NATIONAL REPORT THE NETHERLANDS

1. OBSERVATIONAL ACTIVITIES

1.1 Column measurements of ozone and other gases/variables relevant to ozone loss

The Brewer measurements at station “De Bilt” in in the Netherlands by the Royal Netherlands Meteorological Institute (KNMI) with Brewer #189 have been continued up to present. Brewer #189 has been operated continuously since 1 October 2006. It replaced Brewer #100 which provided observations since 1 January 1994.“De Bilt” had the longest record of ozone measured with an MKIII instrument in the WOUDC database. The Brewer ozone column data from 1994-2022 are presently available from WOUDC.

Measurements at station “Paramaribo” in Surinam with Brewer #159 have been continued into 2020. After careful cleaning, the ozone column dataset from1999-2018 has been submitted to WOUDC and NDACC. In 2022 the Brewer #159 in Paramaribo broke down and is since then waiting for repairs (expected during 2024). Ozone sonde measurements at Paramaribo and in de Bilt have been continued but the various databases where data can be downloaded still need to be updated.

The Netherlands was and is involved in satellite measurements with several instruments: GOME, SCIAMACHY, OMI, GOME-2 and TROPOMI. These are UV-visible satellite spectrometers, from which ozone and several other trace gases, like NO2, SO2, HCHO, are determined. The OMI and GOME-2 instruments are operational. The TROPOMI instrument is presently being prepared for launch in 2017.

SCIAMACHY (July 2002-8 April 2012) was contributed by Germany, the Netherlands, and Belgium to ESA’s Envisat satellite. OMI (1 October 2004 onward) is a contribution from the Netherlands and Finland to NASA’s EOS-Aura satellite. TROPOMI is the successor instrument of OMI and SCIAMACHY. TROPOMI was developed by the Netherlands and ESA, and was launched on the ESA Sentinel-5 Precursor mission on 13 October 2017. KNMI has the PI-role of OMI as well as TROPOMI. TROPOMI total ozone data (DLR) and ozone profile data (KNMI) are now provided operationally in near-real time. A first reprocessing of all TROPOMI data has been performed in 2023.

1.2 Profile measurements of ozone and other gases/variables relevant to ozone loss

The ozone sounding program at station “De Bilt” in the Netherlands by KNMI has been continued up to present, with at least one launch per week, and more when special events or campaigns occurred.

The ozone sounding program in Paramaribo, Surinam has been continued with one launch per week. Paramaribo station is part of the SHADOZ network. The observations at Paramaribo are performed by staff of the Meteorological Service of Surinam and co-processed by KNMI.

After 25 years of operation, during recent years RIVM has gradually handed over responsibility for the stratospheric ozone lidar at the NDACC station in Lauder, New-Zealand to NIWA. Measurements have continued without interruption and will continue. The new instrument PI is now Dr Richard Querel of NIWA. The transfer of the instrument and associated responsibilities has been finalized in 2023.

The measurements from the above under 1.1 mentioned satellite instruments GOME, SCIAMACHY, OMI, GOME-2 and TROPOMI are also used to retrieve profiles of ozone and other trace gases (see table 1)

KNMI in the Netherlands is also responsible for operational processing of GOME-2 ozone profile data as part of the EUMETSAT Ozone SAF. KNMI is similarly responsible for the operational of TROPOMI ozone profile data as part of the ESA operational TROPOMI data processing.

1.3 UV measurements

The National Institute for Public Health and the Environment (RIVM) has continued monitoring spectral UV irradiance at Bilthoven, the Netherlands. The overall UV data record now spans 29 years (1994-2023), the 2023 data remains to be validated and or not included in this report. The solar UV spectrum is recorded at ground level, every 12 minutes, from sunrise to sunset. More than 20 000 spectra are recorded each year. The spectral data are automatically processed with a quality control and data analysis software package (SHICrivm).

The KNMI MSR-2 dataset – see later section 4.1.3 - has also been used as input for generating the unique 60+ year global daily UV index data record (1960-current), available via the TEMIS.nl data portal. The same total ozone column data assimilation system – combined with ECMWF operational weather forecasts - is also used for daily global UV index predictions up to 9 days ahead in time. This service – also available via TEMIS.nl - has over 20,000 users globally. Finally, the MSR-2 total ozone data assimilation data system has also been connected with EUMETSAT SEVIRI cloud data to reconstruct the cloud-modified daily UV dose (2002-current), a measure of the total daily UV dose received at Earth's surface (for the SEVIRI disc, so Europe/Africa) taking cloud cover into account (available at TEMIS.nl).

