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Secular Change in the Geomagnetic Field in West Africa for Thirty Years: Comparison with Fourth Generation IGRF Models

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Comparisons of secular variations computed from geomagnetic reference field models were made against the data obtained at Mbour and Bangui observatories and at 24 magnetic repeat stations in West Africa. The obtained results were very similar between the observatory and the repeat station data, indicating that (1) the IGRF models provide an excellent fit to secular variation data, and (2) there are no significant anomalies in African secular variation.

1. Introduction

In 1986, Working Group I1 of the International Association of Geomagnetism and Aeronomy (IAGA, 1986) decided the form of the fourth generation of the International Geomagnetic Reference Field (IGRF). These models consist of a series of spherical harmonics and represent the Earth's main magnetic field from 1945 to 1985 at 5 year intervals and secular variation predicted for 1985–1990. We compared the secular variation derived from these models to (1) first differences of the annual mean values from two African observatories, and (2) the data from 24 African magnetic repeat stations reoccupied by ground magnetic surveys in West Africa from 1983 to 1986.

2. Comparison with Observatory Values

The secular variation, derived by interpolation from IGRF models, is compared with the first differences of the annual mean values from Mbour (Senegal) and Bangui (Central Africa) magnetic observatories. We analysed H, Z, and D (magnetic northward, downward components and declination, respectively) which were measured components by Lacour apparatus in both observatories.

Figure 1 shows, for H, Z, and D at both observatories, the values of the first differences of the annual mean data (circle) and the secular variation computed for each five-year interval of time from IGRF models (straight line). The mean value and standard deviation in H, Z, and D of observatory data minus values computed from IGRF models with every 5 years are listed in Table 1. We can see that mean differences are small at both observatories (except for Z for 1960–1965 at both observatories and Z for 1975–1980 at Mbour), but the scattering is larger with the data at Bangui. The

