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Transient Reconnection

Search for Ionospheric Signatures

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The concept of magnetic reconnection originated with the suggestion by *Giovanelli* [1946] that particles could be energized during solar flares near nulls in the magnetic field. *Hoyle* [1949] subsequently proposed that such a process could also act at nulls between the geomagnetic field and the interplanetary magnetic field (IMF) to generate the energized particles responsible for auroral displays. However, the idea of the interconnection of the two magnetic fields, as we know it today, was first presented by Hoyle's student, *Dungey* [1953, 1961].

A simple theoretical basis for reconnection can be derived from Ohm's law which, for an electrically conducting fluid (a plasma) of scalar conductivity σ, has the form:

$$\mathbf{j} = \sigma (\mathbf{E} + \mathbf{v} \times \mathbf{B}) \qquad (1)$$

where $\mathbf{j}$ is the current density, $\mathbf{E}$ and $\mathbf{B}$ are the electric and magnetic fields and $\mathbf{v}$ is the plasma velocity. Using two of Maxwell's equations, Faraday's and Ampere's law (the latter neglecting the displacement current because σ is high):

$$\partial \mathbf{B}/\partial t = - \nabla \times \mathbf{E} \qquad (2)$$

$$\mu \, \mathbf{j} = \nabla \times \mathbf{B} \qquad (3)$$

where μ is the permeability of the medium, equation (1) can be written as

$$\partial \mathbf{B}/\partial t = \nabla \times (\mathbf{v} \times \mathbf{B}) + \nabla^2 \mathbf{B}/(\sigma \, \mu) \qquad (4)$$

The ratio of the first ("convective") term over the second ("diffusive") term on the right-hand side of equation (4) is called the magnetic Reynolds number, R_m. This is of order $V\sigma\mu L$, where L and V are the characteristic scale length and speed of the plasma, respectively. In the magnetosphere and interplanetary space, L and σ are so large that $R_m \sim 10^{15}$ and $\sim 10^{12}$, respectively, and the second term in (4) is negligible. The magnetic field then moves with the plasma (the magnetic flux is "frozen in" with the plasma flow). If this condition strictly applied, then the supersonic solar wind flow, with the IMF (which is of solar origin) frozen in it, would compress the dayside geomagnetic field until pressure balance was achieved (Figure 1*a*). The shocked solar wind plasma of the "magnetosheath" is kept apart from the plasma of the magnetosphere and the boundary between the two, the magnetopause, carries a current associated with the discontinuity in the magnetic field. All geomagnetic field lines are then termed "closed," which means they connect the ionospheres of opposite hemispheres. However, the magnetopause current layer would then be so narrow that L (and hence R_m) is small enough for the second term in (4) to become important, that is, the magnetic field diffuses through the plasma in the boundary (Figure 1*b*). At the center of the current sheet a southward component of the magnetosheath field (as shown in Figure 1) and the oppositely directed geomagnetic field line form an "X-line" (extending out of the page). The process of field lines diffusing into the X-line and then out with a different configuration is called magnetic reconnection and produces "open" magnetic field lines that directly connect the ionosphere with the interplanetary medium, through the magnetopause. The ensemble of all open field lines map to two large and roughly circular regions in the ionosphere (of variable radius of order 2000 km) called the polar caps. The rate at which magnetic flux is opened per unit length of X-line is called the reconnection rate and by Faraday's law is equivalent to an electric field E along the X-line consistent with both the motion of IMF/closed field lines toward the X-line and the motion of open field lines away from it. A voltage therefore exists across the length of the X-line, equal to the integral of the reconnection rate along that length.

