# HOW CAN WE IMPROVE THE ISC LOCATION PROCEDURES?

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# Basics - 1

- Location routine HYPOSAT (Schweitzer, 2001), a Geiger-type inversion algorithm using Generalized Matrix Inversion with SVD.
- Seismic phases used as defining during all tests:
  Pg, Pb, Pn, P (= "P")
- Seismic phases used in some tests (and when reported) as defining:
  surface reflections p"P", s"P", s"S", p"S"
  core phases PKPdf, PKPbc, PKPab (= "PKP")
  core reflections PcP, PcS, ScS, ScP
  direct S onsets Sg, Sb, Sn, Lg, S and SKSac
- Velocity models tested:
  Jeffreys-Bullen, PREM, IASP91, SP6, AK135
- The ISC location was used as start solution including the ISC depth as fixed. Then, the found solution was again inverted with free depth.

# Basics - 2

- The ISC listed (i, e, ' ') qualities were converted in assumed reading uncertainties σ:

  i: σ = 0.1 s
  e: σ = 0.5 s
  ' ': σ = 1.0 s

  In the case of readings given with an accuracy of 1/100 s,

  i: σ = 0.1 s
  e: σ = 0.25 s
  ' ': σ = 0.5 s

  Secondary onsets:

  P type phases: σ = 1.5 * σ
  S type phases: σ = 2.0 * σ

- Because the total number of backazimuth and ray parameter observations in the test-data set is very small, the influence of these parameters could no be tested.

# Basics - 3

- The inversion stopped, whenever the (3D) distance between the solutions of became smaller than 0.5 km.
- The 80 earthquakes and 76 explosions were altogether tested for 278 parameter combinations. This resulted in 24.408 valid locations; 15.433 earthquakes and 8.975 explosions.
- **No** new phase association was tried. Phase renaming was only allowed inside of one phase type (e.g., Pg < > Pb).
- No correction of obvious input-data errors.

