REPORT UAG-103

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for
Solar-Terrestrial Physics

GEOMAGNETIC POLAR CAP (PC) INDEX
1975-1993

April 1994

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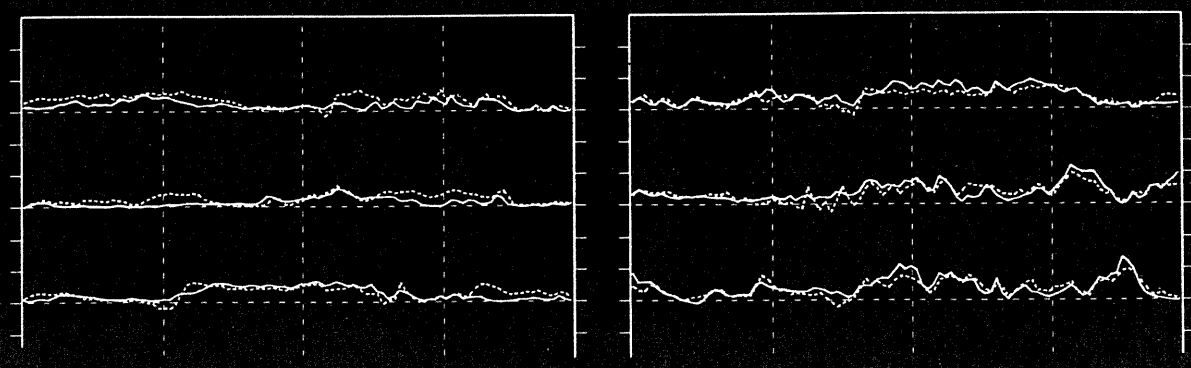

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Geomagnetic Polar Cap (PC) Index 1975-1993

by

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Geomagnetic Polar Cap (PC) Index 1975-1993

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1. INTRODUCTION

The first series of PC index values were published by WDC B in Moscow (see Troshichev et al., 1991), for the years 1975-1982. Here we present a reprint of this data series, together with a continuation for the years 1983-1993.

PC is an index for magnetic activity in the (P)olar (C)ap. It is based on data from a single nearpole station, and is aimed to monitor the polar cap magnetic activity. This activity is generated by such solar wind parameters as the southward component of the interplanetary magnetic field (IMF), the azimuthal component of the IMF (B_y), and the solar wind velocity v. The station Thule, placed in the village Qaanaaq in Greenland at 86.5° geomagnetic invariant latitude, fulfills the requirement of being close to the magnetic pole in the northern hemisphere. The station Vostok at 83.3° does the same in the southern hemisphere. The PC index is derived independently for these two stations.

The PC-index is based on an idea by Troshichev et al. (1979) and developed in papers by Troshichev and Andresen (1985), Vennerstrøm and Friis-Christensen (1987), Troshichev et al. (1988), Vennerstrøm (1990), Vennerstrøm et al. (1991).

2. THE METHOD OF CALCULATION

The method is based on the results of numerous investigations which show that the southward component of the IMF generates a two-cell equivalent current pattern in the polar regions. Although the earth is rotating under the two-cell pattern, a station in the polar cap which is located very close to the pole will always be located under the sun-aligned part of the current system. The idea was, therefore, to base the index on data from a single nearpole station and simply to use the projection of the horizontal disturbance on the dawn-dusk direction. The equivalent current crossing the polar cap is, however, known to be somewhat skewed with respect to the noon-midnight meridian and this has to be taken into account when deriving the index. Therefore, the projection formula is chosen as:

$$\mathrm{Hproj} = \Delta H \sin\gamma \pm \Delta D \cos\gamma$$
$$\gamma = \lambda \pm D_E + \varphi + UT$$

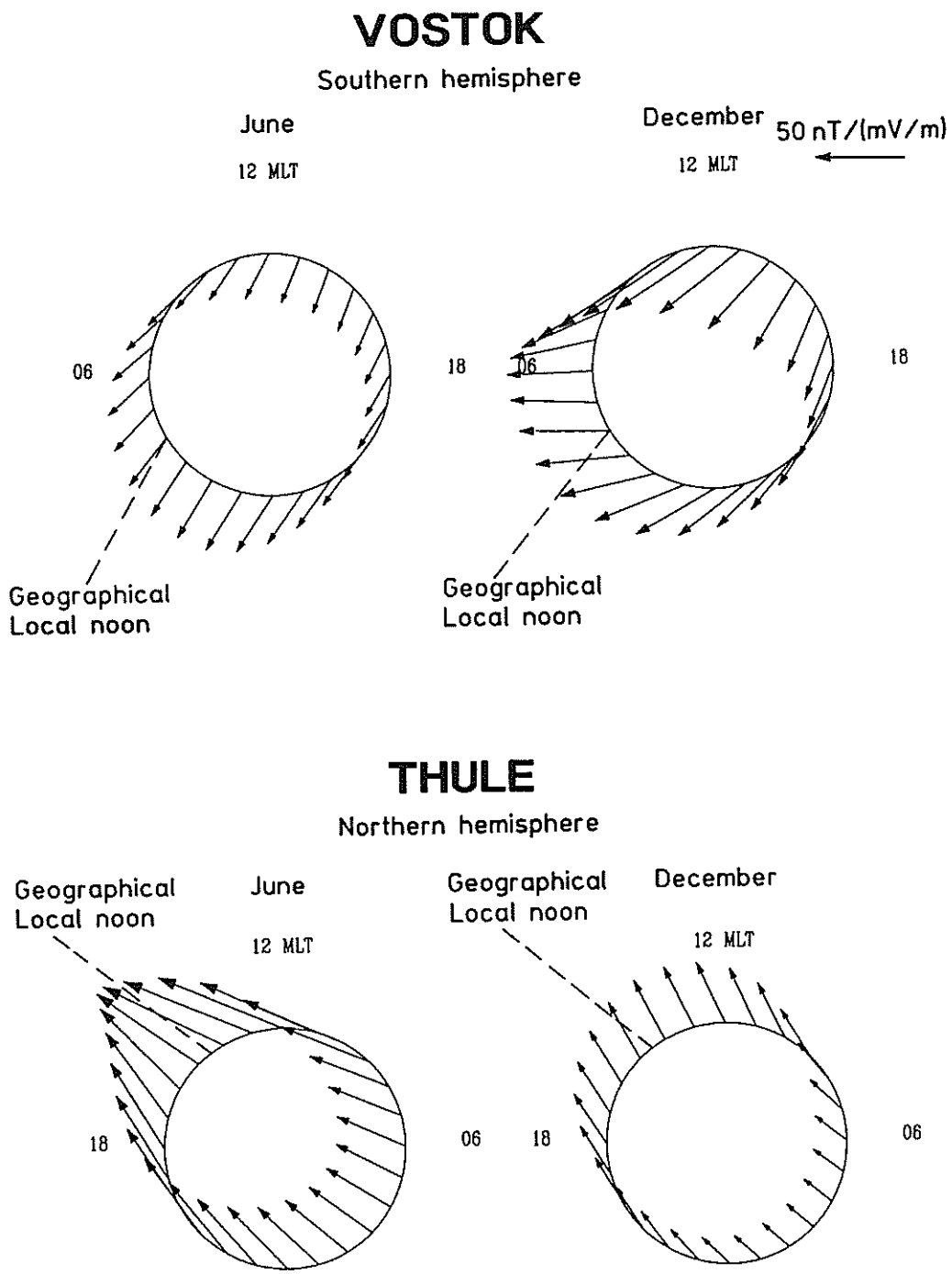

Figure 1: Invariant latitude - Magnetic local time diagram of the projection directions used in the algorithm of the index. Only the directions for June and December are shown. The size of the vectors indicate the size of the regression coefficient α.

ΔH and ΔD are the deviations of the H and D traces from the quiet level, D_E is the average value of the declination at the station, λ is the geographical longitude and φ is the angle between the direction of the current flow and the noon-midnight meridian. The quiet level is chosen as a constant baseline determined from specially selected quiet winter days. The plus sign must be used for a station in the southern hemisphere, and the minus sign in the northern. The angle φ is chosen as the angle that gives the best linear correlation with the solar wind. An analysis has shown that the parameter $vB_T\sin^2(\Theta/2) = v(B_z^2+B_y^2)^{1/2}\sin^2(\Theta/2)$, where Θ is the angle between the IMF and the earth's magnetic field at the subsolar point of the magnetopause, gives a better correlation than just B_z or vB_z. This parameter was therefore chosen to determine the directions.

The optimal direction is found to vary both with season and local time of the station, so the angle φ is therefore a function of both local time and month. The correlation is optimal when the time delay between the IMF-parameters and the polar cap disturbances is taken to be 20-25 minutes. Figure 1 shows the optimal directions for December and June for Vostok and Thule. The coordinates used in the diagram are invariant latitude and magnetic local time. The length of the vectors indicates the size of the response to a given size of the solar wind parameter. This can be seen to vary, both with month, local time, and station. In order to avoid diurnal and seasonal variations, the projected horizontal perturbation is then normalized with respect to the solar wind. The normalization coefficients are taken from the linear correlation analysis:

$$\mathrm{Hproj} = \alpha \cdot vB_T \sin^2(\frac{\theta}{2}) + \beta$$

$$\mathrm{PC} = (\mathrm{Hproj} - \beta)/\alpha$$

where α and β are functions of local time and month. Since we use the inversion of the regression formula, the so-called orthogonal regression coefficients have been selected. To avoid jumps in PC caused by a statistical uncertainty in the determination of the regression coefficients and the directions, a smoothing procedure was applied to α, β and φ. The smoothing is done by a digital low-pass filter of the binomial type, first as a function of month and then as a function of local time. As a function of month a second order filter is used, and as a function of time a tenth order filter is used. The PC-index is given as 15 minute values and the coefficients were determined as hourly averages. To avoid jumps in PC caused by the hourly exchange of coefficients in the algorithm, we finally made a spline interpolation to obtain 15 minute values of α, β and φ. The calculation of the PC-index is thus based on a set of 12 (months) by 96 (daily) values of α, β and φ. The analysis is performed for a period with good data coverage of the IMF, namely the IMS-period 1977-80. The coefficients are determined independently for Thule and Vostok, and used for the calculation of PC in 1977-80 and other years. Figure 2 shows the coefficients α and β as functions of UT and month.

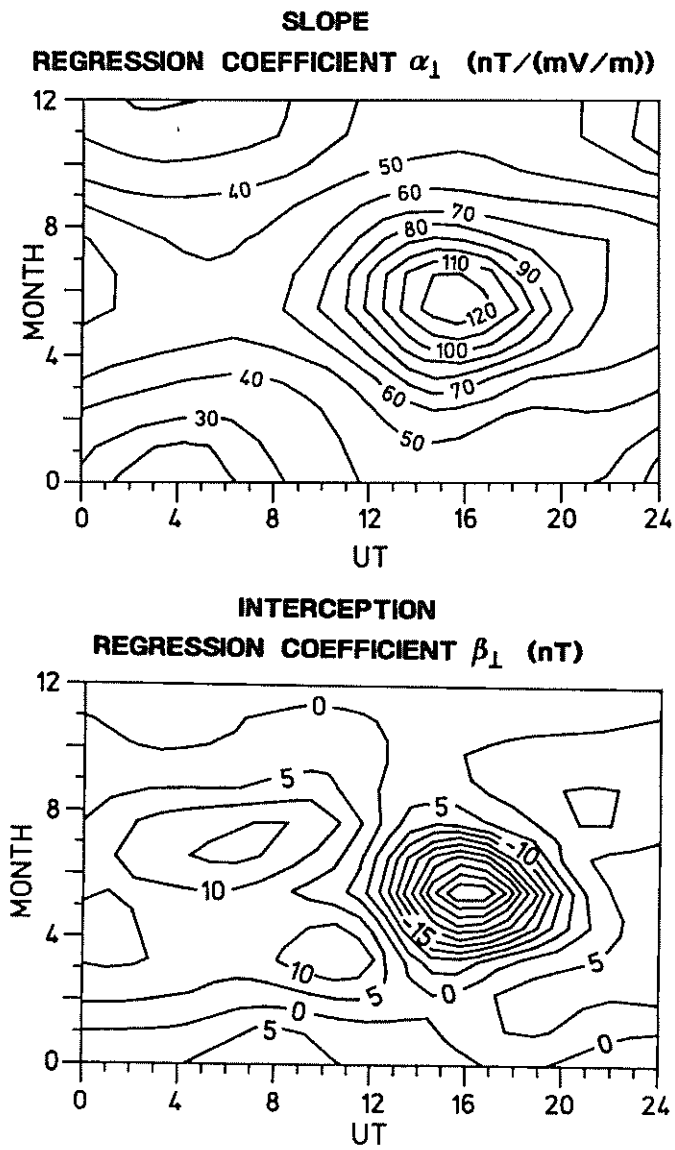

Figure 2. Contour plot of the regression coefficients α and β used in the algorithm for PC in Thule.

3. *THE PHYSICAL MEANING OF PC*

Although PC is derived using solar wind parameters in the correlation analysis, it is primarily an index of geomagnetic activity and only in a statistical sense it can be considered as a measure of the solar wind parameter $vB_T\sin^2(\Theta/2)$. This parameter has the unit of electric field and since it is used for normalization of the PC-index, PC also has the unit of electric field in the sense that a PC value PC=1 statistically corresponds to a situation where $vB_T\sin^2(\Theta/2)$=1 mV/m.

The skewed equivalent currents measured by the PC-index are thought to have two main sources: 1) ionospheric Hall-currents in the polar cap; 2) distant field-aligned currents at the poleward rim of the auroral oval. The Hall currents and field-aligned currents are expected to be of roughly equal importance with a strong seasonal effect on their relative contribution. During winter practically no ionospheric currents can exist in the low conductivity dark near pole region, and the distant field-aligned currents have to be dominant. During summer when the near pole region is sunlit both sources seem to be present. At the dayside, the Hall currents probably dominate, but at the night side the effects of the field-aligned currents seem to be essential.

When the IMF becomes strongly northward the equivalent current distribution in the polar cap changes qualitatively. The auroral oval in this case contracts, and the electrojets become very weak, so the equivalent currents discussed above disappear. Simultaneously a new current system is formed within the polar cap, with quite a different character and direction. This current system, which is often referred to as a "reversed convection event", can have a seriously disturbing

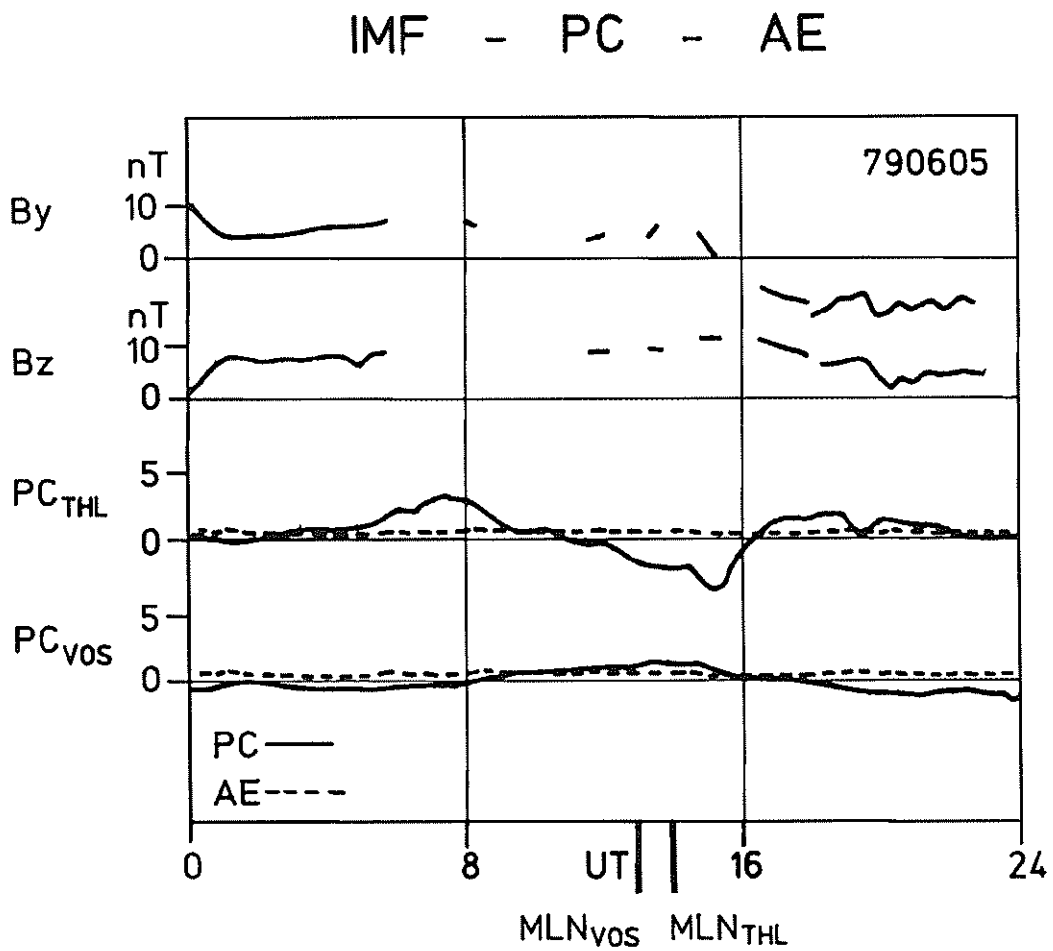

Figure 3: An event illustrating how "reversed convection events" can influence the PC-variations. The two top curves show IMP-8 measurements of the IMF B_y- and B_z-component. The bottom curves show PC in Thule and Vostok as solid lines with AE as a dashed line on top. It is seen that such events can cause both negative and positive PC-disturbances in the summer hemisphere, depending on local time and the sign of IMF B_y. MLN indicates magnetic local noon.

influence on the PC-index. Fortunately the amplitude of this current system is very seasonally dependent. During winter it almost disappears because of a low conductivity in the dark polar cap. The effect of such a current system on PC is presented in Figure 3. Not only negative, but also positive PC-values can be affected by this system. As a result an unambiguous interpretation of the PC-index is impossible during summer. It is therefore important to have simultaneous access to a PC-index derived separately from both hemispheres.

4. THE RELATIONSHIP BETWEEN PC AND AE

Statistical analyses of the relationship between PC and the auroral zone indices AE, AU, and AL reveal a very high correlation. The linear correlation coefficients, computed separately for each season as a function of local time, are shown in Figure 4. For Thule each hourly correlation coefficient is computed using roughly 2800 data points, while the number for Vostok is about 1600. The best correlation is obtained with the AE-index during winter and equinox (0.8-0.9 for Thule and 0.7-0.8 for Vostok). The correlation with AL is almost as good as that with AE. The correlation with AU is smaller and is seen to be very seasonally dependent. An analysis carried out over ranges of restricted amplitude in AE, i.e. for AE>50nT, AE>100nT, AE>200nT, etc., shows that the correlation gradually decreases with an increasing level of activity, but stays fairly high even during moderately disturbed times. Therefore the PC-index may be used as a rough indicator of the auroral zone magnetic activity. There are, however, also differences between AE and PC. In particular, many "spikes" in AE, which may last up to one hour, are almost unnoticed in PC. Therefore the PC-index cannot substitute for the AE-index, and it should rather be considered as a characteristic of the state of the magnetosphere. The PC-index is convenient for a prompt diagnosis of magnetospheric activity because the use of a single station index reduces the amount of data processing and data collection to a minimum.

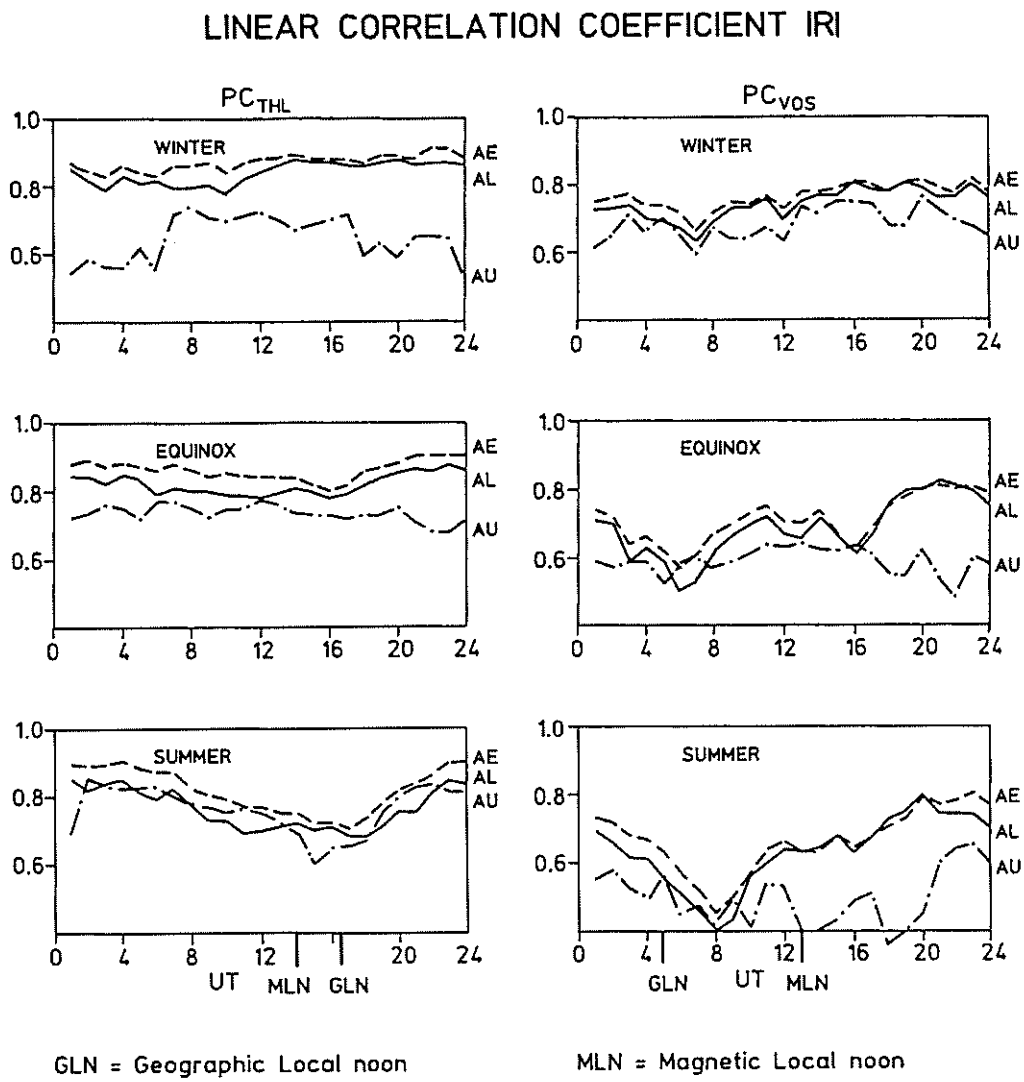

Figure 4: The linear correlation coefficient |R| between PC and the auroral zone indices AE, AL and AU. The results are based on all available data for the years 1978-1984, and the correlation coefficient is computed separately for each season and each hour of UT. The left panel shows the results for Thule and the right panel the results for Vostok.

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DATA PRESENTATION

The following pages contain graphs of 15 minute average values of the PC-index for 1975-1993.

There are two types of graphs: A monthly page containing a graph for each day in the month, and a yearly summary graph on one page.

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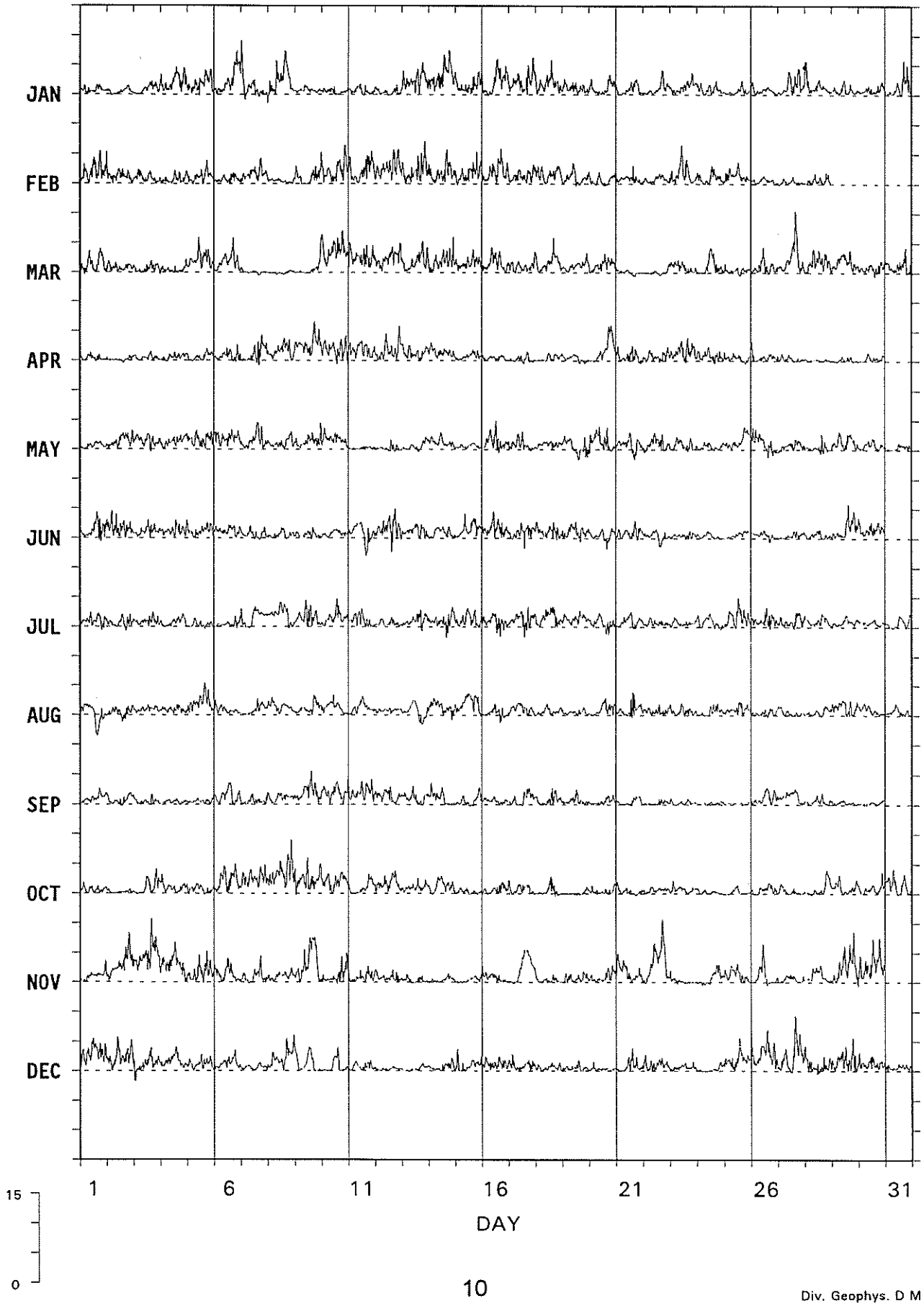
Thule **1975**



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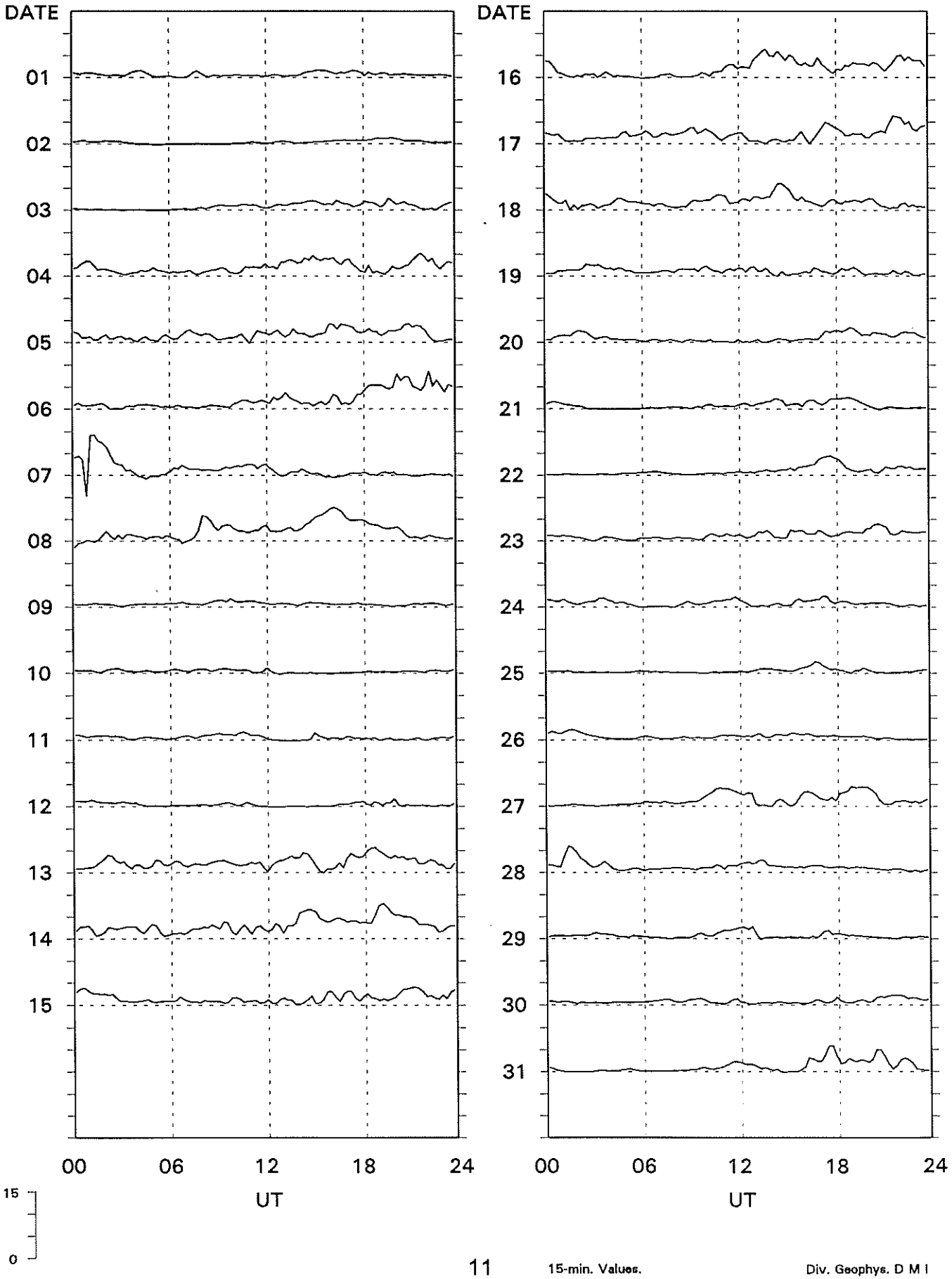

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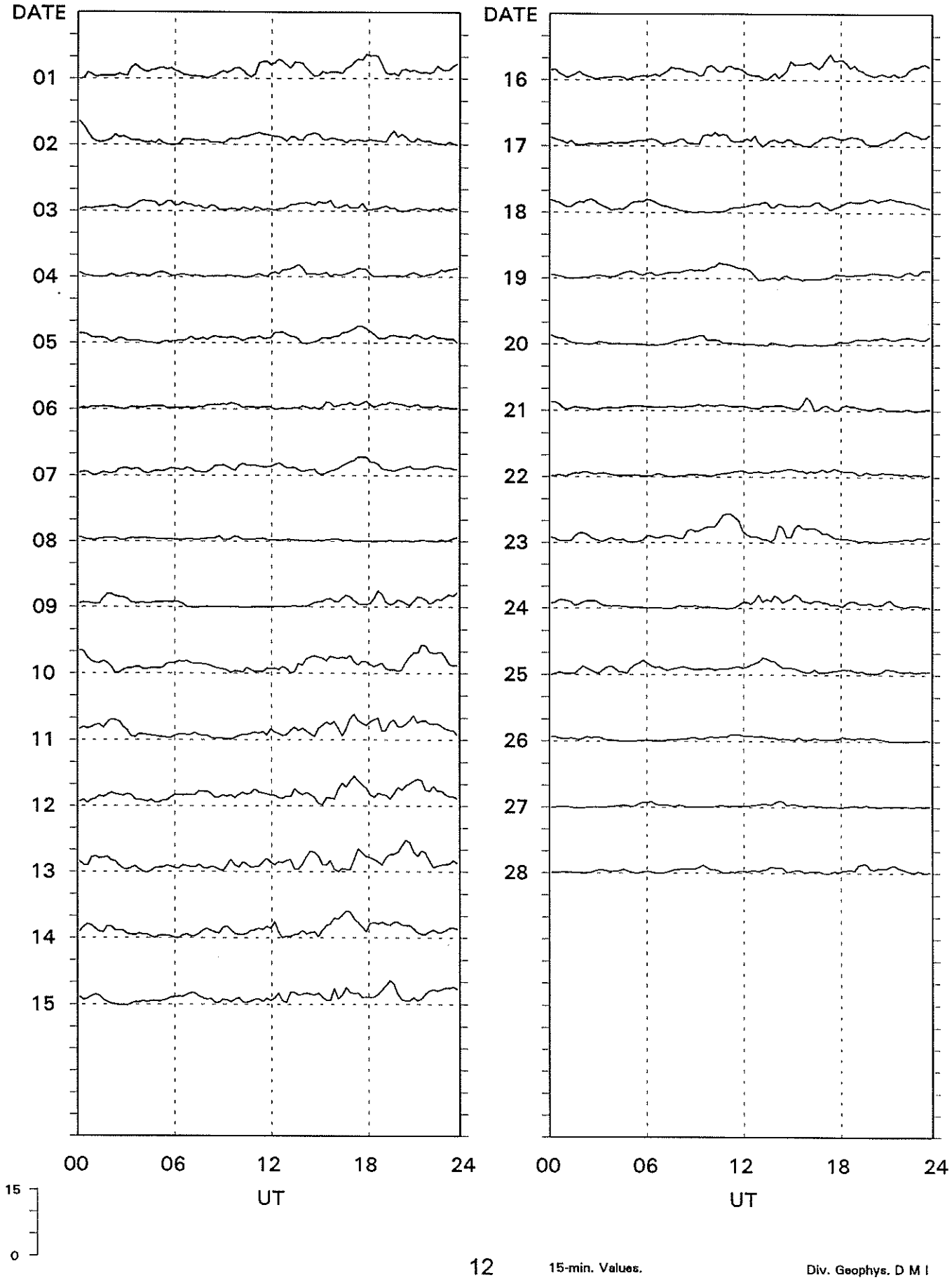

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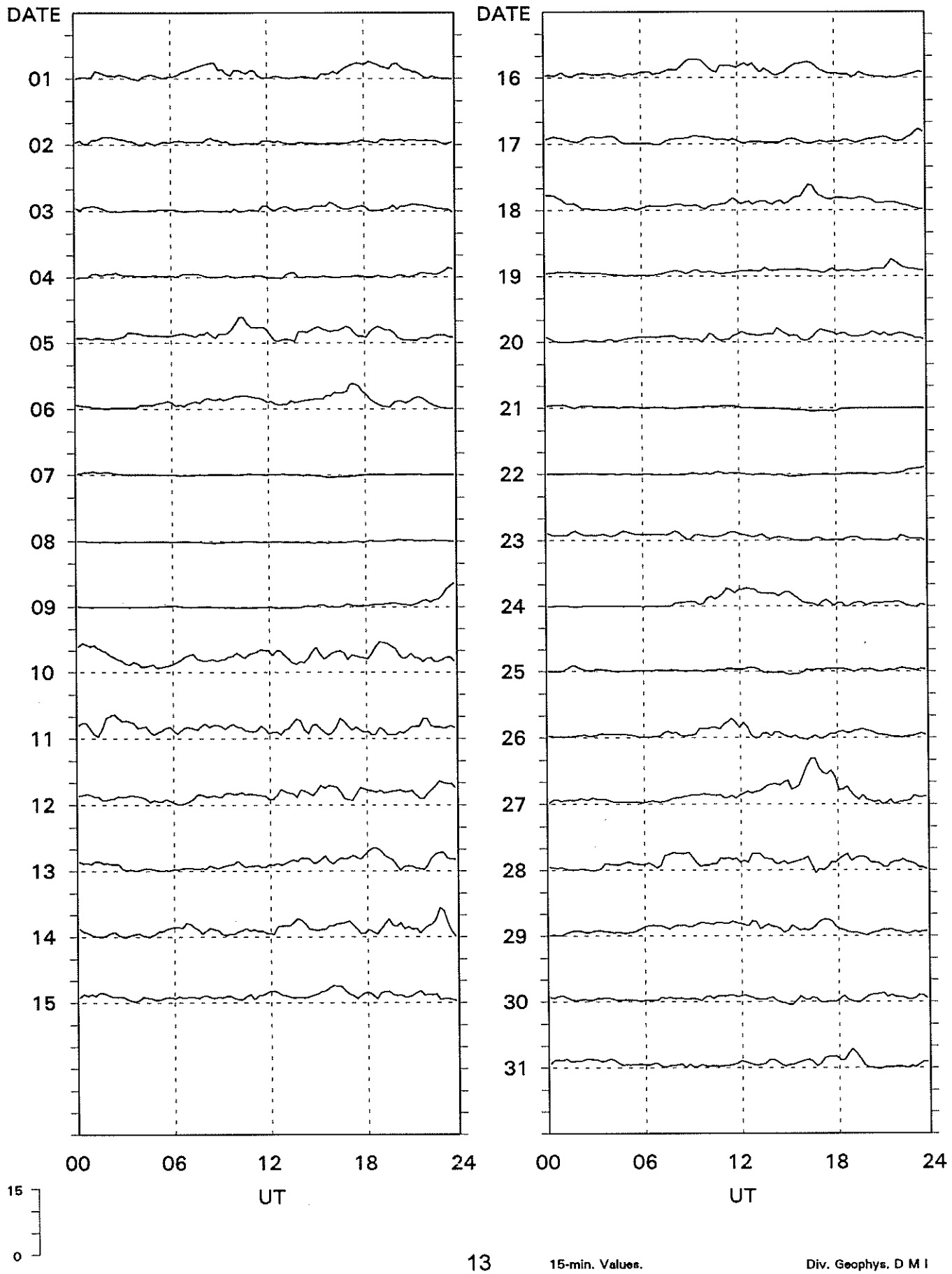

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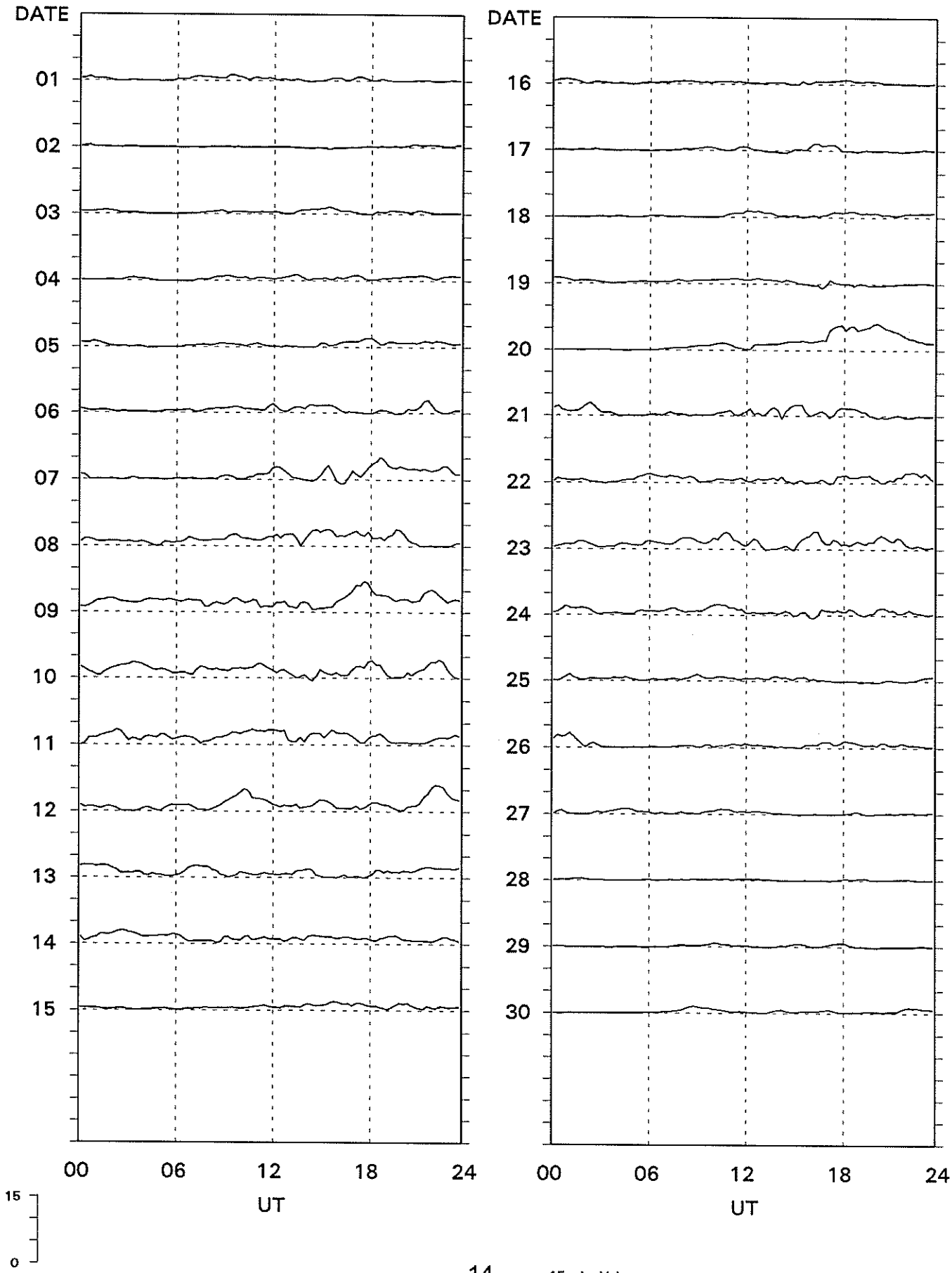

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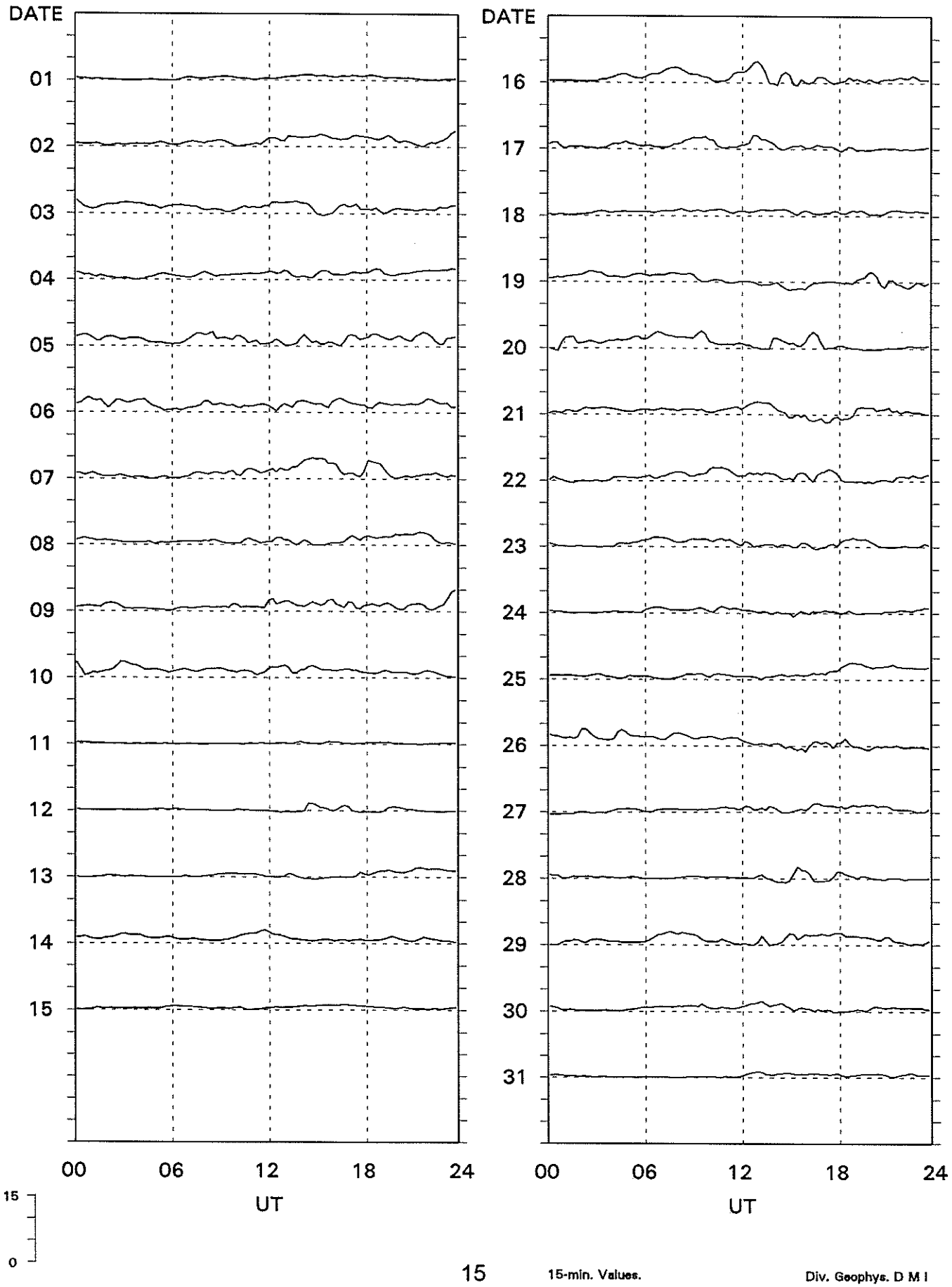

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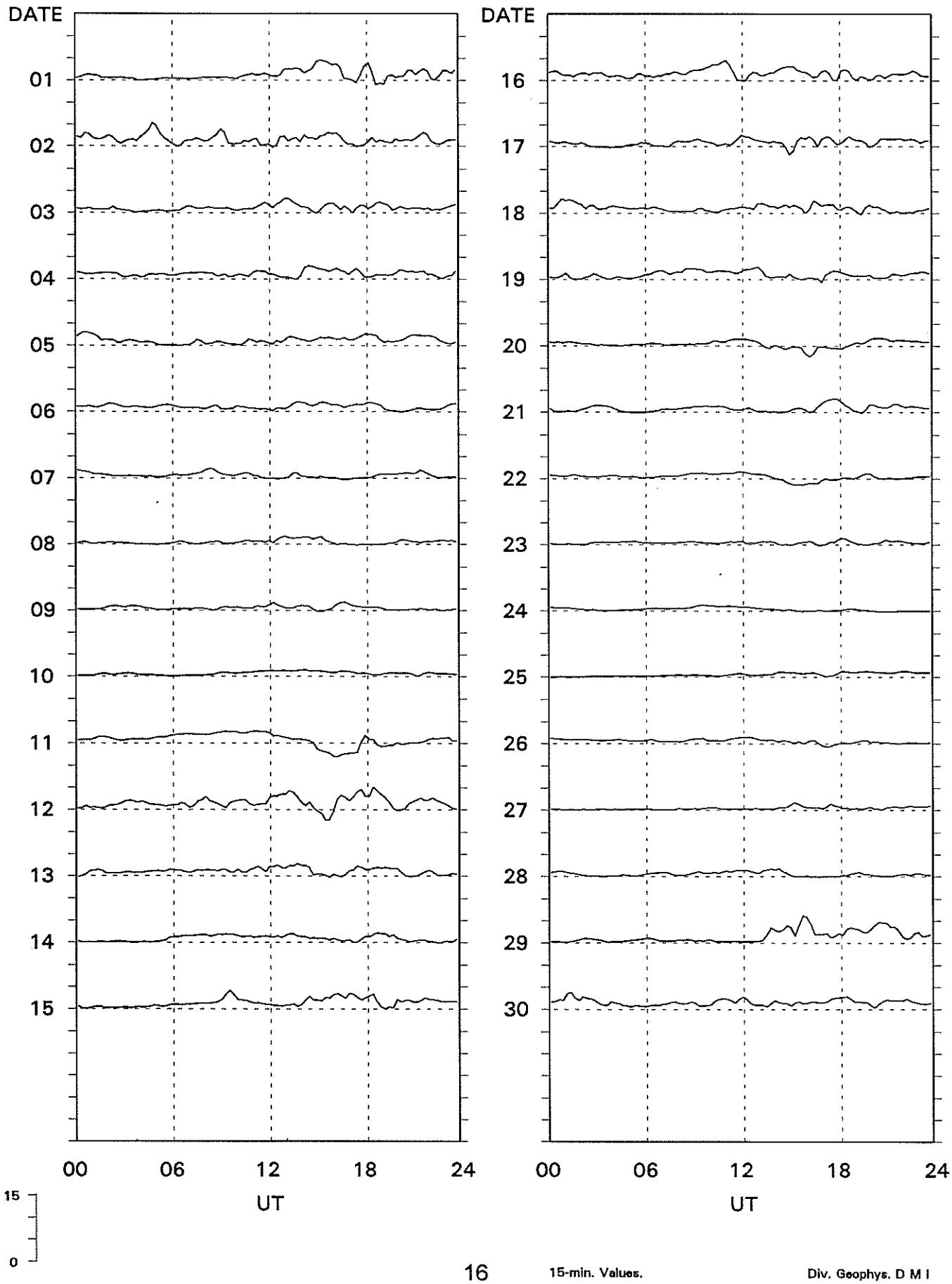

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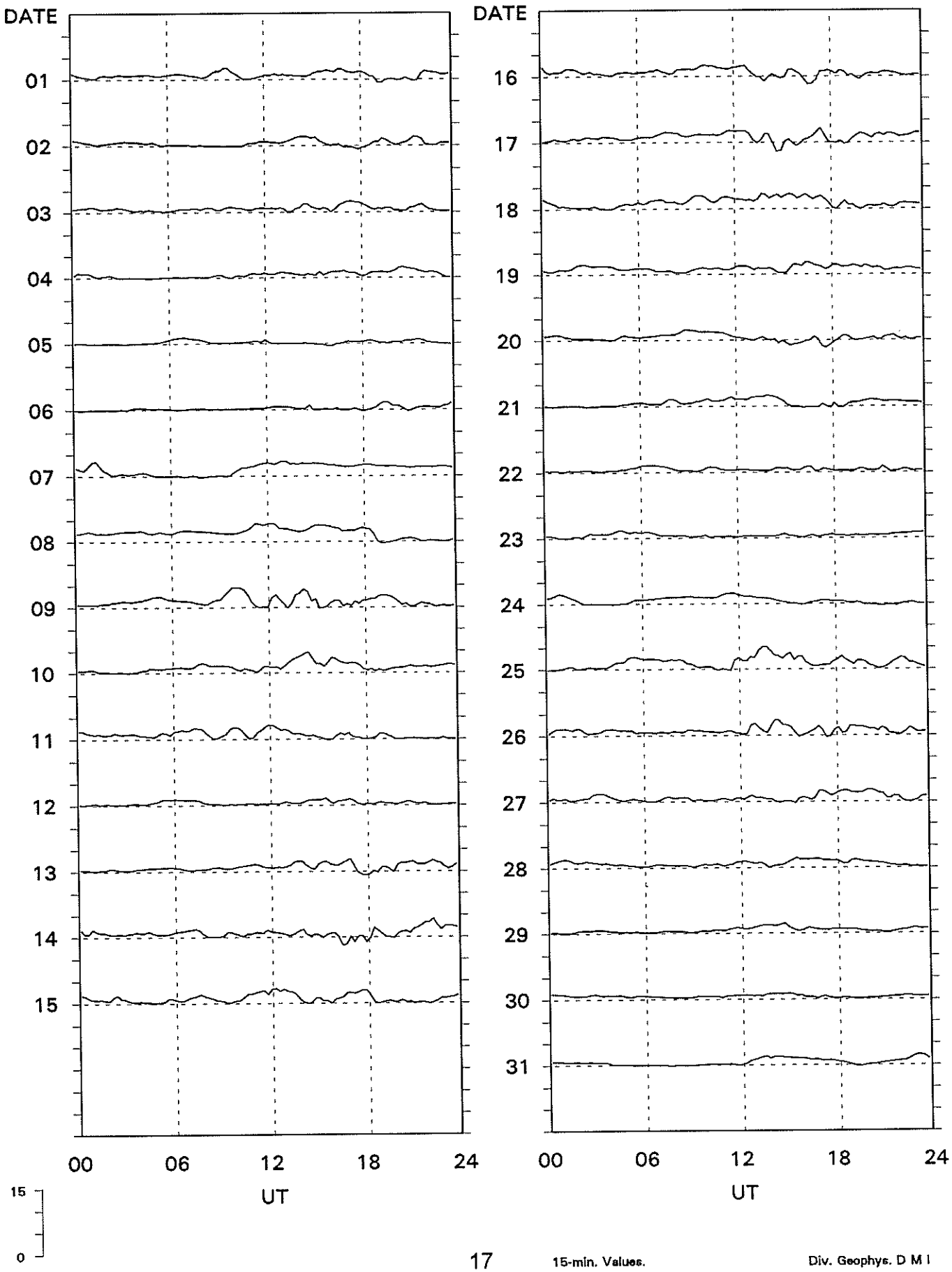

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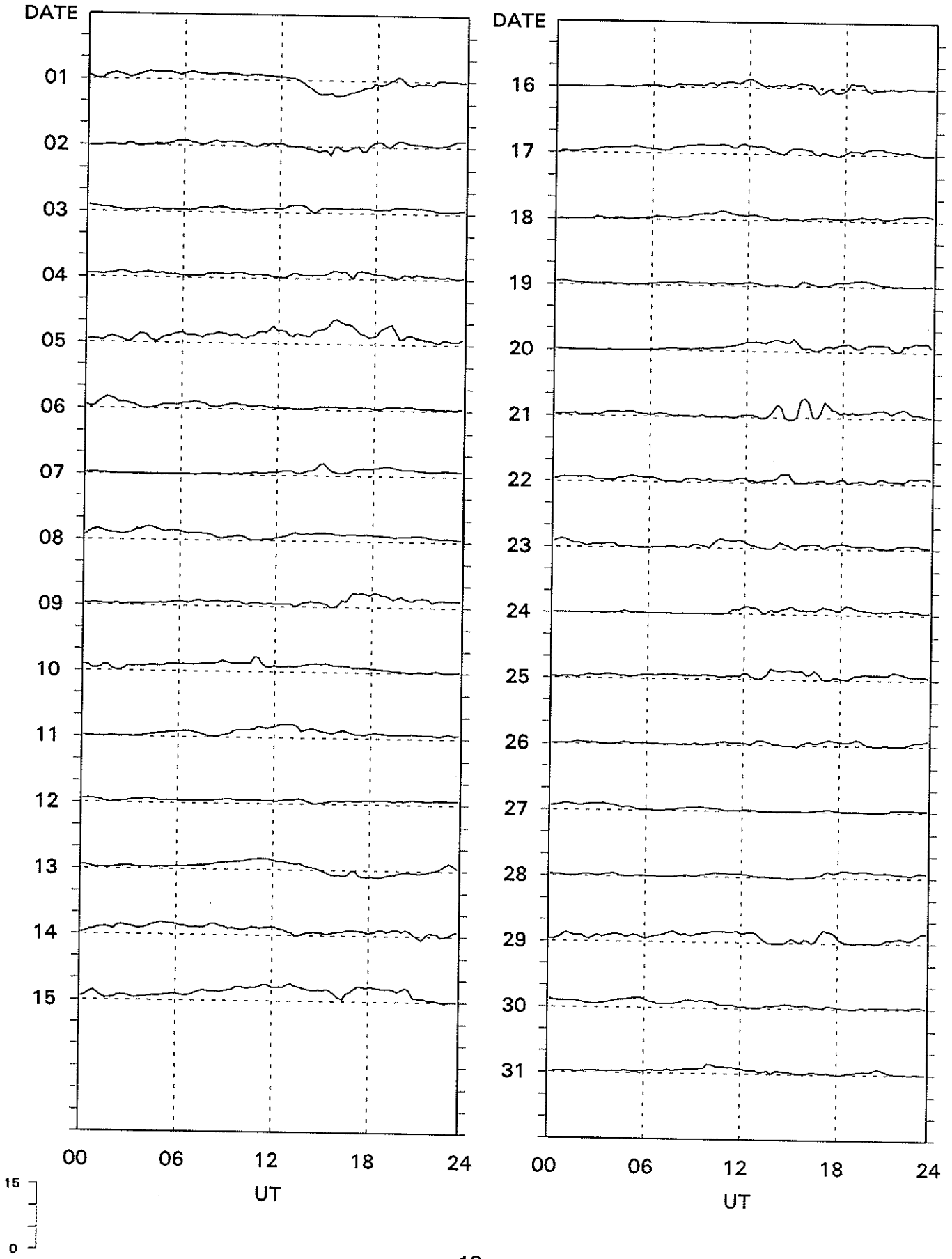

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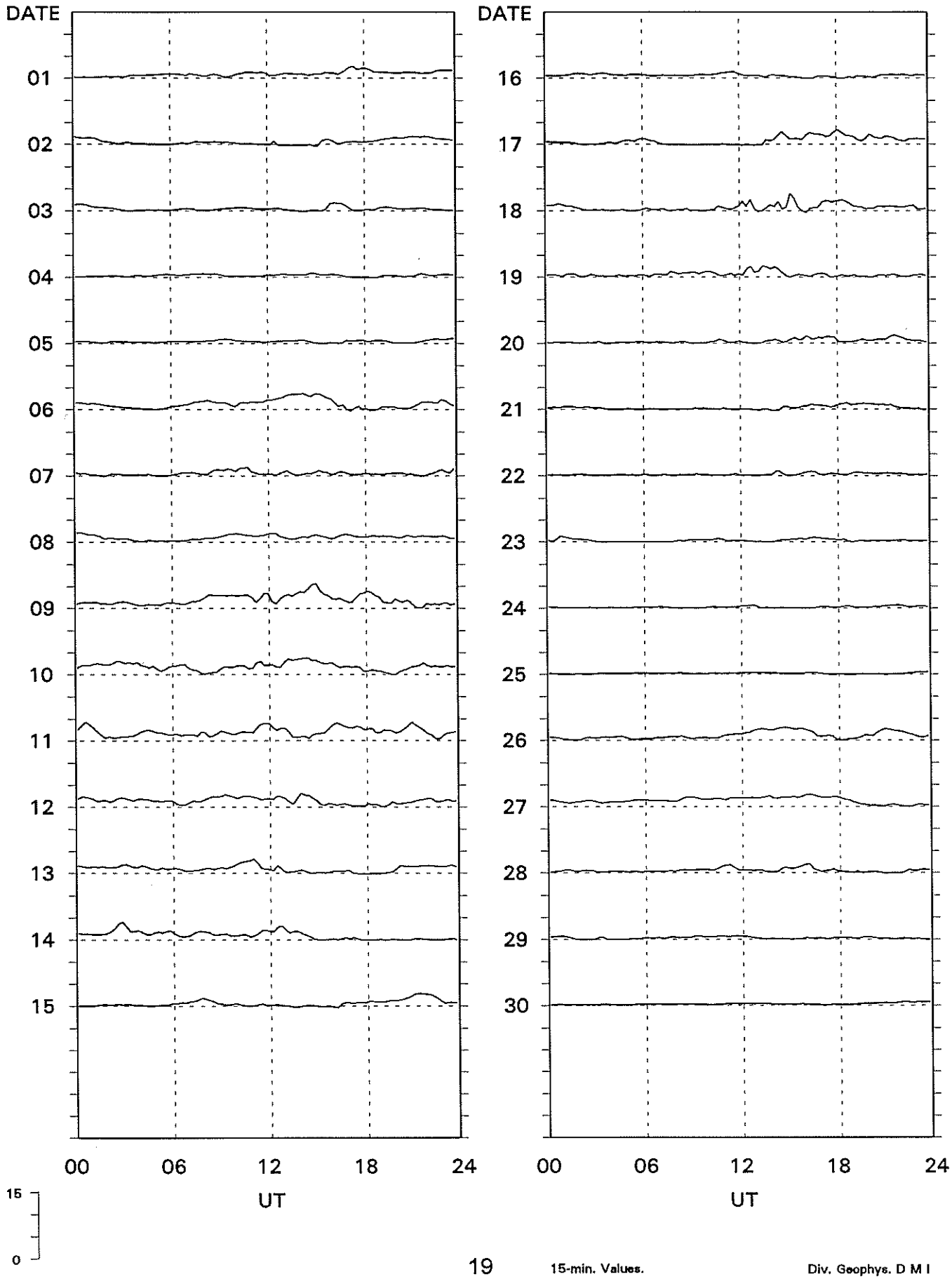

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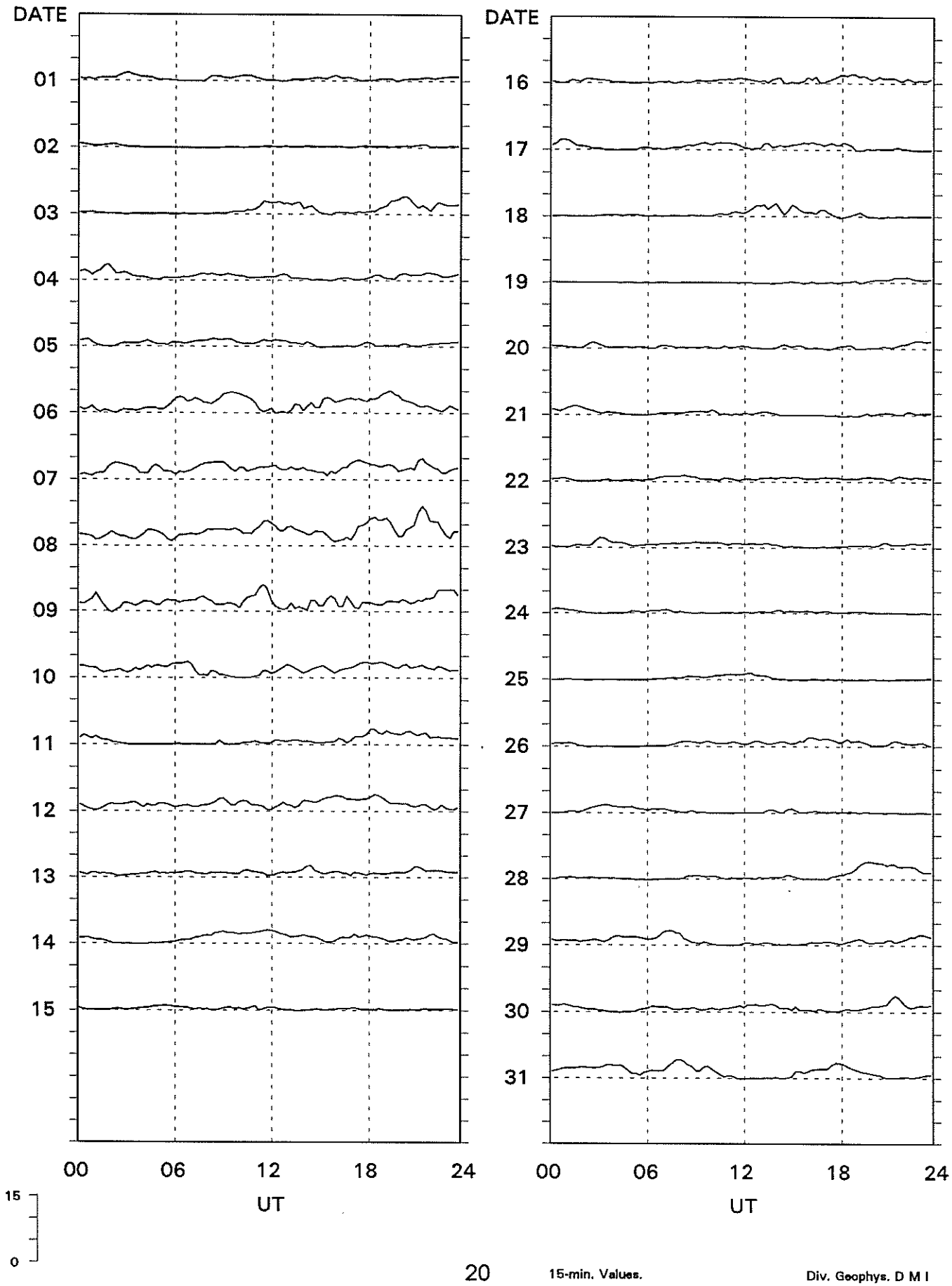

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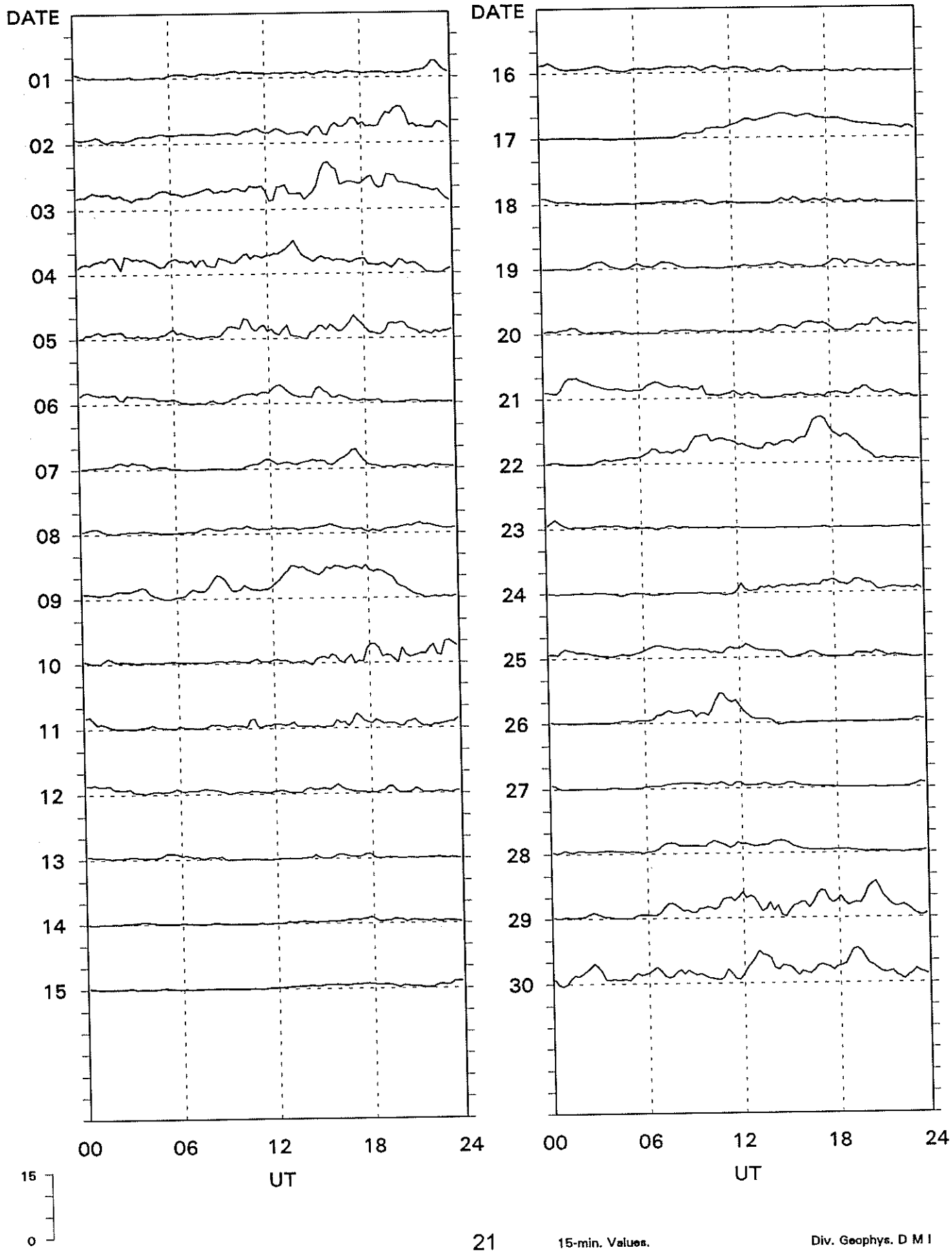

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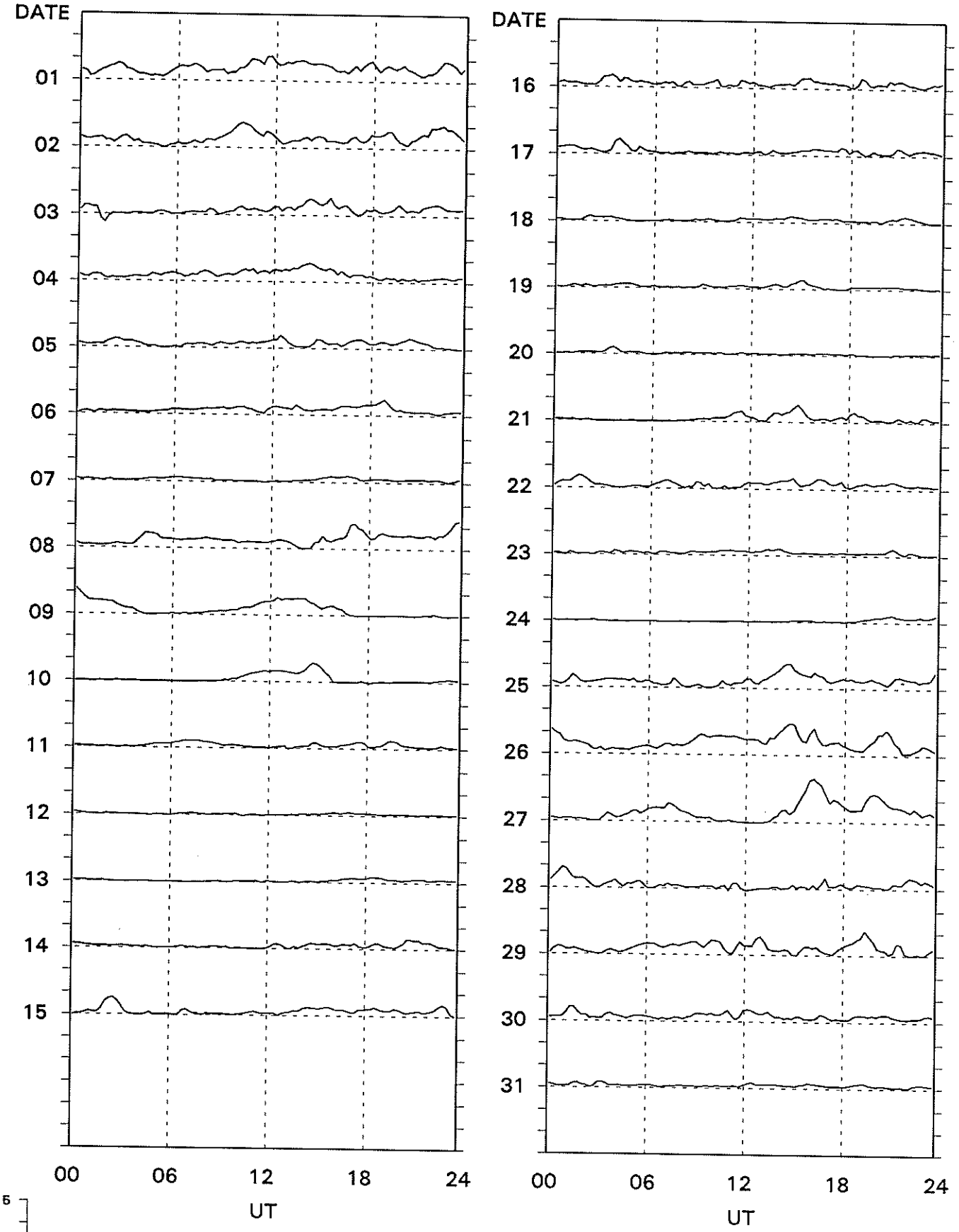

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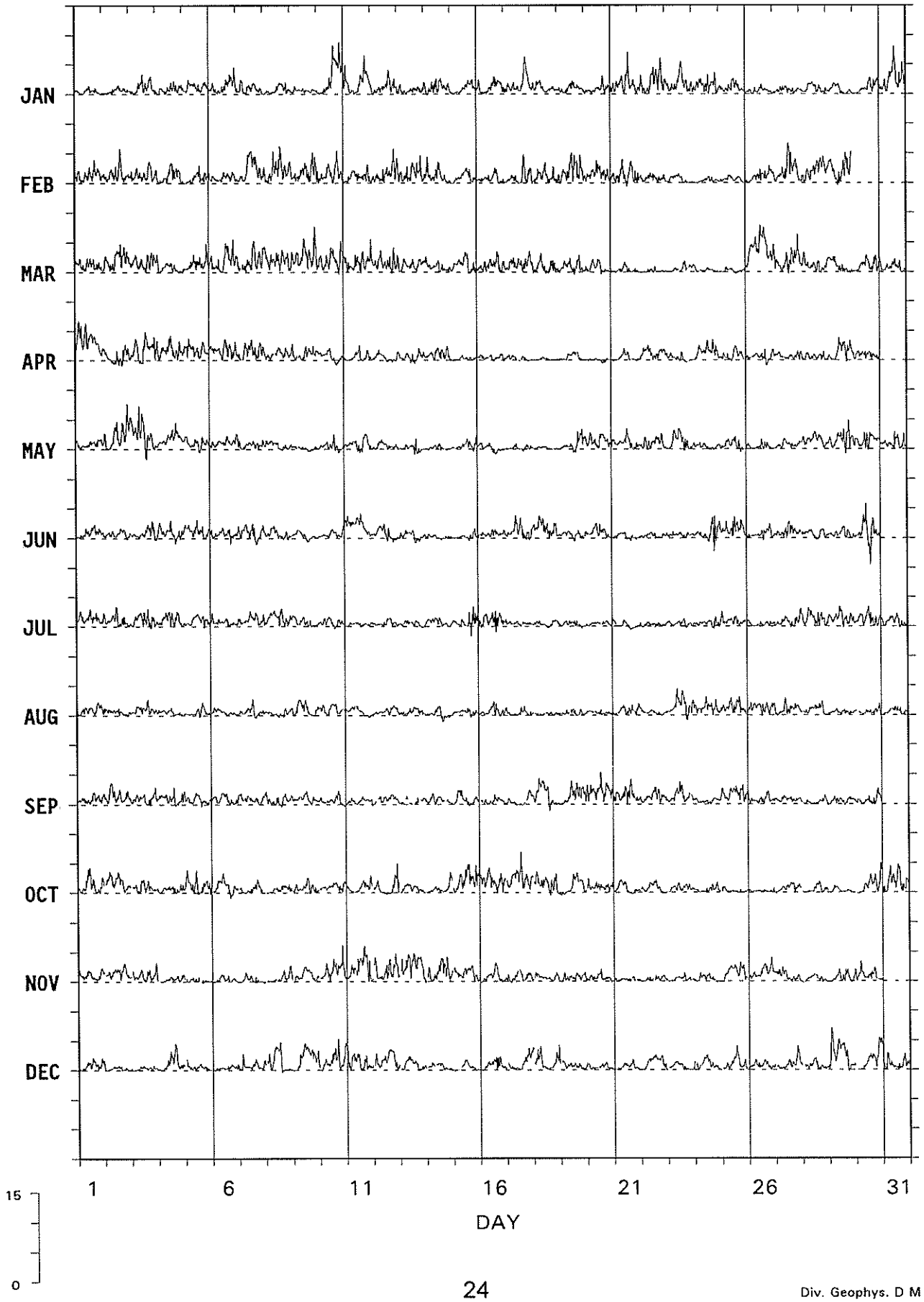

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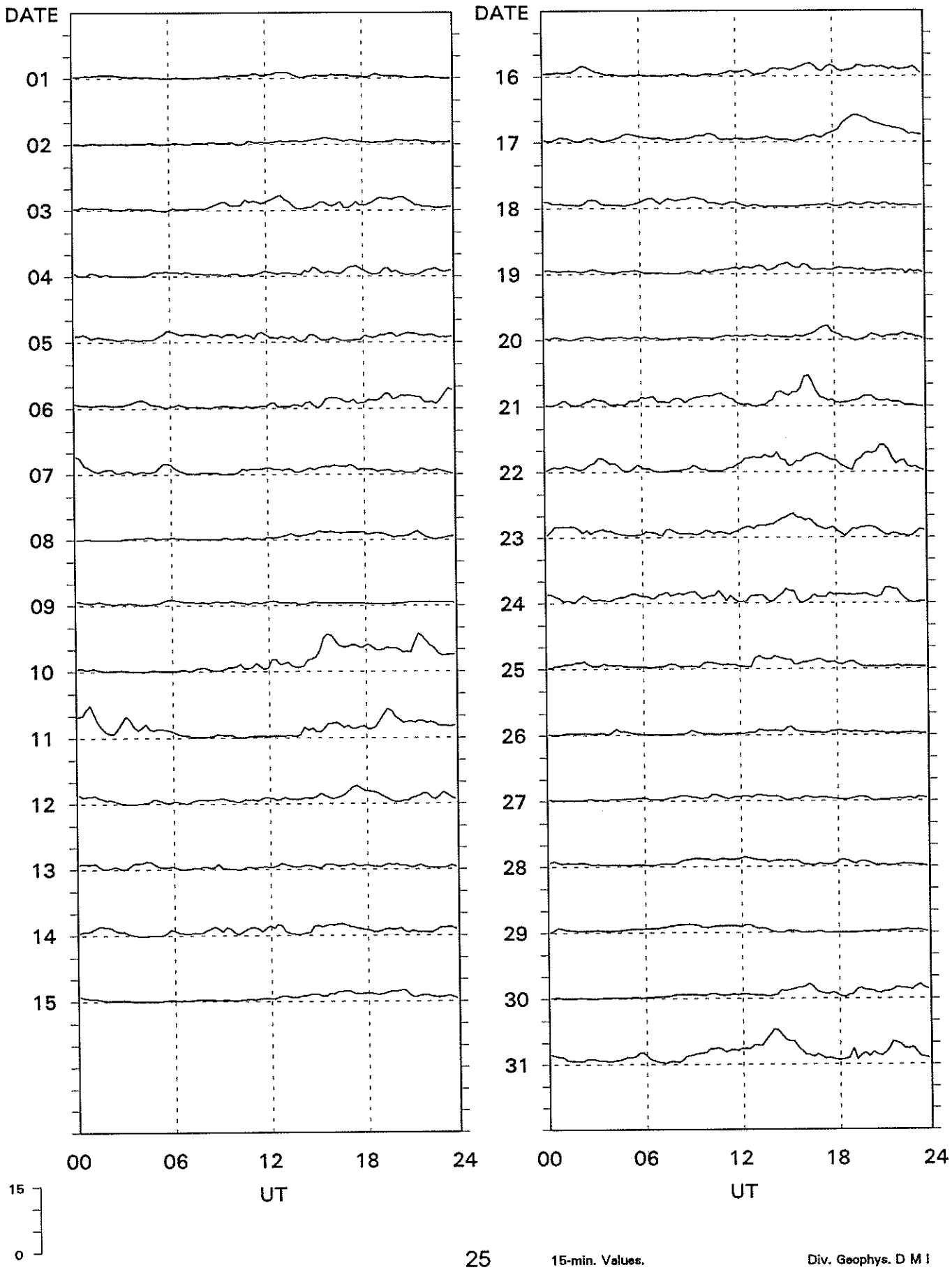

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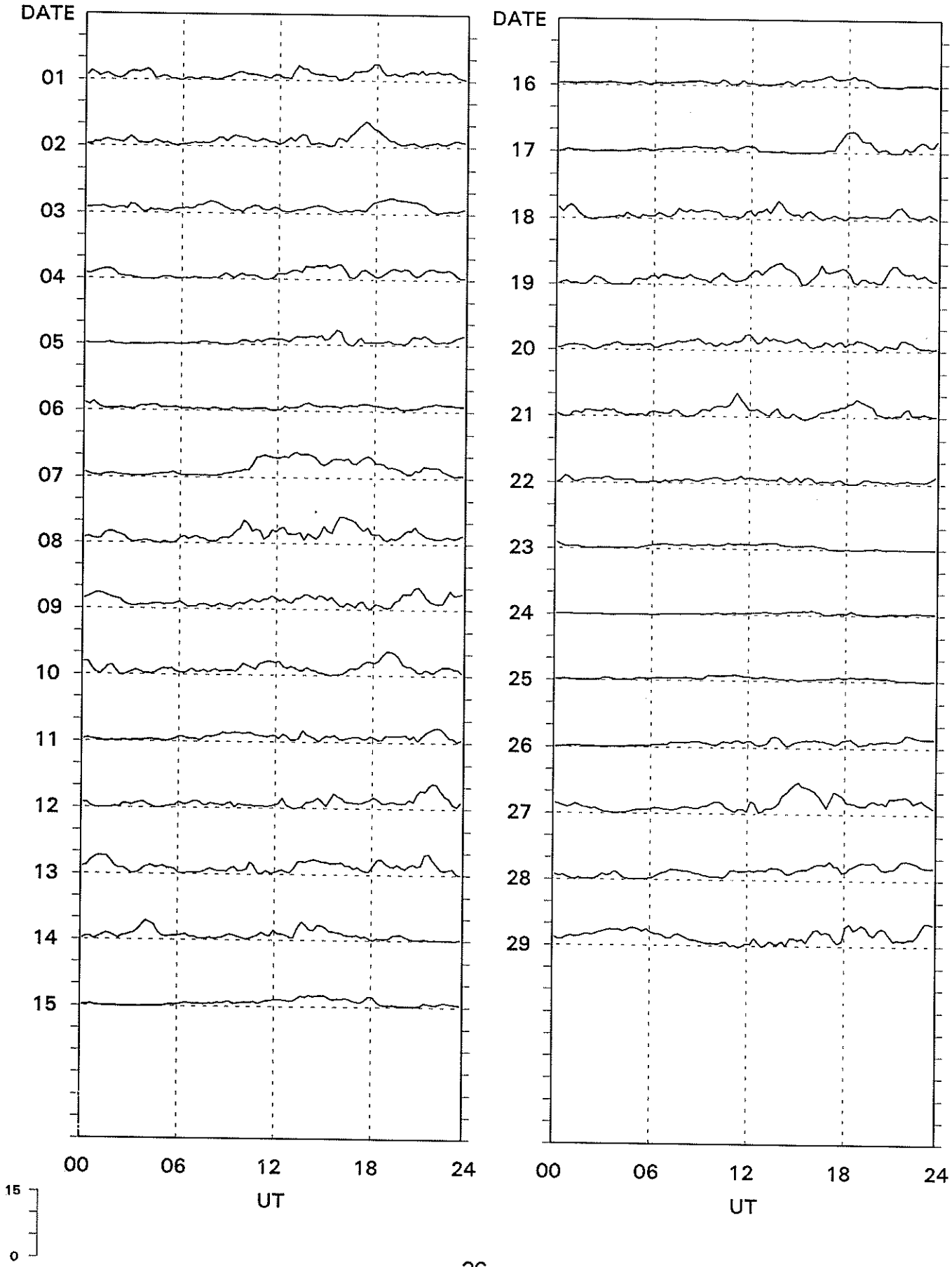

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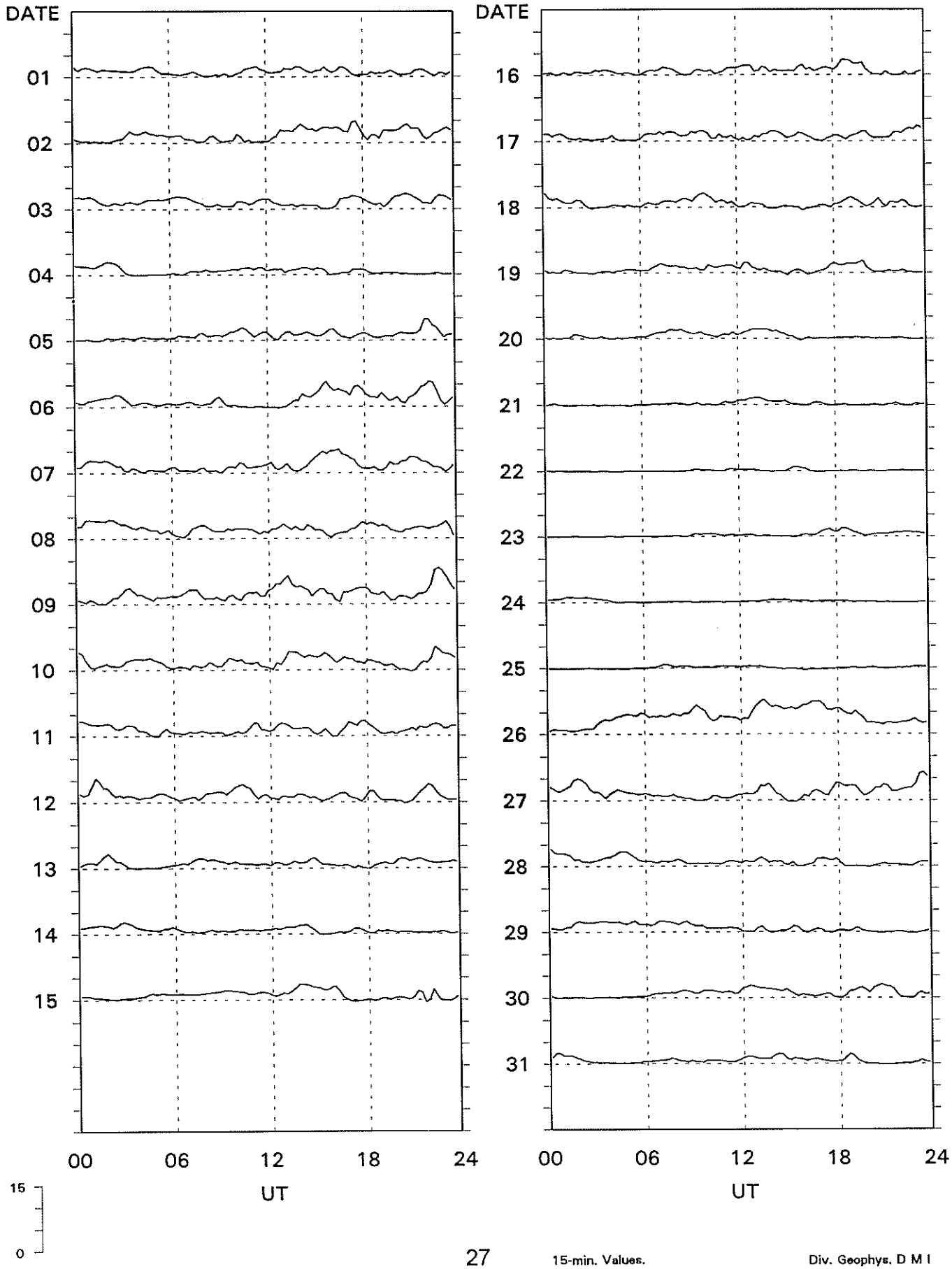

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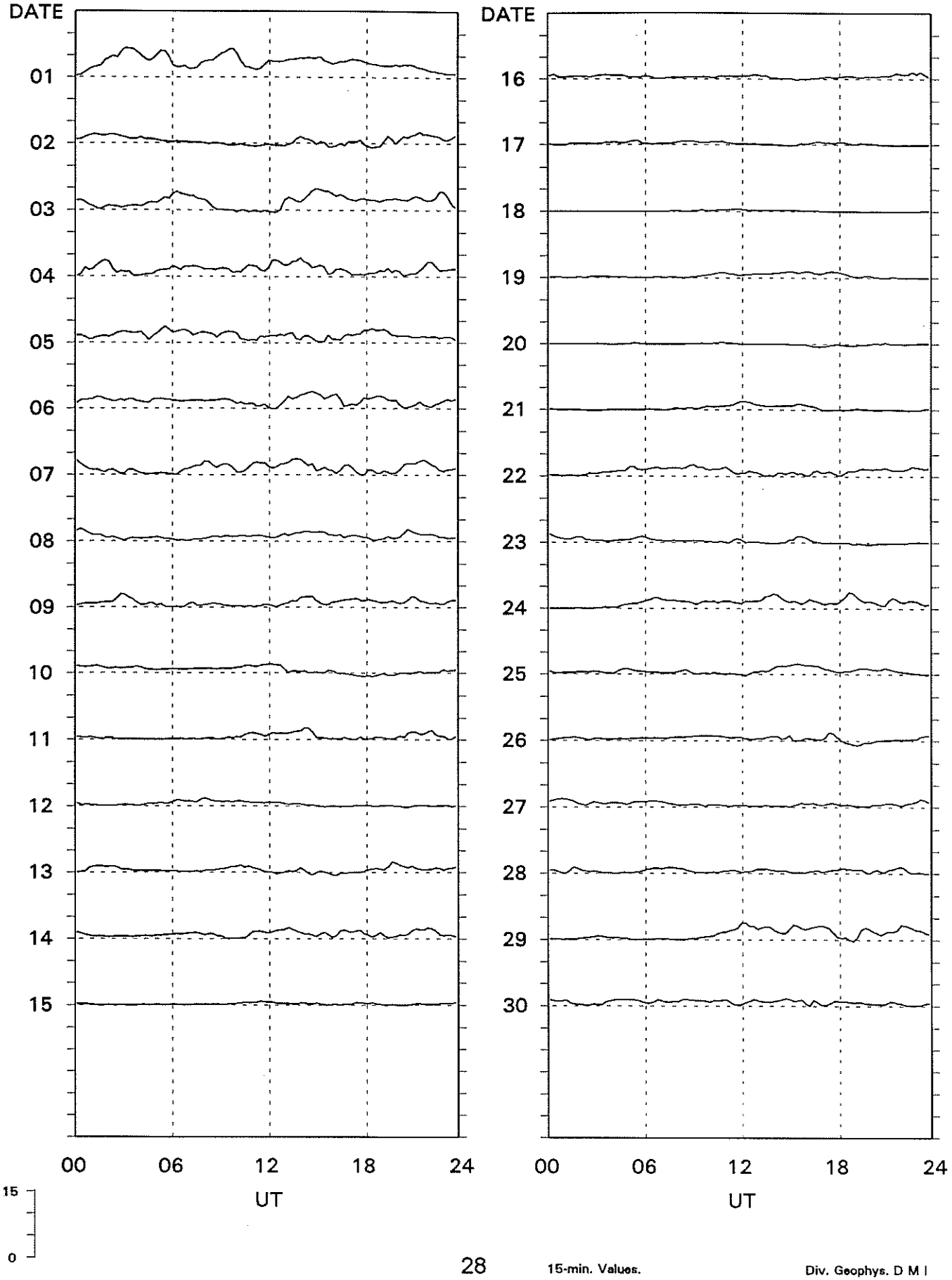

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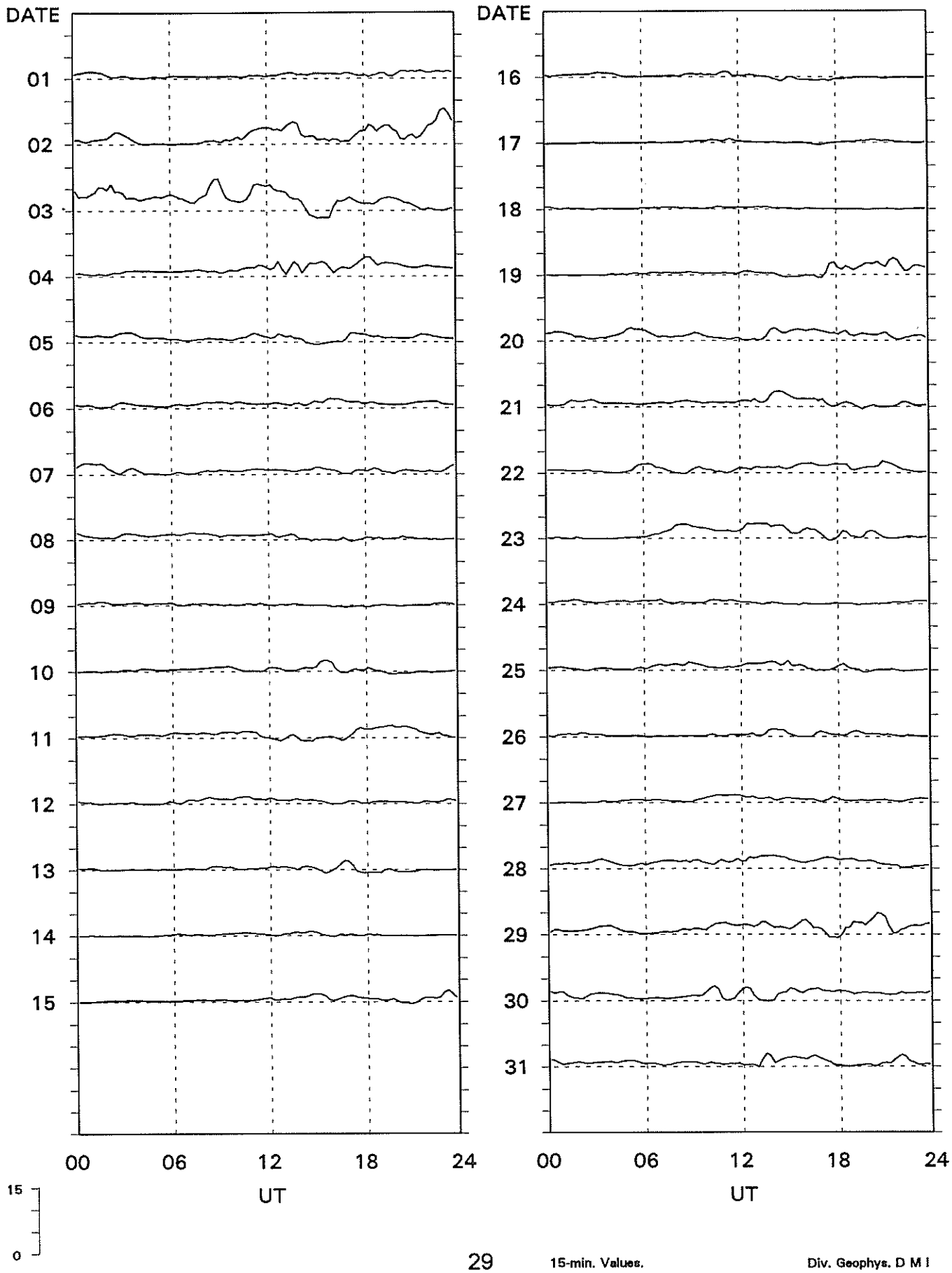

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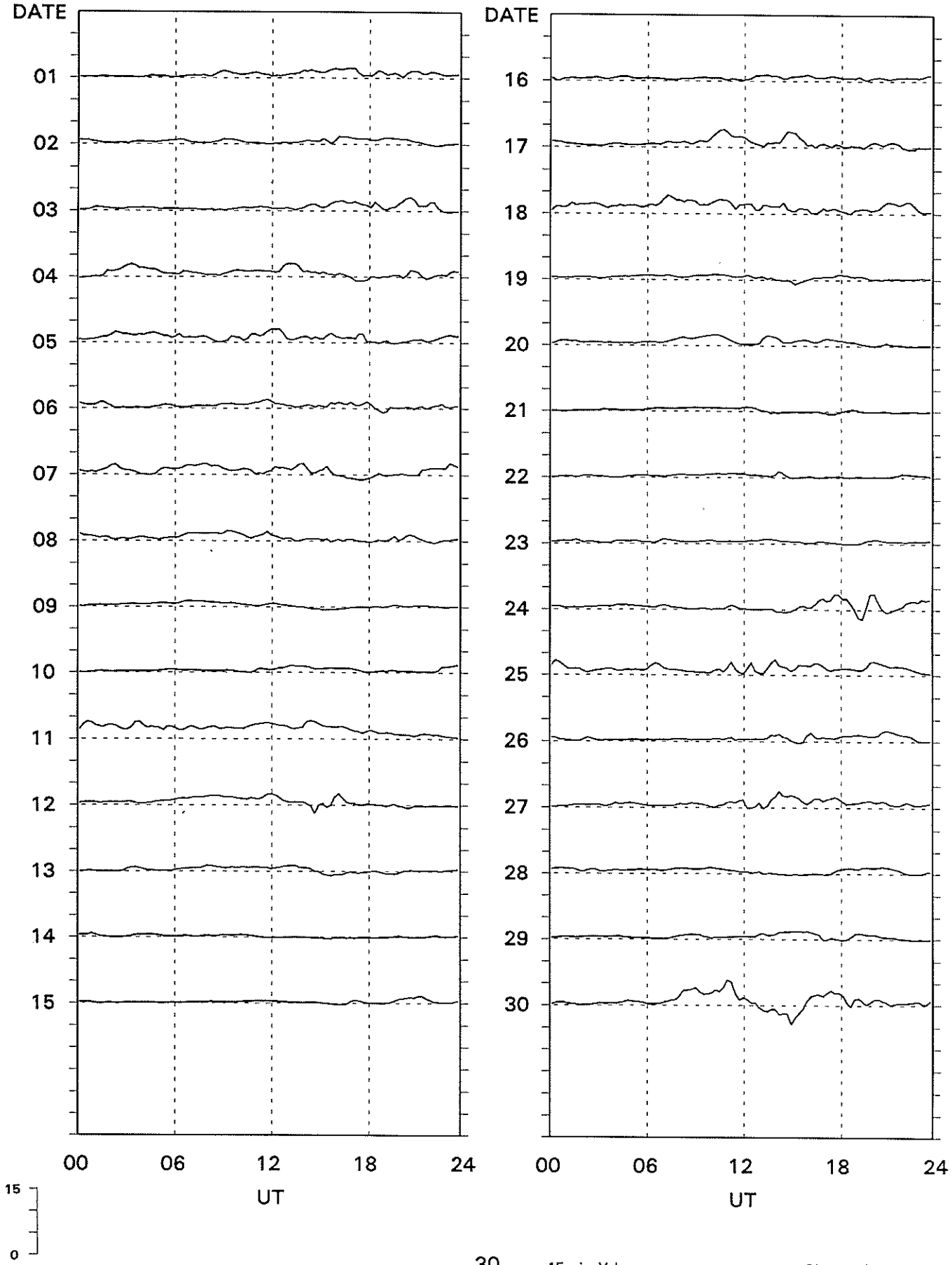

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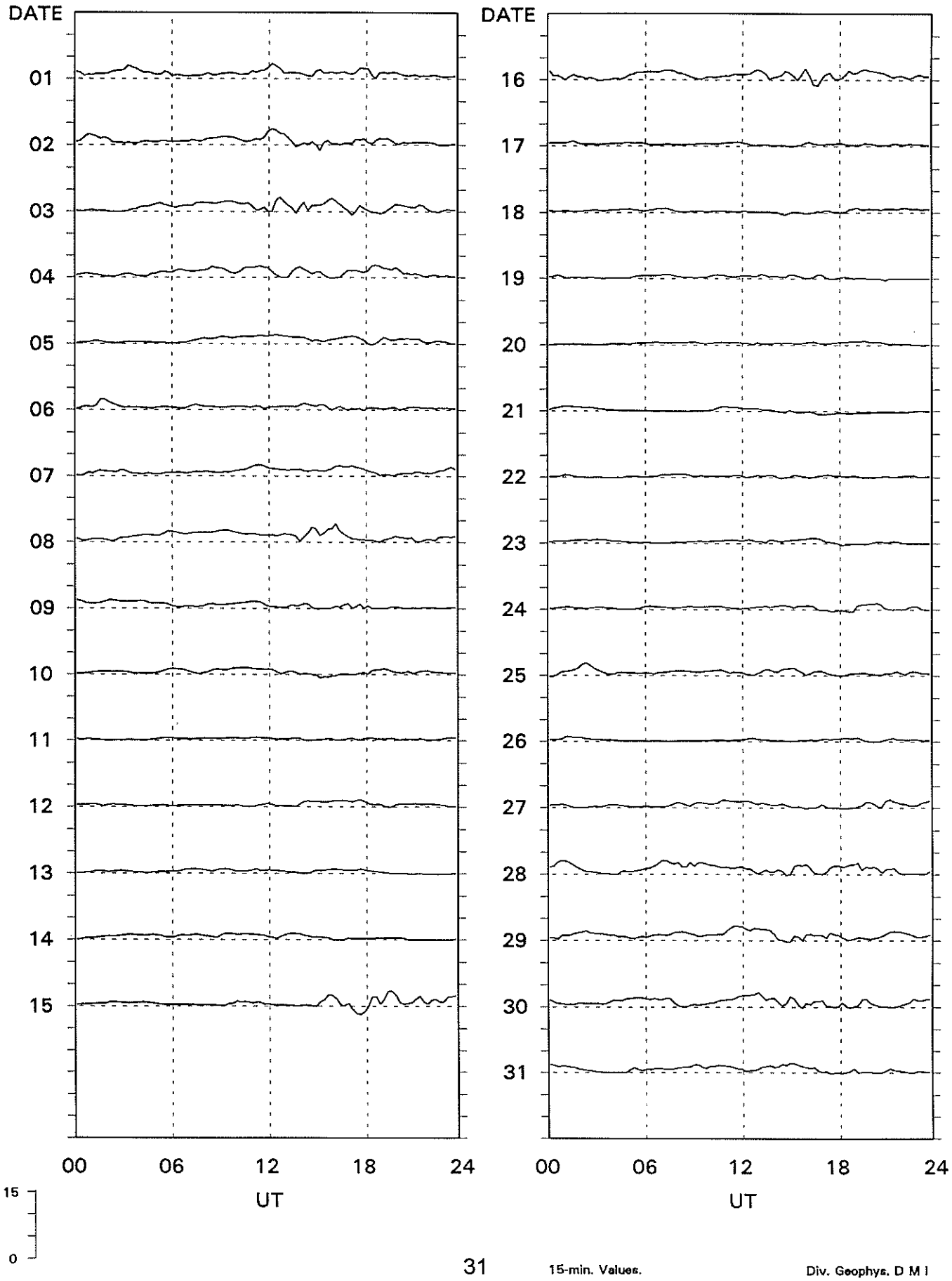

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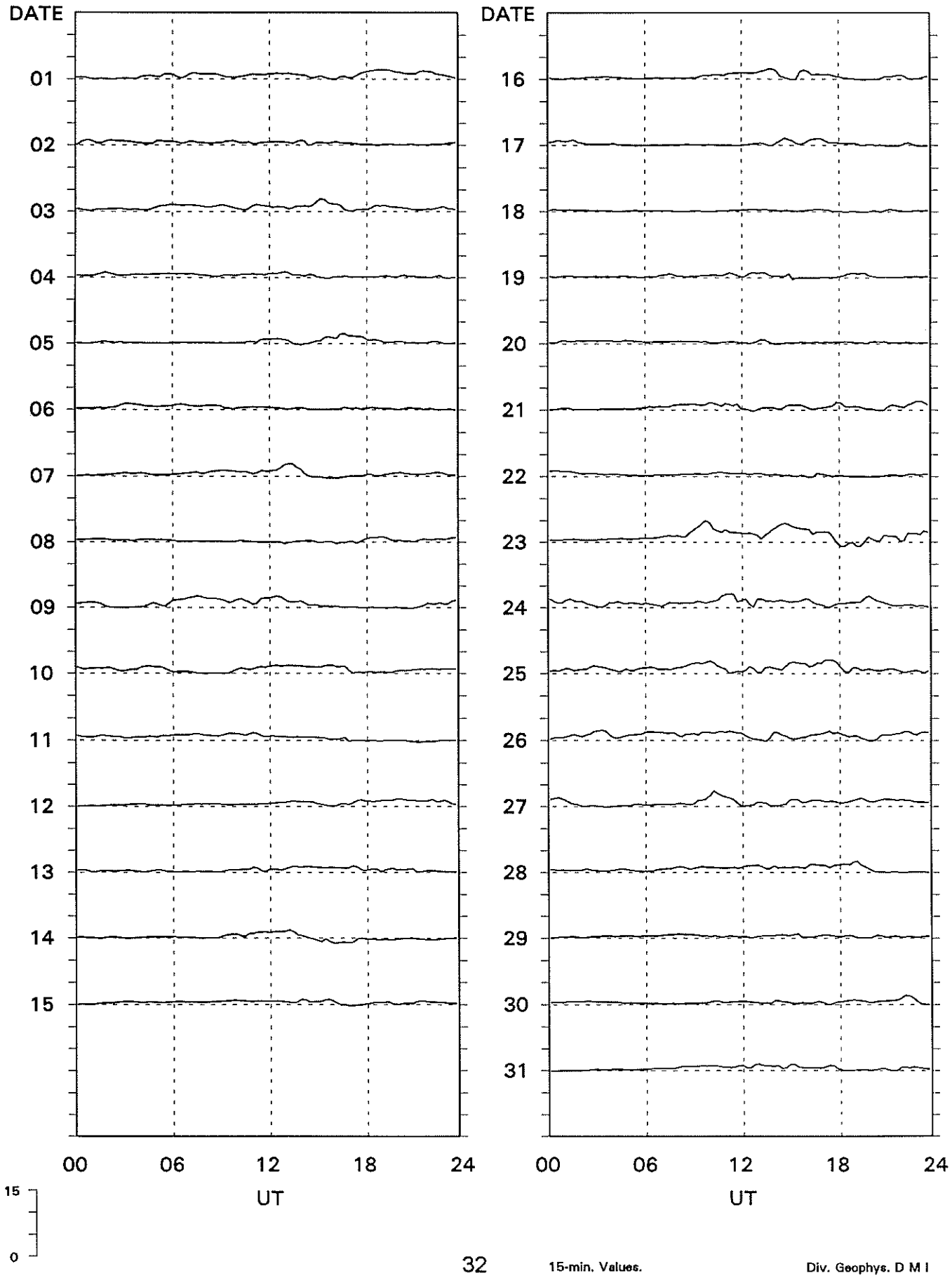

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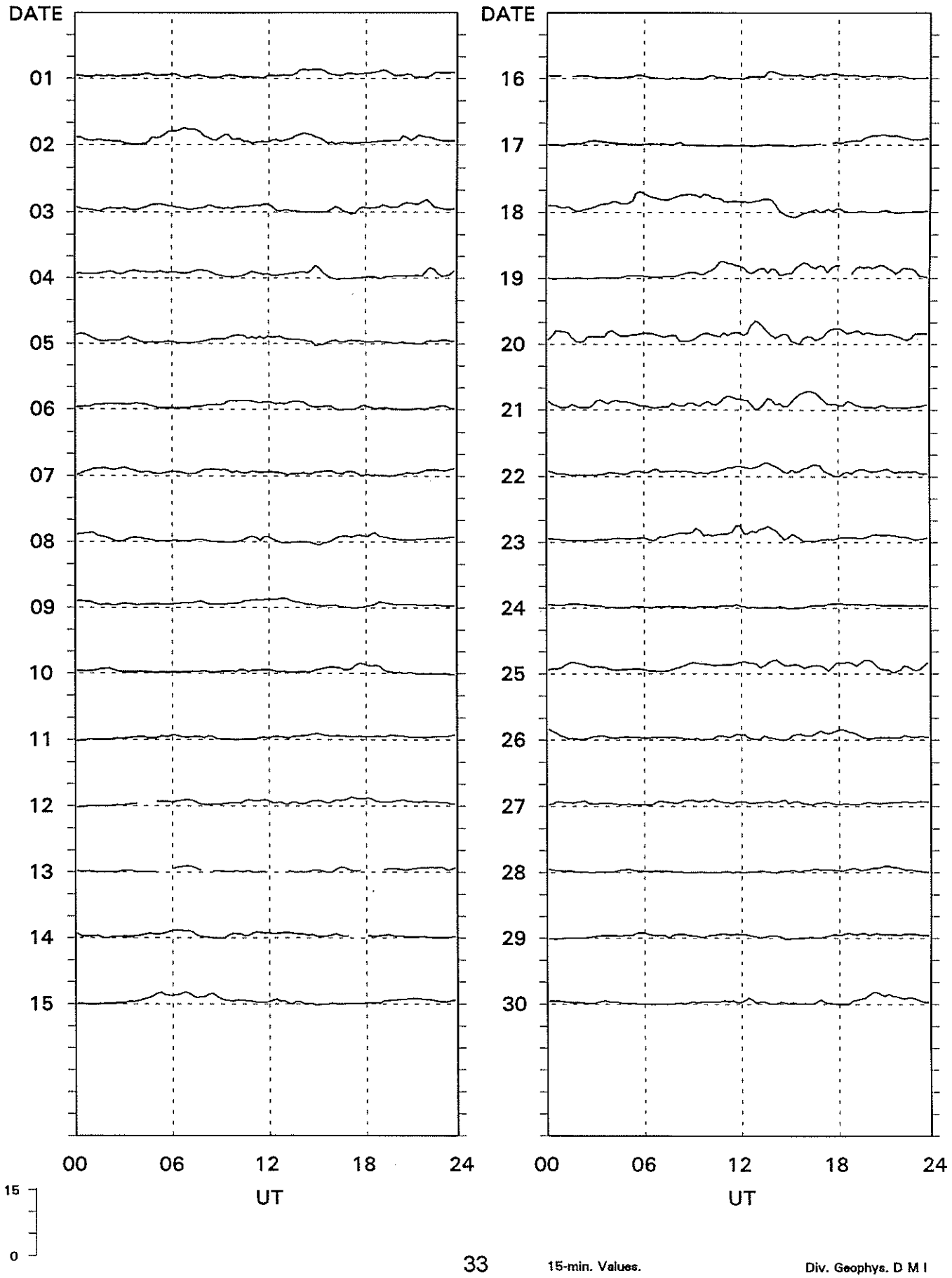

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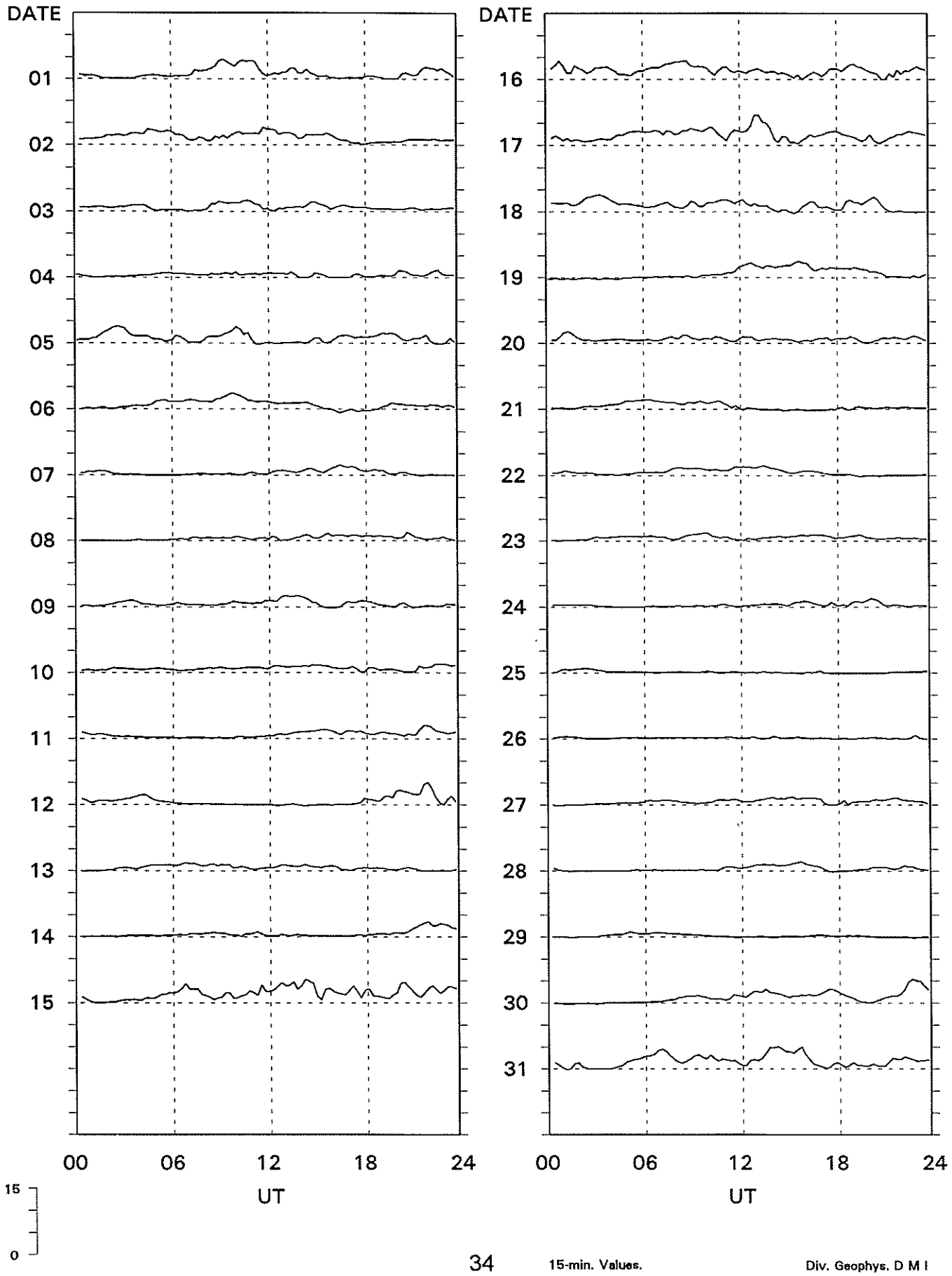

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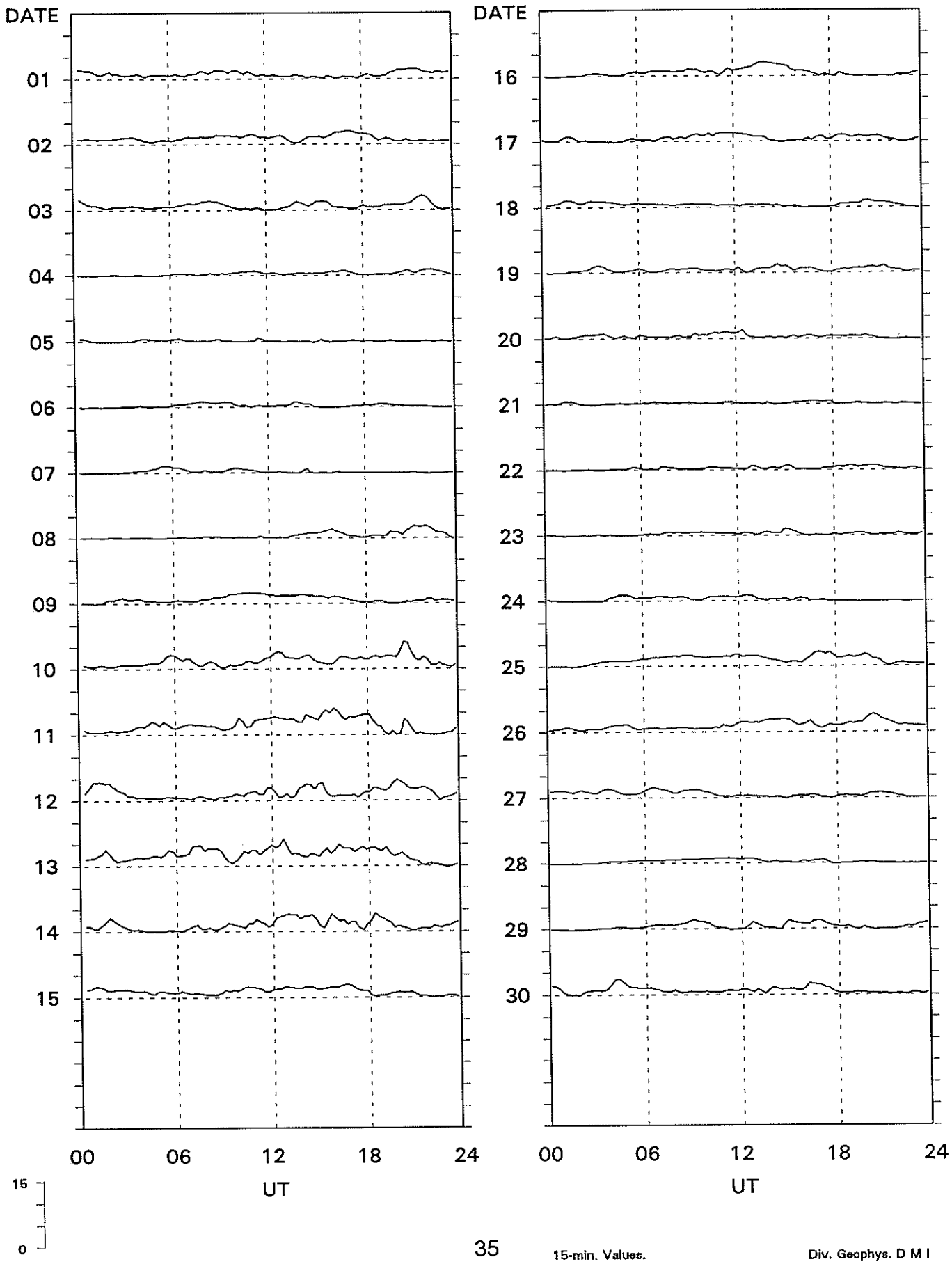

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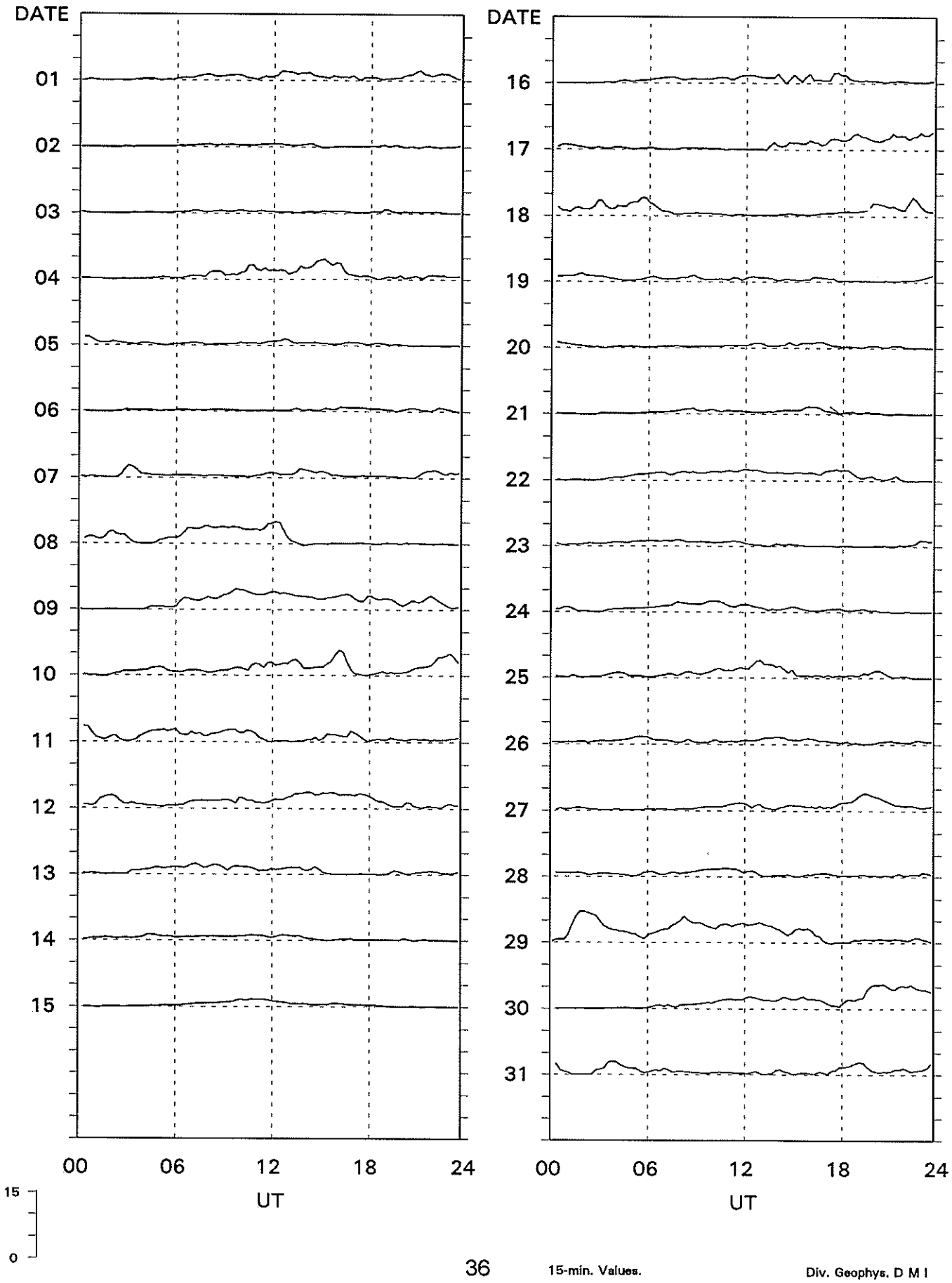

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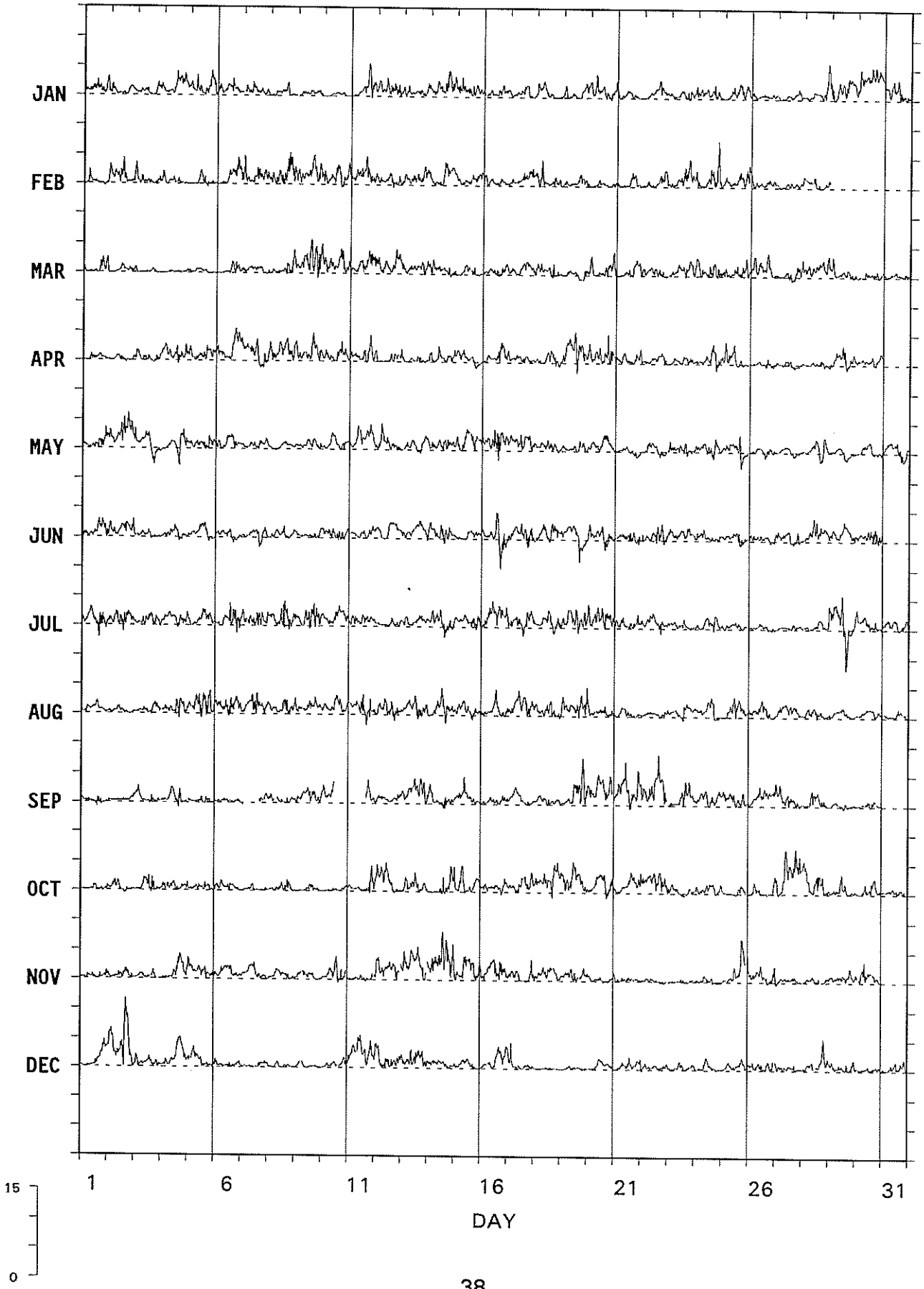