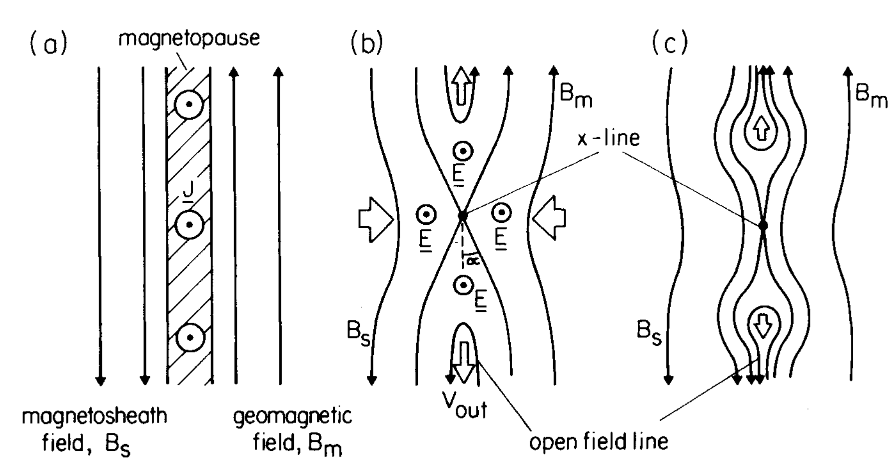

Fig. 1. (*a*) In the absence of magnetic field diffusion the magnetopause is an impermeable, current carrying barrier between the magnetic fields of the Earth and interplanetary space. (*b*) With allowance for diffusion at the magnetopause the magnetic fields can continuously reconnect. (*c*) If the rate of reconnection varies, bubbles in the magnetopause may form, which is one recent explanation of "flux transfer events."

There are four main pieces of observational evidence that this reconnection between the magnetic fields of the Earth and interplanetary space does indeed occur [*Cowley*, 1984].

1. In steady state the rate at which magnetic flux enters the polar cap (equal to the voltage across the magnetopause X-line where field lines are opened) would equal the rate at which it leaves the polar cap (equal to the voltage across an X-line in the geomagnetic tail where field lines are closed again) and so would also equal the voltage across the polar cap (see *Lockwood et al.* [1990] for further discussion). Observations of low-altitude polar-orbiting satellites, which assume such a steady state, show that this transpolar voltage increases when the southward component of the IMF increases, but has a constant, lower value for northward IMF. This behavior is consistent with a dominant reconnection process, which is most efficient when the IMF has a southward component (see review by *Reiff and Luhmann* [1986]).

2. Field-perpendicular flows and currents in the dayside polar cap are controlled by the B_y (dawn-dusk) component of the IMF in a way that is consistent with the effect of magnetic tension on open field lines. This "Svalgard-Mansurov" effect can also explain the observed morphology of field-aligned cusp currents [*Saunders*, 1989]. Also observed are B_y-dependent asymmetries in plasma populations and magnetic field in the outer magnetosphere, which are also consistent with reconnection.

3. Energetic particles of solar origin are known to have ready access to the ionospheric polar caps, for example, during Solar Proton Events. This is consistent with the interconnection of the magnetic fields of solar and terrestrial origins.

4. Particles are energized by magnetic reconnection and high-speed flow streams are observed. Stress and energy balance tests on particles and fields near the dayside magnetopause give results consistent with the reconnection process.

Transient Bursts of Reconnection and FTEs

Because the magnetosphere and magnetosheath are both highly variable, it is likely that steady reconnection at a constant rate will be the exception rather than the rule. *Russell and Elphic* [1978] and, independently, *Haerendel et al.* [1978], found characteristic signatures of the magnetic fields and particle populations near the magnetopause that they interpreted in terms of transient reconnection, respectively calling them "flux transfer events" (FTEs) and "flux erosion events." Subsequent studies showed that these events occur predominantly during southward IMF, with a mean repetition period of about 8 min, which strongly supports an interpretation in terms of magnetic reconnection. The concept put forward by Russell and Elphic was that an isolated tube of newly opened magnetic flux containing a mixture of magnetosphere and magnetosheath plasma was dragged over the magnetopause, past the spacecraft, giving the model of FTEs demonstrated by Figure 2*a*. In this model, the reconnection of the isolated tube took place at some time prior to the satellite observation. However, FTEs often show streams of warmed electrons (energies of about 100 eV) on the boundaries of the region thought to contain newly opened flux, suggesting that some reconnection was continuing at the time of such FTE observations. These considerations led *Southwood et al.* [1988] and, independently, *Scholer* [1988] to suggest a somewhat different model of FTEs, shown in Figures 1*c* and 2*b*.

