Focal Mechanism Framework in Antelope

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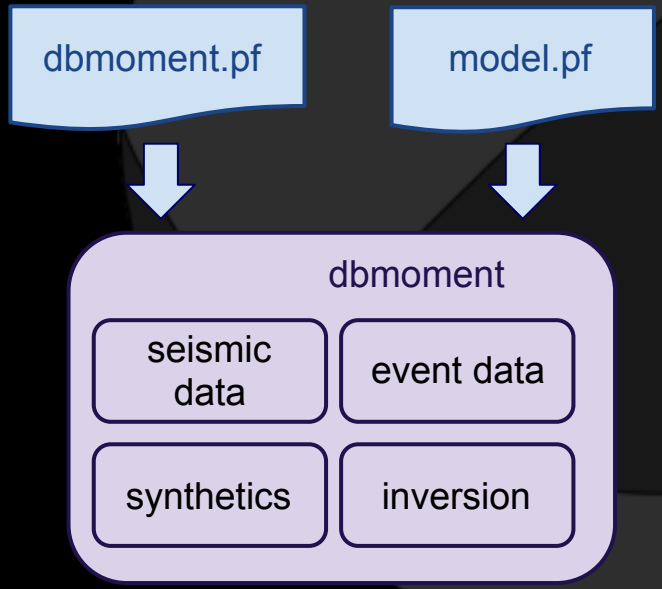
Introduction

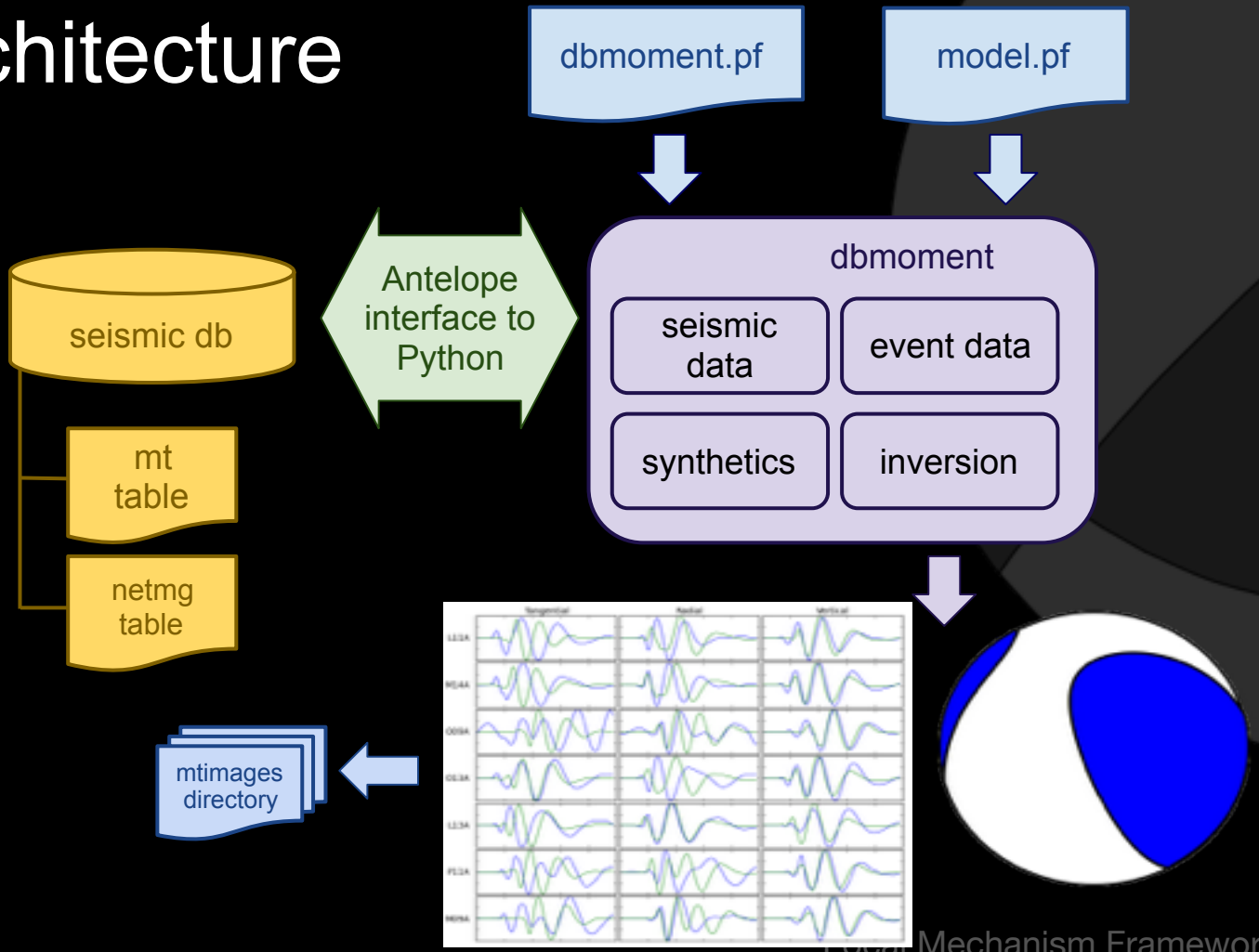
The time domain seismic moment tensor inversion software package written by Dreger has been packaged for inclusion into the Antelope Environmental Monitoring System. The new infrastructure was written natively in Python language.

Architecture

Internally, our code has been designed to be as modular as possible. The configuration parameters got consolidated and simplified. Unavoidably every seismic region will require a dedicated velocity model.



Architecture



Database Requirements

The code requires some information about the stations, the event(s) that will be processed, and the actual data files. The list of tables that are required by the code:

- ***arrival***
- ***assoc***
- ***event*** (if running with the -e flag)
- ***instrument***
- ***netmag***
- ***origin***
- ***sensor***
- ***site***
- ***wfdisc***

The code will later update the ***netmag*** and will update (or create) an ***mt*** table with results. There will be a directory with synthetic traces with a different ***wfdisc*** table than the original data.

2-D Models Archive

/opt/antelope/5.6/contrib/data/dbmoment_models/

ALEUT_MODEL.pf
SCAK_MODEL.pf
gil7_model.pf
PDS1_MODEL.pf
SOCAL_MODEL.pf

2-D Models Format

```
name            SOCAL_MODEL
decay           6.0
start_frequency 1
end_frequency   512
samplerate      4
cmax            10000
c1              30
c2              2.9
cmin            2.5
velocity_reduction  10
distance_min    0
distance_max    500
distance_step   5
# MODEL PARAMETERS
# Layer: thickness(km), p-velocity(km/s), s-velocity(km/s), density(g/cc), Q-alpha, Q-beta
model &Literal{
        5.5     5.5     3.18    2.4     600     300
        8.0     6.3     3.64    2.67    600     300
        19.0    6.7     3.87    2.8     600     300
        400.0   7.8     4.5     3.3     600     300
}
```

Execution

dbmoment [-xvd] [-m MODEL.pf] [-c min_variance] [-p pfname] [-z 'STA1:5,STA2:5'] [-s select] [-r reject] database ORID

dbmoment -e [-xvd] [-m MODEL.pf] [-c min_variance] [-p pfname] [-z 'STA1:5,STA2:5'] [-s select] [-r reject] database **EVID**

Command line syntax:

