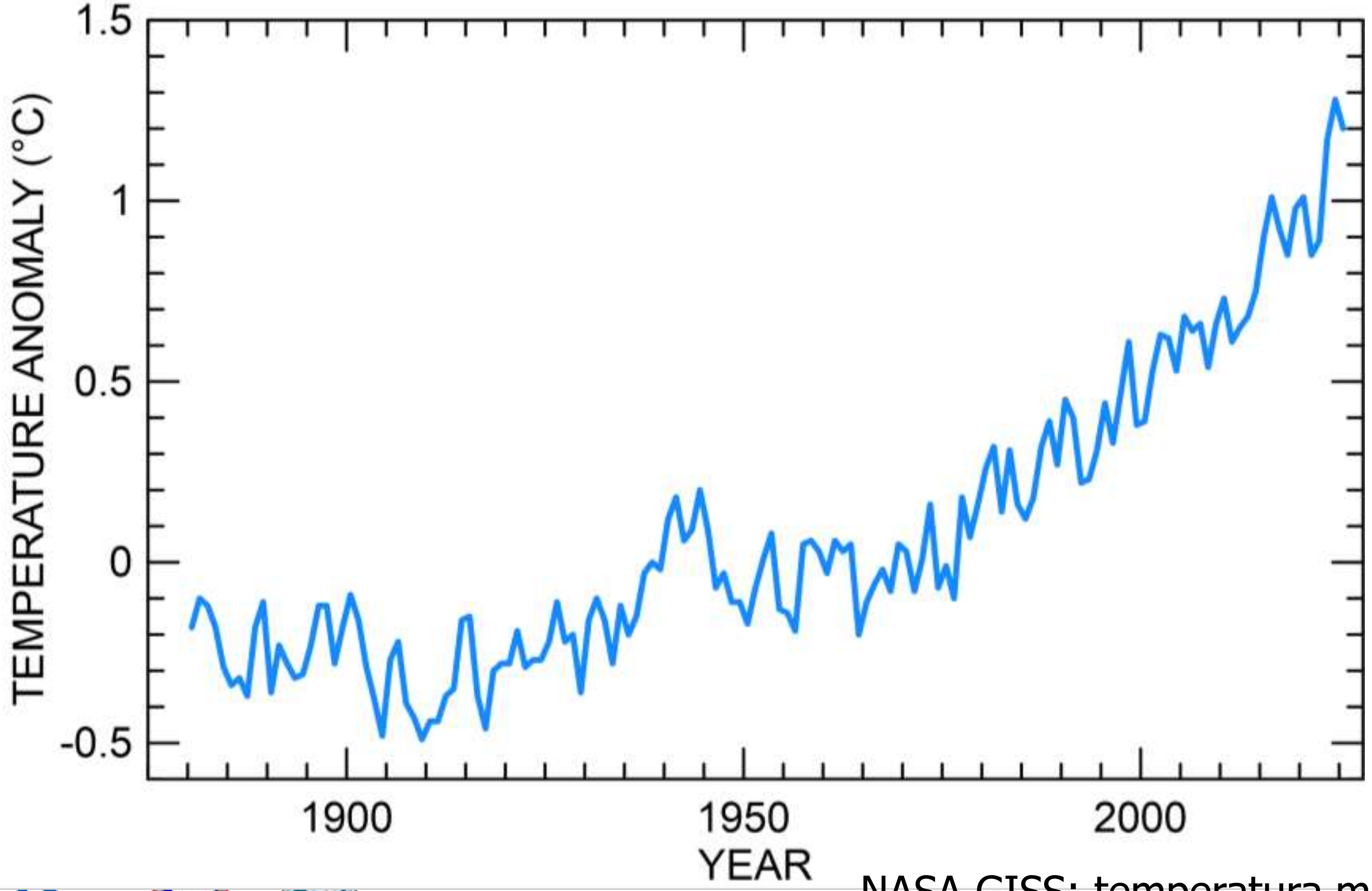
40 anni di osservazioni: l’andamento delle temperature nelle serie di lungo periodo

40 anni di osservazioni in un clima che cambia

Virginia Ciardini, ENEA - Laboratorio Modelli e Misure per la Qualità dell’Aria ed Osservazioni Climatiche

Cambiamenti in atto

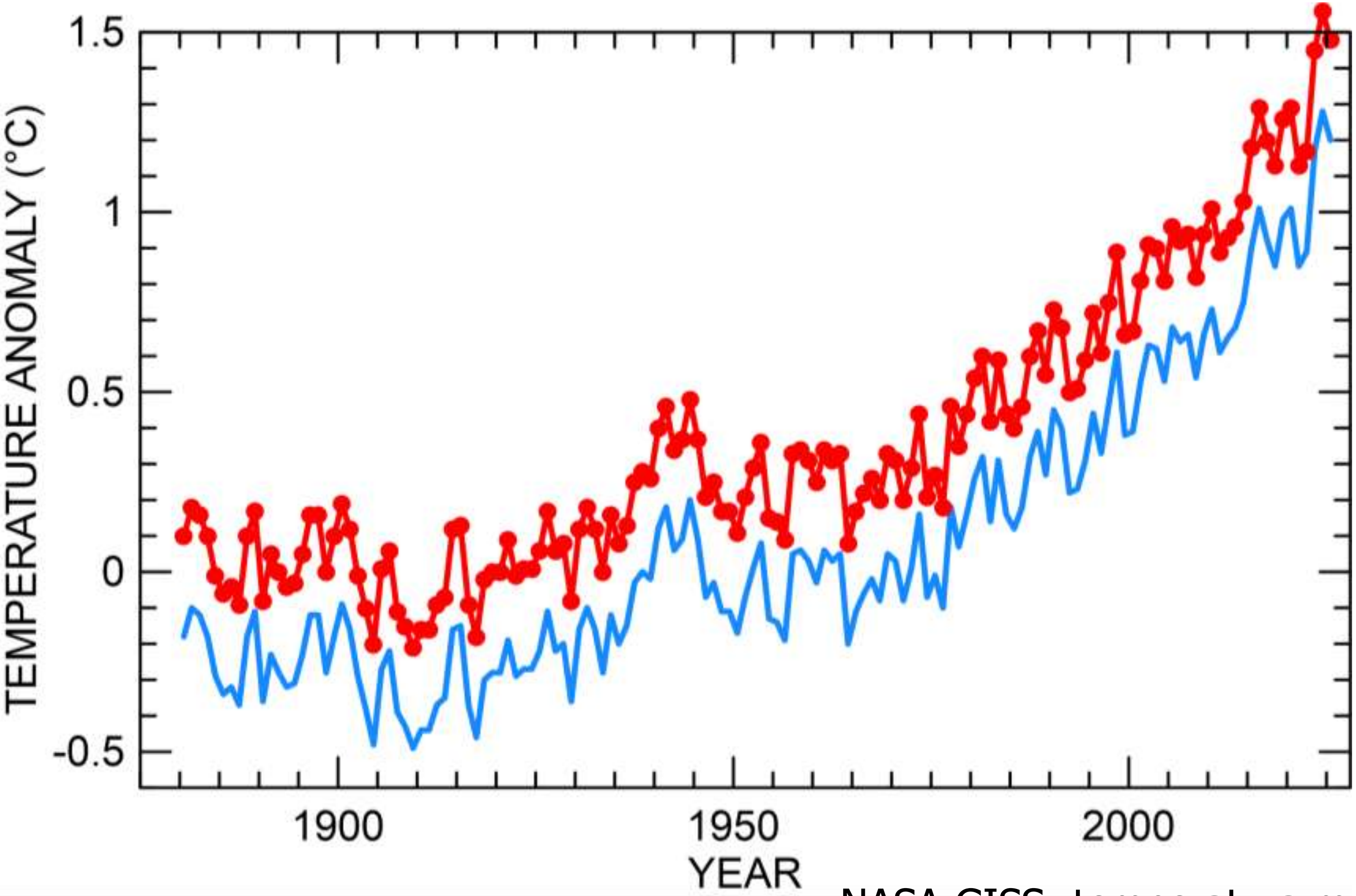
Periodo di riferimento: 1901-2000



NASA GISS: temperatura media globale annuale

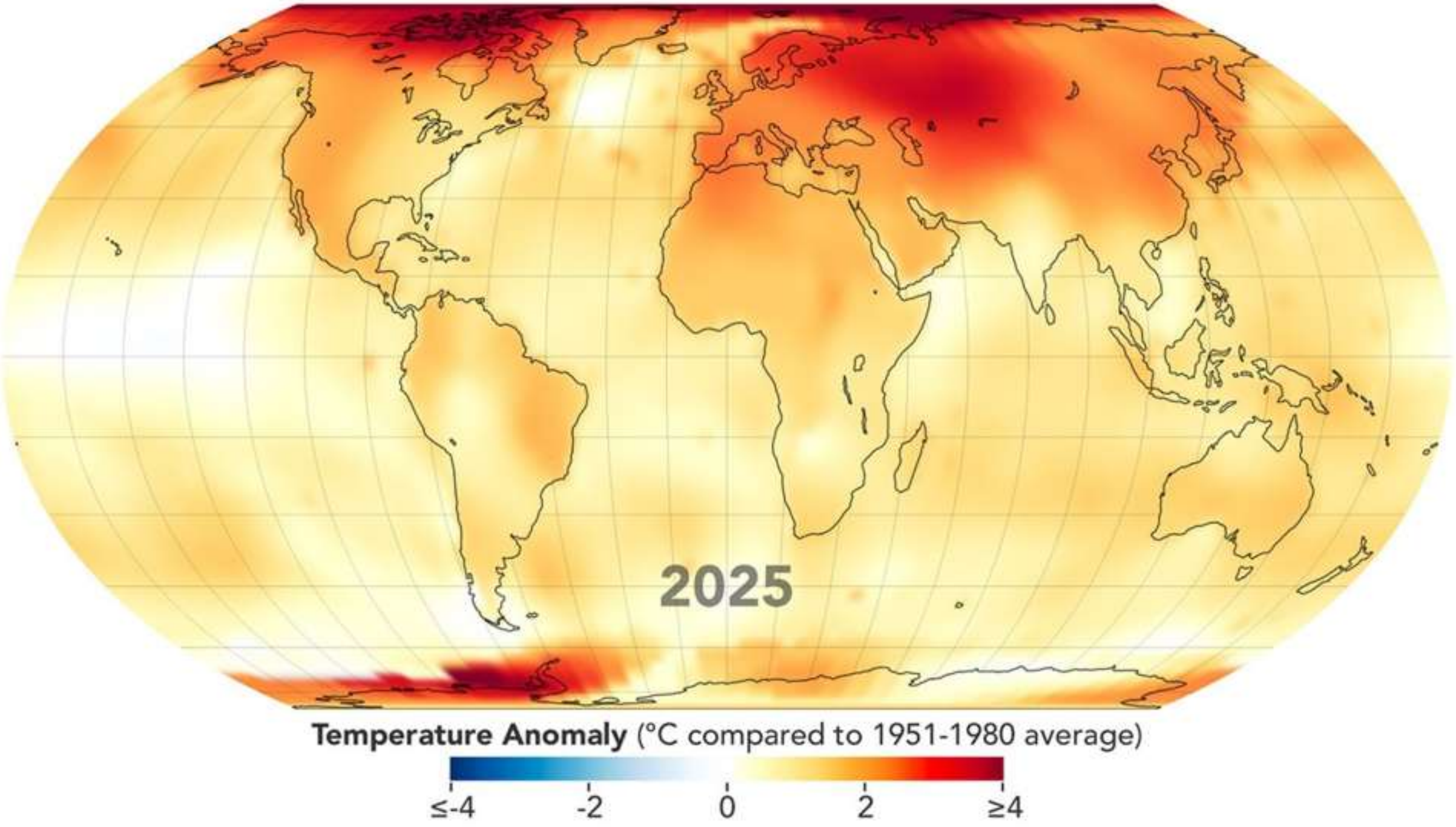
Cambiamenti in atto

Periodo di riferimento: 1880-1920



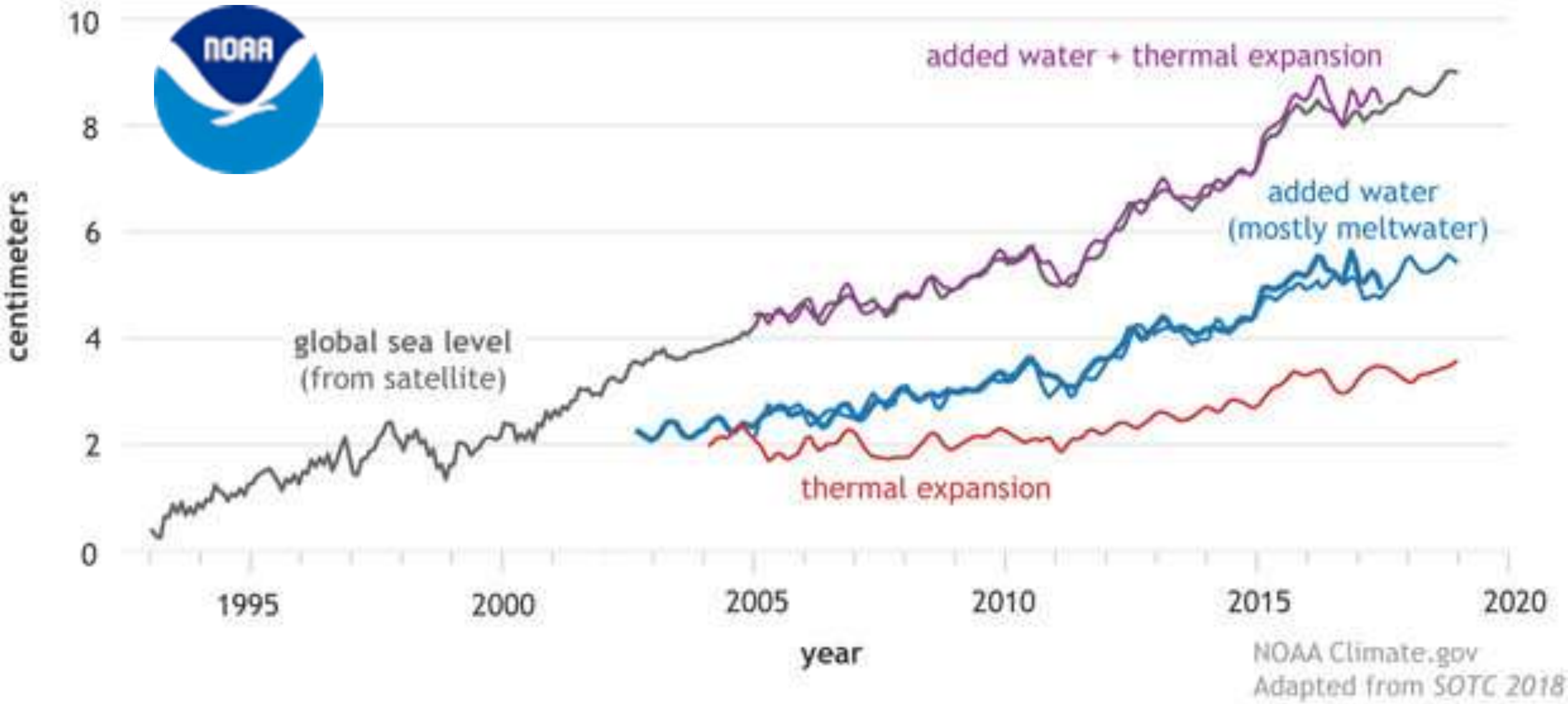
NASA GISS: temperatura media globale annuale

L'Artide così come in alcune regini dell'Antartide la temperatura è aumenta di più rispetto alla media globale.
In Artide, il tasso di riscaldamento osservato durante le ultime due decadi è circa 2-3 VOLTE superiore a quanto si osserva a scala globale.



