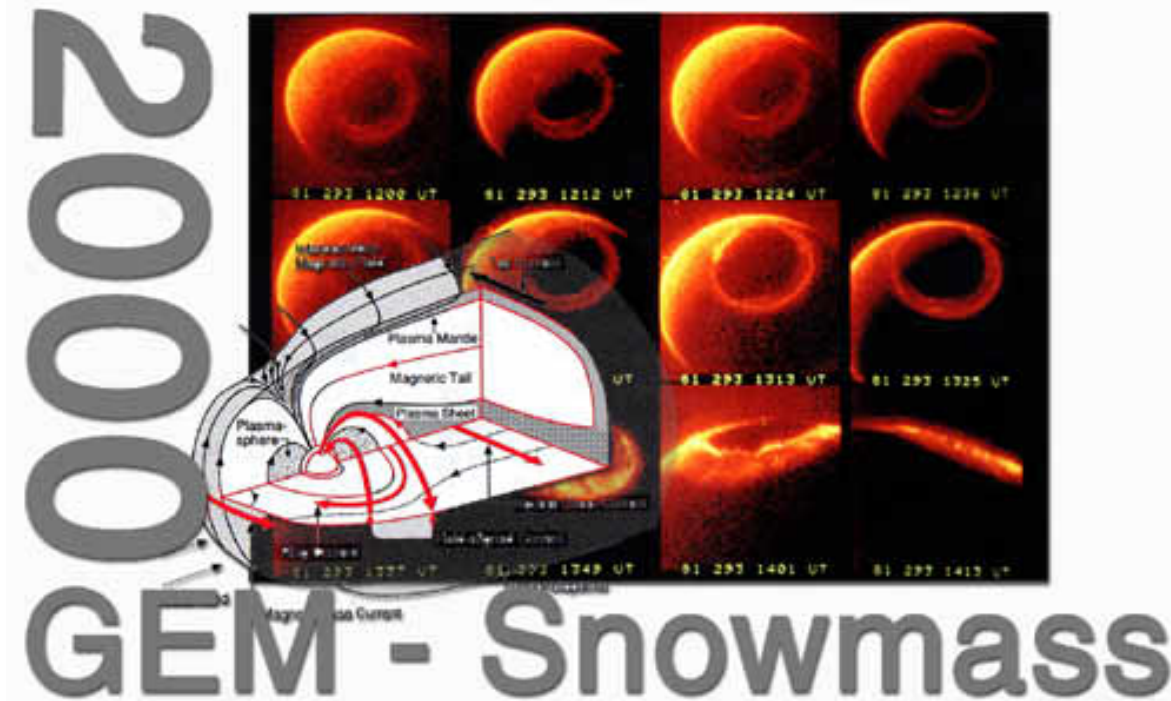
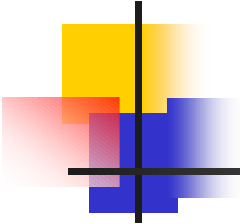


Tail Auroral Current Responses to Solar Wind Dynamic Pressure Enhancements

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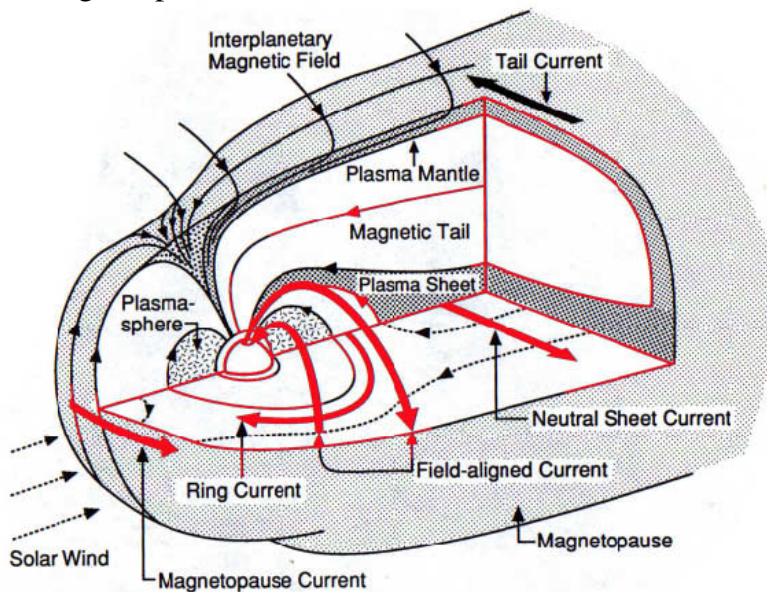


OUTLINE

- Introduction on the effect of SW pressure fronts to the magnetosphere
- Two types of pressure disturbances: [step functions](#) and [pulses](#)
- Step functions – SSC and SI
- Pulses
- Pressure enhancements and substorms
- Pressure enhancements and global current and auror intensifications
- Summary/Conclusions

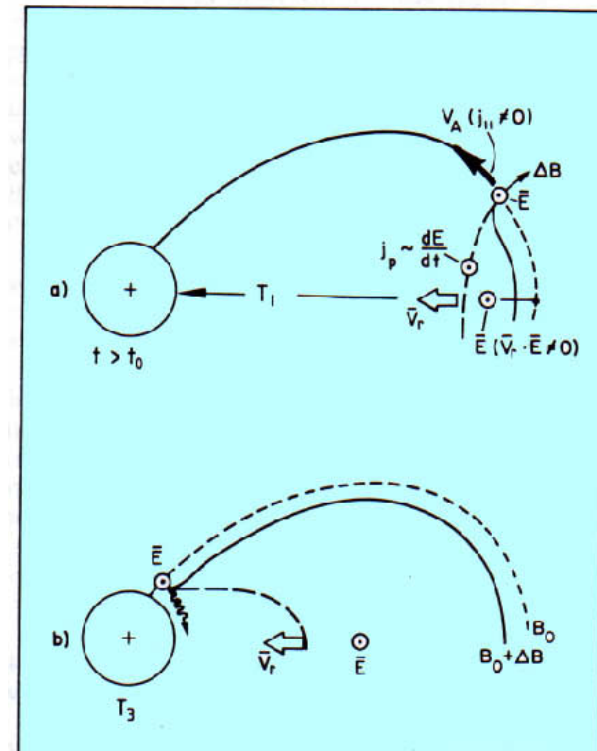
The general response of the magnetosphere to high pressure fronts

When a high pressure front compresses the magnetosphere a new equilibrium location of the magnetopause is established closer to the earth. As a result all the large scale currents, Chapman-Ferraro, R1, and cross-tail, increase in order to sustain the new location of the magnetopause.



From “*Introduction to Space Physics*”
edited by Kivelson and Russell

As the dayside magnetopause is compressed a fast mode wave is launched that propagates isotropically in the magnetosphere with a velocity V_r . The polarization electric field E and the perturbation map down to the high-latitude ionosphere through Alfvén waves that carry the field-aligned currents.

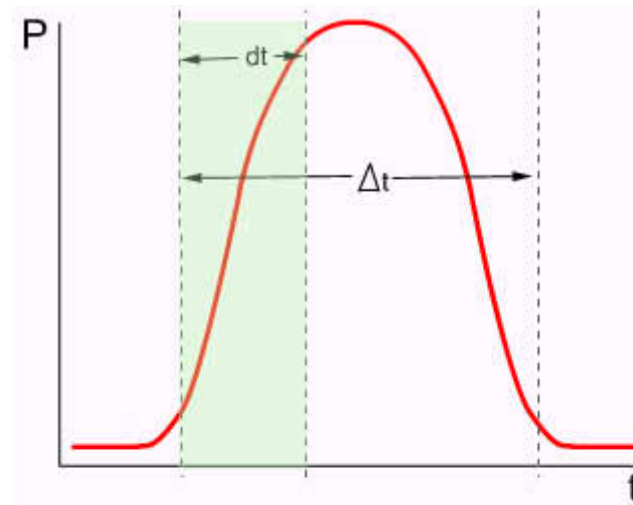


From Wilken et al. [1982]

Two types of SW pressure disturbances

Pressure Pulse

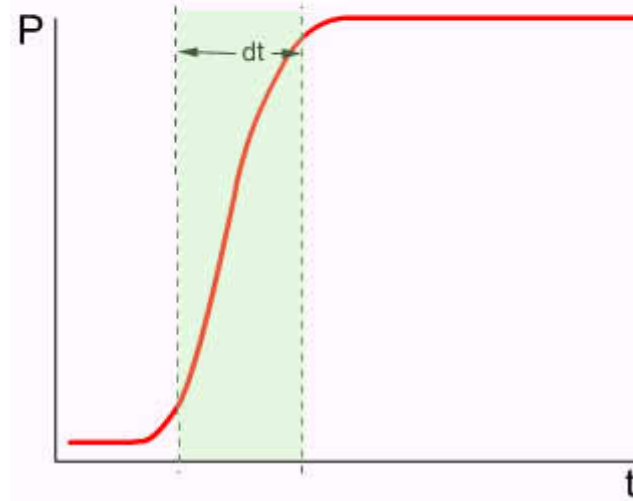
Of importance are the rise time, dt , and the duration, Δt . For a short rise time the magnetosphere does not have time to remain in equilibrium while establishing the new location of the magnetopause boundary. Strong transient perturbations are therefore observed everywhere in the magnetosphere. The duration determines whether the perturbation will be localized and propagating or global and near-instantaneous.



Pressure step Changes

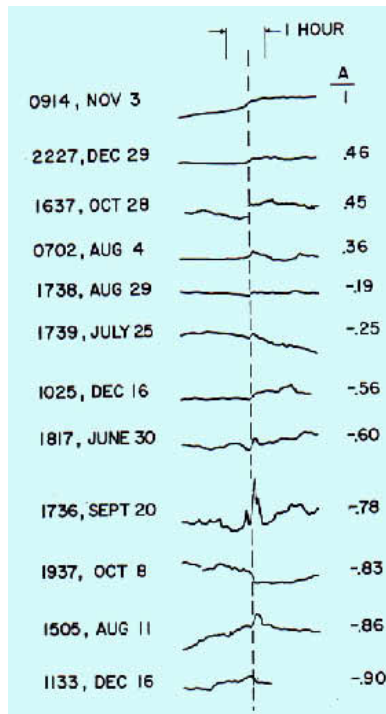
Of importance is the rise time, dt , for the reason mentioned above.

Of importance in both cases is also the absolute and relative magnitude of the pressure change, Δp and $\Delta p/p$ respectively



Step changes in the SW dynamic pressure

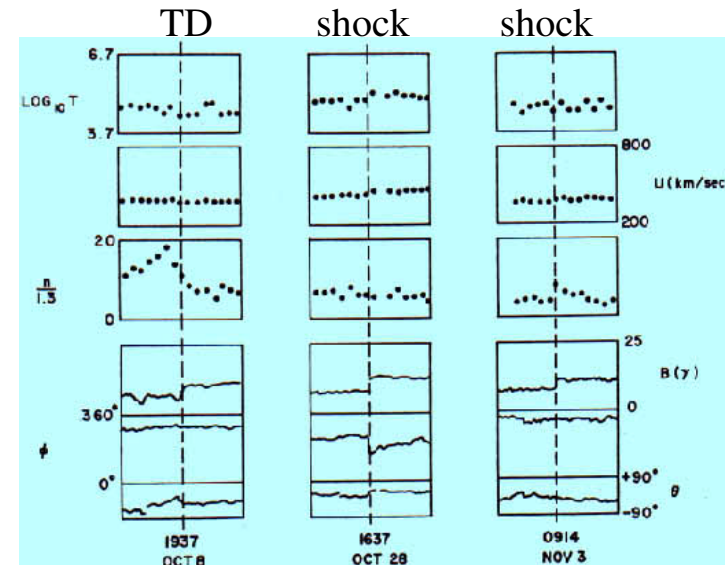
- Magnetosphere will respond with a sudden impulse



- Geomagnetic field intensity shows sudden changes simultaneously all over the world. These are the **SSC** or **SI**, depending on whether or not they are followed by a geomagnetic storm [Chapman and Ferraro, 1931; Parker, 1958]

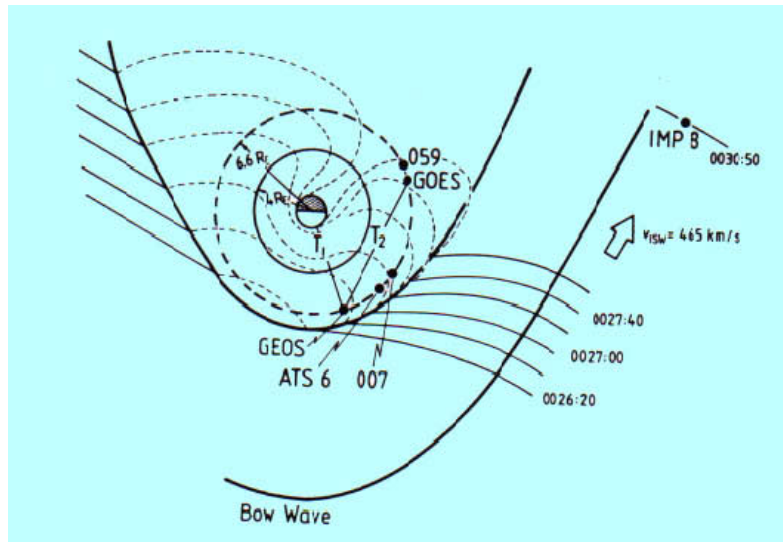
From Burlaga and Ogilvie [1969]

SC and SI are caused by MHD discontinuities: propagating shocks or Tangential Discontinuities [e.g., Gosling et al., 1967; Burlaga and Ogilvie, 1969]



NOTE: The internal pressure, $NkT + B^2/2\mu_0$, increases across a shock but remains constant across a TD. Therefore, N, T and B vary in phase across a shock and in anti-phase across TD.

