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Occurrence Characteristics of Low Latitude

Ionosphere Irregularities Observed by Impedance Probe

on Board the Hinotori Satellite

Shigeto WATANABE and Hiroshi OYA

Geophysical Institute, Tohoku University Sendai, Japan

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The statistical analyses of occurrence characteristics of the plasma bubbles and blobs are made by using more than 1000 cases of observation data from the swept frequency impedance probe aboard the Hinotori satellite. The results show that formations of the plasma bubbles have the following characteristics. 1) The spatial distribution of the occurrence of the plasma bubbles is in the equatorial region within
±30° of the magnetic dip latitude centered around the magnetic equator, 2) the

occurrence of the plasma bubbles is limited in the nighttime; favorable periods of the plasma bubble formation depend on the type of the plasma bubbles; multiple plasma bubbles (MPB) have tendency to be generated in pre-midnight, while quasi periodic plasma bubbles (QPB) show their maximum occurrence in the post-midnight period. Solitary plasma bubbles (SPB) occur, however, rather independently to the local time in so far as in the night period, 3) the magnetic activity also controls the occurrence of the plasma bubbles; the occurrence of MPB phenomena shifts the peak period to the midnight side with increasing magnetic activity and the occurrence of QPB phenomena which covers the period from midnight to the morning side shows the expansion of their occurrence into late morning period with increasing magnetic activity, 4) correlation of the occurrence of the plasma bubbles to the solar radiation flux represented by F10.7 solar radio flux is evident for MPB and QPB while there is no relation between F10.7 and the occurrence of SPB. Occurrence of the plasma blobs has a complementary nature with that of the plasma bubbles. The occurrence region of the plasma blobs is limited in the edge parts of the plasma bubble occurrence region being limited in the nighttime. The occurrence of the plasma blobs decreases with increasing magnetic activity, while there is a strong anti-correlation of the occurrence of the plasma blobs to the solar radiation (F10.7). The relation of occurrence of the plasma bubbles and blobs to the development of the equatorial anomaly and the asymmetrical distributions of the background electron density suggests the impor-tance of the generalized Rayleigh-Taylor instability including the effects of the electric field and the neutral wind in addition to the gravitational force for the generation of the plasma bubbles and blobs.

1. Introduction

Plasma density irregularities in the equatorial ionosphere have long been

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studied since the starting of the research of spread F phenomena using many kinds of techniques such as ionosondes (RASTOGI, 1980a, 1980b) and radar backscatter techniques (FARLEY et al., 1970; WOODMAN and LAHOZ, 1976; TSUNODA, 1980a, 1980b, 1981; TSUNODA and WHITE, 1981; TSUNODA et al., 1979, 1981) as well as using spacecrafts as rockets (SZUSZCZEWICZ et al., 1980, 1981; RING et al., 1981; NARCISI and SZUSZCZEWICZ, 1981; KELLEY et al., 1982) and satellites (CLARK and RAITT, 1976; MCCLURE et al., 1977; MULDREW, 1980; BENSON, 1981). One of the remarkable outcome of these observations is the discovery of plasma bubbles in the region of the equatorial F region ionosphere. The plasma bubbles are identified as the phenomena which are detected as depletion of the plasma density within a certain restricted region of scale sizes from several tens km to several hundreds km. The depletion of the plasma density is very large with the depletion rate of a few % to 99.9% as detected by the backscatter radar techniques. The remarkable movement of the plasma bubbles in a vertical direction across the magnetic field line with a form of plume in the equatorial ionosphere has also been shown by WOODMAN and LAHOZ (1976). Successful works to simulate numerically the process based on the equations which can describe the Rayleigh-Taylor type instabilities in a nonlinear regime have been carried out (OSSAKOW and CHATURVEDI, 1978; OSSAKOW et al., 1979; ZALESAK and OSSAKOW, 1980; ZALESAK et al., 1982). These results could simulate to some extent of the observational results of the drift velocity and the shape of the plasma bubbles. Crosssectional features of the plasma density distribution in the plasma bubbles have been observed by the Hinotori satellite (OYA et al., 1986) at the level of about 600km along the approximately circular orbit of the satellite. The accumulated data for the crosssection of the plasma bubbles provide further information on the plasma bubbles that could not be obtained by the previous observations based on the radar backscatter techniques.
In the previous paper (OYA et al., 1986), we have shown that the equatorial plasma bubbles are classified in three characteristic types; the multiple plasma bubbles, the quasi periodic plasma bubbles and the solitary plasma bubble. The variety in structure of the equatorial plasma bubbles suggests that there are different types of generation mechanisms of plasma bubbles in the equatorial ionosphere. The Hinotori satellite has discovered, for the first time, the plasma blobs observed as local enhancement of plasma density in the equatorial F region (OYA et al., 1986). The equatorial plasma blobs are classified into two types, that is
type Ⅰ plasma blobs and type Ⅱ plasma blobs. The characteristic length of the spatial extent of the type Ⅰ plasma blobs is formed a few tens km to a few hundred
km while that of the type Ⅱ plasma blobs is more than a few hundred km.