NASA GISS

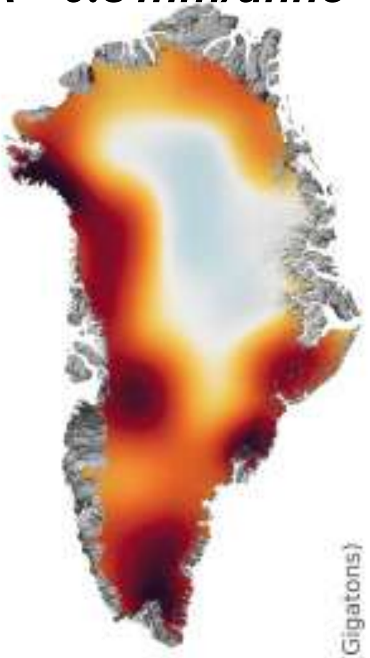
Contributors to global sea sea level rise (1993-2018)

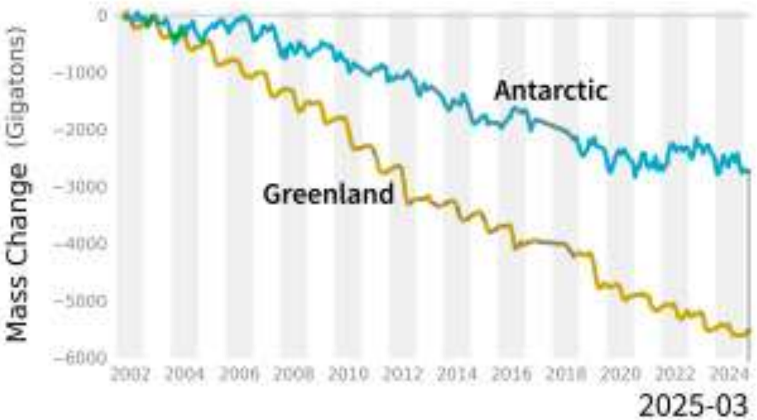


GRACE AND GRACE-FO Observations OF Polar Land Ice Mass Changes

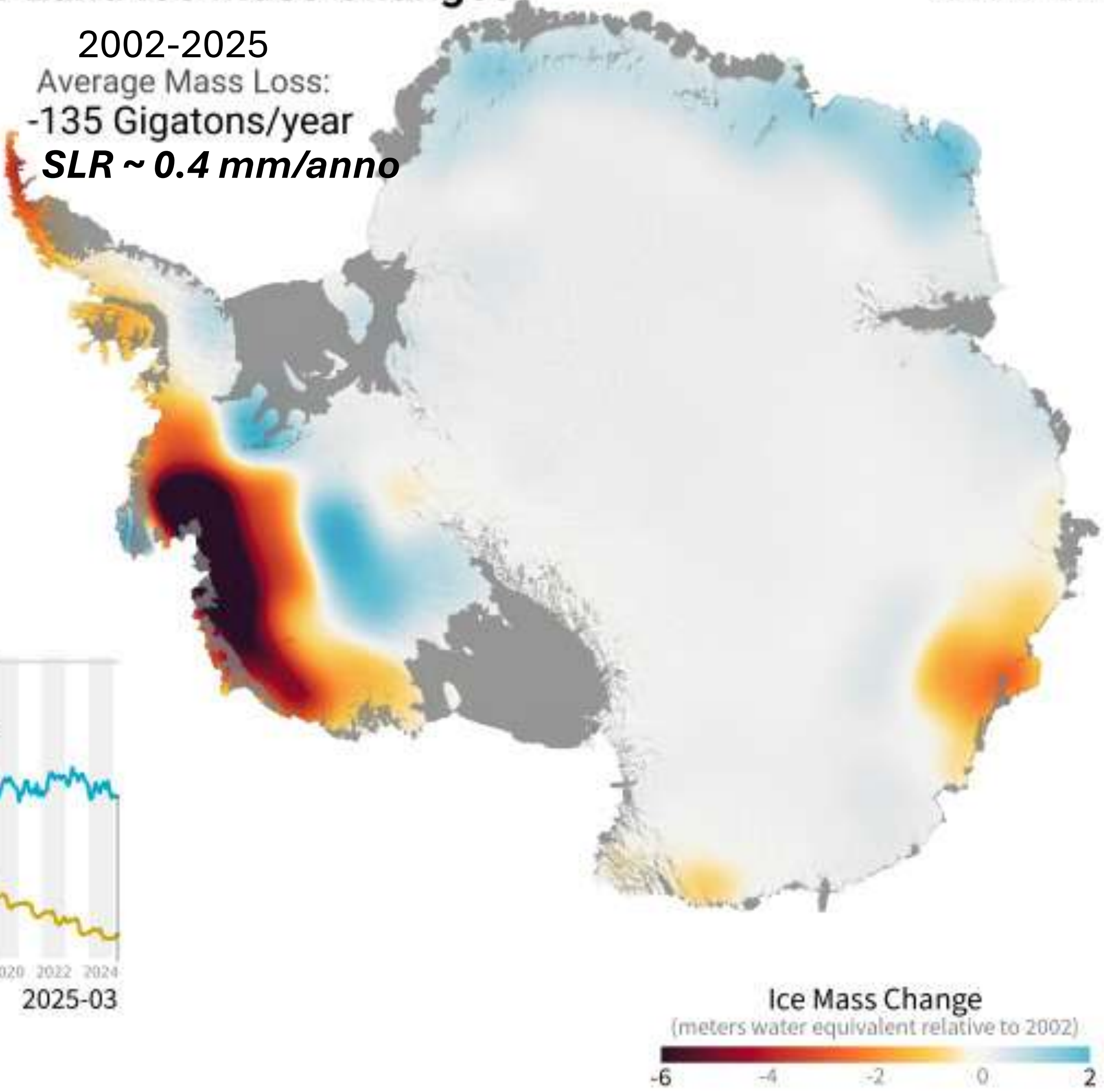
2025-03

Average Mass Loss:
-264 Gigatons/year
SLR ~ 0.8 mm/anno





2002-2025
Average Mass Loss:
-135 Gigatons/year
SLR ~ 0.4 mm/anno



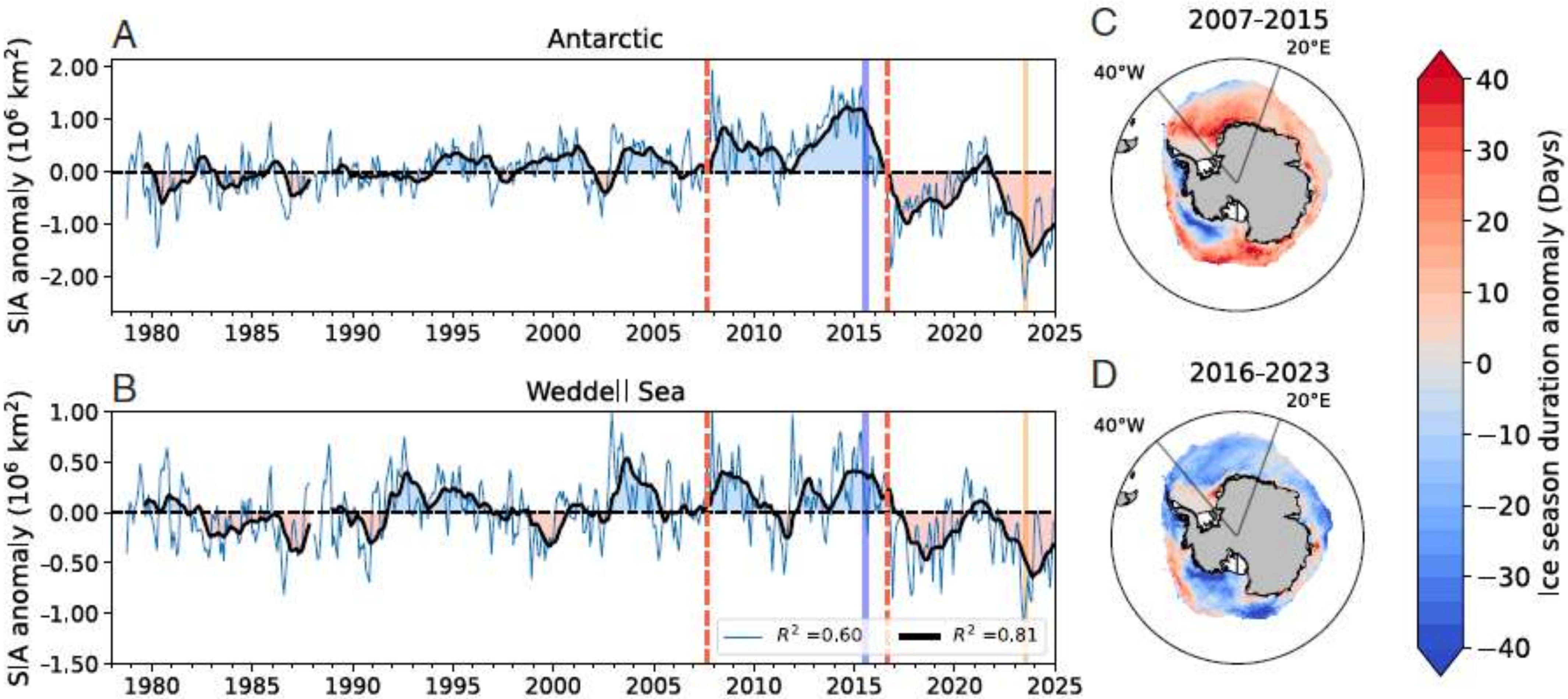


Fig. 1. Southern Ocean sea ice trends. (*A* and *B*) Monthly sea ice area (SIA) for the Antarctic and Weddell Sea, between 40°W and 20°E. Anomalies are defined relative to the monthly climatology for 1980–2010. Black lines represent a 12-mo running mean. The dashed red lines highlight September 2007 and 2016, the starts of the accelerated sea ice expansion and decline periods as defined by ref. 8. The blue and orange vertical bars indicate the winter SIA maximum and minimum in 2015 and 2023, respectively. R^2 values in (*B*) indicate the fraction of variance in circumpolar SIA anomalies explained by corresponding anomalies in the Weddell Sea since 2007. (*C* and *D*) Sea ice season duration anomalies for 2007–2015 and 2016–2023 for regions where the climatological season duration is greater than 3 mo (*Materials and Methods*).

Wilson et al., 2023

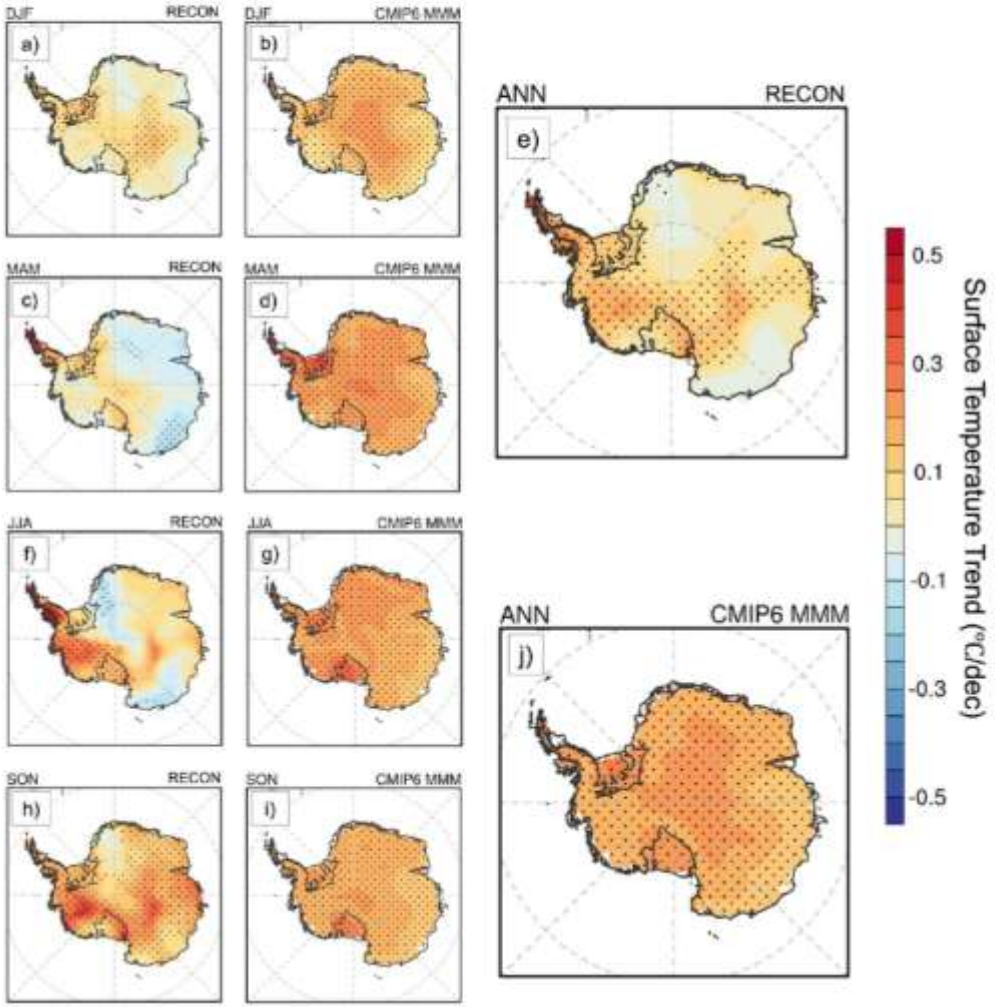
Trend temperatura alla superficie 1958-2022

Trend continentale 0.13°C/decade

Disomogeneità spaziale e stagionale

Differenze reanalisi/modelli

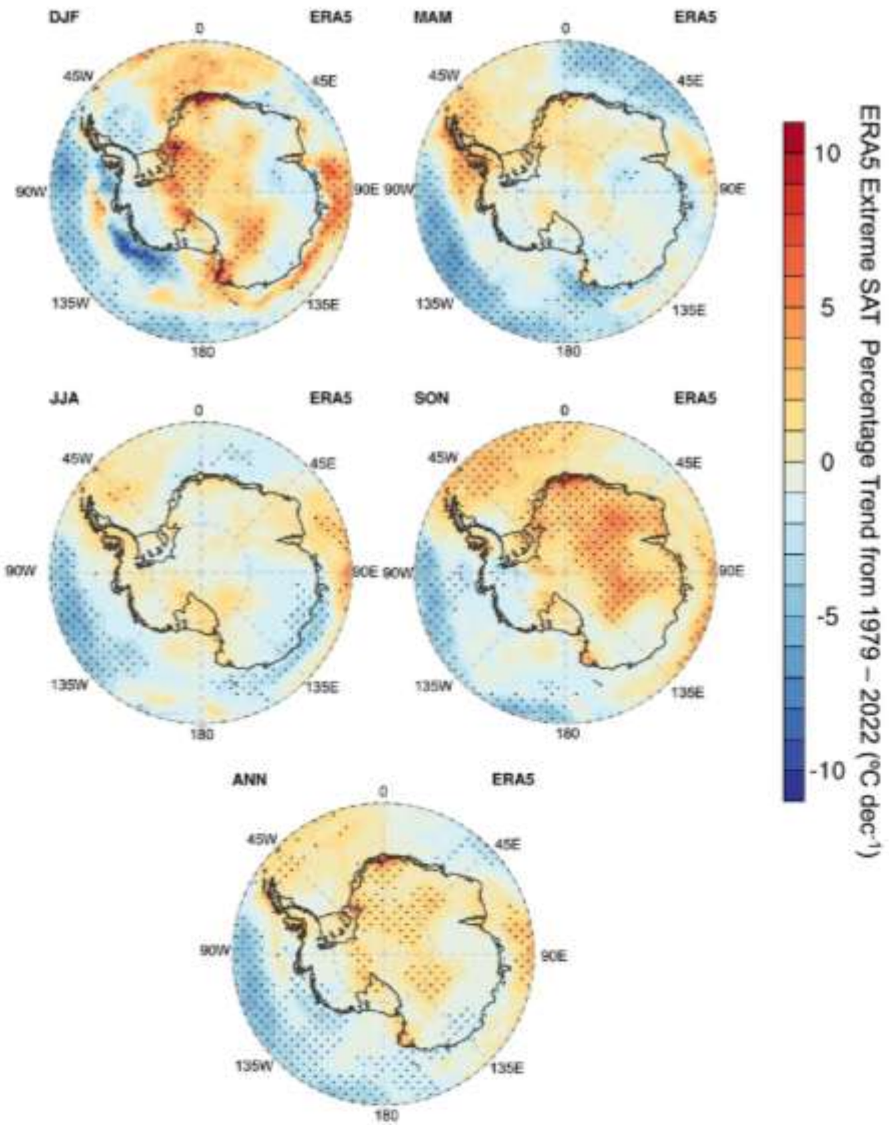
Fig. 1: **Antarctic air temperature trends from RECON and CMIP6**



Spatial map of annual and seasonal surface air temperature (SAT) trends from 1958 to 2022 based on RECON (a,c,f,h,e) and CMIP6 MMM (b,d,g,i,j). The dot pattern represents trends that are significantly different from zero at $P < 0.05$ after removing the impact of autocorrelation from the residuals[79].

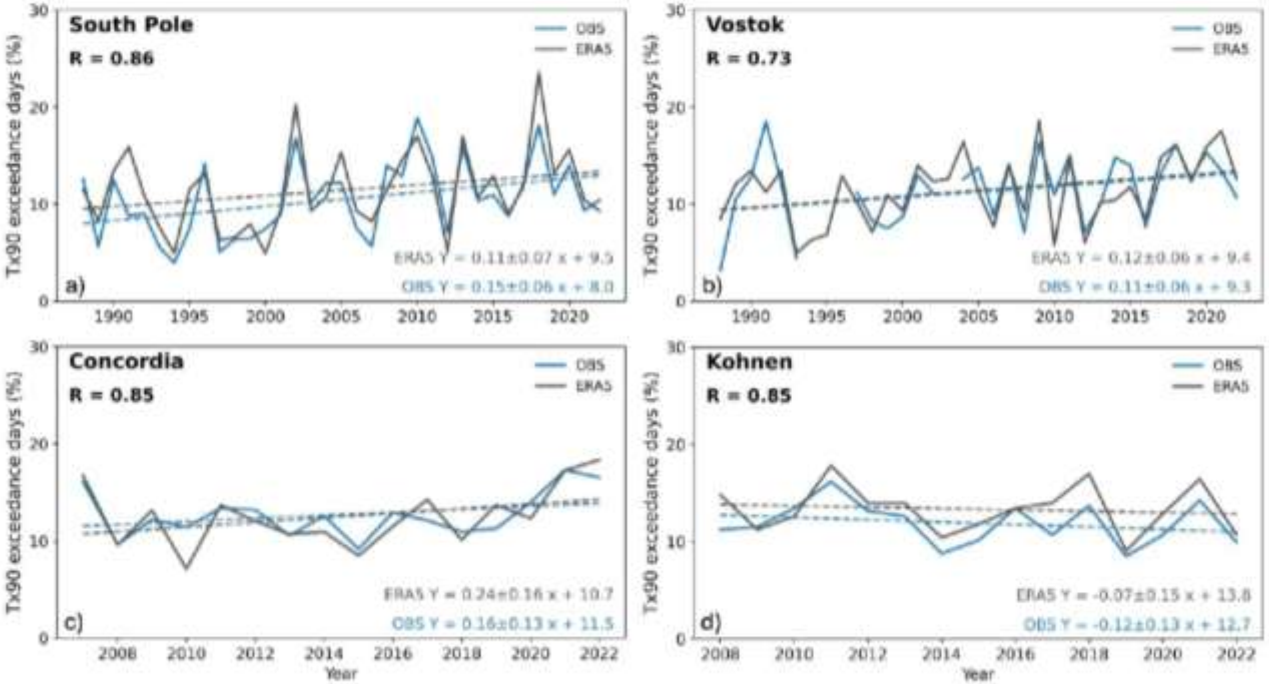
Bromwich et al., 2026 – in press

estremi di temperatura



Annual and seasonal extreme warm surface air temperature (SAT) trend based on 3-hrly ERA5 reanalysis data from 1979 to 2022. The dot pattern represents extreme SAT trends that are significantly different from zero at P < 0.05. Extreme warm SAT trend is calculated based on the percentage of timesteps with a daily maximum SAT greater than the reference threshold.