-m SCAK_MODEL.pf

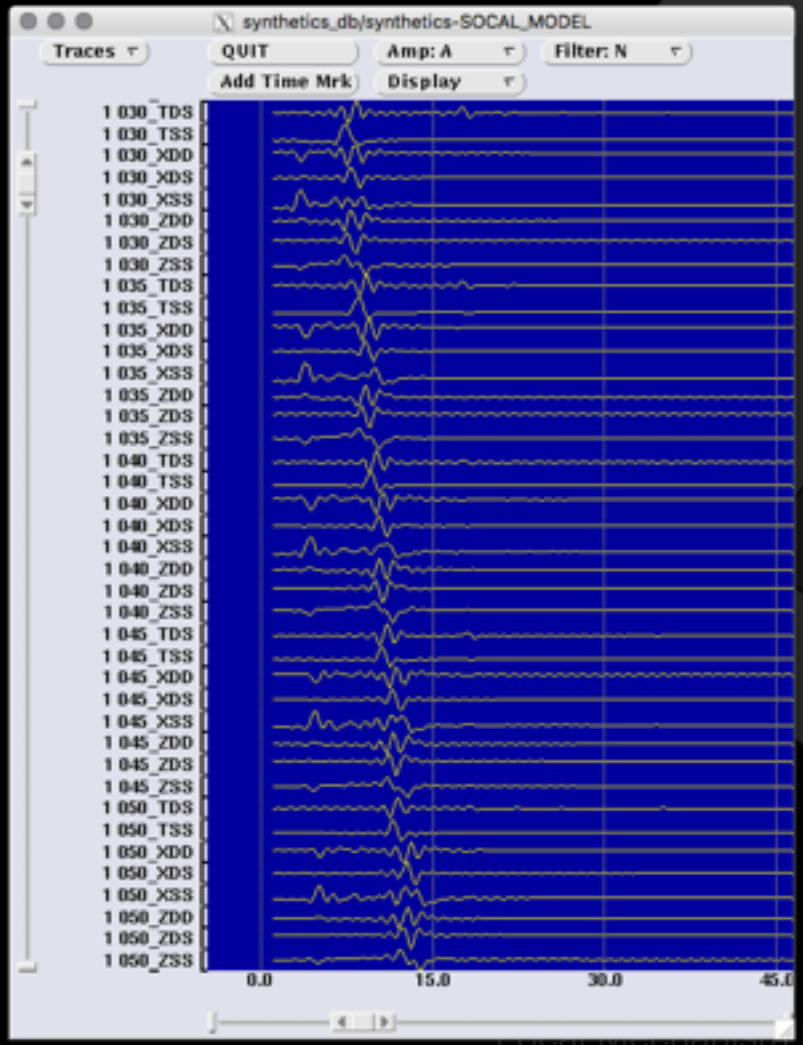
-f 'BW 0.02 4 0.05 4'

-s 'STA1|STA2|STA3'

-r 'STA1|STA2|STA3'

-z 'STA1:3,STA2:3,STA3:5'

Synthetics



Framework in Antelope

Output

Focal Mechanism Framework in Antelope

Examples

system:~ reyes$ **dbmoment_run_example**

RUN DBMOMENT DEMO

ANTELOPE VERSION: /opt/antelope/5.6

CHANGE TO DIRECTORY: [/opt/antelope/5.6/contrib/example/dbmoment]

REMOVE TEMP FOLDER: [/opt/antelope/5.6/contrib/example/dbmoment/.dbmoment]

REMOVE TEMP FOLDER: [/opt/antelope/5.6/contrib/example/dbmoment/synthetics_db]

