CTBT: SCIENCE AND TECHNOLOGY 2017 CONFERENCE

T3.5-09

NORSAR

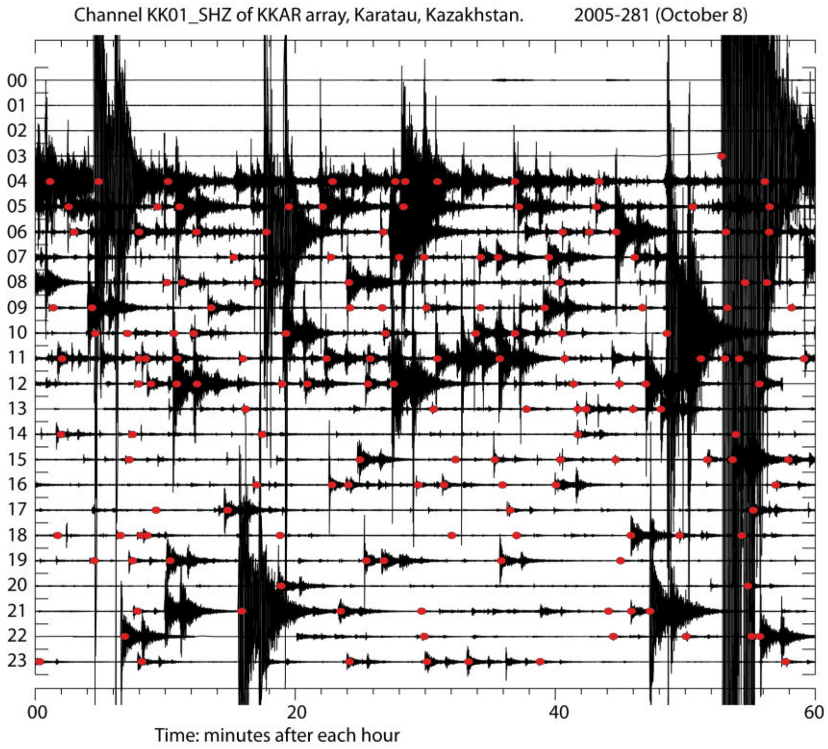
Exploring the Earth

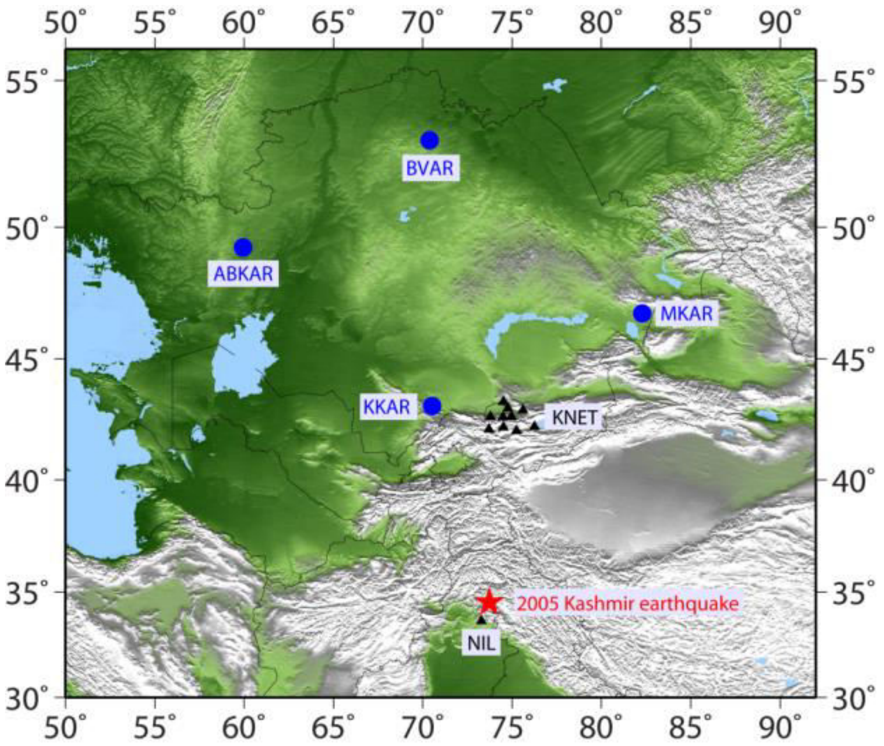
Strategies for Coping with Large Aftershock Sequences

by Tormod Kvaerna and Steven J. Gibbons

CTBT: Science and Technology Conference 2017

The 2005 Kashmir sequence (M_w 7.6)





Current pipeline architectures process waveform data into parameter streams in a single pass

