Progress and application of the in-situ monitoring for marine radioactive environment

Hongzhi Li, Jinzhao Zhang, Lei Wang, Chunfang Li

National Ocean Technology Center

2015.10.23

Contents

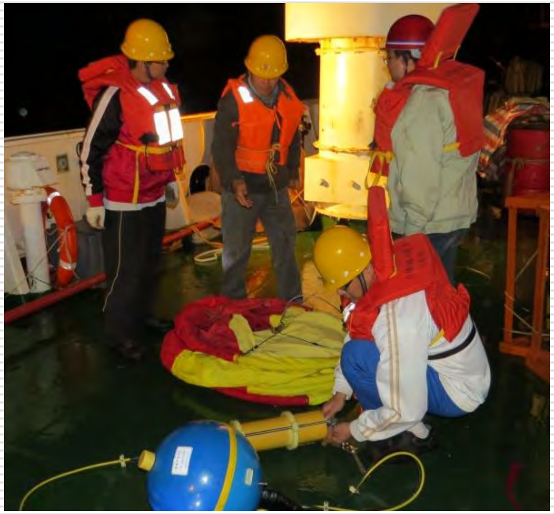
A Dose rate in-situ monitoring

A1 The laying of the drifting buoys

A2 The acquirement of the buoy data

A3 The analysis of drifting buoy data

A1 The laying of the drifting buoys



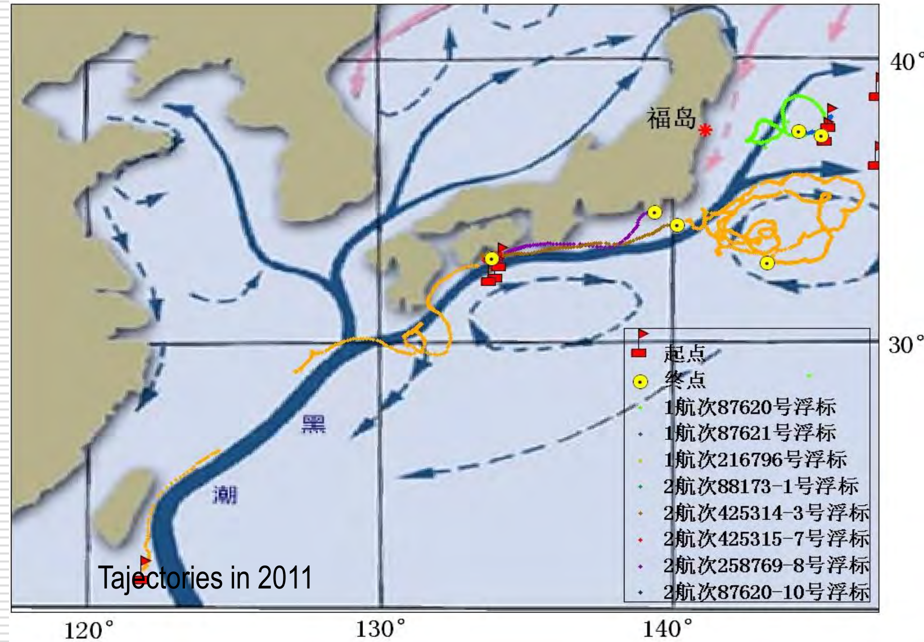
Assembly

Debugging

Laying

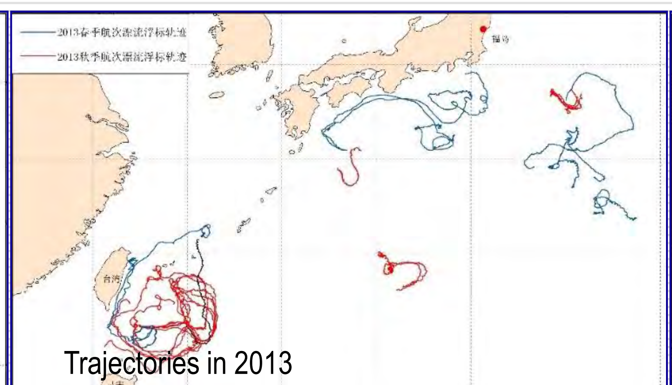
A2 | Dose rate in-situ monitoring

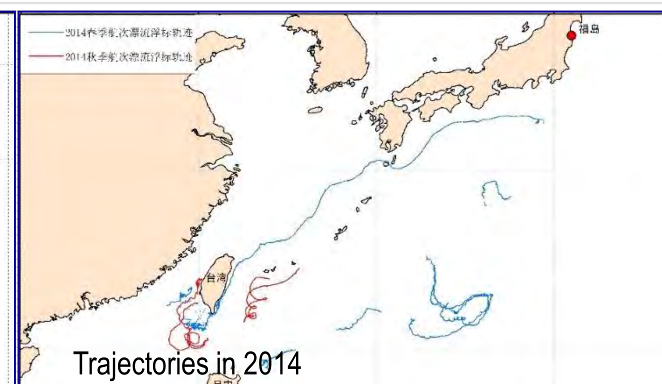
From 2011 to 2014, there are 44 sets of surface drifting buoys were laid by the National Ocean Technology Center, the radiation in-situ monitoring covered the northeastern Taiwan and the Luzon Strait, and received 14053 monitoring data.



