
# Detection of electromagnetic anomalies related to volcanic eruptions by DEMETER micro-satellite

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# Outline

- **Detection of EM anomalies over volcanic eruptions**
  - **August 2004 to December 2007**

    **Time window [-60 days to +15 days] around the eruptive bursts**
  - **January 2008 to December 2010**

- **EM anomalies above the 3 active Aoba, Lopevi and Ambrym volcanoes which erupted between 2004 and 2006**
  - **August 2004 to December 2006**

- **Ionospheric disturbances over active volcanoes submitted to lightnings**
  - **Starting point: St Mac Nutt database (2010) which summarizes observations of ligthnings when ashes clouds are emitted during eruptions**

# Detection of EM anomalies over volcanic eruptions

► **Information on volcanic activity is given by the Smithsonian's Global Volcanism program (http://www.volcano.si.edu/)**

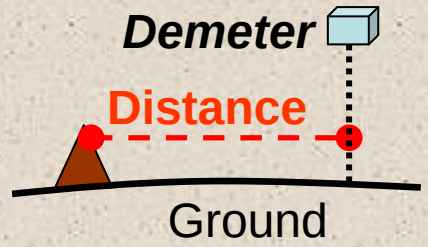
- **VEI (volcanic explosivity index) ≥ 1 (scale of 8) → Explosive eruptions**

► **Sequence and location of volcanoes**

- **Latitudes: -50°S to +50°N**
- **First study: August 2004 to December 2007**

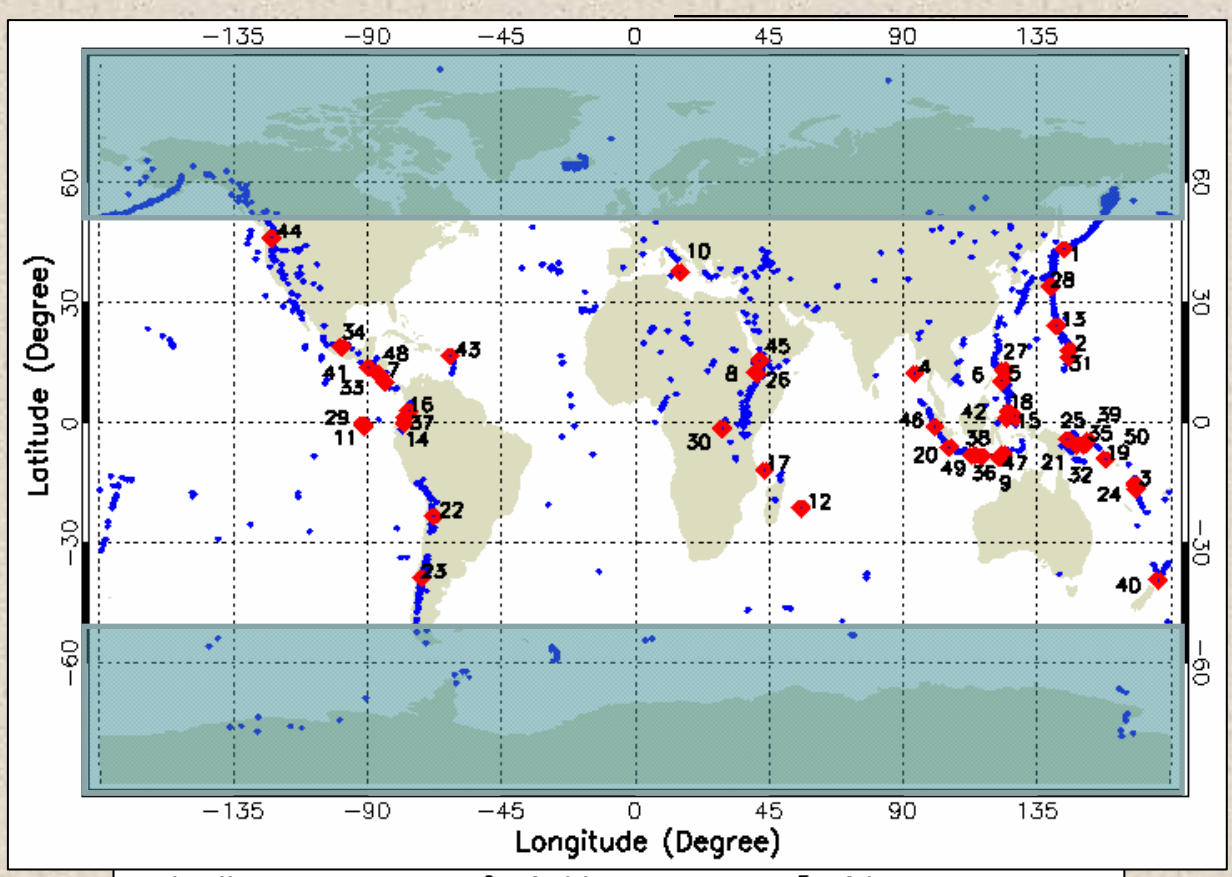
► **We consider Demeter orbits whose distance between the footprint of the satellite and the eruptive center is :**

- **< 500 km for VEI < 3**
- **< 900 km for the events with VEI ≥ 3**
  **[Vulcanian, ashes clouds: 3-15 km, $10 \times 10^6$ $m^3$]**




► **Time window of [-60 days to +15 days] around the eruptive burst**

# 50 volcanoes fill the database requirements




1 – Akan
2 – Anatahan
3 – Aoba
4 – Barren Island
5 – Bulusan
6 – Kanlaon
7 – Concepción
8 – Dabbahu
9 – Egon
10 – Etna
11 – Fernandina
12 – Fournaise, Piton de la
13 – Fukutoku–Okanoba
14 – Galeras
15 – Gamkonora
16 – Huila, Nevado del
17 – Karthala
18 – Karangetang [Api Siau]
19 – Kavachi
20 – Krakatau
21 – Langila
22 – Láscar
23 – Llaima
24 – Lopevi
25 – Manam
26 – Manda Hararo
27 – Mayon
28 – Miyake–jima
29 – Negra, Sierra
30 – Nyamuragira
31 – Pagan
32 – Pago
33 – Poás
34 – Popocatépetl
35 – Rabaul
36 – Raung
37 – Reventador
38 – Rinjani
39 – Ritter Island
40 – Ruapehu
41 – Santa Ana
42 – Soputan
43 – Soufrière Hills
44 – St. Helens
45 – Tair, Jebel at
46 – Talang
47 – Tara, Batu
48 – Telica
49 – Tengger Caldera
50 – Ulawun

