National Taiwan Normal University

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黑潮發電的可行性

Study on the Kuroshio Power Generation

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Introduction

The earth environment has been polluted extendedly due to the presence of human beings. Until now, the most common energy being used includes petroleum, natural gas, and coal. The emission of carbon dioxide from this kind of energy has caused great impact in the global warming. Especially in summer, the energy utilized for air conditioning comprises of about 50% of all energy we use. Therefore how to develop a green energy is the most important issue in the near future.

Green energy includes solar energy, hydroelectric power, wind power and marine current energy etc. Unfortunately, the technology of solar energy is not advanced enough to replace fossil fuel, and it is too expensive to develop extensively at the present time. The hydroelectric power and wind power cannot fully meet our needs for the energy consumption. After all the considerations, the marine current energy draws people's attention recently.

Ocean, covering over 70% of the Earth's surface, contains the potential of power generation that we should not ignore this. Using marine current to generate power is not only beneficial for our environment but also has potential to generate enough power to satisfy human's needs. The marine current plays an important role to serve as a type of useful green energy.

Purpose and Methods

The Kuroshio off the eastern coast of Taiwan is one of the strongest currents in the northern Pacific Ocean, with its maximum velocity reaching approximately 1.5 meter per second. Being able to utilize this advantage to generate power will bring considerable economic values.

The outcome from the numerical model about currents fits the situation in the real life. In this paper, we use a numerical model to present the speed of the current flow. We mainly use the Kuroshio velocity data off east Taiwan in 2003 to investigate the seasonal variation of the Kuroshio, find the best location to install the turbine, and estimate the potential power generated by the Kuroshio.

Data and Result

The Kuroshio Current is from the eastern coast of Taiwan to 123°E. The depth of current is about 1000 meters. The Kuroshio Current migrates seasonally. In general, the Kuroshio moves closer to the east Taiwan during summer (Fig.1) and seaward in winter (Fig.2). The flow speed of current in summer is faster than that in winter. According to the figures, the speed of Kuroshio in 22.3°N and 23.5°N is considerably fast, and the highest speed occurs in 24.0°N, so these three places will be the appropriate choices to set up the turbines. Generally the appropriate speed of generation is over 0.5 meters per second. Figures 3~8 show the three cross-sections of the Kuroshio off east Taiwan, which is used to estimate the potential Kuroshio power (Fig.3~8). The electricity is estimated by:

$$E=d*A*v^3$$

Where E is the current energy (W), d is the density of sea water (1025kg/m^3), A is the area of the flow (m^2), and v is the flow speed (m/s). Kuroshio has two branches along 22.3°N. The one closer to the coast is easier to set up the turbine. The electricity in both winter and summer respectively is about 1.1GW (1GW = one thousand millions), and it is capable of providing the enough electricity to the Lanyu area.

Along 23.5°N, the electricity in winter is different from that in summer. The electricity in winter is about 8.1GW and in summer is about 9.4GW. The most difference of electricity occurs in 24.0°N, which is 9.9GW in winter and 12.5GW in summer.

If we set up turbines in all these three latitudes, the sum of electricity in summer is about 23.0GW, and in winter is 19.1GW.

Limitations

A few problems of setting turbines:

1. Setting turbines in the ocean needs a lot of manpower, and people cannot work under the sea for a long time, so it will raise the cost.
2. The turbines have to face the damages from the storms (typhoons), especially during summertime.
3. Sea water can corrode the components of the turbines. It will make extra obstruction to reduce the efficiency in power generation.

Marine current power generation can bring significant economic values. However, since setting up the turbines under the sea is extremely difficult, we have to face many challenges if we decide to do this.

Conclusion

1. After setting up the turbines, the generating of Kuroshio can bring up to 23.0GW electricity. This will be about 10 times of energy from the current operating nuclear plants in Taiwan, which is 2.6GW in total from all three power plants.
2. Because there are two branches of Kuroshio in 22.3°N, the one closer to the coast has higher velocities, which contributes electricity of 1.1GW. The electricity is enough to provide the use of the Lanyu Island, so that is a good place to set up the turbine.
3. If we can progress the technology of setting turbines, the Kuroshio power generation will make even more economic benefits and be beneficial to the human living.