# Example for Double Entries

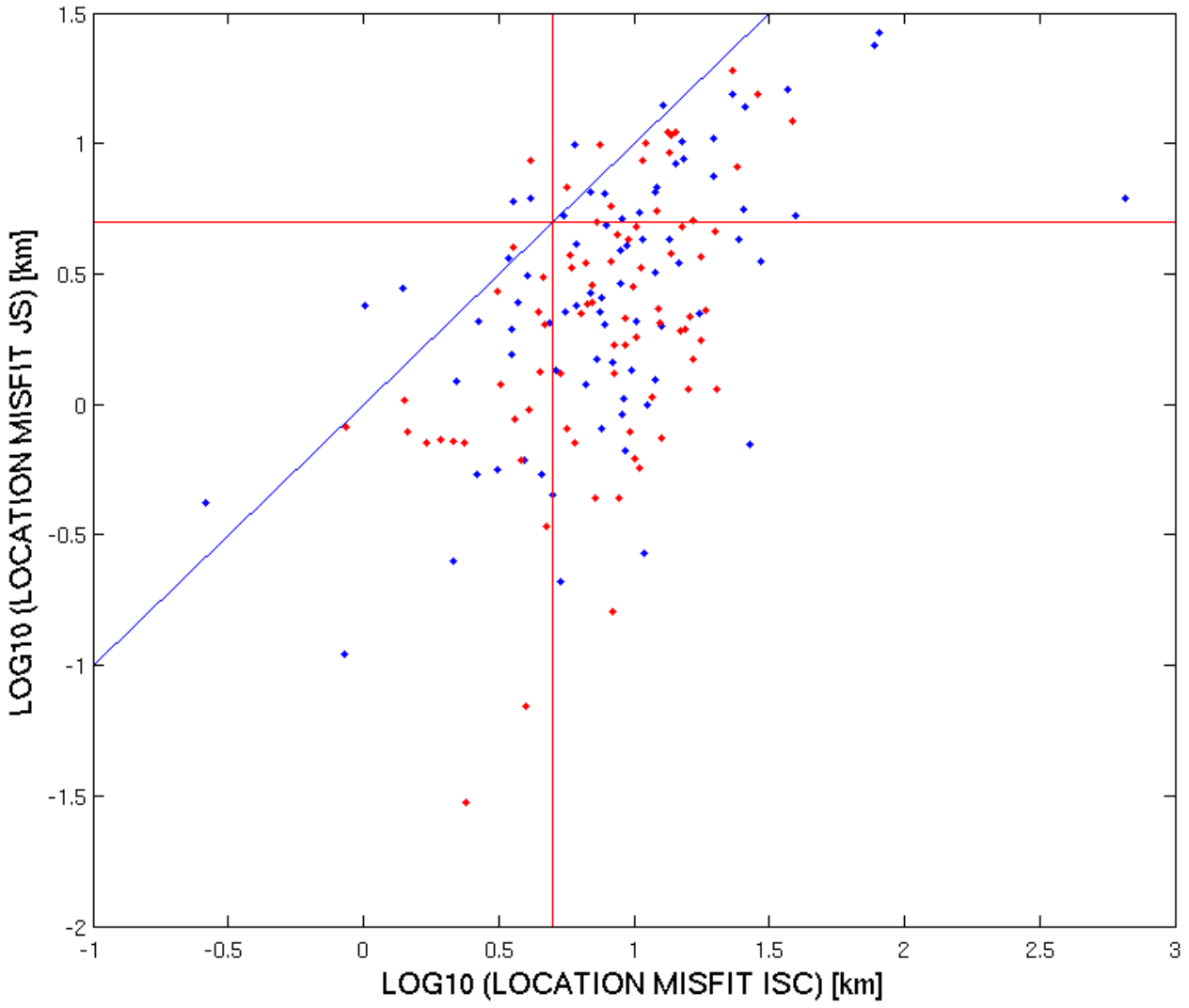
```
DATA_TYPE BULLETIN IMS1.0:short
ISC Comprehensive Bulletin
Event    97710 Sweden
   Date        Time        Err   RMS Latitude Longitude  Smaj  Smin  Az Depth   Err Ndef Nsta Gap  mdist  Mdist Qual   Author      OrigID
1995/06/08 21:19:00                  62.6700   17.9800                  0.0                                               IASPEI     4565104
1995/06/08 21:19:00.00               62.6700   17.9800                  0.0        10            2.20                   IWREF      6353900
1995/06/08 21:19:59.30               62.7900   17.8800                  0.0             6                                 EIDC        224909
1995/06/08 21:20:02.40               62.8360   17.8180                  0.0                                               BER         224910
1995/06/08 21:19:57.93   0.71  0.76  62.9196   17.7987 8.276   9.5  90   0.0f        10   10 146   2.00  14.00 m i    ISC1        224911


Sta     Dist  EvAz Phase       Time       TRes  Azim AzRes   Slow   SRes Def   SNR       Amp   Per Qual Magnitude    ArrID
VAF     2.23  85.0 PN       21:20:37.8     1.2                            T__                          __             3233021
VAF     2.23       Sn       21:21:07.1                                    ___                          __             3233022
VAF     2.23       Lg       21:21:08.8                                    ___                          __             3233023
HFS     3.42 217.0 PN       21:20:53.43   -0.1                            T__             3.1  0.10    __             3233024
HFS     3.42       Sn       21:21:33.58                                   ___             2.7  0.30    __             3233025
HFS     3.42       LG       21:21:45.13                                   ___                          __             3233026
NORES   3.69 236.0 PN       21:20:57.5     0.1                            T__                          __             3233027
