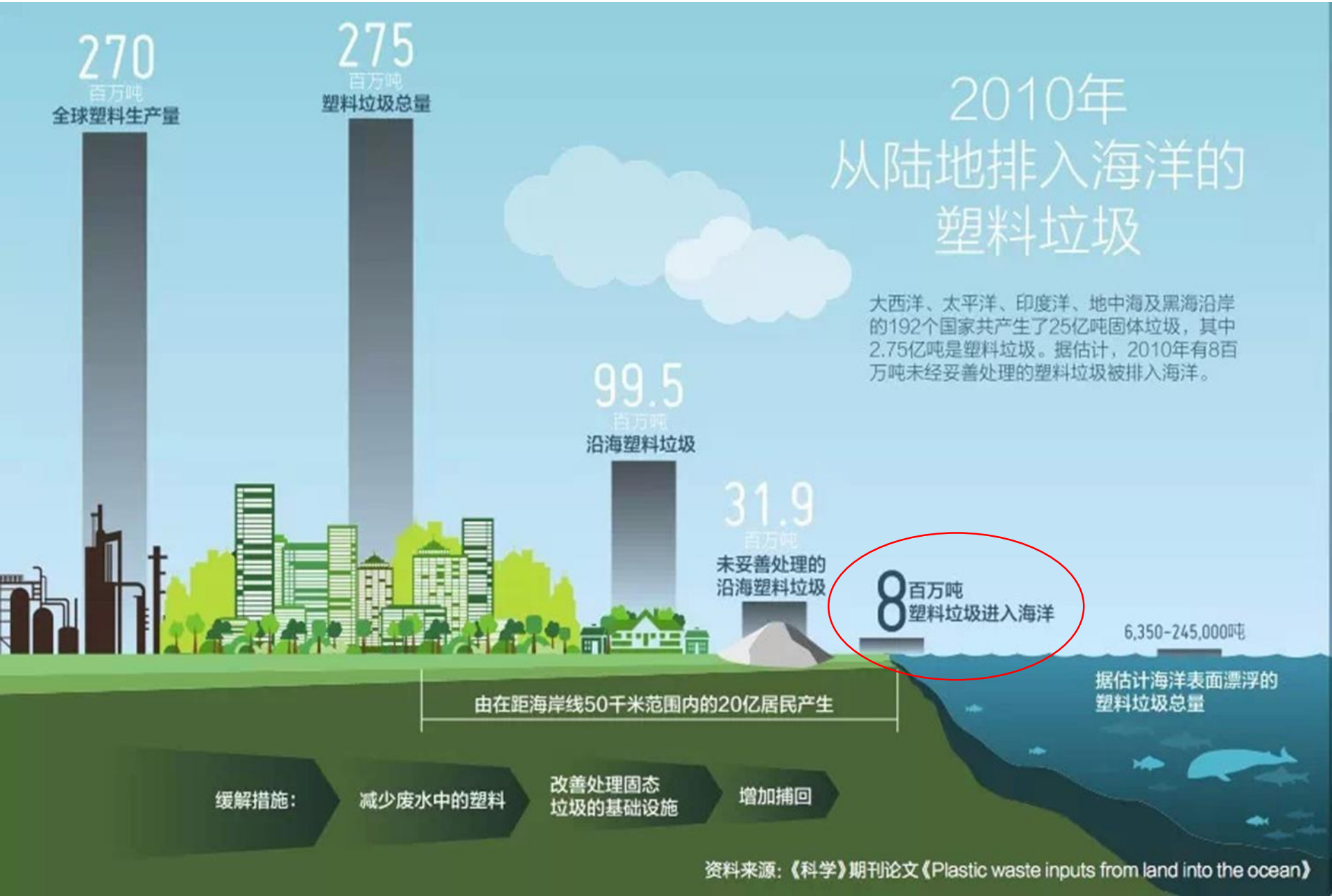
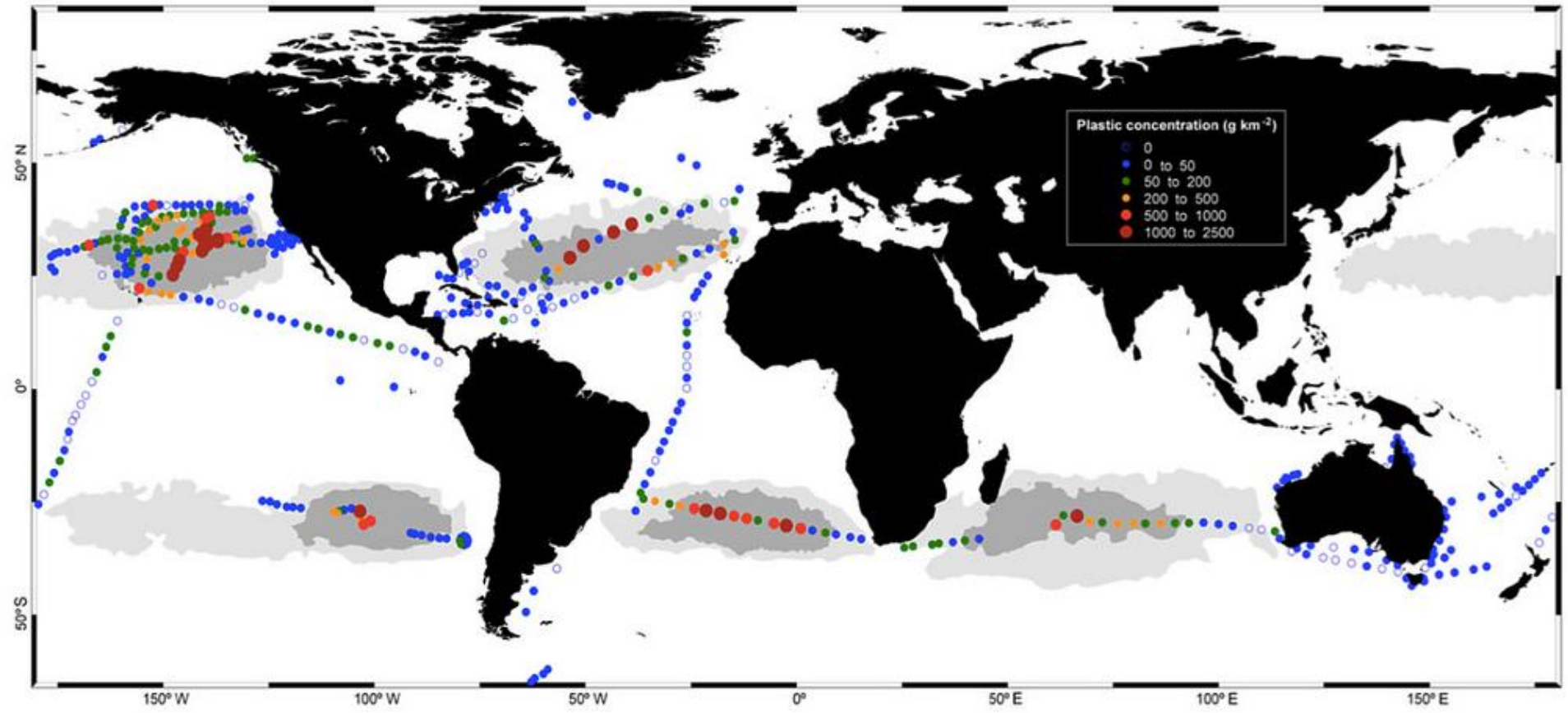
桃園近海水文與海岸垃圾

錢樺
國立中央大學水文與海洋科學研究所

8 MT of Plastic Debris into Global Ocean Annually

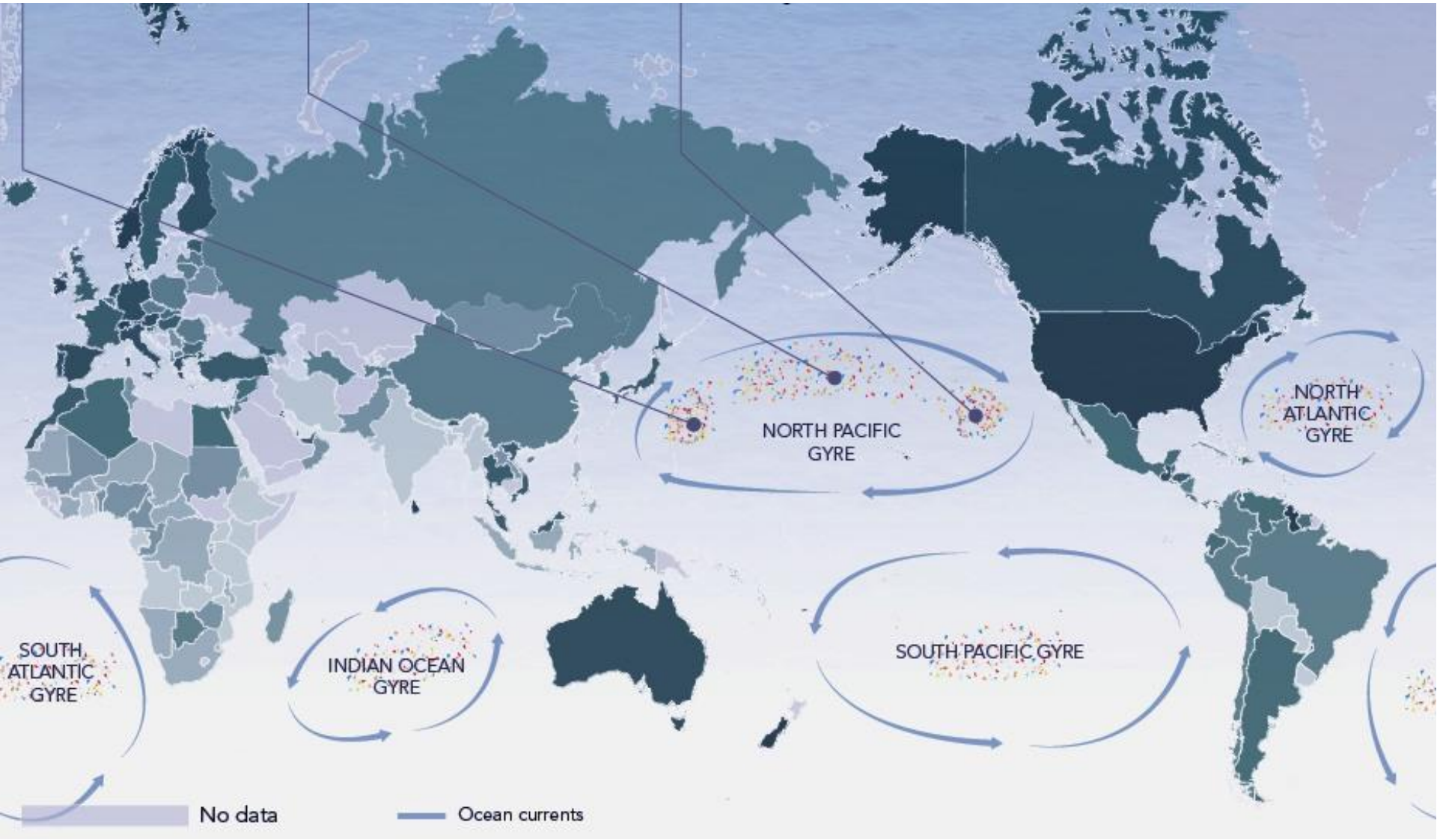


Plastic Debris Concentrations in Ocean Basins



Currently, **NO** remote sensing technology can satisfactorily detects the concentration of marine plastic debris in global basin.

Garbage Patch due to Ocean Gyres



Whale Shark ‘marine filter feeder’ in plastic garbage

Pic from German Deutsche Welle Website

Average **15** plastic litters every meter of coastline

Recreation beach resort at
Penghu Island, Taiwan

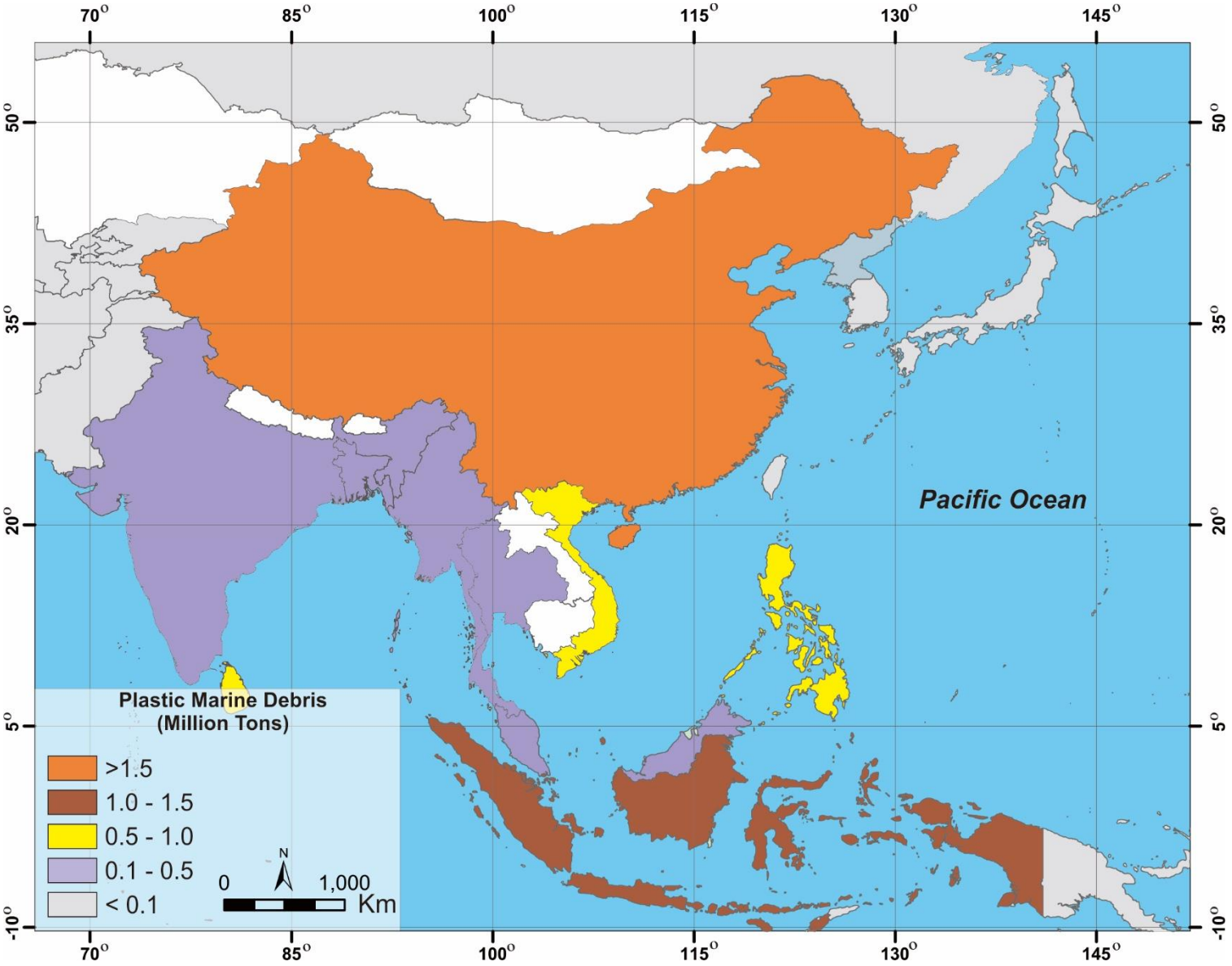

Recreation beach resort at
Penghu Island, Taiwan

WHO Generate the PMD? Top 20 Rank Countries

Rank	Country	Coastal Pop (millions)	Waste Gen. Rate (kg/ppd)	Plastic waste (%)	Mismanaged waste (%)	Mismanaged plastic waste (MMT/year)	Plastic marine debris (MMT/year)
1	China	262.9	1.10	11	76	8.82	1.32-3.53
2	Indonesia	187.2	0.52	1	83	3.22	0.48-1.29
3	Philipines	83.4	0.50	15	83	1.88	0.28-0.75
4	Vietnam	55.9	0.79	13	88	1.83	0.28-0.73
5	Sri Lanka	14.6	5.10	7	84	1.59	0.24-0.64
6	Thailand	26.0	1.20	12	75	1.03	0.15-0.41
7	Egypt	21.8	1.37	13	69	0.97	0.15-0.39
8	Malaysia	22.9	1.52	13	57	0.94	0.14-0.37
9	Nigeria	27.5	0.79	13	83	0.85	0.13-0.34
10	Bangladesh	70.9	0.43	8	89	0.79	0.12-0.31
11	South Africa	12.9	2.00	12	56	0.63	0.09-0.25
12	India	187.5	0.34	3	87	0.60	0.09-0.24
13	Algeria	16.6	1.20	12	60	0.52	0.08-0.21
14	Turkey	34.0	1.77	12	18	0.49	0.07-0.19
15	Pakistan	14.6	0.79	13	88	0.48	0.07-0.19
16	Brazil	74.7	1.03	16	11	0.47	0.07-0.19
17	Burma	19.0	0.44	17	89	0.46	0.07-0.18
18	Morocco	17.3	1.46	5	68	0.31	0.05-0.12
19	North Korea	17.3	0.60	9	90	0.30	0.05-0.12
20	United States	112.9	2.58	13	2	0.28	0.04-0.11
172	Taiwan	22.2	2.10	12	2.25	0.05	0.01-0.02

