

NET-VISA improvements for regional and aftershock event identification at the IDC

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NET-VISA is a ...

- Generative Model
 - For events
 - For true detections caused by events at seismic stations (up to 14 phases)
 - For noise detections at stations
 - For coda detections generated in turn by large true detections
 - Based on physics
- Learning Engine
 - Learns the parameters for the generative model from the data
- Inference Engine
 - Given the detections at all the stations predicts
 - all the events
 - the association of events to detections
 - Event hypothesis is based on the probability that an event occurred, and not on any hard rules
 - Based on a process to generate candidate events and then refine them in a series of “moves”

History and Current Status

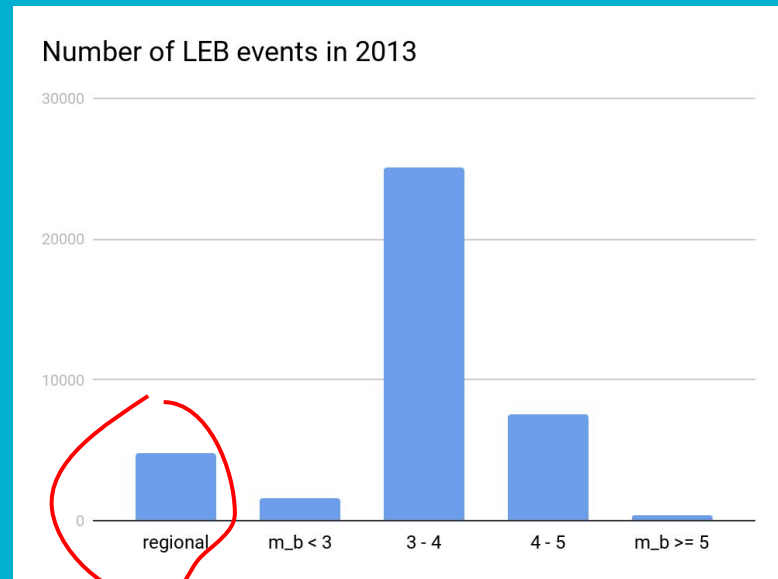
- Initial research started in 2009 based on outreach efforts by CTBTO
- Numerous analyst evaluations, studies have been performed by multiple independent entities
- Rough numbers: 88% Overlap with LEB and 50% Inconsistency with LEB
- Operational Deployment in January 2018 as a post-processing button that pulls in additional events missed by GA3
- Responsible for 10% of all REB events beginning mid-2018.
- Next:
 - Fully independent pipeline in progress
 - Inclusion of hydro and infra in operations
 - Heading to NDC-In-A-Box

Three reasons why an event may not be built

1. The model doesn't propose a candidate event close enough to a true event.
 - This is often a computation cost issue.
2. The model assigns a higher probability to the associated arrivals as noise/coda rather than from the event.
 - This is because we are not modeling some important aspect of the physics of event formation/detection.
3. The arrivals from an event are not automatically detected by DFX.
 - NOTE: This is beyond the scope of NET-VISA, currently.

Regional events

- Built primarily with detections at stations less than 20 degrees away
- Typical phases -- Pn, Pg, Sn, Lg
- Body-wave magnitude (m_b) is not computed for these events.

