Development of an Homogenised Earthquake Catalogue for Africa

Technical Report

AFRICA HAZARD PROJECT

VERSION 1.0

November, 2016

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GEM
GLOBAL EARTHQUAKE MODEL
working together to assess risk

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1 Introduction

The creation of a state-of-art earthquake catalogue with homogenous magnitude representation (Mw) is nowadays an essential step for the development of a probabilistic hazard model. In the following, we present the processing process, main assumptions and subjective choices we made for the creation of the new Harmonised African Earthquake Catalogue (hereinafter GEM-HEAC). The catalogue is obtained by analysis and combination of publicly available earthquake information from GEM datasets and worldwide. Nonetheless, we envisage extending it by progressively including new information from local agencies, temporary networks and regions projects, as soon as they will be made publicly available from Africa partners.

2 Input Earthquake Catalogues and Bulletins

Authoritative sources of information for the creation of the GEM-HEAC are the ISC-GEM catalogue, the ISC-Reviewed bulletin, the EMEC catalogue (only for north Africa), the Harvard-GCMT bulletin and the GEM Historical Catalogue.
The four datasets have been preliminary processed by filtering out events with magnitude (any type) lower than 3.5 and with epicentre location outside a buffer region of roughly 200km (and in all cases not less than 150km) from the Africa coastline (Figure 1). Such selection is essential to expedite and to simplify the subsequent processing steps, but it is nonetheless a quite conservative choice, which does not affects the quality of the seismic hazard analysis results. It has to be noted that the seismicity of Hellenic arc and the Italian peninsula is not embraced within the selection buffer. Rationale behind this choice is to avoid overloading of the GEM-HEAC catalogues. For these regions, in fact, we will use externally calibrated source models (e.g. SHARE).

2.1 ISC-GEM

The ISC-GEM global instrumental catalogue is an improved version of the bulletin of the *International Seismological Centre* (ISC), presently spanning the period range 1900-2012. It benefits from an accurate relocation of earthquake events made using a single location technique and uniform velocity model (Bondar et al. 2015), while magnitudes have been homogenised in Mw scale according to the rules defined in Di Giacomo et al. (2015). On a global scale, the catalogue presently covers the magnitude range from 5 to 9.5, although the magnitude record can be considered complete above 5.5 starting from 1935.

The ISC-GEM catalogue represents the primary source of the GEM Africa catalogue. When selecting and merging events from different sources, ISC-GEM location solutions have always the larger priority on other solutions. On the contrary, magnitude solutions have largest priority only when no direct moment magnitude estimates are available (e.g. form the GCMT bulletin).

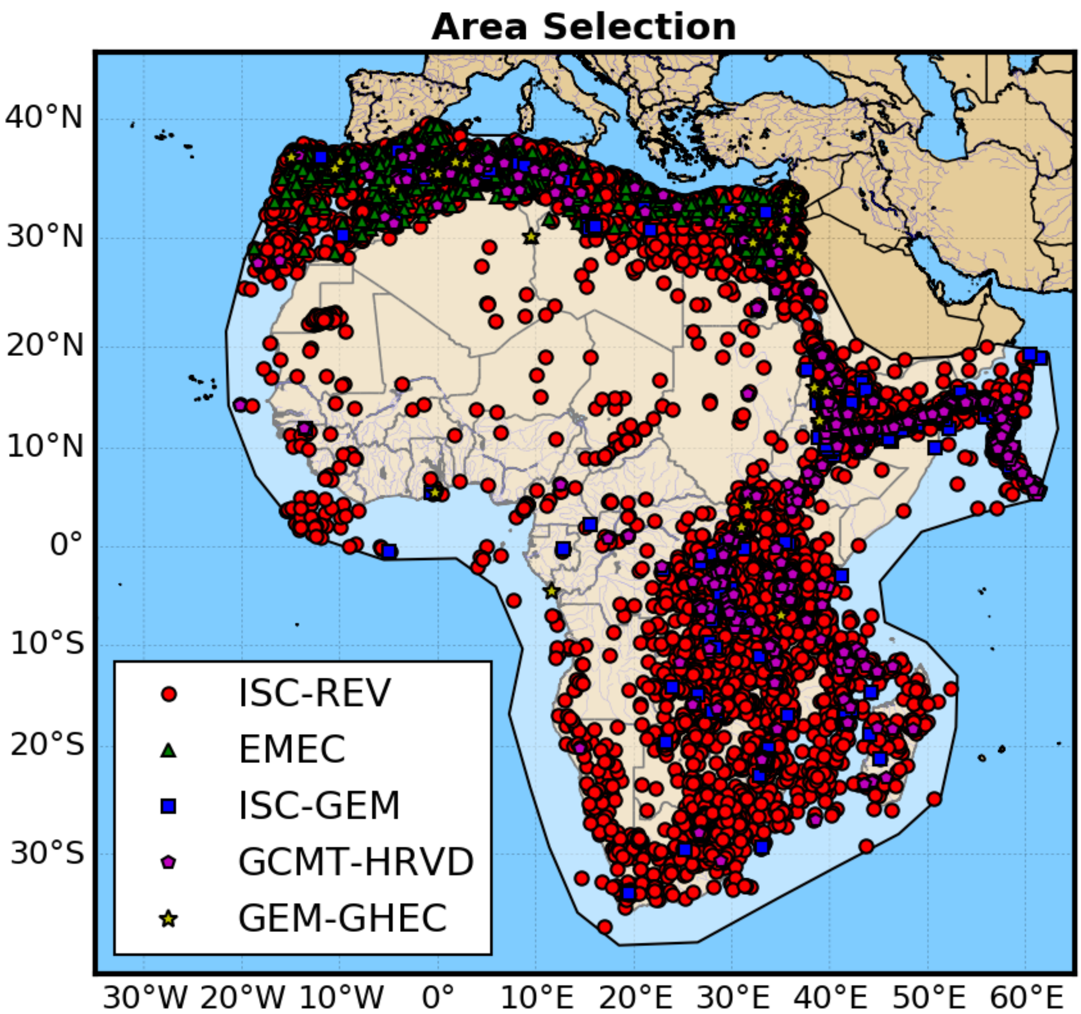

Figure 1 – Comparison of data coverage between the different input catalogues used to create the GEM-HEAC. In background is represented the buffer region used for pre-selection of earthquake events.

The Africa pre-selection of the ISC-GEM catalogue consists of 241 events in the range 5.44 ≤ Mw ≤ 7.8, starting from 1915 (see Figure 2 and Figure 3).

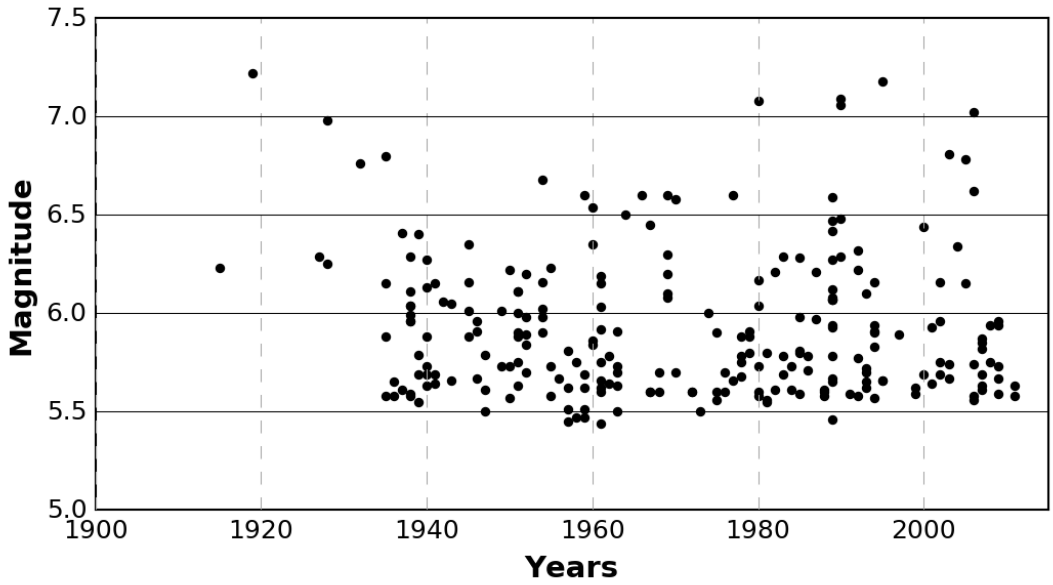

Figure 2 – Distribution over time of 241 African earthquake events from the ISC-GEM catalogue (Mw magnitude scale)

