Fluid Mechanics in Typhoon

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Abstract

It is found that the spiral wind velocity profile of Typhoon can be modeled by the exact non-steady solution of the Navier-Stokes equation. Typhoon Hagibis was not just a blustery storm: The areal extent with winds in excess of 15m/s was as large as 1,400 km in diameter and the minimum pressure at the eye was 915 hPa, accompanying significant rainfall and risk of coastal flooding. There are six main requirements for tropical cyclogenesis, viz. 1. Sufficiently warm sea surface temperature above 26.5℃, 2. Atmospheric instability, 3. High humidity in the lower to middle levels of troposphere, 4. Enough Coriolis force to develop a low pressure center, 5. Pre-existing low pressure focus or seed, and 6. Low vertical wind shear smaller than 10m/s. It is realized that there are always regions, called anticyclones of high pressure, which are tightly connected with the Typhoon. In fact, the flow is usually circulating from the Typhoon to anticyclone, and *vice versa*, until it decays. It is inferred that such a flow circulation plays a vital role in sustaining the life of Typhoon. The Pacific Ocean high pressure is developed at the region covering the middle latitude of the Northern Hemisphere owing to the global circulation of atmosphere air mass surrounding the earth. During the Typhoon moves over the Pacific Ocean, air mass circulation between the Typhoon and the high pressure is sustained as if the toy horse turns around the center column of a revolving machine.

Keywords: Typhoon, Pacific Ocean, Low pressure, Coriolis Force, Jet Stream, Trade Wind

1. Introduction

Typhoon is one of the most complex natural phenomena involving turbulent flow and thermal convection, so that no one could analyze it mathematically so far(Nakagawa et al. 1998, Nakagawa & Suzuki 2001). It may be evident to solve this problem, it is necessary for us to know the instantaneous values of the position vector **x** and momentum vector m**v** for each of the fluid particles. Such a challenging approach to turbulence have been succeeded by Tsugé and his pupils and in fact several noteworthy results have been published for the last half century (Tsugé 1969, 1974, 1978, Endo & Tsugé 1993, Ishibashi et al. 1998, Osonphasop & Nakagawa 2014), though any application of this theory to Typhoon has not been made extensively.

A *tropical depression* is the lowest category that the Japan Meteorological Agency (JMA) uses and is the term used for a tropical system that has wind speeds not exceeding 17m/s (61 km/h). A tropical depression is upgraded to a *tropical storm* if its sustained wind speeds exceed 17.5m/s (63 km/h). Should the storm intensify further and reach sustained wind speeds of 25m/s (89 km/h), then it will be classified as a *severe tropical storm*. Once the system's maximum sustained winds reach wind speeds of 33m/s(119 km/h), it will designated as the tropical cyclone or a *Typhoon*—the highest category on its scale. In general, westerly wind increases associated with the Madden-Julian oscillation(MJO), and leads to increased tropical cyclogenesis in all tropical cyclone basins. MJO is the largest element of the inter-seasonal (30-to 90-day) variability in the tropical atmosphere. It was discovered in 1971 by R. Madden and P. Julian of the American National Center for Atmospheric Research. It is a large-scale coupling between atmospheric circulation and tropical deep atmospheric convection. Unlike a standing pattern like the El Ninõ-Southern Oscillation(ENSO), MJO is traveling pattern that moves eastward at 4 to 8 m/s approximately, through the atmosphere above the warm parts of the Indian and Pacific oceans. This overall circulation pattern manifests itself most clearly as anomalous rainfall. As the oscillation propagates from west to east as stated already, it leads to an eastward march in tropical cyclogenesis with time during the hemisphere's summer season. On average, twice per year tropical cyclones will be formed in the western Pacific Ocean, along the same line of longitude. There is an inverse relationship between tropical cyclone activity in the western Pacific basin and the north Atlantic basin. However, when one basin is active, the other is normally quiet, and *vice versa*. Nearly one-third of the world's tropical cyclones form within the western Pacific. This makes this basin the most active for generating tropical cyclones on Earth. Pacific typhoons have formed year round, with peak months from August to October. The peak months correspond to that of the Atlantic hurricane seasons. Along with a high storm frequency, this basin also features the most globally intense storms on record. One of the most recent busy seasons was 2013. Tropical cyclones form in any month of the year across the north-west Pacific Ocean, and concentrate around June and November in the northern Indian Ocean. The area just north-east of the Philippines is the most active place on Earth for tropical cyclones to exist. Across the Philippines themselves, activity reaches a minimum in February, before increasing steadily through June, and spiking from July through October, with September being the most active month for tropical cyclones across the archipelago. Activity falls off significantly in November. The most frequently impacted areas of the Philippines by tropical cyclones are northern and central Luzon. The genesis and intensity of typhoons are also modulated by slow variation of the sea surface temperature and circulation features following a near-10-year frequency (Markowski et al. 2008).

The main purpose of the present study is to introduce nature of Typhoon, and to propose and discuss the origin, structure, generation, and locus based on fluid mechanics mainly.

2. Modelling of Typhoon

Let us model typhoon by the exact non-steady solution of the Navier-Stokes equation: For the sake of theoretical discussion, it may be convenient to model typhoon in terms of an exact non-steady solution of the Navier-Stokes equations, namely which describes the process of decay of a vortex through the action of viscosity: The distribution of the tangential velocity component v with respect to radial distance r and time t is given by

$$v(r, t)=\Gamma_0/(2\pi r)\cdot \{1-\exp[-r^2/(4\nu t)]\} \qquad (1)$$

as derived by Oseen(1911) and Hamel81916). Eq.(1) can be normalized as

$$\overset{0}{v} =1/\overset{0}{r}\{1-\exp[-\overset{0}{r}{}^2/(4a)]\}, \qquad (2)$$

with

$v_0=\Gamma_0/(2\pi r_0)$, $\mathring{v}=v/v_0$, $\mathring{r}=r/r_0$, $a=\nu t/r^2_0$,

where v_0 the maximum wind velocity at the normalized radius $\mathring{r}=1$, r_0 radius of maximum wind velocity at the outer radius of the eyewall, ν the kinematic viscosity of air, and t the time.

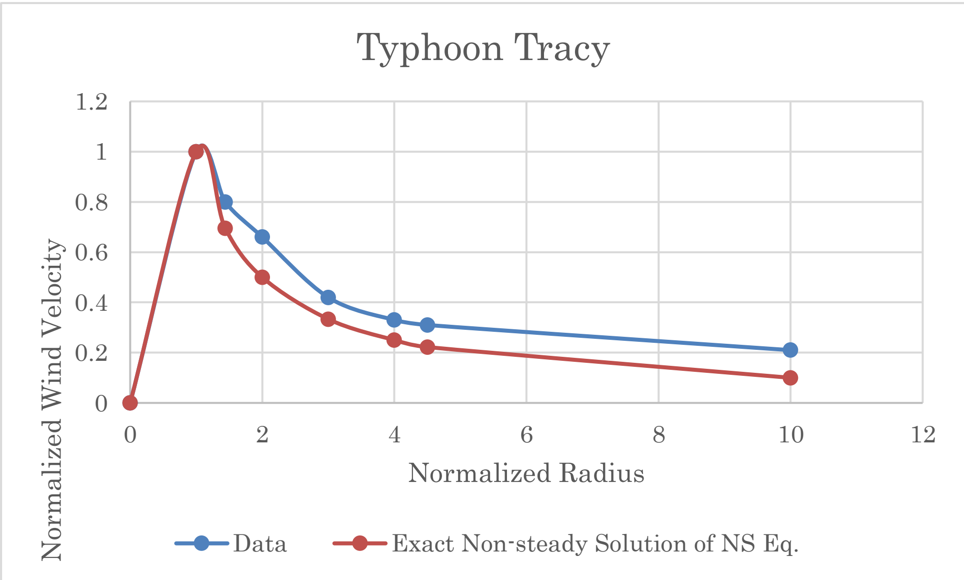

Fig. 1 Normalized wind velocity against normalized radius for typhoon Tracy/

Data are derived by Mayo (1994), while model curve (2) at a=0.08 is plotted for comparison.

Fig.1 shows the comparison between the data for typhoon Tracy and the model curve. It may be evident that the agreement is quite good, so that this model might be useful for the further discussion.