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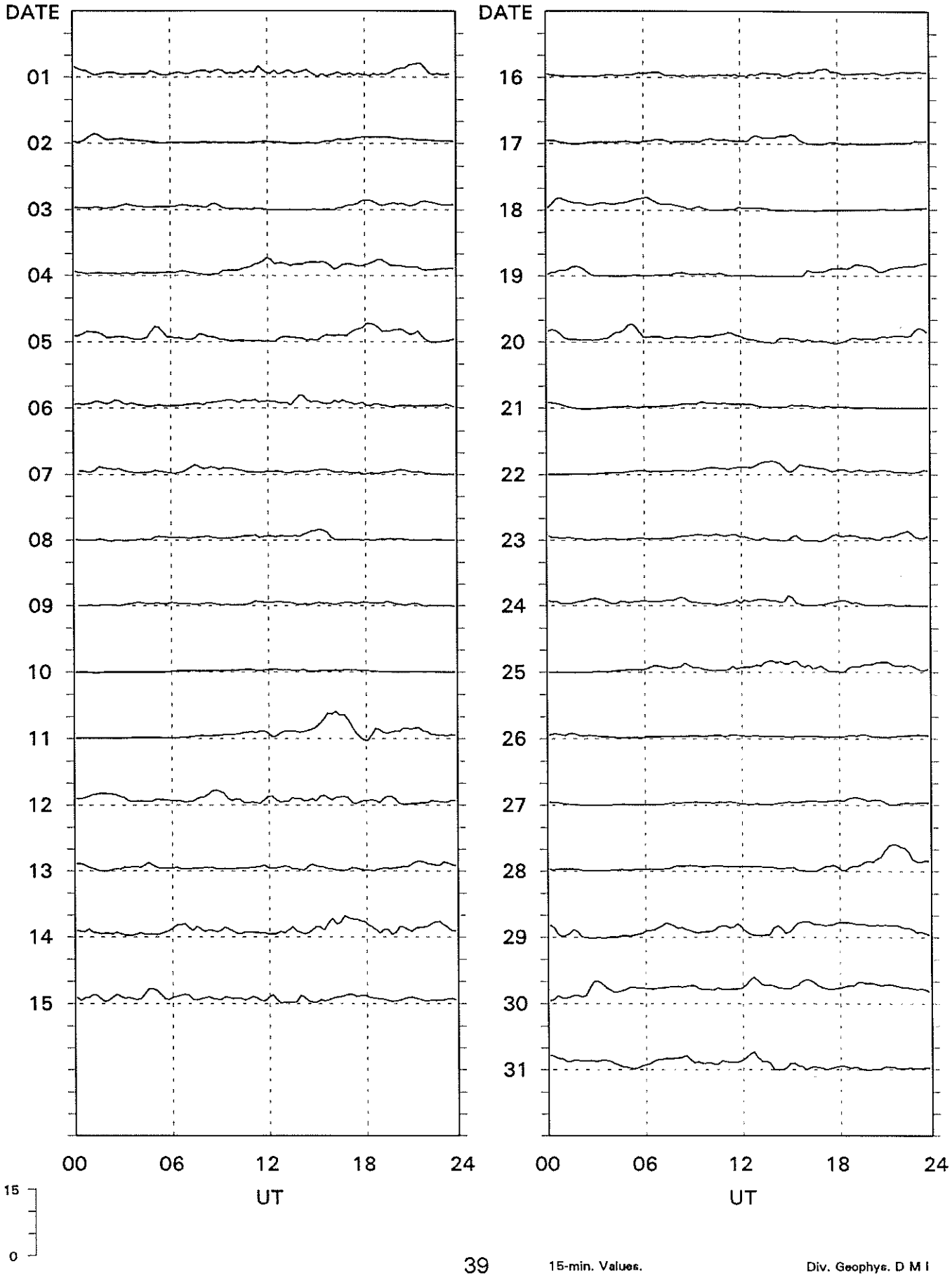

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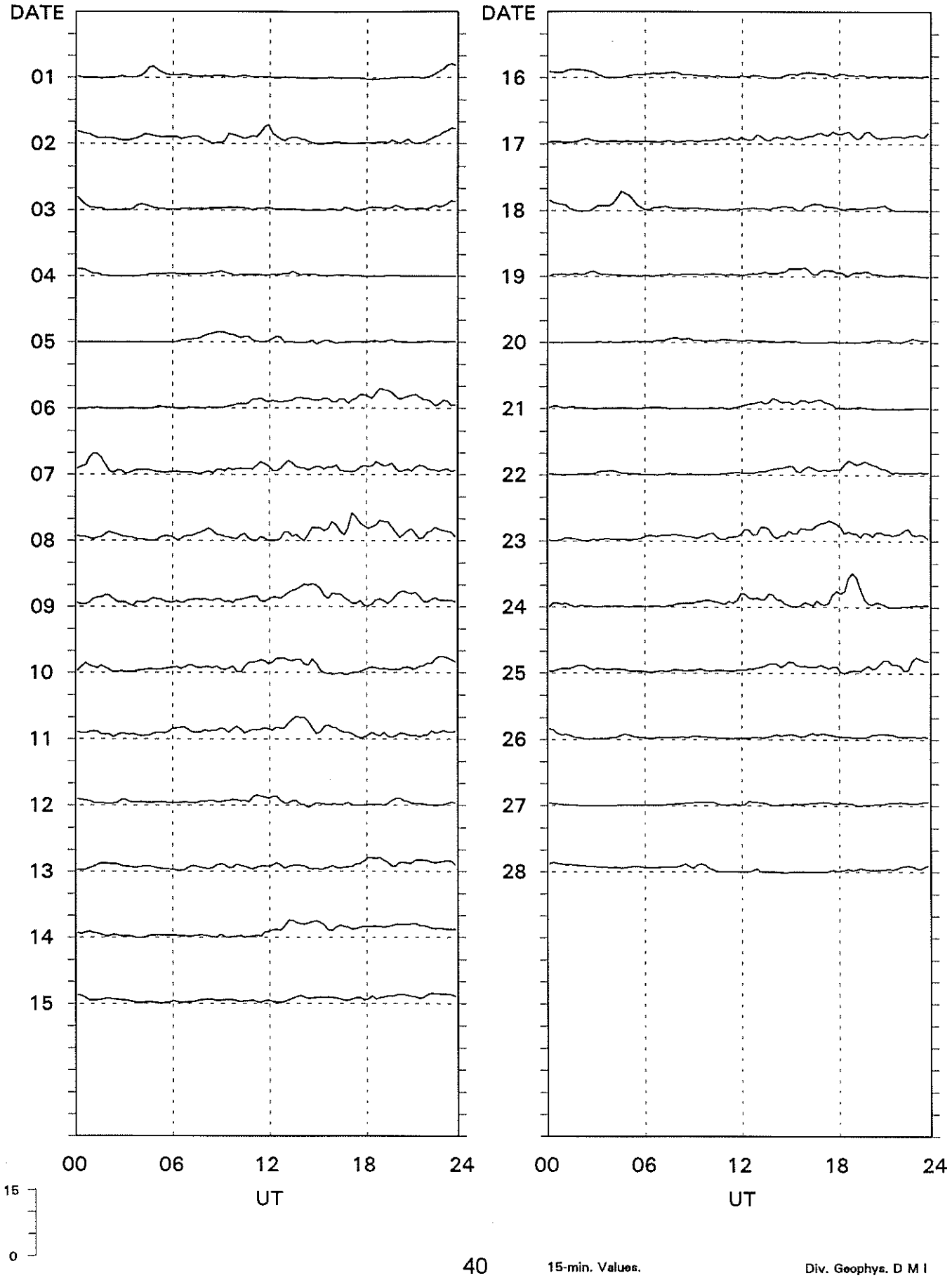

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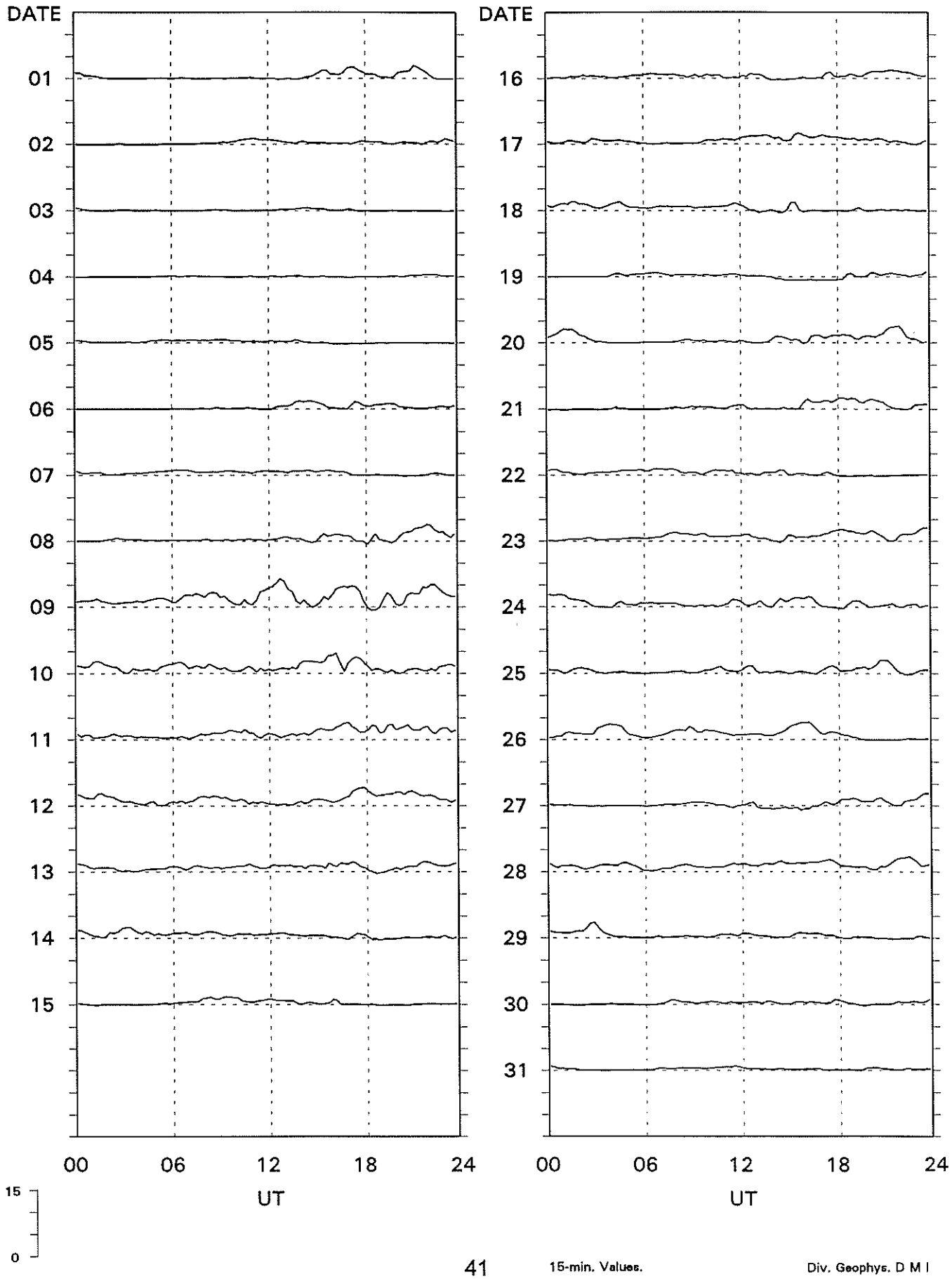

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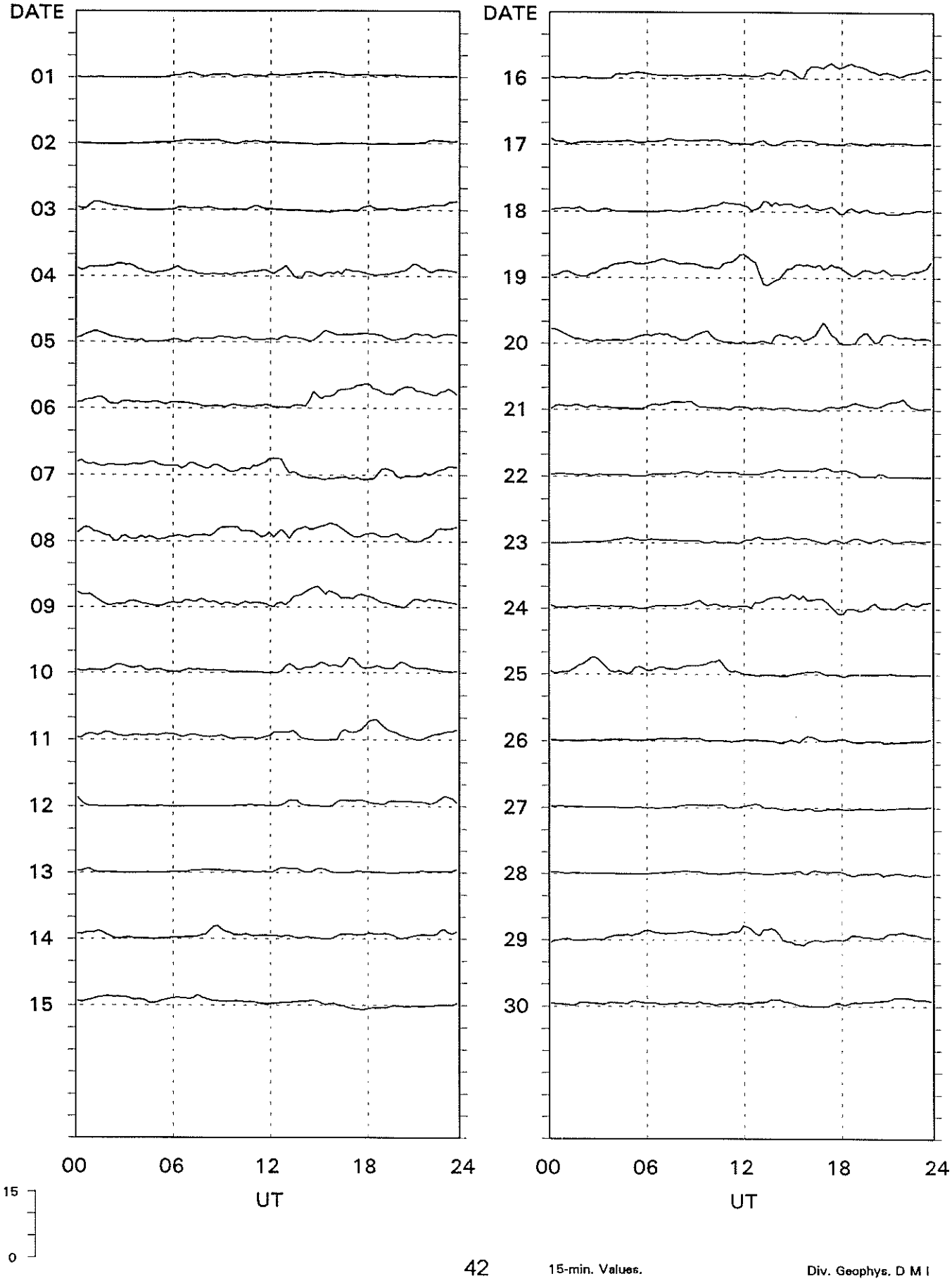

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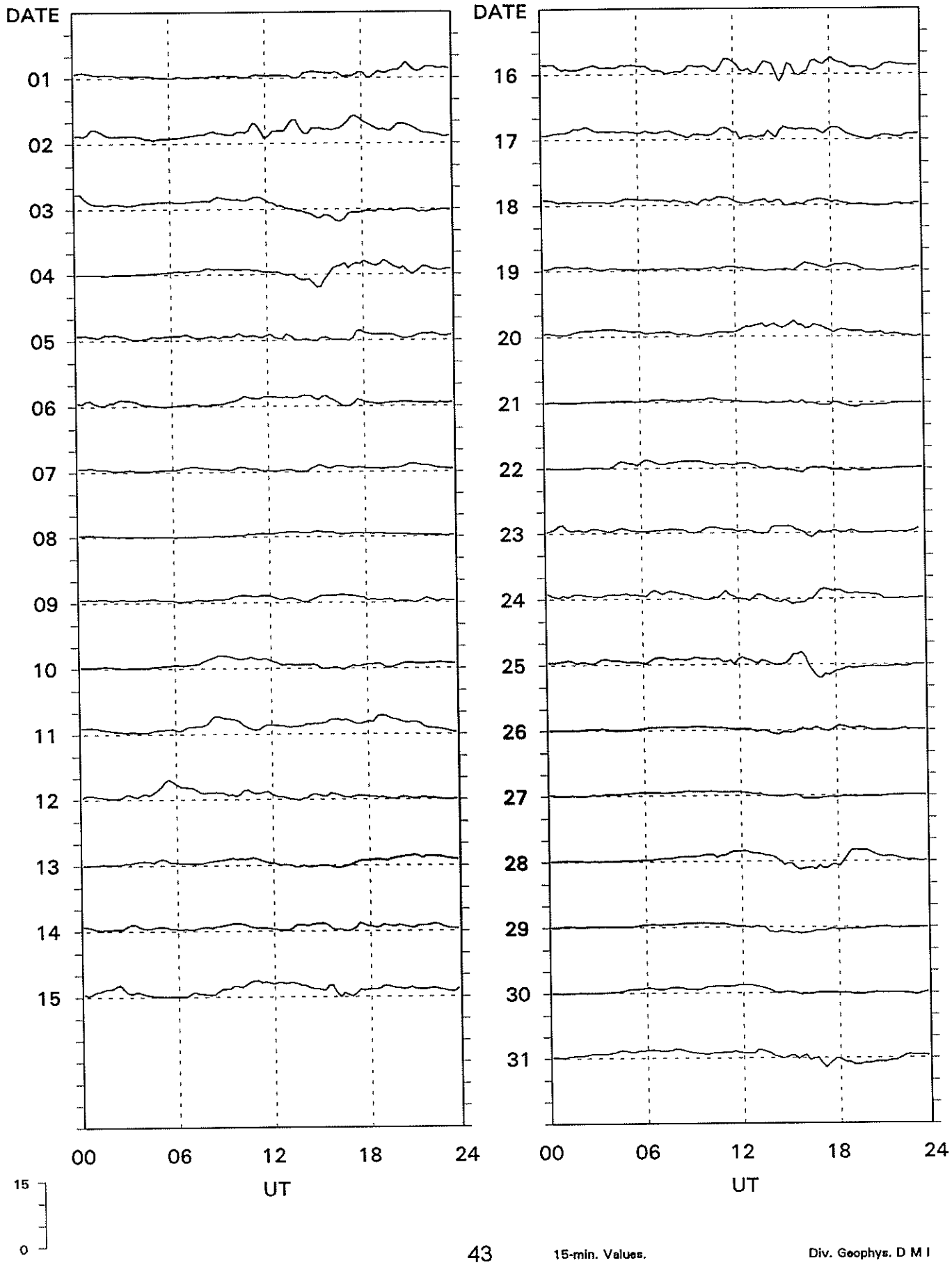

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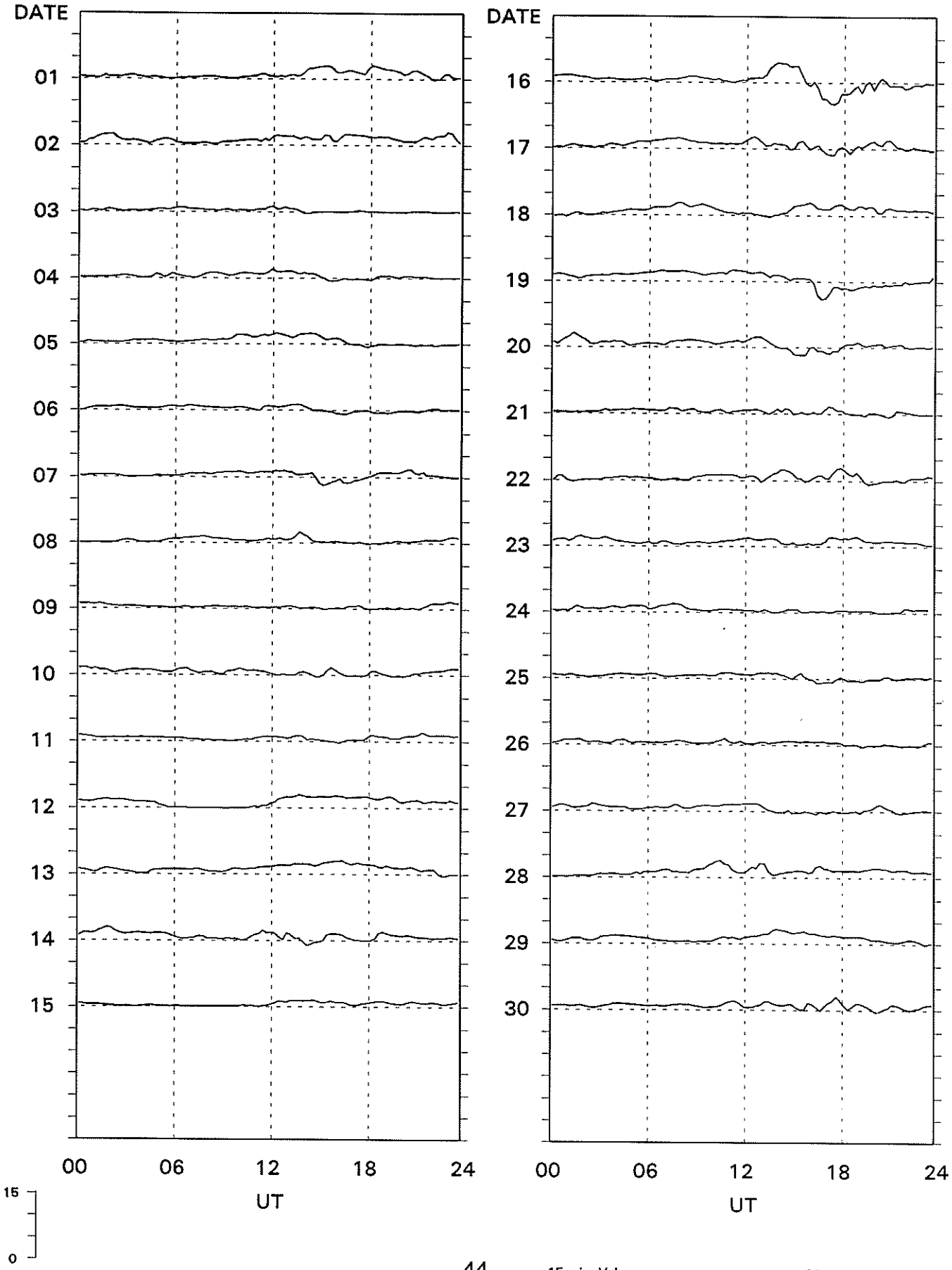

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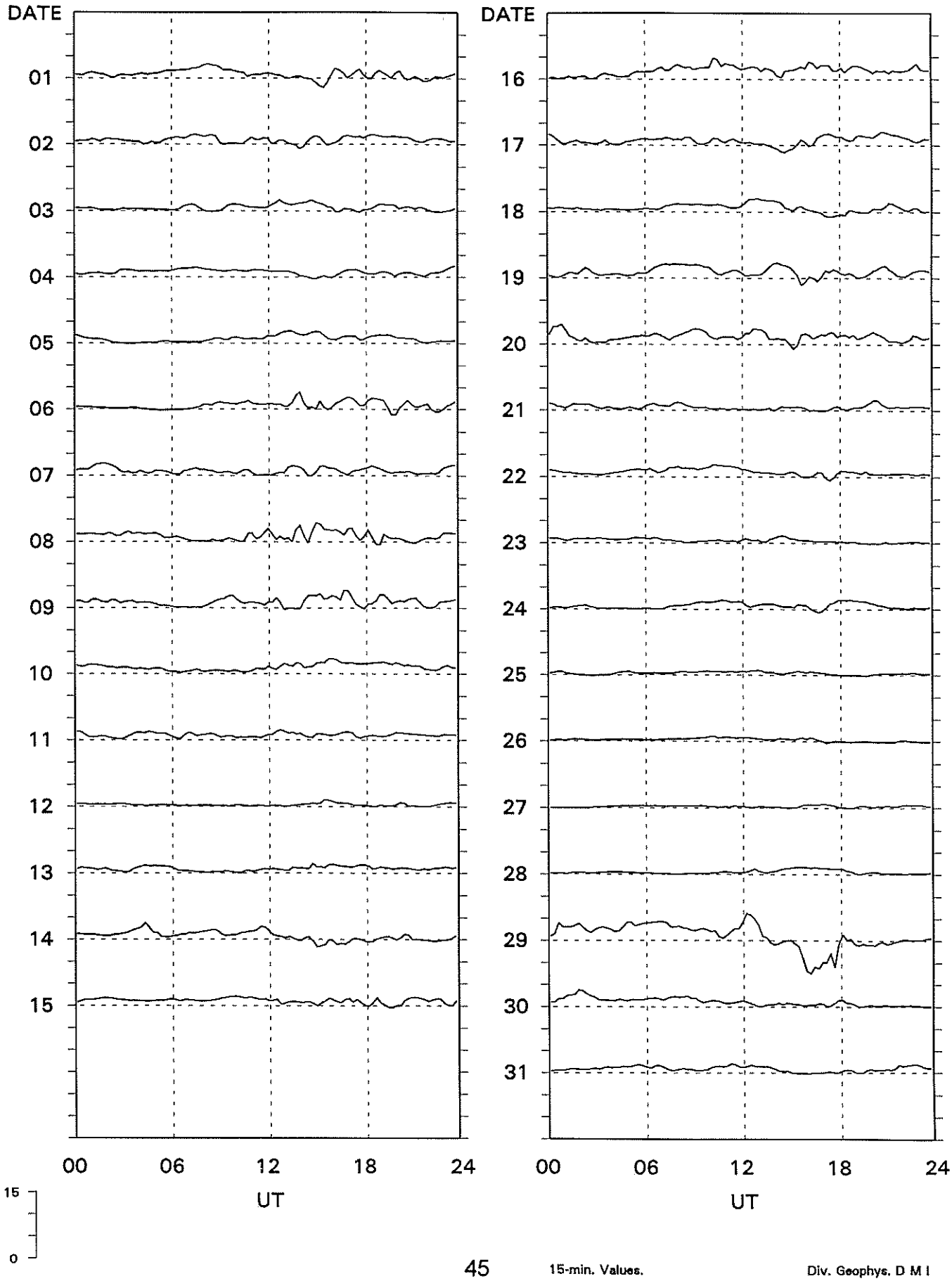

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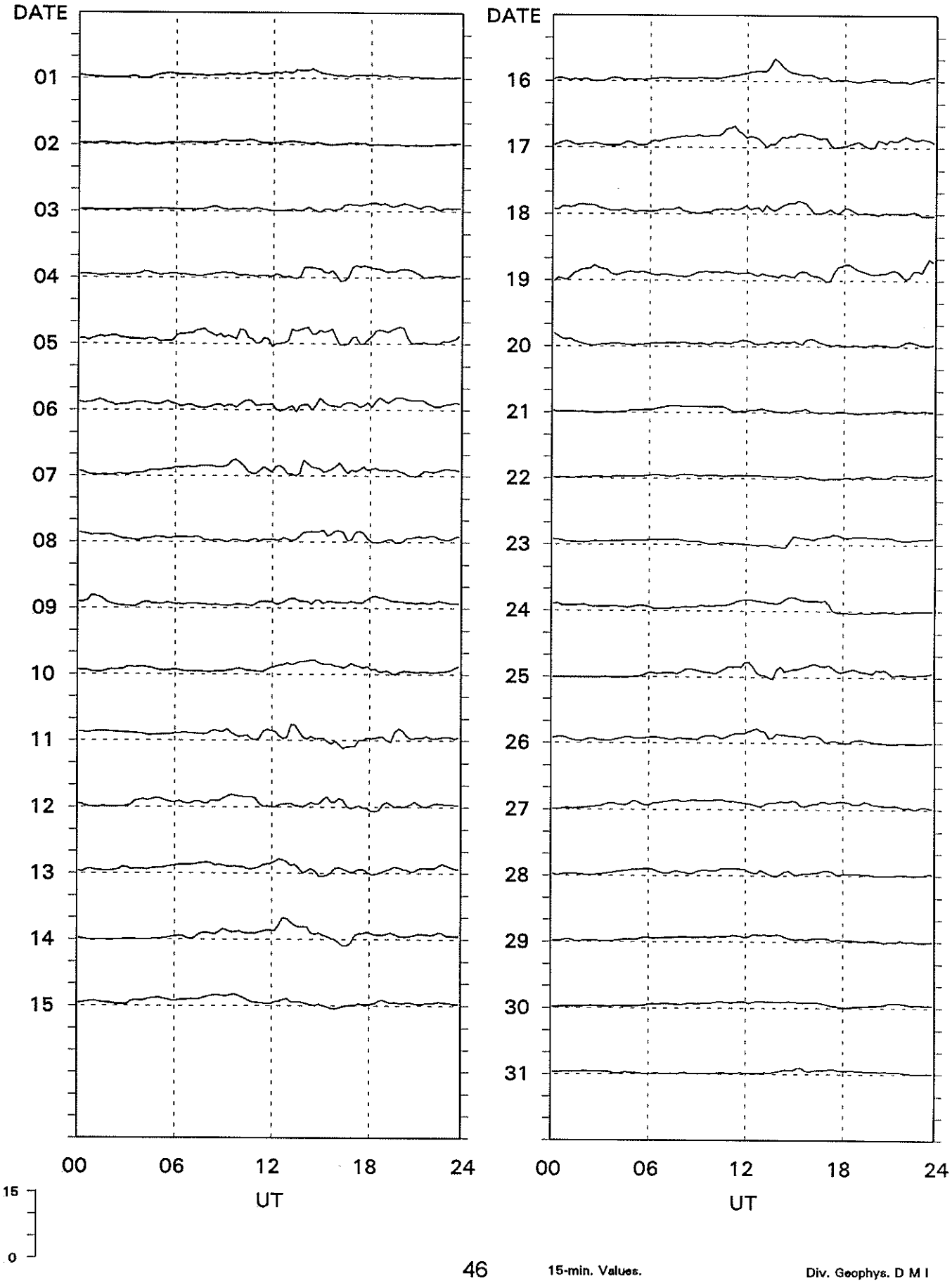

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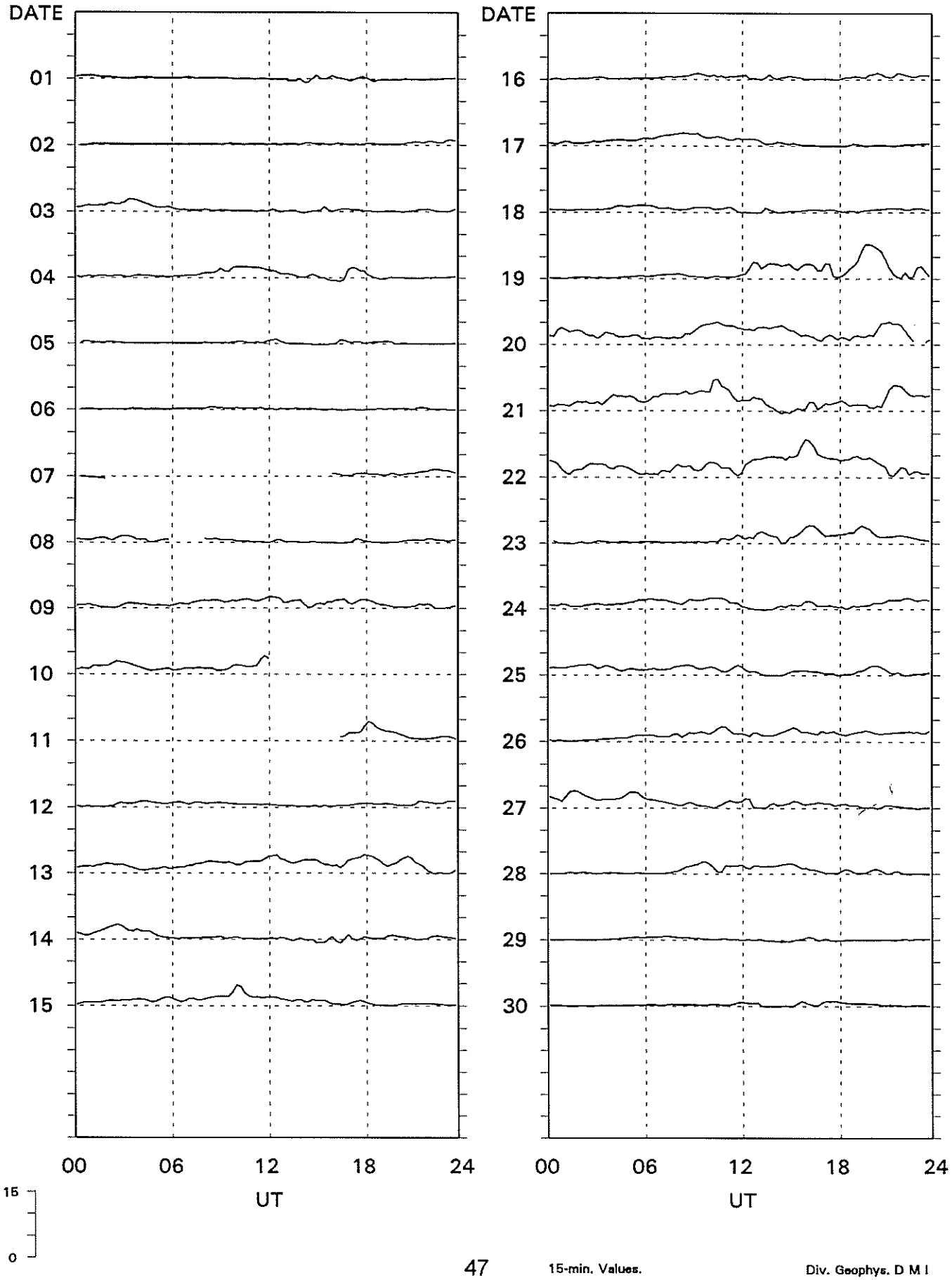

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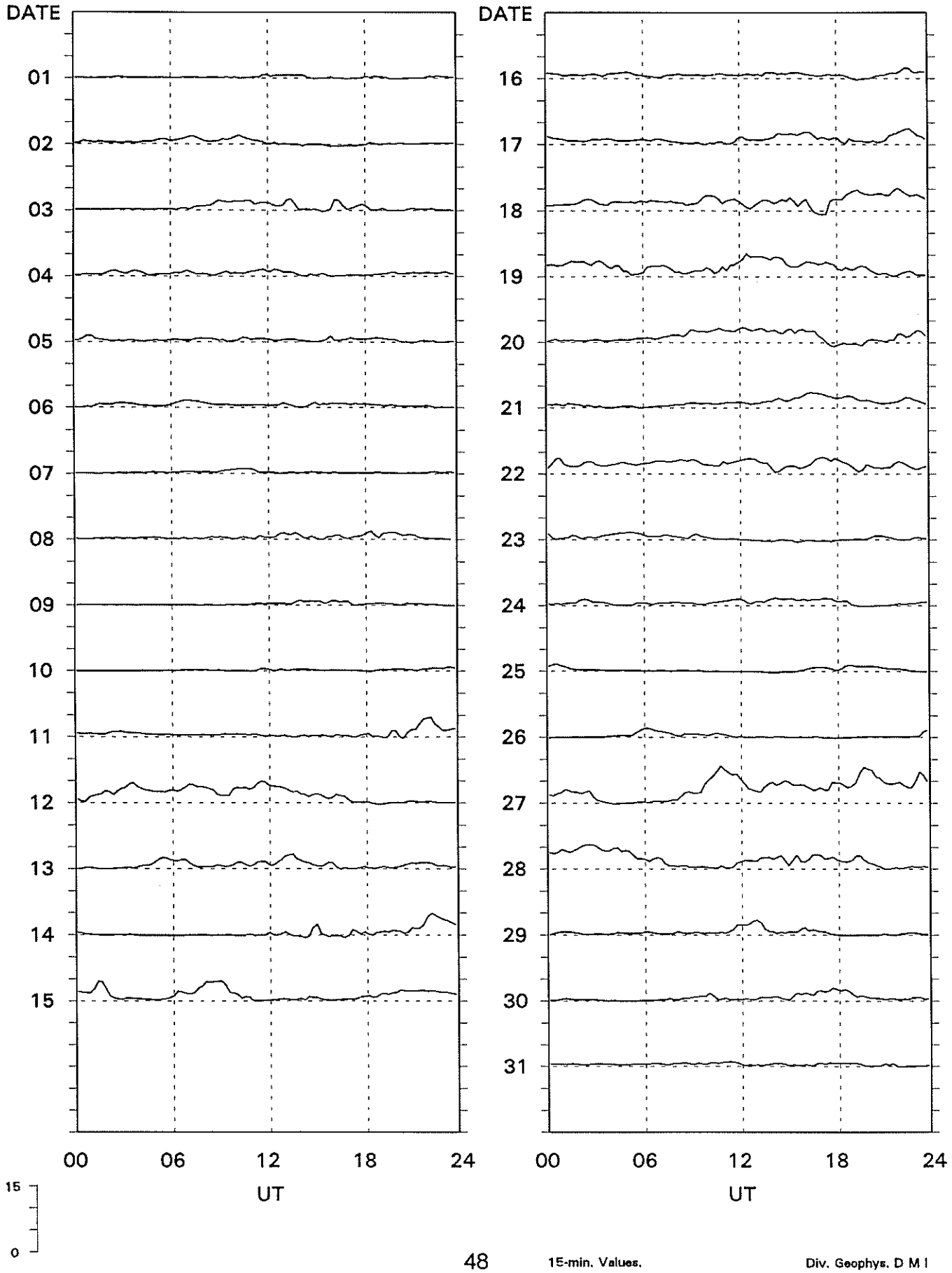

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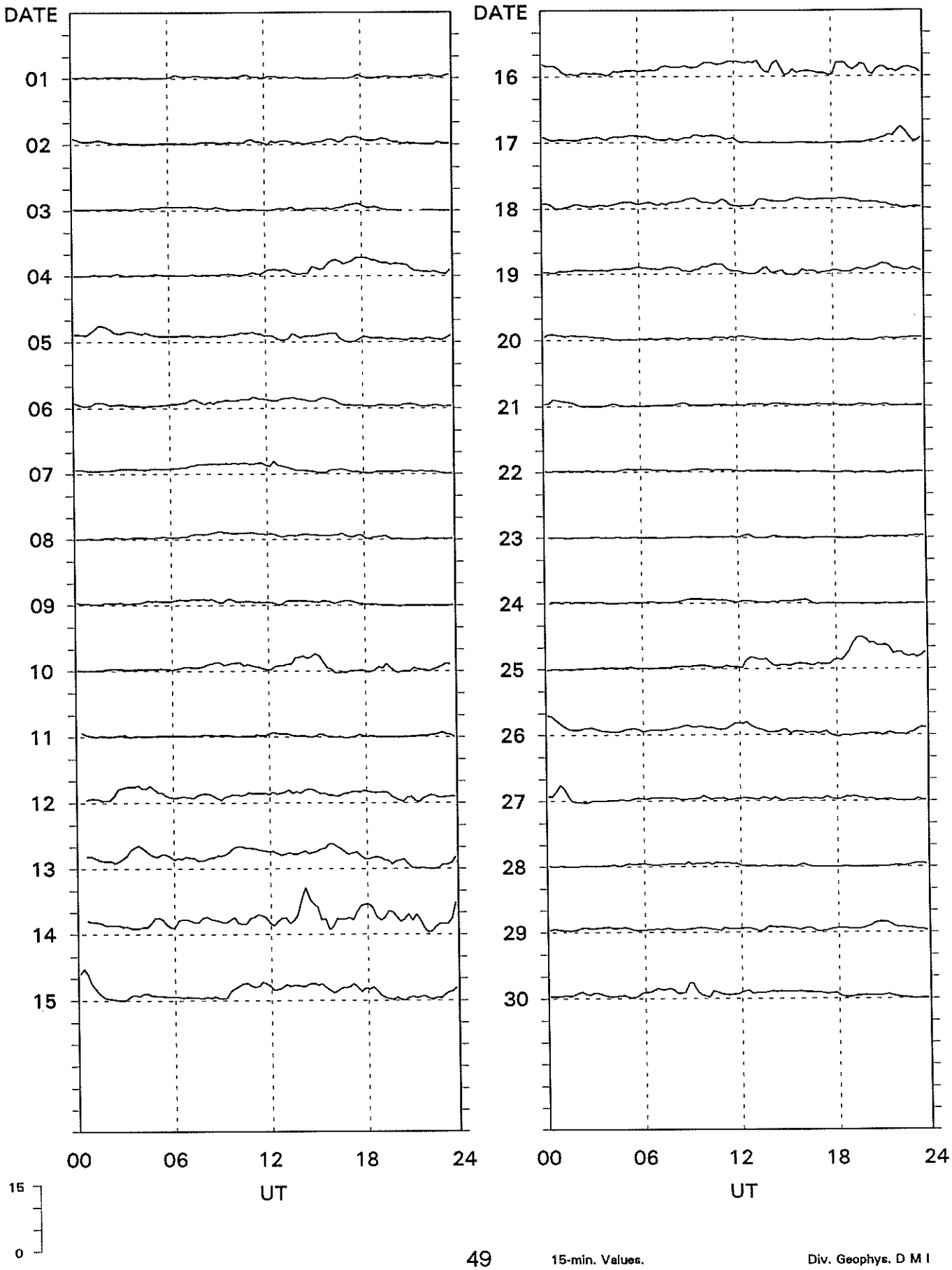

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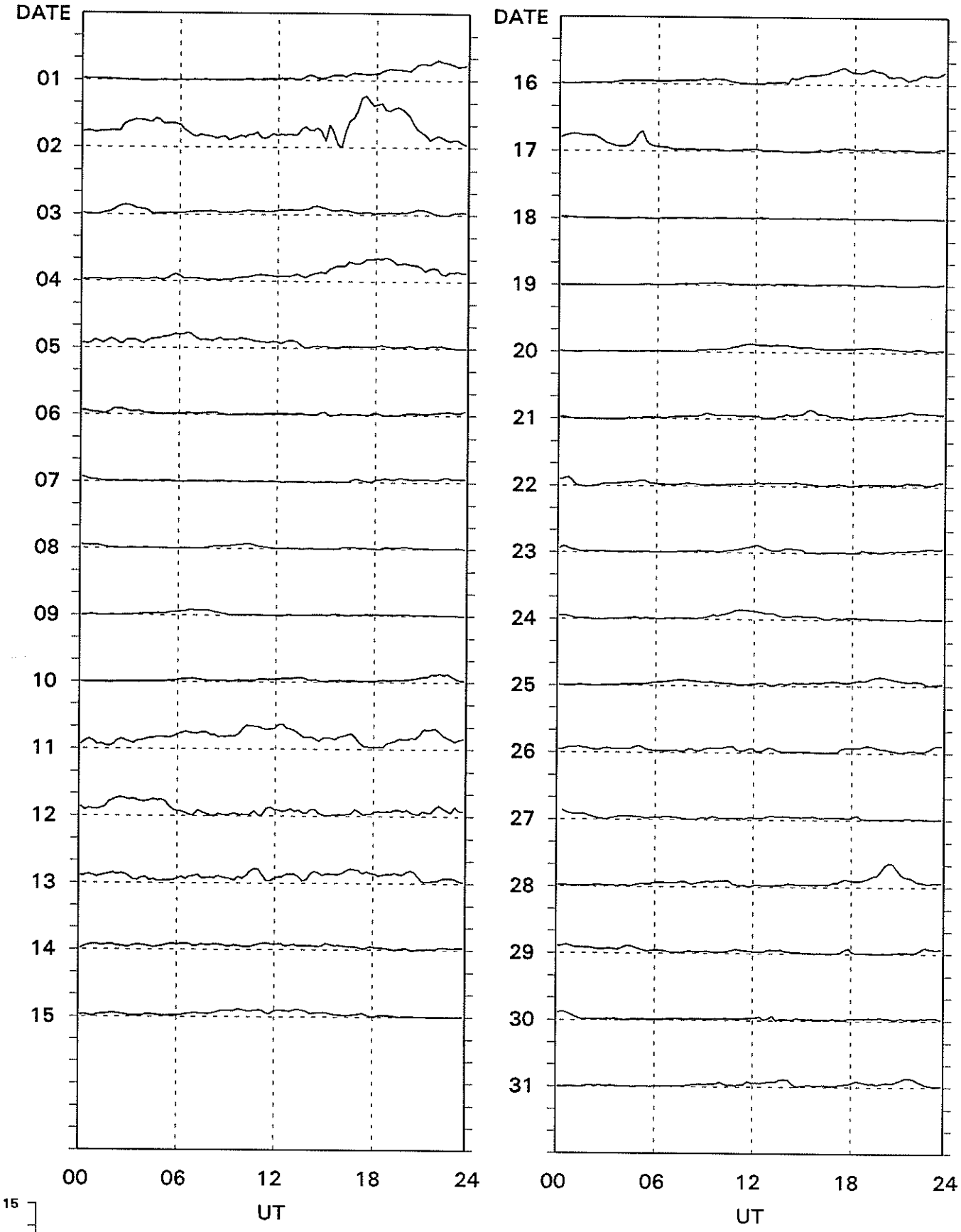

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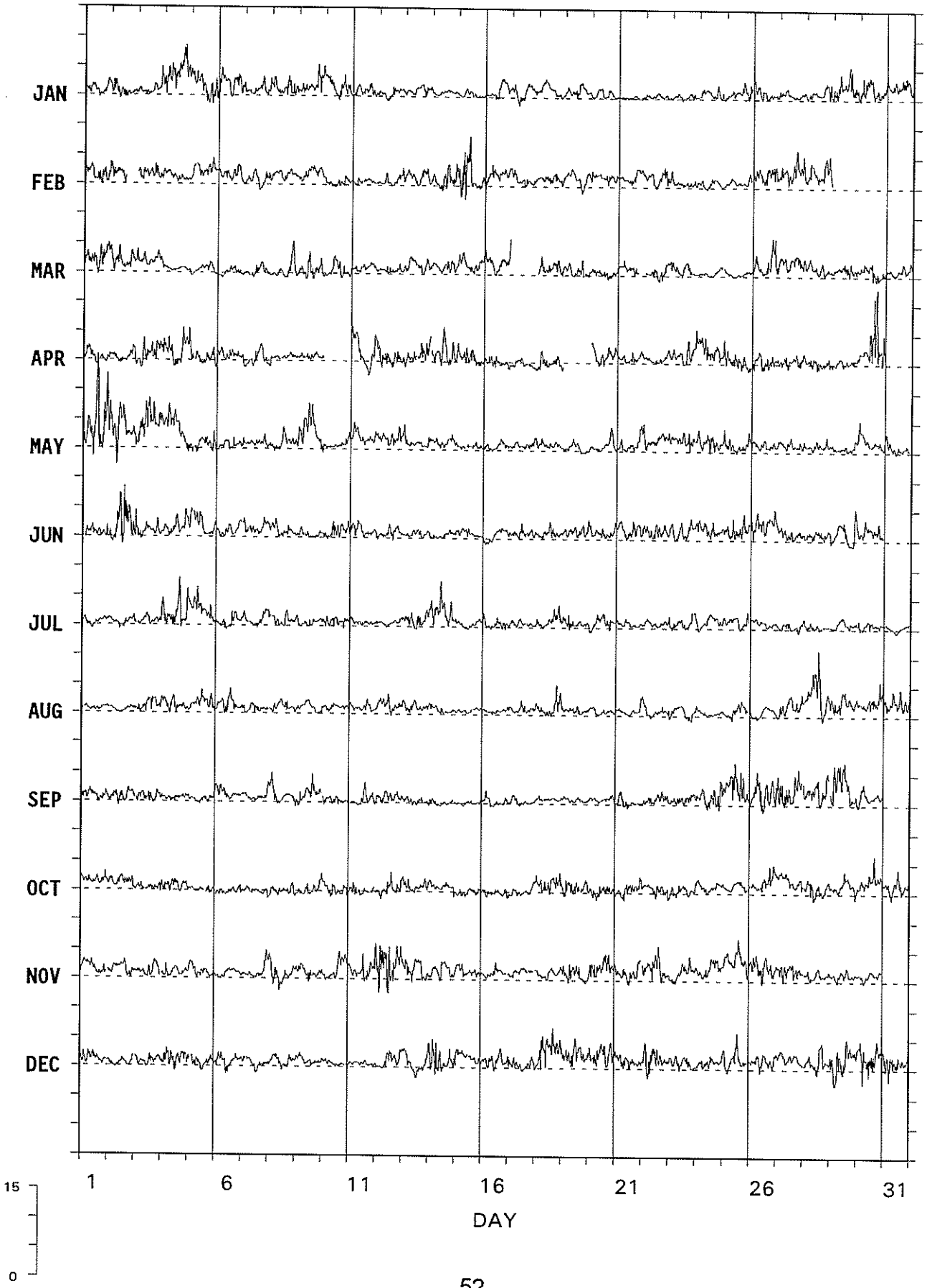

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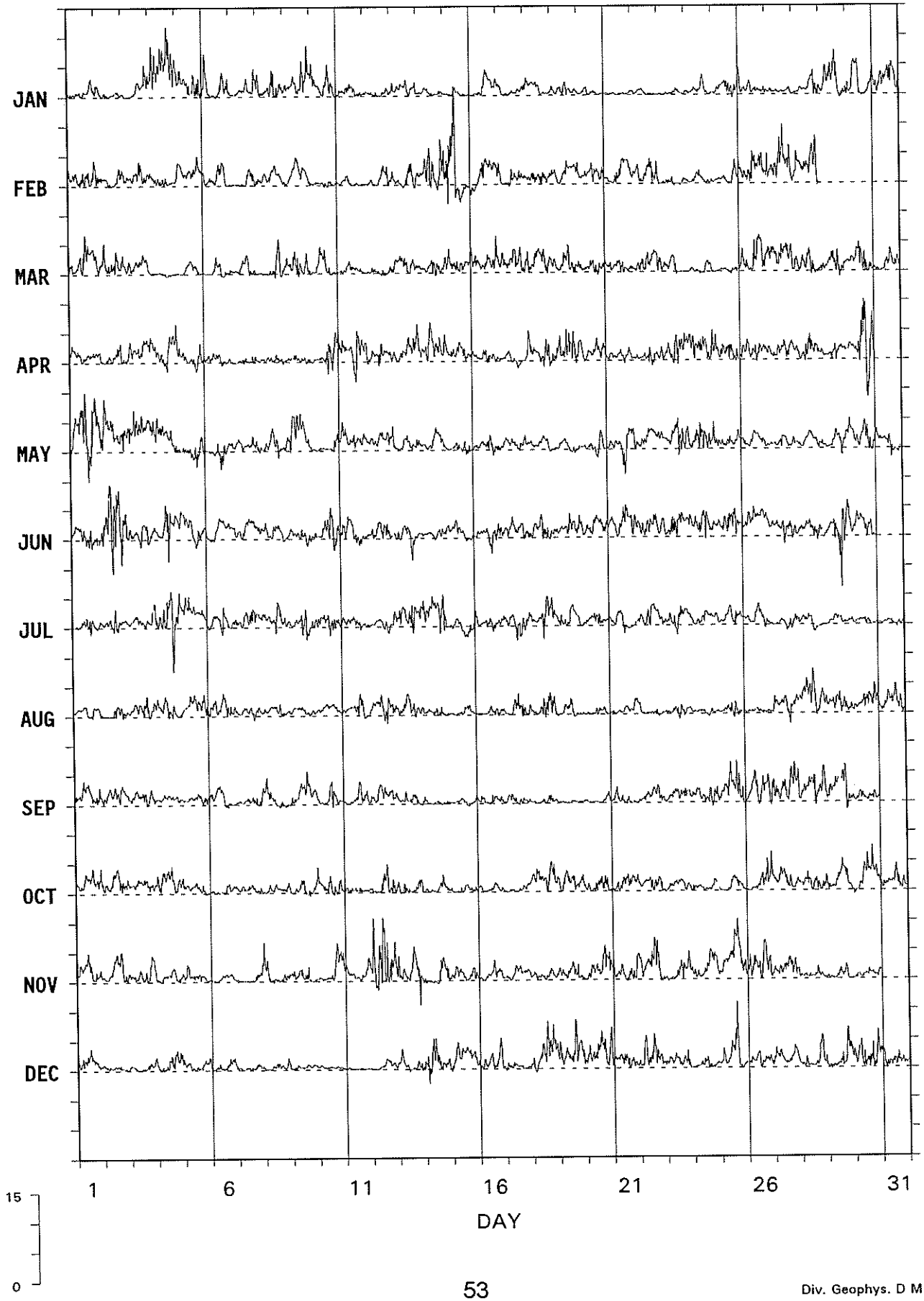

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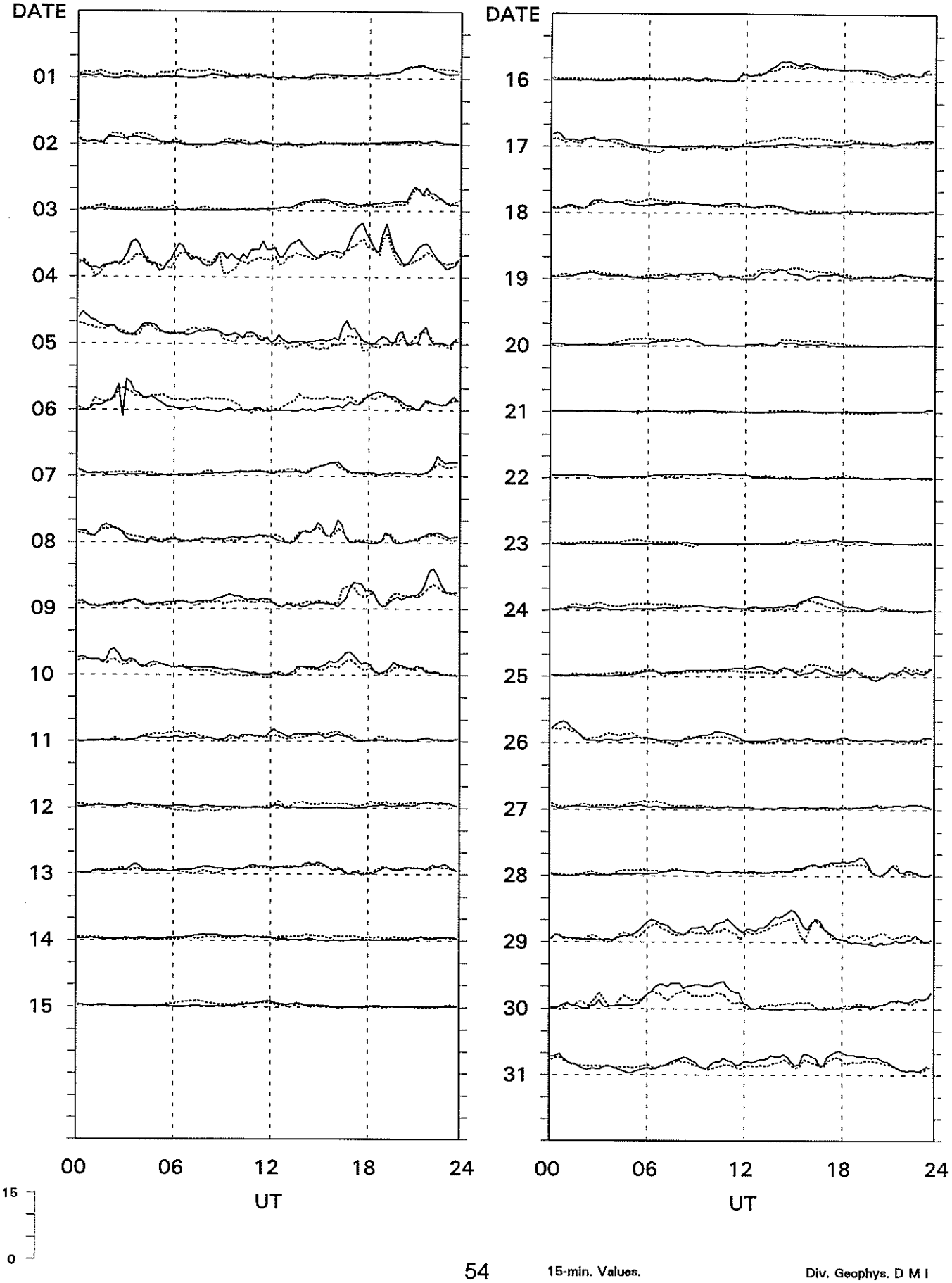

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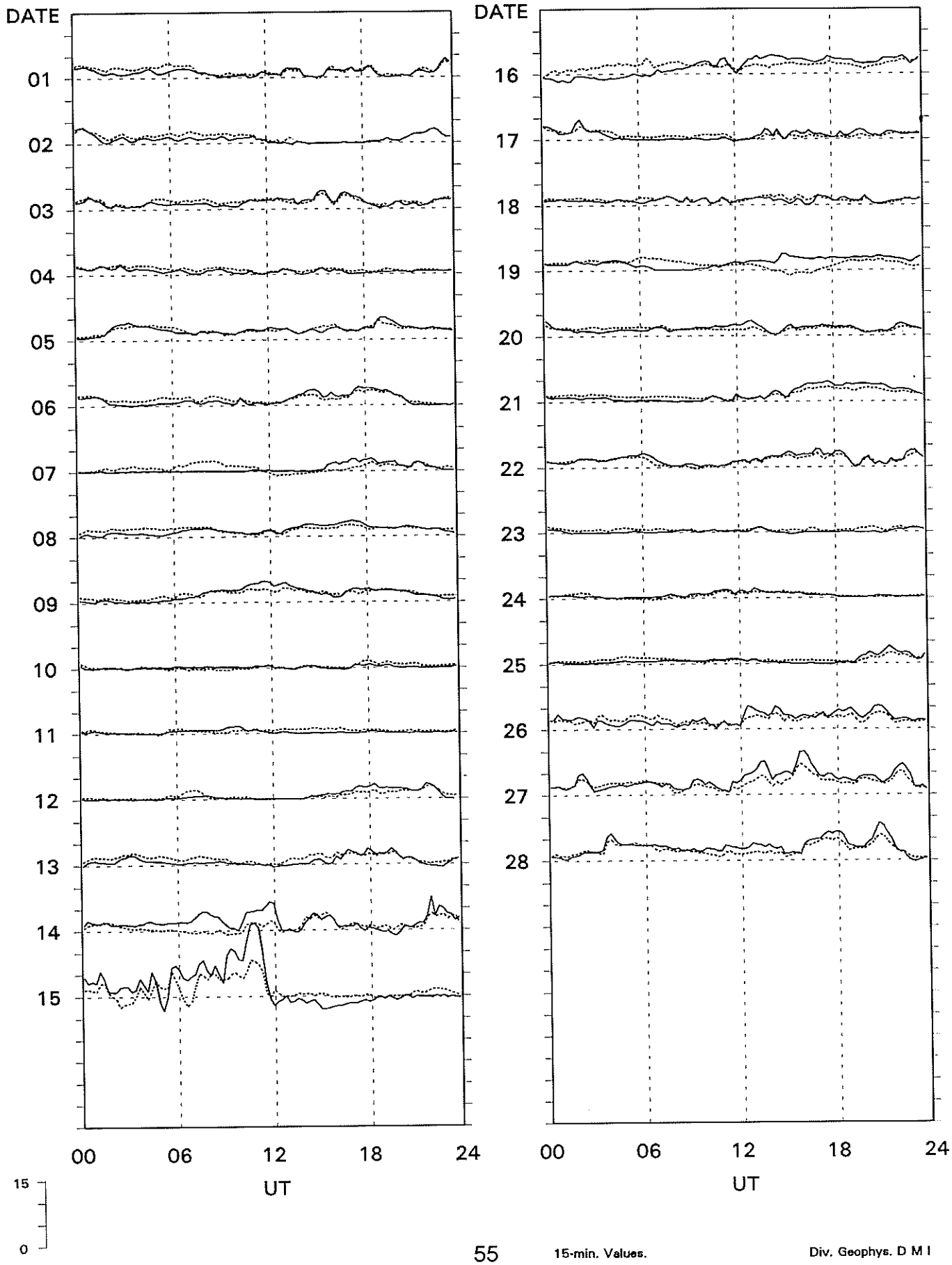

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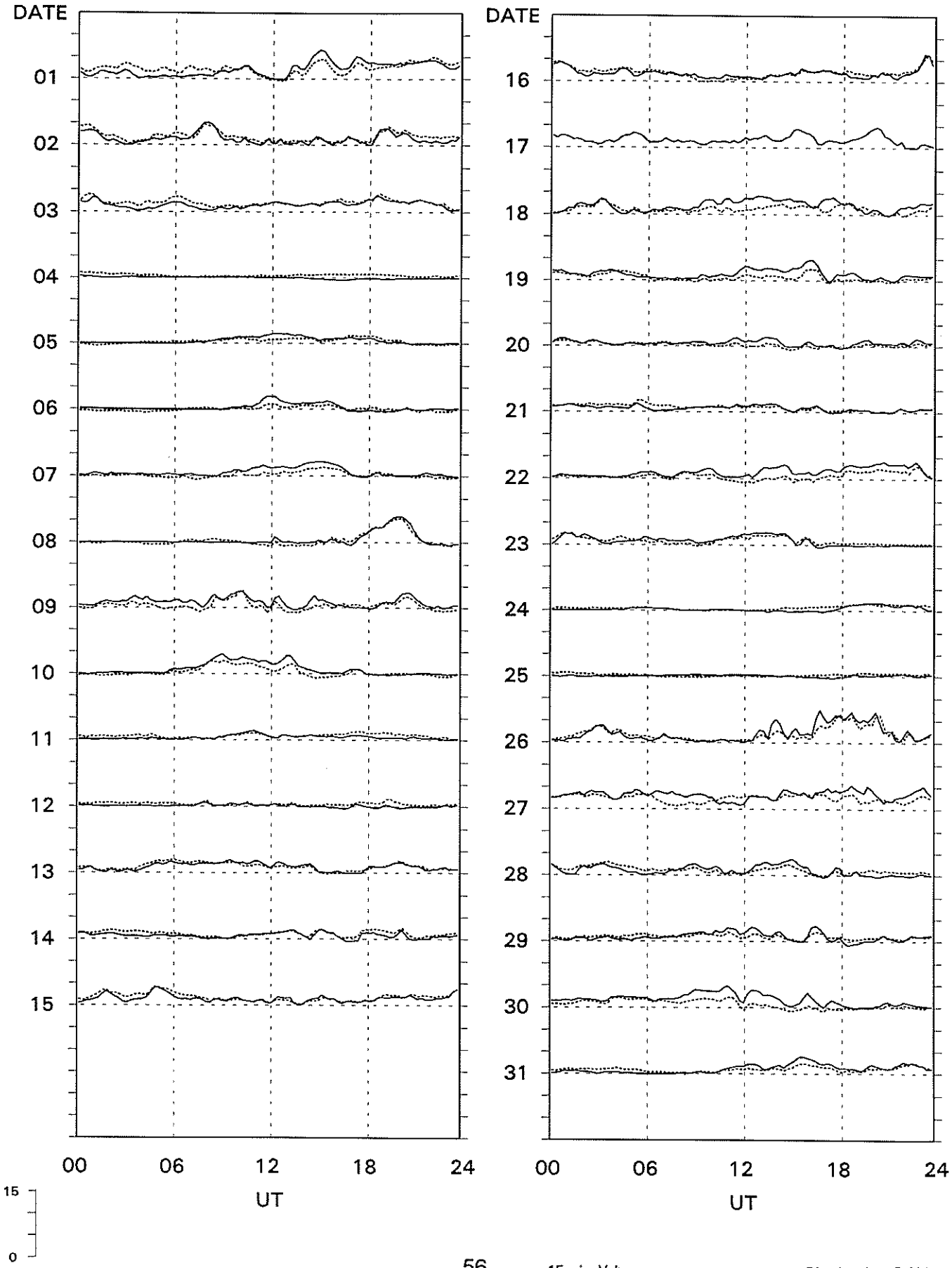

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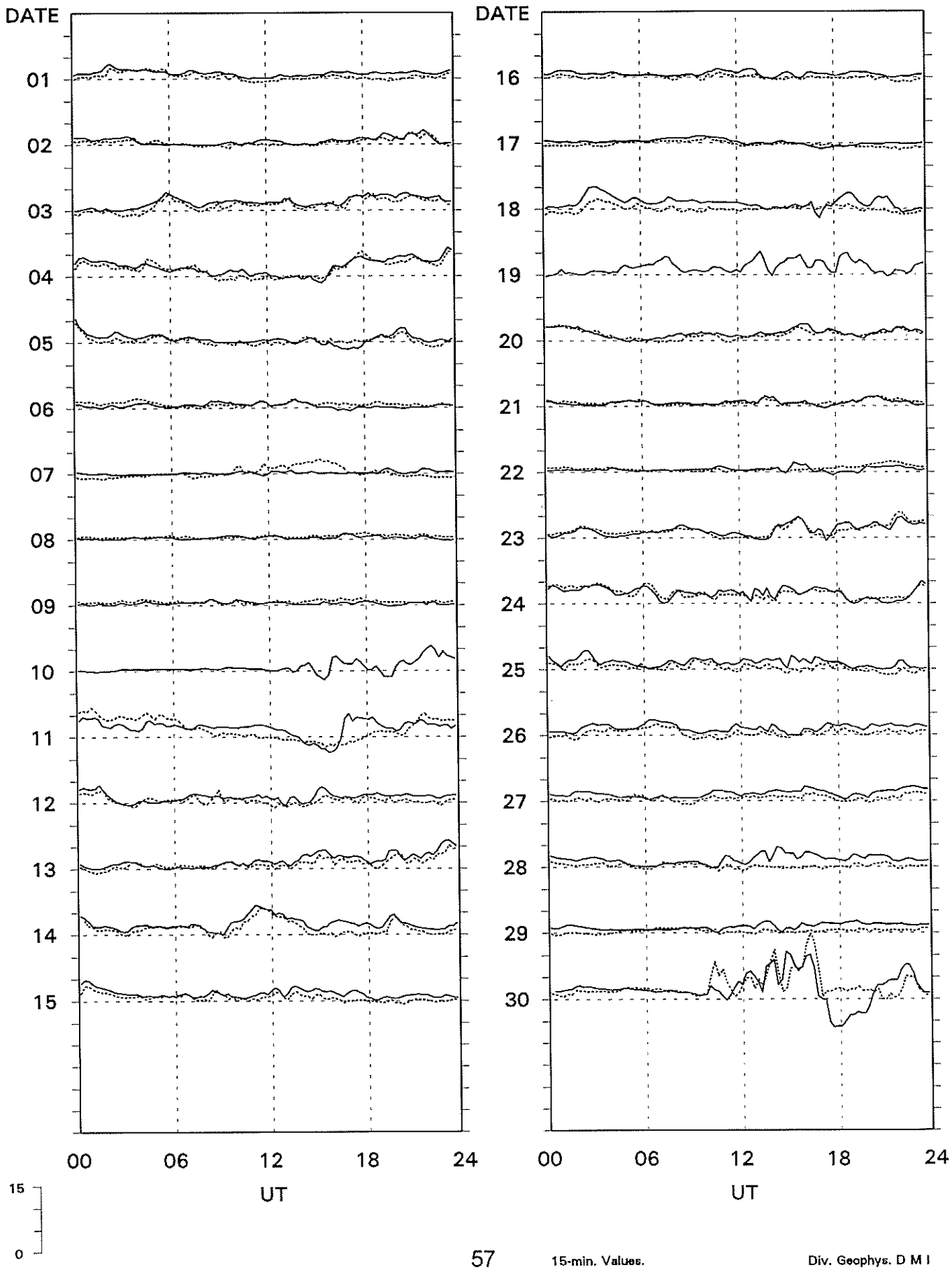

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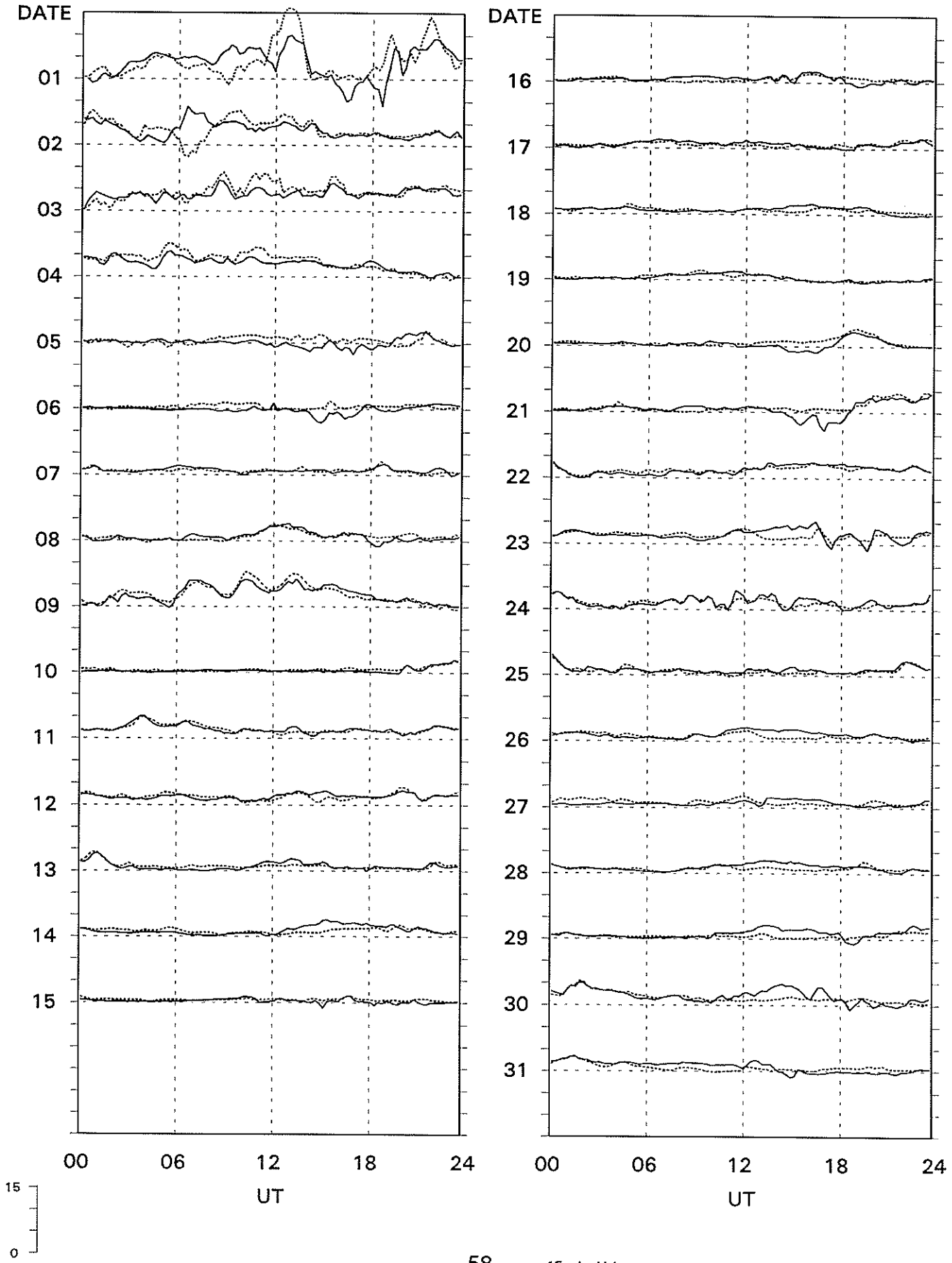

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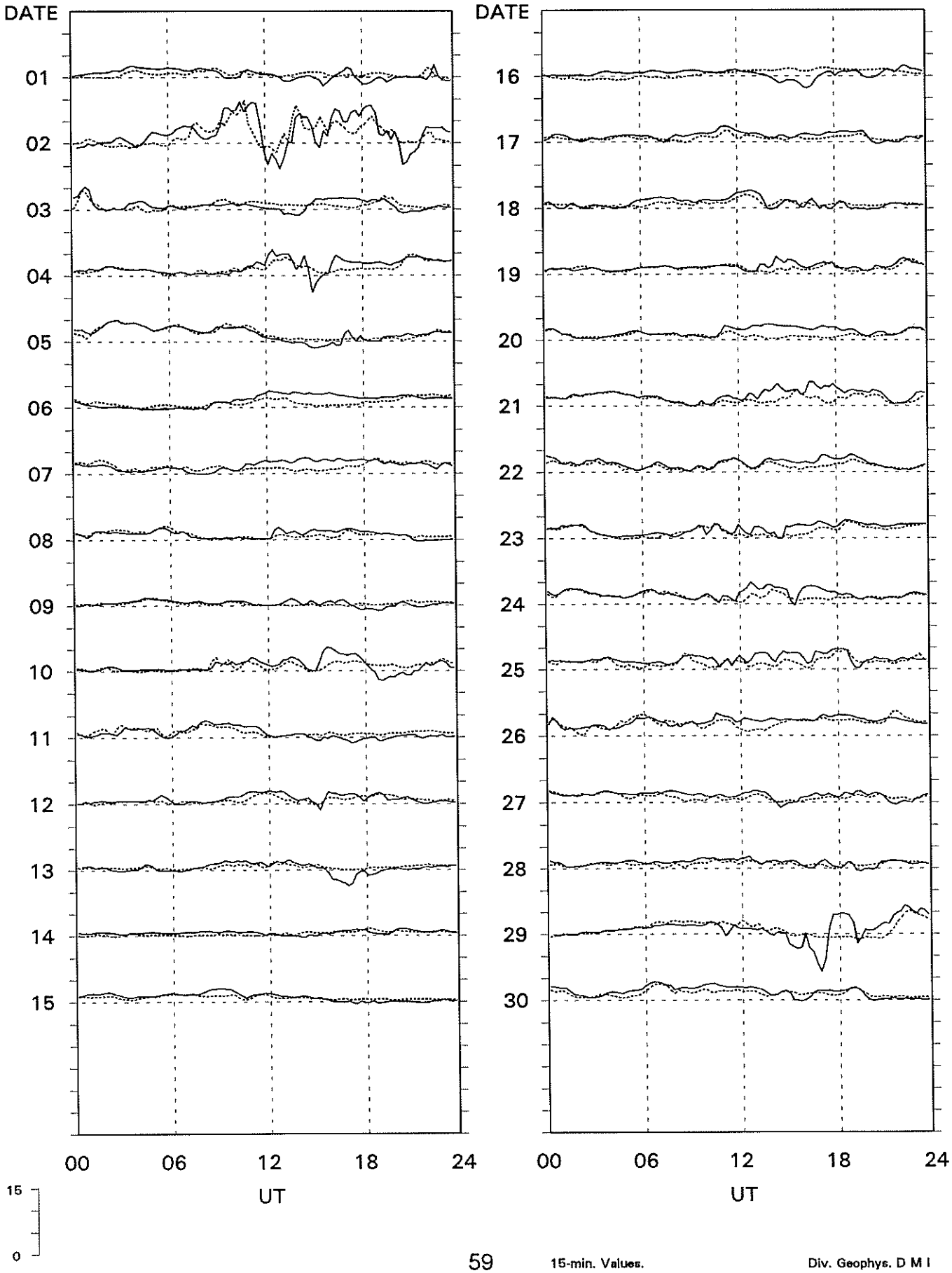

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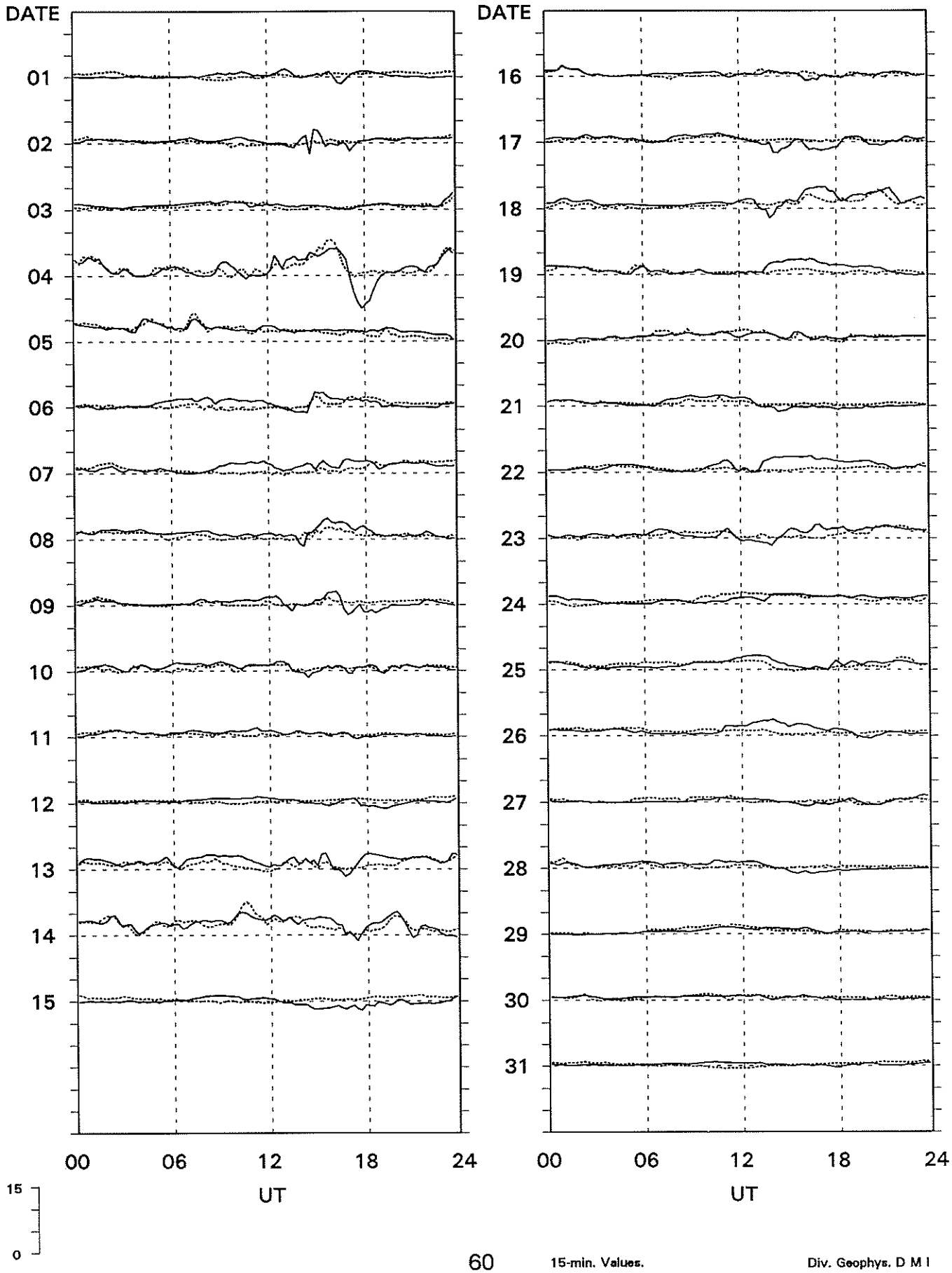

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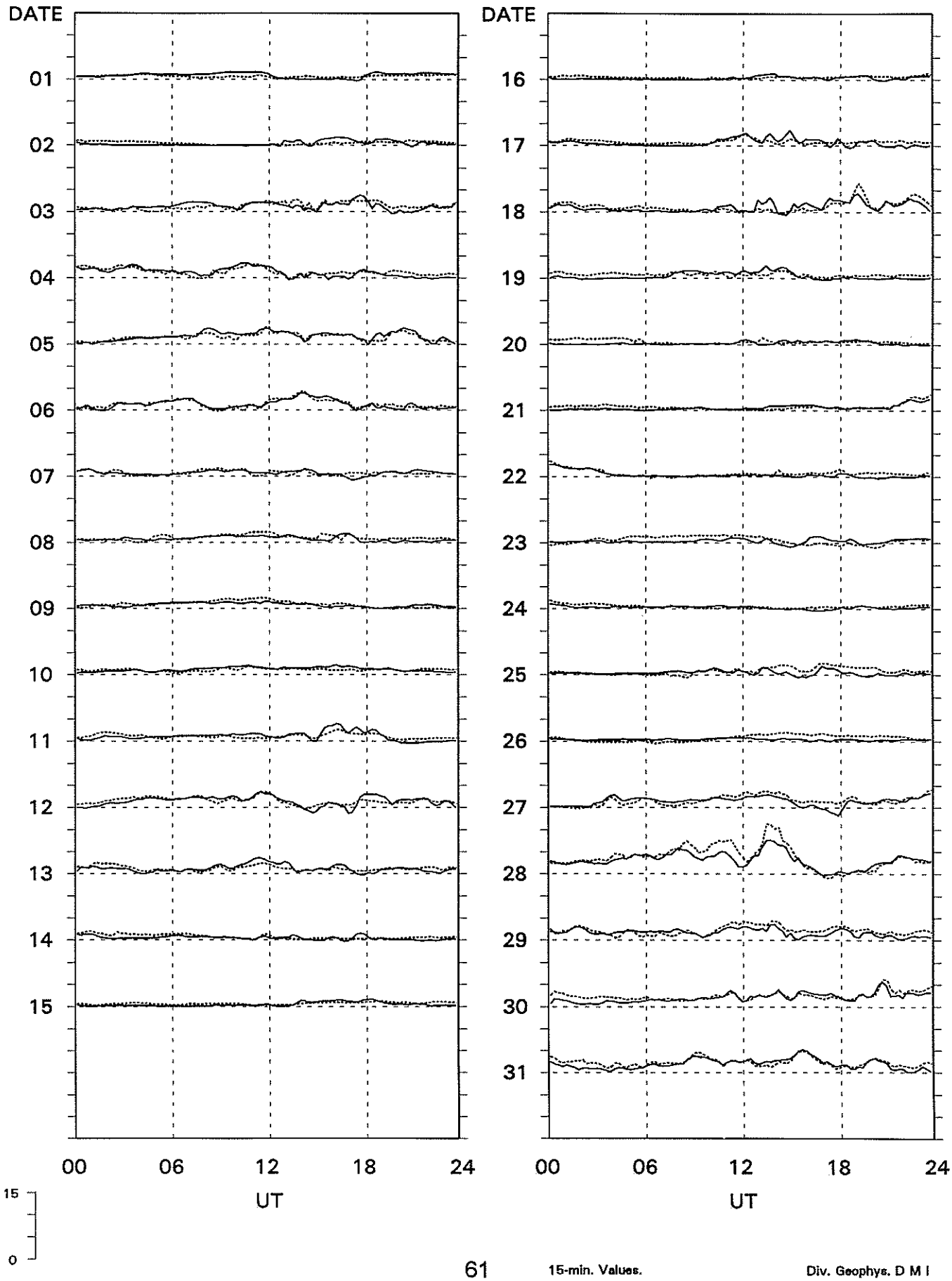

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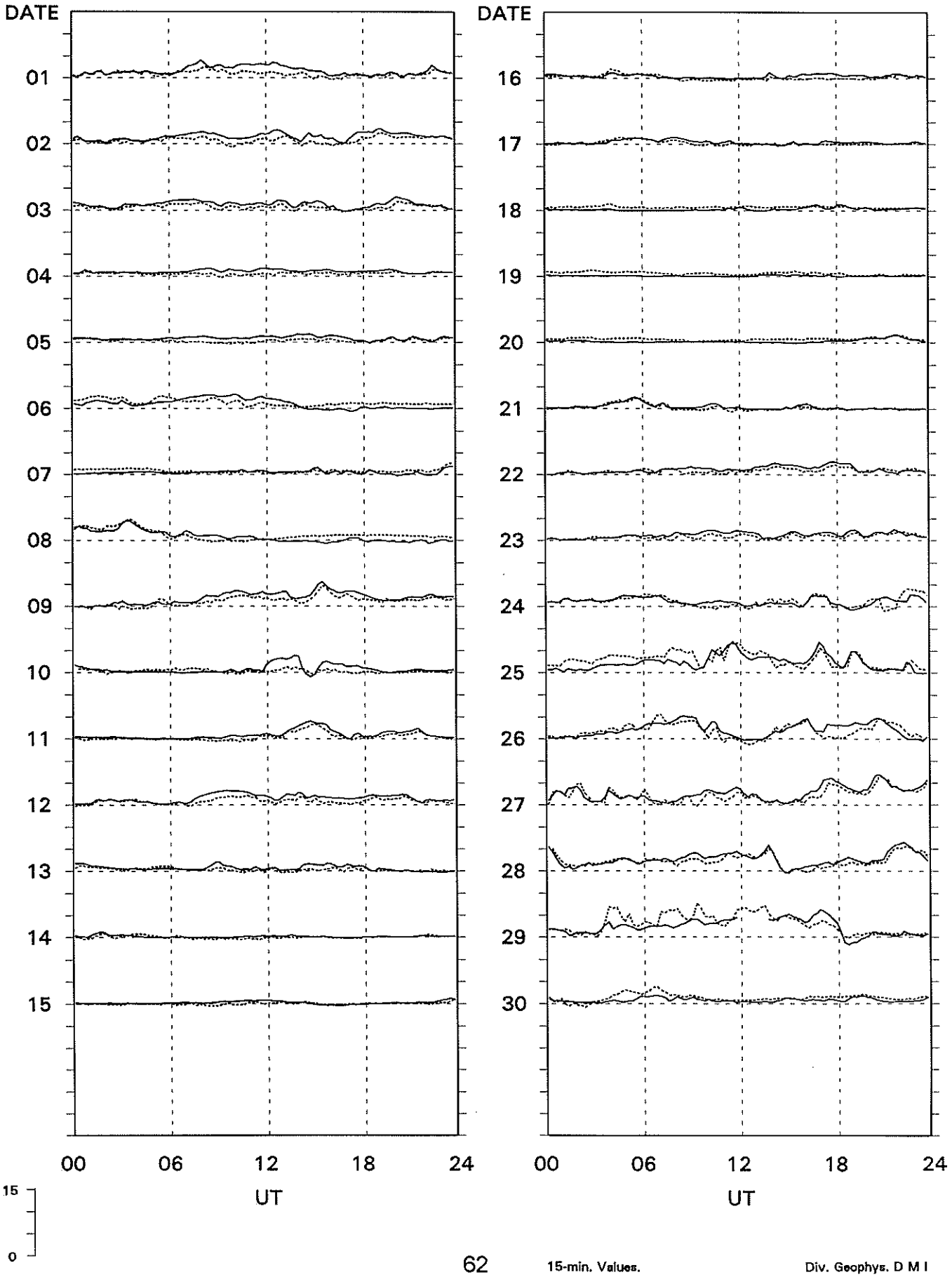

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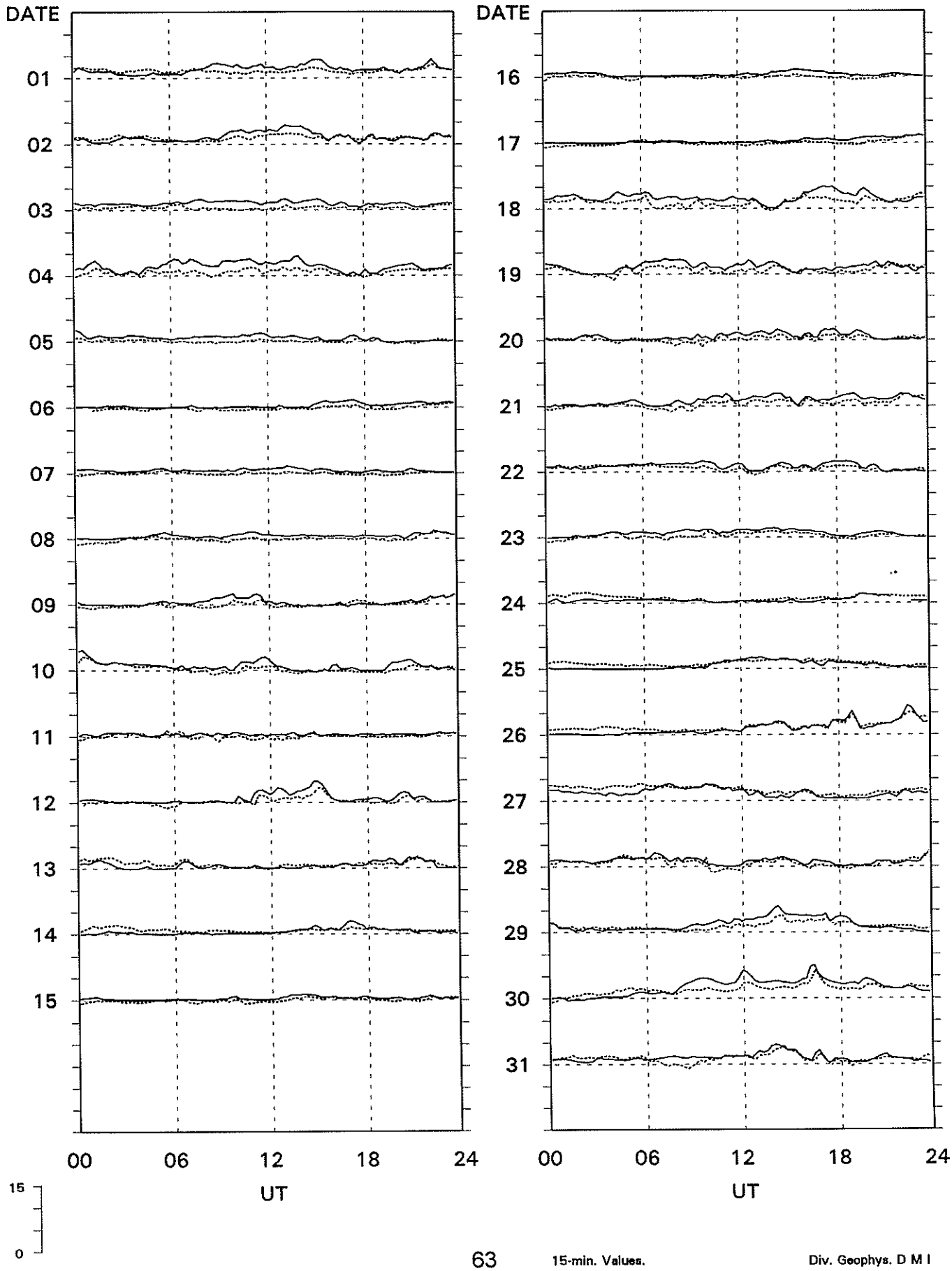

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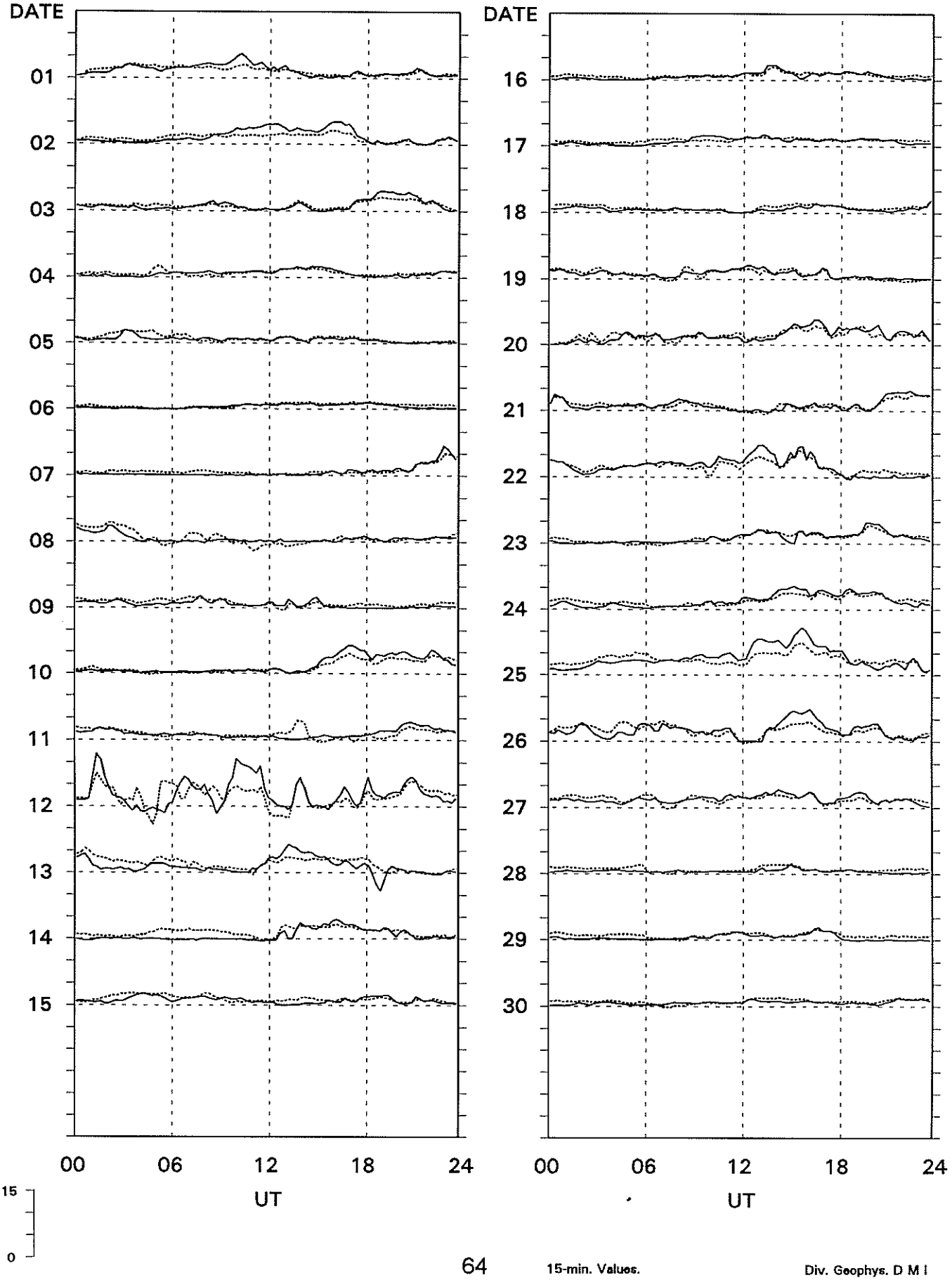

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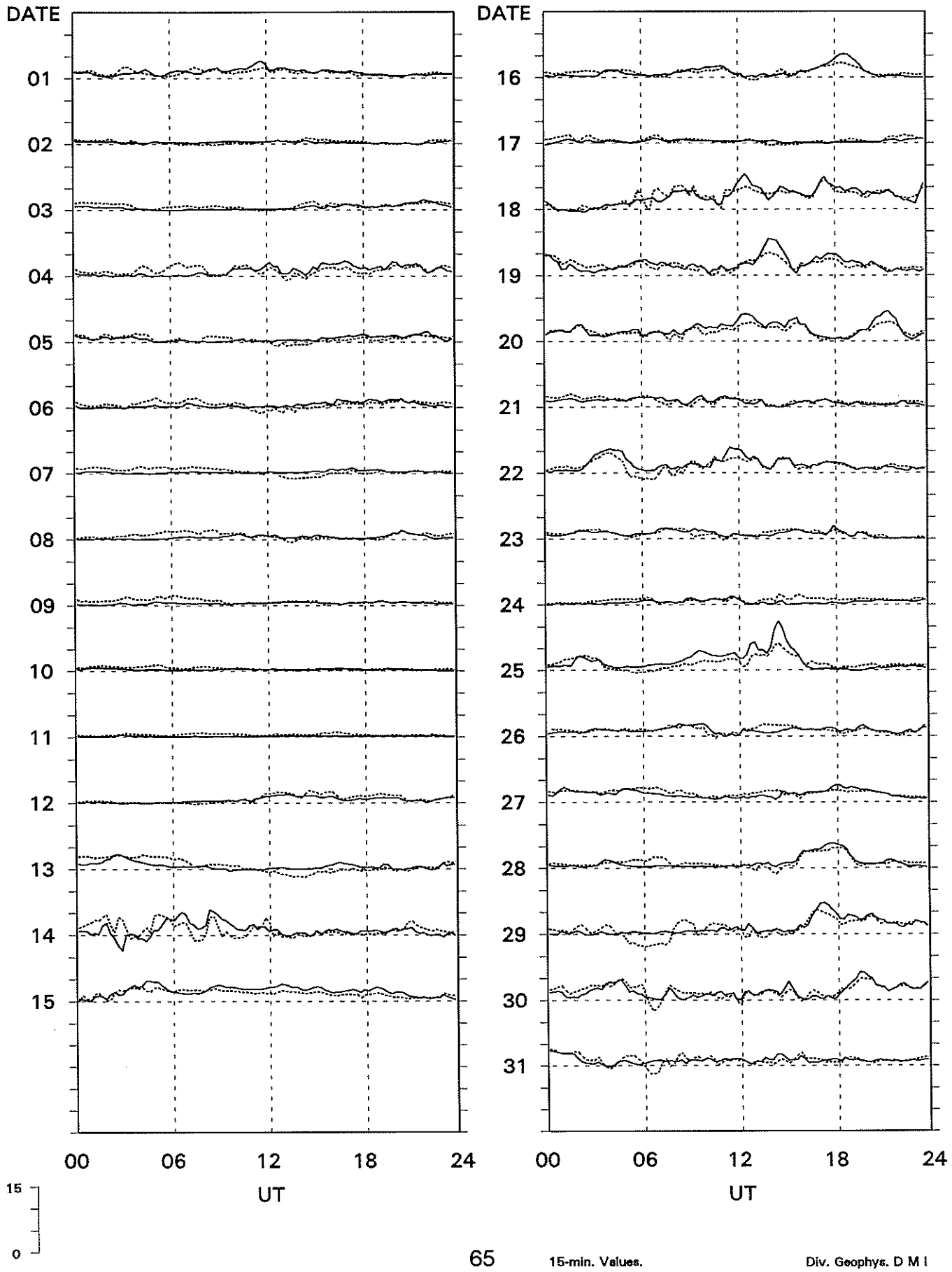

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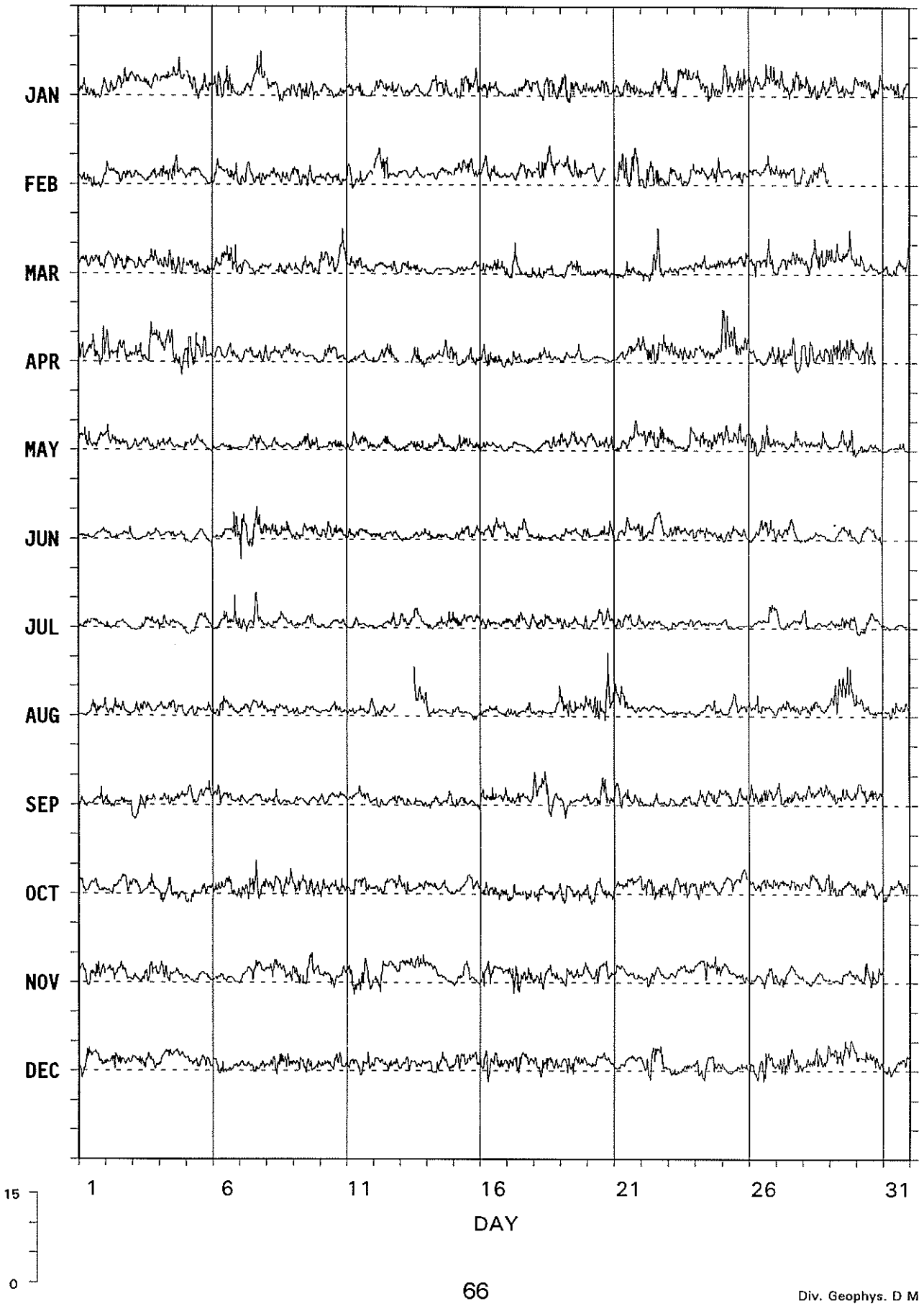

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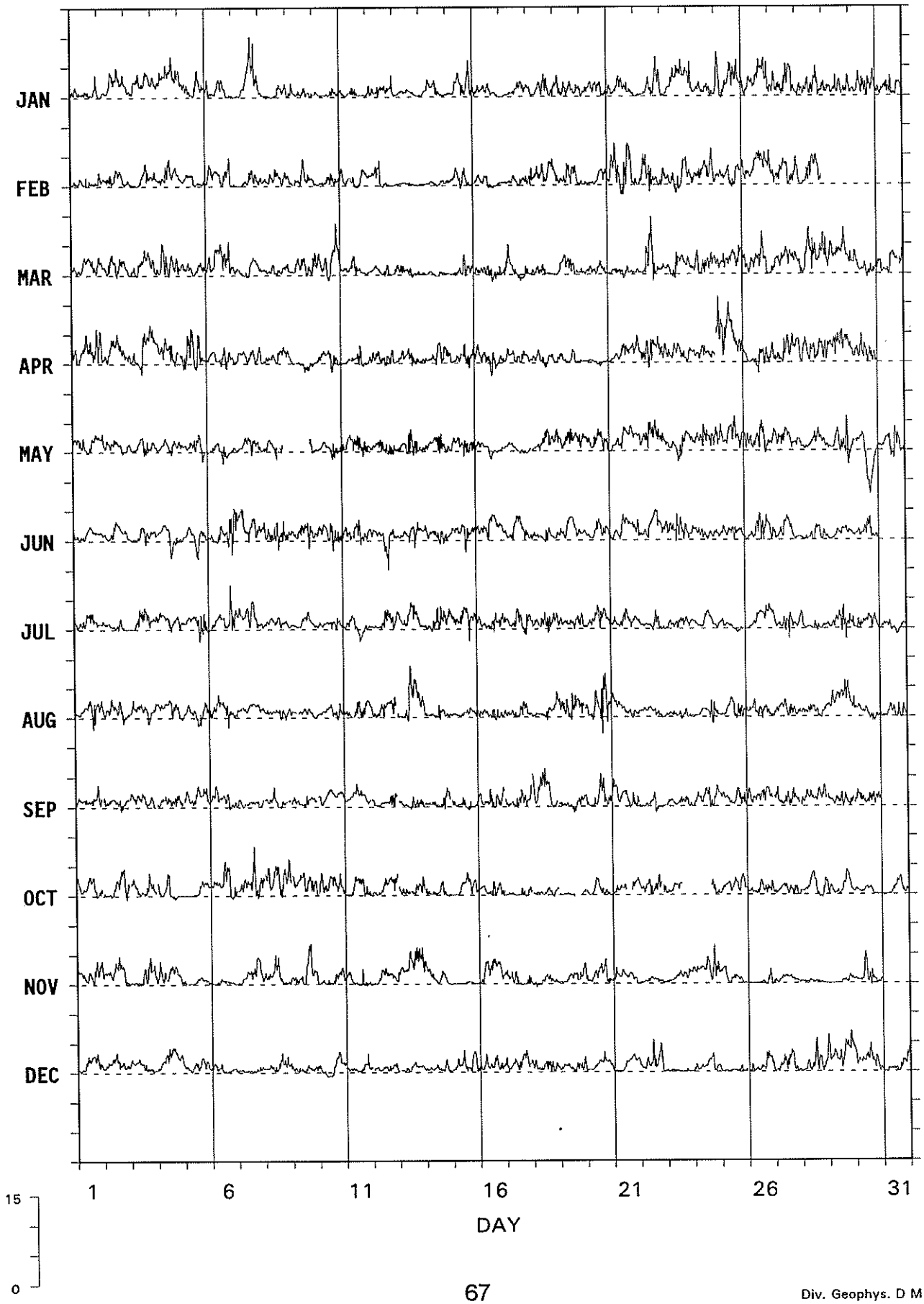

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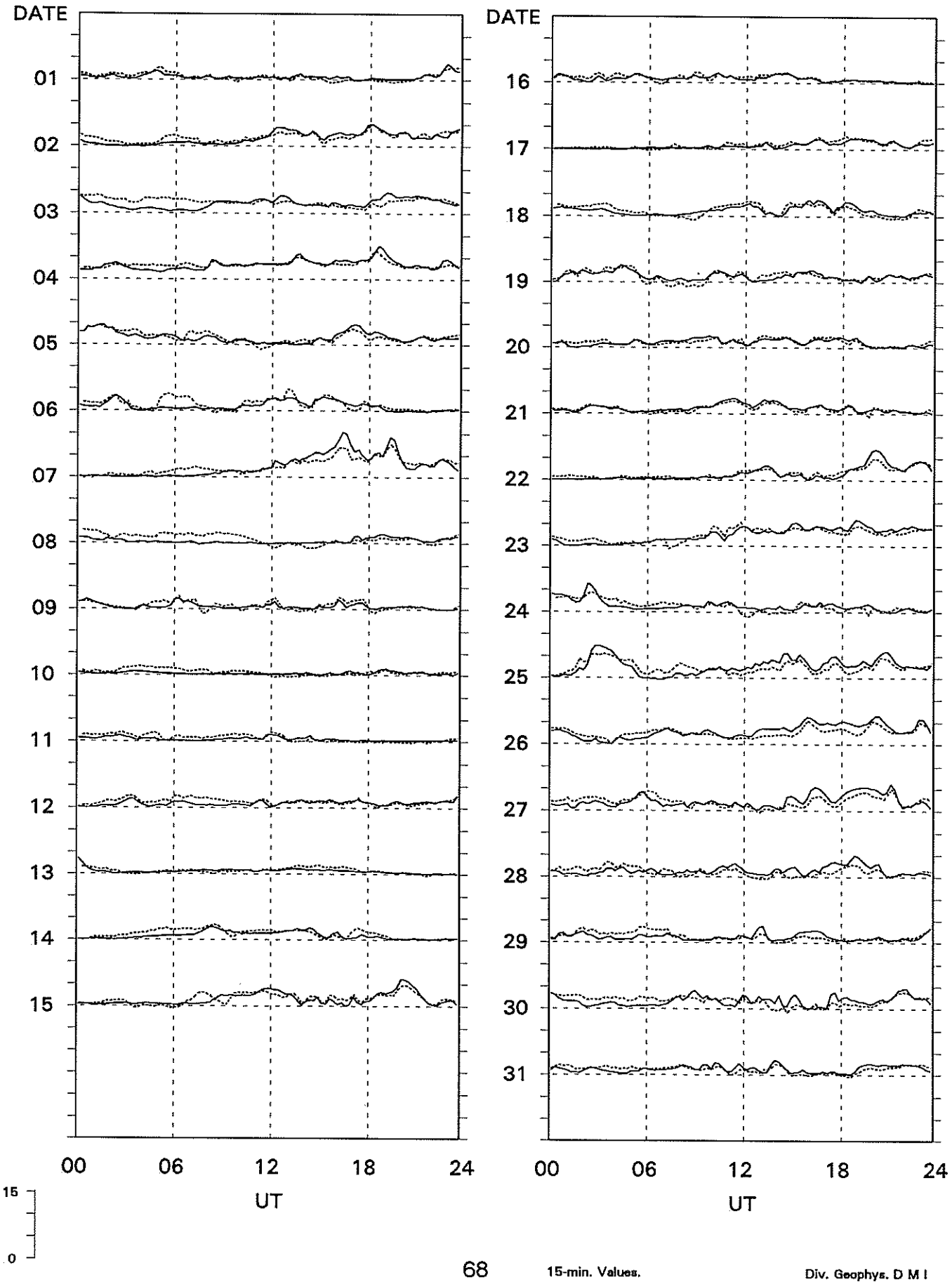

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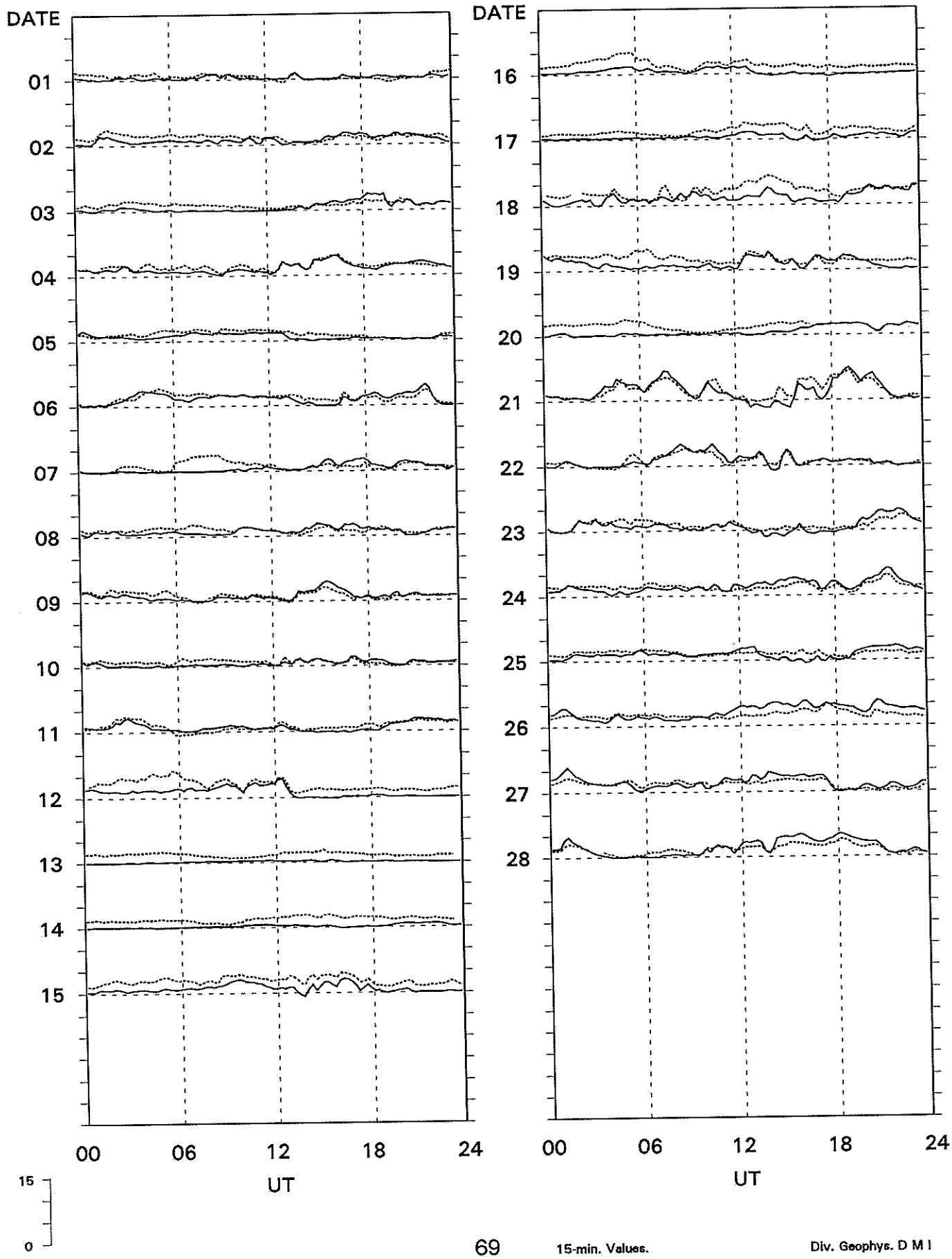

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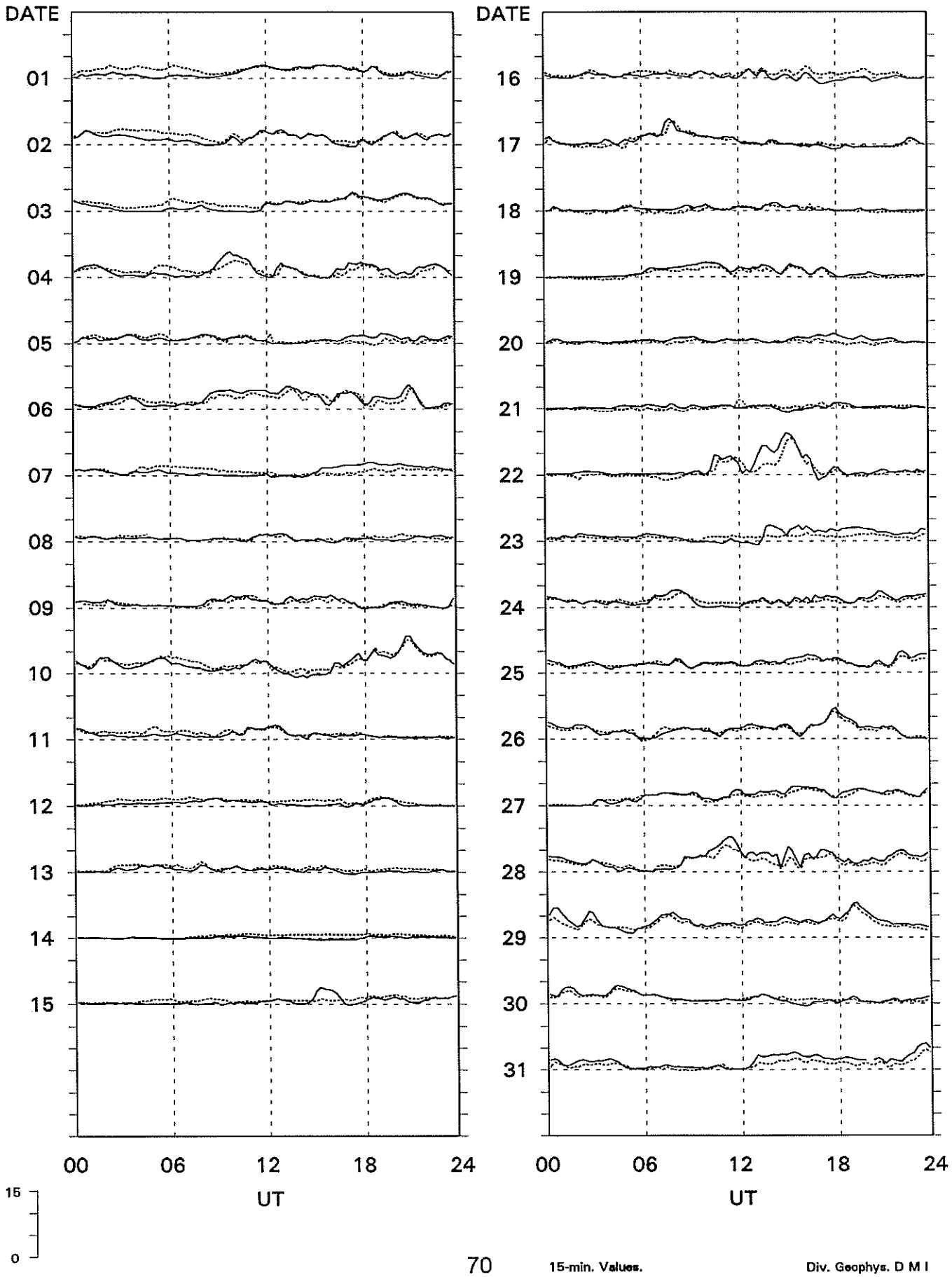

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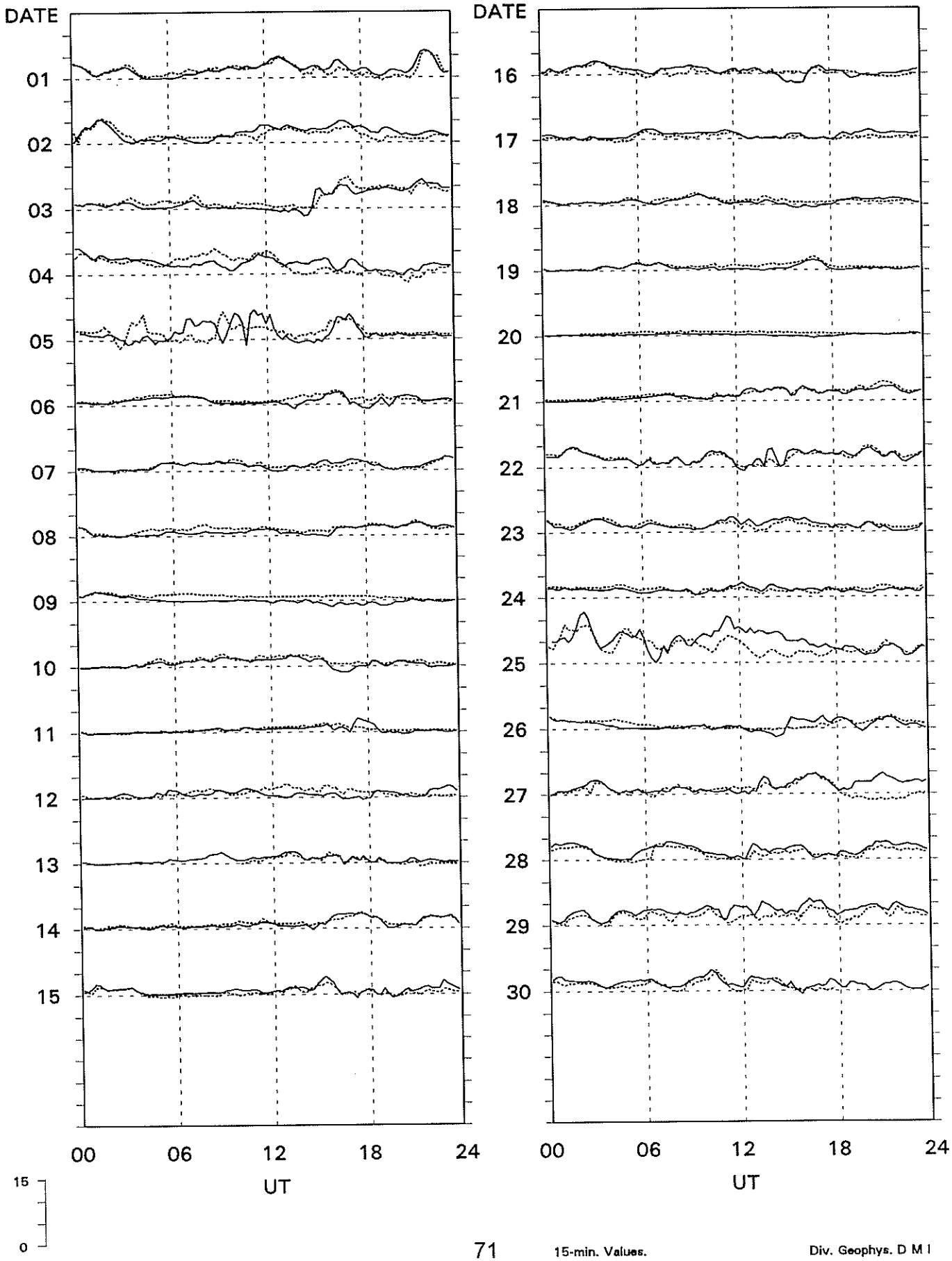

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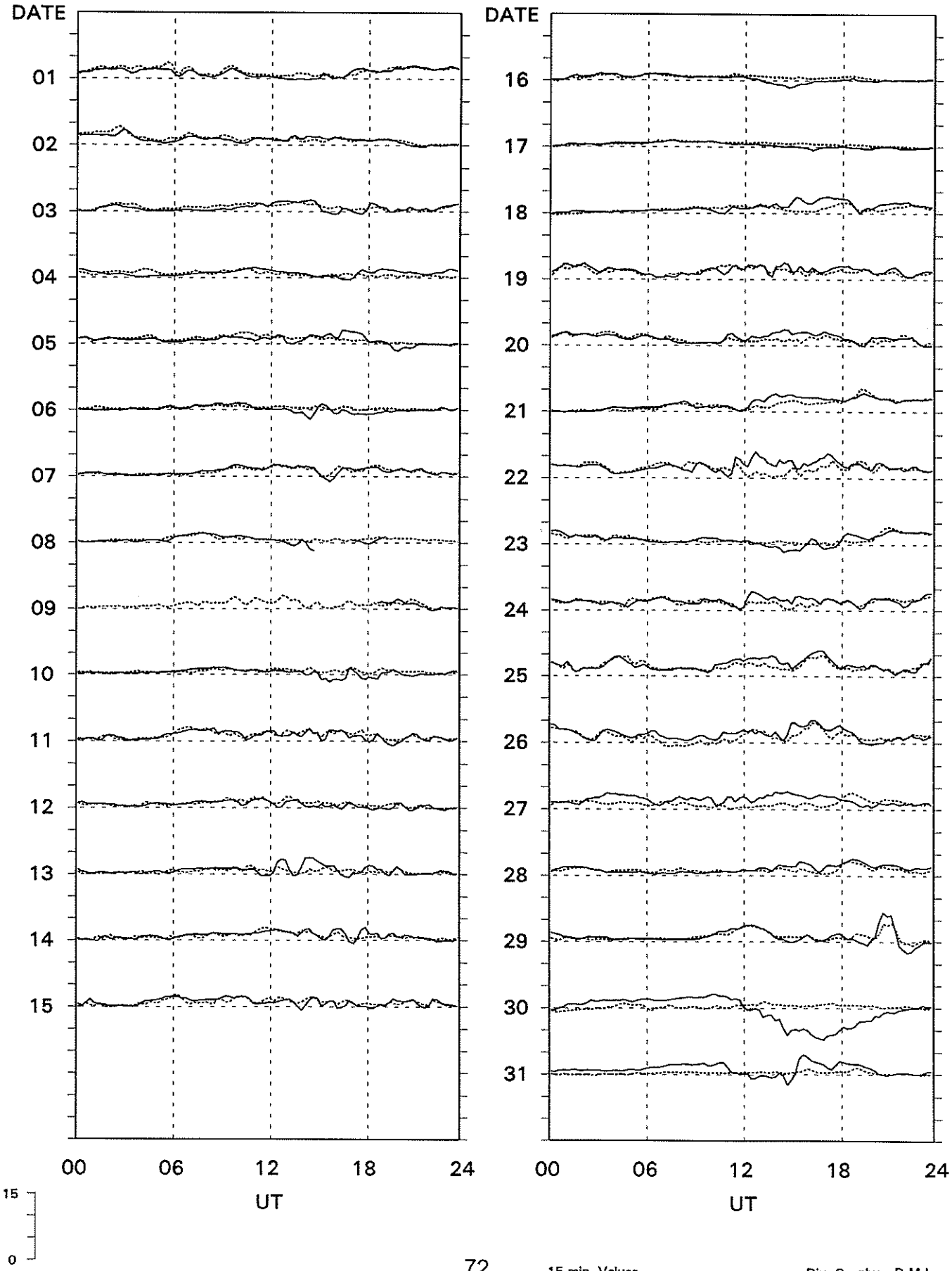