Reference

1. 吳朝榮（2010）：臺灣周邊海域之數值模擬。自然科學簡訊，第二十二卷一期，4-9。
2. Hsin, Y.-C. and P.-T. Shaw (2008): Spatial and Temporal Variations of the Kuroshio East of Taiwan, 1982-2005: A numerical study. Journal of Geophysical Research, 113, C04002, doi:10.1029/2007JC004485. [SCI; IF: 3.147, Rank: 11/143]

Figures

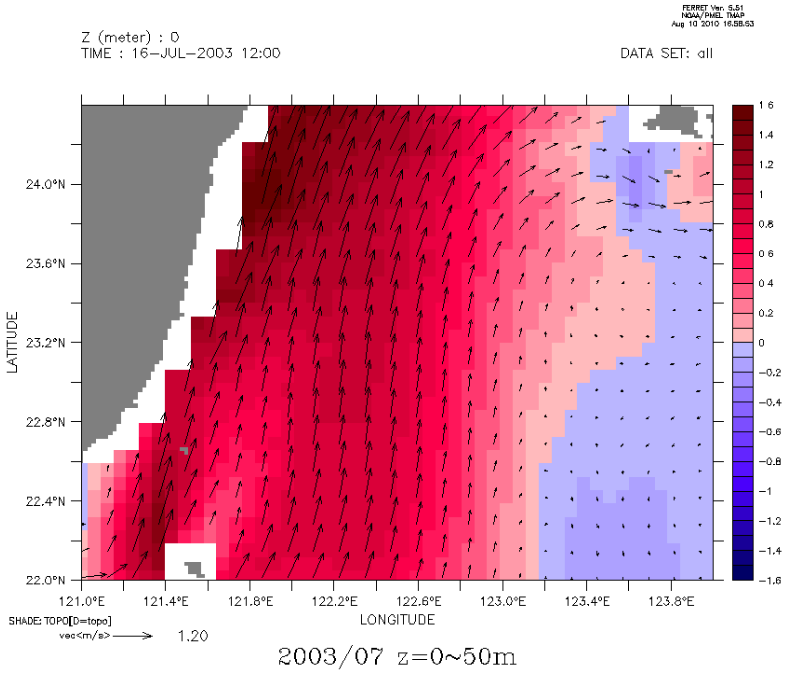

Figure 1　2003 summer current flow speed under the surface to 50m. The red area is the direction to north; the blue area is the direction to south.

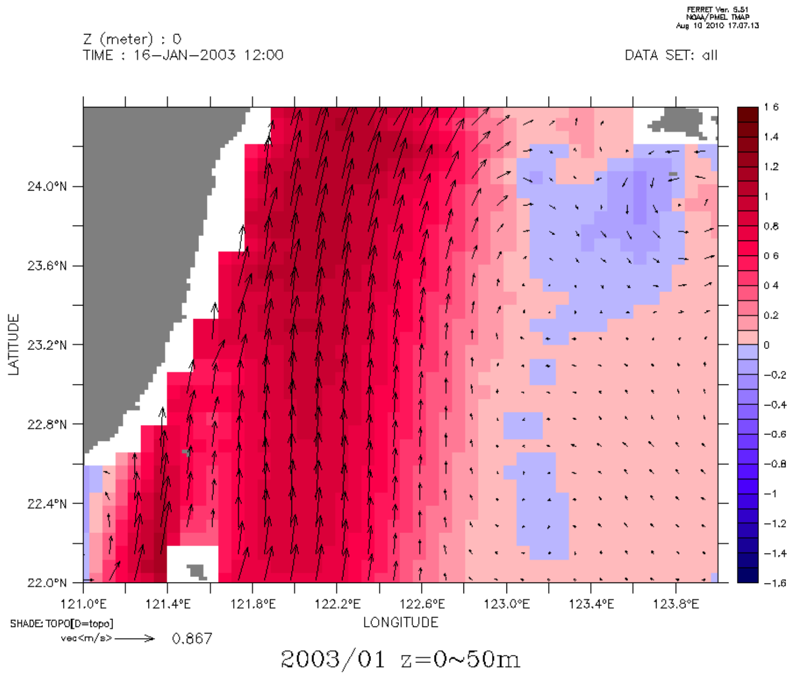

Figure 2　2003 winter current flow speed under the surface to 50m.

