



Training event “Climate change and air quality: challenges and objectives for the atmospheric research.”

IR0000032 – ITINERIS, Italian Integrated Environmental Research Infrastructures System

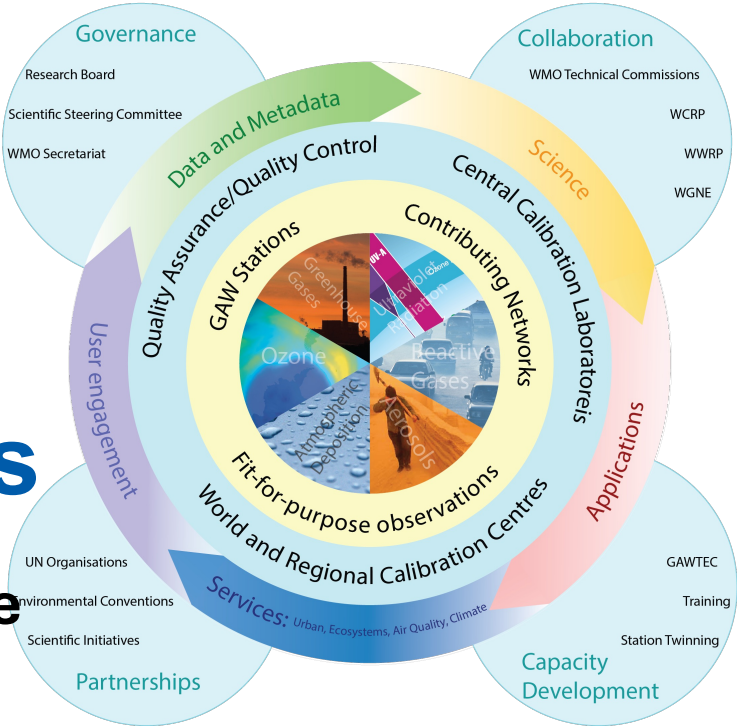
(D.D. n. 130/2022 - CUP B53C22002150006) Funded by EU - Next Generation EU PNRR-
Mission 4 “Education and Research” - Component 2: “From research to business” - Investment
3.1: “Fund for the realisation of an integrated system of research and innovation infrastructures”



Monitoring Atmospheric Composition Changes

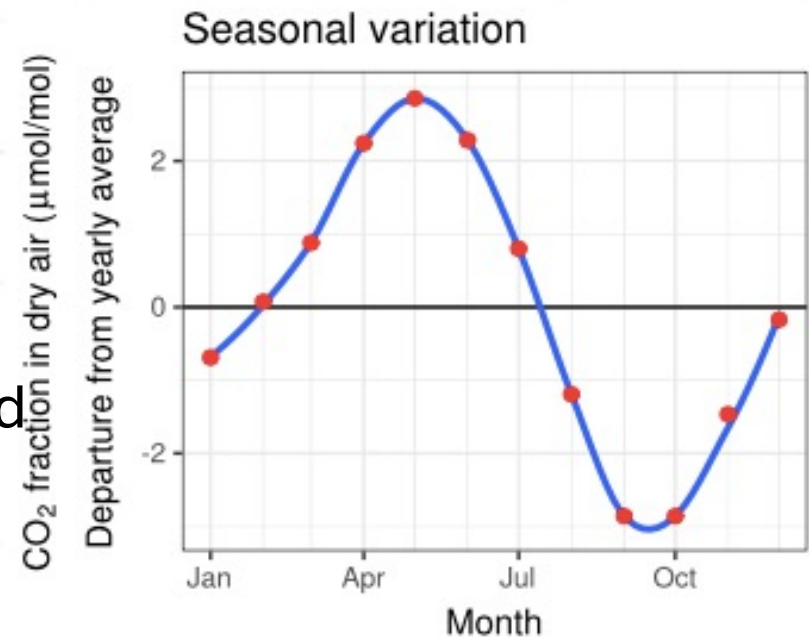
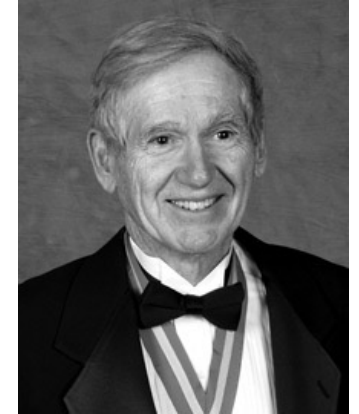
Paolo Laj, Head, Global Atmosphere Watch, WMO

