Alerting Process related to areas of GNSS Disruption

Gerhard BERZ
Senior Expert Navigation Systems
ATM Directorate, Research & SESAR Division, NAV & CNS Unit
gerhard.berz@eurocontrol.int

UN ICG IDM Workshop
Baska, Croatia, 8 May 2018

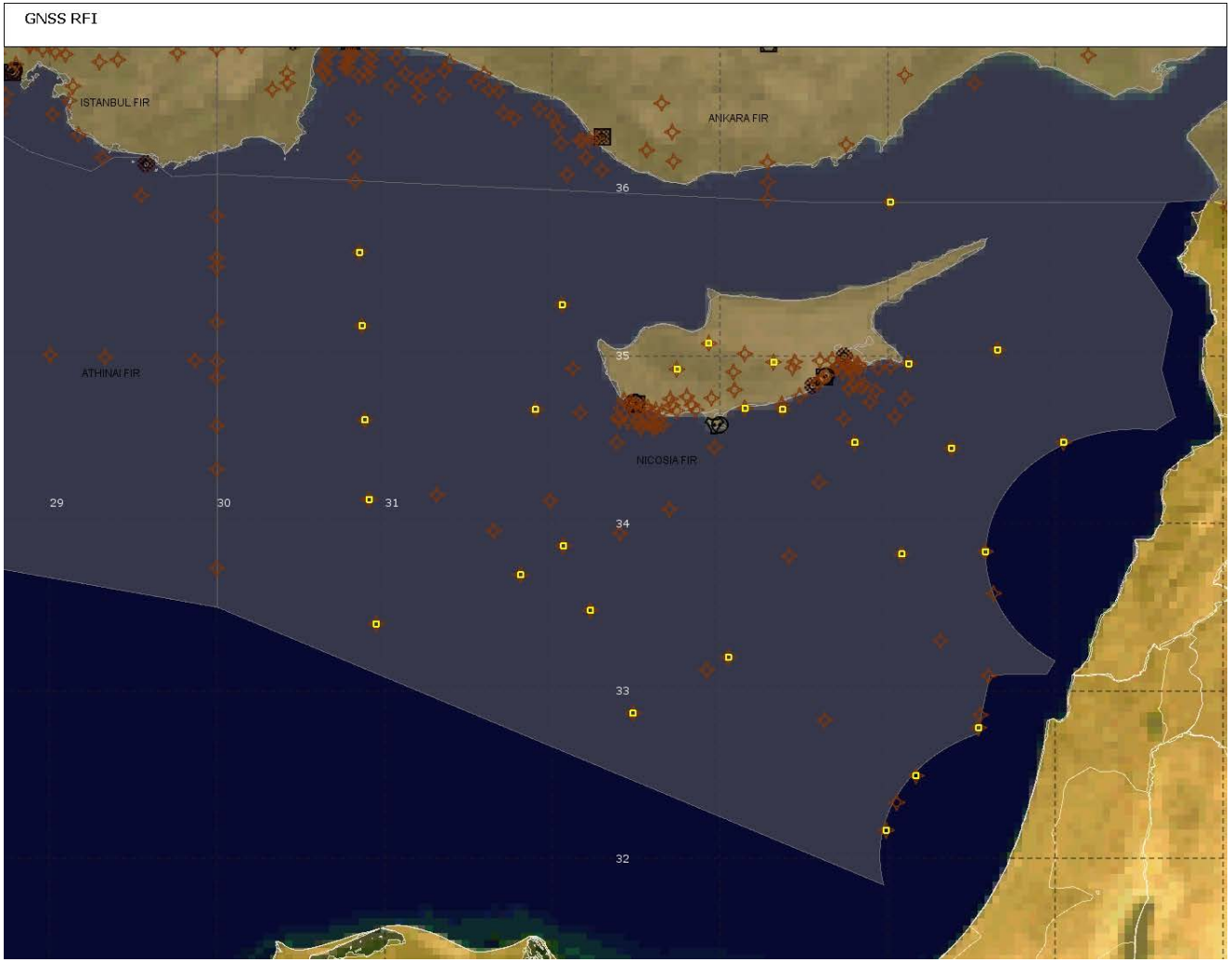
Overview

- Brief update from last year's presentations
  - Recent developments in ADS-B track gap localization
  - See appendix
- Current RFI case in East Mediterranean Region
- Implications for International Coordination
- Recommendations for UN/ICG

