# A model of seismic coda arrivals to suppress spurious events.

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CTBTO PREPARATORY COMMISSION | preparatory commission for the comprehensive nuclear-test-ban treaty organization

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# NET-VISA

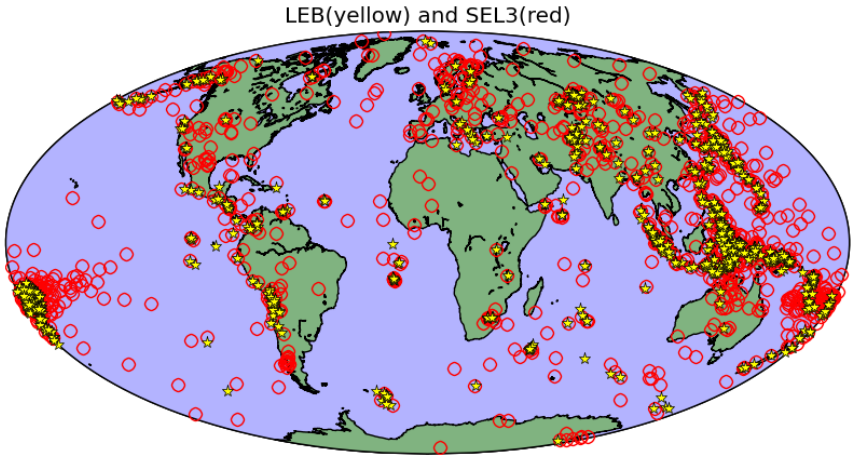
- **NETwork Processing – Vertically Integrated Seismic Analysis**
  - **NET-VISA automatically analyzes arrivals from the International Monitoring System (IMS) of the Comprehensive Test Ban Treaty Organization (CTBTO)**
  - **It is designed to identify and locate seismic events using the time, magnitude, azimuth and slowness of pre-computed arrivals**
  - **NET-VISA operates by probabilistic inference, applied to a decomposable physics-based model in which empirical uncertainty is made explicit**

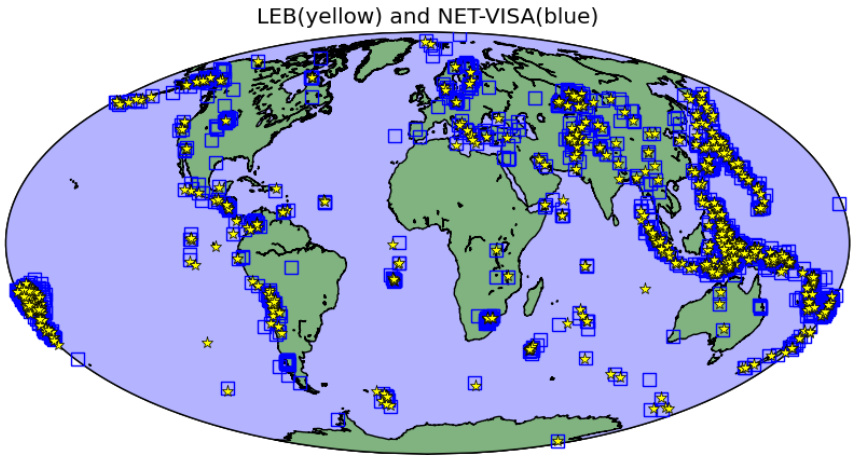
$$P(\text{Events} \mid \text{Arrivals}) \propto P(\text{Arrivals} \mid \text{Events}) * P(\text{Events})$$

Bulletin | Model | Prior

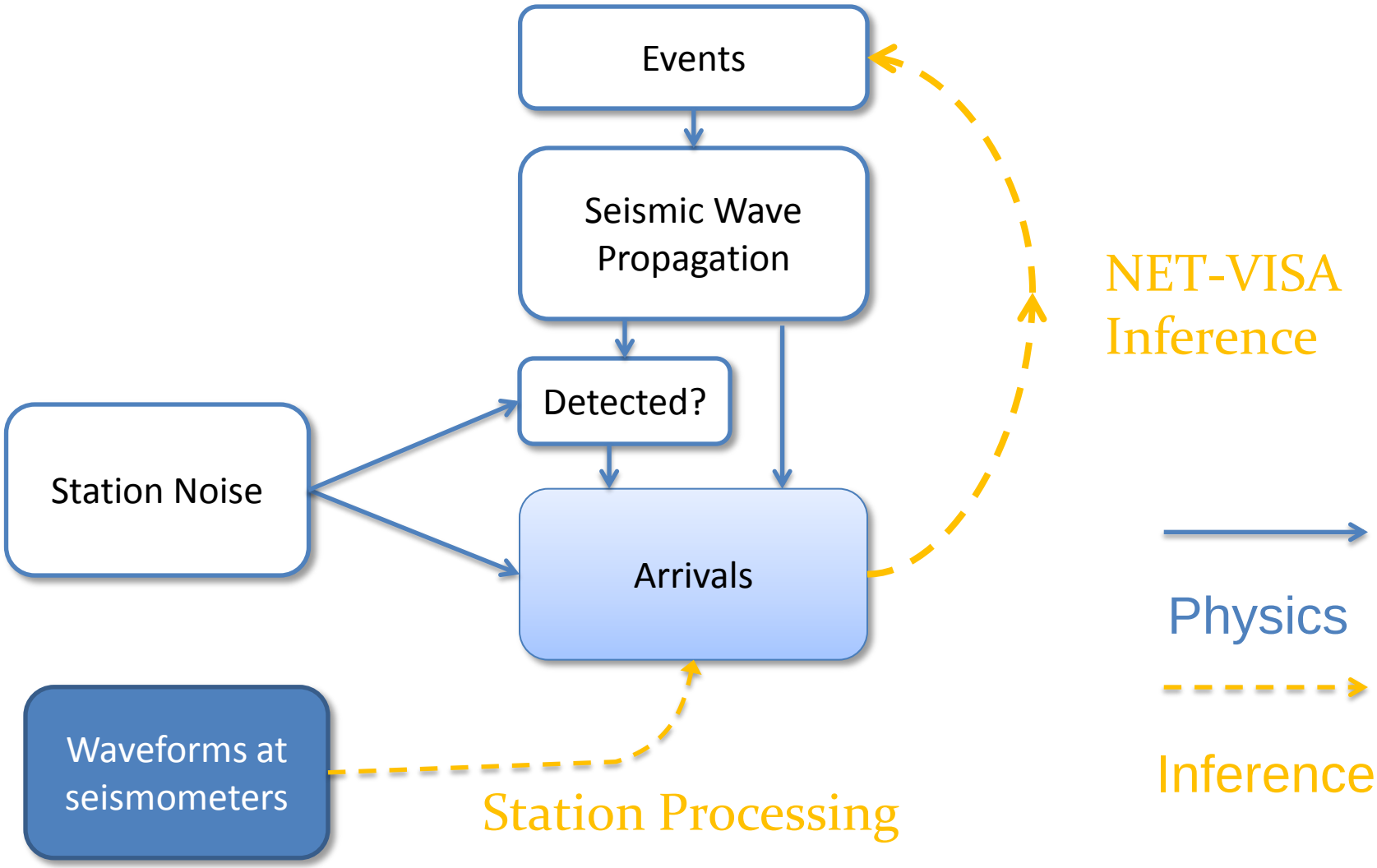
# Outline

- Background: NET-VISA baseline
- Coda arrivals
  - Problem
  - Refined model
  - Results