Fig. 8: Time series of interior warm temperature extremes from ERA5 and observations



Bromwich et al., 2026 – in press

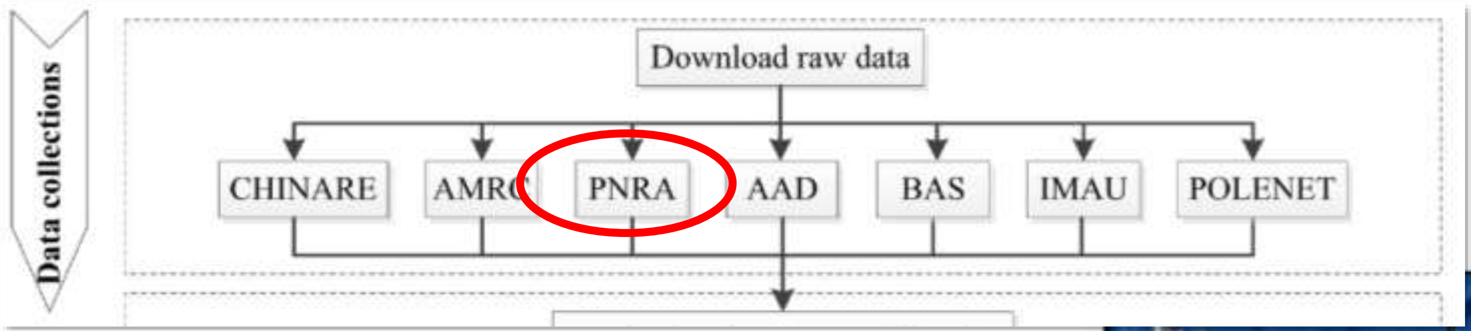
L’importanza delle reti osservative di AWS

- La quantificazione di **variabilità e trend di variabili meteorologiche (es. temperatura)** richiede **misure accurate, continue e di lungo periodo**.

- variazioni delle variabili atmosferiche (in particolare temperatura dell’aria, ma anche vento e accumulo nevoso) hanno **impatti diretti** sul bilancio energetico superficiale, massa e dinamica della calotta glaciale come sugli ecosistemi

- Le **stazioni meteorologiche automatiche (AWS)** permettono osservazioni ad alta risoluzione, in aree remote e condizioni estreme, durante tutto il corso dell’anno.

- Le **AWS forniscono dati necessari per** studi scientifici (es. accumulo nevoso, bilancio energetico, massa della calotta), attività logistiche in Antartide, modelli numerici previsionali, validazione di reanalisi atmosferiche e modelli climatici, verifica di prodotti satellitari, analisi climatiche di lungo periodo.



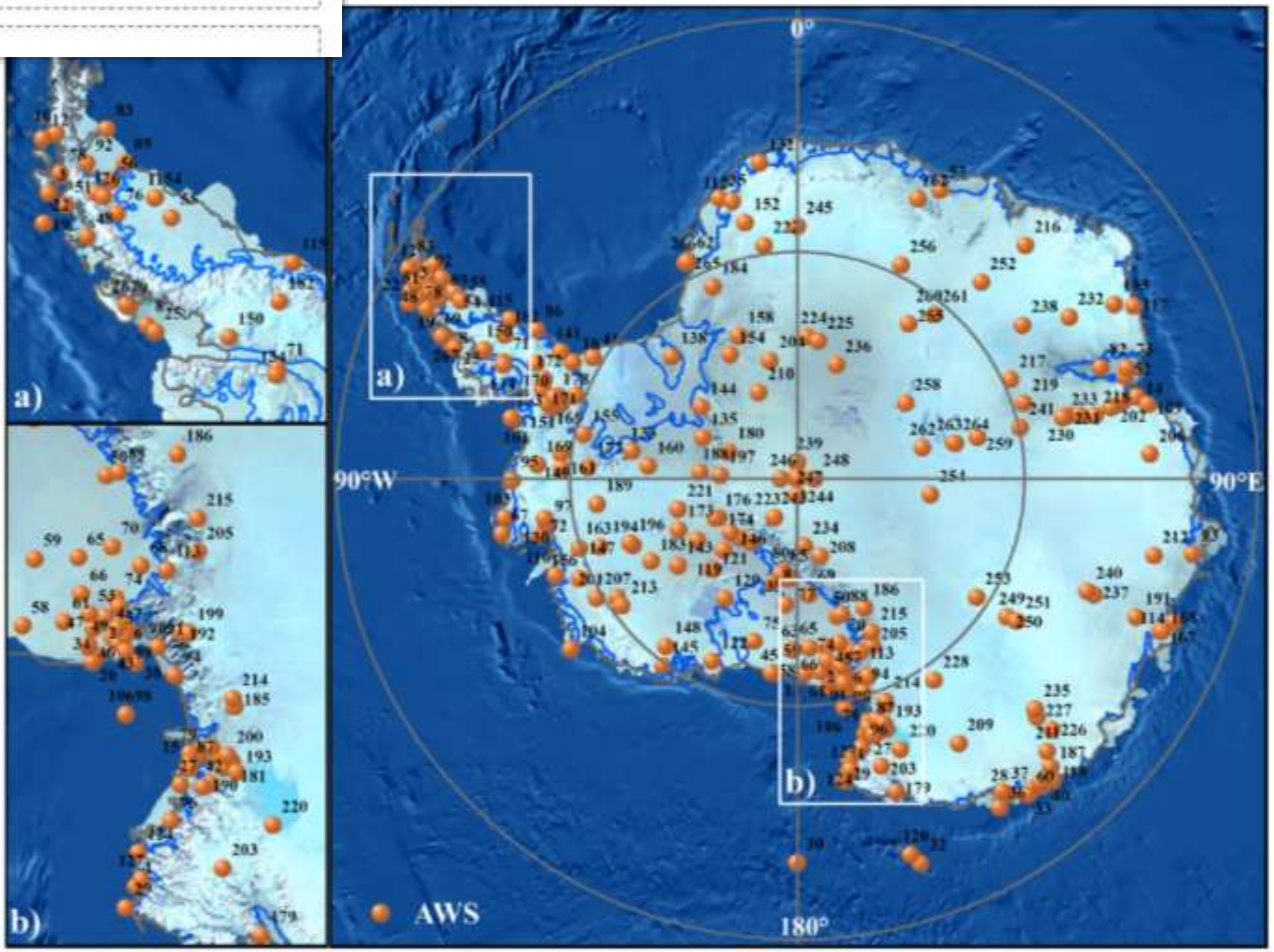
7 Antarctic AWS project databases

The AntAWS dataset: a compilation of Antarctic automatic weather station observations

Yetang Wang[1,★], Xueying Zhang[1,★], Wentao Ning[1], Matthew A. Lazzara[2], Minghu Ding[3], Carleen H. Reijmer[4], Paul C. J. P. Smeets[4], Paolo Grigioni[5], Petra Heil[6,7], Elizabeth R. Thomas[8], David Mikolajczyk[2], Lee J. Welhouse[2], Linda M. Keller[2], Zhaosheng Zhai[1], Yuqi Sun[1], and Shugui Hou[9]

[1]College of Geography and Environment, Shandong Normal University, Jinan 250014, China
[2]Antarctic Meteorological Research and Data Center, Space Science and Engineering Center, University of Wisconsin–Madison, Madison, Wisconsin, USA
[3]State Key Laboratory of Severe Weather, Chinese Academy of Meteorological Sciences, Beijing 100081, China
[4]Institute for Marine and Atmospheric Research Utrecht, Utrecht University, Utrecht, the Netherlands
[5]Laboratory for Measurements and Observations for Environment and Climate, ENEA, 00123 Rome, Italy
[6]Australian Antarctic Division, Kingston, Tasmania 7050, Australia
[7]Australian Antarctic Program Partnership, University of Tasmania, Hobart, Tasmania 7001, Australia
[8]British Antarctic Survey, Cambridge, UK
[9]School of Oceanography, Shanghai Jiao Tong University, Shanghai 200240, China

Earth Syst. Sci. Data, 15, 411–429, 2023
https://doi.org/10.5194/essd-15-411-2023



ap of the 267 automatic weather stations (AWSs) in this study, where the numbers (1–267) correspond to "NO." in https://www.climantartide.it/pub/index.php?lang=it

BILANCIO DI MASSA SUPERFICIALE

The Cryosphere, 19, 5781–5799, 2025

The Cryosphere EGU

Challenges in surface mass balance estimation at Dome C: stake farm comparisons, measurement uncertainties, and station-induced biases

ISOTOPI E PRECIPITAZIONE

The Cryosphere, 18, 3911–3931, 2024

A decade (2008–2017) of water stable isotope composition of precipitation at Concordia Station, East Antarctica

ELSEVIER Polar Science

A statistical study of precipitation on the eastern antarctic plateau (Dome-C) using remote sensing and in-situ instrumentation

Massimo Del Guasta, Philippe Ricaud, Claudio Scarchilli, Giuliano Dreossi

BOUNDARY LAYER

ELSEVIER Polar Science

Diurnal variation of the planetary boundary layer over Dome C (Antarctica) impacting the formation of supercooled liquid water clouds

Philippe Ricaud, Pierre Durand, Paolo Grigioni, Virginia Ciardini, Massimo Del Guasta, Giuseppe Camporeale, Jean-Luc Attié, Eric Bazile

Atmos. Chem. Phys., 22, 9245–9263, 2022

Atmospheric Chemistry and Physics EGU

Factors controlling atmospheric DMS and its oxidation products (MSA and $nssSO_4^{2-}$) in the aerosol at Terra Nova Bay, Antarctica

Journal of Glaciology IGS

Article

Received: 27 March 2020
Revised: 28 July 2020
Accepted: 28 July 2020
First published online: 1 October 2020

Characterization of snowfall estimated by in situ and ground-based remote-sensing observations at Terra Nova Bay, Victoria Land, Antarctica

Claudio Scarchilli[1], Virginia Ciardini[1], Paolo Grigioni[1], Antonio Iaccarino[1], Lorenzo De Silvestri[1], Marco Proposito[1], Stefano Dolci[2], Giuseppe Camporeale[3], Riccardo Schioppo[4], Adriano Antonelli, Luca Baldini[7], Nicoletta Roberto[7], Stefania Argentini[7], Alessandro Bracci[7,8] and Massimo Frezzotti[9]

PRECIPITAZIONE

TREND

atmosphere MDPI

Article

Trends in Atmospheric Humidity and Temperature above Dome C, Antarctica Evaluated from Observations and Reanalyses

Philippe Ricaud, Paolo Grigioni, Romain Roehrig, Pierre Durand and Dana E. Veron

AEROSOL

molecules MDPI

Article

Seasonal Evolution of Size-Segregated Particulate Mercury in the Atmospheric Aerosol Over Terra Nova Bay, Antarctica

Silvia Illuminati, Anna Annibaldi, Sebastien Bau, Claudio Scarchilli, Virginia Ciardini, Paolo Grigioni, Federico Girolametti, Flavio Vagnoni, Giuseppe Scarponi and Cristina Truzzi

PRECIPITAZIONE

remote sensing MDPI

Article

Quantitative Precipitation Estimation over Antarctica Using Different *Ze-SR* Relationships Based on Snowfall Classification Combining Ground Observations

Alessandro Bracci, Luca Baldini, Nicoletta Roberto, Elisa Adirosi, Mario Montopoli, Claudio Scarchilli, Paolo Grigioni, Virginia Ciardini, Vincenzo Levizzani and Federico Porcù

NUBI E MICROFISICA

Atmos. Meas. Tech., 17, 5071–5089, 2024

Atmospheric Measurement Techniques EGU

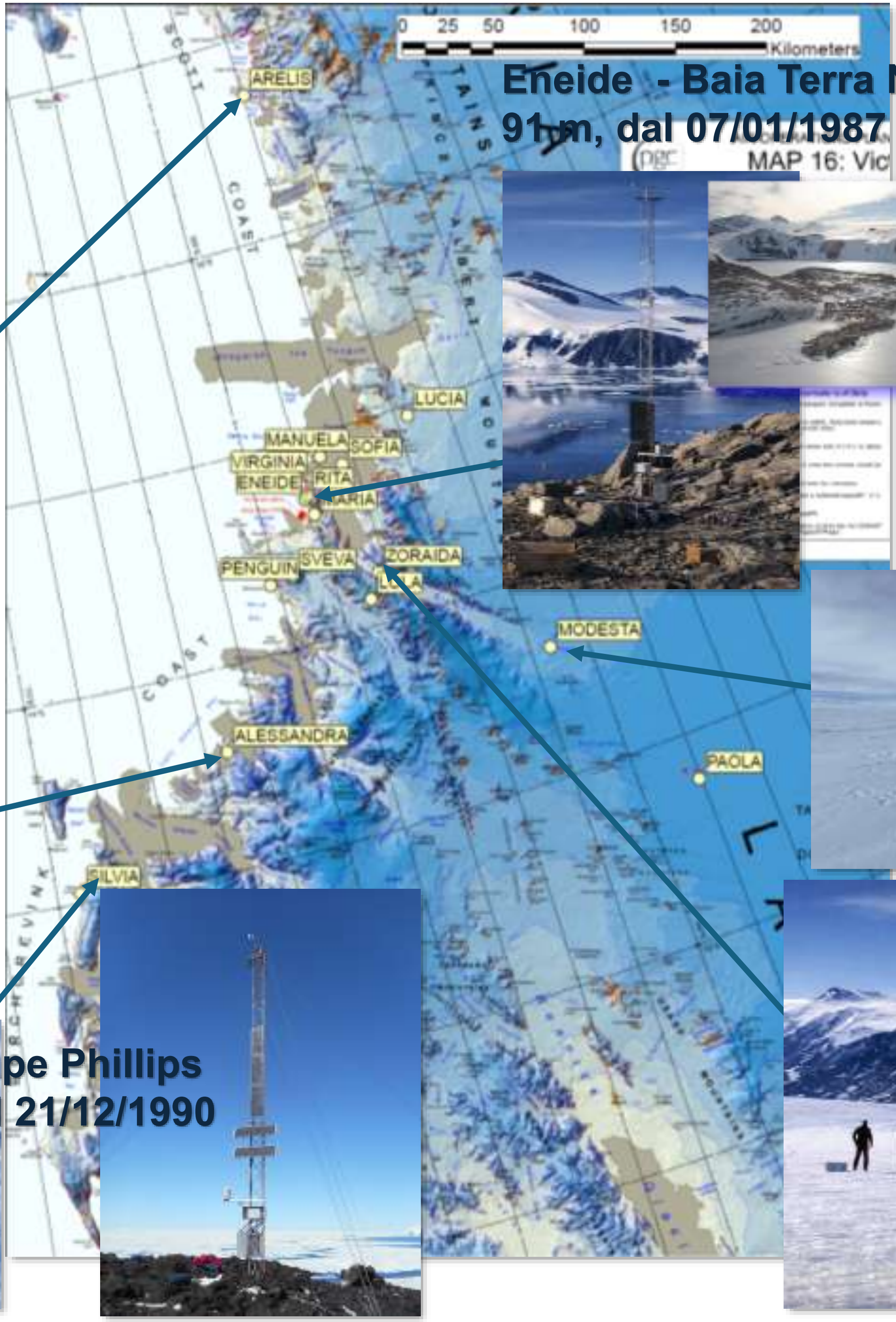
In situ observations of supercooled liquid water clouds over Dome C, Antarctica, by balloon-borne sondes

La rete di AWS di IAMCO

Arelis - Cape Ross
150 m - dal 02/01/1990


Alessandra - Cape King
160 m - dal 01/02/1987


Silvia - Cape Phillips
568 m, dal 21/12/1990



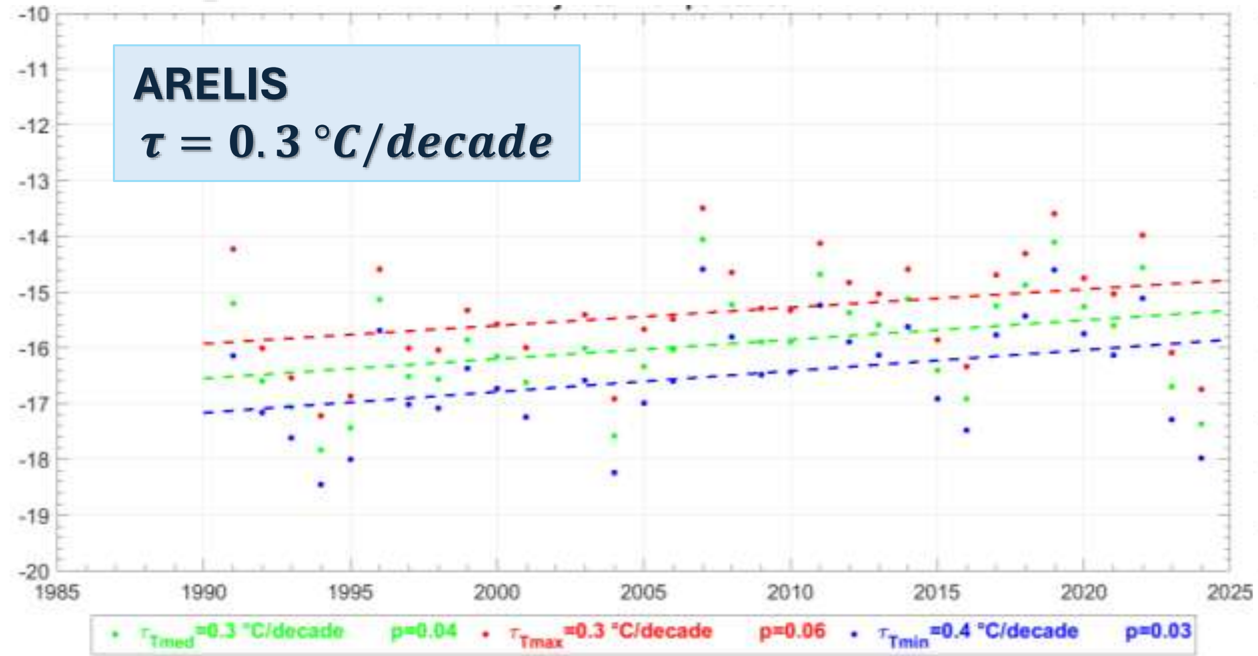
Eneide - Baia Terra Nova
91 m, dal 07/01/1987

