# Global Infrasound Association Based on Probabilistic Clutter Categorization

**Nimar Arora, Bayesian Logic**
**Pierrick Mialle, CTBTO**

# What constitutes a real event in infrasound?

- Clearly, no right answer.
- CTBTO is interested in explosive events, obviously!
- Not interested in repetitive events
  - automobile traffic
  - microbaroms
  - water falls
  - wind farms etc.
- On the other hand, volcanoes and meteorites are of interest!

# How do we frame this in a probabilistic model ?

An event is real if the probability of the event occurring and generating its associated detections and mis-detections is higher than the probability of those same detections being generated by noise (including repetitive clutter) sources.

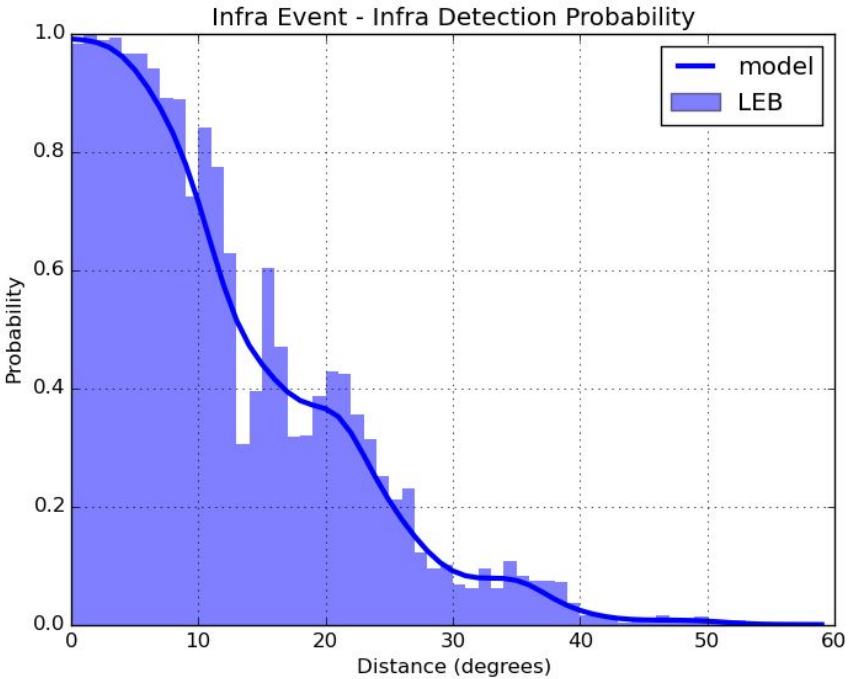
# Contrast this with GA or other approaches

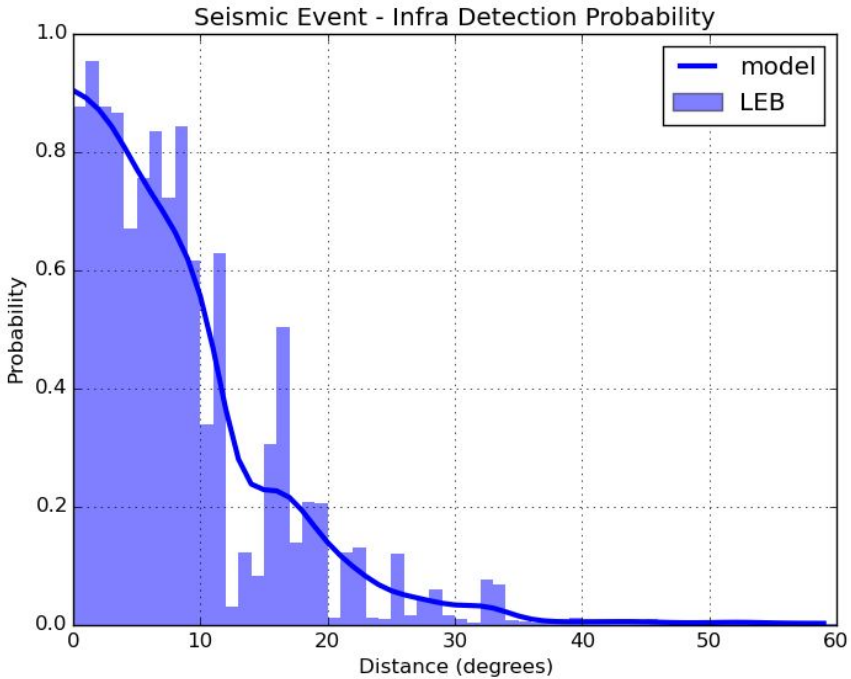
- GA -- An event is real if two or more arrivals are explained by the event within reasonable azimuth and travel time error bounds.
- Doesn’t consider mis-detections
- Doesn’t consider noise rates or typical clutter sources at the detecting stations.
- Doesn’t consider a holistic picture of the event
  - Detection probability
  - Energy
  - Duration, Family size etc.

# Overview

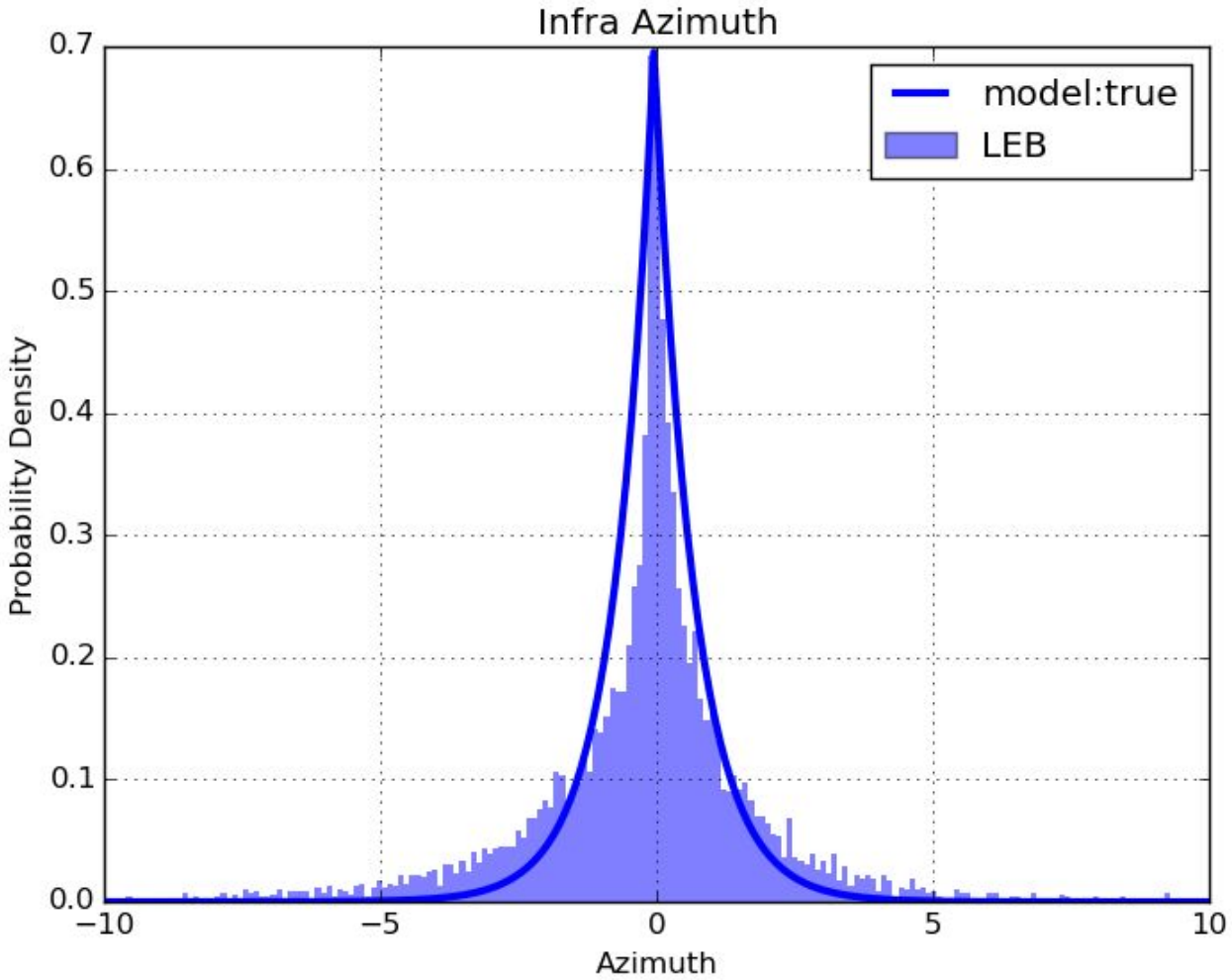
- The generative probabilistic model for infrasound
- The inference algorithm to locate events consistent with the model
- Results

