Ozone Layer Research in NIES

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Office for Global Environmental Database
Center for Global Environmental Research
National Institute for Environmental Studies

Contents of Today's Talk

1) ILAS/ADEOS; ILAS-II/ADEOS-II Project
2) FTIR/Ozonesonde Observation at Syowa Station, Antarctica in 2007
3) Unprecedented Arctic Ozone Loss in 2011

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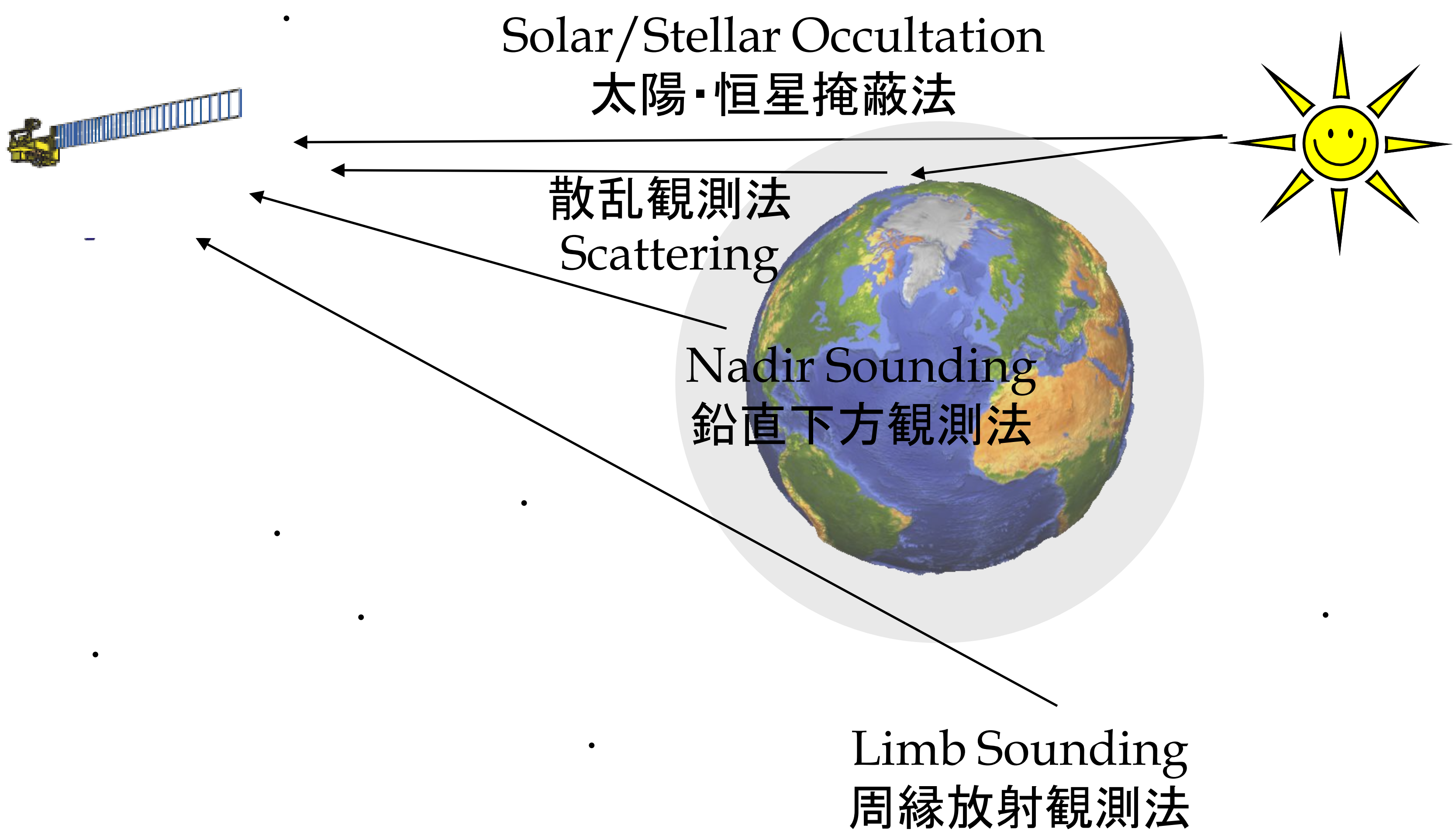
Discovery of Antarctic ozone hole in 1982

- Simultaneously at Two Stations: Japanese Syowa Station and British Halley Bay Station
  - First report at poster presentation at Quadrennial Ozone Symposium (QOS) at Thessaloniki in 1984 by Chubachi et al.
  - First paper by Chubachi (1984) at Mem. Natl. Inst. Polar Res.
  - Famous Nature paper by Farman et al. (1985)
- Japan started a satellite project ADEOS (1996) and ADEOS-II (2003) to monitor ozone layer

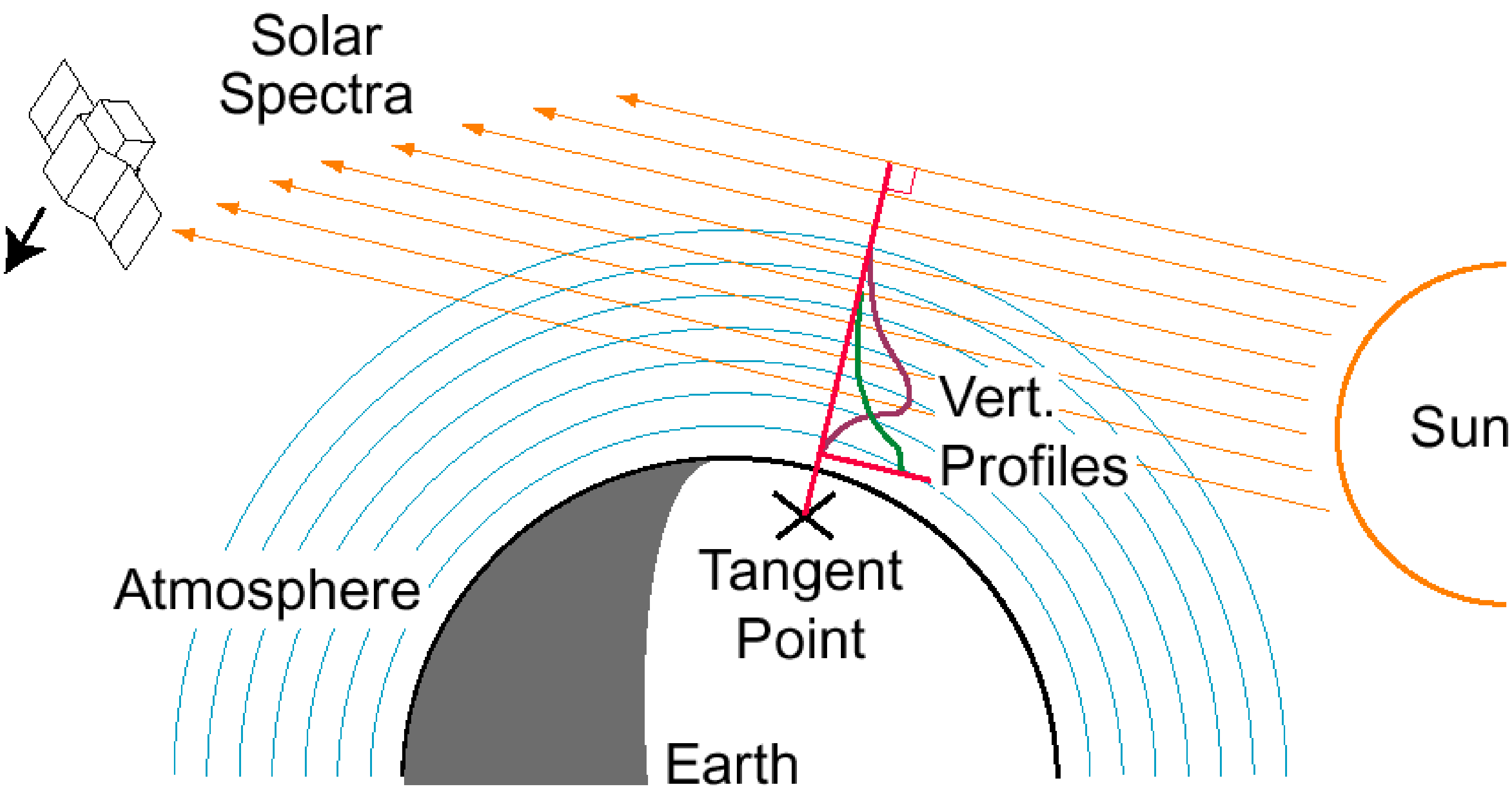
Japanese ILAS/ILAS-II Project

Observation Geometry

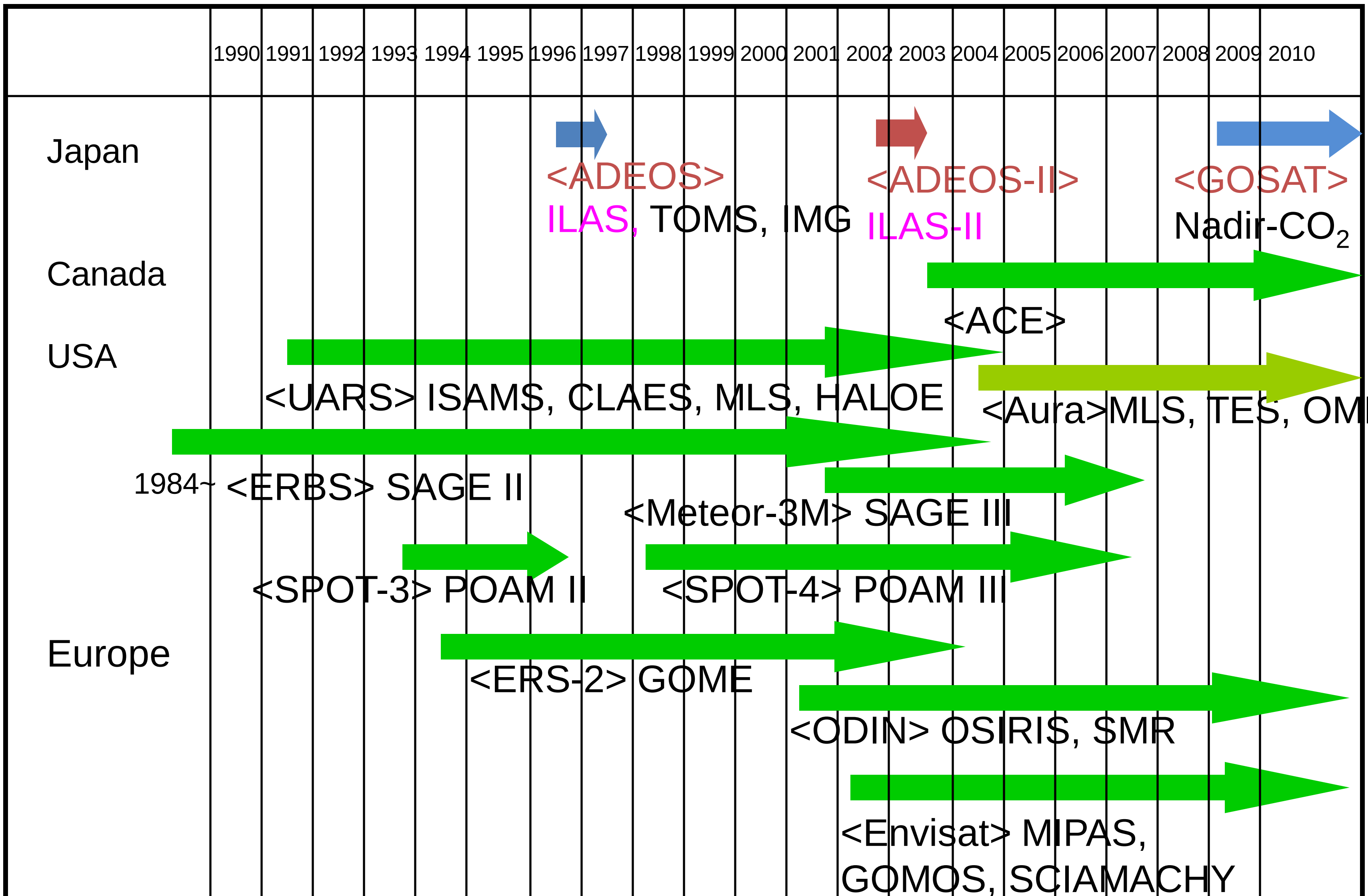


Solar-Occultation Method

Derivation of Vertical Profiles of Gases

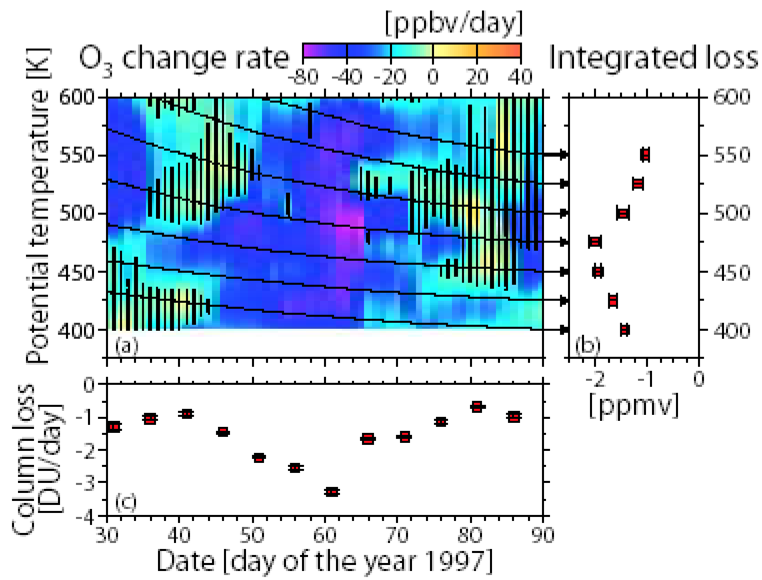


Time Chart Of Satellite Sensors



First satellite match observation using ILAS data

JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 107, NO. D24, 8210, doi:10.1029/2001JD000615, 2002



Stratospheric ozone loss in the 1996/1997 Arctic winter: Evaluation based on multiple trajectory analysis for double-sounded air parcels by ILAS

Yukio Terao
Institute of Geoscience, University of Tsukuba, Tsukuba, Ibaraki, Japan

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National Institute for Environmental Studies, Tsukuba, Ibaraki, Japan

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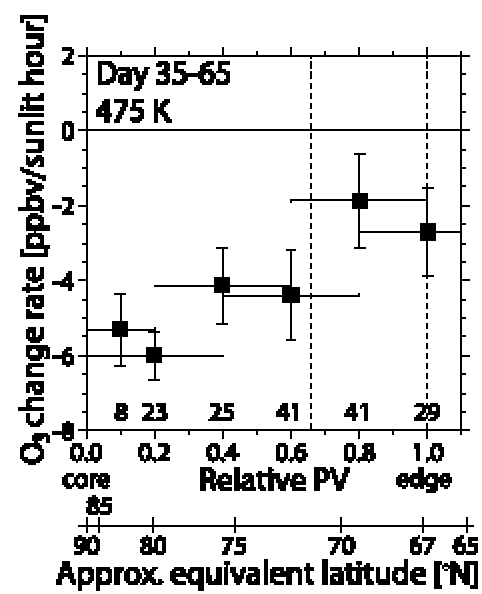
Institute of Geoscience, University of Tsukuba, Tsukuba, Ibaraki, Japan

Received 9 March 2001; revised 30 August 2001; accepted 3 October 2001; published 1 October 2002.