**Several types of volcanoes**
***- composite, shield, lava domes …***

***- Basaltic to dacitic***

***-Continental, Island-arc volcanoes …***

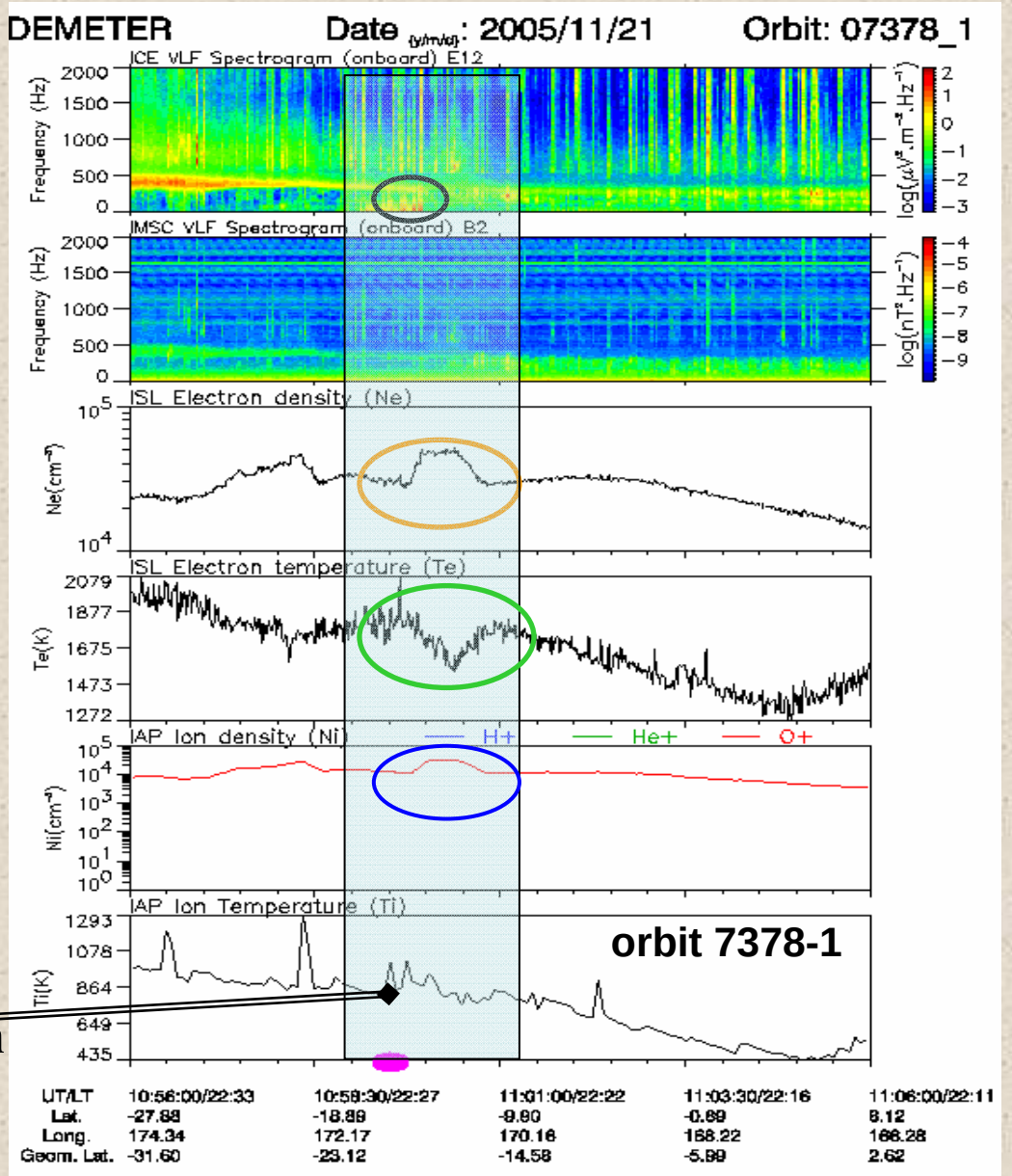
**Several types of volcanic activity:**

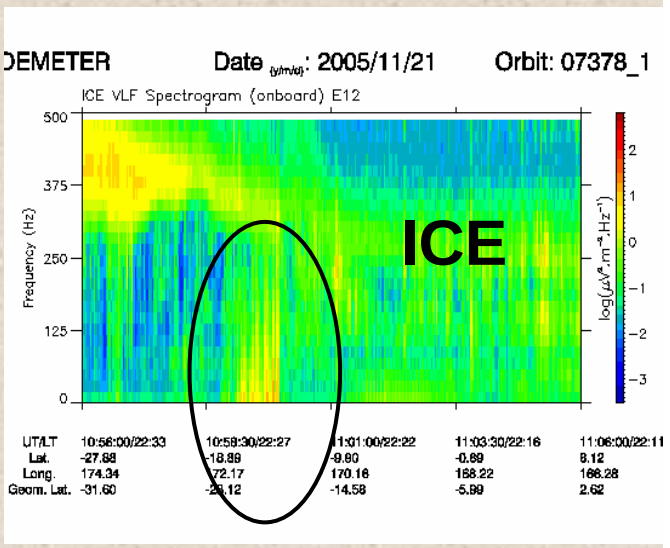
***- Phreatic, phreato-magmatic, vulcanian, plinian …***

