Universal Thesis of Meanders

Takeo R.M. Nakagawa

Academy of Hakusan, 2-14, Meiko, Hakusan 920-2152 Japan

npo.hakusan@kjc.biglobe.ne.jp

Abstract

Proposed is universal thesis of meanders: In any flow, the main thread of flow that is locus of the fastest fluid particle in each the cross-section, governs the whole meandering of flow. The main thread of flow plays the critical role in meanders of flow in such a way that if there is any disturbance the main thread of flow as well as the flow itself meanders under the condition that the system of the surrounding fluid particles including boundaries is unstable. Balance between the disturbing force and the restoring force maintains the meandering of flow.

Keywords：Meanders, Main Thread of Flow, Coriolis Effect, Ocean Current, Photon

Introduction

Nothing is more fascinating phenomenon than meandering river repeating a regular pattern, which is one of the most active agents in shaping surface of the earth. Flying over Ukraine in East Europe, Alberta in North America or Victoria in Australia, one may enjoy fantastic panoramic view of uncountable number of rivers engraving delicate sinuous lines on the surface (Figure 1). The basic feature of a river(or rivers) depends on the premise of the study, and meandering cannot be treated as the basic universal feature, as some rivers in steep terrains and very short length rivers could be devoid of meanders apparently.

Figure 1 Aerial view of river meanders on alluvial plain on April 7, 1991, Hobart, Tasmania, Australia.

Figure 1 shows an example of river meanders on alluvial plain, where flow is from right to left. It may be interesting to point out that not only the main river but also several tributaries meander. In the present study, it is crucial to note the fact that the 'thalweg', which is the engraved locus of the river bed and banks, and is considered to be the same as the plane projection of the locus of the fastest water particle in each the cross-section of flow, never coincides with the locus of the river or the banks (Locus of the fastest fluid particle in each the cross-section of flow is referred as 'main thread of flow' hereafter).

Meanders are not a particular phenomenon associated with rivers on the alluvial plain; under certain appropriate conditions, any flow tends to meander when it flows on the surface such as sediment (Schumm 1963, Parker 1976), ice (Knighton 1972, Parker 1975), rock (Shephered & Schumm 1974), or smooth plate (Tanner 1960, Gorycki 1973, Nakagawa & Scott 1984). It is also reported that ocean currents mender (Stommel 1954). It is, therefore, natural to suppose that any flow of particles such as molecules, photons, electrons, or quanta would meander.

Various researchers have identified several mechanisms as the cause of meanders. These include velocity fluctuations in the flow(Adachi 1967, Engelund & Skovgaard 1973), local disturbances (Penck 1894), excessive energy in stream (Jefferson 1902), the Coriolis effect (Eakin 1911, Einstein, A. 1926), forced oscillation (Werner 1951, Anderson 1967), differential heating (Parker 1975), phase difference between sediment movement and stream (Hansen 1967, Callander 1969), spiral flow (Fujiyoshi 1949, Einstein, H. A. & Shen 1964), sediment transport and stream friction (Parker 1976), sand waves(Reynolds 1965), or transverse shear stress distribution(Nakagawa 1983). It has been reported that all of these causes initiate each the flow to meander, but no unified cause of meanders is identified so far. It may be interesting to note that Parker (1975, 1976) has proposed two different causes, viz., a) differential heating, and b) sediment transport as the causes of meanders. This infers that there must be a common unified cause of meanders for flow of fluid particles. All of the forgoing arguments suggest us that any fluid flow meanders, but no thesis is able to explain why fluid flow meanders in such a way that is consistent with all of the reported experiments in the above together with the other known experiments. Thus, it must be considered that cause and mechanism of meanders have been enigma still as late as today.

The main purpose of the present paper is to elucidate the cause and mechanism of meanders by proposing universal thesis of meanders together with the mathematical modelling.

Universal Thesis of Meanders

Proposed is the thesis, *"In any flow, the main thread of flow that is locus of the fastest fluid particle in each the cross-section, governs the whole meandering of flow. The main thread of flow plays the critical role in meanders of flow in such a way that if there is any disturbance the main thread of flow as well as the flow itself meanders under the condition that the system of the surrounding fluid particles including boundaries is unstable. Balance between the disturbing force and the restoring force maintains the meandering of flow"*. This thesis will be discussed based on the present experiment together with previous experiments in supraglacial melt streams (Parker 1975), on flow over sand bed (Nakagawa 1983), and/or on rivulet over smooth plate (Nakagawa & Scott 1984).

