Observations of VHF and VLF/ELF emissions from high-altitude lightning discharges detected by the Chibis-M satellite

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Outline

- Chibis-M mission
  - Launching
  - Scientific goals
  - Scientific payload
- VLF and VHF observations
- Future missions
  - Chibis-EMC
  - Chibis-AI
- Conclusion

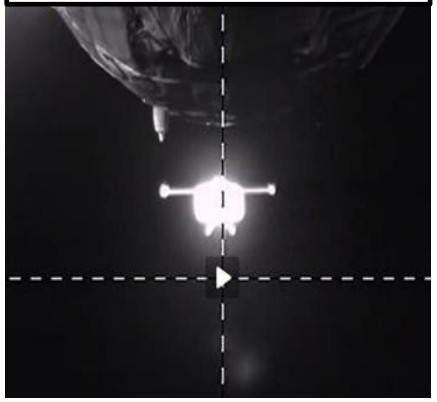
Chibis-M mission: Launching

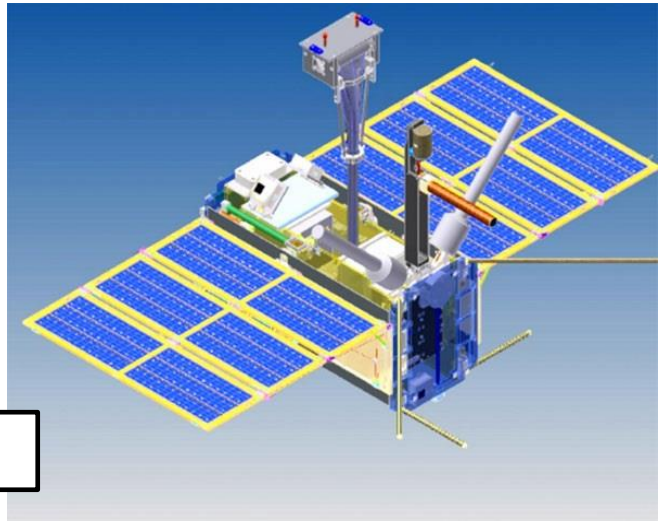
Launching 30.10.2011

Docking with the ISS

Loading of Chibis-M

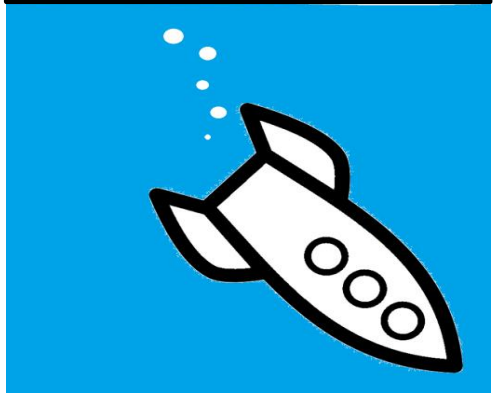
Deployment of Chibis-M



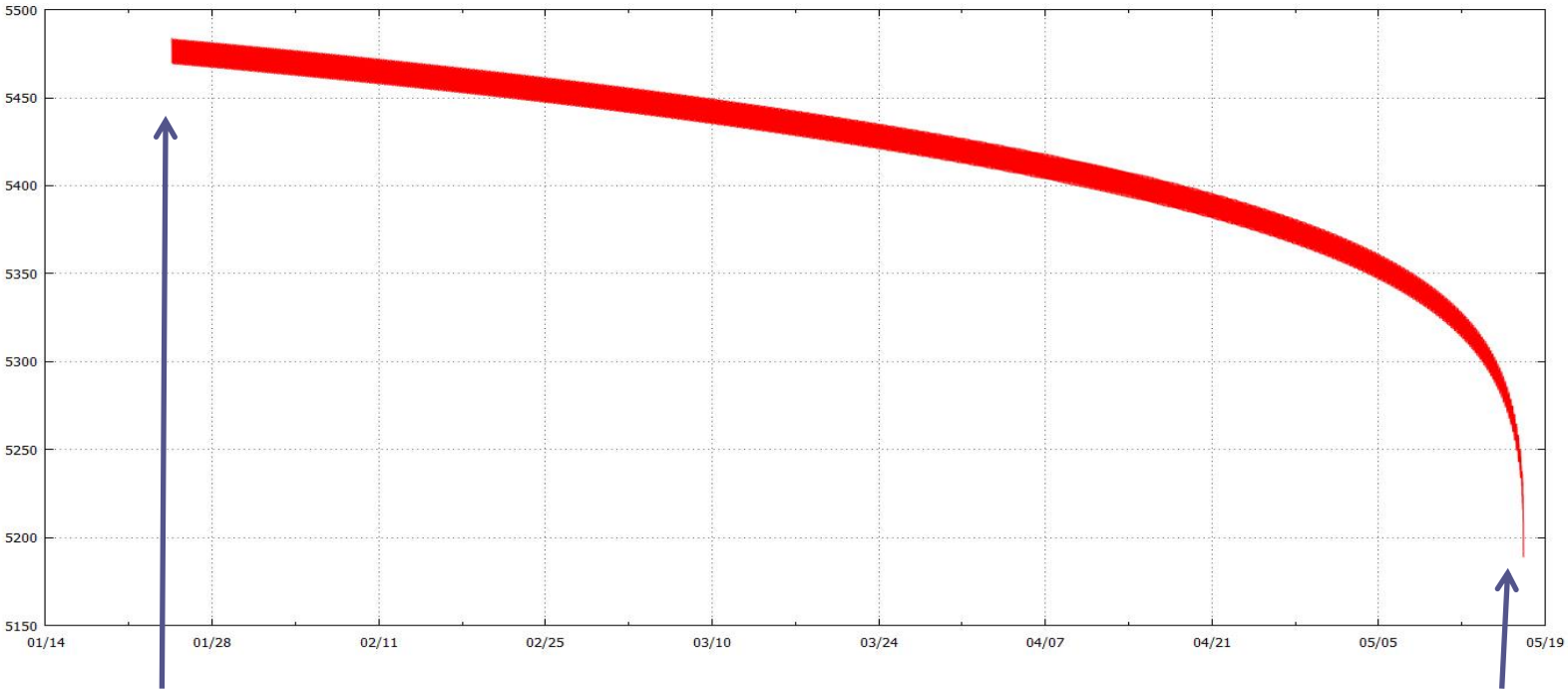


Chibis-M in orbit

The Pacific Ocean



Chibis-M mission: Orbit parameters



- circular orbit (~ 500 km)
- inclination 52°
- lifetime >2 years

Chibis-M mission: Scientific goals

- Testing theories of terrestrial gamma-ray flashes (TGF) origin
- Exploration of physical processes at atmospheric lightning discharges
- Study of electromagnetic parameters of space weather

Chibis-M mission: Payload

VLF ➡ MWC (0.1-40 kHz)

VHF ➡ RFA (26-48 MHz)

