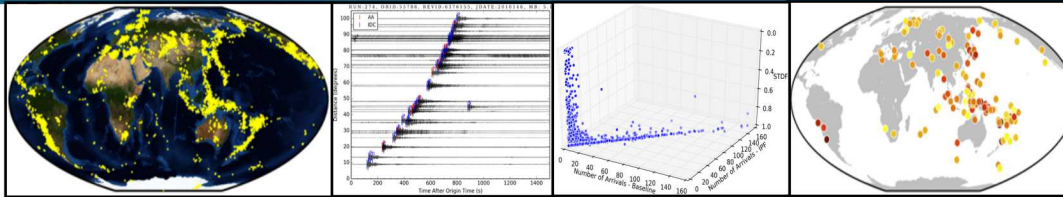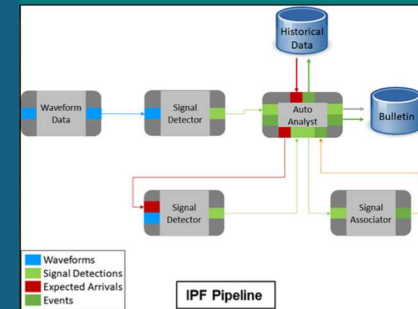SAND2019-1584C

The Iterative Processing Framework: A New Paradigm for Automatic Event Building
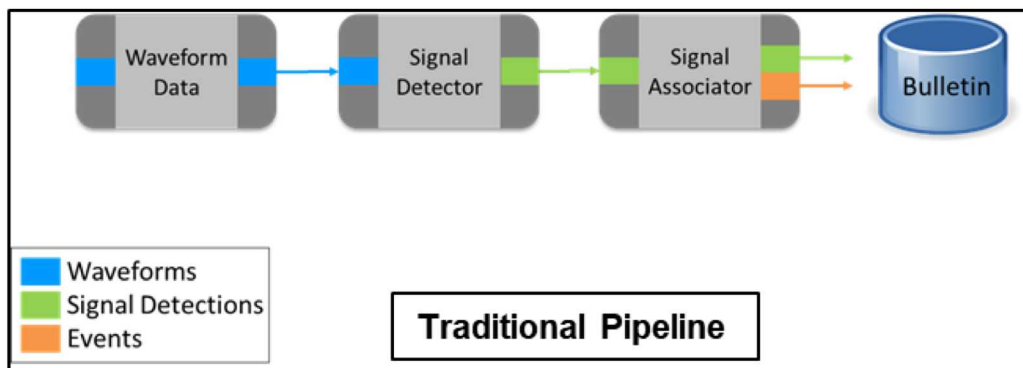

PRESENTED BY

Rigobert Tibi[1]

CO-AUTHORS: Andre Encarnacao[1], Sanford Ballard[1], Christopher Young[1], and Ronald Brogan[2]

[1]Sandia National Laboratories, [2]ENSCO, Inc.

Traditional Pipeline of Event Building

The traditional pipeline requires heavy human analyst involvement to improve the quality of the event bulletin.

- At the IDC, on average ~43% of the yearly events in SEL3 rejected by human analysts

- Proportion of legitimate events added by human analysts to the LEB increases steadily

- The workload on human analysts will continue to increase as additional IMS stations come online

Iterative Processing Framework (IPF)
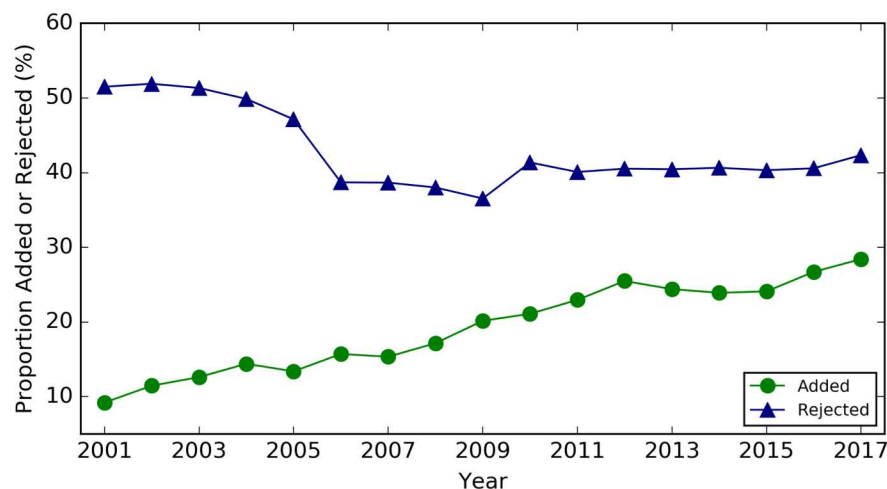
Purpose: Reduce human-analyst workload during the event building process

