Towards the Opening of a Magnetic Observatory at DomeC (Antarctica)

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Abstract

The opening of a new magnetic observatory is one of the activities aimed at by the creation of a scientific base at DomeC, Antarctica (lat. 75° 06'S, long. 123° 21'E, elev. 3200m). There are many reasons supporting this objective: all Antarctic magnetic observatories providing absolute values are located along the shore and are therefore subject to coast effects and crustal field contamination. DomeC and Vostok will be so far the sole observatories free from these effects. On one hand, high latitude absolute observatories are very useful to global or regional modeling based upon satellite data, because, at high latitudes, only total field measurements can be used due to the strong influence of field aligned currents. On the other hand, the availability of magnetic data from the well distributed observatories of Terra Nova Bay (TNB), Scott Base (SBA), Dumont d'Urville (DRV), Casey (CSY) and Vostok (VOS) will provide strong support to auroral and polar cap ionosphere studies as well as asymmetry analyses between Northern and Southern hemispheres. This paper summarizes the results gathered during three summer campaigns, in 1999-2000, 2001 and 2003-2004.

1. Scientific advantages expected

There is a fairly large number of magnetic observatories on the Antarctic continent. However, as shown on figure 1, only three observatories – Dumont d'Urville (DRV), Scott Base (SBA) and Argentine Island (AIA) – provide absolute values according to modern standards like those edicted by Intermagnet (some other observatories enter this category too, even if they do not fit the same accuracy requirements). Let us remind that the data recorded by this type of observatories is appropriate for internal as well as external field studies.

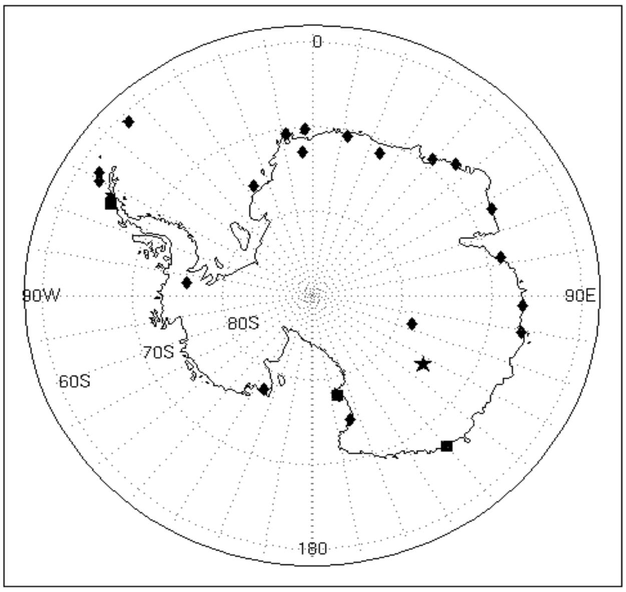

Figure 1. Location of magnetic observatories in Antarctica. Square: Intermagnet observatories; diamond: observatories with various status; star: DomeC observatory

If we now consider the observatories providing absolute values, the lack of balance with the Northern hemisphere is striking. In addition, both DRV and SBA are located on extremely magnetized basements, producing severe observatory biases which are a drawback to be taken into account in global or regional models. They are also submitted to coast effects which influence the power spectrum at diurnal frequencies and beyond.