From conservation of energy and mass, it can be simply shown that the angle of the outflow "wedges" (see Figure 1*b*), α, increases with the reconnection rate E. Figure 1*c* shows how a transient burst of increased reconnection rate could therefore give two "bubbles" of mixed magnetosheath and magnetosphere plasma in the magnetospheric layer, one on each side of, and moving away from, the X-line. The bubbles are sandwiched between two shock fronts generated by the reconnection. *Southwood et al.* [1988] and *Scholer* [1988] have pointed out that such bubbles could have all the observed features of FTEs, including the electron streams, because some reconnection can continue after the formation of the bubble. In three dimensions and for the simplified case of constant E along the X-line, these bubbles appear as cylinders in the magnetopause layer, of the same length as the X-line (Figure 2*b*).

A major difference between these two FTE models is that in the Southwood et al./Scholer case the reconnection occurs at an X-line that need not be longitudinally restricted. This means that the total amount of open magnetic flux added to the polar cap in each event can be considerably greater than in the circular flux tube paradigm of Russell and Elphic. Consequently, the voltage applied to the magnetosphere by each event, which appears across the polar cap, can also be correspondingly greater. Another model of FTEs by *Lee and Fu* [1985] invokes multiple X-lines, giving flux tubes with highly twisted magnetic fields on magnetopause, and again the X-lines can be elongated (Figure 2*c*).

Importance of Ground-Based Observations

The various models of FTEs have important and different implications for the coupling of the terrestrial plasma environment to interplanetary space. Observations by a single spacecraft near the magnetopause only tell us about the event dimension in the direction of motion of the event (roughly normal to the X-line), whereas to differentiate between the above models we must define the length of the X-line, or indeed see if there is more than one X-line. Sufficient coverage of the vast area of the dayside magnetopause by many spacecraft is not a viable proposition. However, there is an alternative in that we can search for signatures of transient reconnection in the dayside auroral ionosphere. The equatorial magnetopause and the high-latitude ionosphere are connected by highly conducting field lines that can transmit stress via Alfvén waves. Predicted flow and field-aligned current signatures corresponding to the FTE models shown in Figures 2*a*-2*c* are presented in Figures 2*d*-2*f* (after *Southwood* [1987], M. Lockwood et al., unpublished manuscript, 1990, *Wei and Lee* [1990] and *Lee* [1986], respectively). In order to explain magnetopause FTE signatures, the Russell and Elphic model flux tube must have a diameter of order 1 R_E at the magnetopause, whereas the cylinders in the Southwood/Scholer model could, in theory, be over 10 R_E in length. In addition, the mapping of field lines from the magnetopause to the dayside auroral ionosphere is not known in detail. As a result, we may be searching either for small-scale (100 km) transient events in the ionosphere or for variations that cover a large fraction of the dayside auroral oval. This search must be made using ground-based or balloon-borne remote-sensing instrumentation as the spatial/temporal ambiguity of in situ data from satellites, due to their motion, prevents events of the short duration of FTEs being unambiguously observed.

A major problem in searching for signatures of transient reconnection in ground-based data is that there appears to be a number of ways that a transient flow and current event can be generated in the dayside auroral ionosphere. For example, *Farrugia et al.* [1989] have shown that a rapid compression of the magnetosphere, caused by an increase in solar wind dynamic pressure, generated a signature at a wide variety of dayside magnetometer stations and that this signature was, for many stations, as had been predicted for one station for a small circular FTE flux tube..*Sibeck et al.* [1989*a*] have shown that other transients, previously interpreted as possible FTE signatures, could also have been caused by dynamic pressure effects. These ionospheric effects of dynamic pressure changes can be explained by a recent theory that involves magnetic field gradients close to the equatorial magnetopause [*Southwood and Kivelson*, 1990; L. C. Lee, unpublished manuscript, 1990]. Much debate has been generated concerning whether FTEs or pressure pulses are the cause of observed transient signatures [*Lanzerotti*, 1989; *Sibeck et al.*, 1989*b*].