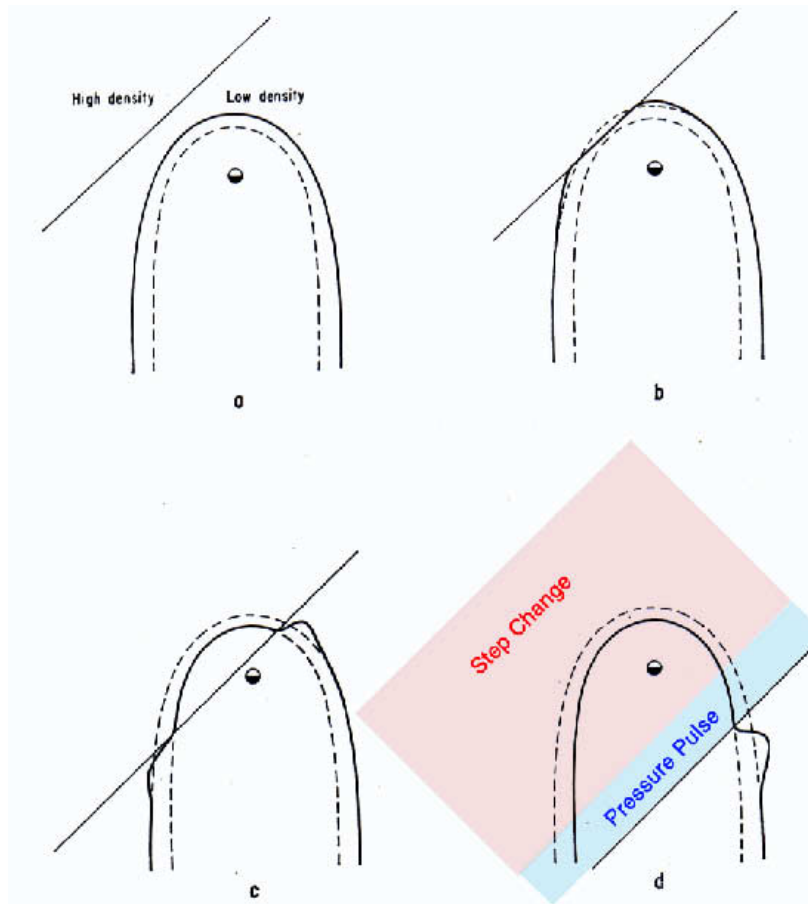
SSC and SI



From Wilken *et al.* [1982]

- Global structure from ground magnetometers was studied in detail [e.g., *Araki, 1997; Araki, 1994; Moretto et al., 2000; Russell et al., 1994a, 1994b*]. These studies show:
 1. H-comp increase at low and mid-latitudes due to increase in CF currents.
 2. Cross tail current also increases. For northward IMF response only near local midnight. For southward IMF response is stronger at nightside, but weaker at dayside, due to enhanced R1 currents.
- Effect of SSC in the magnetotail also studied from early on [e.g. *Patel, 1968; Sugiura et al., 1968*] and a very definite correlation was found, resulting from the propagating compressional wave in the magnetosphere
- *Wilken et al. [1982]* studied the propagation of an SSC through the magnetosphere and proposed a simple model of compressional wave front propagation that showed very good agreement with observations.

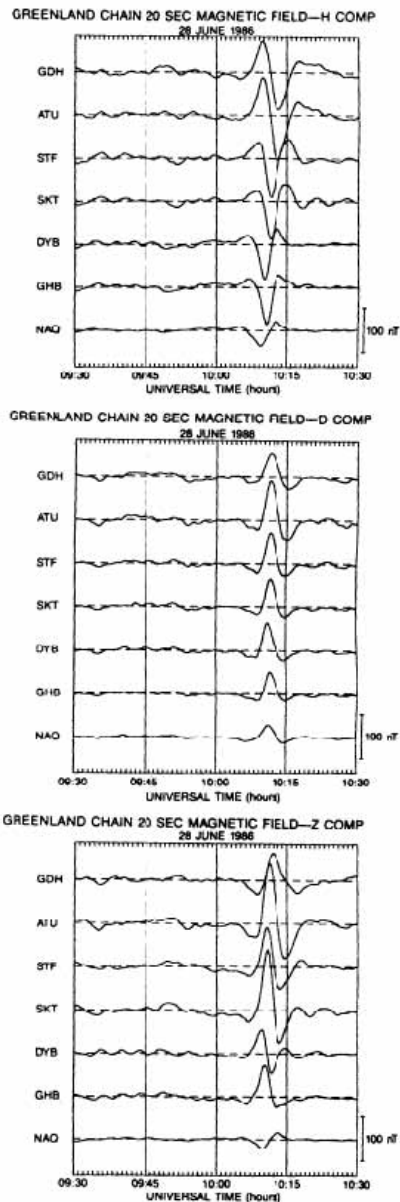
Pressure pulses



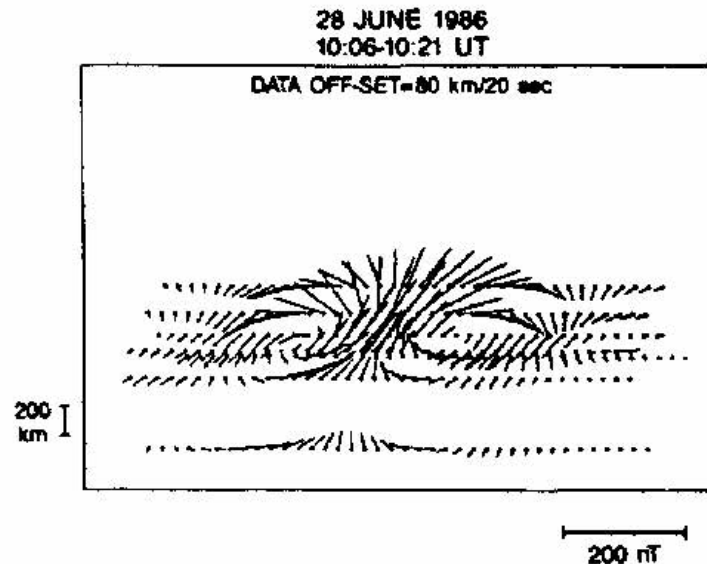
From *Kaufmann and Konradi* [1969]
(with Zesta embellishments)

- Size of the high pressure region is of importance.
- For typical V_{sw} , a pressure pulse lasting a few minutes will create a localized disturbance in the MP [e.g., *Kaufmann and Konradi*, 1969; *Sibeck*, 1990; *Zesta et al.*, 1999]. Result is dayside transients
- A pressure pulse lasting for over $\frac{1}{2}$ to 1 hour will likely have similar effects to a step change in pressure

Traveling Convection Vortices: transient responses to short-lived pressure pulses



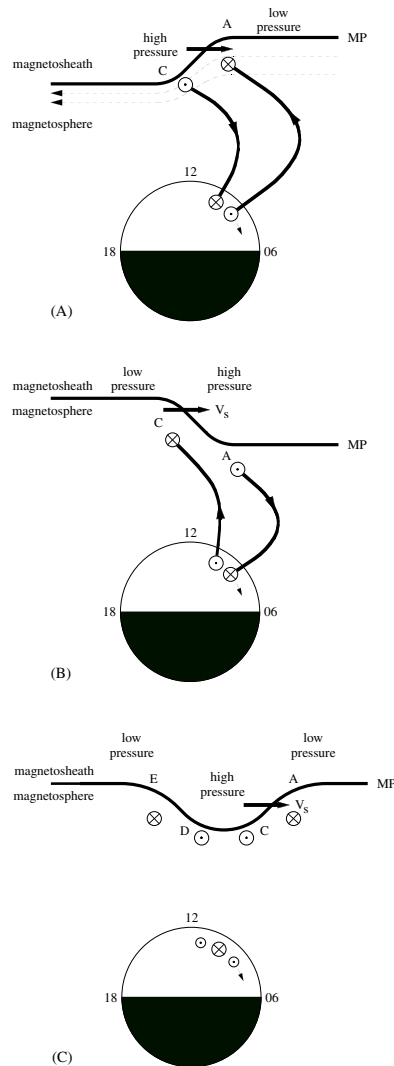
GREENLAND CHAIN MAGNETIC PERTURBATIONS
PLOTTED AS EQUIVALENT CONVECTION



[From Friis-Christensen et al. \[1988\]](#)

The transient response of the magnetosphere to sharp pressure pulses has been shown to create transients lasting ~10-15 min at high-latitudes. When such impulsive signatures from the Greenland ground magnetometers (figure on the left) were converted into a two dimensional equivalent current pattern (figure on the top) a twin-vortex current pattern was determined. The vortices propagate away from local noon. The two dimensional pattern shown above was determined from a meridional magnetometer chain assuming that the current pattern is propagating with a constant speed.

Generation of TCVs from SW pressure pulses

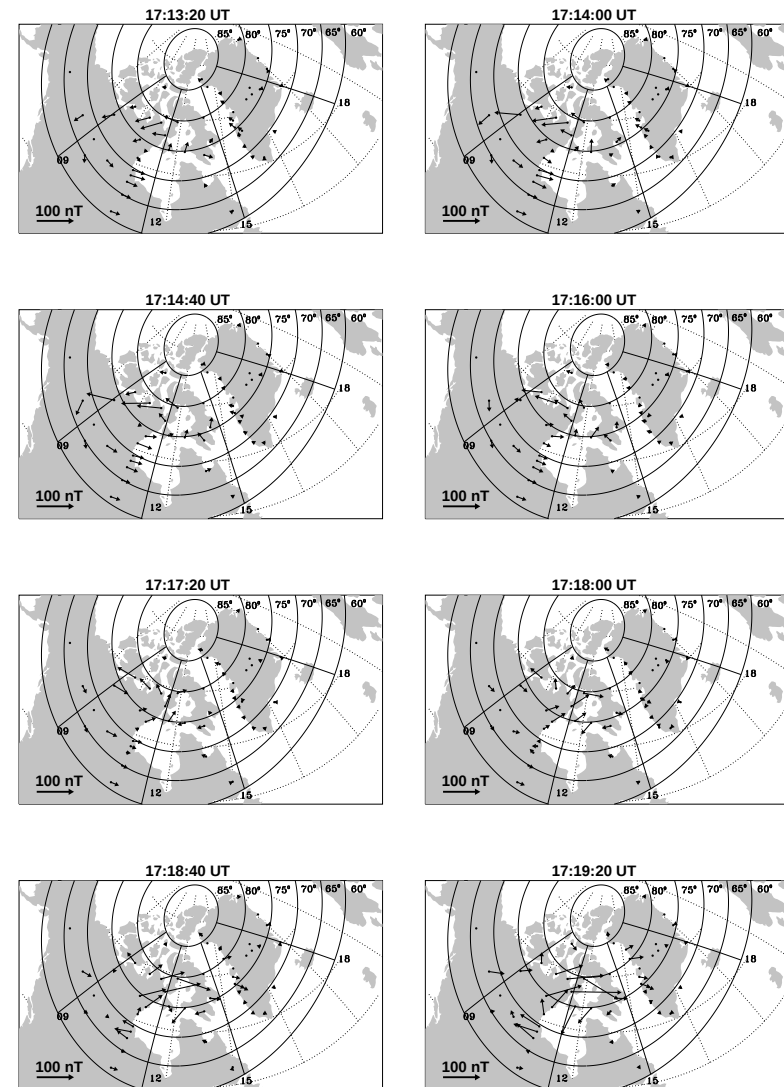
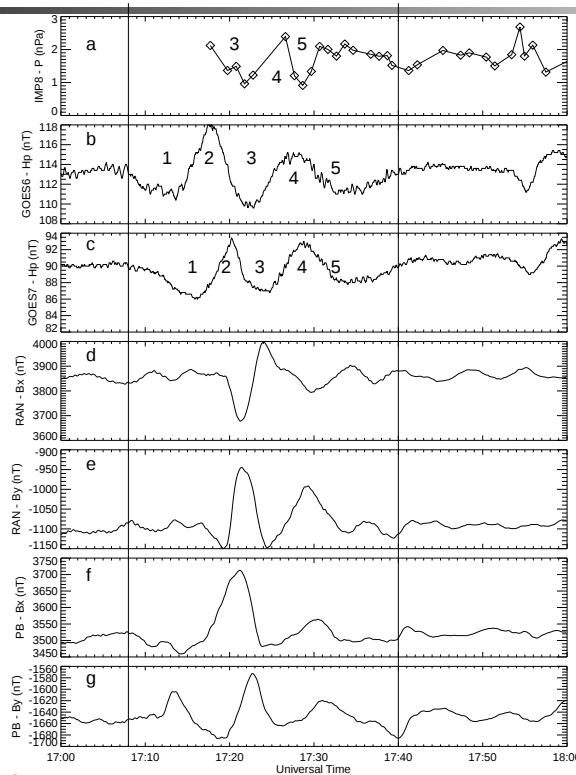


From Zesta, PhD thesis, 1997

The cartoon is based on the model of *Kivelson and Southwood [1991]*:

- (A) For a step-like pressure increase the magnetopause boundary will be indented as shown. Fast mode waves will couple to shear Alfvén waves, and vorticity generated at the magnetopause perturbation region will generate a pair of field-aligned currents with the polarity shown, namely upward and then downward for the ionosphere. The pair of field-aligned currents will generate a set of twin vortical Hall currents, that are the manifestation of Traveling Convection Vortices. The whole perturbation is propagating away from local noon with the solar wind. This is the initial transient response to a pressure step change.
- (B) For a step-like decrease in the solar wind pressure the opposite sense of field-aligned currents and vortical Hall currents will be generated.
- (C) For a pressure pulse of short duration a localized “bump” will be created at the magnetopause boundary. Both senses of the twin field-aligned currents will be generated at the magnetopause. However, the two middle currents are of the same sense, and the result in the ionosphere will be a set of 3 vortical Hall currents, the middle one being the strongest.

Observations of a TCV: currents and SW source

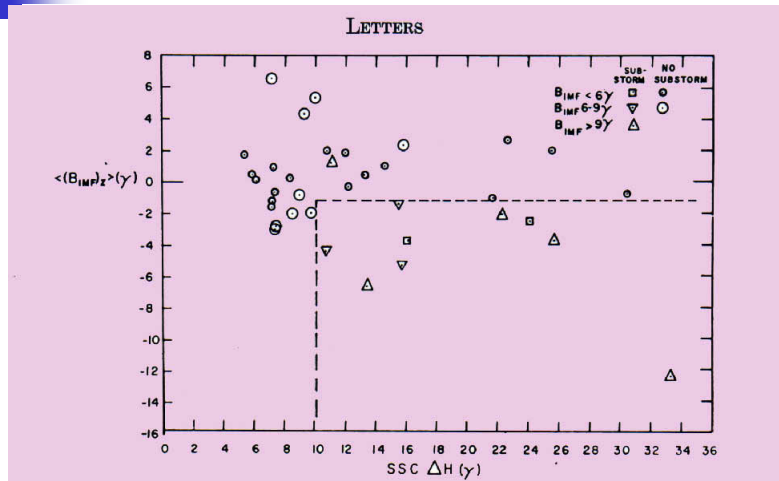


From Zesta *et al.* [1999]

Figure on top shows a series of short-lived pressure pulses in the SW that result in a TCV in the ionosphere. The transient is well correlated with the SW pressure pulses both in geosynchronous (panels b and c) and on the ground (panels d-g).