The purpose of the present paper is to report the new results of the plasma bubbles and the plasma blobs at the altitude of about 600km by providing further information on that given in the previous paper (OYA et al., 1986); the paper is mainly focused on the statistical characteristics of occurrence of the plasma bubbles and the plasma blobs. We will also show in this paper the detailed features of the occurrence characteristics of the plasma bubbles and blobs which are not possible

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to be interpreted only in terms of the simple Rayleigh- Taylor instabilities.

2. Spatial Distribution

During a period from February 22, 1981 to June 11, 1982, about 1000 cases of
the plasma irregularities, such as the plasma bubbles and the plasma blobs have
been observed by the Hinotori satellite. The global distribution of the occurrence of these observed plasma bubbles during a period from February 22, 1981 to December 24. 1981 is shown in Fig. 1. The coverage of the observation region by the

Hinotori satellite is limited within ±31° of the geographic latitude due to the
inclination of the satellite orbit. The range of data recording is limited within the
one satellite revolution before passing the data acquisition station at KSC

(Kagoshima Space Center: 131°E). There are, therefore, also limitations of the data
acquisition in longitudinal ranges from 0° to 130° and from 170° to 310°. Within

the limitation of the observation range, however, we can see that the occurrence region of the plasma bubbles is not homogeneously distributed but remarkably localized around the magnetic dip equator. The occurrence region of the plasma

Fig. 1. The geographic longitude and latitude distribution of the orbits of the Hinotori satellite on which the plasma bubbles were observed during the period from February 1981 to December 1981. The hatched areas show regions inaccessible to the Hinotori satellite due to the limitation resulted from both inclination of orbit and the location of the data acquisition station at KSC (Kagoshima
Space Center: 131°E). The plasma bubbles occurin a region around the magnetic dip equator that is plotted by a thin curve.

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blobs described in the first paper of this series of reports (OYA et al., 1986) is reproduced in Fig. 2 for comparison of their global distributions. The occurrence of the plasma blobs is mainly limited to the edge of the occurrence region of the plasma bubbles. This evidence is illustrated in another way as indicated in Fig. 3, in which the occurrence probabilities of the plasma bubbles and blobs, defined as the ratio of the occurrence period of the plasma bubbles or blobs to the total observational period, are plotted versus the magnetic dip latitude. In the two panels in Fig. 3, we can see that the plasma bubbles and blobs take place in a complementary fashion, indicating occurrence peaks of the plasma blobs around the northern and southern
limiting regions of the plasma bubble occurrence, i.e., from+20°to+30° and from

-30°to-20° of the magnetic dip latitude.

3. Local Time Dependence

Local time dependence of the occurrence of the plasma bubbles has been reported by many workers based on ground observations (RASTOGI, 1980a, 1980b; AARONS et al., 1980; BASV et al., 1980a, 1980b). Since the locations of the ground stations are limited at several fixed positions, the data survey is not necessarily able to cover the whole global range. Using data from the Alouette and the ISIS satellite, the global distribution of the plasma bubbles was studied by MULDREW (1980) and

NINOTORI BLOB 1981 Feb.-1981Dec.

