Environmental Effects Assessment Panel
EEAP

9th ORM,
Geneve

Influences of Ozone Layer Depletion and Climate Change on UV-radiation:

Impacts on Human Health and the Environment

Co-chairs
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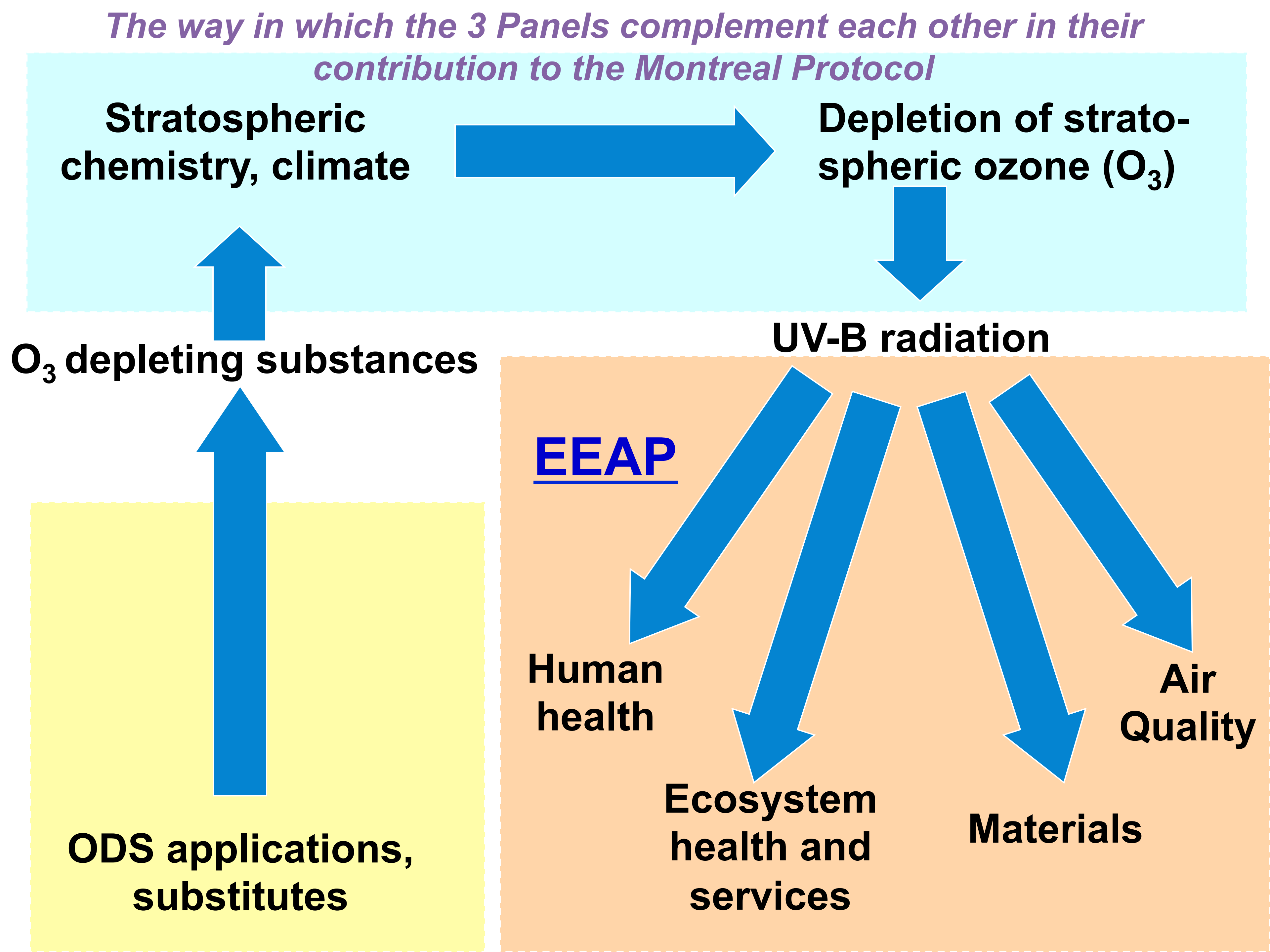
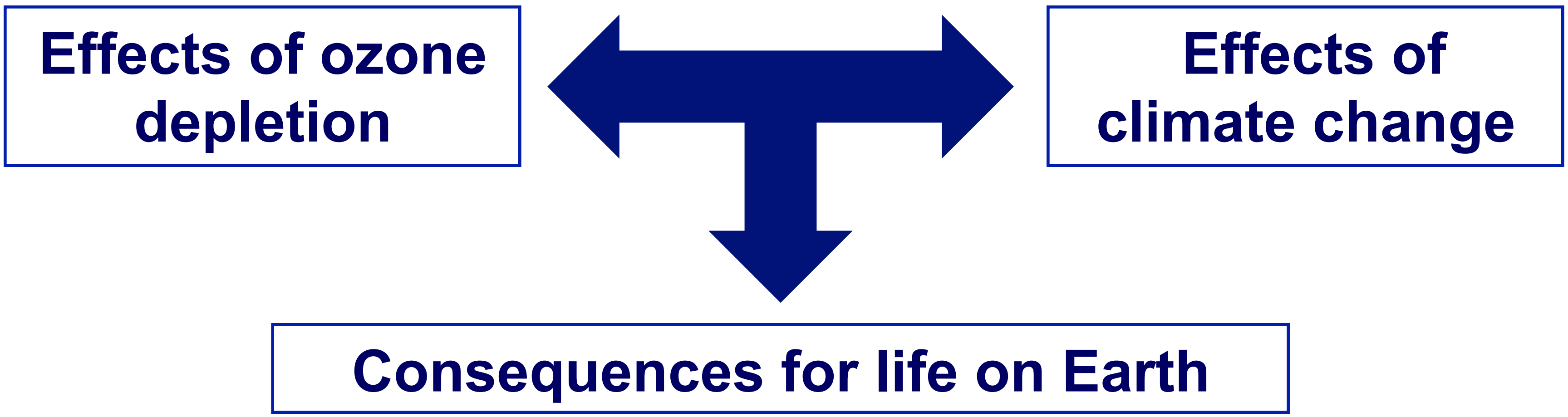
14-16 May 2014


