



ИНСТИТУТ СОЛНЕЧНО-ЗЕМНОЙ ФИЗИКИ
СИБИРСКОГО ОТДЕЛЕНИЯ РОССИЙСКОЙ АКАДЕМИИ НАУК

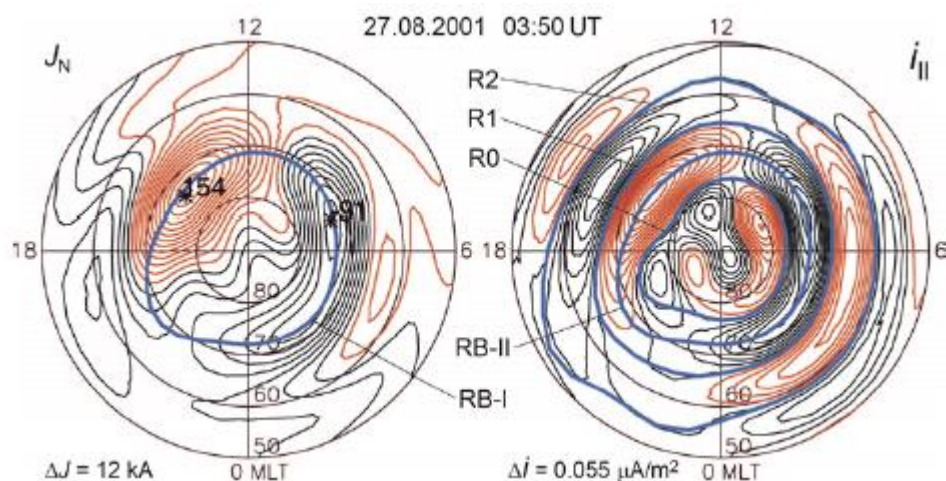
Dynamics of distribution of electric fields and currents in the high- and low-latitude ionospheres in two hemispheres during equinox SMC events with a steady IMF

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We give a summary of main results of the open magnetosphere model on the quadrant asymmetry in the distributions of ionospheric convection and field-aligned currents under the influence of the IMF azimuthal component. Based on the data from the worldwide SuperMAG network of ground-based magnetometers, the dynamics of the dawn–dusk asymmetry in the distributions of electric fields and currents in the high-latitude ionosphere in two hemispheres is studied using the magnetogram inversion method during changes in geomagnetic activity for long intervals of stationary magnetospheric convection. Possible reasons for the obtained examples of non-fulfillment of quadrant asymmetry in two hemispheres are discussed. It is shown that along with the usually discussed external factors, internal factors can have a significant influence - the effects of rotation of the substorm current system and the ring current amplification even during weak magnetic storms

Magnetogram inversion technique (MIT)-modification

MIT was developed at ISTP SB RAS [Bazarzhapov et al., 1979; Mishin, 1990]. MIT calculates time series of 2D maps of distributions of equivalent currents, electric potential, horizontal and field-aligned currents (FACs) in the polar ionosphere from ground geomagnetic data at the SUPERMAG worldwide network of stations. It determines boundaries of auroral oval or oval of FAC's. Such map was initially obtained by Iijima and Potemra [1978] from statistical satellite data. Initially FAC regions boundaries were identified in MIT manually, by visually analyzing maps of field-aligned and equivalent currents and by drawing boundaries with a mouse in a special program on the screen. In 2019 MIT was modified and began to do it automatically every minute, and not only in NH but also in SH [Lunyuskin & Penskikh, 2019, 2021; Penskikh, thesis, 2022]. MIT gives a number of electrodynamic parameters of the magnetosphere – ionosphere system, especially the magnetic flux through the polar cap which is obtained on FAC maps – not postulated by “hands” as some length L in Akasofu Epsilon parameter.



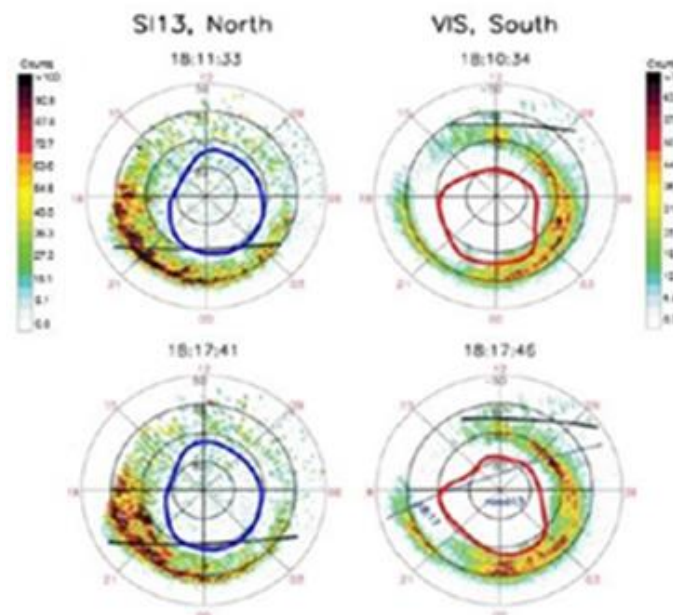
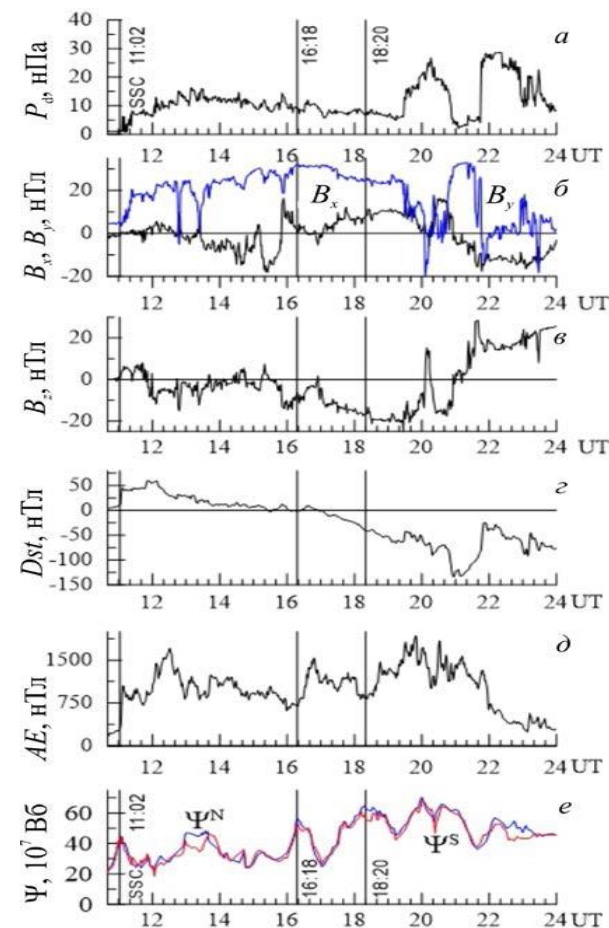
Maps of distributions of the equivalent current function J_N (left) and FAC density (right) in the N Hemisphere for 03:50 UT of August 27, 2001; **black** isolines on the map of $i_{||}$ correspond to **downward** FACs; **red isolines**, to **upward** FACs; ΔJ and Δi are steps between isolines; **blue lines**, R1, and R2 are the polar cap boundary (R0), line of maximum density of auroral electrojets (R1 – FAC Zone 1 border), and auroral oval equatorial boundary (R2).