How is this achieved? By incorporating automatic analyst behaviors into the pipeline
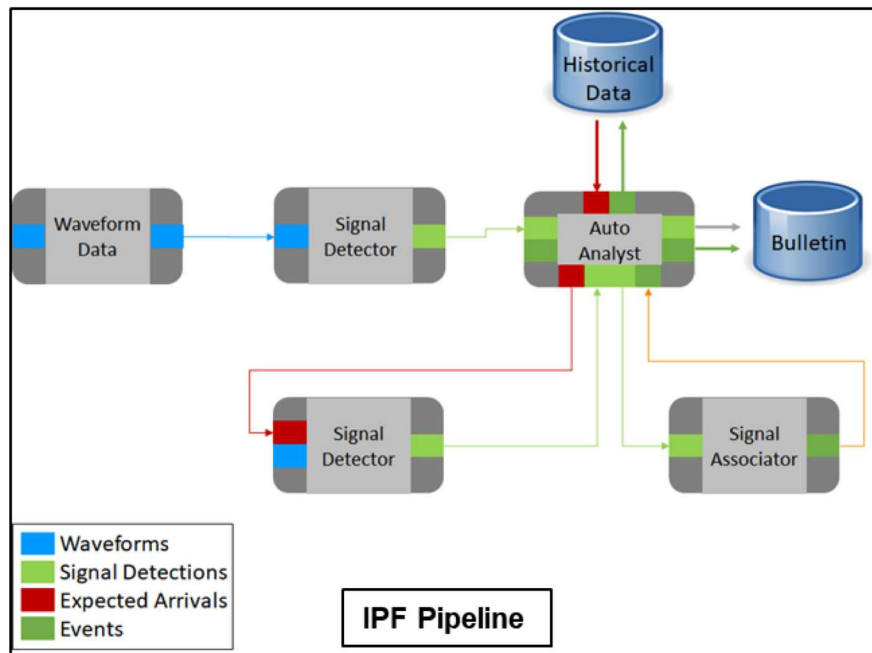
IPF includes:
- All the components of a traditional pipeline, and
- A new module that incorporates automatic analyst behaviors (Auto Analyst) and provides the possibility to query historical data for empirical information

Auto Analyst Behaviors

AA accomplishes the following tasks, grouped into 2 major processes:

- Evaluate small (low *NDEF*) events to improve their formation
  - ➤ Refine arrivals from arrays for low *NDEF* events by performing *f-k* analyses with varying parameters
  - ➤ Rerun associator if any arrivals are modified in the process

- Scan unassociated arrivals to build potential missed events
  - ➤ After running associator, identify unassociated arrivals from array stations
  - ➤ Compute single station locations
  - ➤ Query historical data for missing expected arrivals
  - ➤ Reprocess waveforms searching for missing arrivals
  - ➤ Rerun the associator with any new detected arrivals
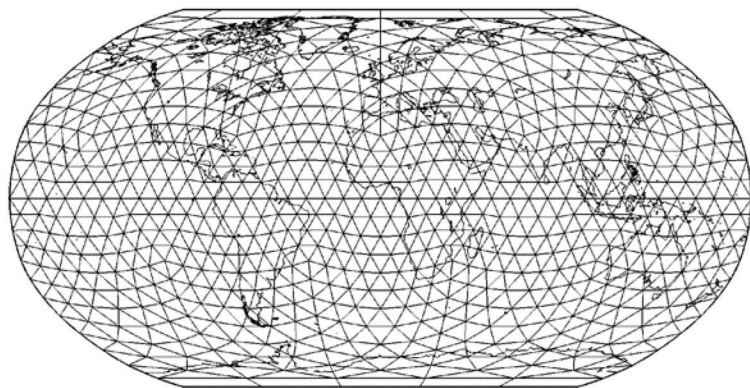

