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Extension of Regional Infrasonic Processing Tools for Global Analysis: A Case Study From the January 15 2022 Tonga Hunga Volcanic Eruption

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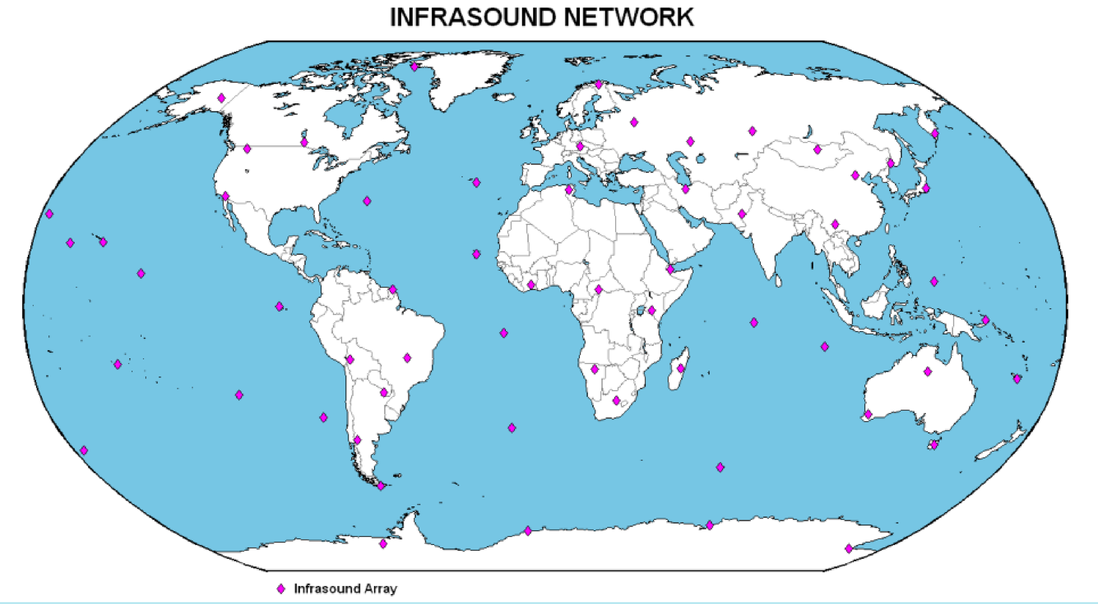
Infrasound sensors are a powerful tool for monitoring of remote volcanoes due to the low frequency-content and long propagation distance of signals. International Monitoring System (IMS) infrasound stations frequently record signals from remote volcanic eruptions, these signals can be used to supplement monitoring or analysis efforts. The Tongan volcanic eruption on January 15, 2022, generated a signal large enough to be recorded across all 53 IMS global infrasound sensors. This eruption is the largest event recorded across the network and as such offers the opportunity to evaluate recent R&D efforts towards improved event characterization.

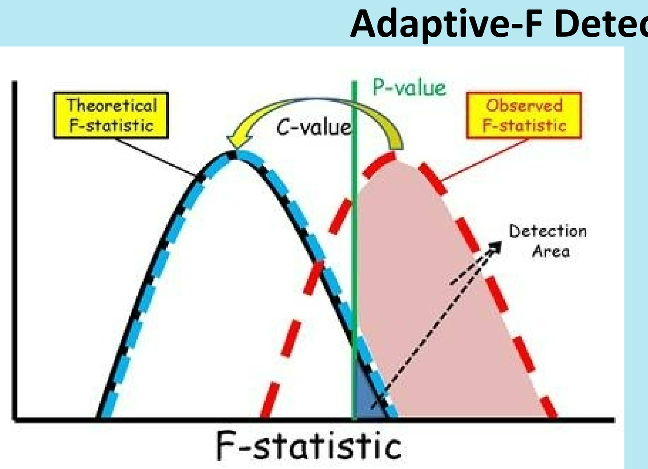
Recent ground-based nuclear detonation detection efforts at both Los Alamos National Laboratory (LANL) and Sandia National Laboratory (SNL) have focused on the development of tools for infrasound signal processing at regional scales. Tools include algorithms and processing pipelines to produce automated station-level signal detections and network-level event association, location, and yield estimates.

The Hunga Tonga eruptive event is used as a calibration tool to compare two distinct automated signal detection algorithms; the Adaptive F-Detector developed by LANL and the Multi-Variate Adaptive Learning Detector, developed by SNL.

