index (SOI), and Southern Annular Model (SAM) indexes for the sixteen ice shelves examined. In each column the correlation values based on MetUM output are shown first, followed by HIRHAM5.

Ice shelf	$T_0 = 273.15$ K (MetUM, HIRHAM5)		
	Niño 4	SOI	SAM
Ronne	0.24, -0.09	-0.11, 0.16	0.21, 0.18
Fimbul	0.12, 0.21	0.00, -0.17	<b>-0.36, -0.34</b>
Baudouin	0.10, 0.15	-0.07, -0.24	<b>-0.57, -0.33</b>
Amery	<b>0.33, 0.20</b>	<b>-0.35, -0.26</b>	<b>-0.47, -0.34</b>
West	<b>0.31, 0.38</b>	<b>-0.31, -0.51</b>	<b>-0.58, -0.60</b>
Shackleton	<b>0.35, 0.46</b>	<b>-0.35, -0.52</b>	<b>-0.58, -0.59</b>
Totten	0.29, <b>0.34</b>	-0.30, <b>-0.46</b>	<b>-0.67, -0.66</b>
Ross	0.25, 0.12	-0.22, -0.30	-0.11, <b>-0.35</b>
Sulzberger	0.22, 0.14	-0.12, -0.26	-0.15, <b>-0.37</b>
Getz	<b>0.31, 0.39</b>	-0.30, <b>-0.41</b>	-0.19, -0.25
Thwaites	<b>0.45, 0.34</b>	<b>-0.41, -0.42</b>	-0.07, -0.07
Pine	<b>0.44, 0.35</b>	<b>-0.43, -0.37</b>	0.04, 0.01
Abbot	0.25, <b>0.34</b>	<b>-0.33, -0.38</b>	0.00, -0.03
George VI	0.00, <b>0.36</b>	-0.11, <b>-0.42</b>	0.22, 0.25
Wilkins	-0.01, 0.24	-0.12, -0.25	0.26, <b>0.35</b>
Larsen C	0.16, 0.04	-0.17, -0.04	0.15, <b>0.37</b>

- **East Antarctic ice shelves: high MPI-freq significantly correlated with negative SAM**
- **East Antarctic ice shelves: response to SAM amplified by El Niño conditions**
- **West Antarctic ice shelves: significant correlation with El Niño conditions**

## Mechanisms responsible for interannual variability of “melt potential” index



Detrended correlation between MPI-freq based on MetUM output for West Antarctic ice shelves and tropical sea surface temperatures and outgoing longwave radiation.

# Mechanisms responsible for interannual variability of “melt potential” index



Detrended correlation between MPI-freq based on MetUM output for West Antarctic ice shelves and tropical sea surface temperatures and outgoing longwave radiation.

- **Positive correlation with central tropical SST**
- **Negative correlation with OLR extending southeastward along the South Pacific convergence zone (SPCZ)**

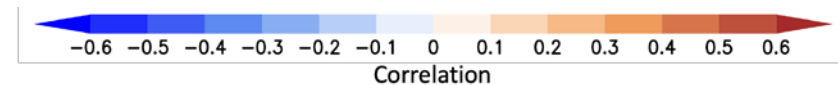


# Mechanisms responsible for interannual variability of “melt potential” index



Detrended correlation (shaded) between MPI-freq based on MetUM output for West Antarctic ice shelves and geopotential height at 500 hPa.

- **West Antarctic ice shelves: enhanced MPI associated with regional high-pressure (low-pressure) anomaly to the east (west) of each ice shelf.**

