Geomagnetic Variations Related to Eruptions of Izu-Oshima Volcano in 1986 - 1987

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The bulk of Oshima volcano is composed of basaltic lava that contains large amount of magnetic minerals such as magnetite and titanomagnetite. Magnetization of the basaltic rocks is as intense as 10^{-2} emu/cc, so that the geomagnetic field on the volcano is substantially disturbed. Consequently, the magnetic anomaly produced in this way is very large. Oshima volcano is, therefore, one of the most appropriate volcanoes for investigation of the magnetic variations caused by the volcanic activity. There are indeed many studies reporting the changes in the magnetic field associated with the activity of Oshima volcano (see, for example, Rikitake, 1951; Yokoyama, 1969).

Three mechanisms are now considered for causing the magnetic change related to the volcanic activity, demagnetization of rocks by thermal heating, by increase or decrease in stress, and by disordering of magnetic particles through mechanical vibration, rotation and displacement.

Remanent magnetization of rocks is highly dependent on temperature (see, for example, Nagata, 1961). Most of rocks on Oshima volcano lose their magnetization below 570°C, Curie temperature for magnetite. Even at lower temperature, magnetization is reduced greatly by heating. It is not difficult to reduce magnetization of the order of 10^{-3} emu/cc by heating up rock to a few hundred degrees.

Magnetization also changes when stress is applied to a magnetized rock. The effect of stress is complicated. There are two kinds of effects, the reversible and the irreversible effect. When a uniaxial pressure is applied, magnetization in the direction of the applied pressure is reduced, whereas magnetization normal to the axis is slightly strengthened. This process is reversible. On the other hand, the irreversible effect in such a weak magnetic field as the geomagnetic field works usually to reduce the magnetization.

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Another mechanism was recently proposed (Hamano, private communication) to cause variation in the magnetic field. Before a volcanic eruption, magnetic particles are fixed statistically with their average magnetization parallel to the geomagnetic field. Due to this alignment, a volcano has magnetization, as a whole, in the direction of the geomagnetic field. At the time of eruption, volcanic gas, steam and highly pressurized thermal fluids penetrate into porous rocks of the cone. This may cause mechanical vibration, rotation and displacement of magnetic particles so as to disorder the alignment of their magnetization and reduce the bulk magnetization of the volcano.

Corresponding to different phases of the volcanic activity, remarkable changes in the magnetic field were observed. Several years before the eruption, anomalous variation started. At the time of eruption, a rapid change in total intensity occurred. Variation after the eruption was particularly large. Associated with a small eruption that took place in November 1987 one year after the major eruption, remarkable changes were also observed.

1. Anomalous variation before eruption

At the southern foot of the central cone, Mihara-yama, a proton magnetometer has been operating since 1978 to measure the total intensity of the geomagnetic field. The total intensity at this site MI* (see Fig.1) started to decrease around the beginning of 1981 in comparison to other sites on the volcano. [* denotes the observation site where the data were discontinued when magnetometers destroyed by eruption.] Figure 2 shows difference in total intensity between the sites MI* and NOM, site at the west coast (Fig. 1). The rate of this anomalous decrease was about 5.3 nT/year (-0.44 nT/month) for the period from 1981 to the end of 1985. In 1986 the intensity decrease was accelerated. The rate of decrease for the last 6 months before the eruption, from May to November 1986, became as large as 2.2 nT/month.

The anomalous decrease in total intensity was found to be a very local phenomenon. In June 1986, a proton magnetometer was installed about 200 m south of the previous site MI*. At this site (MI2*) no such anomalous variation was observed. Figure 3 shows a comparison of the variation in the total intensity at the two sites. Although the observation period was only 6 months at MI2*, the difference is clearly seen between the two. At MI2* the variation is almost flat, whereas at MI* the total intensity decreases rapidly. This implies that the source of the anomalous variation is very localized and perhaps shallow. Until the eruption in November, 1986, the decreasing trend at MI* has continued about 6 years. This decreasing change may be ascribed, for its long time scale, to demagnetization of the region near the volcanic vent by heating.

2. Variation at the time of eruption

A rapid variation was observed at the time of eruption at site MI*. Figure 4 shows time variation in hourly means of the total intensity difference between MI* and NOM. The eruption occurred from the so called A crater around 17h20m on November 15. A rapid decrease of the total intensity was observed around 17h50m. Difference of the hourly mean values between 17h and 18h amounts to 5.8 nT.