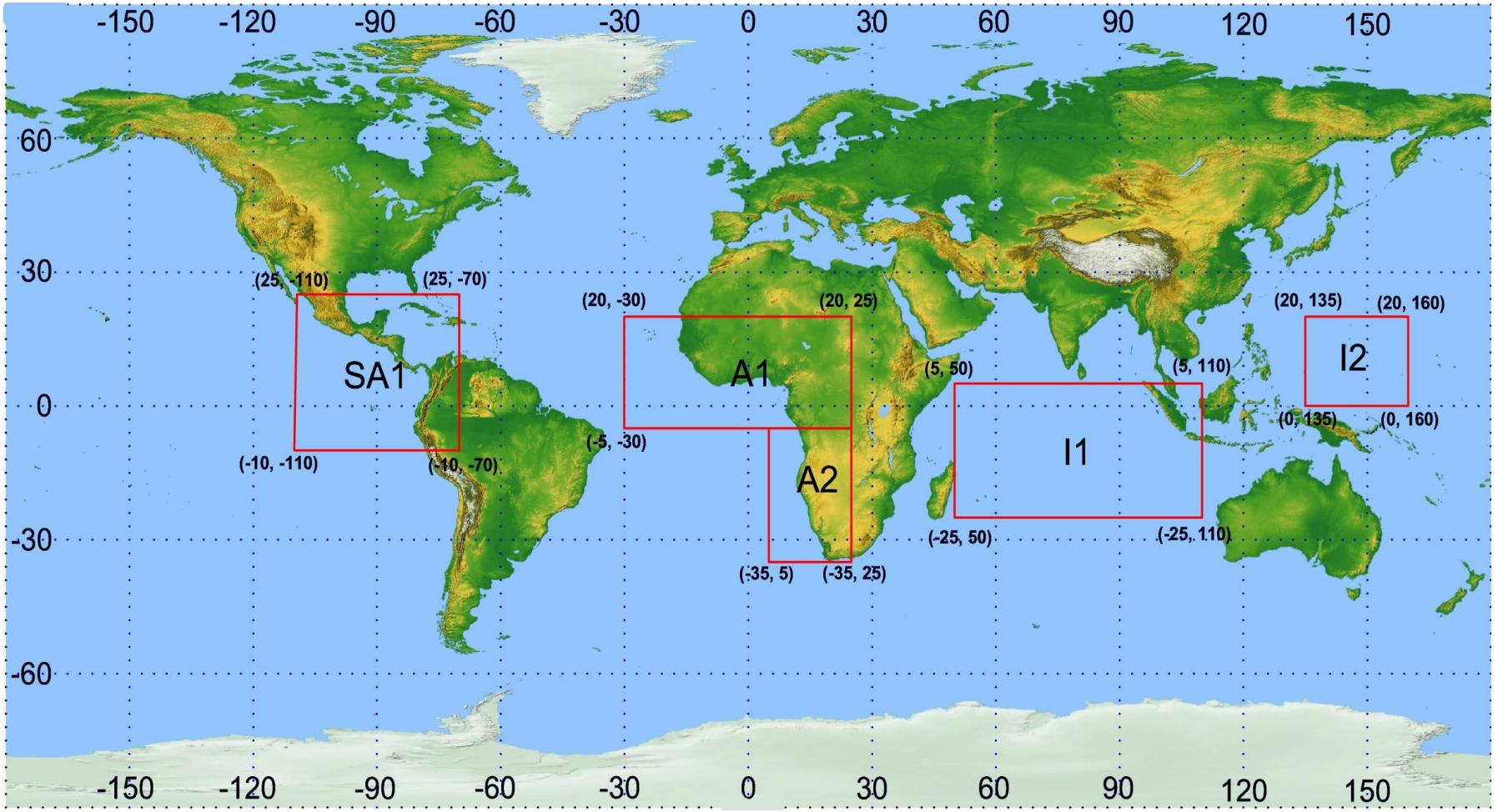
UV/IR ➡ DUV (180-400 nm and 650-800 nm)

Visible light ➡ DC (300 m, 15 frames/s)

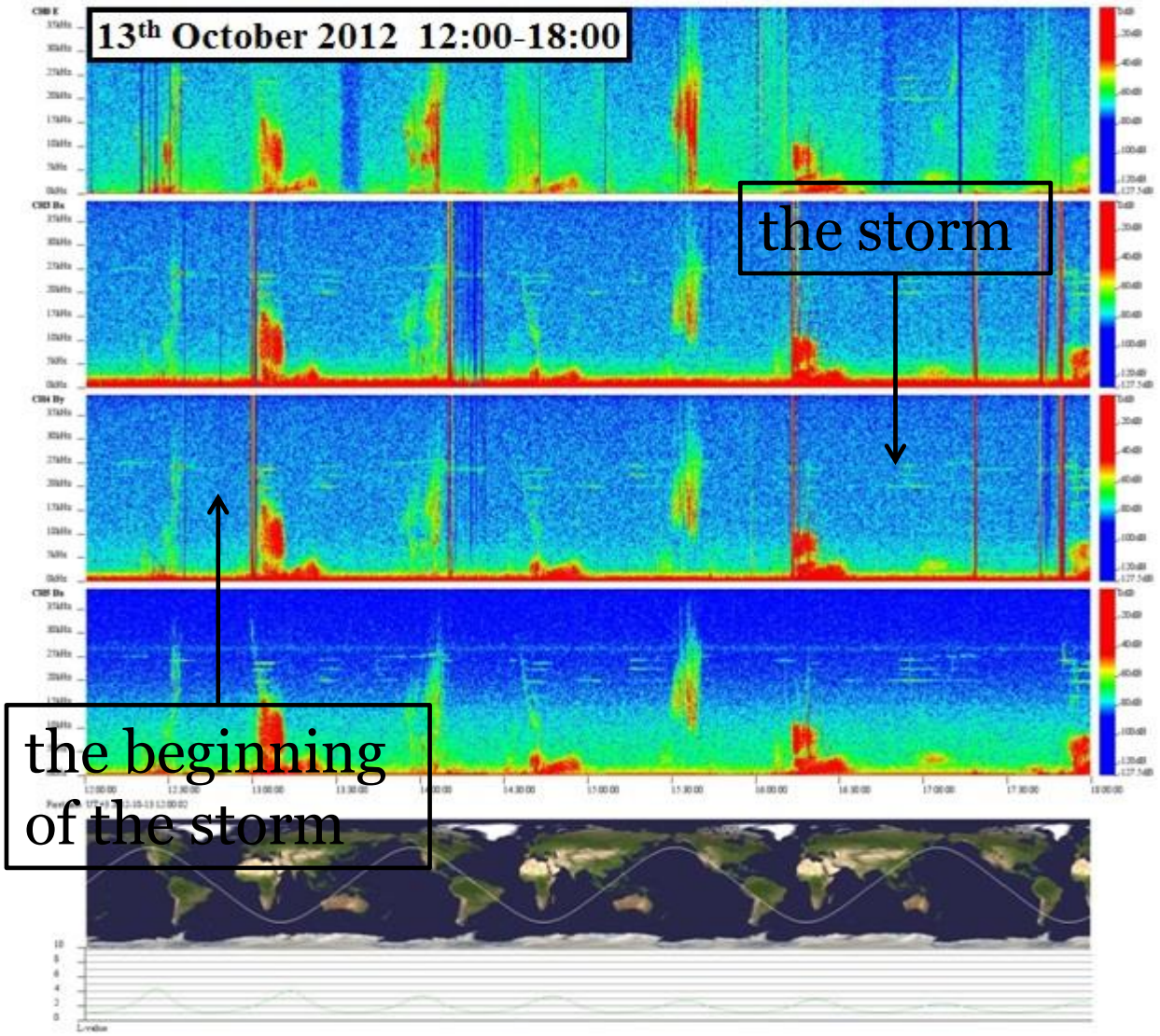
X-ray/γ-ray ➡ RGD (0.02–1.0 MeV)