Source: Jambeck, 2015

Generation of Marine Plastic Litter around SCS



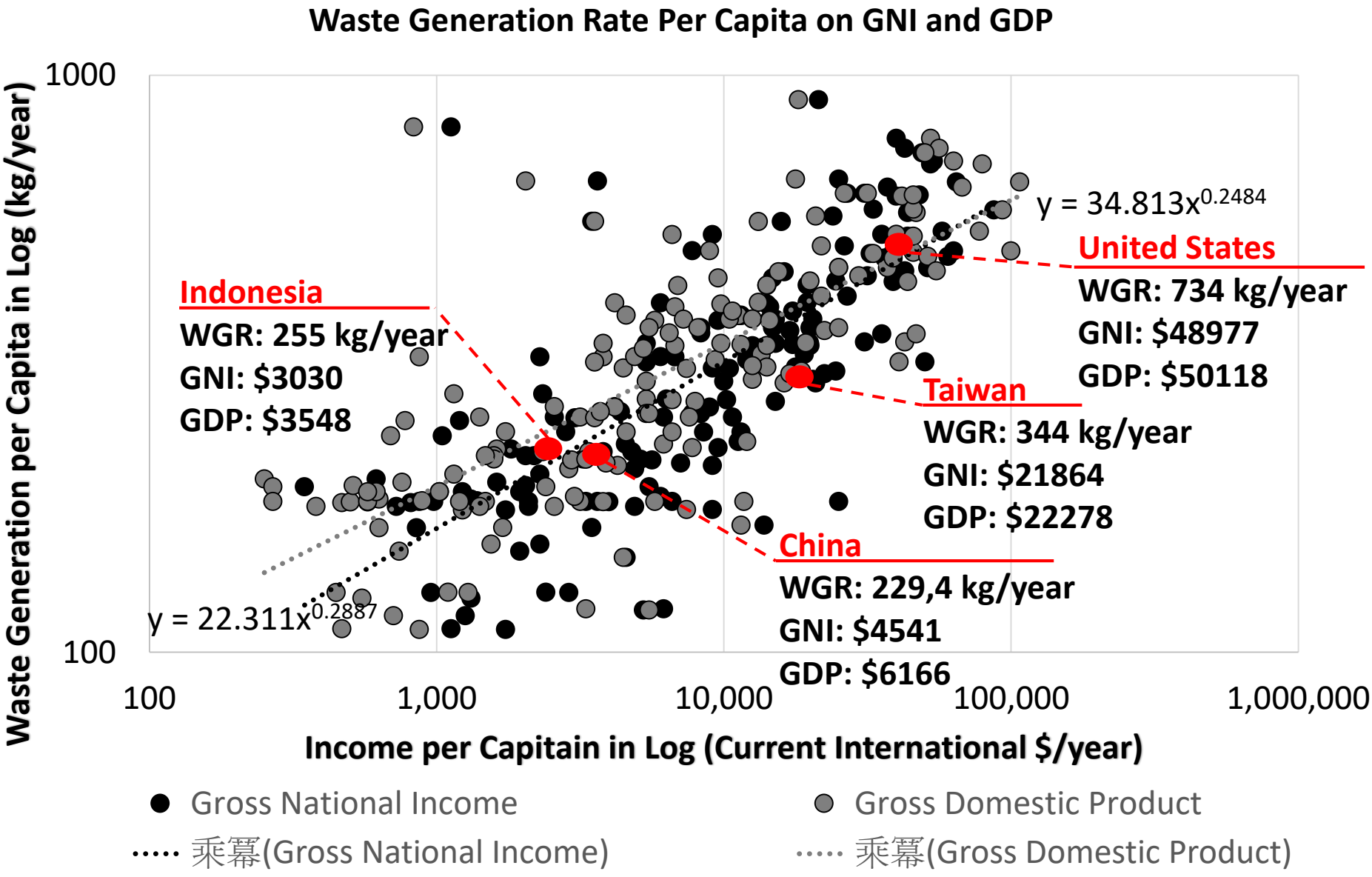
How those PMD ranking estimated?

$$\boldsymbol{PMD} = \boldsymbol{CP} \cdot \boldsymbol{WGR} \cdot (\boldsymbol{PWS}\%) \cdot (\boldsymbol{IMW}\% + \boldsymbol{LW}\%) \cdot \boldsymbol{F}$$

PMD : Plastic marine debris (Million Tons)
CP : coastal population
WGR : waste generation rates (kg/person/day)
$PWS\%$: percentage of plastic waste stream
$IMW\%$: percentage of inadequately managed waste
$LW\%$: percentage of littered waste

F : percentage of waste that enters the ocean

Jambeck, 2015

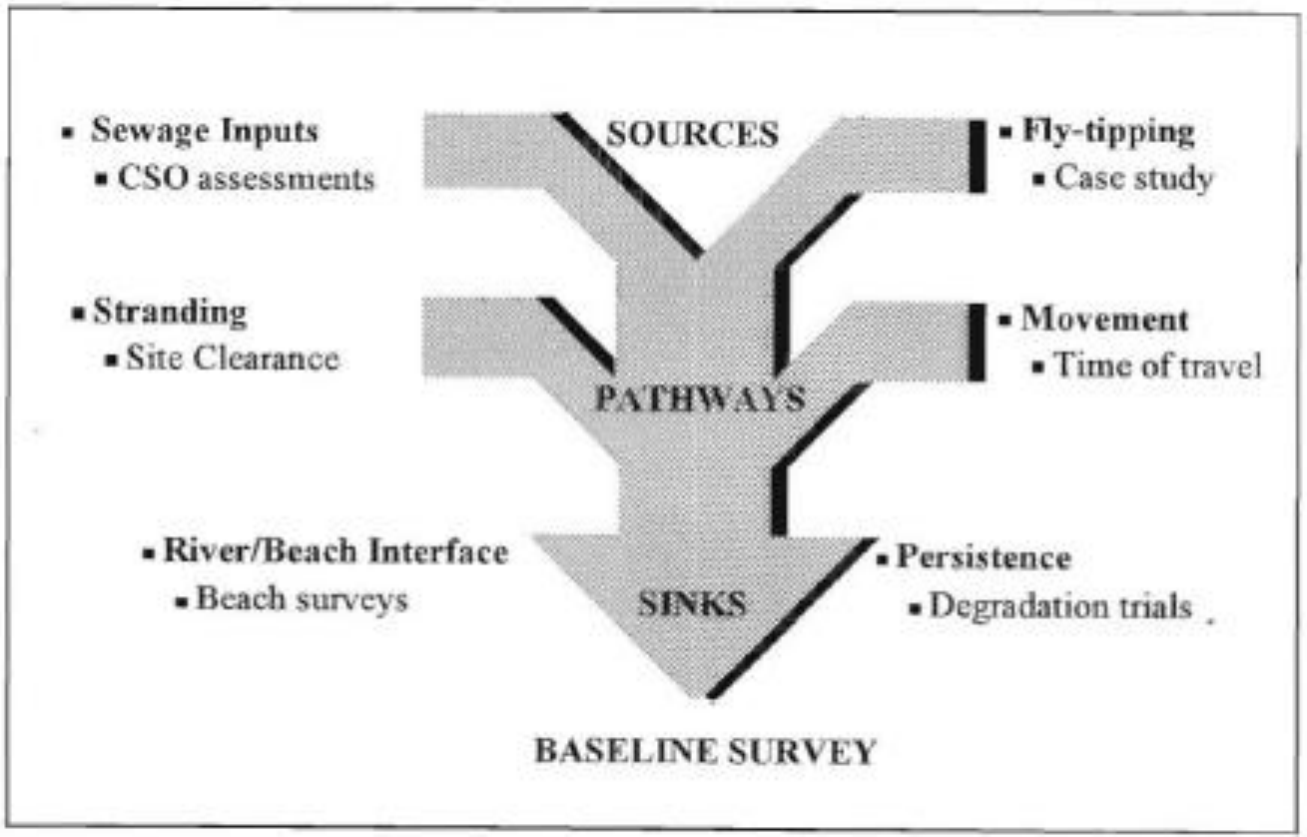


With the rapid economic progress in Mainland China, Indonesia, Vietnam and SCS countries, a increasing trend of marine litter in Penghu can be expected.

F: Percentage of Debris enters the Ocean

The most uncertain parameter: F=15%~40%

- Sewer debris originate from sewer overflows and sewage general litter (Neto and d Fonseca, 2011; William and Simmons,1997b)
- Riverine Litter Discharge (William and Simmons,1997b)



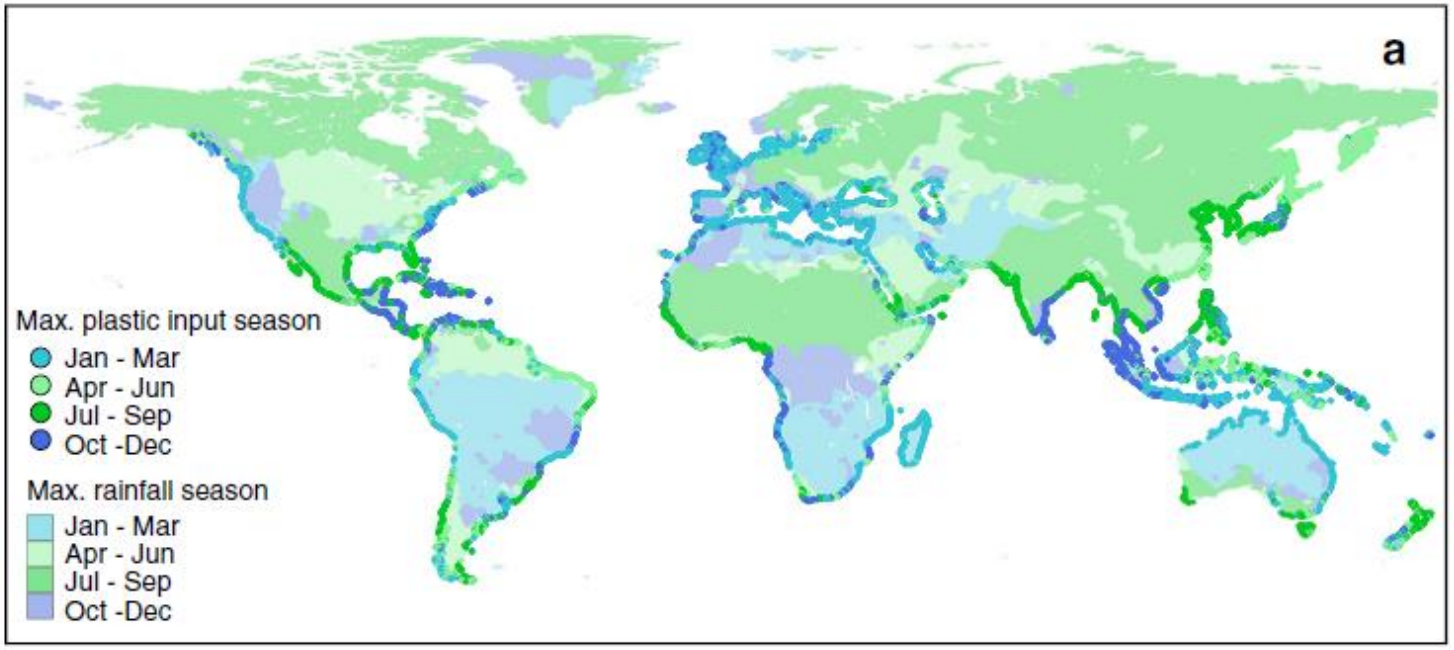
Plastic Debris Come from Riverine Discharge

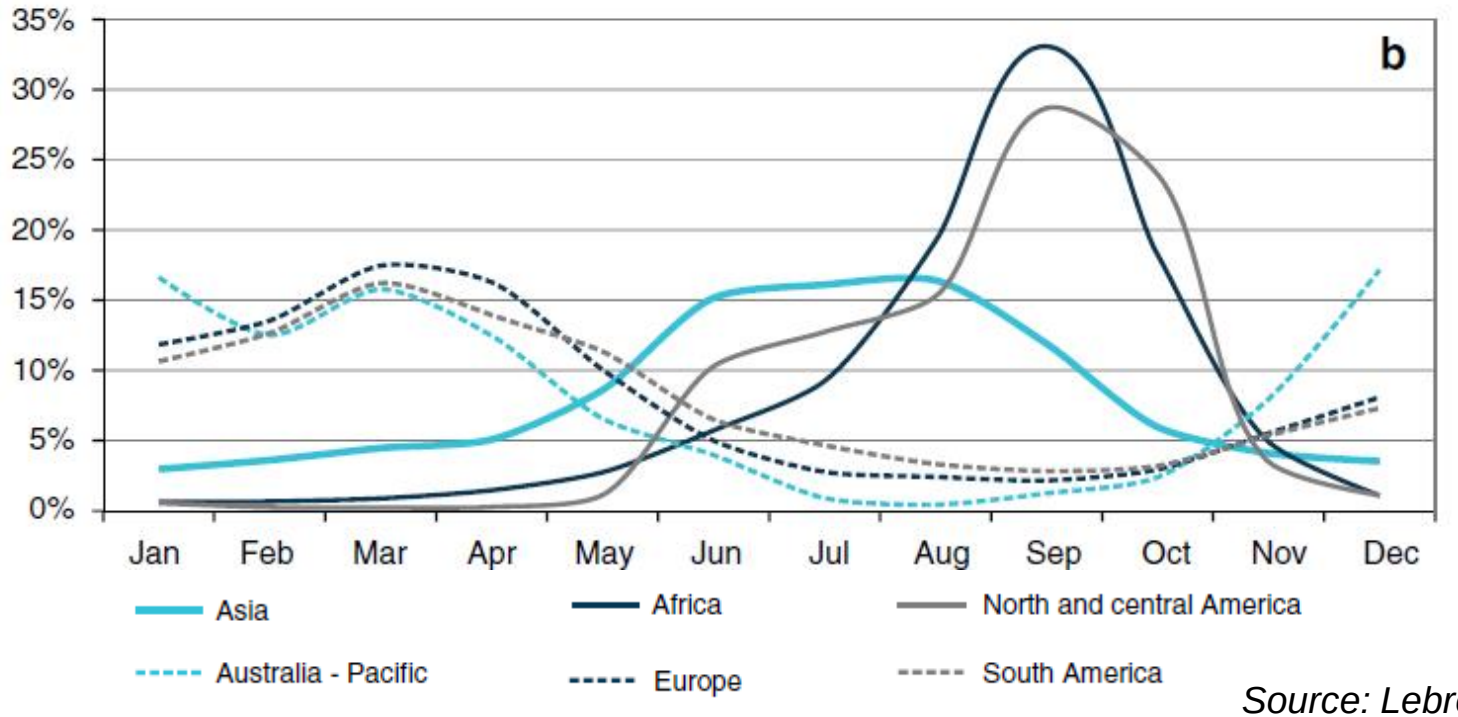
Top 20 Polluting Rivers

Catchment	Country	Lower mass input estimate ($t\,yr^{-1}$)	Midpoint mass input estimate ($t\,yr^{-1}$)	Upper mass input estimate ($t\,yr^{-1}$)	Total catchment surface area (km^2)[21]	Yearly average discharge ($m^3\,s^{-1}$)[21]
Yangtze	China	3.10×10^5	3.33×10^5	4.80×10^5	1.91×10^6	1.58×10^4
Ganges	India, Bangladesh	1.05×10^5	1.15×10^5	1.72×10^5	1.57×10^6	2.08×10^4
Xi	China	6.46×10^4	7.39×10^4	1.14×10^5	3.89×10^5	5.53×10^3
Huangpu	China	3.35×10^4	4.08×10^4	6.73×10^4	2.62×10^4	4.04×10^2
Cross	Nigeria, Cameroon	3.38×10^4	4.03×10^4	6.5×10^4	2.38×10^3	2.40×10^2
Brantas	Indonesia	3.23×10^4	3.89×10^4	6.37×10^4	1.11×10^4	8.18×10^2
Amazon	Brazil, Peru, Columbia, Ecuador	3.22×10^4	3.89×10^4	6.38×10^4	5.91×10^6	1.40×10^5
Pasig	Philippines	3.21×10^4	3.88×10^4	6.37×10^4	4.07×10^3	2.07×10^2
Irrawaddy	Myanmar	2.97×10^4	3.53×10^4	5.69×10^4	3.77×10^5	5.49×10^3
Solo	Indonesia	2.65×10^4	3.25×10^4	5.41×10^4	1.58×10^4	7.46×10^2
Mekong	Thailand, Cambodia, Laos, China, Myanmar, Vietnam	1.88×10^4	2.28×10^4	3.76×10^4	7.74×10^5	6.01×10^3
Imo	Nigeria	1.75×10^4	2.15×10^4	3.61×10^4	7.92×10^3	2.79×10^2
Dong	China	1.57×10^4	1.91×10^4	3.17×10^4	3.33×10^4	8.54×10^2
Serayu	Indonesia	1.33×10^4	1.71×10^4	2.99×10^4	3.71×10^3	3.70×10^2
Magdalena	Colombia	1.29×10^4	1.67×10^4	2.95×10^4	2.61×10^5	5.93×10^3
Tamsui	Taiwan	1.16×10^4	1.47×10^4	2.54×10^4	2.68×10^3	1.08×10^2
Zhujiang	China	1.09×10^4	1.36×10^4	2.31×10^4	4.01×10^3	1.33×10^2
Hanjiang	China	1.03×10^4	1.29×10^4	2.19×10^4	2.95×10^4	7.35×10^2
Progo	Indonesia	9.80×10^4	1.28×10^4	2.29×10^4	2.24×10^3	2.79×10^2
Kwa Ibo	Nigeria	9.29×10^4	1.19×10^4	2.08×10^4	3.63×10^3	1.92×10^2

Input rate estimates (in $t\,yr^{-1}$) are representative of mismanaged plastic waste (MPW) production and catchment runoff. A lower, midpoint and upper estimate is calculated based on three regression analyses accounting for uncertainties in our field observations data set.

Source: Lebreton, 2017



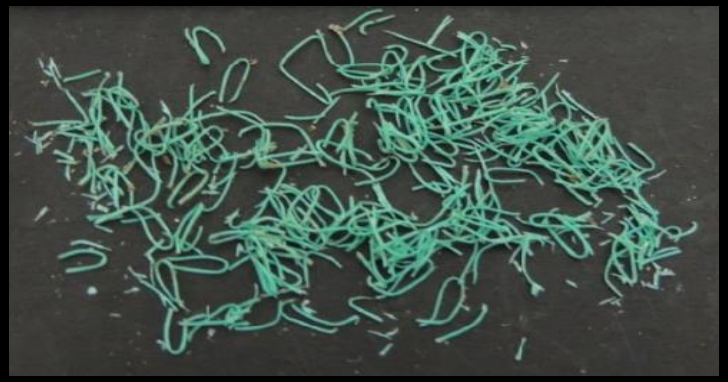


Source: Lebreton, 2017

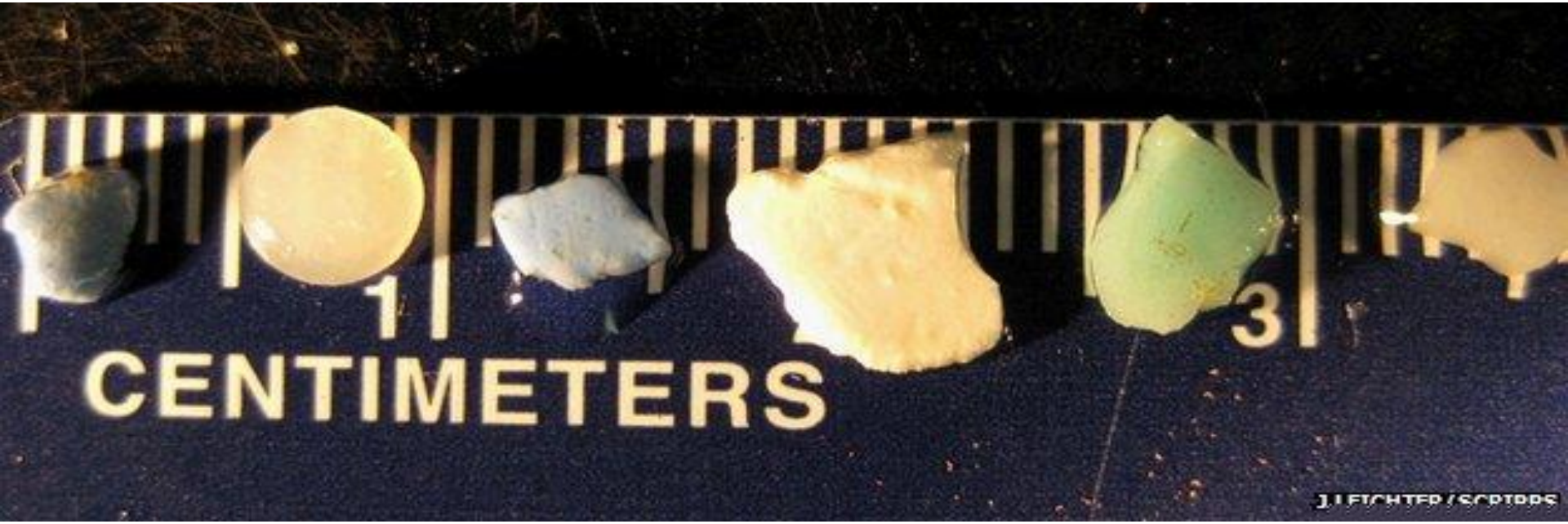
Characteristics of Catchment, Rainfall-runoff system, Riverine discharge variability and Estuary Mixing play important roles on Plastic Debris Transport…

What could we, the hydraulic engineers, do?