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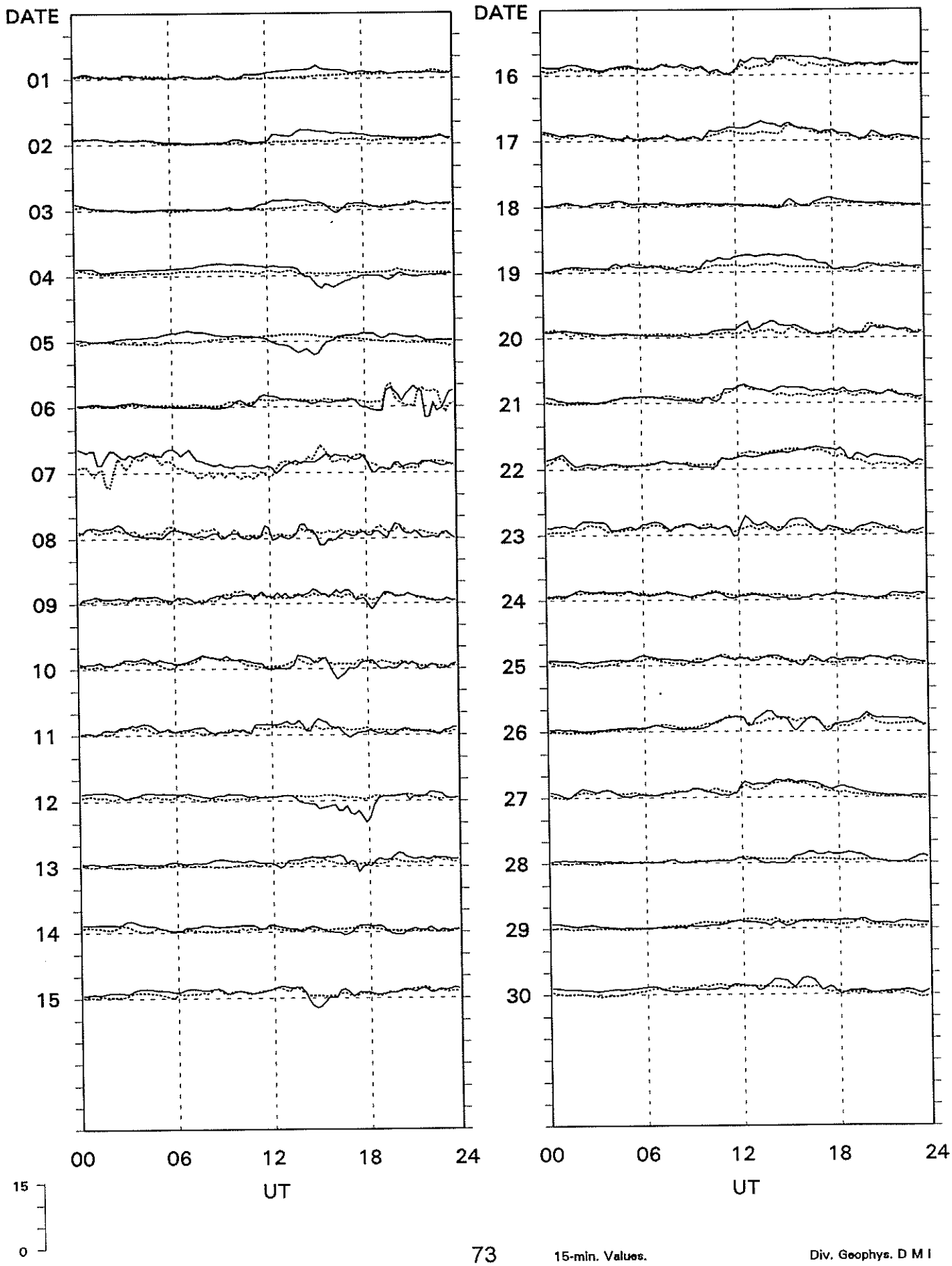

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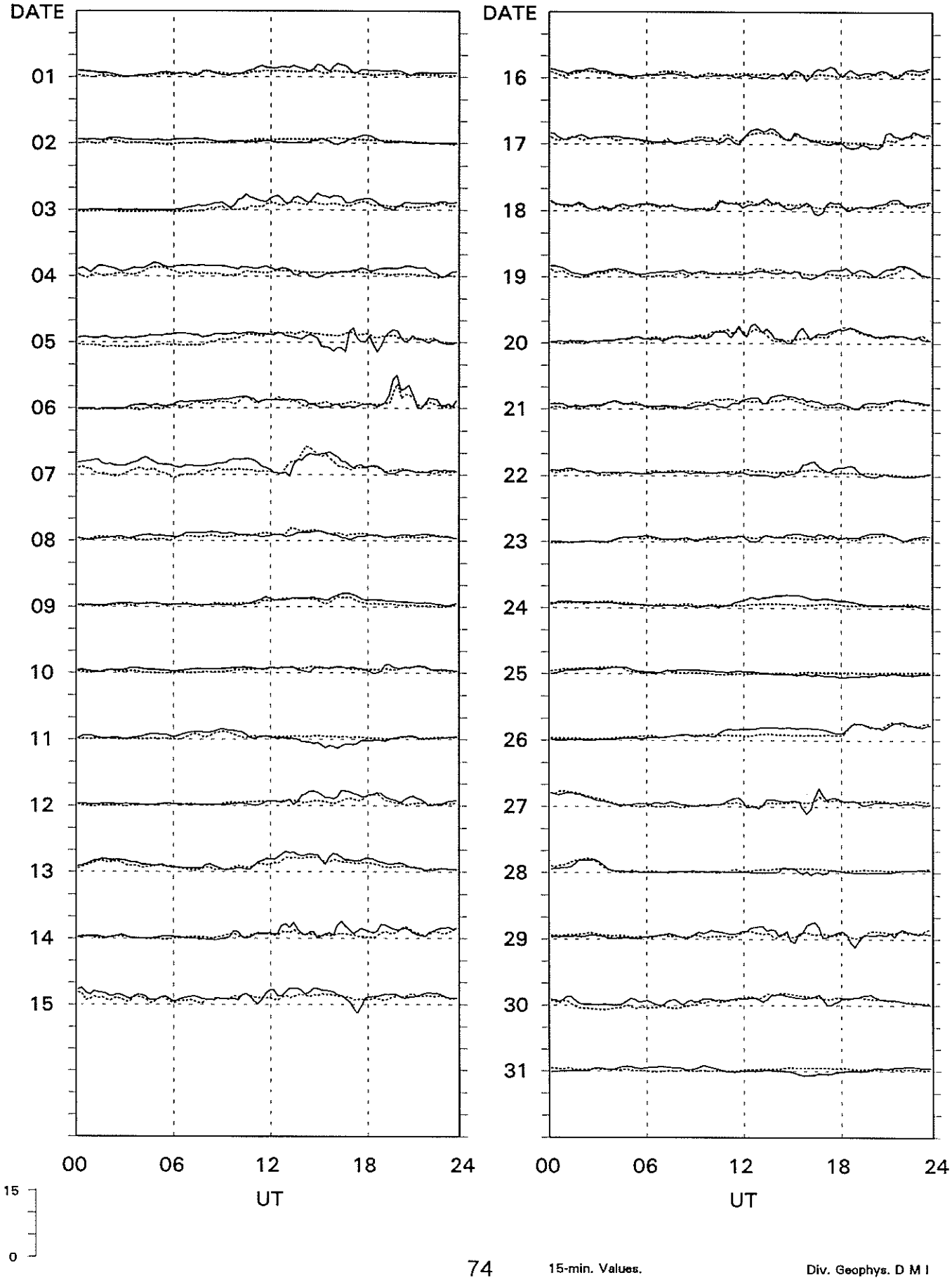

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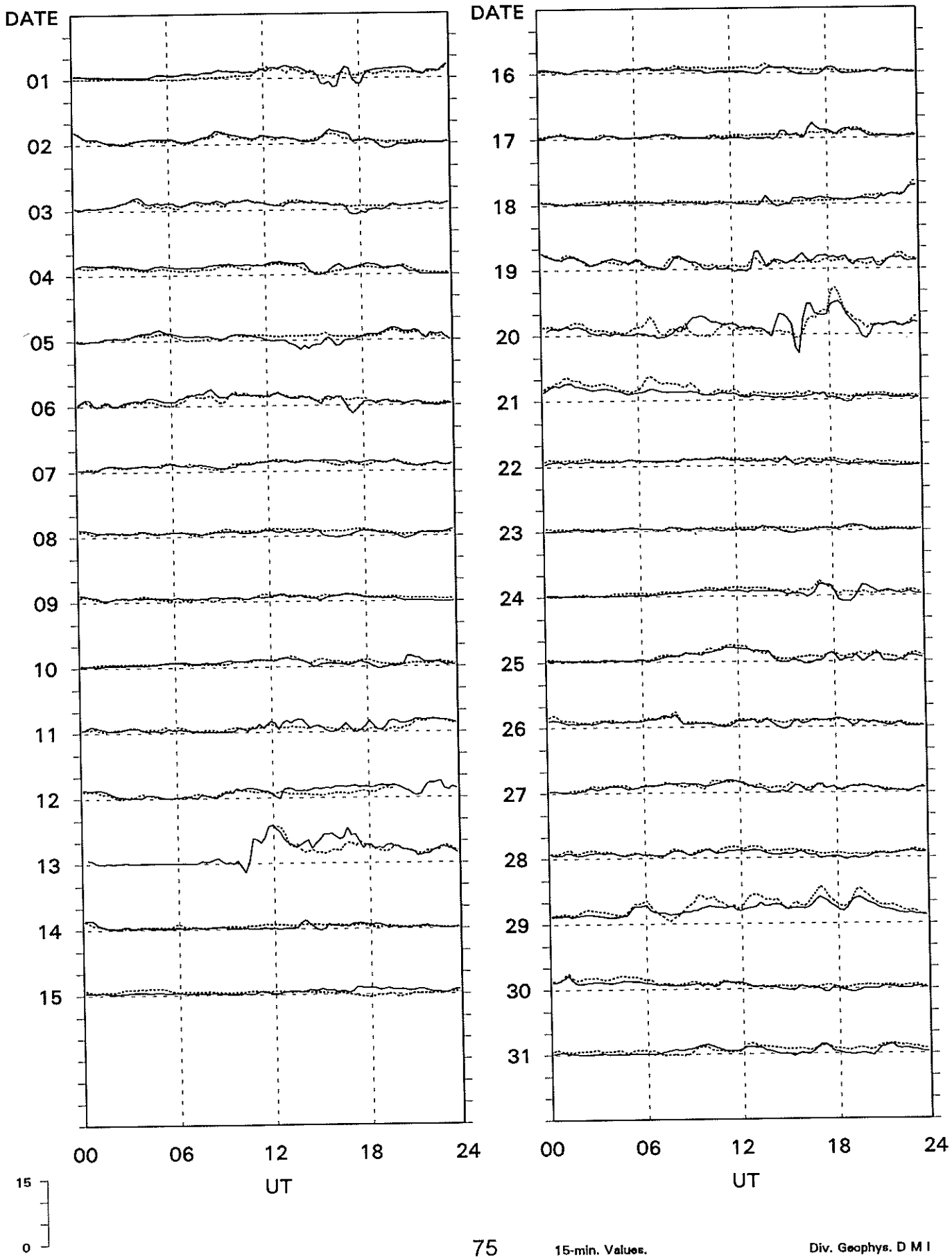

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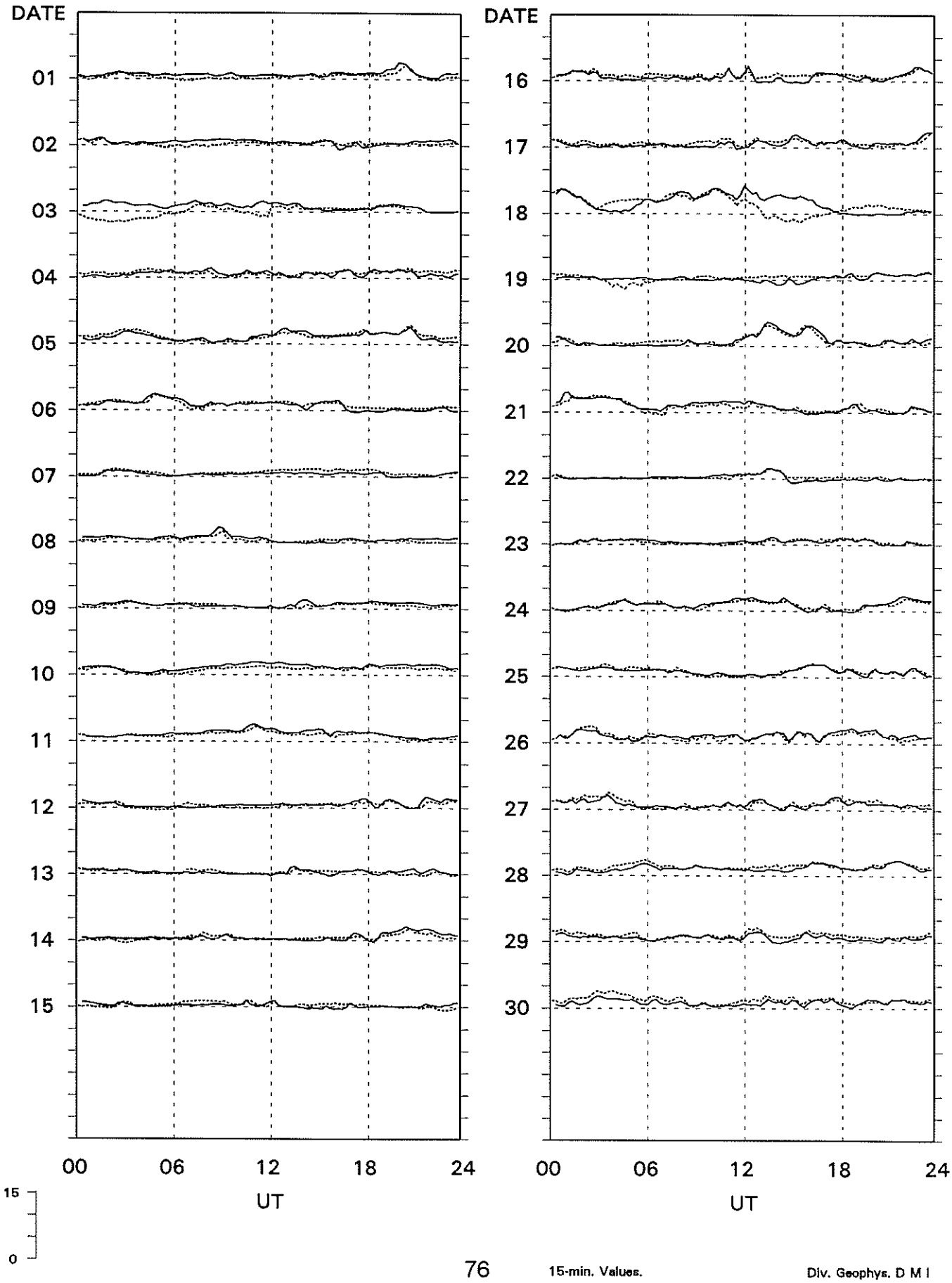

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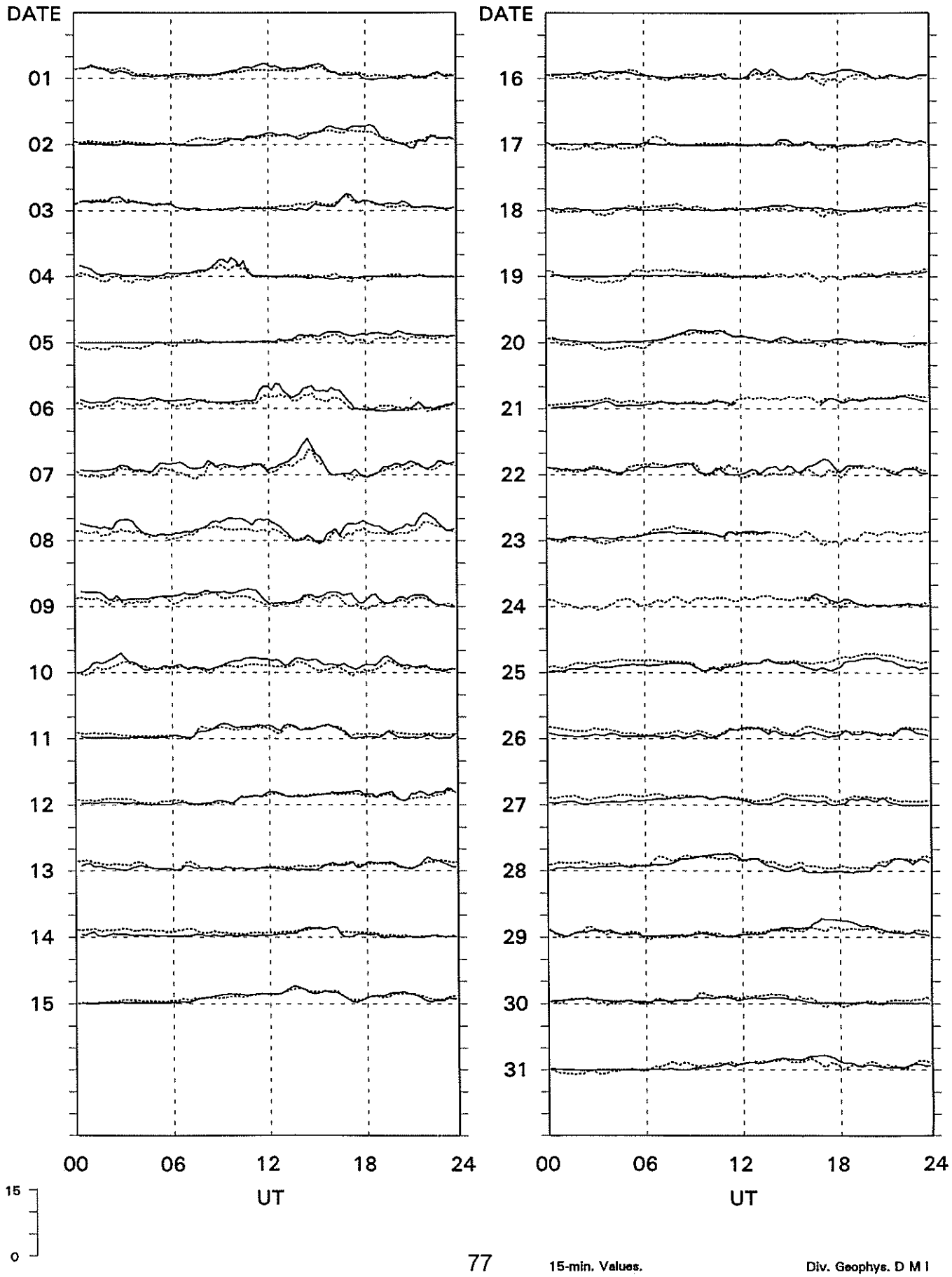

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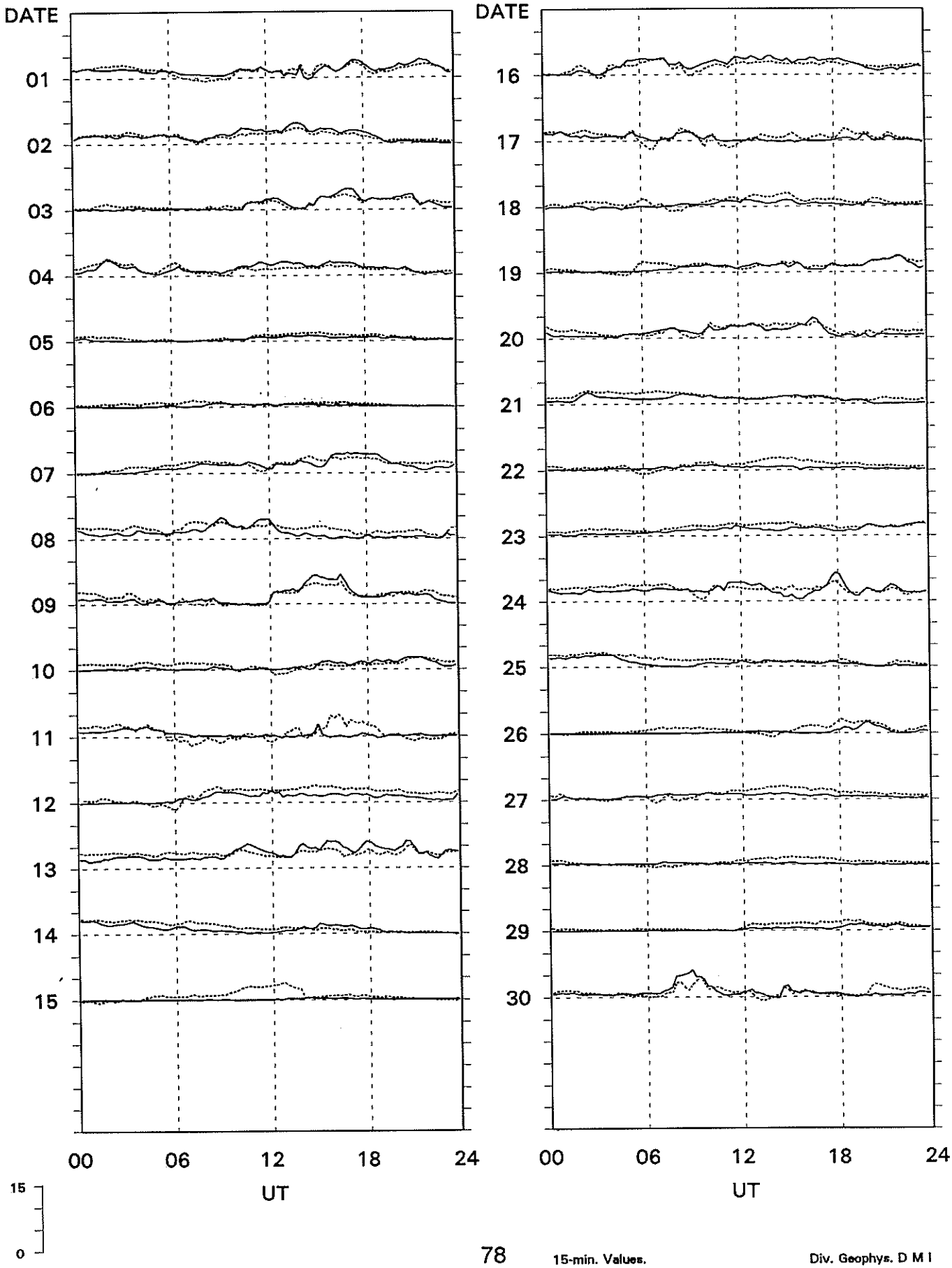

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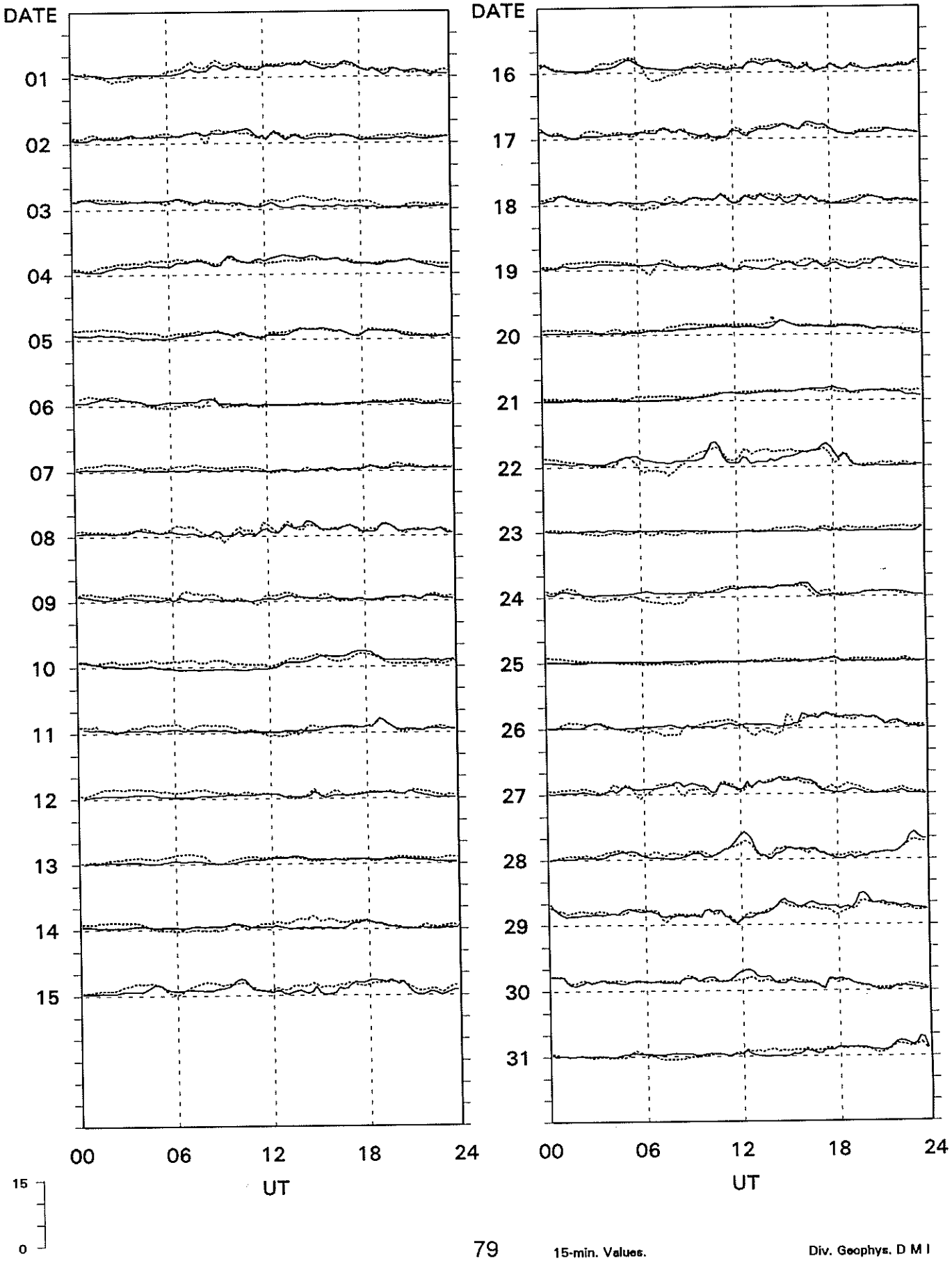

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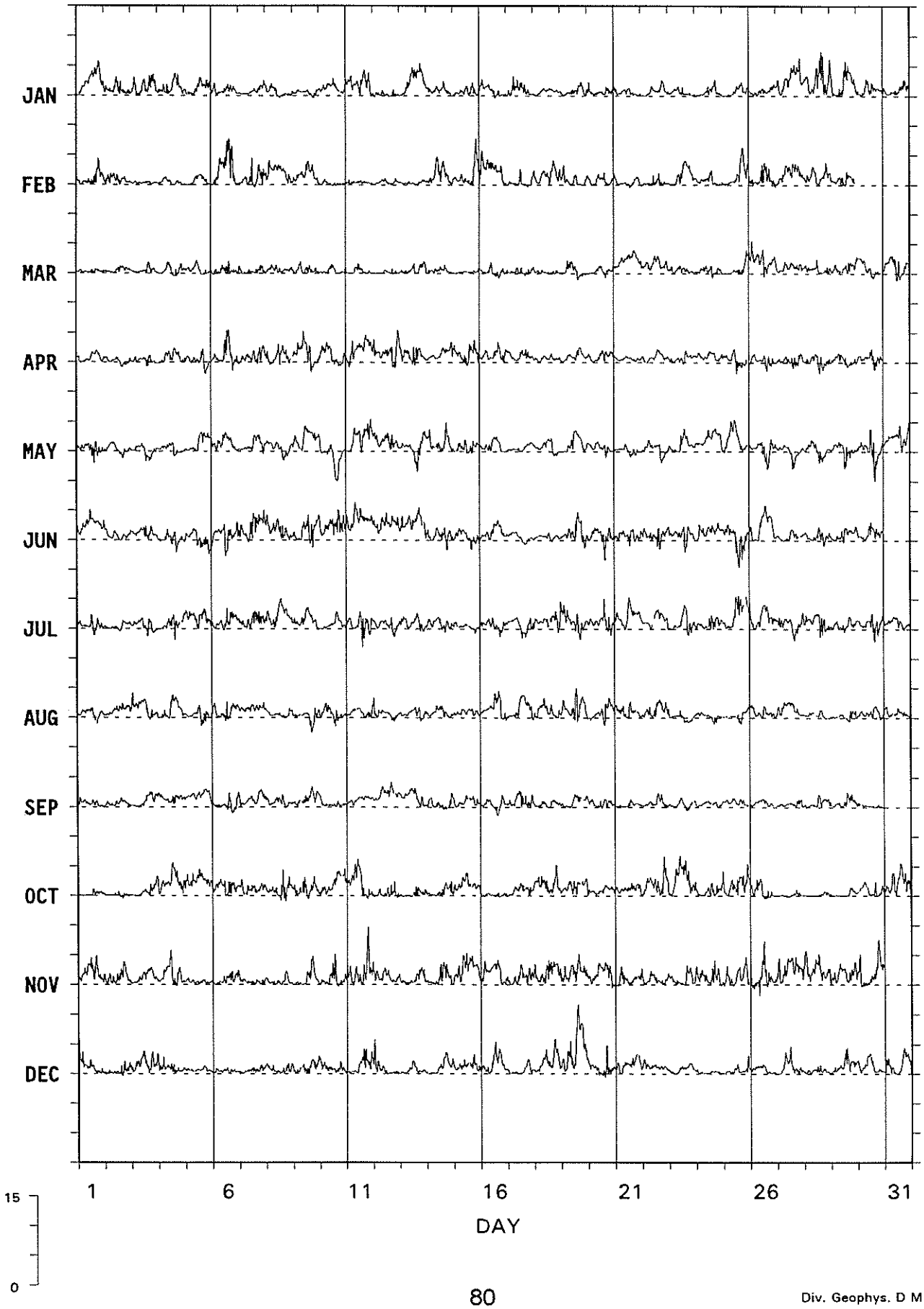

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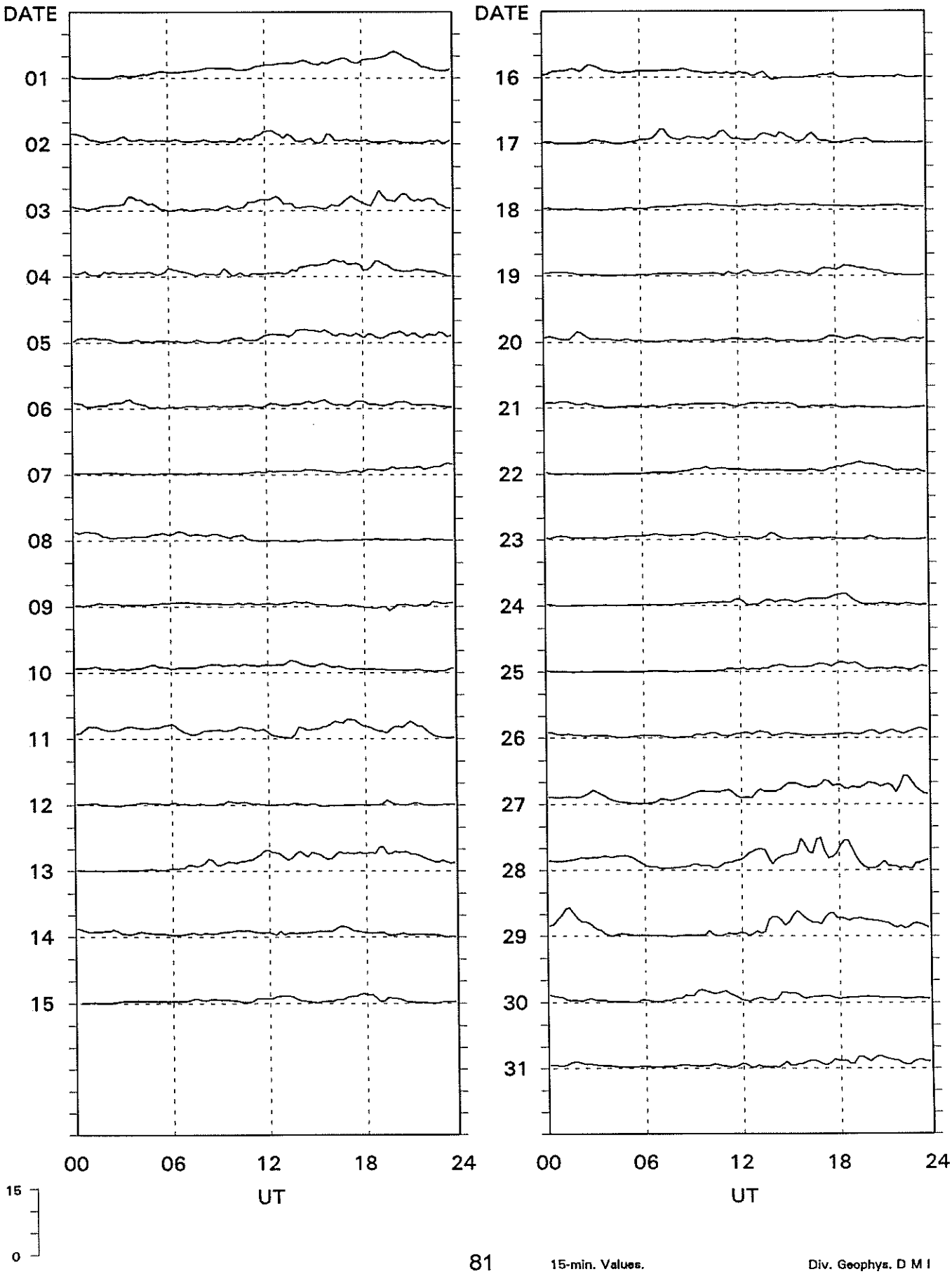

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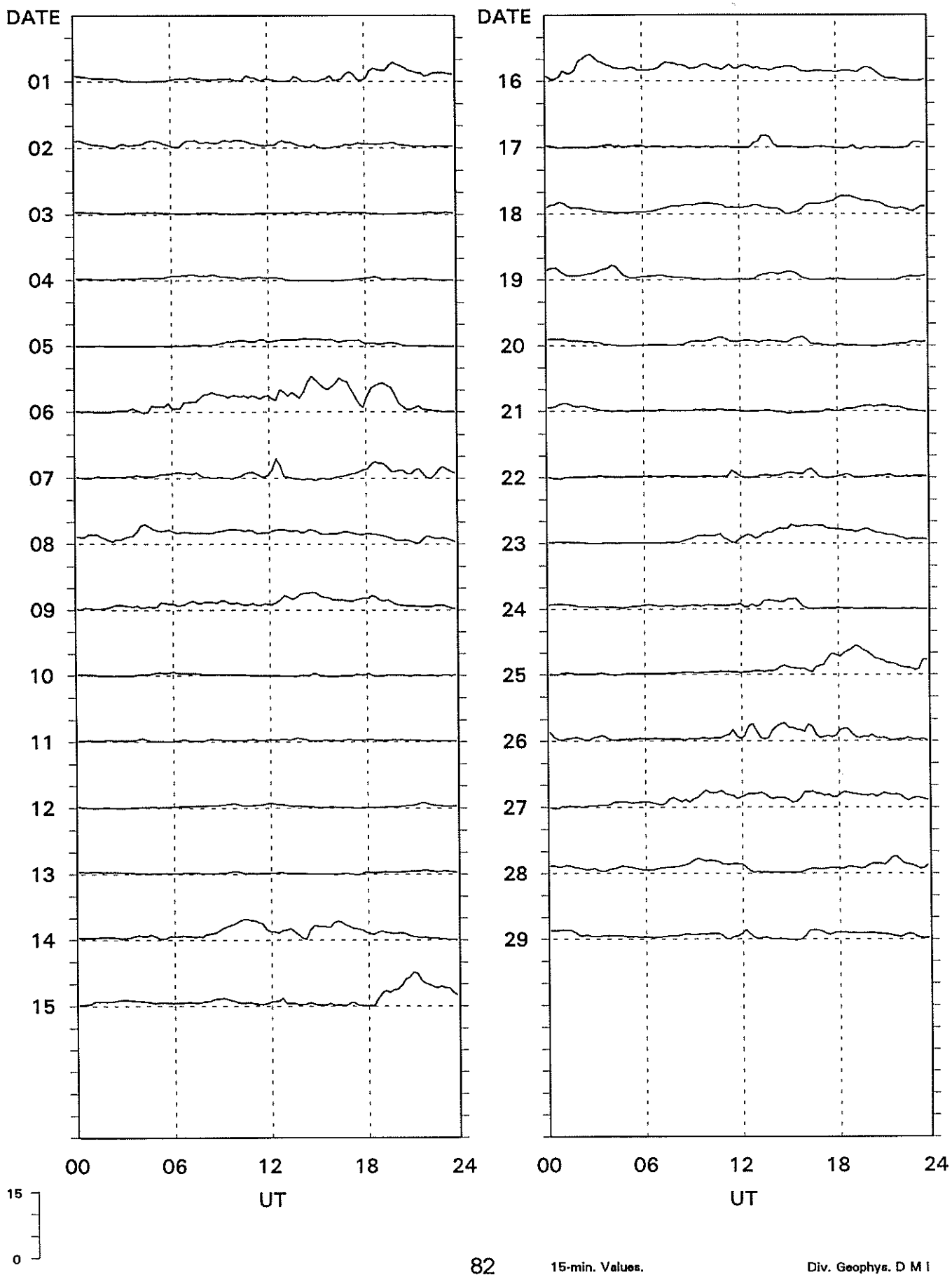

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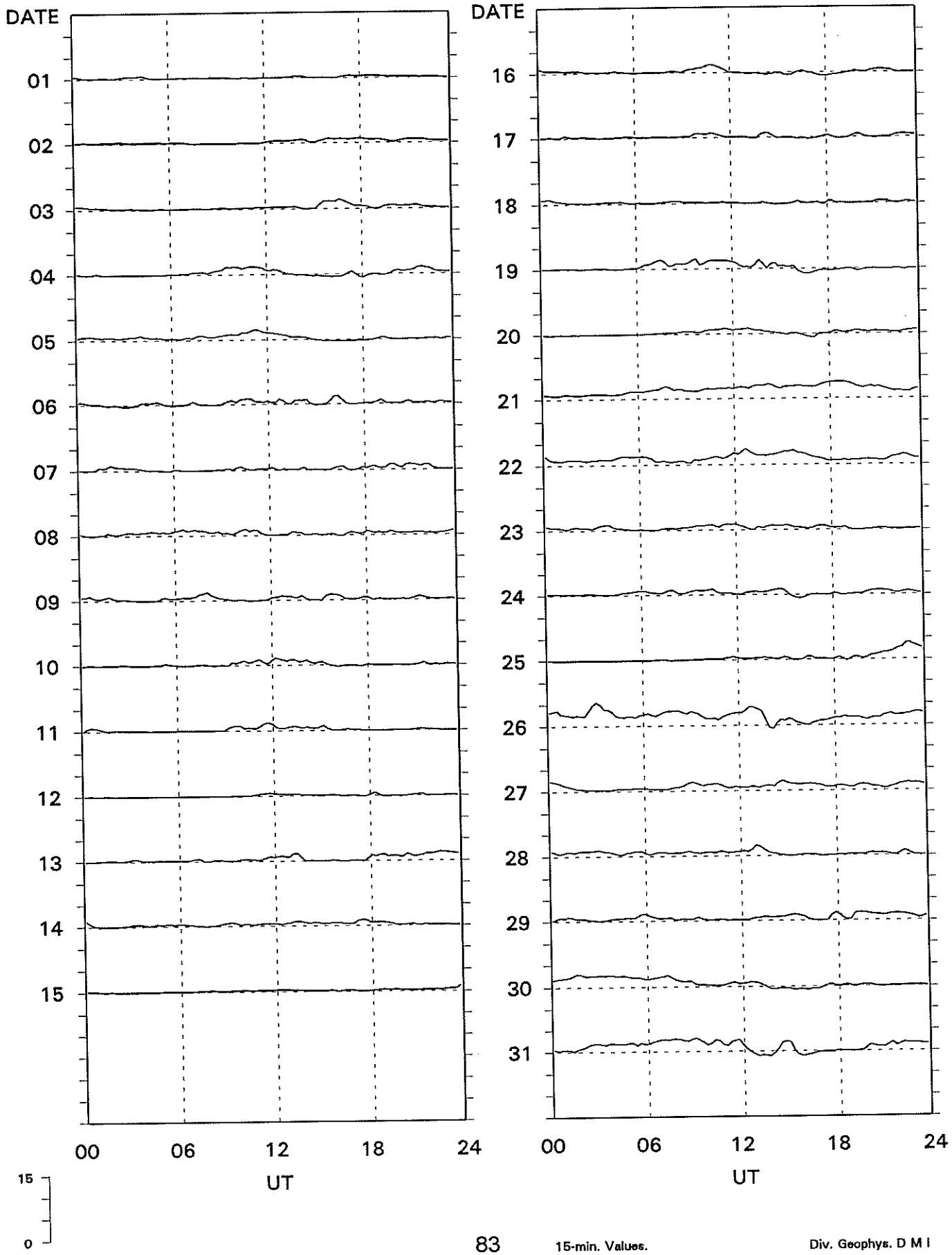

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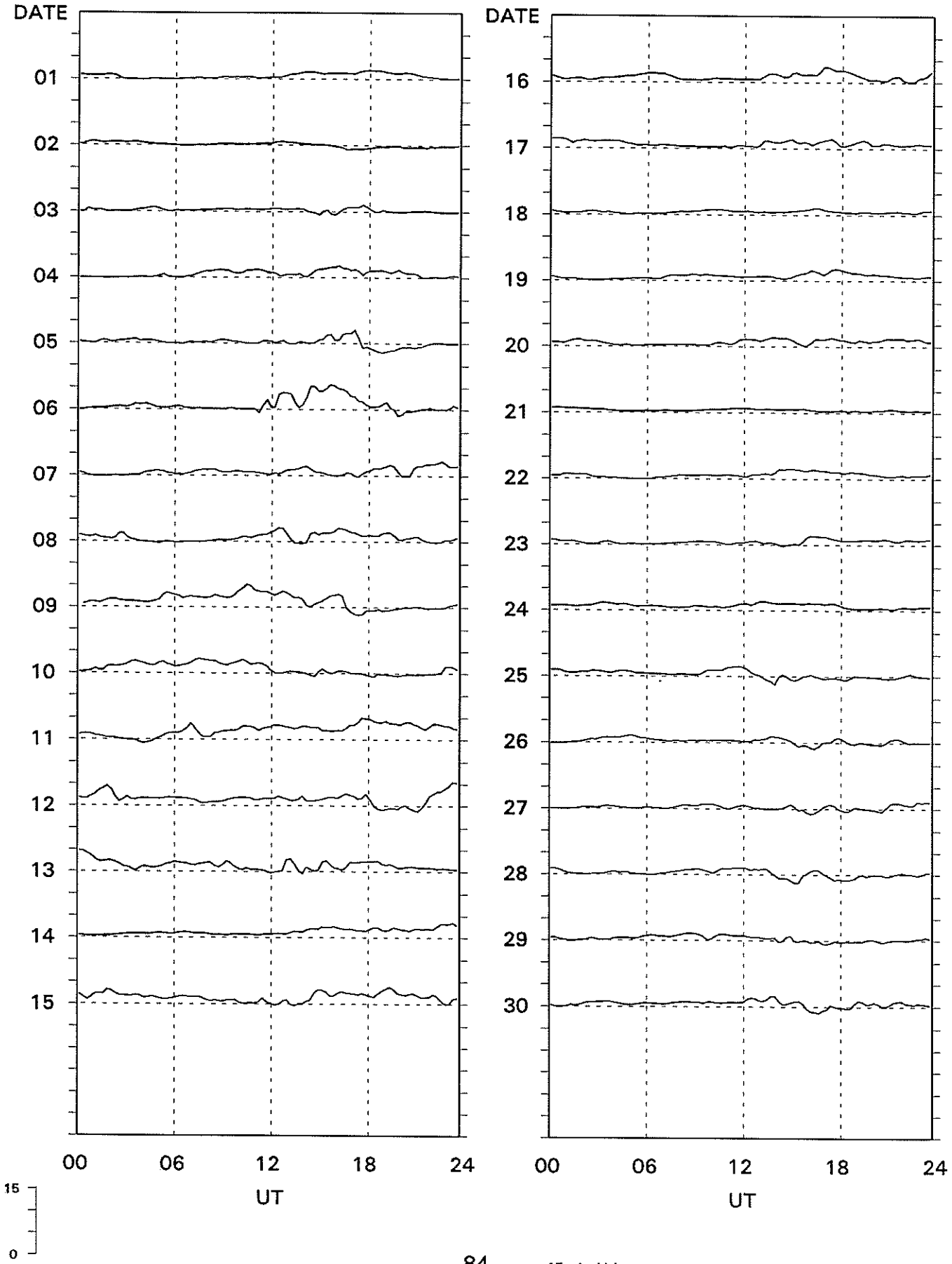

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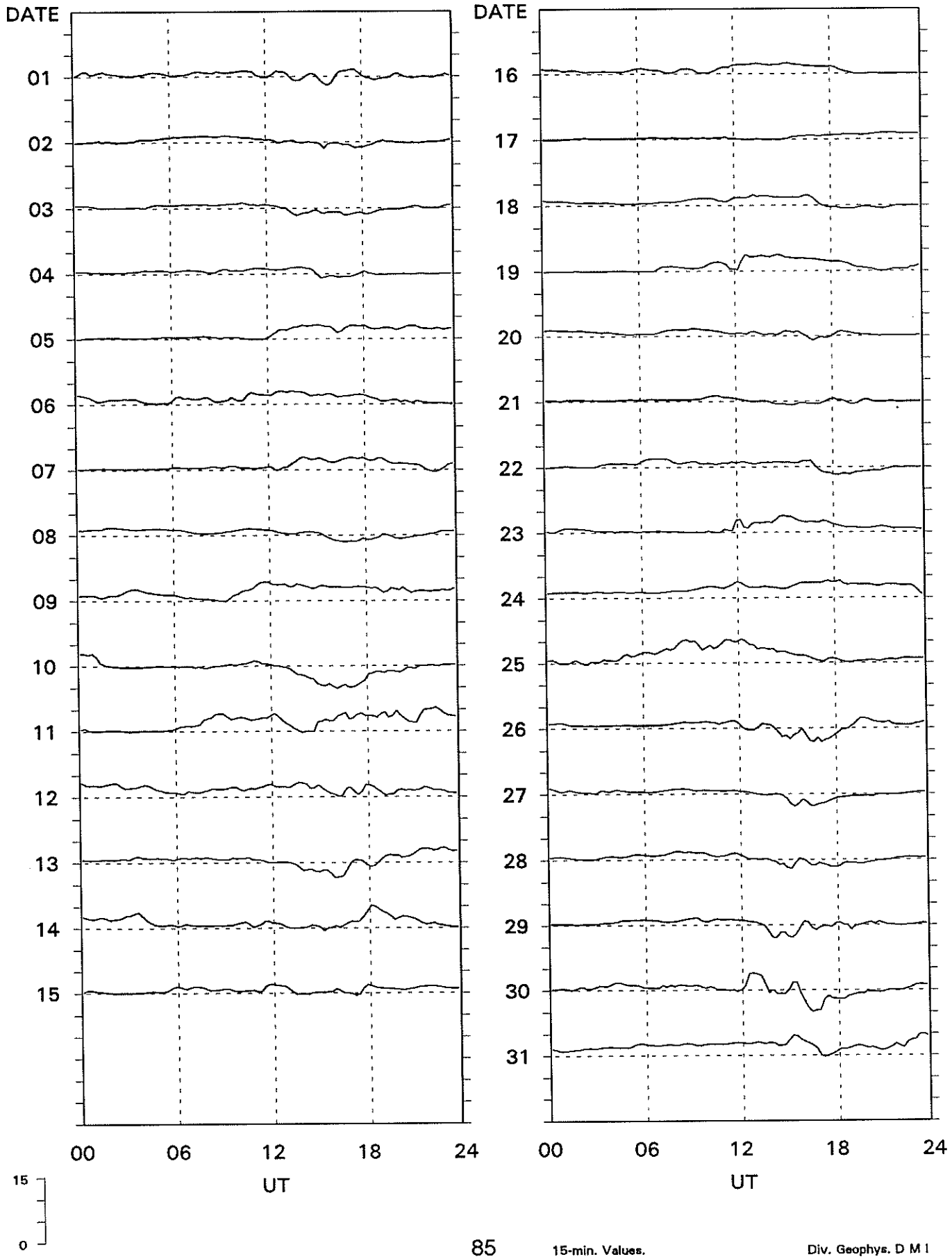

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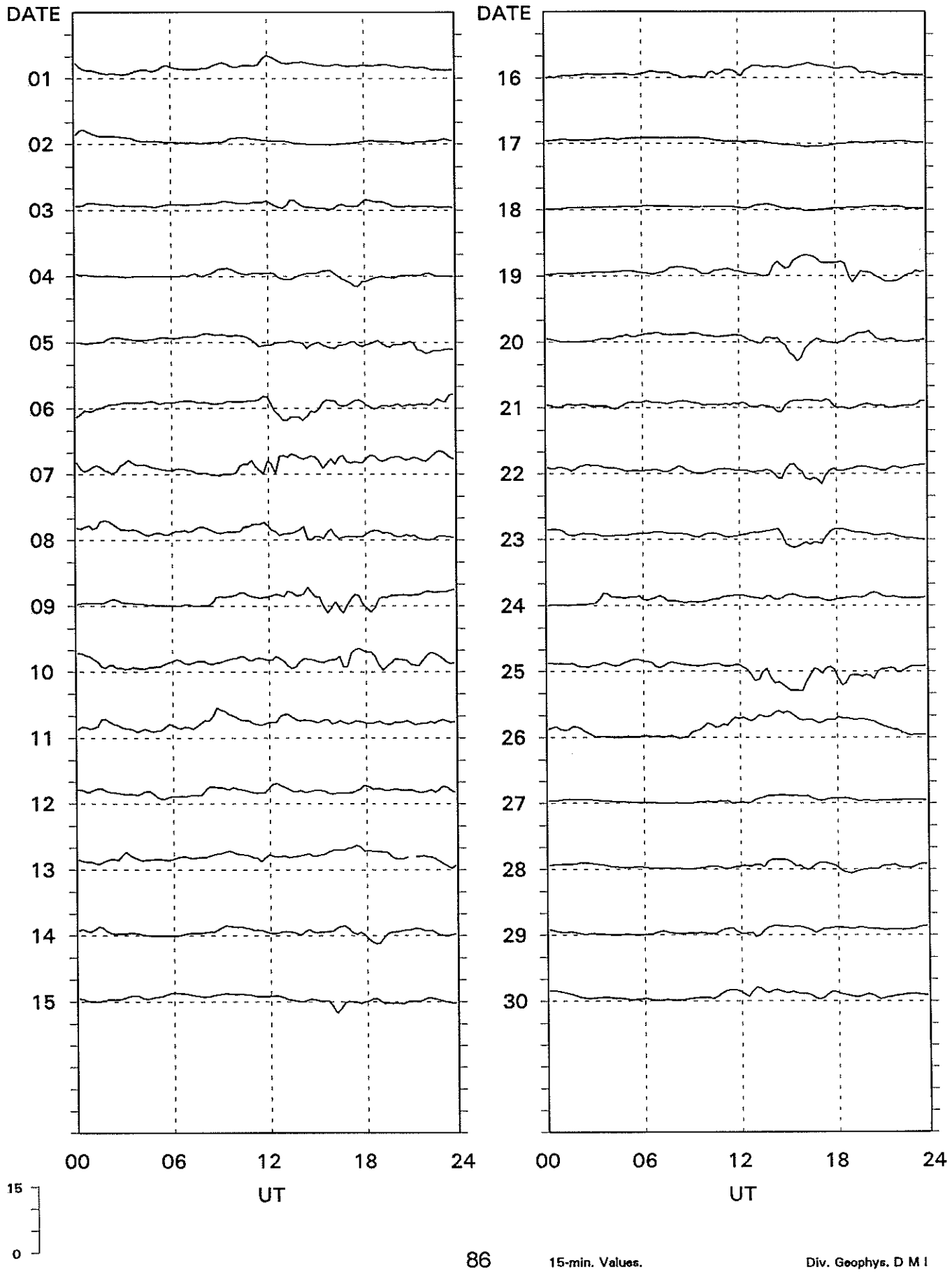

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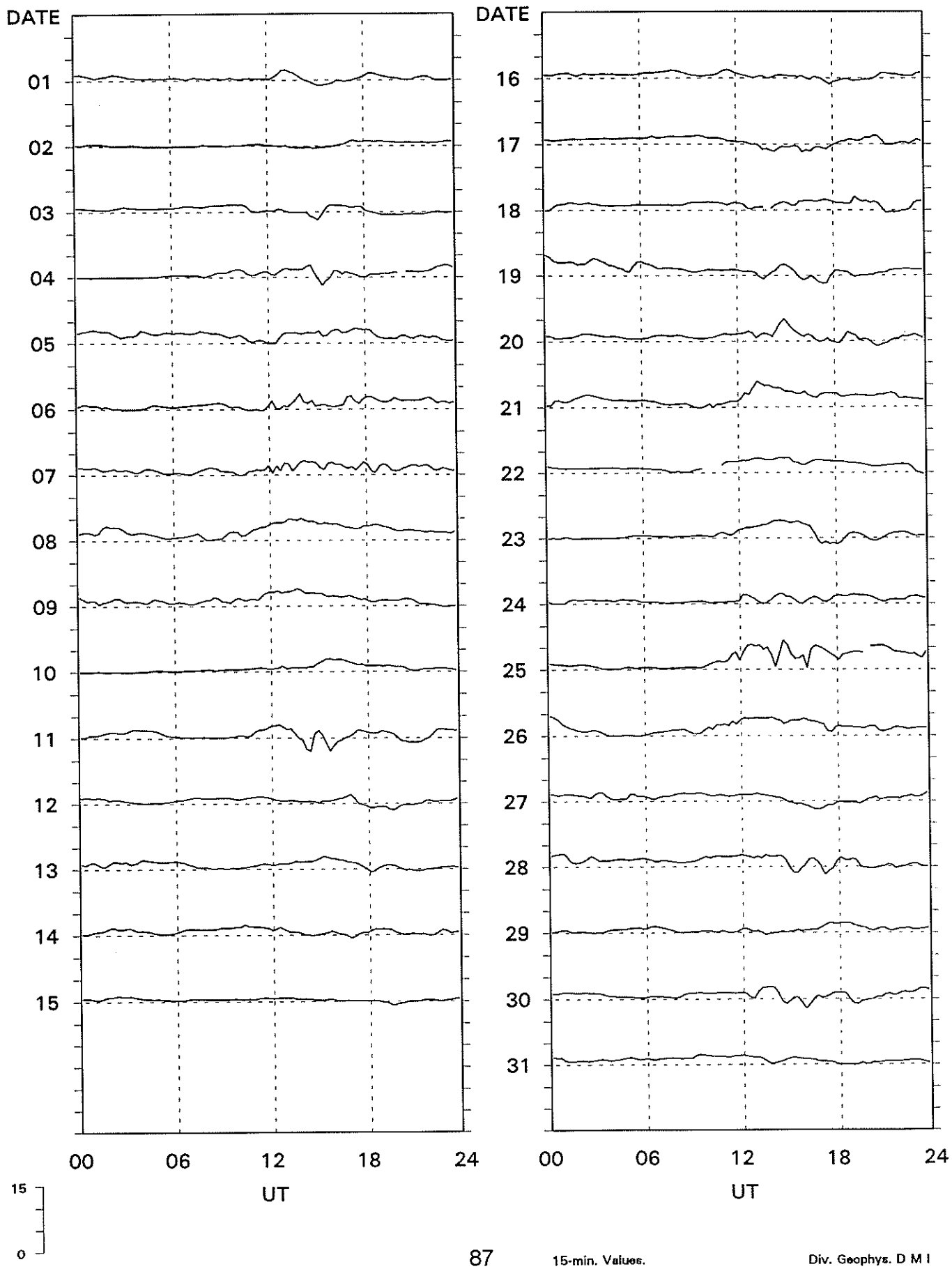

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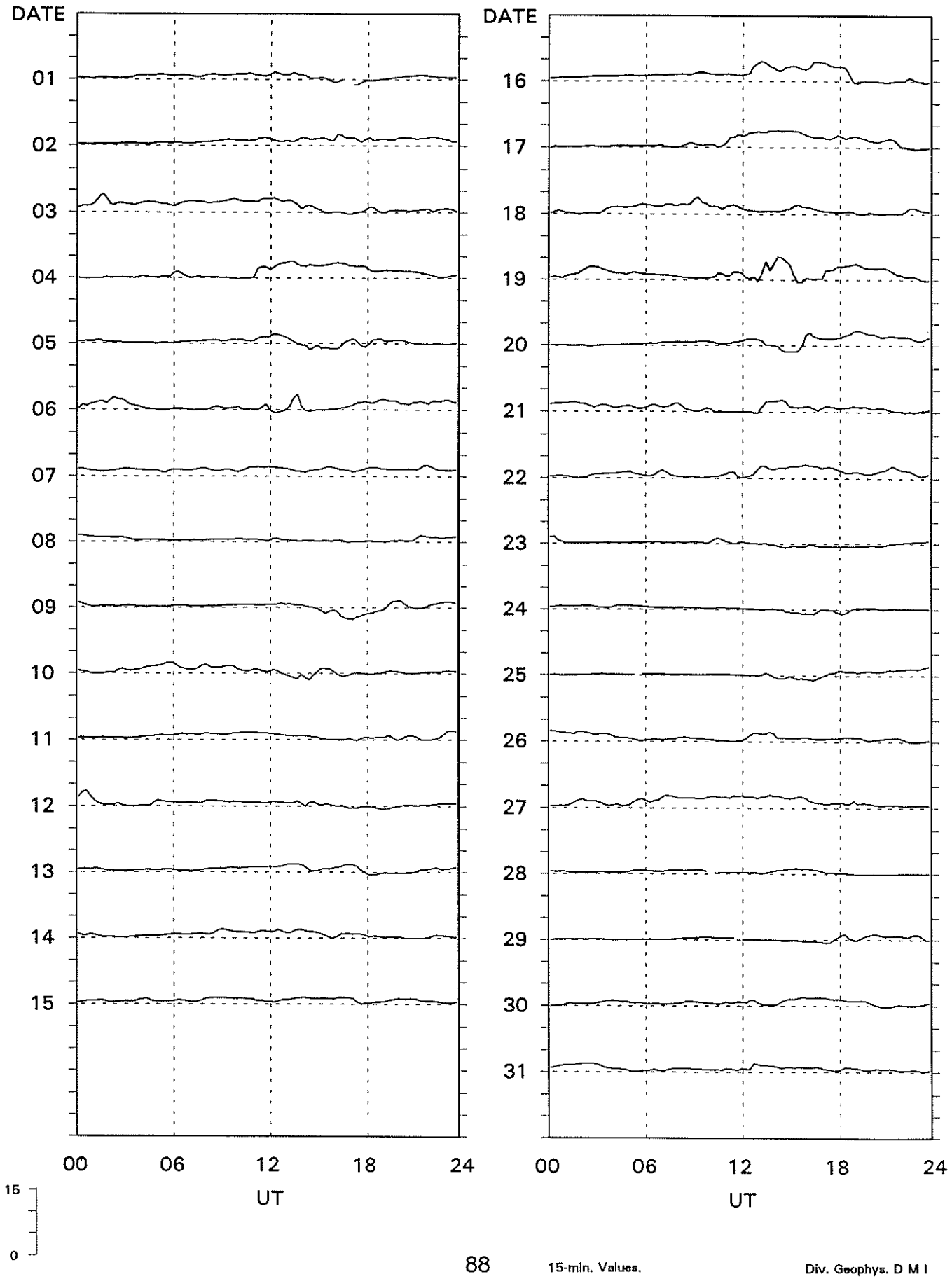

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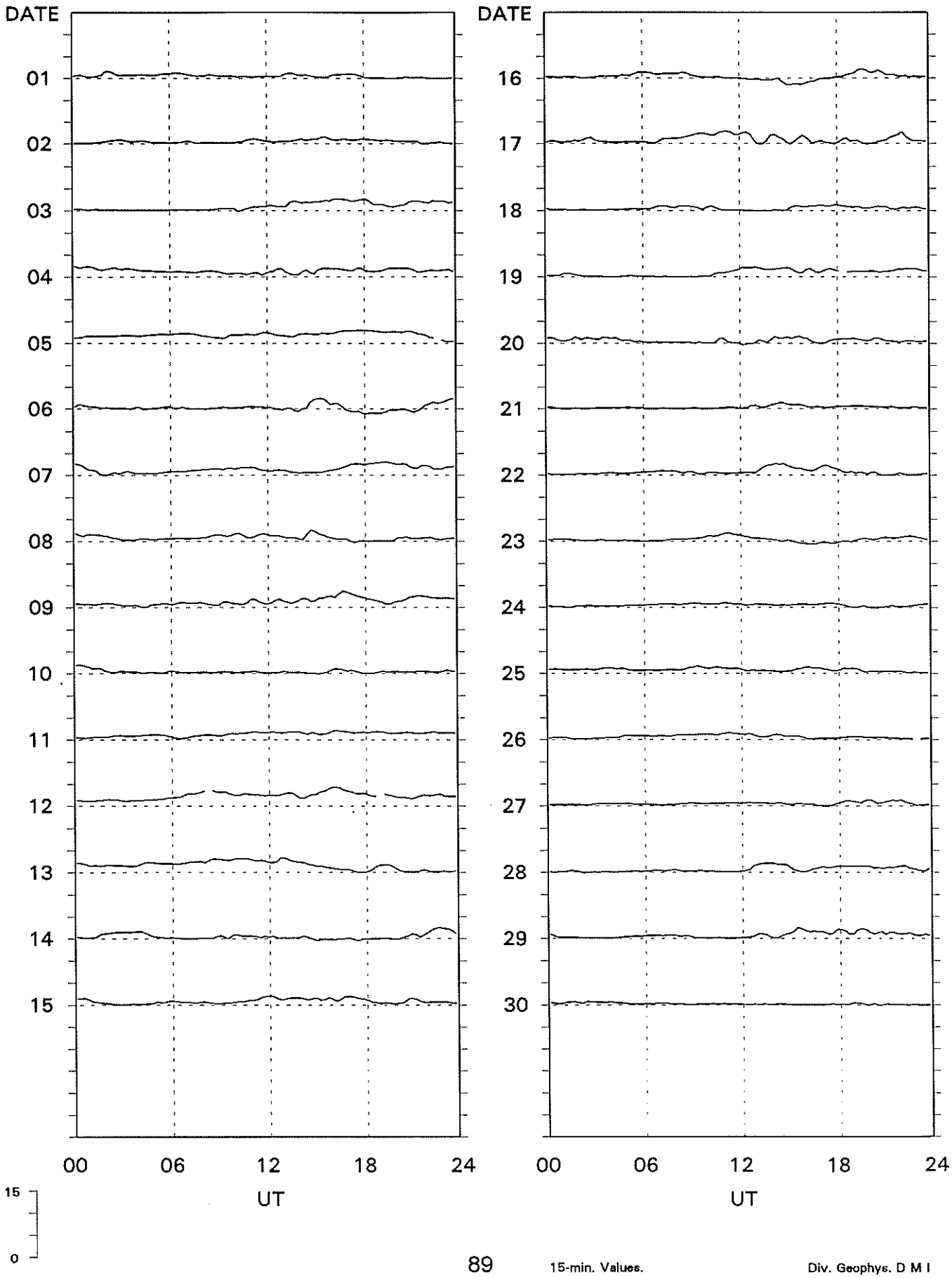

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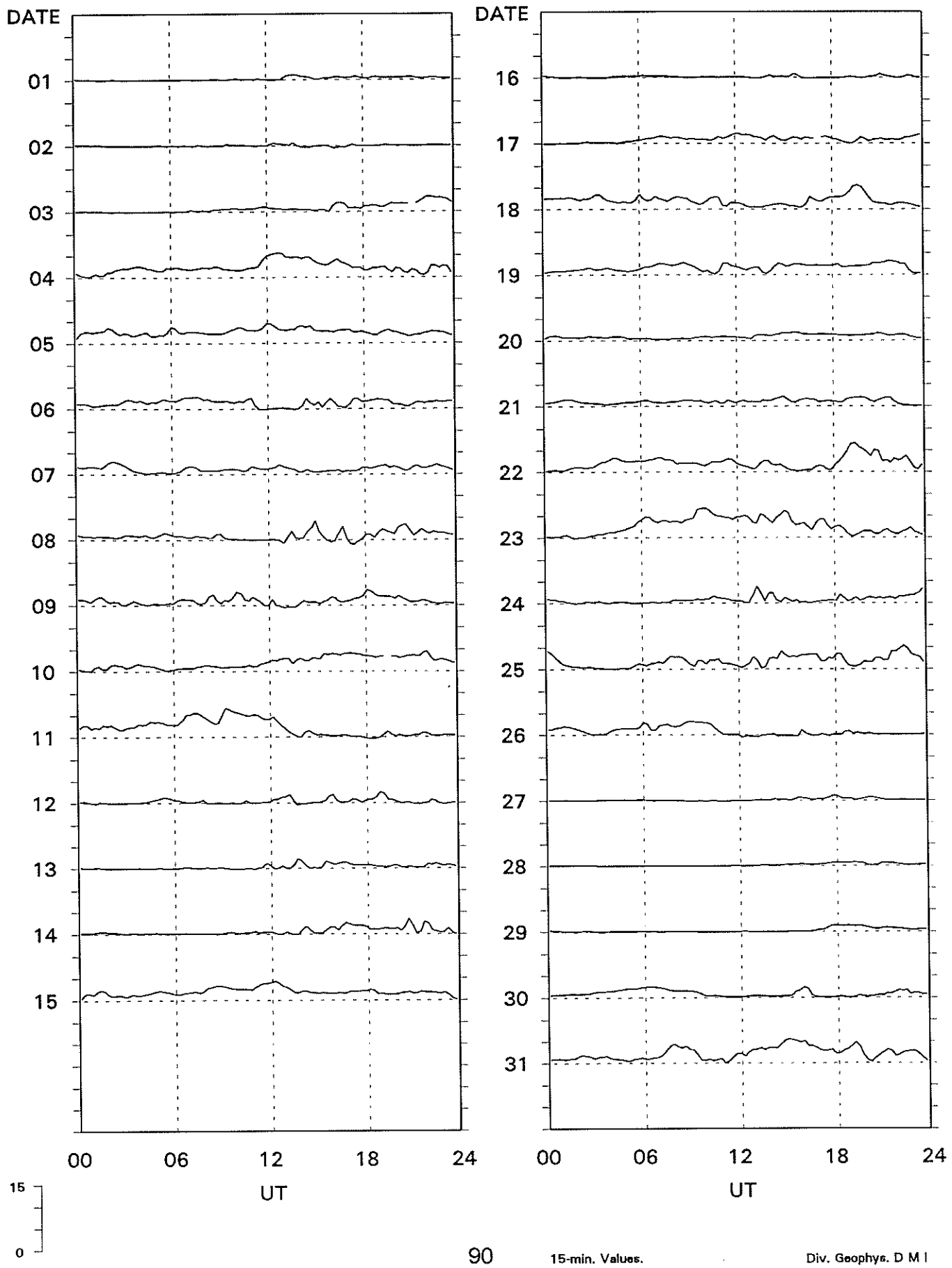

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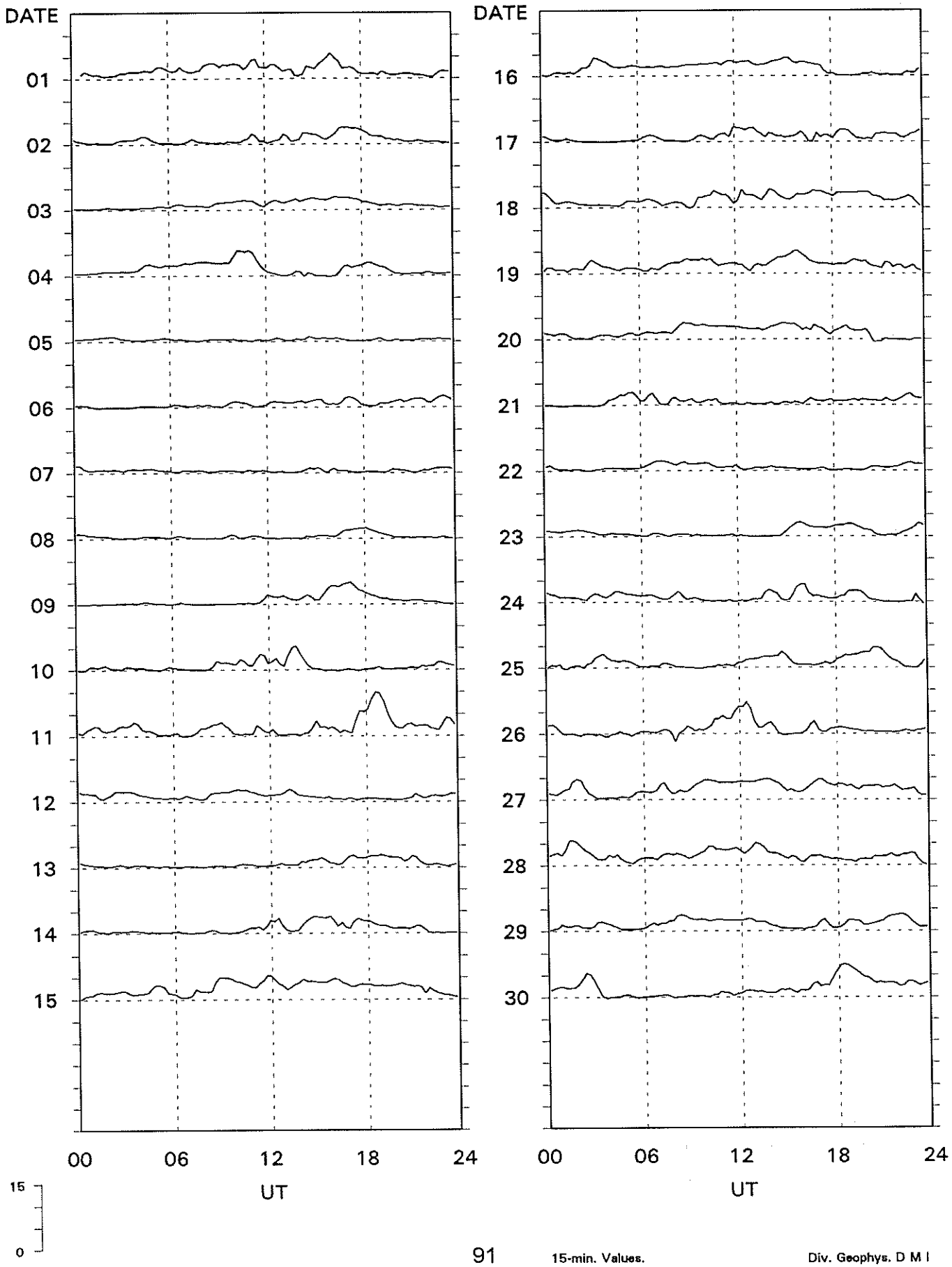

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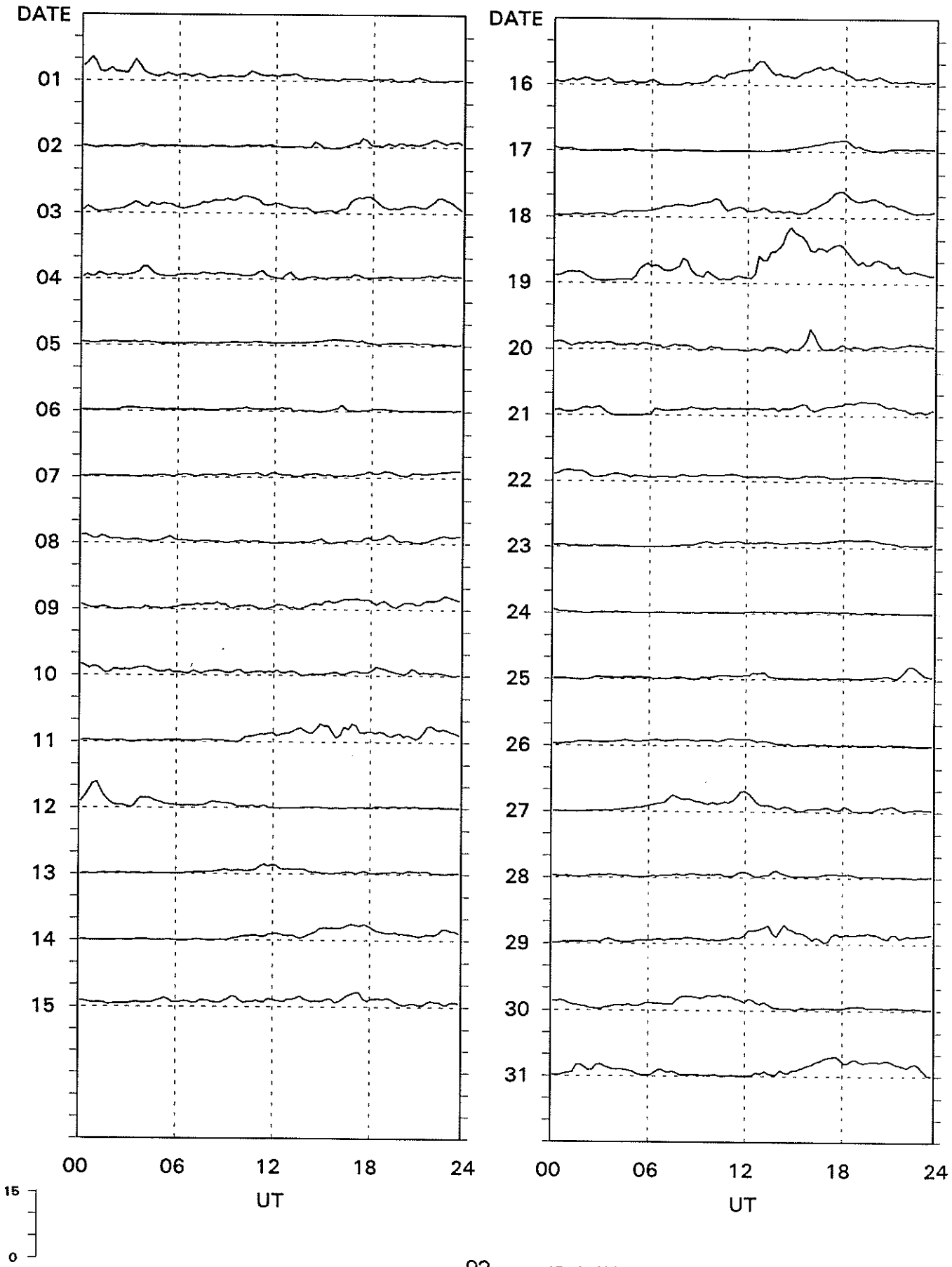

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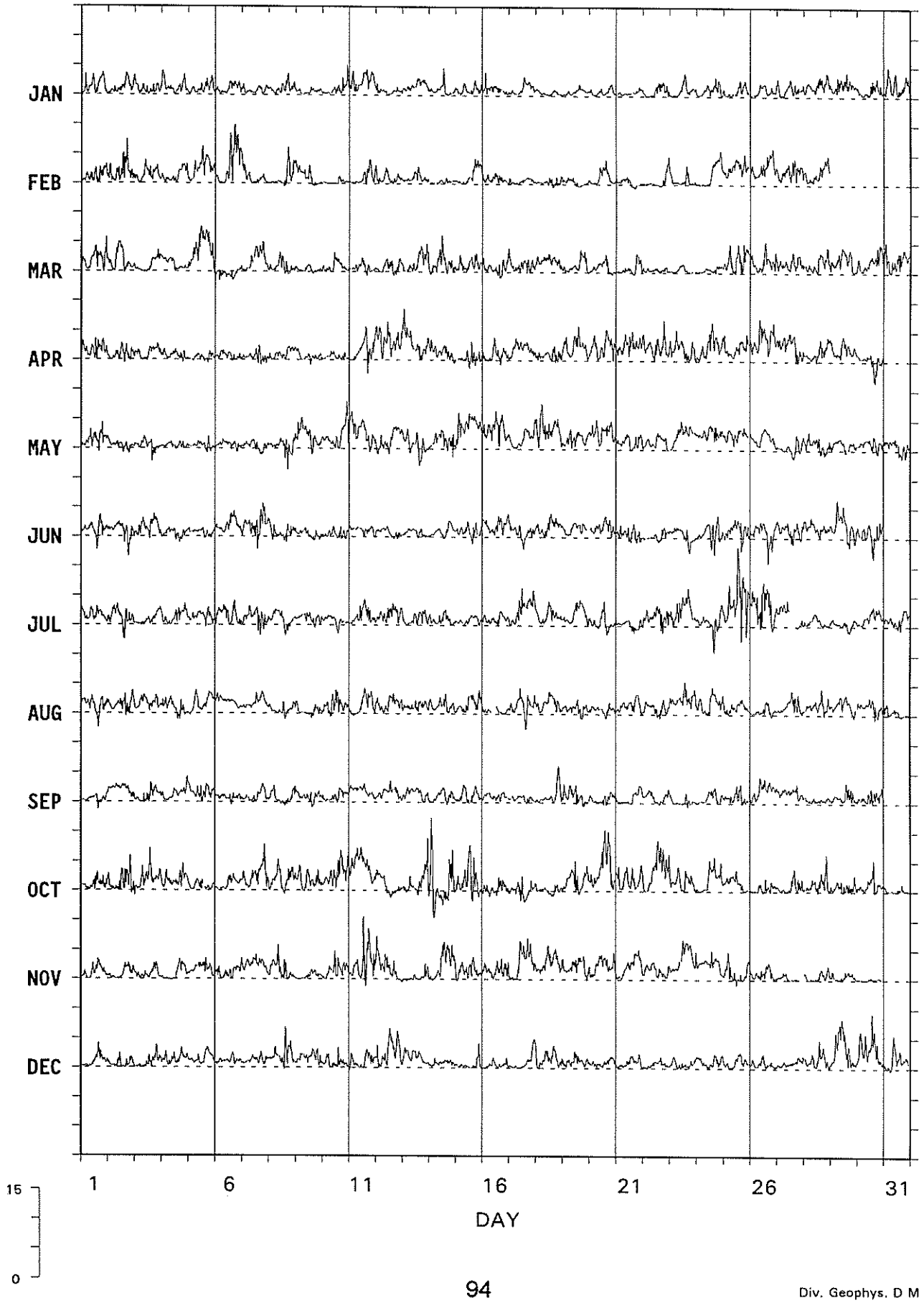

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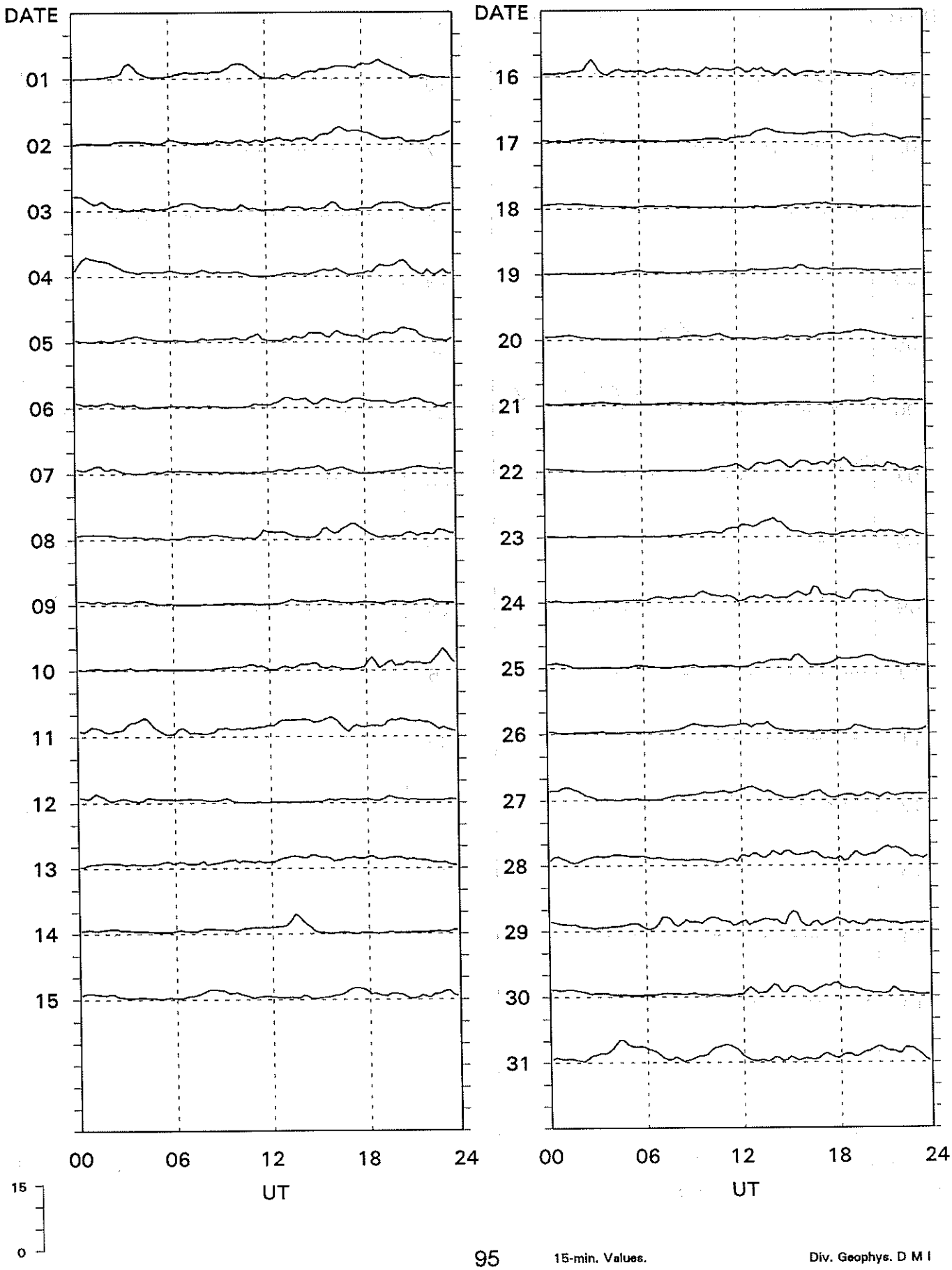

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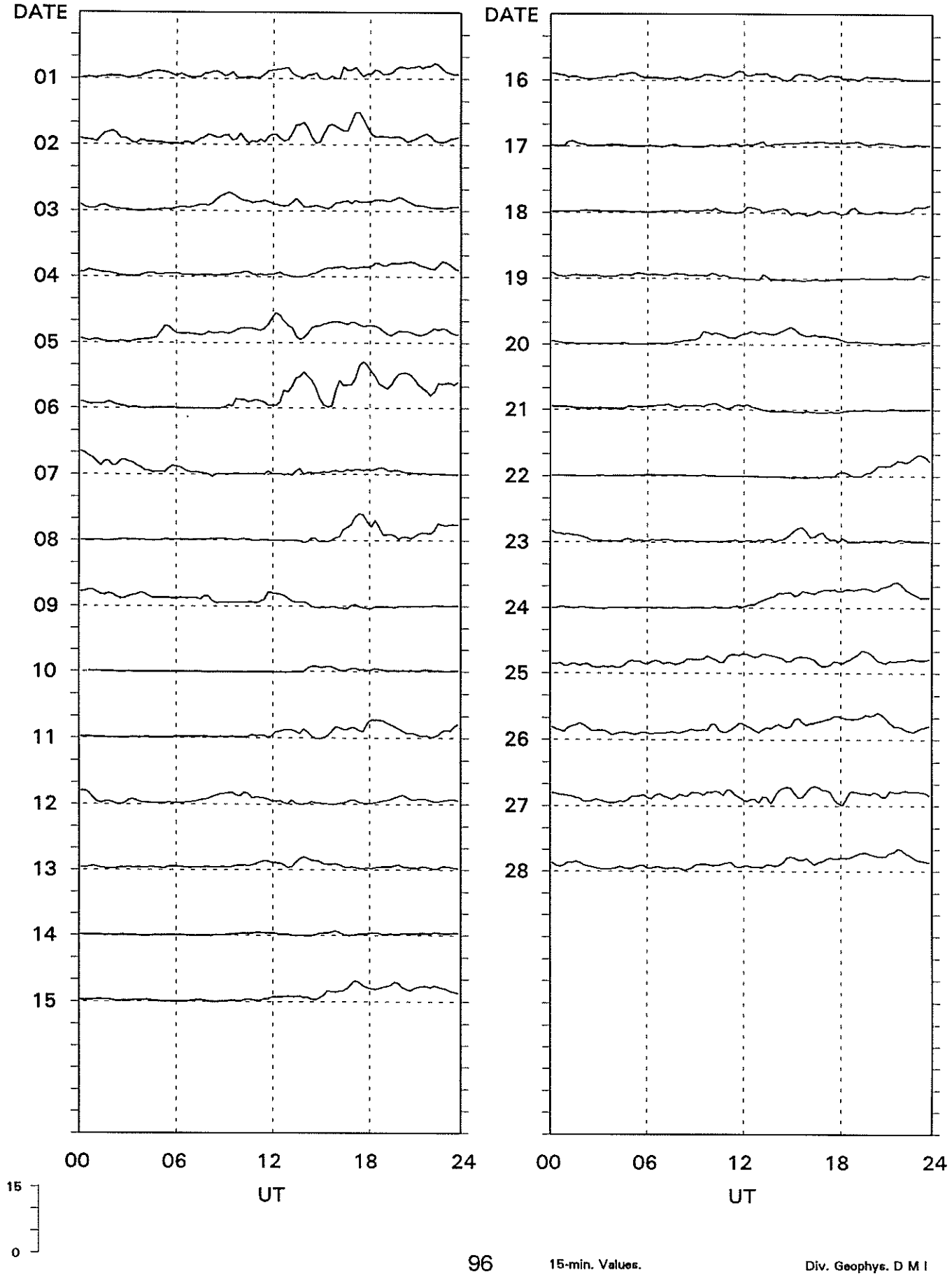

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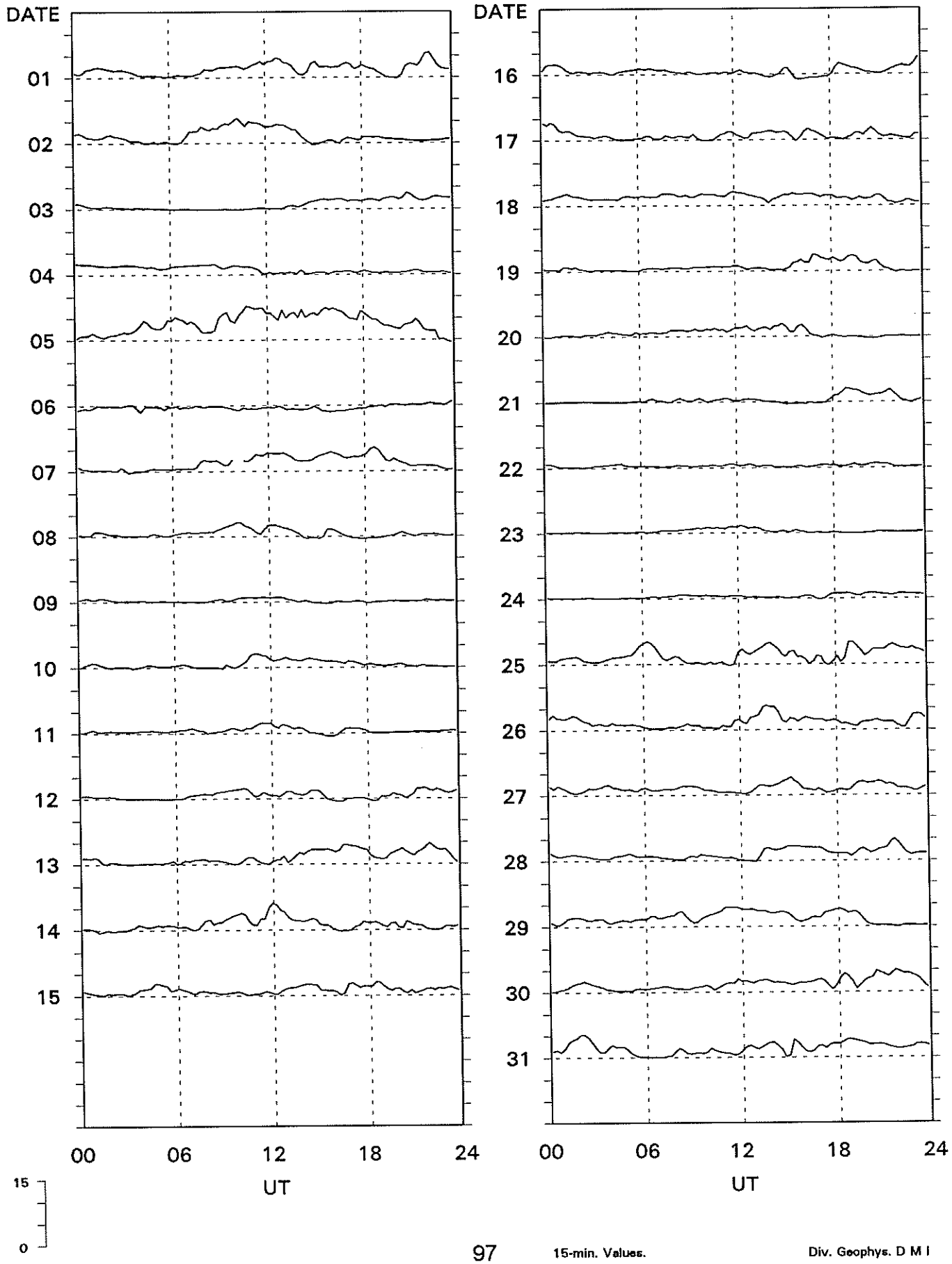

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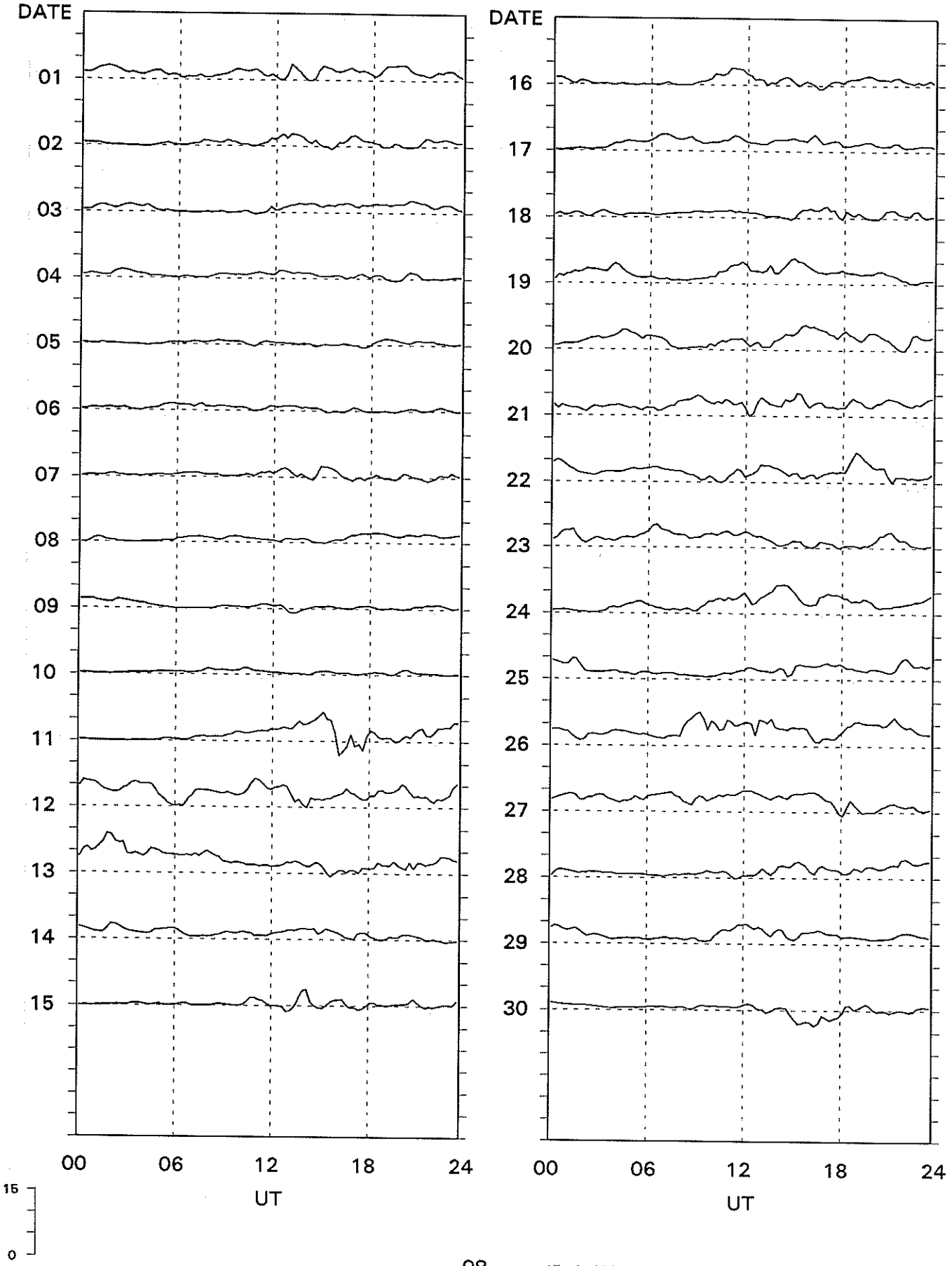

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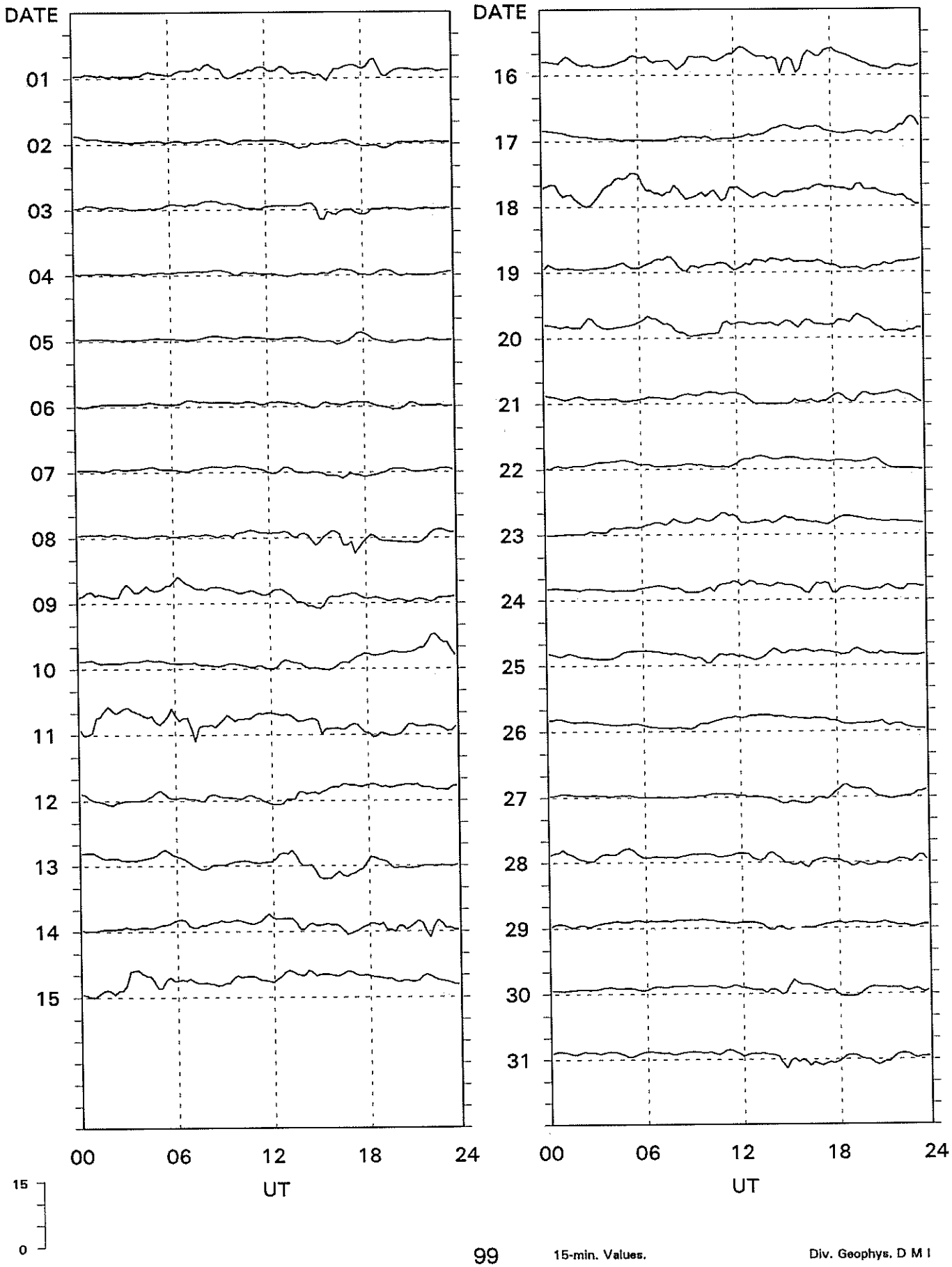

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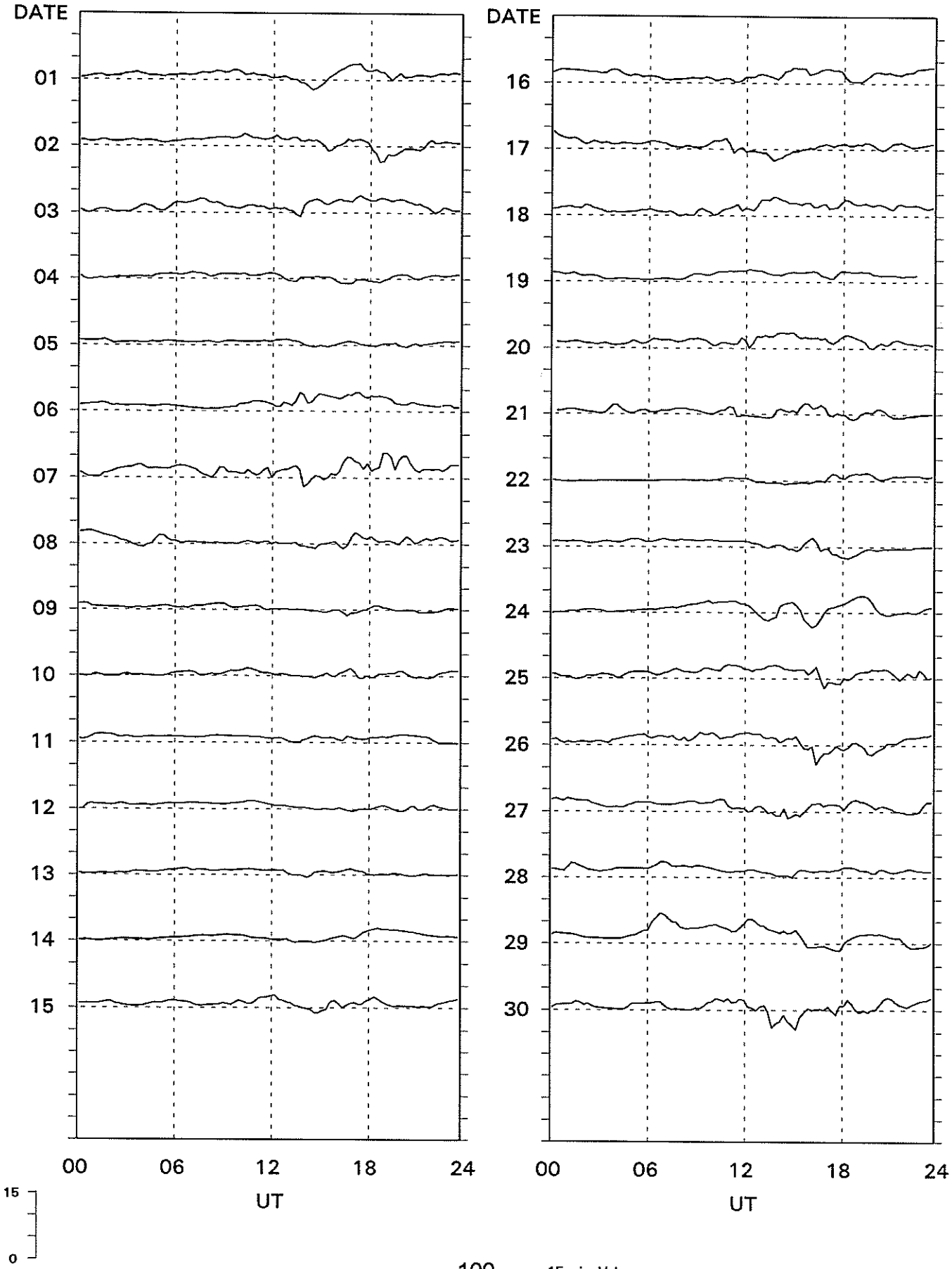

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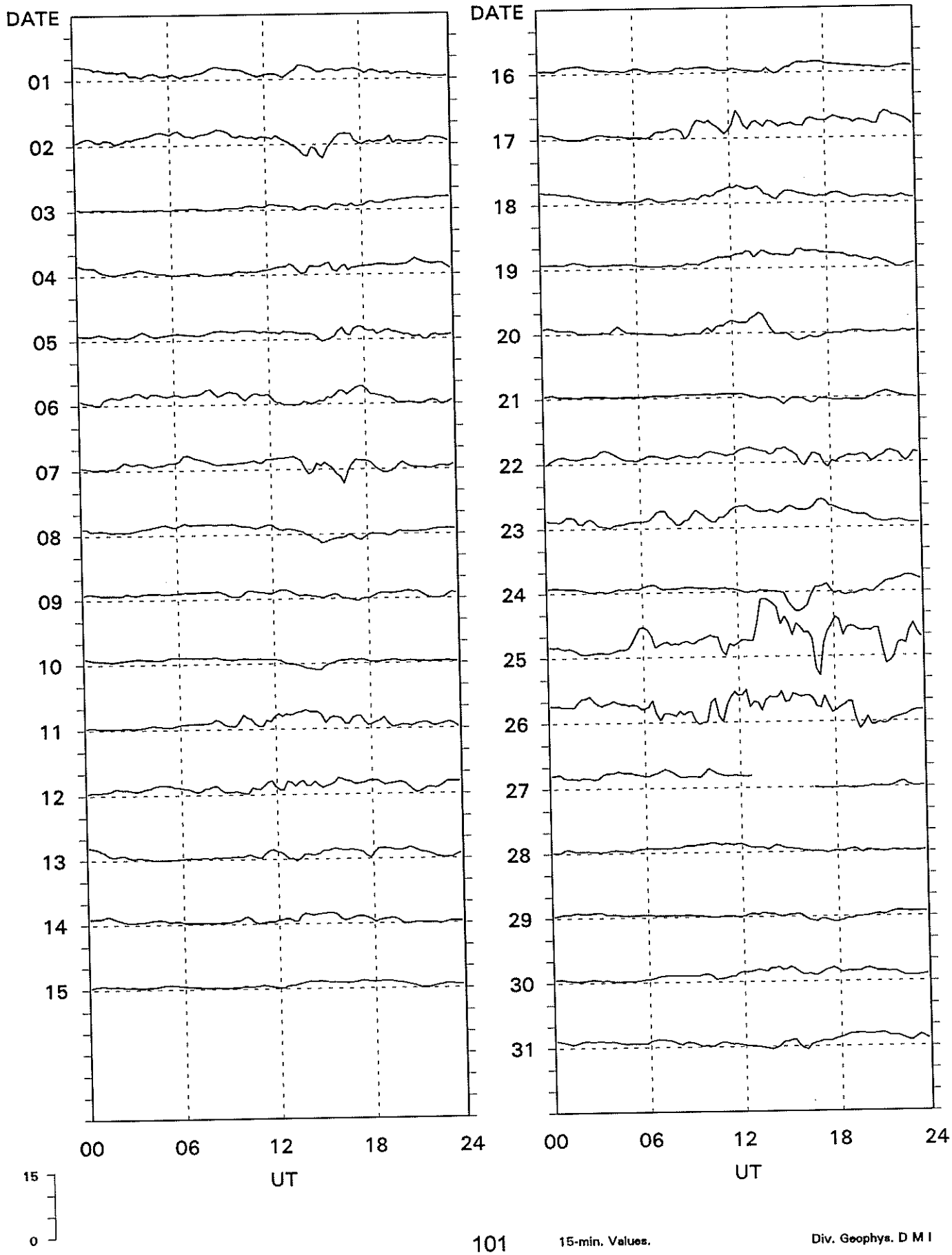

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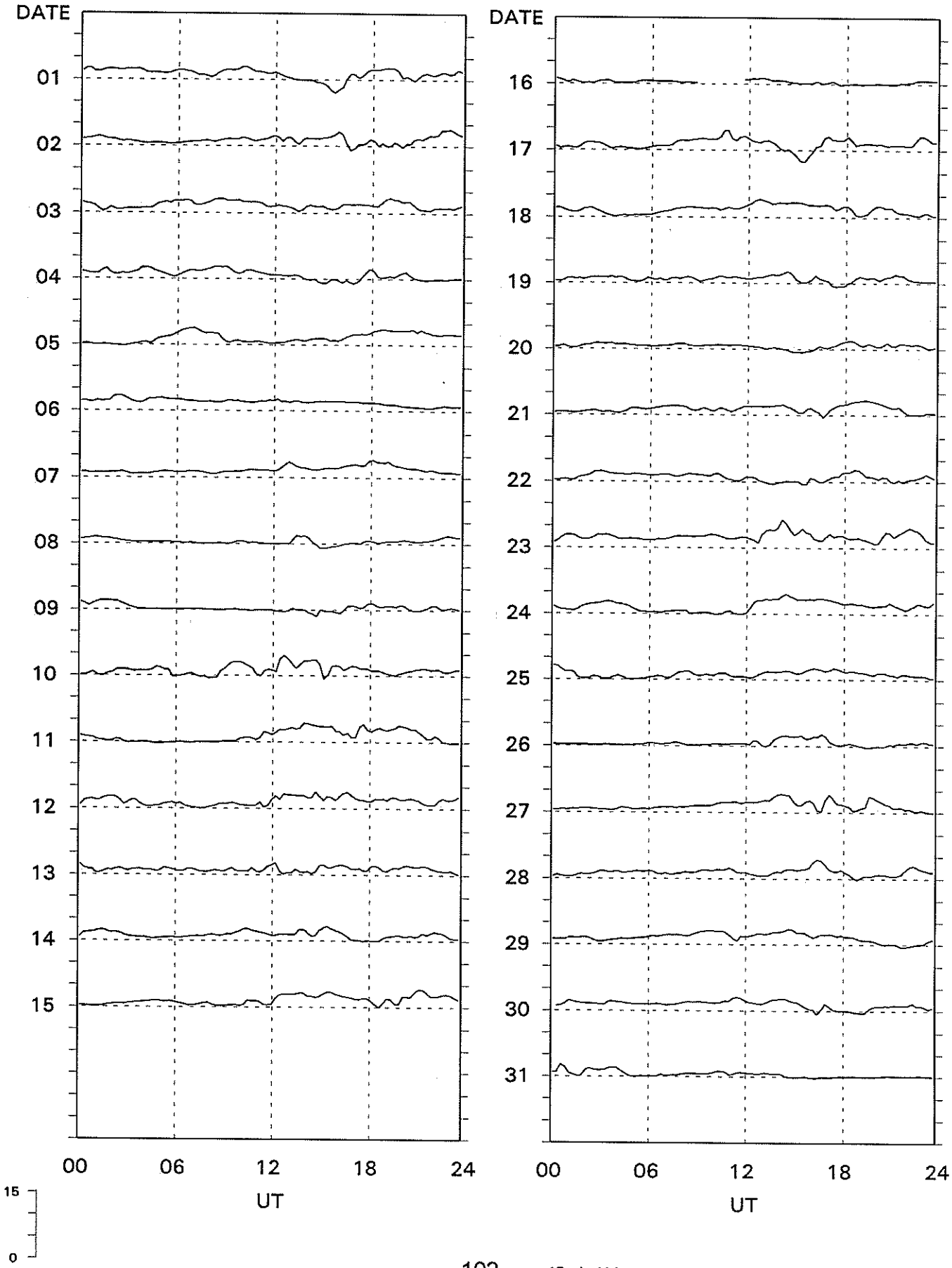

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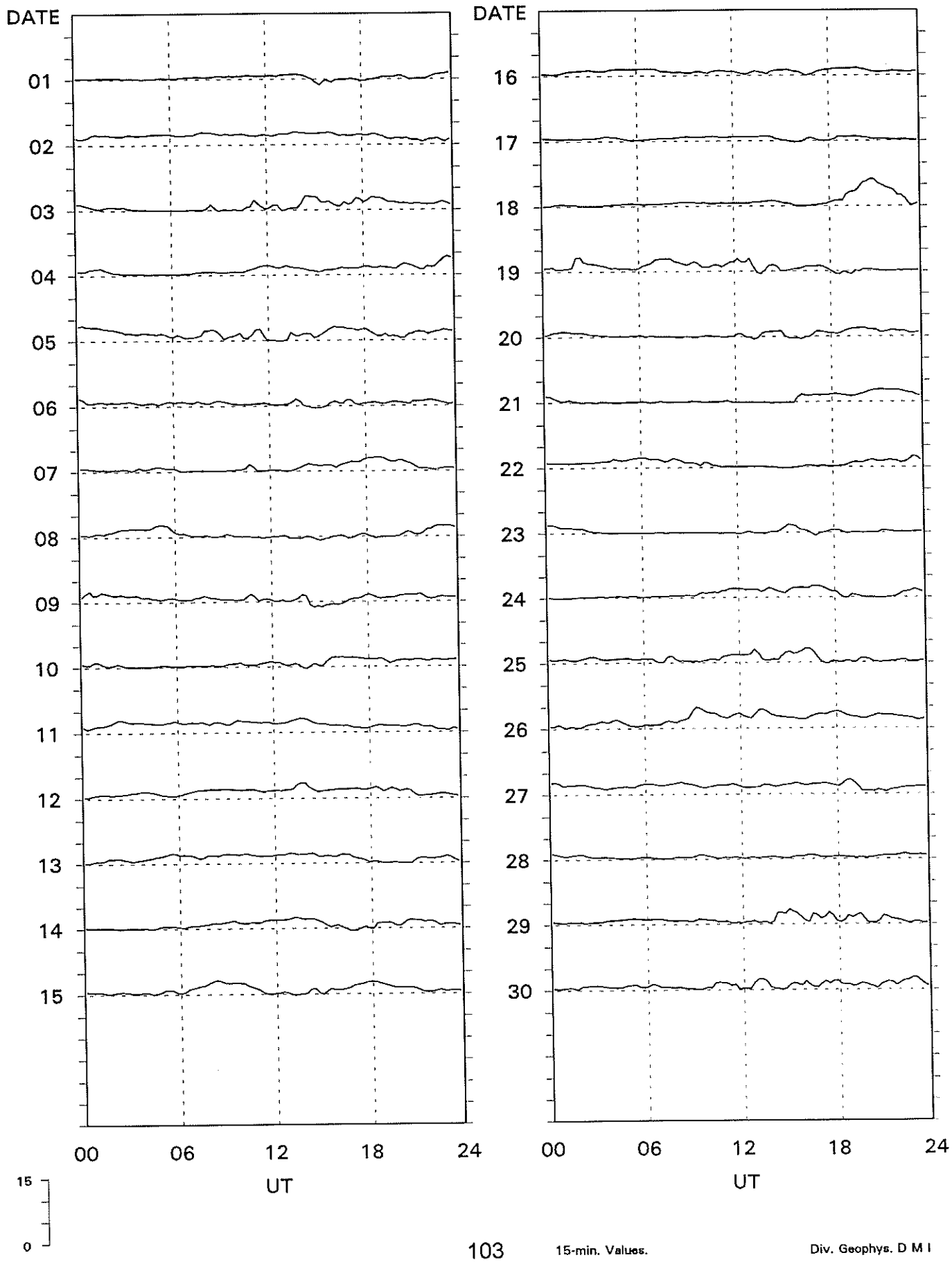

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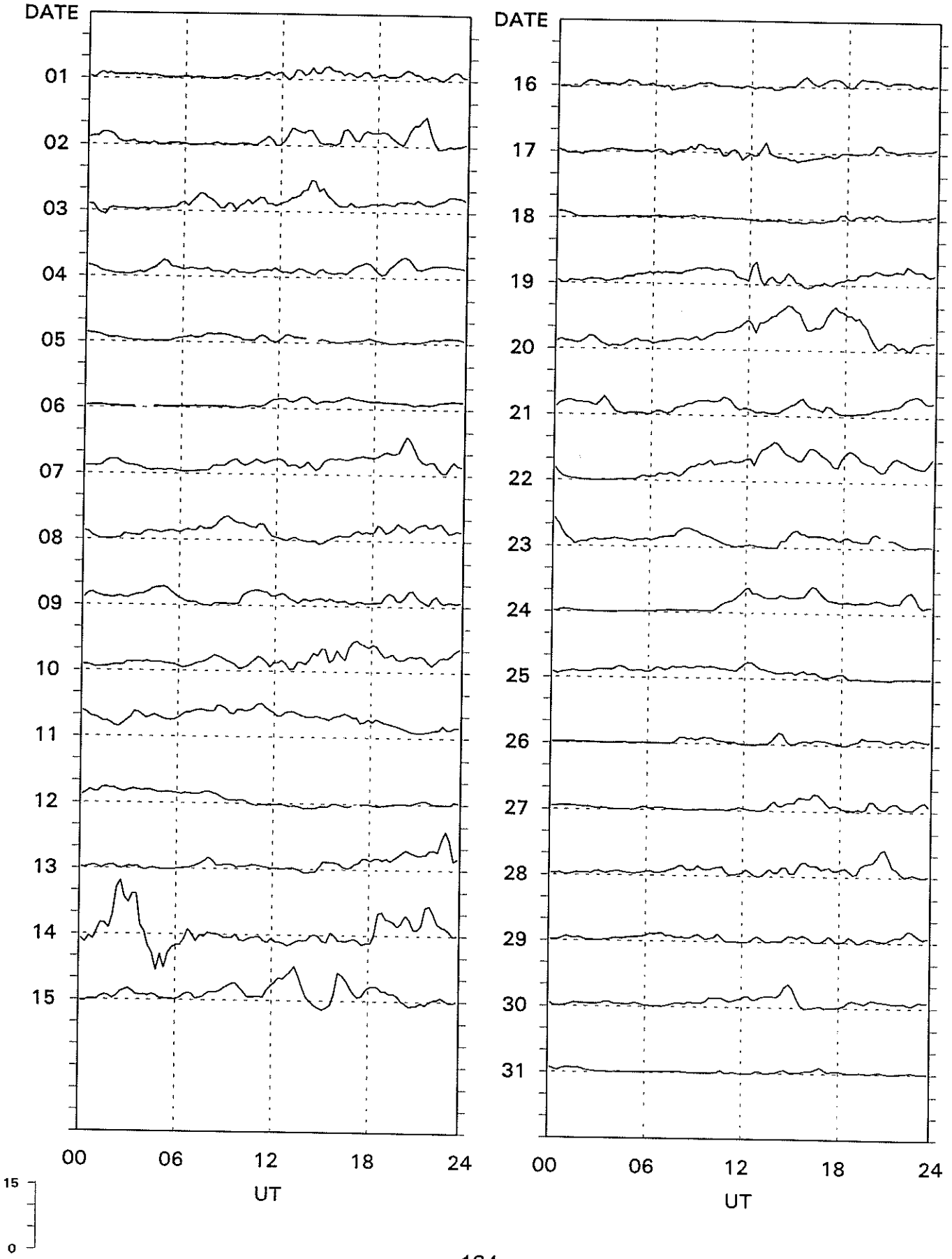

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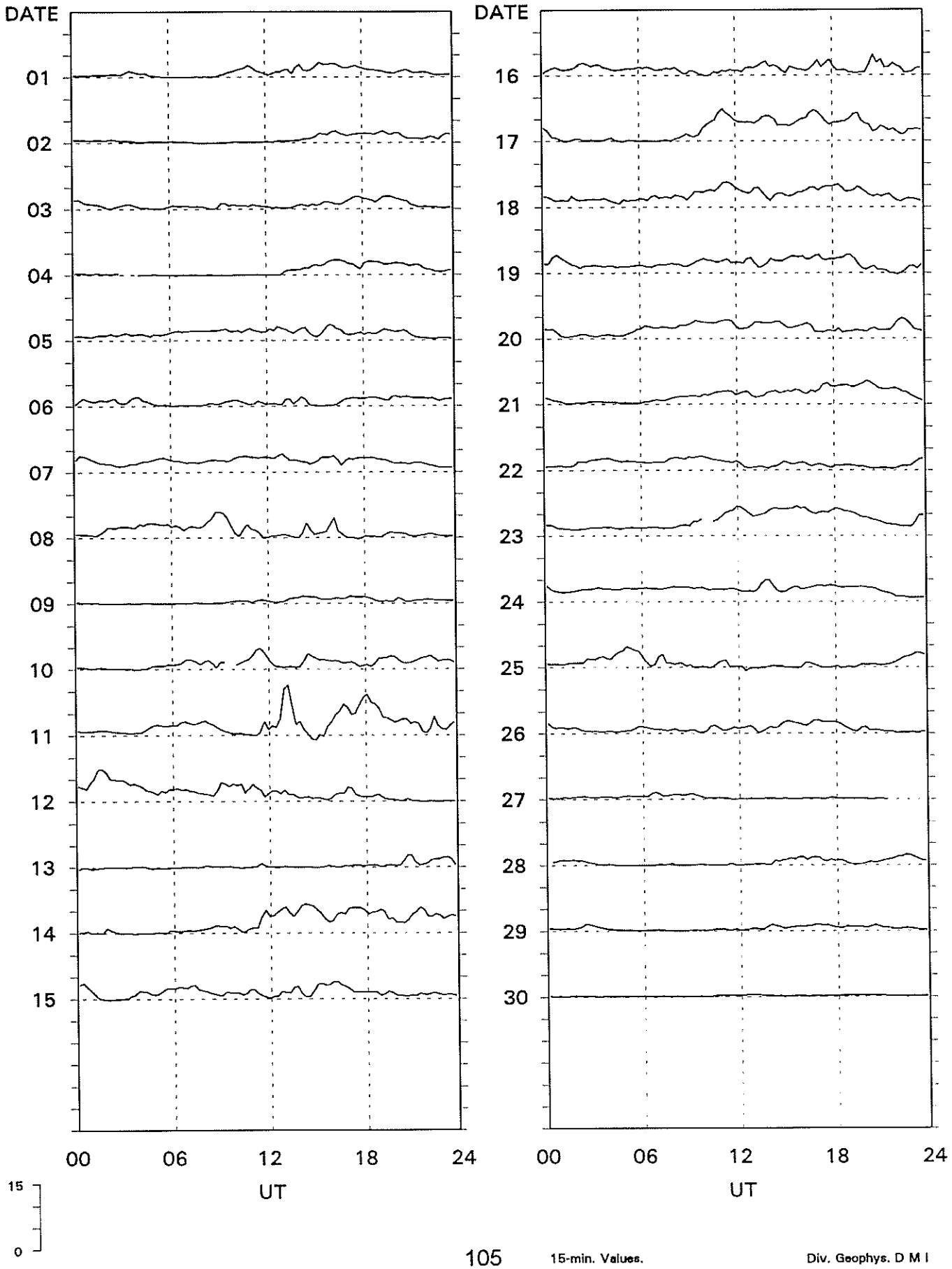

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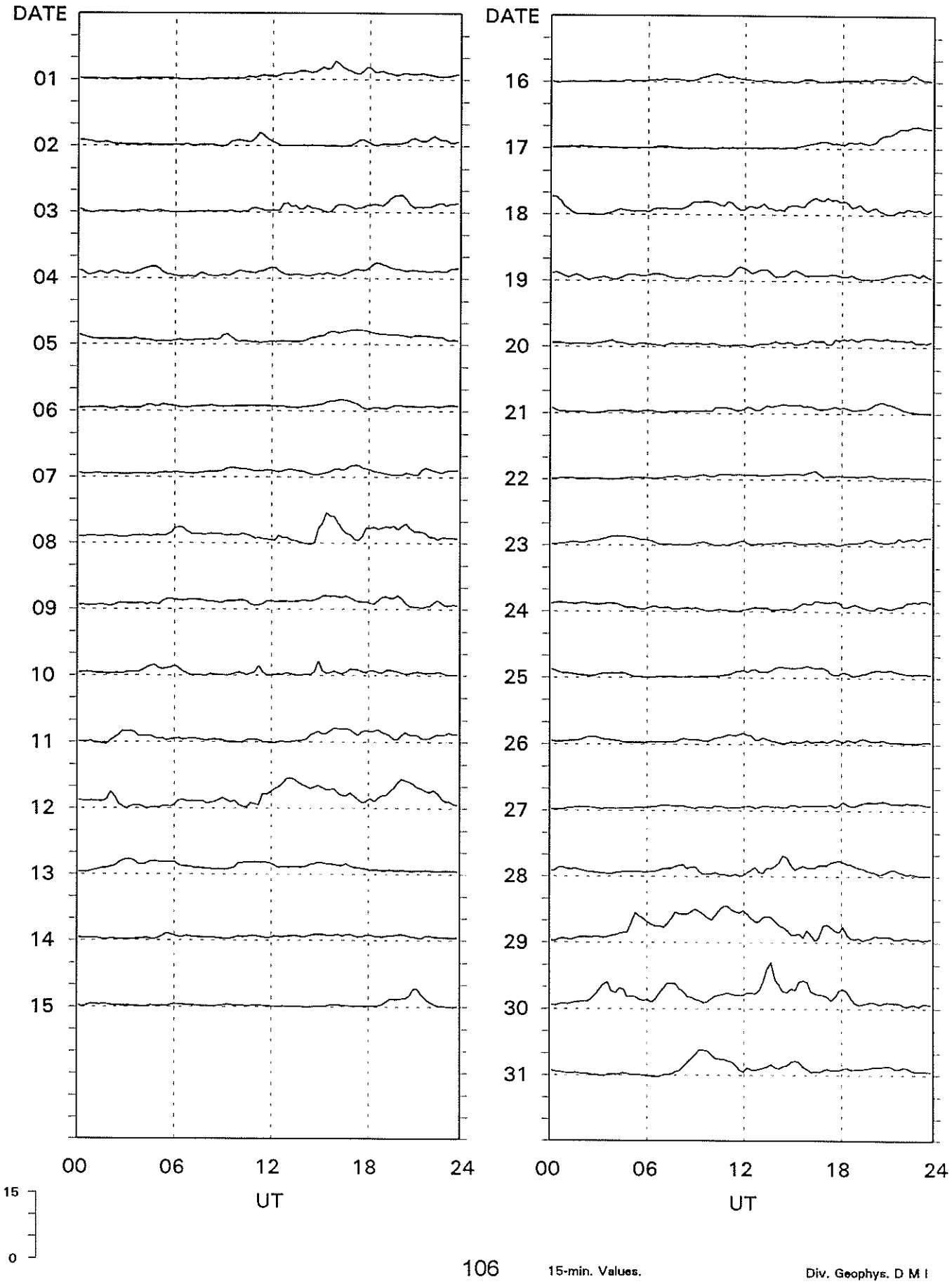

