

Small Satellite Conference 2021

Section ; Advance Technology 1

Paper Number ; [SSC21-WKV-08]

***Design and Development of Prelude, Satellite
for Seismic Precedence Detection and
Verification Using VLF Radio Waves for
Navigation Obtained in Orbit***

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1. Background

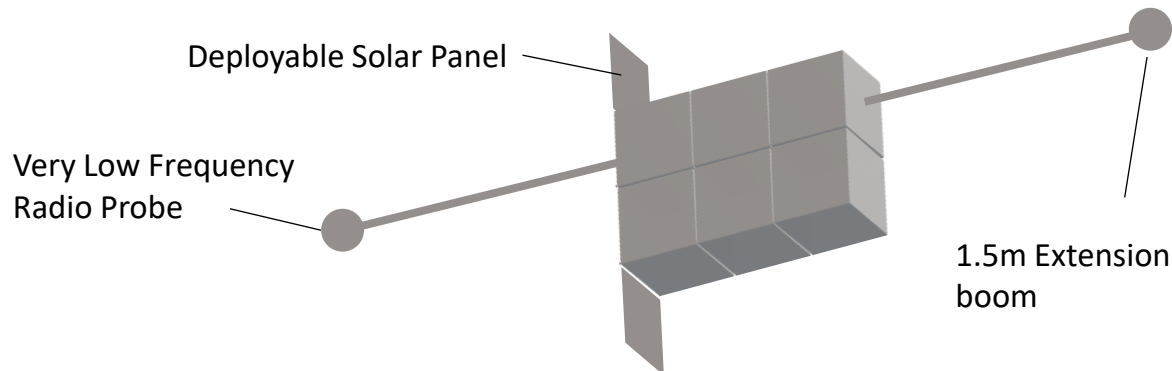
- ❖ DEMETER data was collected over a period of six years and matched to approximately 9,000 earthquakes of magnitude 4.8 or greater that occurred around the world to capture anomalous earthquake precursors.
- ❖ The 6U CubeSat "Prelude" under development is aimed at verifying the reduction of radio wave intensity 4 hours before earthquakes by installing only one pair of electric field probes.



DEMETER (600mm x 600mm x 800mm, 130kg)©CNES



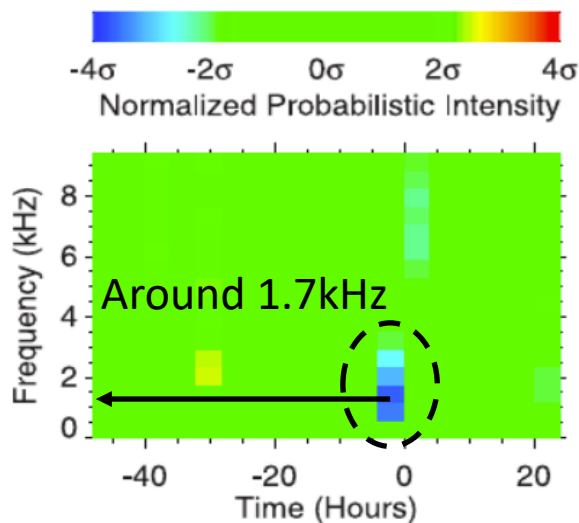
Prelude (6U, 100mm x 226.3mm x 366.0mm, 10kg)



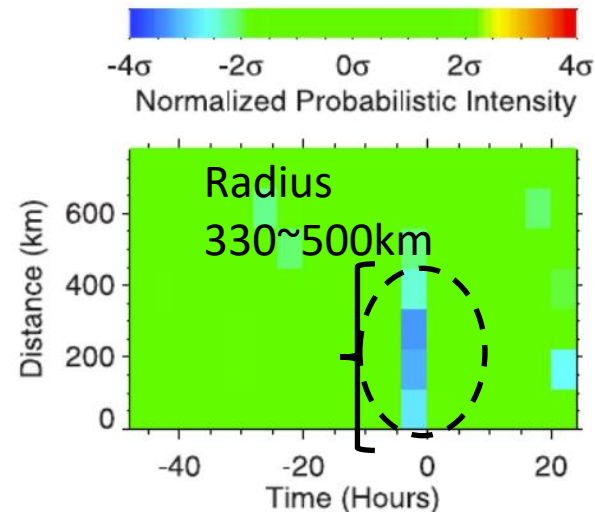
1. Background -Preliminary study-

- ❖ In-orbit satellite observations include lightning-derived electromagnetic waves, spike waves from nearby lightning, and artificial electromagnetic waves.
- ❖ DEMETER is acquired with 0.5 Hz time resolution.
- ❖ Němec analyzed the electric field data at night under stable geomagnetic field conditions, focusing on 10 kHz.

