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Atmospheric Monitoring of Substances Controlled under the Montreal Protocol

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Atmospheric monitoring under the Ozone treaties:

- The Vienna Convention
  for the Protection of the Ozone Layer and
- The Montreal Protocol
  on Substances that Deplete the Ozone Layer

Background information

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Substances Controlled under the Montreal Protocol

- Ozone-depleting substances (ODS)
- Hydrofluorocarbons (HFCs)

Production and consumption data and information reported annually by the parties to the Ozone Secretariat

Phase-out dates
for the consumption and production of controlled ODS

ODS	Phase-out dates	
	Non-Article 5 Parties *(developed countries)*	Article 5 Parties *(developing countries)*
CFCs	1 January **1996**	1 January **2010**
Halons	1 January **1994**	1 January **2010**
Carbon tetrachloride	1 January **1996**	1 January **2010**
Methyl chloroform	1 January **1996**	1 January **2015**
HCFCs	1 January **2020** *	1 January **2030** *
HBFCs	1 January **1996**	1 January **1996**
Bromochloromethane	1 January **2002**	1 January **2002**
Methyl bromide	1 January **2005**	1 January **2015**

* Limited consumption/production allowed for specific uses for 10 years after the phase-out dates

HFC phasedown schedule

	Non-Article 5 parties		Article 5 parties	
	Group 1*	Group 2*	Group 1#	Group 2##
Baseline formula	Average HFC consumption for 2011-2013 + 15% of HCFC baseline	Average HFC consumption for 2011-2013 + 25% of HCFC baseline	Average HFC consumption for 2020-2022 + 65% of HCFC baseline	Average HFC consumption for 2024-2026 + 65% of HCFC baseline
Freeze	-	-	2024	2028
1st step	2019 – 10%	2020 – 5%	2029 – 10%	2032 – 10%
2nd step	2024 – 40%	2025 – 35%	2035 – 30%	2037 – 30%
3rd step	2029 – 70%	2029 – 70%	2040 – 50%	2042 – 50%
4th step	2034 – 80%	2034 – 80%	-	-
Plateau	2036 – 85%	2036 – 85%	2045 – 80%	2047 – 85%

