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自然および人工における渦運動の観察

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Observation of Vortex Motion in Nature and Art

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Abstract

From ancient times to the present day vortex motion has fascinated mankind. There are innumerable cases of appearance, growth and disappearance of vortices in nature. Many designs of vortices have been used in art and life all over the world.

In this paper various kinds of vortex motion in nature and art are presented. Observation of vortex motion of the ocean is studied by using multi-sensor remote sensing. The observation involves the effective use of three satellite remote sensing data of NOAA·AVHRR, MOS-1·MESSR, and LANDSAT·TM. The Kármán vortex street behind a circular cylinder observed in an open channel in a hydraulic laboratory is presented. A brief review of designs of vortex motion which appeared in Japanese traditional art and life is also presented.

Key Words: Vortex, Vortex Motion, Remote Sensing, NOAA, MOS-1, LANDSAT

1. Introduction

Every movement of matter, except for a few special cases, may be considered as vortical (Lugt, 1983). Every moment innumerable vortices occur, grow and disappear in nature and technology. From ancient times to the present day vortices have tremendously attracted the human being. Vortices have sometimes tenderly fascinated us and sometimes impacted on mankind furiously with great violence. Everyone has noted vortex motion in a coffee cup, whirling leaves on a stormy autumn day, or eddies at the surface of a stream. Though human eyes themselves are not able to see all of them, there is an infinite number of vortices from the infinitesimal to those of gigantic scales.

Until recently, only a small part of these vortices have revealed their figures to human eyes. However, the advent of observation methodologies with new observation techniques such as remote sensing has revealed a lot of new fascinating figures of vortex motion.

In recent years many kinds of vortex motion in nature have been studied by using remote sensing

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(Nishimura, 1986).

This paper is composed of three parts. In the first part observation of vortex motion on the sea surfaces of the Seto Inland Sea and the Pacific Ocean off Shikoku are studied by using multi-sensor remote sensing. Three satellite remote sensing data obtained by NOAA·Advanced Very High Resolution Radiometer (NOAA·AVHRR), Marine Observation Satellite 1·Multi Spectral Electronic Self Scanning Radiometer (MOS-1·MESSR), and LANDSAT·Thematic Mapper (LANDSAT·TM) are effectively used to reveal several kinds of vortices in these sea surfaces.

The second part involves the Kármán vortex street behind a circular cylinder in an open channel in a hydraulic laboratory at The Hiroshima Institute of Technology.

In the third part a brief review of vortex motion which appeared in traditional Japanese art and life is presented. From the review it seems that vortices have fascinated mankind considerably not only in the rest of the world but also in Japan.

2. Observation of Vortex Motion by Satellite Remote Sensing

2.1. Multi-Sensor Remote Sensing

In this research, multi-sensor remote sensing data which have characteristics of different wave length and spatial resolution were used. The observation range of each unit of data is 3000 km in width for NOAA·AVHRR data, 100 km×90 km for MOS-1·MESSR data, 185 km×170 km for LANDSAT·TM data, and this is sufficient to get the whole picture of the ocean environment on a scale ranging from the whole the Seto Inland Sea to each individual bay area. Moreover, by each specification including visible, infrared, intermediate infrared, and thermal infrared ranges, it is possible to extract the spectral signature of all oceanic environmental phenomena.

2.2. Observation of Vortices and Water Mass Distribution

The vortex phenomena was observed by using the respective satellite data. Concerning the NOAA·AVHRR data (spatial resolution 1.1 km), as shown in Fig. 1, land area imagery of ch 1, 2, 1 are respectively filtered with red, green and blue for additive color mixture, and sea area imagery of thermal infrared ch 4 is level-sliced to visualize the sea surface temperature in a series of cold and warm colors: then both of them are superimposed to produced colored imagery. In regard to the sea area, in contrast with the low-temperature zone of the Japan Sea, the dynamic flow pattern of the Kuroshio Current can be observed in the high-temperature zone of the Pacific. According to this imagery, it appears that the Kuroshio Current extends across the Pacific below the clouds, and three successive ocean vortices can be seen clearly off Shikoku. Water mass distribution is detected in the Seto Inland Sea, Kuroshio area, and the coastal area of the Japan Sea. It is possible to make the interpretation that the Kuroshio system has entered into the Inland Sea and affected the area. Tidal current is prominent in the Inland Sea, and together with the complicated geographical features, it has formed the flow field which is peculiar to bay and open sea areas, and controls the exchange of sea water extensively. Water mass distribution as of June in 1987 shows that a high-temperature zone is observed in shallow bays and open sea, and cold water is distributed in rapid-flow straits and relatively deep open sea (see Fig. 1).