[1] Quantitative chemical ozone loss rates and amounts in the Arctic polar vortex for the spring of 1997 are analyzed based on ozone profile data obtained by the Improved Limb Atmospheric Spectrometer (ILAS) using an extension of the Match technique. In this study, we calculated additional multiple trajectories and set very strict criteria to overcome the weakness of the satellite sensor data (lower vertical resolution and larger sampling air mass volume) and to identify more accurately a double-sounded air mass. On the average inside the inner edge of the vortex boundary (north of about 70°N equivalent latitude), the local ozone loss rate was 50–80 ppbv/day at the maximum during late February between the levels of 450 and 500 K potential temperatures. The integrated ozone loss during February to March reached 2.0 ± 0.1 ppmv at 475–529 K levels, and the column ozone loss between 400 and 600 K during the 2 months was 96 ± 0.3 DU. Using a relative potential vorticity (rPV) scale, the vortex was divided into some rPV belts, and it was shown that the magnitude of the ozone loss increased gradually toward the vortex center from the edge. The maximum ozone loss rate of 6.0 ± 0.6 ppbv/sunlit hour near the vortex center was higher than near the vortex edge by a factor of 2–3. When we expanded the area of interest to

The 14th ILAS Science Team Meeting in Nara Women's University (1999.3.29)

Estimation of ozone loss from ILAS-II data

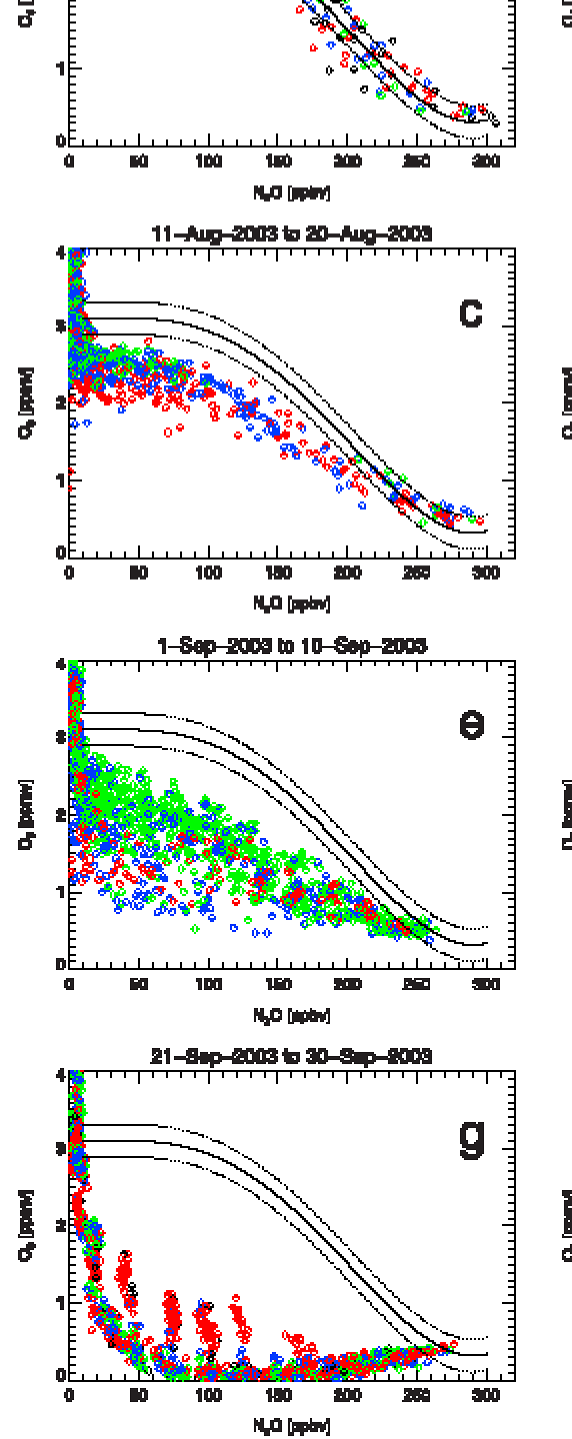
JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 111, D11S12, doi:10.1029/2005JD006260, 2

Chemical ozone loss and related processes in the Antarctic winter 2003 based on Improved Limb Atmospheric Spectrometer (ILAS)–II observations

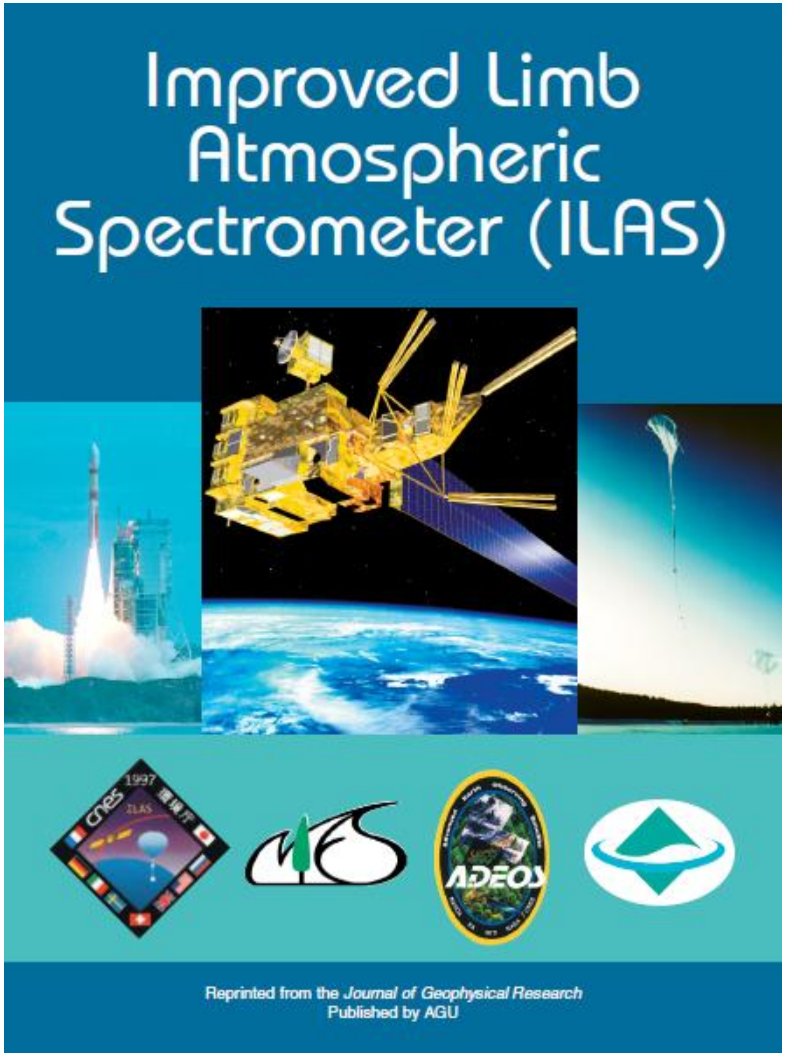
Simone Tilmes,[1,3] Rolf Müller,[1] Jens-Uwe Grooß,[1] Reinhold Spang,[1] Takafumi Sugita,[2] Hideaki Nakajima,[2] and Yasuhiro Sasano[2]

Received 18 May 2005; revised 11 August 2005; accepted 6 September 2005; published 3 May 2006.

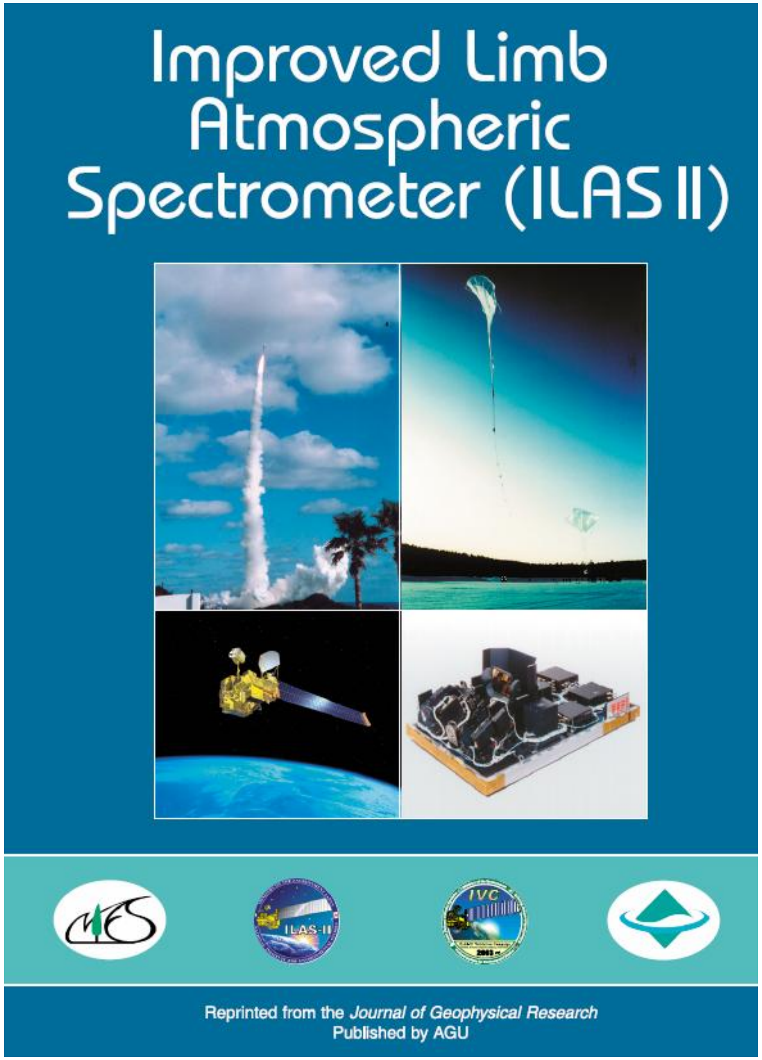
[1] In this study, ILAS-II (Improved Limb Atmospheric Spectrometer) measurements were used to analyze chemical ozone loss during the entire Antarctic winter 2003, using the tracer-tracer correlation technique. The temporal evolution of both the accumulated local chemical ozone loss and the loss in column ozone in the lower stratosphere is in step with increasing solar illumination. Half of the entire loss in column ozone of 157 DU occurred during September 2003. By the end of September 2003, almost the total amount of ozone was destroyed between 380 and 470 K. Further, ozone loss rates increased strongly during September for the entire lower stratosphere. The values of accumulated ozone loss and ozone loss rates are strongly dependent on altitude. Once ozone loss is saturated during September, especially at latitudes between 380 and 420 K, ozone loss rates decrease, and accumulated ozone loss can no longer increase. Moreover, at altitudes above 470 K, accumulated ozone loss depends on the amount of PSCs occurring during winter and spring. During September, ozone mixing ratios show a large day to day variation. Box model simulations by the Chemical Lagrangian Model of the Stratosphere (CLaMS) show that this is a result of the different histories of the observed air masses. Further, the box model supports the general evolution of ozone loss values during September as a result of the strong increase of halogen catalyzed ozone destruction.



Two JGR Special Sections



27 December 2002 Issue ;
15 papers



16 June 2006 Issue;
14 papers

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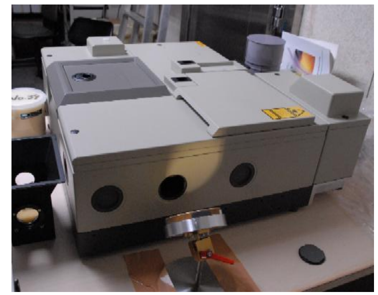
Observations at Syowa Station, Antarctica (69.0ºS, 39.6ºE)

The 48th Japanese Antarctic Research Expedition (JARE48)
2006.12 → 2008.3 (During IPY2007)

High-res. FTIR Obs.