Transient events that may have been FTE signatures have been observed in the dayside auroral ionosphere by a number of techniques, including magnetometers, coherent radar, incoherent scatter radar, balloon-based electric field observations, and optical instruments (see reviews by *Lockwood et al.* [1989*b*]; M. Lockwood et al., unpublished manuscript, 1990). Each of these techniques has advantages and disadvantages. For example, inter-

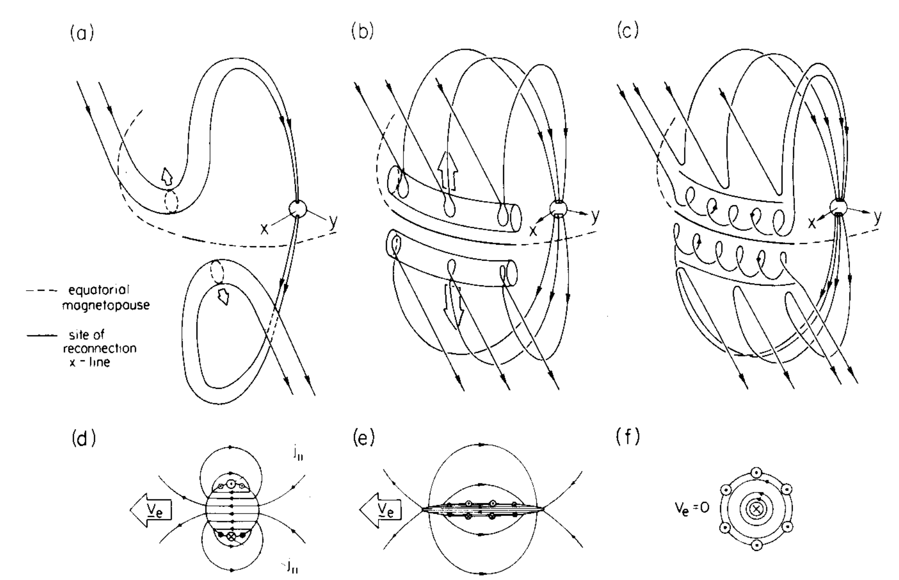

Fig. 2. Three models of flux transfer events. (*a*)-(*c*) The newly opened field line configurations for the three models, giving FTE signatures in both hemispheres. (*d*)-(*f*) Predicted snapshots of the corresponding plasma flow steamlines and field-aligned currents in the ionosphere. The ionospheric signatures are moving with the velocity V_e.

pretation of data from magnetometers is complicated by conductivity changes that may accompany the electric field transient. Also, each instrument is sensitive to changes over an extended spatial region (of radius of order 300 km) so that the effects of successive events can be superposed. Signatures are further complicated by variations in event velocity, shape or size within the field-of-view. On the other hand, the advantage of magnetometers is that large-scale networks of stations are available, increasing the probability of event detection and giving the possibility of defining event dimensions. Radar observations provide precise observations from much smaller scattering volumes, but other limitations arise: bistatic coherent radars can give the pattern of flow over an extended spatial region at high time resolution but require the presence of scattering irregularities. This is not a problem for incoherent scatter radars; however, they usually need to employ the beamswinging technique, which makes assumptions about the spatial and temporal uniformity of the flow that may well be invalid for any FTE signatures. Optical instruments are very useful in charting the motion of transient events, relative to the persistent background dayside aurora, but the association of plasma drifts and auroral motions is not yet known.

Observations Near the Island of Spitsbergen

It is clearly necessary to combine data from various ground-based observations to continue the search for ionospheric FTE signatures. Because of the possibility of making optical observations of the midday aurora at winter solstice, the island of Spitsbergen offers a unique location in the northern hemisphere. For the past two observing seasons, measurements of the plasma flow have been made using the European Incoherent Scatter (EISCAT) facility, operated monostatically from Tromsø, Norway, in the beamswinging "Polar" mode, combined with optical photometer and all-sky TV camera observations from Ny Ålesund, Spitsbergen.

Part (e) of the cover figure gives the relative locations of these measurements. This 1-second all-sky TV image has been mapped onto a geographic grid assuming an emission altitude of 130 km. Also shown are the simultaneous flow vectors derived from the EISCAT radar and the meridian scanned every 18 seconds by the photometers at Ny Ålesund (NA), where there is also a magnetometer. Other magnetometer stations are Hornsund (H), Bjørnøya (B) and, to the south of the map, Tromsø.

