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Antarctic Atmospheric Chemistry: Preliminary Exploration

Abstract. *The particulate and trace gas content of polar air is very similar to that of tropical air despite differences in climatology and biotic activity.*

Results of the examination of field data obtained on a trip to Antarctica in November and December 1966 have included (*1*) details of methods, equipment, locations, and interpretation. However, consideration of the data as a whole and comparison with data from other locations have not been reported.

Data on the monthly mean antarctic turbidity of periods 16 years apart (Table 1) indicate that no pronounced change in the turbidity in the antarctic atmosphere has occurred over the intervening 16 years (*2*). Any changes in the northern temperate regions (*3*) must be local and are not yet reflected in antarctic data.

Data on atmospheric turbidity in Antarctica reveal a concentration of 5 to 50 particle/cm^3 with radii between 0.1 and 1.0 μ in a 10-km column. Examination by optical and electron microscopy of the particles collected with an impactor indicate 0.1 to 1.0 particle/cm^3 in the radius interval between 0.1 and 1.0 μ. This latter finding is lower than the concentration derived from measurements of atmospheric turbidity, a common characteristic in this type of comparison probably due to the contribution to the turbidity from the stratospheric aerosol layer of sulfate near 20 km.

Table 1. Antarctic turbidity.

Month	Atmospheric turbidity B	S.D.
November 1950	0.016	0.007
December 1950	.026	.006
November 1966	.022	.006
December 1966	.024	.004

Although many studies have been made of airborne particles in temperate regions, little is known about the nature and concentration of such particles near the poles. Using an impactor, Fenn *et al.* (*4*) found that about 40 percent of the mass of aerosol particles in the air above the Greenland ice cap consists of sulfate particles. The relative concentration of sulfate is much higher than that commonly found in tropospheric air particles, except near localized sources, in most parts of the world (*5*). Numerically, concentrations of collected particles in the air of Antarctica varied from about 0.01 particle/cm^3 in the upper Taylor Valley and on the Ross Ice Shelf to 1.0 particle/cm^3 at 5000 feet on Mount Discovery. In McMurdo Station the air contained much greater concentrations of particles, mostly dark-colored, that almost certainly consisted mainly of powdered lava from the ground in that area.

Morphology (*6*), electron diffraction patterns, and melting points indicate that the range of particles from nearly pure sulfuric acid to nearly pure ammonium sulfate accounts for more than 50 percent of all particles. Particle shapes and a few electron diffraction patterns also indicate that some (less than 10 percent) of the particles collected may consist of sodium chloride. There is an indication of some mineral content, probably calcium aluminum silicates, particularly in those samples collected around McMurdo Station, which is built on lava and has a fair amount of vehicular traffic.

Table 2. Trace gases and particulates.

Locality	HCHO (ppb)	NO_2 (ppb)	SO_2 (ppb)	Particle/cm^3 with radius between 0.1 and 1.0 μ (No.)
Antarctica (*1*)	0–10(?)	0–3	0–2	~1
Panama (*8*)	0–3	0.5–1.5 (dry); 2.5–5 (rainy)	1–5	<1
Continental (*5, 10*)	0–10	0–20	0–100	10^3
Urban (*11*)	~100	~200	~500	~10^4

The high relative concentrations of sulfate agree with results obtained in the Arctic from the Greenland ice cap (*4*). The low chloride-sulfate ratio agrees with previous arctic data.

Electron diffraction patterns indicate that persulfate, $S_2O_8{}^{2-}$, may be present. If so, the persulfate is evidence for the stratospheric origin of the particles, since Friend (*7*) found this highly oxidized form of sulfur in stratospheric particles. Because downward mixing by subsidence is greatest in winter, measurement of sulfate concentrations in winter might indicate still higher concentrations.

Studies of trace substances in the air of remote tropical locations (*8*) have revealed a wide variety of organic and inorganic compounds. Conditions in Antarctica are such that temperature and biotic activity are much reduced as compared with the tropics, and these trace gases would be expected to be correspondingly reduced, especially if they are short-lived. On the other hand, gases whose lifetimes exceed average tropospheric mixing times should be present in comparable amounts in tropical, temperate, and polar regions; this is true for ozone and carbon dioxide, each of which occurs in comparable amounts throughout the world (*5*).

Table 2 summarizes data on trace gases and particles from several locations. The higher value for formaldehyde from Antarctica is somewhat in doubt as the analytical reagent releases gas bubbles which are very difficult to remove from the surface of the cuvettes. In Antarctica, concentrations of formaldehyde and nitrogen dioxide were highest at McMurdo Station; sulfur dioxide concentrations were highest on the Ross Ice Shelf, at the upper stations on Mount Discovery, and in the aircraft sample at 10,000 feet over Mount Discovery, thus indicating that this gas is not related to any human activity in Antarctica.