Fig. 2. Distribution of the plasma blobs observed by the Hinotori satellite in the same format as Fig. 1. The occurrence of the plasma blobs is limited in the edge of the occurrence region of the plasma bubbles.

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1981 Feb. - 1981 Dec.

Fig. 3. Comparison of occurrence probability of the plasma bubbles with that of the plasma blobs as a function of the magnetic dip latitude.

BENSON (1981). Based on the observational data from the impedance probe (IMP) on board the Hinotori satellite, we have investigated in detail the distribution of both the plasma bubbles and the plasma blobs, using all data in the period from February 1981 to June 1982, as the function of the local time in order to add further information to the previous results. To obtain this result, the dependence of the occurrence on the magnetic latitude has been eliminated by taking summation of the occurrence frequency for the data obtained in all magnetic latitude range within
±30°. It is confirmed that there are homogeneous distribution of data in term of the

magnetic latitude for Hinotori plasma bubble data (OYA et al., 1986). We can, therefore, state that the results in Fig. 4 is purely indicating the local time dependence of the plasma bubble occurrence within magnetic latitude range from -30° to 30°. There are four characteristic periods of the occurrence frequency of

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HINOTORI 1981. 2. - 1982. 6.

Fig. 4. Occurrence probability of the plasma bubbles as functions of the local time observed by the Hinotori satellite in the period from February 1981 to June 1982, whole bubbles which consist of the multiple plasma bubbles, the quasi periodic plasma bubbles and the solitary plasma bubble are denoted by Whole Bubbles.

the plasma bubbles as the function of the local time as have been indicated by the arrows in Fig. 4 which is reproduced from the previous paper (OYA et al., 1986). Two of these characteristic periods appear in the pre-midnight (around 22:00LT) and post-midnight (around 3:00LT) indicating remarkable maxima of the occurrence probability. Around the average occurrence tendency with these two maxima, there are two special periods; one in the evening (around 20:00LT) and the other in the morning (around 7:00LT) forming shoulder shapes of the occurrence probability suggesting additional components of the increasing occurrence probability. As shown in Fig. 4, the occurrence of the plasma bubbles increased rapidly after 19:00LT. At the geographic equator in equinoxes, this local time
coincides with the solar zenith angle of about 105° when the sunlight at 300km

height in the F region of the ionosphere begins to be shadowed by the solid earth

(see Fig. 5). In Fig. 6, the type Ⅰ plasma blobs show a maximum occurrence in the

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period of the post-midnight (3:00LT) while the type Ⅱ plasma blobs indicate maximum occurrence near midnight.

Fig. 5. Positions of the plasma bubbles relative to the solar zenith angle at 600km level in the evening periods. Small circles show positions where the plasma bubbles were observed by the Hinotori satellite.

HINOTORI 8108 1981 Feb. - 1982 Jun.

Fig. 6. Occurrence probability of the type Ⅰ and the type Ⅱ plasma blobs as the functions of local time
observed in the period from February 1981 to June 1982.

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4. Seasonal Dependence

Using the observational data from the impedance probe on board the Hinotori
satellite, seasonal dependence of occurrence of ionospheric irregularities in the
equatorial region has been investigated. Local time of the subsatellite point of the
Hinotori at a fixed latitude and longitude shifts for 24 hours during 2 months. To
eliminate, therefore, the effects of local time dependence in the observed occurrence
probability of the plasma irregularities, we have averaged the occurrence
probability data over 2 months as shown in Fig. 7. The statistics shows that the occurrence probability of the plasma bubbles becomes larger in the periods around the equinoxes than in the period of solstices. On the other hand, the occurrence probability of the plasma blobs becomes maximum in the periods around the
solstices while the probability becomes minimum in the periods around the
equinoxes.

