TROPICAL CYCLONE EFFECT ON IONOSPHERE PARAMETER VARIATIONS IN THE ASIAN REGION OF RUSSIA OVER THE PERIOD 2005-2011

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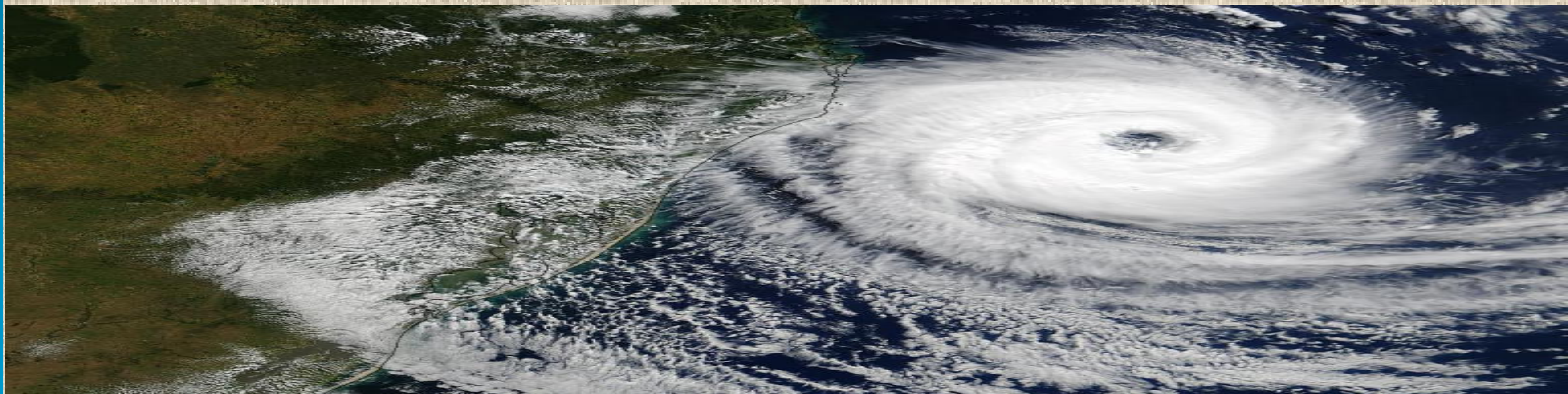
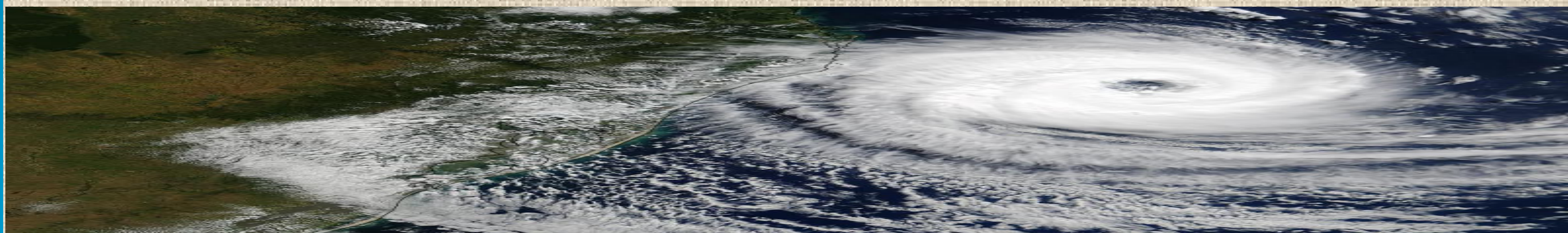
Objective of the study

We have carried out the research to reveal the manifestation of strong meteorological disturbances (like tropical cyclones) in the ionosphere parameter variations in a point distant from the disturbance source region.