ECC Ozonesonde

Low-res. FTIR Obs.



MPL Obs.

OPC Obs.

Stratospheric minor species (O_3, HNO_3, HCl, $ClONO_2$ etc) observation

PSC heights, types, size distribution etc.

First trial to study both PSC characteristics/types and ozone-related minor constituents throughout the winter over the Antarctica

Advantage of the Observation at Syowa Station

・Located relatively at low latitude within the Antarctic continent

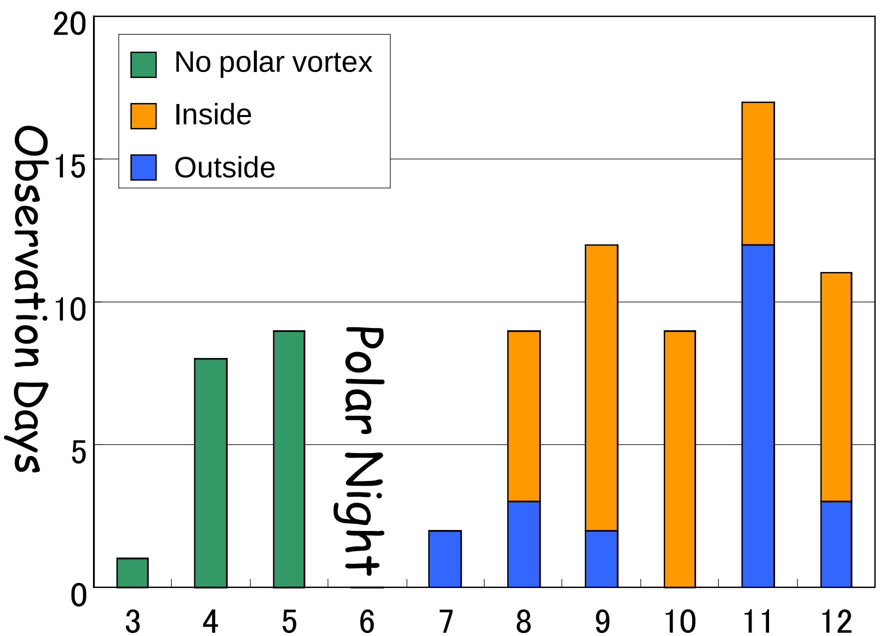
→ Enables us to use sun-light from end of July (can cover whole ozone-hole period)

※At Arrival Heights (77.8ºS, 166.6ºE), sun comes back after September

・Located mainly within polar vortex, sometimes outside

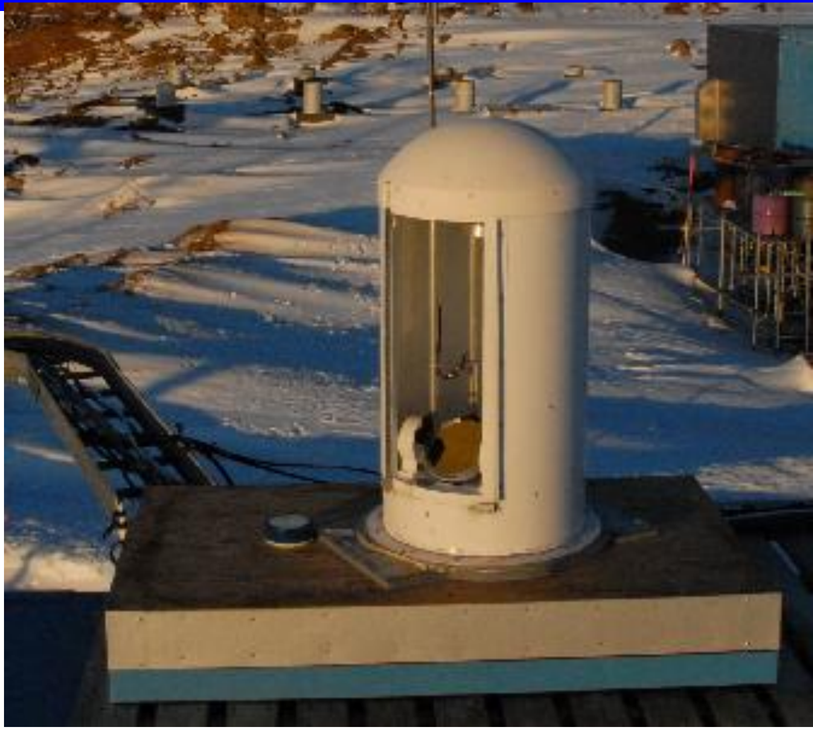
・Other observations (daily rawinsondes, weekly ozonesondes, Dobson, Brewer, Lidar, Radar measurements) are performed at the same site.

→ One of the ideal atmospheric observational station in the Antarctica.



FTIR Observation days in 2007

Setup of IFS-120M at Syowa Station



DU Sun Tracker

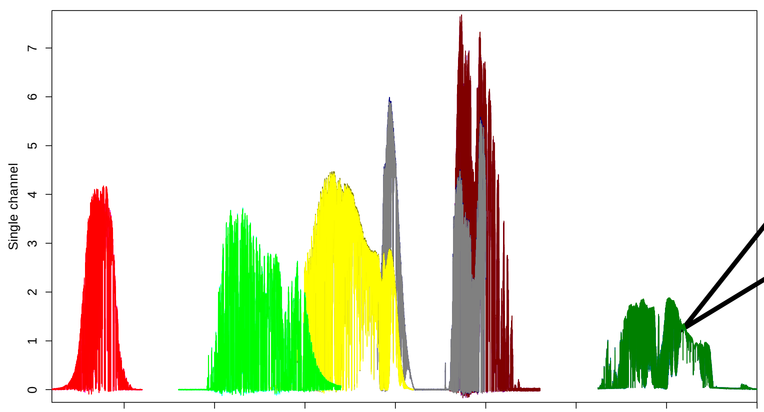
Bruker IFS120M FTIR Installed at Syowa Station

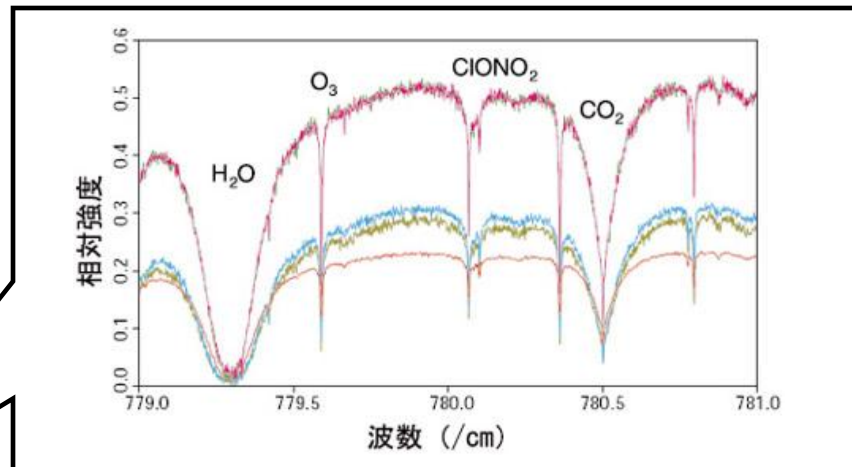
Measurement Parameters by IFS-120M

Measurement parameters

- Location: Syowa Station（69° 00′ S, 39° 35′ E, 18m a.s.l）
- Instrument: Bruker 120M
- OPD: 250cm
- Resolution: 0.0035cm^{-1}
- Spectral range: 500-1380 1700-2200 2000-2600 2400-3200 2800-3700 3900-4400 (cm^{-1})
- Single time scan: 140s
- Detector: MCT, InSb
- Number of scan: 4 scans（16scan）
- Solar zenith angle Min–Max: 46° -89°

87 Days Data Acquired in 2007





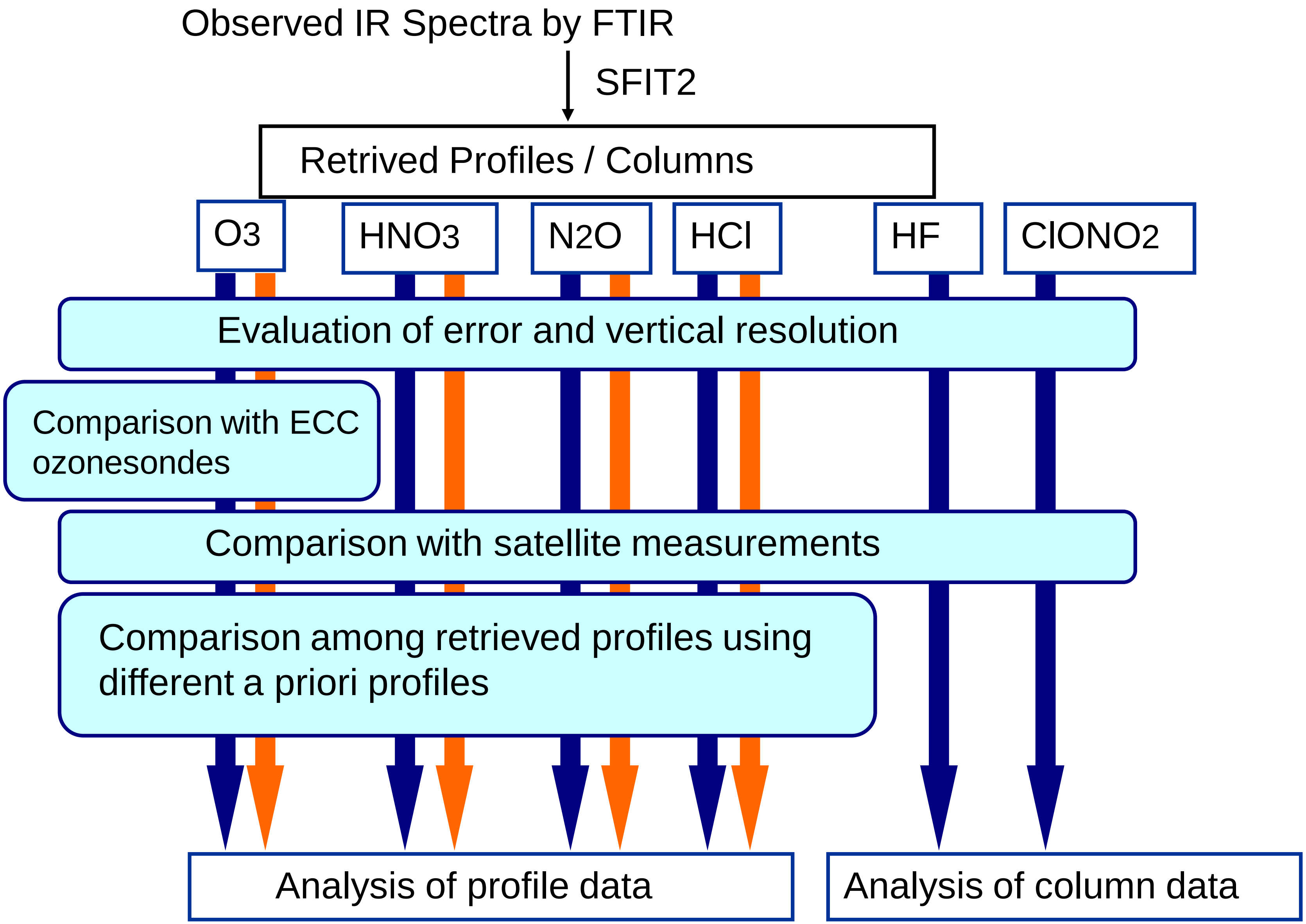
First spectra taken on 25 March 2007

Observation Summary at Syowa Station in 2007

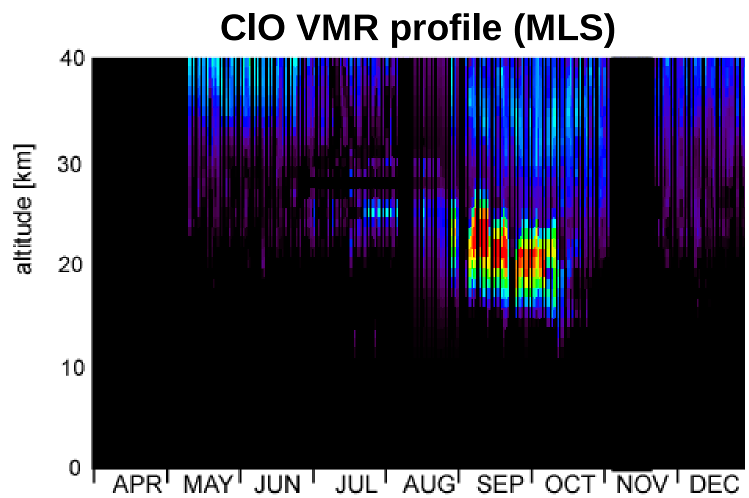
	2007 M&A	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	2008 Jan	**Total**
FTIR（120M）	9	9	0	2	9	12	9	17	11	10	87
FTIR（Eq55）	0	0	1	12	11	16	10	9	3	0	62
Ozonesonde	2	2	3	5	11	12	10	6	6	0	57
OPC sonde	1	0	0	1	1	0	1	0	0	1	5
120M + sonde	0	2	0	0	2	4	4	5	1	1	18
120M + Eq55	0	0	0	2	9	11	9	9	3	0	43