Intensity decreased 4 hours ago.



Intensity decreased 4 hours ago.

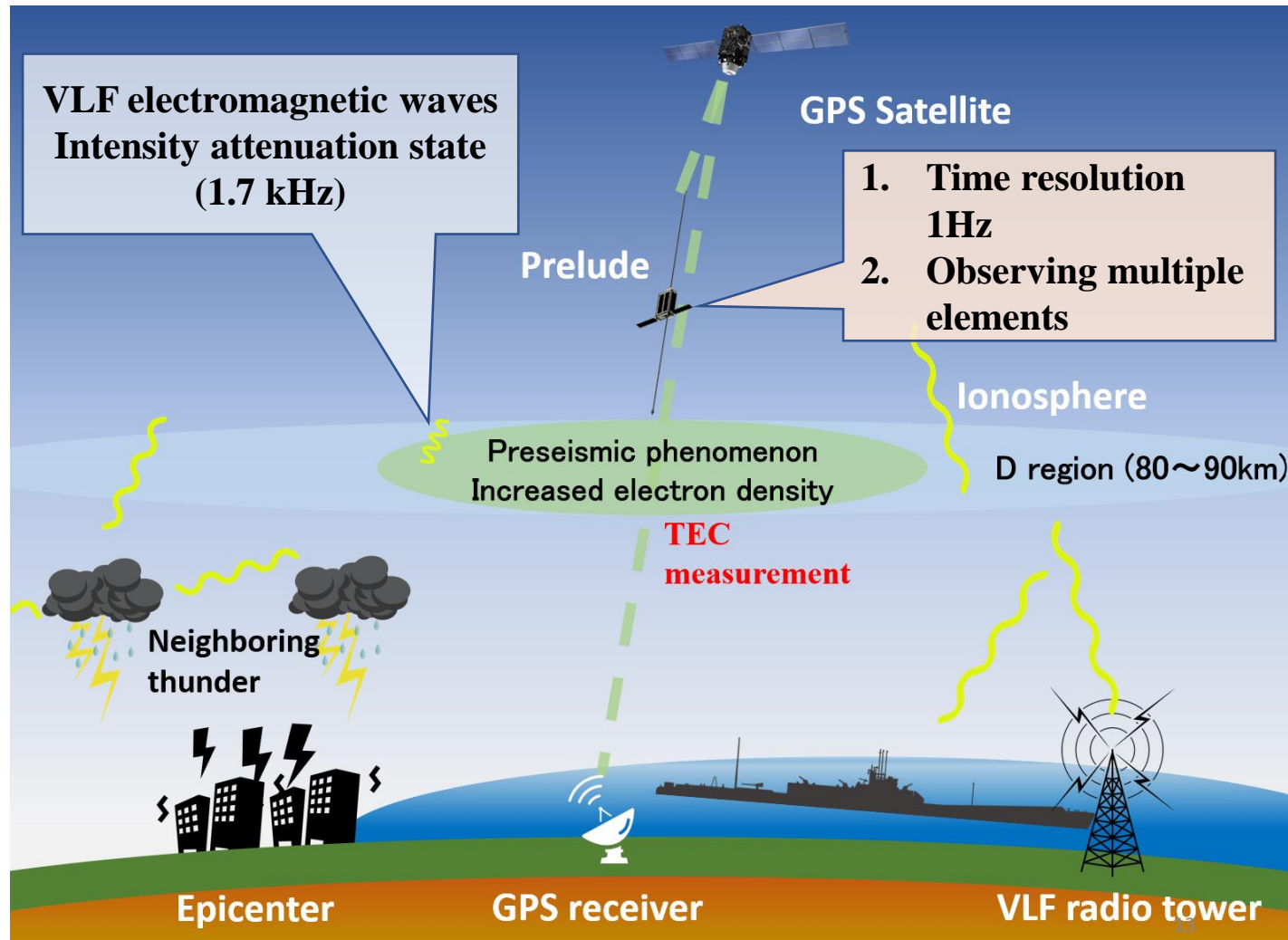


Decrease in VLF band intensity at night and its sphere of influence(*Němec at el. 2008*)

