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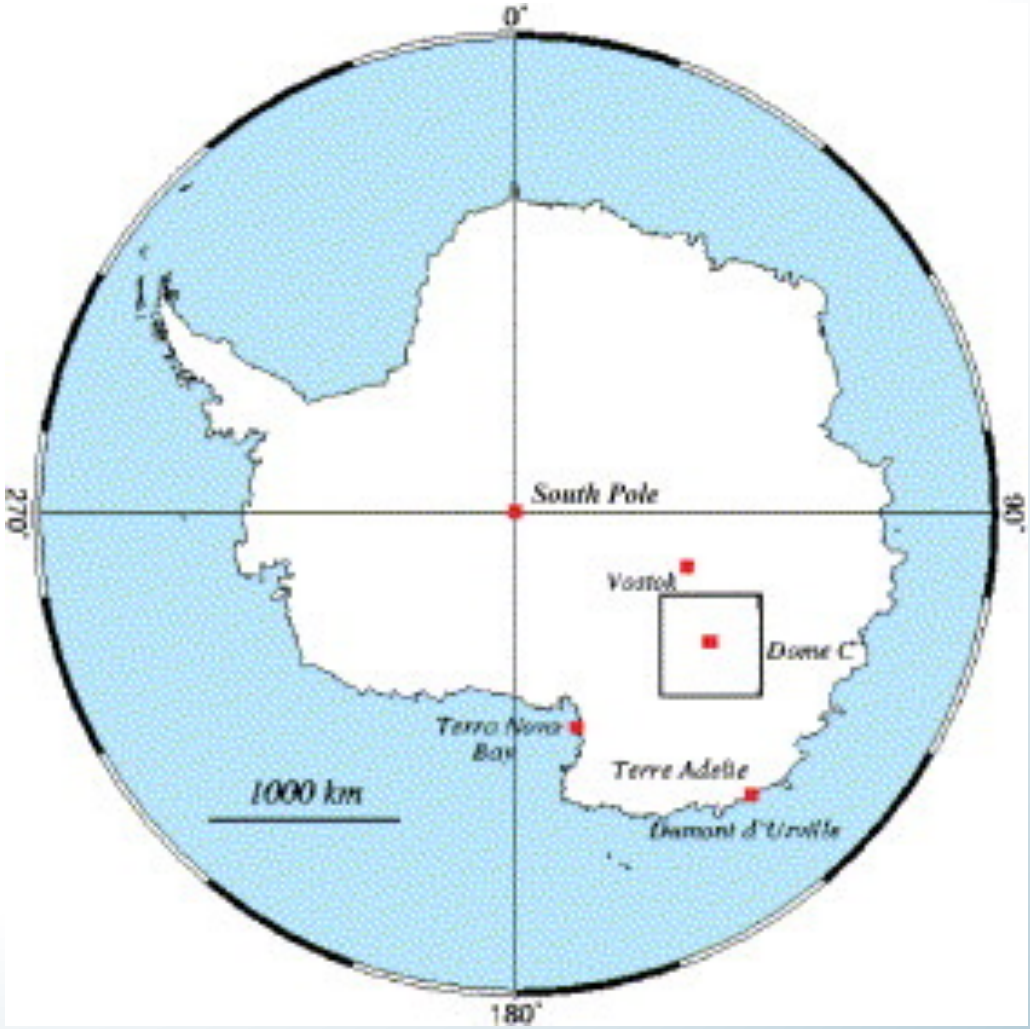
Chimica atmosferica a Dome C (Antartide Orientale): 18 anni di storia e realizzazione di un Nuovo Osservatorio

XII Convegno Nazionale sul Particolato Atmosferico PM2026 - Napoli 26-29 Maggio 2026

Dome C - East Antarctic Plateau



[From: Six et al. 2005. Atmospheric Environment, 39 (28), 5041-5050]

Coordinates: 75° 06' S 123° 20' E
Elevation: 3233 m a.s.l.
Located on one of the many Antarctic Ice Sheets (East Antarctic Plateau)

1100 km inland from the French research station at DDU
1200 km inland from the Italian Mario Zucchelli Station at Terra Nova Bay

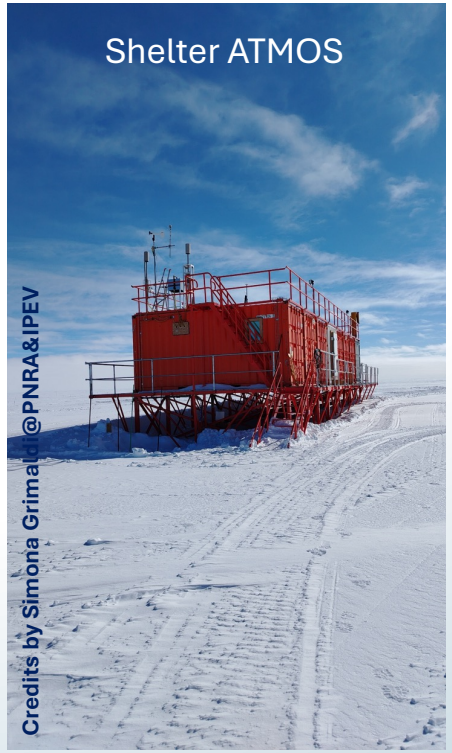
Site of the **Concordia Research Station**, operated jointly by France and Italy

Strategic site for a number of studies: astronomy and astrophysics, biomedicine, glaciology, chemistry and physics of atmosphere and cryosphere

PNRA Project CATCH-O Observatory

Novel Observatory devoted to the study of the chemical composition of atmospheric **aerosol** and **ozone** at the Concordia station

This facility takes advantage of solid infrastructure set up during previous Italian National Antarctic Programs (PNRA Project LTCPAA and STEAR).
Working in synergy with other Projects: SIDDARTA Project (PI Silvia Nava – Univ. Florence) and AIR-FLOC Observatory (PI Maurizio Busetto – CNR ISAC Bologna)



Already able to merge Near-Real Time data (**ozone** concentration and **selected ion markers** of atmospheric sources and processes) with **off-line chemical composition data** obtained from sampling and subsequent chemical analysis of several atmospheric source and process markers.

Off-line measurements

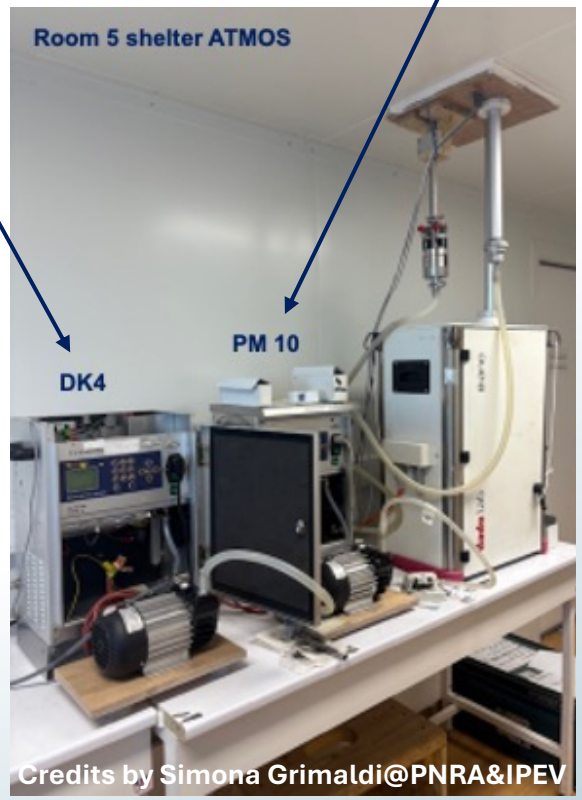
Set-up of aerosol sampling instrumentation at shelter ATMOS

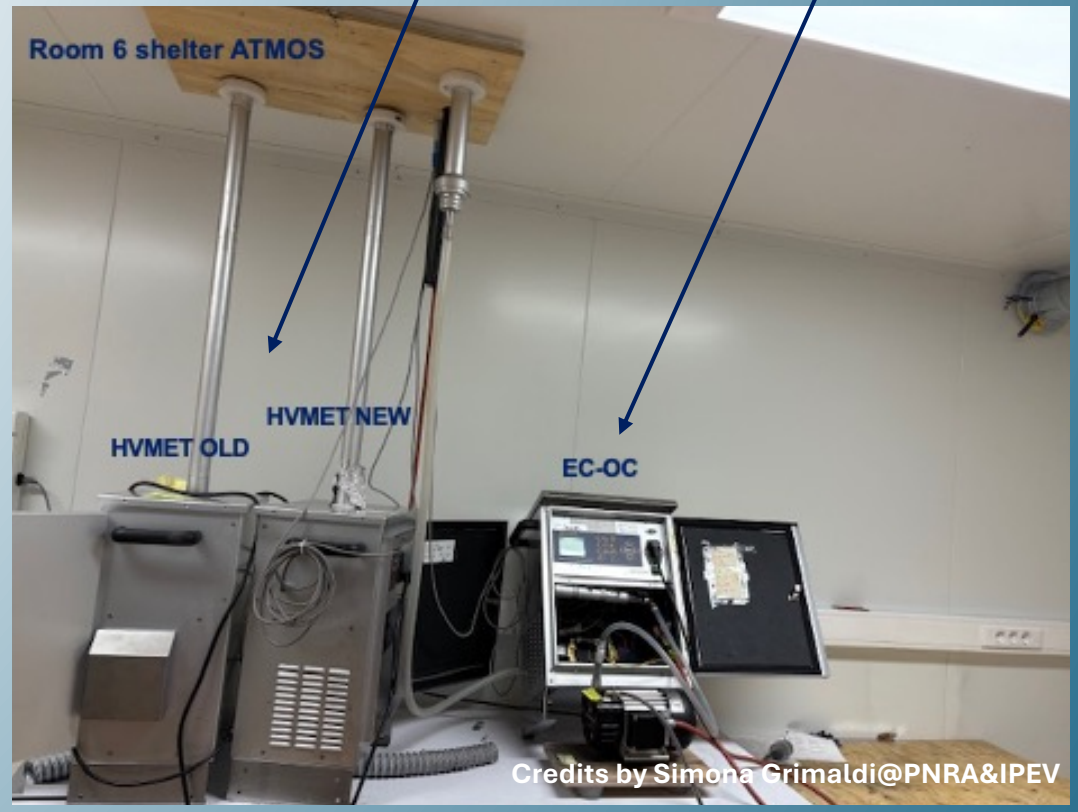
DK-4 Dekati multi-stage sampler: **size segregated aerosol** at **96 h resolution.** Analysis of ion markers