IMF B_y effect

- Consequences of the IMF B_y effect from the open magnetospheric model by Stern, Ляцкий, 1978; Ляцкий, Мальцев, 1983; Cowley, 1981; Cowley, Lockwood, 1992]
- :
- strengthening of magnetospheric convection and, obviously, field-aligned currents (FACs), as well as the polar cap (PC) shift antiparallel to the $\vec{B_y}$ direction in the northern hemisphere (NH) and vice versa in the southern hemisphere (SH) – quadrant asymmetry
- With $B_y > 0$ $I_{\text{dawn}} > I_{\text{dusk}}$ in NH
- $I_{\text{dawn}} < I_{\text{dusk}}$ in SH
- With $B_y < 0$ $I_{\text{dusk}} > I_{\text{dawn}}$ in NH
- $I_{\text{dawn}} > I_{\text{dusk}}$ in SH

We use MIT maps of FAC density distribution, ACE data on SW and IMF, SME indexes and auroral map from Polar (Supermag.com)

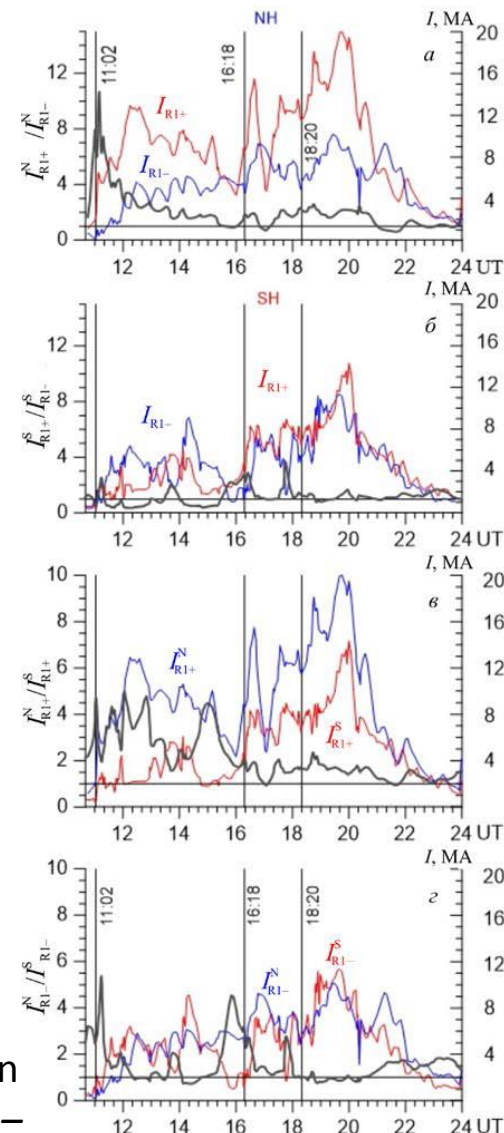
17 AUGUST 2001 STORM By > +20 nT. ELECTRIC CURRENTS AND POLAR CAPS DYNAMICS IN IONOSPHERES OF TWO HEMISPHERES