* Group 1: Non-Article 5 parties not part of Group 2

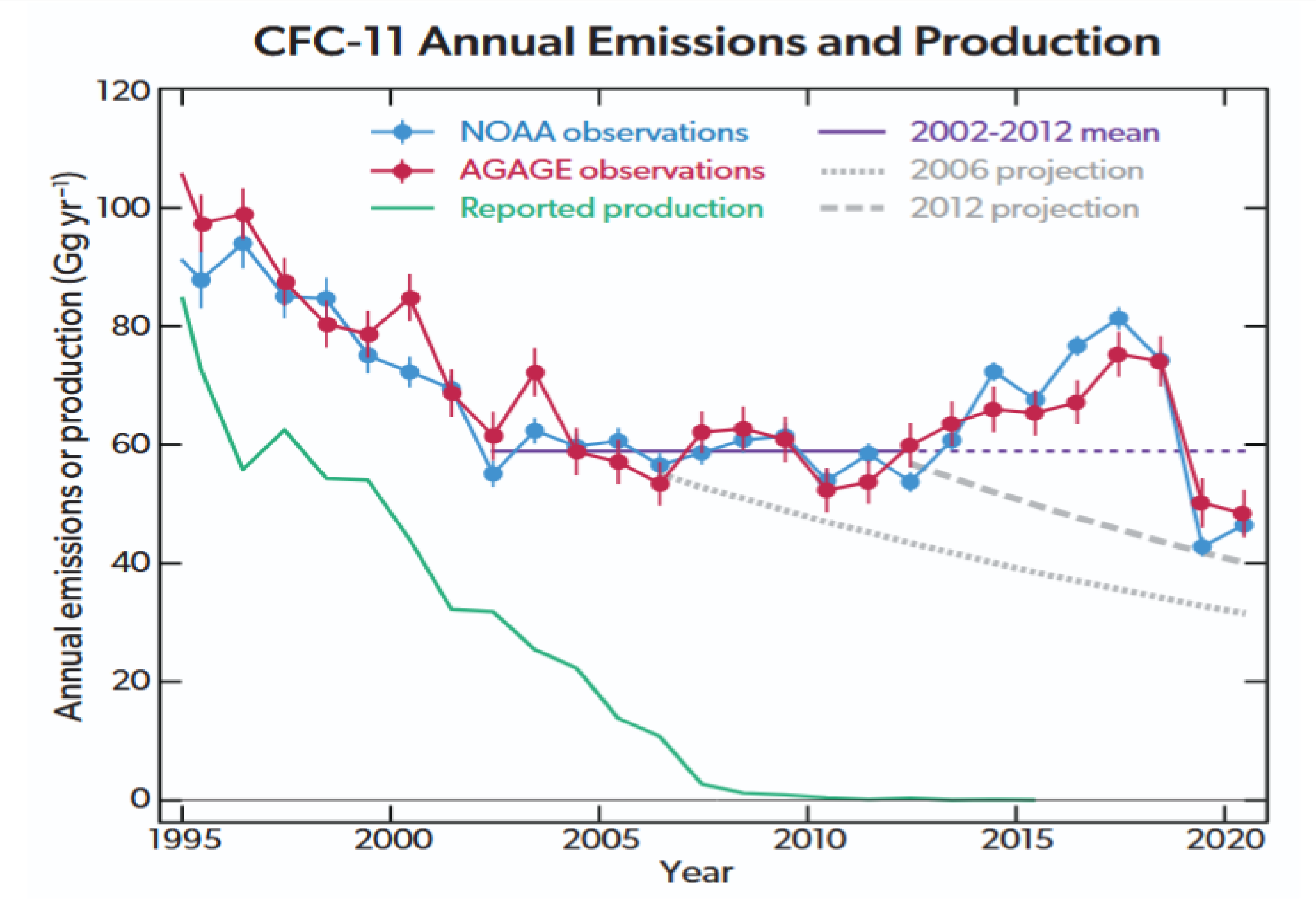
** Group 2: Belarus, Russian Federation, Kazakhstan, Tajikistan, Uzbekistan

\# Group 1: Article 5 parties not part of Group 2

\## Group 2: Bahrain, India, Iran, Iraq, Kuwait, Oman, Pakistan, Qatar, Saudi Arabia, UAE

Trends in CFC-11 global emissions and reported production

- Controlled CFC-11 phased out globally in 2010
- Identification of unexpected CFC-11 emissions during the period 2012-2018 led to scientific investigations and policy responses
- Analyses of atmospheric concentrations revealed the source region for about half of these emissions; substantial emission reductions after 2018
- Findings highlighted the importance of enhancing the regional atmospheric monitoring of controlled substances to identify sources of regional emissions



Source: 2022 Scientific Assessment of Ozone Depletion

Atmospheric monitoring of controlled substances – Key events

SAP: Scientific Assessment Panel
TEAP: Technology and Economic Assessment Panel
ORM: Ozone Research Managers

2018
Scientific findings on the unexpected increase in global CFC-11 emissions *(Montzka et al.)*

2018 2019
MOP Decisions XXX/3 & XXXI/3: Requests to SAP and TEAP to report on the atmospheric monitoring & modeling of CFC-11 emissions and potential sources

2019 2020 2021
Consideration of SAP and TEAP reports/information

ORM11 (2020, 2021)
Consideration of the SAP **White Paper**: ***"Closing the gaps in top-down regional emissions quantification: Needs and action plan"***

MOP35 (2023)
MOP Decision XXXV/14 Refining cost estimates and options for sustainable funding

ORM12 (2024)
Recommendations on gaps in monitoring of controlled substances

COP13/ MOP36 (2024)
COP Decision XIII/2
MOP Decision XXXVI/1

MOP37 (2025)
MOP Decision XXXVII/1

EU-funded pilot project *(Bhola Island, Bangladesh)*

Key funds relevant to atmospheric monitoring

- **The General Trust Fund for Financing Activities on Research and Systematic Observations Relevant to the Vienna Convention (GTF)**
  - An **extrabudgetary** fund, receiving **voluntary contributions** and providing **complementary support to developing countries and countries with economies in transition** to implement, through WMO, activities related to **monitoring of ozone**, **ultraviolet** (**UV**) **radiation and, from 2025 onwards, controlled substances**