START EXAMPLE 1

dbmoment -v EXAMPLE_1/example_1 1
…

START EXAMPLE 2

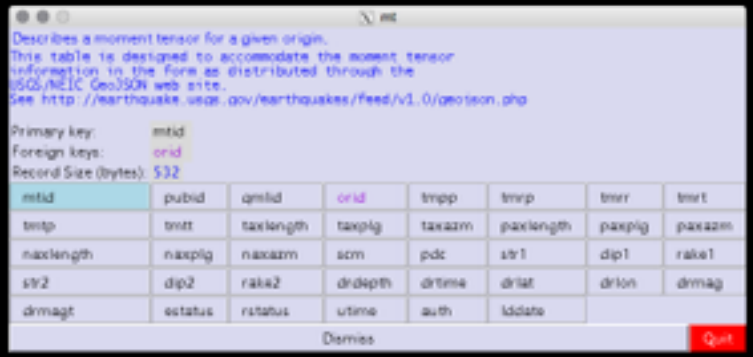
dbmoment -v EXAMPLE_2/example_2 1
…

Output

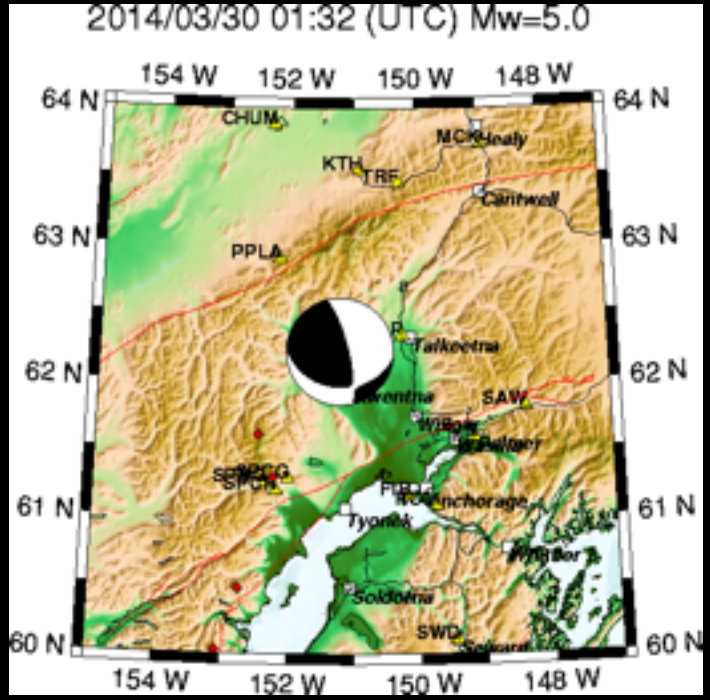
Focal Mechanism Framework in Antelope

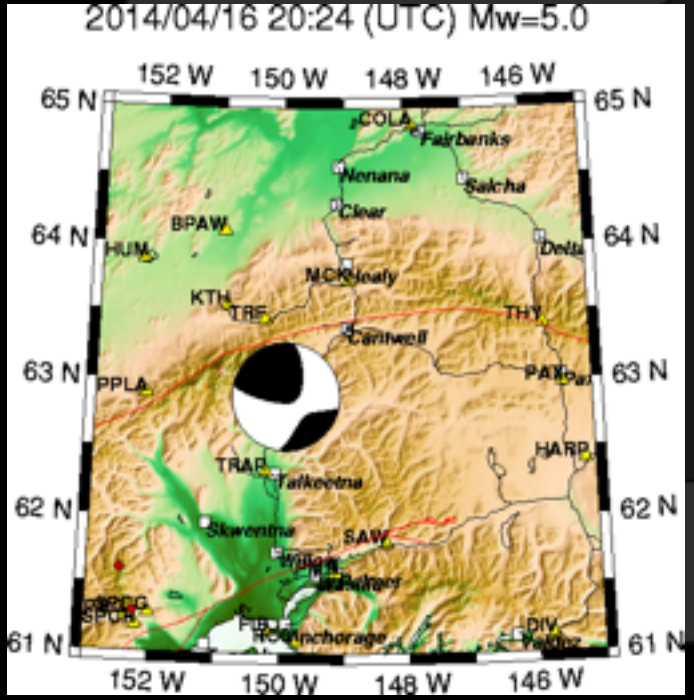
Databases and Maps

qtmapevents example_1

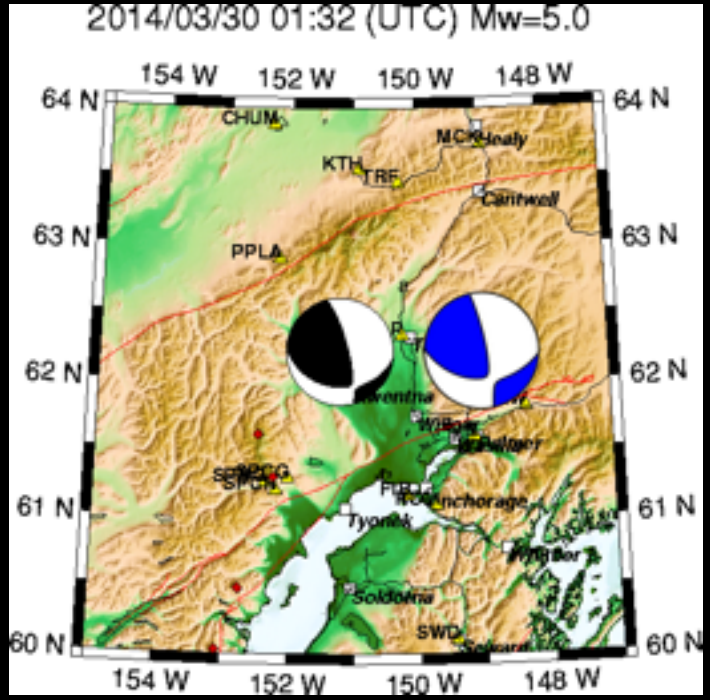


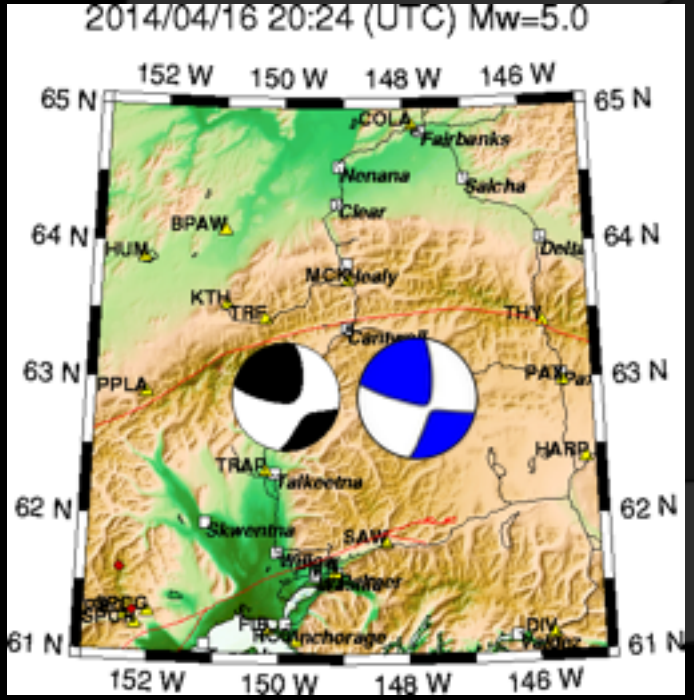
Comparisons ALASKA





Comparisons ALASKA



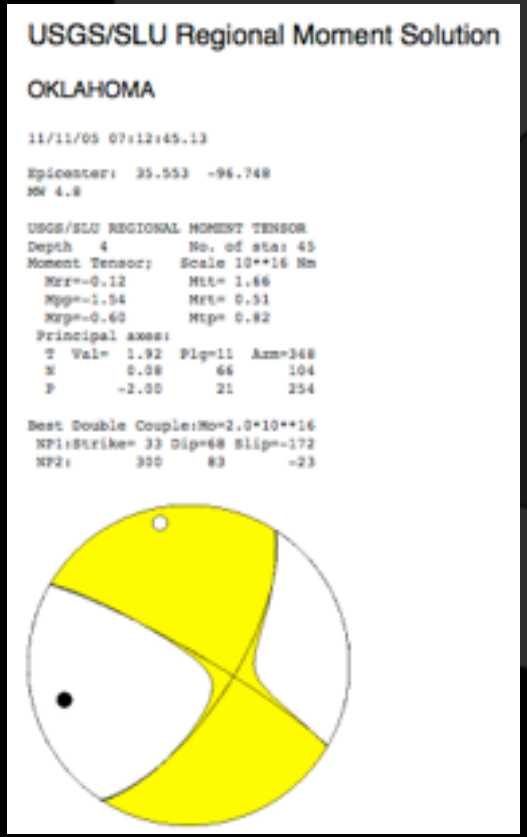


Comparisons ALASKA

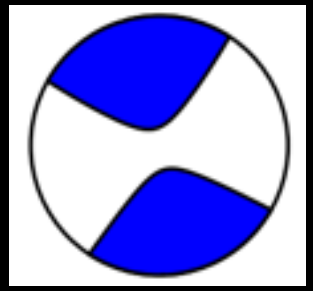
Focal Mechanism Framework in Antelope

Comparisons TransportableArray

Oklahoma 4.7
2011-11-05



Focal Mechanism Framework in Antelope



Mw: 4.9
Strike:[31, 121] Rake:[178, 2] Dip:[88, 88]
Pdc: 78 %
Pclvd: 22 %
VAR: 1.143e-08
VarRed: 9.097e+01
Var/Pdc: 1.464e-10
Mo: 2.27856e+23
Mxx:2149.965 Mxy:-1041.353 Mxz:142.987
Myy:-1894.060 Myz:-40.750 Mzz:-255.905

USGS/SLU Regional Moment Solution

OKLAHOMA

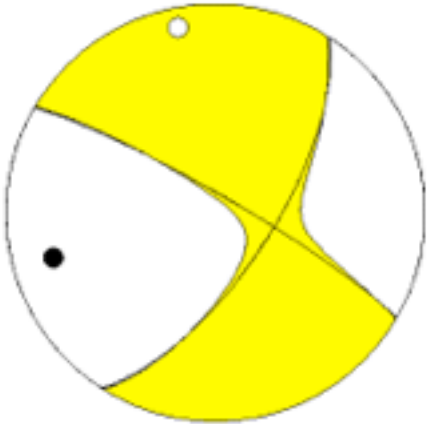
11/11/05 07:12:45.13

Epicenter: 35.553 -96.748
MW 4.8

USGS/SLU REGIONAL MOMENT TENSOR
Depth 4 No. of sta: 45
Moment Tensor; Scale 10**16 Nm
Mrr=-0.12 Mtt= 1.66
Mpp=-1.54 Mrt= 0.51
Mrp=-0.60 Mtp= 0.82
Principal axes:

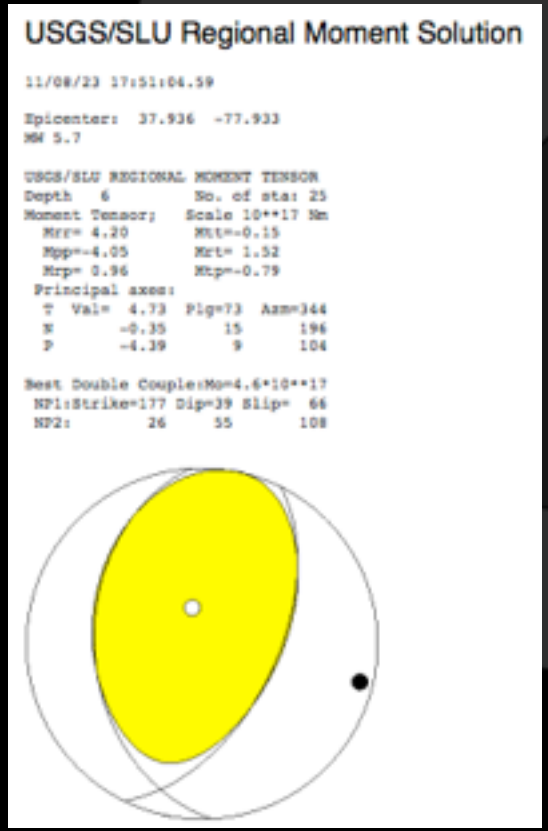
	Val=	Plg=	Azm=
T	1.92	11	348
N	0.08	66	104
P	-2.00	21	254

