Passive Geolocation using Lightning as a Signal of Opportunity

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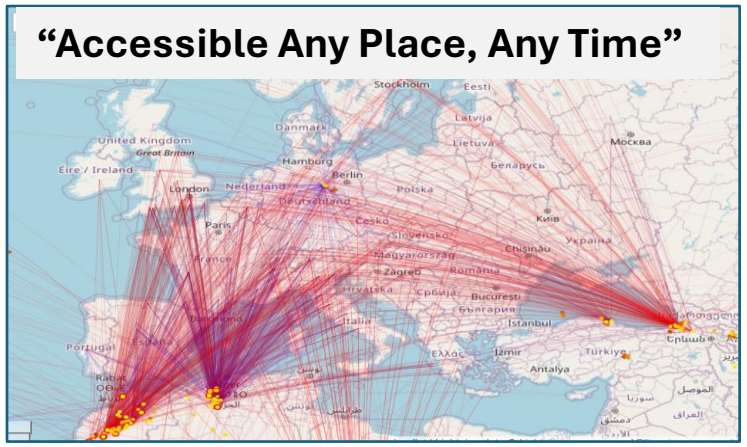
The Problem We Address and Our Solution

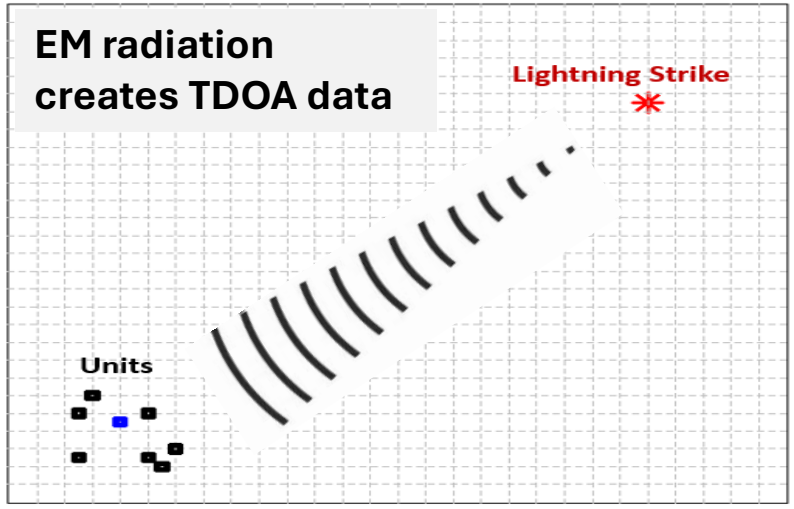
- The Problem
  - Assume the GNSS system has been disabled, spoofed or jammed.
  - Platforms are scattered and need to regroup.
  - They may need to operate covertly, minimizing emissions.
- Our Solution
  - Exploit signals of opportunity (SoO) in the radio spectrum, especially those from lightning but also from CODAR, NDB, Time Stations, etc.
  - Minimize the cost to equip many platforms.
  - Automate operation as much as possible to minimize crew distraction.

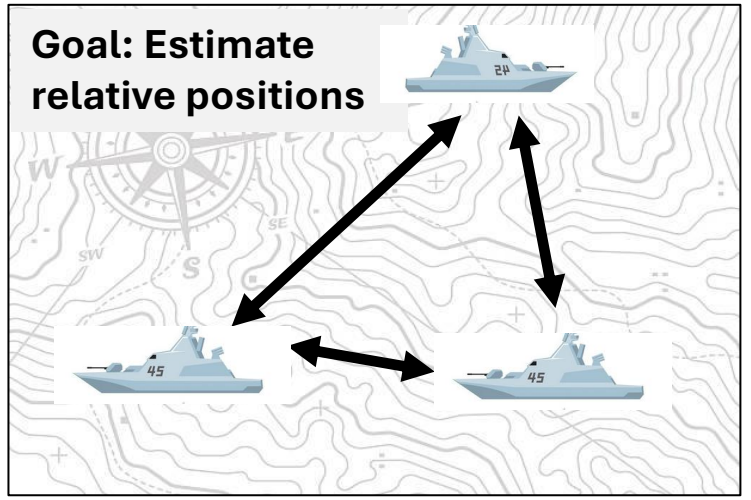
Why Lightning?

