duction in early 1975 were essentially the same as in 1966. Data for two stations within 250 km of the coast, together with the data shown in Fig. 1, suggest that the 1975 El Niño conditions limited the offshore extent of the coastal zone of production, but did not affect the magnitude of production within the compressed coastal zone.

As discussed by Wyrtki *et al.* (*2*), by late April 1975 conditions in the equatorial zone of the eastern tropical Pacific were rapidly returning to normal. Cool, nutrient-rich water was present at the surface at all but four equatorial stations, with up to fivefold increases in primary production. Vertical profiles of the equatorial conditions in late April and early May are similar to Fig. 2B, which emphasizes the short duration of the 1975 El Niño–like event.

The environmental conditions that result in increases or decreases of important fish stocks have not been well established, but Lasker (*10*) has shown that anchovy larval survival is dependent on the availability of phytoplankton cells of the proper size above a critical concentration, and he has been able to relate the population size of fish born in a particular year to the observed quantity and quality of phytoplankton food. Although Lasker's exciting information is based on the northern anchovy, *Engralis mordax*, found off the west coast of North America, it is reasonable to expect a similar mechanism for the Peruvian anchovy, *Engralis ringens*, whose overall biology is similar. If survival of the year's population depends on having a high concentration of the right kind of phytoplankton, it appears that the 1975 event would have no detrimental effect on the anchovy, because the conditions for normal high primary production persisted throughout the coastal region even at the maximal development of the 1975 event in February and March. Table 1 is a list of the dominant phytoplankton species present in coastal surface waters in 1966 and 1975 (*11*). If the phytoplankton conditions necessary for survival were provided by the conditions prevailing in 1966 and 1968, our data indicate that they were also provided by the conditions prevailing in 1975. The 1975 event, while it affected a large area of the southeastern tropical Pacific, did not change the character of the coastal upwelling zone off Peru.

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References and Notes

1. W. H. Quinn. [*CUEA Newslett.* **3**, 12 (1974)] predicted weak El Niño–like developments for 1975. He distinguished between a true El Niño, characterized by a disastrous invasion of anomalously warm surface waters along the Peru coast, and the weaker El Niño–like disturbance, characterized by anomalously warm sea-surface temperatures in the equatorial Pacific along with abnormally heavy precipitation over the central and western equatorial Pacific. The resulting developments agreed with his predictions.
2. K. Wyrtki, E. Stroup, W. Patzert, R. Williams, W. Quinn, *Science* **191**, 343, 1976.
3. *Data Report, R.V.* Moana Wave, *El Niño Watch Expedition* (Univ. of Hawaii, Honolulu, and Scripps Institution of Oceanography, La Jolla, Calif., 1975), vols. 1 and 3.
4. E. Steeman-Nielsen, *J. Cons. Cons. Int. Explor. Mer* **18**, 117 (1952).
5. S. A. Huntsman, *CUEA Newslett.* **3**, 8 (1974); ——— and R. T. Barber, *Deep-Sea Res.*, in press.
6. R. W. Owen and B. Zeitzschel, *Mar. Biol.* **7**, 32 (1970).
7. *Cruise Report, R.V.* Anton Bruun, *Cruise 15* (Marine Laboratory, Texas A & M Univ., Galveston, 1966); *Data Report, R. V.* Te Vega, *Cruise 17* (Stanford Univ., Stanford, Calif., 1968).
8. R. T. Barber and J. Ryther, *J. Exp. Mar. Biol. Ecol.* **3**, 191 (1969).
9. J. Walsh, *Limnol. Oceanogr.* **21**, 1 (1976).
10. R. Lasker, *Fish. Res. Bull. 73* (1975), p. 453; paper presented at the Joint Oceanographic Assembly, Edinburgh, Scotland, September 1976.
11. J. H. Ryther, D. W. Menzel, E. M. Hulburt, C. J. Lorenzen, N. Corwin, *Invest. Pesq.* **35**, 43 (1971).
12. We thank K. Wyrtki, W. Patzert, and E. Stroup for the opportunity to participate in the El Niño Watch Expedition, T. Owens for assistance in data collection, and the captain, crew, and scientific party of the R.V. *Moana Wave*. We also thank R. Williams and the GEOSECS (Geochemical Ocean Section Study) Operations Group for chemical analyses and prompt data processing. This is a contribution of the Coastal Upwelling Ecosystems Analysis (CUEA) program of the International Decade of Ocean Exploration (IDOE) of the National Science Foundation (NSF grant IDO72-06422).