ECHO PM TECORA sampler: **PM10 aerosol at 48 h resolution.** Analysis of ion markers

ECHO HV TECORA/DADOLAB PMx HV and low vol. samplers: **PM10 aerosol at monthly resolution.** Analysis of metals, Pb isotopic composition, organic markers – synergy with SIDDARTA project

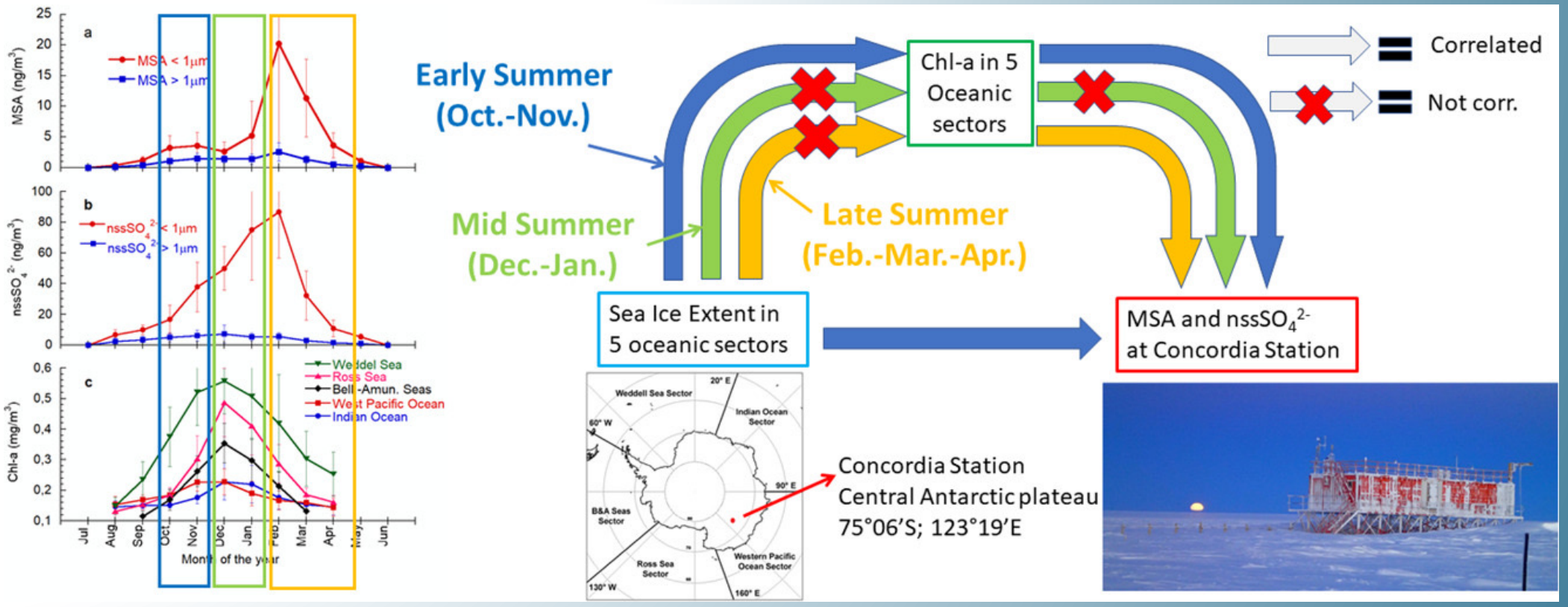
ECHO PM TECORA sampler: **PM10 aerosol at weekly resolution.** Analysis of EC/OC





Off-line measurements: examples of achieved results

Relationship between biogenic markers (MSA and $nssSO_4^{2-}$) in atmospheric aerosol at Dome C and environmental variables (Chl-a, SAM) in in 2004-2013 period [Becagli et al. 2022, STOTEN, 810, 151285].



Early summer: biogenic aerosol significantly correlated to sea ice retreats through phytoplankton biomass increases

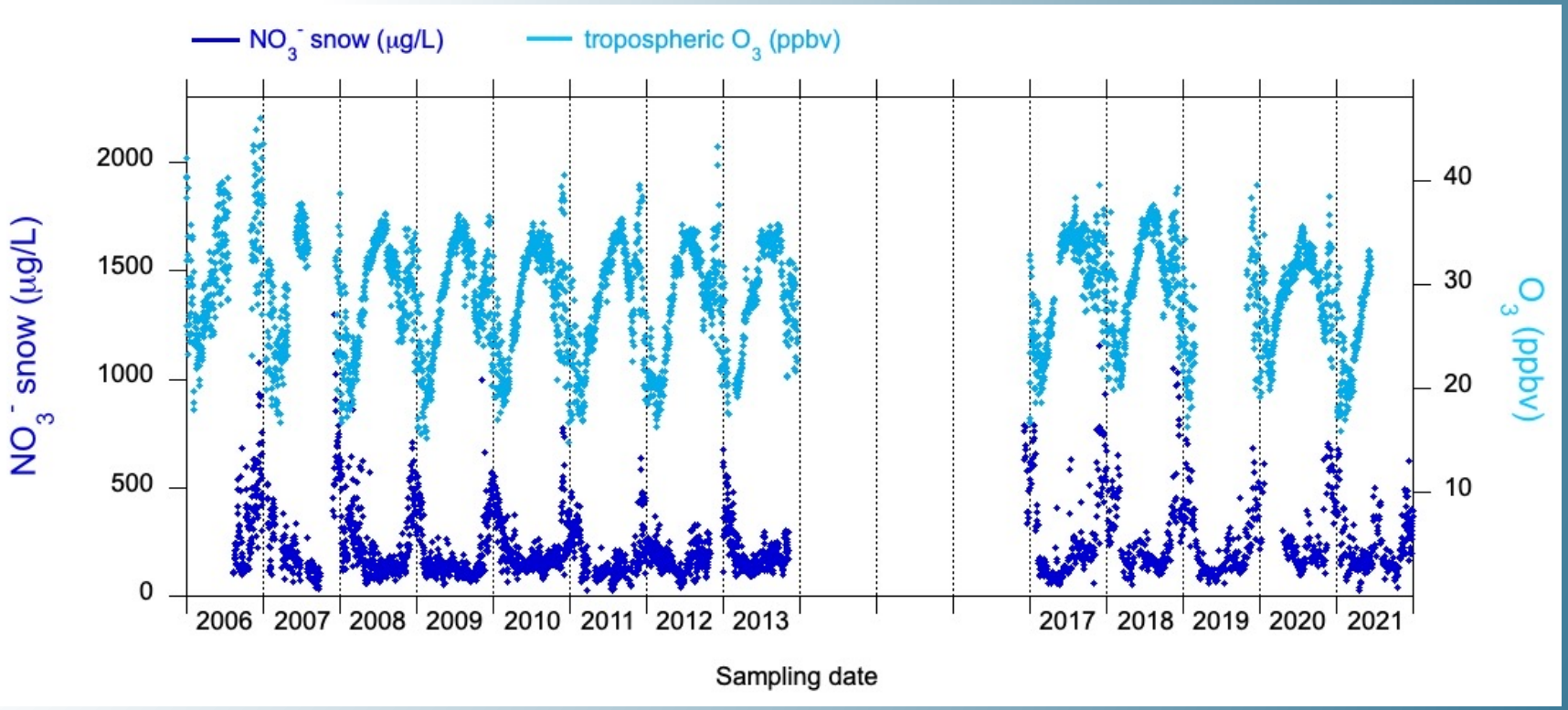
Mid-summer: Peak of Chl-a concentrations, not related to sea ice melting. Complex transport processes.