Lightning

1. Free
2. Abundant
3. Exploitable
4. Un-Jammable
5. Un-spoofable

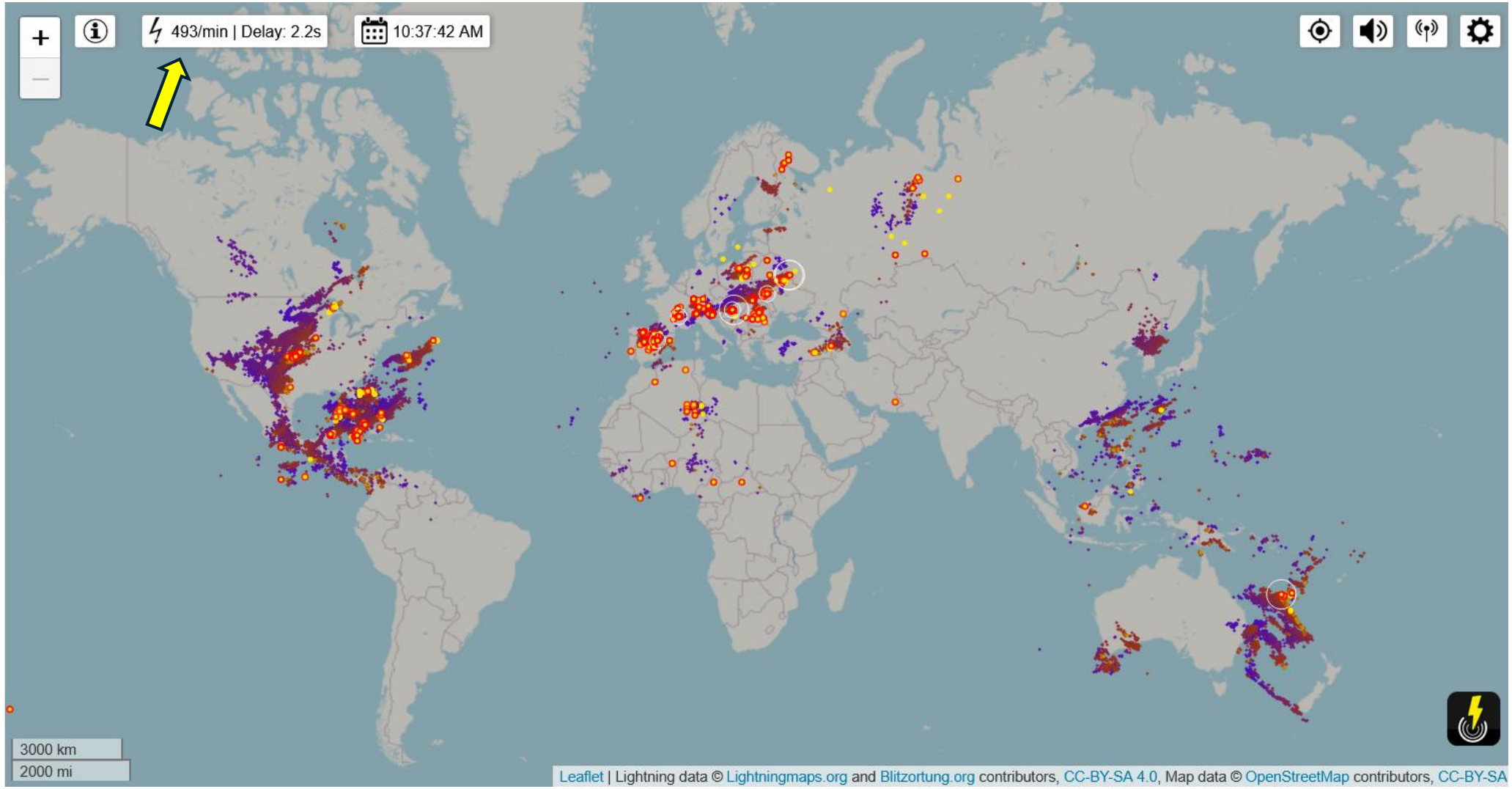




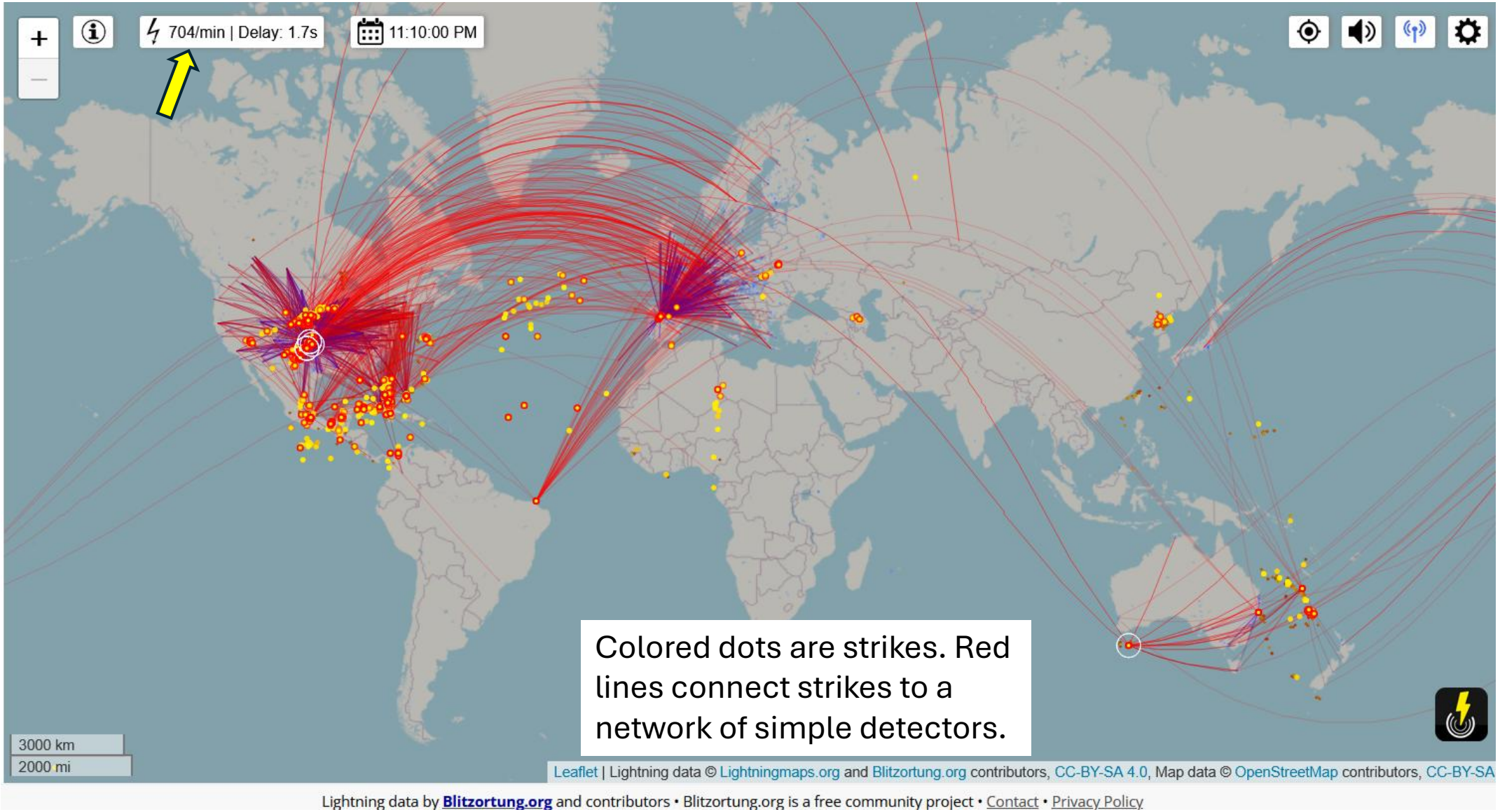