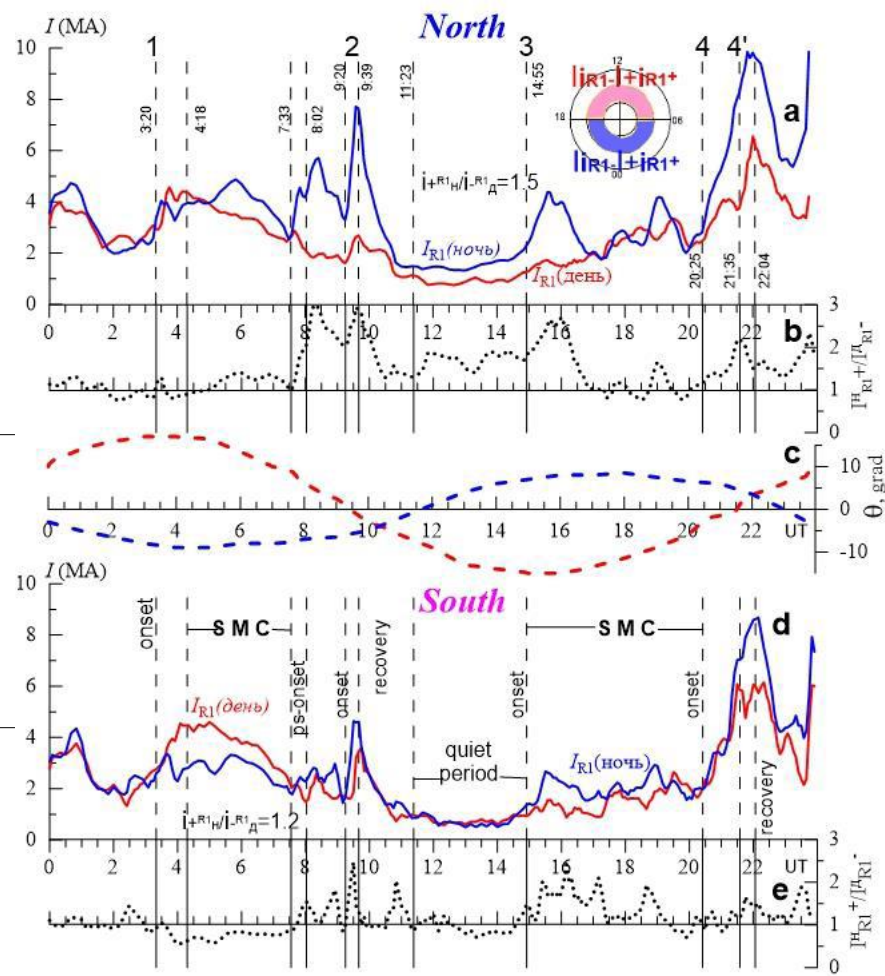
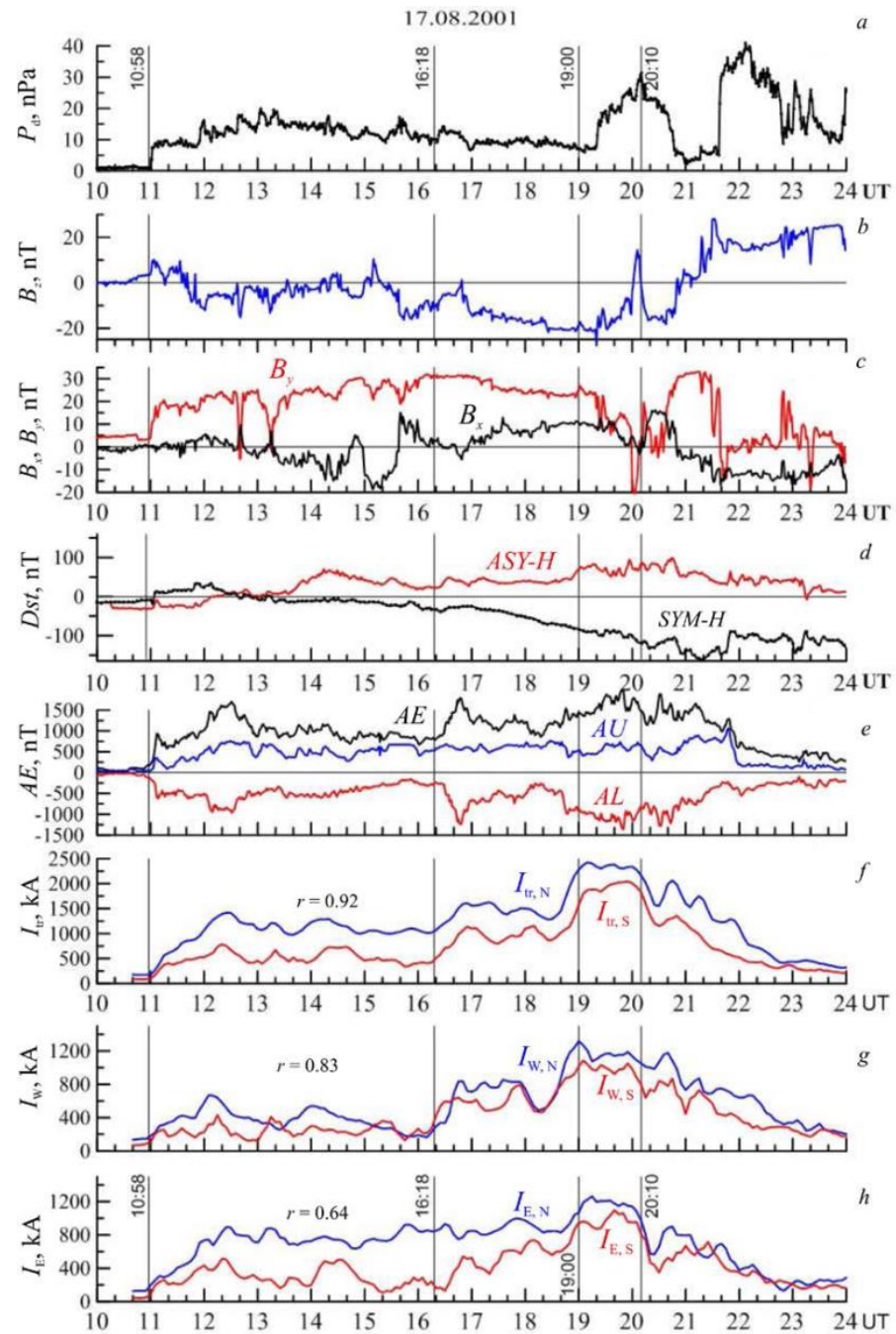
Video overlay of polar cap borders from MIT FAC maps with aurora images from satellites: opposite displacement of PC in two hemispheres.

In NH $IR1+ > IR1-$ corresponds to the downward PC expansion under $B_y \sim +20$ nT. In the SH the inequality sign at 11:00–15:30 UT reversed: $IR1+ < IR1-$. Two substorms led to a disappearance of the dawn–dusk asymmetry in the dark S hemisphere

17 августа 2001 г.



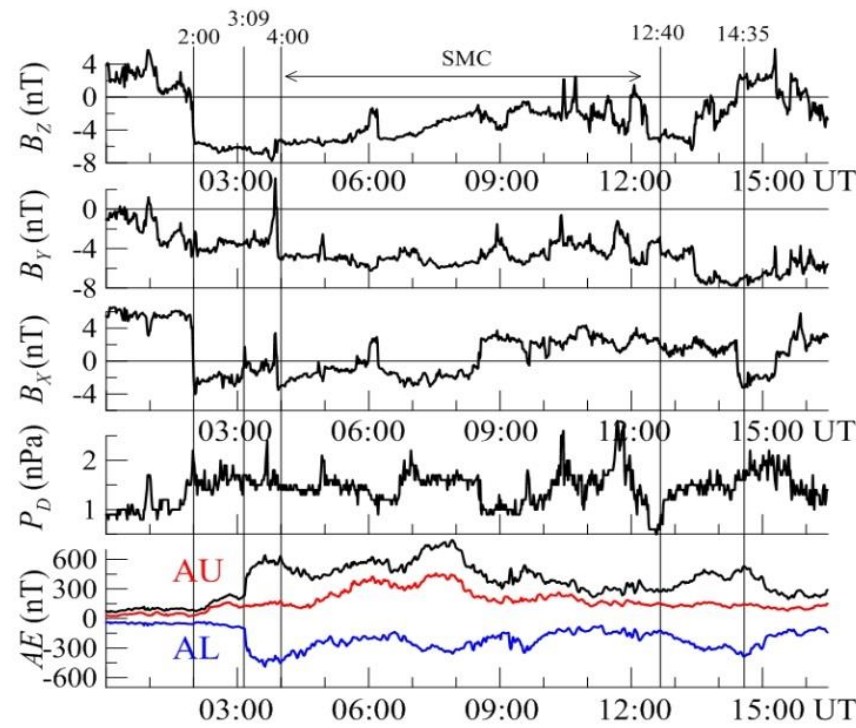
Bottom panel shows synchronous variation of Polar cap magnetic fluxes in two hemispheres



Equinox events of stationary magnetospheric convection with a moderate, stable IMF By component