NORES   3.69       Sn       21:21:41.5                                    ___                          __             3233028
NORES   3.69       Lg       21:21:55.5                                    ___                          __             3233029
NRA0    3.69 236.0 PN       21:20:57.92    0.5                            T__             0.9  0.10    __             3233030
NRA0    3.69       LG       21:21:55.67                                   ___             6.0  0.20    __             3233031
FIA0    4.15 107.0 PN       21:21:03.86   -0.2                            T__             2.2  0.20    __             3233035
FIA0    4.15       Sn       21:21:52.89                                   ___                          __             3233036
FIA0    4.15       LG       21:22:08.71                                   ___             7.7  0.30    __             3233037
FINES   4.15 107.0 PN       21:21:03.6    -0.4                            T__                          __             3233032
FINES   4.15       Sn       21:21:52.7                                    ___                          __             3233033
FINES   4.15       Lg       21:22:07.3                                    ___                          __             3233034
ARA0    7.33  22.0 PN       21:21:48.95    0.1                            T__             1.8  0.20    __             3233040
ARA0    7.33       Sn       21:23:11.03                                   ___             0.2  0.20    __             3233041
ARCES   7.33  22.0 PN       21:21:48.4    -0.5                            T__                          __             3233038
ARCES   7.33       Sn       21:23:13.5                                    ___                          __             3233039
APA0    7.91  47.0 PN       21:21:56.71   -0.2                            T__                          __             3233042
GERES  14.29 191.0 P        21:23:19.7    -3.6                            T__                          __             3233043

STOP
```