Figure on the right shows a series of snapshots of the development of the vortical currents of the TCVs, determined by a 2-D grid of ground magnetometers. A counterclockwise vortex is evident up to 1717:20 UT and by 1719:20 UT a much stronger clockwise vortex has been established, the whole perturbation is moving westward over the ground magnetometer stations.

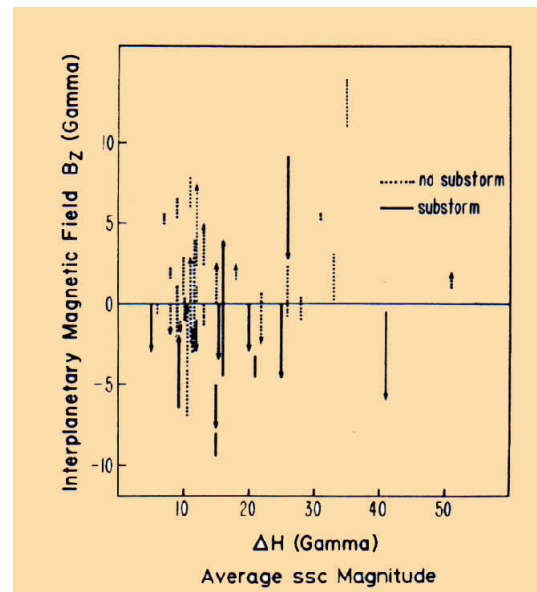
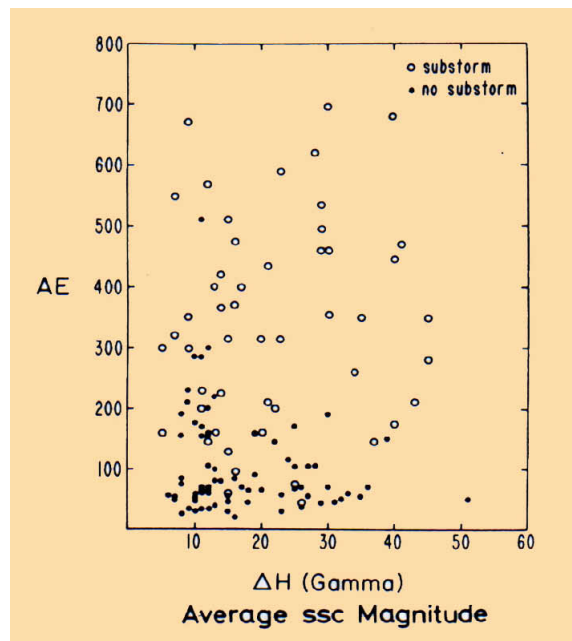
SSC, substorm triggering, and global current and precipitation increase



From *Burch [1972]*

Burch investigated 36 SSC and found that 10 of them triggered simultaneous negative bays at midnight. For 9 of them the IMF had been southward prior to the SSC for at least 30 minutes.

NOTE: Most of the original studies that investigated the possible triggering of substorms from SSC used only the AE index to determine the occurrence of a substorm. However, we know today that the AE index is not sufficient to determine a substorm onset. Global DP2 current perturbations will also have an AE signature much like a substorm.



From *Kokubun et al. [1977]*

Investigated 39 SSC events and the negative bays following the SSC. They found that:

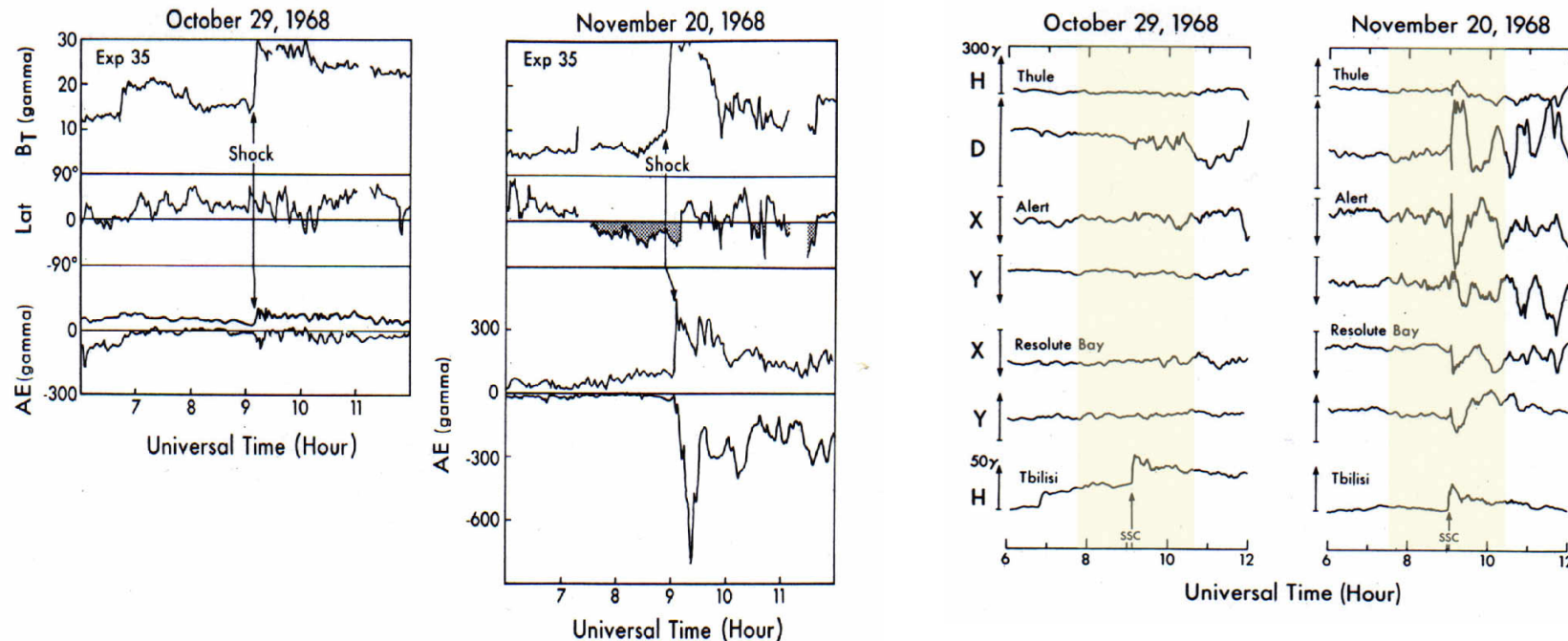
Preconditioning is necessary for triggering:

- Southward Bz for at least 30 prior to SSC

- Large AE prior to SSC

NOTE: Substorms were identified more carefully and when they were triggered from the SSC they occurred at least 15-30 minutes after the SSC.

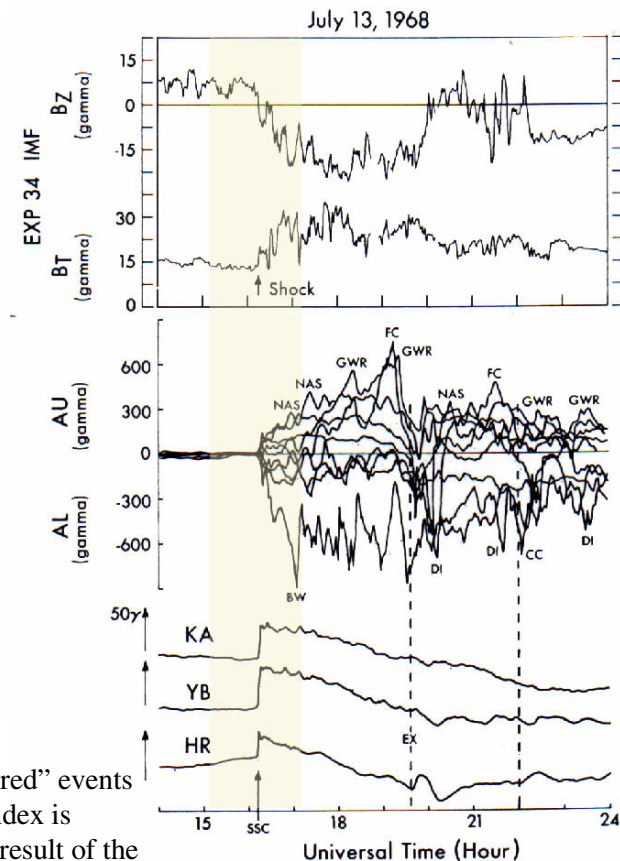
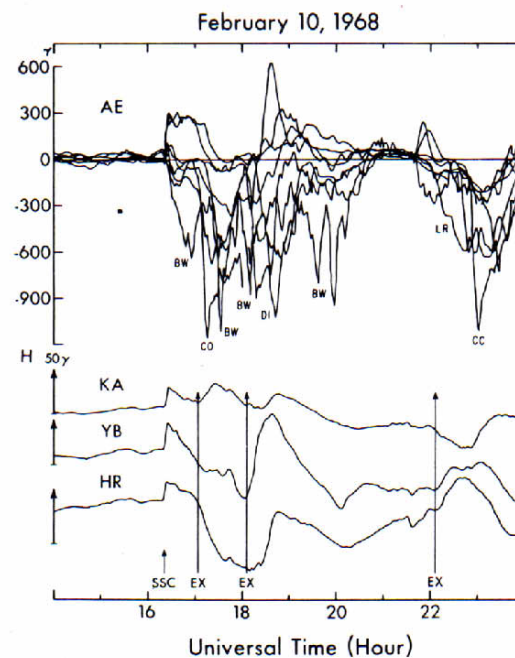
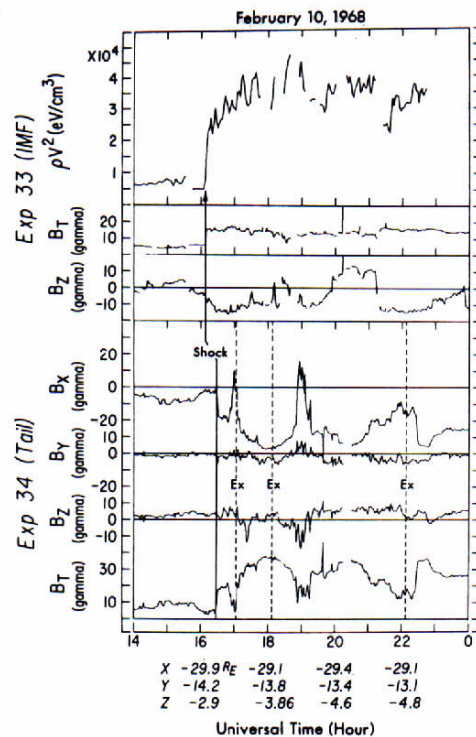
Different geomagnetic responses to a similar compression for IMF Bz north and south



From Kokubun et al. [1977]

Two SSC events of similar magnitude: the Oct 29 and Nov 20, 1968 events have very similar magnitudes at the low latitude station of Tbilisi (right two panels). IMF was northward prior to the Oct 29, and southward prior to the Nov 20 event (see data from the Explorer 35 spacecraft, left two panels). The AU and AL indices respond very different to the similar strength shocks. There is an almost immediate strengthening of the AU and AL indices for southward IMF, but only a minimal response for northward IMF. This is also seen at the signatures of the high latitudes stations of Thule, Alert and Resolute for the two events. Therefore similar strength shocks create similar SSC signatures at low latitudes but very different responses at high latitudes for northward and southward IMF orientation prior to the SSC

Case studies of *Kokubun et al. [1977]*



Kokubun et al. looked in more detail at the global signature of some of the classified as “triggered” events in their study. Two of those events are shown above. They found that the increase of the AE index is caused by the simultaneous increase of both the AU and AL indices and the signatures are the result of the global strengthening of the DP2 current system, rather than the result of a midnight substorm electrojet. For these events IMF turned southward during the event increasing the convection electric field.

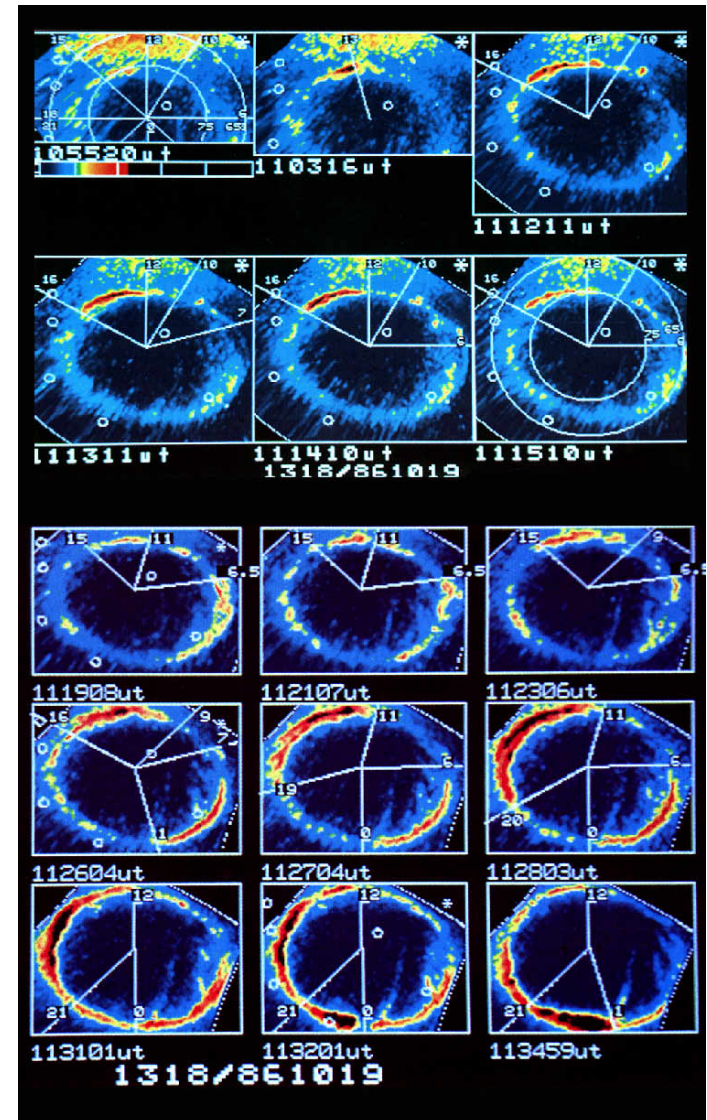
- “This work strongly suggests that the triggering of substorms occurs when some preconditions are satisfied”.
- “It seems likely that the compression of the magnetosphere accelerates intrinsic processes in the magnetosphere which lead to the substorm occurrence or it changes the instability threshold but is not the direct cause”.