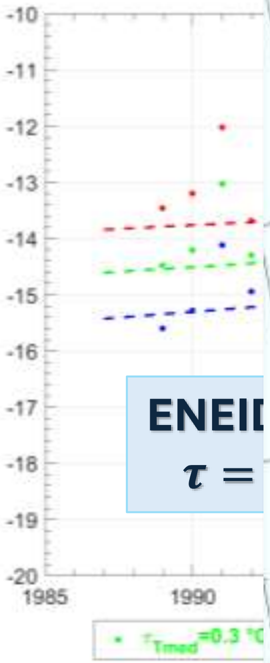
Concordia – Dome C
3230, dal 24/01/2005

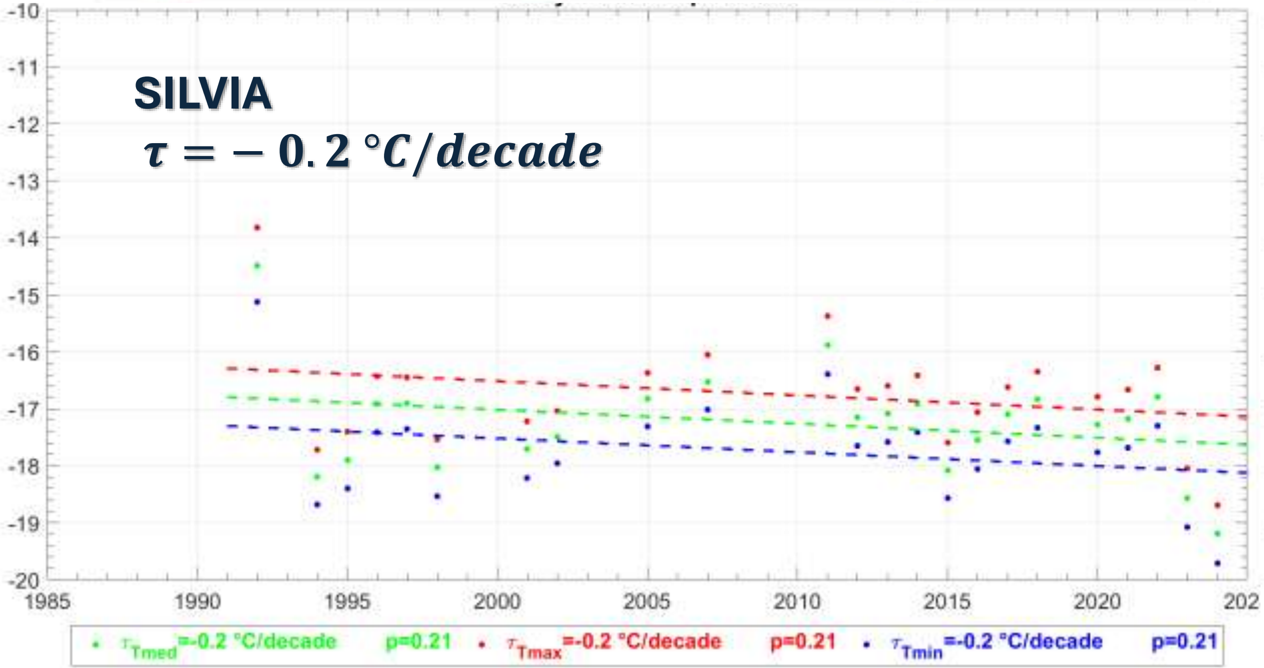

Modesta – Priestley Névé
1924 m, dal 01/02/1989

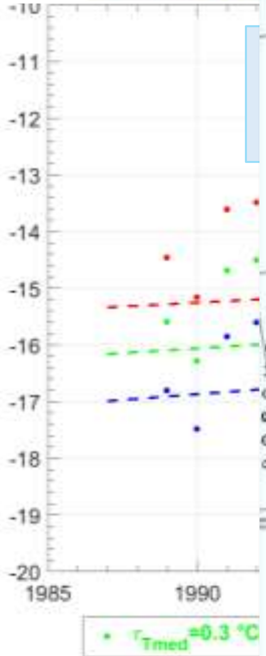
Zoraida – Priestley Glacier
880 m, dal 18/01/1987