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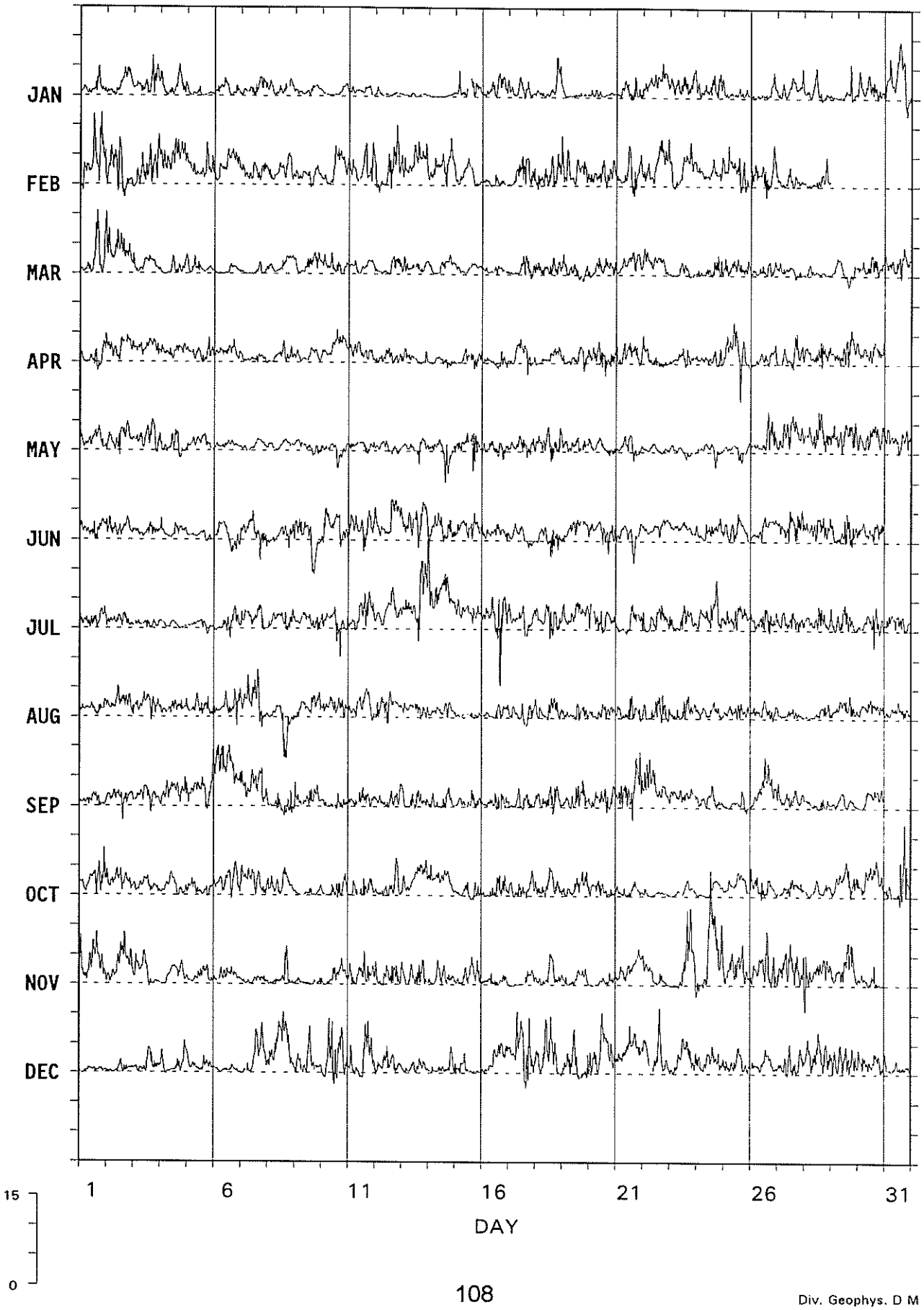

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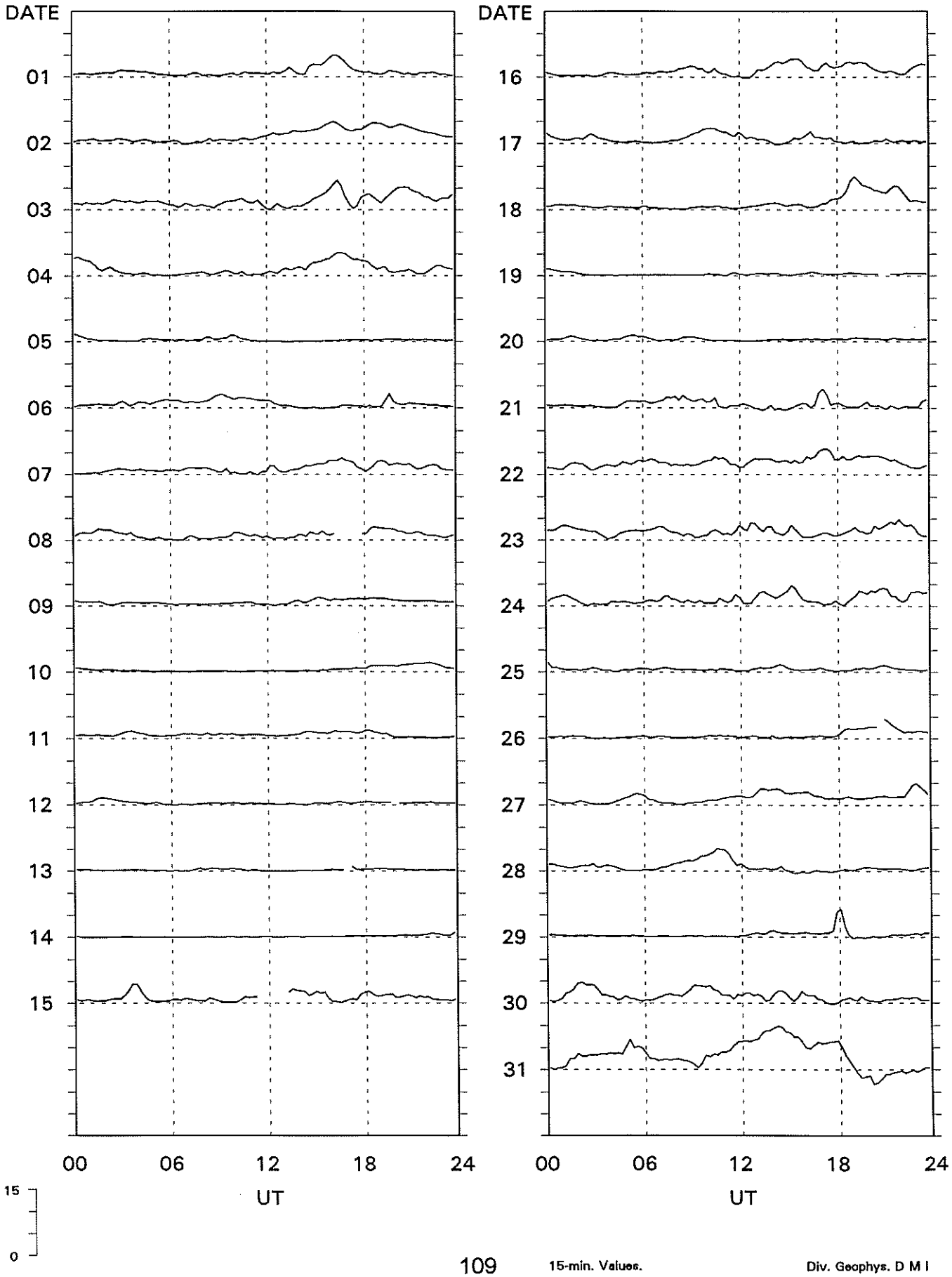

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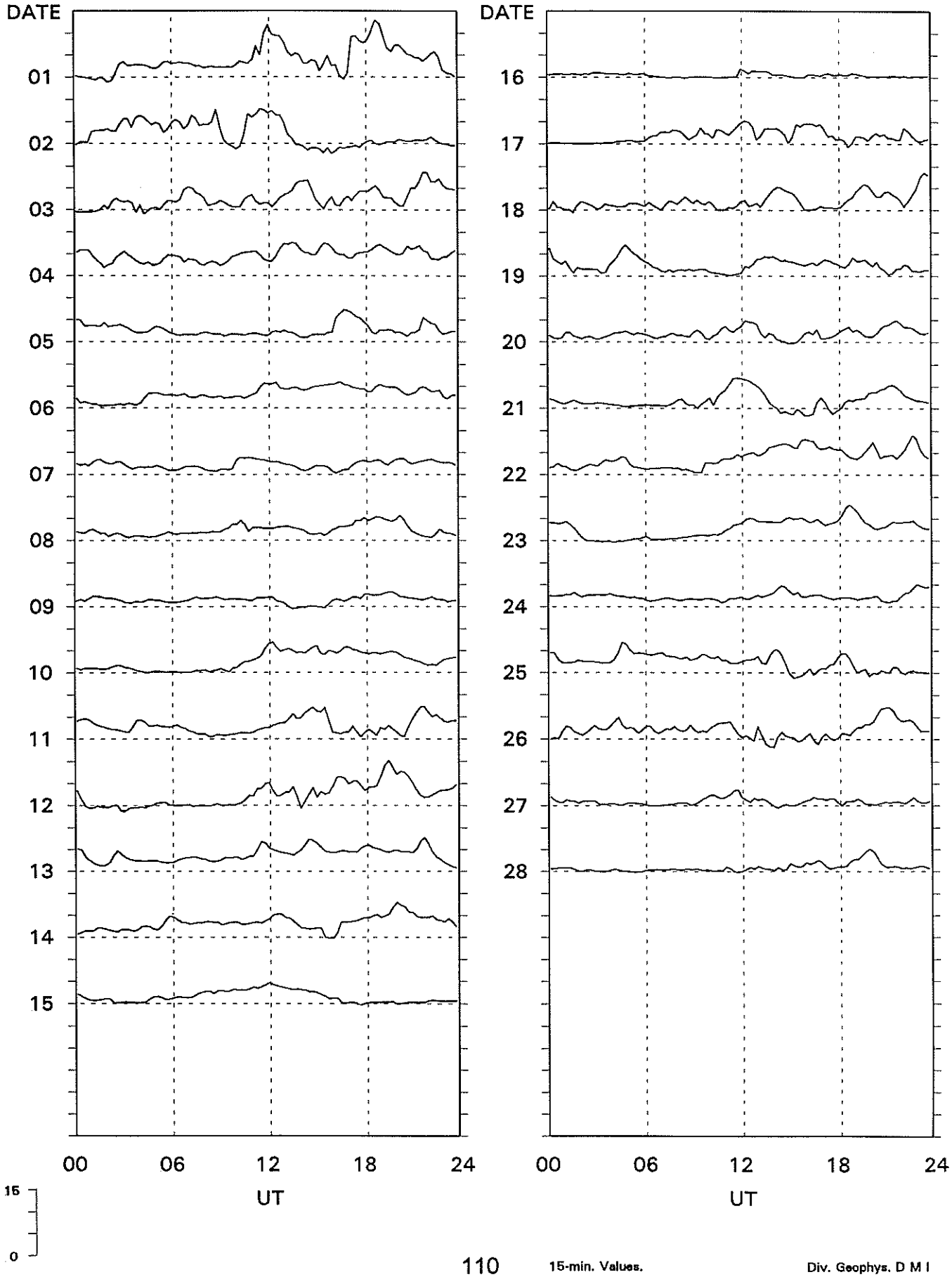

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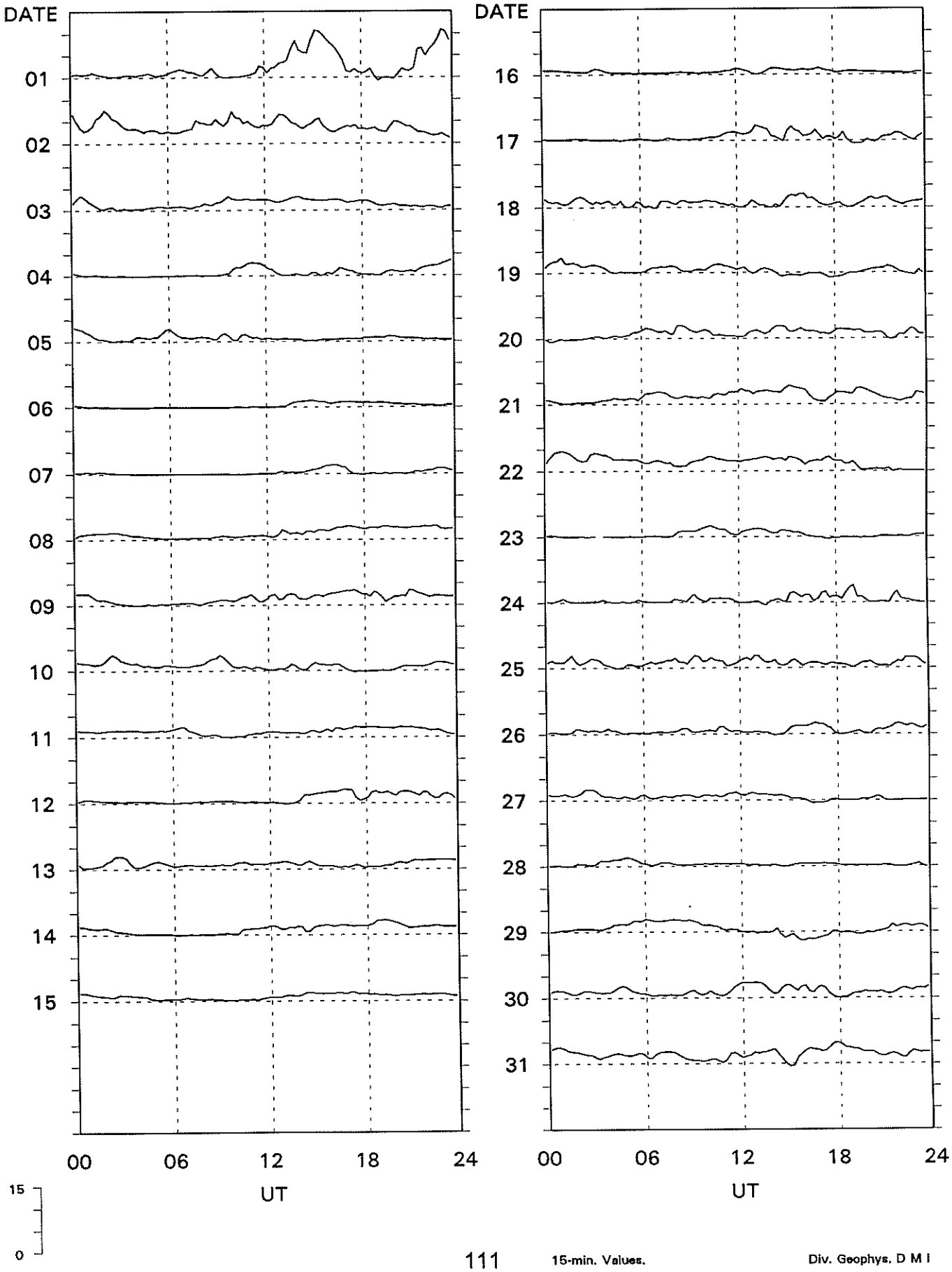

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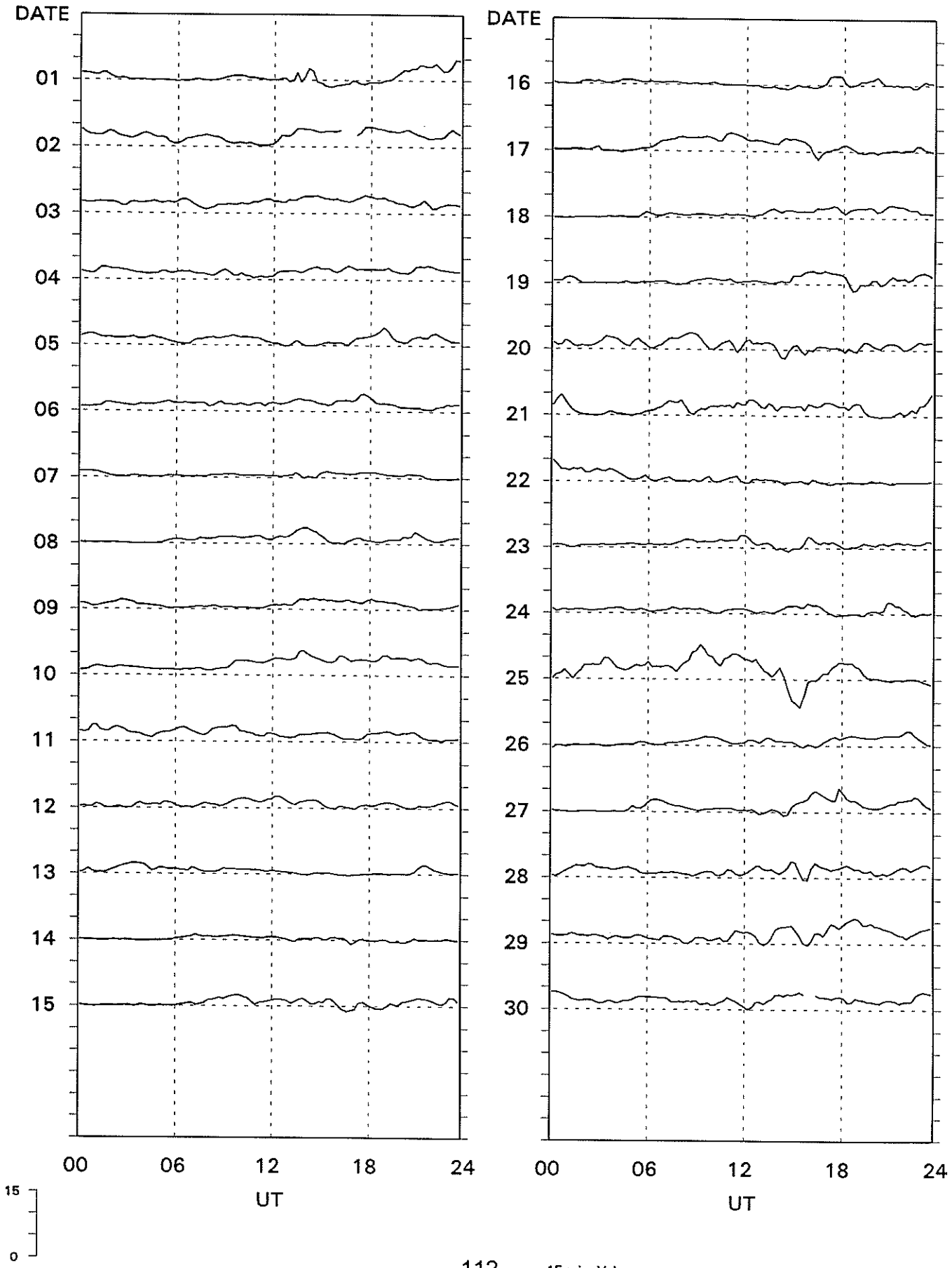

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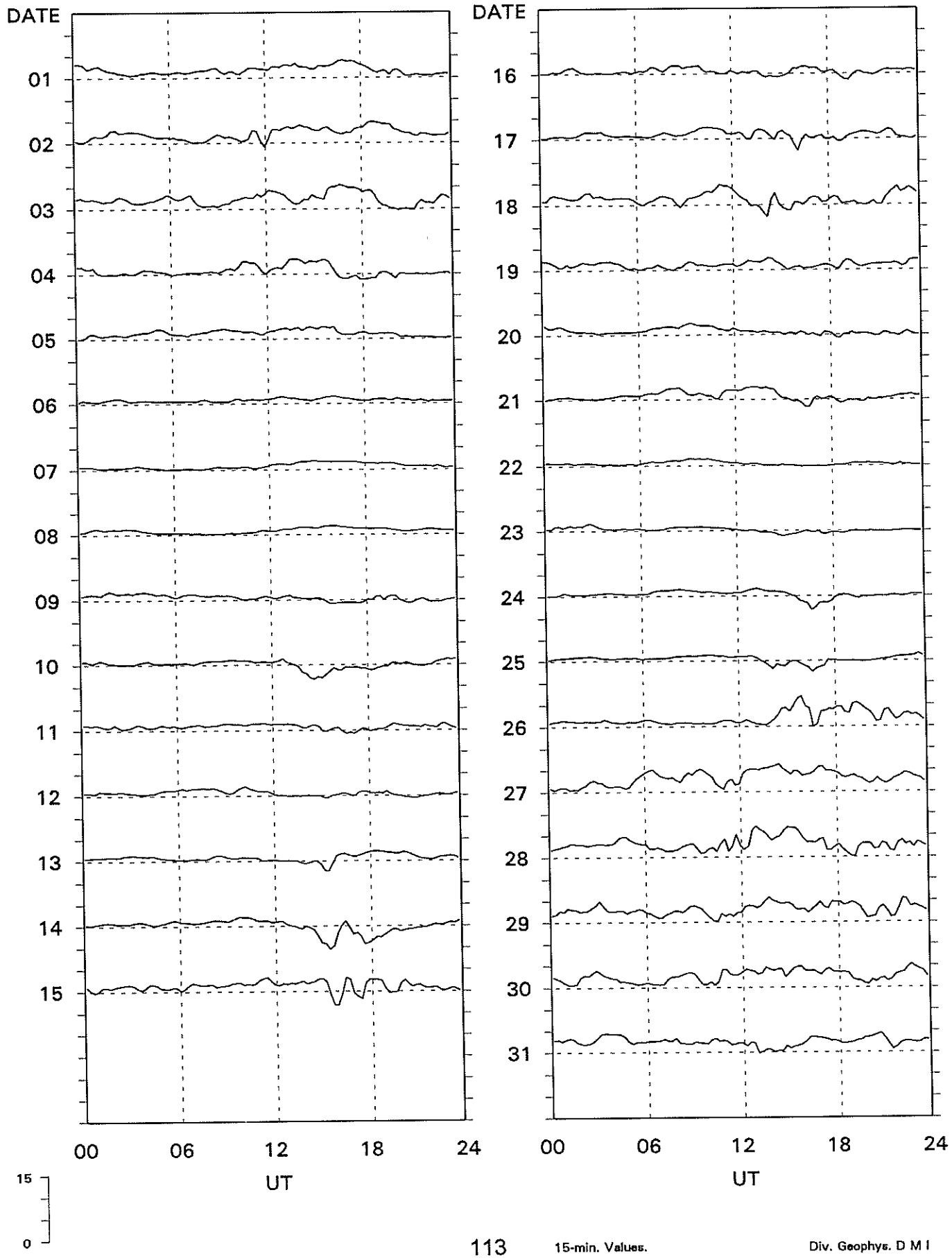

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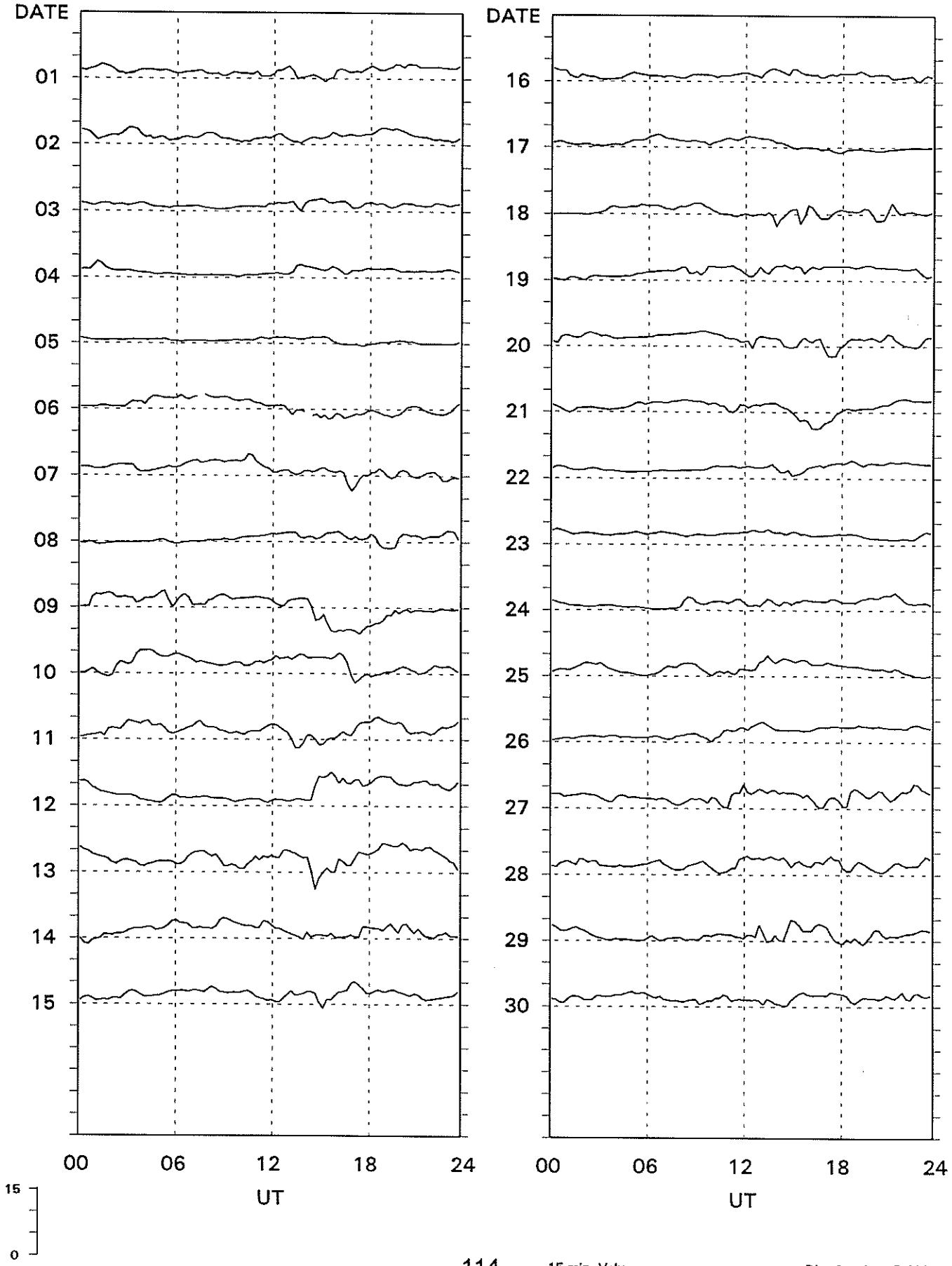

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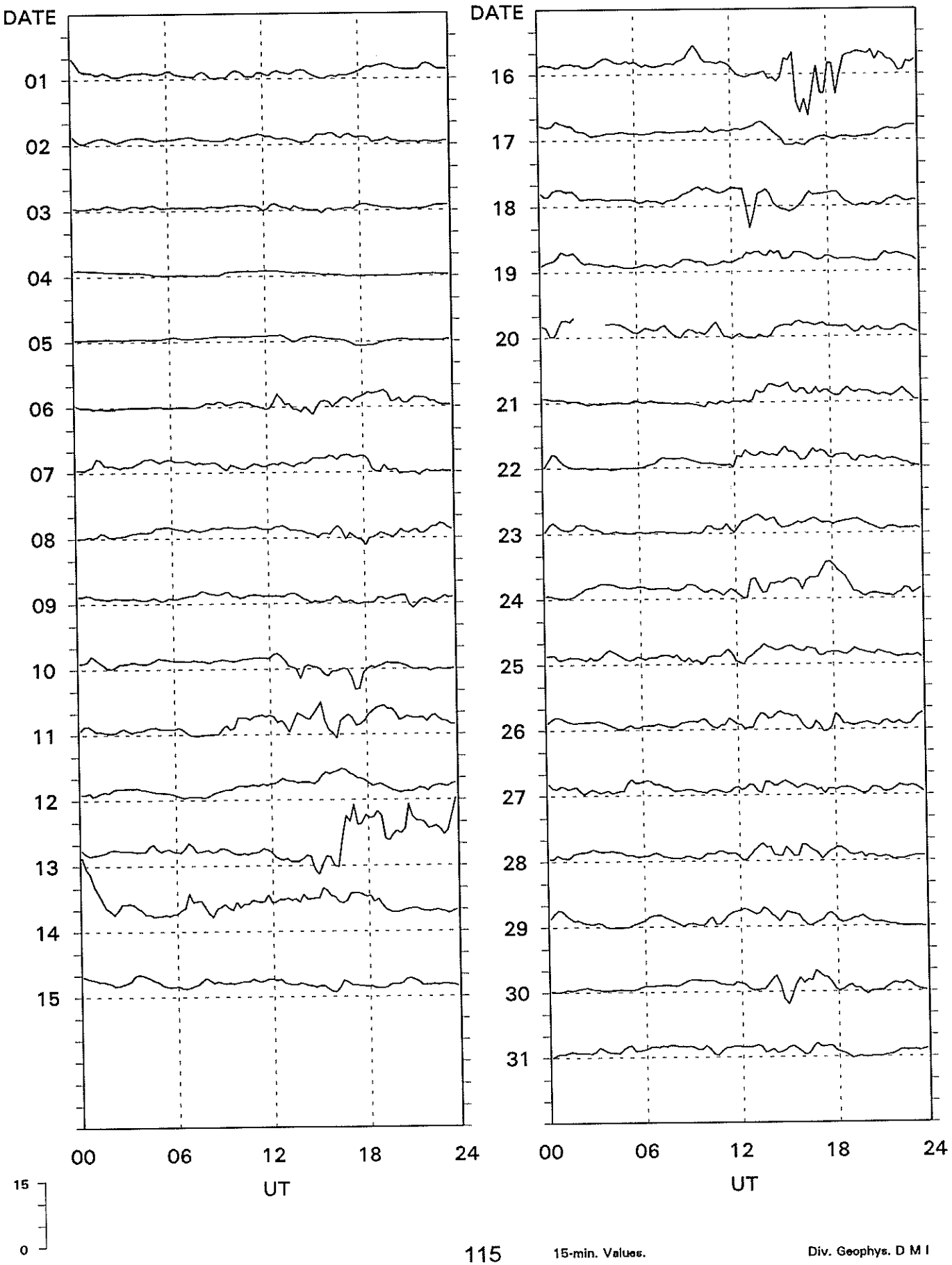

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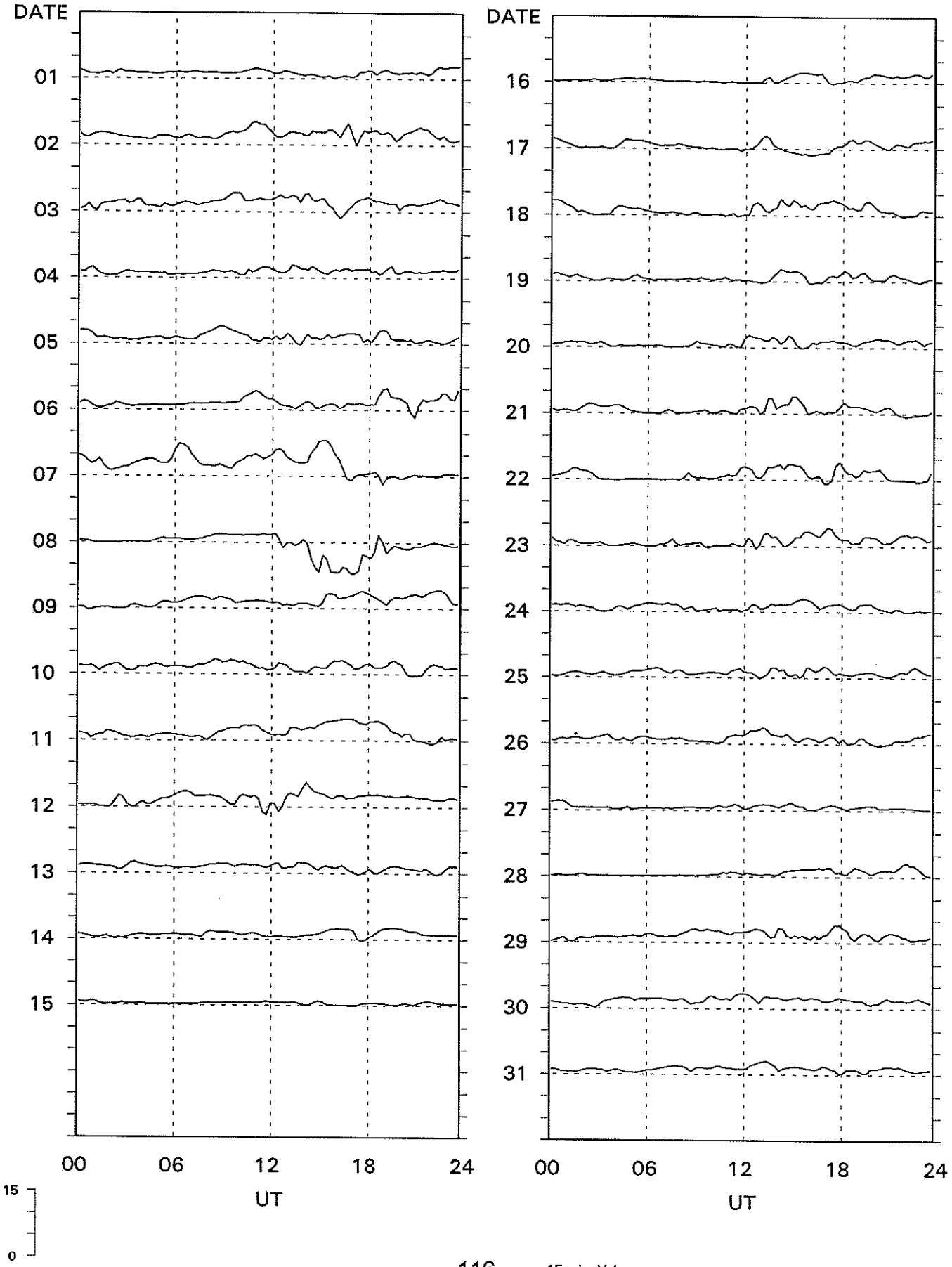

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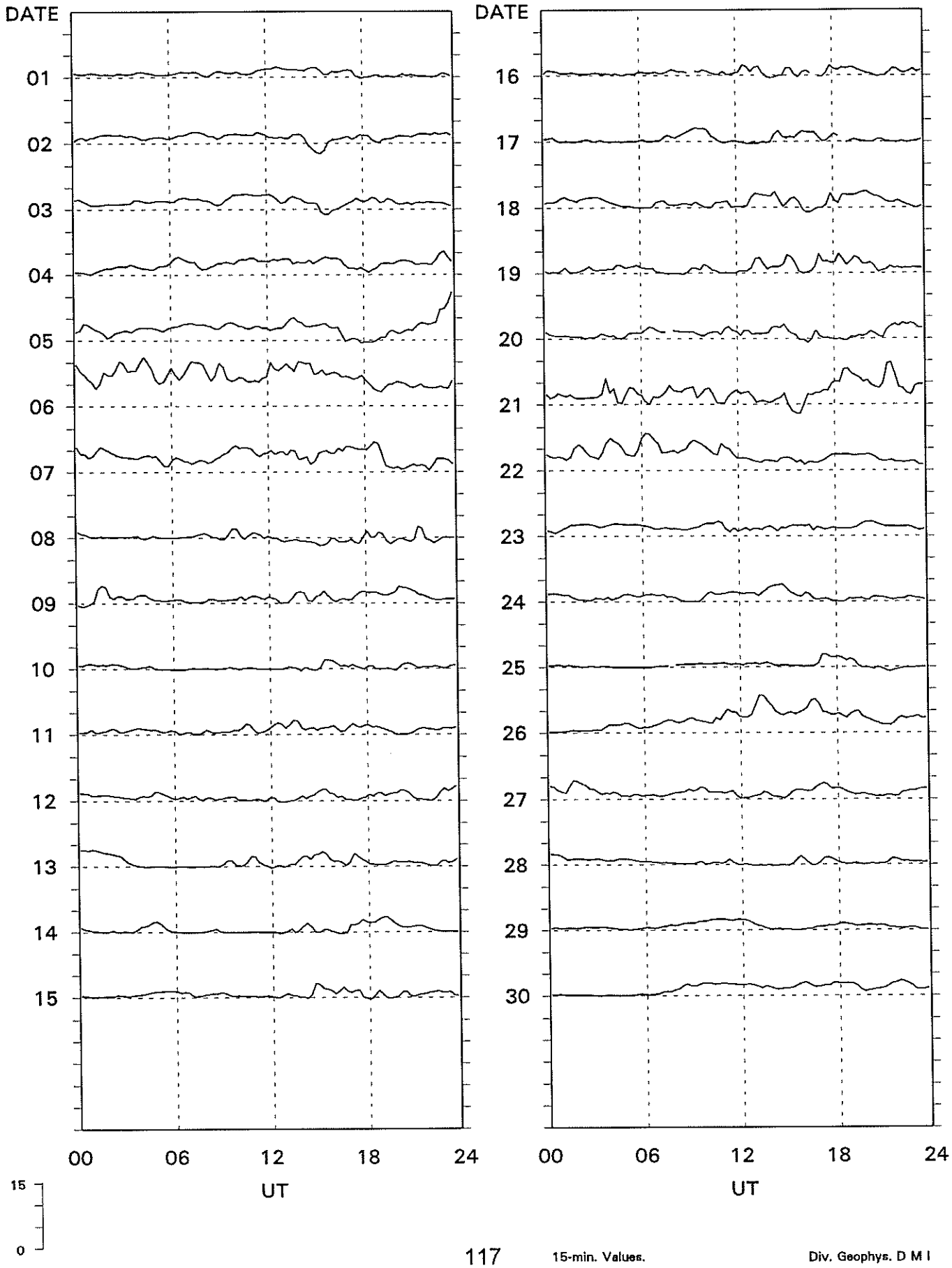

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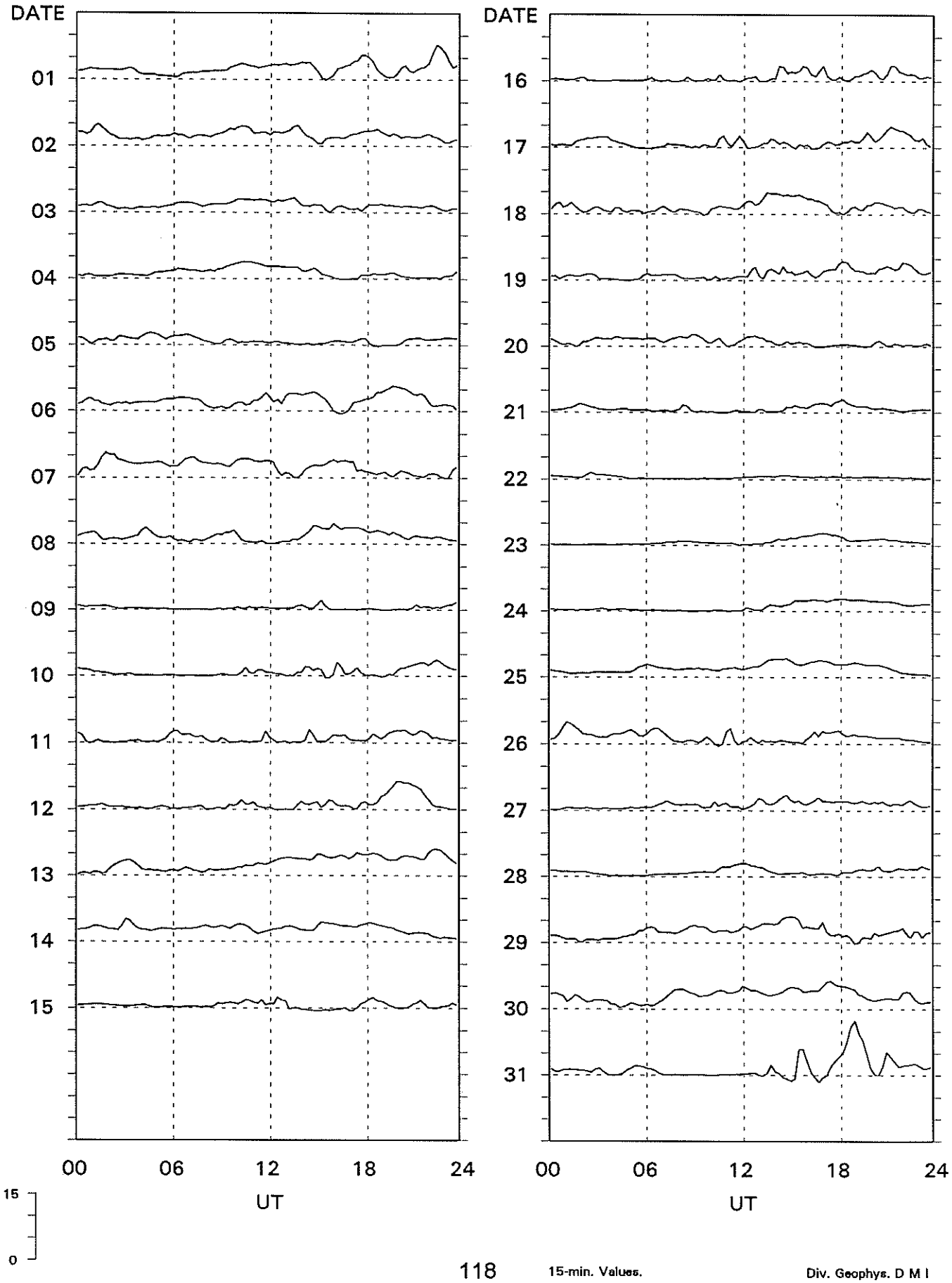

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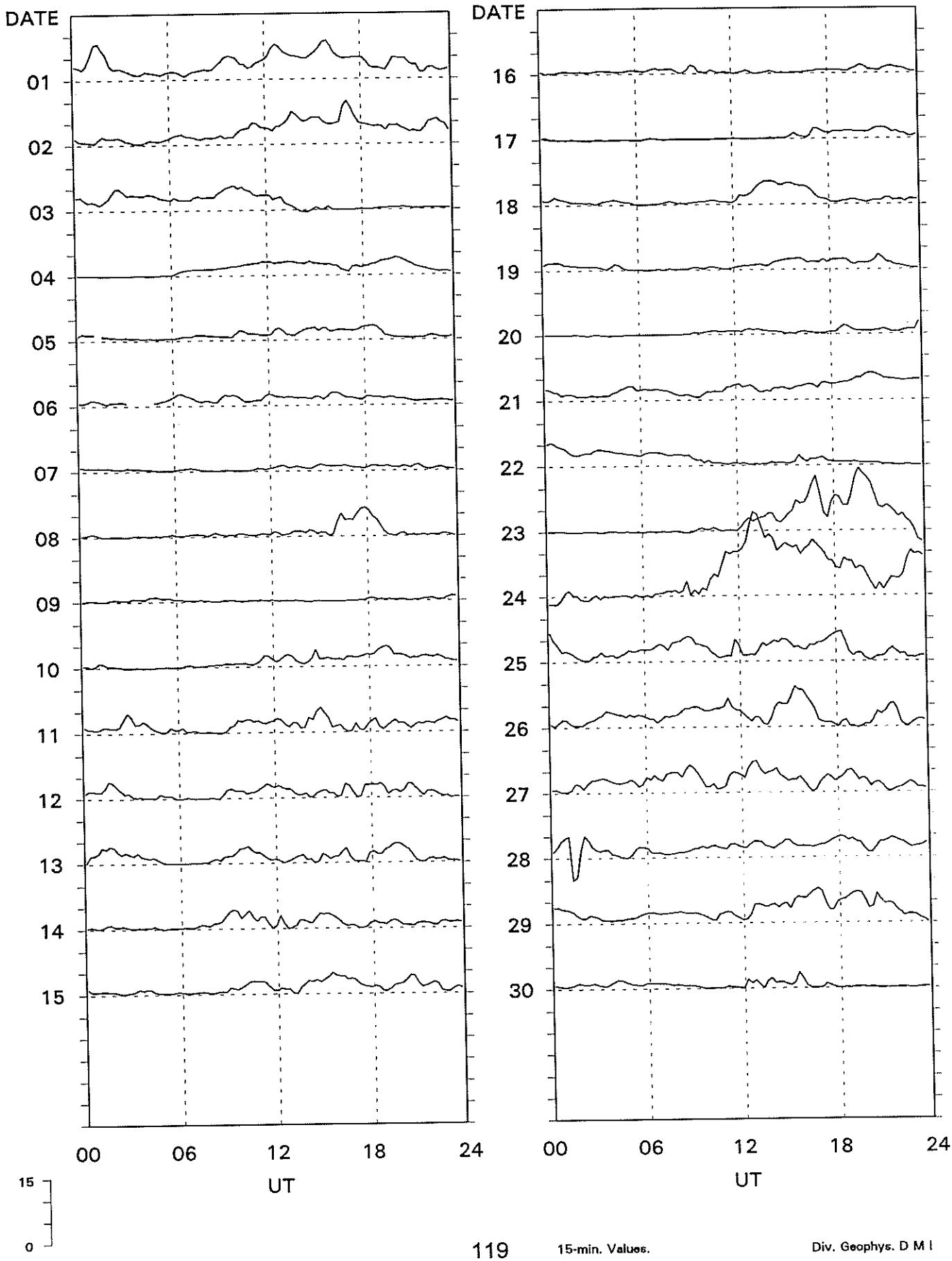

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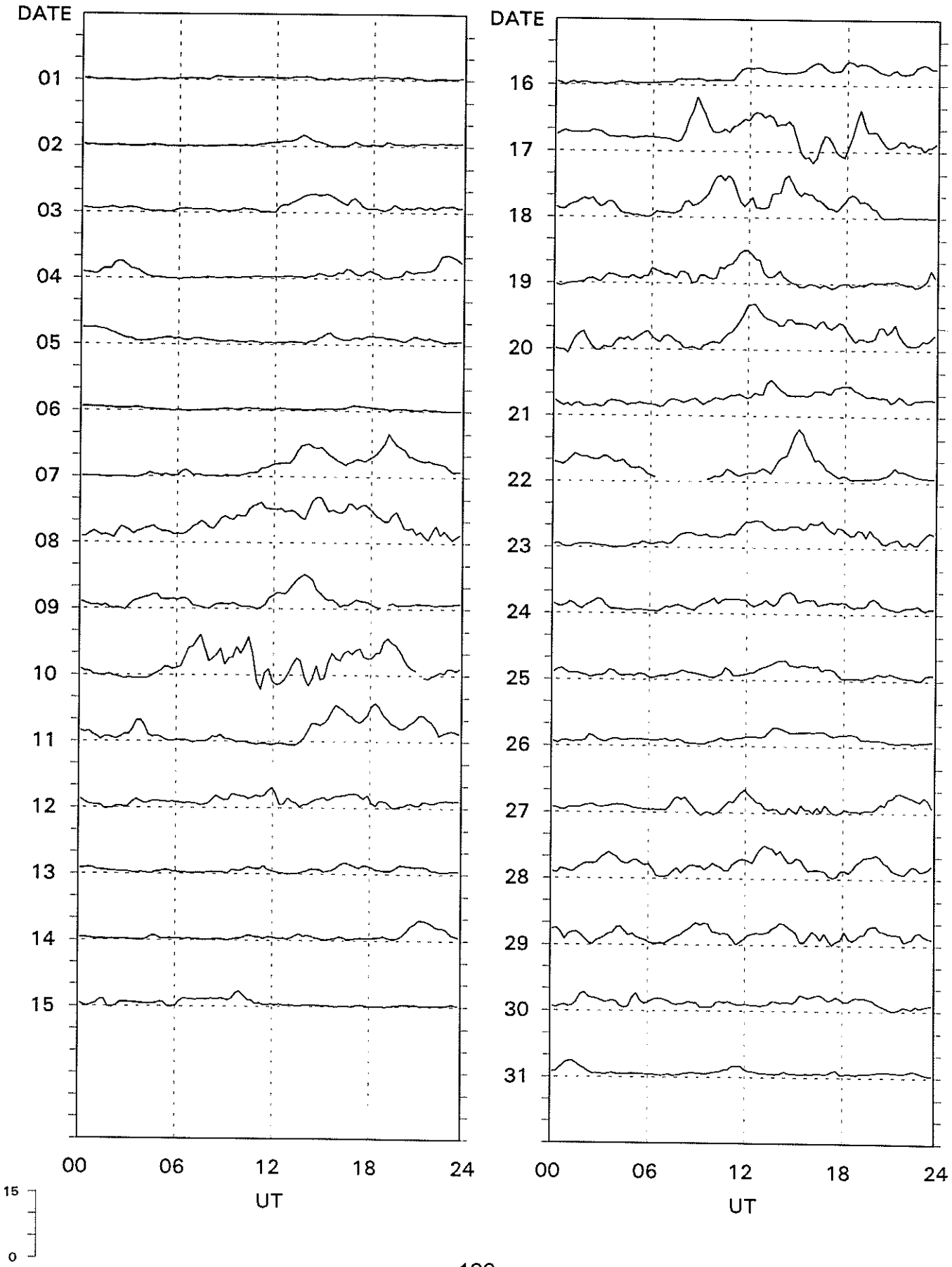

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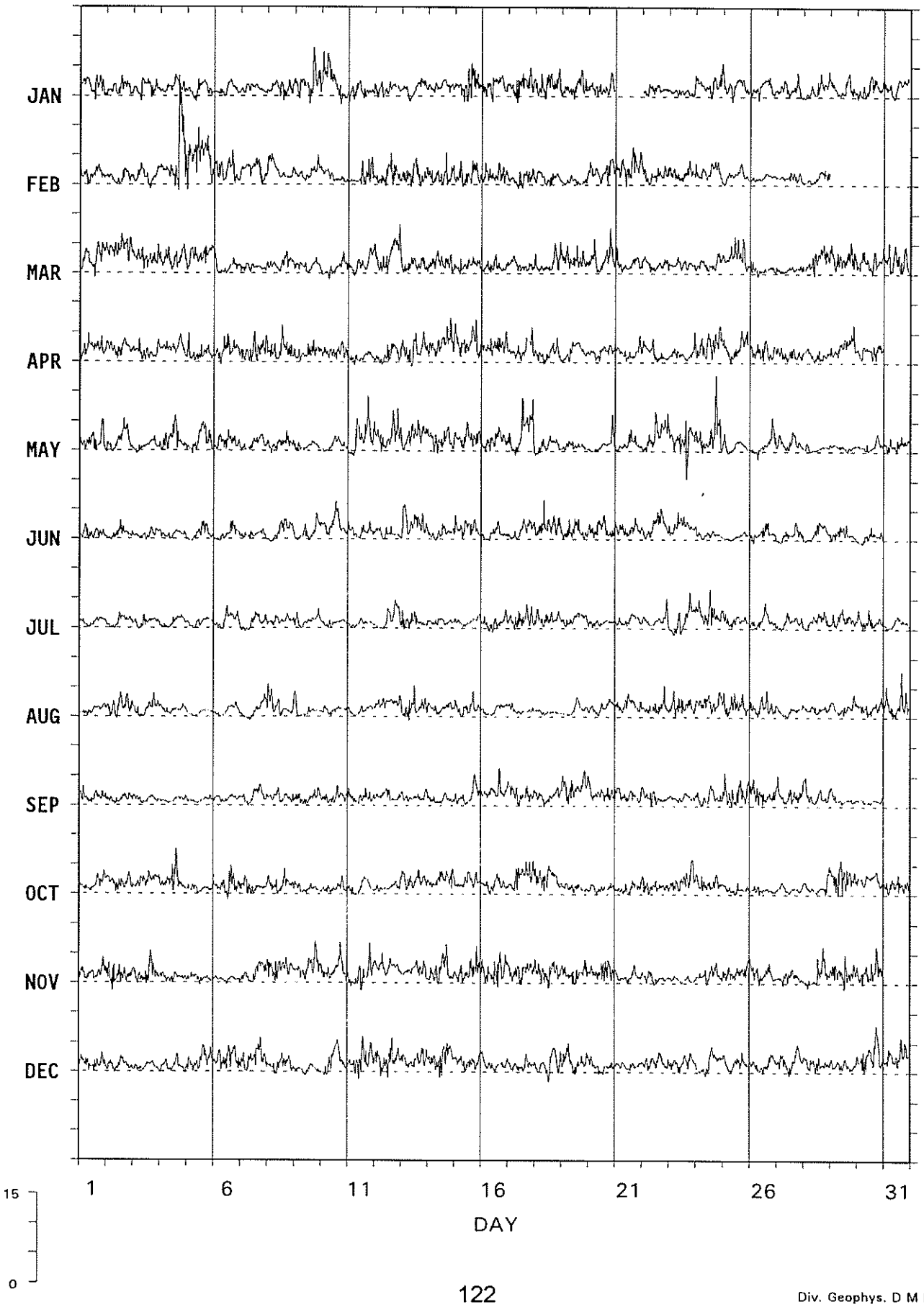

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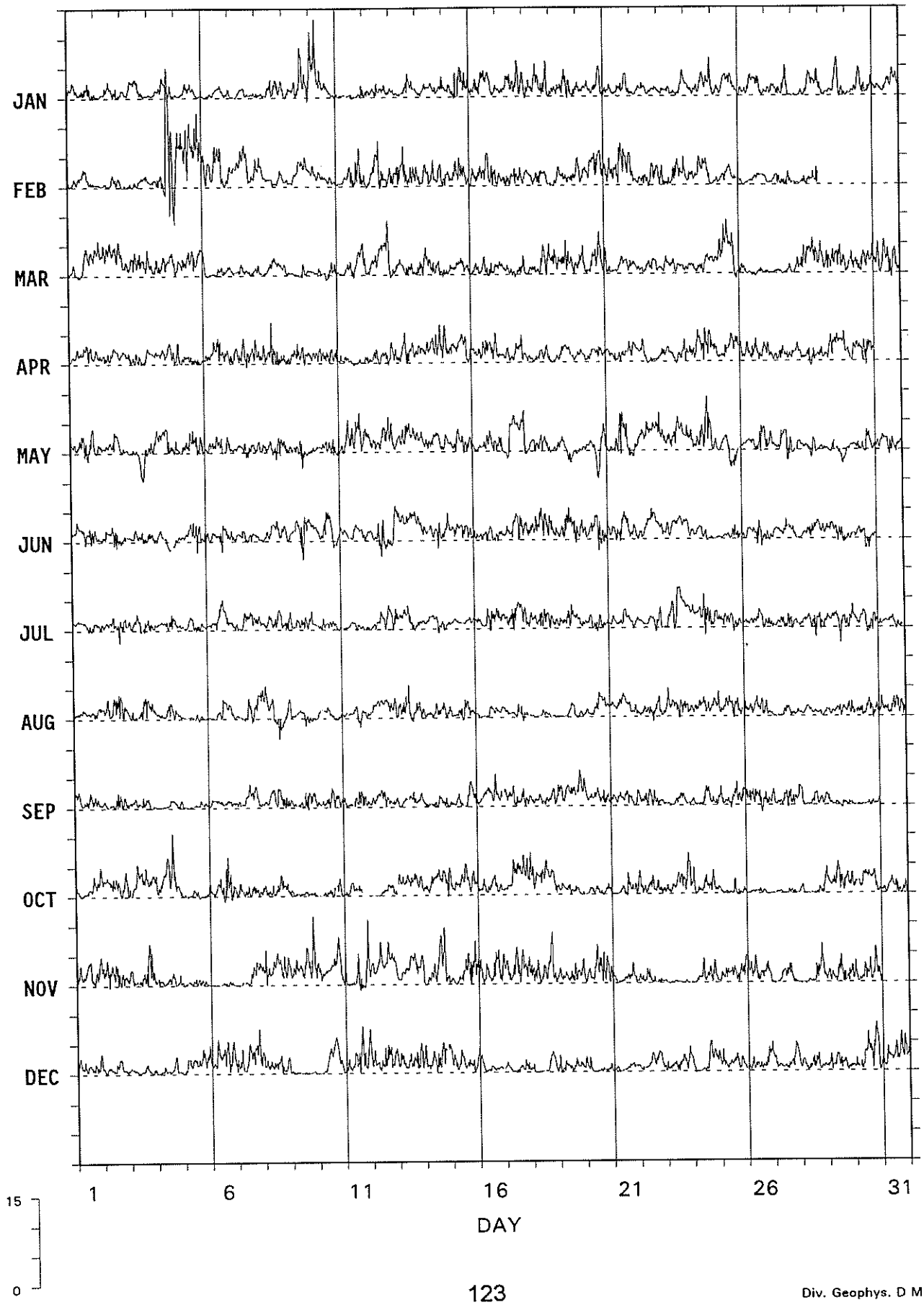

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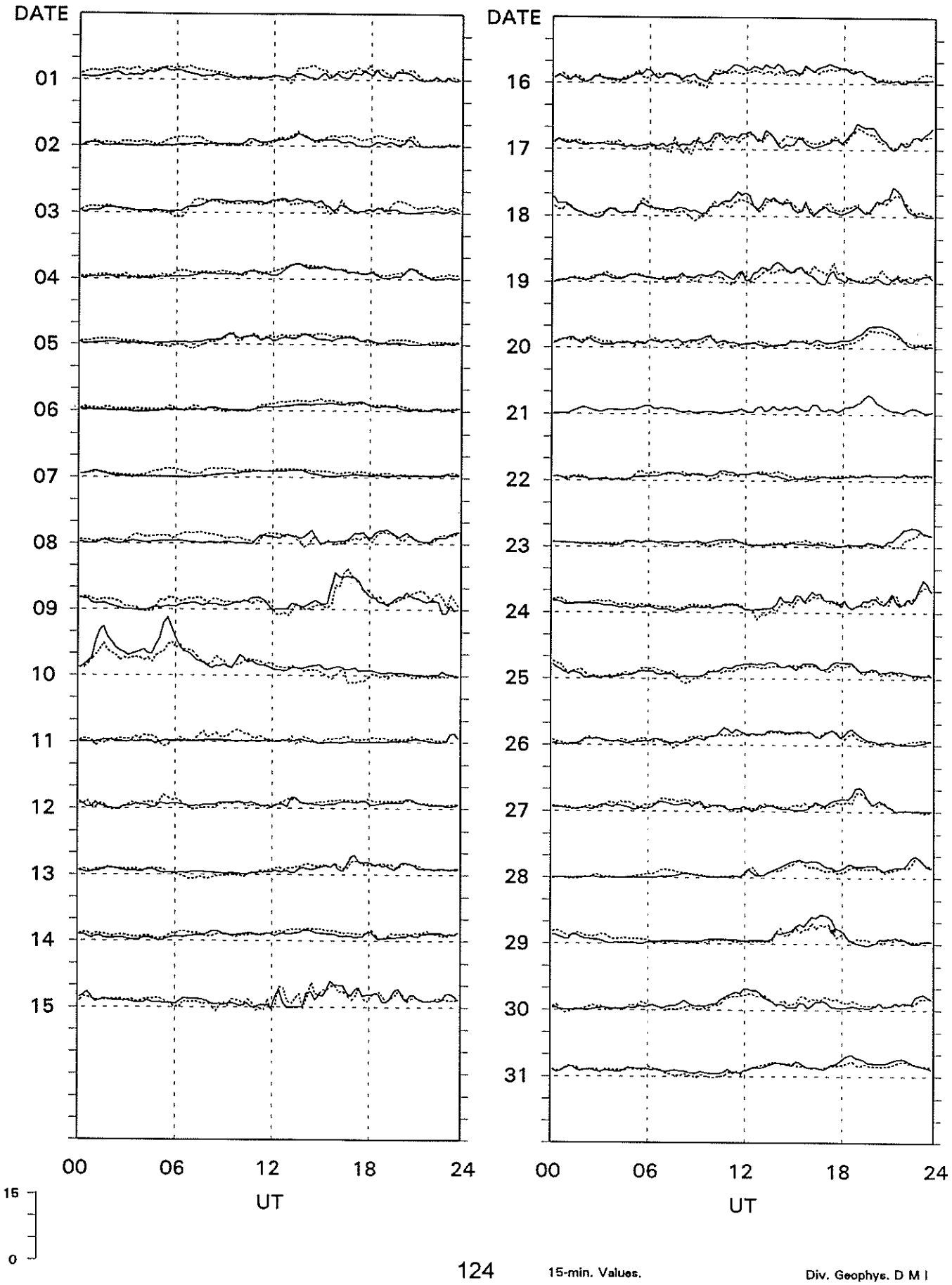

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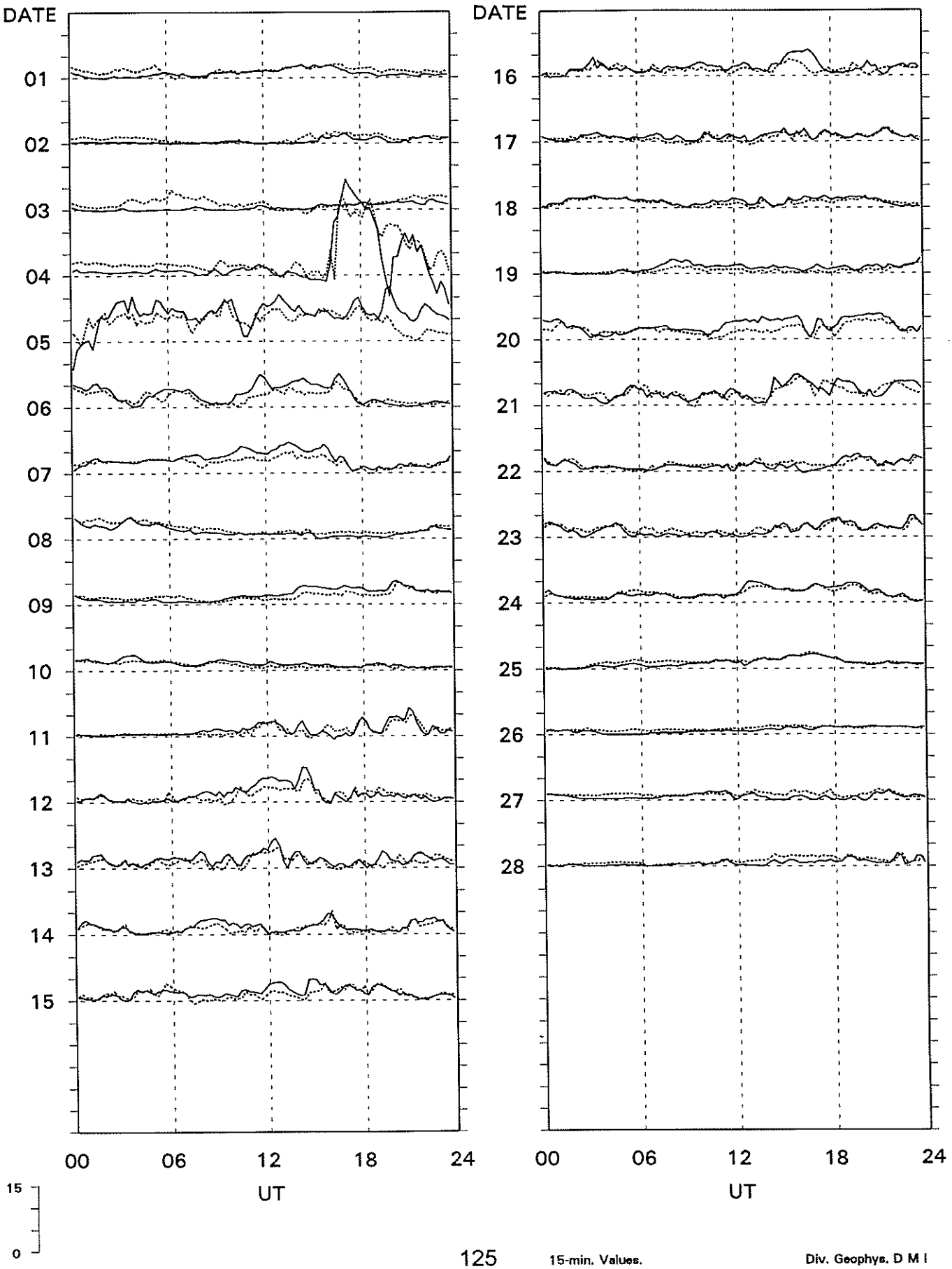

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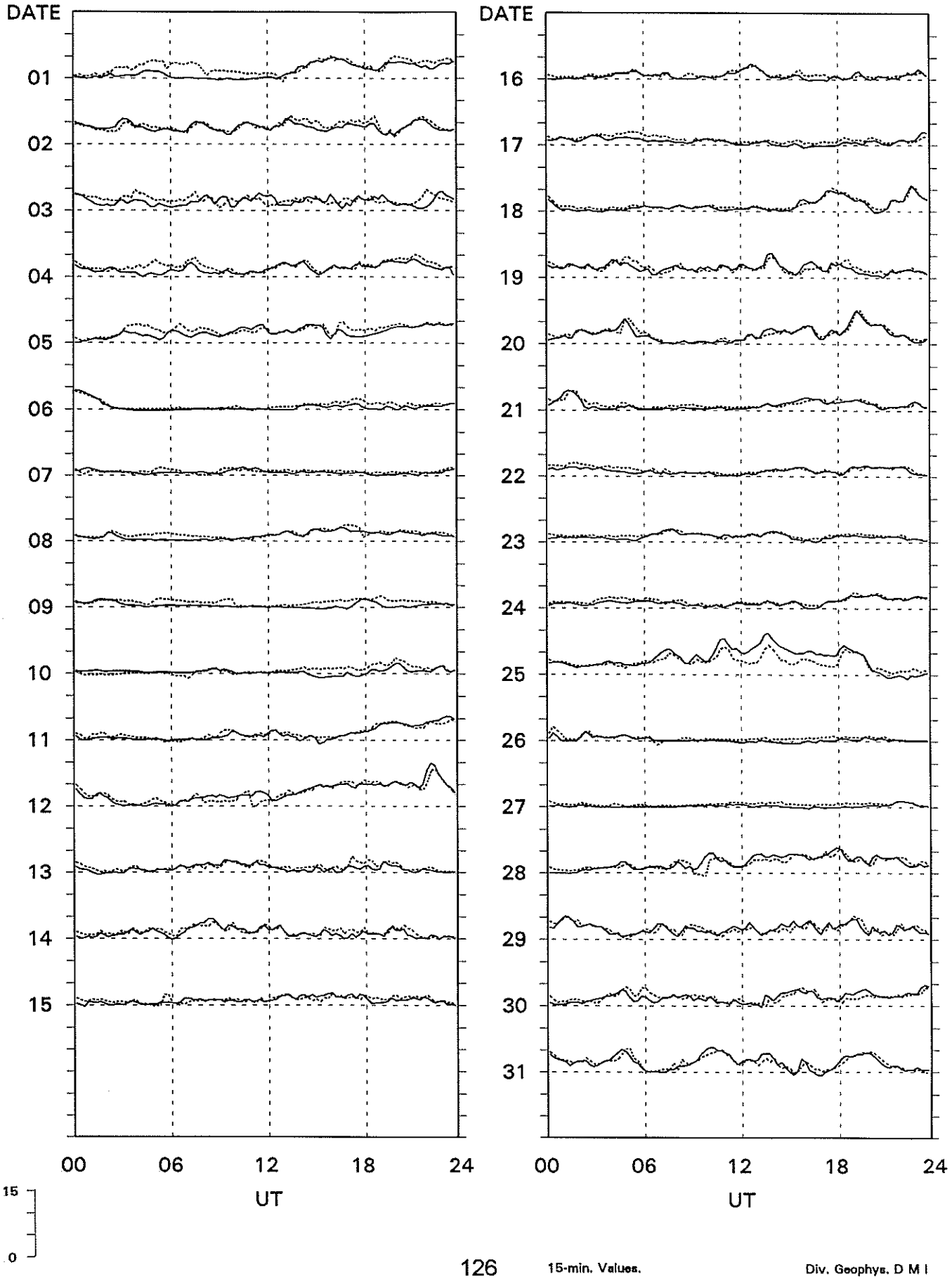

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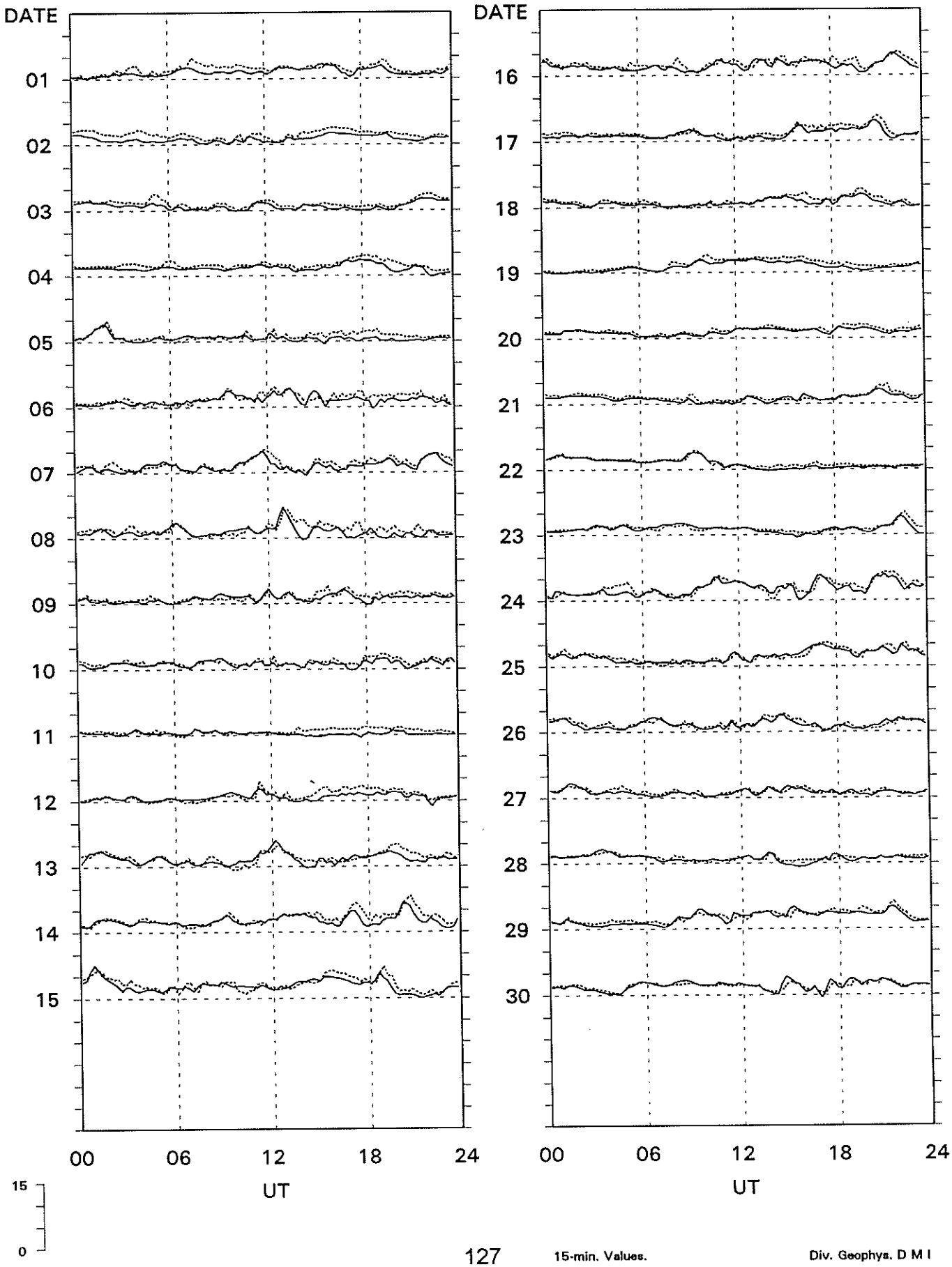

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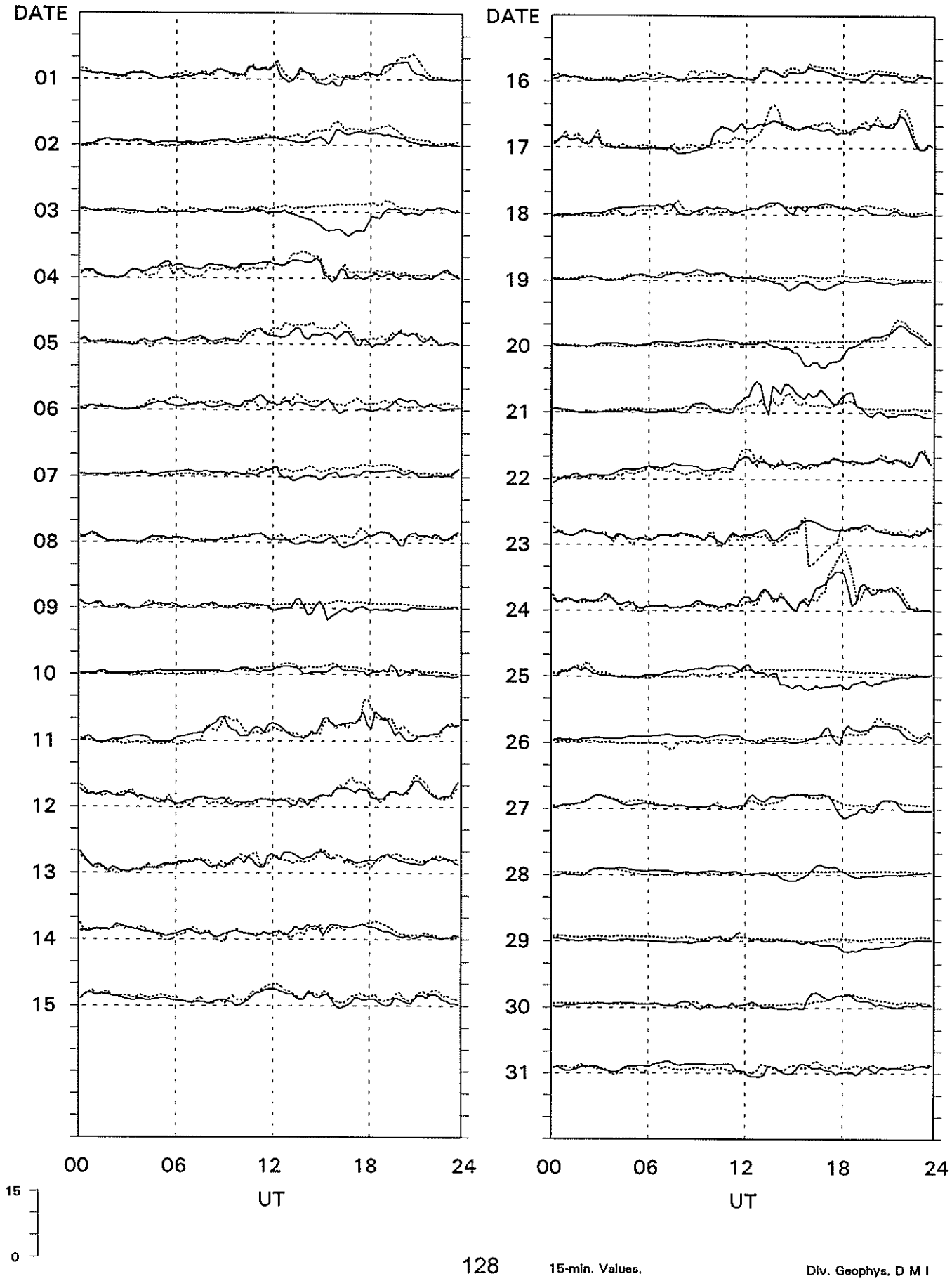

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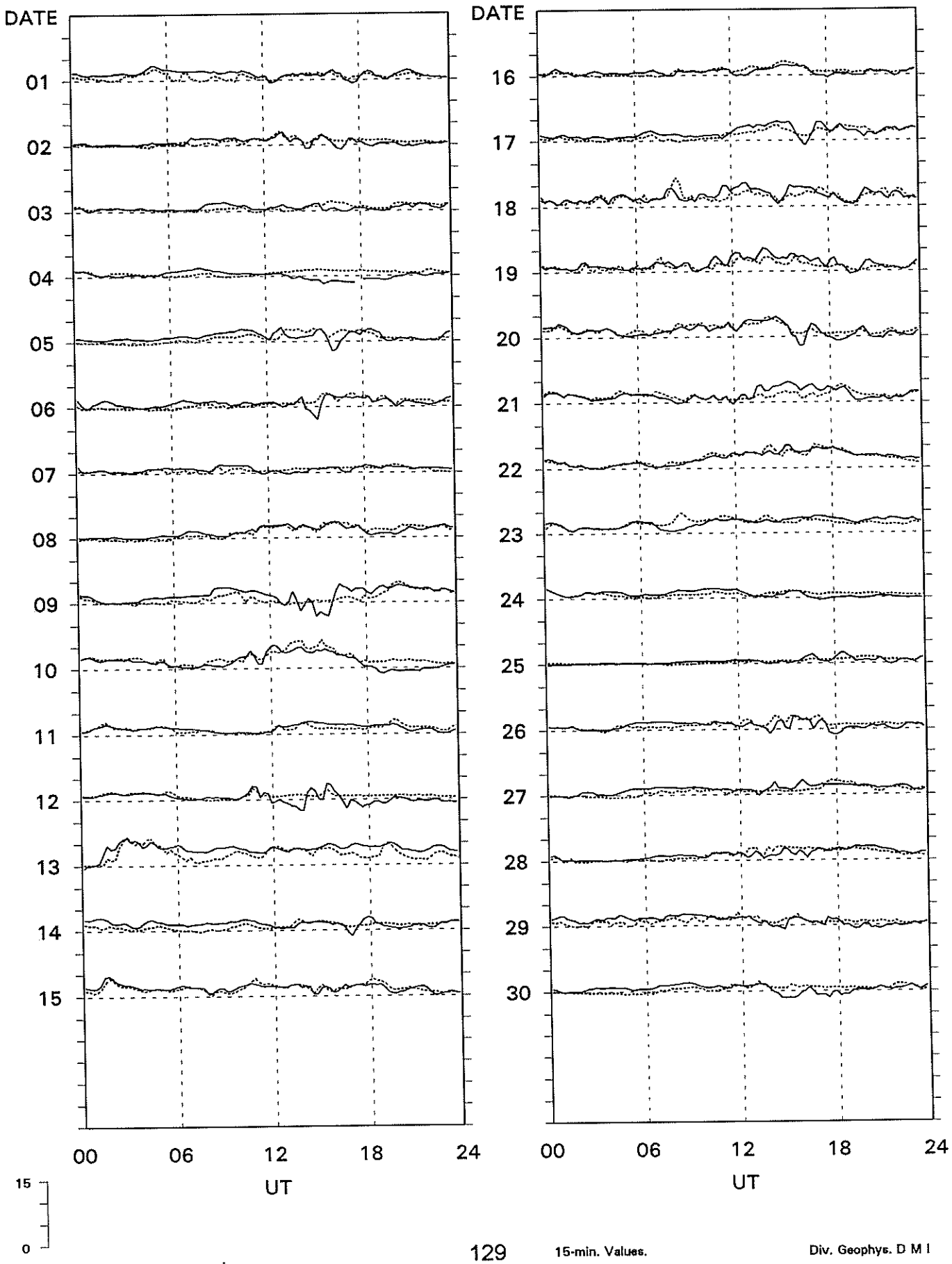

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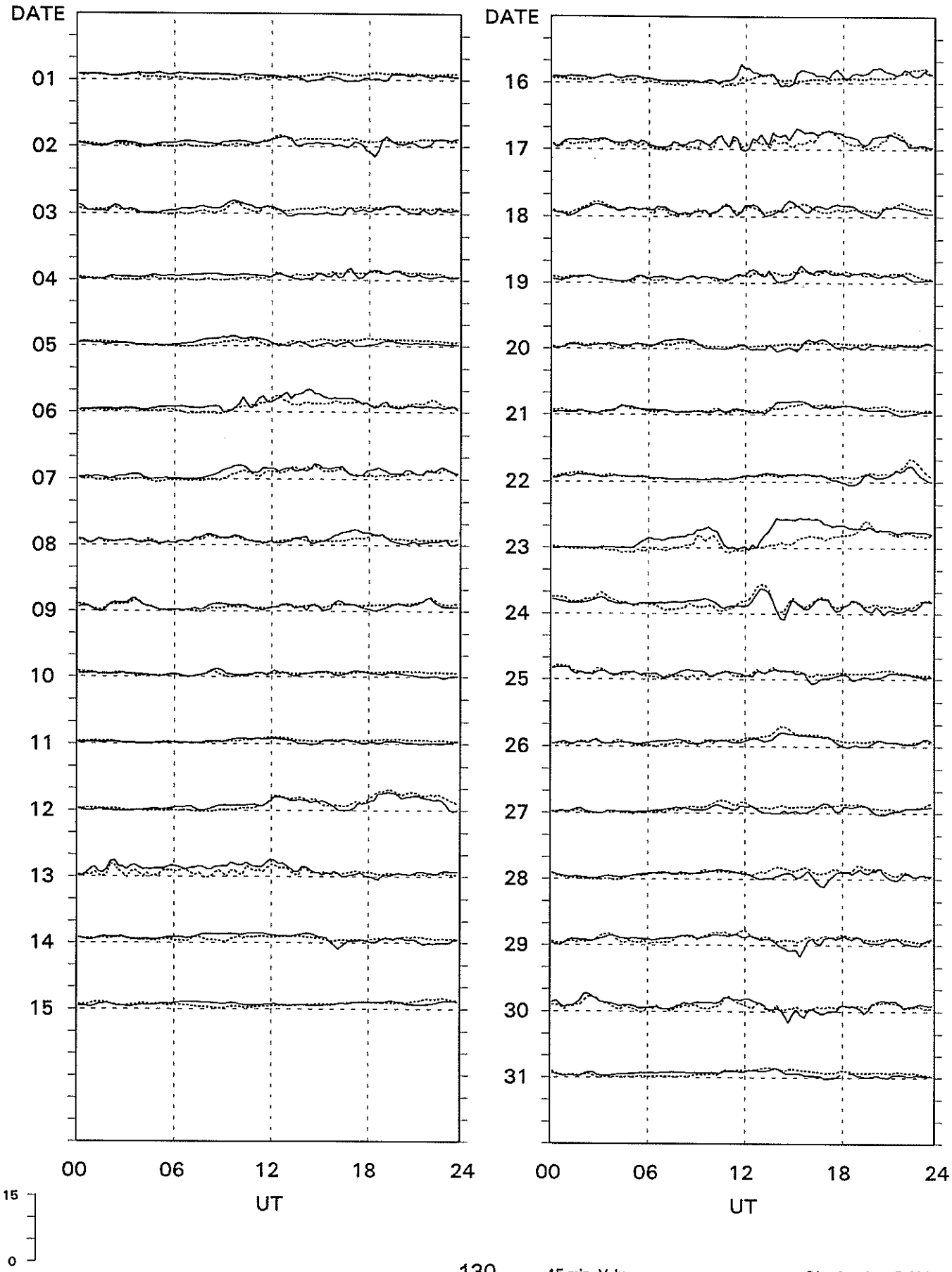

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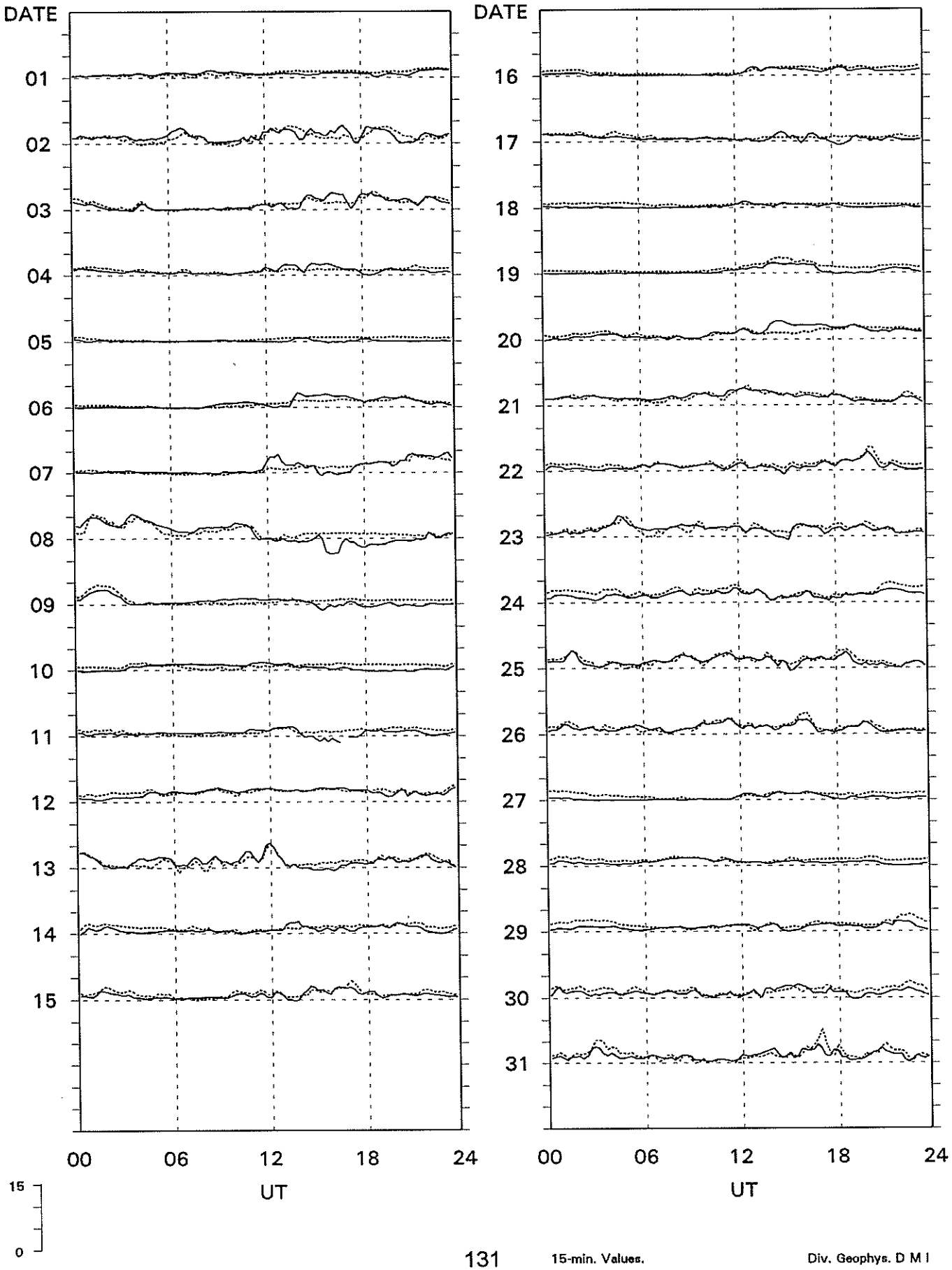

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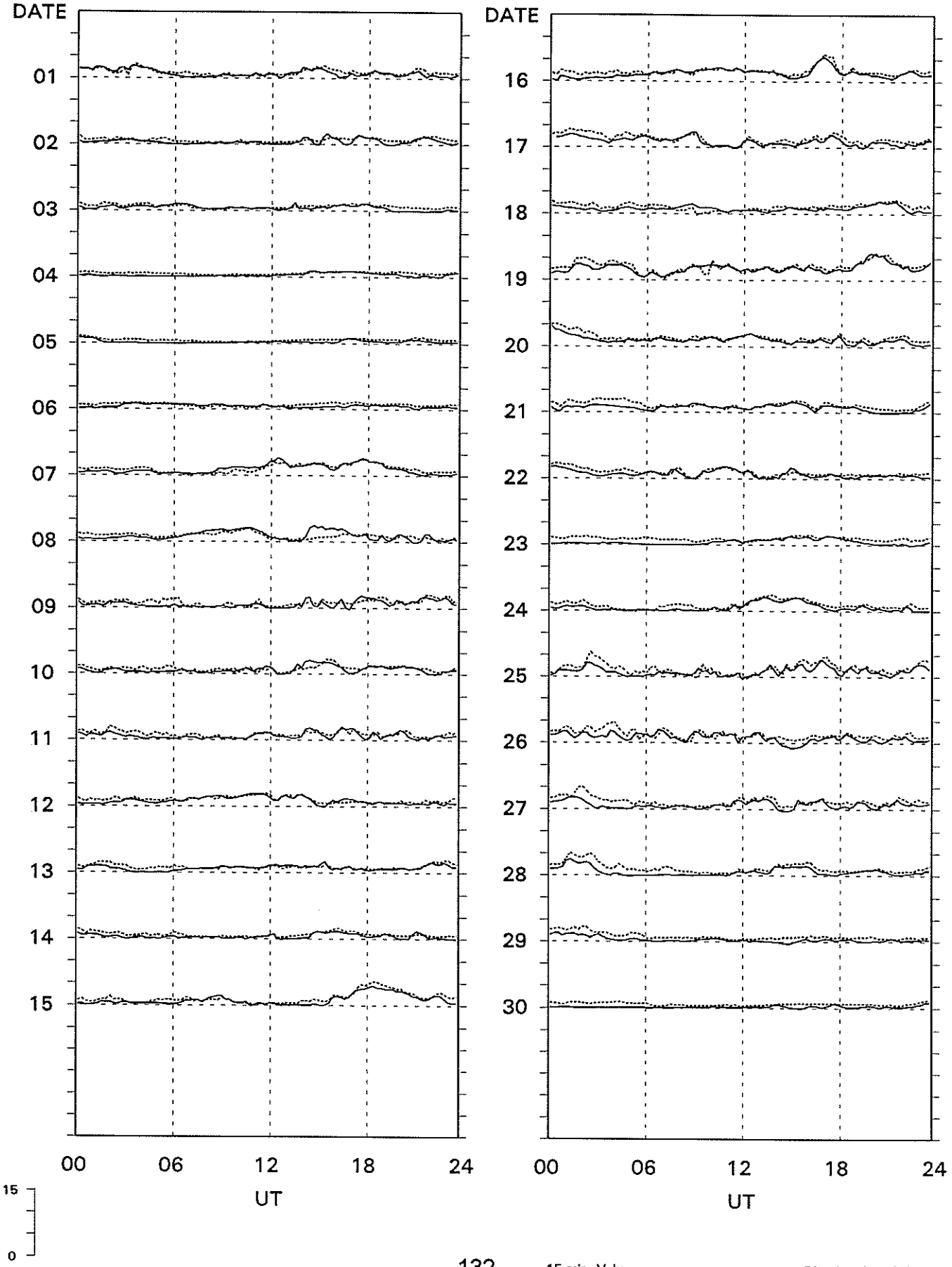

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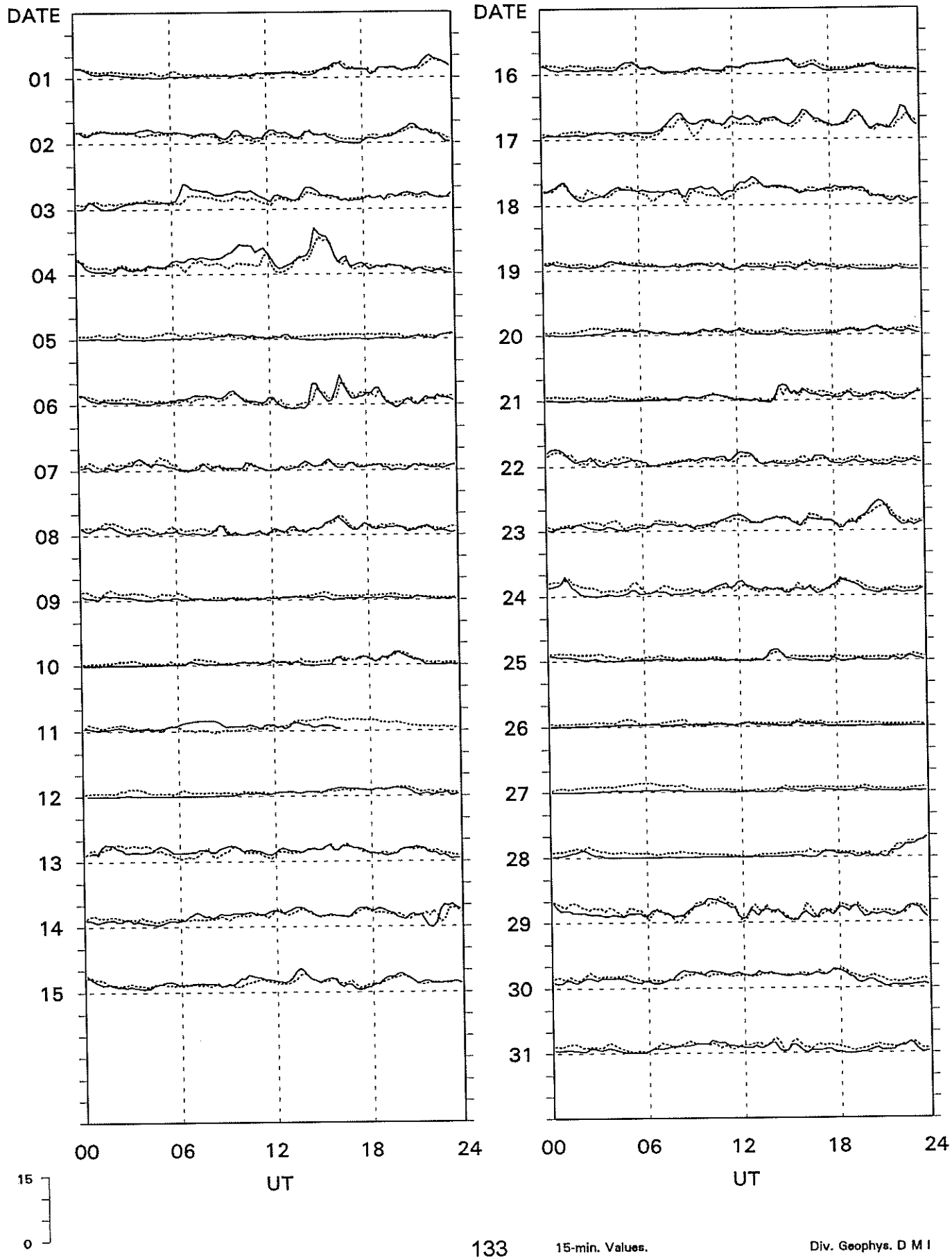

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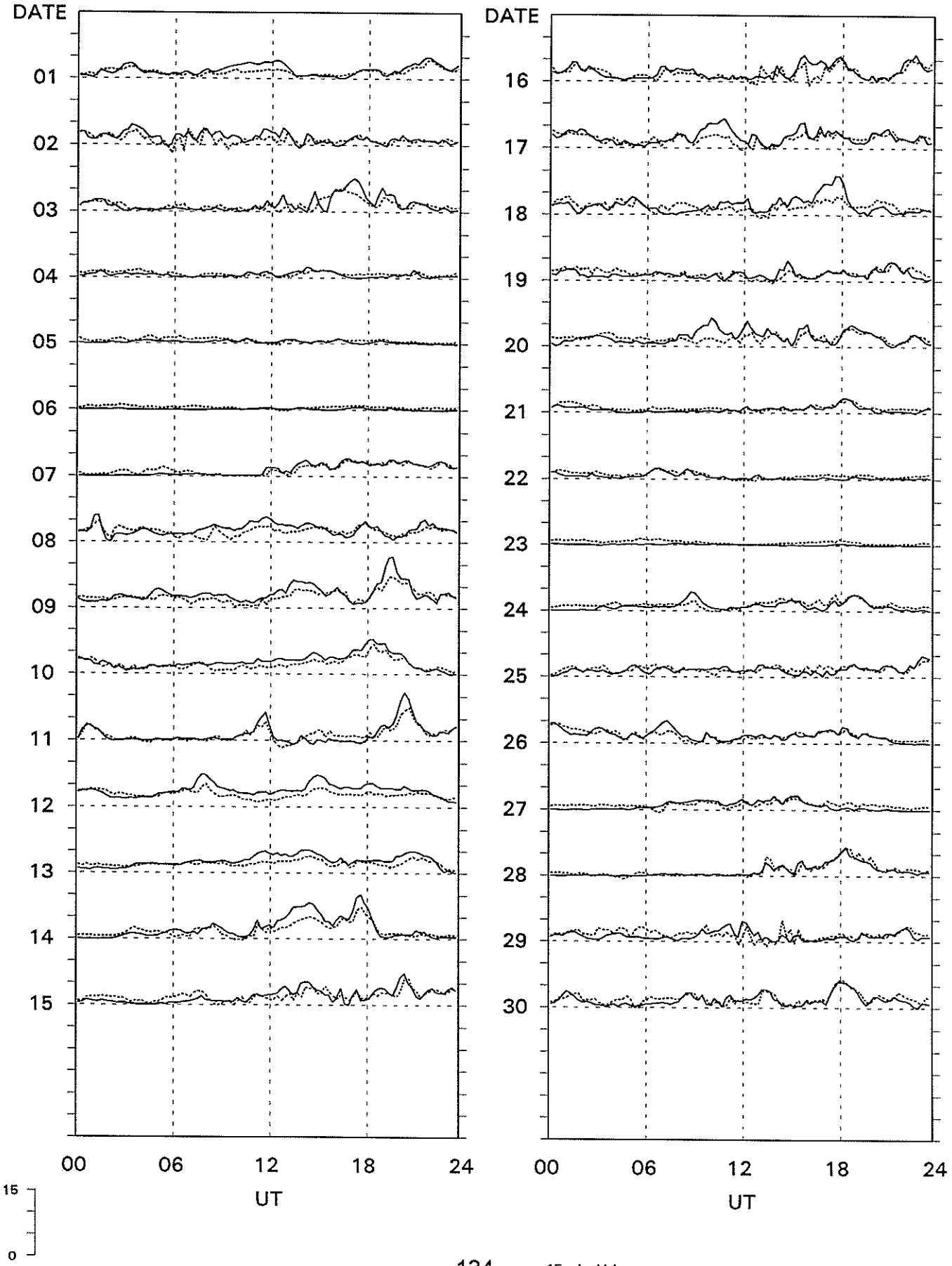

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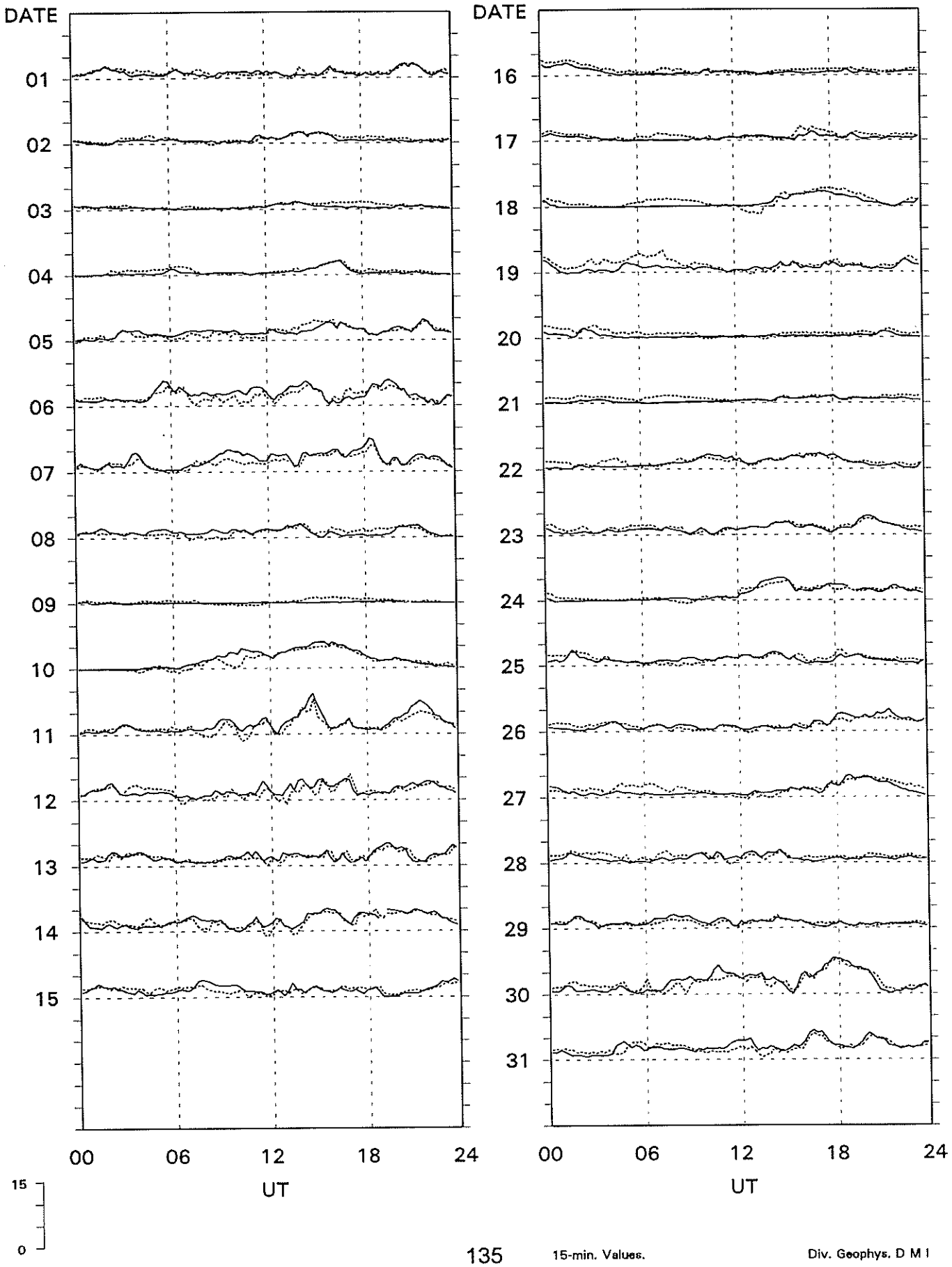

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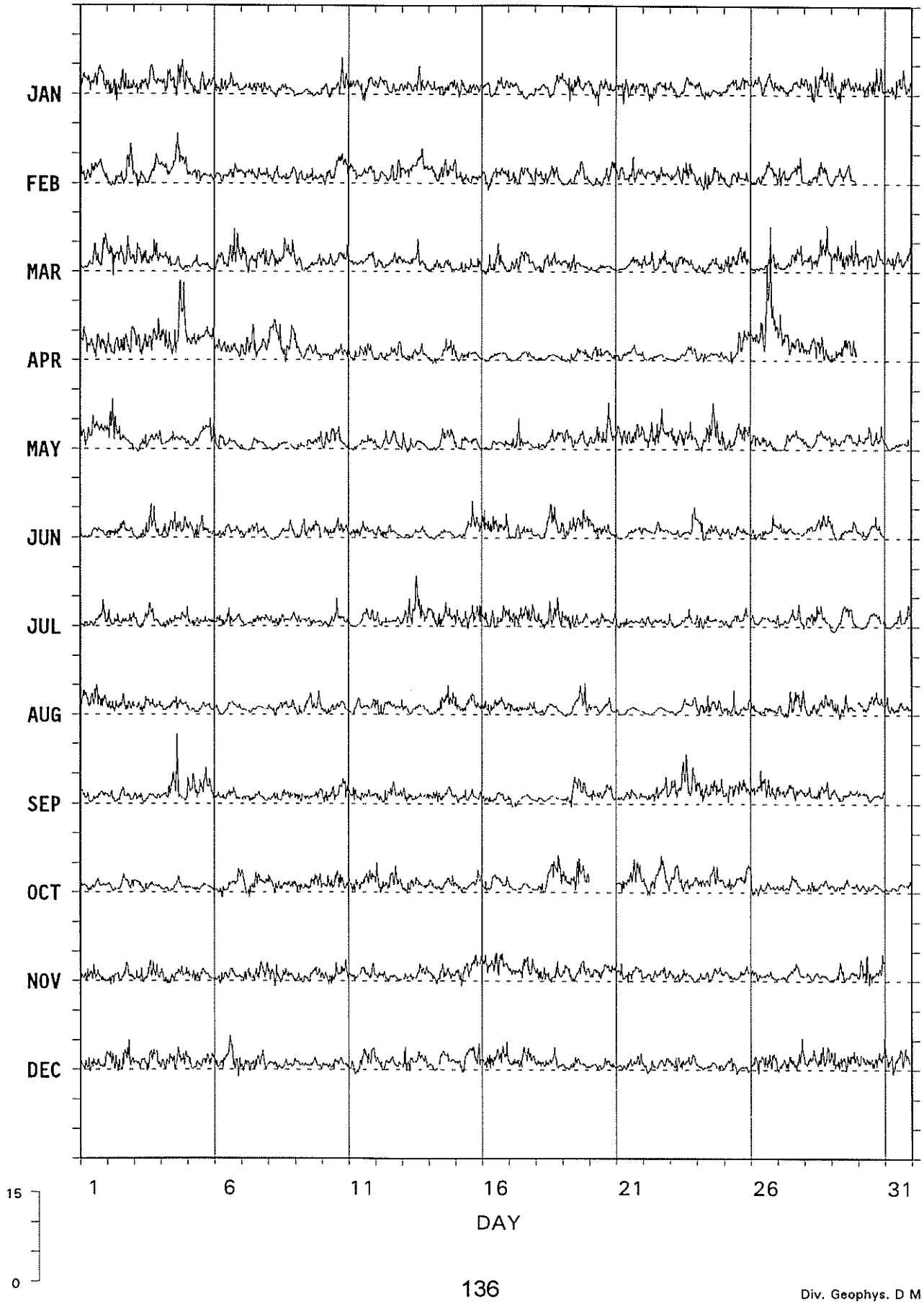

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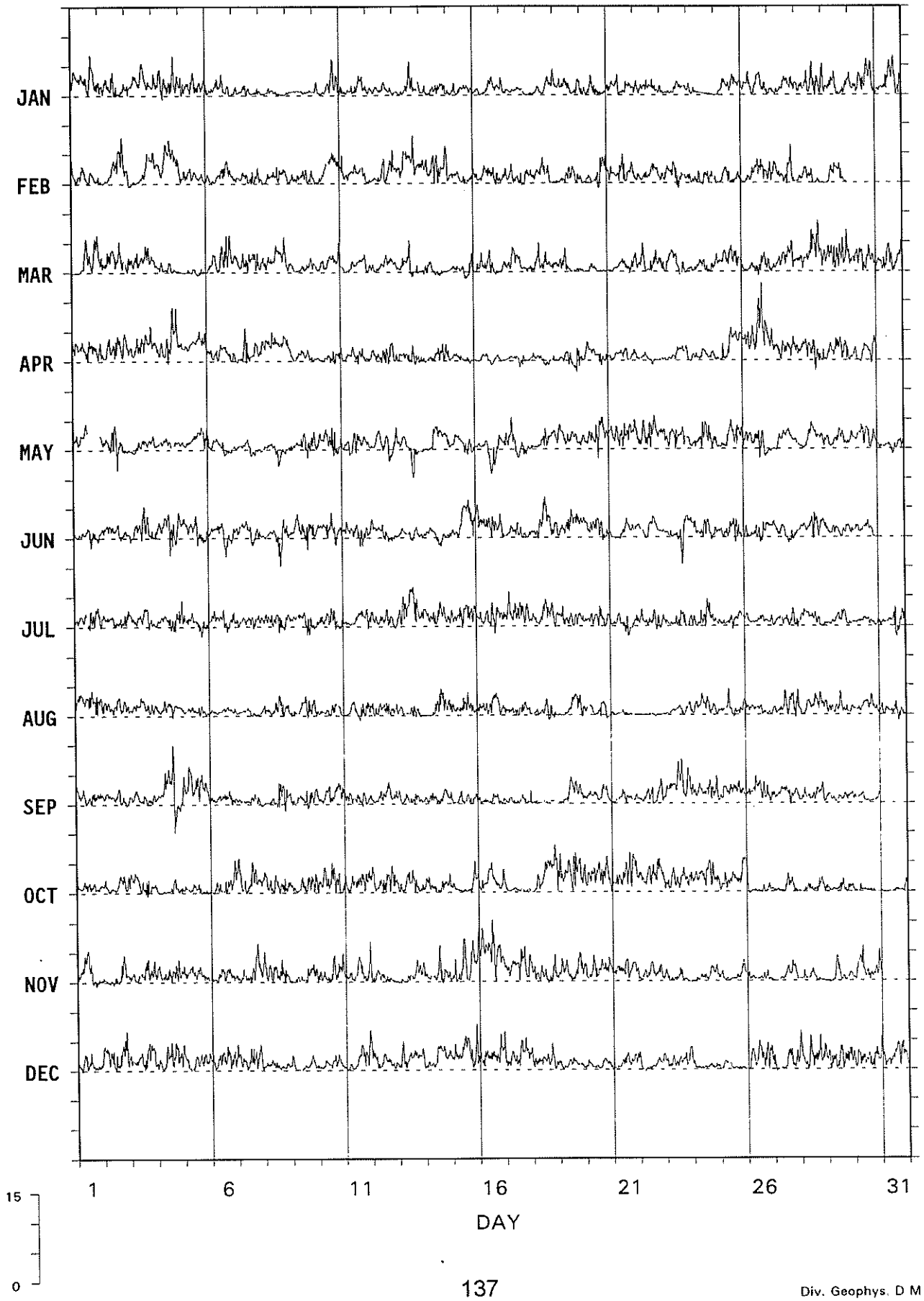

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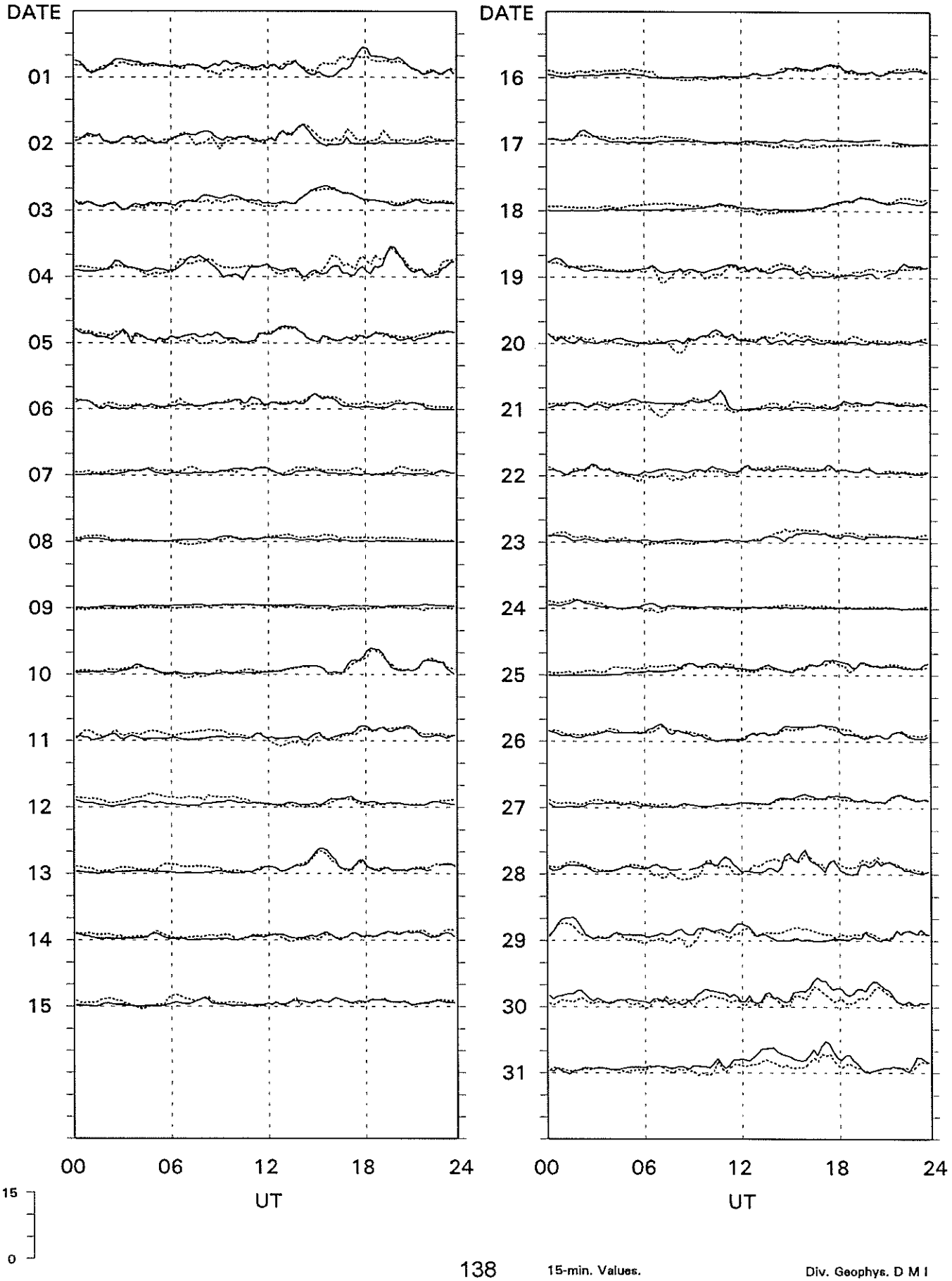

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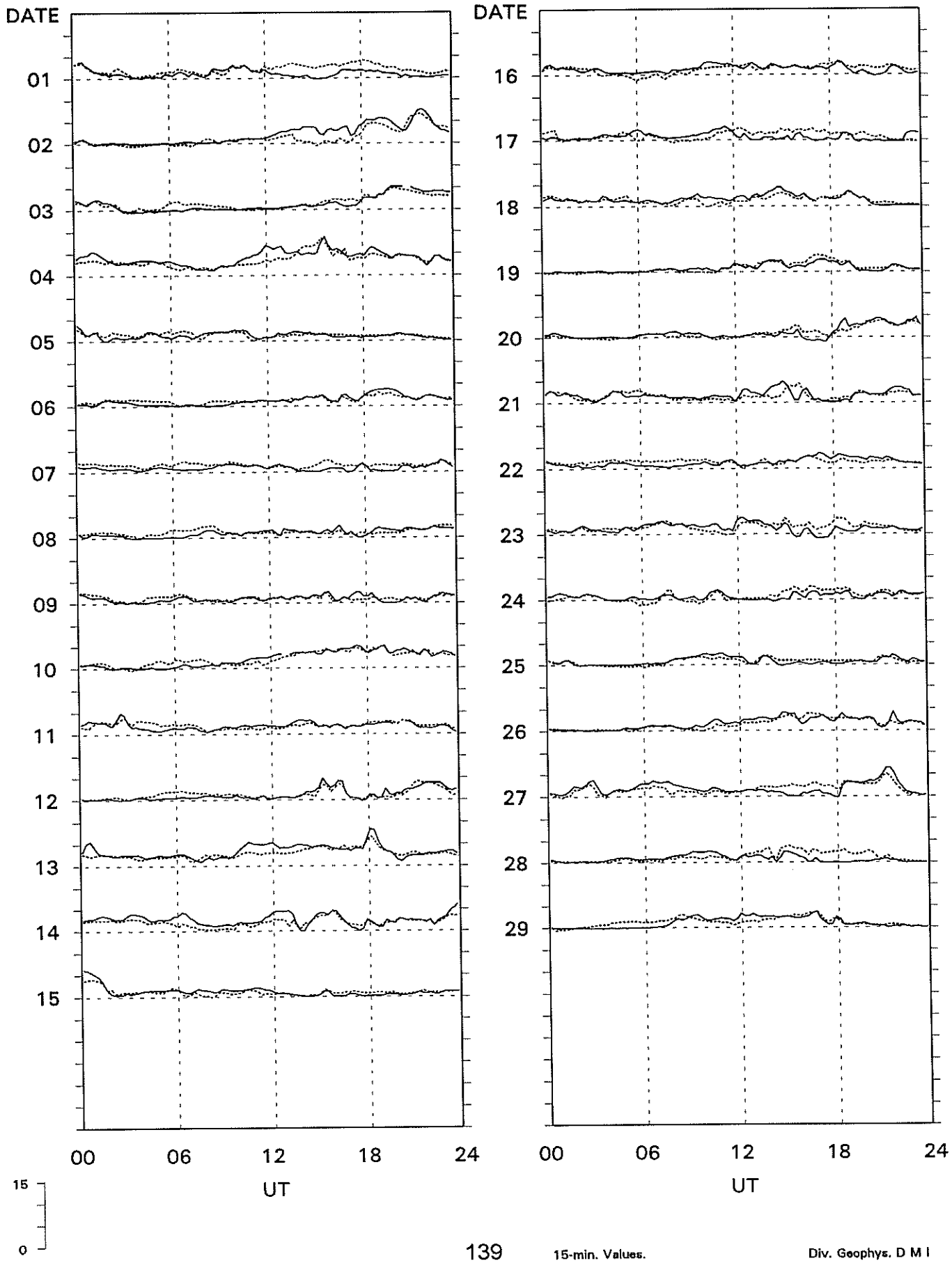

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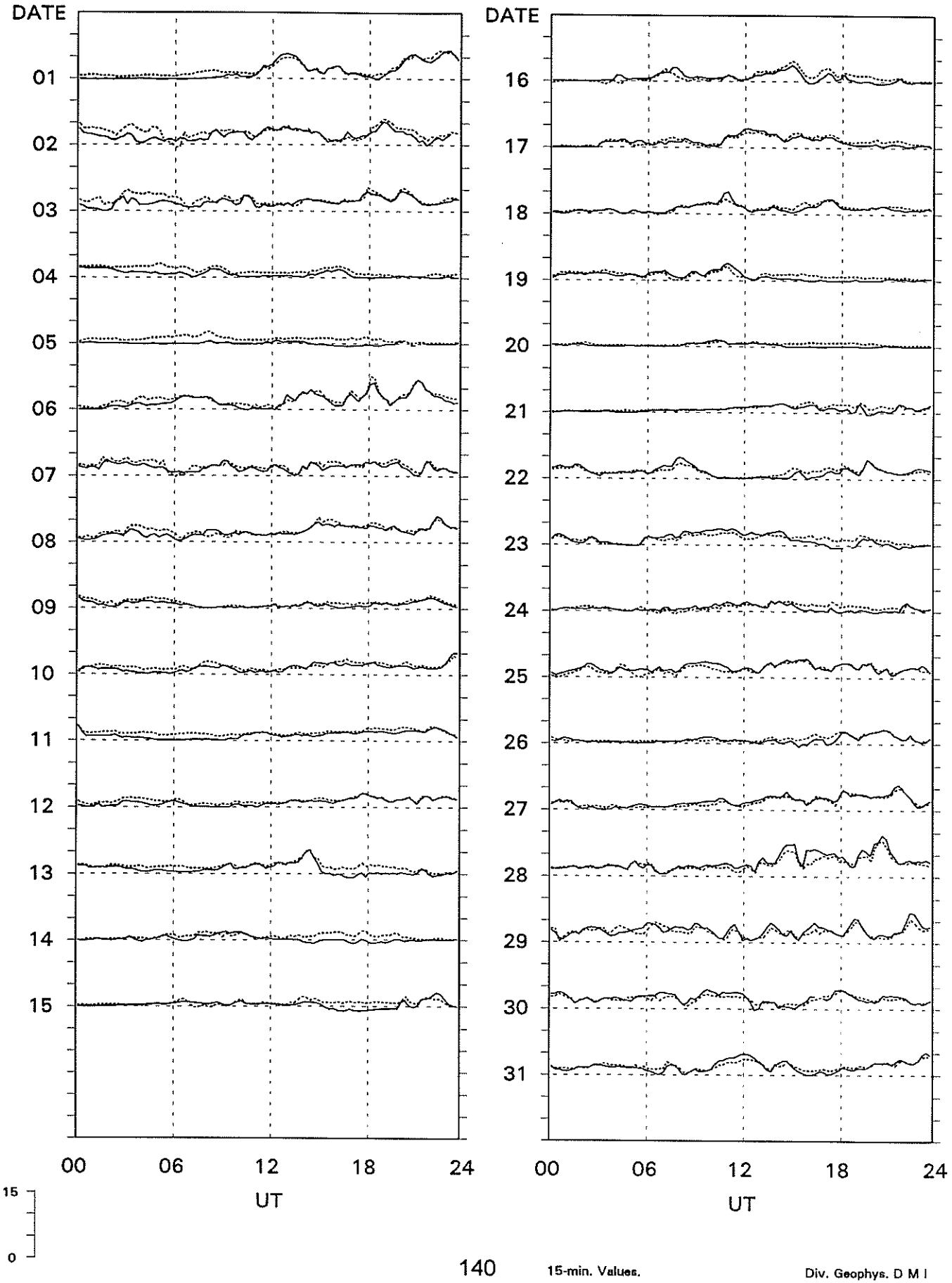

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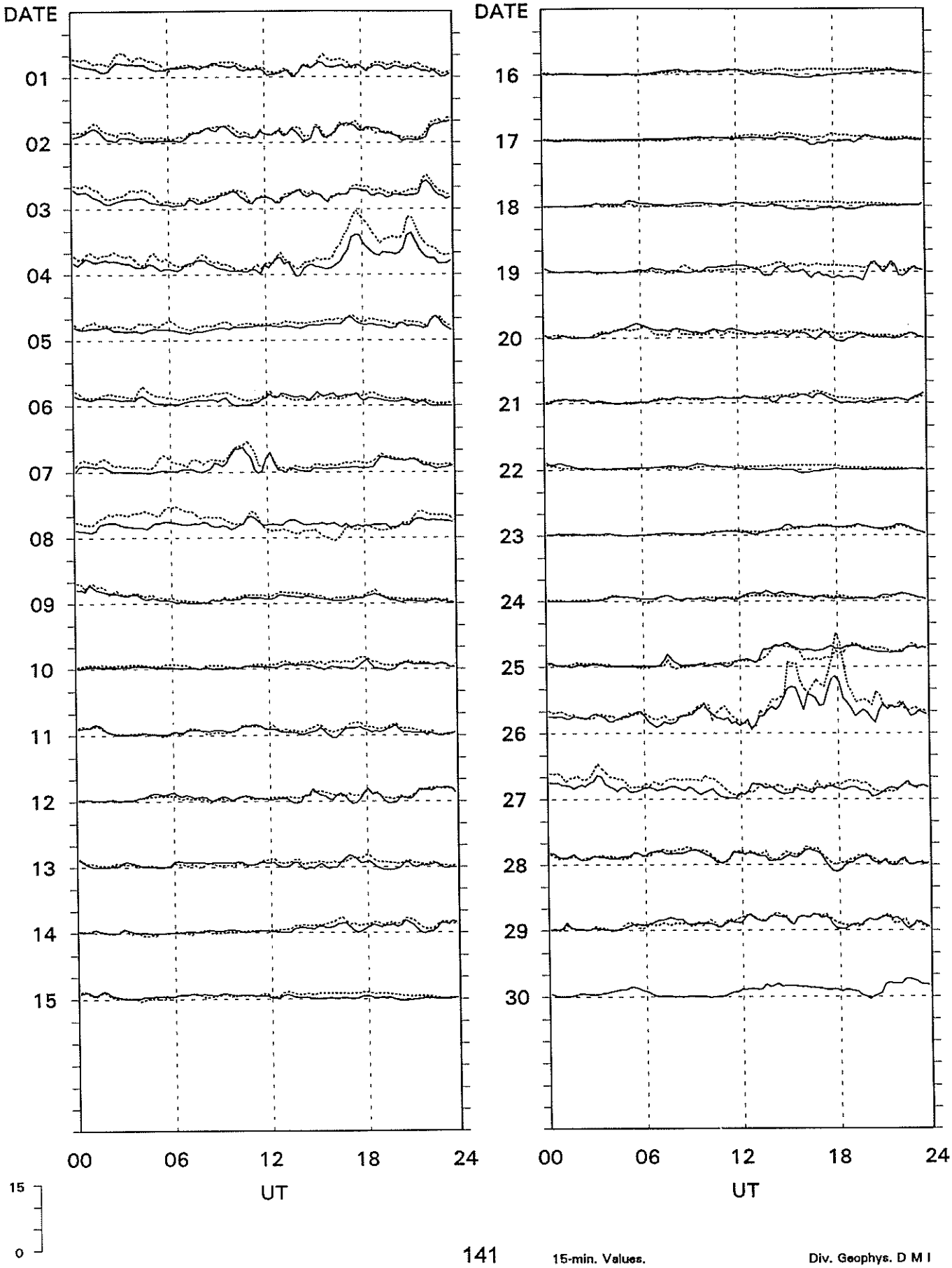