Current GNSS RFI Case

- EUROCONTROL is supporting Cyprus
  - Over 140 pilot reports of GPS problems submitted to Cyprus Air Navigation Service Provider between mid March 2018 to now
    - Cyprus Dept. of Electronic Communications confirmed in one measurement Syria as origin of two 10MHz wide jamming signals on L1 and L2 center frequencies
  - Cyprus initiated infringement procedure with ITU (article 15 of radio regulation), ITU sent letter to neighbouring States
- Other reports being sent to IATA (International Air Transport Association) and EUROCONTROL EVAIR system
  - Additional reports in Turkish and Israeli airspace
- Other reported RFI cases include VHF COM, SSR (ATC Radar), COSPAS SARSAT link

Nicosia Flight Information Region (FIR)



Operational Impact

- In general, GNSS RFI to aircraft while en-route is mainly an operational nuisance
  - Integrated navigation capabilities including INS
  - Assumes that there is suitable coverage of terrestrial navigation aids, and SUR and COM capabilities
  - These capabilities are more limited in extended over-water regions
- Operational Mitigations by Air Traffic Control
  - May lead to increased staffing of ATC sectors to ensure that navigation assistance can be provided if requested
  - May lead to suspension of maintenance activities of CNS equipment
  - ***Any simultaneous impact on 2 or 3 of the COM, NAV and SUR elements can quickly become a serious safety risk***

Challenges for RFI Source Elimination

- In current example, no evidence exists other than Syria as a source of the RFI (active zone of conflict)
  - But cannot exclude that multiple sources exist
  - Difficult to measure and locate on ground an RFI source far away and impacting aircraft at altitude

- If RFI source would be over international open waters, it will be extremely difficult for impacted State to identify source and start escalation procedure
  - State radio regulator has no legal authority
  - Even if able to identify State of Registry of maritime vessel or aircraft, unlikely to lead to a resolution if of a military nature
    - *However, also note that in many cases, military gets blamed prematurely*
  - Due to drone warfare, can expect such cases to increase

Aviation Principles and Consequences

- ICAO legal framework provides basis to assign unique responsibility of an ANSP in airspace over international open waters
  - ANSP must be able to assume that ITU regulations are being respected to provide CNS services
- Currently, process exists to close airspace to civil aircraft operations over declared zones of conflict
  - Aviation currently learning that outside of that zone, cases of RFI to all CNS systems are becoming more frequent and need to be managed
  - Impact range for GNSS RFI can be very significant
  - RFI in extended over-water regions can be especially difficult
  - Aviation will work on improving associated reporting and coordination processes

Recommendations to UN ICG

- Make States aware that:
  - All airspace where aircraft operate is assigned to a unique ANSP which must provide interference-free CNS services
  - RFI sources inside zones of conflict can impact civil air traffic far outside of such zones with possible safety impact
  - RFI sources in or over international open water can be extremely difficult for aviation to resolve
- Invite States to evaluate if their civil-military coordination arrangements are appropriate to:
  - Ensure that anyone exercising electronic warfare capabilities outside of declared zones of conflict will fully coordinate with the responsible ANSP, including over international open water
  - Consider sharing information about GNSS RFI sources and impact areas when available to help maintain the safety or air traffic

Appendix

- ADS-B Track Localization Method Description
  - Developed by Valeriu Vitan and Petr Jonas
- Including test case data courtesy of Novatel (Thank you!)
- Aviation is currently discussing a downlink capability of RFI detection status in next generation GNSS receivers, using the ADS-B downlink (discussion between NAV and SUR in RTCA and EUROCAE)