Late summer: MSA and $nssSO_2^{4-}$ highest concentrations. Both significantly correlated with Chl-a but not with sea ice

MSA interannual variability significantly correlated with SAM with a different time lag in early and late summer (0 vs. 4-months lag). Correlation likely occurring through the effect of the SAM on phytoplankton bloom

Off-line measurements: examples of achieved results

Comparison of long-term temporal series of nitrate in surface snow and ground-level ozone to better address the atmospheric processes involving the atmosphere-snow exchanges of N-cycle species and atmosphere oxidative properties
[Traversi et al. vAS.18 EGU23_5749]



Summer **nitrate** peak in in phase with the narrow **ozone** peak in early-full summer

Possible reasons:
-enhanced **re-emission of HNO_3(g)/NOx** from the snow to the atmosphere, possibly increasing ozone atmospheric concentration. High acidity of snow layers and aerosol, favouring the formation of acidic species and subsequent re-emission into the atmosphere.
-larger occurrence of **Stratospheric-Tropospheric Exchanges** in early summer [Traversi et al., 2017 Chemosphere, 172, 341-354; Cristofanelli et al., 2018 Atmos. Environ., 177, 54-63].

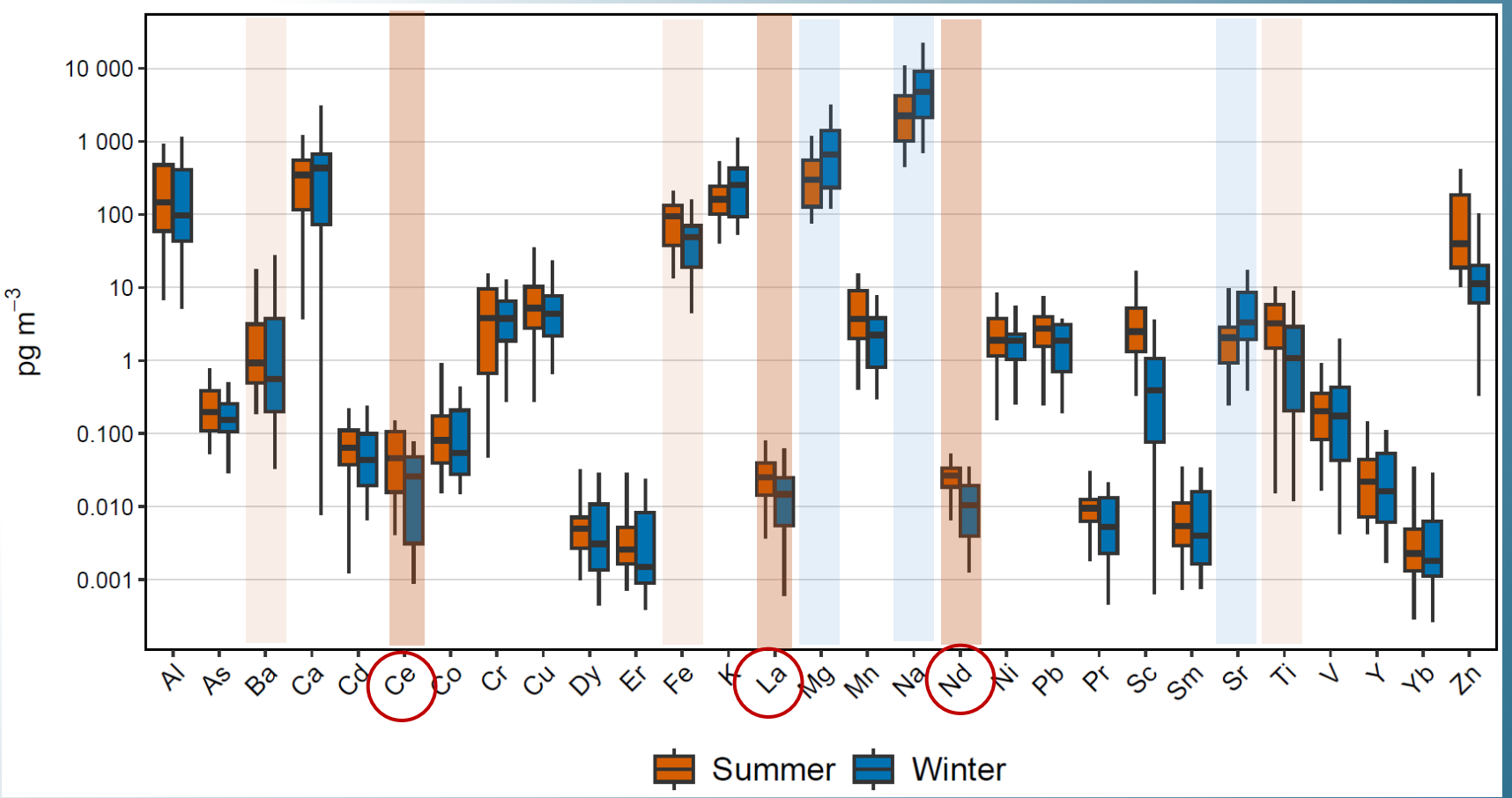
Off-line measurements: examples of achieved results

PM10 bulk medium-high volume - Metals and Pb isotopes

Highest concentrations shown by Na (sea spray source dominant), with a significant summer–winter difference (Wilconxon test, p-value < 0.05. Same significant seasonal pattern for Mg and Sr.

On the contrary, many typically crustal elements show slightly higher concentrations in summer (Ba, Fe, Ti).

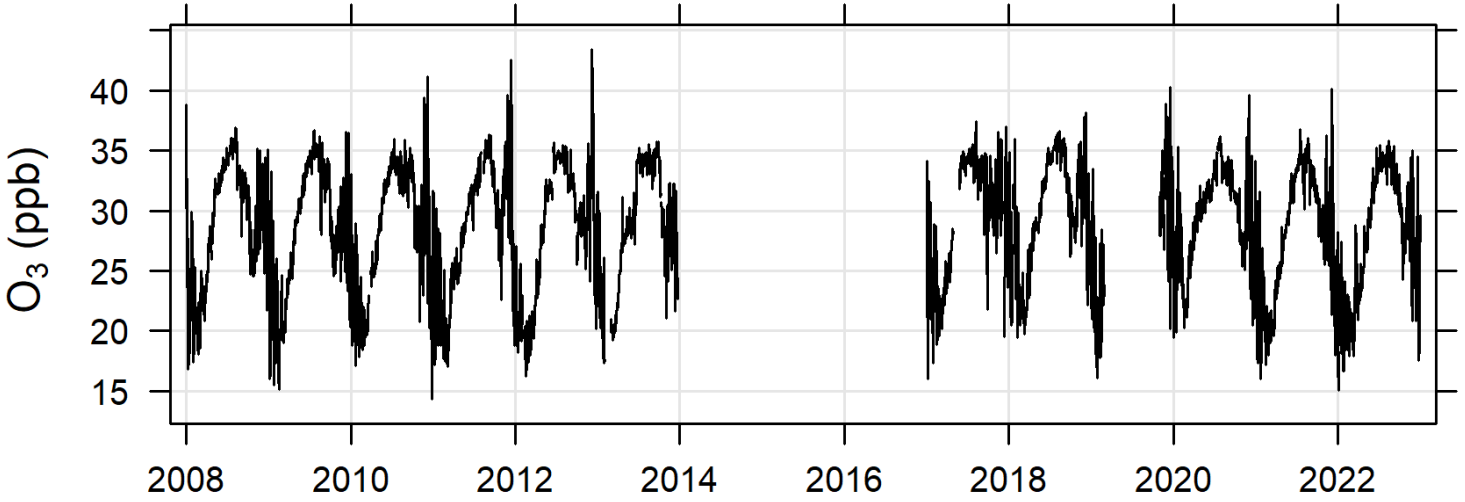
Only significant seasonal discrimination observed for Nd, Ce and La (p value <0.05).



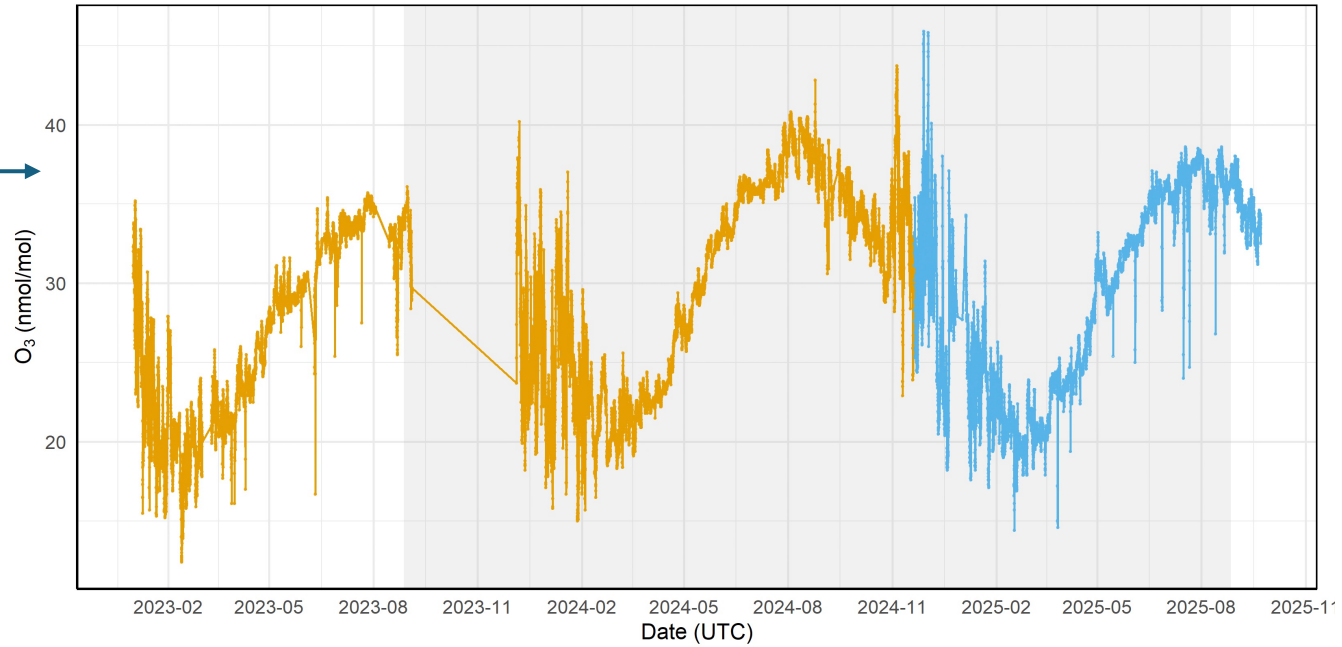
Data distribution of metal and As concentration measured on PM10 by ICP-MS/MS, sorted for sampling season. Sampling period: 2017-2023 (2018 left out due to contamination issues). Monthly resolution. Summer: October – March. Winter: April – September. SIDDARTA-CATCH-O projects synergy