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Energetic Radiation Belt Electron Precipitation: A Natural Depletion Mechanism for Stratospheric Ozone

Abstract. *During geomagnetically disturbed periods the precipitational loss of energetic electrons from the outer radiation belt of the earth can readily provide the major ionization source for the mesosphere and upper stratosphere. One particularly intense manifestation of this interaction between the radiation belts and the lower atmosphere is the relativistic electron precipitation (REP) event which occurs at subauroral latitudes during magnetospheric substorm activity. At relativistic energies the precipitating electrons produce copious fluxes of energetic bremsstrahlung x-rays, the major portion of which penetrate deep into the stratosphere before undergoing excitation and ionization collisions with the neutral atmosphere. If such REP events occur more than a few percent of the time, they can, on an annual basis, provide a local source of upper stratospheric nitric oxide molecules (via the dissociation of molecular nitrogen) comparable to that from either galactic cosmic rays or energetic solar proton events. Since nitric oxide plays a major role in the removal of stratospheric ozone, it appears that the influence of REP events must also be considered in future photochemical modeling of the terrestrial ozone layer.*

It is now well established that the direct removal process for stratospheric O_3 first proposed by Chapman (*1*)

$$O + O_3 \rightarrow 2O_2$$

can explain only 20 percent of the loss rate needed to balance photochemical production (*2*). Catalytic reactions with water compounds (hydroxyl radicals) probably account for an additional 10 percent of the required O_3 removal rate. The most acceptable mechanism for the bulk (70 percent) of O_3 destruction involves catalytic reactions with oxides of nitrogen (NO_x) (*3*):

$$NO + O_3 \rightarrow NO_2 + O_2$$

$$NO_2 + O \rightarrow NO + O_2$$

The precise role played by other catalytic agents [such as atomic chlorine (*4*)] remains controversial, but it is probably fair to conclude that these are not as important as NO_x.

The principal source of NO in the lower stratosphere (below 30 km) is from the upward diffusion and subsequent oxidation of tropospheric N_2O by excited oxygen [$O(^1D)$] atoms (*3*); NO is also produced directly throughout the stratosphere by energetic particle precipitation. The primary particles produce an intense flux of secondary electrons (with an energy of 10 to 100 ev) which readily dissociate N_2; the atomic nitrogen subsequently recombines with O_2 to yield NO and atomic oxygen. Current estimates suggest that the rate of NO production is comparable (within a factor of 2) to that of ion pair production (*5–7*). The detailed knowledge gained from studies of precipitation-induced ionization of the lower atmosphere (*8*) can therefore be used to estimate the altitude profile of NO production (and subsequent O_3 removal) during certain types of particle precipitation.

Several examples of energetic ion precipitation and their potential role in modifying stratospheric O_3 have already been

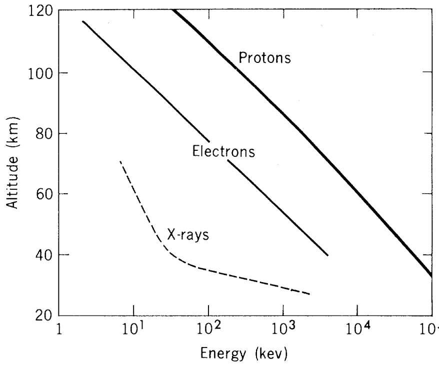

Fig. 1. The nominal penetration depth for energetic electrons, protons, and x-rays normally incident at the top of the earth's atmosphere.

analyzed. As illustrated in Fig. 1, protons must have energies above 10 Mev in order to penetrate to stratospheric altitudes. Heavier ions require even greater energy. Because of this energy threshold, recent investigators of the stratospheric response to energetic ion precipitation have concentrated on the role played by ultraenergetic galactic cosmic rays (GCR) (*6*, *9*) and energetic solar protons (*7*) which are emitted in association with intense flare activity on the sun.

Thus far, to my knowledge there has been no mention of the possible role played by the precipitation of geomagnetically trapped particles. This is understandable for the case of radiation belt protons since the precipitation fluxes are generally negligible at the energies needed to penetrate the stratosphere. Such a neglect, however, is not acceptable for geomagnetically trapped electrons. During geomagnetically disturbed periods there is substantial precipitation of relativistic electrons ($E \gtrsim 500$ kev) from the outer radiation zone. Although it is clear from Fig. 1 that such electrons can directly influence only the uppermost part of the stratosphere, the generated bremsstrahlung x-rays (which may have energies up to a significant fraction of the incident electron energy) (*10*) can penetrate to as low as 30 km. It is therefore important to quantitatively estimate the relative role played by such radiation belt electron precipitation as compared to GCR or solar proton events.