INTERNATIONAL MONITORING SYSTEM
INFRASOUND NETWORK



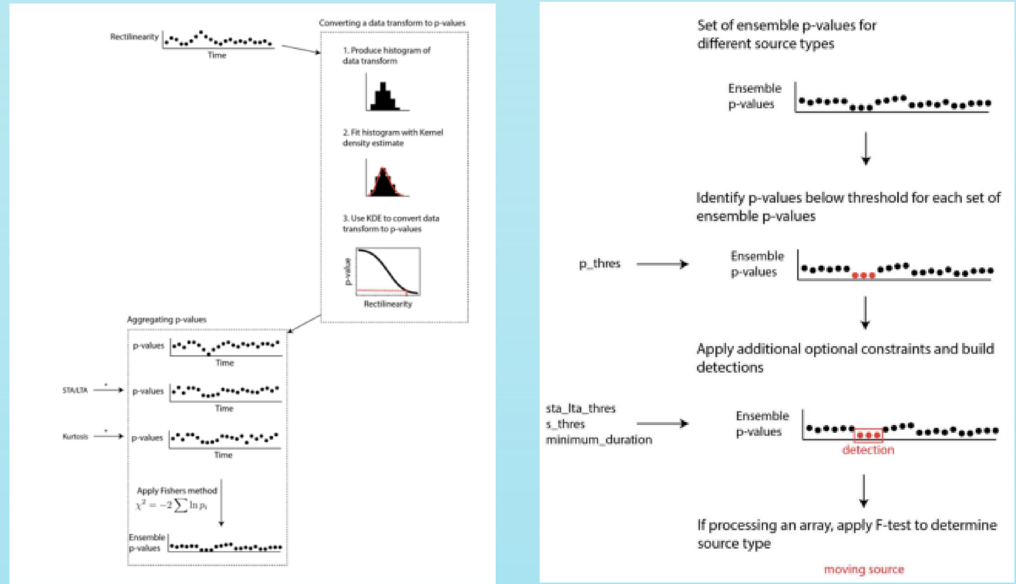
Adaptive-F Detector (AFD)



High-Frequency Configuration
Frequency Band: 0.5 – 3.0 Hz
Window Length/Step: 20/10 seconds
AFD Adaptive Window Length: 5400 seconds (1.5 hours)
p-value: 0.95
Min Detection Length: 30 seconds
Threshold ceiling (f-stat): 10.0

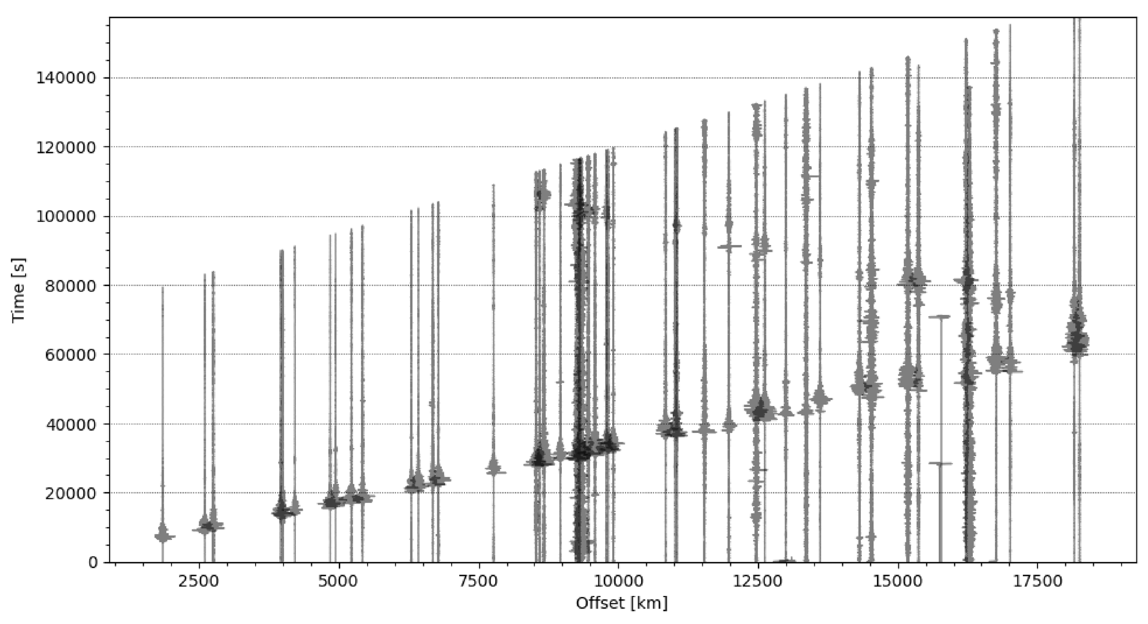
Figure from Arrowsmith et al., 2009; publication includes additional information on detection algorithm