Best Double Couple:Mo=2.0*10**16
NP1:Strike= 33 Dip=68 Slip=-172
NP2: 300 83 -23



Comparisons TransportableArray

Virginia 5.7
2011-08-23



Focal Mechanism Framework in Antelope

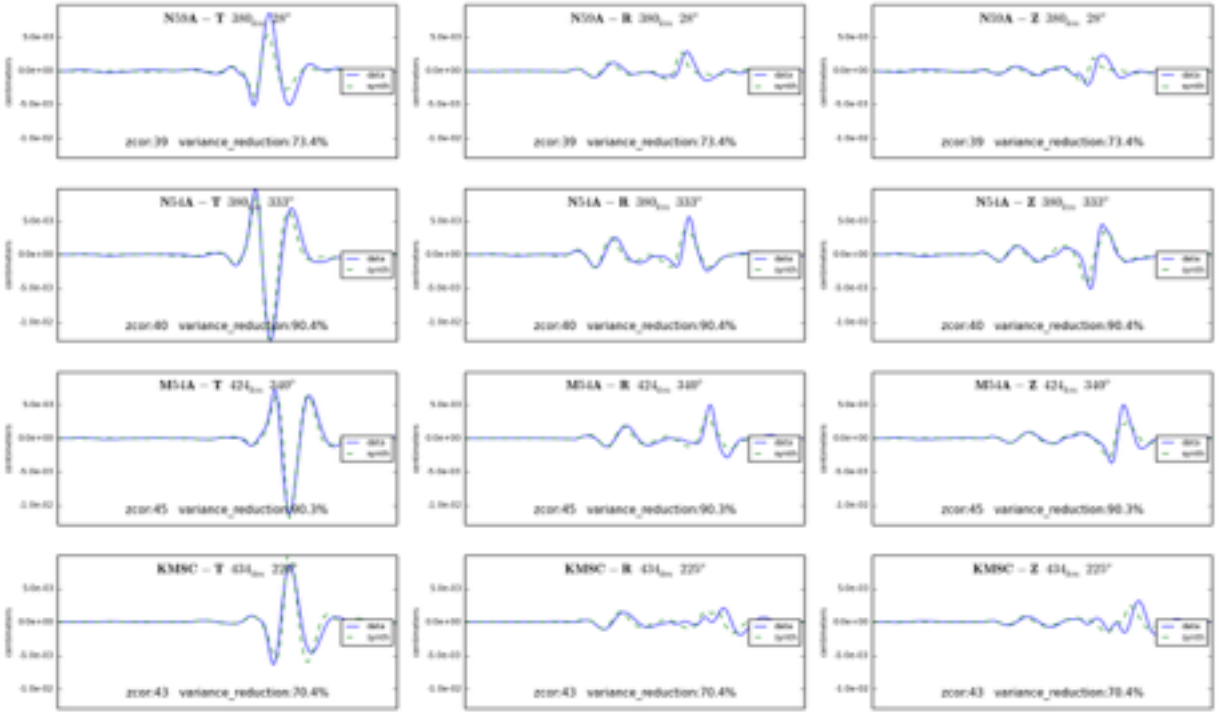
5.7 Mw 8/23/2011 17:51:04.590

8/23/2011 17:51:04.590

ID: 265866 Quality: 4

Location:
Lat: 37.936
Lon: -77.933
Depth: 6 km
Filter: BW 0.02 4 0.05 4
Model: SOCAL_MODEL

Mw: 5.7
Strike:[26, 185] Rake:[105, 75] Dip:[47, 45]
Pdc: 98 %
Pclvd: 2 %
VMR: 3.666e-07
VarRed: 8.429e+01
Var/Pdc: 3.733e-09
Mo: 3.74606e+24
Mxx:-1163.780 Mxy:10683.607 Mxz:7024.665
Myy:-34792.345 Myz:67.655 Mzz:35956.125



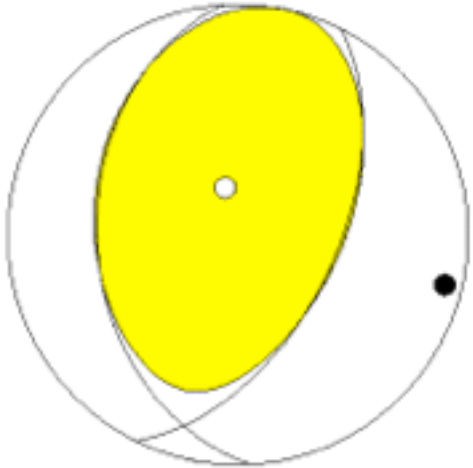
USGS/SLU Regional Moment Solutio

11/08/23 17:51:04.59

Epicenter: 37.936 -77.933
MW 5.7

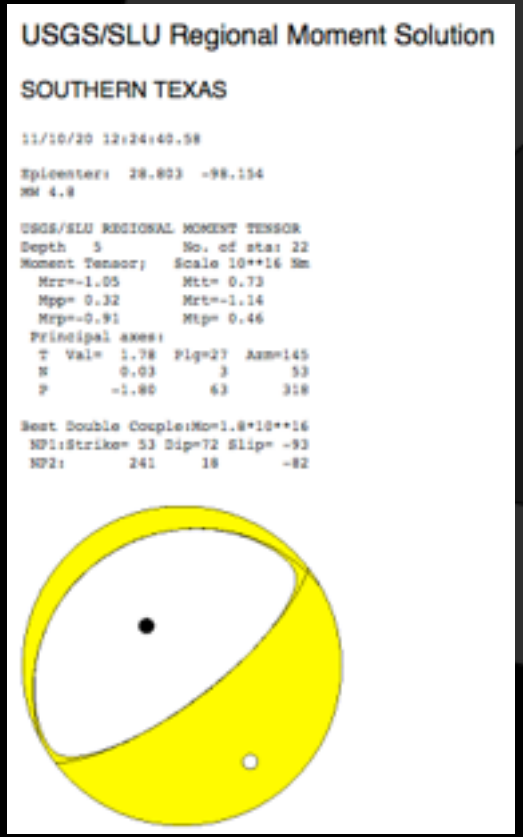
USGS/SLU REGIONAL MOMENT TENSOR
Depth 6 No. of sta: 25
Moment Tensor; Scale 10**17 Nm
Mrr= 4.20 Mtt=-0.15
Mpp=-4.05 Mrt= 1.52
Mrp= 0.96 Mtp=-0.79
Principal axes:
T Val= 4.73 Plg=73 Azm=344
N -0.35 15 196
P -4.39 9 104

Best Double Couple:Mo=4.6*10**17
NP1:Strike=177 Dip=39 Slip= 66
NP2: 26 55 108



Comparisons TransportableArray

Southern Texas 4.8
2011-10-20


USGS/SLU Regional Moment Solution

SOUTHERN TEXAS

11/10/20 12:24:40.58

Epicenter: 28.803 -98.154
MW 4.8

USGS/SLU REGIONAL MOMENT TENSOR
Depth 5 No. of sta: 22
Moment Tensor; Scale 10**16 Nm
Mrr=-1.05 Mtt= 0.73
Mpp= 0.32 Mrt=-1.14
Mrp=-0.91 Mtp= 0.46
Principal axes:
T Val= 1.78 Plg=27 Azm=145
N 0.03 3 53
P -1.80 63 318