Lightning Is “Always On”

24 Hours of Lightning at 1437Z on 3 June 2025



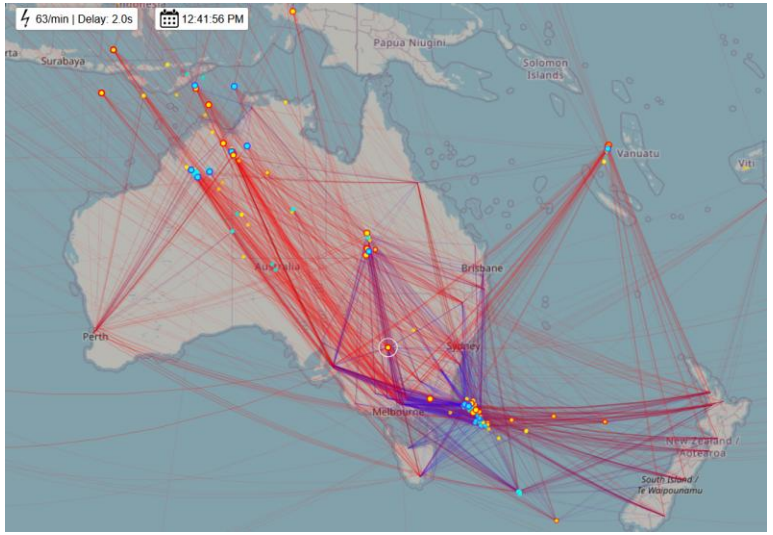
Real Time Lightning at 0310Z on 3 June 2025



