CMCC - SISC WEBINAR

June 26, 2018 - h. 12.30 pm CEST

Antarctic climate variability over the last 2000 years

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Antarctic climate variability over the last 2,000 years

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Climate of the Past
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Antarctic climate variability on regional and continental scales over the last 2000 years

Barbara Stenni[1,2], Mark A. J. Curran[3,4], Nerilie J. Abram[5,6], Anais Orsi[7], Sentia Goursaud[7,8], Valerie Masson-Delmotte[7], Raphael Neukom[9], Hugues Goosse[10], Dmitry Divine[11,12], Tas van Ommen[3,4], Eric J. Steig[13], Daniel A. Dixon[14], Elizabeth R. Thomas[15], Nancy A. N. Bertler[16,17], Elisabeth Isaksson[11], Alexey Ekaykin[18,19], Martin Werner[20], and Massimo Frezzotti[21]

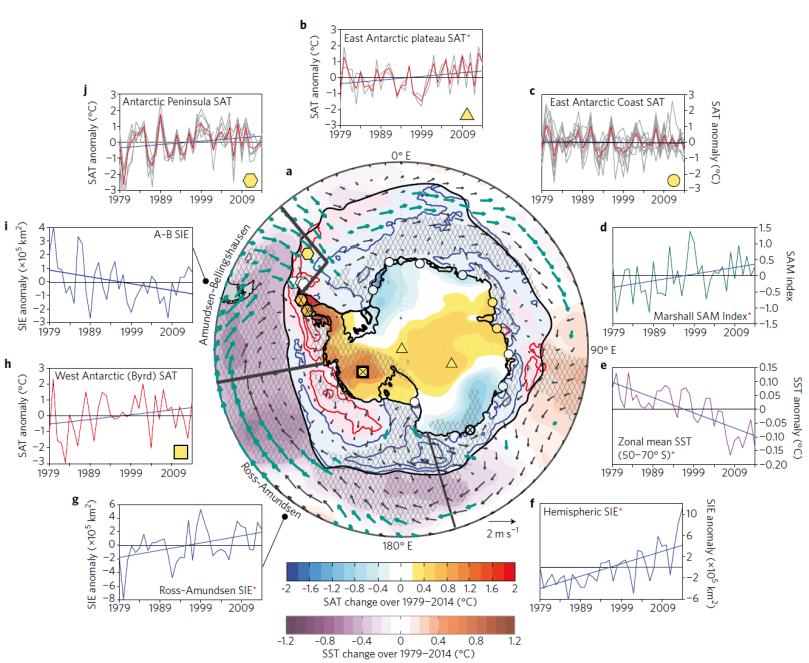
ANTARCTICA 2K

Presentation outline

ANTARCTICA 2K

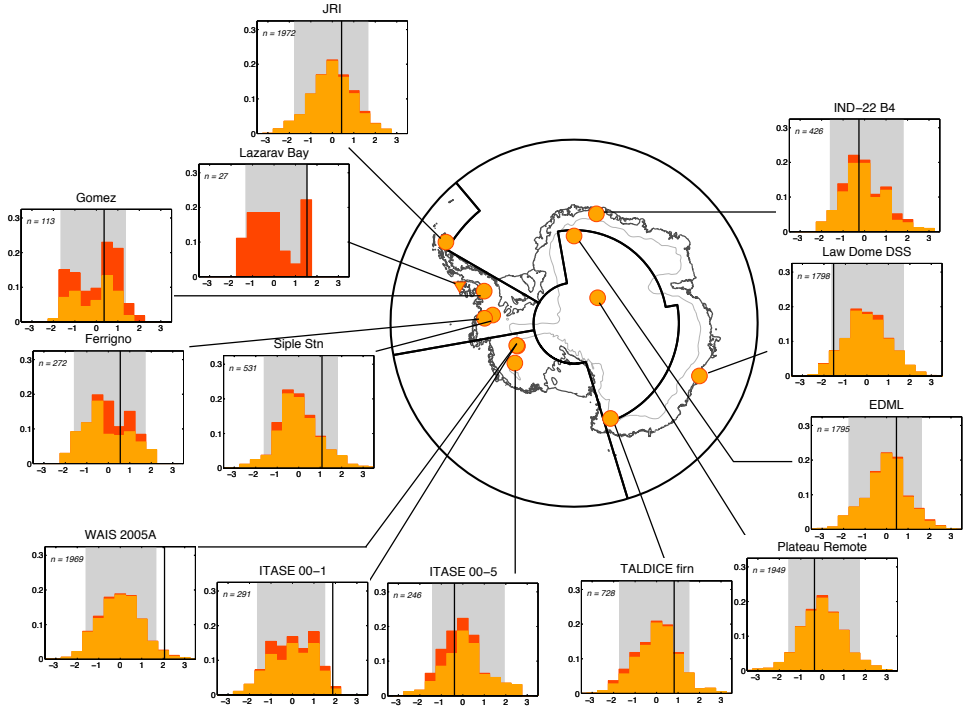
- Short introduction on Antarctic ice cores and the isotopic temperature proxy;
- Previous studies;
- The new PAGES Antarctica 2k data collection and region selection;
- Isotopic and temperature reconstructions at regional and continental scale: more records and different approaches;
- Comparing the 2013 (PAGES2k Consortium, 2013) and 2017 reconstruction using the same approach but with an expanded database;
- Conclusions/Perspectives

Antarctic atmosphere–ocean–ice changes over 1979-2014

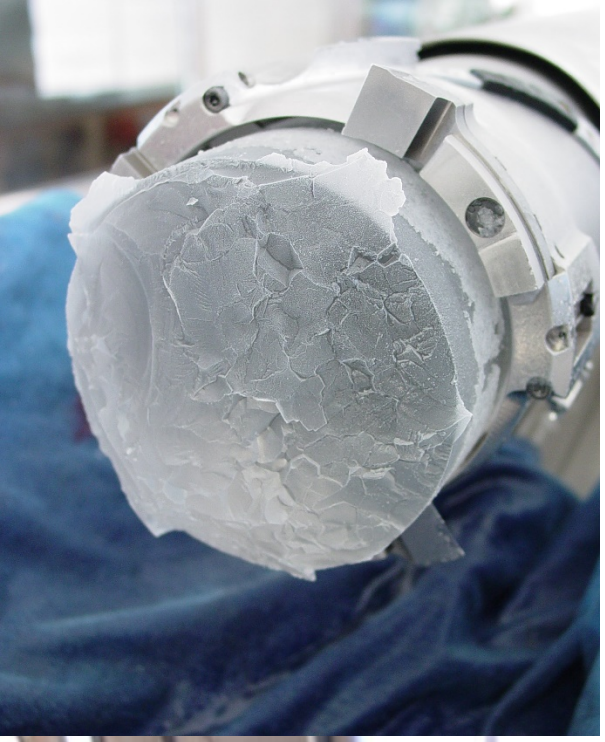


Recent trend not unprecedented

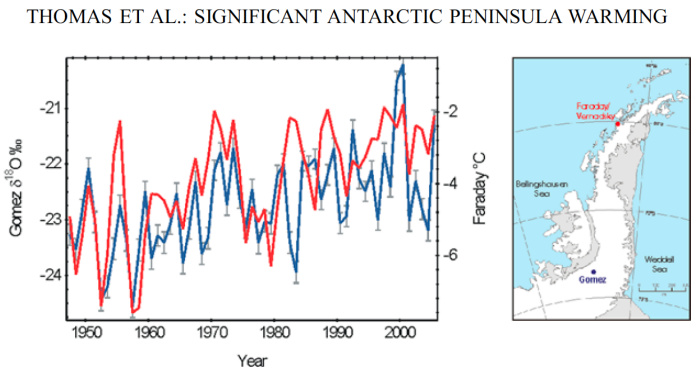
36y temperature/isotope trends:
Histograms = distribution of all 36y trends (light shading). Dark shading shows trends beginning in the last 100 years (since 1915)
Grey shading = 5-95% range of 36y trends in full record (excluding last trend)
Black line = last/most recent 36y trend in the record
n = number of 36y trends in the record (excluding last trend)



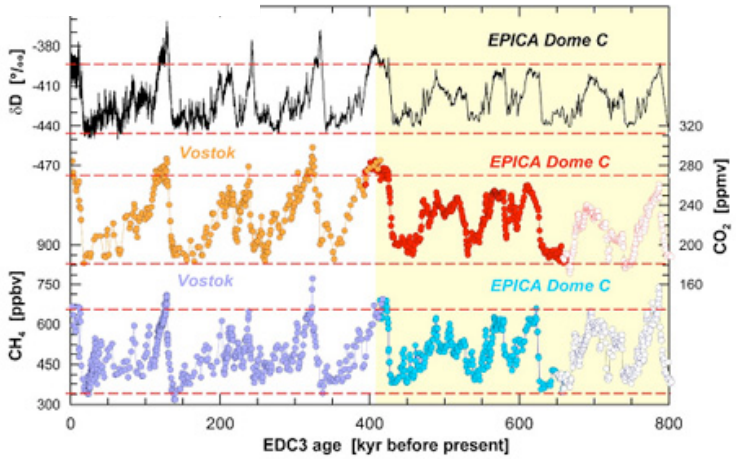
Jones et al, Nature Climate Change 2016



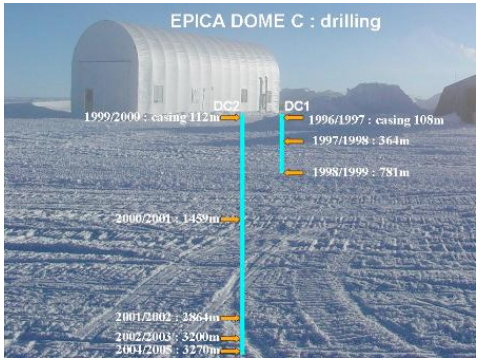
Antarctic ice cores: from decades to hundreds of millennia

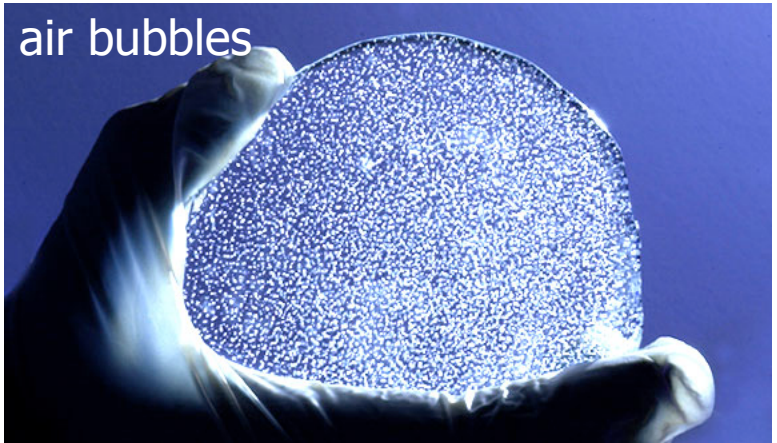


Gomez ice core (AAP)
Thomas et al., 2009



EPICA Dome C ice core.
Jouzel et al., 2007





Different proxies (water stable isotopes, aerosol concentrations, CH_4 and CO_2 in air bubbles, dust content etc.)