1.4 Measurements of substances controlled under the Montreal Protocol

Netherlands Organisation for Applied Scientific Research (TNO) has been involved in an eighth month field campaign (December 2021 – July 2022) at the Ruysdael observatory site in the Netherlands (Cabauw tower; https://ruisdael-observatory.nl/). During this field campaign several substances controlled under the Montreal Protocol have been measured and analysed using a MEDUSA instrument (Rust et al., 2023).

In addition, TNO has since 2021 started taking daily flask samples at the top of the Cabauw tower (200 m.a.s.l.) for the presence of halocarbons and to start building a long term data record. Note that those measurements are also made available for the European Union PARIS project funded by the European HORIZON program (https://horizoneurope-paris.eu/).

2. RESULTS FROM OBSERVATIONS AND ANALYSIS

2.1 Assessment contributions, input to negotiations on the amendment of the Montreal protocol

Netherlands scientists (Guus Velders from RIVM, and Jos de Laat and Ronald van der A from KNMI) have contributed to several chapters of the last UNEP/WMO Scientific assessment report.

Guus Velders has for many years provided important information on the future atmospheric abundances and climate forcings from scenarios of global and regional HFC emissions. The Montreal Protocol has been very successful in phasing out the global production and consumption of ozone-depleting substances (ODSs). In response, the use of HFCs as ODS replacements has increased strongly since the mid-1990s for refrigerants and foam blowing agents, medical aerosol propellants and miscellaneous products. HFCs do not deplete the ozone layer, but are greenhouse gases and therefore contribute to the radiative forcing of climate. Almost all HFCs currently used as CFC and HCFC replacements have high (100-yr time horizon) global warming potentials (GWPs) ranging from about 150 to 8000. Observations show that the abundances of many HFCs are increasing in the atmosphere. Therefore without regulations, HFCs would contribute significantly to future climate forcing.

2.2 UV trend analysis

As mentioned above, RIVM has continued monitoring the spectral UV irradiance in Bilthoven, the Netherlands. In the summer of 2020, Brewer #251 was installed at the RIVM, the intended successor to the DILOR spectrometer. The Brewer became operational on April 2021.

The RIVM uses its measurements to calculate the annual doses of UV radiation at ground level and makes a comparison with modelled annual UV doses. The model uses total column ozone data to calculate the cloud free annual UV dose, and measurements of global solar radiation (data from KNMI) as a proxy for the impact of cloudiness, see Den Outer et al., 2010. A second set of annual UV doses is constructed by excluding the effect of cloudiness. These procedure allows for a separation of trends caused by changes in the total ozone column and changes in cloudiness as inferred from measurements of global solar radiation. The results are shown in Figure 1.