# NET-VISA model components



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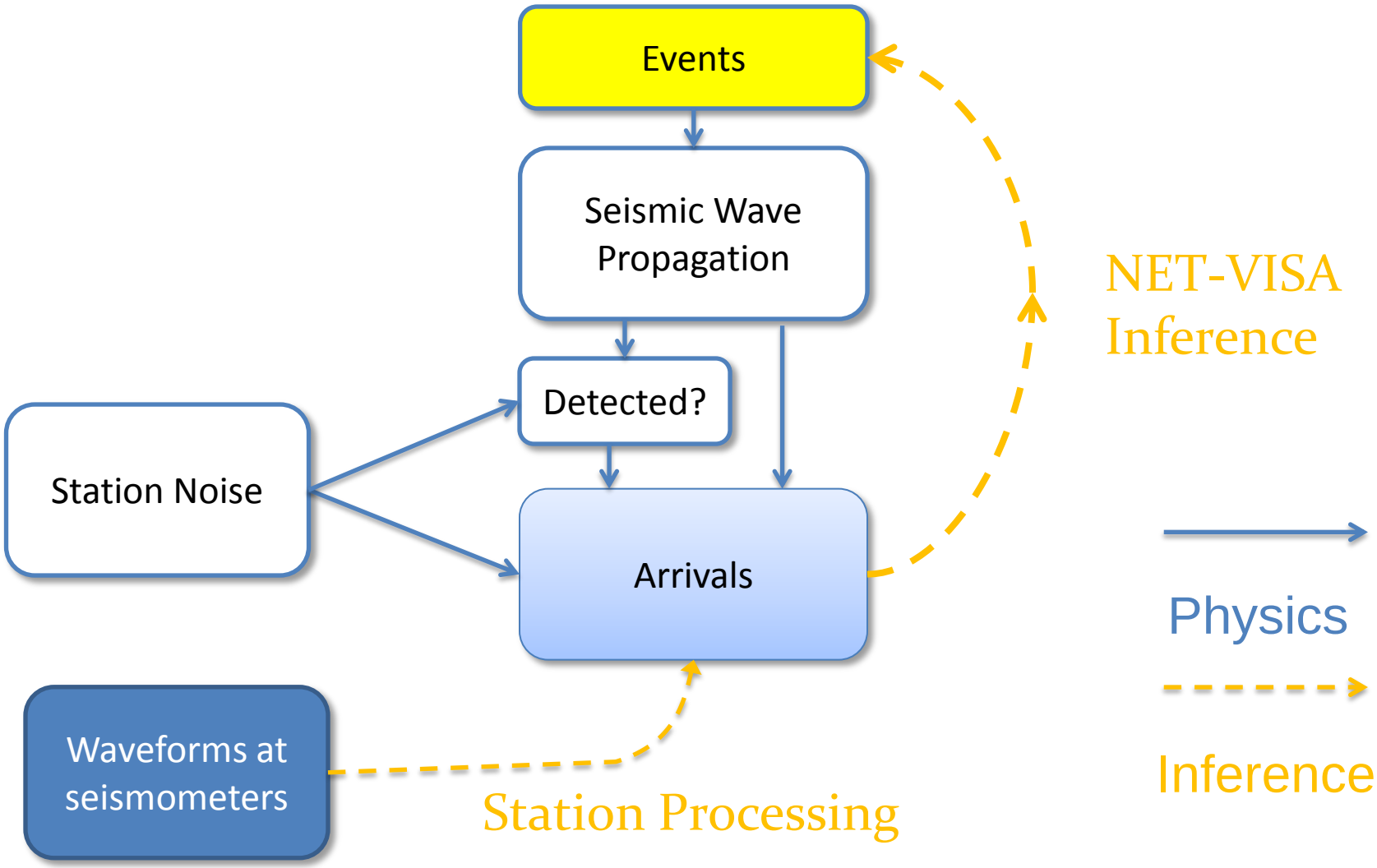
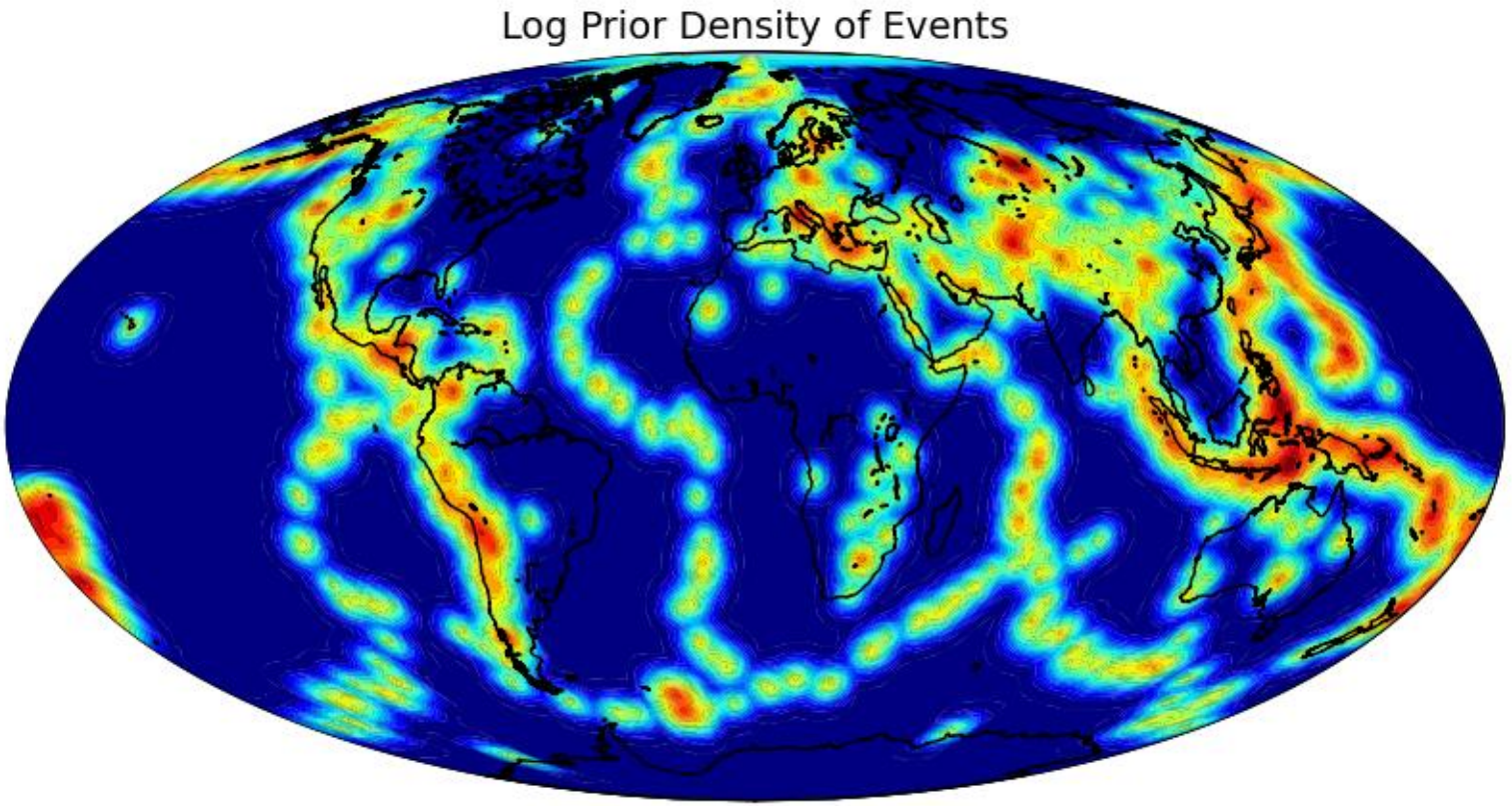