- ❖ Possibility that **lightning** electromagnetic waves **themselves are affecting** the ionosphere.
- ❖ Important : Exploring the relationship between earthquakes and ionospheric fluctuations by focusing on radio waves other than lightning

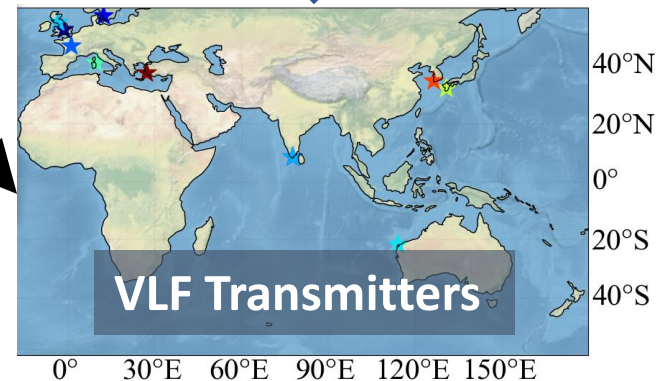
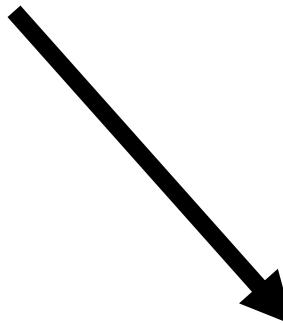
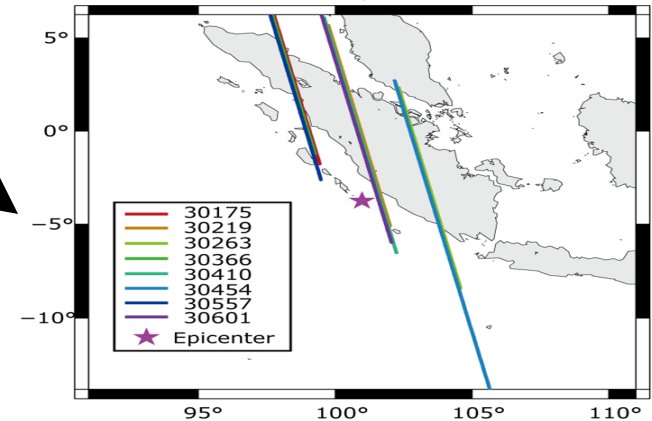
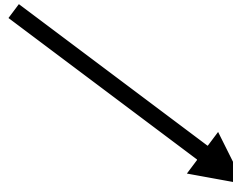
2. Purpose

- ❖ Focusing on VLF radio waves for navigation.
- ❖ whether we can capture earthquake precursor phenomena, which will be a **new target of Prelude's mission analysis.**



3. Approach

- ❖ Use electric field data from DEMETER
- ❖ the trajectory just before the earthquake : 30366
- ❖ Reference Orbit: Orbit temporally and spatially different from the seismic orbit (7 orbits)
- ❖ The radio wave from the nearest transmitting station to the earthquake was noticed and analyzed.