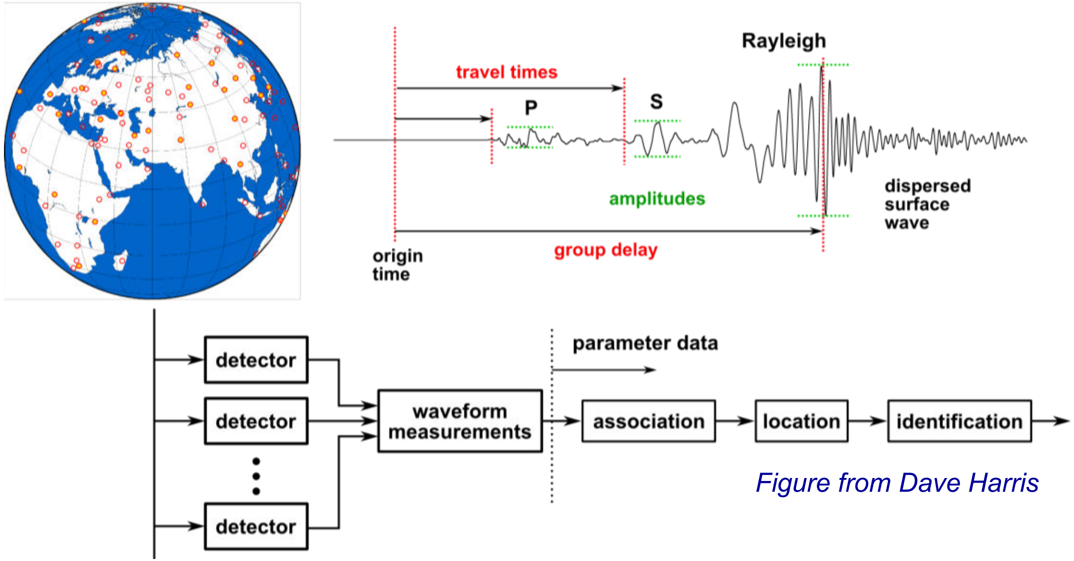
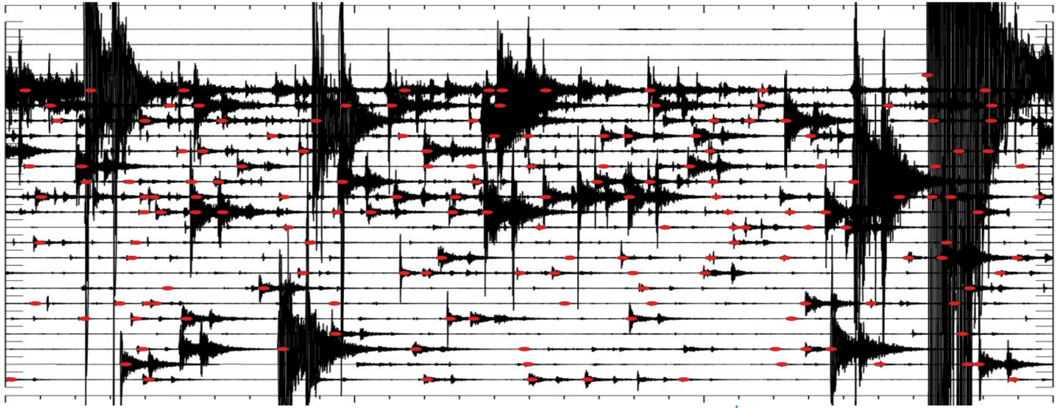


Figure from Dave Harris

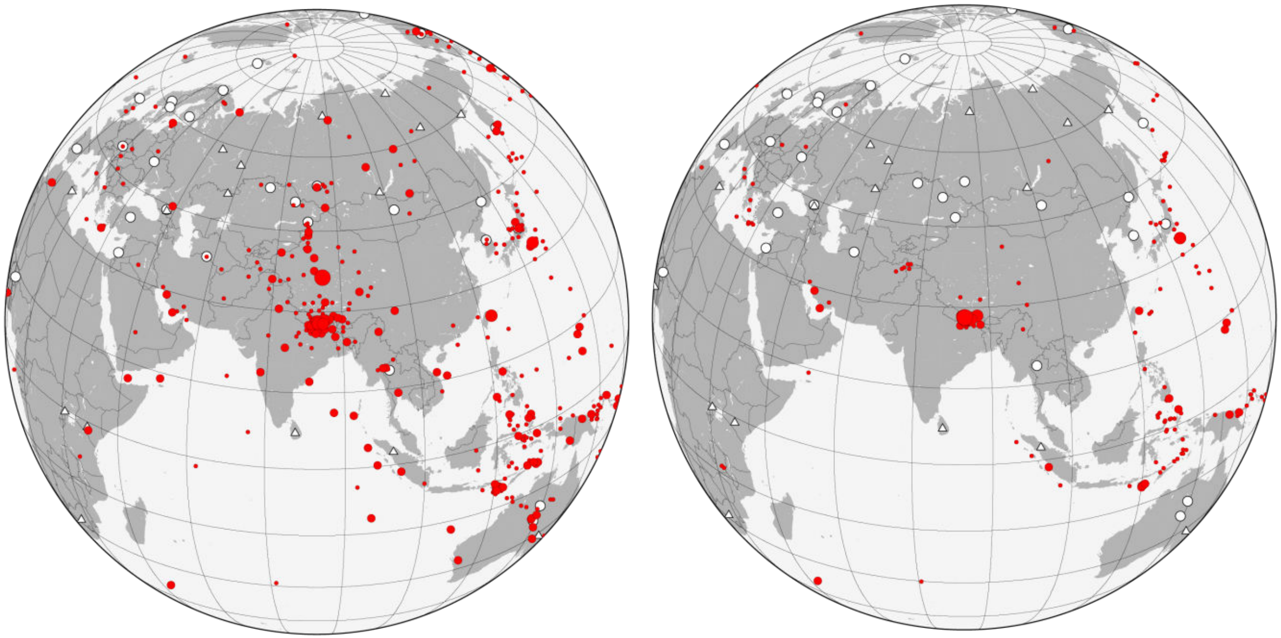
- Subsequent processing is largely on parametric data
- Architecture a legacy of computing platforms of the 80s and 90s

