Statistics of pan-oceanic extreme near-surface winds

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Department of Meteorology and Bolin Centre for Climate Studies, Stockholm University, Sweden

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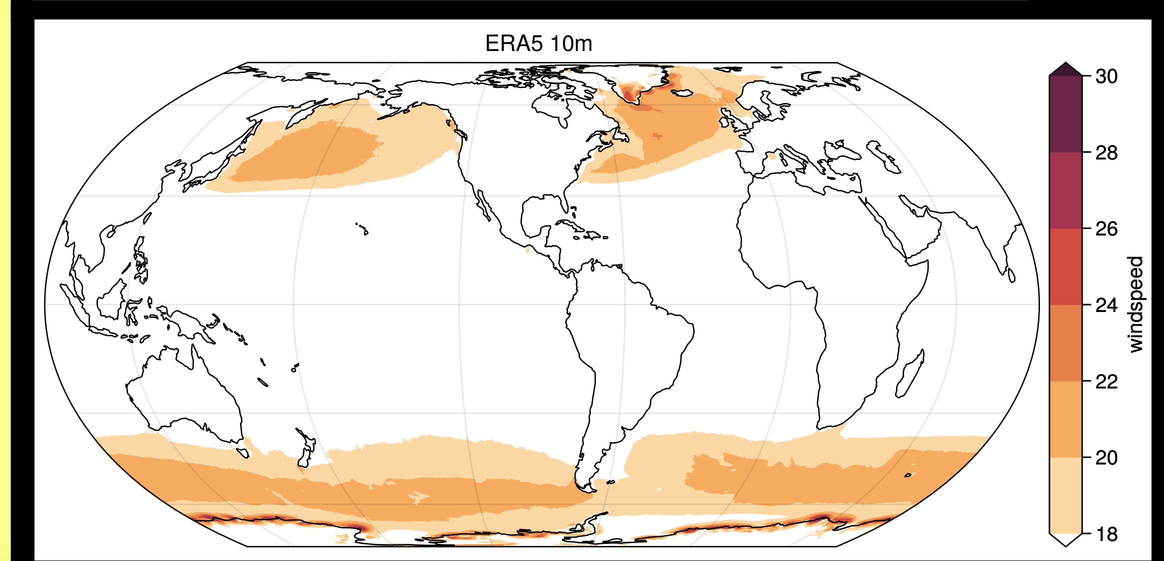

Annual 98th percentile of daily-mean 10 m windspeed

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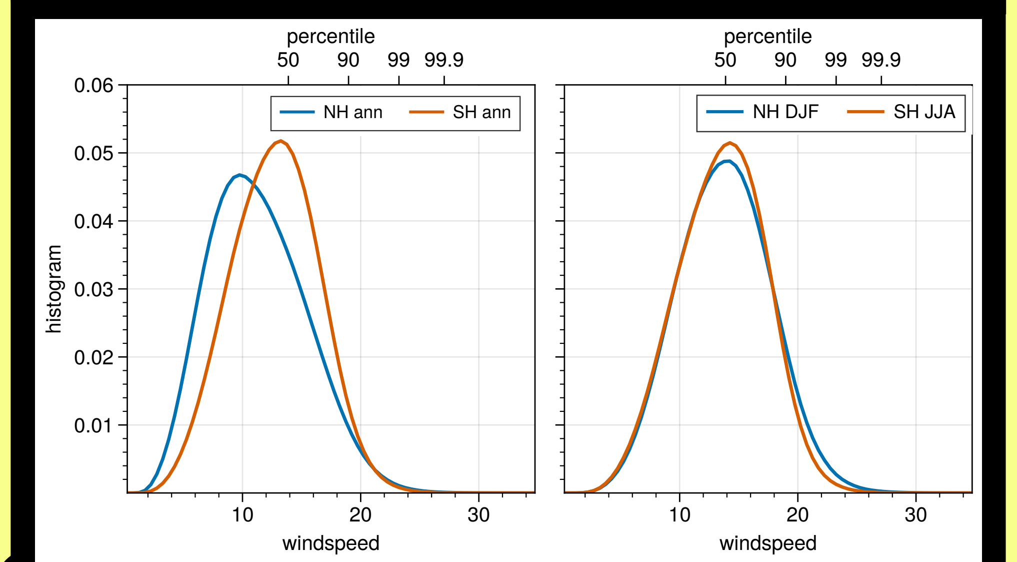

PDFs of annual daily-mean 10 m windspeed

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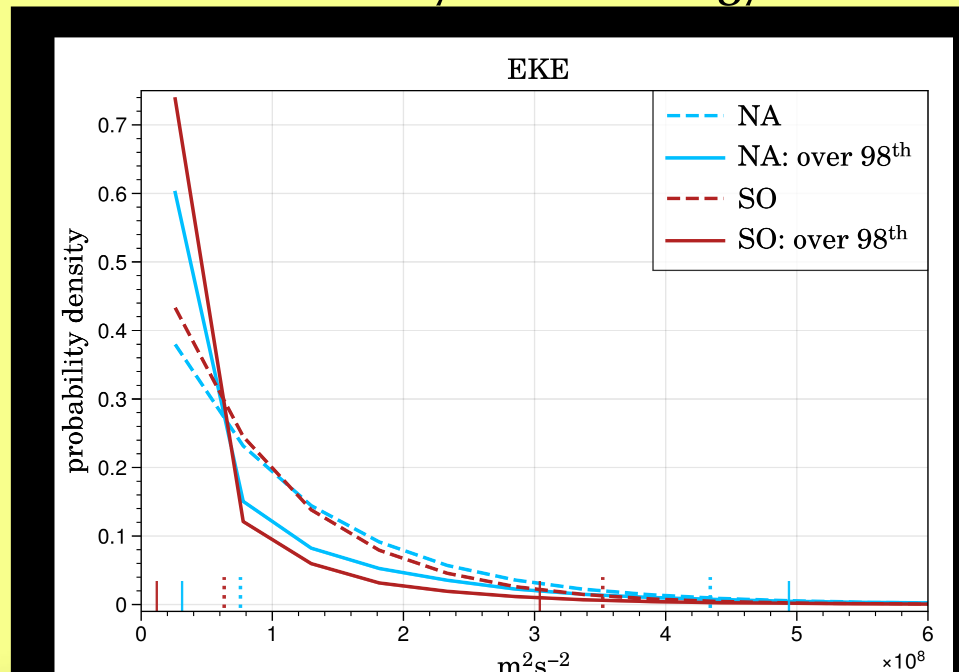
PDFs of winter eddy kinetic energy



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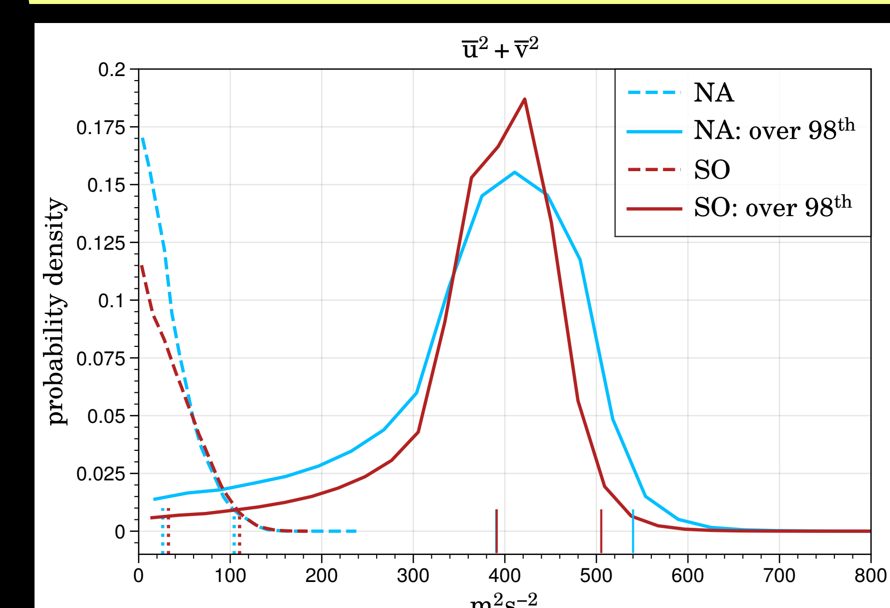