Tajectories in 2011

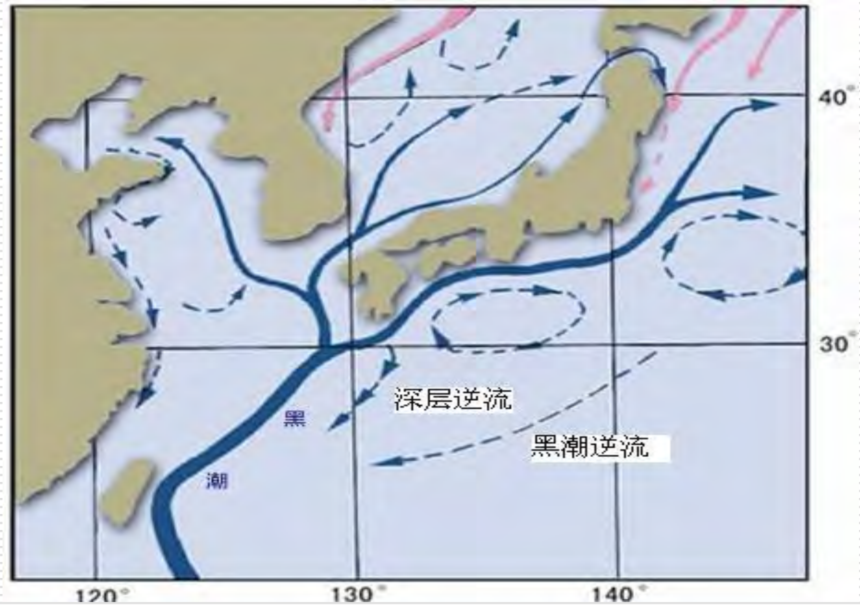

Trajectories in 2012

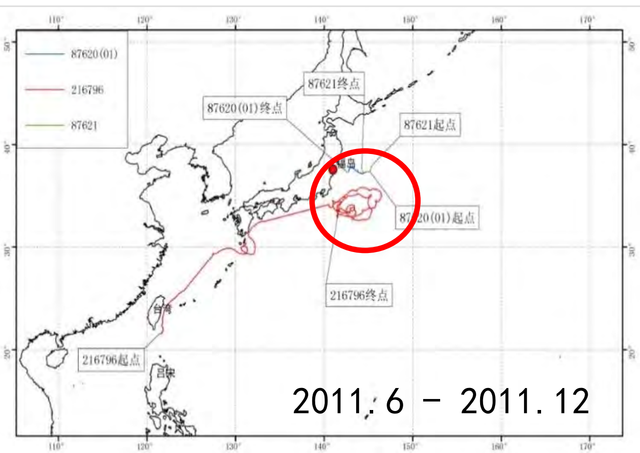

Trajectories in 2013

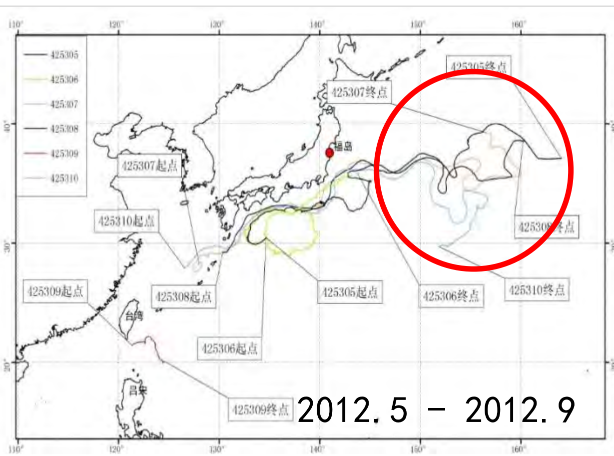

Trajectories in 2014

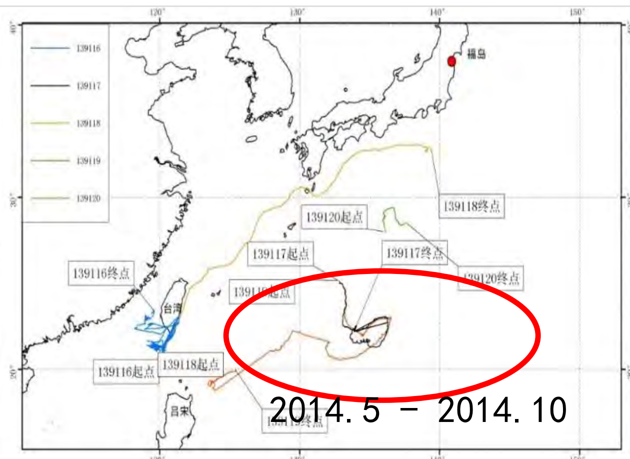
A2 | The acquirement of the buoy data

- Most of buoys drift follow mainstream of Kuroshio;
- Part of buoys move with the Kuroshio countercurrent to the southwest;