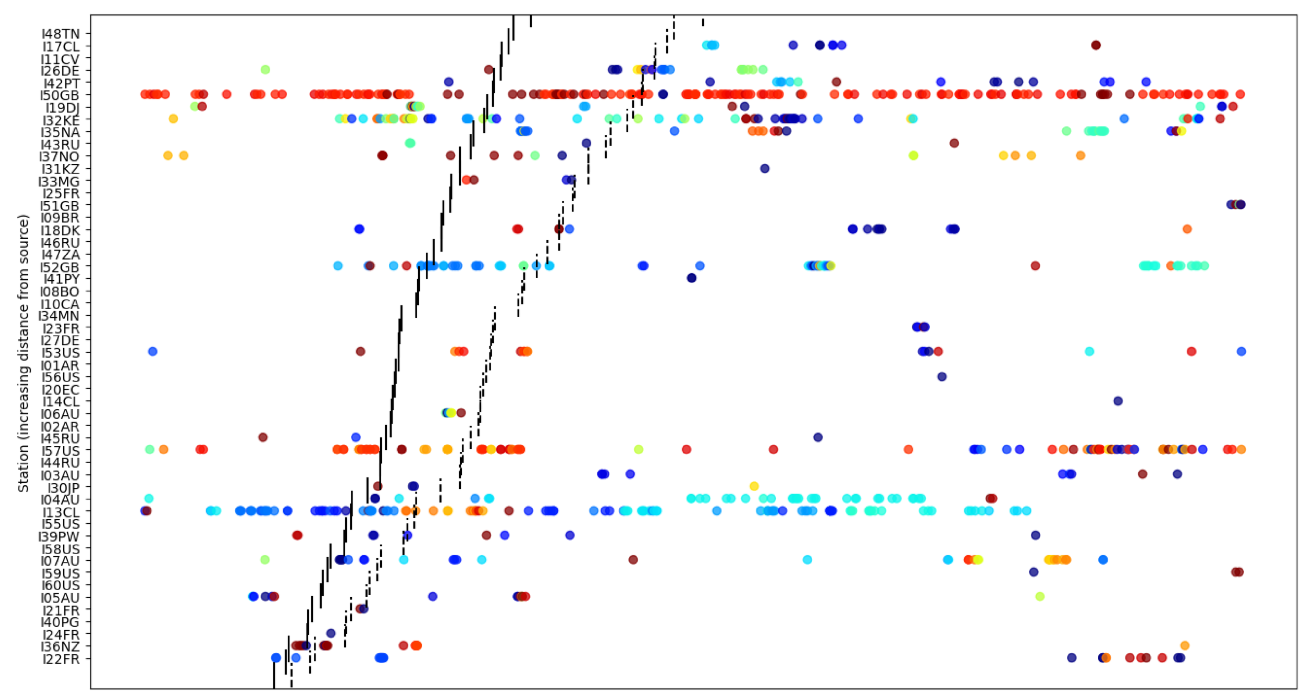
Multi-Variate Adaptive Learning Detector (MALD)