Near-Real Time measurements: ozone (established)

- **Ground-level ozone** observations carried out since 2008, within several project activities (e.g., LTCPAA, STEAR, CATCH-O)
- Several **intercomparisons** performed during the summer campaigns, to guarantee the quality of the collected data following the **WMO/GAW guidelines** (data quality objective ±1 ppb)
- Annual data submission to EBAS



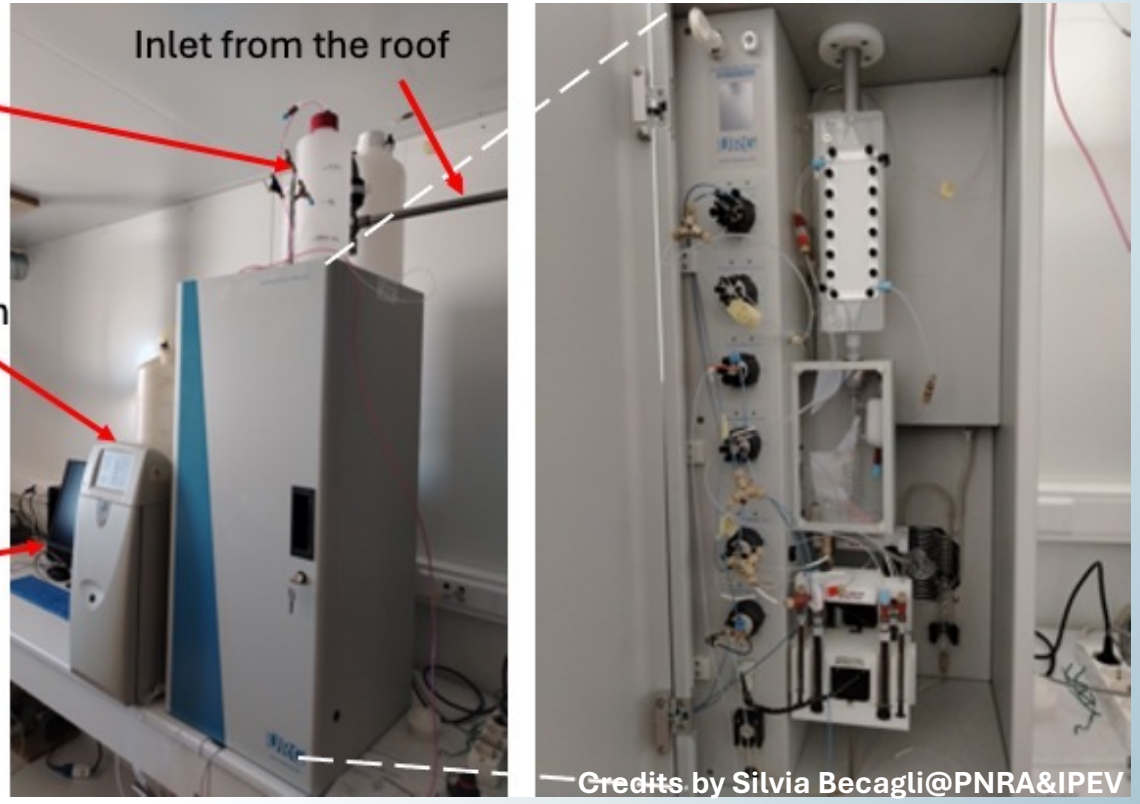
- Ozone temporal series (hourly averages) at Dome C from 2022 to 2025: measurements accomplished within CATCH-O project highlighted in grey.
- Annual ozone cycle characterized by a large winter maximum, a minor peak in summer (November-January) and one minimum in February



Data source: STEAR and CATCH-O

Near-Real Time measurements: AIM-URG (novel)

Ambient Air Monitor



URG-9000C Ambient Ion Monitor (AIM) provides
time-resolved direct measurement of the **particulate** and **gases** found in PM2.5

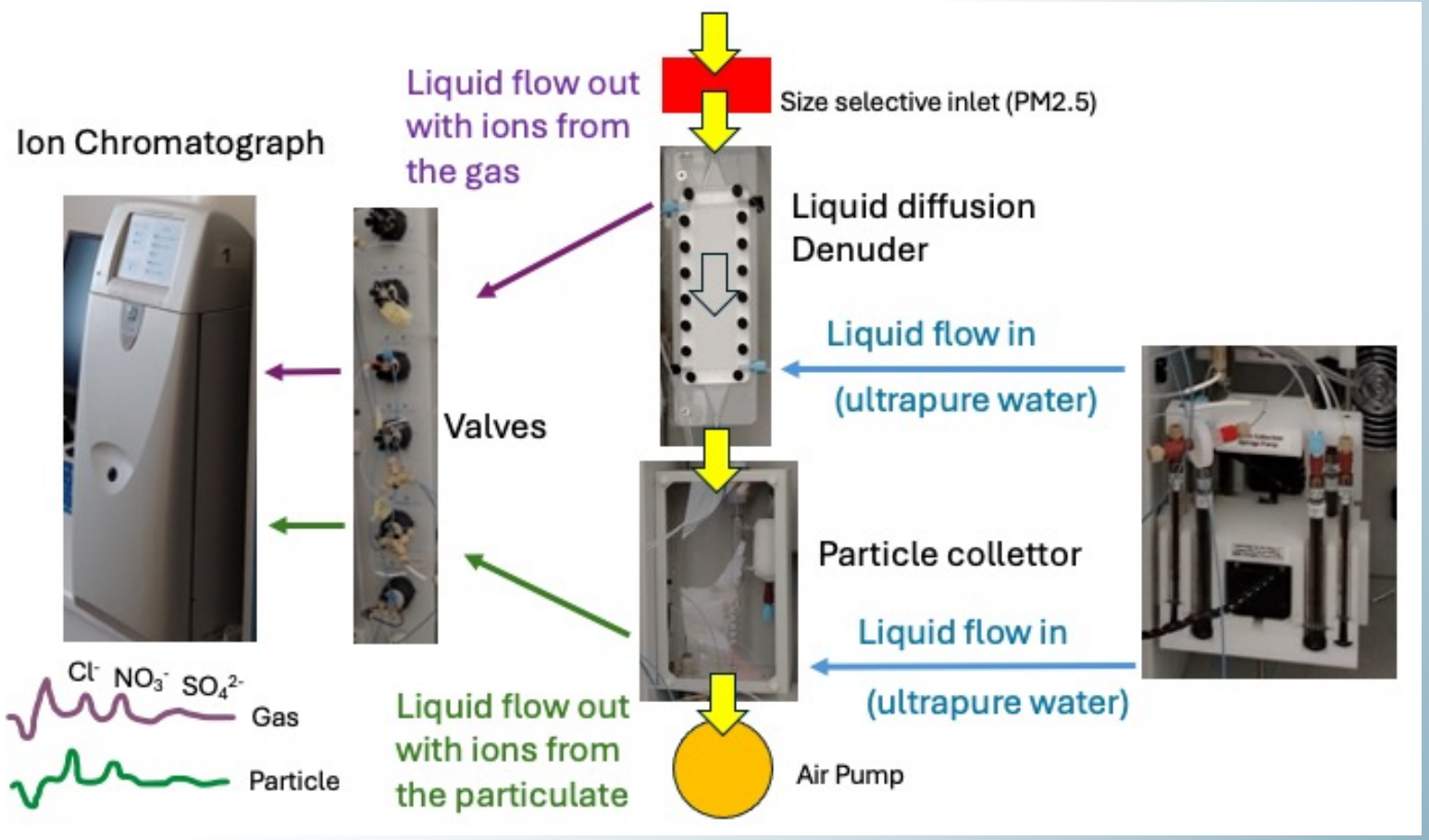
The AIM separates and analyzes each ion individually by
Ion Chromatography technique

Based on a flow rate of 3L/min,
the AIM uses a 2.5µm cut-point cyclone
(as used in the US EPA 2.5 network)

- Time-resolved direct measurements
- User-friendly software for system setup, programming, calibration and maintenance
- Flexible sampling times

Calibrated with aqueous standards

Near-Real Time measurements: AIM-URG (novel)



Credits by Silvia Becagli@PNRA&IPEV

AIM draws air in through a PM2.5 cyclone to remove the larger particles from the air stream.