Waveforms
Signal Detections
Expected Arrivals
Events

IPF Pipeline

Auto Analyst Behaviors
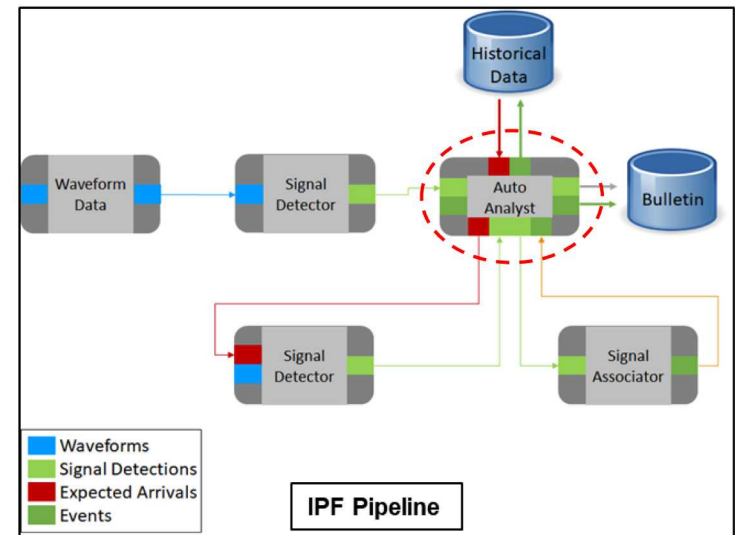
▪Search for missing expected arrivals performed only for first *P* phases with *POD* ≥ 0.9
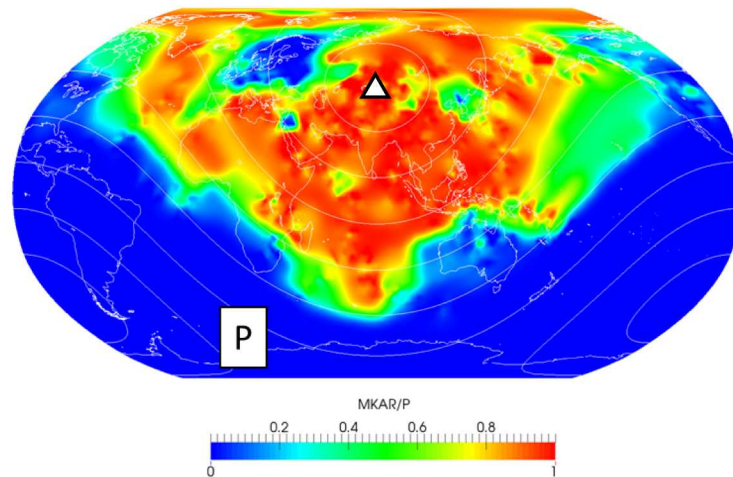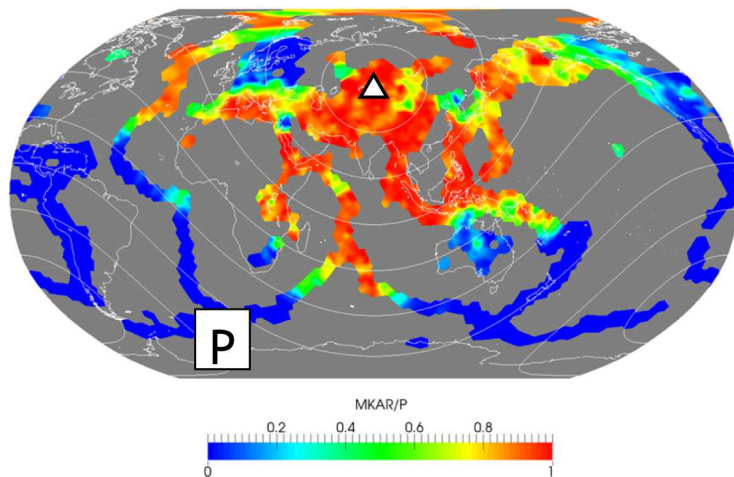
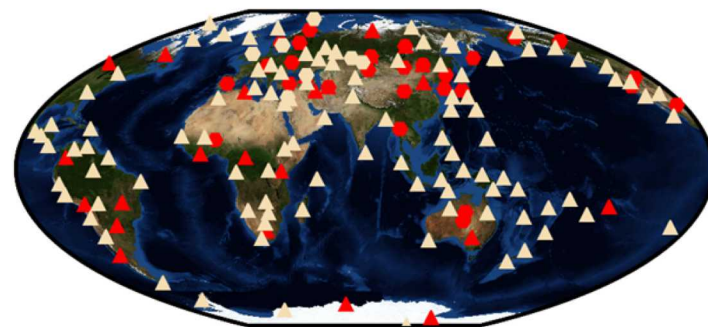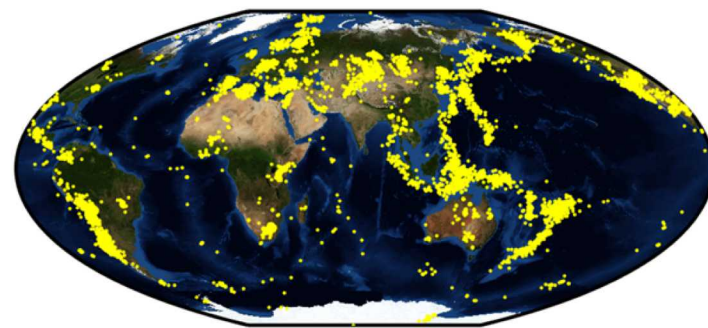Probability of Detection (*POD*) for MKAR

Test Settings and Data
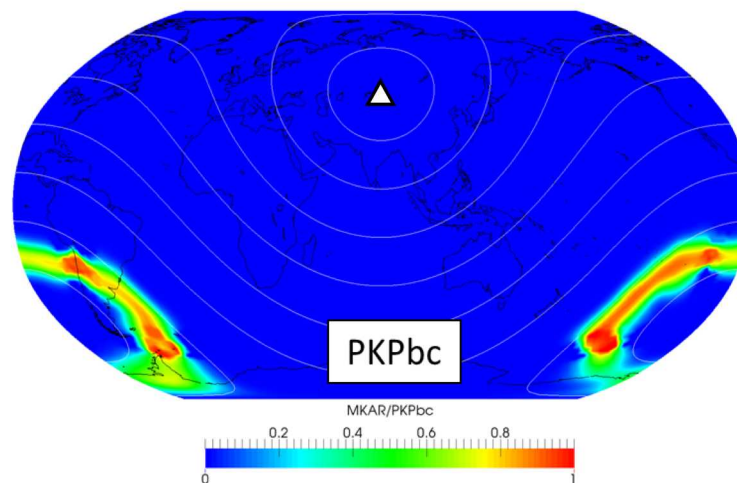
- The associator used in IPF is PEDAL (Draelos *et al.*, 2015)

- The Earth is divided into 2°-grids uniformly spaced, resulting in ~13,000 nodes