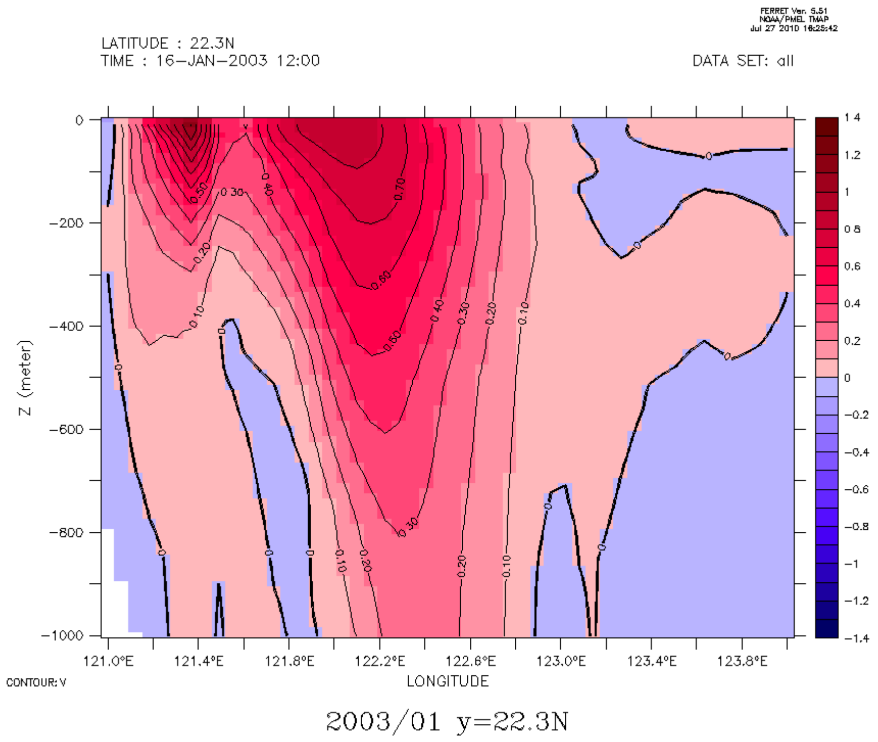

Figure 3 2003 profile in winter in 22.3°N.

The flow speed over 0.5 meters per second can generate efficiently.

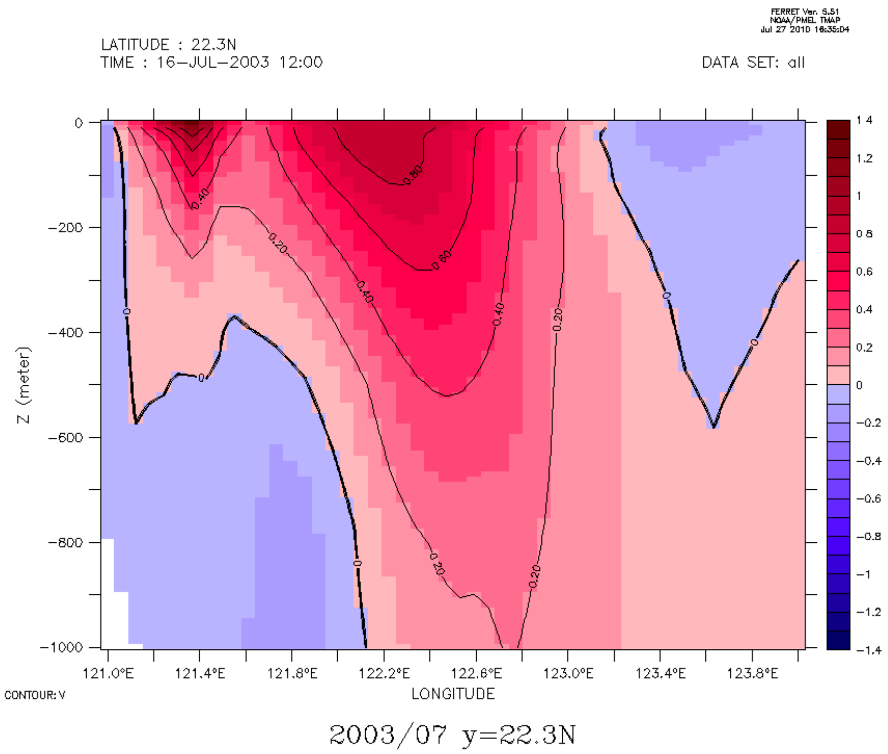

Figure 4 2003 profile in summer in 22.3°N.

