MOP37

Nairobi, Kenya

3-7 November 2025

Enhancing the regional atmospheric monitoring of substances controlled by the Montreal Protocol (decision XXXVI/1)

Report by the Ozone Secretariat and the Advisory Committee of the General Trust Fund for Financing Activities on Research and Systematic Observations Relevant to the Vienna Convention (GTF)

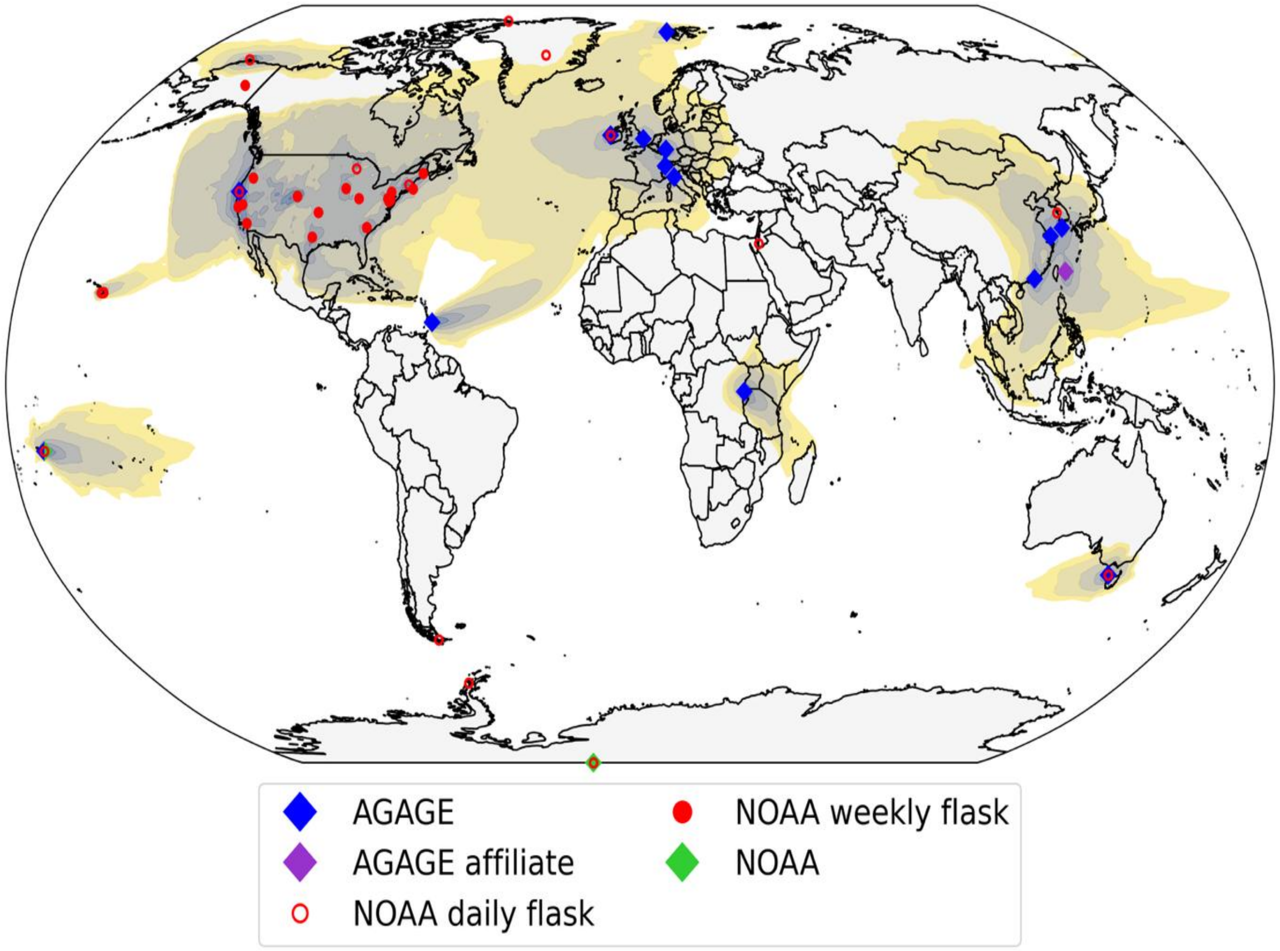
Vienna Convention
MONTREAL PROTOCOL

Progress reports in response to decision XXXVI/1

- The Secretariat and the Advisory Committee provided a progress report to the 47th meeting of the Open-ended Working Group (OEWG47)
- The progress report to MOP37 focuses on the following issues:
  - Evaluating the suitability of potential sites for monitoring regional emissions of controlled substances
  - Updates to cost estimates and options for long-term financing associated with enhancing atmospheric monitoring provided under decision XXXV/14
  - Workplan under funding streams in support of atmospheric monitoring of controlled substances

Evaluating the suitability of potential sites for monitoring regional emissions of controlled substances

Need for monitoring Montreal Protocol (MP) gases:
During the accountability phase, the parties may wish to know how the regional emissions of MP gases are changing to ensure the success of the Protocol



Goal: Fill the large gaps in monitoring and enable the parties to be aware of regional (and global) emissions for their consideration

Advisory Committee tasks for MOP37

- Identify and prepare a map of *possible monitoring locations* and the regions from which the emissions could be measured (XXXVI/1, para. 2) *(Done)*
- Identify and prepare a map of the *potential sites* for establishing monitoring stations in those locations (XXXVI/1, para. 3a(i), (iii)) *(Done)*
- Assist the Ozone Secretariat in updating its cost estimate options for long-term financing associated with enhancing atmospheric monitoring *(Done)*
- Develop a list of scientific institutions and projects (national and international) that work on atmospheric monitoring and related issues, with whom the Committee should ensure coordination, cooperation, synergies, and partnership (XXXVI/1, para. 3a(ii)) *(In progress)*
- Start planning for the longer-term work on calibration, validation of data, and data sharing (XXXVI/1, para. 3a(iv), (v)), as well as capacity building *(In progress)*

Summary of the Committee's work progress to date

1. Identification of locations for monitoring based on known controlled substance emission regions
2. Prevailing wind analyses to approximately determine locations.
3. Observation System Simulation Experiments (OSSEs) to identify locations for the establishment of stations to monitor emissions from regions of high emissions
4. A study on the impact of measurement frequency in deriving emissions of controlled substances
5. Lessons Learned from setting up a monitoring station on Bhola Island, Bangladesh

Items 3, 4, and 5 carried out under by the EU-funded Pilot project

Lessons learned from the Bhola Island Observatory

- Two years of measurements are necessary to have confidence in data and emissions
- Seasonal variations are (can be) significant (little regional emission signatures are observed when the wind flow is not favorable)
- Measurement difficulties are unavoidable; it takes time to overcome them
- Examination of the correlation between species with co-located sources or co-emissions provides confidence in data quality
- Oceanic emissions, e.g., CH_3I, show elevated levels due to the proximity of the site to the Bay of Bengal
- Local hydrocarbon (HC) emissions can interfere with the quantification of some measured MP gases. These interferences could be reduced or minimized, with a taller tower to minimize surface-level local emissions (data to date may be refined by accounting for HCs)
- Better to have a tower higher than 30 meters

Other lessons learned from Bhola Island and Advisory Committee discussions

- Imperative to have a qualified and willing partner at the sampling location (e.g., Prof. Salam from the University of Dhaka, Bangladesh)
- Logistical issues, including customs and transportation challenges, can delay data collection
- It takes time to identify, diagnose, and fix instrumental problems because of the distance between sampling and chemical analysis/expertise locations
- Data examination by multiple scientific groups is necessary
- Common propagation scale (for calibration) is essential (used AGAGE standards)

Key issues for monitoring MP gases *(1)*

- Calibration standards and calibration scales (propagation scales)

  Same propagation scales needed to place all data (measured and existing) and calculated emission strengths on a common footing. It is best to use the currently existing propagation scales of AGAGE and NOAA networks.