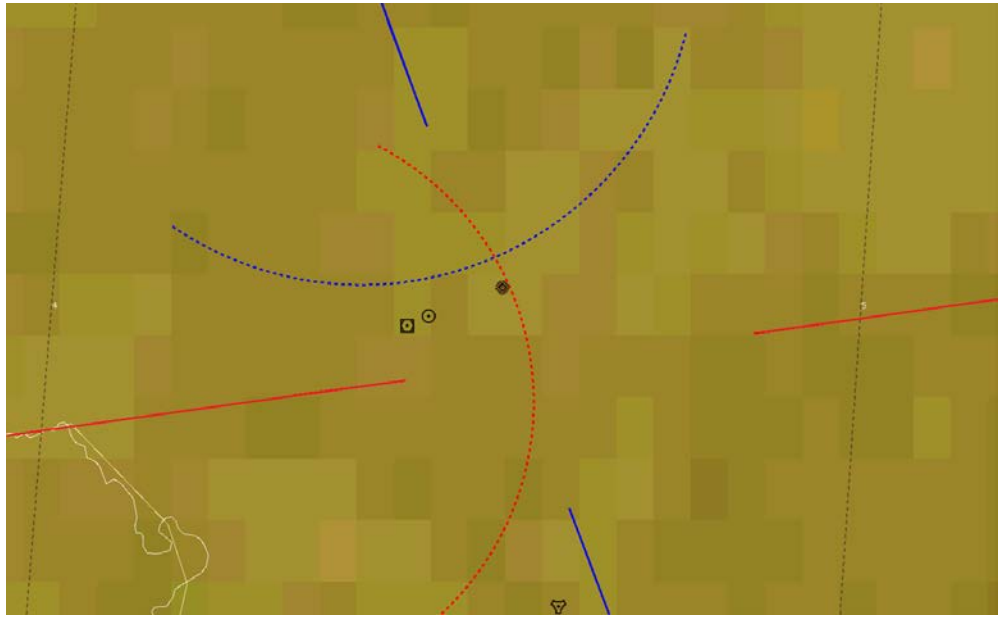
Localisation using ADS-B Track Gaps

Assumptions:

- Omnidirectional RFI
- No masking
- Continuous transmission
- Constant RFI power level ration between loose/recover tracking for all gaps

First approach: intersect possible position circles

- Difficult to compute intersection points
- Not all curves intersect each other



GPS track 1 (eastbound)

Possible RFI position

GPS track 2 (southbound)