# Best Epicenter Solutions

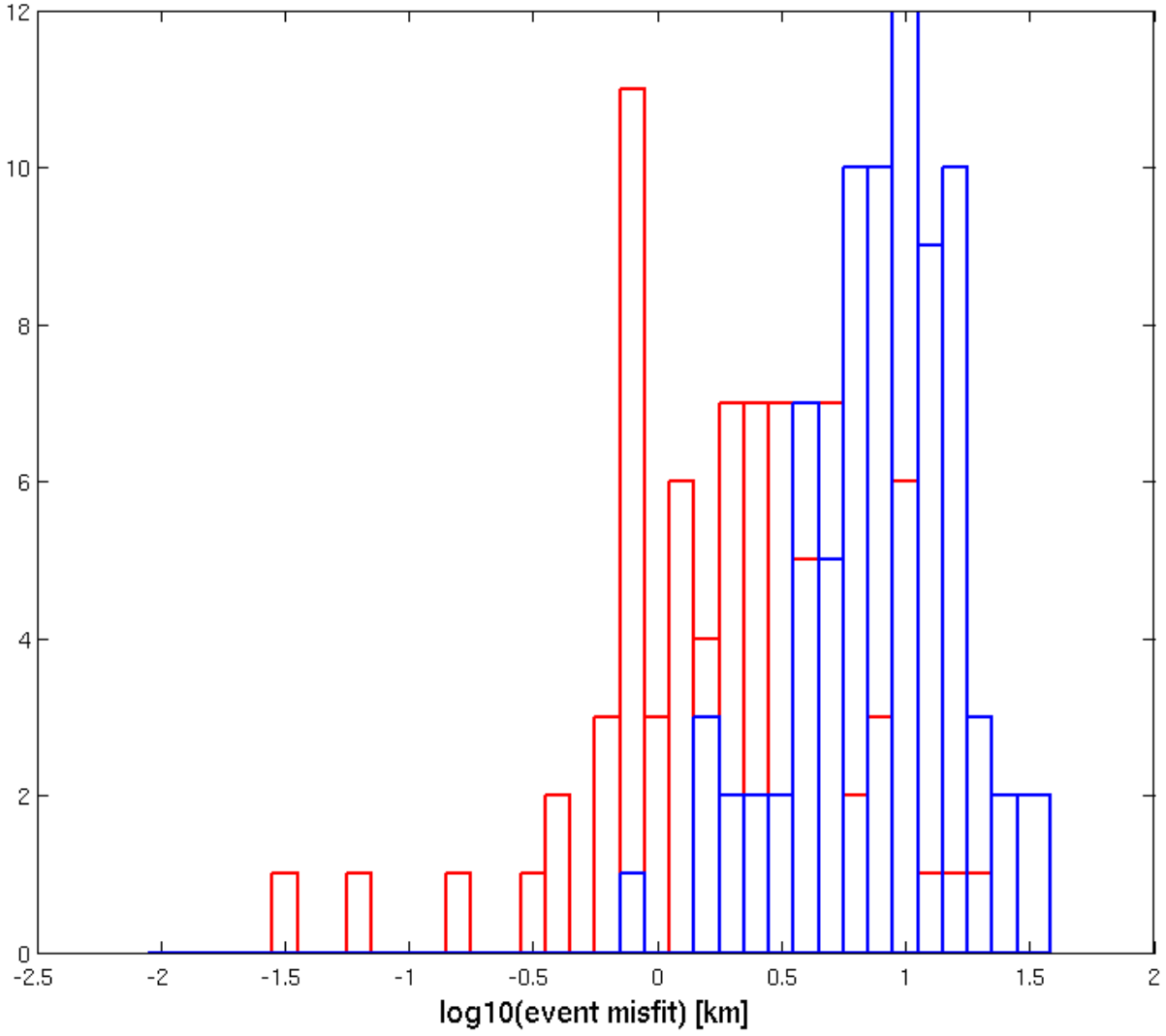
Location errors of the best of all epicenters:

| | ISC | JS |
|---|---|---|
| Earthquakes, mean error | 9.83 km | 3.53 km |
| Earthquakes, median | 8.59 km | 2.21 km |
| Explosions, mean error | 20.54 km | 8.61 km |
| Explosions, median | 4.47 km | 2.73 km |

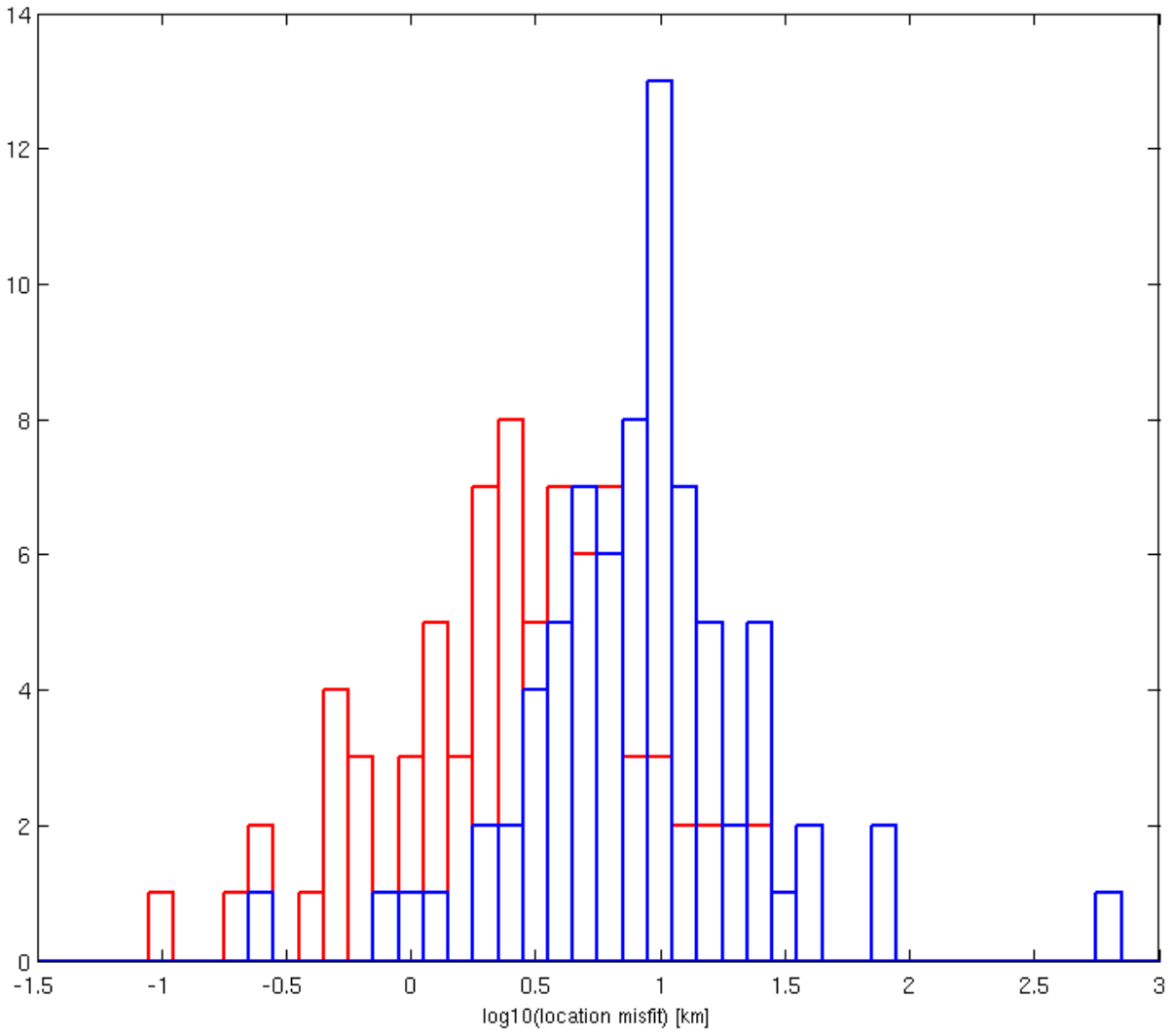
# Best Epicenter Solutions



# Best Epicenter Solutions: Earthquakes



# Best Epicenter Solutions: Explosions



# Problems

No common rule of parameter settings

to achieve these locations!

Many different parameter settings result in solutions

better than the ISC solutions!

# Definition of 'Well' Located Events – 1

epicentral error after relocation <= ISC epicentral error

or

absolute epicentral error after relocation <= 5 km (GT-5)

From the 15.433 earthquakes and 8.975 explosions located remain **4.622** earthquakes and **3.018** explosions.

# Definition of 'Well' Located Events – 2

depth error after relocation <= ISC depth error

or

absolute depth error after relocation <= 5 km

From the 4.622 earthquakes and 3.018 explosions located remain **2.889** earthquakes and **2.240** explosions:

# Definition of 'Well' Located Events – 3

'Well' located are:

2.889 / 15.433 = **18.72**% of all earthquakes
2.240 / 8.975 = **24.96**% of all explosions

5.129 / 24.408 = **21.01**% of all events

# Earth Model Test – Jeffreys-Bullen

In this case 'well' located are:

678 / 3944 = **17.19**% of all earthquakes (ref: 18.72%)
713 / 2681 = **26.59**% of all explosions (ref: 24.96%)

1391 / 6625 = **21.00**% of all events (ref: 21.01%)

# Earth Model Test – PREM

In this case 'well' located are:

404 / 2887 = **13.99**% of all earthquakes (ref: 18.72%)
335 / 1598 = **20.96**% of all explosions (ref: 24.96%)

739 / 4485 = **16.48**% of all events (ref: 21.01%)

# Earth Model Test – IASP91

In this case 'well' located are:

614 / 2911 = **21.09**% of all earthquakes (ref: 18.72%)
393 / 1589 = **24.73**% of all explosions (ref: 24.96%)

1007 / 4500 = **22.38**% of all events (ref: 21.01%)

# Earth Model Test – SP6

In this case 'well' located are:

576 / 2725 = **20.81**% of all earthquakes (ref: 18.72%)
331 / 1423 = **23.26**% of all explosions (ref: 24.96%)

898 / 4448 = **21.65**% of all events (ref: 21.01%)

