DENMARK

1. OBSERVATIONAL ACTIVITIES

The Danish Meteorological Institute (DMI), in collaboration with the Danish Environmental Protection Agency, conducts permanent measurements of the stratospheric ozone layer. Daily ground-based measurements of the ozone layer thickness as well as weekly balloon based measurements of the vertical ozone profiles are performed in Denmark and Greenland. The measurements are reported to international databases. In addition the measurements are incorporated in validation of satellite measurements. Balloon-based measurements of the ozone layer are often conducted as part of larger international projects such as Match-campaigns.

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

Daily observations of total ozone are performed by the DMI in Denmark and Greenland:

<table>
<thead>
<tr>
<th>Station</th>
<th>Location</th>
<th>Instrument</th>
<th>Start of observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Copenhagen</td>
<td>56°N, 12°E</td>
<td>Brewer Mark IV</td>
<td>May 1992</td>
</tr>
<tr>
<td>Sondre Stromfjord</td>
<td>67°N, 51°W</td>
<td>Brewer Mark II</td>
<td>September 1990</td>
</tr>
<tr>
<td>(Kangerlussuaq)</td>
<td></td>
<td>Brewer Mark III</td>
<td>February 2010</td>
</tr>
<tr>
<td>Thule Air Base</td>
<td>77°, 69°W</td>
<td>SAOZ 1024 diode array</td>
<td>September 1990</td>
</tr>
<tr>
<td>(Pituffik)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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

Weekly ozone soundings have been performed using balloon-borne EEC sensors from Scoresbysund (Illoqqortoormiut, 71°N, 22°W) since January 1993. Ozone soundings have also been performed on campaign basis from Thule Air Base each winter since January 1992 and occasionally from Copenhagen.

1.3 UV measurements

1.3.1 Broadband measurements

A Yankee Environmental Systems model UVB-1 radiometer has been operated by DMI in Copenhagen since 1996. A custom UV radiometer (erythemally weighted UV and total UV-A) has been in operation in Thule (Pituffik) since 1993. The latter instrument is owned by the Health Protection Agency in the U.K. (former National Radiological Protection Board) and the UV-B part of the instrument is similar to the Solar Light model 500.

1.3.2 Narrowband filter instruments

A narrowband filter instrument – Biospherical Inc., model GUV2511 – has been operated on the east coast of Greenland at Scoresbysund (Illoqqortoormiut) by DMI since 2008.

1.3.3 Spectroradiometers

At Sondre Stromfjord (Kangerlussuaq) the Brewer MkII instrument has measured spectral UV-B (290-325nm) since late 1990 and the Brewer MkIII instrument since February 2010.
2. RESULTS FROM OBSERVATIONS AND ANALYSIS

Summer (June, July, August) average column ozone measurements, based on NASA TOMS Nimbus 7 version 8 (years 1979-1991) and DMI Brewer (years 1992-2013) from Sondre Stromfjord (Kangerluissuaq), Greenland, are shown in left-hand side in the figure below.

Likewise summer (June, July, August) average column ozone measurements, based on NASA TOMS Nimbus 7 version 8 (years 1979-1991) and DMI Brewer (years 1992-2013) from Copenhagen, Denmark, are shown in the right-hand side of the figure. Neither of the two data sets shows significant trends since 1992.

Below is shown the 20-year long record of weekly ozone soundings from Scoresbysund (Illoqqortoormiut). Shown are the vertical profiles of ozone partial pressure (mPa).
3. THEORY, MODELLING, AND OTHER RESEARCH

DMI has participated in major European Arctic and tropic campaigns since the beginning of the 1990's including EASOE, SESAME, THESEO, THESEO-2000-SOLVE, VINTERSOL, HIBISCUS, and Scout-AMMA, as well as a long series of EU-projects. The research is based on a broad spectrum of accessible observations and analyses of meteorological conditions in the stratosphere. DMI participates in the EC-Earth climate model development, in particular regarding an improved representation of the stratosphere, and studies are performed on the downward influence from the stratosphere on tropospheric climate. Using the personal exposure data combined with satellite and ground station data DMI has participated in the development of more accurate models to assess the impact of climate change on future UVR exposure to European populations.