The observed occurrence probability of the plasma bubbles, the type Ⅰ, and the
type Ⅱ plasma blobs are mapped as the functions of the geographic longitude and
the magnetic dip latitude in Figs. 8, 9, and 10, respectively, where the figures refer to
all local time. The most frequent occurrence of the plasma bubbles takes place in a
region over the continent of Africa in the northern summer condition and takes
place over the continent of South America in the northern winter condition. In the
equinox, the occurrence probability of the plasma bubbles becomes higher in the
region of the longitude from-30° to 70° compared with the occurrence probability
in the other region. The results in Figs. 9 and 10 indicate that the plasma blobs (type
Ⅰ and type Ⅱ) do not appear in the region of the magnetic dip equator but frequently
appear in the region of the magnetic dip latitude of about ±20°. Both the
occurrence probability of the type Ⅰ plasma blobs and that of the type Ⅱ plasma blobs

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Fig. 7. Seasonal variation of the 2 months mean occurrence probability of the plasma bubbles and blobs. Percentage of the occurrence is given by the ratio of the 2 months occurrence number of the plasma bubbles or blobs to the total occurrence number.

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BUBBLE 1981 Feb. - 1982 Jun. EQUINOX

NORTHERN SUMMER

NORTHERN WINTER

Fig. 8. Contour maps of occurrence probability (in percentage) of the plasma bubbles on the plane of the magnetic dip latitude (ordinate) and the geographic longitude (abscissa): top panel shows the results under the equinox condition from February 22, 1981 to May 8, 1981 and from February 3, 1982 to May 7, 1982; middle panel shows the results under the northern summer conditions from May 9, 1981 to August 6, 1981 and from May 8, 1982 to June 10, 1982; and the bottom panel shows
the results under the northern winter conditions from November 10, 1981 to February 2, 1982. The region of no observations are indicated by shaded regions as shown in the case of Fig. 1.

show seasonal dependence;especially, the occurrence of the type Ⅱ plasma blobs is localized in the region of winter hemisphere. This seasonal dependence of the

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BLOB TYPE Ⅰ 1981 Feb. - 1982 Jun. EQUINOX

NORTHERN SUMMER

NORTHERN WINTER

Fig. 9. Contour maps of occurrence percentage of the type Ⅰ plasma blobs in the same format as Fig. 8.

occurrence probability of the large plasma irregularities (the plasma bubbles and the plasma blobs) seems to reflect the seasonal variation of control parameters of the original plasma instabilities. One of the control parameters may be the plasma density distribution of the ionospheric F layer which is strongly affected by the

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BLOB TYPE Ⅱ 1981 Feb. - 1982 Jun. EQUINOX

NORTHERN SUMMER

NORTHERN WINTER

Fig. 10. Contour maps of occurrence percentage of the type Ⅱ plasma blobs in the same format as Fig. 8.

ionospheric electric field, the neutral wind and the geomagnetic field configuration as well as the solar EUV radiations. The seasonal dependences of the occurrence of the plasma irregularities discovered from the statistic studies on the plasma bubbles and blobs from the Hinotori satellite data are summarized into two evidences. The

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first is the seasonal variation of the occurrence probability in scale for all over the globe integrated within data coverage regions. The second is the seasonal variation of the longitudes where the maximum occurrence of the plasma bubbles and blobs are taking place. These two evidences are considered as an important manifestation
of the occurrence of the underlying ionospheric instabilities. We will consider the possible plasma instabilities which can consistently interpret the observed seasonal variations in the section of "Discussion".

5. Dependence on Magnetic Disturbances

It is widely understood that the ionospheric F region is remarkably affected by the magnetic storm, increasing or decreasing of electron density depending on the phase of the magnetic storm. Storm induced heating of the neutral atmosphere which affects the atmospheric composition may be responsible for these effects (BAUER, 1973; and the reference therein). We, then, investigated the dependence of the occurrence of the plasma bubbles and blobs on the magnetic activity given by the Kp index using electron density measured by the Hinotori satellite in a period from February 1981 to June 1982, since the formation of the plasma bubbles and blobs is closely associated with the plasma density distribution in the F region. In Fig. 11, the occurrence probabilities of the plasma bubbles are plotted as functions of the local time with the Kp index as a parameter. The results show that the dependence of the occurrence probability of the plasma irregularities on the magnetic activity reveals different features corresponding to the type of the plasma irregularities. The occurrence probability of MPB (Multiple Plasma Bubbles) during magnetically active periods increases for the local time from midnight to morning while it decreases for the local time in pre-midnight. The occurrence probability of QPB (Quasi Periodic Plasma Bubbles) during magnetically active periods for the local time increases in the morning while it decreases for the local time in post-midnight. The occurrence probability of SPB (Solitary Plasma Bubble), however, does not show any remarkable dependence on the magnetic activity.
The dependence of the occurrence of the plasma blobs on the magnetic activity
is shown in Fig. 12, where the occurrence probability of the plasma blobs is plotted as functions of the local time with the KP index as a parameter. In contrast with the occurrence probability of the plasma bubbles shown in Fig. 11, the occurrence probability of the plasma blobs becomes small during magnetically active periods.
Especially, the occurrence ofthe type Ⅱ plasma blobs is limited to the period of the magnetically quiet condition.

