Fine-Scale Event Location and Error Analysis in NET-VISA (S31A-2710)

Nimar S. Arora and Stuart Russell

Bayesian Logic, Inc. and University of California, Berkeley.

BACKGROUND

- NET-VISA is a network processing software. In other words, it takes raw detections (created from the waveforms by station processing software) as input and outputs a bulletin of events.
- Events are created based on a generative probabilistic model, which is trained on historical data. There is no explicit "event definition criteria". Any event is considered valid if the probability of the event's occurrence is greater than the probability of its non-occurrence.
- The NET-VISA model supports all three waveform technologies used by CTBTO -- seismic, hydro-acoustic and infrasound. The main features of the model are as follows:
  - The model can be decomposed into sub-model that can be individually inspected and visualized.
  - There is a sub-model for detections and mis-detections.
  - There is a sub-model for false detections at each station to account for local clutter and noise.
  - There is a sub-model for coda detections.
- Inference in NET-VISA is performed by a series of "moves" or iterative transformation to the initial, empty bulletin. The following is a list of all the moves:
  - The birth move proposes new events by back-projecting individual detections using their azimuths and slowness (to get a distance estimate). In infrasound, all possible distance values are used.
  - Reassociate move associates detections to events based on the model likelihood that the event generated the detection.
  - Relocate move finds the best location for an event based on the currently associated set of detections.
  - Death move kills an event that is more likely to have not occurred based on the prior probability of occurrence as well as the likelihood of the associated detections and all mis-detections.
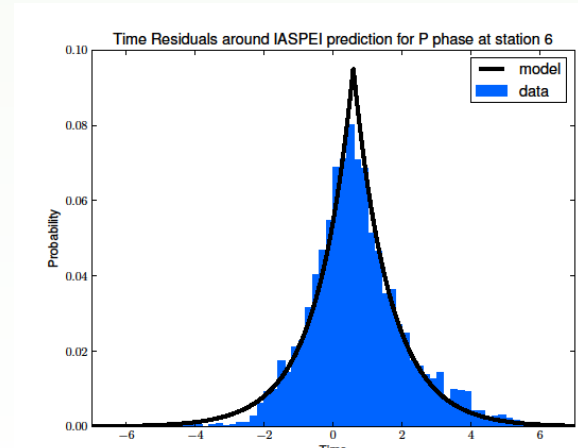
NET-VISA Model

- Location prior is a mixture of a uniform prior and a depth-dependent location prior learned from 10 years of ISC data. Pure infrasound and hydroacoustic event priors are completely uniform.

Location Density Depth 0 - 20
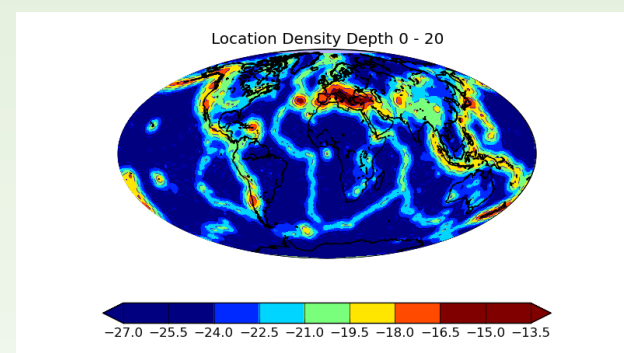
- Seismic detection probability is a station-dependent probability which depends on the event magnitude, depth, and distance from the station. This is modeled as a logistic regression with additional derived features.


Detection probability at station 6 for P phase, surface event
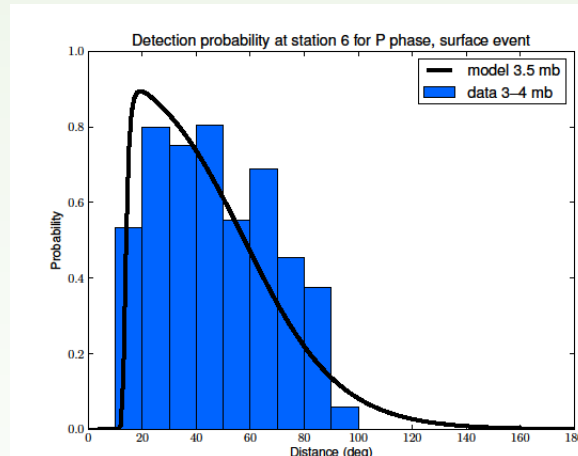
- Detection time, azimuth, and slowness are modeled as Laplace distributions.