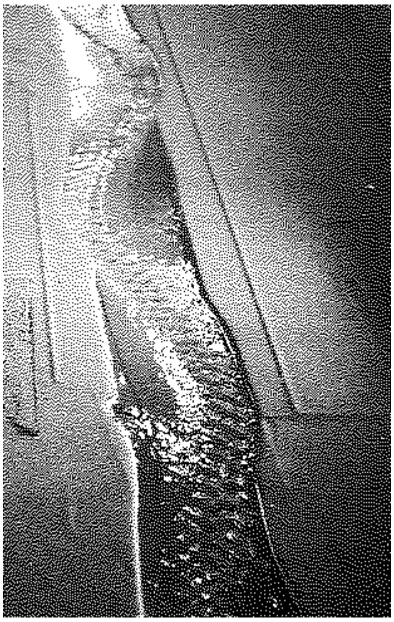

Figure 2 Transverse oscillation of the main thread of flow in a sand flume.

mean flow velocity u=20.2 cm/s, mean water depth d=1.7 cm, slope of initial sand bed=1/100, water discharge=500 cm^3/s, median sand grain size by weight=0.43 mm, Froude number $u/(dg)^{0.5}=0.5$, where g is acceleration due to gravity.

Figures 2 and 3 show a transverse oscillation of the main thread of flow, soon after the water flows into the initial one-dimensional sand channel having reversed trapezoidal cross-section(upper side length=92mm, lower side length=35mm, height=50mm). Note that both of the sand banks are almost on a parallel with each other, but the main thread of flow (visualized with tiny surface waves) itself meanders. It is realized that the amplitude of the main thread of flow increases with time and the bank impingement points moves in the downstream gradually. At this stage, the amplitude exceeds half the channel width, so that the sand bed under the main thread of flow as well as the bank impingement points is selectively eroded and thus delineates its locus. This means that even in a channel having two parallel and straight banks the flow meanders. In another words, meandering of the main thread of flow synchronizes with flow itself, but not with shape of channel or banks. Note that the upstream area with 5m in length and 2m in width is reserved as a still water basin for the one-dimensional sand channel, so that the water is smoothly introduced into it so as not to disturb the flow. This is absolutely necessary procedure in this study, for any oblique flow component with respect to the channel axis might induce the transverse oscillation of the flow. It is of significance to point out that the flow in a straight one-dimensional sand channel initiates transverse oscillation of the main thread of flow if there is any infinitesimal disturbance (or disturbances).

Figure 2 provides critical evidence to the present thesis, where the main thread of flow is visualized by the tiny surface waves and its locus has been identified by the velocity measurements using small propeller flow meter. It has been also reported by Nakagawa (1983) that the bed and banks are eroded along the meandering locus of the main thread of flow.

Fluid particles surrounding the main thread of flow are, therefore, considered as background particles. If there is no disturbance at all in the flow, the main thread of flow would be straight as a special case. However, even an infinitesimal disturbance in the flow may induce a transverse oscillation of the main thread of flow at start. Then, the amplitude of the transverse oscillation will increase with time and the locus of the main thread of flow would evolve into complex three-dimensional form eventually, when the system of surrounding fluid particles and boundaries is unstable. On the contrary, when the system is stable, the main thread of flow will be back to the original locus by the restoring force due to gravity or boundaries. The balance between the disturbing force and the restoring force results in remarkably regular series of sine (or cosine) waves tracing the main thread of flow as shown in Figures 2 and 3. In this study, no perfectly straight locus of the main thread of flow has been observed, but it is always sinuous.

Hence, the proposed thesis is sustained by this experiment together with existing experiments (e.g. Reynolds 1965, Callander 1969, Parker 1975, Nakagawa 1983, Nakagawa & Scott 1984), so it may be worth modelling the main thread of flow mathematically. This thesis naturally suggests such an idea that the main thread of flow is modelled by the Fourier series, consisting of numeral trigonometric functions, as to be presented in the next section.

Figure 3 Transverse oscillation of the main thread of flow in a sand flume at the entrance of initial one-dimensional channel immediately after the water flows into the channel. See Figure 2 for the caption.

