Record Arctic ozone loss in 2011

In March 2011 the satellite instruments SCIAMACHY and GOME-2 measured the lowest ozone values above the Arctic since the start of the European data record in 1995. The origin of the strong ozone losses are very low temperatures in the stratosphere (about 20 km altitude) that release chlorine and bromine atoms from the chlorofluorocarbons (cfc) and related brominated substances emitted by humans and catalytically destroy ozone. The measurements by SCIAMACHY confirm high chlorine activation in March 2011.

Stratospheric temperatures in the Arctic are very variable from winter to winter. Last year temperatures and ozone above the Arctic were very high. The year-to-year variability is related to the global upper atmosphere circulation. In winters with a strong circulation more ozone is transported into high latitudes and polar stratospheric temperatures are getting higher resulting in less polar ozone depletion.

In the science community there is currently a debate on why just this Arctic winter was very cold. In a changing climate, it is expected that on average stratospheric temperatures cool which means more chemical ozone depletion will occur. On the other hand many studies show that the stratospheric circulation in the northern hemisphere may be enhanced in the future and consequently more ozone will be transported from the tropics into high latitudes and reduce ozone depletion. The measures by the Montreal protocol banning cfc's and related species have succeeded in that the stratospheric halogen (chlorine and bromine) load is now slowly declining. Nevertheless strong chemical ozone depletion will still occur during unusually cold Arctic winters in coming decades.

The Institute of Environmental Physics of the University of Bremen (IUP) is routinely processing satellite data from GOME (since 1995), SCIAMACHY (since 2002), and GOME-2 (since 2007). IUP has initiated the GOME and SCIAMACHY projects. Spectral data from the satellite instruments are provided by ESA (GOME/ERS-2, SCIAMACHY/Envisat) and EUMETSAT (GOME-2/Metop-A). Calculations using a chemistry-transport model at IUP have shown that about half of the Arctic ozone has been chemically depleted during this winter.

Other links:

see ESA (European Space Agency) web-portal:

http://www.esa.int/esaCP/SEMIF24SZLG_index_0.html

see University of Bremen press release:

http://www.uni-bremen.de/universitaet/presseinfos/pressemitteilungen/einzelanzeige/article/rekord-ozonverluste-in-der-arktis-in-2011.html?cHash=5706954d220721e7a6daec1114cb0859

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Rekord-Ozonverluste in der Arktis in 2011

Im März 2011 messen die europäischen Satelliteninstrumente SCIAMACHY und GOME-2 über der Arktis die niedrigsten Ozonwerte seit Beginn der Messungen in 1995. Ursache hierfür sind sehr niedrige Temperaturen in der Stratosphäre (ca. 20 km Höhe). Dadurch werden Chlor- und Bromatome aus den von Menschen in die Atmosphäre entlassenen Fluorchlorkohlenwasserstoffen (FCKW) und verwandten bromhaltigen Substanzen frei und führen zu verstärktem Ozonabbau. Messungen von SCIAMACHY belegen, dass die Chloraktivierung in diesem März ungewöhnlich hoch ist.

In der Arktis unterliegen die stratosphärischen Temperaturen starken Schwankungen von Jahr zu Jahr. So waren die Temperaturen und Ozonwerte über der Arktis im Jahr 2010 sehr hoch. Diese Schwankungen hängen mit der großräumigen Zirkulation in der oberen Atmosphäre zusammen. Ist diese Zirkulation in einem Winter besonders stark, nimmt der Ozontransport in hohe Breiten zu, gleichzeitig steigen die stratosphärischen Temperaturen in der Arktis und weniger Ozon wird zerstört.

Wissenschaftler debattieren zurzeit warum die Temperaturen gerade in diesem arktischen Winter besonders niedrig sind. In einem sich ändernden Klima wird generell erwartet, dass die Stratosphäre sich im Mittel weiter abkühlt was zu stärkerem Ozonabbau führt. Gleichzeitig wird aber voraussichtlich auch die Zirkulation zunehmen, wodurch mehr Ozon aus den Tropen in hohe Breiten gelangt und weniger Ozon chemisch zerstört wird. Obwohl die Maßnahmen des Protokolls von Montreal zur Vermeidung der FCKWs greifen und der Halogengehalt (Chlor- und Bromgehalt) in der oberen Atmosphäre langsam abnimmt, kann in ungewöhnlich kalten arktischen Wintern auch in den nächsten Jahrzehnten weiterhin viel Ozon zerstört werden.