Strategies for Aftershock Classification

- Large earthquakes (e.g. magnitude > 7) can generate vast numbers of aftershocks in the hours and days (sometimes weeks) following the main event.
- This increases the workload for analysts preparing seismic bulletins at Data Centers involved in Nuclear Explosion Monitoring.
- Not only are there more events to process – the quality of automatic bulletins becomes worse (more false alarms and spurious events) **...**



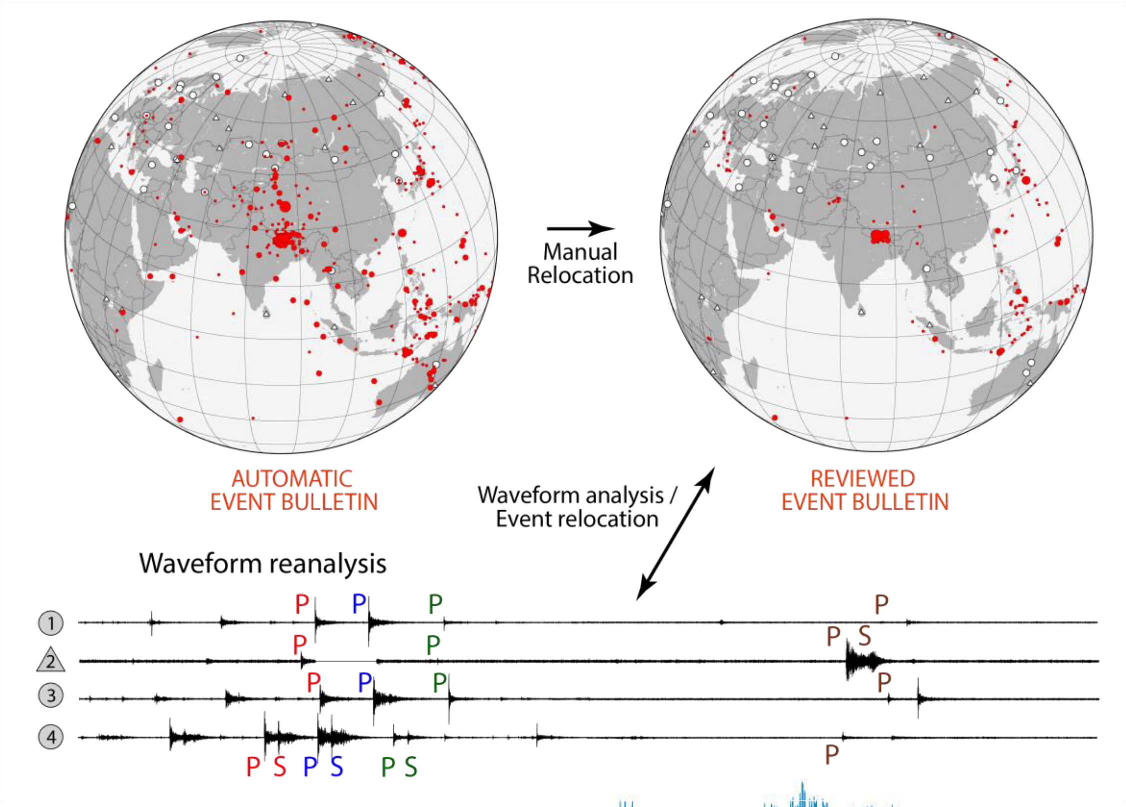
Nepal earthquake sequence, 25 – 30 April 2015



AUTOMATIC EVENT BULLETIN (SL3)

REVIEWED EVENT BULLETIN (REB)

Current Pipeline Procedures



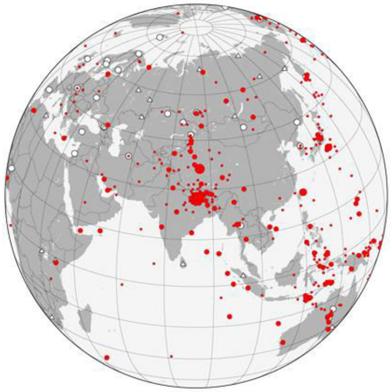
Revised Pipeline Strategy

when we know an aftershock sequence has started in a given area

But how would such a process be initiated, and the aftershock area defined (time interval and region)?

1. Based on automatic processing results from the SEL-3?

2. A very large earthquake?



AUTOMATIC
EVENT BULLETIN
(SL3)

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Revised Pipeline Strategy
when we know an aftershock sequence has started in a given area