The sample is drawn through a Parallel Plate Denuder where gases are removed

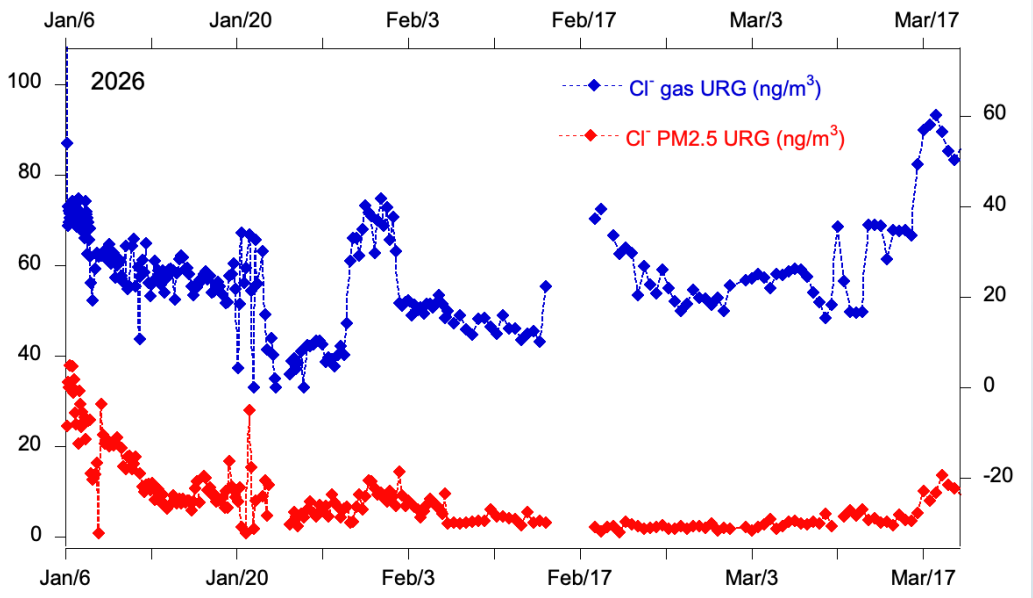
The particle-laden air stream next enters the aerosol super-saturation Collector

Both gas- and particulate-extracts are injected into the Ion Chromatograph

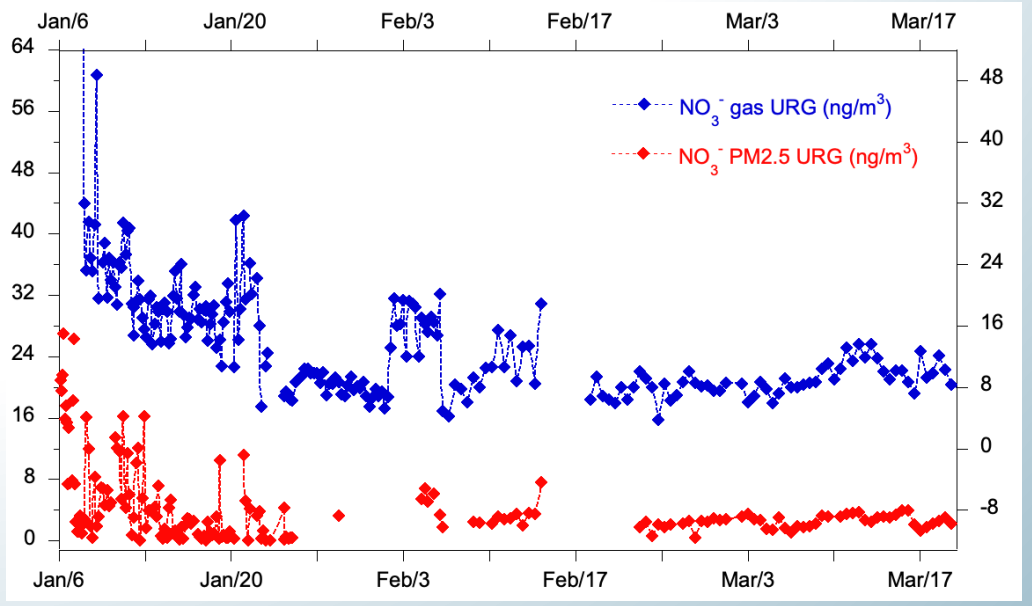
The data is automatically analyzed every hour and results are reported in in $\mu g/m^3$ (d.l. around 0.1 $\mu g/m^3$)

Near-Real Time measurements: AIM-URG (novel)

Cl^-



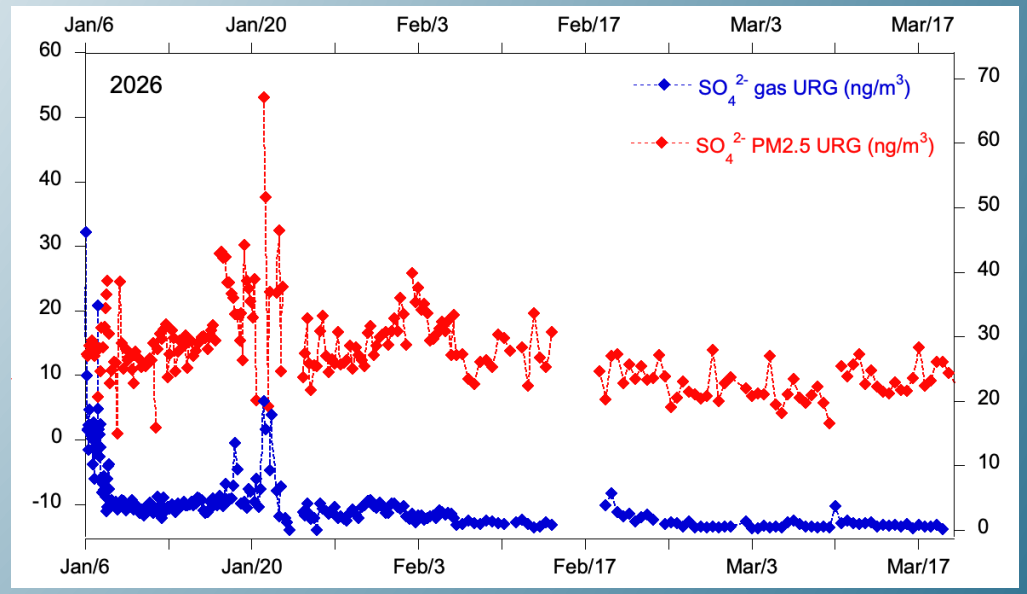
NO_3^-



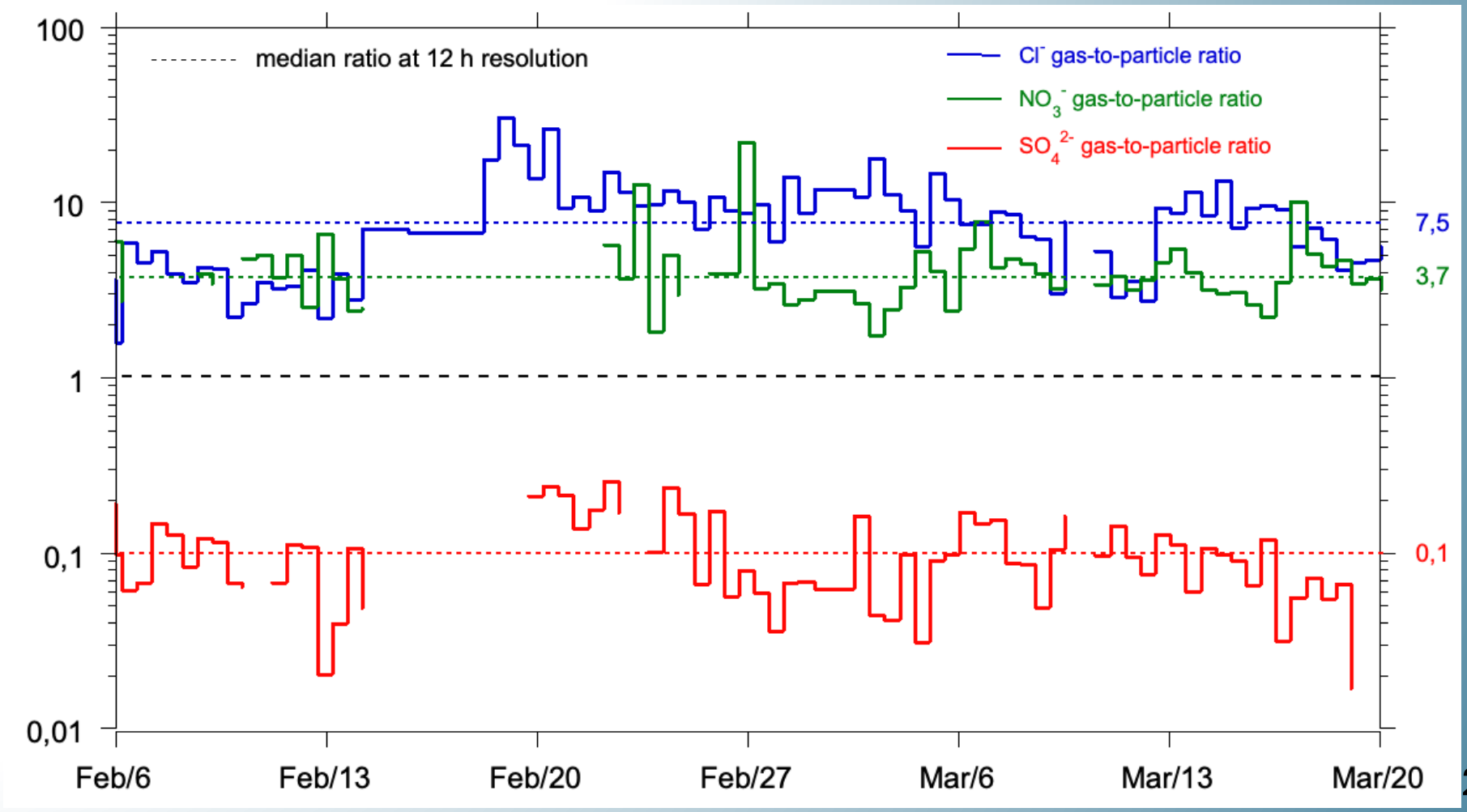
Temporal profile of chloride, nitrate, sulphate in gas and particulate phase (PM2.5) as provided by the Ambient Ion Monitor (AIM-URG).