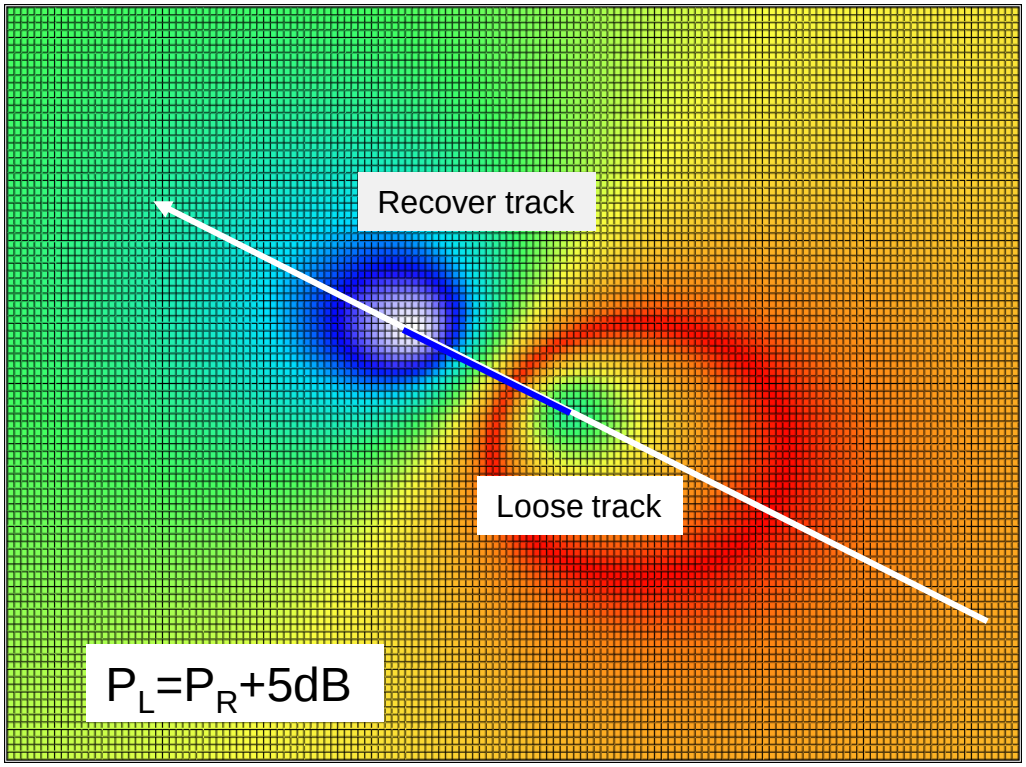
Possible RFI position

Improved Method: Probability Contours

Second approach: Heat Map

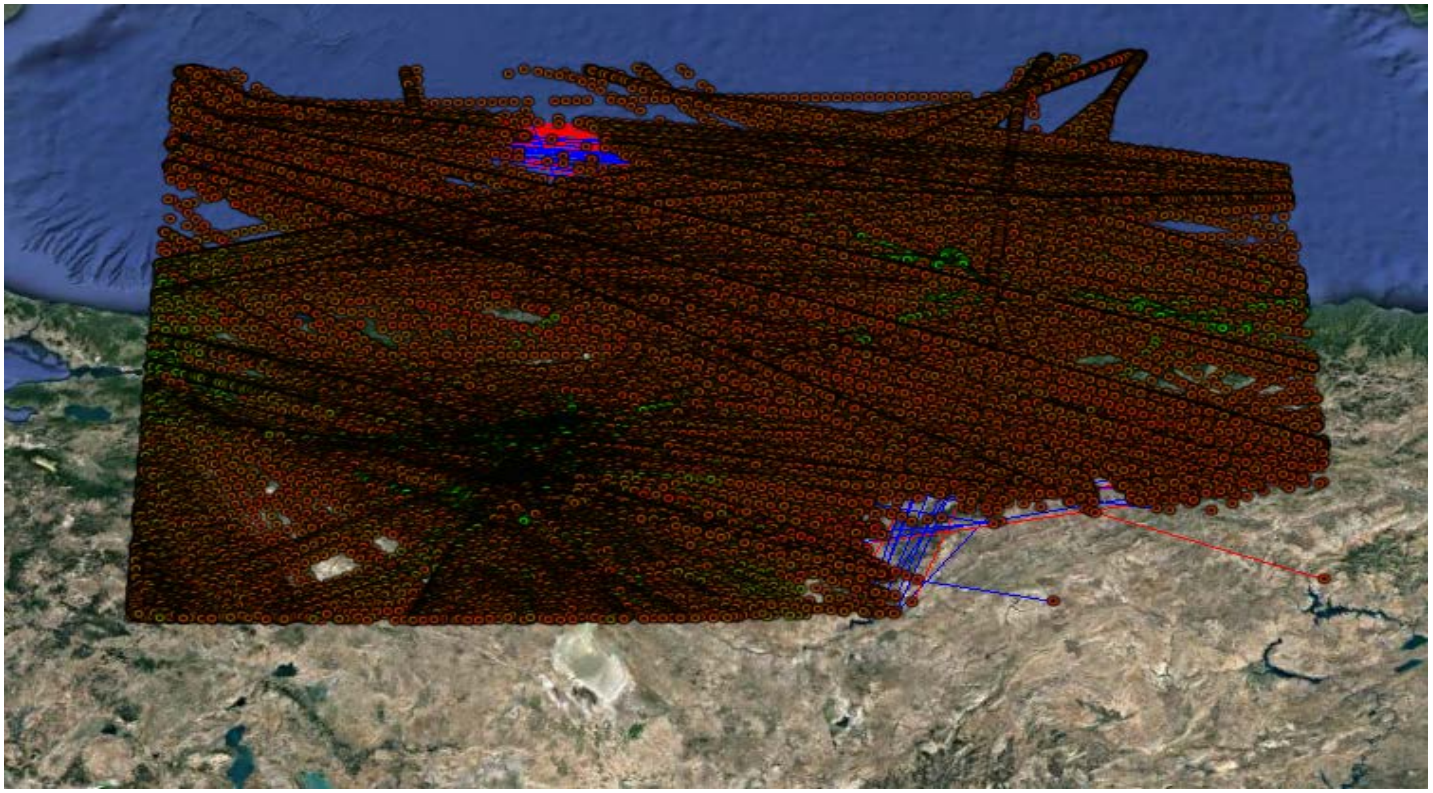
- Calculation on a grid
- Compute RFI position probability for each gap
- Sum up all individual probability values

- Highest probability on the first approach circles
- Probability is a function of the ratio of distances to the gap start/end (determined by the assumed lose/recover power ratio)
- Flight testing indicates that recovery occurs “early” due to tail shading