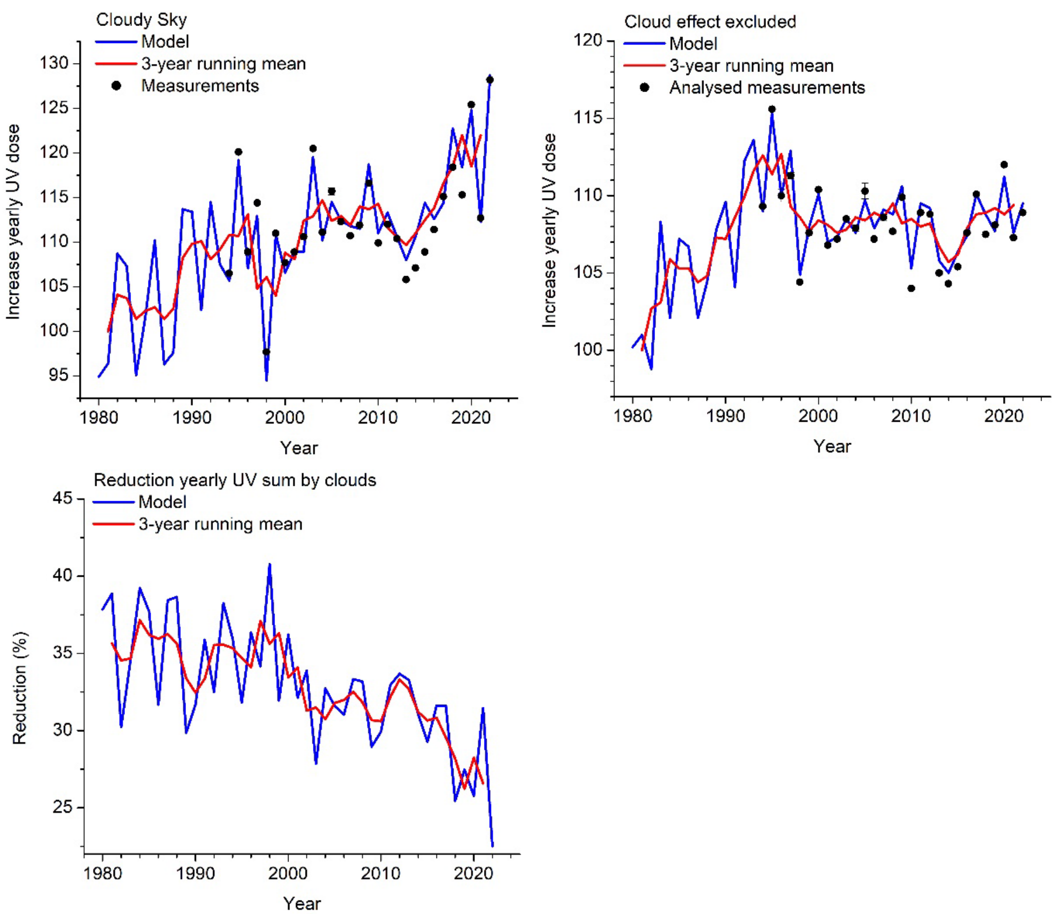

Figure 1

Observed (black dots) and modelled annual UV dose (blue curve, red curve is three-year running mean) in past decades in Bilthoven, the Netherlands. All values are relative to the modelled average for the years 1980-1982. The upper left panel shows the relative dose received at the ground including changes and variations caused by clouds and by ozone; the upper right panel shows solely the ozone related changes in UV irradiation; the lower panel shows solely the contribution of cloudiness to the variations in the annual UV dose.

When cloud effects are excluded, the maximum UV doses were found in the mid-nineties of the last century (see Figure 1, lower panel). Since that period, the cloud free annual UV dose decreased but appears to stay on a higher level than in the early eighties. The three-year running average (red line in

Figure 1 middle panel) follows the calculated values using the AMOUR-model that implements the anticipated influence of the Montreal Protocol plus amendments (van Dijk et al., 2013; not shown here). Thus, observations of the UV-radiation in the Netherlands are in line with an expected recovery of the ozone layer.

However, the actual UV doses measured at ground level (Figure 1, upper panel) continues at a positive trend and show maxima more recently (2020 and 2022). This is due to a change in cloudiness in the passed decade as inferred from measurements of the global solar radiation (Figure 1 lower panel). Whether less clouds, a change of cloud type or seasonal changes play a role has still to be determined. The apparent change in cloudiness negates the decrease in UV due to increased total ozone column (Figure 1, upper panel).

Since the start of cancer registration in the Netherlands in 1989, the yearly number of new melanoma cases has gone up by a factor of four for men and by a factor of five for women. About half of this growth comes from the growing life expectancy. After age-standardization of the population, the remaining incidence signal for melanoma still shows an upward trend of a factor two for men and three for women. These trends cannot be attributed to the climatological or environmental increase in available UV alone. There must be other causes such as increased exposure (1), increased sensitivity (2), changes affecting cancer registration (3) or other skin carcinogenic agents that have been overlooked (4). For all of these four types of factors, many different (plausible and less plausible) candidate attributions are available, but the evidence for causality is still lacking.

There is an international need to close this knowledge gap because a lack of knowledge about the true causes of skin cancer trends is preventing society from solving this issue efficiently and effectively. The registry data show that the increasing trend in the incidence of melanoma stems exclusively from new diagnoses of 'stage I' melanoma in people over 45 years of age. Stage I is the melanoma diagnosis with the best expectation of cure. There is no observable trend in the age-standardized incidence for the higher melanoma stages.