IMS Stations

UEB

- Test dataset consist of a 2-week period (1−14 May 2010) of IDC signal detections

- For the same period, an expert analyst compiled a more complete, high-resolution bulletin (UEB)

- UEB contains 11,378 events, including the LEB and many legitimate non-LEB events

- UEB is the ground truth (GT) used to assess the quality of IPF bulletins

Bulletin Comparison

For bulletin comparison, we used the event commonality score (ECS) between the events from the bulletin to be evaluated and the events in the GT. We leverage from AFTAC.

$$ECS = STDF + FAF + MAF$$

$STDF$ – Spatiotemporal difference factor

FAF – False association factor

MAF – Missed association factor

$$STDF = e^{-(d/A)^2},$$

$$d = D_{epi} + (\Delta T_0 \times V_P)$$

D_{epi}: Distance between the two epicenters

ΔT_0: Difference in adjusted event origin times

V_P: P-wave velocity of 10 km/s

A: Distance scaling factor of 1500 km

$$ECS = STDF + FAF + MAF$$

$$FAF = \frac{a_S}{a_{AUTO}}$$

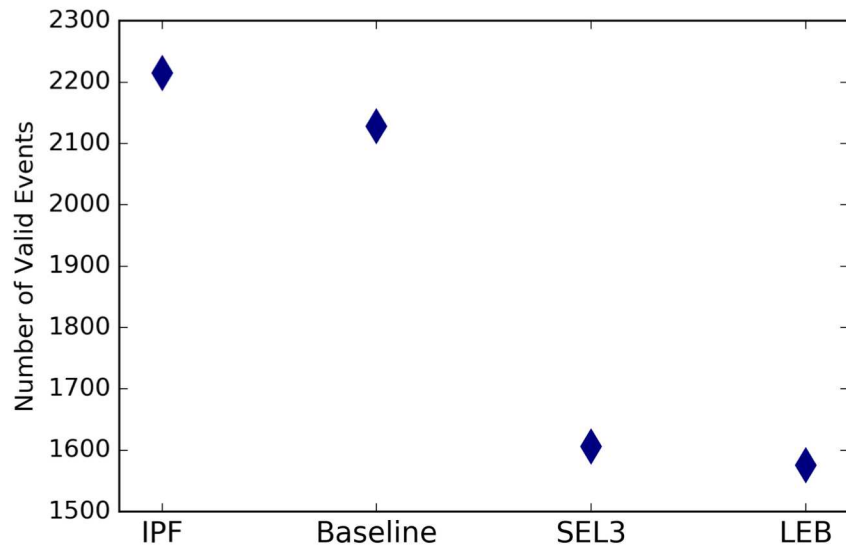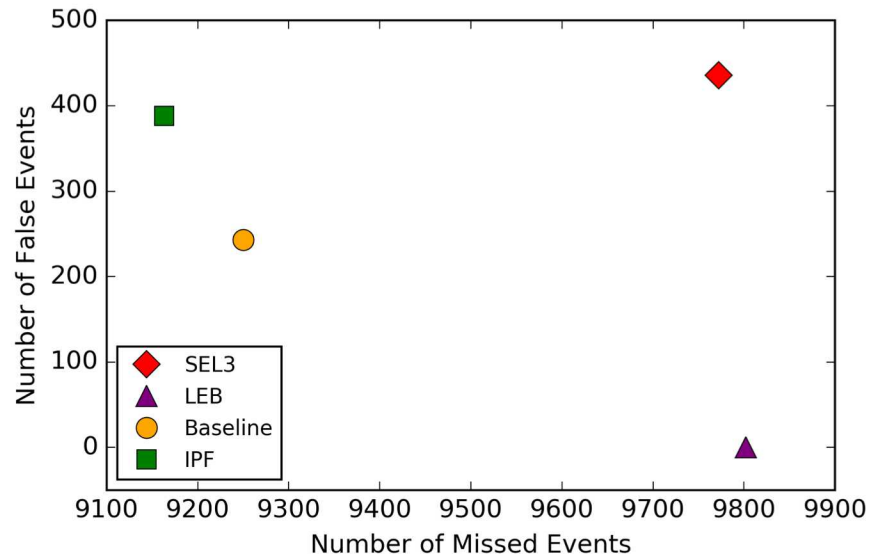a_s – Number of shared associations between the events