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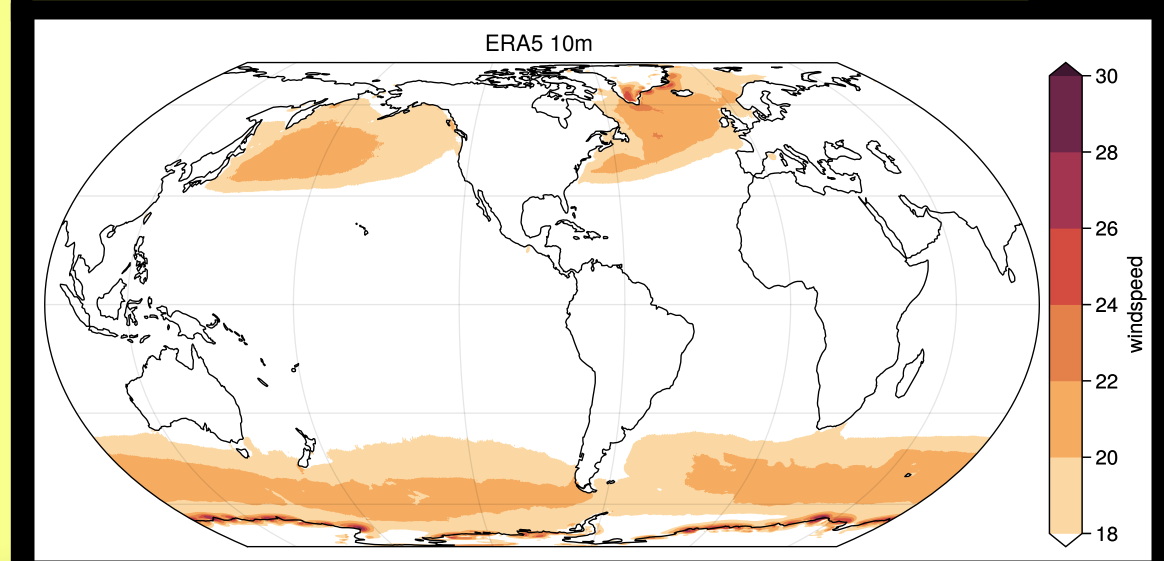

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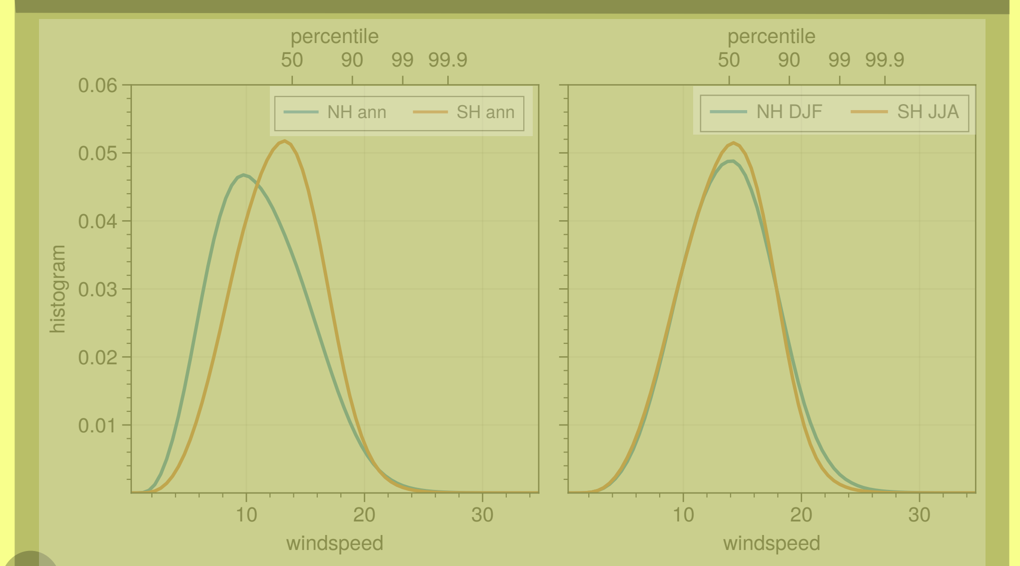

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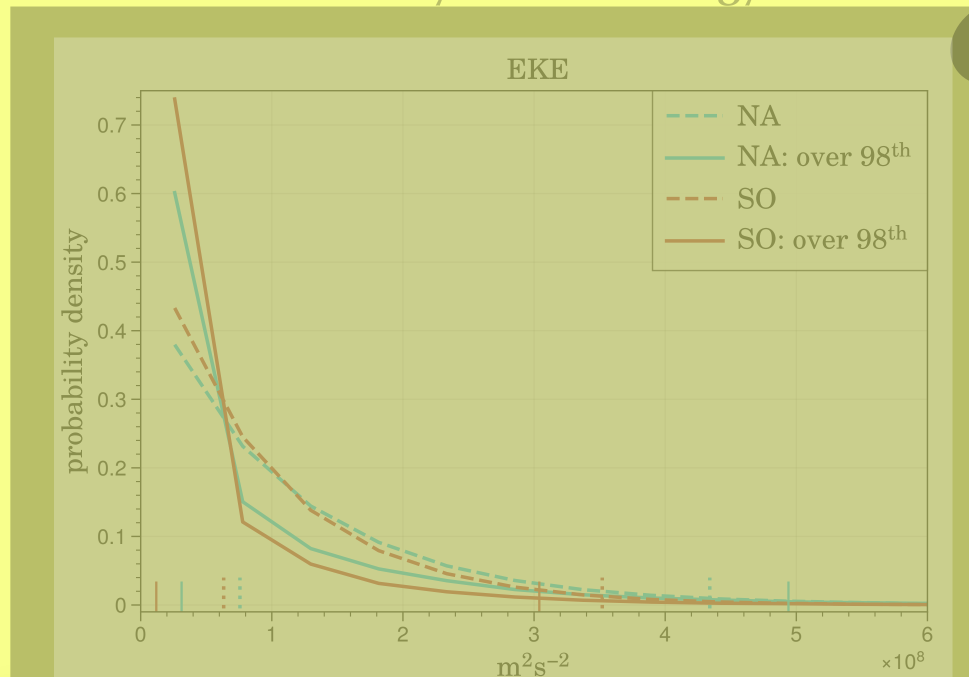

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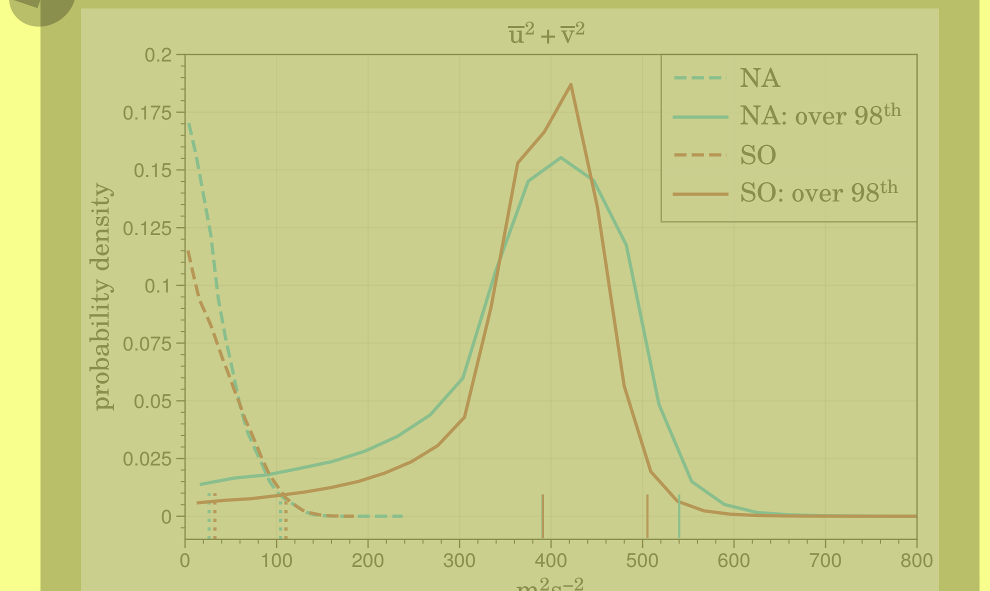

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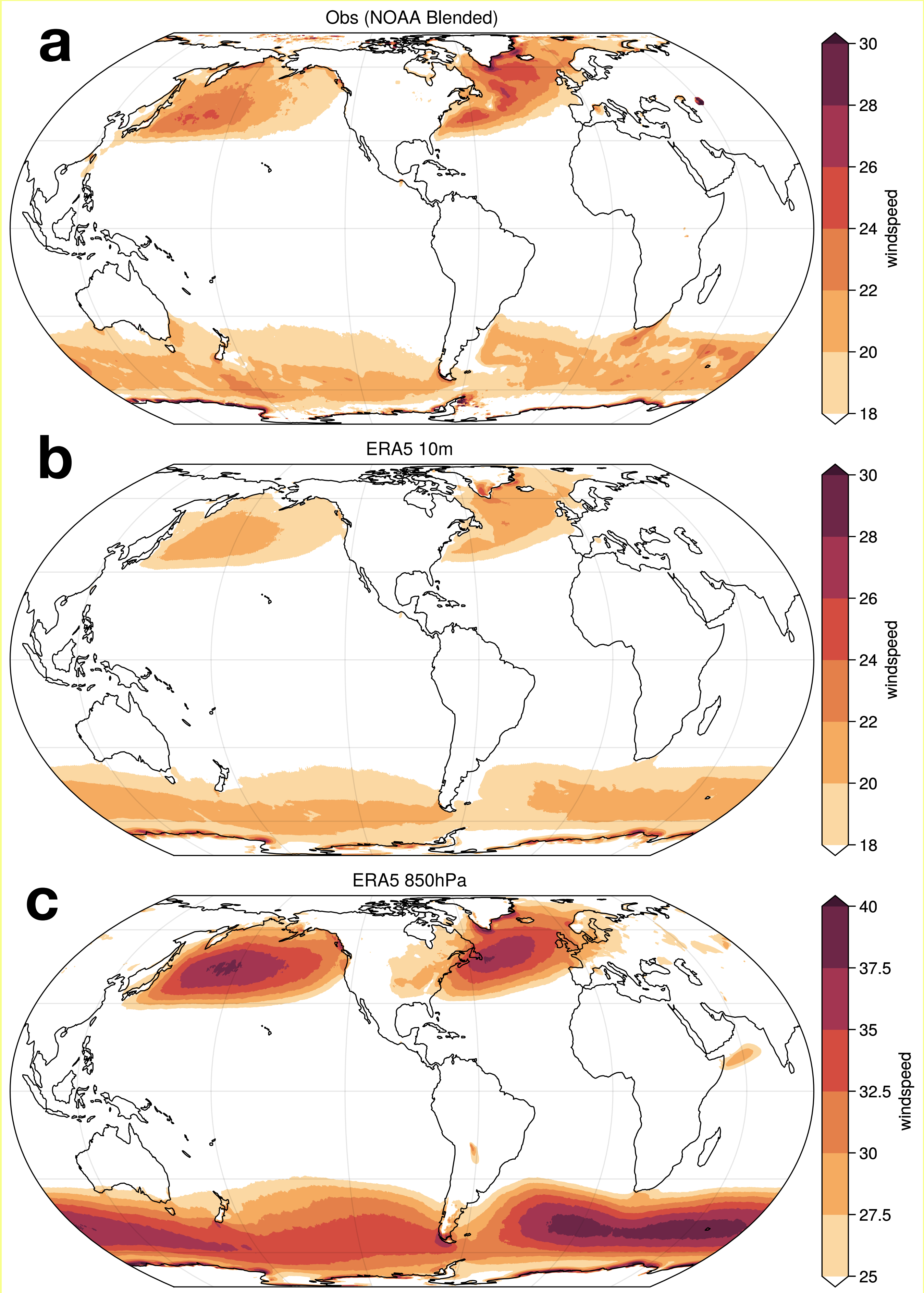

