PAGES OSM 2017 5th Open Science Meeting *#01882*

Estimating Antarctic climate variability of the last millennium

Thomas Münch & Thomas Laepple *(Contact: tmuench@awi.de)*

ALFRED-WEGENER-INSTITUT
HELMHOLTZ-ZENTRUM FÜR POLAR- UND MEERESFORSCHUNG

ECUS

1 Introduction

Knowledge of **Antarctic climate variability** is important for understanding the climate system, and for detecting the anthropogenic influence and projecting the evolution of the Antarctic ice sheet.

Oxygen isotope data from ice cores provide **information on past temperature variability**, but their **quantitative interpretation** is challenged by strong **non-climate effects**.

We present a new **spectral method** (Box 2) **to separate climate signal and noise** in a large collection of published, annually-resolved firn core records (FIGURE 1) from East Antarctic Dronning Maud Land (**DML**) and the West Antarctic Ice Sheet (**WAIS**), spanning the last 200—1000 years.

We derive the first **timescale-dependent estimate of Antarctic temperature variability** and isotopic **signal-to-noise ratio** (**SNR**) on decadal to centennial time scales (Box 3).

2 Spectral separation of signal and noise

We estimate power spectral densities (PSD) as a measure of the time-scale dependent variability of isotopic time series (FIGURE 2).

We assume the spectrum of a single record to be the sum of a climate signal component and an independent noise term:

$$\mathcal{M}(f) = \mathcal{C}(f) + \mathcal{N}(f).$$

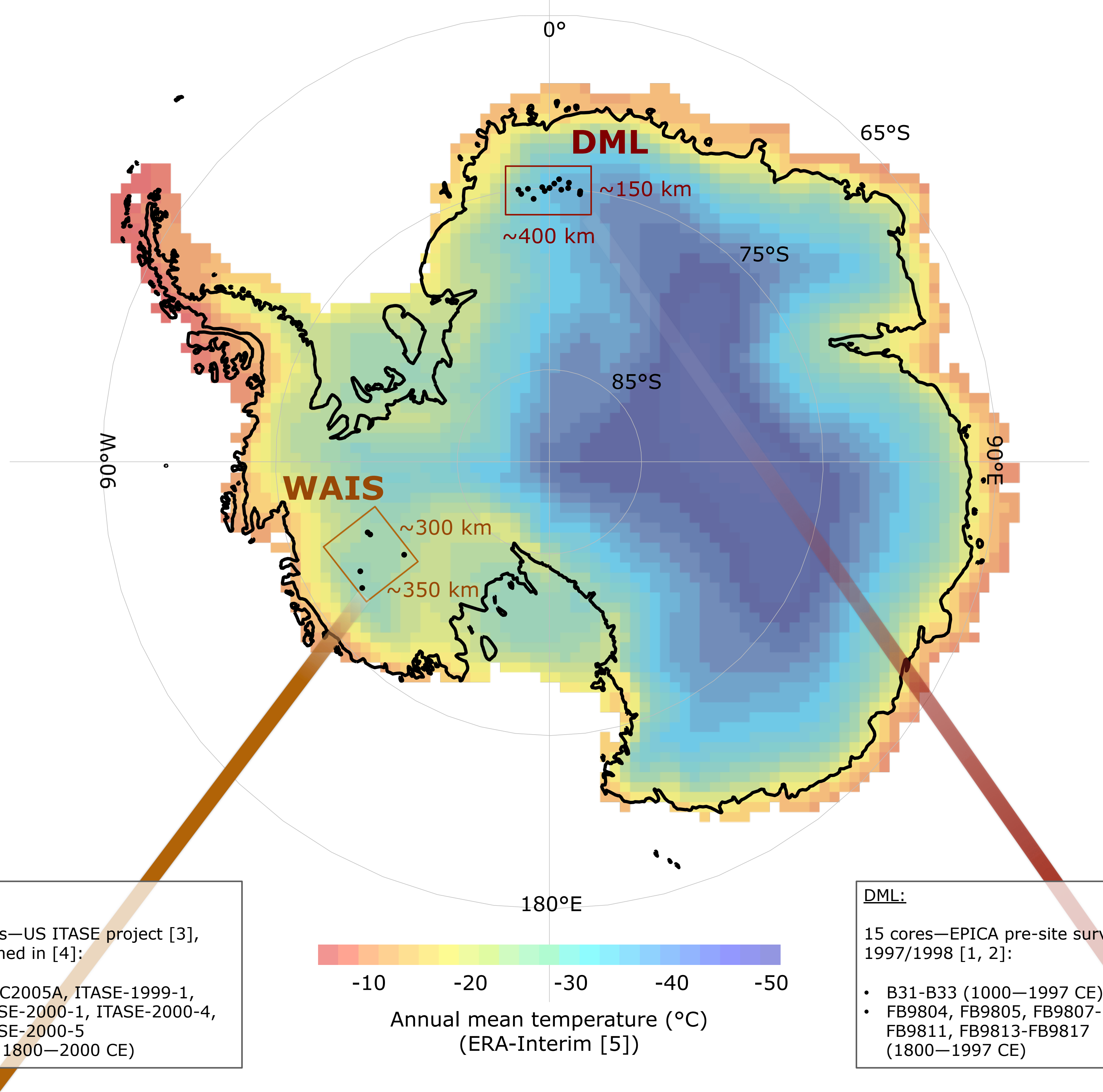
Assuming a common signal but independent noise between individual records of a given core array, the average time series over all cores ("stack") will have a spectrum of

