Synthesis of the 2022 Assessment reports of the Scientific Assessment Panel, the Environmental Effects Assessment Panel and the Technology and Economic Assessment Panel

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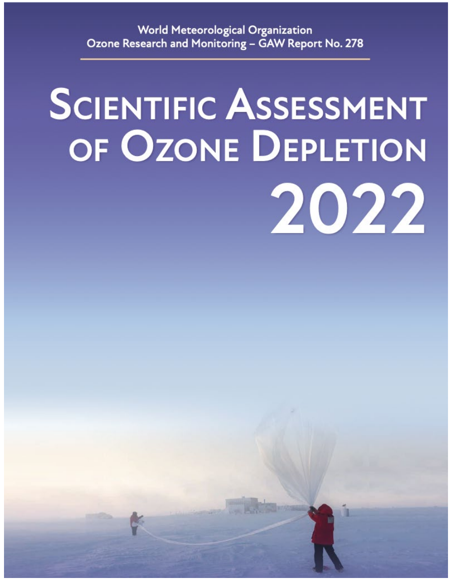
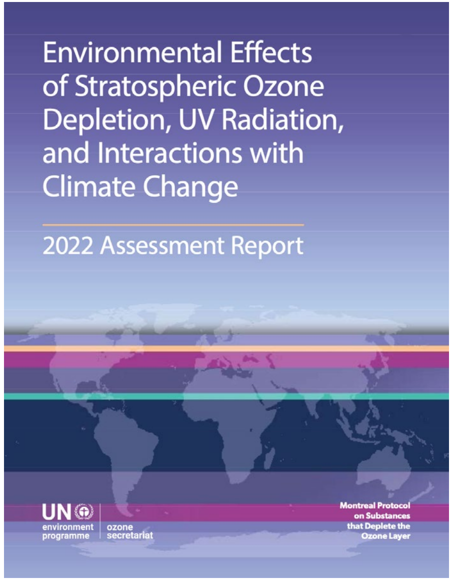
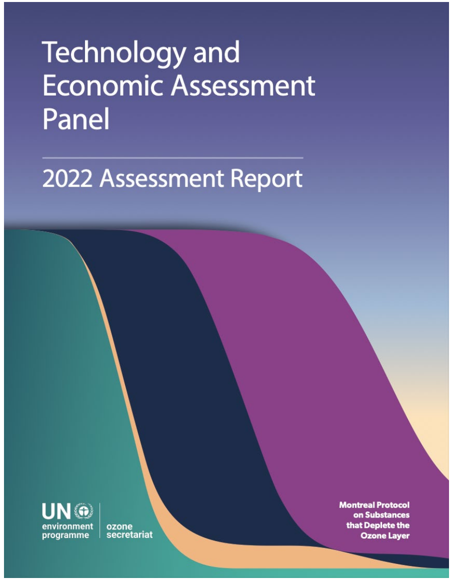
The 2022 Quadrennial Assessment of the Montreal Protocol (Decision XXXI/2)
35th Meeting of the Parties, Nairobi, Kenya, 23 October 2023

The Synthesis Report is the combined key findings from the three Assessment Reports of the SAP, EEAP, and TEAP







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We are grateful to the various authors of SAP, EEAP, TEAP and its TOCs reports - without them, this report would not have been possible

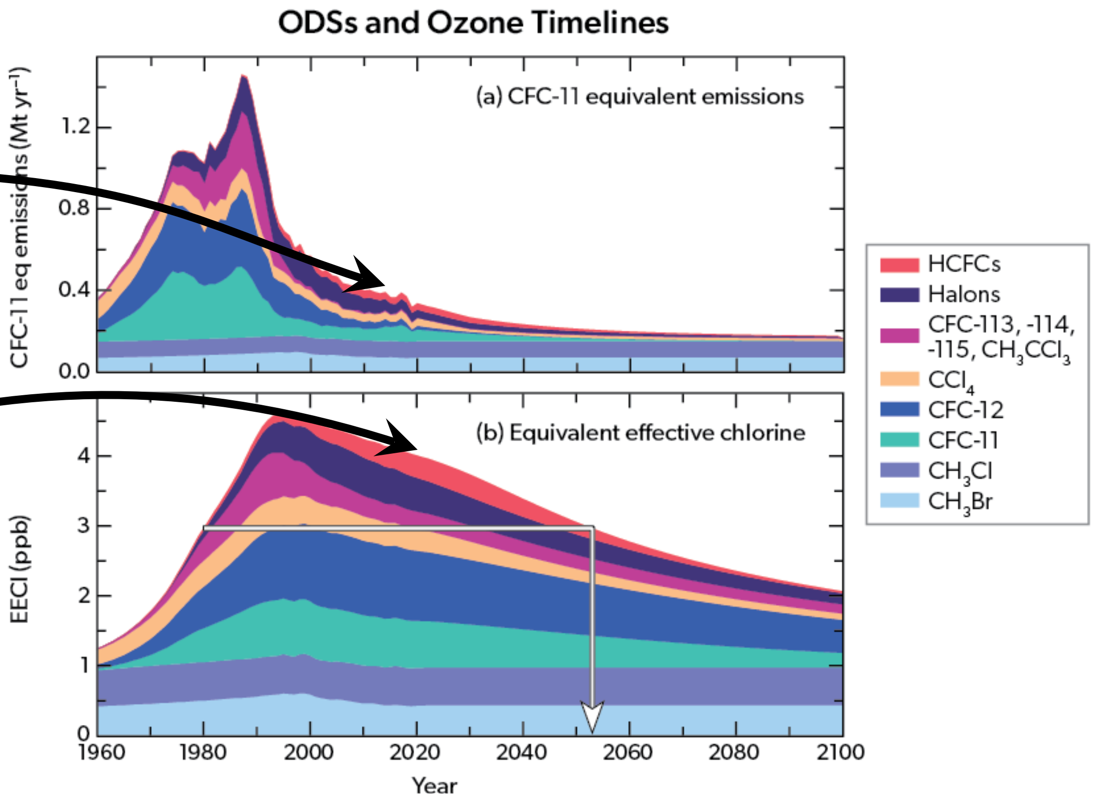
Ozone Depleting Substances

- Actions under the Montreal Protocol support continued progress in consumer, commercial, industrial, agricultural, medical and military sectors, with ODS no longer used in many applications worldwide
- Actions taken under the Montreal Protocol have continued to decrease atmospheric abundances of controlled ozone-depleting substances and advance the recovery of the stratospheric ozone layer