Best Double Couple:Mo=1.8*10**16
NP1:Strike= 53 Dip=72 Slip= -93
NP2: 241 18 -82

Focal Mechanism Framework in Antelope

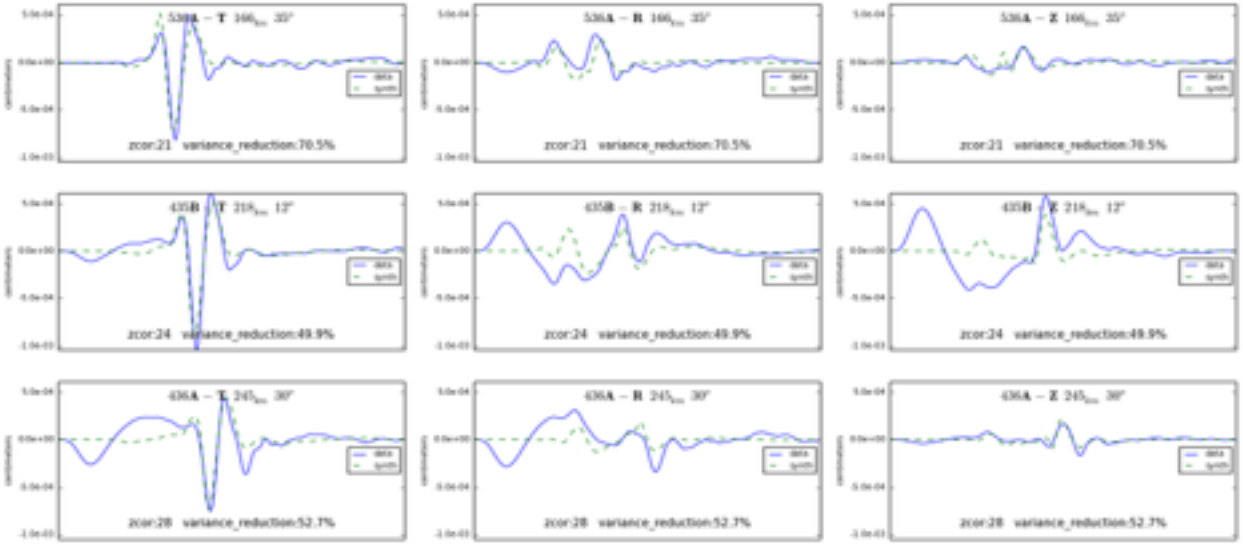
4.7 Mw 10/20/2011 12:24:41.600

10/20/2011 12:24:41.600

ID: 267274 Quality: 2

Location:
Lat: 28.865
Lon: -98.079
Depth: 5 km
Filter: BW 0.01 4 0.05 4
Model: SOCAL_MODEL

Mw: 4.7
Strike:[244, 53] Rake:[-84, -99] Dip:[57, 33]
Pdc: 88 %
Pclvd: 12 %
VAR: 8.725e-09
VarRed: 5.379e+01
VarPdc: 9.961e-11
Mo: 1.39514e+23
Mxx:943.740 Mxy:-629.896 Mxz:537.164
Myy:280.062 Myz:-183.567 Mzz:-1223.802



USGS/SLU Regional Moment Solution

SOUTHERN TEXAS

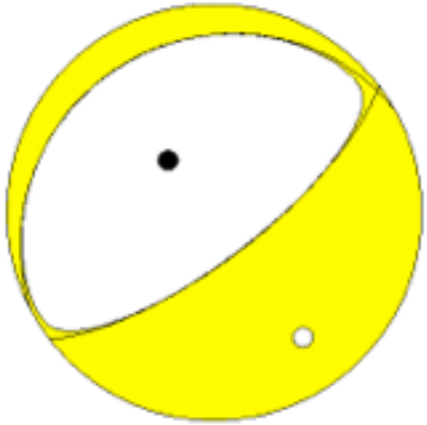
11/10/20 12:24:40.58

Epicenter: 28.803 -98.154
MW 4.8

USGS/SLU REGIONAL MOMENT TENSOR
Depth 5 No. of sta: 22
Moment Tensor; Scale 10**16 Nm
Mrr=-1.05 Mtt= 0.73
Mpp= 0.32 Mrt=-1.14
Mrp=-0.91 Mtp= 0.46
Principal axes:

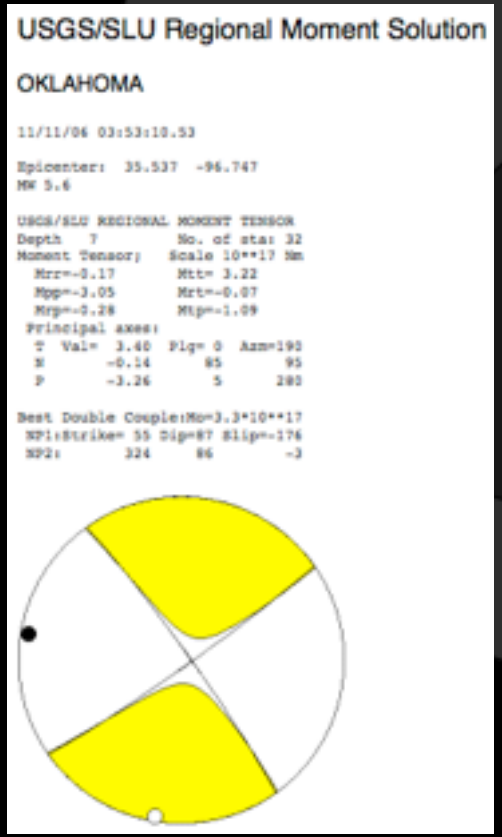
T	Val= 1.78	Plg=27	Azm=145
N	0.03	3	53
P	-1.80	63	318

Best Double Couple:Mo=1.8*10**16
NP1:Strike= 53 Dip=72 Slip= -93
NP2: 241 18 -82

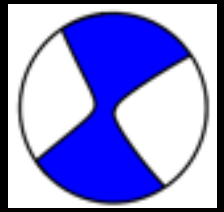


Comparisons TransportableArray

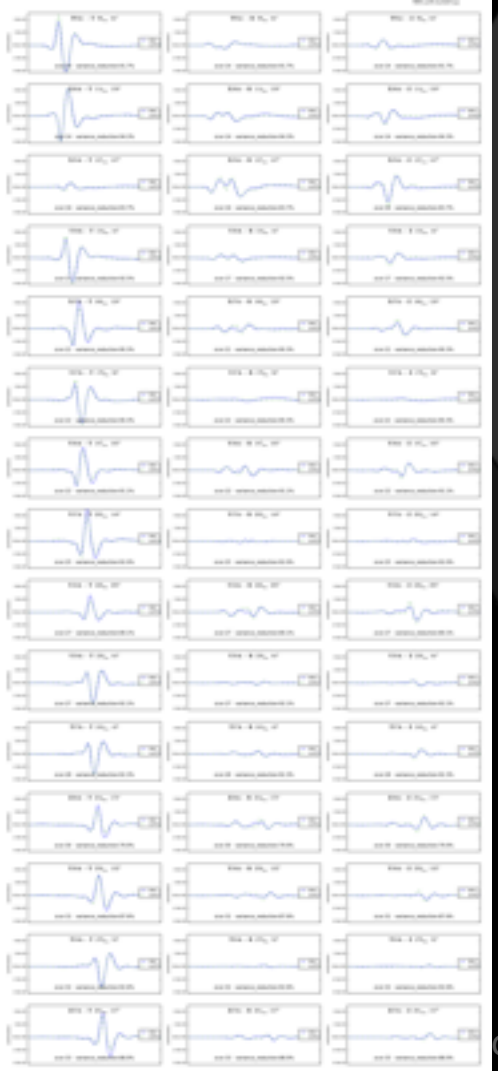
Oklahoma 5.6
2011-11-06



Focal Mechanism Framework in Antelope



Mw: 5.7
Strike:[237, 146] Rake:[-171, -5] Dip:[85, 81]
Pdc: 91 %
Pclvd: 9 %
VAR: 2.568e-06
VarRed: 8.958e+01
Var/Pdc: 2.810e-08
Mo: 3.63997e+24
Mxx:32795.212 Mxy:13642.491 Mxz:3110.743
Myy:-33245.207 Myz:-6370.573 Mzz:449.995