Weathering and Wave Force incur Marine Plastic Debris Fragmentation



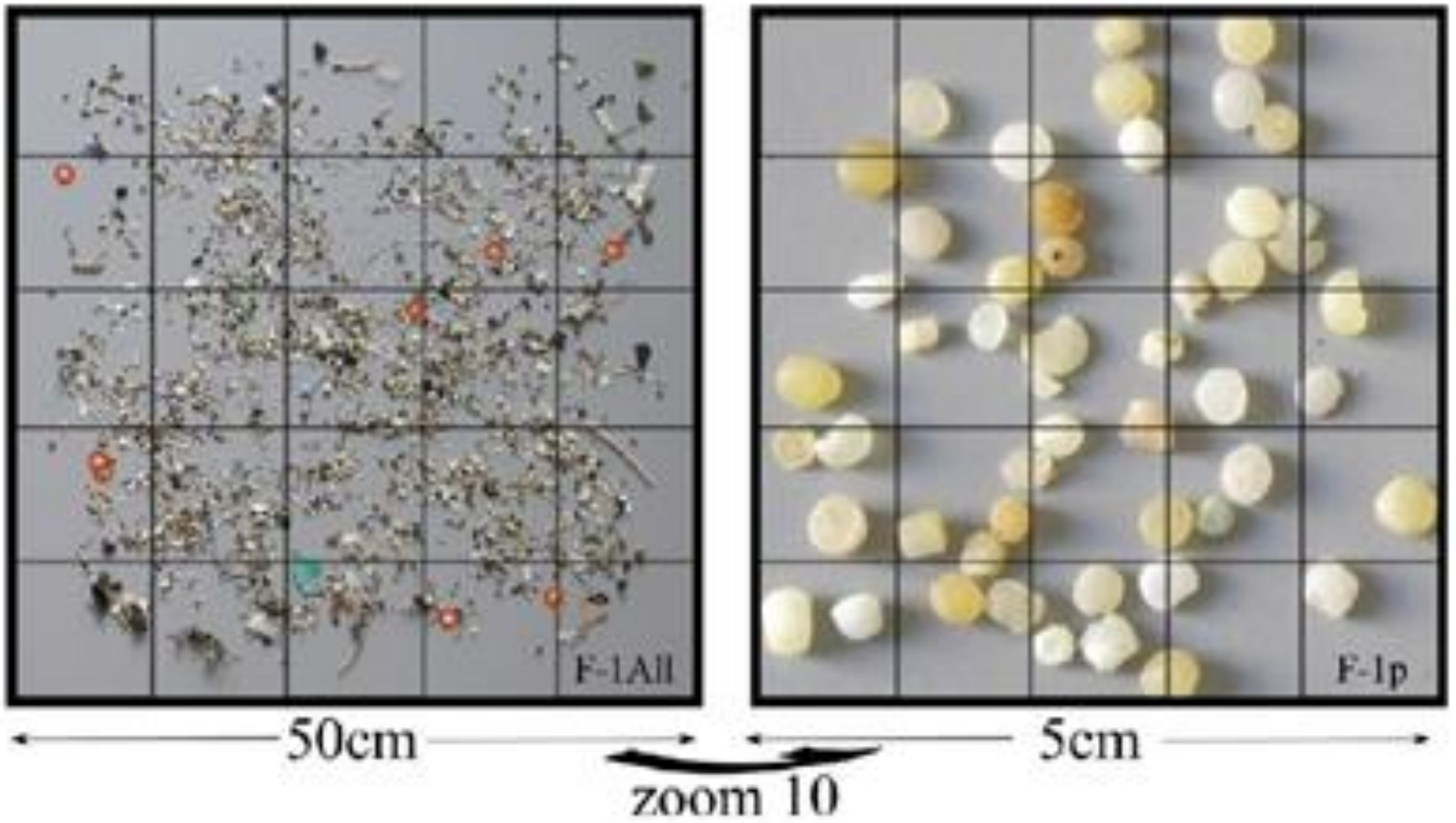
And then turn into **Microplastics**



In 2004, Prof. R. C. Thompson at University of Plymouth first proposed the idea of microplastic

- **d < 5mm**
- **Suspended in water, long-term persistent and could be uptaken by marine organisms into ecosystem**

Thompson, *et al.* (2004，Science）


F-1All
F-1p
50cm
5cm
zoom 10

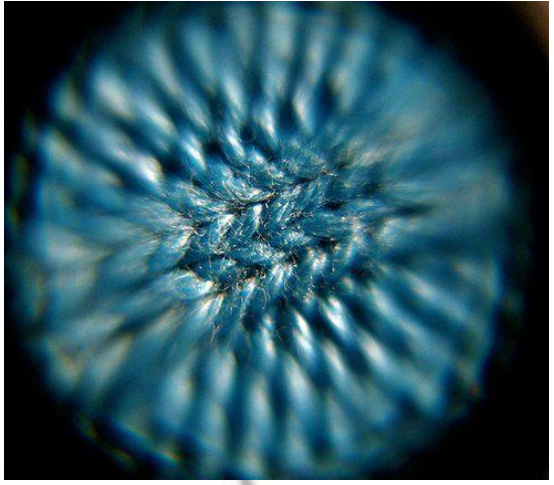
Ian Hutton / Fairfax Media

Other Source: Cosmetic & Facial Cleanser


Recollections
Signature · Especial
Heather
Bruyère
Brezo
www.polishartaddiction.blogspot.com


www.goosesglitter.com
Goose

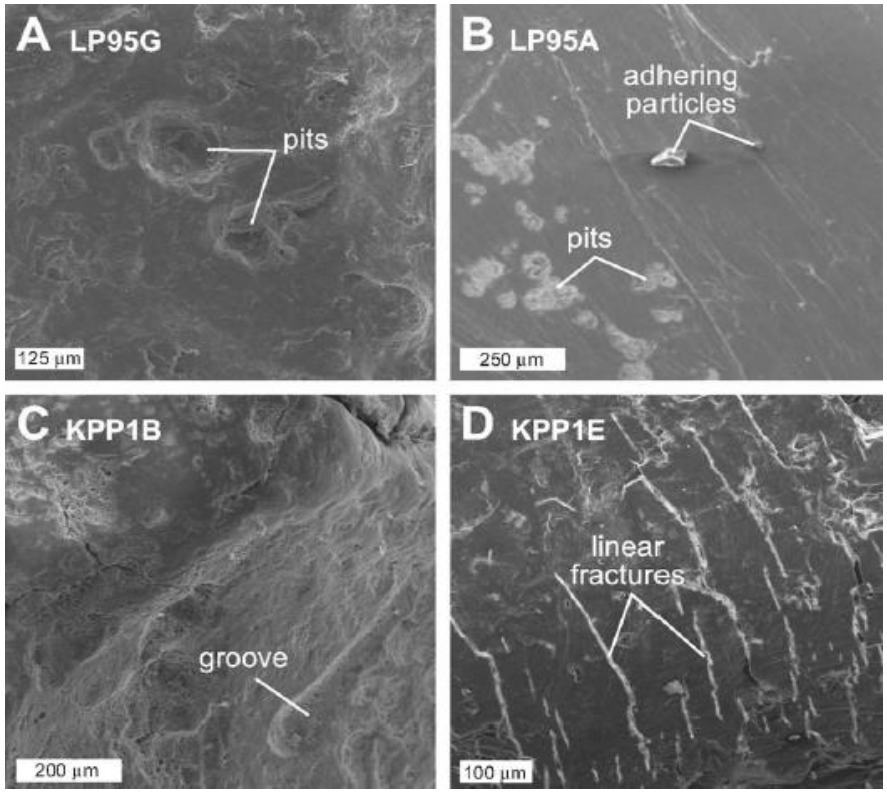
Other Source : Textile fiber



每洗一件合成纖維的衣物，大概有 **1,900個**微纖維脫落，通過污水管道進入海洋（***Environ. Sci. Technol*. 2011, 45, 9175–9179**）

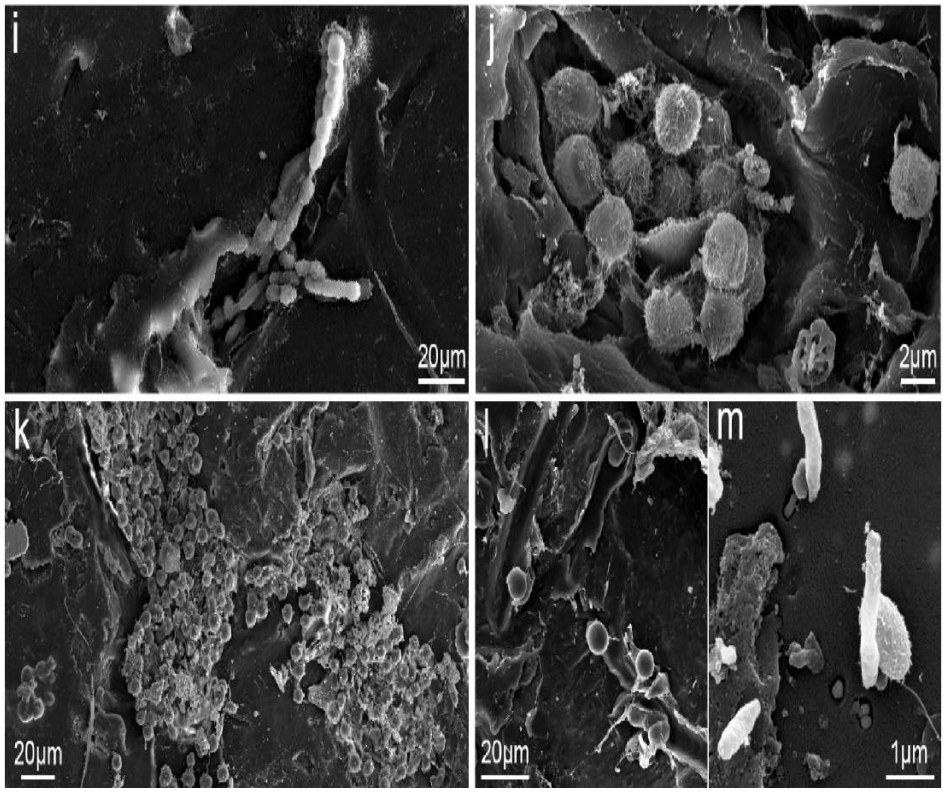
Microplastic particles are the carrier of POPs

Surface micromorphology



Corcoran *et al*., 2009

POPs and bacteria can be adsorbed on the rough surfaces



Reisser *et al*., 2014

This planktonic arrow worm, Sagitta setosa, has eaten a blue plastic fiber about 3mm long.

Photograph: Richard Kirby/from Orb Media

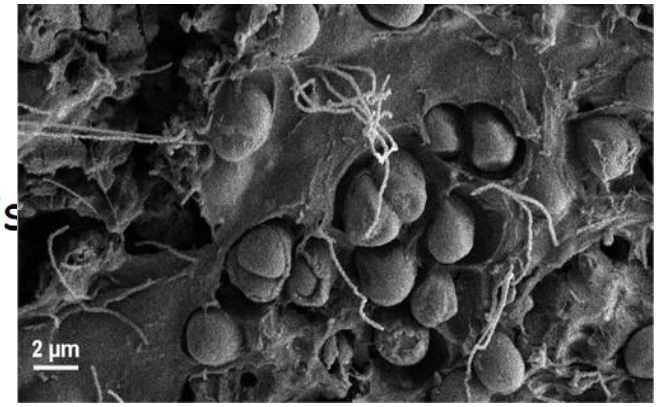
Invasion of pathogenic microorganisms and harmful species

Brief Communications

Nature **416**, 808-809 (25 April 2002) | doi:10.1038/416808a

Biodiversity: Invasions by marine life on plastic debris

David K. A. Barnes

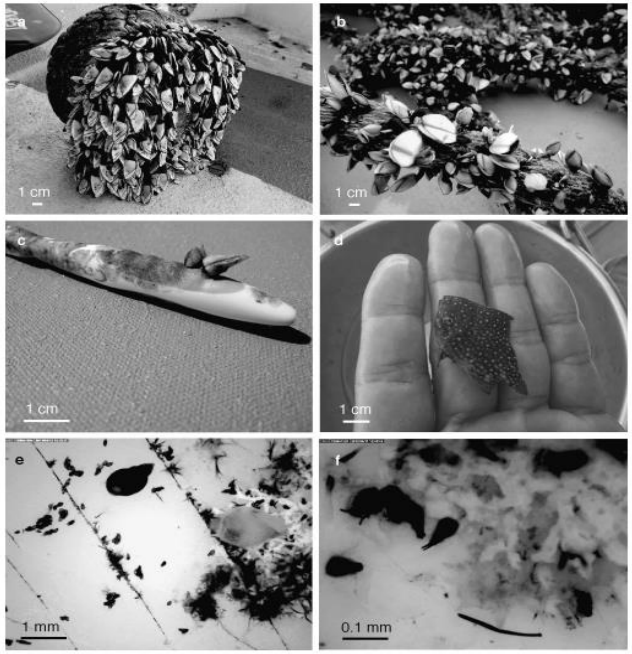


Mar Biol (2014) 161:1441–1453
DOI 10.1007/s00227-014-2432-8

ORIGINAL PAPER

Relationship of diversity and habitat area in North Pacific plastic-associated rafting communities

Miriam C. Goldstein · Henry S. Carson · Marcus Eriksen



The plastic-associated microorganisms of the North Pacif

Henry S. Carson [a,*], Magnus S. Nerheim [a,b], Katherine A. Carroll [a], Marcus

[a] Marine Science Department, University of Hawai'i at Hilo, 200 W. Kawili St., Hilo, HI 96720, USA
[b] Department of Biology, University of Bergen, Bergen, Norway
[c] Five Gyres Institute, Los Angeles, CA, USA

Microplastic has been identified in Atmospheric rainfall drop, groundwater, Tap water and even bottled water.

- The vertical/horiozntal transfer of microplastic is inseparable from the **Hydrological Cycle**.
- How the processes of evaporation, precipitation, infiltration, surface water runoff and ocean circulation drive the movement of microplastic among atmosphere, ocean and land remain unclear.

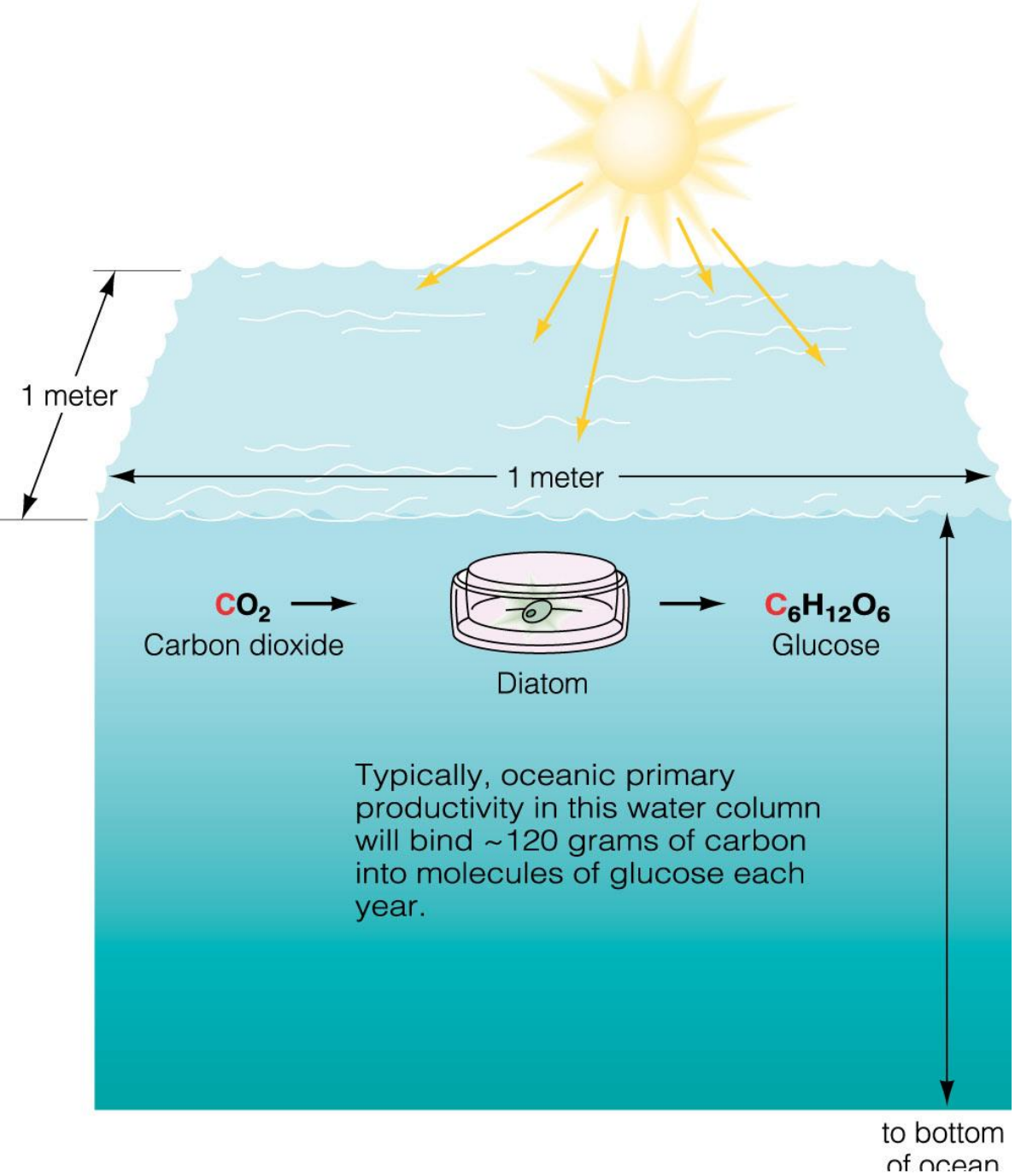
海裡的草是甚麼?