The way in which the 3 Panels complement each other in their contribution to the Montreal Protocol
Stratospheric chemistry, climate
Depletion of strato-spheric ozone (O3)
UV-B radiation
O3 depleting substances
EEAP
Human health
Ecosystem health and services
Materials
Air Quality
ODS applications, substitutes

The role of the Environmental Effects Assessment Panel



Environmental Effects Assessment Panel
EEAP

KEY FOCUS AREAS
Full Assessment Report 2014

Addresses negative and positive effects
of solar UV radiation on:

Human health
Terrestrial ecosystems
Aquatic ecosystems
Carbon and other global chemical cycles
Air quality
Materials

FOCUS ON INTERACTIONS
Ozone depletion, climate change, UV radiation

KEY FINDINGS

Ozone Depletion and Climate Change: Impacts on UV Radiation

Response of UV radiation to ozone recovery

Not yet detectable with statistical significance

UV projections by 2100:

- Ozone recovery and super-recovery (due to GHGs) lead to decreases of UV radiation
- Small increases in the tropics where ozone will be lower due to GHGs
- Clouds: Increase at high latitudes

Ozone depletion, climate change, UV radiation

KEY FINDINGS

Ozone Depletion and Climate Change: Impacts on UV Radiation

UV projections by 2100:

- Aerosols: decreases in UV radiation over polluted regions
- Increases in UV radiation over cleaned areas - possibly the most important factor for future UV radiation at some area
- Ice melting increases UV radiation entering the ocean, llakes
- Personal dosimeters: more realistic quantification of UV exposure for humans than ground-based or satellite