The object of MOS-1·MESSR data (spatial resolution 50 m) is the observation of oceanic color and land color (see Fig. 2). In this research, level-sliced imagery of ch 1, green visible zone, was produced for the scene from the Sea of Iyo to Hiroshima Bay. Computer Compatible Tape (CCT) digital number for the sea area was 9–15, and vortices were observed in Obatake Strait, Moroshima, Washima, Kudako Channel, Katsurashima Channel and Neko Strait, and water mass distribution was detected in Hiroshima Bay.

The level-sliced imagery was produced by using ch 1 of LANDSAT·TM data (spatial resolution 30

m), whose object is the interpretation of coastal areas in the spectral wave length of visible range from blue to green (see Fig. 3). In the above-mentioned sea areas, vortex and water mass formation were detected at CCT digital number 45-54. But as the wave length was short, it is regarded that some places may have been affected by atmospheric dispersion. Moreover, the temperature distribution of the sea surface was detected from the thermal infrared imagery of ch 6 (spatial resolution 120 m). This distribution shows that in winter, contrary to summer, water in shallow sea areas is cooled off, and high-temperature water is distributed in areas from the Bungo Channel, from which the open sea water (Pacific) flows into the Seas of Iyo and Aki.

2.3. Composition of Satellite Remote Sensing Imagery with Tidal Flow Pattern

In an attempt to grasp the occurrence, location and contour of vortices, mean data for tidal currents during spring tides was converted into vector-typed data, and this was composed with the above satellite analysis of remote sensing to visually interpret the correlation between the two. By composing the tidal flow map at 7 and 9 hours, which seems to correspond to the result of the satellite analysis imagery, the occurrences of tidal flow and vortex can be visualized and interpreted more concretely and clearly. For instance, as shown in Fig. 2, the size of vortex can easily be recognized in proportion to the size of the flow vector. Also, Fig. 3 clearly detects the inflow distribution pattern of the open sea and river in winter, and it is possible to realize the relationship between temperature distribution of sea surface and tidal flow in closed sea areas formed by coastal geographic features.

3. Vortex Motion in Hydraulic Laboratory

The Kármán vortex street behind a circular cylinder in open channel flow is studied. We use an experimental open channel established in the hydraulic laboratory at The Hiroshima Institute of Technology for this study. The width of the open channel is 40 cm and the length is 1200 cm. Streaklines are shown by precipitation of black ink in water. These streaklines reveal Kármán vortex streets (see Figs. 4 and 5). The initially spreading wake shown opposite develops into two paralell rows of staggered vortices. The vortex streets are seen to grow in width down stream.

4. Vortex Motion in Traditional Japanese Art and Life

From the earliest humans to their present-day descendants vortices have fascinated mankind (Lugt, 1983). Until recently, humans had thought that supernatural forces were the causes of vortices.

Thyphoons and hurricanes devastate the shores of Asia and America, and many people die in tornadoes every year. The circulation patterns of the deep sea are as mysterious as ever, and the great astronomical enigmas, such as the origin of the solar system and the structure of galaxies, are unsolved vortex problems. Obviously vortices play a much more powerful role in nature than merely whirling leaves or eddies in a stream. Indeed, vortices are not rare caprices of nature but are essential for the movement of matter. Thus it is not surprising that the vortex concept is of central importance in the history of not only science and philosophy but also of art and life.

Since prehistoric times vortex motion has been used to explain basic phenomena in nature and adopted as the symbols of the origin and basic energy of life. So many designs of vortex motion have appeared in art and life all over the world.

In the following a brief review of vortex motion which appeared in traditional Japanese art and life is presented.

1) Jomon ware (Straw-rope pattern pottery)

Jomon ware (straw-rope pattern pottery) was named after the characteristic patterns on its surface made by the impression of twisted cord (straw-rope). The Jomon culture persisted throughout most of

Japan from c. 10,000 BC to just a few centuries BC, and was for most of that long period an economy of hunters, fishers and gatherers with little settled agriculture and people living in small groups.