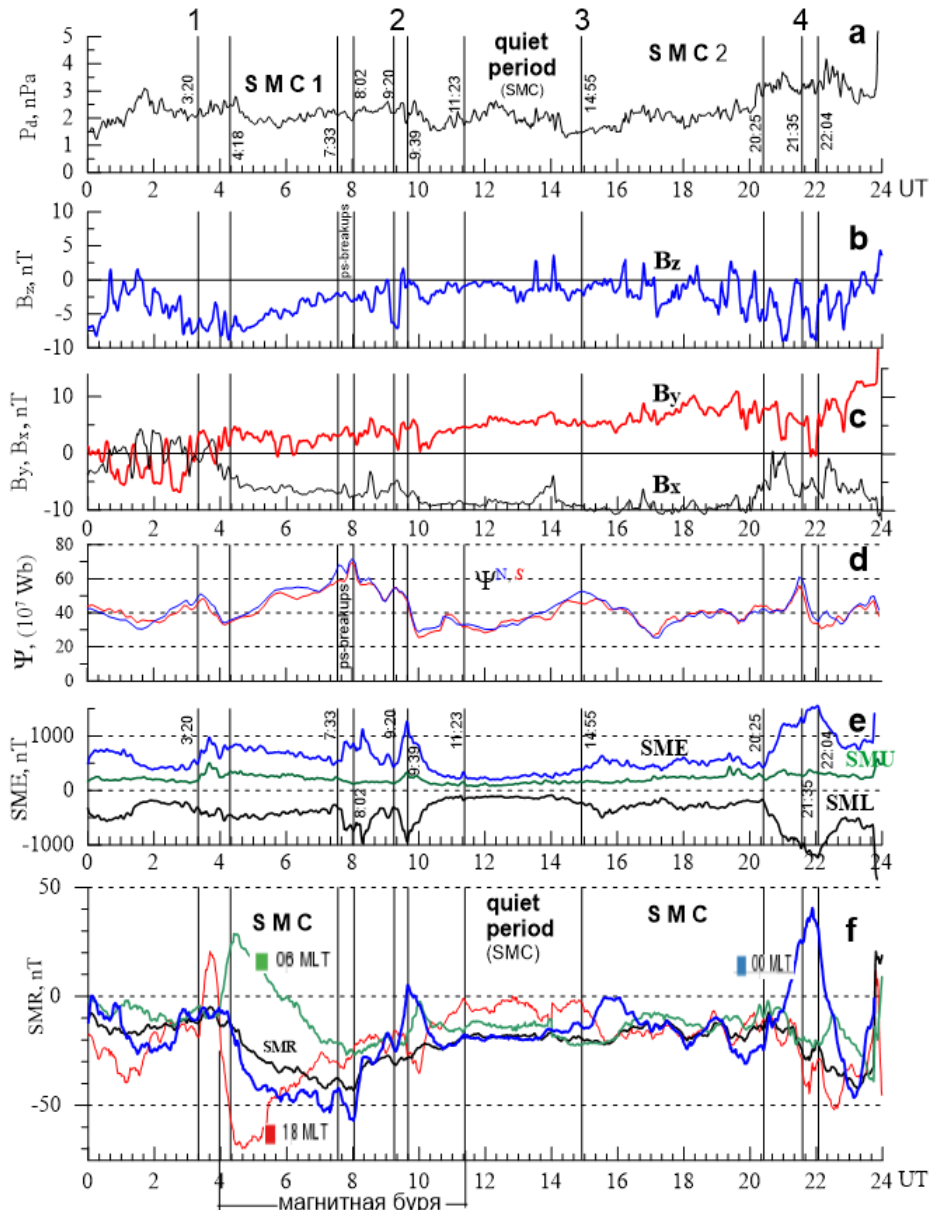
The 6 April 2000 pre-storm interval SSC at 16:40 UT) $B_y < -4$ nT

6 April 2000



Variations: IMF B_z , IMF B_y , SW dynamic pressure P_d , auroral electrojet indexes, and energetic electron fluxes at $L=6.6$. Expansion phase onset (EPO) was at 03:10 UT.

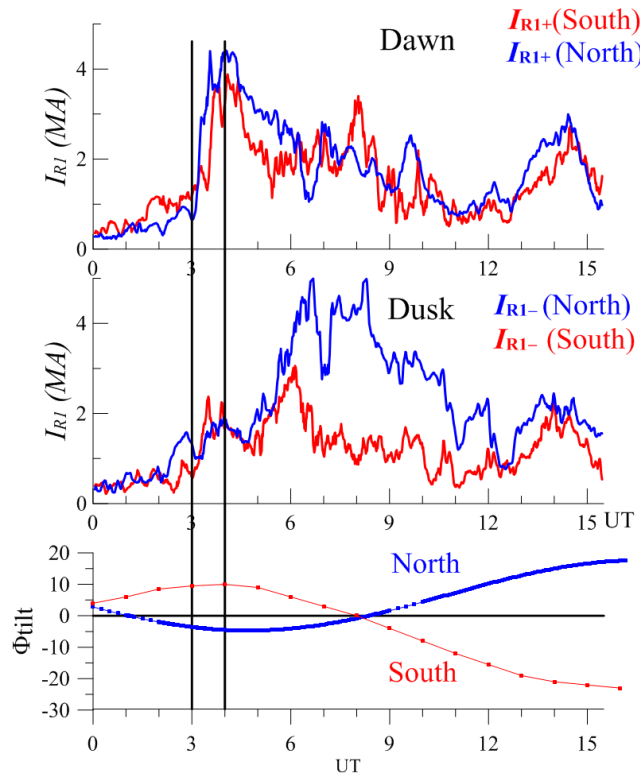
24 Sep 1998, SSC at 23:45 UT, $B_y < +10$ nT



Field-aligned currents (FAC)

