Magnetospheric Wind

Abstract. *An experiment designed to detect the bulk flow of cool plasma within the magnetosphere has been flown on the ATS-1 (Applications Technology Satellite) synchronous satellite. This experiment has yielded evidence for gusts of streaming positive ions in the magnetospheric equatorial plane. This directed ion flow is interpreted as the result of large-scale electric fields of the order of several millivolts per meter.*

An experiment designed to detect the convective motion of low-energy plasma within the magnetosphere has established the existence, at certain times, of large gusts of streaming positive ions. We have called these gusts the "magnetospheric wind."

The most probable cause for these ion drifts is a large-scale electric field normal to the equatorial geomagnetic field. On the basis of the energy spectra of the observed ions, we estimate that the electric field must be of the order of 5 mv/m. The ion drift energy often greatly exceeds the ion thermal energy; therefore, electric fields must play a dominant role in the dynamics of the low-energy magnetospheric plasma.

Following a suggestion by Gold (*1*), Axford and Hines (*2*) proposed that there might exist a large-scale convective motion of the magnetosphere resulting from viscous interaction between the high bulk velocity plasma flowing immediately outside the magnetosphere and cool plasma within the magnetosphere. Nishida (*3*), Brice (*4*), and Kavanagh *et al.* (*5*) have pursued various related convection models. The Rice University positive-ion detector aboard the NASA/ATS-1 (Applications Technology Satellite) satellite is designed to detect this convective motion of the cool ($kT < 1$ ev, where k is Boltzmann's constant and T is absolute temperature) magnetospheric plasma by observing the plasma anisotropy in the magnetic equatorial plane.

The ATS-1 satellite was launched 10 December 1966. Coincident with several magnetic storms early in the life of the satellite, the ion detector reported the existence of strong directional flows for positive ions (*6, 7*). Figure 1 illustrates the time history of the flow pattern observed during the storm that occurred 13 to 14 January 1967.

The directional flow of positive ions was first detected as the satellite was approximately 1 hour past the noon meridian and heading toward the dawn meridian on the 6.6-earth-radii orbital path. The direction of ion flow was approximately 30° clockwise from the direction to the sun as seen from the north. During the ensuing hour, the flow direction gradually shifted to approach the direction to the sun. At this time the angular distribution of the ion flux was such that over 90 percent of the flux was confined to an angular region less than 25° wide. At the same time the energy spectrum was sharply peaked between 3 and 5 ev per unit charge (*6*).

As the ATS-1 satellite continued along its orbital path, the magnetosphere became compressed by increased pressure from the solar wind to such an extent that the sunward boundary of the magnetosphere (the magnetopause) was driven all the way into the synchronous orbit. During the next hour of this fortuitous event, the magnetopause remained close to the synchronous orbit with occasional excursions inward and outward, such that the satellite was either inside or outside the magnetosphere for intermittent intervals. At this time we were able to examine the positive ion flow immediately inside and outside the magnetopause.

Unlike the positive-ion fluxes of lower energy observed during the previous hour, the ion energy spectrum at this time consisted of ions of energies predominantly above 50 ev (*7*). The directions of ion flow in the equatorial plane were predominantly parallel to the magnetospheric boundary. Furthermore, unlike the directed ion flows deep within the magnetosphere, the angular distribution was much broader, thus indicating a greatly enhanced ion temperature. The patterns of ion flow close to the boundary, both inside and outside, were very similar. The magnetic discontinuities associated with the magnetospheric boundary have been determined by data from a magnetometer on the same satellite (*8*).

After the magnetopause retreated beyond the synchronous orbit for the final time, the direction of ion flow changed back to that seen prior to the magnetopause crossings, namely, flow toward the sun with an energy spectrum that peaked around several electron