Actions taken under the Montreal Protocol have continued to decrease atmospheric abundances of controlled ozone-depleting substances and advance the recovery of the stratospheric ozone layer

- Total emissions of ODSs continue to decline

- Atmospheric chlorine and bromine levels continue to decline



MOP35

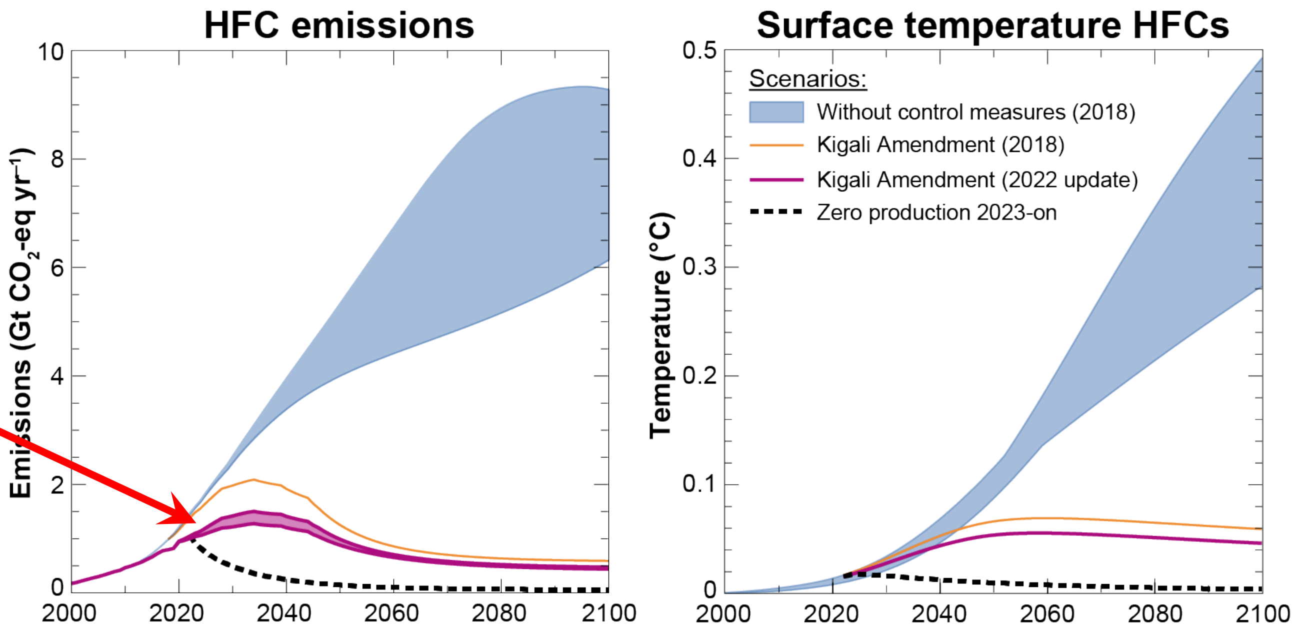
HFCs and Kigali Amendment

- 95% of future HFC use will be for the Refrigeration Cold Chain and Space Cooling, demand for which is increasing.
- HFC are powerful greenhouse gases – without HFC controls there would be a substantial impact on climate
- The planned HFC phase-down under the Kigali Amendment, as well as national and regional regulations, are driving industry towards lower-GWP HFC alternatives or not-in-kind technologies, particularly in RACHP and foam applications
- If Kigali is fully implemented, it will almost completely mitigate the climate impact of HFCs

The significant decreases in projected HFC emissions from the provisions of the Kigali Amendment will substantially protect future climate

HFC emissions and temperature

Currently, global atmospheric abundances and emissions of most HFCs are increasing.

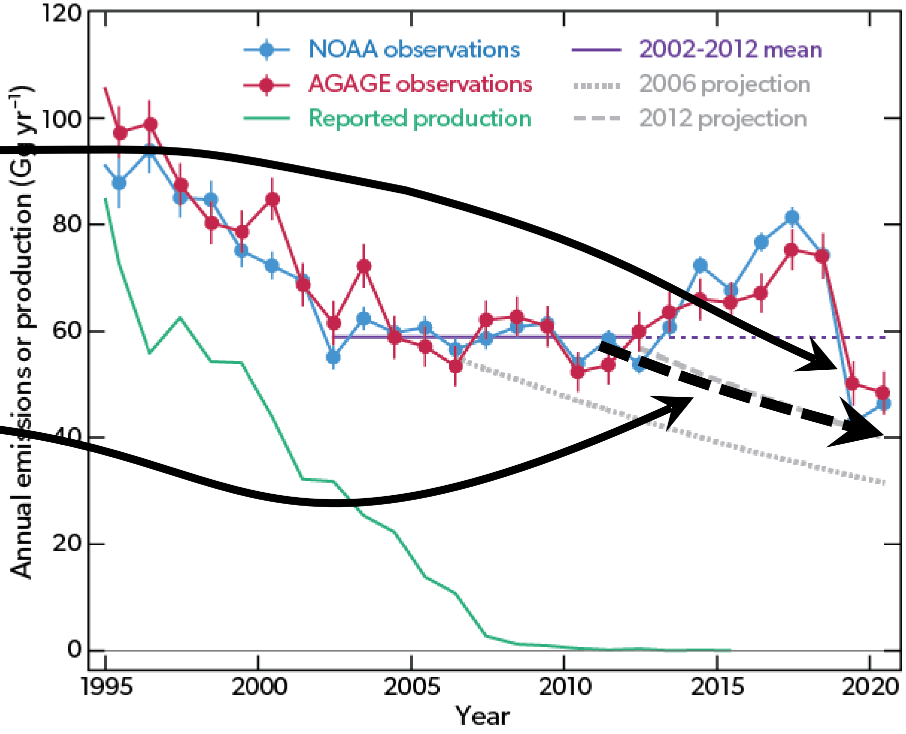


MOP35

Successful actions by the Parties have reversed the upward trend of unexpected CFC-11 emissions observed between 2013 and 2017