The very first data ever achieved in Antarctica for gas and particulate phase sampled and measured simultaneously

SO_4^{2-}

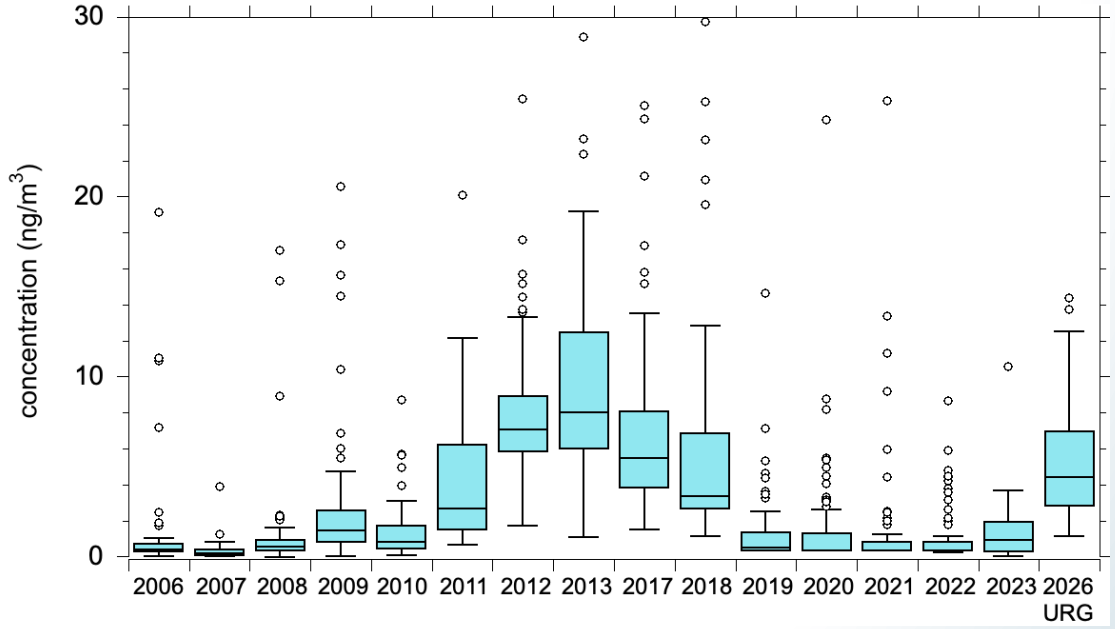


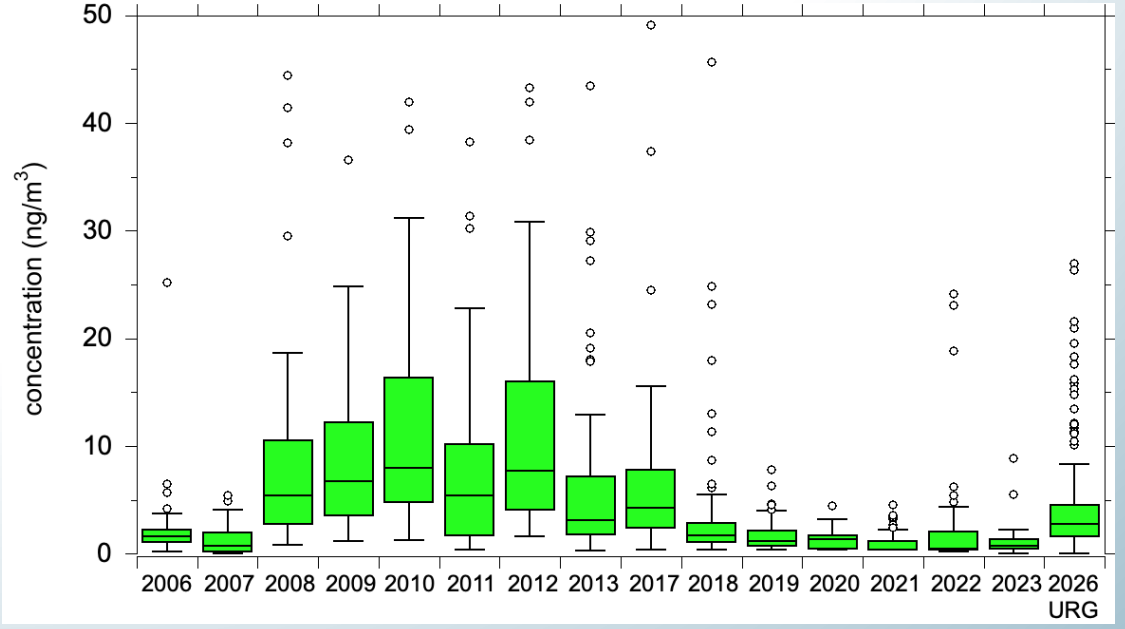
Near-Real Time measurements: AIM-URG (novel)



The gas-to-particulate phase ratio is plotted for each marker.
Chloride and nitrate are dominant in the gas phase
while sulphate is mainly present in particulate phase

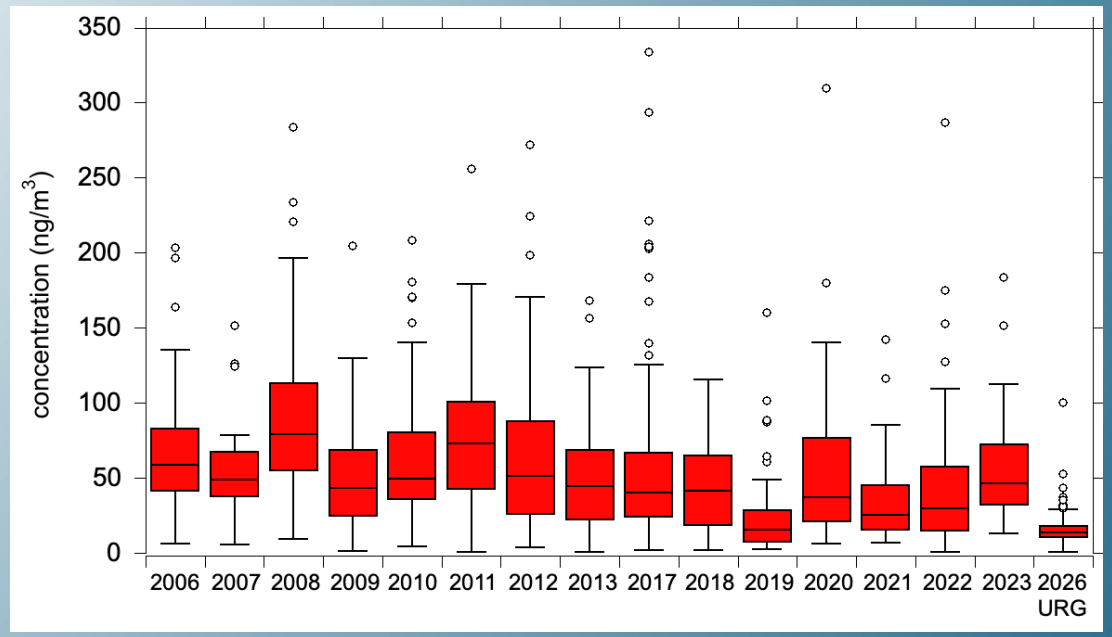
Comparison between on-line and off-line chromatographic measurements





The aerosol concentration data for chloride, nitrate and sulphate obtained by AIM-URG in 2026 (PM2.5) are compared with all the available data obtained at Dome C in the framework of a number of PNRA projects (PM10)

Covered years: 2006-2013 2016-2023
Seasonal time frame considered: January-March



Future perspectives

Keeping on with current off-line and on-line measurements and samplings working on the following tasks:

- **data validation** and **availability** for AIM-URG
- **analysis time** for off-line measurements in Italy
- **optimising** snow samplings so to achieve the best representative information on depositional and post-depositional processes

Increasing the number of markers that can be determined on-line (such as **cations** by acquiring and installing a new Ion Chromatograph)

