Investigations in to the “tropical cyclone- ionosphere" interaction

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Poster ASI1

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Advanced international investigations in to the “tropical cyclone (TC) – ionosphere” interaction are connected with extreme difficulties of proving the action of possible mechanisms of TC effect on the ionosphere. TCs are the greatest troposphere disasters. Powerful surges of charged particles and neutrals, internal gravity wave radiation and low-frequency electromagnetic wave radiation from central points of TCs to considerable altitudes and distances are a manifestation of TC action mechanisms. For a long time the TC has been considered as a thermodynamic system with additional charging by the latent heat of water vapour evaporating directly from the ocean surface, or as the closed thermal machine (Carnot’s cycle). However, satellite investigations have shown that the TC has no relation to the closed thermal machines. It represents the so-called (in the statistical physics) open system working due to continuous exchange of various forms of energy with an ambient medium. And, once the exchange breaks, the cyclone is “filled-in” and transformed into post-typhoon forms of various type. The authors of this presentation analyse the ionosphere parameters, received in the process of both ground and satellite probing above TC and at a certain distance from it.

Ionosphere & Tropical Cyclone

Some historical facts **of atmosphere –ionosphere interactions**

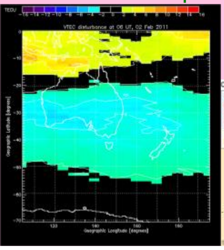
*1.**The radio transmissions strength** (received via the E-layer) varied with the occurrence of cyclones and anticyclones (below the propagation path) (e.g. Colwell 1932). 2.**The ionisation density of the E-layer & the under-lying surface pressure patterns**: direct relation (Ranzi 1932, Martyn 1934). 3. **Thunderstorms** (Prasad et al 1975) , **tornados** (Hung, 1979), **tsunamis**(Peltier, Hines, 1976) and **earthquakes** (Weaver et al 1970) have all been observed to cause **atmospheric gravity waves** which affect the ionosphere.4. **It might reasonably be expected that typhoons would also affect conditions in the ionosphere through both the atmospheric GWs from their strong convective towers and the associated synoptic -scale motions in the stratosphere and ionosphere**. Tsutsui and Ogawa (1974) used a high frequency Doppler sounder to determine vertical motions in the ionosphere as typhoon Helen crossed Honshu (Japan) on 16-17 Sept. 1972. They observed GWs at their sounding frequencies of 5 and 8 MHz. 5.J.Bell repeated the experiments at Hong Kong with Gherzi's cooperation but found no such simple correlation. The strong synchronous seasonal change in the frequency of occurrence of air masses (or of high and low pressure) and of the echoes suggests a relationship. For example, in winter echoes from the F- layer prevail as does high pressure and Siberian air. Whereas in June and July one expects and finds, neither F-echoes nor Siberian air. It is the transition months which test the theory, and it is then that the one to one relationship fails. In both May and September, for example, the returns (on 6 MHz) on days with Pacific (tropical maritime) air prevailing were distributed; E 15%, F1 30% and F2 55%. 6. Gherzi (1946) was the first to suggest that ionospheric soundings could be used as an aid for weather forecasting and for predicting the movement of typhoons. But much of this work was based on misconceptions and some of his claims on this subject have not stood up to scrutiny. 7.Observations have shown that the **passage of tropical storms can lead to perturbations in the plasma drift** [Bishop et al., 2006].*

Relationships between meteorological and ionospheric phenomena

come about through vertical motions in the ionosphere induced by underlying large scale weather systems or from gravity waves (GWs) which originate from the surface or upper troposphere. The amplitude of GWs of certain frequencies increases exponentially with height because of the decreasing density. The growth factor is given, if by the square root of the ratio of the atmospheric density at source and at the height of interest. A displacement at the earth's surface of a few centimetres can originate an atmospheric GW which will grow in amplitude to several kilometres at ionospheric levels. Growth factors of 10^4 to 10^5 are typical. The layers of constant electron density move up and down with oscillatory motions similar to the acoustic pressure wave itself. This phenomenon has been proposed as a method for detecting tsunamis (Peltier and Mines 1976).

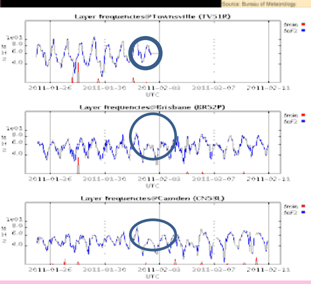
About TEC mapping. (http://www.ips.gov.au/Satellite/2/3/4) This near-real-time ionospheric TEC disturbance map is produced at IPS by removing the 30-day climatology map from the current (observed) TEC conditions. It is therefore representative of the devitation of current ionospheric conditions from those expected for the current time/day/season/solar cycle. The disturbance map shows colour contours of TEC difference (dTEC) in units of TECU (10^{16}electrons/m^2). The data on this map can be used to qualitatively determine whether the regional ionosphere is mildly enhanced (yellow), strongly enhanced (red), mildly depressed (light blue), strongly depressed (purple), or near expected monthly values (black) in the Australasian region. To quantitatively determine the effect of current ionospheric conditions on single frequency GPS positioning, please refer to the real time GPS L1 positioning error map. Displayed here is a dynamically updated recent climatology TEC map produced at IPS from the previous 30 days of observations. The map is produced using a empirical orthogonal function (EOF) analysis over the 30 days in intervals of 15 minutes. EOF is a powerful mathematical tool that decomposes data (in this case the TEC maps) into basis functions that account for as much of the variance in the data as possible. The empirically derived basis functions are ordered from the most significant to the least. Typically, we find the that first four EOFs account for around 95% of the observed variance over the 30 day period. This climatology map is produced from the EOF analysis by determining the median of the coefficients of the EOFs at the given time of day over the 30 day period. By comparing this climatological map with the currently observed conditions, we derive the disturbance map.