Ozone depletion, climate change, UV radiation

Ozone Depletion and Climate Change: Impacts on UV Radiation

Simulations of surface UV radiation for the future:

- Limited in accuracy due to difficulties in assessing combined effects of clouds and aerosols that are expected to change
- Significant positive & negative changes in aerosol concentrations expected in the future
- Assessments of long-term changes in UV radiation must be based both on observations from space and from the ground
- Ground measurements of UV irradiance - more accurate than the inversion results from satellite data, but spatial coverage of surface observations - sparse in some regions

Ozone depletion, climate change, UV radiation

Projected future changes in UV: ozone and clouds

At high latitudes: cloud cover increases (by ca 5%)

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Reduction of UV radiation (UV already low)

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Less easy to achieve exposure times needed to produce sufficient vitamin D

At low latitudes (near the equator): cloud cover decreases

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Increase in UV radiation (UV already high)

↓

Greater risk of skin cancer, eye damage, changes in the immune system

Human health

KEY FOCUS

Assessment of the effects of UV radiation, and interactions with other environmental change, on human health, including:

- **Immune responses**
- **Skin and eye diseases (especially cancers)**
- **Vitamin D production**

Human health

KEY FINDINGS

Exposure to UV-B radiation has both adverse and beneficial effects on human health

Changing sun exposure behaviours over the past century

- more time in the sun, less clothing cover, preference for a tan
- May have contributed more to higher levels of UV-B exposure than has ozone depletion in some regions

Melanoma skin cancers - still increasing in many countries but has stabilised over the past 5 years

Non-melanoma incidence - still increasing in most locations

Human health

KEY FINDINGS

Exposure to UV-B radiation has both adverse and beneficial effects on human health

Sun exposure of the skin

Causes systemic immune suppression

- may have adverse effects on health

Example:

- through reactivation of latent viral infections
- possibly an impaired immune response to vaccination

Human health

KEY FINDINGS

Exposure to UV-B radiation has both adverse and beneficial effects on human health

But also some beneficial effects of UV radiation through suppression of autoimmune reactivity

Autoimmune diseases where UV-B may have positive effects
Examples:
multiple sclerosis, rheumatoid arthritis

Other effects
Combination of changes in climate and UV radiation
- may alter microbe levels in surface waters
(high UV acts as a sterilising agent)

Human health

KEY FINDINGS

Exposure to UV-B radiation has both adverse and beneficial effects on human health

Eye damage may increase with UV exposure

- pterygium (invasive growth on the eye)
- ocular melanoma
- age-related macular degeneration may increase with UV exposure

Other UV-related diseases

"Cancer eye" in cattle worldwide

10-20% of animals in some Australian herds diagnosed

Most common malignant tumour affecting cattle in the USA

Economic losses - ca $20 million/annum (USA)

Human health

KEY FINDINGS

Exposure to UV-B radiation has both adverse and beneficial effects on human health

UV-B irradiation of the skin
- Main source of vitamin D

Vitamin D plays a critical role in:
- Maintaining body calcium levels and bone health
- Severe deficiency - rickets in children, osteomalacia in adults

Human health

KEY FINDINGS

Continues to be difficult to provide public health messages to guide safe sun exposure

Problems faced:

- Accuracy of this information for different skin types
- Different locations receive different UV radiation levels
- Time of day and duration outdoors – key factors for harmful or beneficial exposure

Human health

Models have estimated that skin cancer incidence world-wide would have been 14% greater (2 million people) by 2030 (van Dijk, Slaper et al. 2013) without implementation of the Montreal Protocol and its amendments

Largest effects in the South West USA and in Australia

Terrestrial ecosystems

KEY FOCUS

Realistic assessment of the impacts of changing UV climate on terrestrial ecosystems requires consideration of

beneficial and detrimental effects of UV-B radiation on organisms and ecosystem processes