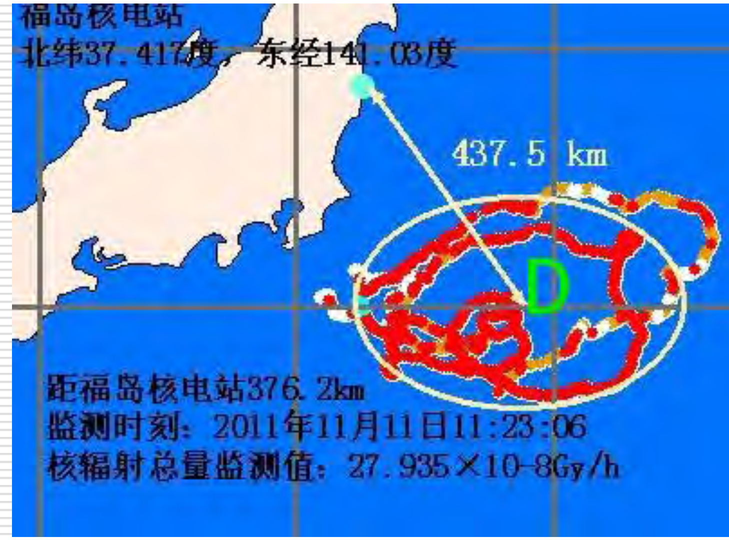


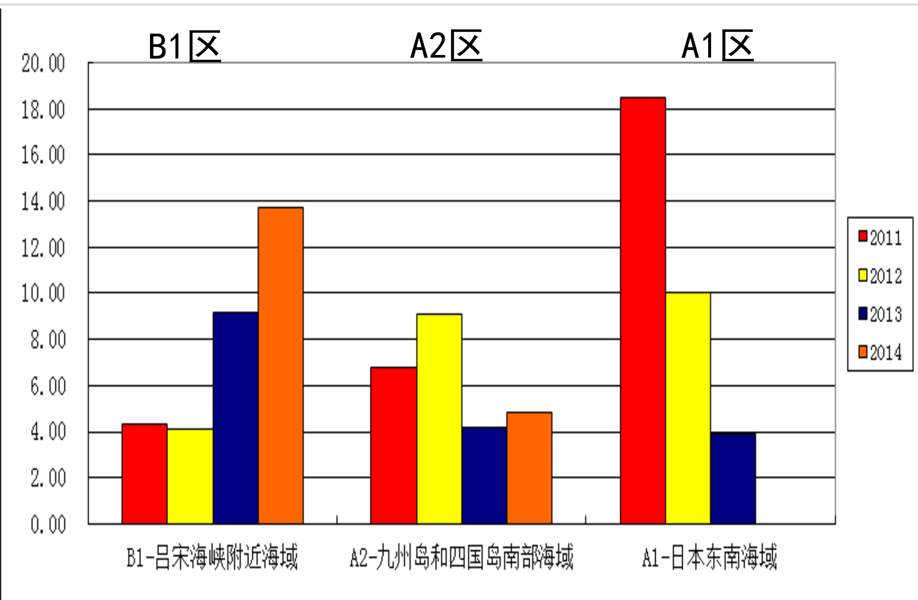




A3 The analysis of drifting buoy data

- A large area of higher levels of radioactive was shaped in A1 from 2011.9 to 2012.
- The radioactive dose rate value reduced in this area from 2012 to 2014.
- The radiation dose rate increased in B1 from 2012 to 2014.





A3 | Drifting buoy data analysis

1. We made it possible for in-situ monitoring of mainstream Kuroshio surface sea water dose rate with unmanned operation.

2. We acquired the time and location distribution of marine dose rate in section A1, A2 and B1.

3. We proved that West Pacific has some influence on diffusion of nuclear waste.

B γ spectral in-situ monitoring

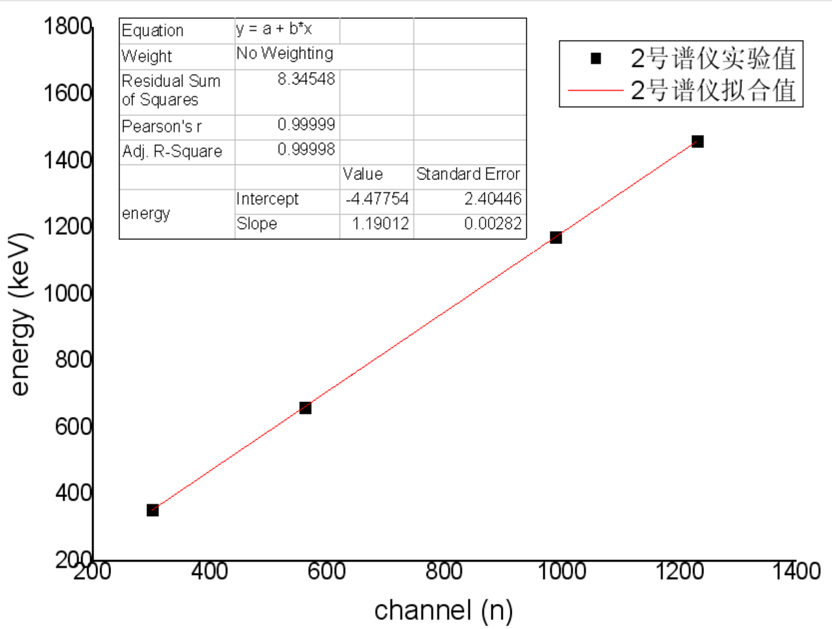
B1 Calibration and spectral unfolding

B2 Arrangement and recovery of subsurface buoy

B3 Monitoring data analysis

Energy calibration of gamma ray spectrometer

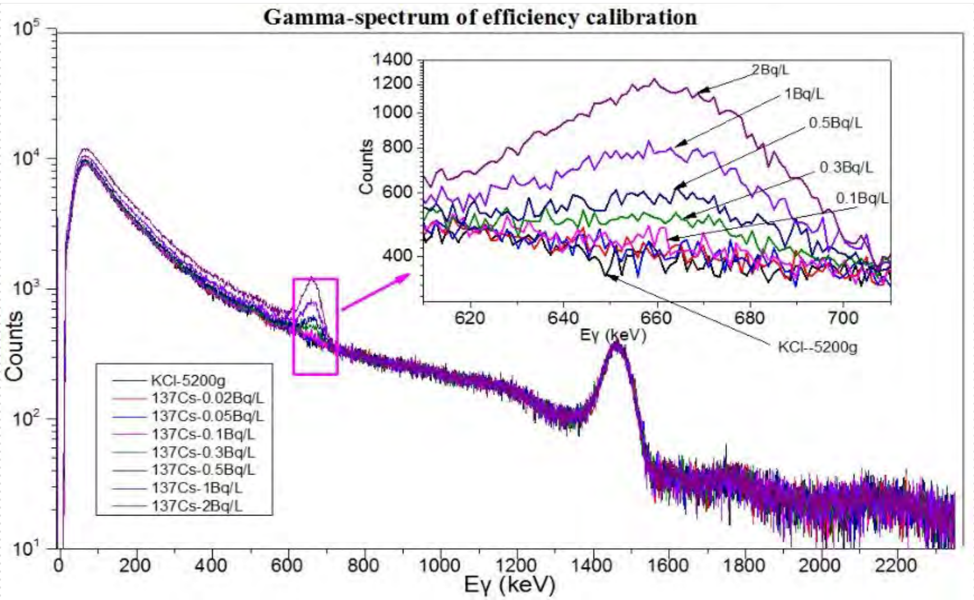
We used point source in Lab to calibrate the spectrometer, such as ^{133}Ba（356keV），^{137}Cs（662 keV），^{60}Co（1173.2 keV），^{40}K（1460.8 keV）。