Das Institut für Umweltphysik der Universität Bremen (IUP) wertet routinemäßig die Satellitendaten von GOME (seit 1995), SCIAMACHY (seit 2002), und GOME-2 (seit 2007) aus. Das Institut war führend an dem Aufbau des GOME und SCIAMACHY Projekts beteiligt. Die spektralen Daten der Satelliteninstrumente werden von der ESA (GOME, SCIAMACHY) und EUMETSAT (GOME-2) zur Verfügung gestellt. Rechnungen mit einem Chemie-Transport Model am IUP zeigen, dass in etwa die Hälfte des Ozons in diesem Winter in der Arktis chemisch abgebaut wurde.

Weitere Links:

ESA (European Space Agency) web-portal:

http://www.esa.int/esaCP/SEMIF24SZLG_index_0.html

Universität Bremen Pressemitteilung:

http://www.uni-bremen.de/universitaet/presseinfos/pressemitteilungen/einzelanzeige/article/rekord-ozonverluste-in-der-arktis-in-2011.html?cHash=5706954d220721e7a6daec1114cb0859

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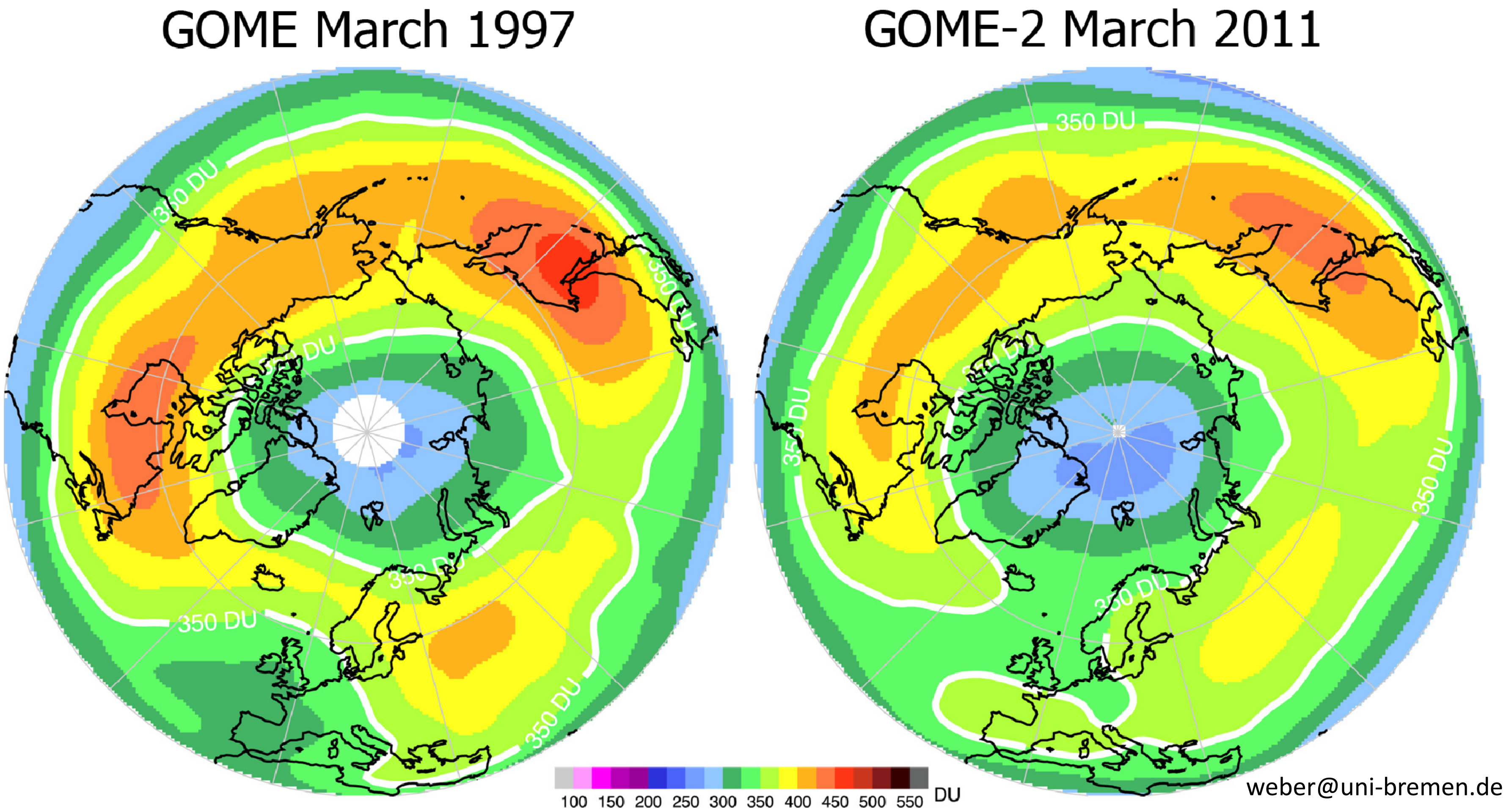

