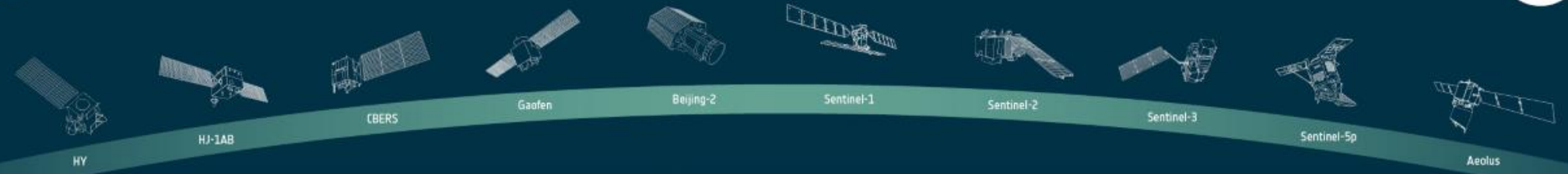


2022 DRAGON 5 SYMPOSIUM

MID-TERM RESULTS REPORTING

17-21 OCTOBER 2022

PROJECT ID. 58393

BIG DATA INTELLIGENT MINING AND VISUAL ANALYSIS OF OCEAN MESOSCALE EDDIES

<INSERT DAY & DATE In PROGRAMME>

ID. 58393

Project Title: Big Data Intelligent Mining And Visual Analysis Of Ocean Mesoscale Eddies

Principal Investigator: Fenglin Tian

Co-authors: Shuang Long, Ying Ma, Shuai Wang

Presented By: Fenglin Tian

Project's Objectives

- **A new algorithm for parallel identification and hybrid tracking method of mesoscale eddies from global satellite altimetry data;**
- **Global long-time-scale eddy identification data products;**
- **Multiple paper.**

EO Data Delivery

ESA Third Party Missions	No. Scenes
1. Sea Level Anomaly (SLA)	ftp
2. Sea Surface Temperature (SST)	ftp
3. Sea Surface Salinity (SSS)	ftp
4. Chlorophyll-a (Chl-a)	ftp
Total: 4 datasets	~600 GB
Issues: none	

EO Data Collection

Variable	Temporal Coverage	Spatial Coverage	Time Scale	Spatial Scale	Download Time
SLA	1993.01~ongoing	Global Ocean	Daily	0.25°×0.25°	2020.07~2020.10
SST	1981.12-~ongoing			0.25°×0.25°	
SSS	1993.01~2020.05			0.083°×0.083°	
Chl-a	1997.09 ~2020.03			4 km	

Result 1: Eulerian Eddy Identification and Tracking

- An algorithm named *EddyGraph* for tracking mesoscale eddy splitting and merging events is proposed and the corresponding dataset of eddy trajectories in the Northwest Pacific for the past 27 years (1993-2019) is available.

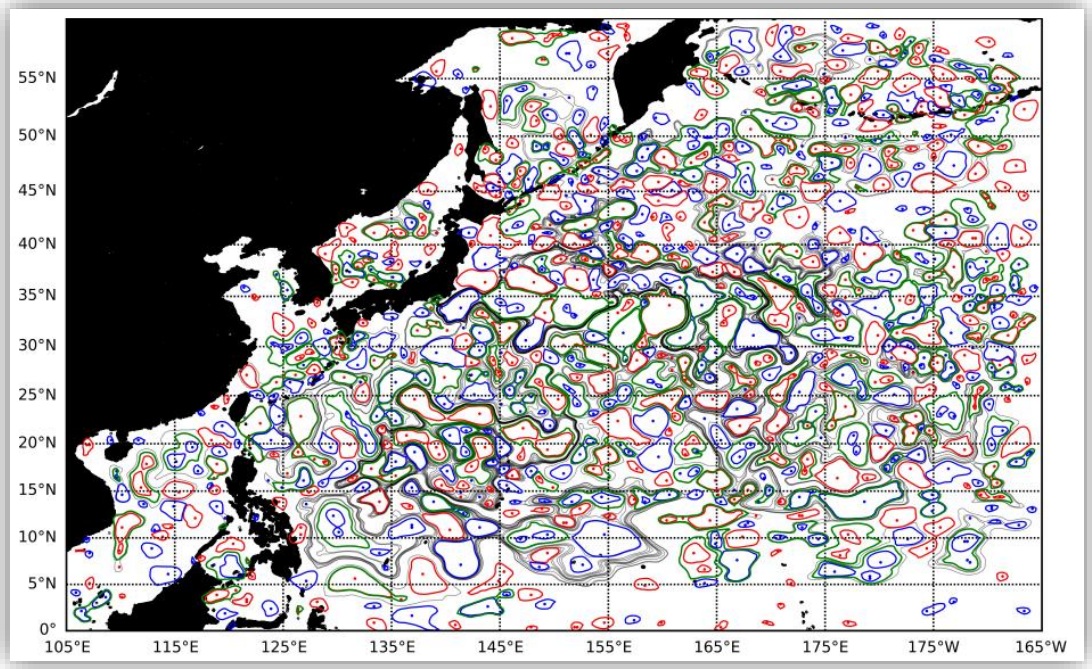


Fig.1 Eddies and eddygoups in northwest Pacific on 20 Jul 2000. The red (blue) lines represent AEs (CEs). Eddygroups (green lines) whose children are all eddies and other eddygroups (black lines).

Tian et al., *Remote Sensing*, 2021.

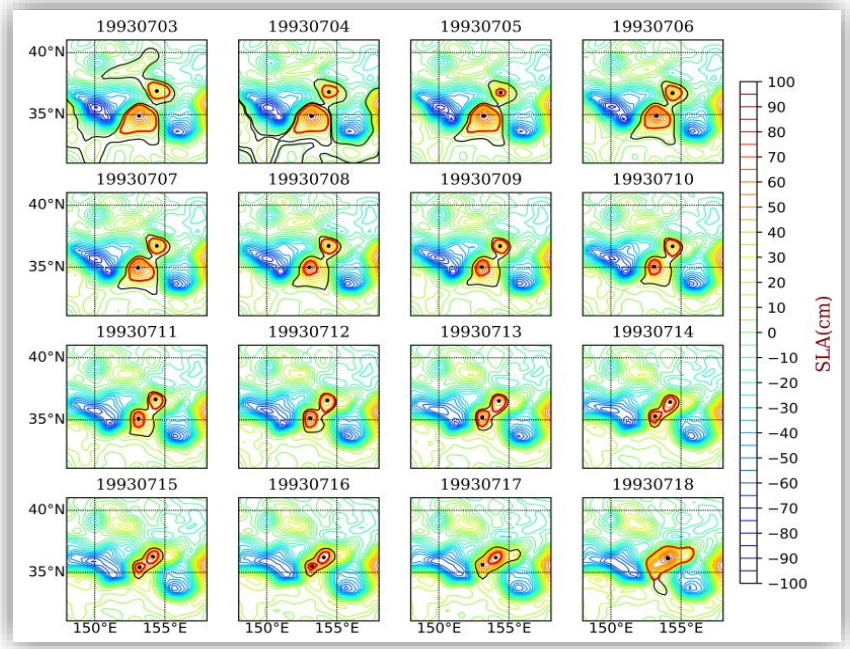


Fig.2 A merging event of AE. Mononuclear eddies/multicore eddies and eddygroups are represented by red lines and black lines, respectively, while the eddy cores of mononuclear eddies/multicore eddies and eddy seeds are expressed by black dots.