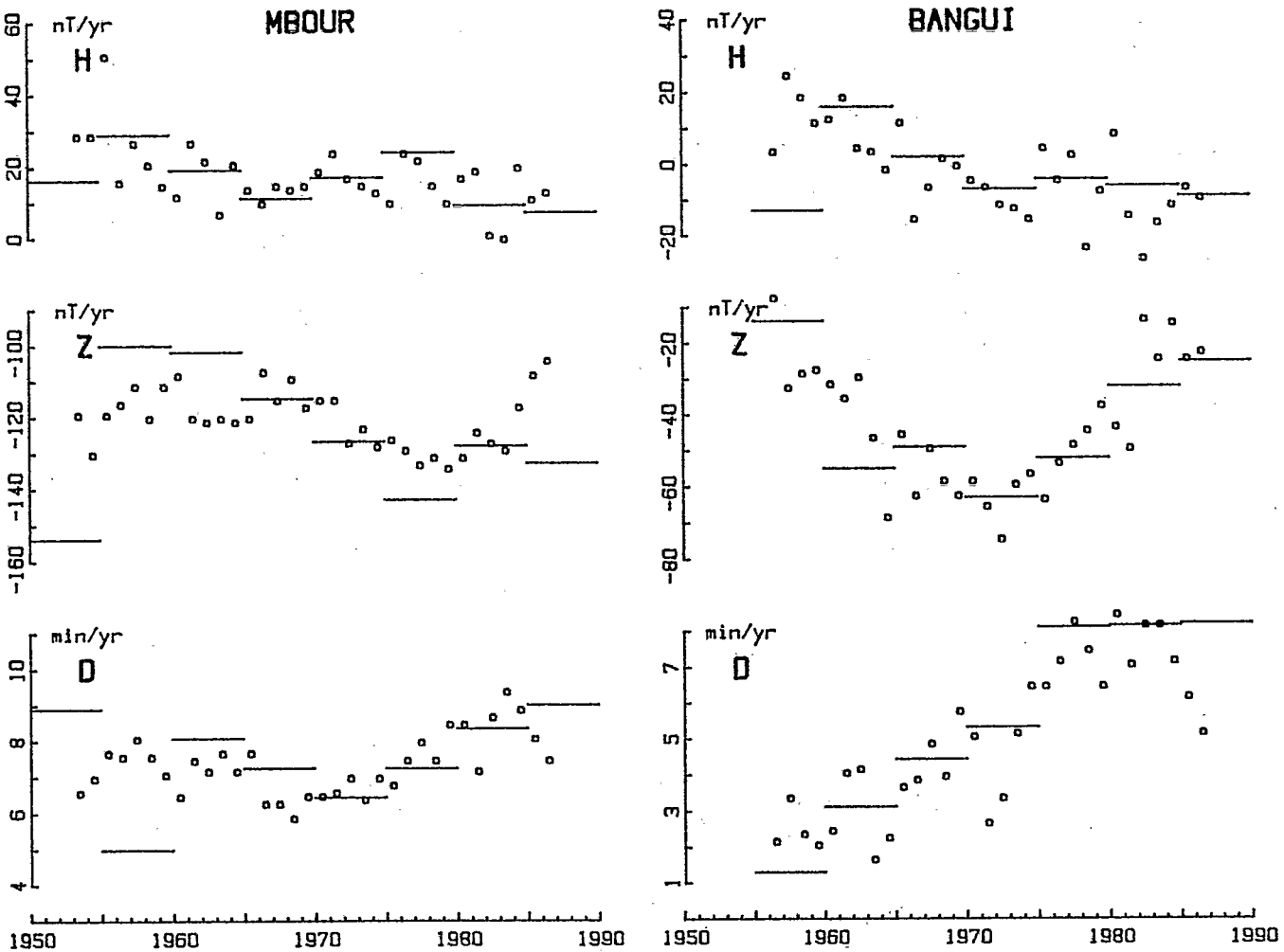

Fig. 1. Values of first differences of the annual mean data (O) and five-year interval IGRF secular variation (—) from Mbour and Bangui observatories.

Table 1. The mean value and standard deviation of first difference observatory values minus secular variation IGRF values with every 5 years.

		MBOUR observatory		BANGUI observatory	
Component	Epoch	Mean	Standard deviation	Mean	Standard deviation
H nT/yr	1960–1965	−1.4	8.0	+8.0	7.9
	1965–1970	−2.6	2.1	+3.4	10.0
	1970–1975	−0.6	4.2	+2.6	4.5
	1975–1980	+6.4	5.6	+1.2	11.1
	1980–1985	−1.4	9.3	+1.0	14.0
Z nT/yr	1960–1965	+16.2	5.7	−13.2	16.1
	1965–1970	−1.4	5.5	+6.2	7.8
	1970–1975	−5.2	6.1	−0.6	7.3
	1975–1980	−12.4	3.2	−3.0	9.8
	1980–1985	−2.4	5.5	−3.6	16.6
D min/yr	1960–1965	+0.86	0.46	+0.17	1.13
	1965–1970	+0.69	0.68	−0.02	0.89
	1970–1975	−0.28	0.29	+0.75	1.52
	1975–1980	−0.44	0.65	+0.91	0.76
	1980–1985	−0.19	0.82	+0.32	0.64

existence of a large magnetic anomaly in Central Africa (REGAN and MARSH, 1982) probably explains this scattering. Figure 1 and Table 1 show that:

1) in all components, both observatory results are not much different.

2) the IGRF model provides a good compromise, especially for the period 1960–1985. A similar conclusion is obtained by DAWSON and NEWITT (1982) in North America by comparing observatory values with IGRF models.

3) the predictive ability of the model for the period from 1985–1990 does not seem very good. This confirms MALIN (1983) on the unpredictability of the secular change.