# Detection Probability -- The First Element Of The Model

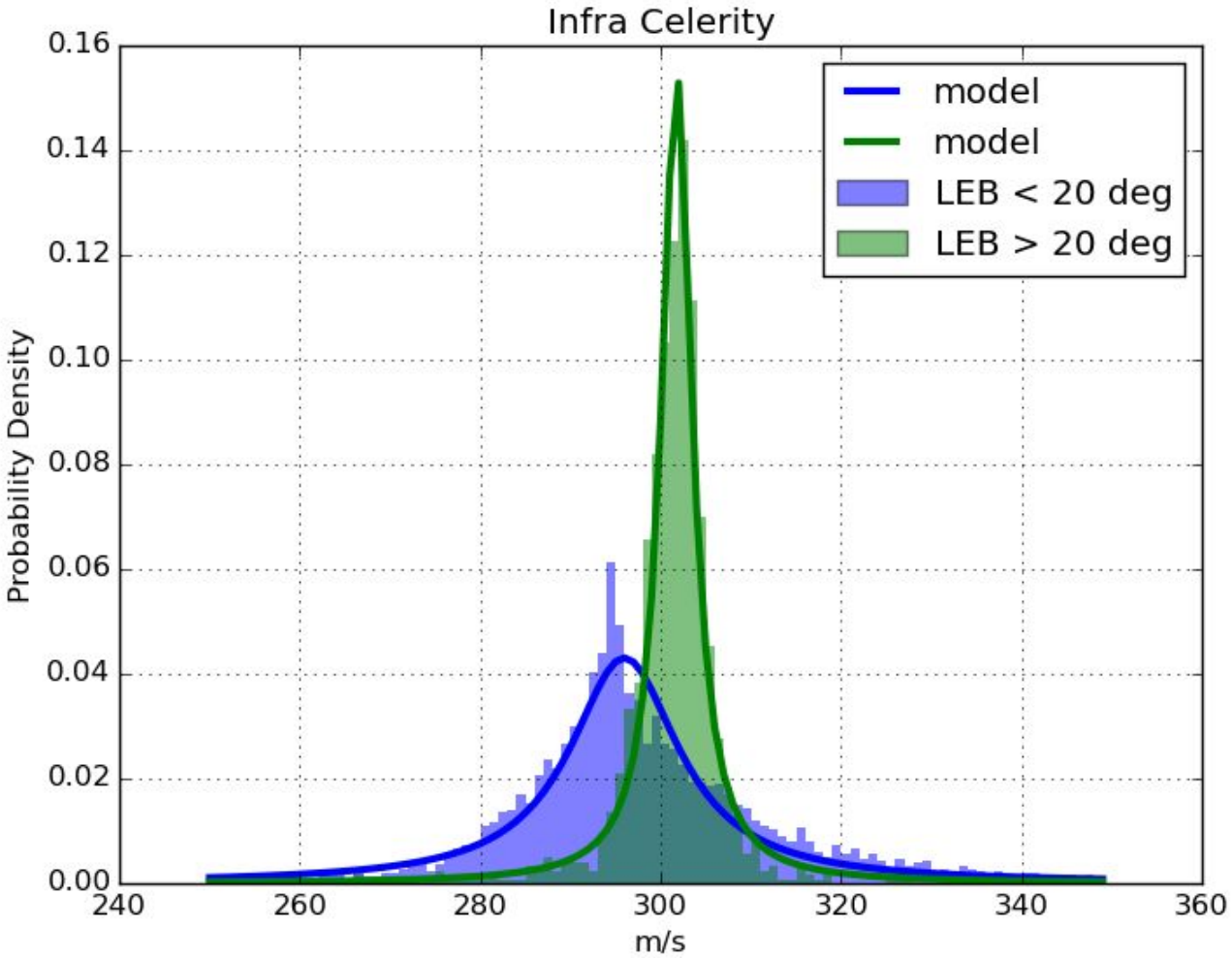



Detection Probability learned empirically.

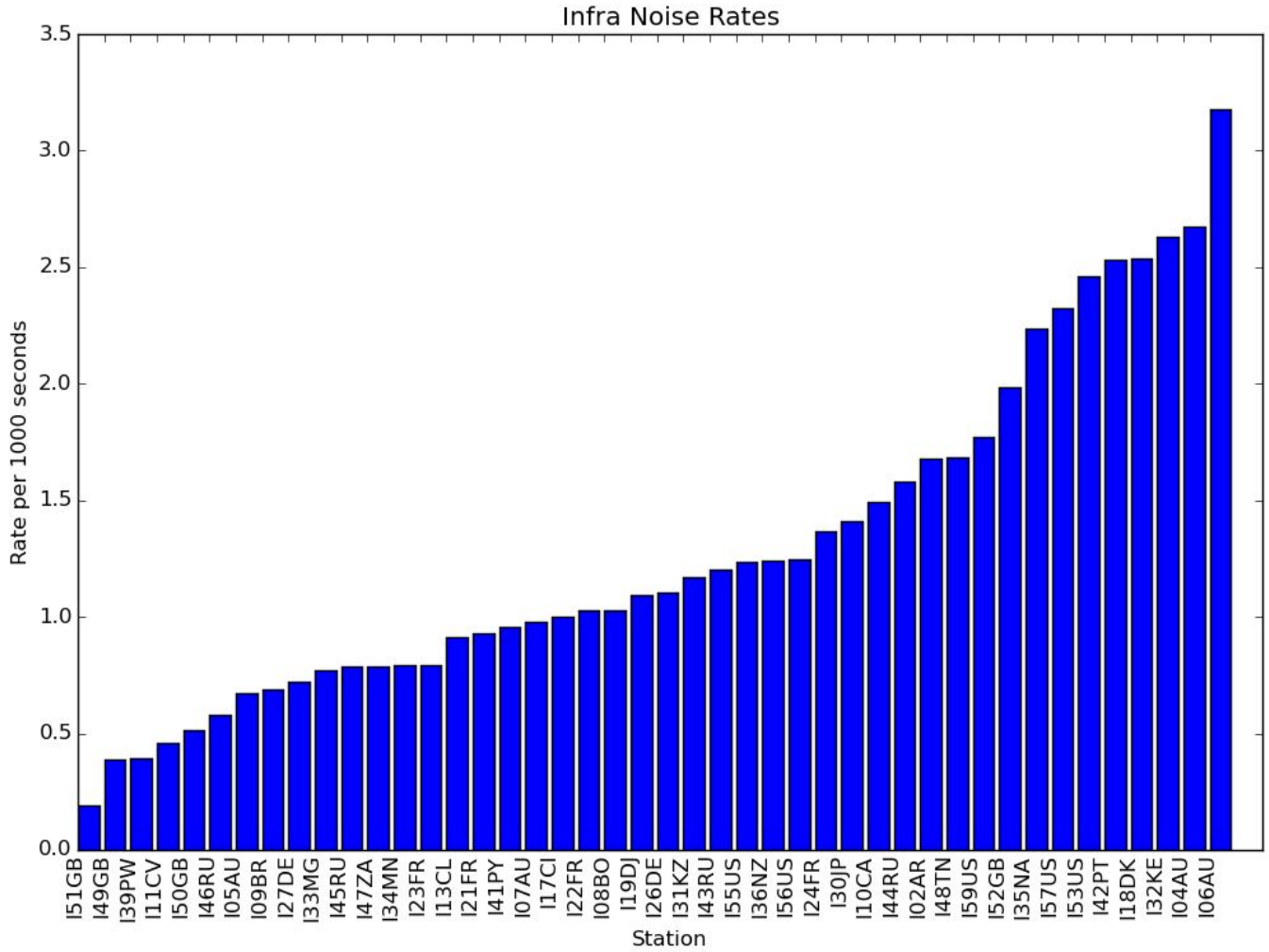



Azimuth is very tightly peaked and is the best attribute for infrasound.

