Surface UV Radiation in the 21st century: Environmental effects in response to changes in ozone and climate

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EEAP assesses effects from changes in the stratospheric ozone layer and ultraviolet radiation, and their interaction with the climate system

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7 integrated Working Groups
WG 1 Ozone-UV radiation-Climate interactions
WG 2 Human Health
WG 3 Terrestrial Ecosystems
WG 4 Aquatic Ecosystems
WG 5 Biogeochemical Cycles
WG 6 Air Quality
WG 7 Natural and Synthetic Materials
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- Some examples of areas of concern:
  - skin cancers, microplastics, biodiversity
- Implications of unexpected events:
  - COVID-19 pandemic

Implications of the role of the Montreal Protocol in climate change mitigation
**Ozone depleting substances (ODS):** responsible for ca 33% of global warming between 1955 and 2005 and 50% of the warming observed over the Arctic

**2019 study:** Warming of 0.5 – 1.0 °C has been avoided over large mid-latitude land regions and ca 1.1 °C over parts of the Arctic

**2050:** the Montreal Protocol is predicted to prevent warming of:
- 1.5 – 2.0 °C over most extra-polar land areas
- 3.0 – 4.0 °C over the Arctic
- 1 °C globally

**Thawing in the Arctic** is disrupting ecosystems and releasing carbon dioxide and methane from permafrost soils; and organic nitrogen from peatlands, increasing emission of N\textsubscript{2}O, a major ODS
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UV-B radiation at low and mid-latitudes is projected to increase in the second half of the 21st century due to reduced cloud cover resulting from climate change: **UV-ozone-climate interactions**
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Potential consequences for ecosystems, agriculture and human health

UV-B radiation and climate change
(e.g., temp., drought, floods) affect plant growth, pathogen and pest defence, and food crop quality

**Changes/extinctions in biodiversity?**
**Increased invasive species?** outcompeting native species

**Food security variability?**
**Increases in skin cancer at mid-latitudes?**
**Increased risk of infections?**
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Effects of UV radiation and climate change on biodiversity

- Reduced geographical range/availability of suitable habitats for plants and animals → species extinction

  Predicted that some native species from open, dry habitats will move towards higher elevations (increased UV radiation), while species from current wetter habitats will diminish as the Earth warms (biodiversity loss)

- The shift of habitat to higher latitudes is predicted to increase with increasing climate warming

- At low latitudes: numbers of species will likely decrease
HOWEVER, most modelling studies do not test whether UV-B radiation and its interaction with other abiotic stressors are potential constraints on species distributions and biodiversity.

Need for inclusion of UV-B radiation among climatic variables that are currently used to predict species occurrence, and geographical shifts of species.

Available modelling shows:
- Temperature
- UV radiation
- Wet-day frequency

} Important factors in shaping habitats of species
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Climate change feedback:
Photodegradation (breakdown) of dead plant material by UV radiation:
accelerates carbon loss

UV radiation and climate

- The degradation contributes to carbon dioxide (CO$_2$) emissions and global warming
- Increased fires and soil erosion add to the CO$_2$ emissions
- Exposed organic matter of permafrost soils also leads to emissions of CH$_4$, N$_2$O, CO$_2$
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Human health

- Model estimates* of **skin cancers and cataracts avoided** in the USA (for those born 1890 – 2100) due to the Montreal Protocol:
  - Melanoma
    - 11 million cases;
    - 2.3 million deaths
  - Keratinocyte cancer
    - 432 million cases
  - Cataract
    - 63 million cases

- UV-B radiation can contribute to **photosensitivity from oral medications** (e.g., thiazide, diuretics, quinine, antibiotics, anti-depressants)
  
Potential significant public health risk: photosensitising drugs may induce skin cancer

*United States EPA; updated Atmospheric and Health Effects Framework (AHEF) model
Many organic compounds emitted by human activities and natural processes are transformed (photo-oxidised) by solar UV radiation into toxic products, decreasing also air quality and damaging human health. Examples: ambient ozone, carbon monoxide, formaldehyde, and aerosols.

UV radiation: likely a major driver of contaminant breakdown in aquatic environments.

Many plastics are photo-oxidised by UV radiation to CO₂ and dissolved organic carbon, contributing to climate warming.
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Microplastics and other contaminants (pollutants)
COVID-19, solar UV radiation, and the Montreal Protocol

- SARS-CoV-2 particles can remain viable on surfaces up to ca 28 days depending on surface material, temperature and UV radiation
- Solar UV radiation can deactivate SARS-CoV-2 particles
- However, the far-reaching, positive outcomes of the implementation of the Montreal Protocol for life on Earth outweigh any potential advantage for disinfection by higher amounts of solar UV radiation
- UV radiation can reduce the efficacy of vaccines against, e.g., poliovirus, influenza, TB, measles, and hepatitis B

The action of UV radiation on vaccines against SARS-CoV-2 is as yet unknown.
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IN CONCLUSION

Our findings highlight the contribution of the Montreal Protocol to environmental and societal sustainability, and mitigation of climate change aligning with many of the UN Sustainable Development Goals (SDGs)