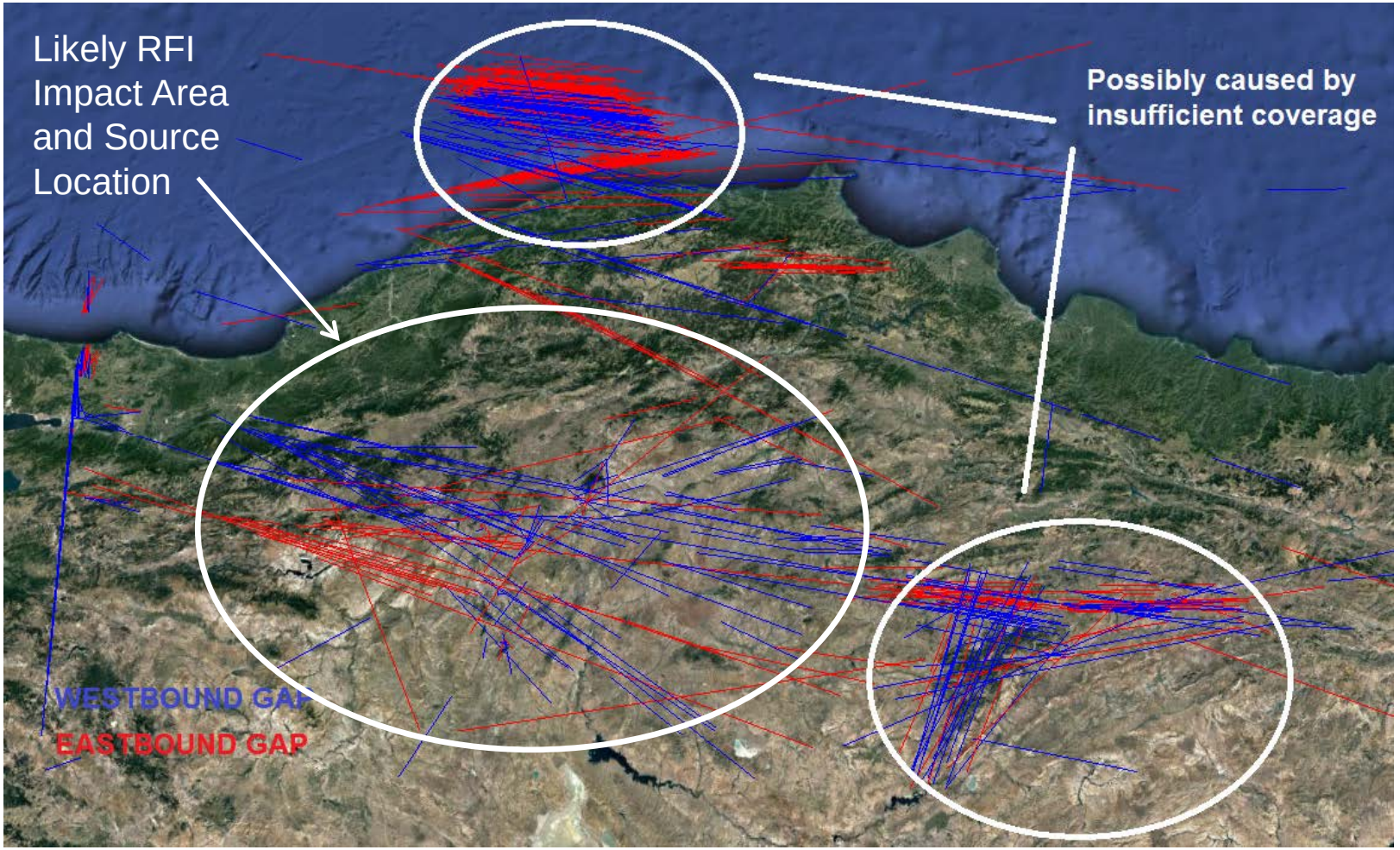
- Dependency with distance can be considered
- Areas before loose track should be disregarded

Test Case: Verification of ADS-B Coverage
(Requires ADS-B Ground Recorder AND Aircraft Reporting)

