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The influence of time variations on aeromagnetic surveying

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ABSTRACT

Time varying magnetic fields can influence the accuracy of aeromagnetic surveys. The effect is more pronounced at lower latitudes. It can be quite small at higher latitudes if the induction vector points towards the equator. In any latitude, east–west variations have little effect.

INTRODUCTION

Aeromagnetic surveys are now of sufficient precision that the time varying field is a major source of noise (Milligan and Barton, 1998).

It is well known that in most places the time varying vectors, with time scales of a few minutes to a few hours, tend to lie in a plane, sometimes called the 'preferred plane' (Parkinson, 1962). This is often described by the formula

$$z = A.h + B.d \qquad (1)$$

where h, d, z are the components of the variation vector in the magnetic north, east and vertical (down) directions.

This paper describes a parameter relating A and B to the direction of the total magnetic force. The cosine (C) of the angle between the variation vector **V** and the direction of the total force **I** is a measure of how serious a given time change will be in interpreting the results from the aeromagnetic survey.

ANALYSIS

Take magnetic north, east and down as the unit directions in the coordinate system. The variation vector is

$$\mathbf{V} = \mathbf{i}\, h + \mathbf{j}\, d + \mathbf{k}(Ah + Bd) \;.$$

Now introduce the azimuth φ of the variation vector so that

$$\mathrm{d} = \mathrm{h}.\tan\varphi \;.$$

Writing t for $\tan\varphi$ we get

$$\mathbf{V} = h\{\mathbf{i} + \mathbf{j}\,\mathrm{t} + \mathbf{k}(A + Bt)\}$$

To ensure that this is a unit vector we choose

$$h = \pm\,\{1 + t^2 + (A + Bt)^2\}^{-1/2},$$

the + sign when $-\pi/2 < \varphi < \pi/2$,

and the – sign when $\pi/2 < \varphi < 3\pi/2$.

The unit vector in the direction of the total force is

$$\mathbf{F} = \mathbf{i} \cos I + \mathbf{k} \sin I \;,$$

where I is the inclination. The scalar product (C) of these two unit vectors is the cosine of the angle between them. This indicates the component of the variation field in the direction of the total force.

$$C = \mathbf{V.F} = \{\cos I + (A + Bt) \sin I\}\; \{1 + t^2 + (A + Bt)^2\}^{-1/2} \;. \qquad (2)$$

This depends on the azimuth t. To form a useful parameter we look for a 'worst case', i.e. we find a value of $|C|$ which is a maximum with respect to t. This is done as part of the computation.

The fact that h, the north component, has been given a finite value may cause some difficulty when $\varphi = \pi/2$ or $3\pi/2$, i.e. when h = 0.

It can be shown that in this case (2) approaches $\pm\, B \sin I\, (1 + B^2)^{-1/2}$.

Figure 1 shows values of $|C|$ as a function of A and B for various values of inclination. Some comments are worth noting:

(1) The values of the parameter are higher for lower values of inclination. It must be remembered that at low latitudes magnetic variations tend to be in a north–south direction, so the 'worst case' will be the usual one.

(2) At higher values of inclination a minimum develops for low values of B and positive values of A (in the southern hemisphere). This is the 'amphidrome' pointed out by Lilley et al. (1998).

(3) **V** and **F** are parallel when $A = \tan I$, $t = \tan\varphi = 0$ so the parameter $|C|$ is unity regardless of B.

(4) It must be remembered that this is a 'worst case' situation. If φ is near $\pi/2$ or $3\pi/2$ the effect of **V** on **F** will be minimal.

So far we have assumed that the vertical component of **V** is in phase with h and d. If it is not, A and B can be considered to be complex, the imaginary part representing the out of phase part of z. If this is not negligible, it has the effect of spreading the plane represented by (1) into a disc. This has the effect of blurring the parameter $|C|$ in Fig. 1, generally without seriously distorting the plotted value.

CONCLUSIONS

Generally a time change in the magnetic field can influence the total field by a fraction which varies with azimuth from zero to almost the full amount (parameter $|C|$ near unity), but there are certain conditions at higher inclinations under which time changes will have practically no effect on the total field.