Regarding the mortality from melanoma, after age-standardization, the upward trend that was manifest until 2010 has been countered and mortality has now fallen by approximately 25% compared to the maximum in 2010. This is the result of new successful forms of melanoma treatment, such as targeted immunotherapy, that have now become available. For non-melanoma skin cancer, as with melanoma, there is an upward trend in the annual number of new cases, and about half of the trend is due to ageing. Despite the upward trend in the (age-standardized) incidence of non-melanoma skin cancer, the age-standardized mortality from squamous cell carcinoma surprisingly shows no trend since the start of the registration: mortality remains at a fixed level.

Skin cancer risks might further increase due to the presently observed increase in UV radiation levels. Furthermore, climate change could lead to behavioural changes in people that increase their UV exposure, and thus climate change could indirectly contribute to an increase in the future risk of skin cancer. It is unclear to what extent changes in air quality affect and have already affected people's sensitivities to developing skin cancer. This possible cause of health effects should also be included when studying climate change and health.

3. THEORY, MODELLING, AND OTHER OZONE RELATED RESEARCH

De Laat et al. [2024] explore the use of TROPOMI total nitrogen dioxide columns (NO_2) for monitoring the nitrogen processing within the Antarctic stratospheric vortex (ozone hole). Because high southern hemisphere latitudes are devoid of tropospheric NO_2 sources the total column actually NO_2 represents the total stratospheric NO_2 column. Furthermore, stratospheric nitrogen processing is crucial for catalytic ozone destruction in the Antarctic ozone hole. During wintertime the so-called denitrification process depletes the Antarctic vortex from nitrogen oxides which normally bond chlorine into a reservoir species.

Without nitrogen oxides chlorine can freely roam around and activate during spring under the influence of sunlight to start the rapid catalytic ozone destruction cycle. The authors show that this innovative use of TROPOMI NO_2 data allows for detailed monitoring of Antarctic ozone hole dynamics as well as stratospheric chemistry. Although not completely new – there are two explorative research papers from the early 2000s on this topic – this application has been shelved for two decades. This innovative earth observation application is also welcomed with the dwindling stratospheric earth observation capacity – especially with the end of the MLS (EOS-Aura) mission in 2026. With at least 20 years of high quality daily total NO_2 column data from satellite instruments such as SCIAMACHY, OMI, GOME-2 and now TROPOMI – and combined with also 15+ years of IASI HNO_3 total column data - there is great potential for further exploring the stratospheric nitrogen cycle in and around the Antarctic vortex from short term daily variability to long term decadal trends. An example of a daily image of TROPOMI total nitrogen dioxide columns (NO_2) and its correspondence with total O_3 columns is provided in Figure 2.