Scientific payload **~ 12.8 kg**
Total weight **~ 40 kg**

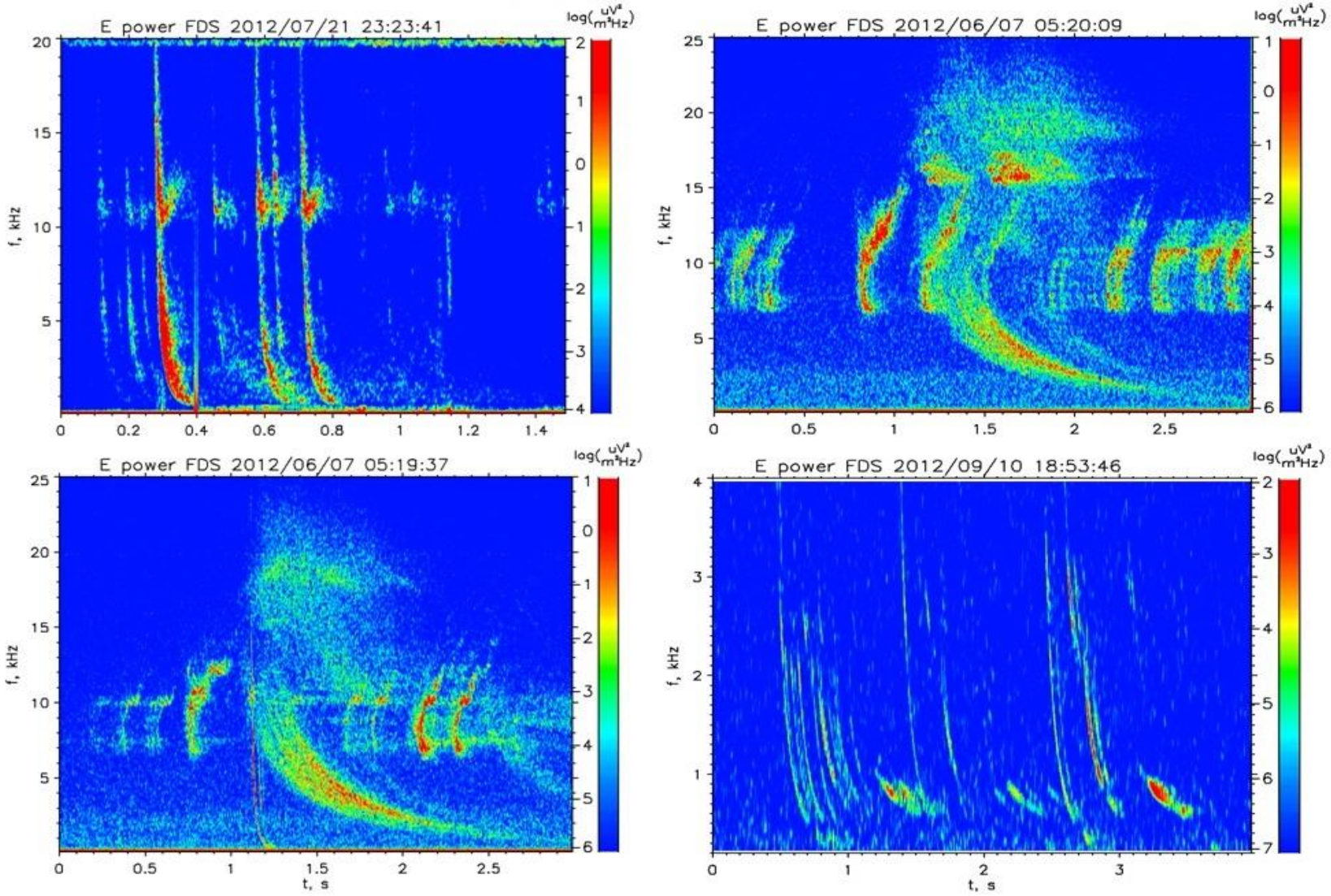
Chibis-M mission: search areas



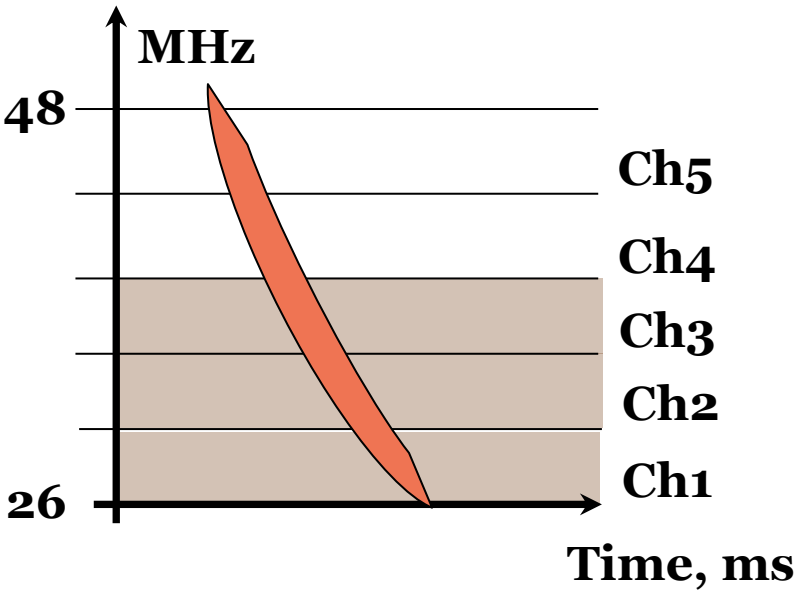
VLF observations: EM environment

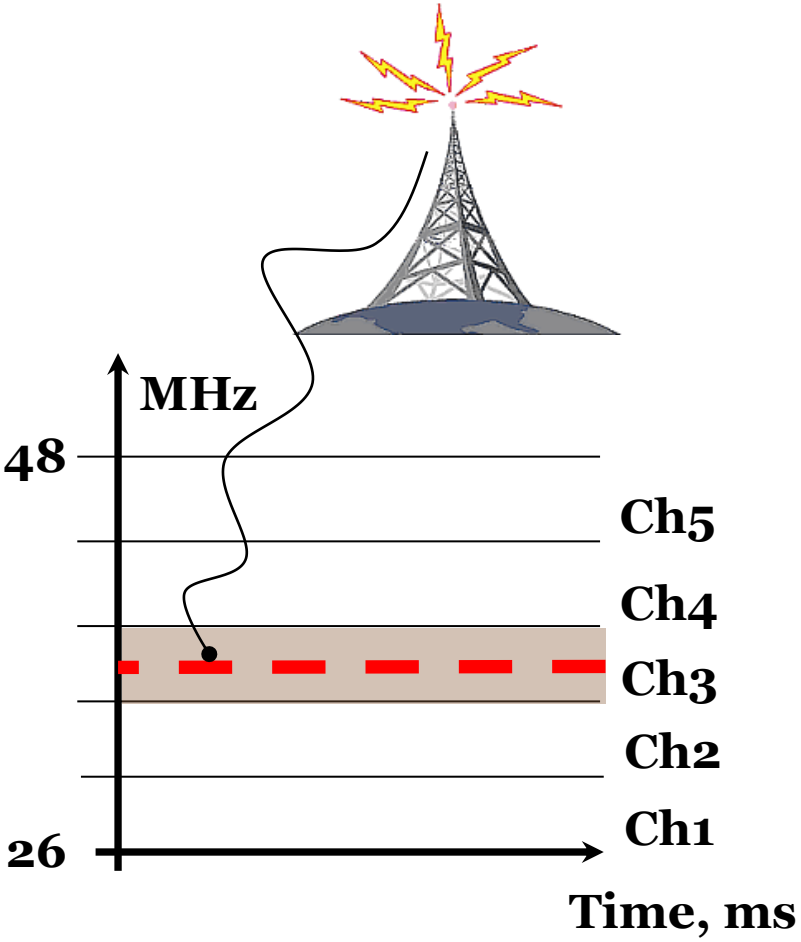


VLF observations: whistlers



The Chibis-M mission: Triggering

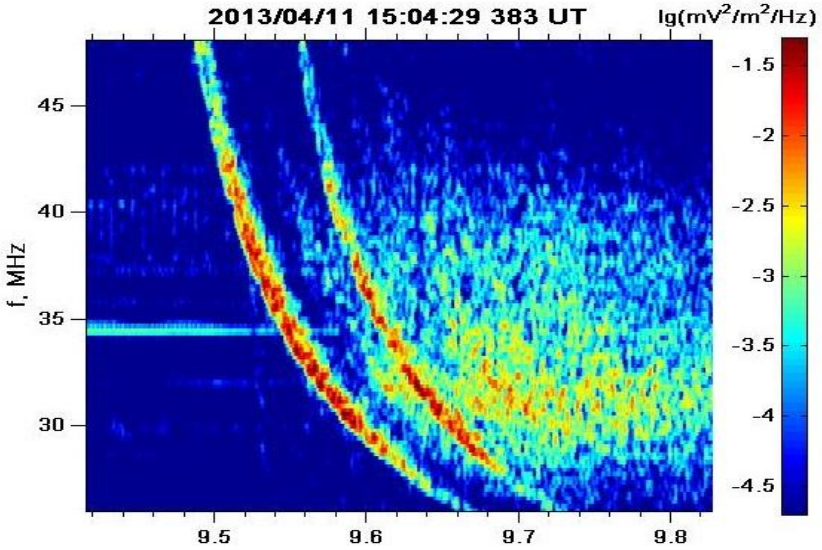