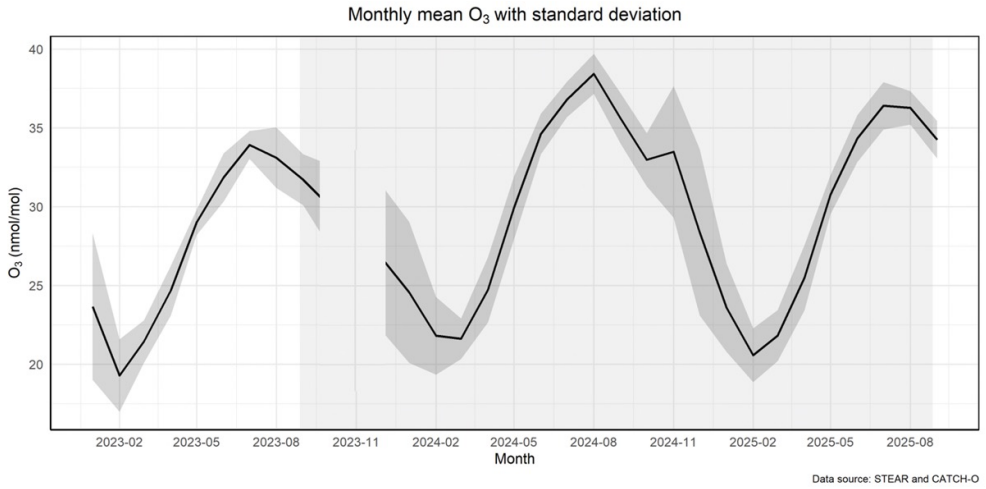
Finding a closure among the different parameters and activities accomplished within CATCH-O also in collaboration with other long-term projects at Dome C (particularly AIR-FLOC)

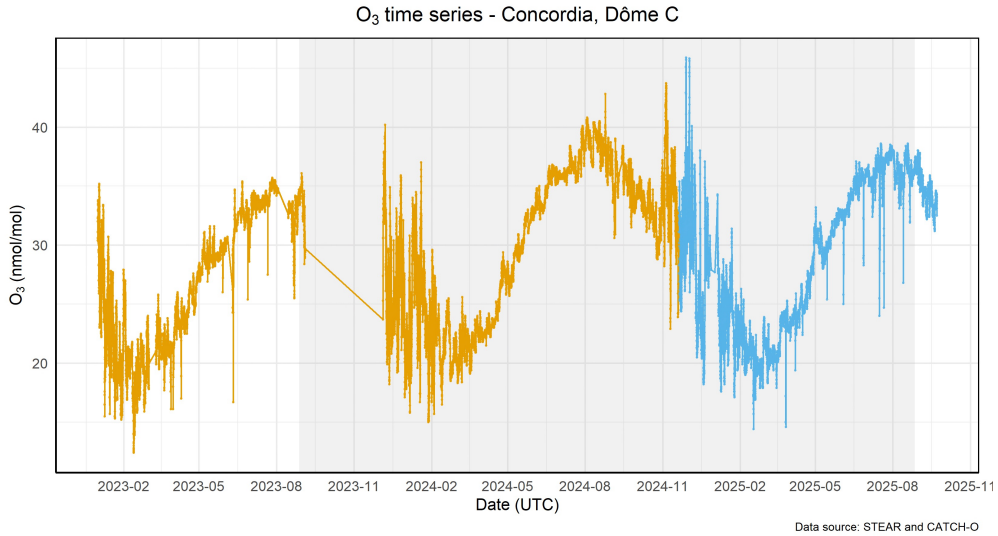
Developing collaborations with foreign research partners who might find CATCH-O as a unique opportunity to perform pivotal studies in the Antarctic Plateau (e.g. CO_2 measurements by Scripps Institute of Oceanography)

Thank you for your attention till this late!

Near-Real Time measurements: ozone (established)

Ozone analyzer (ISAC-CNR Bologna) ATMOS shelter

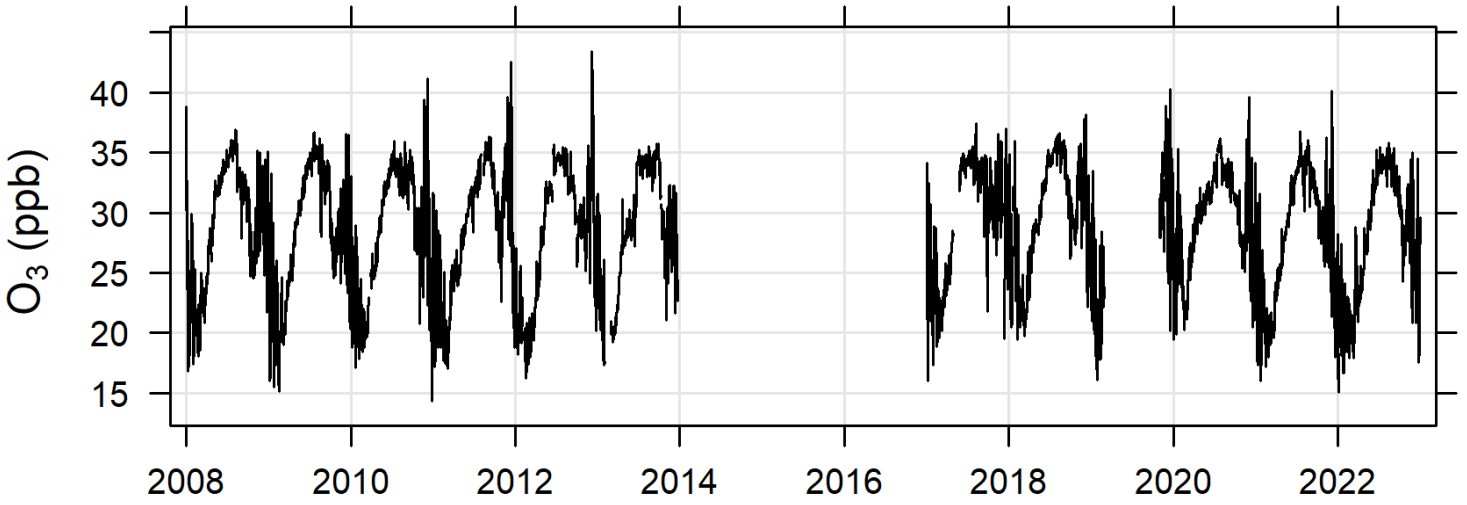


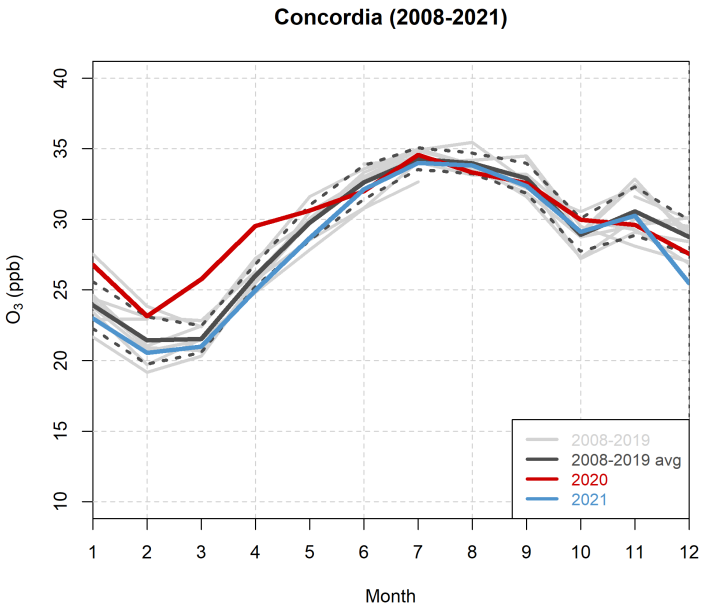


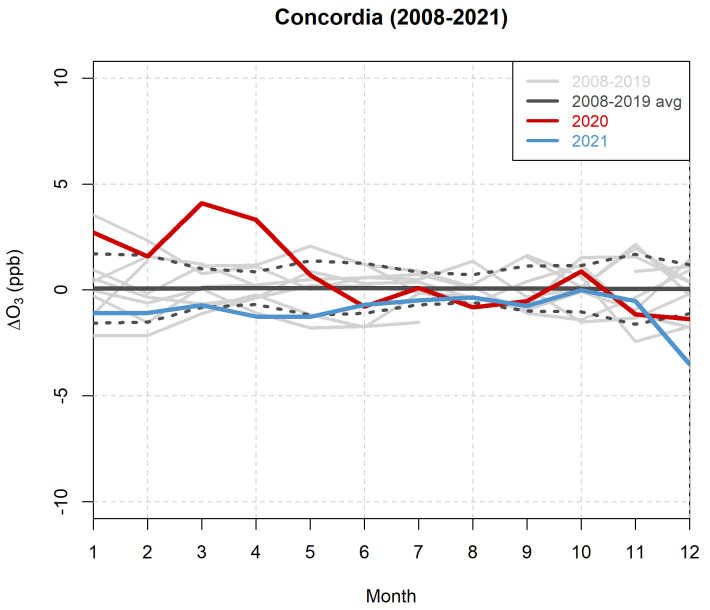
Ozone temporal series (hourly and monthly averages) at Dome C from 2022 to 2025: the measurements accomplished within CATCH-O project are highlighted in grey. Temporal series obtained in 2023 and 2024 were submitted to World Data Center for Reactive Gases (WDCRG) belonging to GAW/WMO program.
See: https://ebas-data.nilu.no/Pages/Plot.aspx?key=4716A262042C4A71910B737C4E16FA34)
Similarly to what observed during previous years, annual ozone cycle is characterized by a large winter maximum, a minor peak in summer (November-January) and one minimum in February