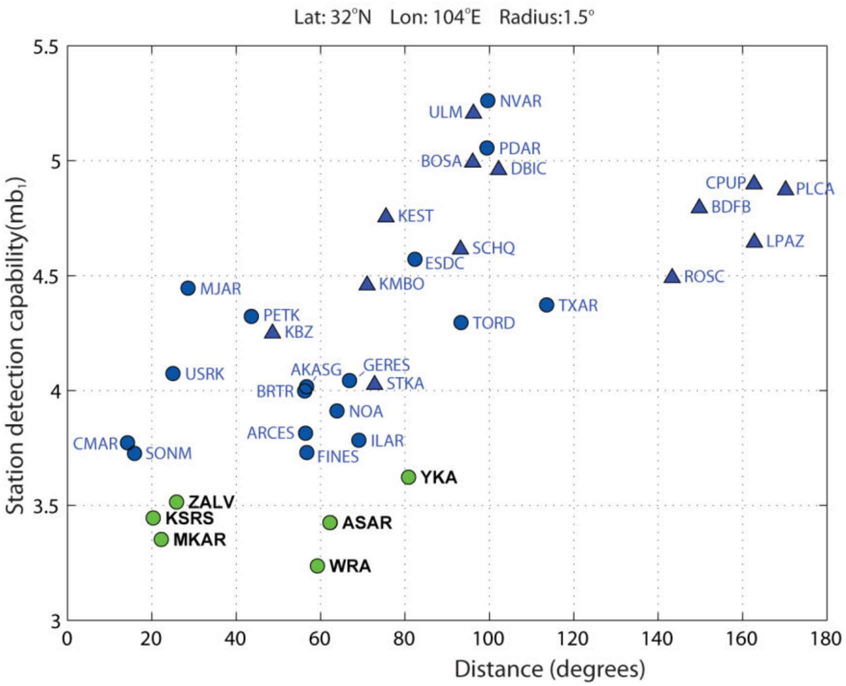
But how would such a process be initiated, and the aftershock area defined (time interval and region)?

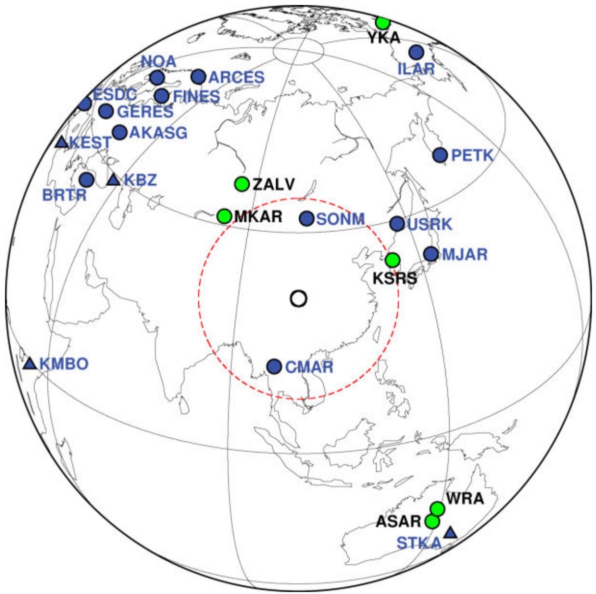
3. The processing procedure is initiated manually?

   The region, the time interval and the station configuration is defined interactively by an analyst (a new aftershock processing tool)?

   Select stations with a good detection capability for the aftershock area.
   Could be based on SNR considerations for the initial event(s)
   or
   from studies of the detectability of different stations.