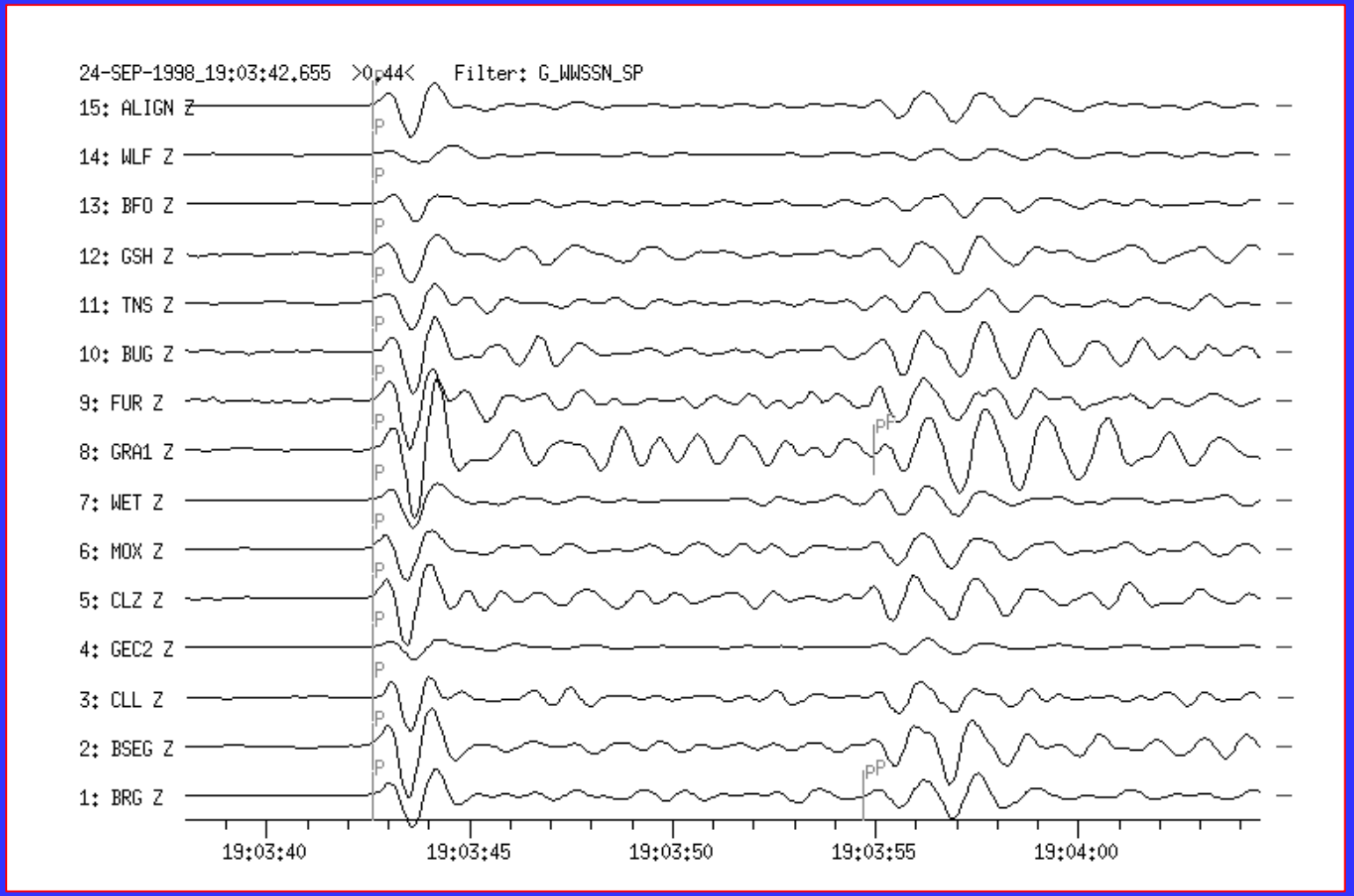
# Earth Model Test – AK135

In this case 'well' located are:

626 / 2966 = **21.11**% of all earthquakes (ref: 18.72%)
468 / 1684 = **27.79**% of all explosions (ref: 24.96%)

1094 / 4650 = **23.53**% of all events (ref: 21.01%)