This rapid phenomenon is difficult to explain by thermal demagnetization of rocks, since the thermal process usually takes a much longer time. Demagnetization due to pressure effect is one possible mechanism. Increase of pressure is supposed to decrease magnetization. However, it is not known why the rapid magnetic variation took place about 30 minutes after the initial eruption. If this is due to the pressure effect, demagnetization is expected to proceed gradually as pressure increases before eruption. When eruption occurs, rapid demagnetization could take place by release of pressure, and the demagnetization is suspected to be the largest at the time of eruption. Another possible mechanism to explain this rapid variation is disordering of magnetic particles by explosive flow of gases and fluids through pores inside rocks. However, the same question as in the case of pressure effect remains, that is, why the largest variation did not occur by the first eruption. A certain unknown phenomenon might have happened 30 minutes after the first eruption.

3. Magnetic variations associated with the fissure eruptions

Since many instruments had been destroyed by eruptions of the central cone, only a few magnetometers far from the crater were operating at the time of the fissure eruptions. One of them is the proton magnetometer at the site FUT (see Fig. 1) about 2 km southeast of the central cone. In association with the fissure eruption, about 7 nT decrease in total intensity was observed. Figure 5 shows time variations in the total intensity with reference to the site NOM. This phenomenon was not as rapid as that observed at the time of eruption of the central cone. It took one and a half days for the total intensity to decrease by 7 nT. Unfortunately, at a northern site WST, no data was available at the time of the eruption, but increase of about 8 nT is seen in Fig. 5 during 12 days before and after the eruption. At both sites the total intensity after the eruption is gradually recovering to the state before the eruption. These variations are likely to be caused by a pressure effect associated with dike-like intrusions of magma.

4. Variations after the eruption of the central cone

After the eruption of the central cone, proton magnetometers were installed again at the southern sites MI0, MI1, MI2. MI1 and MI2 are close to the previous sites MI* and MI2* but slightly different. After re-installation it was found that the total intensity was still decreasing, and the decreasing rate was by far larger than before the eruption. Figure 6 shows the variations at MI0 and MI2. The decreasing rate at MI0 in March and April 1987 was as large as 15 nT/month. This is about 35 times larger than that before eruption at site MI*. The total intensity decreased exponentially, and seemed to approach a steady state in August. This suggests that thermal demagnetization continued even after the eruption, and transport of heat was much more efficient after the eruption than before.

5. Variations associated with the eruption of the central cone in November, 1987

The total intensity at the southern foot of Mihara-yama appeared to be converging to a steady state around August of 1987. However, another phase of activity of the central cone started, and the decrease of the total intensity accelerated towards the end of August as seen in the plots of MIO in Fig. 6. Eruptions occurred twice in November, on 16th and on 18th. The decreasing trend of the total intensity was further accelerated by the eruption on November 16. At the time of the eruption the total intensity decreased by 7 nT for 1 minute. However, such a large variation was not observed at the time of eruption on November 18. On the contrary, the decreasing trend ceased after the eruption. This is also a remarkable feature of the variations in the total intensity observed during the current activity of the volcano. The phenomenon is too rapid to be explained by a thermal process. A better explanation may be that this rapid variation is caused by disordering of magnetic particles. After the pressure inside the vent was released by the eruption on November 18, no brisk penetration of gases and fluids seems to have occurred. Subsequently, neither movement nor rotation of magnetic particles could be provoked, and the decrease of the magnetic field stopped.

References

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Fig. 1 Observation sites.