# Generative Model – Event Location



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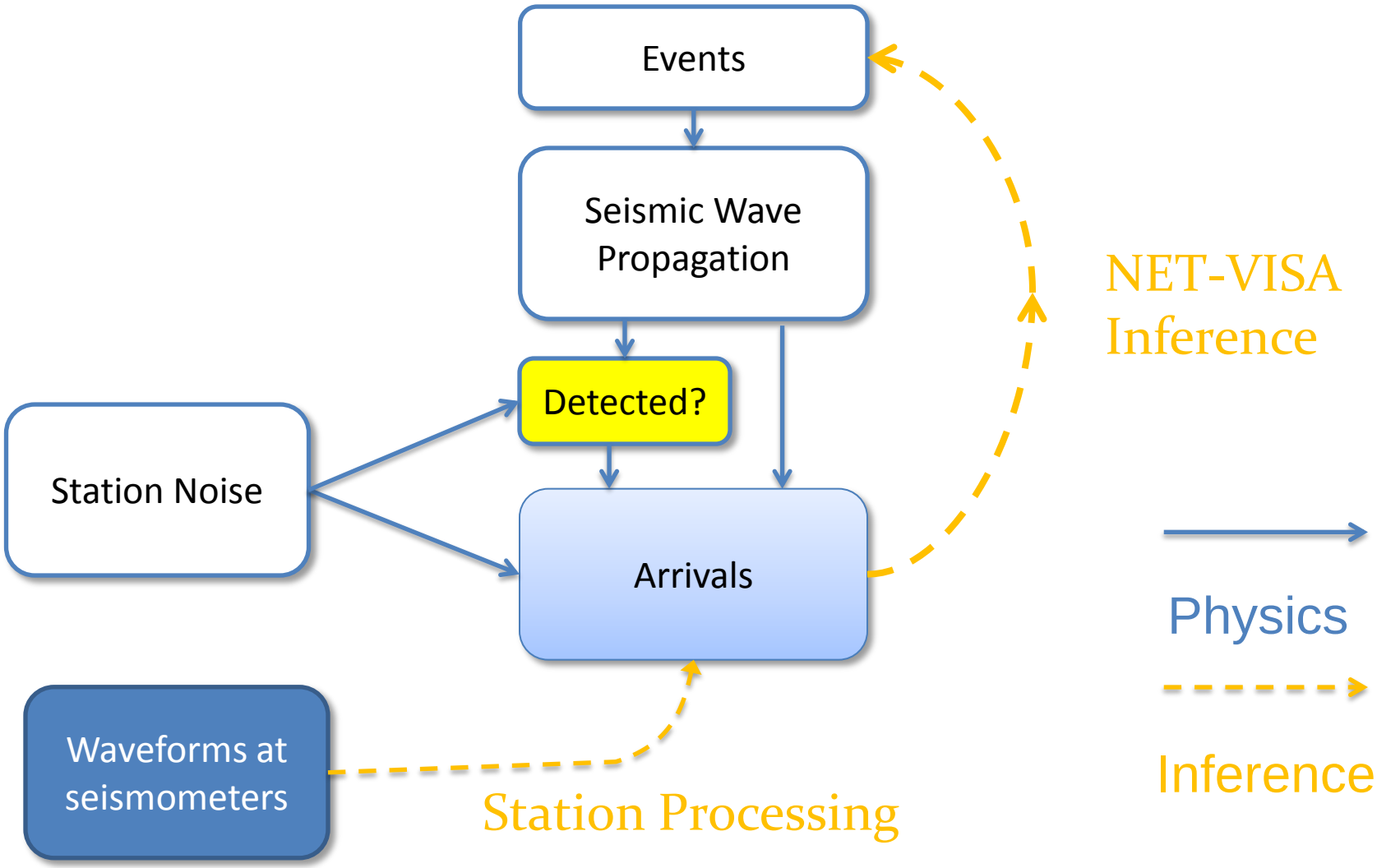
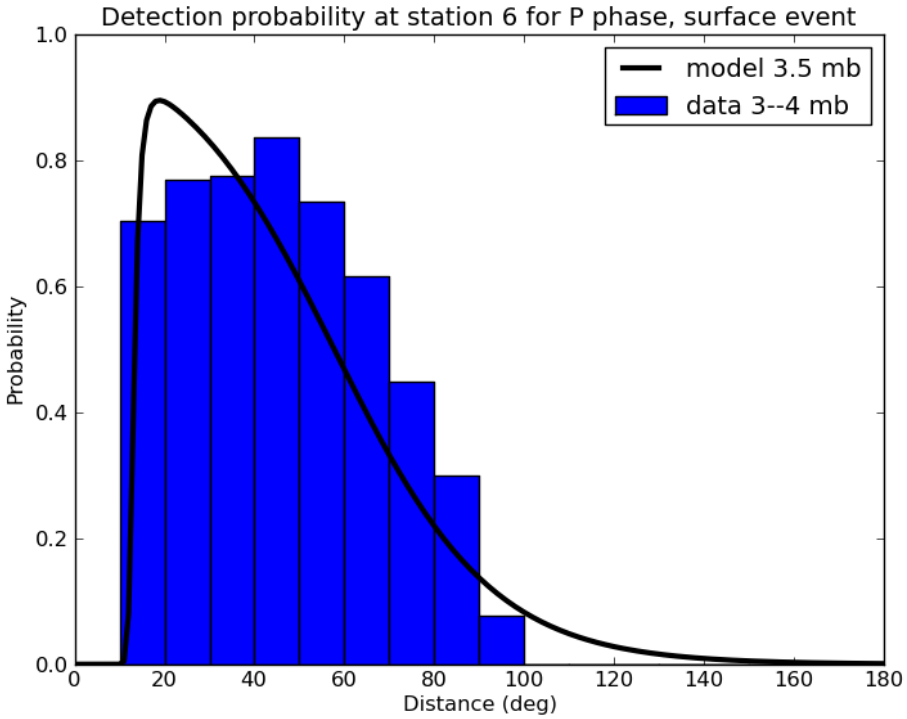
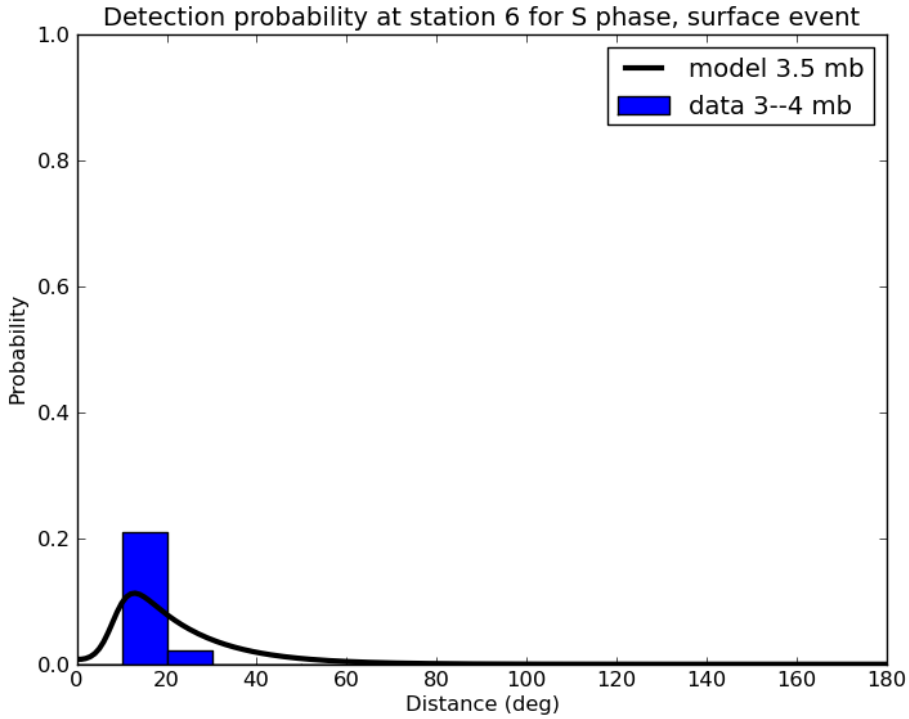