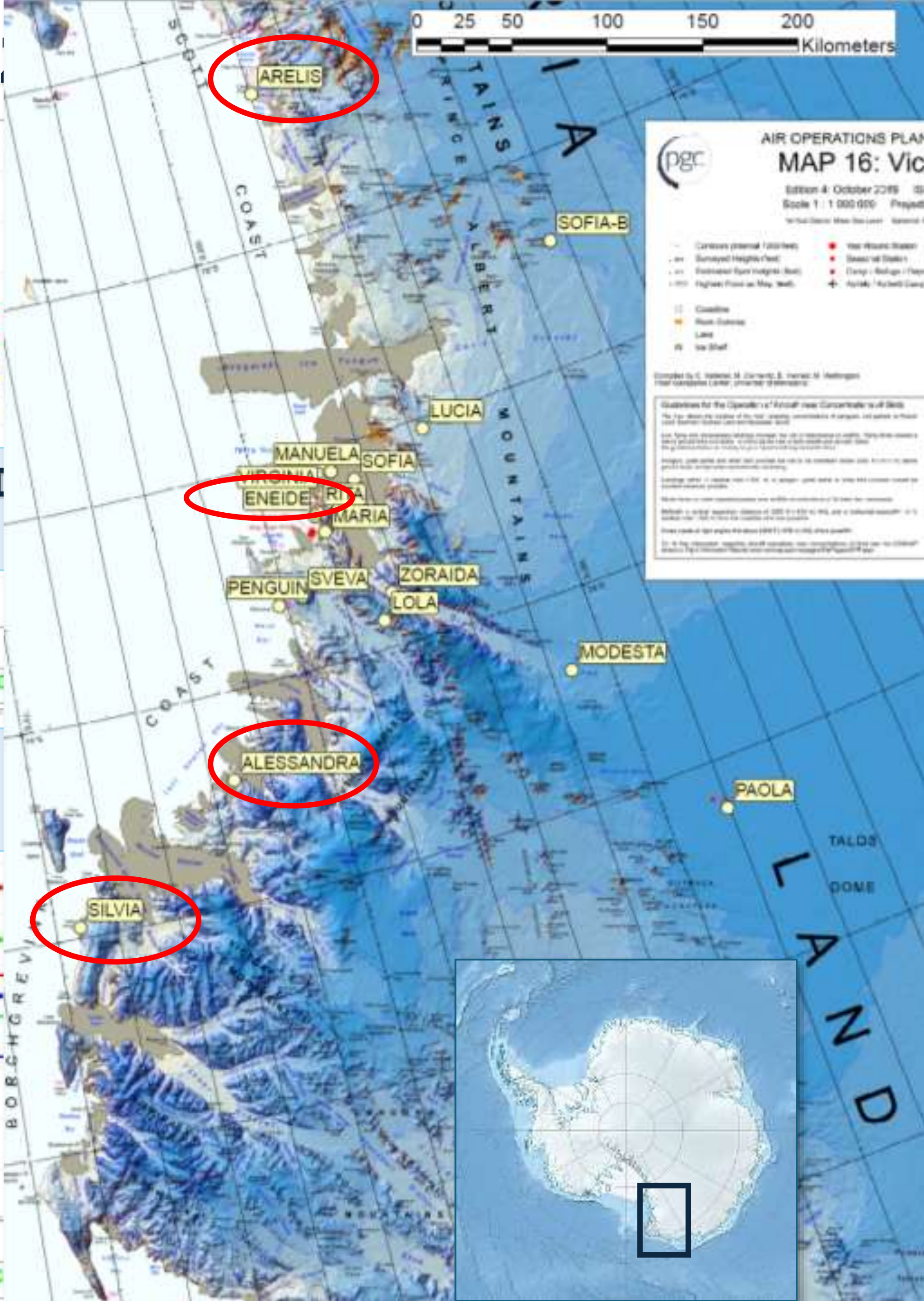

Temperatura media annuale – sta



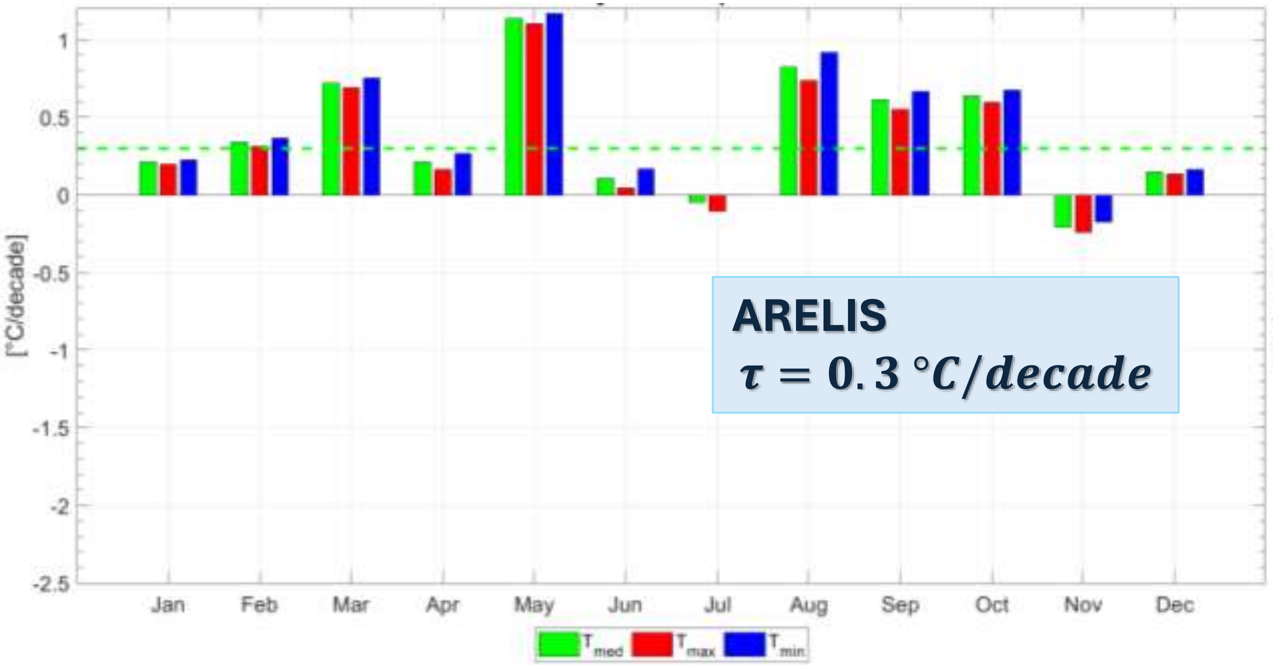




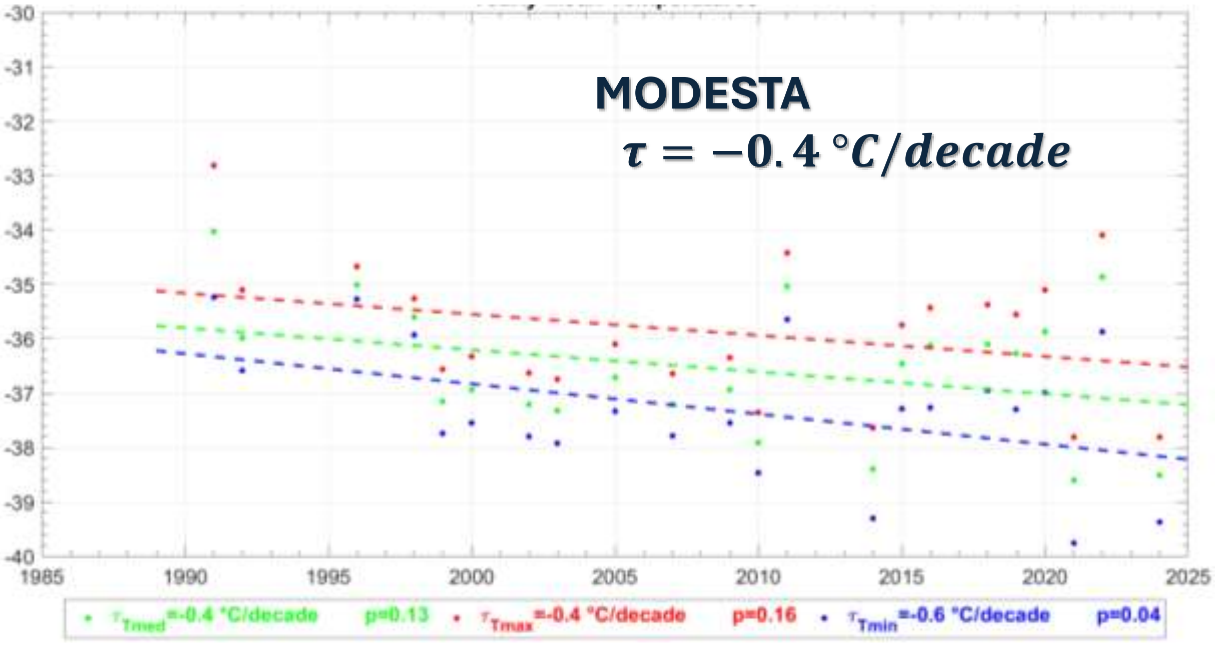


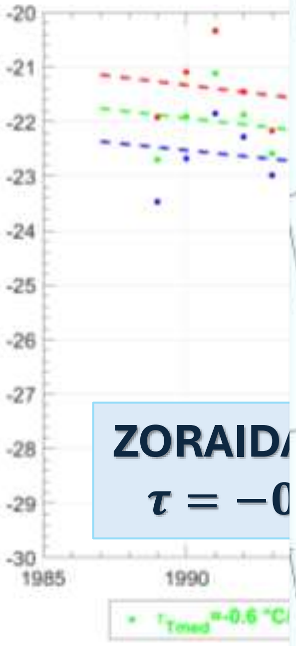


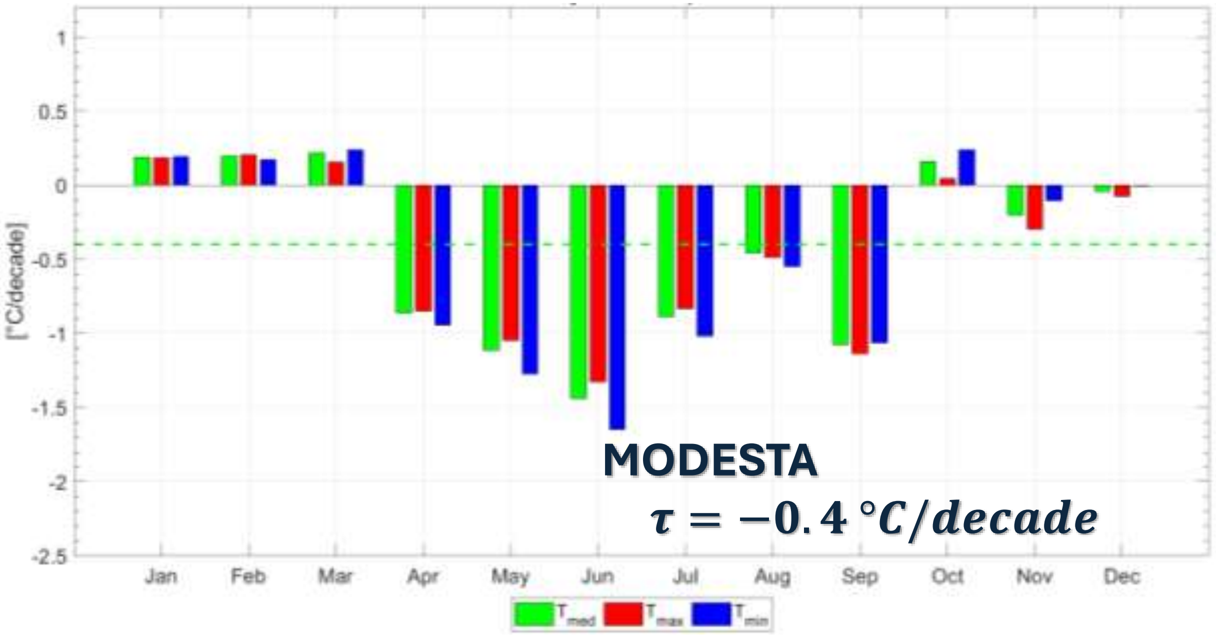
Trend medie mensili – stazioni costiere

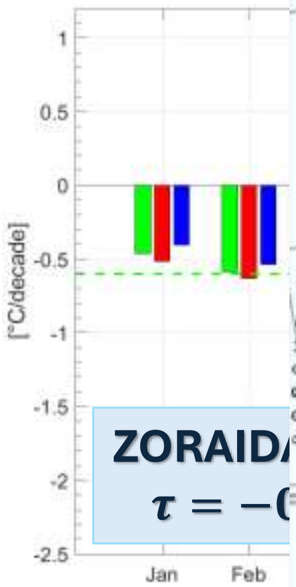


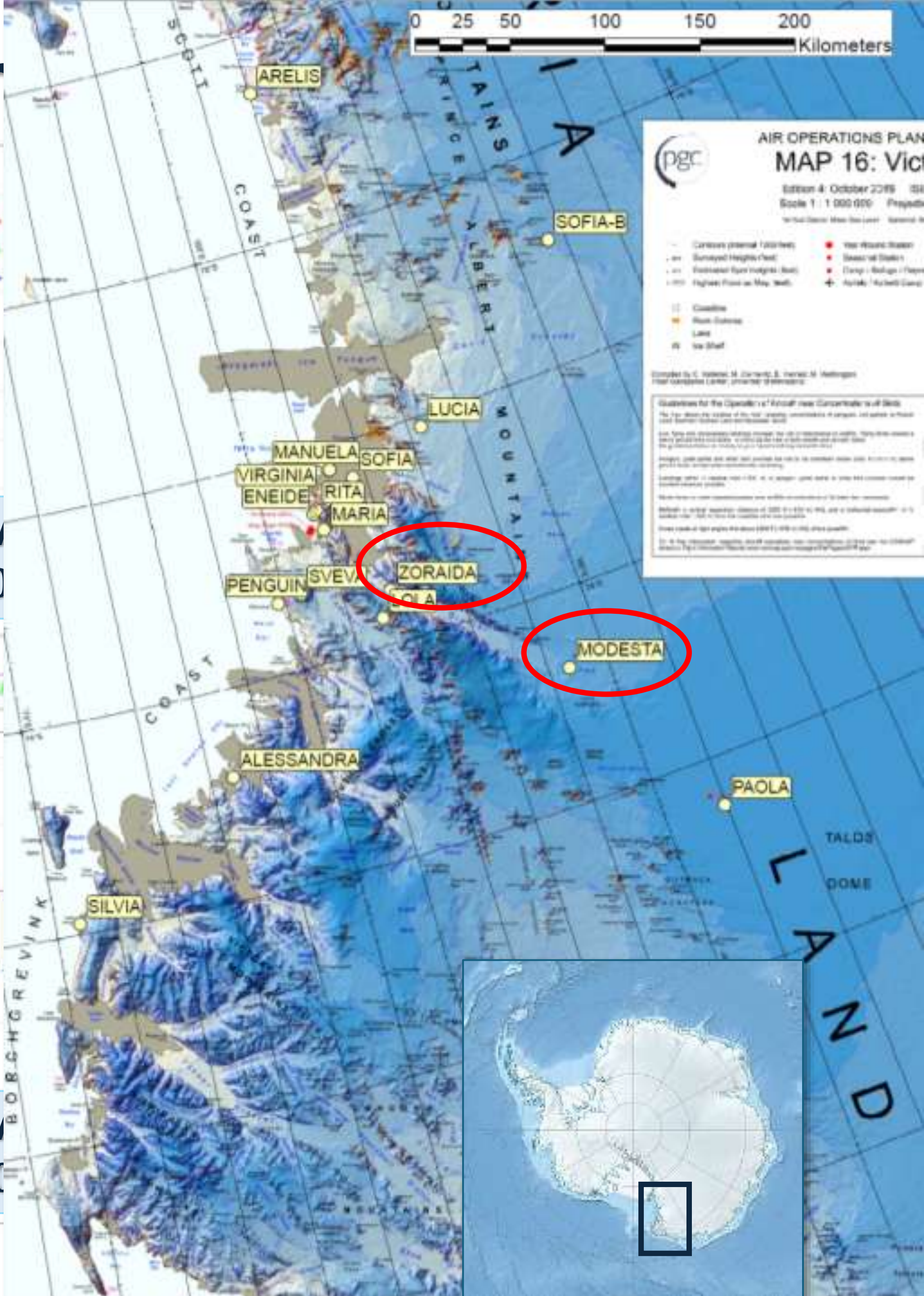
Trend medie mensili – stazioni in



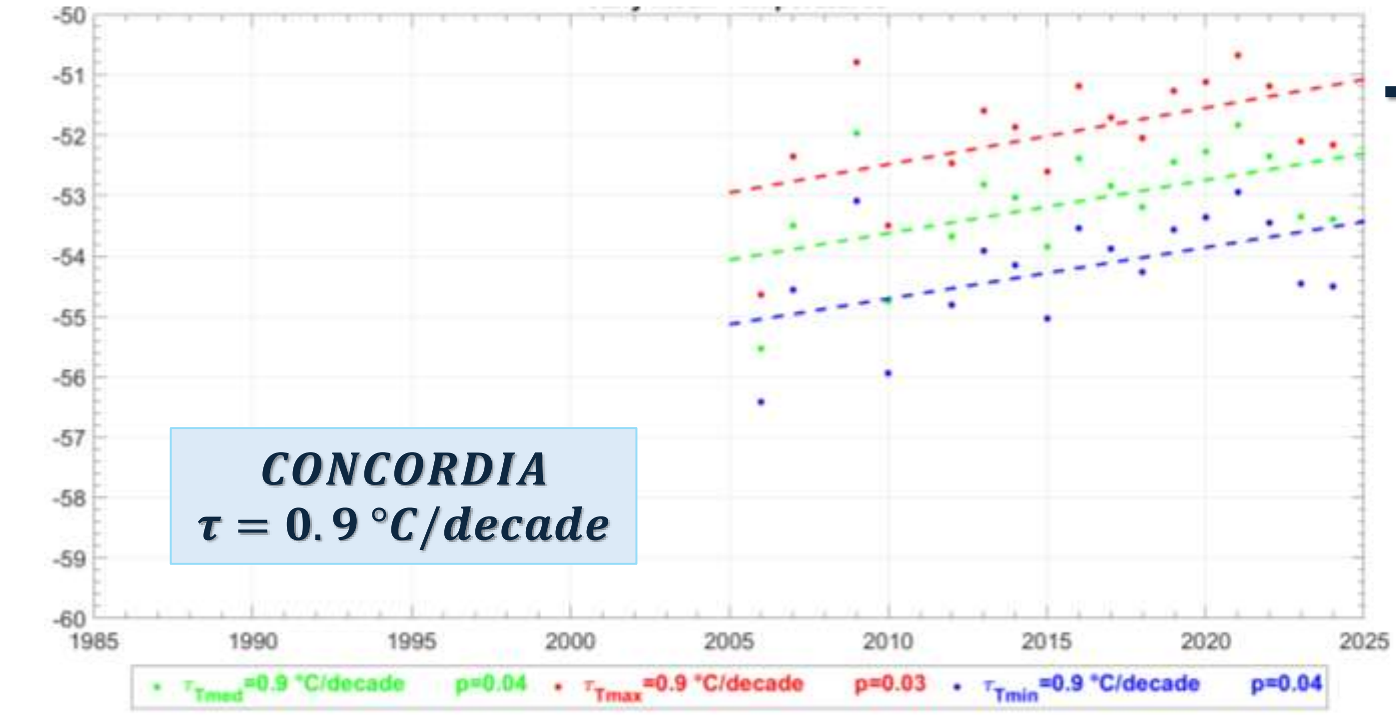


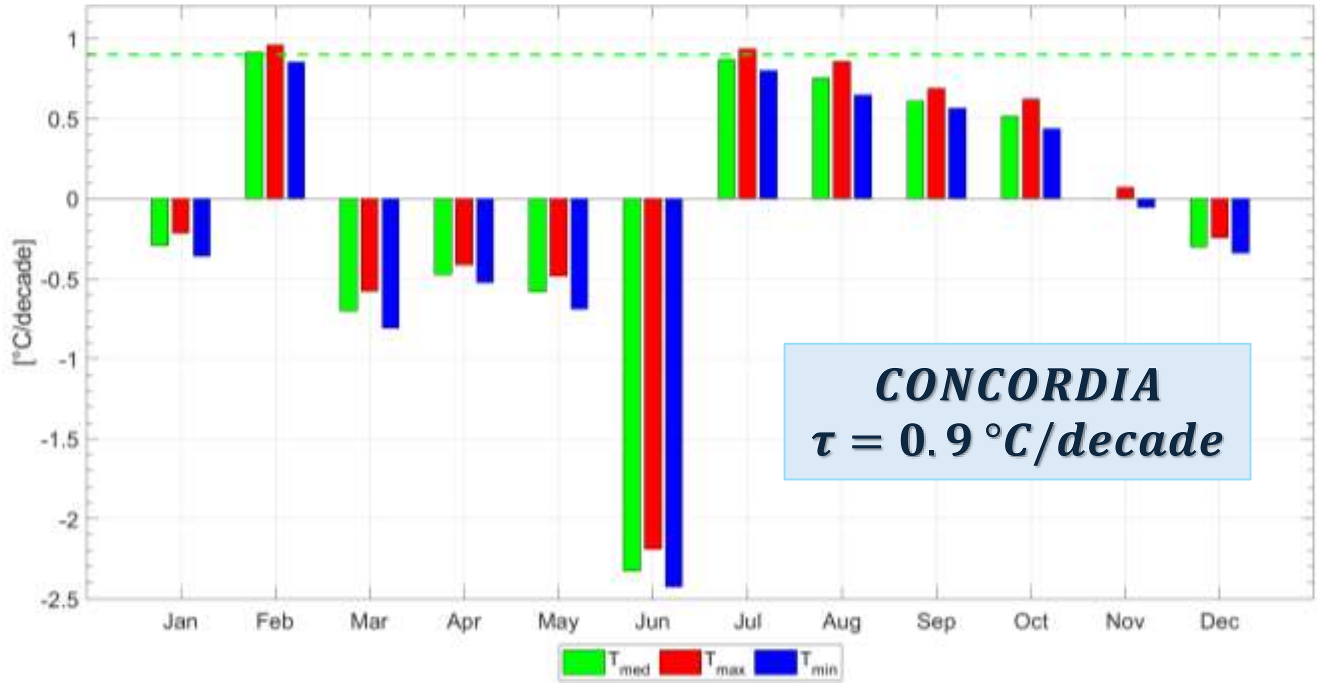






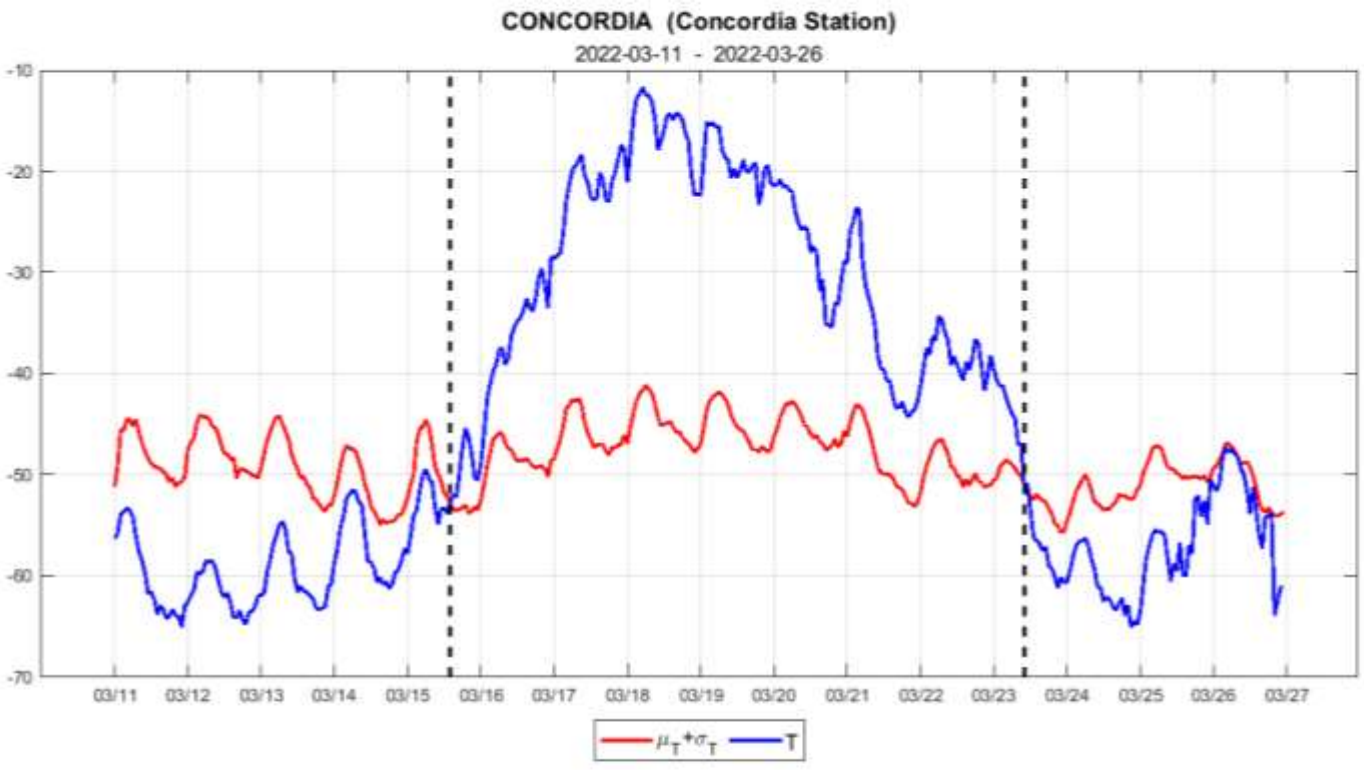
Trend – stazione di plateau





eventi estremi (ondate di calore)

- eventi di durata superiore a 3 giorni consecutivi con temperatura oraria superiore di almeno una deviazione standard (calcolata sull'intero periodo disponibile) rispetto alla temperatura media oraria;
- eventi osservati su Concordia il cui segnale è visibile anche sulle altre stazioni;
- sono presentati 2 eventi fra i più intensi:
  - *marzo 2022*
  - *luglio 2016*



La selezione degli eventi è stata ripetuta considerando come soglia il 90° percentile della T nel periodo di riferimento.

Geophysical Research Letters

RESEARCH LETTER
10.1029/2023GL104910

The Largest Ever Recorded Heatwave—Characteristics and Attribution of the Antarctic Heatwave of March 2022

Edward Blanchard-Wrigglesworth[1], Tyler Cox[1], Zachary I. Espinosa[1], and Aaron Donohoe[1,2]

[1]Department of Atmospheric Sciences, University of Washington, Seattle, WA, USA, [2]Applied Physics Lab, University of Washington, Seattle, WA, USA

Key Points:

- The March 2022 Antarctic heatwave registered the warmest temperature anomaly on record, and resulted from extreme atmospheric heat fluxes
- A widely used climate model cannot simulate equivalent events in a large ensemble, a bias that is improved after nudging its winds to observations
- The thermodynamic amplification of the heatwave by climate change was 2°C, and equivalent heatwaves may warm a further 5–6°C by 2100

Supporting Information:

Supporting Information may be found in the online version of this article.

Abstract An unprecedented heatwave impacted East Antarctica in March 2022, peaking at 39°C above climatology, the largest temperature anomaly ever recorded globally. We investigate the causes of the heatwave, the impact of climate change, and a climate model's ability in simulating such an event. The heatwave, which was skillfully forecast, resulted from a highly anomalous large-scale circulation pattern that advected an Australian airmass to East Antarctica in 4 days and produced record atmospheric heat fluxes. Southern Ocean sea surface temperatures anomalies had a minimal impact on the heatwave's amplitude. Simulations from a climate model fail to simulate such a large temperature anomaly mostly due to biases in its large-scale circulation variability, showcasing a pathway for future model improvement in simulating extreme heatwaves. The heatwave was made 2°C warmer by climate change, and end of 21st century heatwaves may be an additional 5–6°C warmer, raising the prospect of near-melting temperatures over the interior of East Antarctica.

Volume 37 JOURNAL OF CLIMATE 1 February 2024

The Extraordinary March 2022 East Antarctica "Heat" Wave. Part I: Observations and Meteorological Drivers

Jonathan D. Wille,[a,b] Simon P. Alexander,[c,d] Charles Amory,[a] Rebecca Baiman,[e] Léonard Barthélemy,[f] Dana M. Bergstrom,[c,g,h] Alexis Berne,[i] Hanin Binder,[b] Juliette Blanchet,[a] Deniz Bozkurt,[j,k] Thomas J. Bracegirdle,[l] Mathieu Casado,[m] Taejin Choi,[n] Kyle R. Clem,[o] Francis Codron,[f] Rajashree Datta,[e] Stefano Di Battista,[p] Vincent Favier,[a] Diana Francis,[q] Alexander D. Fraser,[d] Elise Fourré,[m] René D. Garreaud,[k,r] Christophe Genthon,[s] Irina V. Gorodetskaya,[t] Sergi González-Herrero,[u,v] Victoria J. Heinrich,[w] Guillaume Hubert,[x] Hanna Joos,[b] Seong-Joong Kim,[n] John C. King,[l] Christoph Kittel,[a] Amaelle Landais,[m] Matthew Lazzara,[y,z] Gregory H. Leonard,[aa] Jan L. Lieser,[bb] Michelle Maclennan,[e] David Mikolajczyk,[y] Peter Neff,[cc] Inès Ollivier,[dd,m] Ghislain Picard,[a] Benjamin Pohl,[ee] F. Martin Ralph,[ff] Penny Rowe,[gg] Elisabeth Schlosser,[hh] Christine A. Shields,[ii] Inga J. Smith,[jj] Michael Sprenger,[b] Luke Trusel,[kk] Danielle Udy,[d,hh,ll] Tessa Vance,[d] Étienne Vignon,[s] Catherine Walker,[mm] Nander Wever,[e,nn] and Xun Zou[ff]

[a] Institut des Géosciences de l'Environnement, CNRS/UGA, Saint Martin d'Hères, France
[b] Institute for Atmospheric and Climate Science, ETH Zurich, Zurich, Switzerland
[c] Australian Antarctic Division, Kingston, Tasmania, Australia

(Manuscript received 27 March 2023, in final form 25 October 2023, accepted 30 October 2023)

ABSTRACT: Between 15 and 19 March 2022, East Antarctica experienced an exceptional heat wave with widespread 30°–40°C temperature anomalies across the ice sheet. This record-shattering event saw numerous monthly temperature records being broken including a new all-time temperature record of −9.4°C on 18 March at Concordia Station despite March typically being a transition month to the Antarctic coreless winter. The driver for these temperature extremes was ... deep into the Antarctic interior. The ... the heat wave's meteorological driv... rature records along with the intricate ... ast Antarctica. These efforts describe ... ean. This led to an atmospheric river ... eric blocking deep into East Antarc... pical surface temperature inversions ... Antarctica exceeded previous March ... 100 years, a closer recurrence of such ... us impacts this extreme event had on ...

... ver caused some of the highest tem... rctic science community. Using our ... t within a historical climate context. ... bations in the midlatitudes and sub... pite the rare chance of occurrence ... possible, especially given anthropo...