Instrument energy calibration curve fitting formula is: $E_{\gamma} = 1.19Ch - 4.478$， correlation coefficient R is 0.999。

Efficiency calibration of gamma ray spectrometer

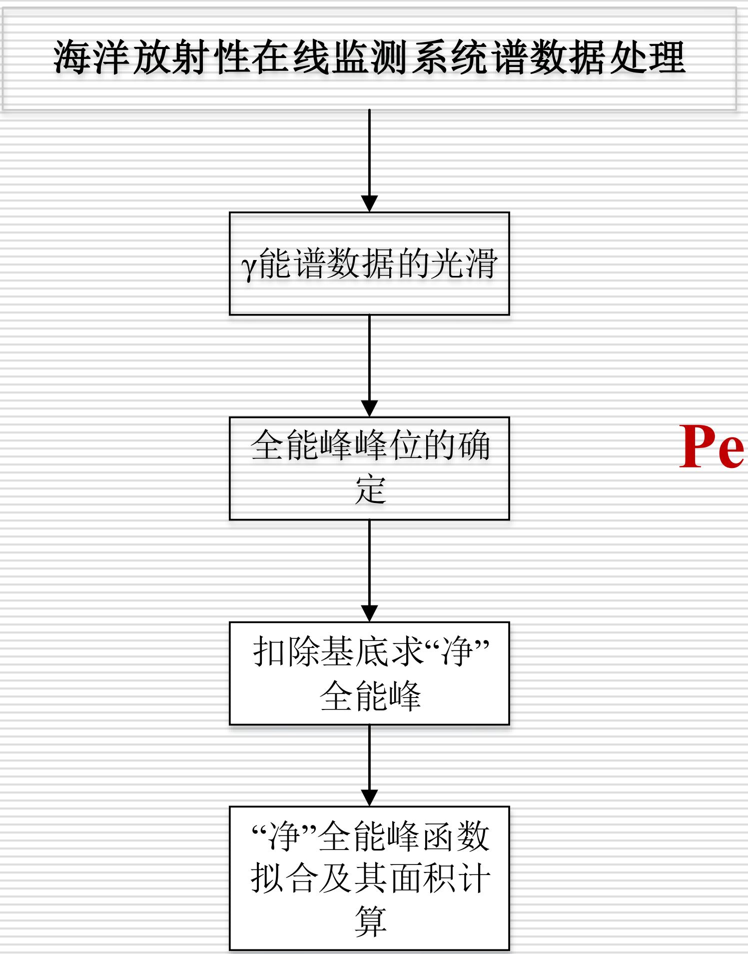
We calculated and designed a tank (2m radius, 2.5m height) as a ocean environmental to calibrate the spectrometer. Standard ^{40}K and ^{137}Cs liquid source were used in calibration.



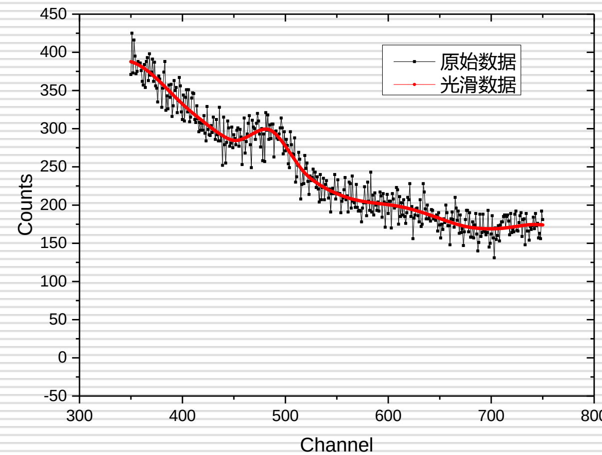
Detection Efficiency	Efficiency （L）
^{137}Cs	0.182
^{40}K	0.128