Comparison of chemical data with weather records of cloudiness at McMurdo Station and our turbidity records gives a faint suggestion that high concentrations of these trace gases were associated with cloudy rather than sunny days. The apparent anticoincidence of the appearance of these gases with sunlight intensity in Antarctica is at variance with their coincidence with sunlight in episodes of urban smog.

Concentrations of these trace gases in Antarctica are surprisingly similar to those reported in Panama (*8*) and are consistent with the lowest continental concentrations reported by Junge *et al.* (*9*) and Johnson (*10*). As expected, they are considerably lower than in a typical urban atmosphere (*11*). Particle counts are also very similar for Antarctica and Panama (Table 2). In fact, the atmosphere of Panama has slightly fewer particles than that of Antarctica in the radius size range between 0.1 and 1.0 μ. However, the total mass loading of atmospheric particulates is some 500 times higher in Panama than in Antarctica, which indicates that the Panamanian atmosphere contains some very large particles. In Panama, most of the particles are sulfuric acid over land areas and ammonium sulfate over ocean areas; this suggests that the ocean is an atmospheric ammonia source and that the land is a sink for the ammonia. This source for ammonia was absent in Antarctica.

The atmosphere of Antarctica is very clean as compared with the industrial atmosphere of the Northern Hemisphere and is similar in that respect to the Arctic. Its similarity (insofar as we have measured it) to the Panamanian atmosphere is surprising, especially since the latter is much more damaging. Man-made materials and objects have been left exposed to the elements in Antarctica for generations with very little deterioration, whereas only short-term exposure to the Panamanian atmosphere results in drastic deterioration.

The differences in deterioration rates between the antarctic and Panamanian atmospheres can probably be explained by a combination of four factors: (i) temperature, (ii) moisture, (iii) nature of the particulates, and (iv) residence time of contaminants. The mean annual temperature in McMurdo Station is somewhat below freezing whereas in Panama it is in the low 20's (centigrade). The atmosphere of Panama contains two to eight times as much moisture as that of Antarctica, and rain, very common in Panama, is rare in Antarctica. Most of the time in Antarctica, therefore, slow, solid-state reactions take place, whereas in Panama much faster reactions of ionic solutions can occur. Corrosion, as measured by corrosion plates exposed to the Panamanian atmosphere, is principally associated with large hygroscopic particles. Furthermore, attacks by bacteria and fungi occur in Panama but not in Antarctica. Sterile nonnutrient agar plates exposed in Panama, either open to the sky or inverted, in a few days show organic growth, thus indicating that both nutrient materials and viable organisms or spores are being deposited. Materials introduced into the Panamanian atmosphere quickly deposit onto surfaces (*12*) which become loaded with contaminants. These four factors indicate that, despite the similarities in the properties measured to date in the Panamanian and antarctic atmospheres, the corrosive effect of the atmospheres can be quite dissimilar. It would thus appear that gaseous components may not be as important in causing atmospheric corrosivity as inorganic and biologic particulates and moisture.

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Synodic Month: Variations in the Geologic Past

Abstract. *The value of 31.56 ± 0.74 days for the synodic month in the Upper Cambrian is used together with a maximum in the expected number of days in a synodic month to argue that solar tidal dissipation is important in the dynamics of the earth-moon system and that the moment of inertia of the earth cannot have been much larger then than it is now. The tendency of the measurements to remain near 30 days may be a resonance effect.*

The determinations of the number of solar days in a synodic month at various geologic epochs by Pannella, MacClintock, and Thompson (*1*) offer the possibility of solving for some of the parameters of the earth-moon system. Paleontological data have been used in this manner (*2, 3*).

Because of the tidal dissipative coupling of the earth's rotation to the moon's orbit, both the orbital period of the moon and the rotational period of the earth change. If the dissipation due to the sun's contribution to earth tides is ignored, then the earth-moon system conserves angular momentum. As the earth's rotation slows, the number of (present epoch) hours per day increases, but the moon's orbit gains angular momentum and thus the moon's orbital period increases. Because the synodic month involves both the moon's orbital period and the earth's rotation rate, large changes in the two periods produce a relatively small change in the synodic month. Thus the synodic month is not very sensitive to the earth's rotation rate in the geologic past. In fact, there is a maximum in the number of solar days per synodic month. This must have occurred some time in the past with the earth and the moon in a configuration not too different from that at present. The determination of Pannella *et al.* (*1*) can be used to draw some inferences about the earth-moon system by making use of the length of the synodic month at this maximum.

With the simplest assumptions [the moon's orbit is circular; differences in the moon's orbital plane, the plane of the ecliptic, and the earth's equatorial plane are ignored; there is negligible angular momentum transfer to the earth's orbit or to the moon's rotation, and the like—these seem to be the usual assumptions (*3*)], the maximum is about 31.4 days if the solar tidal dissipation is ignored, and about 32.5 days when