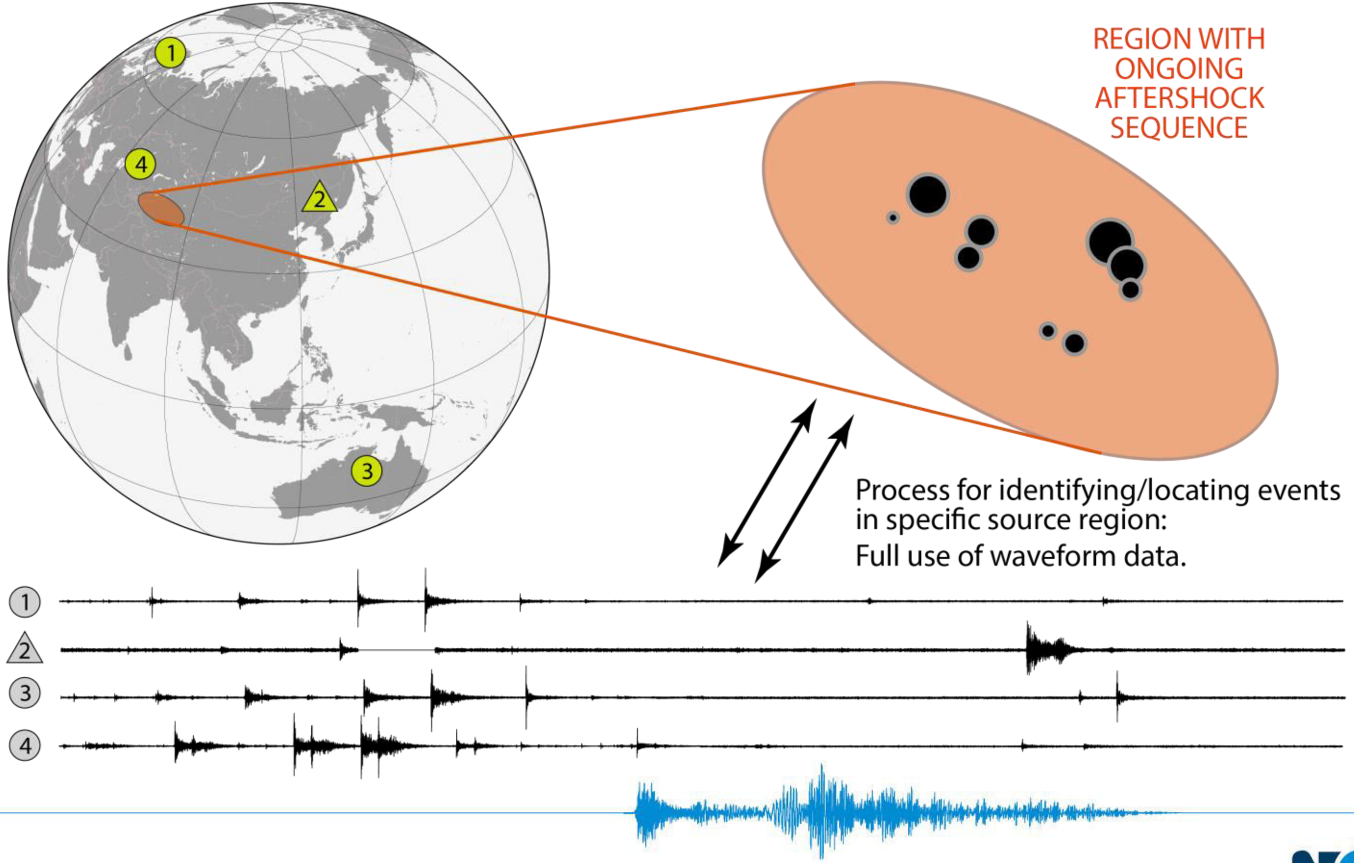
Example: 32°N 104°E



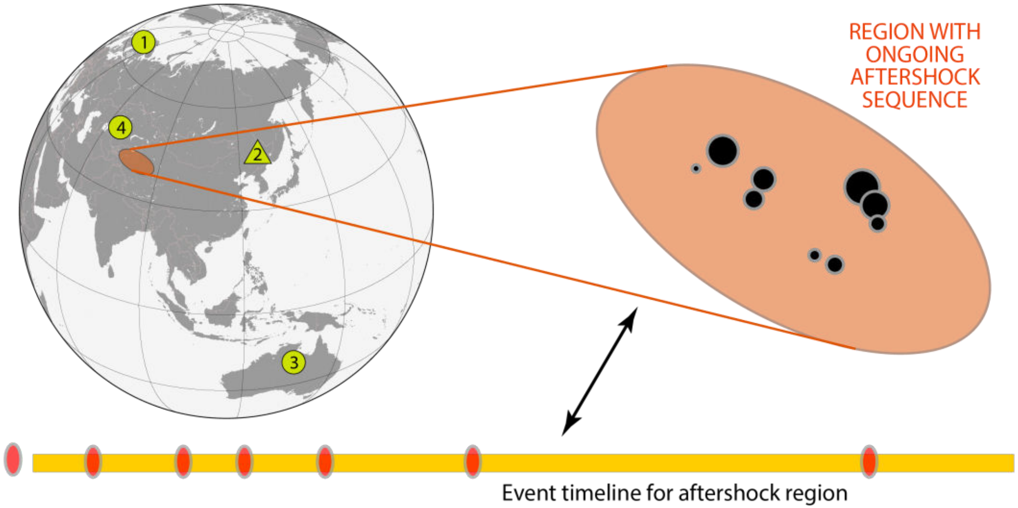


- Sometimes distant stations have better detection thesholds
- Best performers are dominated by arrays

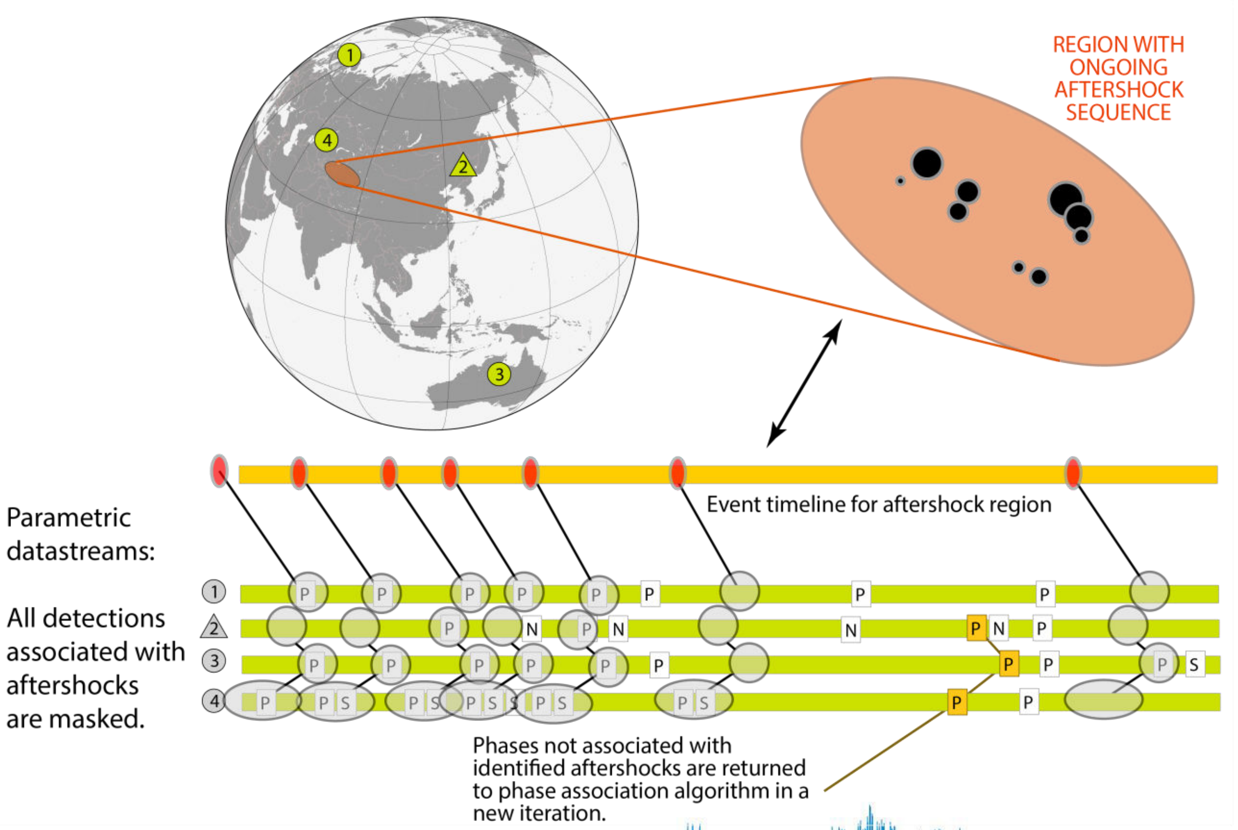
Revised Pipeline Strategy?



