Figure 2. Two-dimensional contour plots of wave function amplitudes for He atom in the ground state.

We are in the process of completing the calculations on the entire helium sequence and extending the calculations to the fully correlated systems. We will shortly return to these results.

1. Holland, J. H., *Adaptation in Natural and Artificial Systems: An Introductory Analysis with Application in Biology, Control and Artificial Intelligence*, MIT, 1998.
2. Goldberg, D. E., *Genetic Algorithms in Search, Optimization and Machine Learning*, Addison Wesley, Reading, MA, 1989.
3. Chaudhury, P. and Bhattacharyya, S. P., Numerical solutions of the Schrödinger equation directly or perturbatively by genetic algorithm: test cases. *Chem. Phys. Lett.*, 1998, **296**, 51–60.
4. Makarov, D. E. and Metiu, H., Fitting potential energy surfaces: A search in the function space by directed genetic programming. *J. Chem. Phys.*, 1998, **108**, 590–598.
5. Makarov, D. E. and Metiu, H., Using genetic programming to solve the Schrödinger equation. *J. Phys. Chem.*, 2000, **A104**, 8540–8545.
6. Saha, R., Chaudhury, P. and Bhattacharyya, S. P., Numerical solution of Schrödinger equation by genetic algorithm. *Phys. Lett.*, 2001, **A291**, 397–406.
7. Nakanishi, H. and Sugawara, M., Numerical solution of the Schrödinger equation by a microgenetic algorithm. *Chem. Phys. Lett.*, 2000, **327**, 429–438.
8. Zeiri, Y., Fattal, E. and Kosloff, R., Application of genetic algorithm to the calculation of bound states and local density approximations. *J. Chem. Phys.*, 1995, **102**, 1859–1862.
9. Saha, R., Bhattacharyya, S. P., Christopher Taylor, Jhou, Y. and Cundari, T., Direct solution of the Schrödinger equation by a parallel genetic algorithm: Cases of an exactly solvable 2D interacting oscillator and the hydrogen atom. *Int. J. Quant. Chem.*, 2003, **94**, 243–250.
10. Davis, H. L., Radial limit in the configuration-interaction method for the 1's state of the helium isoelectronic sequence. *J. Chem. Phys.*, 1963, **39**, 1827–1832.

Signature of early ozone hole recovery during 2002

S. L. Jain*, Sachin D. Ghude and B. C. Arya
Radio and Atmospheric Sciences Division, National Physical Laboratory, New Delhi 110 012, India

Total column ozone has been measured using Microtop Sunphotometer at Maitri (70°45′S, 11°44′E), Antarctica during the 21st Indian Antarctic Scientific Expedition. Observations show that the ozone hole in the year 2002 was not as deep as that of the previous few years. The minimum value of total ozone of about 185 DU was observed in the last week of September during 2002 and 135 DU during 1997. Observations also reveal the early recovery of ozone hole during 2002 compared to 1997. The Maitri observations were also compared with TOMs data as well as a nearby Russian station data and were found to be in good agreement.

OZONE is one of the most important constituents in the atmosphere and in spite of its low concentration, a few ppmv in mixing ratio, it plays an important role not only in the chemistry of this region, but it also affects the dynamics and biological activity near the surface. The amount of ozone over any particular place depends not only on photochemical balance, but also on the stratospheric climate, the winds that transport the ozone[1].

The reporting of catalytic depletion of ozone by ClO_x and NO_x by Johnston[2] in general, and ozone hole over Antarctica in particular by Farman *et al.*[3] has generated an unprecedented surge of interest in the scientific community in the monitoring of ozone. Very low temperature during winter leads to the formation of polar stratospheric clouds (PSCs)[4]. The heterogeneous chemical reactions that take place on the surface of the PSCs, are responsible for the ozone hole phenomenon during springtime over Antarctica[4]. Chemical reactions in the presence of liquid or ice particles either as ice or nitric acid trihydrate, or other mixtures lead to the conversion of chlorine compounds, which normally are present as HCl and $ClONO_2$ in the stratosphere. Normally, these gases do not react with ozone. However, in the presence of ice particles, HCl and $ClONO_2$ are converted into Cl_2 and HNO_3, and if UV-solar radiation is available, then Cl_2 is converted into Cl atoms, which then react with ozone to form ClO. Thereafter, a new chemical scheme, involving Cl_2O_2 as intermediate, comes into action, which destroys ozone efficiently[5–9].