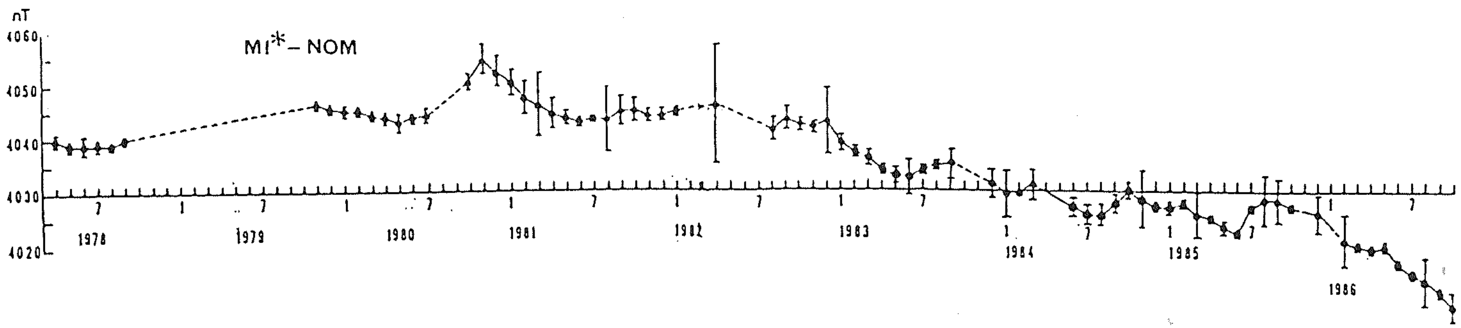


Fig. 2 Anomalous decrease in total intensity at the south of Mihara-yama MI^*. Monthly means of difference in the total intensity between MI^* and NOM are plotted.