Result 2: Automatic Recognition Algorithm of Global Mesoscale Dipoles

- An automatic recognition method of global mesoscale dipoles is proposed by using the K–D tree for cutting space.
- Through analyzing typical fast propagation dipoles, it is found that the dipole eddies cause the change of the marine environment steadily and has an internal uniform temperature and salinity structure.

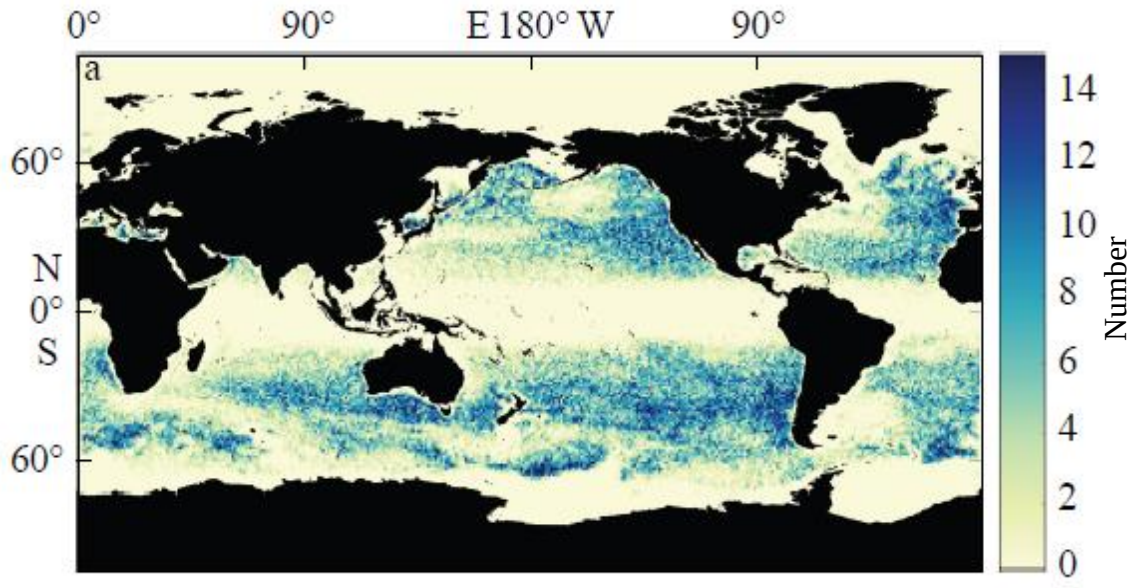


Fig.3 Distribution of the number of global dipoles with cumulative pairing days over 60 days.

Tian et al., *Haiyang Xuebao*, 2021.

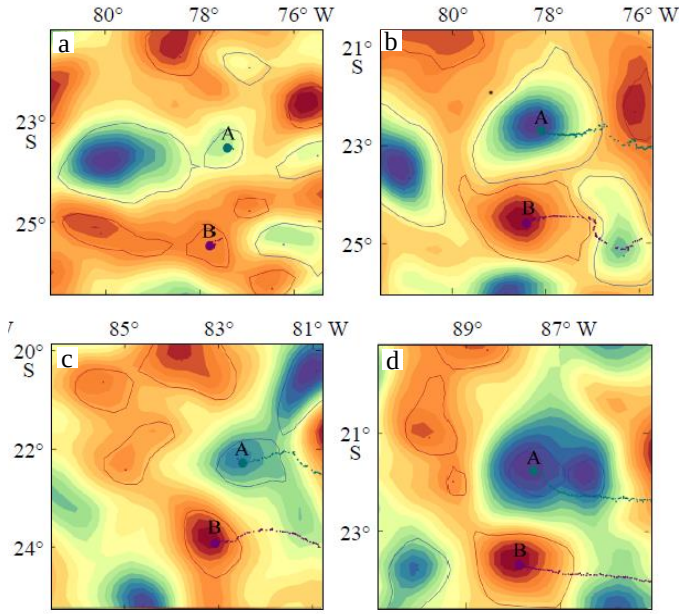


Fig.4 A mesoscale dipole on 7 Jan, 16 Apr, 2 Sep and 26 Dec 2015. The shaded color represents SLA (unit: cm). A(B) is an AE (a CE). The bold dotted lines represent their historical track.

Result 3: Black-hole eddy on material transport in the Western Pacific

- Using the method of elliptic Lagrangian Coherent Structures (eLCSs) and choosing a targeted eddy (Eddy A) in the Western Pacific Ocean to analyze. Sea surface temperature, sea surface salinity and chlorophyll concentration data are used to verify that the Eddy A is coherent in horizontal material transport.
- The temperature, salinity and dissolved oxygen (DO) data obtained by Argo in different depths are used to prove the coherence in vertical of Eddy A.