... stations; Climate records

The Extraordinary March 2022 East Antarctica "Heat" Wave. Part II: Impacts on the Antarctic Ice Sheet

Jonathan D. Wille,[a,b] Simon P. Alexander,[c,d] Charles Amory,[a] Rebecca Baiman,[e] Léonard Barthélemy,[f] Dana M. Bergstrom,[c,g,h] Alexis Berne,[i] Hanin Binder,[b] Juliette Blanchet,[a] Deniz Bozkurt,[j,k] Thomas J. Bracegirdle,[l] Mathieu Casado,[m] Taejin Choi,[n] Kyle R. Clem,[o] Francis Codron,[f] Rajashree Datta,[e] Stefano Di Battista,[p] Vincent Favier,[a] Diana Francis,[q] Alexander D. Fraser,[d] Elise Fourré,[m] René D. Garreaud,[k,r] Christophe Genthon,[s] Irina V. Gorodetskaya,[t] Sergi González-Herrero,[u,v] Victoria J. Heinrich,[w] Guillaume Hubert,[x] Hanna Joos,[b] Seong-Joong Kim,[n] John C. King,[l] Christoph Kittel,[a] Amaelle Landais,[m] Matthew Lazzara,[y,z] Gregory H. Leonard,[aa] Jan L. Lieser,[bb] Michelle Maclennan,[e] David Mikolajczyk,[y] Peter Neff,[cc] Inès Ollivier,[dd,m] Ghislain Picard,[a] Benjamin Pohl,[ee] F. Martin Ralph,[ff] Penny Rowe,[gg] Elisabeth Schlosser,[hh] Christine A. Shields,[ii] Inga J. Smith,[jj] Michael Sprenger,[b] Luke Trusel,[kk] Danielle Udy,[d,hh,ll] Tessa Vance,[d] Étienne Vignon,[s] Catherine Walker,[mm] Nander Wever,[e,nn] and Xun Zou[ff]

[a] Institut des Géosciences de l'Environnement, CNRS/UGA, Saint Martin d'Hères, France
[b] Institute for Atmospheric and Climate Science, ETH Zurich, Zurich, Switzerland

ABSTRACT: Between 15 and 19 March 2022, East Antarctica experienced an exceptional heat wave with widespread 30°–40°C temperature anomalies across the ice sheet. In Part I, we assessed the meteorological drivers that generated an intense atmospheric river (AR) that caused these record-shattering temperature anomalies. Here, we continue our large collaborative study by analyzing the widespread and diverse impacts driven by the AR landfall. These impacts included widespread rain and surface melt that was recorded along coastal areas, but this was outweighed by widespread high snowfall accumulations resulting in a largely positive surface mass balance contribution to the East Antarctic region. An analysis of the surface energy budget indicated that widespread downward longwave radiation anomalies caused by large cloud-liquid water contents along with some scattered solar radiation produced intense surface warming. Isotope measurements of the moisture were highly elevated, likely imprinting a strong signal for past climate reconstructions. The AR event attenuated cosmic ray measurements at Concordia, something previously never observed. Last, an extratropical cyclone west of the AR landfall likely triggered the final collapse of the critically unstable Conger Ice Shelf while further reducing an already record low sea ice extent.

SIGNIFICANCE STATEMENT: Using our diverse collective expertise, we explored the impacts from the March 2022 heat wave and atmospheric river across East Antarctica. One key takeaway is that the Antarctic cryosphere is highly sensitive to meteorological extremes originating from the midlatitudes and subtropics. Despite the large positive temperature anomalies driven from strong downward longwave radiation, this event led to huge amounts of snowfall across the Antarctic interior desert. The isotopes in this snow of warm airmass origin will likely be detectable in future ice cores and potentially distort past climate reconstructions. Even measurements of space activity were affected. Also, the swells generated from this storm helped to trigger the final collapse of an already critically unstable Conger Ice Shelf while further degrading sea ice coverage.

KEYWORDS: Antarctica; Ice shelves; Snow; Energy budget/balance; Paleoclimate

EGU General Assembly 2025

EGU25-19112, updated on 10 Apr 2025
https://doi.org/10.5194/egusphere-egu25-19112
EGU General Assembly 2025

March 2022 warm event detected in precipitation and surface snow at Concordia Station in East Antarctica

Giuliano Dreossi[1], Mauro Masiol[1], Daniele Zannoni[1], Claudio Stefanini[1], Claudio Scarchilli[2], Virginia Ciardini[2], Paolo Grigioni[2], Massimo Del Guasta[3], Amaëlle Landais[4], Mathieu Casado[4], Inès Ollivier[4,5], Stefan Terzer-Wassmuth[6], Lorenzo Copia[6], and Barbara Stenni[1]

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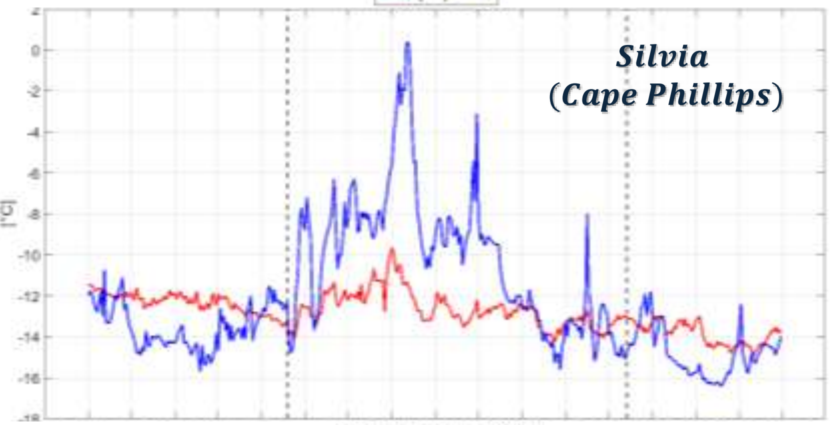
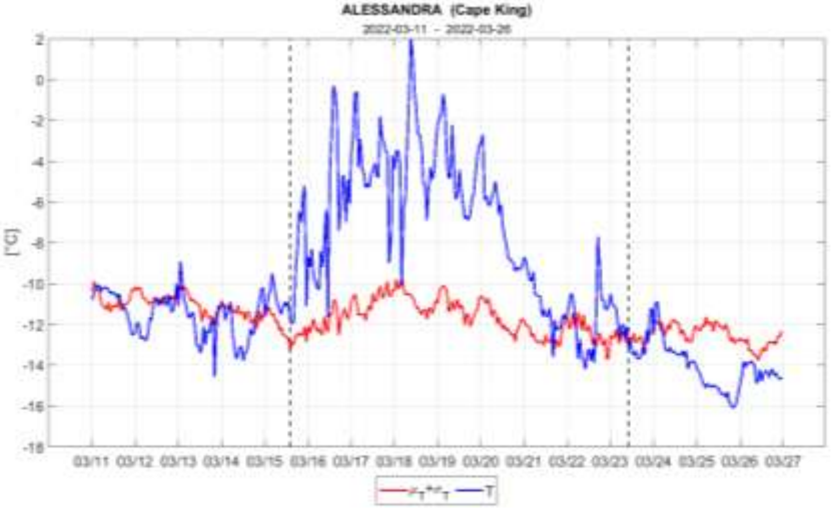
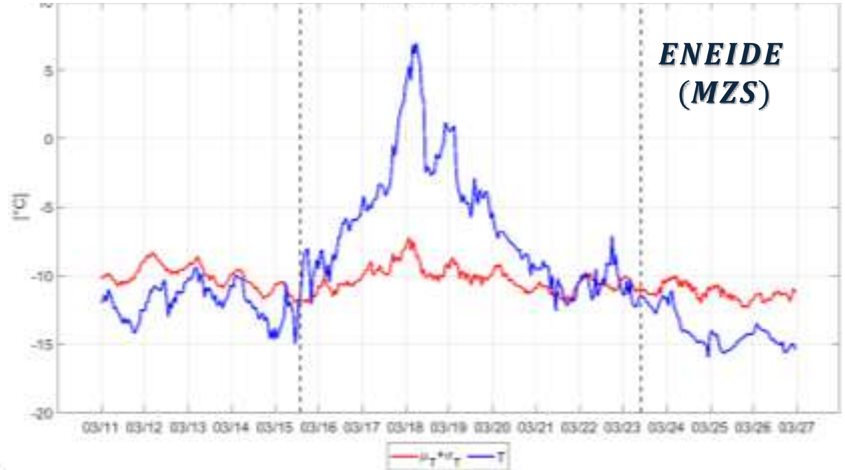
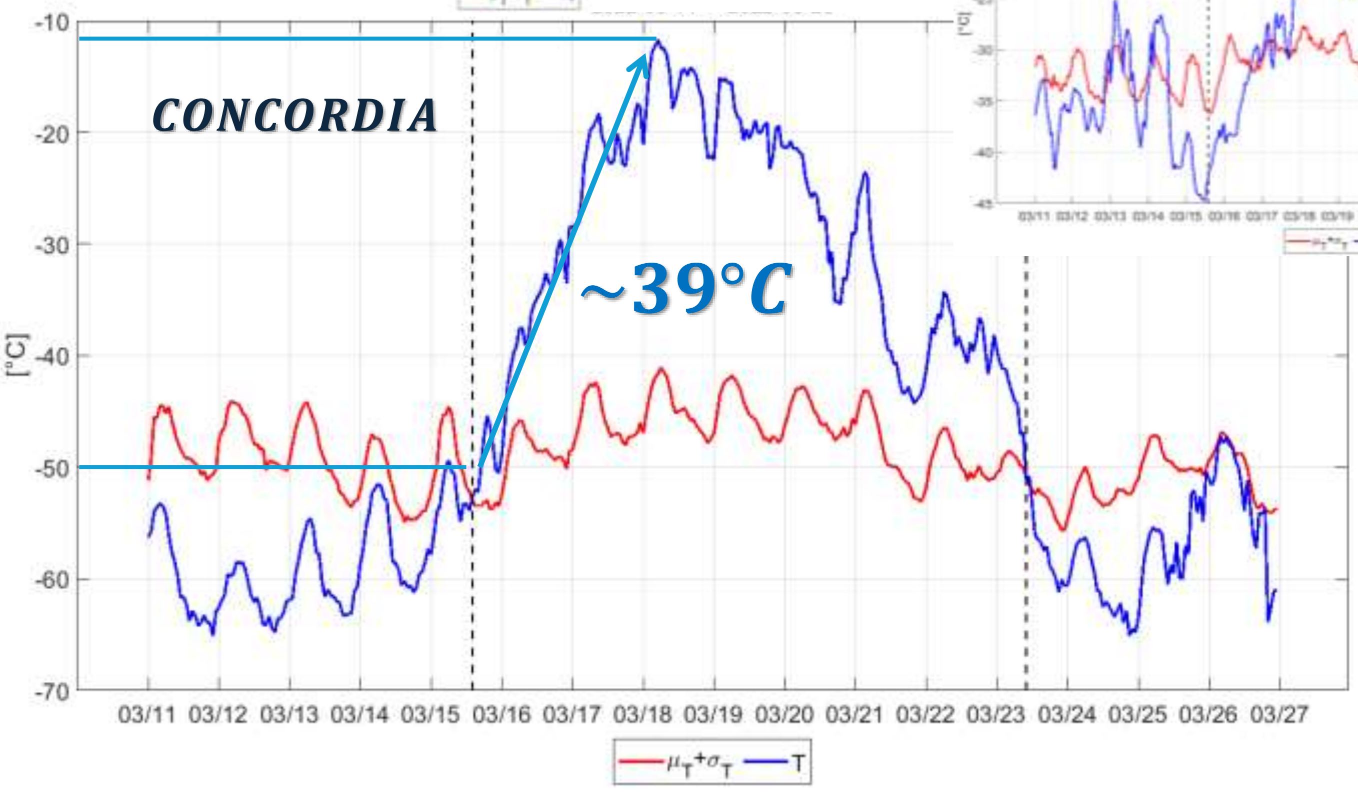
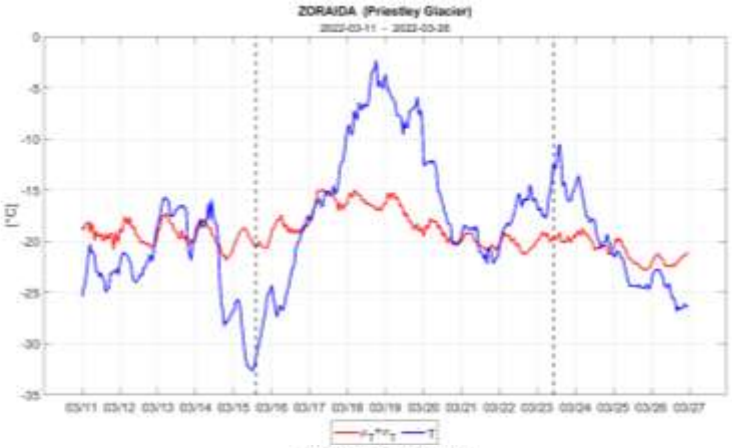
Serie temporali temperatura atmosferica da AWS - evento 2022

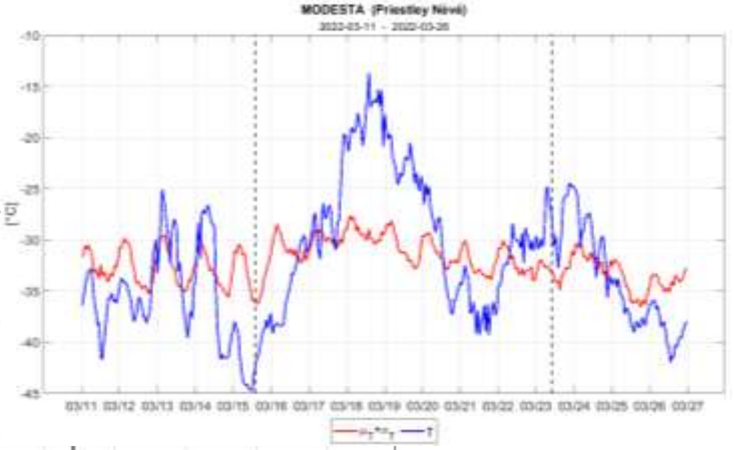




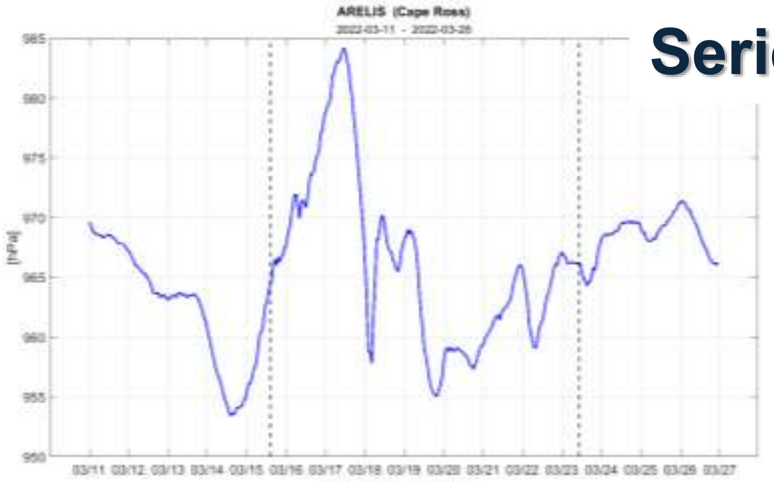


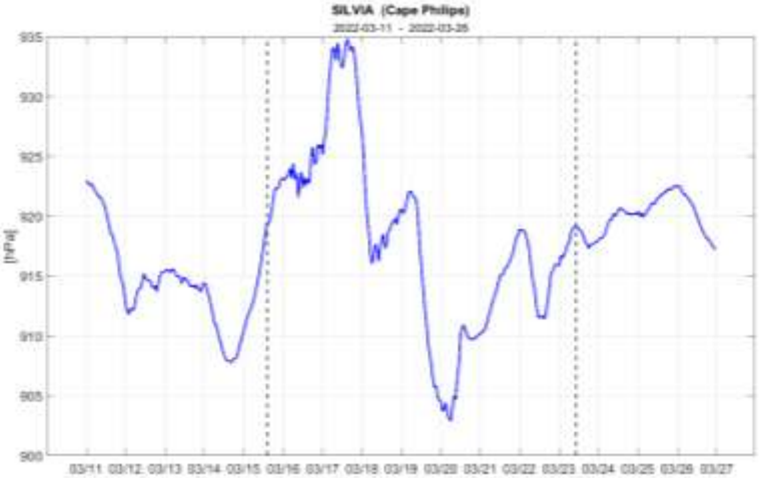


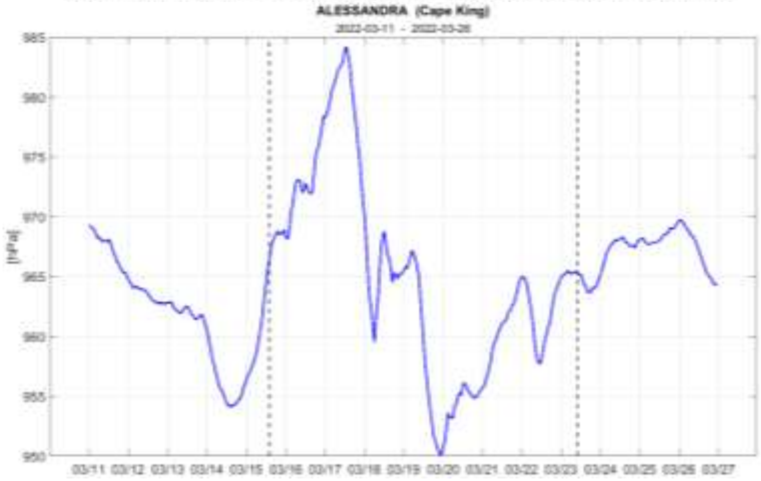


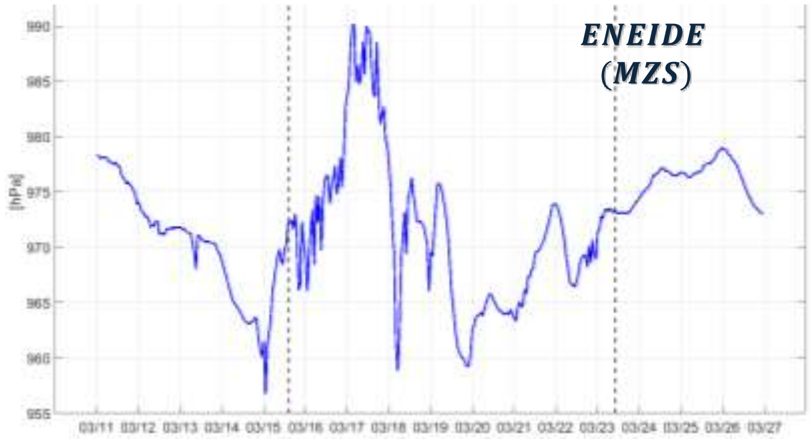


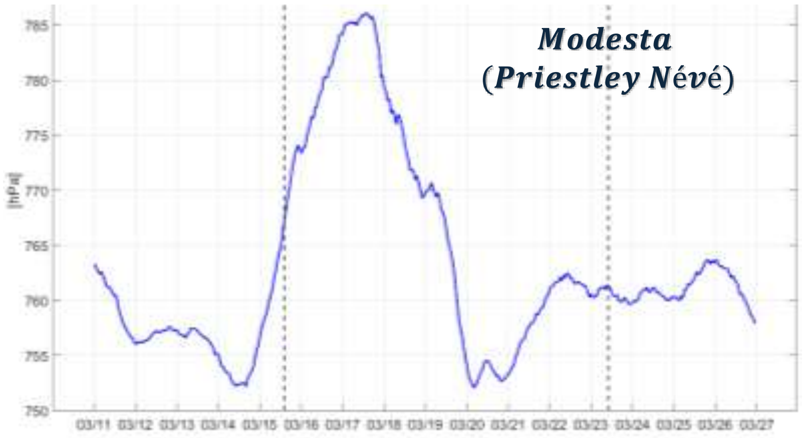
Serie temporali pressione atmosferica da AWS – evento 2022