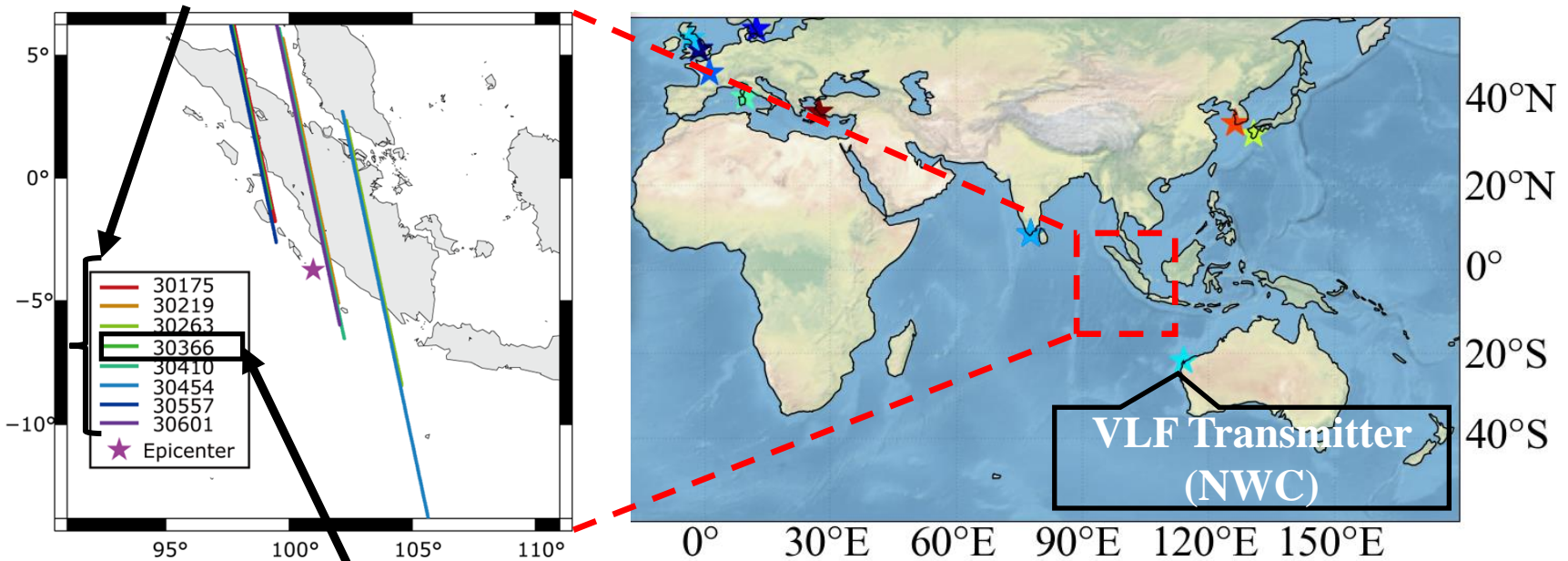
Using these trajectories, compare the seismic trajectory with the reference trajectory.

3. Approach -Select VLF radio wave for navigation-

Assuming that anomalies are more visible as the magnitude increases, the following analysis targets.

- Earthquake off South Sumatra (**M6.8**); **2010-03-05 16:07:00 (UT)**
 - * Closest orbit of earthquake (30366) ; **2010-03-05 15:07:47 (UT)**
- Analysis frequency ; **NWC (19.8 kHz)** radio waves for navigation