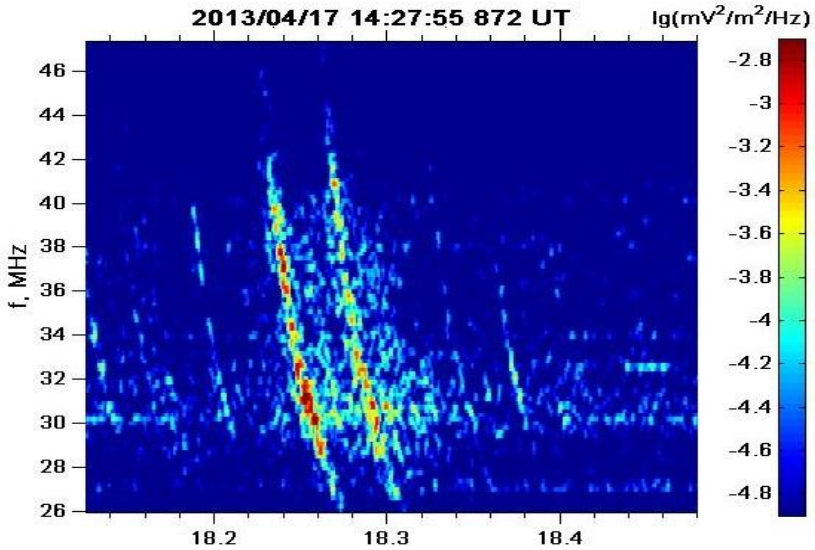


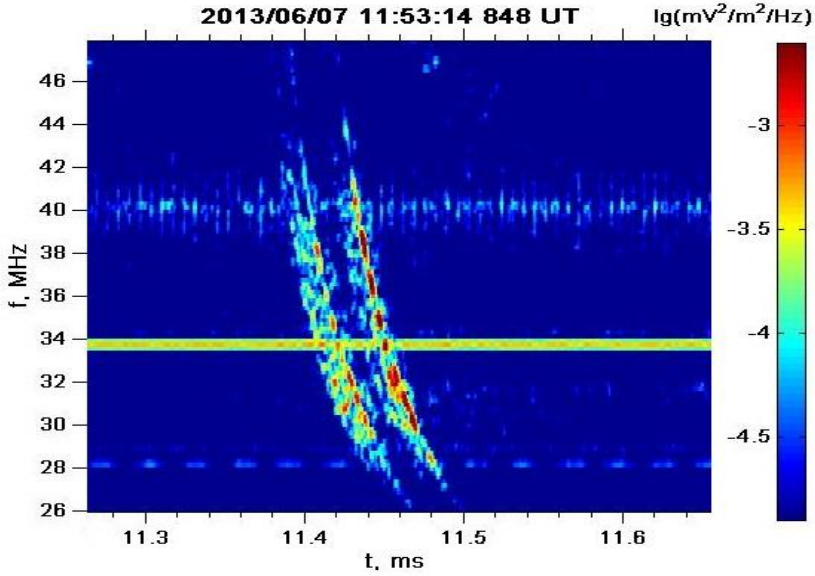
Trigger!

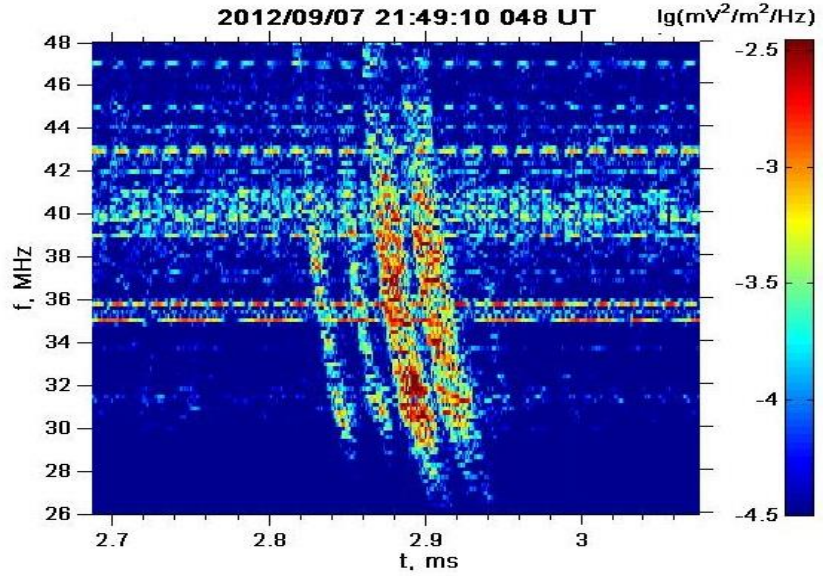
No trigger!

VHF observations: TIPP





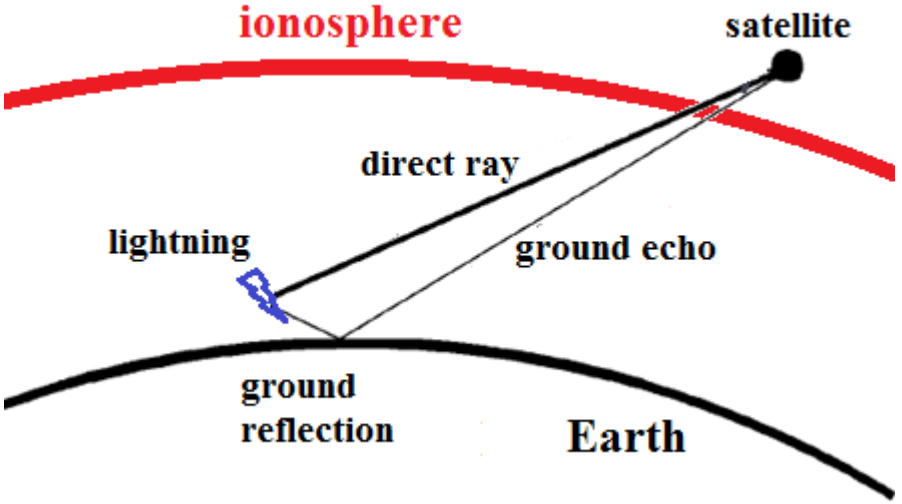


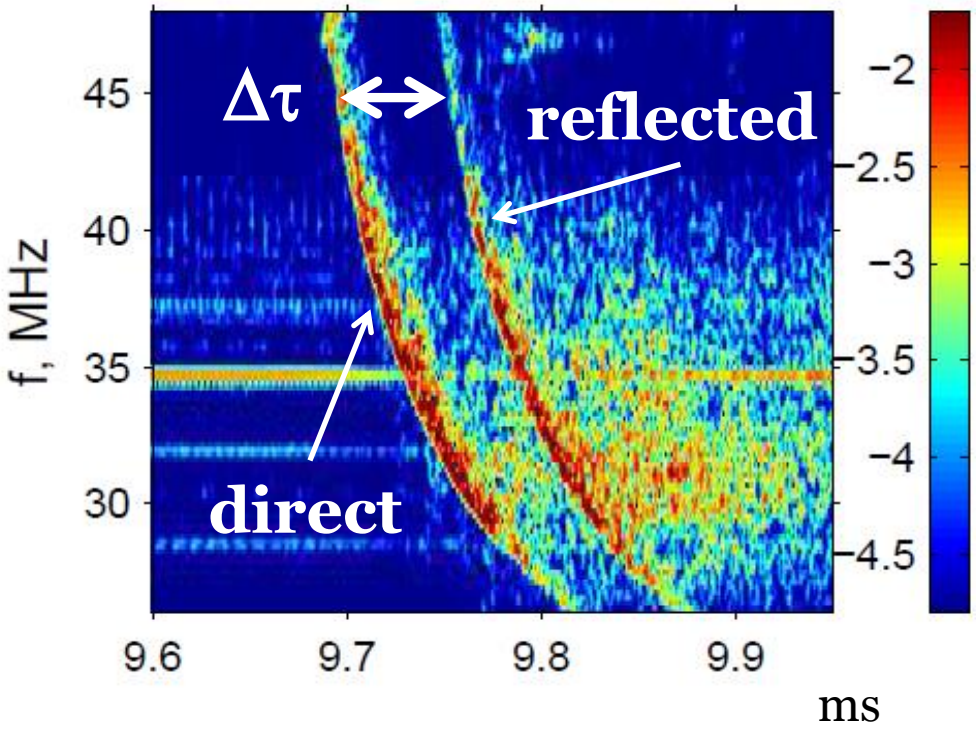


VHF observations: source altitude

$$h = \frac{\Delta\tau \cdot c}{2 \cdot \cos\theta}$$

?