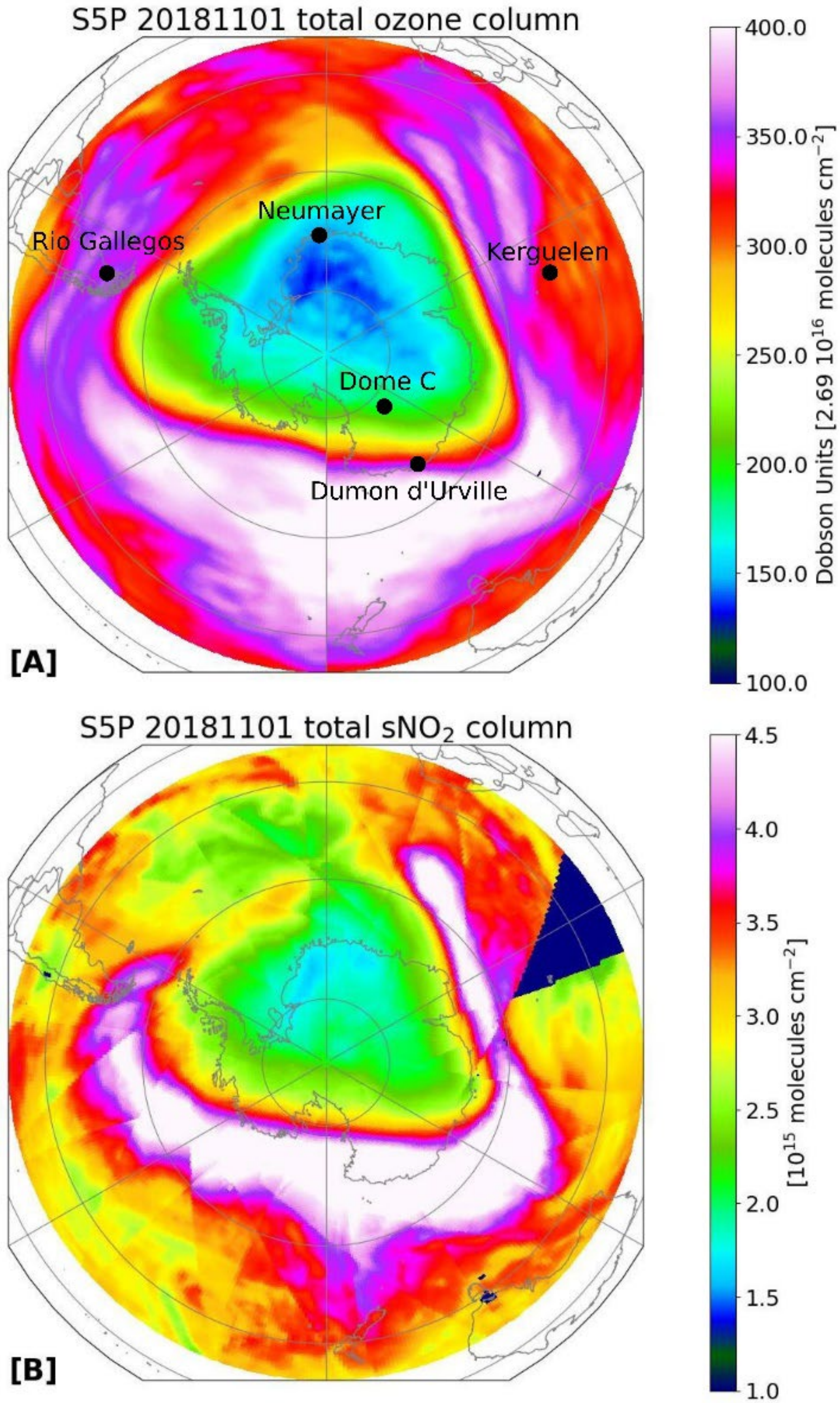

Figure 2. Maps of globally gridded TROPOMI-based and globally gridded local solar noon assimilated total column O_3 (top; in Dobson Units or DU) and stratospheric NO_2 (bottom; in µmol m^{-2}) on 1 November 2018. The filled dark blue area in panel B denote areas without TROPOMI data.

4. DISSEMINATION OF RESULTS

4.1 Data reporting

4.1.1 Ozone column reporting

The ozone column data from Brewer #189 in De Bilt for 1994-2022 are available from WOUDC. The ozone column data from Brewer #159 in Paramaribo for 1999-2022 are available from both WOUDC and NDACC. Total ozone column data is also provided to the GCOS Reference Upper Air Network (GRUAN) for both Paramaribo and Cabauw (close to de Bilt). Cabauw is part of the newly Ruisdael Observatory, a national Dutch initiative for a nationwide measurements of the atmosphere. Data for 2023 is being finalized for submission to the various data repositories.

4.1.2 Ozone profile reporting

The ozone sounding data from De Bilt for 1992-2022 are available from WOUDC. The ozone sounding data from Paramaribo for 1999-2022 are available in the SHADOZ archive https://tropo.gsfc.nasa.gov/shadoz/Paramaribo.html and from WOUDC. Ozone profile data is also provided to the GCOS Reference Upper Air Network (GRUAN) for both Paramaribo and de Bilt. Data for 2023 is being finalized for submission to the various data repositories.

4.1.3 Satellite data processing and reporting

At KNMI near-real time and off-line data processing of satellite ozone columns and ozone profiles is taking place; see Table 1. Also data assimilated products are made. Most of the products are being delivered to users via the web portal www.temis.nl. Originally the multi-sensor reanalysis 1 (MSR1) covered 1978-2008 which in 2015 was upgraded, refined and extended into the MSR2 dataset covering 1970-2012. The MSR2 dataset has more recently been further upgraded, refined and using for example of ground-based total ozone data. It has been extended back to 1960 and there have been continued annual updates [de Laat and van der A, 2024; in preparation]. The data is available at http://www.temis.nl/protocols/O3global.html.