Elphinstone et al. [1991], global auroral images of the effect of SSCs

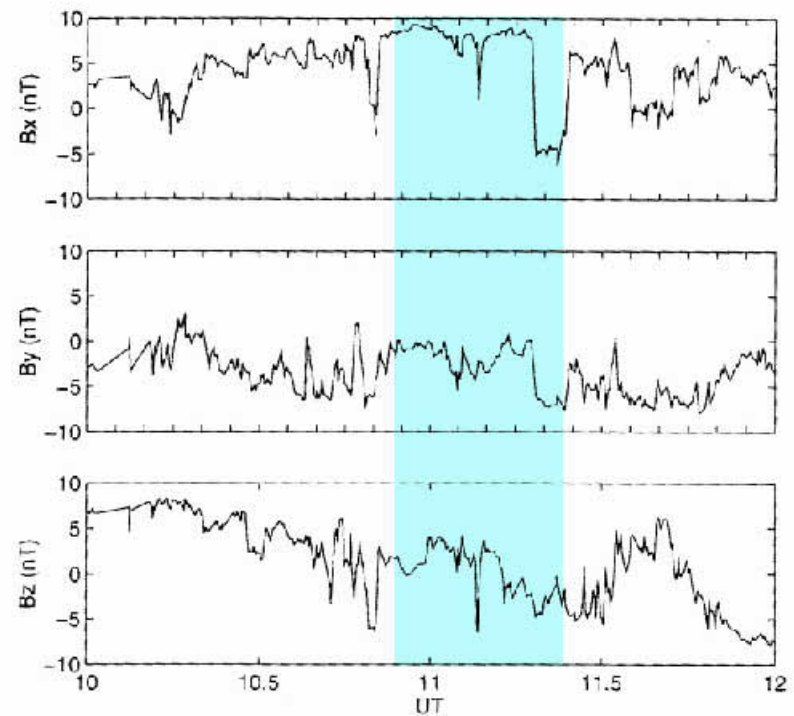
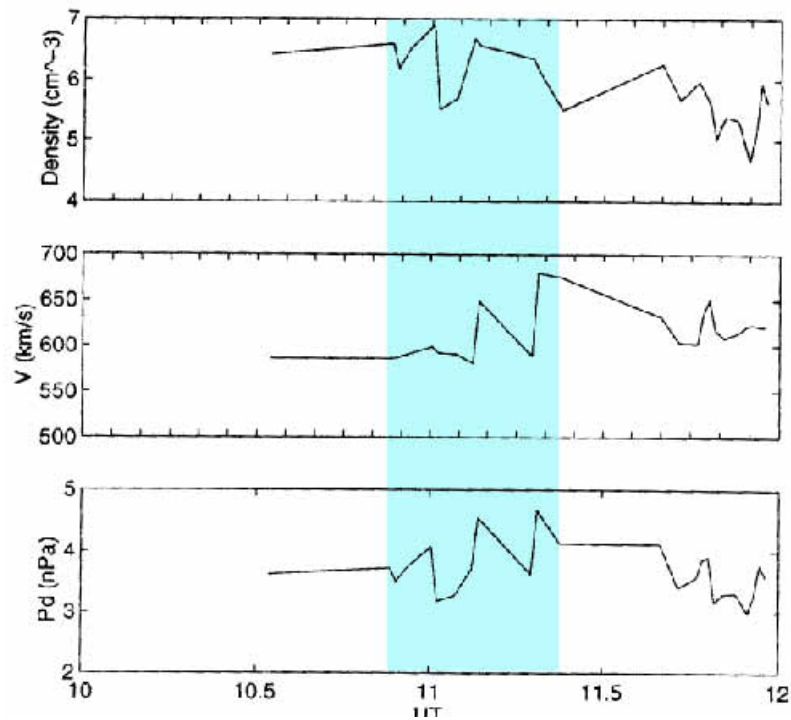
Elphinstone et al. [1991] studied the global and small-scale structure of the aurora during a 40-minute time interval before the onset of substorms. The figure shows the time series of the Viking auroral images for the 40 minutes prior to the substorm onset of Oct 19, 1986. The onset of the expansion phase is at 1132 UT (middle image of the bottom row). *Elphinstone et al.* explored the dayside auroral activity during the growth phase of substorms, such as the Oct 19, 1986 onset, trying to determine possible “precursor” events for substorm onsets. Their conclusion was that the aurora activates at dayside and spreads toward the nightside during the growth phase of a substorm.

However, *Elphinstone et al.* did not examine the IMF and SW for this event. *Winglee and Menietti* [1998] did that and the IMP8 data is shown in the next slide. *Winglee and Menietti* found that there were 2 pressure pulses at the time of the event. The first, at 1104 UT, occurred during northward IMF and lasted for about 10 minutes. The second, at 1117 UT, occurred for southward IMF and the pressure went high and remained at that high level for a longer time period. The auroral images between 1055 and 1115 UT show the response to the first pressure pulse, which is only a localized enhancement in the early afternoon. The initial response to the second pressure enhancement is seen in the images of 1119 and 1121 UT. It is a more global intensification of the oval at all local times. The substorm occurs at 1132, 15 minutes after the pressure front hits the magnetosphere and while the IMF is southward.

We thus offer an alternative explanation: *The Elphinstone et al. and Winglee and Menietti results are in agreement with the Kokubun et al. [1977] results. A short-lived pressure pulse and under northward IMF will only have a limited and localized (if any) effect in the aurora and no substorm is triggered. A pressure front under southward IMF has a global and almost immediate response of the aurora at all local times, implying that the global DP2 currents are enhanced. The substorm onset does not occur until at least 15 minutes later, so it is not directly triggered by the pressure front.*

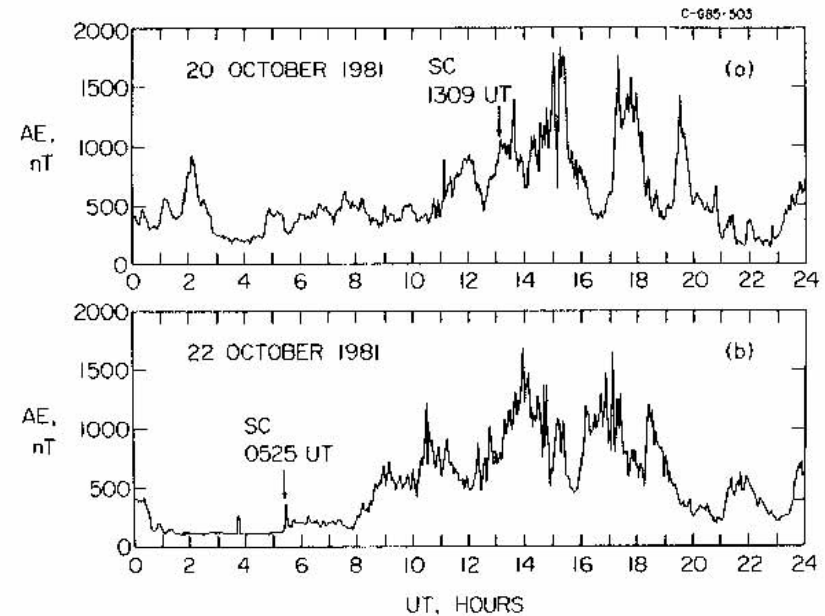
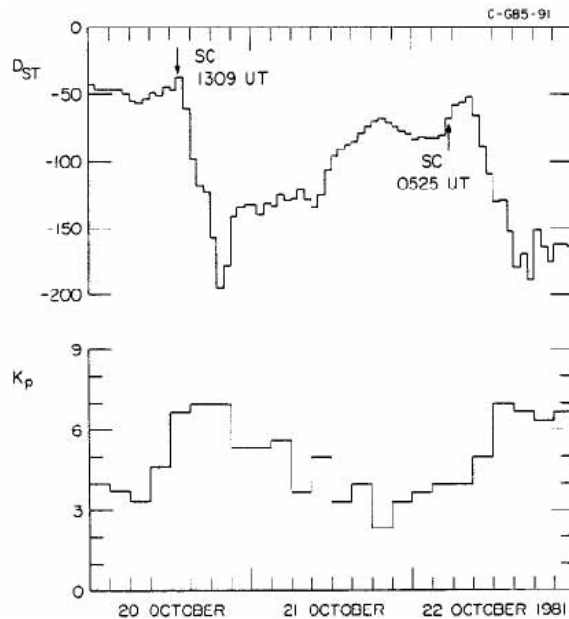


Event of October 19, 1986



From Winglee and Menietti [1998]

The October 20 and 22, 1981 SSC events

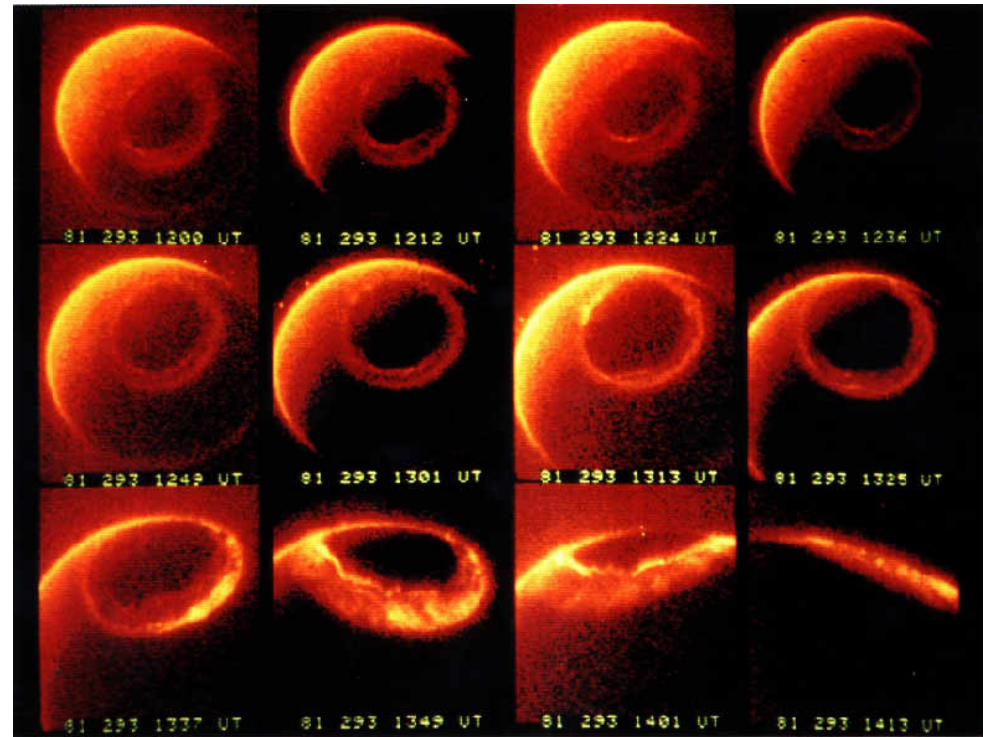
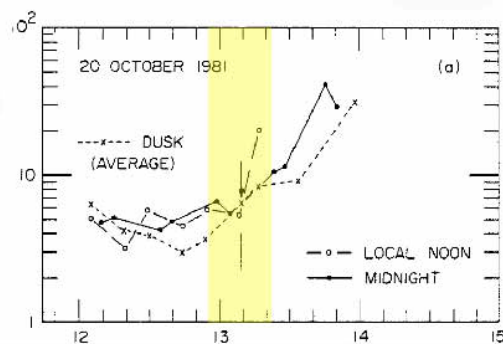
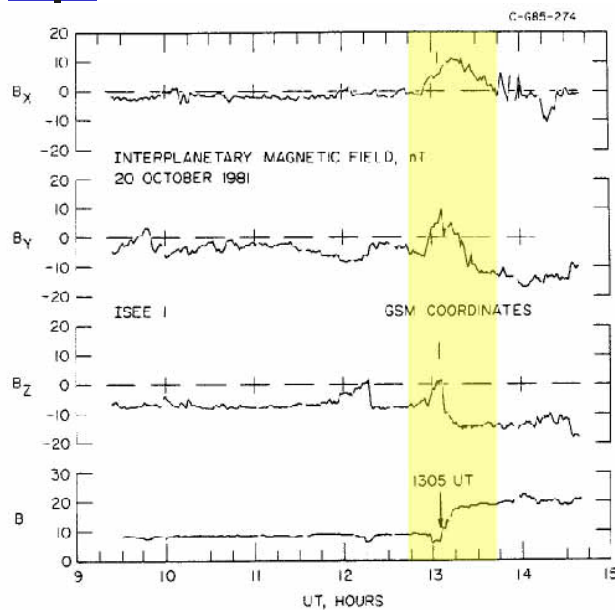


From *Craven et al.* [1986]

This paper studied the global effect of two different SSC to the auroral oval under southward and northward IMF conditions.

The two SSC occurred on Oct 20 and Oct 22, 1981 and were followed by storms as seen by the Dst and Kp indices (left panels). The AE index indicates the level of ground auroral activity for each SSC (right panels). The IMF was southward prior to the Oct 20 event and northward prior to the Oct 22 event (this is also indicated by the level of activity of the AE index prior to the two events).

