Advanced School on Non-Linear Dynamics and Earthquake Prediction

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Exercises for better understanding the M8 algorithm

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Exercises for better understanding the M8 algorithm

Exercise 1:
Seven functions of the M8 algorithm are defined according to the following listing –

		Magnitudes M and MM				Intervals				
No.	Func	m	mm	a	aa	s/dt	u/dt	To	beta	d
F1:	n	act		10		12				
F2:	n	act		20		12				
F3:	l	act		10		12		1967		
F4:	l	act		20		12		1967		
F5:	s	act	shf	10	0.50	12			0.46	0.67
F6:	s	act	shf	20	0.50	12			0.46	0.67
F7:	b	shf	shf	2.00	0.20	2				

Form the four groups of functions so that the members of each group differ by a choice of numerical parameters only.

> The functions vote for the declaration of a warning or *time of increased probability* (TIP) for an earthquake of magnitude M_0+ in the circle of investigation (CI). Any function cast a vote for a TIP when it is *anomalously large*, i.e., in the top Q% of its empiric range (for `b`, Q% = 25%; for other functions, Q% = 10%).

Exercise 2:
In the two Tables below mark anomalously large values of the M8 functions.

Exercise 3:
In the two Tables below fill the column of votes `g:h` counting the number of groups of the functions, which members voted sometime in the preceding three years (`g`) and the number of functions voted sometime in the preceding three years (`h`).

> A time of increased probability is declared for the CI, when `g` equals 4 and `h` is greater than 5 in two successive six-month evaluations. Once a TIP is declared it lasts for five years from the time of declaration.

Exercise 4:
In the two Tables below determine the TIP's, if any.