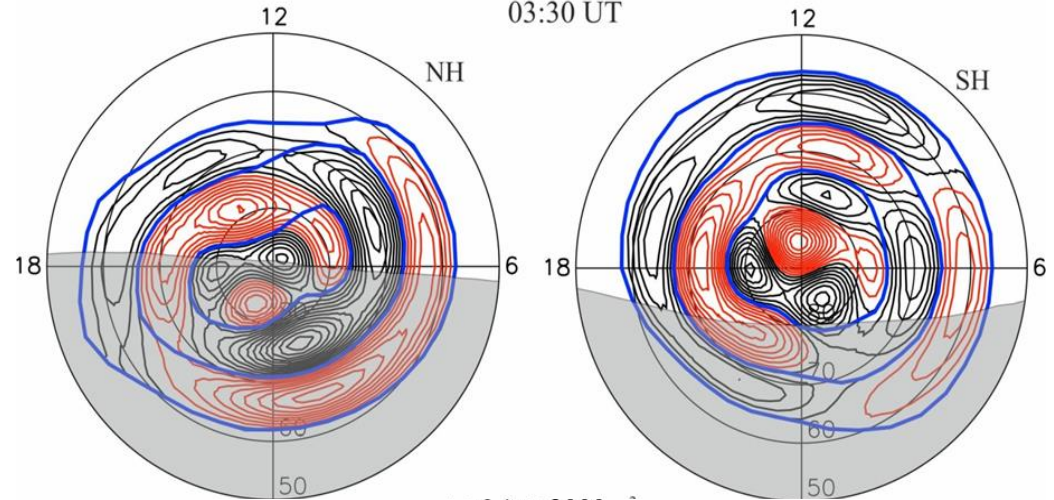
6 April 2000, $B_y < -4$ nT

6 April 2000

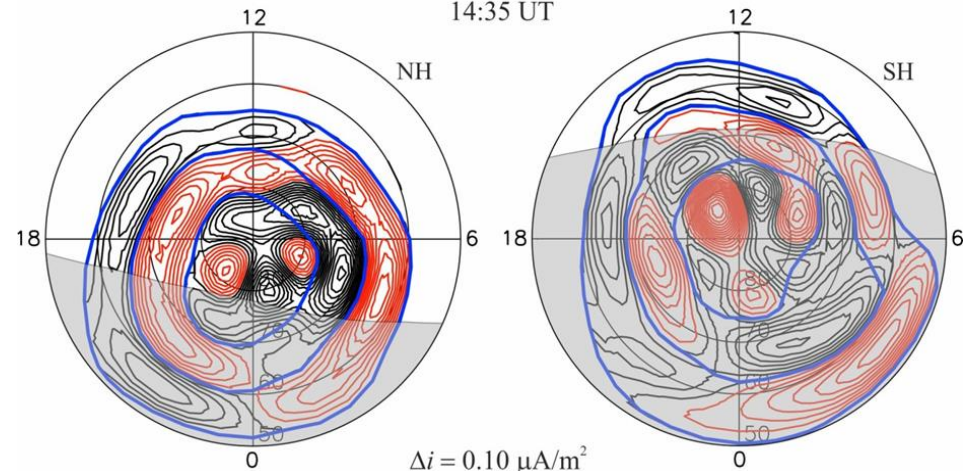


Variations in in the N/S Hemispheres of:
 Region 1 FAC intensities I_{R1}^+ , I_{R1}^- and the
 dipole title angle Φ . The effect of greater
 illumination in SH is weakly visible: in the
 dawn sector during the substorm growth
 phase (up to 3 UT) and in the dusk sector
 during the expansion phase (3-4 UT)

6 Apr 2000
 03:30 UT



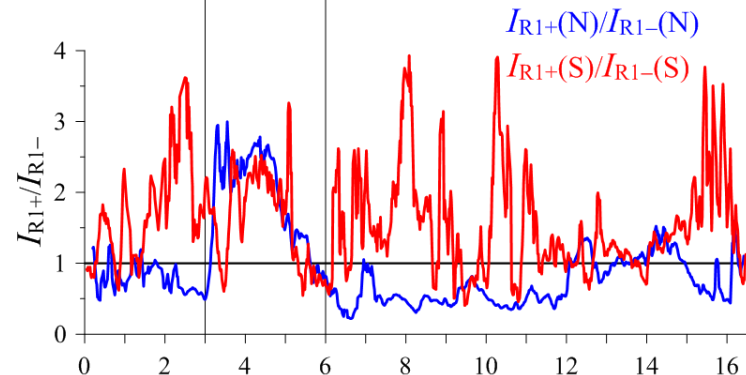
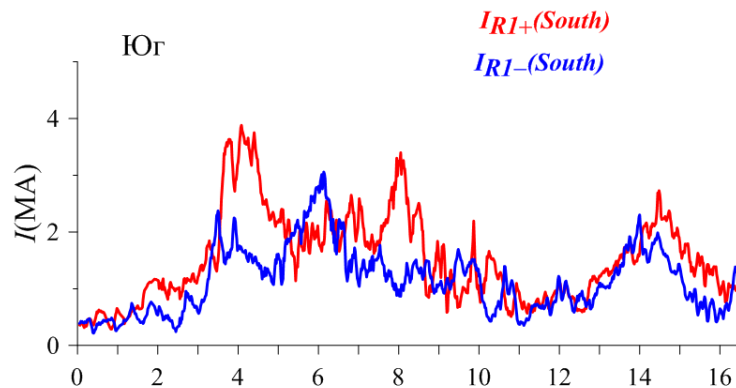
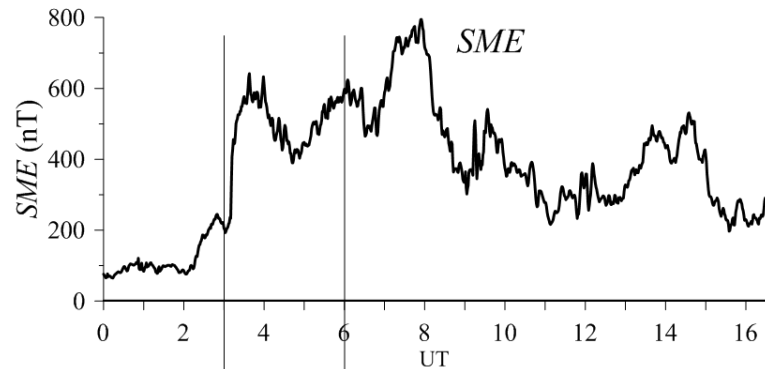
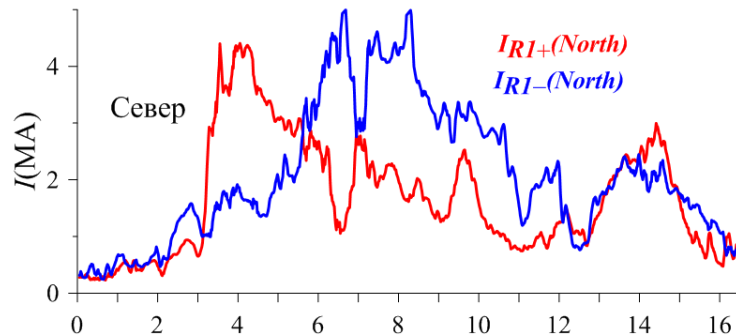
6 Apr 2000
 14:35 UT



Diurnal variations in the inclination of the axis
 of the geomagnetic dipole leads to a visible
 change in the illumination of the PC and the
 FAC oval in the equinox season