Mathematical Modelling of Meanders

As a mathematical modeling, it is heuristically proposed to represent the main thread of flow as a function F(x) by the Fourier expansion, where x is a coordinate along the main thread.

This proposition is based on the experiment (Figures 2 and 3), flow over sand bed (Nakagawa 1983), and rivulet over smooth plate (Nakagawa & Scott 1984), in which the main thread of flow delineates a remarkably regular series of sine (or cosine) waves in the downstream; the main thread of flow is visualized by the tiny surface waves in case of the flow over sand bed, and by dye in case of the rivulet over smooth plate.

Let us assume this process that is repeated every X interval (or wavelength) in coordinate x. Since, by hypothesis, the process repeats itself every X interval, we have

$$F(x+X) = F(x) \quad (1)$$

Let us make the condition that F(x) is single-valued and finite, and has finite number of discontinuities and that of maxima and minima in X interval.

Under these conditions, which are known as Dirichlet conditions, the function F(x) may be represented over a complete wavelength X, and thus from $x=-\infty$ to $+\infty$, except at the discontinuities, by a series of simple harmonic functions, wave numbers of which are integral multiples of the fundamental wave number 2π./X, where the wave number denotes the number of waves that lie in a distance of 2π units.

In Dirichlet's treatment, the sum of n terms of the series is taken, and it is shown that when n becomes infinitely great, the sum approaches to F(x), provided the above conditions are satisfied. At a discontinuity in F(x), the value of the series is the mean of the values of F(x) on both sides of the discontinuity.

The method of determining the coefficients will be given. It is most convenient to start from the complex Fourier series representation for the main thread of flow and write

$$F(x) = \sum_{n=-\infty}^{n=+\infty} a_n e^{in\omega x}, \quad (2)$$

where $\omega = 2\pi/X$ is no more than the fundamental wave number, and n is the wave number in the Fourier series. The complex Fourier series representation (2) for the main thread of flow might be justified by the present and the relevant experiments (Nakagawa 1983, Nakagawa & Scott 1984). Since the left member of (2) is real, the coefficients of the series on the right must be such that no imaginary terms occur. To determine a_0, we integrate both sides over one complete wave length, that is, from 0 to $X=2\pi/\omega$. We thus obtain

$$a_0 = 1/X\int_0^X F(x)dx \quad (3)$$

To determine the other coefficients, we multiply both sides of (2) by $e^{-in\omega x}$ and integrate as before from 0 to $X=2\pi/\omega$. Again all terms on the right are equal to zero because of the periodicity of the imaginary exponentials, except for a_n term, which contains no exponential factor. We then have

$$a_n = 1/X\int_0^X F(x)\, e^{-in\omega x}dx \quad (4)$$

Eq. (4) gives the coefficient of the general term in the expression (2). The coefficient a_0 is a special case of (4). We have also from (4) the relation, by replacing n with $-n$

$$a_{-n} = 1/X\int_0^X F(x)\, e^{in\omega x}dx \quad (5)$$

Eq. (2) may be re-written in the following manner

$F(x) = a_0 + \sum_{n=1}^{n=\infty}(a_n e^{in\omega x} + a_{-n} e^{-in\omega x})$ (6)

By using Euler's relation, this may be written in the form

$F(x) = a_0 + \sum_{n=1}^{n=\infty}(a_n + a_{-n}) \cos n\omega x + \sum_{n=1}^{n=\infty} i\ (a_n - a_{-n}) \sin n\omega x$ (7)

If we now let

$A_n = a_n + a_{-n}$, $B_n = i\ (a_n - a_{-n})$, $A_0/2 = a_0$ (8)

We obtain from (7) and (8)

$F(x) = A_0/2 + \sum_{n=1}^{n=\infty}(A_n \cos n\omega x) + \sum_{n=1}^{n=\infty}(B_n \sin n\omega x)$ (9)

By using (4), (5) and (8), we obtain the coefficients A_n and B_n directly in terms of F(x). That is

$A_n = 2/X\int_0^X F(x) \cos n\omega x\, dx$ (10)

We also have

$B_n = 2/X\int_0^X F(x) sinn\omega dx$ (11)

The $A_0/2$ term is introduced in (9), so that (10) giving the general tem A_n will be applicable for A_0 as well. That is, in either the complex or the real form of Fourier series, the constant term is always equal to the mean value of the function.