DomeC (hereafter noted DMC) will be operated jointly by Ecole et Observatoire des Sciences de la Terre, Strasbourg, France, and by Istituto di Geofisica e Vulcanologia, Roma, Italy, with the logistic and partly financial support of the French Institution Institut Polaire Français Paul Emile Victor (IPEV) and the Italian Institution Ente per le Nuove Tecnologie, l'Energia e l'Ambiante (ENEA). DMC and VOS will be the ones observatories free of crustal contamination and coast effects. DMC will be operated in accordance to the accuracy requirements set by Intermagnet and hence, to provide data constraining helpfully global and regional models of the main field and its secular variation [1], [2]. If we include the recently upgraded observatory at Argentina Island (AIA), after the permanent opening of DMC, there will be only four observatories on the whole Antarctic continent operated according to Intermagnet standards, much lesser than in the Northern hemisphere, at similar magnetic latitudes. Regarding the external field, DMC is situated inside the polar cap, close to the invariant pole and the geomagnetic South pole. The auroral zones and polar caps are areas where the spatial variation of phenomena like magnetic storms, substorms, pulsations, is sharp. Hence, their study requires the availability of a dense network of stations. Once again, this is the case in the Northern hemisphere. In the Southern hemisphere, VOS, Casey (CSY), DMC, DRV, SBA and Terra Nova Bay (TNB) will built up a fairly dense network in the particular region mentioned above. The paper published by [3], based upon data from TNB and DMC, highlights the interest for DMC from external point of view.

The results summarized hereafter were obtained during three preliminary summer campaigns achieved in December 1999-January 2000, December 2001 and December 2003-January 2004.

2. Equipment and protocol of measurements

The observatory is equipped with standard instruments for continuous three-component field variation records and absolute measurements.

The field variations are recorded with a suspended triaxial fluxgate magnetometer (FGE type) especially manufactured by the Danish Meteorological Institute for low temperatures, with suitable damping silicon oil and silicon connection cables. It is put on a pillar penetrating about one meter into the ice. Although the horizontal component is weak (around 10400 nT), the variometer has been oriented with respect to the local magnetic meridian. The technical specifications are: dynamic range ±4000 nT; resolution 0.2nT; temperature coefficient of sensor lower than 0.2nT/°C; temperature coefficient of electronics lower than 0.1nT/°C; band pass DC to 1Hz; sampling rate 1Hz. An Overhauser proton magnetometer SM90R records the field intensity at a sampling rate of 0.2Hz. Both instruments are installed in a cave, two meter deep, situated beneath the shelter containing the electronics and acquisition system. The summer temperature of the cave is –40°C. The acquisition system was built up by INGV. It comprises mainly a 24bits AD converter and a PC driving both the AD converter and the SM90R. Accurate timing is provided by GPS signal. A second PC connected to the acquisition displays a control board and current records. Electronics and acquisition are located inside a thermally controlled box.

The absolute measurements are carried out on a pillar made with a polyethylene tube, supporting temperatures down to lesser than –40°C. Its dimensions are : length 3m, diameter 40cm, thickness 2.27cm. It penetrates 1.75m into the ice. It is located inside a shelter which may be heated during the measurements. The absolute measurements consist of D, I measurements with a D-I flux amagnetic theodolite and F measurements performed with a second Overhauser proton magnetometer SM90R. The theodolite is a Zeiss 010A type with reading in grades, 0.5 second of arc resolution. The original lubricant was replaced by a lighter one for working at low temperatures. However, due to the shelter heating, the theodolite should never experience negative temperatures during measurements. The sensor is a LEMI fluxgate driven by an electronics constructed by EOST. An azimuth mark was fixed onto the variometer shelter, about 25m distant. Its true North bearing was determined from sun observations [4]. Due to magnetic activity, declination and inclination are measured using a close-to-zero method [5] and all readings are reduced to a common time, nearly the mean time of the whole sequence time span.

To summarize, three component field variations are recorded at 1Hz sampling rate. Intensity is recorded at 0.2Hz sampling rate. Both kind of data are filtered according to Intermagnet recommendations and resampled at one minute sampling rate. In addition, one minute spot values are recorded, mainly for base line determination purposes.