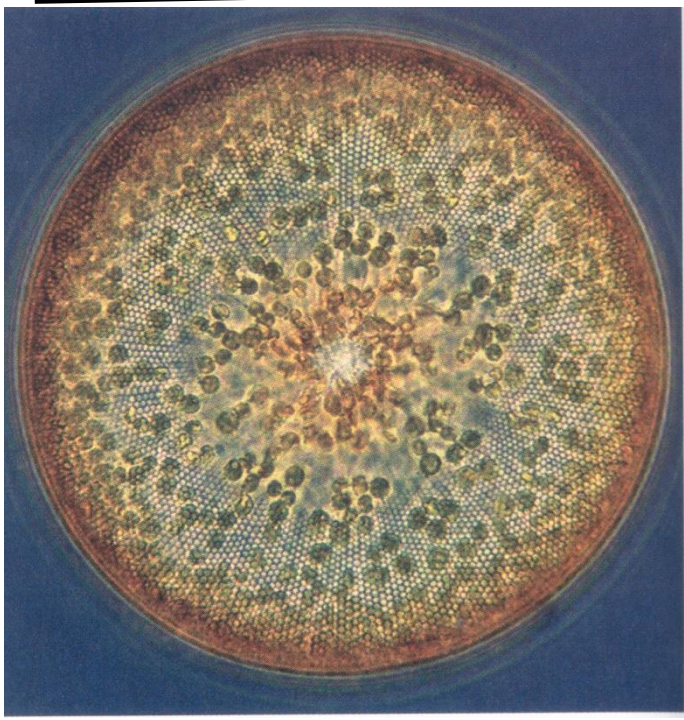
藻類

浮游植物：

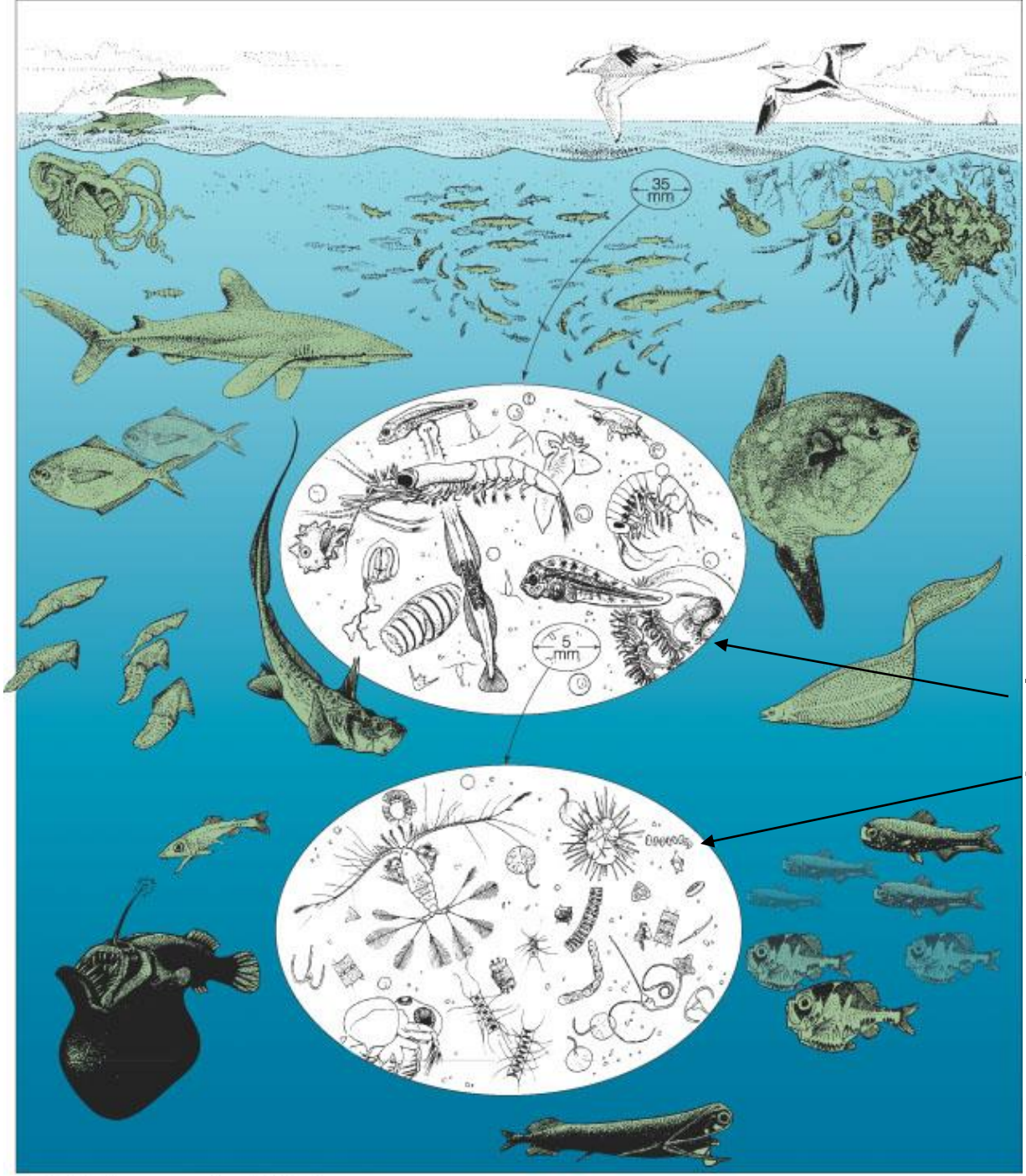
矽藻

~0.01 mm





游泳生物
Nekton:
swimmers



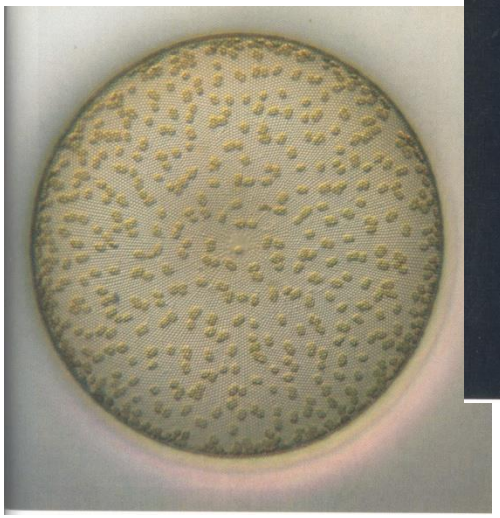
浮游生物
Plankton:
floaters

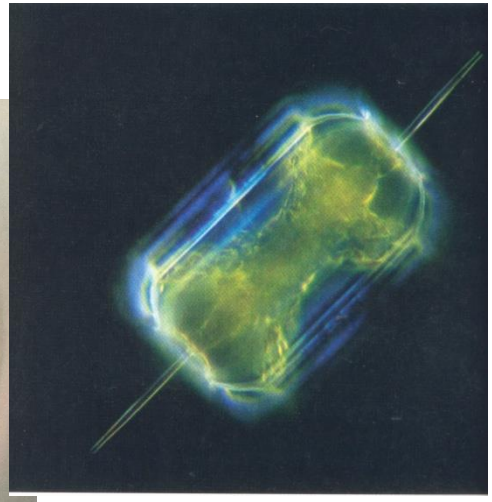
Zooplankton

Phytoplankton

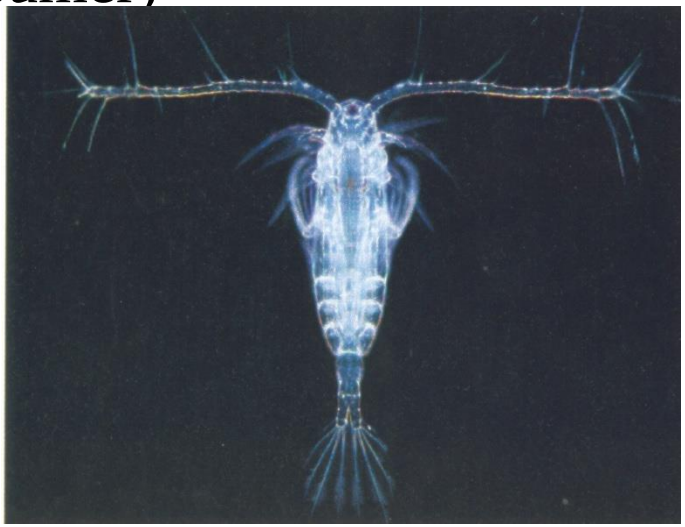
浮游生物 (Plankton)

- 浮游植物 (Phytoplankton): 初級生產者(primary producer)

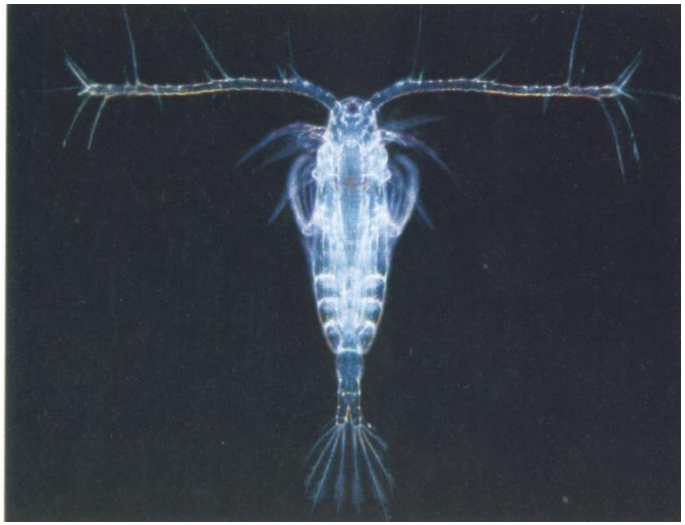


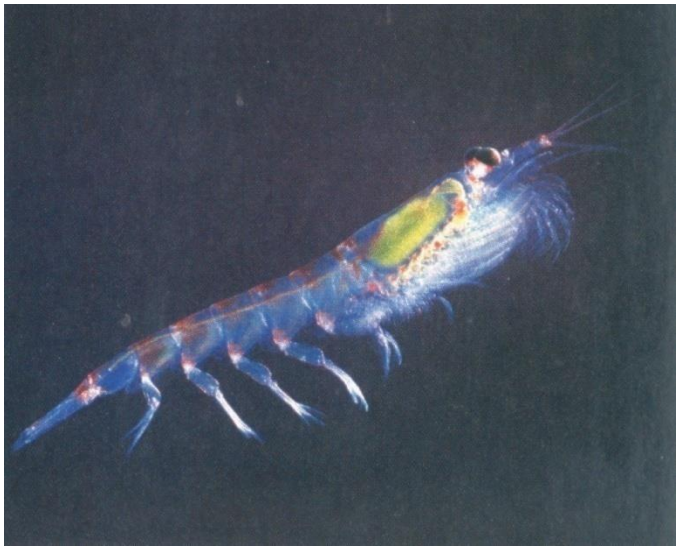


- 浮游動物 (Zooplankton): 初級消費者(primary consumer)



Zooplankton

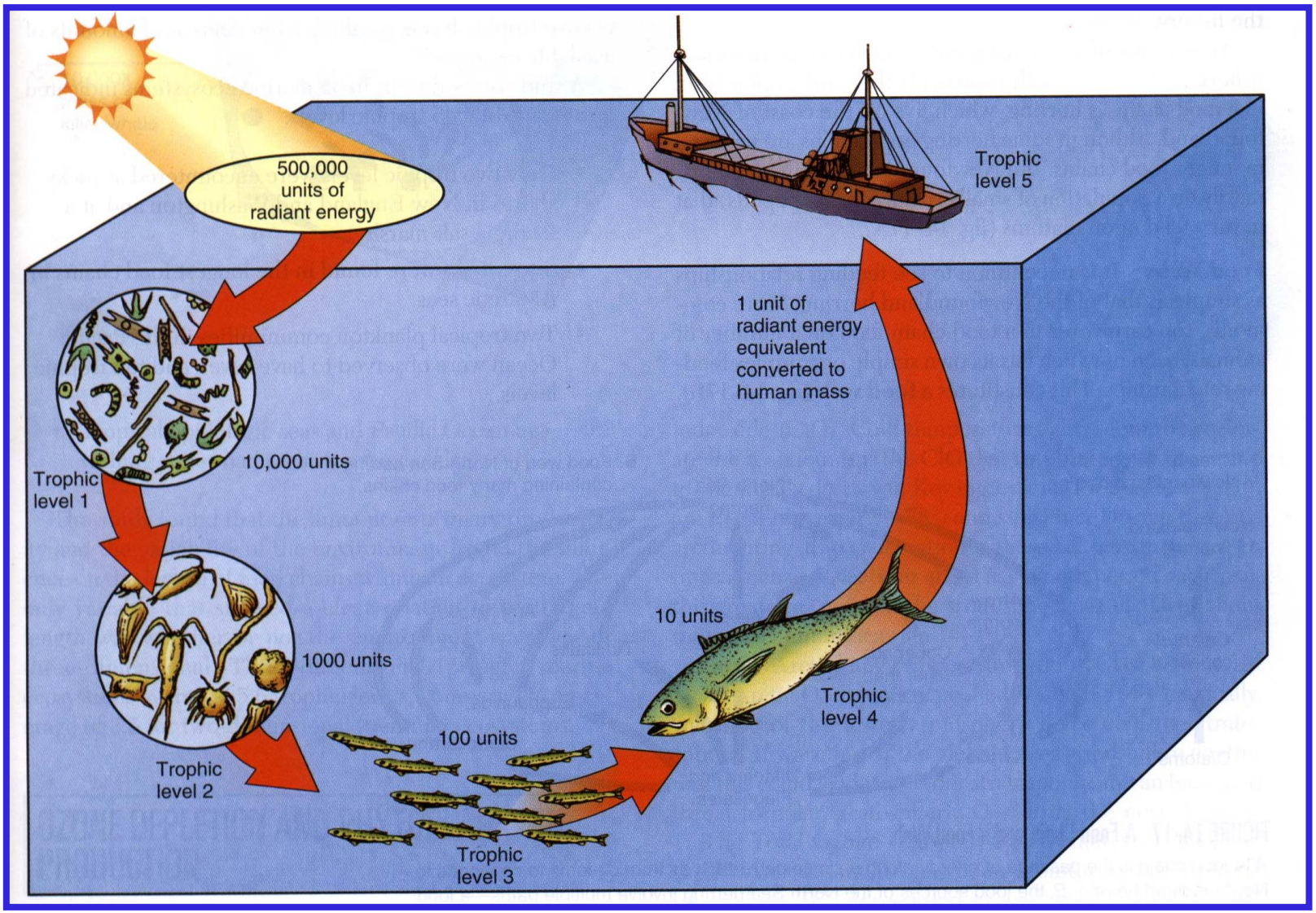




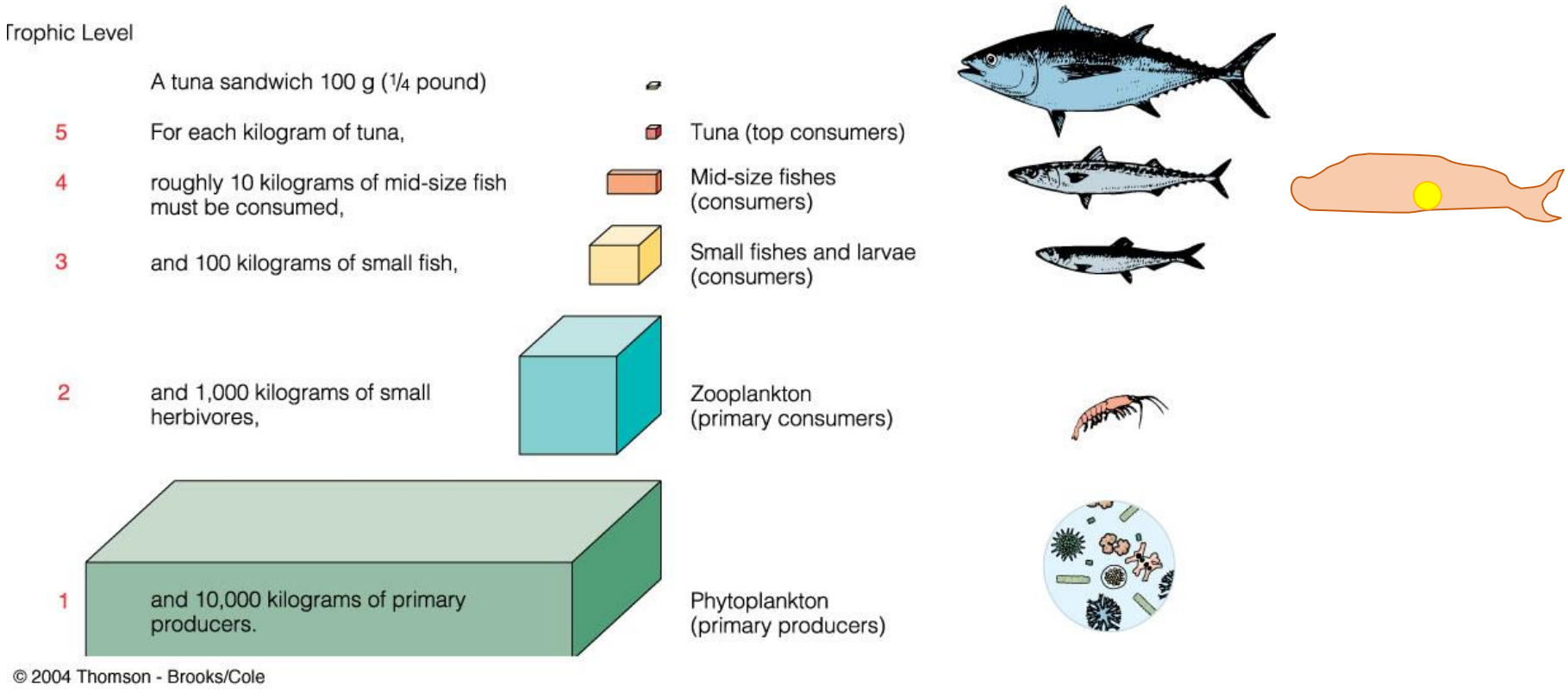
- Arthropoda（節肢動物）:

  Copepod（撓腳類）, krill（磷蝦）

海洋中的食物鏈


500,000
units of
radiant energy
Trophic
level 5
1 unit of
radiant energy
equivalent
converted to
human mass
10,000 units
Trophic
level 1
1000 units
10 units
Trophic
level 4
100 units
Trophic
level 2
Trophic
level 3

食物階層金字塔之生物累積作用 (Bio-accumulation)

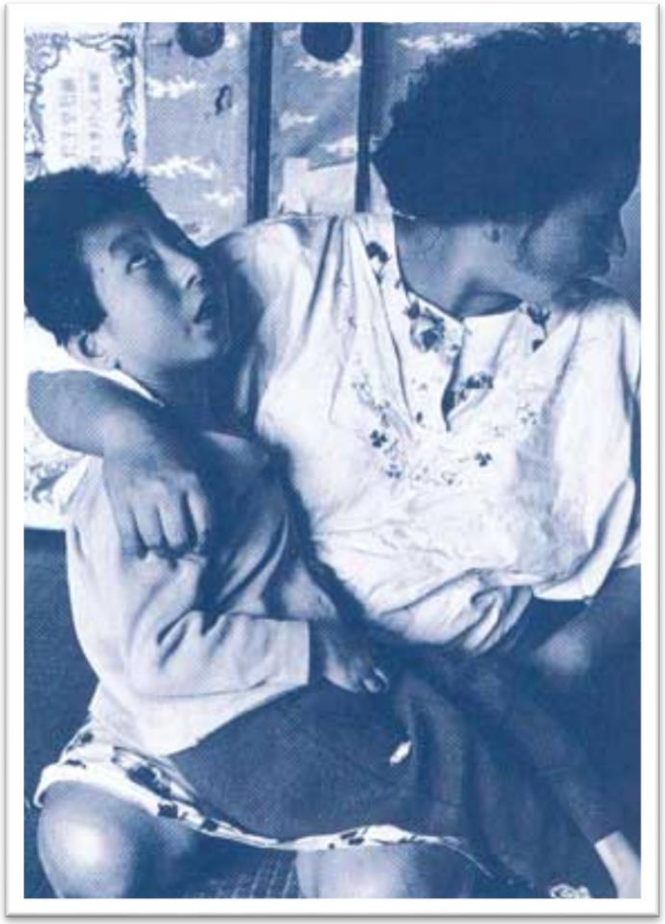


持久性有機污染物
Persistent Organic Pollutants (POP)