Figure 1: Annual 98th percentile of daily-mean 10 m (a,b) and 850 hPa (c) windspeed from ERA5 reanalysis (b,c) and NOAA Blended scatterometer retrievals (a).

We compute statistics of daily-mean grid point 10 m windspeed from ERA5 reanalysis and scatterometer retrievals (NOAA Blended). We do the same for 850 hPa winds from ERA5 reanalysis, the height above the boundary-layer height in most cases. To investigate the most extreme 10 m winds, we focus our analysis only on regions where the local 98th percentiles are above 18 m/s. The climatologies of 98th percentiles of 10 m windspeed in these regions are shown in Figure 1. Comparison of data coming from reanalysis and observational datasets shows quantitative and qualitative similarities, with the regions with the strongest 10 m windspeed being over the storm track regions. Similar regions are selected when focusing on the highest 98th percentiles of 850 hPa windspeed (those higher than 25 m/s).

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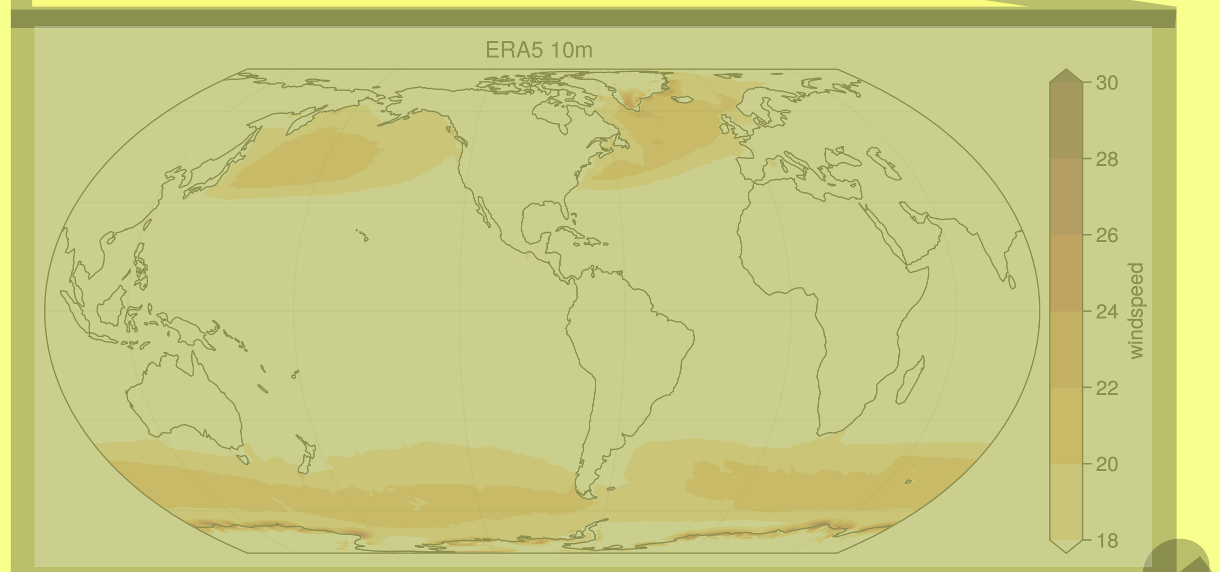

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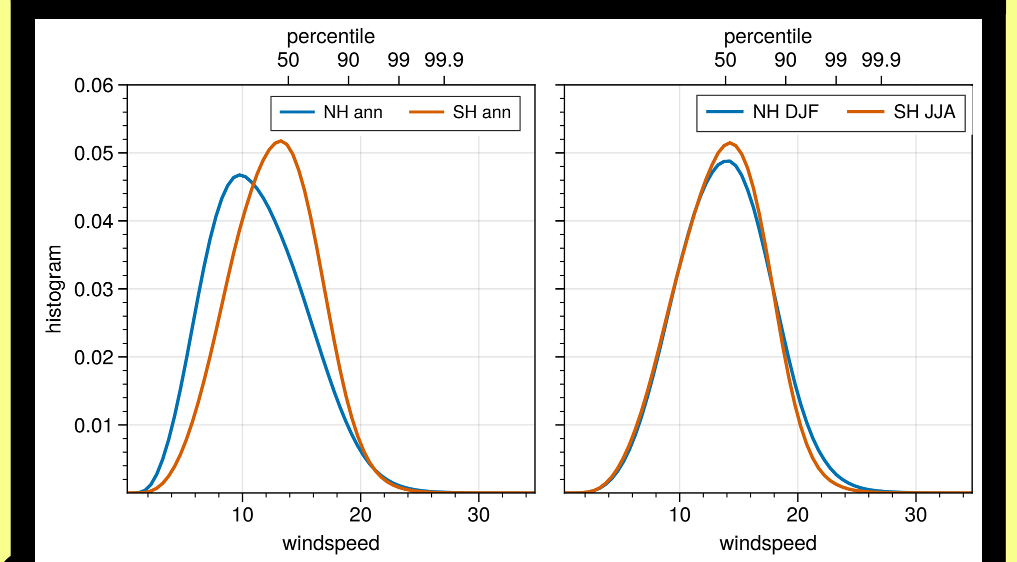

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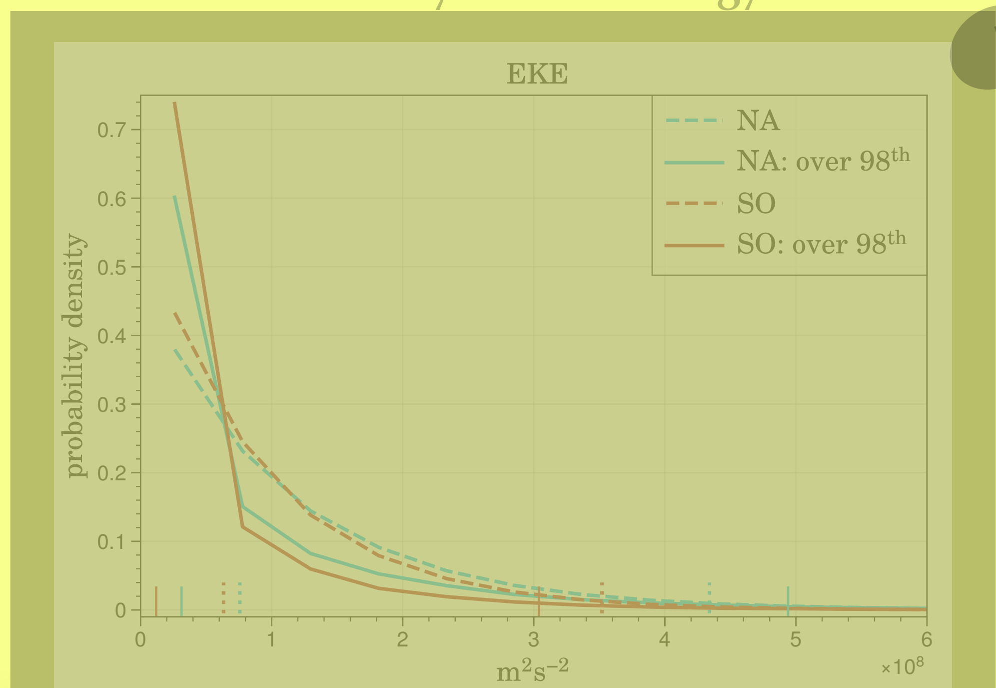