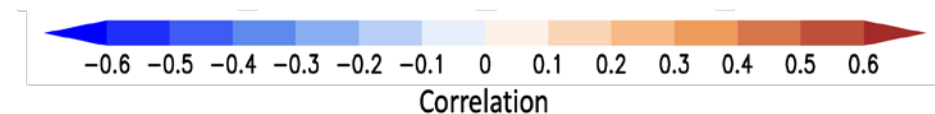


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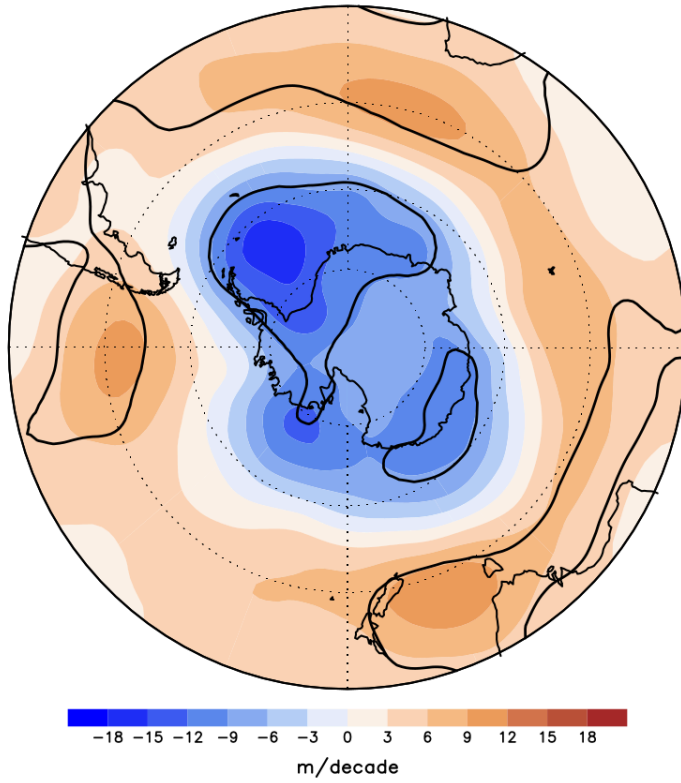
As previous figure, but for East Antarctic ice shelves

- **East Antarctic ice shelves: enhanced MPI due to zonally symmetric pattern with strong positive correlations over continental Antarctica and negative correlations across middle latitudes**



# Mechanisms responsible for interannual variability of “melt potential” index

DJF Z500 Trend 1979/80 – 2018/19



DJF OLR Trend 1979/80 – 2018/19

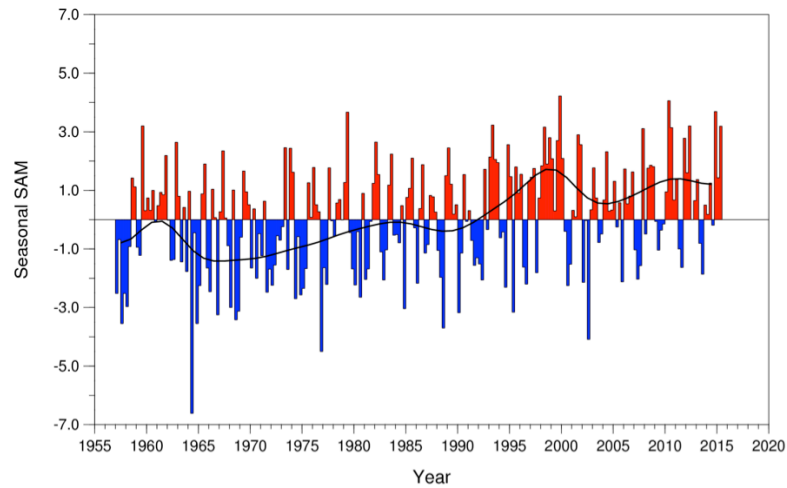
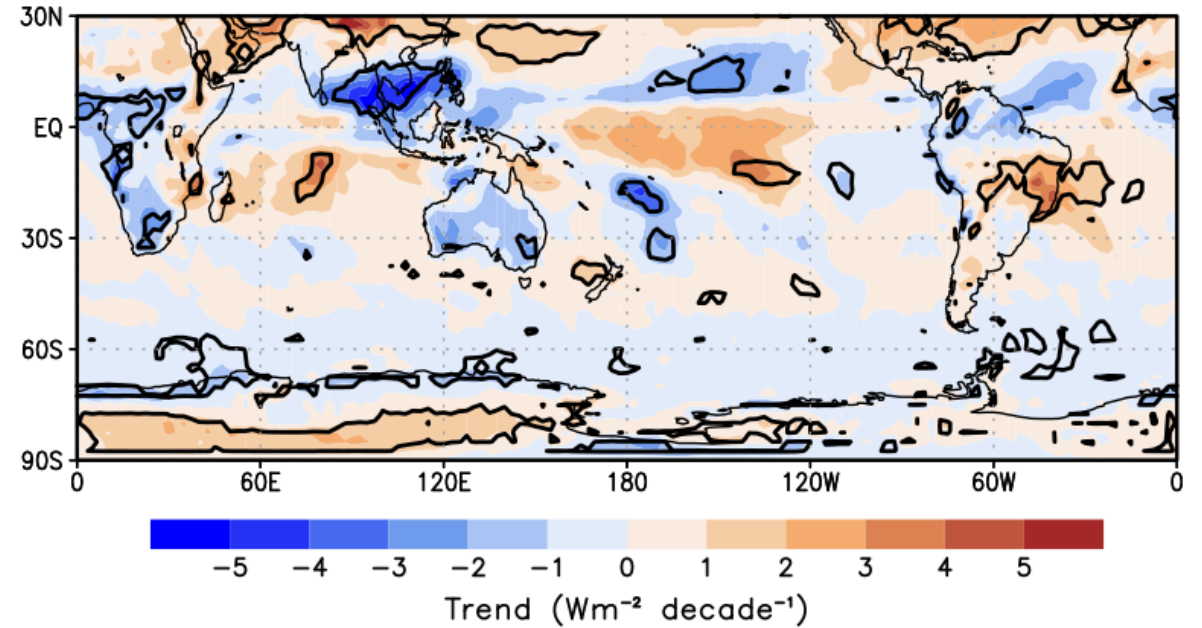
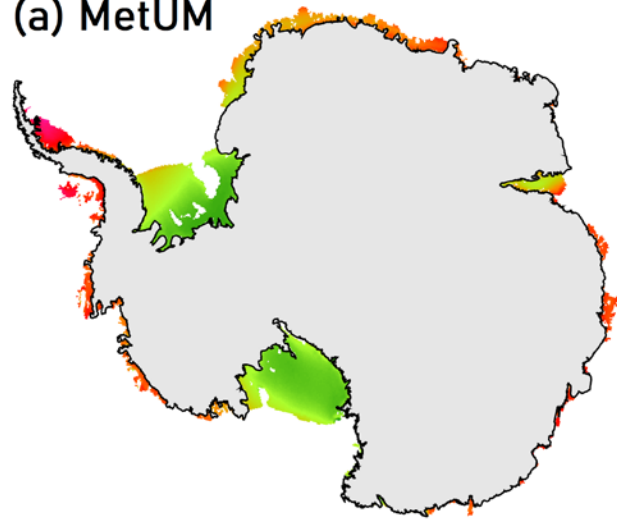