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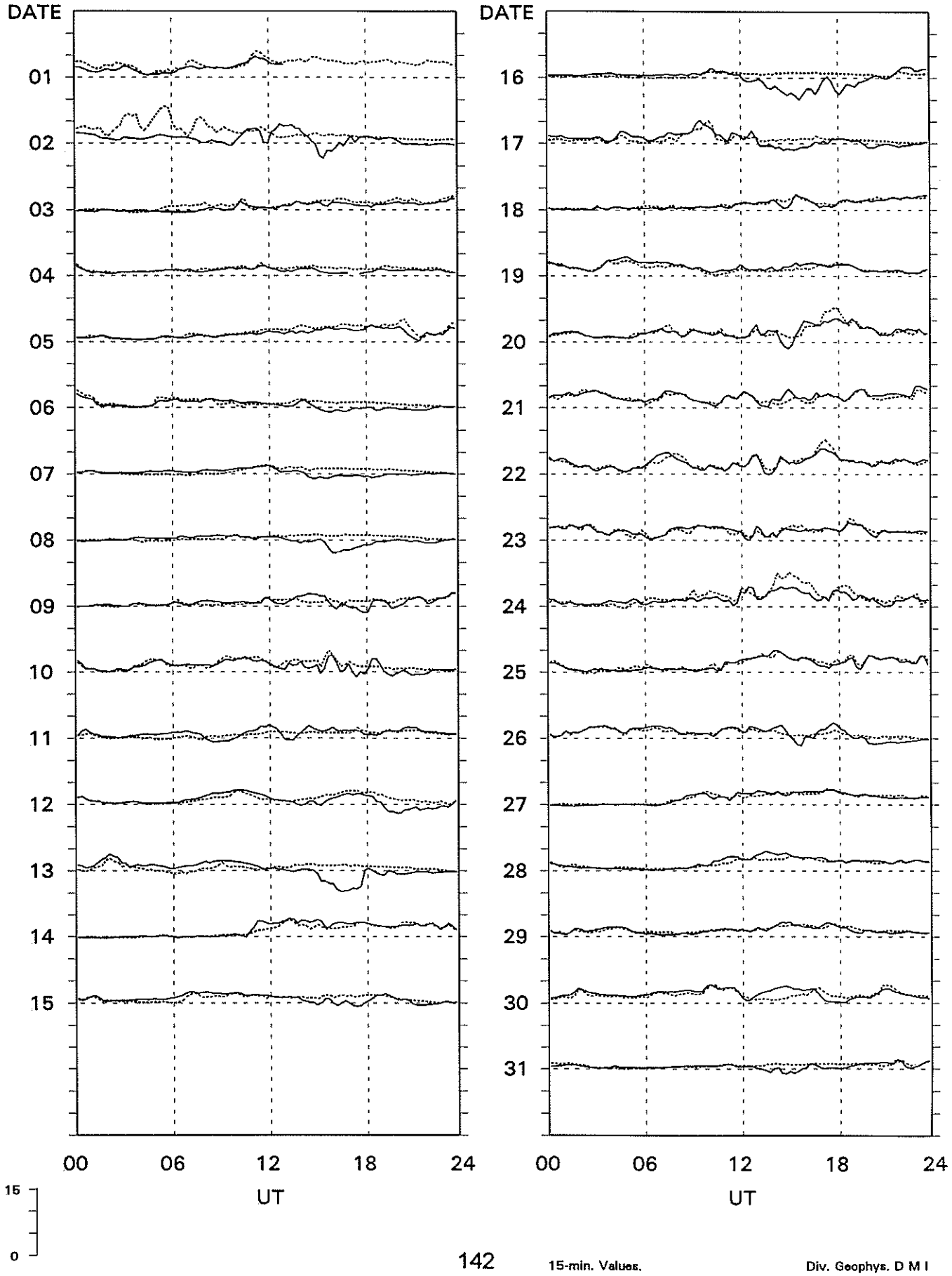

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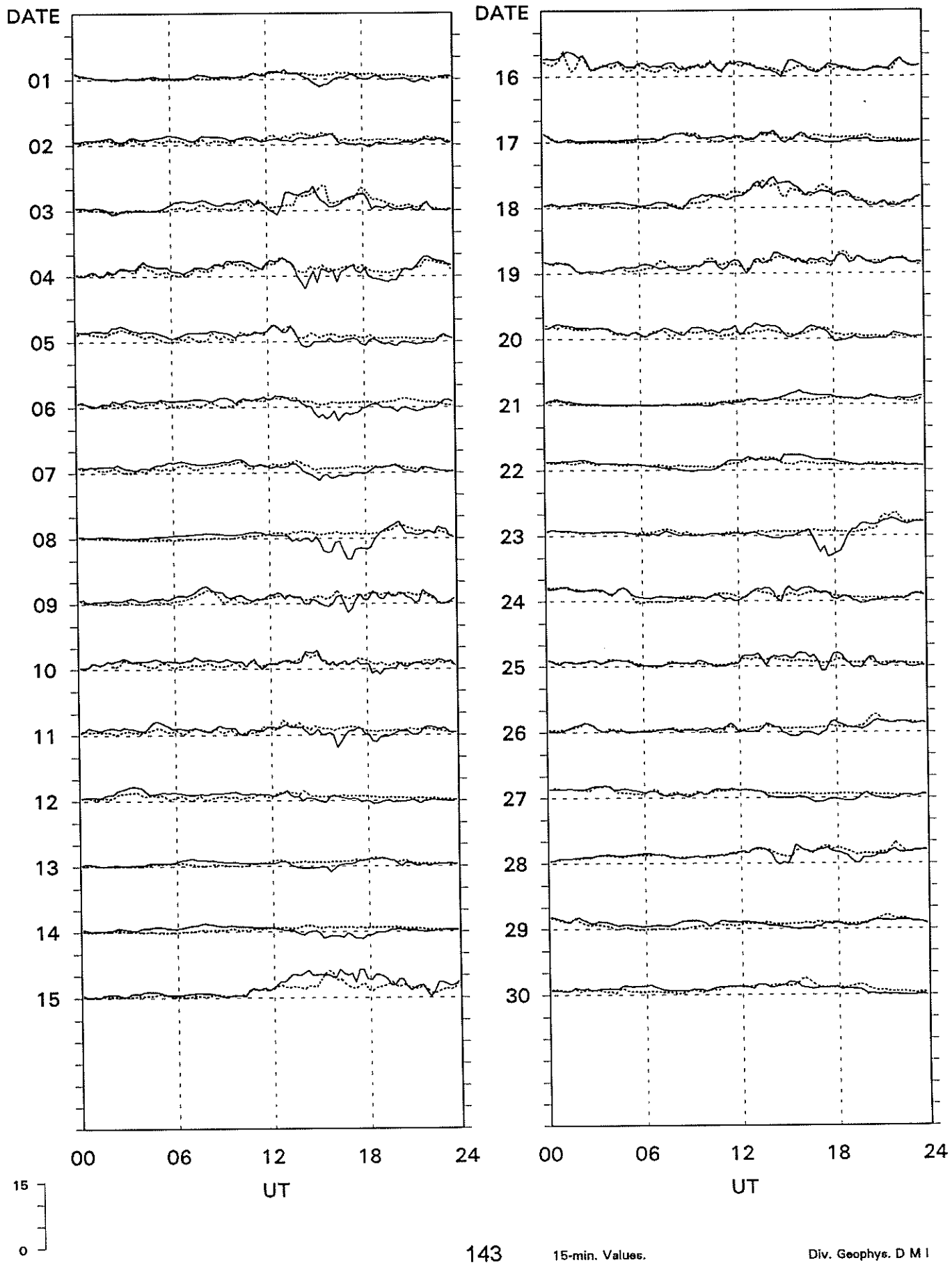

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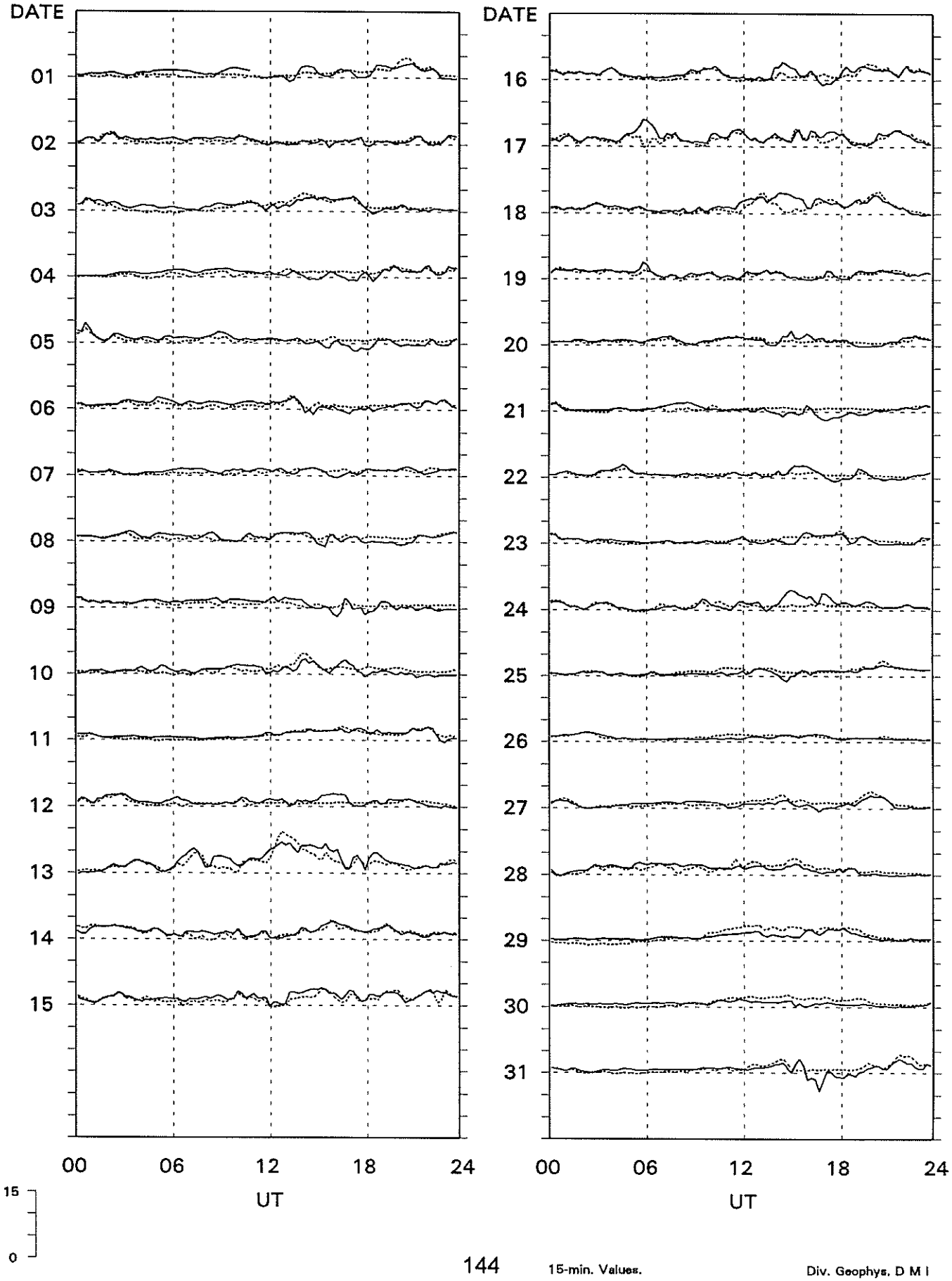

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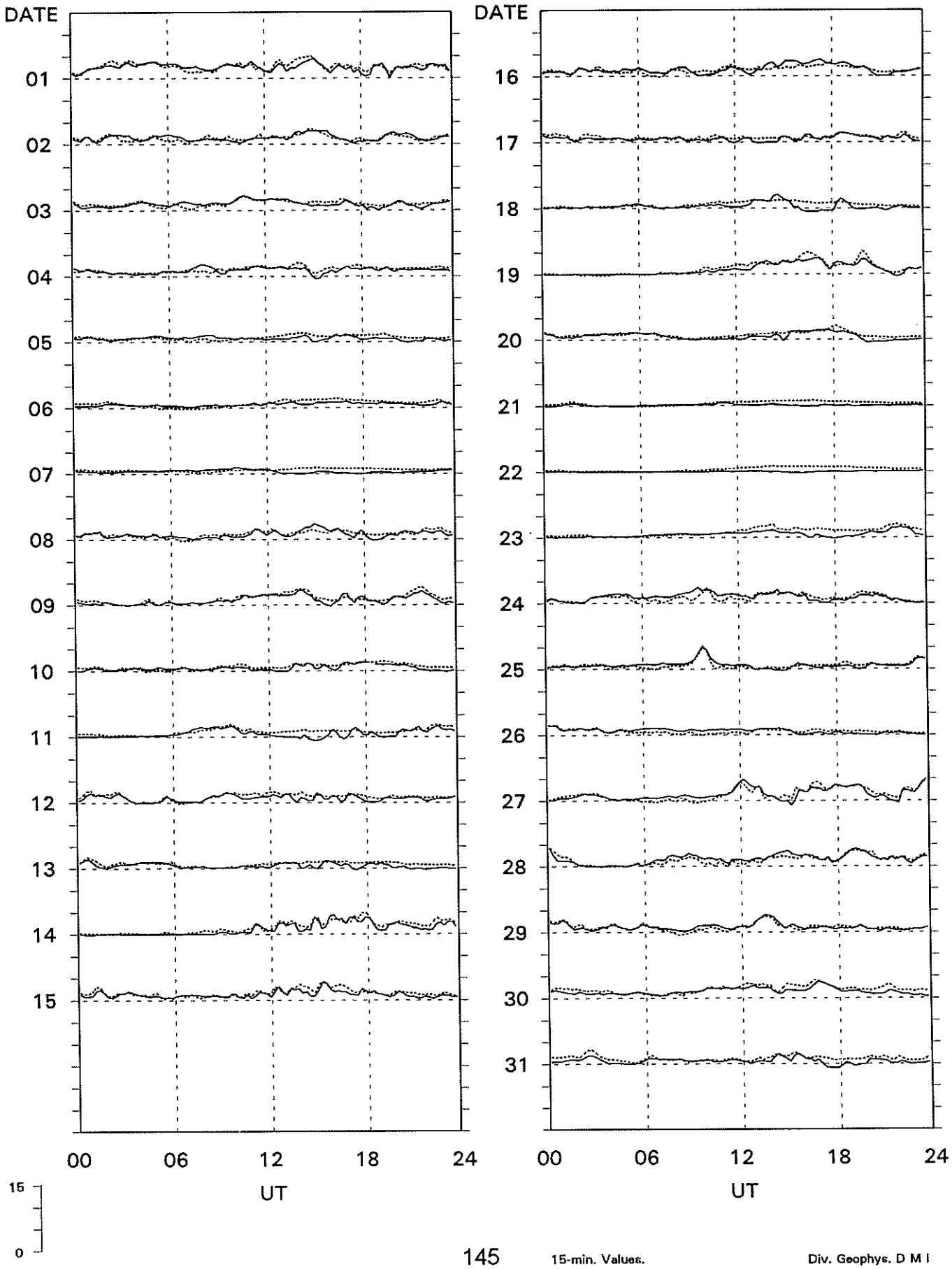

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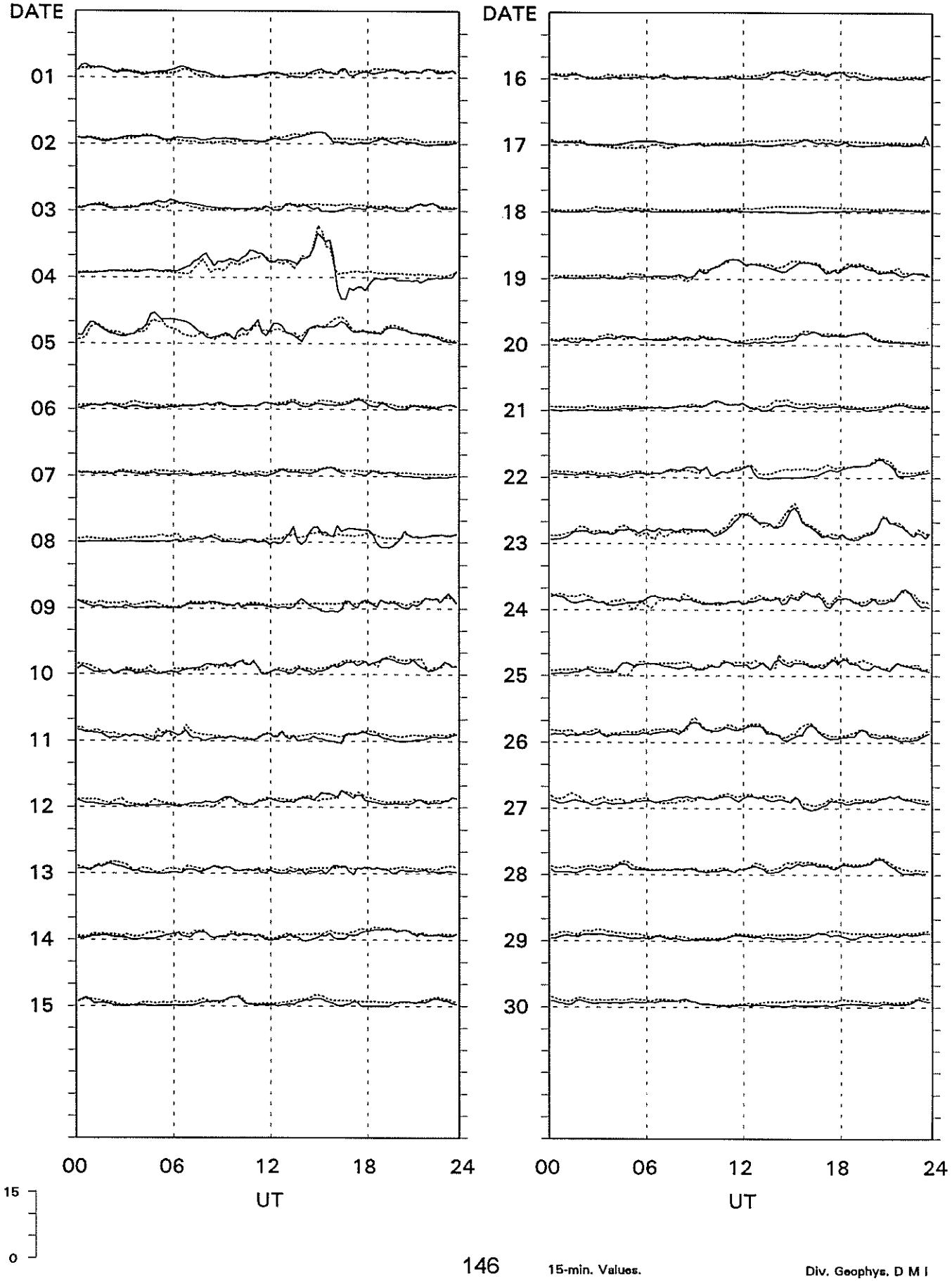

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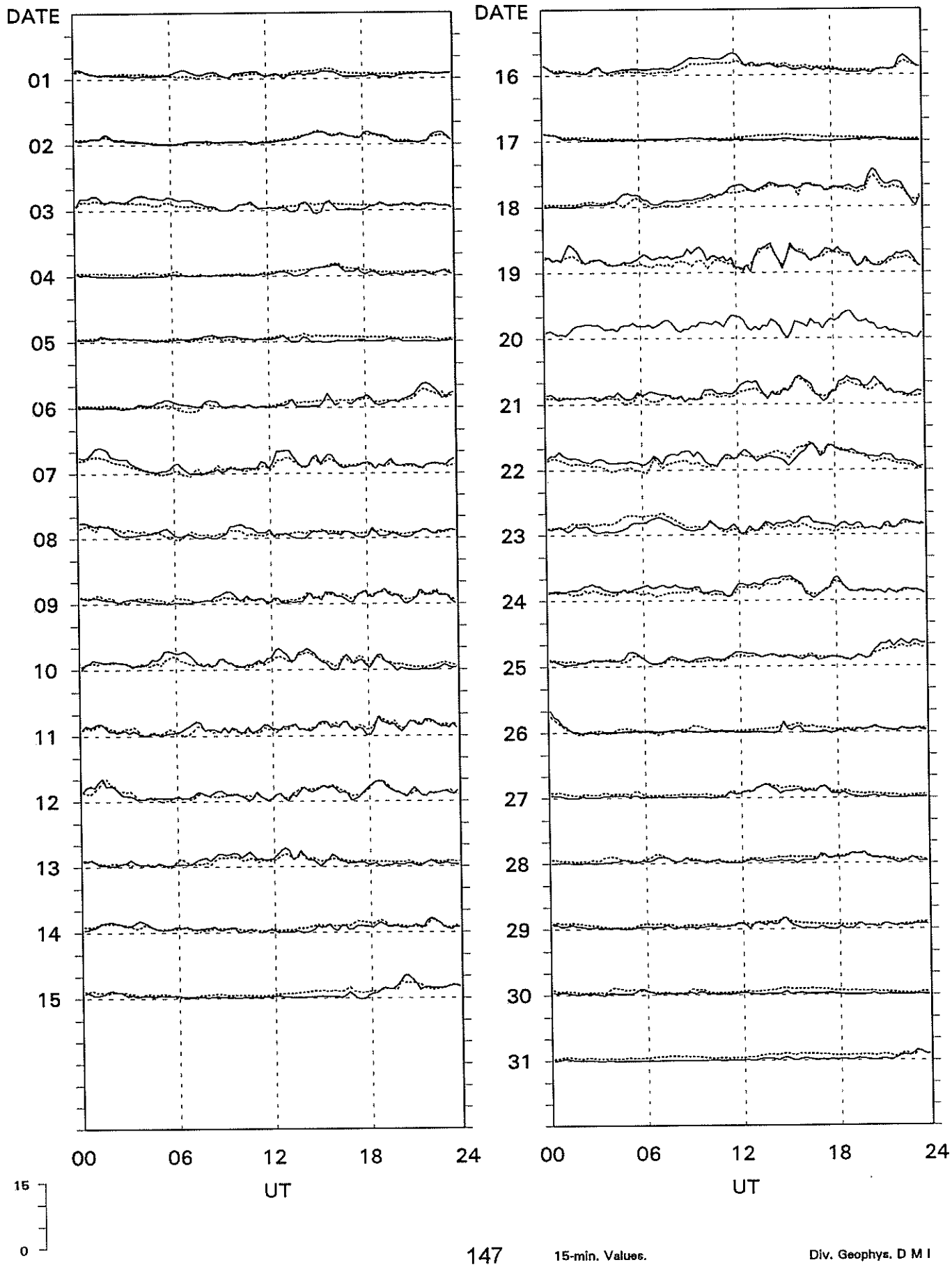

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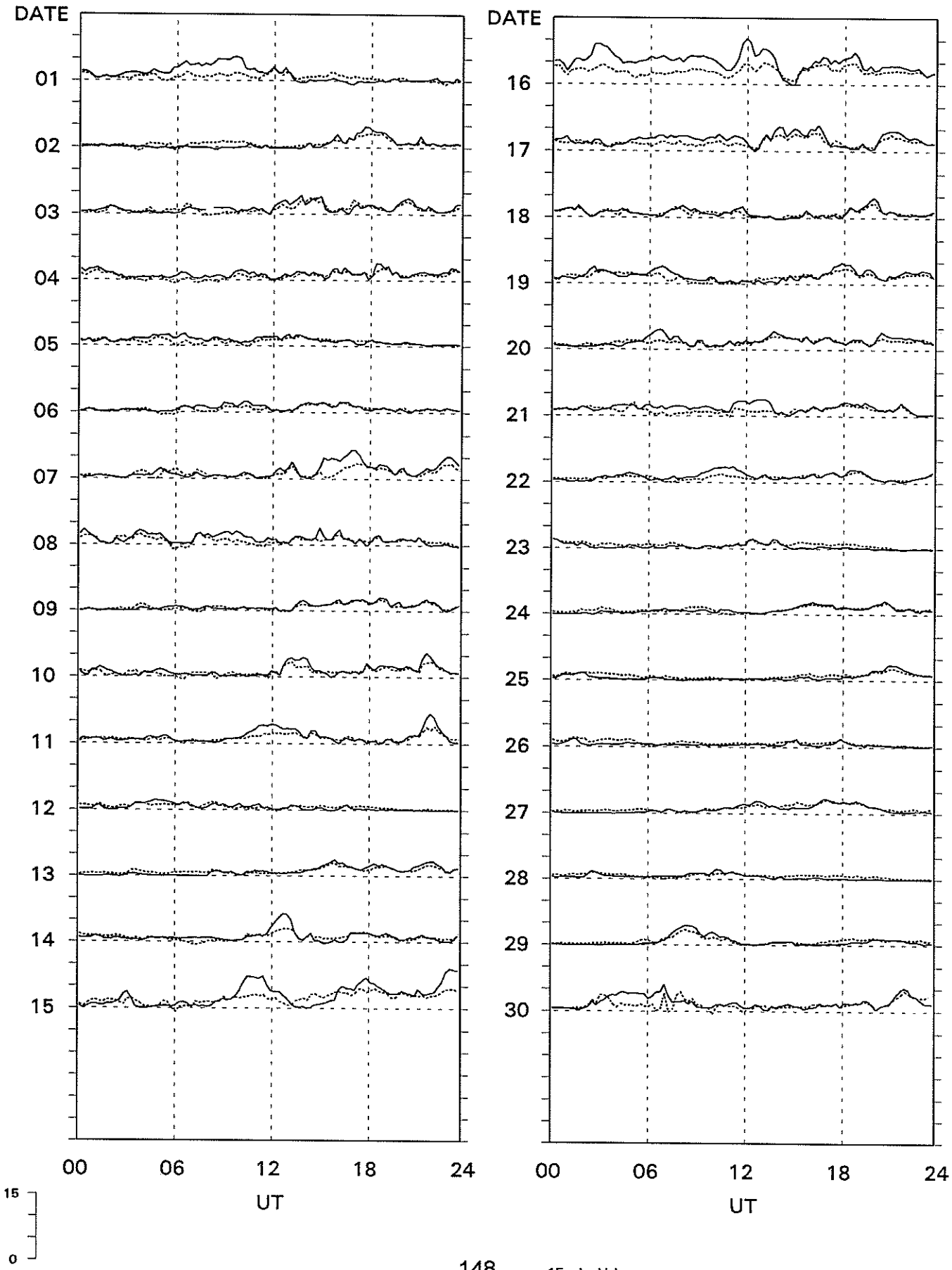

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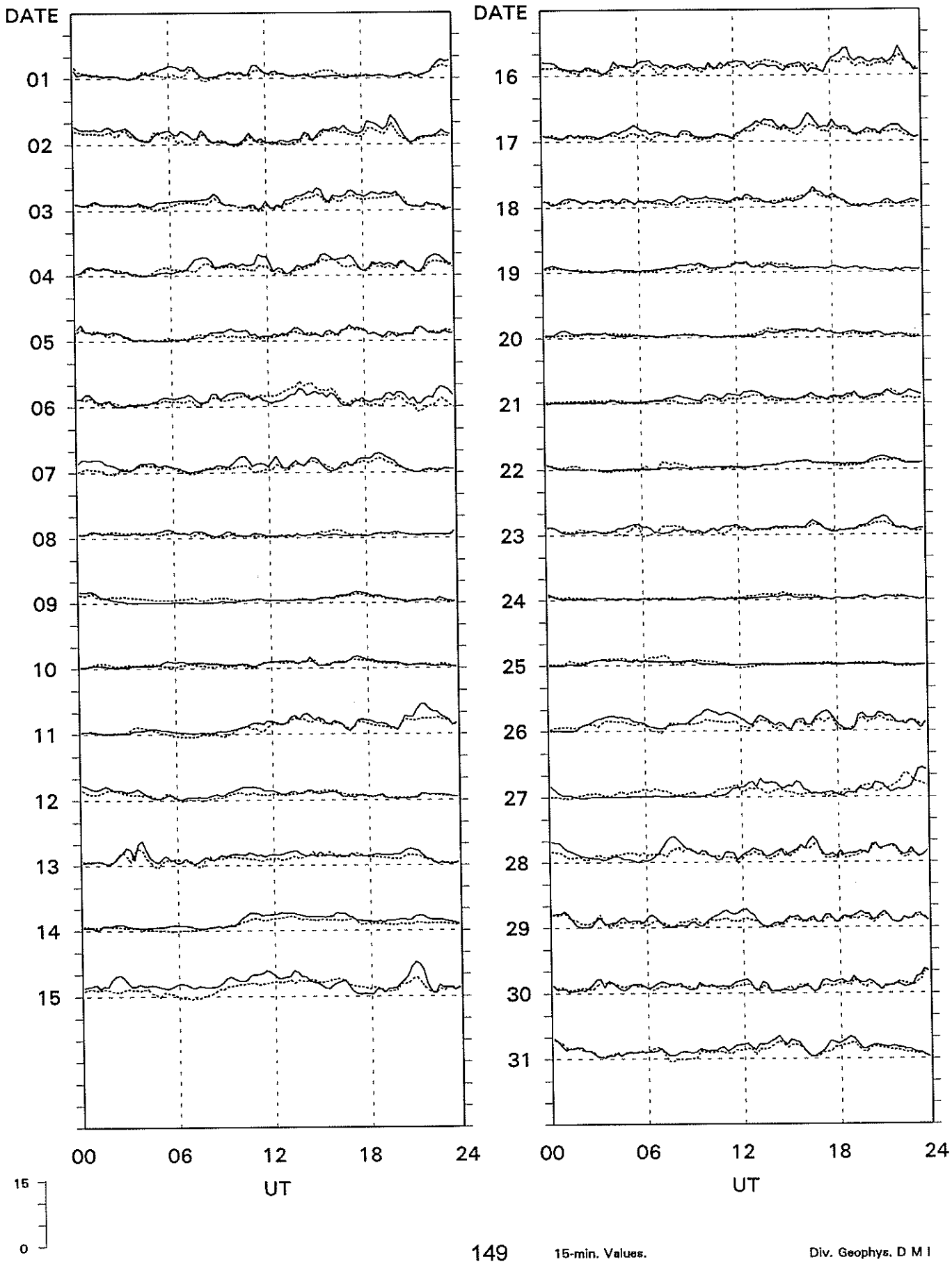

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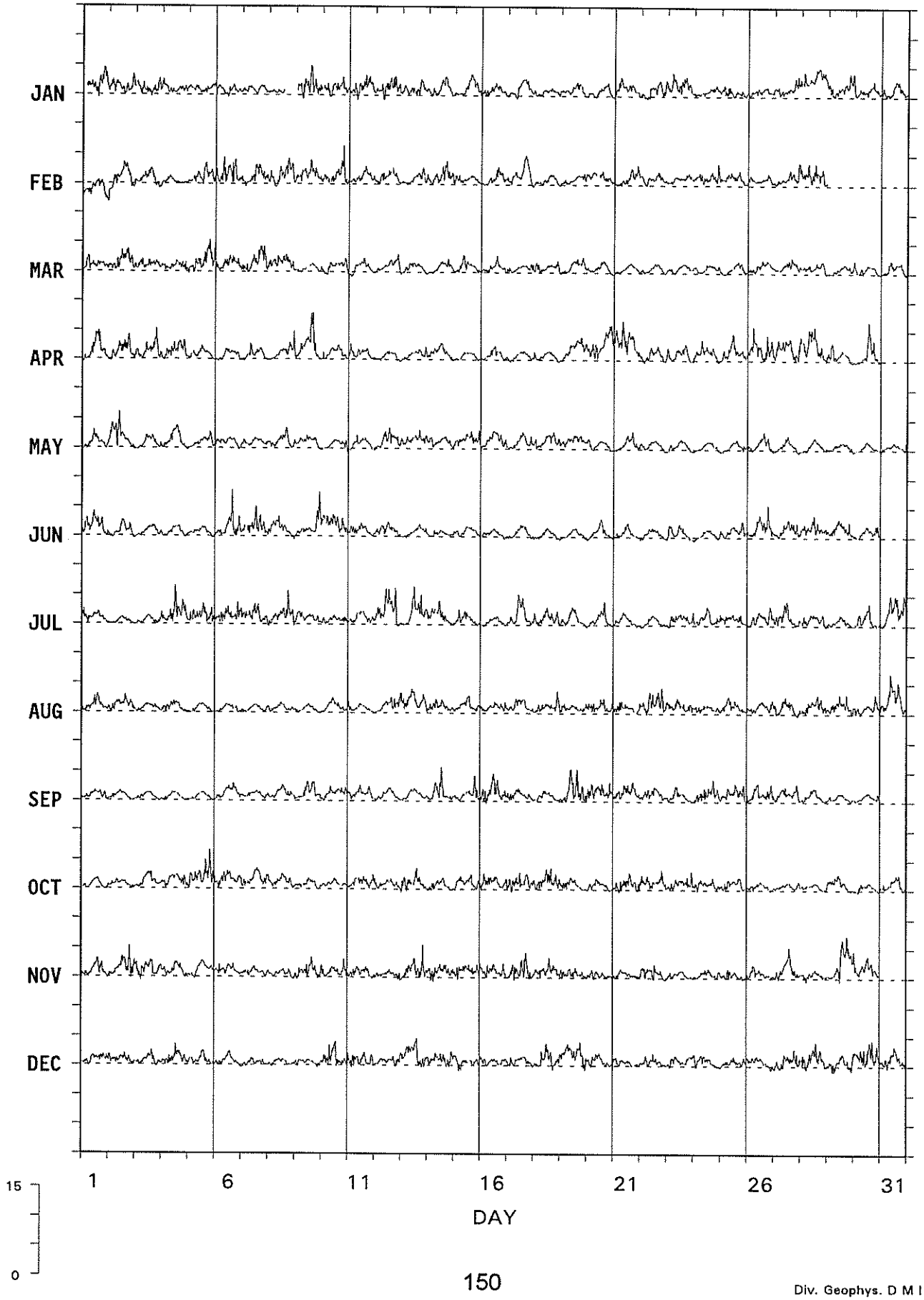

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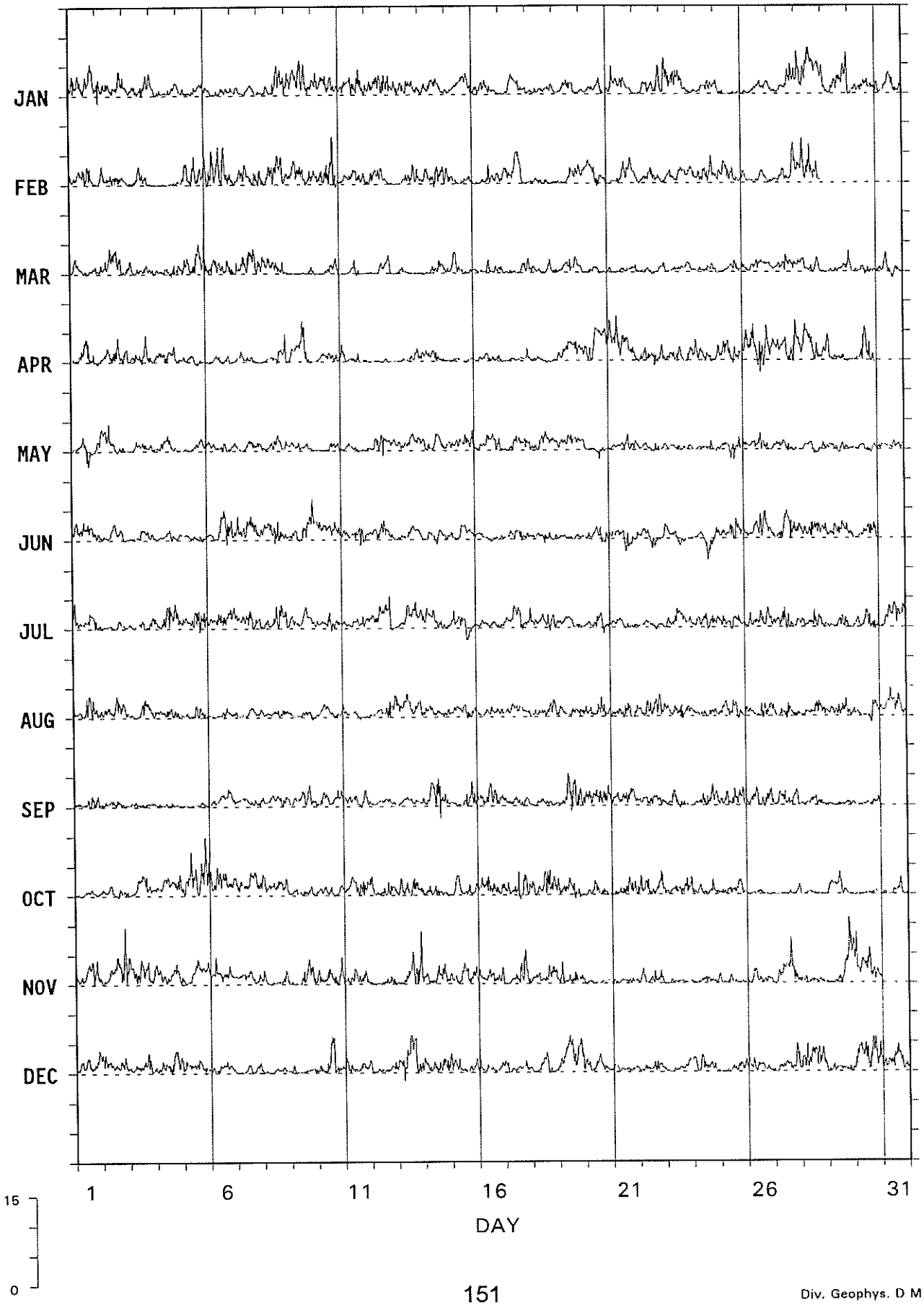

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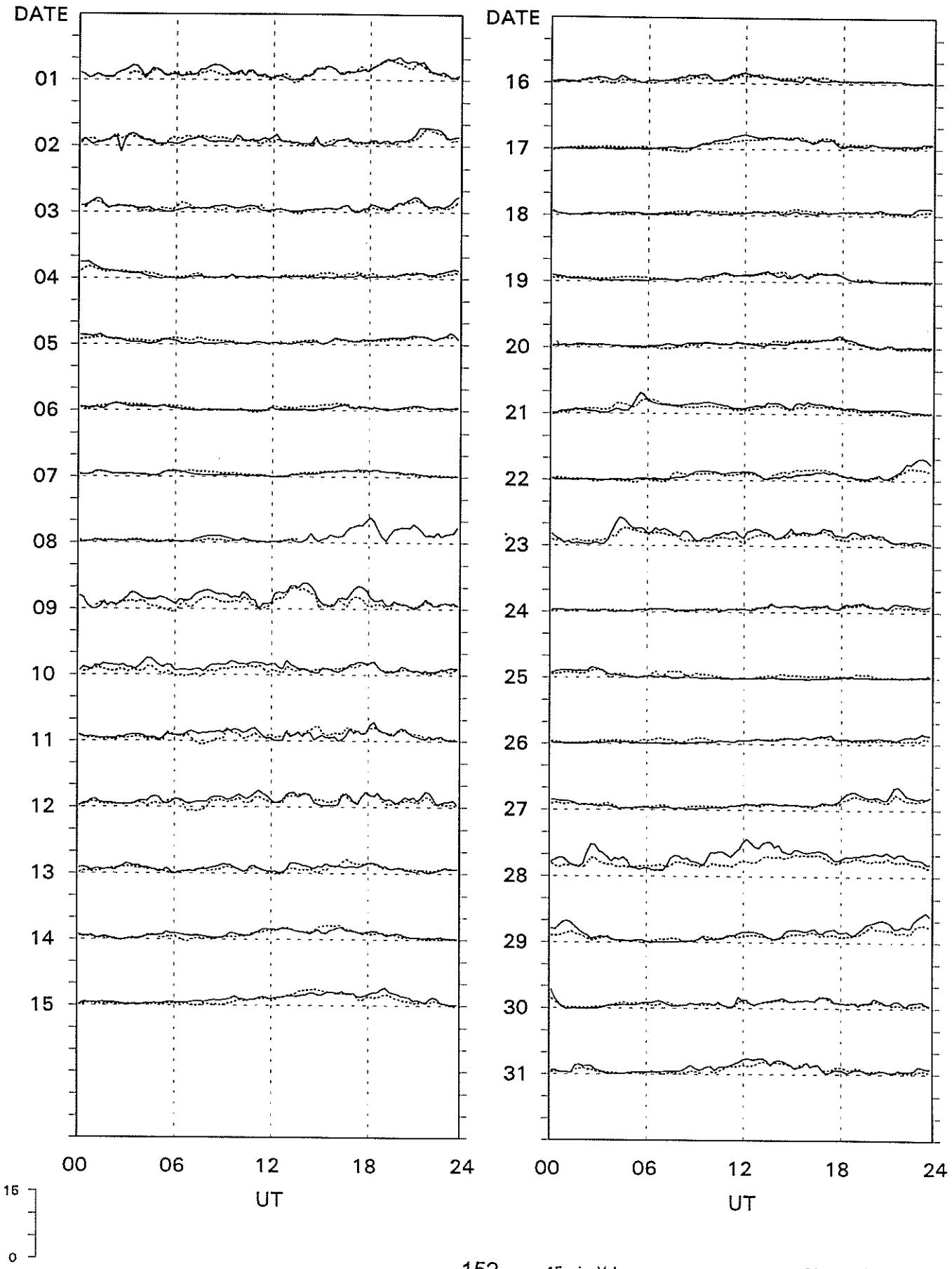

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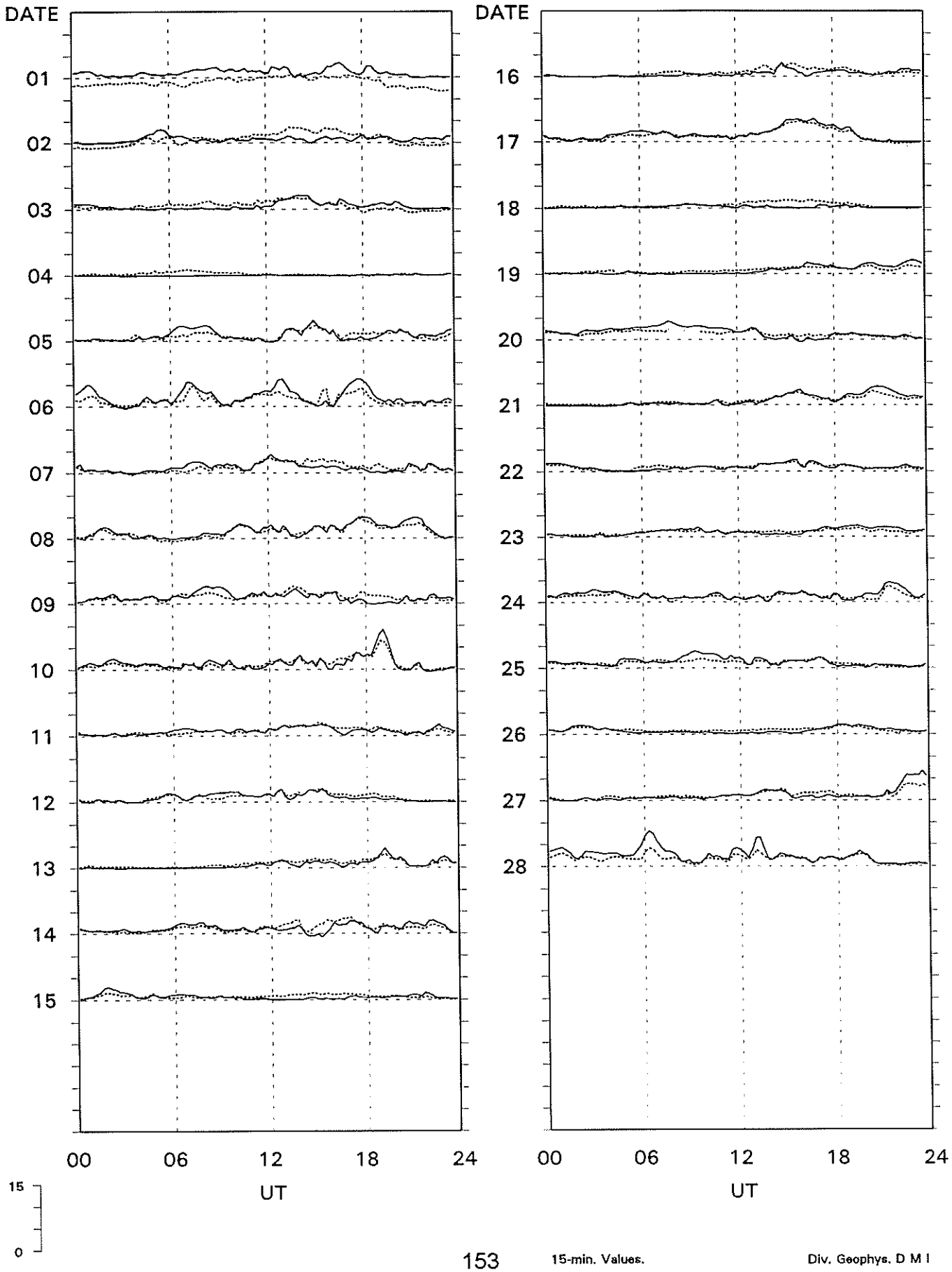

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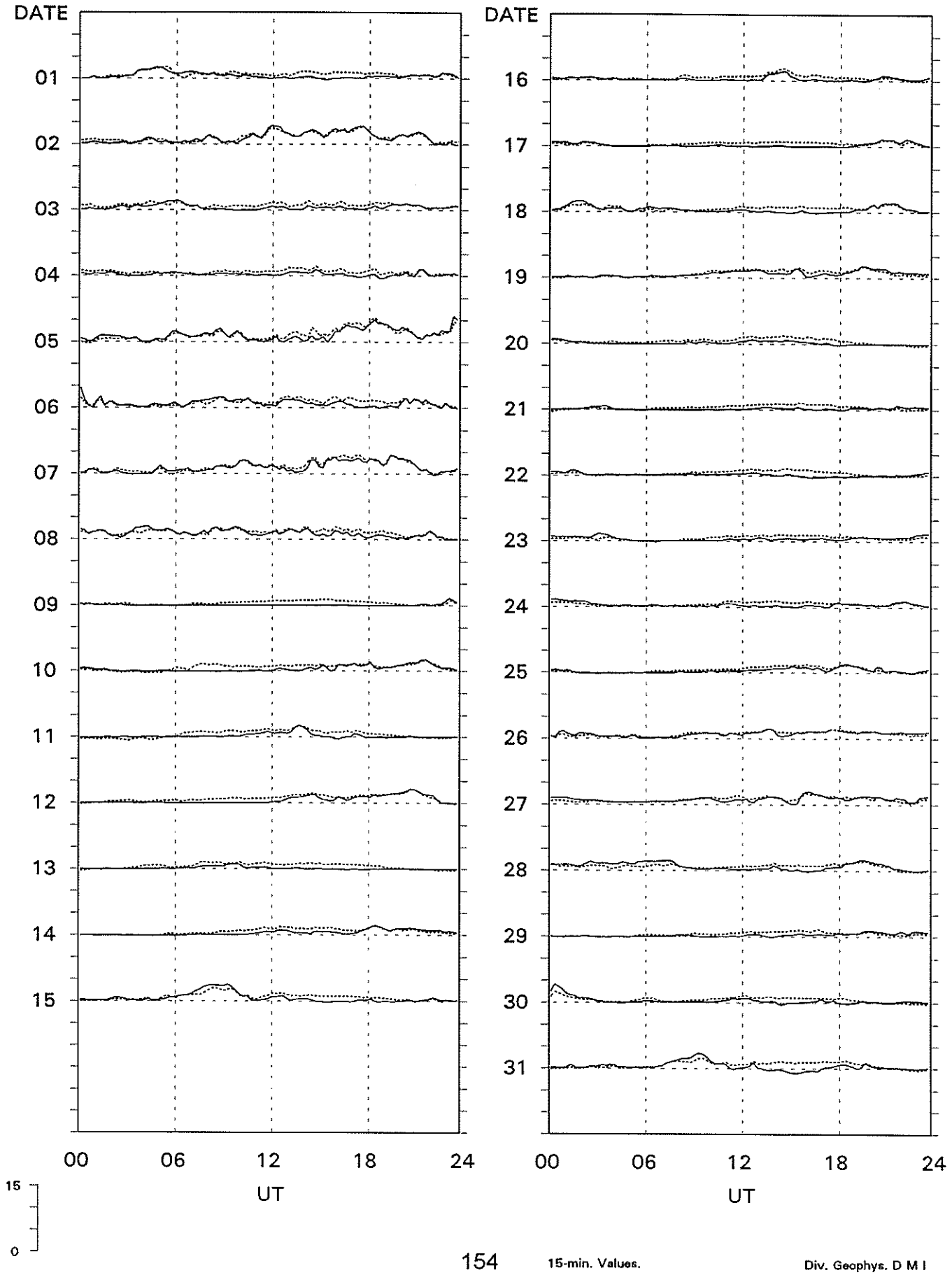

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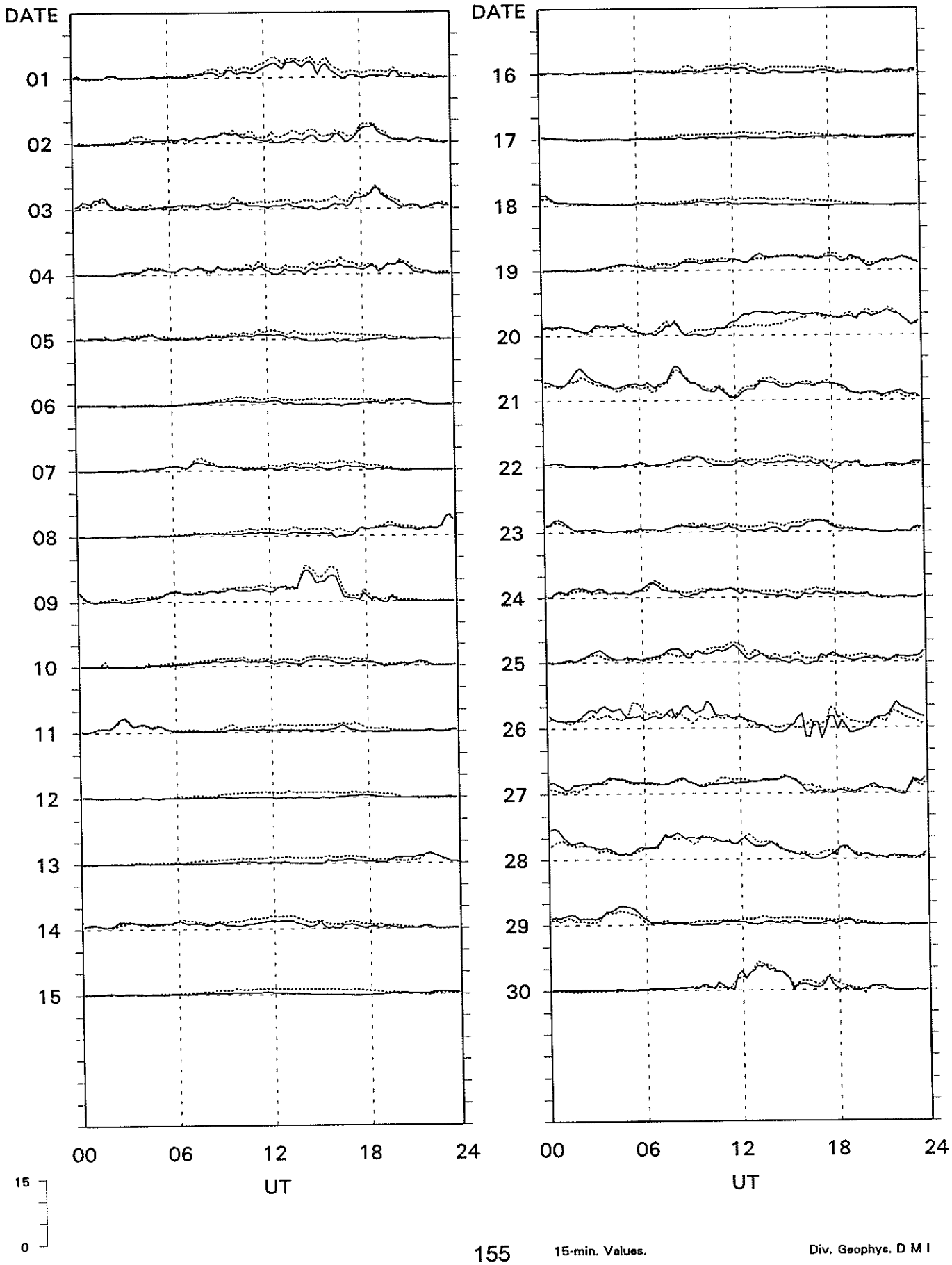

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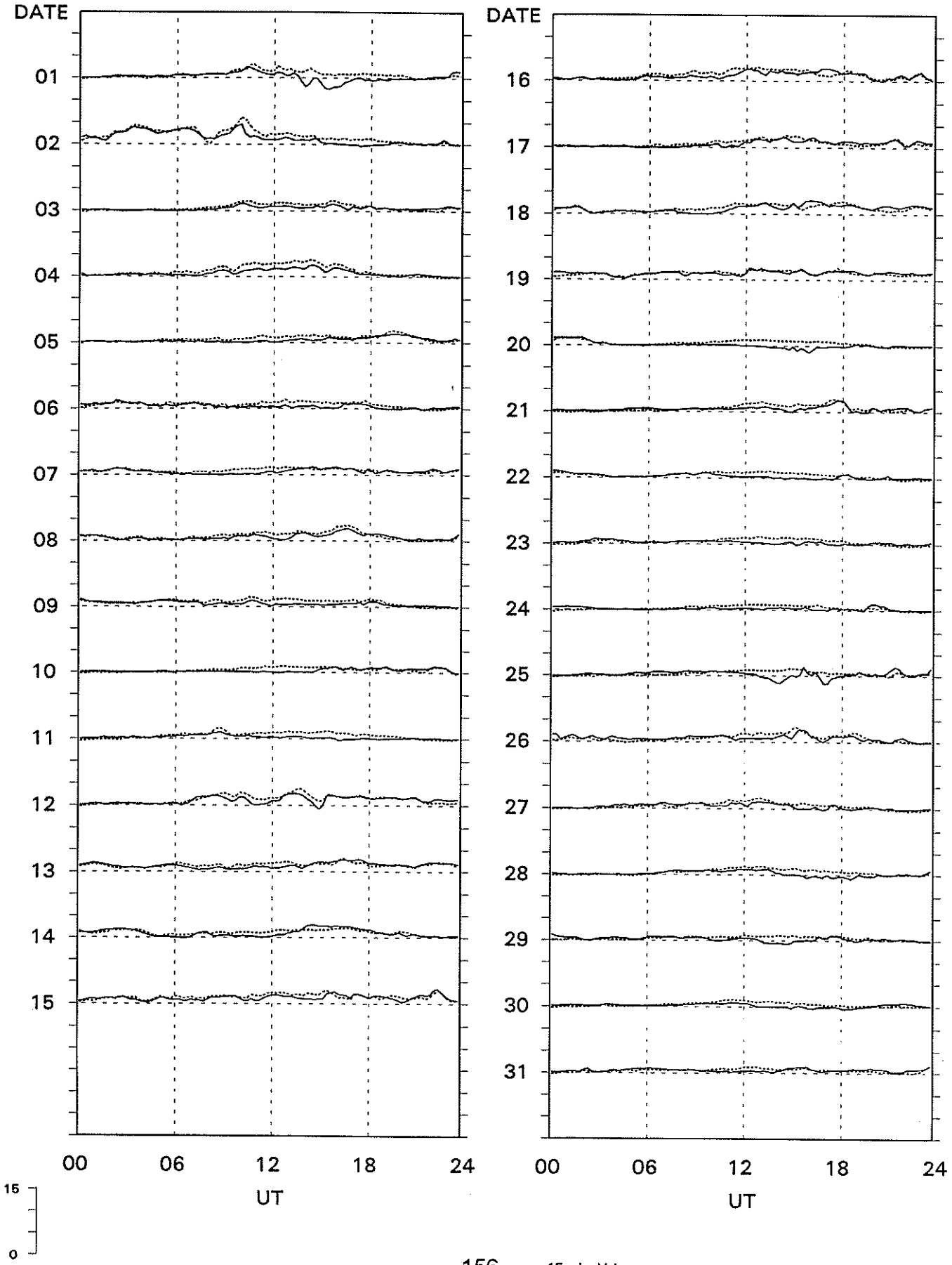

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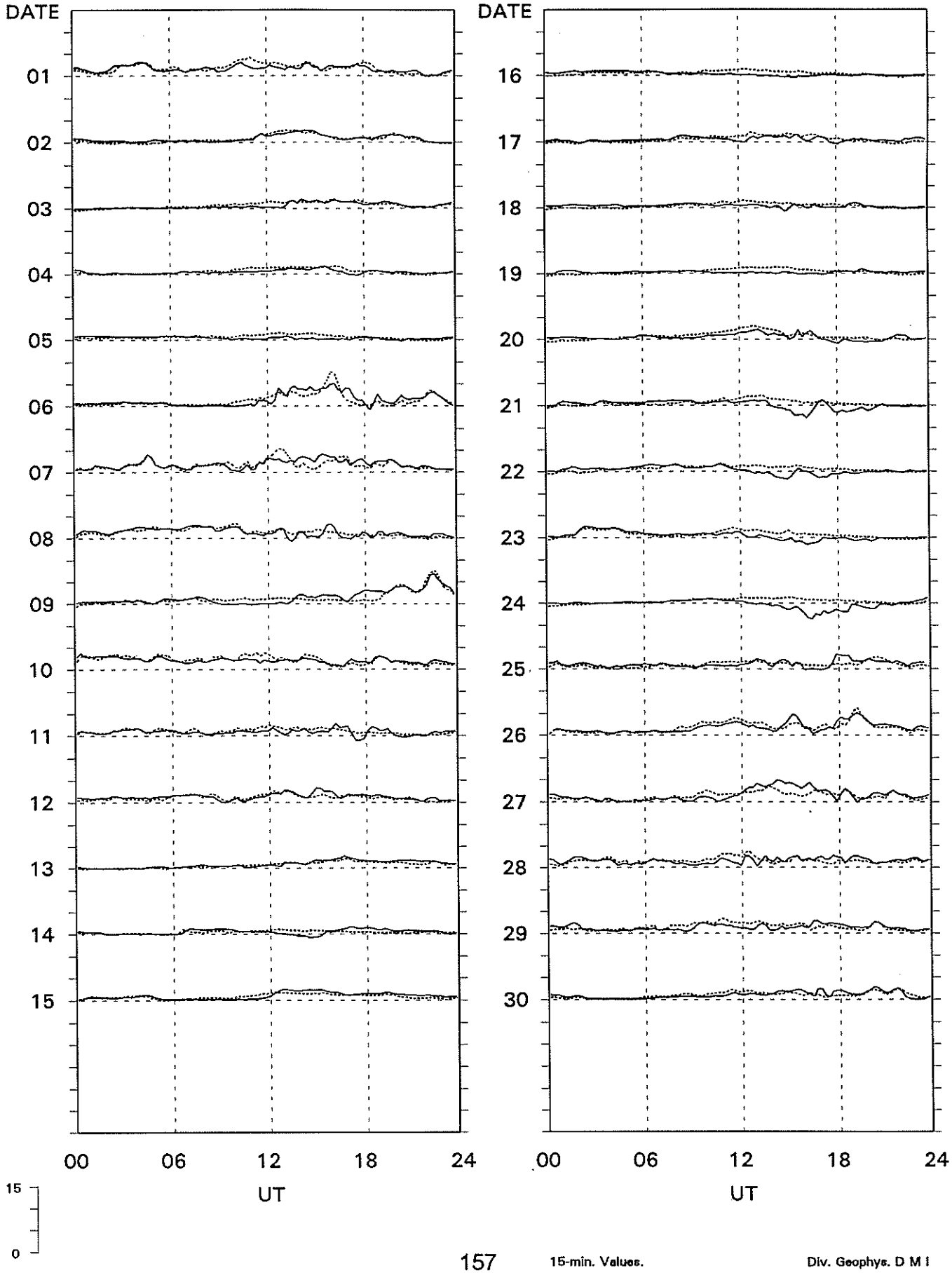

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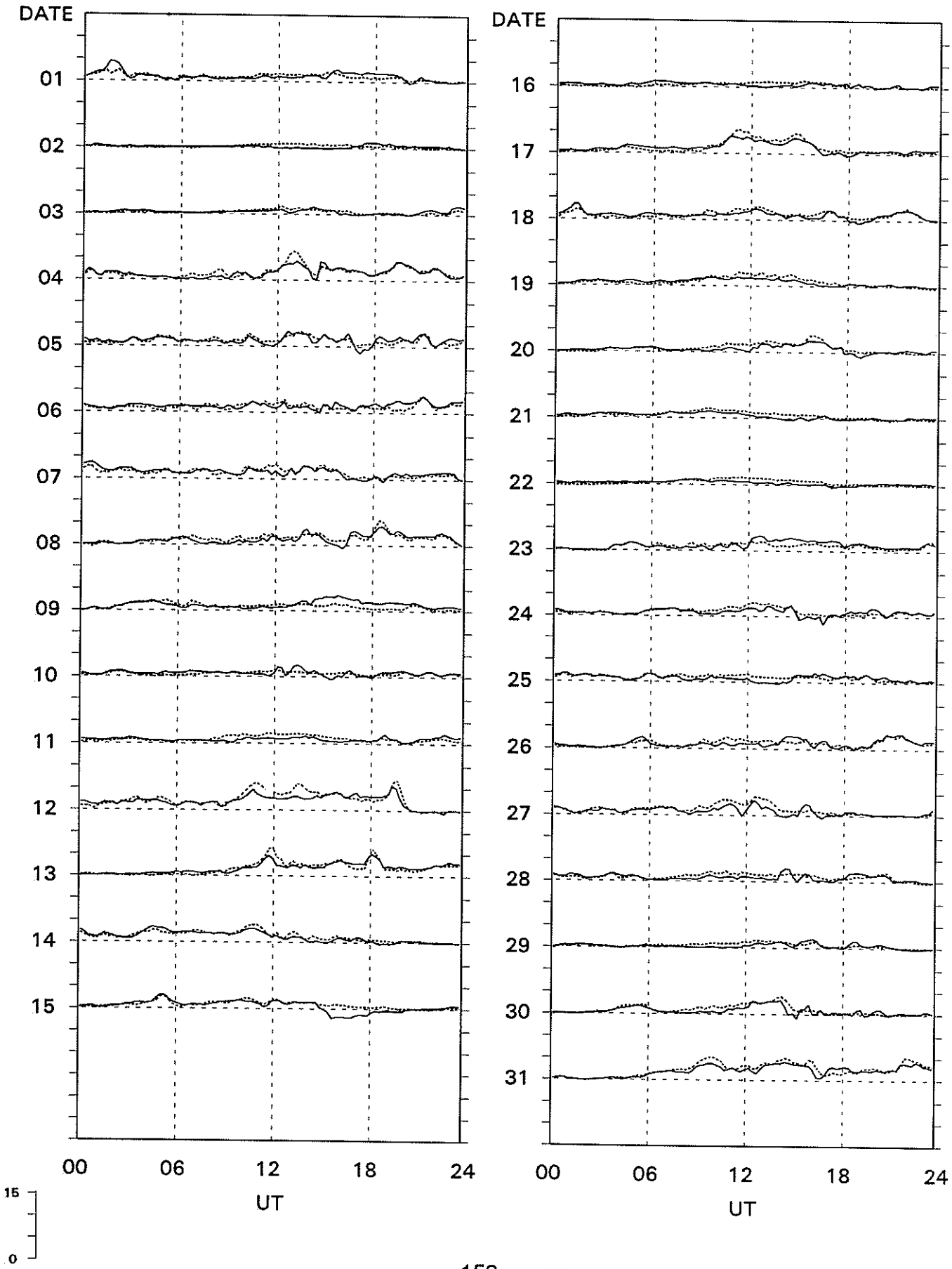

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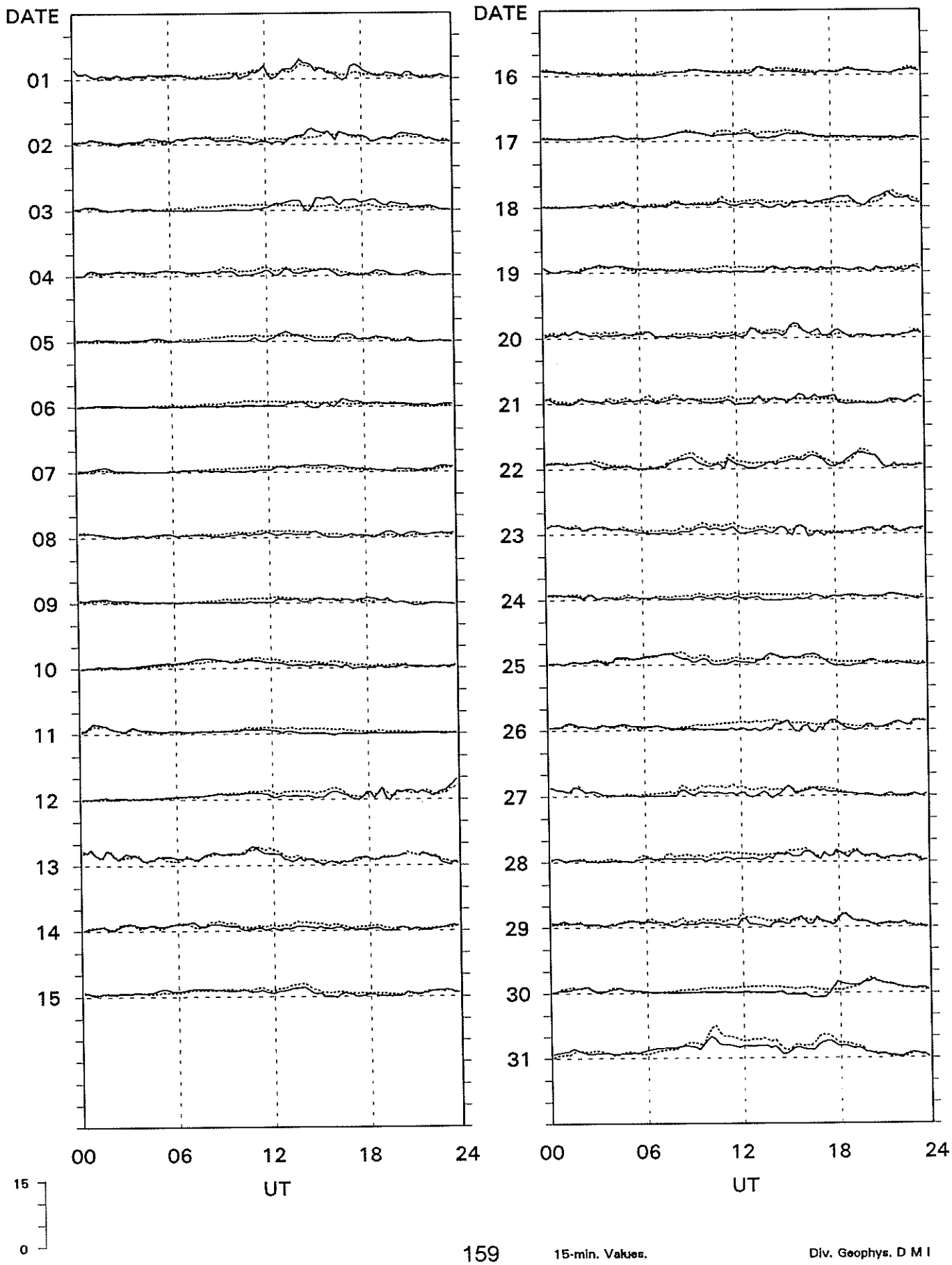

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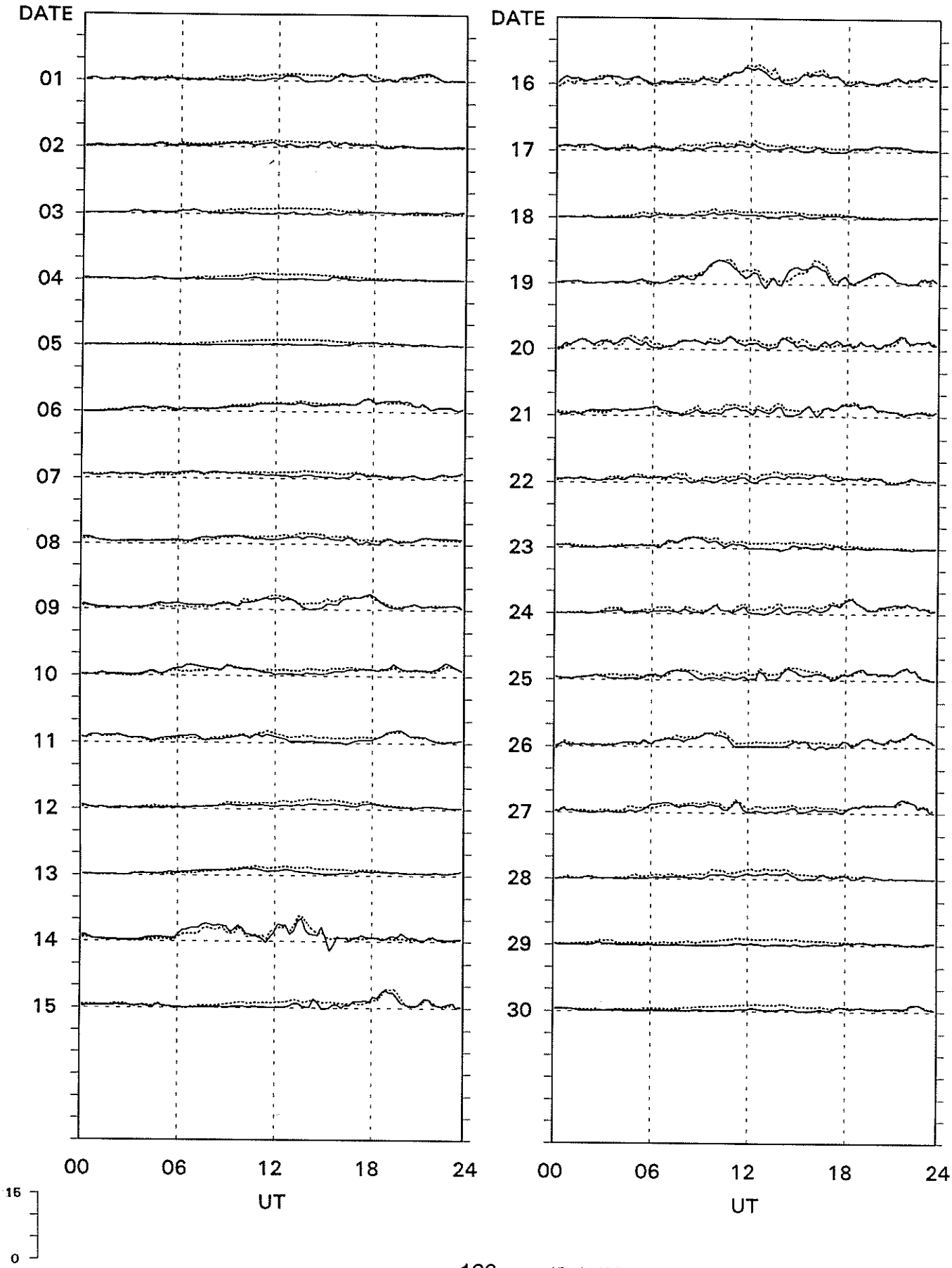

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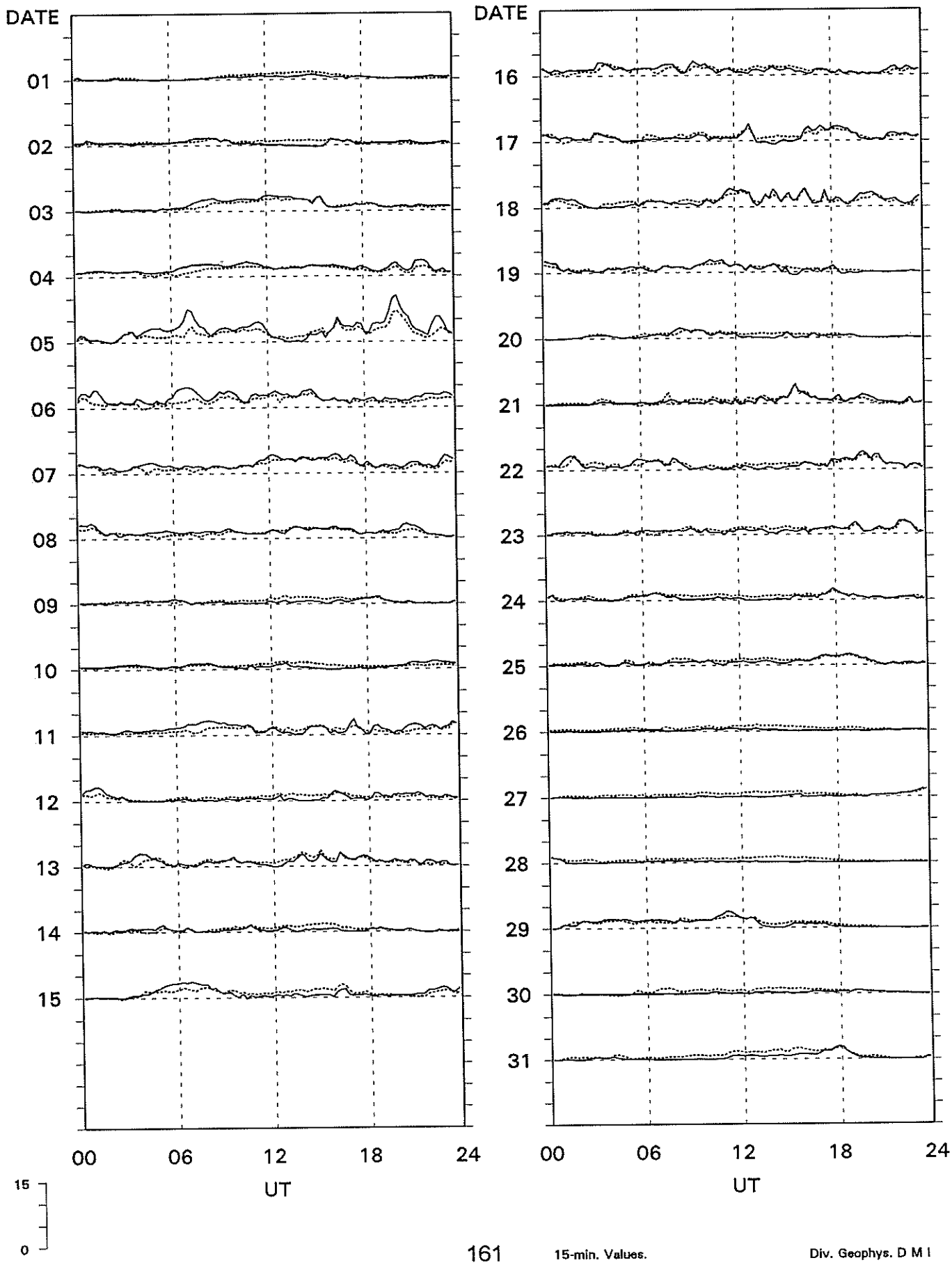

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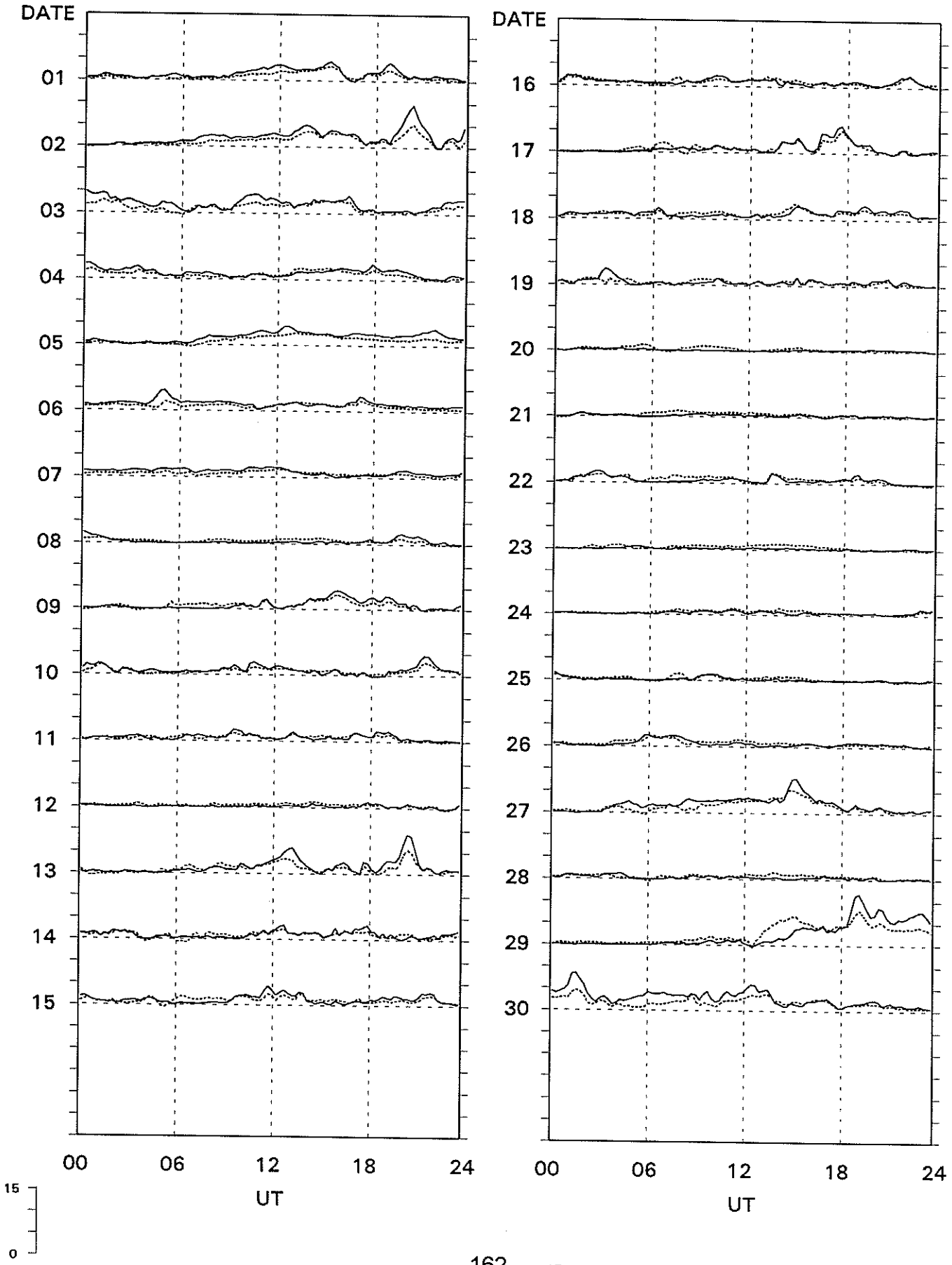

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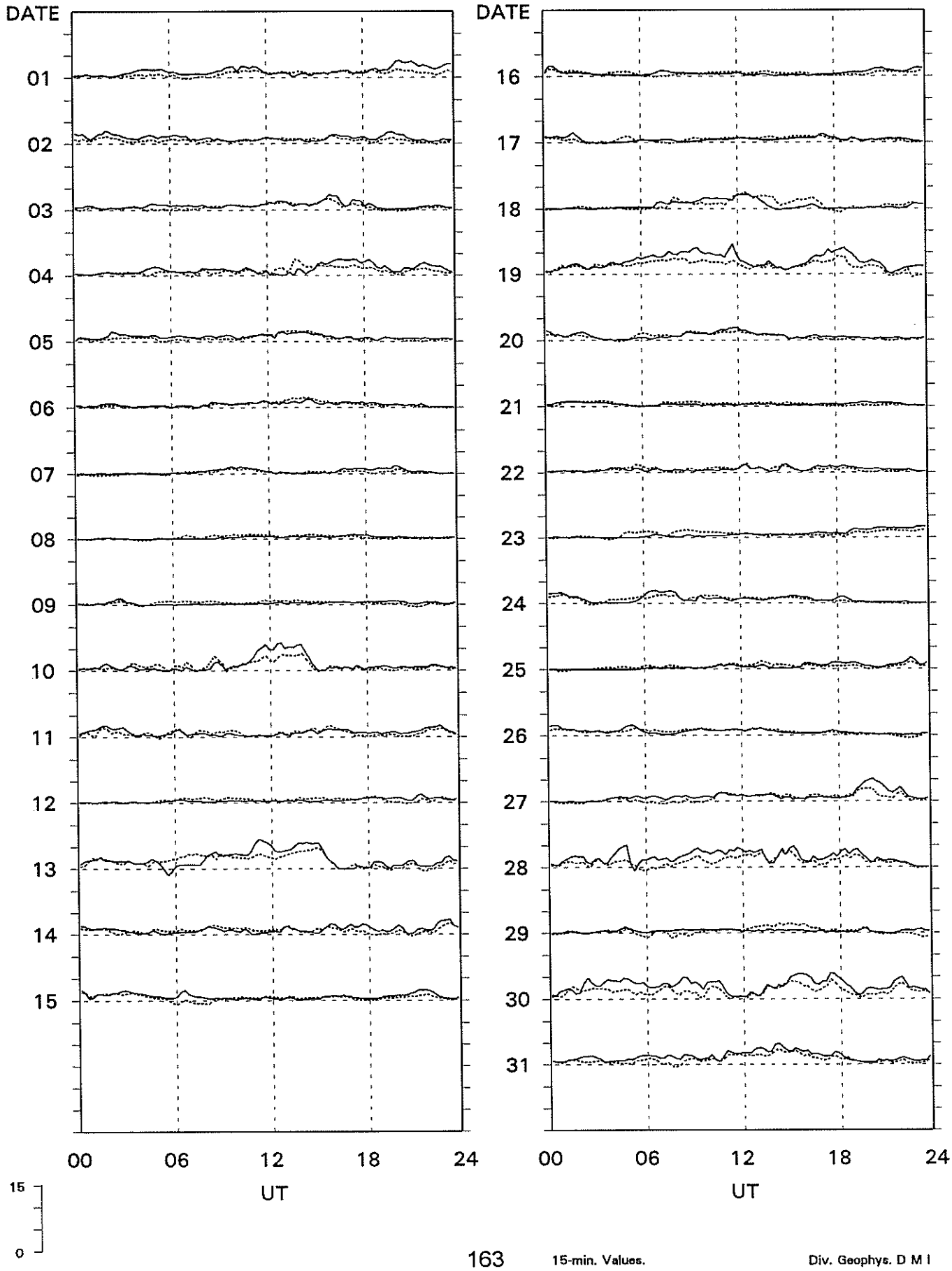

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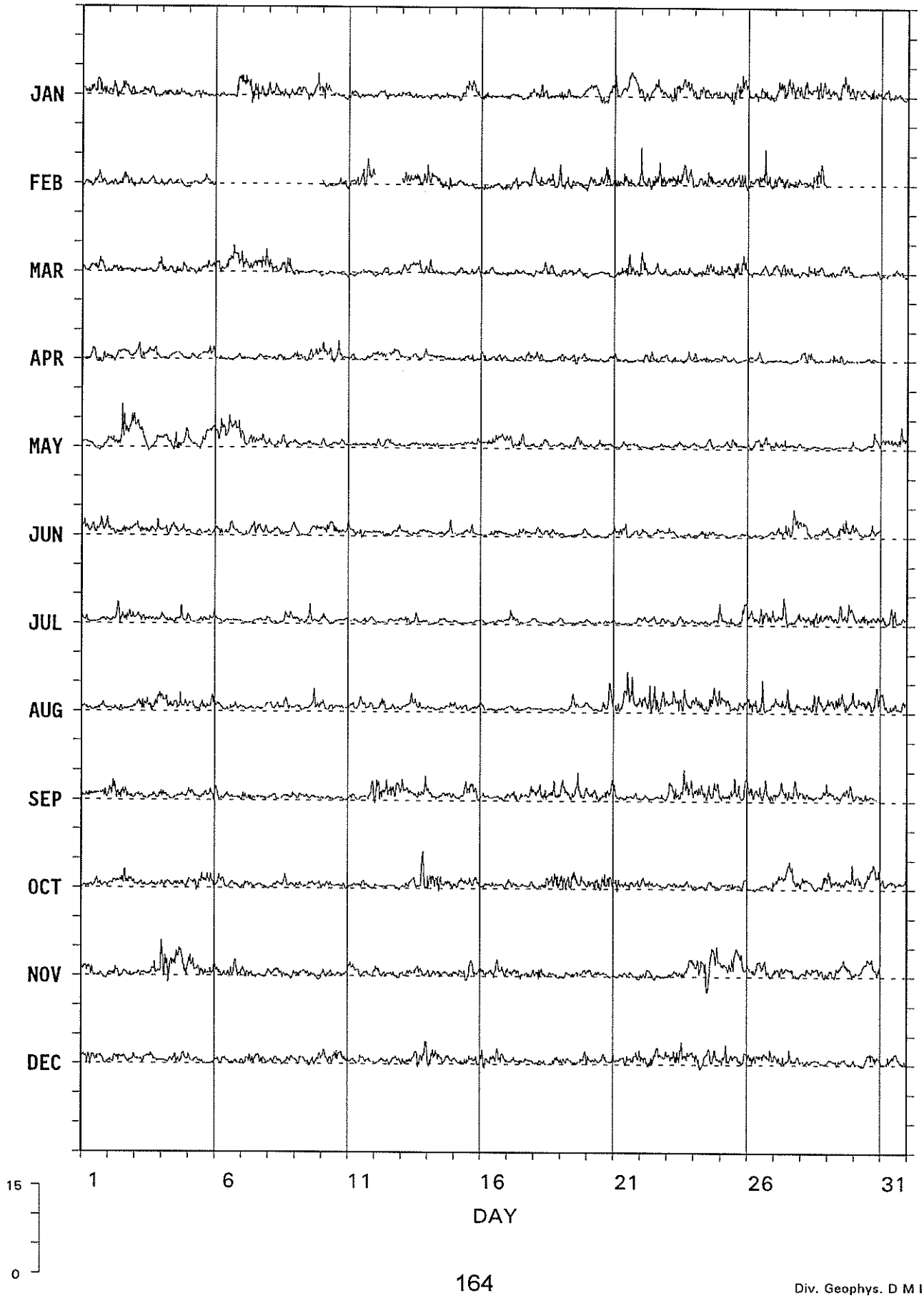

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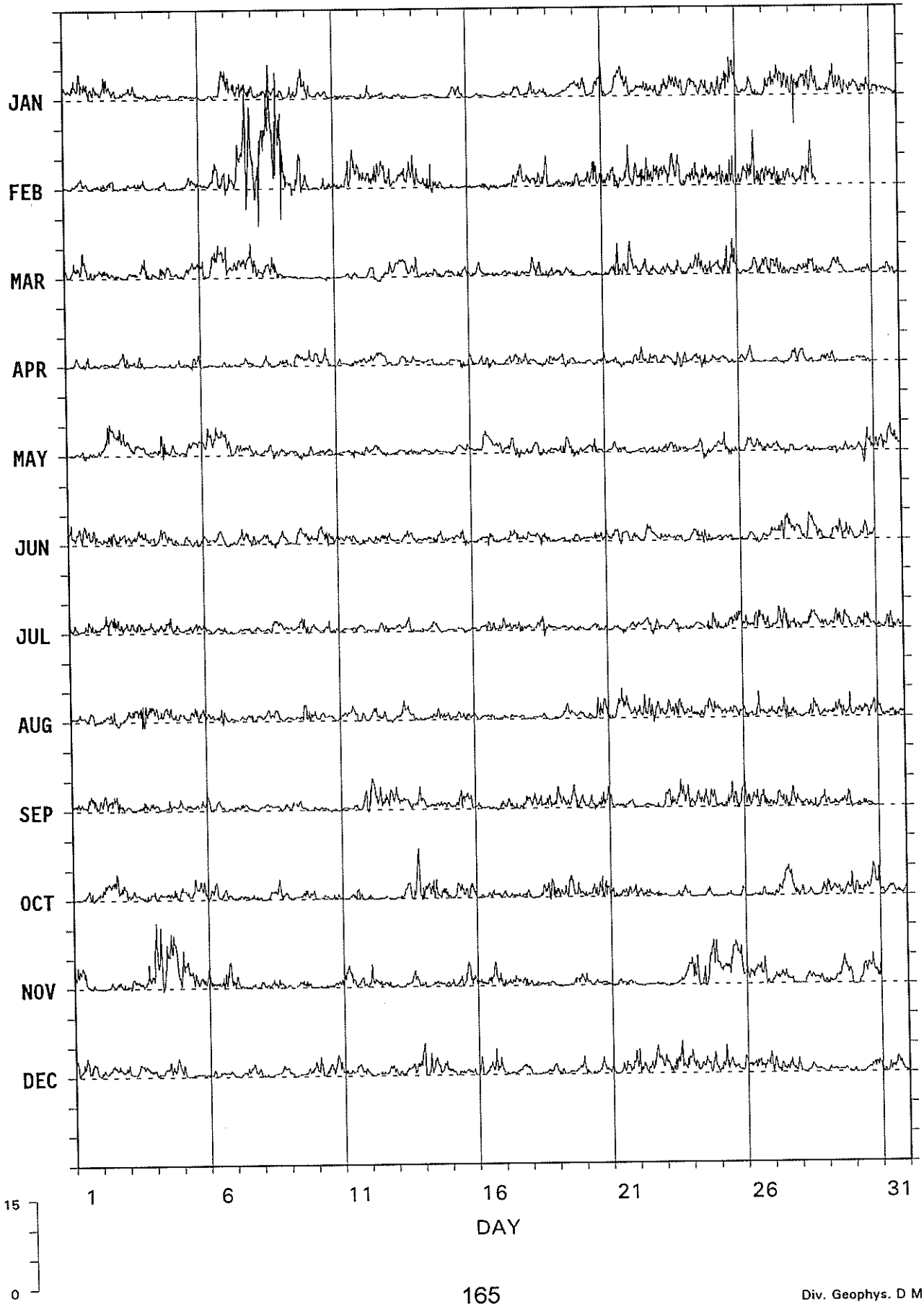

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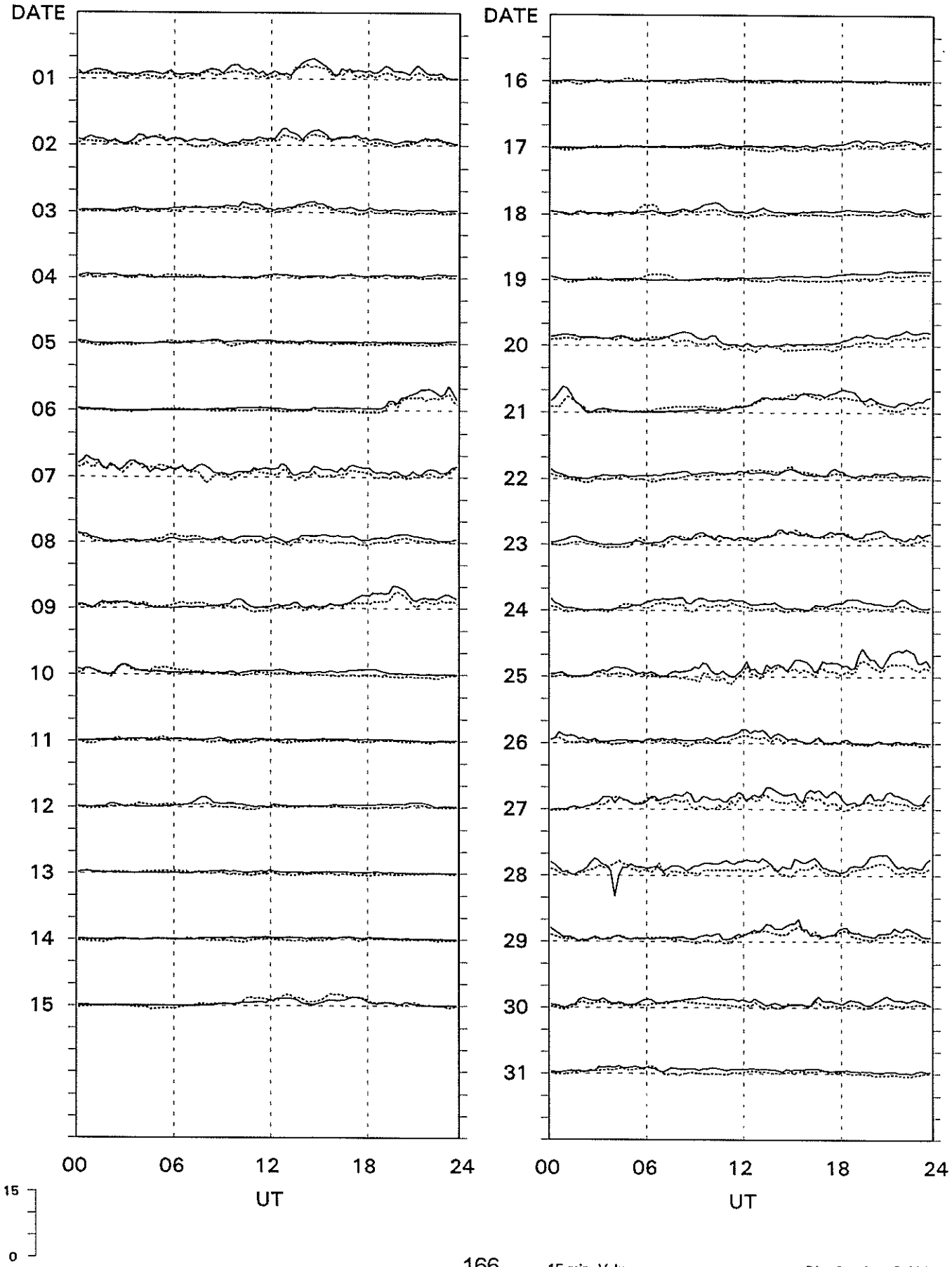

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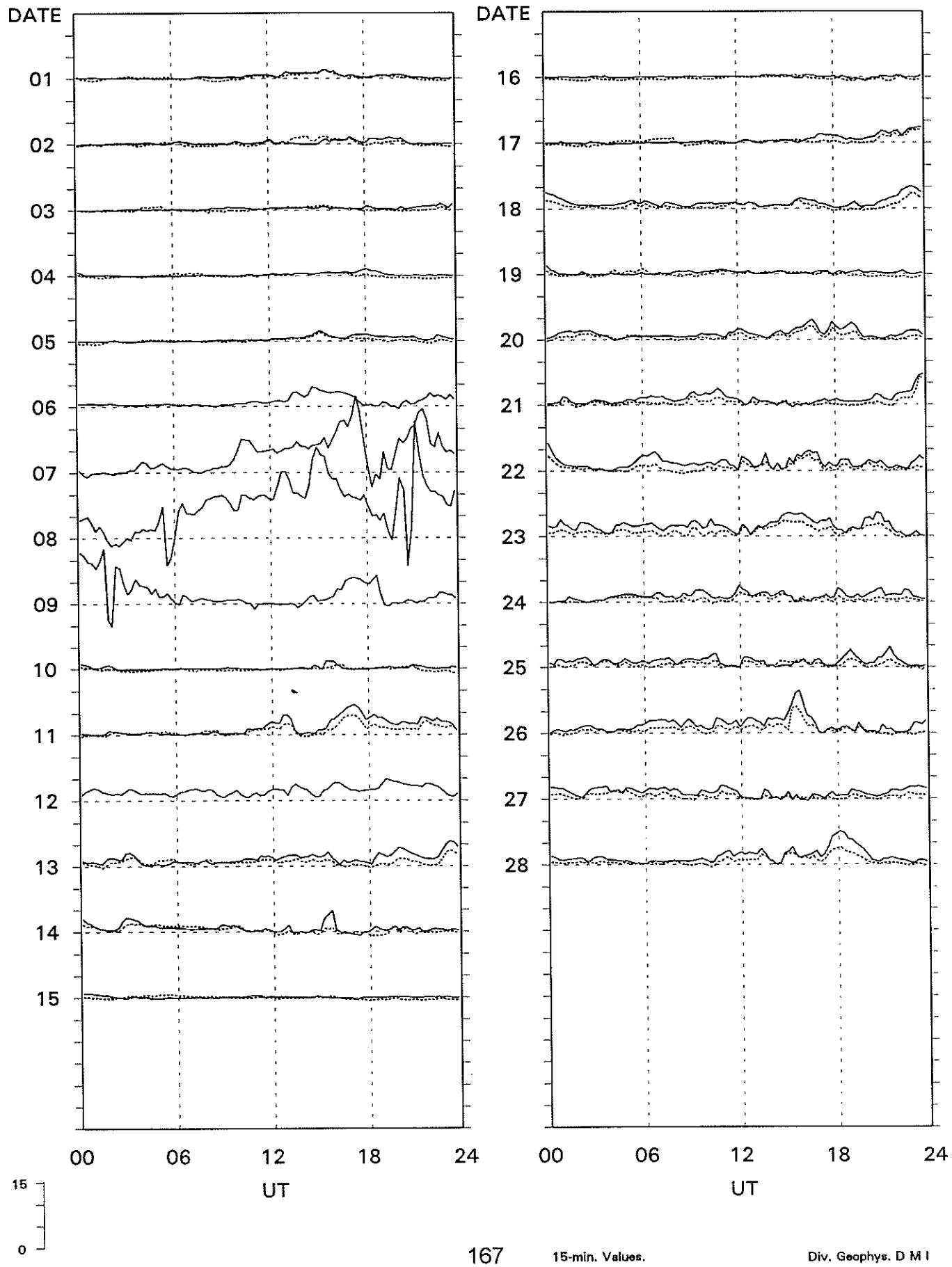

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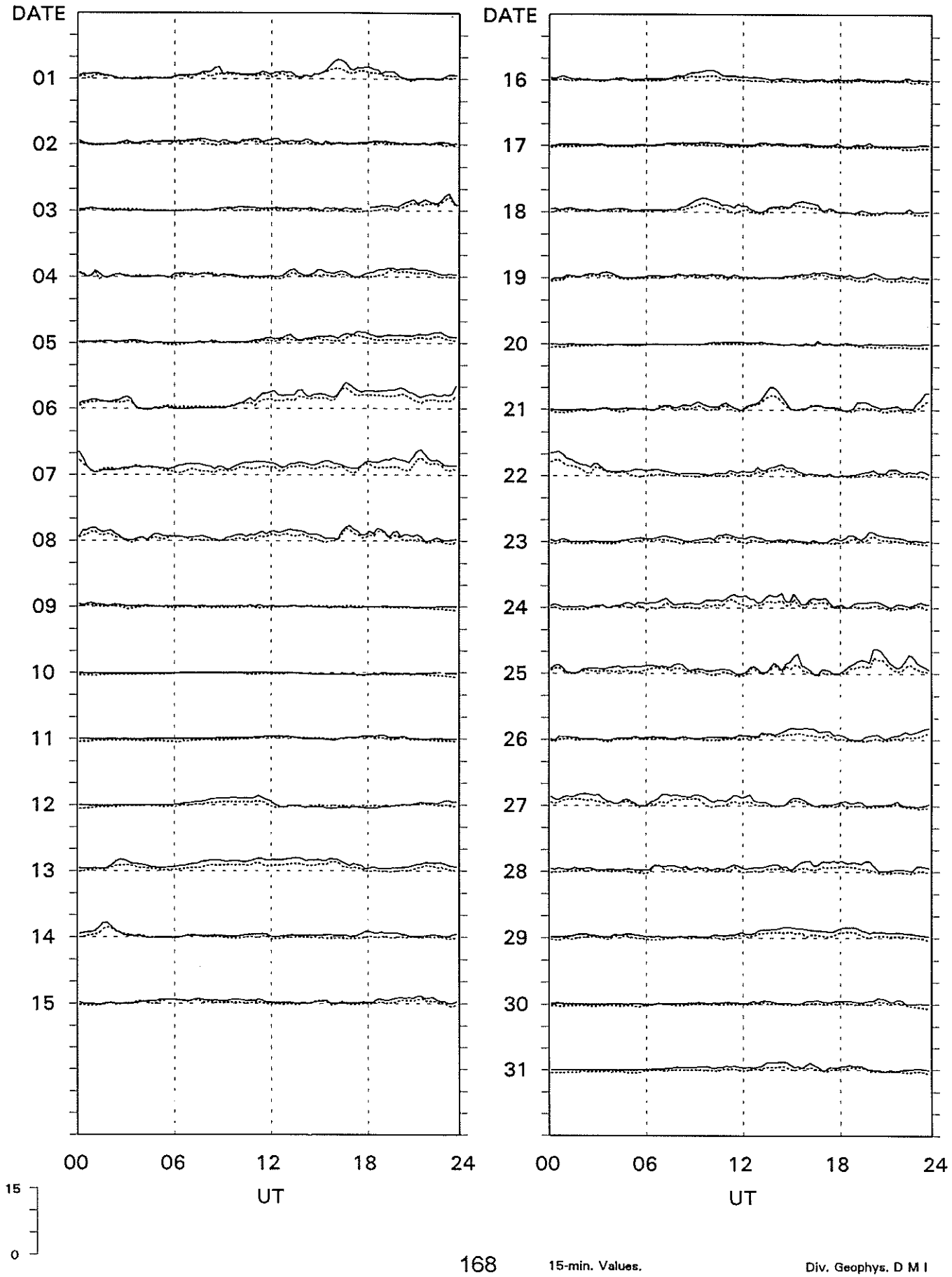

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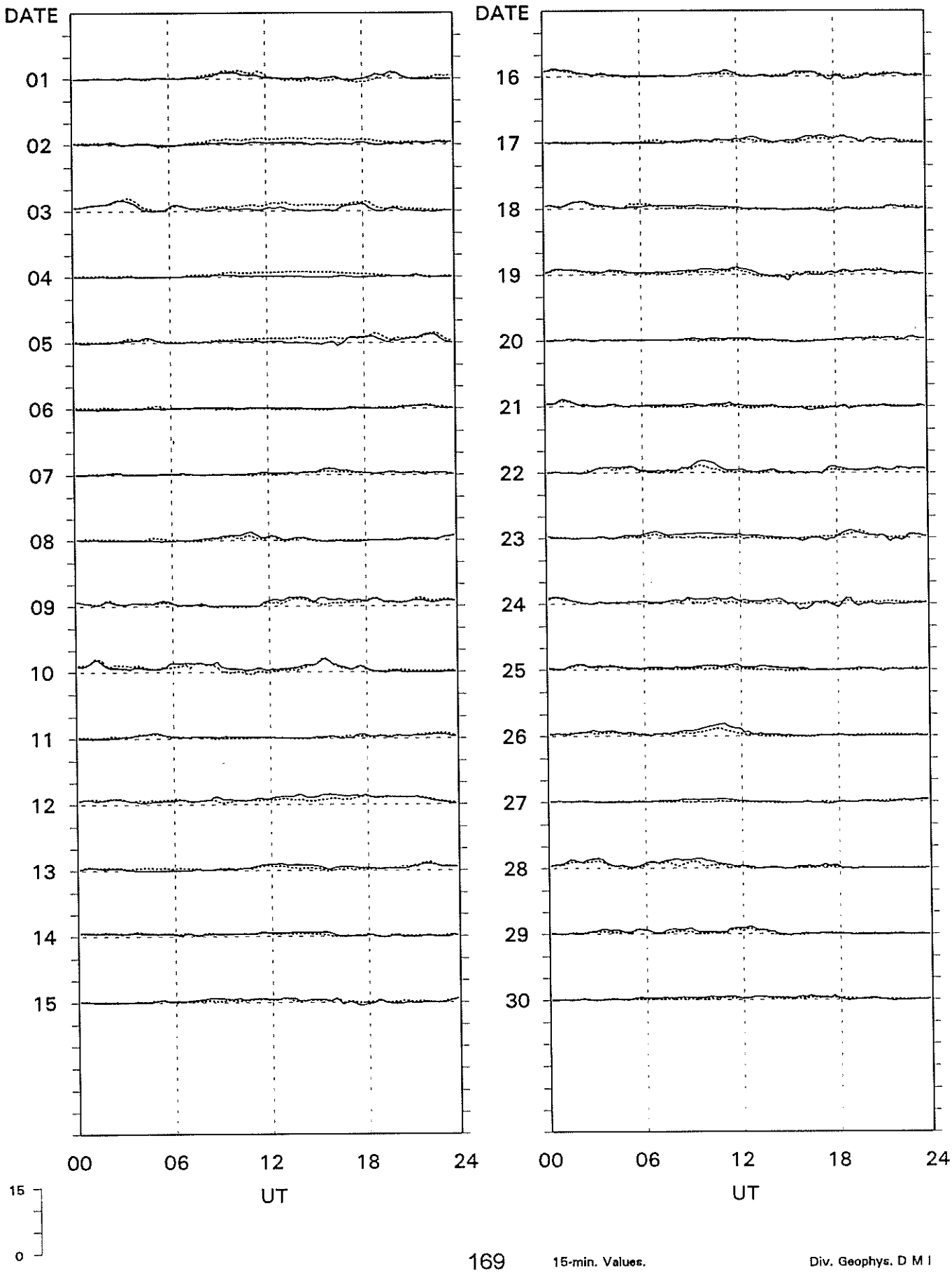

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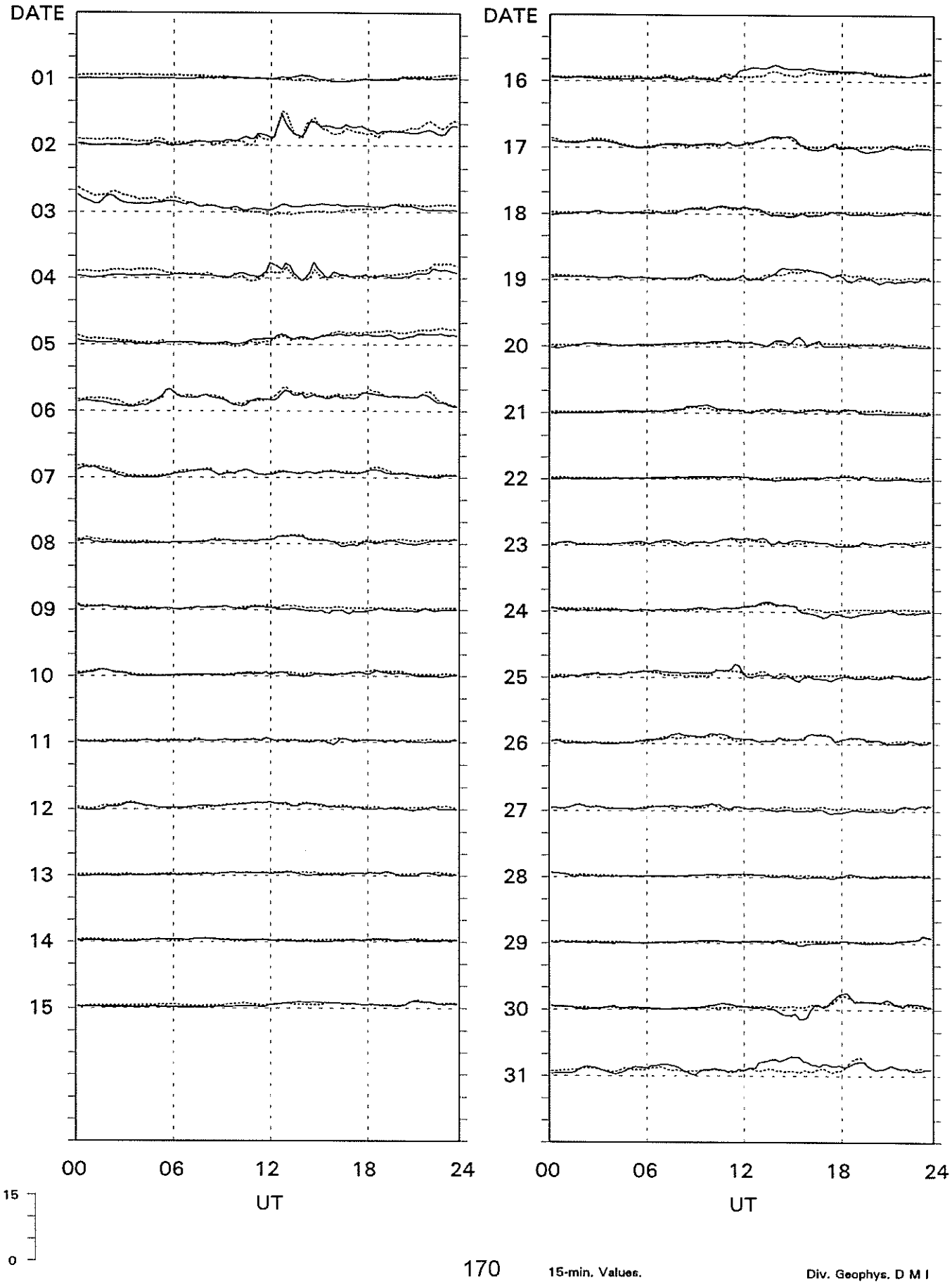

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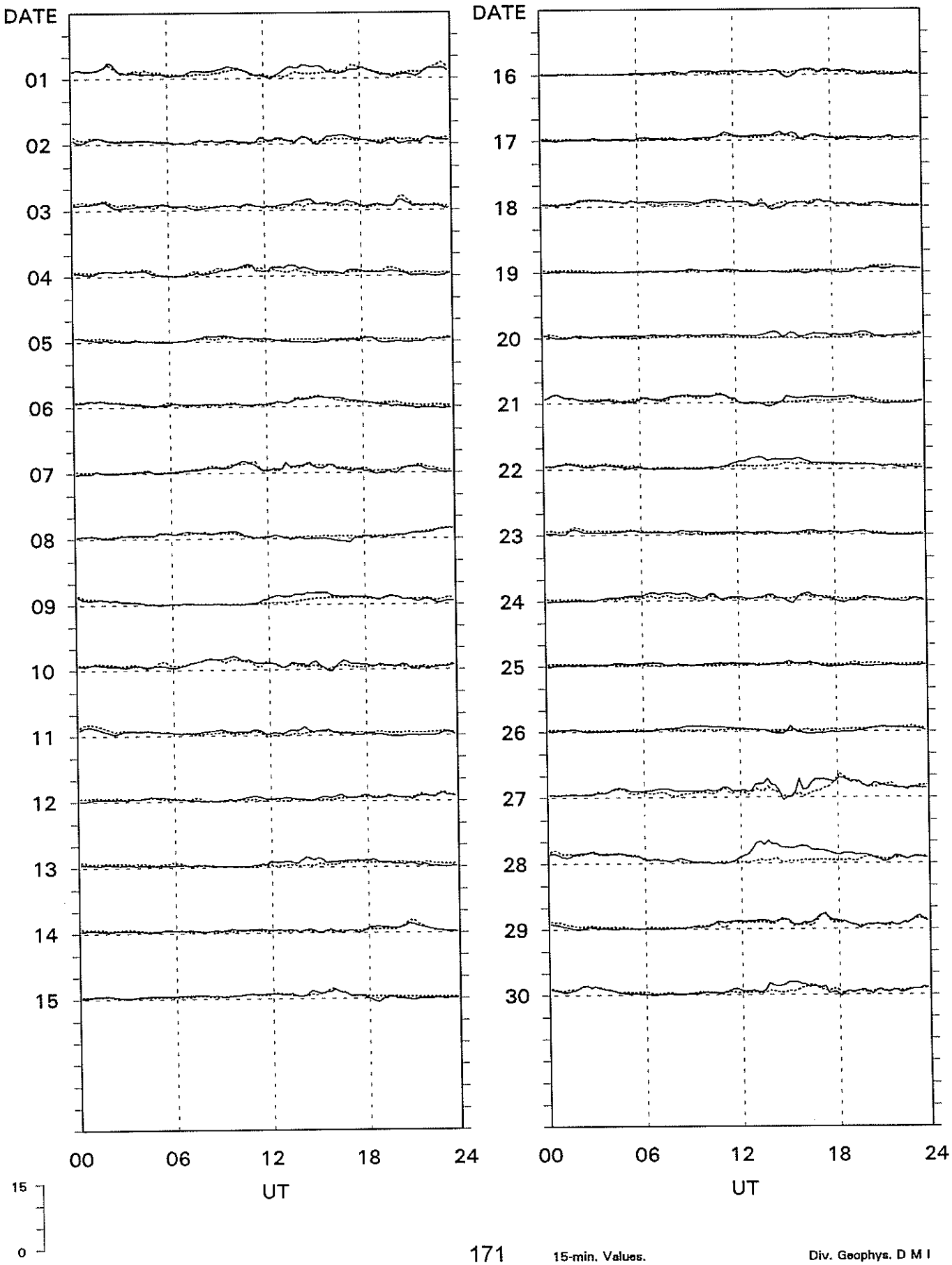

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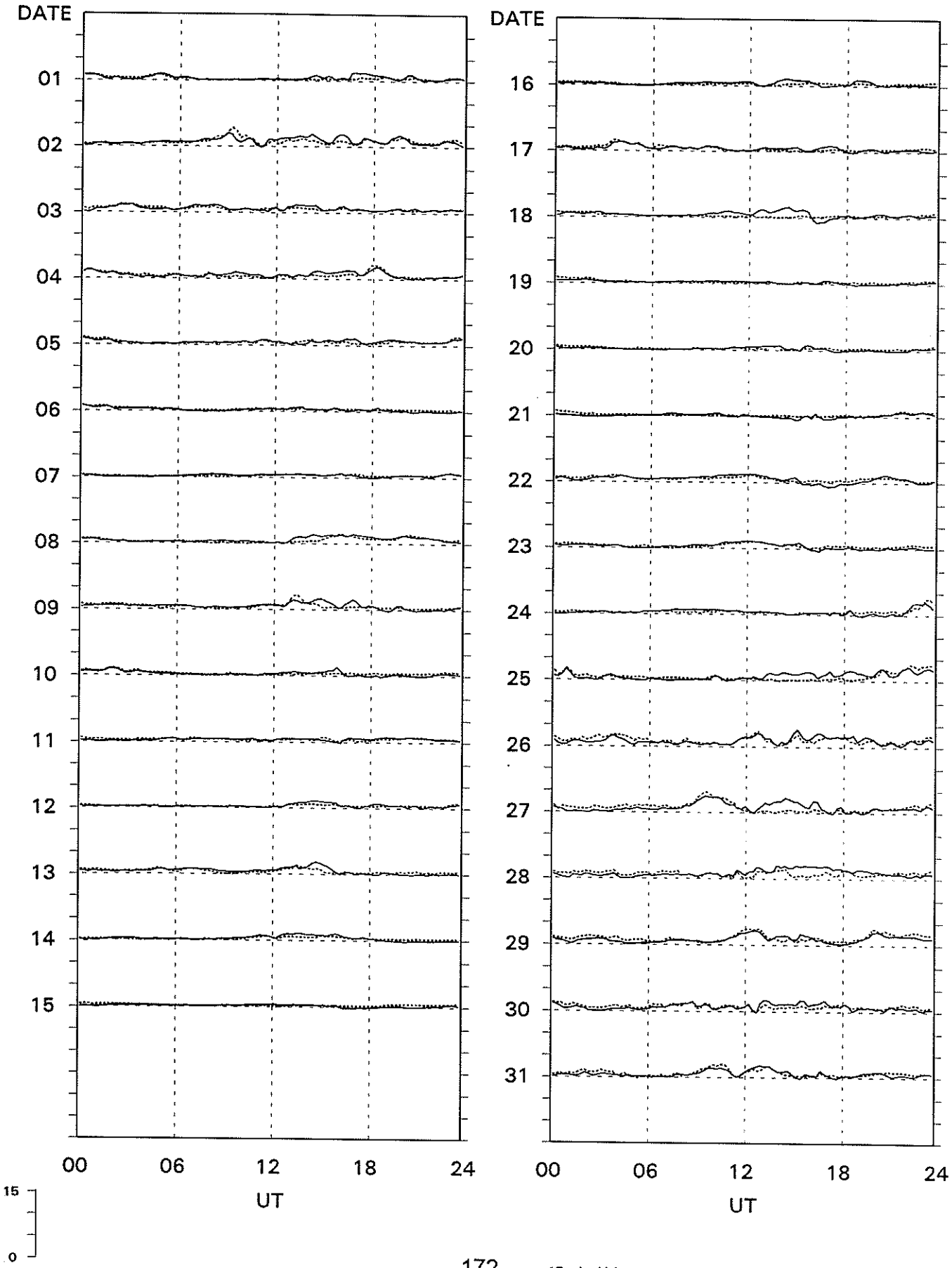

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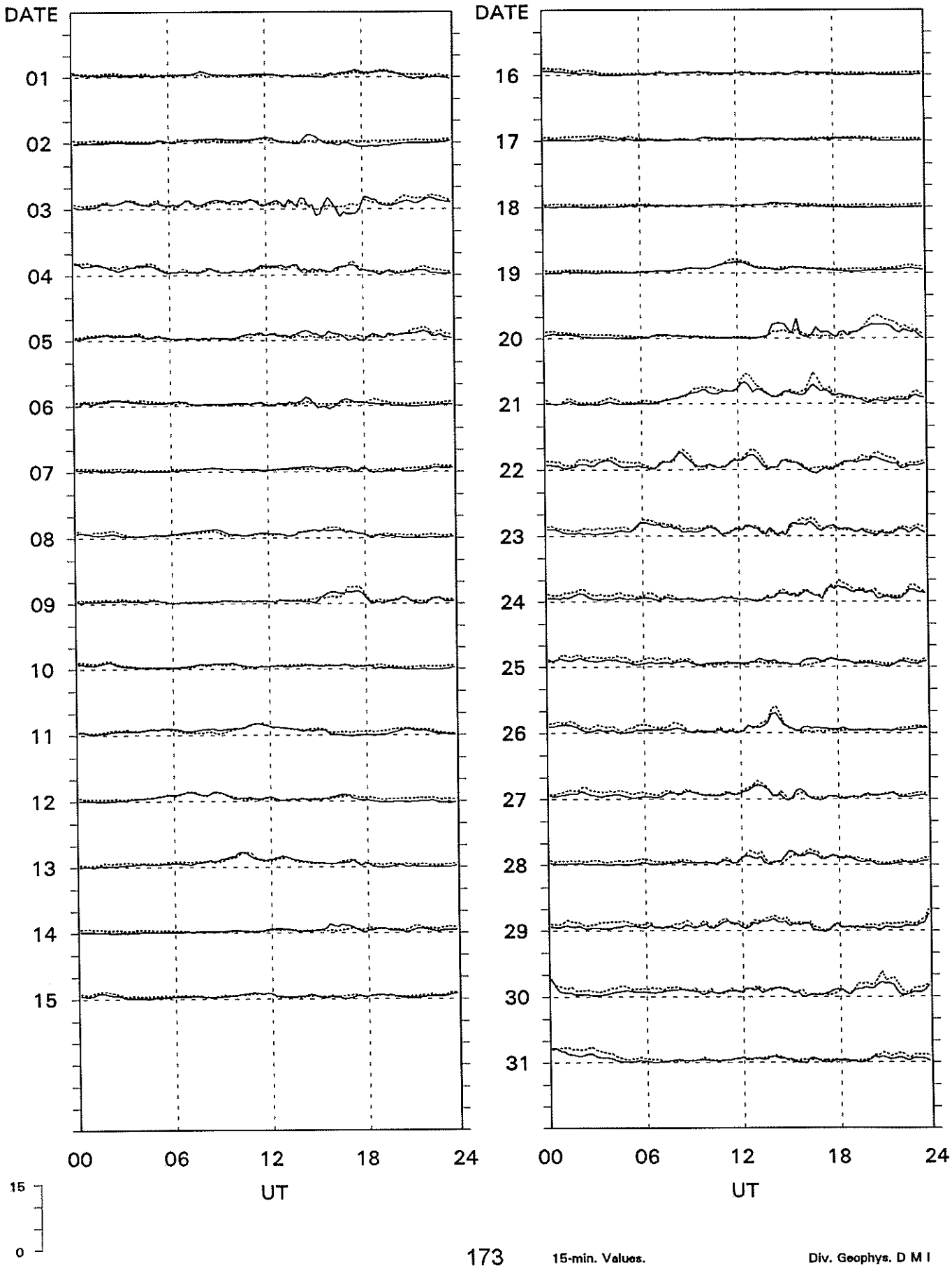

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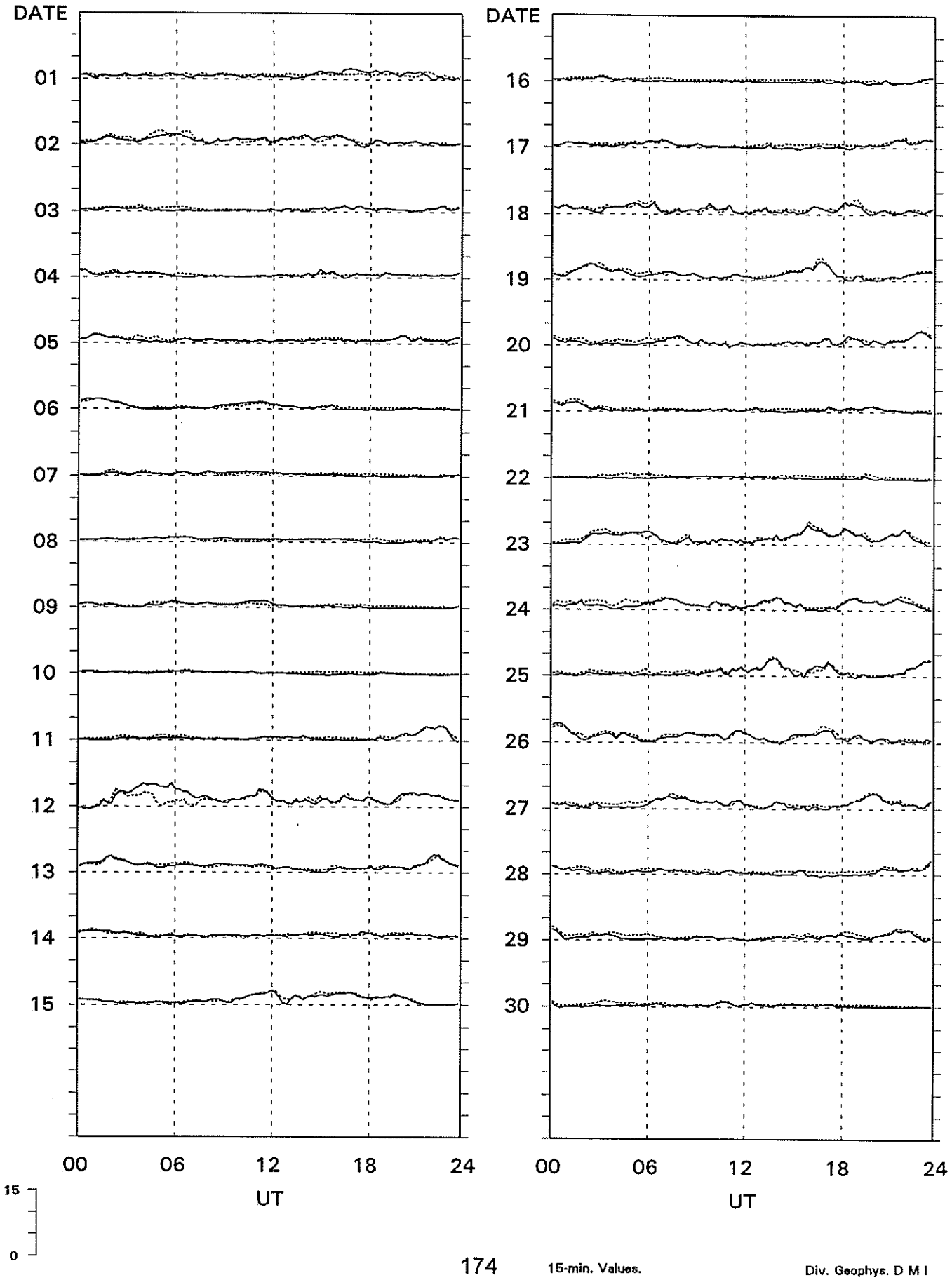