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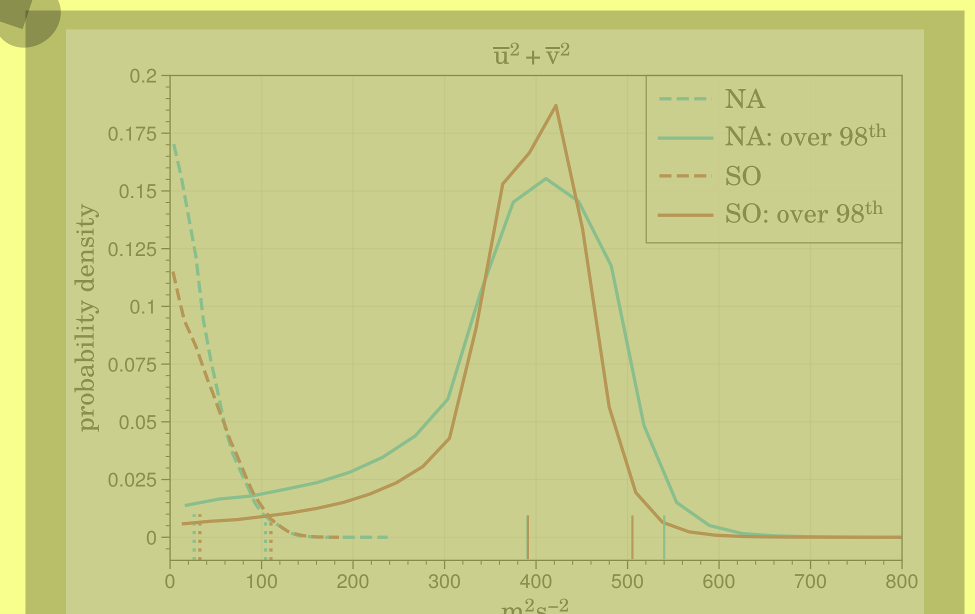

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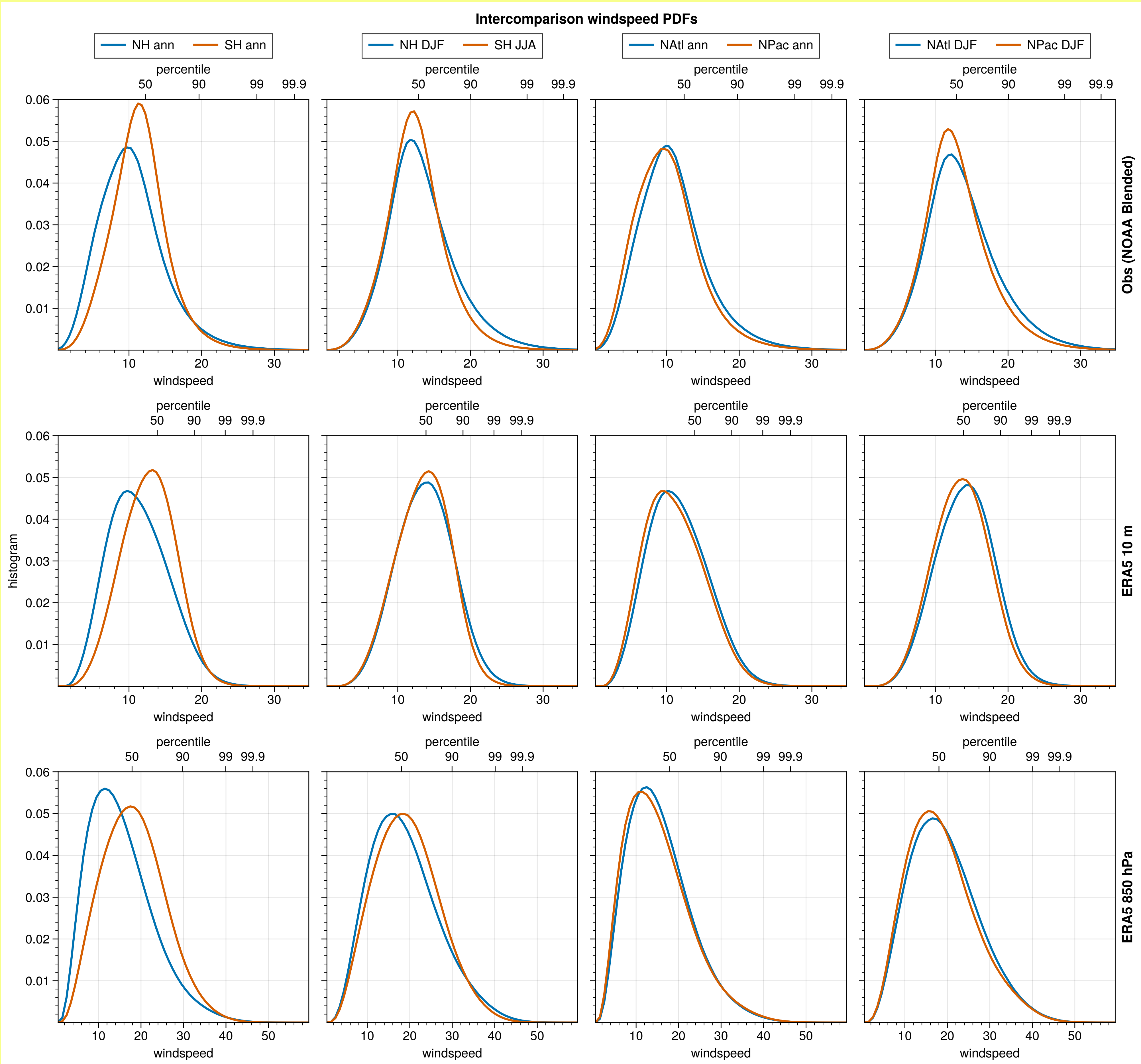

Figure 2: Inter-comparison of 10 m windspeed (a,b) and 850 hPa winds (c) PDFs in the regions highlighted in Figure 1.

Figure 2 shows inter-comparison of windspeed PDFs among basins and seasons. Median of windspeed is higher in the Southern Hemisphere (SH) than in the Northern Hemisphere (NH). Extremes, however, are higher in the NH. In the winter seasons when there is the peak in extratropical cyclone activity, difference in extremes between the hemispheres is even greater. Among the basins, the North Atlantic has the strongest 10 m windspeed extremes. These conclusions are consistent among different datasets analysed (observational vs reanalysis).

Differences in the median and the extreme 10 windspeed are also found in 850 hPa winds, suggesting that the inter-hemispheric differences are due to differences in large-scale characteristics associated with the extremes.

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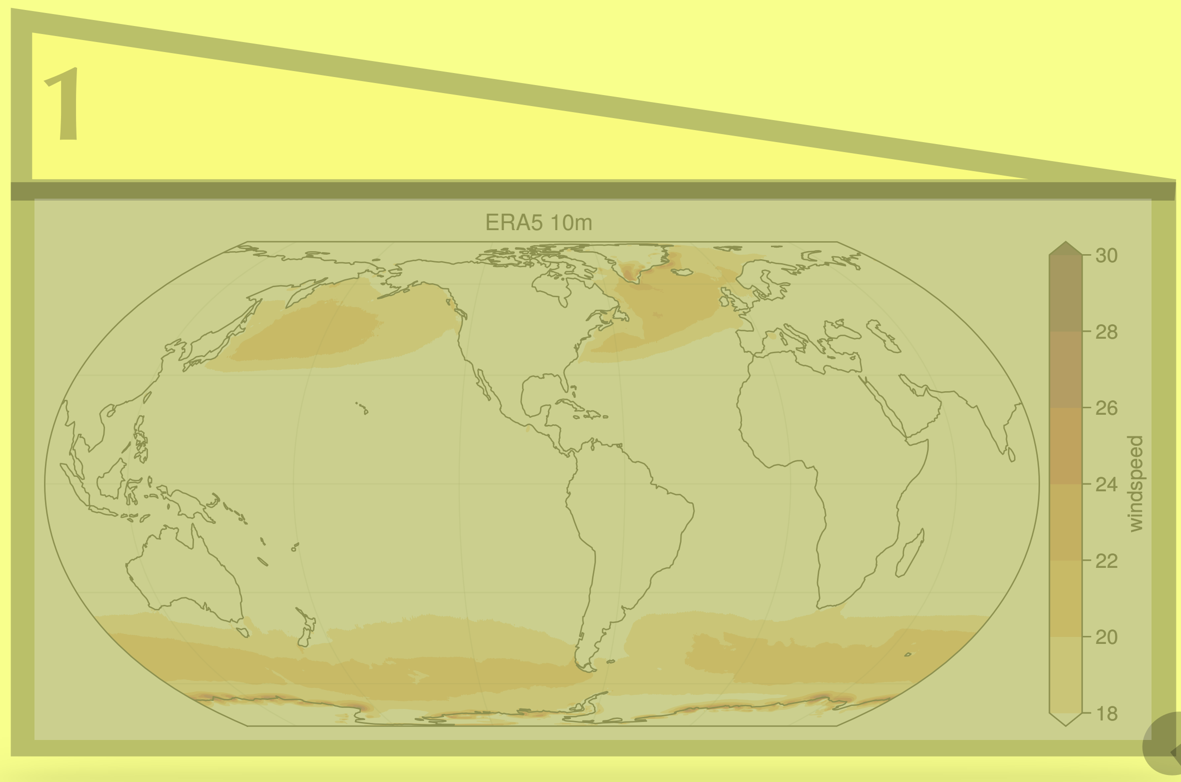