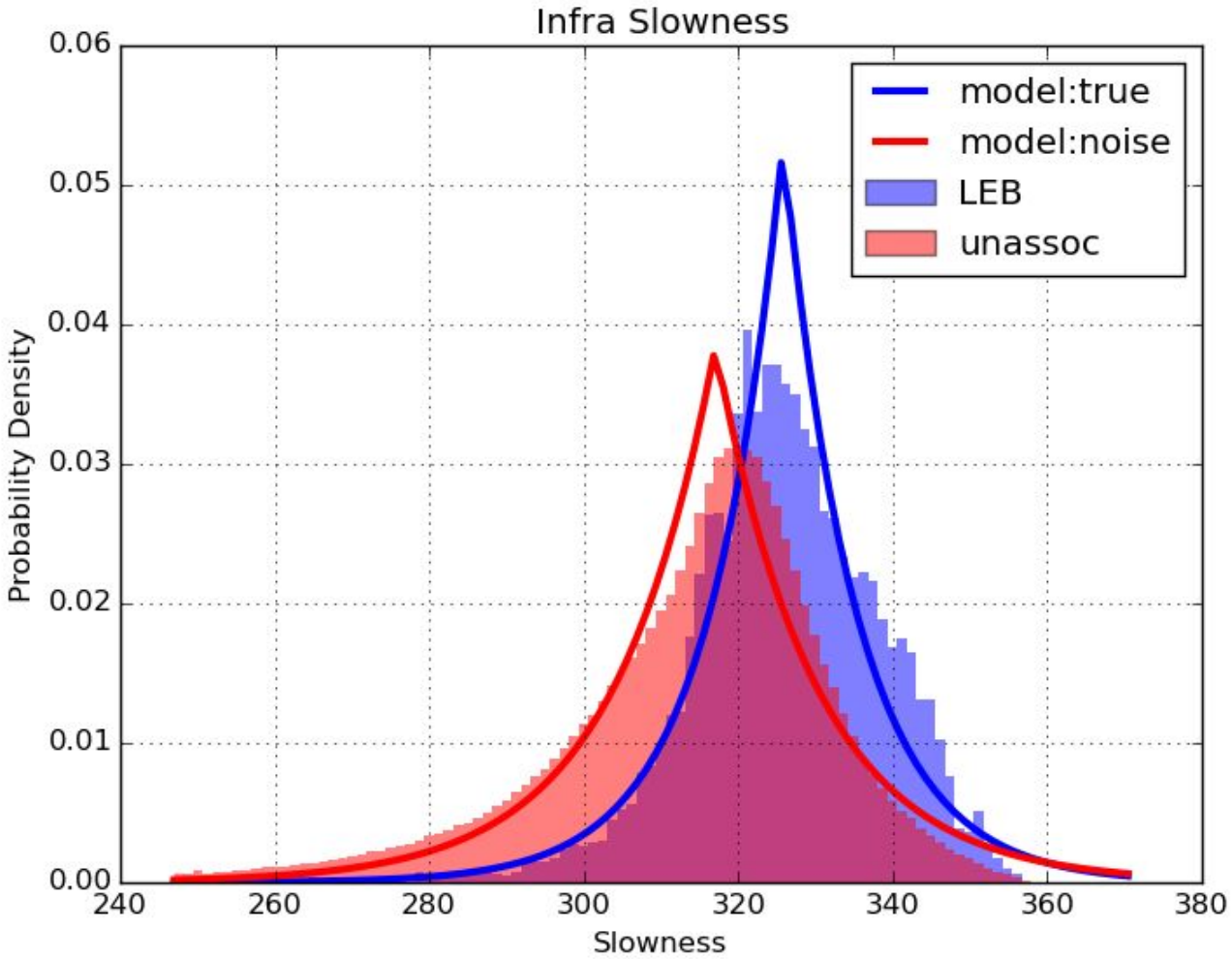



Celerity (metres per second) is the inverse of the travel time.

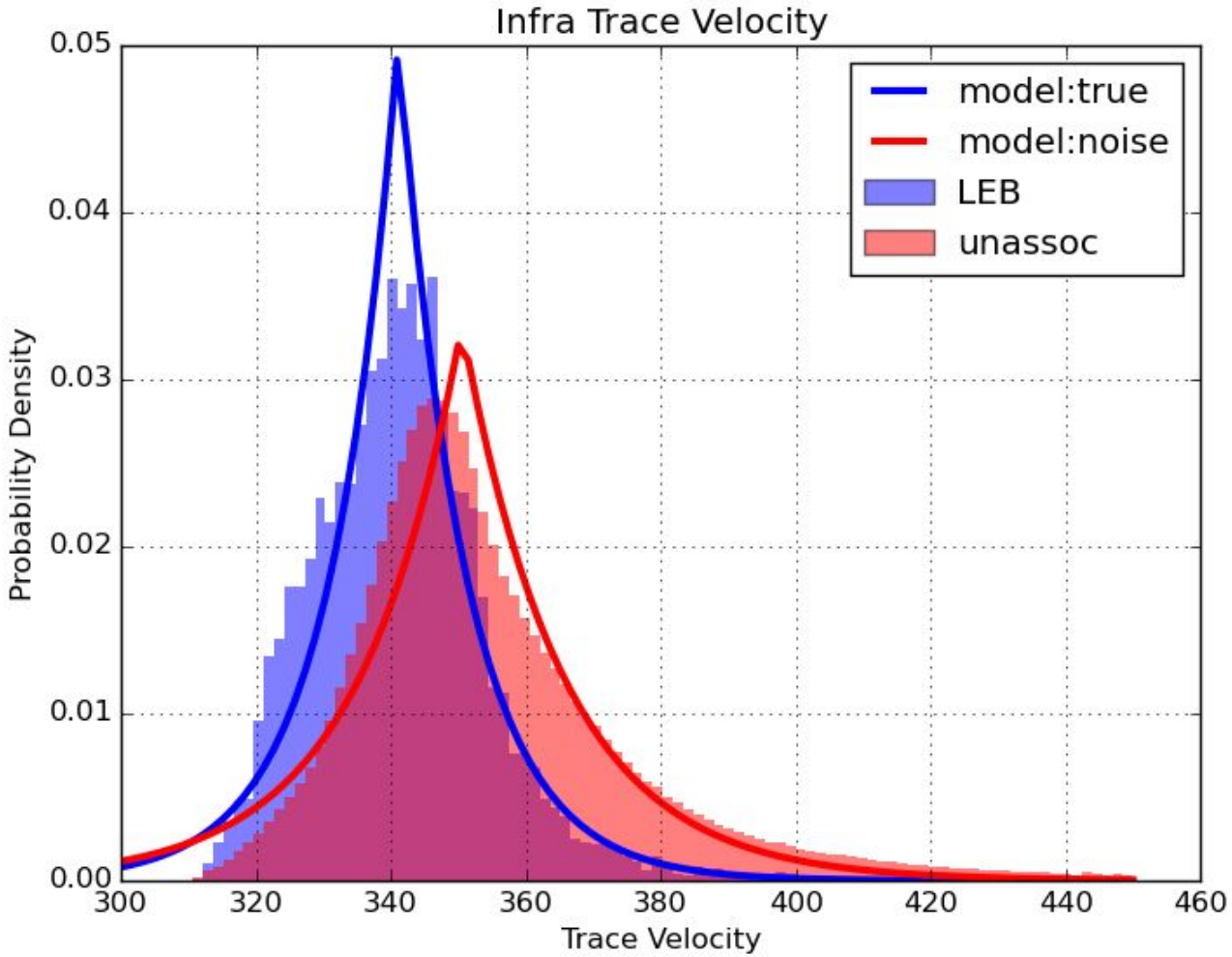
Small uncertainty in celerity can lead to large uncertainty in arrival time.




Noise rate at each station is inferred to be the number of unassociated arrivals.