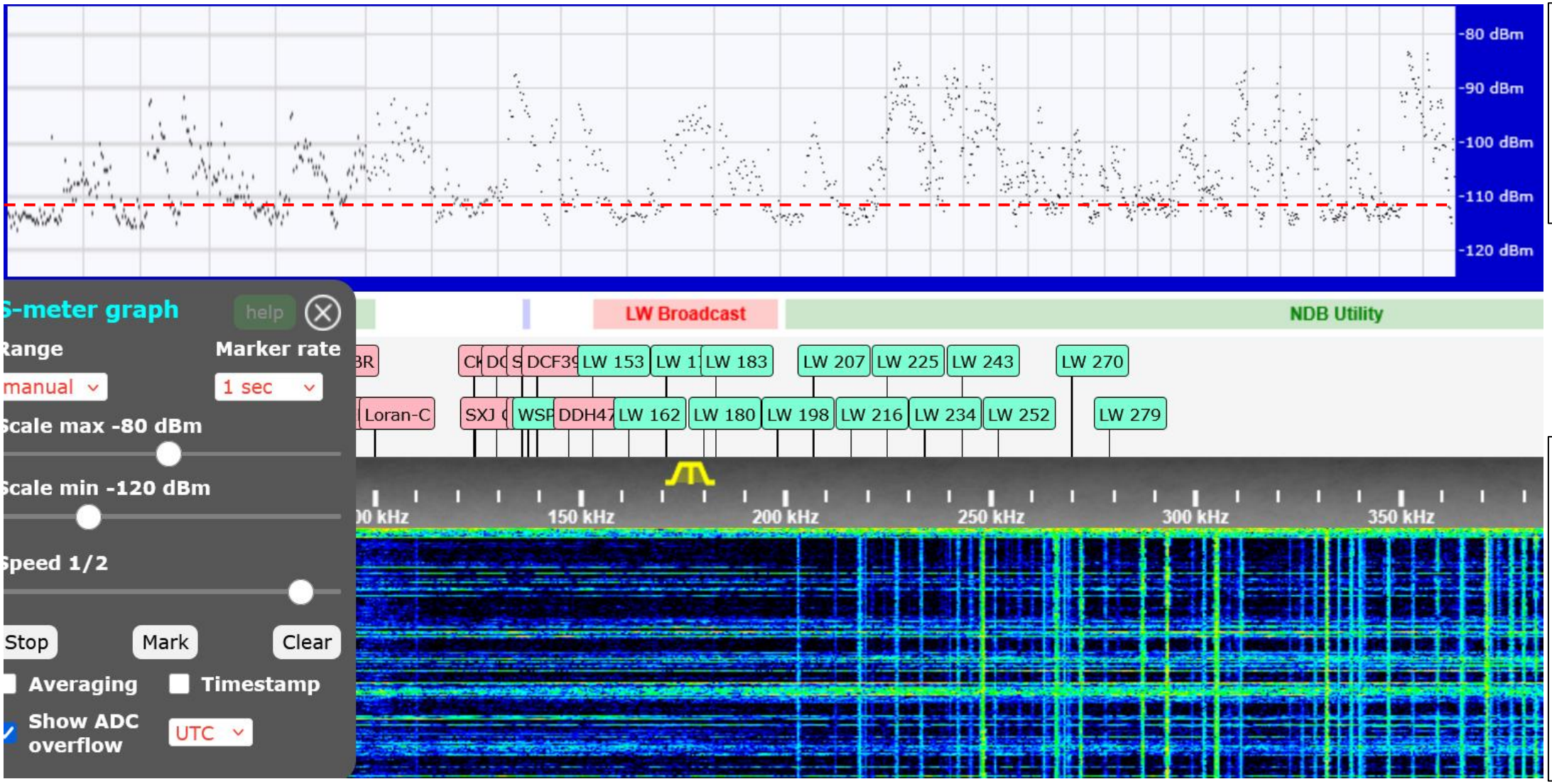
Harvesting Lightning Signals

Timing Lightning Strikes

- Our research uses software defined radios (SDRs) to detect the VLF, LF and HF radio signals generating by lightning strikes.
- SDR's provide two forms of visual display.
  - S-Meter: Plots a time series of the strength of the radio signal.
  - Waterfall plot: Plots the signal energy level by frequency across time.
- The next slide shows both plots during a strong storm in Australia.



Lightning Detected by a Software Defined Radio



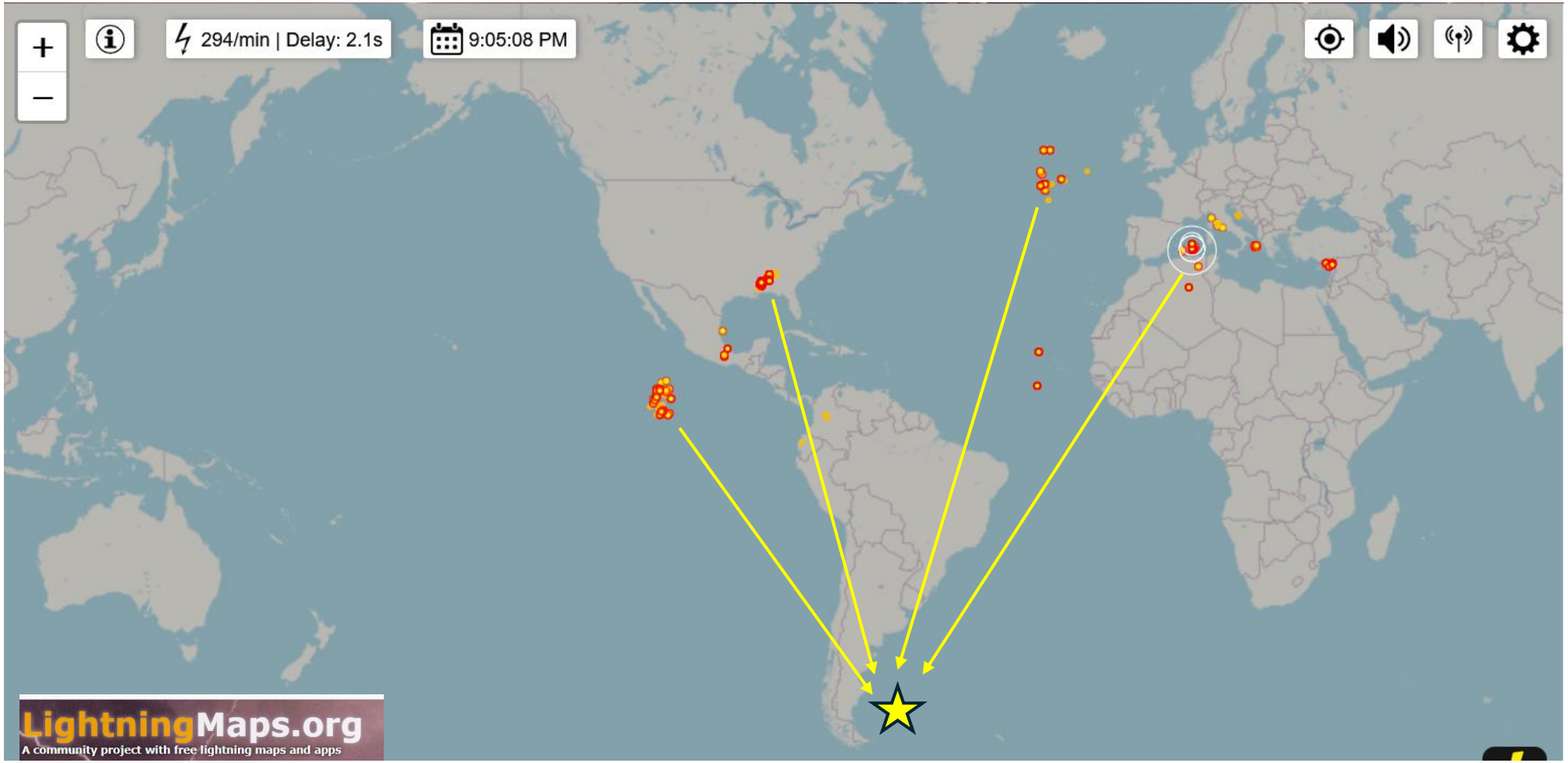
S-Meter plot; lightning shows as vertical spikes over baseline.

Waterfall plot: newer observations on top, older below; lightning shows as bright horizontal lines.