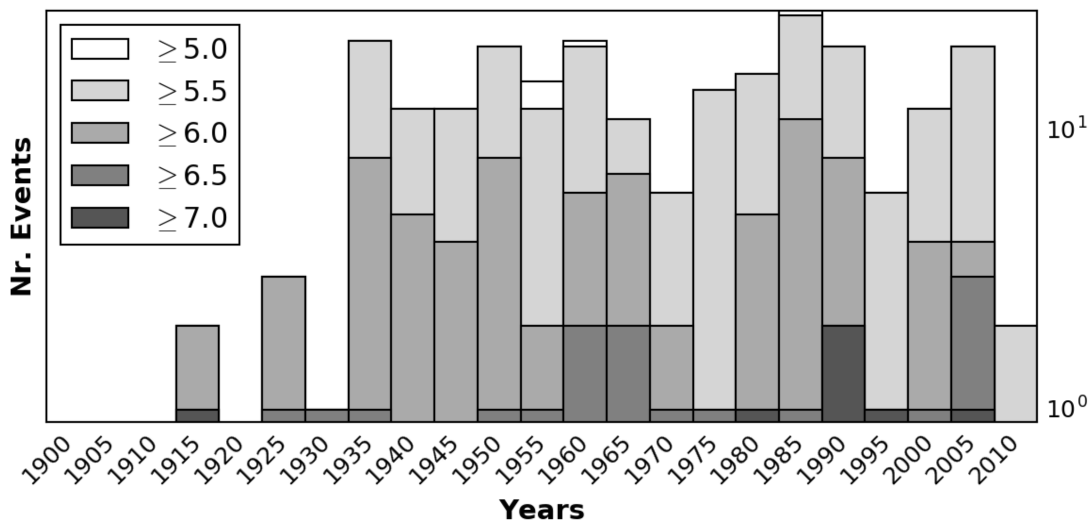

Figure 3 – Distribution over time of the cumulative number of African earthquake events from the ISC-GEM catalogue for different Mw magnitude thresholds.

2.2 ISC Reviewed Bulletin

The reviewed version of the ISC bulletin is used to complement those events not captured by the ISC-GEM catalogue, particularly relevant for magnitude below about 5.5.
The Africa selection of the bulletin consists of 25651 events from 125 location and 188 magnitude agencies, covering the period 1904-2013 (Figure 4 and Figure 5). The maximum reported magnitude is 7.3. It must be noted that many events reported in the bulletin have typically multiple location and magnitude solutions form different agencies. For catalogue harmonisation, we implement a selection procedure based on agency prioritisation rules. The procedure will be described more in detail in the next sections.

2.3 EMEC Catalogue

The European-Mediterranean Earthquake Catalogue (EMEC; Grünthal & Wahlström, 2012) is an Mw-homogenised catalogue consisting of 45000 events (Mw > 3.5) in the period 1000-2006. The Africa selection covers the Mediterranean belt of North Africa, with 3699 events up to magnitude 8.7 (Figure 6 and Figure 7). Although many of the large events are identically reported in the ISC-GEM and ISC Review catalogues, the EMEC contributes with several unreported historical events (1016-1900) and with small magnitude earthquake solutions from local networks not available from other databases (as for the case of Algeria).

2.4 GCMT Bulletin

The Global Centroid Moment Tensor catalogue (GCMT, Ekström et al., 2012) is a collection of moment tensor solutions for earthquakes with Mw>4.5, from 1972 to 2013. In the catalogue, while hypocentre solutions are derived from external agencies (such as the ISC) and are therefore generally discarded from our analysis (or marked as duplicates), Mw solutions are assumed as reference estimates.
The Africa selection consists in 463 events with Mw between 4.7 and 7.21 (see Figure 8 and Figure 9).

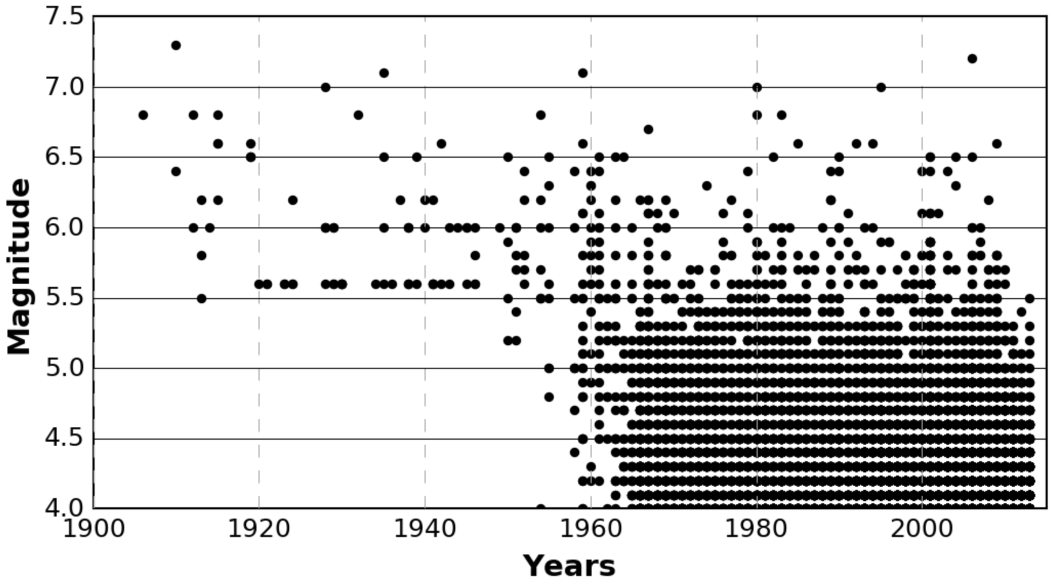

Figure 4 – Distribution over time of 25651 African earthquake events from the ISC-REV bulletin (all available magnitude types).

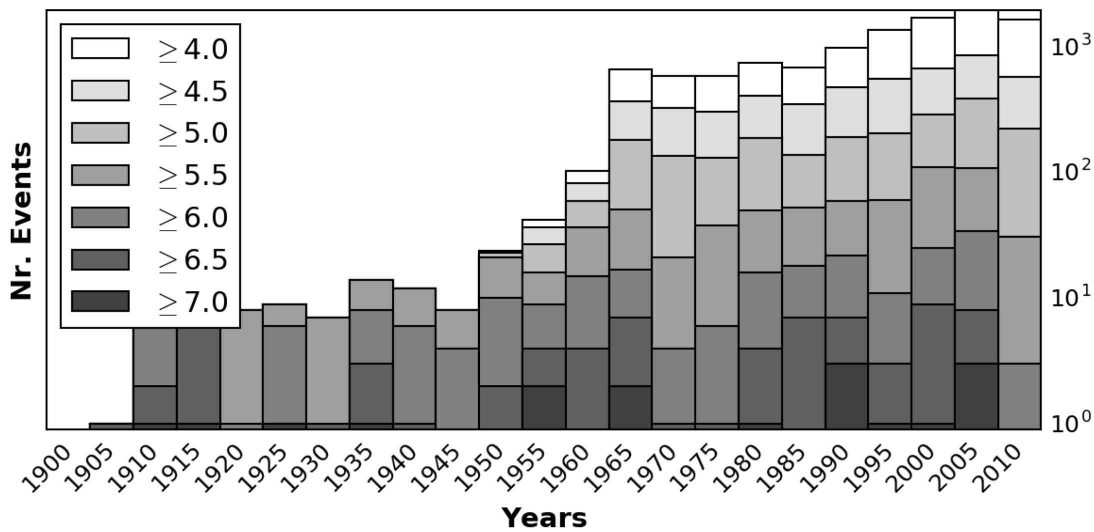

Figure 5 – Distribution over time of the cumulative number of African earthquake events from the ISC-REV bulletin for different magnitude thresholds (all available magnitude types).