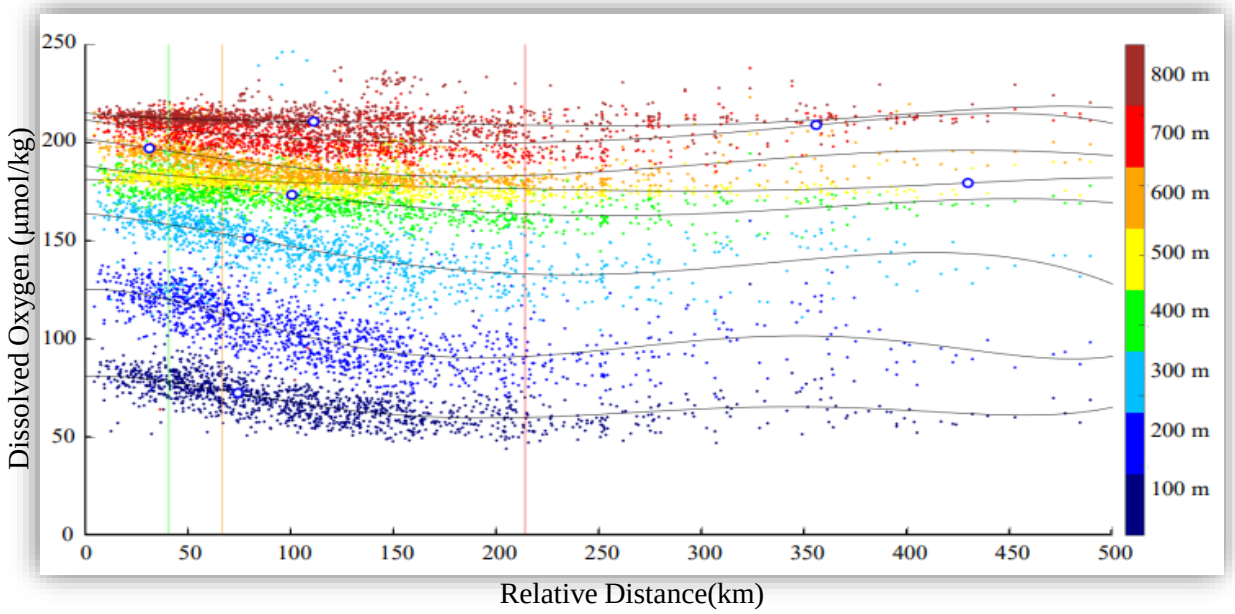


Fig.5 The statistical graphs of the relative distance between the Argo data point of DO and the eddy center. The color of points represents the depths.

Tian et al., *Haiyang Xuebao*, 2021.

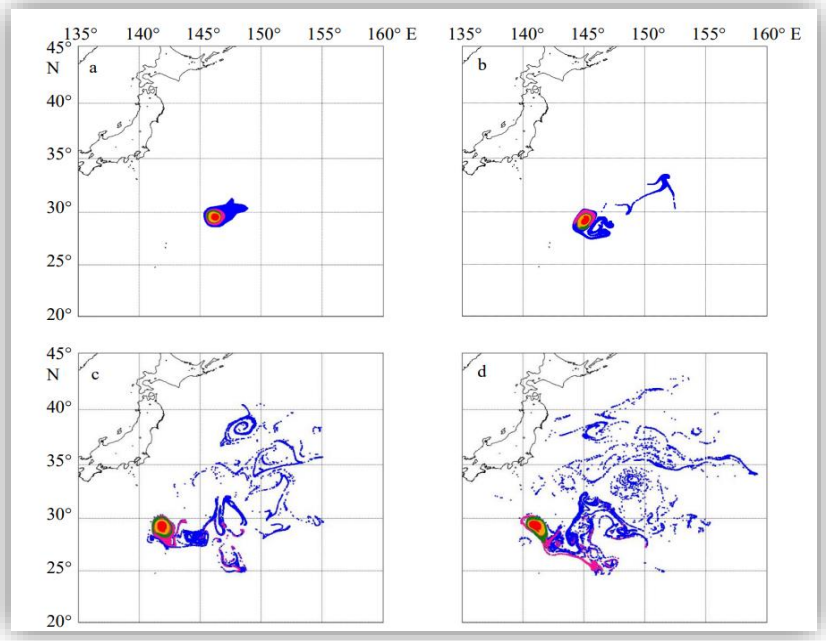


Fig.6 Eddy boundaries of the black-hole (pink, green, orange, and red are T=30 d, 60 d, 90 d, and 120 d), and Eulerian C (blue) filled with virtual particles moves with the geostrophic.

Result 4: Lagrangian eddies in the Northwestern Pacific Ocean

- The Lagrangian eddies in the western Pacific Ocean are identified and analyzed based on Maps of Sea Level Anomaly data from 1998 to 2018.
- The transportation volume of the Lagrangian eddy is calculated quantitatively, and several major transport routes have been identified.

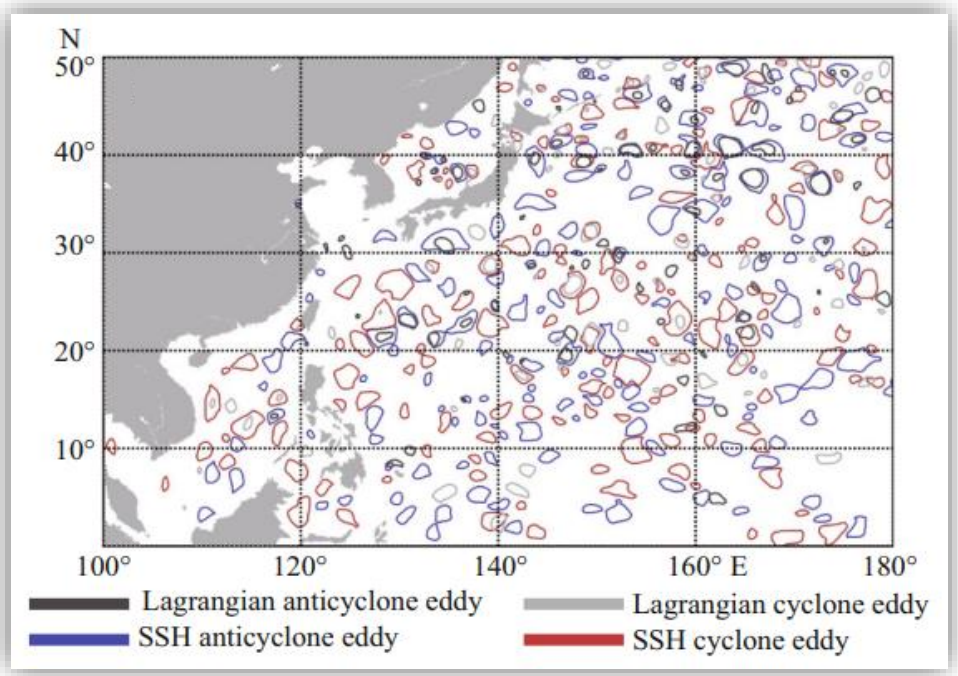


Fig.7 Lagrangian eddies in the western Pacific Ocean on 1 Jan 2018.