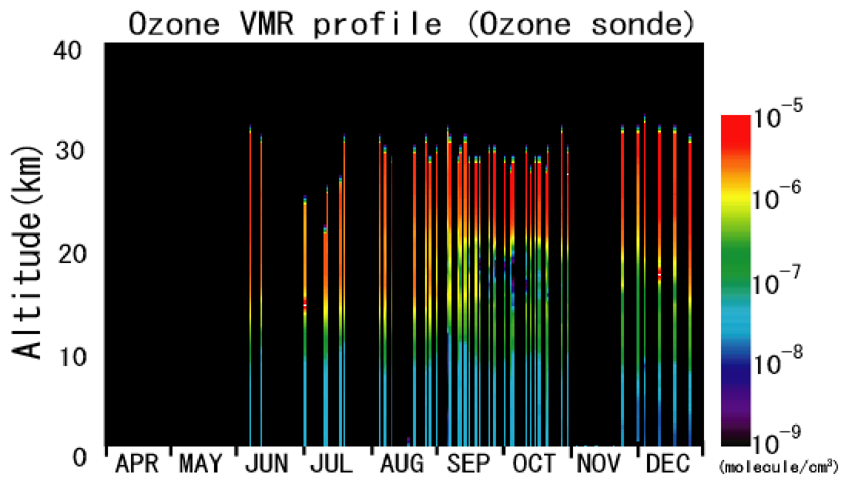
※ Ozonesonde Match campaign

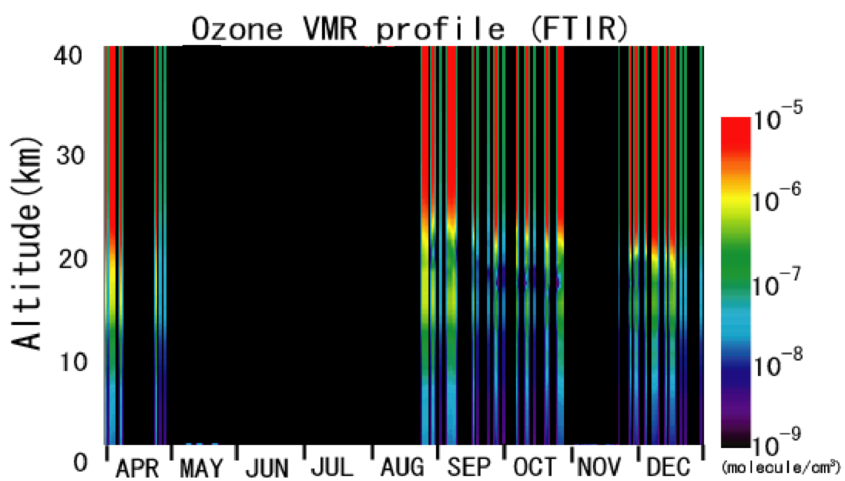
Analysis of Retrieved Parameters by FTIR



Time Variation of ClO/O_3 Vertical Profiles over S/S







ClO activation from early Sep.

$$ClO + ClO + M \longrightarrow ClOOCl + M$$
$$ClOOCl + h\nu \longrightarrow ClOO + Cl$$
$$ClOO + M \longrightarrow Cl + O_2$$
$$(2\times)Cl + O_3 \longrightarrow ClO + O_2$$

$$2O_3 \longrightarrow 3O_2$$

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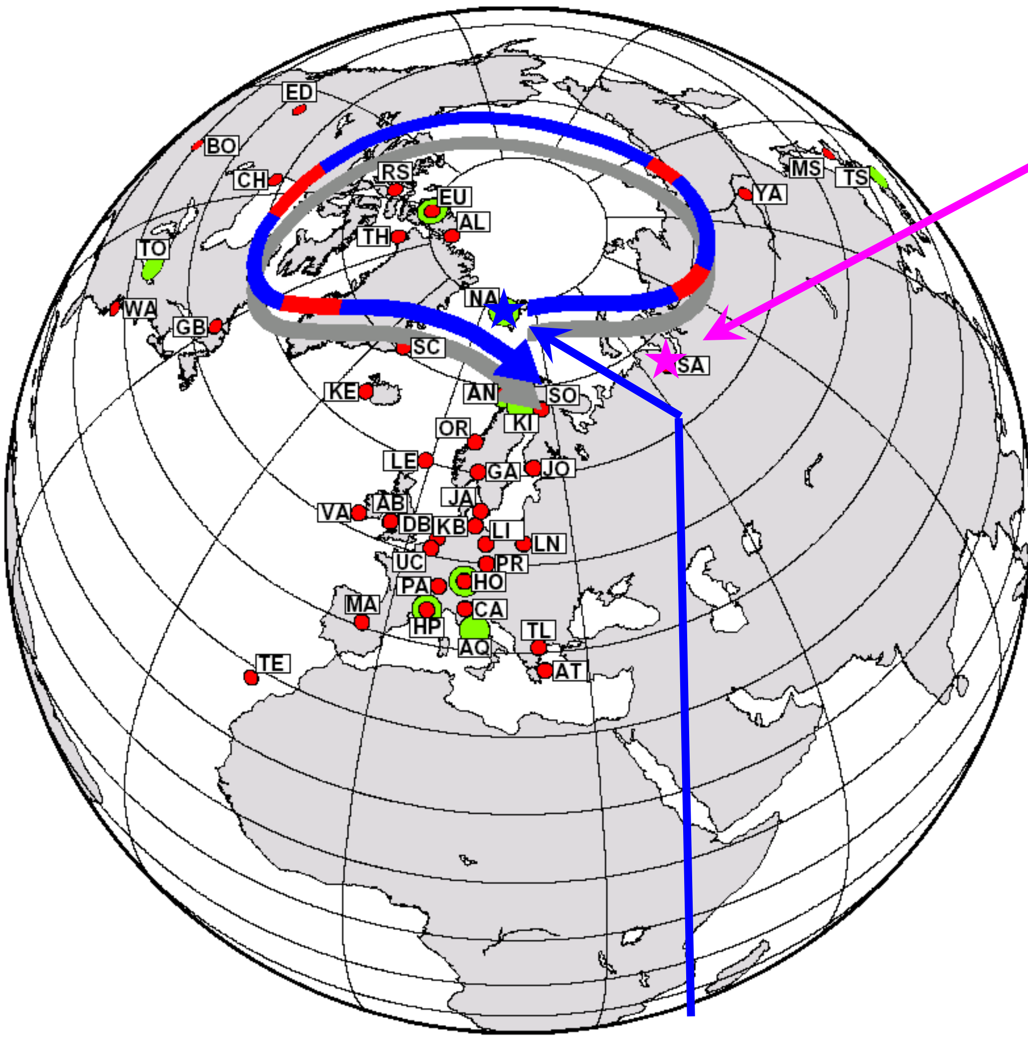
Salekhard Station in Russia

Ozonesonde Observation in Salekhard Station

Campaigns: 2002/03(32), 2005(19), 2009/10(7), 2010/11(4), 2011/12(3)

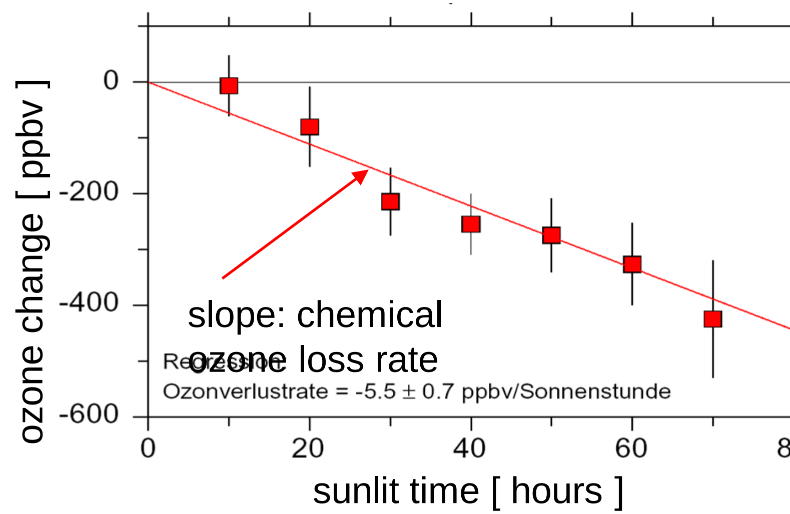
Ozonesonde observations at Salekhard: 2010/1/26, 30(2), 2/6, 7, 16, 19 (7)
2011/2/25, 3/15, 4/13, 4/19 (4)