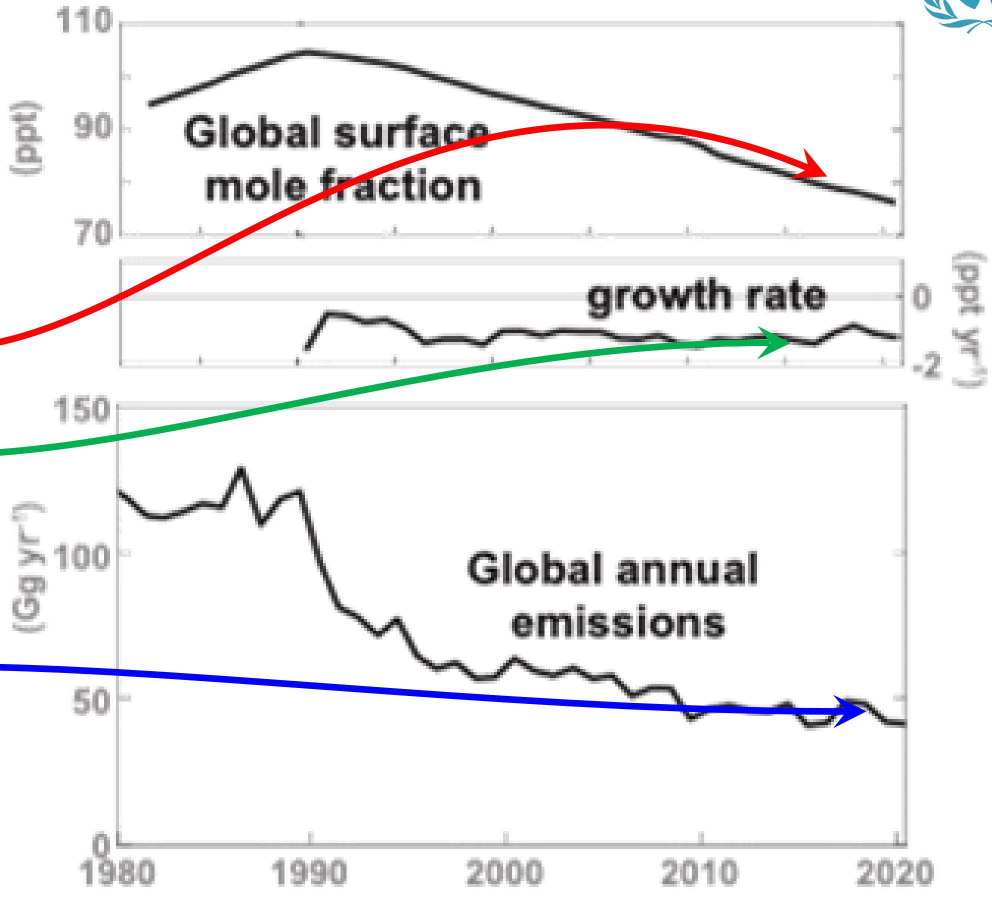
CFC-11 Annual emissions and production

- Global CFC-11 emissions declined after 2018, dropping to 45 ± 10 Gg in both 2019 and 2020.
- This drop suggests the elimination of most of the unexpected emissions occurring in the years after 2012



Carbon tetrachloride (CCl_4)

- Abundances continue to decline
- Decline rates are slower (1-2 % per year) than expected (3% per year)
- Emissions remain > 30 Gg yr^{-1}

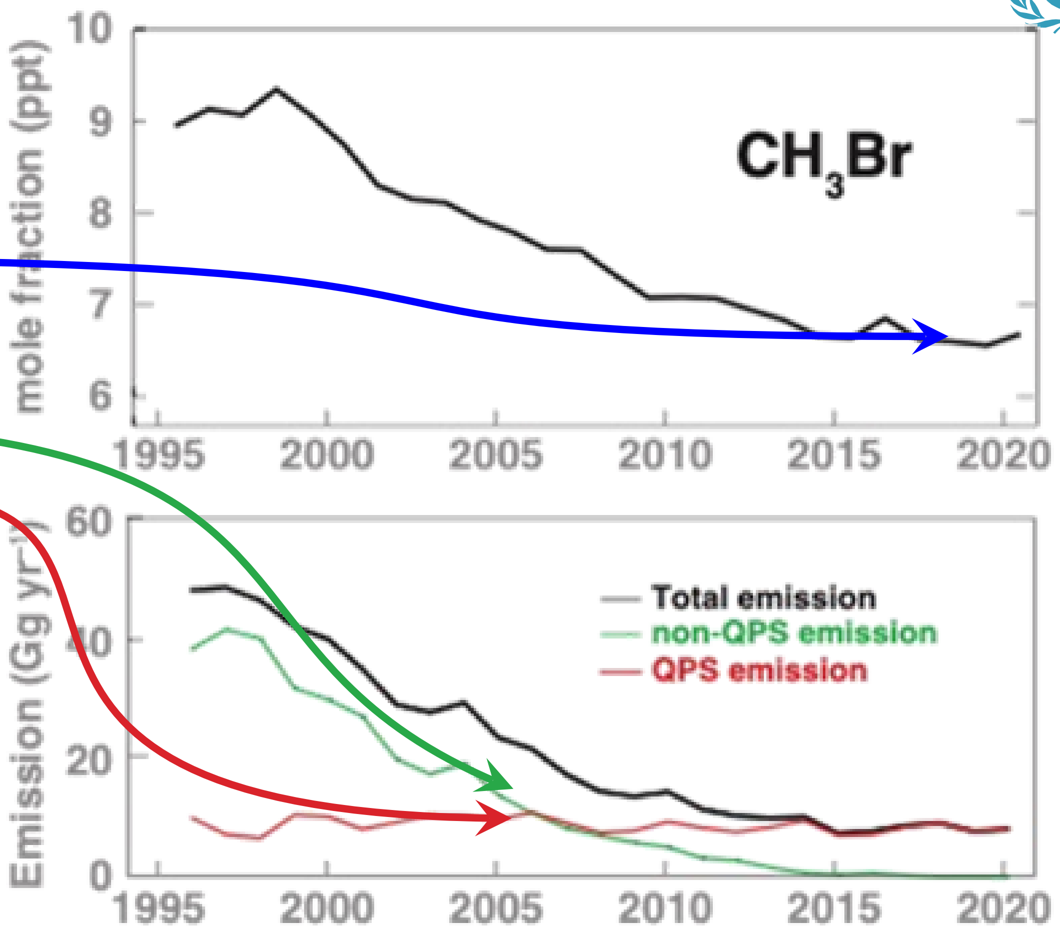


Methyl Bromide (CH_3Br)