$$\mathcal{S}(f) = \mathcal{C}(f) + \frac{1}{N}\mathcal{N}(f).$$

We can thus directly solve for the spectrum of the noise and of the climate signal:

$$\mathcal{N}(f) = \frac{N}{N-1}\Big[\mathcal{M}(f) - \mathcal{S}(f)\Big], \; \mathcal{C}(f) = \mathcal{S}(f) - \frac{1}{N}\mathcal{N}(f).$$

Figure 1



WAIS:

5 cores—US ITASE project [3], published in [4]:

- WDC2005A, ITASE-1999-1, ITASE-2000-1, ITASE-2000-4, ITASE-2000-5 (all 1800—2000 CE)

DML:

15 cores—EPICA pre-site survey 1997/1998 [1, 2]:

- B31-B33 (1000—1997 CE)
- FB9804, FB9805, FB9807-FB9811, FB9813-FB9817 (1800—1997 CE)

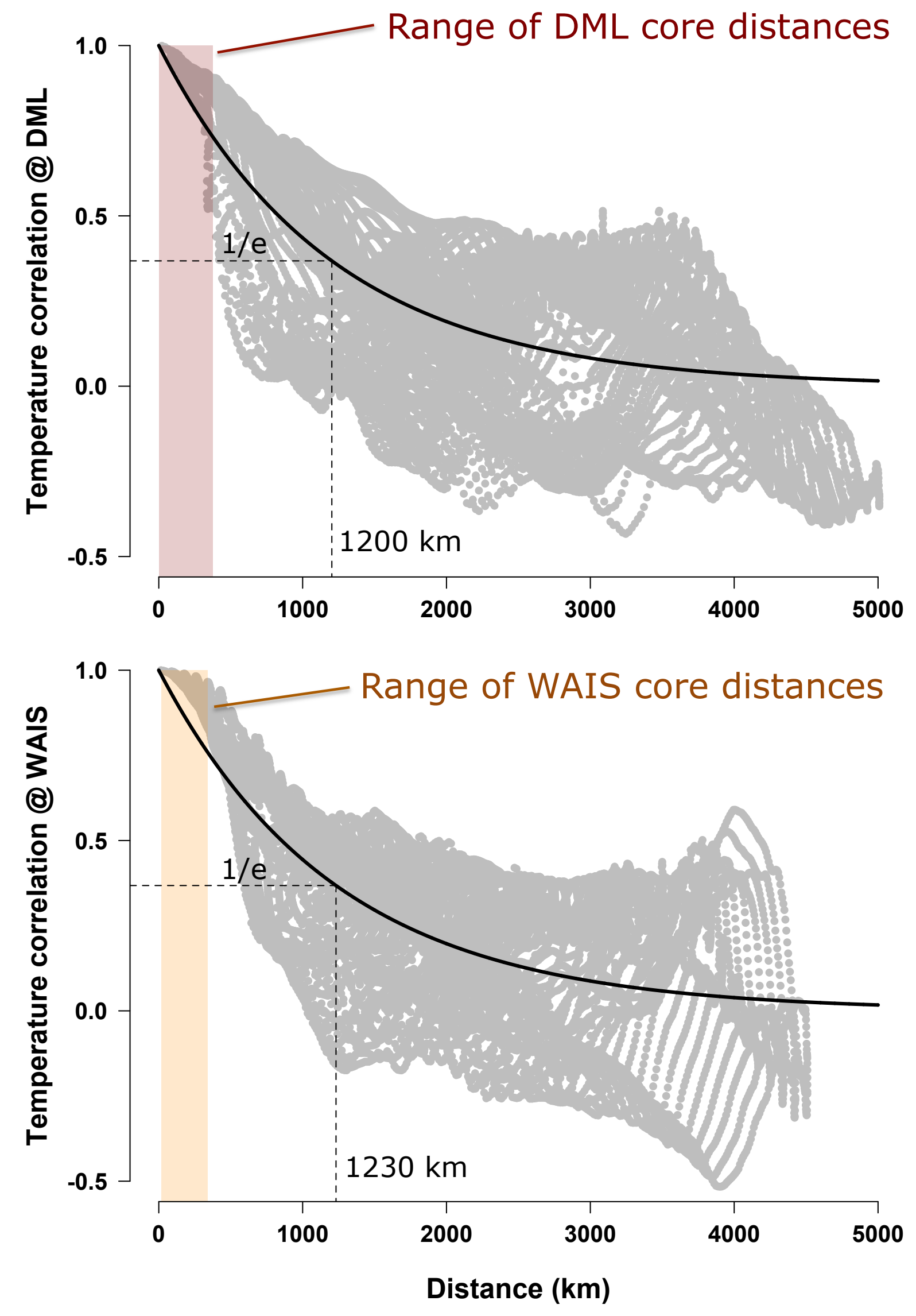


Figure 3

Spatial decorrelation scales of present-day annual-mean temperature (ERA-Interim [5]) are similar between Kohnen Station (75°S, 0°E; upper panel) and the location of the WAIS Divide ice core WDC (79.5°S, 112°W; lower panel). Shown are the correlations of the time series at the given location with the rest of the Antarctic continent. Black lines are exponential fits to the data.