- **Ozone depletion**
- **Exposure to increased UV-B radiation (land-use change, behaviour)**
- **Rapid climate change**

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Affect biological and ecological systems with intricate feedbacks and interactions

Terrestrial ecosystems

KEY FINDINGS

Consequences of interactive effects of ozone depletion, UV radiation, & climate change

Effects of increased temperature, drought and UV-B
Indicative of evidence of a changing climate
Long-term and multiple stress exposure may decrease plant productivity and crop quality

Increased exposure to UV radiation
<u>Examples</u>
-predicted decreased cloudiness in e.g., the Mediterranean area
-decreasing trend in aerosol load (air pollution) in some areas

Terrestrial ecosystems

KEY FINDINGS

Consequences of interactive effects of ozone depletion, UV radiation, & climate change

Volatile organic compounds (VOCs)

Emitted from a range of terrestrial and marine systems

Caused by conditions of

- UV radiation
- drought
- soil moisture
- temperature
- ozone
- herbivores (e.g. insects, grazers)

Terrestrial ecosystems

KEY FINDINGS

Consequences of interactive effects of ozone depletion, UV radiation, & climate change

Volatile organic compounds (VOCs)
Contribute to increasing greenhouse gases
E.g, by extending lifetimes of methane

- Environmental factors that stimulate VOC emission, including enhanced UV-B radiation: result in an energy cost to plants
- Potential loss in productivity as a result of allocation of energy and carbon into VOC synthesis

Wetland ecosystems- important sources of methane

Microbially produced methane - well documented (e.g. from peatlands, wetlands)

<u>Methane production from plants</u> – recent research shows Stimulation by:

- **Plant injury**
- **UV-B radiation**
- **temperature**

Terrestrial ecosystems

UV-B radiation and breakdown of dead plant material (litter decomposition)

Decomposition - crucial component of nutrient & element cycling (biogeochemical cycles)

-affects soil fertility, the fate and residence times of carbon and nutrients, plant community composition and production