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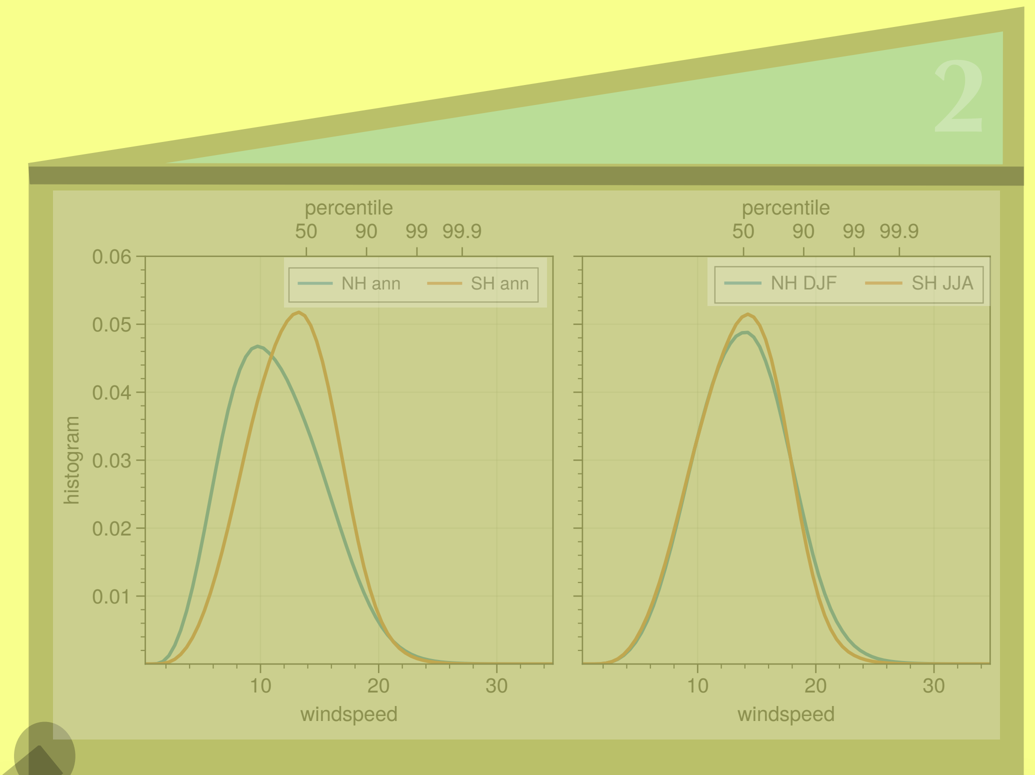

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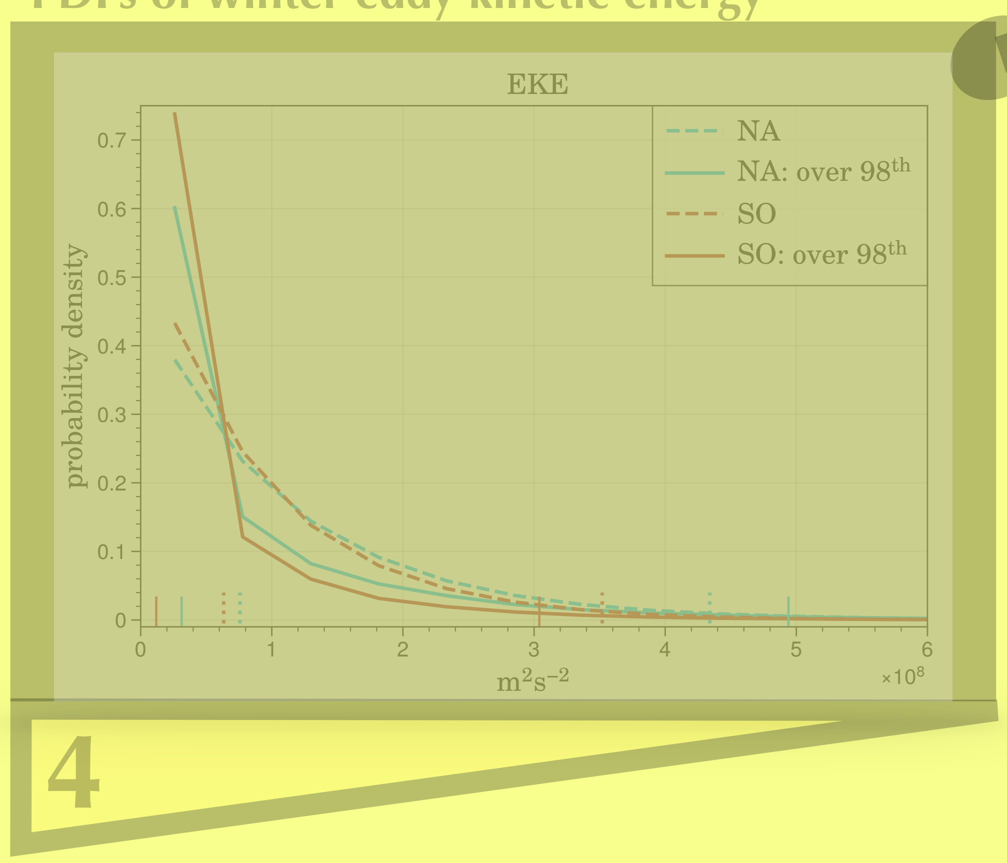

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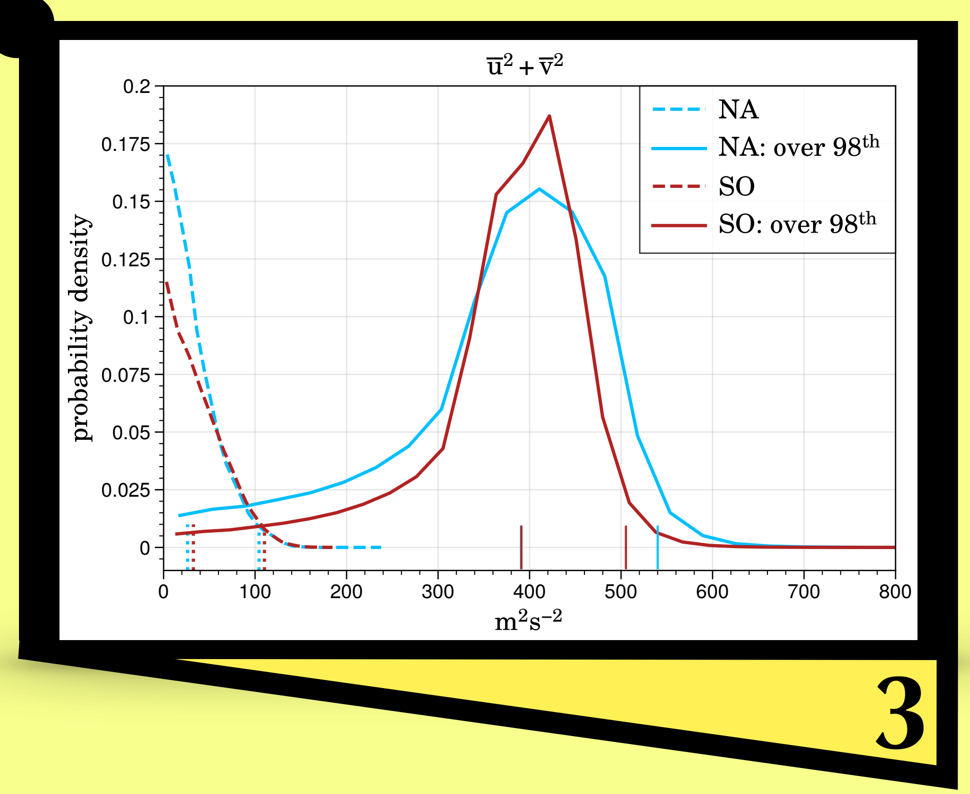