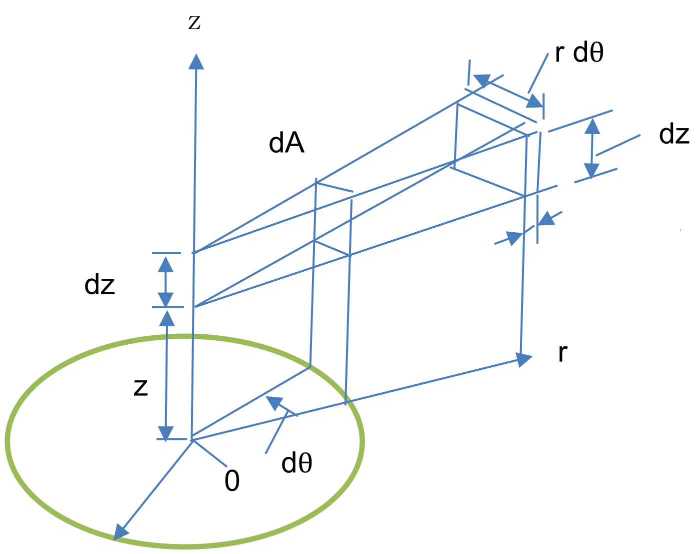

Fig. 2 Definition of coordinate system for discussing typhoon.

Having completed the mathematical modeling of typhoon, let us start by selecting a small air mass of dm, located at radius r and at height z above the sea surface. The centripetal force F_c required to keep it in circular orbit at speed v is the sum of centrifugal and horizontal component of the Coriolis force:

$d F_c = (v^2/r + 2v\omega \sin\varphi)dm,$ (3)

where F_c is the cenripetal force (N), r radius (m), v =v(r) tangential wind velocity (m/s) at radius r, ω Earth's angular speed(1/s), φ latitude (degree), and m air mass(kg). It must be noted that not only the Coriolis force but also the centrifugal force are vital for Typhoon formation. For example, if we ignore the Coriolis force the air would flow radially into the eye with low pressure having no rotation, and consequently the centrifugal force would never be operative properly.

In the coordinate system in Fig.3, when air mass dm occupies volume dV=rdrdθdz and is assumed to be compressible, it has density that can be approximated by $\rho=\rho_0 \cdot e^{-kz}$, where ρ_0 is the air density at sea level and k is a constant, which value is so chosen that the density becomes half at altitude of 7000 m. Then, the infinitesimally small air mass dm is expressed by

$dm = \rho_0 \cdot e^{-kz} \cdot r d\theta dr dz,$ (4)

where z the height (m) above sea surface and ρ_0=1.2 kg/m^3 the air density at the sea surface. Substituting (4) in (3), we have

$d F_c = (v^2/r + 2v\omega \sin\varphi) \cdot \rho_0 \cdot e^{-kz} \cdot d\theta dr dz.$ (5)

The centripetal force d F_c is caused by the reduced eye pressure due to the strong vertical convective flow, acting on the vertical area dA of the eyewall as shown Fig. 3. Note this area dA is the footprint of dV projected radially inward:

$dA = r_0 d\theta dz.$ (6)

The inward pressure difference d(Δp), where Δp is the pressure(Pascal) across the eyewall, radially across the eyewall, requires to keep the air mass dm in circular orbit at wind veocity v.

3. Nature of Typhoon

In this section, nature of Typhoon has been introduced.

Fig.3 Typhoon Trami from satellite 'Zoasiri' navigating over the west Pacific Ocean.

Trami was heading for Japan on 25 Sept. 2018.

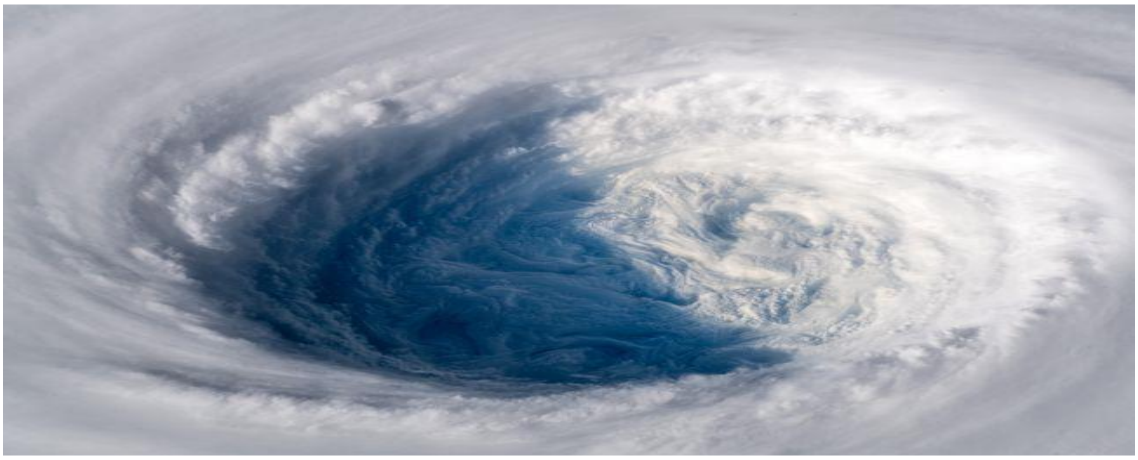

Fig.4 Enlarged picture at the eye of Trami.

Typhoon Trami creeps to north-west across the Pacific Ocean towards Japan and Taiwan, astronauts on the international Space Station got quite a good view of the intense storm. European Space Agency Astronaut, Alexander Gerst took this picture, and twittered “Eye of Trami looks like that water flushing down a drain”.

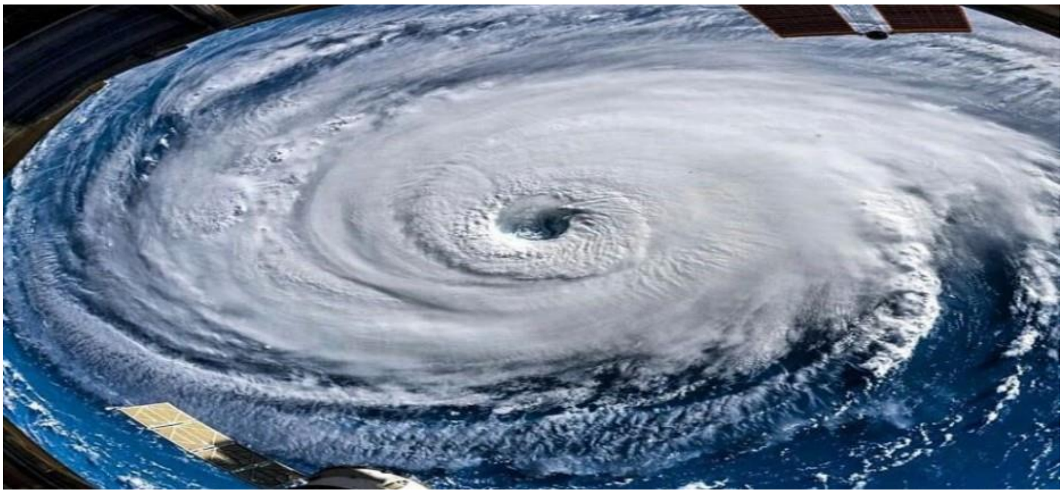

Fig.5 Typhoon Hurtles over Philippines in 2018

Fig 5 shows another satellite picture of Typhoon Hurtles. In this picture, the counter clockwise spiral circulation of the wind into the center, is clearly visualized by the clouds, in which the concave hole is the *eye* and the rectangular plates at bottom-left and top-right, are parts of the satellite. It may be instructive to know that the wind velocity pattern of the Typhoon can be represented schematically as Fig.6,