- Capacity for chemical analyses at various analytical facilities around the world

  There is sufficient capacity in existing analytical laboratories (approximately 2000 additional flask samples per year) to analyze expected increases in samples.

- Identification of potential partners in countries and regions of interest

  Ongoing activity - Contacts have been made with scientists in the Indian subcontinent and southern Africa. Contacts with a few other regions are to be established.

Key issues for monitoring MP gases *(2)*

- Knowledge of the available infrastructure

  The Ozone Secretariat, in collaboration with WMO, has cataloged various potential locations with available infrastructure. Global Atmospheric Watch (GAW) stations, The Comprehensive Nuclear-Test-Ban Treaty (CTBTO) sites, and other monitoring stations (e.g., for Greenhouse Gases) are being evaluated.

- Optimal heights of sampling towers

  Extensive discussions and OSSEs suggests that at least a 30-meter tower is needed. Higher towers would be beneficial. The cost of towers increases with height. Co-opting other towers (e.g., telecommunication towers) is being examined.

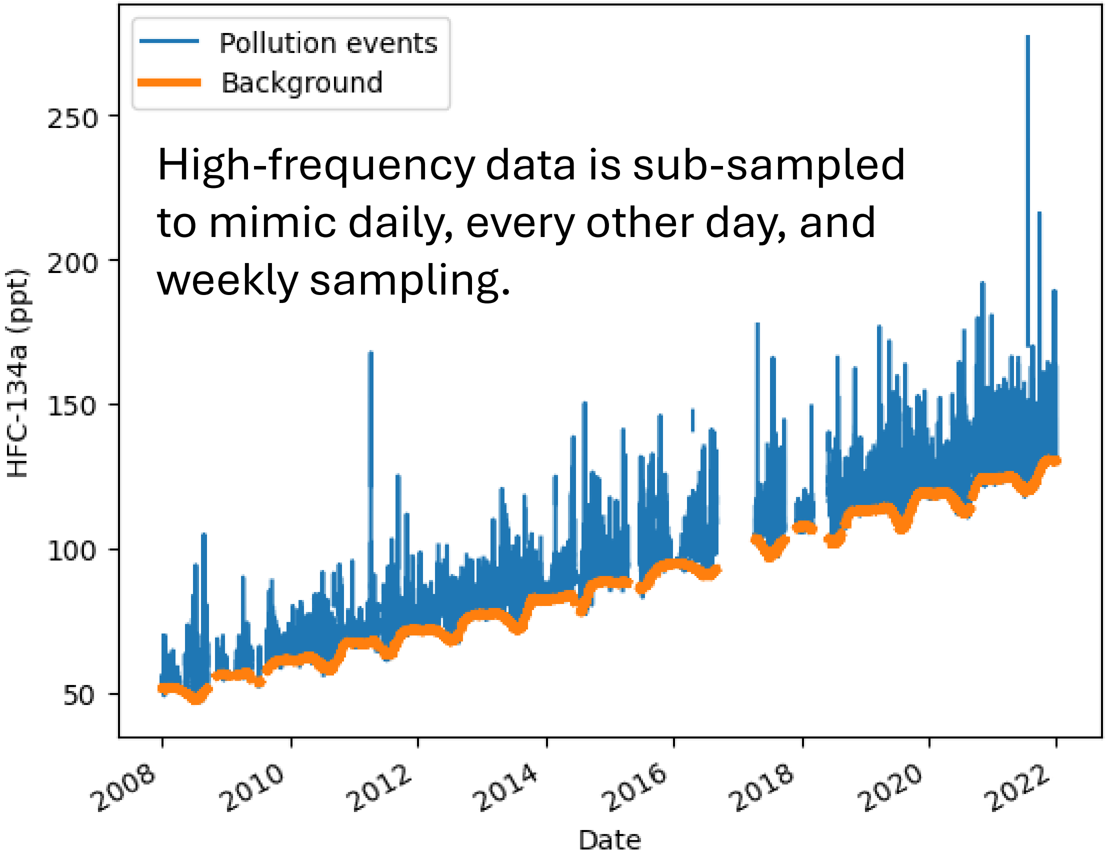
- Collaboration with other projects

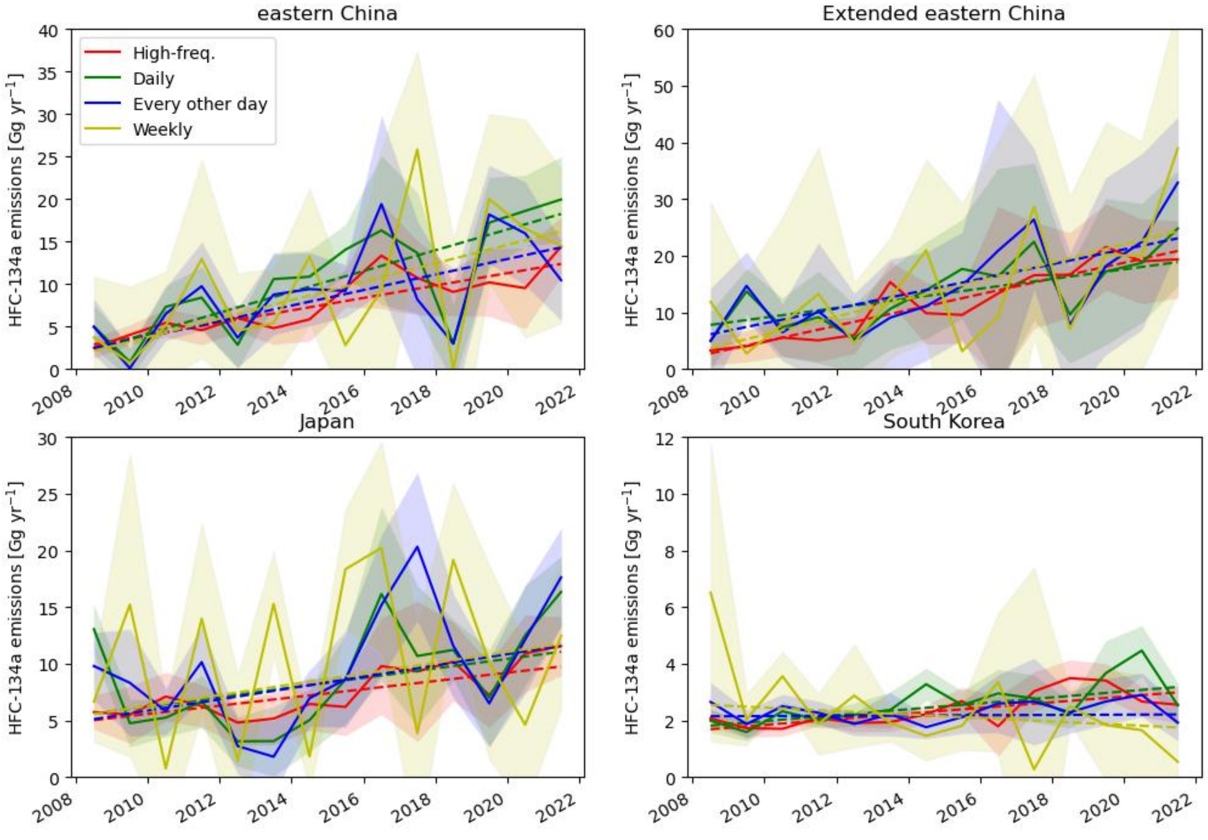
  10 potential sites examined so far as a starting set. To cover the globe, collaboration with other projects may help fill the gap; and such interactions are ongoing.