Activities overseen by the ***Advisory Committee of the GTF***

Photo Credit: AEMET, MeteoSwiss, Stefan Christmann, SMN

- **The Multilateral Fund for the Implementation of the Montreal Protocol (MLF)**
  - A dedicated fund, supporting developing countries to comply with their obligations under the Montreal Protocol:
    - Phase out the production and consumption of ODS;
    - Phase down the production and consumption of HFCs

Activities overseen by the ***Executive Committee*** *of the MLF*

VC decision XIII/2 and MP decision XXXVI/1 (2024)

- Expanded the scope of the GTF to include support for activities on the atmospheric monitoring of controlled substances and its Advisory Committee to include experts in such monitoring
- Requested the Ozone Secretariat:
  - In consultation with the Advisory Committee, to organize **activities for evaluating the suitability of potential sites for monitoring emissions of controlled substances**
  - To report on the **work progress** to the meetings of the parties in 2025 and on **costs estimates and options for long-term financing**
- Requested the Executive Committee of the MLF to consider **funding modalities to support a limited number of pilot projects**

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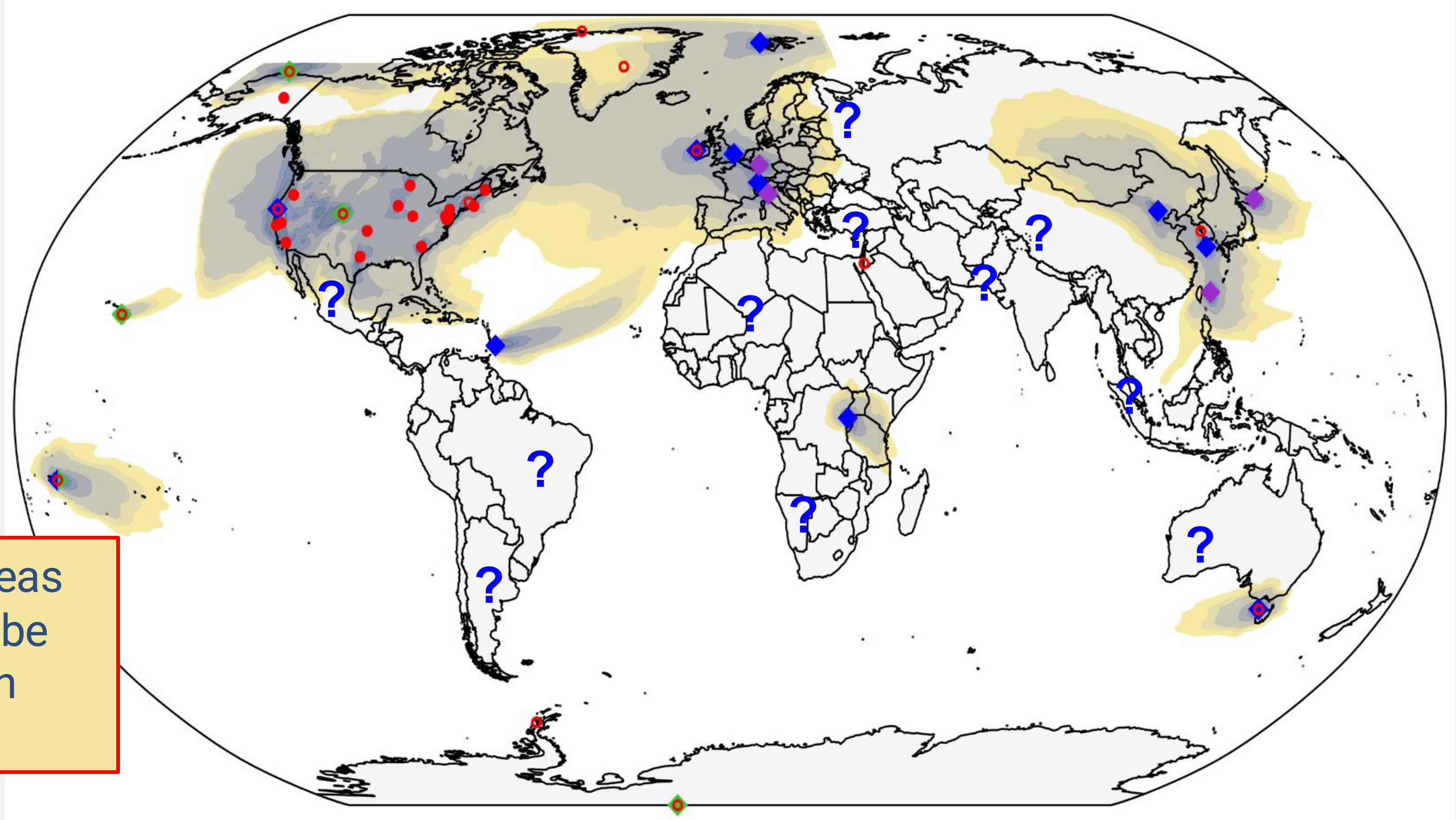
Closing the gaps