Time Residuals around IASPEI prediction for P phase at station 6

Please refer to the following for full details:
Arora, N. S., S. Russell, and E. Sudderth, 2013, **NET-VISA: Network Processing Vertically Integrated Seismic Analysis**, Bulletin of the Seismological Society of America, volume 103(2A), pages 709-729, http://dx.doi.org/10.1785/0120120107
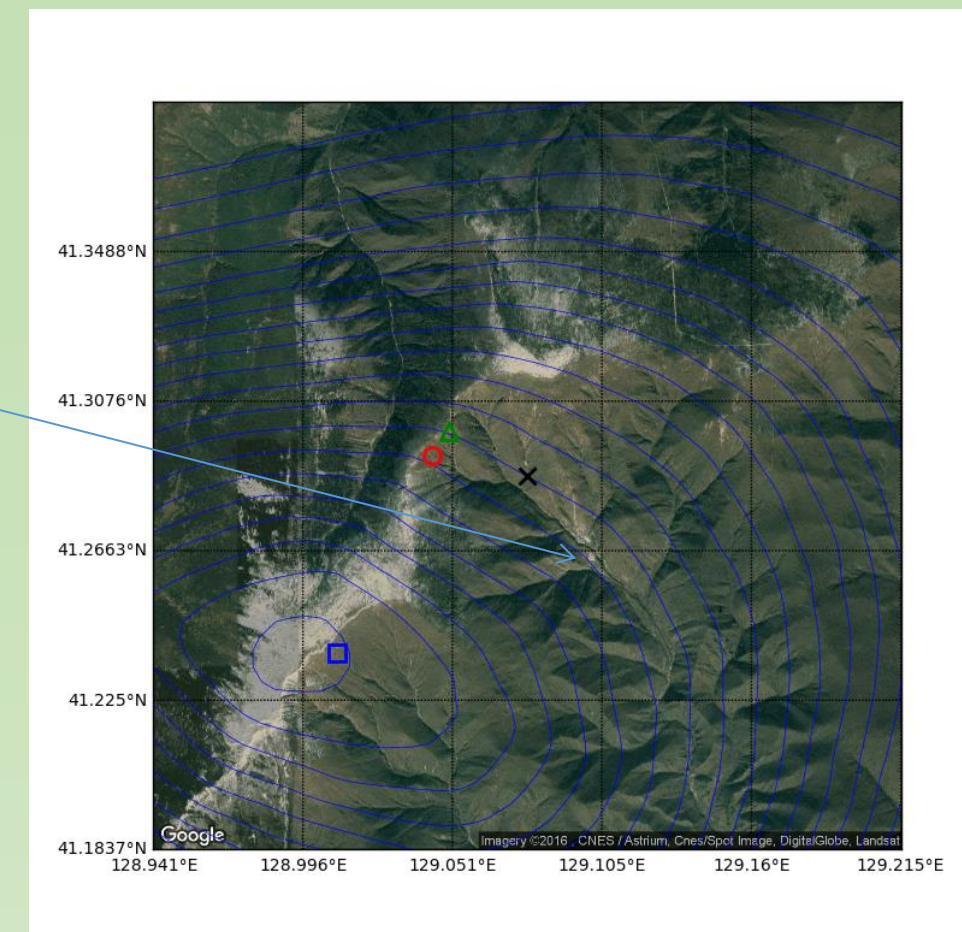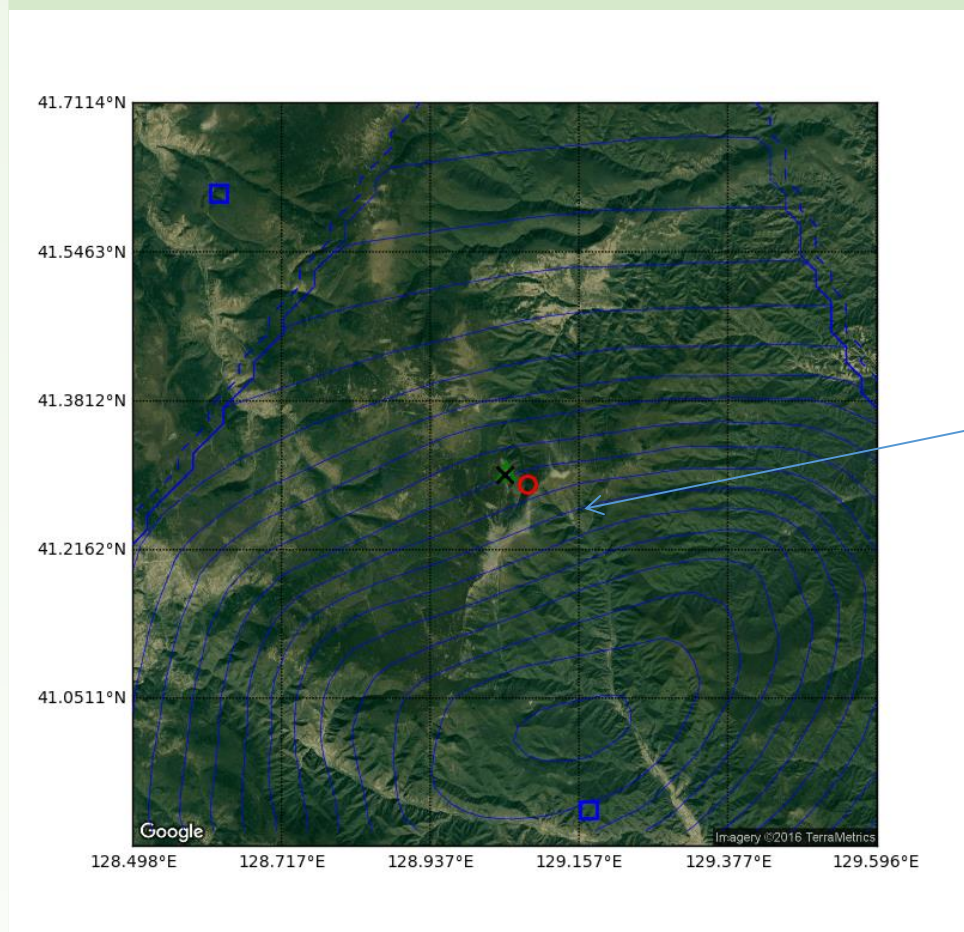www.PosterPresentations.com