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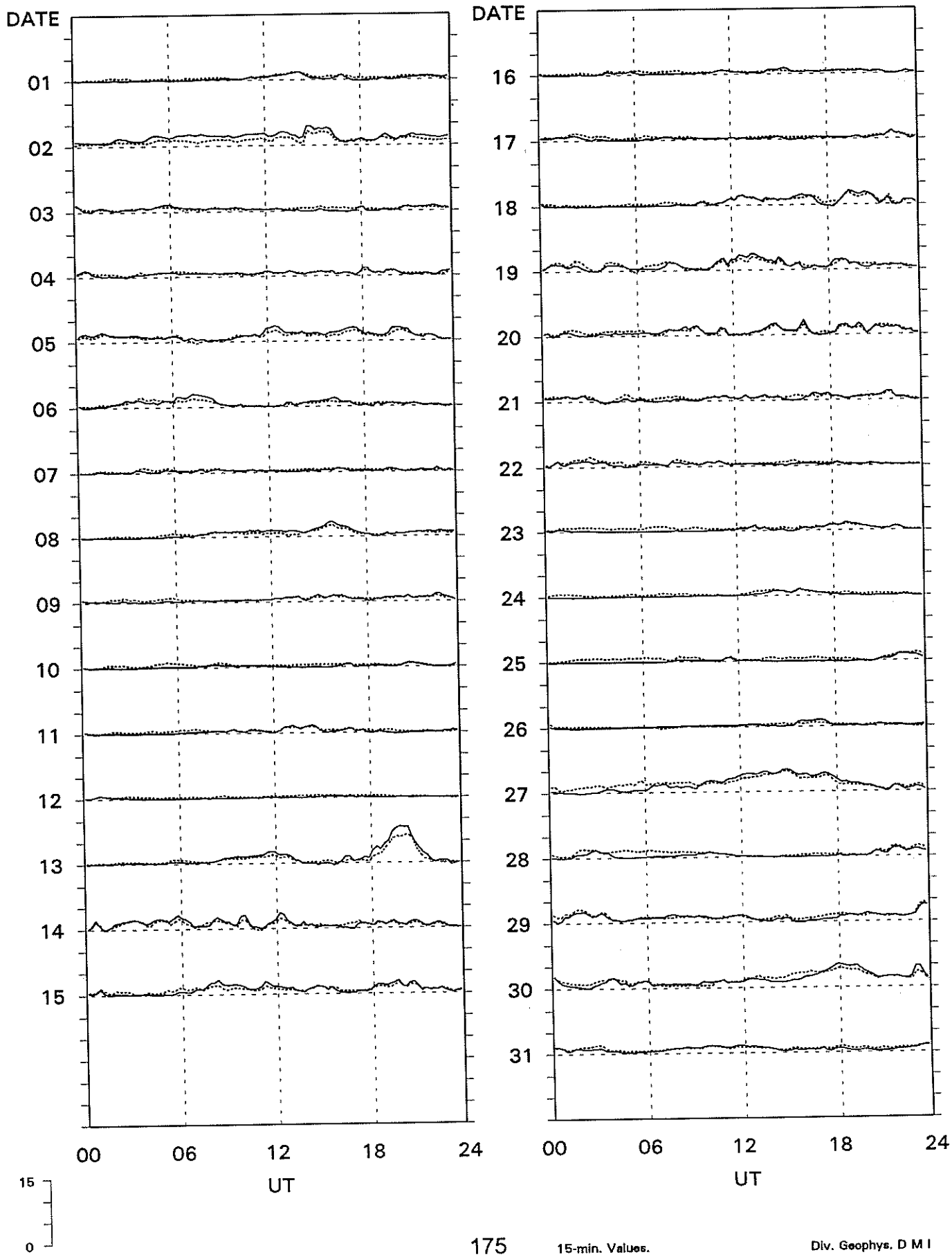

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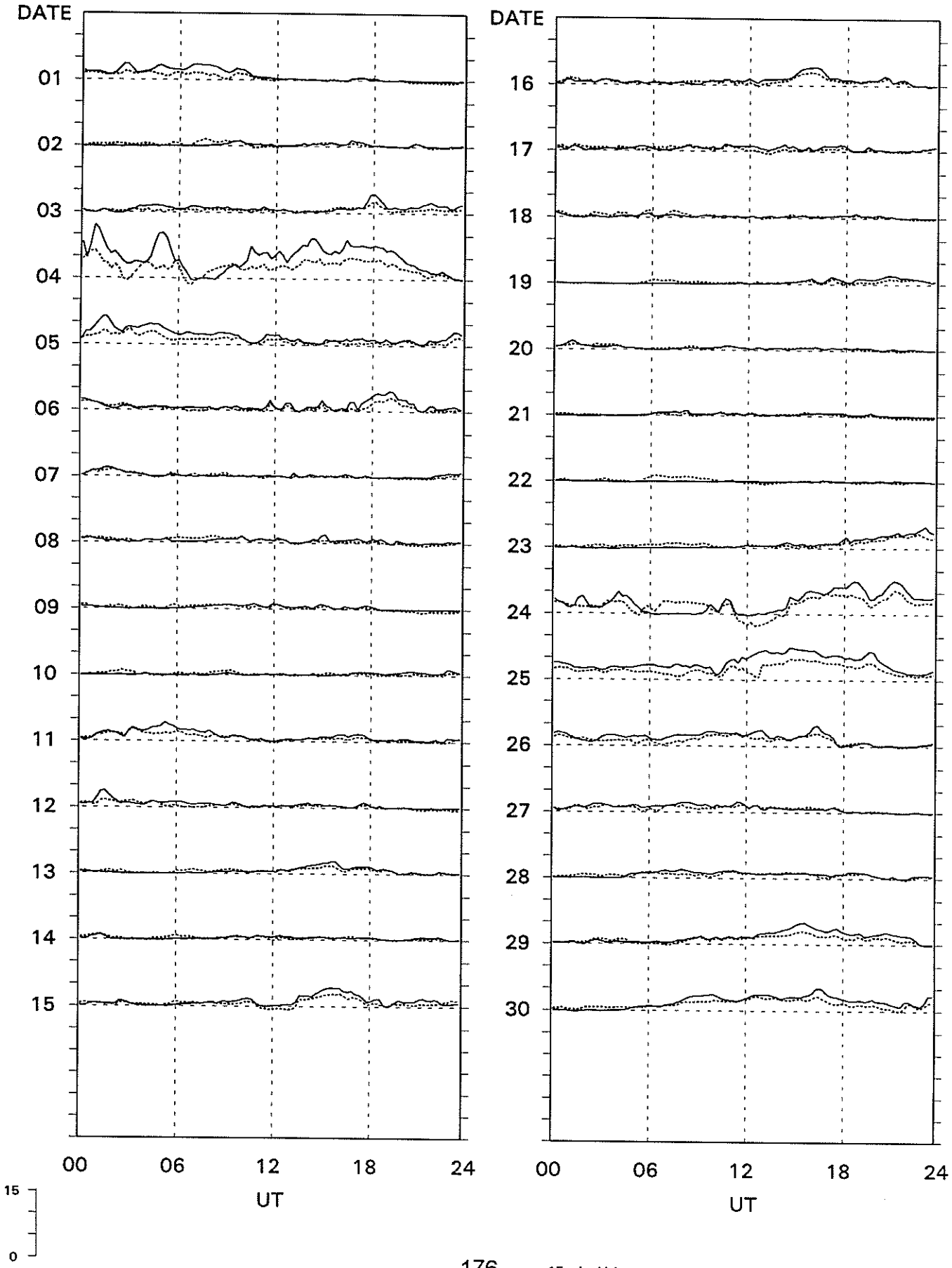

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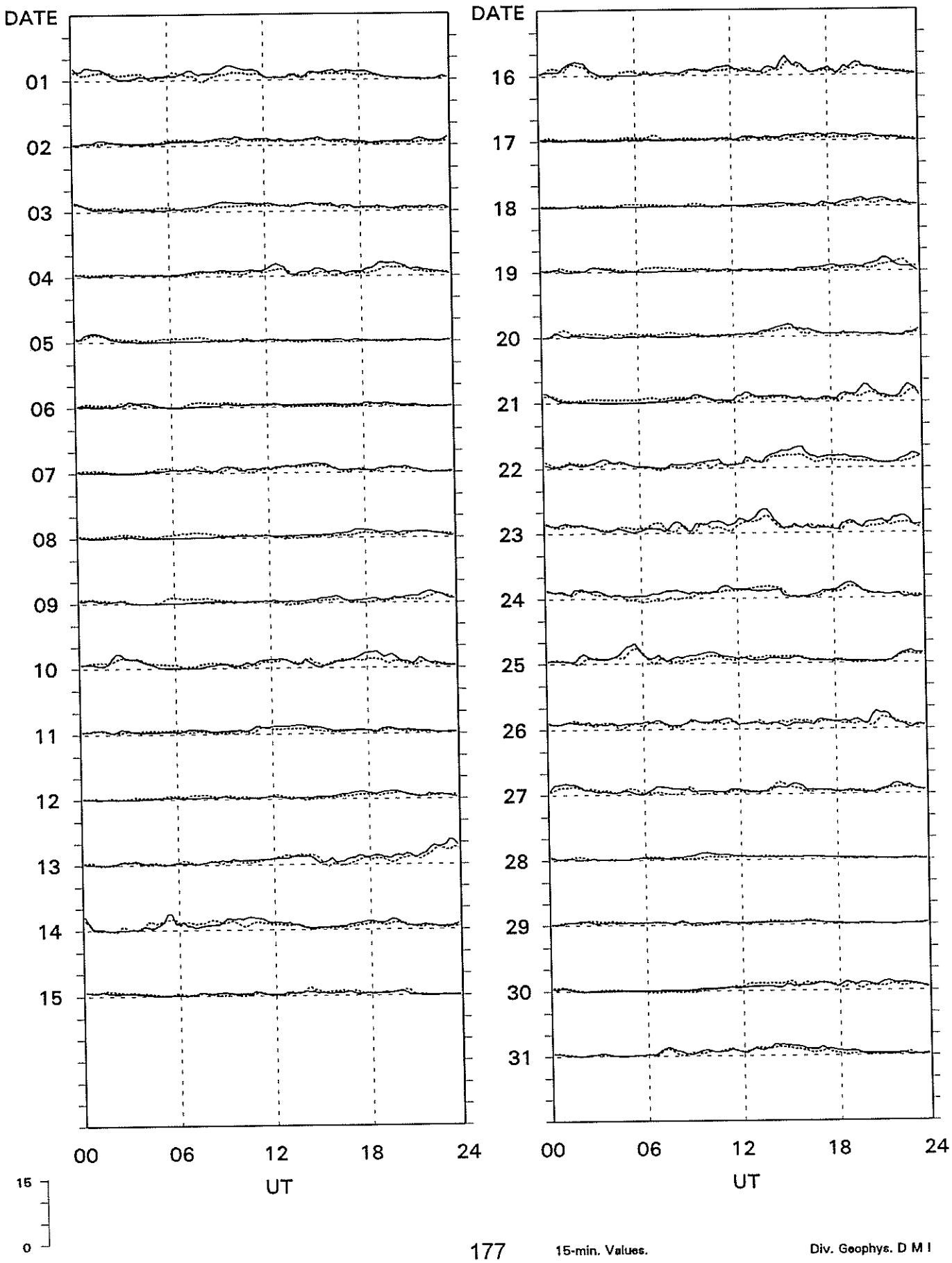

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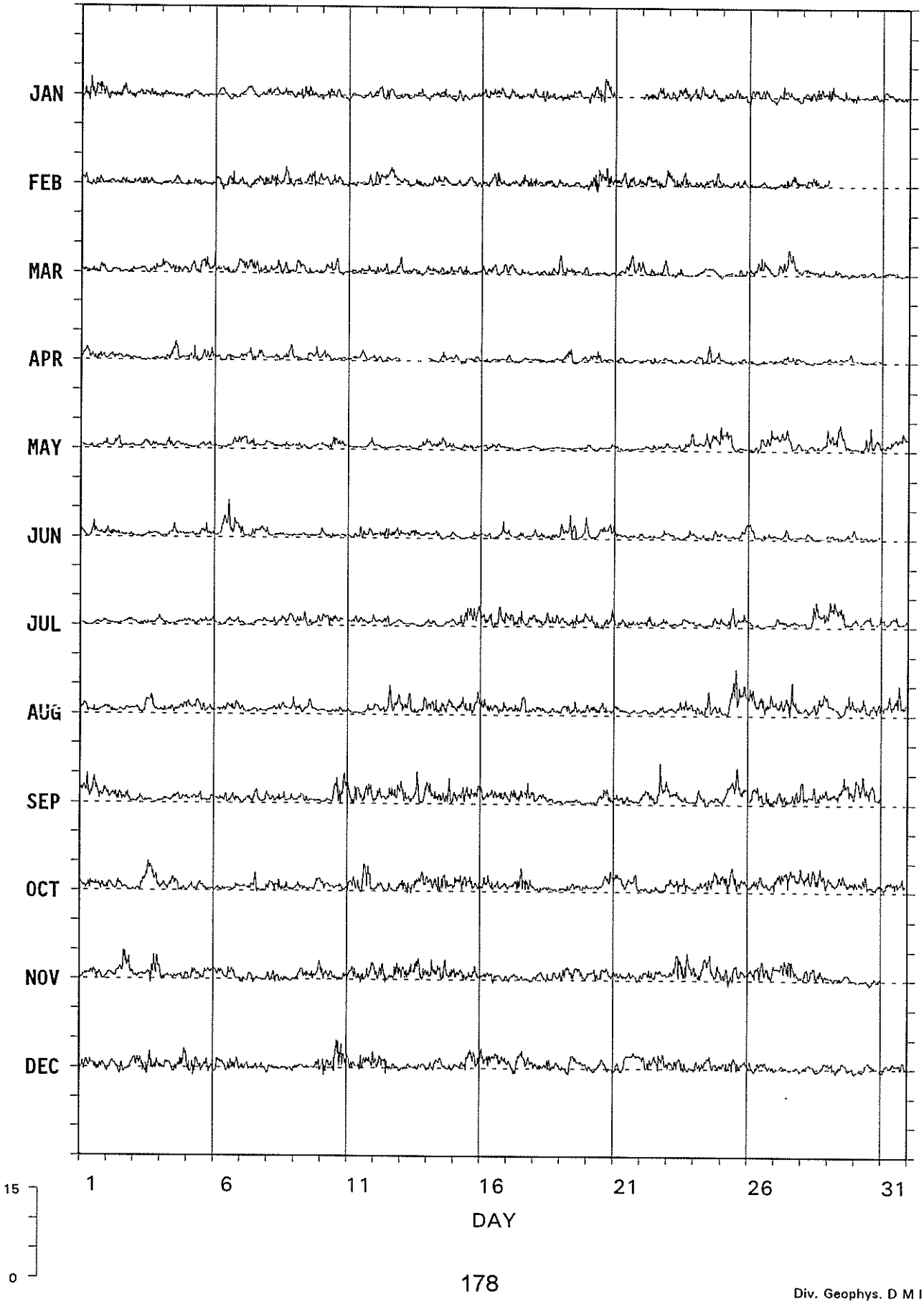

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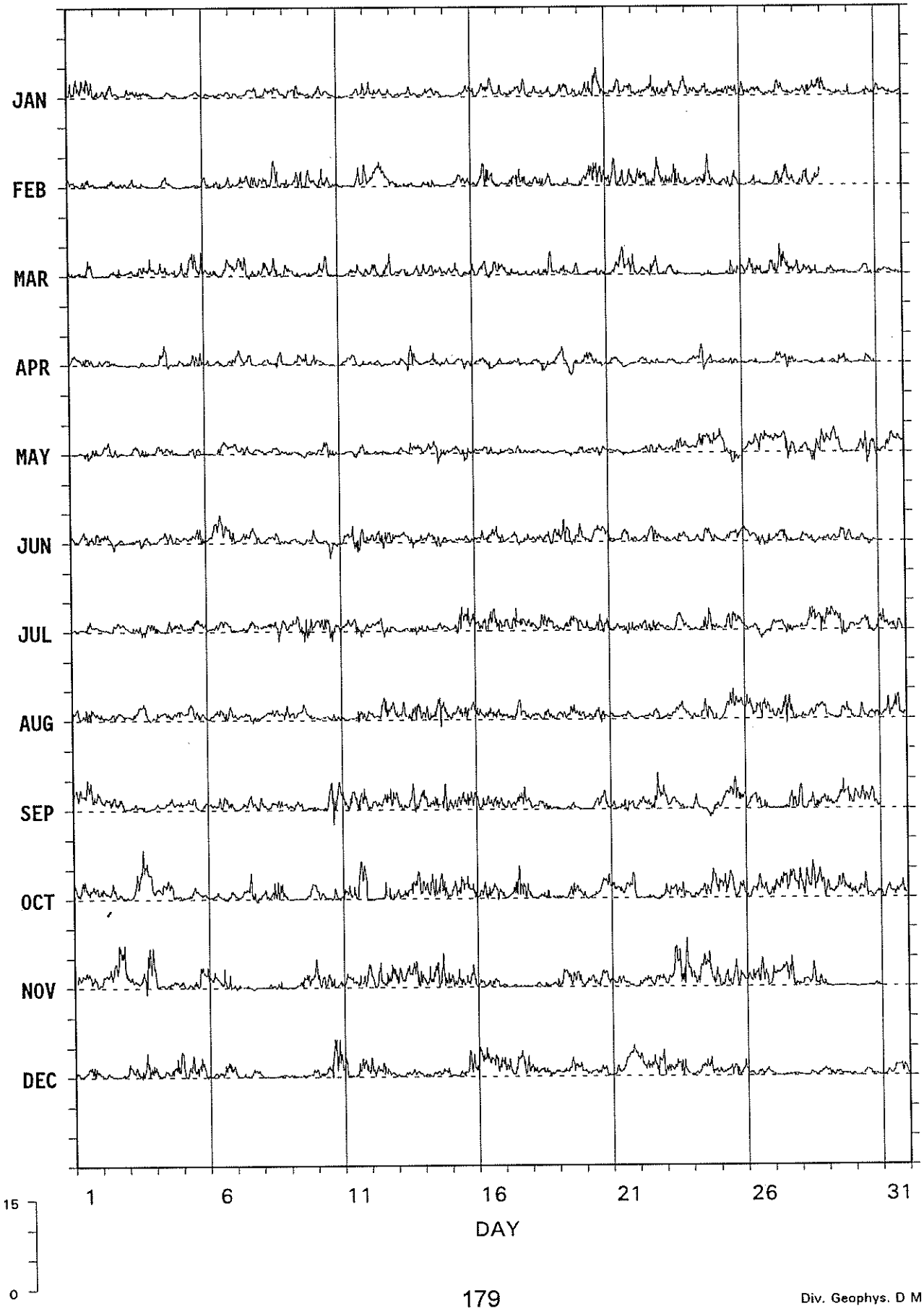

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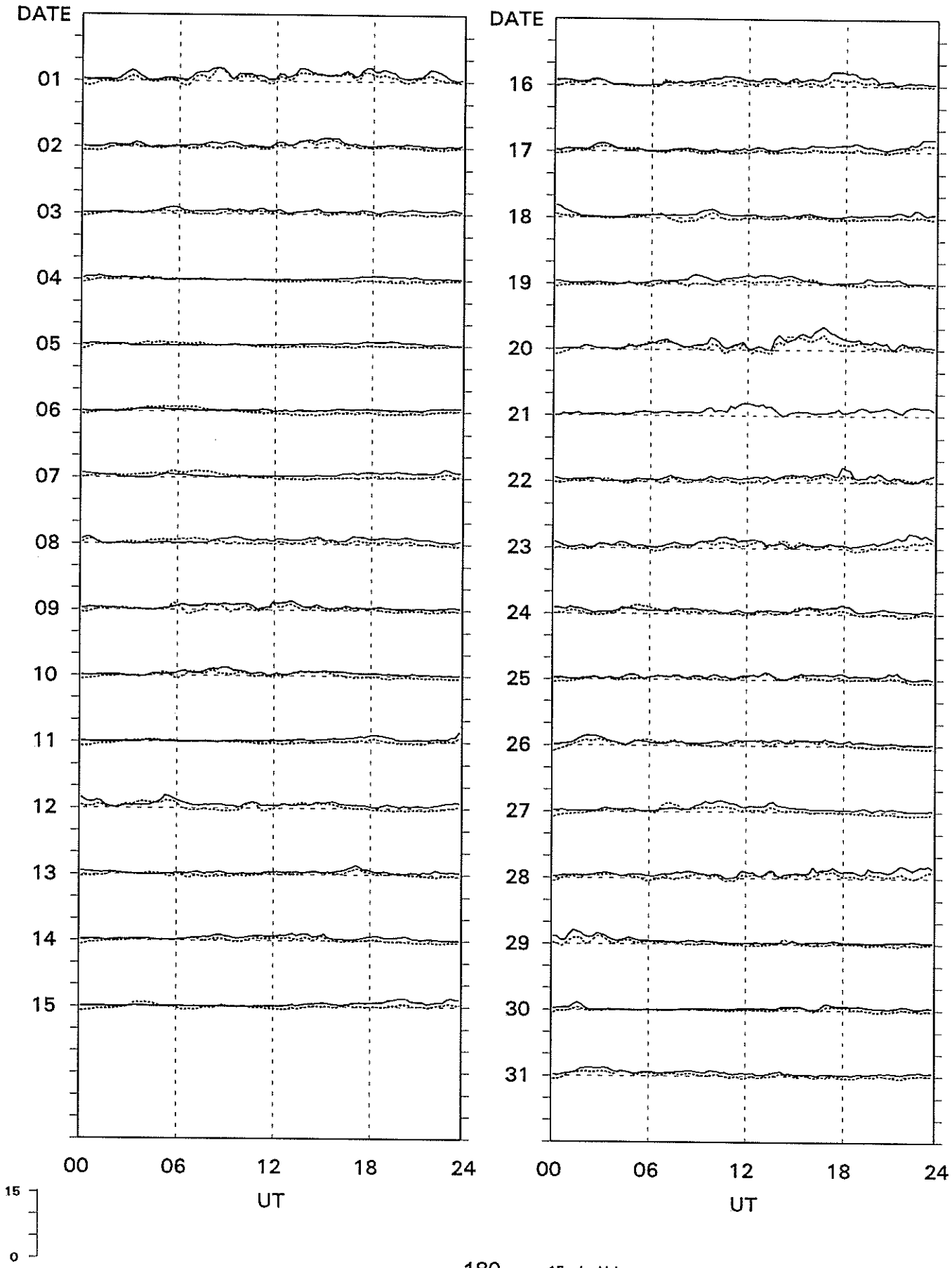

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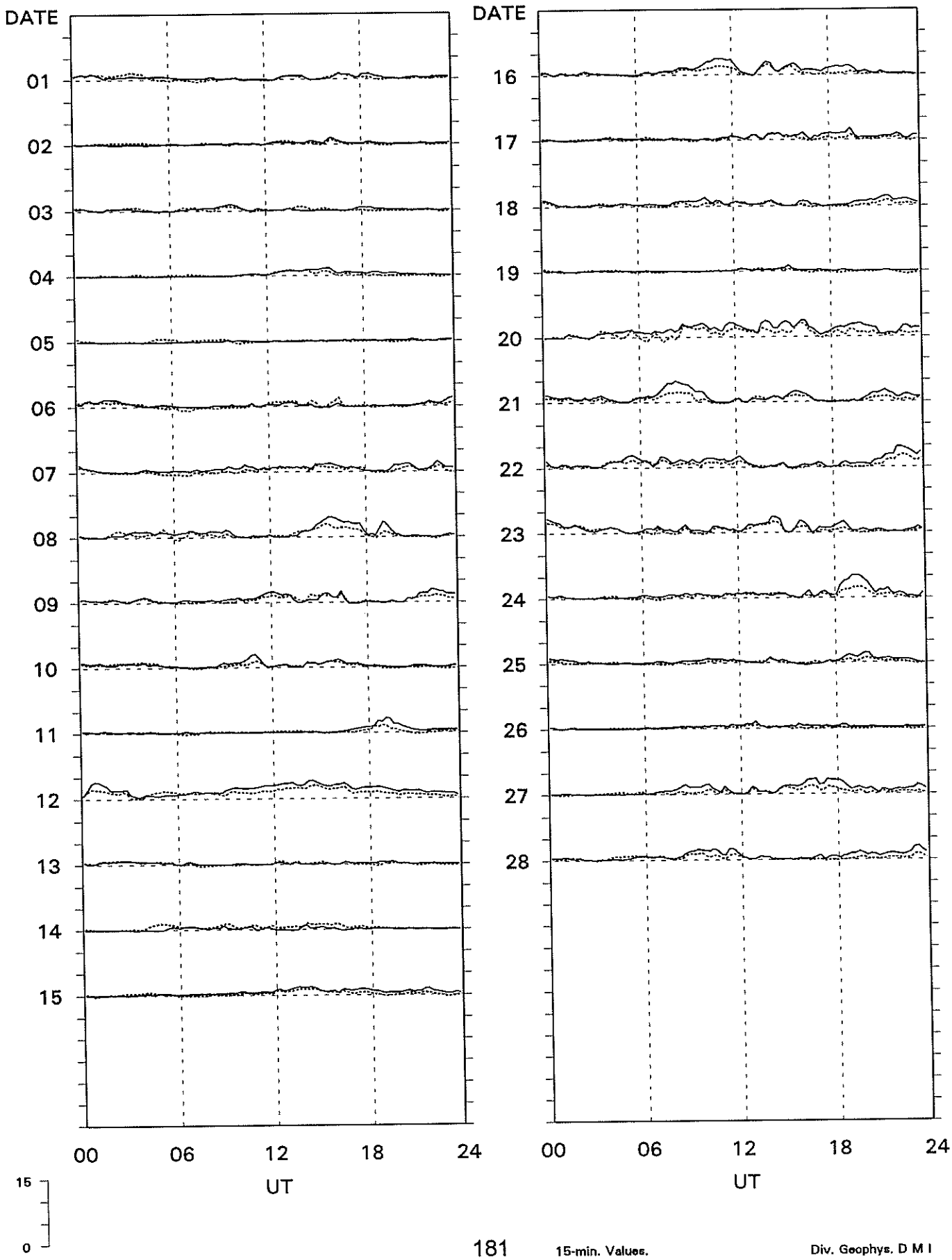

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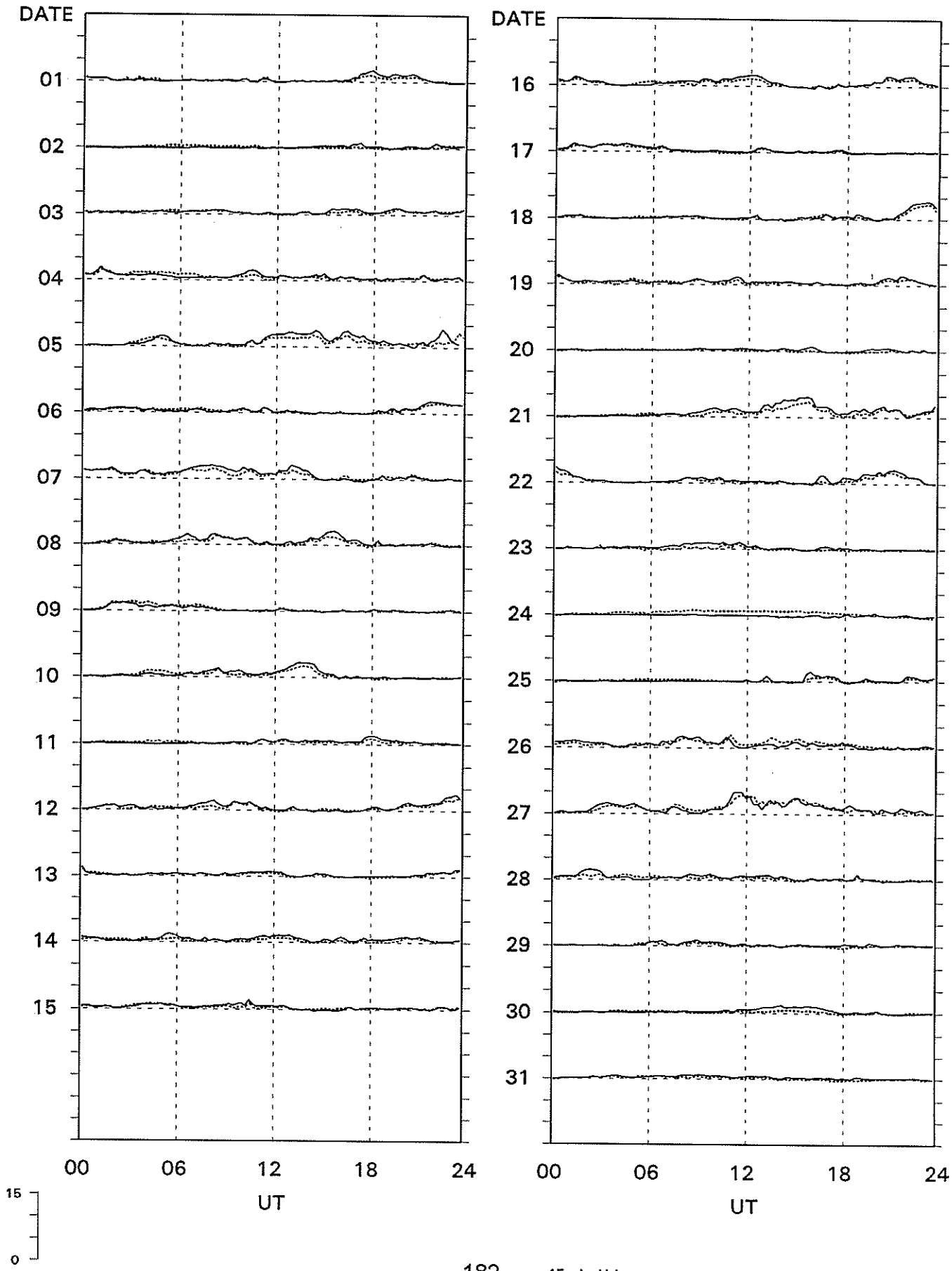

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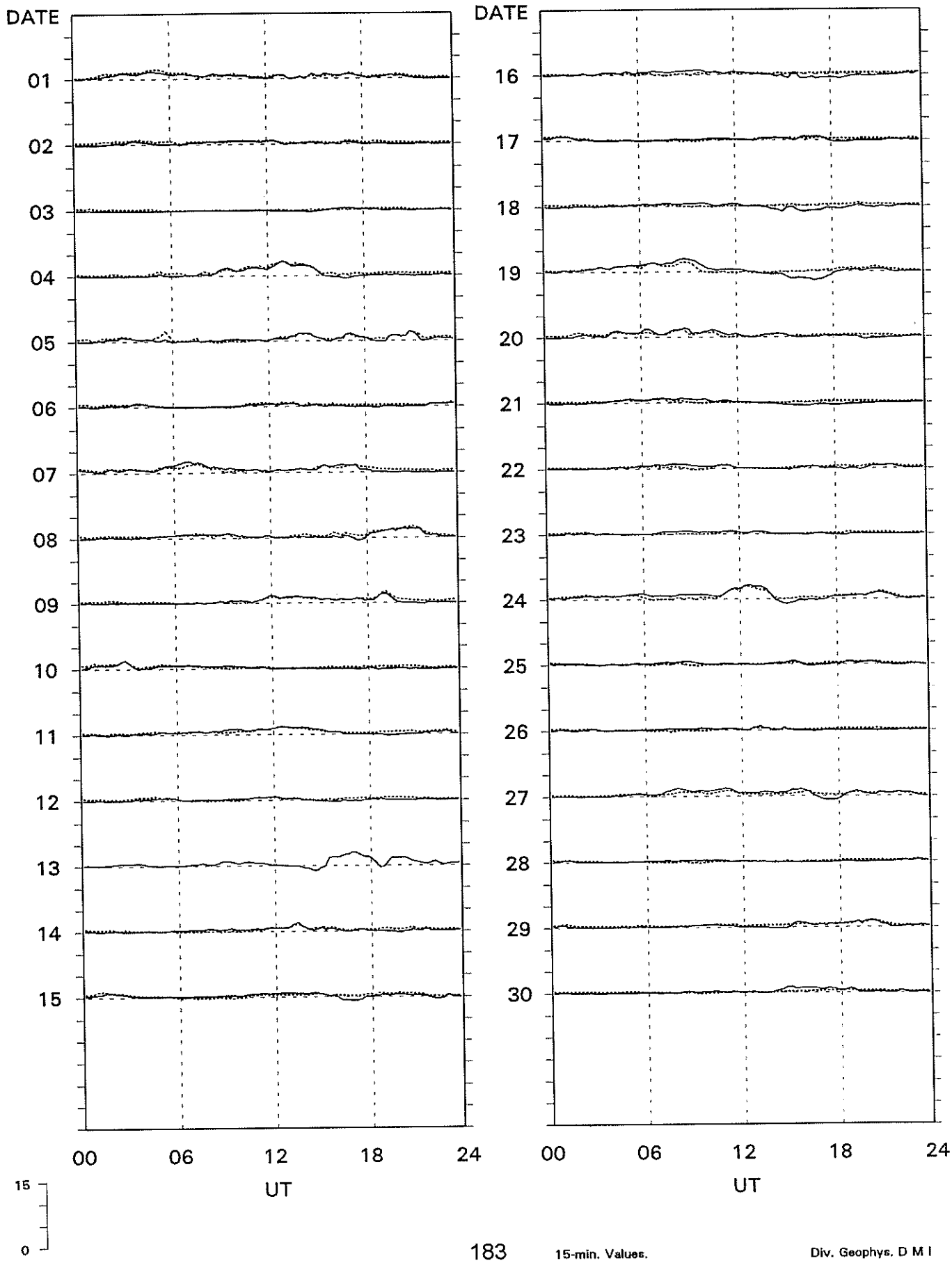

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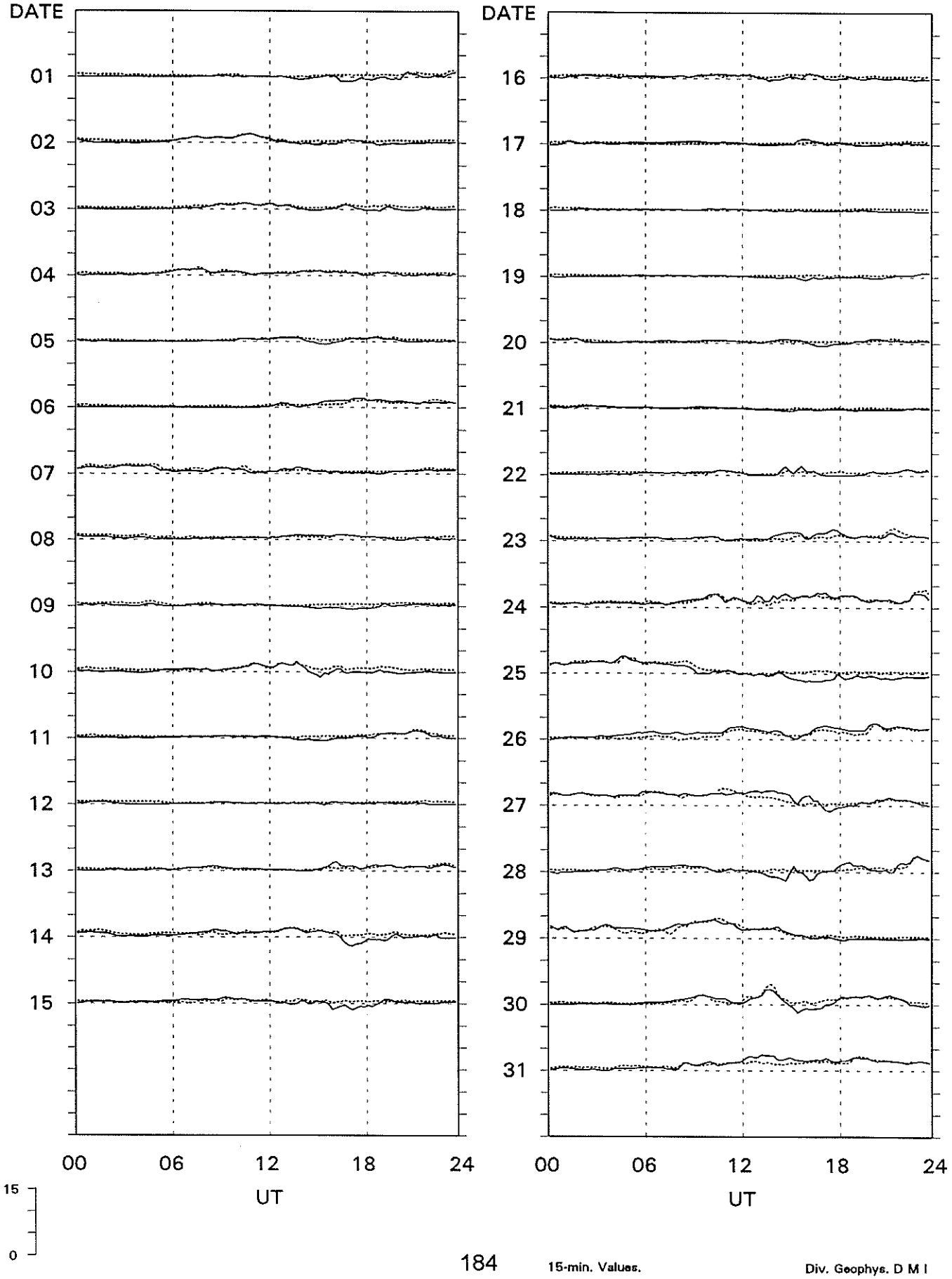

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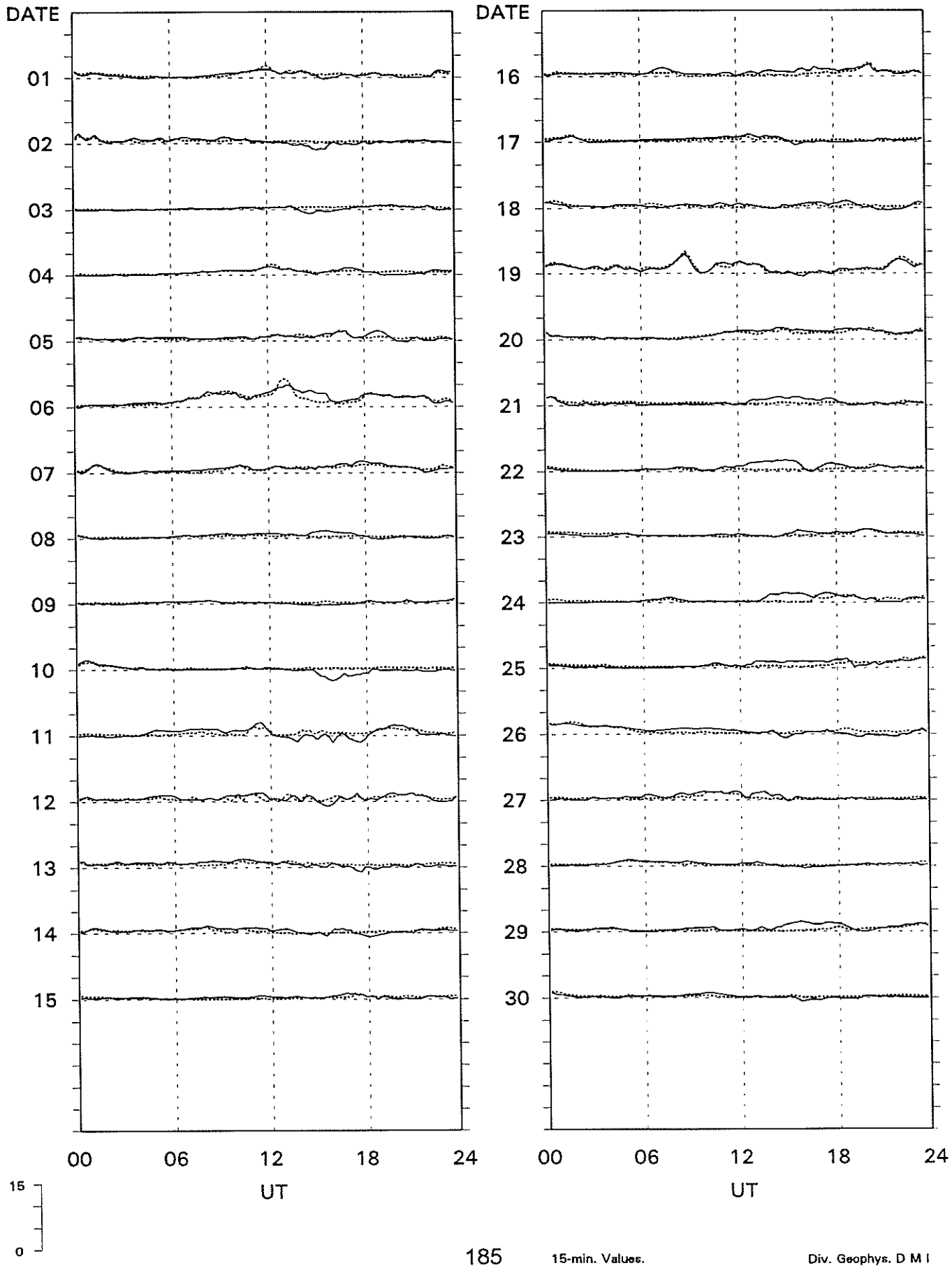

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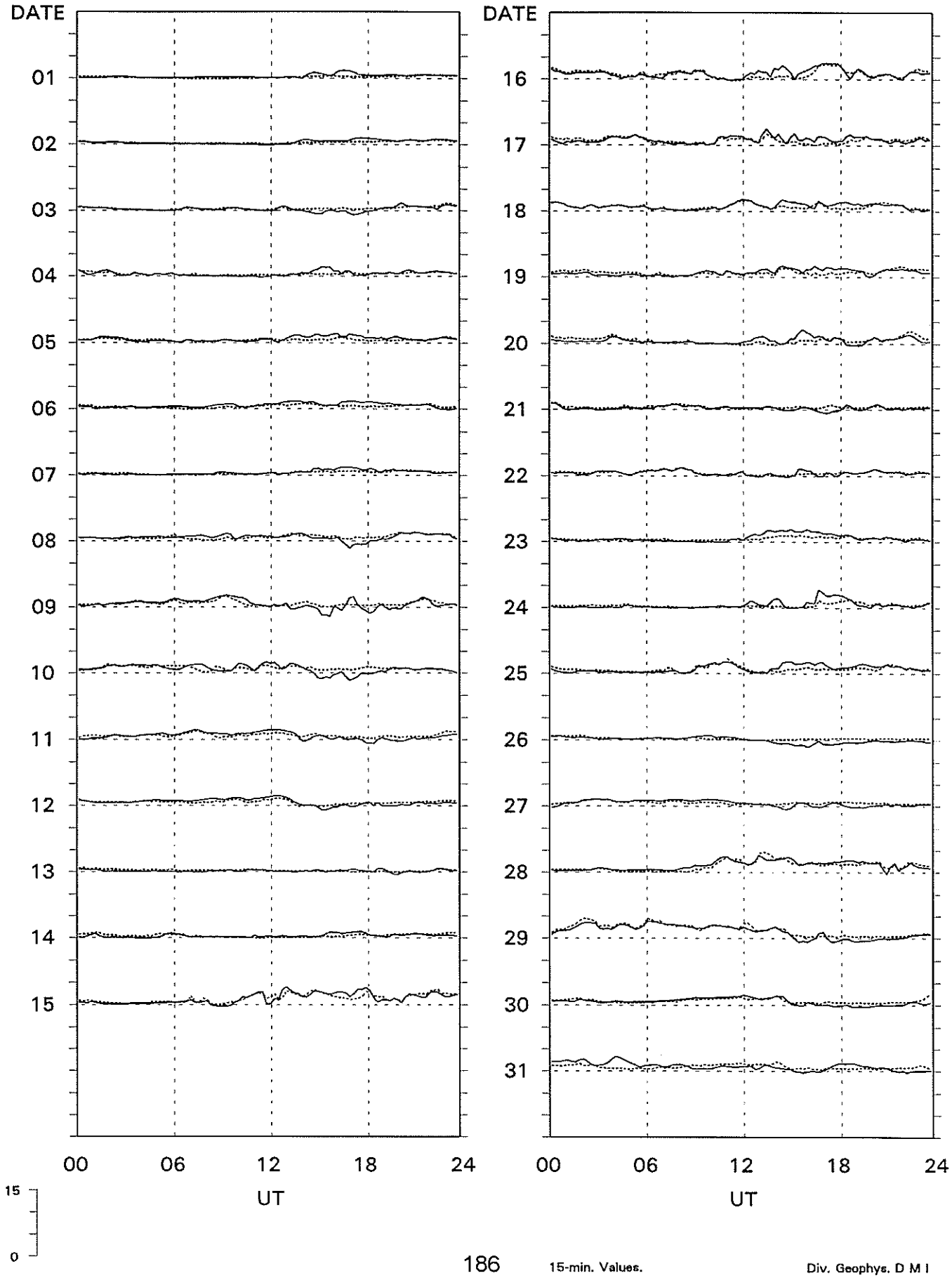

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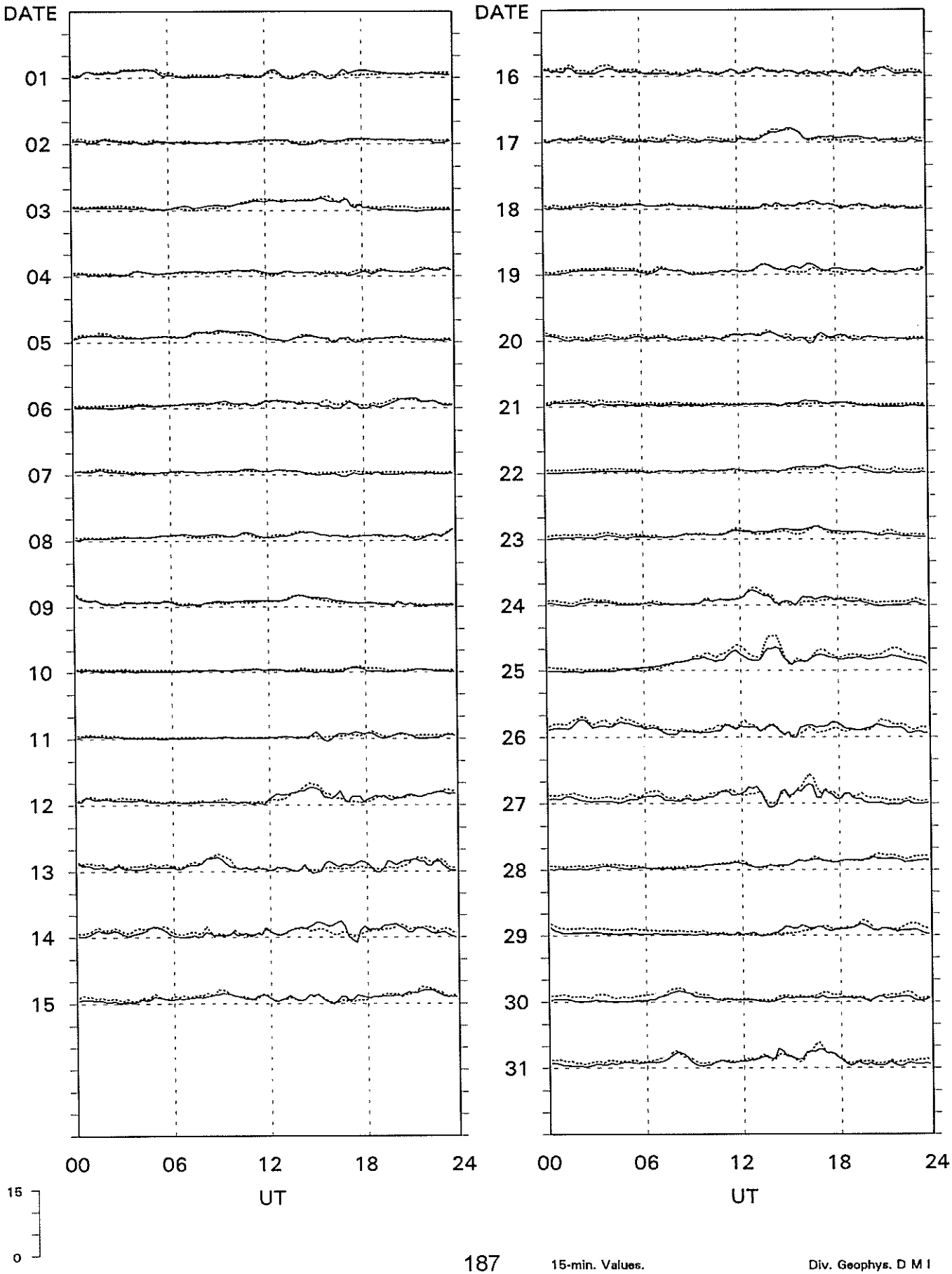

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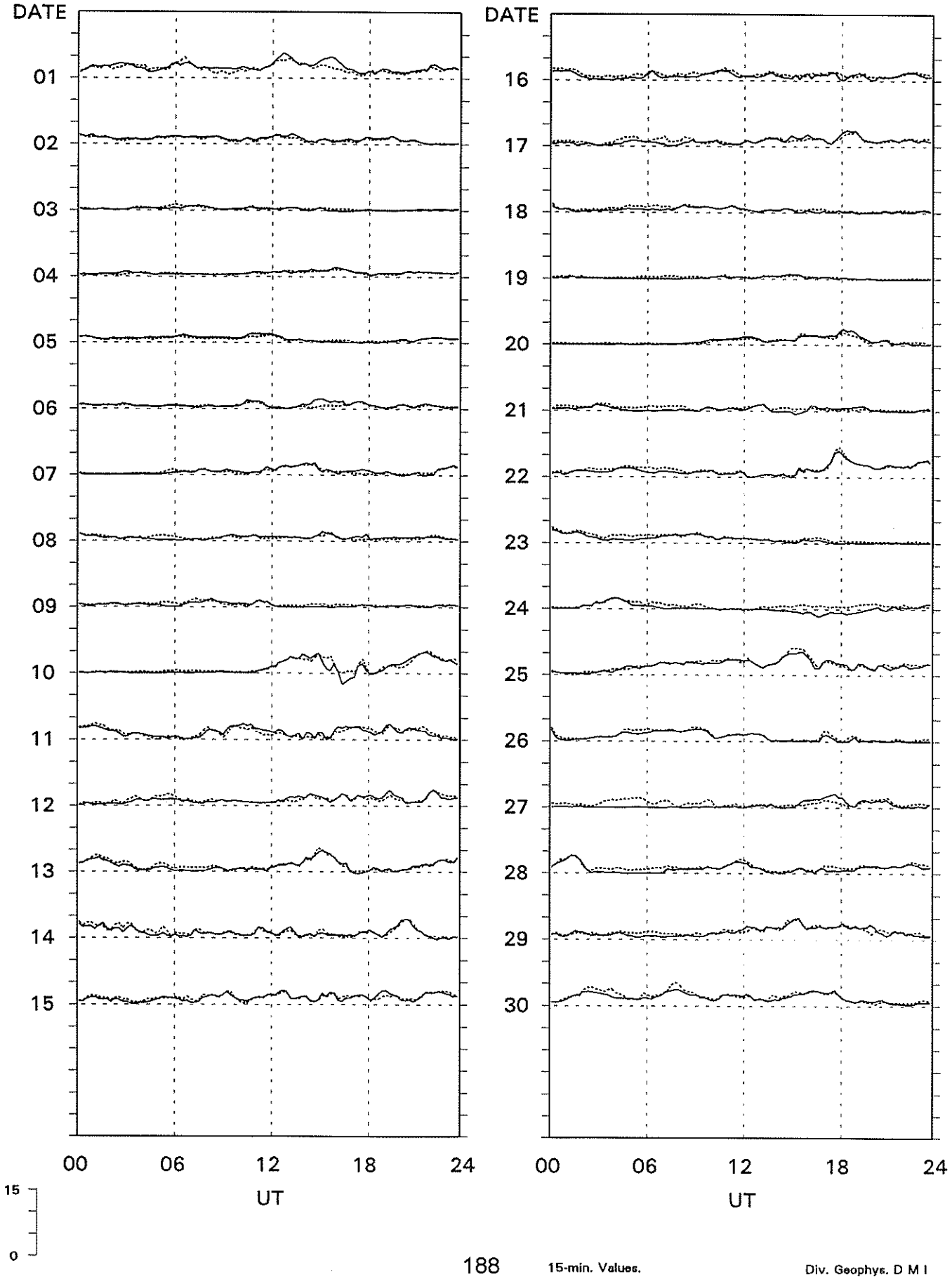

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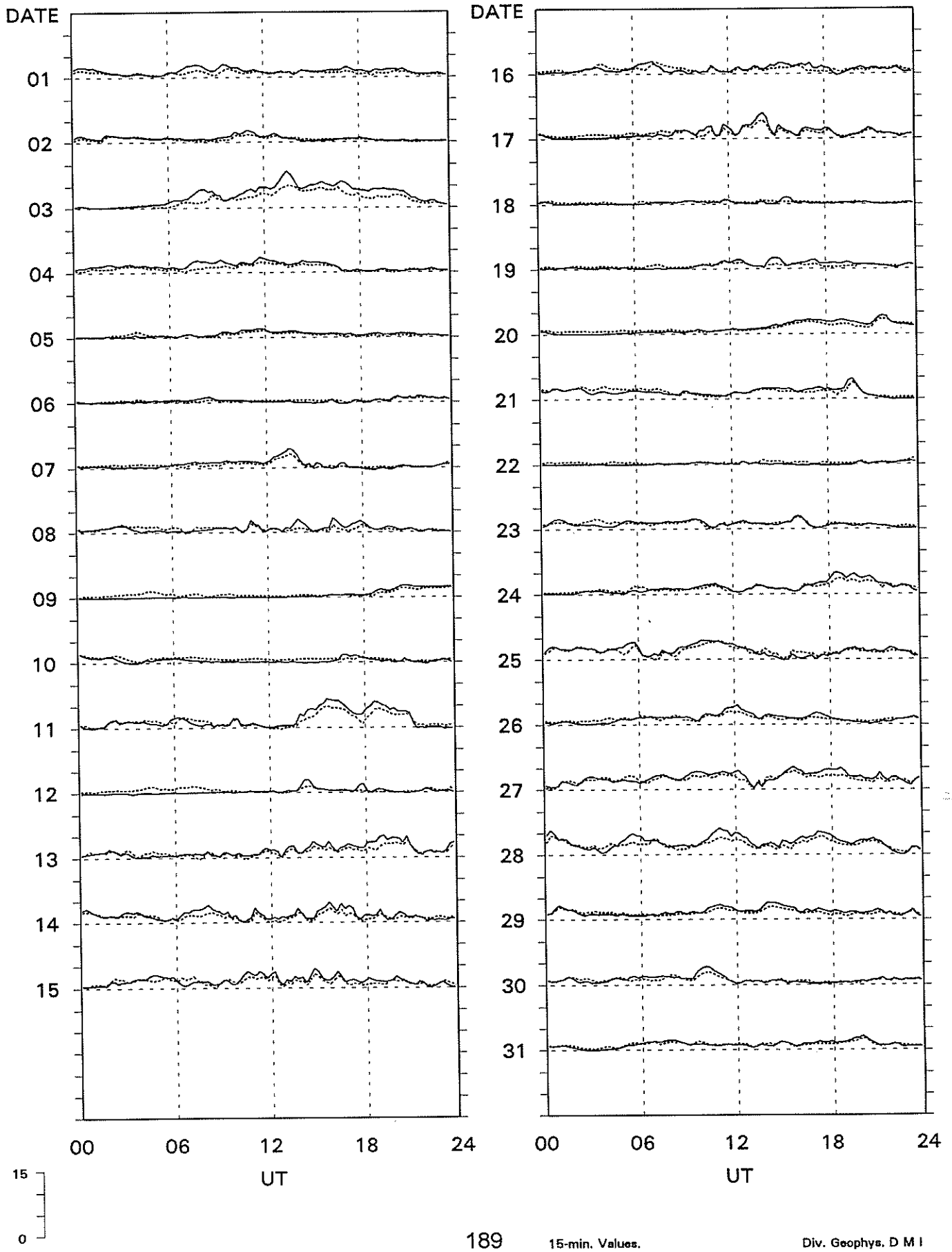

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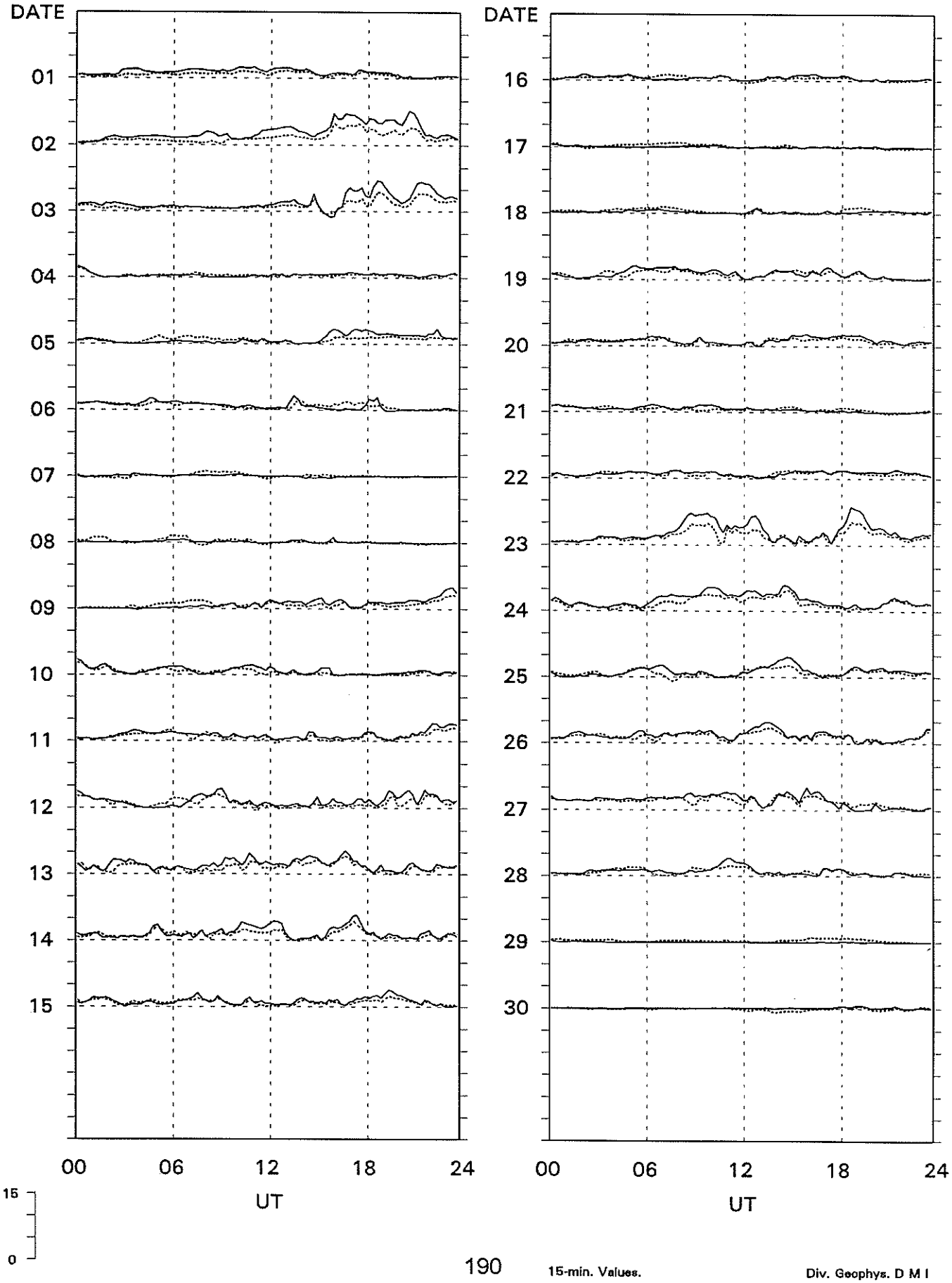

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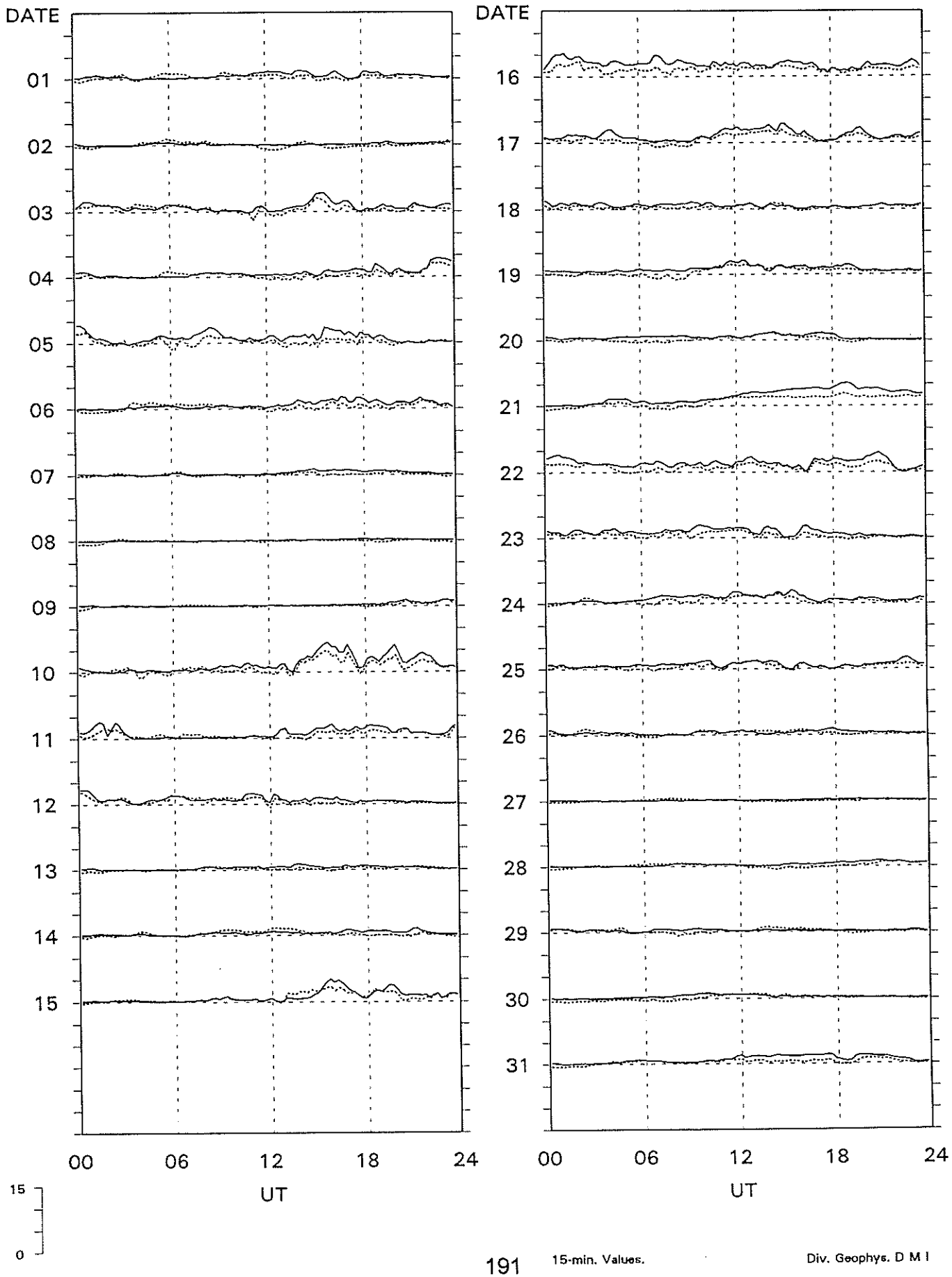

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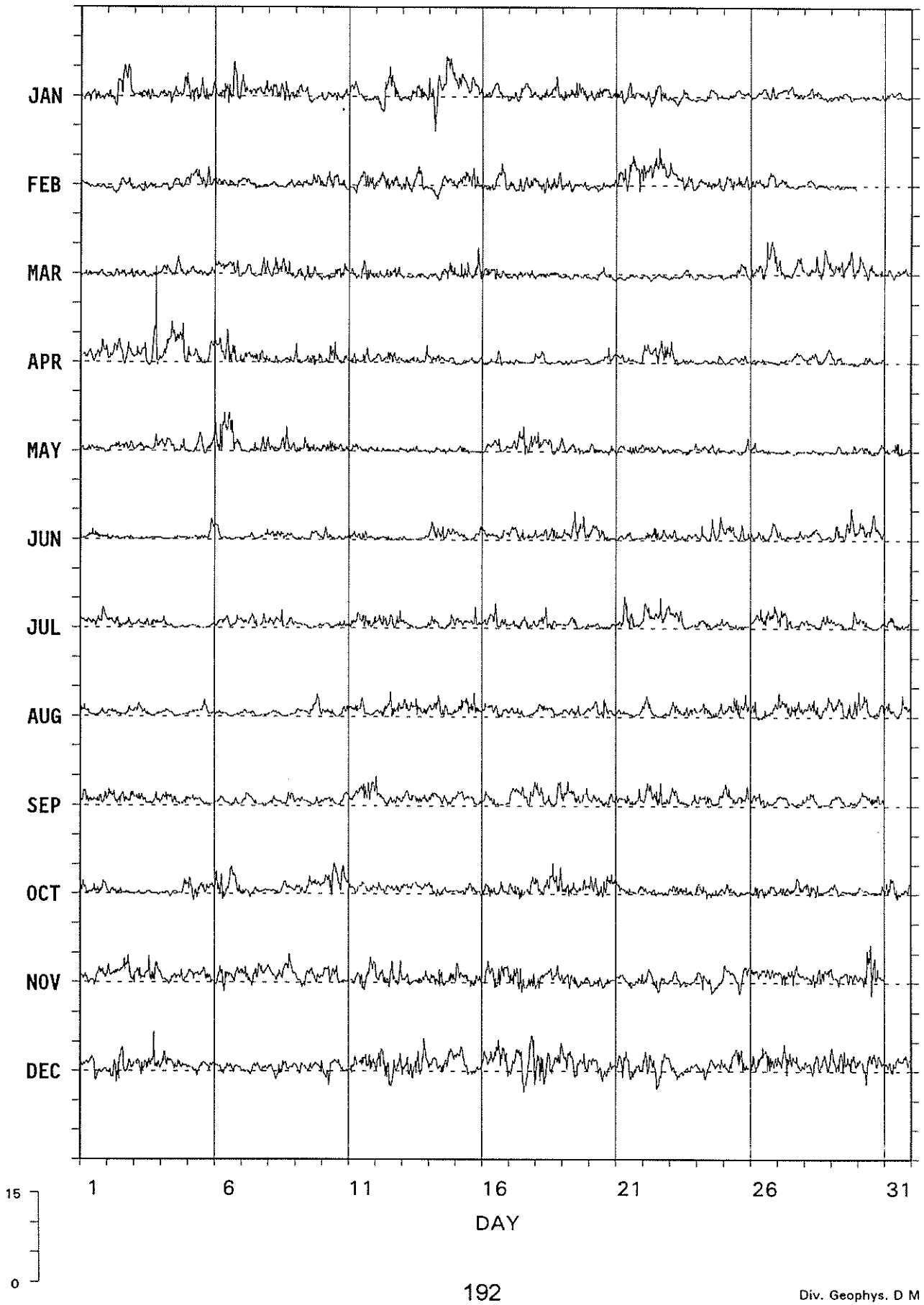

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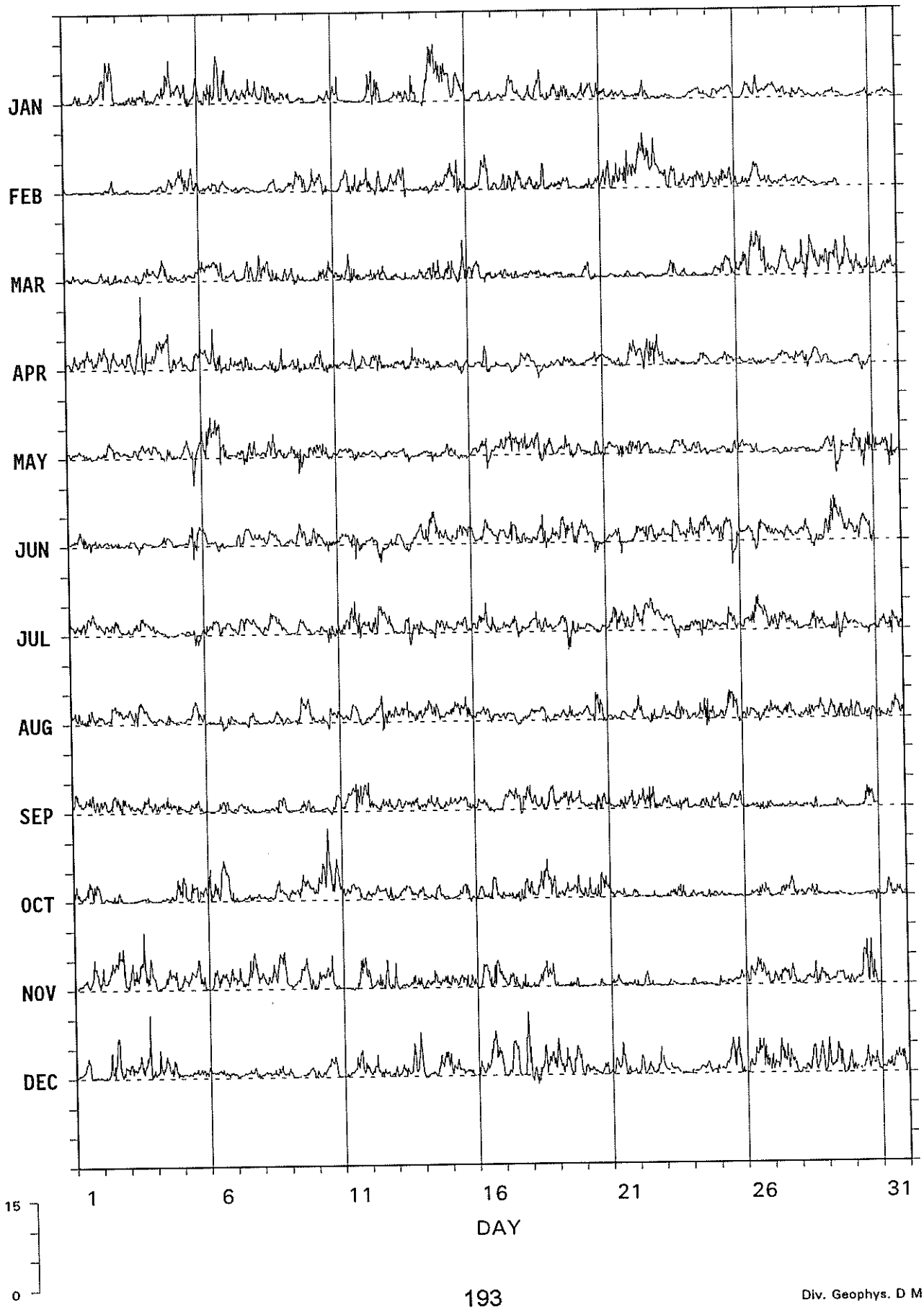

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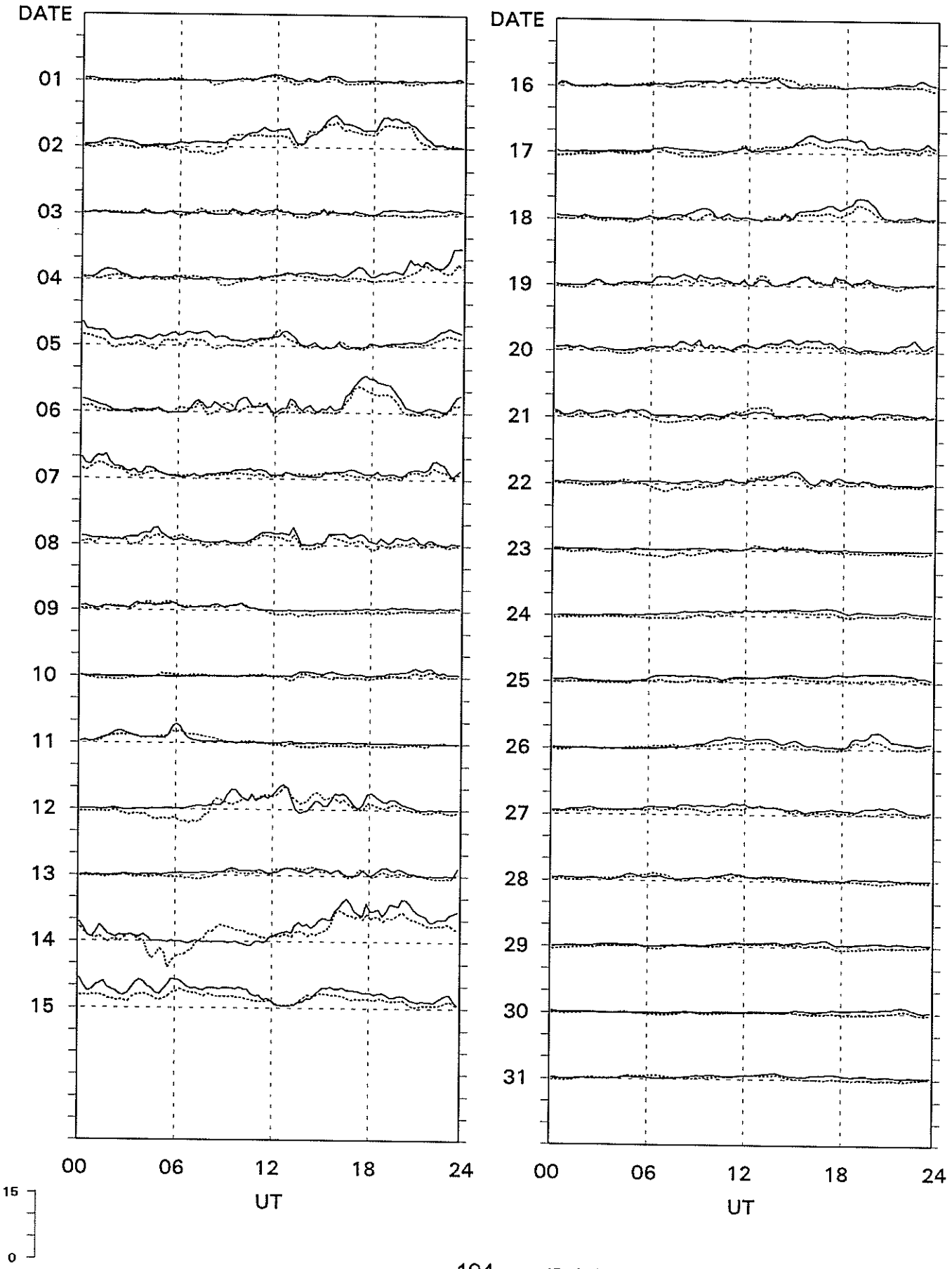

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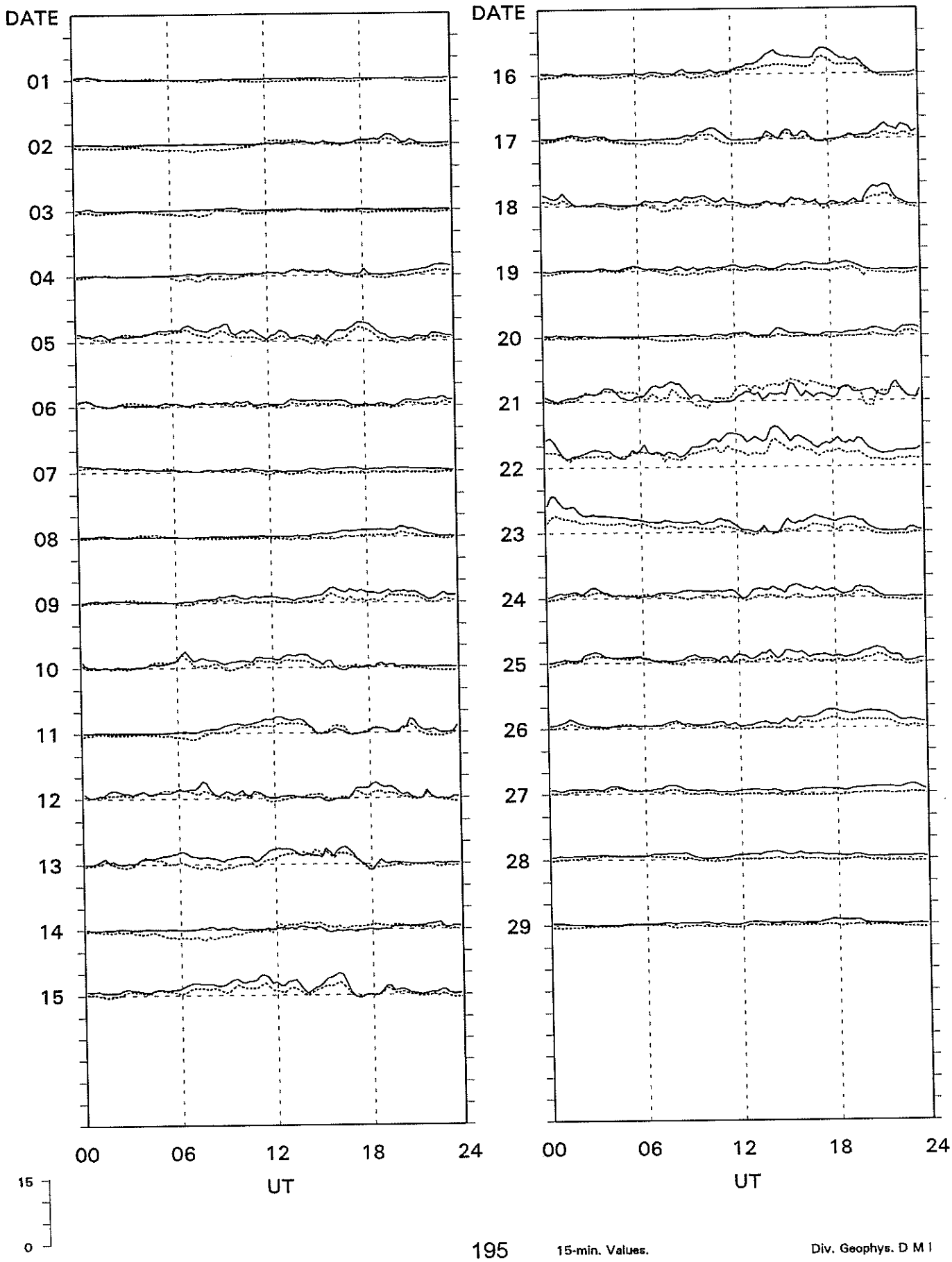

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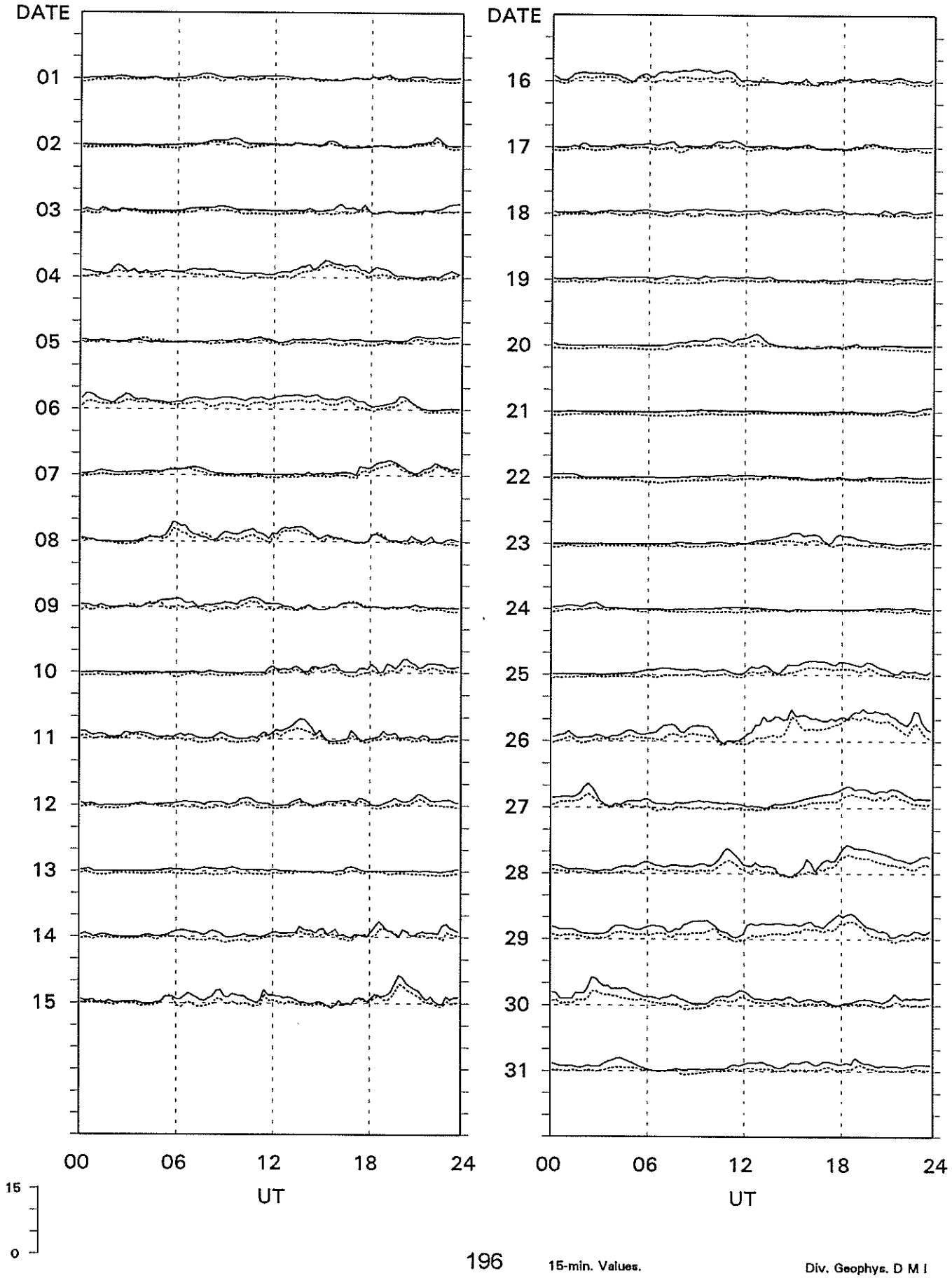

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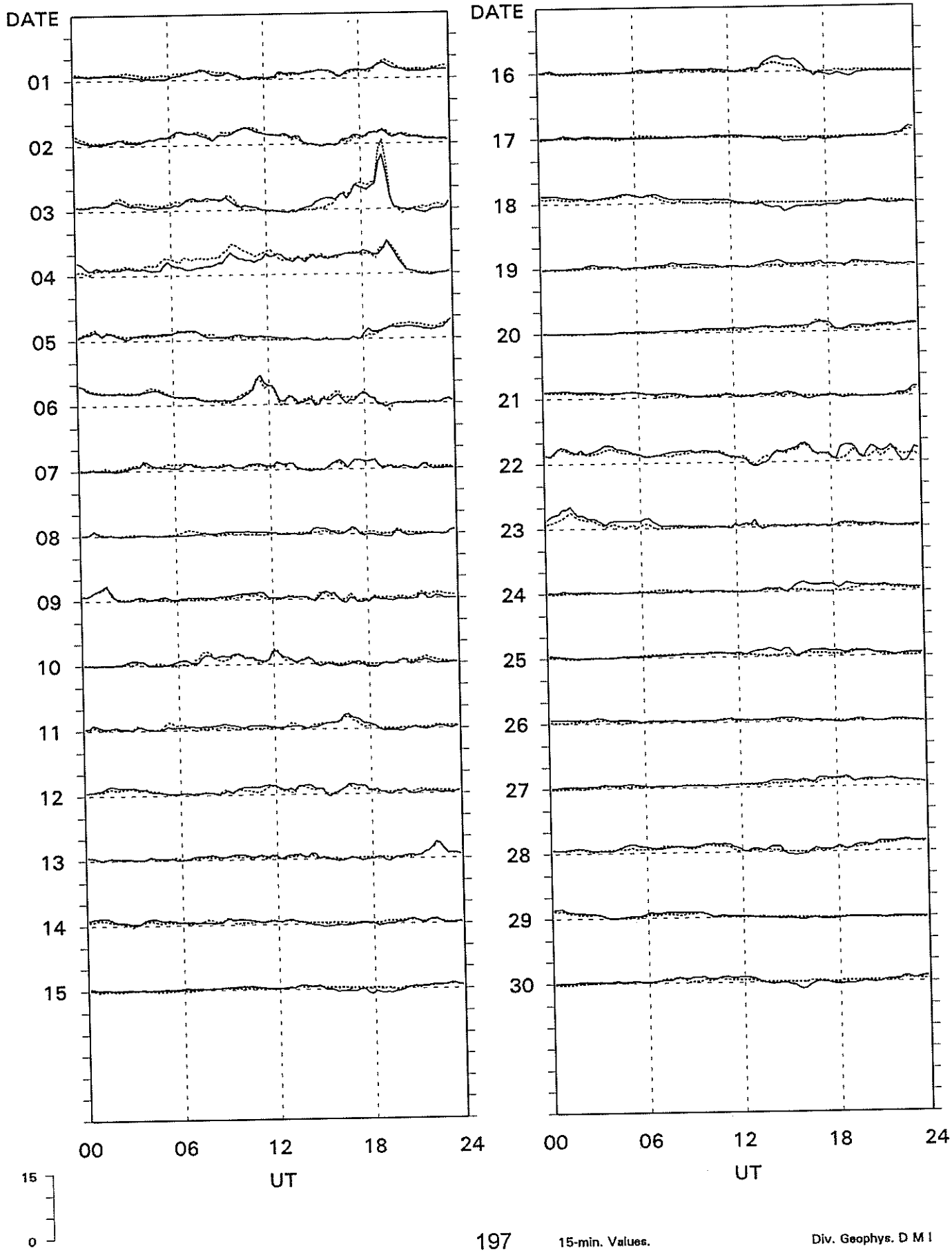

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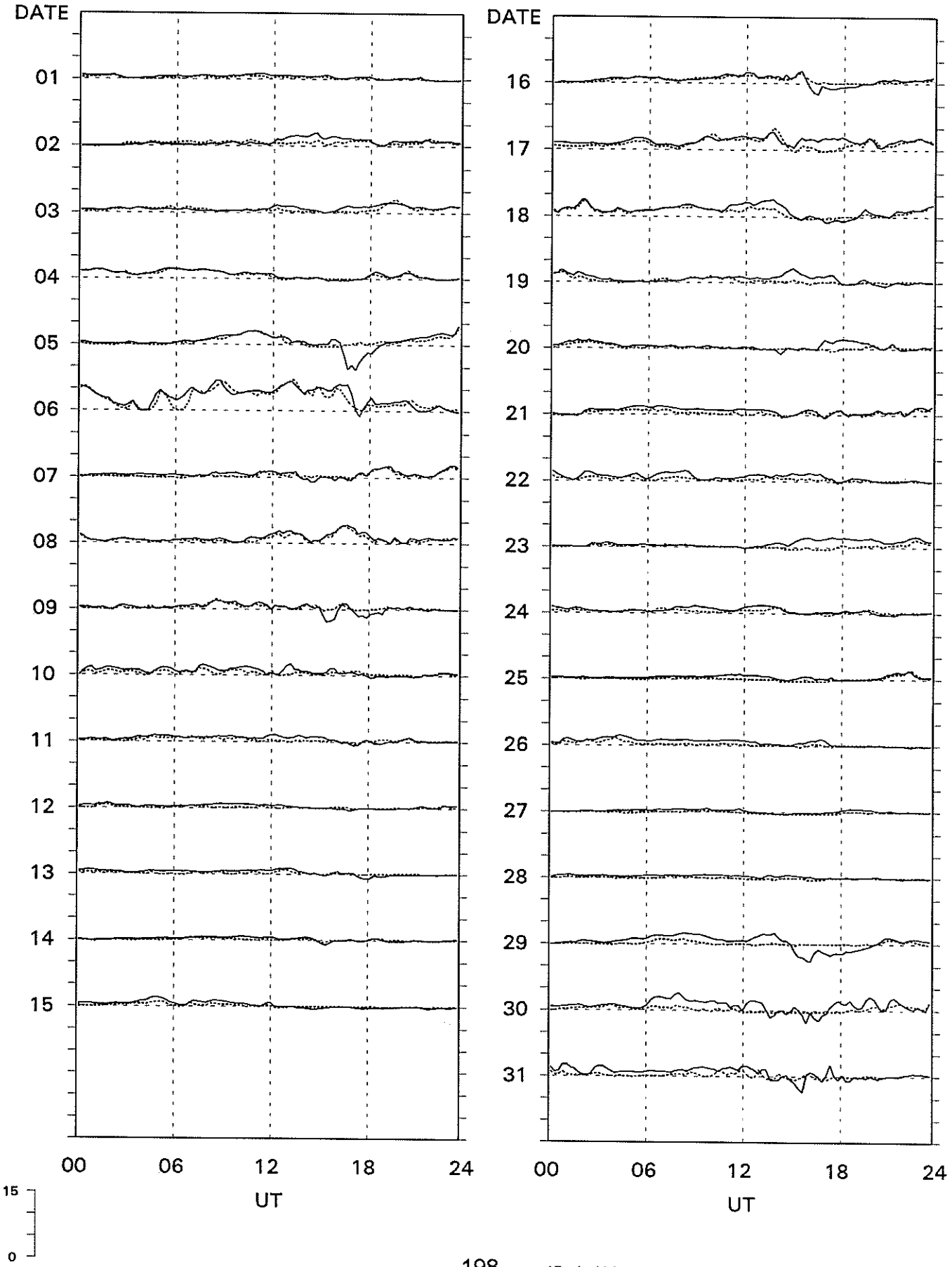

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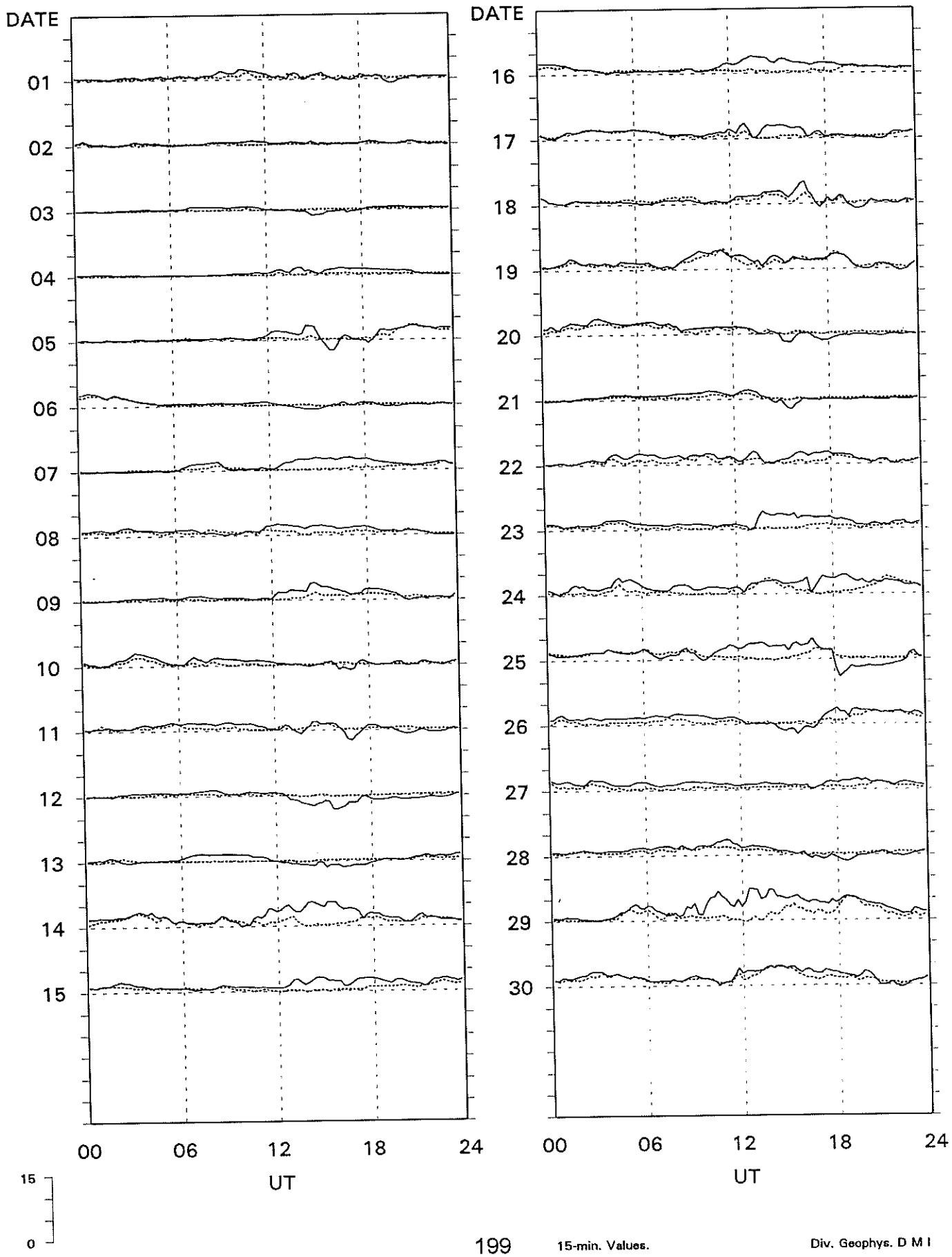

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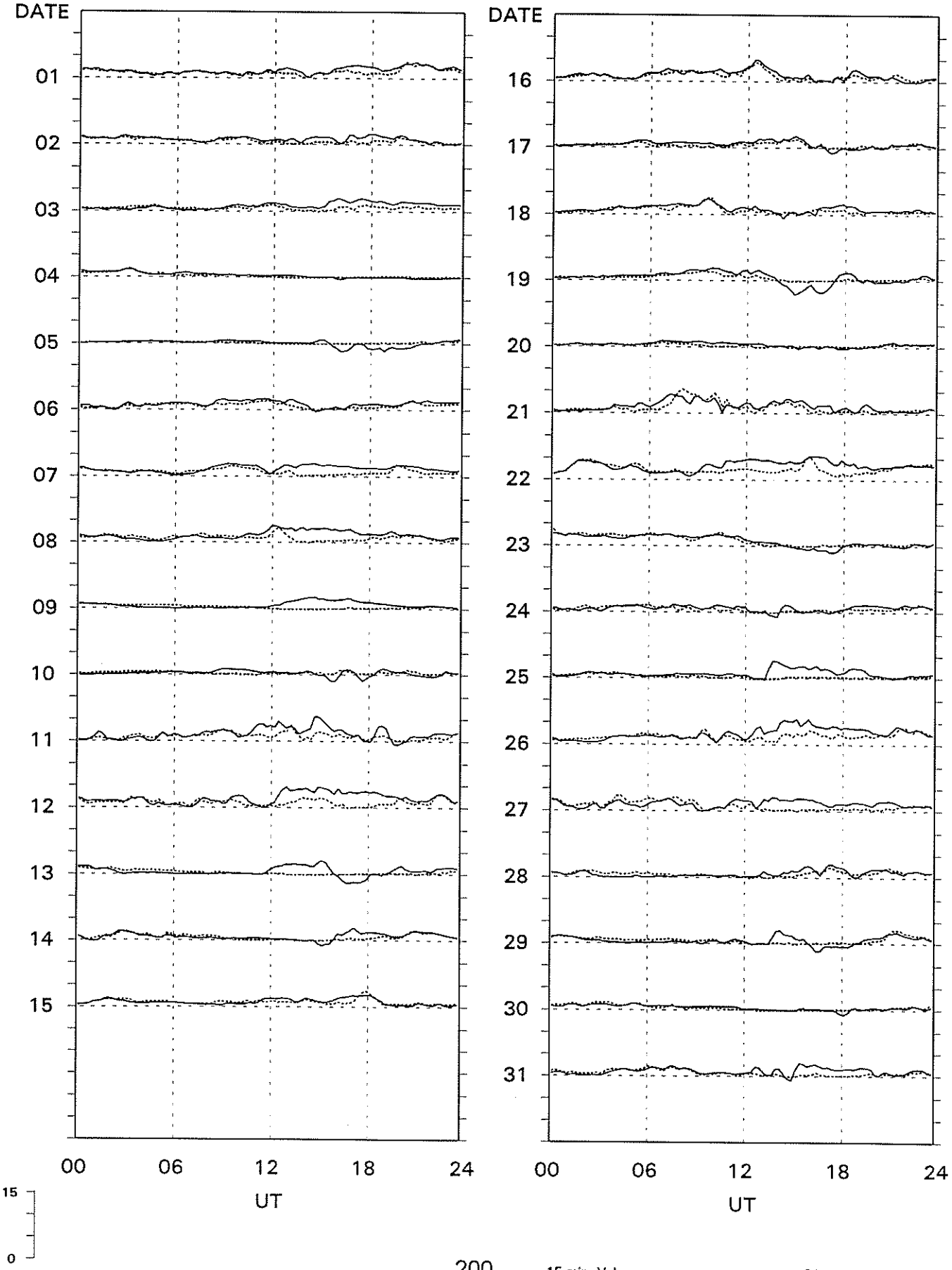

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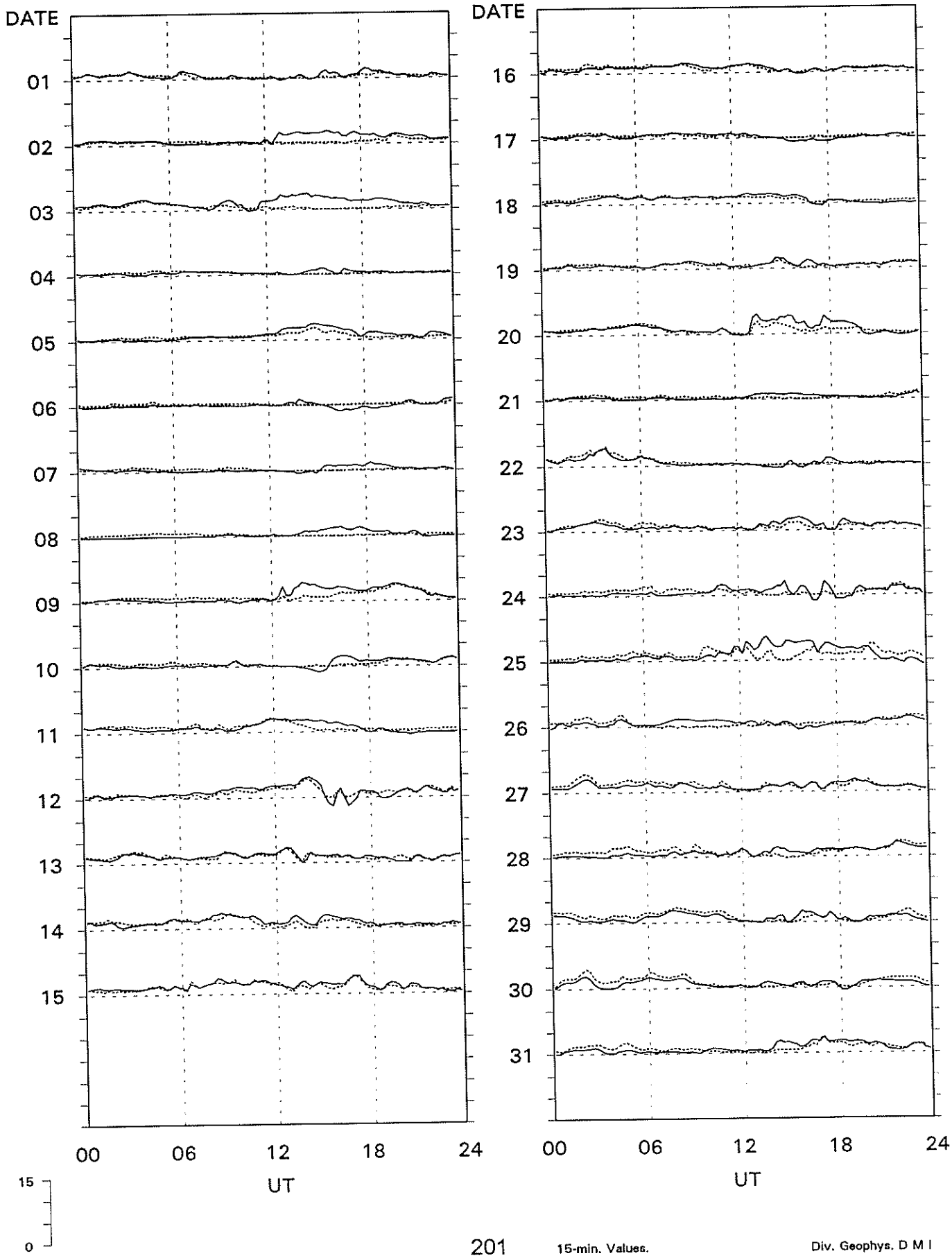

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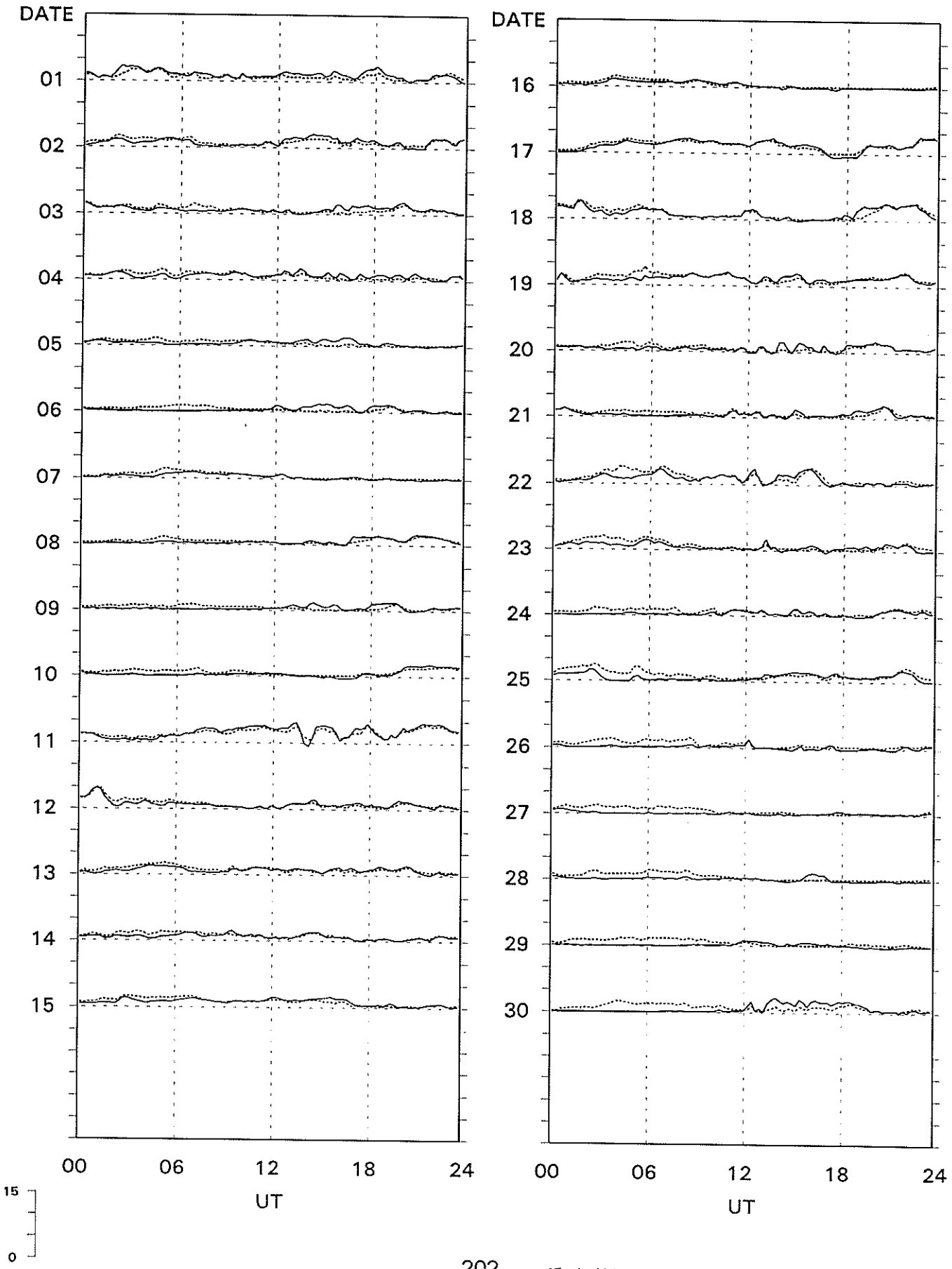

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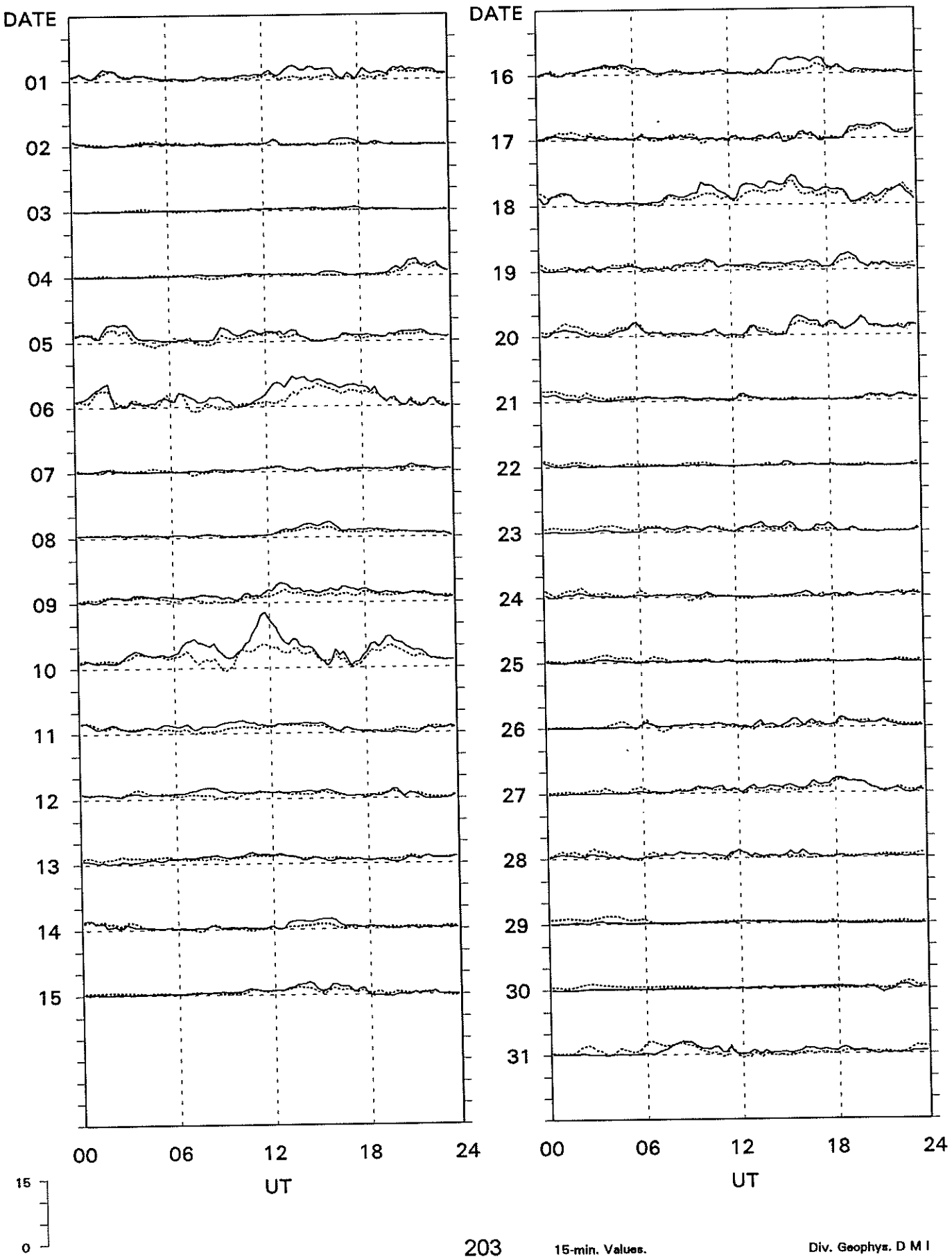

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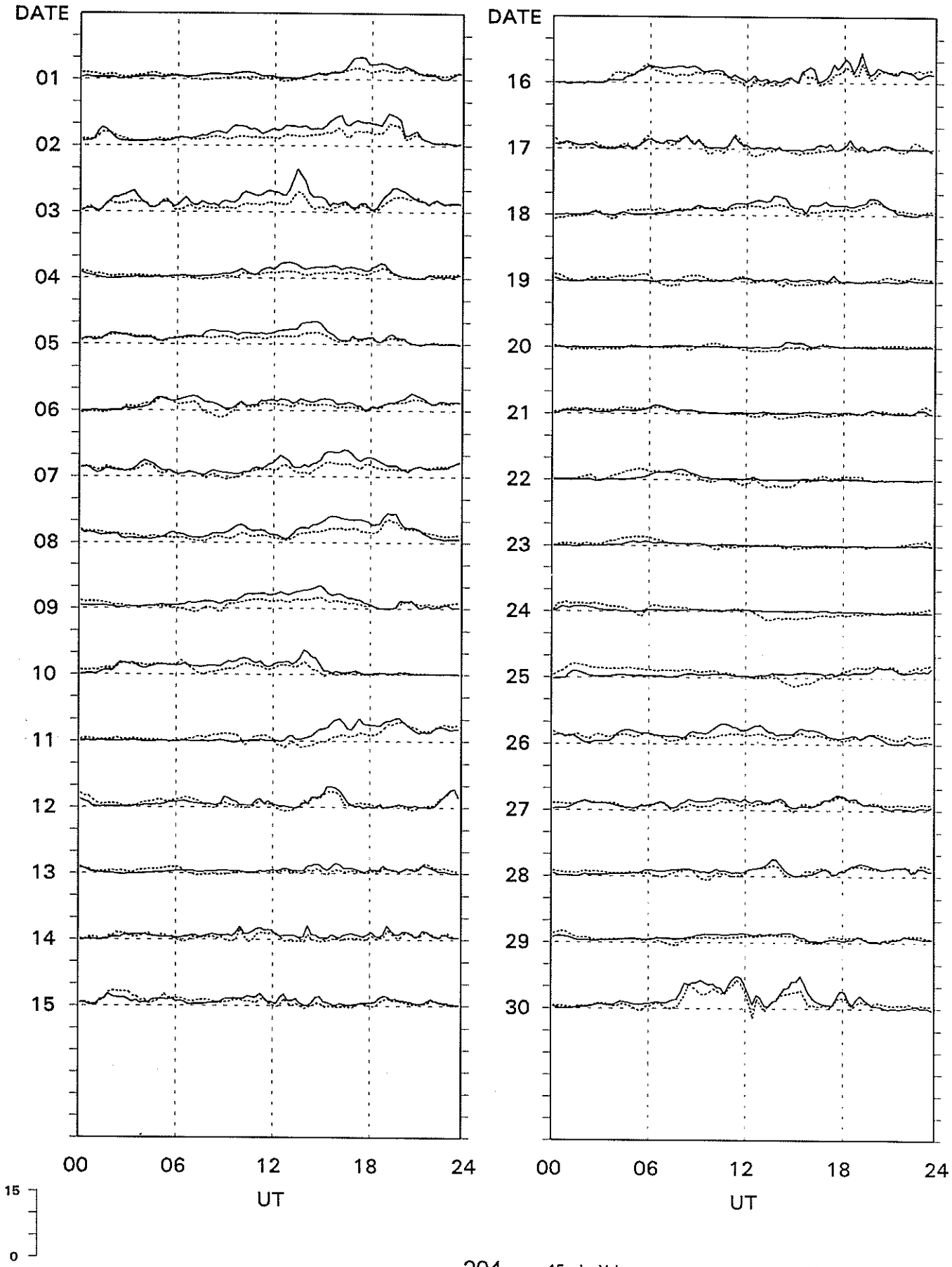

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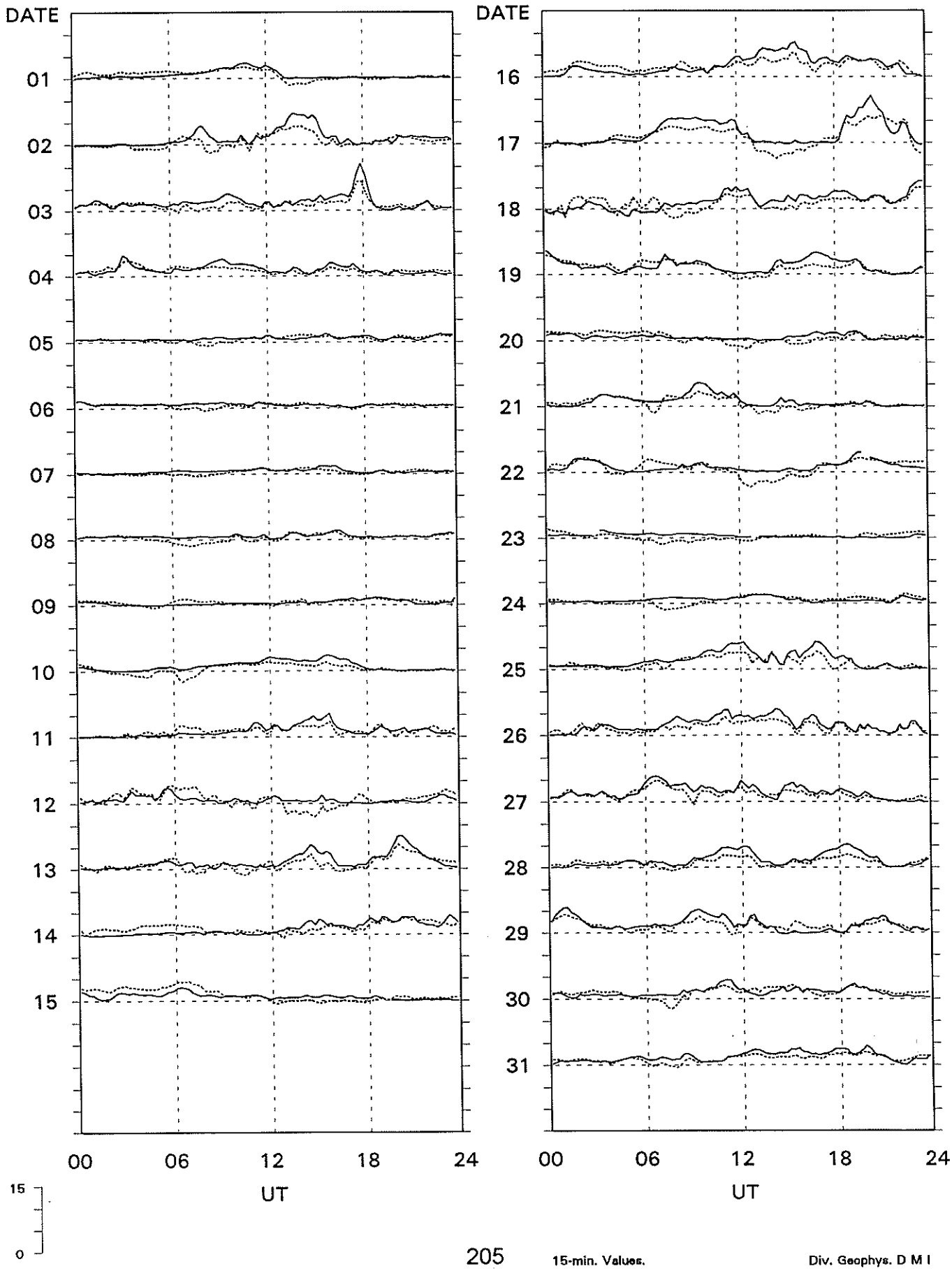

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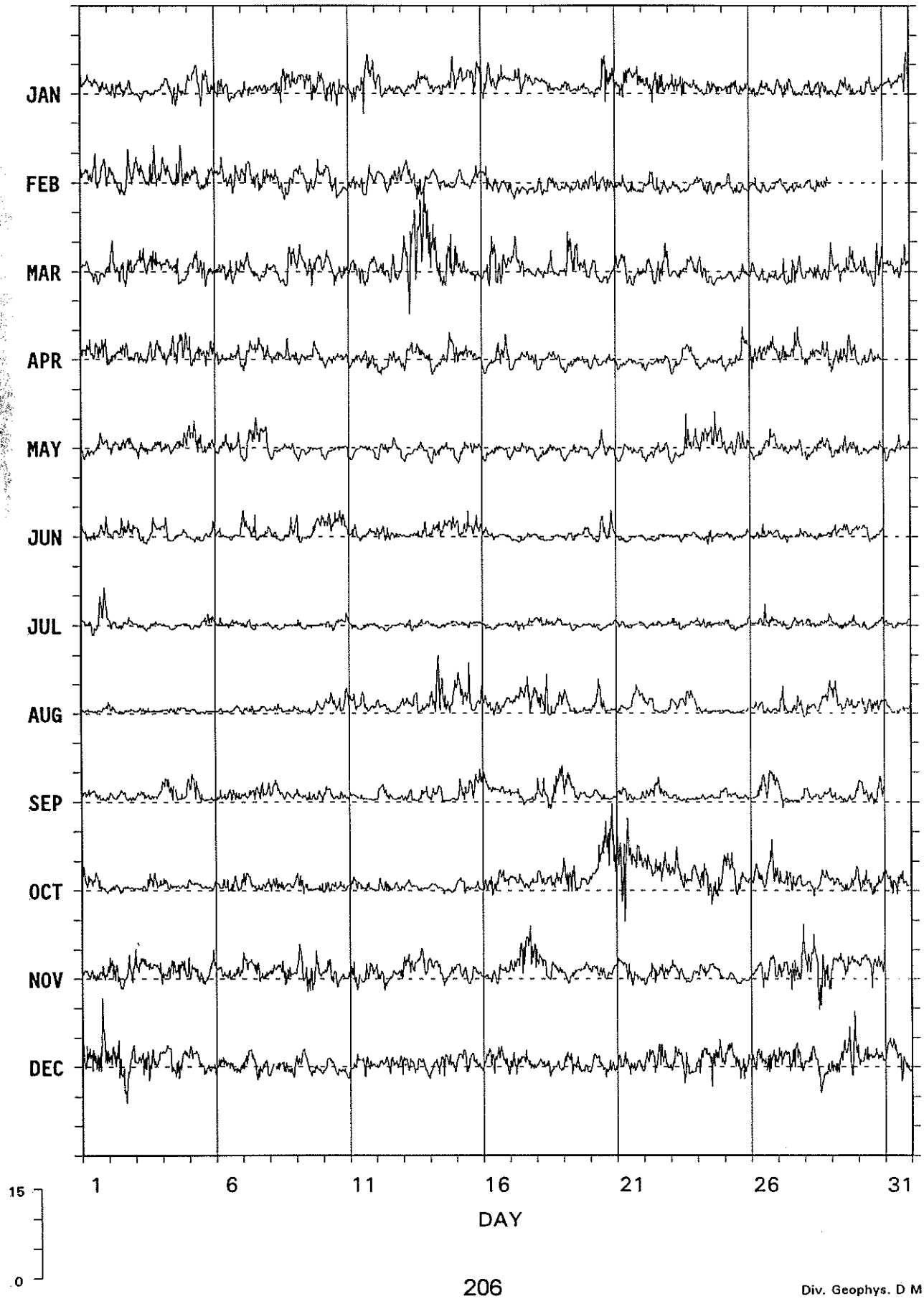

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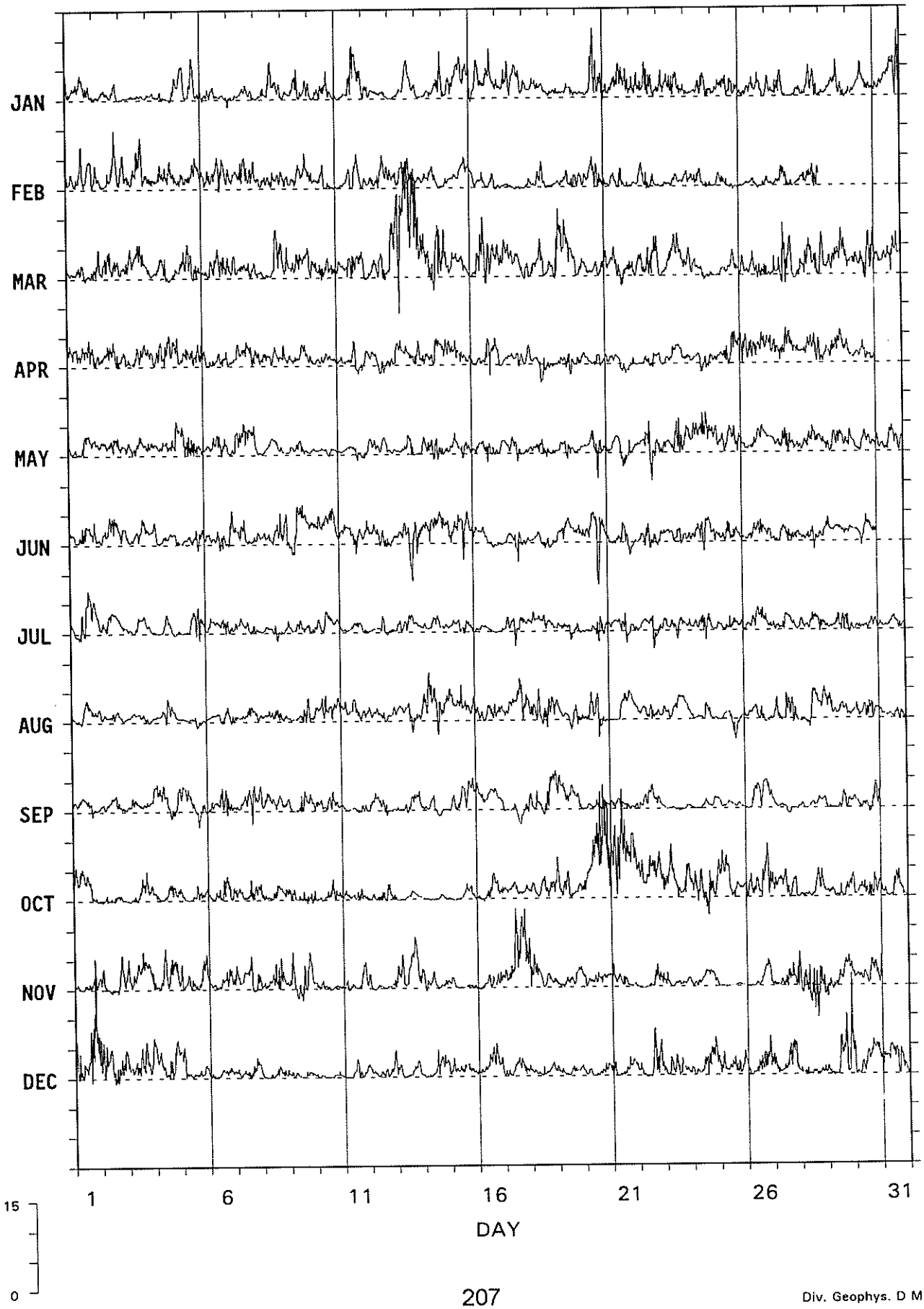