However, planetary waves work against CFC-induced ozone destruction. These vast pressure waves influence ozone destruction in several ways and can have relevant impact on the size and stability of the massive jet stream

encircling Antarctica called the 'Antarctic vortex'[10,11]. Ozone has been found to be strongly affected by the dynamical behaviour of the polar vortex[12]. When the strength of planetary waves picks up, they exert a force on the vortex, which blows it apart. As the vortex breaks down, the surrounding warm, ozone-rich air mixes with the cold air over Antarctica, raising ozone concentration observed in Antarctica during ozone hole period[13].

In view of the above, a hand-held microprocessor-based sun-photometer, MICROTOP-II, has been used to measure total ozone, water vapour, optical depth, etc. at Maitri, Indian Antarctica research station during the years 1997 and 2002. Observations were made throughout the expedition on an hourly basis during clear sunny days. In the present communication, the experimental set-up and results obtained are discussed in detail.

MICROTOP-II is a five-channel hand-held microprocessor-based sun-photometer with a full field of view of 2.5°. The instrument has five optical collimators aligned to aim in the same direction. A narrow-band interference filter and a photodiode suitable for the particular wavelength range are fitted with every channel. All the channels directly face the solar disc simultaneously when the image of the sun is centred at the cross-hairs of the sun target. When the radiation captured by the collimators falls onto the photodiodes, it produces an electrical current proportional to the received radiant power, which is amplified and converted into digital form in a high-resolution A/D converter. Signals are processed in a series of 20 conversions per second. Among the five channels at 300, 305, 312, 940 and 1020 nm, the first three filter channels are used to derive atmospheric total ozone column and the other two for water vapour[14].

The variation of total ozone from January to December 1997 and January to December 2002 is shown in Figure 1. Maximum ozone up to 320 DU has been recorded in the months of January and February during both the years. The gap in Figure 1 is due to non-availability of data during polar nights. The minimum value of total ozone of about 185 DU was observed in the last week of September 2002 and with the same instrument total ozone values of about 135 DU were observed in the first week of October 1997. The observation shows that the ozone hole in the year 2002 was not as deep as in the year 1997. The observation also shows the early recovery of ozone hole in the year 2002 compared to 1997, as depicted in Figure 1.

The ozone depletion started from 1 September onwards. Exceptionally high values up to 361 DU of total ozone column were observed during ozone hole period during 7 and 8 September 2002. The ozone hole started recovering around 23 September; however, some variations were also observed during the recovery period of the ozone hole, as shown in Figure 1. The observations taken at Maitri were compared with TOMS[15] as well as a nearby Russian station (70°46′S, 11°50′E) data and found to be in good agreement, as depicted in Figure 2.

The observation at Maitri showed recovery around 24–25 September 2002; the early recovery of the ozone hole in last week of the September 2002 can be explained by the findings of Kondratyev and Varotsos[16]. Varotsos[17] has performed a Fourier analysis of the 10 hpa height and the temperature–time series at the high latitude of the south-
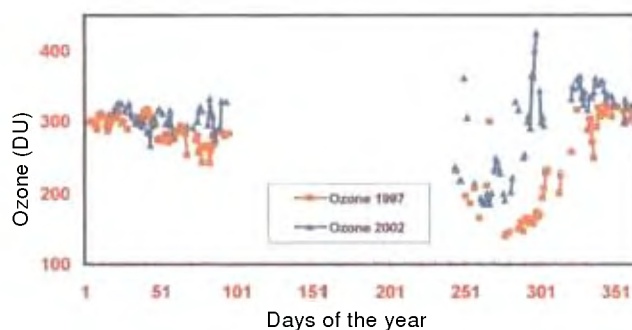