DPRK 5
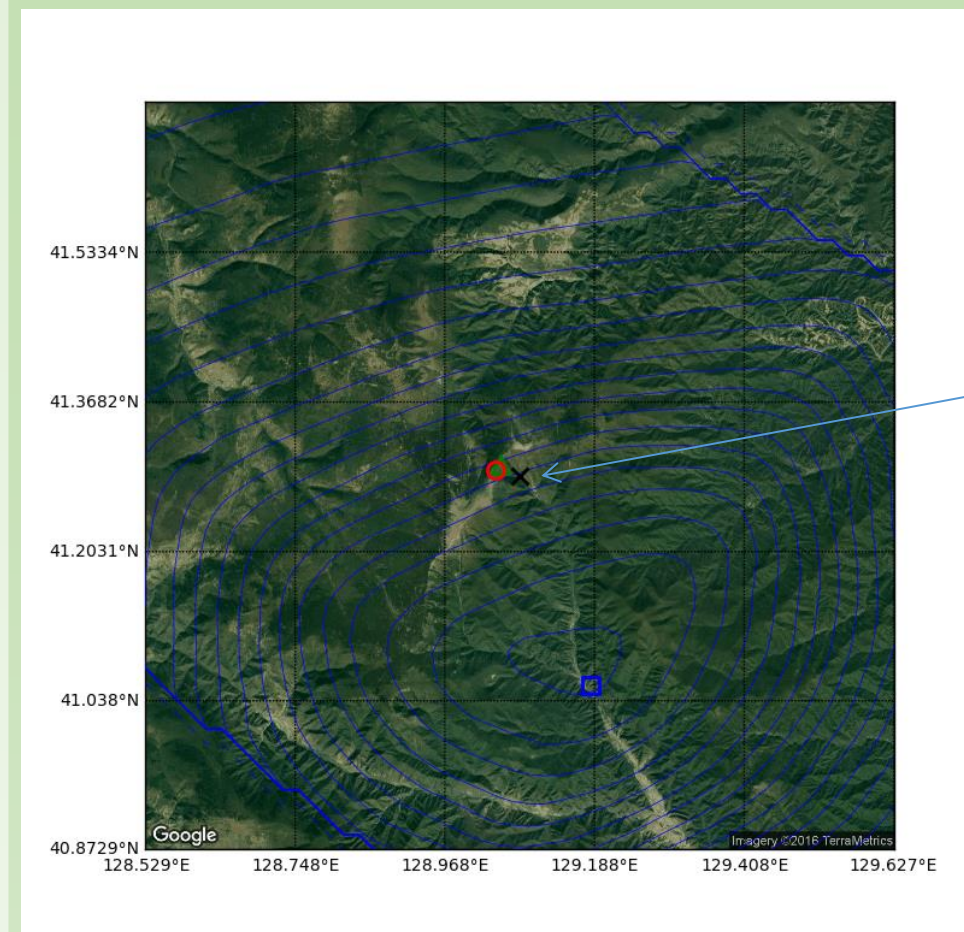
BEFORE

Nuclear Testing Base Camp

Green Triangle – LEB location
Red Circle – SEL3 location
