Environmental Effects Assessment Panel

10th ORM
Geneve

Surface UV radiation in the 21st century: Environmental effects of changes in ozone and climate

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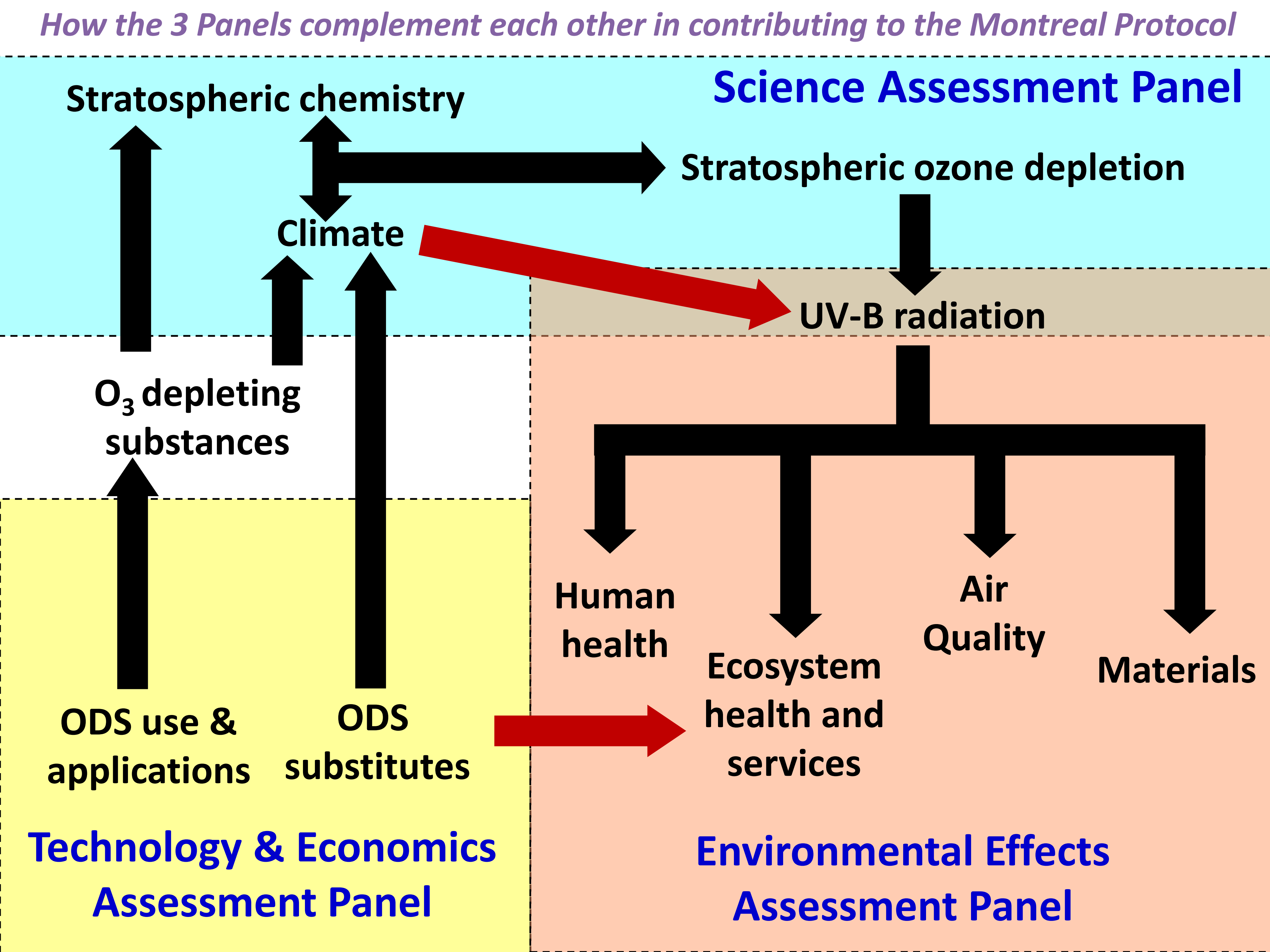