# Generative Model – Detection Probability

**P(Detected) = Logistic(f(distance,magnitude,depth))**

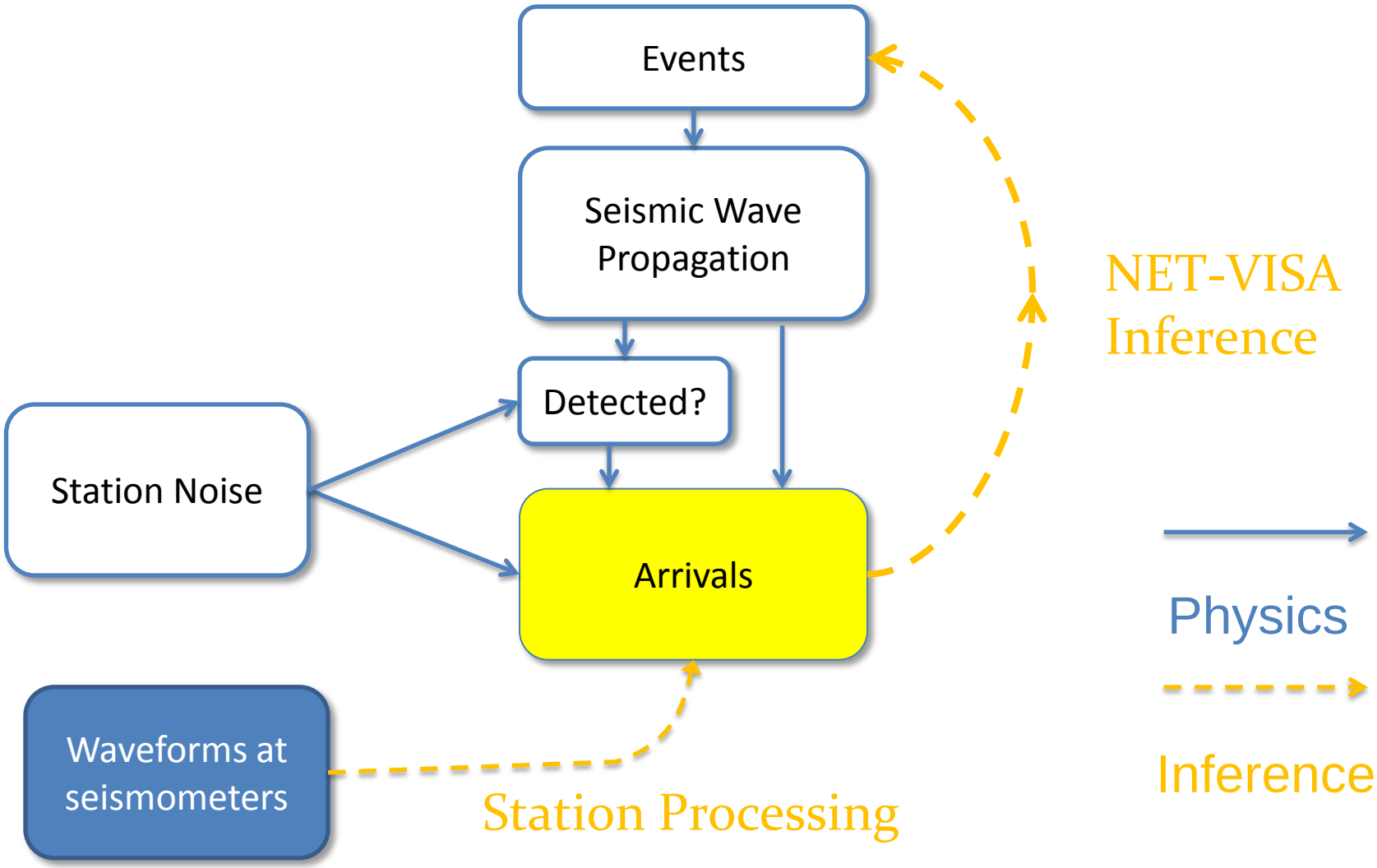



P phase, station 6



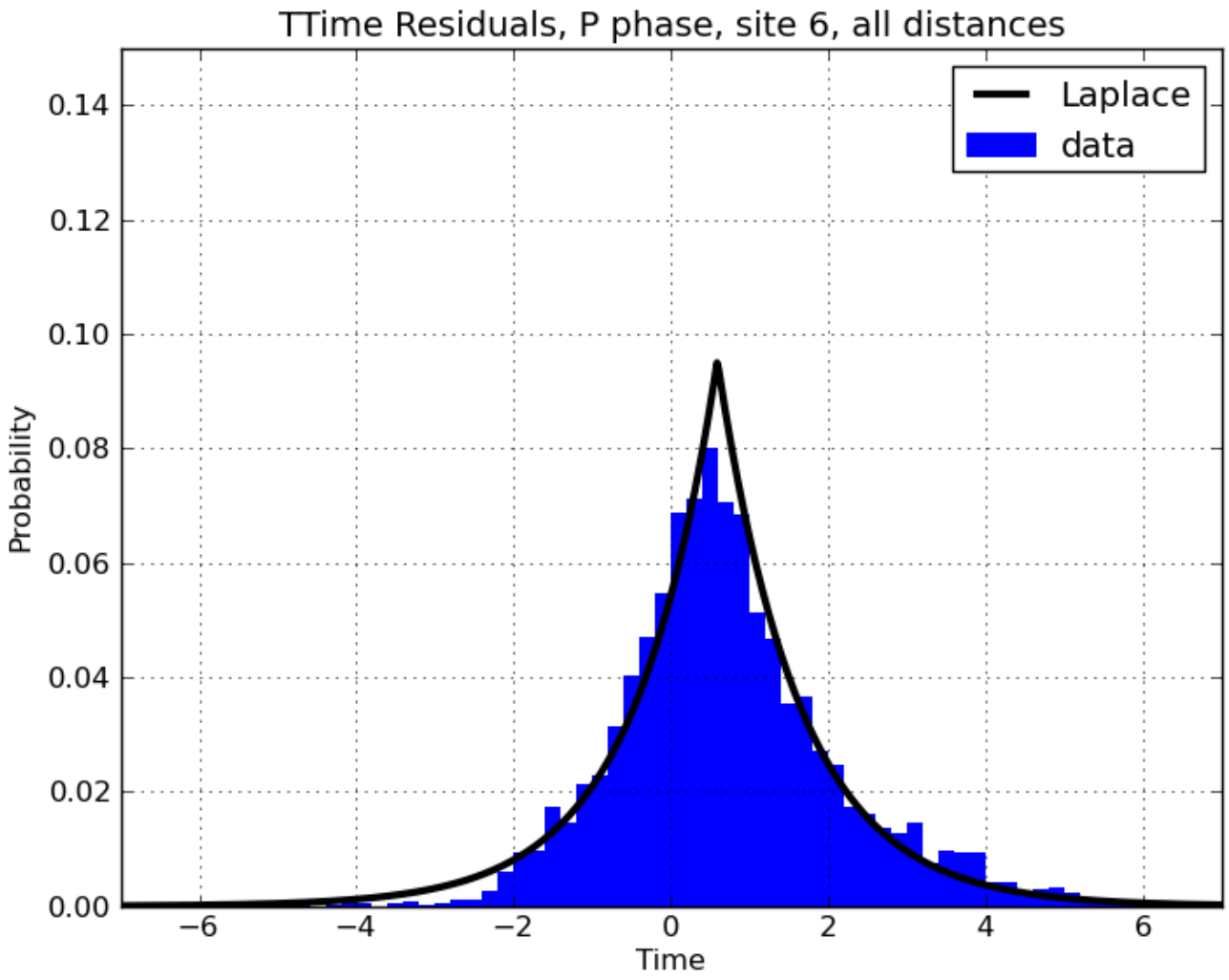

S phase, station 6

# NET-VISA model components



# Generative Model – Arrival Time

**Arrival time = Event time + IASPEI + corrections + Laplacian residual**



# Inference Overview

- *Max a-posteriori* (MAP) seismic event bulletin

  **Max P(Events | Arrivals) α P(Arrivals | Events) *P(Events)**

- Probability-driven search over number-of-events/association/phase-label/location/depth/time/magnitude
- Easily parallelizable – runs in real time on Tohoku and Sumatra