Strategy of Ozonesonde Match Analysis



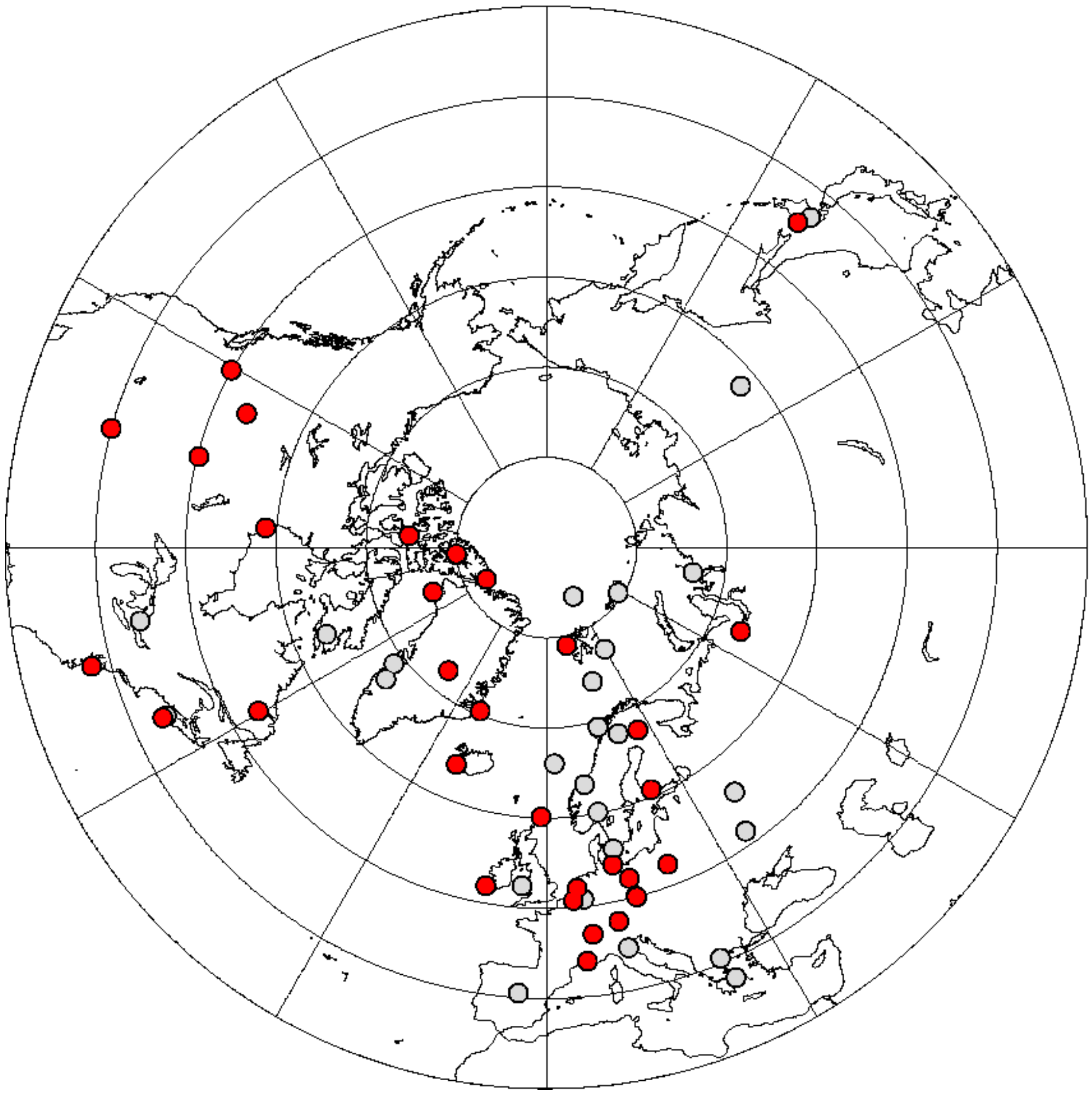
★ Ny-Ålesund
★ Salekhard

● Ozonesonde station
Trajectory（Sunlit/Dark）

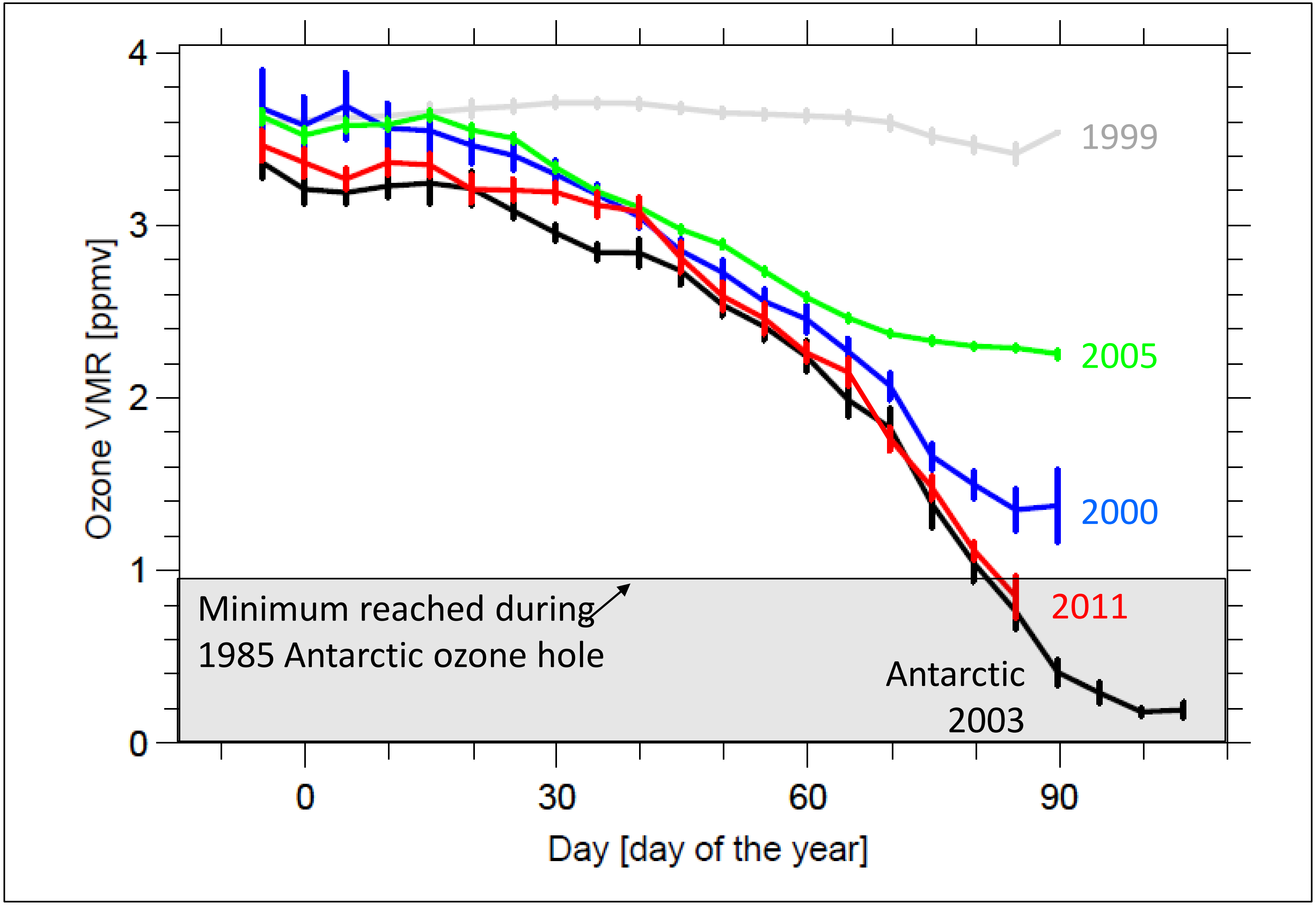


Match pairs from Ny-Ålesund to Salekhard:
＜2000＞: 1/15, 1/16, 1/21, 1/22, 1/23, 1/25, 1/26, 1/29, 2/4, 2/5 （10 days）
＜2005＞: 1/5, 1/25, 1/30, 2/15, 2/23, 2/25, 2/27, 3/1, 3/5, 3/7, 3/8, 3/15, 3/16 （13 days）

Change in Ozonesonde Stations 2000→2010

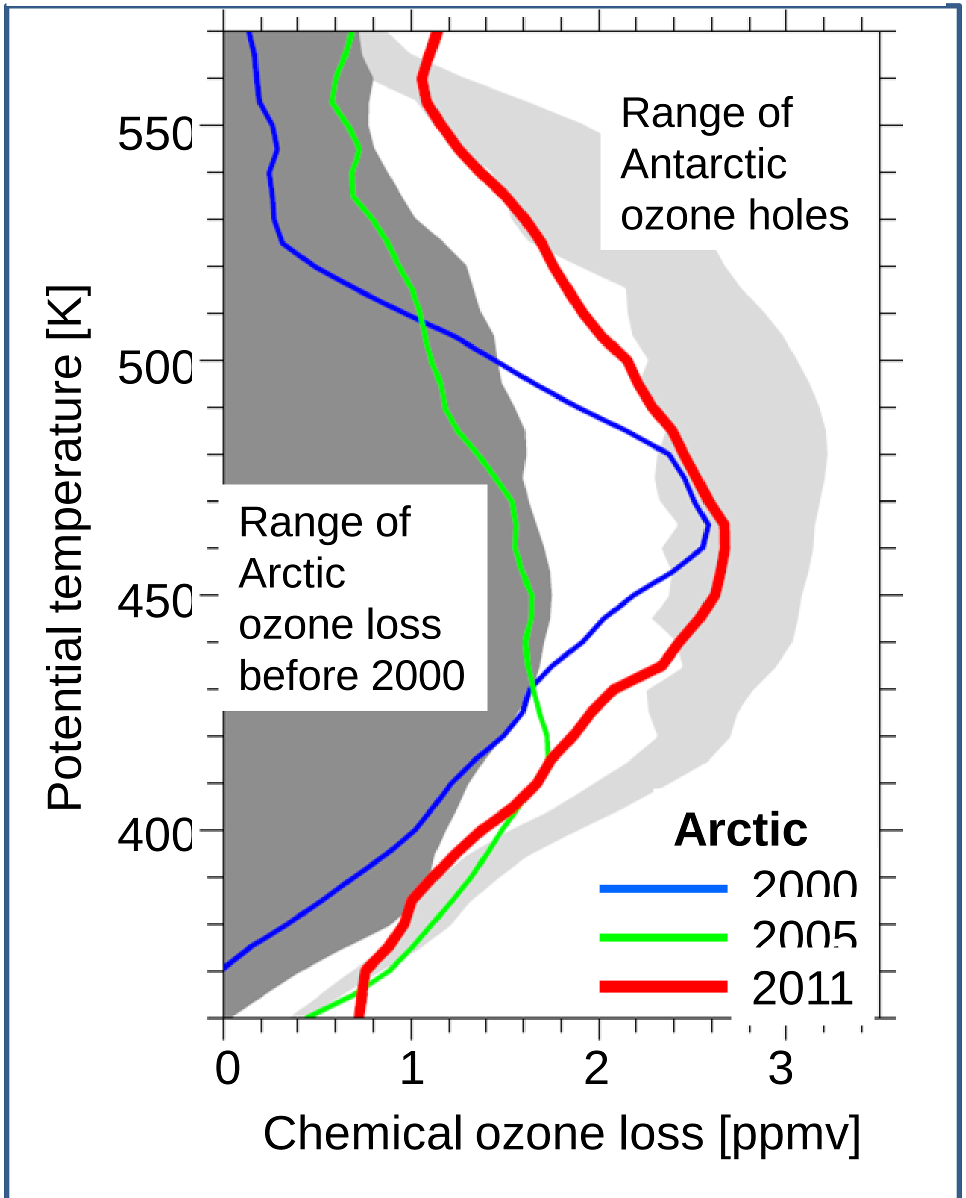


Average ozone inside vortex @ eΘ=465K



[EGU Presentation, Rex et al., 2011.4]

Ozone Loss Profiles by Ozonesonde Match Analysis



[EGU Presentation, Rex et al., 2011.4]

Nature article on 2011.10.2

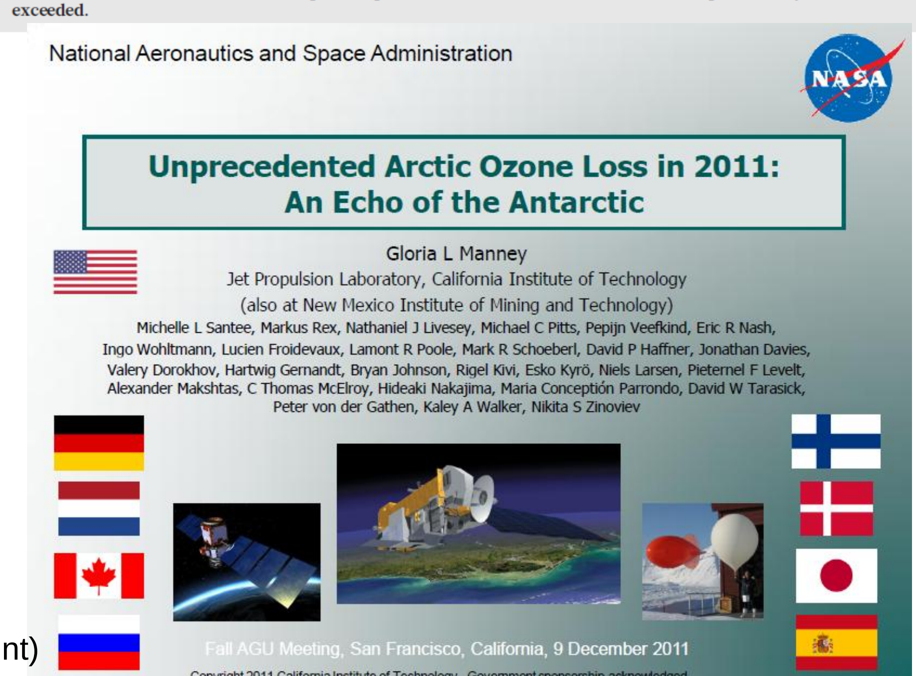
ARTICLE

doi:10.1038/nature10556

Unprecedented Arctic ozone loss in 2011

Gloria L. Manney[1,2], Michelle L. Santee[1], Markus Rex[3], Nathaniel J. Livesey[1], Michael C. Pitts[4], Pepijn Veefkind[5,6], Eric R. Nash[7], Ingo Wohltmann[3], Ralph Lehmann[3], Lucien Froidevaux[1], Lamont R. Poole[8], Mark R. Schoeberl[9], David P. Haffner[7], Jonathan Davies[10], Valery Dorokhov[11], Hartwig Gernandt[3], Bryan Johnson[12], Rigel Kivi[13], Esko Kyrö[13], Niels Larsen[14], Pieternel F. Levelt[5,6,15], Alexander Makshtas[16], C. Thomas McElroy[10], Hideaki Nakajima[17], Maria Conceptión Parrondo[18], David W. Tarasick[10], Peter von der Gathen[3], Kaley A. Walker[19] & Nikita S. Zinoviev[16]

Chemical ozone destruction occurs over both polar regions in local winter–spring. In the Antarctic, essentially complete removal of lower-stratospheric ozone currently results in an ozone hole every year, whereas in the Arctic, ozone loss is highly variable and has until now been much more limited. Here we demonstrate that chemical ozone destruction over the Arctic in early 2011 was—for the first time in the observational record—comparable to that in the Antarctic ozone hole. Unusually long-lasting cold conditions in the Arctic lower stratosphere led to persistent enhancement in ozone-destroying forms of chlorine and to unprecedented ozone loss, which exceeded 80 per cent over 18–20 kilometres altitude. Our results show that Arctic ozone holes are possible even with temperatures much milder than those in the Antarctic. We cannot at present predict when such severe Arctic ozone depletion may be matched or exceeded.



Submitted on 3 May, 2011
1st Revised on 18 July, 2011
2nd Revised on 22 August, 2011
3rd Revised on 1 Septemver, 2011
Accepted on 7 September, 2011
Published 2 October, 2011 (electronic), 27 October, 2011 (print)

International Research Group (9 Countries, 19 Organaizations)

- **U.S.A.** : Jet Propulsion Laboratory, New Mexico Institute of Mining and Technology, NASA Langley Research Center, Science Systems and Applications, Science and Technology Corporation, NOAA Earth System Research Laboratory
- **Germany** : Alfred Wegener Institute
- **Netherland** : Royal Netherlands Meteorological Institute, Delft University of Technology, Eindhoven University of Technology
- **Canada** : Environment Canada, University of Toronto
- **Russia** : Central Aerological Observatory, Arctic and Antarctic Research Institute
- **Finland** : Finnish Meteorological Institute
- **Denmark** : Danish Meteorological Institute
- **Japan** : National Institute for Environmental Studies
- **Spain** : National Institute for Aerospace Technology

- Contributed for Aura/MLS, CALIPSO, Aura/OMI Analysis
- Contributed for Ozonesonde Match Analysis

Dr. Gloria L. Manney, NASA/JPL

2005.5 at SPARC PSC meeting in WV, U.S.A.