Tables of the M8 functions in the two CI's

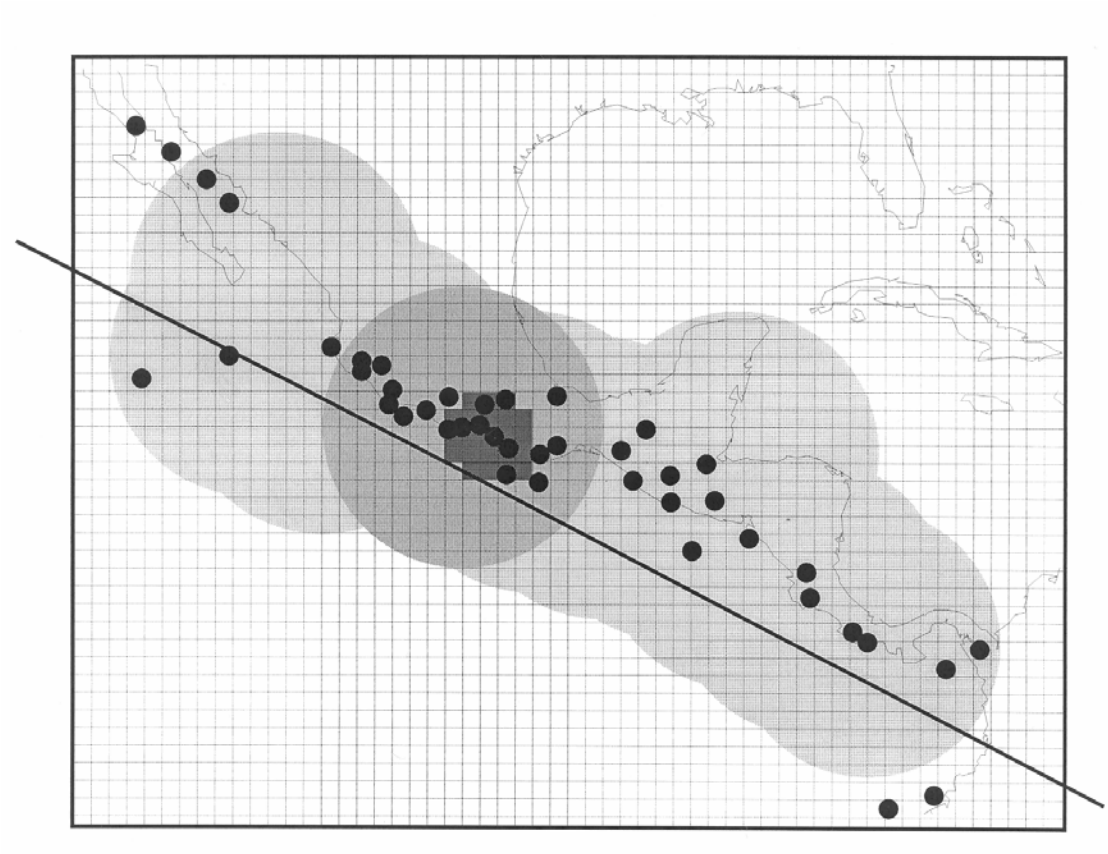
Region No. 7 -1.00 100.00

g:h	Mmax	Date	F1	F2	F3	F4	F5	F6	F7
	6.2	1979/07/03	74	113	0	20	1638	1540	1
	6.6	1980/01/01	75	116	3	24	1726	1602	2
	5.9	1980/07/02	72	113	-2	17	1721	1591	2
	6.3	1981/01/01	71	109	-4	7	1600	1503	2
	5.7	1981/07/02	71	109	-3	7	1583	1488	2
	5.4	1982/01/01	71	112	-2	12	1481	1408	-
	5.9	1982/07/02	76	119	4	19	1419	1368	-
	6.1	1983/01/01	76	121	5	23	1447	1389	1
	5.6	1983/07/03	76	127	5	28	1435	1376	1
	5.6	1984/01/01	77	129	6	30	1421	1366	-
	5.8	1984/07/02	76	130	5	30	1384	1336	-
	7.4	1985/01/01	78	139	8	40	1496	1414	2
	5.4	1985/07/02	70	136	-3	33	1441	1359	2
	5.2	1986/01/01	67	129	-6	26	1333	1283	-
	5.4	1986/07/02	68	129	-5	25	1321	1276	-
	5.4	1987/01/01	68	131	-5	26	1287	1256	-
	6.6	1987/07/03	72	136	0	31	1368	1317	5
	5.2	1988/01/01	69	132	-3	27	1361	1308	5
	5.5	1988/07/02	68	132	-5	24	1336	1291	-
	5.5	1989/01/01	67	136	-5	29	1312	1274	-
	5.8	1989/07/02	64	131	-8	21	1297	1260	-
	5.6	1990/01/01	65	136	-7	26	1304	1270	-
	5.4	1990/07/02	63	134	-9	23	1288	1256	-
	6.8	1991/01/01	69	135	-3	22	1242	1237	6
	6.2	1991/07/03	73	140	0	26	1301	1283	6
	5.8	1992/01/01	78	151	6	39	1336	1314	0
	6.4	1992/07/02	80	158	8	46	1387	1351	3
	5.9	1993/01/01	81	152	9	39	1397	1356	3
	6.2	1993/07/02	76	149	3	35	1356	1319	0
	6.5	1994/01/01	83	155	11	42	1456	1394	1
	7.0	1994/07/02	81	149	9	34	1574	1468	9
	6.2	1995/01/01	91	157	19	42	1626	1524	9
	5.4	1995/07/03	92	155	21	40	1615	1518	0
	7.1	1996/01/01	93	155	22	38	1807	1653	3
	5.5	1996/07/02	90	147	19	30	1812	1656	3
	6.3	1997/01/01	84	139	12	21	1796	1634	0
	5.9	1997/07/02	79	138	6	18	1776	1600	0
	5.9	1998/01/01	80	134	7	13	1786	1618	-
	7.0	1998/07/02	72	121	-1	-1	1828	1633	1
	5.8	1999/01/01	71	124	-2	2	1836	1627	1
	5.4	1999/07/03	73	125	0	3	1788	1602	-
	6.2	2000/01/01	67	123	-7	1	1738	1544	0