Water isotopes and temperature

Two key challenges to reconstruct past changes in Antarctic temperatures:

- To develop methodologies to combine different individual ice core records in order to deliver regional-scale climate signals.
- To quantify the temperature changes represented by water stable isotope variations.

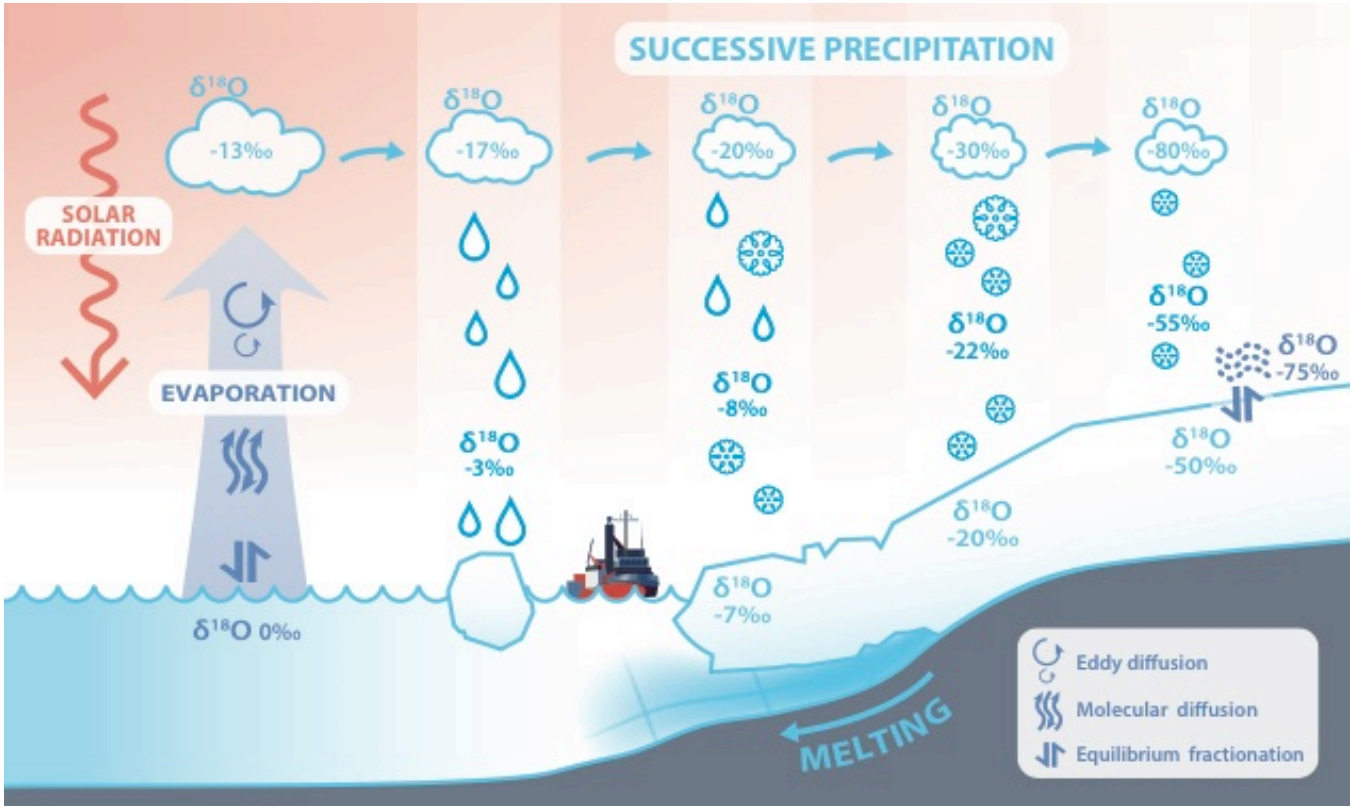
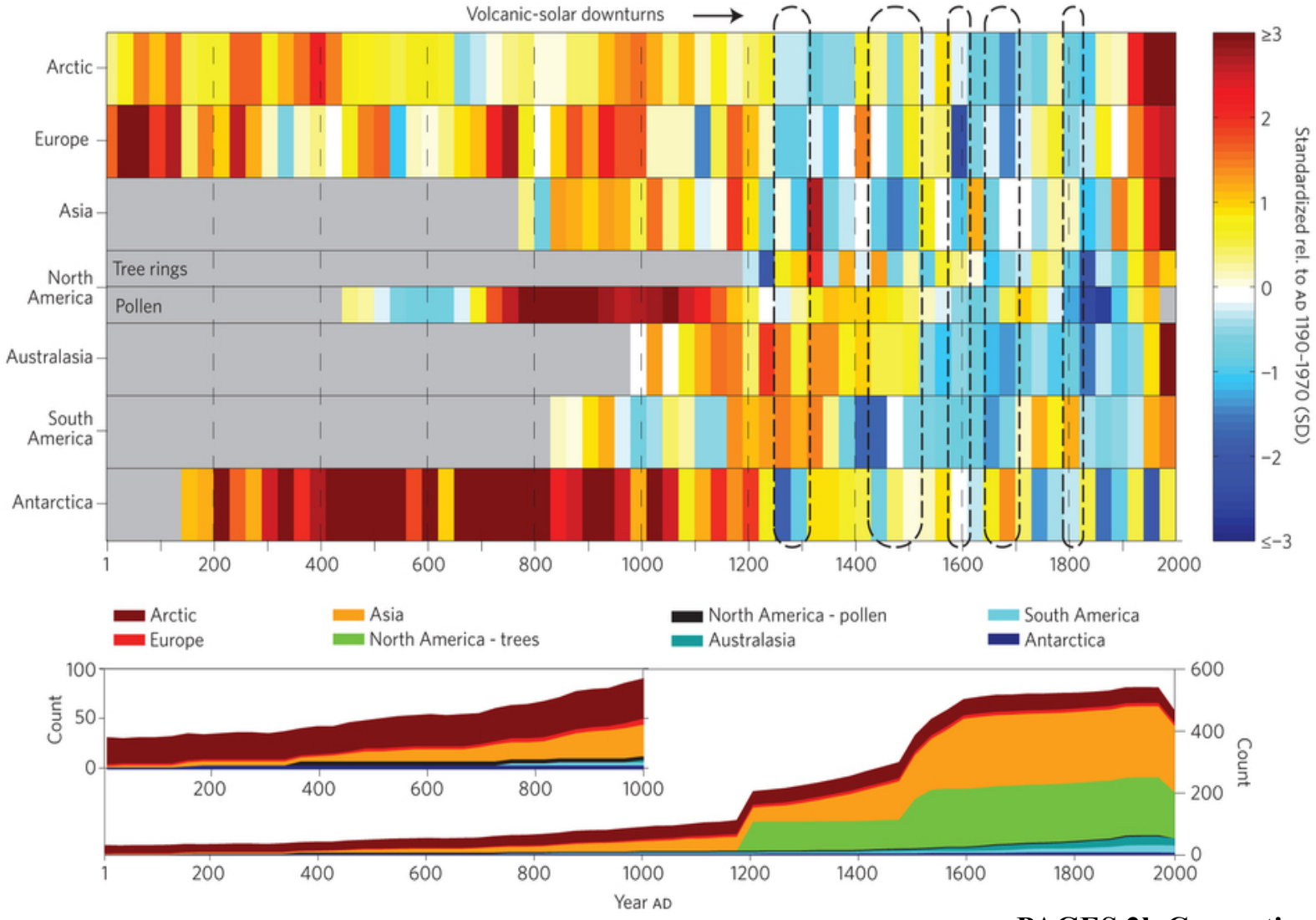


Figure from Casado et al,, 2016

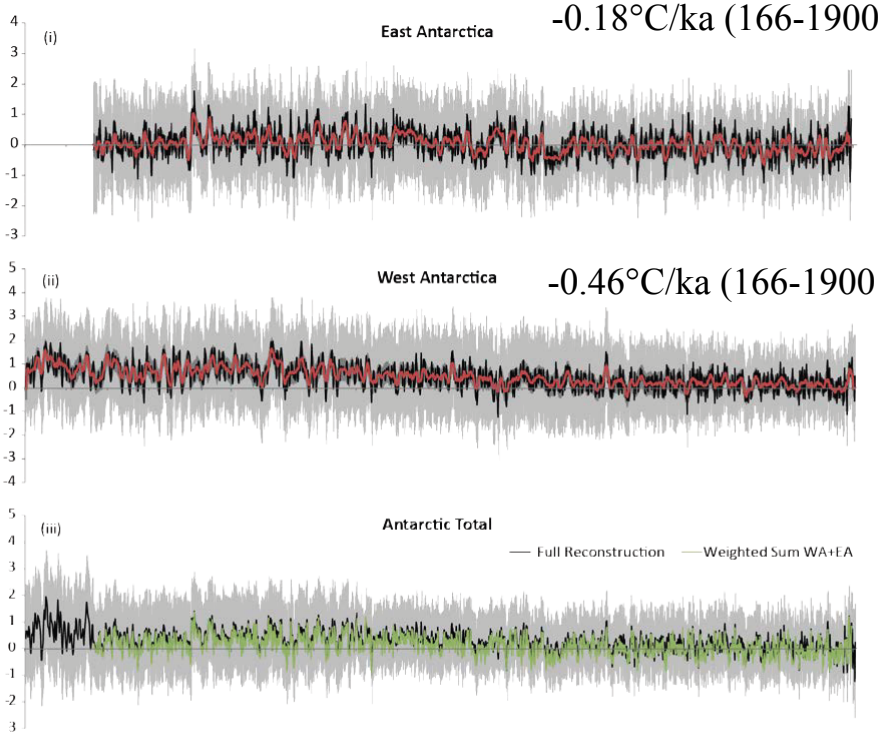
nature geoscience
PROGRESS ARTICLE
PUBLISHED ONLINE: 21 APRIL 2013 | DOI: 10.1038/NGEO1797