- Polyaromatic hydrocarbons (PAHs)
多環芳香烃（火坣）
- Organochlorines
（有機氯化物）
  - PCBs（多氯聯苯）
  - Dioxins（戴奧辛）
  - DDT：殺蟲劑
  - BHC：殺蟲劑

Minamata disease (水俣病)

以1950年代日本九州爆發的水汞症，由於業者偷偷將含有水銀的工業廢水排入海域，讓熊本縣漁民捕獲並食用吃水銀污染物長大的魚類，造成水銀沉積在大腦中、中樞神經系統病變，在20年後才逐漸發病，患者陷入昏迷、手指扭曲、無法控制的狂吼，終致死亡。經過日本政府的追蹤調查，花了12年才證實是工業污染。



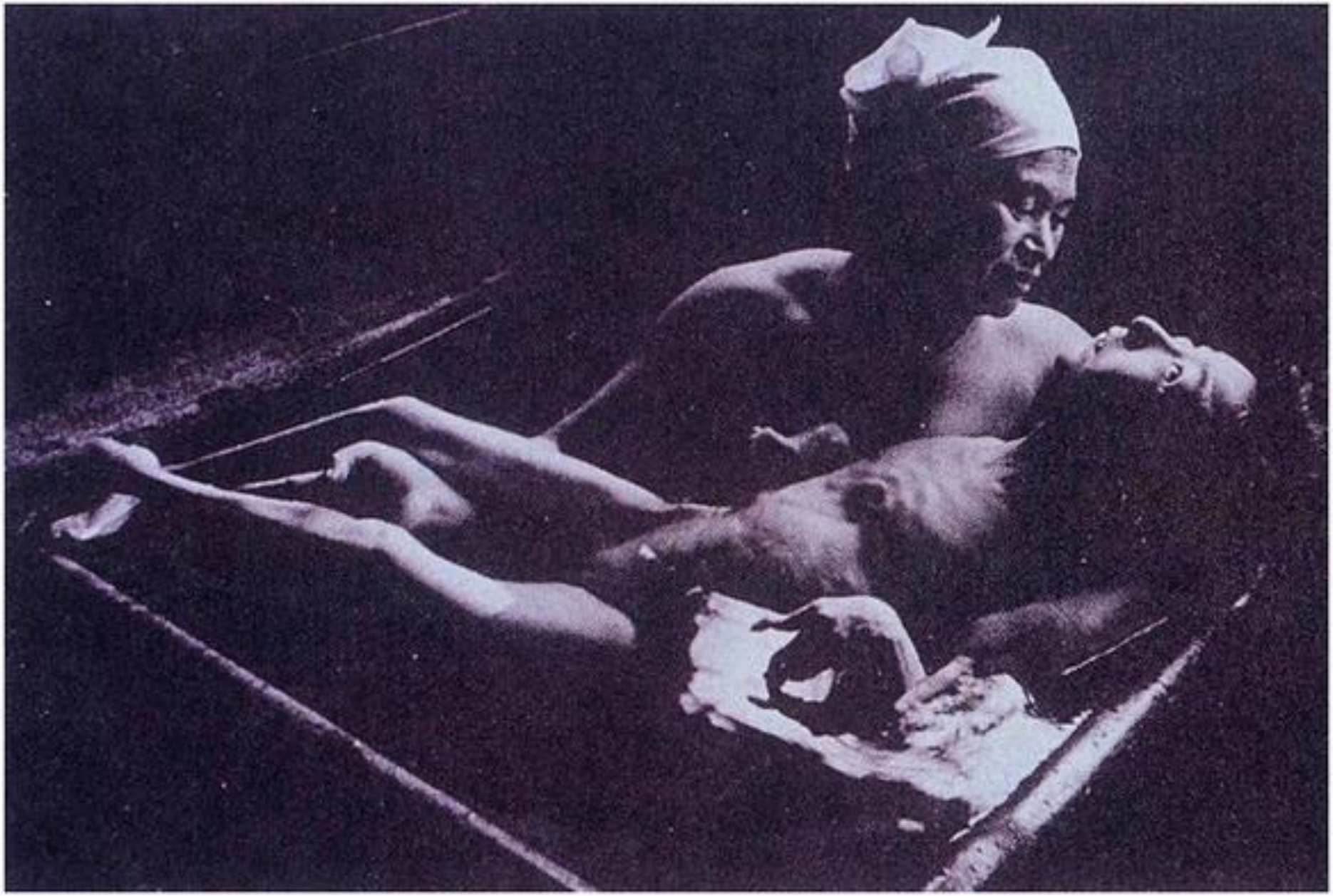


Photo: William Eugene Smith (智子入浴, Tomoko in the Bath, 1972)

台灣歷年來重大污染事件簿

1982	高銀化工鎘米事件 農地大污染
1986	綠牡蠣事件 吸收重金屬變綠色
1988	林園石化園區污染 賠償逾13億
1994	RCA挖井 傾倒有機溶劑等毒廢料
2008	大寮鄉空污事件 國中小師生中毒
2010	台塑仁武廠二氯乙烷 重罰千萬

寂靜的春天(1962)

- 美國生態作家 瑞秋卡森 Rachel Carson 女士，觀察到 DDT 殺蟲劑對作物的影響，在1962年出版了“寂靜的春天”一書，在書中提到人類過度使用農藥，污染土壤將使得田野、森林、沼澤帶的生物死若過同時再生，所有的生態環境留下的是一片寂靜，春天成為沒有生命無法季節。鳥叫的

- 此書出版前，環境從來不是政府部門的公共政策議題。

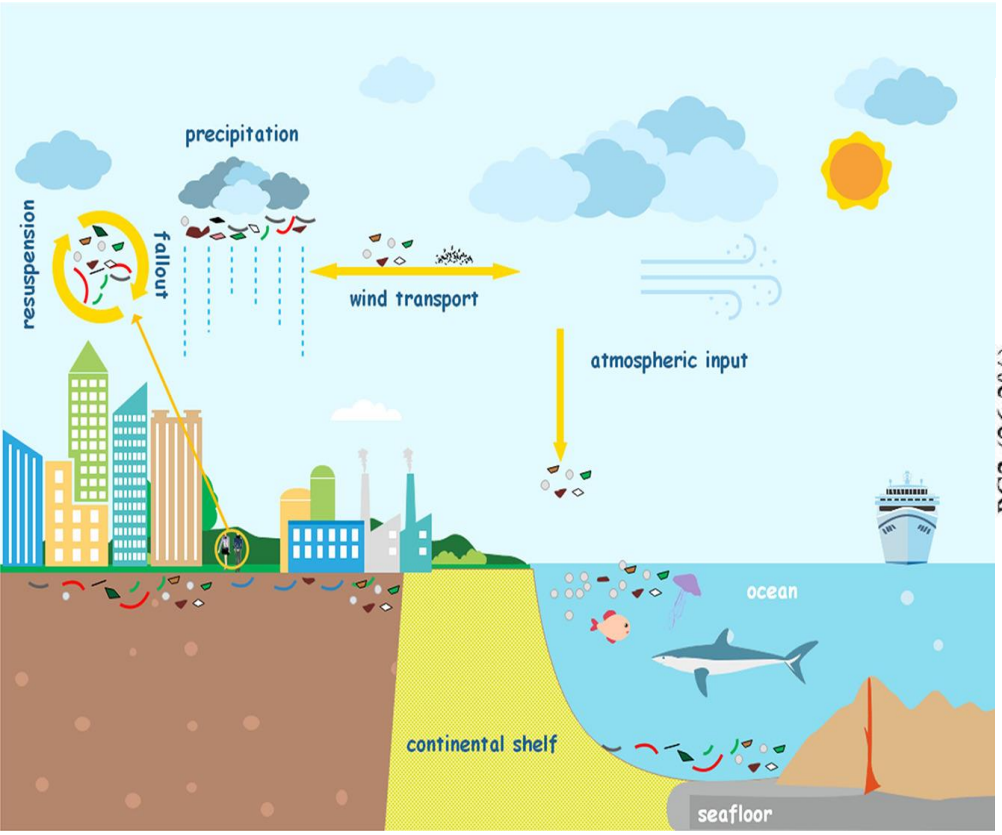
- 此書出版後，美國國會確認了殺蟲劑的潛在危險警告，成立了一個農業環境組織來面對此問題(1965)，而此書所播下的新行動主義的種子，已深深植根於廣大群眾間。

- “寂靜的春天”的出版應是現代環境運動的肇始。

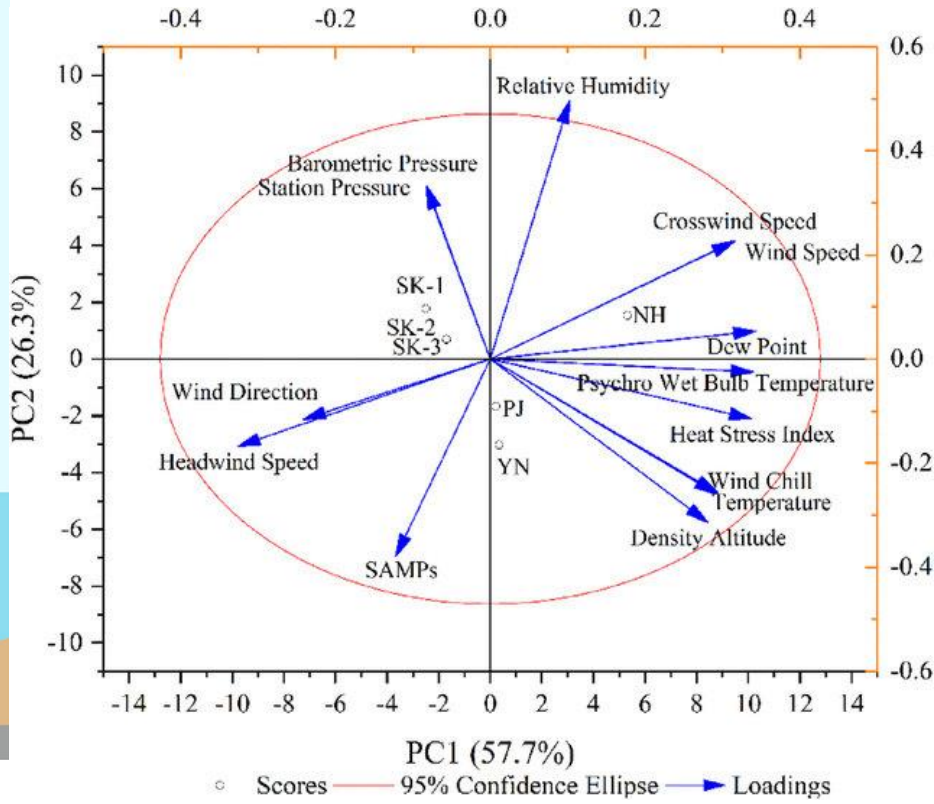
- 全球由單純“發展”的思考，轉而為“環境與發展”的思考的一個重關鍵，且為日後“永續發展”的思考與理念奠基。

ＤＤＴ剛使用時，並不知其危害程度，
後來演變成為環境議題，開啟全球環境運動

Microplastics Transport vs. Hydrological Cycle



Source : KaiLiu. 2019



Microplastics (MPs) are an emerging concern and potential risk to marine and terrestrial environments. MPs was included in the hydrological cycle and transport. Microplastic can be vertically and horizontally transported as suspended particles in atmosphere

Microplastics in the hydrological cycle are categorized as fibers (67%), fragments (30%), and a granule (3%).

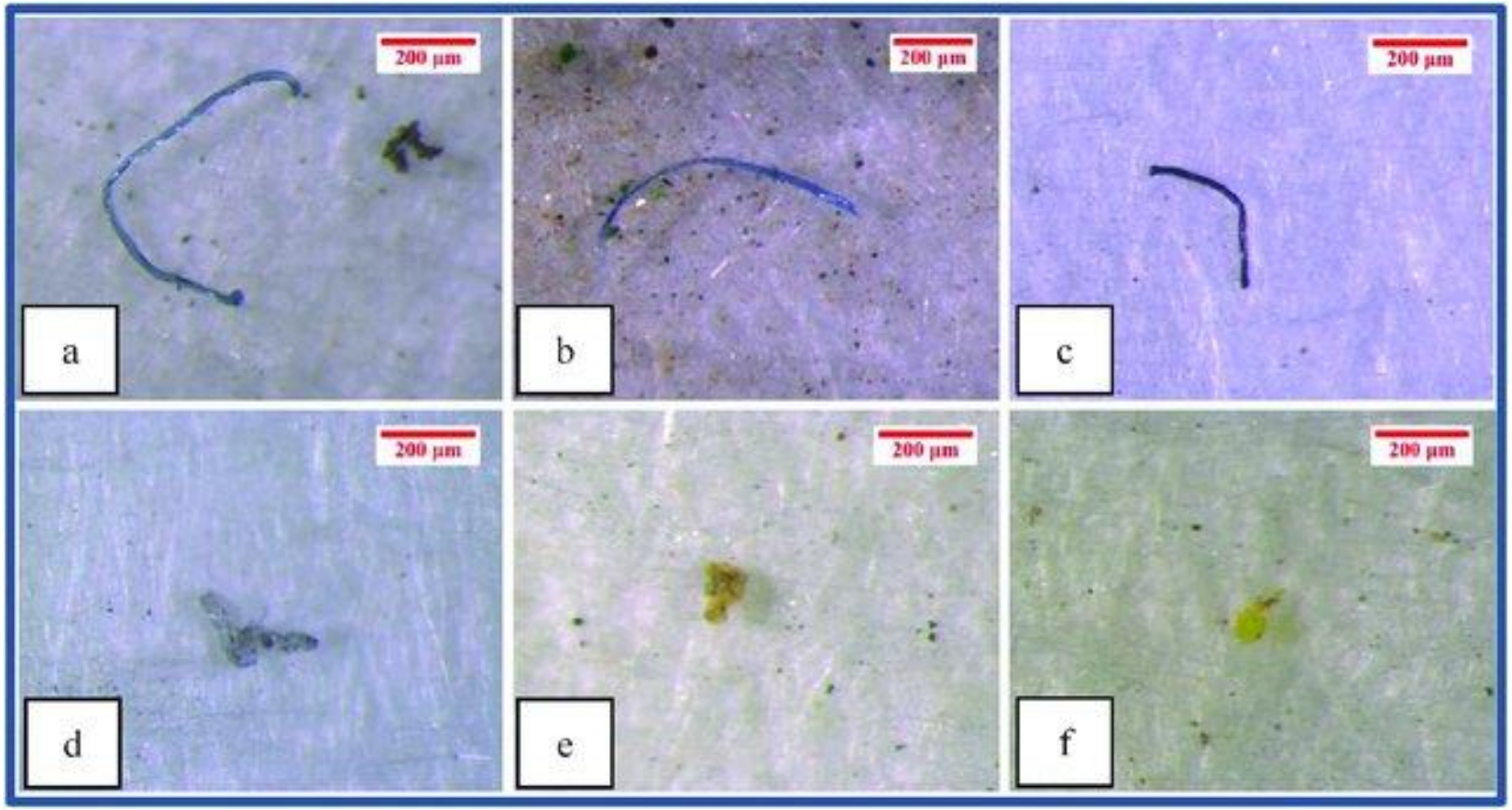


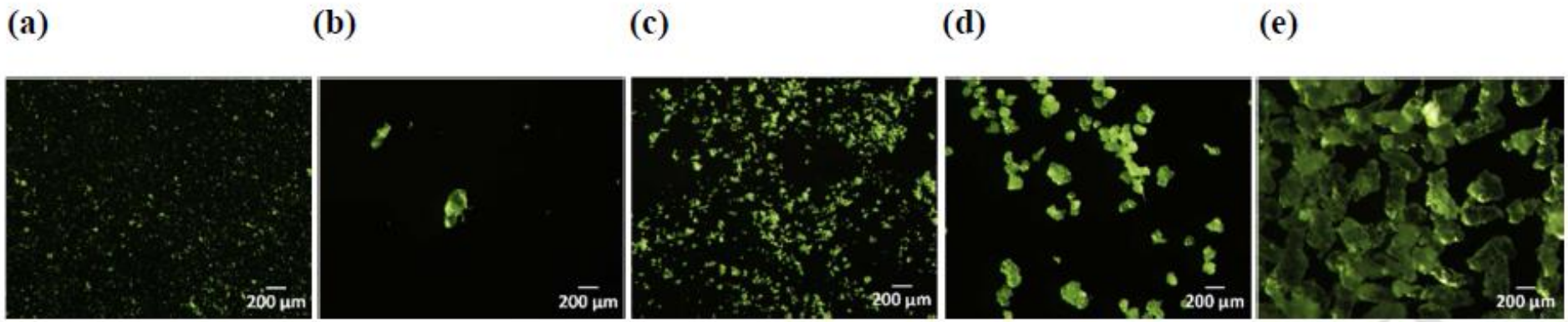
Figure 3. Photographs of typically observed microplastics. a-c: fibers; d-e: fragments; f: a granule.
Source : KaiLiu 2019

Microplastic migrates vertically and penetrates into the soil through infiltration (Steve Allen 2019)

- The average penetration depth was calculated as 5.24 m [1].
- Particle size in the initial surface and groundwater concentration with sand to derive MP-sand mixture concentrations of 0.07%, 0.13%, 0.27%, 0.53%, 1.06%, 2.09% and 4.09% (w/w). To each column, single infiltrations of 100 ml of infiltration fluid were applied [1].