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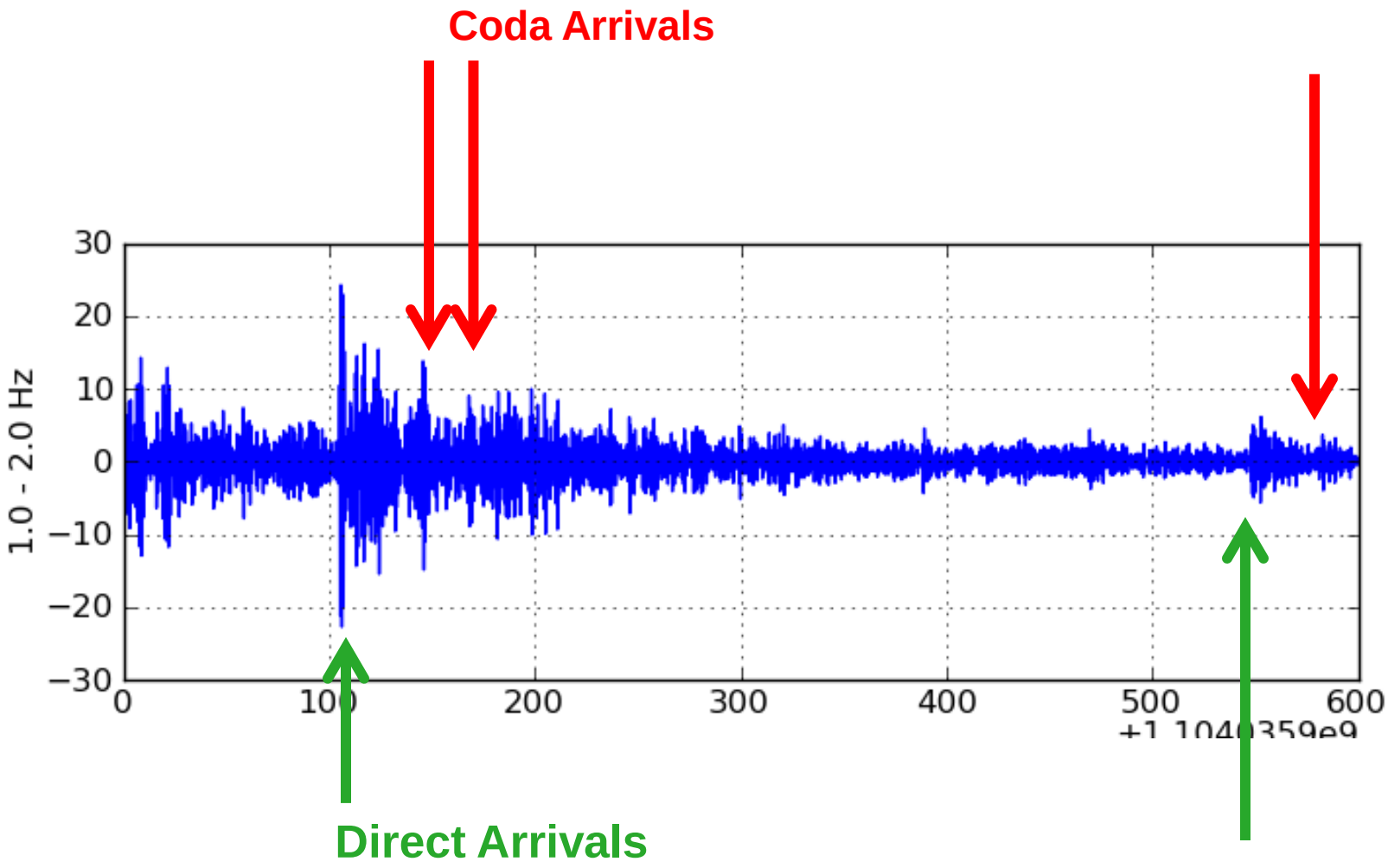
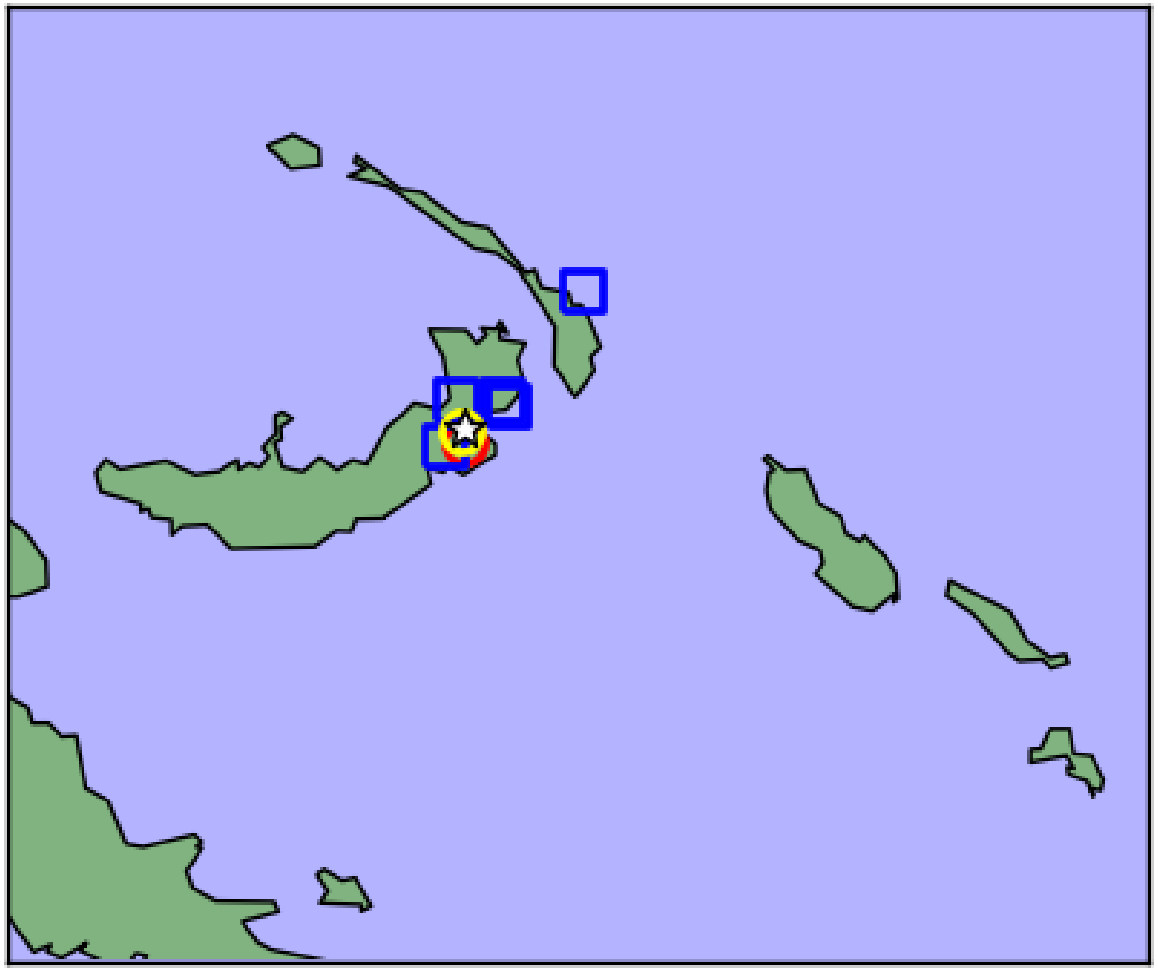
# Coda arrivals