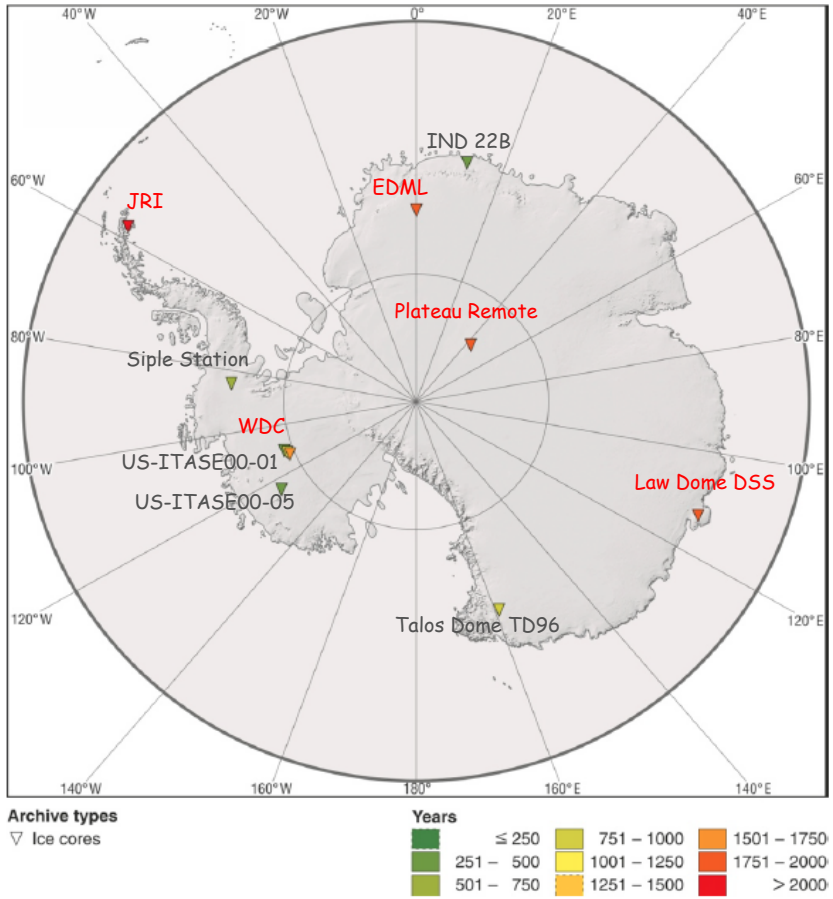
Continental-scale temperature variability during the past two millennia

PAGES 2k Consortium*



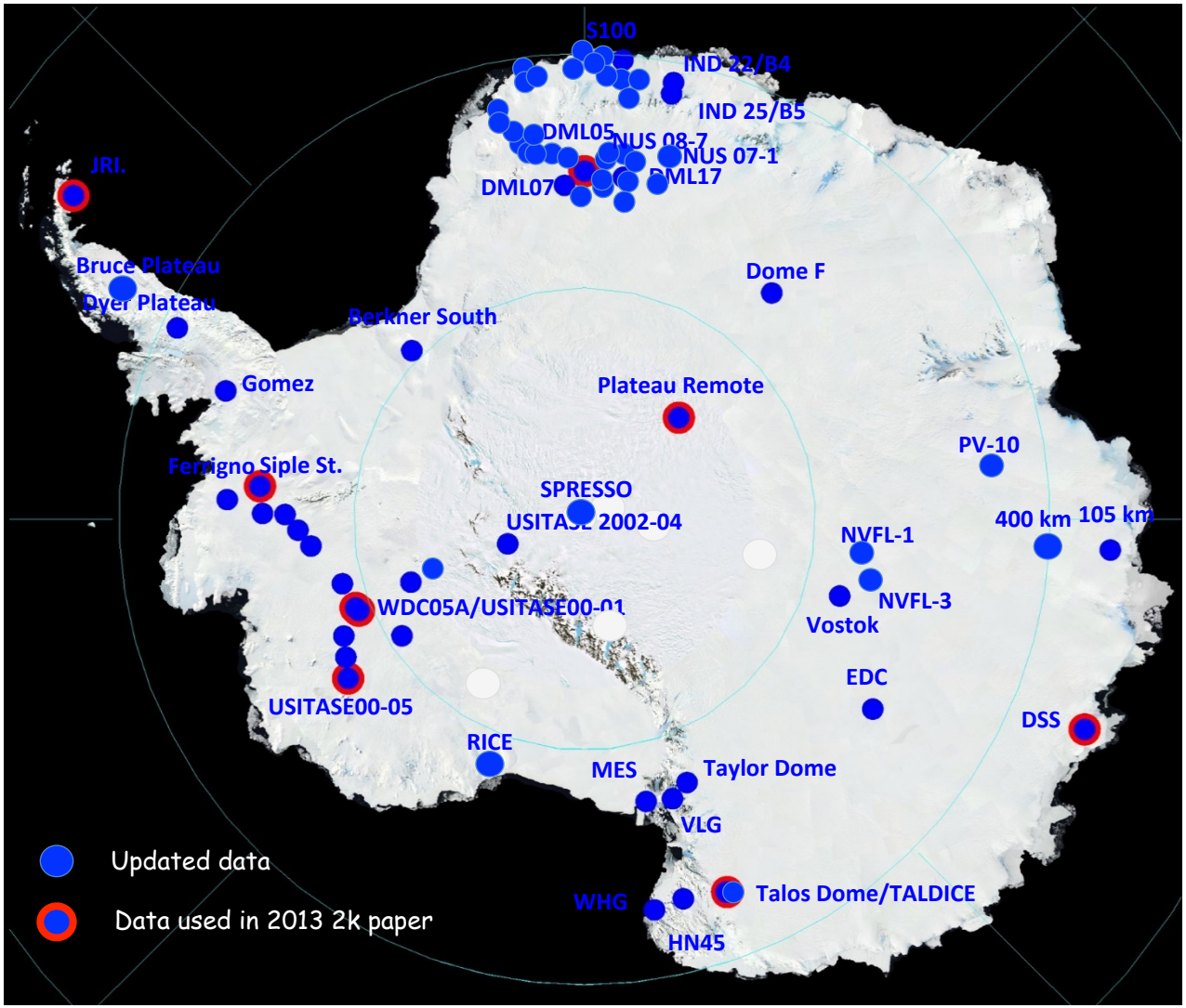
PAGES 2k Consortium, 2013





Water stable isotope records from 11 ice cores:
- high resolution;
- coherent chronology (42 volcanic events).