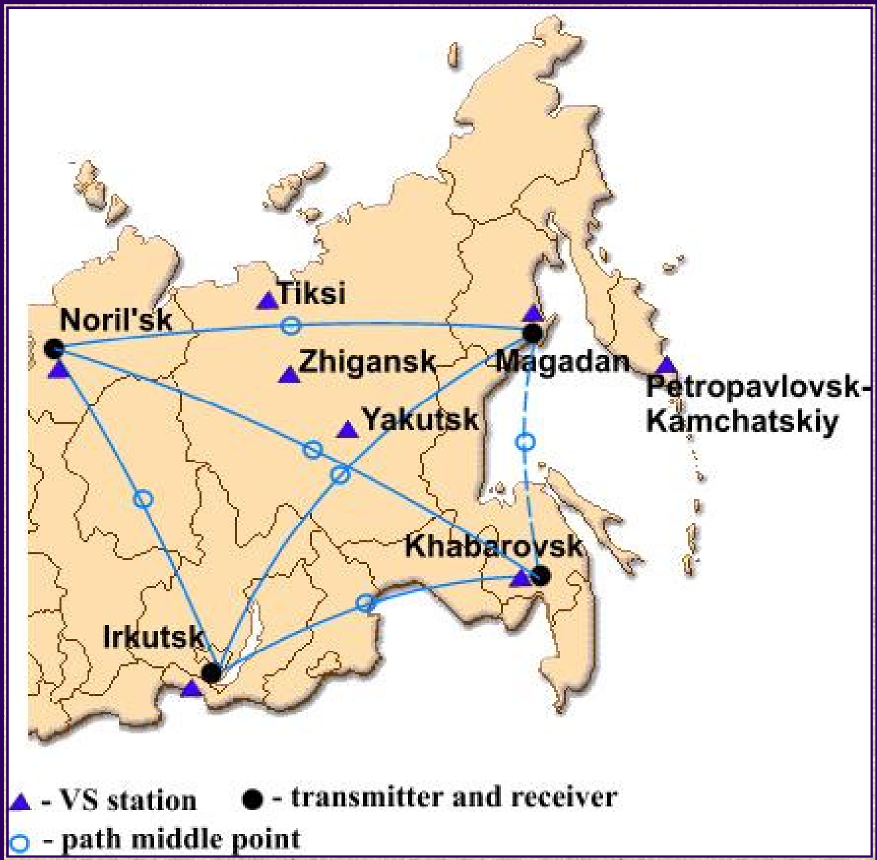
Observational data

- Experimental data of oblique sounding (OS) CHIRP ionosonders (3-30 MHz) are used, namely the maximal observed frequencies (MOFs) along the Norilsk-Irkutsk, Magadan-Irkutsk, Khabarovsk-Irkutsk paths for the 2005-2011 equinoctial periods and for the 2010-2011 summers;
- Data on tropical cyclones (TCs) over the north-western Pacific;
- Data on a helio-geomagnetic disturbances (K_p, D_{st}, $F_{10.7}$ indices).

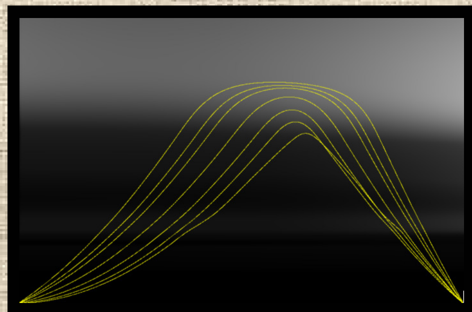


Scheme of the OS paths

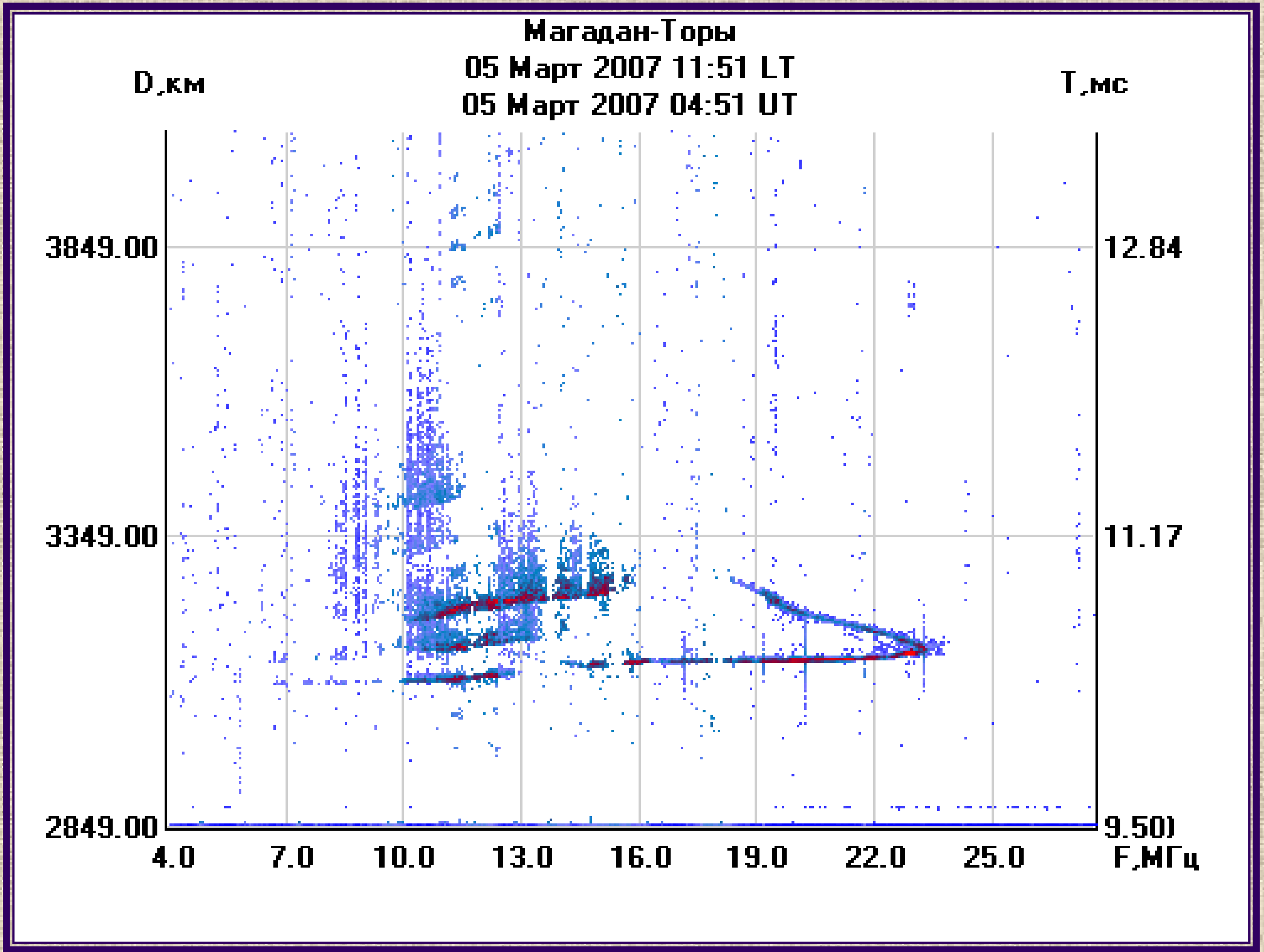
Radio paths go through the Eastern Siberia and the Far East regions. The path geometries differ. Path midpoints characterize the regions of OS signal reflection from the ionosphere:



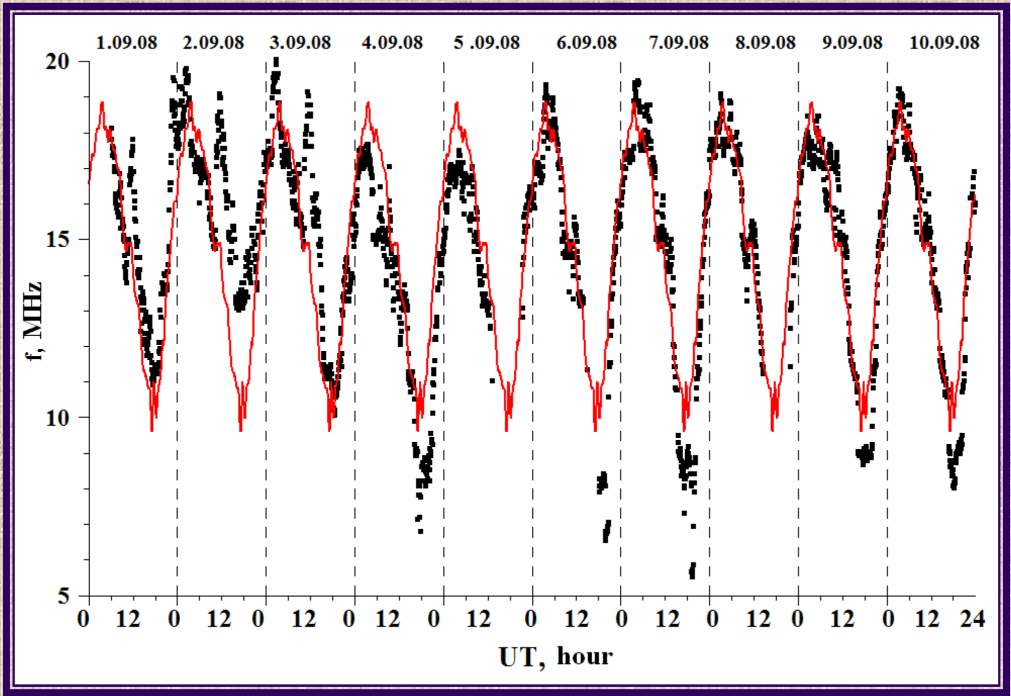
- **west of Podkamennaya Tunguska 60.8N, 96.2E (Norilsk-Irkutsk path);**
- **southwest of Yakutsk 58.1N, 123.3E (Magadan-Irkutsk path);**
- **territory of China 51.3N, 119.7E (Khabarovsk-Irkutsk path).**



Example of the OS ionogram for the Magadan-Irkutsk path



Example of the MOF time series for the Magadan-Irkutsk path in 2008 Sep



The point spreads (MOF experimental data) relative to the median values during the experiment (red line) are associated with the presence of <u>traveling ionospheric disturbances</u> (TIDs) on individual days. TIDs are related to the <u>internal gravity wave</u> (IGW) propagation in the ionosphere.

Frequency analysis method

From the initial experimental MOF data, we calculated the energy R_i running spectra (time/wave-like period) on the 0.5÷5 h period grid with a half-hour step.
An increase in the spectrum energy R_i at certain T_i was interpreted as a TID manifestation associated with the IGW propagation in the ionosphere.