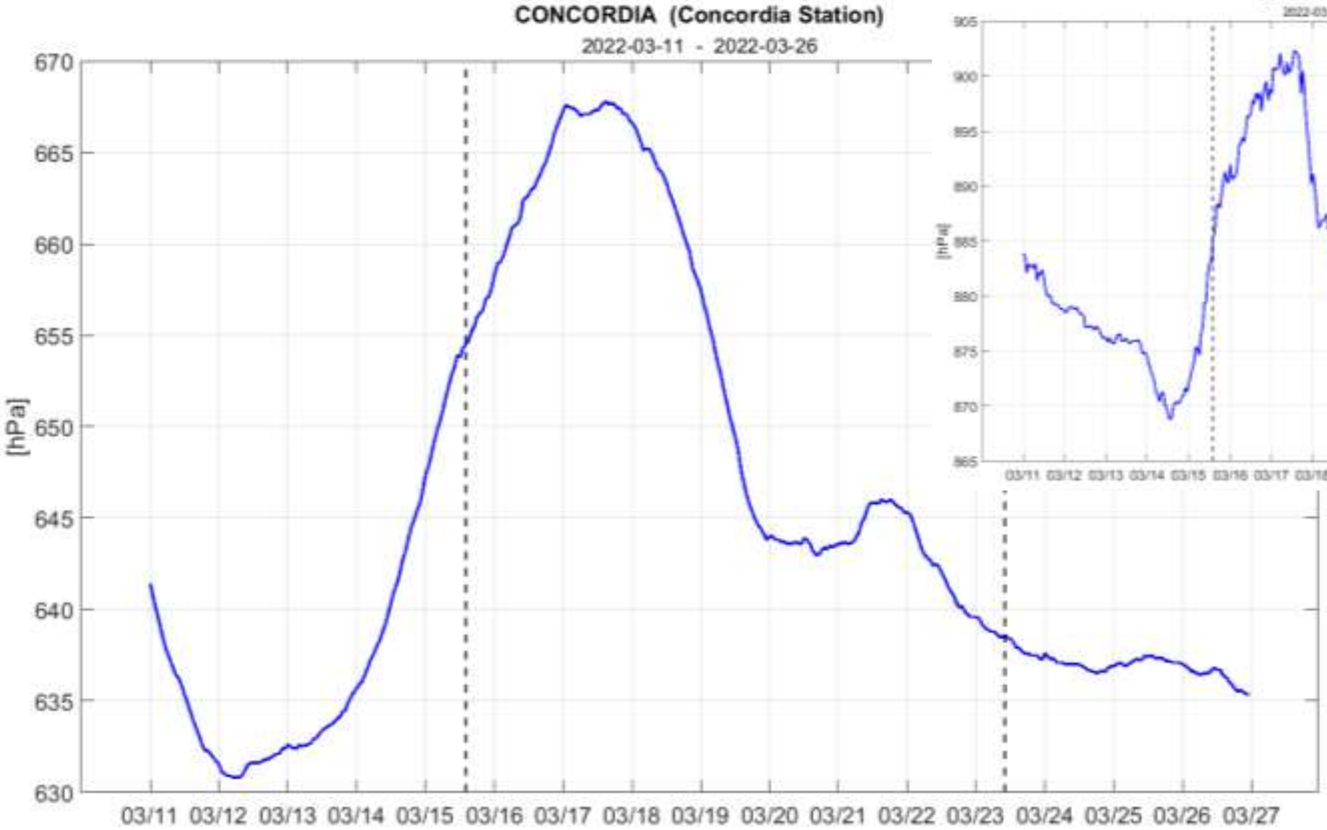






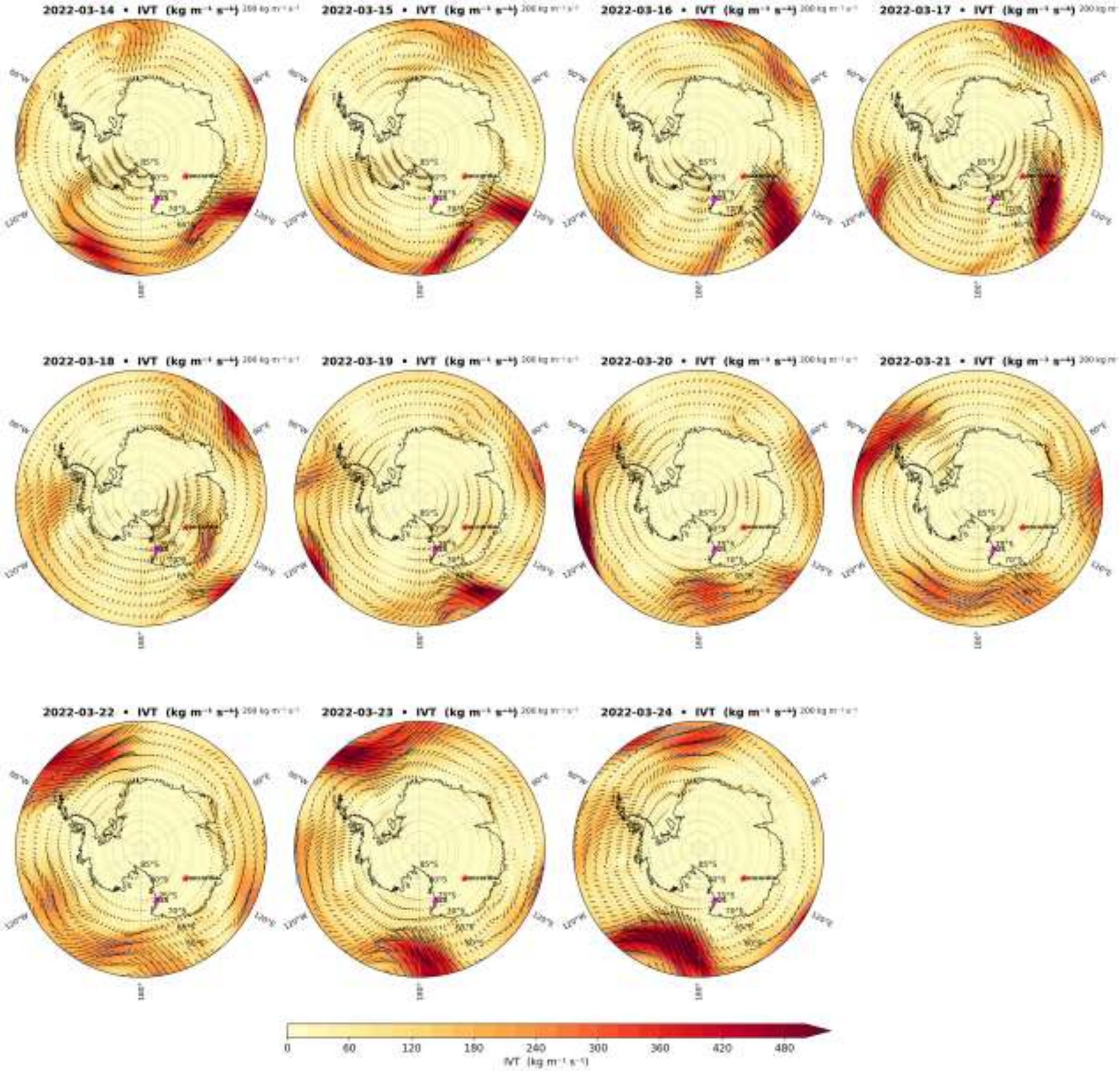


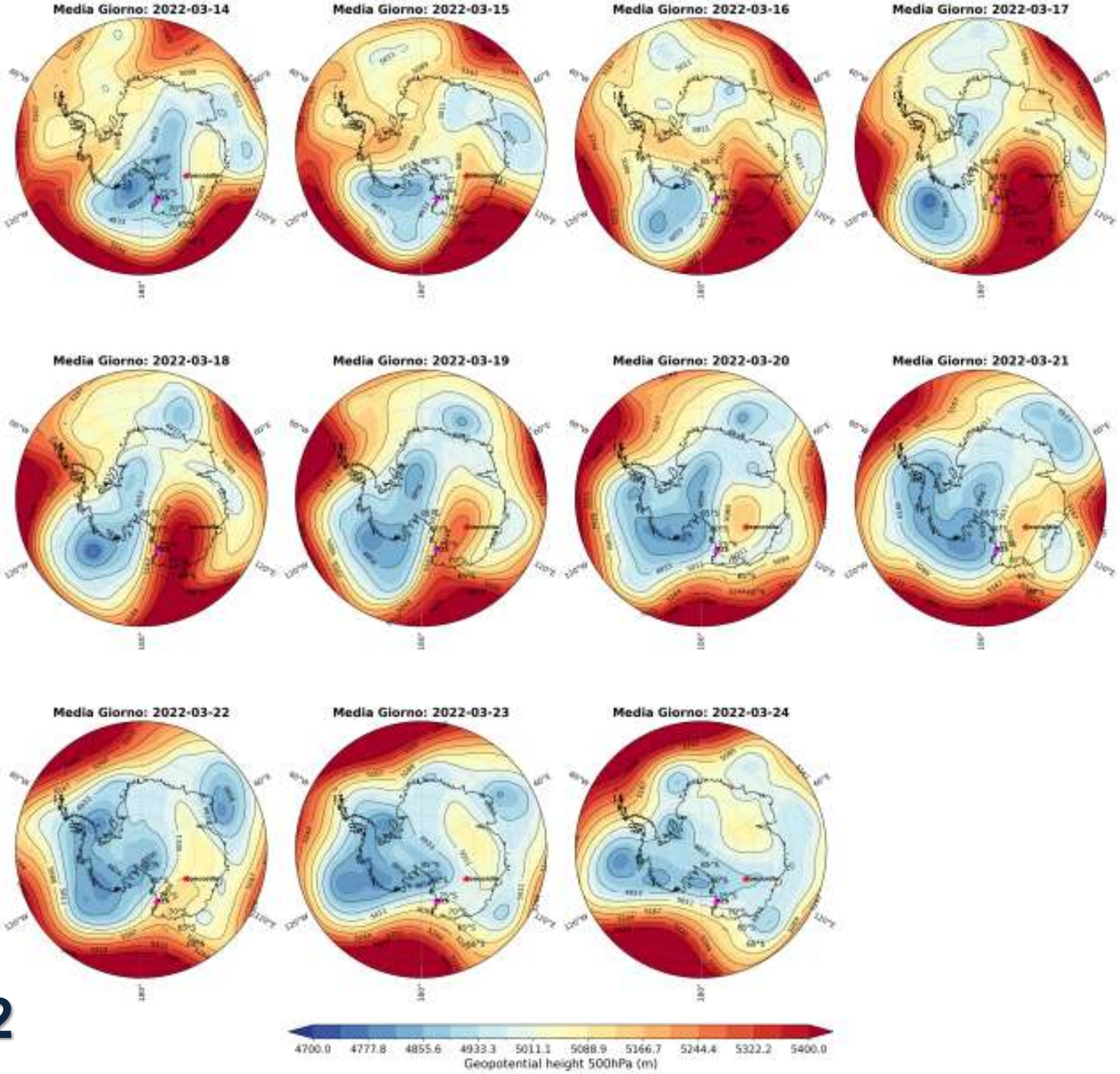




Reanalisi ERA 5 - ECMWF

altezza geopontenziale 500 hPa

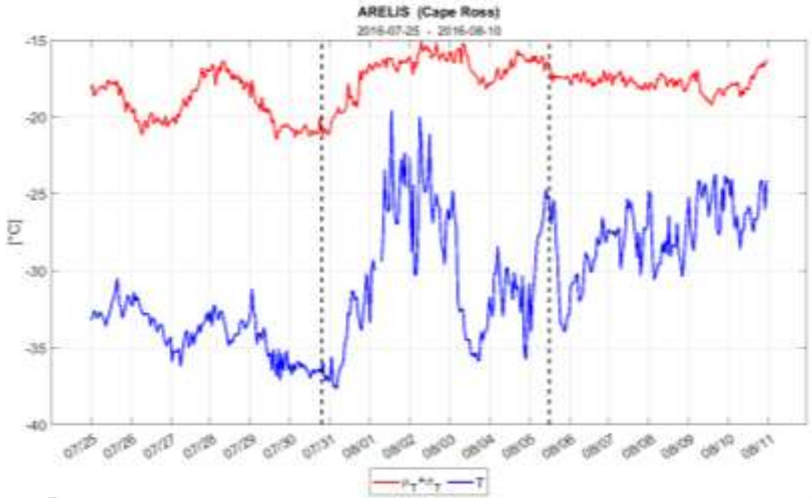


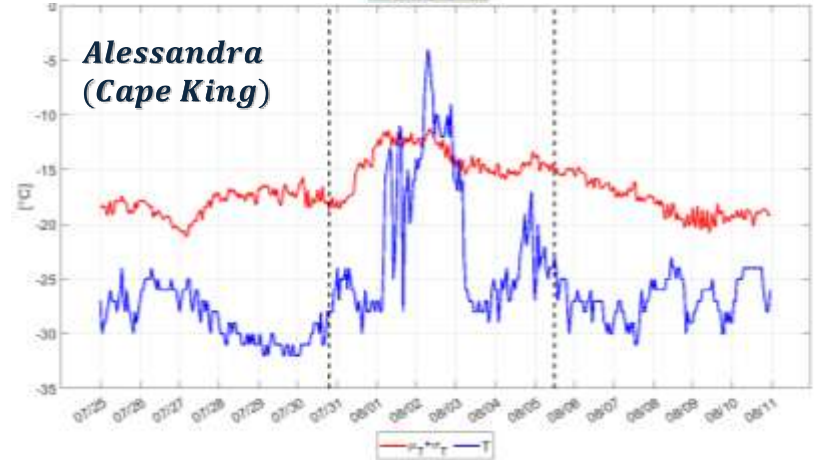


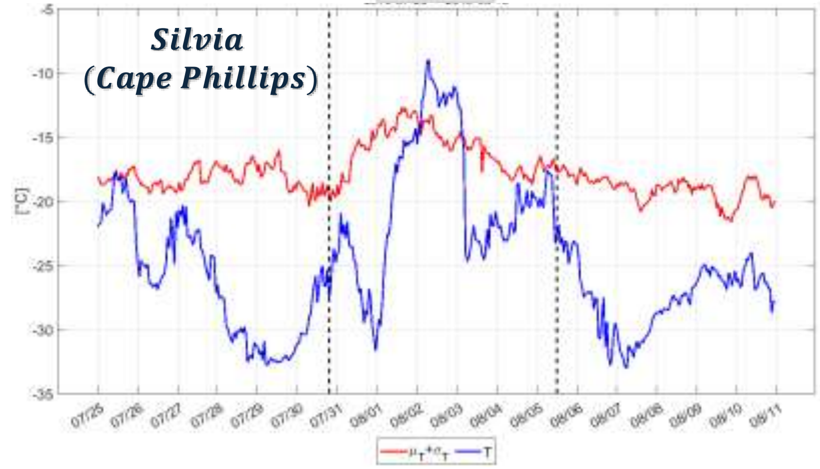
integrated water vapor transport (IVT)

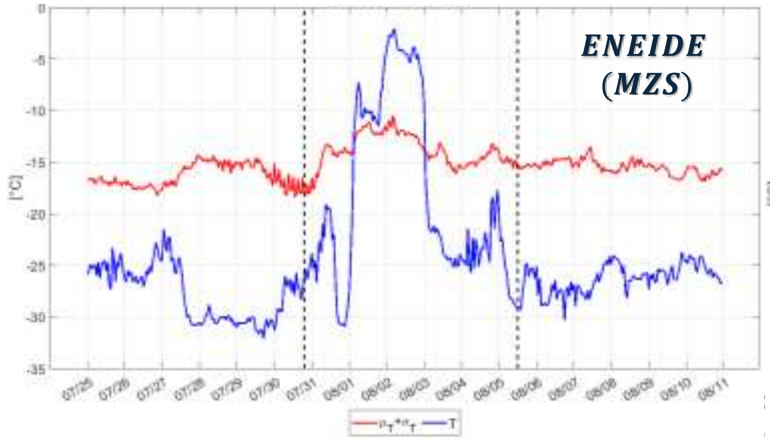
marzo 2022

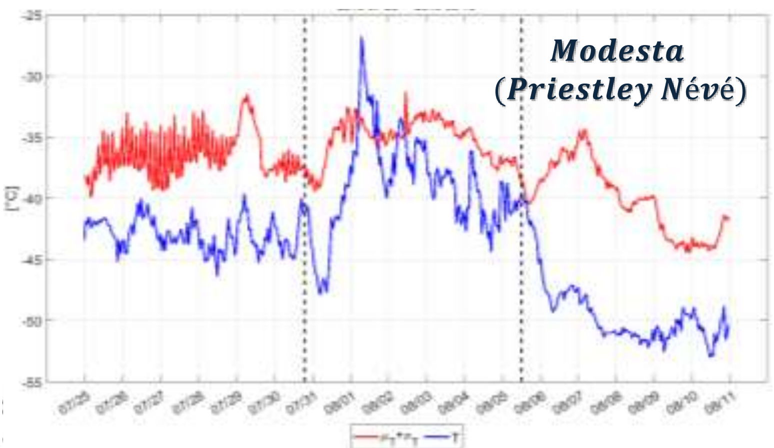
Serie temporali temperatura atmosferica da AWS - evento 2016