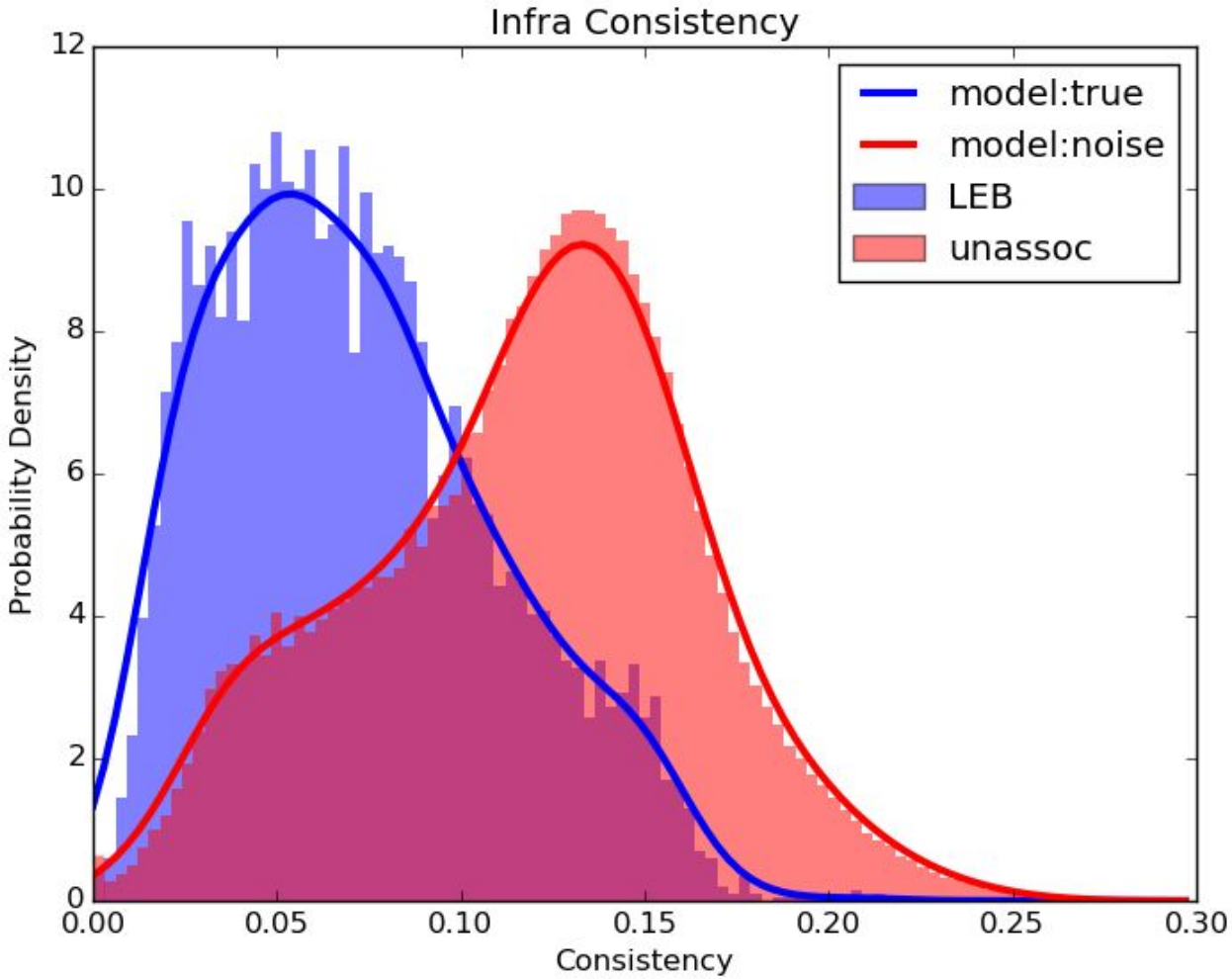



Slowness (seconds per degree)

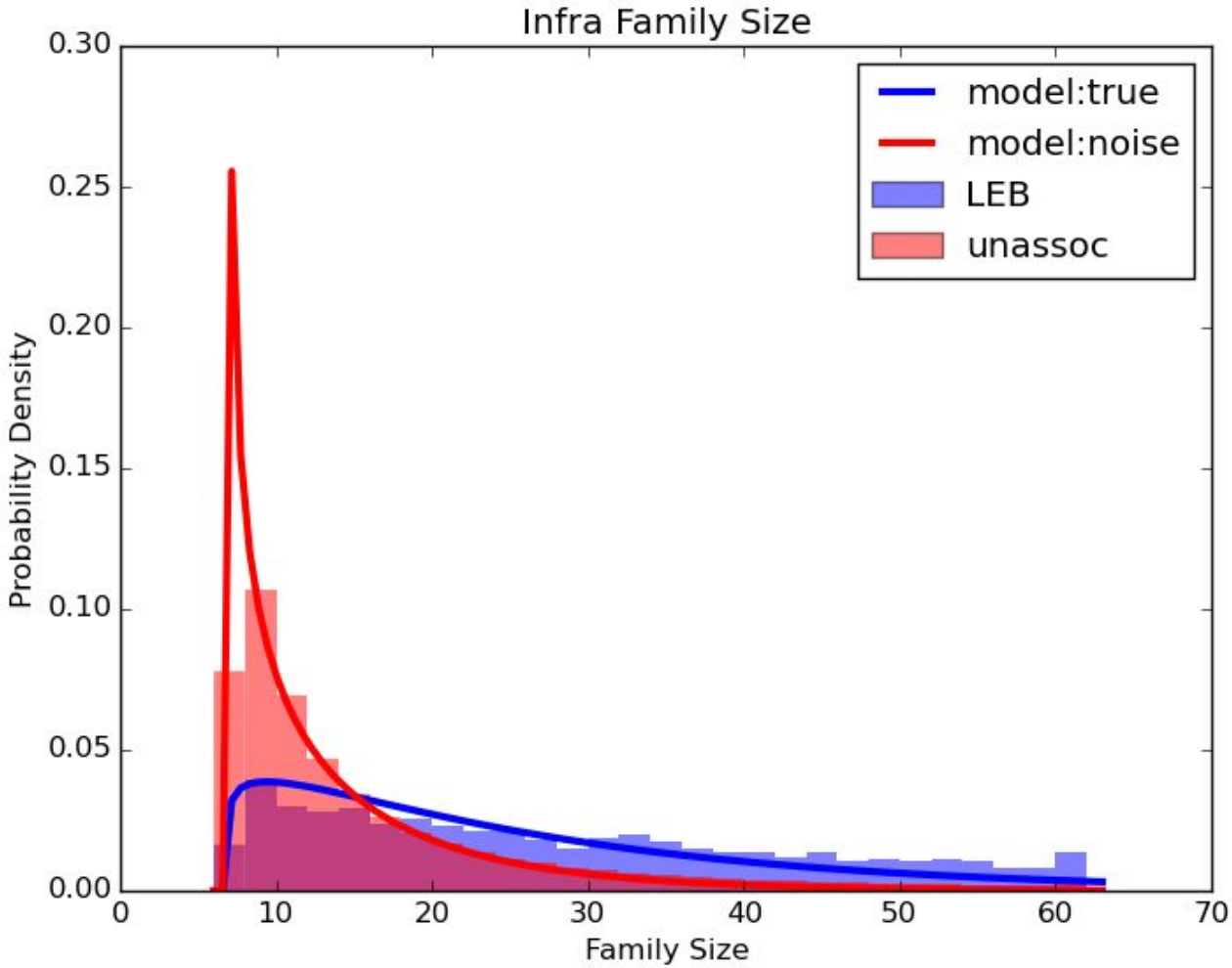



Trace Velocity (metres per second).

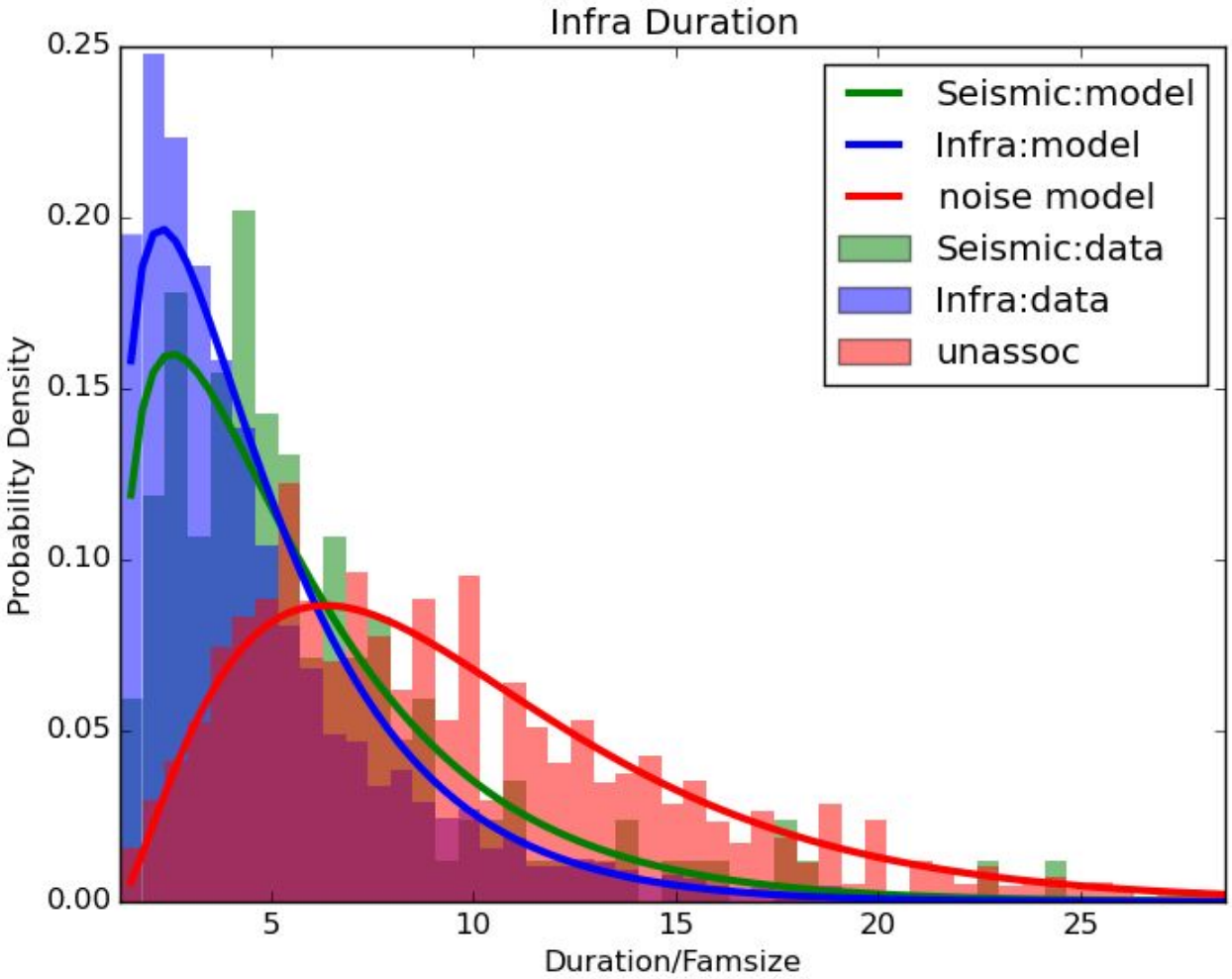
Equivalent to slowness.