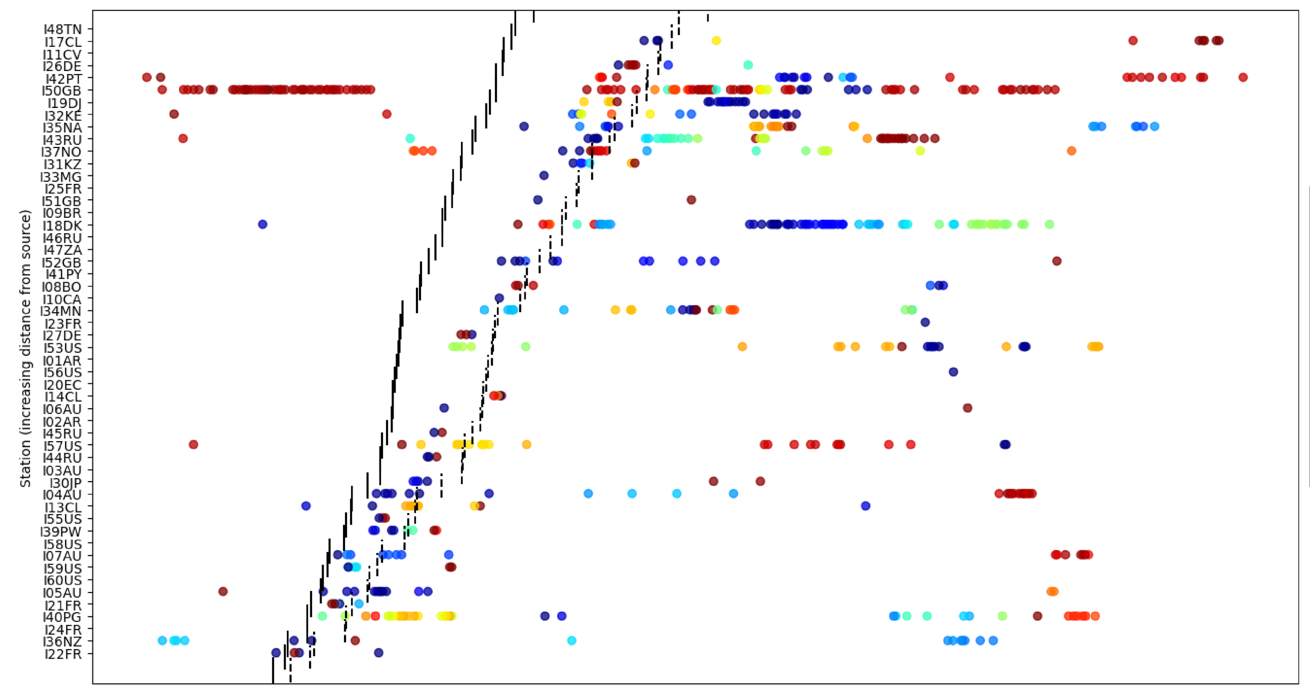


High-Frequency Configuration
Frequency Band: 0.5 – 3 Hz
Window Length/Step: 40/20 seconds (50% overlap)
P-value: 0.01
Min Duration Length: 80 seconds
Adaptive Window Length: 3600 seconds *24 hours (full day)

Figures from Arrowsmith et al., 2018; publication includes additional information on detection algorithm

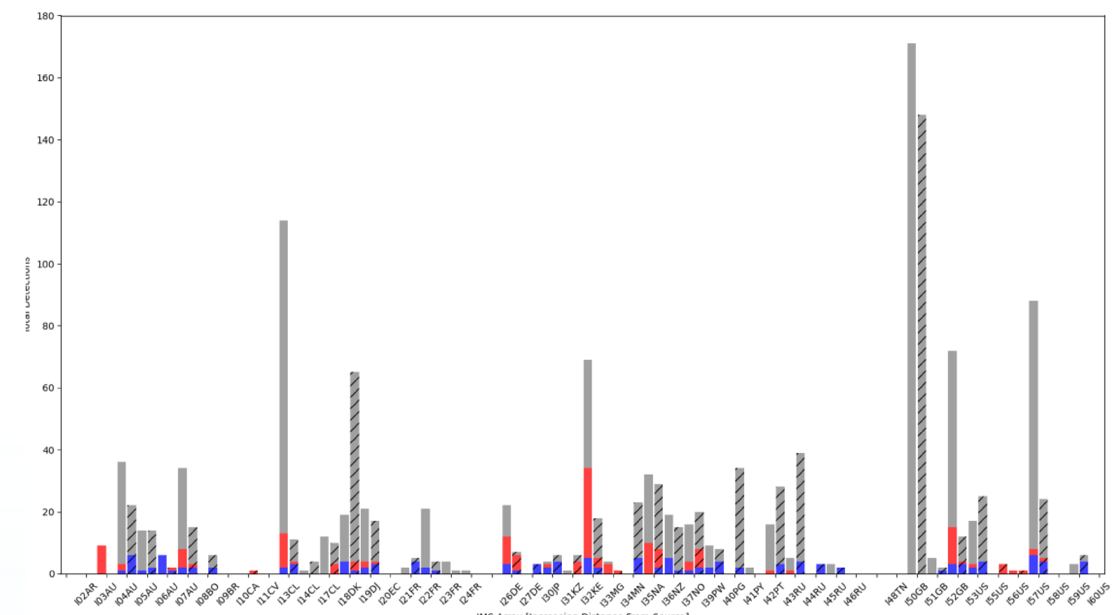






Detection comparisons as a function of time, distance from source and backazimuth deviation illuminate key trends across each bulletin:

1. Dashed vertical lines indicated predicted signal arrival windows from the known explosion time – detectors identify signals both within these windows (associated with initial blast) and outside of the window (associated with noise or continuing eruptive activity)
2. Both detectors (InfraPy: top right; Bloodhound: bottom right) identify consistent, coherent noise sources
3. There are no discernable trends between distance from source and detection numbers – at a first glance stations closer to, or further from, the source do not perform better than the opposite



Definitions for Bulletin Comparisons

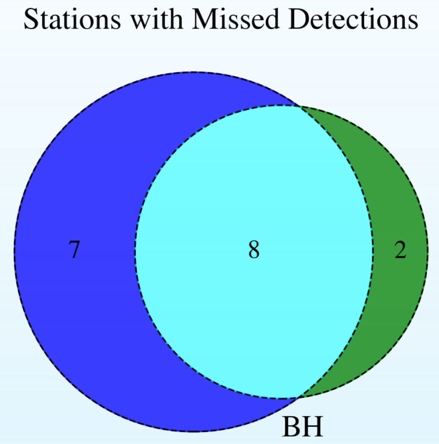
True Detection (True Positive)
Automatic detection WITHIN +/- 10° of true backazimuth arrives within predicted signal travel time [0.25-0.4 km/sec] window

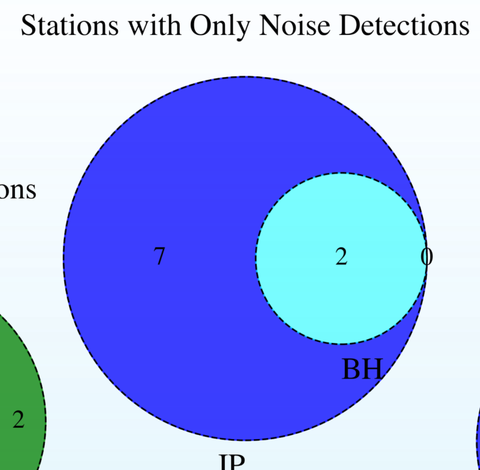
False Detection (False Positive)
Automatic detection NOT WITHIN +/- 10° of true backazimuth arrives WITHIN predicted signal travel time [0.25-0.4 km/sec] window

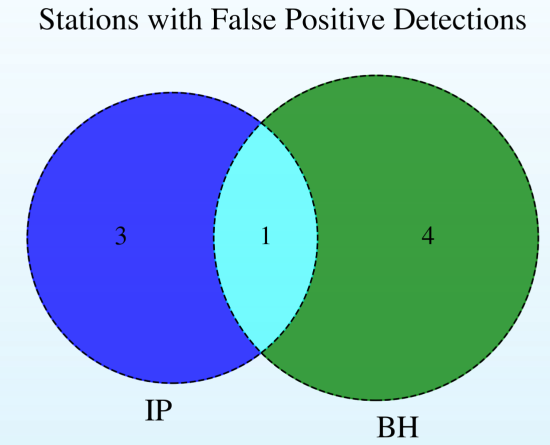
Noise Detection (True Negative)
Automatic detection NOT WITHIN +/- 10° of true backazimuth arrives OUTSIDE OF predicted signal travel time [0.25-0.4 km/sec] window

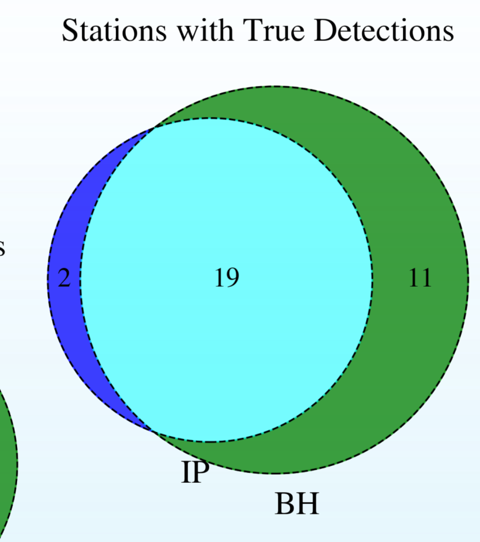
Missed Detection (False Negative)
NO Automatic detection WITHIN +/- 10° of true backazimuth arrives WITHIN predicted signal travel time [0.25-0.4 km/sec] window

Station-Level Comparisons	IP #	IP %	BH #	BH %
No Detections (False Negative)	15	31%	10	21%
Noise Only (True Negative)	9	18%	2	4%
False Detections (False Positive)	4	8%	5	10%
True Detections (True Positive)	21	43%	30	63%