a_{AUTO} – Total number of associations for the automated event

$$MAF = \frac{ta_S}{ta_{REF}}$$

ta_s – Number of shared time-defining associations between the events

ta_{REF} – Number of time-defining associations for the reference event

Bulletin Comparison

- SEL3 – high numbers of false events and missed events
- LEB – has the largest number of misses
- Baseline (PEDAL) – misses 522 fewer legitimate events and forms 193 fewer false events compared to SEL3 (IDC GA)
- IPF – ~6% more legitimate events and ~11% fewer false compared to SEL3
- IPF bulletin contains ~6% (639) more legitimate events than LEB
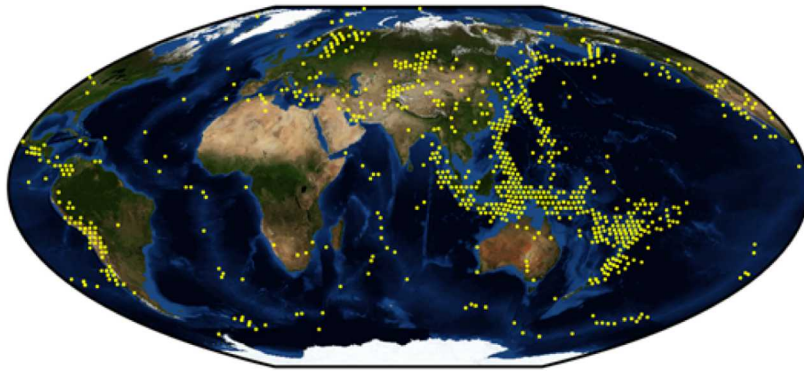- IPF forms 87more than the baseline

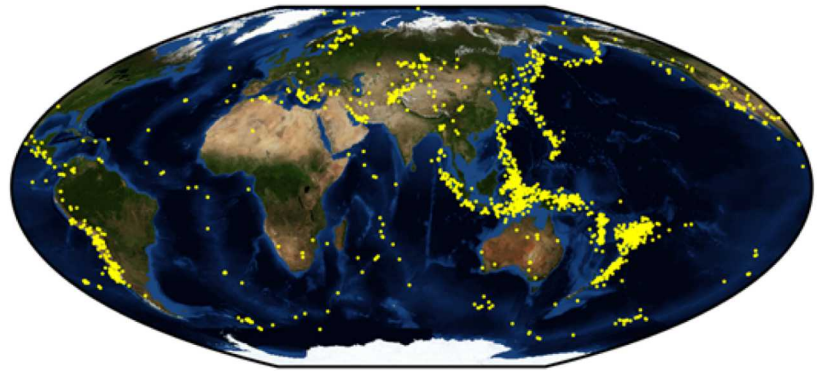In general, IPF performs better than the traditional pipelines.

