Indications for a Diurnal and Annual Variation in the Anisotropy of Diffusion Patterns — A Reanalysis of Data Presented by J. Dai (2014, Nat. Sci.)

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Anisotropic diffusion patterns of a toluidine blue colloid solution in water were recently reported by J. Dai (*Nat. Sci.*, 2014, v. 6 (2), 54–58). According to Dai's observations the fluctuation of anisotropy showed a diurnal and annual periodicity. Since these observations were only qualitatively described in the original manuscript, the data was reassessed by performing a detailed statistical analysis. The analysis revealed that indeed (i) the diffusion patterns exhibit a non-random characteristic (i.e. the maximum diffusion trend is not uniformly distributed), and (ii) a diurnal as well as an annual oscillation could be extracted and modeled with a sinusoidal function. In conclusion, the present analysis supports Dai's findings about anisotropy in diffusion of colloids in water with a daily and annual periodicity. Possible explanations of the observed effect are discussed and suggestions for further experiments are given.

1 Introduction

Recently, J. Dai published an interesting observation [1]: the diffusion of a toluidine blue colloid solution in water measured over a 3-year time span showed anisotropic patterns, i.e. a preferred direction of diffusion (quantified by the maximum diffusion trend (MDT)) could be detected. Additionally, the MDT values showed non-random fluctuations with daily (diurnal) and yearly (annual) periods.

In the manuscript published by Dai the observed diurnal and annual variability was only qualitatively described and lacks a statistical analysis of the obtained data. This fact motivated the author of the present paper to reassess the data by performing a detailed statistical analysis. Thus, the aim of the present paper was to reanalyze the interesting experimental results reported by Dai using statistical methods.

2 Materials and methods

As reported by Dai [1] the experimental setup and the procedure was following: a circular plastic disc, covered in a container, was filled with deionized water, and 10 μl of a 0.5% Toluidine blue ($C_{15}H_{16}ClN_3S$) solution was dropped in the center of the disc filled with water. Under constant illumination and temperature, the developing diffusion pattern was then photographed at different times (t = 30 s, 630 s, 1230 s, 1830 s and 2430 s; i.e. every 10 minutes for 40 minutes after initially waiting 30 seconds). The MDT with respect to the local north-south direction of the geomagnetic field (0° = 360° = east, clockwise scaling) was determined according to the diffusion trend at t = 1830 s. According to Dai, the diffusion experiment was performed on 15 days between December 22, 2011 and March 23, 2013. On each day, the experiment was repeated each hour over the whole day (i.e. 24 experiments/day).

For the subsequent analysis, the raw data were extracted from Figure 3 of [1]. The analysis aimed to address two specific questions: (i) Do the measured MDT values follow a uniform distribution (indicating that the underlying process is purely random)? To evaluate this, the values for each day were tested using the Chi-square test to determine whether they obey a uniform distribution. The significance level was set to $\alpha = 0.05$. (ii) Is there a diurnal and annual oscillation present in the data? This was analyzed using two approaches. First, a sinusoidal function of the form $f(\text{MDT}) = a_0 + a_1 \cos(\text{MDT}\omega)$ (with the free parameters a_0, a_1 and ω) was fitted to the daily and the seasonally grouped data using the Trust-Region-Reflective Least Squares Algorithm. The grouping of the data according to the seasons was performed as in Dai (i.e. Table 1 of [1]). Second, it was tested whether the distributions of the MDT values differ for the four seasons. Therefore a nonparametric test (Wilcoxon rank-sum test) was employed. Due to the multiple comparison situations, a False Discovery Rate correction to the obtained p-values was applied. The data analysis was performed in Matlab (version 2008b, The MathWorks, Natick, Massachusetts).

3 Results

Figure 1(a) shows the raw (hourly) MDT data as obtained from Figure 3 of [1]. In Figure 2(b), the median values and the respective median absolute deviations of daily intervals are plotted. The data grouped according to the seasons are depicted in Figure 2(c), and Figure 2(d) shows the block average for the daily values.

The analysis about the randomness in the data revealed that neither the daily nor the seasonally grouped MDT values follow a uniform distribution ($p < 0.05$). The seasonally grouped data showed a significant trend: the MDT values in spring were higher compared to summer ($p < 0.0001$), autumn ($p < 0.0001$) and winter ($p = 0.0131$) whereas no statistically significant difference could be detected between the distribution of the MDT values for the combinations summer vs. autumn ($p = 0.7269$), summer vs. winter ($p = 0.8509$)