Existing atmospheric monitoring network *(White paper)*

- **AGAGE*** sites
  (*blue* & *purple*)
- **NOAA**** sites
  (*red* & *green*)



Shading represents areas where emissions can be reliably estimated on regional scales

Identification of suitable locations in under-sampled regions

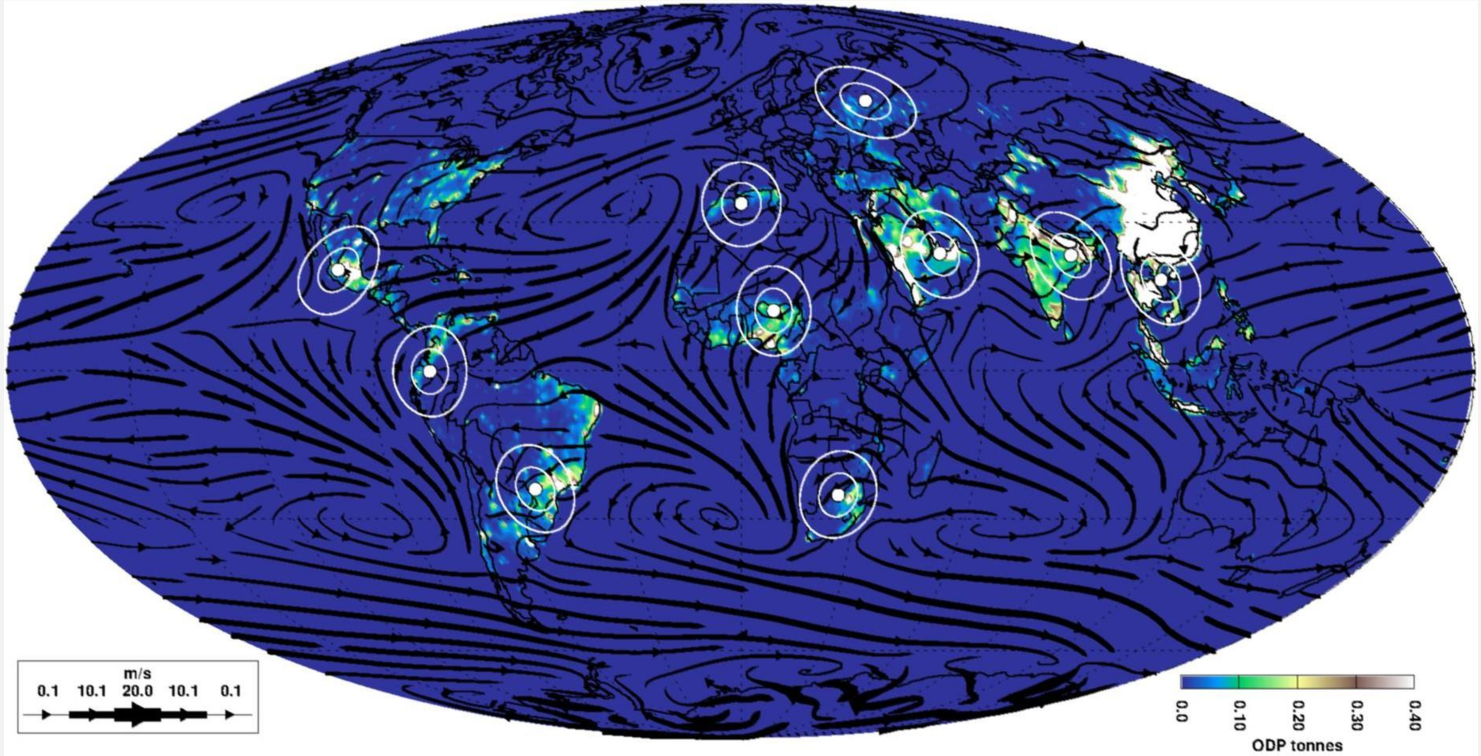
- Need to overlap potential emission regions with sites capable of "sensing" these emissions
- Well situated stations less than about 1000-2000 km from the source regions would be ideal