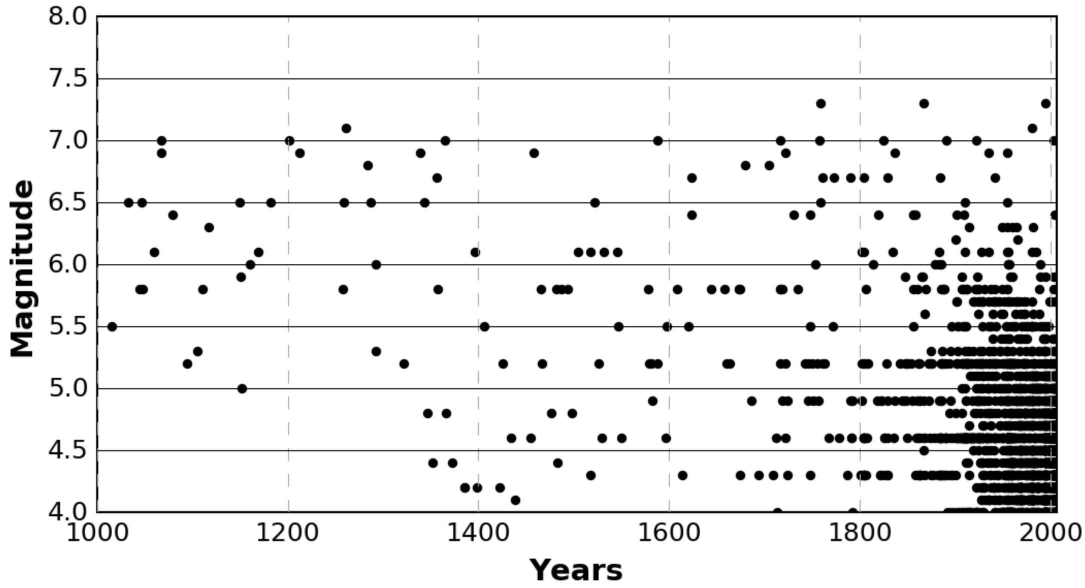

Figure 6 – Distribution over time of 3699 African earthquake events from the EMEC catalogue.

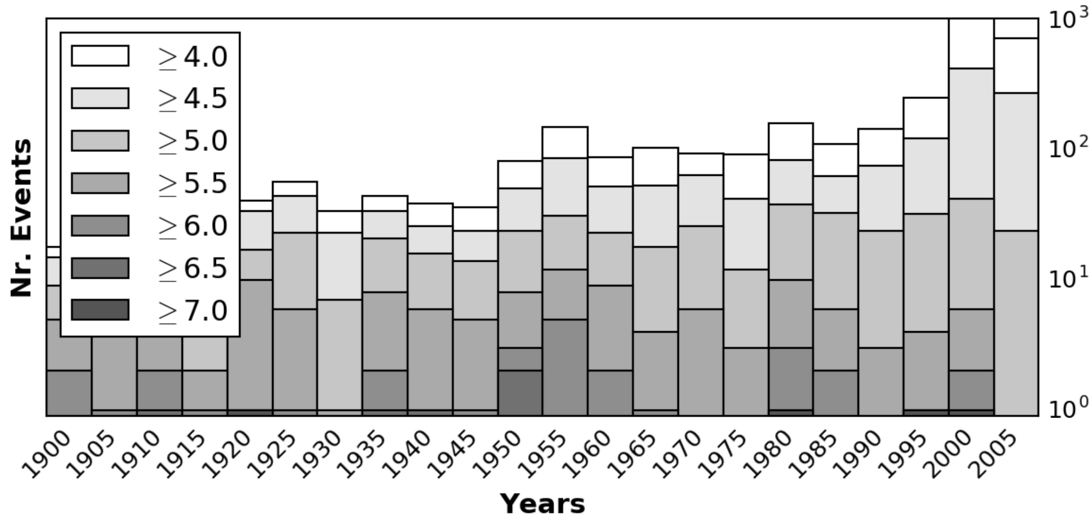

Figure 7 – Distribution over time of the cumulative number of African earthquake events from the EMEC catalogue for different magnitude thresholds (only modern- and early-instrumental period 1900-2006).

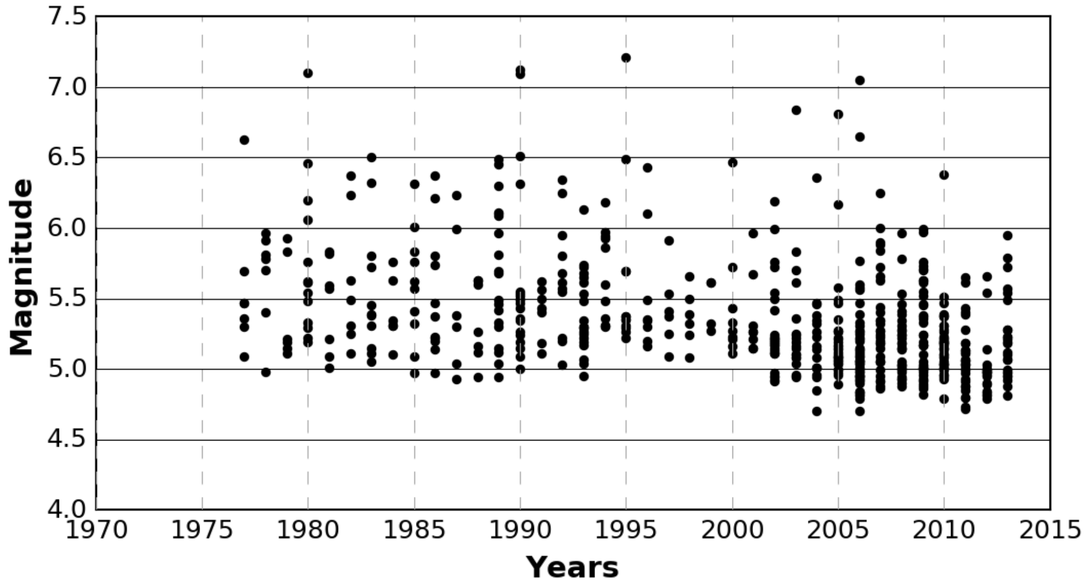

Figure 8 – Distribution over time of 463 African earthquake events from the GCMT bulletin (Mw magnitude).

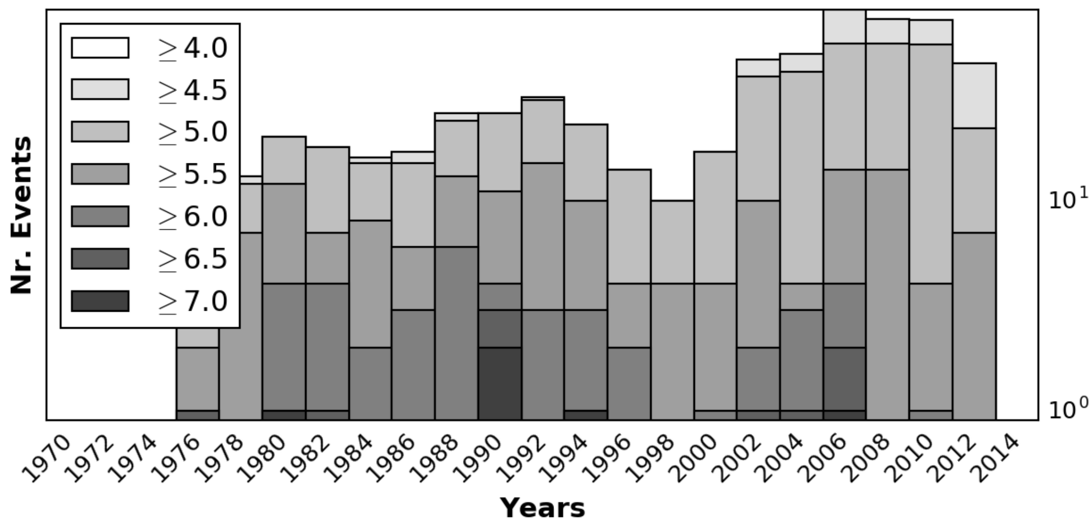

Figure 9 – Distribution over time of the cumulative number of African earthquake events from the GCMT bulletin for different magnitude thresholds (Mw magnitude).

2.5 GEM Historical Earthquake Catalogue

The GEM Global Historical Earthquake Catalogue (GHEC) reports 829 earthquake events from the pre-instrumental period 1000-1903. Its Africa selection, however, consists of only 26 records with magnitude larger than 6 (Figure 10), most of them being localised along Mediterranean belt. Unfortunately, the central Africa record is missing or largely incomplete in most parts.

Although the uncertainty of these historical events is actually quite large, they are nonetheless essential to constrain the occurrence rate of long return period events, whose record is generally not complete for the instrumental period.