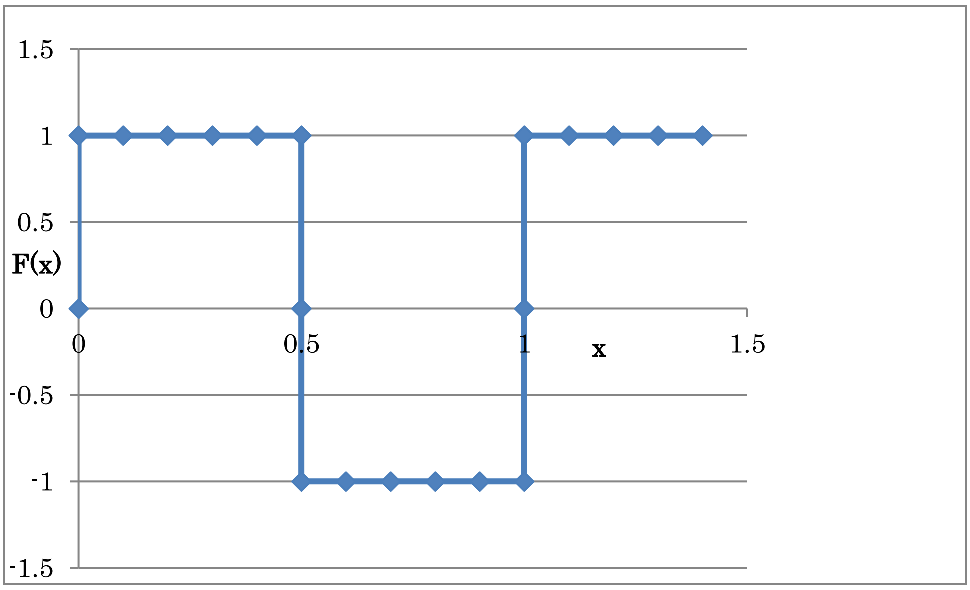

Figure 4 Function F(x) representing a disturbance against the coordinate x.

As a simple but illustrative case, let us obtain the Fourier expansion of the initial wave function as depicted in Figure 4, representing the main thread of flow of the particles moving along the locus F(x)= 1 for $0 \leq x < 0.5$, while these particles move along the locus $F(x)= -1$ for $0.5 \leq x < 1$, where the wavelength X=1. This function is assumed to continue in the same fashion in both directions of the co-ordinate x, where the origin of the coordinate is arbitrarily chosen. The coefficients of the complex Fourier series are given by (4). We thus have

$$a_n = 1/X\,\{\int_0^{\frac{X}{2}}(e^{-in\omega x})dx - \int_{\frac{X}{2}}^{X}(e^{-in\omega x})dx\}=1/(in\pi)\,(1 - \cos n\pi + i\sin n\pi)$$

This gives us

$a_n = 0$ (n=0, or n is even) (12)

or

$a_n = 2/(in\pi)$ (n is odd) (13)

The complex Fourier series expansion of this function (2) is therefore

F(x)=0 (n=0, or n is even) (14)

or

$F(x)=2/(i\pi)\sum_{n=-\infty}^{n=+\infty}(e^{in\omega x}/n)$ (n is odd) (15)

The coefficients of the real Fourier series are given by (10) and (11). Since if n=0 or n is even, all of these coefficients are zero, so that the real Fourier series expansion of this function is given by

F(x) =0 (n=0 , or n is even). (16)

Now we will consider the case when n is odd. Using (4) and (5), we have from (8)

$A_n=0$, $B_n=4/(n\pi)$ (17)

Hence, using (9), the real Fourier series expansion of this function is represented by

$F(x) =4/\pi \sum_{n=1}^{n=\infty}(\sin n\omega x/n)$ (n is odd) (18)

Eqs. (16) and (18) are examples of the present mathematical model for the main thread of flow of particles. It is clear that if there is no disturbance, always the function F(x) =0. On one hand, if there is a disturbance, or wave function as depicted in Figure 4, the main thread of flow is expressed by (18), which consists of infinite sine waves. Physically, this denotes two important facts; firstly, the main thread of flow meanders if there is any disturbance. Secondly, the main thread of flow is represented as a superposition of infinite trigonometric waves.