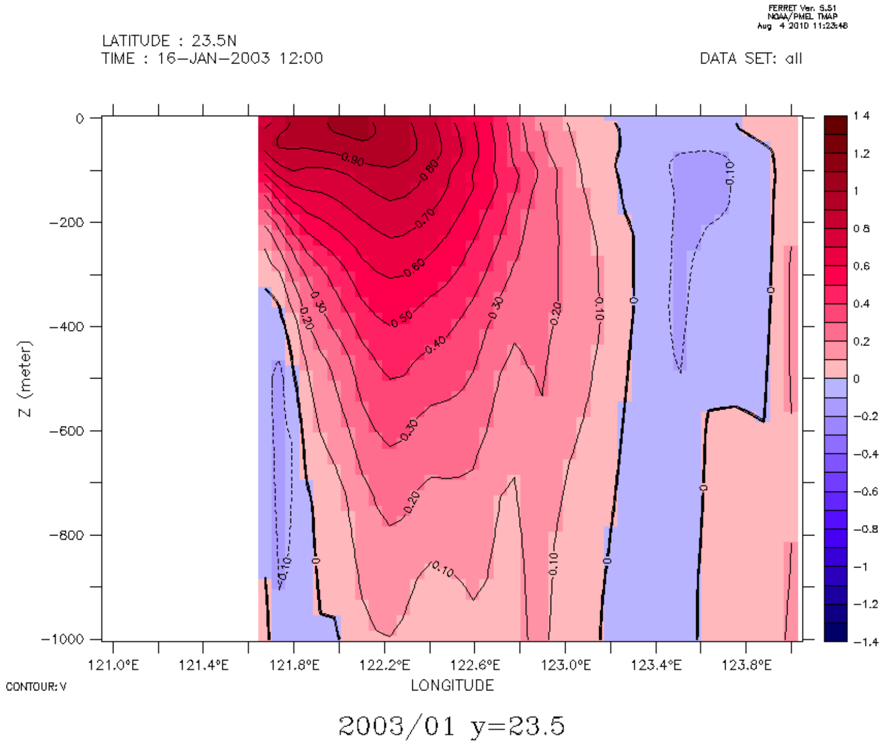

Figure 5 2003 profile in winter in 22.3˚N.

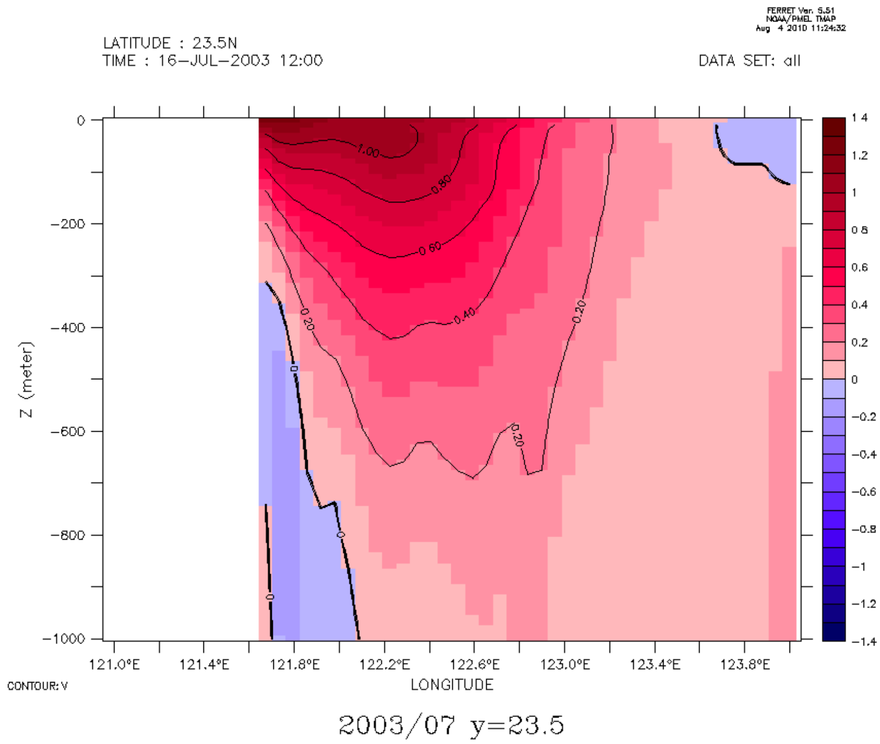

Figure 6 2003 profile in summer in 23.5˚N.

The white area is land.