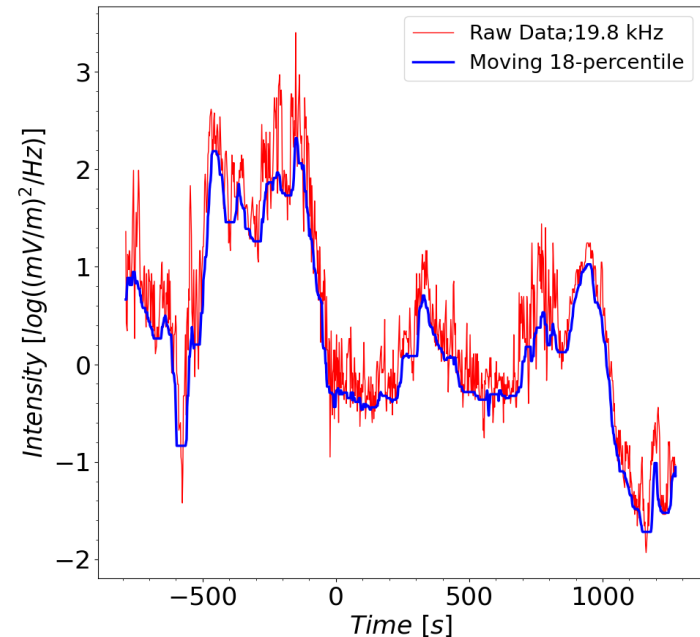
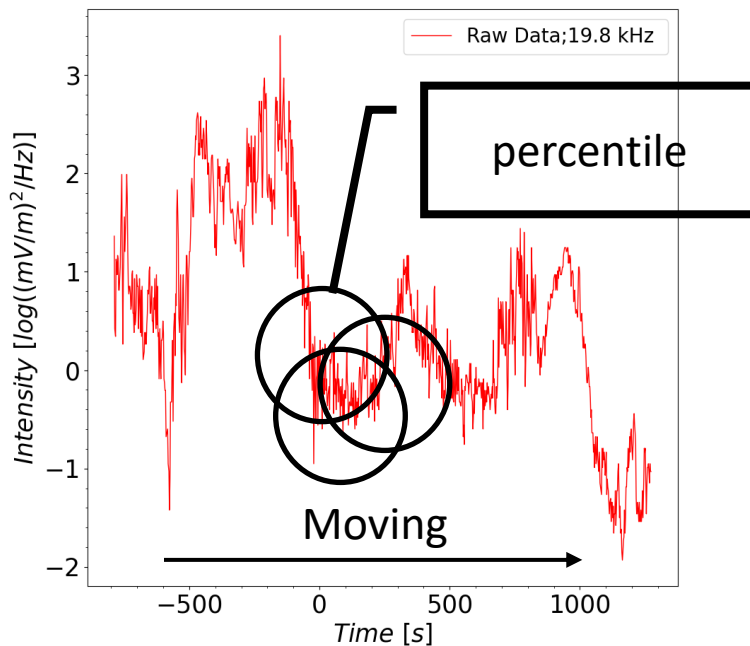
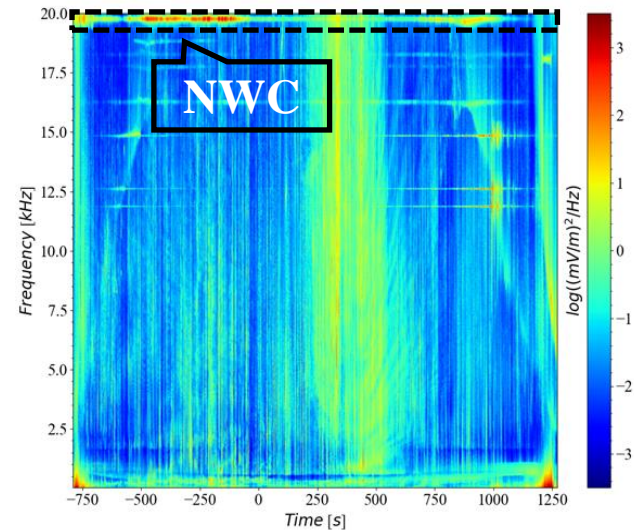
Orbit to compare