USGS/SLU Regional Moment Solution

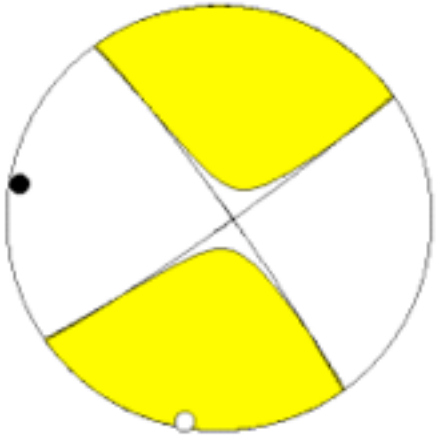
OKLAHOMA

```
11/11/06 03:53:10.53

Epicenter:  35.537  -96.747
MW 5.6

USGS/SLU REGIONAL MOMENT TENSOR
Depth    7          No. of sta: 32
Moment Tensor;   Scale 10**17 Nm
  Mrr=-0.17        Mtt= 3.22
  Mpp=-3.05        Mrt=-0.07
  Mrp=-0.28        Mtp=-1.09
 Principal axes:
  T  Val=  3.40  Plg= 0  Azm=190
  N       -0.14      85       95
  P       -3.26       5      280

Best Double Couple:Mo=3.3*10**17
 NP1:Strike= 55 Dip=87 Slip=-176
 NP2:       324     86        -3
```



Comparisons ANZA

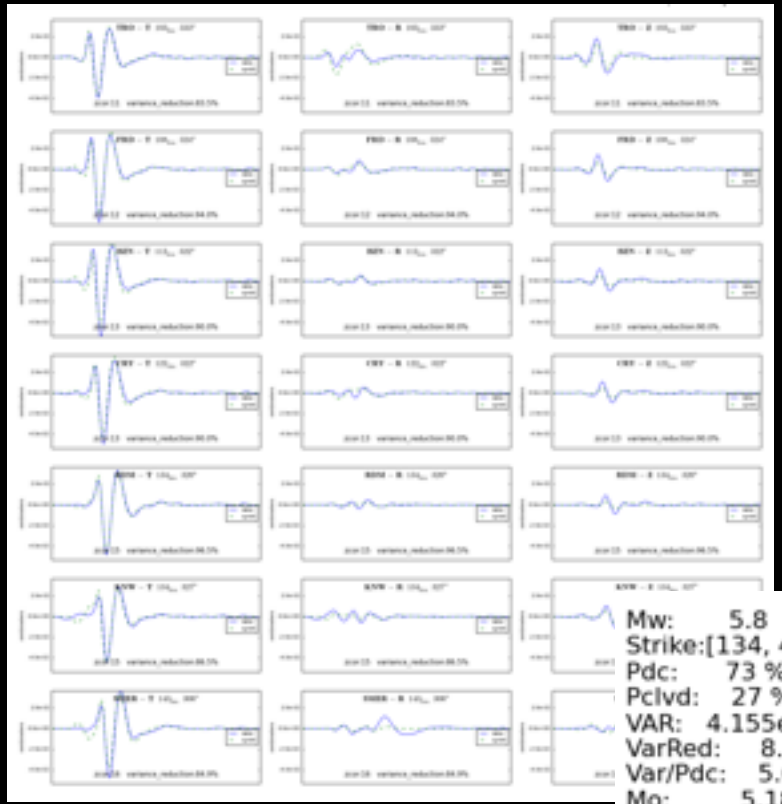
El Centro 5.7
2010-06-15

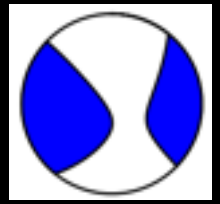
Global CMT Project Moment Tensor Solution

June 15, 2010, SOUTHERN CALIFORNIA, MW=5.4

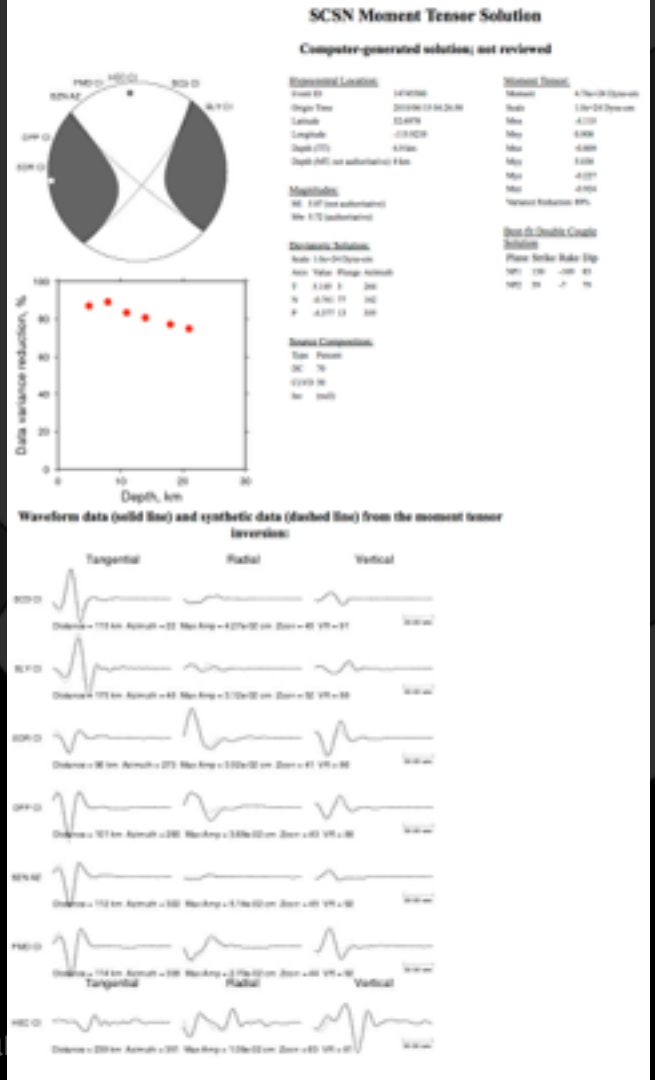
Goran Ekstrom

CENTROID-MOMENT-TENSOR SOLUTION
GCMT EVENT: C201006150426A
DATA: IU CU II IC G GE
L.P.BODY WAVES: 938, 1RSC, T= 40
MANTLE WAVES: 798, 9SC, T=125
SURFACE WAVES: 1118, 24SC, T= 50
TIMESTAMP: Q-2010061516200J
CENTROID LOCATION:
ORIGIN TIME: 04:27:01.1 0.1
LAT:32.71N 0.01;LON:116.00W 0.01
DEP: 13.5 0.4;TRIANG HDUR: 1.9
MOMENT TENSOR: SCALE 10**24 D-CM
RR=-1.810 0.048; TT=-3.040 0.053
FF= 4.850 0.055; RT=-0.218 0.189
RF= 0.664 0.105; TF=-1.140 0.043
PRINCIPAL AXES:
1.(T) VAL= 7.008;PLG= 4;AZM=265
2.(N) -1.852; 85; 117
3.(P) -5.156; 3; 355
BEST DBLE.COUPLE:M0= 6.04*10**24
NP1: STRIKE= 40;DIP=85;SLIP= 1
NP2: STRIKE=310;DIP=89;SLIP= 175