- Atmospheric concentrations of methyl bromide **have not declined since 2016**

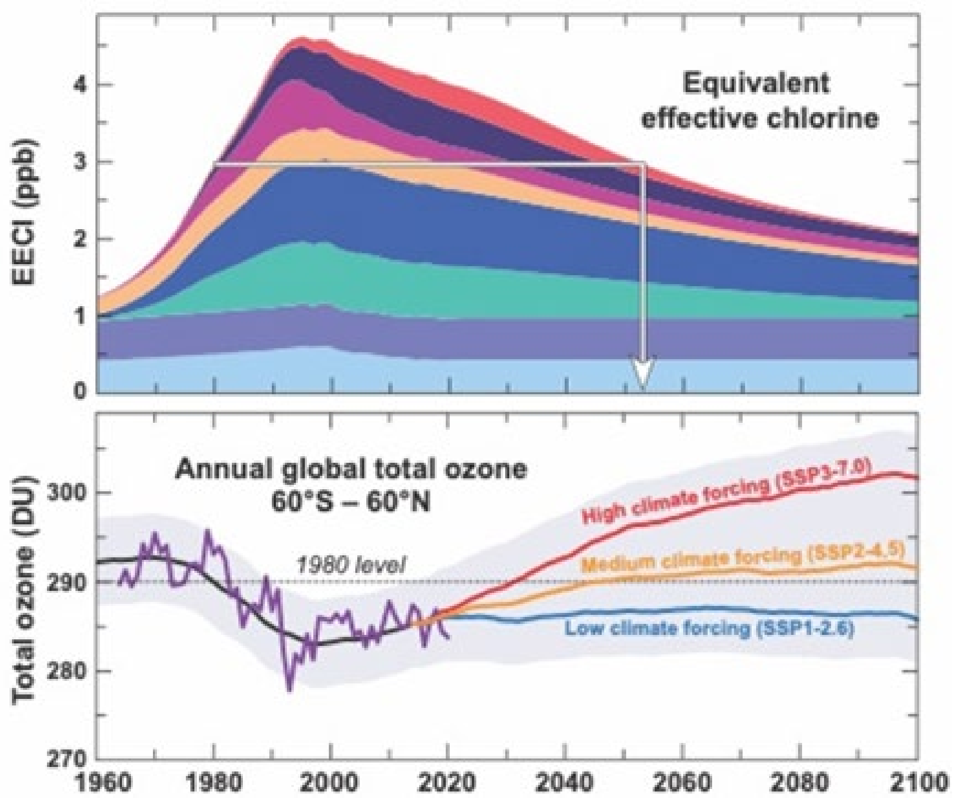
- A majority of anthropogenically produced CH_3Br has been phased out except for quarantine and pre-shipment (QPS) fumigation, leaving natural emissions as the dominant source.

- Reported QPS consumption (10,000 tonnes) has been relatively stable for more than two decades.
- Around 40% of QPS could be phased out by non-MB alternatives



Stratospheric ozone recovery depends on future concentrations of both ODSs and GHGs

- The recovery of ozone is dependent on changing levels of nitrous oxide, methane, and CO_2.
- There is heightened concern about how climate change will impact levels of tropical total column ozone



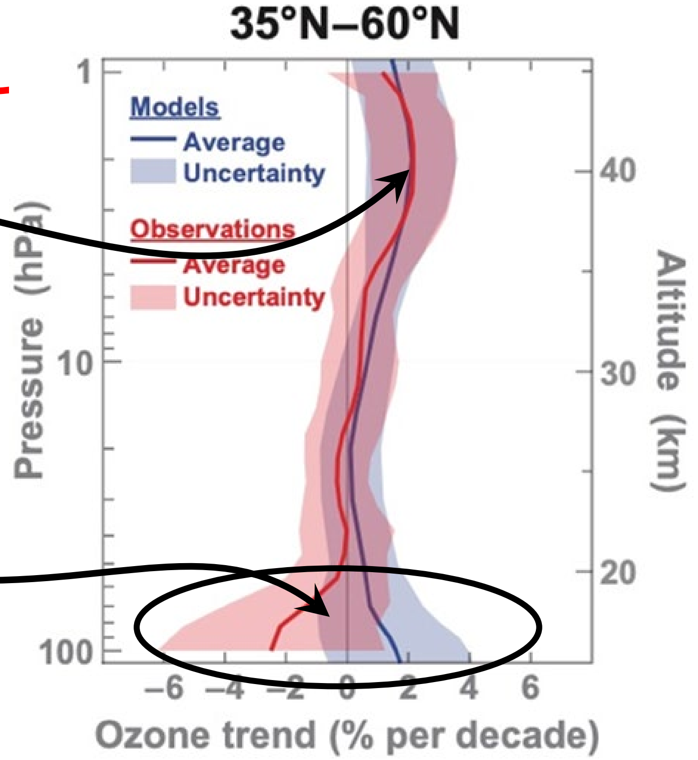
Stratospheric ozone depletion and climate change are linked

- Continuing ozone recovery and increases in atmospheric greenhouse gas (GHG) concentrations will be key to future Southern Hemisphere climate changes. The relative importance of ozone recovery for future Southern climate will depend on changes of atmospheric GHG concentrations.
- The global middle and upper stratosphere is cooling at an estimated rate of 0.6 K $decade^{-1}$, primarily driven by changing CO_2 and stratospheric ozone.
- In the future, increasing GHGs and the effects of ozone recovery will have opposing effects on stratospheric temperatures and circulation.
- The calculated total direct radiative forcing due to CFCs, HCFCs, halons, CCl_4 and CH_3CCl_3 decreased by 0.006 W m^{-2} since 2016 (0.337 W m^{-2} in 2020). This forcing is approximately 16% of the CO_2 radiative forcing.
- Declining ODS emissions due to the Protocol avoids additional warming of 0.5-1.0 K by mid-century compared to uncontrolled ODS increases of 3–3.5% per year (an extreme scenario) with the resulting ozone changes.

