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SEISMIC SHIFTS IN OCEANIC UNDERSTANDING

IOCAS research into the fundamental forces shaping the oceans has improved our understanding of major Earth processes, from climate change, to earthquakes.

Covering about 71% of the planet, the ocean is pivotal in shaping global climate, ecosystems, and natural resource availability. Focusing on ocean circulation and geological processes in the Western Pacific, researchers at the Institute of Oceanology, Chinese Academy of Sciences (IOCAS) have been seeking to understand their environmental effects, supporting disaster prevention and resource conservation efforts.

LINKING OCEAN CIRCULATION AND CLIMATE CHANGE

Ocean currents are essential to global heat transport, atmosphere cycle regulation, temperature, and climate patterns. Particularly, the currents flowing along the western boundaries of the major ocean basins, known as the western boundary currents (WBCs), attract much attention, as they are more powerful, and mostly transport heat from the tropics to the polar regions. Yet, the complex Pacific WBCs, with multiple boundary currents colliding, have not been adequately studied, despite wide recognition of their importance. Researchers at IOCAS's Key Laboratory of Ocean Circulation and Waves have made WBCs a central focus.

The Pacific WBCs, associated with the largest heat and moisture supply to the atmosphere over the Pacific basin, influence processes such as the El Niño Southern Oscillation (ENSO), which severely disrupts worldwide weather patterns and creates extreme events, and the Indonesian Throughflow (ITF), which refers to the transfer of water from the Pacific to the Indian Ocean, and Asian monsoons. Due to their direct connections with seas bordering China, Pacific WBCs are crucial to China's climatic events, such as typhoon, flood, and drought.

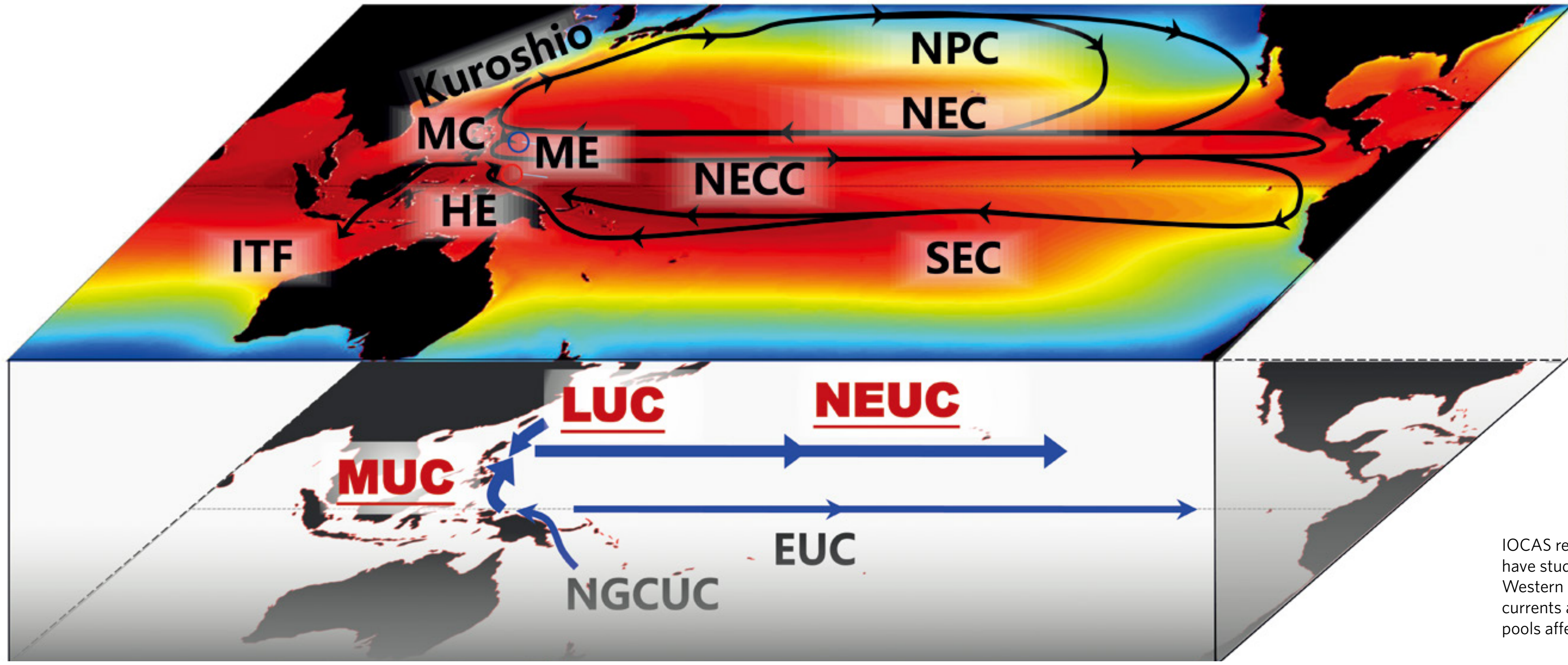
In a *Nature* article published in 2015, IOCAS researchers reviewed the structure and variability of the Pacific WBCs, and evaluated their far-reaching climatic impacts. They showed that the currents move north and south simultaneously on seasonal and interannual timescales. Yet, how they are affected by global warming is unclear. IOCAS modelling of climate changes, is shedding light on the ENSO forecast, disaster control, marine environment protection, and sustainable use of marine resources.