GOME March 1997
GOME-2 March 2011
350 DU
100 150 200 250 300 350 400 450 500 550
DU
weber@uni-bremen.de

Figure 1: March total ozone above the Arctic in 2011 (right) and 1997 (left). Total ozone column is measured in Dobson units (DU). The stratospheric meteorology (low temperatures, high winds, strong polar vortex in late winter/early spring) is very similar in 1997 and 2011. Despite the similarity between these years, ozone levels are lower in 2011 than in 1997.

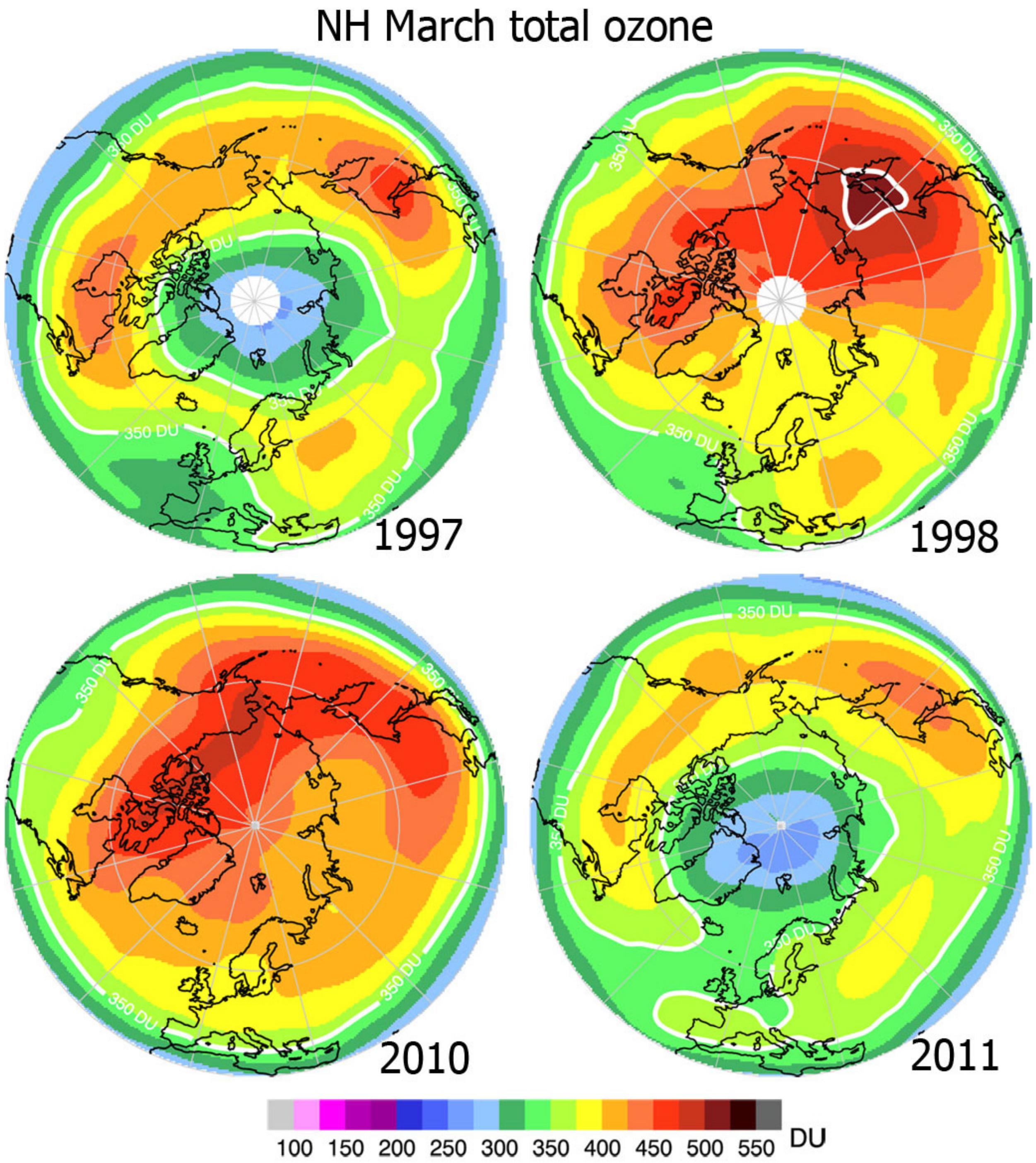
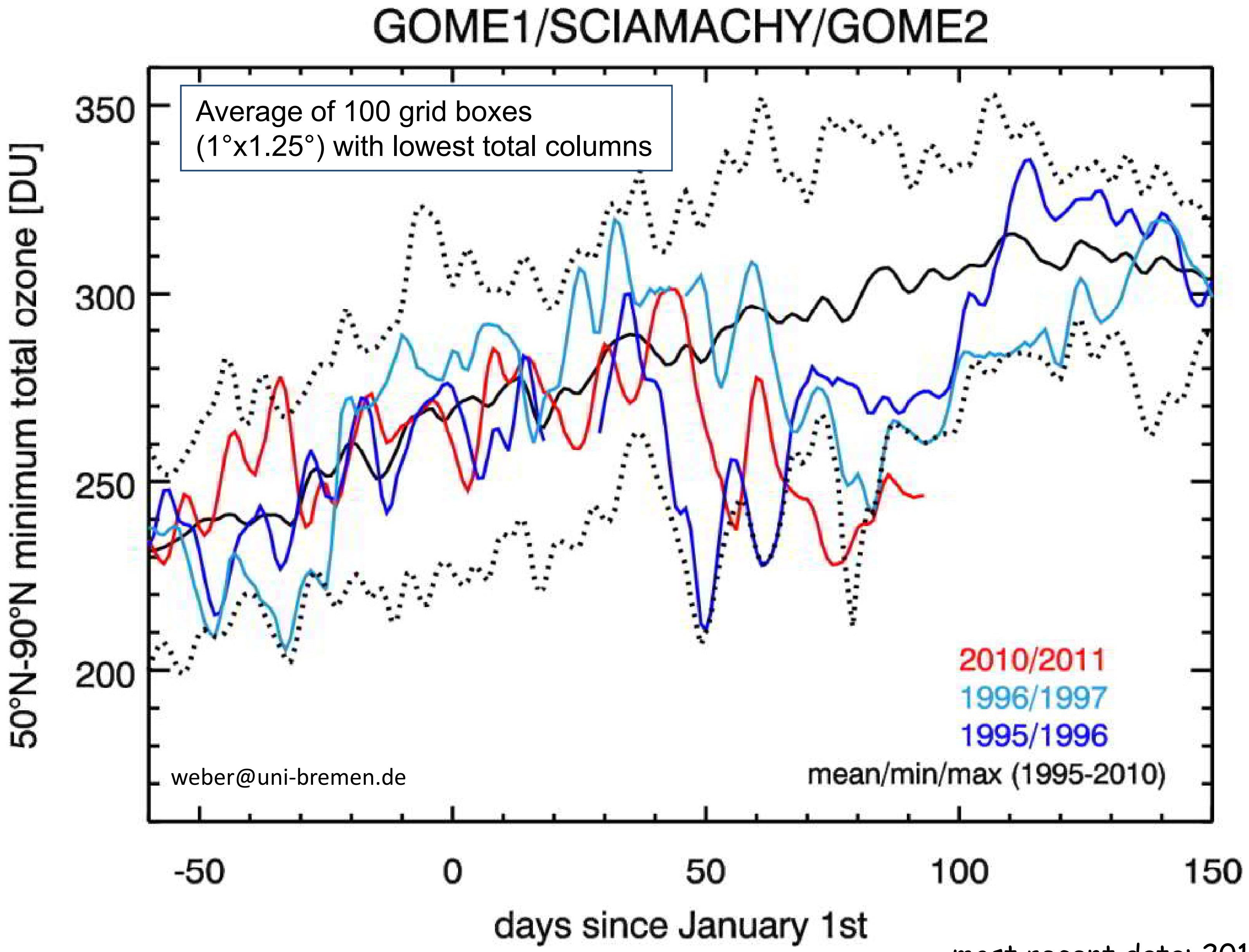
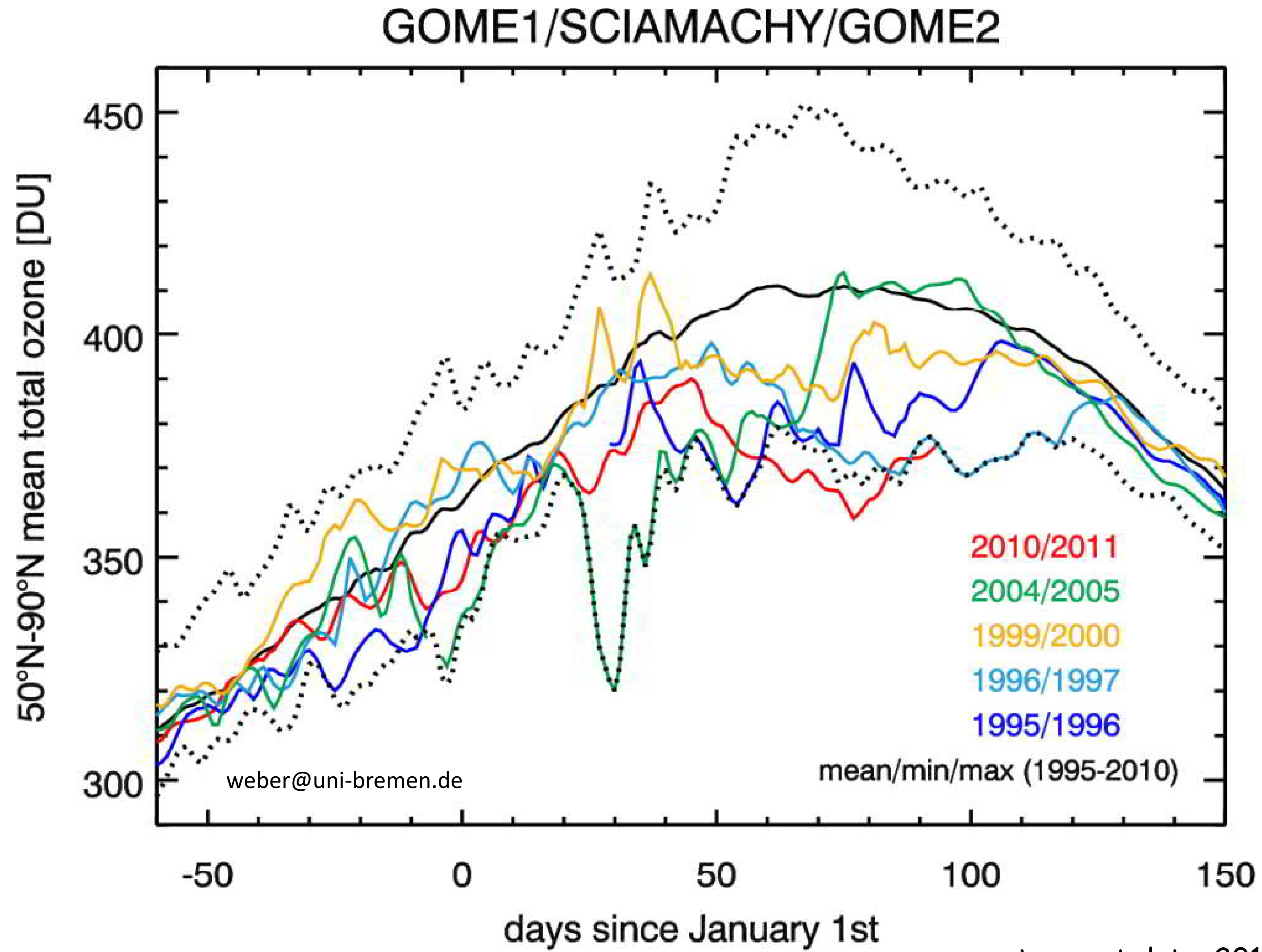