Transient phenomena have been observed simultaneously by each of these instruments [*Lockwood et al.*, 1989*a*, *b*; M. Lockwood et al., unpublished manuscript, 1990; *Sandholt et al.*, 1990]. The photometers have revealed transient events, with an initial intensification of the 630 nm (red line) aurora at the equatorward edge of the background cusp/cleft aurora, followed by a strong 557.7 nm (green line) transient auroral form. Both these intensifications subsequently drifted poleward and faded. Successive all-sky TV images showed that while intensifying, the 557.7 nm events moved rapidly westward around the auroral oval. Such events had previously been termed "midday auroral breakup" by *Sandholt et al.* [1989]. The closest magnetometers simultaneously observed complex impulsive signatures. The radar showed bursts of strong westward flow (3 km s^{-1}), swinging around to slower poleward motion (1 km s^{-1}). Indeed, the motion of the auroral luminosity seen by the all-sky TV camera was found to be the same, to within measurement uncertainties, as the local plasma flow deduced from the radar data.

Two of these transient events, observed at magnetic local noon on January 12, 1988, can be seen in the cover figure. Panels (a) and (b) show the red- and green-line photometer scans, respectively, while part (c) shows the flow vectors derived from the radar data. The one-second integration all-sky camera image (part e) shows that the westward-moving green-line auroral transient was just poleward of the part of the flow burst seen by the radar. It should be noted, however, that the radar flow data make use of the beamswinging technique, which in this case yields 3-point running means of 2.5-min data; hence there will be temporal smoothing inherent in the flow data. Furthermore, spatial and temporal structure in the flow will introduce errors, and it is important to complement future observations with other radar data [*Cowley et al.*, 1990]. For the data presented here, some check on the derived plasma flows has been made by using them to compute the ion temperatures from the ion energy balance equation: these derived values are found to compare well with the observed values.

Panel (d) of the cover figure shows the voltage, Φ, across the first 7 range gates of the radar field of view, obtained by integrating the observed northward electric field. The full sequence of this Φ data is shown in Figure 3, along with the zenith angle (at Ny Ålesund) of each red-line transient arc. The dashed lines show that each peak in Φ occurred close to the onset of a transient aurora, which was also associated with a transient 557.7 nm arc and an impulsive magnetometer deflection at Hornsund.

Are These Transient Events FTE Signatures?

Prior to 09:45 in Figure 3, the IMF was continuously southward and the transient events were observed every 8.3±0.6 min. This is very similar to the repetition period of magnetopause FTEs under the same conditions. Subsequently, the IMF was predominantly northward but each transient event can be associated with an isolated, short-lived excursion to a southward orientation. The initial westward motion of the events is consistent with the concept of magnetic tension on newly reconnected flux tubes because the IMF B_y component was strongly positive. Indeed, the pattern of motion of the events (zonal then poleward into the polar cap) is as predicted for newly opened flux tubes by *Saunders* [1989], in his explanation of the cusp field-aligned currents. It is also highly significant that all patches of increased luminosity had some poleward motion at all times and the auroral events as a whole drifted poleward of the persistent dayside aurora before fading. Also, there was always a poleward component of the plasma flow into the polar cap. *Cowley* [1986] has pointed out that some poleward motion into the polar cap is an important requirement of any ionospheric FTE signature. It has been suggested that magnetosheath plasma can impulsively cross the magnetopause in "plasma transfer events" [*Heikkila et al.*, 1989]. However, were this different transient breakdown of the "frozen in" condition possible, then the penetrating patch of plasma would give equatorward (and tailward) motion on closed field lines, that is, away from the polar cap. Likewise, flow signatures due to pressure pulses would move around the polar cap boundary, rather than drift into it.