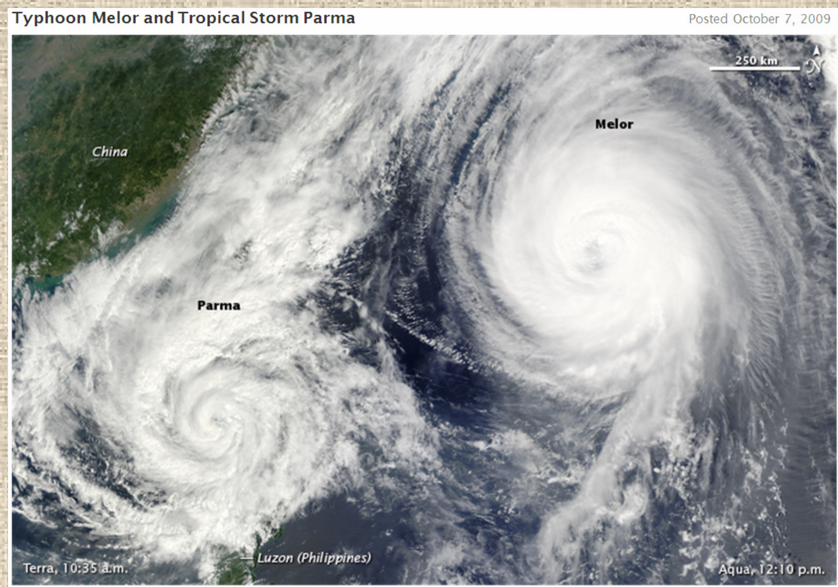
It is known IGW sources may be:

- **disturbances in helio-geomagnetic conditions (so-called, <u>external factor or "from upper" effect</u>);**
- **atmospheric processes (so-called, <u>internal factor or "from below" effect</u>) that include tropospheric cyclones, frontal systems, jet streams, solar terminator, stratospheric warming, earthquakes, etc.**

Tropical cyclones may be one of the most powerful sources of the "from below" effect on atmospheric and ionospheric processes.

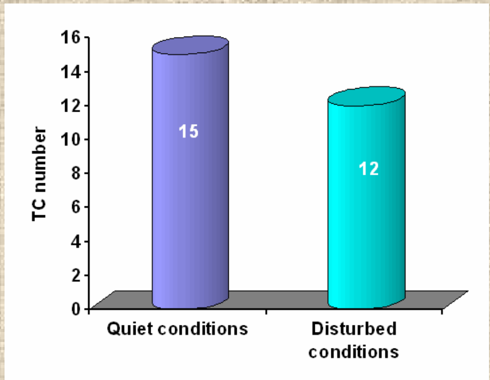
Giant atmospheric vortexes that appear at equatorial latitudes and develop in the tropical regions are the effective mechanism of the excess atmospheric energy release, when the action of usual mechanisms (such as, convective transport and global circulation) becomes insufficient.

Passage of a powerful cyclonic front occurs with excitation of the wide IGW spectrum.



Analyzed periods and TCs over the north-western Pacific

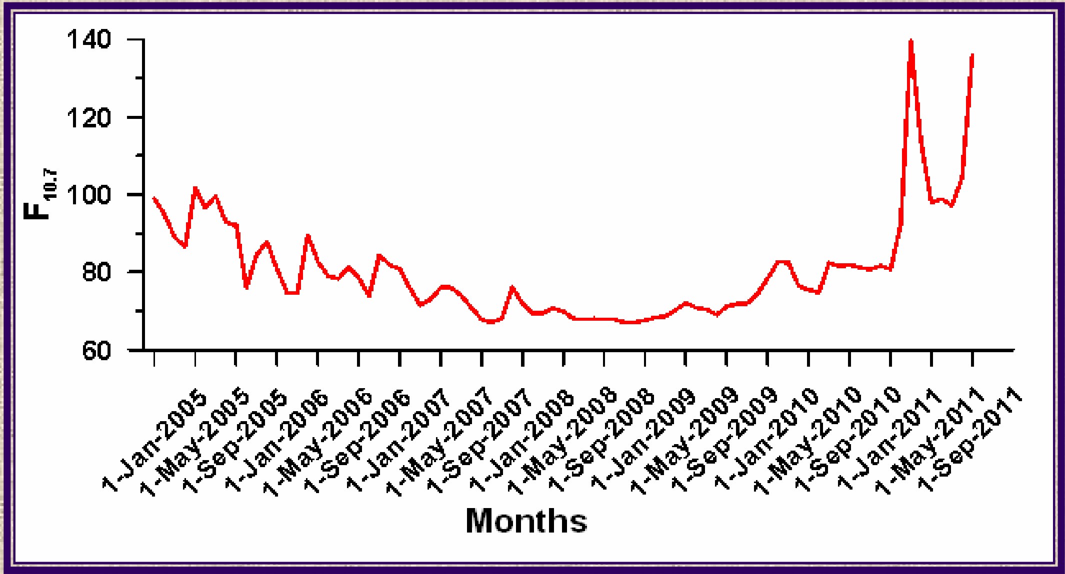
Years	Seasons				
	Spring	Summer		Autumn	
	TC number	TC number	TC category	TC number	TC category
2005	–	no OS measurements		5	Typhoon-4 KHANUN 05-11/09/2005 Typhoon-2 SAOLA 20-26/09/2005 Super Typhoon-4 LONGWANG 25/09-02/10/2005 Tropical storm TEMBIN 07-11/11/2005 Typhoon-1 BOLAVEN 13-20/11/2005
2006	–	no OS measurements		3	Super Typhoon-5 IOKE 19/08-05/09/2006 Typhoon-4 SHANSHAN 10-17/09/2006 Super Typhoon-5 YAGI 17-24/09/2006
2007	–	no OS measurements		4	Typhoon-2 FITOW 28/08-07/09/2007 Tropical storm DANAS 07-11/09/2007 Typhoon-4 NARI 12-16/09/2007 Super Typhoon-4 WIPHA 15-19/09/2007
2008	–	no OS measurements		3	Super Typhoon-4 SINLAKU 07-24/09/2008 Typhoon-4 HAGUPIT 14-25/09/2008 Super Typhoon-5 JANGMI 23/09-01/10/2008
2009	–	no OS measurements		3	Super Typhoon-5 CHOI WAN 12-20/09/2009 Super Typhoon-4 PARMA 27/09-14/10/2009 Super Typhoon-5 MELOR 29/09-08/10/2009
2010	–	2	Typhoon-1 CONSON 11-17/07/2010 Typhoon-1 CHANTHU 18-22/07/2010	3	Typhoon-3 FANAPI 14-20/09/2010 Typhoon-2 MALAKAS 20-25/09/2010 Super Typhoon-5 MEGI 13-23/10/2010
2011	–	4	Typhoon-4 MA_ON 11-22/07/2011 Typhoon-1 NOCK_TEN 24-30/07/2011 Super Typhoon-5 MUIFA 25/07-08/08/2011 Typhoon-1 MERBOK 03-08/08/2011	no OS measurements	
Итого	–	6		21	