Key issues for monitoring MP gases *(3)*

- Observation System Simulation Experiments (OSSEs) - need & plans for using them
  Based on experts' input, one set of OSSEs is sufficient to identify the location.
  However, additional OSSEs are needed if the station is too far from the original location and/or if the orography is different
- Number of inverse models to extract emission strengths from observations
  Converting observations to emission strengths critically depends on modeling.
  Based on experts' input, at least two or more models need to be used to ensure accuracy and reproducibility of emission estimates.
- The wide availability of data to scientists around the world is essential to ensure good regional emission estimates.
- Data centers are needed to house the obtained data (along with metadata)
  The current plan is to use the ICOS data center. Mirroring data centers is essential for preserving data.

How often do we need to measure? A paper exercise *(1)*





Daily and every-other-day sampling close to that from high-frequency emissions and trends

Work done by Drs. Alistair Manning and Luke Western under the EU-funded project

Used UK Met Office Numerical Atmospheric dispersion Modelling Environment (NAME) (Jones et al., 2006)

How often do we need to measure? A paper exercise *(2)*

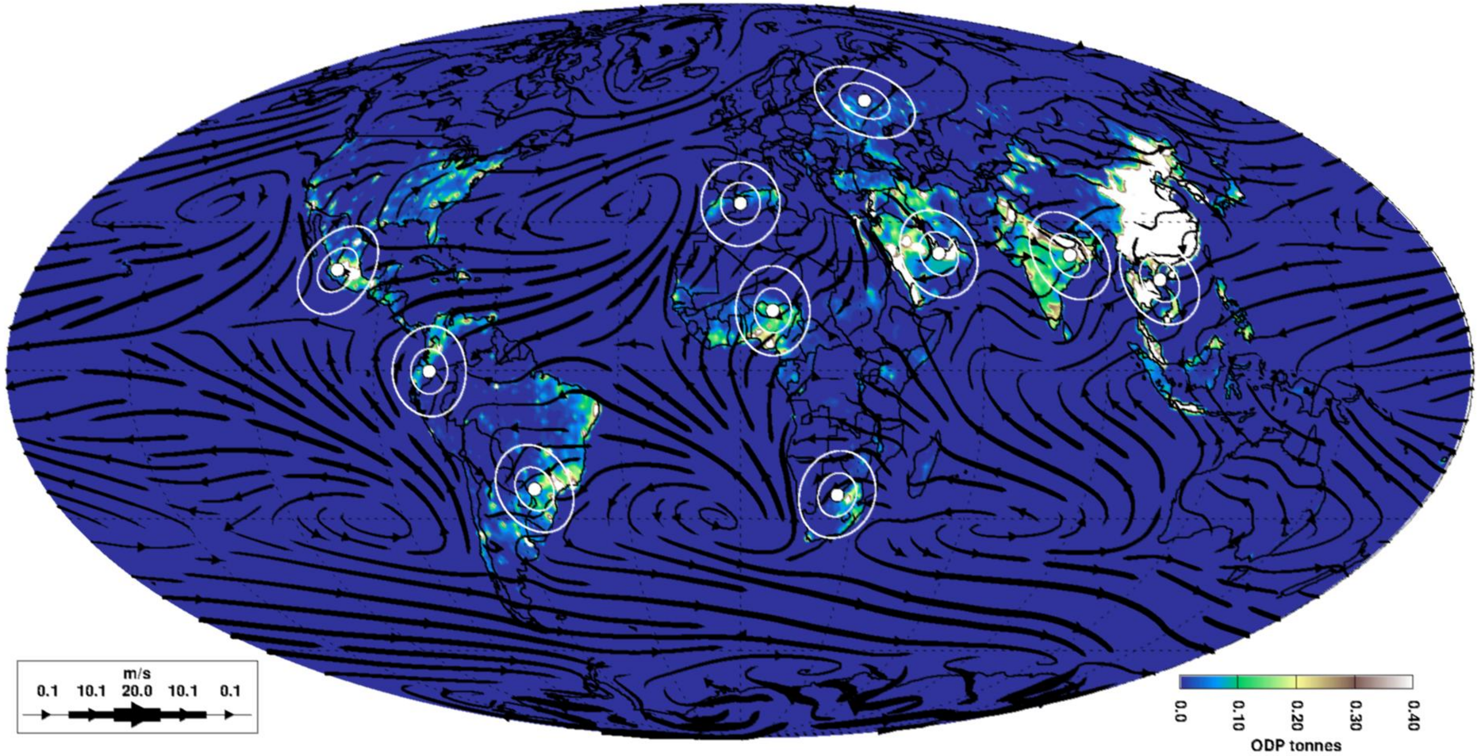
The linear increase in emissions of HFC-134a for countries and regions in East Asia over the period 2008-2021 in Gg per yr per yr. Uncertainties are one standard deviations.

	Eastern China	Extended eastern China	Japan	South Korea
High-frequency	0.7 ± 0.1	1.4 ± 0.2	0.4 ± 0.1	0.1 ± 0.02
Daily	1.2 ± 0.3	0.9 ± 0.3	0.4 ± 0.3	0.1 ± 0.03
Every other day	0.9 ± 0.2	1.3 ± 0.4	0.5 ± 0.3	0.005 ± 0.03
Weekly	1.1 ± 0.4	1.6 ± 0.5	0.5 ± 0.5	-0.06 ± 0.06

Key findings:

- Need twice-weekly sampling for survey period and daily sampling for two years.
- Uncertainties in regional emission trends were reduced with increased frequency.
- The higher the frequency of measurement, the better the definition of emission locations
- Similar conclusions were found for CFC-11 in this study
- Triangulation can improve the location of emission sources/regions.