Figure from Kyle Clem

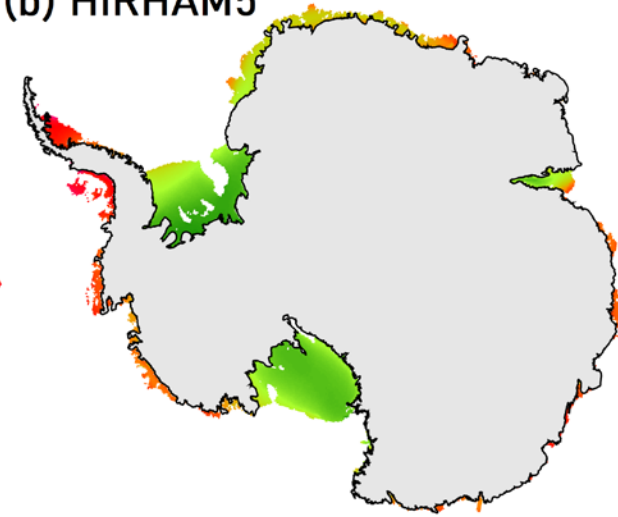
# Sensitivity test using a temperature / melt threshold of 271.15 K

Maps of the climatological values of MPI-freq (top) and MPI-int (bottom) for a lower temperature / melt threshold of 271.15 K (-2°C)