PAGES 2k Consortium, 2013



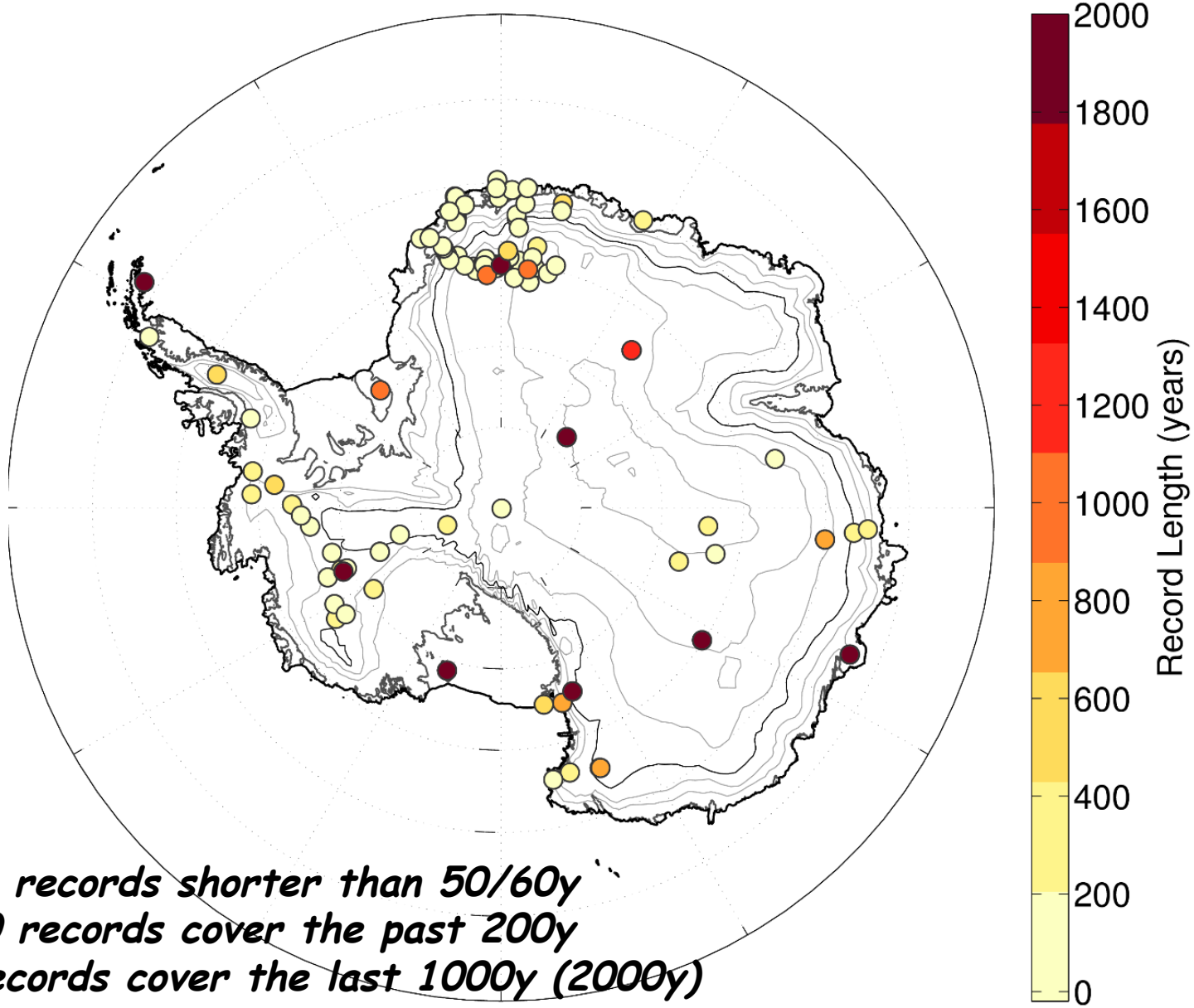
More records

PAGES Antarctica2k working group

Isotopic records data collection

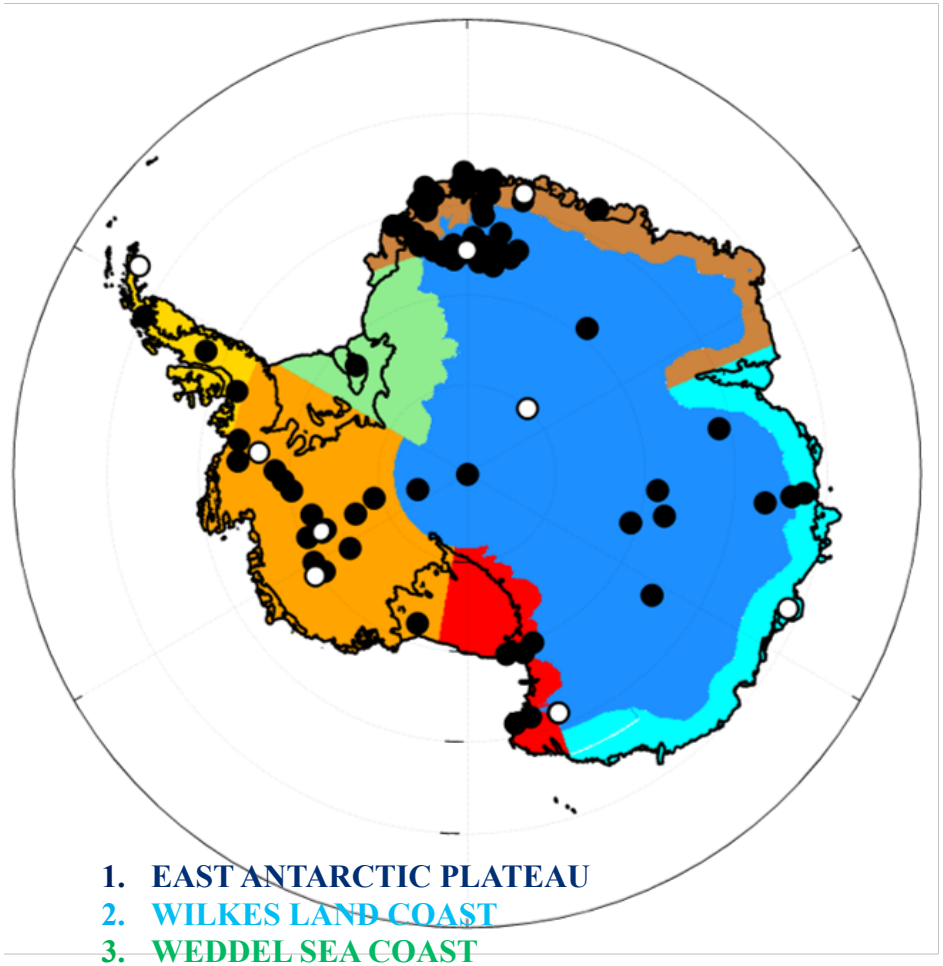
112 records

Length of records (years) for the new PAGES Antarctica2k database

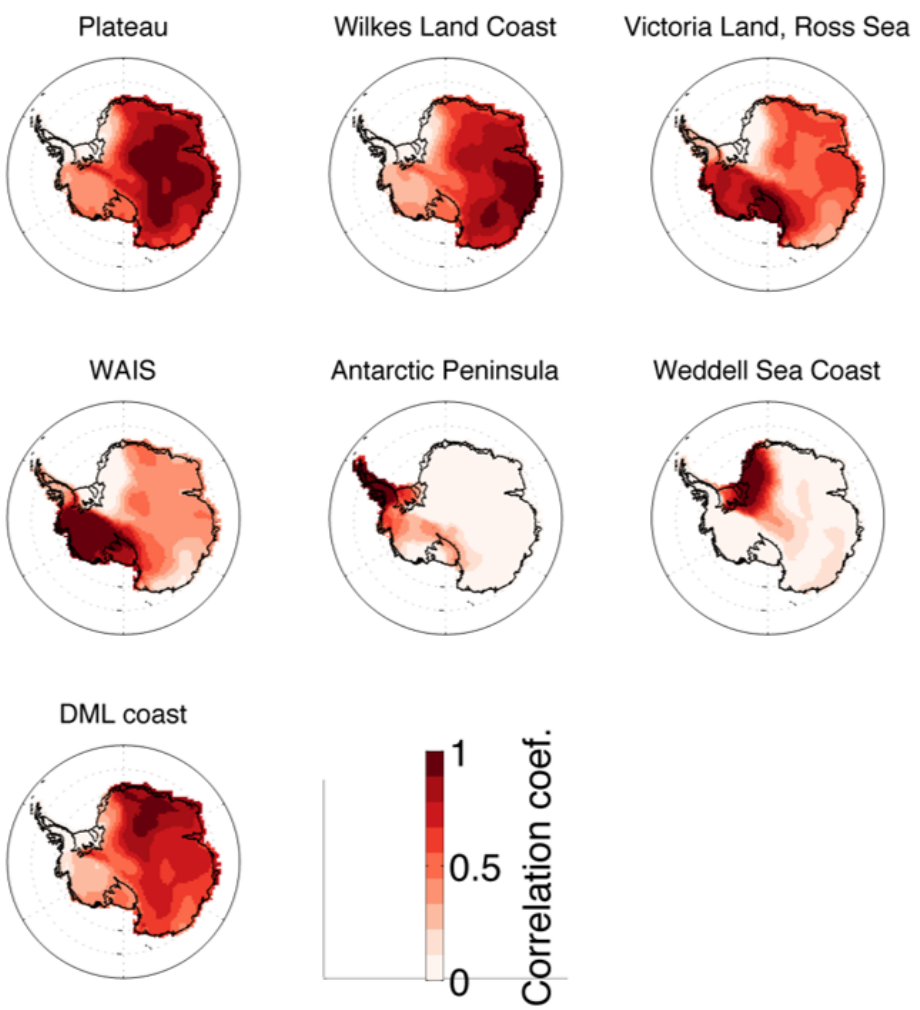


36 records shorter than 50/60y
50 records cover the past 200y
15 (9) records cover the last 1000y (2000y)

Definition of regions based on coherency of temperature variations



1. EAST ANTARCTIC PLATEAU
2. WILKES LAND COAST
3. WEDDEL SEA COAST
4. ANTARCTIC PENINSULA
5. WEST ANTARCTIC ICE SHEET
6. VICTORIA LAND COAST - ROSS SEA
7. DRONNING MAUD LAND COAST



New methodology 1 – un-weighted composites

Step1: Ice core $\delta^{18}O$ database

Each record assigned to a region; δD values converted into $\delta^{18}O$.

Step 2: Annual average records

Stepped pseudo-annual records for lower resolution records.

Step 3a: 5y anomaly records

Convert to anomalies relative to the 1960-1990 reference interval. Minimum data coverage 6 bins (30y) since 1800. ***79 records meet this requirements.***

Step 3b: 10 y anomaly records

Convert to anomalies relative to the 1900-1990 reference interval. Minimum data coverage 9 bins (90y). ***67 records meet this requirements.***

Step 4: Data reduction

Average records within a region that are within the same grid 10°lon vs 2°lat (avoid bias from data-rich regions such as DML).

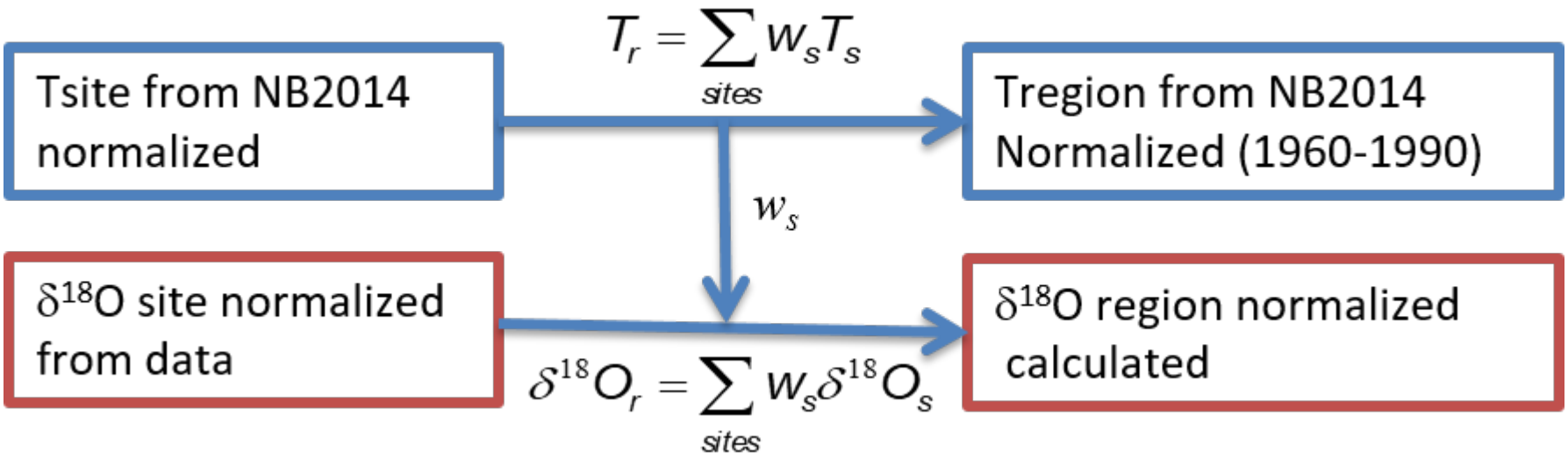
Step 5a: Simple unweighted composites for each region

5y binned composite anomalies ($\delta^{18}O$ equivalent) for last 200 years and 10y binned composites for last 2000 years.