One type of the Jomon ware is called the Kaen-gata ware (Blaze-shaped pottery), after the shape like fire burning with flame (see Fig. 6 (d), (e), (f)). This is named by Kanjiro Kondo, the first excavator, with his son, of this type of pottery.

Hideo Nakazawa, the director of NHK, tried to approach from a different agnle, on the hypothesis that "vortices=flow=the energy of nature" (Kato and NHK Team, 1987). To ask the expert's opinion, he showed the replica of the pottery to Prof. Y. Nakayama at Tokai University, an authority in hydraulic engineering. The interpretation of Prof. Nakayama was that the vortex pattern on the surface of Jomon ware was also the pattern of flow, and through the detailed observation, he found the twin-vortex pattern repeated many times. The twin-vortex pattern resembled those obtained in the hydraulic laboratory. Fig. 6 shows the Jomon ware with vortex pattern.

2) Dogu (Clay figures), Gangu (Stone figures) and Ganban (Stone plates)

Dogu is tiny clay figure baked at low temperature. It first appeared early in the Jomon period, and from the middle of the period, dogu had begun to show a clear image of a human being with eyes, nose, body and limbs, and then it disappeared in the Yayoi period. Gangu and Ganban appeared also in the Jomon period. Fig. 7 shows several typical dogu, gangu and ganban with vortex design.

3) Ritual bell (Dotaku)

In the Yayoi period, unlike the Jomon, metal ware was introduced along with the rice from the Eurasian Continent, especially from China. And through the social and cultural changes influenced by the Continental Culture, a person in power appeared in each state (kuni), and glittering metal ware such as the ritual bell (dotaku), sword and mirror, become the symbol of authority and military power. Fig. 8 shows several typical ritual bells with vortex design.

4) Buddhism

Since Buddhism was first introduced into Japan in the 6th century, it has spread throughout the country and there are many masterpieces of Buddhist art. Vortex designs are frequently used in these masterpieces as shown in Figs. 9 and 10.

5) Paintings

One of the characteristics of Japanese painting is supposed to be the ornamentation. Korin OGATA was endowed with exquisite graphic technique and a distinguished sense of ornamentation, and depicted the famous Red and White Plum Blossoms as shown in Fig. 11. In this picture, through his acute observation, a number of vortices in the flow are depicted elaborately and ornamentally. Also, many other painters depicted various patterns of vortex motion in their works.

Fig. 12 shows Hiroshige ANDO's woodcut print of Naruto, the most famous whirlpool phenomena in Japan. It is said that Hiroshige went to Naruto himself to make sketches for this woodcut print. Fig. 13 shows Hokusai KATSUSHIKA's sketch of Naruto.

6) Clothing and Artifacts

Vortex design has been often used for clothing patterns. Fig. 14 shows several excellent designs of clothing. Many excellent vortex designs have also appeared in artifacts as shown in Figs. 15 and 16.

7) Mon (Family crests)

The design of "Tomoe" in the shape of a vortex had been often used for mon (family crests). Two or three vortices are frequently used in a Tomoe pattern as shown in Fig. 17. It may be possible to make the interpretation that Tomoe were used to wish for the prosperity of the family (clan), as several small vortices are united and grown into a larger vortex.

5. Conclusions

Vortex motion in nature and art was studied.

Based on the specification of each set of satellite data, it is possible to extract the oceanic environmental phenomena of the Seto Inland Sea which is characterized by rapid tidal flow and prominent geographic change of the channel. And by composing the spatial information of satellite analysis imagery with the tidal flow information of the vector-typed flow map, it became possible to interpret the location and contour of the tidal vortex and water masses in comparison with the tidal flow.

It seems that remote sensing has become a powerful technique in vortex flow visualization, especially in broad spatial areas such as the ocean.

Designs of vortex motion which appeared in traditional Japanese art and life were studied.

In spite of a brief review of the designs, it was found that vortices have played a great role in traditional Japanese art and life.

Many designs of vortex motion which resembled those obtained in nature and the hydraulic laboratory have appeared in our traditional art and life.