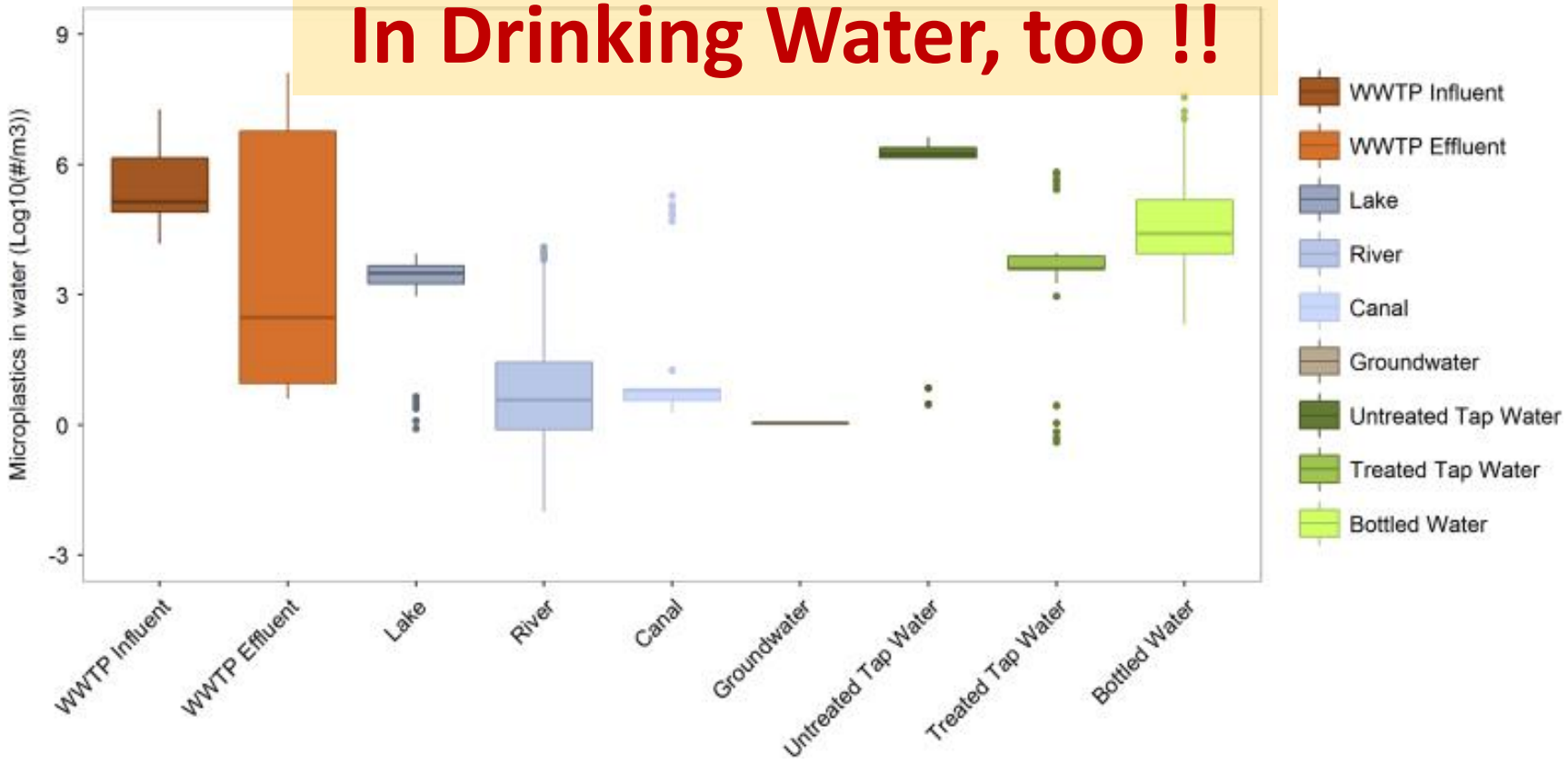
Figure 6 (a-e) Stereomicroscopic photographic images (false colour) of the five MPs used showing granular, pellet, or spherical morphotype particles of (a) PE-fine, (b) PE-coarse, (c) PP, (d) facewash, and (e) body scrub particles.

Density (g/cm^3)	0.893	0.884	0.833	0.898	0.876

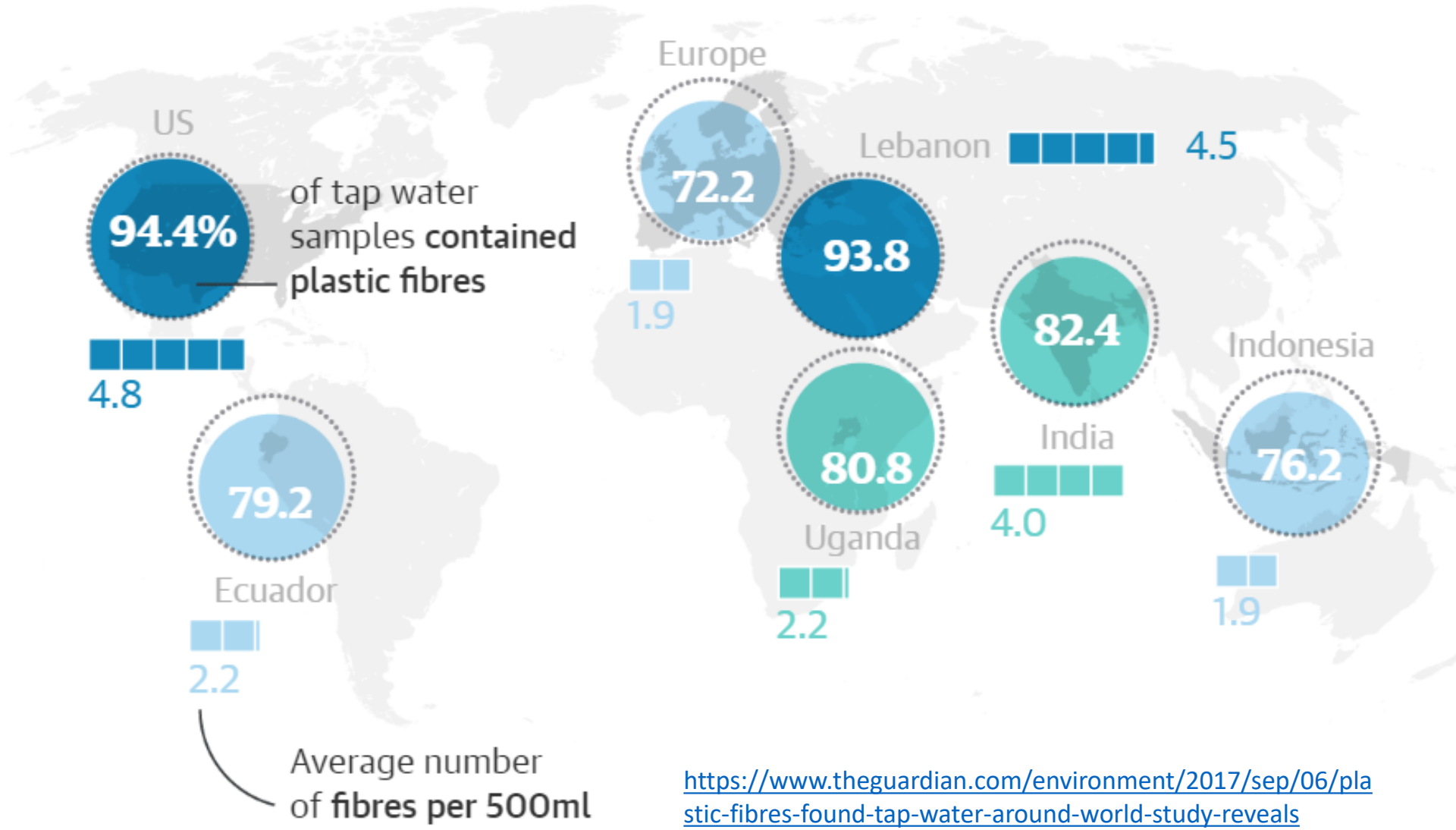


- The GESAMP (2015) : report the presence of microplastics in air samples, food and drinking water
- Albert A. Koelmans (2019) : The ubiquity of microplastics of all sizes in surface water, groundwater, and wastewater, has raised the question of pollution of drinking water occurs.
- The presence of microplastics in tap water and bottled water are reported by Kosuth et al., 2018; Mason et al., 2018; Mintenig et al., 2019a, Mintenig et al., 2019b; Schymanski et al., 2018.

In Drinking Water, too !!



Tap water is widely contaminated by plastic



https://www.theguardian.com/environment/2017/sep/06/plastic-fibres-found-tap-water-around-world-study-reveals

Let’s do something…

Taiwanese preliminary, ongoing efforts

Trans-disciplinaries Integration





Marine Research	Laws and regulations strategies	Numerical Simulation	Emerging technology	Program development	Actual NGO practice
Ocean Affairs Council, National Academy of Marine Research		Yung-Fang Chiu	Decision making analysis		
		Hsun-Chieh Chuo	Data quality control analysis		
Ocean Conservation Administration, Ocean Affairs Council		Hsiao-Hsia Li	Problem analysis, strategic planning, environmental protection laws and regulations		
Center for Space and Remote Sensing Research (CSRSR)		Kuo-Shin Tseng	Quality service, communication system		
		Chi-Fan Chen	Web composition, image recognition		
National Central University (NCU)		Hwa Chien	Programming practicals, mobile application development		
		Tsung-Hsien Juan	Program development, algorithm		
Greenpeace		Ning Yen	Policy analysis, public communication, popular science communication, team coordination		
		Chien-Wu Lai	Ocean drifting, oceanographic investigation, ocean-atmosphere environmental data		
		Chien-Ming Liao	Ocean numerical simulation		

Discover problems, propose plans

Strategy - Phase 1

1. Constrain plastic usage
2. Remove former Coastal and River bank garbage landfill sites

Reduce the terrestrial sources

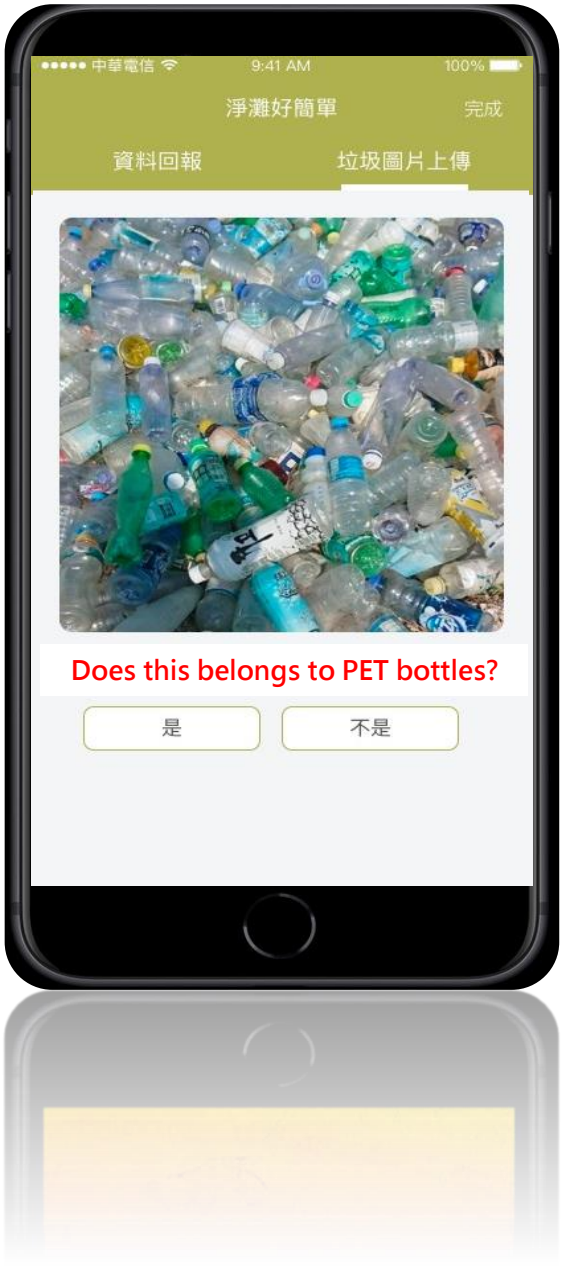
1. **Marine Plastic Beach Survey APP**
2. **Drone image AI recognition**
3. **MPD trajectory monitoring and prediction**

R&D of Technologies of MPD survey and monitoring

Dynamic marine plastic debris database

Beach Survey APP for Coastal Cleanup

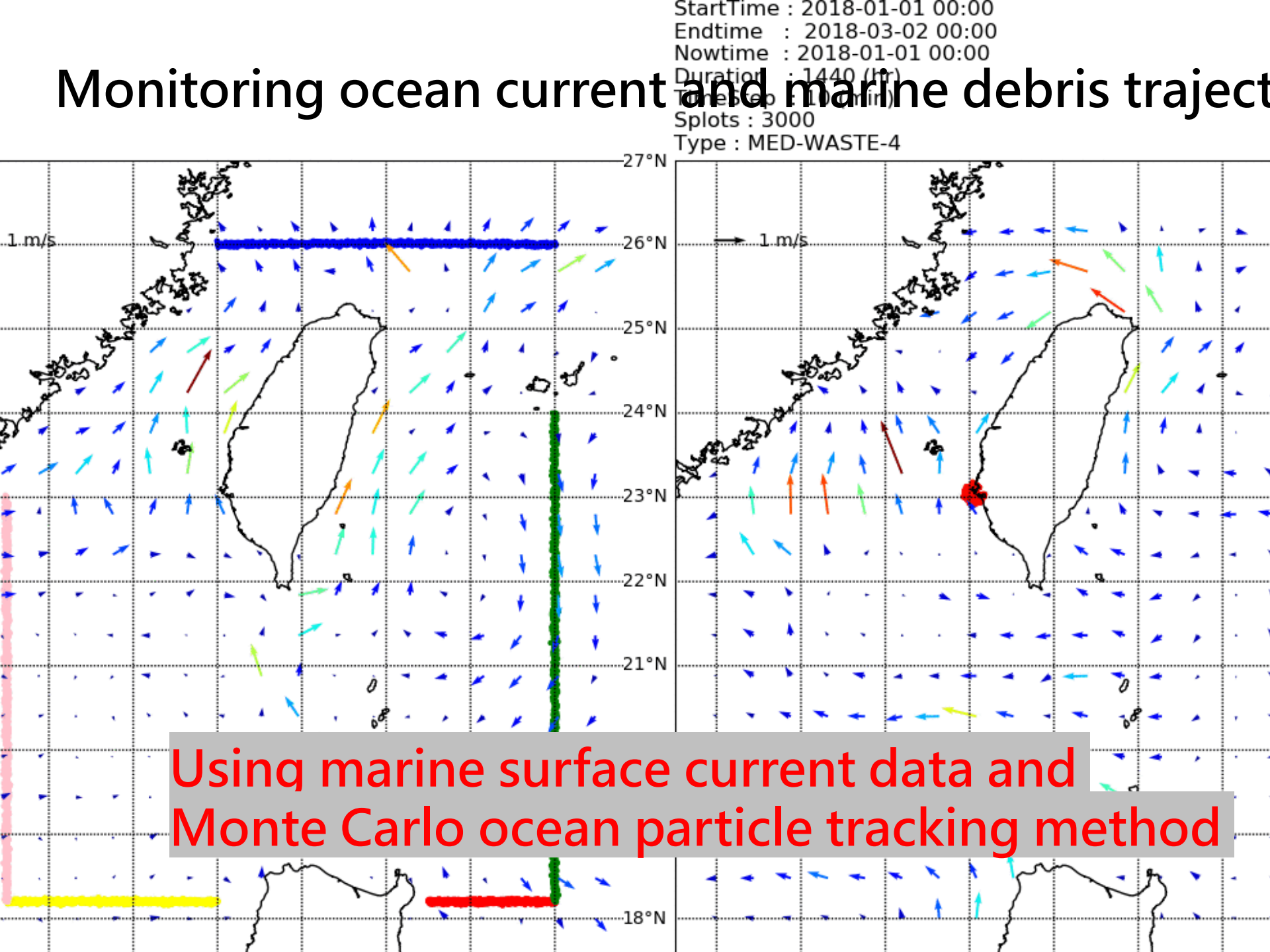
- Beach cleanup made easy APP
- ✓ Nationwide participation in big data collection
- ✓ Reporting back of data from beach cleanup activities
- ✓ Set up a single database
- ✓ Immediate reporting statistical data
- ✓ Establishment of marine debris image recognition training sample