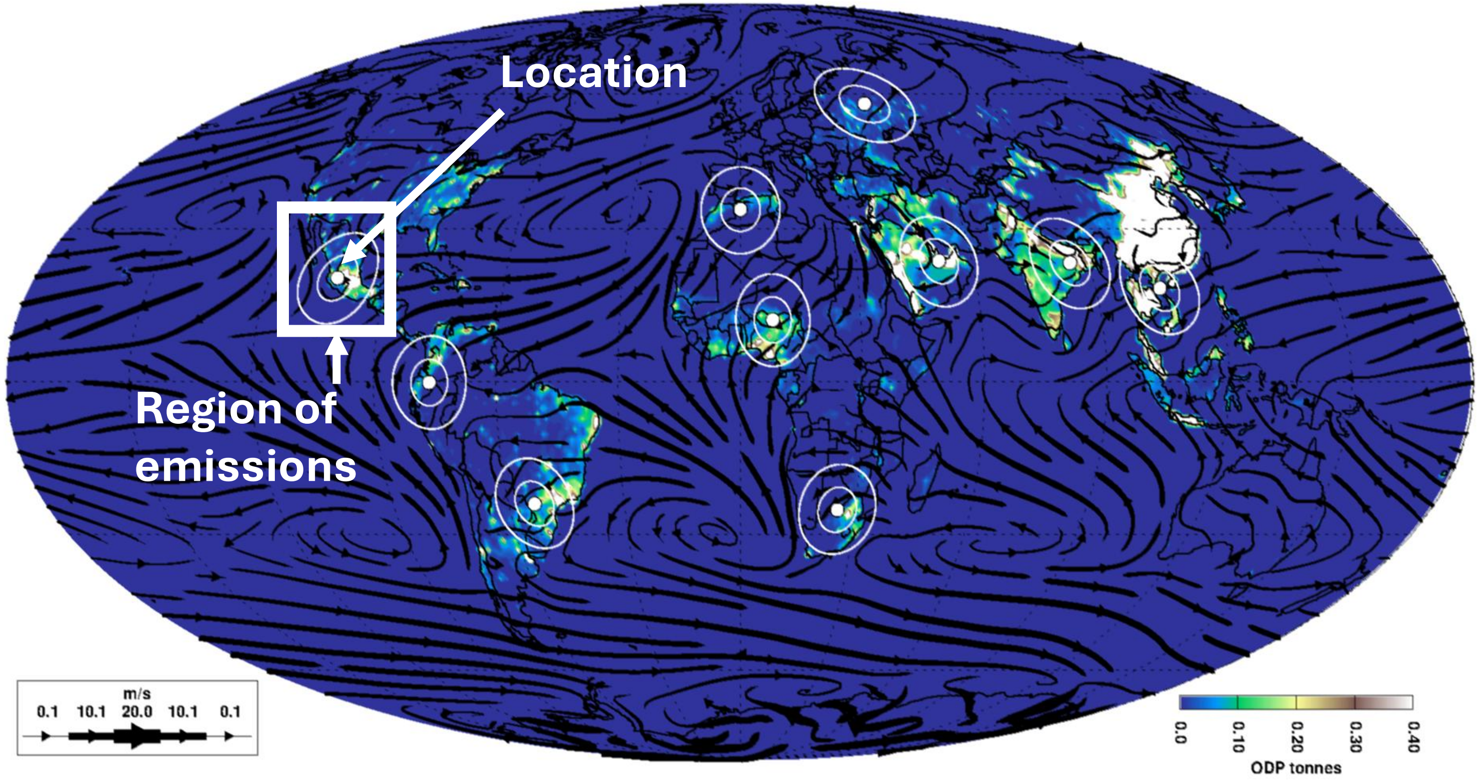
Potential locations for monitoring emissions



HFC/CFC-11/CFC-12/CCl4 consumption 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).

- Circles 500 and 1000 km around sampling sites, indicate the approximate regions the sites could sample
- The central points are potential suggested monitoring sites
- Based on the wind field at 50 meters above ground
- The plot shows the likely regions with large future emissions of MP gases
- Sites chosen may need new OSSEs

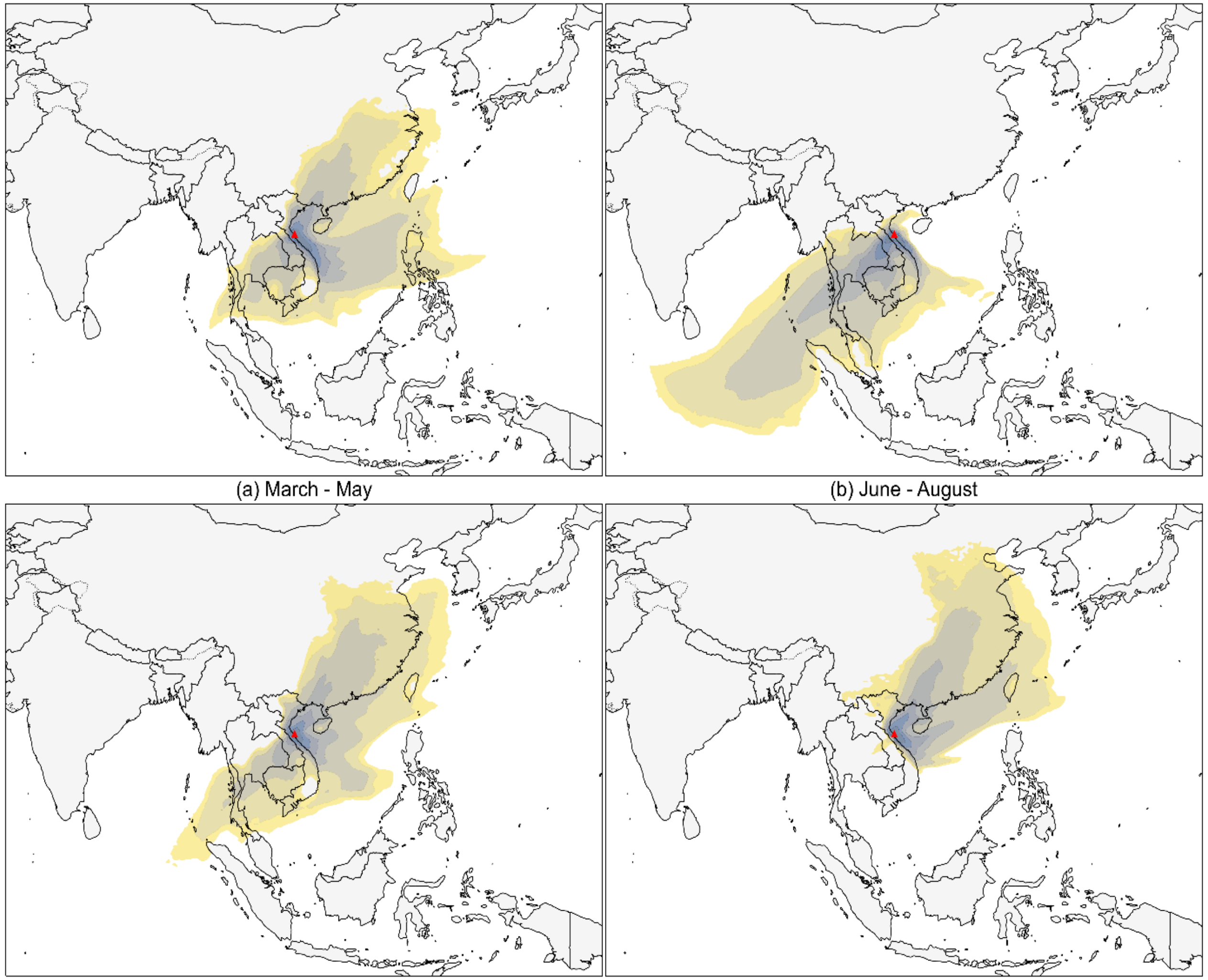
Definition of terms



Region - Geographical area from which emissions occur
Location - Geographical area suitable for monitoring from region of interest
Site - Exact place for monitoring
Station - Physical infrastructure to be built up (or existing) suitable for monitoring