Region No. 8 -3.00 101.50

g:h	Mmax	Date	F1	F2	F3	F4	F5	F6	F7
	6.2	1979/07/02	81	136	-1	30	1675	1595	1
	6.6	1980/01/01	81	136	0	29	1754	1649	2
	6.0	1980/07/01	75	131	-7	19	1752	1637	2
	6.3	1980/12/31	72	127	-10	10	1615	1538	2
	5.2	1981/07/02	67	120	-15	2	1589	1510	2
	5.4	1981/12/31	66	122	-15	6	1470	1427	-
	5.9	1982/07/02	67	127	-13	12	1498	1449	-
	6.1	1983/01/01	70	128	-7	14	1523	1471	1
	6.1	1983/07/02	74	140	-3	27	1553	1496	2
	5.6	1984/01/01	74	141	-3	28	1547	1495	2
	6.1	1984/07/01	74	142	-3	27	1519	1475	2
	7.4	1984/12/31	76	149	-1	35	1683	1588	2
	5.7	1985/07/02	73	145	-8	25	1630	1545	2
	6.6	1985/12/31	72	142	-9	22	1580	1513	12
	5.3	1986/07/02	74	138	-5	17	1555	1500	12
	5.4	1987/01/01	77	141	-1	20	1521	1481	-
	6.6	1987/07/02	82	151	5	32	1599	1543	5
	5.4	1988/01/01	82	150	6	31	1599	1542	5
	5.5	1988/07/01	83	153	7	33	1576	1529	-
	5.5	1988/12/31	79	151	4	32	1553	1508	-
	5.8	1989/07/02	73	142	-3	19	1499	1462	-
	5.4	1989/12/31	69	144	-7	21	1479	1441	-
	5.6	1990/07/02	68	140	-8	16	1453	1422	-
	5.7	1991/01/01	67	140	-10	14	1284	1315	-
	6.2	1991/07/02	67	139	-11	10	1319	1333	0
	5.8	1992/01/01	67	143	-11	16	1300	1325	0
	6.4	1992/07/01	73	152	-4	26	1378	1383	3
	5.9	1992/12/31	75	152	-2	25	1406	1407	3
	5.9	1993/07/02	70	145	-7	16	1334	1349	-
	6.5	1993/12/31	73	147	-4	19	1400	1395	0
	7.0	1994/07/02	71	139	-6	10	1523	1467	9
	5.7	1995/01/01	83	154	7	26	1562	1516	9
	5.4	1995/07/02	81	147	5	19	1547	1503	-
	7.1	1996/01/01	81	140	6	11	1669	1587	3
	5.5	1996/07/01	76	132	1	4	1664	1573	3
	5.8	1996/12/31	72	125	-2	-4	1662	1565	-
	6.4	1997/07/02	65	118	-10	-12	1666	1550	2
	5.9	1997/12/31	67	120	-8	-10	1678	1562	2
	7.0	1998/07/02	60	109	-16	-23	1714	1569	1
	5.8	1999/01/01	58	107	-19	-25	1712	1561	1
	5.8	1999/07/02	63	108	-13	-24	1693	1573	-
	6.5	2000/01/01	61	106	-15	-25	1749	1606	1

Exercise 5:
Denote μ-measure of area $A \subseteq C$ being the number, n(A), of epicenters from the sample catalog that fall into A normalized to the total, n(C), of epicenters from the same catalog that fall into the region considered C, i.e., $\mu(A) = n(A)/n(C)$.
Given CI's shaded grey in the Figure below determine the μ-measure of alerted areas of the two approximations (dark circle and darker rectangular zone for the first and the second approximations, correspondingly) using the sample catalog of epicenters (black dots), which do not repeat each other.



Areas of alert in "Central Ambrica" (light grey):
Predictions of the first (dark) and second (darker) approximations and epicenters from the sample catalog (black dots).

Exercise 5*:
Compare the estimates for the same territories in km squared.

Exercise 5:**
Compare the estimates for the projections of the same territories onto the axis of the fault zone (straight line).

Answers:

Exercise 1: F1 and F2 (n), F3 and F4 (l), F5 and F6 (s), F7 (b)

Exercise 2 and 3:

STIP 7 (-1.00: 100.00)*(1996/07/02-2001/07/02)
Strong quake: 2000/06/04 16:28 -4.72 102.09 33 8.00 in Region No. 7
Region No. 7 2001 -1.00 100.00

