Texas A&M University
Physical Oceangography PhD Programme

RESEARCH PROJECT PROPOSAL

Name of Candidate: Tianxiang Gao

Date of Admission to this programme: October 30, 2017

Full time mode

1. Project Title:

Sinuosity in Geophysical Flows and Its Dynamical Role

2. Project Objectives:

First of all, define and obtain the sinuosity of different regions e.g. Kuroshio Extension, Gulf Stream and its variability with observation data (AVISO adt, for example) and simulation data. At the same time, compare the difference in result between two types of data. Additionally, introduce differential geometry into geophysical fluid dynamics to establish a connection between the geometric pattern of ocean system and its dynamics (control equations).

3. Scope and Background of Research:

Sinuosity, i.e. the length of the current along its course between two points divided by the shortest length between the same points, which is examined in river formation by geomorphologists, is related to the information content and symmetry of the system. Besides, many conservative dynamical systems in mathematical physics describe geodesic flows on appropriate Lie groups. Hence, there is a clear relation between the (differential) geometry and the dynamical system.

In addition, though it is difficult to understand nonlinearity and chaos, the machine learning, or neuro-networks present an empirical approach to a system as a supplement to theoretical analysis. Long short-term memory method is well-suited to classify, process and predict time series given time lags of unknown size and duration between important events. It can be used as a forecast instrument for sinuosity, deepening the understanding of ocean dynamic process, in turn we could describe the behavior of air-sea system better.

4. Research Methodology:

Firstly, this project requires a fine technique or algorithm to extract dimensionless sinuosity (take average width as 1) from absolute dynamic topography. The major problem is to get average width of a current and the axis when the flow swings violently just as Antarctic Circumpolar Current region. Secondly, apply some empirical analysis to examine the dynamic behavior with the help of machine learning. For instance, use cluster method to divide time into different modes and its robustness. Thirdly, apply topological fluid dynamics and nonlinear dynamics to the sinuosity time series and propose a plausible mechanism. Last, synthesize all result above, forecasting the dynamics region like Kuroshio Extension.

5. Project Significance and Value:

It goes without saying that ocean plays a significant role in global climate. Regions as Kuroshio Extension have huge impact on climate through intensive air-sea interaction. Furthermore, the dynamics of those regions determine the upper ocean productivity even fishery via mesoscale physics-biology interaction. Apart from that, unveil the vague dynamic process of ocean will help us understand climate variability (e.g. ENSO). In conclusion, the introduction of differential geometry approach into physical oceanography may start a bright new era.

6. Details of Any External Collaboration:

Generally, this project is highly theoretical, however, it can help a lot if the high resolution data is implemented to obtain sinuosity and other dynamical properties. Moreover, the collaboration with experts with background of mathematical physics, especially of topological fluid dynamics is like to be a huge benefit. Last but not least, a decent compute platform (better with GPU Parallel computing feature) is needed for machine learning.

7. Project Schedule

Aug, 2018 - Aug, 2018 Test and modification of topic focus (peers, supervisors and etc)
Sep, 2018 - Dec, 2018 Establishment of bibliography, Library Research
Jan, 2019 - Mar, 2019 Data collection and preprocessing
Apr, 2019 - Jun, 2019 Calculation and analysis
Jul, 2019 - Sep, 2019 Theoretical modeling
Oct, 2019 - Dec, 2019 Paper drafting and seeking feedback
Jan, 2020 - Apr, 2020 Revise paper and conduct further research if needed

8. Bibliography

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