3. Comparison with Magnetic Repeat Station Values

The Institut Francais de Recherche pour le Developpement en Cooperation (ORSTOM) undertook a ground magnetic survey in West Africa from 1983 to 1986 (VASSAL and VILLENEUVE, 1987). Among 60 magnetic measurement stations, 24 were old repeat stations already reoccupied, some since 1913 by Carnegie Institution, then by ORSTOM from about 1958 (RECHENMANN and REMIOT, 1962), 1947 (DUBIEF, 1948) 1968 (BARSCZUS, 1969) and 1973 (Mbour observatory archives). Figure 2 shows the spatial distribution of stations in West Africa. We can see the location of Mbour and Bangui observatories near the western and the eastern boundaries of the studied area. The ground location of IGRF 1985 dip equator is also drawn. Table 2 brings together all the measurements conducted at these stations since

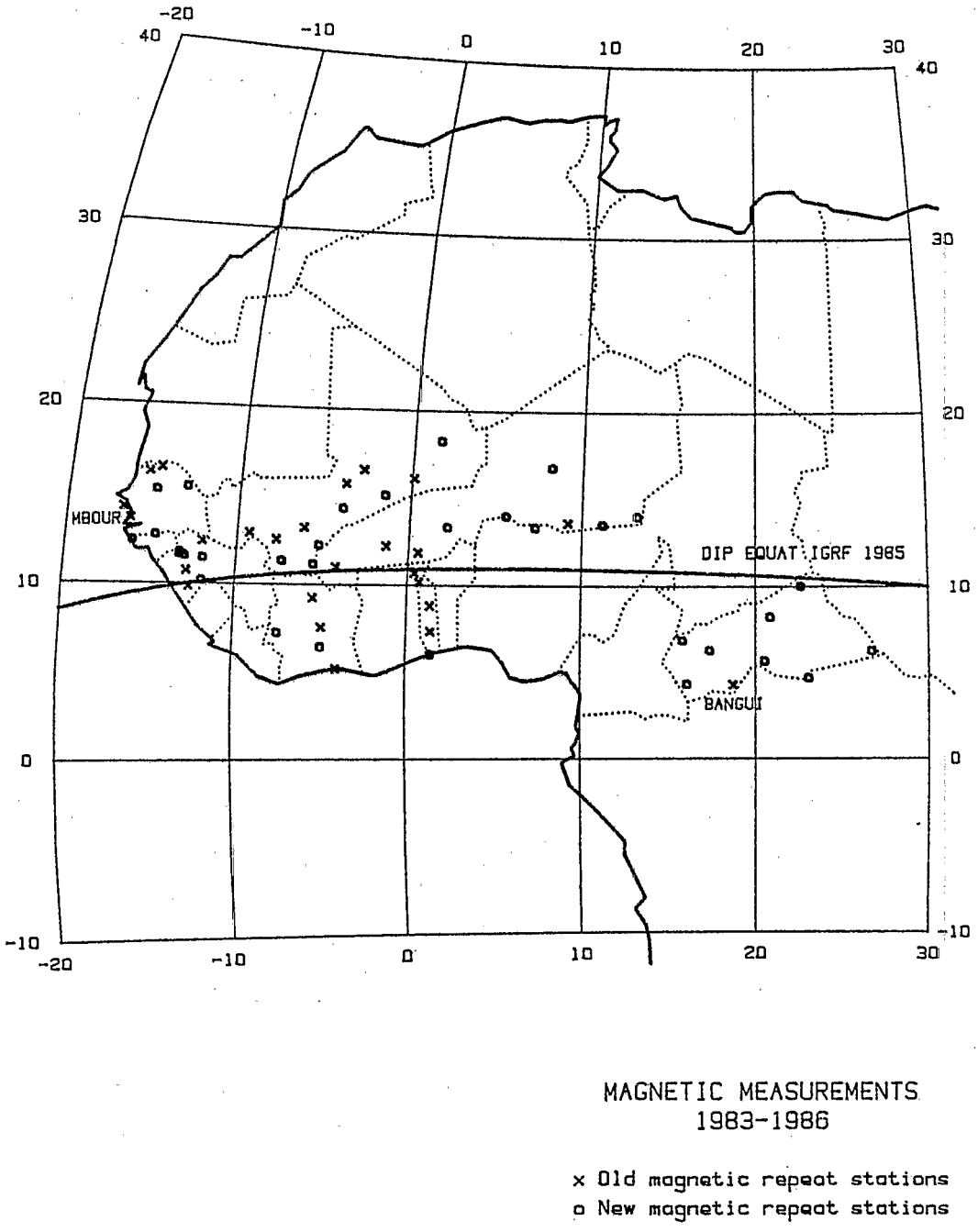

Fig. 2. Location of old (×) and new (○) magnetic repeat stations in Africa.

Table 2. Measured field components in 60 African repeat stations: Name, north latitude, east (+) or west (−) longitude date, horizontal, vertical and declination components.

Station	Lat	Long	Epoch	*H* nT	*Z* nT	*D* degree
BANGUI-observ.	4.433	18.567	1986.04	32063	−9191	−2.43
Mbako	4.459	15.927	1986.04	31456	−10064	−0.24
Bangassou	4.821	22.894	1986.04	32780	−8482	−2.78
Abidjan	5.251	−3.928	1946.98	30918	−4112	−13.20