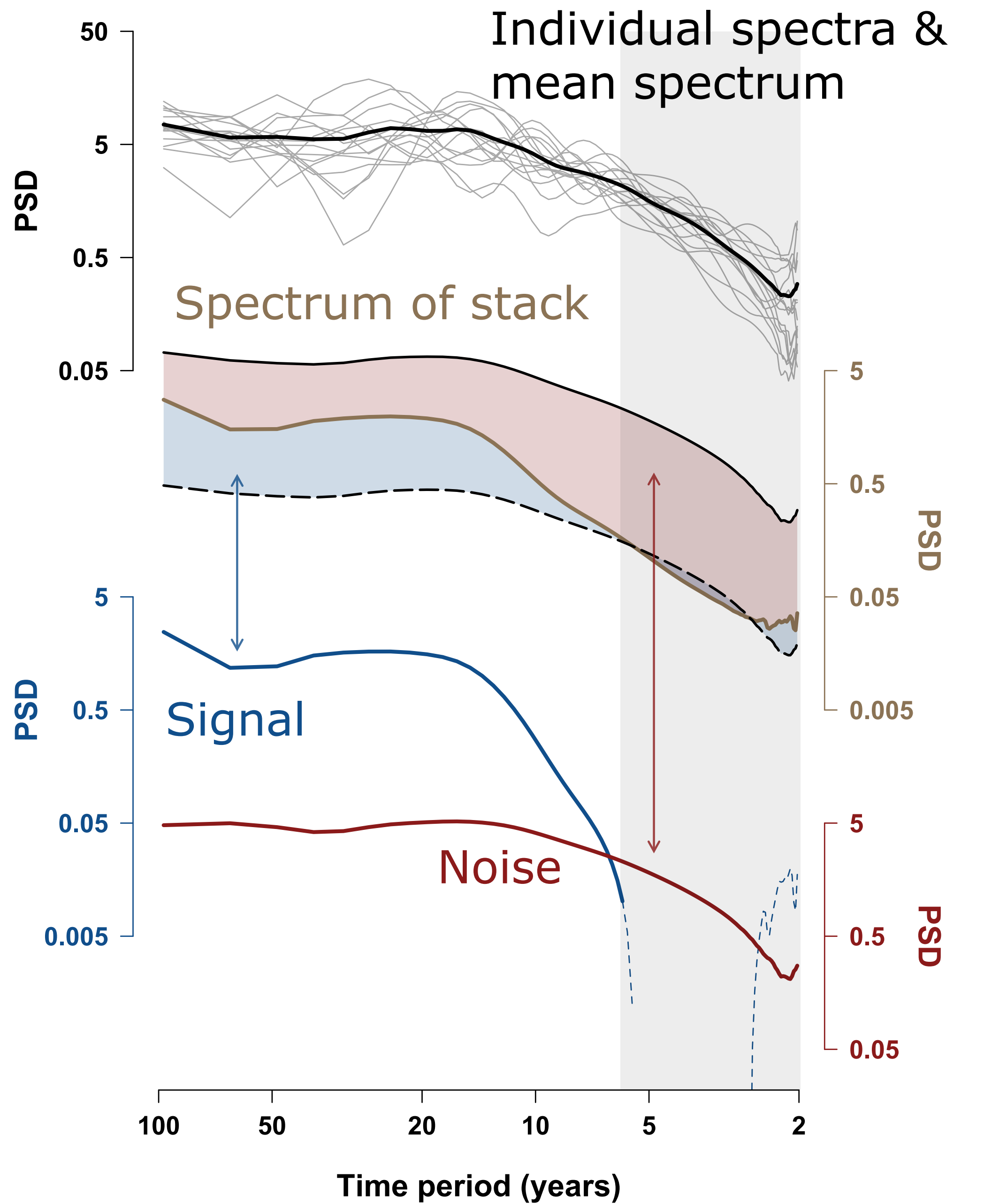


Figure 2

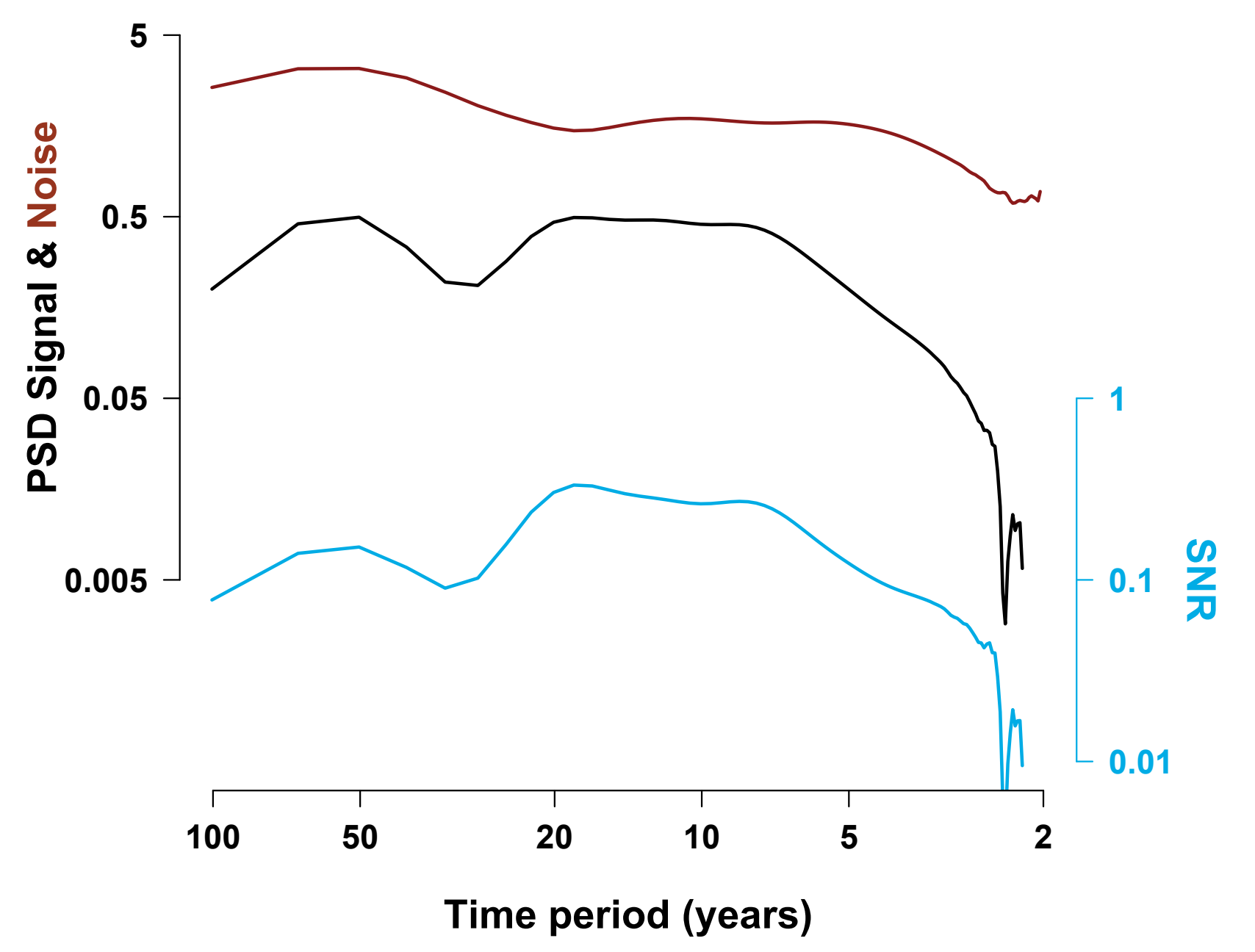
Power spectral densities of the DML data illustrating the steps explained in BOX 2. From top to bottom:

- Spectra of individual isotope records and mean spectrum
- Spectrum of the stacked DML record (brown)
- Estimated signal and noise spectra (uncertain in vertically shaded area).

3 Results

Key points

- ✧ Estimated DML climate variability increases with timescale.
- ✧ Pronouncedly different results found for WAIS despite similar present-day spatial temperature decorrelation scales.
- ✧ This might indicate regional differences between the WAIS cores in precipitation intermittency or circulation patterns.