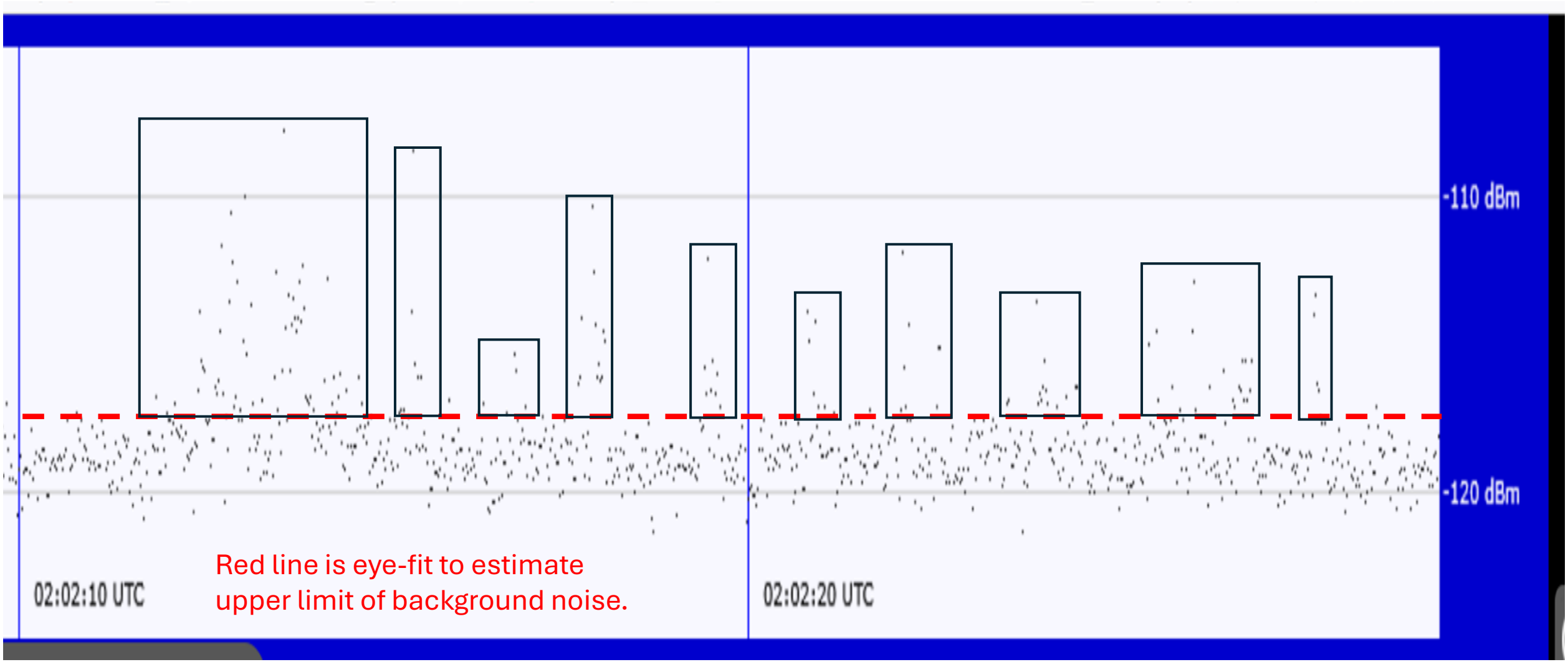
Kiwi.com Software Defined Radio

Detecting Distant Lightning
Example #1 of 3:
using an SDR in the Falkland Islands