How the 3 Panels complement each other in contributing to the Montreal Protocol
Science Assessment Panel
Stratospheric chemistry
Stratospheric ozone depletion
Climate
UV-B radiation
O_3 depleting substances
Human health
Ecosystem health and services
Air Quality
Materials
ODS use & applications
ODS substitutes
Technology & Economics Assessment Panel
Environmental Effects Assessment Panel

Ozone, UV radiation, and climate change

KEY QUESTIONS: PAST, PRESENT AND FUTURE

- How stratospheric ozone depletion has been affecting climate in the southern hemisphere? Will the effects be reversed when ozone recovers?
- How increasing GHGs modify the ways stratospheric ozone changes (depletion or recovery) influence UV-B radiation?
- What are the direct and indirect beneficial effects of the Montreal Protocol?
- Have the effects of the Montreal Protocol been reflected in measurements of UV-B radiation?
- When and where should we expect damaging or beneficial effects of UV-B?

Ozone, UV radiation, and climate change

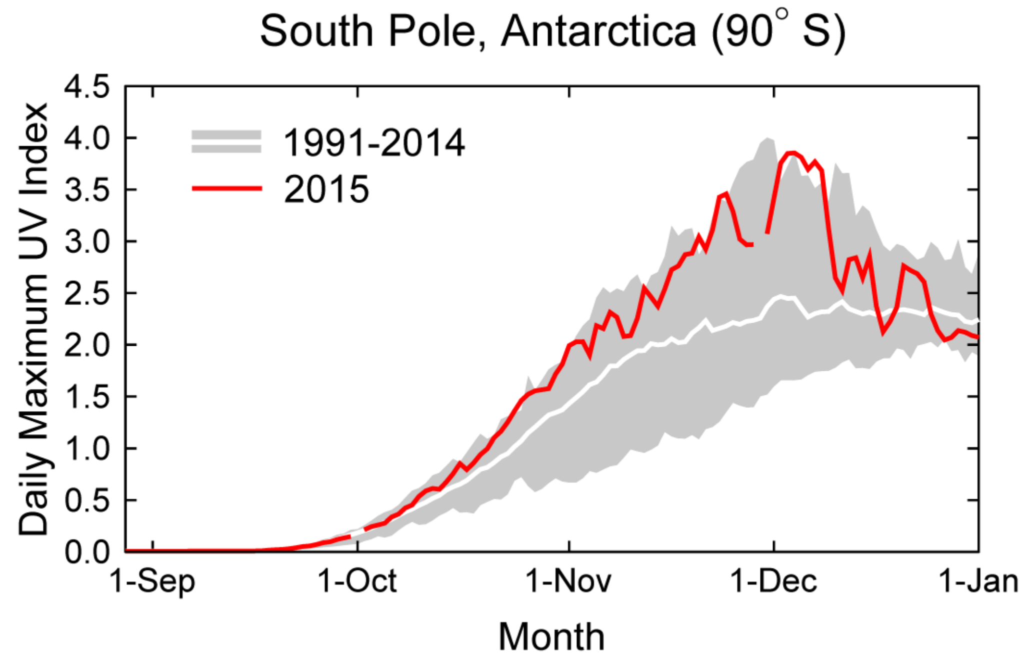
KEY FINDINGS

- Increased confidence that stratospheric ozone depletion is a major driver of climate change in the Southern Hemisphere.
- Stratospheric ozone depletion and increasing greenhouse gases cause changes in the tropical atmospheric circulation, resulting in a pole-ward shift of the boundaries of climatic zones.
- The Montreal Protocol has been the most effective tool to date for mitigating climate change, in addition to the benefits for stratospheric ozone and surface UV radiation. Mitigating the adverse effects of intensifying tropical cyclones is a recent example.