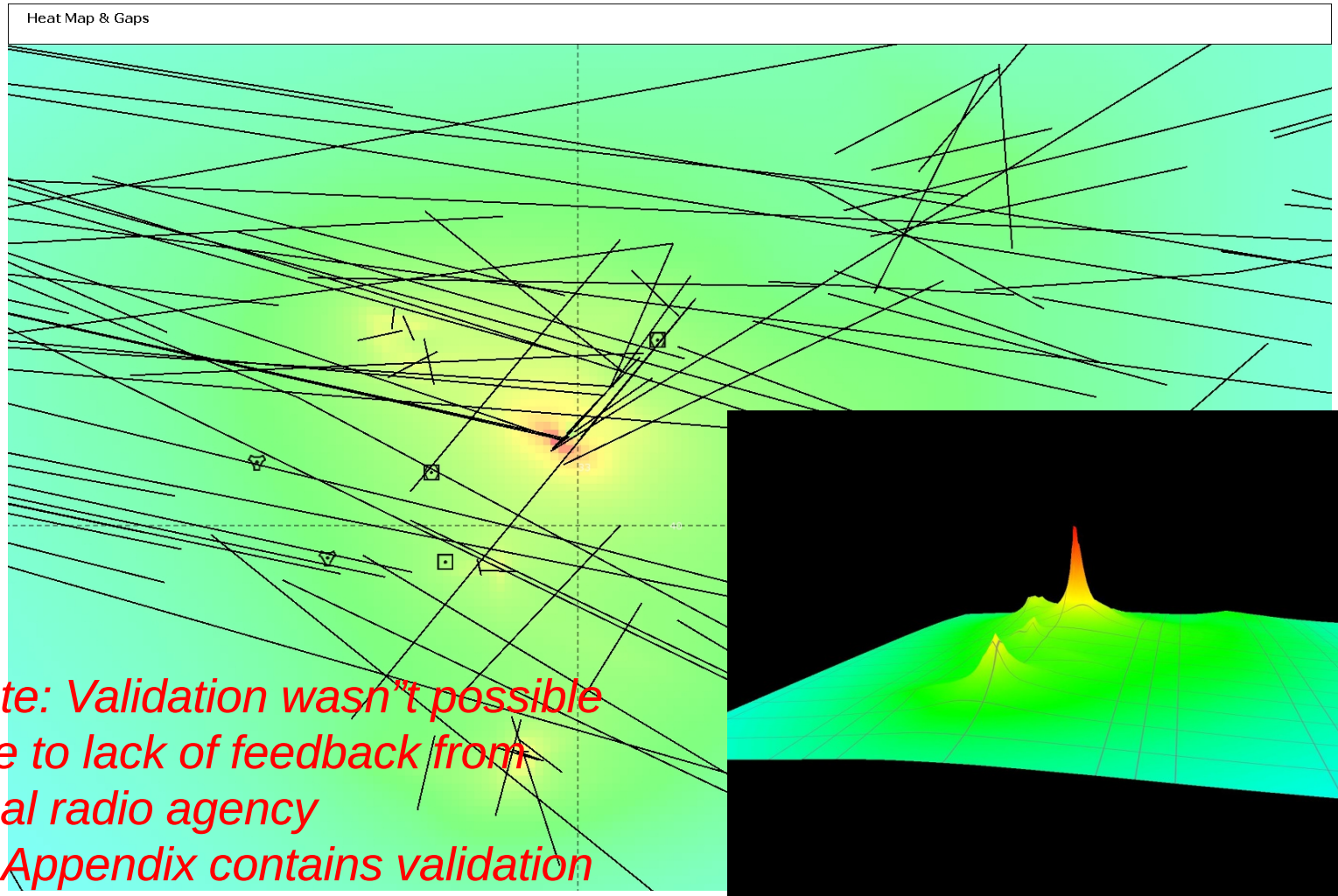


- Can be difficult to get to raw data or historical data
- Many commercial providers close reporting gaps by extrapolation, need to check source (ADS-B, not MLAT for example)