Long-Distance Detection from Falklands 12Feb25

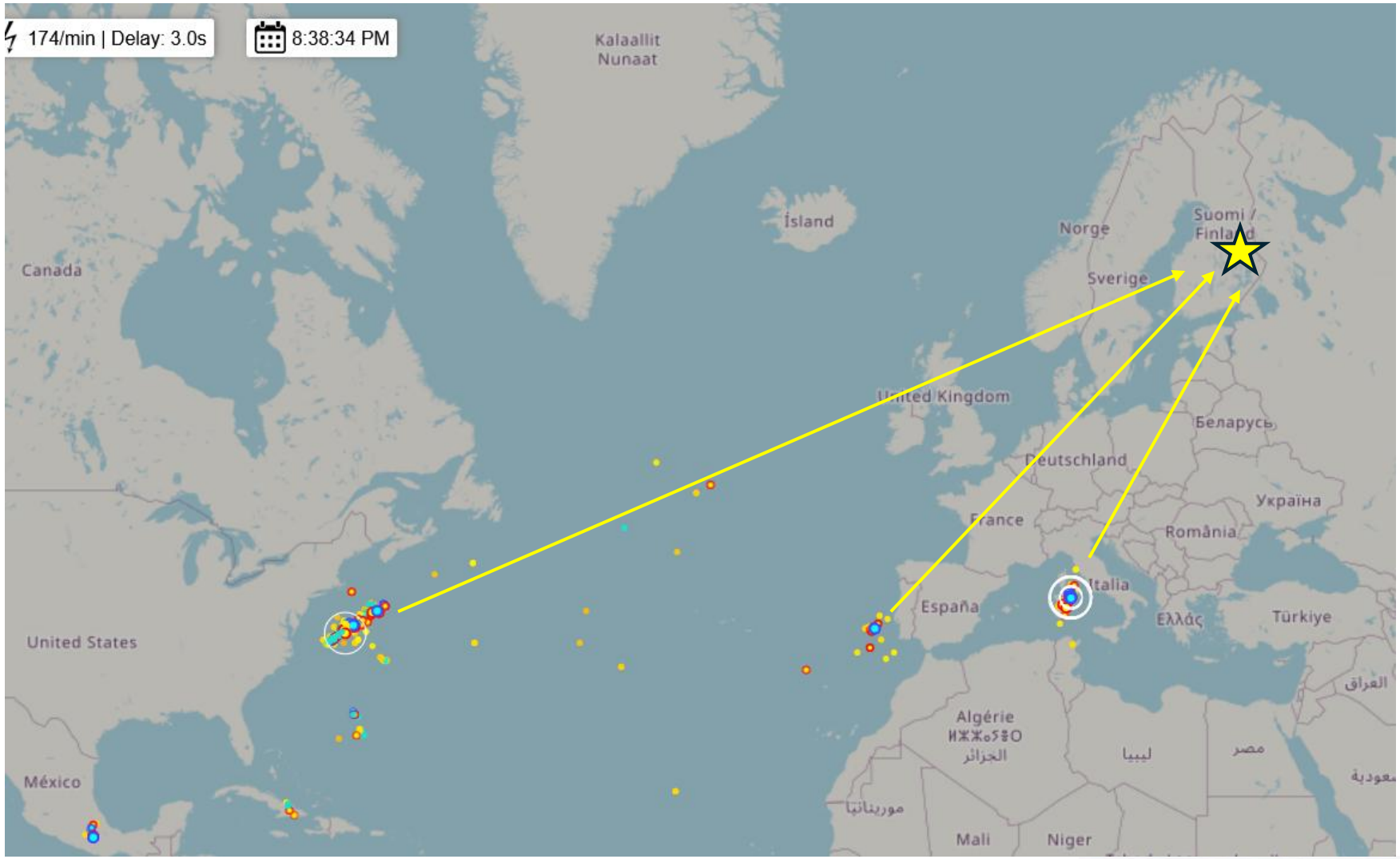


S-Meter Readings in Falklands

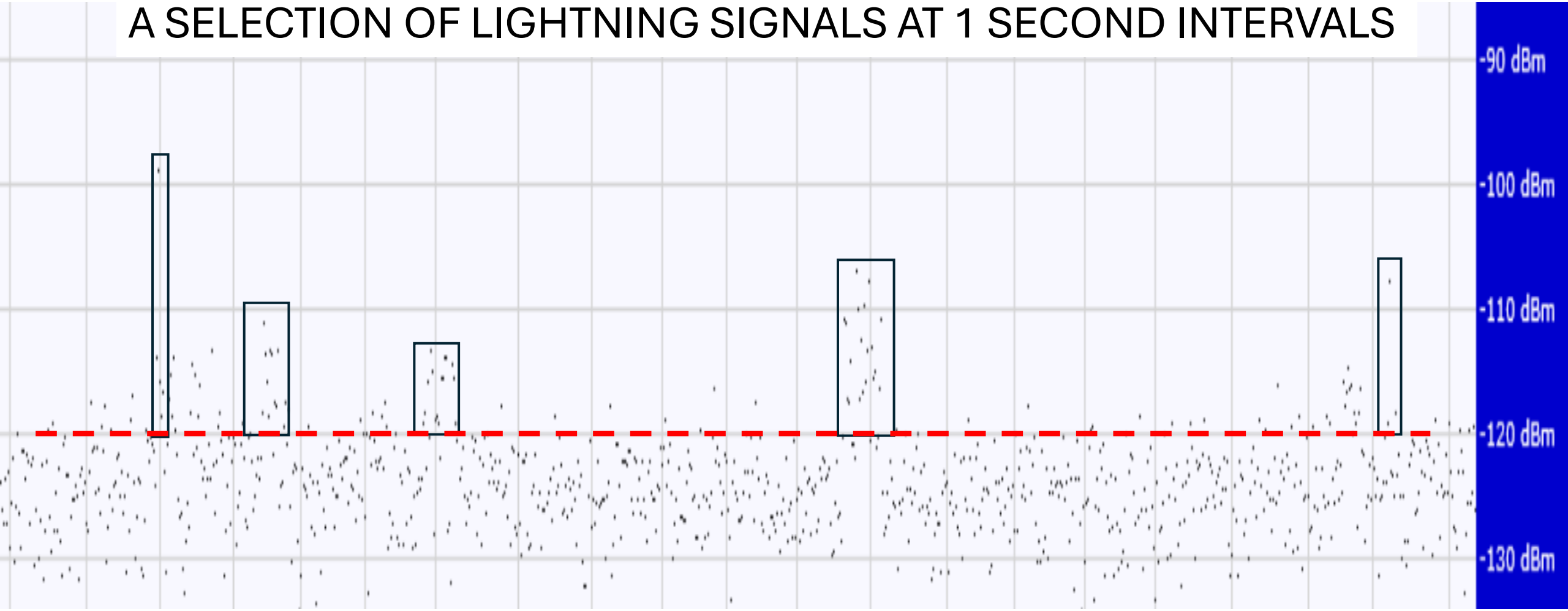


Detecting Distant Lightning
Example #2 of 3:
using an SDR in Finland