Ozone, UV radiation, and climate change

KEY FINDINGS

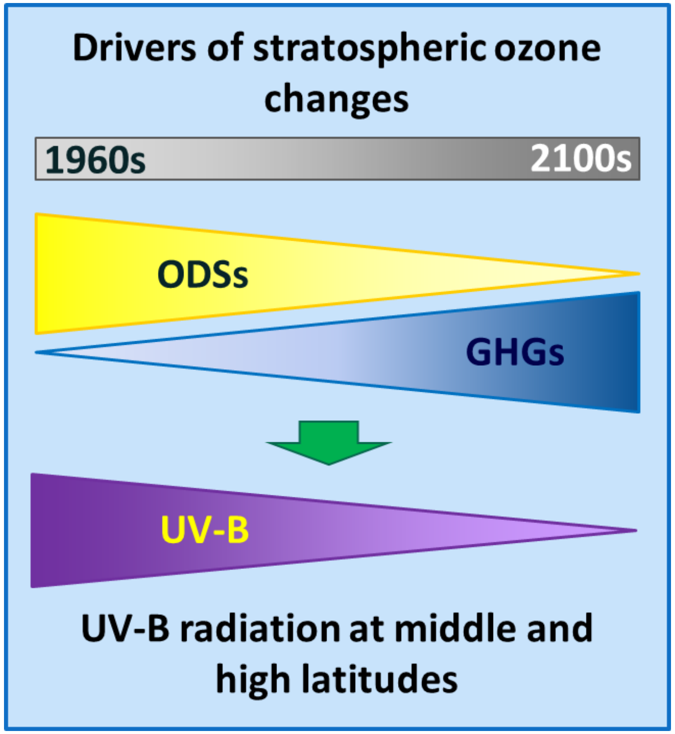
- **Despite indications of ozone healing in Antarctica in early spring, this is not yet detectable in surface UV-B radiation data.**



- **Delayed ozone effects are potentially important for UV-B radiation as the sun gets higher in the sky in later months.**

Ozone, UV radiation, and climate change

- **Outside Antarctica other factors (aerosols, clouds, albedo, air pollution) dominate the effects on UV-B radiation, masking changes due to stratospheric ozone. These factors are influenced strongly by increasing GHGs.**



- **As concentrations of ODSs decrease over the next decades, GHGs will become the dominant driver of stratospheric ozone changes.**
- **UV radiation will decrease in the middle and high latitudes relative to the historical period 1955–1975.**
- **The sign of change in the tropics depends on the emission scenario.**

Human health

- Effects on human health from changes in stratospheric ozone are through alterations in **exposure to solar UV-B radiation**.
- Human **exposure** to UV-B radiation **depends on multiple factors**, including individual choices (e.g. relating to sun behaviour, clothing, use of sun protection).
- **Warmer temperatures** as a result of climate change will alter how much **time people spend outdoors** and thus their exposure to solar radiation across all wavelengths.
- While focus remains on exposure to UV-B radiation for risks or benefits to human health, **longer wavelengths of solar radiation should also be considered**.

Human health

Exposure to UV radiation has both risks and benefits

Adverse effects of exposure to UV radiation include:

- **Skin cancers,** including cutaneous malignant melanoma and keratinocyte cancers (previously: non-melanoma skin cancers)
- **Eye diseases,** including cataract
- **Immune suppression,** causing reactivation of latent viruses