Hence, the occurrence and motion of the events is as expected for newly opened flux tubes, but is the plasma flow pattern as one would expect for any of the FTE models discussed previously? *Southwood* [1987] showed that the circular FTE model of Russell and Elphic would generate a twin-vortical flow

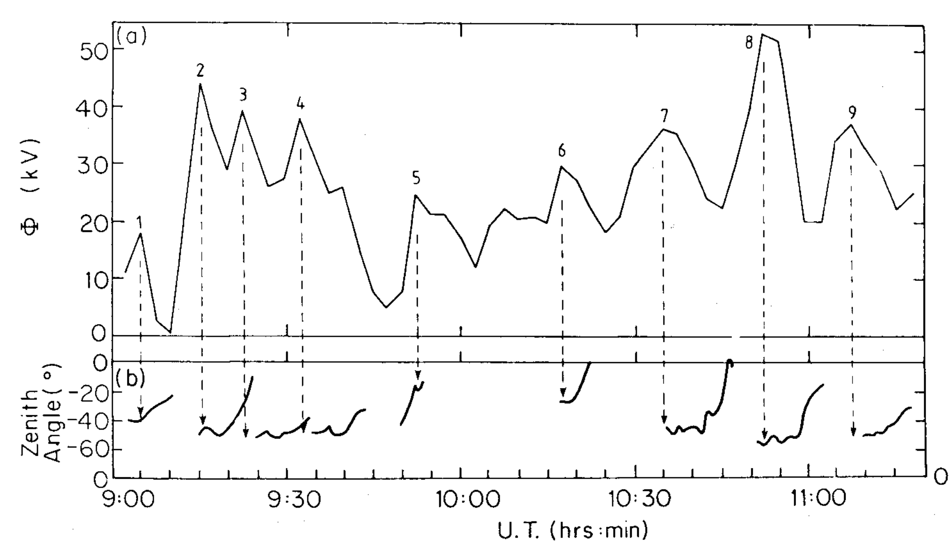

Fig. 3. Voltage across the EISCAT radar field of view, Φ, and the zenith angle of transient 630 nm aurora at Ny Ålesund on January 12, 1988. The onset of each transient auroral event is associated with a peak in Φ.

pattern in the ionosphere, and *Lee* [1986] predicted a single vortex from the Lee and Fu model (Figures 2*d* and 2*e*). In general, we would expect a superposition of the two: this is because any motion of the rotating Lee flux tube would generate the Southwood pattern and the reconnected tube will untwist as it convects in the Southwood model. However, these signatures have proven very hard to detect with any clarity or regularity. There are indications that the events discussed here are broadly consistent with Southwood prediction. Firstly, the magnetometers at Tromsø and Ny Ålesund showed deflections consistent with eastward flow, whereas at Hornsund and Bjørnøya the inferred flows were westward, as observed by the radar. Note, however, that when events recurred every 8 min, Tromsø and Ny Ålesund were unable to resolve individual events. Second, the plasma flow velocity in the center of an event appears always to equal the phase velocity of the event as a whole. This is an important characteristic of the Southwood pattern and contrasts with, for example, the predicted effect of pressure pulses where these two velocities are not the same in either direction or magnitude. The dimensions of the required open flux tube are very interesting. From the various radar range gates we find that the events were typically 200 km wide in north-south extent, but by integrating the observed westward speed over the duration of the event, we obtain estimates of 1000-2000 km for the east-west extent. The corresponding dimensions on the magnetopause are uncertain because the field line topology is not known sufficiently well; however, these great longitudinal extents could imply a reconnection X-line as great as 10-15 R_E. The all-sky TV images also show that the green-line arcs were elongated in the east-west direction. Extending the Southwood flow predictions to flux tubes of elliptical cross section (Figure 2*e*), it is found that the eastward flows outside a westward-moving open flux tube will be much weaker when the newly opened flux tube is elongated in the east-west dimension than for the circular flux tube case, as is observed. Hence, events may initially appear as a channel of flow with only weakly vortical return flows. This east-west elongation of the events may therefore be one reason why the search for the predicted twin-vortical flow and current features has been so frustrating in the past.