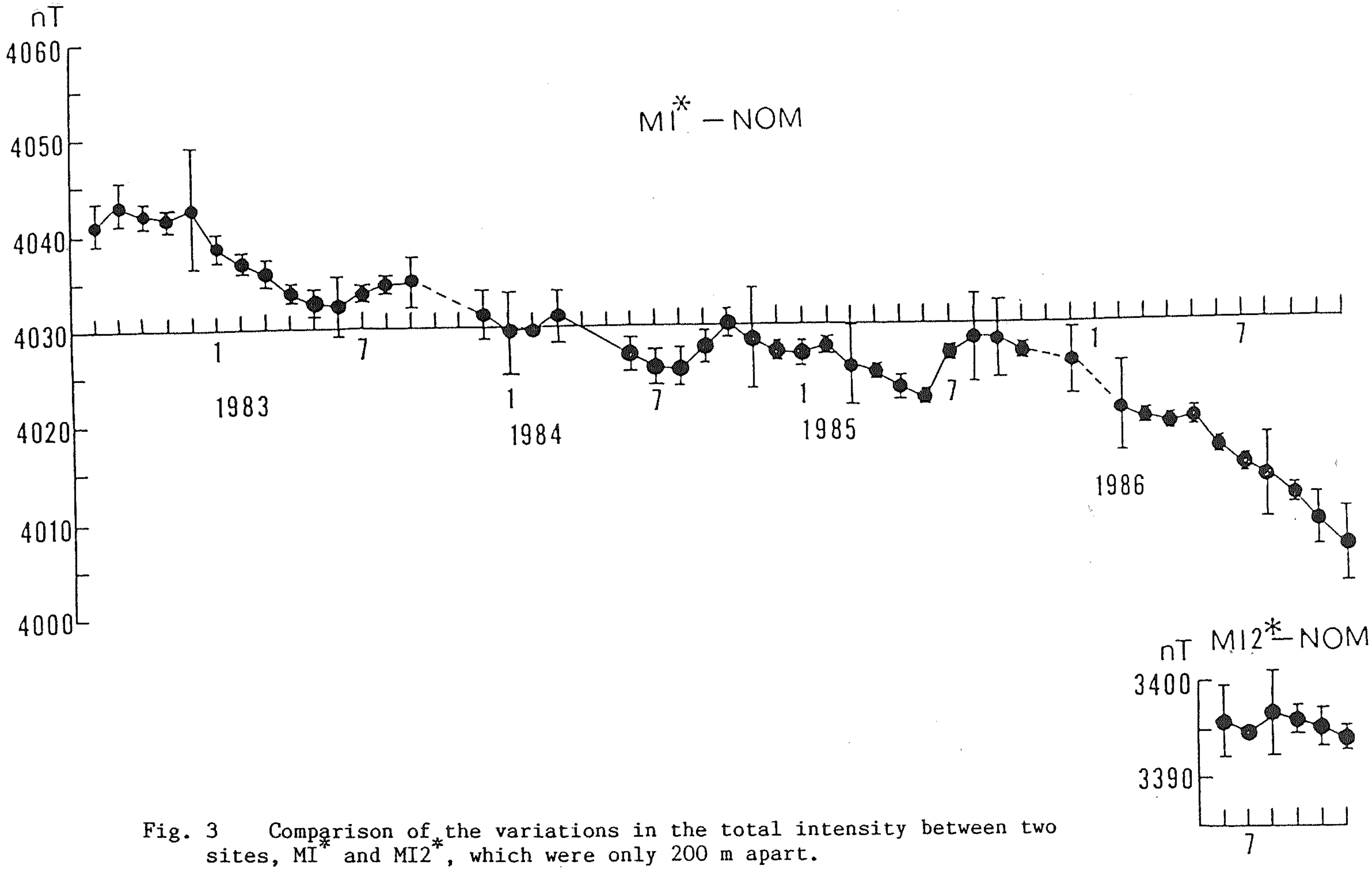


Fig. 3 Comparison of the variations in the total intensity between two sites, MI* and