**From Aug. 2004 to Dec. 2007 (3.5 years), 74 volcanic eruptions have occurred on the 50 volcanoes**

# Aoba: 6 days before the Nov./27/2005 eruption (VEI=2)

## Type 1




***Above the volcano and the conjugate point, disturbances are observed on the :***

***- Electric field***

***- Electronic density and temp.***

***- Plasma density***

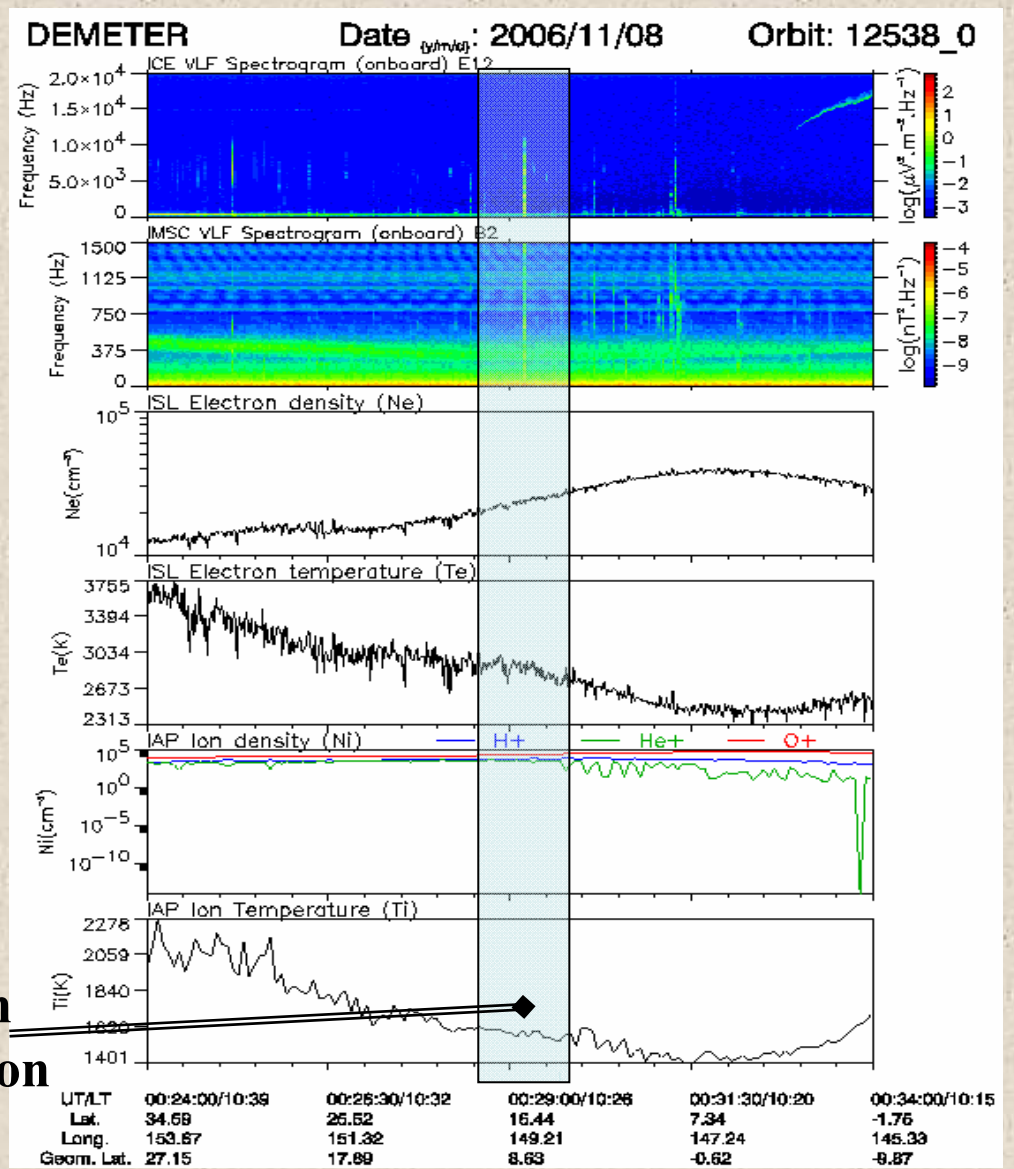
**Aoba location**

**(15.4°S, 167.83°E)**

**Electrostatic disturbance**

# Pagan 26 days before Dec./04/2006 eruption (VEI=1)

## Type 2




**Pagan location**

**(18.13°N , 145.8°E)**

***Above volcanoes, sferics may appear.***

***They can be observed on the magnetic and electric fields***

***No noticeable changes of the other parameters emerge.***

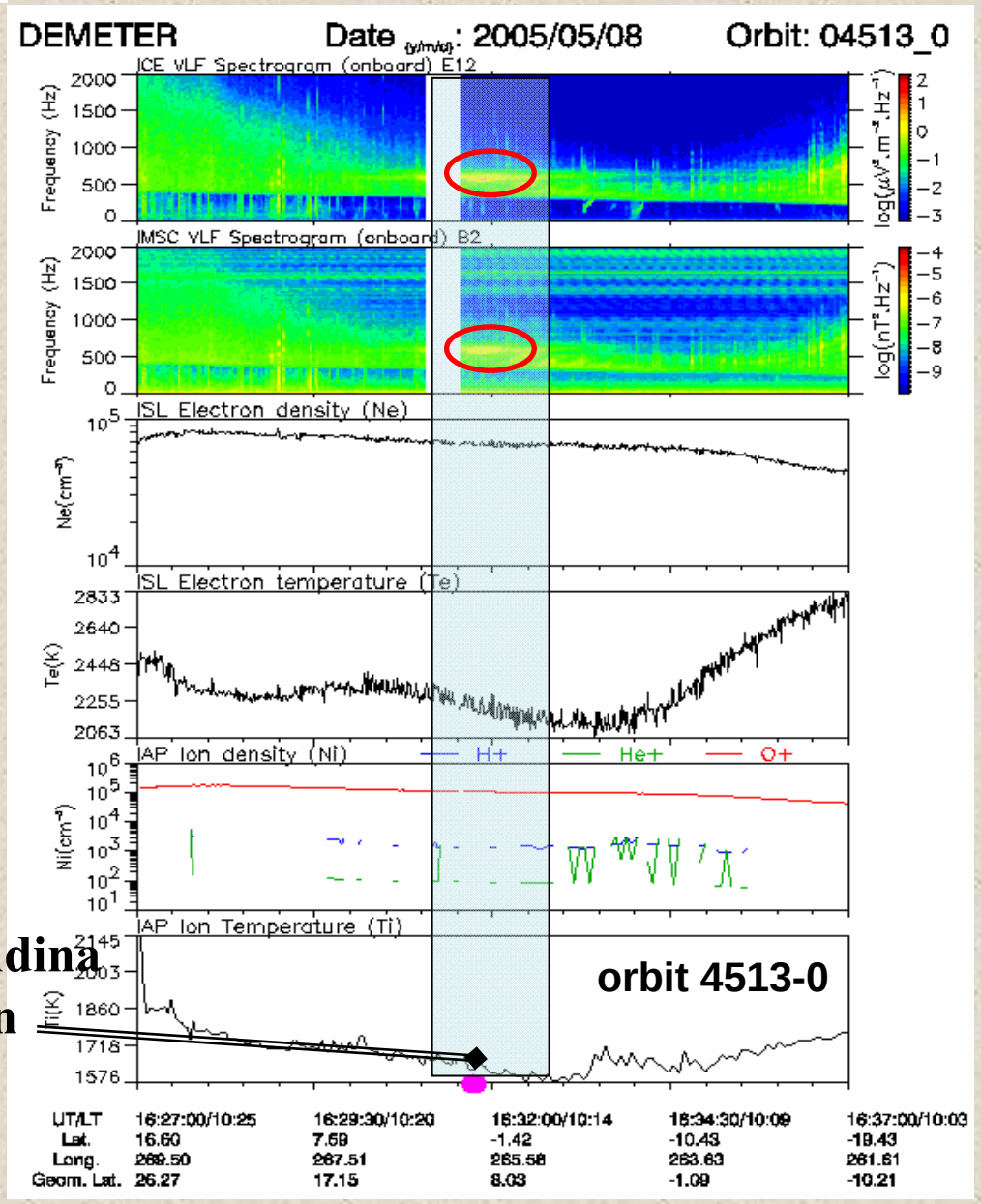
⇩