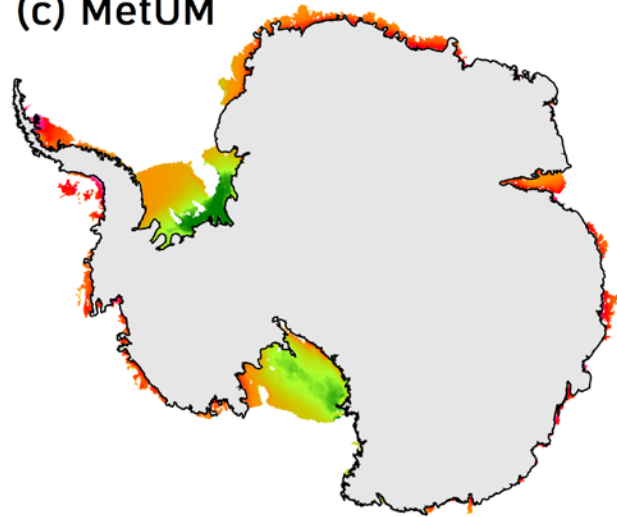
(a) MetUM



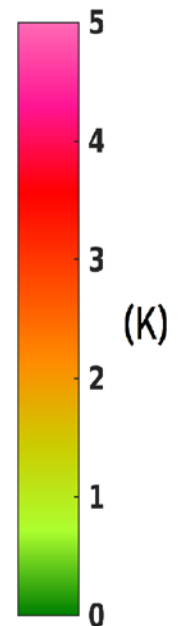
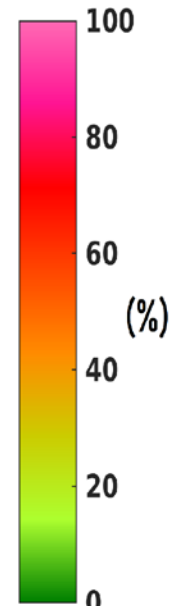
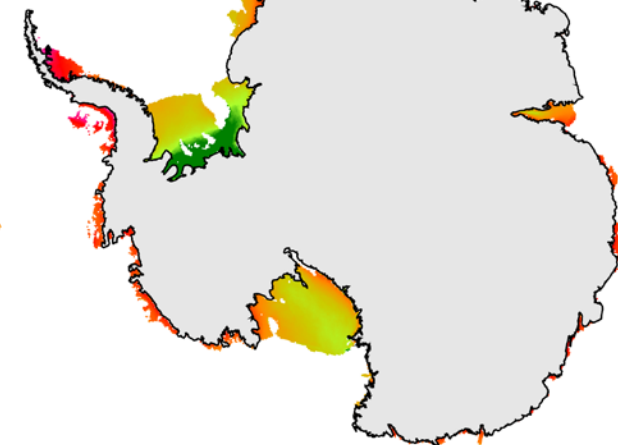
(b) HIRHAM5



(c) MetUM



(d) HIRHAM5



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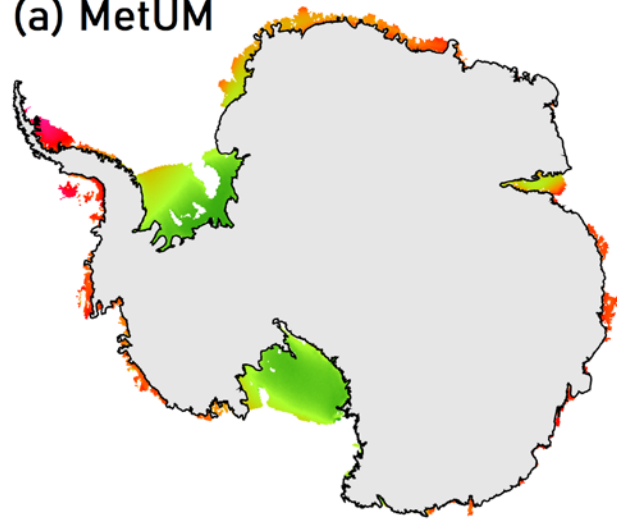


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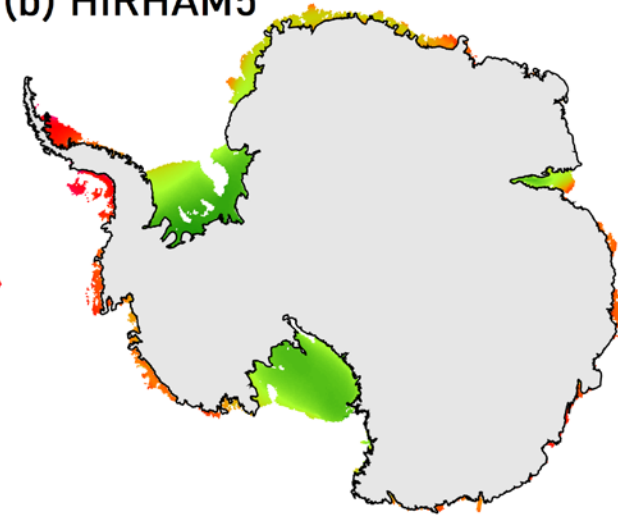
Maps of the climatological values of MPI-freq (top) and MPI-int (bottom) for a lower temperature / melt threshold of 271.15 K (-2°C)