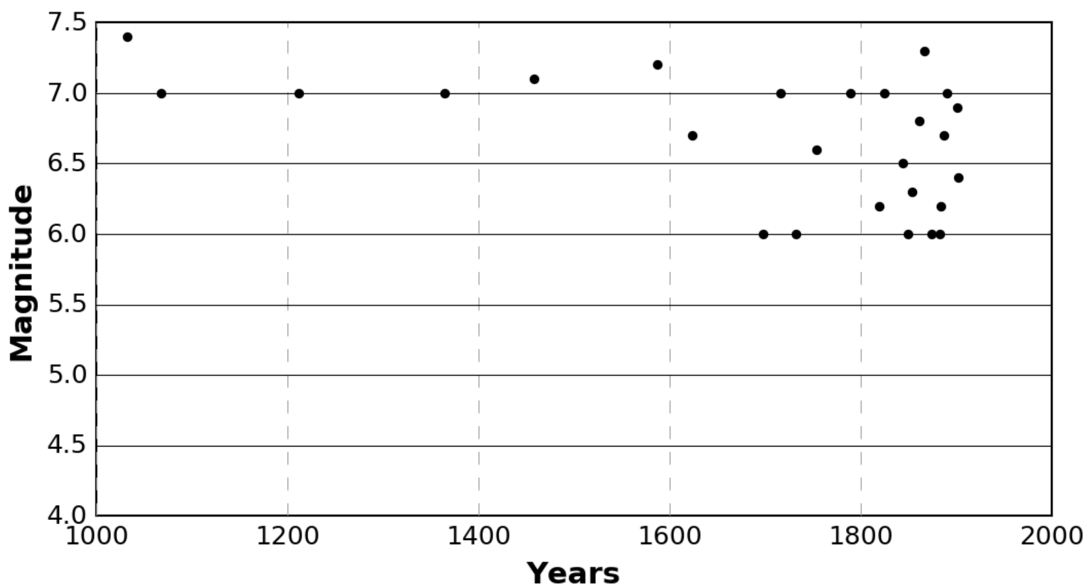

Figure 10 – Distribution over time of 26 African earthquake events from the GEM-GHEC catalogue (mixed magnitude types).

2.6 Local and Regional Earthquake Catalogues

Local and regional catalogues are not included in the analysis at present stage. Nonetheless, the tools developed ad-hoc for the creation of the GEM-HEAC have been designed with a focus on to facilitate subsequent integration of newly available information.

3 ISC Location Solution Selection

As previously mentioned, the ISC bulletin provides various hypocentre location solutions for most of the events (**Table 1**). However, solutions from certain agencies are often preferable on other solutions, e.g. because of a better network coverage or the use of more advanced algorithms. Criteria of selection and prioritization for location agencies are therefore needed in order to produce a final catalogue with a single best-estimated solution for each event. Similar considerations can be done when merging duplicate events from different catalogues.

African Location Agencies (All)

ISC(18003), NEIC(8358), MDD(6912), IDC(4873), CSEM(4852), BUL(4185), ISCJB(3931), DHMR(2707), PRE(2439), INMG(2298), LDG(2274), MOS(1829), EHB(1574), CNRM(1328), IPRG(1308), BJI(1278), NEIS(1263), IGIL(1133), CRAAG(1037), JSO(1024), EIDC(904), LIS(852), NAO(775), SFS(755), HFS(557), EAF(538), USCGS(472), SPGM(454), RYD(431), GII(408), BCIS(362), HLW(354), ARO(340), IASPEI(334), STR(323), HRVD(320), RBA(297), LAO(246), LSZ(246), GCMT(218), SGS(215), SZGRF(207), ISS(176), HFS2(176), SNSN(174), NAI(173), ROM(168), NSSC(160), GRAL(150), CENT(134), PEK(125), IAG(108), OMAN(101), TUN(101), HFS1(99), GUTE(98), MED_RCMT(90), ZUR_RMT(86), NIC(85), ASM(80), TAN(79), DJA(73), SYKES(67), DSN(61), ATH(59), CGS(55), DUSS(47), ISK(43), CNG(43), ZUR(37), SYO(33), BGS(30), ISN(29), THE(27), ENT(26), LIC(25), PDA(25), BER(24), DDA(23), PDG(23), PTO(21), TEH(20), BGR(18), JOH(16), TZN(16), AAE(14), NAM(11), TTG(10), PDE(8), VIE(7), BEO(7), SSN(7), LWI(7), SHL(6), ORF(6), KISR(5), DMN(5), KBC(5), KUK(5), ALG(5), QUE(5), EBM(4), PRU(3), IPEC(3), CRT(3), CANSK(2), KSA(2), SVSA(2), NDI(2), PUL(2), HRVD_LR(2), LIT(1), TIF(1), TAS(1), KNET(1), SSNC(1), SKO(1), UPP(1), MAL(1), AVE(1), BKK(1), SOF(1), ESK(1), GFZ(1), EBR(1)

Table 1 List of location agencies from the ISC review bulletin for available African events. The number of hypocentre solutions for each agency is within brackets.

The ISC reviewed bulletin provides for most events an indication of a preferred solution, marked as "*prime*" (Figure 11). On a total of 25651 African earthquakes, 19751 records have a preferred solution. We use these solutions as authoritative locations for the final harmonised catalogue (**Table 2**).

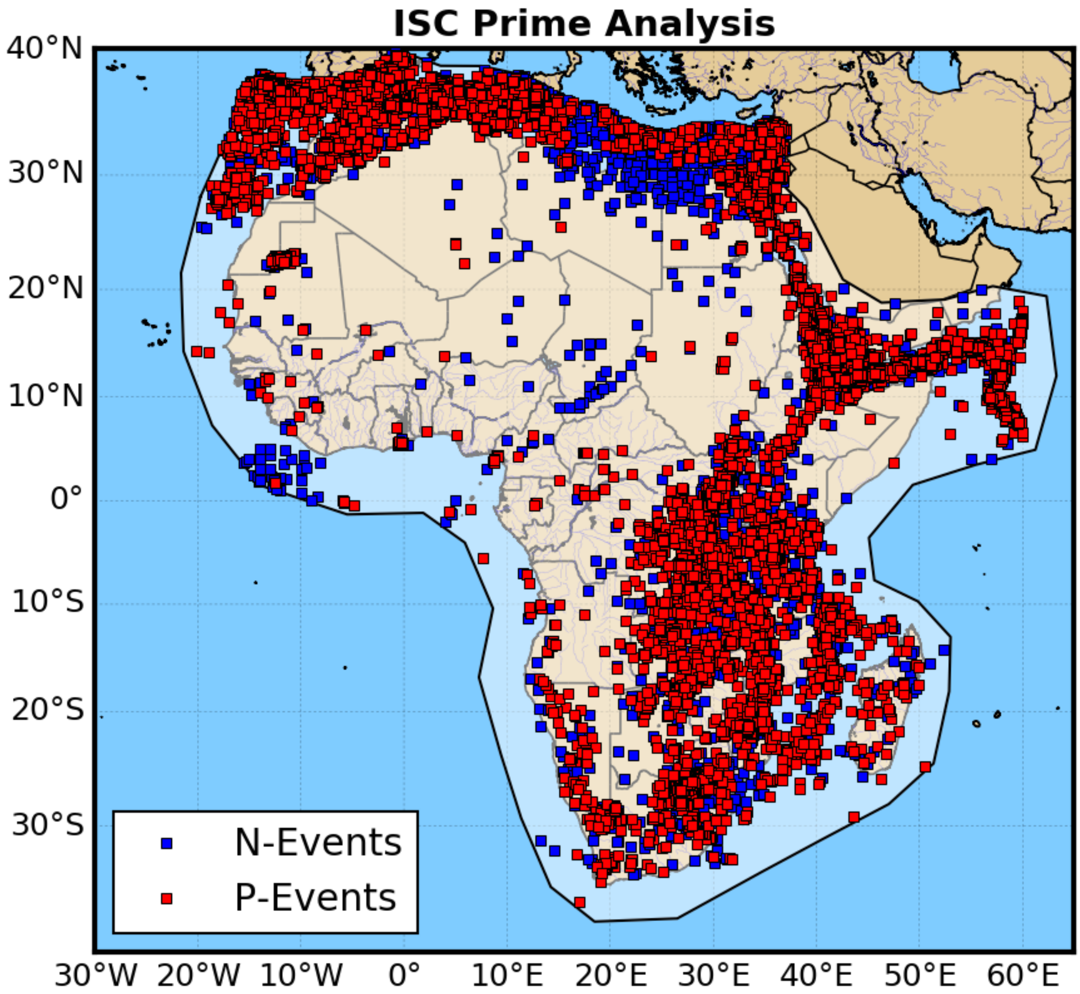

Figure 11 – Distribution event locations in the ISC Reviewed bulletin marked as prime (P) or not-prime (N).

Of the remaining 5900 unassigned events, 5809 location solutions have been manually assigned by applying rules for agency prioritisation (**Table 3**); this was done on the base of several criteria, such as reliability of the agency, quality of the location solutions, number of available events and period of activity (e.g. Figure 12 and Figure 13). Prime and not prime events with selected solutions have been then merged into a final catalogue of 25560 records (**Table 4**). Of the original 25651, then, only 91 events were discarded.