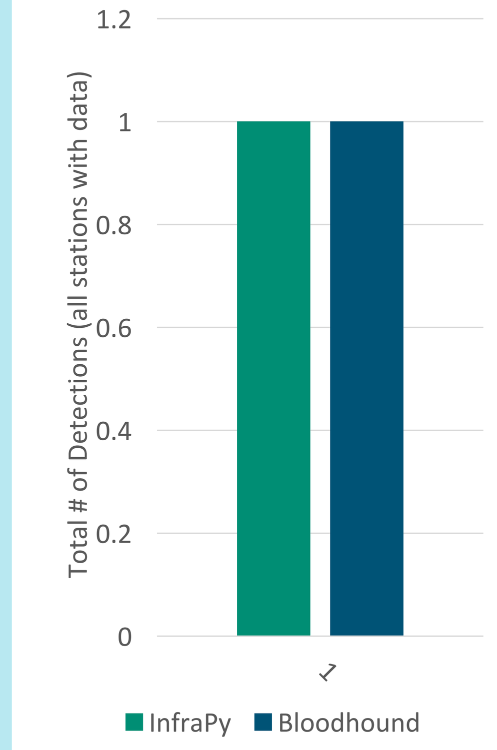


Conclusions from Automated Detector Comparisons

- Bloodhound detects 628 signals across 38 stations
- Infrapy detects 844 signals across 34 stations
- Detection bulletin comparisons indicate that Bloodhound **correctly detects** signals associated with the eruptive event at 30/47 stations with data, or **63% of stations**
- Infrapy **correctly detects** signals associated with the eruptive event at 21/49 stations with data, or **43% of stations**
- Infrapy has more False Negative, True Negative and False Positive results than Bloodhound

Bloodhound detects fewer signals overall but detections are more accurate (associated with the event of interest)

Infrapy has lower detection rates – i.e. algorithm is identifying non-signals of interest

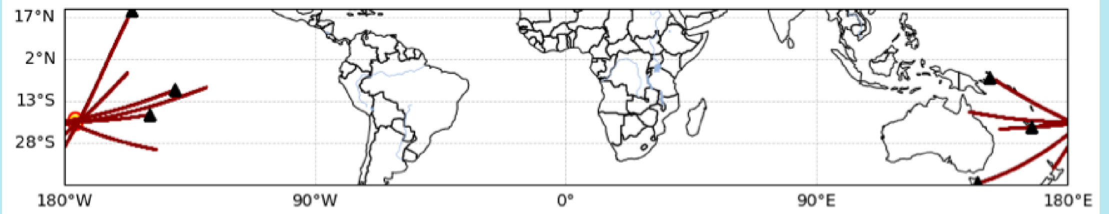


Note: both algorithms were designed for *regional* scales – failure to perform with global distance signals is not a short-coming! This simply indicates the tools work well for situations they were optimized for

Looking Forward: Event Association and Location

- Will association algorithms work on global scales?
- Will event location algorithms work for global scales?
- Are detections at all stations necessary for event characterization? Or are there diminished returns once you exceed a distance threshold from the source?
- How will false detections during predicted signal arrival windows impact association?

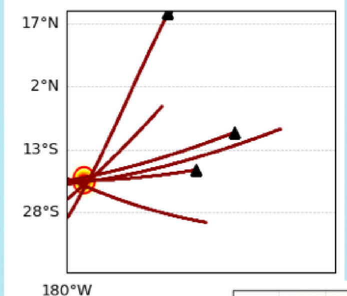
Example Event Location Results

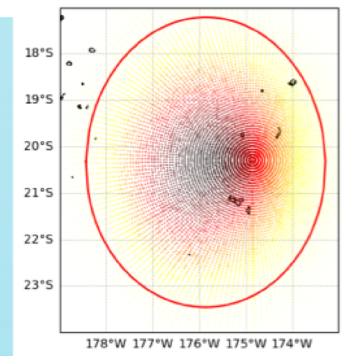


Stations used: I22FR, I24FR, I40PN, I21FR, I05AU, I59US
Station Distances from source: 1850 – 4500 km

BISL Estimate:
-20.337 deg lat +/- 162 km N/S
-175.856 deg lon +/- 125 km E/W
2022-01-15 04:09:09 +/- 490 seconds (~8 minutes)

Ground Truth:
-20.567, -175.380
2022-01-15 04:14:45





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