- Values of MPI are 3-4 times larger for a lower threshold of 271.15 K

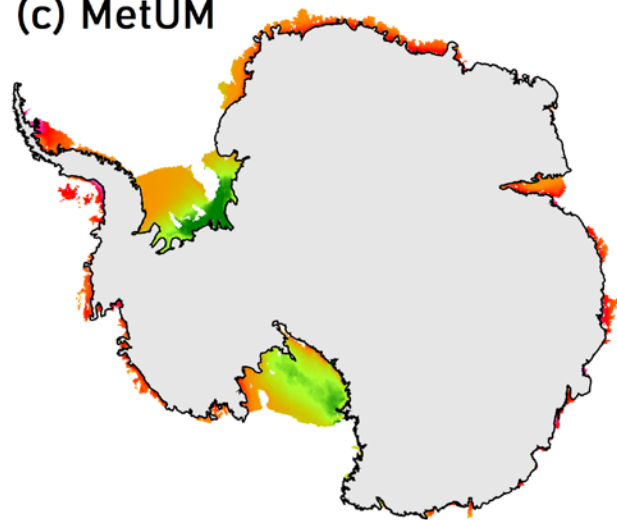
(a) MetUM



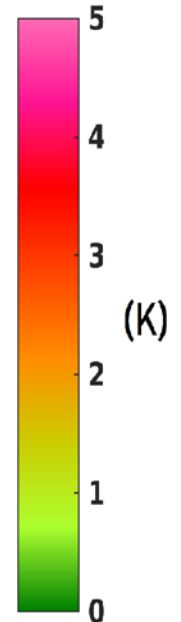
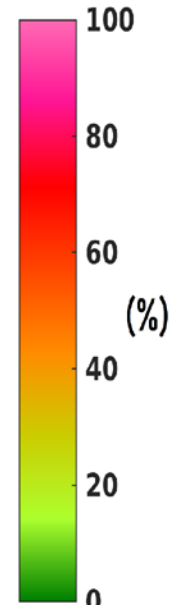
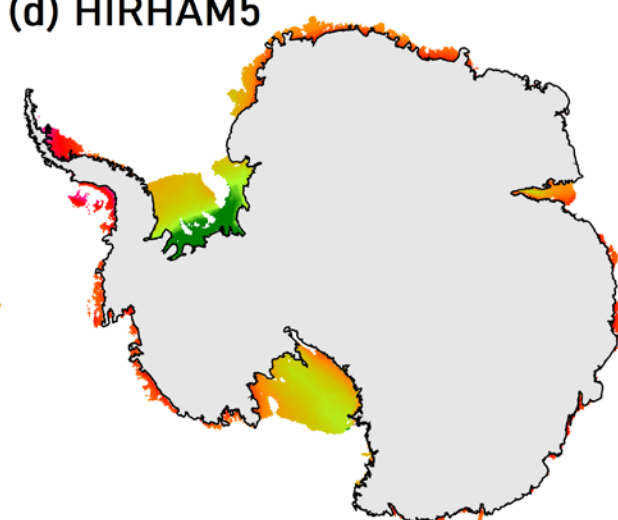
(b) HIRHAM5



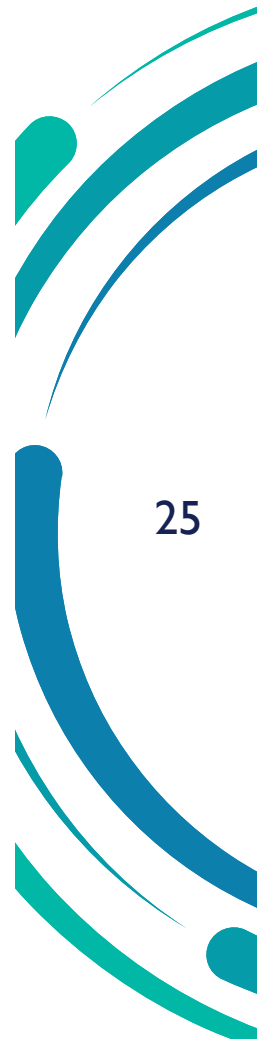
(c) MetUM



(d) HIRHAM5



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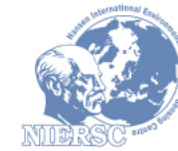


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## Conclusions



- MPI-freq is
  - highest for Antarctic Peninsula ice shelves (23-35%; 1.2-2.2 K),
  - lowest (2-3%; <0 K) for Ronne-Filchner and Ross,
  - 10-24% and 0.6-1.7 K for the other West and East Antarctic ice shelves
- Many ice shelves are characterized by pronounced spatial gradients in MPI
  - warm signatures associated by local effects
- Distinctly different local and large-scale circulation patterns governing MPI variability over West and East Antarctic ice shelves.
- Estimates of MPI based on threshold of  $T_0 = 273.15$  K are conservative / underestimated, and more realistic estimates require using a lower temperature threshold
- Values of MPI are 3-4 times larger for a lower threshold of 271.15 K (-2°C) used in a sensitivity test



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