A preliminary indication of this comparison is shown in Fig. 2. In each case the ionization rate for a certain class of precipitation event is plotted against altitude. It is implicitly assumed that this plot also provides a reasonable estimate of the NO production rate (*5*–*7*). The production by GCR (*6*, *9*) varies slightly over the solar cycle, being most intense during solar minimum conditions. The production rate for energetic solar proton events is highly variable. The example shown here corresponds to conditions of intense polar cap absorption (PCA) (*11*). With the exception of the extreme (and rare) events reported by Crutzen *et al.* (*7*), this curve represents a reasonable upper limit for the solar proton–induced NO production rate. But since solar proton events generally last for several days it is clear, as reported by Crutzen *et al.* (*7*), that one intense PCA event each year will predominate over the annual GCR production of NO at altitudes above 40 km.

There is surprisingly little published information on the ion pair production profile during relativistic electron precipitation events. The two examples shown in Fig. 2 were either obtained directly from satellite electron flux measurements (*12*) (case B) or deduced indirectly from observations of radio wave absorption and the bremsstrahlung x-ray flux (*13*) (case A). The satellite data used to construct curve B were limited to energies below 150 kev. An exponential extrapolation of the electron flux of the form $J(>E) \sim \exp(-E/E_0)$ with $E_0 = 18$ kev was used for $E > 150$ kev. A similar exponential energy spectrum (with $E_0 \sim 40$ kev) was also used by Bailey *et al.* (*13*) to model the dayside relativistic electron precipitation (REP) event (curve A). One should therefore treat the lower portion of these REP production curves with some caution since the adoption of an exponential energy spectrum tends to significantly underestimate the flux of relativistic electrons. As an example, the spectrum used by Bailey *et al.* (*13*) yields $J(> 500 \text{ kev}) \sim 50$ electron cm^{-2} sec^{-1} whereas direct satellite measurements generally indicate substantially larger relativistic electron flux [$J(> 500 \text{ kev}) \gtrsim 10^4$ electron cm^{-2} sec^{-1}] during intense precipitation events (*14*). The REP production rates shown in Fig. 2 (curves A and B) are therefore undoubtedly underestimated below 70 km. In view of the greater efficiency of bremsstrahlung x-ray production by relativistic electrons (*10*), one must also conclude that the bremsstrahlung ion pair production curves in Fig. 2 must also be underestimated for the events considered. Even so, it is clear that in the upper stratosphere the NO production by bremsstrahlung x-rays should predominate over that by galactic cosmic rays provided that REP events occur more than a few percent of the time.

In order to obtain a more quantitative comparison, direct satellite observation

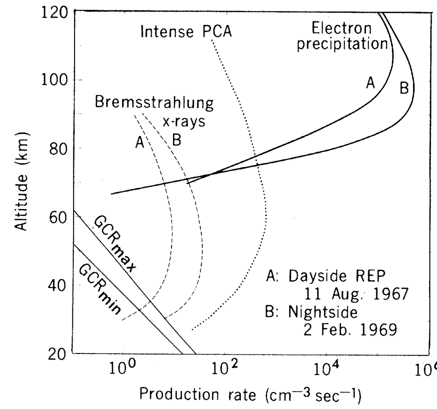

Fig. 2. Vertical profiles of the ionization (or NO production) rate during certain types of particle precipitation. The two solid lines below 60 km show the variability of GCR production over the solar cycle. The dotted line is an example of production during an energetic solar proton event characterized by intense PCA. Two examples of intense radiation belt electron precipitation are given including the production rate by the concomitant bremsstrahlung x-ray flux.

of precipitating relativistic electrons should be used to estimate the total columnar production rate of NO during an REP event. From Fig. 1 it is clear that electrons with energy greater than 500 kev are able to directly penetrate into the stratosphere and, together with their bremsstrahlung x-rays, produce NO molecules in the altitude range between 30 and 60 km. During the event reported by Vampola [see (*14*)] the precipitating electrons were distributed isotropically with a power law differential energy spectrum $dJ/dE \sim E^{-3.4}$; $j(1 \text{ Mev}) \sim 10$ electron cm^{-2} sec^{-1} ster^{1} kev^{-1}. The total relativistic electron energy deposition rate was therefore $\xi\,(E > 500 \text{ kev}) \approx 10^{11}$ ev cm^{-2} sec^{-1}. With the usual assumption that each ion pair requires about 35 ev, this calculation yields a columnar production rate $Q_{\text{REP}} \approx 3 \times 10^9$ cm^{-2} sec^{-1}, which may be compared directly with that by GCR, $Q_{\text{GCR}_{\text{max}}} \approx 6 \times 10^7$ cm^{-2} sec^{-1}. Thus, although the REP event reported by Vampola probably represents an extreme case, an occurrence rate of only 2 percent would make such events locally competitive with GCR, even during solar minimum conditions. As with the case of PCA events, the comparison becomes even more favorable during solar maximum conditions when the GCR flux is less and REP events are more prevalent.