Discussion

It may be interesting to discuss the reported causes of meanders. They are velocity fluctuations in the flow(Adachi 1967, Engelund & Skovgaard 1973), local disturbance (Penck 1894), excessive energy in stream (Jefferson 1902), the Coriolis effect (Eakin 1911, Einstein, A. 1926), forced oscillation (Werner 1951, Anderson 1967), differential heating (Parker 1975), phase difference between sediment movement and stream (Hansen 1967, Callander 1969), spiral flow (Fujiyoshi 1949, Einstein, H. A. & Shen 1964), sediment transport and stream friction (Parker 1976), sand waves(Reynolds 1965), or transverse shear stress distribution (Nakagawa 1983). It is impossible to exaggerate the importance to point out that all of these causes play a common role of inducing disturbances to the main thread of flow of particles through the background particles.

Meandering flows on alluvial sediment (Shumm 1963, Parker 1976, Nakagawa 1983), ice (Knighton 1972, Parker 1975), rock (Shephered & Schumm 1974), smooth plate (Tanner 1960, Gorycki 1973, Nakagawa & Scott 1984), and in ocean current (Stommel 1954, Appendix 1) are not enigmatic any more, for in all of these flows infinitesimal disturbances existing normally in nature deviate the locus of the main thread of flow to a different direction from the original one. Depending on the background particles and the boundary conditions, the locus of the main thread of flow increases or decreases the deviation, and eventually the balance between the disturbing force and the restoring force will determine the shape of the locus of the main thread of flow.

In the present thesis, it may be evident that there is no limitation to the scale and speed of particles in the flow, and it is independent of gravity, so that it must have wide applicability. Among the many (Appendix 2), the first example is the application to light, where the locus of the main thread of flow of photons meanders as an oscillating string: Imagine a case that light passes through a very narrow iron tube with constant diameter (one micron, say). In the tube, owing to the infinitesimal disturbances, the main thread of flow of photons meanders, but the meandering is suppressed by the tube wall together with the surrounding photons. However, with increasing the tube diameter, the main thread of flow could meander more freely, thus its locus is not on a parallel with the axis of the iron tube. The second example is flow in an open and straight channel with constant cross-section: The main thread of flow meanders due to the infinitesimal disturbances, but the meandering is restricted by the wetted boundary. The locus of the main thread of flow is not on a parallel with the boundary. The third example is the Kuroshio (Appendix 1), in which the main thread of flow could meander, for this current flows through open sea water with no solid boundary except for sea bed and/or islands. The fourth example is the Jet Stream, in which the main thread of flow must meander, for it penetrates through open air with no boundary effectively. It may be already evident that there is no question that the main thread of flow of electrons, protons, atoms, quanta, neutrinos, quarks or Higgs particles also meanders, so that the locus of the main thread of each the flow must be like a wavy string (Appendix 2).

Navier-Stokes equation, which is the basic equation for fluid mechanics, is not useful for describing the motion of each the particle in the main thread of flow, for Navier-Stokes equation is no more than the Newton's Second Law applied for an imaginary cube in the fluid, where the averaged motion of fluid particles in and around the cube is mainly concerned with (Schlichting 1968). This is the reason why in this study the kinetic theoretical approach to describe motion of fluid particles has been adopted, rather than recourse to Navier-Stokes equation. According to the kinetic theory, the Liouville equation describes motion of N particles in the flow (Osonphasop & Nakagawa 2014): In principle, it is possible to determine the position and velocity for each the particle, though number of particles involved is normally too many to trace their trajectories. Tsugé(1974) has proposed the kinetic theory of turbulence, which has been successfully applied to boundary layer flow, turbulent combustion, mixing layer flow, grid-produced turbulence or Bénard convection. However, it is much remained, to be done to solve the problem of meanders in terms of Tsugé's kinetic theory of turbulence. For discussion on core values of scientific theses and dark side of science, refer Appendix 3.

Conclusions

New knowledge and insights which have been obtained through the present study are summarized as follows.

1. The proposed thesis, "in any flow, the main thread of flow that is locus of the fastest fluid particle in each the cross-section, governs the whole meandering of flow. If there is any disturbance to deviate the main thread of flow, the flow meanders under the condition that the system of the surrounding fluid particles including boundaries is unstable. Balance between the disturbing force and the restoring force maintains the meandering of flow", has been sustained by the inductive reasoning based on the present and existing experimental evidences.