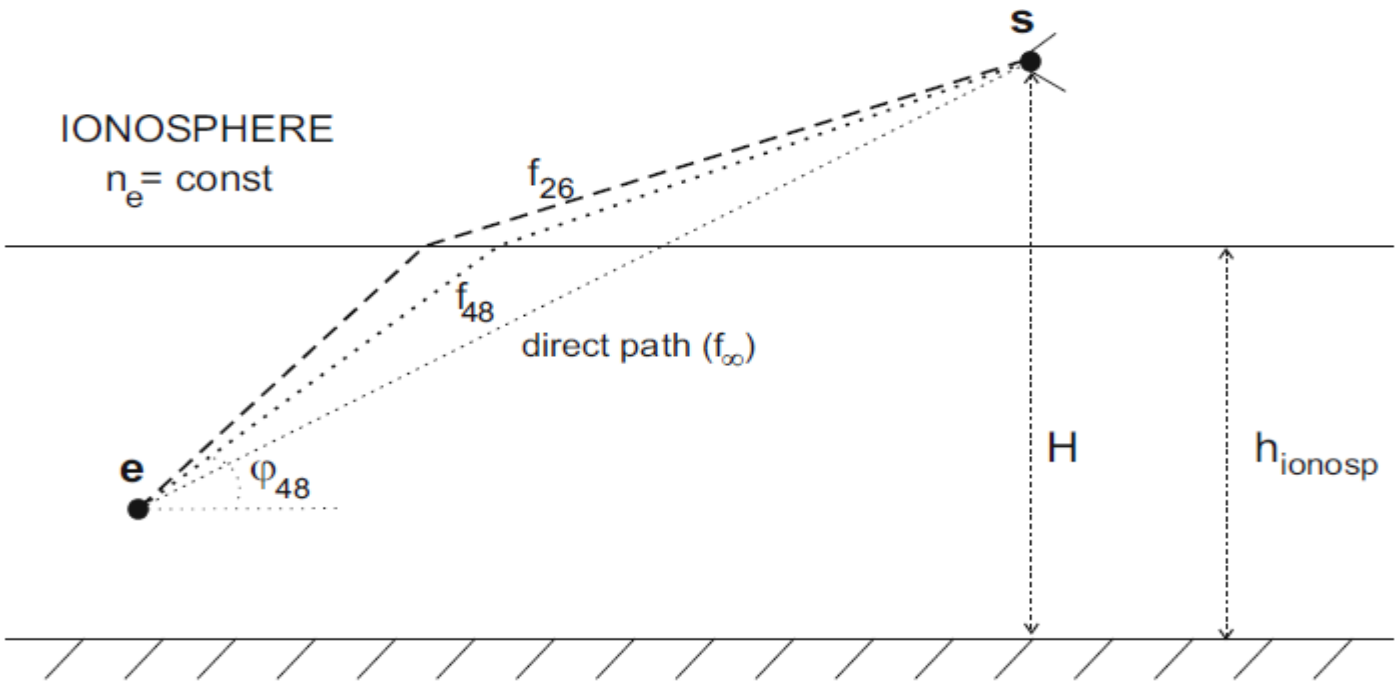
The second pulse results from reflection of VHF emssion from the Earth surface (soils and oceans)

VHF observations: source altitude

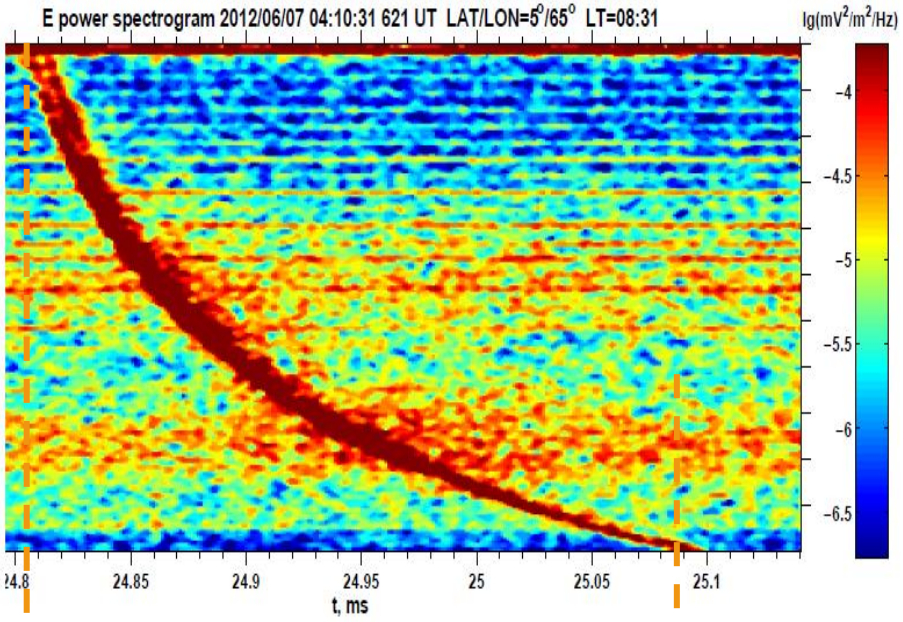
Refractive index of electromagnetic waves (Appleton-Hartree equation):

$$n^2 = 1 - \frac{X(1-X)}{(1-X) - 0.5Y_T^{1/2} + s\sqrt{0.25Y_T^4 + (1-X)^2 Y_L^2}}$$

where $X=(f_p/f)^2$, $Y=f_{ce}/f$, $Y_T=Y\sin\beta$, $Y_L=Y\cos\beta$.

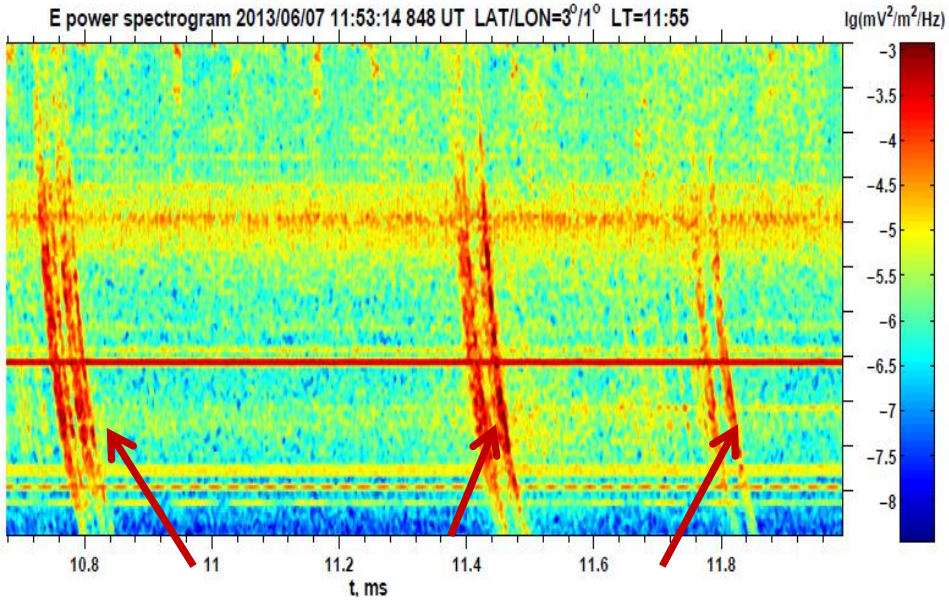


VHF observations: source altitude



~300 μs ➡ 63°

h=2.6 km



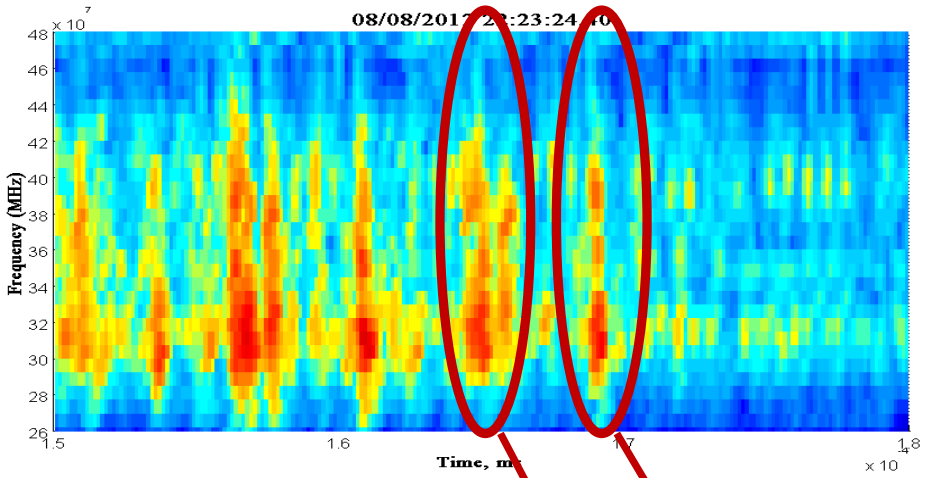
Taking V~10^8 m/s , we get
h_1=13, h_2=12 and h_3=8 km

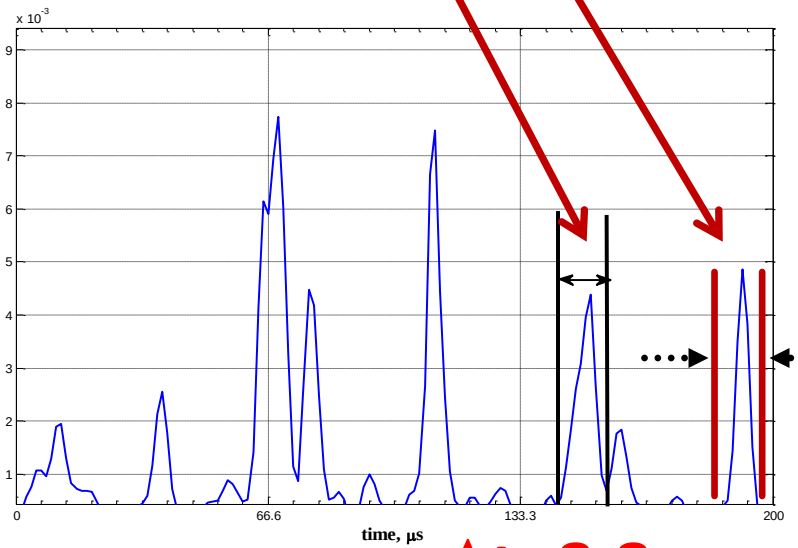
Descending runaway avalanche???