Prime Agencies

Prime (9126)	*ISC(17862), MDD(656), DHMR(491), IPRG(92), CRAAG(90), INMG(81), GUTE(76), CSEM(58), BCIS(39), EAF(29), CNRM(29), BUL(21), ISS(19), LSZ(19), NEIC(16), HLW(15), CNG(15), TUN(15), LIS(14), PRE(13), ROM(12), SGS(12), NAI(12), IDC(10), JSO(9), SPGM(8), GII(6), RYD(5), USCGS(4), MOS(3), EIDC(2), LIC(2), SYKES(2), SNSN(2), JOH(2), ENT(2), PEK(1), GRAL(1), RBA(1), CGS(1), ASM(1), NEIS(1), NSSC(1), ARO(1)*
Not-Prime (2050)	*BUL(1034), DHMR(994), PRE(648), IDC(604), MDD(387), HFS(230), LAO(200), EAF(190), NAO(179), ISC(141), IPRG(115), NAI(108), JSO(89), EIDC(81), RYD(81), HLW(71), ARO(63), TAN(54), CSEM(45), MOS(44), LSZ(42), HFS1(41), ATH(35), SPGM(32), LDG(31), NEIC(28), ROM(27), ASM(27), HFS2(23), LIS(21), NSSC(21), GII(20), LIC(19), BCIS(19), SZGRF(19), ISK(18), ENT(17), ZUR(15), CNRM(15), SNSN(14), RBA(14), INMG(10), TUN(10), CRAAG(8), BJI(8), USCGS(7), GRAL(7), PDG(7), BGS(6), TTG(6), DDA(6), NIC(5), GUTE(5), ISCJB(5), SYKES(5), IGIL(5), OMAN(4), BEO(4), STR(4), JOH(3), MED_RCMT(3), NEIS(3), DMN(3), ISS(3), LWI(3), PRU(2), DJA(2), EHB(2), THE(2), DUSS(2), SFS(2), BER(2), NAM(1), BGR(1), CANSK(1), TZN(1), GCMT(1), KSA(1), UPP(1), KUK(1), PEK(1), ORF(1), AAE(1), SOF(1), SGS(1), CNG(1)*

Table 2 – Location agencies with solutions marked as prime or not prime from ISC. The number of events for each agency is within brackets.

Agency Priority List (For not-prime events)

DHMR, PRE, BUL, ISC, MDD, IDC, IPRG, EAF, NAI, TAN, JSO, SPGM, HLW, ARO, LIC, ASM, TUN, RYD, SNSN, CNRM, LSZ, ENT, NSSC, RBA, CRAAG, ATH, ISK, GII, BCIS, LDG, STR, ROM, LIS, ZUR, GUTE, NEIC, CSEM, NAO, LAO, HFS, HFS1, HFS2, MOS, SZGRF, EIDC

Table 3 – List of agencies used to prioritize location solutions. Agencies are sorted following a decreasing priority.

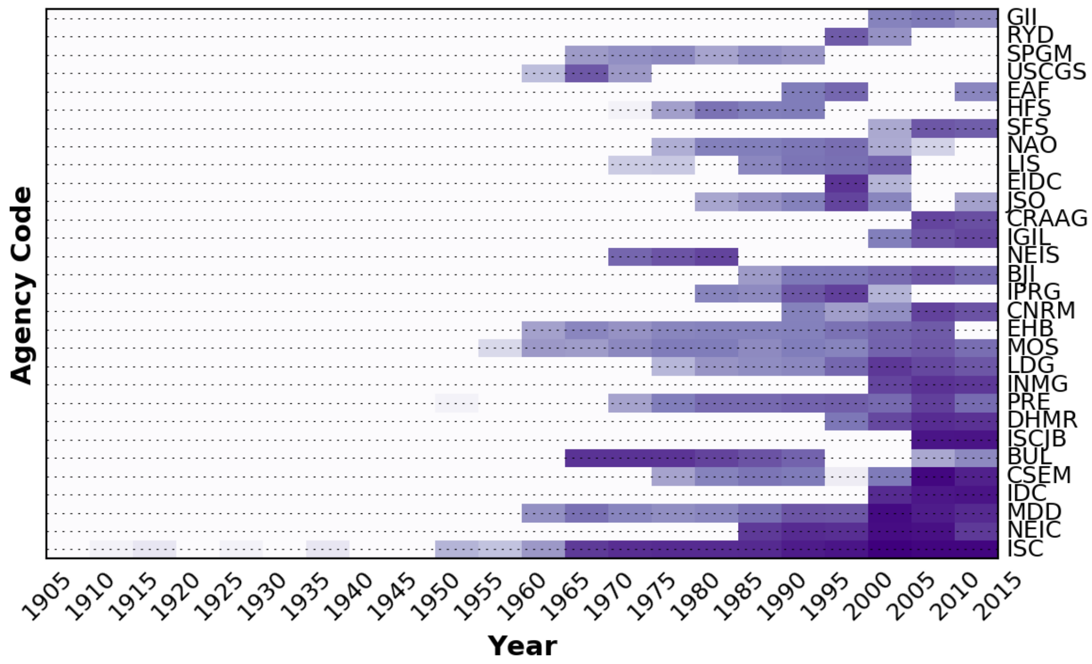

Figure 12 – Time-histogram distribution of the first 30 location agencies sorted by total number of located events. Colour shading represents the relative number of events falling within 5 years bins. Catalogue has not been yet processed and solution duplication occurs between events.

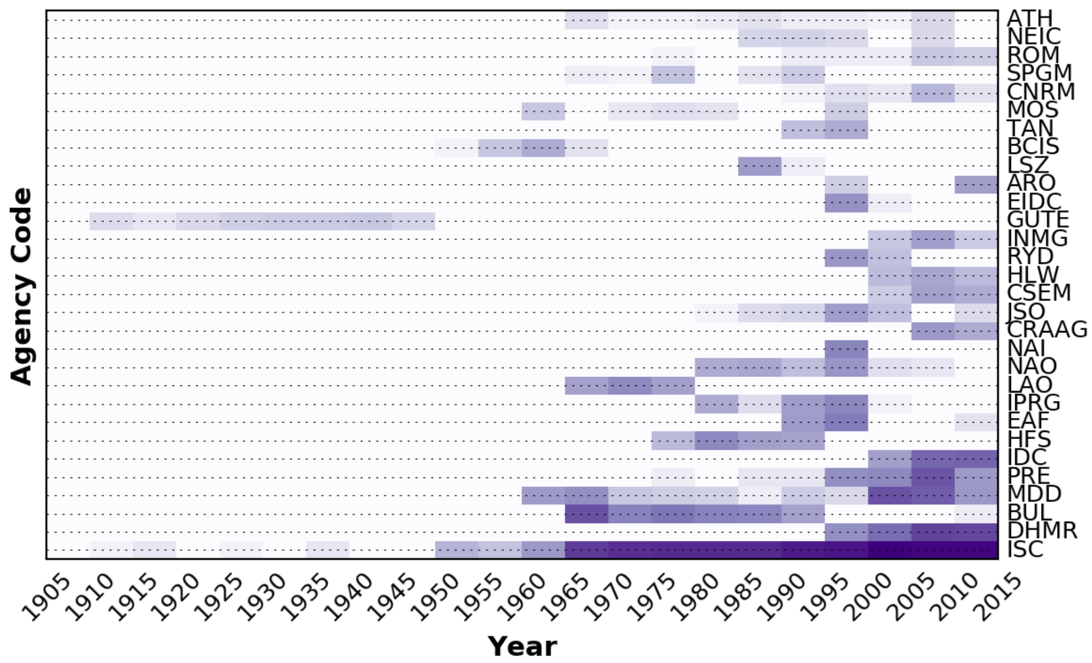

Figure 13 – Time-histogram as in **Figure 12**. Catalogue is here processed according to agency priority rules and no solution duplicates are then present.

GEM-HEAC Location Agencies (Selected)
ISC(18003), DHMR(1485), BUL(1055), MDD(1043), PRE(661), IDC(614), HFS(224), EAF(219), IPRG(207), LAO(194), NAO(176), NAI(120), CRAAG(98), JSO(96), CSEM(95), HLW(86), RYD(85), INMG(81), GUTE(81), EIDC(79), ARO(64), LSZ(61), BCIS(58), TAN(54), MOS(43), CNRM(42), SPGM(40), ROM(39), NEIC(36), ATH(35), HFS1(34), LIS(32), LDG(28), ASM(28), TUN(25), LIC(21), GII(21), NSSC(21), ISS(19), ENT(19), SZGRF(19), HFS2(18), ISK(17), SNSN(15), CNG(15), RBA(14), ZUR(12), SGS(12), STR(4), USCGS(4), SYKES(2), JOH(2), PEK(1), GRAL(1), CGS(1), NEIS(1)

Table 4 – List of selected location agencies of the final GEM-HEAC catalogue.