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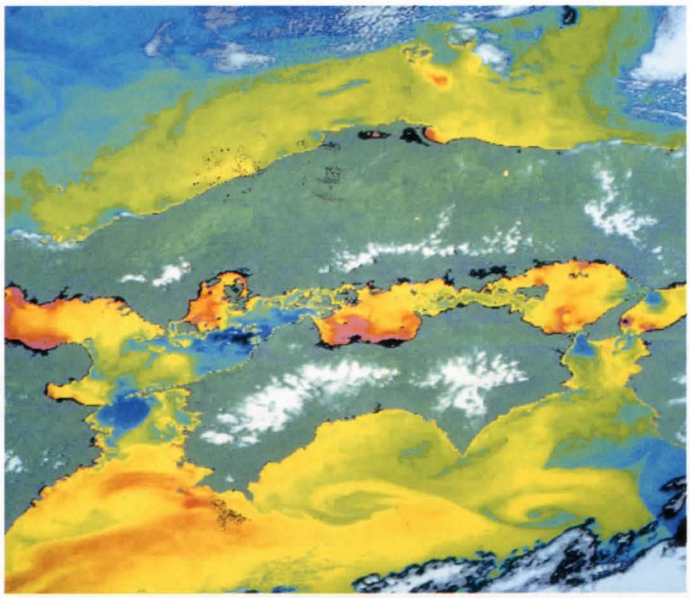
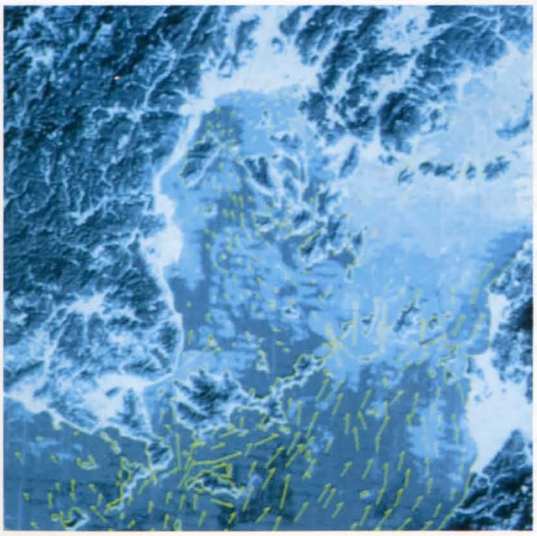


Fig. 1



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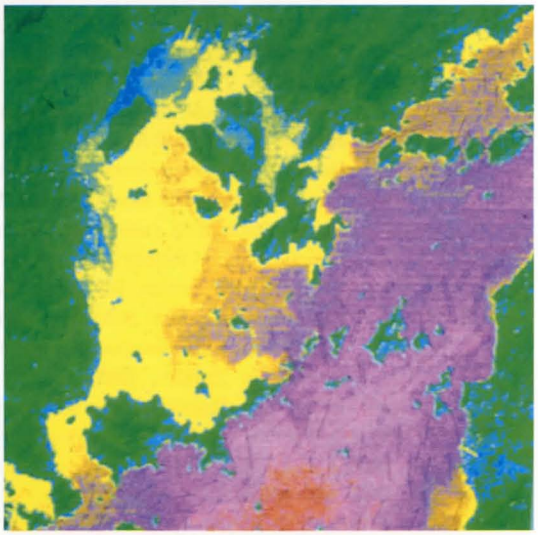

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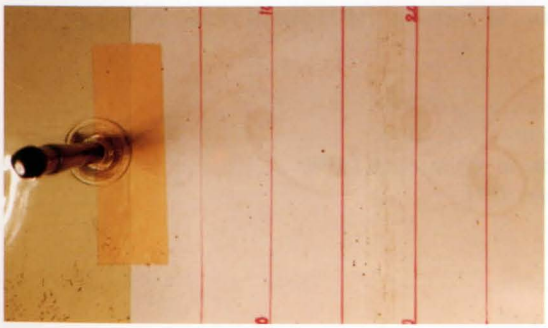

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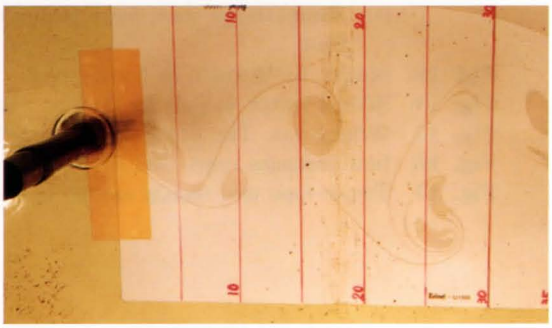

Fig. 5

Fig. 6 (a)