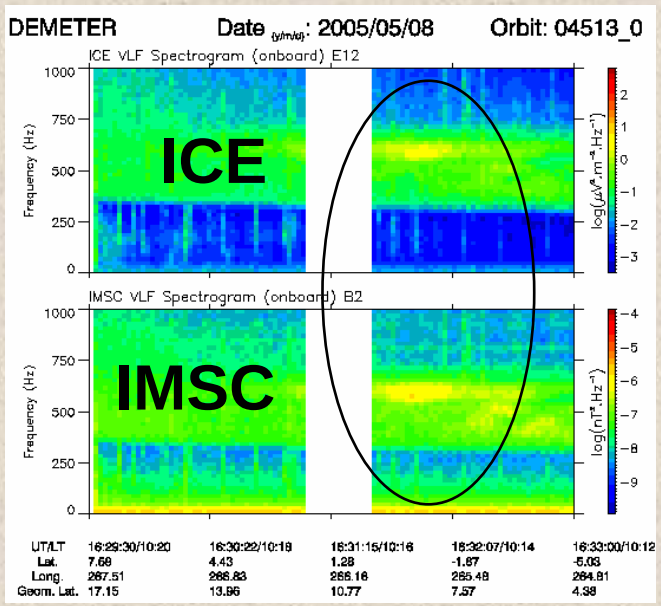
**Electromagnetic discharges**

**orbit 12583-0**

# Fernandina 5 days before May/13/2005 eruption (VEI=2)

## Type 3



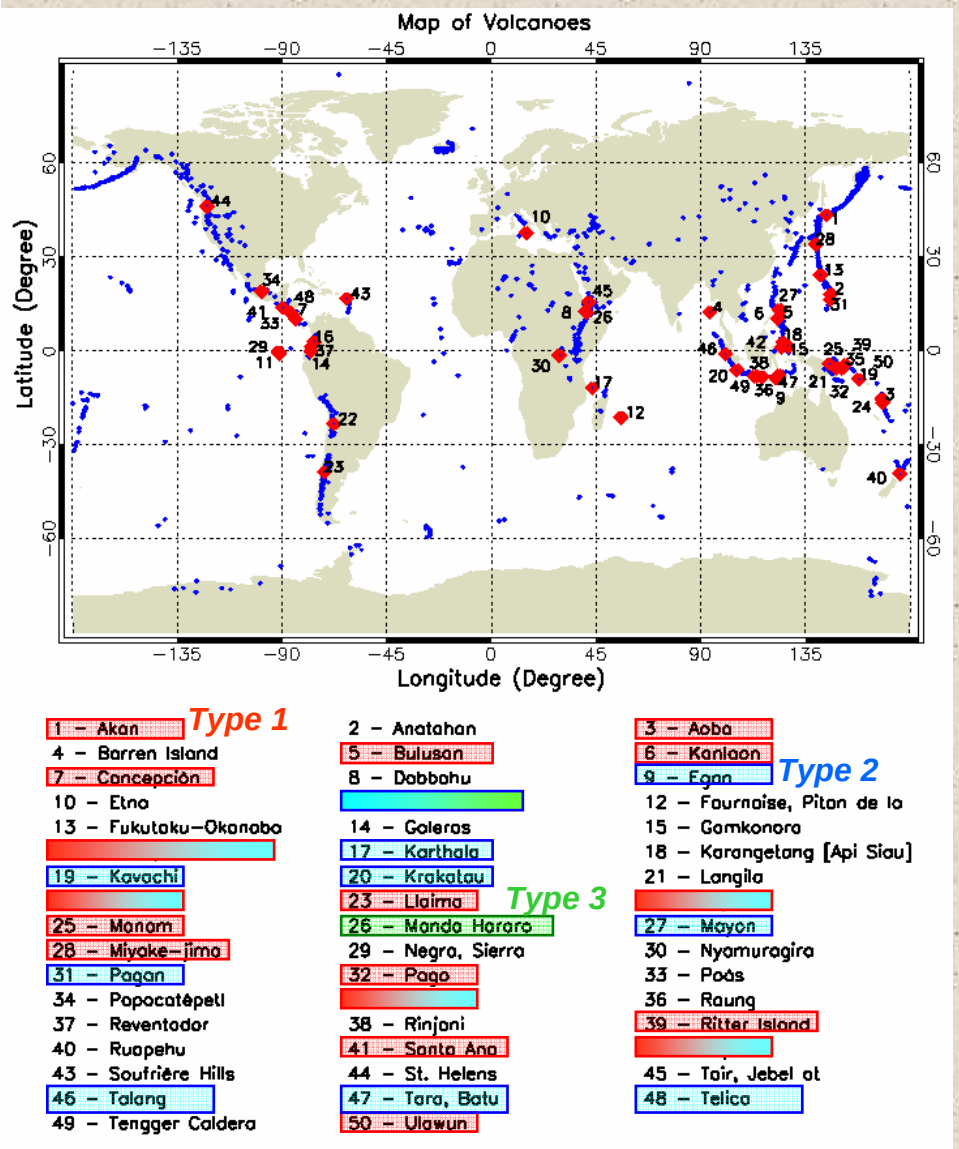

**Fernandina location**

**(0.37°S , 268.45°E)**

***Unknown anomaly has been recognized:***

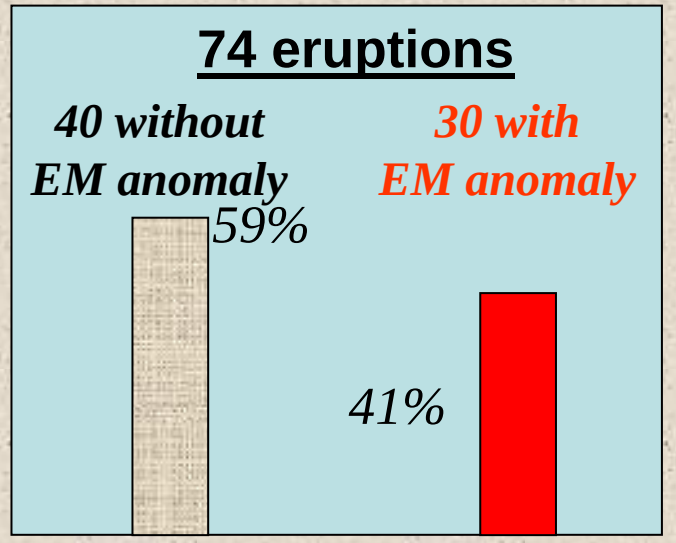
***No change of other parameters has been recognized yet***

# Observations: August 2004- December 2007




*Depending on the 500 to 900 km threshold, only 1-2 mn (7 km/s) of DEMETER records can be related to a particular volcano …*

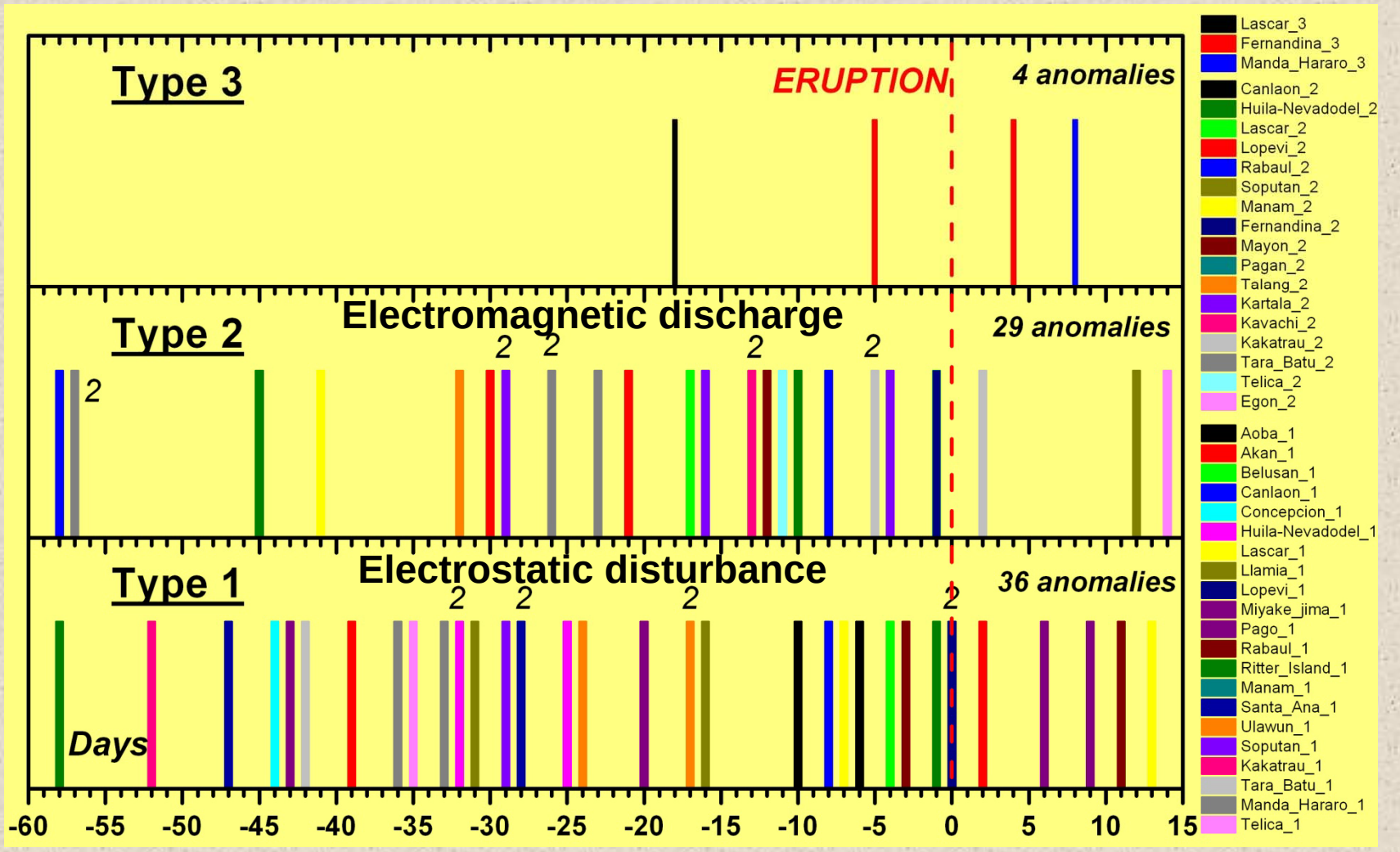
**74 eruptions have occurred on 50 volcanoes**




*30 eruptions on 28 volcanoes*

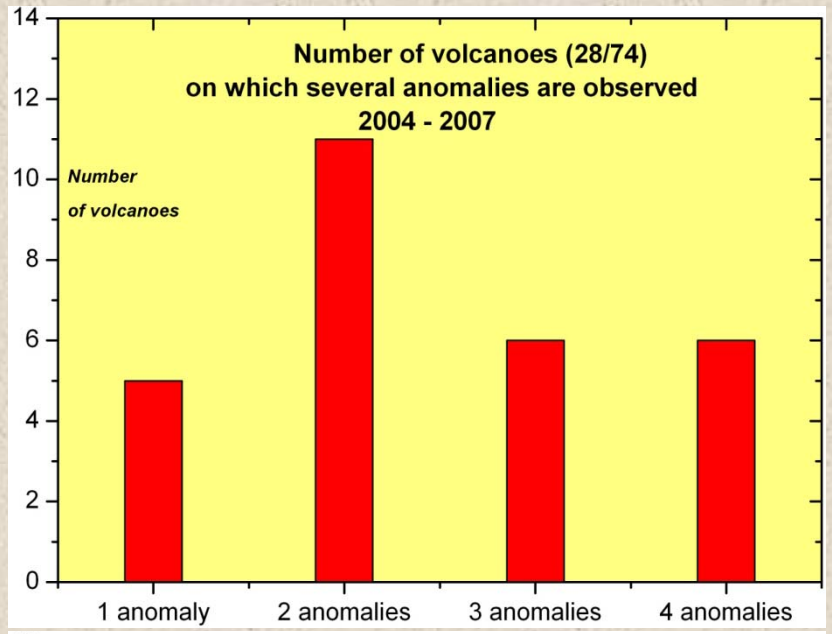
# Classification of the 69 anomalies in 3 types