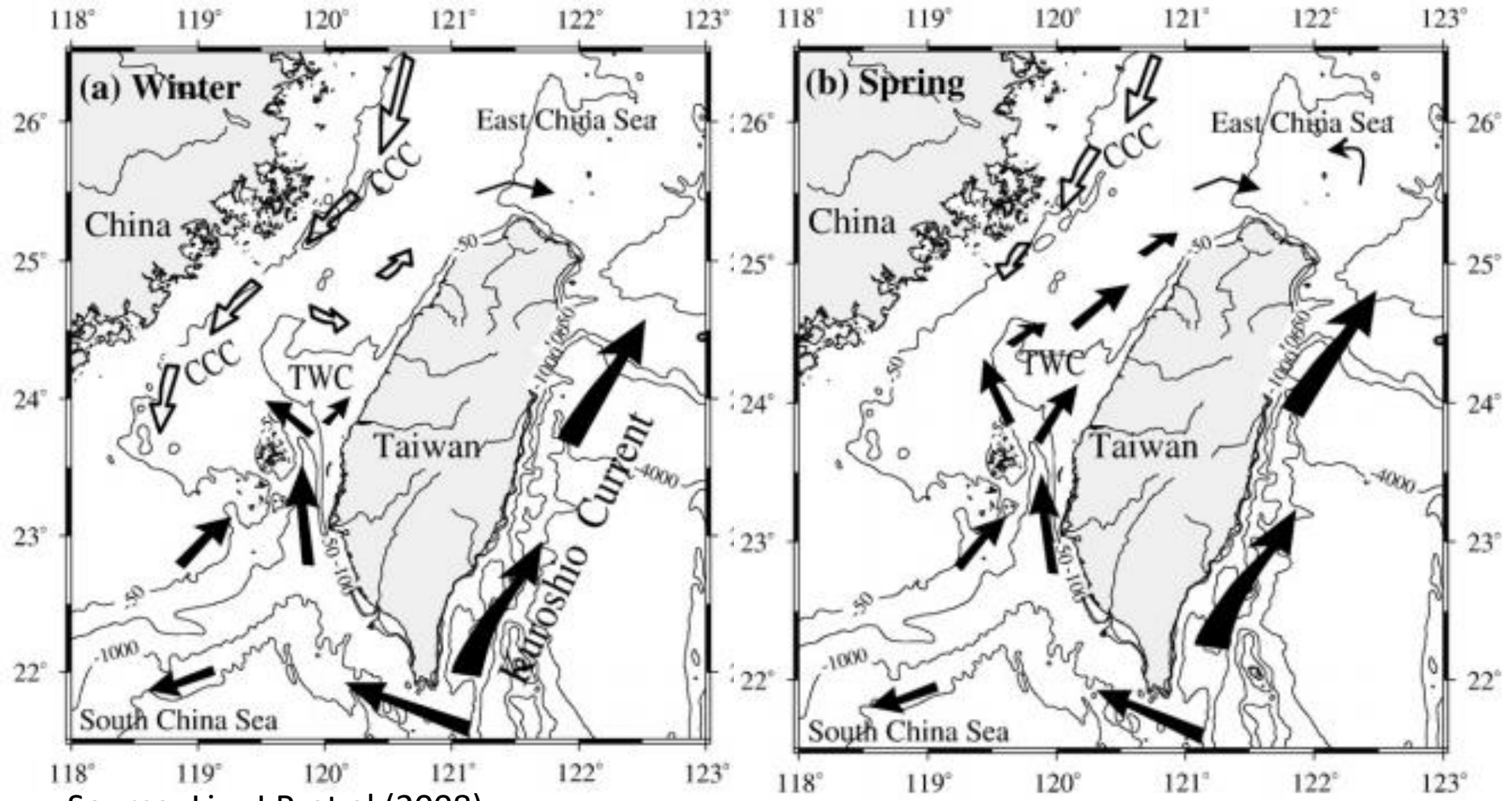
Drone Image Recognition

20 June, 2019 5pm: North wing ocean image from An Ping Sihcao Bridge

Monitoring ocean current and marine debris traject

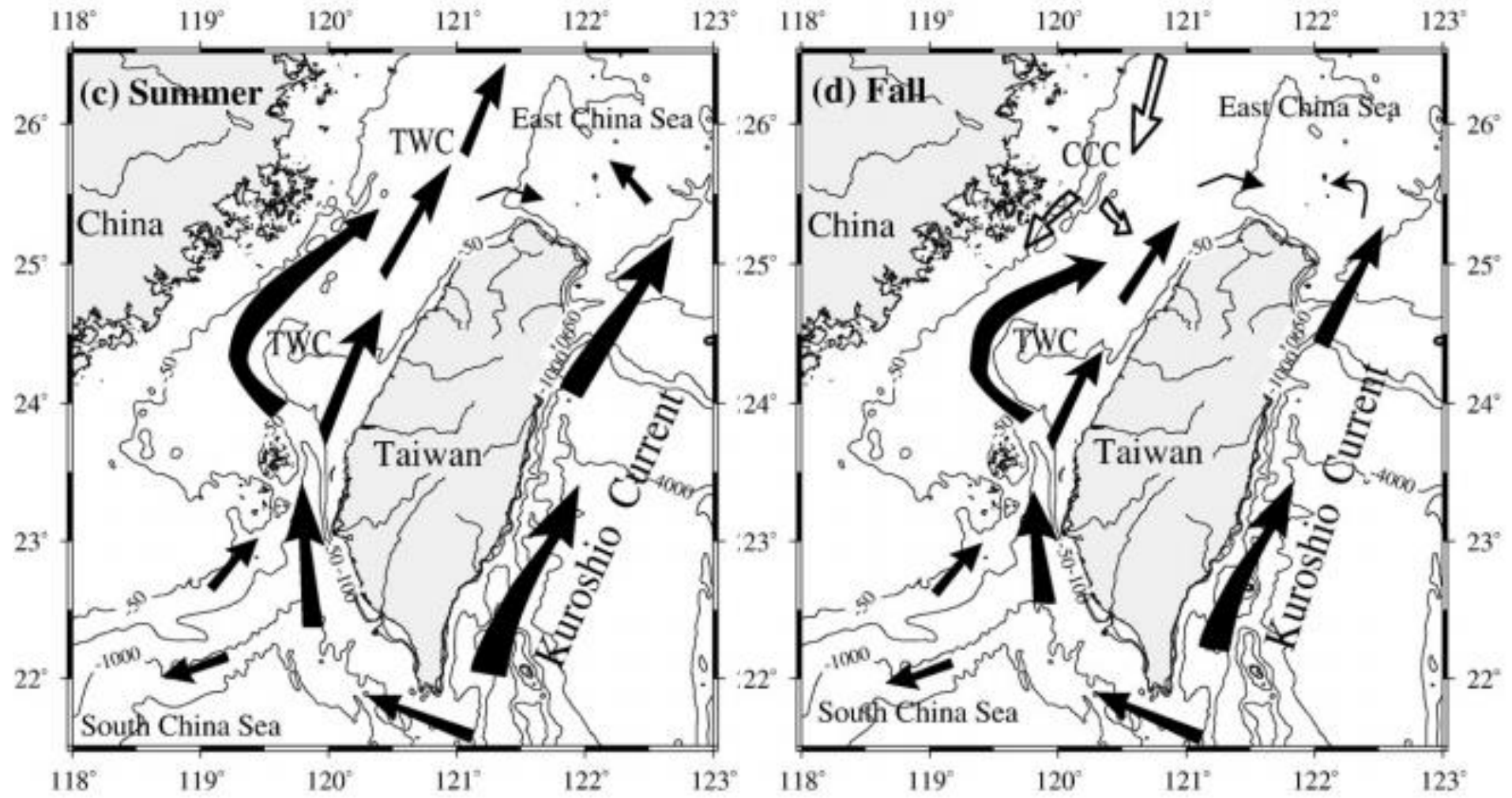


Using marine surface current data and
Monte Carlo ocean particle tracking method



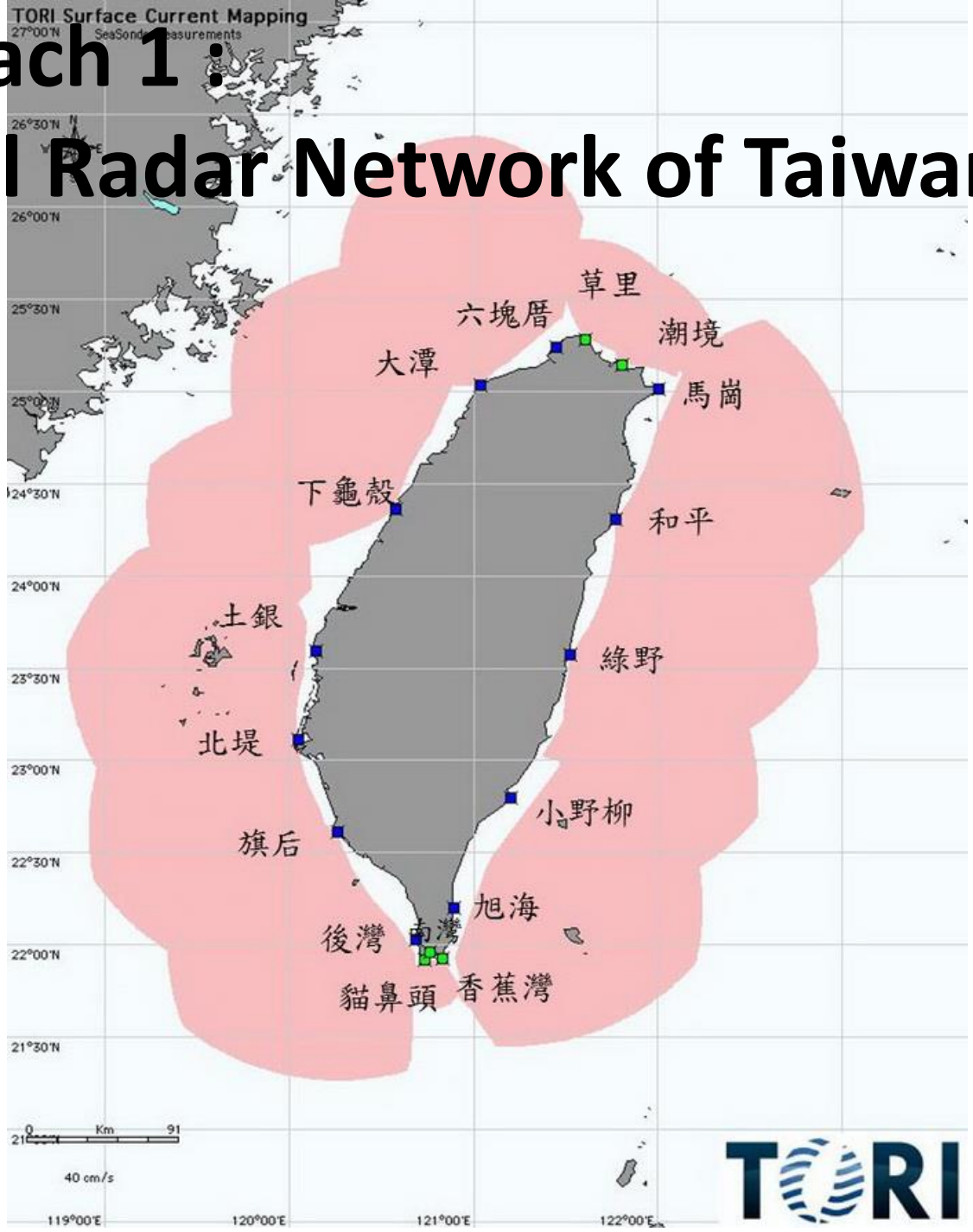
Source: Liu, J.P. et al (2008)

Seasonal Variation of Circulation in Taiwan Strait



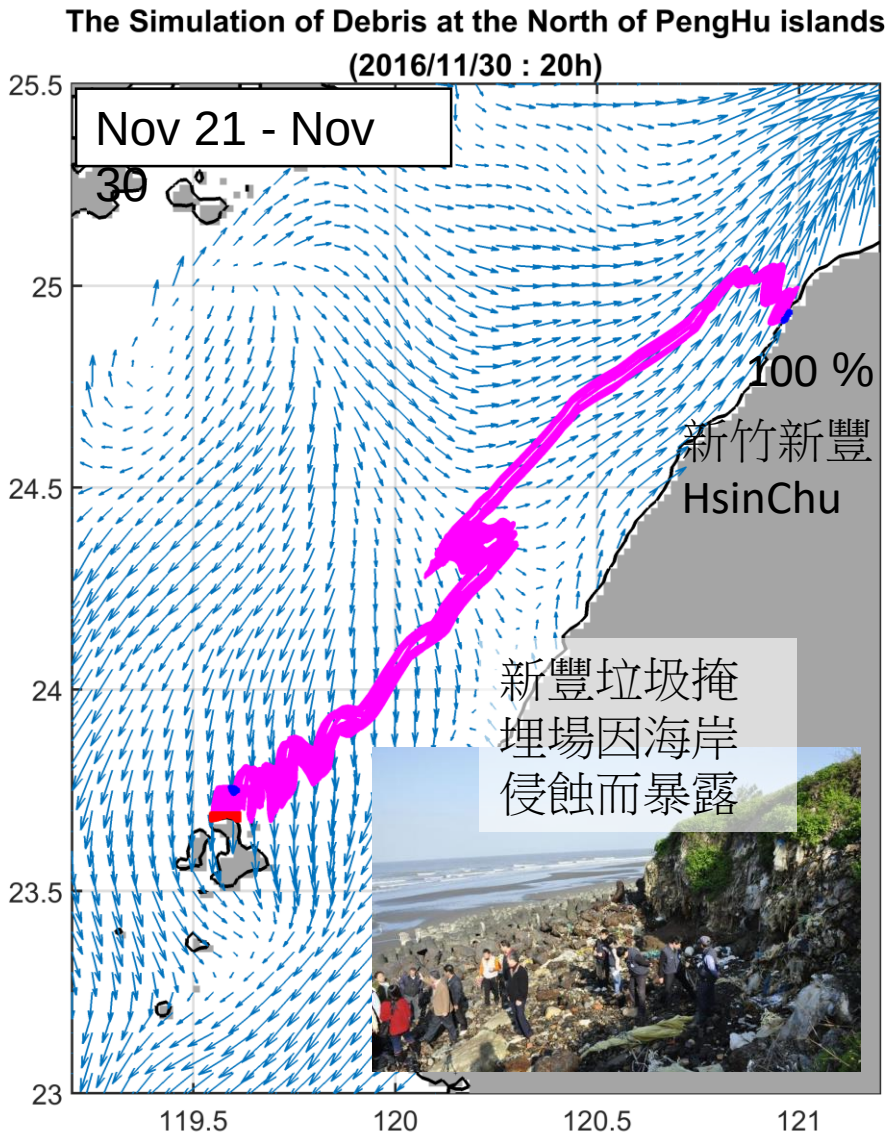
Source: Liu, J.P. et al (2008)

Approach 1 : Coastal Radar Network of Taiwan

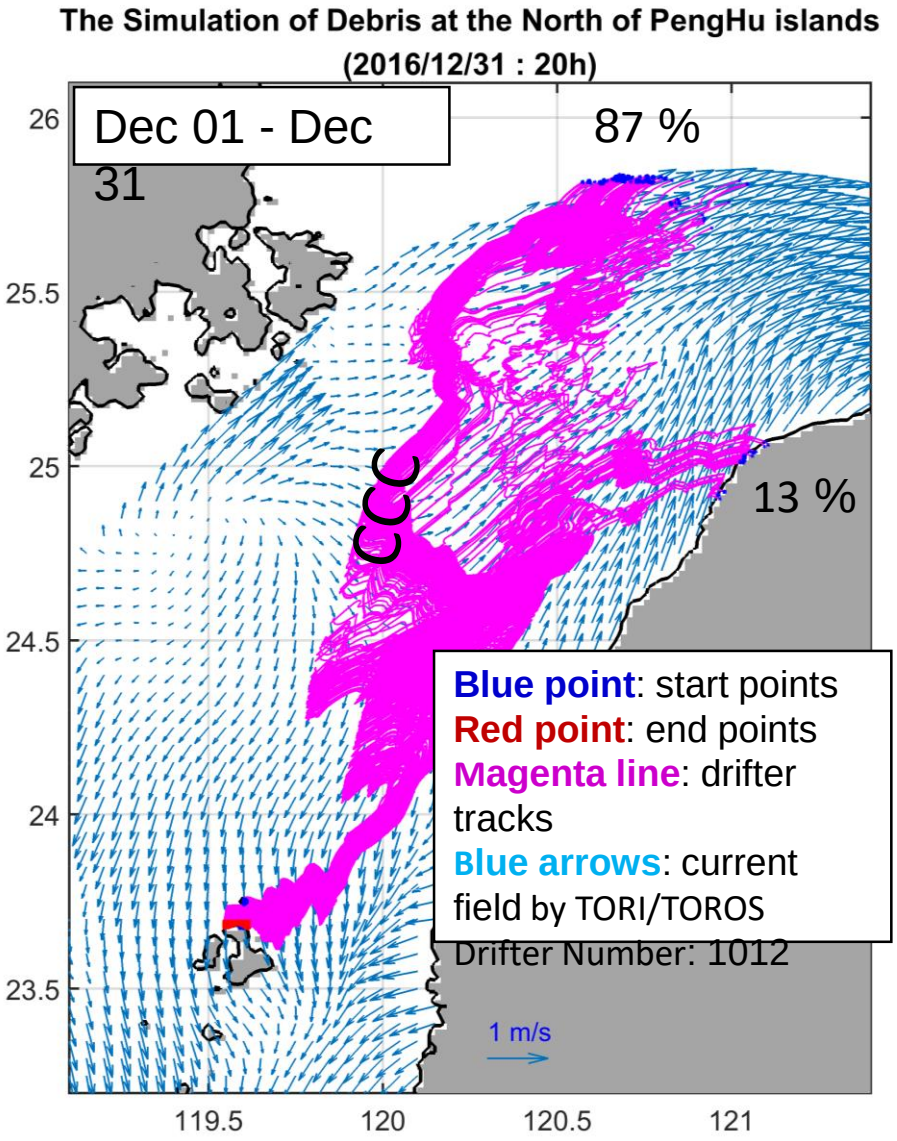


Source of Penghu Marine Debris (Winter)

November 2016

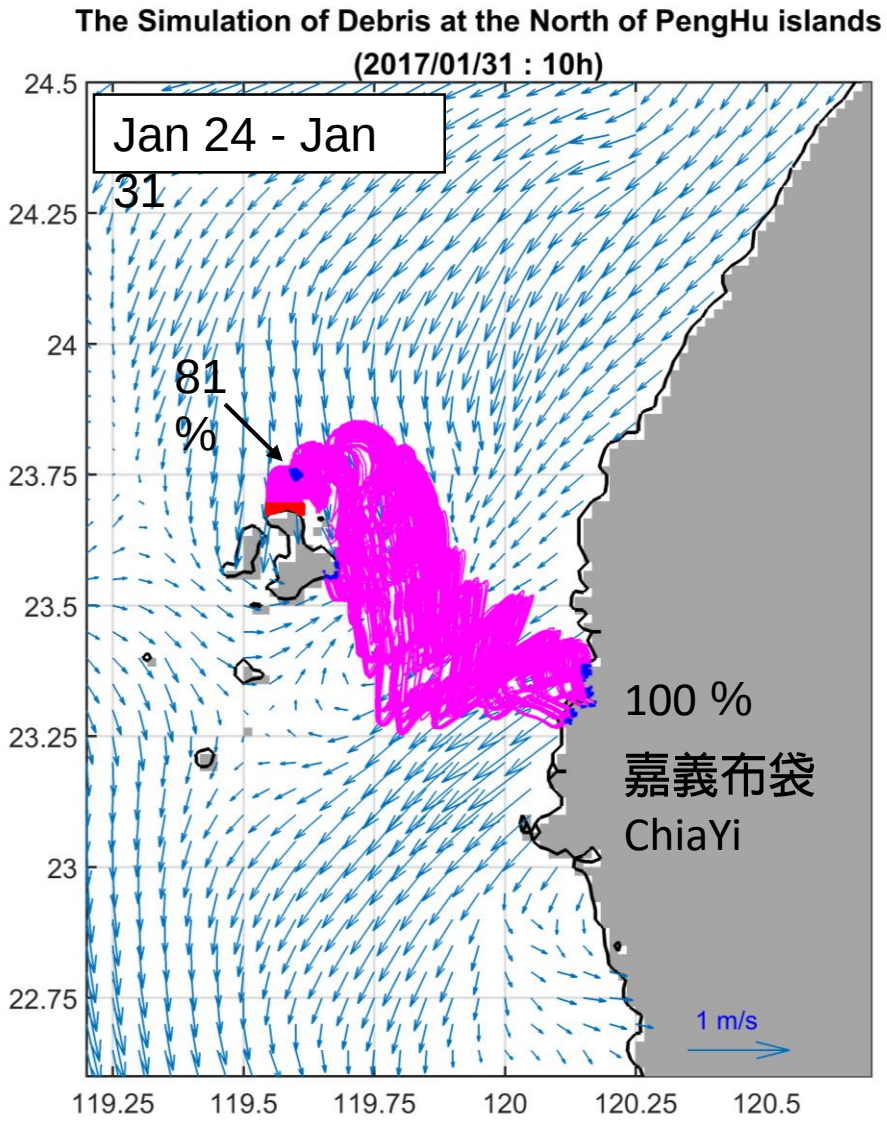


December

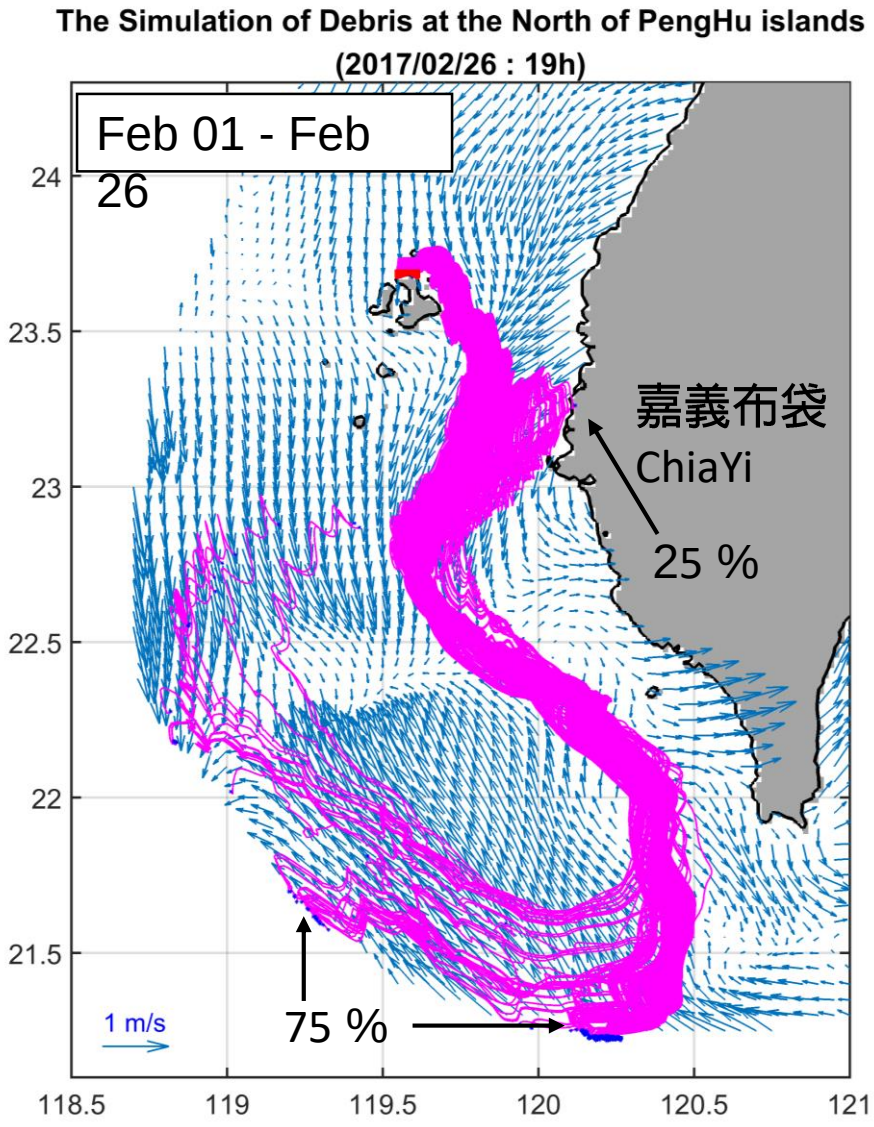


Source of Penghu Marine Debris (Winter)