~80 μs ➡ 40°

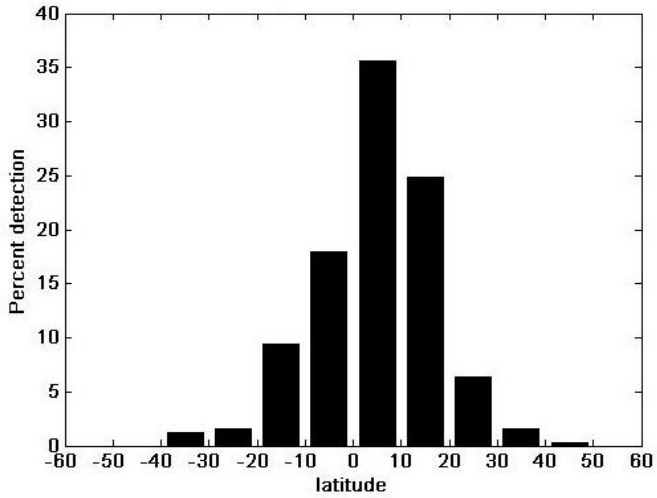
VHF observations: burst duration

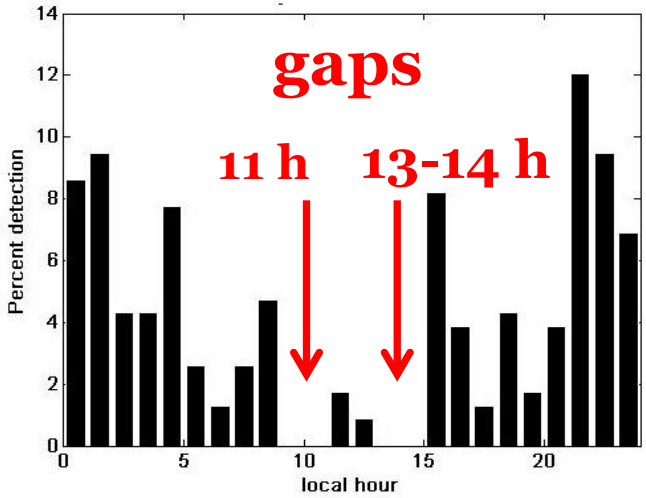
08 Aug 2012
UT 19:23:24





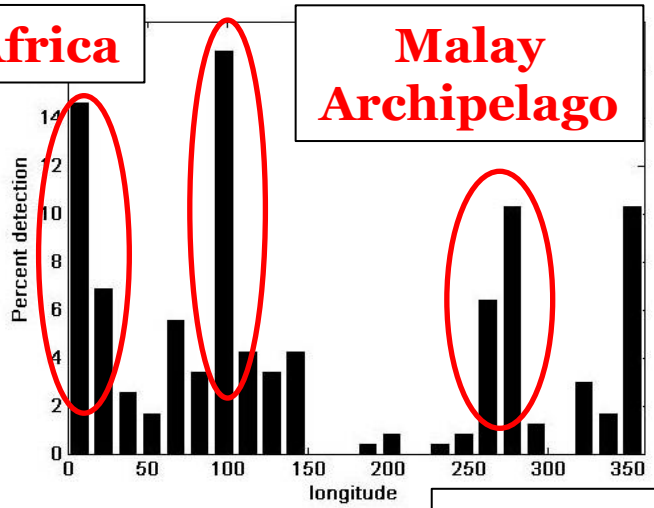
Probability of detection of tracks

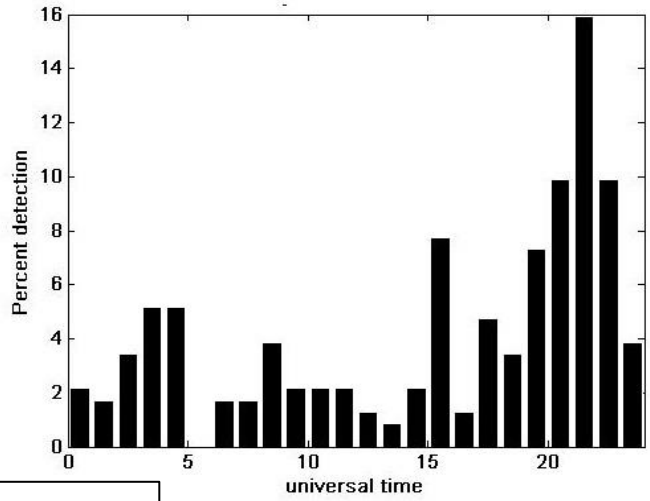




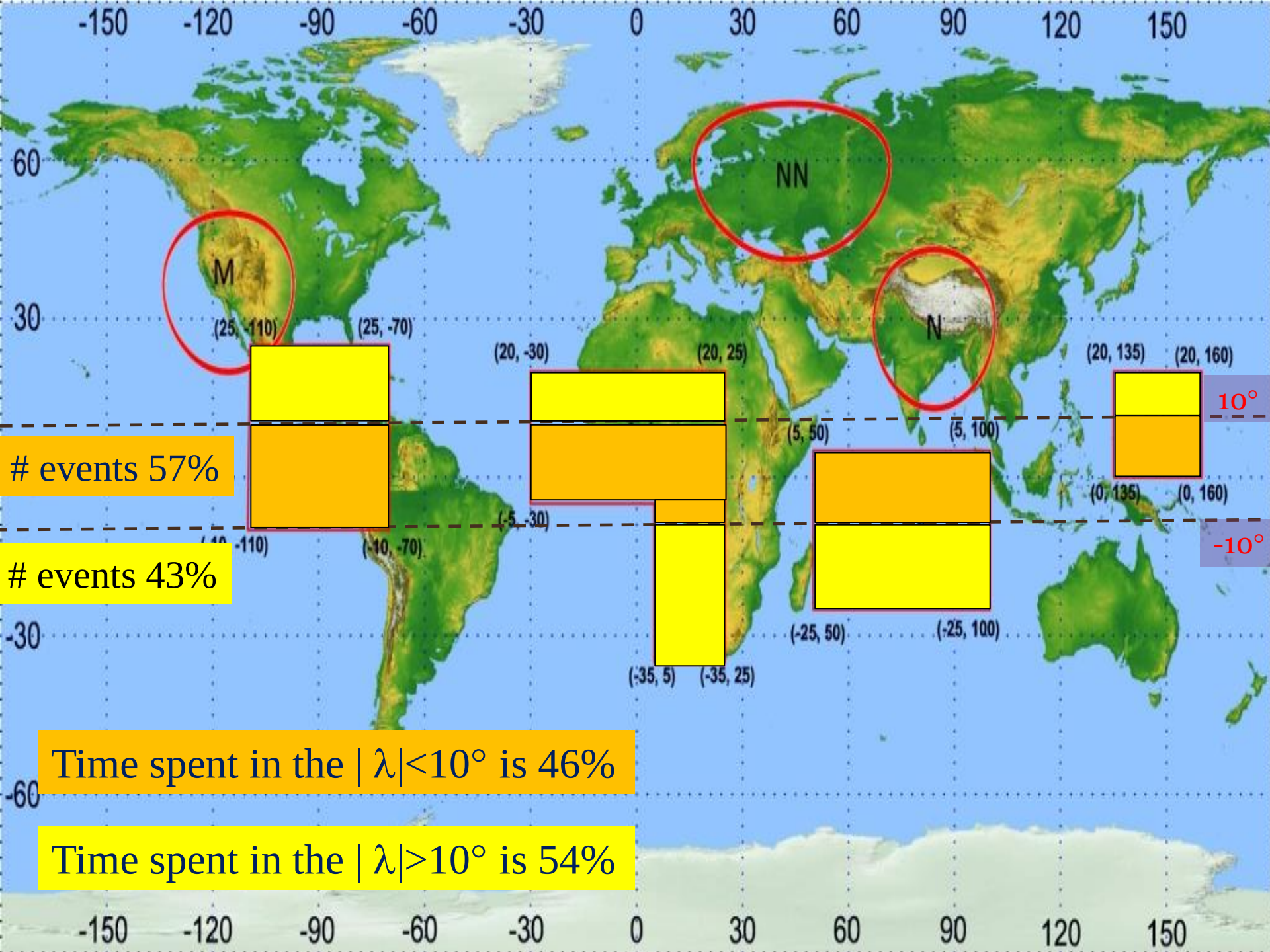
West Africa

Malay Archipelago

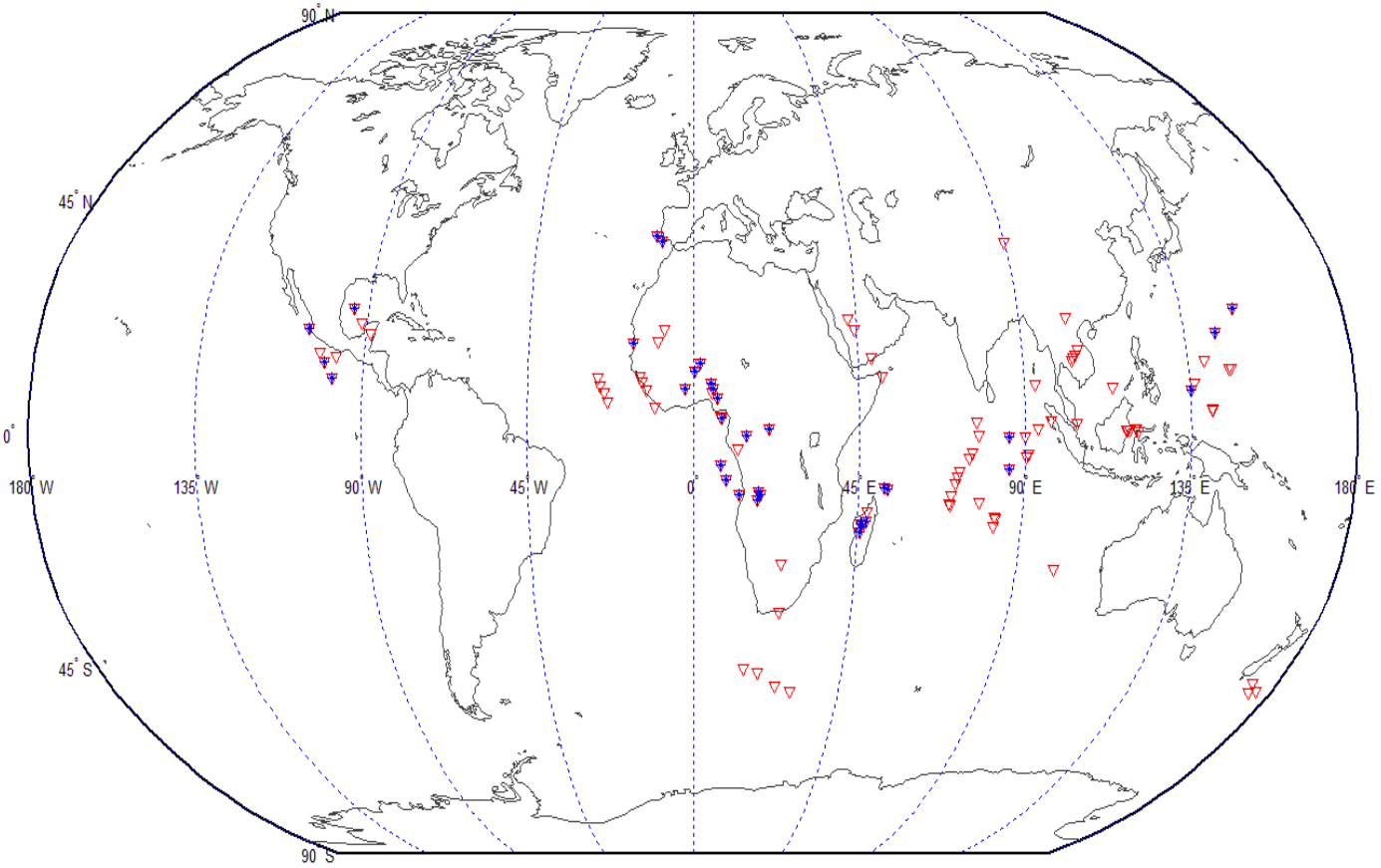