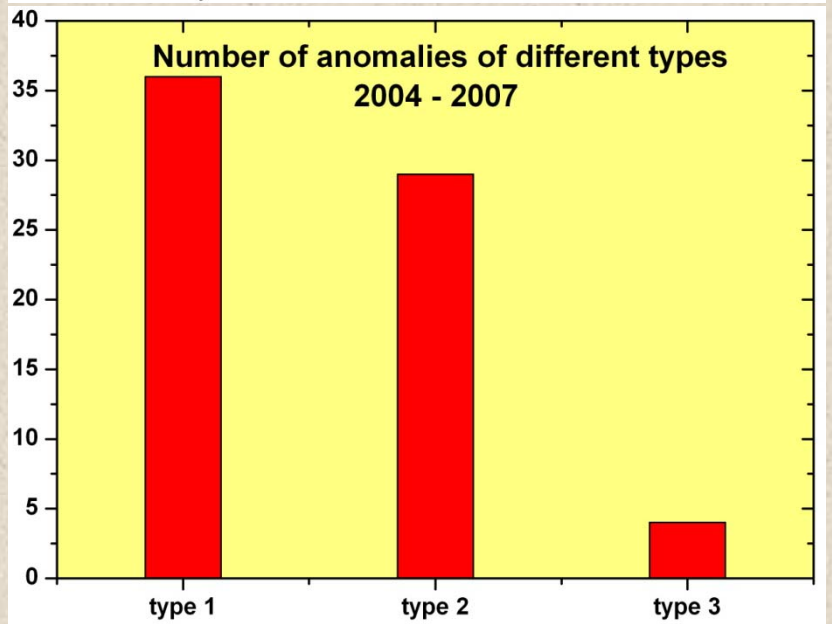
*[-60 days to +15 days]* *August 2004 to December 2007*

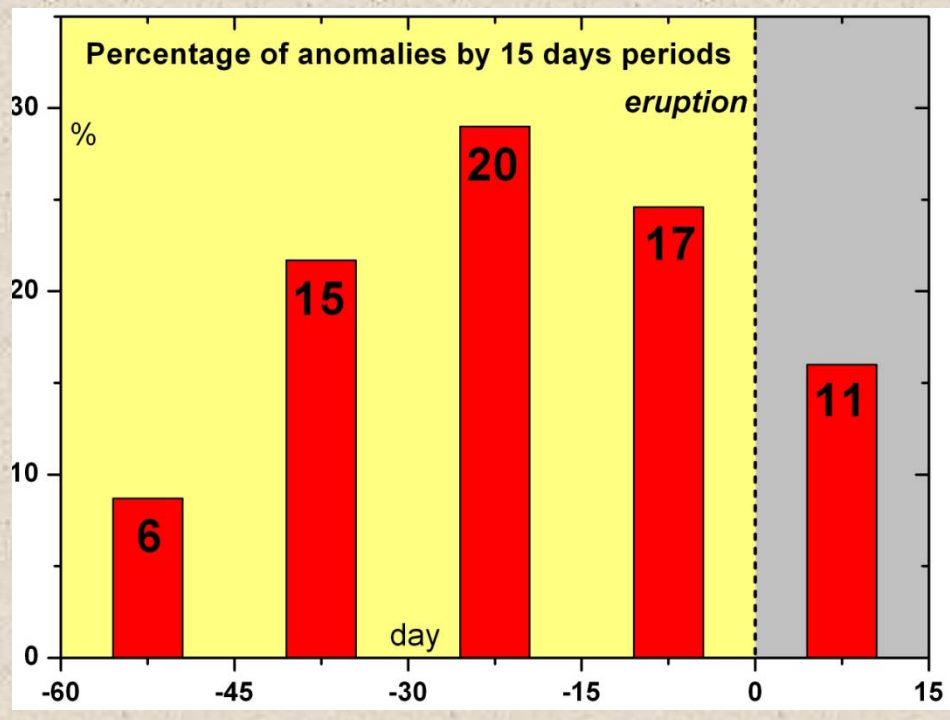



***69 anomalies are observed along 30 eruptions on a total of 74 eruptions***

# Distribution of anomalies : 2004.5 to 2007



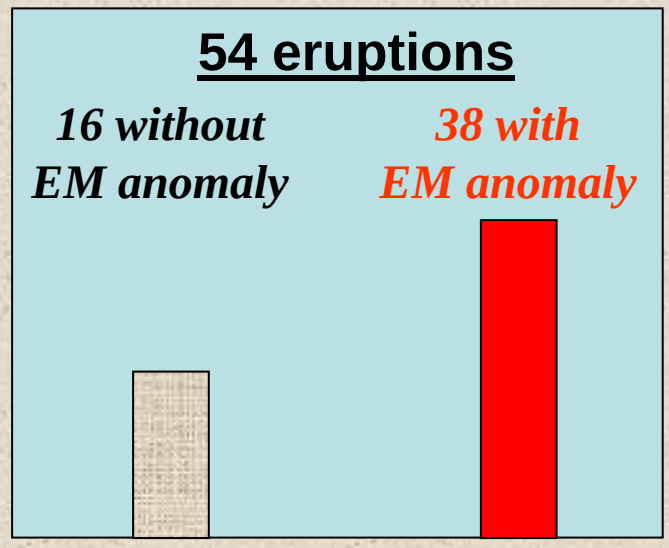



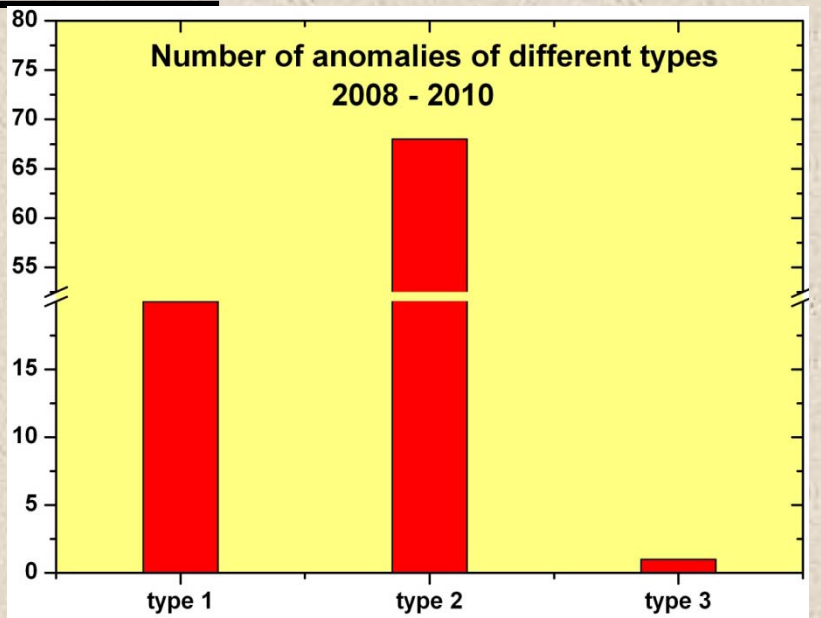



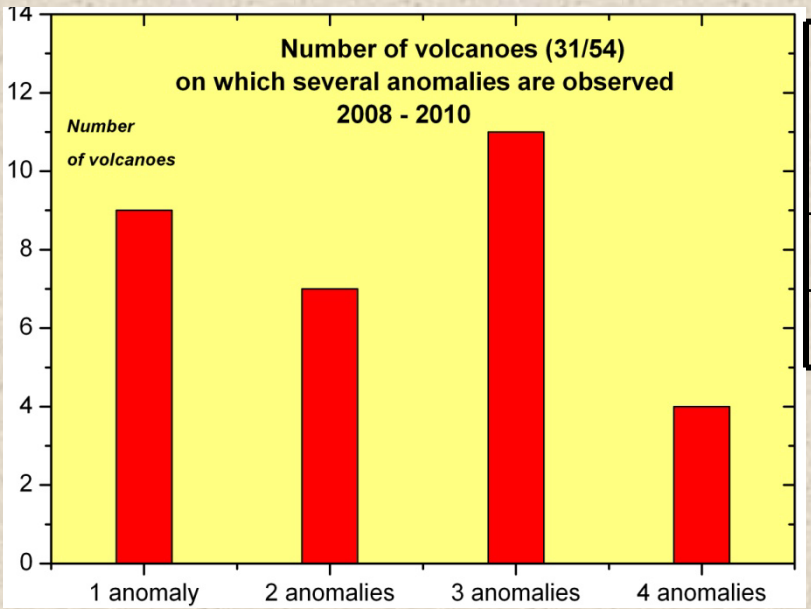

► **The number of anomalies become small when we consider periods far before the eruption**

► **Most of the anomalies occur within 45 days before the eruption (i.e. 52/69)**