During the 7 years under analysis, there were 27 TCs over the north-western Pacific (we took into account the categories of TCs from tropical storm and above). We selected 15 cyclones which were in effect, partially or completely, in quiet helio-geomagnetic conditions.

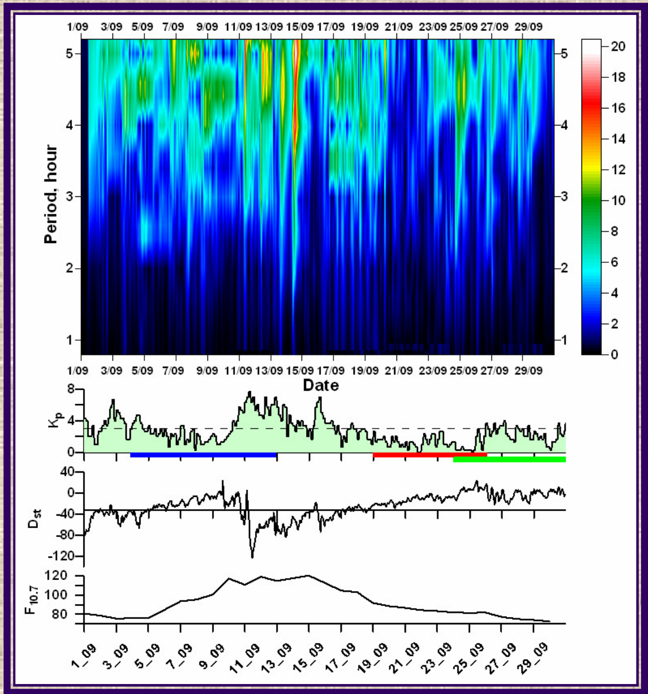
- In the 2005-2011 autumn months, during active tropical cyclogenesis, there were 21 TCs, including 13 super-typhoons (Categories 4, 5). There were cases when several cyclones were in effect simultaneously or closely followed one another.
- In 2010-2011 July-August, there were 6 TCs, including 2 super-typhoons (Categories 4, 5).
- There were no TCs during spring months.

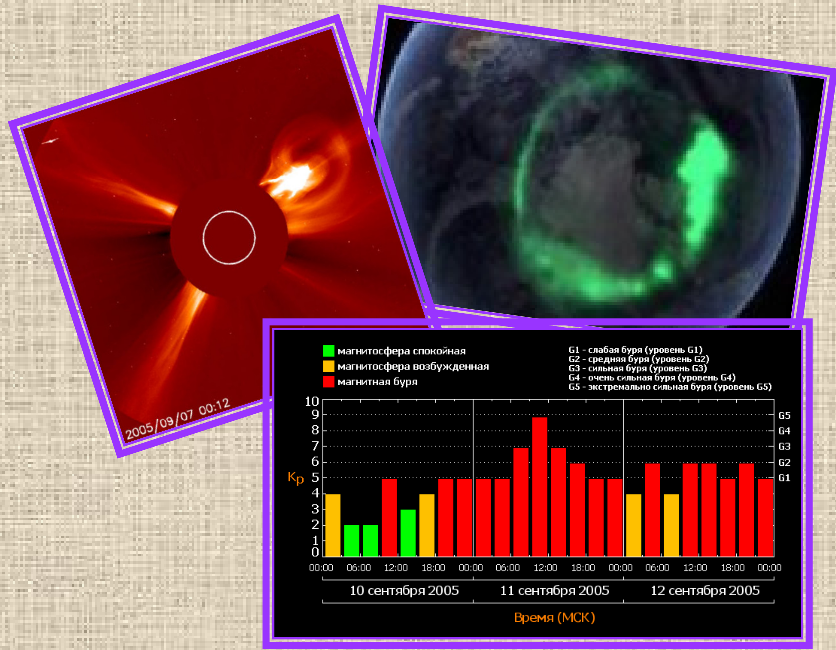
Solar activity during the 2005-2011 experiments



The 2008-2009 period is defined as long solar activity minimum with low intensity of active events on the Sun and geomagnetic disturbances accompanying them. This essentially increased the efficiency in studying ionospheric disturbances associated with the effect of internal atmospheric processes (including meteorological effects).