NH March total ozone
350 DU
1997
1998
2010
2011
100 150 200 250 300 350 400 450 500 550
DU

Figure 2: From one year to the next extreme variations in Arctic ozone are observed. High ozone in 1998 followed low ozone in 1997, and high ozone in 2010 is followed by low ozone in 2011. Do we see in a changing climate more extremes (high and low ozone) in Arctic ozone?



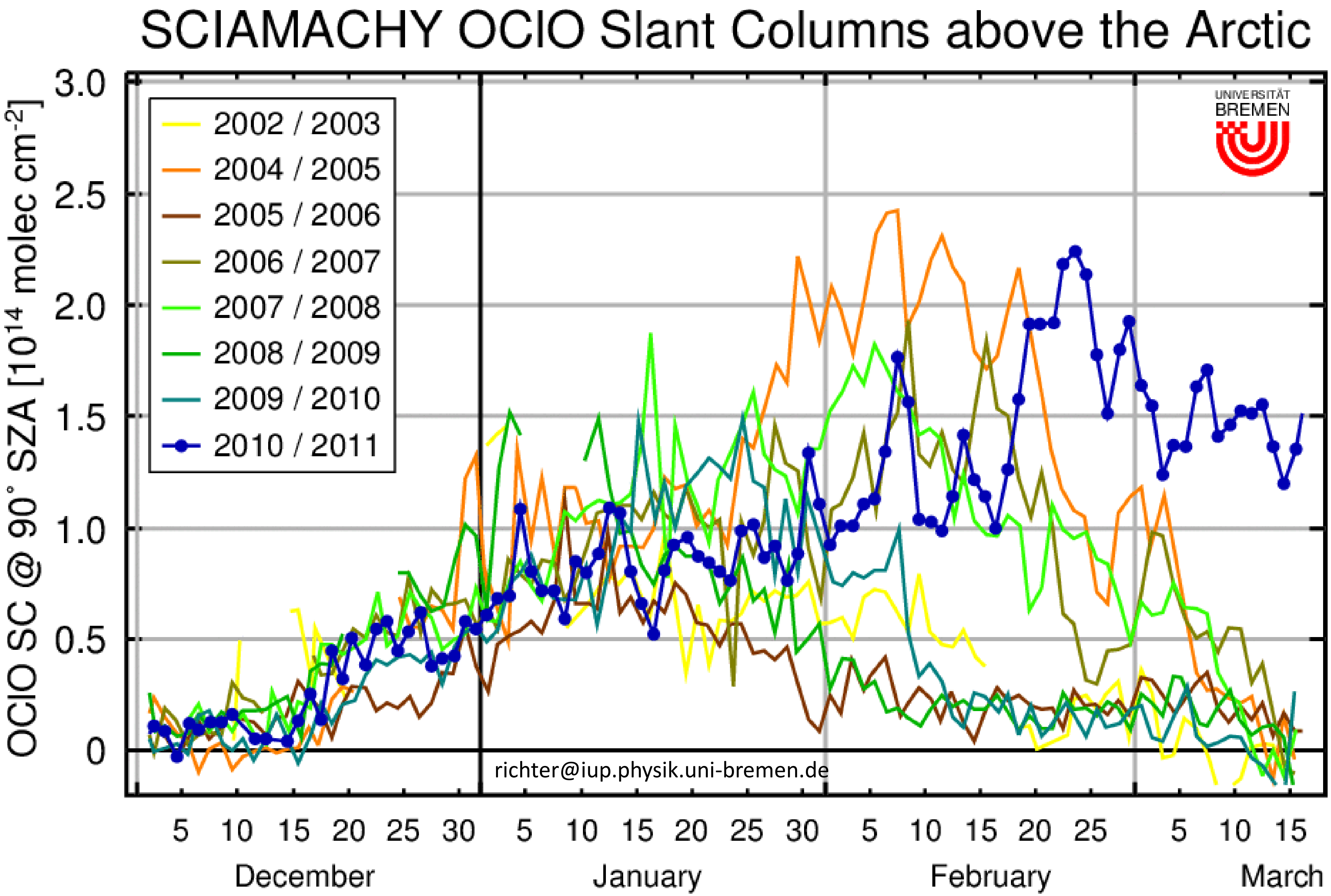
most recent data: 2011/04/04

Figure 3: Time series of minimum total ozone poleward of 50°N from November (day -60) until May (day 150) . Black curve shows the mean and extremes of minimum ozone from 1995 until 2010 (excluding 2011) based upon data from GOME, SCIAMACHY, and GOME-2. Data for selected Arctic winters (1996, 1997, and 2011) are shown as well. In March 2011 record low ozone were measured.



most recent data: 2011/04/04

Figure 4: Time series of mean total ozone above the Arctic polar cap for several cold Arctic winters (1996, 1997, 2000, 2005, and 2011) are shown. The Arctic mean ozone in March 2011 was the lowest in the 16 year data record from GOME, SCIAMACHY, and GOME-2.