MI2*, which were only 200 m apart.

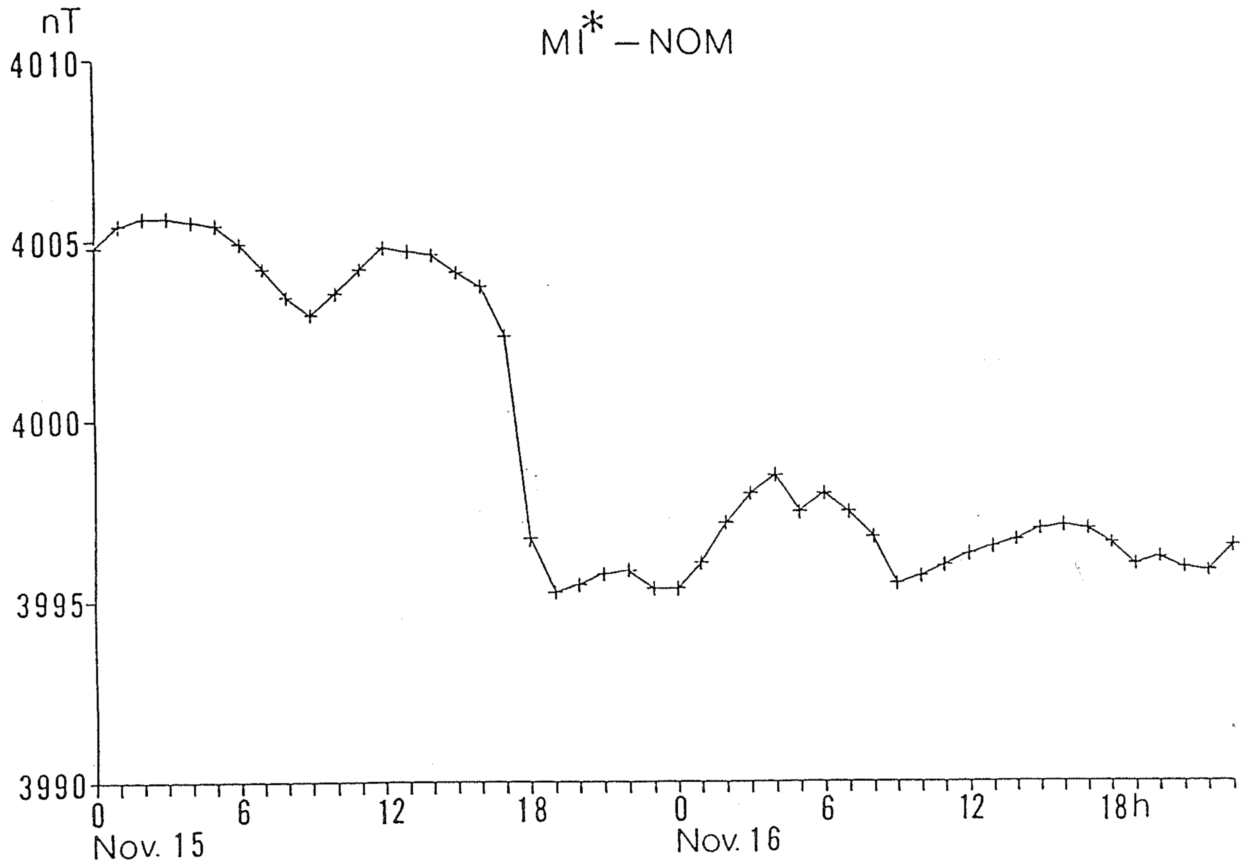
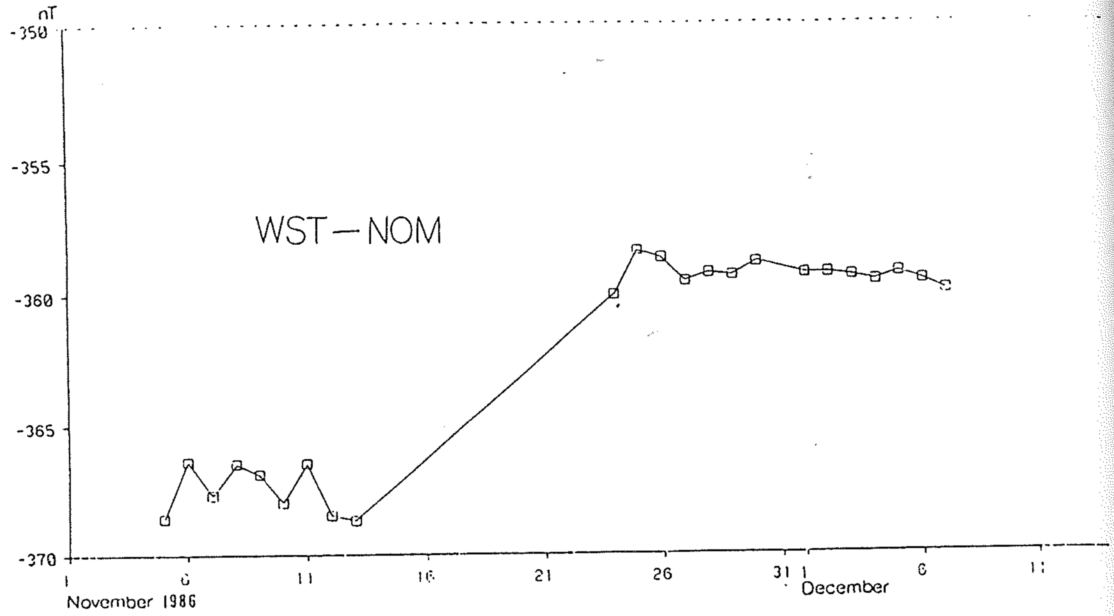