			1958.29	30630	−5020	−11.72
			1968.21	30520	−5860	−10.75
			1973.62	30566	−6580	−10.38
			1986.04	30303	−7485	−8.53
Adiopodoume	5.325	−4.133	1958.29	30570	−4960	−11.75
			1968.29	30470	−5750	−10.53
			1986.04	30226	−7438	−8.54
Obo	5.413	26.527	1986.04	32836	−7840	−0.03
Yakota	5.825	20.378	1986.04	32122	−5837	−2.45
Lome	6.175	1.210	1986.04	31315	−6850	−6.33
Bossangoa	6.444	17.232	1986.04	32777	−7982	
Toumodi	6.584	−5.065	1986.04	30777	−5842	−8.53
Bocaranga	7.018	15.652	1986.04	33154	−5737	
Man	7.354	−7.597	1986.04	31121	−4359	−9.17
Atakpame	7.517	1.200	1955.29	31770	−2970	
			1973.94	31826	−4470	−7.42
			1986.04	31836	−4812	−5.94
Bouake	7.728	−5.072	1958.29	31290	−1890	−11.33
			1963.46	31280	−2270	−10.73
			1968.21	31270	−2670	−10.27
			1973.63	31264	−3236	
			1986.04	31118	−4318	−8.07
Ndele	8.391	20.693	1986.04	34162	−3686	−1.29
Sokode	8.994	1.150	1955.29	32170	−1050	−8.93
			1974.18	32261	−2261	−7.35
			1986.04	32334	−3019	−5.67
Korhogo	9.413	−5.623	1948.89			−12.32
			1958.20	31660	360	−11.08
			1963.45	31720	−60	−10.47
			1968.20	31720	−440	−9.97
			1986.04	31775	−2058	−7.81
Kindia	10.000	−12.867	1958.13	31400	2810	−14.43
			1986.04	31467	−310	−10.86
Takalama	10.180	22.463	1986.04	34691	−380	−2.32
Mango	10.374	0.473	1955.20	32400	940	−8.80
			1974.41	32566	−232	−7.04
			1986.04	32653	−1004	−5.44

Table 2. (continued).