Revised Pipeline Strategy?



Revised Pipeline Strategy?



Revised Pipeline Strategy?

- How do we characterize aftershocks in the source region?

  Correlation detectors?
  Subspace detectors?

- Possible – but in the largest sequences, the correlation across wide source regions is often poor (e.g. Slinkard et al.)

Revised Pipeline Strategy?

- How do we characterize aftershocks in the source region?

  Correlation detectors?
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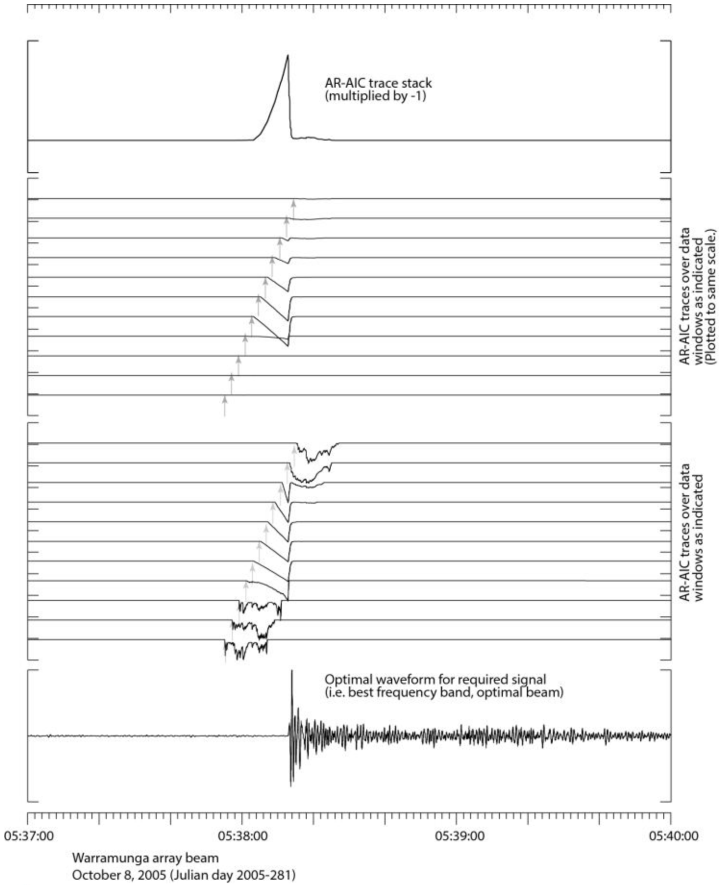
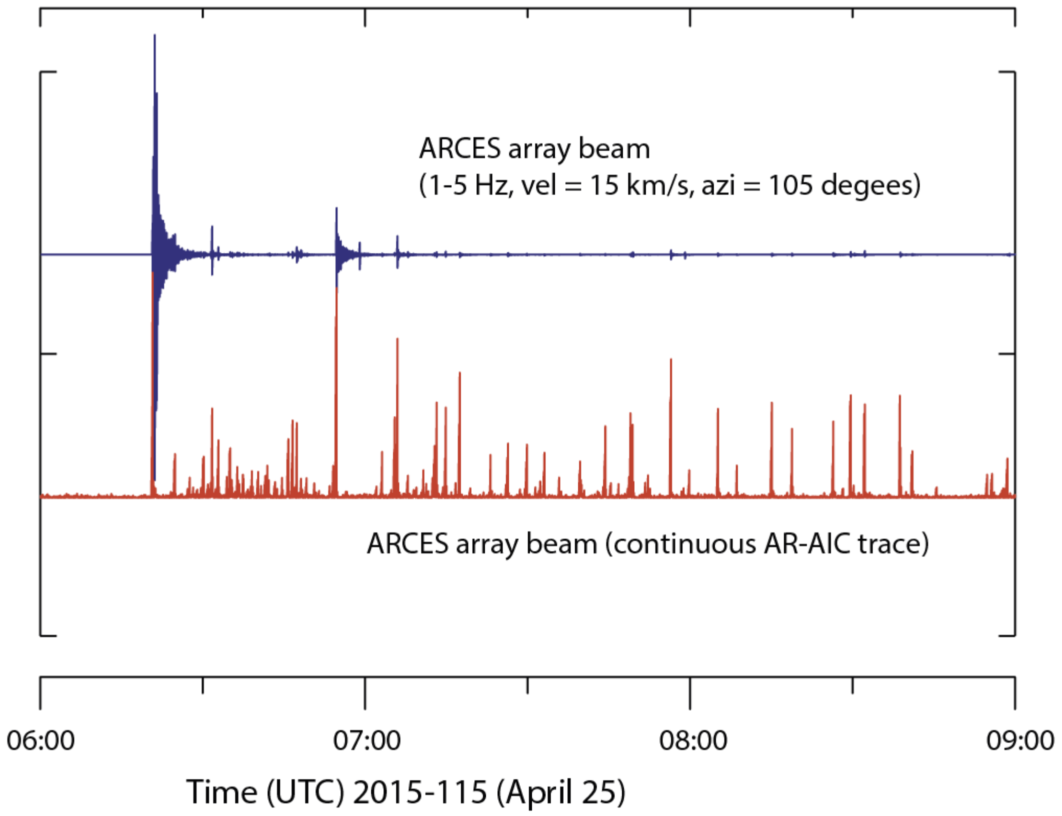
- Possible – but in the largest sequences, the correlation across wide source regions is often poor (e.g. Slinkard et al.)