Dr. Markus Rex, AWI/Potsdam

2009.3 at Potsdam

Articles on Japanese Press


朝日新聞

2011年(平成23年)

10月3日

月曜日

北極にもオゾンホール

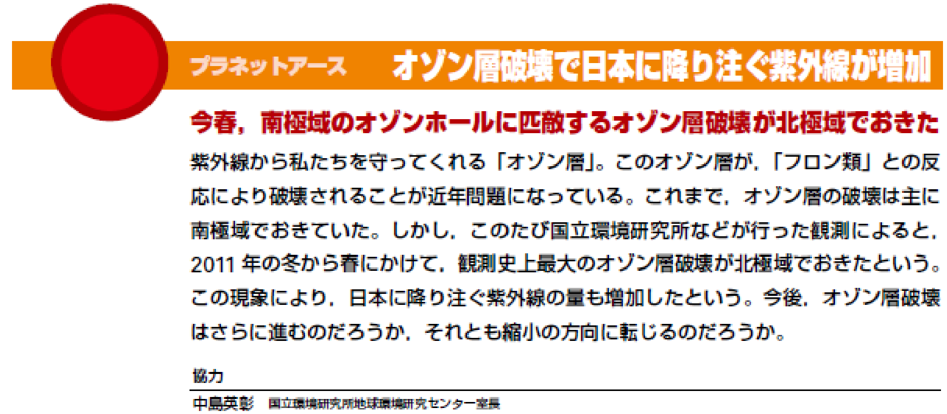
今春観測 紫外線増加の恐れ

オピニオン・社説・声 15面

国際 「脱原発」仏でも高まる声 3面

太陽光、そのまま室内照明に 7面

ゴルフ 馬場、国内メジャー初優勝 25面


プラネットアース　オゾン層破壊で日本に降り注ぐ紫外線が増加

今春，南極域のオゾンホールに匹敵するオゾン層破壊が北極域でおきた

紫外線から私たちを守ってくれる「オゾン層」。このオゾン層が，「フロン類」との反応により破壊されることが近年問題になっている。これまで，オゾン層の破壊は主に南極域でおきていた。しかし，このたび国立環境研究所などが行った観測によると，2011 年の冬から春にかけて，観測史上最大のオゾン層破壊が北極域でおきたという。この現象により，日本に降り注ぐ紫外線の量も増加したという。今後，オゾン層破壊はさらに進むのだろうか，それとも縮小の方向に転じるのだろうか。

協力

中島英彰　国立環境研究所地球環境研究センター室長

Journal “Newton” December 2011


よくわかる環境ニュース エコ教室 68

北極でも"オゾンホール"

南極のオゾンホールと同じような現象が、今春の北極上空で起きていたと、国立環境研究所の中島英彰さんらの国際チームが発表しました。オゾンは太陽からの有害な紫外線を遮り、生き物を守っています。監視を強めることが急がれます。

南極上空ほど冷えないはず… 監視を強め原因探る

毎日新聞科学環境部 田中泰義

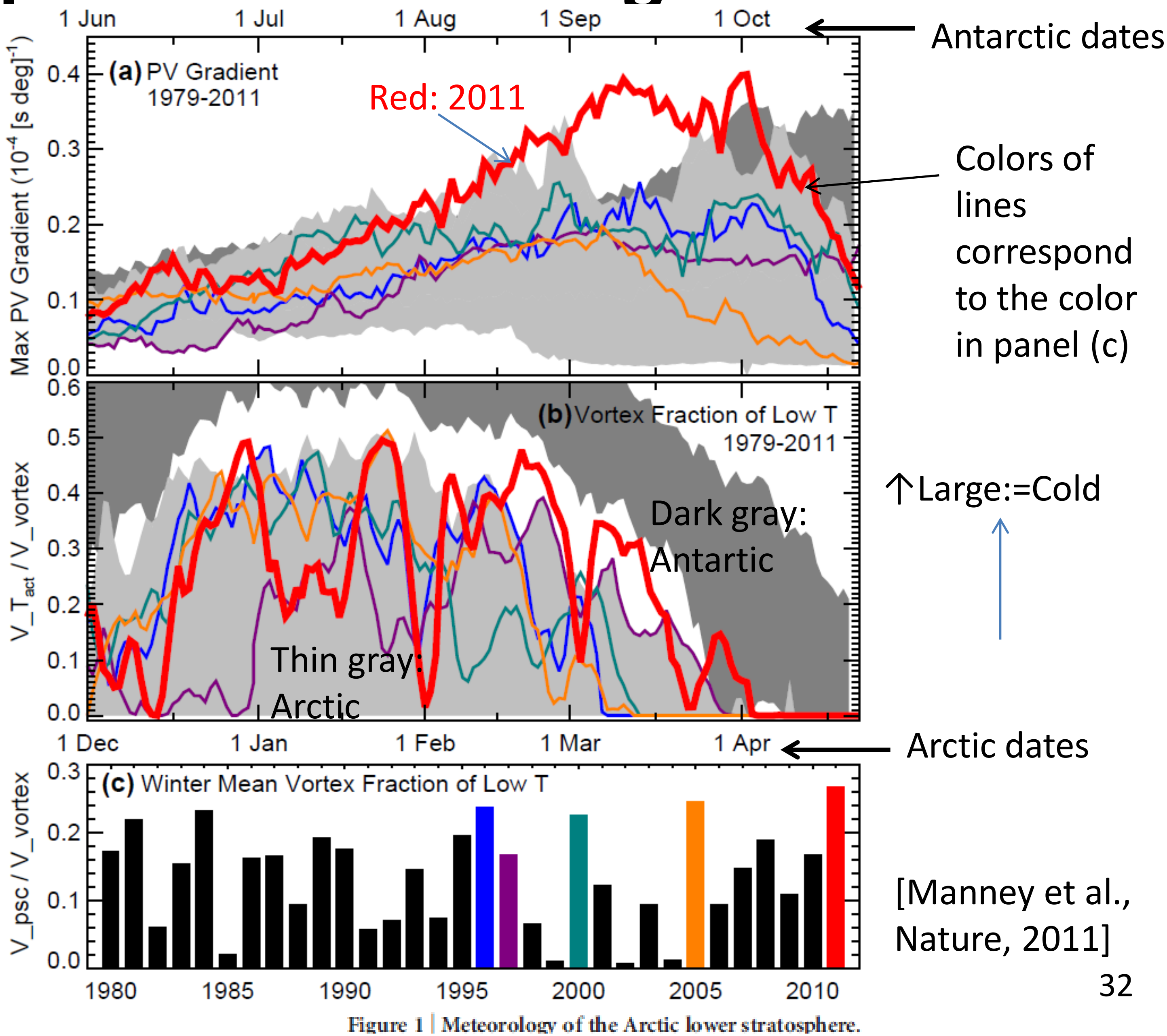
毎日小学生新聞2011.10.24

Stratospheric Meteorological Condition

Index for the strength of polar vortex

Area Ratio (T<Possible PSC / Polar Vortex)

Annual variation of winter mean (b) ratios



[Manney et al., Nature, 2011]

Variation of minor species by Aura/MLS

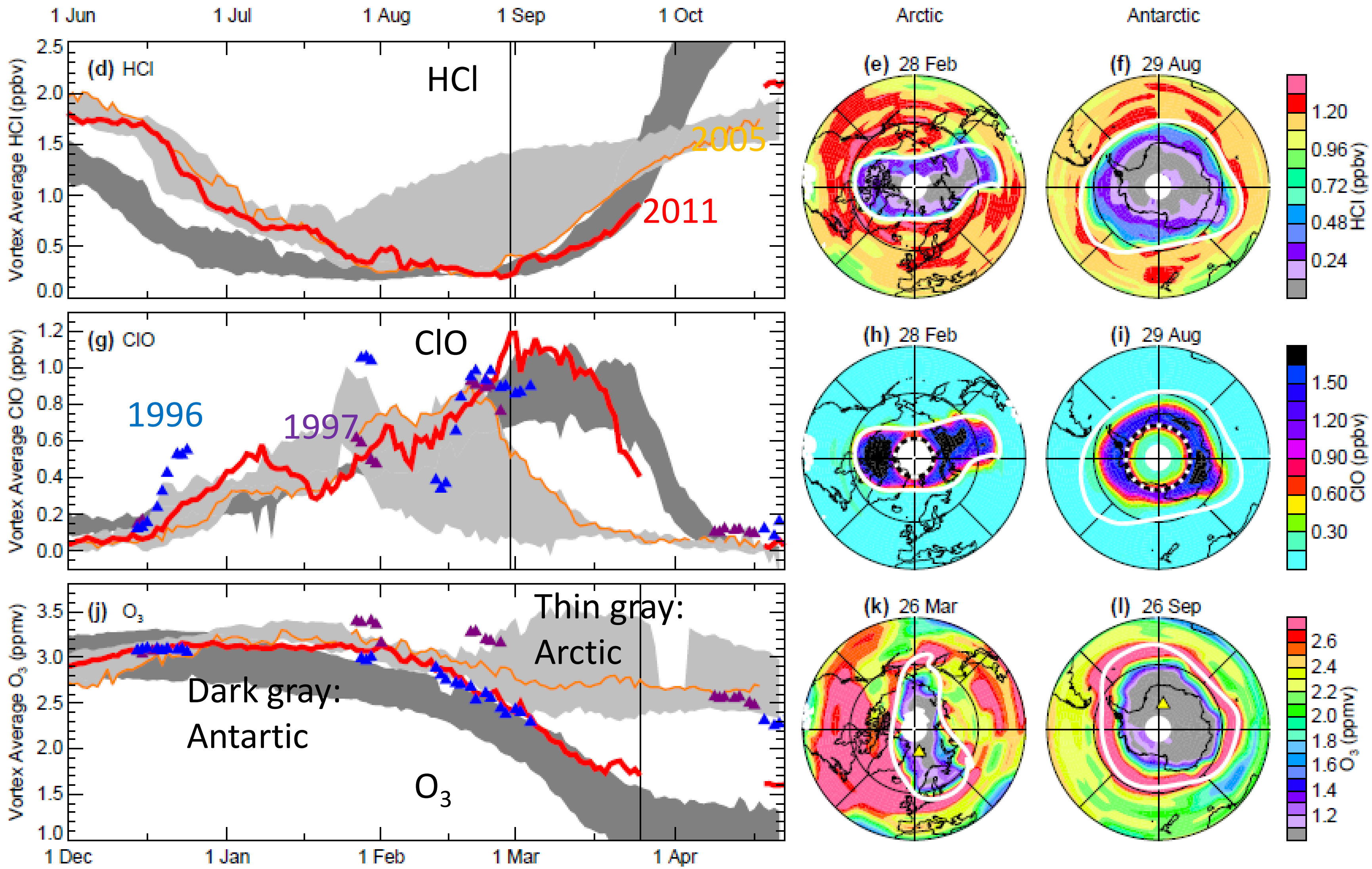
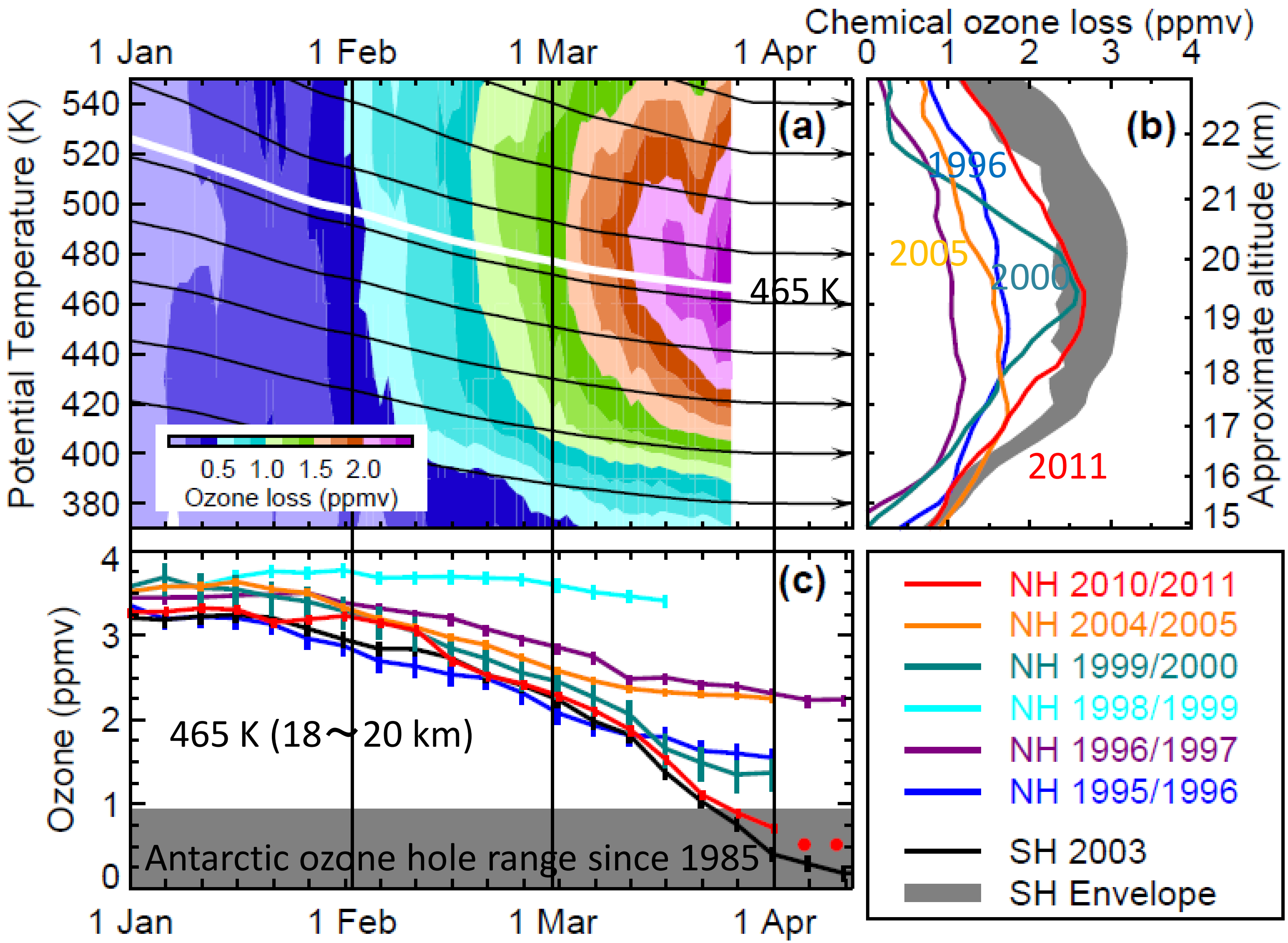


Figure 2 | Chemical composition in the lower stratosphere.