Mw: 5.8
Strike:[134, 41] Rake:[-148, -4] Dip:[86, 58]
Pdc: 73 %
Pclvd: 27 %
VAR: 4.155e-06
VarRed: 8.955e+01
Var/Pdc: 5.656e-08
Mo: 5.18957e+24
Mxx:-40074.086 Mxy:5581.297 Mxz:-18011.894
Myy:47737.180 Myz:-20165.020 Mzz:-7663.094



SCSN Moment Tensor Solution

Computer-generated solution; not reviewed

Data variance reduction, %

Depth, km

Waveform data (solid line) and synthetic data (dashed line) from the moment tensor inversion:

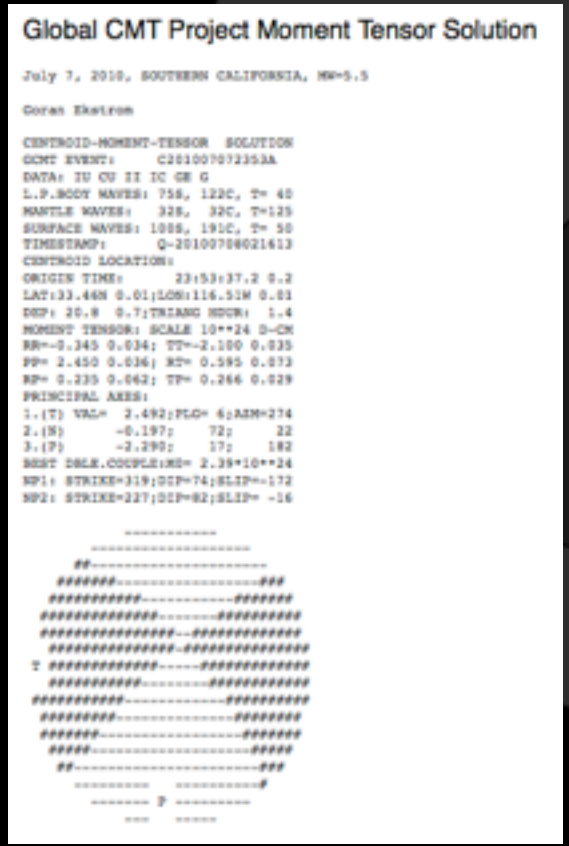
Tangential Radial Vertical

Tangential Radial Vertical

Focal Mecha

Comparisons ANZA

Borrego 5.4
2010-07-07

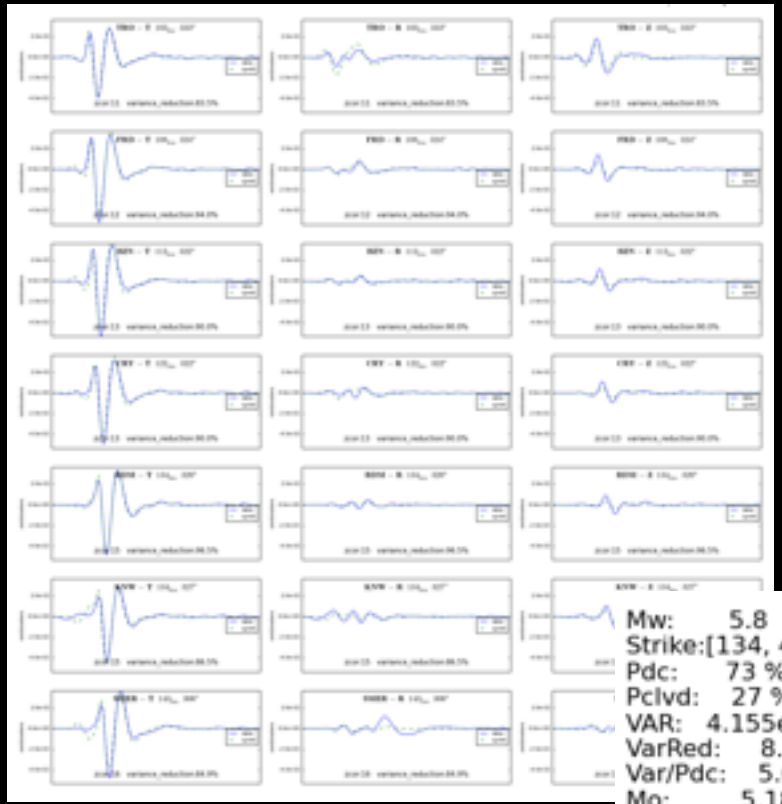


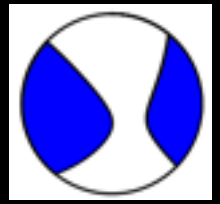
Global CMT Project Moment Tensor Solution

July 7, 2010, SOUTHERN CALIFORNIA, MW=5.5

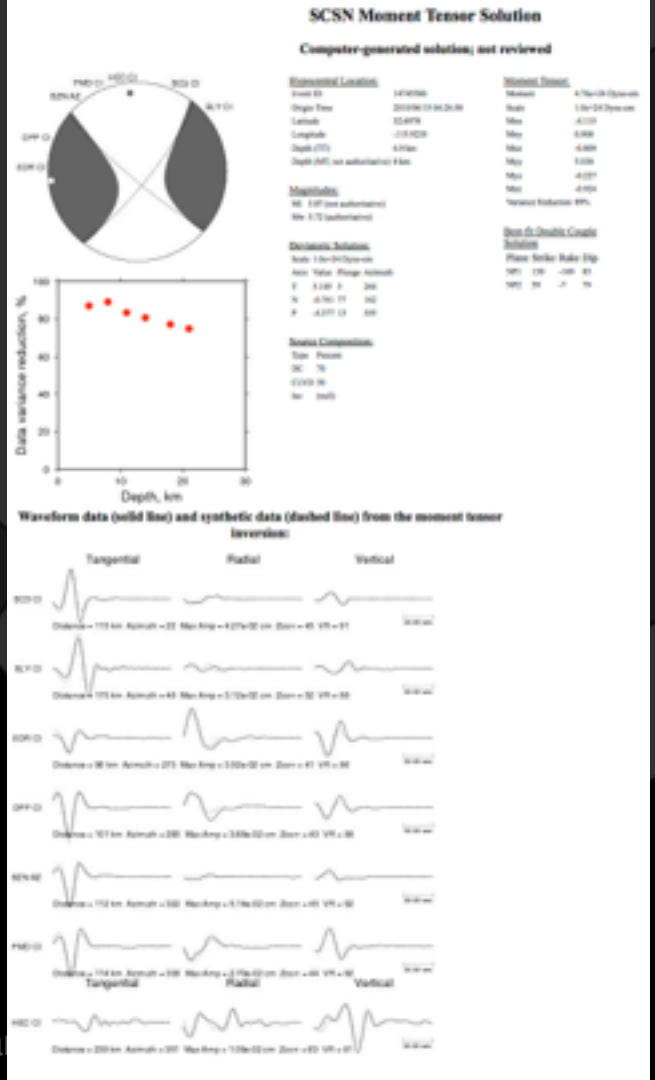
Goran Ekstrom

CENTROID-MOMENT-TENSOR SOLUTION
GCMT EVENT: C201007072353A
DATA: IU CU II IC GE G
L.P.BODY WAVES: 75S, 122C, T= 40
MANTLE WAVES: 32S, 32C, T=125
SURFACE WAVES: 108S, 191C, T= 50
TIMESTAMP: Q-2010070802161J
CENTROID LOCATION:
ORIGIN TIME: 23:53:37.2 0.2
LAT:33.46N 0.01;LON:116.51W 0.01
DEP: 20.8 0.7;TRIANG HDUR: 1.4
MOMENT TENSOR: SCALE 10**24 D-CM
RR=-0.345 0.034; TT=-2.100 0.035
PP= 2.450 0.036; RT= 0.595 0.073
RP= 0.235 0.062; TP= 0.266 0.029
PRINCIPAL AXES:
1.(T) VAL= 2.492;PLG= 6;AZM=274
2.(N) -0.197; 72; 22
3.(P) -2.293; 17; 182
BEST DBLE.COUPLE:MO= 2.39*10**24
NP1: STRIKE=319;DIP=74;SLIP=-172
NP2: STRIKE=227;DIP=82;SLIP= -16