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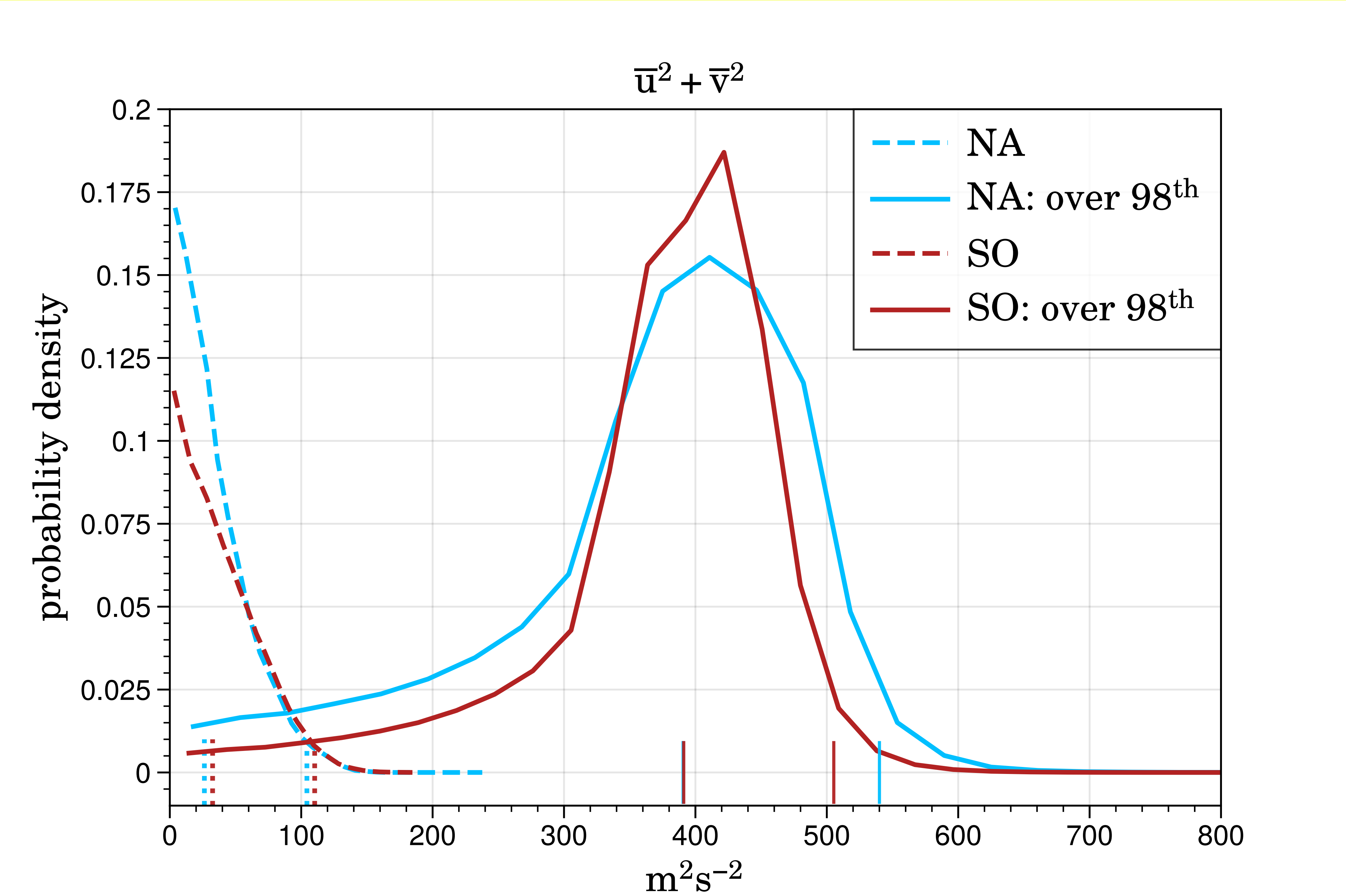

Figure 3: PDFs of monthly-mean kinetic energy collected over gridcells in the North Atlantic (NA, blue) and the Southern Ocean (SO, red) where local 98th percentiles of 10 m windspeed exceed 18m/s. Monthly-mean kinetic energy is collected from ERA5 on all days in winter seasons from 1979 to 2021 (dotted lines) and on the days where local 10 m windspeed exceeded local 98th percentiles (full lines). Short vertical lines show the medians and the 98th percentiles.

To answer the question of what causes extreme 10 windspeed from statistical point of view and find the reasons for differences in extreme 10 m winds among the basins, we investigate kinetic energy associated with 10 m winds. We further make a decomposition of 10 m kinetic energy into mean state kinetic energy (monthly-mean kinetic energy) and transient eddy kinetic energy (deviations from basic state). We focus on the Souther Ocean and the North Atlantic basins and compute PDFs based on ERA5 data of mean and eddy kinetic energy components for all days in winters from 1979-2021 and the days where local 10 m windspeed have exceeded local 98th percentiles. As Figure 3 shows, when 10 m windspeed extremes occur, monthly mean kinetic energy component significantly increases - medians of PDFs in both basins when extremes occur are around four times higher than 98th percentiles in all winter days. This increase drives the occurrence of extreme 10 m winds in both basins.

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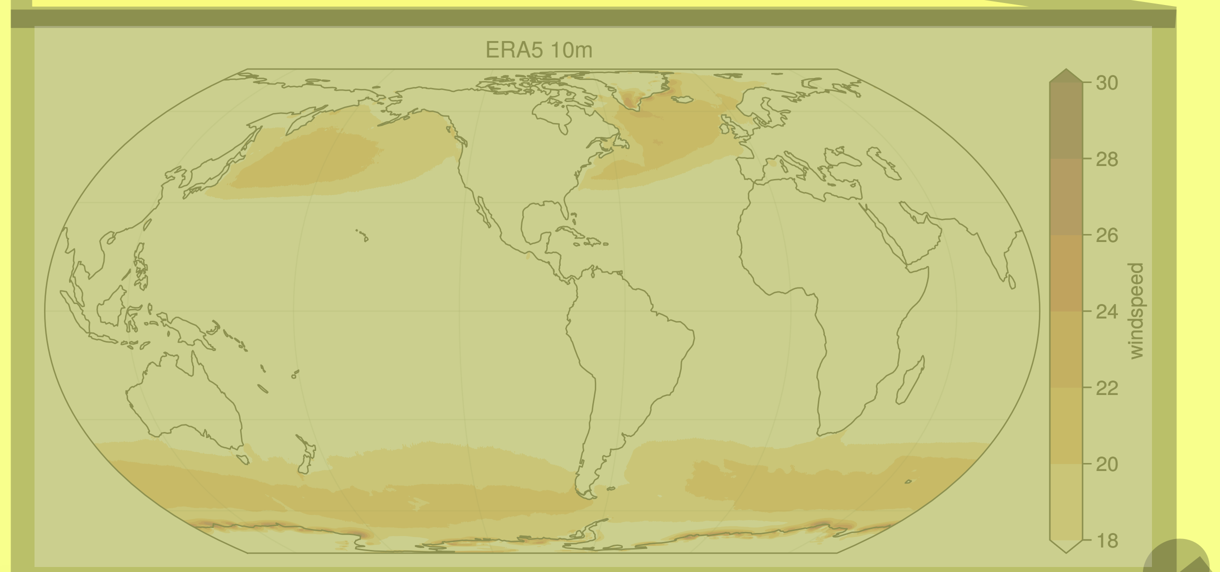

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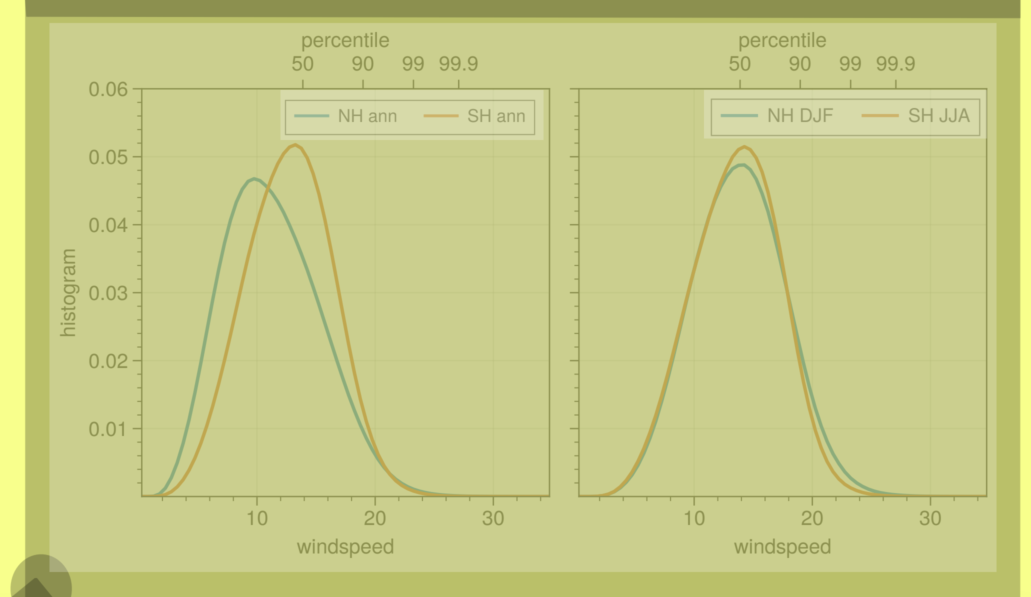