Station	Lat	Long	Epoch	H nT	Z nT	D degree
Dapango 1	10.800	0.250	1974.41	32703	394	−7.04
			1986.04	32736	−368	−5.46
Dapango 2	10.857	0.195	1986.04	32578	−371	−5.22
Telimele	10.893	−13.037	1958.13	31670	4090	−14.08
			1986.04	31614	924	−10.58
Bobo-dioulasso	11.167	−4.327	1958.29	32150	2500	−10.22
			1968.20	32280	1730	−9.12
			1986.04	32407	281	−6.98
Sikasso	11.338	−5.695	1986.04	32290	567	−7.37
Bougouni	11.450	−7.517	1986.04	32179	848	−8.07
Tiangel	11.638	−12.110	1986.04	32020	1715	−10.04
Gaoual	11.738	−13.203	1986.04	31756	2152	−10.46
Koumbia	11.807	−13.493	1986.04	31596	2201	−10.86
Kambala	11.920	−13.468	1986.04	31591	2498	−10.57
Fada	12.042	0.361	1955.24	32610	3240	−8.43
			1963.50	32760	2630	−7.58
			1986.04	33026	1460	−5.09
Koutiala	12.350	−5.433	1986.04	32508	2243	−6.99
Ouagadougou	12.382	−1.503	1963.41	32600	3430	−8.05
			1986.04	32872	1871	−5.63
Ziguinchor	12.555	−16.280	1986.04	31744	3828	−11.36
Kedougou	12.565	−12.217	1972.03	31905	4602	−11.85
			1986.04	32007	3075	−9.85
Bamako	12.657	−7.932	1946.97	32232	6133	
			1986.04	32423	2622	−7.98
Kolda	12.878	−14.958	1986.04	31939	3889	−10.93
Kita	13.070	−9.493	1957.01	31860	6142	−12.28
			1986.04	32331	3315	−8.46
Segou 1	13.425	−6.277	1986.04	32648	3592	−7.19
Segou 2	13.441	−6.280	1947.07	32230	6694	−11.97
			1954.36	32293	6130	−10.75
			1957.02	32200	5900	−10.58
			1986.04	32708	3605	
Maradi	13.500	7.100	1986.04	33926	3736	−3.10
Niamey	13.558	2.050	1986.04	33457	3643	−4.28
Goudoumaria	13.705	11.183	1986.04	34251	4128	−2.22
Toubakouta	13.783	−16.480	1975.70	31719	6823	−13.07
			1986.04	31791	5554	−11.35
Zinder	13.783	8.990	1958.40	33740	5214	−5.15
			1986.04	34165	4139	−2.78
Dabnou	14.157	5.365	1986.04	33755	4541	−2.95
Nguigmi	14.243	13.100	1986.04	34403	5022	−1.82
MBOUR-observ.	14.392	−16.958	1986.04	32013	6553	−11.33
Mopti-Sevare	14.512	−4.090	1986.04	32973	5009	−6.19
Hombori	15.283	−1.700	1986.04	33171	6121	−5.20
Linguere	15.398	−15.102	1986.04	32192	7418	−10.40
Matam	15.600	−13.328	1986.04	32263	7519	

Table 2. (continued).

Station	Lat	Long	Epoch	*H* nT	*Z* nT	*D* degree
Niafunke	15.930	−3.990	1955.01	32430	9060	−9.38
			1957.12	32439	8949	−9.21
			1986.04	33142	7007	−5.85
Gao (Airfield)	16.250	0.000	1957.96	32930	9560	−7.05
			1986.04	33191	7564	−4.48
Gao (Carnegie)	16.273	−0.052	1986.04	33230	7563	−4.55
Richard-Toll	16.437	−15.657	1956.22	31463	12295	−14.78
			1986.04	32071	9057	−10.21
Podor	16.680	−14.963	1956.22	31530	12290	−14.18
			1986.04	32143	9182	−10.06
Tombouctou	16.730	−3.005	1955.10	32530	10120	−9.50
			1957.10	32575	10027	−8.77
			1986.04	33212	8204	−5.43
Agadez-Azel	17.052	8.055	1986.04	34008	9130	−2.48
Kidal	18.472	1.383	1986.04	33596	10836	−3.77

1945: Name of station, north latitude, longitude (+ eastward, − westward) in degrees, data reduction epoch, *H*, *Z* (nT) and *D* (degree) components.