4 Merging catalogues and duplicate finding

Events from the four input catalogues have been merged into a single database labelled as GEM-HEAC. Duplicated events between reports were identified and grouped into a single ID. Search for duplicated events is made based on a spatial-temporal matching window. Events falling within a time windows of 120s and inside a region of 50km radius were marked as duplicated. Location solutions for the duplicated events were prioritized by catalogue in the following order (from higher to lower priority): ISC-GEM, ISC-REV (Selected), EMEC, GCMT-HRVD and GEM-GHEC. It might be useful for the future to include additional conditions for duplicate findings based on magnitude matching. The new augmented catalogue includes now 27879 individual events.

5 Mw Magnitude Homogenisation

5.1 Agency Selection

For magnitude homogenisation we applied a magnitude agency selection criteria similar to what has been used for the selection of the preferred location. In a first step, we explored the availability of different magnitude types from each available agency (see Appendix 1). Subsequently, the most reliable agencies have been selected and sorted according to specific priority rules. Prioritisation is made based on magnitude type (from higher to lower priority: Mw → Ms → mb → Ml → Md) and agency-specific selection criteria. See **Table 5** for the final agency priority list.

Of 27879 initial events, we selected 26610 events with an acceptable magnitude estimate (**Table 6**), while only 1269 remained unassigned.

5.2 Magnitude Conversion

As last step of the catalogue homogenisation procedure, magnitude has to be represented using a uniform magnitude scale. We use Mw as target magnitude. When converting between magnitude scales, best practice would be to locally calibrate conversion rules for each reporting agency and magnitude type against the reference scale (in this case, Mw from an arbitrary reporting agency). However, the amount of records available for Africa was not sufficient to perform ad-hoc calibrations, with the exception of very few agencies, such as Ms and mb magnitudes from ISC and NEIC. For these cases, however, the African subset is in close agreement with globally calibrated models (e.g. Figure 14 and Figure 15) such as those in Weatherill et al. (2016) or Di Giacomo et al. (2015). For other agencies and magnitude types with too few reported events, some grouping was necessary to perform a reasonable statistical analysis.

Magnitude Selection - Agency Rules

Type	Agencies
Mw	ISC-GEM, EMEC, GCMT-NDK, GCMT, HRVD, NEIC, HRVD-NEIC, USGS-NEIC, ZUR_RMT, MED_RCMT, CSEM, IPRG, GII, IAG, GEM-GHEC
Ms	ISC, IDC, NEIC, NEIS, HFS, MOS, PAS, GEM-GHEC
mb	ISC, NEIC, NEIS, CSEM, USCGS, BJI, MOS, MDD, DHMR, IPRG, GEM-GHEC, GII, EIDC, HFS
Ml	BUL, PRE, DHMR, IDC, EAF, CSEM, ARO, CNRM, GII, ROM, LDG, ARO, EAF, TAN, NAI, PRE, JSO, IPRG, EIDC, DHMR, ARO, LDG
Md	EAF, JSO, RYD, RBA, ASM, CNRM, GRAL, CSEM, TUN, DHMR, MDD, LIS

Table 5 List agencies used to prioritize magnitude solutions. Agencies are grouped according to magnitude type and sorted from higher to lower priority.

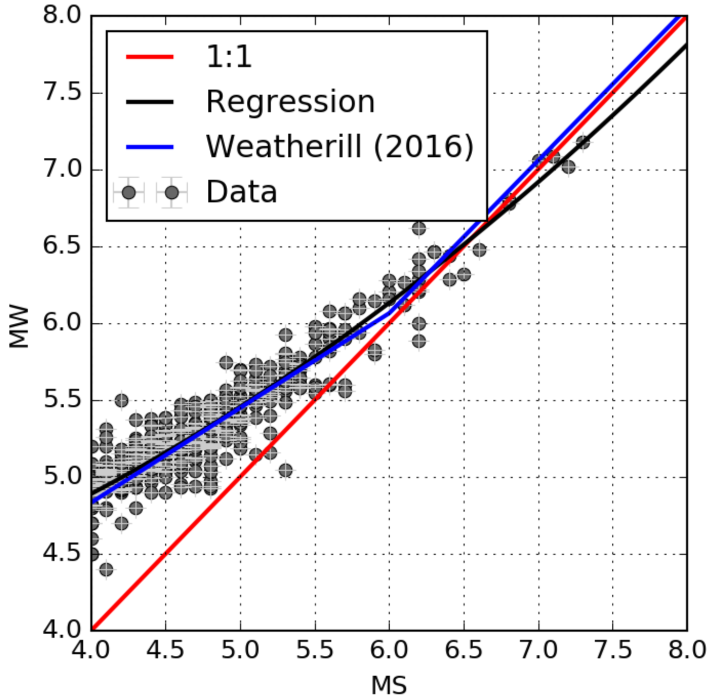

Figure 14 – Example of correlation between Mw and Ms estimates from different reporting agencies (450 events).

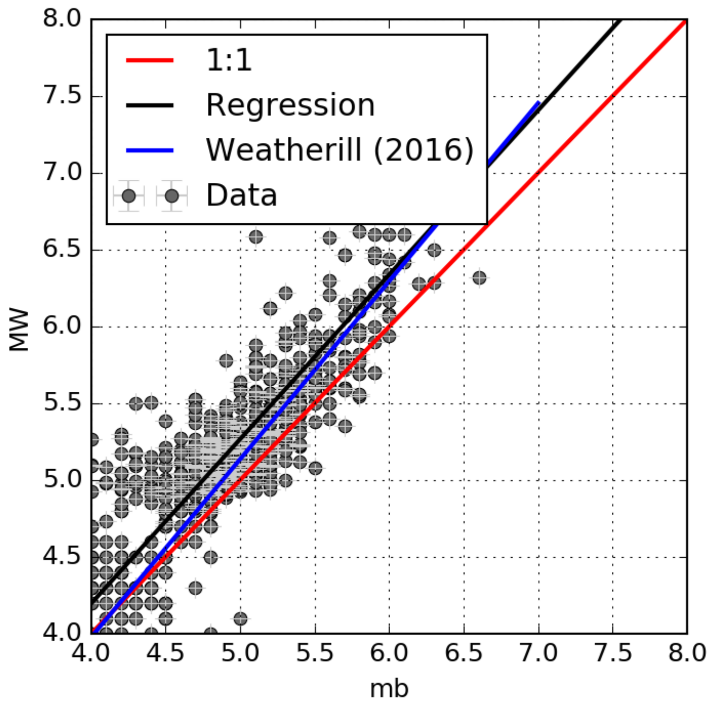

Figure 15 – Correlation between Mw and mb estimates from different reporting agencies (634 events).

GEM-HEAC Magnitude Agencies (Selected)

Agency	Events	Magnitude Type
ISC	6210	mb (4630) MS (1569) Ms (11)
MDD	3945	mb (3319) MD (626)
EMEC	3679	MW (3679)
BUL	3166	ML (3166)
DHMR	1928	ML (1580) mb (198) mL (117) MD (33)
PRE	1290	ML (730) mL (560)
IDC	1116	mb (570) MS (419) mb1 (115) ML (12)
CSEM	1048	ML (523) mb (452) Mw (44) MD (29)
IPRG	796	mb (405) mL (353) Mw (38)
GCMT-NDK	466	MW (466)
ISC-GEM	304	MW (304)
JSO	286	mL (224) MD (55) md (7)
EAF	265	md (193) mL (51) ML (21)
NEIS	255	mb (241) MS (14)
LDG	208	mL (133) Ml (75)
RYD	179	md (129) MD (50)
CNRM	164	MD (128) ML (36)
ARO	161	mL (66) Ml (57) ML (38)
GII	126	Mw (65) ML (34) mb (27)
NEIC	121	mb (110) MSZ (6) MS (4) MW (1)
RBA	120	md (117) MD (3)
NAI	115	mL (115)
MOS	96	MS (94) mb (2)
USCGS	84	mb (84)
LIS	74	MD (74)
PAS	64	MS (64)
MED_RCMT	62	MW (62)
EIDC	58	mb (50) mL (8)
TAN	43	mL (43)
GRAL	38	MD (38)
IAG	37	MW (19) Mw (18)
ASM	34	MD (34)
HFS	24	MS (18) mb (6)
ROM	18	Ml (18)
GEM-GHEC	15	MS (8) MW (7)
GCMT	6	MW (6)
HRVD;NEIC	5	Mw (5)
HRVD	4	Mw (3) MW (1)

Table 6 List of selected magnitude agencies and types of the final GEM-HEAC catalogue. Number of events is within brackets.