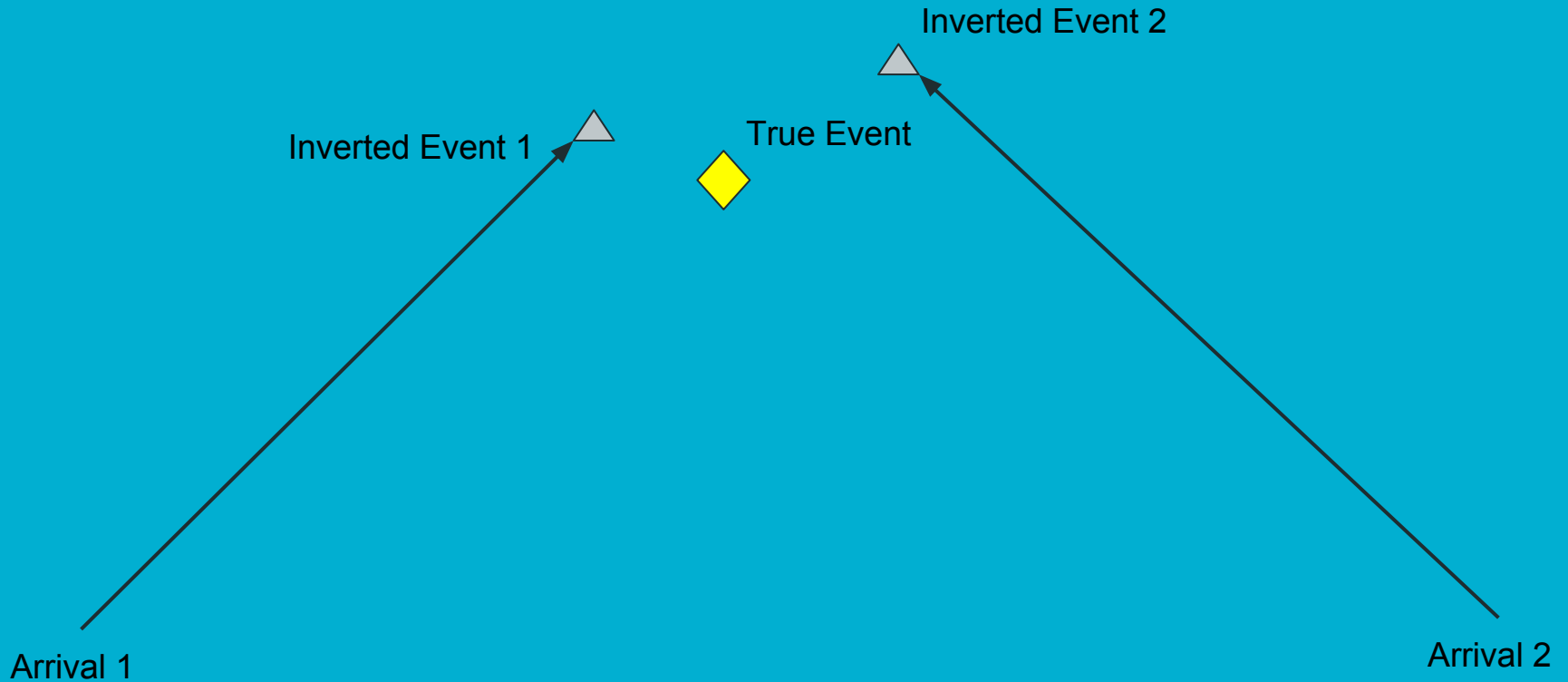


~ 10%

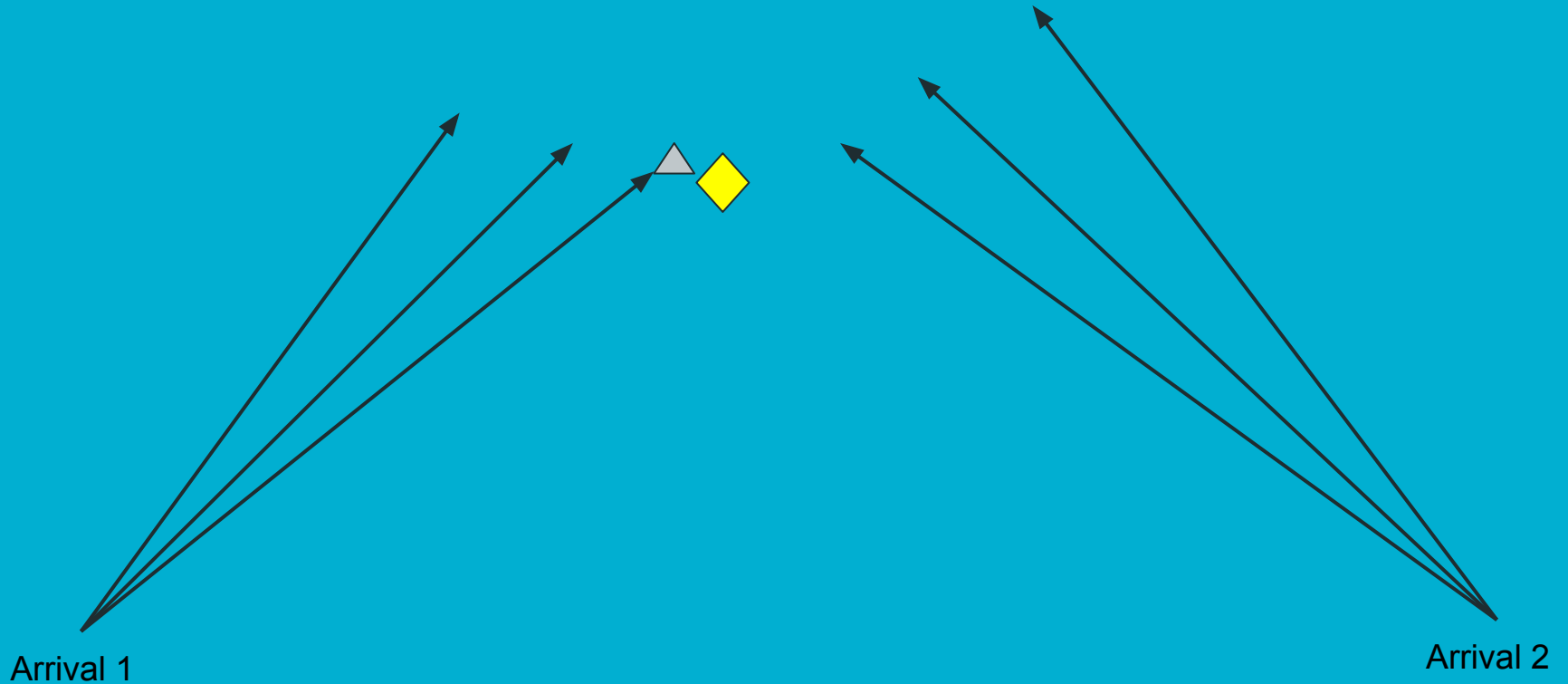
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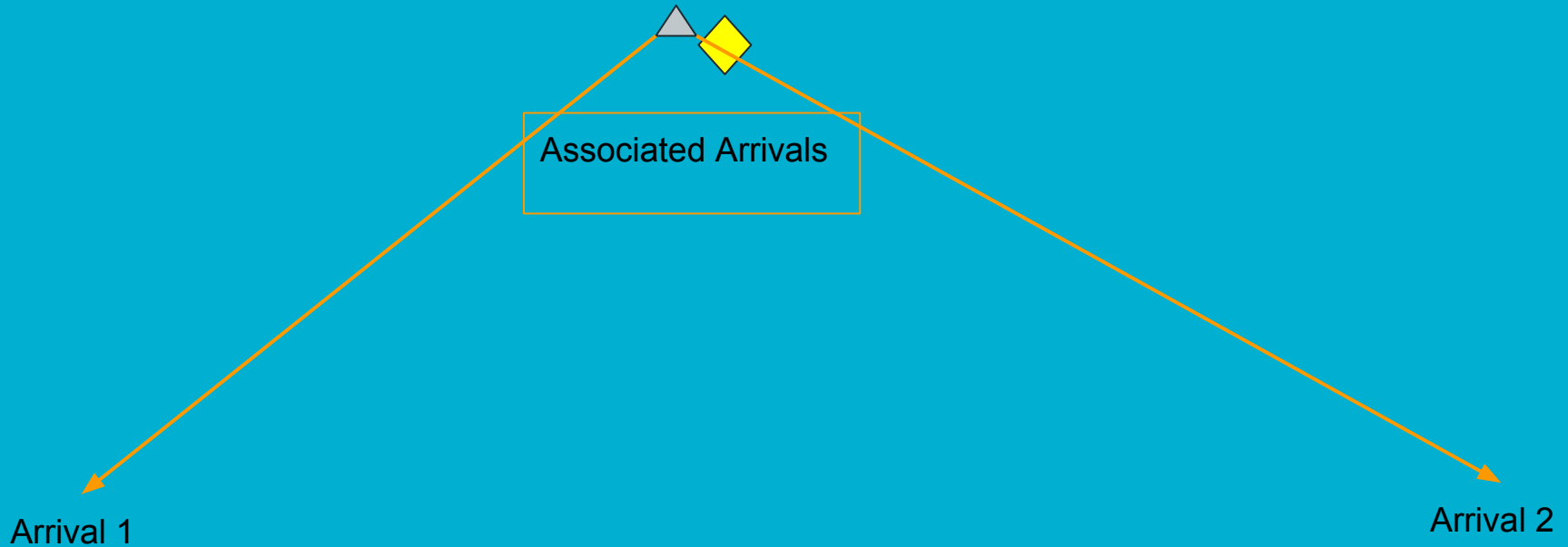
Candidate Proposal -- Invert arrivals