ITINERIS School, 20 June



Tribute to Charles David Keeling, 1928-2015

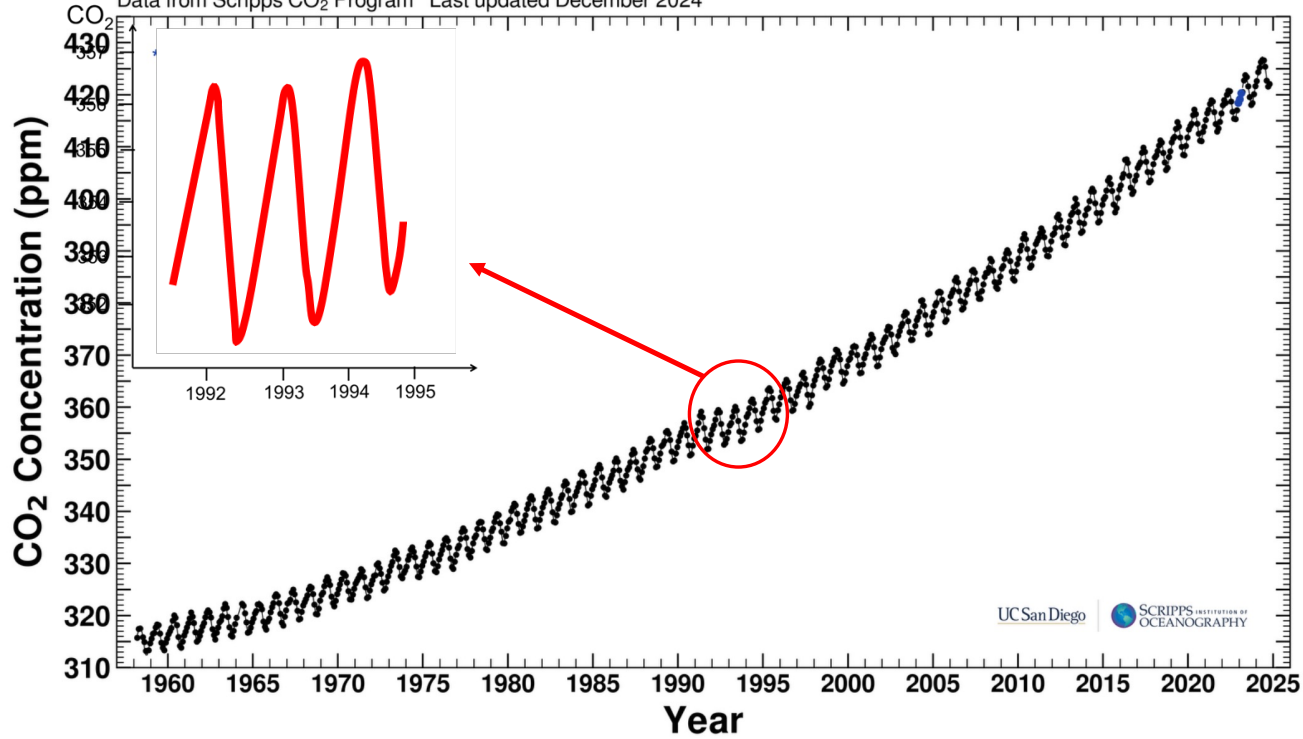
- Professor Scripps Institution of Oceanography
- 1957 : Received 2-year funding grant to buy and install CO₂ monitors at Mauna Loa
- 1958 : Reveals the seasonal variations of CO₂ concentrations
- 1960 : National Science foundation stops funding. He decides to continue
- 1963 : Keeling results are used to evidence the CO₂ increase and the risks for the climate
- 2025: MaunaLoa the longest direct record of CO₂ concentrations