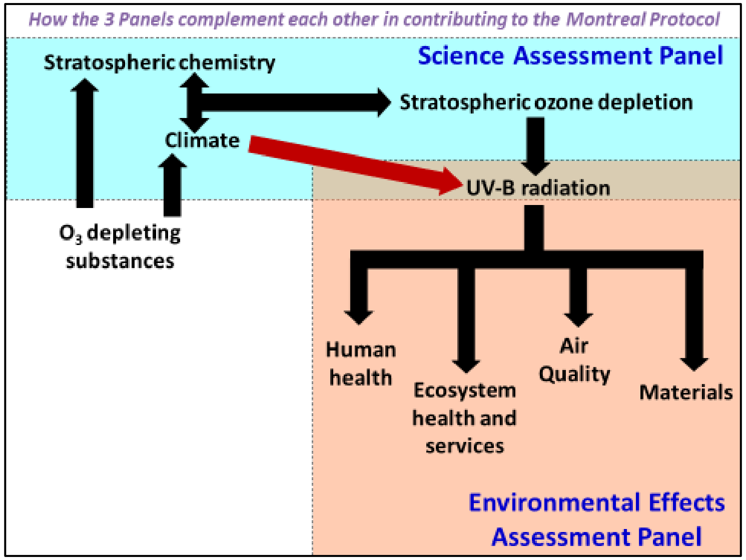
Possible benefits of exposure to solar radiation (UV-VIS) include:

- **Improved vitamin D status** (known to be primarily from UV-B)
- **Reduced risk of myopia** (short sightedness)
- **Immune suppression** (reducing risk of autoimmune diseases)
- **Benefits for cardio-metabolic health**

Human health

- Despite strong public-health programs for effective sun protection being widely available, risky sun exposure behaviour resulting in sunburn (and ultimately skin cancer) remains common in many countries.
- Such behaviour will continue to influence the health effects of future changes in UV exposure due to changes in ozone and other factors.
- Benefits of exposure of both the skin and eyes to solar radiation (UV-B and longer wavelengths) are still being investigated, and could be of considerable importance.
- Vitamin D deficiency due to reduced UV-B exposure is common, particularly at high latitude locations. Reliable data for vitamin D levels remain very limited for many regions of the world.

Ecosystem health and services



Assessments of the effects of current and future changes in stratospheric ozone on ecosystems need to consider both:

- Changes in UV radiation

and

- Ozone-related changes in climate

- **Changes in precipitation and temperature related to Antarctic ozone depletion have now been shown to have affected both terrestrial and aquatic ecosystems in the Southern Hemisphere.**

Ecosystem health and services

- **Terrestrial systems are affected by UV radiation and constraints from climate change (water availability, higher temperatures, CO_2)**
  - Ozone-depletion driven climate changes have affected plant growth and plant distribution patterns in natural ecosystems in some parts of the Southern Hemisphere.
  - Potential of changes in crop yield and food quality in agricultural systems (e.g. faster ripening of some crops by CO_2, and changes in nutrient status)
- **UV radiation effects depend on interacting environmental factors**

Increases the challenge of reliably predicting overall impact of changes by UV-B radiation on natural or agricultural ecosystems