# Jan. 2008 to Dec. 2010 : [-30 days to +15 days]



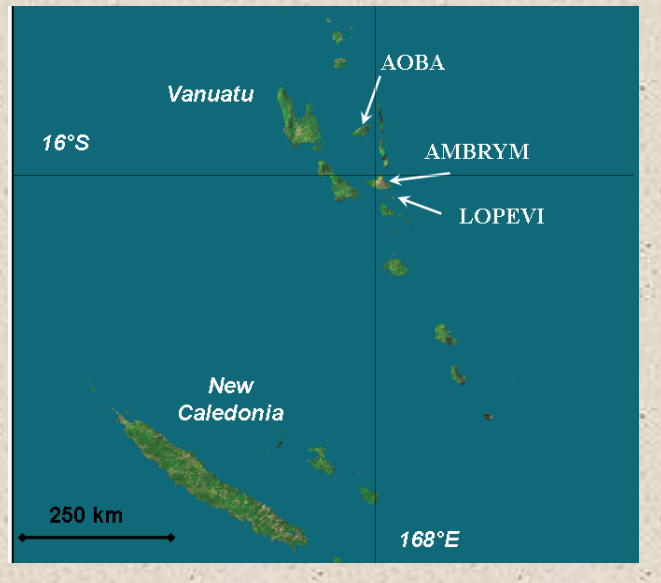




| Period | Nb of eruptions | eruptions with anomalies | Nb of anomalies |
|---|---|---|---|
| 2004.5_07 | 74 | 28 | 69 |
| 2008_10 | 54 | 38 | 93 |

***The number of anomalies/eruption largely increased in 2010 with large eruptions (VEI#3)***

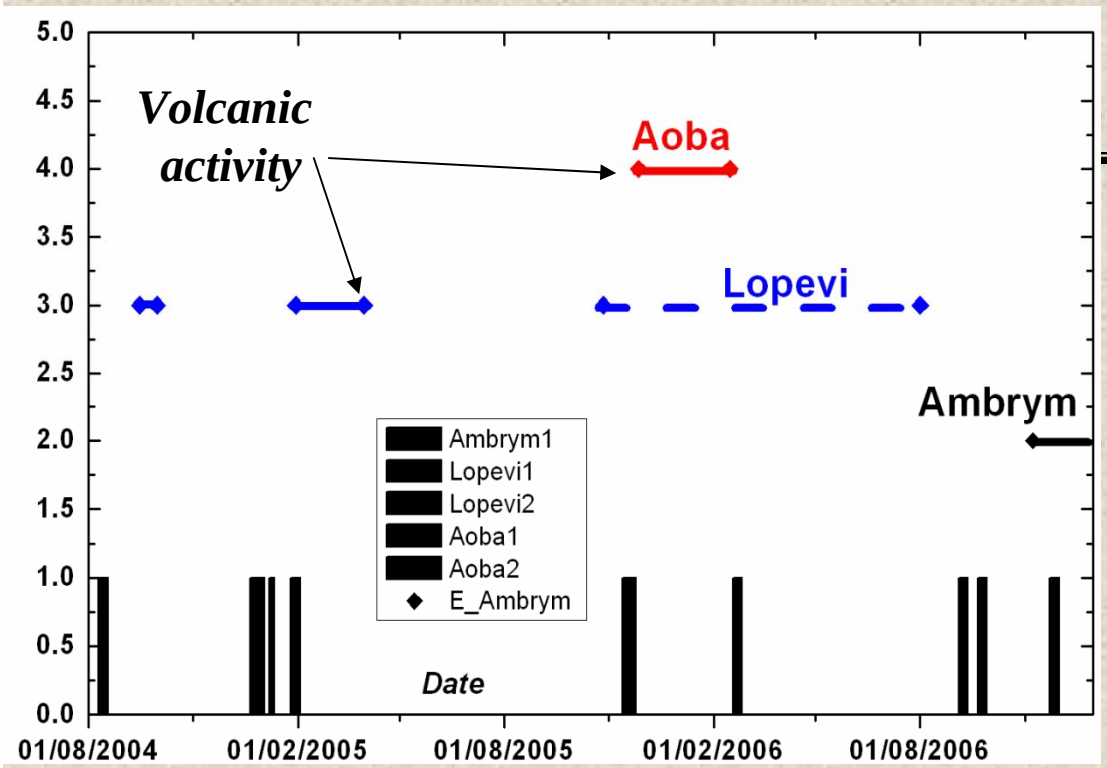
***(Merapi, Belusan, Karangetang, Tengger, Tungurahua)***

# Systematic research of EM anomalies above the 3 active Aoba, Lopevi and Ambrym volcanoes




- **The volcanoes are at mid-latitudes and suffer weak ionospheric disturbances**
- **Period: From September 2004 to December 2006**
- **Distance between the footprint of the satellite position and the eruptive center less than 500 km**
- **All the downwards and upwards orbits are analyzed**

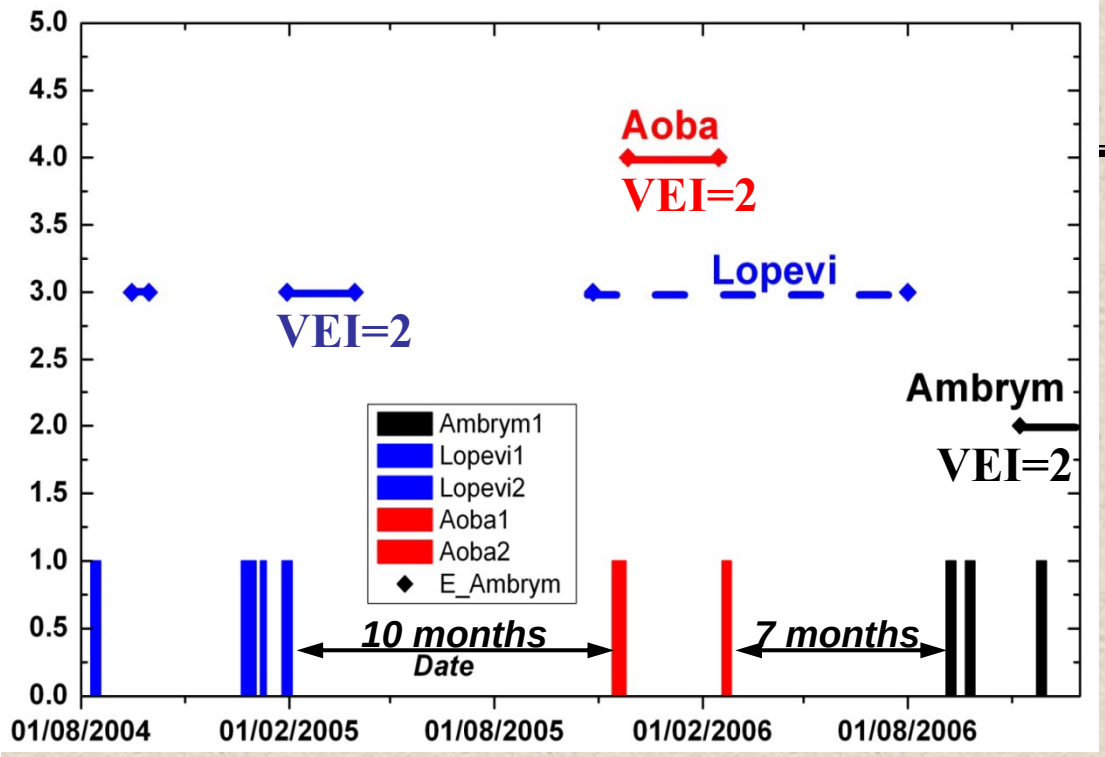
***Day to day analysis was achieved, corresponding to the complete examination of 4950 orbits***




- **11 anomalies of type 1 or 2 are observed during the 2.3 years period**
- **They are only observed during unrest periods of the volcanoes**

**Unfortunately, distance between volcanoes is less than 200 km in comparison to the 680-km altitude of the satellite**

***Statement: No anomaly on any volcano has been observed 1.5 year before an eruption. No anomaly was observed during a decreasing/weak activity.***

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**⇒ Therefore anomalies before Feb. 2005 should be associated with Lopevi which is the only volcano active**

**⇒ Anomalies observed after Aug. 2006 should be attributed to Ambrym**

**⇒ After Feb. 2005 Lopevi activity resides in smooth lava flow, while Aoba becomes active with phreatic explosions and ashes plumes …. Late 2005 and Feb. 2006 anomalies would be associated with Aoba activity *(Zlotnicki et al., 2010)***