6. Effects of Solar Radiations

The variations in the solar radiation flux in the EUV ranges caused by the changes in solar activity affect the plasma density distribution of the F region ionosphere as the results of the variations in the ionization rates. The enhancement

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(a) Type Ⅰ Plasma Blobs

(b) Tvpe Ⅱ Plasma Blobs

Fig. 12. Same as Fig. 11 for (a) type Ⅰ plasma blobs and (b) type Ⅱ plasma blobs. Clear anti-correlations with the Kp value are evident for the occurrence of these two types of blobs.

of EUV radiations also causes the increase of the temperature of the thermosphere which affects the neutral wind and the dynamo electric field. Since the formation of the plasma bubbles and blobs is closely associated with the plasma density distribution in the ionospheric F region, we may expect the dependence of the occurrence of the plasma bubbles and blobs on the EUV radiations.
HALL et al., (1969) and HINTEREGGER (1970) have investigated the relation between the intensity of EUV radiations and that of the radio wave at 10.7cm (F10.7) which is mainly caused by synchrotron radiation and is closely related to the distribution of the sunspot containing a complicated magnetic field. Their results show a good correlation of the intensity of F10.7 with the intensity of EUV radiations. Therefore, we can use F10.7 data as the indicator of the average activity of the sun.

In the present work, we have found the positive correlation between F10.7 intensity and the occurrence of the plasma bubbles and blobs, for the first time. In Figs. 13 and 14, the occurrence probabilities of the plasma bubbles and blobs are plotted as functions of the local time with solar flux intensity F10.7 as a parameter. In

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(a) Type Ⅰ Plasma Blobs

(b) Type Ⅱ Plasma Blobs

Fig. 14. Same as Fig. 13 for (a) type Ⅰ and (b) type Ⅱ plasma blobs. Anti-correlation with F10.7 value of the occurrences for both types of the blob is evident.

In Fig. 13 (a), the occurrence probabilities of MPB (Multiple Plasma Bubbles) clearly indicate that the peak values of the occurrence probability in the pre-midnight period remarkably increase with the F10.7 intensity. The dependence of the occurrence probability of QPB (Quasi Periodic Plasma Bubbles) on the F10.7 intensity is indicated in Fig. 13 (b) where the peak values of QPB occurrence in the post-midnight period are fairly dependent on the F10.7 intensity. Contrary to these two cases of the MPB and QPB, the occurrence probability of SPB (Solitary Plasma Bubble) in Fig. 13 (c) shows no dependence on the F10.7 intensity.
The occurrence probability of the plasma blobs in Fig. 14 indicates a tendency
of the anti-correlation with the F10.7 data; i.e., the occurrence probability decreases
with the increasing F10.7 intensity. Especially, the occurrence of the type Ⅱ plasma

blobs is limited only in the period of the very low F10.7 intensity. These phenomena are similar to the results of SHIMAZAKI (1959) and SINGLETON (1968), which indicate that spread F observed by the bottomside sounder occurs more frequently during the sunspot minimum year than during the sunspot maximum year in the low latitude region. In our analyses, it has been indicated that the plasma bubbles

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mainly appear in the periods of the increased F10.7 value while the plasma blobs do not appear in these periods. These results show that the generation of the plasma bubbles and blobs is closely associated with the formation of the ionospheric F region which is strongly affected by the EUV radiations.