The OMI ozone products are being delivered via the GSFC Data and Information Services Center (DISC). GOME-2 data processing at KNMI (January 2007 onward) is performed in the framework of the Ozone and Atmospheric Chemistry Monitoring Satellite Application Facility (ACSAF) of EUMETSAT. Data delivery of near-real-time ozone profile products is done via EUMETCast broadcasting**.** The TROPOMI ozone products data delivery has been changed from the ESA Copernicus Open Access Hub to the COPERNICUS Data Space Ecosystem, while an Amazon cloud repository has also been made public.

There are many users of the satellite ozone data; for example, OMI ozone column data is being delivered in near-real-time to ECMWF for assimilation in the model, amongst others for the Copernicus Atmosphere Monitoring Service (CAMS) forecasts and reanalyses.

Instrument	**Product**	**Period**	**Data delivery**
GOME	Ozone column	1995 – 2011	http://www.temis.nl

		(global until 2003)	
SCIAMACHY	Ozone column	2002 – 2012	http://www.temis.nl
OMI	Ozone column, Ozone profile, Assimilated ozone column	2004 – now	http://www.temis.nl http://disc.sci.gsfc.nasa.gov/Aura
TROPOMI	Ozone column, Ozone profile, Assimilated ozone column	2017- now	https://dataspace.copernicus.eu/ https://documentation.dataspace.copernicus.eu/APIs/S3.html
GOME-2	Ozone profile, Assimilated ozone column	2007 – now	http://www.temis.nl http://o3msaf.fmi.fi http://wdc.dlr.de/data_products/SERVICES/GOME2NRT/o3.php
Multi-Sensor Reanalysis2 (MSR2)	Assimilated ozone column	1960-2023	http://www.temis.nl

Table 1: Near-real-time and offline satellite ozone products made by KNMI

4.2 Information to the public

The Netherlands satellite ozone observations have been used in the Antarctic and Arctic Ozone Bulletins given out by WMO. Each year on World Ozone Day a national news item – in Dutch - is published on the website of KNMI about the status and evolution of the ozone layer and UV, e.g.:

- in 2020 https://www.knmi.nl/over-het-knmi/nieuws/zeldzaam-ozongat-boven-de-noordpool
- in 2020 https://www.knmi.nl/over-het-knmi/nieuws/het-antarctisch-ozongat-2020-uitzonderlijk-maar-niet-verassend
- in 2023 https://www.knmi.nl/over-het-knmi/nieuws/herstel-van-het-ozongat

A near-real time solar UV index (or *zonkracht* in Dutch) based on observations is presented on the RIVM website (www.rivm.nl/zonkracht). Forecasts of the solar UV index are daily presented on the KNMI website (https://www.knmi.nl/nederland-nu/weer/waarschuwingen-en-verwachtingen/zonkracht).

KNMI also contributed to the WMO “Ozone and UV Bulletin” via membership of the WMO Ozone and UV Science Advisory Group (https://library.wmo.int/idurl/4/66208).

KNMI also regularly reports about other interesting stratospheric phenomena, for example:

- in 2022 https://www.knmi.nl/over-het-knmi/nieuws/onverwacht-klimaateffect-van-de-vulkaanuitbarsting-hunga-tonga-in-2022
- in 2022 https://www.knmi.nl/over-het-knmi/nieuws/klimaateffecten-van-vulkaanuitbarsting-tonga-waarschijnlijk-klein
- in 2023 https://www.knmi.nl/over-het-knmi/nieuws/nog-weinig-lichtende-nachtwolken-te-zien-dit-jaar

4.3 Scientific papers

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*Flerlage, H., **Velders, G. J.**, & de Boer, J.: A review of bottom-up and top-down emission estimates of hydrofluorocarbons (HFCs) in different parts of the world. Chemosphere, 283, 131208, 2021*

*Guo, L., Yang, Y., Fraser, P.J., **Velders, G.**, et al. Projected increases in emissions of high global warming potential fluorinated gases in China. Commun Earth Environ 4, 205, https://doi.org/10.1038/s43247-023-00859-6 , 2023*