Earthquake Track Orbit

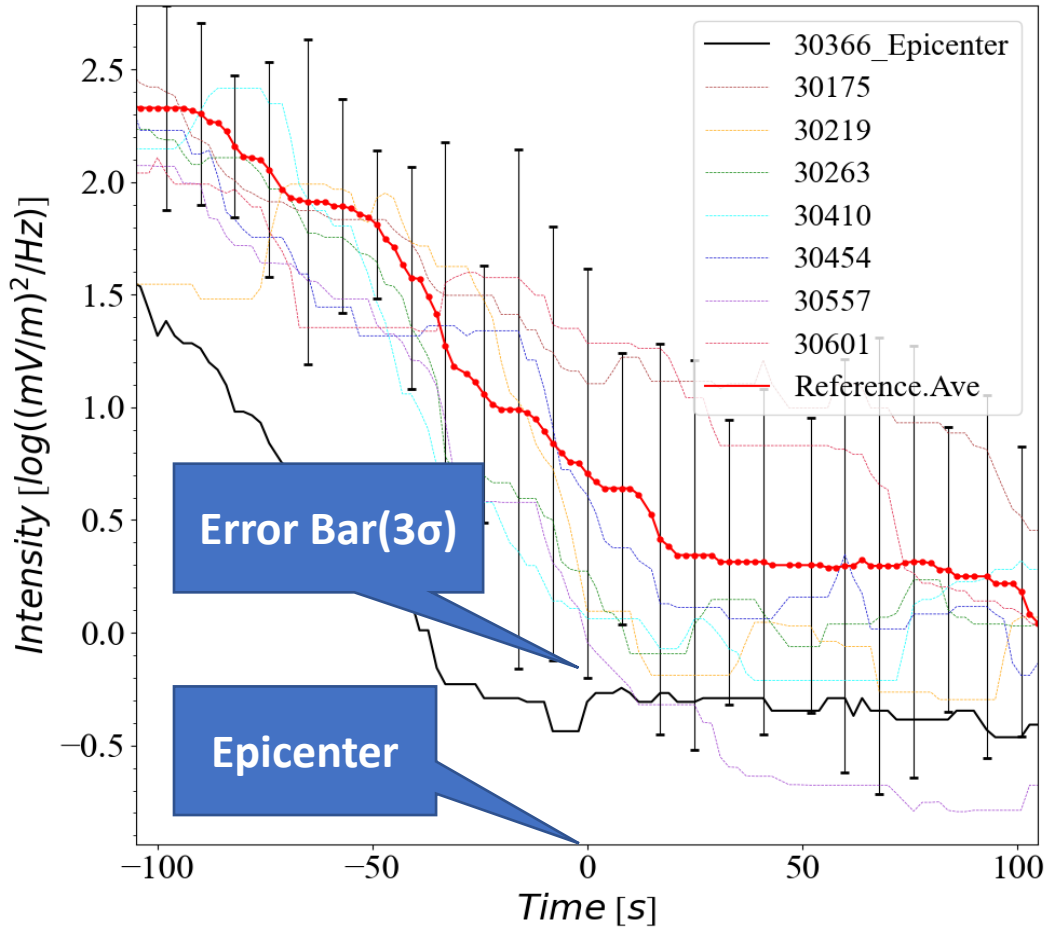
3. Approach -Extract VLF radio waves-

- ❖ The bandwidth of the NWC was checked and extracted.
- ❖ **Lightning electromagnetic waves was considered noise**
- ❖ The lightning noise is high frequency noise, so **low-pass filter** is applied.
 - ❖ Using **Moving percentile**.



3. Approach -Evaluate precursor-

- Overlay selected VLF radio waves for navigation.
- If the electric field strength **decreases by more than 3σ** , it is regarded as an anomaly before the earthquake.