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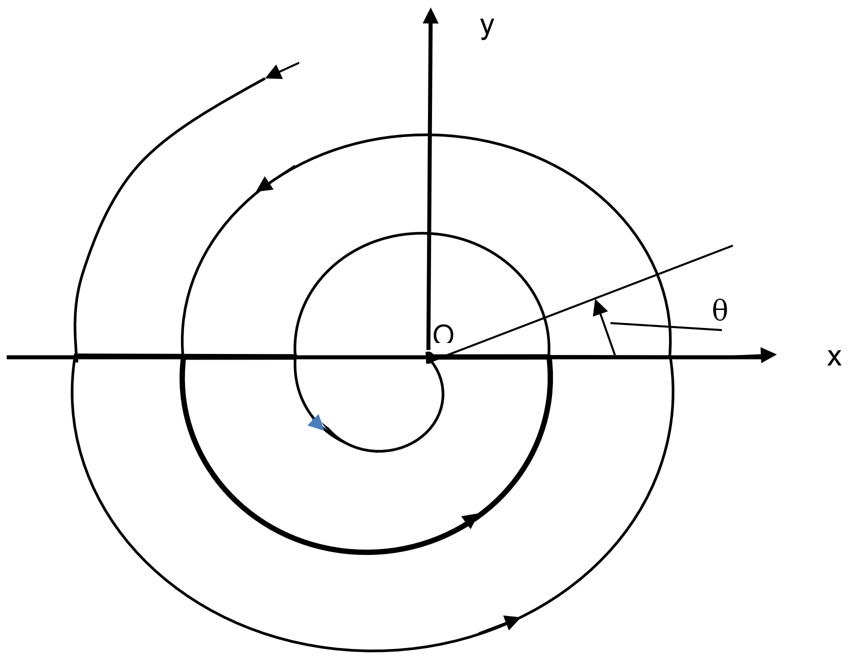

Fig. 6 Model flow of the locus of typhoon near sea surface.

The spiral wind flow locus of a Typhoon near sea surface may be modeled by the following complex function.

$Z = e^{-\alpha\theta}\cdot(\cos\theta + i \sin\theta)$, (7)

where α is a constant, and θ the angle defined in this figure.

Eq.(7) gives us

$x = e^{-\alpha\theta}\cdot\cos\theta$,

and

$y = e^{-\alpha\theta}\cdot\sin\theta$ (8)

we have then,

$\lim_{\theta=\infty} x = 0$,

and

$\lim_{\theta=\infty} y = 0$. (9)

Hence,

$\lim_{\theta=\infty} Z = \lim_{\theta=\infty} (x + iy) = 0$. (10)

This denotes that as θ → ∞, a variable point in the complex plane (Fig. 6) moving along the spiral curve in the direction of the arrow approaches unboundedly the point 0, which depicts the limit of the function.

In 2019, two super Typhoons, Faxai and Hagibis attacked to Japan. At 5 AM on 9th September 2019, Faxai hit the central area of Japan. This typhoon left serious damages. Faxai passed from Kanagawa and Chiba prefectures to Miyagi and Fukushima prefectures, respectively, as shown Fig. 7.

The average wind speed was 45m/s, and the recorded maximum instantaneous wind speed was 58.1 m/s at Tokyo prefecture.

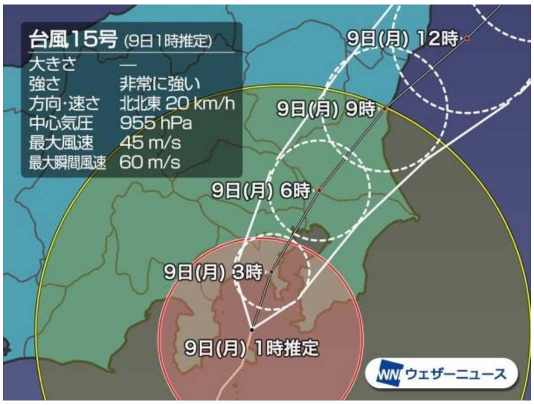

Fig. 7 Locus of Faxai on 9 Sep. 2019.

By Faxai's attack, 1 person dead, 84 people injured, 832 houses got damage and 27 houses was flooded above floor level.

At Chiba prefecture where the maximum wind speed of 57.5 m/s was recorded, the fence of the golf fell over to the houses. Over 10 houses got damage and a woman got a serious injury.

On one hand, at 09:00 on 11 Oct., Hagibis was moving towards eastern Japan from off Chichijima island in Tokyo at 25 km/h. On 10 Oct. Hagibis recorded a central atmospheric pressure of 915 hPa. It got a maximum wind speed near the center of 55m/s, gusting to as much as 75m/s.

Fig. 8 Hagibis approaching to Japan

Before Hagibis recorded 915 hPa in 2019, the most intense storm, in terms of low pressure in Japan was Typhoon Nancy in 1961, which had 925hPa when it landed on Shikoku. For the Tokai region, the record is

Typhoon Tess in 1953 with 946 hPa. This killed over 400 people and injured almost 2,500 people. For the Kanto region, which includes Tokyo, the record is 960 hPa.

Hagibis is not just a blustery storm, but also a huge storm. The area with winds in excess of 15m/s is as large as 1,400km in diameter. The impact of the storm lasted long, which in turn, dumped significant rainfall.

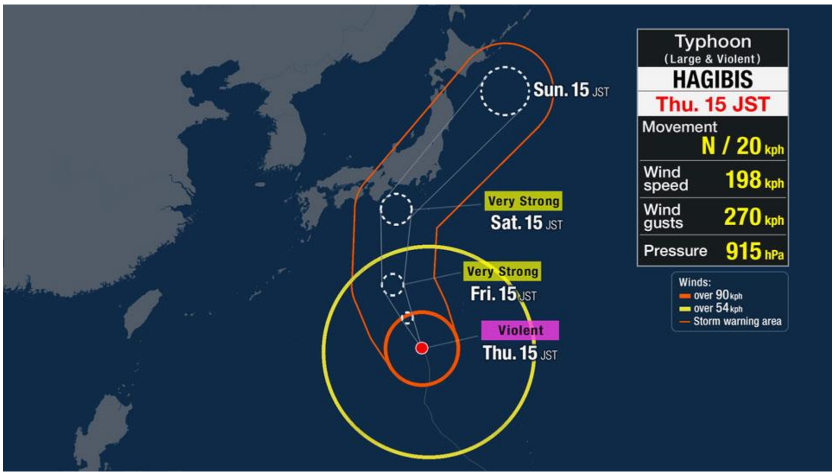

Fig. 9 Locus of Hagibis from 10 to 13 Oct. 2019

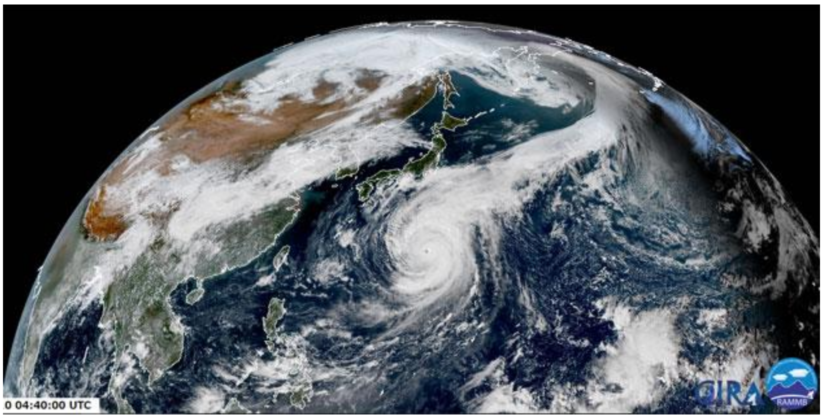

Fig.10 Perspective view of the Northern Hemisphere of the Earth from the Satellite, while Hagibis was attacking to Tokyo area early October in 2019.

Being stated already, Hagibis recorded a central pressure of 915hPa as of 10 Thursday, making it the most intense tropical systems of Japan in her history. What makes Hagibis even more daunting is the timing of its landing on Tokyo area. The weekend viz. 12 Saturday , and 13 Sunday , is close to a full moon, meaning sea levels was higher than normal. The combination of the high tide, giant waves and storm surges due to the Typhoon brought a significant risk of coastal flooding.