3. Some results

3.1. Example of one-minute record

Figure 2 displays one minute filtered records for the days 22 and 23 January 2004 provided par PAF, DRV, TNB, DMC and SBA. The beginning of a moderate magnetic storm may be noticed at 1h36 UT. The aspect of the field variation may be correlated with the corrected geomagnetic coordinates of the observatories which are given in table 1. They were computed with the facilities of the NSSDC Web site http://nssdc.gsfc.nasa.gov/space/cgm [6]. Note the large variation in magnetic local time (MLTMN is magnetic midnight local time) due to the proximity of the South corrected geomagnetic pole.

Table 1. Geographical and corrected geomagnetic coordinates

Station	Geographical coordinates Latitude	Longitude	altitude	Corrected geomag. coordinates		MLTMN in UT
PAF	-49.35	70.26	35m	-58.27	121.91E	20:56
DRV	-66.67	140.02 E	40m	-80.49	235.78 E	12:55
TNB	-74.69	164.12 E	0m	-80.04	307.52 E	8:19
SBA	-77.85	166.76 E	5 m	-73.28	219.00 E	14:40
VOS	-78.47	106.82 E	3488m	72.91	177.43 E	17:09
DMC	**-76.10**	**123.33 E**	**3200m**	**-87.80**	**39.17 E**	**2:11**

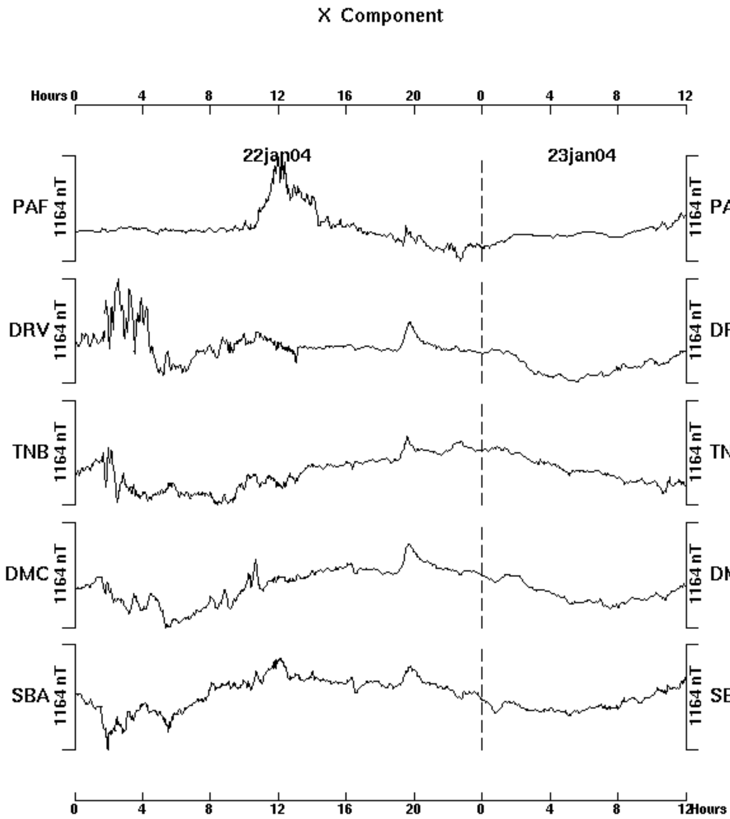

Figure 2. Comparison of one minute records of the horizontal X component provided by DMC and observatories near-by (PAF: Port-aux-Français; DRV: Dumont d'Urville; TNB: Terra Nova Bay; SBA: Scott Base).

3.2. Example of computation of absolute values

The data have been processed in order to incorporate the base line values. Absolute measurements were carried out from January 23 to February 02 and extrapolated towards the beginning of January. Figure 3 shows an example of results for January 2004. The absolute hourly means are displayed along with the daily means and monthly means. The diurnal variation, although irregular, is clearly seen mainly on the horizontal components. The bottom part shows in addition the total field computed from component values (F) minus the total field recorded by the proton magnetometer (P). This F-P line exhibits a slight 2 nT drift during the extrapolated time interval of the absolute measurements. Figure 4 shows a sensor temperature increase of about 3 °C over the same period, which would mean a temperature sensitivity of the sensor close to 1nT/°C, at variance with the instrument specifications. Although the temperatures unfortunately failed to be recorded during the absolute measurement period, it seems that the temperature tended towards an equilibrium. Anyway, no clear drift can be observed on the base lines. The thermal sensitivity of the acquisition cannot be responsible for the variation either, because, as shown on figure 4, its temperature oscillates around a fairly constant value. Thus, there is no clear explanation for the F-P drift.