B1 Calibration and spectrum unfolding

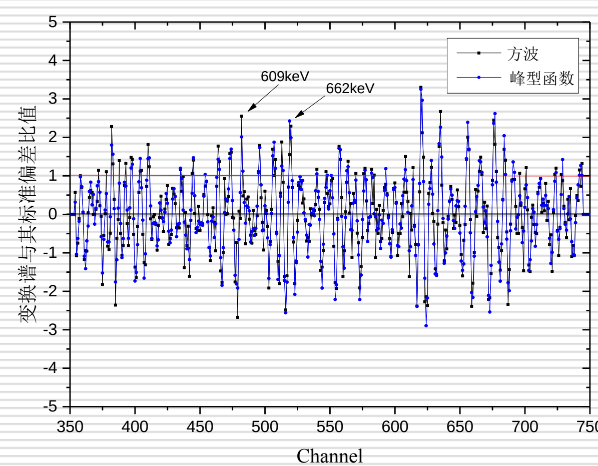
Flow chart of γ spectral process



Spectral Smoothing----wavelet

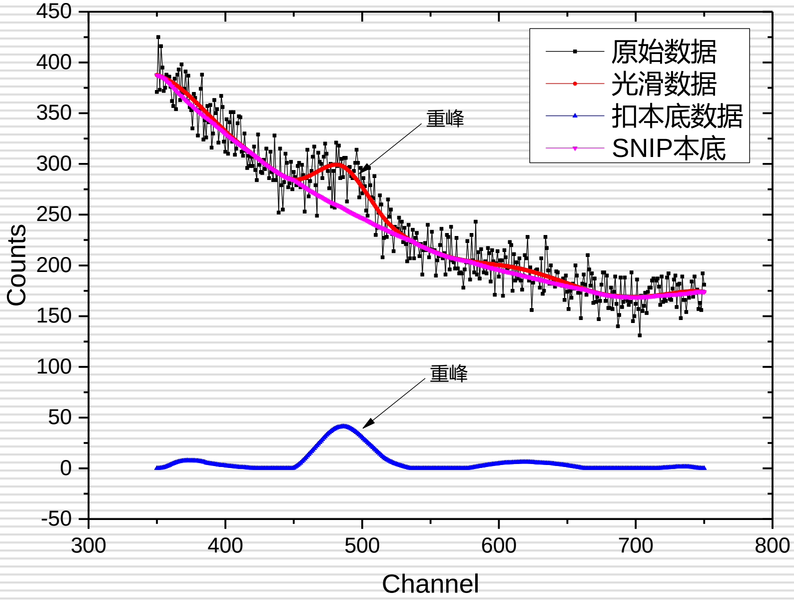


Peak searching ----Symmetric zero area transformation

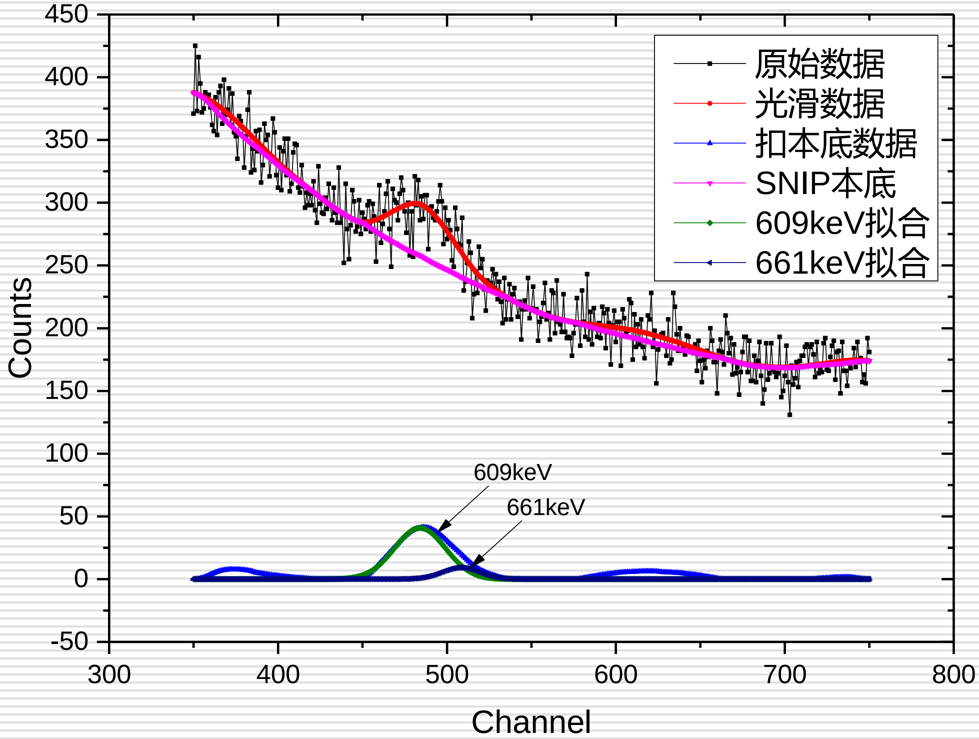


B1 | Calibration and spectrum unfolding

Background rejection----SNIP

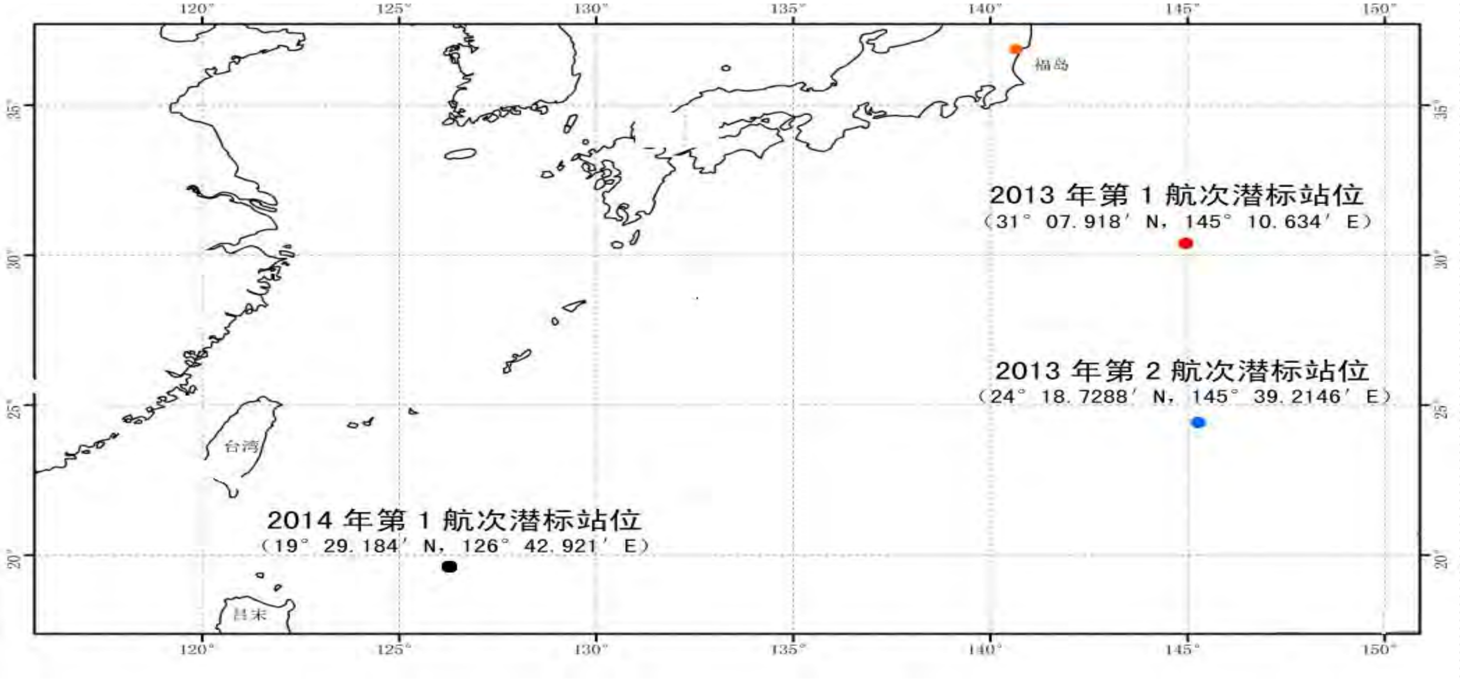


Full-energy peak fitting --weighted least squares



B2 | Subsurface buoy laying and recycle

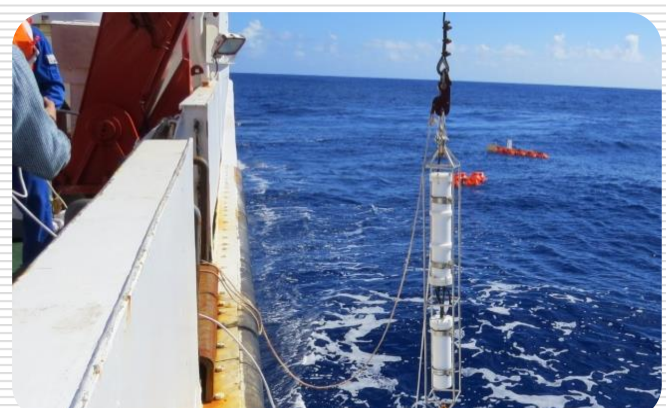
- There is still 1 set in place, and the laying and recycling rate is 100%;
- Marine radioactivity was monitored for more than one year consecutively in the Northwest Pacific region;
- 300-400 meters underwater nuclear radiation spectrum data were got and identified to be ^{137}Cs.



B2 | Subsurface buoy laying and recycle

布放时间	核数据	水文数据		
		海流	温盐	深度
13 年第 1 航次	2701 组	6060 组	18004 组	18004 组
13 年第 2 航次	2383 组	15346 组	94380 组	72600 组

Operating Depth: 5600m
γ spectrum: 400m
In time: 1 year



B2 | Subsurface buoy laying and recycle

Results of data acquisition and nuclide identification:

- In 2013 spring voyage we used subsurface buoy which equipped with two sets of γ spectrometer, 48 measurement cycles have been finished, more than 99.1% monitoring data are available;

- Artificial radionuclide ^{137}Cs can be identified in mostly measurement cycle.