Long-Distance Detection in Finland 01Mar25



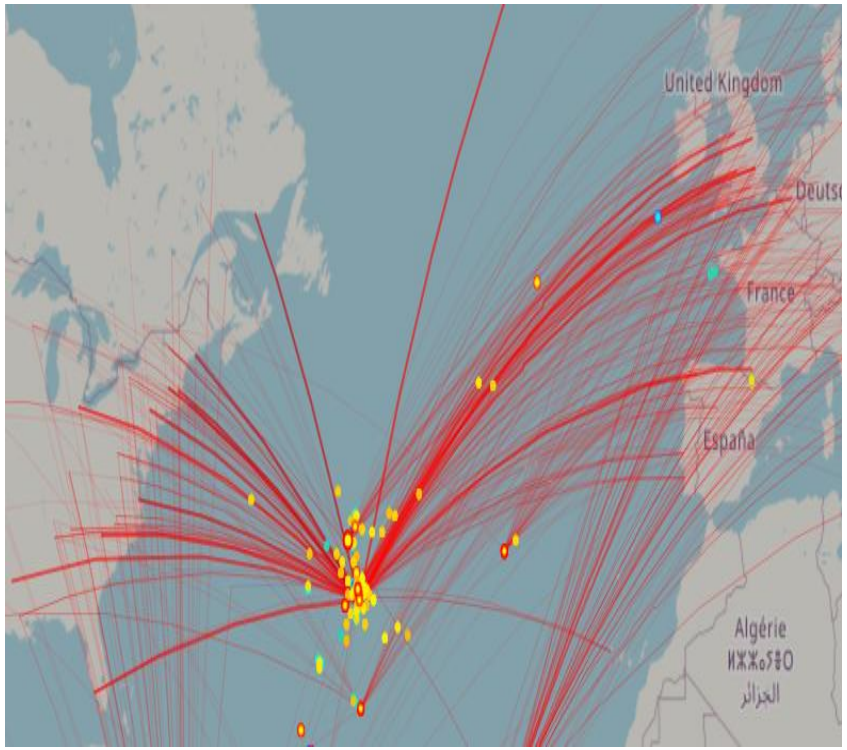
A SELECTION OF LIGHTNING SIGNALS AT 1 SECOND INTERVALS



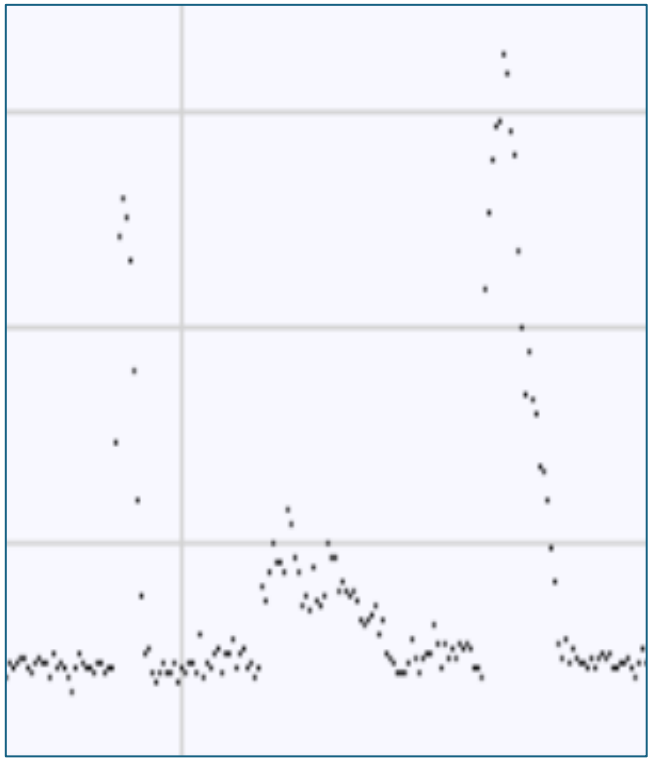
Detecting Distant Lightning
Example #3 of 3:
Trans-Oceanic Range