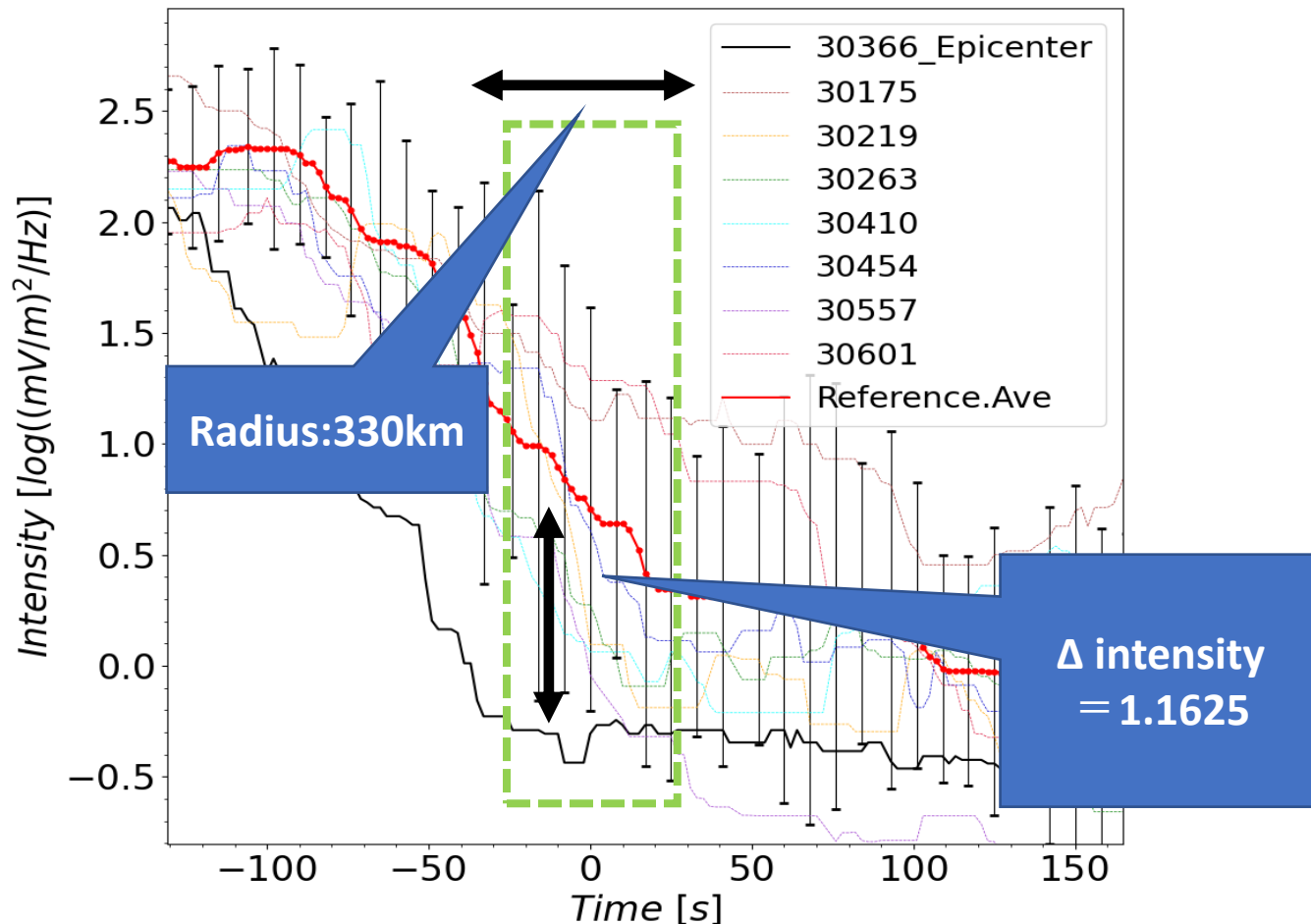


Time = Distance from the epicenter

Orbit Number	Universal time nearest the epicenter	Day of Year
30366	2010/3/5 15:07:47.729	64
30175	2010/2/20 15:08:17.707	51
30219	2010/2/23 15:00:14.645	54
30263	2010/2/26 14:52:48.677	57
30410	2010/3/8 15:00:17.179	67
30454	2010/3/11 14:52:49.38	70
30557	2010/3/18 15:07:43.330	77
30601	2010/3/21 15:00:17.876	80
Reference Average		

4. Result

- ❖ The electric field strength captured in the orbit closest to the epicenter **decreased by more than 3σ from the average.**
 - * The amount of decrease is $1.1625 [\log[(mV/m)^2/Hz]]$
- ❖ There was no decrease before the earthquake, and the electric field strength **returned to normal after the earthquake.**



5. Conclusion

- ❖ We found that the electric field strength of the VLF radio wave for ships **decreased more than 3σ** just before the earthquake.
- ❖ The analysis of the VLF electric field strength for navigation can be implemented without major changes in the current design because the data to be analyzed remains the same.

★ Future issues

Since this study is an analysis of **one case**, statistical evaluation is not possible.

- ❖ **By increasing the number of cases** in the analysis, we aim to show the number of **anomalies**, the observable **scale**, and the **probability** of earthquake occurrence.

A satellite with solar panels is shown in orbit against the backdrop of Earth and a bright sun. The satellite is a rectangular box with several long, thin solar panel arrays extending from it. The Earth's surface is visible below, showing a mix of dark land and bright, glowing city lights. The sun is a large, bright yellow-orange sphere in the upper right corner, creating a lens flare effect.

Thank you for Listening

Pre|ude