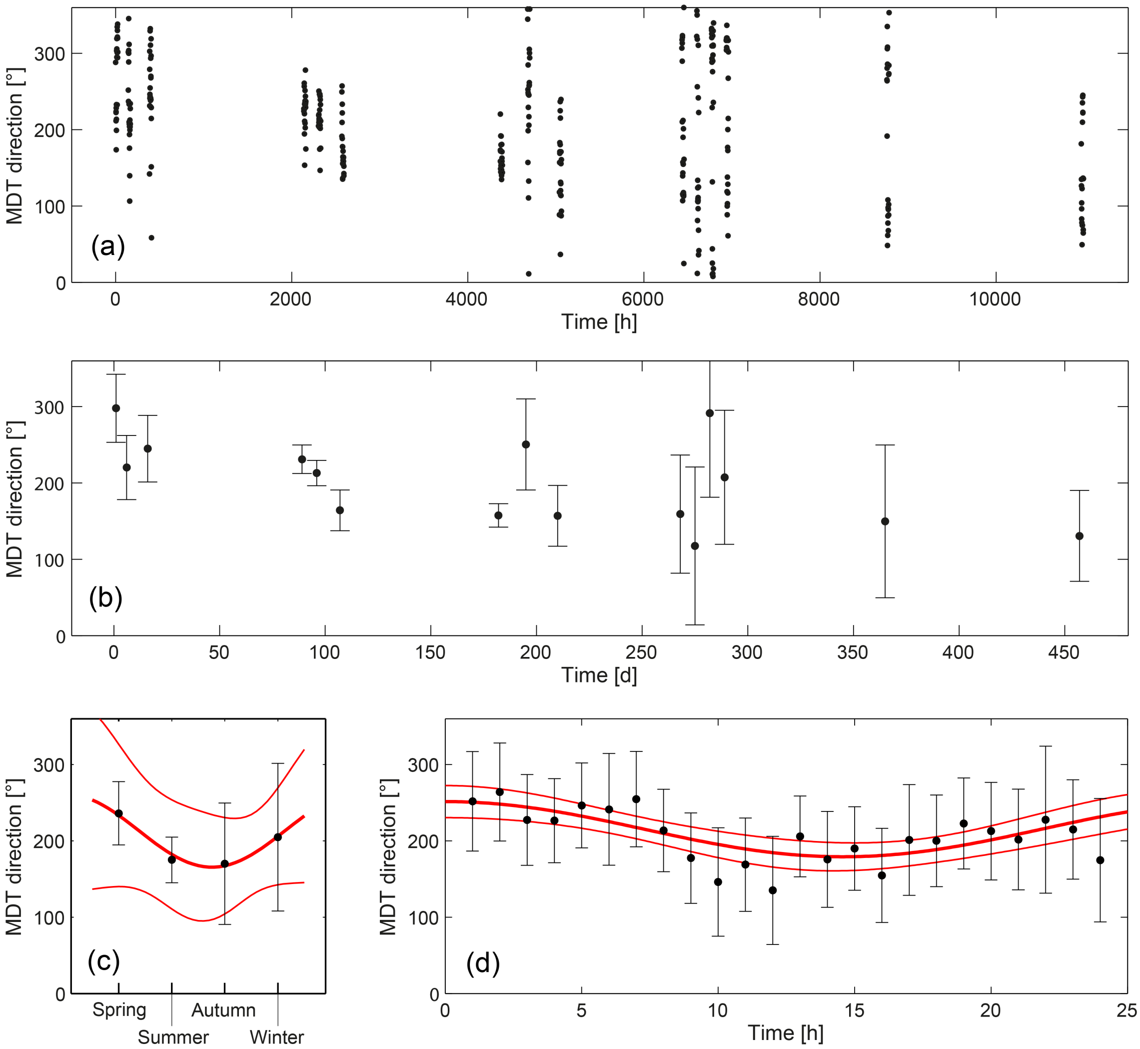

Fig. 1: (a) Raw data as given in Table 1 and Figure 1 of Dai [1]. (b) Daily averaged MDT values (median ± median absolute deviation). (c) Averages MDT values according to the seasons with fitted sinusoidal function (bold red line) and error bounds (95%, thin red lines). (d) Block average of daily MDT values with fitted sinusoidal function (bold red line) and error bounds (95%, thin red lines).

and autumn vs. winter ($p = 0.8902$). Fitting a sinusoidal function to the daily and seasonally grouped MDT data resulted in a good correlation quantified by the squared Pearson correlation coefficient (r^2) and root-mean-square error (RMSE): (i) seasonally grouped data: $r^2 = 0.9821$, RMSE = 50.25, and (ii) daily grouped data: $r^2 = 0.4885$, RMSE = 26.21. The fit with a linear function showed lower r^2 values (seasonally grouped data: $r^2 = 0.1735$, RMSE = 33.96, daily grouped data: $r^2 = 0.1579$, RMSE = 32.86).

4 Discussion

Based on the analysis performed the following two conclusion can be drawn:

(i) The measured MDT values obtained by Dai do not follow a random uniform distribution, i.e. there is a statistically significant ($p < 0.05$) trend in the direction of diffusion.