Compliance with Protocol provisions ensures the protection of stratospheric ozone and climate

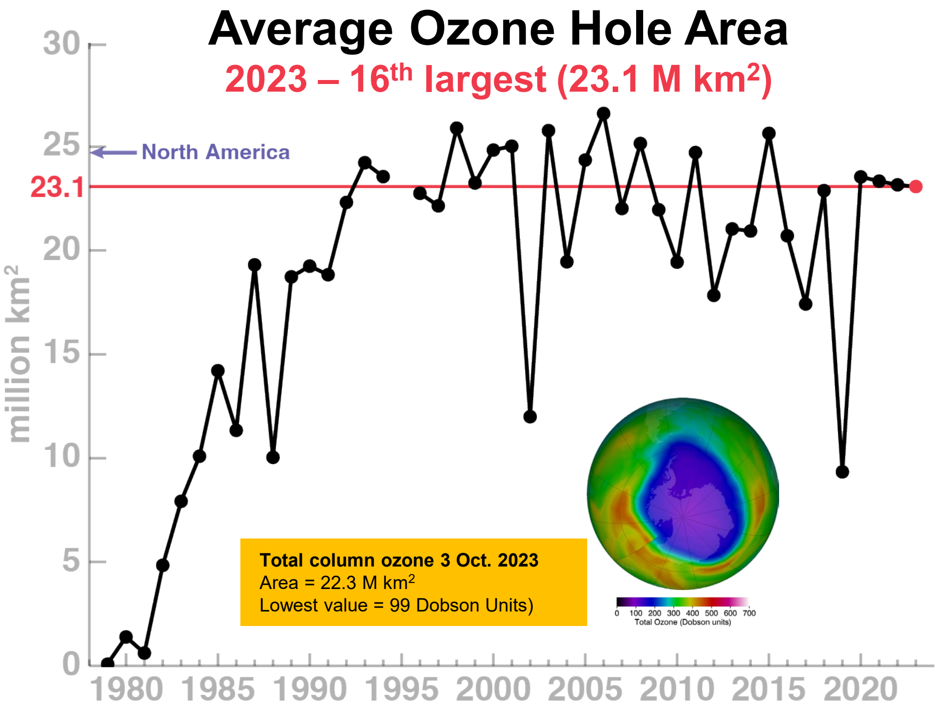
Ozone trends (2000-2020)

- **Observations** show increased ozone in the upper stratosphere
- **Observations** and **models** are in good agreement on the upper stratospheric ozone recovery.
- Upper stratosphere continues to cool at 0.6 K/decade from CO_2 increases.
- **Models** show that the increase of upper stratospheric ozone is due to both the ODS decline and the CO_2 increase
- **Observations** suggest small decreases in lower stratospheric ozone in the mid-latitudes of both hemispheres, while **models** suggest small increases. Ozone in mid-latitudes has large year-to-year variability; thus trends have large uncertainties, and they are not robust across all datasets and models.



2023 Antarctic Ozone Hole

- The ozone hole is caused by CFCs and halons
- Models projected the 2023 hole would be larger than normal because of the Hunga Tonga volcanic eruption
- Early observations showed Hunga volcanic material in the Antarctic vortex – in agreement with model projections
- Stratospheric weather activity in September was higher than average, limiting the hole's growth
- **The 2023 ozone hole was modest in depth and area** – less than model predictions of Hunga effects



Daily averaged from Sept. 7 to Oct. 13

The Montreal Protocol contributes to environmental sustainability and human health and well-being, in line with many Sustainable Development Goals

The Montreal Protocol contributions to the United Nations Sustainable Development Goals (SDGs) originate from protection of the stratospheric ozone layer and the mitigation of climate change (ODS; Kigali Amendment).

EEAP focus on SDGs includes:

Areas related to climate change, human health, air and water quality, contaminants and pollution, biodiversity and ecosystems, sustainable production and consumption, and food security

The Montreal Protocol contributes to environmental sustainability and human health and well-being, in line with many Sustainable Development Goals

The Montreal Protocol has avoided adverse health outcomes

United States EPA modelling study:

- 11 million cases of melanoma avoided for those born in the US from 1890 - 2100
- 432 million cases of basal cell carcinoma & squamous cell carcinoma (keratinocyte cancers avoided between 2010 – 2019
- 63 million cases of cataracts (leading cause of blindness globally) avoided for people born in the United States between 1890 – 2100
- Beneficial health effects (e.g., vitamin D production, improved immune systems) from moderate exposure to solar radiation because of the Montreal Protocol

The Montreal Protocol contributes to environmental sustainability and human health and well-being, in line with many Sustainable Development Goals

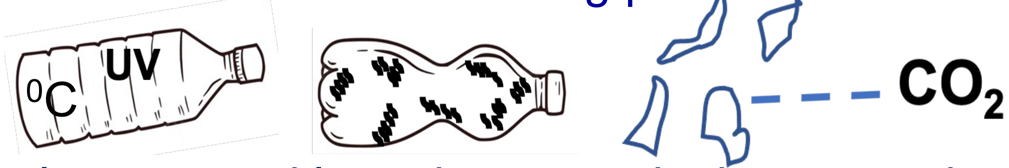
Changes in ozone, UV radiation and climate: environmental consequences

- **Without the Montreal Protocol** surface levels of solar UV-B radiation would have increased world-wide but highest in polar regions:
  - Antarctic mid-summer UV index estimated increase from 3 to 33 (1975 – 2065)
- An extreme UV-B scenario estimated the impact on terrestrial vegetation without the Montreal Protocol:
  - drastic reduction of photosynthetic uptake & storage of carbon dioxide by plants, leading to increased atmospheric carbon dioxide levels with additional rise of global mean surface temperature of 0.5-1.0 ºC by 2100.