TEC Disturbance Map



BBC news

Cyclone Yasi made landfall between Innisfail and Cardwell at around midnight local time (1400 GMT Wednesday). The eye of the storm was reported to be 35km (22 miles) in width, with a front stretching across 650km (400 miles).



-19,7⁰S, 146.9⁰E

-27.5⁰S, 152.9⁰E

-34⁰S, 150.7⁰E

Possible ways TC-ionosphere interactions

1. TCs would also affect conditions in the ionosphere through both the atmospheric GWs from their strong convective towers and the associated synoptic-scale motions in the stratosphere and inosphere. (G.J.Bell,1981).

2. An effect of external electric currents on the global atmosphere-ionosphere el. circuit may be one of possible mechanisms of interaction between atmospheric and ionospheric components. External currents with a horizontal scale of about one hundred of kms may be related to the vertical large-scale convection of the cloudy atmosphere in the zone of a TC and to the charge separation in this region. The electric field disturbance arises due to perturbation in the atmosphere – ionosphere electric circuit generated by the upward transport of charged water drops and aerosols in TC convection zone (Isaev et al, 2005).

GWs generated at tropospheric altitudes propagate to the F-region ;GWs generated from storms break near 100 km and produce secondary waves that continue to propagate upward ;GWs modulate the E-region plasma producing polarization fields that map to F-region altitudes; Strong convection cells produce a wide spectrum of GWs ;GWs increase in amplitude with increasing altitude and may become unstable ;Only waves propagating at the certain angles and with the correct amplitude can reach thermospheric altitudes ;Once in the thermosphere, only those waves oriented to the magnetic field in a particular manner may produce ionospheric disturbances (dr.Rebecca Bishop, PSL/SSAL, 30 March 2012)

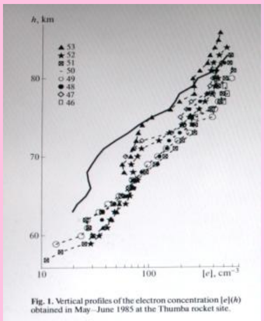


Fig. 1. Vertical profiles of the electron concentration [e](h) obtained in May–June 1985 at the Thumba rocket site.

Response of the Lower Equatorial Ionosphere to Strong Tropospheric Disturbances

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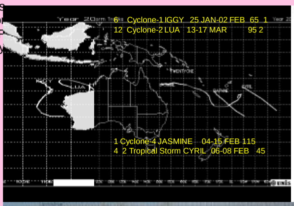
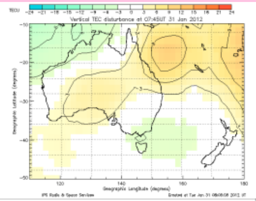
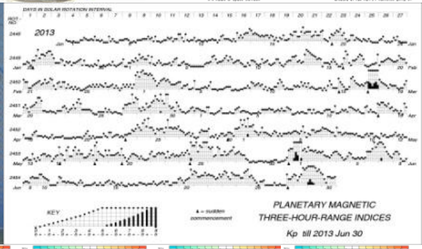
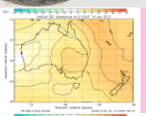
Table 1. Solar and geophysical information accompanying rocket flights in May–June 1985

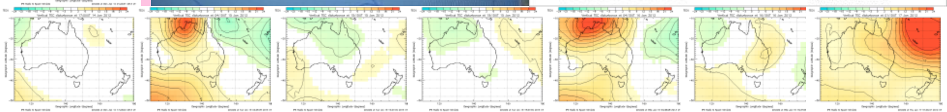
Flight N	Flight data	Flight time (UT)	Zenith, deg angle χ	F10.7	Kp	Ap	Dst, nT
46	01.05.1985	11.34	71	81	3	10	34
47	08.05.1985	11.55	76	84	3	8	5
48	16.05.1985	11.54	76	95	2	11	19
49	22.05.1985	11.35	71	83	1	5	3
50	29.05.1985	11.55	75	73	0	4	4
51	05.06.1985	11.37	70	84	1	5	1
52	19.05.1985	11.58	74	72	1	3	8
53	27.05.1985	12.16	77	70	2	13	13



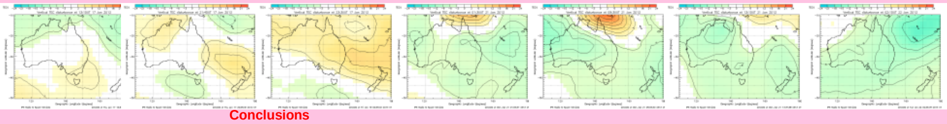








The Examples of the TEC Disturbance Map during TC-events



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3. Sorokin V.M.,Isaev, N.V., Yaschenko A.K., Chmyrev V.M. And .Hayakawa, (2005). Strong DC electric field formation in the low latitude ionosphere over typhoons. J. Atmos. Solar-Terr. Phys. 67, 1331-1342.

4. Rebecca Bishop, PSL/SSAL, 30 March 2012, *http://www.irowg.org/docs/Presentation/bishop.pdf*

Conclusions

1.Analysis of the ionospheric TEC disturbance map demonstrates the possible TC reply. 2.Previus analysis of the electron concentration at altitudes of 60–80 km demonstrate [e] fault after several days after TC beginning. 3. The character of ionosphere variations is dependent on stage and spatio -temporal state of TC, and, of course, on the distance between the TC centre and the point of the ionosphere measurement.**4.** ***It might reasonably be expected that typhoons would also affect conditions in the ionosphere through both the atmospheric GWs from their strong convective towers and the associated synoptic-scale motions in the stratosphere and ionosphere.***