7. Effects of Ionospheric Electric Field and Neutral Wind

It is known that the plasma density distribution of the ionospheric F layer in the equatorial region is strongly affected by the electric field and the neutral wind; i.e., the development of the equatorial anomaly is associated with the enhancement of the eastward electric field, and the asymmetry of the plasma density distribution with respect to the magnetic equator is associated with the meridional neutral wind flowing across the magnetic equator as well as with the seasonal effect on the atmospheric composition. Since the occurrence probability of the plasma bubbles and blobs is closely associated with the formation of the ionospheric Flayer, we can expect existence of the relation of the occurrence probability of the plasma bubbles and blobs to the distribution of the ionospheric plasma density. In the orbit, Rev. 4039 of the Hinotori satellite, the plasma bubbles with the depletion of 90% of background electron density appeared in the periods of 14:41UT and 14:44UT when the background electron density in the period between 13:56UT and 14:47UT shows remarkable increase from the level in the orbit of Rev. 4038. The plasma bubbles representing the same structure observed in the orbit of Rev. 4039 are also detected in the orbit of Rev. 4040. The positions of the plasma bubbles are plotted with the bars crossing each of the satellite orbit in the map (lower panel in Fig. 15). The shift of longitudinal positions may be caused by the drift of the ionospheric plasma containing the plasma bubbles. If the plasma bubbles are aligned along the magnetic field line (TSUNODA, 1980b; BENSON, 1981), the movement corresponding to the eastward drift motion is estimated from the time interval of Revs. 4039 and 4040 to have a speed of about 68m/sec in the direction perpendicular to the magnetic field line.
The relation of the plasma bubbles and blobs to the background electron density during the 6 months period from February 1981 to August 1981 is shown in Fig. 16. The background electron density values in the region of the plasma bubbles and that of the plasma blobs are compared with the electron density, containing the effect of the magnetic latitude, observed in the orbits, Revs. 351,455 and 570 where no plasma bubbles and blobs are detected. Figure 16 indicates that the background electron density for the condition of the plasma bubble formation and that for the plasma blob formation are always higher and lower than the electron density without the plasma bubbles and blobs, respectively. The background electron density distributions for the condition of the plasma bubble formation, measured by the Hinotori satellite, are indicated in Figure 17, where the magnetic dip latitude is given in the ordinate and the local time is given in the abscissa. The data used here were obtained in equinox condition from February 23, 1981 to April 8, 1981. It is evident from Fig. 17 that the background electron density distributions for the

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Fig. 15. Time variation of electron density along the path of the Hinotori satellite for Rev. 4038, 4039 and 4040 successively observed on November 18, 1981 during time given in the corresponding panels. Arrows indicate the positions of the plasma bubble (see top two panels). Corresponding satellite paths are shown in bottom panel where open circles and bars plotted on the satellite paths show positions of the peak electron density enhancement and positions of the plasma bubbles
indicated by arrows in the top panels, respectively. Curves for the magnetic dip latitude of 10° and
the magnetic longitude of 250°, 260° and 270° are also shown by dotted lines.

condition of the plasma bubble formation (see bottom two panels) indicate existence of well developed equatorial anomaly in the evening hours which is seen by the separation of the ionization peaks at both sides of the magnetic equator. It is well-known that the formation of the equatorial anomaly is caused by the existence of the eastward electric field. It may be therefore thought that the formation of the plasma bubbles appearing in the evening periods are associated with the eastward electric field. In the period of the post-midnight, the plasma bubbles occur with the asymmetrical distribution of the background electron density with respect to the
magnetic dip equator (see Fig. 17). In the longitudinal range from 0° to 110°, the

background electron density is higher in the northern hemisphere than that in the southern hemisphere. The asymmetry of electron density distribution with respect

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Fig. 16. Background electron density values at a close region of the plasma bubbles (plotted by short bold lines) and that of blobs (series of dots) as a function of the local time for the data obtained by the Hinotori satellite in the period from February 1981 to August 1981. The electron density values under the condition of neither plasma bubbles nor blobs, i.e., Revs. 351,455 and 570, are indicated
by broken curves; these values are evidently in the middle range between the background density values for the bubble formation and those for blob formation.