The Keeling curve

Mauna Loa Observatory, Hawaii*
Monthly Average Carbon Dioxide Concentration

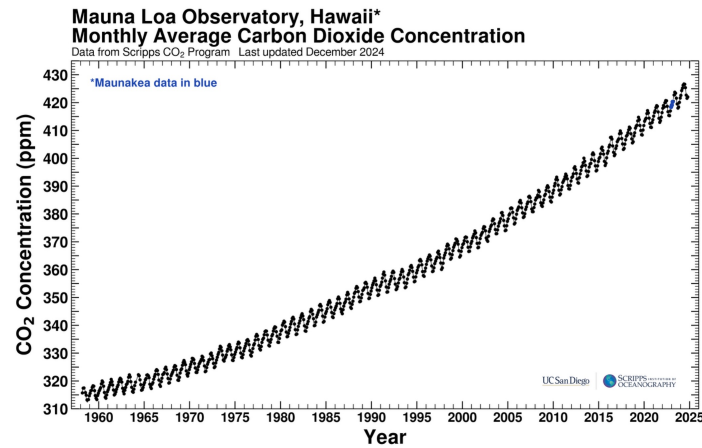
Data from Scripps CO₂ Program Last updated December 2024



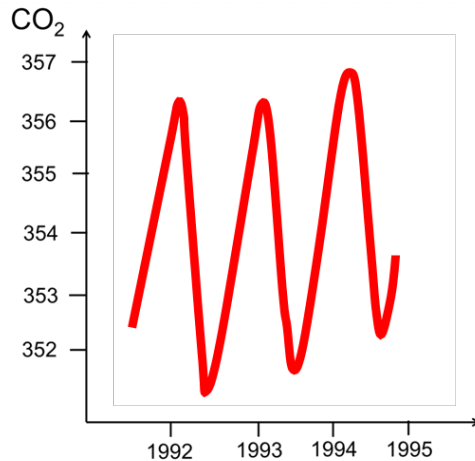
UC San Diego

SCRIPPS INSTITUTION OF OCEANOGRAPHY

Ingredients to an observing network



Long time series

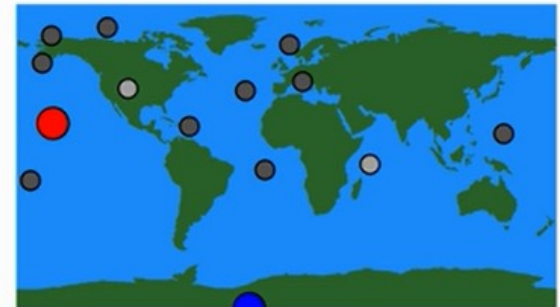


High precision measurements

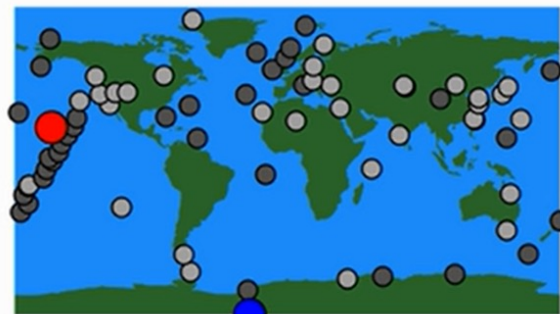
Ingredients to an observing network



1960



1980



2000



2025

Sufficient
network
density



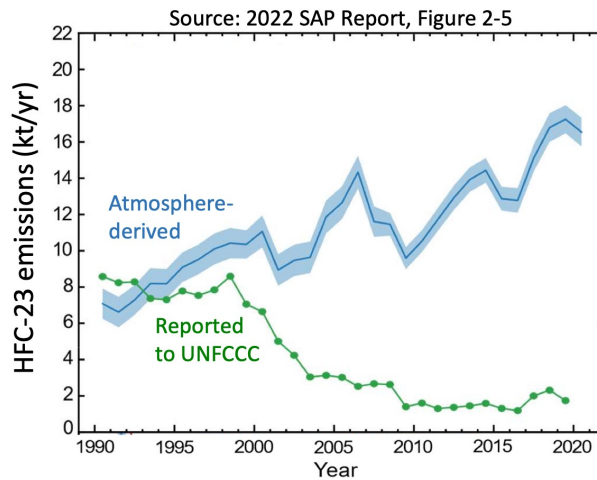
Observing Systems

Systematic long-term monitoring of the Earth system is a fundamental prerequisite to understand its change and the resulting consequences, and a key factor in decision-making at all levels.