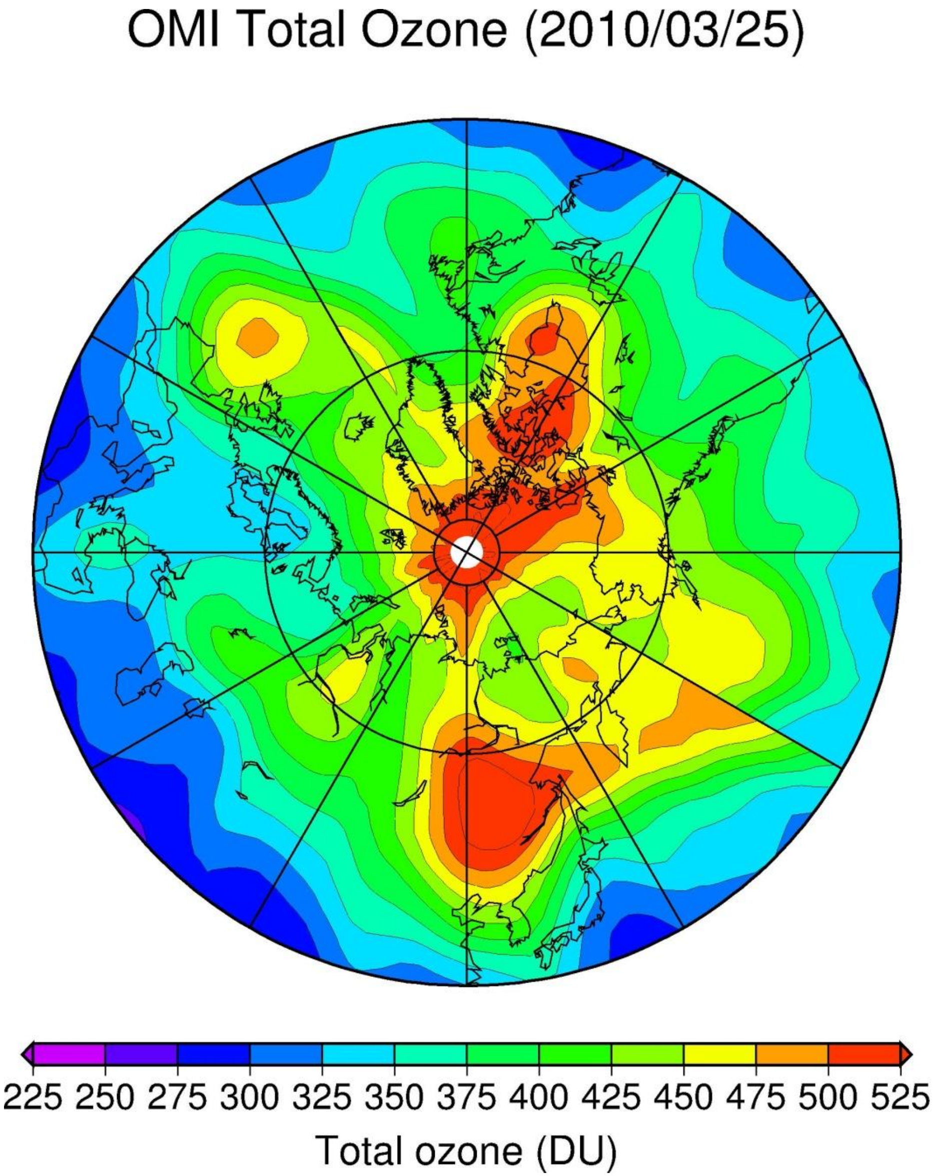
[Manney et al., Nature, 2011]

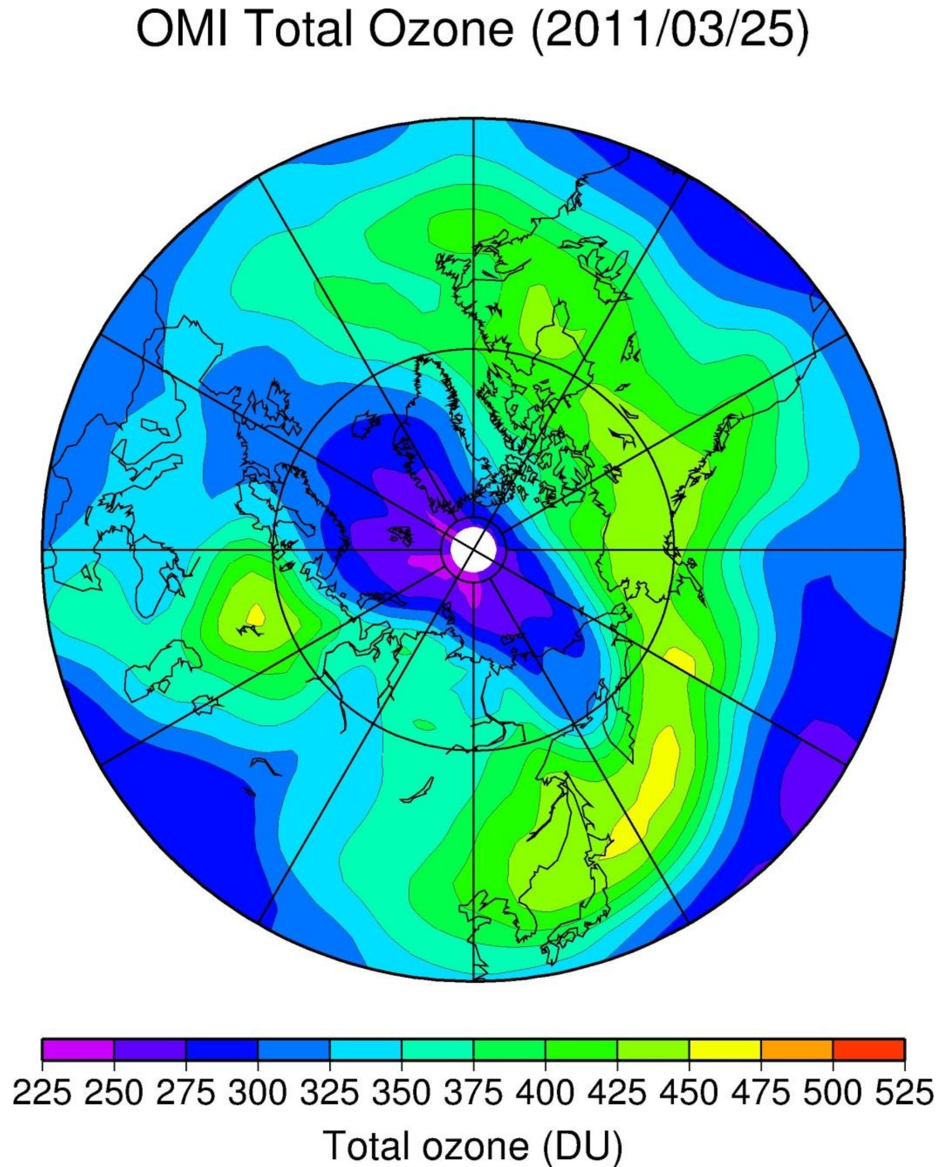
Quantification of Chemical Ozone Loss



[Manney et al., Nature, 2011]

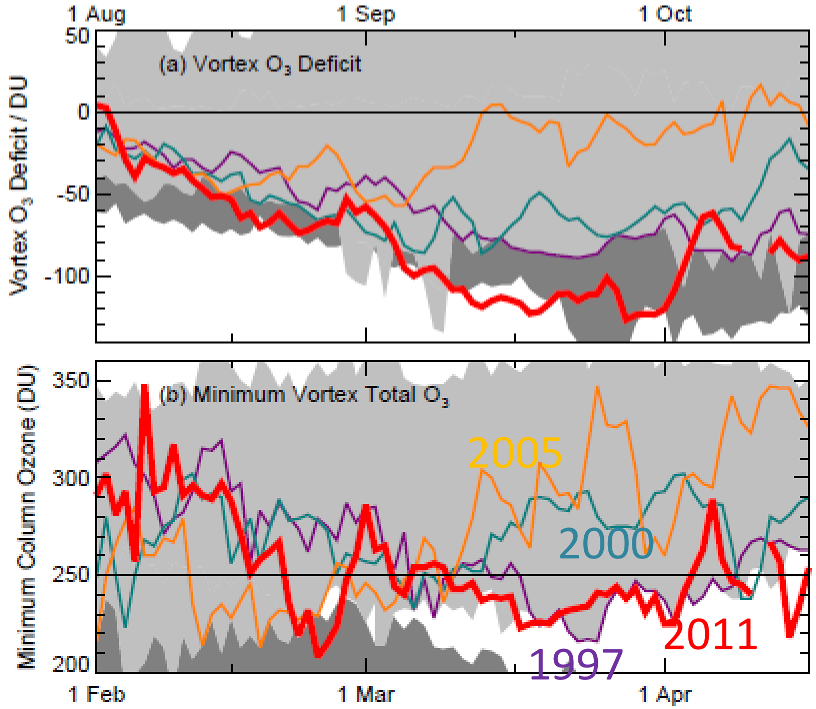
Total Ozone Amount by OMI





[Figures produced in NIES using NASA's OMI data]

Temporal Variation of Column Ozone



Supplementary Figure 5. Deficit and Minimum in Column Ozone.

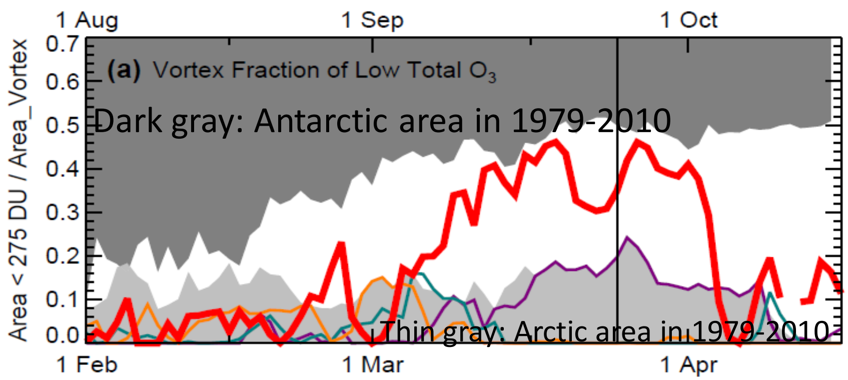


Figure 5 | Total column ozone.

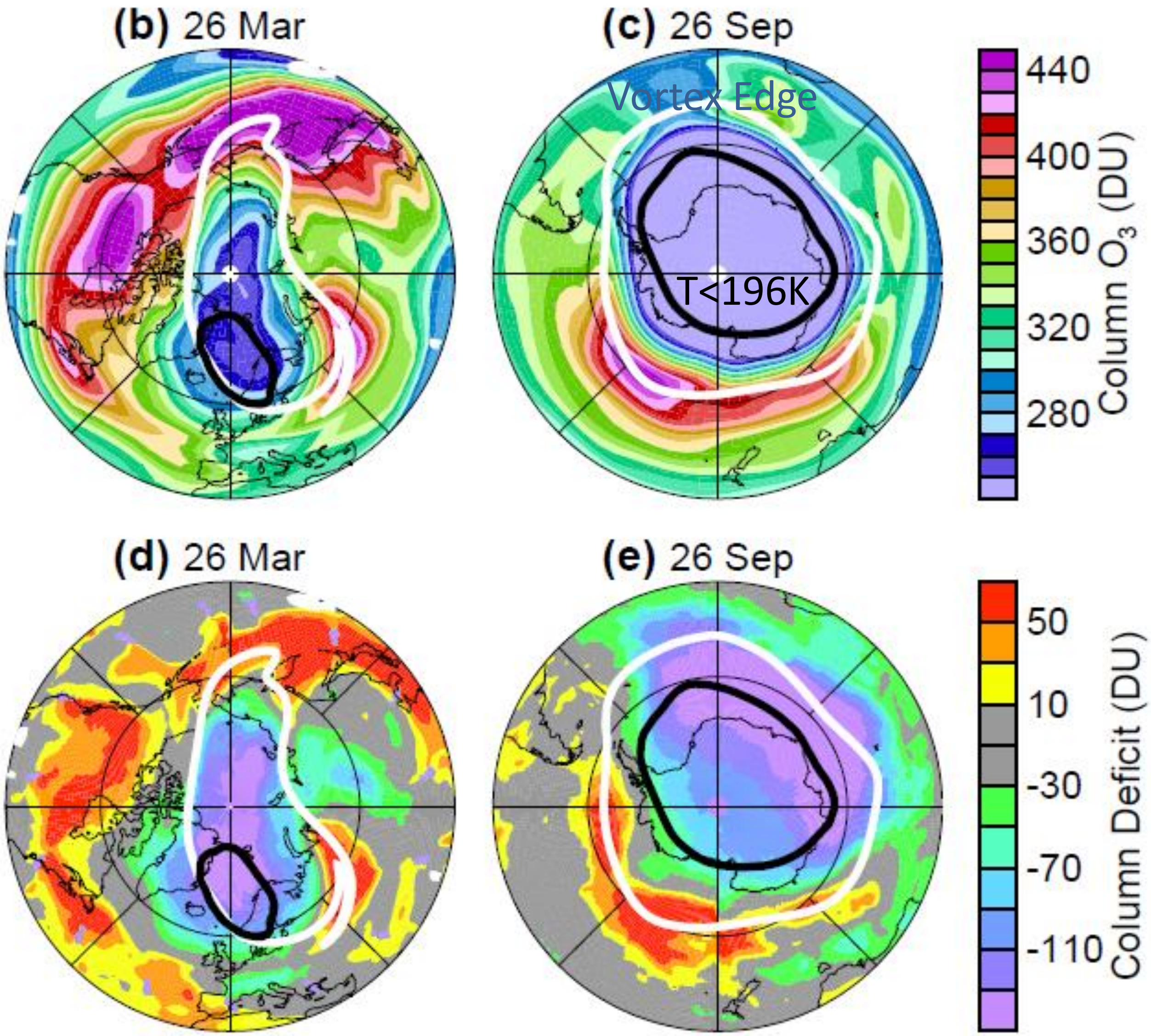
[Manney et al., Nature, 2011]