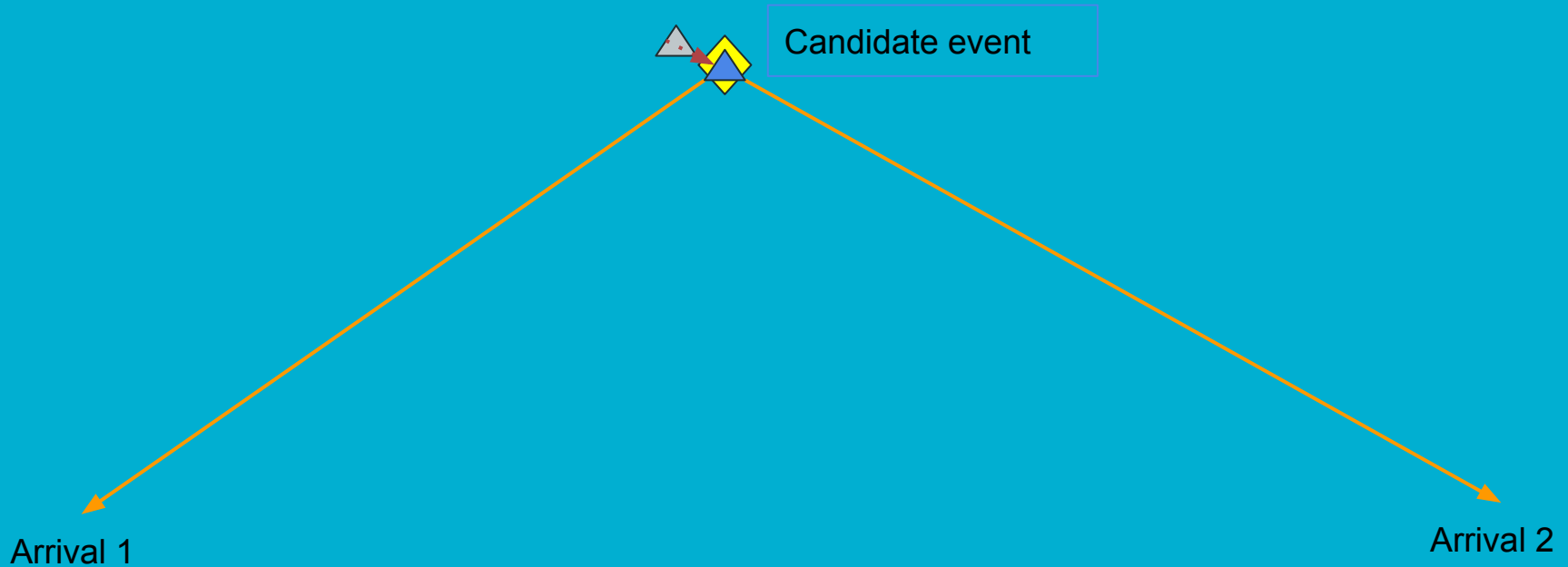
Candidate Proposal -- Perturb Inverted arrivals



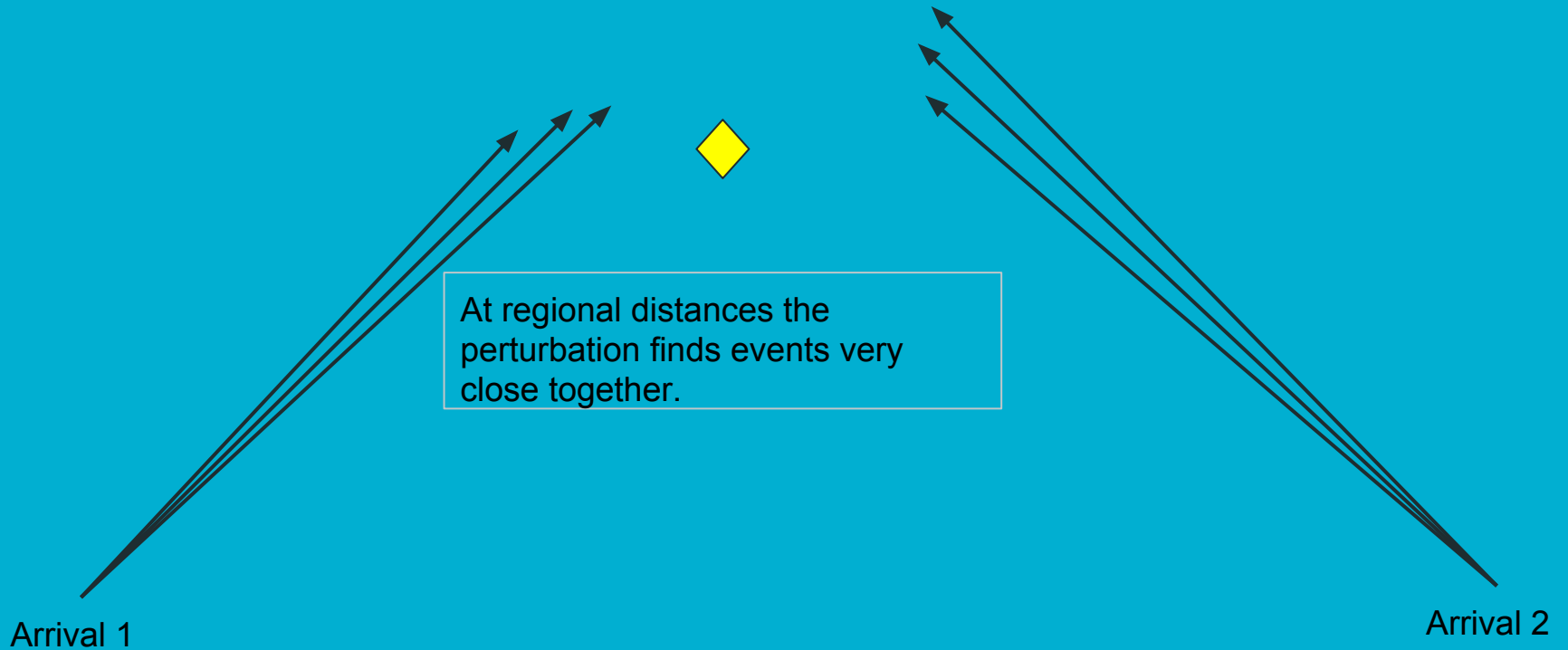
Candidate Proposal -- Keep best inverted event