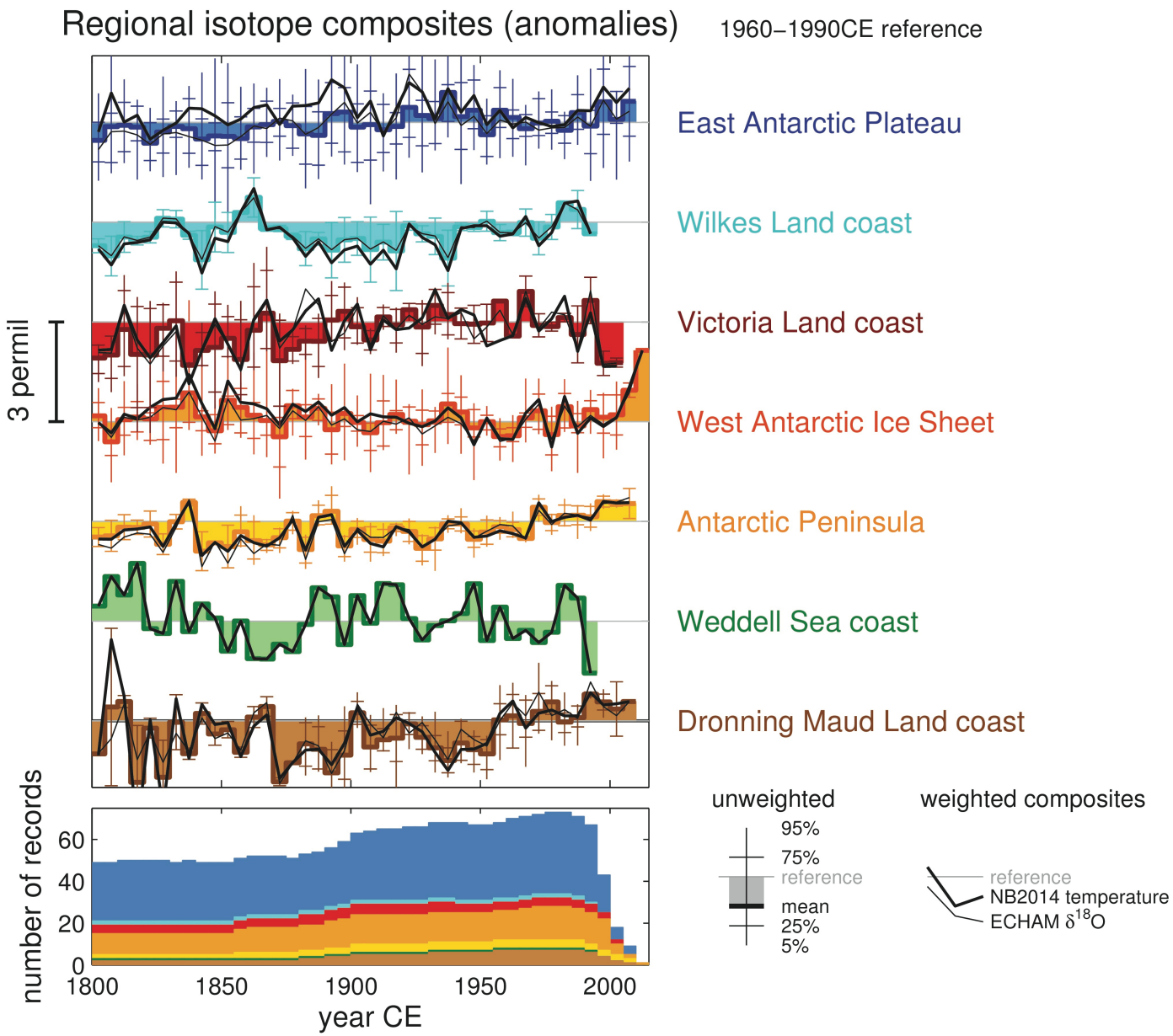
New methodology 2 – Weighted composites

Step 5b: weighted composites for each region using normalized data

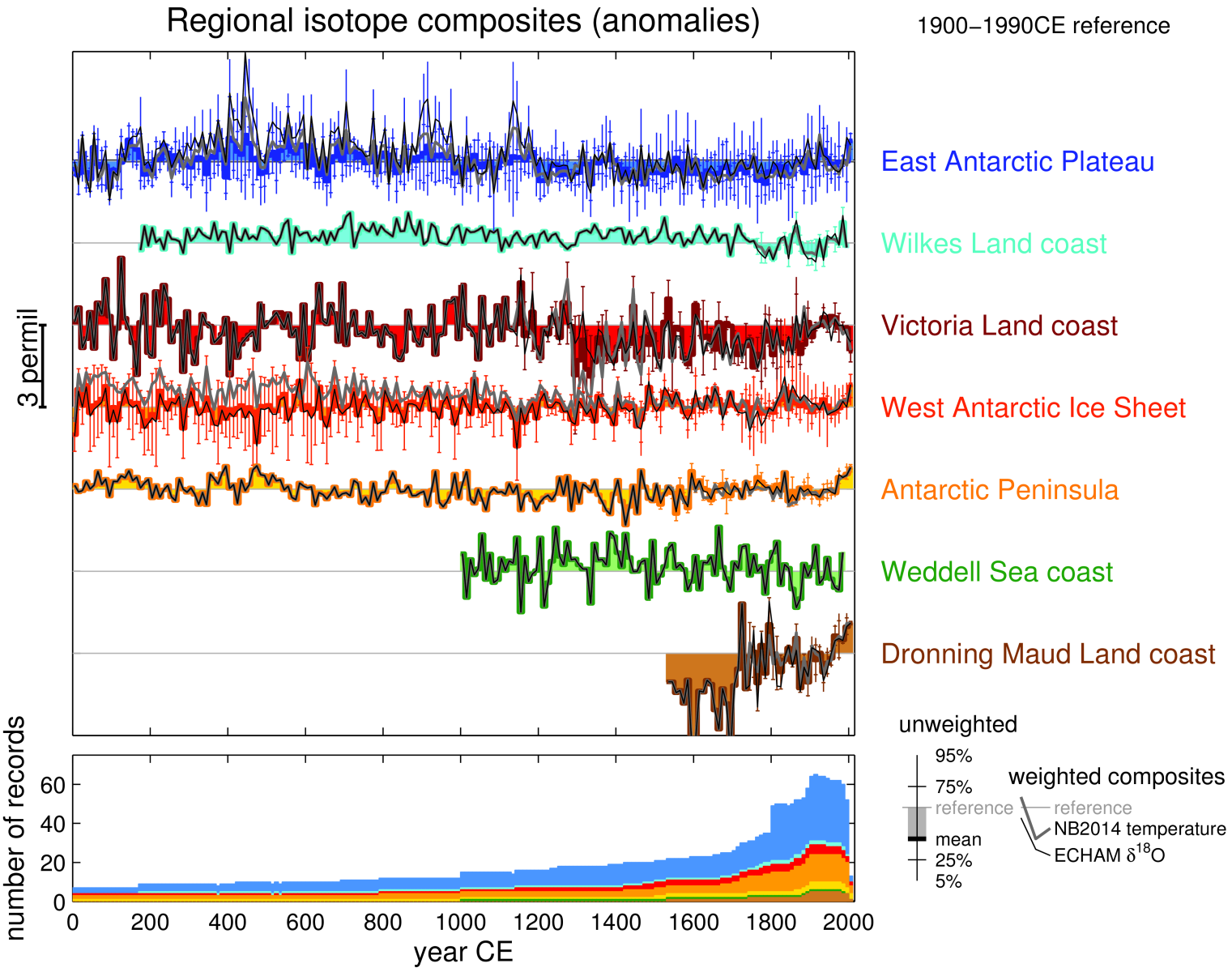
weights based on multiple regression of each site T against the regional T (the sum of the weight is 1). The weights change with time because of the changing number of records (nested method). ***The Nicholas and Bromwich (2014) T data and the $\delta^{18}O$ and T data from the ECHAM5-wiso model have been used.***



$\delta^{18}O$ composite reconstructions over the last 200 years using 5y-binned data



$\delta^{18}O$ composite reconstructions over the last 2000 years using 10y-binned data



Temperature reconstructions at regional and continental scale

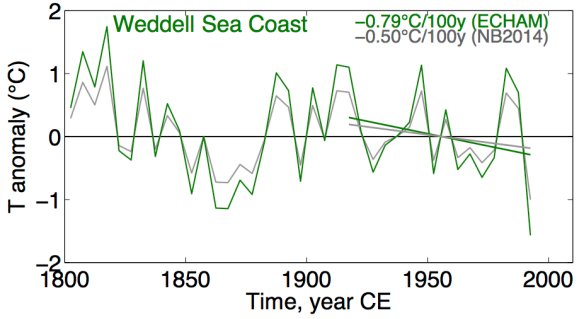
1) a temperature scaling based on the $\delta^{18}O$-temperature relationship output from an ECHAM5-wiso model simulation nudged to ERA-interim atmospheric reanalyses from 1979 to 2013, and adjusted for the West Antarctic Ice Sheet region to borehole temperature data;
2) a temperature scaling of the isotopic normalized anomalies to the variance of the regional reanalysis temperature;
3) a composite-plus-scaling approach used in a previous continental scale reconstruction of Antarctic temperature since 1 CE but applied to the new Antarctic ice core database.

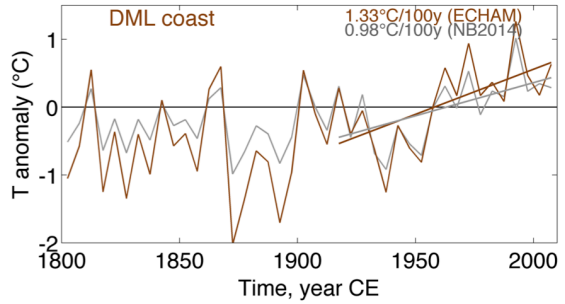
Scaling using ECHAMwiso regional $\delta^{18}O$-T relationships

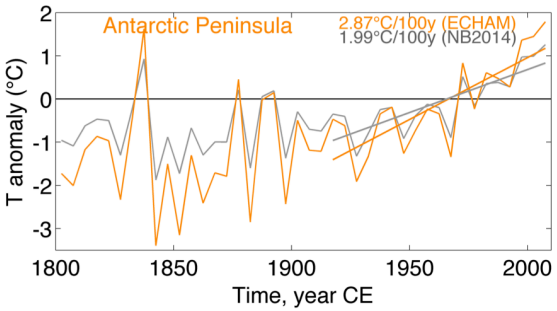
Linear regression analysis (slope with ±1σ uncertainty, correlation coefficient r, and p-value) of the simulated $\delta^{18}O$-temperature relationships extracted from the ECHAM5-wiso model for each climatic region, as well as the broad East Antarctic, West Antarctic and whole Antarctic regions.