SCIAMACHY OClO Slant Columns above the Arctic
OClO SC @ 90° SZA [10^14 molec cm^-2]
3.0
2.5
2.0
1.5
1.0
0.5
0
2002 / 2003
2004 / 2005
2005 / 2006
2006 / 2007
2007 / 2008
2008 / 2009
2009 / 2010
2010 / 2011
UNIVERSITÄT BREMEN
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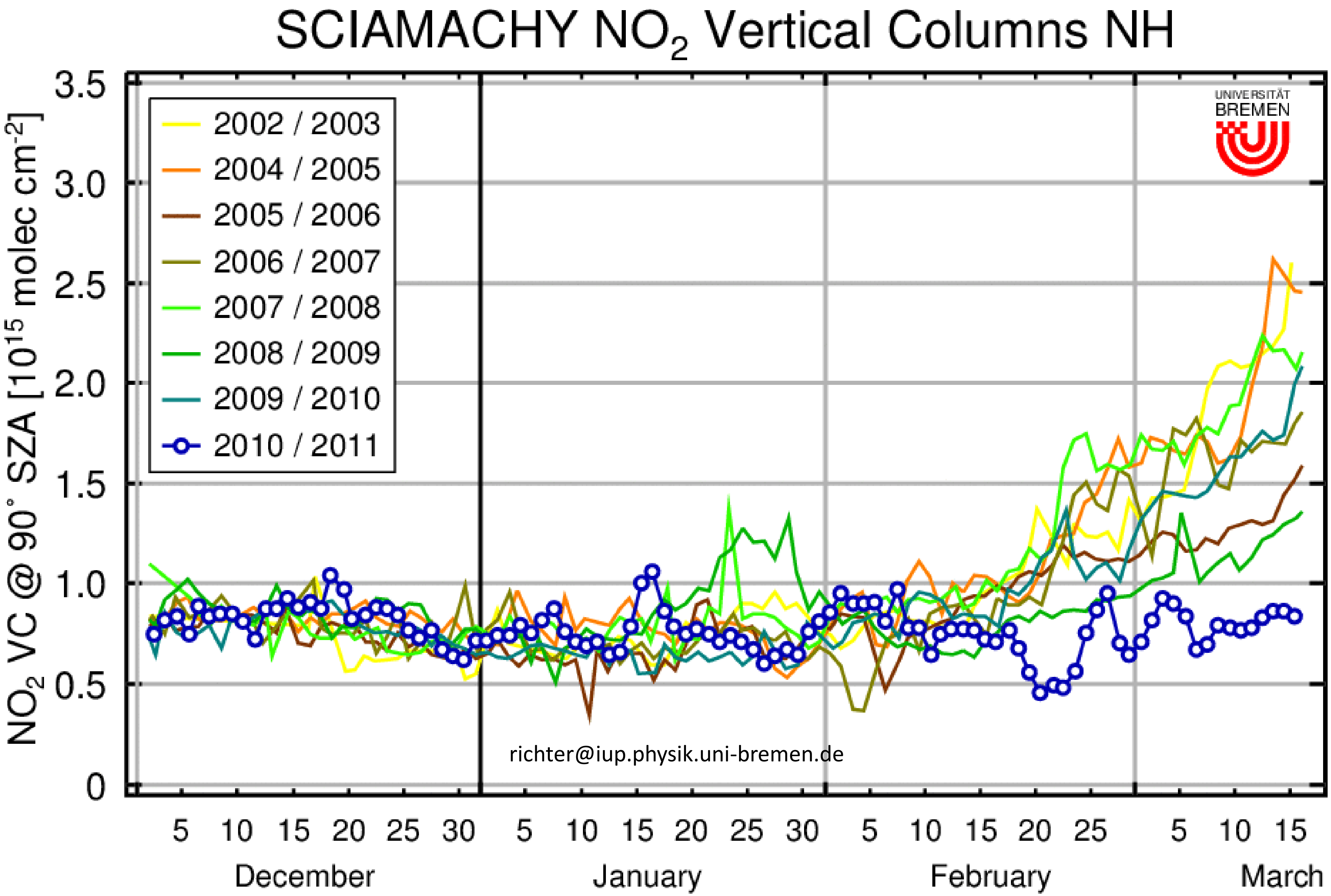
5 10 15 20 25 30 5 10 15 20 25 30 5 10 15 20 25 5 10 15
December
January
February
March

Figure 5: Time series of OClO (chlorinedioxide) slant columns at 90° solar zenith angle for all winters as measured by SCIAMACHY. OClO slant columns are unusually high in March 2011, indicating strong chlorine activation resulting in chemical ozone depletion.