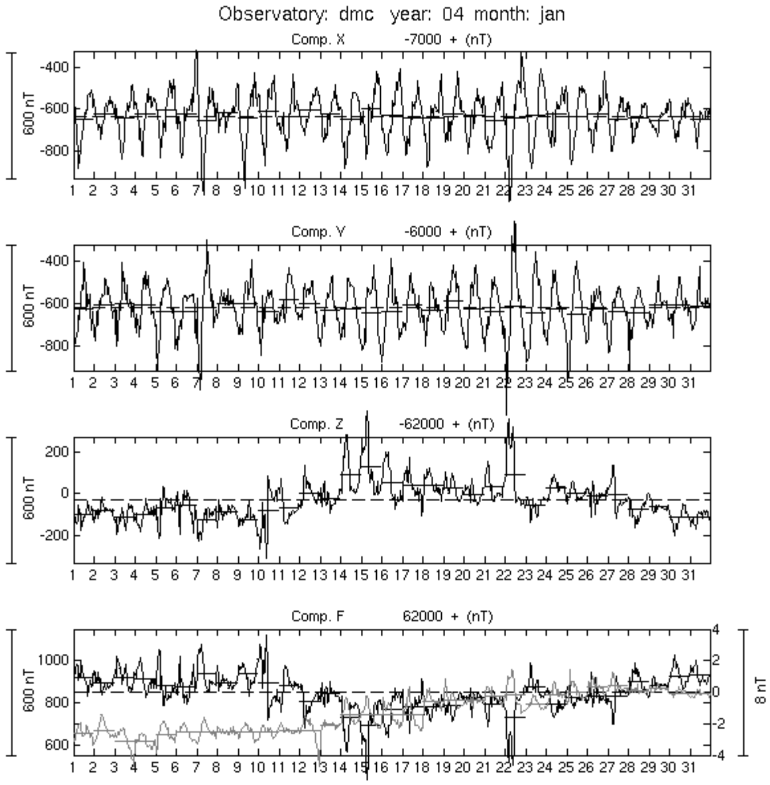

Figure 3. Example of records of absolute values. Solid lines: hourly means; solid horizontal lines: daily means; dashed lines: monthly means; bottom grey lines: F-P hourly and daily means (see text for definition)

3.3. Long term evolution

Figure 5 shows the variation of the daily mean of the vertical component over the three years spanned by the summer campaigns compared to the evolution predicted by the IGRF models 1995 and 2000. The figure shows a fairly good overall agreement with small departures which may be attributed to regional features of the secular variation. For DRV and SBA, this agreement is obtained provided that a bias field, calculated by [7], is subtracted from the observatory data. This bias field is very large for DRV and SBA, as table 2 shows. It is due to the strongly magnetized basement which creates a very heterogeneous field in both observatories.