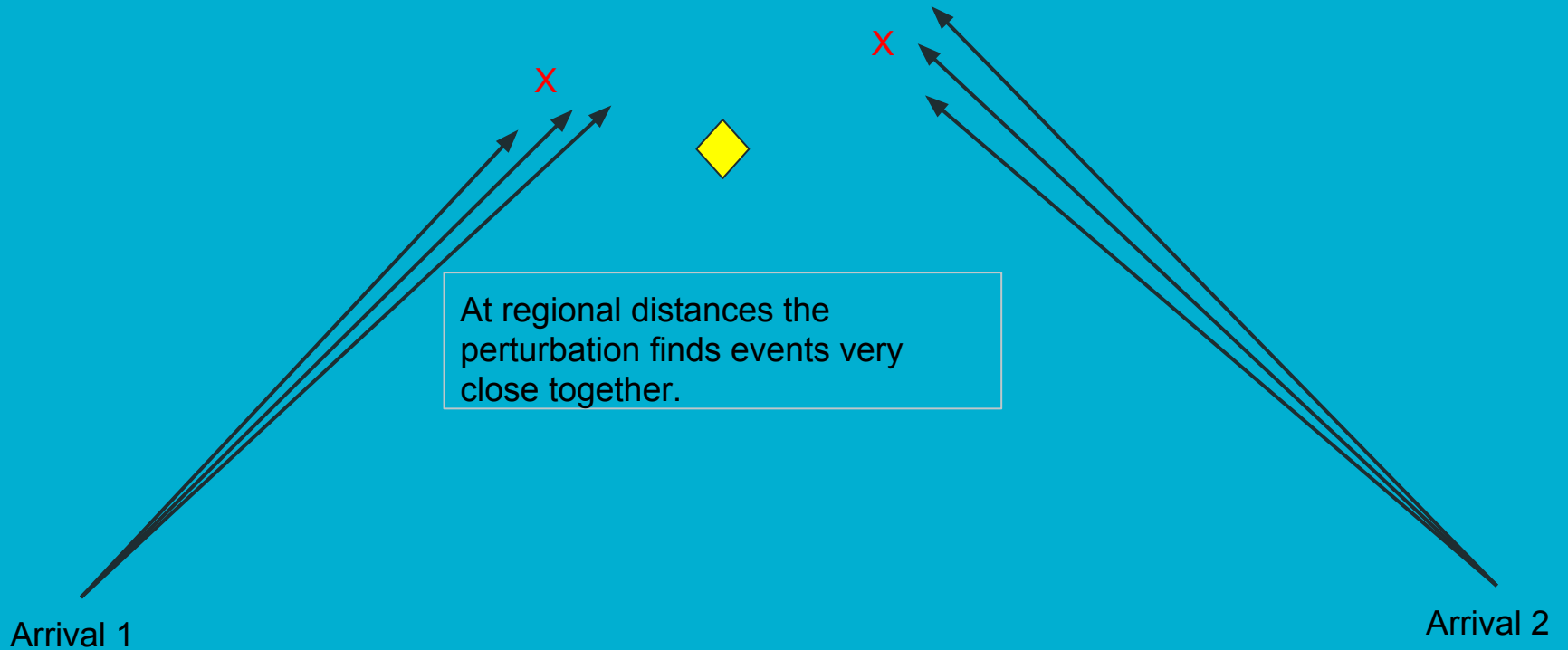
Candidate Proposal -- Improve best event



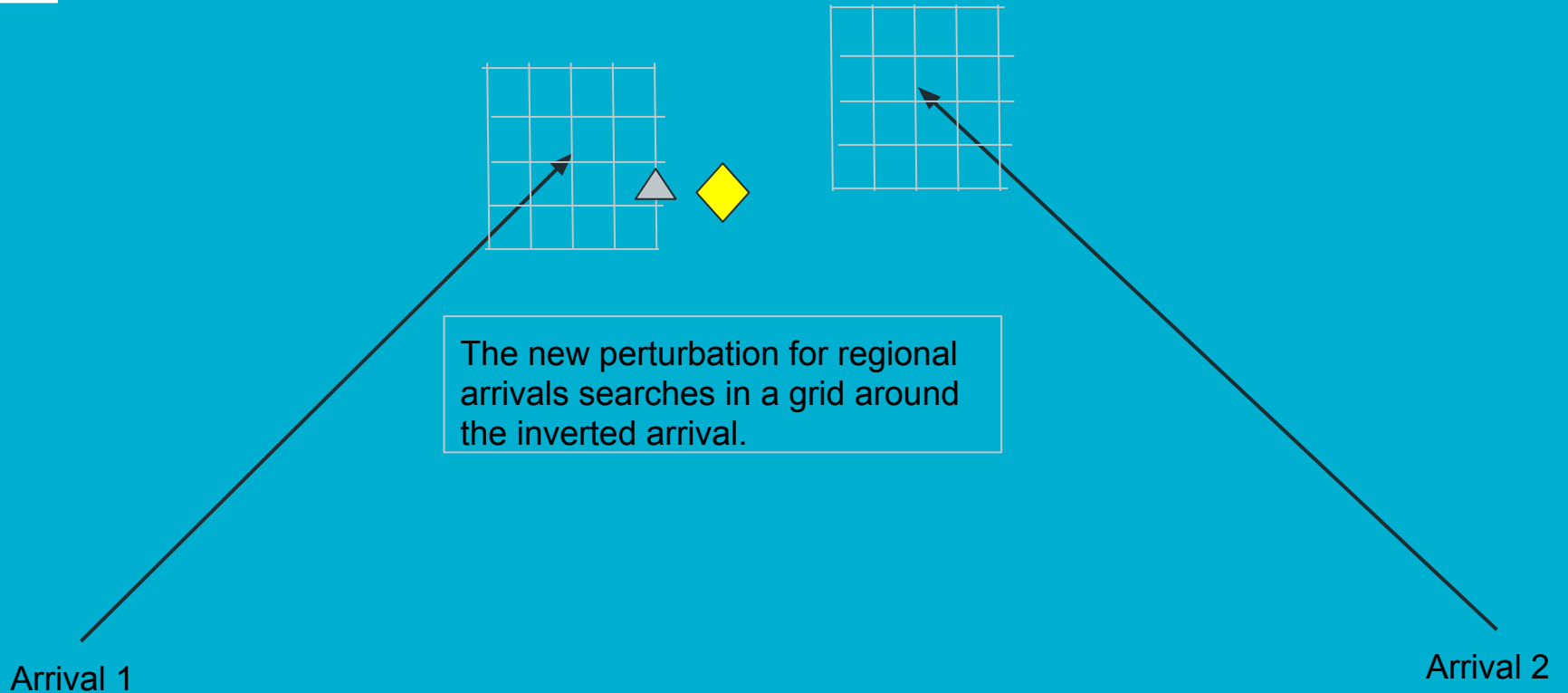
Candidate Proposal -- Perturb Regional Arrivals



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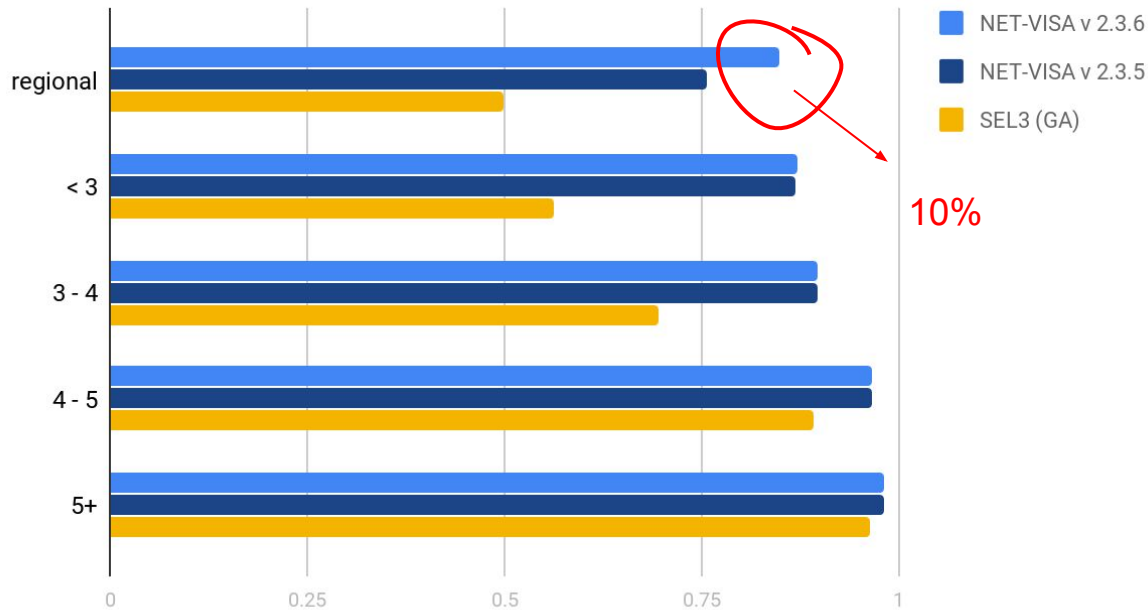