B3 | Data analysis of γenergy spectrum

In-situ testing achievement of subsurface buoy γ energy spectrum

Data acquisition

We obtained the 300-400 meters deep underwater γ spectrum monitoring data, which is the first one in China in the area of long monitoring data.

Detecion mode

The monitor method can monitor the radionuclide species, activities and concentrations , achieved a continuous and longtime monitoring data.

Analysis result

Averages concentration activity of ^{137}Cs is about $10Bq/m^3$.

C Research progress

C1 Study of dose rate in-situ monitoring

C2 Study of spectral in-situ minitoring

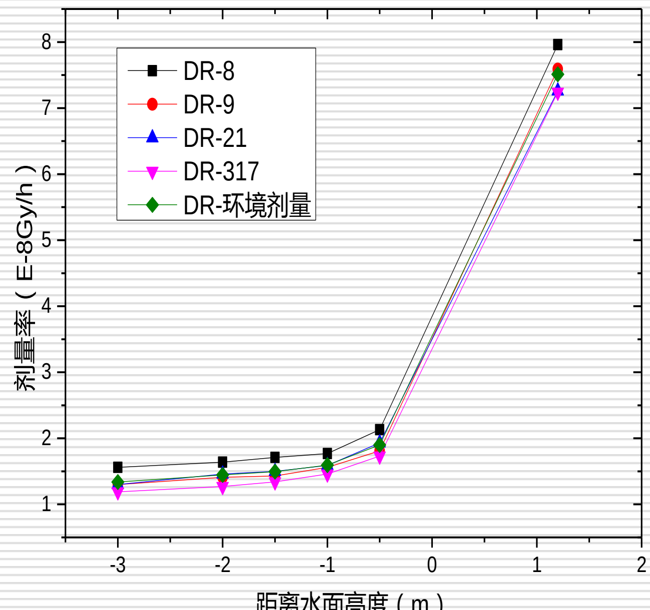
C3 Detectors development

C4 Platform development

C1 | Study of does rate in-situ monitoring

Study of effects of cosmic rays on the measurement of dose rate

We studied relationship between sea water depth and cosmic ray shielding. Seeked an optimal measurement depth to reduce the effect of cosmic rays in the real monitoring, which can improve the accuracy in radiation dose rate measurement.

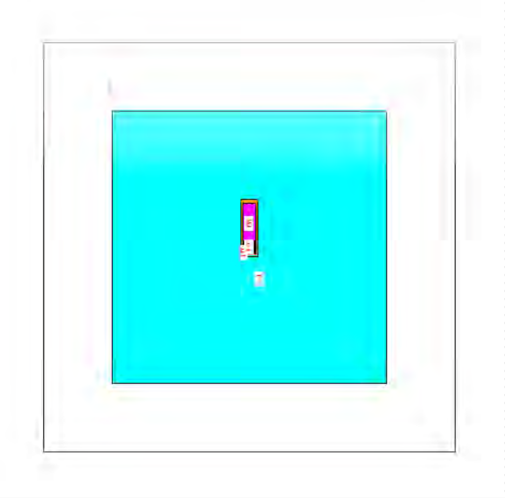


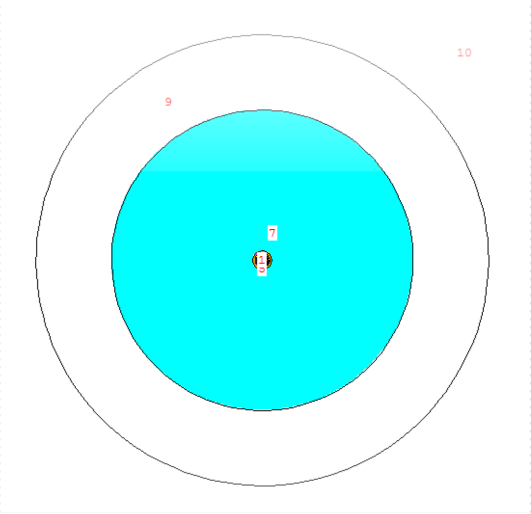
We compared the measurement data of different depths below the surface, the water environmental dose rate increases weaken with depth change, especially in the depth below 1.5m, that shows the shielding effect is stabilized by water.