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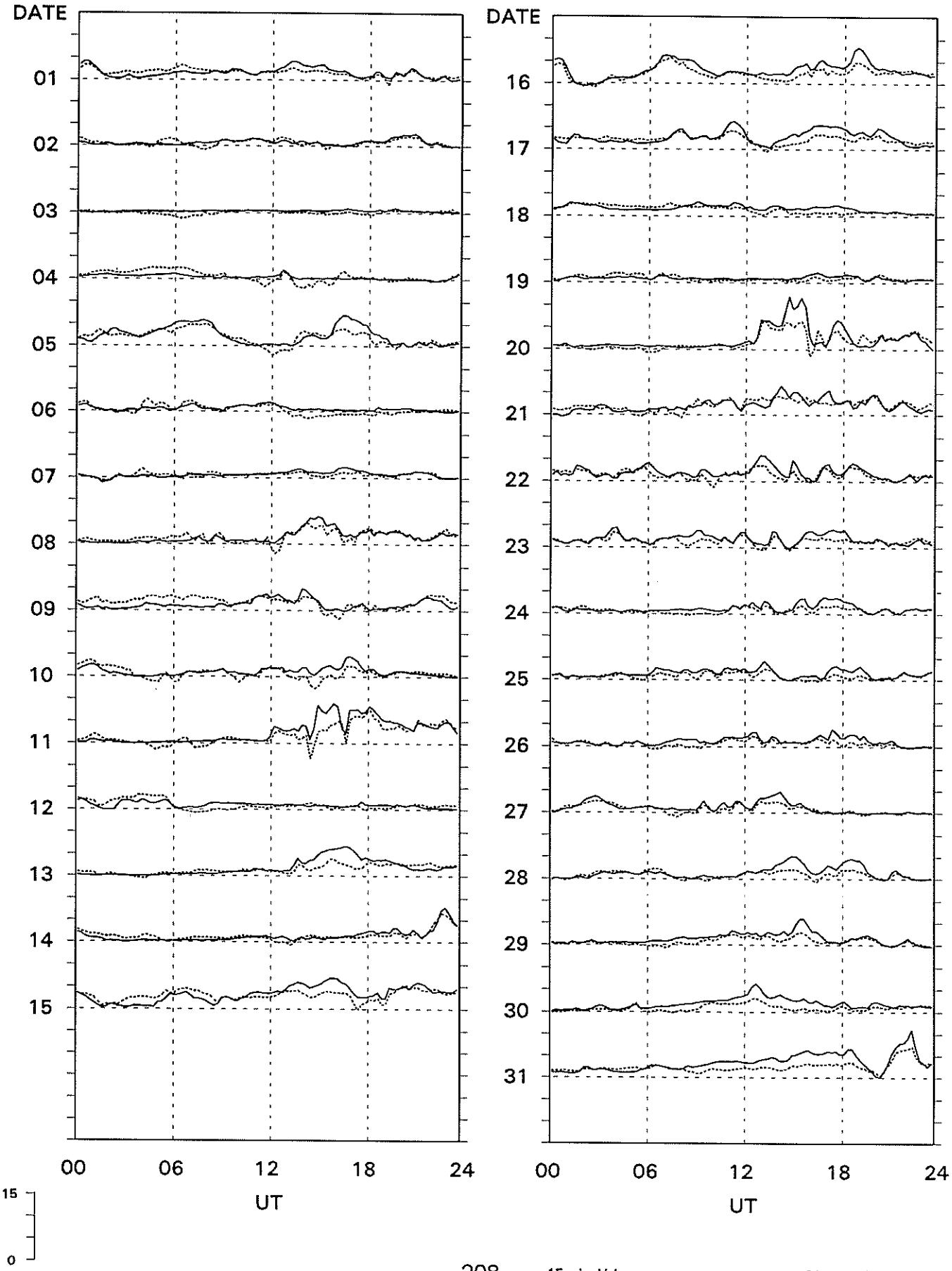

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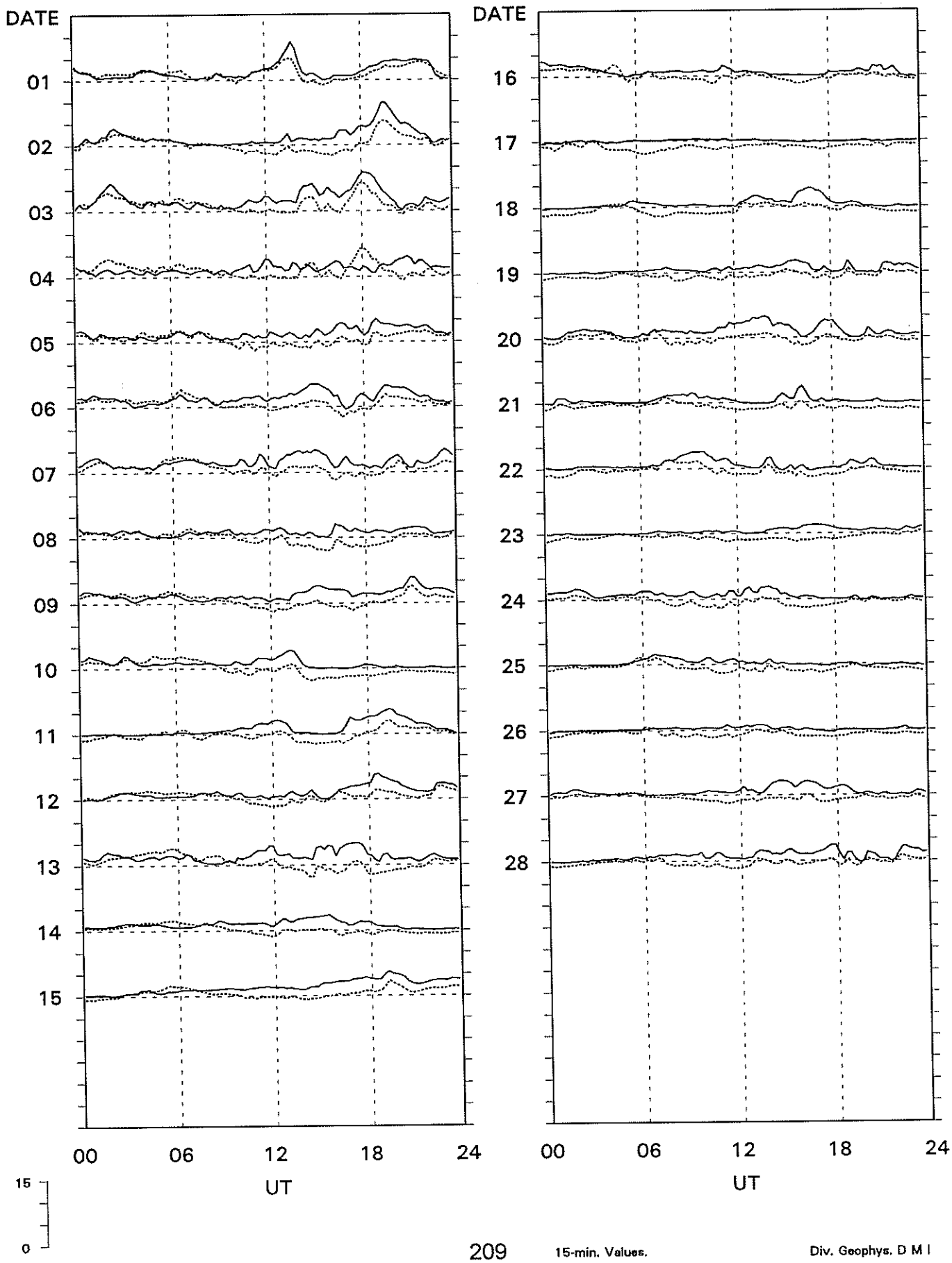

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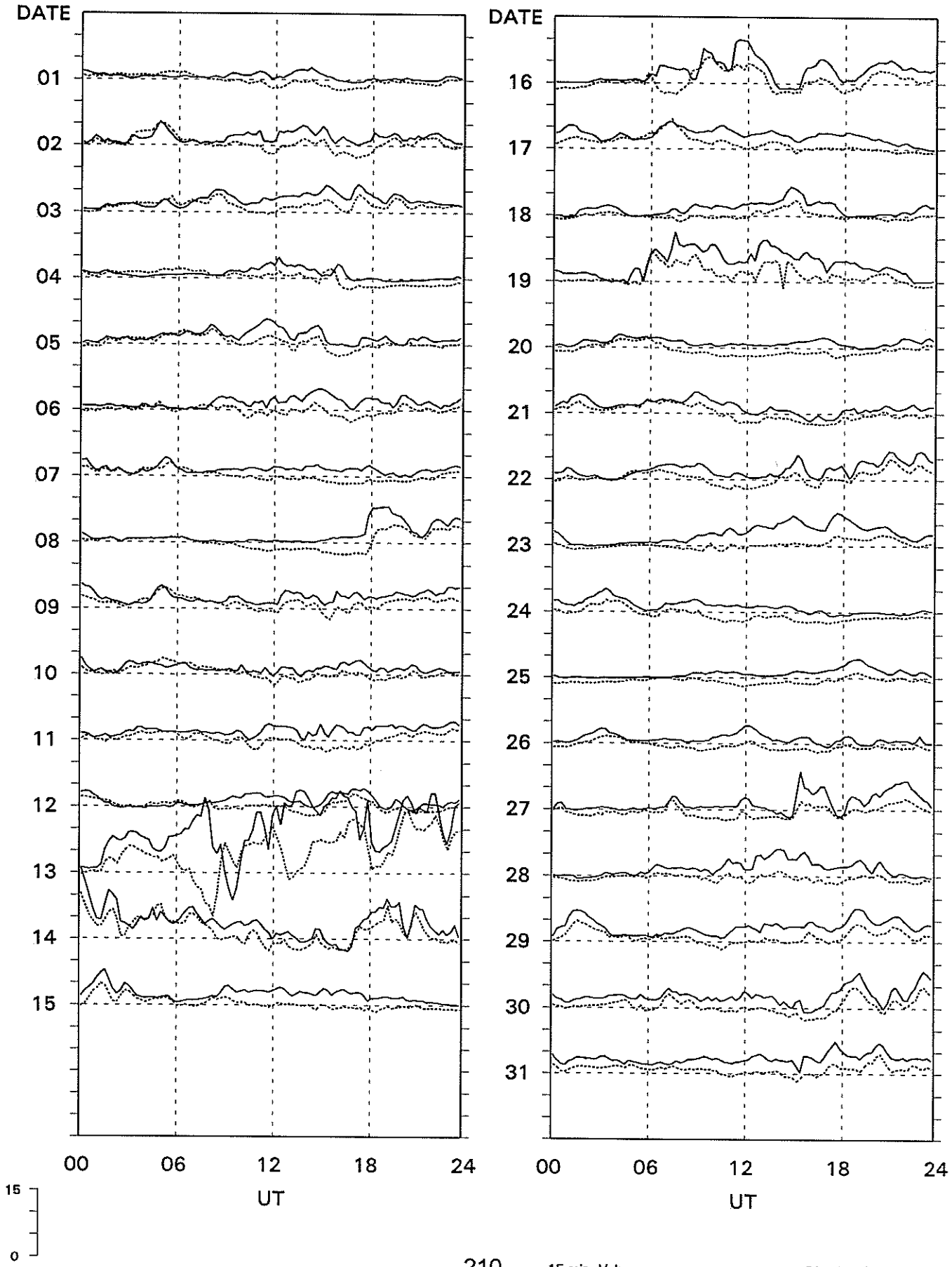

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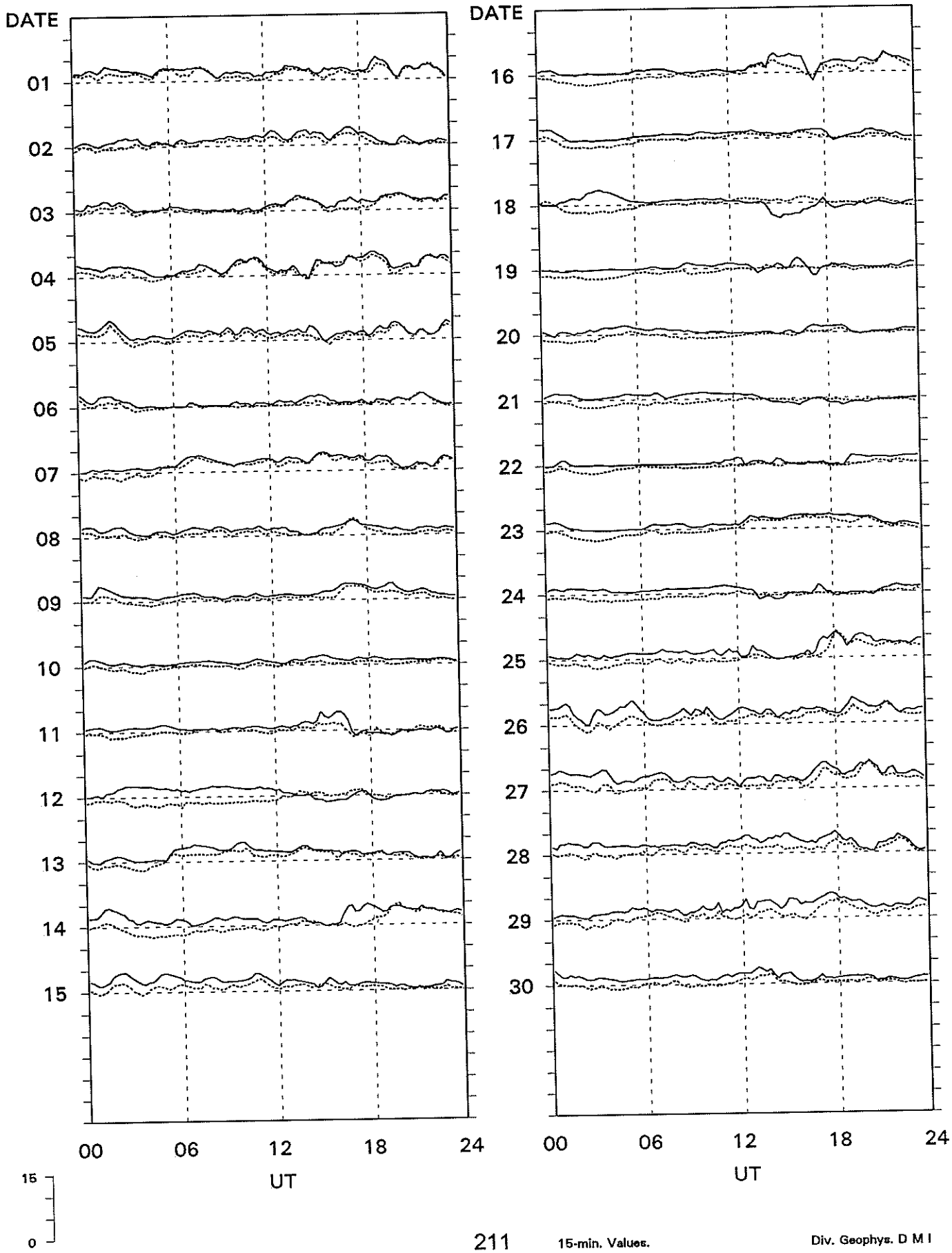

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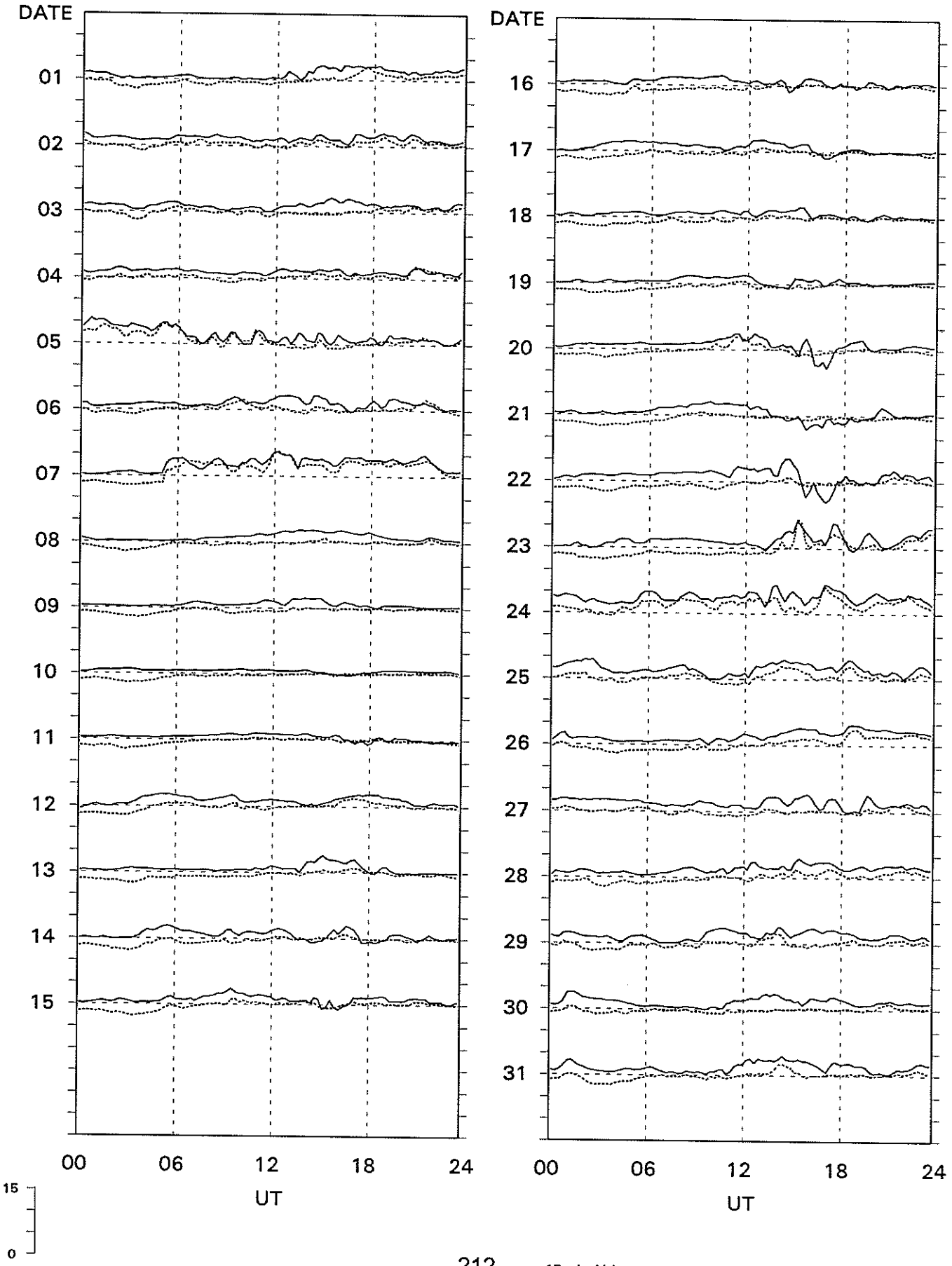

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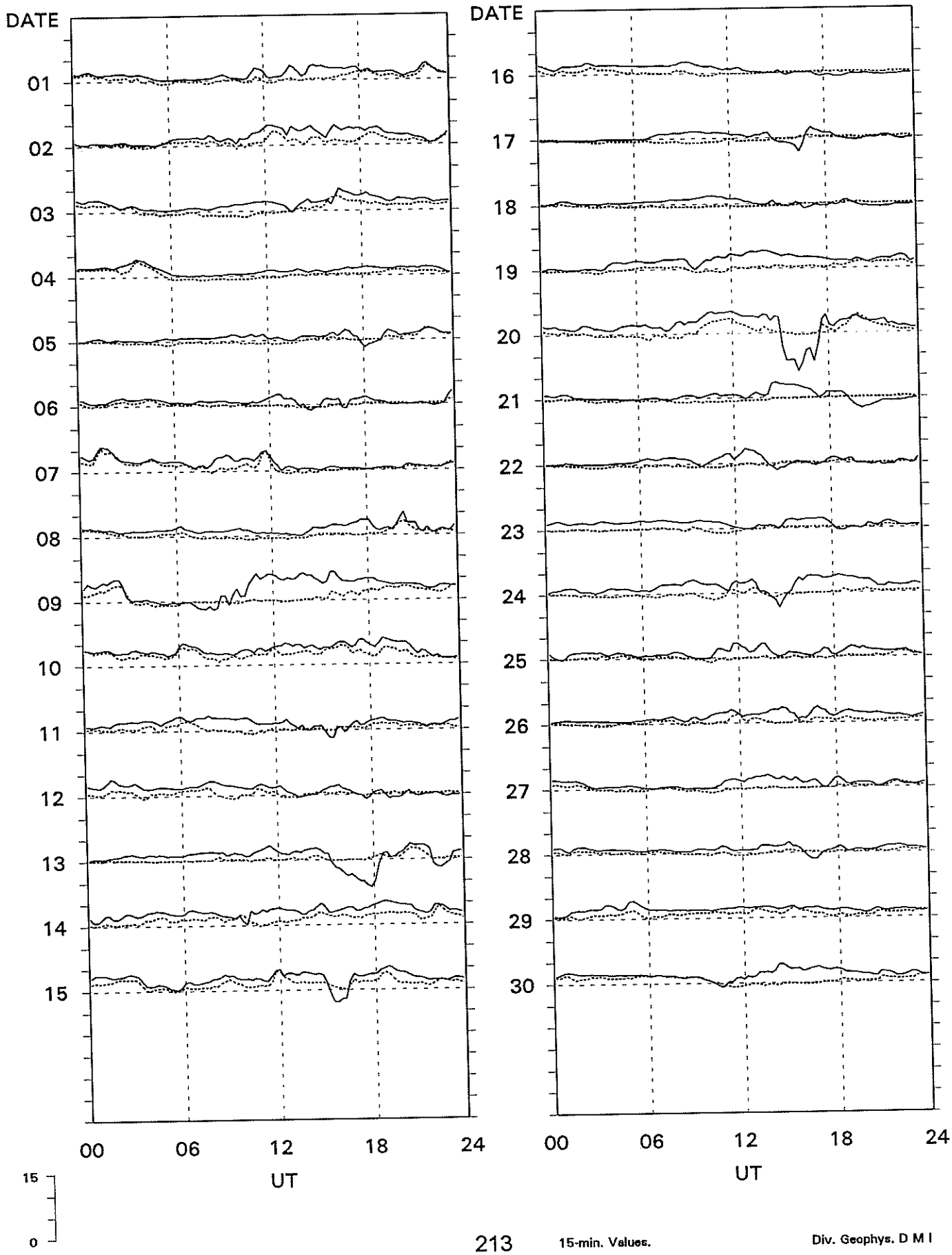

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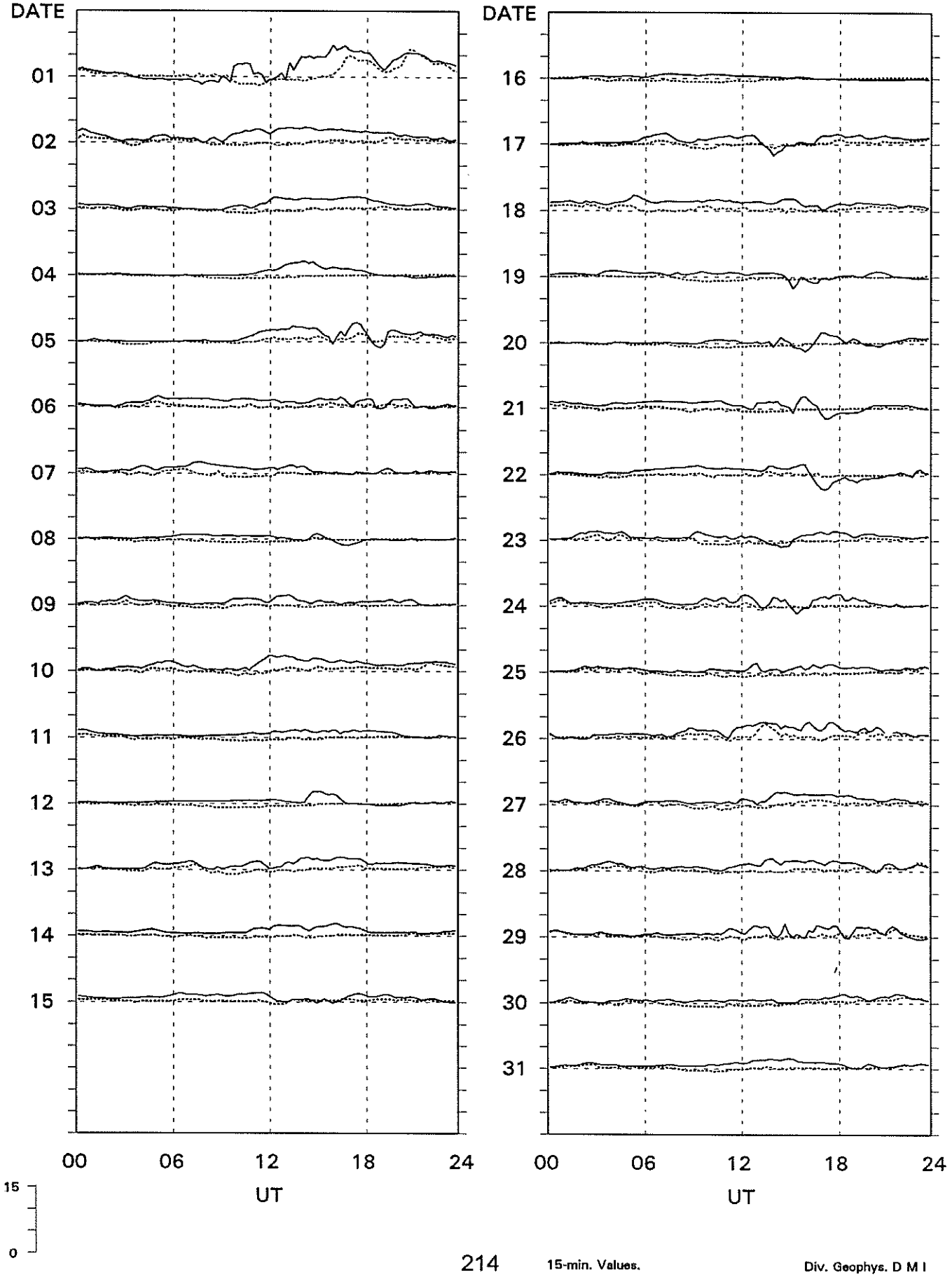

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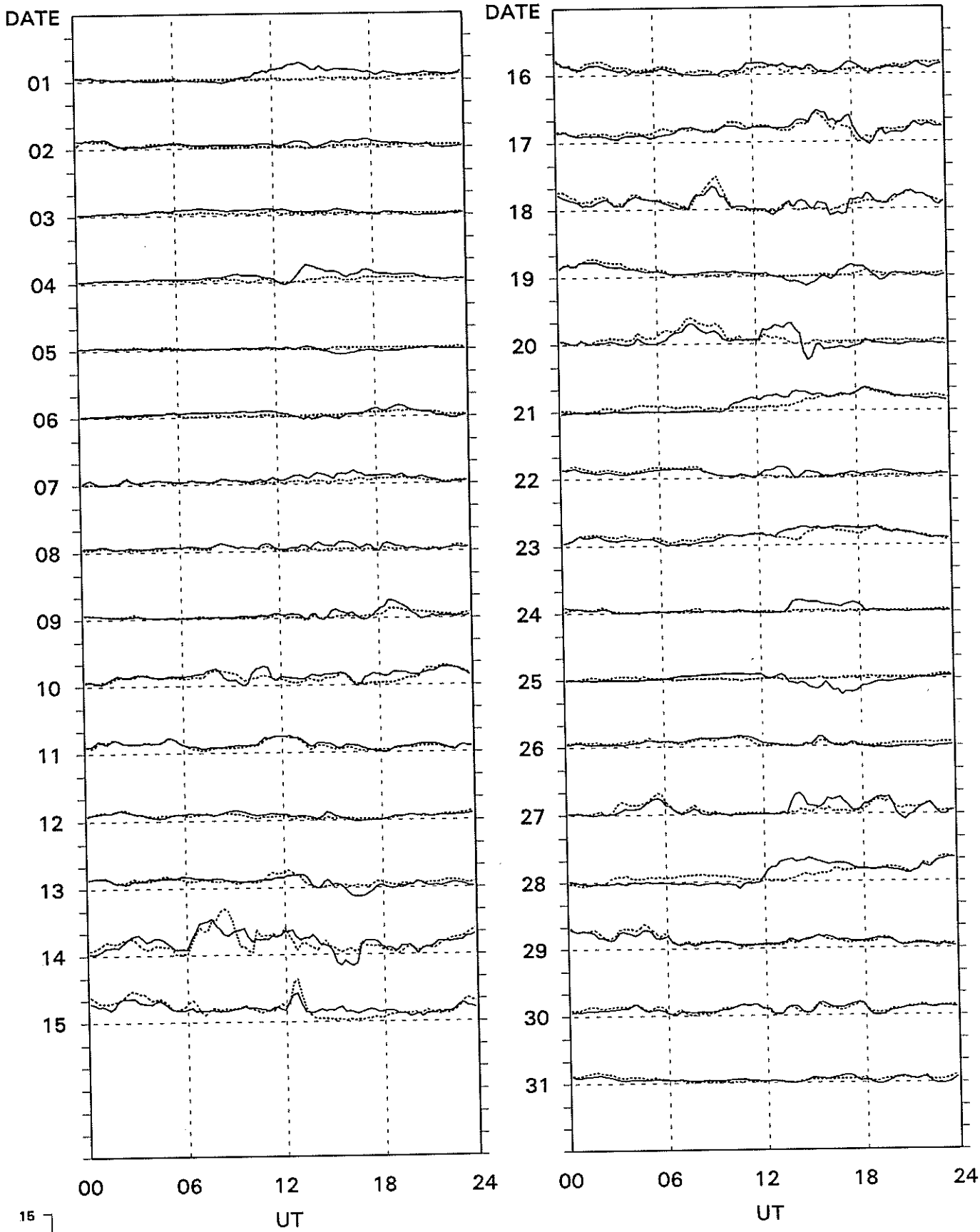

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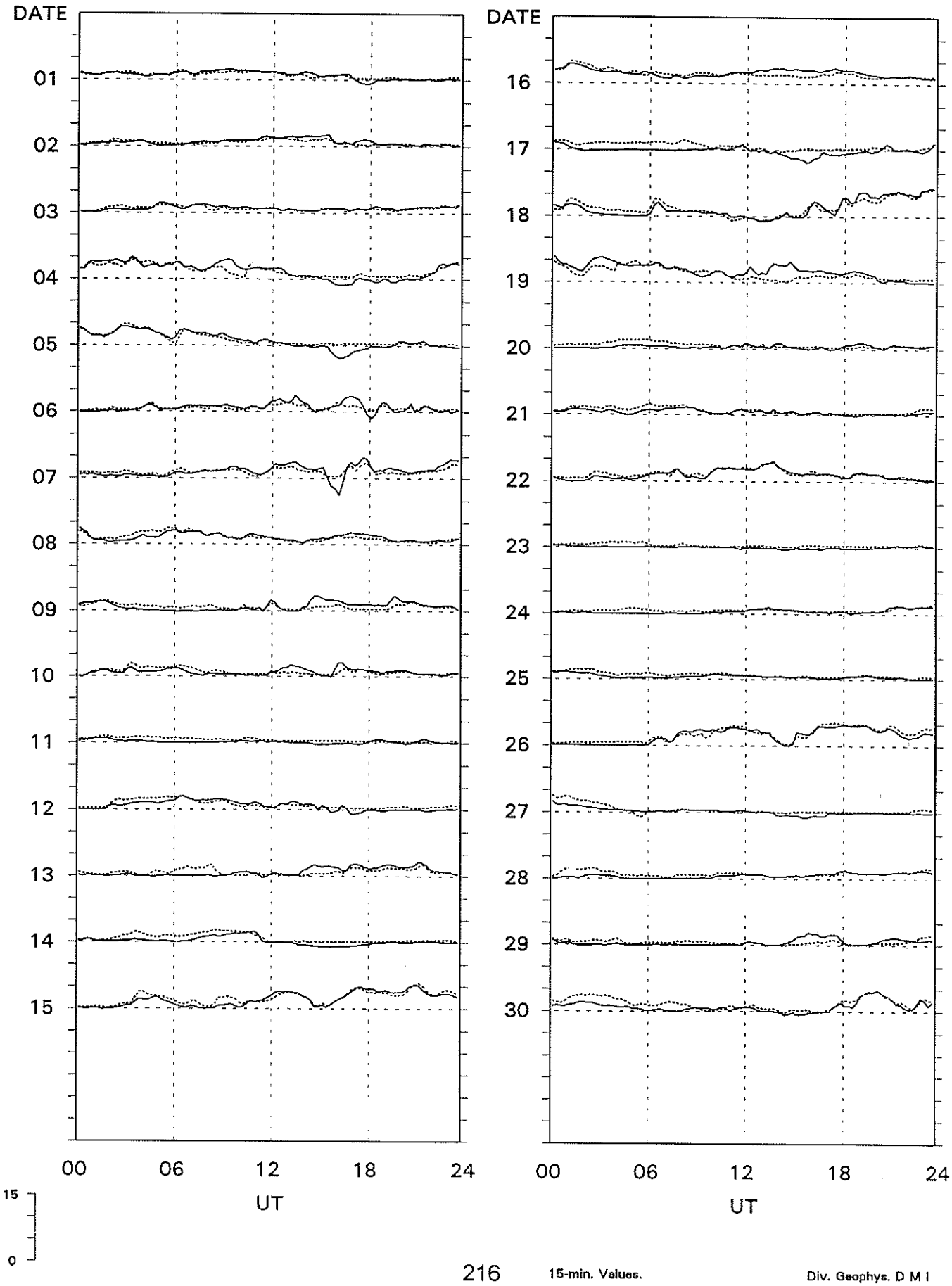

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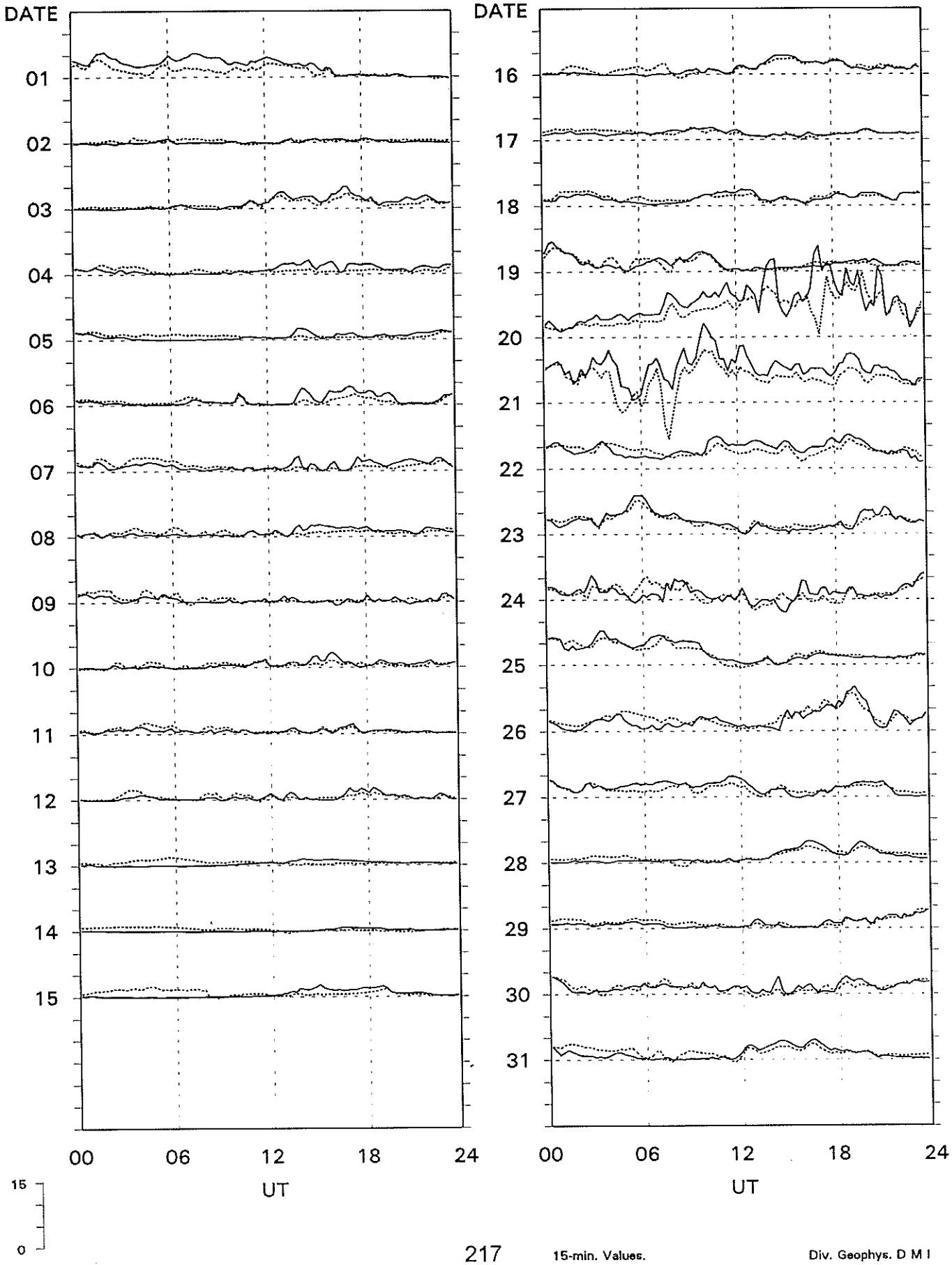

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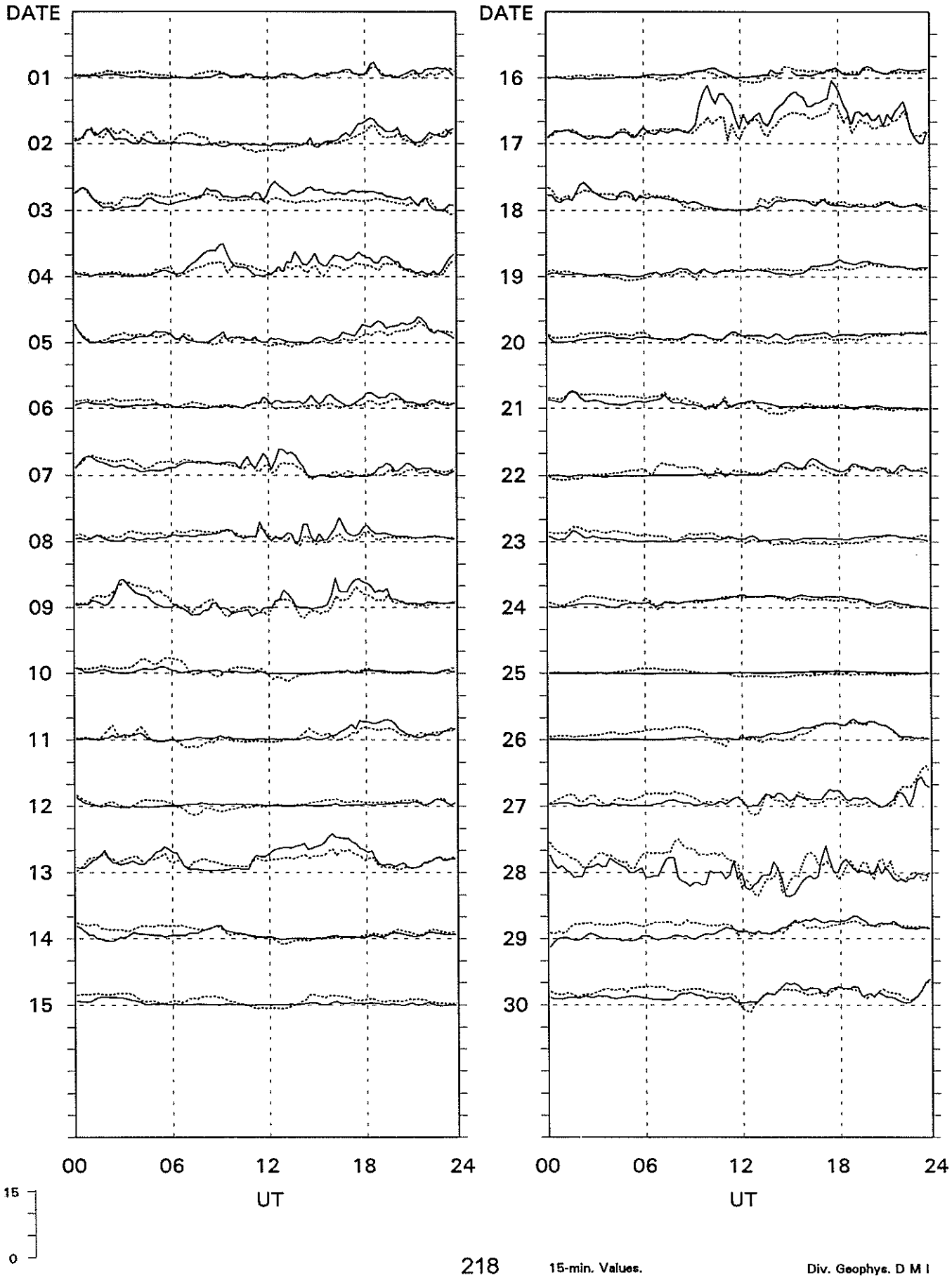

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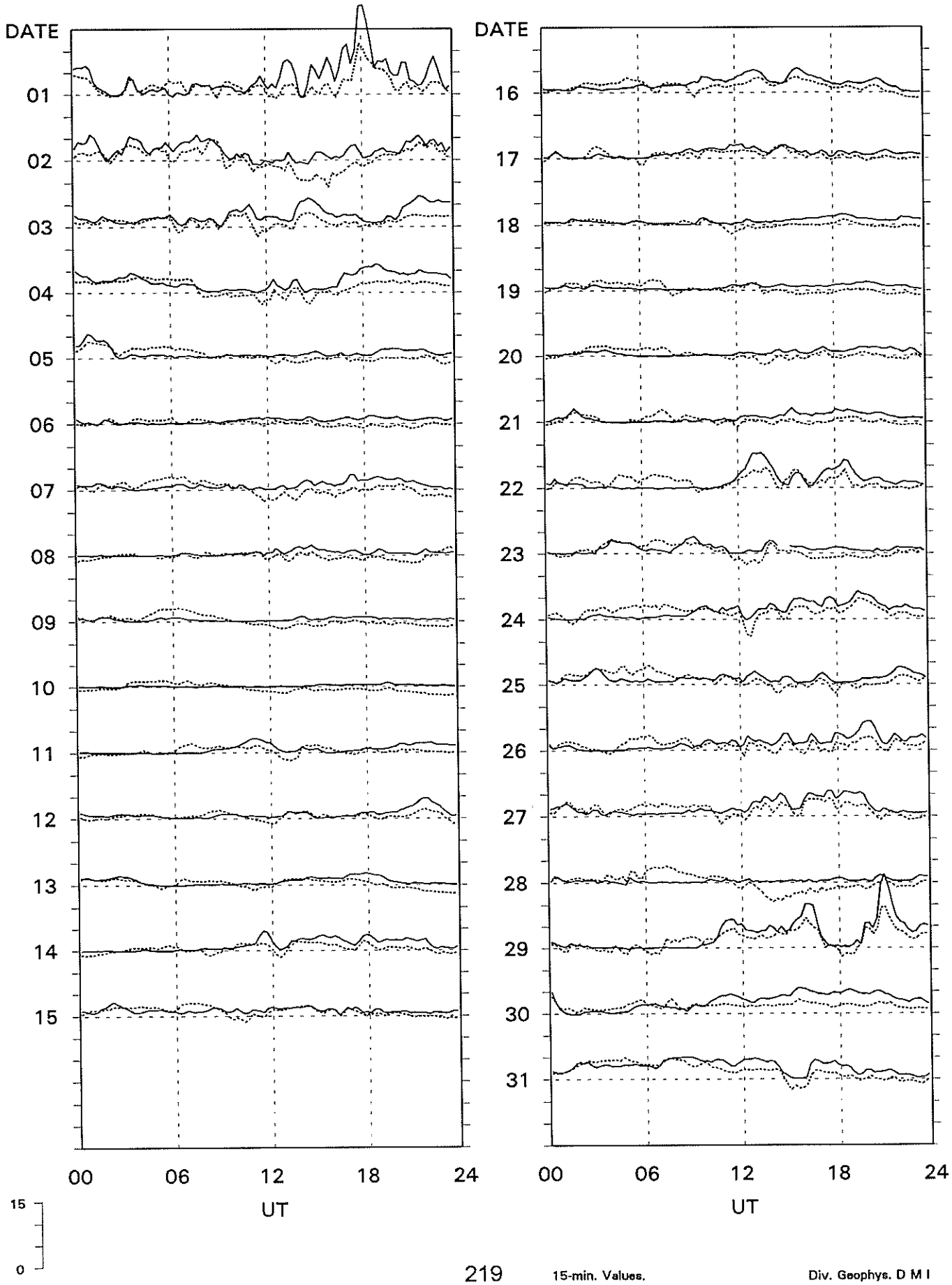

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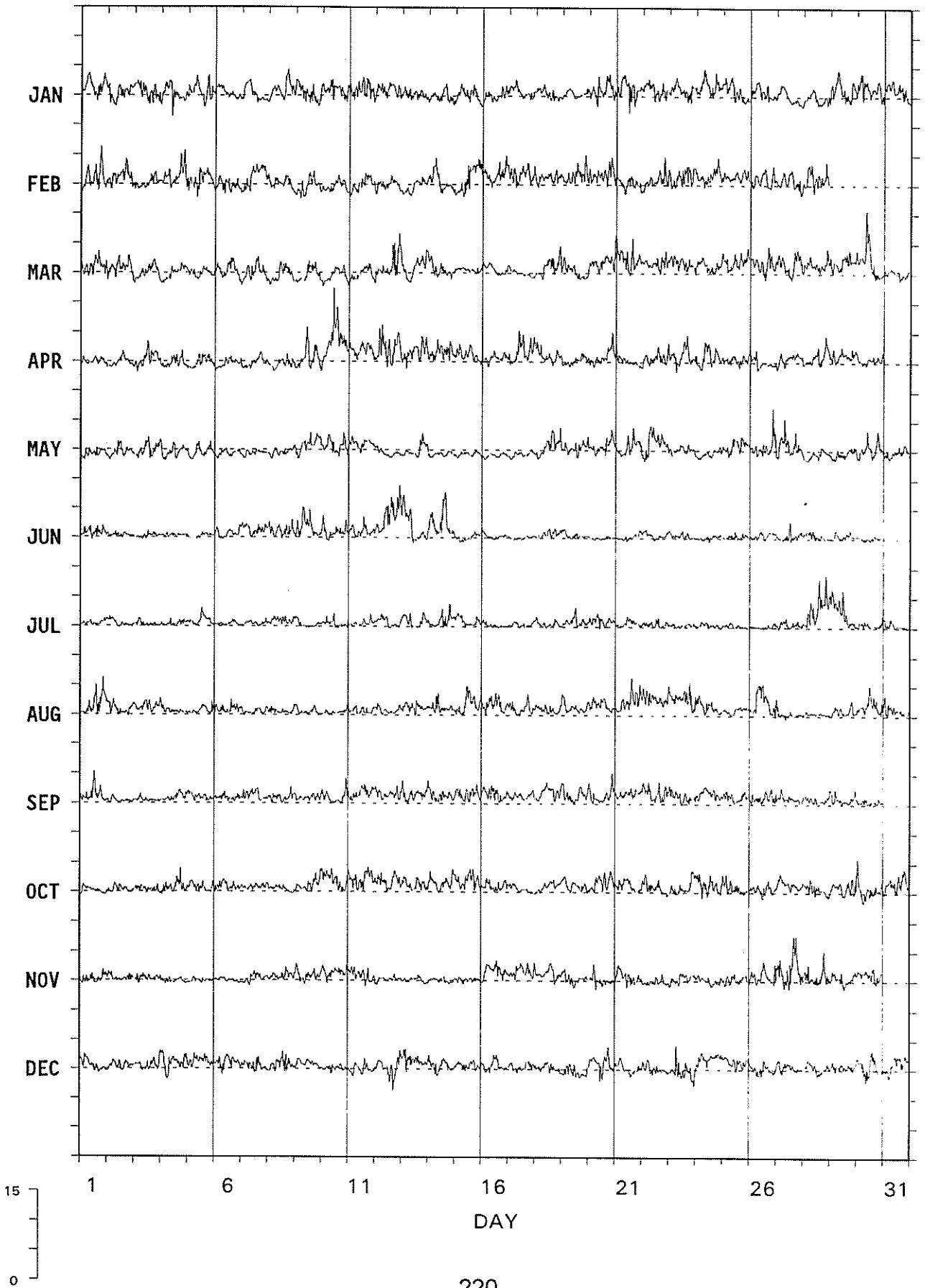

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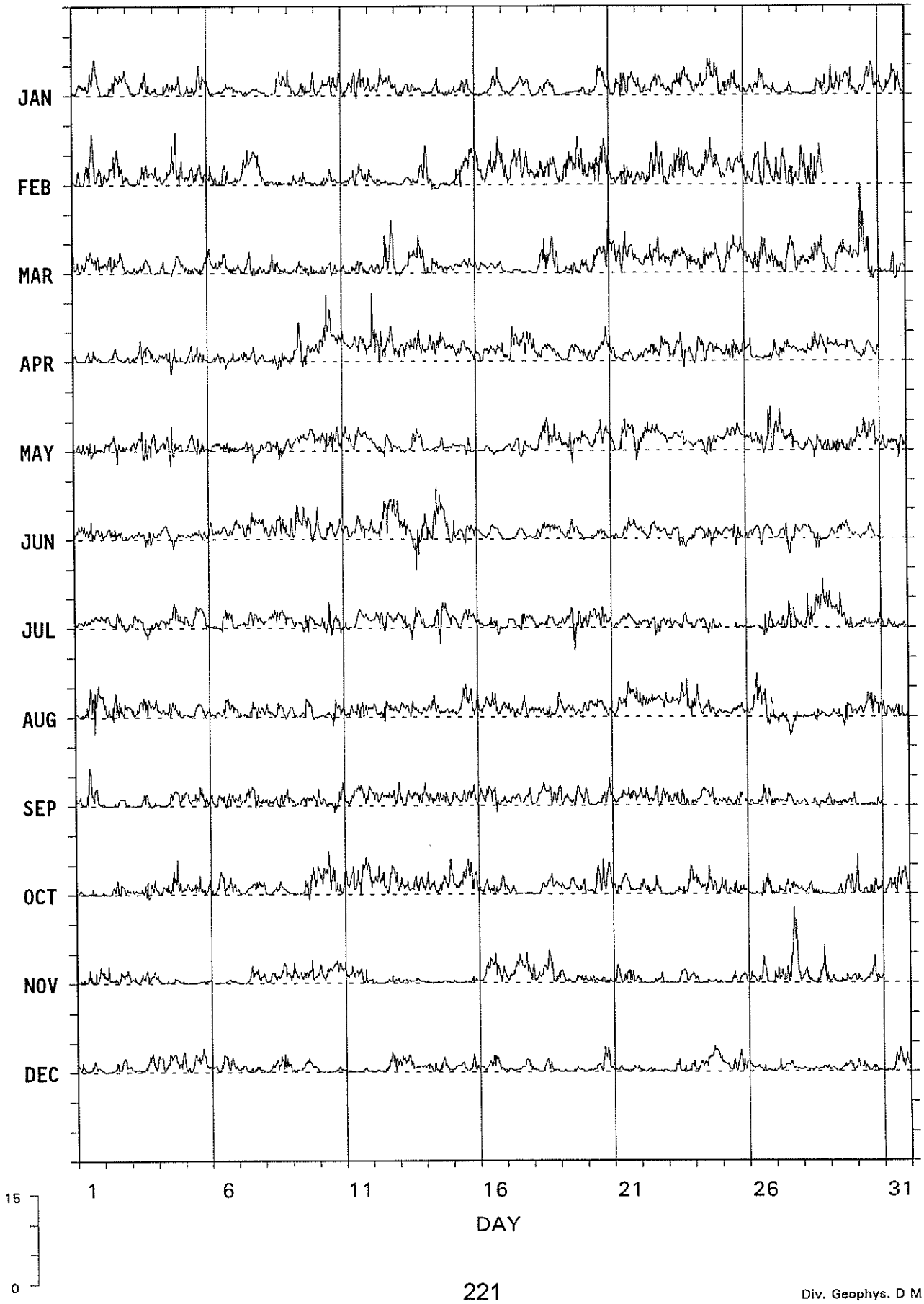

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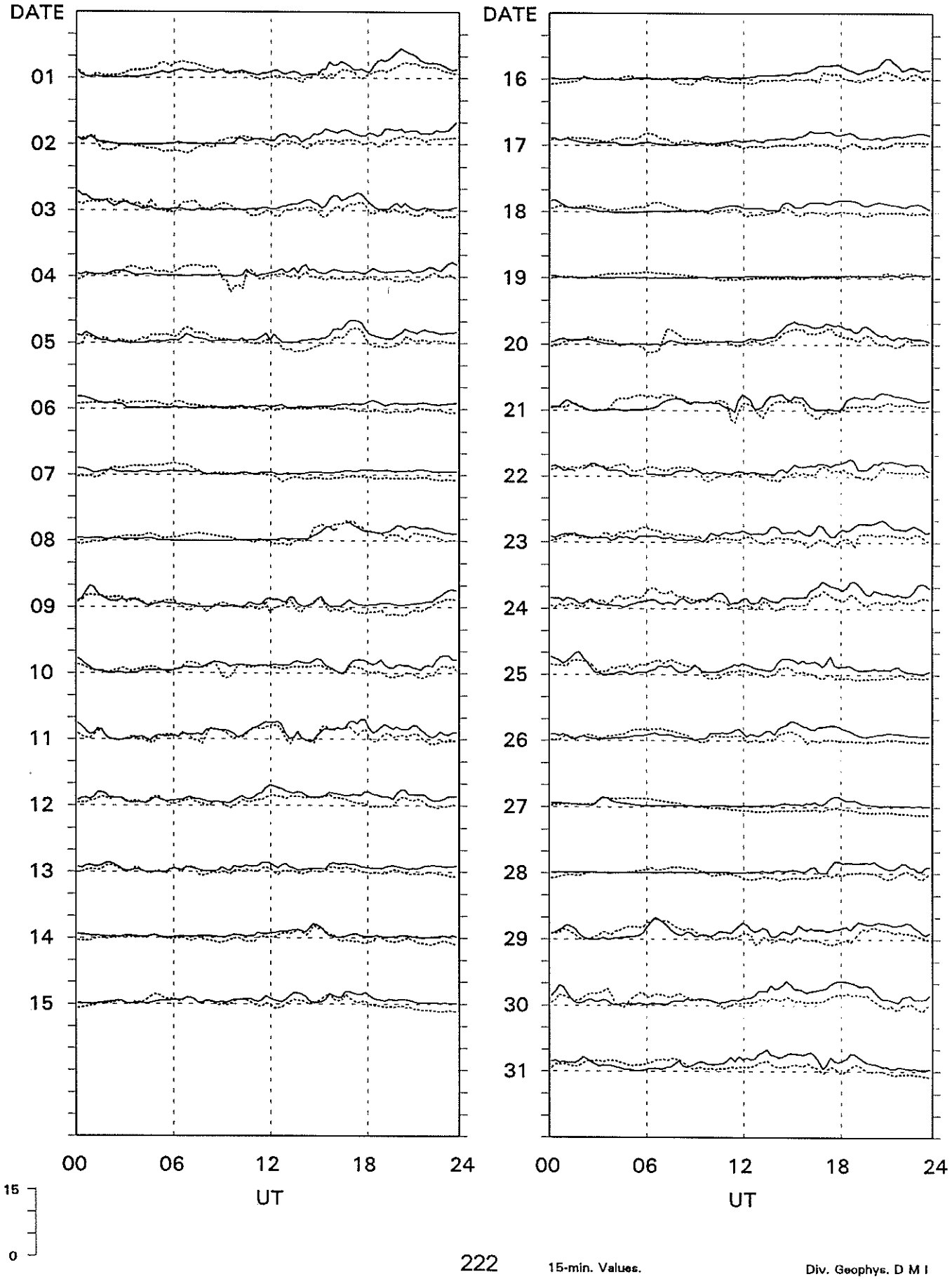

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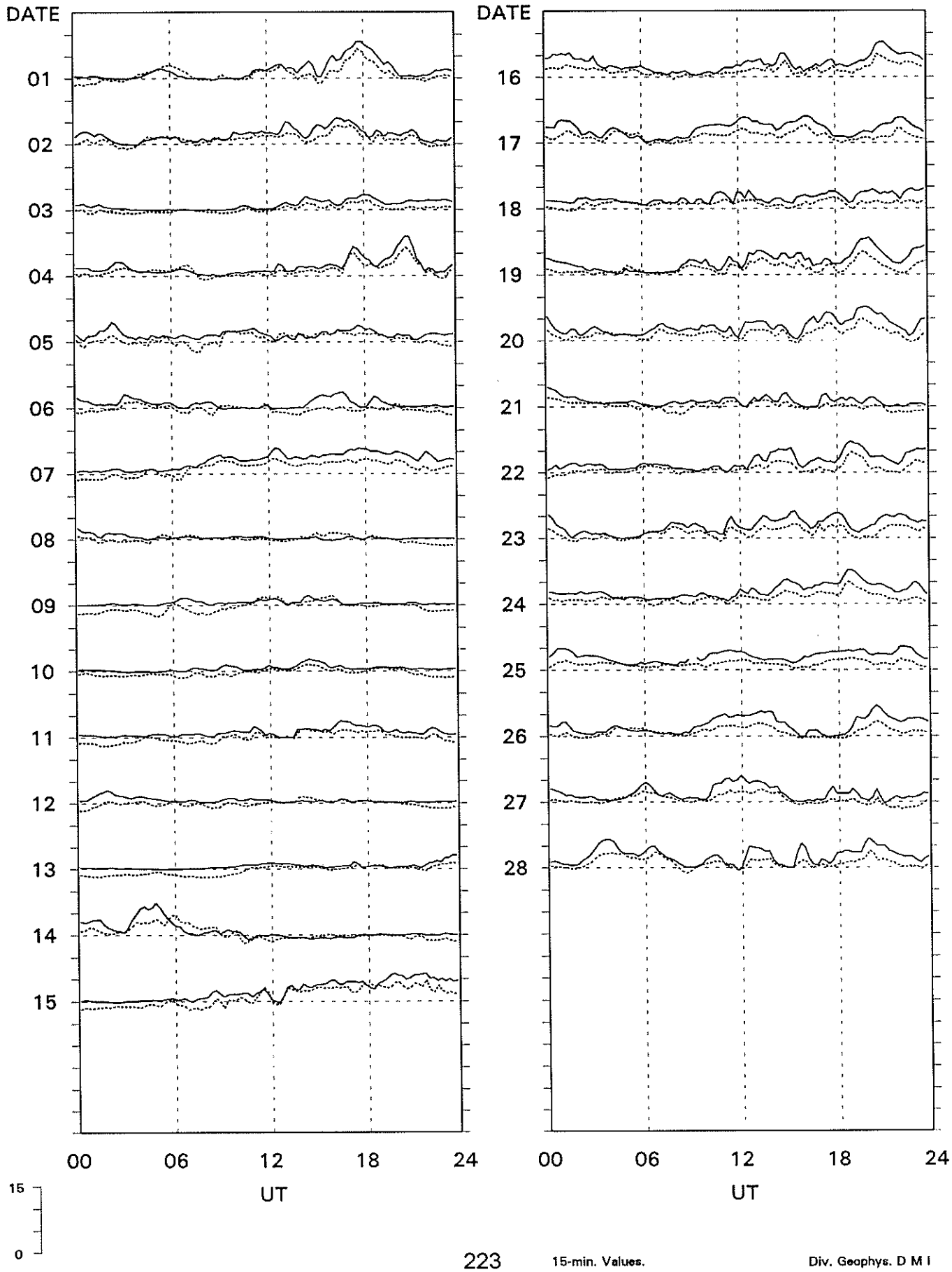

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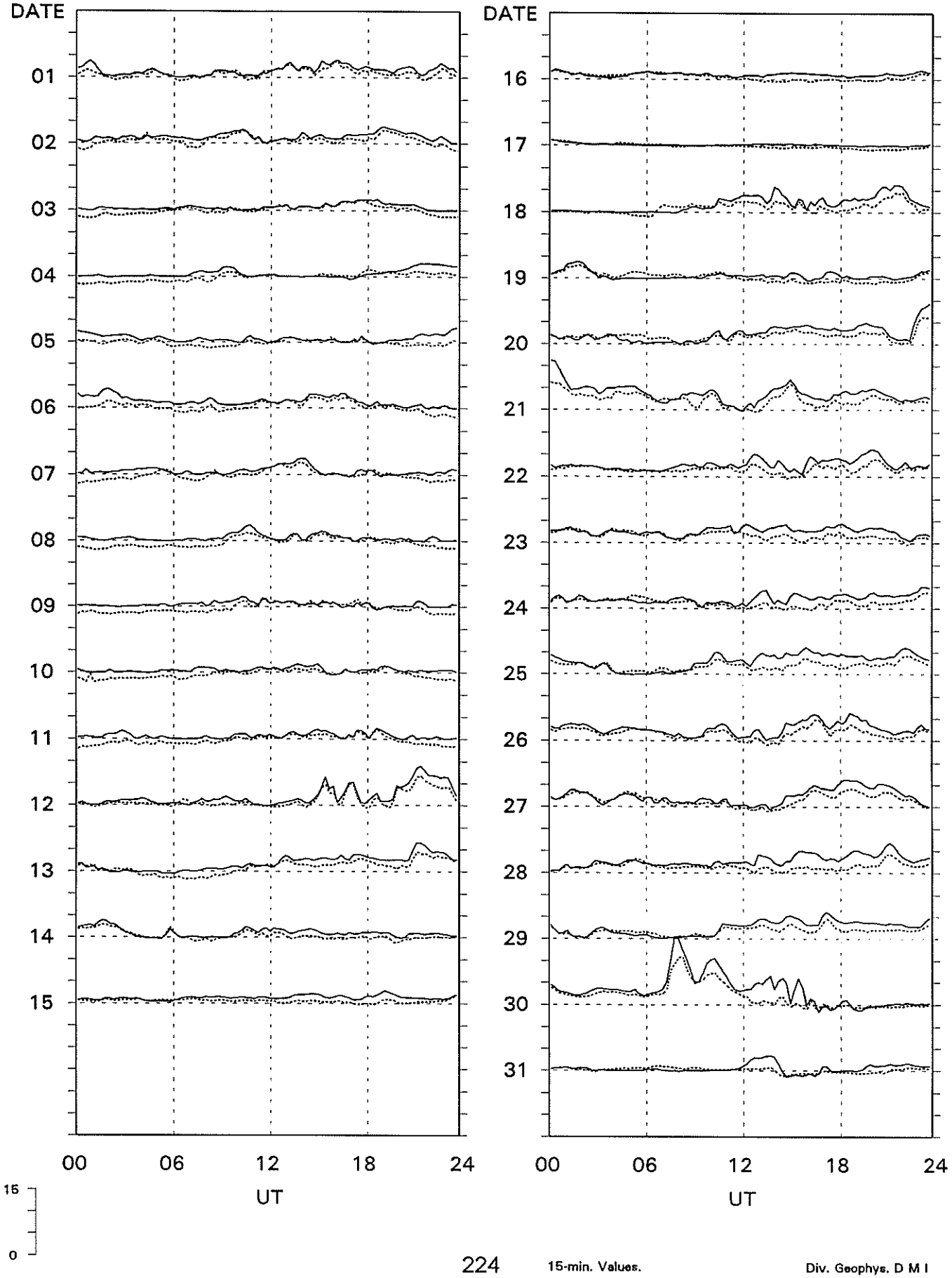

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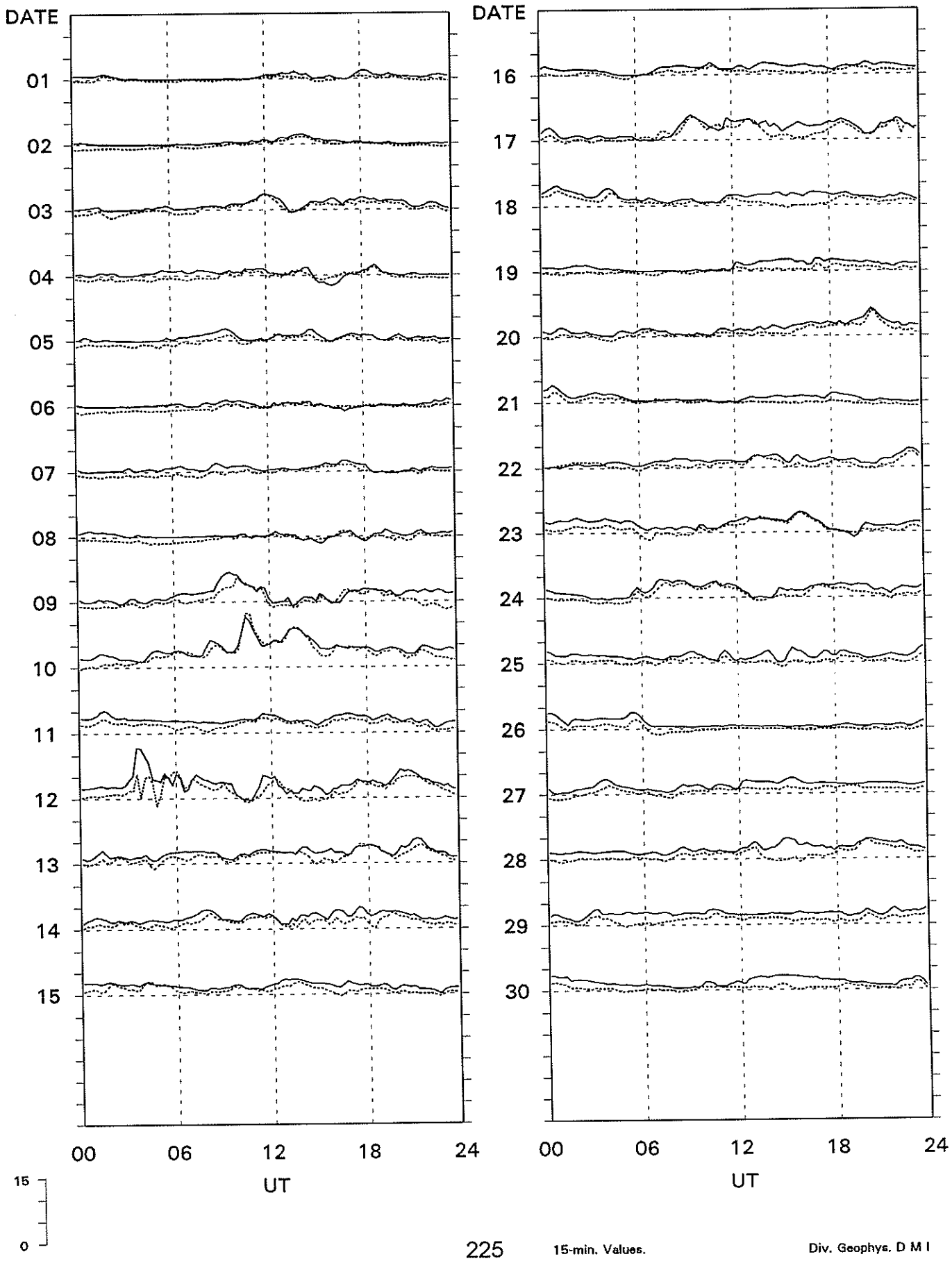

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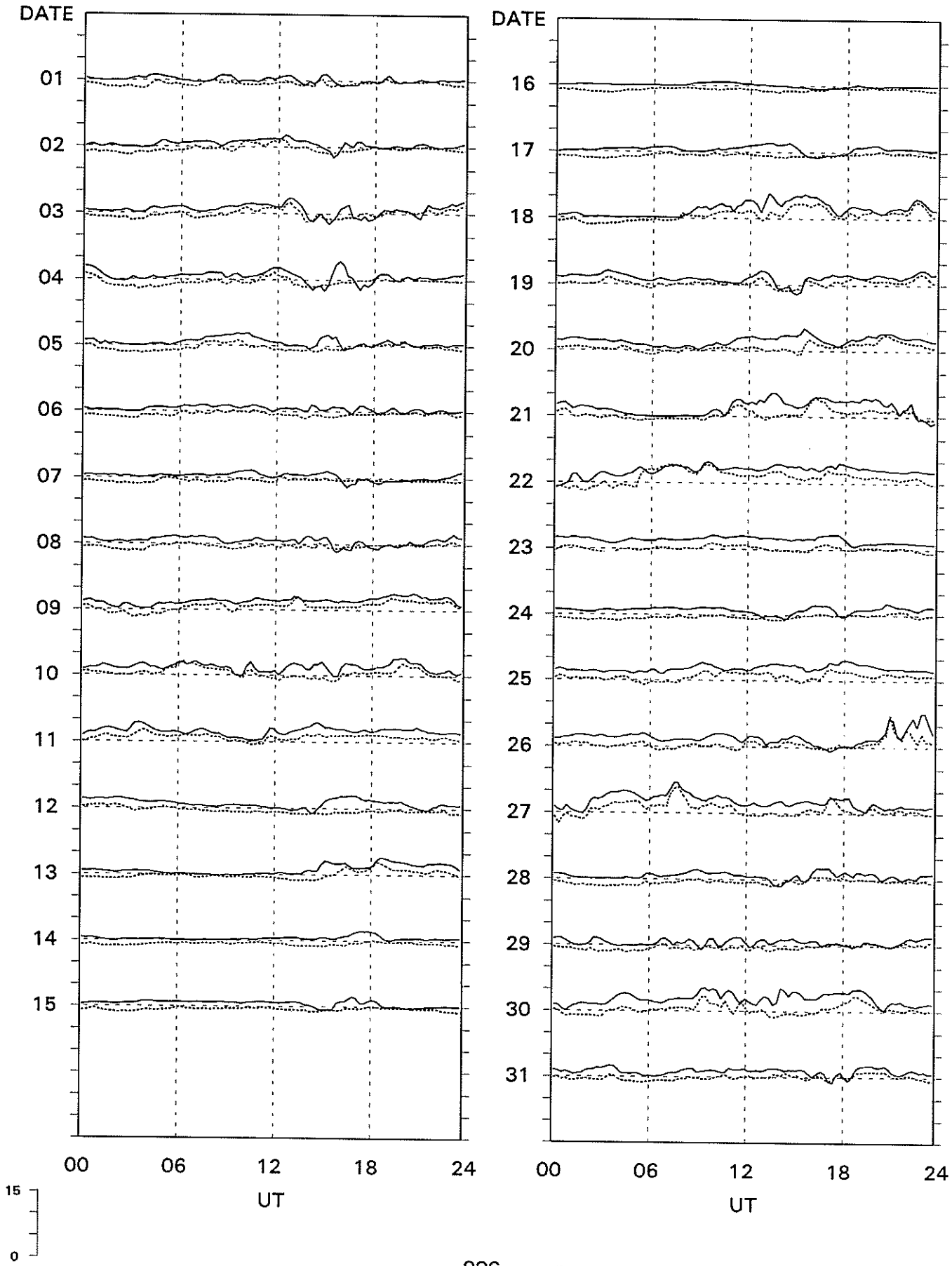

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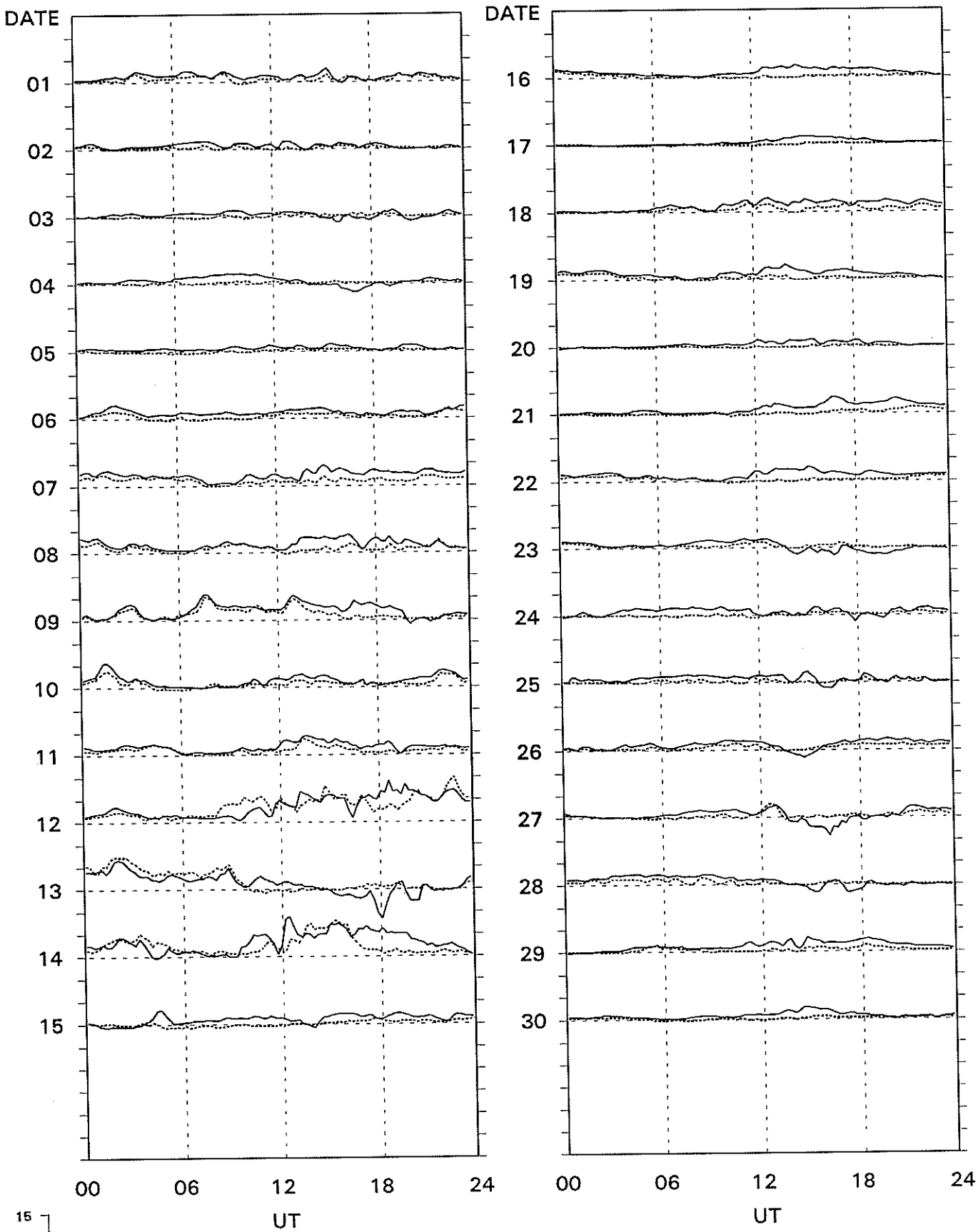

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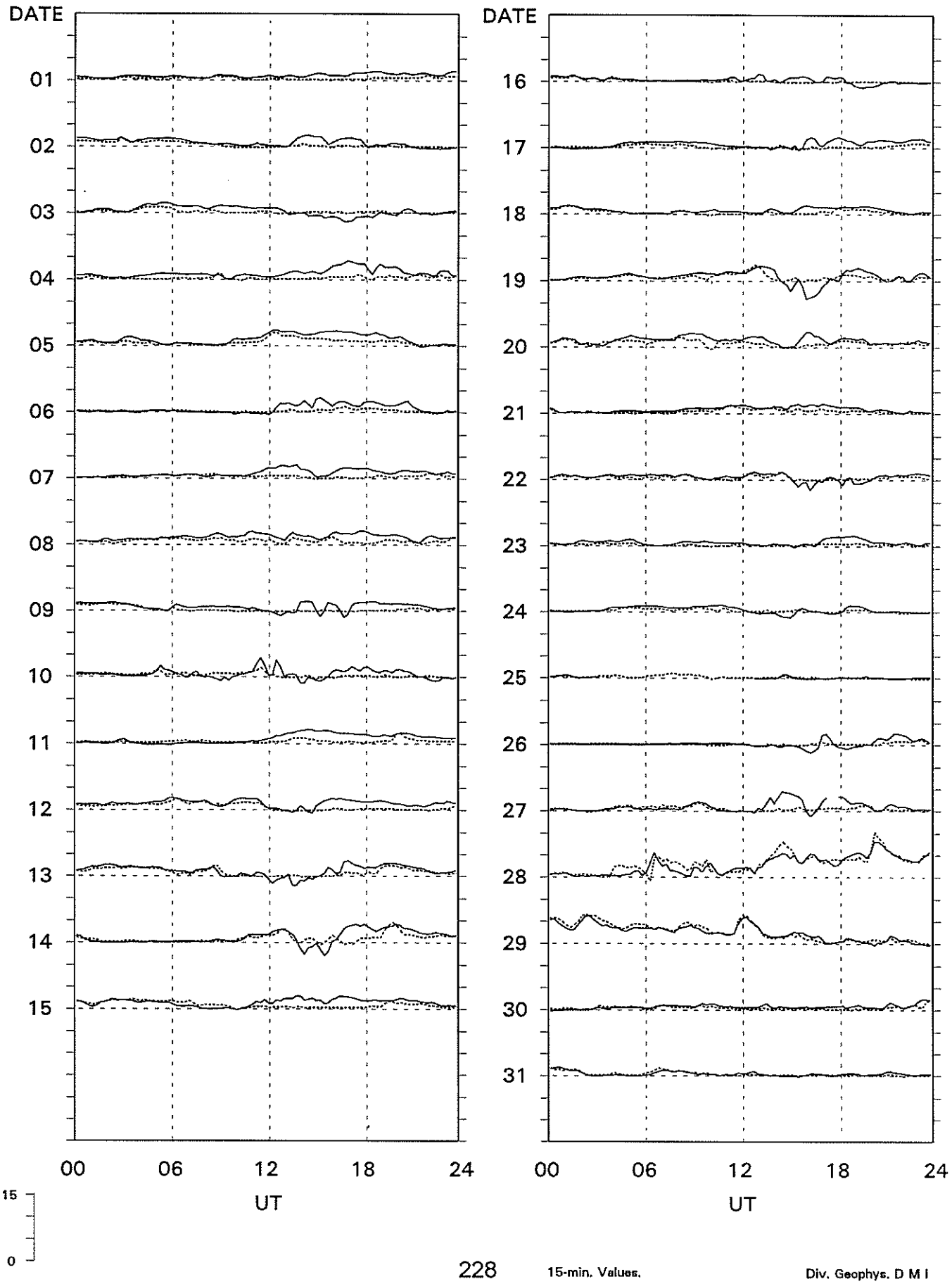

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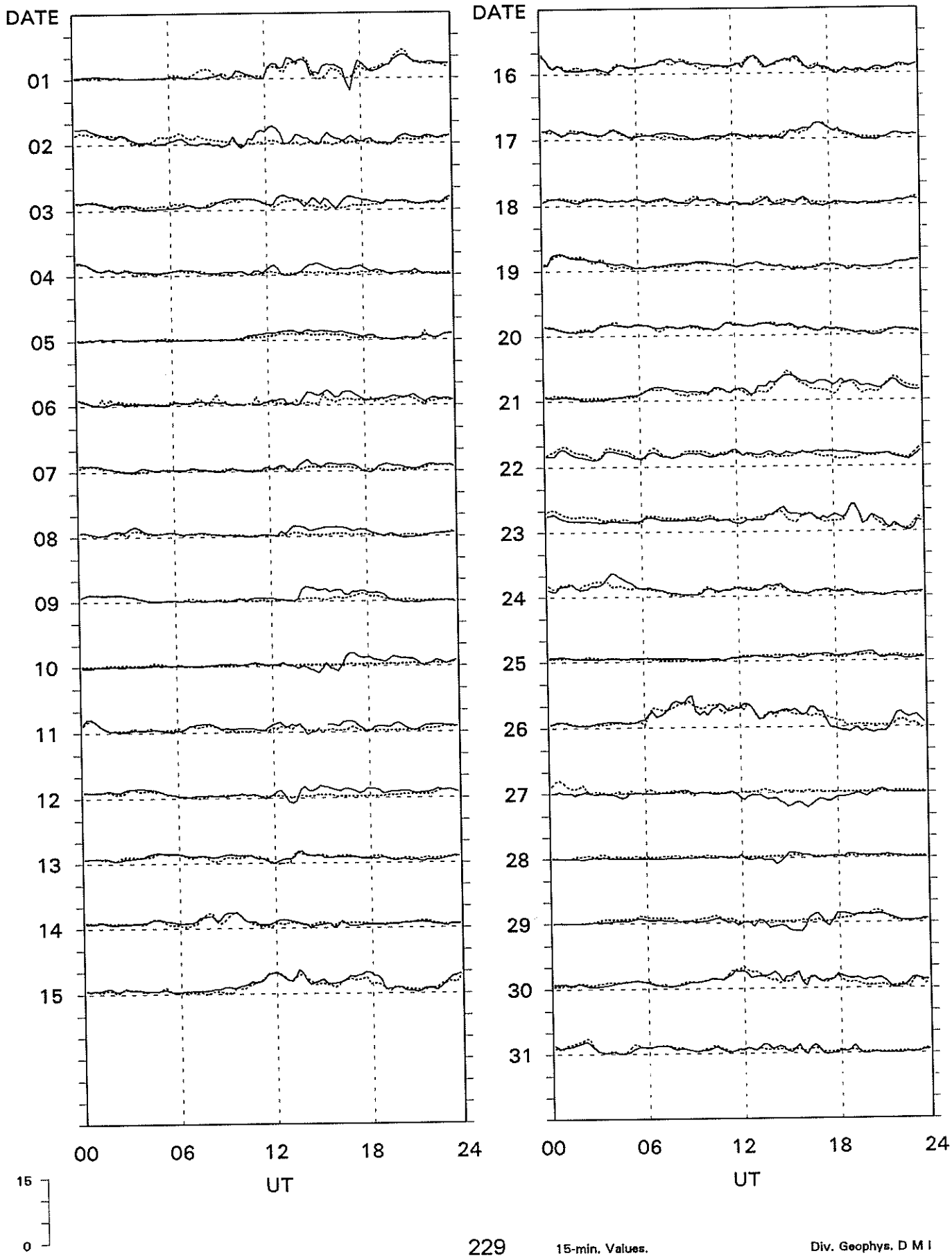

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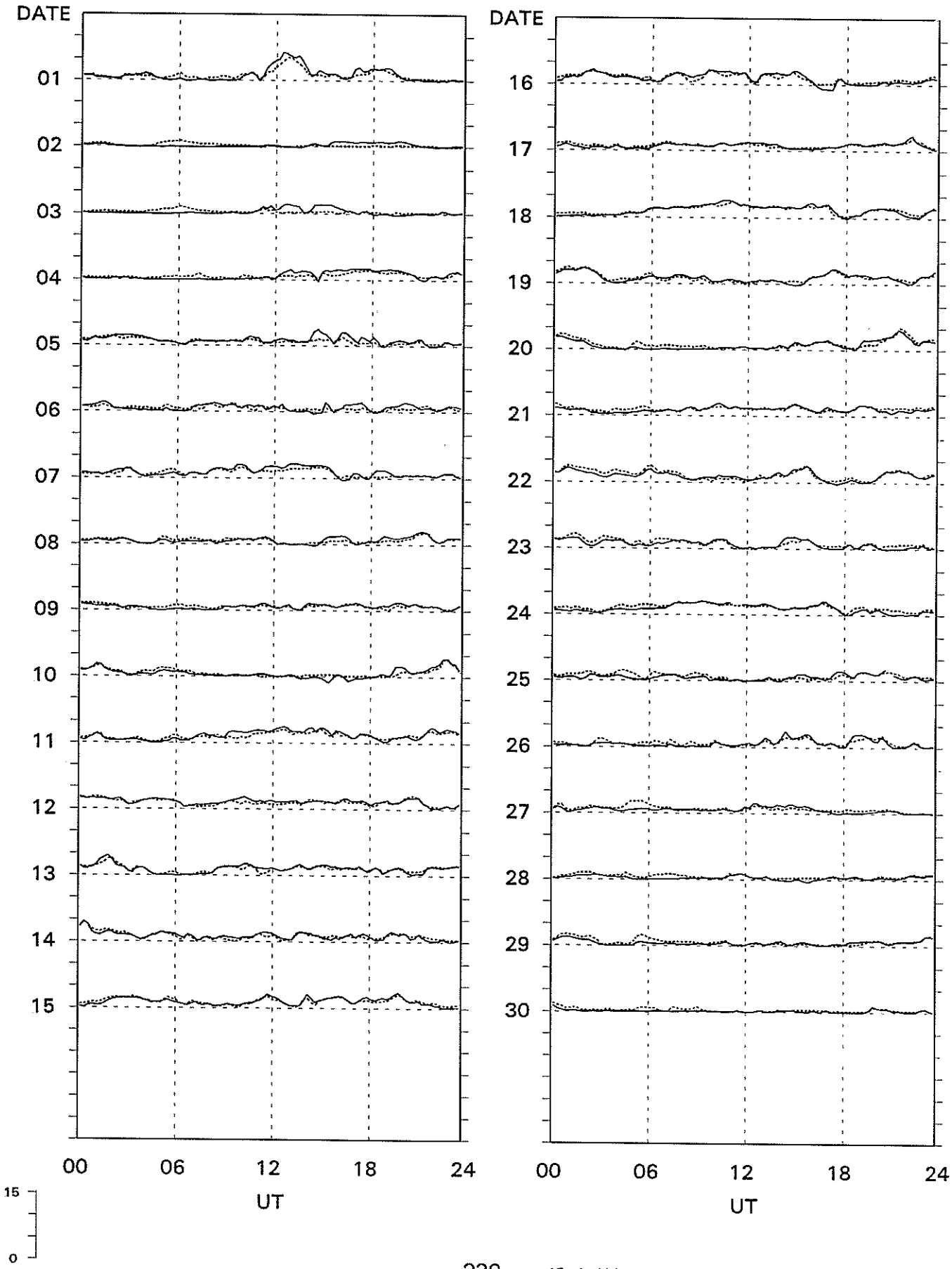

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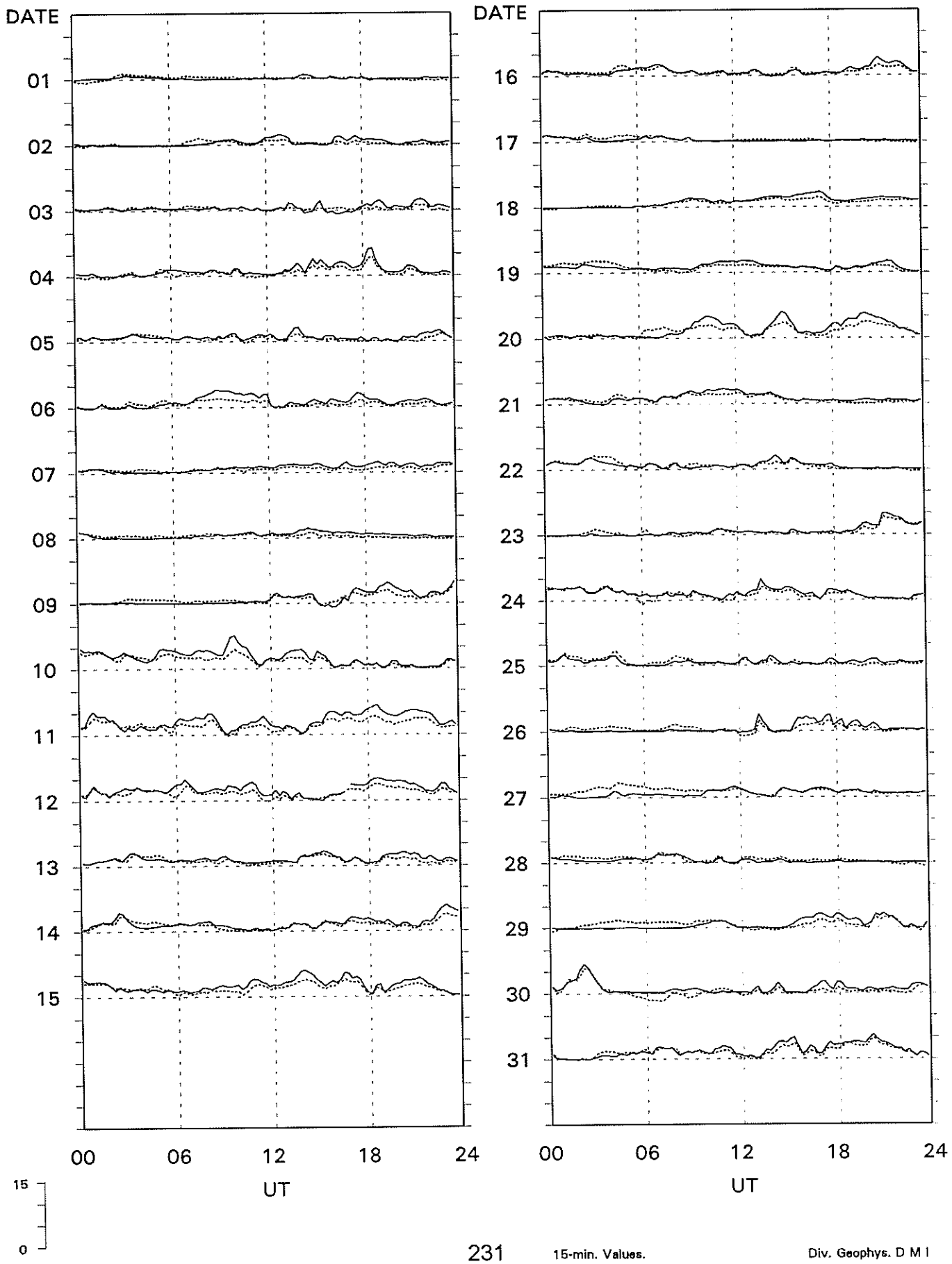

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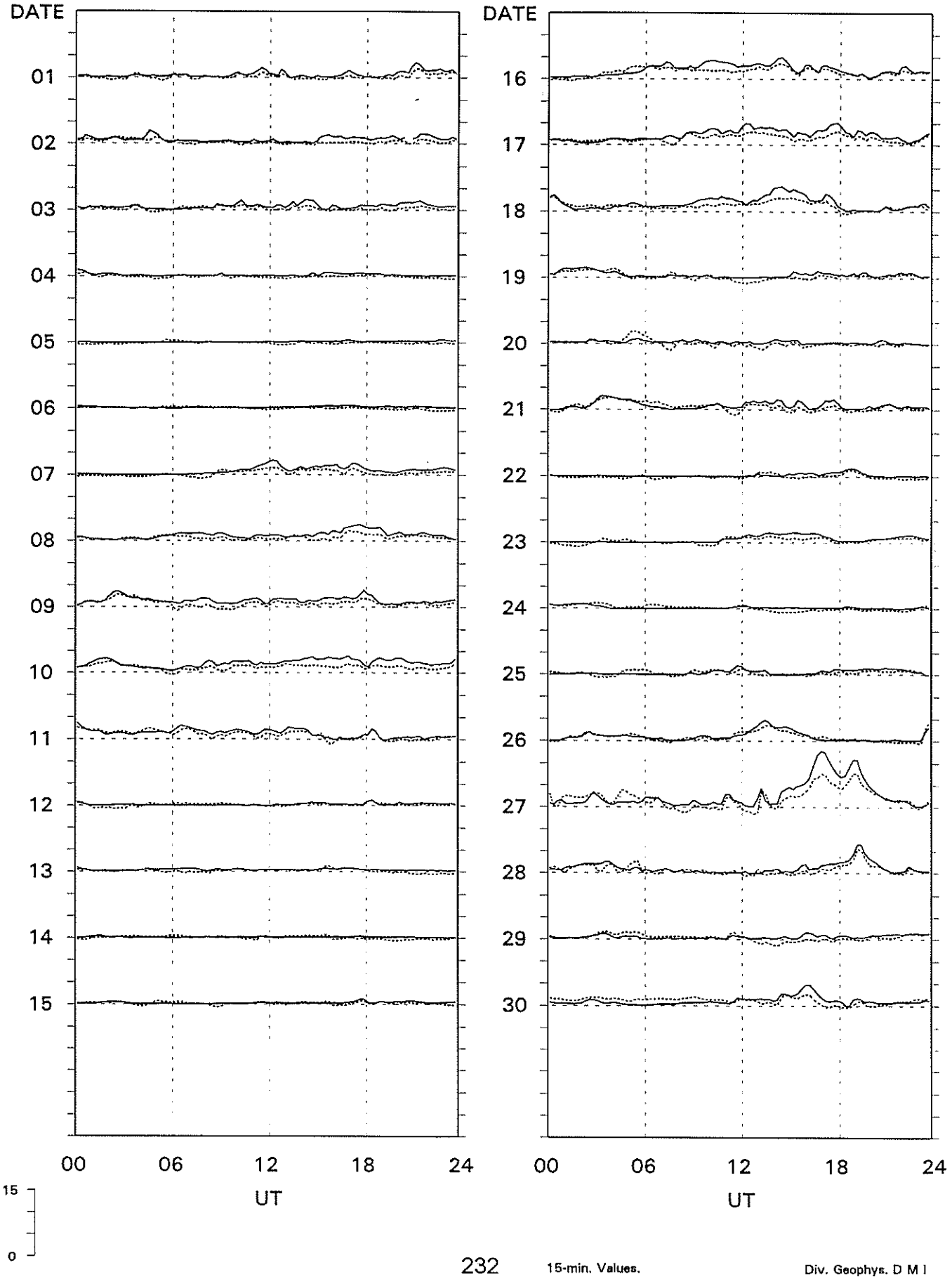

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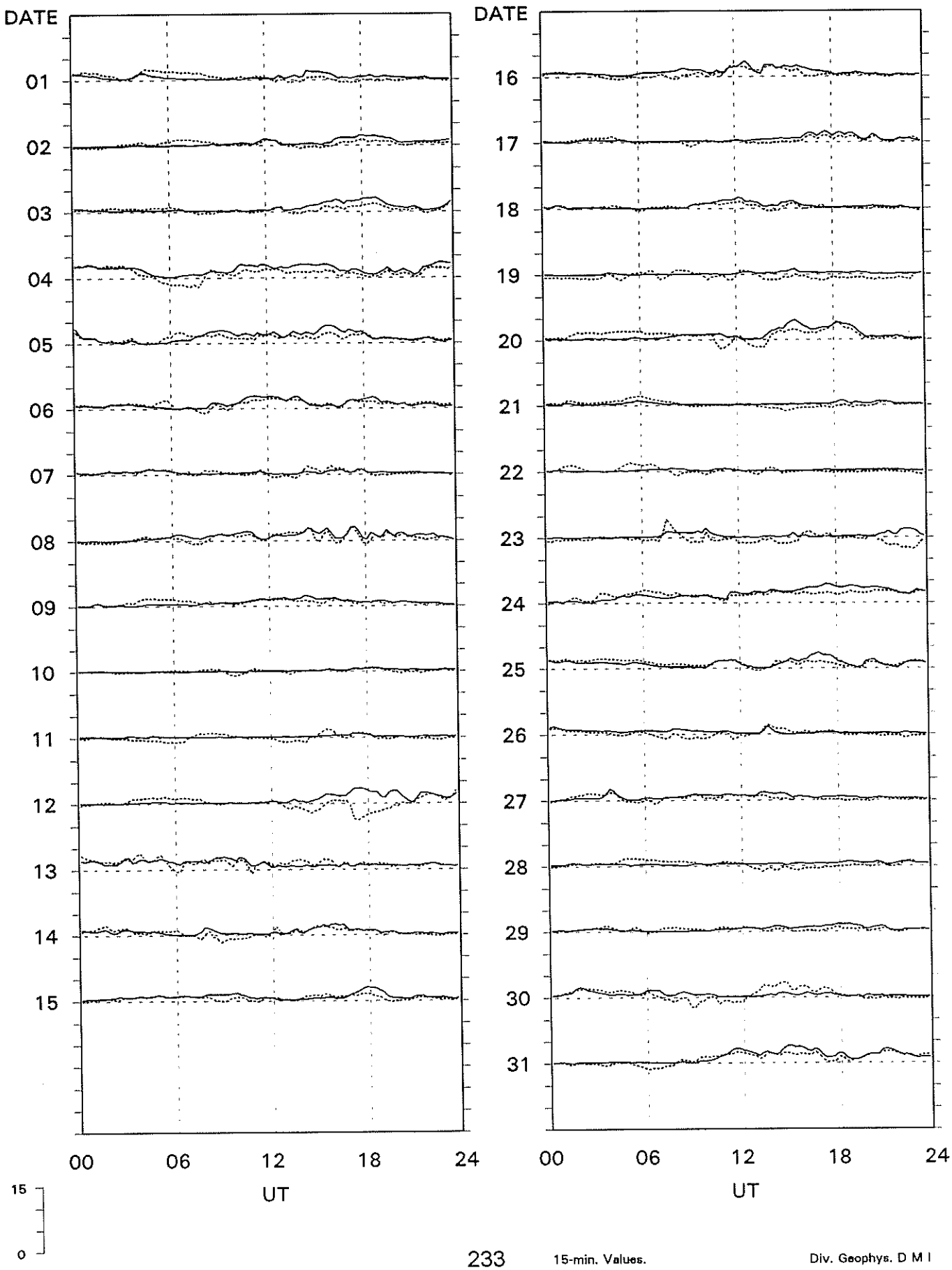

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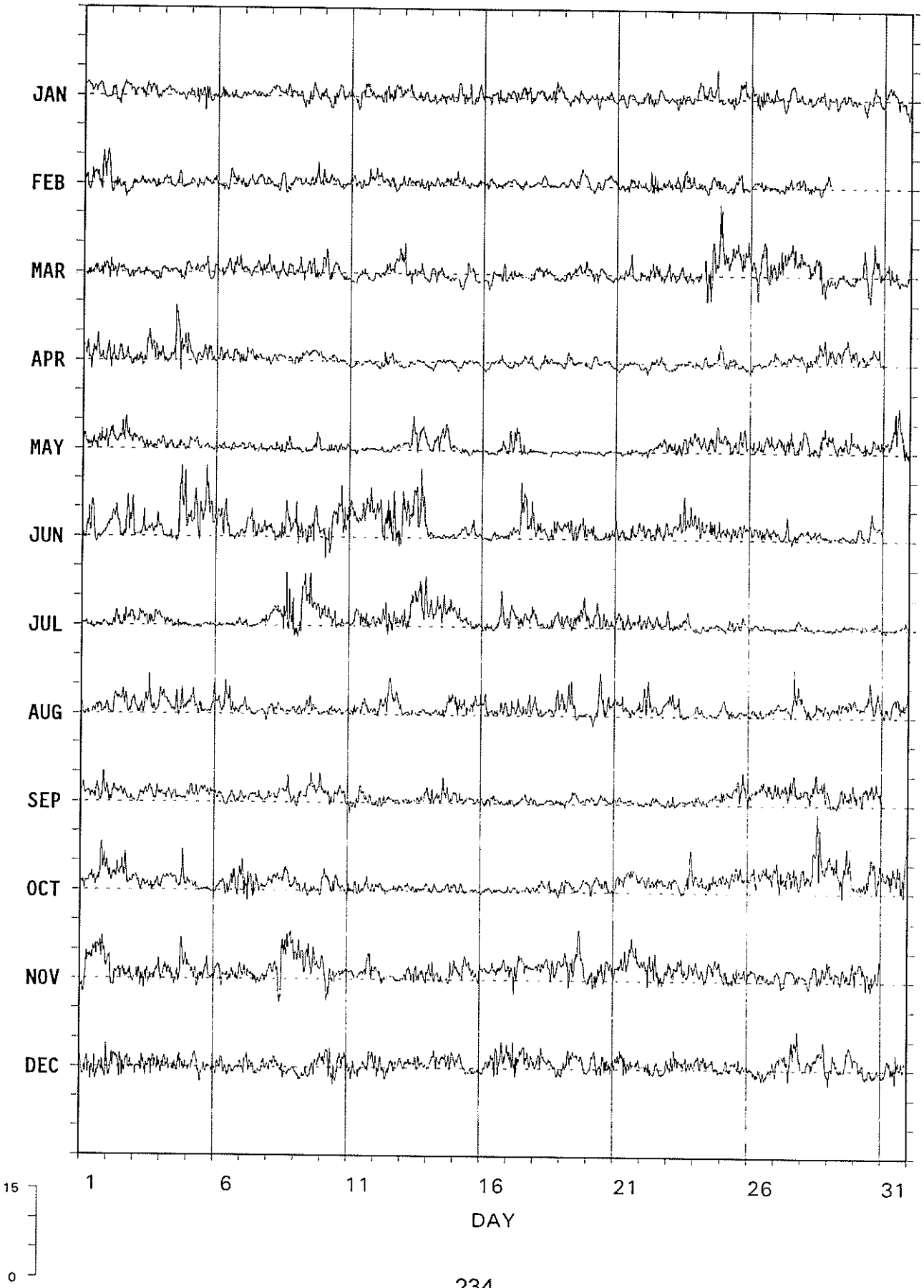

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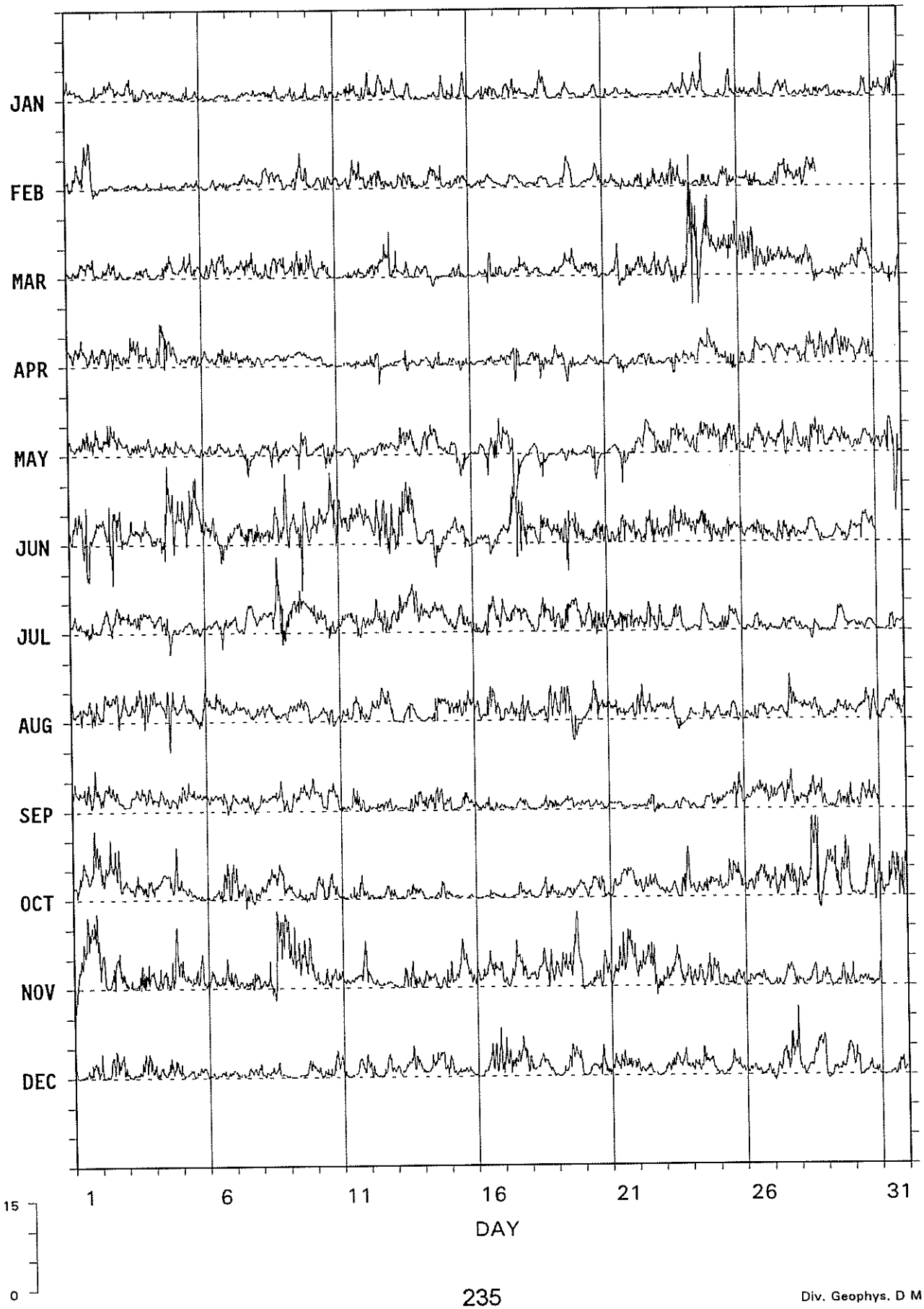

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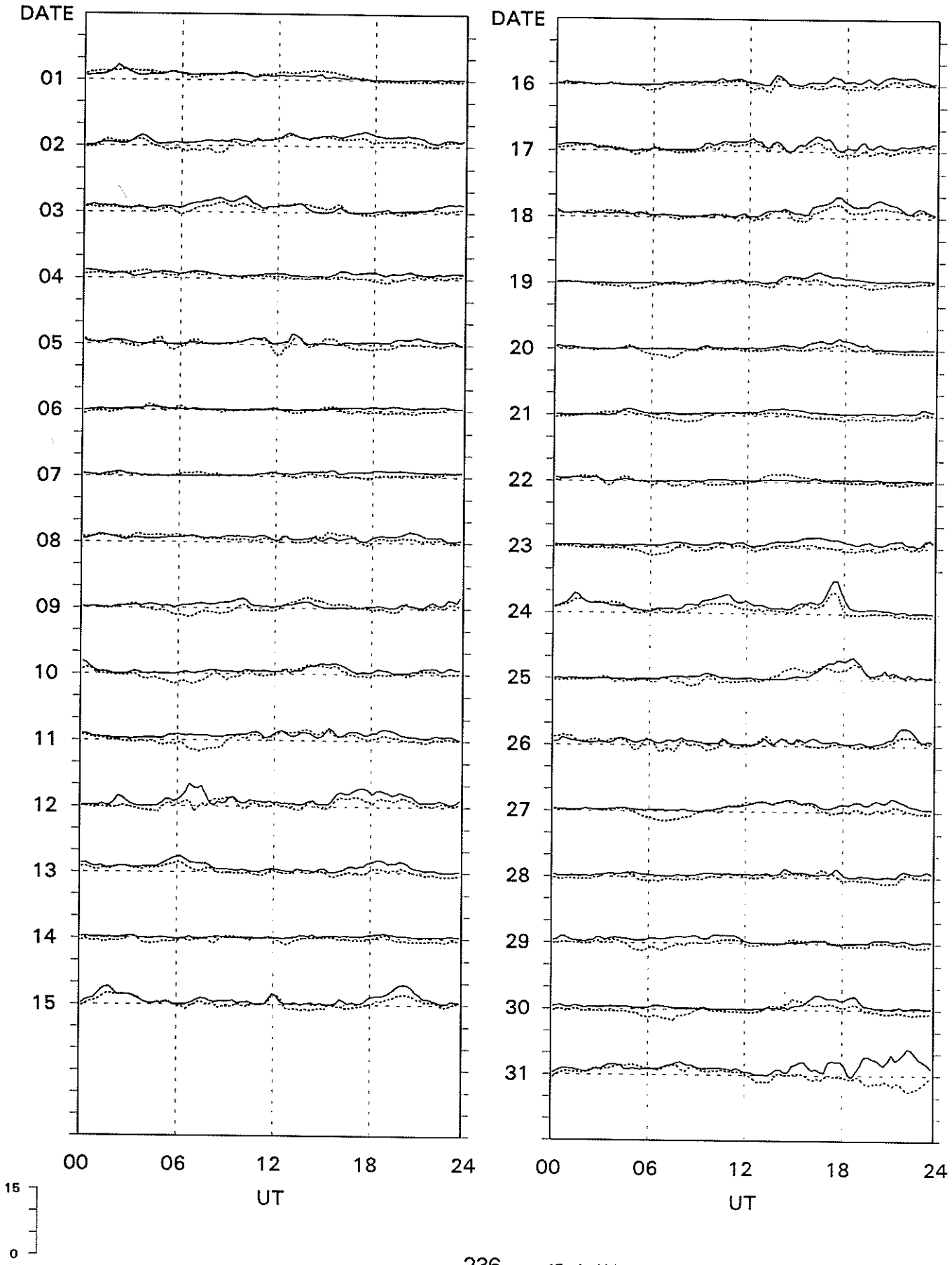

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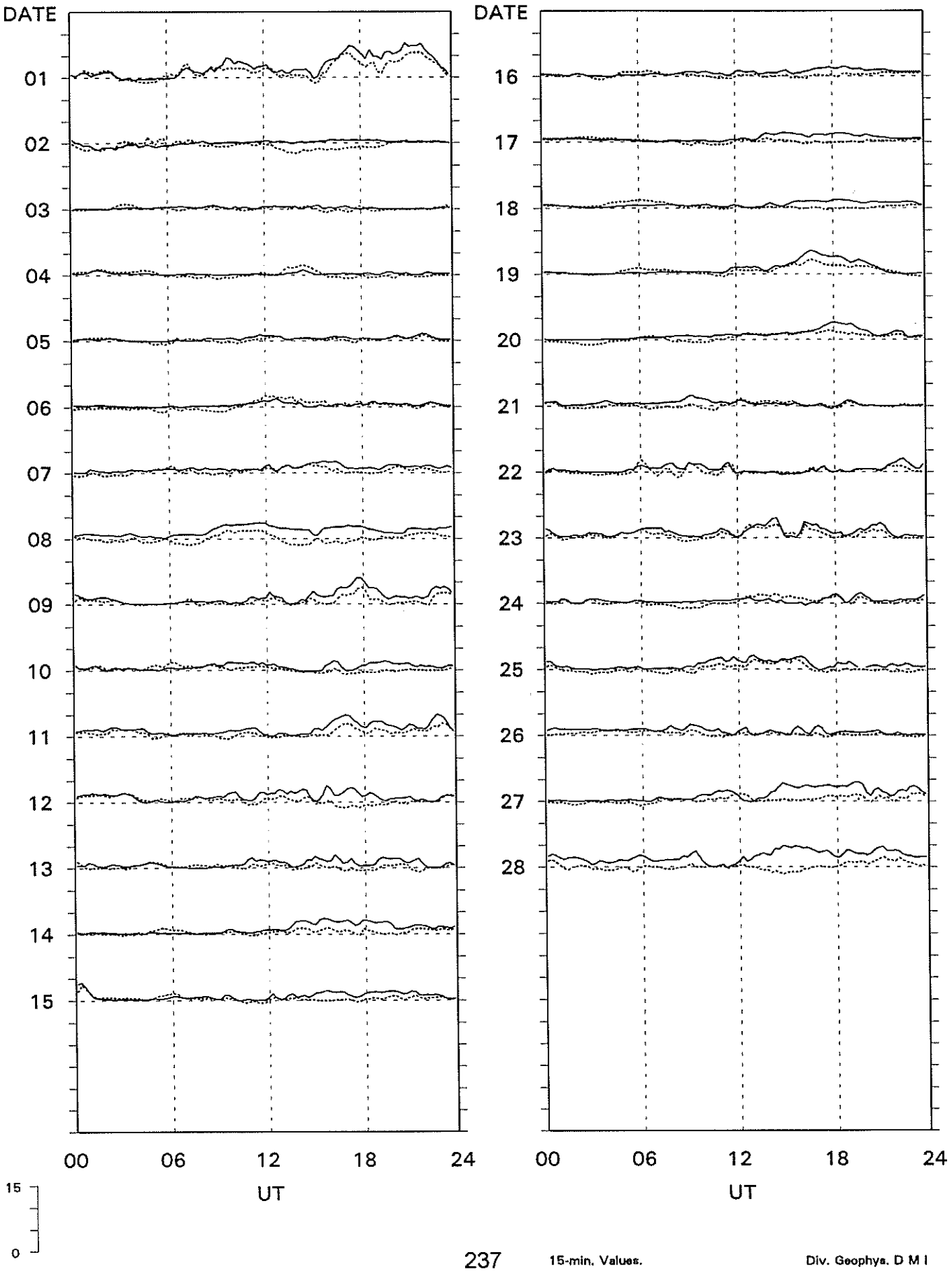

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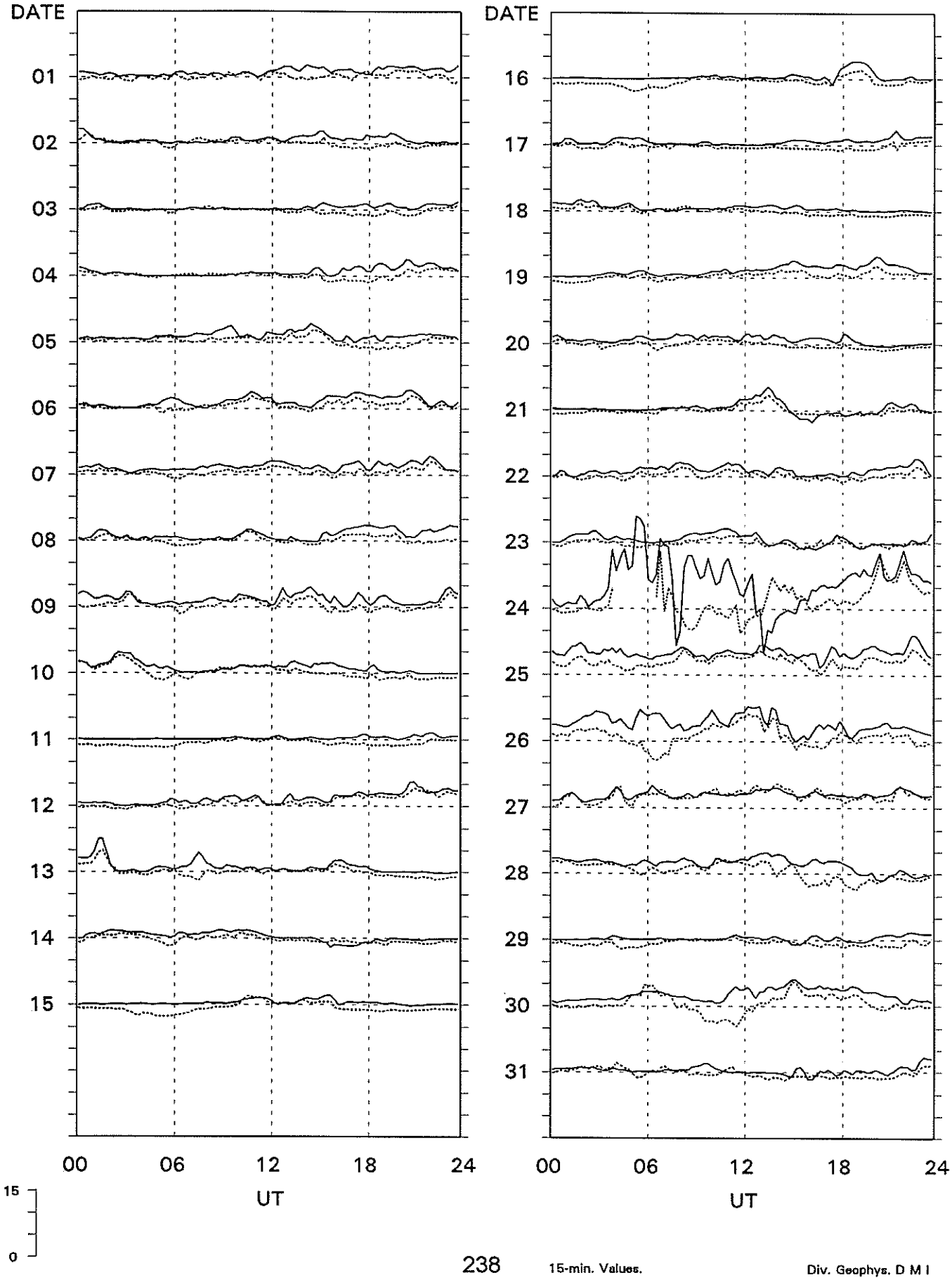

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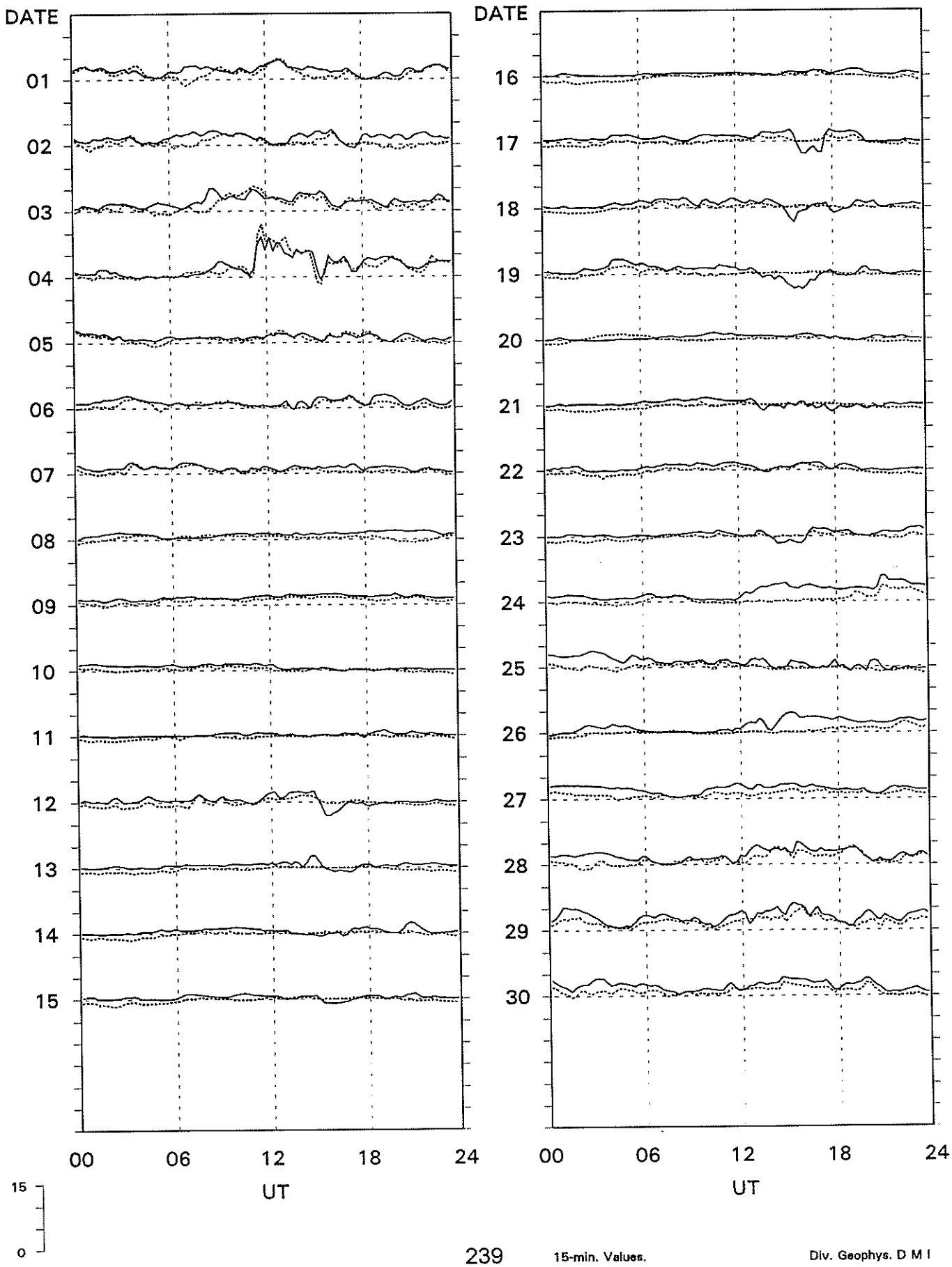

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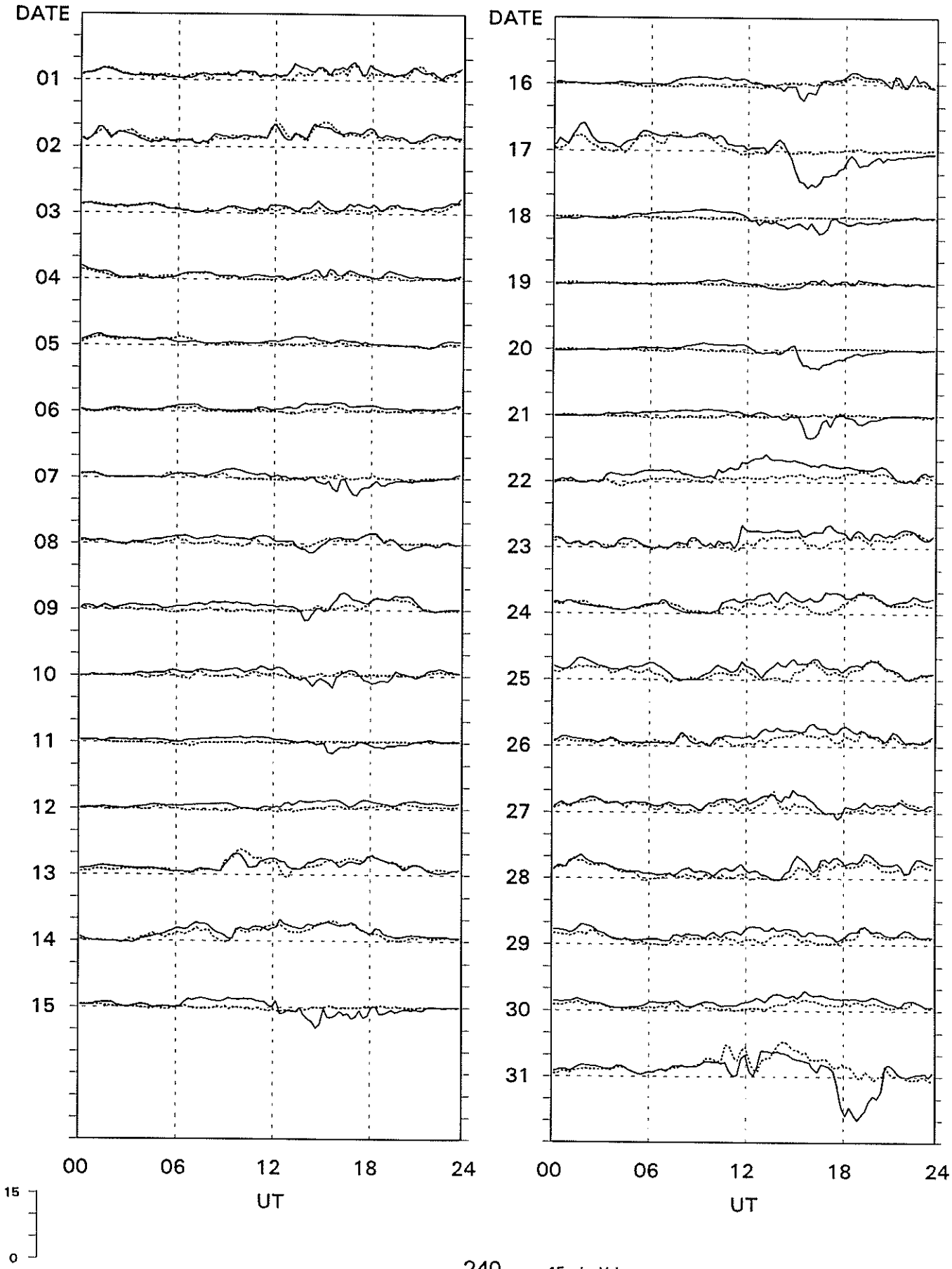