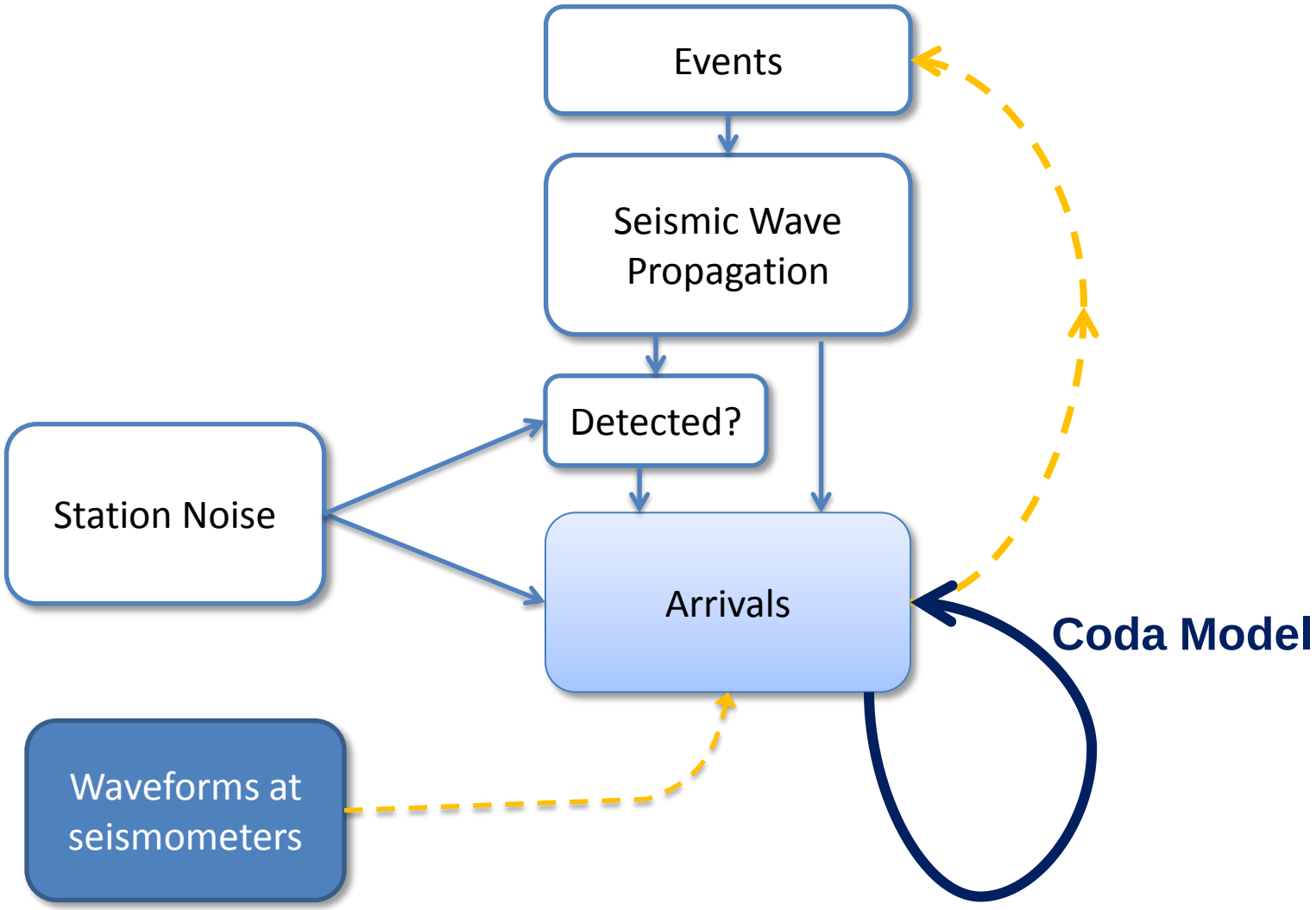
# NET-VISA finds shadow events from the coda arrivals.

1 real event,

4 shadow events



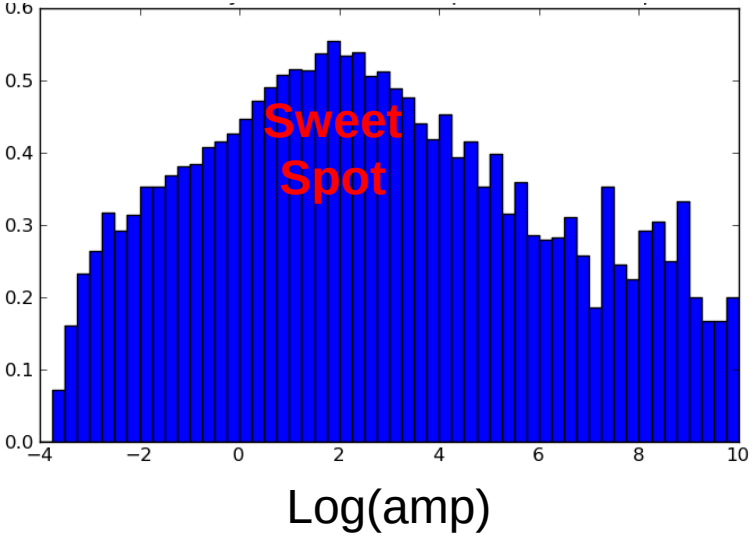
# A coda model was introduced to NET-VISA



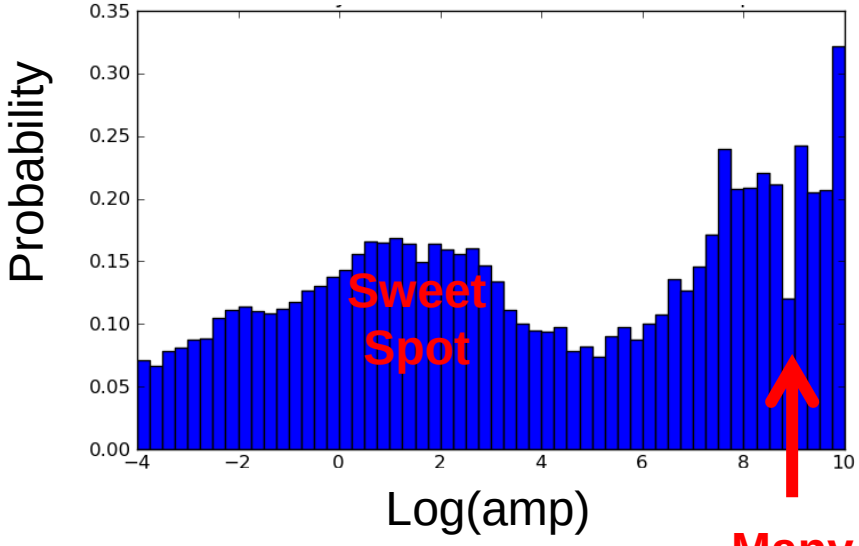
# Coda Model I: Probability of coda arrivals depends on prior arrival's amplitude

Detector finds arrivals based on ratio of Short Term Average Energy to Long Term Average Energy (STA/LTA)