Stations may sample different regions in different seasons

Lat: 18.2°N, Long: 106.3°E, height 20 m above ground



(a) March - May (b) June - August (c) September - November (d) December - February

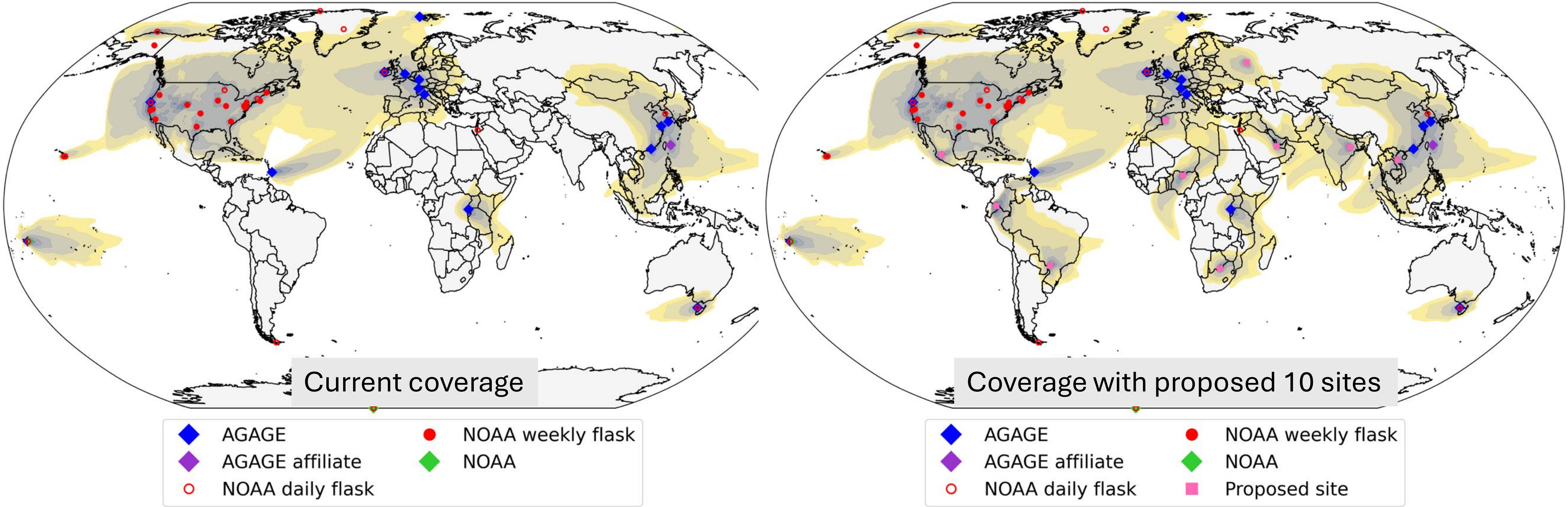
- Essential to examine multiple seasons
- Need for multi-year measurement
- Seasonality also helps locate emission regions

Essential needs for a successful station - beyond science

Messages from the whitepaper, workshop, pilot project and extensive discussions

- Scientific capability, interest, and willingness to be a part of the effort
- OSSEs for the specific site before setting up a station
- Infrastructure – Electricity, AC, internet connectivity, roads, security, etc.
- Logistical support to transport sampling flasks through customs and other regulations (especially for the "survey period")
- Capable analytical facilities for chemical analyses of the collected samples (only a few facilities in the world, and they are stressed, but enough for the next few years. Additional capabilities emerging including in European and Chinese facilities)
- A common propagation (calibration) standard to place measurements on a common footing (AGAGE and NOAA networks now provide calibration standards; frequently intercompared). Additional calibration centers planned.
- Sharing data with the scientific community for extensive examination & placing data in accessible data centers

Selected ten locations fill major gaps in emissions



- OSSEs carried out for the proposed 10 sites (annual footprint shown, but seasonal footprints available)
- Extending to 10 proposed locations provides better global coverage
- Further funding beyond a pending EU grant is needed to initiate all the proposed 10 stations
- Collaborating with others (e.g., those funded by NGOs) would further enhance coverage
- Funding needed to expand and continue beyond the pending EU funding

Two (complementary) measurement approaches

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

Transport

e.g., NOAA Laboratory

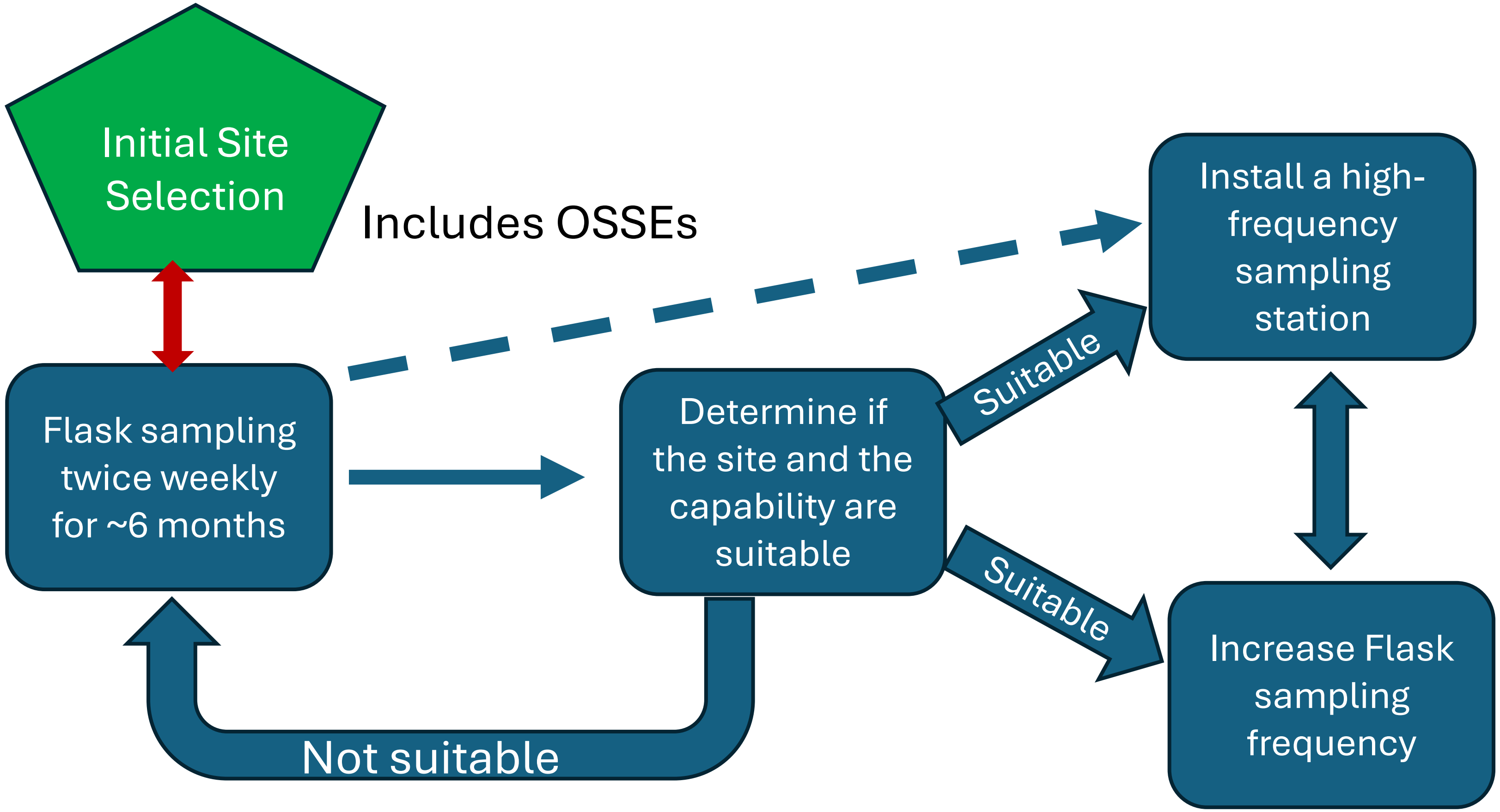
2. High-Frequency measurement- collect and chemically analyze them at the station