- What about grid search and association with characteristic functions?



Revised Pipeline Strategy?

- We take the most sensitive stations for our source region ...
- We calculate an optimal trace directed at the source region.
- We calculate an autoregressive characteristic function.



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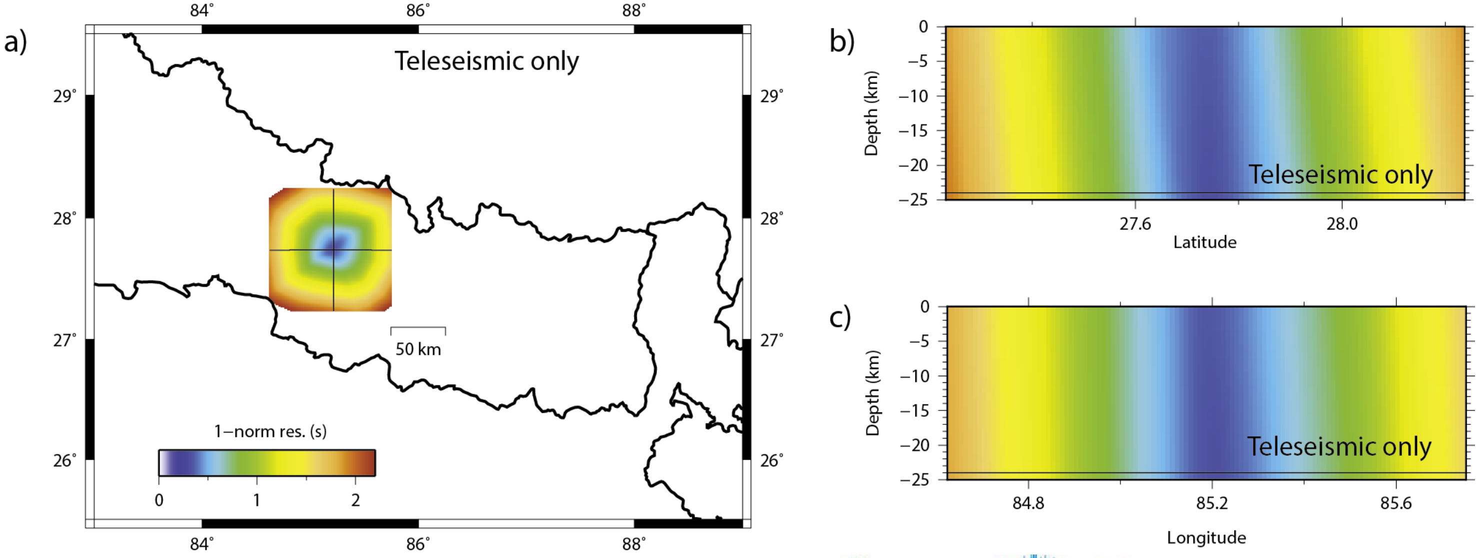
A grid search algorithm for the source region

- This procedure is followed for all stations ...
- Aftershock event hypotheses are formed by finding hypocenters which best match the significant peaks in the characteristic functions.