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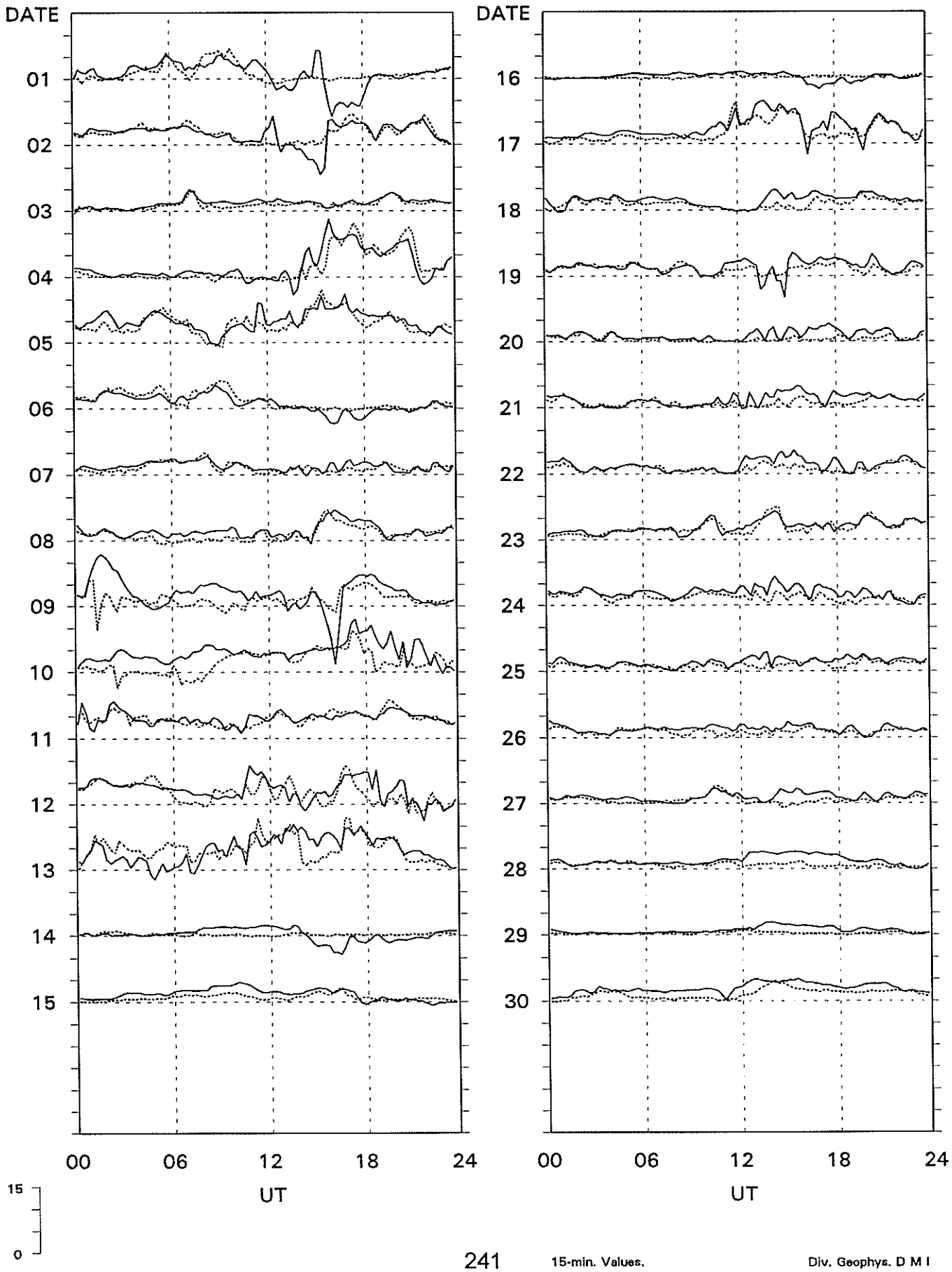

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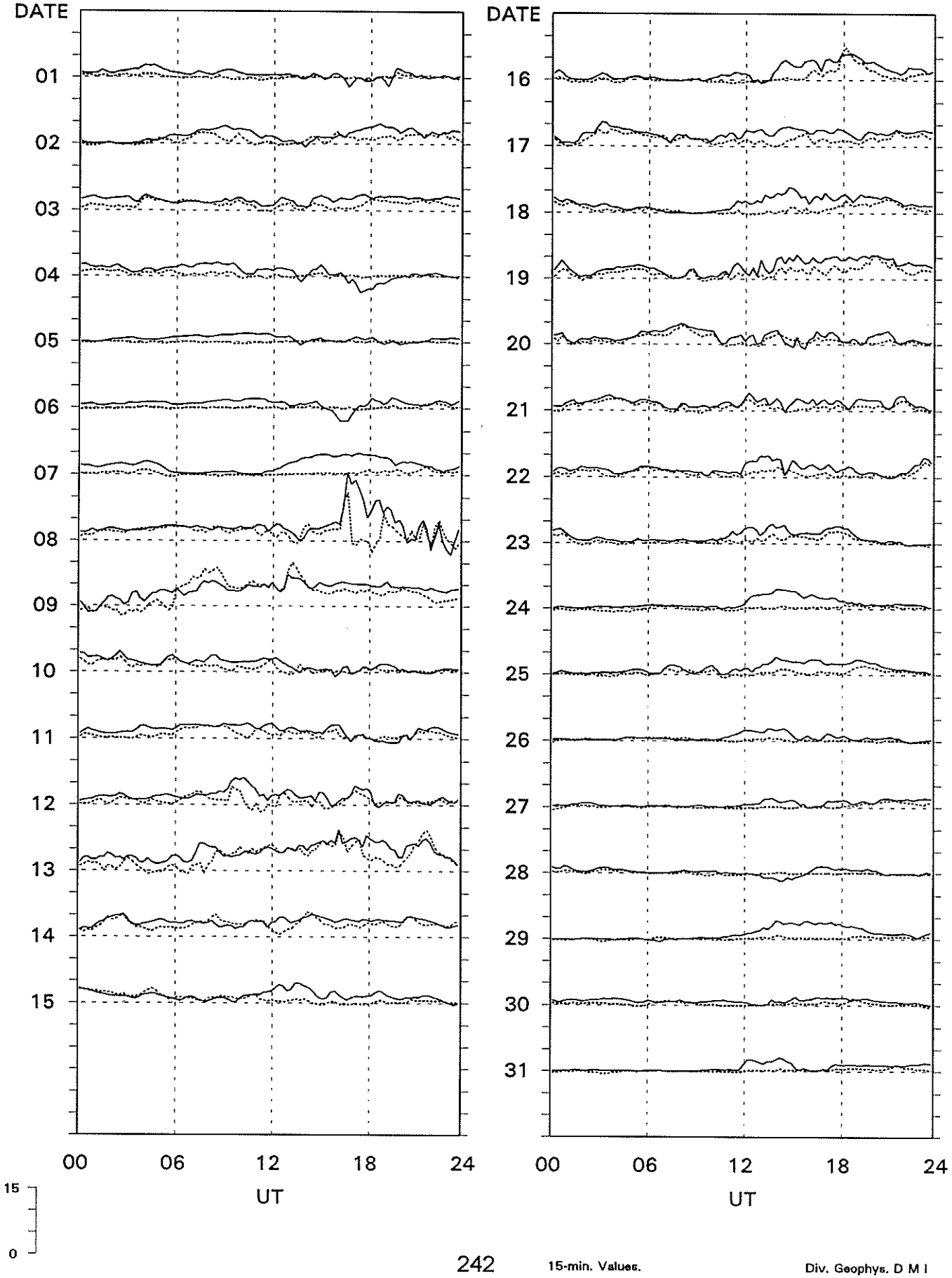

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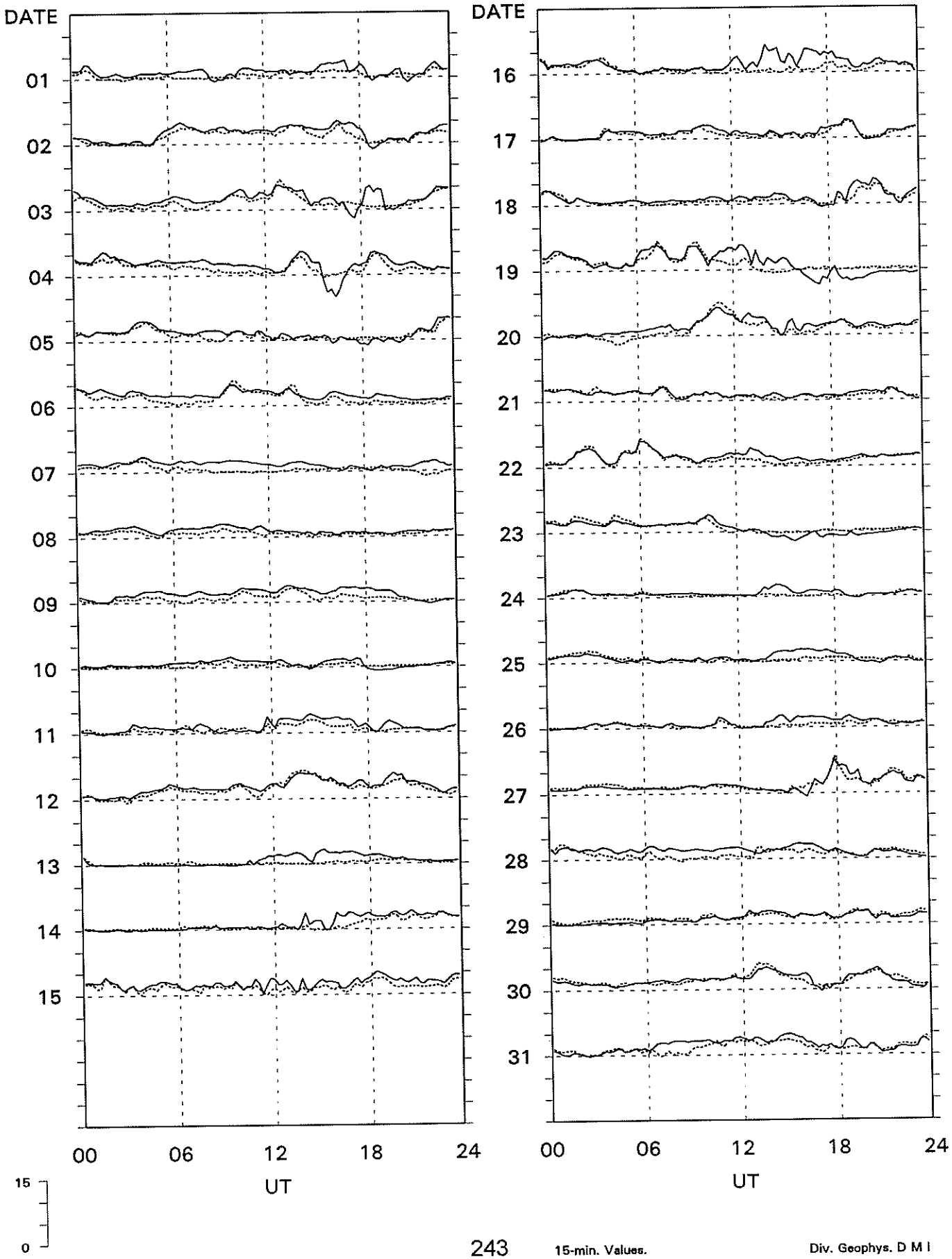

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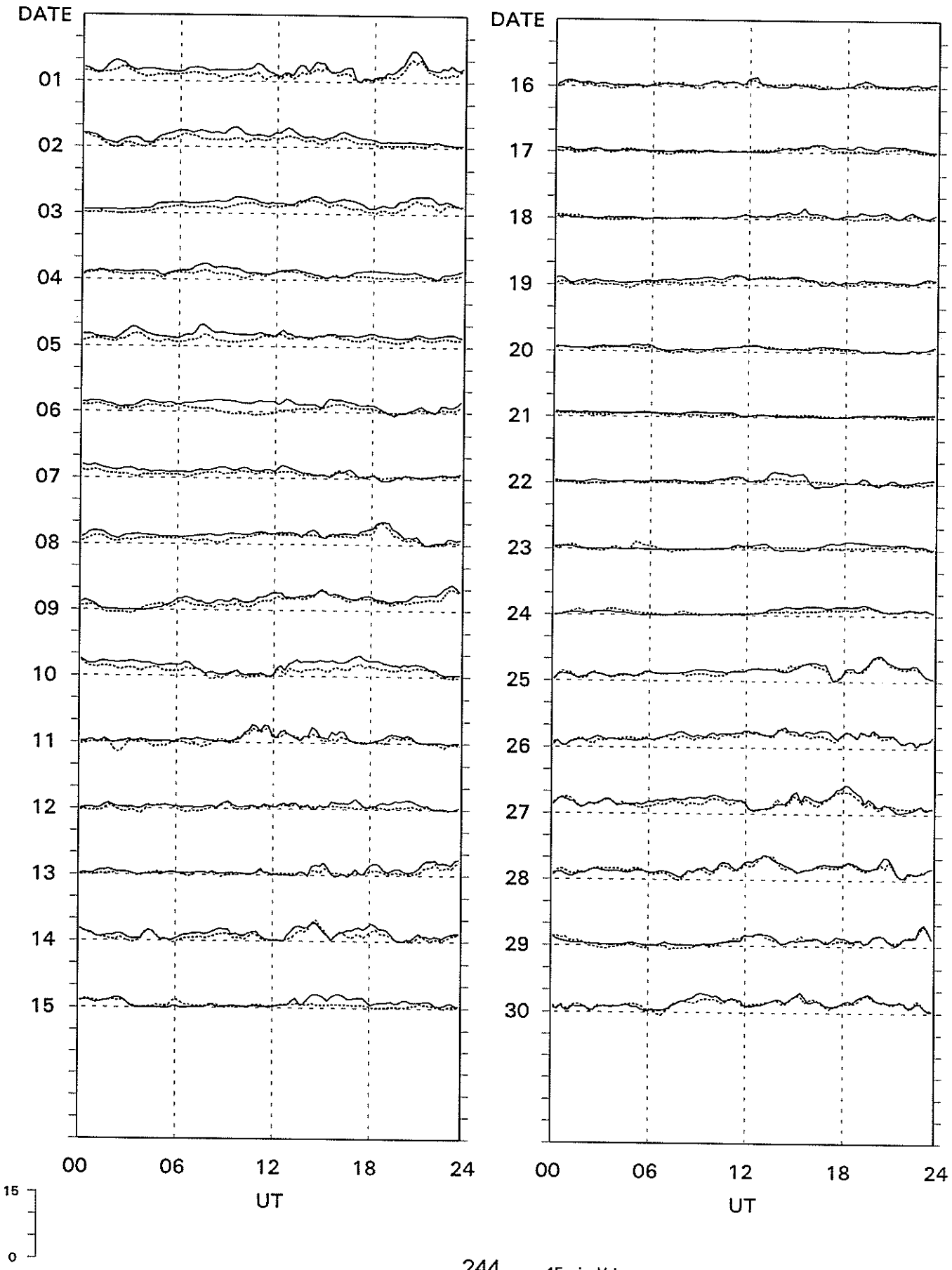

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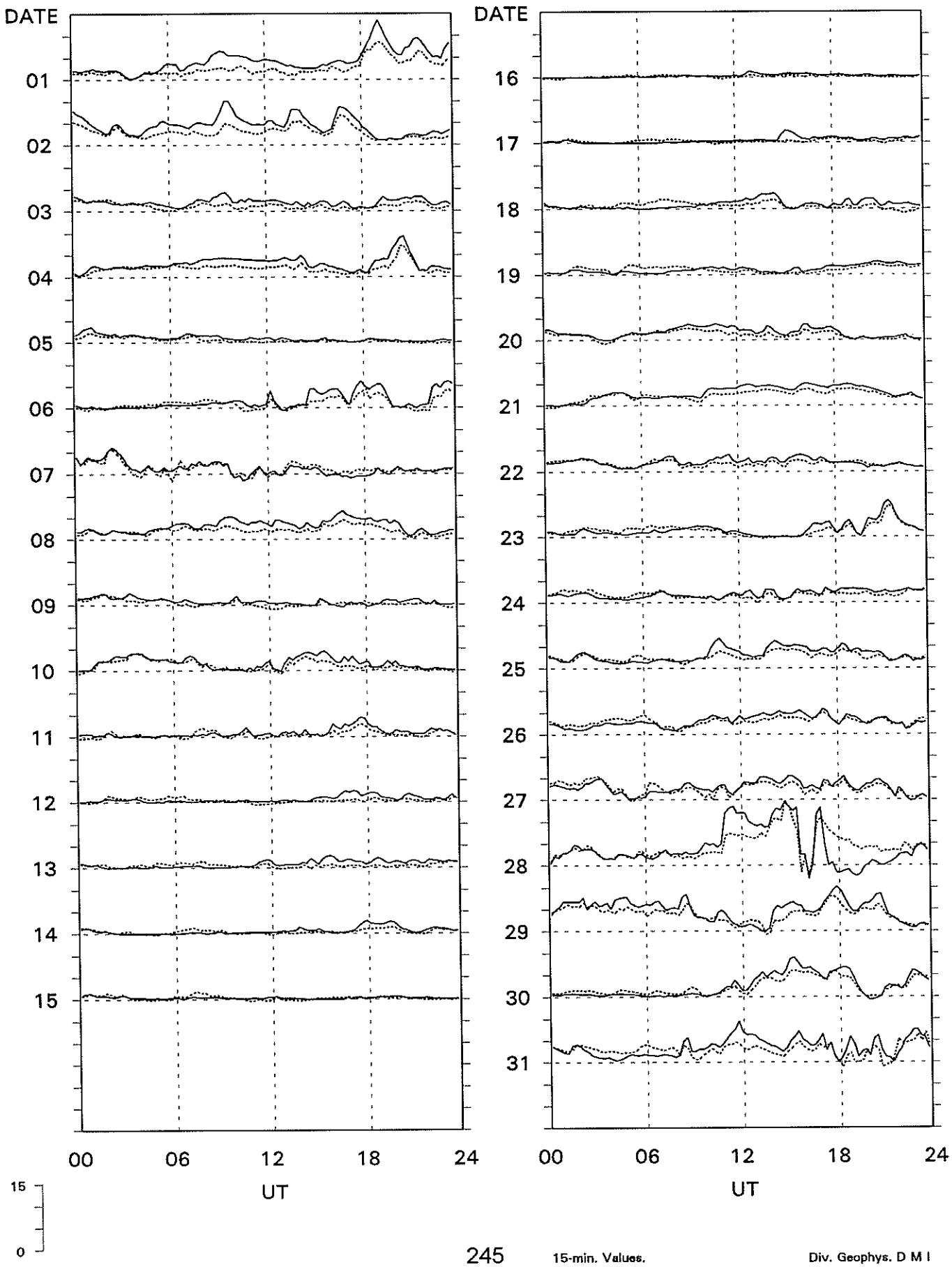

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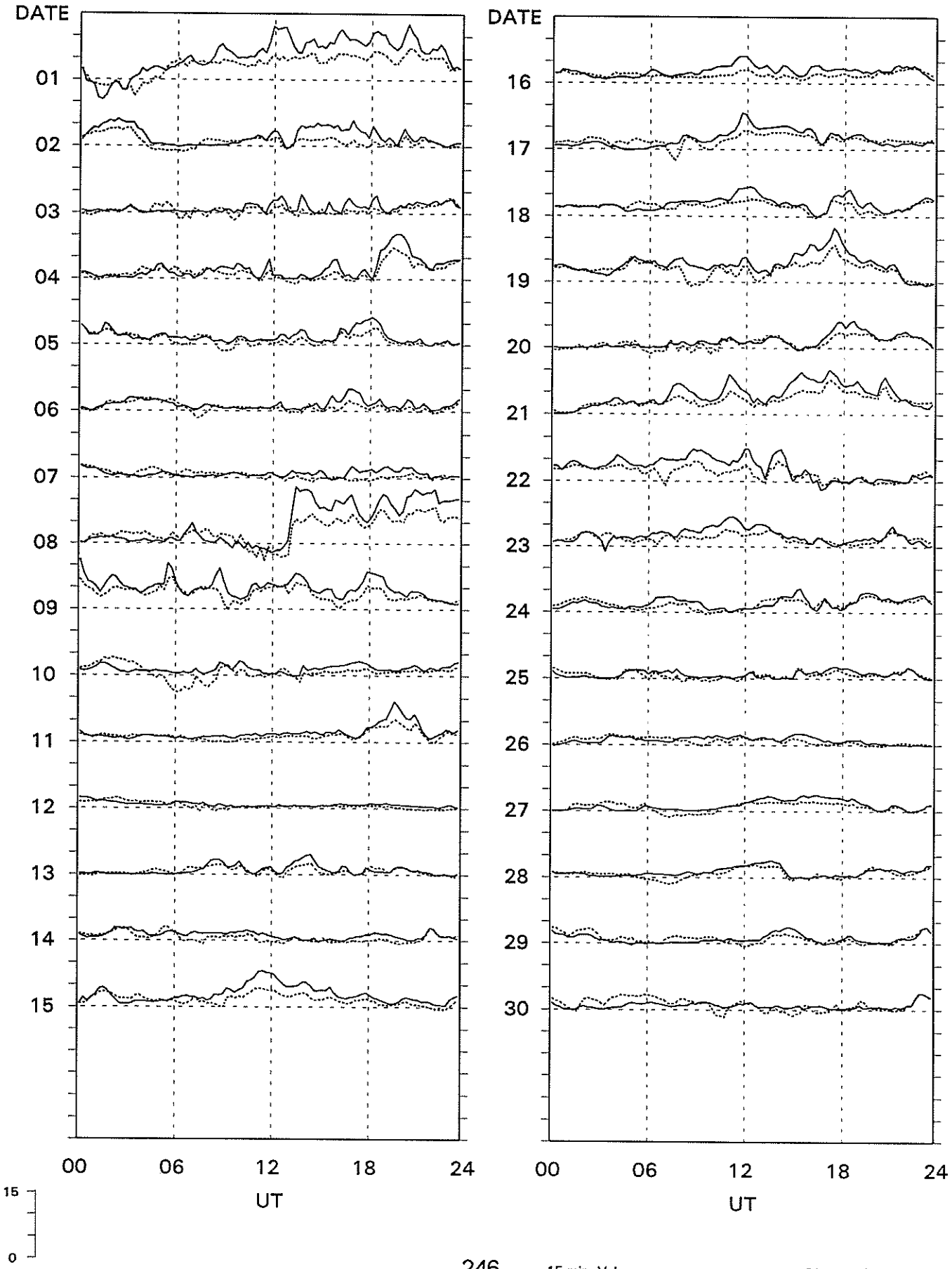

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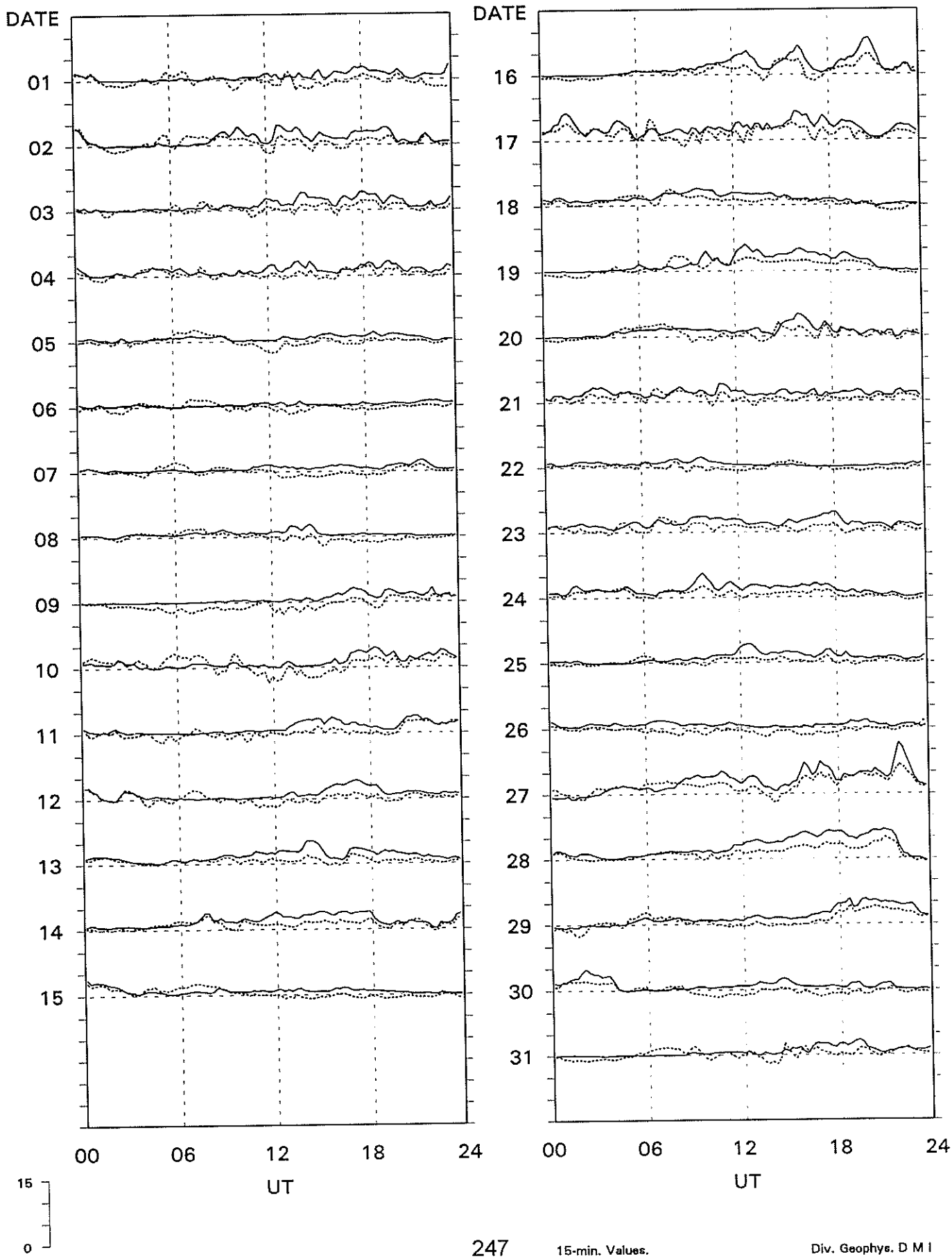

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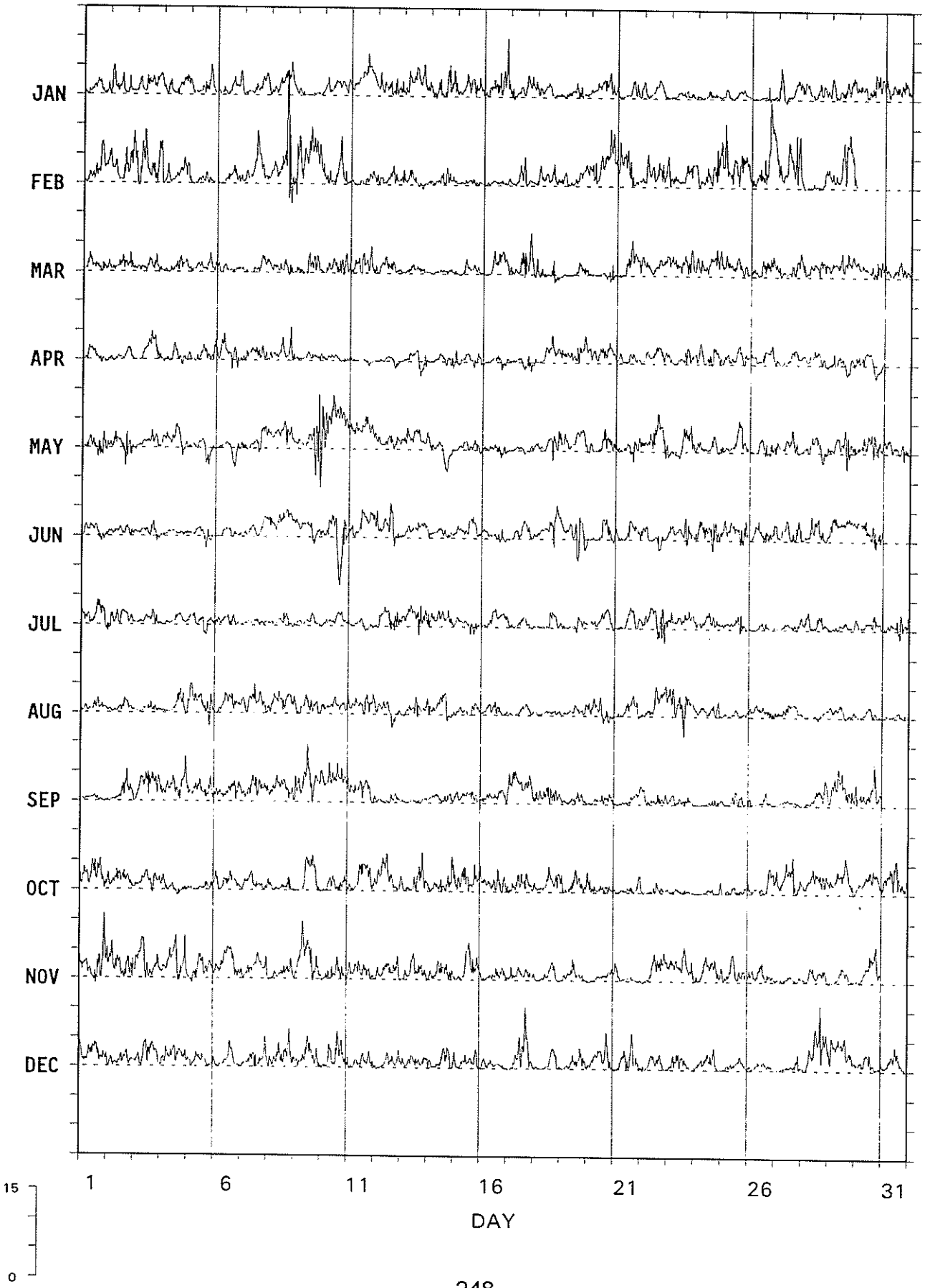

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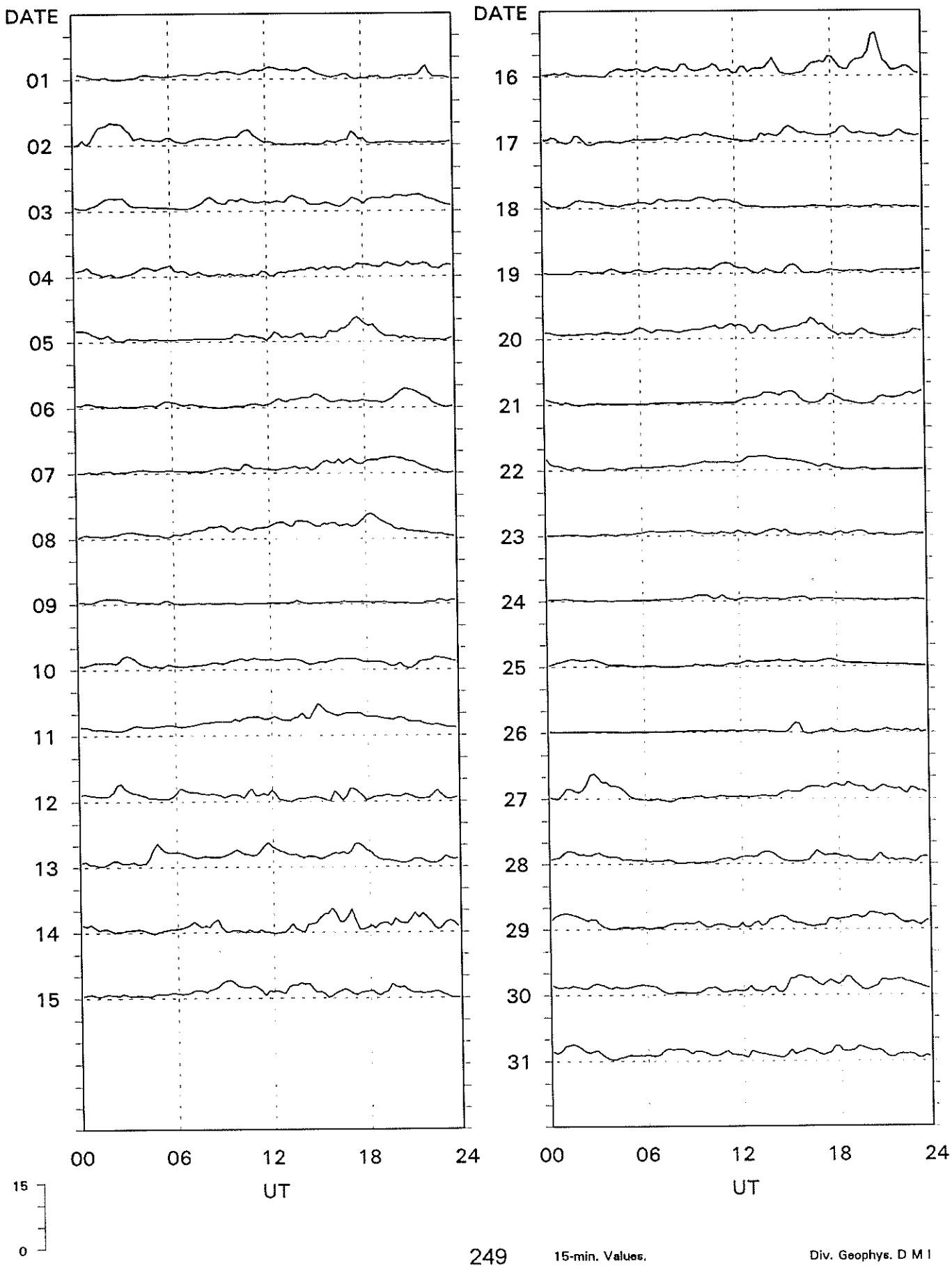

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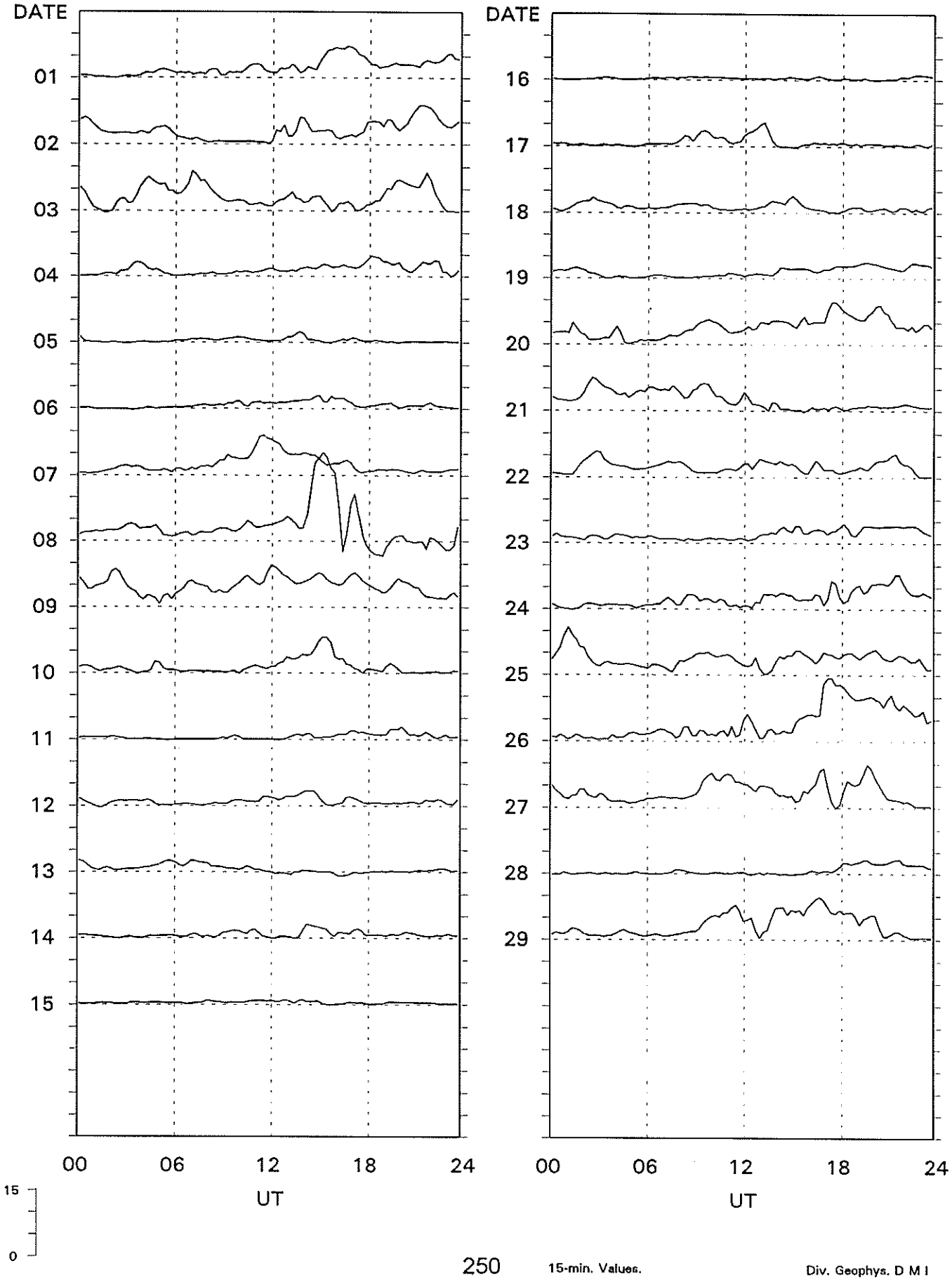

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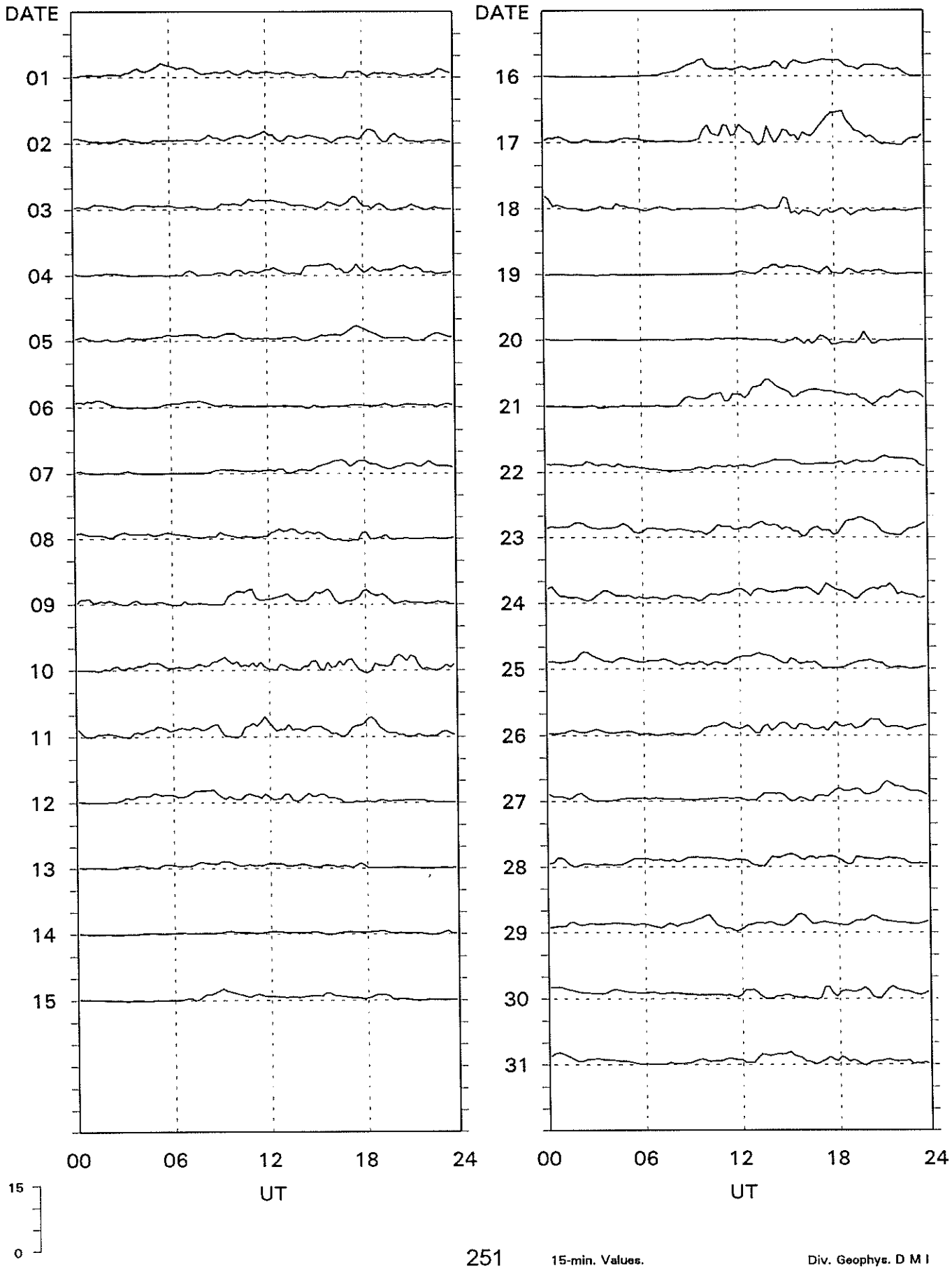

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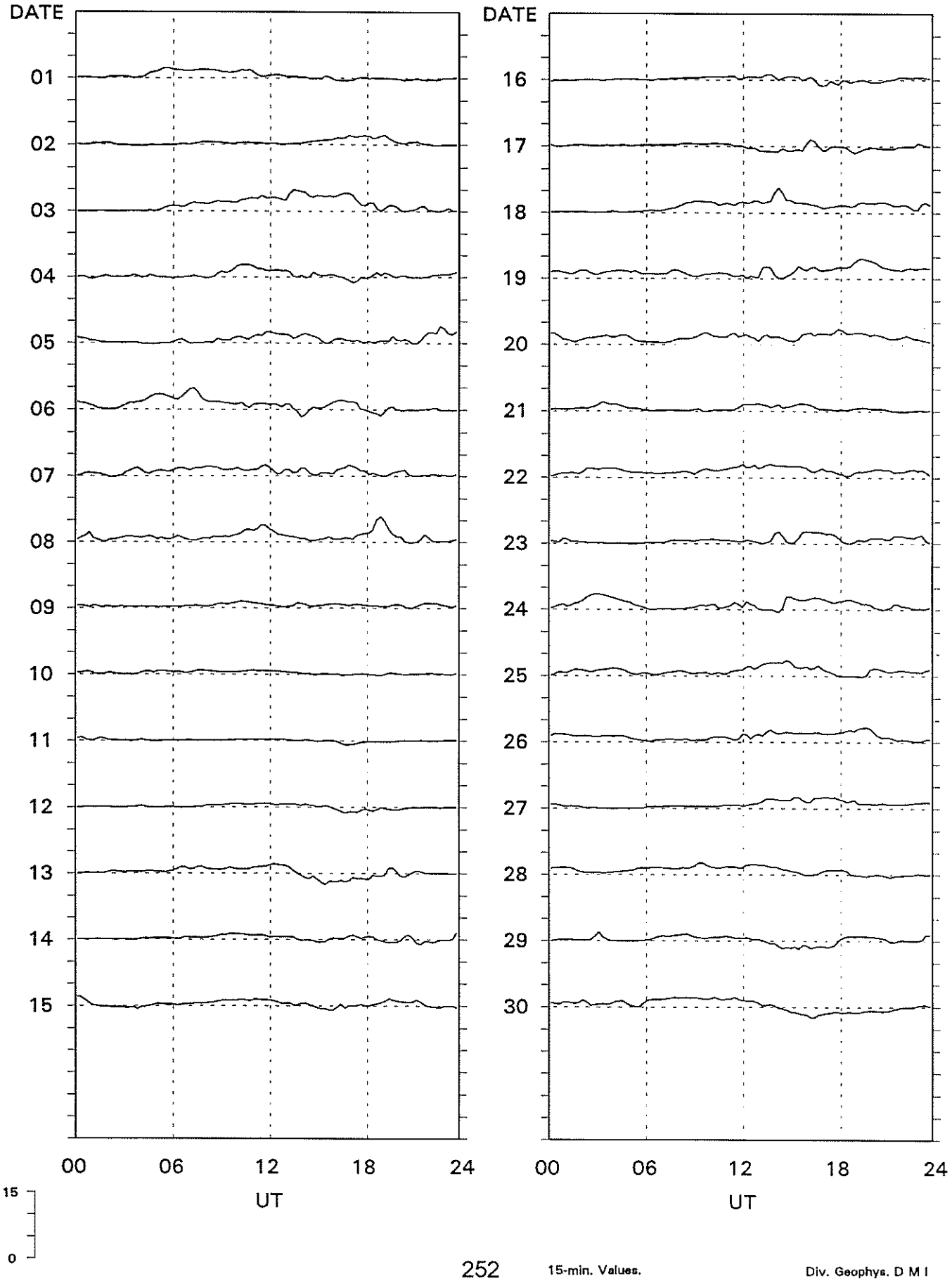

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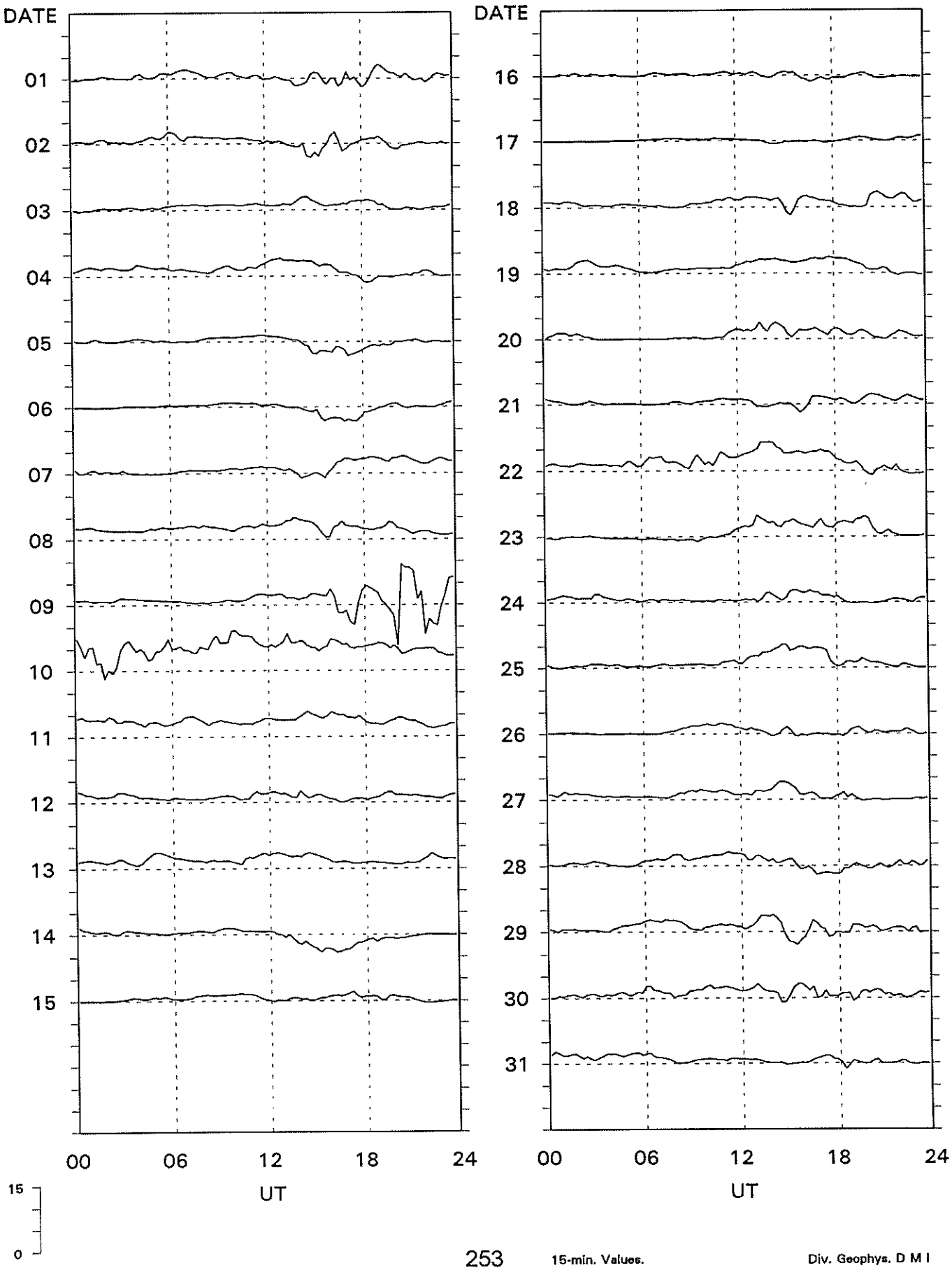

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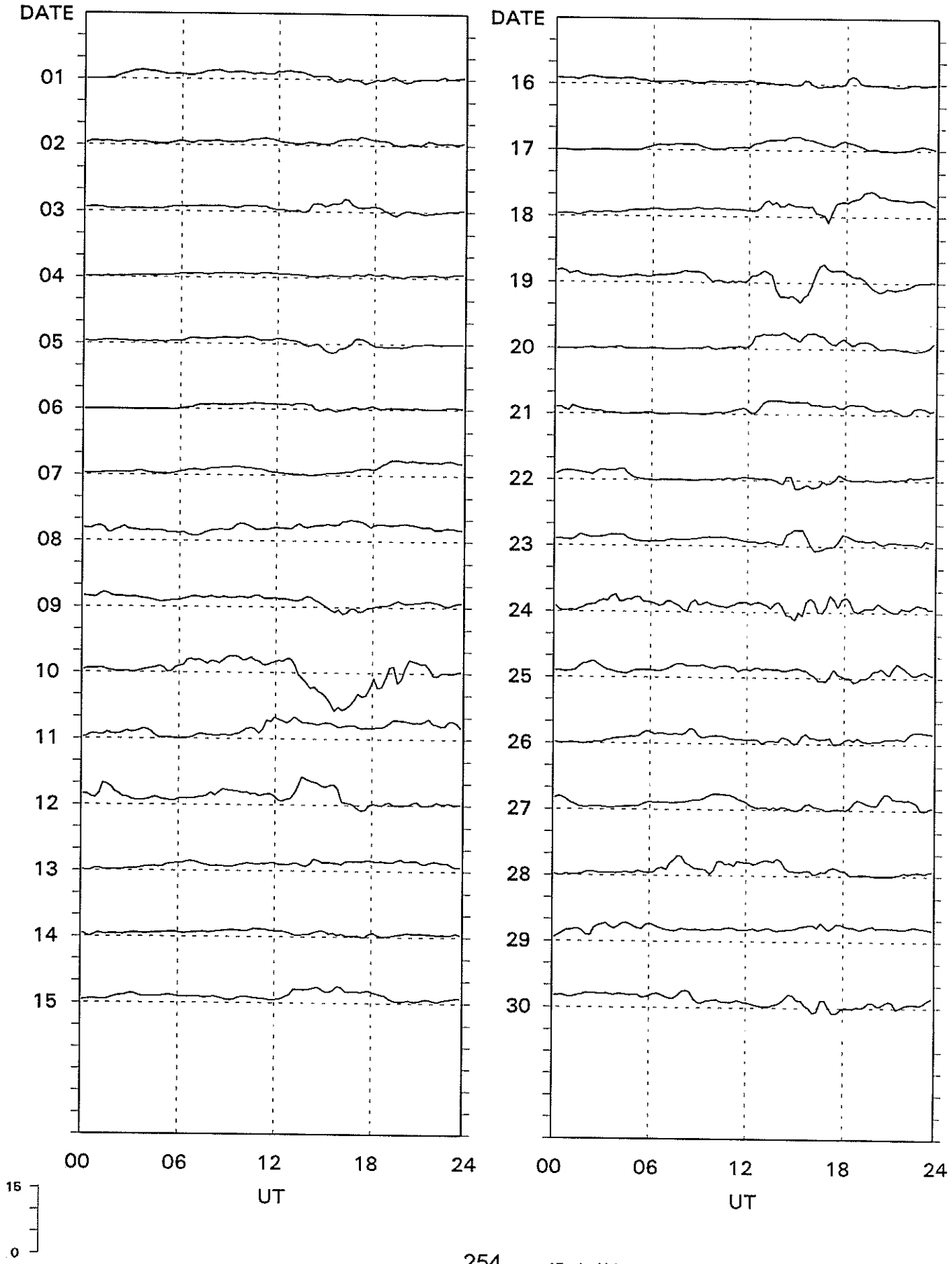

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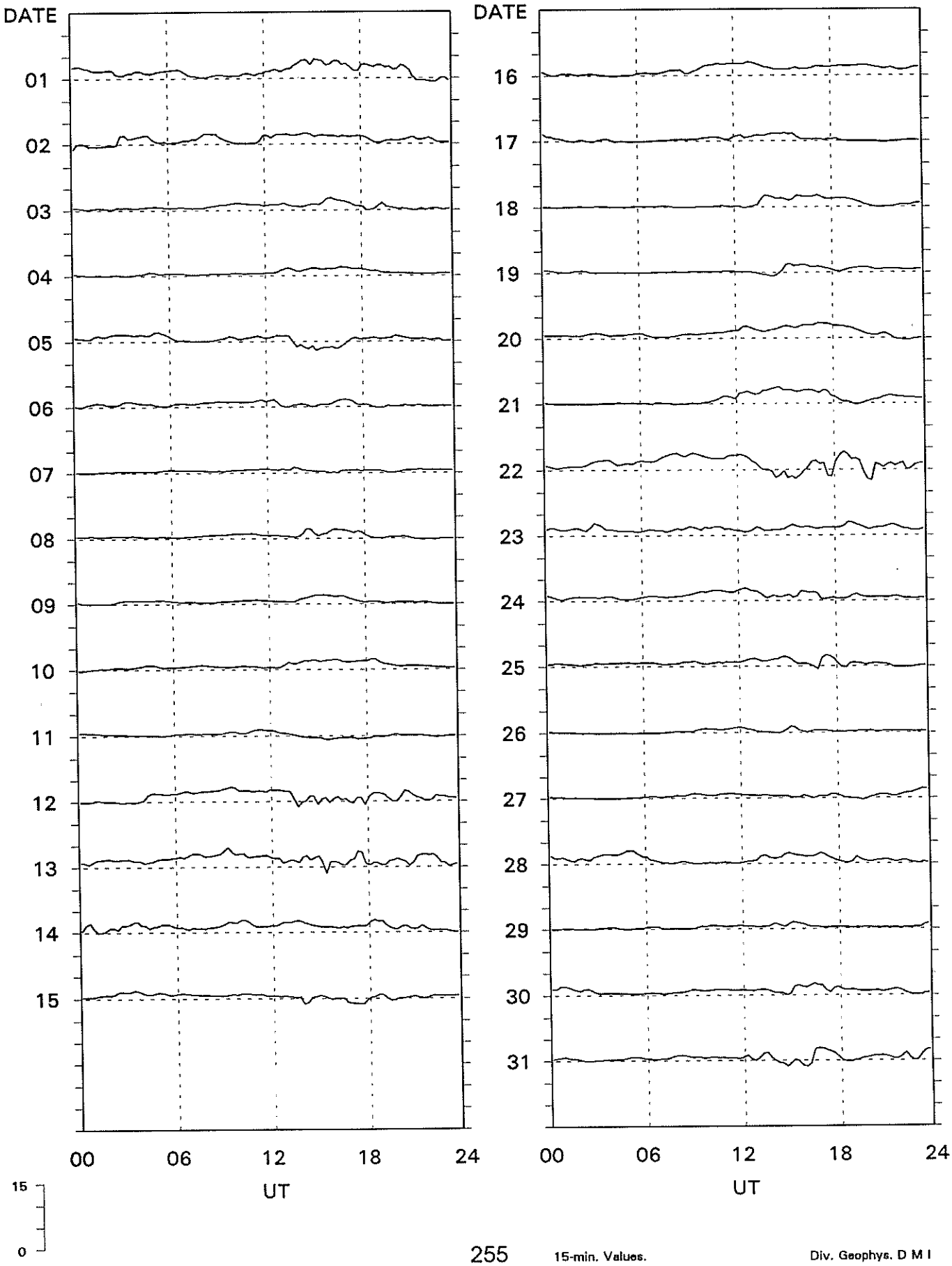

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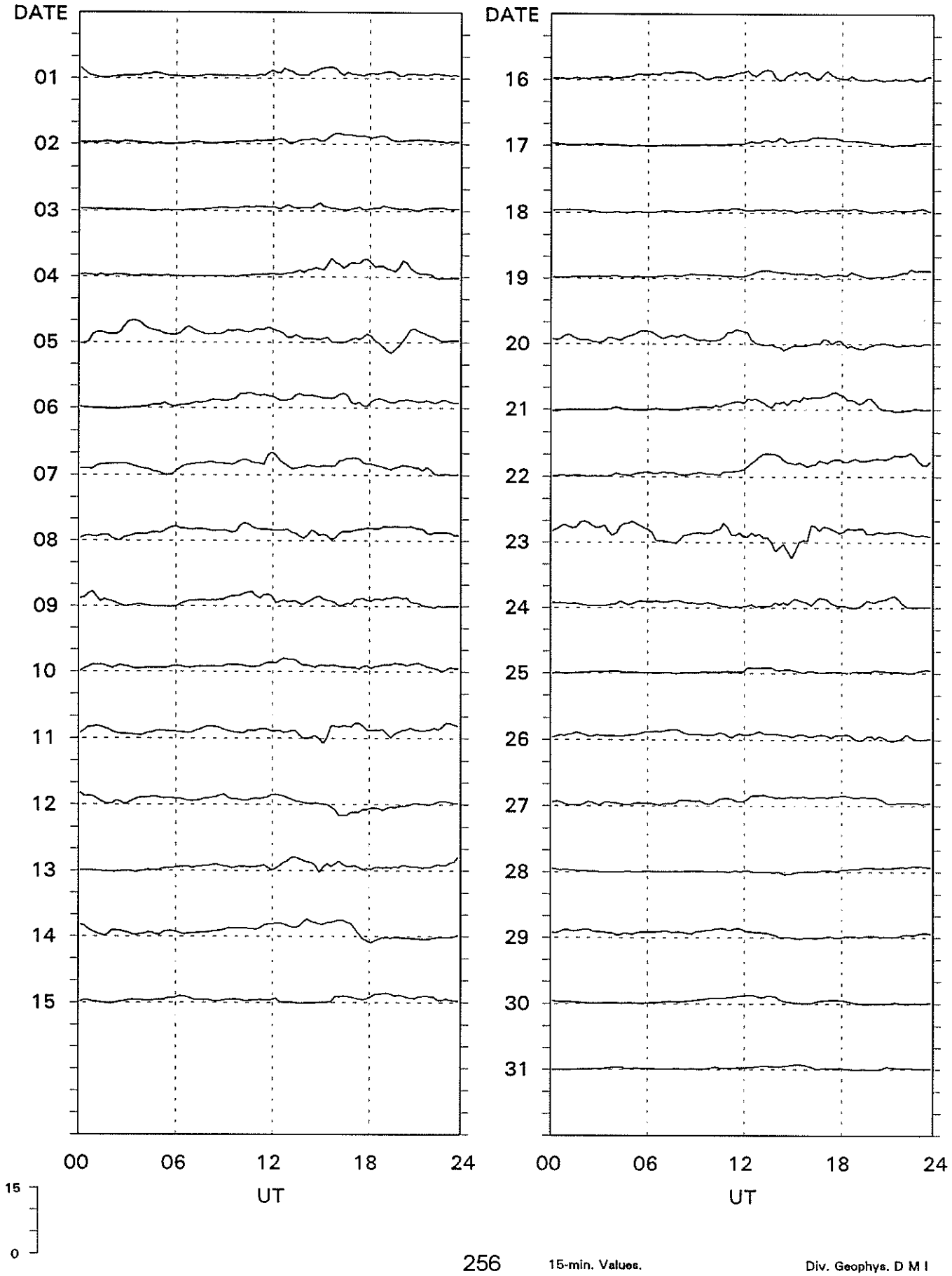

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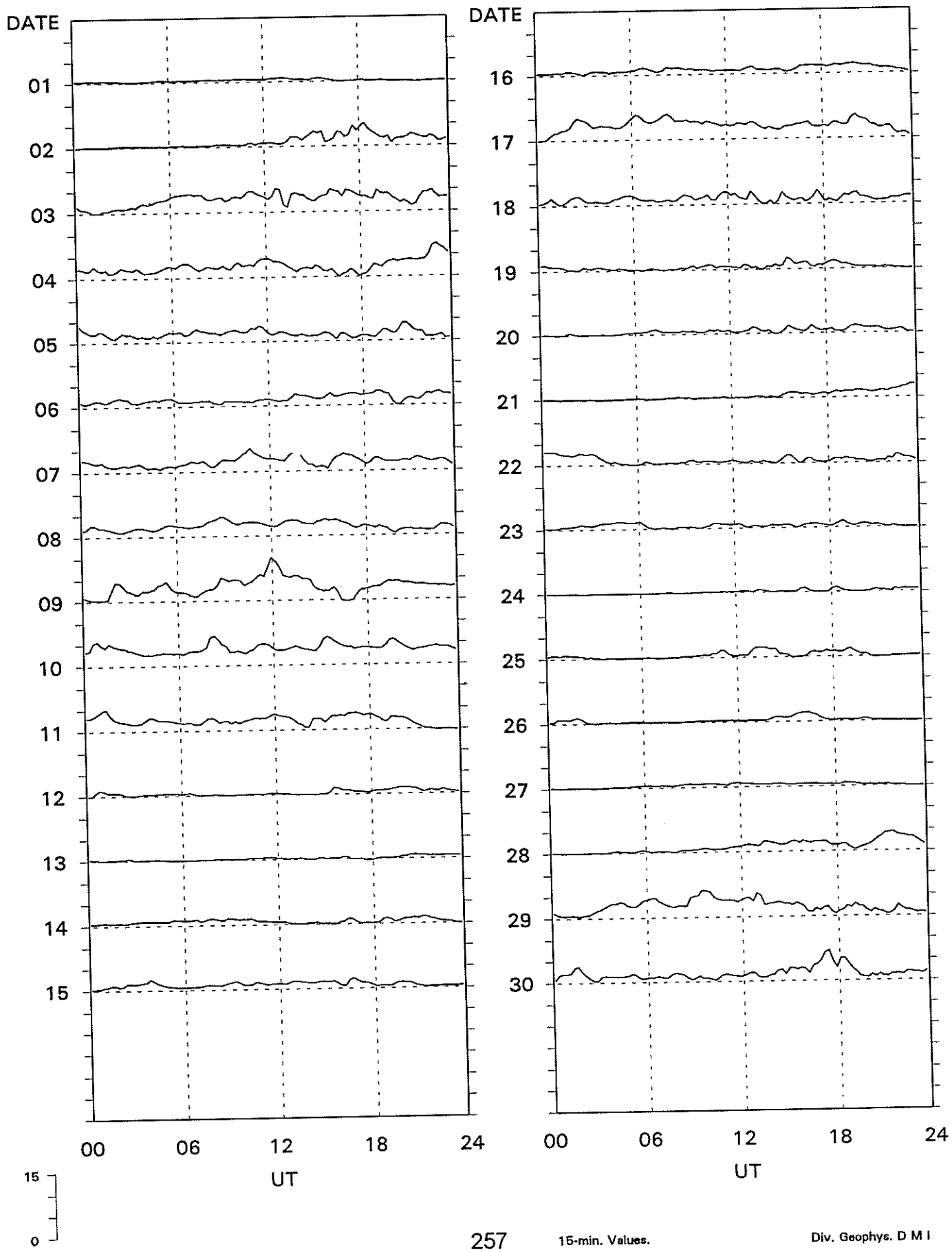

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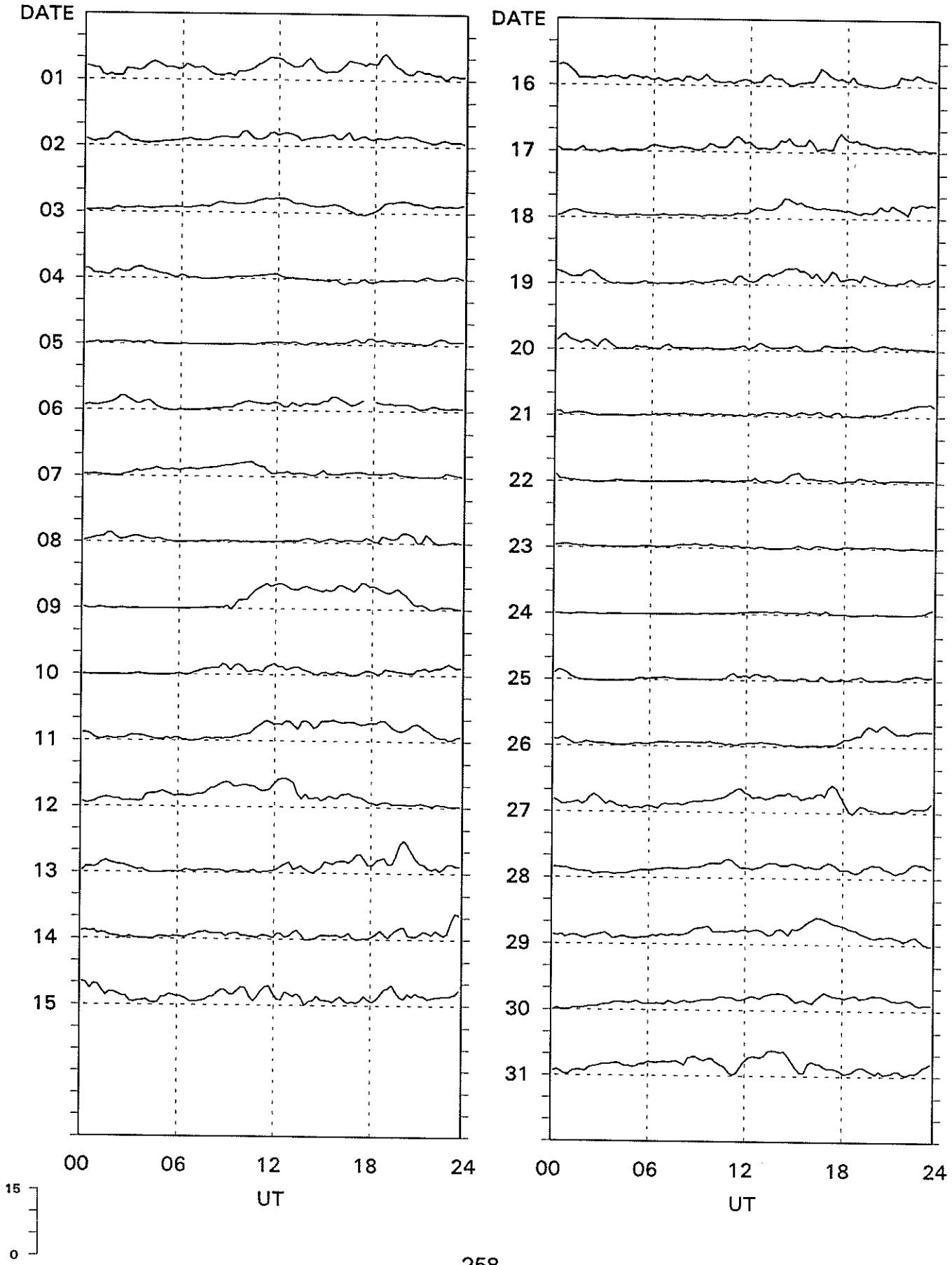

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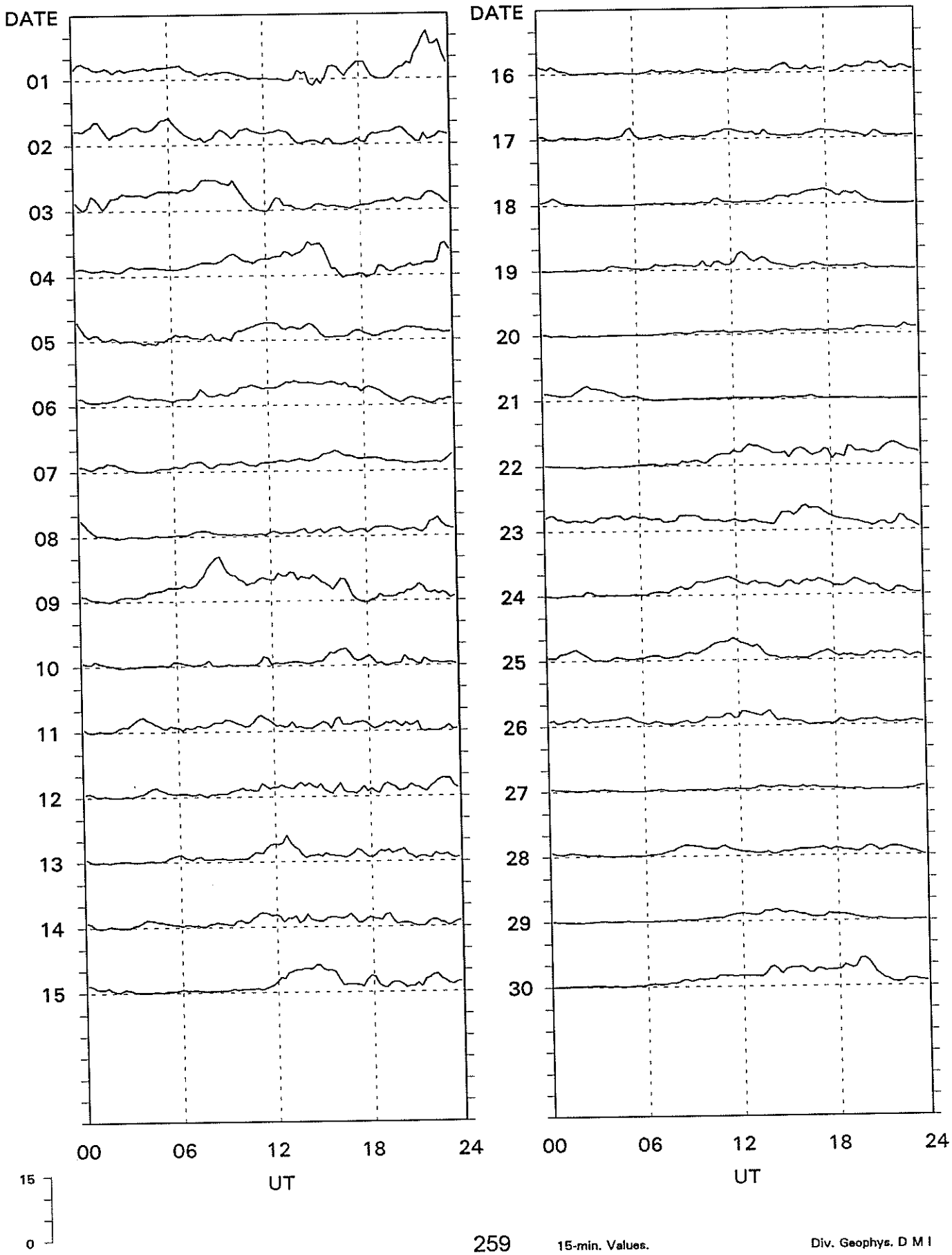

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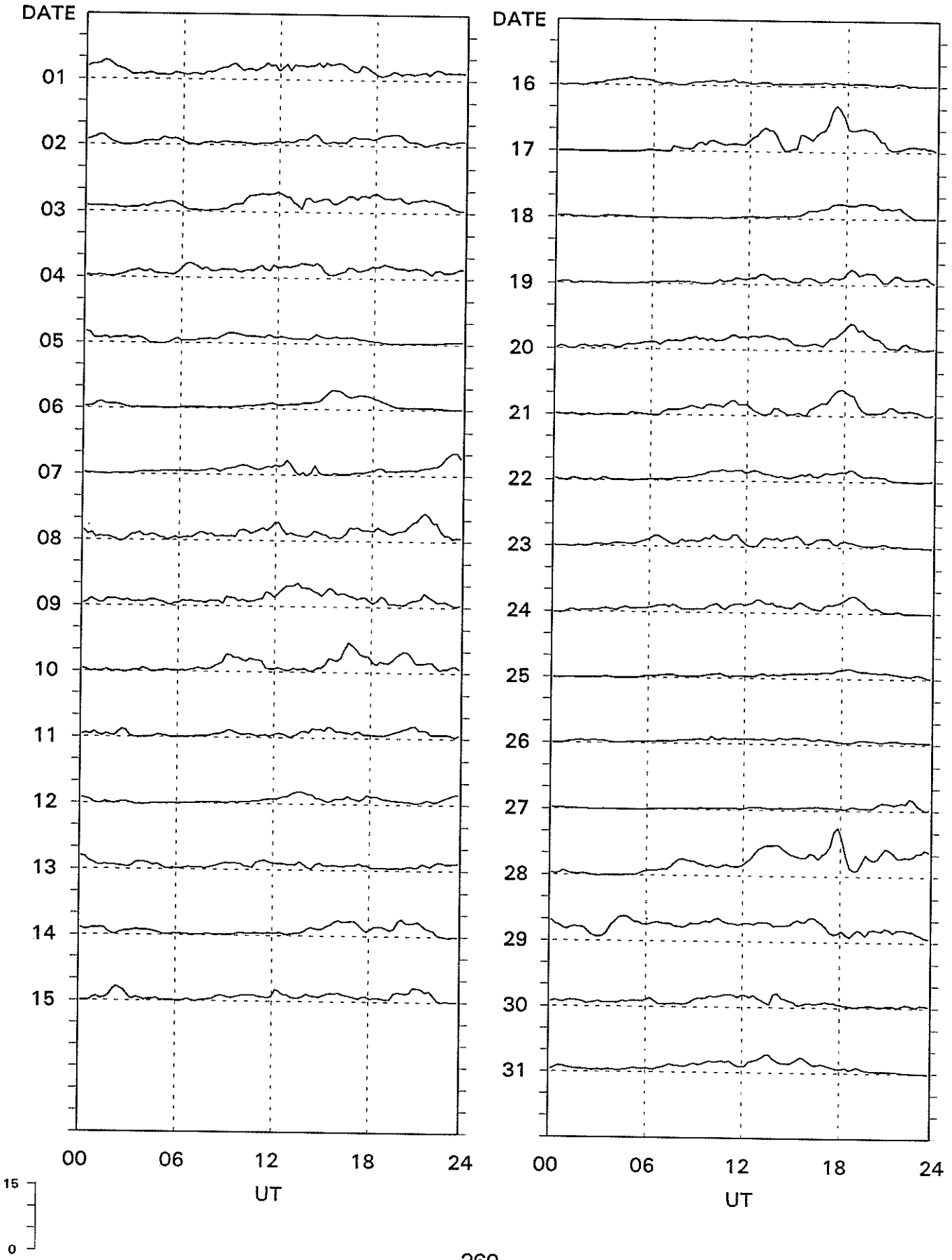

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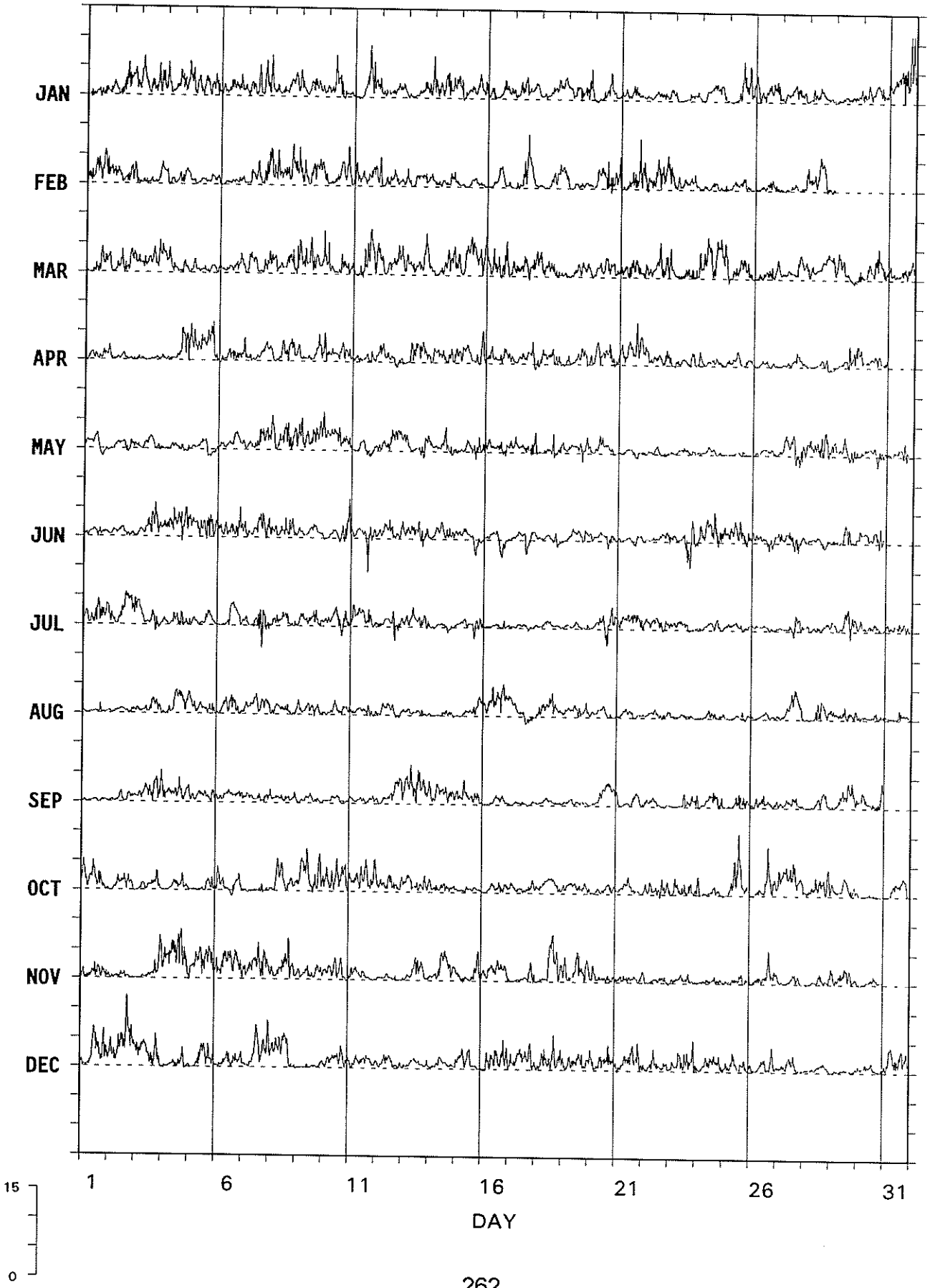

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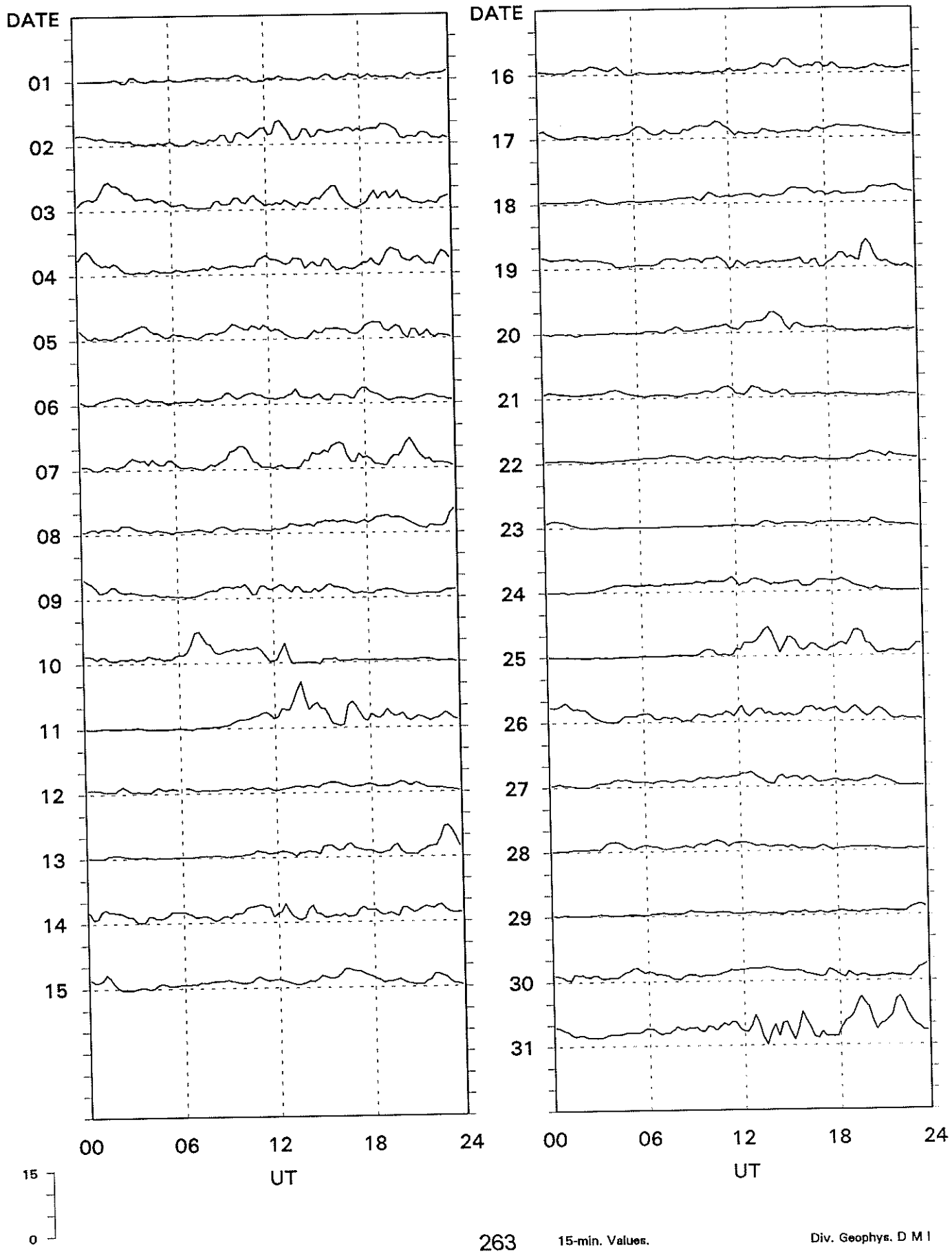

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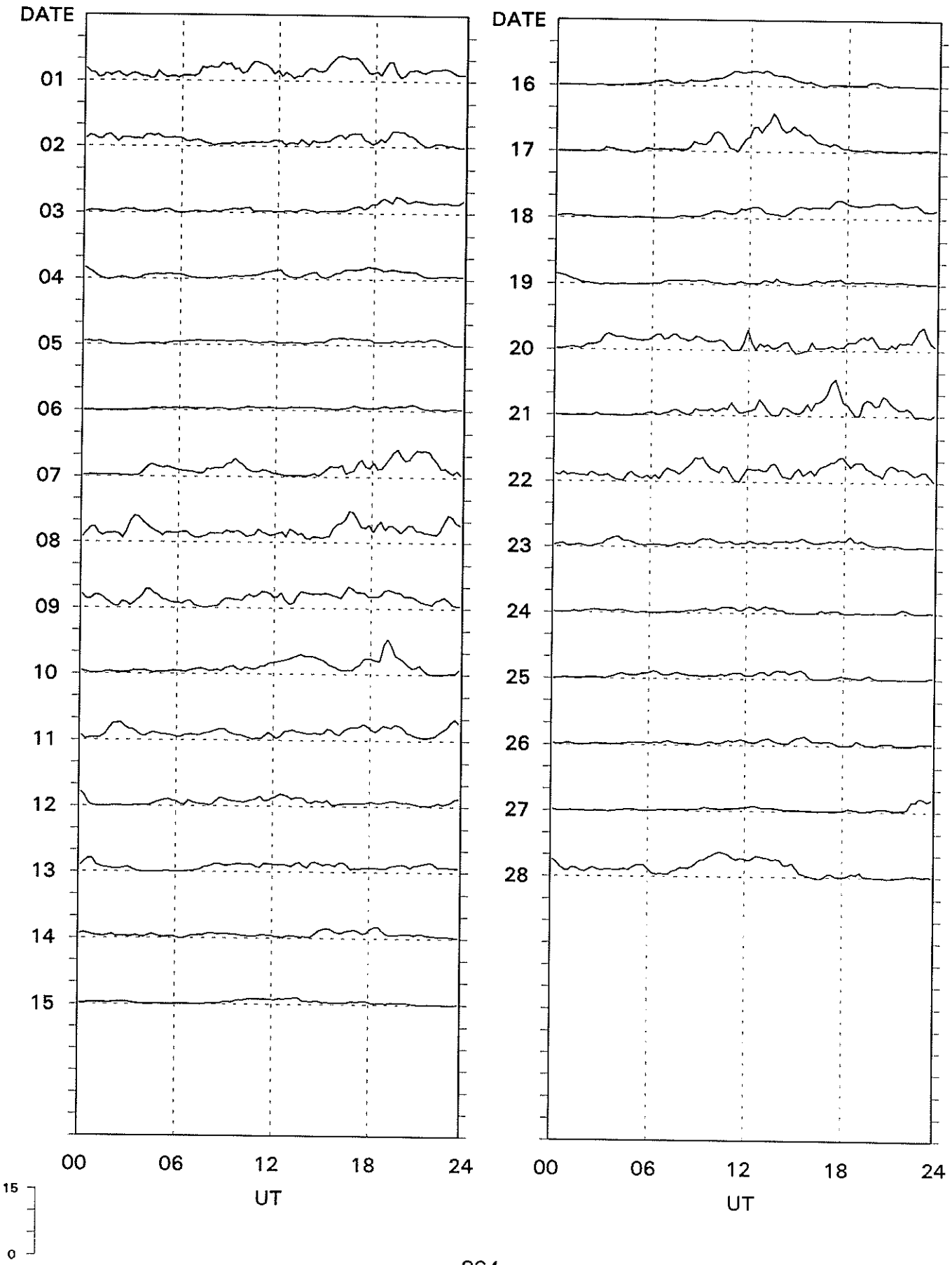

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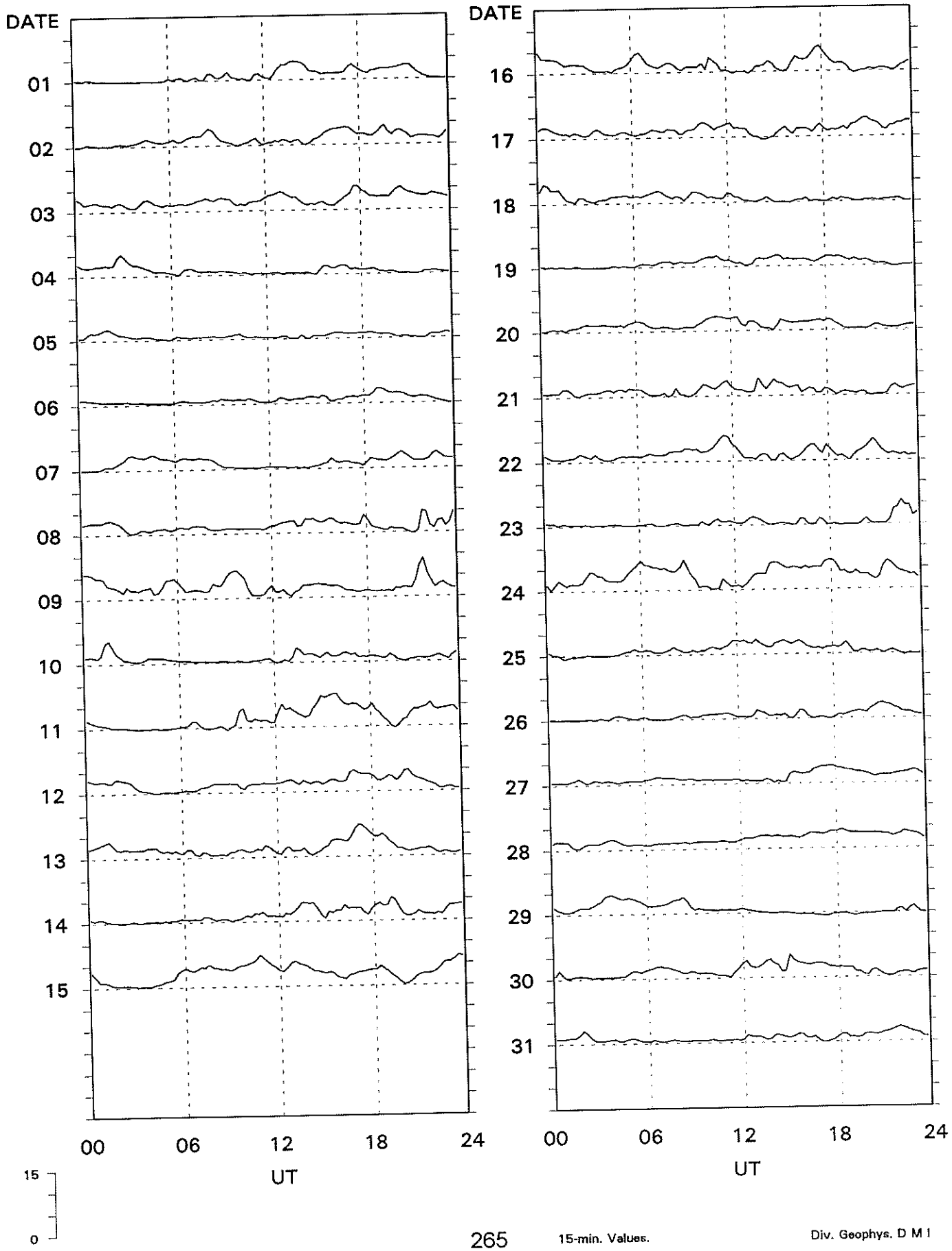

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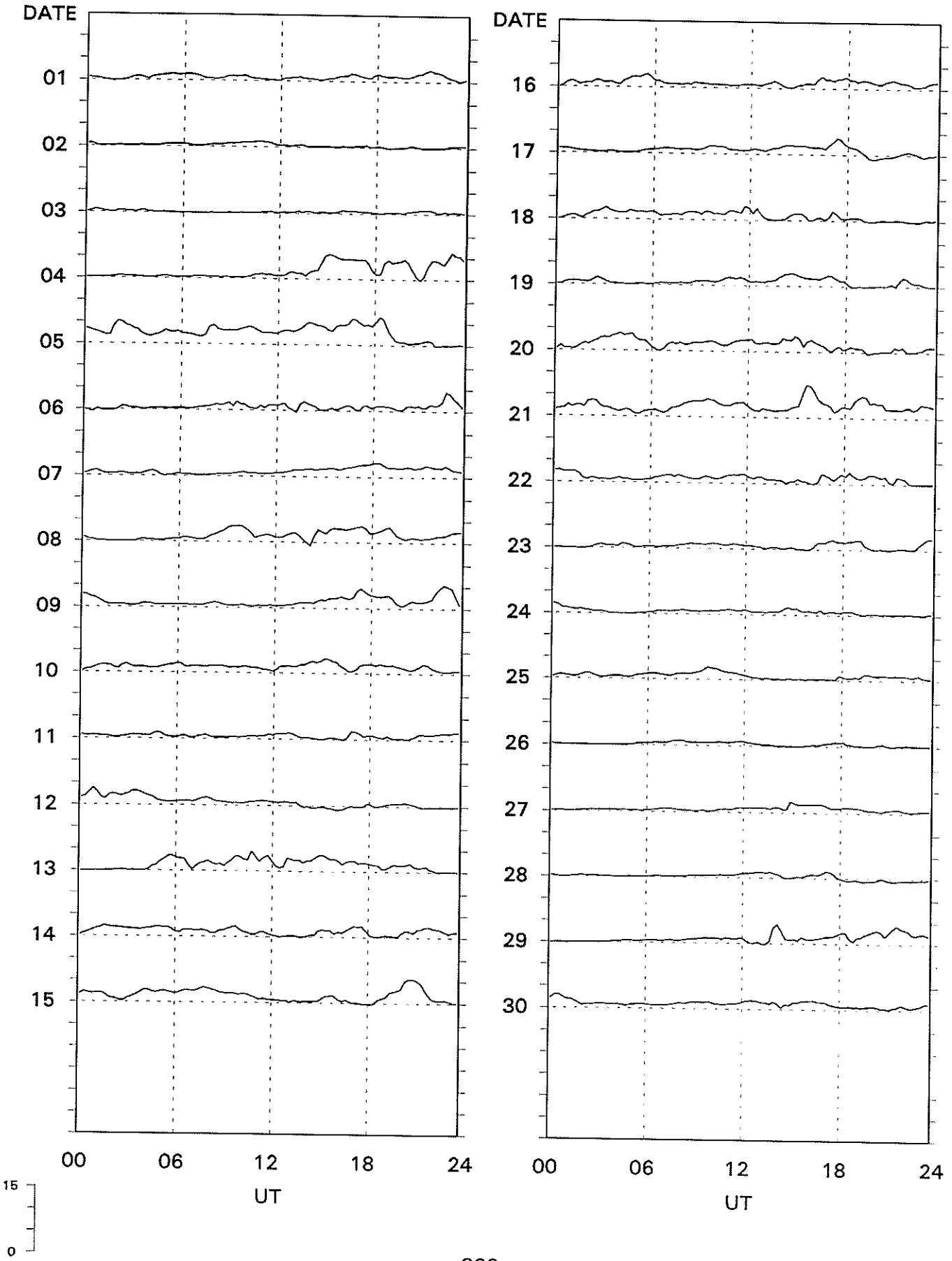

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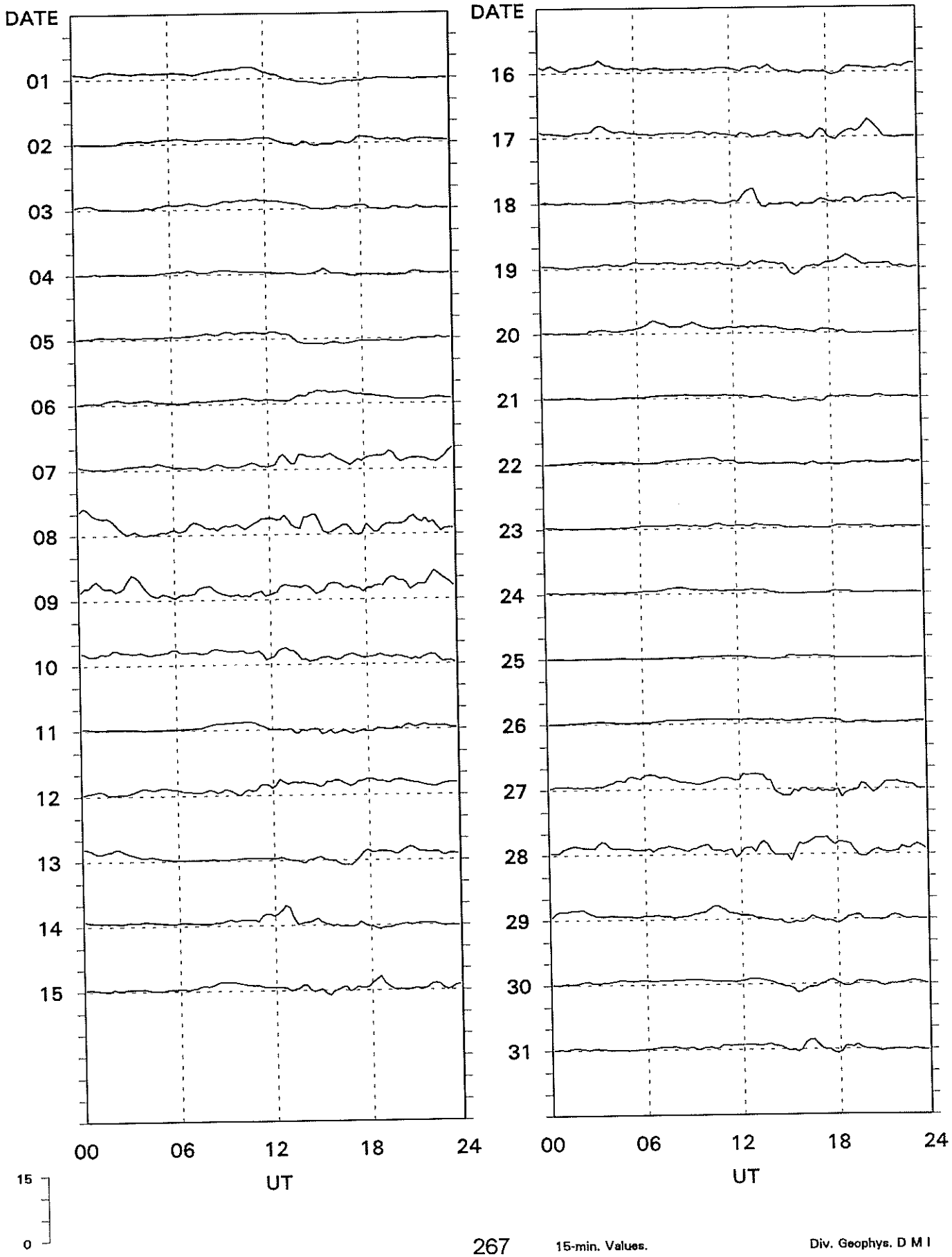

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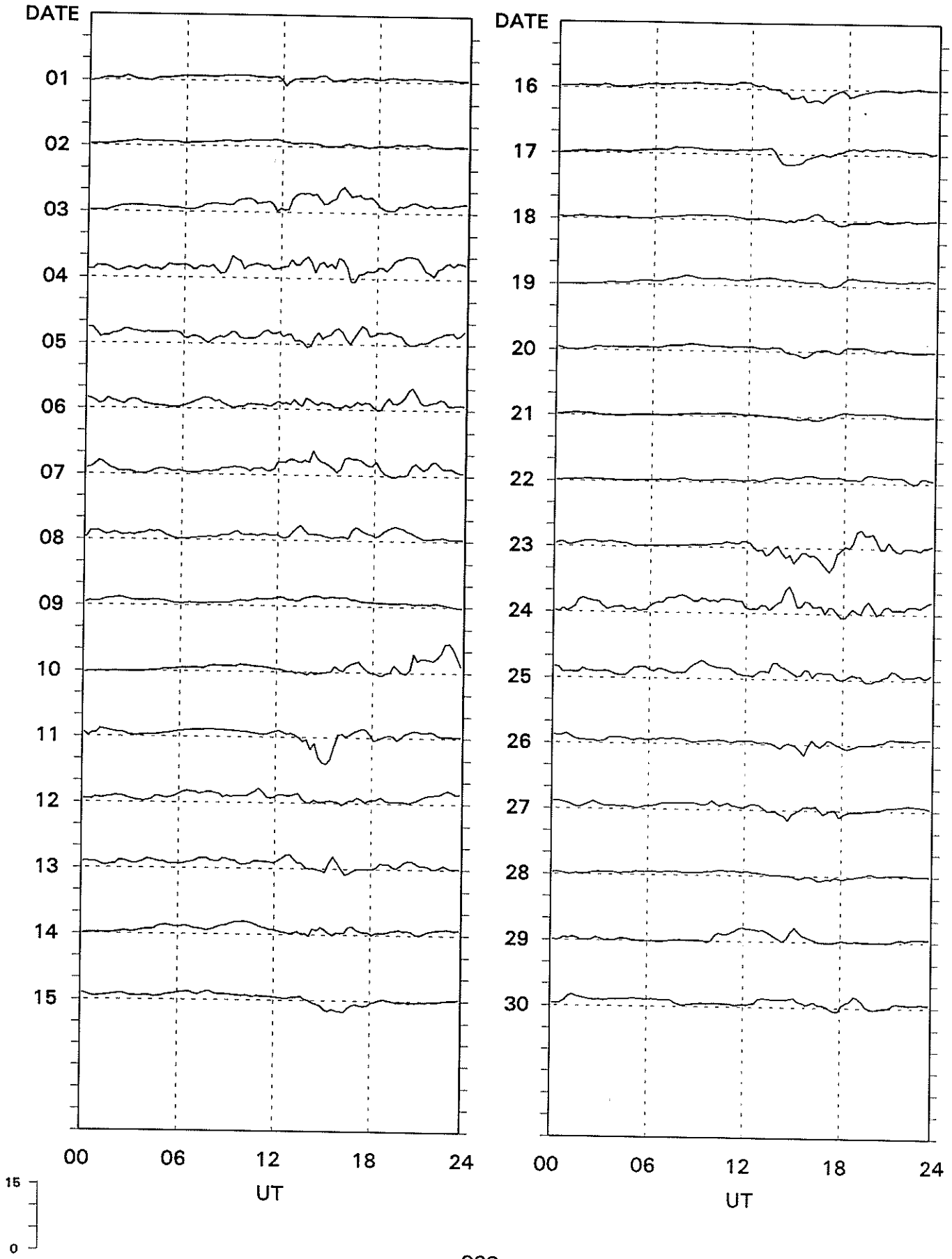

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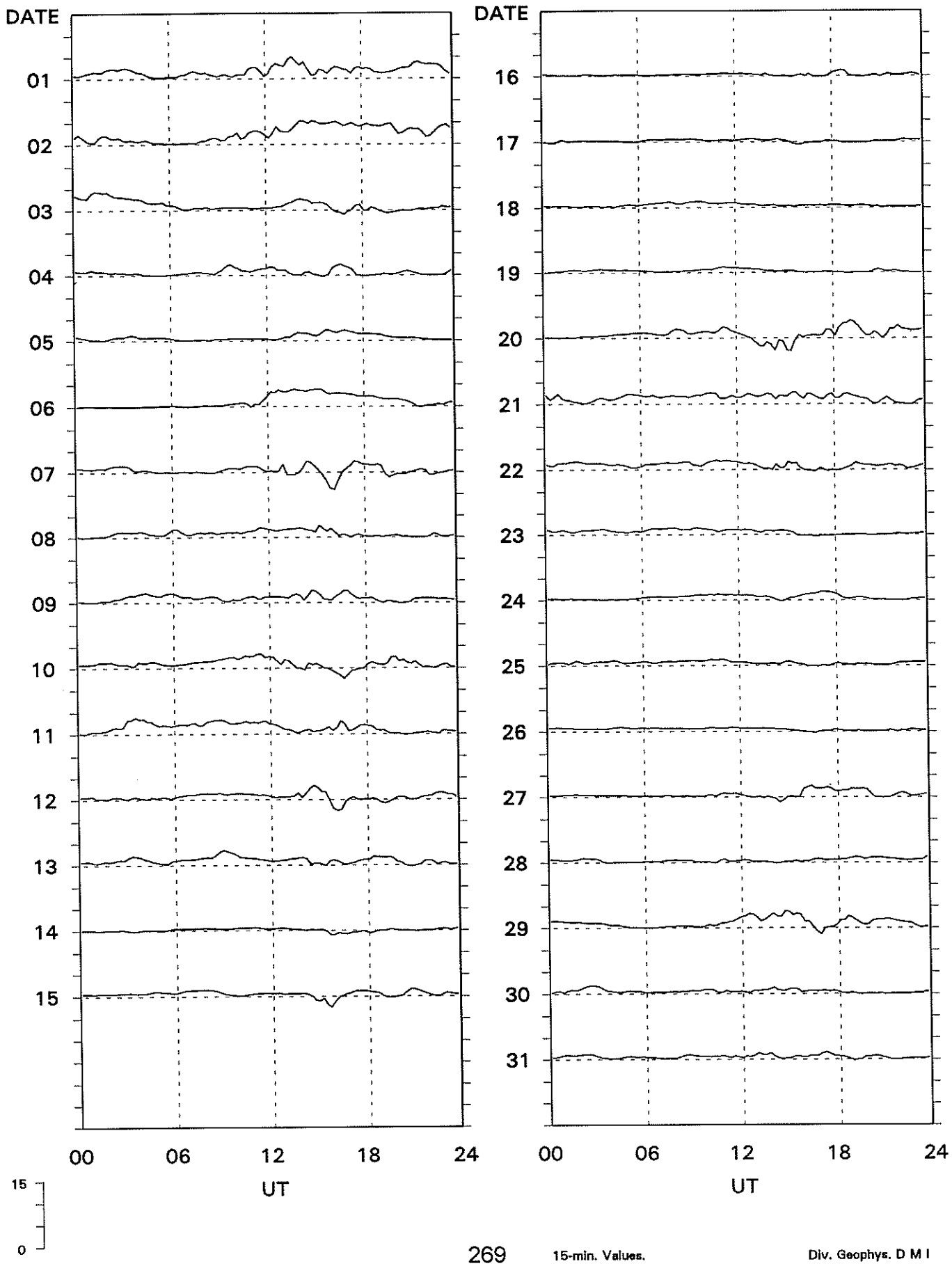

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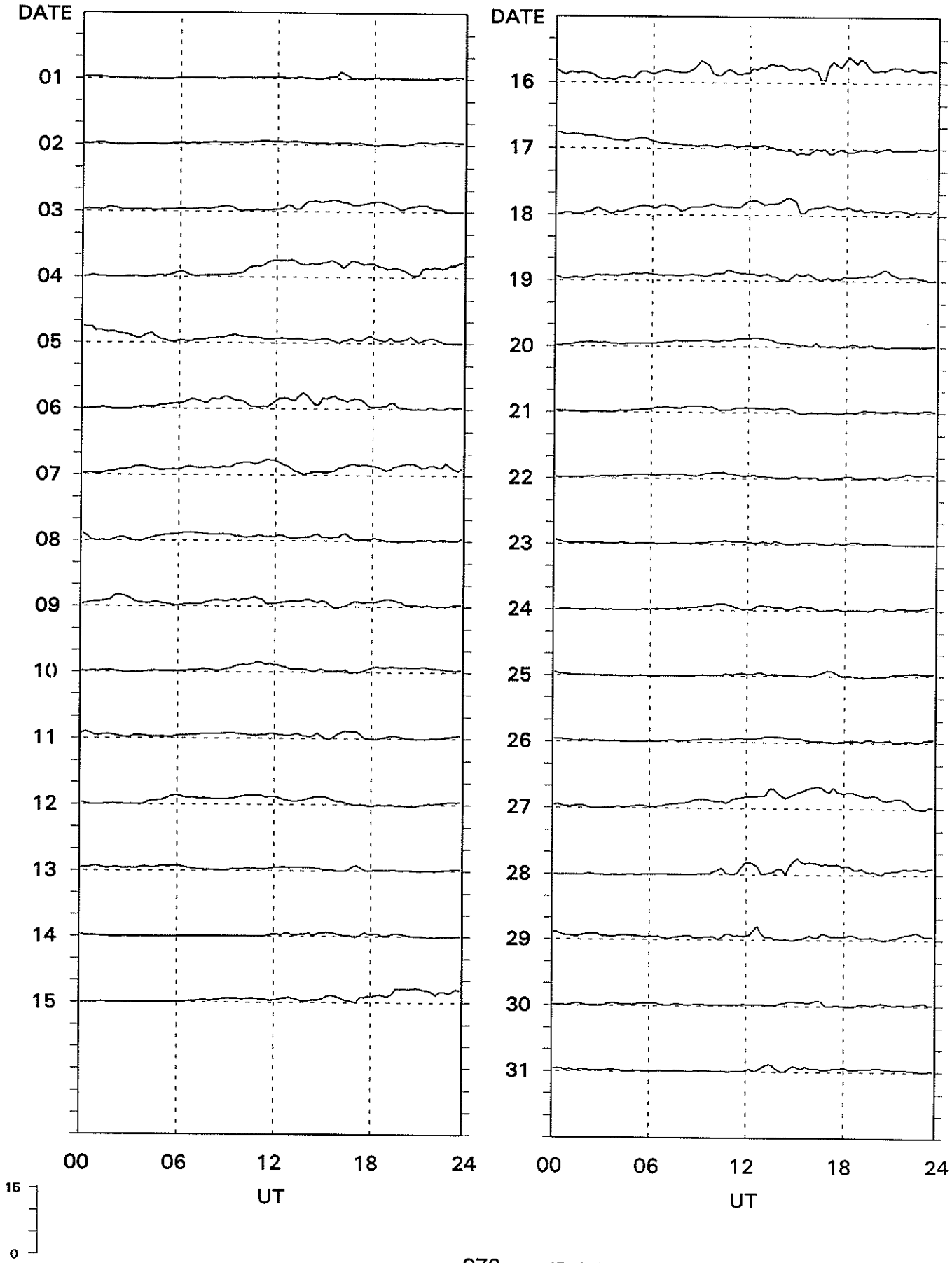

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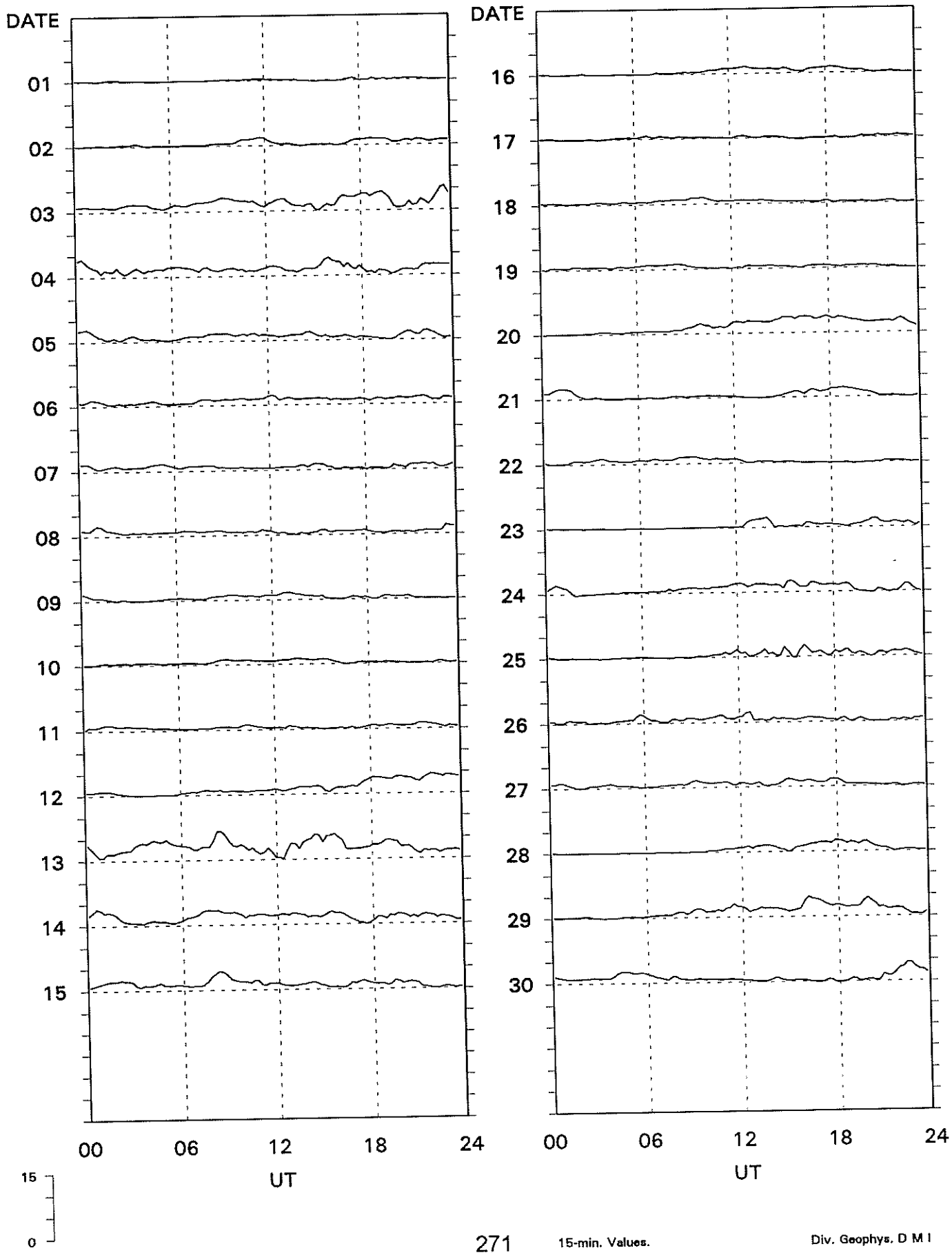

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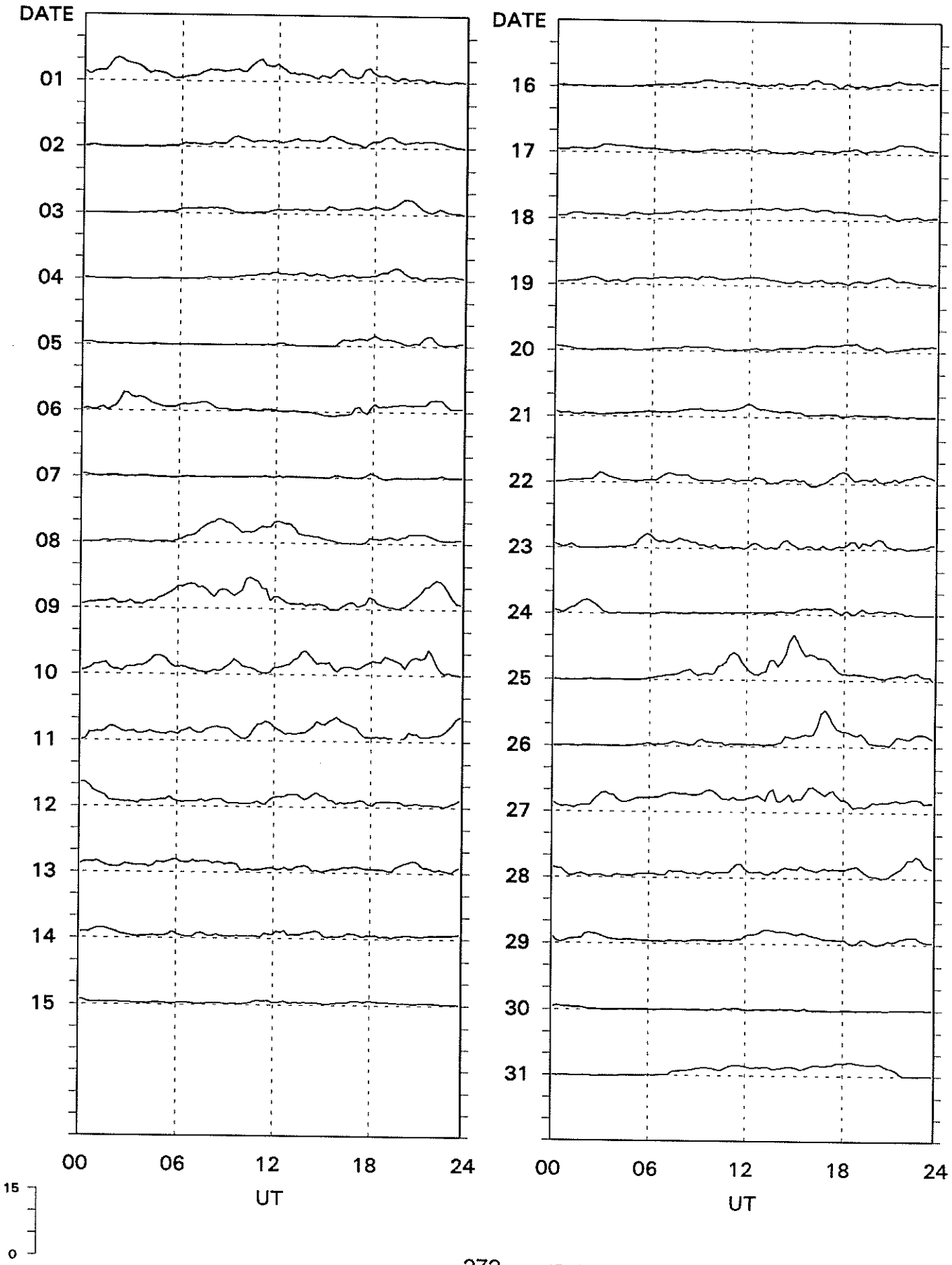

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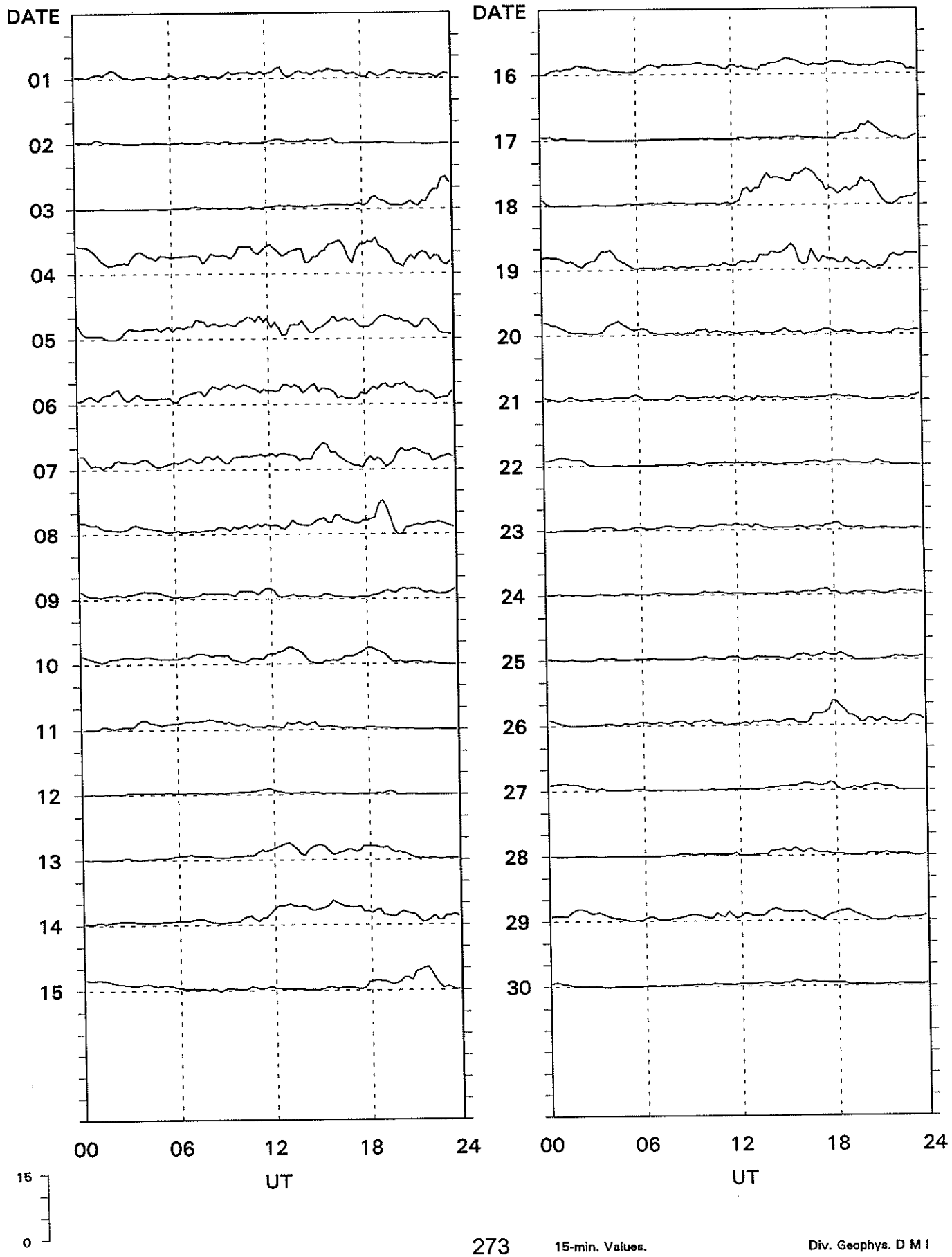

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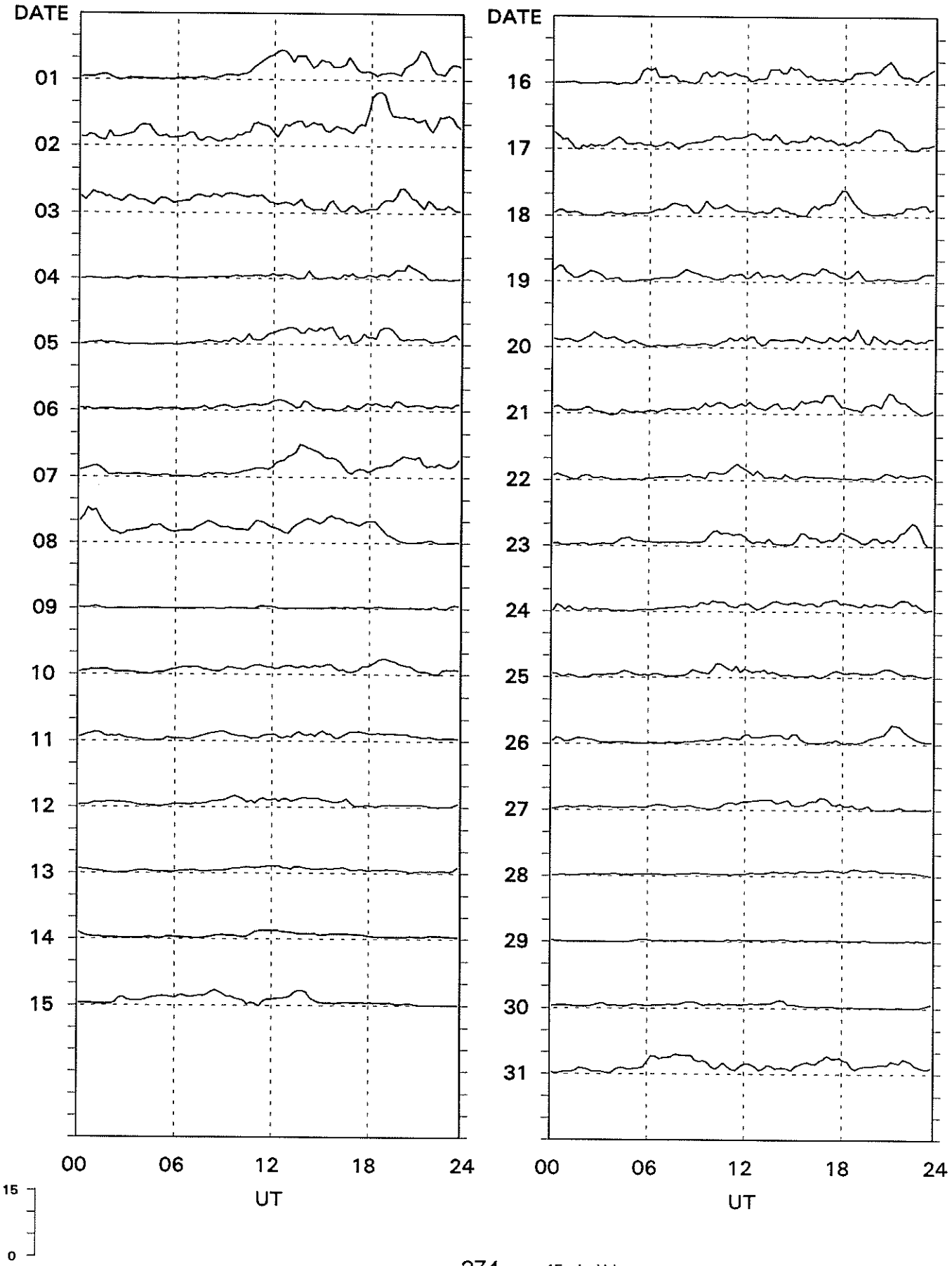

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