3. Structure of Typhoon

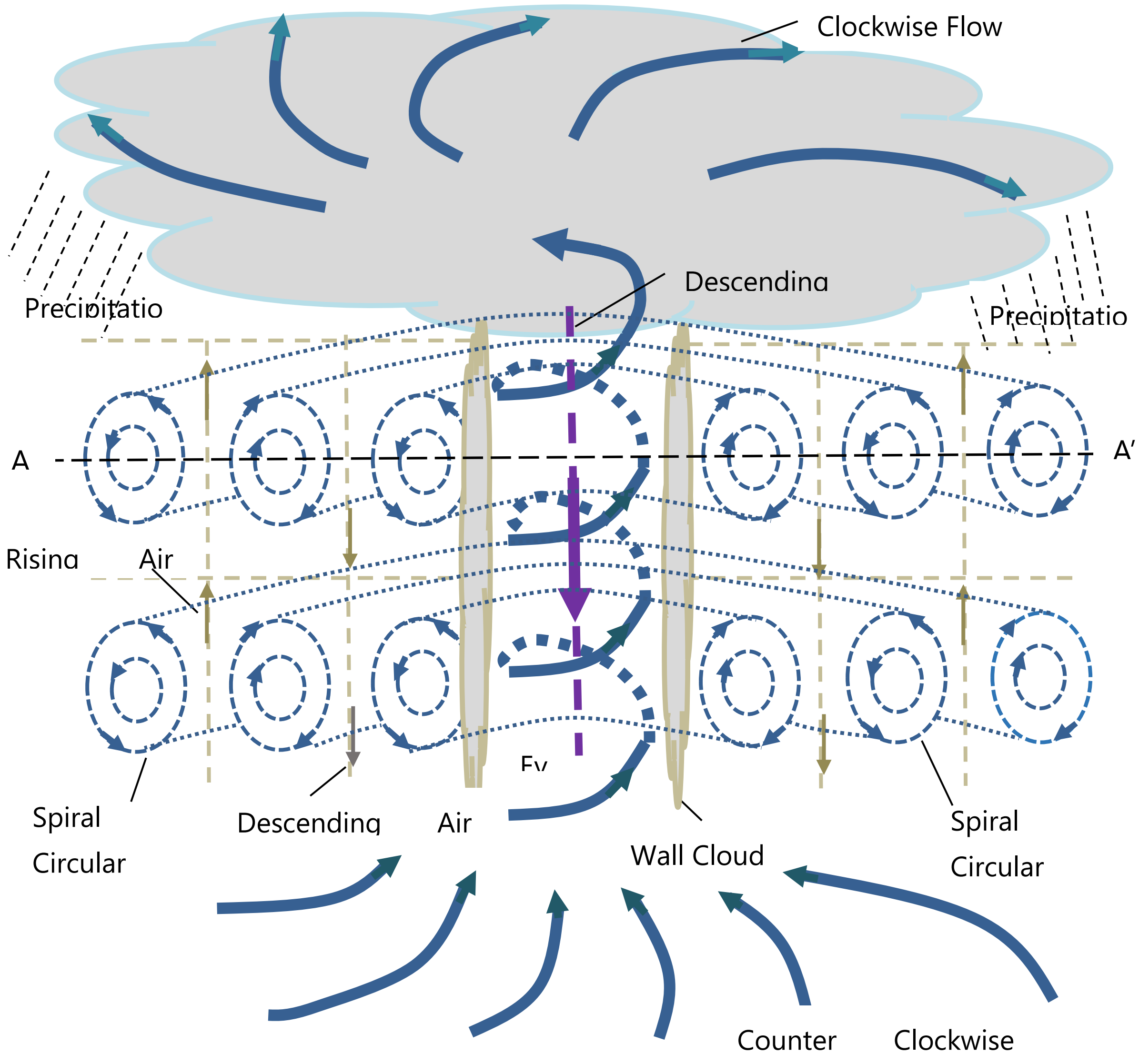

Fig.11 Pictorial sketch of the vertical structure of Typhoon.

The center of Typhoon is called *eye*, where there is no cloud contrary to intuition. This is because the circulatory flow, having the sense of counter clockwise when one looks it from above, induces the centrifugal force against the fluid particles to the outwards. Thus, wall cloud or eye wall is formed around the eye, as depicted in Fig.11. The humid air mass

into the eye cylinder from the surrounding sea will be lifted up, and so the wall cloud is developed, but the region below the cloud feeds heavy rainfall.

While the air mass is climbing up in keeping the spiral motion as depicted in Fig.11, it forms the cylindrical eye wall. Once the air mass arrives at the top of the eye cylinder however, it alters the flow direction from vertical to horizontal. Then, a small fraction of the air mass descends to the bottom along the inner wall of eye cylinder. On one hand, the blown air mass out of the top of the eye cylinder turns to the clockwise gradually with increasing the distance and finally joins into the highest part of neighboring high pressure(s). As the air mass descends, its temperature increases, for the latent heat is absorbed by the water droplets while they are transformed into the vapor. Therefore, in the eye cylinderical warm core, the temperature is higher than that of the rest air mass well over 10 degrees (Klemp 1987). As the result, the warm core enhances the thermal convection and so decreases the air pressure there, so that ambient humid air must be introduced into the eye. This sustains the Typhoon and enhances the development, for the surrounding vapor is the more concentrated to the eye cylinder accompanying strong wind and heavy rainfall. Note that along the spiral circular bands formed outside of the eye cylinder, thermal convection is also active, so heavy rainfall occurs in those bands.

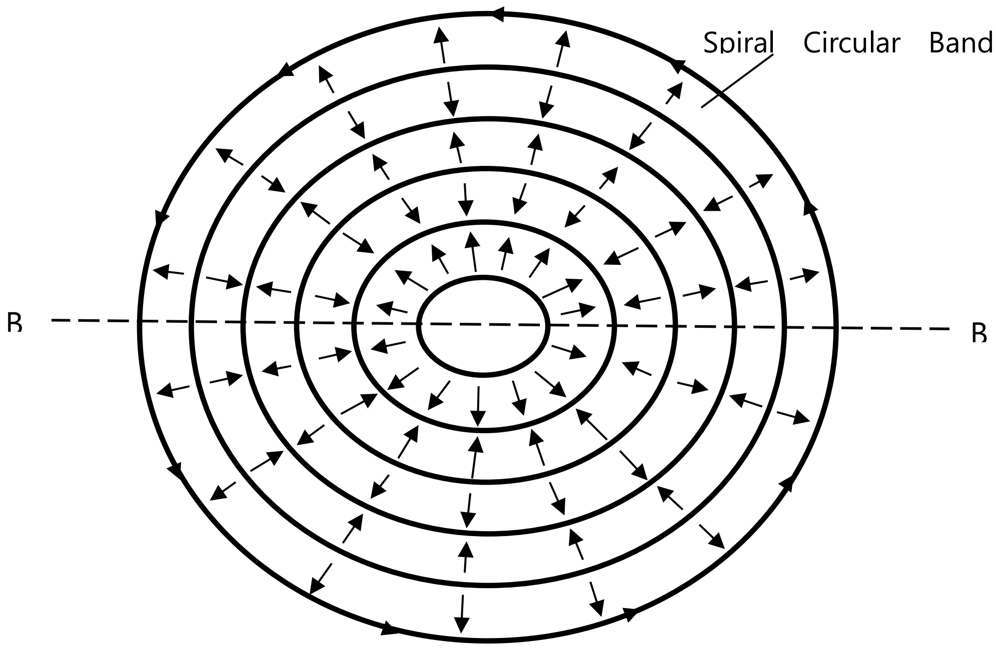

Fig.12 Pictorial plan-sectional sketch of Typhoon near sea surface.

Section A-A' in Fig.11. Arrows indicate the flow direction.