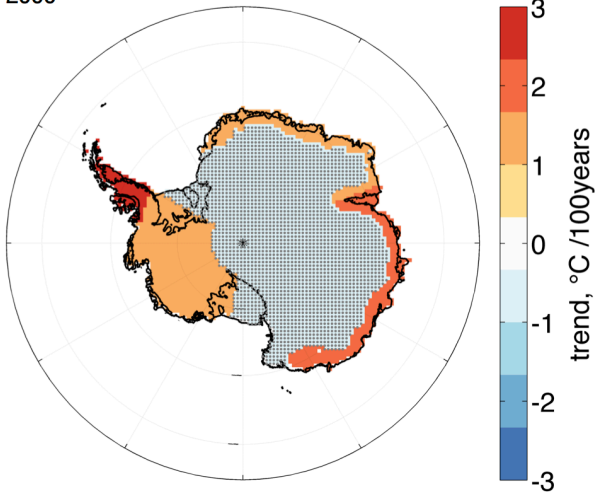
Geographic region	**slope (°C/‰)**	**slope (‰/°C)**	**r**	**p-value**
1. East Antarctic Plateau	0.95 ± 0.05	1.05 ± 0.06	0.62	0.0001
2. Wilkes Land Coast	1.91 ± 0.11	0.52 ± 0.03	0.44	0.0084
3. Weddell Sea Coast	1.01 ± 0.06	0.99 ± 0.06	0.34	0.0449
4. Antarctic Peninsula	2.50 ± 0.15	0.40 ± 0.02	0.31	0.0658
5. West Antarctic Ice Sheet	1.04 ± 0.06	0.96 ± 0.05	0.59	0.0002
6. Victoria Land Coast	0.83 ± 0.05	1.21 ± 0.07	0.49	0.0027
7. Dronning Maud Land Coast	1.08 ± 0.06	0.93 ± 0.05	0.39	0.0217
West Antarctica	1.03 ± 0.06	0.97 ± 0.05	0.62	0.0001
East Antarctica	1.00 ± 0.05	1.00 ± 0.05	0.58	0.0002
All Antarctica	1.02 ± 0.06	0.98 ± 0.05	0.56	0.0004

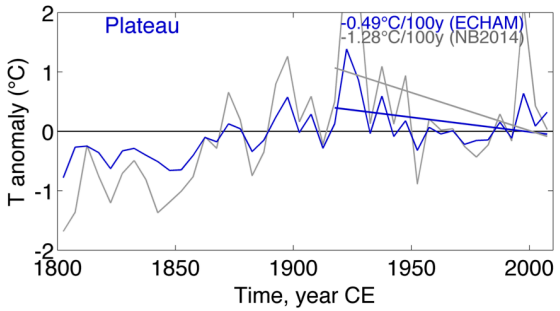
Regional temperature (T anomalies in °C, referenced to the 1960-1990 CE interval) reconstructions using 5y-binned data for the past 200y

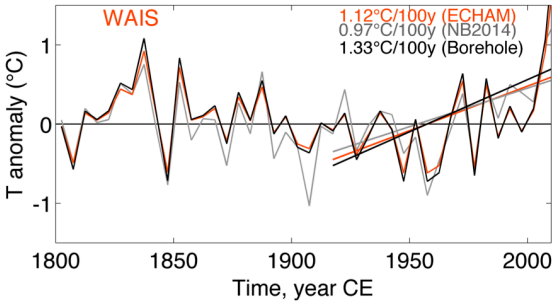


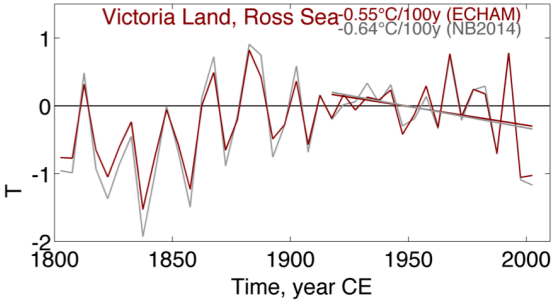


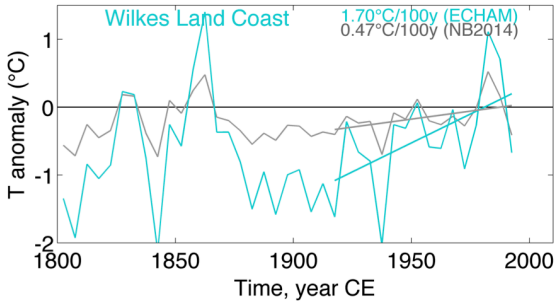




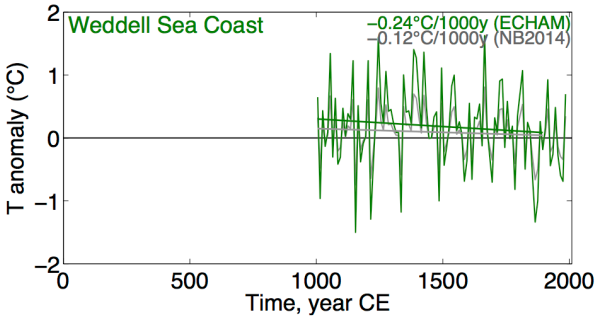


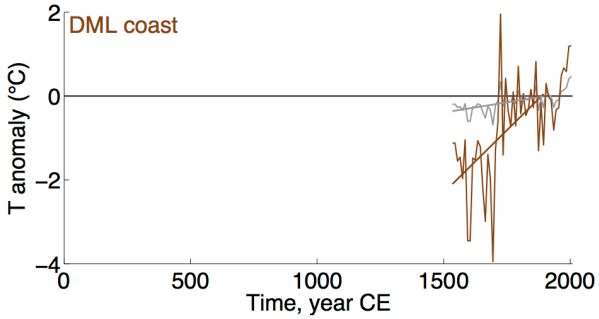


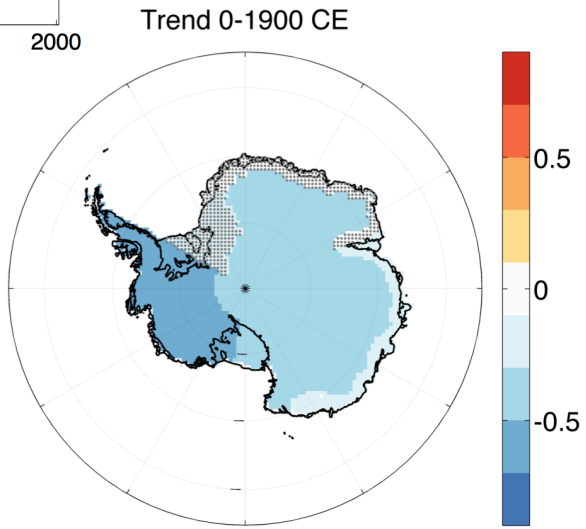


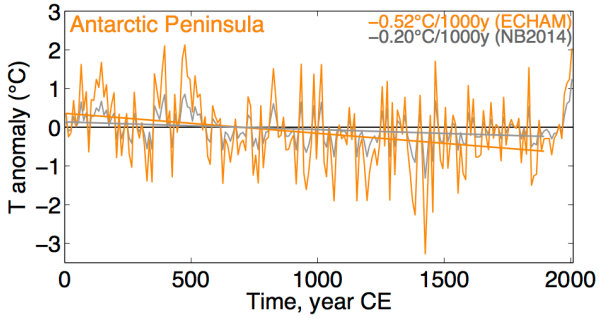


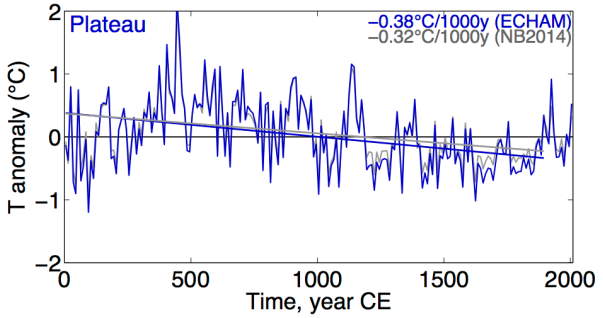
Regional temperature (T anomalies in °C, referenced to the 1900-1990 CE period) reconstructions using 10y data for the past 2000y