The IGRF models were compared with *H*, *Z*, and *D* values resulting from magnetic repeat station where measurements were repeated more than twice. For each measuring site and for the dates of measurements, we calculated the IGRF values by linearly interpolating between successive main-field models or by using the secular variation models for 1985–1990. Then we computed the secular variations at respective sites by taking differences between successive field values at each site both for those measured and for calculated from IGRF models.

We compared this calculated secular variation (SV) with measured SV. The residual SV obtained for *H*, *Z* and *D* components (calculated SV minus measured SV) are listed in Table 3. The blanks are due to no measurement being made. The mean and standard deviations for each component are calculated on the bottom of the table.

The residual values of SV are small on all components and are similar to observatory values. These results denote no significant long wavelength anomalies in West Africa.

4. Conclusion

The main conclusion of this work is that the IGRF secular variation models provide a satisfactory fit to secular variation data in West Africa. There are not sufficient repeat stations to draw an up-to-date secular variation chart. However, the combination of the IGRF chart, the ORSTOM magnetic chart for 1958 and observatory data allow good precision in obtaining actual magnetic values.

Table 3. Residual secular variation of 24 repeat stations where measurements were repeated more than twice (calculated SV minus measured SV). H and Z in nT/yr, D in min/yr.

Station	Lat	Long	Time interval	Residual SV		
				H	Z	D
Abidjan	5.251	−3.928	1946–1958	4	2	−0.1
			1958–1968	3	14	0.2
			1968–1973	−14	37	1.7
			1973–1986	12	−31	−1.4
Adiopodoume	5.325	−4.133	1958–1968	2	8	−1.2
			1968–1986	6	−7	0.6
Atakpame	7.517	1.200	1955–1973	−5	20	
			1973–1986	2	−57	0.0
Bouake	7.728	−5.072	1958–1963	−4	7	−0.4
			1963–1968	7	7	0.4
			1968–1973	3	9	
			1973–1986	11	−16	
Sokode	8.994	1.150	1955–1974	−2	5	0.3
			1974–1986	2	−19	−1.1
Korhogo	9.413	−5.623	1948–1958			−2.7
			1958–1963	−11	13	−2.8
			1963–1968	9	5	0.1
			1968–1986	2	−9	1.1
Kindia	10.000	−12.867	1958–1986	0	−4	−0.3
Mango	10.374	0.473	1955–1974	−2	2	
			1974–1986	4	−14	−0.8
Dapango	10.800	0.250	1974–1986	10	−15	−0.6
Telimele	10.893	−13.037	1958–1986	7	−2	−0.1
Bobo-Dioulasso	11.167	−4.327	1958–1968	−3	15	−0.3
			1968–1986	4	−10	0.1
Fada	12.040	0.360	1955–1963	−15	28	−0.6
			1963–1986	6	−19	0.0
Ouagadougou	12.382	−1.503	1963–1986	5	−6	0.4
Kedougou	12.565	−12.217	1972–1986	4	−11	−0.8
Bamako	12.657	−7.932	1946–1986	5	−1	
Kita	13.070	−9.493	1957–1986	−3	2	−0.6
Segou	13.441	−6.280	1947–1954	−4	−5	−1.3
			1954–1986	2	−3	
Toubakouta	13.783	−16.480	1975–1986	6	−12	−2.0
Zinder	13.783	8.990	1958–1986	8	−1	0.4
Niafunke	15.930	−3.990	1957–1986	−2	0	0.0
Gao	16.273	−0.052	1957–1986	15	17	1.1
Richard-Toll	16.437	−15.657	1956–1986	3	0	−1.8
Podor	16.680	−14.963	1956–1986	3	−1	−0.9
Tombouctou	16.730	−3.005	1957–1986	2	1	0.0
		Mean		+2.1	−1.3	−0.4
		Standard deviation		6.4	16.1	1.0

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