Implications and the Future

There are a number of important implications of these observations. First, whatever the cause of these transients, they are very significant events. Figure 3 shows that in the largest event, the voltage across the radar field-of-view peaks at 55 kV. Allowing for the smoothing inherent in the radar data and by extrapolating using the magnetometer data, *Lockwood et al.* [1989*a*] estimate that the total potential may be as large as 80-100 kV. Another estimate of voltage can be obtained from the TV images because the arcs have been found to move with the same velocity as the local plasma. Later in its lifetime, each transient arc typically moved poleward at 1 km s^{-1} and extended up to 1000 km east-west. This implies a voltage of up to 50 kV along the length of the arc. These figures are a significant fraction of the typical transpolar voltage observed by satellites for steady, strongly southward IMF (typically 100 kV). These estimates should also be compared with the 10 kV per event, derived from FTE observations at the magnetopause using the circular flux tube model [*Russell and Elphic*, 1978], suggesting any reconnection X-line must have been extended in length to up to about 10 R_E. This is also consistent with the derived dimensions of the ionospheric event, although we must remember the great uncertainties in attempting to map these dimensions to the magnetopause. That the voltage in transient events can be comparable with the total transpolar voltage suggests that a succession of elliptical FTE tubes could be the dominant mechanism for driving dayside convection, when the IMF is southward. The dayside flow pattern would then vary quasi-periodically with a mean period of about 8 min as new reconnection events take place and the effects of older ones decay. However, the presence of three or four successive events contributing to the excitation of convection, with the addition of the continuing, background reconnection and "viscous-like" interaction on the flanks of the magnetopause, would tend to smooth out these variations. In addition, some of the dayside flow will be the result of the reconnection that closes field lines in the geomagnetic tail [*Lockwood et al.*, 1990]. Note that flow fluctuations on time scales of several minutes could not have been observed by polar-orbiting satellites, and the response of ground-based magnetometers would be complicated by their extended field of view and by conductivity changes. In the events described here, only the magnetometer close to the arcs (Hornsund) could resolve separate impulses when they occurred every 8 min. Hence, it is possible that FTE signatures are not the small-scale flow vortices that we have previously sought with insufficient spatial resolution. Rather, they may be the large-scale flows and currents that we have failed to define as the superposition of a series of events because we have not had the required combination of temporal resolution, spatial resolution and extensive geographical coverage. Ground-based observations are the only way that such requirements could all be met.

Last, we note that the events described here are not the only transient events observed by the combined optical, radar and magnetometer observations. Other events appear to map to the low-latitude boundary layer (LLBL) and may be associated with Kelvin Helmholtz waves on the magnetopause or "blobs" or magnetosheath plasma that have been observed within the LLBL. Events of a third class are found considerably equatorward of the persistent background aurora and appear to be consistent with the effect of dynamic pressure changes on closed field lines. Like the midday auroral breakup events discussed above, these observations provide an opportunity to greatly enhance our knowledge of the coupling of the interplanetary and terrestrial plasmas. The initial evidence does suggest that midday breakup events and associated plasma flows and currents are ionospheric signatures of transient reconnection. However, many more observations are required to give good occurrence statistics that can be compared with those of magnetopause FTEs. Recently, events similar to those described here have been found a few minutes after magnetopause FTEs were observed by the International Sun-Earth Explorer (ISEE) satellites (R.C. Elphic, private communication, 1989). Again, however, many more simultaneous ionospheric and magnetopause observations are required to confirm this association and it is hoped they will be supplied by the CLUSTER mission in conjunction with improved ground-based measurements.

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News

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This is the fourth announcement in a continuing series from the Division of Ocean Sciences of the National Science Foundation to alert the biological and chemical oceanography communities of opportunities for participation in global ocean flux research. The announcement is based on research priorities developed by the U.S. Joint Global Ocean Flux Study (U.S. JGOFS). U.S. JGOFS is moving toward a fully operational phase in the early 1990s. Research priorities have and continue to be reviewed by the U.S. JGOFS Steering Committee with recommendations directed to the NSF Division of Ocean Science and other federal agencies involved with U.S. JGOFS. This announcement calls for proposals for completing the core measurements and for individual, process-oriented proposals.

The broad goal of JGOFS (Joint Global Ocean Flux Study)—to improve our understanding of the processes controlling the cycling of carbon and related biogenic elements in the oceans—has been articulated in detail in a series of reports that are available through U.S. JGOFS Planning and Implementation Office, Woods Hole Oceanographic Institution, Woods Hole, Mass. 02543; tel. 508-548-1400, ext. 2834; H.LIVINGSTON/OMNET. The overall direction and objectives of the U.S. program are detailed in the long-range science plan available from the U.S. JGOFS Planning and Implementation Office. The U.S. JGOFS is a component of the U.S. Global Change Research Program; additionally, it is the U.S. component of the Joint Global Ocean Flux Study (JGOFS), sponsored by the Scientific Committee for Ocean Research (SCOR). It is a Core Project of the International Geosphere Biosphere Program. For the international plans for JGOFS contact E. Tidmarsh, SCOR/JGOFS Secretariat, Department of Oceanography, Dalhousie University, Halifax, N.S., B3H 4J1, Canada; tel. 902-424-8865; E.TIDMARSH/OMNET.