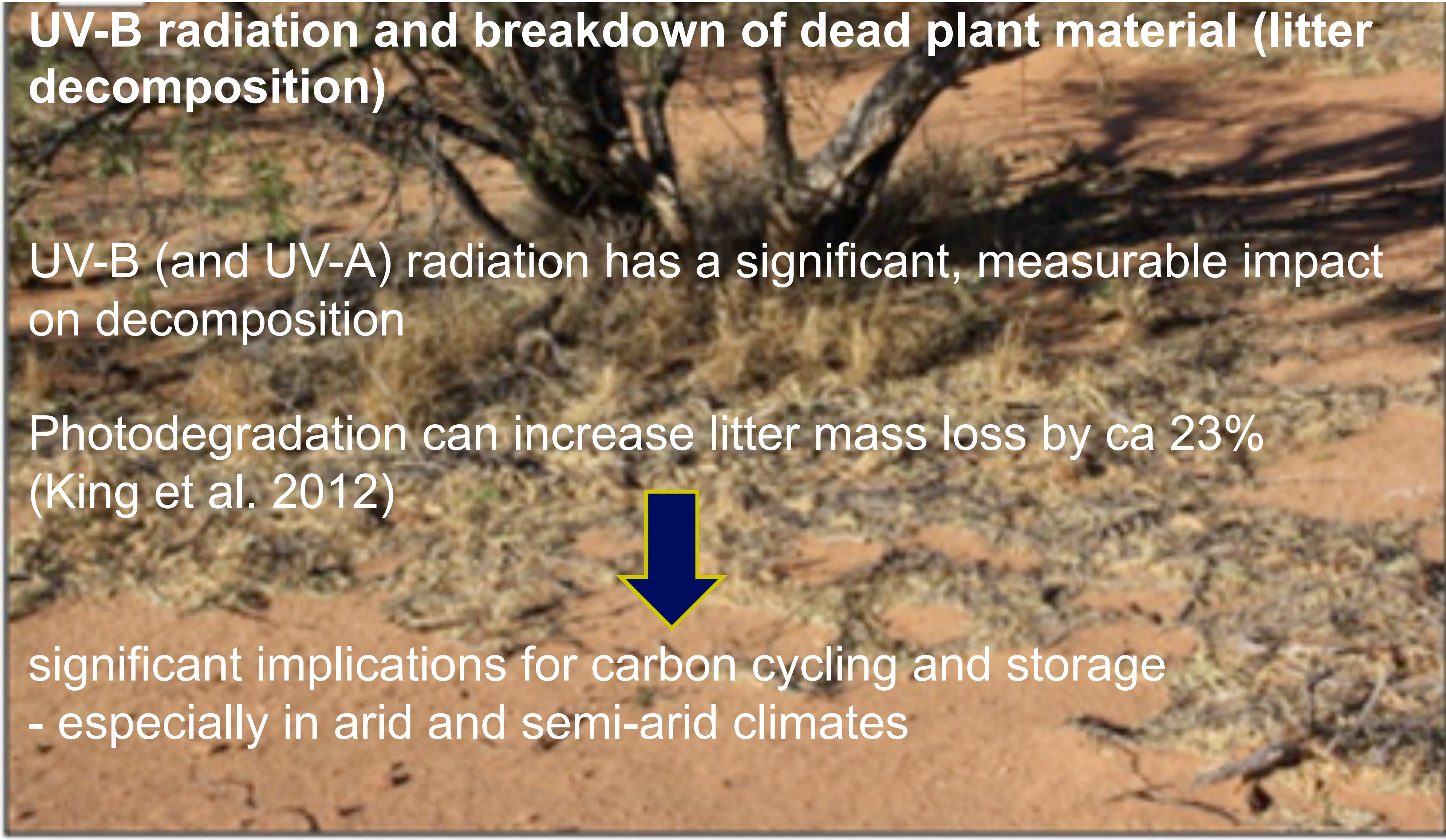
Direct effects of UV radiation on litter decomposition

- Generally negative effect on microbes – retards litter decomp.
- Photodegradation **of** photoreactive material (plant lignin)

- results in efflux of CO_2, CH_4, carbon monoxide, nitrous oxide

- Thus UV-driven photodegradation affects atmospheric CO_2 levels and carbon sequestration

Terrestrial ecosystems



UV-B radiation and breakdown of dead plant material (litter decomposition)

UV-B (and UV-A) radiation has a significant, measurable impact on decomposition

Photodegradation can increase litter mass loss by ca 23% (King et al. 2012)

↓

significant implications for carbon cycling and storage
- especially in arid and semi-arid climates

Terrestrial ecosystems

KEY FINDINGS

Interdependent effects on terrestrial and agricultural systems from solar UV radiation, stratospheric ozone and climate interactions

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Implications for food production and food quality

↓

negative and positive effects

Terrestrial ecosystems

KEY FINDINGS

UV radiation, stratospheric ozone & climate interactions

Implications for food production and food quality

- **Decreased crop biomass**
- **Reduced leaf area**
- **Stimulated phenolic production, resulting in:**

- decreased herbivory
- increased amounts of terpenes (VOC) induced by UV-B radiation - may affect wine flavours!!