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HFC-23 global emissions and the influence of mitigation measures



Take-home messages:

- * **HFC-23 emissions continue to increase;**
→ 2016-2020 mean at an all-time high

Ideal observation system for atmospheric composition



- **Network design:** where ideally to place observations
- **Provision of data:** which measurements being carried out
- **Harmonized methods:** comparability of measurements
- **Data quality :** remove wrong data
- **Curation of data:** store data in a secured place
- **Access to users:** make data available in a recognized format
- **Impact :** Ensure your data is being used

Ideal observation system for atmospheric composition



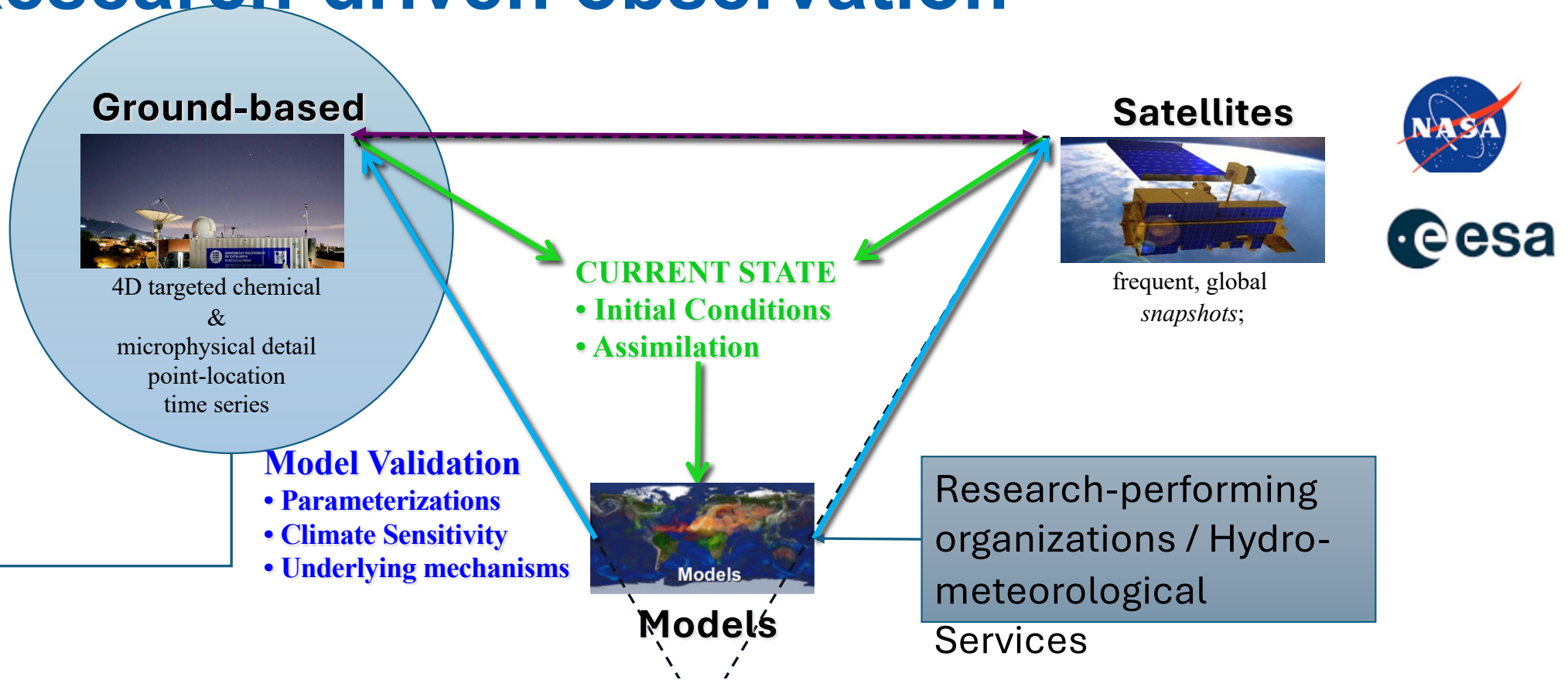
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- **Existing stakeholders** : there is a general request for the observations
- If the network is part of a (inter)national treaty / agreement, there should be sustainable financial support for making the observations

Different types of observing networks

- Society-driven networks: respond to both policy, research and societal requests
→ WMO hydrometeorological services
- Policy-driven networks : respond to specific country-level agreement (Under EPAs, Environment Ministeries)
→ EMEP, CASNET, IMPROVE, Local Air Quality Networks
- Research-driven networks: respond to (less-specified) scientific community needs (under Research Ministeries)
→ AERONET, NDACC, EARLINET,...