Total Ozone Map

Arctic 2011 | Antarctic 2010

Total Ozone

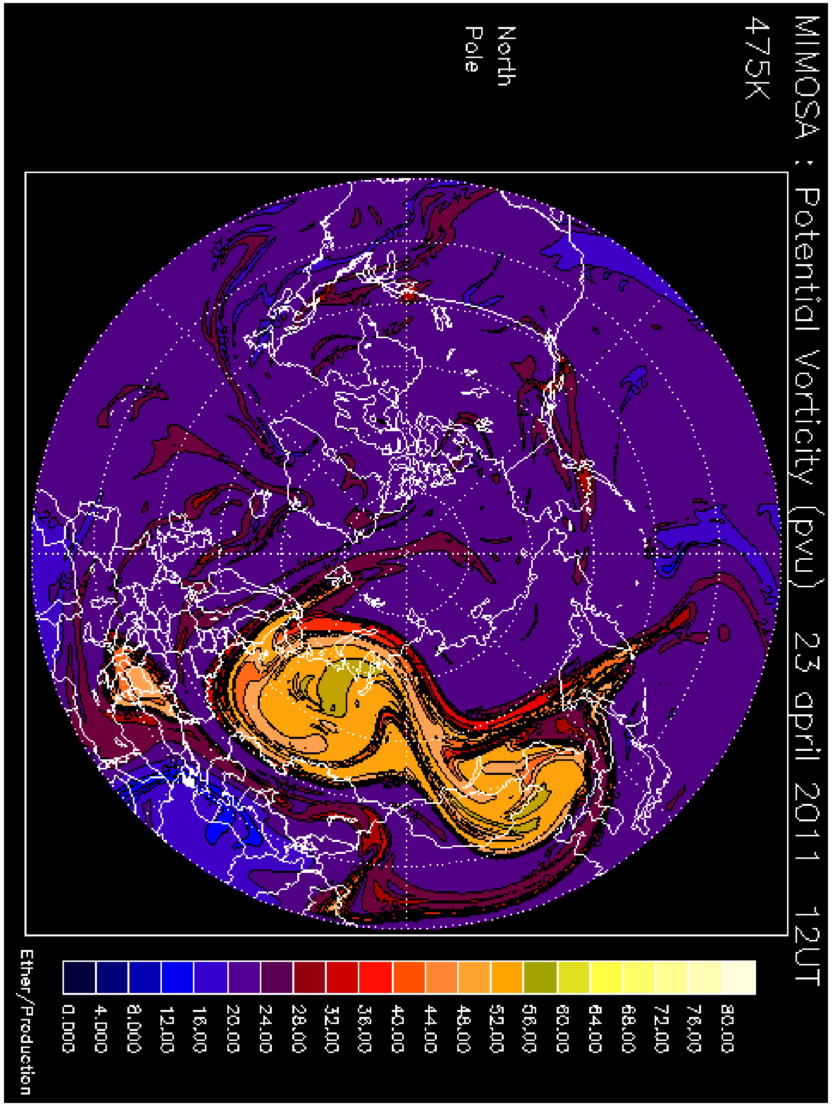
Ozone Deficit

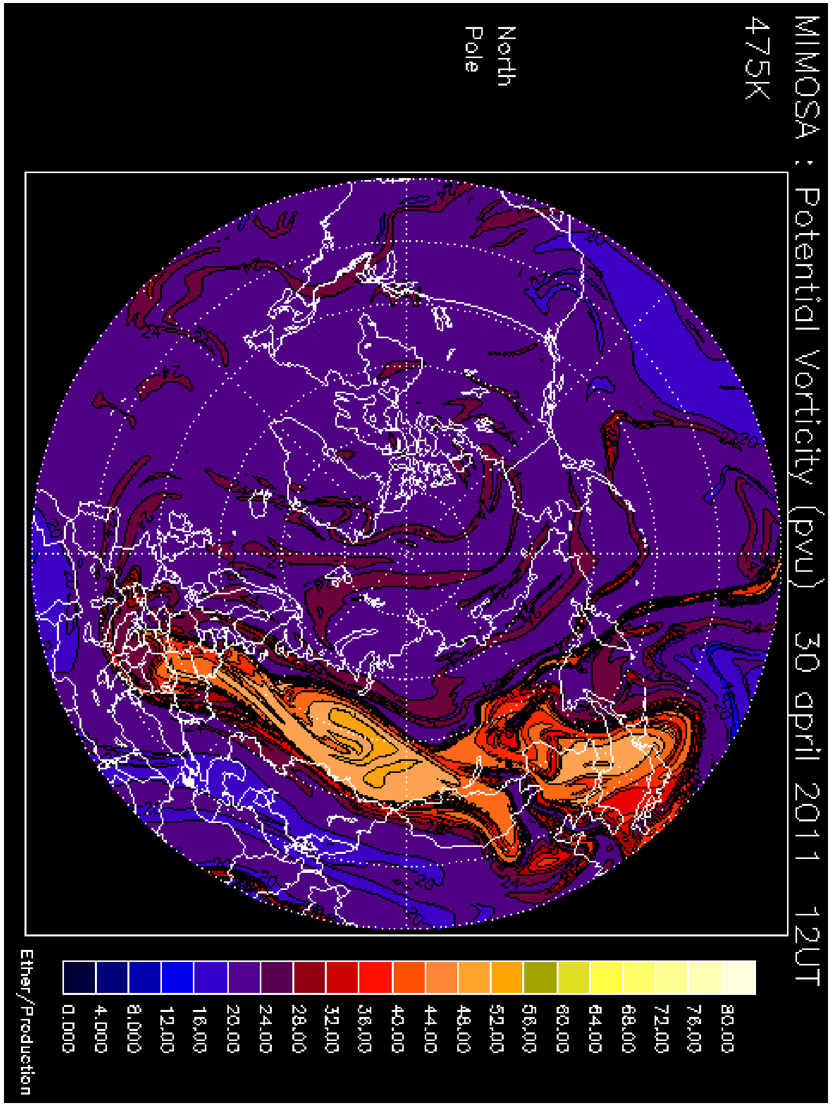


150/400 DU = -40% loss

-40〜-60% loss [Manney et al., Nature, 2011]

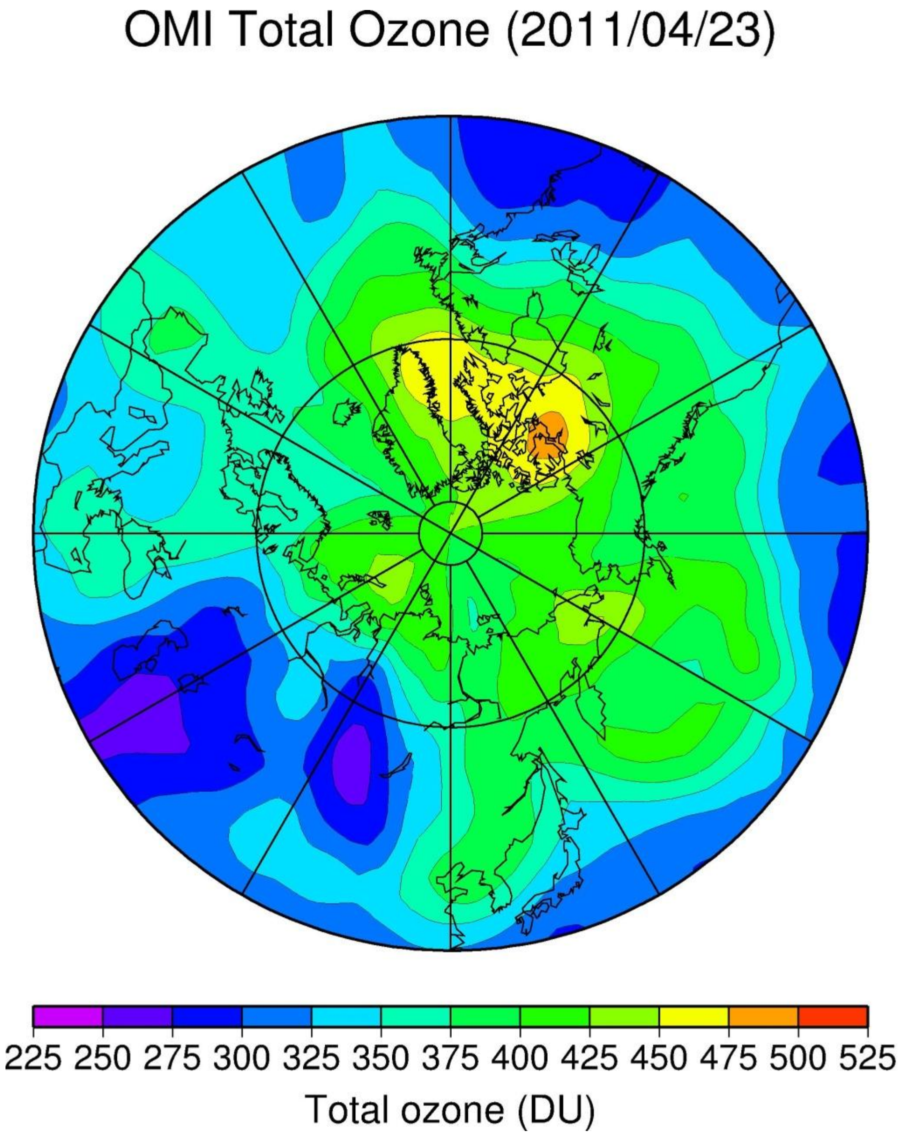
Effect of Arctic Ozone Hole to Asia

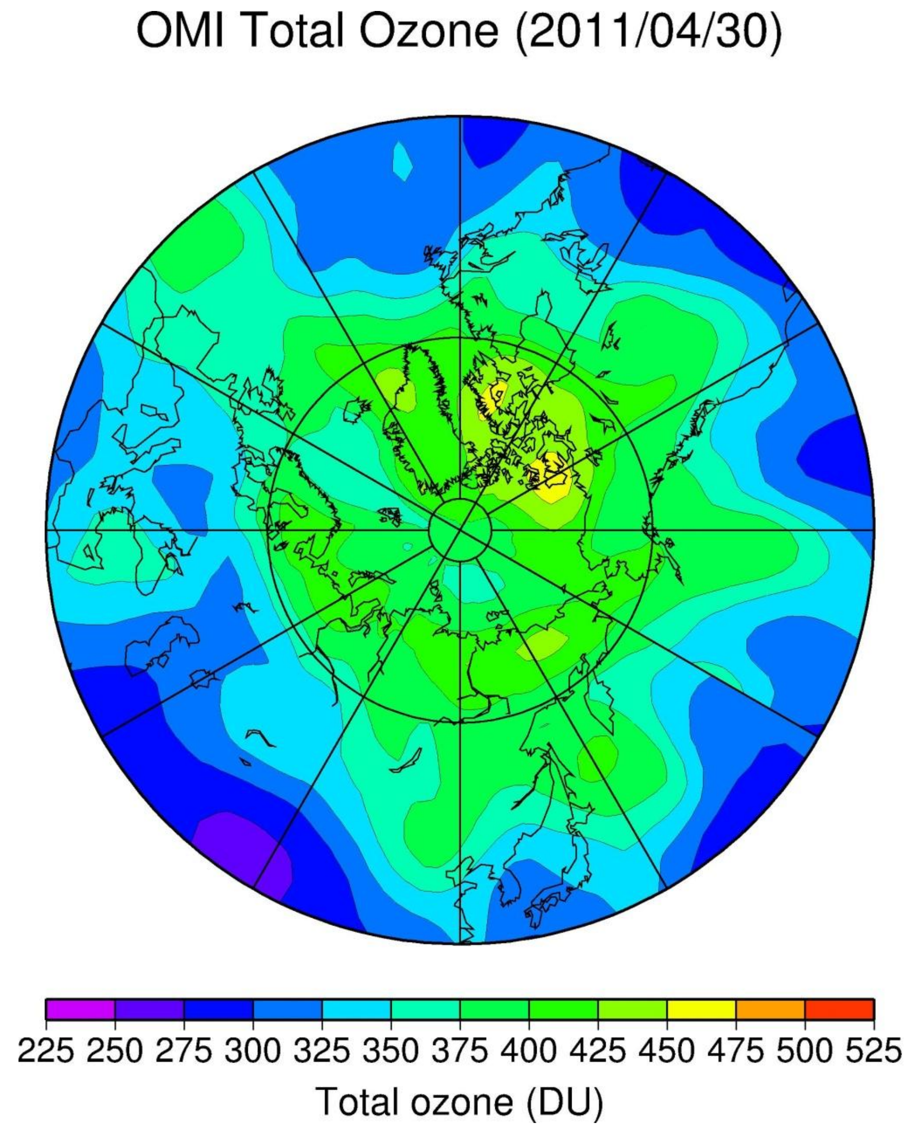




[Figures produced in NIES using NASA's OMI data]

Effect of Arctic Ozone Hole to Asia





[Figures produced in NIES using NASA's OMI data]

SUMMARY

- The Arctic ozone loss in 2011 was the largest in history. For the first time, Arctic ozone loss expanded to the similar degree to that of Antarctic ozone loss.
- The direct cause of the ozone loss is attributed to the long-lasting low temperatures, and the strongest polar vortex in the Arctic stratosphere.
- We cannot deny the possibility of future severe Arctic ozone loss matched or exceeded to this spring.
- We need to monitor the Arctic ozone hole in addition to the Antarctic ones until the stratospheric chlorine amount will decrease for a few tens more years. Also, we need to improve the accuracy of future ozone projection models.