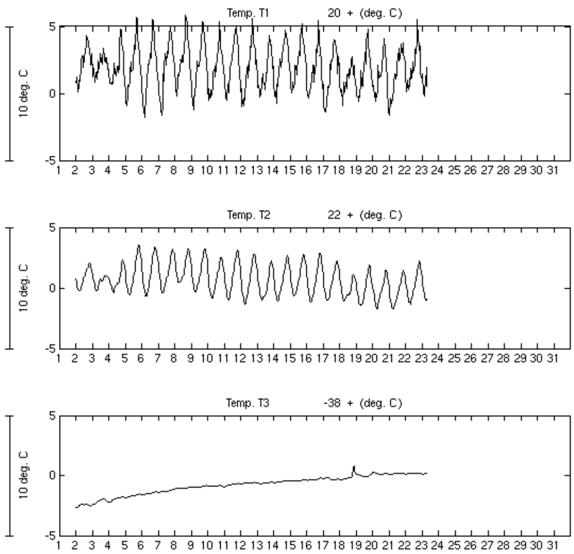

Figure 4. Temperature records in the variometer shelter. T1: electronic box; T2: room ; T3 : cave beneath the shelter, containing the sensors

No bias correction is necessary for DMC data, supporting the assumption that the crustal field is negligible at DomeC.

Table 2. Observatory bias field at DRV and SBA

	X(nT)	Y(nT)	Z(nT)
DRV	-119	-382	-2837
SBA	-2190	-924	-3683

4. Conclusions

The preliminary tests conducted during the three summer campaigns, 1999-2000, 2001, 2003-2004, demonstrate the feasibility of installing a magnetic observatory under the extreme temperature conditions prevailing at Dome C. However, definitive conclusions will be drawn only after an extended test period including winterage when the external temperature will drop to –70°C. Another yet unknown point is the long term stability of the ice shelf and hence the stability of the reference absolute measurement pillar. These uncertainties notwithstanding, the site is excellent for magnetic observations, due to the negligible influence of both crustal field and coast effects. Both internal and external field studies will benefit from data recorded under such favourable conditions. The average field will be quite representative of the main field originating in the outer core as well as its secular variation. Along with the observatories nearby, DMC will provide helpful data for studying polar ionospheric and magnetospheric short scale processes.

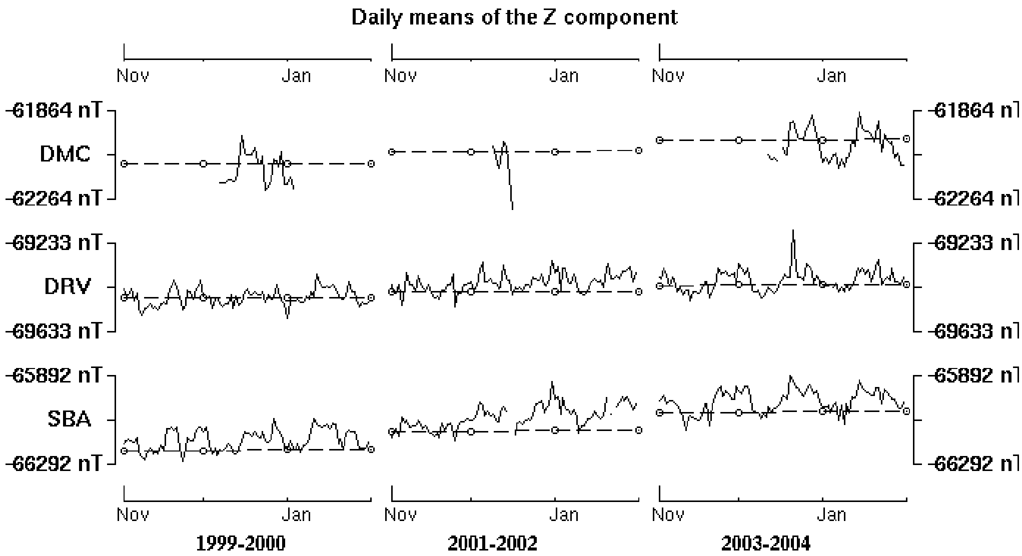

Figure 5. Daily mean summarize of the three year measurements carried out at DMC and comparison with DRV and SBA records. The internal field predicted by the IGRF (circles and dashed lines) is shown for inspection of the long term evolution.

Acknowledgements

L. Tomlinson provided us with the early processed data from Scott Base, January 2004.

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