Research-driven observation



Contrary to air-quality networks or to meteorological networks, the earth observing system does not respond to any policy



Atmospheric Composition

- What should networks monitor ?
- Which variables should you suggest to monitor if you were to organize an global monitoring network ?

Global Climate Observing Network



<https://gcos.wmo.int/>

Essential Climate Variable (ECVs)

- An ECV is variable or a group of linked variables that critically contributes to the characterization of Earth's climate.
- Criteria for ECVs
 - Relevance : critical thus limited in numbers
 - Feasibility: technically, on global scale
 - Cost effectiveness:

Global Climate Observing Network

ECV	Proposed products for IP 2022
Cloud properties	<ul style="list-style-type: none"> Cloud cover Cloud liquid water path Cloud Ice water path Cloud drop effective radius Cloud optical depth Cloud top temperature Cloud Top Height
Carbon dioxide, Methane and other greenhouse gases	<ul style="list-style-type: none"> N₂O mole fraction CO₂ Total Column CO₂ mole fraction CH₄ Total Column CH₄ mole fraction
Ozone	<ul style="list-style-type: none"> Ozone Mixing Ratios in the Troposphere Ozone Mixing Ratios in the Upper Troposphere/ Lower Stratosphere (UTLS) Ozone Mixing Ratios in the Middle and Upper Stratosphere Ozone Stratospheric Column Ozone Tropospheric Column Ozone Total Column
Precursors (supporting the aerosol and ozone ECVs)	<ul style="list-style-type: none"> CO Total Column CO Tropospheric Column HCHO Total Column SO₂ Total Column NO₂ Total Column (suggested to change to tropospheric) CO Mole fraction NO₂ mole fraction
Aerosols properties	<ul style="list-style-type: none"> Aerosol light extinction vertical profile (troposphere, stratosphere) Multiwavelength aerosol optical length Chemical composition of aerosol Number of cloud condensation nuclei Aerosol single scattering albedo Aerosol number size distribution

Essential Climate Variables

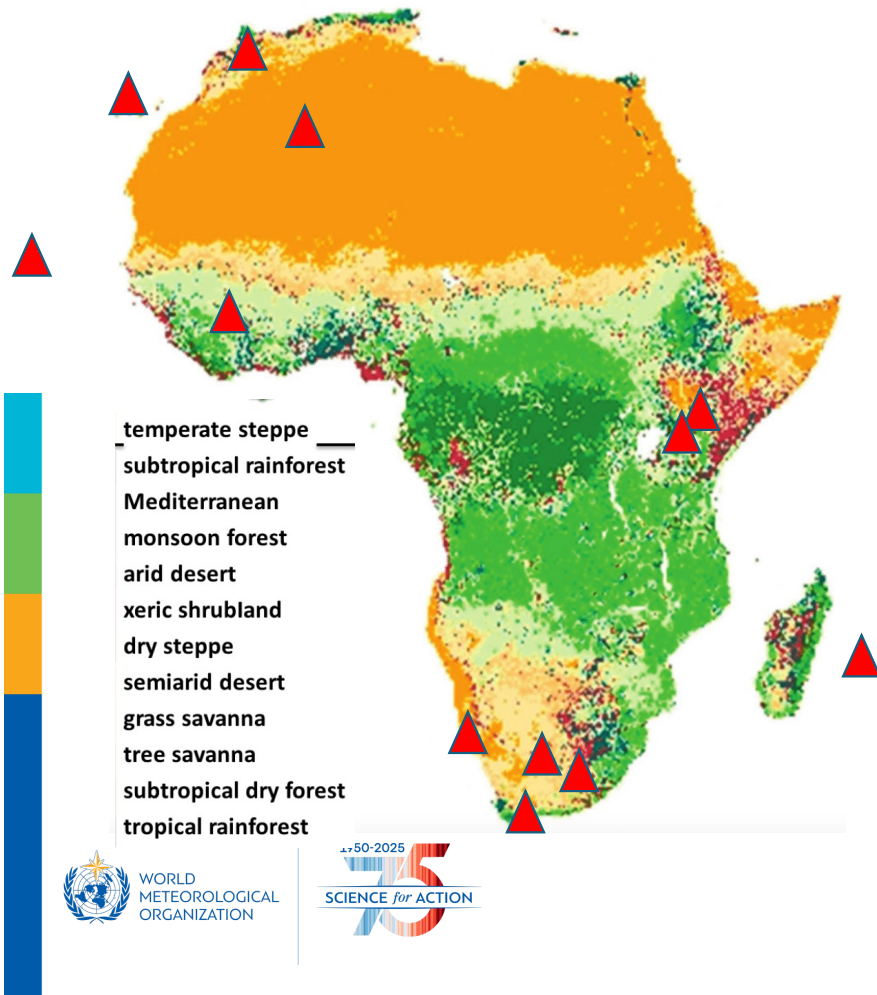
For each ECV product, need to define and justify Threshold /Breakthrough/ Goal for:

- Horizontal, Vertical and Temporal Requirements
- Uncertainty and Stability required for application
- Timeliness

Resolution	Treshold	Breakthrough	Goal	unit
Horizontal	500	100	50	km
Vertical	Depends on ECV	5	1	km
Temporal	30	1	0.01	day
Tlmeliness	360	7	1	day
Uncertainty	Treshold	Breakthrough	Goal	
Measurement	25%	5%	2%	
Stability	5%	2%	0.5%	

Reaching Aerosol ECV horizontal thresholds

- 500 km = approx 200 000 km²
 - Africa : 30 Mkm²
- = 150 stations



Below 150 regional stations, our understanding is incomplete

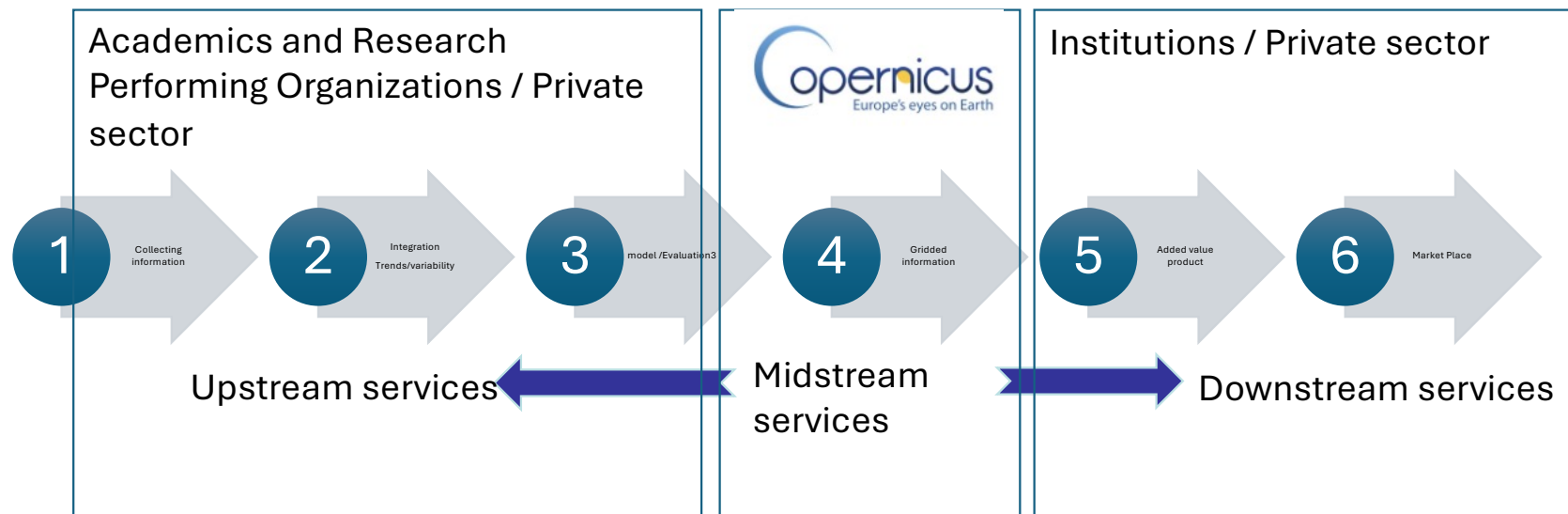
**12 or more climate biomes
54 Countries**