Mid-Atlantic Storm Detected Simultaneously in Vermont and Ireland

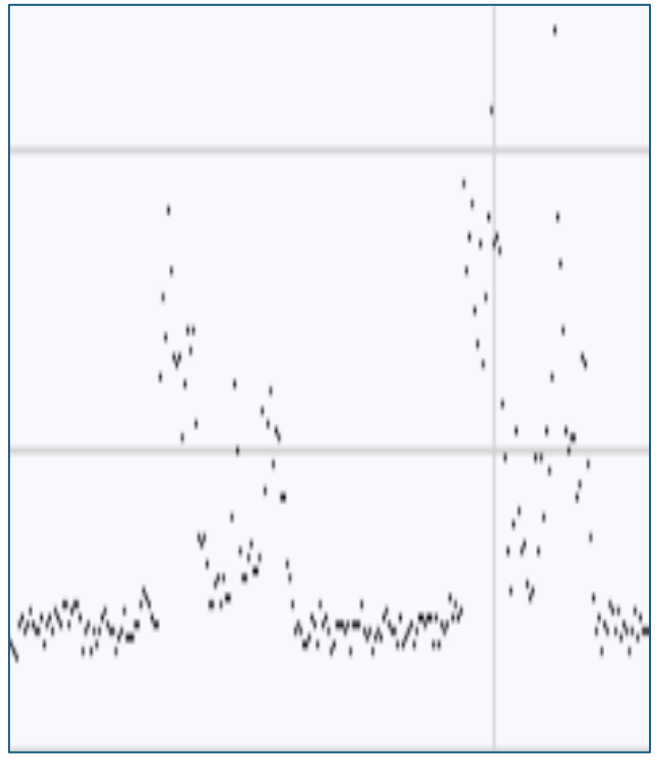
~0300Z 20Mar25



Vermont



Ireland

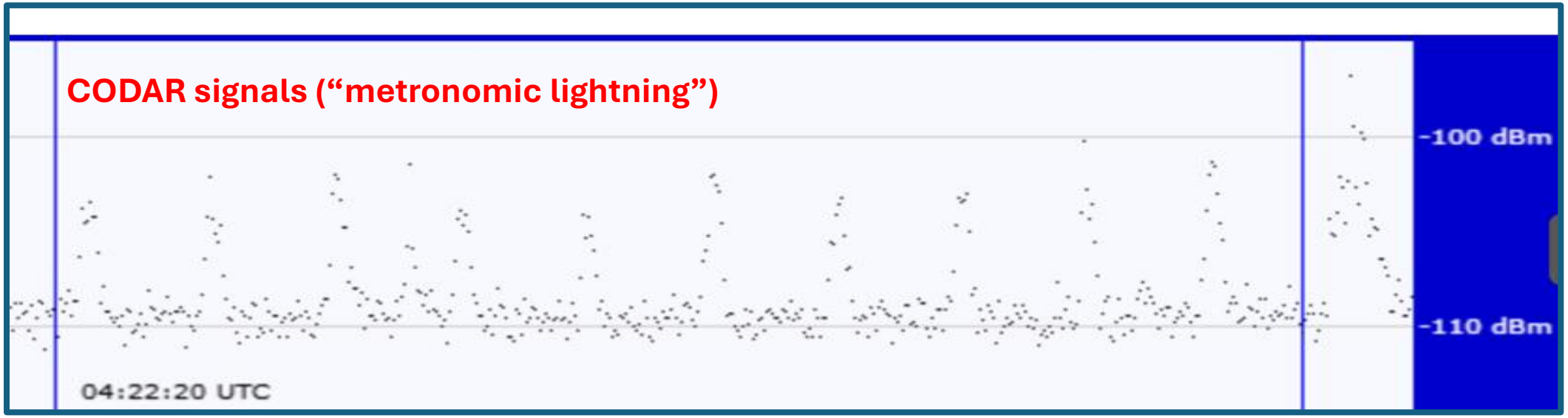


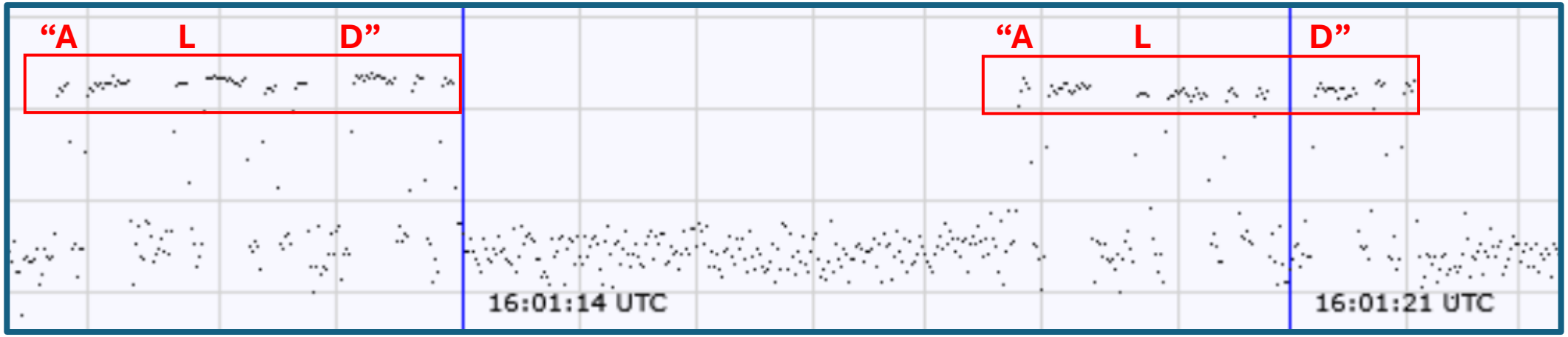
Other Signals of Opportunity

“Beaconing” as a Supplement to “Blitzing”

- A multitude of terrestrial radio signals are available to supplement lightning as a resource for geolocation.
  - Russian and Chinese LORAN
  - CODAR
  - Worldwide NDB aviation beacons
  - US, Canadian, Japanese and Russian time signals (WWV, etc.)
  - Russian letter stations used to communicate with submarines
  - International Beacon Project (IBP)
  - Etc., etc.
- These can be used for traditional direction (DF) or as sources for time-difference-of-arrival (TDOA) calculations.

Samples of Other SoO: CODAR and “ALD” Beacon





Proposed System to Exploit Lightning Signals

Key Components of Proposed System

Two Prototype Geolocation Algorithms Using TDOA Data

Time Difference of Arrival (TDOA) Data

Time of Arrival = T2

Time = T1

TDOA = T2 – T1

“Parallax” Method

“Reverse LORAN”

About

Keraunos Systems, Inc.

- Company
  - Incorporated 6 March 2025
  - For-profit, Delaware C-Corporation
  - Headquarters in Massachusetts
- President: Thomas R. **Willemain**, PhD Electrical Engineering, MIT
  - Faculty career: MIT, Harvard Kennedy School, Rensselaer Polytechnic Institute
  - Public service: FAA, National Security Agency (GS15 rank=O6), IDA/CCS
  - Co-Founder and SVP/Research, Smart Software, Inc. (acquired 2024 by Epicor Software)
- Vice President: Nelson S. **Hartunian**, PhD Physics, Brandeis University
  - Co-Founder, Chairman and CEO, Smart Software, Inc. (acquired 2024)
  - 4 US patents (with Willemain)
- Vice President: Brock E. **Osborn**, PhD Applied Math, Brown University
  - Corporate experience: IBM, GE Global Research Center
  - 23 US patents