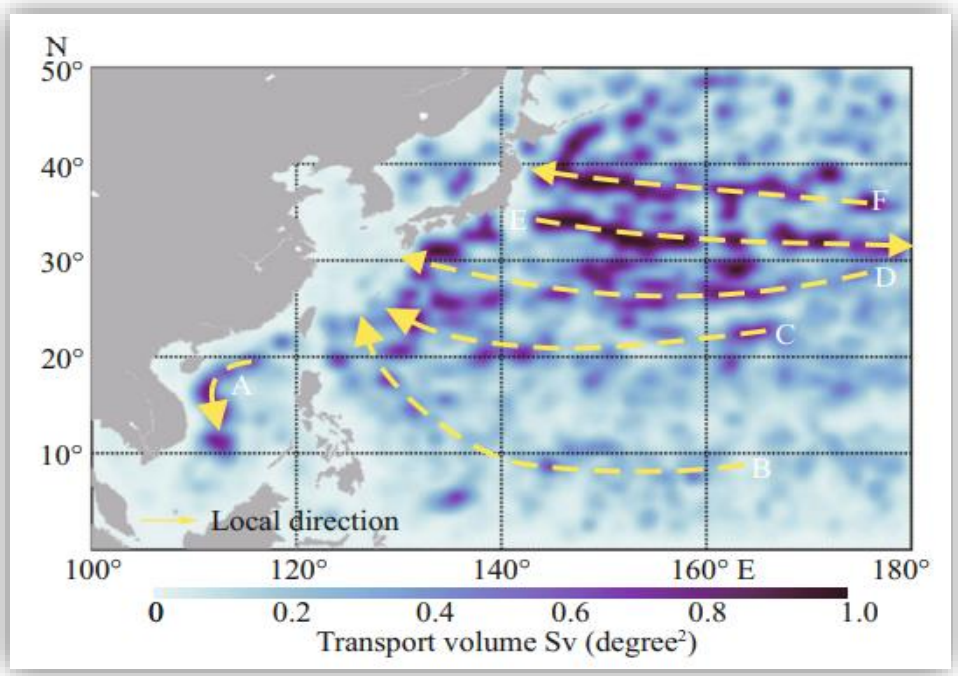


Fig.8 Average transport intensity of Lagrangian eddies in the Northwest Pacific. The large yellow arrows indicate the main transport corridors of Lagrangian eddies.

He et al., *Journal of Oceanology and Limnology*, 2022.

Result 5: Orthogonal parallel detection of global Lagrangian vortices

- A multiprocess CPU-based rotationally coherent Lagrangian vortices (RCLVs) algorithm is presented that makes the extraction process approximately 20 times faster than a nonparallel algorithm.
- Based on the orthogonal parallel architecture, a long-time-scale global RCLVs product from 1993 to 2019 containing 52,567 vortices is produced with a 90-day time interval.

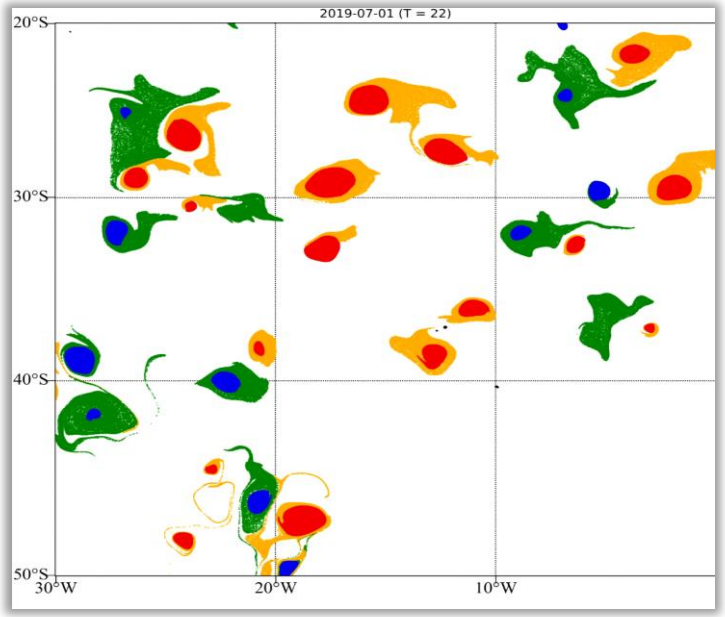


Fig.9 Cyclonic RCLVs (blue), anticyclonic RCLVs (red), cyclonic Eulerian eddies (green), and anticyclonic Eulerian eddies (orange) are filled with virtual particles on the original detection date (1 Jul 2019, T=90 days) extracted by the orthogonal parallel method using the LAVD contours.

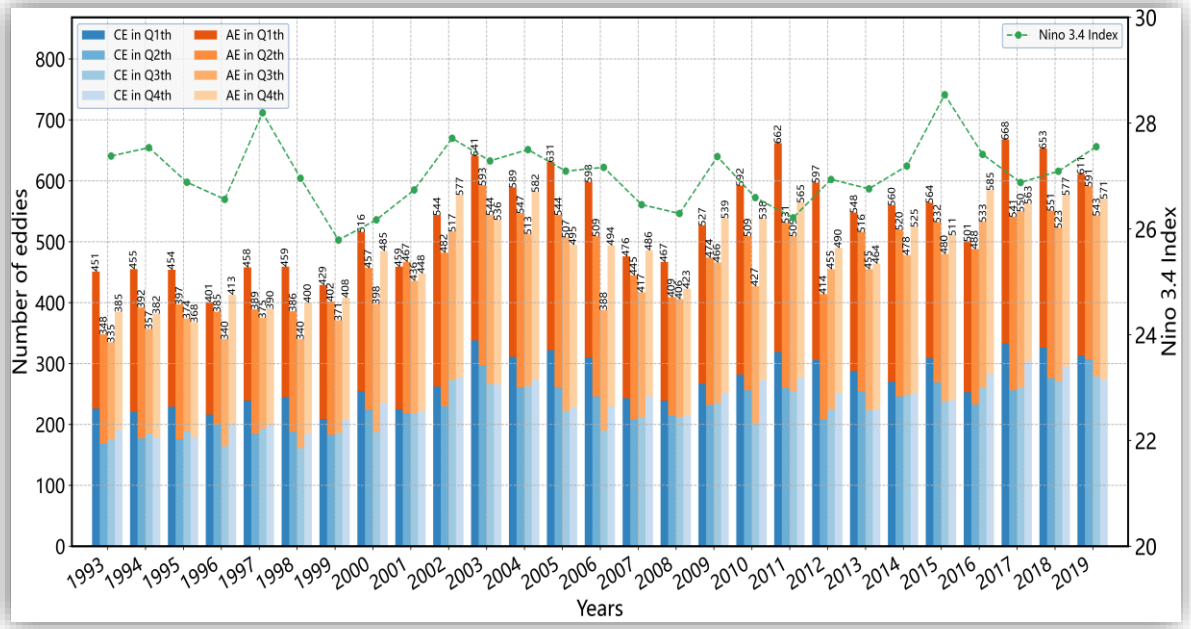


Fig.10 Histogram of the number of eddies in different quarters spanning 27 years. The green dotted line represents the Nino-3.4 index.