Fig. 4　A rapid variation observed at MI* at the time of eruption on November 15, 1986. Hourly mean values of difference in the total intensity between MI* and NOM are plotted.



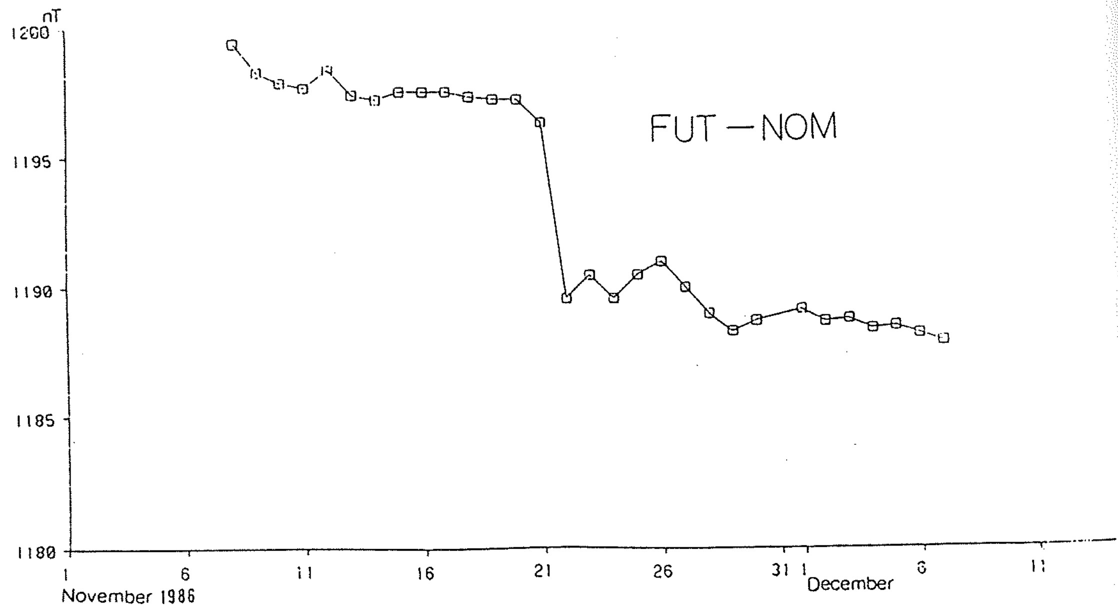


Fig. 5 Variations in the total intensity associated with the fissure eruptions on November 21, 1986. Daily means of difference in the total intensity between FUT and NOM and those between WST and NOM are plotted.

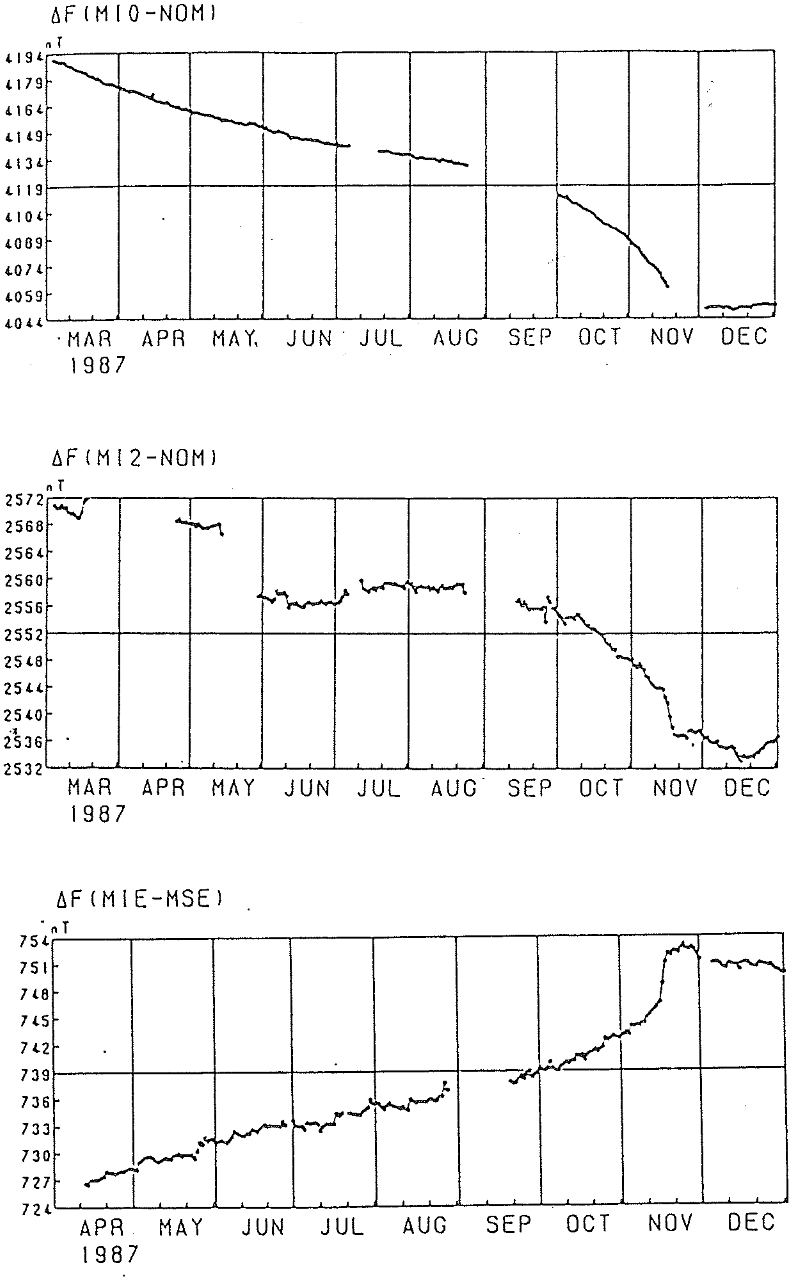


Fig. 6 Variations in the total intensity after the eruption of the central cone, Mihara-yama. Daily means of difference in the total intensity between the respective stations and NOM station are plotted.