U.S. JGOFS began to explore the scientific issues in the Pacific Basin in 1986 (U.S. JGOFS report number 2). This report, as well as those from subsequent meetings, identified the equatorial Pacific as an important region of new biological productivity. This new production plays an important role in global biogeochemical cycling of carbon and related biogenic elements. At the third meeting of the Scientific Committee of JGOFS (see *Eos*, November 28, 1989, p. 1515), the central equatorial Pacific was identified as a site for integrated ocean process studies planned for 1991 and 1992. Plans for the U.S. JGOFS contribution to this study are now rapidly taking shape.

Overall Plan

Following the precedent set by the U.S. JGOFS North Atlantic Bloom Experiment, scientists designated by the U.S. JGOFS Steering Committee coordinated U.S.-sponsored scientific activities with those planned by other JGOFS nations at an international meeting in Tokyo, Japan, April 17–20, 1990. A report of the meeting, including decisions made, will be available from the U.S. JGOFS Planning and Implementation Office by May 15, 1990. Revisions to the current plan will be announced on OMNET by May 15 and will be published in *Eos* shortly thereafter. Based upon the discussions held to date, the U.S. JGOFS Steering Committee recommends the location for process-oriented studies in the central equatorial Pacific along a transect from 9°N-15°S on 140°W. The studies will include a suite of core measurements, to be repeated on several cruises tentatively planned for fall 1991 and spring 1992. It is anticipated that some measurements will require occupation of specific comprehensive stations for extended periods of time, while others will require shorter station duration for profiling or noncomprehensive studies at other locations along the transect. The program will include cruises emphasizing water column and sedimentary processes, as well as deployment and recovery of moorings or other equipment. The specific strategy and the proposed comprehensive station locations are included in the planning document (U.S. JGOFS draft Equatorial Pacific plan, 1989, edited by M. Leinen and J. Murray).

Core Measurement Proposals

The list of core measurements has been described by the U.S. JGOFS Steering Committee (U.S. JGOFS Overview, December 1987). Core measurement proposals should be submitted as integrated proposal packages indicating plans to address all or a significant subset of the core measurement suite. Ship facilities will be limited, and the use of available platform space must be optimized. Therefore the degree of optimization will be a criterion in evaluating proposals. In evaluating proposals of otherwise equal scientific merit, preference will be given to proposals for integrated measurement programs. We do not encourage nonintegrated, individual proposal submissions for individual measurements; we do encourage the scientific community to collectively submit more than a single integrated proposal that can be compared in the evaluation process.

Core proposal packages, with a program overview, must be received at NSF by August 1, 1990. They will be reviewed by the normal NSF peer review process. It is anticipated that successful proposals will be funded in early 1991 for field work to begin in the fall of 1991, subject to the availability of funds and facilities.

Process-Oriented Proposals

Following the model established by the JGOFS North Atlantic Bloom Experiment, the U.S. JGOFS central equatorial Pacific program will include a substantial number of process-oriented research programs, for example, new production, foodweb structure and function, radionuclide tracers, bioturbation rates, sediment burial rates and mineralization. Problems appropriately addressed by such studies are documented in the central equatorial Pacific plan (JGOFS draft Equatorial Pacific plan). Individuals with an interest in proposing such studies should notify the U.S. JGOFS Steering Committee as soon as possible. Please contact Margaret Leinen, Graduate School of Oceanography, University of Rhode Island, Narragansett, RI 02882-1197; tel. 401-792-6268; M.LEINEN/OMNET; or James Murray, School of Oceanography, WB-10, University of Washington, Seattle, WA 98195; tel. 206-543-4730; J.MURRAY/OMNET. Proposals for such studies on one or more cruises must be received at NSF by August 1, 1990. They will be reviewed by the normal NSF peer review process. It is anticipated that successful proposals will be funded in early 1991 for field