Tian et al., *Journal of Atmospheric and Oceanic Technology*, 2022.

Result 6: Mesoscale Eddy 3D Structure Visualization

- Based on volume rendering technology, with numbers of feature points, feature color mapping and the line shape to design a standard morphological model of the transfer function for ocean pressure anomaly data. It can intuitively and effectively represent the 3D pressure anomaly structure of mesoscale eddy.
- Optimized the ray casting algorithm, the rendering efficiency is increased by 2 times compared with the traditional algorithm without reducing the rendering quality.

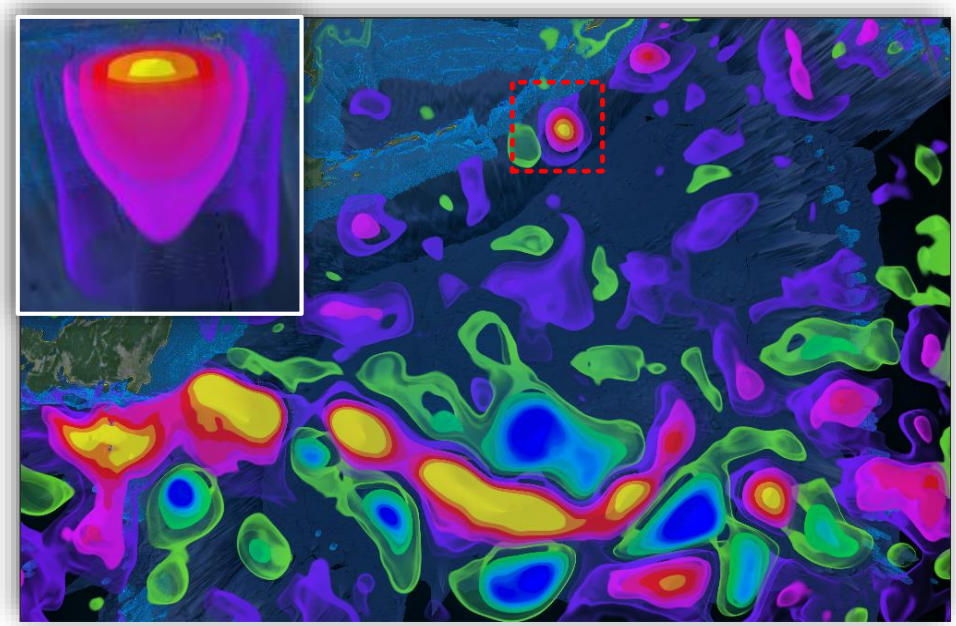


Fig.11 Visualization of eddy pressure anomaly structure. The upper left is the enlarged side view of the eddy marked in the red frame area.

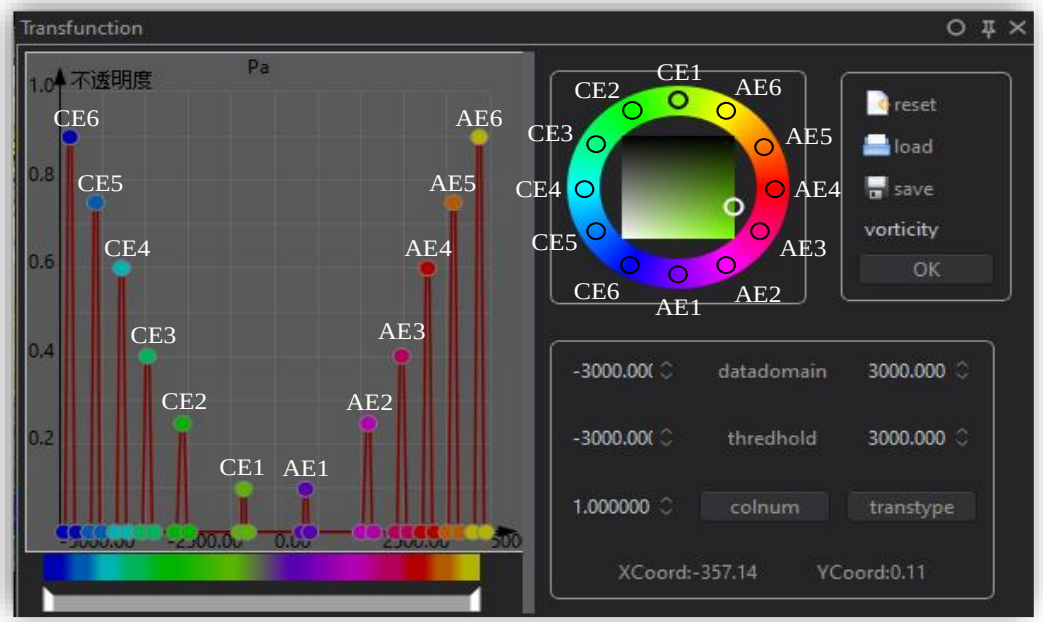
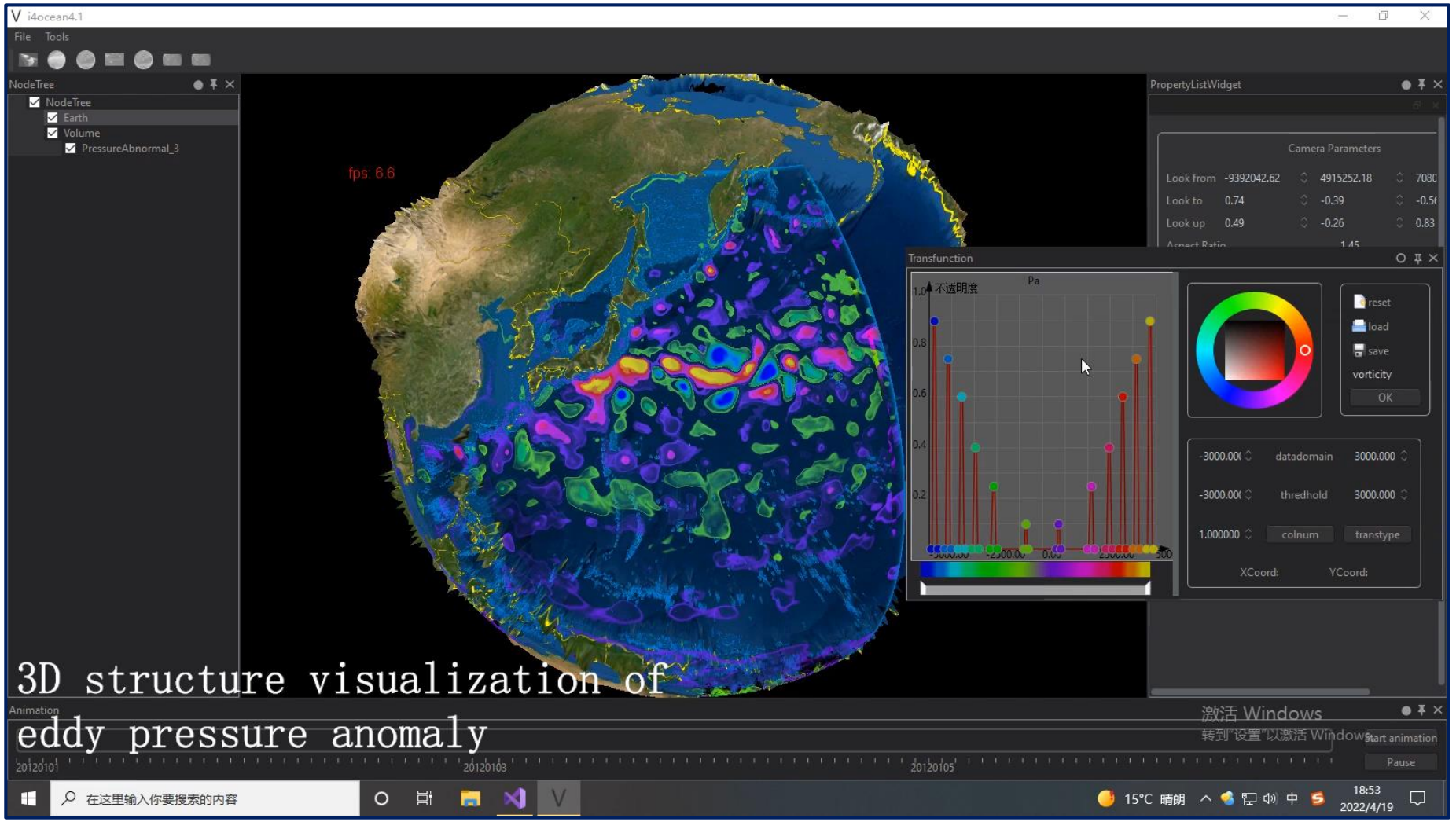