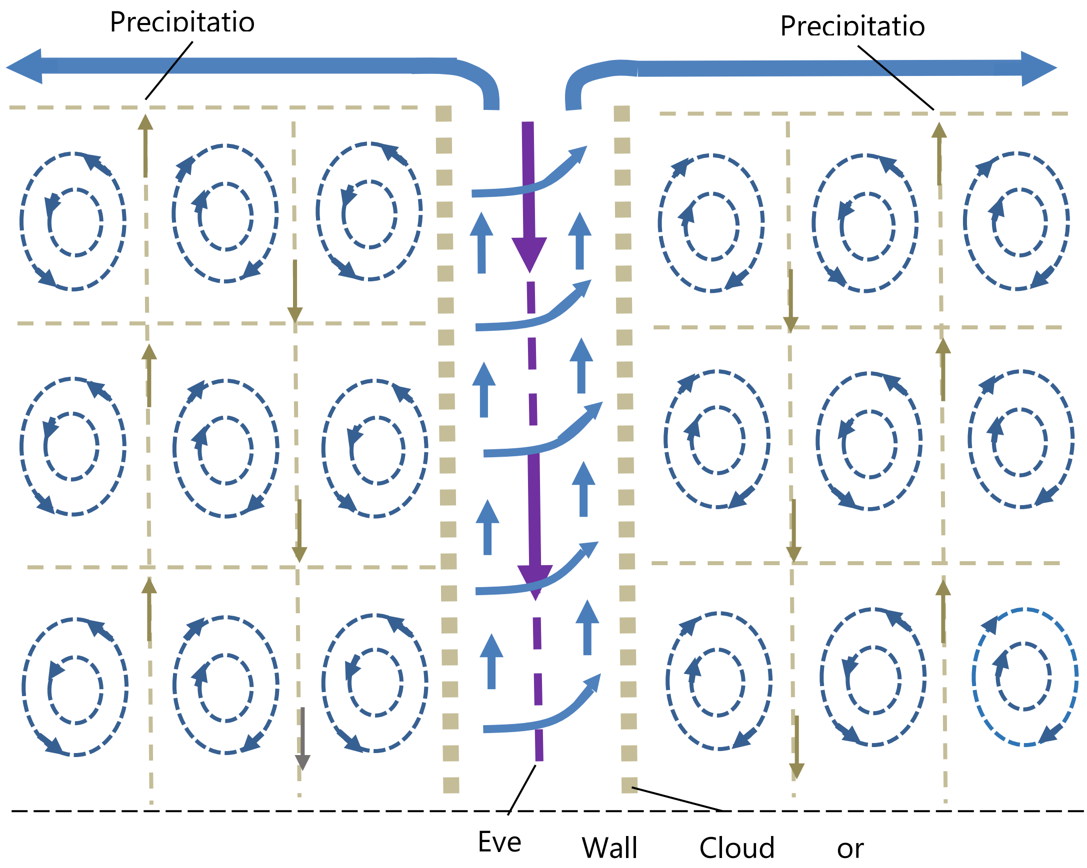

Fig.13 Vertical cross-sectional view of Typhoon.

Section B-B' in Fig.12. Vortices are a hypothetical and tentative drawing based on a fluid dynamist's point of view.

4. Discussion

In this section, origin, generation and sustainable mechanism of Typhoon have been discussed.

Origin: There are six main requirements for tropical cyclogenesis: 1. Sufficiently warm sea surface temperatures, 2. Atmospheric instability, 3. High humidity in the lower to middle levels of the troposphere, 4. Enough Coriolis force to develop a low pressure center, 5. A pre-existing low level focus or disturbance, and 6. Low vertical wind shear. While these conditions are necessary for tropical cyclone formation, they do not guarantee that a tropical cyclone will form. Normally, an ocean temperature of 26.5 °C spanning through a depth of at least 50 meters is considered the minimum requirement to maintain the special mesocyclone that is the tropical cyclone (Markowski et al. 1998). These warm waters are needed to sustain the warm core that plays a critical role in tropical systems. A minimum distance of 500 km from the equator is normally needed for tropical cyclogenesis. Whether it is either a depression in the monsoon trough, Intertropical Convergence Zone, a surface front, or an outflow boundary, a low level feature with sufficient vorticity and convergence is required to begin tropical cyclogenesis. It is known that 85 to 90 percent of Pacific typhoons form within the monsoon trough. Even with perfect upper level conditions and the required atmospheric instability, even the lack of a surface focus may prevent the development of organized convection and a surface low level feature. In fact, vertical wind shear of less than 10 m/s between the ocean surface and the tropopause is required for tropical cyclone development. Typically with Pacific typhoons, there are two recognized outflow jets: one to the north ahead of an upper trough in the Westerlies, and the other is towards the equator.

Generation Mechanism: Any large low pressure accompanying strong spiral wind motion is called, Typhoon in south-east Asia, but it is called Cyclone in India, Hurricane in USA. Typhoon is a wind system with an intensely strong pressure depression with Mean Sea Level(MSL) pressures sometimes below 915 hPa, The normal areal extent is about 100-200km in diameter, the isobars are closely spaced, so winds are strong and spiraling with anti-clockwise sense of circulation in the northern hemisphere if one views it from above. The center of the Typhoon called the *eye*, which may extend to about 10-50km in diameter, will be relatively quiet. However, the right region of Typhoon facing to the moving direction, very strong wind speed is recorded as much as 55m/s. The wind speed gradually decreases from the eye towards the outer edge, while the pressure increases accompanying to this change. The precipitation may be heavy in the entire area occupied by the Typhoon.

During summer and autumn, Typhoon originates in the open ocean at around 5-10° latitudes and move at speeds of about 10-30 km/h to higher latitudes along an irregular path selecting the local hot spots such as the locus of the Kuroshio. They get their energy mainly from the latent heat released during the condensation of the humid vapor and increase in size as they move on the ocean surface. Therefore, once a Typhoon lands on islands, naturally its energy source is cut off, so it dissipates very fast. Hence, the intensity of Typhoon decreases rapidly. Typhoons cause heavy damage of life and property on their land path, and intense rainfall and heavy floods in streams are its usual consequences.

Sustainable Mechanism: It is natural that there are regions, called anticyclones, of high pressure next to Typhoon, and of large areal extent distributed in the Pacific Ocean. It is considered that any Typhoon is tightly connected with anticyclone(s), and the flow is circulating from the Typhoon to anticyclone(s), and returns to the starting point, and so on. Such a continual flow circulation plays a vital role in sustaining the life of Typhoon(s). Figs.14 and 15 illustrate the indispensable mutual relation between the low and high pressure(s): At the low pressure, heated air at the bottom areal rises by thermal convection. After reaching at the highest position in the sky, the air is going horizontally to the space over high pressure, and then it descends to the bottom area of the high pressure, from this region air returns to the original low pressure areal. It may be repeated cyclically among the high pressures and low pressures. As a matter of fact, the longevity of Typhoon depends on such a circulatory flow between the Typhoon and the high pressure(s). Fig.16 depicts Archimedes' spiral for counter clockwise spiral flow into high pressure core, for it is instructive for understanding the structure of high pressure areal. At the central part of the Pacific Ocean, where strong and stationary high pressure normally appears during the Typhoon season from summer to autumn as depicted in Figure 15.