Generally, stress factors increase proteins and antioxidants

- but reduce starch and fat
- potential negative effects for crop quality

Aquatic ecosystems

KEY FOCUS

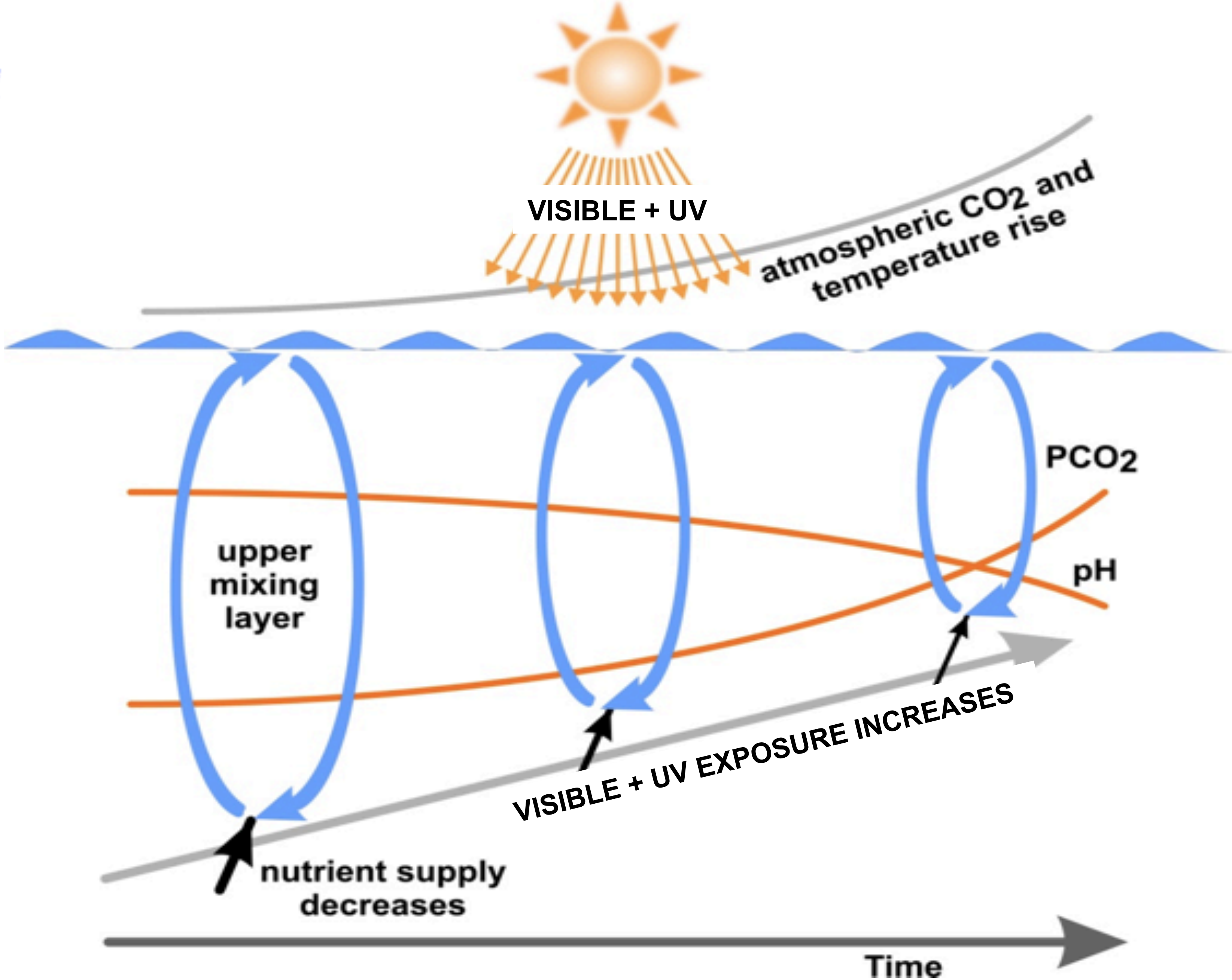
Assessment of the feedbacks between temperature, UV radiation, and GHG production on aquatic systems

Implications for aquatic organisms and the ecosystem services they provide

Food supply

Tourism

Global biodiversity



Modified from Gao et al. 2012

Aquatic ecosystems

KEY FINDINGS

Feedbacks between temperature, UV radiation, and climate

In Arctic and alpine regions

- decreased duration and amount of snow and ice cover on lakes and oceans
- increased exposure to UV radiation