Central America

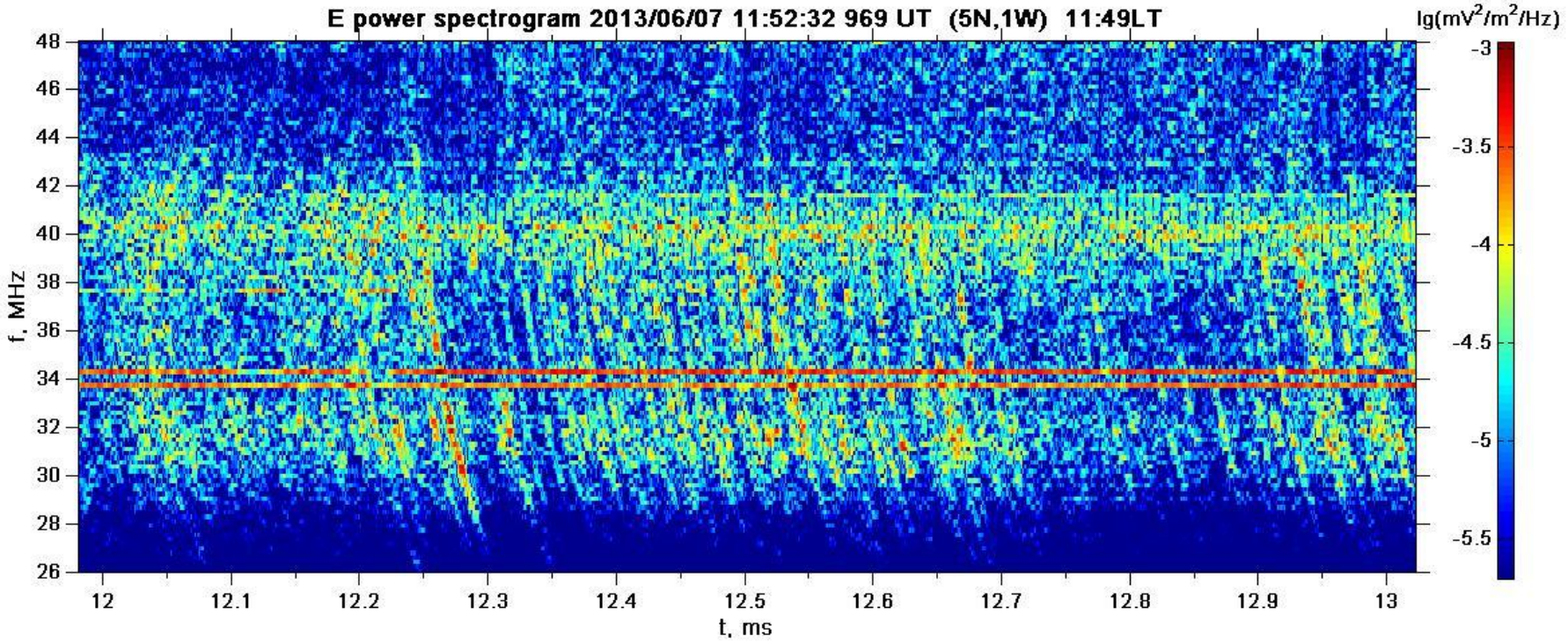

-150
-120
-90
-60
-30
0
30
60
90
120
150
60
30
-30
-60
NN
M
N
(25, -110)
(25, -70)
(20, -30)
(20, 25)
(20, 135)
(20, 160)
10°
(5, 50)
(5, 100)
(0, 135)
(0, 160)
-10°
(-5, -30)
(-10, -70)
(-25, 50)
(-25, 100)
(-35, 5)
(-35, 25)
events 57%
events 43%
Time spent in the | λ|<10° is 46%
Time spent in the | λ|>10° is 54%