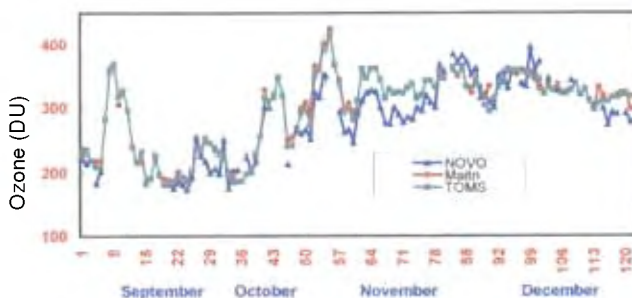**Figure 1.** Variation of column ozone during 1997 and 2002 at Maitri, Antarctica.

Figure 2. Comparison of Maitri, Russian and TOMS column ozone values over Maitri during ozone hole period.
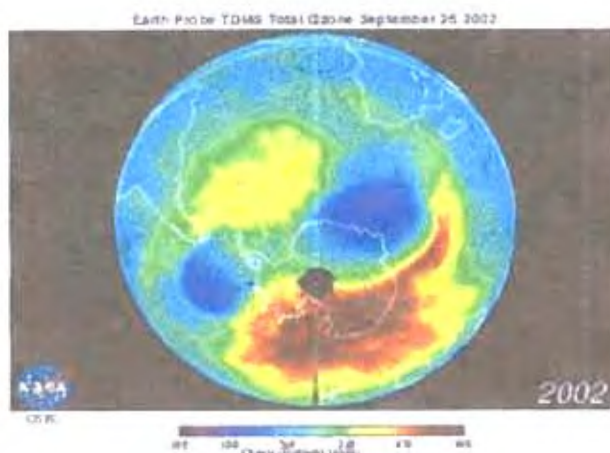

Figure 3. Satellite imagery of ozone hole[18] over Antarctica on 26 September 2002.

ern hemisphere. He found that planetary waves of extremely large amplitude were present, which broke up the Antarctic ozone hole into two holes[17] on 24–25 September 2002, as seen in Figure 3. After the break-up, the polar vortex was reformed and subsequently disappeared early. A NASA press release[18] also represented the prevalence of strong planetary waves in Antarctica. The vortex break-up and disappearance have been attributed to the occurrence of a major sudden stratospheric warming in the Antarctica due to the occurrence of very strong planetary waves.

The Maitri station is situated in the fringe region of the vortex. The observed abrupt high total ozone on 7 and 8 September and also during the recovery period from 23 September onwards, as shown in Figure 2, may be attributed to the planetary wave phenomenon. The planetary wave phenomenon forces the ozone-rich air masses from mid latitude to polar latitude region and the rapid displacement of the polar vortex from a roughly symmetric circulation about the pole to a circulation that is offset from the pole, which leads to the stratospheric sudden warming for a short period over the fringe region of the vortex. If the strengths of these waves is high enough, then this forces the ozone-rich air mass into the polar vortex and a sudden increase in the total ozone may take place[19–21].

The measurement of total ozone by MICROTOP sun-photometer at Maitri station, Antarctica during the 21st Antarctica Scientific Expedition showed the earlier recovery of ozone hole in the year 2002 compared to 1997. The earlier recovery of ozone hole can be attributed to major stratospheric warming due to the prevalence of very strong planetary waves. The agreement between the TOMS data and the sun-photometer data has proved MICROTOP-II sun-photometer to be an important tool to measure total ozone. Ozone hole data for the year 2002 does not by itself give any indication of the long-term trend, but measurements show that the CFC concentrations in the stratosphere are leveling-off and in the lowest layer of the atmosphere, the troposphere, CFC concentrations have started to decline due to the decisions taken by international community under Montreal Protocol, its subsequent adjustments and amendments to stop the use of ozone-depleting chemicals. These measurements indicate that the ozone hole may soon start to improve. However, this improvement will come slowly.