4. DISSEMINATION OF RESULTS

4.1 Data reporting

The measurements are reported to databases under Network for the Detection of Atmospheric Composition Change (NDACC) and World Ozone and UV-radiation Data Center (WUDDC) under the WMO-programme Global Atmosphere Watch (GAW).

4.2 Information to the public

UV-index forecasts, based on Danish total ozone measurements, were initiated at DMI in summer 1992. This public service runs permanently, made public on the Internet and in several media. DMI is responsible for the Near Real Time UV-index processing as part of the EUMETSAT Satellite Application Facility on Ozone and Atmospheric Chemistry Monitoring and provides daily global maps of clear sky UV-indices. DMI has initiated a UV service for Greenland in collaboration with the Greenland Department for Health. DMI's ozone measurements are made available on the Internet (www.dmi.dk) together with a yearly updated status report (in Danish language).

4.3 Relevant scientific papers


B. Christiansen, Stratospheric bimodality: Can the equatorial QBO explain the regime behavior of the NH winter vortex?, J. Climate, 23(14), 3953-3966, 2010.


5. PROJECTS AND COLLABORATION

Thule (Pituffik), Sondre Stromfjord (Kangerlussuaq), and Scoresbysund (Iltoqqortoormiit) are Arctic stations within the Network for the Detection of Atmospheric Composition Change. In addition to the DMI instrumentation, aerosol lidars are operated at these stations by the University of Rome (Italy) and SRI International (USA), respectively, together with an FTIR spectrometer at Thule, operated by National Center for Atmospheric Research (USA). DMI also collaborates with Laboratoire Atmosphères, Milieux, Observations Spatiales (LATMOS) (France) for daily total ozone measurements by a SAOZ instrument at Scoresbysund. DMI participates from Thule and Scoresbysund in the yearly Match-campaigns, coordinated by the Alfred Wegener Institute in Germany, with ozone soundings in the Arctic to quantify the chemical ozone depletion. DMI ozone measurements have been used for validation of the Suomi-NPP.

Aerosol robots (Aeronet) from NASA are installed in Thule, Sondre Stromfjord, Scoresbysund and Narsarsuaq in Greenland.

Within the EU-project COMBINE, DMI has been involved in modelling aspects of the stratosphere-troposphere coupling, investigating the importance of a well-resolved stratospheric representation for modelling the tropospheric climate. DMI participated in the EU-project ICEPURE investigating the adverse and beneficial health effects of ultraviolet radiation (UVR) exposure.

The DMI participates in EUMETSAT’s Satellite Application Facility on Ozone and Atmospheric Chemistry Monitoring, developing operational UV-index products, based on satellite measurements of the ozone layer.

6. FUTURE PLANS

National funding for ozone and UV monitoring in Denmark and Greenland is secured until the end of 2015. After this period the funding situation will be renegotiated.

Research efforts will be directed towards improved understanding of the role of stratospheric changes for tropospheric climate including the dynamical coupling between the troposphere and the stratosphere. It is intended to include a stratospheric representation in new developments of the EC-Earth model complex.

7. NEEDS AND RECOMMENDATIONS

It is considered important to monitor the recovery of the ozone layer at high latitudes during changing stratospheric climatic conditions (decreasing temperatures, perhaps increased water vapour concentrations and other changes in chemical composition, changes in stratospheric dynamics). Maintaining and running stratospheric monitoring stations in the Arctic and elsewhere is becoming an increasingly heavy burden on national funding sources and possibilities for direct funding of ground-based monitoring activities and data provision should be considered to be included in major international programmes such as the European Copernicus.