**12 GAW operational in 2022
20 AERONET operational in 2022
1 AGAGE operational in 2022
2 NDACC operational in 2022
3 GMOS operational in 2022**

**Others
may
exist, but
not**

The EO Value Chain

The use of data is not over after the scientific assessments



World Meteorological Organisation (WMO-OMM)

- Established in 1950 to coordinate the activities of national meteorology and hydrology services.
- It promotes cooperation for environmental observations.
- It defines protocols, exchange, processing, and standardization of data.
- 193 Member States





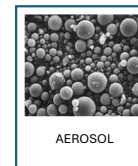
The Global Atmosphere Watch Programme

Monitoring Infrastructure: provision of atmospheric composition data from GAW network of stations.

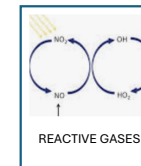
Scientific assessments: advance scientific understanding coordinating assessments on the state of the atmospheric composition

Science-for-Service Initiatives: engage with user communities for supporting Services, Policies, and Treaties

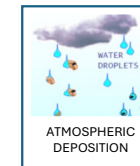
Capacity Building and education: provide training opportunities for GAW users from all regions



AEROSOL



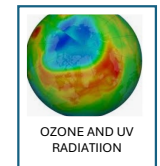
REACTIVE GASES



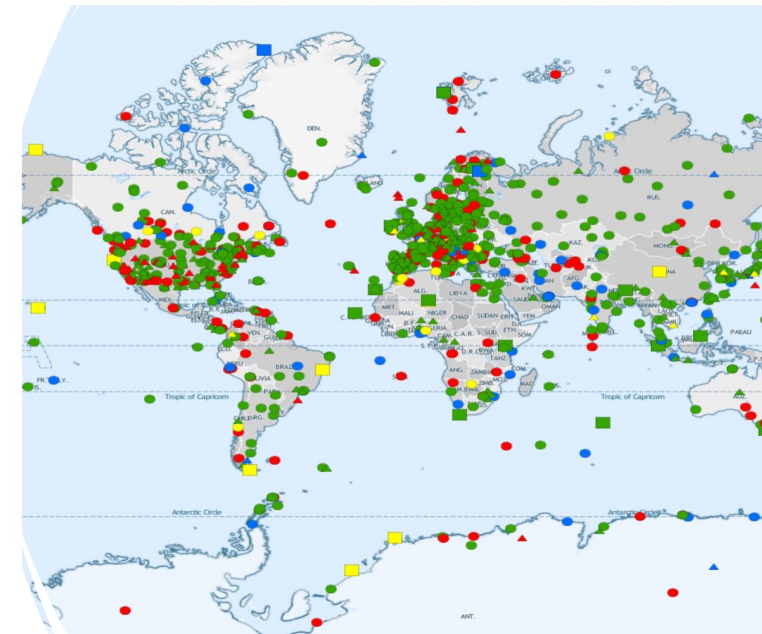
ATMOSPHERIC DEPOSITION



GREENHOUSE GASES



OZONE AND UV RADIATION





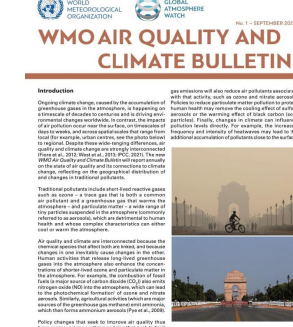
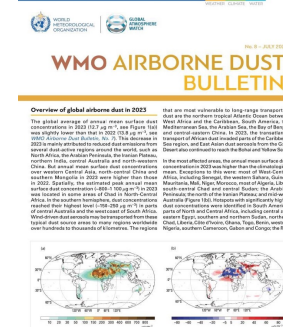
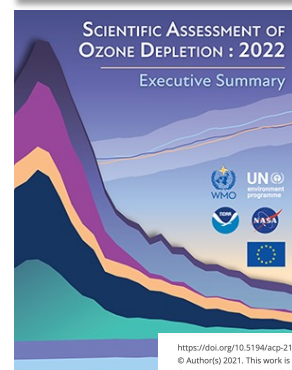
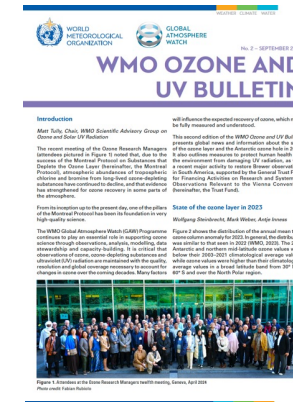
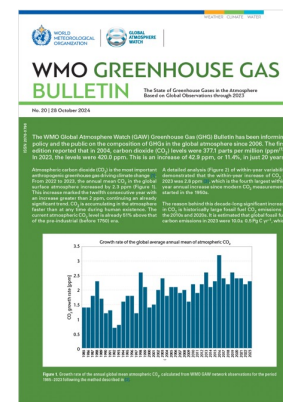
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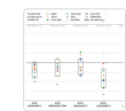
Research article |

Article Assets Peer review Metrics Related articles

06 Jan 2021

AeroCom phase III multi-model evaluation of the aerosol life cycle and optical properties using ground- and space-based remote sensing as well as surface in situ observations