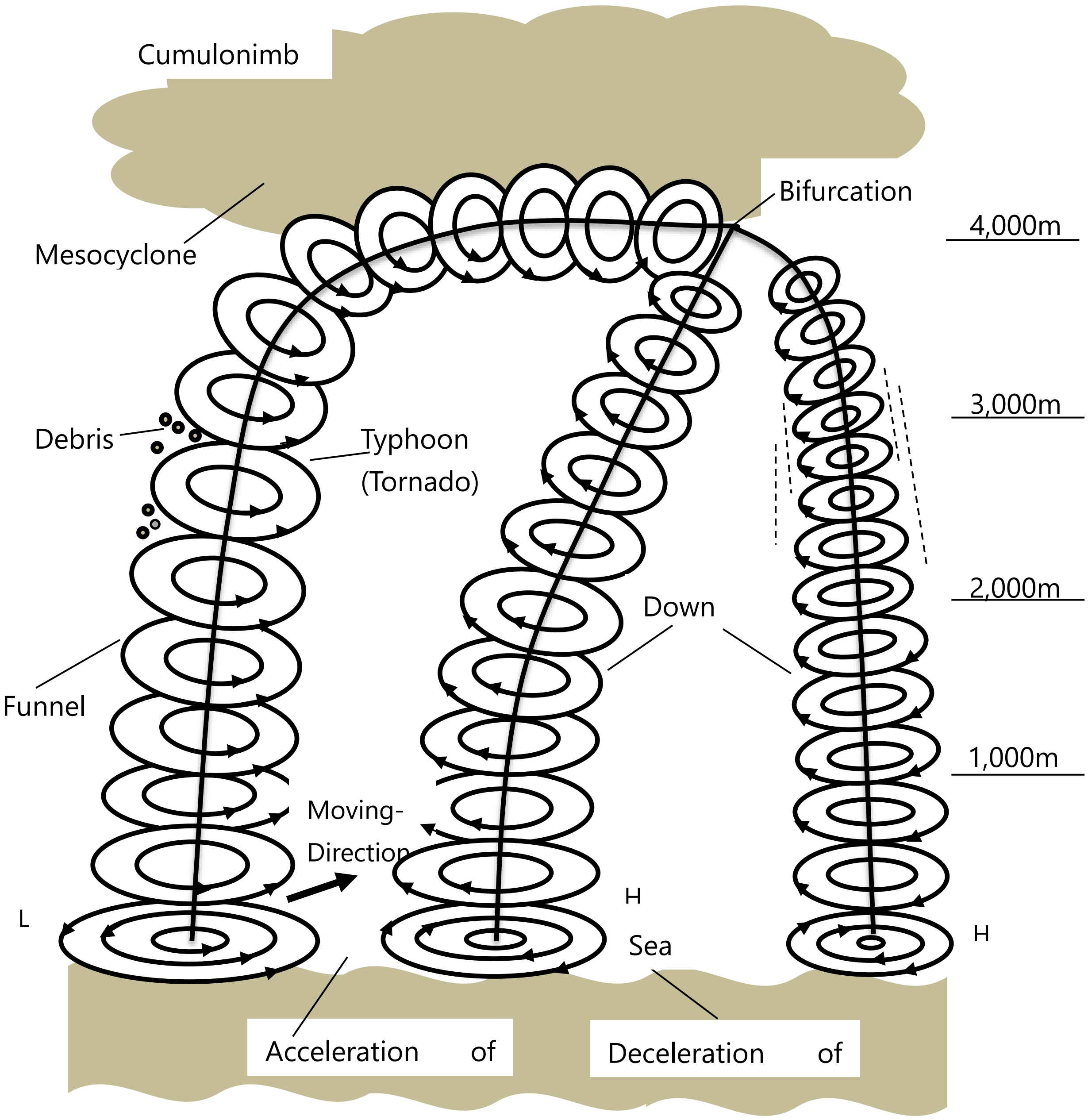

Fig.14 The air mass circulation among one low pressure and two high pressures。

This figure explains how one low pressure and two high pressures interact with each other in order to sustain the continuous circulation of air mass even though they change the positions at the same time.

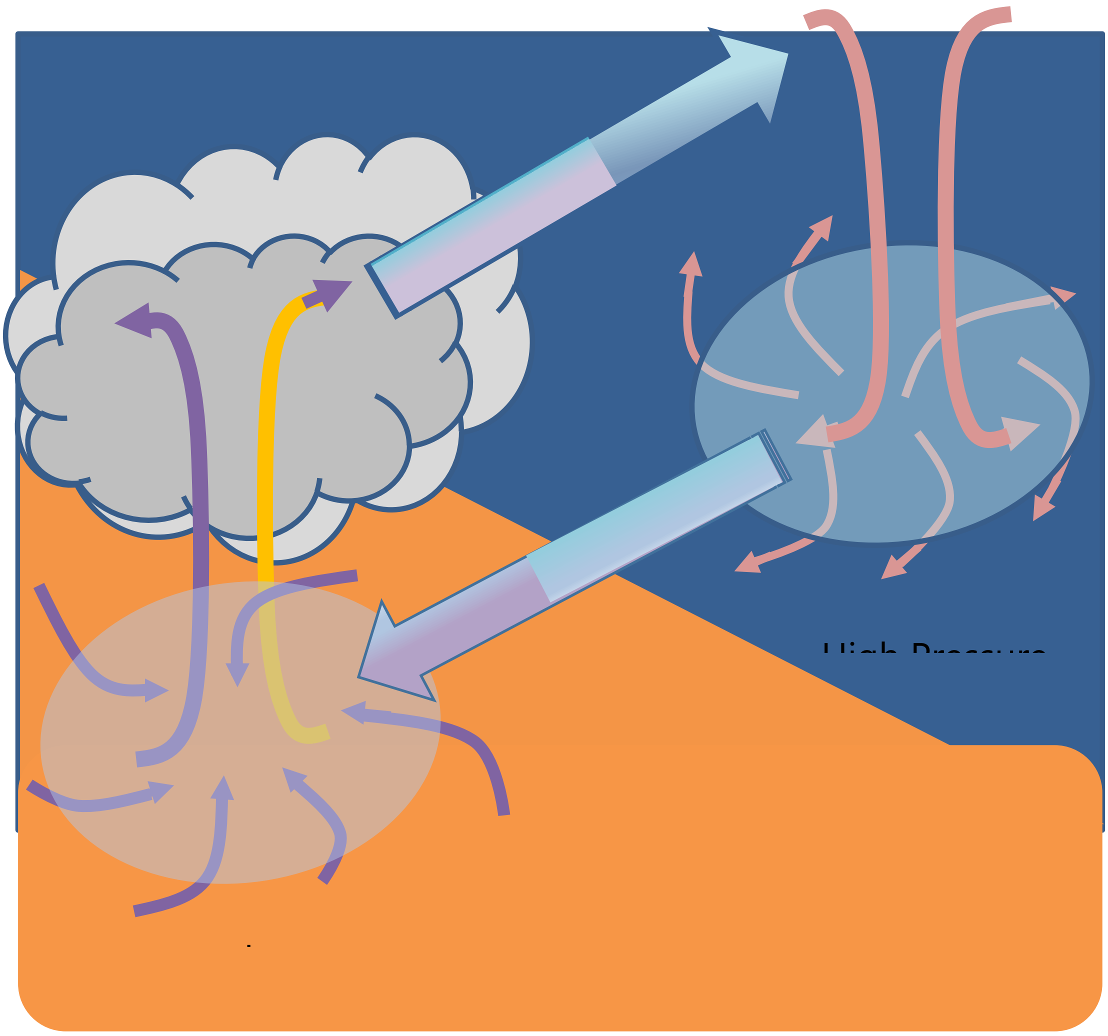

Fig.15 Air mass circulation between low and high pressures, respectively.

This figure depicts how one low pressure cooperates with the other high pressure in order to maintain the continuous circulation.

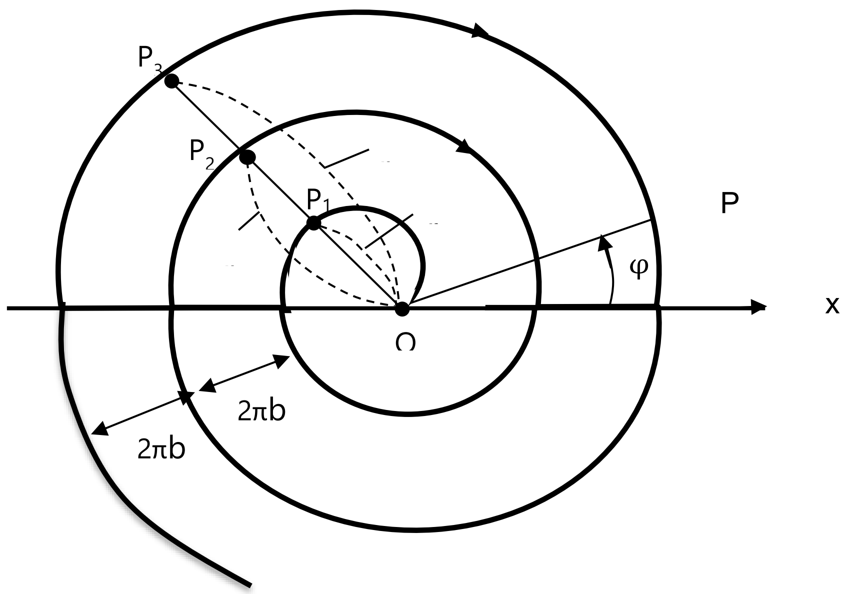

Fig.16 Archimedes' spiral for counter clockwise spiral flow into high pressure core.