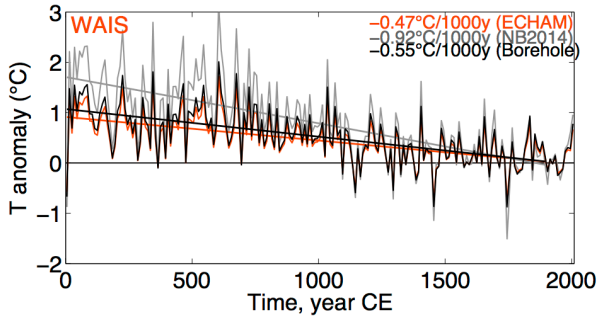


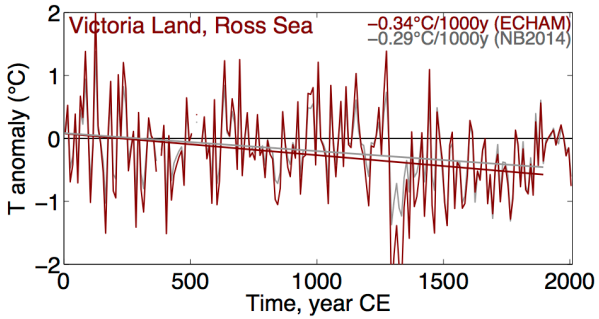


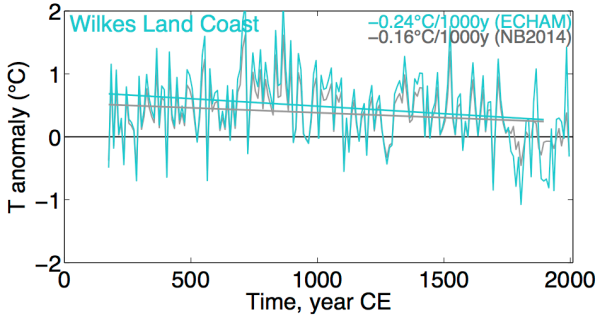




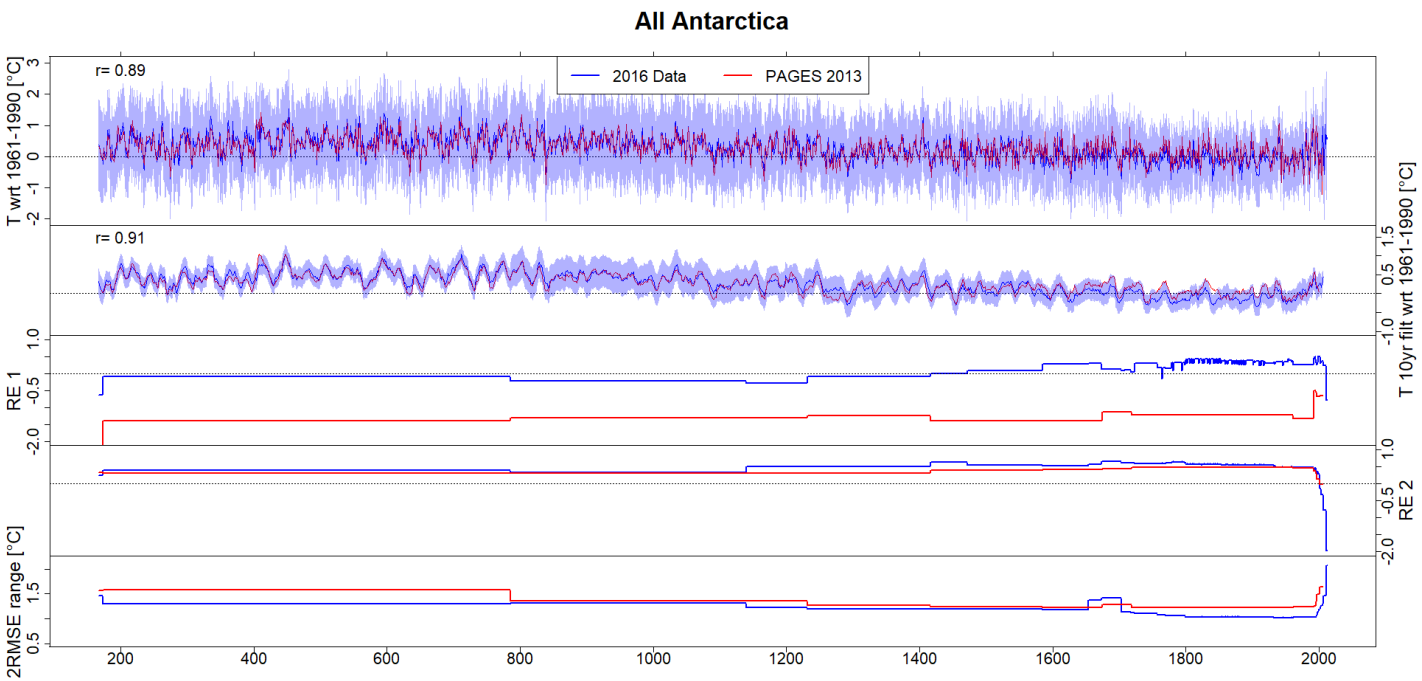








Applying the method published in 2013 to the new database

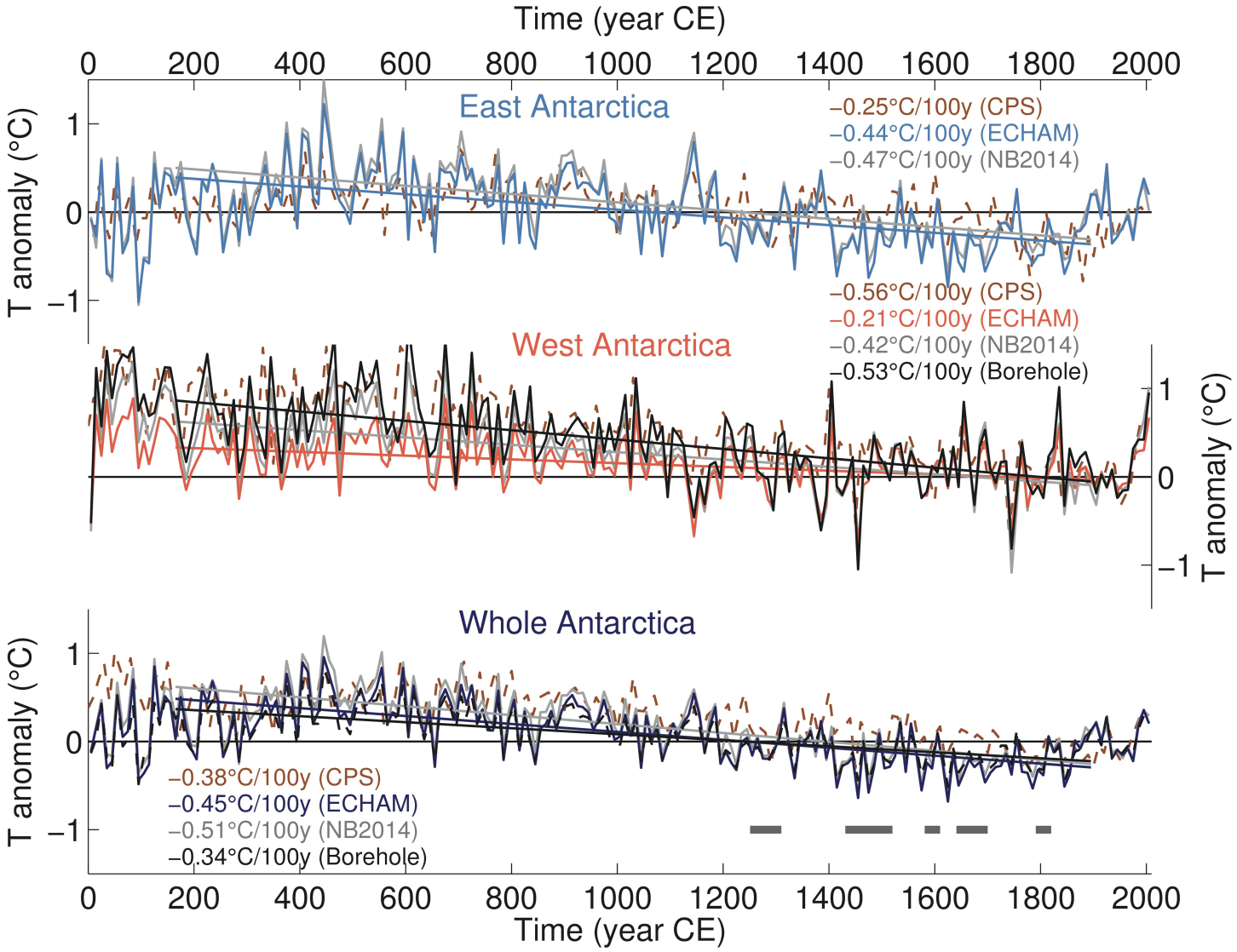


Method details:

1. Calibration period: 1961-1991
2. proxies correlated with instrumental target T data over calibration period
3. Records are normalized
4. Weighted mean of records based on the strength of positive corr. with T
5. Scale the composite to the mean and standard deviation over the 1961-1991.

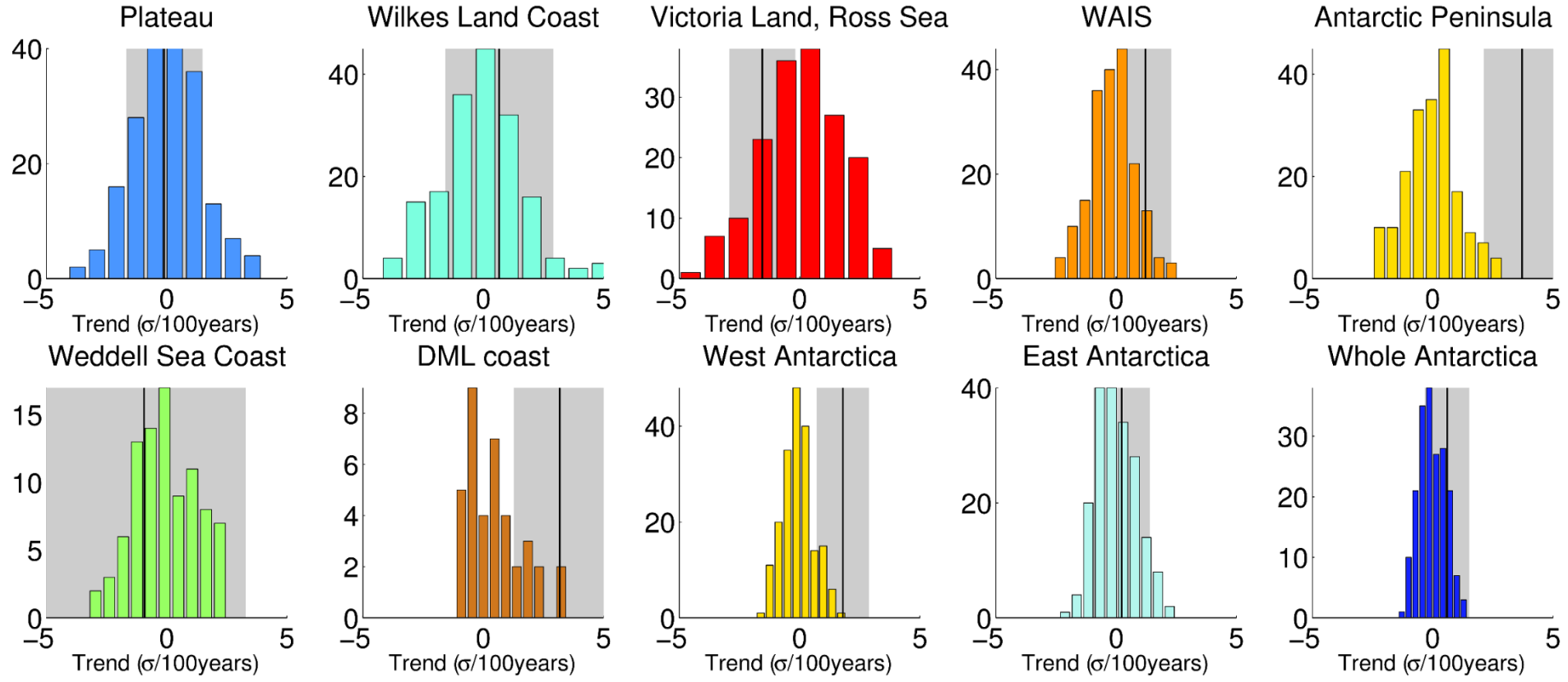
The target T dataset used in this new reconstruction is from Nicolas & Bromwich (2014).