Fig. 6 (b)

Fig. 6 (c)

Fig. 6 (d)

Fig. 6 (e)

Fig. 6 (f)

Fig. 6 (g)

Fig. 6 (h)

Fig. 6 (i)

Fig. 7 (a)

Fig. 7 (b)

Fig. 7 (c)

Fig. 7 (d)

(back)

(front)

Fig. 7 (e)

Fig. 8 (a)

Fig. 8 (b)

Fig. 8 (c)

Fig. 9

Fig. 10

Fig. 11

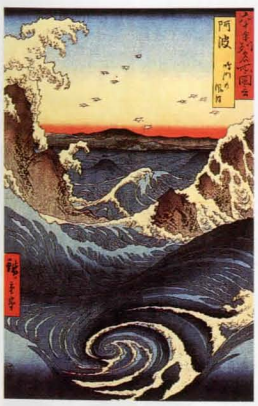

Fig. 12 (a)

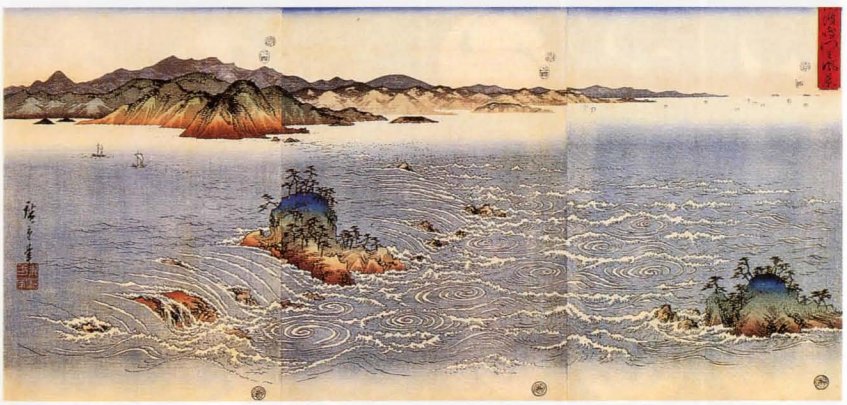

Fig. 12 (b)

Fig. 13

Fig. 15

Fig. 14

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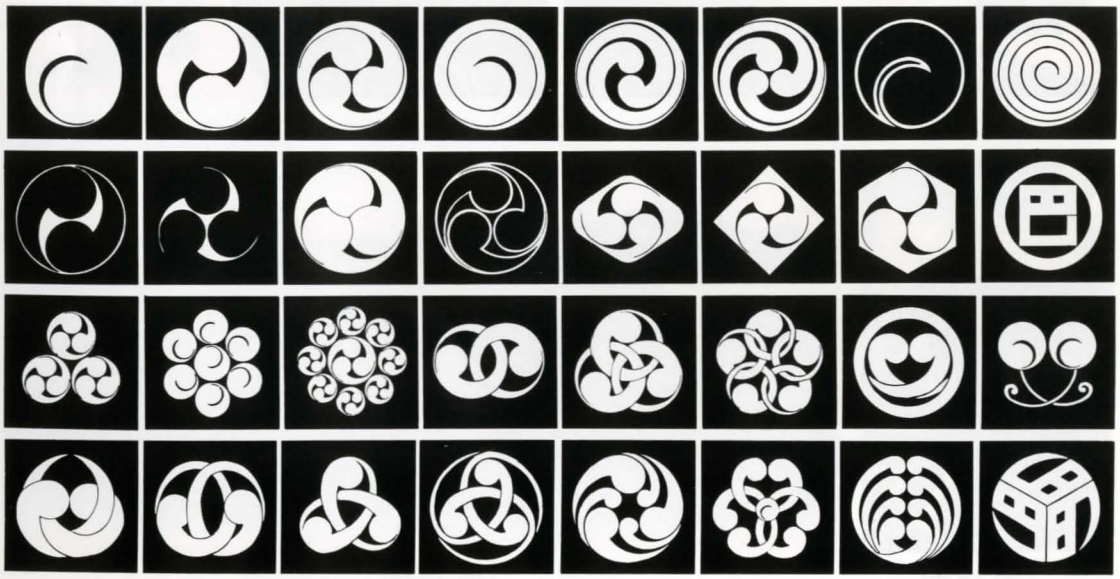

Fig. 17