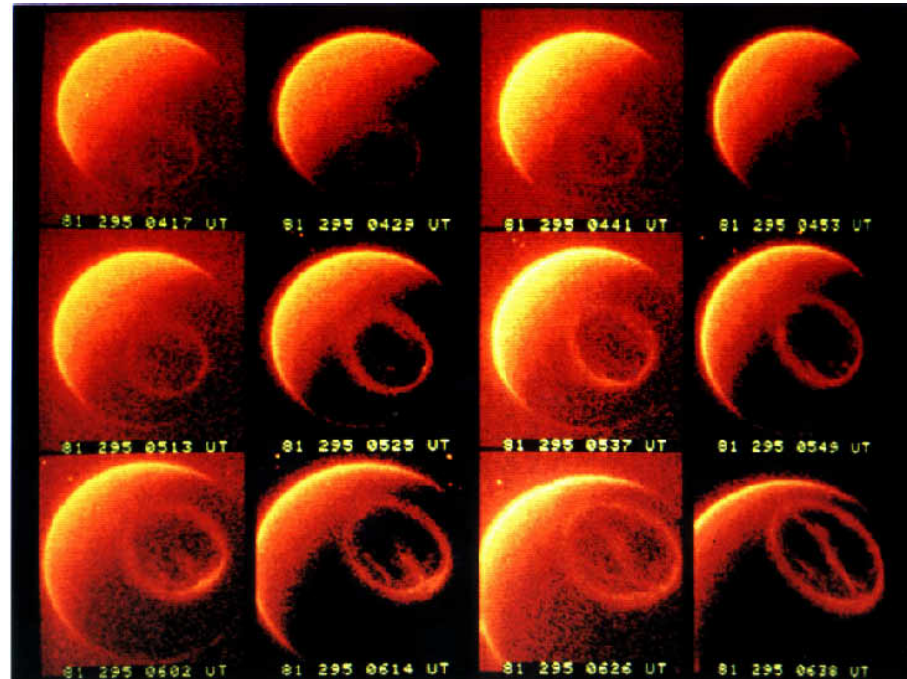
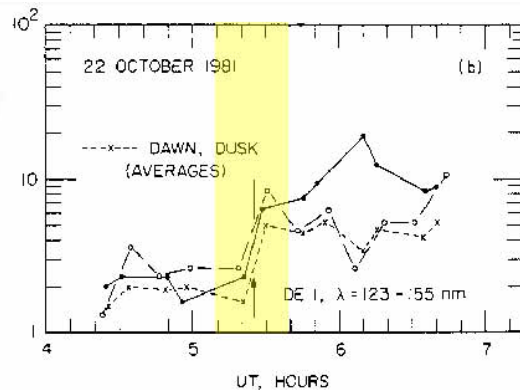
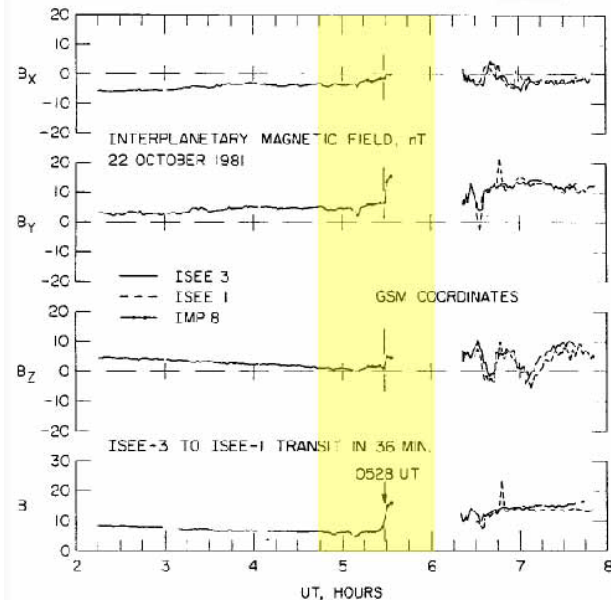
The October 20, 1981 SSC: IMF B_z is southward



From Craven *et al.* [1986]

The IMF (top left figure) was southward prior and during the SSC. The shock front hit the magnetosphere a couple of minutes after 1305 UT. There is a global intensification of the aurora, simultaneously at all local times, between the images of 1301 and 1313 UT. This is seen better at the bottom left figure that plots the maximum intensity of atomic oxygen emissions at dawn, dusk, noon, and midnight. The emissions intensify simultaneously at all local times shortly after the shock hits the magnetosphere. A substorm eventually occurs, its onset at ~1337 UT, about 30 minutes after the SSC.

The October 22, 1981 SSC: IMF B_z is northward

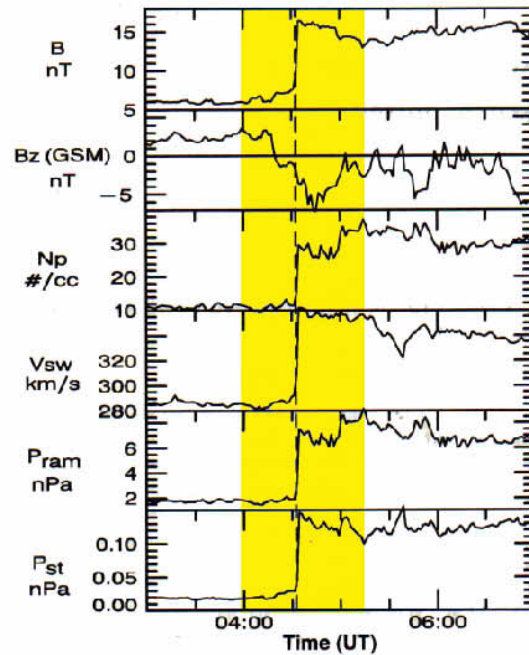


From Craven *et al.* [1986]

The IMF was northward prior to the Oct 22 SSC. There is still a global intensification of the aurora at all local times almost instantaneously with the shock hitting the magnetosphere. However the intensification is not as strong as in the southward IMF case and there is no substorm following the global auroral intensification. Instead a theta aurora occurs later.

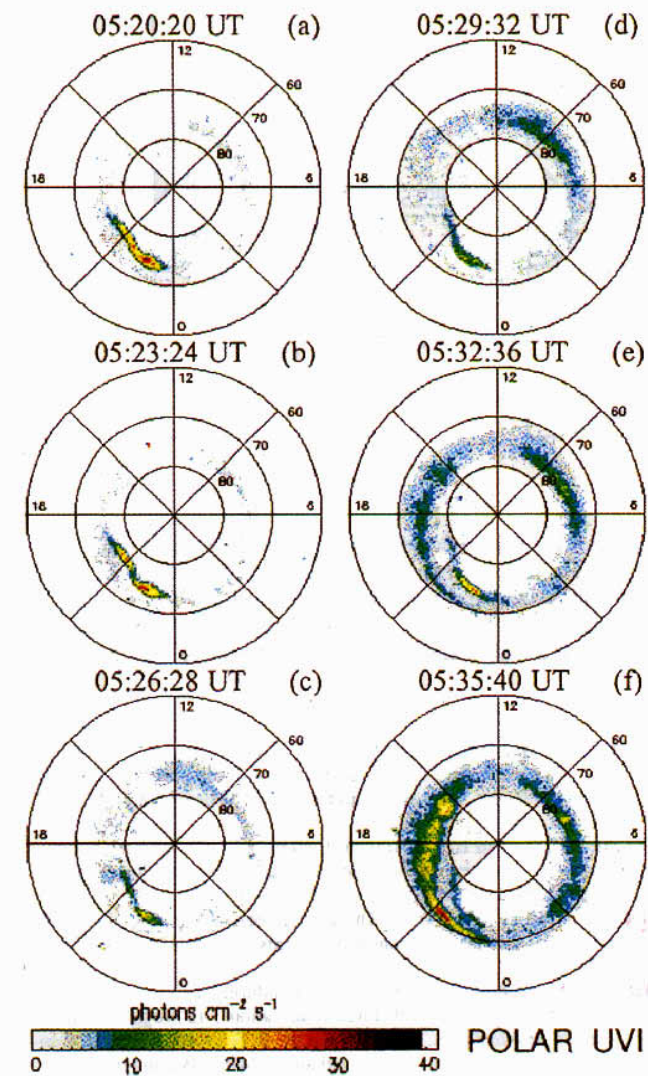
This study clearly showed the global response of the aurora to pressure fronts. Under southward IMF a substorm occurred 30 minutes after the SSC, but it was not directly triggered by the SSC.

The event of December 10, 1997

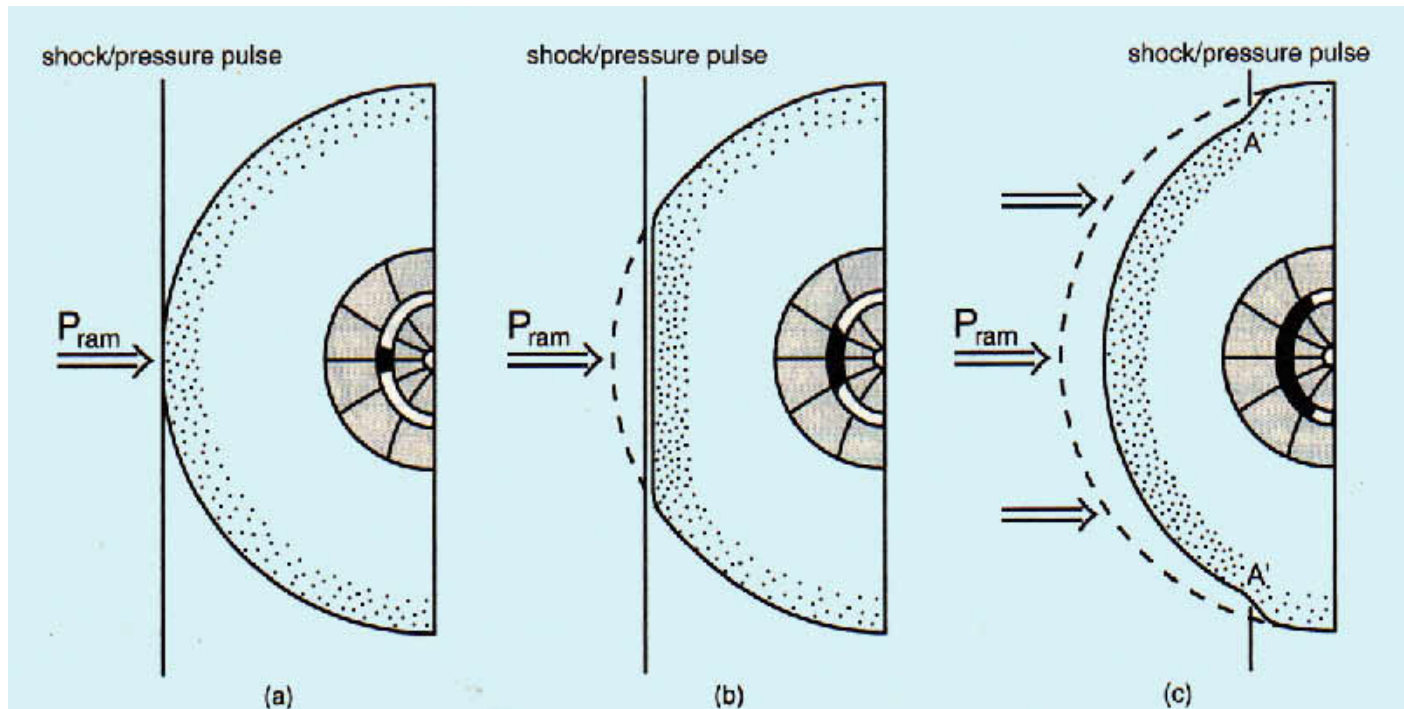


From *Zhou and Tsurutani [1999]*

Yet another example of the global response of the aurora to a pressure front. No substorm occurred after the SSC and there was evidence of some propagation of the auroral intensification from the noon region to the early morning and late afternoon. *Zhu and Tsurutani* report ionospheric propagation speeds of 6-11 km/s.



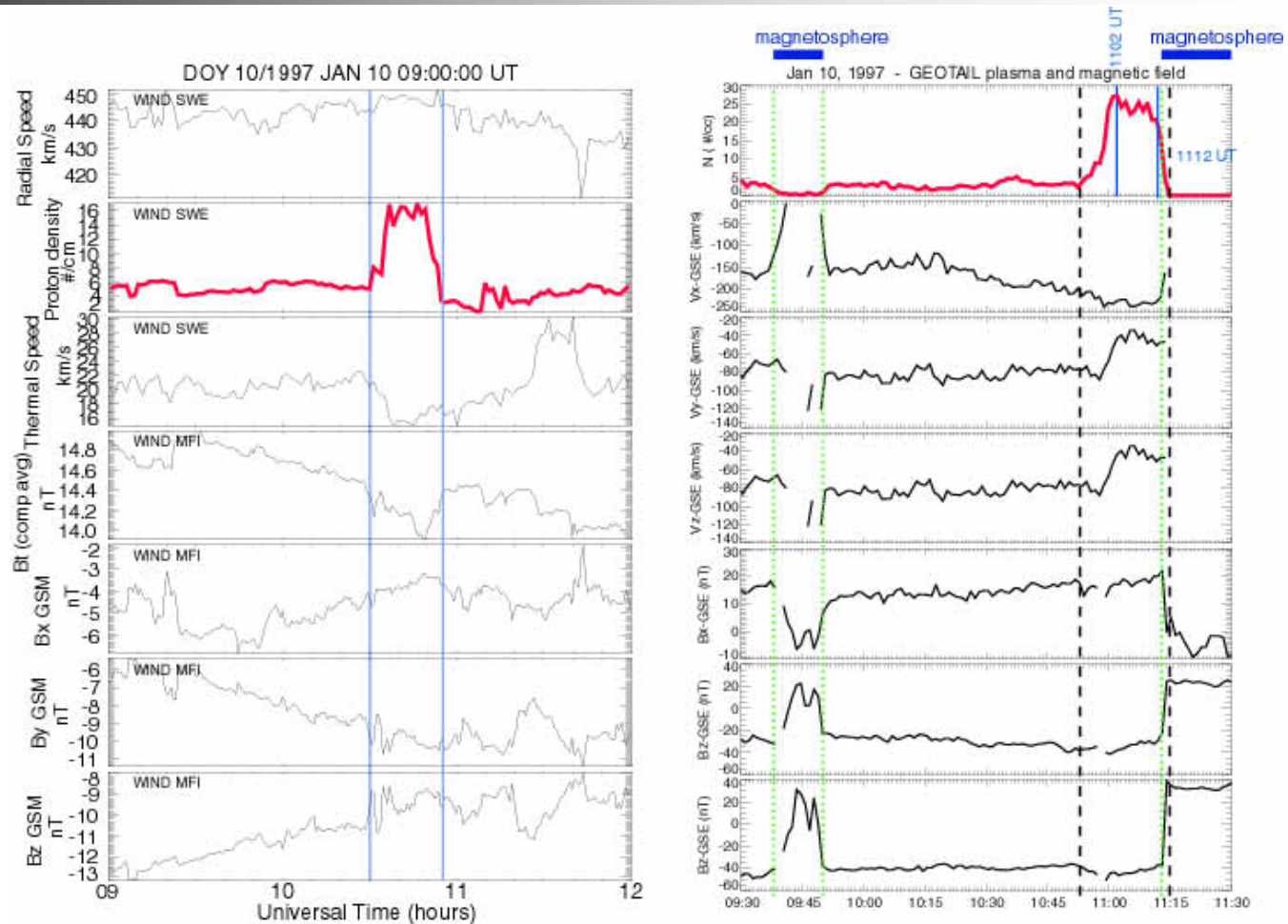
The Zhou and Tsurutani [1997] model



The *Zhu and Tsurutani* model tries to explain the shock-induced dayside auroral brightening and its fast expansion toward the night side. The shock first compresses the LLBL and the outer magnetosphere. To first order the compressed particles will conserve their first adiabatic invariant, $\mu = W_{\text{perp}}/B$. Since B is increasing, W_{perp} will increase as well for both protons and electrons. This means that $T_{\text{perp}}/T_{\parallel}$ will increase creating a loss cone instability and therefore the growth of whistler waves. Whistler waves increase the pitch angle scattering and fill the loss cone. This will increase the precipitation and the auroral brightening will be observed first around noon and then spreading toward the night side as the compression is propagating inside the magnetosphere.