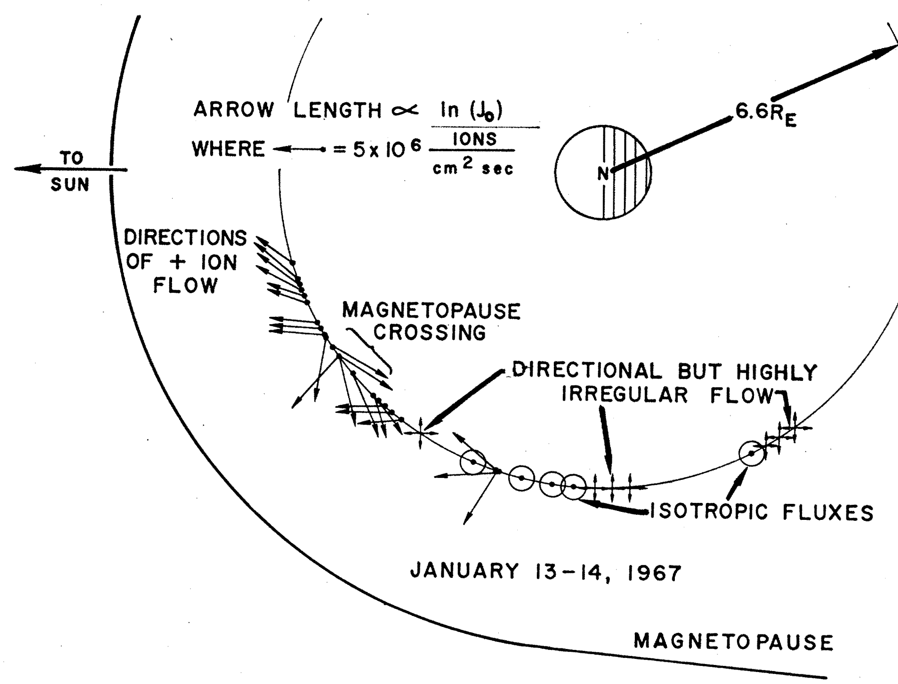

Fig. 1. A partial view of the ATS-1 orbital pattern in the magnetospheric equatorial plane showing the ion flow directions in the quadrant from noon to dusk on 13 to 14 January 1967. The satellite crossed the noon meridian at 2200 U.T. on 13 January. The magnetospheric boundary (magnetopause) is shown in its undisturbed position; however, during this orbit it was actually pushed in to the vicinity of the ATS-1 orbit by heightened solar wind pressure. The section of the orbit labeled "magnetopause crossing" indicates where the satellite was at this time. The disruption in the normal ion flow pattern can be clearly seen. The quantity R_E represents earth radii; J_o is omnidirectional flux; and N is the North Pole.

volts. Shortly thereafter and close to the dusk meridian, the ion flow patterns took on a highly erratic character and alternated with high isotropic fluxes.

Five additional examples of directed ion flow in the magnetosphere during magnetic disturbances were included in the data from the ATS-1 ion detector. Of these, three resemble the event of 13 to 14 January 1967; they show flow in the quadrant from noon to dusk with the flow being predominantly toward the sun; however, they do not possess the remarkable boundary-crossing feature.

Another of the examples takes place during a magnetic sudden commencement. This shows flow near the noon meridian initially toward the earth, after which a more complex time-varying pattern occurs.

Statistically significant anisotropies have also been found in data averaged over 3 hours from a few of the approximately 30 magnetically quiet days examined. The flow pattern seen on these days is not, in general, repeatable from day to day. However, trends in the data appear to support the magnetic storm pattern associated with nonsudden commencement events—flow toward the sun in the quadrant from noon to dusk.

Thus large-scale motion of the magnetospheric thermal plasma exists at least during certain intervals of both high and low magnetic activity. The flow pattern observed is consistent with present models of magnetospheric convection for the day hours of local time. The pattern for the nightside hours has not been established. The work of Carpenter (*9*), when considered together with the popular convection models, probably points to the continuous presence of large-scale electric fields with the ion gusts accounted for by a varying ion number density.