Trinidad
Head
California
41°N

Collect
And
Analyze on site

Flowchart for establishing monitoring stations

Phased approach - endorsed by the Advisory Committee at its 19th meeting (2 October 2025)



Once a station (and associated personnel expertise) is ”tested and found suitable”, consider establishing high-frequency measurement instrumentation at the site (can happen after 6-24 months)

Note: There is no specific timeline. Specifying timeline critical after a project is proposed or started.

Selected regions and locations

- Based on strengths of emissions, OSSEs, knowledge of available infrastructure, and expertise, the Advisory Committee selected the following regions and locations:

    1. Southern Asia (India/Bangladesh)
    2. South-East Asia (Viet Nam)
    3. Southern Africa (Botswana/South Africa)
    4. Middle East (Saudi Arabia)
    5. Central/Southern South America (Brazil/Argentina)

- Other potential regions examined

    - North Africa (Algeria)
    - North America (Mexico)
    - Northern South America (Ecuador)
    - Eastern Europe (Russian Federation)
    - West Africa (Nigeria)

These regions have not yet been prioritized

Updates to cost estimates associated with enhancing atmospheric monitoring

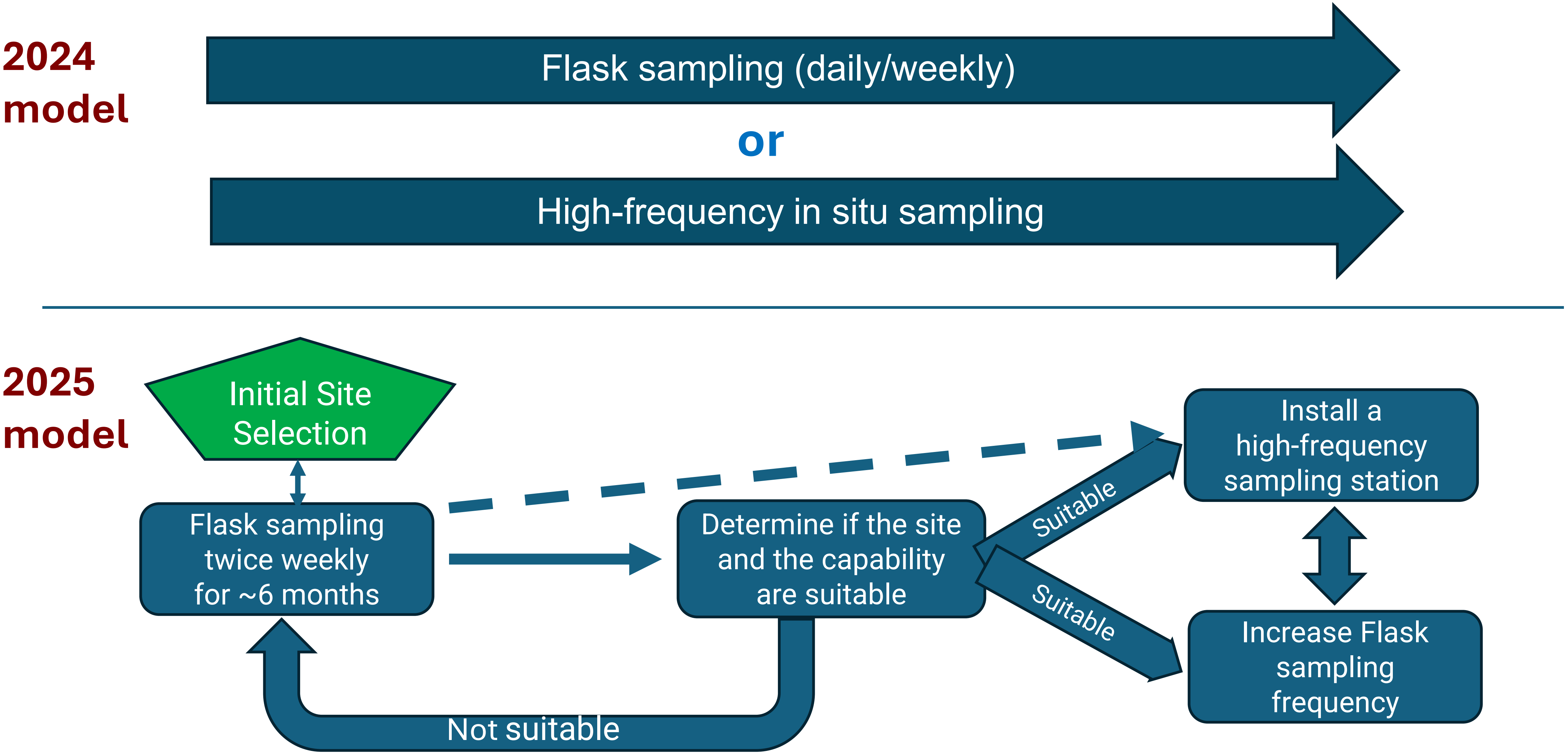
- Updates to the costing model in response to decision XXXV/14 (2024 model):
  (a) A new monitoring approach
  (b) Refinements to cost categories including previously missing cost items (e.g., personnel) and explicit consideration of specific activities (e.g., site identification and knowledge transfer)
  (c) Costs for establishing and operating all required elements depending on site location and available infrastructure

- The updated costing model (2025 model) is based on inputs from current monitoring groups and informal discussions held with Advisory Committee experts in atmospheric monitoring

Key costing model updates

2024 Model	2025 Model
Monitoring Approach	
A “fixed approach” involving either: - low frequency flask sampling or - high-frequency in situ sampling throughout the monitoring period	A “phased approach” involving: (a) Site selection (b) A twice-a-week flask sampling survey (c) 2-year alternate-day flask sampling (d) Long-term monitoring with high-frequency in situ or daily flask sampling
Cost categories	
6 cost categories comprising 11 cost items, with costs classified as either capital or operational	9 cost categories comprising 36 cost items, with capital and operating costs for each cost item, as appropriate
Low and high-cost estimates	
Range of estimates based on available or non available infrastructure	Range of estimates based on variability in costs depending on site location and type of available infrastructure

Monitoring approach



Cost refinement examples

2024 Model	2025 Model
Cost item: Sampling tower	
Only capital costs included (i.e., tower construction)	Capital (e.g., tower, foundations, lightning protector) and operational costs (e.g., safety inspections, painting, tensioning) included
Cost item: GC/MS* instrument of a high-frequency in situ station	
Only capital costs included (i.e., GC/MS instrument with ancillary equipment)	Capital (i.e., GC/MS instrument with ancillary equipment) and operational costs (e.g., maintenance, replacement of plumbing and fitting parts) included