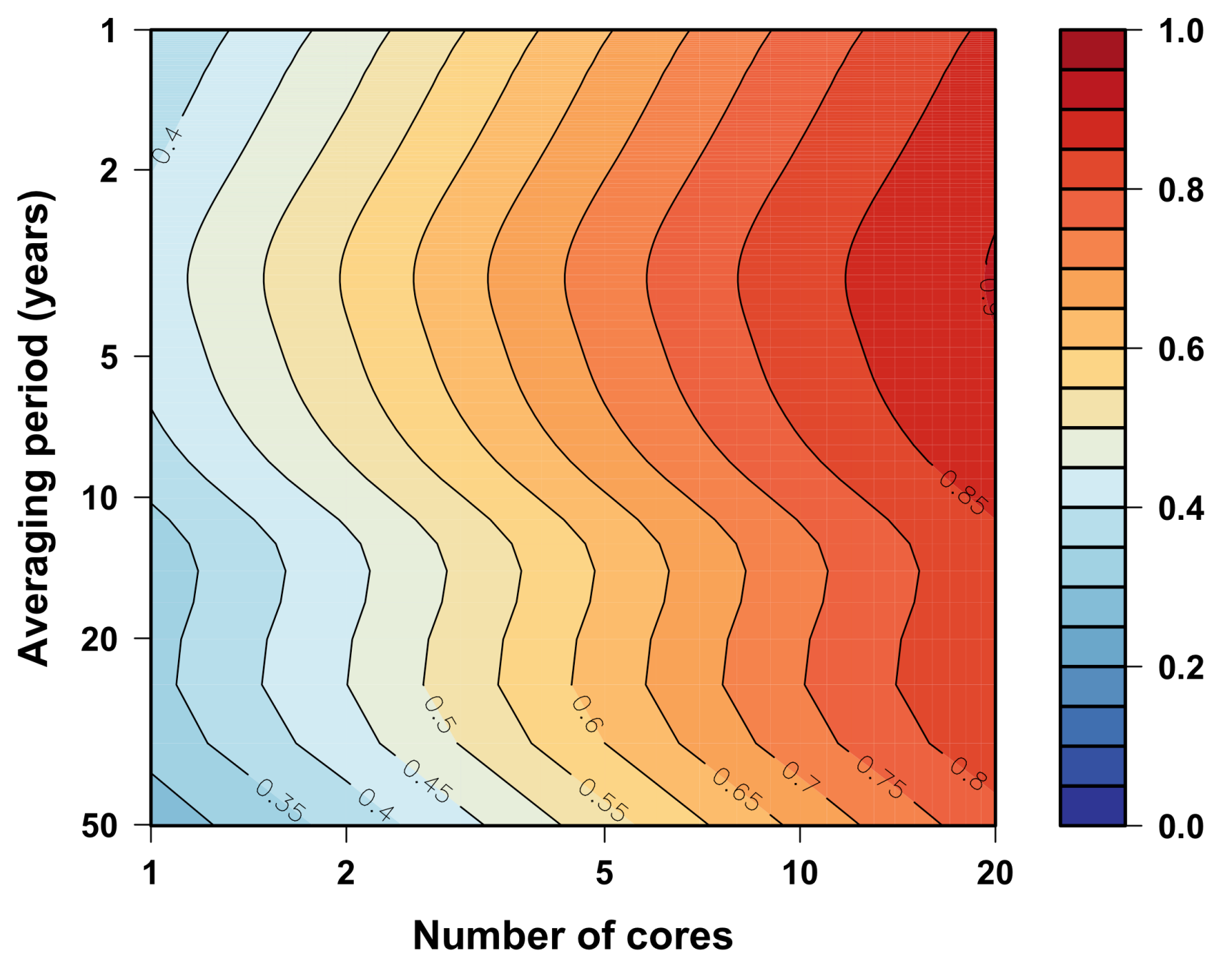