“Spaghetti Analysis” of Track Gaps



Applying Heat Map Method to Test Case

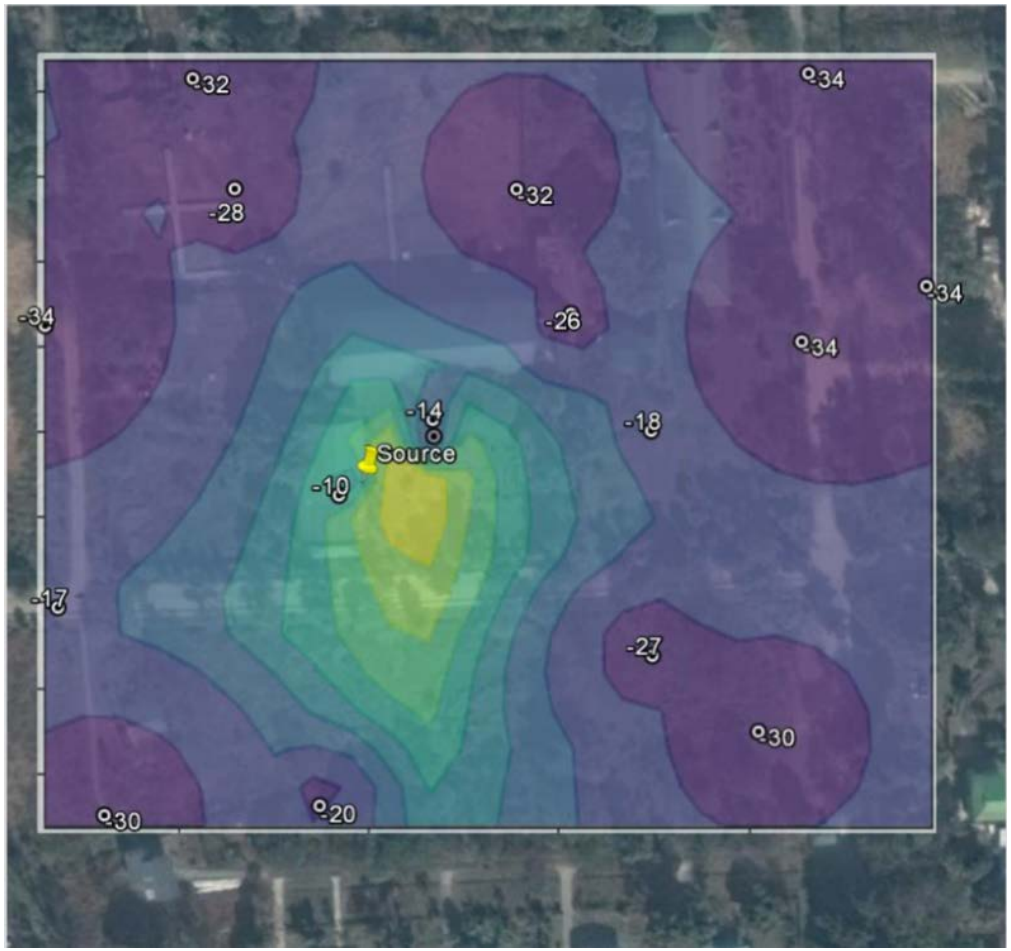


Note: Validation wasn't possible due to lack of feedback from local radio agency

➔ Appendix contains validation using Novatel Test Case

Novatel test case

- Accurate RFI power level measurements in different locations
- The most probable location of the source is estimated based on a RMS fit error method (comparing observed and expected power level)
- Assumptions on RFI source
  - Static
  - Continuous
  - Omnidirectional

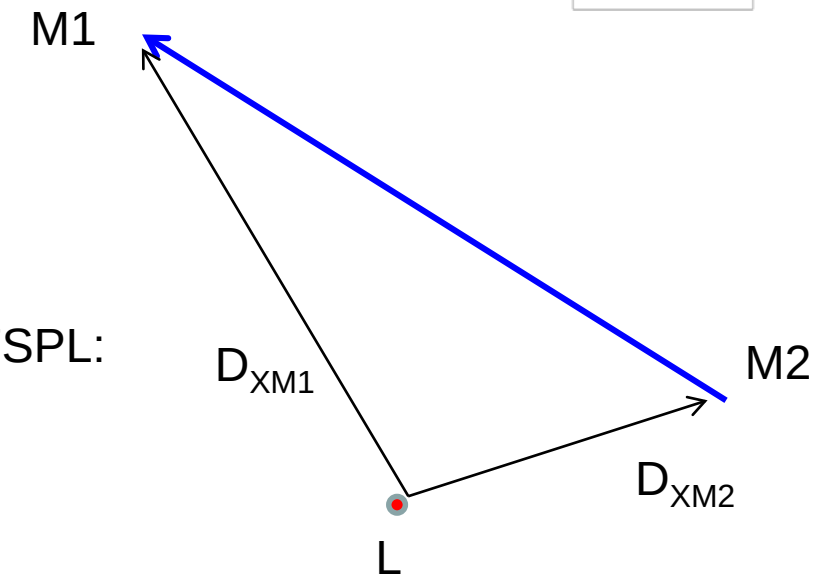


RFI source location

RFI location: Point L
P_{M1}= Power measured in point M1
P_{M2}= Power measured in point M2

Assuming omnidirectional radiation and FSPL:

$$(P_{M1} - P_{M2})[dBW] = 20log\frac{D_{LM2}}{D_{LM1}}$$



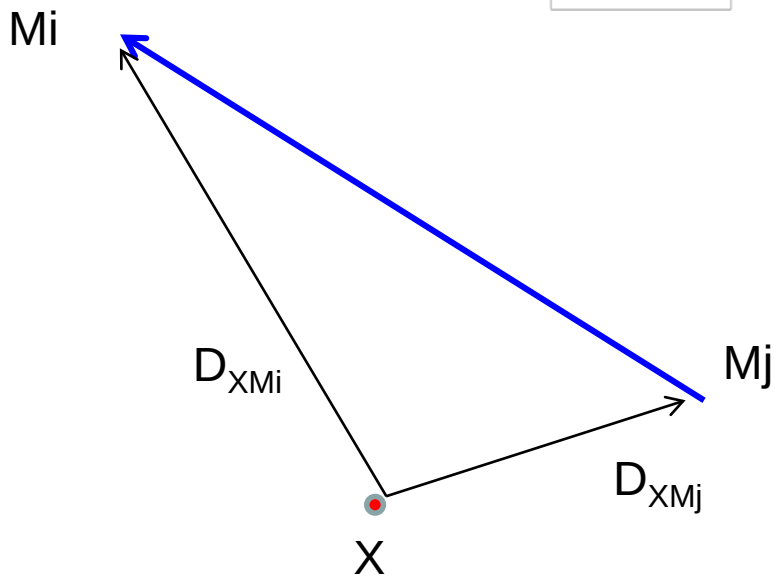
A probability can be associated with each assessed location X and each pair of measurement points as a function of the measured power levels and the distances to these points.

The overall probability level is the sum of probabilities associated with all possible pairs.