Квадрантная асимметрия – нарушается во время суббури-преобладание ПТ в утреннем секторе обоих ПШ

6 Apr 2000



6 April 2000 event. By < 0

Table 1. Ratios of average intensities of downward and upward FACs in Zone R1 ($\langle I_{R1+} \rangle / \langle I_{R1-} \rangle$) (dawn/dusk asymmetry) at By < 0 in the 6 April 2000 event.

interval	North	South
Growth phase, SMC interval	0.73	1.83
Active phase	2.15	1.87

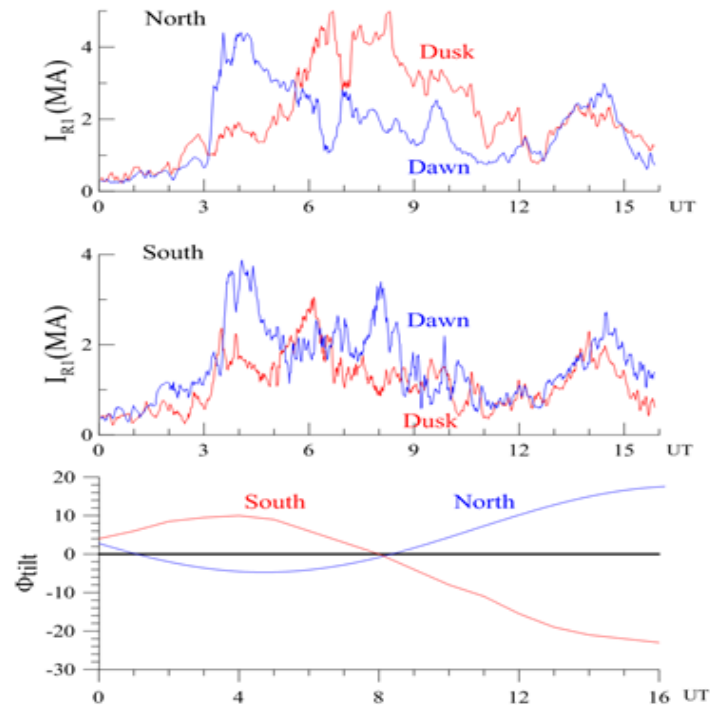
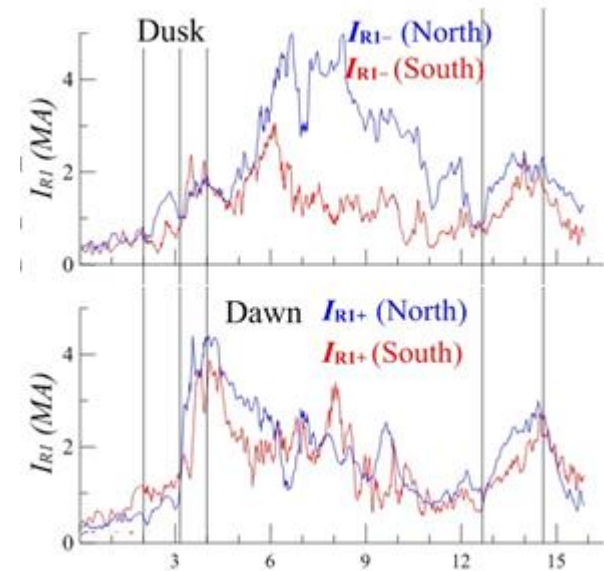
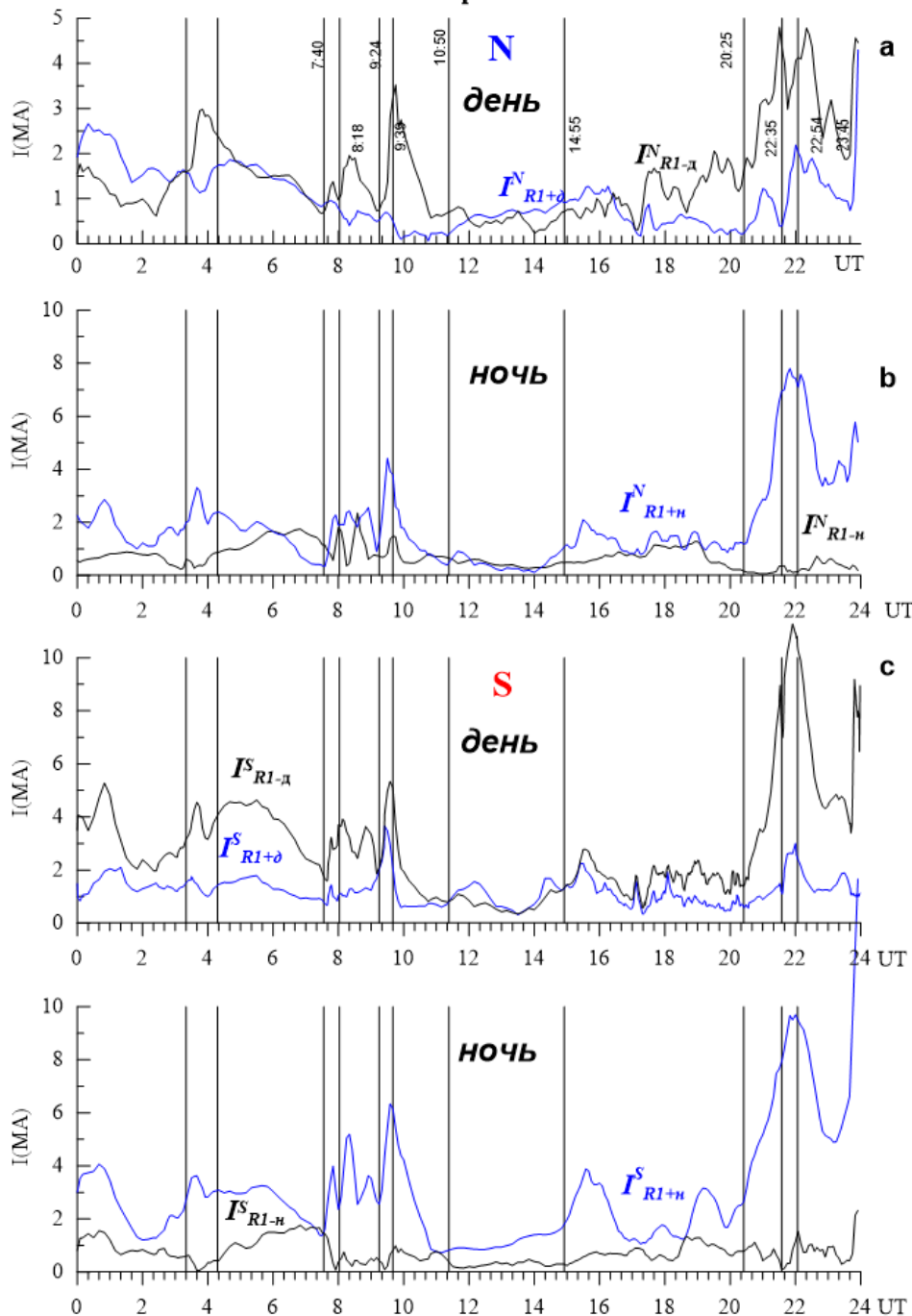