Bulletin Comparison
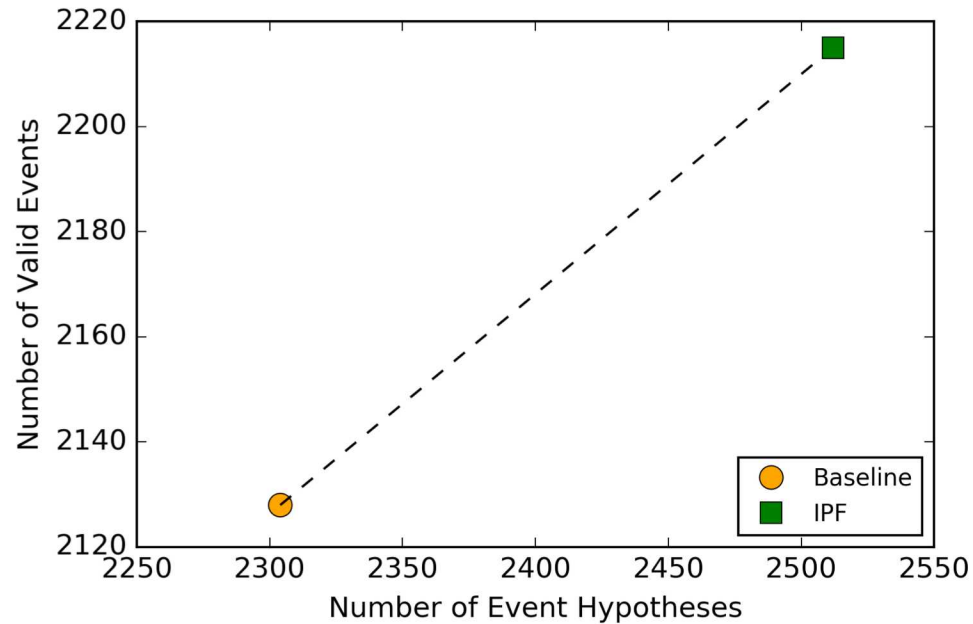
- IPF creates many more event hypotheses thanks to its single-station location capability
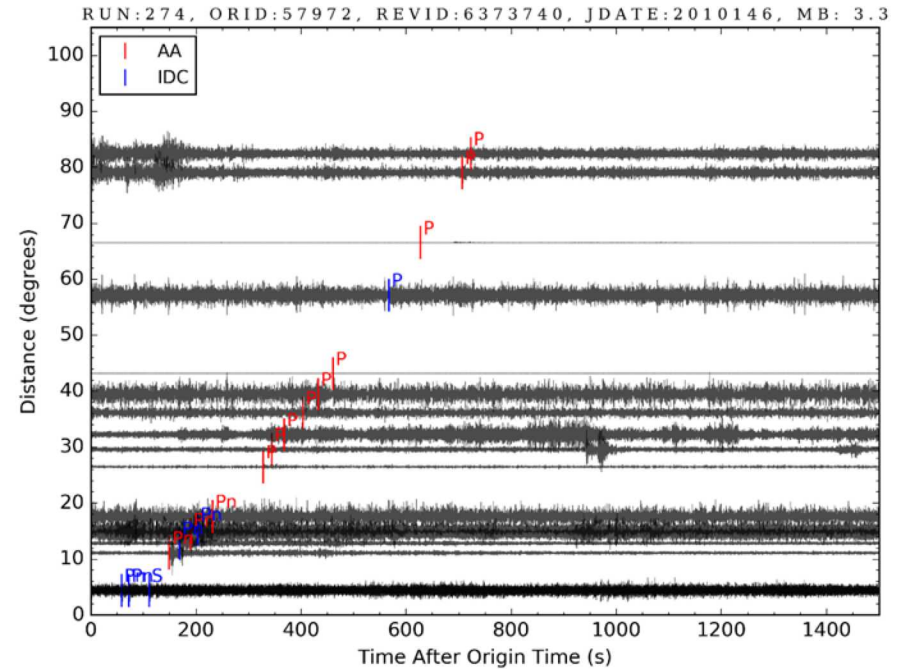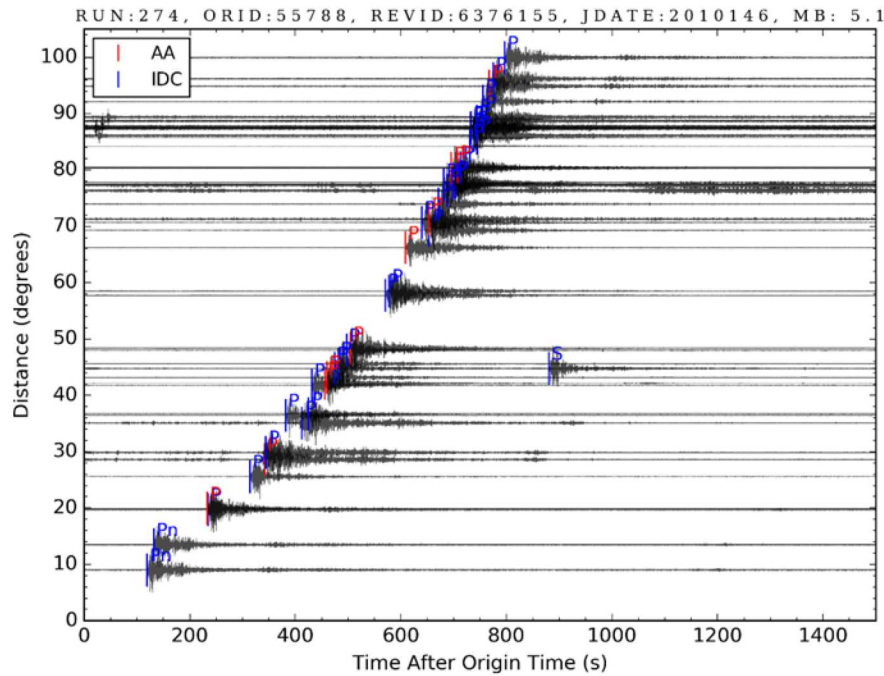
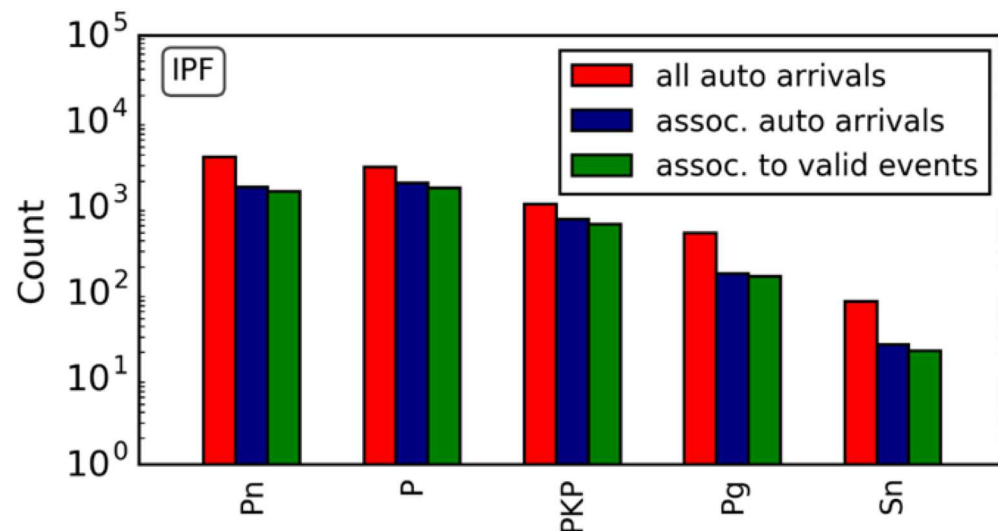- This leads to improvement in the pipeline performance

Bulletin Comparison

For the most part, location patterns are consistent between IPF bulletin and the best matches from the GT.