Archimedes' spiral as depicted in Fig.16, may be represented by the mathematic expression of polar coordinate (r,φ),

$r = \nexists\varphi$

$r_1 = \nexists\varphi$,

$r_2 = \nexists(\varphi + 2\pi) = \nexists\varphi + 2\pi\nexists = r_1 + 2\pi\nexists$

.

.

$r_n = r_{n-1} + 2\pi\nexists$

where r the radius vector OP, $\nexists$ a constant, φ the argument of the point P from the initial line(x axis) taking the positive when it rotates to the counter clockwise, and n the integer.

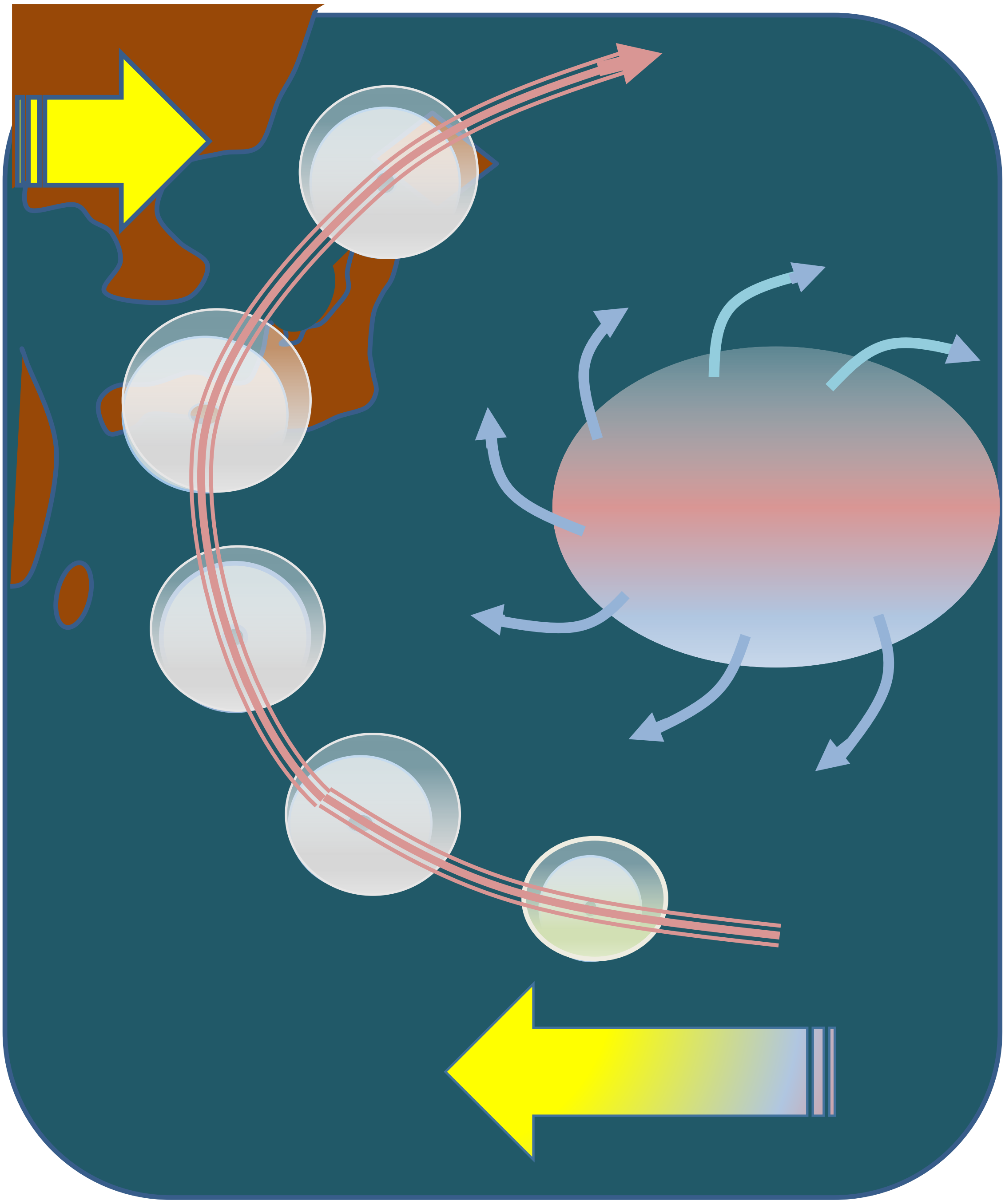

Fig.17 The Pacific Ocean high pressure controlling and sustaining the motion of Typhoon together with the trade wind flowing from east to west, and the Jet Stream flowing from west to east.

In Fig.17, small circle denotes Typhoon, the pink lines draws the rough locus, and the ellipse is the Pacific Ocean high pressure, from which the spiral flow having the clockwise circulation is blowing, the arrow at the upper-left is the Jet Stream, and the arrow at bottom-right is the trade wind.

The Pacific Ocean high pressure is developed at the region covering the middle latitude, as the result of global circulation of atmospheric air mass surrounding the earth: The heated air is lifted up from the equator and then descends to the middle latitude. In summer, since the orbit of the sun moves to the north, and so the air band of descending air mass also moves to the same direction. Accordingly, the high pressure band covers the Japan islands. This is no more than the Pacific Ocean high pressure.

Course: The typhoon born at the low latitude near equator normally attacks to Philippines, Taiwan, China, Korea or Japan, which is far away from the birth spot. However, there is

good reason why it travels such a long distance until being faded out at Okhotsk Sea. The major factors to determine the Typhoon course is trade wind and the Jet stream together with Pacific Ocean low pressure. It is known that the trade wind is blowing from east to west throughout the year, so that any Typhoon born at low latitude on the sea surface is conveyed towards west initially. However, in summer, the Pacific Ocean high pressure stayed near the center of this ocean blows out the wind being spiraling to the clockwise sense of rotation. It is certain that the air mass blown to the outwards must flow into the Typhoon During this process, the continual air circulation from the Typhoon to the high pressure, and *vice versa* is maintained as if the spiraling horse toy turns around the central column of a revolving machine. This is the motion pattern of the Typhoon, which turns to the north-east direction off the Japanese archipelagoes. During which the Typhoon is fed the heat energy from the sea as well as the latent heat when the vapor is transformed into the water drops while it is lifted in the eye cylinder. Then, as the Typhoon moves to the north-east direction, it is deflected to the right with respect to the moving direction by the Jet Stream blowing from west to east, together with by the Coriolis force. It is certain that the Typhoon is affected by not only the trade wind, the Pacific Ocean high pressure, the Jet Stream and the Coriolis force, but tidal currents such as the Kuroshio, and the Tsushima providing the Typhoon heat energy, but the Okhotsk and the Oyashio absorbing the heat energy from it. Furthermore, the high or low pressures appearing spontaneously in this region must affect the moving locus of the Typhoon to some extent. As the result, loci of Typhoon are not constant, but are unsteady over the south-east Asia: In June, July, November, and December, Typhoon takes its course to west attacking to Philippines, Taiwan, Korea, or sometimes China, while in August, September and October, it often attacks Japanese archipelagoes. Note the word Typhoon is used only if it occurs at the west of longitude of 180° in the Pacific Ocean