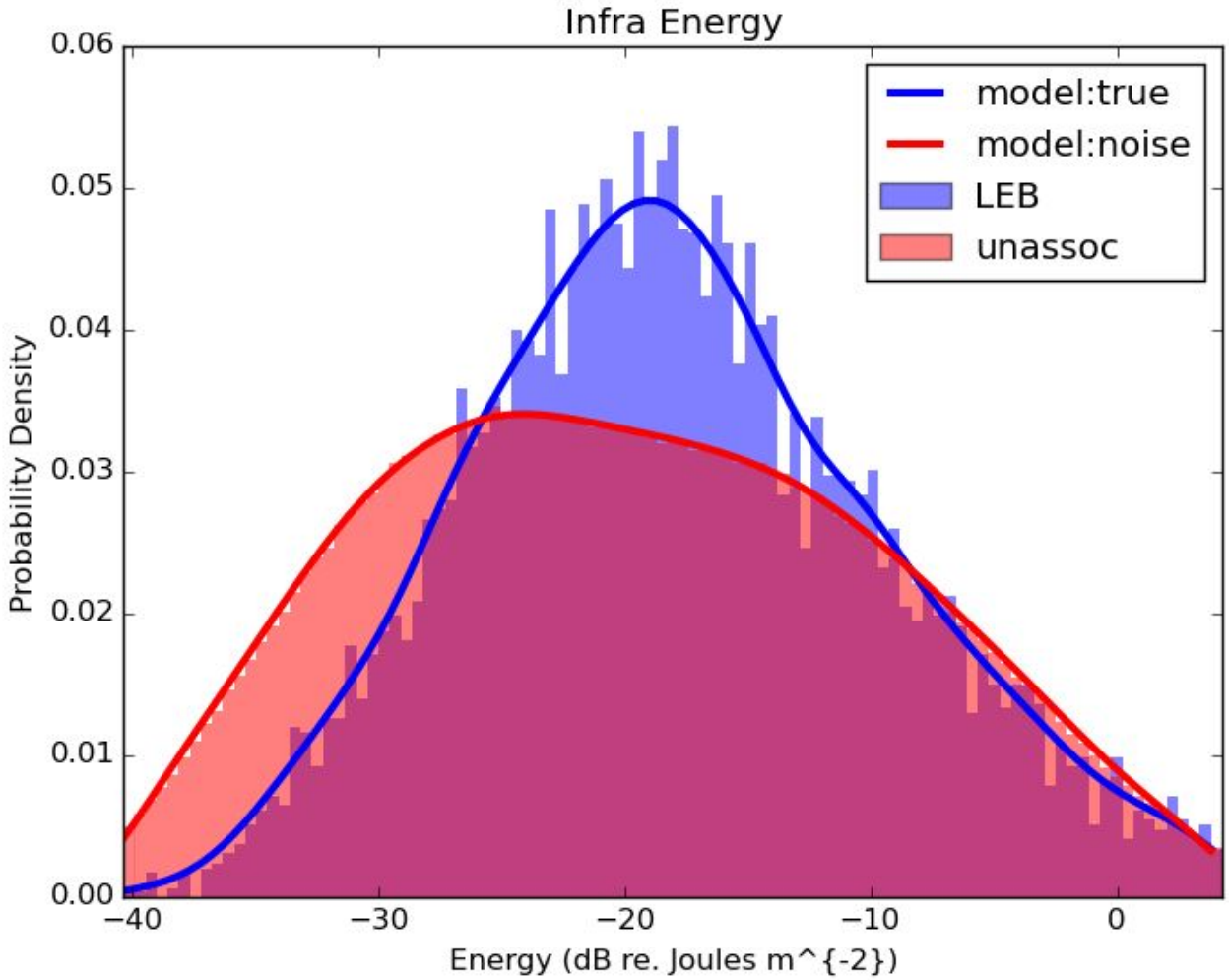

Low consistency numbers indicate good coherence.




The more PMCC pixels light up for a detection the more likely that it will be associated to an interesting event.

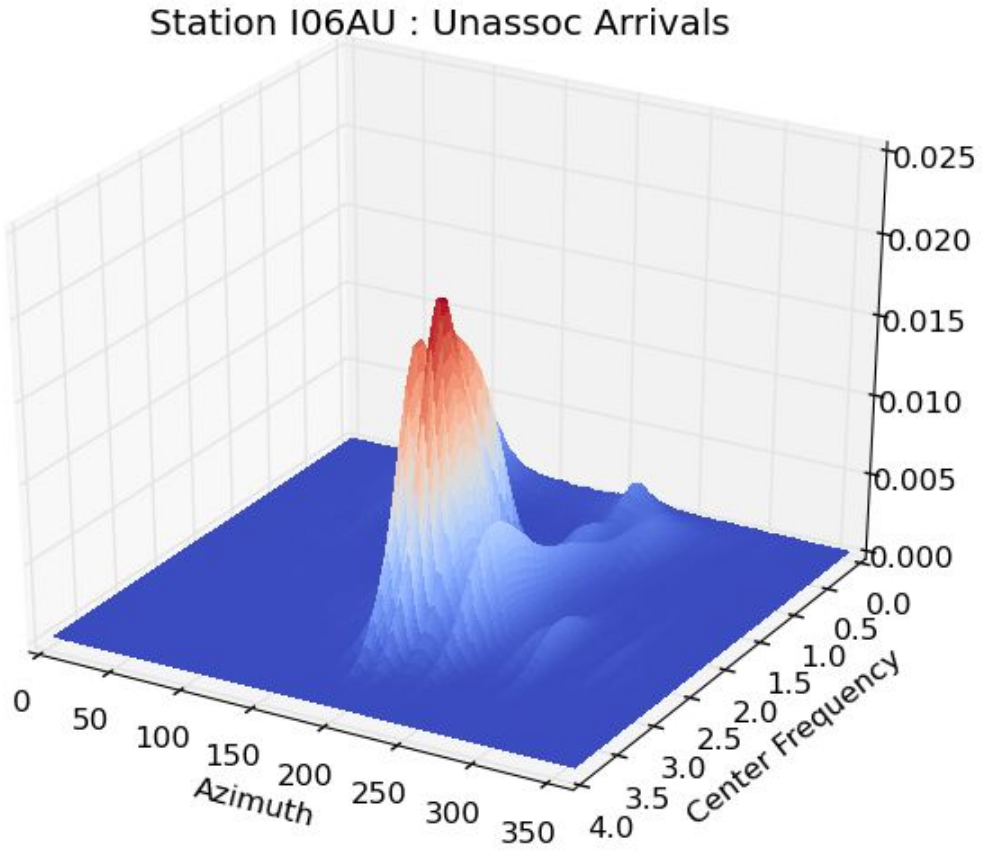



Duration of event divided by family size indicates the narrowness of the signal in frequency bands!