to the magnetic dip equator is remarkably seen by comparing (a) and (b), and also (c) and (d) around 18-22h and 1-15h LT in Fig. 17. Due to the tilt of the magnetic dipole axis with respect to the earth's rotation axis, the geographical equator is
located at about-10° of the magnetic dip latitude in the longitudinal range from 0°
to 110°, while the geographical equatoris located+10° ～+15° of the magnetic dip
latitude in the longitudinal range from 200° to 330°. These conditions provide the

possibility to increase electron density due to the meridional neutral wind in the region of the geographical equator asymmetrically with respect to the magnetic dip equator. The evidence may suggest that the neutral wind in the meridional plane is strictly related to the formation of the plasma bubbles.

8. Discussion

Using the data obtained with the impedance probe on board the Hinotori satellite, the occurrence characteristics of the equatorial plasma bubbles and blobs in the F region ionosphere have been investigated based on statistical studies. Though the phenomena themselves are already familiar, the present results reveal

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the new features of occurrence characteristics of the equatorial plasma irregular-ities. Especially, important clues are obtained for the understanding of the generation mechanisms of the equatorial plasma bubbles and blobs.
The previous understanding on the generation of the equatorial plasma bubbles, based on the theoretical results of OSSAKOW (1981), is the following. After local sunset, the gradient in the ionospheric electron density of bottomside Fregion begins to be steepen. When the altitude of the F region is high enough and the gradient in the bottomside electron density distribution is steepen due to the fast recombination processes between ions and electrons, the plasma bubbles begin to grow as a results of a Rayleigh-Taylor type instability in the region of bottomside F layer.
Since the altitude of the equatorial F region becomes high in evening in summer conditions due to the strong eastward electric field as has been discovered based on the measurements of plasma drift motion at Jicamarca using radar technique (FEJER et al., 1979), the Rayleigh-Taylor instability is driven in the bottomside of the equatorial F region. The strong eastward electric field itself may also generate the plasma instabilities which may be seeds for the formation of the plasma bubbles;
i.e., in the form of the E×B drift instability. As shown in Fig. 4, the occurrence

probability of the plasma bubbles forming the shoulder-like shape in the evening period (20:00LT) corresponds to the period of the strong eastward electric field reported by FEJER et al. (1979). Furthermore, we indicate that the plasma bubbles occurring in the evening are associated with the development of the equatorial anomaly which is resulted from the strong eastward electric field (see Fig. 17). The deviation of the location of the magnetic dip equator from the geographic equator causes the longitudinal variation of the F region height at the region of the magnetic dip equator. The occurrence probability of the plasma bubbles observed by the Hinotori satellite is, therefore, considered to show the longitudinal variation, i.e., the maximum occurrence probability of the plasma bubbles, which appear at
the region around 0° of the geographic longitude in the equinox condition, shifts to the region around 30° of the geographic longitude in the northern summer condition and shifts to the region around 340° of the geographic longitude in the

northern winter condition (see Fig. 8).
ZALESAK et al. (1982) suggested that the E region conductivity is very important to generate the plasma bubbles in the bottomside of the Fregion because the polarization electric field in the plasma bubbles is partially shorted out by this E region conductivity. Though the occurrence of the plasma bubbles observed by the Hinotori satellite is mainly limited to the condition when the region near the magnetic dip equator is in the summer condition. Furthermore, the plasma bubbles occur in the whole region of the geographical longitude near the magnetic dip equator in the equinox condition (see Fig. 8). This result may suggest that the effect of the E region conductivity controls the occurrence of the plasma bubbles whose occurrence probability enhances in the equinox condition (see Figs. 7 and 8) when the E region conductivity at the end of the magnetic field lines becomes to be small in the evening period.