Table 2. Ratios of average N and S intensities of R1 FACs ($\langle I_{R1+}^N / I_{R1+}^S \rangle$) (N>S asymmetry)

interval	Dawn sector	Dusk sector
	I_{R1+}^N / I_{R1+}^S	I_{R1-}^N / I_{R1-}^S
Growth phase (2:00-3:09)	0.96	2.36
Active phase (3:09-4:00)	1.45	1.13
SMC (4-15:40)	1.25	3

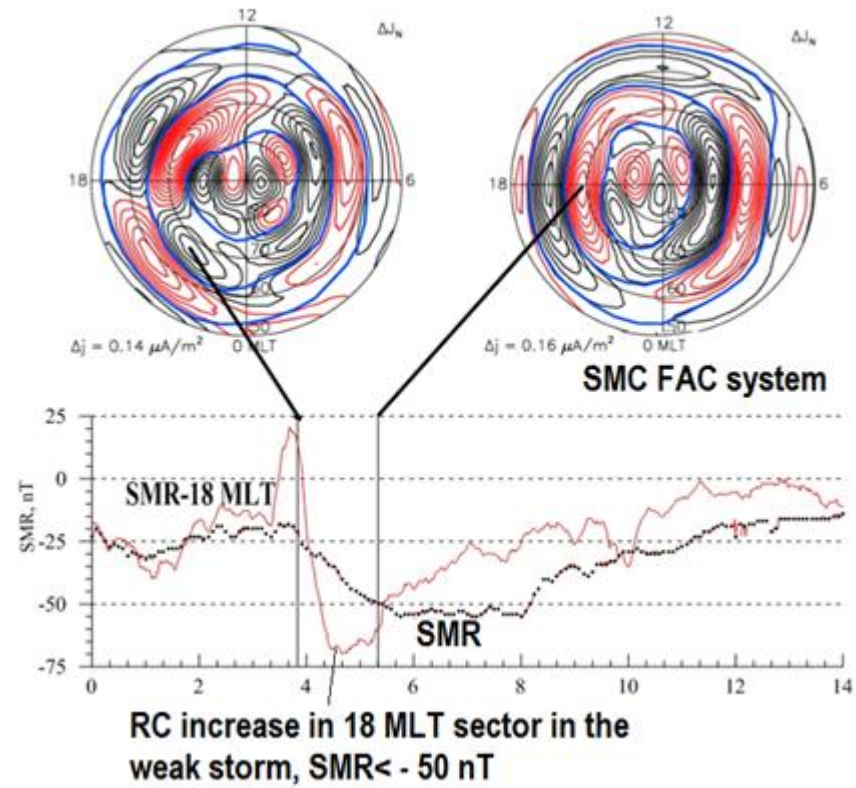


24 Sep 1998



NH 03:50 UT

NH 05:20 UT



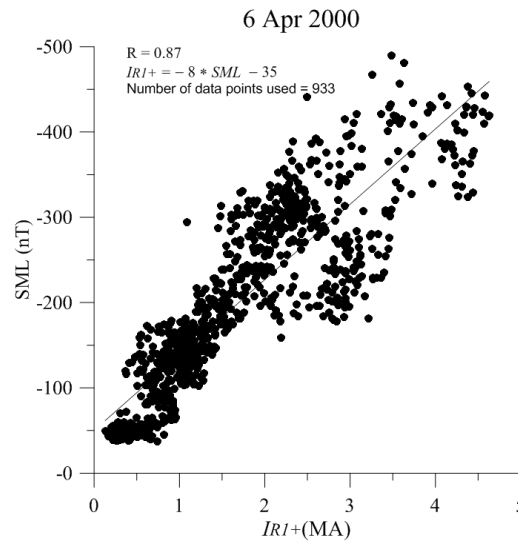
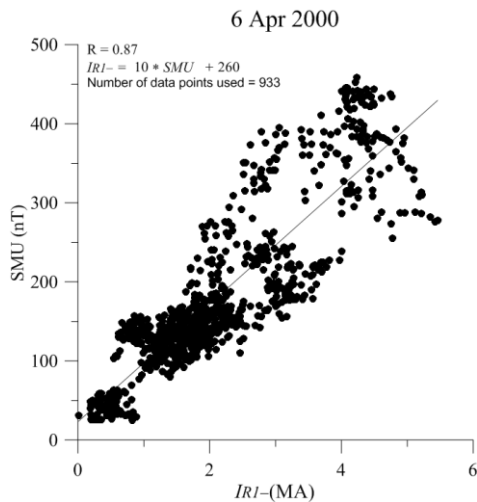
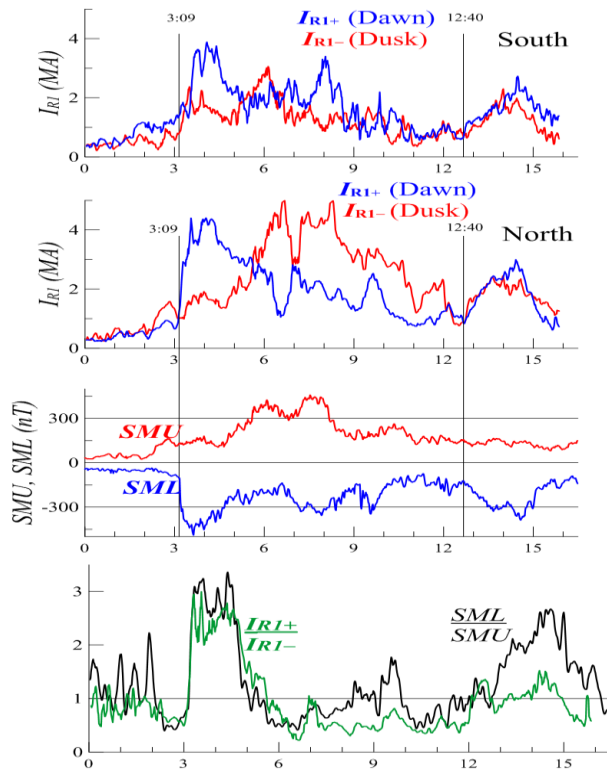
Duskward (opposite to $B_y > 0$ effect) polar cap displacement in a weak storm on 05:20 UT, Усиление ПТ в вечернем секторе приводит к компенсации эффекта B_y в темном NH и заметному усилению ПТ в освещенном SH