***Keurentjes A.J.**, Jakasa I, **van Dijk A**, et al. Stratum corneum biomarkers after in vivo repeated exposure to sub-erythemal dosages of ultraviolet radiation in unprotected and sunscreen (SPF 50+) protected skin. Photodermatol Photoimmunol Photomed. 2022; 38: 60–68. https://doi.org/10.1111/phpp.12717*

*Kyle R. Clem; Susheel Adusumilli; Rebecca Baiman; Alison F. Banwell; Sandra Barreira; Rebecca L. Beadling; Deniz Bozkurt; Steve Colwell; Lawrence Coy; Rajashree T. Datta, **Jos de Laat** et al., 2022 Antarctic ozone hole [in "State of the Climate in 2022; Antarctic and the Southern Ocean"], Bulletin of the American Meteorological Society, DOI: 10.1175/bams-d-23-0077.1. 2023*

*Kyle R. Clem; Marilyn N. Raphael; Susheel Adusumilli; Rebecca Baiman; Alison F. Banwell; Sandra Barreira; Rebecca L. Beadling; Steve Colwell; Lawrence Coy; Rajashree T. Datta, **Jos de Laat** et al, 2021 Antarctic ozone hole [in "State of the Climate in 2021; Antarctica and the Southern Ocean"], Bulletin of the American Meteorological Society DOI: 10.1175/bams-d-22-0078.1, 2022*

*Khaykin, S.M., **de Laat, A.T.J**., Godin-Beekmann, S. et al. Unexpected self-lofting and dynamical confinement of volcanic plumes: the Raikoke 2019 case. Sci Rep 12, 22409, https://doi.org/10.1038/s41598-022-27021-0, 2022*

*Lickley, M., Solomon, S., Fletcher, S., **Velders, G.**, et al.: Quantifying contributions of chlorofluorocarbon banks to emissions and impacts on the ozone layer and climate. Nat Commun 11, 1380 (2020). https://doi.org/10.1038/s41467-020-15162-7, 2020*

***de Laat, A., van Geffen, J., Stammes, P., van der A, R., Eskes, H., and Veefkind, P.**: The Antarctic stratospheric Nitrogen Hole: Southern Hemisphere and Antarctic springtime total nitrogen dioxide and total ozone variability as observed in Sentinel-5p TROPOMI data, EGUsphere [preprint; accepted for publication March 2024], https://doi.org/10.5194/egusphere-2023-2384, 2024*

*O. Morgenstern, S. M. Frith, G. E. Bodeker, V. Fioletov, **Ronald J. van der A**. Reevaluation of Total-Column Ozone Trends and of the Effective Radiative Forcing of Ozone-Depleting Substances, Geophysical Research Letters, Year: 2021, DOI: 10.1029/2021GL095376*

*Rust D, Vollmer MK, Henne S, Bühlmann T, **Frumau A, van den Bulk P**, Emmenegger L, Zenobi R, Reimann S. First Atmospheric Measurements and Emission Estimates of HFO-1336mzz(Z). Environ Sci Technol. 2023 Aug 15;57(32):11903-11912. doi: 10.1021/acs.est.3c01826. Epub 2023 Jul 28. PMID: 37506302.*

*Sharon Stammerjohn; Ted A. Scambos; Susheel Adusumilli; Sandra Barreira; Germar H. Bernhard; Deniz Bozkurt; Seth M. Bushinsky; Kyle R. Clem; Steve Colwell; Lawrence Coy, **Jos de Laat et al**, 2020 Antarctic Ozone Hole [in "State of the climate in 2020; Antarctica and the Southern Ocean"], Bulletin of the American Meteorological Society, DOI: 10.1175/bams-d-21-0081.1, 2020*

***Velders, G. J. M.**, Daniel, J. S., Montzka, S. A., Vimont, I., Rigby, M., Krummel, P. B., Muhle, J., O'Doherty, S., Prinn, R. G., Weiss, R. F., and Young, D.: Projections of hydrofluorocarbon (HFC) emissions and the resulting global warming based on recent trends in observed abundances and current policies, Atmos. Chem. Phys., 22, 6087–6101, https://doi.org/10.5194/acp-22-6087-2022, 2022*