Coda occurs after direct arrival

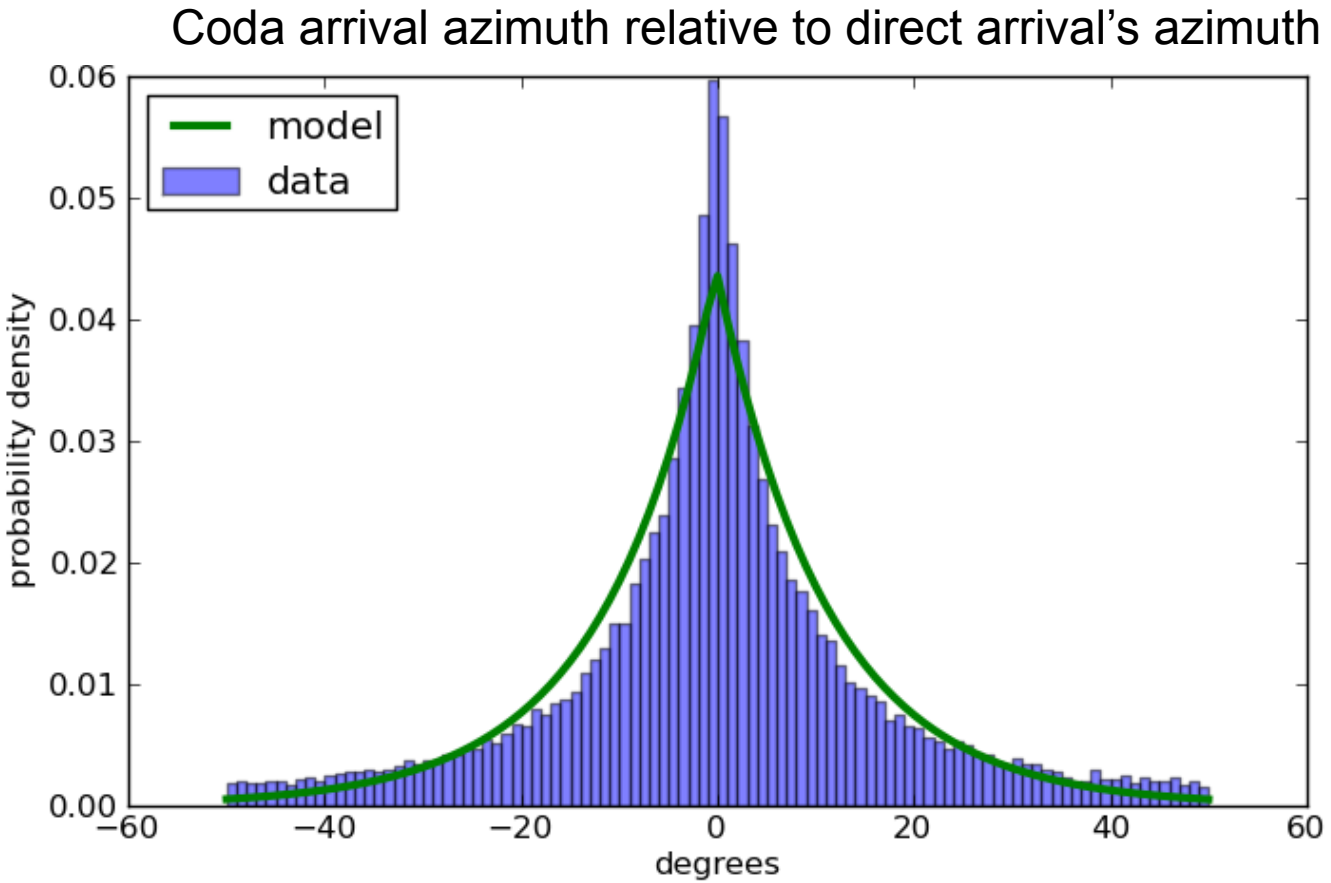



After coda arrival



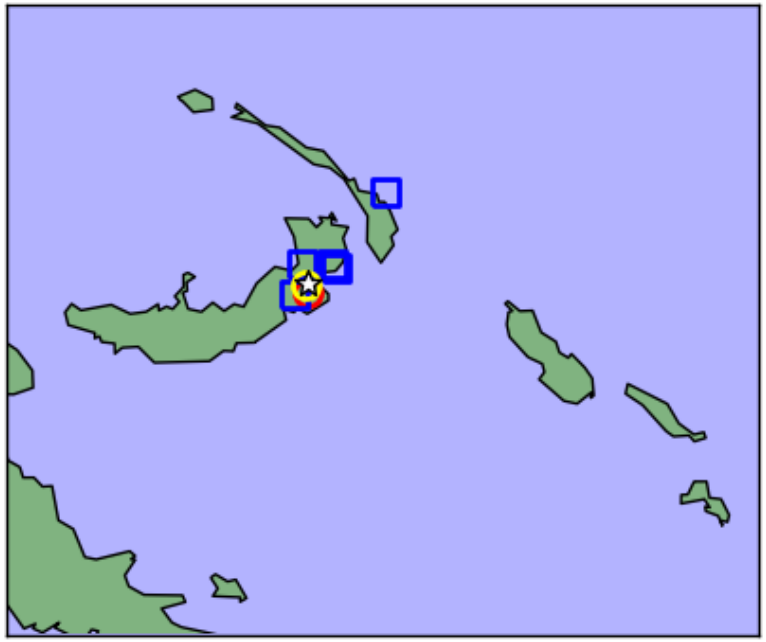

**Many codas for large events**

# Coda Model II: Can recognize a coda arrival because its attributes are highly correlated with direct arrival's attributes

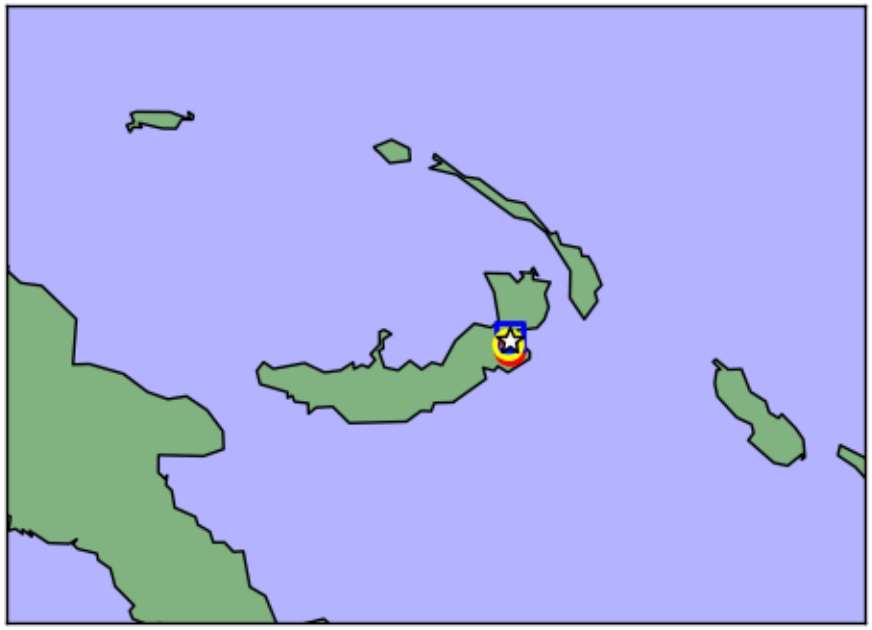


# Example of results with coda added to the model

**Before:** NET-VISA produced 5 events.



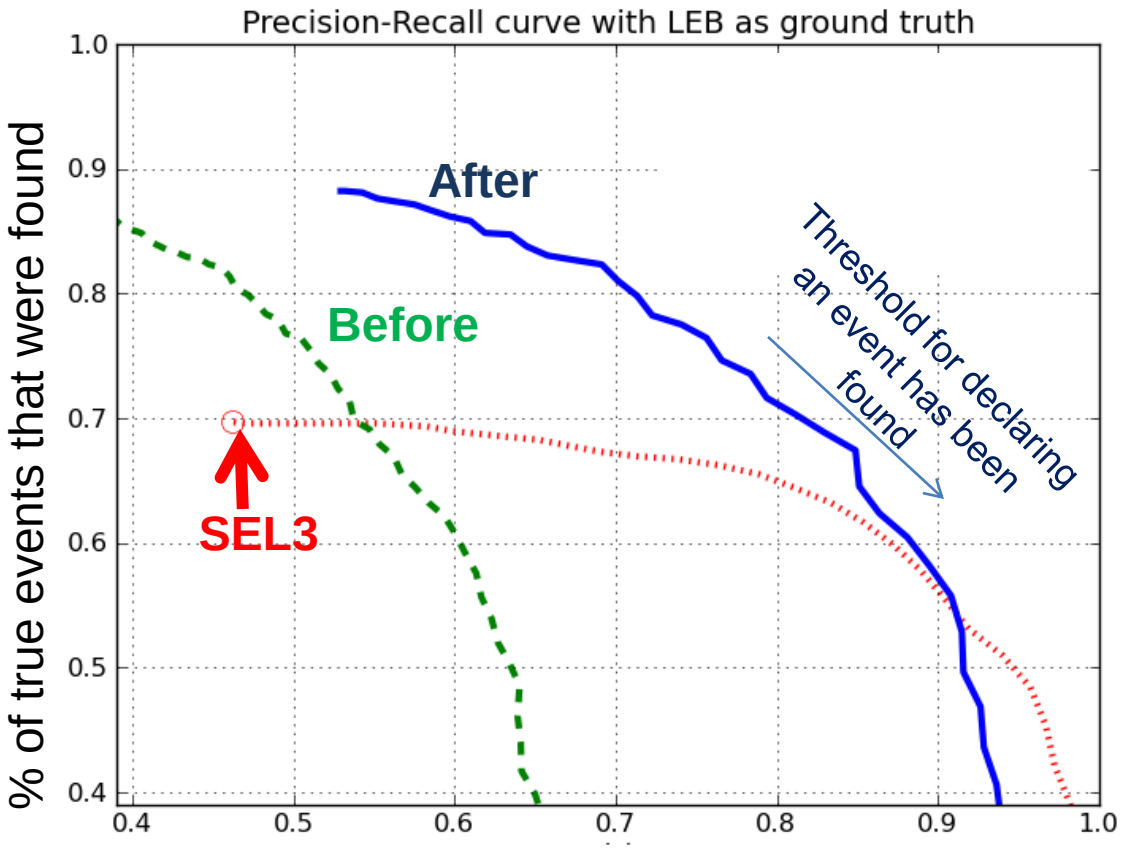
**After:** Only one event is produced from same sequence of arrivals.