g:h	Mmax	Date	F1	F2	F3	F4	F5	F6	F7
	6.2	1979/07/03	74	113	0	20	1638	1540	1
	6.6	1980/01/01	75	116	3	24	1726	1602	2
	5.9	1980/07/02	72	113	-2	17	1721	1591	2
	6.3	1981/01/01	71	109	-4	7	1600	1503	2
	5.7	1981/07/02	71	109	-3	7	1583	1488	2
0:0	5.4	1982/01/01	71	112	-2	12	1481	1408	-
0:0	5.9	1982/07/02	76	119	4	19	1419	1368	-
0:0	6.1	1983/01/01	76	121	5	23	1447	1389	1
0:0	5.6	1983/07/03	76	127	5	28	1435	1376	1
0:0	5.6	1984/01/01	77	129	6	30	1421	1366	-
0:0	5.8	1984/07/02	76	130	5	30	1384	1336	-
0:0	7.4	1985/01/01	78	139	8	40	1496	1414	2
0:0	5.4	1985/07/02	70	136	-3	33	1441	1359	2
0:0	5.2	1986/01/01	67	129	-6	26	1333	1283	-
0:0	5.4	1986/07/02	68	129	-5	25	1321	1276	-
0:0	5.4	1987/01/01	68	131	-5	26	1287	1256	-
1:1	6.6	1987/07/03	72	136	0	31	1368	1317	5*
1:1	5.2	1988/01/01	69	132	-3	27	1361	1308	5*
1:1	5.5	1988/07/02	68	132	-5	24	1336	1291	-
1:1	5.5	1989/01/01	67	136	-5	29	1312	1274	-
1:1	5.8	1989/07/02	64	131	-8	21	1297	1260	-
1:1	5.6	1990/01/01	65	136	-7	26	1304	1270	-
1:1	5.4	1990/07/02	63	134	-9	23	1288	1256	-
1:1	6.8	1991/01/01	69	135	-3	22	1242	1237	6*
1:1	6.2	1991/07/03	73	140	0	26	1301	1283	6*
1:1	5.8	1992/01/01	78	151	6	39	1336	1314	0
3:3	6.4	1992/07/02	80	158*	8	46*	1387	1351	3
3:3	5.9	1993/01/01	81	152	9	39	1397	1356	3
3:3	6.2	1993/07/02	76	149	3	35	1356	1319	0
3:3	6.5	1994/01/01	83	155	11	42*	1456	1394	1
3:3	7.0	1994/07/02	81	149	9	34	1574	1468	9*
3:5	6.2	1995/01/01	91*	157*	19*	42*	1626	1524	9*
3:5	5.4	1995/07/03	92*	155	21*	40	1615	1518	0
4:7	7.1	1996/01/01	93*	155	22*	38	1807*	1653*	3
4:7	5.5	1996/07/02	90*	147	19*	30	1812*	1656*	3
***:*	6.3	1997/01/01	84	139	12	21	1796	1634*	0
***:*	5.9	1997/07/02	79	138	6	18	1776	1600	0
***:*	5.9	1998/01/01	80	134	7	13	1786	1618	-
***:*	7.0	1998/07/02	72	121	-1	-1	1828*	1633*	1
3:4	5.8	1999/01/01	71	124	-2	2	1836*	1627	1
1:2	5.4	1999/07/03	73	125	0	3	1788	1602	-
1:2	6.2	2000/01/01	67	123	-7	1	1738	1544	0
1:2	8.0	2000/07/02	64	122	-9	0	1609	1446	0
1:2	6.0	2001/01/01	53	109	-22	-14	1576	1388	0
1:1	5.9	2001/07/02	54	111	-20	-12	1600	1404	0
0:0	5.1	2002/01/01	48	102	-27	-22	1297	1204	-
0:0	5.8	2002/07/02	50	106	-24	-16	1307	1217	-
1:1	7.6	2003/01/01	47	99	-27	-23	1254	1171	21*
1:1	5.7	2003/07/03	45	89	-28	-34	1251	1165	21*