# Ionospheric disturbances detected over active volcanoes submitted to volcanic lightning

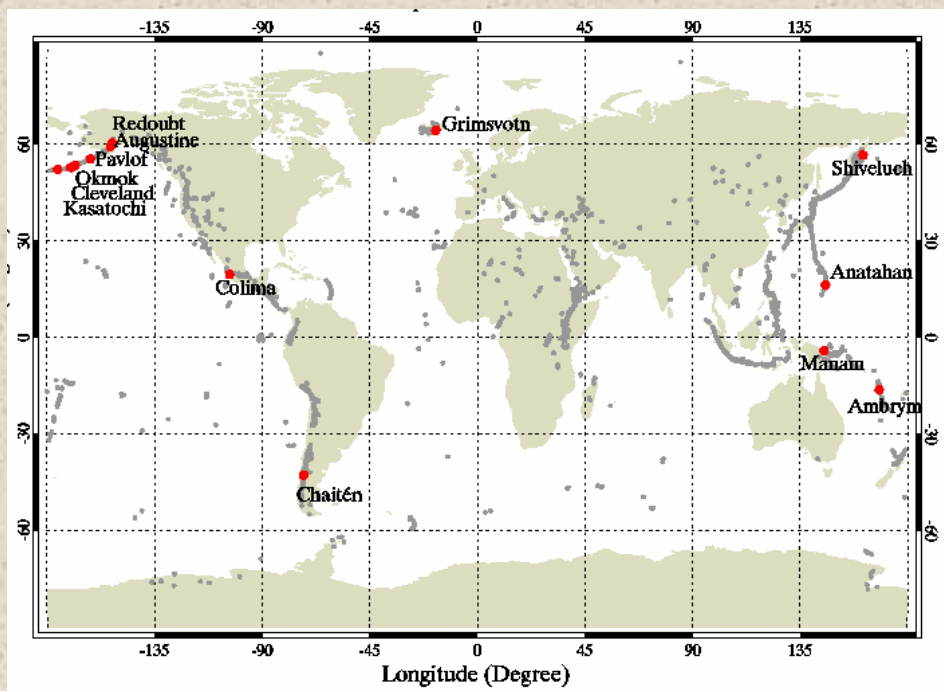
- **Goal: Do ionospheric disturbances appear more frequently above volcanoes on which volcanic lightnings are observed?**
- **The study is based on the database given by Mc Nutt (2010) in which land observations list electric discharges on 80 volcanoes (XVII$^{th}$ century up to 2009)**
- **The study with DEMETER records covers the last part of the database whatever the latitude of the volcano is (> 50°N)**

  → *From August 2004 to April 2009*

  → *time window [-10 days, +5 days]*

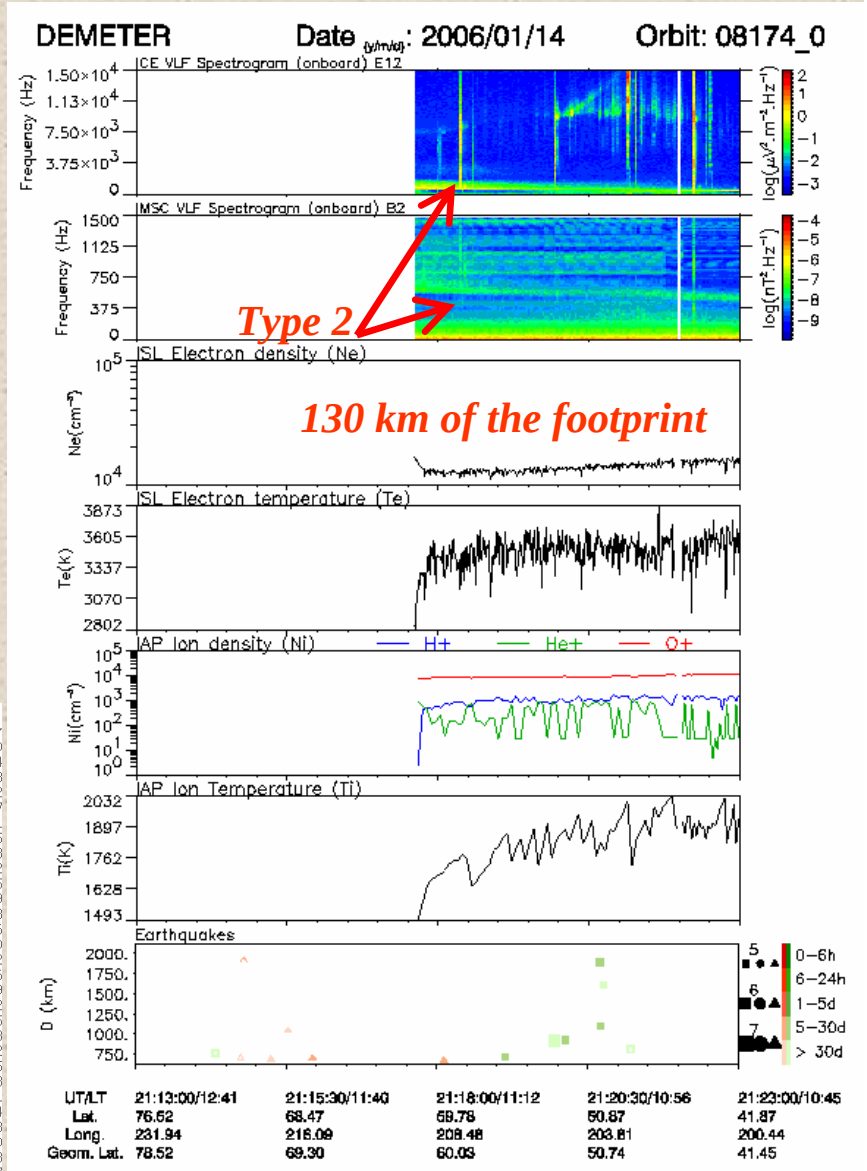
  → *No restriction is applied to the VEI index*

  → *The distance of the footprint of the satellite is limited to about 500 km*

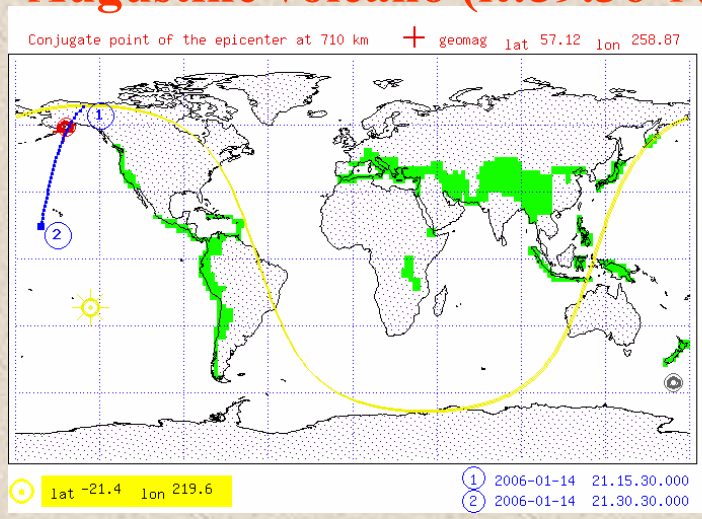



# Ionospheric anomalies around electric discharges

- **The database is reduced to 44 electric discharges occurring during 11 eruptions on 11 volcanoes**
- **For 18 on the 44 electric discharges, DEMETER did not flight above the volcanoes the same day**
- **For 4 electric discharges on a total of 26 a ionospheric anomaly in the DEMETER records was observed the same day**