The Montreal Protocol contributes to environmental sustainability and human health and well-being, in line with many Sustainable Development Goals

Changes in ozone, UV radiation and climate: environmental consequences

- Extreme climate events will lead to unexpected consequences for life on Earth exposing ecosystems to changes in UV radiation and temperature
- Also of growing concern to the environment is the increasing plastic waste
  - Solar UV radiation breaks down many plastics

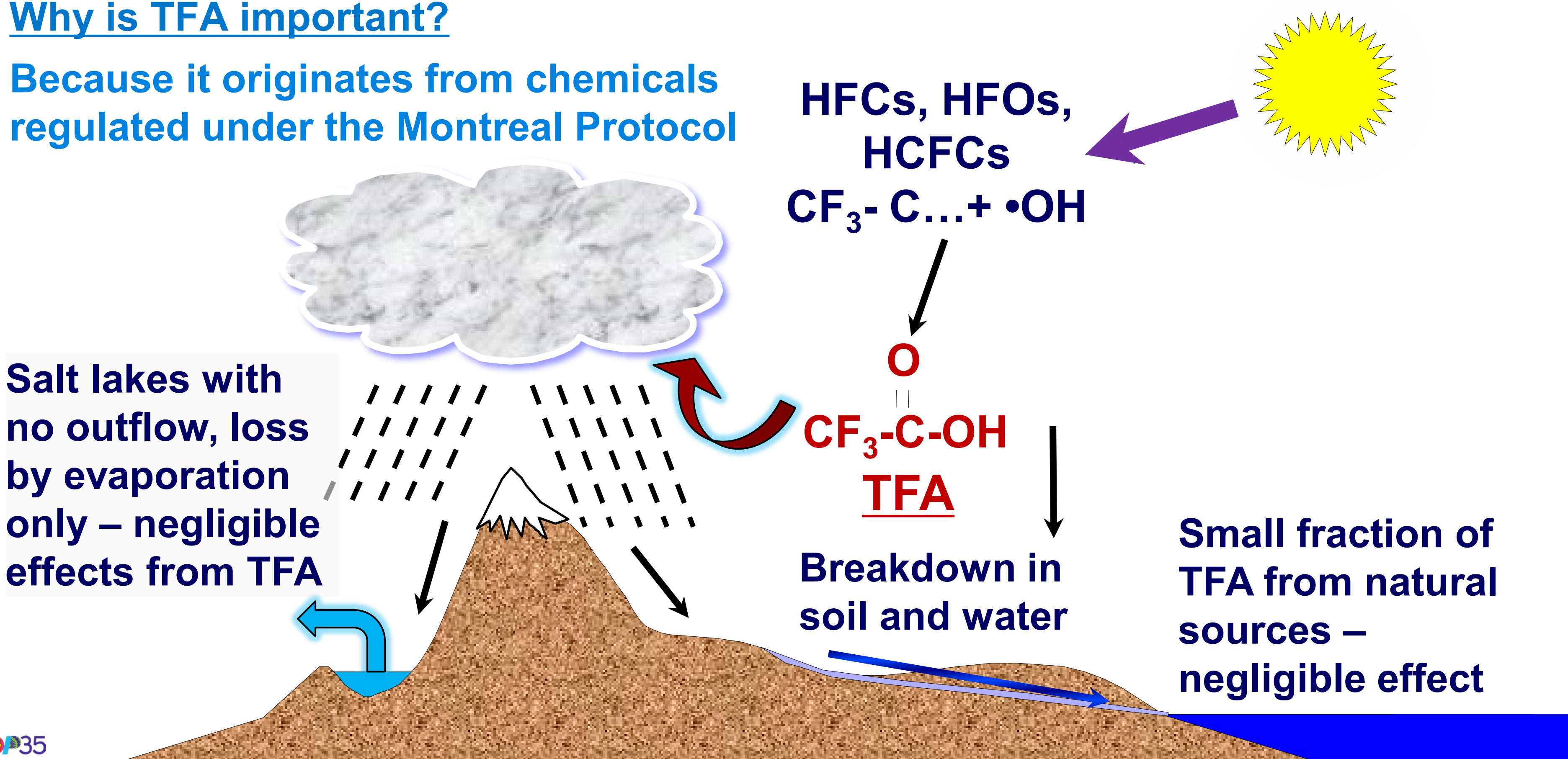


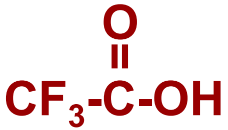
  - The Montreal Protocol has likely prevented large increases in the generation of microplastics by more extreme UV irradiation
  - Biological risk factors are still uncertain at present

Breakdown of CFC replacements to trifluoroacetic acid (TFA)

Why is TFA important?

Because it originates from chemicals regulated under the Montreal Protocol





Main messages for trifluoroacetic acid (TFA)

- A breakdown product in the atmosphere of some HFCs, HCFCs, HFOs, HCFOs
- Used as a feedstock in industry; incorporated into pharmaceuticals and pesticides to enhance biological properties
- At Earth's surface: forms salts with alkali metals (sodium, potassium, calcium)
- Rapidly deposited in precipitation; TFA salts accumulate in oceans and salt lakes
- TFA salts are unreactive, have long environmental lifetimes, but easily excreted by animals; therefore, TFA salts do not bioaccumulate in the food chain
- Formation of TFA in the atmosphere is expected to increase due to increased use of HFOs and HCFOs for cooling purposes
- Environmental concentrations are very low - unlikely to have adverse toxicological effects for humans, other organisms, or ecosystems
- Continued monitoring and assessment are advised due to uncertainties in potential future effects and low number of studies of biological consequences

The Montreal Protocol contributes to environmental sustainability and human health and well-being, in line with many Sustainable Development Goals

Changes in ozone, UV radiation and climate: Environmental consequences

- **Many challenges remain** in assessing the interactive effects of future changes in surface solar UV radiation and climate on human health, food security, ecosystem health and biodiversity
- There is uncertainty in how effects of gradual climate change and periodic extreme climate events will alter UV irradiation at the Earth's surface
- Therefore, solar UV radiation with other climate change factors in experimental and modelling studies of human health and ecosystems are required for more robust assessments of current and future environmental effects from changes in UV radiation under different future global climate scenarios

Foams; Fire Protection

- **Foam Blowing Agents**
  - Transitions to zero ozone depletion potential and low global warming potential Foam Blowing Agent alternatives to HCFCs continue to progress
- **Fire Protection**
  - Halons continue to be needed for enduring uses (e.g., oil & gas, nuclear power plants, military, civil aviation), the last of which is growing.
  - Halon supply beyond 2030 is potentially compromised with halon emissions higher than previously predicted.