# Two Sided Uncertainty – 1




correct onset time: $t_0 - \sigma_1 < t_0 > t_0 + \sigma_2$

# Two Sided Uncertainty – 2

Negative residuals (obs-Cal) σ = 0.5 * σ :

34 / 166 = **20.48**% of all earthquakes (ref: 18.72%)
49 / 154 = **31.82**% of all explosions (ref: 24.96%)

Negative residuals (obs-Cal) σ = 0.75 * σ :

58 / 330 = **17.58**% of all earthquakes (ref: 18.72%)
97 / 317 = **30.60**% of all explosions (ref: 24.96%)

# Secondary Phases – Direct S

In this case 'well' located are:

2056 / 11568 = **17.77**% of all earthquakes (ref: 18.72%)
1158 / 5763 = **20.09**% of all explosions (ref: 24.96%)

But for model AK135 only:

470 / 2326 = **20.21**% of all earthquakes (ref: 18.72%)
252 / 1153 = **21.86**% of all explosions (ref: 24.96%)
722 / 3479 = **20.75**% of all events (ref: 21.01)

# Secondary Phases – "PKP"

In this case 'well' located are:

612 / 3741 = **16.36**% of all earthquakes (ref: 18.72%)
286 / 1452 = **19.70**% of all explosions (ref: 24.96%)

# Secondary Phases – Surface Reflections

In this case 'well' located are:

1021 / 5503 = **18.55**% of all earthquakes (ref: 18.72%)
197 / 1662 = **11.85**% of all explosions (ref: 24.96%)

# Secondary Phases – Surface Reflections & Correcting for Reflection Points

In this case 'well' located are:

483 / 2568 = **18.81**% of all earthquakes (ref: 18.72%)
88 / 724 = **12.15**% of all explosions (ref: 24.96%)

# Secondary Phases – Core Reflections

Distance range for PcP and ScS: 45 – 75°
Distance range for PcS and ScP: 20 – 42°

In this case 'well' located are:

783 / 4588 = **17.07**% of all earthquakes (ref: 18.72%)
204 / 1440 = **14.17**% of all explosions (ref: 24.96%)

# Secondary Phases –
# Surface Reflections & Core Reflections

In this case 'well' located are:

646 / 3206 = **20.15**% of all earthquakes (ref: 18.72%)
194 / 978 = **19.84**% of all explosions (ref: 24.96%)

# Station Corrections From Crust 5x5

In this case 'well' located are:

108 / 491 = **22.00**% of all earthquakes (ref: 18.72%)
169 / 470 = **35.96**% of all explosions (ref: 24.96%)

# Removing Data – 1

To increase the location accuracy defining onsets with larger residuals were systematically removed during the last inversion steps:

In this case 'well' located are:

77 / 317 = **24.29**% of all earthquakes (ref: 18.72%)
90 / 260 = **33.83**% of all explosions (ref: 24.96%)

# Removing Data – 2

To increase the location accuracy defining data with with very little new information (diagonal elements of the Information Density Matrix) were systematically removed during the last inversion steps:

In this case "well" located are:

1) smaller than 0.5% of the maximum diagonal element

242 / 1048 = **23.09**% of all earthquakes (ref: 18.72%)
184 / 583 = **31.56**% of all explosions (ref: 24.96%)

2) smaller than 1.0% of the maximum diagonal element

71 / 325 = **21.78**% of all earthquakes (ref: 18.72%)
94 / 287 = **32.75**% of all explosions (ref: 24.96%)

# Conclusions – 1

To achieve better locations, the tests show a preference for :

- AK135 (over all and for "S")
- specific corrections for local structures (station corrections, reflection point corrections)
- removing in a late inversion stage the data set for bad or un-informative entries
- a combined usage of surface and core reflections
- usage of double-sided uncertainties

# Conclusions – 2

To achieve better locations, the tests show no(!) preference for :

- a general usage of PKP-type onsets
- a general usage of core reflections