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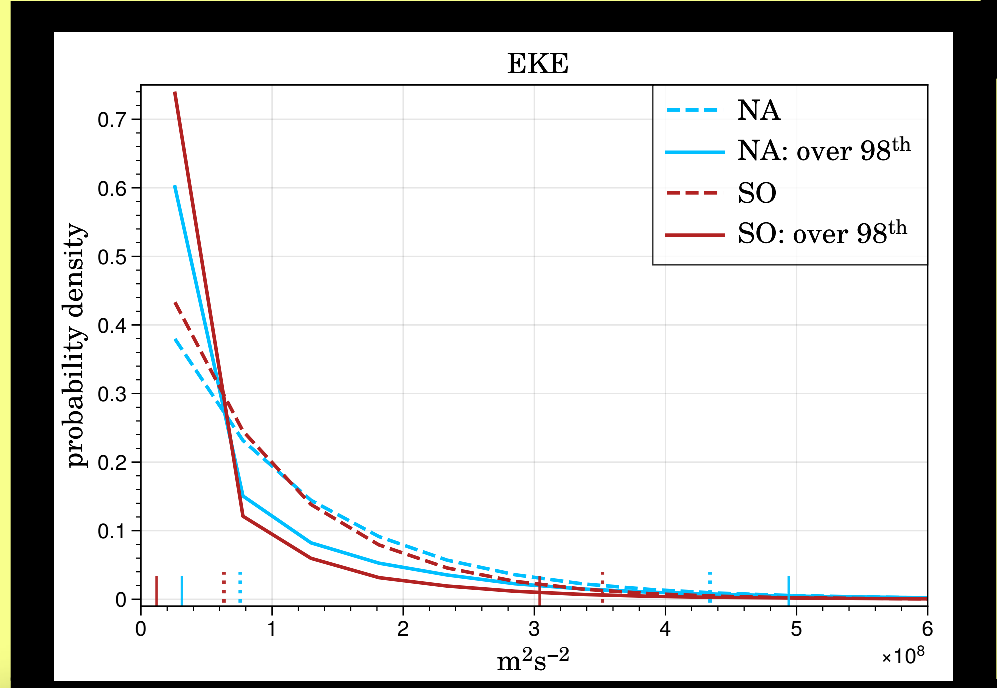

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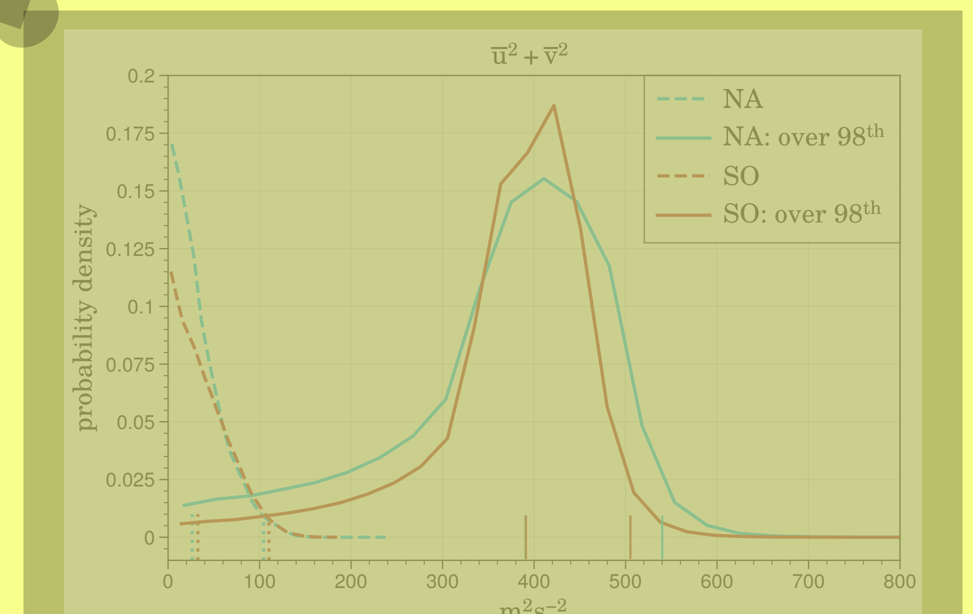

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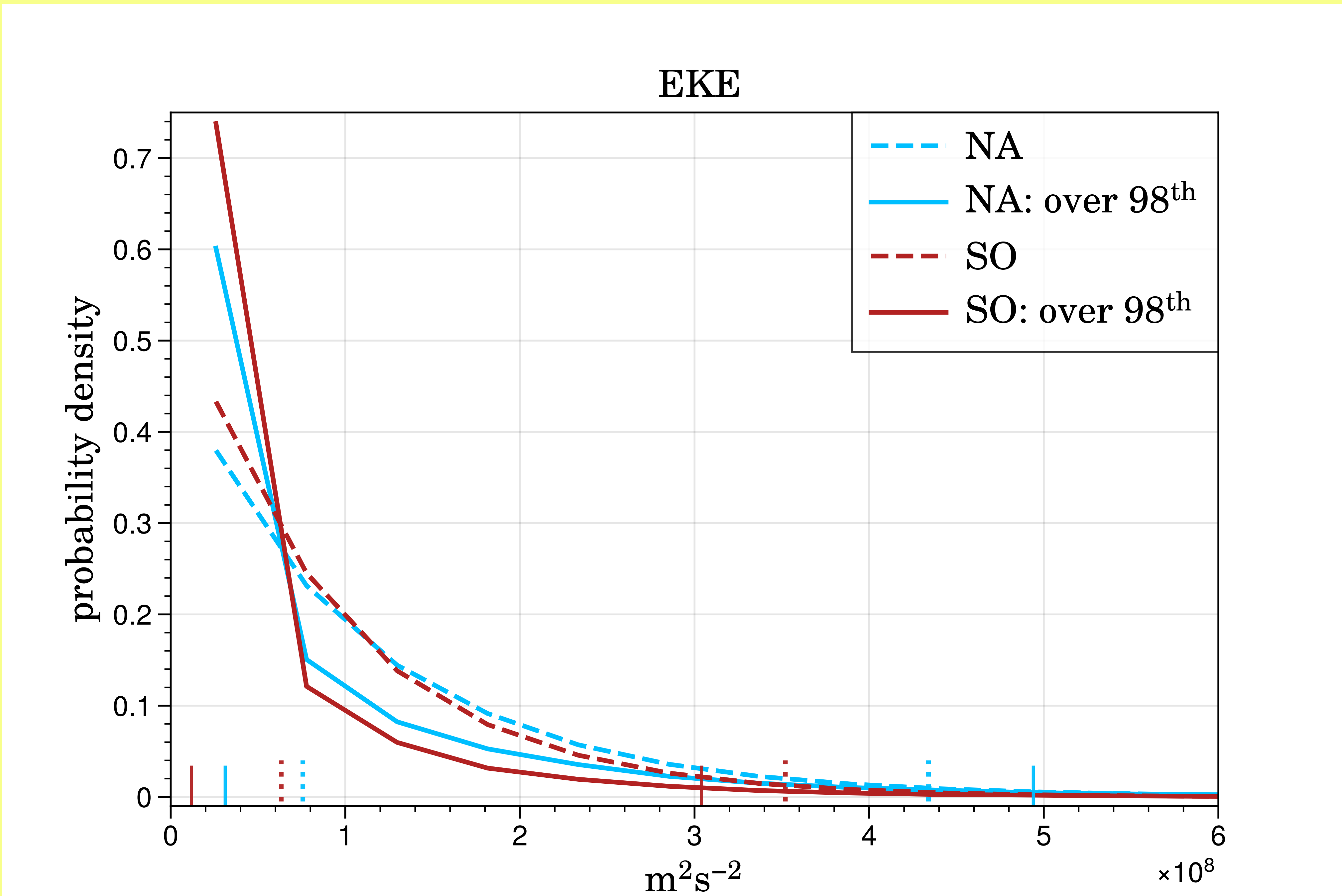

Figure 4: PDFs of vertically integrated eddy kinetic energy (b) collected over gridcells in the North Atlantic (NA, blue) and the Southern Ocean (SO, red) where local 98th percentiles of 10 m windspeed exceed 18m/s. Eddy kinetic energy is collected from ERA5 on all days in winter seasons from 1979 to 2021 (dotted lines) and on the days where local 10 m windspeed exceeded local 98th percentiles (full lines). Short vertical lines show the medians and the 98th percentiles.

Differences in 10 m windspeed extremes between the SO and the NA basin occur due to differences in the 10 m kinetic energy carried by the transient eddies. Median of basic state kinetic energy is higher in the SO than in the NA during all winter days, but two medians become equal in the days with extreme winds. Eddies, however, carry more energy in the NA than in the SO during all winter days and this difference remains during the days with extreme winds, thus creating a difference in the total energy that can be connected to the differences in the extreme 10 m winds across the basins.

Vertically integrated eddy kinetic energy shown in Figure 4 highlights differences between the basins - the NA having a greater median and 98th percentile of eddy kinetic energy than the SO. A decrease in the median of eddy kinetic energy that occurs in the days with extreme 10 m winds might be suggestive of a transfer of kinetic energy from eddies to the mean flow, which was shown to be important for the occurrence of 10 m windspeed extremes. More work on mechanistic understanding of these differences is in progress.