In contrast, in non-Arctic and alpine regions

- greater runoff (more rain, more frequent extreme storms)
- increased concentration & colour of UV-absorbing dissolved organic matter (DOM) from terrestrial ecosystems
- UV radiation breaks down DOM, more available for microbial activity --- release of GHGs into the atmosphere

Aquatic ecosystems

KEY FINDINGS

Feedbacks between temperature, UV radiation, and climate

Fish production, including fish farms

- Expected to exceed that of meat (FAO 2012) in 10 years time
- Aquatic ecosystems provide recreation and tourism coral reefs – generate ca 9.6 billion US$ annually (Parisi & Kimlin 2004)

All of these ecosystem services are being influenced by changes in climate and UV radiation exposure

Carbon and other global chemical cycles

KEY FOCUS

Ways in which climate change enhances effects of UV radiation on biogeochemical cycles in terrestrial and aquatic ecosystems

Interactions and feedbacks

Carbon and other global chemical cycles

KEY FINDINGS

Interactions and feedbacks

Net CO_2 sink strength of these ecosystems may decrease due to multiple interacting effects of solar UV radiation and climate change

Result: positive climate-carbon cycle feedbacks

Carbon and other global chemical cycles

KEY FINDINGS

Interactions and feedbacks

Climate change enhances effects of UV radiation on:

- carbon
- nitrogen
- halogen compounds
- essential trace metals
- pollutants (eg., mercury)

Hence: UV-mediated positive feedbacks on climate

Carbon and other global chemical cycles

KEY FINDINGS

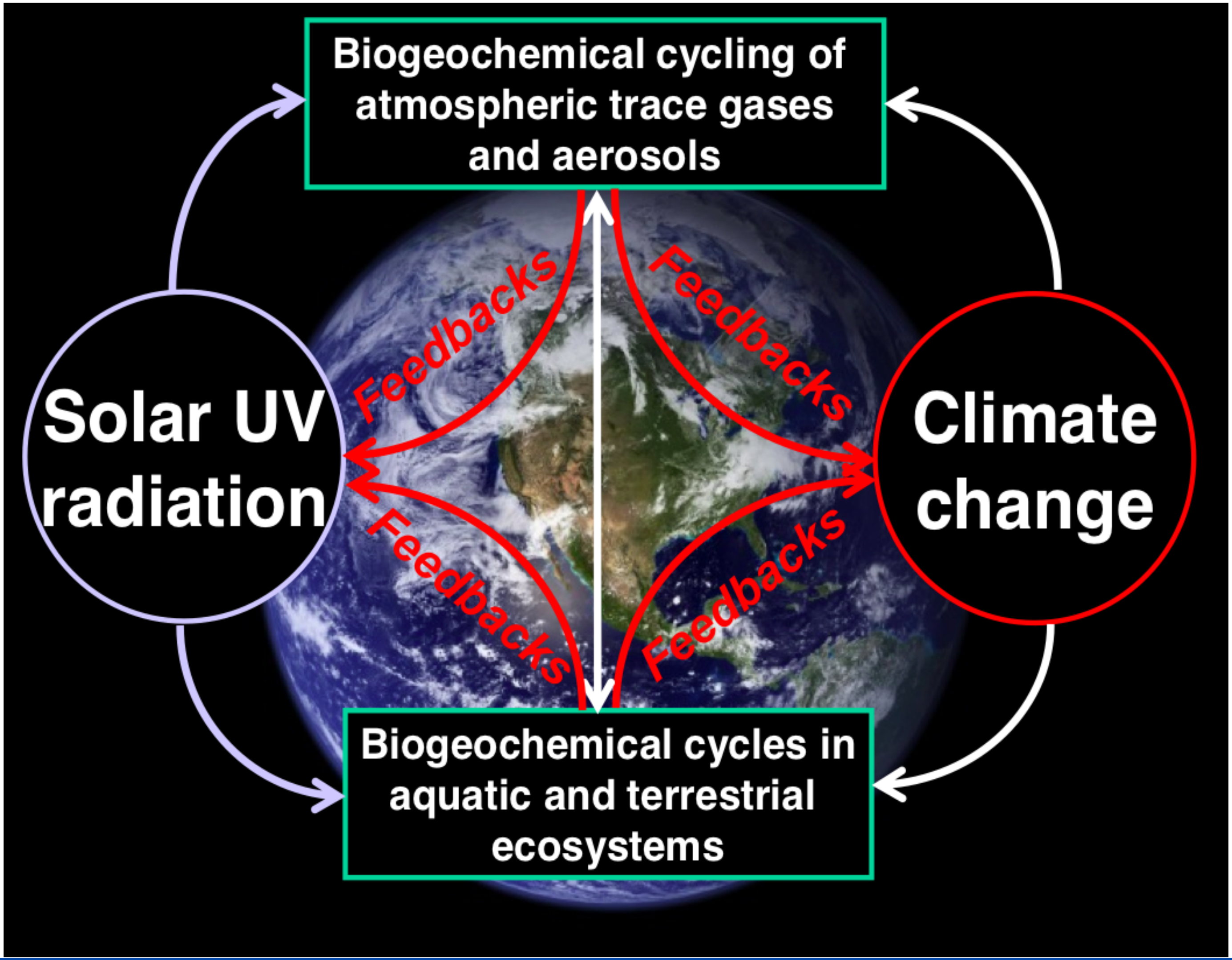
Feedbacks include:

- Increased release of CO_2 to the atmosphere from terrestrial ecosystems due to aridification
- *favours UV-induced mineralisation of above-ground litter*

- Reduced uptake of atmospheric CO_2 by phytoplankton due to UV-induced bleaching of coloured dissolved organic matter

- Enhanced UV-induced mineralisation of dissolved organic matter from coastal and inland waters due to changes in continental runoff and ice melting

Carbon and other global chemical cycles



Materials damage

KEY FOCUS

The Assessment addresses how recent technical advances in degradation and stabilisation techniques impact lifetimes of materials exposed to solar UV radiation

Of the 280 million tons of plastics produced globally, ca 23% are used in building construction

- second largest market for plastics after packaging applications (Plastics Europe, 2012)

Annually, ca 1.8 billion cubic meters of industrial roundwood is harvested worldwide

Carbon and other global chemical cycles

KEY FINDINGS

Environmental damage to materials

- **Routine exposure** to solar UV radiation decreases service life of wood and plastic building materials
- **However**, existing light-stabiliser technologies partly mitigate the damaging effects
- **Personal exposure to UV radiation**

- reduced by clothing fabrics and glass windows used in buildings and automobiles

Clothing protection relies more on the fabric weave and density than on its chemistry

Materials damage

Effect of climatic variables on light-induced degradation of materials

+ effectiveness




	Increase in Solar UV	Increase in Temp.	Increase in Humidity	Increase in Pollutants S, NOx, O_3
Polymer	++++	+++	+	+
Wood	+++	++	+++	+

Key conclusions and future projections

- Assessment of interactive effects of UV radiation, ozone depletion and climate change on organisms and ecosystems recognises that the effects of UV radiation often represent a balance of both positive and negative influences
- Dynamics of ozone depletion - responsible for multiple changes & environmental effects, especially to Southern Hemisphere climate (drought, wind, precipitation)
- Need to understand how ozone recovery will feedback on these climate processes as they impact ecosystems and human health

The end

Ozone depletion, climate change, UV radiation

EXPLANATION FOR PRESENTER OF THE AQUATIC FIGURE: slide number 27

Combined effects of anthropogenic changes in the environmental conditions in aquatic ecosystems. Increasing atmospheric and water CO_2 concentrations reduce the calcifying abilities of many organisms. Increasing water temperatures and incoming solar radiation decrease the depth of the mixing layer (exposing organisms to higher irradiances) and increase the temperature difference between surface and deeper layers. This temperature difference limits the exchange of materials such as nutrients between layers