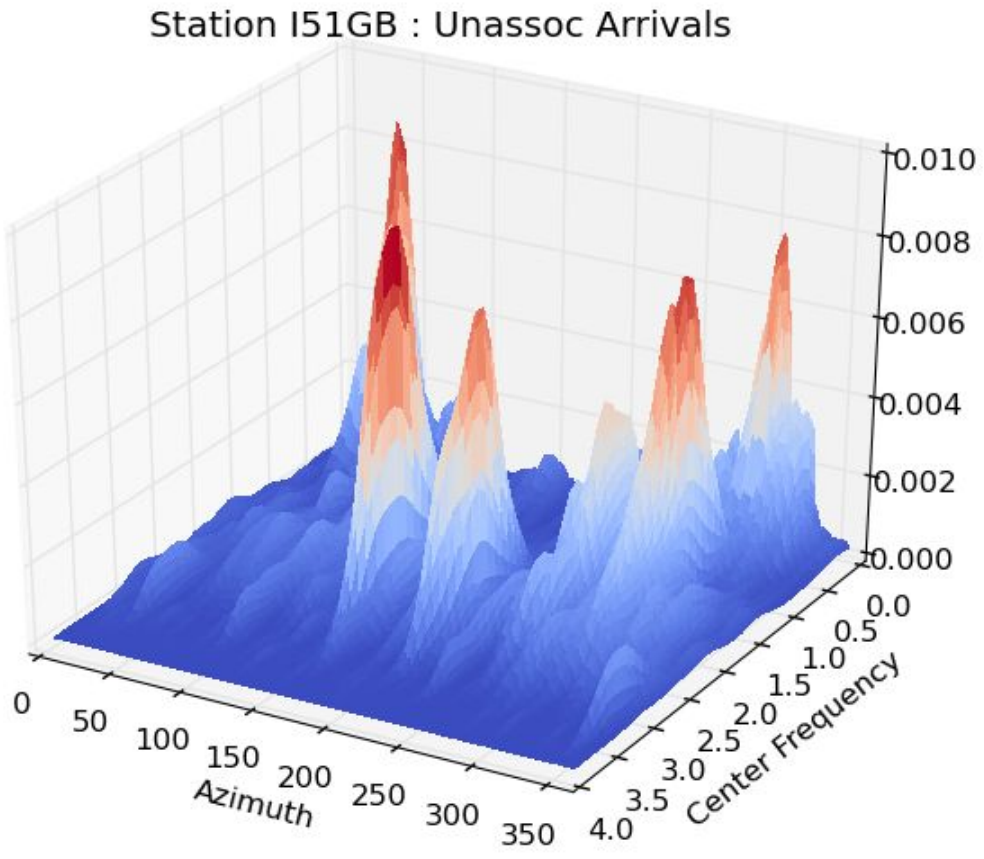

Energy Model

**The station with the most number of unassociated arrivals!**



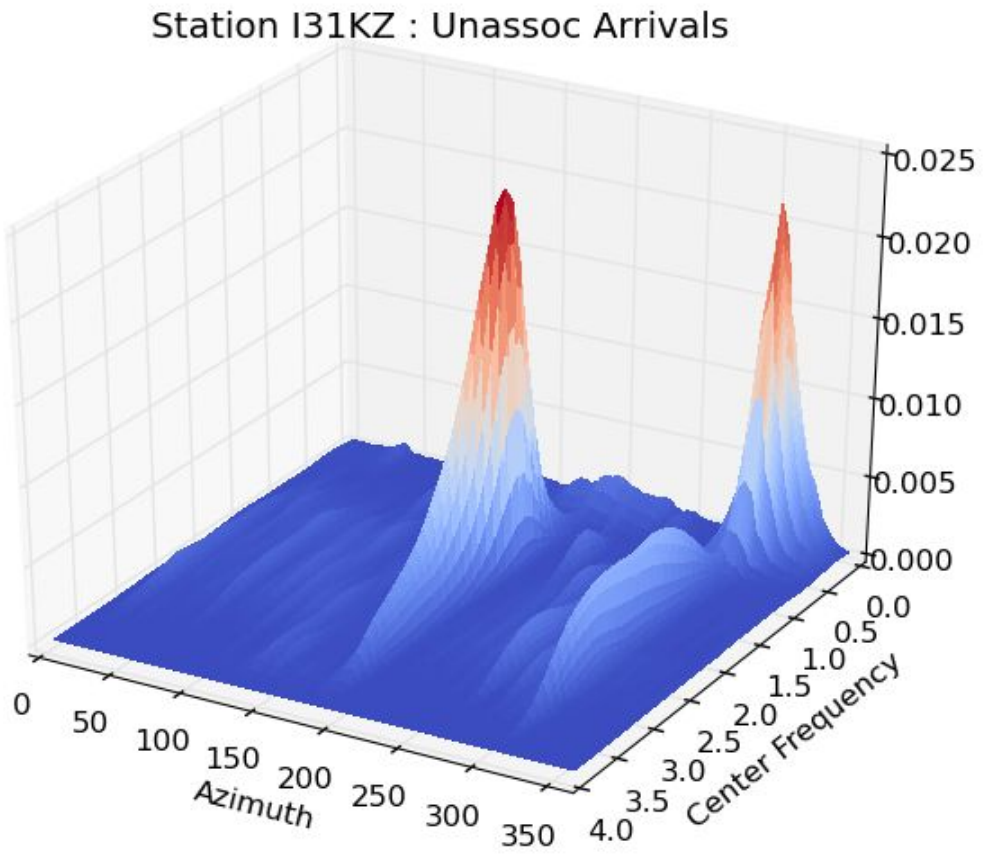

Clutter Model

The station with the least number of unassociated arrivals.




Clutter Model

A typical station (median number of unassociated arrivals)




Clutter Model

# Dealing with high uncertainties in infrasound travel time.

An event is real if the probability of the event occurring **within a 100 second interval** and generating its associated detections and mis-detections is higher than the probability of those same detections being generated by noise (including repetitive clutter) sources.

# Inference -- main idea

- Propose events along backazimuth of detection at 0.5 degree interval upto 60 degrees away. Plus additional events with 2 degree perturbation of backazimuth
- Existing algorithm (from seismic) for associating proposed events to detections.
  - Reassociation i.e. find the best event for a detection.
  - Relocation i.e. changing location of an event to best explain associated detections.
  - Kill events not justified by model
- **Infra events have preference for associating with an infra detection (i.e. at an infrasound station)**

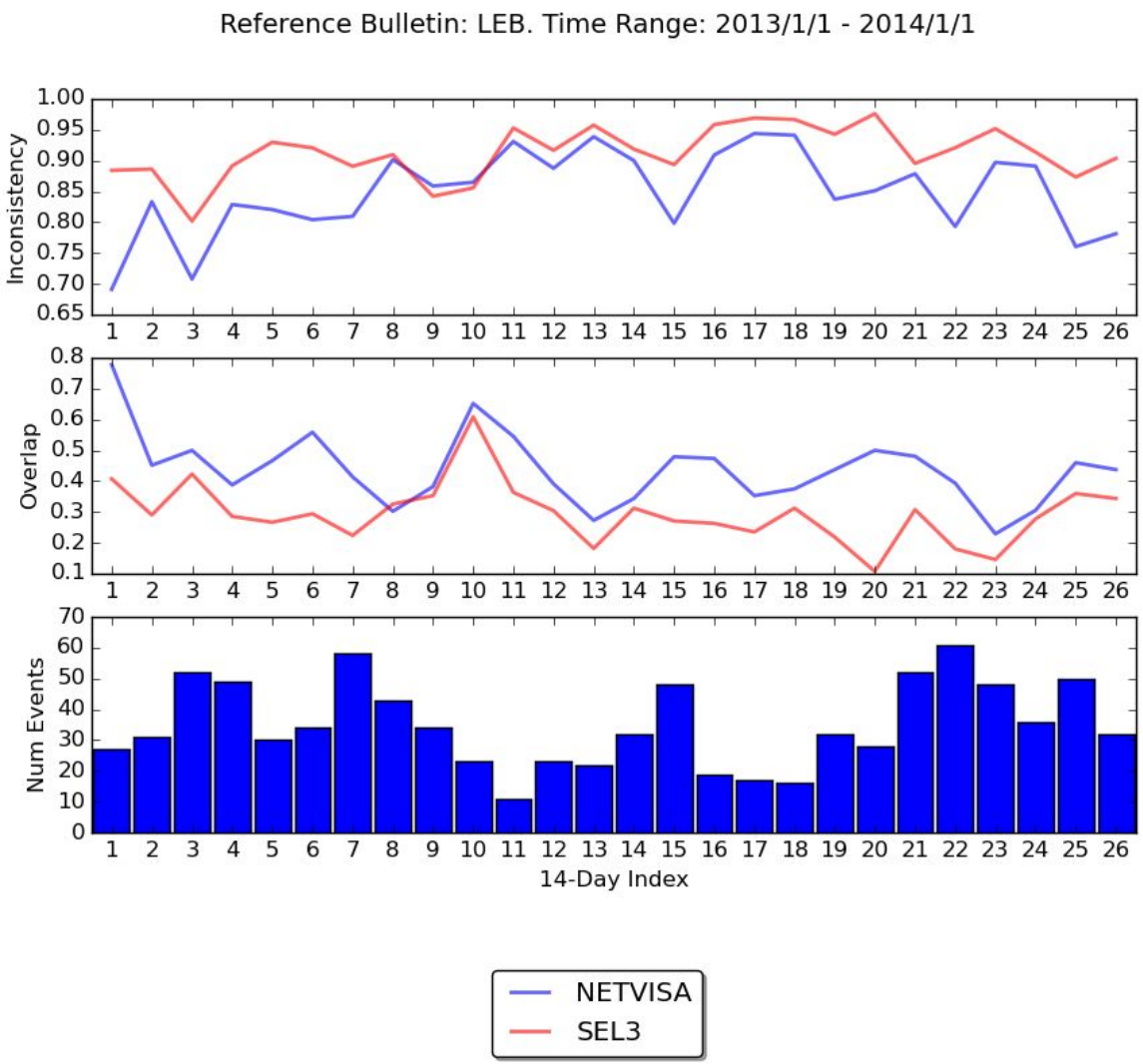
# Infrasound Evaluation

Two events in two different bulletins are identical if they share two similar arrivals where the arrivals are