* *Advanced Global Atmospheric Gases Experiment*

** *National Oceanic and Atmospheric Administration*

Potential locations for monitoring emissions

Suggested by the Advisory Committee of the GTF



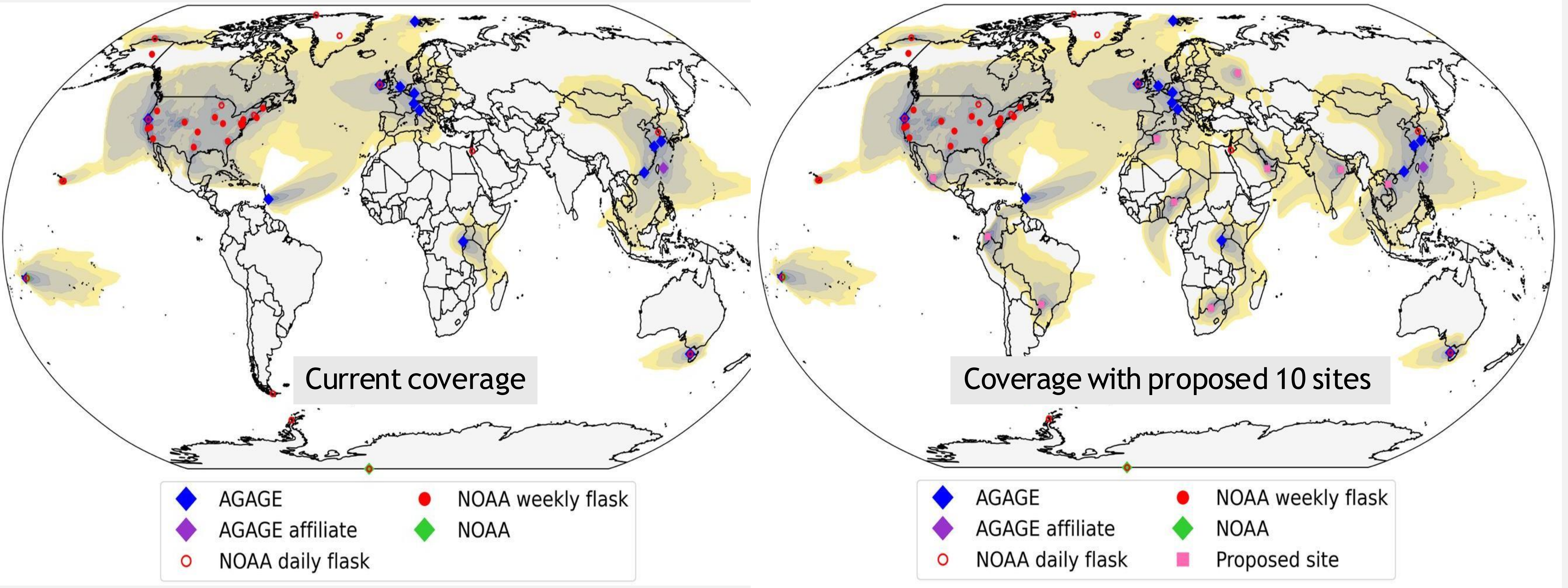
The plot shows:

- Regions with large emissions of MP gases
- Wind fields at 50 meters above ground
- Potential monitoring locations (central points of circles)
- Approximate regions from which potential sites could sample (circles of 500 and 1000 km around sampling sites)

HFC/CFC-11/CFC-12/CCl4 consumption (2011-2023) estimates for regions are available at: https://acd-ext.gsfc.nasa.gov/People/Newman/sfc_wind/surface_wind_climo_v3.html HCFC consumption data by Luke Western (Univ. of Bristol), shown in the above link. Similar results are obtained when consumption of other MP gases is used. Wind field analyses by Paul Newman (NASA/GFFC/UMBC).

*Based on **Observing System Simulation Experiments (OSSEs)***

Selected 10 locations fill major gaps in emissions



- Extending monitoring to 10 proposed locations provides better global coverage
- Collaborating with other institutions would further enhance coverage

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Monitoring approaches

Two (complementary) measurement approaches

1. **Flask sampling -** collect air samples, transport and chemically analyze them in central analytical laboratories

Transport

e.g., NOAA Laboratory

2. **High-Frequency in situ sampling** - collect and chemically analyze air samples at the station

Trinidad
Head
California
41°N

Collection
and analysis
on site

Measurement methods and needed infrastructure

Flask sampling

Infrastructure

High Frequency in situ

Some Critical Requirements:

- **Air Sampling Tower**
- **Road Access**
- **Reliable Electric Power**
- **Reliable Internet**
- **Air-Conditioned Lab**
- **No influence from local sources**

Making the necessary observations at the parts per trillion level is very hard

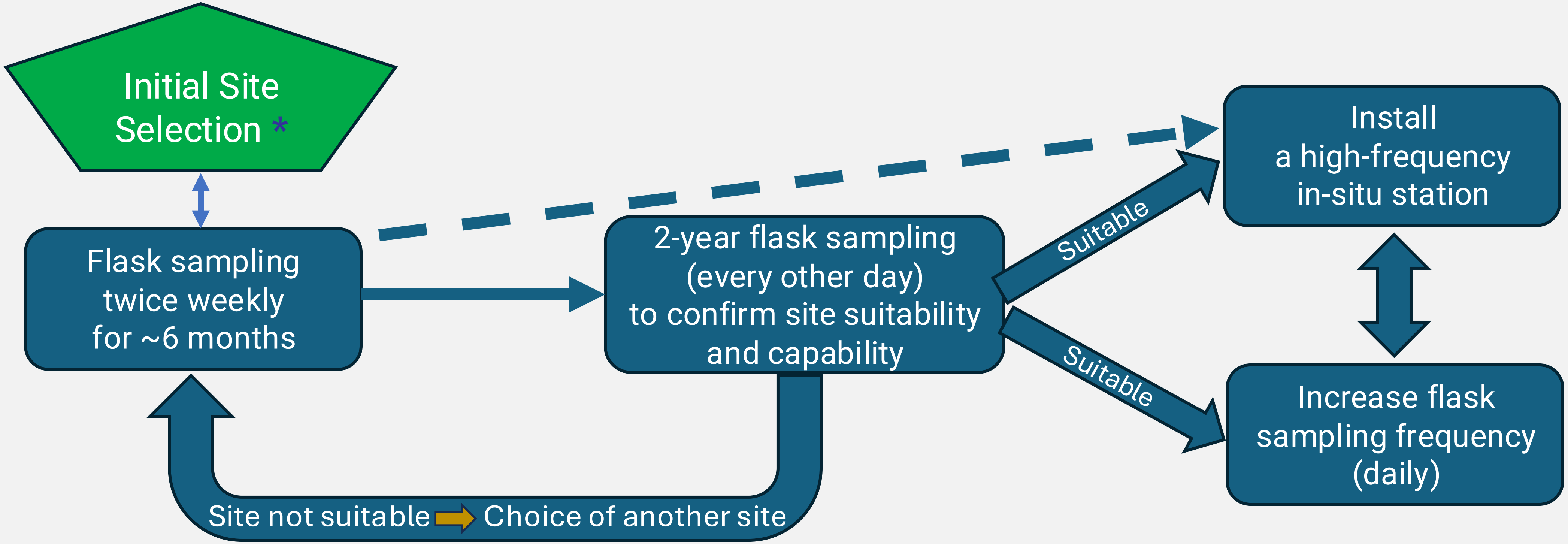
Mace Head
Ireland, 52°N

Cape Matatula
American Samoa, 14°S

Cape Grim, Tasmania,
Australia, 41°S

Phased approach for establishing monitoring stations

proposed by the Advisory Committee (October 2025)