Jonas Gllß, Augustin Mortier, Michael Schulz, Elisabeth Andrews, Yves Balkanski, Susanne E. Bauer, Anna M. K. Benedictow, Huiheng Bian, Ramiro Checa-García, Mian Chin, Paul Ginoux, Jan J. Griesfeller, Andreas Heckel, Zak Kipling, Alf Kirkevåg, Harri Kokkola, Paolo Laj, Philippe Le Sager, Marianne Tronstad Lund, Cathrine Lund Myhre, Hitoshi Matsui, Gunnar Myhre, David Neubauer, Twan van Noije, Peter North, Dirk J. L. Ollivé, Samuel Rémy, Larisa Sogacheva, Toshihiko Takemura, Kostas Tsigaridis, and Svetlana G. Tsyro





The Global Atmosphere Watch Programme

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Conclusions: Key factors for sustainable observations

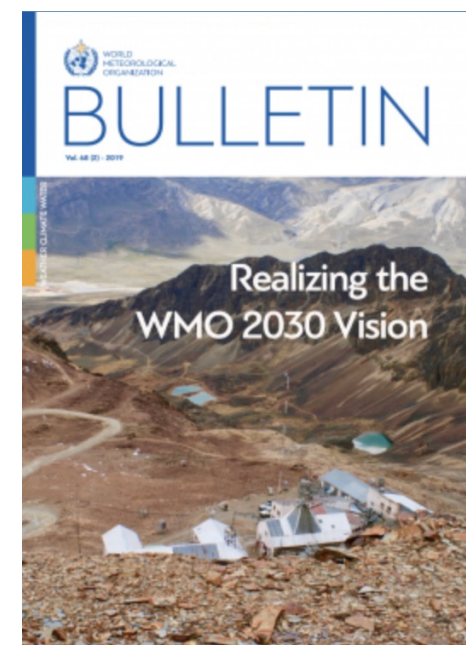
Raising awareness and stimulating demand for observations and information on climate and air quality

Holistic partnerships not restricted to National Meteorological and Hydrological Services but with relevant research communities.

Continued integrated GAW training and capacity- building not restricted to the technical dimension

Participation of women and empowering local people to make effective use of the environmental information and services provided.

Tailored implementation embedded in National and Regional Strategies avoiding fragmented flow of projects by different partners, resulting in a patchwork of observation infrastructures



Conclusions

- We are missing observation data from many areas of the World, technology-related but also data sharing issues
- Observations follow rules, otherwise not usable
- Open data is the future
- Imagine your downstream services
- **WE NEED A NEW GENERATION OF WOMEN AND MEN TAKING LEADERSHIP IN MAINTAINING EARTH OBSERVATION RUNNING**



GAW Newsletter

[View this email in your browser](#)



NEWSLETTER - *May 2025*

Announcements

WMO News

GAW Symposium 2026 (April 13-17)





THANKS!

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