Blue Square – NET-VISA location
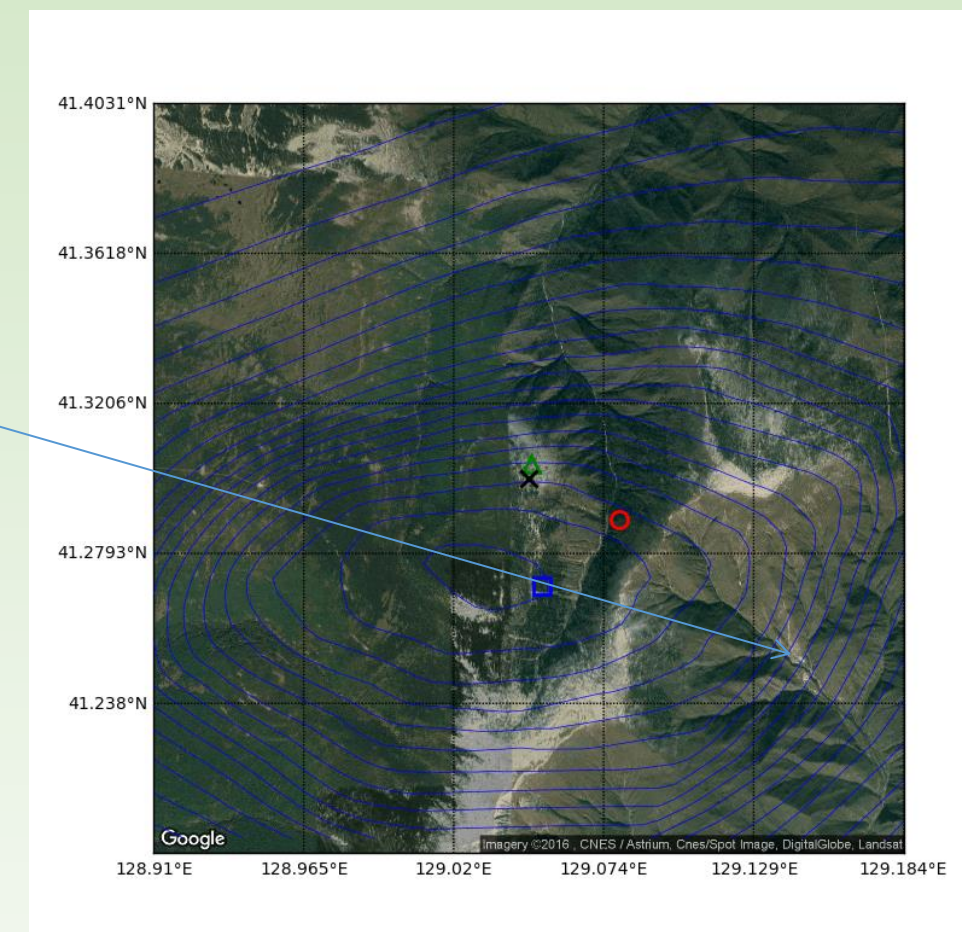Blue contours – NET-VISA posterior
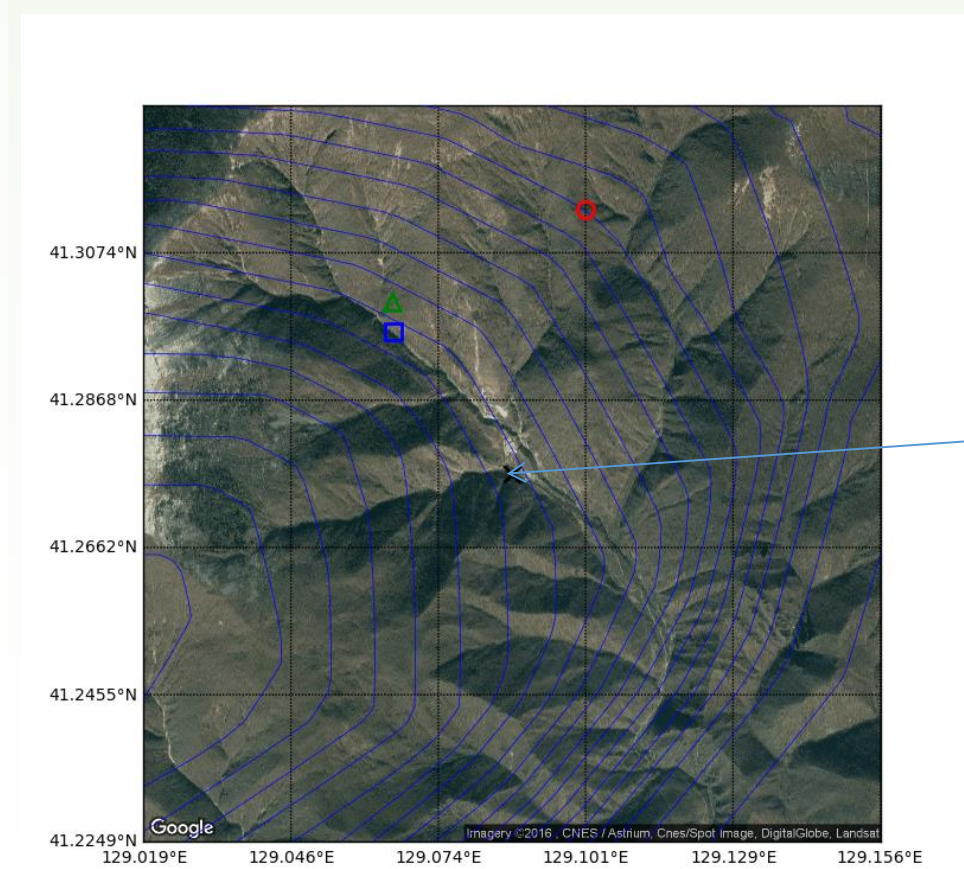Black X – USGS location