This model however, does not explain the almost instantaneous brightening of the aurora at all local times observed in the events mentioned before and which will also be described below.

The January 10, 1997 pressure pulse event



From Zesta *et al.* [2000]

The pressure pulse occurred between 1030 and 1055 at the WIND spacecraft and is seen at Geotail 22 minutes later. This pressure pulse occurs during the main phase of a magnetic storm and while the IMF is strongly southward and steady. Analysis of the SW and IMF signatures indicate that the pressure enhancement is due to a tangential discontinuity that is large enough to engulf the whole magnetosphere. This pressure pulse therefore has the same effect on the magnetosphere as a shock front.

The Jan 10, 1997 event (continued)

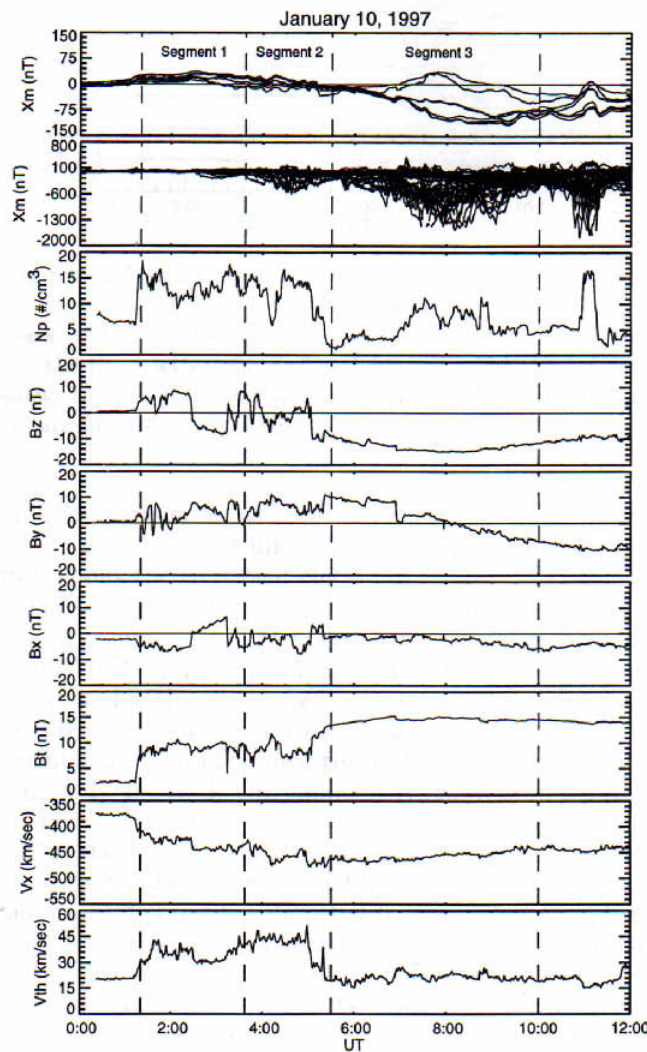
Effects of solar wind density on the westward electrojet

From Shue and Kamide [1998]

They studied the effect of the pressure enhancements of Jan 10, 1997 on the auroral electrojet. The top panel in their figure shows the northward magnetic field component from ground station in 20 to 40 degree magnetic latitudes. The second panel shows perturbations from stations in the auroral zone. There are 3 segments of enhanced solar wind density (3rd panel) studied by Shue and Kamide. In segments 1 and 2 the auroral electrojet shows minimal response to the high density/pressure due to the northward or very small IMF B_z . In segment 3, even though the density enhancement is not as large as before, the response of the auroral electrojet is very strong due to the strongly southward IMF. The same is true of the density (pressure) pulse at 1100 UT. That is the pressure pulse studied in detail by Zesta *et al.* [2000].

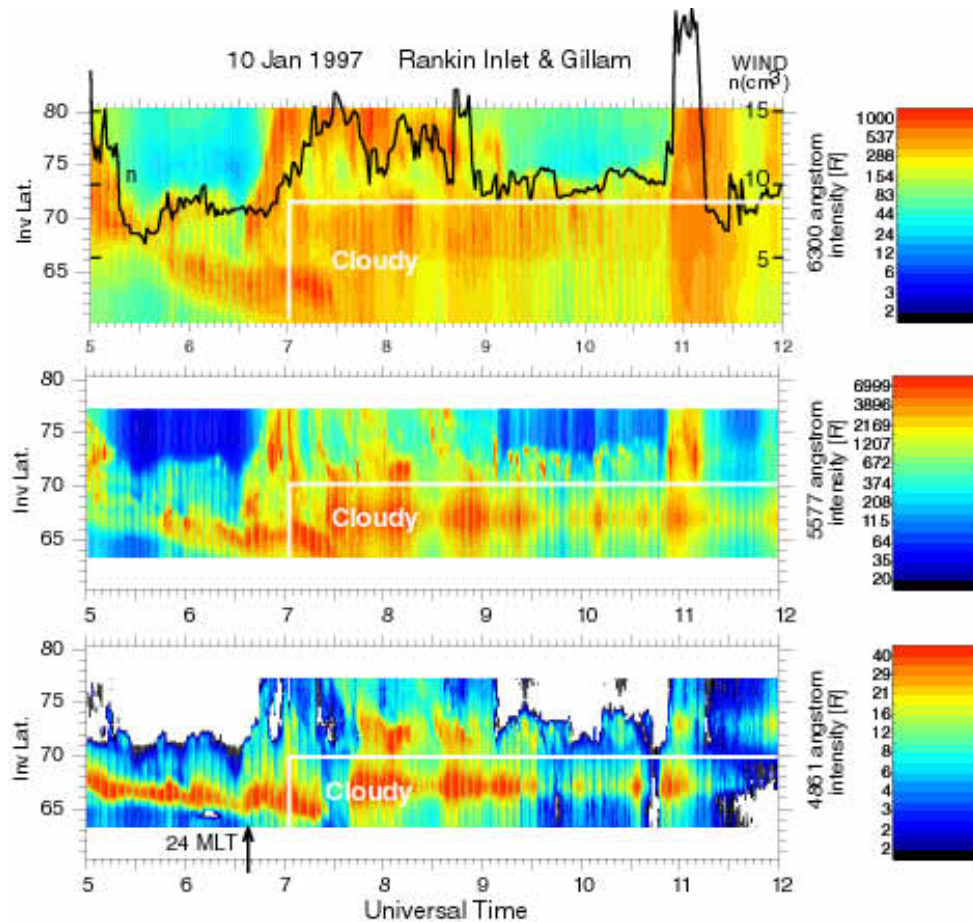
Shue and Kamide conclude:

“... All of these observations support the notion that solar wind density plays an important role in increasing/decreasing the westward electrojet under a necessary condition that the magnetosphere-ionosphere is already “activated” by southward IMF.”



The Jan 10, 1997 event (continued): effects of solar wind density (pressure) on auroral emissions

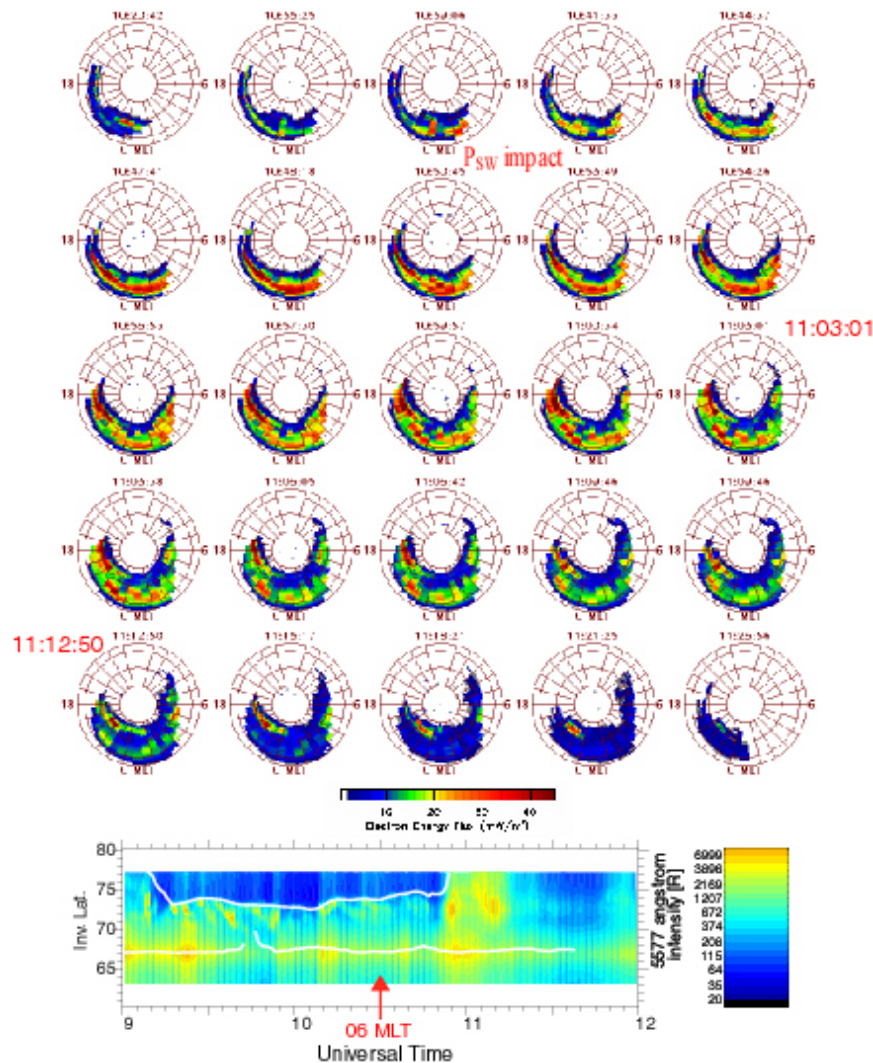
From Lyons *et al.* [2000]



Lyons *et al.* also looked at the effect of the density enhancements of Jan 10, 1997 on the auroral emissions. Their figure next shows a merging of meridional scanning photometer (MSP) data from the CANOPUS stations Rankin Inlet and Gillam, which are located along the same magnetic meridian at geomagnetic latitudes of 73.3° and 67.1° , respectively. The MSP measures the intensity of auroral emissions at various wavelengths and completes one full meridional scan every minute. By assuming that the auroral emissions at one wavelength come from the same altitude in the ionosphere one can convert the intensity measured versus zenith angle to intensity versus geomagnetic latitude. The top panel of Figure 2 shows 6300 Å emissions, which result from the diffuse electron aurora precipitation (energies <1 keV), as a function of invariant latitude and UT. The middle panel shows 5577 Å emissions, which result from harder (>1 keV) electron precipitation. Intensifications at 5577 Å help identify discrete auroral forms. The 4800 Å aurora is mostly due to protons. The poleward boundary of the 6300 Å aurora tracks the separatrix boundary [Blanchard *et al.*, 1997]. The black solid line in the top panel emissions is the solar wind density measured by WIND and delayed by 20 minutes. The poleward boundary of the oval tracks the density variations very well (except during the substorm onset at ~ 0635 UT), in agreement with the Shue and Kamide [1998] result (previous slide). During the period of enhanced solar wind density and after the substorm of 0635 UT the major activity at the high auroral latitudes are PBI (poleward boundary intensifications) seen as discrete auroral intensifications in the 5577 Å emissions initiating at the poleward boundary and subsequently extending equatorward.

The Jan 10, 1997 event (continued): effects of solar wind density (pressure) on the global auroral emissions

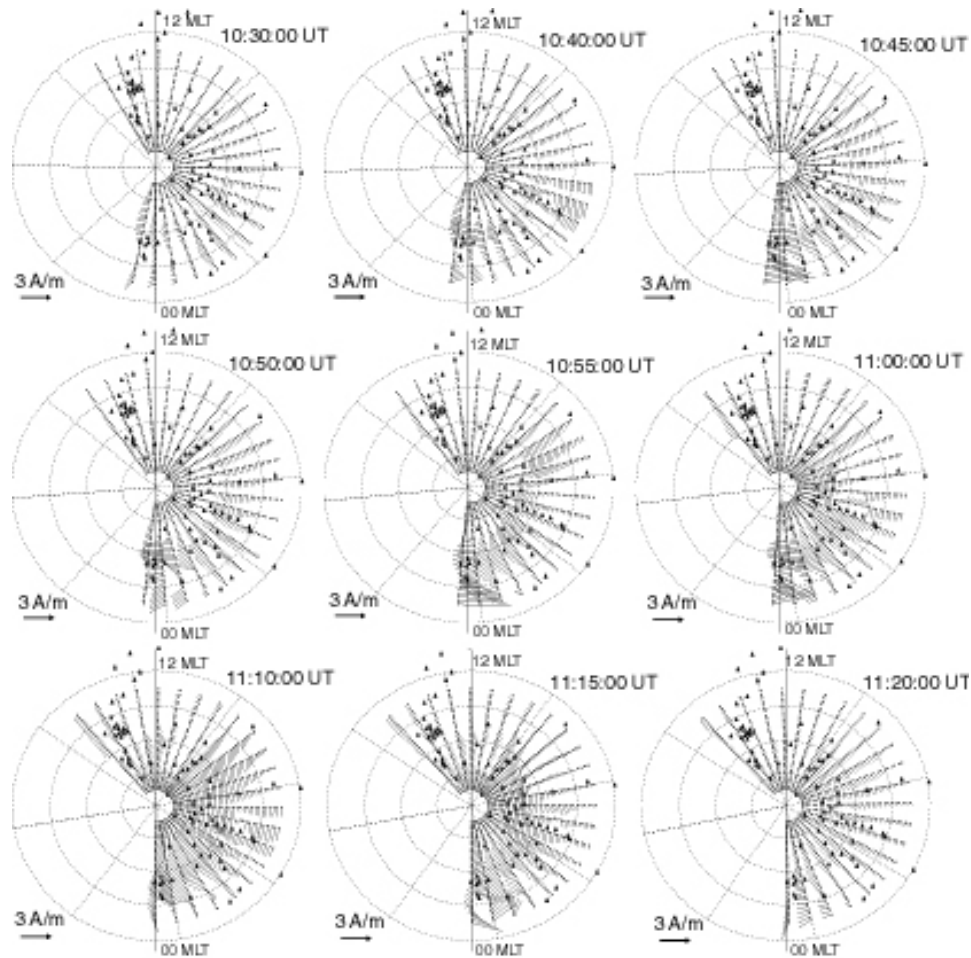
From Zesta *et al.* [2000]



This figure from Zesta *et al.* shows a series of 25 auroral images from 1020 to 1126 UT, observed with the Polar UVI imager. Each image shows the two-dimensional distribution of the precipitating particle flux in a MLT-magnetic latitude coordinate system. Lack of fluxes in the dawn sector is due to limited field of view of Polar. The impact of the pressure front with the magnetosphere is shortly after 1050 UT, indicated in the figure between the two images of the second row. Almost immediately after the shock impact the auroral oval starts widening and its poleward boundary moves poleward at all local times. The oval has reached maximum width and intensity by 1103 UT, which corresponds to the time when the pressure pulse reaches its peak intensity (see Geotail data 3 slides before). The width of the auroral oval and its intensity start to decrease around 1112 UT, corresponding to the time the pressure at Geotail starts to decrease sharply. By 1125 UT the intensity has decreased dramatically and the oval has shrank to its original state (compare first and last images). **Therefore it appears that the auroral response is directly driven by the onset, peak and decrease of the pressure pulse.**

The bottom panel in the figure next shows the 5577 Å emissions from the MSP of Rankin and Gillam. The stations are located at 0630 MLT during the pressure pulse event. The data show clearly the widening and strengthening of the auroral oval between 1050 and 1115 UT, exactly the duration of the pressure pulse at Geotail. The top white line in the keogram identifies the separatrix boundary as determined by the Blanchard *et al.* [1997] method. This is yet another indication of the directly driven response of the magnetosphere to the pressure pulse.