Auto Analyst Impact in the Pipeline

- For existing events, AA detections are consistent with reviewed IDC or expert-analyst's detections
- AA outperforms IDC detector in less optimal conditions (e.g., noisy data)

Auto Analyst Impact in the Pipeline

- ~54% of AA detections are associated to event hypotheses (valid or false)

- ~48% are associated to valid events

Many AA detections consist of refined IDC detections

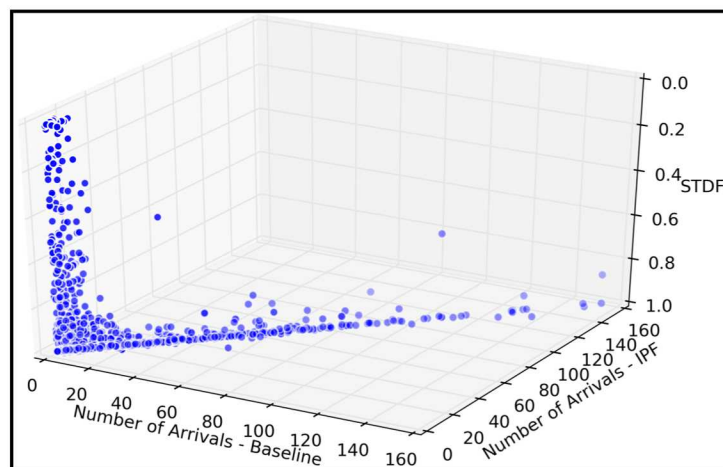# Auto Analyst Impact in the Pipeline
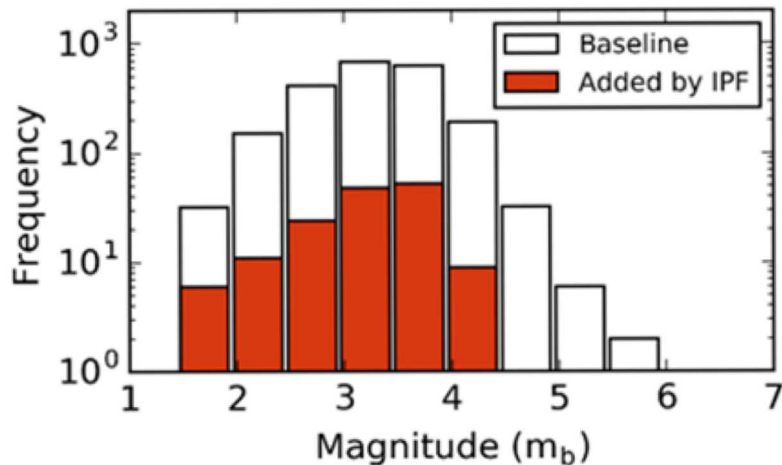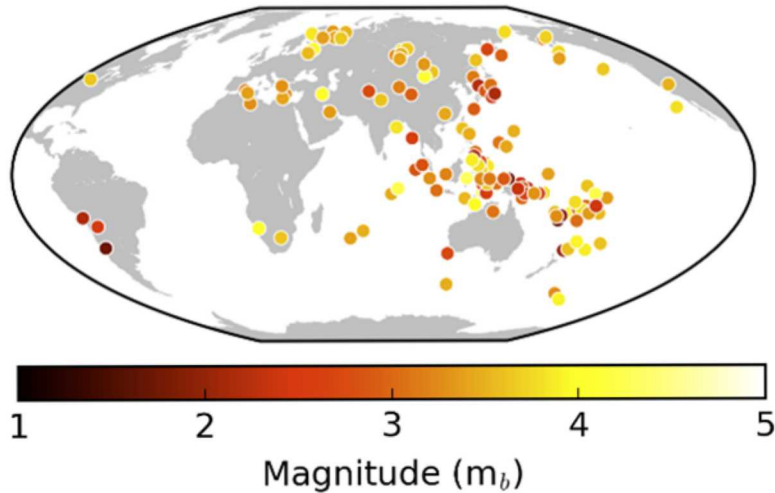
- The AA built 150 additional events (not available in the baseline)

- Most of the additional events are low-magnitude events that evaded the traditional pipeline of event building

Auto Analyst Impact in the Pipeline
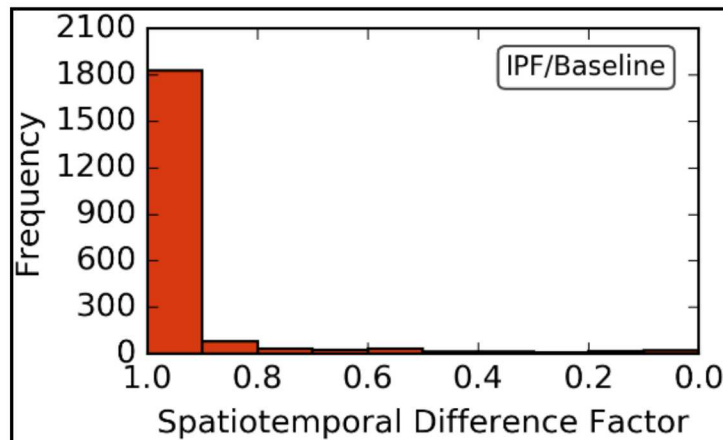
- A small STDF value indicates that the 2 events (baseline and IPF) are distant in space and/or time.

- For most events, the locations in space and time are not significantly affected by the IPF processing.

- Only events with limited number of associated arrivals in the baseline are prone to significant changes in location and/or origin time after IPF processing.

- For most events in the baseline, the AA in the IPF pipeline provides additional arrivals.