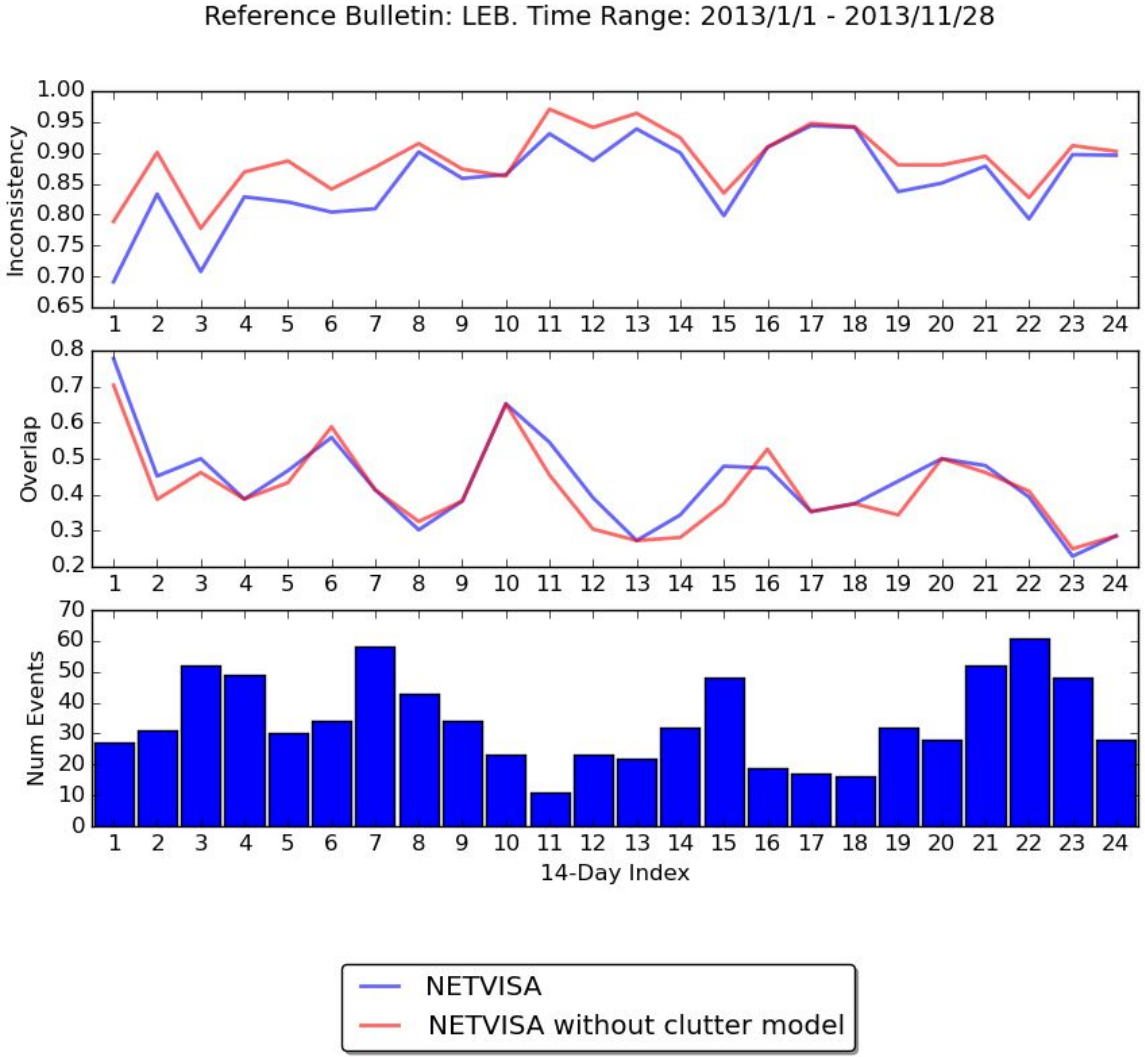
- are detected at the same station
- within 500 seconds in time of each other
- point to a back azimuth within 5 degrees of each other

High inconsistency is bad.

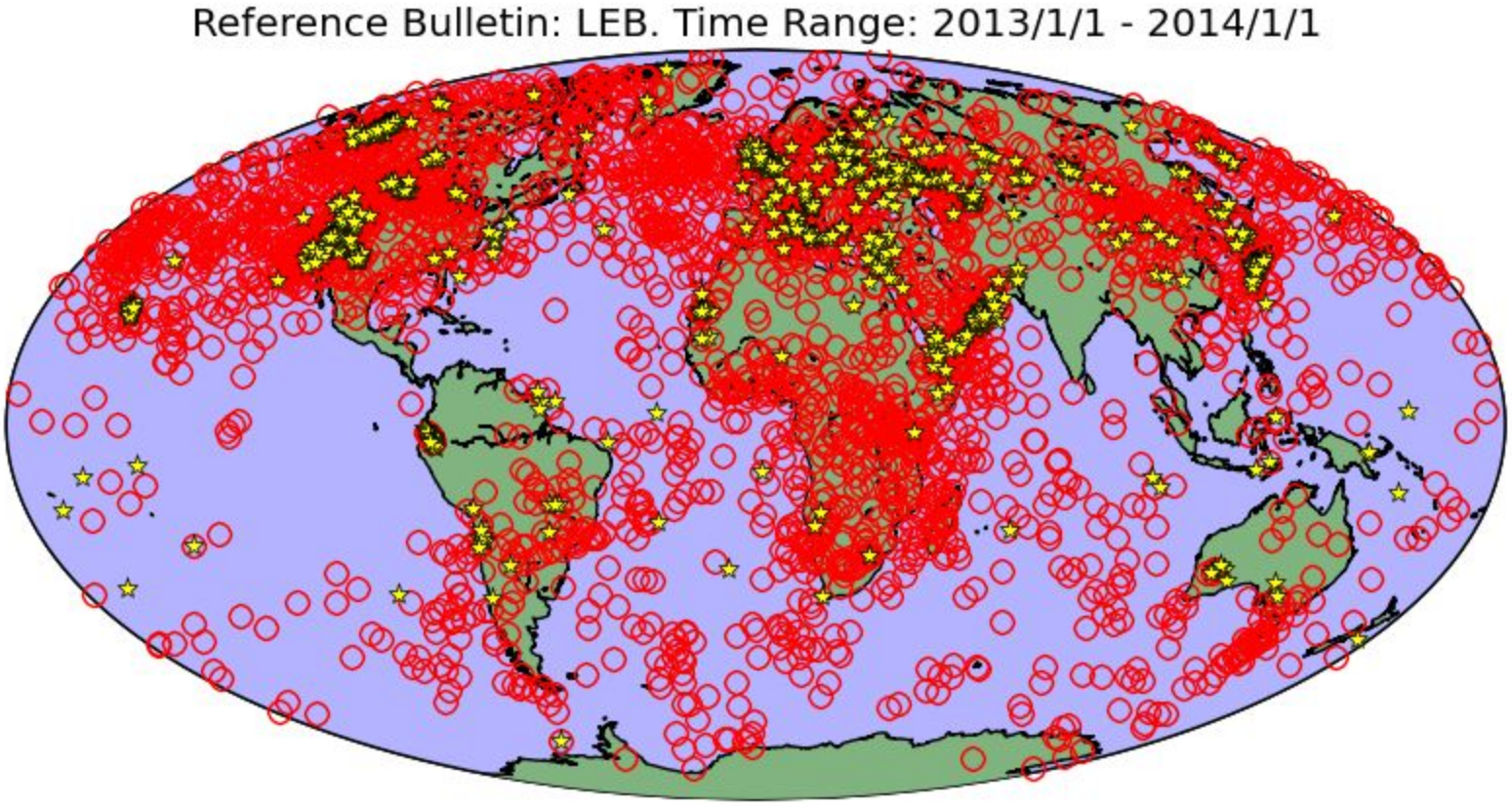
Higher overlap is good !