To understand the heat and mass balances of the Pacific, and to produce a more reliable projection of Pacific WBCs and climate change, IOCAS initiated the Northwestern Pacific Ocean Circulation and Climate Experiment (NPOCE) programme to engage international collaboration.

Data-driven observations, enhanced by remote sensing, ocean system simulation and modelling, facilitate the key laboratory's studies on ocean circulation, wave dynamics, disaster prediction and risk evaluation. IOCAS has established a comprehensive Western Pacific observation network, which is the first to cover all major current systems in the region, leading to fundamental discoveries.

Fed by more than 30 subsurface moorings, and capable of real-time data transmission at some mooring sites, this platform has enabled safe data transmission from 6,000 metres below the ocean surface, and the research has garnered intellectual property rights.

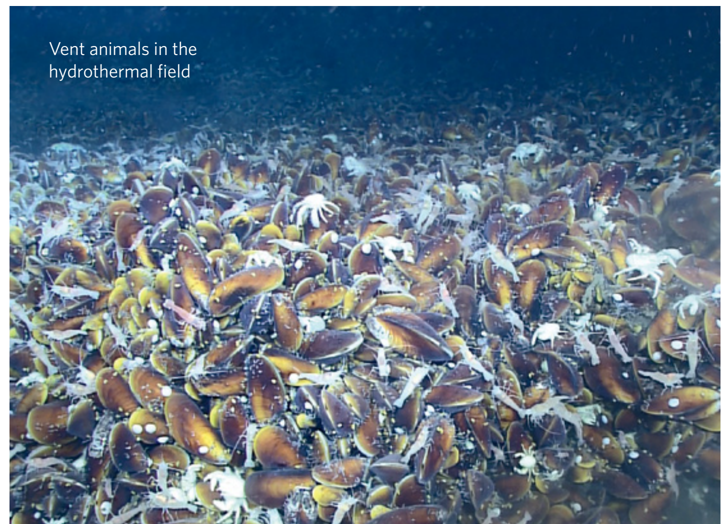
The laboratory has also been developing ocean-atmosphere coupled models for ENSO studies. One of them, the Intermediate Coupled Model (ICM) for the tropical Pacific, has been routinely used for real-time ENSO predictions. In 2015, this model was named IOCAS ICM, making sea surface temperature predictions.



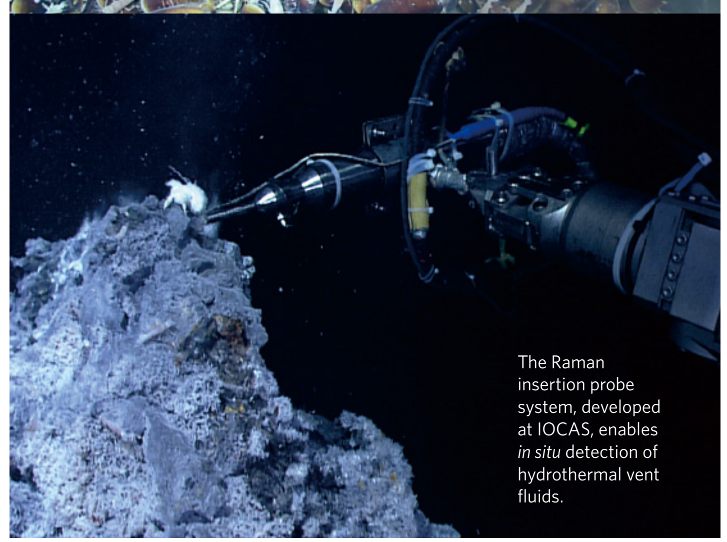
IOCAS researchers have studied how Western Pacific ocean currents and warm pools affect climate.