Magnitude Selection - Conversion Rules		
Type	**Mw Conversion rule**	**Range**
Ms (MS, MSZ)	Bilinear - Weatherill et al. (2016)	3.5≤M≤8.0
mb (mb1)	Linear - Weatherill et al. (2016)	3.5≤M≤7.0
ML (Ml, mL)	Polynomial – Edwards et al. (2016)	M≤6.0
MD (md)	1:1 conversion	

Table 7 – Conversion rules used to convert different magnitude types into Mw. Events outside the range of applicability of the rule have been discarded.

6 Catalogue Statistics

The final version of the GEM-HAEC consists of 11786 events, in the magnitude range between 4 and 8.7 (Figure 16 and **Figure 17**), although for seismicity analysis we will subsequently use events above 4.5 only; note that this value is conventionally assumed the minimum completeness magnitude for the region using available data. Adding information from local catalogues can subsequently lower such threshold, where appropriate.

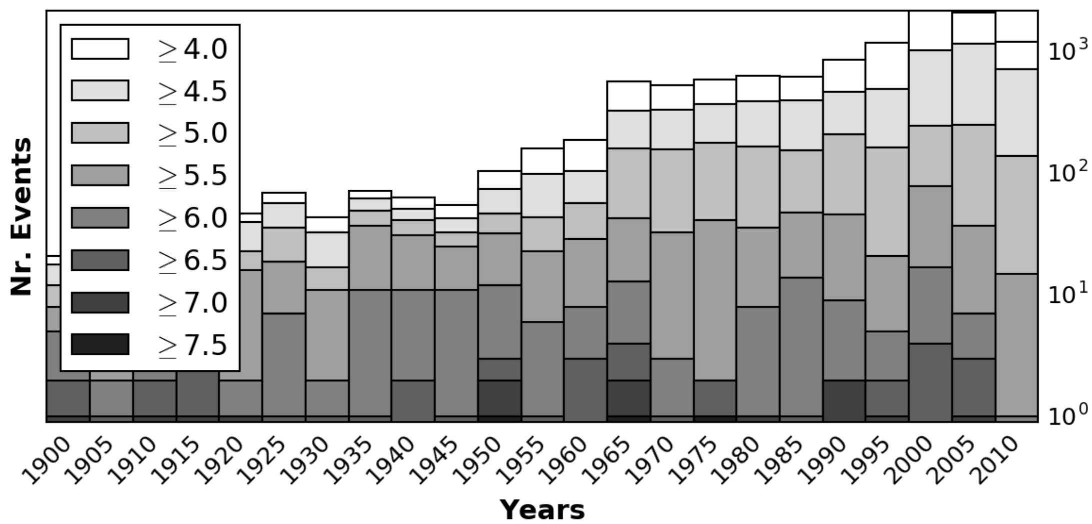

Figure 16 – Distribution over time of the cumulative number of African earthquake events from the GEM-HEAC catalogue for different magnitude thresholds (Mw magnitude).

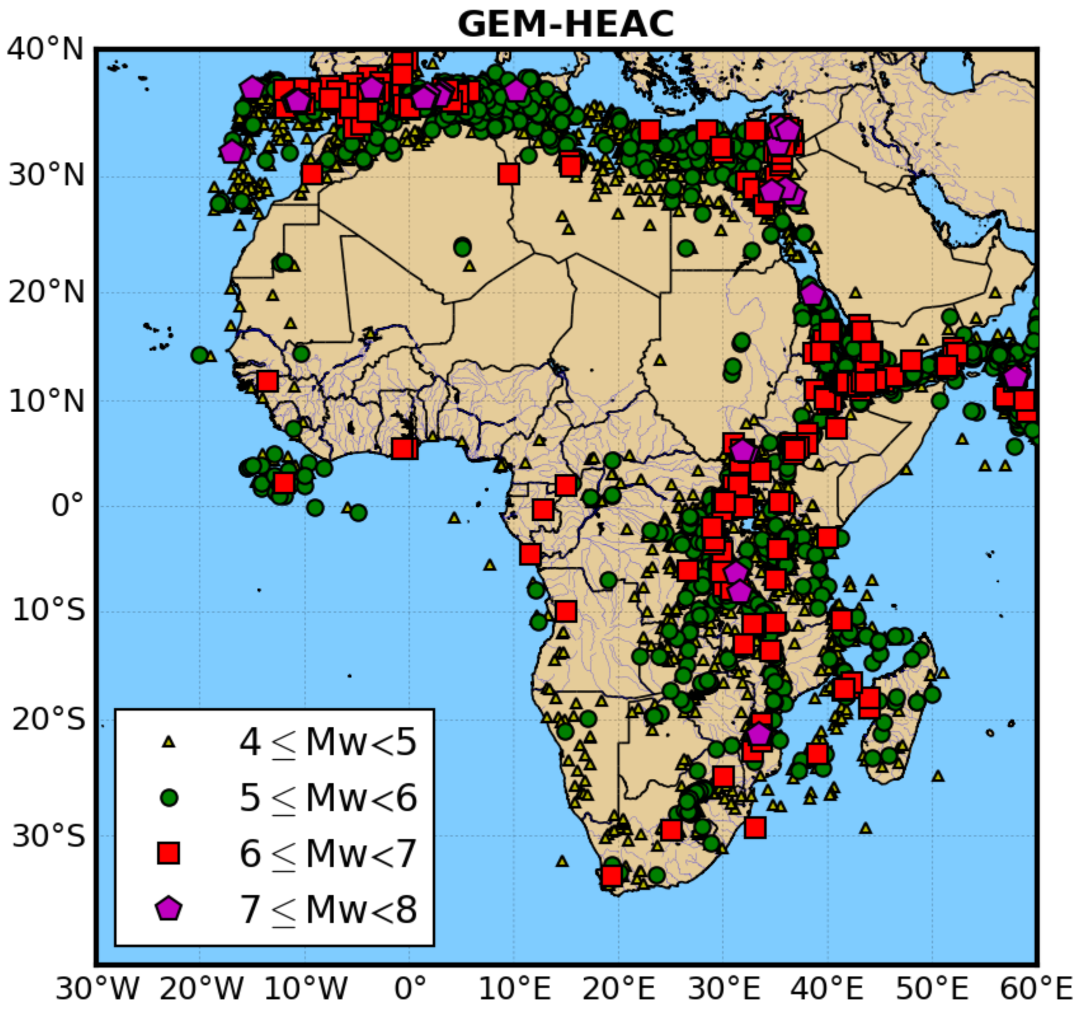

Figure 17 – Distribution of the 11786 earthquake events of the final GEM-HEAC catalogue for Africa.

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8 Appendix 1

African magnitude agency list and available magnitude types from the GEM-HEAC catalogue before magnitude selection and homogenisation.

Agency	Events	Magnitude Types
IDC	23996	mb (4701) mb1 (4642) mb1mx (3939) mbtmp (3685) ML (2598) MS (1810) Ms1 (1709) ms1mx (912)
ISC	10825	mb (8316) MS (2431) Ms (76) ML (2)
MDD	7131	mb (4657) None (1131) MG (980) mbLg (179) MN (164) mL (9) MW (5) ML (3) md (1) Mn (1) mb_Lg (1)
NEIC	5175	mb (4401) MSZ (301) MS (301) MW (72) ME (25) MN (23) Ms (20) ML (16) Me (3) Mw (3) Mwb (3) Ms_20 (3) None (2) md (1) Mww (1)
BUL	4053	ML (4053)
EMEC	3776	MW (3776)
BJI	3714	mb (1281) Ms (756) mB (744) Msz (422) Ms7 (326) MS (185)
CSEM	3679	ML (1775) mb (1320) MD (236) Ms (179) Mw (159) Mc (10)
DHMR	2816	ML (2328) mb (261) mL (145) MD (68) Mb (14)
MOS	2764	mb (1302) MS (678) MB (284) Mb (267) Ms (165) None (67) MW (1)
PRE	2178	ML (1095) mL (1000) None (62) mb (18) MW (2) MS (1)
LDG	2059	Ml (917) mL (433) Md (221) ML (195) Mb (153) Ms (77) ms (56) mb (3) MS (2) MD (2)
EIDC	1891	mb (1016) MS (300) mL (283) mbmle (134) ML (119) msmle (39)
IPRG	1879	mL (1067) mb (660) ML (88) Mw (45) None (18) Ms (1)
NEIS	1491	mb (1274) MSZ (97) MS (92) Ms (27) ML (1)
NAO	976	mb (908) Mb (68)
CNRM	802	MD (607) ML (55) None (52) ml (49) md (33) mb (6)
JSO	788	mL (489) MD (104) ML (66) md (63) None (25) M (13) MLv (13) Mjma (8) MS (3) mb (2) MW (2)
HFS	787	mb (608) MS (179)
CRAAG	663	Ml (566) Mb (82) Mw (14) Ms (1)
ATH	652	mL (350) MD (152) ML (94) md (32) None (22) MG (2)
GCMT-NDK	642	MW (642)
LIS	547	None (282) MD (88) ML (82) mL (63) md (28) Mb (3) UK (1)
GII	530	ML (169) mb (141) Mw (90) MD (82) Md (25) Mb (17) Mm (5) MW (1)
EAF	484	md (305) MD (97) mL (56) ML (25) MS (1)
USCGS	453	mb (429) MS (17) Ms (7)
RYD	411	md (302) MD (108) mL (1)
INMG	395	ML (261) MD (83) Mb (50) MS (1)