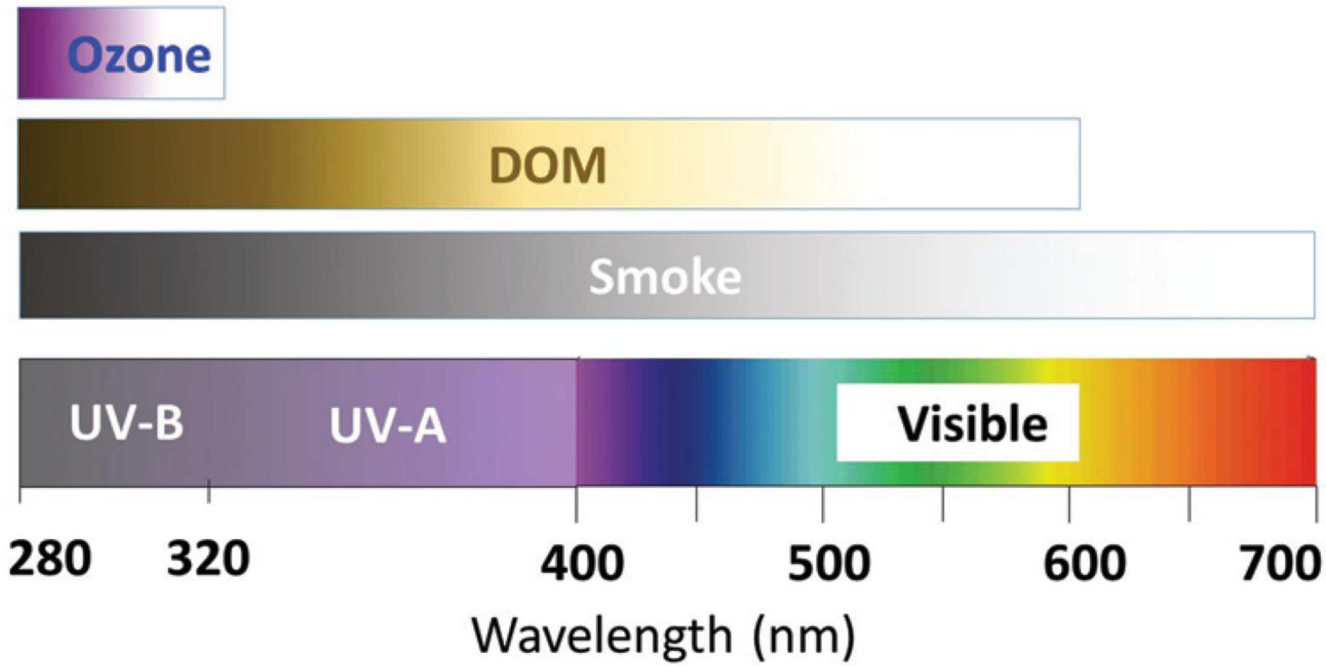
Ecosystem health and services

<u>Strong evidence that dissolved organic matter (DOM) is increasing in many aquatic ecosystems ("browning"):</u>

- **Increases as much as two-fold in some inland waters**
- **Related to climate change (increases in precipitation, extreme rain events) and other factors (e.g., recovery from anthropogenic acidification, changes in land use)**

Ecosystem health and services

- **DOM selectively absorbs potentially damaging UV radiation in aquatic ecosystems**

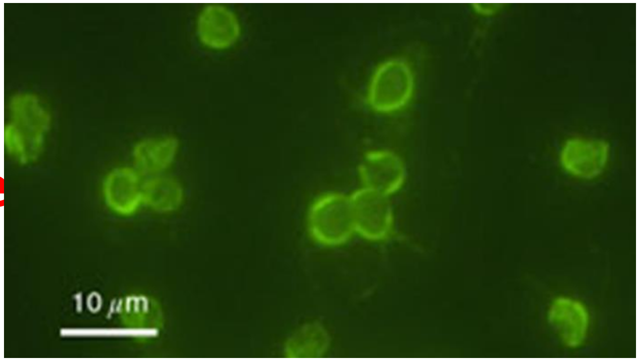


Ecosystem health and services

Consequences of reduced penetration of UV radiation into aquatic ecosystems due to "browning"

- Increased survival of water-borne human pathogens that would otherwise be inactivated by exposure to solar UV radiation