EXPLAINING MARINE GEOLOGY AND THE ENVIRONMENT

IOCAS's Key Laboratory of Marine Geology and Environment has also studied the role of oceans in climate change, through a historic geologic lens. They were the first to demonstrate the role played by the weathering of tropical shelf sediments during glacial periods in the carbon cycle.



Vent animals in the hydrothermal field



The Raman insertion probe system, developed at IOCAS, enables *in situ* detection of hydrothermal vent fluids.

For the past 800,000 years, the high correlation between the Earth's CO_2 concentration and the global climate during the glacial-interglacial periods demonstrates the role of greenhouse gases in regulating climate changes. But what drives the rapid drop of atmospheric CO_2 concentration during ice ages has been long debated. The conventional wisdom emphasizes the influences of physical, chemical and biological processes of the ocean, while the effects of shelf weathering due to sea level changes are often overlooked, especially in the tropical Western Pacific.

Using findings from the Ocean Drilling Programme (ODP), IOCAS researchers showed that the volume of detritus in the South China Sea during the Quaternary glaciation is significantly larger than that during the interglacial period, suggesting enhanced silicate weathering of tropical shelf sediments. Further analysis revealed that the carbon consumption in this process contributed to approximately 9% of atmospheric CO_2 reduction in the glacial period, indicating the significant role of shelf silicate weathering in the glacial-interglacial carbon cycles. This mechanism is further supported by evidence from the West Philippine Sea.

Inspired by the results, published in leading international journals, nearly 20 scientists from seven countries proposed collecting more evidence by drilling, further elucidating the role of shelf weathering in the global carbon cycle and climate change.

Marine geology research also enriches the understanding of geo-hazards, such as earthquakes and volcanic eruptions. These are often associated with subduction zones, regions of the Earth's crust where tectonic plates converge. Conditions controlling major earthquakes in these zones, and their relationship with slow earthquakes, in which energy is released over hours and months, have long occupied geoscientists, including researchers at IOCAS.

By comparing subduction zones with frequent large earthquakes, and those without, researchers found that, contrary to conventional understanding, weaker subduction faults, with low frictional strength, are more likely to produce large earthquakes. The strength of megathrust is determined by the ruggedness of the subduction seafloor, with smoother seafloor leading to weaker faults.

Further research on fault zone rheology to explore the role of temperature and fluids on subduction zone earthquakes, revealed that subduction faults have two separate friction regions, corresponding to the seismic zone and the slow slip zone, respectively. These results, published in *Nature* and *Science*, shed light on the prevention and mitigation of earthquakes and tsunamis.

Studies on hydrothermal activities are fuelled by new investigation methods and detection technologies developed at the key laboratory to explore the underlying geological processes and their effects on resources and the environment. IOCAS researchers have established a 'two-stage, six-process' model for investigating submarine hydrothermal activities, leading to the discovery of a new hydrothermal field called Tangyin.

By revealing the sources and controlling factors of hydrothermal products, particularly, sulphides, researchers constructed their formation process model, established new methods to calculate helium/heat ratio, isotopic composition of hydrothermal sulphides, and their discrete degree and variation rate, helping to determine the origins of hydrothermal ore deposits. As the first to use organisms such as sea snail shells to glean information on hydrothermal activities, IOCAS researchers enabled a multi-dimensional explanation of how hydrothermal activities influence the seafloor geological environment, promoting the progress of submarine hydrothermal geology.

New devices developed include the acoustic turbidity sensor, and hydrothermal plume detection equipment, offering useful tools for protecting the submarine hydrothermal environment. The laboratory has also developed *in situ* spectrum detection technology to explore the deep-sea extreme environment, informing understanding of the effects of hydrothermal vent fluids on the marine environment.

Their studies on the processes underlying sea ice reduction provide reference points for weather forecasts. ■

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