Chemical Substances

- CFCs have been phased out worldwide
- HCFC-22 phase out is complete in non-Article 5 parties and progressing in A5 parties.
- Feedstock:
  - HCFC feedstock use is increasing;
  - CTC feedstock is increasing due to HFO production.
  - Manufacture of HCFC-22 generates high GWP HFC-23 as a by-product. Emissions are greater than 0.1% that would be expected with implemented controls
- Manufacture of Semi-conductors, Electronics, Magnesium: all use high GWP HFCs; controls reduce HFC emissions
- Inhalers for asthma and chronic obstructive pulmonary disease (COPD)
  - transition from high GWP HFCs is underway but is a major undertaking with serious potential public health risks

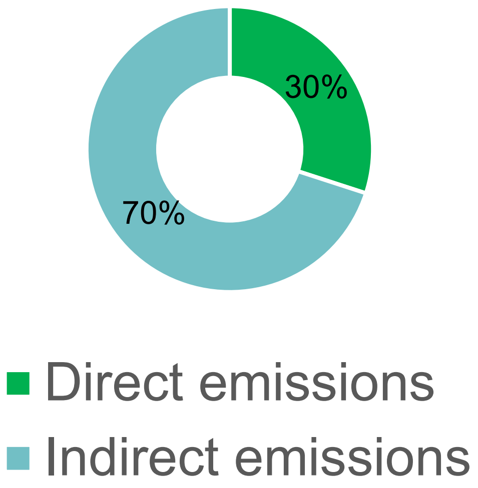
Refrigeration, Air Conditioning and Heat Pumps

- Ultralow-, low-, and/or medium-GWP alternative refrigerants are now available for all RACHP sectors
- There are challenges in finding the optimal solution for each application, considering especially cost of the refrigerant, energy efficiency rating, safety, and ease of use.
- Accessibility is a major hindrance for the widescale adoption and progress toward the HFC phasedown.
- Revisions of safety standards has enabled increased use of flammable refrigerants in many applications, but the expanding use of flammable refrigerants in A5 parties requires support for training and capacity building
- Proposed broad PFAS regulations limit the use of HFOs. This could impact HFC phasedown.

Refrigeration, Air Conditioning and Heat Pumps Energy Efficiency

- The HFC phasedown focuses on direct greenhouse gas (GHG) emissions from the RACHP sector.
- Indirect GHG emissions, due to energy consumption, are much more impactful to climate change.
- RACHP indirect GHG emissions can be reduced significantly through improved equipment energy efficiency, reduced demand using high-performance buildings and cold-chain, and reduced carbon intensity of the electricity network.

RACHP GHG Emissions



Servicing

- In most A5 parties, but especially in low- and very low-volume consuming countries, the majority of ODS and HFC refrigerants are used for RACHP servicing
- Restricting the growth of products containing high-GWP and energy-inefficient RACHP equipment would reduce the servicing tail of unwanted high GWP refrigerants
- Ensuring support for proper training for servicing and recovery would reduce direct emissions of ODS and HFC refrigerants, and also reduce indirect emissions from the loss in energy efficiency through proper maintenance of RACHP equipment.

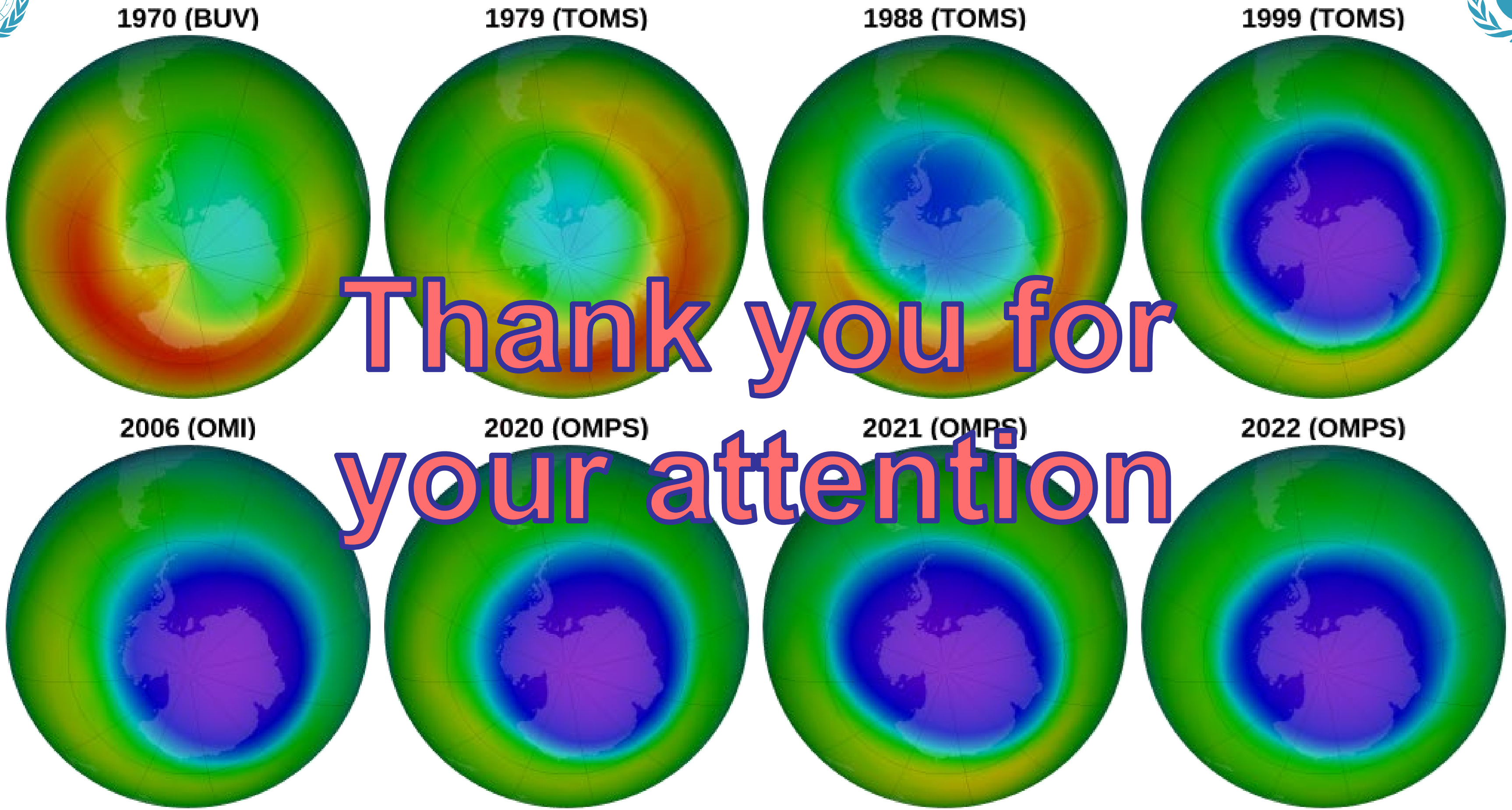
Effective Management of Banks of Controlled Substances can minimise global impacts