(ii) The MDT value fluctuations are not random either, i.e. a diurnal and annual oscillation explains the variability better than a linear fit.

Both conclusions are in agreement with the conclusion drawn by Dai in the original paper [1]. In order to establish the causes behind these observations, three possibilities should be considered:

Systematic errors. Changes in environmental parameters (e.g. temperature, humidity, pressure and illumination), electrostatic effects and surface irregularities of the experimental setup could have an effect on diffusion processes observed. However, even though such effects could explain the first finding (i.e. non-randomness of the MDT data) the second finding (i.e. diurnal and seasonal periods in the MDT data) is hard to explain since such systemic influences must then create gradients in the diffusion process with diurnal and annual variability. In a temperature-controlled room with constant illumination and with a setup operating on a flat surface (as was the case according to Dai [1]) the formation of such periodic changes of spatial gradients is quite unlikely.

Classical geophysical and astrophysical effects. Particles of a medium in a rotating system experience a deviation of the isotropic distribution due to the centrifugal and Coriolis force [2]. Whereas the centrifugal force causes a radially outward drift of the particles, the Coriolis force induces a force perpendicular to the particle's direction of motion. Considering the earth's rotation and it's revolution around the sun, a net force can be calculated that represents a "helical force field over the earth" [3]. As discussed by He et al. [3–6] this force has a diurnal and annual variability. Another possible factor contributing to the anisotropic diffusion may be the anisotropy in arrival direction of cosmic rays. The anisotropy of cosmic rays is well documented [7–11], but it is difficult to explain how cosmic rays would cause the changes in MDT since the transported momentum of cosmic rays is very small (e.g. for a muon with a mass of $1883531475 \times 10^{-28}$ kg and travelling with light speed, a momentum in the order of 10^{-11} Ns results).

Other effects. A third option in explaining the experimental results of Dai is to consider them caused by (i) the "anisotropy of space" (as experimentally investigated over decades by Shnoll et al. [12–17]), interaction with (ii) the (quantum) vacuum (which, according to experimental findings of Graham and Lahoz, can be regarded as "something in motion" [18]), (iii) a "cosmological vector potential" [19], or (iv) a fundamental medium [20–31], also regarded as a "complex tension field" [32]. In this context, a relation of the observed anisotropic diffusion to the Saganc effect [33–36] should be considered too. Dai himself considers the observed effect caused by a global astrophysical force or entity (termed "universal field") [1, 37]. In addition, the anisotropic diffusion effect could be related to the signal (with an annual oscillation) detected by the DAMA/LIBRA/NaI experiments designed to detect dark matter [38–40], or the observation of direction-dependent temporal fluctuations in radiation from radon in air at confined conditions [41–43]. Finally, the effect could be related to the observation of an annual fluctuation in radioactive decay which was reported by several groups so far (e.g. [44–47]).

The most similar experiment to the present one was conducted by Kaminsky & Shnoll [12] who analyzed the dynamical behavior of fluctuations of the velocity of Brownian motion. Therefore, the motion fluctuations of two aqueous suspensions of 450-nm polystyrene microspheres were measured by dynamic light scattering. By analyzing the dynamical characteristics of the fluctuations with the histogram analysis method developed by the research group of Shnoll, it was discovered that the "shapes of the histograms in the independent Brownian generators vary synchronously". In a further analysis it could be shown that the direction of the experimental setup with respect to the cardinal directions has an influence on the results: the shape of the histograms were most similar when the recorded time series were not shifted to each other (in case of the alignment to the north-south direction), or shifted with $\Delta t = 11.6$ ms (in case of the alignment to the west-east direction). This clearly indicates that there is an anisotropy of the observed effect. One could speculate that the source of this anisotropy and the source of the anisotropy of diffusion as described in the present paper are similar, or even identical.

5 Conclusion

In conclusion, the re-analysis of the data obtained by Dai [1] revealed that measured MDT values (i) do not follow a random uniform distribution, and (ii) exhibit two fluctuations with a daily and annual period, respectively. For further research, the diffusion experiments need to be repeated and the experimental setup optimized. Examples of optimization include improved shielding the experimental setups against environmental influences and the simultaneous measurement of environmental parameters (e.g. temperature, humidity, pressure, illumination, acceleration of the setup in all three directions of space, fluctuations of the geomagnetic field, etc.). Performing the same experiment simultaneously at different geographical positions could also put forward new indications about the origin of the effect. Also repeating the experiments with different kinds of shielding could offer new insights.

Acknowledgement

I thank Prof. Jiapei Dai (Wuhan Institute for Neuroscience and Neuroengineering, South-Central University of Nationalities, Wuhan, China) for discussions and manuscript reviews, and Rachel Scholkmann for proofreading of the manuscript.

Submitted on August 23, 2014 / Accepted on September 1, 2014

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