Temperature reconstructions for East, West and whole Antarctica using 10y averages and the different temperature scaling approaches



100y trends on normalized, weighted composites over the last 2000 years

Only for the Antarctic Peninsula does the most recent 100-year trend stand out as unusual compared to the natural range of century-scale trends over the last 2000 years



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Climate of the Past
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Regional Antarctic snow accumulation over the past 1000 years

Elizabeth R. Thomas[1], J. Melchior van Wessem[2], Jason Roberts[3,4], Elisabeth Isaksson[5], Elisabeth Schlosser[6,7], Tyler J. Fudge[8], Paul Vallelonga[9], Brooke Medley[10], Jan Lenaerts[2], Nancy Bertler[11,12], Michiel R. van den Broeke[2], Daniel A. Dixon[13], Massimo Frezzotti[14], Barbara Stenni[15,16], Mark Curran[3], and Alexey A. Ekaykin[17,18]

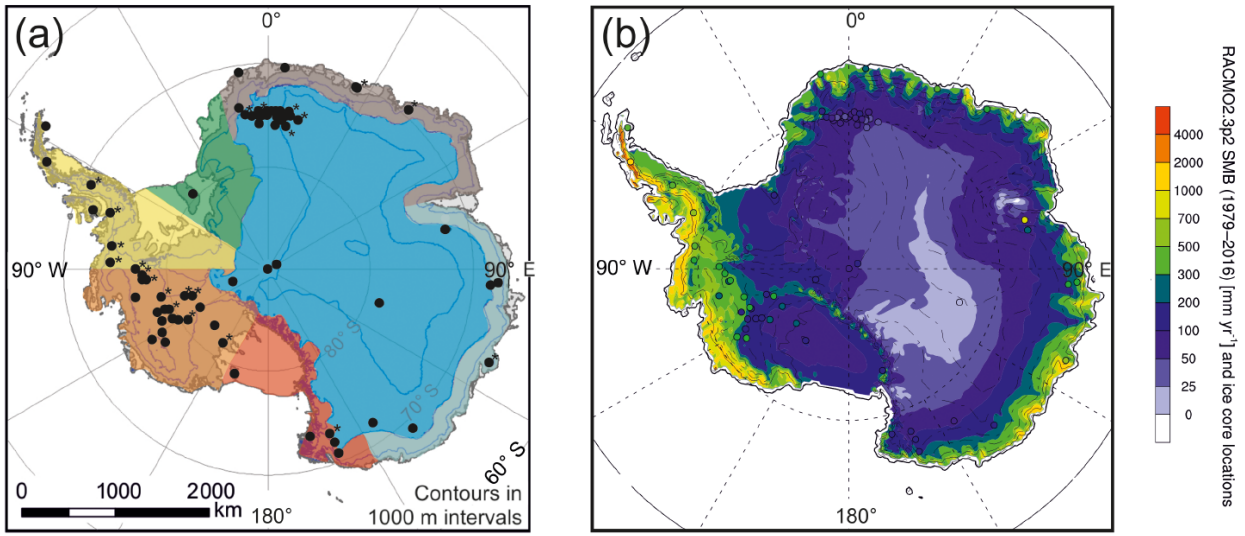
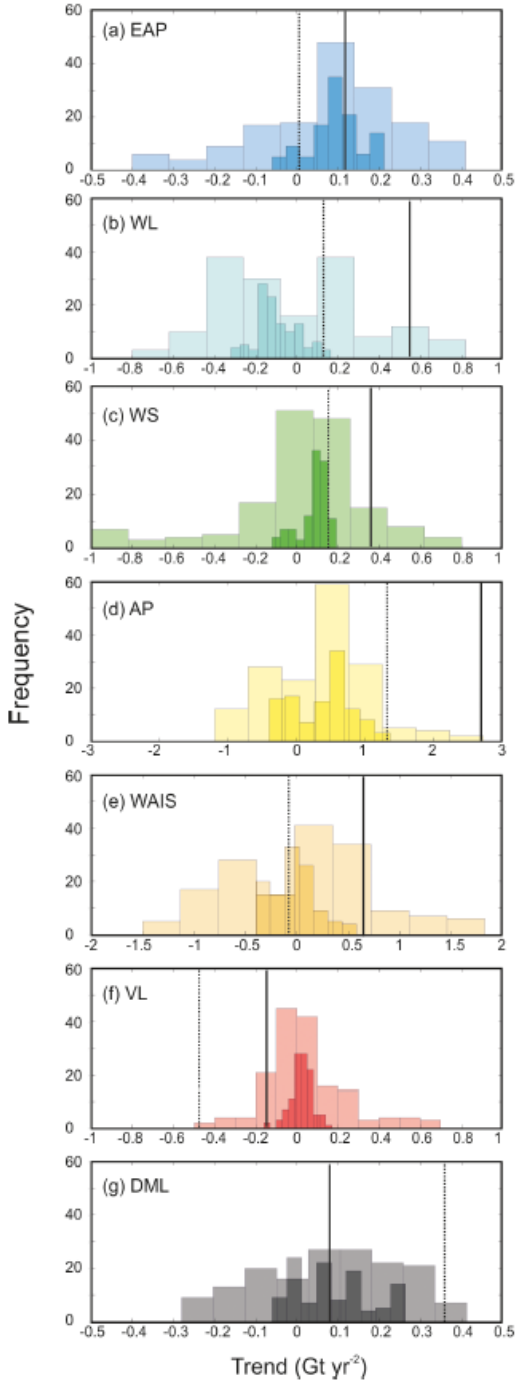


Figure 1. **(a)** Location of all ice cores and the regional boundaries used in this study. EAP (blue), WL (cyan), WS (green), AP (yellow), WAIS (orange), VL (red), and DML (brown). Stars denote sites where correlation between ice core snow accumulation and RACMO2.3p2 SMB is significant at $p < 0.05$. **(b)** RACMO2.3p2 SMB (1979–2016) overlain with ice core SMB since 1979 at each location.



Conclusions 1/2

- We showed here isotopic and temperature composite records at regional and continental scale from the PAGES Antarctica2k working group.
- Enlarged database.
- Selection of 7 climatic regions.
- Different reconstruction methodologies: - Simple average un-weighted and weighted composites.
- We use 3 methods for T reconstructions. ECHAM and NB2014 use two independent datasets for scaling the $\delta^{18}O$ signal to temperature, and the difference between them is a measure of the uncertainty in the temperature reconstruction.

1. Scaling using ECHAM model-based regional $\delta^{18}O$-Temperature relationships and adjusted for the WAIS region to borehole temperature data;
2. A temperature scaling of the isotopic normalized anomalies to the variance of NB2014 reanalysis temperature;
3. A composite-plus-scaling approach used in a previous reconstruction of Antarctic temperature but applied to the new Antarctic ice core database.

Conclusions 2/2

- A significant cooling trend from 0 to 1900 CE across all Antarctic regions where records extend back into the 1st millennium.
- Since 1900 CE significant warming trends are identified for the West Antarctic Ice Sheet, the Dronning Maud Land coast and the Antarctic Peninsula regions.
- Only for the Antarctic Peninsula is this most recent century-scale trend unusual in the context of natural variability over the last 2000-years.
- The first long-term quantification of regional climate in Antarctica presented herein is a basis for data-model comparison and assessments of past, present and future driving factors of Antarctic climate.

Perspectives 1/2

CLIVASH2k - Climate variability in Antarctica and Southern Hemisphere in the past 2000 years

CLIVASH2k timeline

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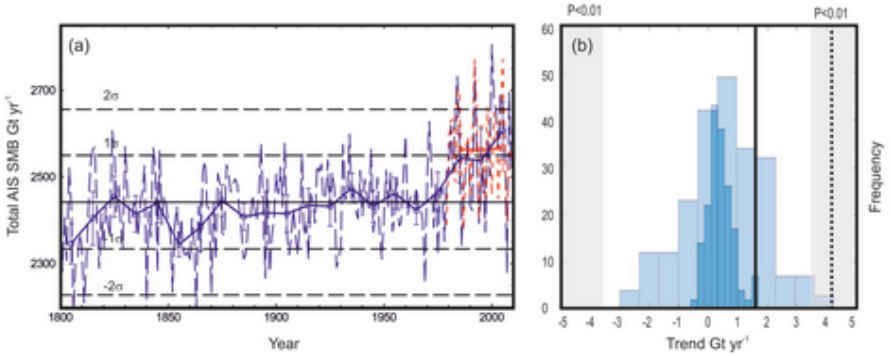
Perspectives 2/2

CLIVASH2k scientific goals

CLIVASH2k will build upon the PAGES regional networks (Antarctica2k, LOTRED-SA and Aus2k) to investigate southern hemisphere climate variability over the past 2000 years. We will explore the links and teleconnections between mid and high-latitudes through the assimilation of a range of proxy archives, such as ice cores, lake sediments, ocean sediments, and peat records, from Antarctica, the sub-Antarctic and the wider Southern Hemisphere.



Antarctic Surface Mass Balance (SMB) since 1900. Outcome from Antarctica 2k regional working group. Figure 9 from Thomas et al. (2017) Antarctic regional snow accumulation over the past 1000 years, doi:10.5194/cp-2017-18.

The aims of this working group are:

- To enhance our understanding of Antarctic, sub-Antarctic and Southern Hemisphere climate variability over the past 2000 years.

- Evaluate the key drivers of Southern Hemisphere climate variability on regional to hemispheric scales.

- Work towards a community based multi-proxy reconstruction of key modes of variability over the past 2000 years and how they relate to climate in Antarctica, the sub-Antarctic and the wider Southern Hemisphere.

Link: http://pastglobalchanges.org/ini/wg/2k-network/projects/clivash

Thanks for your attention!

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Q&A session

To participate in the Q&A Session, please use the chat room provided by the Go-to-Webinar system

Forthcoming Webinar

CMCC-BIOECON Webinar: “Improving the design of Payment for Ecosystem Service Schemes”

Presenter: Nicholas Hanley
Professor of Environmental and One Health Economics
at the University of Glasgow, Scotland

Moderator: Jaroslav Mysiak
Director of the RAAS Division, Fondazione CMCC –
Centro Euro-Mediterraneo sui Cambiamenti Climatici

17 July 2018
12:30 pm CEST

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Thank you for attending this CMCC webinar.

This webinar was recorded and will be uploaded to the CMCC website: www.cmcc.it

If you have any further question about the webinar, please email: webinar@cmcc.it

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