C1 | Study of does rate in-situ monitoring

Study on the relationship between does rate and ^{137}Cs activity

We studied the relation between dose rate and ^{137}Cs activity concentration by the Monte Carlo calculation and experimental.





The figure shows the Monte Carlo model we established. By using this model, we can calculated the relationship between different concentrations of ^{137}Cs activity and dose rate change with a stable effect from ^{40}K and other natural radionuclides . Then we verified by performing experiment.

C2 | Study on γ spectral in-situ minitoring

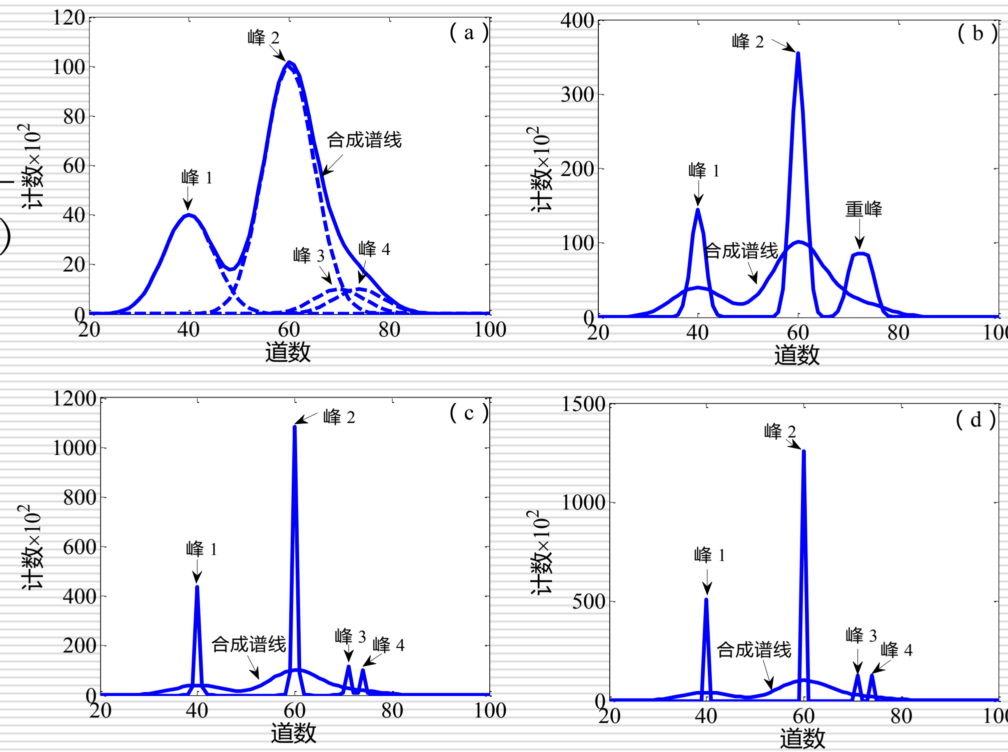
Iterative deconvolution calculation method - to improve the energy resolution of the detector, and to lower the detection limit.

$$\int h(j, x) f(x) dx = y(j)$$

$$x^{(n+1)}(i) = x^{(n)}(i) \sum_{j=0}^{N-1} h(j, i) \frac{y(j)}{\sum_{k=0}^{M-1} h(j, k) x^{(n)}(k)}$$

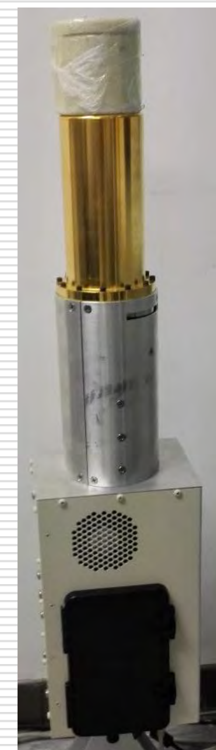
$$i = 0, 1, 2, \cdots, M-1$$

$$H = \begin{pmatrix} h(1) & 0 & \dots & 0 \\ h(2) & h(1) & \dots & 0 \\ \cdot & \cdot & & \cdot \\ \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & & \cdot \\ h(N) & h(N-1) & \dots & h(1) \end{pmatrix}$$



C3 Detectors development

1. We solved some technical problem of the total radiation dose sensor in the ocean environment, calibration, temperate drift;
2. We developed a low detection limit sodium iodide γ spectroscopy sensor, and applied to the West Pacific Nuclear Monitoring buoy;
3. We used high-purity germanium detector and lanthanum bromide detector for in-situ monitoring measurement. We solved the energy resolution problem of traditional sodium iodide detector.

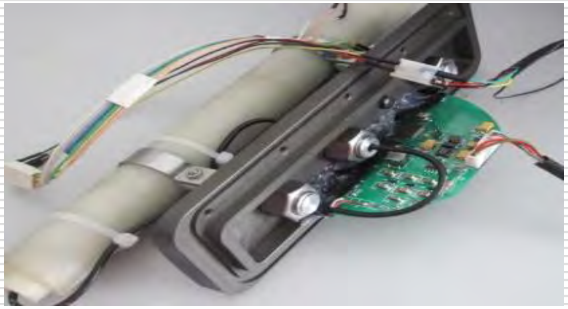


Autonomous Underwater glider（AUG）

Fnuction： **Automatic & intelligent observation**

- Section cruise observation
- Section Point observation
- Navigation Planning Observation
- Manual Remote observation

Below is a self-developed AUG with total radiation dose rate detector. Maximum voyage range is over 1800km, Maximum depth is 300m.