The Jan 10, 1997 event (continued): effects of solar wind pressure on the global ionospheric current

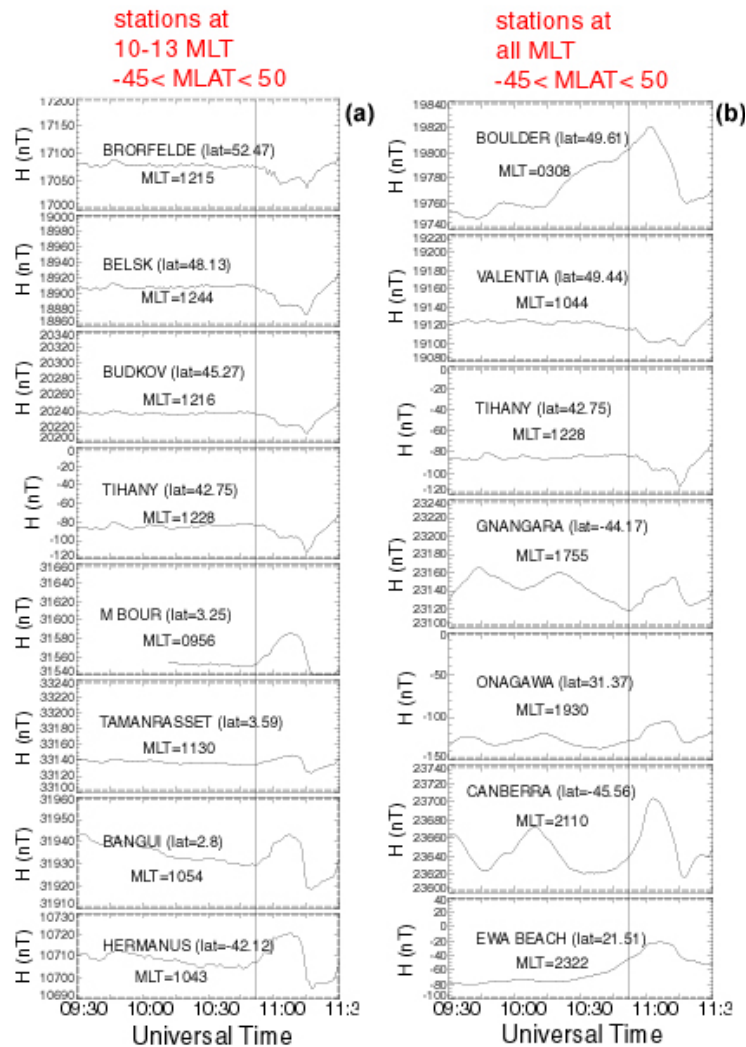


From Zesta *et al.* [2000]

Shown next are the interpolated equivalent ionospheric current patterns determined from a global network of magnetometers. The current vectors are plotted in a MLT-magnetic latitude coordinate system. The locations of the ground magnetometers are marked with solid triangles and magnetic local noon is at the top of each dial. The equivalent currents are spherically interpolated to a 10° by 1° longitude-latitude grid.

After the pressure front hits at 1050 UT we see a global strengthening of the ionospheric current system. By 1110 UT the auroral electrojet extends from 50° to 80° in excellent agreement with the very wide oval observed in the images of the previous slide. The strengthening and widening of the ionospheric current system is indirect evidence for the significant strengthening of the Region 1 field-aligned currents. By 1120 UT the global current has returned to its pre-pressure pulse lower strength.

The Jan 10, 1997 event (continued): local noon ground magnetometer signatures



From Zesta *et al.* [2000]

Further evidence for the increase of the Region 1 currents is given in the figure next. Panel (a) is a stack plot of the H-component of 8 stations in the 1000 to 1300 MLT regions ranging in magnetic latitude from +52 ° to -42 °. The vertical line indicates the time of the pressure pulse onset at Geotail.

Stations as low as 42 ° (L=1.5) show a negative bay instead of the customary positive deflection. The general consensus is that SI and SSC events have a sharp signature at all latitudes, but at the dayside sub-auroral, mid-, and low-latitudes the ground magnetometers all observe a positive main signature in the H components, as a direct response to the increased Chapman-Ferraro current at the magnetopause.

The fact that stations as low as L=1.5 in panel (a) do not show the response to the Chapman-Ferraro current means that these stations respond directly to the much strengthened Region 1 currents that cancel out and overshoot the effect of the increased Chapman-Ferraro current. It is only at latitudes lower than 40 ° that we see the response to the magnetopause current.

Panel (b) shows the response of mid- to low-latitude stations at all local times. It is clear that only near local noon the effect of the strengthened R1 currents penetrates to lower latitudes, while at all other local times these latitudes observe the effect of the increased Chapman-Ferraro current (the effect of a negative H-comp from the Region 1 currents is intensified in the noon region where upward and downward R1 currents both add to the effect).

The Jan 10, 1997 event: geosynchronous signatures

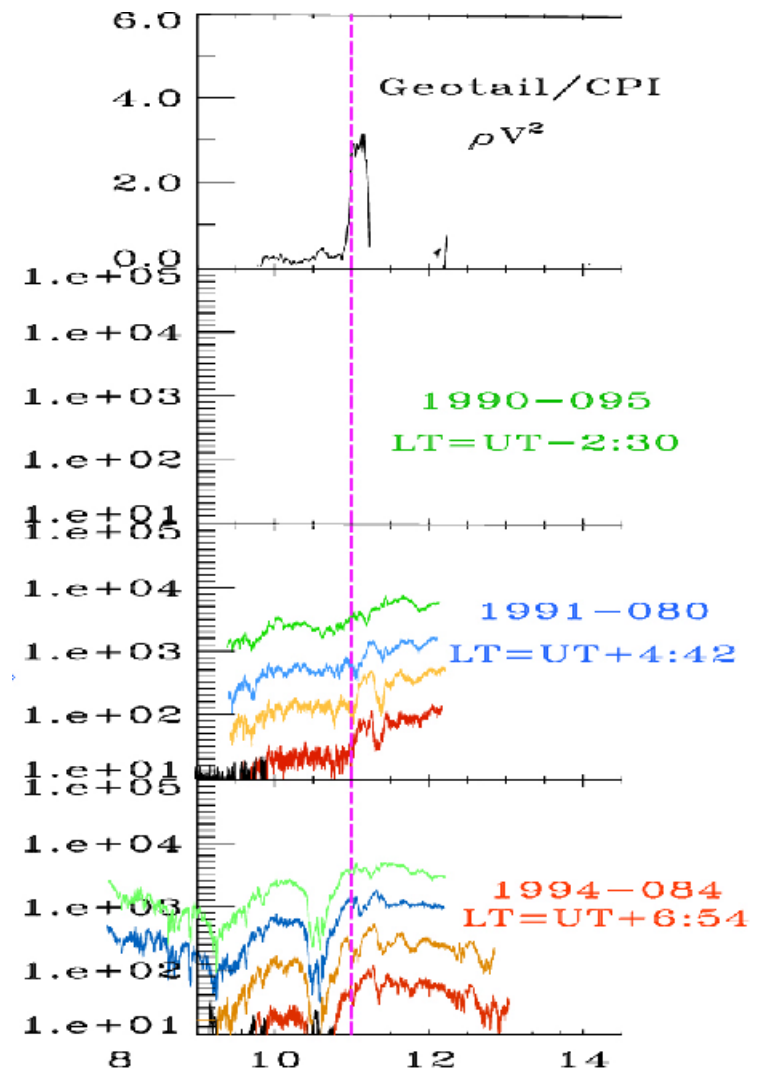
Adapted from *Li et al. [1998]*

Li et al. [1998] found that the Jan 10, 1997 pressure pulse was almost immediately followed by a rapid enhancement of the 0.4-1.6 MeV electrons in the magnetosphere at L=4-6 and that this enhancement was near simultaneous at all local times.

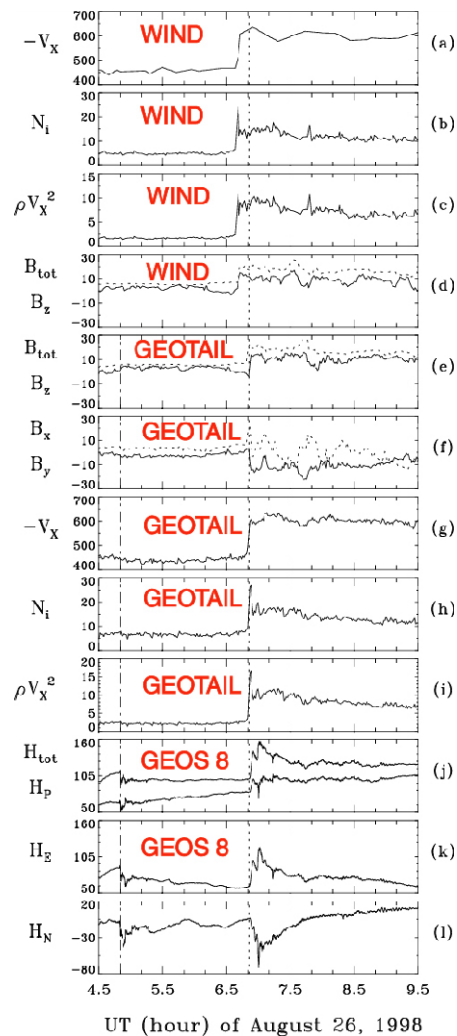
In the figure next, adapted from a *Li et al.* figure, the vertical dashed line indicates the onset of an energetic electron injection coinciding with the pressure pulse. The red trace is the highest energy (0.5-0.75 MeV), and the green is the lowest energy (0.15-0.22 MeV). The 084 spacecraft is located at ~1800 MLT and observes a small energy dispersion in the electron injection signature at 1100 UT.

The observed time delay between the 0.2 MeV and 0.7 MeV electrons is ~8 min. If we assume a midnight substorm-like injection with electrons drifting downward, the time delay between those two energies should have been ~18 min at 1800 MLT.

Clearly the injections associated with the pressure pulse are not substorm-like injections. They are more global.



The effect of pressure pulses at geosynchronous



From *Li et al.*, submitted to JGR

Li et al. studied the effect of a typical solar wind shock on the particle signatures at geosynchronous.

The shock of August 26, 1998 is shown in the figure next from two solar wind spacecraft (WIND and Geotail) and the geosynchronous GOES 8 spacecraft. The shock impact in the magnetosphere is at ~0650 UT.

The effect of pressure pulses at geosynchronous (continued)

From *Li et al.* submitted to JGR

The energetic electron and proton signatures associated with the shock at 0650 UT and with a prior substorm injection at 0450 UT is shown next. The location of the 3 LANL and one GOES spacecraft is shown on the top.

Li et al. modeled the two injections and studied their similarities and differences. They found that even though both the substorm and the shock associated injections led to rapid enhancements of energetic particle fluxes in the inner magnetosphere, there were significant differences. The injection associated with the isolated substorm at 0450 UT is more localized in local time due to a localized field dipolarization, which affects more the lower energy particles. The interplanetary shock injection is global. It resulted in an initial enhancement of energetic particles at different local times almost simultaneously. It also caused variations in the higher energy particles.

This conclusion agrees with all the previous observational evidence that shocks and longer lasting pressure pulses have an almost instantaneous and global effect on the magnetosphere.