The MOF running spectrum for the Magadan-Irkutsk path, 2005 Sep





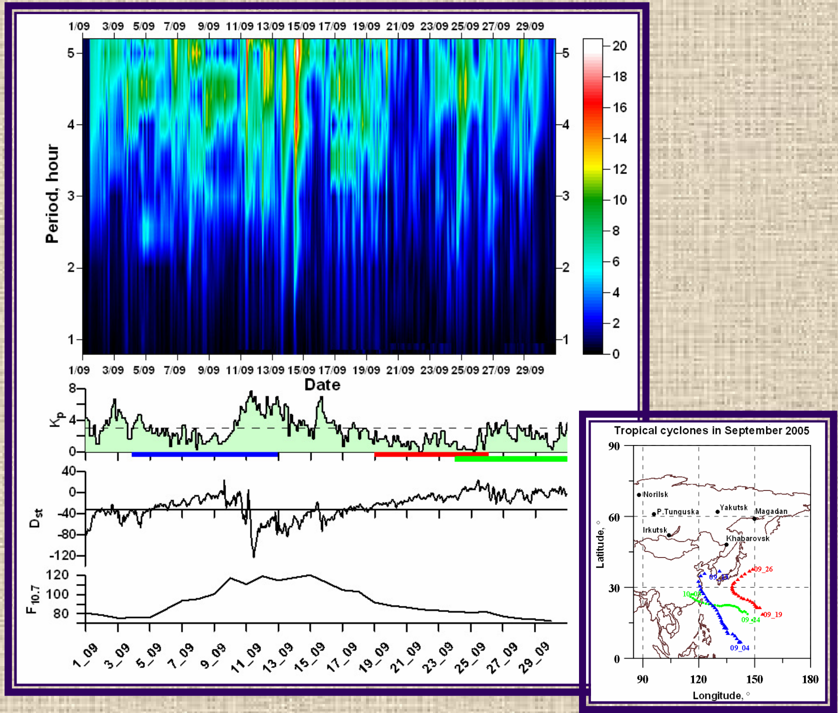
2005, the Cycle 23 decay phase.

2005 Sep 07, an X17 flare (fifth strongest for all the X-ray regular observation time since 1975). It was followed by the 2005 Sep 09 X6.2 flare.

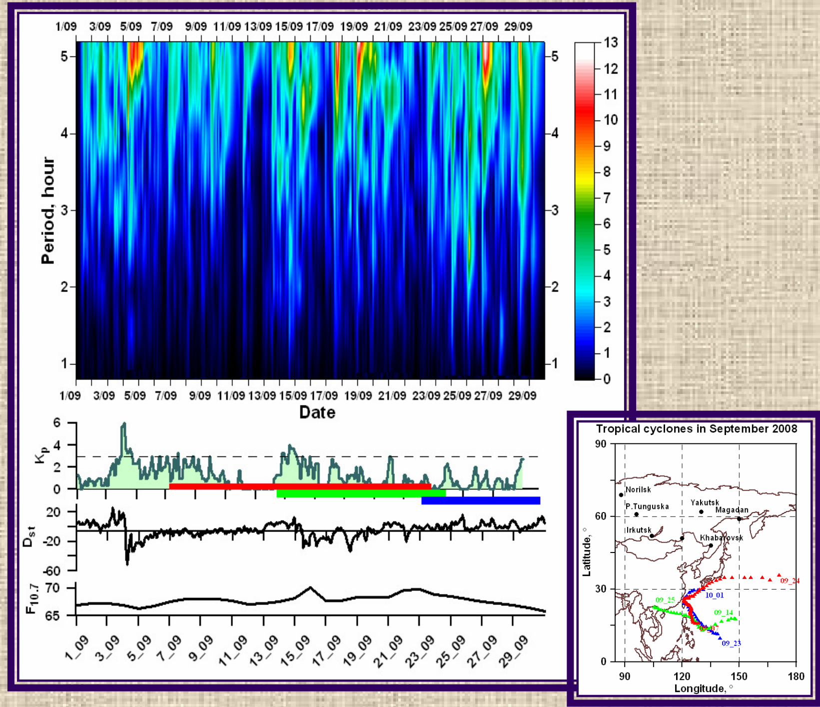
2005 Sep 11-14, two very strong magnetic storms were recorded:

K_p - = 9_- and D_{st} =-139 nT.