Summary of Improvements to Proposal

- Search in a small space-time ball around the inverted arrival for regional arrivals (distance less than 20 degrees)
- Also do a uniform search over the whole earth using a sparse 5 degree grid and a simplified model.
 - The uniform proposer is very CPU intensive, and so we have to currently limit the grid size as well as the model.
- Infer the inverted event magnitude rather than attempt all magnitudes
 - This actually gives runtime improvements as well
- Ignore the coda model for the proposal phase.
 - This causes fewer detections to be classified as false arrivals, and hence more events are built.

Results for 2013 with LEB as reference

Overlap with LEB by m_b



Matching Criteria - 2 common associations

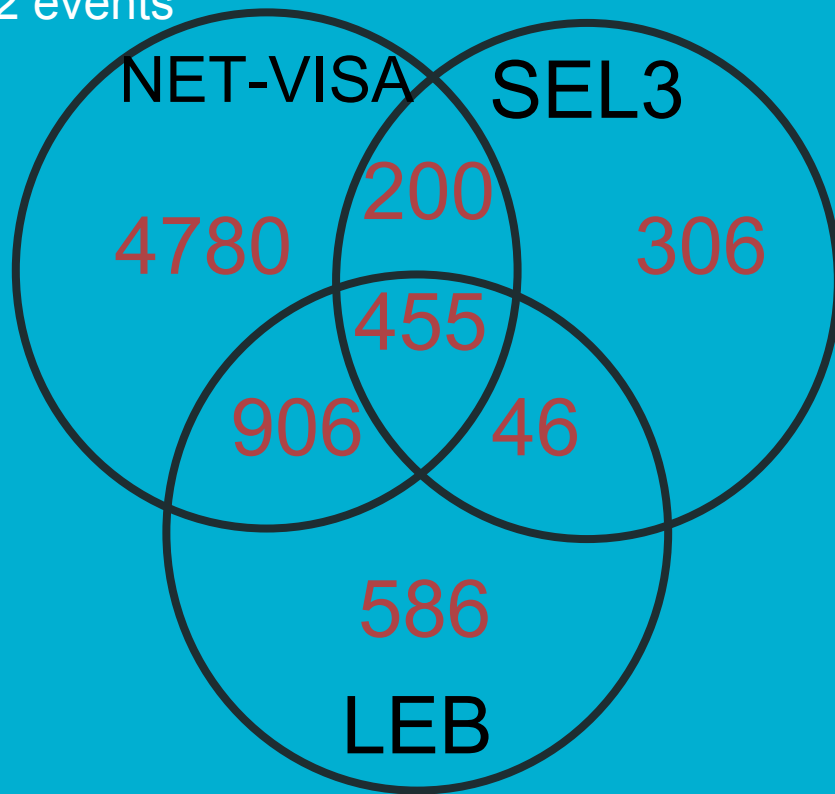
	Overlap	Inconsistency
NET-VISA v 2.3.6	90.5 %	47.8%
NET-VISA v 2.3.5	89.3%	43.4%
SEL3 (GA)	70.6%	42.3%

ISC events not linked to IDC

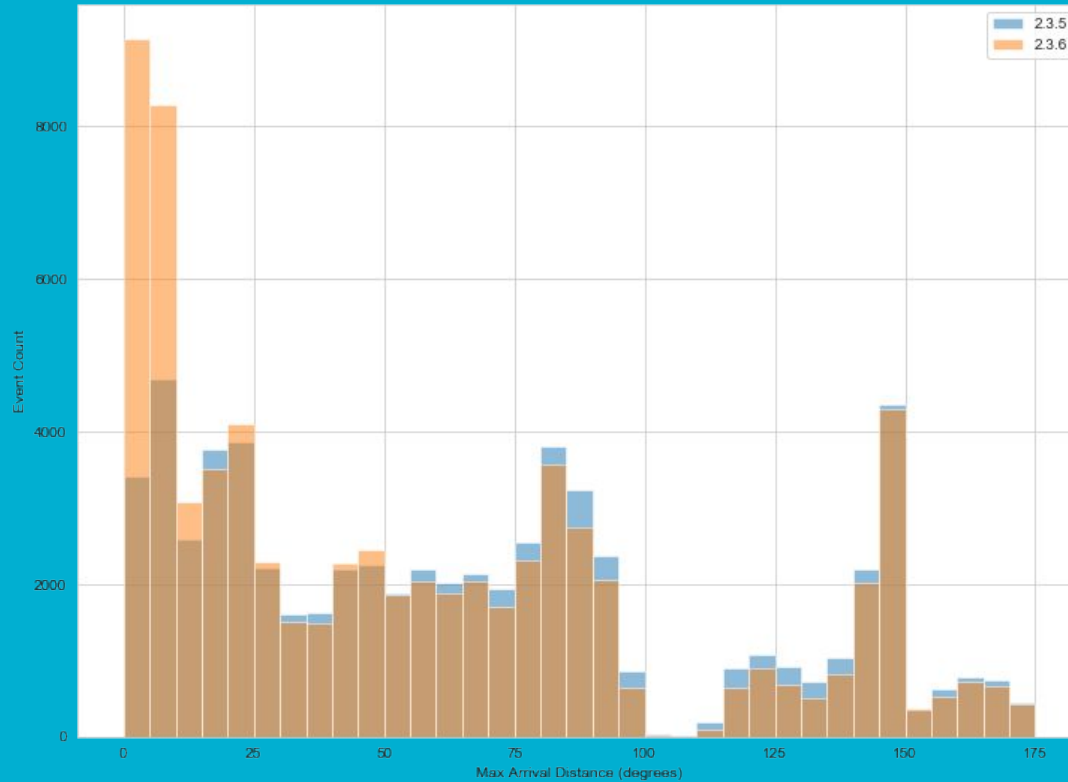
2013 Comprehensive ISC bulletin -- 379432 events

Matching Criteria - 2 degrees 10 seconds

Bulletin Name	Overlap	Distance Error (km)
NET-VISA v 2.3.6	6341	55.9
NET-VISA v 2.3.5	3482	59.4
SEL3 (GA)	1007	51.9
LEB	1993	43.8