SCIAMACHY NO2 Vertical Columns NH
NO2 VC @ 90° SZA [10^15 molec cm^-2]
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0
2002 / 2003
2004 / 2005
2005 / 2006
2006 / 2007
2007 / 2008
2008 / 2009
2009 / 2010
2010 / 2011
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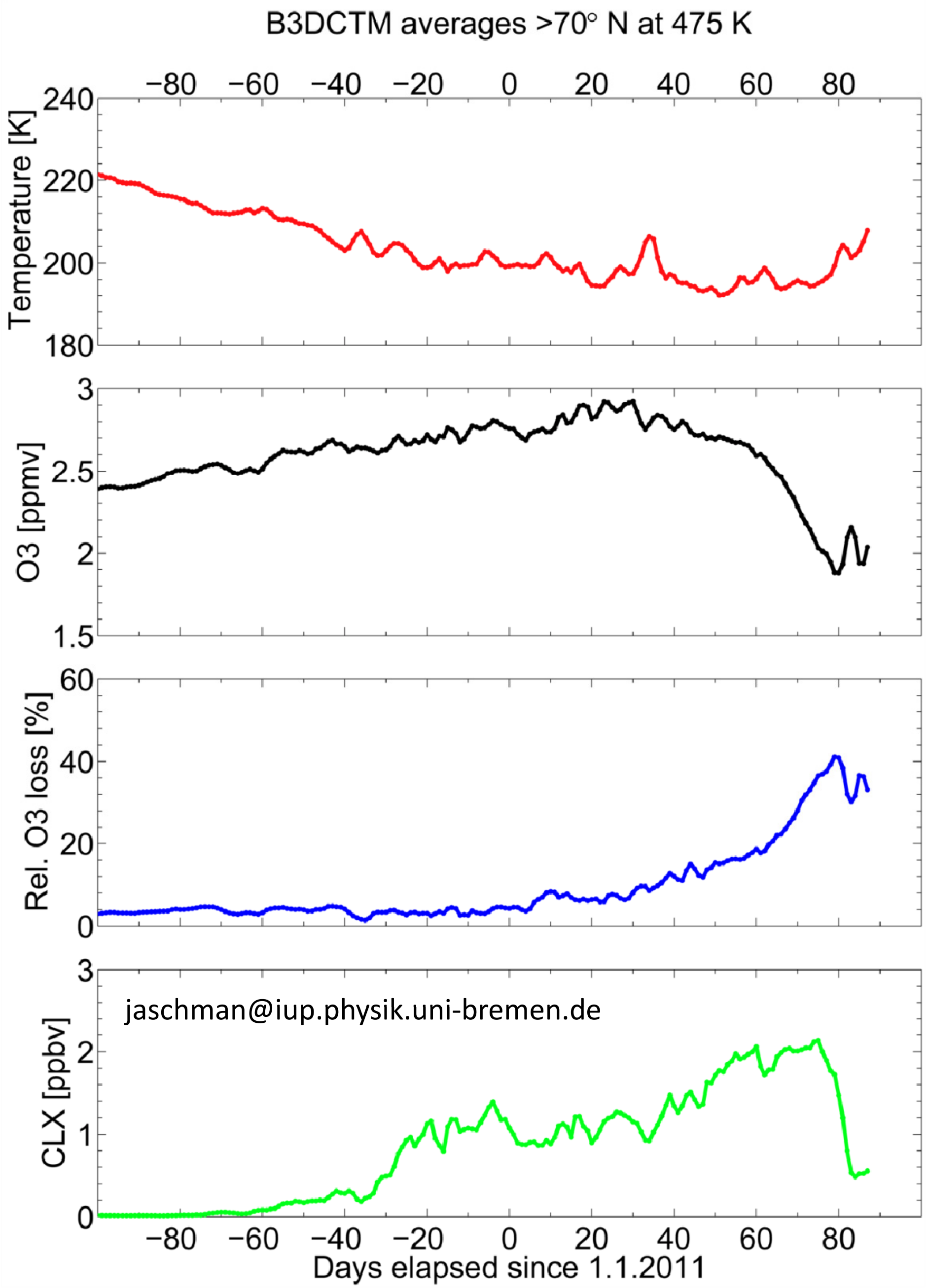
5 10 15 20 25 30 5 10 15 20 25 30 5 10 15 20 25 5 10 15
December
January
February
March

Figure 6: Time series of NO2 columns (nitrogendioxide) for all Arctic winters measured at 90° solar zenith angle by SCIAMACHY since 2002. In March 2011 nitrogen dioxide levels are unusually low, probably due to denitrification (sedimentation of polar stratospheric clouds). Increasing nitrogen dioixide levels during spring are important to convert active chlorine into reservoir gases stopping further ozone depletion.



Chemistry-Transport modelling of Arctic winter 2010/11

Figure 7: Chemical ozone loss calculation with the B3DCTM chemistry-transport model. Until March 2011 about 40% chemical ozone loss was estimated (average loss northward of 70°N at 18 km altitude).