Improving the locations of earthquakes using the double difference method, HypoDD, for the Composite Alberta Seismicity Catalog

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Introduction

The Composite Alberta Seismicity Catalog (CASC) is a compilation of earthquake catalogues from three agencies: Nanometric/TransAlta (NMX), Geological Survey of Canada (GSC), Alberta Geological Survey (AGS), and two composite catalogs [2]. This work aims to improve the location of earthquakes in the CASC provided by NMX, GSC and AGS. Using the double difference algorithm [5], and program HypoDD [6] we aim to locate the earthquakes with higher precision to enable us to examine spatial and temporal changes related to mining, oil, and gas activity.

This work presents a summary of the requirements for the double difference program in terms of the catalog, some preliminary double difference locations, as well as future work to be implemented for the project.

Method and Dataset

To run HypoDD three primary resources are required: a **velocity model**, **catalog earthquake locations**, and **arrival** times for the earthquakes.

Velocity Model

Depth	V_p
0 km – 36 km	6.20 km/s
36 km +	8.20 km/s

Table 1 — Preliminary 1D velocity model used in HypoDD for the Western Canada Sedimentary Basin.

Catalog Earthquake Locations

The Composite Alberta Seismicity Catalog (CASC) contains earthquakes in the Western Canada Sedimentary Basin (WCSB). Using NMX, GSC (internal catalog) and AGS earthquake catalogs a Composite Alberta Arrival Catalog (CAAC) was generated. **Figure 1** shows both CASC and CAAC earthquakes in the WCSB.

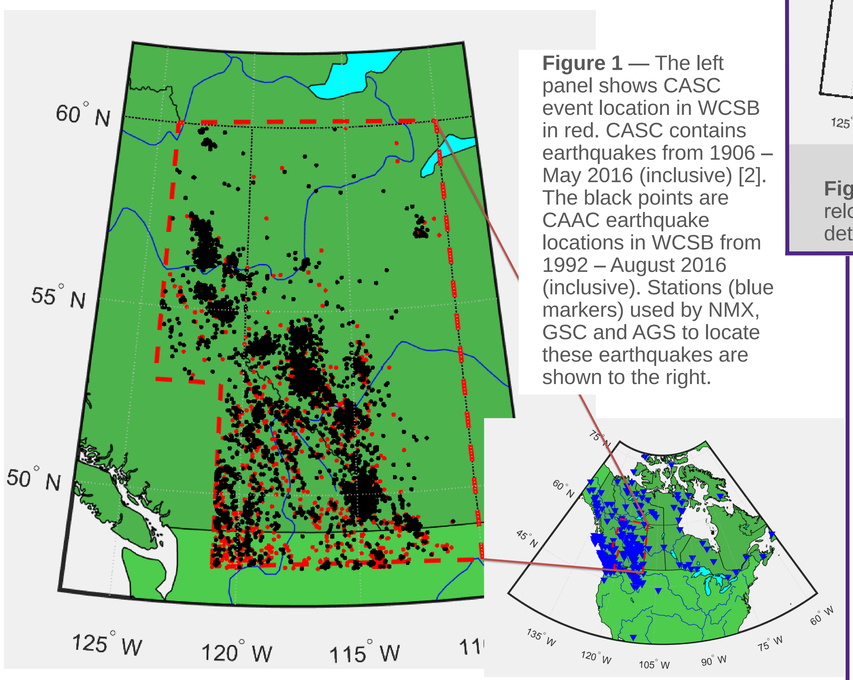

Figure 1 — The left panel shows CASC event location in WCSB in red. CASC contains earthquakes from 1906 – May 2016 (inclusive) [2]. The black points are CAAC earthquake locations in WCSB from 1992 – August 2016 (inclusive). Stations (blue markers) used by NMX, GSC and AGS to locate these earthquakes are shown to the right.

Due to overlapping seismic networks used by the three agencies, duplicate events had to be removed. The compilation process identifies duplicates and creates a single event when the following windows were observed:

- Time ≤ 3 seconds,
- Space ≤ 30 km,
- Magnitude ≤ 1 magnitude unit
- with a priority of input catalogs as NMX, GSC, and AGS [2].

Preliminary Results

Using the velocity model, catalog earthquake locations, and arrivals **Figure 4** shows the preliminary double difference locations.