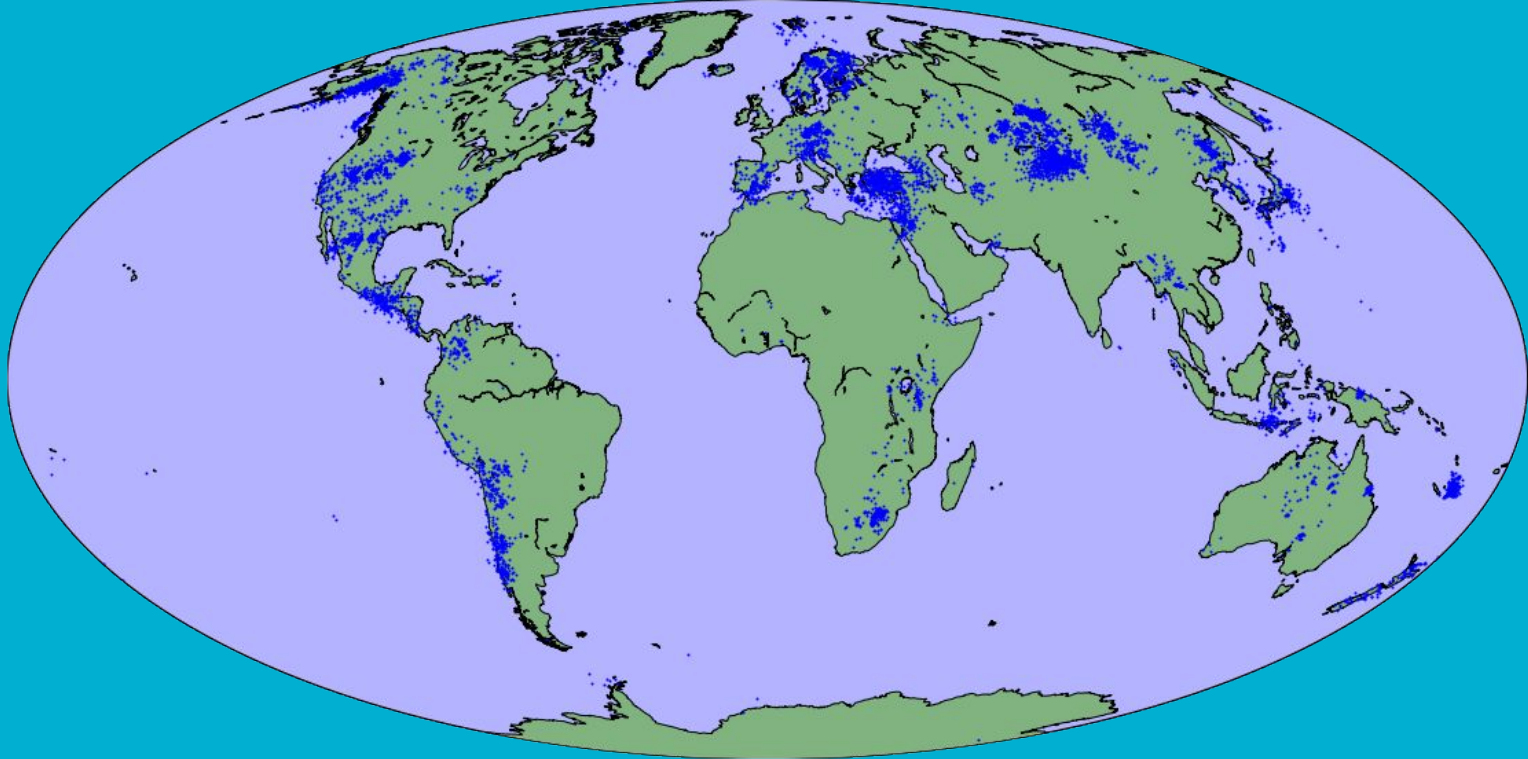


Max Arrival Distance of Events



New Regional Events

New Regional Events in v2.3.6



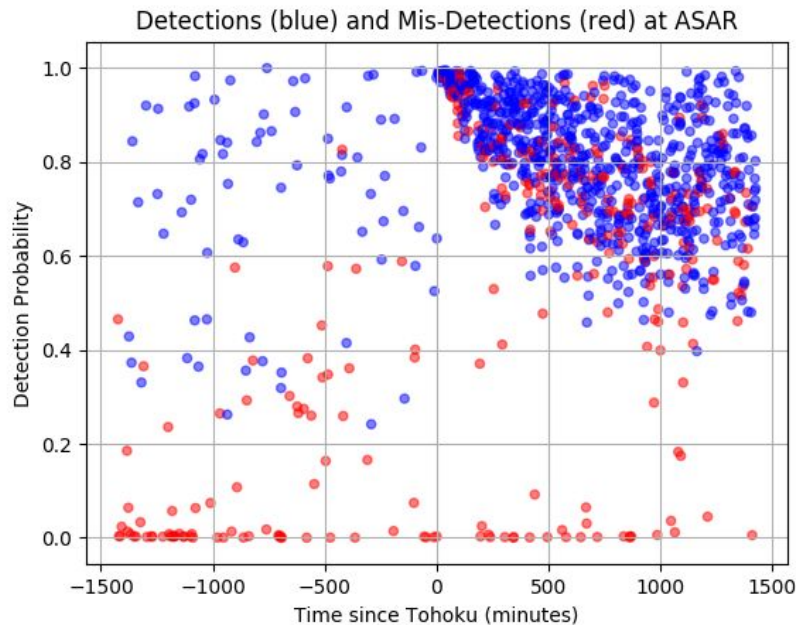
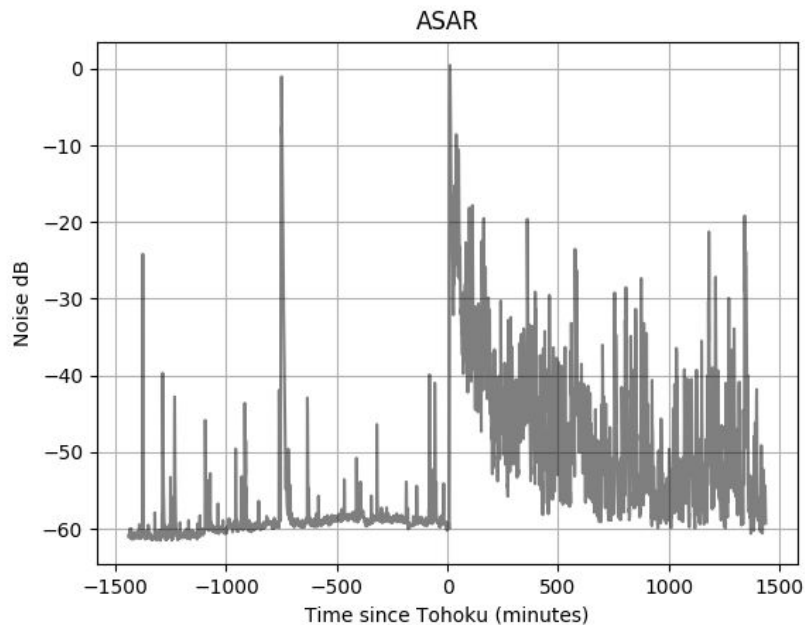
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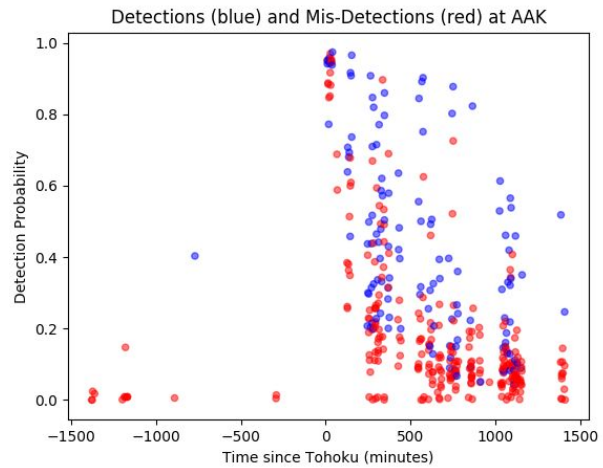
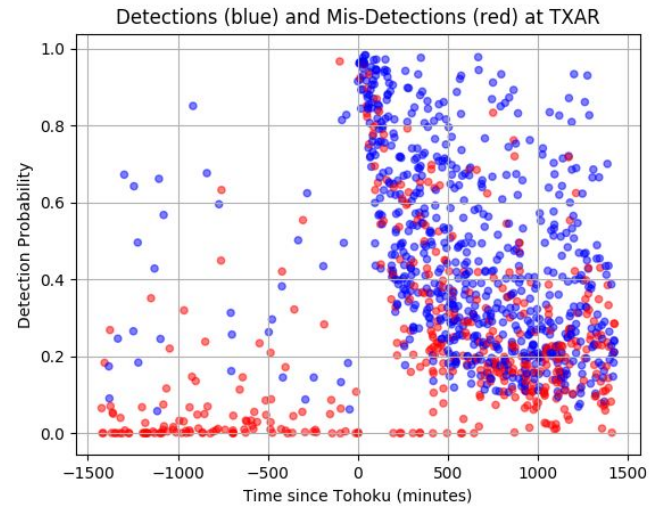
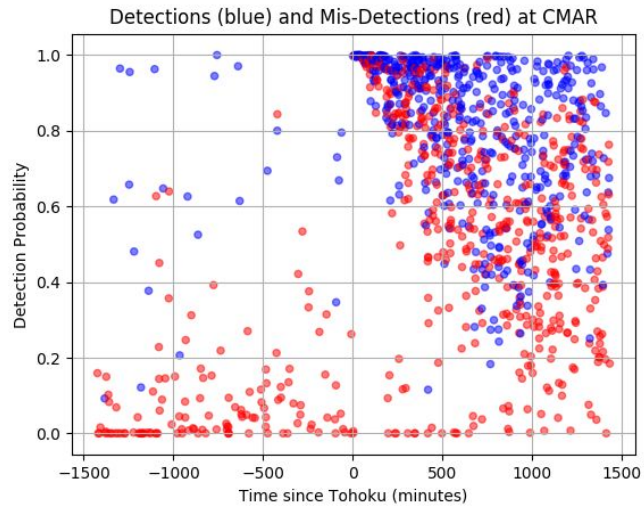
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Detection Probability in NET-VISA

- Detection probability is learned from