VHF and DUF observations

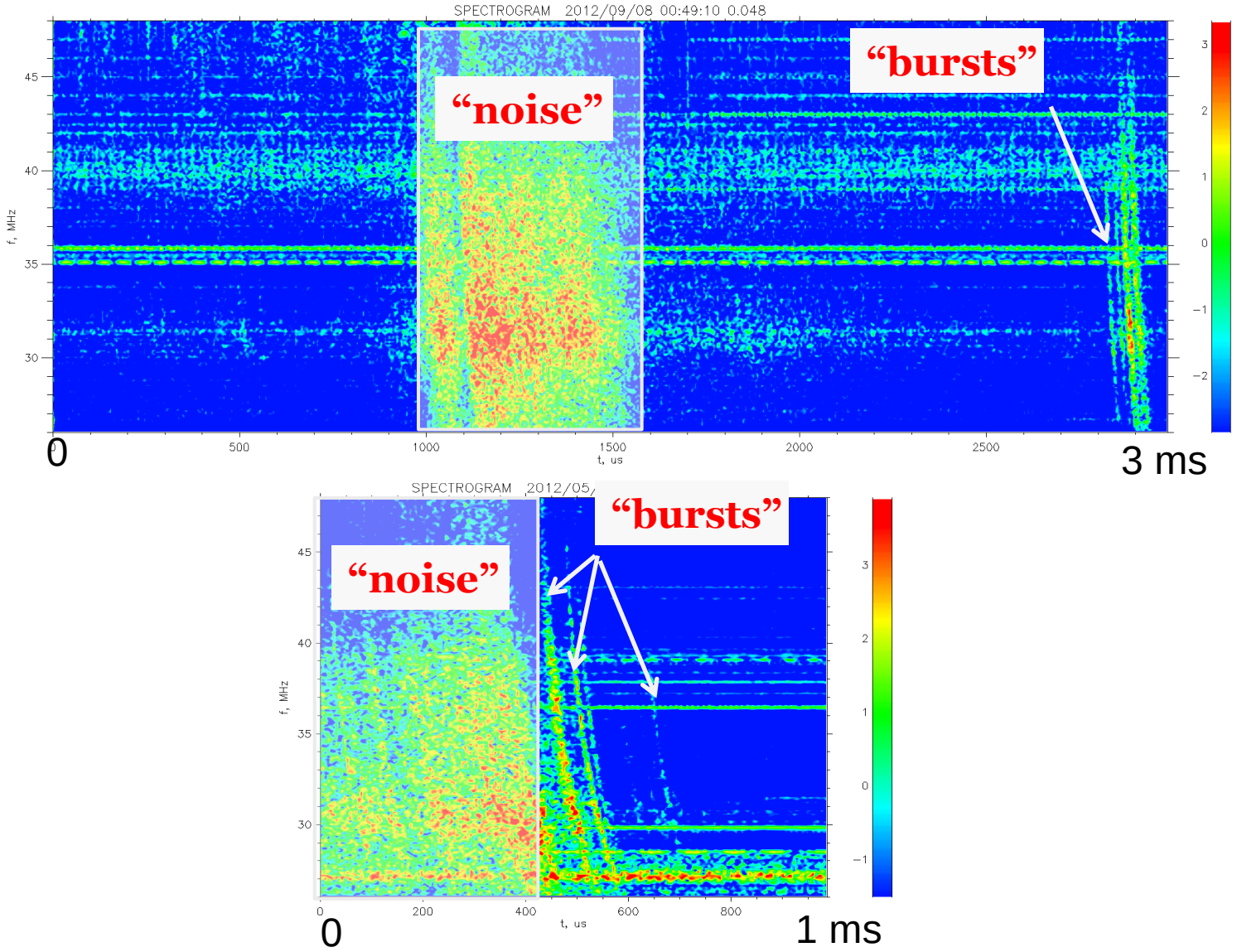


Blue stars: simultaneous observations of the IR+UV emission and radio bursts
Red triangles: no IR+UV emission detected

VHF observations: other signals



VHF observations: noise



Future missions

Chibis-EMC

- DC magnetic field
- VLF detector
- VHF detector
- Electron density

Chibis-AI

- VHF detector
- X-ray/γ-ray detector
- …

2017???

Conclusions

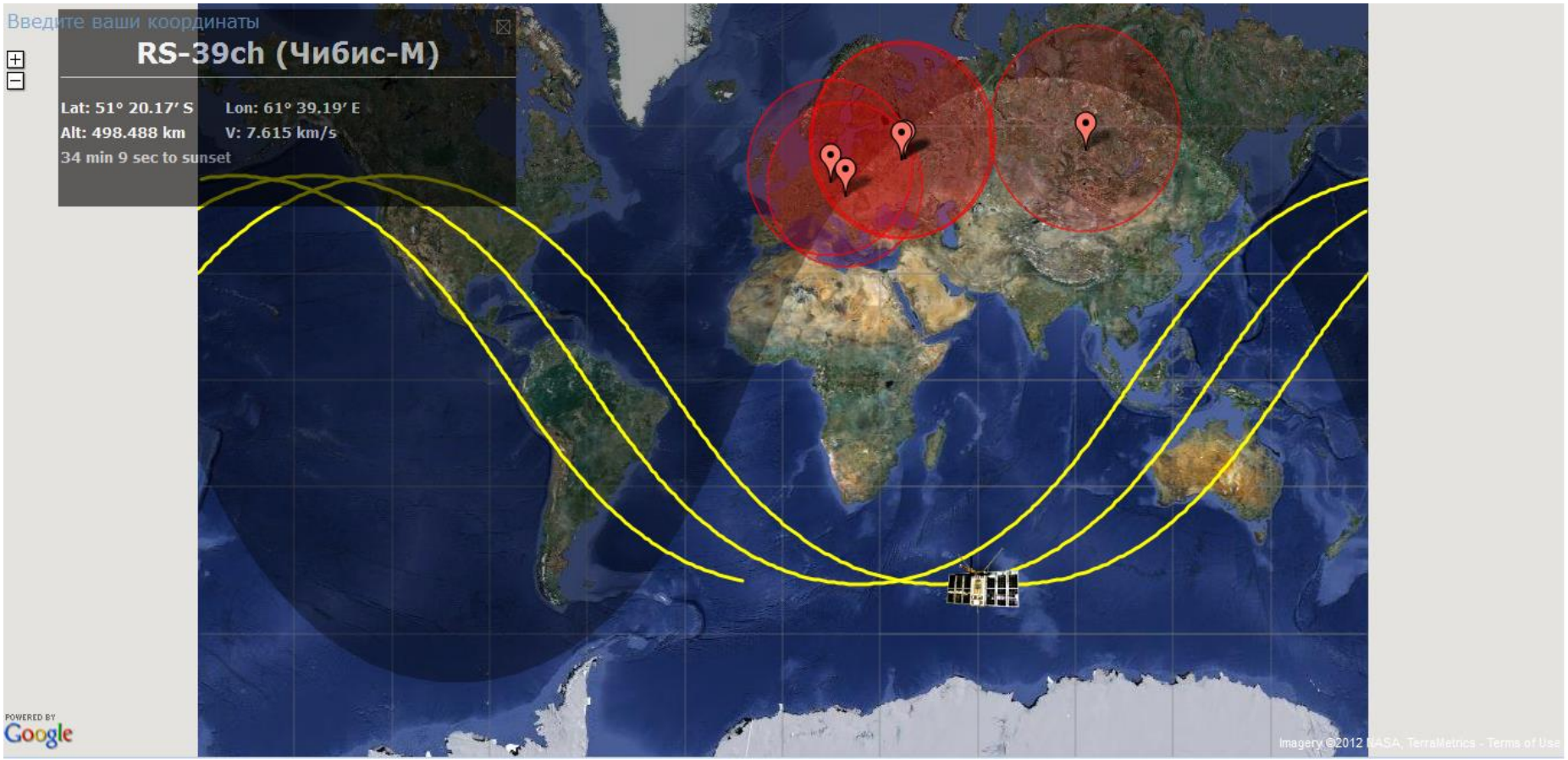
VLF/ELF observations:

1. Measurements of electromagnetic waves in the VLF range can be used as space weather parameters monitoring.
2. Appearing of whistlers indicates high lightning activity at the particular time and place.

VHF observations:

1. Two main classes of signals are observed: TIPP and “noise”.
2. TIPP have subionospheric origin, duration of several microsecond and time lag between traces of 50-300 μs, which corresponds to height of the source at $h \in [2;15]$ km.
3. The most active regions of VHF «burst» generation are West Africa, Central America and Malay Archipelago.
4. Spatial distribution of TIPPs are wider then it was supposed: only 57% of events registered in $|\lambda| < 10°$ and time spent by «Chibis-M» in the region ~46%.
5. Global diurnal distribution function of this «bursts» have gaps at 11 AM and 1-2 PM of the local time.
6. Only part of the VHF «bursts» was accompanied by UV and IR emissions.
7. VHF “noise” with duration from hundreds of microseconds up several milliseconds. The registration of «noise» is usually accompanied by TIPPs.

http://chibis.cosmos.ru



Thanks!!!