C4 | Platform development

Wave energy glider

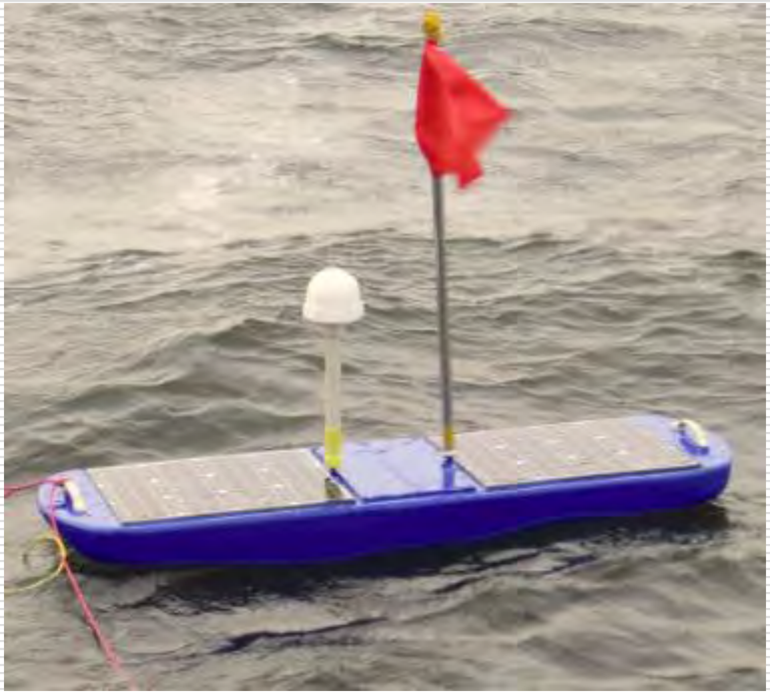
Fuction： Autonomous intelligent observation

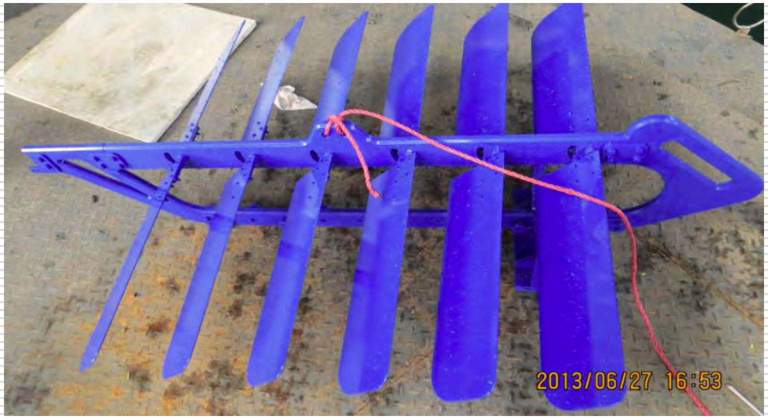
◆The wave energy transferred to forward power
◆Solar energy as supply for control and work system
◆Section cruise observation
◆Section Point observation
◆Navigation Planning Observation
◆Manual Remote observation

Performance

◆It's multipurpurse which can carry a variety of sensors, for measurement such as radiation, climate and water and basin.
◆A large voyage range
◆Low cost
◆Easy coperation

Application： Far-reaching sea observation

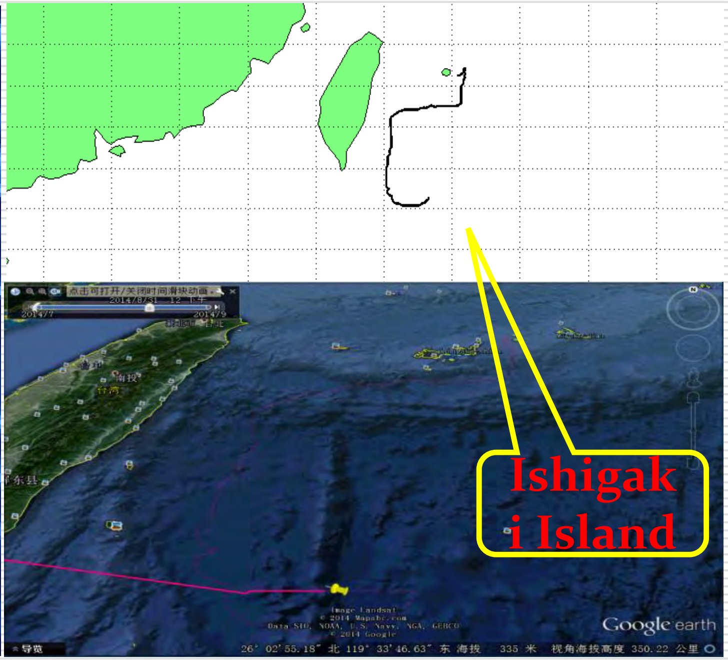




C4 | Platform development

Study of disposable buoy

Disposable buoy is capable of observing real-time wind speed, wind direction, wave, temperature, pressure, water temperature, which can improve the real-time, fast, mobile observation capacity in extreme weather, and as protection for the marine environment, marine disaster prevention and mitigation. Below is a disposable dose rate buoy equipped with 3 inches plastic scintillator.



D Suggestions in PICES frame

D | Suggestions in PICES frame

Proposal:

Marine environmental radioactivity monitoring in-situ is continuous, time-consuming, real-time data and diversity in platform. The results can be used as a useful complement to the marine environment laboratory measurement, as well as provide technical support evaluation and research on the marine environment. Our proposal are as following:

1. To improve the level of marine in-situ environmental radioactivity measurement;
2. To build the West Pacific marine environmental radioactivity measurement in-situ network;
3. Conduct a multi-platform in-situ measurement study of the marine environment.

Thank You !