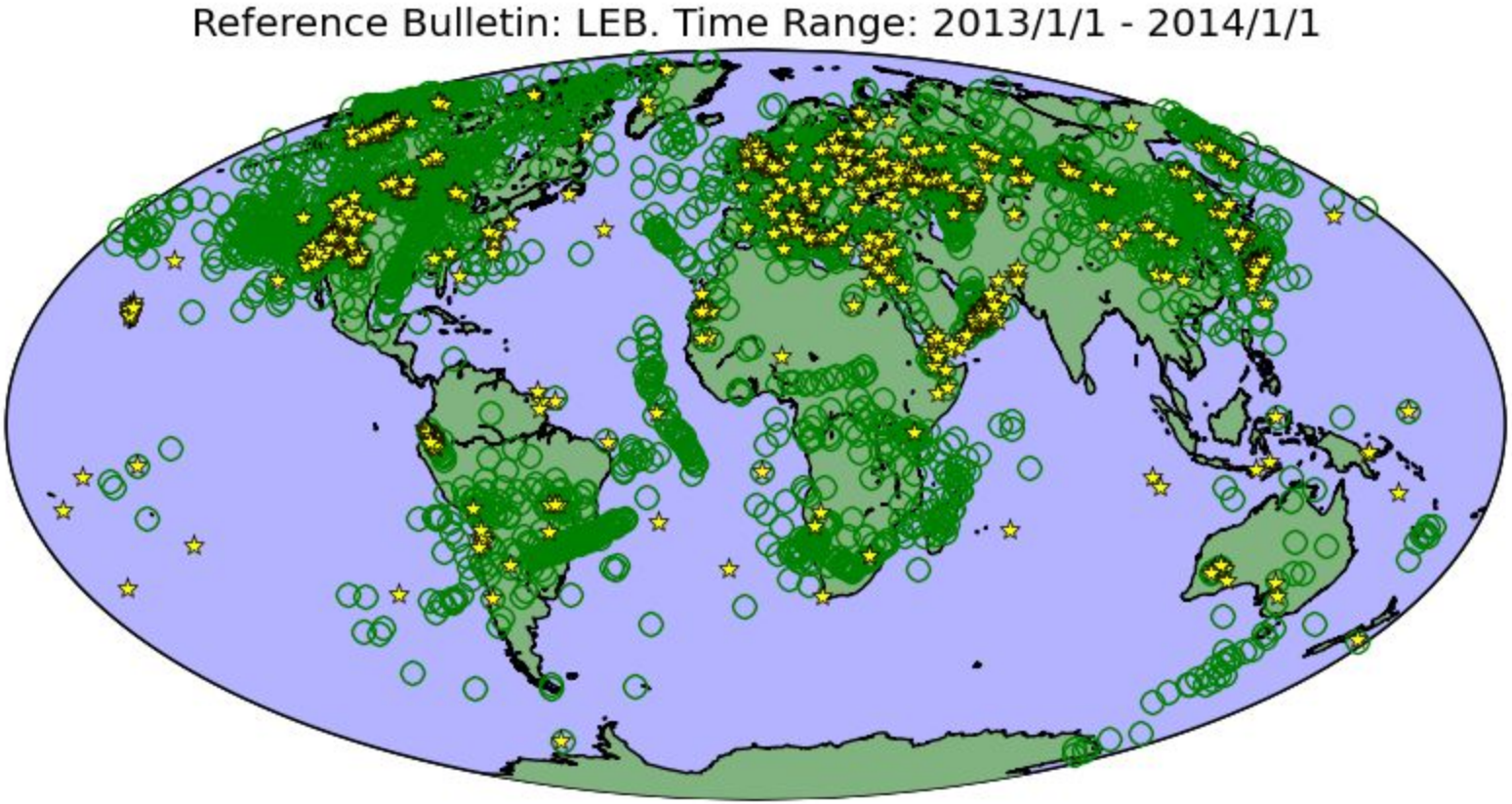



Comparison vs LEB for all of 2013 divided into 14 day intervals.

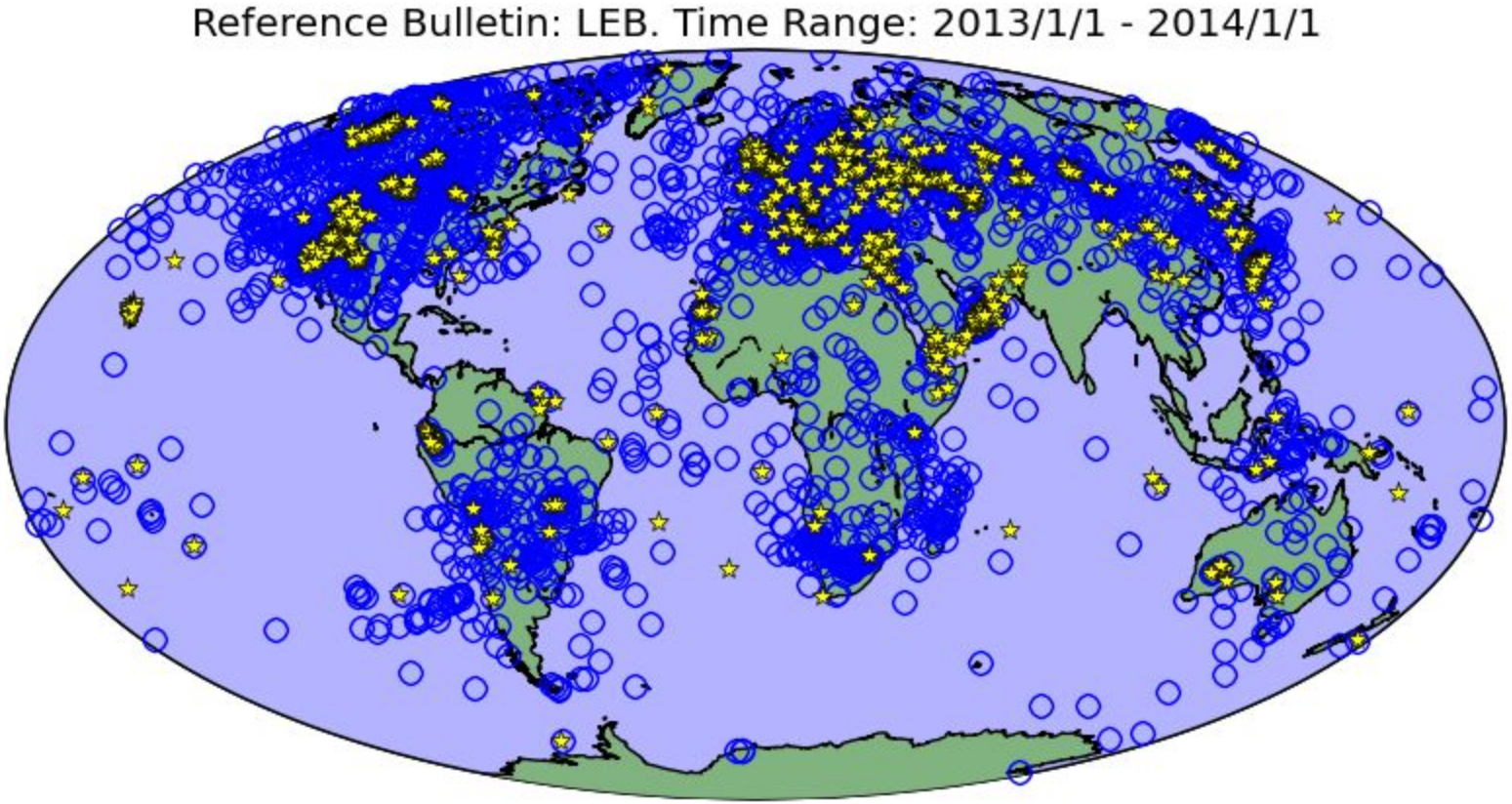



Performance with and without clutter model.


Reference Bulletin: LEB. Time Range: 2013/1/1 - 2014/1/1




NET-VISA without the clutter model




NET-VISA events (new version).

# Median Overlap and Inconsistency

| | Overlap | Inconsistency |
|---|---|---|
| NET-VISA | 43.7 % | 83.8 % |
| NET-VISA without clutter model | 39.4 % | 88.7 % |
| SEL3 | 29.3 % | 91.4 % |

Without the clutter model NET-VISA generates about 25% more events.

# Future Work

- Disentangling Seismic-Infra detections versus Infra-Infra detections
- Weak infra events versus spurious infra events
  - other detection attributes for disambiguating these two cases