2. It is found that all of the reported causes of meanders play a single common role of inducing disturbances to deviate the main thread of flow of particles to a different direction from the original one through the surrounding particles. Thus, mechanism of flow meanders on alluvial sediment, ice, rock, smooth plate or in ocean currents is not enigmatic any more.

3. It is heuristically proposed based on inductive reasoning that the main thread of fluid particles can be modelled by the Fourier series as a superposition of trigonometric curves with infinite wave numbers.

4. It is suggested that the proposed thesis is applicable to any flow of particles, such as photons, electrons, protons, molecules, atoms, quanta, neutrinos, quarks, or Higgs particles together with particles in debris flow, and must be independent of gravity. However, it is much remained to be done, to solve these problems, which are left for the future.

Acknowledgements

The author is grateful for anonymous referee's critical comments on the original manuscript, which improve the quality of this paper significantly.

References

1. Adachi, S. (1967) A theory of stability of streams. Proc. 12th Cong. IAHR, Fort Collins, Colorado, vol. 1, 338-44

2. Anderson, A.G.(1967) On the development of stream meanders. Proc. 12th Cong. IAHR, Fort Collins, Colorado, vol. 1, 370-78

3. Callander, R.A. (1969) Instability and river channels. J. Fluid Mech. 36, 465-80

4. Eakin, H.M. (1911) The influence of the Earth's rotation upon lateral erosion of streams. J. Geol. 18, 435-37

5. Einstein, A. (1926) Die Ursache der Mäanderbildung der Fluβläufe und des sogenannten Bärschen Gesetzes. Naturwissenschaften, 11, 223-24

6. Einstein, H.A. & Shen, H.W. (1964) A study on meandering in straight alluvial channel. Geophys. Res. 69, 5239-47

7. Engelund, F. & Skovgaard, O. (1973) On the origin of meandering and braiding in alluvial streams. J. Fluid Mech. 57, 289-302

8. Fujiyoshi, Y. (1949) Kasenno-Dako-to-Saigai, Sakaki Press, Tokyo(in Japanese)

9. Gorycki, M. A. (1973) Hydraulic drag: a meandering initiating mechanism. Bull. Geol. Soc. Am. 84, 175-86

10. Hansen, E. (1967) On the formation of meanders as a stability problem. Basic Res. Prog. Rep. 13, 9-13, Hydraulic Laboratory, Technical University of Demark

11. Jefferson, M. S. W. (1902) Limiting width of meander belts. Natn, Geogr. Mag. 13, 373-84

12. Knighton, A. D. (1972) Meandering habit of supraglacial streams. Bull. Geol. Soc. Am. 83, 201-04

13. Kuhn, T.S. (1962) The structure of Scientific Revolutions. Chicago, University of Chicago Press

14. Ladyman, J. (2002) Understanding philosophy of science. London, Routledge

15. Nakagawa, T. (1983) Boundary effects on stream meandering and river morphology. Sedimentology, 30, 117-27

16. Nakagawa, T. & Scott, J. C. (1984) Stream meanders on a smooth hydrophobic surface. J. Fluid Mech. 149, 89-99

17. Nakagawa, T.R.M.(2019) Introduction to Basho's Haiku. Social Sci. J. 4(to appear)

18. Nishida, H. (1978) An observation of the Kuroshio current using the satellite tracking drifter. Great meanders of the Kuroshio current and the cold-core ring. Report submitted to Ministry of Education, Japan. 81-90

19. Osonphasop, C., Nakagawa, T.R.M. (2014) Novel power law of turbulent spectrum. Open Journal of Fluid Dynamics, 04(02) 140-53

20. Parker, G. (1975) Meandering of supraglacial melt streams. Wat. Resour. Res. 11, 551-52

21. Parker, G. (1976) On the cause and characteristic scales of meandering and braiding in rivers. J. Fluid Mech. 76, 457-80