 - Body-wave magnitude
 - Event depth
 - Distance between the event and the station
 - Phase label
 - Station name
- If a large number of stations with high probability of detection for an event don't detect said event then the probability that the event is real becomes low!
- Existing model doesn't account for real-time conditions at the stations

Effect of Noise on Detections after Tohoku

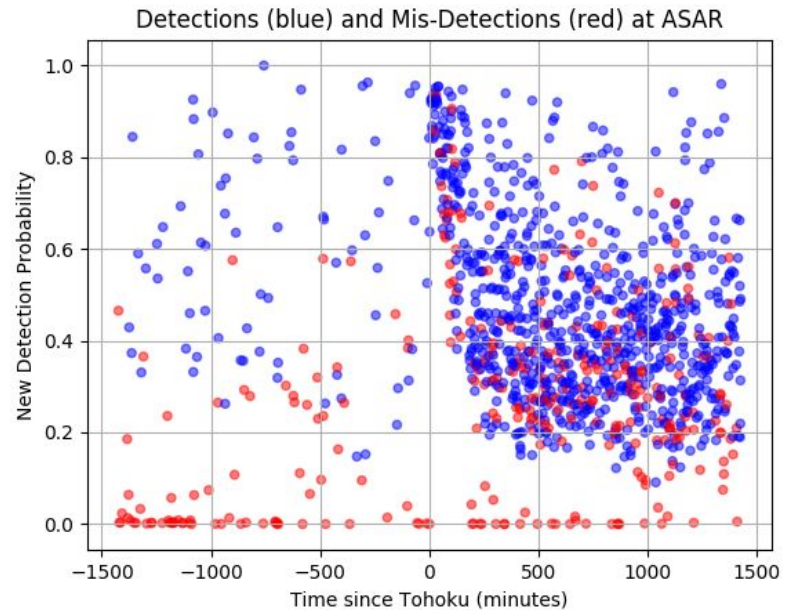
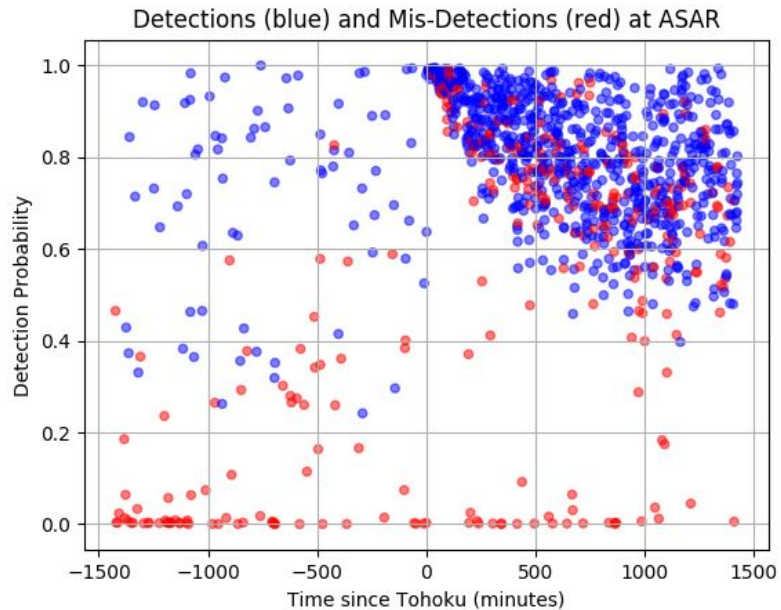