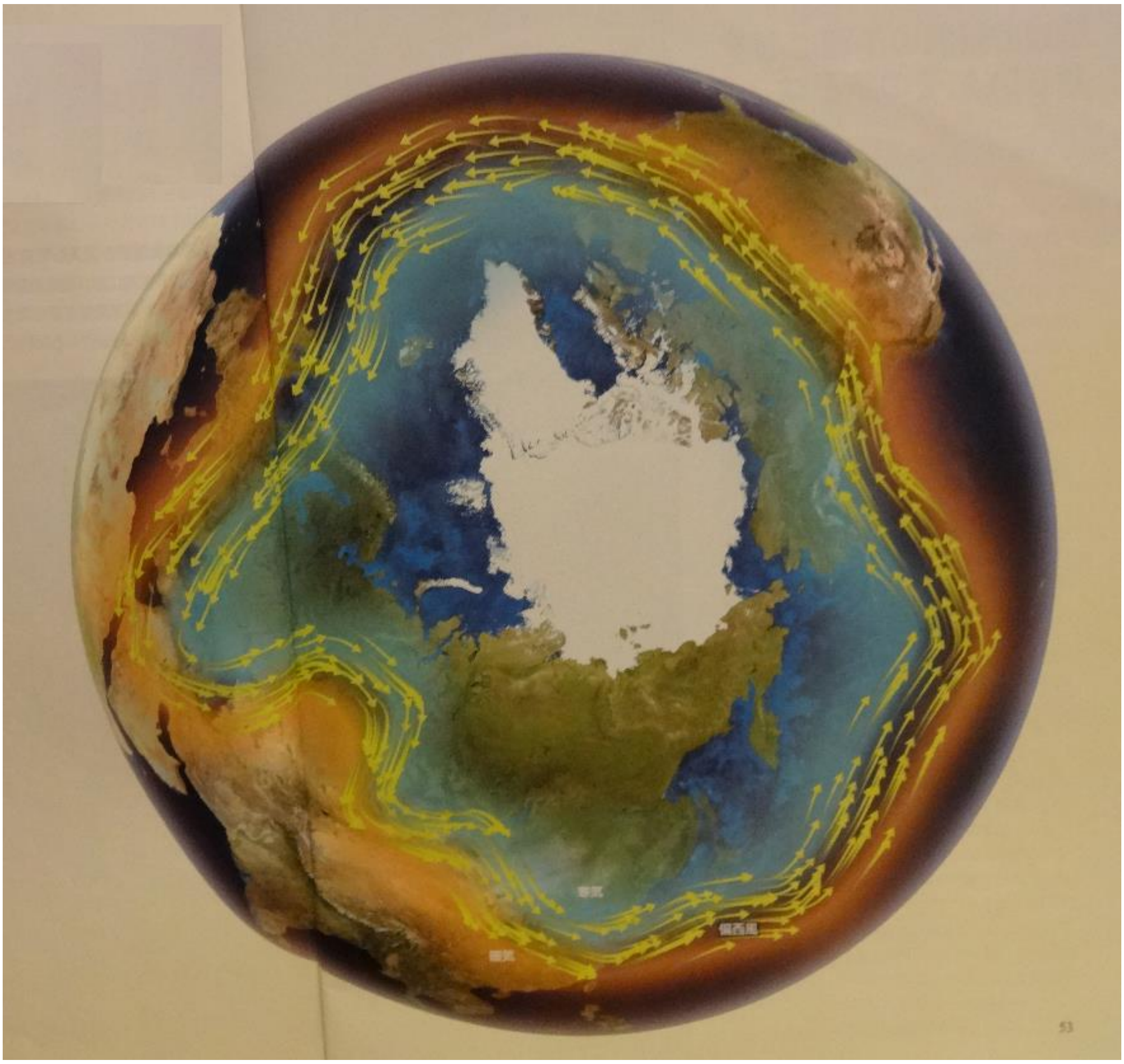

Fig.18 Global meandering circulation of the Jet Stream.

This photograph is taken from a Satellite. After Arai(2019)

As already being pointed out, the locus of a Typhoon is mainly determined by 1. Trade wind flow east to west along the equator at around 5-10 latitude, 2. Jet Stream flowing from west to east above China, Korea, and Japan, 3. the Pacific Ocean high pressure and 4. the Coriolis force, and 5. Ocean currents such as the Kuroshio and/or the Tsushima, for they provides heat energy to the Typhoon(s),. Fig.18 shows the global meandering circulation of the Jet Stream(Nakagawa 2019), while Fig.19 shows the longitudinal vortex rolls in the Jet Stream over China, Korea and Japan. The strong steady flow from west to east alter the direction of the Typhoon to the east. Finally, 5. the Coriolis force, which changes the flow direction to the right facing to the flow direction in the Northern Hemisphere. It is known that the locus of the Kuroshio circulating north Pacific Ocean along the equator, Philippine, Taiwan, Japan, Chishima-islands, Aleutian-islands, Alaska, Canada, USA, Mexico, and back to the equator again.

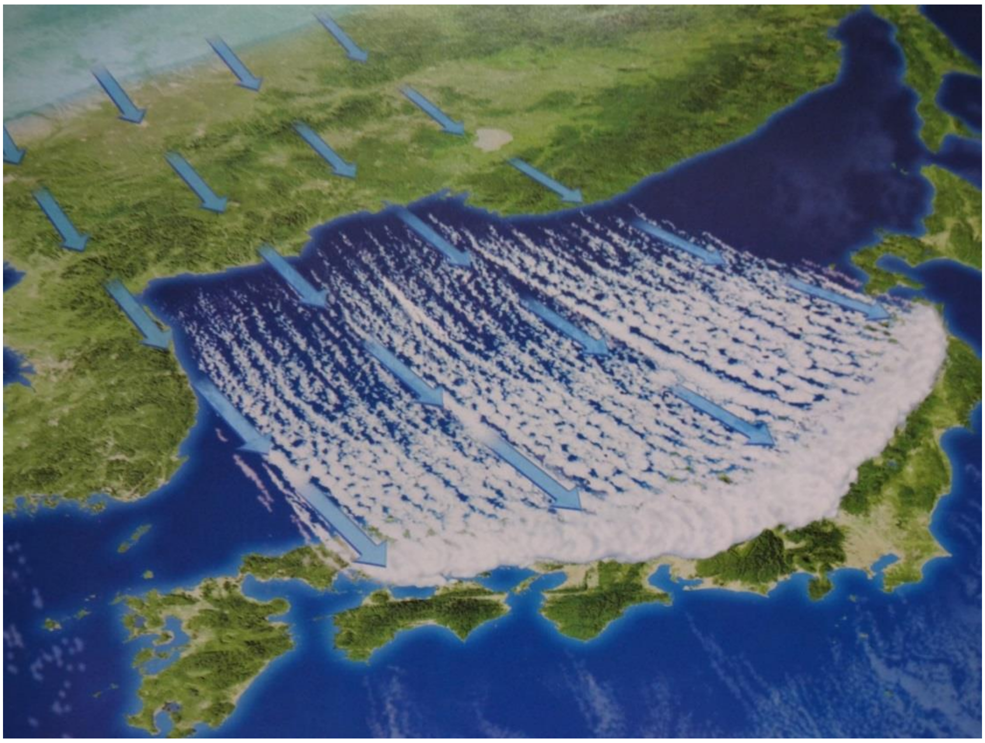

Fig.19 Longitudinal vortex rolls visualized by white clouds, which are generated by the interaction between thermal convection and strong shear flow in the Jet Stream. After Arai(2019).

It should be noted that the *air jump* appears at the end of rolls for the flow direction is suddenly altered in its direction upwards by the long and high mountain range along the central part of Honshu-island of Japan. *Hydraulic jump* (Imai & Nakagawa 1993, 1995) is often observed in irrigation channel, and/or river, but the air jump is quite rare. In this respect, this picture is valuable, as the evidence of air jump. In this figure, the blue arrows indicates the westerly flow direction.

5. Conclusion

In this section, new knowledge and insights obtained through the present study have been summarized:

It is found that the spiral wind velocity profile of Typhoon can be modeled by the exact non-steady solution of the Navier-Stokes equation.

The Hagibis was not just a blustery storm: The areal extent with winds in excess of 15m/s was as large as 1,400 km in diameter and the minimum pressure at the eye was 915 hPa, accompanying significant rainfall and risk of coastal flooding.

There are six major requirements for tropical cyclogenesis, viz. 1. Sufficiently warm sea surface temperature above 26.5 ℃, 2. Atmospheric instability, 3. High humidity in the lower to middle levels of troposphere, 4. Enough Coriolis force to develop the eye, 5. Pre-existing low pressure focus seed, and 6. Low vertical wind shear being smaller than 10 m/s.

It is realized that there are always regions, called anticyclones of high pressure tightly connected with the Typhoon, which is a low pressure: The flow is circulating from the Typhoon to anticyclone, and vice versa, until it decays. It is suggested that such a flow plays the vital role in sustaining the life of Typhoon.

The Pacific Ocean high pressure is developed at the area covering the middle latitude owing to the global circulation of atmosphere air mass surrounding the earth. During the Typhoon moves over the Pacific Ocean, air mass circulation between the Typhoon and the high pressure is kept as if the toy horse turns around the center column of a revolving machine.

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