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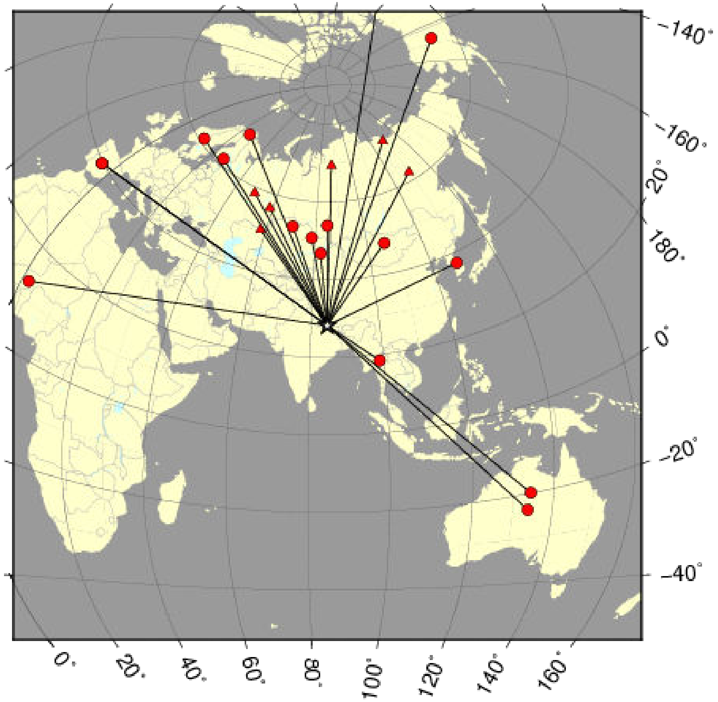
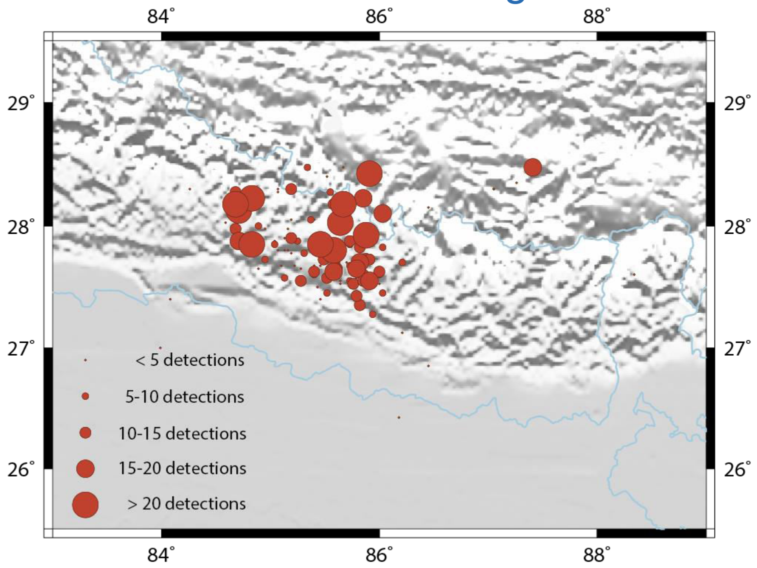
A grid search algorithm for the source region

With a global network, we catch most of the significant events in the selected region - i.e. those recorded by a large number of stations.





25-26 April 2015. 294 REB events.
158 events automatically found.
23 km median location difference.

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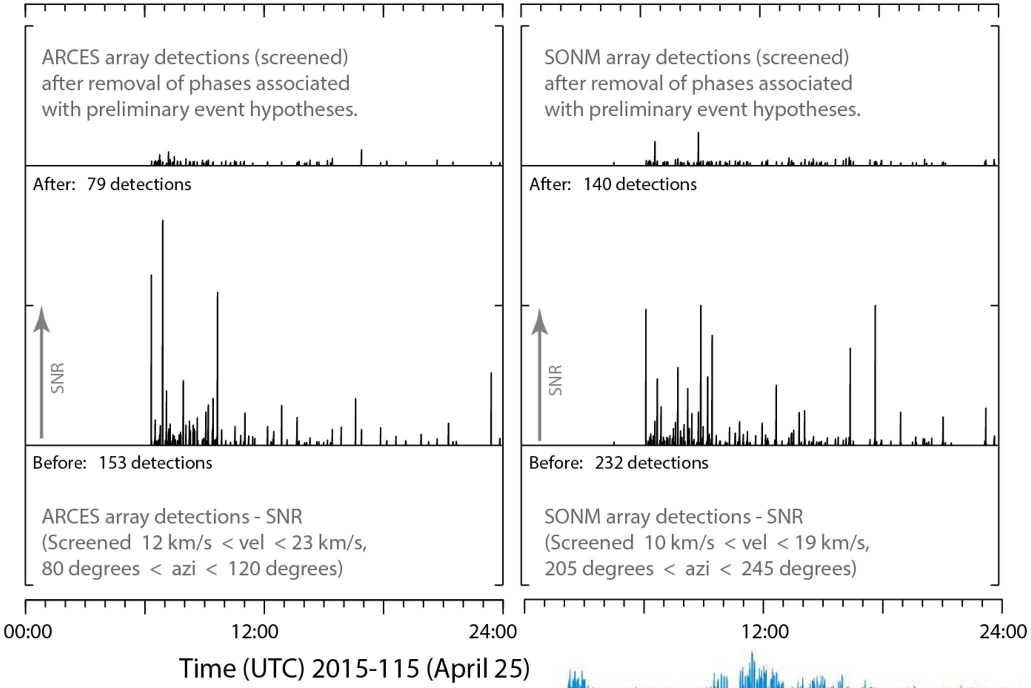
A grid search algorithm for the source region

We then find all the arrivals that could possibly be associated with these events – and strip them away from the parametric datastreams.



Strategies for Aftershock Classification: Conclusions

- Large earthquakes generate large numbers of aftershocks!
  We want to mitigate the effect they have on the generation of bulletins.

- The goal is to reduce the analyst effort to make a reviewed bulletin.

- Suggest an iterative approach

  - associate and locate well-defined events automatically in a specially targeted region

  - remove all associated phase detections from parametric datastreams

  - rerun phase association on the cleaned detection lists

  - analysts should have better automatic bulletins
    (better locations AND fewer false alarms)

Strategies for Aftershock Classification: Next steps

Empirical Matched Field Processing

Utilize frequency-dependent time-delay pattern of main event across each array

This «spatial fingerprint» may be highly characteristic for a given source region.