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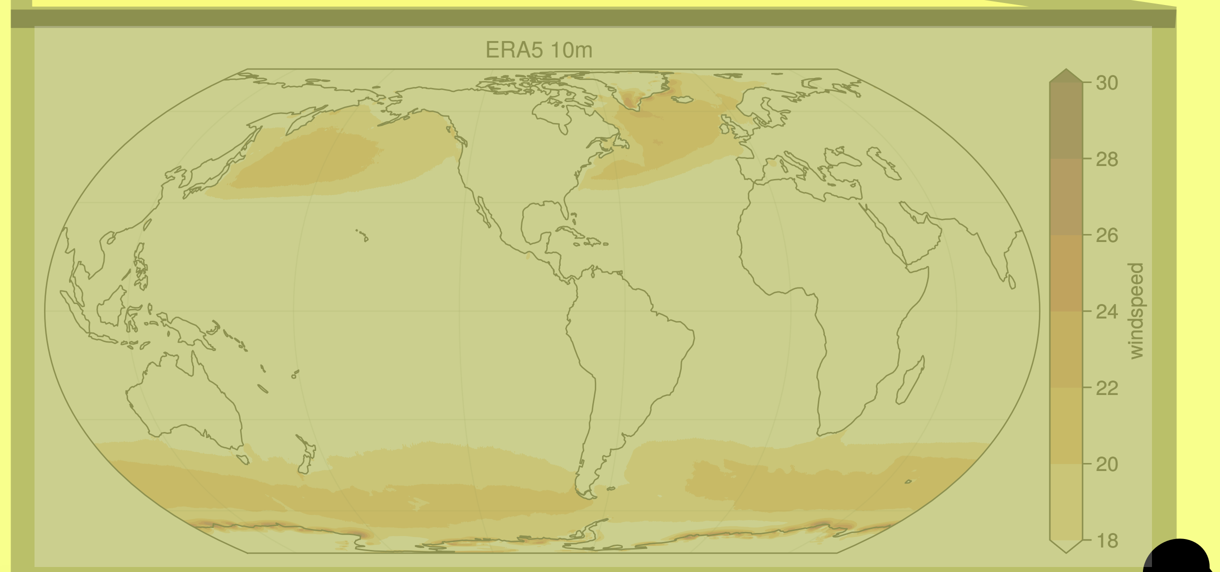

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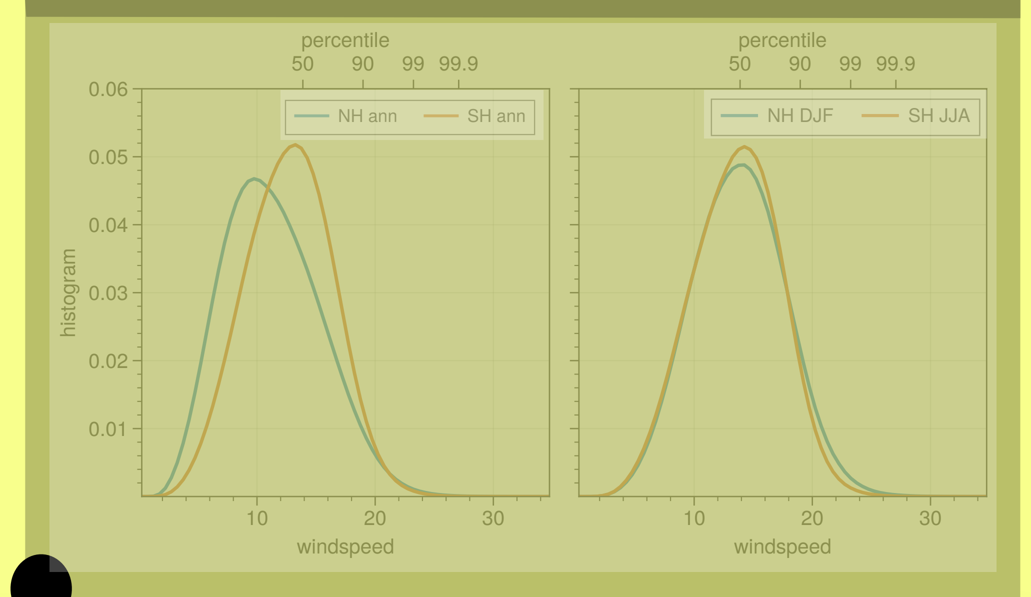

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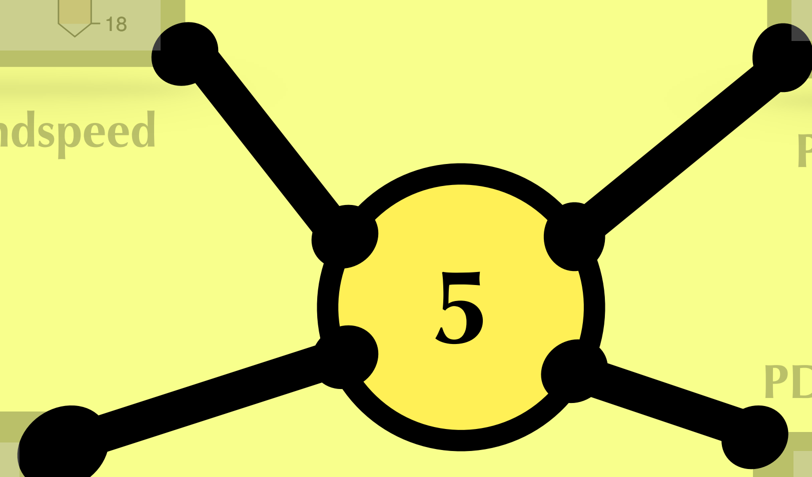

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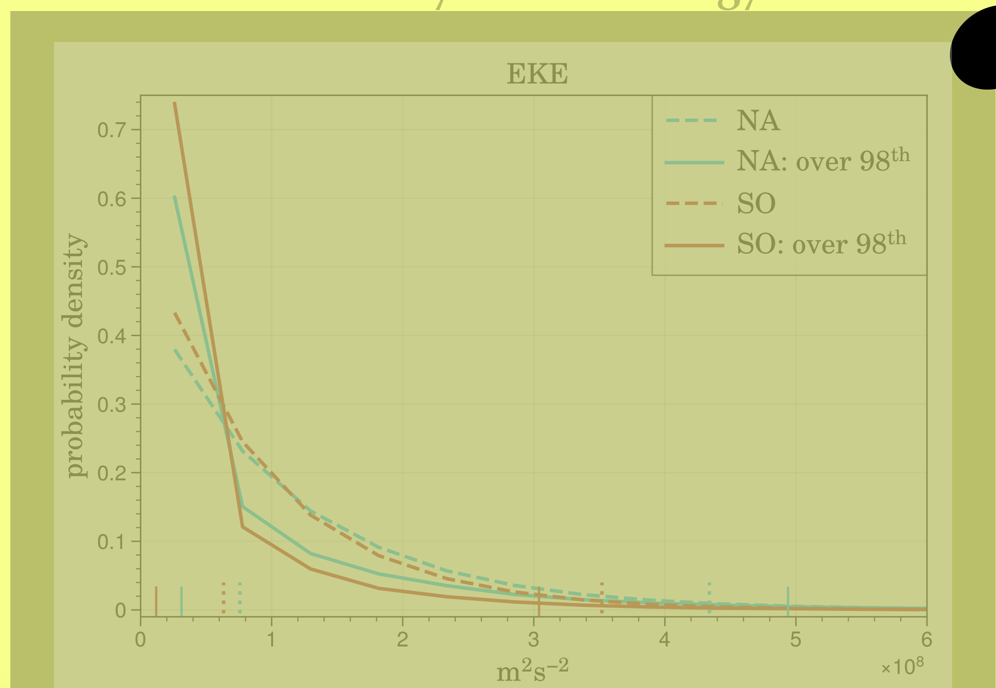

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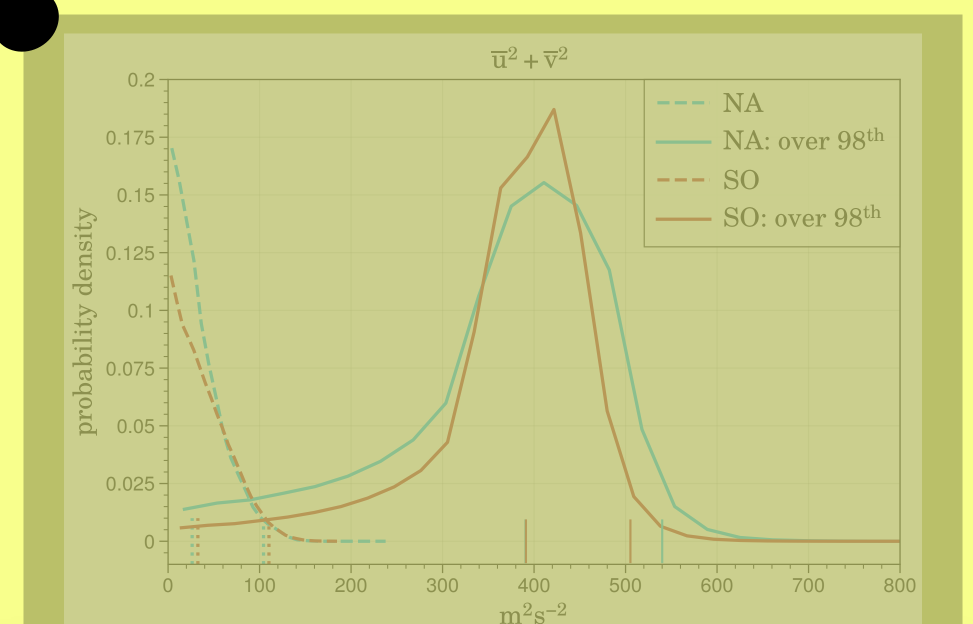

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