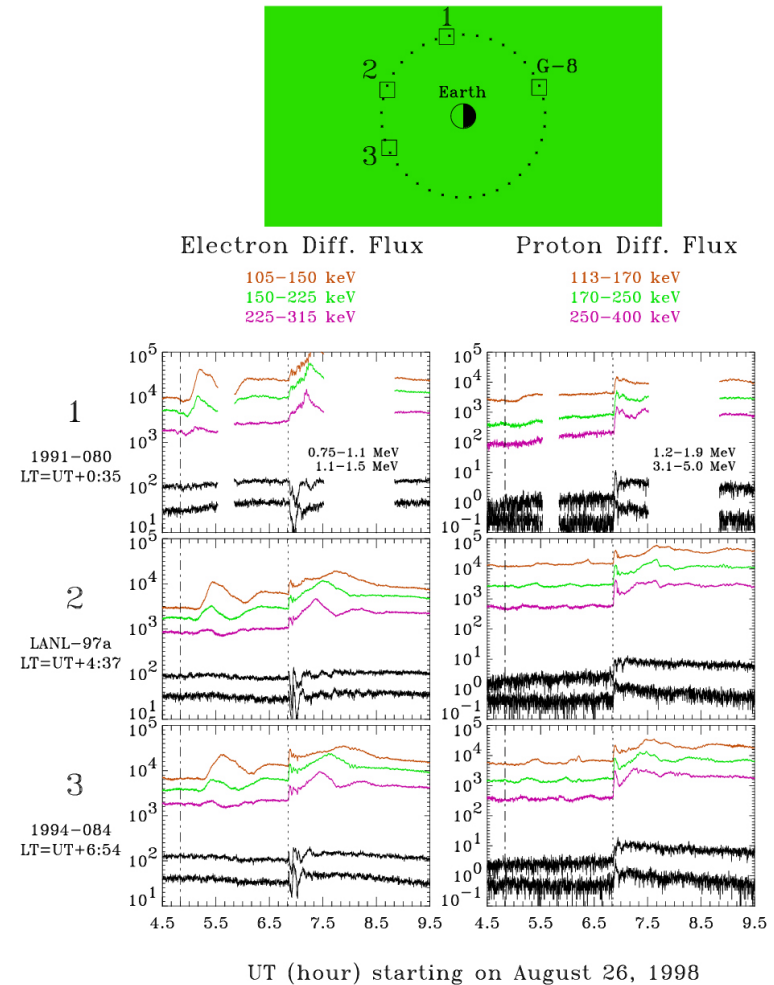
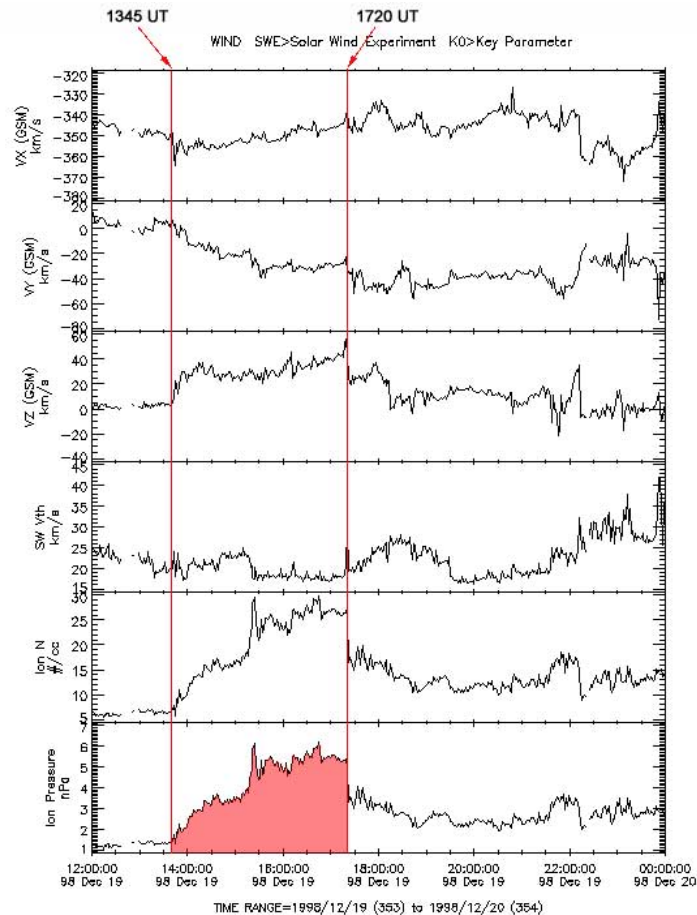
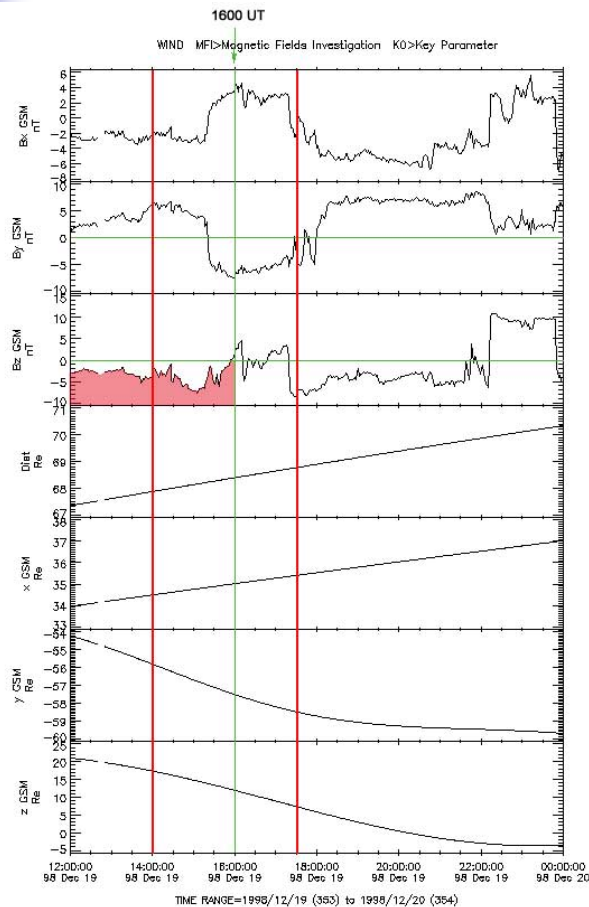


Figure 2

The Dec 19, 1998 event: solar wind signature

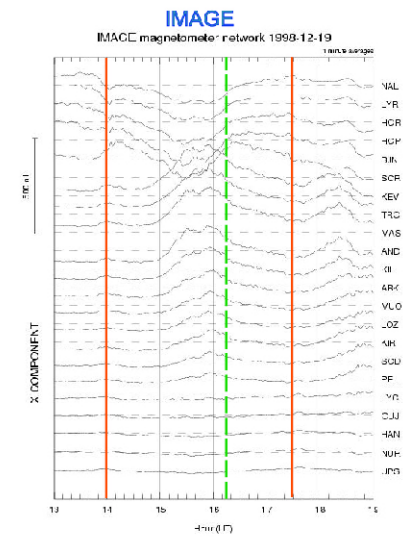
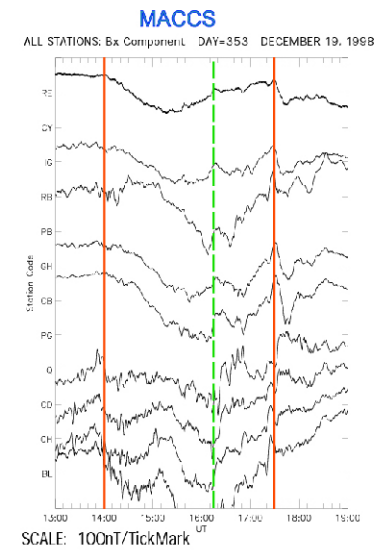
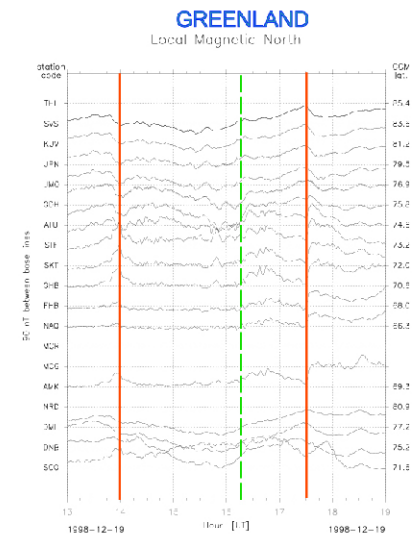
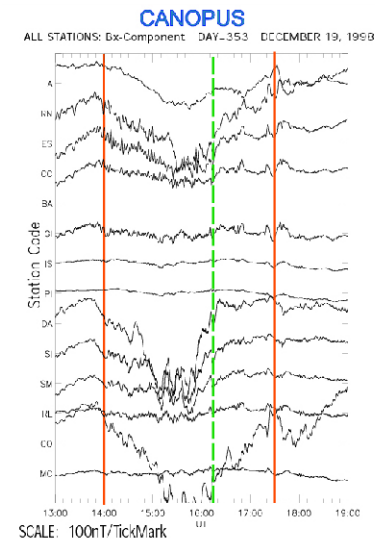


The final example of the global effect of solar wind pressure enhancements under southward IMF. At ~1345 UT on Dec 19, 1998 there is a strong enhancement in the solar wind pressure (right bottom panel) that lasts until ~1720 UT. For the first half of that period, until ~1600 UT the IMF remains southward, and then turns northward. For the 1600-1730 UT, the IMF is northward or very small and the dynamic pressure is high. We will show next that only during the first half of the high pressure period, while the IMF is southward, the magnetosphere has a strong and global response to the pressure enhancement.

The Dec 19, 1998 event: ground magnetometer signatures

The CANOPUS and MACCS chains are in the morning and noon regions during the 1400 to 1730 UT period of enhanced solar wind pressure. Greenland is in the afternoon sector and IMAGE is in the late evening region. All chains show a response at ~1400 UT when the high pressure front hits the magnetosphere under southward IMF conditions. At ~1615 UT all chains, but primarily CANOPUS and MACCS, show a partial recovery of the initial perturbation coinciding with the northward turning of the IMF even though the pressure is remaining at high levels.

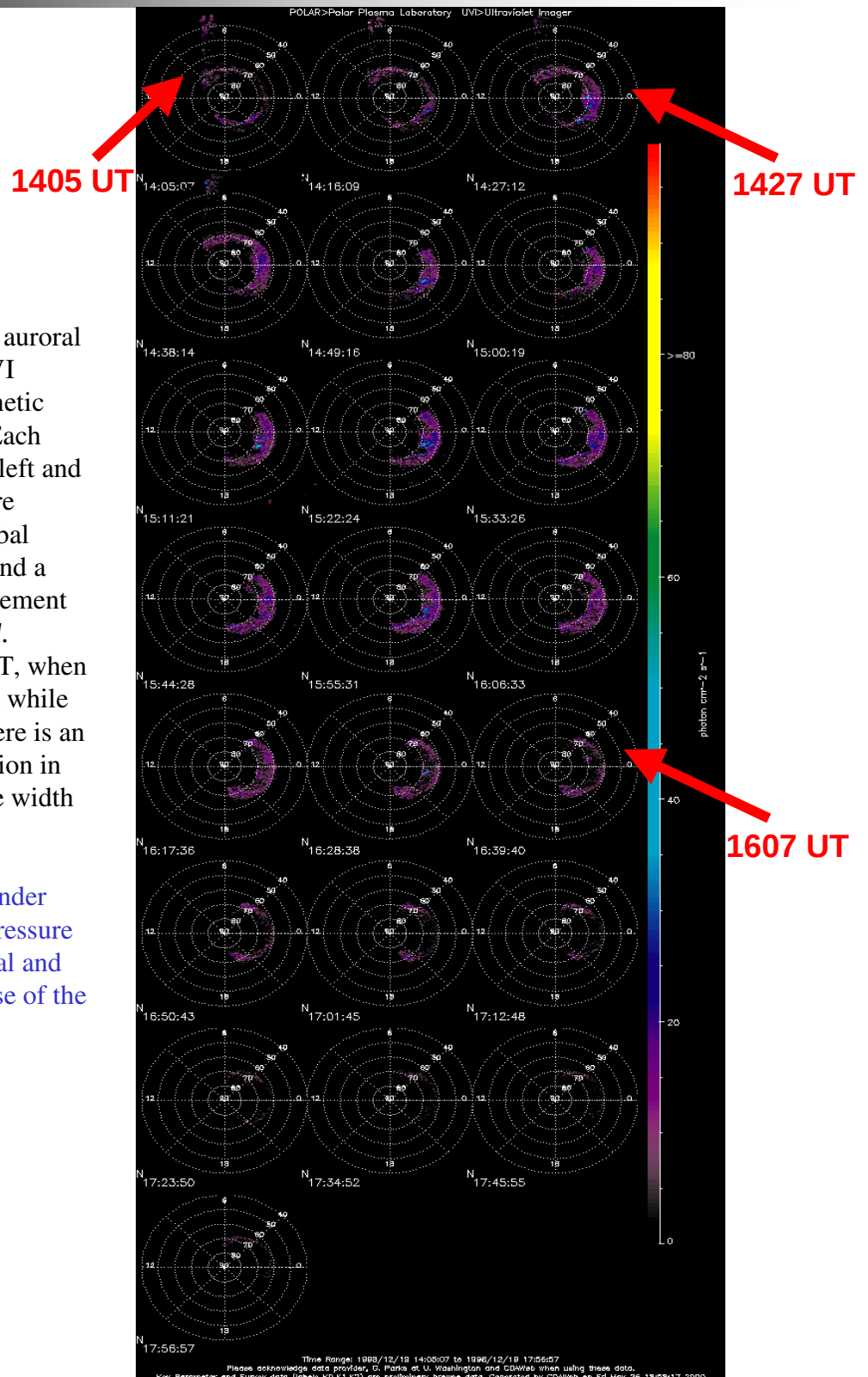
This is direct evidence that high pressure enhances the global ionospheric current under southward IMF conditions, but has a much smaller effect (or none at all) under northward IMF conditions.

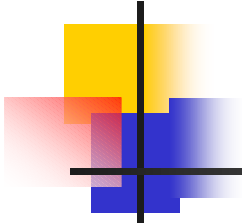


The Dec 19, 1998 event: auroral signature

The figure next is a series of auroral images from the POLAR UVI instrument, in an MLT-magnetic latitude coordinate system. Each image has local noon on the left and dawn on the top. The pressure enhancement produces a global strengthening of the aurora and a widening of the oval, in agreement with the results of *Zesta et al.* [2000]. Shortly after 1600 UT, when the IMF turns northward and while the pressure remains high there is an immediate and global reduction in the auroral emissions and the width of the oval.

This is again evidence that under southward IMF conditions pressure enhancements lead to a global and almost instantaneous response of the magnetosphere.

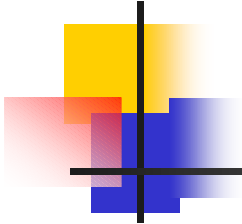




Summary/Conclusions

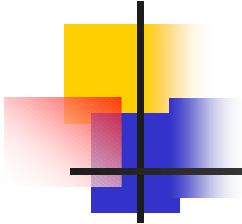


- The magnetosphere responds very different to solar wind pressure step changes (shocks or TD) under southward and northward IMF conditions
- For northward IMF there is no significant enhancement in the R1 and ionospheric currents or in the auroral precipitation. There is a global response seen at ground magnetograms but it is mostly the response to the CF and tail currents and transient current loops at high latitudes
- For southward IMF there is an almost immediate and global response of the magnetospheric currents and auroral precipitation. “**Preconditioning**” of both the magnetosphere and the IMF is necessary for such a global response. The response seems to be directly driven by the onset, peak, and decrease of the solar wind pressure.
- Substorm expansion phase, when it occurs, starts at least 15-30 min after the SSC.
- *Kokubun et al. [1977]: “It seems likely that the compression of the magnetosphere accelerates intrinsic processes in the magnetosphere which lead to the substorm occurrence or it changes the instability threshold but is not the direct cause”.*



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