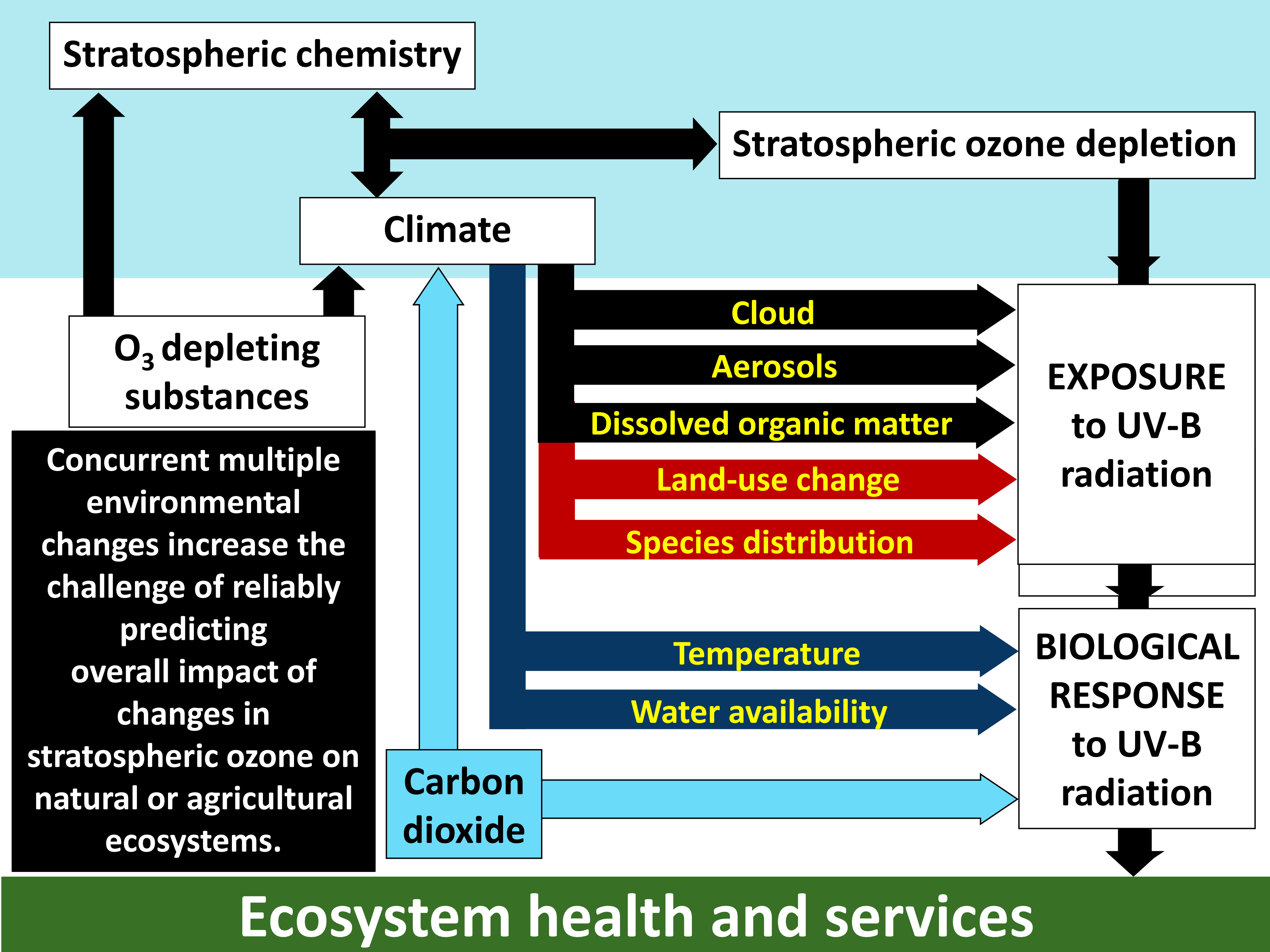
- Increased survival of pathogens in surface waters increases the risk of infectious disease in humans and wildlife (e.g. *Cryptosporidium*)



- Altered behaviour of aquatic organisms affects water quality, aquatic food webs and fishery productivity.