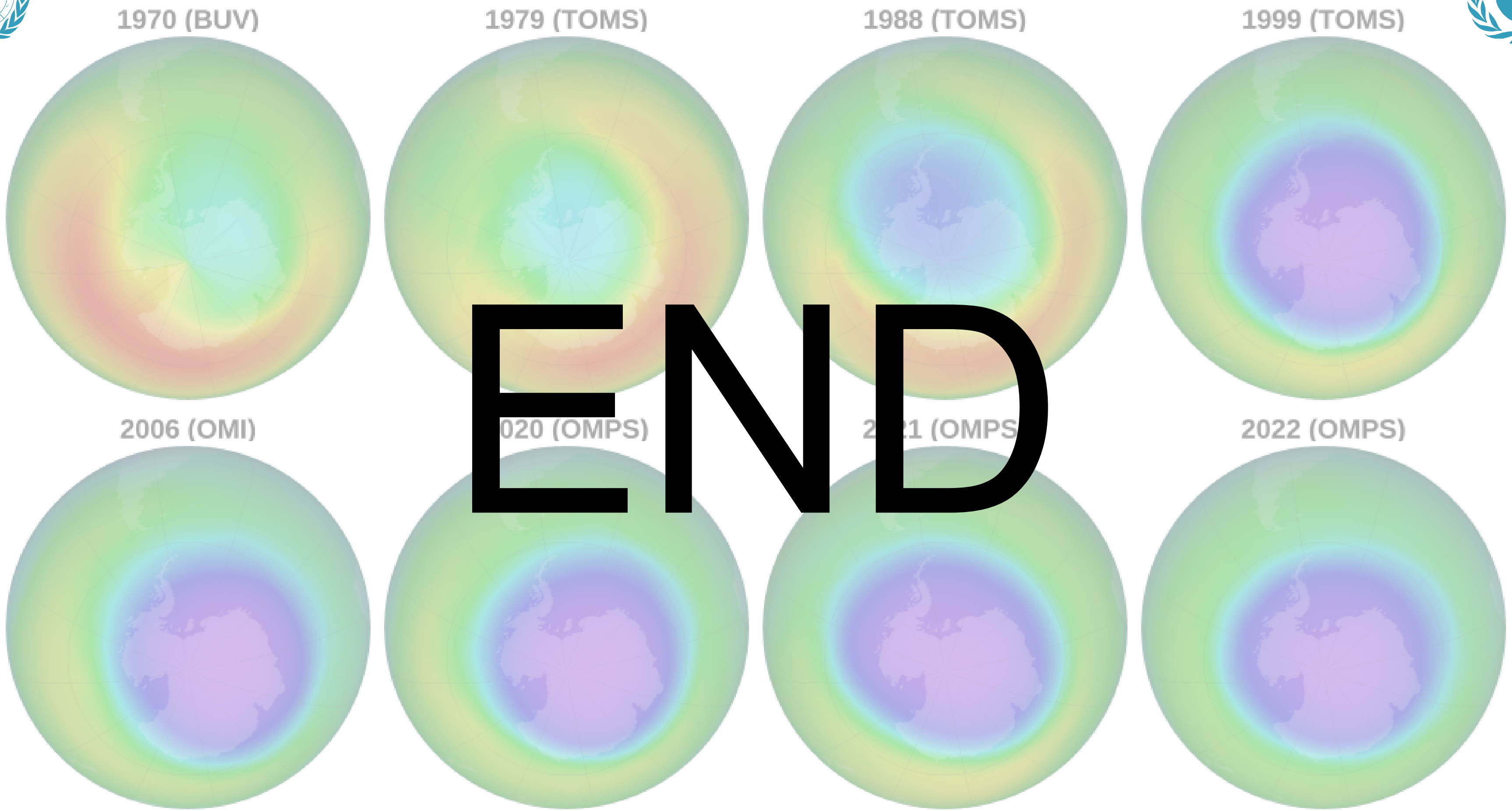
- Comprises recovery, reuse, recycling, reclamation, and destruction of banks, mainly in RACHP and foams
- ODS banks have been more concentrated in non-A5 parties
- HFC banks are currently evenly distributed between non-A5 and A5 parties
- Banks in non-A5 parties will rapidly reach the end-of-life in the next decade
- Banks are declining in non-A5 parties and rapidly increasing with HFCs in equipment in A5 parties

Some Key Messages

- The Montreal Protocol is working for both the ozone layer and climate
- ODS emissions have declined substantially
- Accessibility and implementation of HFC alternatives in A5 parties will be critical for further progress

Thank you for your attention





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