It has been established that REP events are one manifestation of magnetospheric substorm activity (*15*). The events are most intense at subauroral latitudes ($4 < L < 10$, where L is the magnetic parameter) and typically have a duration of a few hours. Although statistical information on the occurrence frequency of REP events is sparse, such events appear to be more prevalent at night. The average occurrence rate probably amounts to at least one event each day. It therefore seems fair to conclude that radiation belt REP may provide a significant natural sink for upper stratospheric O_3.

One must, however, recall that the O_3 destruction associated with REP (and solar proton) events will be primarily confined to altitudes above 30 km. This natural sink for upper stratospheric O_3 can be expected to be most pronounced (implying minimum O_3 content) during solar maximum conditions. Such a behavior makes the observed solar cycle variation of stratospheric O_3 (*16*) even more difficult to understand, since it is anticorrelated with the anticipated response of lower stratospheric O_3 to GCR (*17*). It is therefore clear that detailed models of the vertical transport of NO will be required in order to assess the ultimate response of terrestrial O_3 to variations in particle precipitation over the solar cycle.

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References and Notes

1. C. Chapman, *Mem. R. Meteorol. Soc.* **3**, 103 (1930).
2. H. S. Johnston, *Rev. Geophys. Space Phys.* **13**, 637 (1975).
3. P. J. Crutzen, *Q. J. R. Meteorol. Soc.* **96**, 320 (1970); H. Johnston, *Science* **173**, 517 (1971); M. B. McElroy and J. C. McConnell, *J. Atmos. Sci.* **28**, 1095 (1971); M. Nicolet and W. Peetermans, *Ann. Geophys.* **28**, 751 (1972).
4. M. J. Molina and F. S. Rowland, *Nature (London)* **249**, 810 (1974); P. J. Crutzen, *Geophys. Res. Lett.* **1**, 205 (1974); M. Nicolet, *Rev. Geophys. Space Phys.* **13**, 593 (1975).
5. A. Dalgarno, *Space Res.* **7**, 849 (1967); H. S. Porter, C. H. Jackman, A. E. S. Green, *J. Chem. Phys.* **65**, 154 (1976).
6. P. Warneck, *J. Geophys. Res.* **77**, 6589 (1972).
7. P. J. Crutzen, I. S. A. Isaksen, G. C. Reid, *Science* **189**, 457 (1975).
8. W. Webber, *J. Geophys. Res.* **67**, 5091 (1962); T. A. Potemra and A. J. Zmuda, *ibid.* **75**, 7161 (1970); W. N. Spjeldvik and R. M. Thorne, *J. Atmos. Terr. Phys.* **37**, 777 (1975).
9. G. Brasseur and M. Nicolet, *Planet. Space Sci.* **21**, 939 (1973); M. A. Ruderman and J. W. Chamberlain, *ibid.* **23**, 247 (1975).
10. M. J. Berger and S. M. Seltzer, *J. Atmos. Terr. Phys.* **34**, 85 (1972).
11. G. C. Reid, in *Magnetosphere-Ionosphere Interaction*, K. Folkestad, Ed. (Oslo Univ. Press, Oslo, 1972), p. 39.
12. T. R. Larsen, "Report 62" (Norwegian Defense Research Establishment, Kjeller, 1973).
13. D. K. Bailey, R. R. Brown, M. H. Rees, *J. Atmos. Terr. Phys.* **32**, 149 (1970).
14. A. J. Vampola, *J. Geophys. Res.* **76**, 4685 (1971); D. L. Mathews and D. J. Simons, *ibid.* **78**, 7539 (1973).
15. T. J. Rosenberg, L. J. Lanzerotti, D. K. Bailey, J. D. Pierson, *J. Atmos. Terr. Phys.* **34**, 1977 (1972); R. M. Thorne, *ibid.* **36**, 635 (1974); ______ and T. R. Larsen, *J. Geophys. Res.* **81**, 5501 (1976).
16. J. K. Angell and J. Korshover, *Mon. Weather Rev.* **101**, 426 (1973).
17. M. A. Ruderman, H. M. Foley, J. W. Chamberlain, *Science* **192**, 555 (1976).