Near-Real Time measurements: ozone (established)

- **Ground-level ozone** observations carried out since 2008, within several project activities (e.g., LTCPAA, STEAR, CATCH-O)
- Several **intercomparisons** performed during the summer campaigns, to guarantee the quality of the collected data following the **WMO/GAW guidelines** (data quality objective ±1 ppb)
- Annual data submission to EBAS
- Evaluation of the **O_3 trend** at Concordia (0.32 [±1.05] ppb/decade, p = 0.55), and analysis of the possible effects due to the COVID-19 economic downturn (Putero et al., 2023, Atmos. Chem. Phys., 23, 15693–15709)
- Evaluation of the ozone enhancement events and comparison with **South Pole** data

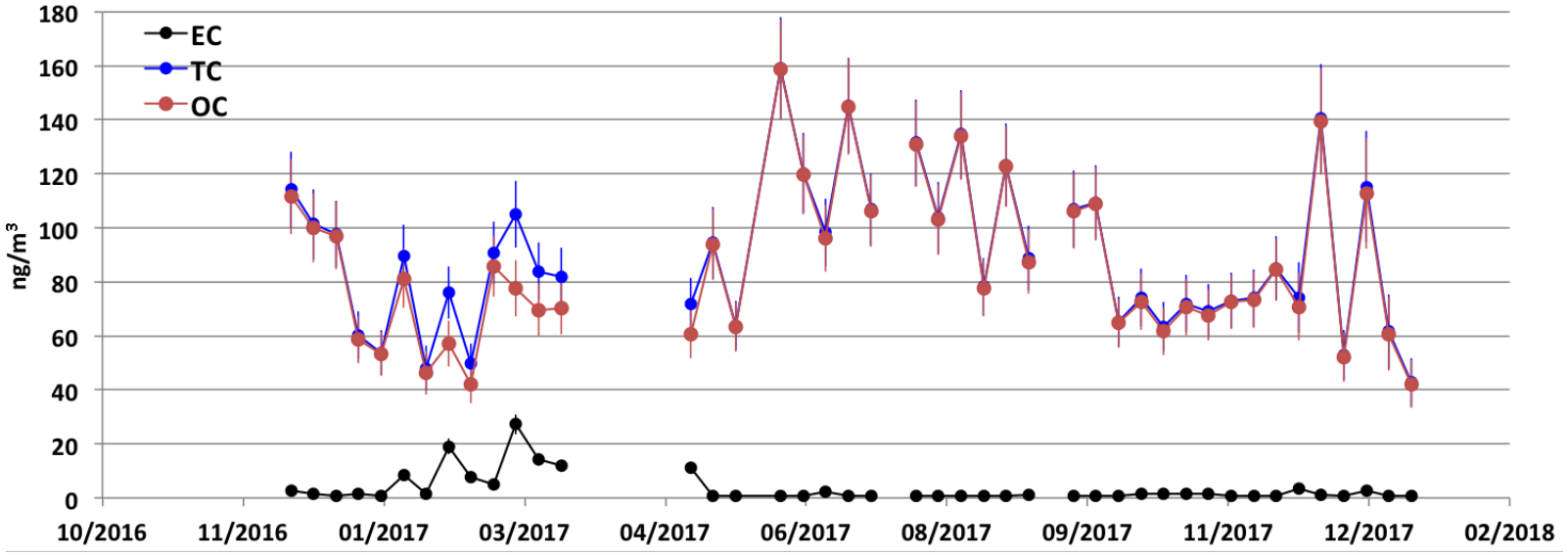






[From Putero et al. ACP (2023)]

Off-line measurements: examples of achieved results

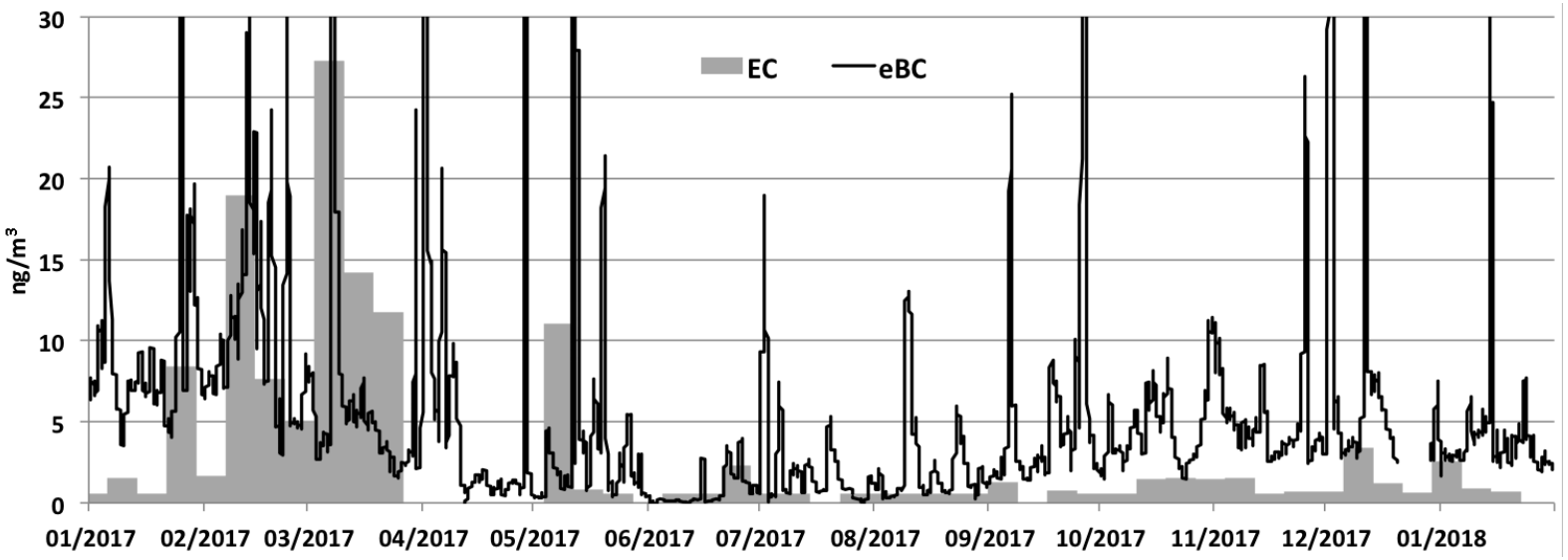


First continuous temporal series of Elemental Carbon (EC), Total Carbon (TC) and Organic Carbon (OC) from the Antarctic Plateau (Dome C) by thermo-optical analyzer Sunset Inc.
[Caiazzo et al., 2022, Atmosphere, 12, 320]

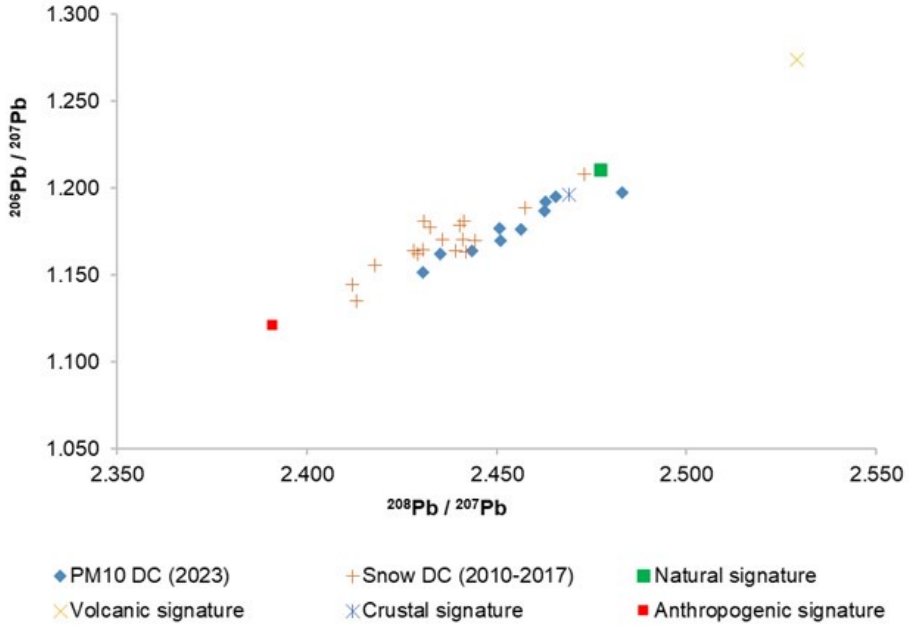
EC data are generally lower than eBC: different resolution (8 days vs. 1h) and eBC data calculated as "upper estimations" [Virkkula et al., 2022, ACP, 22, 5033–5069].

eBC shows anomalously high peaks, likely to be ascribed to contamination events whereas sampling for EC measurements should be controlled by meteo trigger (to be investigated further).

Comparison of EC data with eBC data (FMI&Univ. Helsinki)



PM10 bulk medium-high volume
Metals and Pb isotopes
(University of Torino and Genova – Chemistry Dept.)



Pb isotopic composition in PM10 aerosol sampled at Dome C in 2023. Reference values are taken from Bertinetti et al., 2020, Chemosphere, Sep:255:126858.