22. Penck, A. (1894) Morphologie der Erdoberflache. 259-385, Verlag Englhorn, Stuttgart, Germany

23. Reynolds, A. J. (1965) Waves on the erodible bed of an open channel. J. Fluid Mech. 22, 113-33

24. Schlichting, H. (1968) Boundary-Layer Theory (translated by J. Kestin). McGraw-Hill Book Company, New York, 44-64

25. Schumm, S. A. (1963) Sinuosity of alluvial rivers on the Great plains. Bull. Geol. Soc. Am. 74, 1098-100

26. Shepherd, R. & Schumm, S. A. (1974) Experimental study of river incision. Bull. Geol. Soc. Am. 85, 257-68

27. Stommel, H. (1954) Circulation in the North Atlantic Ocean. Nature, 173, 886-88

28. Tsugé, S. (1974) Approach to the origin of turbulence on the basis of two-point kinetic theory. Physics of Fluids, 17, 22-33

29. Tanner, W. F. (1960) Helicoidal flow, a possible cause of meandering. J. Geophy. Res. 65, 993-95

30. Werner, P. W. (1951) On the origin of river meanders. Trans. Am. Geophy. Un. 32, 370-78

Appendix 1 Kuroshio

Meanders of the Kuroshio has been demonstrated using a neutral buoyant drifter tracked by a satellite named 'Nimbus no.6', equipping RAMS (Random Access Measurement System) for communication among the satellite, ground station and drifter (Nishida 1978). The drifter emits an electric wave with the frequency of 401.2 Mega Hz. The satellite goes around the earth every 109 minutes, and receives several signals per day from the drifters, whose positions are determined by the Doppler shift. Each of the drifters emits the data every 64 seconds for one second as an electric wave: Unknown drifter at first sends ID (Identification number) to the satellite, and then 4 words, each of which consists of 28 bit data. Since the scale of the drifter(order of one meter) is much greater than that of water particle, the drifter may not trace the locus of the main thread of the Kuroshio faithfully, thus this information is just for reference when we consider the cause and mechanism of the meanders.

On February 20, 1977, a total of 4 drifters are released into the Kuroshio in such a way that the line connecting their positions crosses the Kuroshio: The positions are located off Toi-peninsula of Kyushu-island, Japan.

Number and position for each the drifter, respectively, are as follows;

no.106 at $30^0$51'N, $131^0$49'E,

no.130 at $30^0$49'N, $131^0$55'E,

no.307 at $30^0$42'N, $132^0$01'E,

no.341 at $30^0$31'N, $132^0$13'E

Figure 5 illustrates the locus of drifter no.106, ranging from south of and off Kyushu-island, Japan to North Pacific Ocean. This shows that the Kuroshio always meanders. Since depth of the water in the North Pacific Ocean is even greater than several thousands in meter, it is unlikely that the bed topography causes and maintains the meandering of the Kuroshio, though islands may influence motion of the current to some extent. It is suggested that the meandering of the Kuroshio is, primarily, caused by the Coriolis force that deviates the main thread of flow to the right with respect to the flow direction in the Northern Hemisphere, and the transverse oscillation is maintained by the balance among the Coriolis force, the centrifugal force, to appear subsequently and the restoring force due to the resulting locally elevated water head and/or islands.