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References and Notes

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17 January 1969

Thyroid-Stimulating Hormone and Prostaglandin E_1 Stimulation of Cyclic 3′,5′-Adenosine Monophosphate in Thyroid Slices

Abstract. *Thyroid-stimulating hormone increased the cyclic 3′,5′-adenosine monophosphate concentration in dog thyroid slices during a 1-minute incubation period and produced a maximum effect soon thereafter. The elevation persisted for at least 30 minutes. The concentrations of the cyclic 3′,5′-adenosine monophosphate increased as the TSH concentration was increased from 0.125 to 50 milliunits per milliliter. Prostaglandin E_1, which increases glucose oxidation in dog thyroid slices, also increased the concentration of cyclic 3′,5′-adenosine monophosphate. Although sodium fluoride stimulates thyroid adenyl cyclase, it did not increase concentration of cyclic 3′,5′-adenosine monophosphate. Carbamylcholine and menadiol sodium diphosphate augment glucose oxidation in dog thyroid slices but do not change concentrations of cyclic 3′,5′-adenosine monophosphate.*

Current evidence suggests that thyroid-stimulating hormone (TSH) regulates thyroid gland metabolism as a consequence of stimulation of the enzyme adenyl cyclase and generation of cyclic 3′,5′-adenosine monophosphate (AMP). Thyroid-stimulating hormone rapidly increased adenyl cyclase activity in beef thyroid homogenate (*1*), and the metabolic and morphologic effects of TSH on the thyroid have been reproduced with dibutyryl cyclic 3′,5′-AMP (*2, 3*). Gilman and Rall reported that TSH increased cyclic 3′,5′-AMP concentrations in beef thyroid slices (*4*). Many other substances besides TSH also stimulate glucose oxidation in thyroid slices, and a mechanism involving cyclic 3′,5′-AMP has been implicated for some. Sodium fluoride augments glucose oxidation (*5, 6*) and stimulates adenyl cyclase in thyroid homogenate (*6*). We have demonstrated that prostaglandin E_1 increased glucose oxidation in thyroid slices but, differing from TSH, did not stimulate incorporation of ^{32}P into phospholipid (*7*). Although acetylcholine and menadione both augmented glucose oxidation in thyroid (*8*), acetylcholine did not reproduce TSH stimulation of adenyl cyclase in thyroid homogenate (*1*). Although the hypothesis that cyclic 3′,5′-AMP is the intracellular mediator of hormone action is most attractive (*9*), the available data indicate that similar effects on thyroid metabolism may be produced by other mechanisms.

In order to obtain more direct evidence for the role of cyclic 3′,5′-AMP in the control of thyroid gland function, we have studied the effects of various substances on the concentration of this nucleotide. Dog thyroid slices weighing between 20 and 60 mg were prepared and incubated in Krebs-Ringer bicarbonate buffer (*10*). After an initial incubation for 20 minutes in 2 ml of buffer containing 2 mg of glucose, the slices were transferred to flasks containing the same buffer and the appropriate hormone or substance. The time of this second incubation is indicated in the tables. Cyclic 3′,5′-AMP was measured by a modification (*11*) of the method of Breckenridge (*12*). After the second incubation, tissue slices were immediately frozen between blocks of dry ice. The frozen slice was homogenized in 5 percent trichloroacetic acid; the trichloroacetic acid was removed by ether extraction. Cyclic 3′,5′-AMP was then separated from adenosine triphosphate (ATP), adenosine diphosphate (ADP), and 5-AMP by barium hydroxide and zinc sulfate precipitation and column chromatography with Dowex-50 (*13*). The cyclic nucleotide was converted to ATP by incubation with phosphodiesterase, myokinase, and pyruvate kinase. The resulting ATP was assayed with glucose-1-^{14}C (*14*). This method was modified to include pyruvate kinase and phosphoenolpyruvate so that the ADP formed would be recycled to generate more ATP. The sensitivity of this method is 10^{-12} mole. Cyclic 3′,5′-AMP labeled with tritium was used as an in-

Table 1. Time course of TSH stimulation in vitro of cyclic 3′,5′-AMP in dog thyroid slices. Four experiments, each with a different dog thyroid, are shown. The TSH concentration was 10 milliunit/ml. The results are the averages of duplicate determinations on each slice.

Treatment	Cyclic 3′,5′-AMP (pmole/g) after incubation with TSH			
	1 min	3 min	10 min	30 min
None	1512	1247	2026	682
TSH	2983	7194	8679	1700
None	580		576	
TSH	3707		10990	
None			557	386
TSH			4254	3840
None		1478		1096
TSH		5790		6920