* Gas Chromatograph-Mass Spectrometer

Updated cost estimates for a 5-year measurement programme at a station

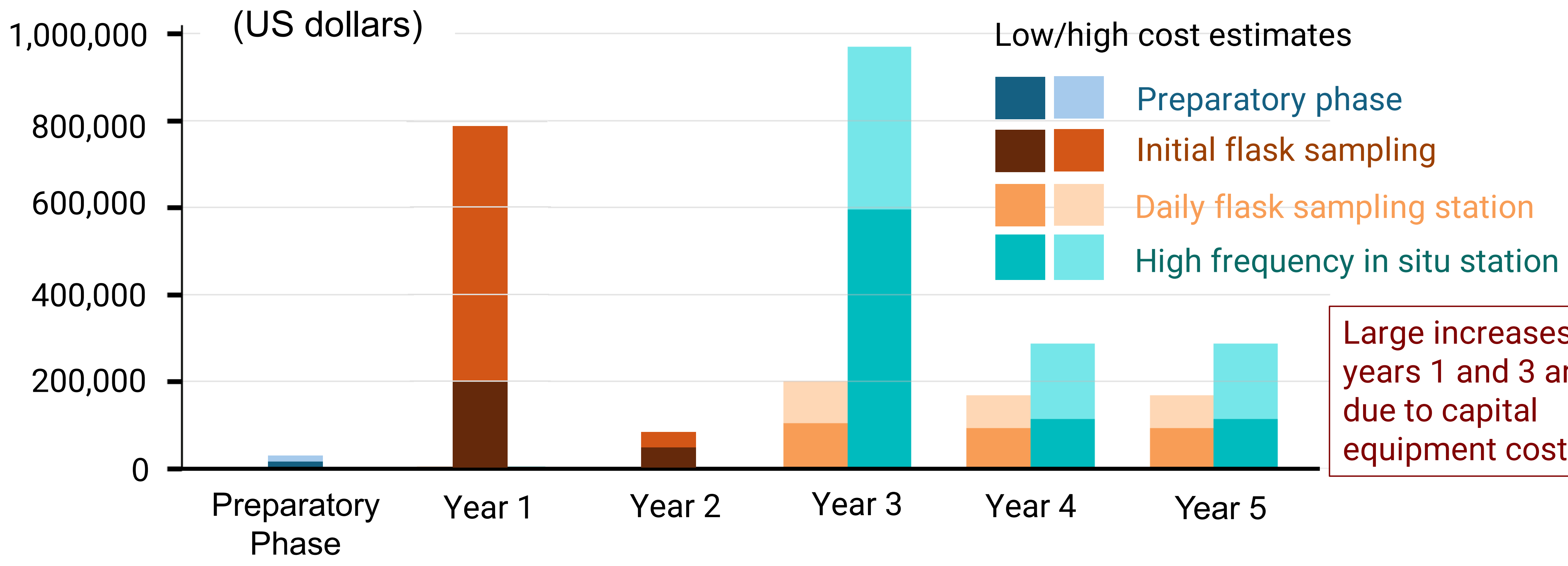
(in US dollars)