Mw: 5.8
Strike:[134, 41] Rake:[-148, -4] Dip:[86, 58]
Pdc: 73 %
Pclvd: 27 %
VAR: 4.155e-06
VarRed: 8.955e+01
Var/Pdc: 5.656e-08
Mo: 5.18957e+24
Mxx:-40074.086 Mxy:5581.297 Mxz:-18011.894
Myy:47737.180 Myz:-20165.020 Mzz:-7663.094



SCSN Moment Tensor Solution

Computer-generated solution; not reviewed

Data variance reduction, %

Depth, km

Waveform data (solid line) and synthetic data (dashed line) from the moment tensor inversion:

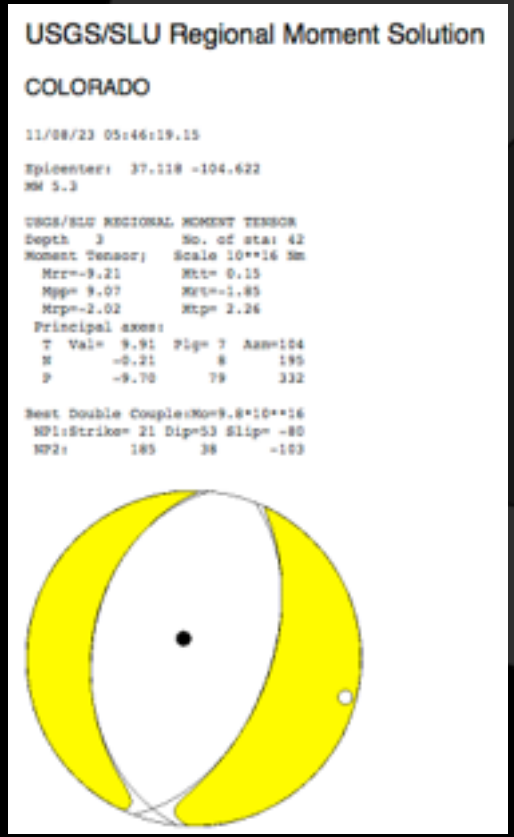
Tangential Radial Vertical

Tangential Radial Vertical

Focal Mecha

Comparisons TransportableArray

Colorado 5.3
2011-08-23



Focal Mechanism Framework in Antelope

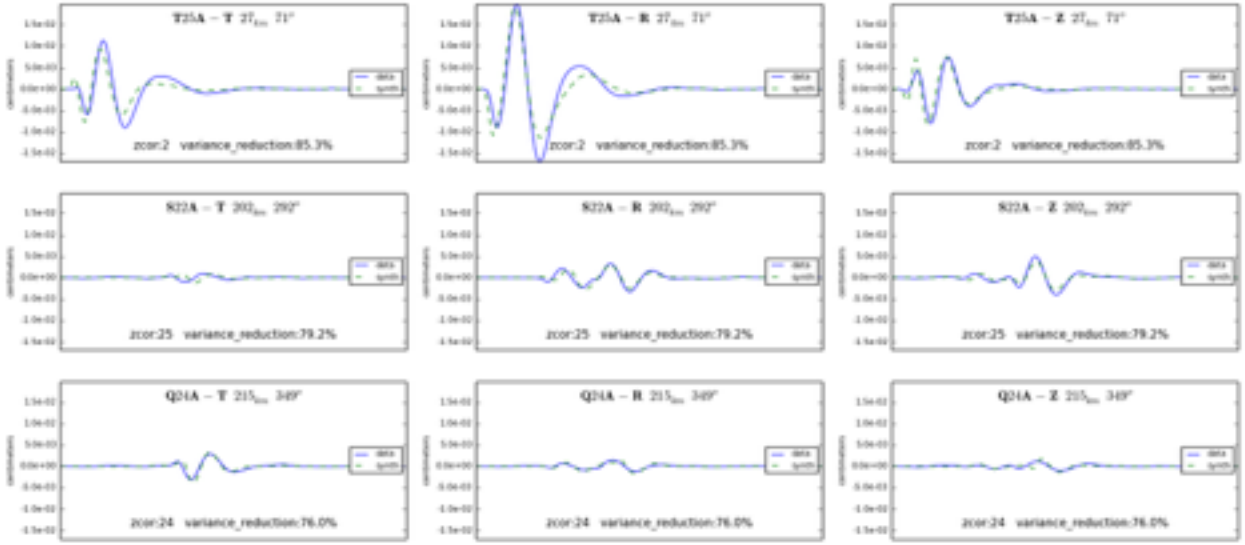
5.3 Mw 8/23/2011 5:46:18.250

8/23/2011 5:46:18.250

ID: 265845 Quality: 4

Location:
Lat: 37.063
Lon: -104.701
Depth: 4 km
Filter: BW 0.02 4 0.05 4
Model: SOCAL_MODEL

Mw: 5.3
Strike:[354, 216] Rake:[-118, -56] Dip:[55, 44]
Pdc: 54 %
Pclvd: 46 %
VAR: 7.562e-07
VarRed: 8.255e+01
Var/Pdc: 1.391e-08
Mo: 1.06183e+24
Mxx:1214.061 Mxy:-2379.114 Mxz:4634.829
Myy:8356.645 Myz:3124.339 Mzz:-9570.706



Moment tensor computed using the MMI-inv package developed by Douglas Dreger of the Berkeley Seismological Laboratory, and Green's functions were computed using the FKRPROG software developed by Chandan Saikia with URS.

Antelope's implementation of code by "Juan Reyes" <reyes1108@gmail.com>

USGS/SLU Regional Moment Solution

COLORADO

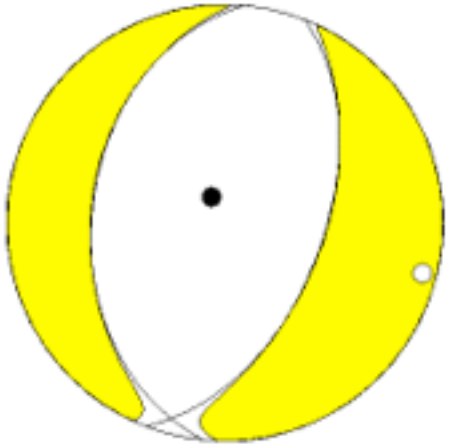
11/08/23 05:46:19.15

Epicenter: 37.118 -104.622
MW 5.3

USGS/SLU REGIONAL MOMENT TENSOR
Depth 3 No. of sta: 42
Moment Tensor; Scale 10**16 Nm
Mrr=-9.21 Mtt= 0.15
Mpp= 9.07 Mrt=-1.85
Mrp=-2.02 Mtp= 2.26
Principal axes:

	Val=	Plg=	Azm=
T	9.91	7	104
N	-0.21	8	195
P	-9.70	79	332

Best Double Couple:Mo=9.8*10**16
NP1:Strike= 21 Dip=53 Slip= -80
NP2: 185 38 -103



Q & A