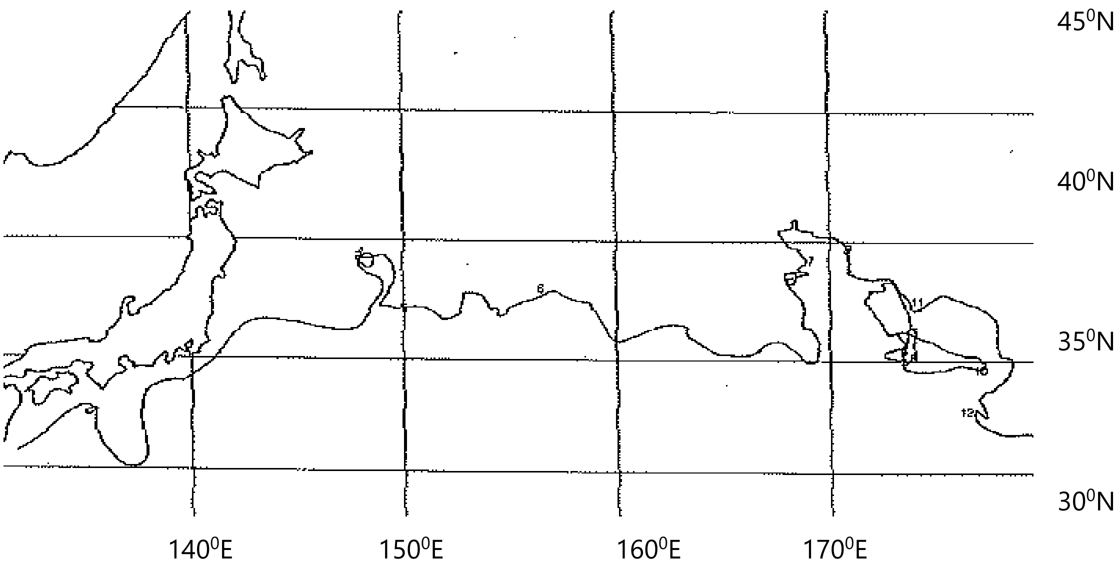

Figure 5 Locus of drifter no.106 (After Nishida 1978)

Appendix 2 Candidates of flow of particles, to be modelled by Fourier Function

There is no question that important goals of scientist working include and extend to account for electrical and magnetic phenomena, light, and the way how the gravitational force acts across space in terms of underlying mechanical processes (Ladyman 2002).

Other examples include: Combustion is consumption by fire, and development of light and heat accompanying oxidation of organic material. Electricity is a form of energy presented in proton and electron, which is energy associated with the movement of charge. Heat is a form of energy arising from the random molecular motion of a substance and capable of transmission by conduction, convection or radiation, which is manner that the energy of a vibrating body is transmitted in all directions by a surrounding medium. Light is a visible form of electromagnetic radiation produced by energy changes within the atoms of a substance, and have dual properties as particle and wave. In relativistic physics, the time elapsed between events is relative to a frame of reference, and in quantum physics, the energy possessed by material objects or electromagnetic waves comes in discrete units, rather than taking a continuous range of values.

The proposed thesis is considered to be applicable to the flow of protons, electrons, molecules, atoms, and quanta together with other particles such as magnetons, photons, neutrinos, Higgs particle, or particles in debris flow. It may be interesting to compare pointillism in physics, which is kinetic theoretical approach to turbulence (Tsugé 1974), and that in Haiku, which is the shortest poem consisting of 17 syllable points (Nakagawa 2019).

Appendix 3 Core values of scientific theses

The core values which are common to all scientific theses may be summarized as follows: A thesis should be empirically accurate, consistent with other accepted theses, wide in scope, as simple as possible, and fruitful for ongoing research (Kuhn 1962).

It is evident that the present proposed thesis fulfills all of the above five core values, and provides the common cause and mechanism of meanders on flow of particles.

It may be worth knowing dark side of science: It is known that, far from being based on the evidence, sometimes scientific progress is even driven by nothing more than mob psychology, and the empirical confirmation of hypotheses is a rhetorical sham. The scientific truths may be determined in whole or in part by social forces.

Scientists are often very much attached to a paradigm, and sometimes particular individuals will do almost anything to retain it in the face of contradictory evidence, including distorting experimental data, using institutional power to stifle dissent, using poor reasoning, or bad arguments to defend the status.

Disreputable behavior and fallacious reasoning seem to be features of all spheres of human life, so it would be pretty surprising if they are never found in science, and clearly an idea that all scientists are saint-like pursuers of the truth is unrealistic. Of course, it is true that the author is a scientist, and not a saint-like pursuer of the truth.

It may be critical to us that changes in scientific theses are partly determined by social and psychological factors, rather than being purely a matter of rational appraisal of the evidence. However, this cannot be the whole story because revolution in scientific thought happens, even if they are very inconvenient for the scientific establishment, so that it is hard to believe that thesis acceptance in science is merely a matter of whim, or prejudice.

The five core values of scientific theses exclude complete irrationalism because they impose some limits on what theses scientists can rationally accept. Non the less, these values are necessary, but not sufficient to determine what decisions they ought to make in most interesting cases, because these values may conflict; a thesis may be simple but not accurate, fruitful but not wide in scope, or wide in scope but not consistent.

Contrary to the traditional view, science is not always cumulative because paradigm shifts involve the abandonment of old theses, rather than the steady accumulation of knowledge. Science is not unified because everything within a sub-branch of science is relative to the dominant paradigm. Science is not value-free because social and psychological factors play unavoidable role in thesis choice and thus there is no sharp distinction between scientific thesis and social belief.