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

Updated cost estimates for 5-year measurement programme

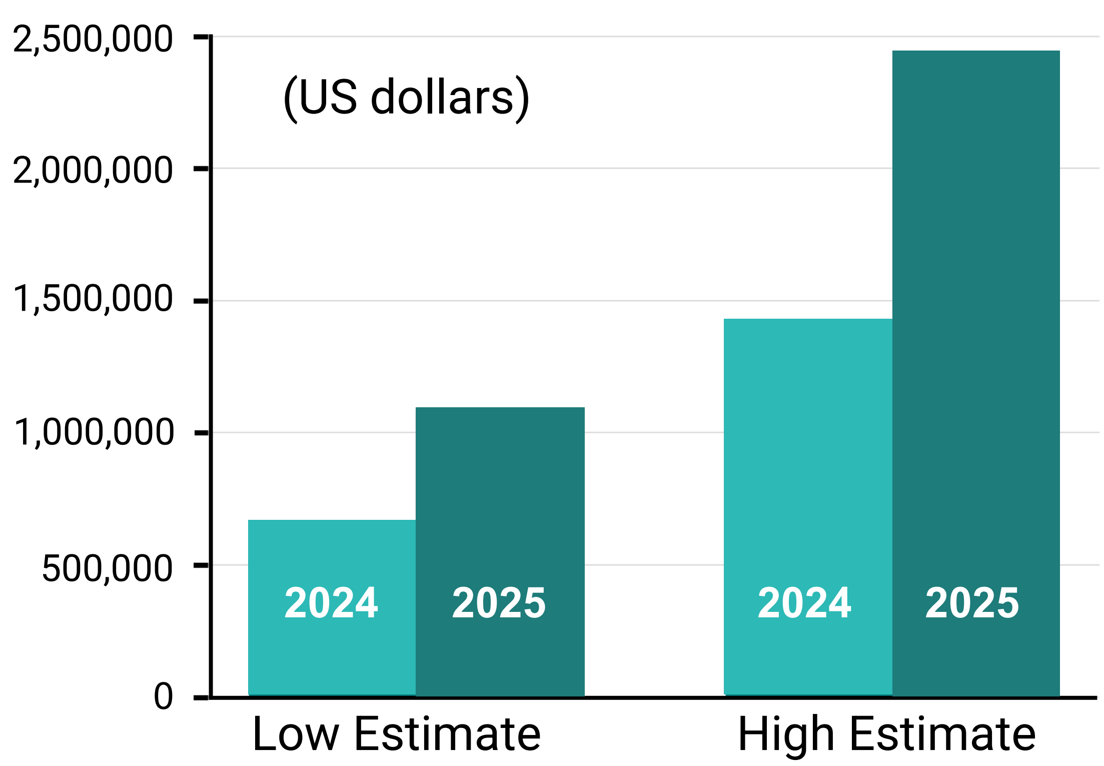


Large increases in years 1 and 3 are due to capital equipment costs

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

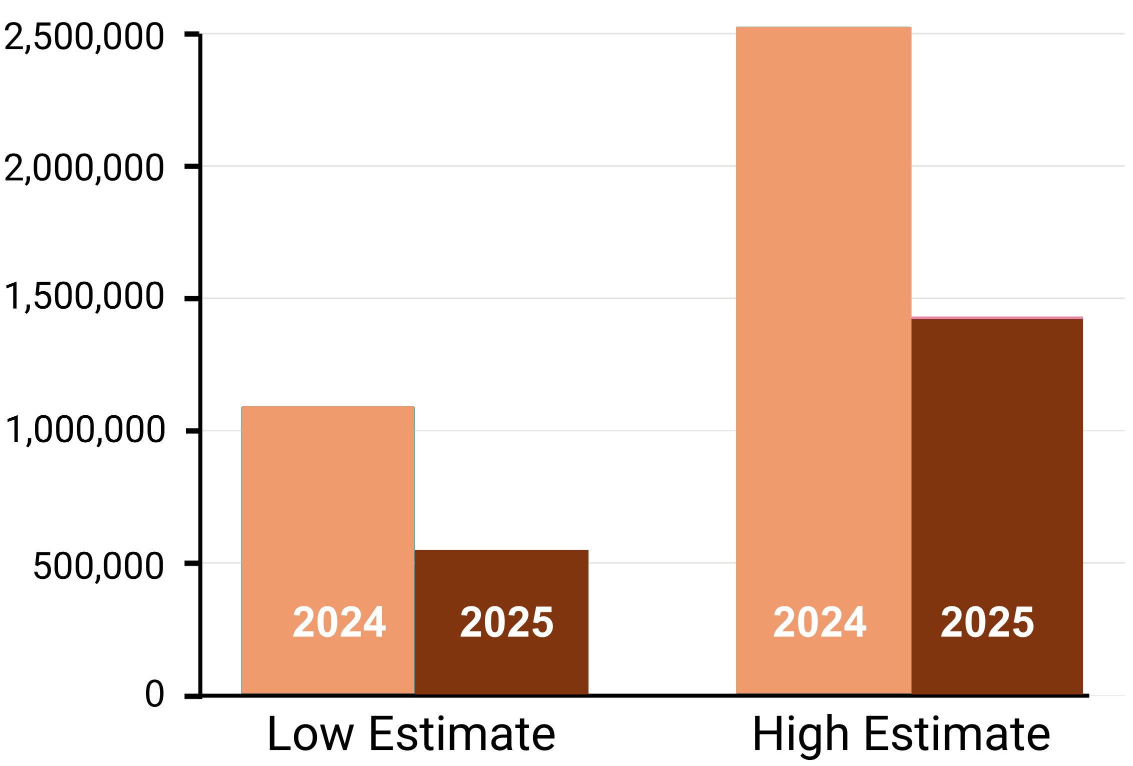
Total cost estimates for the establishment and operation of one station based on the 2024 and 2025 models

High-frequency in situ station



Higher 2025 model estimates due to inclusion of additional capital cost items for towers, itemized operational costs and personnel costs

Daily flask sampling station



Lower 2025 model estimates due to assumptions about infrastructure reuse and phased capacity building

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Programmatic approach *(mix of stations)*

Costs ranges for a 5-year measurement programme using the phased approach

Expansion type	Low cost	High cost
	Grand totals * (US dollars)	
- Modest expansion: 2 high-frequency and 3 daily flask-based sampling stations	5 208 593	12 541 970
- Aggressive expansion: 4 high-frequency and 6 daily flask-based sampling stations	10 417 186	25 083 939

* Including estimated capital and operational costs plus contingency, programme management and programme support costs

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, CTBTO sites), can reduce start-up costs and accelerate deployment – these options are still being explored

2025 model development

- Current user-defined variables:
  - Height of sampling tower (30 m or 100 m)
  - Method of flask sampling during survey period (automated or manual flask sampling)
  - Number of years of flask sampling at every-other-day sampling frequency
  - Choice of daily flask sampling or high-frequency in situ measurement for long-term monitoring
- The Secretariat is developing the 2025 model into a user-friendly interactive online tool for use by interested parties to estimate costs for establishing and operating of stations in their countries

Workplan under funding streams in support of atmospheric monitoring

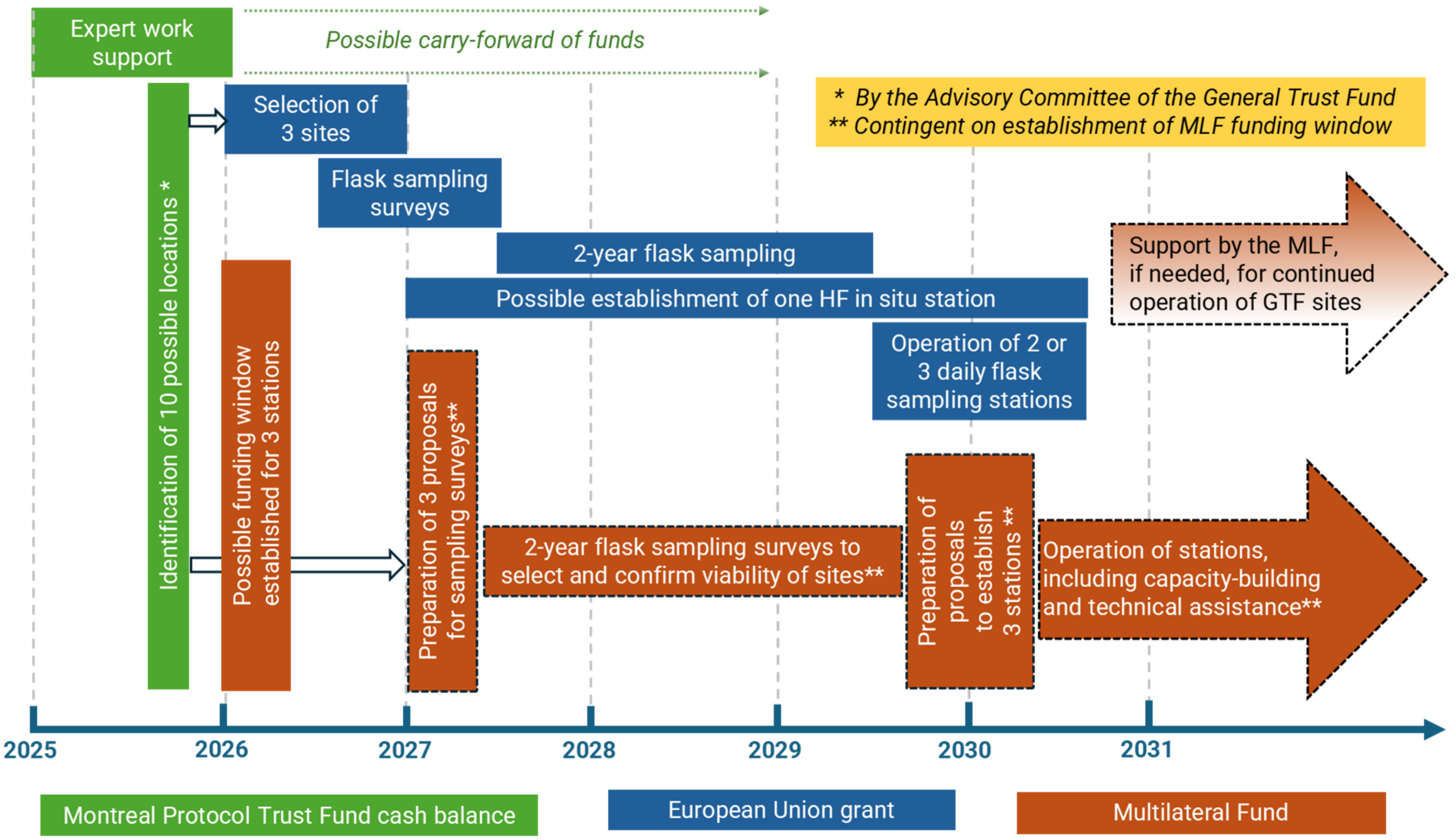
- Existing and potential financial streams to support work on atmospheric monitoring of controlled substances:

  (a) The 2025 budget of the Trust Fund for the Montreal Protocol (MPTF) – Cash balance (US$ 400,000)

  (b) Pending EU grant to the GTF (€ 4.5 million / ~ US$ 5.2 million)

  (c) Pending funding window under the Multilateral Fund

Action areas and estimated timeline of existing and potential funding streams



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Thank you for your attention

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