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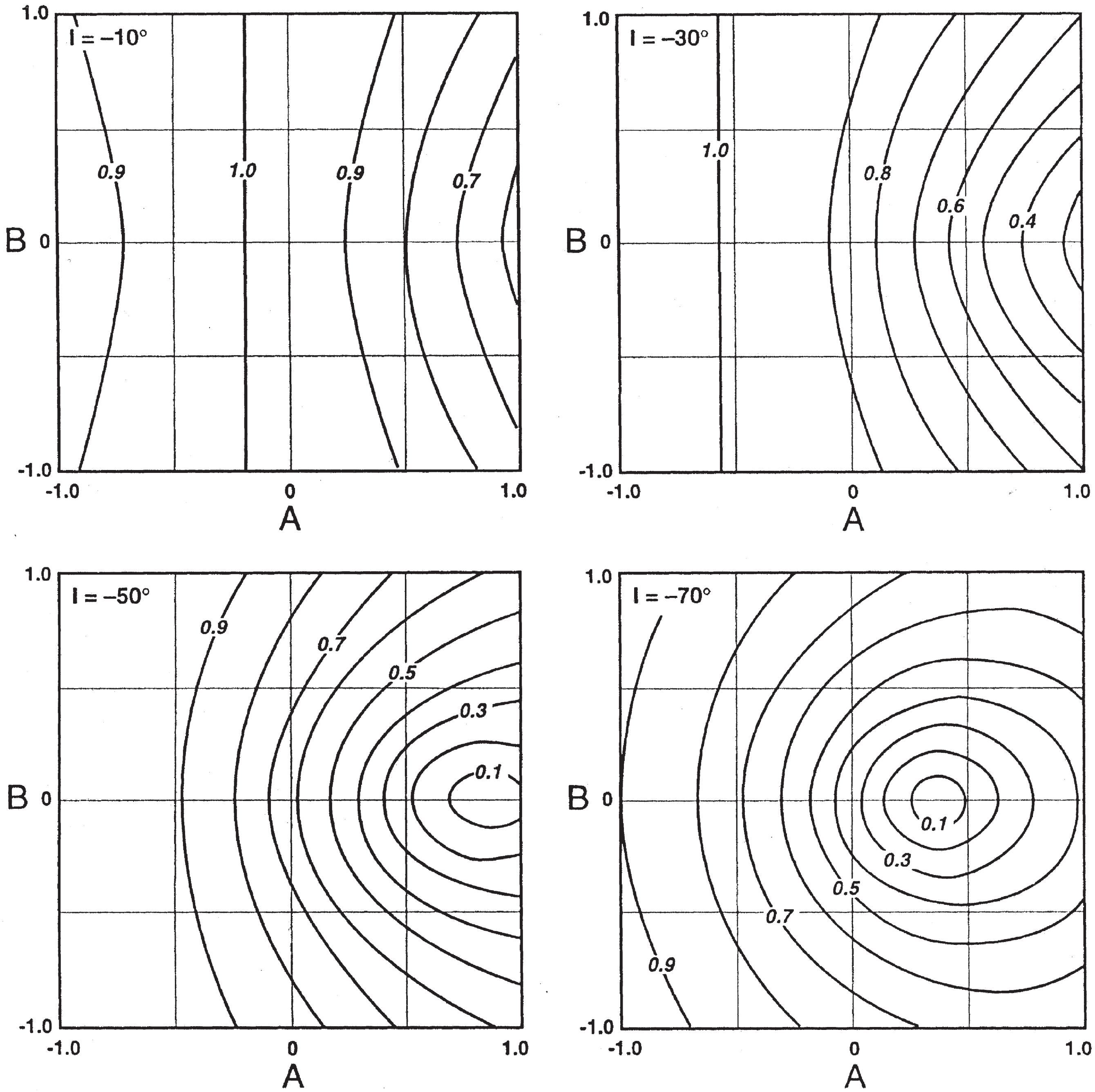

Fig. 1. Contour lines of the parameter |C| for various values of A and B for selected inclinations.

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