Fig.12 Transfer functions of eddy multi-structural features.

Tian et al., *Marine Science Bulletin*, accepted.

Result 6: Mesoscale Eddy 3D Structure Visualization



Result 7: Ocean current field visualization

- Based on MSLA and Omega3D ocean data, we propose a visualization scheme of ocean current field oriented to ocean mesoscale eddies. By using the interactive transfer function and spatiotemporal continuous visualization framework, we have realized high perception 2D vortex visualization and 3D vortex visualization, which is convenient for users to intuitively understand ocean flow field data.

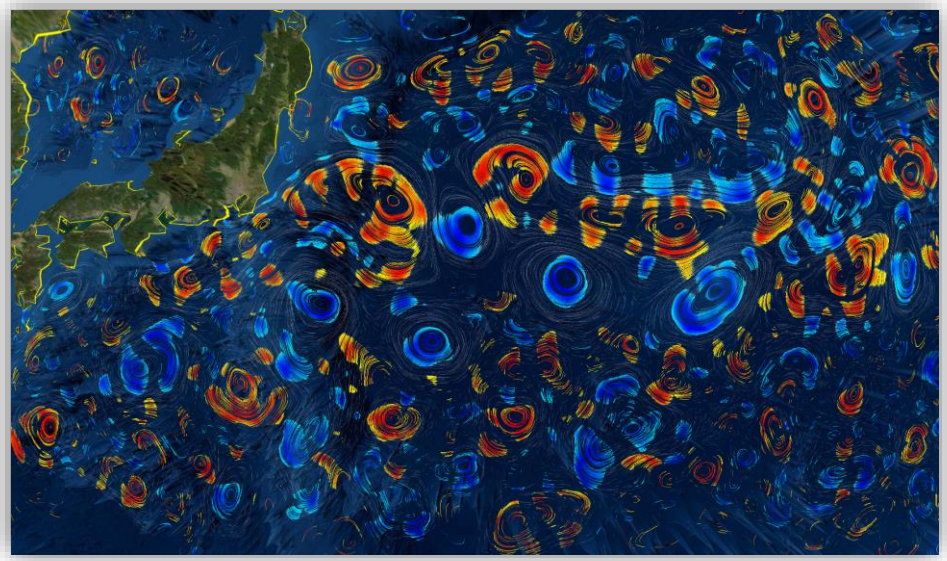


Fig.13 Effect diagram of 2D vortex visualization on 1 Jan 2012.Cold colors represent cyclonic vortices and warm colors represent anticyclonic vortices.