RFI source location

Simple probability allocation function:

$$Prob_{Xij} = \begin{cases} \frac{K_{XDij}}{K_{XPij}} & if \frac{K_{XDij}}{K_{XPij}} < 1 \\ \frac{K_{XPij}}{K_{XDij}} & if \frac{K_{XDij}}{K_{XPij}} \geq 1 \end{cases}$$

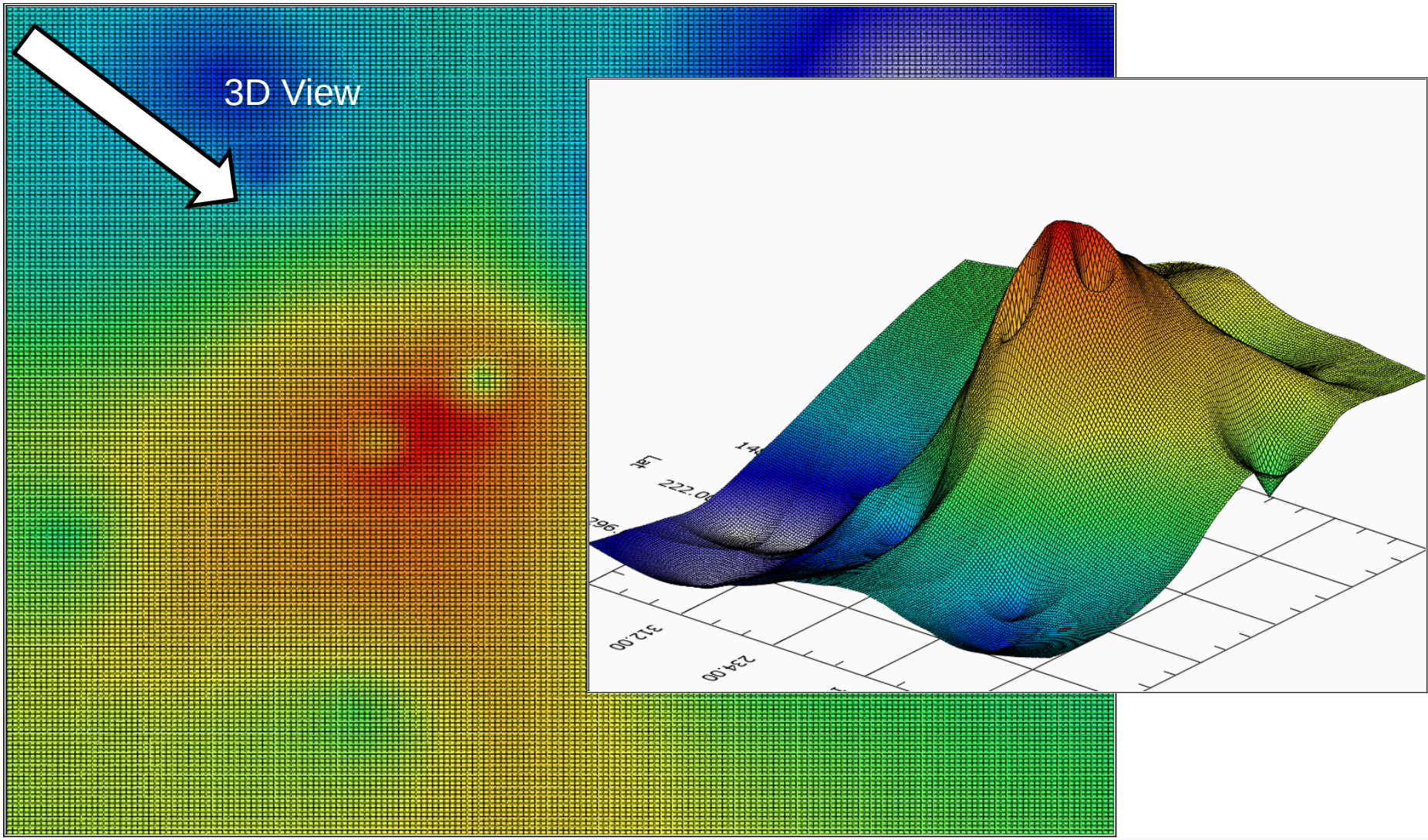


where $K_{XDij} = \frac{D_{XMj}}{D_{XMi}}$ $K_{XPij} = \sqrt{10^{\frac{P_{Mi}-P_{Mj}}{10}}}$ (ratio of measured power in Watts)

$$Prob_X = \sum_{ij} Prob_{Xij}$$

- Calculations made on a grid of points
- Results presented in 2D or 3D format
- The hotspot indicates the most probable location of RFI source

Novatel test case – our results



Novatel test case - comparison