1. Hartmann, Dennis, L., *Global Physical Climatology*, Academic Press, San Diego, CA, 1994.
2. Johnston, H. S., Reduction of stratospheric ozone by nitrogen catalyst from supersonic transport exhaust. *Science*, 1971, **173**, 517.
3. Farman, J. C., Gardiner, B. G. and Shanklin, J. D., Large losses of ozone in Antarctica reveal seasonal ClO_x/NO_x interaction. *Nature*, 1985, **315**, 207.
4. Manney, G. L. and Waters, Froidevaux, L, Arctic ozone depletion observed by UARS MLS during the 1994–95 winter. *Geophys. Res. Lett.*, 1996, **23**, 85–88.
5. Cadle, R. D., Crutzen, P. J. and Ehhalt, D. H., Heterogeneous chemical reactions in the stratosphere. *J. Geophys. Res.*, 1975, **80**, 3381.
6. Hanson, D. R. and Ravishankar, A. R., The reaction probabilities of $ClONO_2$ and N_2O_5 on 40 to 75 percent sulfuric acid solutions. *J. Geophys. Res.*, 1991, **96**, 17307.
7. Crutzen, P. J. and Arnold, F., Nitric acid cloud formation in the winter Antarctic stratosphere: a major cause for the springtime ozone hole. *Nature*, 1986, **324**, 651.
8. Molina, M. J., Tso, T. L., Monila, L. T. and Wang, F. C. Y., Antarctic stratospheric chemistry of chlorine nitrate, hydrogen chloride and ice. *Science*, 1987, **238**, 1253.
9. Molina, L. T. and Molina, M. J., Production of Cl_2O_2 from the self reaction of the CLO radical. *J. Phys. Chem.*, 1987, **91**, 433.
10. Newman, P. N., The final warming and polar vortex disappearance during the southern hemisphere spring. *Geophys. Res. Lett.*, 1986, **13**, 1228.
11. Chandra, S. and McPeters, R. D., Recent trends in stratospheric total ozone: Implications of dynamical and EL chichon perturbations. *Geophys. Res. Lett.*, 1986, **13**, 1224.
12. Carswell, A. I., Bird, J. C., Donovan, D. P., Duck, T. J., Pal, S. R., and Velkov, D., Lidar measurement of stratospheric ozone at the eureka NDSC station, 1993–1998. 19th ILRC NASA, 1998, p. 327.
13. Newman, P., Incredible shrinking ozone hole. Science News, NASA, 2002 (http://www.science.nasa.gov/.)
14. Jain, S. L., Monitoring of ozone, water vapour, etc. during voyage to Antarctica. *Asian J. Phys.*, 2001, **10**, 315.
15. Kohmyr, D., In *Operations Handbook–Ozone Observations with a Dobson Spectrometer*, WMO, 1980.
16. Kondratyev, K. Y. and Varotsos, C., *Atmospheric Ozone Variability: Implications for Climate Change, Human Health and Ecosystems*. Springer-Praxis, Chichester, UK, 2000, p. 617.
17. Varotsos, C., The southern hemisphere ozone hole split in 2002. *Environ. Sci. Pollut. Res.*, 2002, **9**, 375–376.
18. NASA/NOAA, *Ozone hole press release*, 02-185, 30 September 2002 (http://toms.gsfc.nasa.gov).
19. Brinksma, E. J., Meijer, Y. J., Connor, B. J., Manney, G. L., Bergwerff, J. W. and Swart, D. P. J., Analysis of record breaking low ozone values during the 1997 winter over NDSC–station Lauder, New Zealand, 19th ILRC, NASA, 1998, p. 319.
20. Schoeberl, M. R. *et al.*, Reconstruction of the constituent distribution and trends in the Antarctic polar vortex from ER-2 flight observations. *J. Geophys. Res.*, 1989, **94**, 16815.
21. Kirchoffs, V. W., Casiccia, C. A. R. and Zamorano, F., The ozone hole over Punta Arenas. *J. Geophys. Res.*, 1997, **102**, 8945–8953.