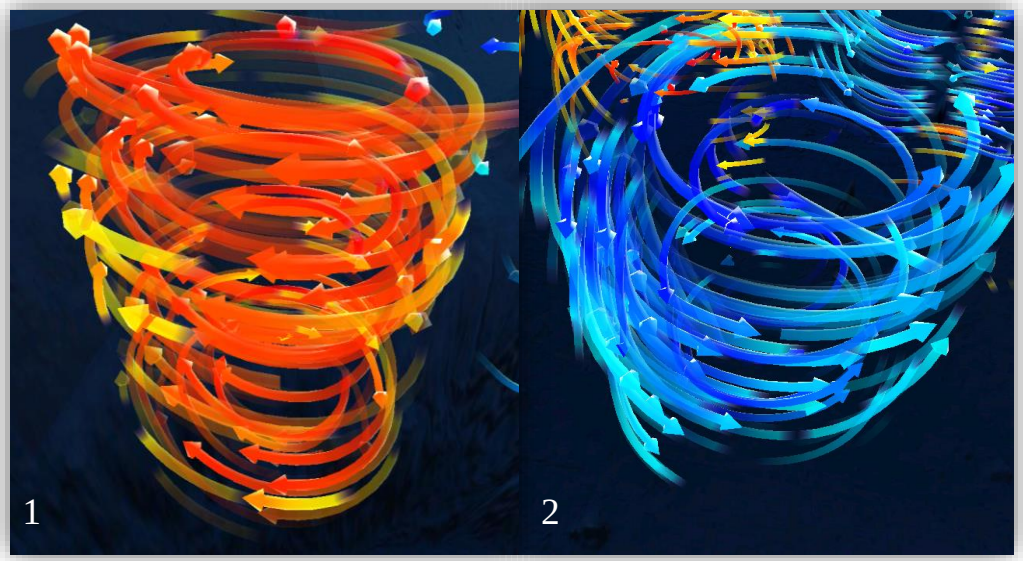
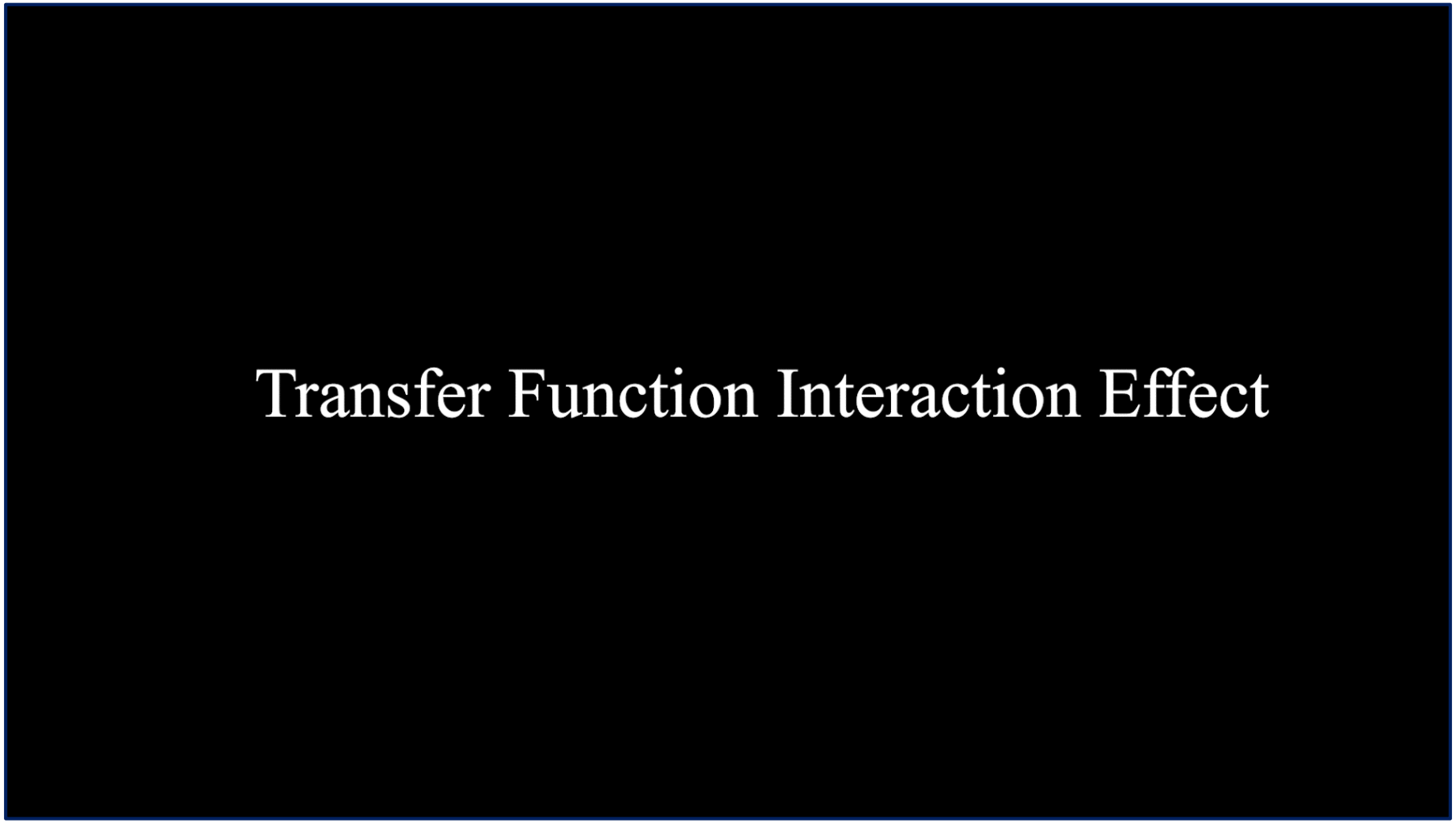


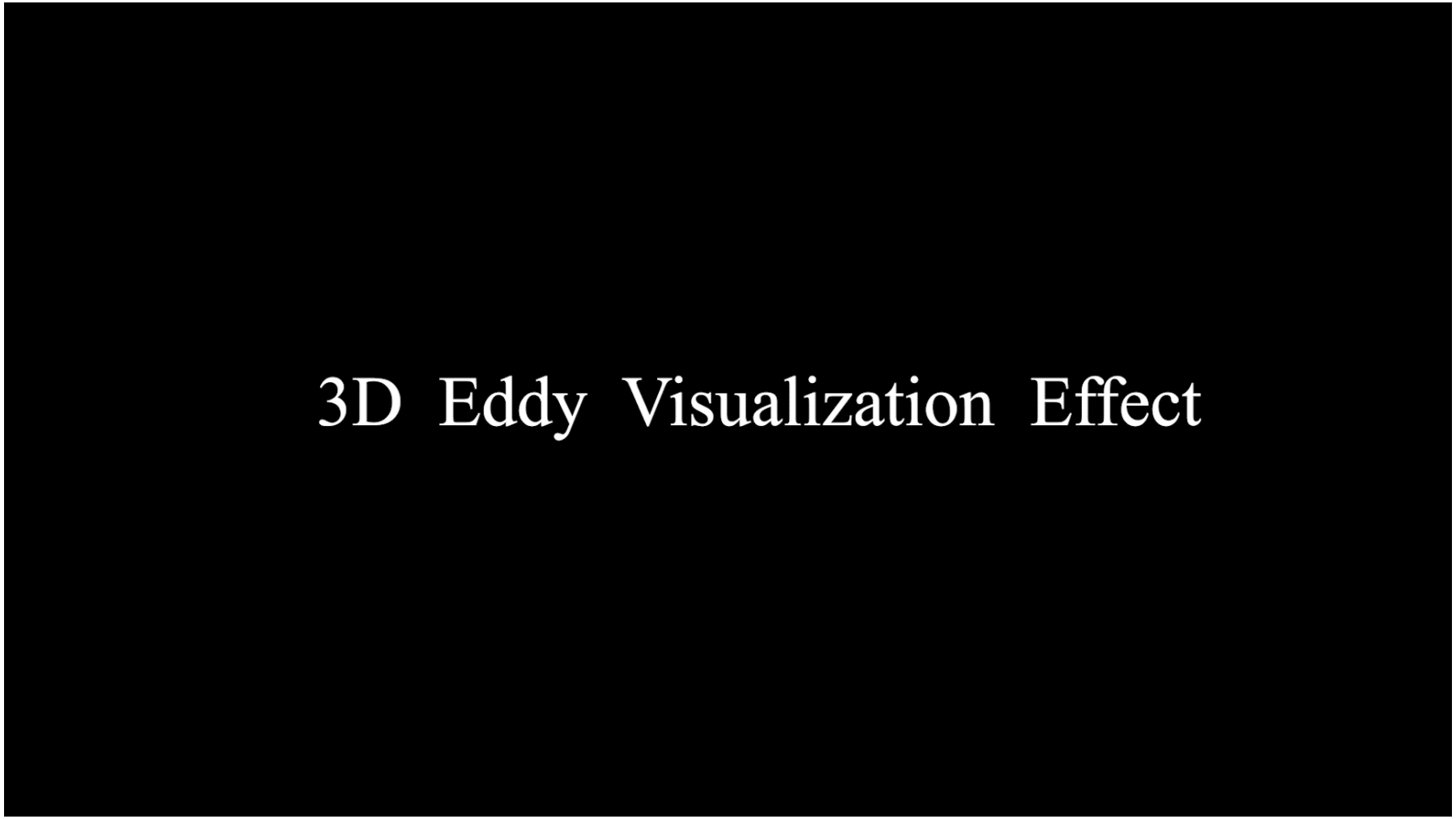
Fig.14 Effect diagram of 3D vortex visualization on 11 Jan 2012. No. 1 is the anticyclone vortex and No. 2 is the cyclone vortex.