Strong quake: 2000/06/04 16:28 -4.72 102.09 33 8.00 in Region No. 8

Region No. 8 2003 -3.00 101.50

g:h	Mmax	Date	F1	F2	F3	F4	F5	F6	F7
	6.2	1979/07/02	81	136	-1	30	1675	1595*	1
	6.6	1980/01/01	81	136	0	29	1754*	1649*	2
	6.0	1980/07/01	75	131	-7	19	1752*	1637*	2
	6.3	1980/12/31	72	127	-10	10	1615	1538	2
	5.2	1981/07/02	67	120	-15	2	1589	1510	2
1:2	5.4	1981/12/31	66	122	-15	6	1470	1427	-
1:2	5.9	1982/07/02	67	127	-13	12	1498	1449	-
1:2	6.1	1983/01/01	70	128	-7	14	1523	1471	1
0:0	6.1	1983/07/02	74	140	-3	27	1553	1496	2
0:0	5.6	1984/01/01	74	141	-3	28	1547	1495	2
0:0	6.1	1984/07/01	74	142	-3	27	1519	1475	2
1:1	7.4	1984/12/31	76	149	-1	35*	1683	1588	2
1:1	5.7	1985/07/02	73	145	-8	25	1630	1545	2
2:2	6.6	1985/12/31	72	142	-9	22	1580	1513	12*
2:2	5.3	1986/07/02	74	138	-5	17	1555	1500	12*
2:2	5.4	1987/01/01	77	141	-1	20	1521	1481	-
3:3	6.6	1987/07/02	82*	151	5	32*	1599	1543	5*
3:4	5.4	1988/01/01	82*	150	6*	31	1599	1542	5*
3:5	5.5	1988/07/01	83*	153*	7*	33*	1576	1529	-
3:5	5.5	1988/12/31	79	151	4	32*	1553	1508	-
3:5	5.8	1989/07/02	73	142	-3	19	1499	1462	-
3:5	5.4	1989/12/31	69	144	-7	21	1479	1441	-
3:5	5.6	1990/07/02	68	140	-8	16	1453	1422	-
2:4	5.7	1991/01/01	67	140	-10	14	1284	1315	-
1:1	6.2	1991/07/02	67	139	-11	10	1319	1333	0
0:0	5.8	1992/01/01	67	143	-11	16	1300	1325	0
1:1	6.4	1992/07/01	73	152*	-4	26	1378	1383	3
1:1	5.9	1992/12/31	75	152*	-2	25	1406	1407	3
1:1	5.9	1993/07/02	70	145	-7	16	1334	1349	-
1:1	6.5	1993/12/31	73	147	-4	19	1400	1395	0
2:2	7.0	1994/07/02	71	139	-6	10	1523	1467	9*
3:4	5.7	1995/01/01	83*	154*	7*	26	1562	1516	9*
3:4	5.4	1995/07/02	81	147	5	19	1547	1503	-
3:4	7.1	1996/01/01	81	140	6*	11	1669	1587	3
3:4	5.5	1996/07/01	76	132	1	4	1664	1573	3
3:4	5.8	1996/12/31	72	125	-2	-4	1662	1565	-
3:4	6.4	1997/07/02	65	118	-10	-12	1666	1550	2
1:1	5.9	1997/12/31	67	120	-8	-10	1678	1562	2
2:2	7.0	1998/07/02	60	109	-16	-23	1714*	1569	1
1:1	5.8	1999/01/01	58	107	-19	-25	1712	1561	1
1:1	5.8	1999/07/02	63	108	-13	-24	1693	1573	-
1:2	6.5	2000/01/01	61	106	-15	-25	1749*	1606*	1
1:2	8.0	2000/07/01	58	106	-17	-24	1614	1497	1
1:2	6.8	2000/12/31	48	89	-29	-44	1678	1510	2
1:2	5.9	2001/07/02	51	94	-25	-37	1697	1531	2
1:2	5.1	2001/12/31	48	91	-27	-39	1531	1411	-
2:3	6.9	2002/07/02	52	97	-22	-31	1660	1509	21*
1:1	5.8	2003/01/01	52	93	-22	-35	1648	1504	21*
1:1	5.7	2003/07/02	51	88	-22	-40	1612	1483	-

Exercise 4: “Successful” TIP in Region 7 centered at (-1.00; 100.00) from 1996/07/02 to 2001/07/02 and confirmed by the 2000/06/04 strong earthquake of M=8.0 with epicenter coordinated at (-4.72; 102.09).

Exercise 5: $n(C) = 40$, $n(A_1) = 20$ and $n(A_2)=8$ imply $\mu(A_1) = 50\%$ and $\mu(A_2) = 20\%$.

Exercise 5*: $n(C) = 920$ units of area, $n(A_1) = 64\pi$ and $n(A_2) = 22$ imply $\sigma(A_1) = 22\%$ and $\sigma(A_2) = 2.4\%$.

Exercise 5**: $n(C) = 48$ units of length, $n(A_1) = 14$ and $n(A_2)=5$ imply $\lambda(A_1) = 29\%$ and $\lambda(A_2) = 10\%$.