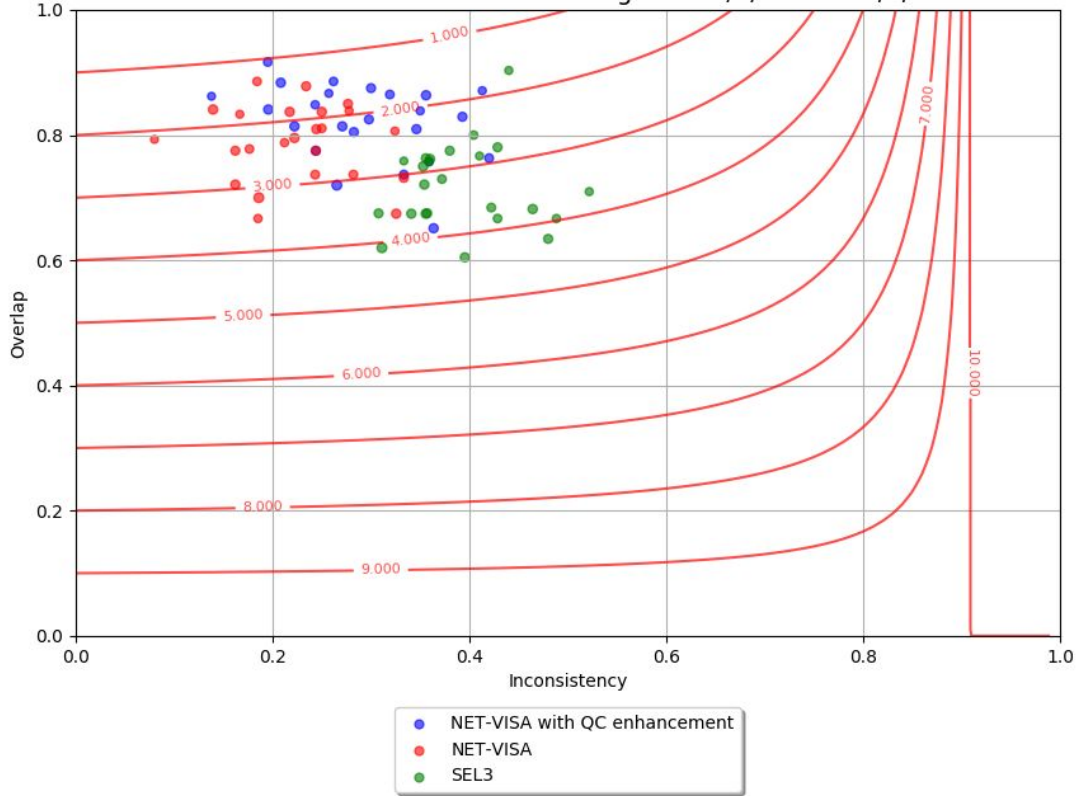
Change to Detection Probability

- CTBTO is now collecting real-time noise level at each station
 - Average energy levels collected in 1 minute intervals
 - For array stations the median across the array is computed
- Reduce the effective body-wave magnitude of the event at a station if the station is noisy
- Learn the historic noise levels for each station
- Reduce magnitude by
 - 1 if noise above P95
 - .5 if noise between P90 - P95
 - .25 if noise between P80 - P90

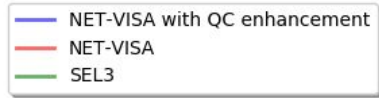
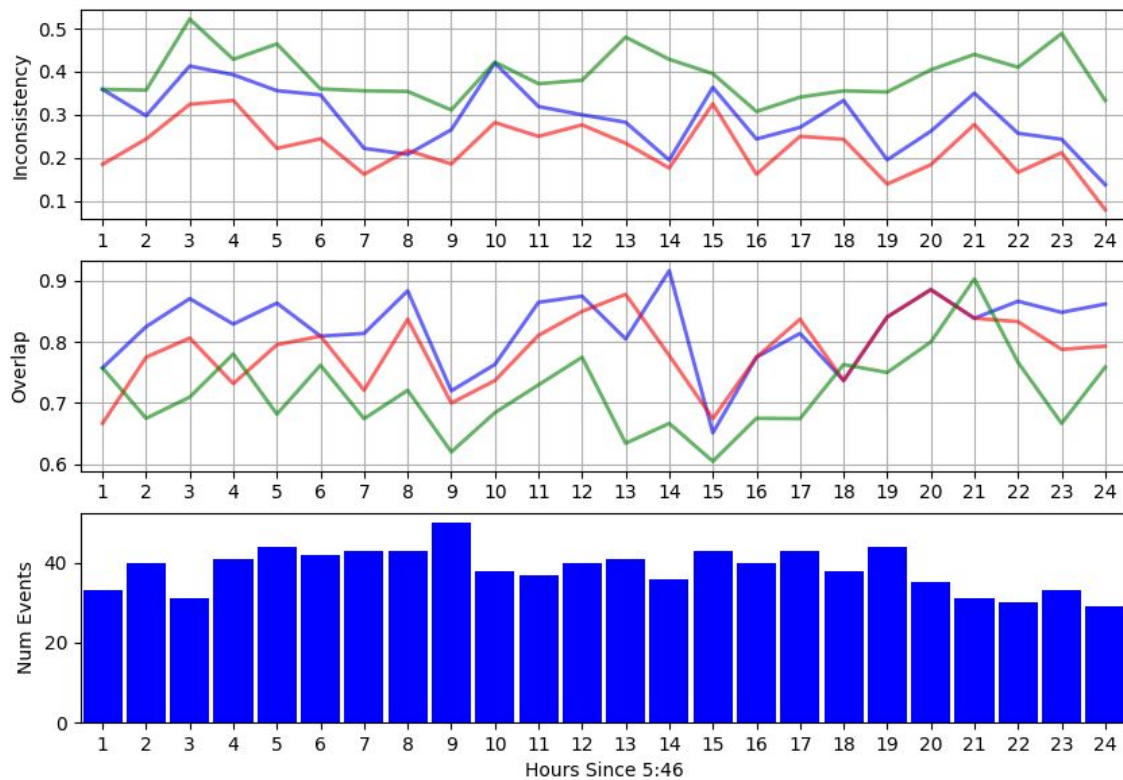
New Detection Probability under noise



Reference Bulletin: LEB. Time Range: 2011/3/11 - 2011/3/12



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Summary

- Performance of NET-VISA for regional events not at par with tele-seismic events.
- Root cause was related to candidate proposals for regional events.
- LEB-based analysis and ISC-based analysis both confirmed an improvement in regional events
- A number of events in the aftershock sequence of large quakes were being missed because of noise-saturation at stations
- New real-time noise data together with model improvements helped to recover these events