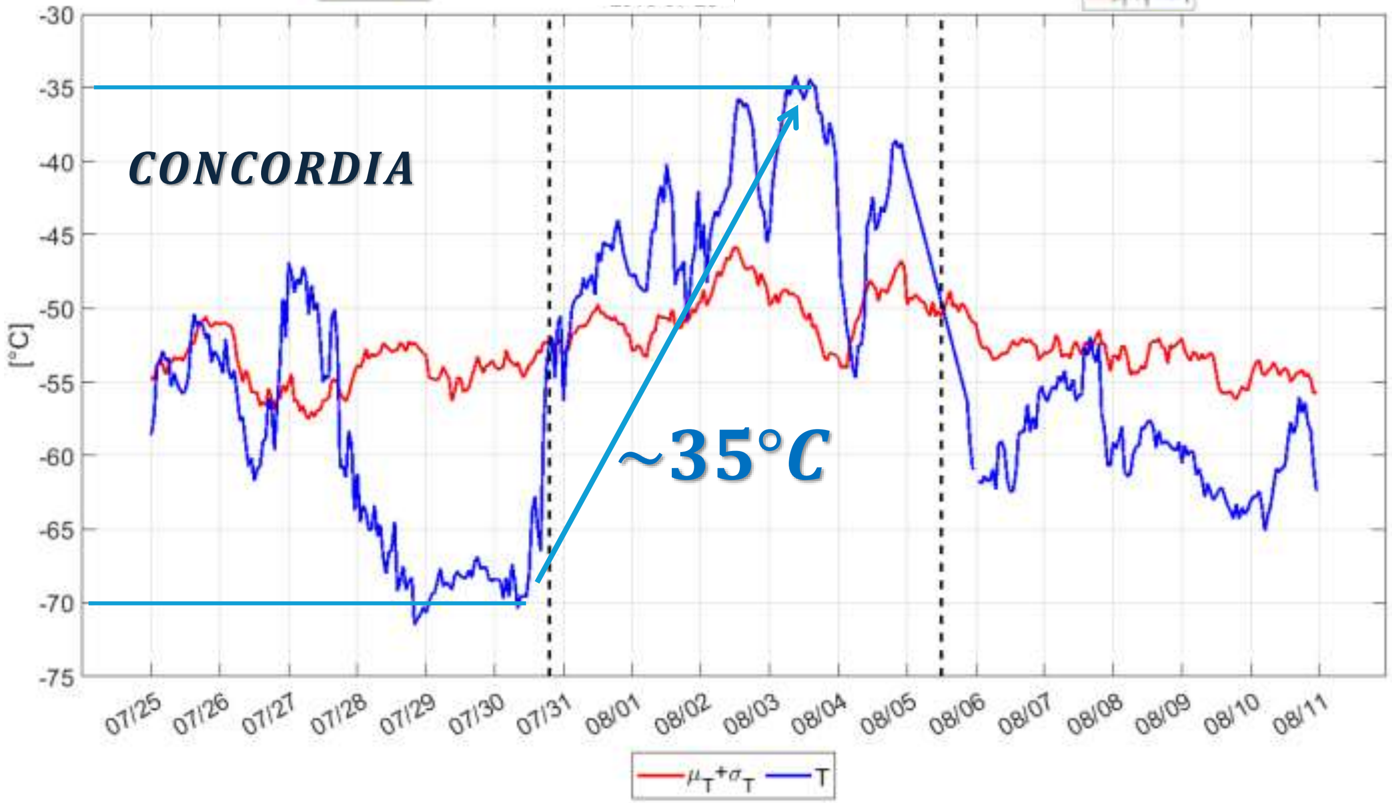




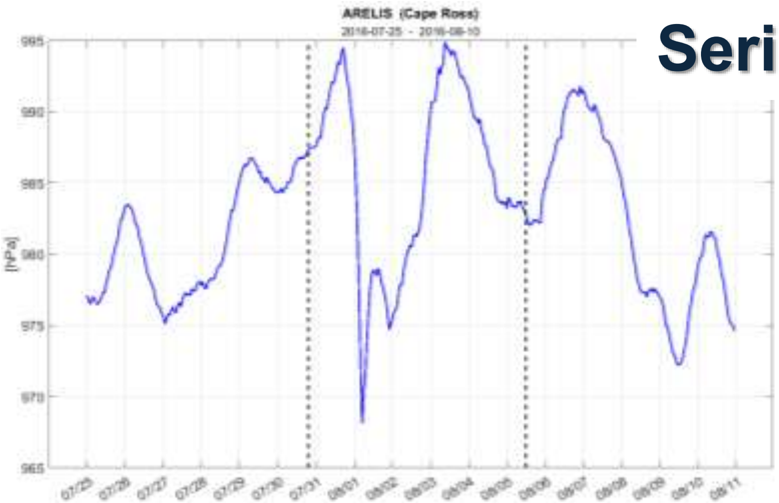


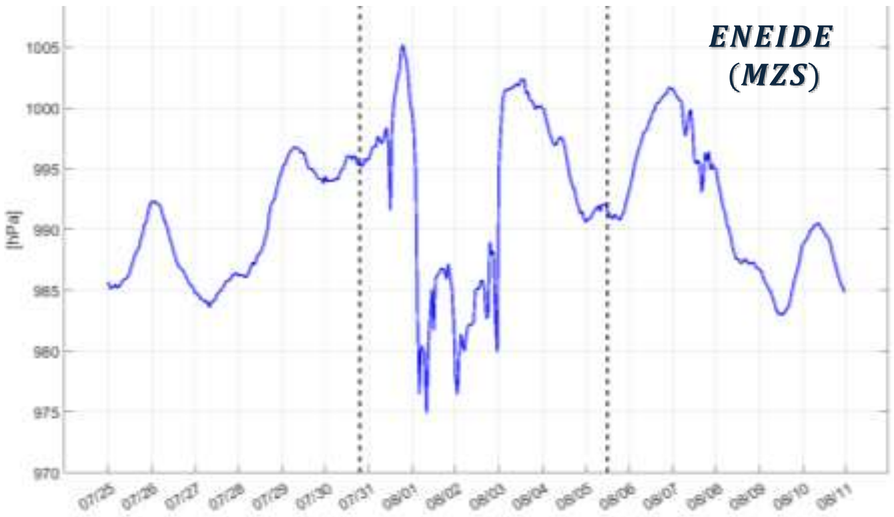


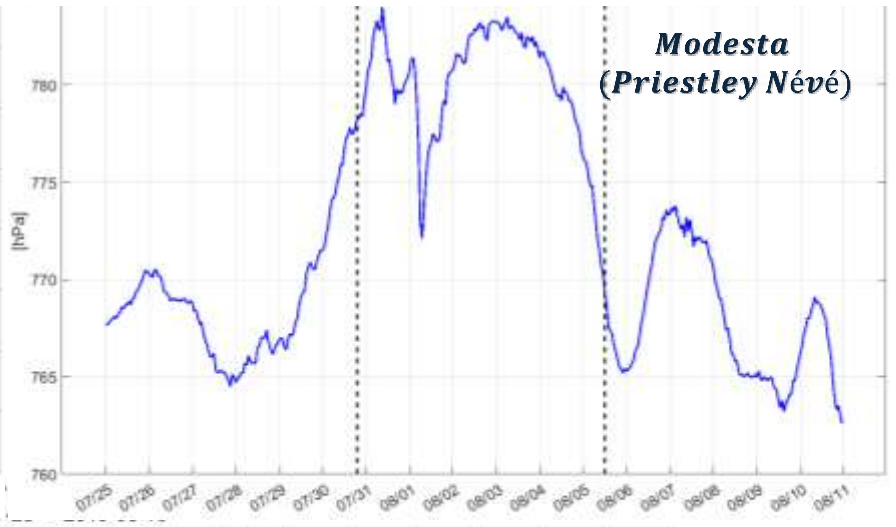


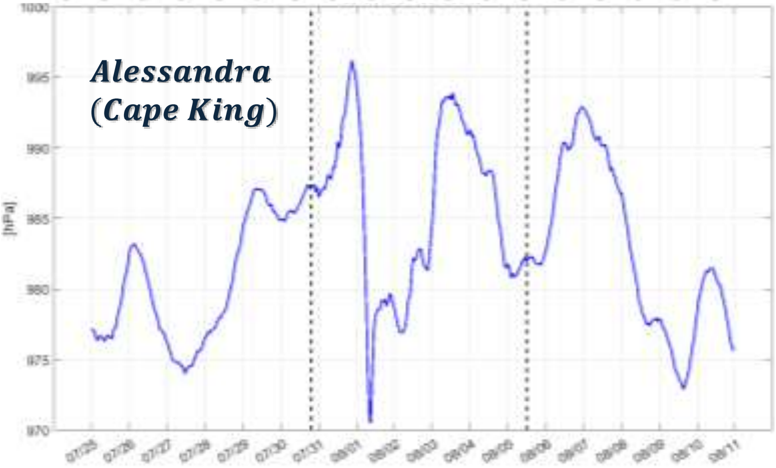


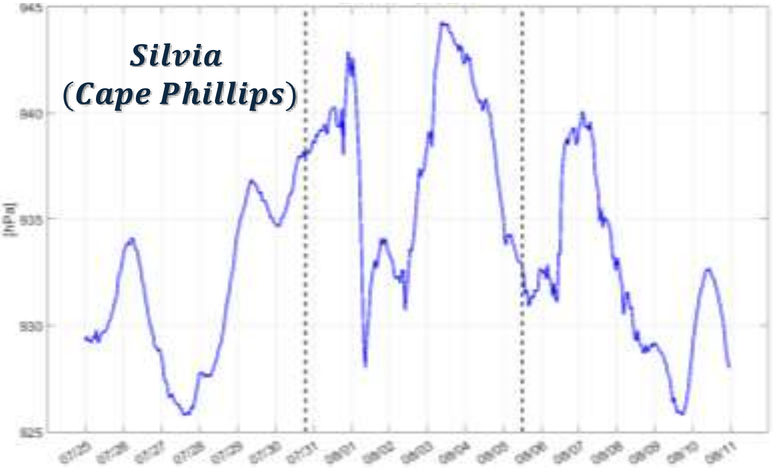
Serie temporali pressione atmosferica da AWS – evento 2016





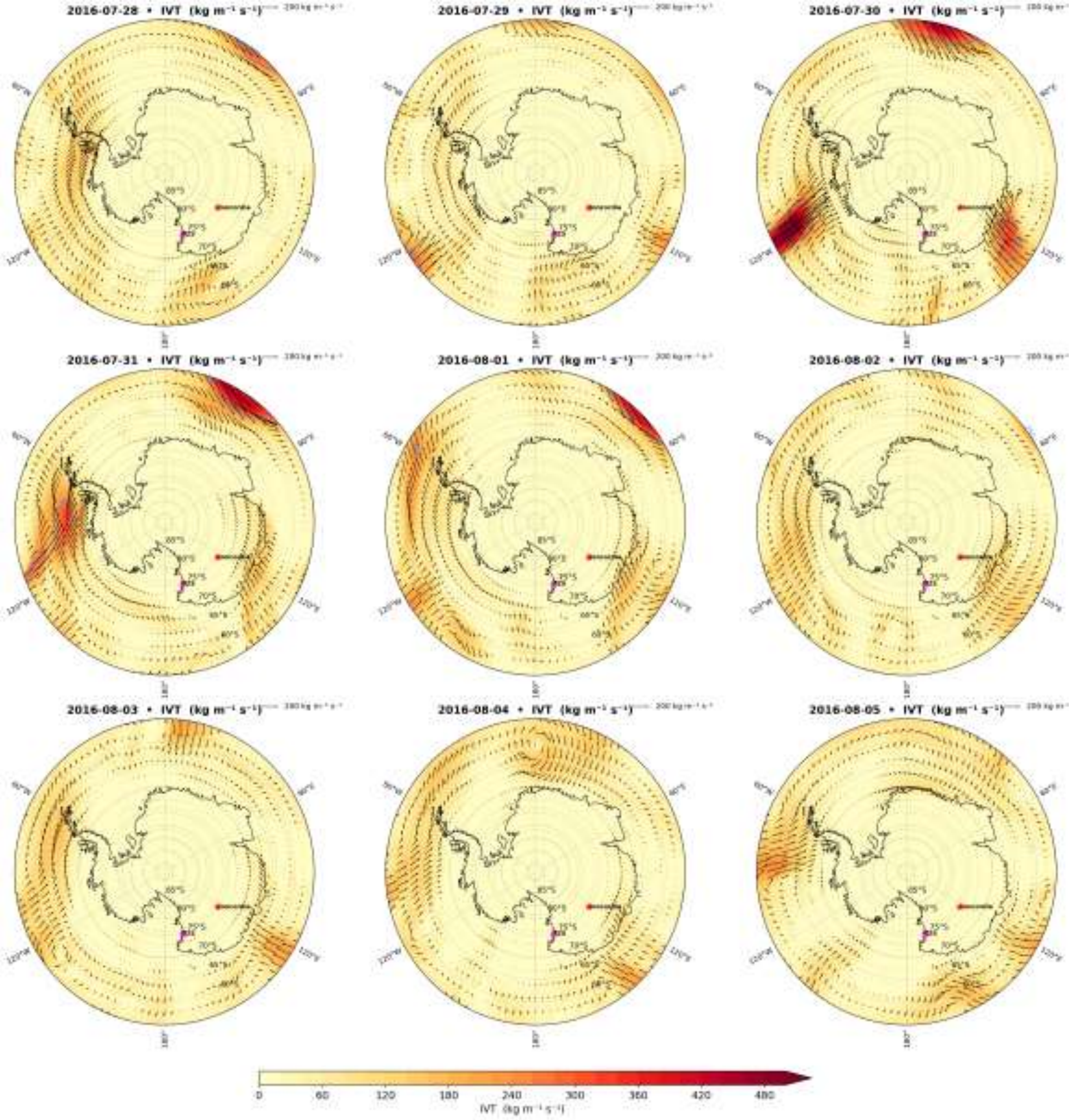


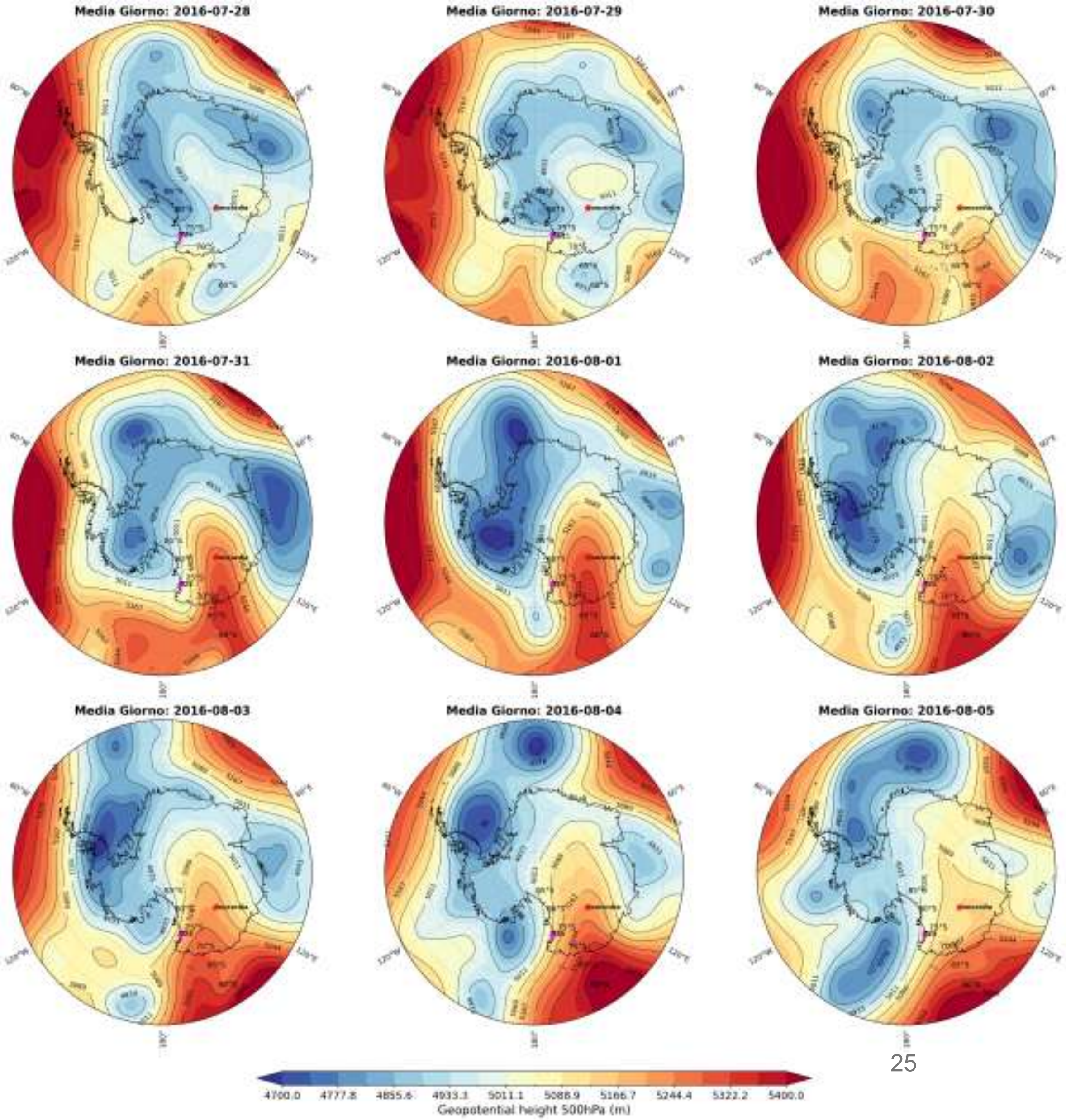




Reanalisi ERA 5 - ECMWF

altezza geopontenziale 500 hPa





integrated water vapor transport (IVT)

luglio 2016

Conclusioni

- le osservazioni in situ sono fondamentali per studiare la variabilità del sistema sul lungo periodo, in particolar modo in un contesto di cambiamento climatico come quello attuale.
- 40 anni di osservazioni continue grazie a una rete che si è progressivamente ampliata.
- Dati affidabili e di lungo periodo, essenziali per la caratterizzazione meteo-climatica della regione.
- Le osservazioni meteorologiche forniscono un background indispensabile per studi atmosferici, glaciologici, biologici, così come oceanografici,...
- Continuità garantita da personale scientifico, tecnico e logistico
- Operatività mantenuta per 40 anni in condizioni ambientali tra le più difficili del pianeta


Grazie