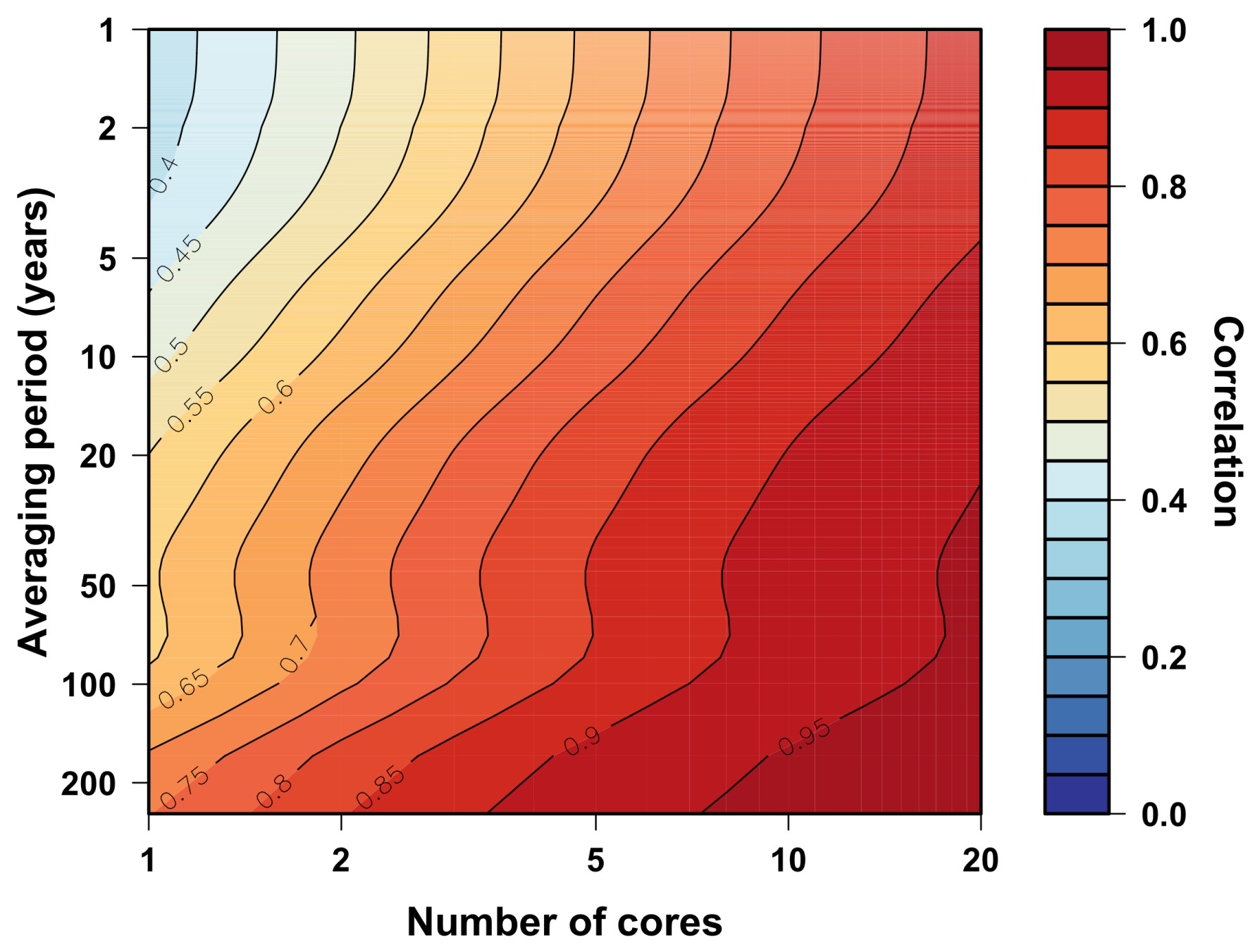