Auto Analyst Impact in the Pipeline
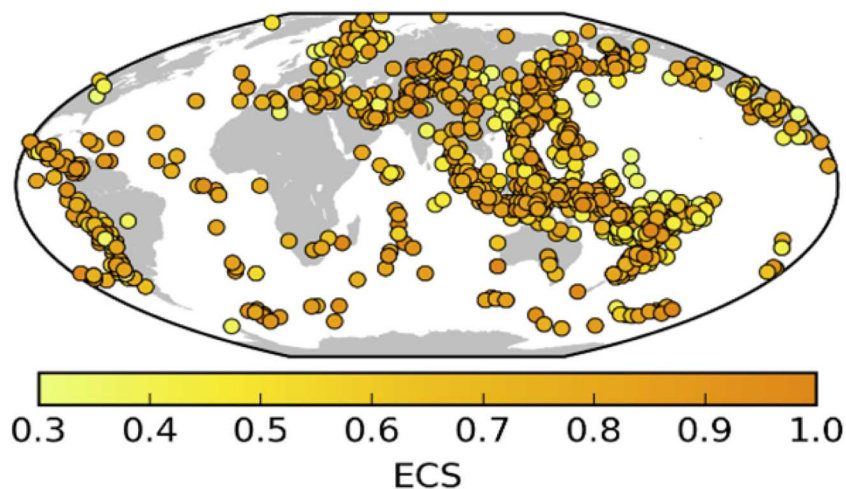
- For most events, IPF improves the *ECS* values compared with the baseline

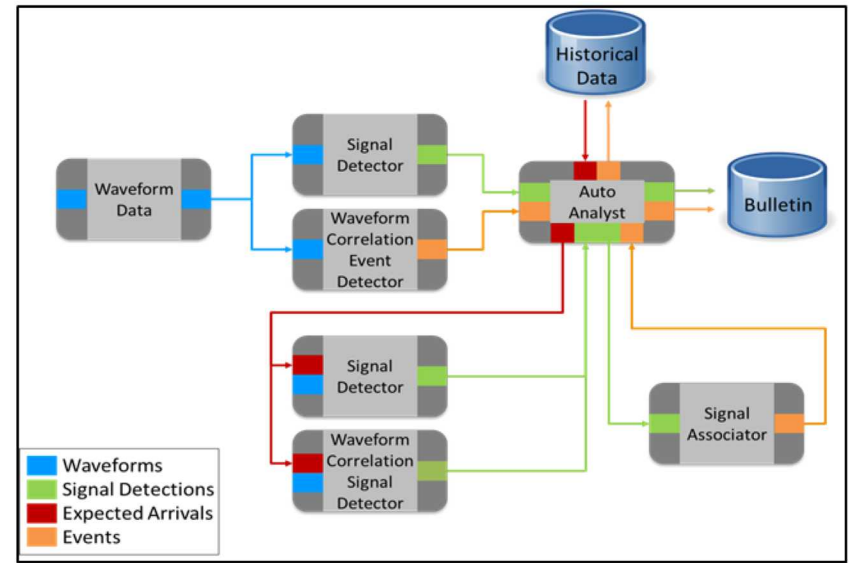- i.e., IPF processing leads to better matches to events in the GT

Conclusions
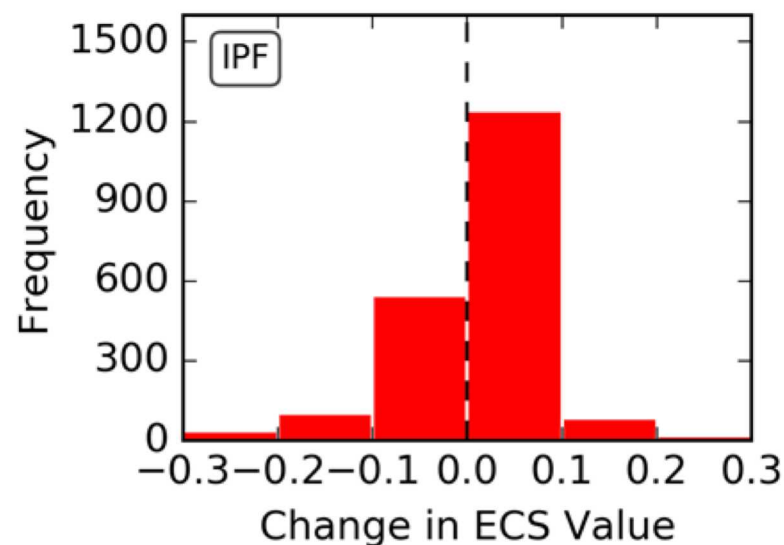
- IPF performs better than the traditional pipelines.

- Most of the additional events built by AA are low-magnitude events that evaded the traditional processing pipelines.

- The AA adds additional signal detections to existing events, which saves analyst time, even if the event locations are not significantly affected.

- On average, ~90% of event hypotheses result each in a valid event.

Outlook

- For repeating events, waveform correlation is known to be superior to traditional detection algorithms.

- Incorporating a waveform-correlation detector (WCD) to the pipeline is expected to dramatically increase the number of event hypotheses during the event building process.

- The impact of a WCD on the pipeline performance will be the focus of a future study.

THANK YOU FOR YOUR ATTENTION