6 April 2000

Связь ПТ и электроджетов

Две верхние панели: вариации интенсивностей втекающих и вытекающих ПТ Зоны 1 в Северном и Южном полушариях

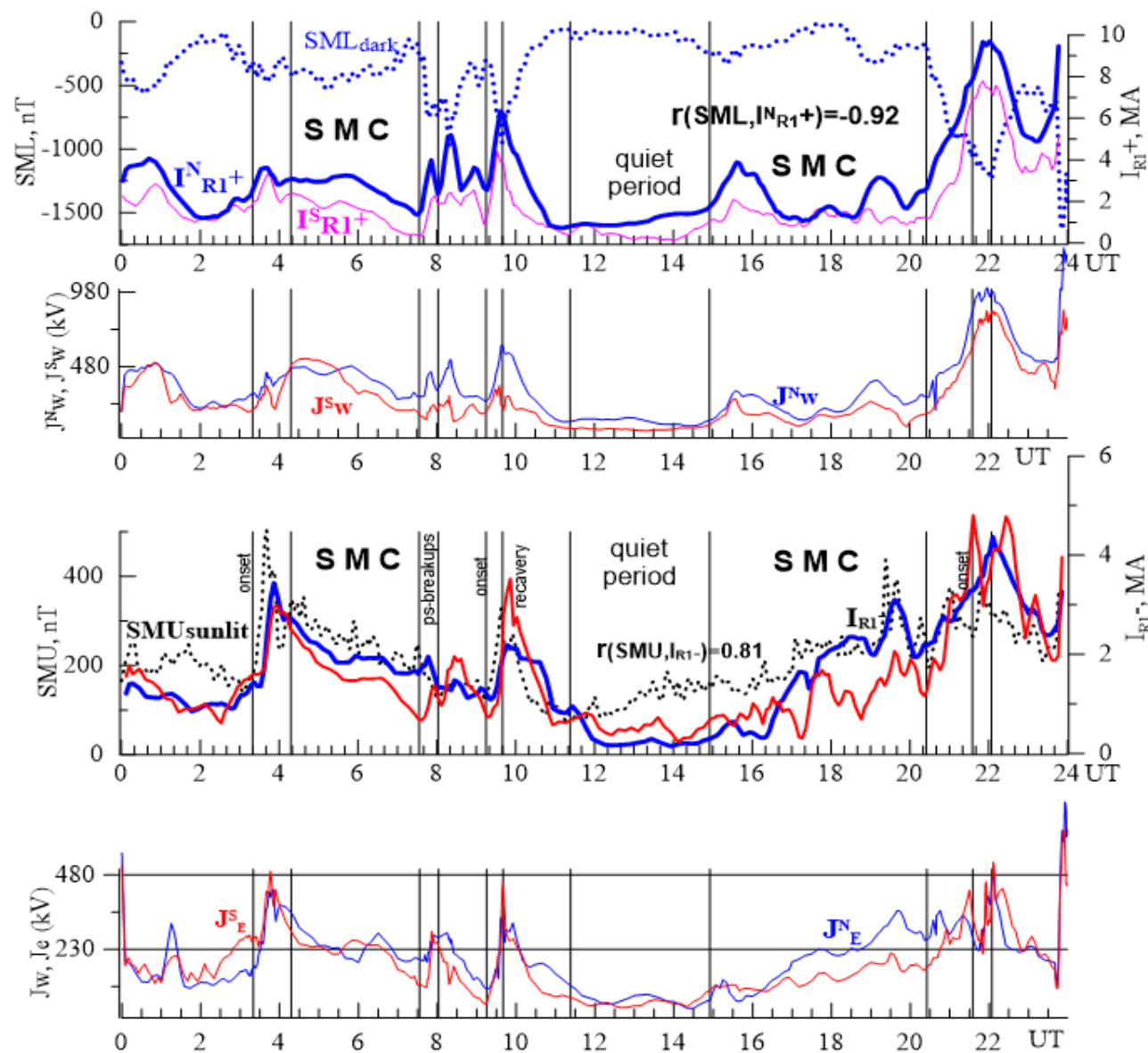
Две нижние панели: вариации отношений: индексов SML/SMU, интенсивностей втекающих и вытекающих ПТ Зоны 1 в NH.



Обнаружена хорошая связь (коэффициент корреляции 0.87) втекающих ПТ Зоны 1 Северного полушария с SML индексом и вытекающих ПТ с SMU индексом.

Высокая степень корреляций в вариациях эквивалентных токов и
 ПТ с индексами электроджетов (пунктир) в ДВУХ ПОЛУШАРИЯХ –
 возможность аппроксимировать вариации индекс AL and AU in SH

24 08 1998



Результаты

- **Эффекты B_y**
- **Для бури 17 Авг 2001 (сезон лето-зима) с очень сильным $B_y > +20$ нТл квадрантная асимметрия реализуется в летнем освещенном полушарии, а в неосвещенном зимнем полушарии суббури ослабляют эффекты B_y**
- **Сезон равноденствия с умеренными значениями B_y , интервалы со стационарной конвекцией.**
- **00-16 UT, 6 апреля 2000:** при устойчивых компонентах ММП B_z , $B_y < -4$ нТл при отсутствии резких изменений активности реализуется противоположная в двух полушариях асимметрия в распределении ПТ -квадрантная
- $I_{вечер} > I_{утро}$ в Северном полушарии, $I_{вечер} < I_{утро}$ в Южном полушарии.
- **24.09.1998 $B_y < +8$ нТл, наличие резких изменений активности, изменчивость ММП B_z**
- Квадрантная асимметрия реализуется только во втором интервале SMC. В первом SMC во главной фазы слабой бури ее нарушает усиление КТ в вечернем секторе.
- Во время активной фазы суббури в событиях равноденствия при любом знаке ММП B_y в обоих полушариях преобладает западный электроджет и в ПТ имеет место асимметрия $I_{утро} > I_{вечер}$,

Взрывная фаза суббури может уменьшать влияние ММП B_y в неосвещенном полушарии

Распределение интенсивности ПТ, полученное ТИМ, можно использовать в качестве показателей геомагнитной активности- индексов электроджетов AU, AL в тех случаях, когда эти индексы недоступны, а также в южном полушарии, где они не определяются