* Includes **OSSEs** (Observing System Simulation Experiments) to assess site suitability on the basis of atmospheric transport patterns

Essential needs for a successful station

- **Scientific capability, interest and willingness** to be a part of the effort
- **OSSEs** for a specific site to assess its suitability before setting up a station
- **At least two inverse models to derive emission strengths from observations** – converting observations to emission strengths critically depends on modeling
- **Infrastructure** – Electricity, AC, internet connectivity, roads, security, etc.
- **Logistical support** to transport sampling flasks through customs and other regulations
- **Capable analytical facilities** for chemical analyses of collected samples (one per trillion level)
- **Common propagation (calibration) standards** to place measurements on a common footing
- **Data sharing** with the scientific community for extensive examination and placing data in accessible data centers

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Costs involved

Cost estimates for a 5-year measurement programme at a station

(in US dollars)

Costs *	Preparatory *phase*	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Phased approach leading to establishment of a high-frequency in-situ station							
Low-cost	13 000	201 700	44 400	595 000	114 000	114 000	**1 082 100**
High-cost	26 000	785 300	82 900	969 000	287 000	287 000	**2 437 200**
Phased approach leading to establishment of a daily flask sampling station *(manual)*							
Low-cost	13 000	201 700	44 400	104 300	92 500	92 500	**548 400**
High-cost	26 000	785 300	82 900	201 400	168 600	168 600	**1 432 800**

* Capital and operational costs

Preparatory phase: Costs for site identification and evaluation
Year 1 - Costs for survey sampling and first year of every-other-day flask sampling
Year 2 - Continued flask sampling at every-other-day sampling
Years 3-5 - High-frequency in-situ measurements or daily flask sampling

Estimated impact of infrastructure availability on cost savings

Station type	Key infrastructure *	Cost savings (% of total low costs)
High frequency in situ	Available	22
	Partly available	6
Daily flask sampling *(automated)*	Available	58
	Partly available	16

* E.g., Tower, building and power supply

“Piggybacking”, by integrating monitoring activities into existing monitoring programmes/networks (e.g., GAW stations), can reduce start-up costs and accelerate deployment – these options are still being explored

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Looking ahead

Implementation of MOP37 decision XXXVII/1 (2025)

Key elements

- The Ozone Secretariat requested to:
  - Continue, in consultation with the Advisory Committee, the evaluation of the suitability of potential sites within the 10 regions and locations identified so far, **and with the voluntary participation of and in consultation with the concerned parties**
  - Prepare, in consultation with the concerned parties that have expressed interest, for **possible next steps towards establishing monitoring activities at sites prioritized by the Committee, taking into account the suggested phased approach**
- The Executive Committee of the MLF requested to take into consideration the information provided when **developing guidelines and considering a funding window to support pilot projects**

Reports on progress and any outcomes of those activities to be provided to the 2026 meetings of the parties for their consideration

Cooperation and synergistic actions

- **Knowledge of the available infrastructure**

  Working with other observation programmes and networks such as WMO/GAW, other monitoring networks (e.g., for greenhouse gases and air quality) can help identify potential sites and available infrastructure, while developing synergies

- **Use of existing facilities (esp. towers) and in-kind contributions can greatly reduce costs**

- **Important to have qualified and willing partners at the sampling locations**

  Key lesson learned during the implementation of the EU-funded pilot project on Bhola Island, Bangladesh

- **Collaboration with other projects**

  10 potential sites examined so far as a starting set. To cover the globe, collaboration with other projects may help fill the gap

- **The wide availability of data to scientists around the world is essential to ensure good regional emission estimates**

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Thank you

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