NET-VISA events

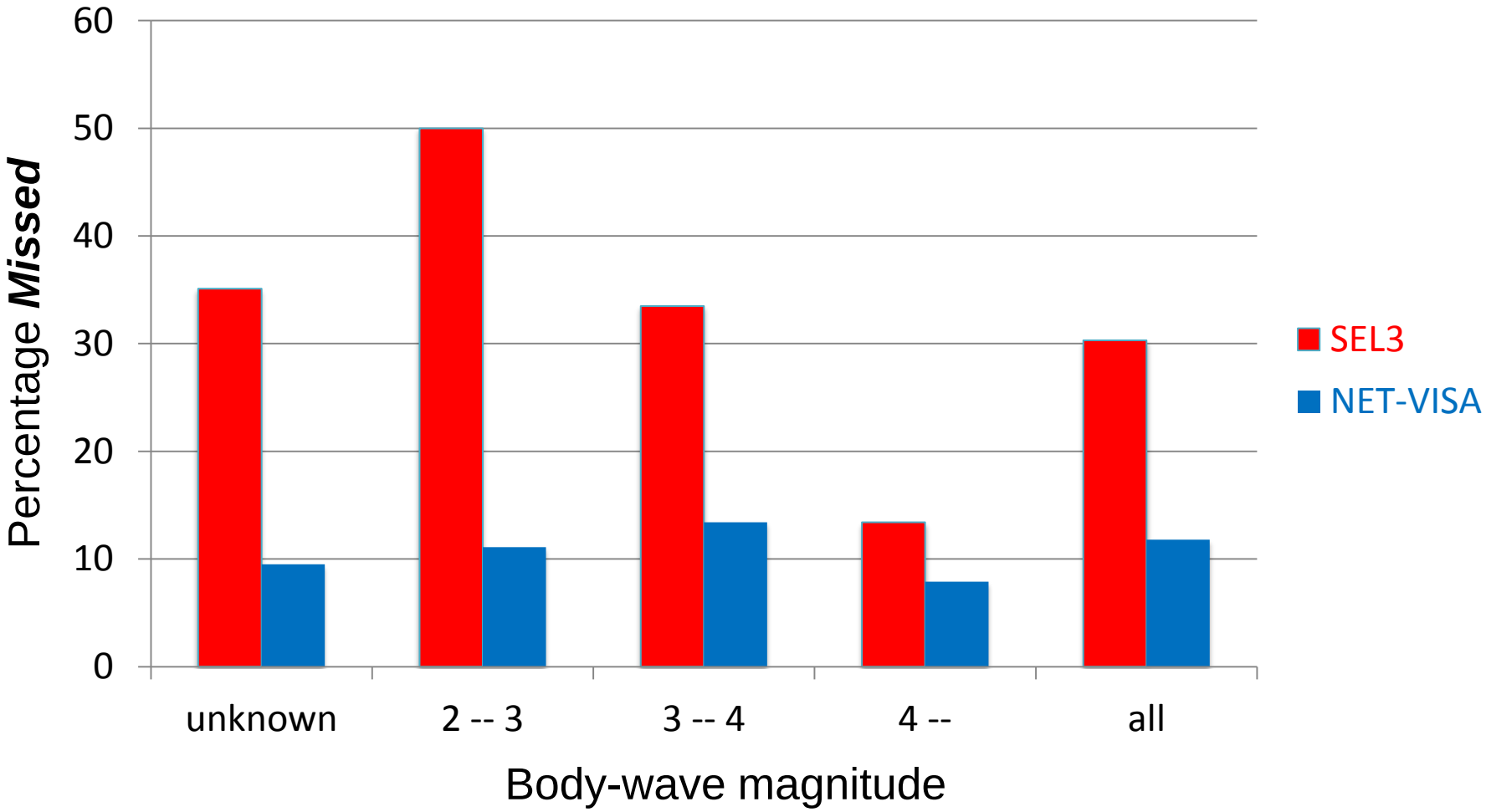
LEB event

# NET-VISA performance before and after coda model



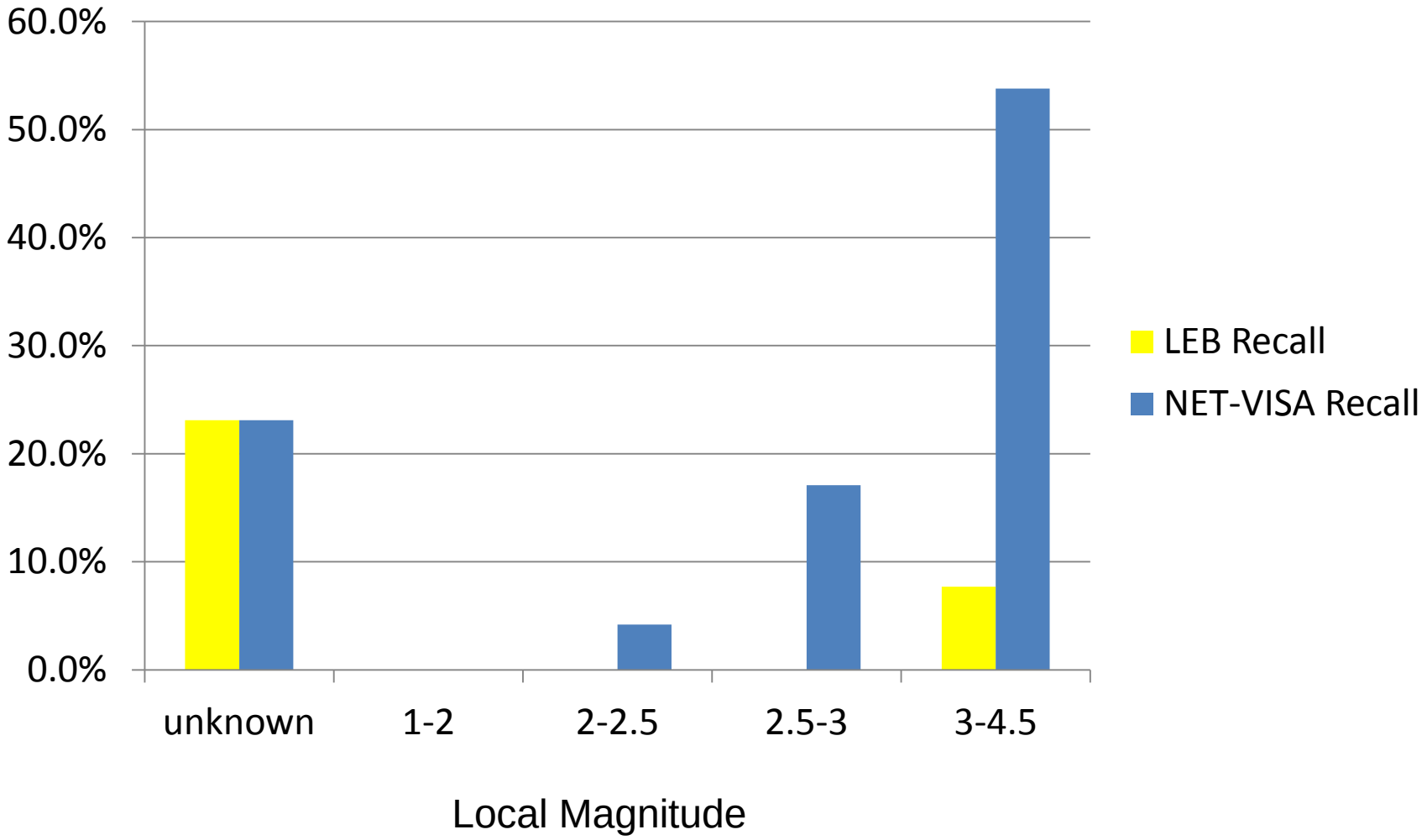

Coda model significantly reduces the number of false events produced by NET-VISA while continuing to find 90% of true events. Both implementations outperform SEL3.

# Percentage of Missed Events by Event Magnitude




SEL3 misses 30% of LEB events. NET-VISA with coda model misses 12% overall and 5x improvement in detection of small events (that took place close enough to network stations to be detected).

# Recall on Continental US




LEB is missing more than 90% events in the continental USA listed in NEIC (IRIS). NET-VISA finds half of them.

# Conclusions

- Adding coda model to NET-VISA significantly improves performance.
  - No need to prune spurious events using arbitrary rules
  - 3x reduction in missed events compared to SEL3
  - Comparison with independent regional networks suggest potential to lower detection threshold by one order of magnitude