The MOF running spectra for the Magadan-Irkutsk path, 2005 Sep and 2008 Sep



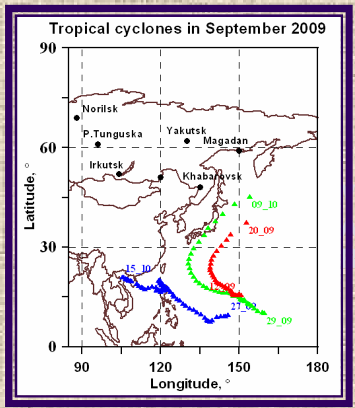
2005, the Cycle 23 decay phase

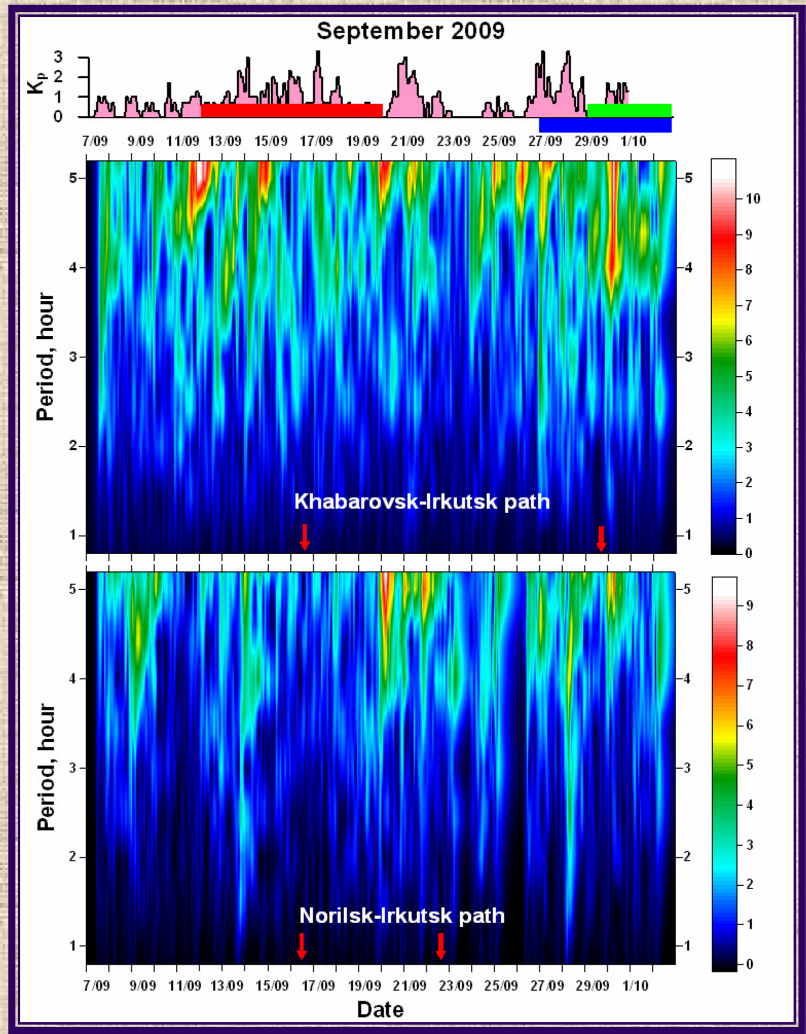


2008, solar activity minimum

Helio-geomagnetic disturbances cause the ionosphere disturbances that are essentially more intensive than those associated with the manifestations of meteorological effects.

The MOF running spectra for the Khabarovsk-Irkutsk and Norilsk-Irkutsk paths, 2009 Sep