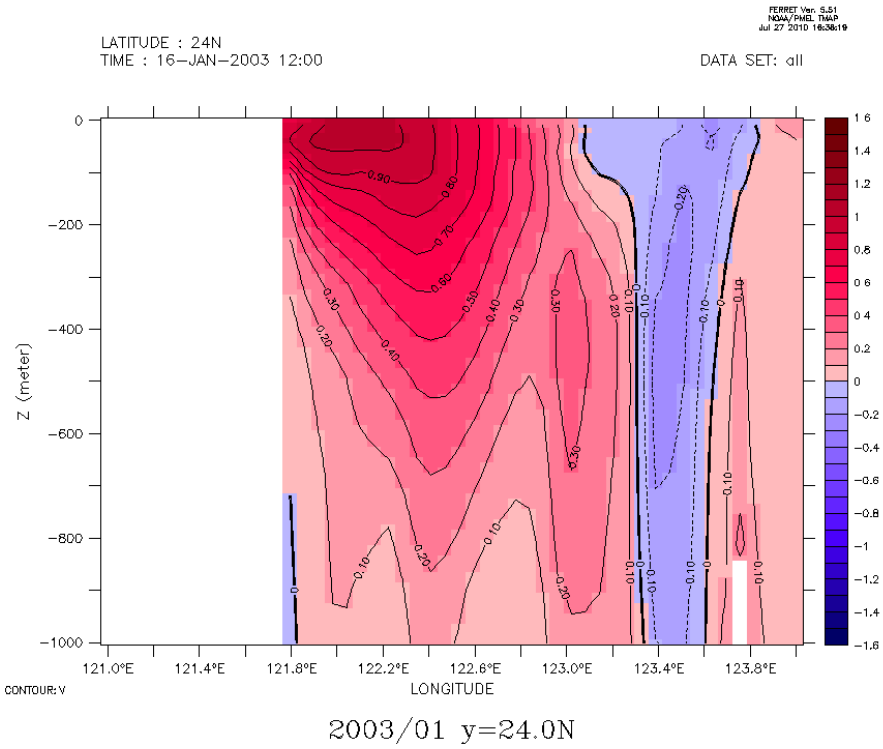

Figure 7　2003 profile in winter in 23.5°N.

The white area is land.

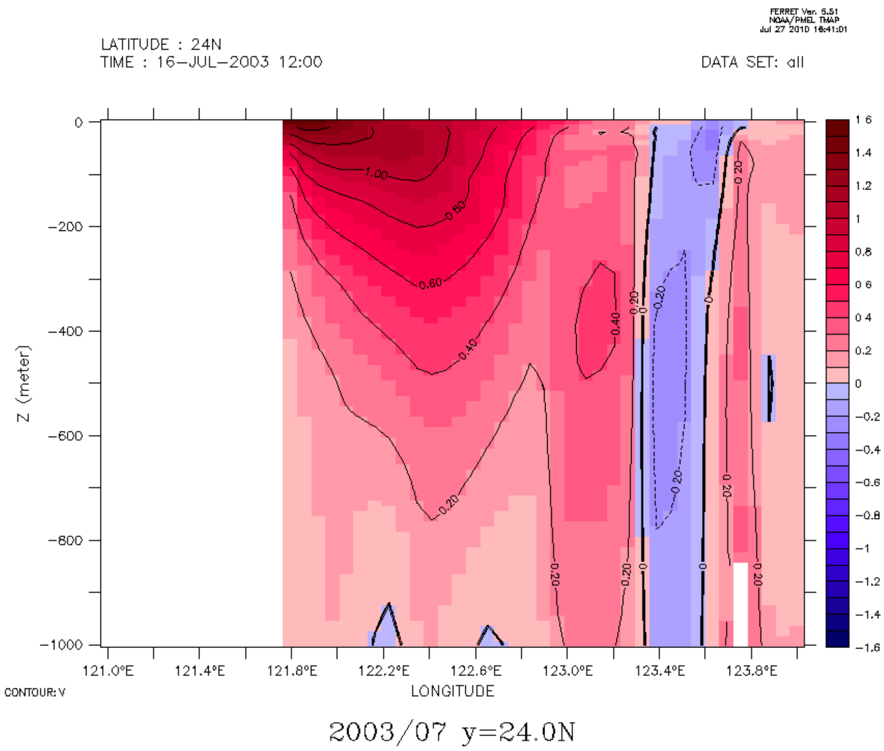

Figure 8　2003 profile in summer in 24.0°N.

The white area is land.