AFTER

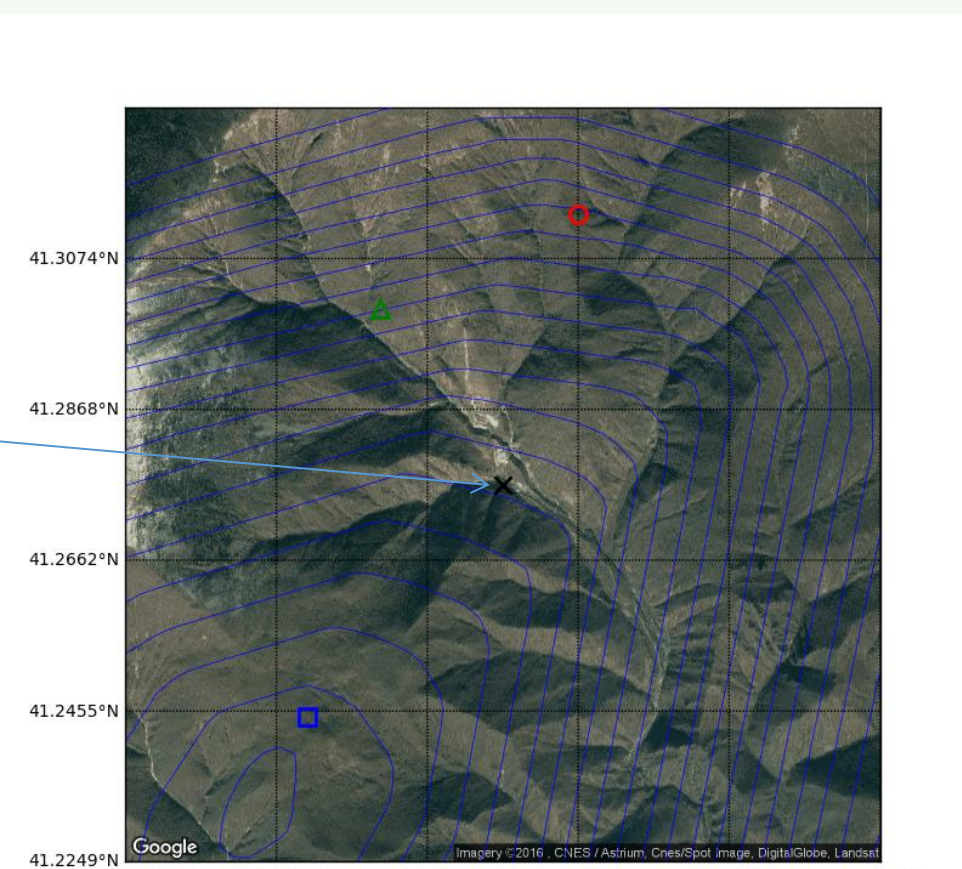## DPRK 4

BEFORE

Nuclear Testing Base Camp

AFTER

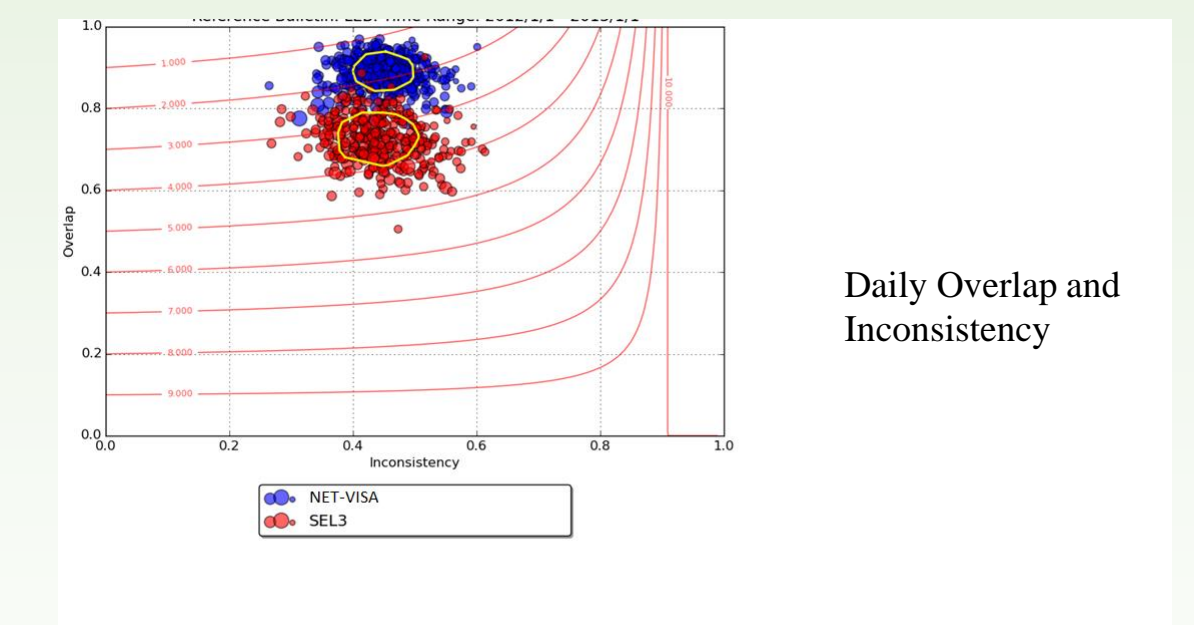## DPRK 3

BEFORE

Tunnel Entrance

AFTER

Improvements to Location

- Our analysis of the location errors from the existing version (2.2.44) of NET-VISA indicated that the birth move was very coarse and was proposing events 20-30 km away from the optimal location.
- Analysis also showed that unless we move in small step sizes such as 1 km we couldn't improve many of the events. Other events needed larger step sizes to improve.
- Our solution involved multiple steps sizes from 100km to 100m, and iteratively reducing the step size if we found a better event location.
- Various optimizations were done in order to not impact the running time.
- The new version 2.2.47 has all of the location plus runtime improvements. This is about 15% slower but it searches for events at a scale that is 10x finer than the previous version.

Results

- 10% reduction in location errors on average compared to LEB on 2013 data.
  - SEL3(GA) average error 229 km s.d. 458 km
  - NET-VISA v 2.2.44 average error 151 km s.d. 273 km
  - NET-VISA v 2.2.46 average error 133 km s.d. 272 km
- In the following we describe overlap and inconsistency where,
  - Overlap is the fraction of reference events that are in the test bulletin
  - Inconsistency is the fraction of prediction events in the test bulletin that are not present in the reference bulletin.

	Overlap	Inconsistency
NET-VISA	87.7 %	45.2 %
SEL3 (GA)	71.6 %	46.9 %

Daily Overlap and Inconsistency

Acknowledgements

Disclaimer