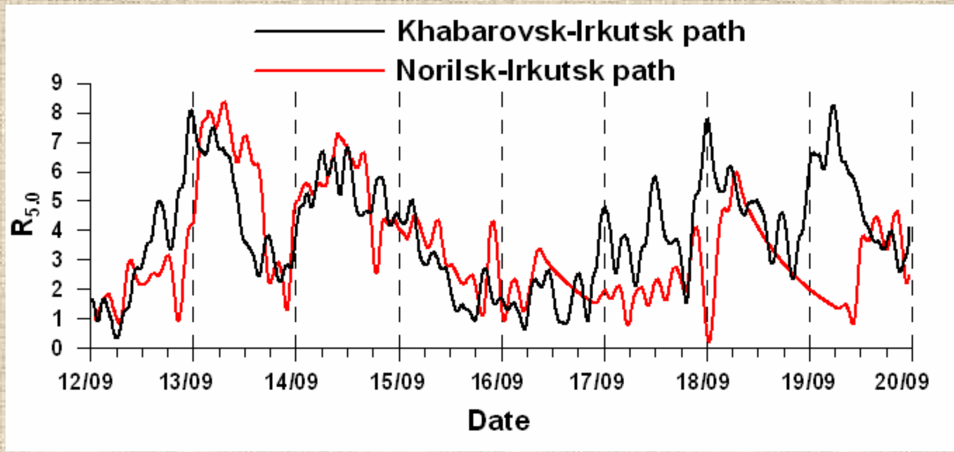


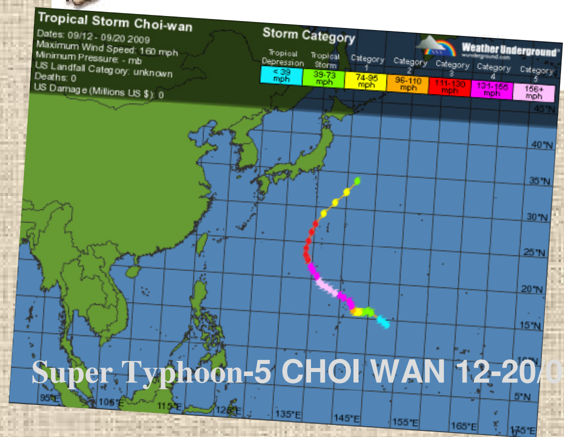


Nevertheless, we revealed the time intervals with an increased energy of 1-5 h wave-like variations, which correspond to periods of TCs in north-western Pacific.

Color lines on plot of the geomagnetic index K_p indicate the lifetimes of tropical cyclones over the north-western Pacific.

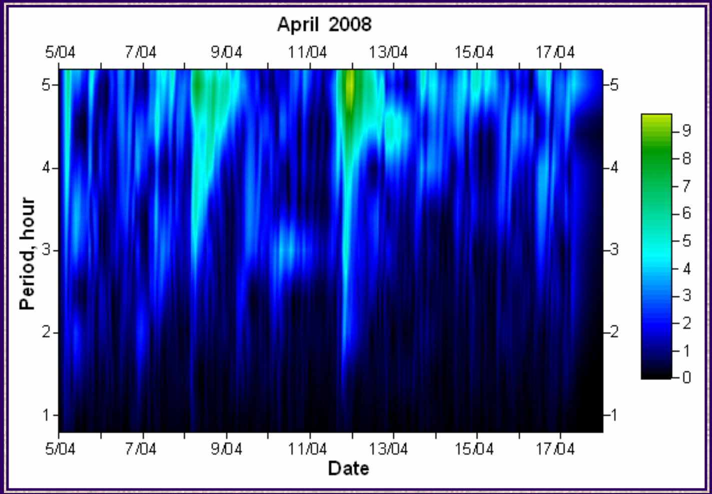
The distance between the midpoints of the Khabarovsk-Irkutsk and of the Norilsk-Irkutsk paths is ~1800 km.
The delay between the TID passing the midpoints of this paths is $\Delta t \approx 3\div6$ h.
Correspondingly, the TID propagation velocity $V \approx 90\div170$ m/s.

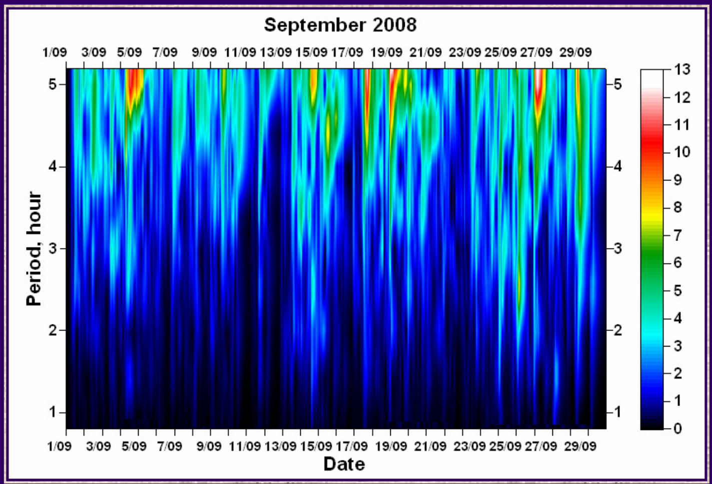




It is known from theoretical estimates, the IGW velocity from the pulsed source may be ~200-300 m/s.
From the experimental estimates, the IGW velocity varies from several tens to a hundred m/s.

The MOF running spectra for the Magadan-Irkutsk path, 2008 Apr and 2008 Sep





One may consider the MOF variation running spectra for the 2005-2011 spring with <u>no TCs</u> and in quiet helio-geomagnetic conditions as the "<u>background</u>" ones.

We compared the background spectra with the disturbance amplitude spectra obtained during the active tropical cyclogenesis in summer and autumn. During spring months, the 1-5 h TIDs were also noted, but their energy was 1.5-2 times lower compared with that of the autumn TIDs.

Results

- **Helio-geomagnetic disturbances cause the ionosphere disturbances that are essentially more intensive than those associated with the manifestations of meteorological effects. Therefore, it is possible to study these manifestations in the ionospheric parameter variations only in quiet helio-geomagnetic conditions.**

- **By using the MOF frequency analysis in quiet helio-geomagnetic conditions, we revealed the time intervals with an increased energy of 1-5 h wave-like variations, which correspond to periods of TCs in north-western Pacific. We also estimated the averaged velocity of wave-like disturbance propagation as ~90-170 m/s. The TIDs intensities depends on the distance from TC.**

- **In quiet helio-geomagnetic conditions, for summer and autumn, during seasons of high cyclonic activity in the north-western Pacific, the intensities of the observed TIDs were much higher compared with that for spring with no TCs.**

THANK YOU FOR YOUR TIME!