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Oncornavirus: Isolation from a Squirrel Monkey (*Saimiri sciureus*) Lung Culture

Abstract. *An oncornavirus isolated from a squirrel monkey (*Saimiri sciureus*) lung culture has a density of 1.16 to 1.17 grams per milliliter, contains 70S RNA, and has an RNA-directed DNA polymerase that prefers* Mg^{2+} *over* Mn^{2+} *in an assay in which polyribocytidylate · oligodeoxyguanylate (12–18) is used as a synthetic template. Morphologically, the virus resembles Mason-Pfizer monkey virus but is antigenically distinct from this virus. The virus grows in cells of human, chimpanzee, rhesus monkey, canine, and mink origin, but not cells of squirrel monkey origin. On the basis of its properties, the newly isolated virus can be classified as a retravirus.*

A number of oncornavirus isolates have been recovered from tumors and various "normal" cell cultures of avian and mammalian tissues. Not all members of this group of viruses have been shown to produce cancer in vivo or cell transformation in vitro, but their common properties have led to the proposal that they should be grouped, along with slow and foamy viruses, in the family *Retraviridae* (*1*). Members of this family have enveloped virions (about 100 nm in diameter) that mature by budding from cytoplasmic membranes. They contain single-stranded RNA, an antigenically specific RNA-directed DNA polymerase (RDDP), and several proteins showing different degrees of antigenic specificity. The oncornaviruses, on the basis of morphological criteria, have been placed in four genera, oncornavirus A, B, C, or D. A number of these viruses are endogenous and may (ectropic) or may not (xenotropic) grow in cells of their natural host. An endogenous, xenotropic primate type C oncornavirus has been isolated from fetal and postnatal baboon (*Papio cynocephalus*, *P. hamadryas*) tissues, including the placenta (*2*).

Although type C viral particles have been observed in other primate placentas, including human, attempts to propagate these viruses in culture have been unsuccessful (*3*, *4*). Mason-Pfizer monkey virus (M-PMV), type species, for the candidate oncornavirus D group, has been isolated from the rhesus monkey (*Macaca mulata*) placenta and other fetal and postnatal tissues, including a mammary tumor (*5*). Both the baboon and rhesus are Old World monkey species. Although type C virus particles have been observed under the electron microscope in cebus and marmoset tissues (*4*, *6*) and a type C virus, woolly monkey sarcoma virus, was isolated from a woolly monkey tumor (*7*), there have been no previous reports of a type D oncornavirus in tissues of these or any other New World monkey species. We are now reporting the isolation of an oncornavirus with properties similar to M-PMV from a squirrel monkey lung-cell culture.

Lung tissue was obtained from a stillborn, term, male squirrel monkey (*Saimiri sciureus*) shortly after delivery. The tissue was finely minced, trypsinized at room temperature and the cells were suspended in Eagle's minimal essential medium containing fetal bovine serum (10 percent) and antibiotics (100 units of penicillin, 100 μg of streptomycin, 1 unit of bactracin, and 100 μg of neomycin per milliliter). After three passages of the resulting cell outgrowth, attempts were made to isolate an endogenous virus by cocultivating the squirrel monkey lung cells (SqMLu) with a fetal canine thymus culture (FCf2Th) (*8*), a continuous dog kidney cell culture (MDCK), or a diploid chimpanzee fetal lung culture

Table 1. Divalent cation and template preference for viral DNA polymerase (*10*). Results are expressed as 10^3 counts per minute. The figures in parentheses represent the ratio of Mg^{2+} to Mn^{2+} results.

Virus	Poly(rA) · oligo(dT)$_{12-18}$			Poly(dA) · oligo(dT)$_{12-18}$			Poly(rC) · oligo(dG)$_{12-18}$		
	Mg^{2+}		Mn^{2+}	Mg^{2+}		Mn^{2+}	Mg^{2+}		Mn^{2+}
SMRV	636.6	(2.3)	279.2	69.0	(1.8)	39.4	519.7	(39.4)	13.2
M-PMV	75.7	(4.5)	16.8	7.6	(1.9)	3.9	142.0	(25.2)	5.6
M7	5.7	(0.02)	315.9	2.1	(0.6)	3.9	6.0	(0.9)	6.8
RLV	10.9	(0.02)	527.5	5.9	(1.9)	3.2	12.9	(0.3)	44.8