Tian et al., *Marine Sciences*, accepted.

Result 7: Ocean current field visualization



Result 7: Ocean current field visualization

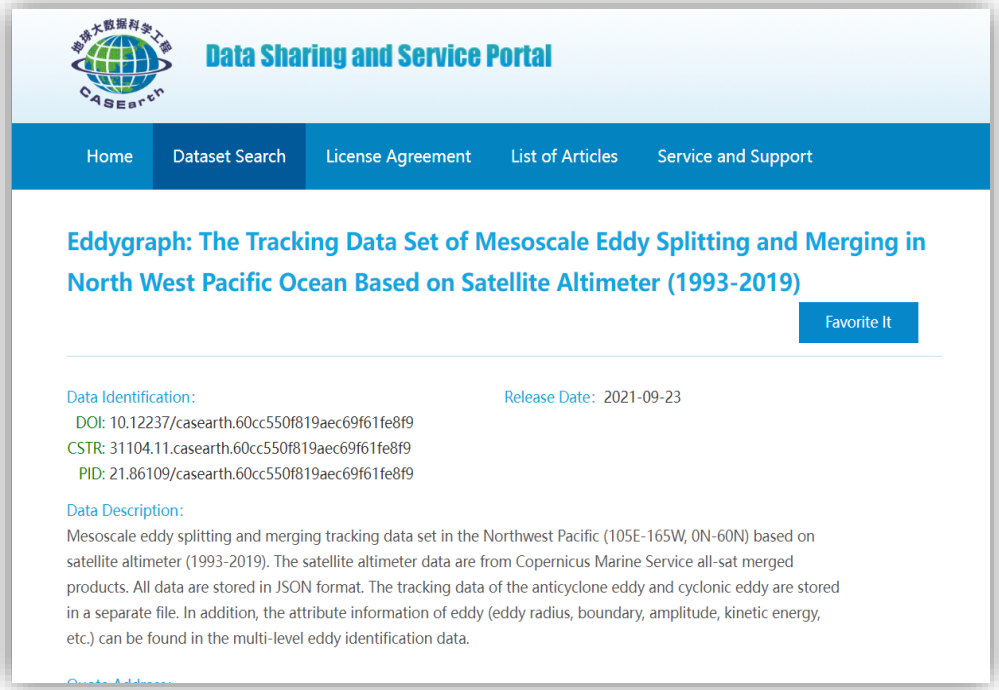


Summary of Related Results

Number	Articles
1	Tian F, Li Z, Yuan Z, et al. *EddyGraph*: The Tracking of Mesoscale Eddy Splitting and Merging Events in the Northwest Pacific Ocean[J]. Remote Sensing, 2021, 13(17).
2	Tian F, Yang X, Liu X, et al. Analysis of black-hole eddy on material transport in the western pacific[J]. Haiyang Xuebao, 2021, 43(12): 1–14.
3	Tian F, Yuan Z, Liu W, et al. An automatic recognition algorithm of global mesoscale dipole based on eddy tracking data[J]. Haiyang Xuebao, 2021, 43(1): 122–136.
4	Han G, Tian F, Ma C. The geometry of mesoscale eddies in the South China Sea: characteristics and implications[J]. International Journal of Digital Earth, 2021, 14(4), 464-479.
5	He Q, Tian F, Yang X, et al. Lagrangian eddies in the Northwestern Pacific Ocean[J]. Journal of Oceanology and Limnology, 2022, 40(1):66-77.
6	Tian F, Wang M, Liu X, et al. SLA-based orthogonal parallel detection of global rotationally coherent Lagrangian vortices[J]. Journal of Atmospheric and Oceanic Technology, 2022, 39(6): 823-836.
7	Tian F, Mao Q, Zhang Y, et al. i4Ocean: transfer function-based interactive visualization of ocean temperature and salinity volume data[J]. International Journal of Digital Earth, 2021, 14(6):23.
8	Tian F, Wang H, Liu W, et al. Real time visualization of 2D/3D whole spatiotemporal continuous ocean mesoscale vortices flow field based on transfer function[J]. Marine Sciences.(Accepted)
9	Tian F, Cheng Y, Liu W, et al. Visualization of three-dimensional thermohaline and pressure anomaly structure of ocean eddies based on standard morphological models of transfer functions[J]. Marine Science Bulletin. (Accepted)

Summary of Related Results

Number	Datasets
1	*Eddygraph*: The Tracking Data Set of Mesoscale Eddy Splitting and Merging in North West Pacific Ocean Based on Satellite Altimeter (1993-2019). DOI: 10.12237/casearth.60cc550f819aec69f61fe8f9
2	Identification and Trajectory Data Set of Global Ocean Rotating Quasi-ordered Lagrange Vortices Based on Satellite Altimeter. DOI: 10.12237/casearth.6184d24d819aec4095ff4d7f



Next-stage Schedule and Deadlines

Expected Results	Time
Global product development	**2022.09 – 2022.12**
Summary and publication of achievements	**2023.01 – 2023.05**
Projects completion, final results publication and reporting	**by 2023.05**

Chinese Young scientists contributions in Dragon 5

Name	Institution	Poster title	Contribution
Xiaokun Yang	Ocean University of China	Big Data Intelligent Mining and Visual Analysis of Ocean Mesoscale Eddies	Black-hole eddy on material transport in the Western Pacific
Zhonghao Yuan	Ocean University of China		Automatic Recognition Algorithm of Global Mesoscale Dipoles
Zhijiao Li	Ocean University of China		Eulerian Mesoscale Eddy Splitting and Merging Events
Qiu He	Ocean University of China		Lagrangian eddies in the Northwestern Pacific Ocean

THANKS !