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Due to the deviation of the location of the magnetic dip equator from the geographic equator, the neutral wind in the direction of meridional plane is able to flow across the magnetic dip equator in the nighttime. In this condition, the plasma bubbles may be also generated in the bottomside of the F region in the summer condition by the neutral wind as a result of the neutral wind driven instability (CHID and STRAUS, 1979; ZALESAK et al., 1982). The importance of this generation mechanism can be inferred from the relation between the occurrence of the plasma bubbles and the background electron density values at a close region of the plasma bubbles; the plasma bubbles occur with the asymmetrical distribution of the background electron density with respect to the magnetic dip equator in the period of the post-midnight as shown in Fig. 17.
The generation mechanism of the plasma blobs which has been discovered by OYA et al. (1986) for the first time in the equatorial topside F region can be understood by considering both the seasonal variation and the local time dependence of the plasma blobs; the plasma blobs mainly appear in the winter hemisphere and in the post-midnight period when the meridional neutral wind strongly flows across the magnetic dip equator. This result suggests that the plasma blobs grow as a results of instabilities driven by the neutral wind in the topside F region in the winter hemisphere. This is under the complementary situation for the formations of the plasma bubbles.

9. Conclusion

We have investigated the occurrence characteristics of the plasma bubbles and blobs based on statistical studies for the spatial distribution in terms of i) magnetic dip latitude, ii) local time dependence, iii) seasonal dependence, iv) dependence on the magnetic activities, v) dependence on the solar radiation, vi) relation to the equatorial anomaly, and vii) relation to the asymmetrical distribution of the electron density with respect to the magnetic equator, using the electron density data from the impedance probe experiments on board the Hinotori satellite. The investigations have provided us a greater understanding of the plasma bubbles and blobs.

The complementary feature of the occurrence regions of the plasma bubbles and blobs was reported in a previous paper (OYA et al., 1986). The present results provide additional information to confirm this evidence. That is, through this study, it is clearly confirmed that the plasma blob was not observed near the
magnetic dip equator but observed in the region from ±10° to ±30° of the

magnetic dip latitude unlike the plasma bubble whose occurrence probability is maximized at the magnetic dip equator. Further confirmation has also been made for the occurrence probability of the plasma bubbles and blobs which shows a clear seasonal dependence and the local time dependence (see OYA et al., 1986). New evidence for the longitudinal distribution of the occurrence probability of the plasma bubbles is discovered. The maximum occurrence probability of the plasma
bubbles appears at the region around 0° of the geographic longitude in the equinox

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condition. The maximum occurrence probability shifts to the region around 30° of
the geographic longitude in the northern summer condition and shifts to the region
around 340° of the geographic longitude in the northern winter condition. The
occurrence probability of the plasma blobs is enhanced to the condition of solstices.
Especially, the type Ⅱ plasma blobs are only observable in the winter hemisphere.

The occurrence of the plasma bubbles and blobs shows remarkable depen-dence on the magnetic activity and the solar radiation flux. The dependence shows, however, different features for different type of the plasma irregularities. The occurrence probability of the multiple plasma bubbles (MPB) during magnetically active periods increases in the local time period from midnight to morning and decreases in the local time period of pre-midnight; and the occurrence probability of the quasi periodic plasma bubbles (QPB) increases during the magnetically active period in morning while it decreases in the local time period of post-midnight. In the period of pre-midnight and post-midnight, the occurrence probability of MPB and QPB increases with increasing solar radiation. Contrary to the cases of MPB and QPB, the occurrence probability of the solitary plasma bubble (SPB) depends neither on the solar radiation, nor on the magnetic activity. The plasma blobs occur exclusively in a period of the magnetically quiet condition. Furthermore, the occurrence probability of the plasma blobs decreases with increasing solar radiation.
We have investigated the relationship of the plasma bubbles and blobs to the equatorial anomaly and the asymmetrical distribution of the background electron density with respect to the magnetic equator. The results indicate that the generation of the plasma bubbles in the period of pre-midnight are associated with the strong eastward electric fields which contribute to the development of the equatorial anomaly. It is also indicated that the generation of the plasma irregularities in the period of post-midnight is associated with the meridional neutral winds which results in the asymmetrical distribution of the background electron density with respect to the magnetic dip equator. We can, then, indicate the
importance of the E×B drift instability and the neutral wind driven instability as

the seeds of generation of the plasma irregularities in the equatorial ionosphere; i.e., the instability which includes the effects of the electric field and the neutral wind in addition to the gravitational force, called the generalized Rayleigh-Taylor instability, plays a remarkably important roles in the formation of plasma bubbles and blobs.

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