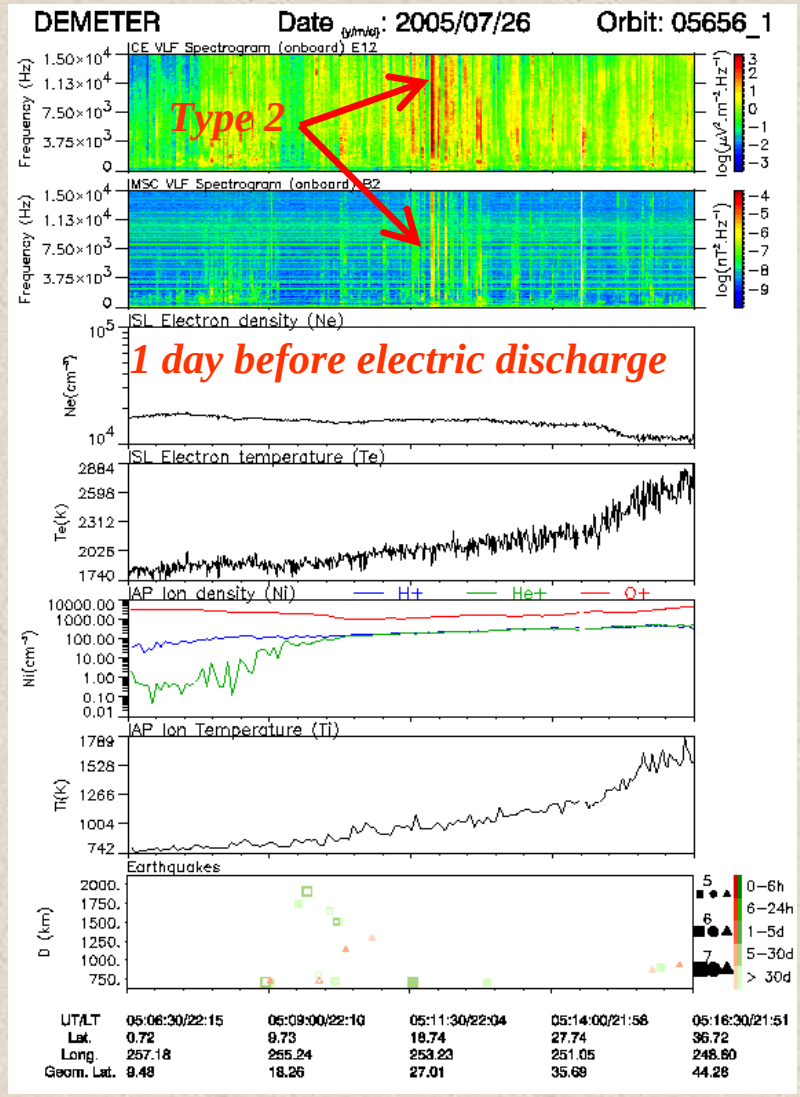

## Augustine volcano (lt:59.36°N, lg:206.57°E)



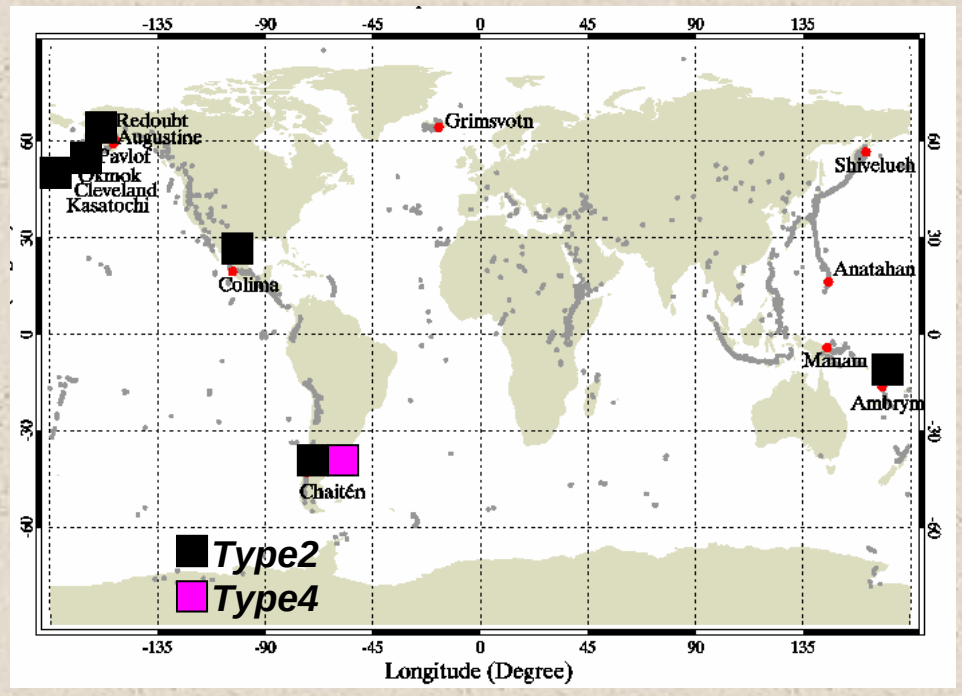

| | == geographic == | | | | |
|---|---|---|---|---|---|
| UT | lat | lon | tloc | dist | dist |
| 21.15.30 | 68.47 | 216.09 | 11.7 | 1113 | 14250 |
| 21.16.00 | 66.76 | 214.18 | 11.6 | 907 | 14044 |
| 21.16.30 | 65.03 | 212.51 | 11.4 | 702 | 13838 |
| 21.17.00 | 63.29 | 211.02 | 11.3 | 497 | 13632 |
| 21.17.30 | 61.54 | 209.69 | 11.3 | 297 | 13427 |
| 21.18.00 | 59.78 | 208.48 | 11.2 | 117 | 13221 |
| 21.18.30 | 58.01 | 207.39 | 11.1 | 158 | 13015 |
| 21.19.00 | 56.23 | 206.39 | 11.1 | 349 | 12808 |
| 21.19.30 | 54.45 | 205.46 | 11.0 | 551 | 12602 |
| 21.20.00 | 52.66 | 204.61 | 11.0 | 756 | 12395 |
| 21.20.30 | 50.87 | 203.81 | 10.9 | 961 | 12189 |
| 21.21.00 | 49.08 | 203.06 | 10.9 | 1167 | 11983 |
| 21.21.30 | 47.28 | 202.35 | 10.8 | 1373 | 11776 |
| 21.22.00 | 45.48 | 201.68 | 10.8 | 1580 | 11570 |
| 21.22.30 | 43.67 | 201.05 | 10.8 | 1787 | 11362 |
| 21.23.00 | 41.87 | 200.44 | 10.8 | 1993 | 11156 |
| 21.23.30 | 40.06 | 199.86 | 10.7 | 2200 | 10949 |
| 21.24.00 | 38.25 | 199.31 | 10.7 | 2406 | 10742 |
| 21.24.30 | 36.44 | 198.78 | 10.7 | 2613 | 10535 |
| 21.25.00 | 34.63 | 198.26 | 10.6 | 2820 | 10328 |
| 21.25.30 | 32.82 | 197.76 | 10.6 | 3026 | 10122 |
| 21.26.00 | 31.01 | 197.28 | 10.6 | 3232 | 9915 |
| 21.26.30 | 29.19 | 196.81 | 10.6 | 3440 | 9708 |
| 21.27.00 | 27.38 | 196.35 | 10.5 | 3646 | 9501 |
| 21.27.30 | 25.56 | 195.90 | 10.5 | 3853 | 9294 |
| 21.28.00 | 23.75 | 195.46 | 10.5 | 4059 | 9088 |
| 21.28.30 | 21.93 | 195.04 | 10.5 | 4266 | 8880 |
| 21.29.00 | 20.11 | 194.61 | 10.5 | 4473 | 8673 |
| 21.29.30 | 18.30 | 194.20 | 10.4 | 4679 | 8467 |
| 21.30.00 | 16.48 | 193.79 | 10.4 | 4886 | 8260 |
| 21.30.30 | 14.66 | 193.39 | 10.4 | 5093 | 8053 |

# Ionospheric anomalies in the time window -10 to +5 days

## Colima volcano
(lt:19.51°N, lg:256.38°E)




- **Only 11 standalone type2 electromagnetic discharges and 1 type4 [ionic density] anomaly embraced in a low geomagnetic activity were observed**




***12 anomalies are observed along 6 eruptions on a total of 11 eruptions***

# EM anomalies related to volcanic eruptions
# State of the present day results

- **Satellite observations allow global analyses of EM perturbations of the ionosphere by volcanic activity.**
  - **The DEMETER database is still too small for reliable statistical studies**
  - **Only 1 or 2 mn records are at most available every day over a specific edifice**
- **About half of the eruptions may be accompanied by ionospheric disturbances. Along each eruption, several anomalies can be recorded during 2 months preceding the burst**
- **Ionospheric disturbances are not systematic on a given volcano**
- **The ionospheric disturbances seem randomly distributed, and are not clearly correlated with ashes clouds or/and volcanic lightnings**
- **There is no evident relationship between the features of the volcanoes and the type of ionospheric anomalies**
- **Several anomaly types of different mechanisms are recognized in the considered database**