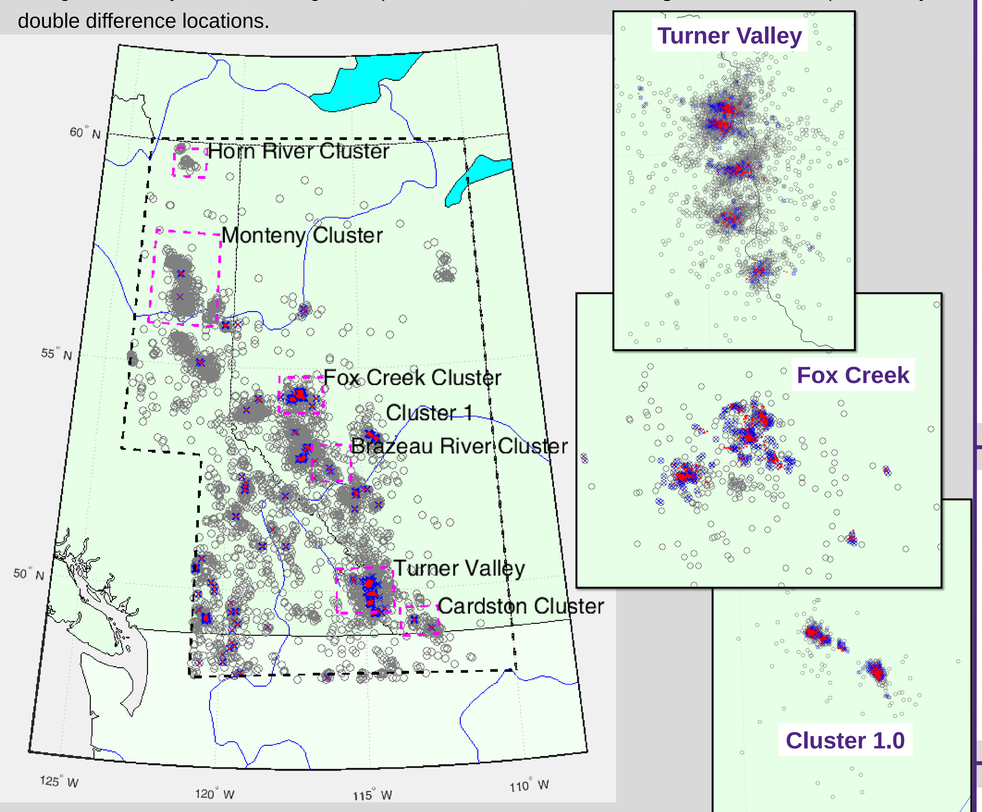

Figure 4 — Double Difference Locations of CAAC (red points). CAAC catalog locations that are relocated (blue x's). Grey circles show all CAAC catalog locations. Insets are provided to show detailed changes between catalog locations (blue x's) and double difference locations (red circles).

Figure 2 shows the contributions from each catalog which together generate CAAC, as well as the percentage of duplicates when joined to the catalog.

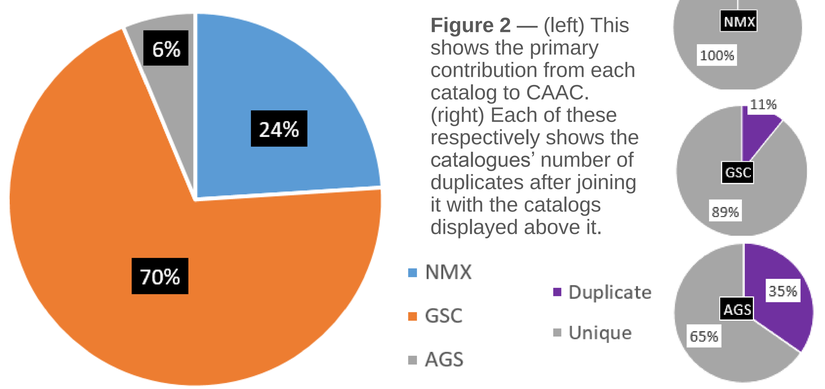

Figure 2 — (left) This shows the primary contribution from each catalog to CAAC. (right) Each of these respectively shows the catalogues' number of duplicates after joining it with the catalogs displayed above it.

Arrival Times

CAAC differs from CASC in terms of:

- Utilizes the internal GSC database, not the online database
- CAAC contains arrival pick times for each earthquake

Each agency has a set of seismic stations they locate earthquakes with and often similar stations are used between agencies. **Figure 1** shows the stations used to locate earthquakes in CAAC. Duplicate arrivals were dealt with in the same manner as duplicate earthquakes. CAAC contains many different arrival phases as shown in **Figure 3**.

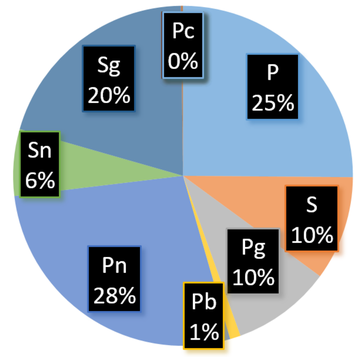

Figure 3 — Many different arrival phases are present in the CAAC. We show the percentage of the different arrival phases for the CAAC.

HypoDD was designed for direct wave arrival, therefore CAAC only contains phase arrivals: P, S, Pg, and Sg. A large number of indirect phases are present. An alternative program called MultiDD [1], a modified version of HypoDD, could be used to include some of these other arrivals in future work.

Future Work

- Optimize hypoDD input parameters
- Utilize MultiDD on catalog data
- Analyze individual clusters and optimize HypoDD input parameters for them
- Calculate errors on locations
- Use new locations to:
  - Reanalyze: statistical model for hydraulic fracturing [4]
  - Reanalyze: distinguishing between quarry blasts and natural earthquakes [5]

Acknowledgments

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References

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