Figure 5

Top: WAIS signal (black) and noise (red) spectra, and time-scale dependent signal-to-noise ratio (blue). Right contour plot: Resulting integrated proxy—climate correlation.

- Interestingly, in contrast to DML, the WAIS climate signal shows no increase towards longer timescales.
- Noise exhibits diffused white-noise behaviour on short but increased variance on longer periods, indicating non-coherent isotope signals e.g. from regional-scale varying precipitation intermittency or circulation patterns.
- Consequently, the proxy—climate correlation shows basically no increase with the averaging period.



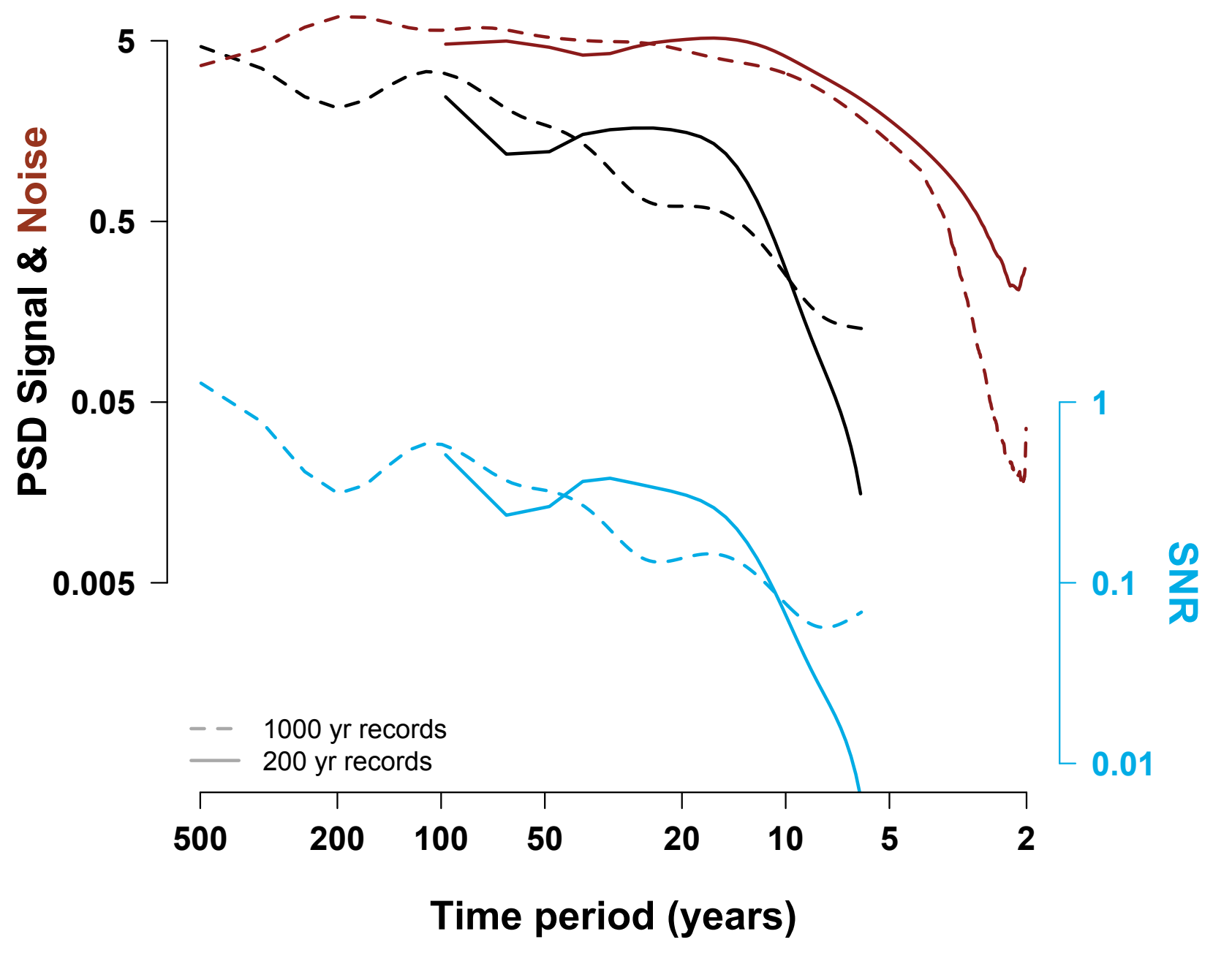


Figure 4

Top: DML signal (black) and noise (red) spectra, and time-scale dependent signal-to-noise ratio (blue). Left contour plot: Resulting integrated proxy—climate correlation.

- Signal spectrum shows increasing variability on longer timescales consistent with marine proxy records [6] and theoretical considerations [7].
- Noise spectrum is essentially white with clear influence of diffusion on short periods.
- Correlation of isotope records with the climate signal increases with the averaging period and with the number of averaged records.

References:
[1] Oerter et al., *Ann. Glaciol.*, **30**(1), 183—194, 2000.
[2] Graf et al., *Ann. Glaciol.*, **35**(1), 195—201, 2002.
[3] Mayewski et al., *Ann. Glaciol.*, **41**(1), 180—185, 2005.
[4] Steig et al., *Nat. Geosci.*, **6**(5), 372—375, 2013.
[5] Dee et al., *Q. J. R. Meteorol. Soc.*, **137**(656), 553—597, 2011.
[6] Laepple & Huybers, *PNAS*, **111**(47), 16682—16687, 2014.
[7] Rypdal et al., *J. Climate*, **28**(21), 8379—8395, 2015.

ECUS

Estimating **C**limate variability by quantifying proxy
Uncertainty and **S**ynthesizing information across archives