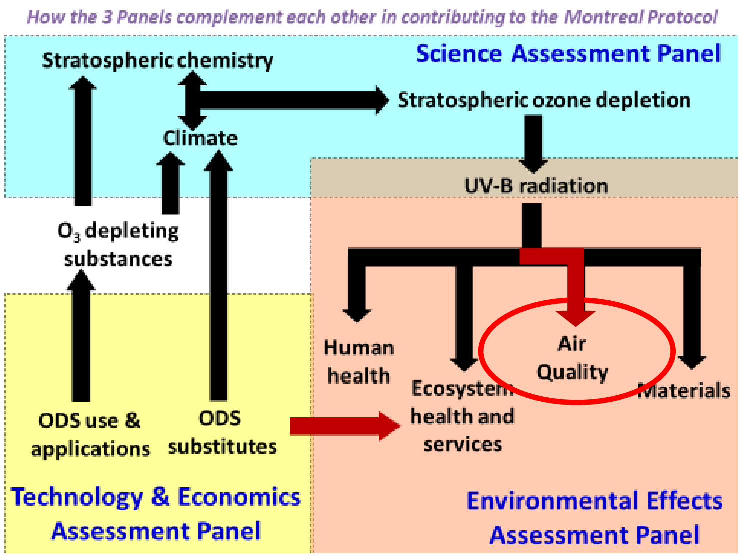
Ecosystem health and services

- **DOM entering the aquatic ecosystems is broken down to release CO_2, a process driven by solar UV-B radiation**
- **Future changes in exposure to UV-B radiation will therefore affect how much of the carbon entering aquatic ecosystems due to "browning" is released to the atmosphere as CO_2**
- **Future changes in exposure to UV-B radiation will also affect the release of CO_2 from organic matter in terrestrial ecosystems by**
  - Photochemical degradation of dead plant material
  - altering the chemical composition of dead plant material in ways that affect its biological degradation rate
- **Reduced UV-B radiation in the future would result to less CO_2 released by terrestrial and aquatic ecosystems**


Stratospheric chemistry
Stratospheric ozone depletion
Climate
O_3 depleting substances
Cloud
Aerosols
Dissolved organic matter
Land-use change
Species distribution
EXPOSURE to UV-B radiation
Concurrent multiple environmental changes increase the challenge of reliably predicting overall impact of changes in stratospheric ozone on natural or agricultural ecosystems.
Temperature
Water availability
BIOLOGICAL RESPONSE to UV-B radiation
Carbon dioxide
Ecosystem health and services

Air quality

<u>Substitutes for ODS must be monitored for potential risks</u>:



1. **Formation of persistent compounds, e.g. TFA from HFCs**

At present, amounts of TFA produced from HFCs and HCFCs are small relative to other sources, and therefore unlikely to pose a risk to humans or the environment.

2. **Small but non-zero contributions to urban pollution, for example through the use of volatile organic compounds (hydrocarbons) as ODS substitutes**

Air quality

UV radiation drives the chemistry of the troposphere

Examples:

1. **Removal of ODS and GHG (e.g. HCFCs, HFCs, CH_4, tropospheric ozone) by OH radicals**
   - UV radiation is an important factor affecting the lifetime of CH_4 and temporal trends in its amounts in the global atmosphere

2. **Formation and destruction of ground-level ozone**
   - Decreasing UV radiation resulting from stratospheric ozone recovery will lead to slower production and slower destruction of tropospheric ozone:
     - small decreases in O_3 in cities
     - small increases in rural O_3 regionally.

Materials damage

- **Outdoor service lifetimes of plastics, wood and other construction materials is determined by (i) exposure to solar UV radiation and (ii) temperature.**
- **Increased UV radiation levels and ambient temperatures can shorten replacement time for products used outdoors. The control technologies in use today, or their improved versions, mitigate additional damage, but add to the cost of these products.**

UV-shielding pigments are presently used to stabilize PVC against UV radiation.

UV damage to wood is avoided by surface coatings (paints) or chemical modi-fication of wood.

Main conclusions and research needs

- **Projecting future changes in UV-B radiation and the effects of those changes on health and other factors (including food production) demands that research is not limited simply to changes in stratospheric ozone and ODS.**
- **Climate change will influence UV-B exposure through changes in ozone but also cloud, aerosols and DOM and, for human health, changes in behavior.**
- **The biological effects of changed exposure to UV-B will be further modified by interactions with other changes, e.g. in temperature, water availability and quality, CO_2.**
- **The scale and scope of the necessary research is increasingly under-threat due to the perception of funders that ozone depletion/UV-B are no longer major environmental threats.**

Thank you!