*Willi, K., Ravishankara, A. R., **Velders, G. J.**, Daniel, J. S., McFarland, M., & Andersen, S. O. (2021). The Precautionary Principle and the Environment: A Case Study of an Immediate Global Response to the Molina and Rowland Warning. ACS Earth and Space Chemistry, 5(11), 3036-3044.*

5. PROJECTS, COLLABORATION, TWINNING AND CAPACITY BUILDING

Below follows a list of projects related to UV and ozone research during 2020-2023:

- SHADOZ: The Brewer observations and ozone soundings at Paramaribo are performed by and analysed together with the staff of the Meteorological Service of Surinam. In the past several training sessions have been organized by both KNMI and SHADOZ (NASA).
- ESA Climate Change Initiative project extension CCI+ (Ozone_cci, http://www.esa-ozone-cci.org). KNMI contributes with the further development and evaluation of the MSR2 total ozone column dataset.
- WOUDC (World Ozone and Ultraviolet radiation Data Center)
- NDACC (Network for the Detection of Atmospheric Composition Change)
- GRUAN (GCOS Reference Upper-Air Network)
- COPERNICUS/CAMS (EU project, KNMI leading the task for developing the atmospheric chemistry modelling component of the IFS system (IFS-COMPO); in 2023 extended with interactive full stratospheric chemistry module BASCOE)
- AC-SAF (EUMETSAT's Satellite application facility on ozone and atmospheric chemistry): (https://acsaf.org/)

6. IMPLEMENTATION OF THE RECOMMENDATIONS OF THE 11th OZONE RESEARCH MANAGERS MEETING

- The possibility that Kip & Zonen will end the production and maintenance of Brewer instruments provides a potential problem for continuation of ground-based total ozone column observations as part of the reference network. KNMI has started in 2023 exploring use of other instrumentation as alternative or future replacement of the Brewer instruments (in particular Pandora instruments). The coming years should provide clarification what is achievable and if alternatives are viable.
- The upgrade, refinement and extension of the global daily MSR2 total ozone column dataset contributes to "efforts for supporting ongoing and new observations of ozone".

7. FUTURE PLANS

TNO is working on a proposal for continued halocarbon measurements at the Dutch Cabauw measurement site (Ruysdael observatory) which includes purchase of a MEDUSA instrument in order to be able to conduct their own analyses. Currently daily flask samples take at the site are analysed at Bristol University.

KNMI aims to continue its contribution to the ozone monitoring networks (WOUDC, NDACC, SHADOZ, GRUAN) with its ground based an sonde measurements; its contribution to producing and updating the homogenized global total ozone column dataset MSR-2 as well as the derived UV data (UV index; daily UV dose); operational total ozone and UV Index forecasting; production of ozone profile data from GOME-2 and TROPOMI satellite observations; CAMS task on developing and improving the atmospheric chemistry modelling component of the IFS system (IFS-COMPO).

Furthermore, KNMI will continue to act as key player with regard to satellite instruments as PI institute for TROPOMI on the Sentinel-5-precursor with also strong contributions the upcoming satellite Sentinel-5 mission as well as contributing to other satellite missions (OMI as co-PI; CMSAF for GOME-2).

8. NEEDS AND RECOMMENDATIONS

The AMOUR assessment Model for UV-radiation and Risks, which has been developed at RIVM, can be used to assess the UV-related health consequences of different climate scenario's and compare the impact. It has for example been used to assess the health gain from the Montreal Protocol. The model however does not yet include developments in behaviour. Cancer registry data demonstrate that a good representation of future health development requires inclusion of behavioural changes and impact from skin cancer prevention campaigns. Therefore, we recommend to invest in extension of the AMOUR model to include these factors.

The trends in skin cancer (incidence and mortality) cannot be explained by the climatological/environmental increase in available UV alone. Other causes must be at stake, such as (1): increased exposure, (2): increased sensitivity, (3): changes affecting cancer registration or (4): other skin carcinogenic agents that have been overlooked. For all of these four types of factors, many different (plausible and less plausible) candidate attributions are available as correlates, but the evidence for causality is still lacking. There is an international need to fill this knowledge gap, as lack of knowledge of the true causes of trends in skin cancer prevents society from efficient and effective solution of the issue.