STR	387	Ml (190) Mb (70) ML (40) Ms (37) mL (37) None (6) MLv (4) md (2) mb (1)
MDD;NEIC	384	mbLg (362) MD (22)
SFS	367	ML (367)
HLW	349	Mb (165) Ml (82) Md (53) ML (46) MW (2) mb (1)
ARO	342	ML (142) mL (119) Ml (81)
NIC	336	ML (163) mb (98) MW (64) mL (6) Ml (5)
IGIL	311	ML (283) MS (16) mb (8) MW (4)
ISC-GEM	306	MW (306)
LAO	275	None (275)
SZGRF	271	mb (209) MS (62)
GCMT	226	MW (223) Mwc (3)
RBA	221	md (209) MD (12)
BUL;NEIC	216	mbLg (181) MG (33) MD (2)
ROM	214	Ml (53) md (43) ML (40) mb (38) mL (16) MD (10) MW (7) Md (5) None (2)
LSZ	209	None (198) ML (5) MD (4) mL (1) UK (1)
NAI	182	mL (159) md (22) mb (1)
ISK	174	MD (75) md (46) ML (33) None (19) MG (1)
SPGM	169	None (93) md (76)
IASPEI	166	mb (136) ms (20) ml (10)
HRVD	158	MW (142) Mw (16)
PAS	153	MS (99) None (23) UK (21) Ms (10)
HLW;NEIC	150	MD (140) ML (8) MG (1) None (1)
GRAL	138	MD (138)
THE	123	ML (73) mL (42) md (8)
JER;NEIC	117	ML (117)
SGS	116	Ml (116)
PEK	109	MS (68) Mb (22) MB (12) None (6) MLV (1)
TAN	108	mL (49) None (26) MD (23) Md (5) md (5)
MED_RCMT	108	MW (108)
HFS1	107	None (107)
IAG	102	Mw (70) MW (32)
RYD;NEIC	100	MD (99) MG (1)
DJA	94	mb (62) mB (21) Mw (8) Mwp (2) MLv (1)
DSN	93	mb (52) Ms (33) ML (8)
ZUR_RMT	92	Mw (92)
HRV	88	Ms (71) Mw (17)
SNSN	86	Ml (72) ML (13) MB (1)
TUN	80	MD (54) None (25) ML (1)
ASM	75	MD (75)
LWI	69	None (69)
HRVD;NEIC	65	Mw (65)
ALG	65	ML (62) None (2) MG (1)
BHL;NEIC	62	ML (62)
ARO;NEIC	54	ML (30) MD (22) MG (1) None (1)

SYO	52	MB (35) Msz (10) MS (7)
DUSS	49	ML (32) MS (12) mb (4) MD (1)
BER	49	mb (26) MS (23)
PDG	47	ML (23) mL (15) MD (7) md (2)
DDA	44	ML (15) Ml (12) MD (9) Md (8)
ZUR	42	mb (31) ML (11)
BGS	39	mb (28) MS (11)
NSSC	39	ML (24) Mc (8) None (4) md (3)
GEM-GHEC	35	MS (17) MW (14) m (4)
CSS;NEIC	34	ML (32) MD (2)
ENT	28	mL (16) md (12)
CNG	28	None (28)
LIC	25	mL (14) Mb (4) md (4) MD (3)
PAL	24	None (23) UK (1)
BGR	21	mb (19) Ms (2)
TTG	21	mL (20) MD (1)
BRK	20	Ms (18) UK (2)
TEH	20	ML (19) Mn (1)
BRK;NEIC	19	MS (15) Ms (4)
OMAN	17	ml (5) mb (5) ms (4) Mwp (3)
USGS;NEIC	16	Mw (10) Me (6)
BCIS	16	None (15) UK (1)
CGS	15	None (15)
UPP	14	None (14)
PDA	14	mb (9) ML (5)
ATH;NEIC	14	MD (13) ML (1)
SFS;NEIC	14	MD (14)
PRA	13	None (13)
GS	11	Mw (6) ME (5)
P&S	11	Mw (6) Ms (5)
ABE1	11	Ms (6) mB (5)
ISN	11	ML (11)
VIE	10	mb (8) Ms (2)
TZN	10	mL (6) None (2) md (2)
GUTE	9	UK (9)
MAT	8	None (8)
ROM;NEIC	8	MD (4) ML (4)
PAS;NEIC	8	MS (8)
PMG;ISC	7	ML (7)
B&D	7	UK (7)
BRK;NEIS	7	None (3) Ms (3) MS (1)
LDG;NEIC	6	ML (5) mbLg (1)
BEO	6	ML (6)
ORF	6	mb (5) ML (1)
NAM	5	MD (5)
PRU	5	M (5)

KISR	5	ML (3) mb (2)
KBC	5	None (5)
BKK	5	mb (1) M (1) None (1) MLv (1) mB (1)
PAS;NEIS	5	Ms (3) None (2)
ISK;NEIC	4	MD (3) ML (1)
ROTHE	4	Ms (4)
PMG;BUL	4	ML (4)
SSN	4	mb (4)
GII;NEIC	4	ML (4)
JER;NEIS	4	ML (4)
QUE	4	None (4)
TIR	3	mL (1) ML (1) Md (1)
KIR	3	None (3)
ABA;NEIC	3	MG (3)
KSA	3	None (3)
AN2	3	Ms (3)
PTO	3	None (3)
ABE3	3	mB (3)
RMP	3	ML (3)
STR;NEIC	3	MD (3)
LSZ;NEIC	3	None (2) MG (1)
TIR;NEIC	2	ML (2)
NAO;CSEM	2	None (2)
TAF;NEIC	2	MD (2)
THR	2	ML (2)
COL	2	None (2)
SVSA	2	ML (1) Mb (1)
KUK	2	None (2)
RAB;ISC	2	ML (2)
LAT;ISC	2	ML (2)
HRVD_LR	2	MW (2)
AVE;NEIC	2	MG (2)
LIB	1	ML (1)
LAT;SPGM	1	ML (1)
TIR;NEIS	1	ML (1)
FAM;ISC	1	ML (1)
CSS;NEIS	1	ML (1)
SSNC	1	MS (1)
HQL;ISC	1	None (1)
LJU;PEK	1	MLV (1)
AAE;ISC	1	MD (1)
AAE;NEIC	1	ML (1)
KEW	1	None (1)
SKO;NEIC	1	None (1)
TIO;NEIC	1	MD (1)
USGS	1	MW (1)

PMG;TUN	1	ML (1)
JER	1	None (1)
PMG;SPGM	1	ML (1)
AAE	1	ML (1)
NDI	1	mb (1)
RBA;NEIC	1	MD (1)
LJU;NEIC	1	MD (1)
ZST;PEK	1	MLV (1)
ATH;NEIS	1	ML (1)
KUK;NEIC	1	ML (1)
LMM;NEIC	1	MG (1)
LJU;NEIS	1	MLV (1)
TOL	1	ML (1)
ALG;NEIC	1	MG (1)
TOL;NEIS	1	ML (1)
SKO	1	ML (1)
CSS;ISC	1	ML (1)
VIE;NEIC	1	MD (1)
BHL;NEIS	1	ML (1)
LAT;BUL	1	ML (1)
GFZ	1	MW (1)
PRE;NEIC	1	ML (1)
SFS;NEIS	1	ML (1)
LAT;MDD	1	ML (1)