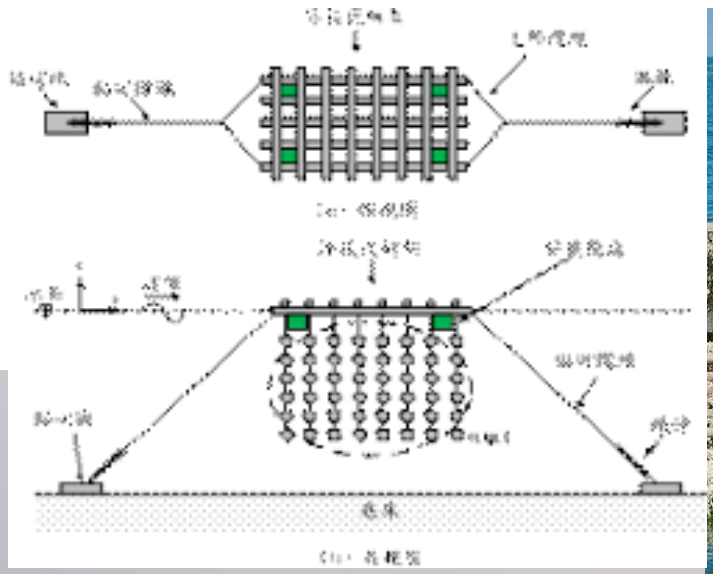
January 2017

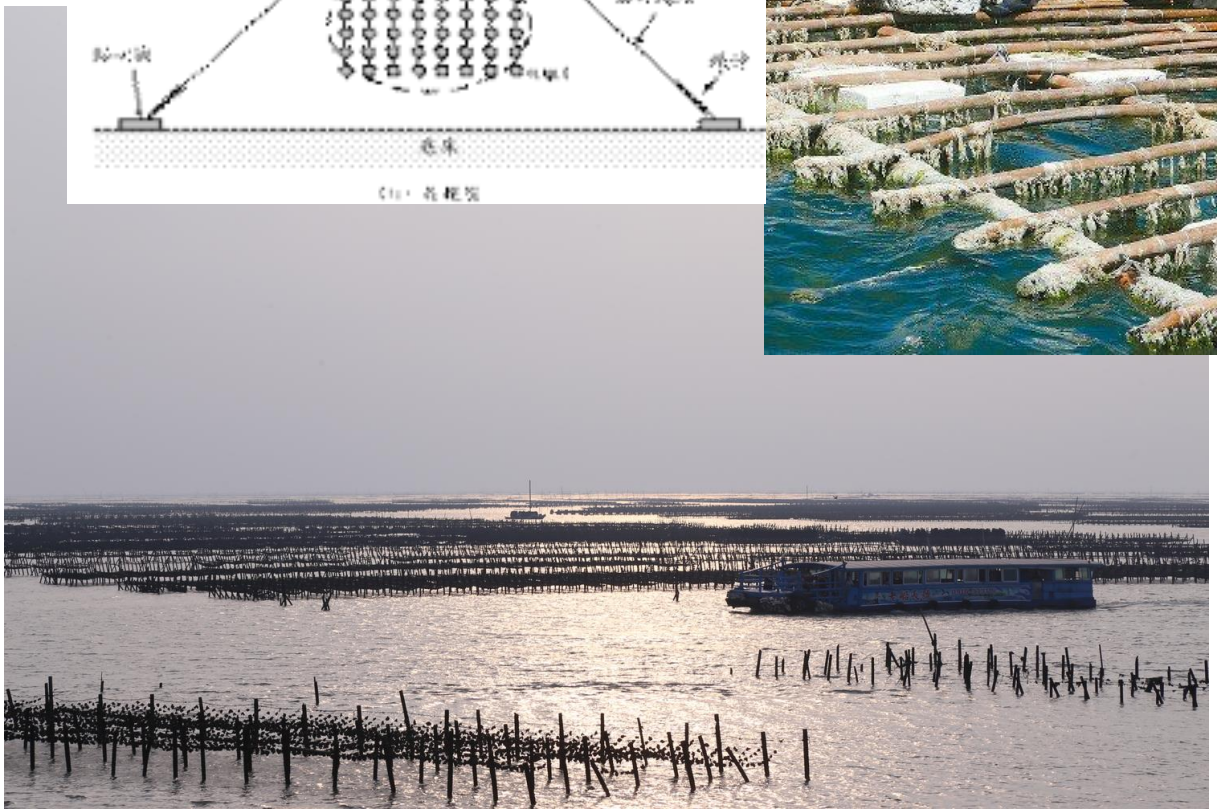


February 2017

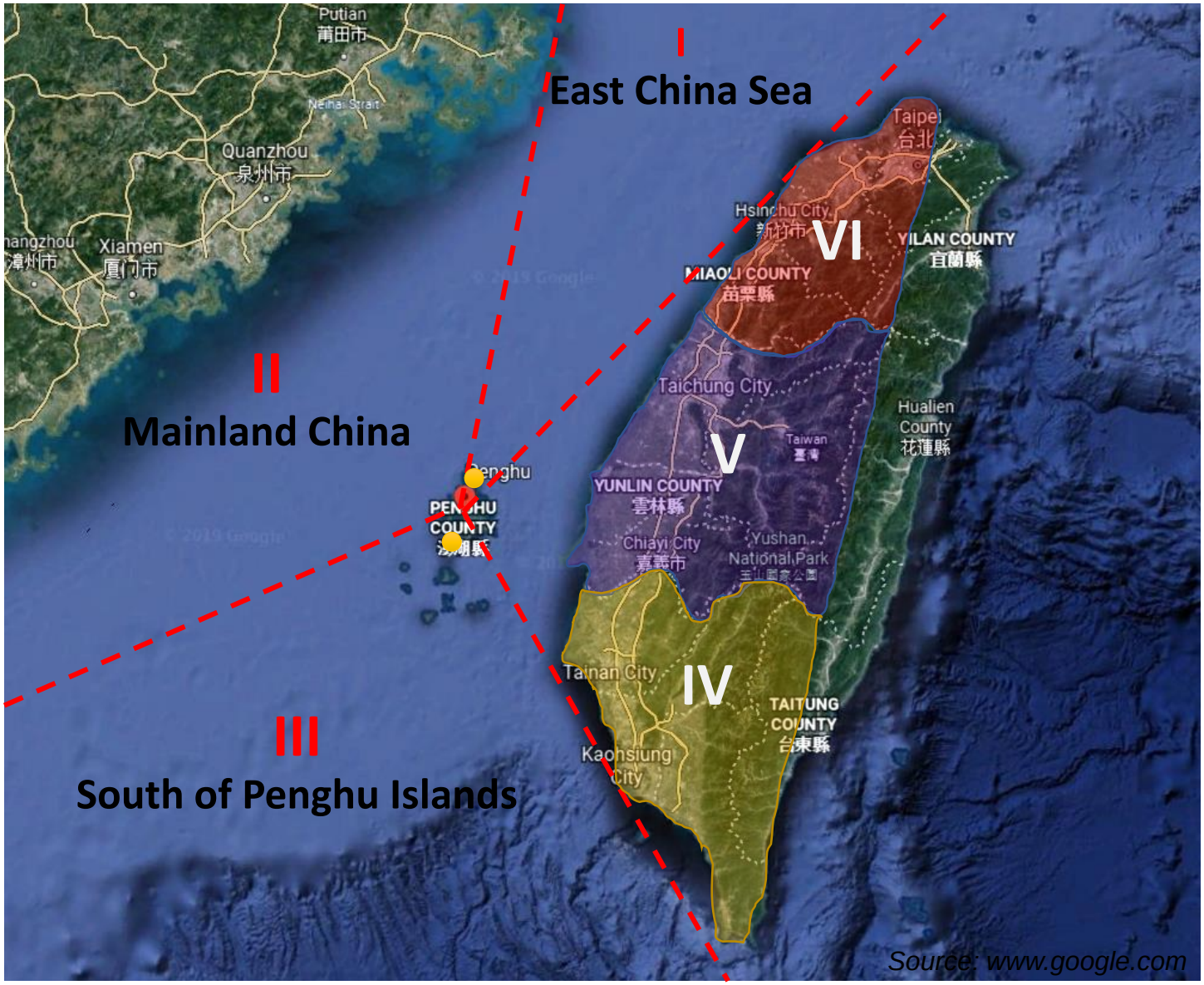


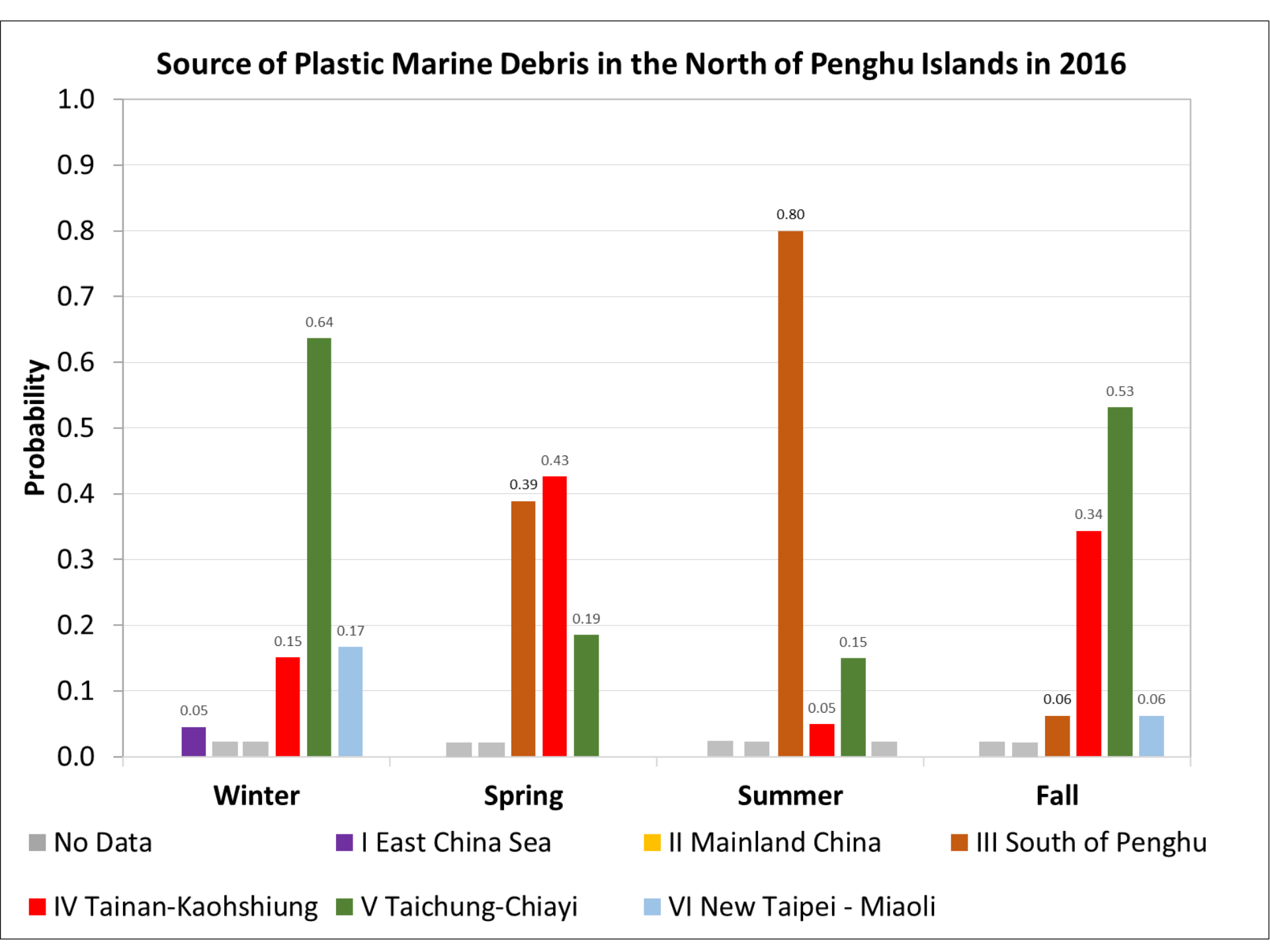
Oyster Agriculture in ChiaYi



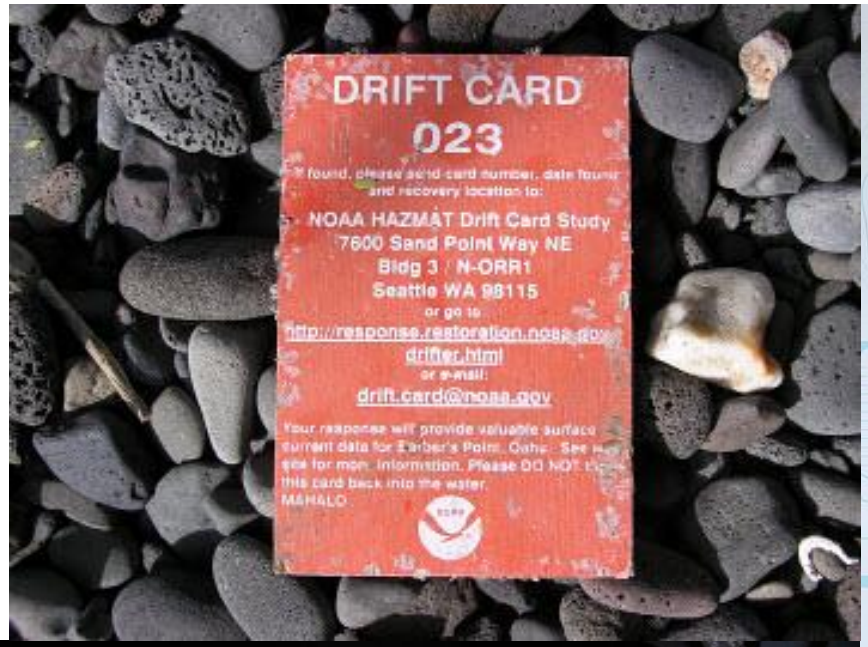


Possible sources of marine debris' region



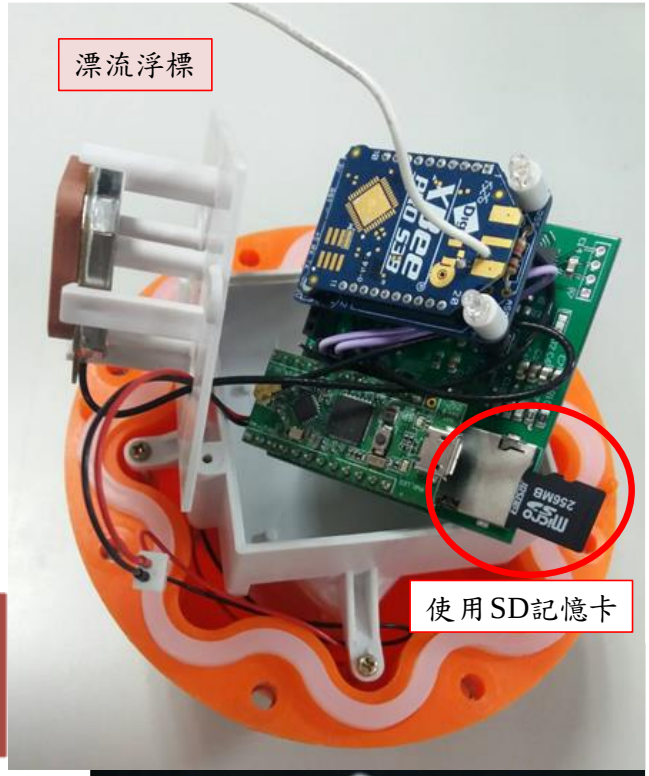

Source of Plastic Marine Debris in the North of Penghu Islands in 2016
Probability
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0.05
0.15
0.64
0.17
0.39
0.43
0.19
0.80
0.05
0.15
0.06
0.34
0.53
0.06
Winter
Spring
Summer
Fall
No Data
I East China Sea
II Mainland China
III South of Penghu
IV Tainan-Kaohshiung
V Taichung-Chiayi
VI New Taipei - Miaoli

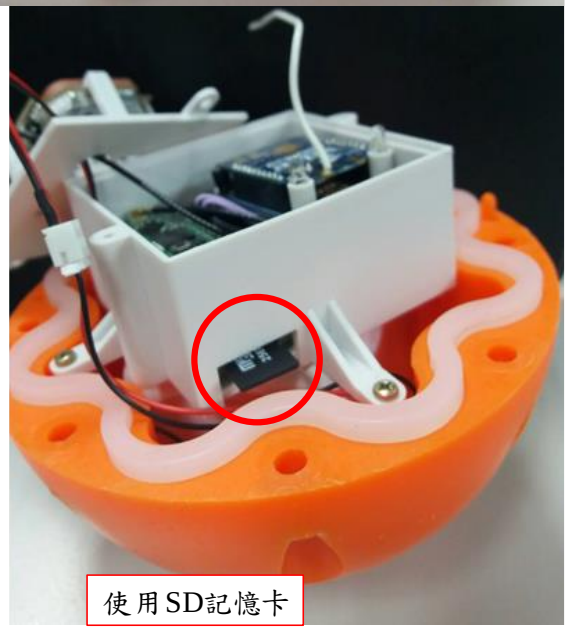
Approach 2 : From river to ocean: Low-Cost Tracking Drifter Applications

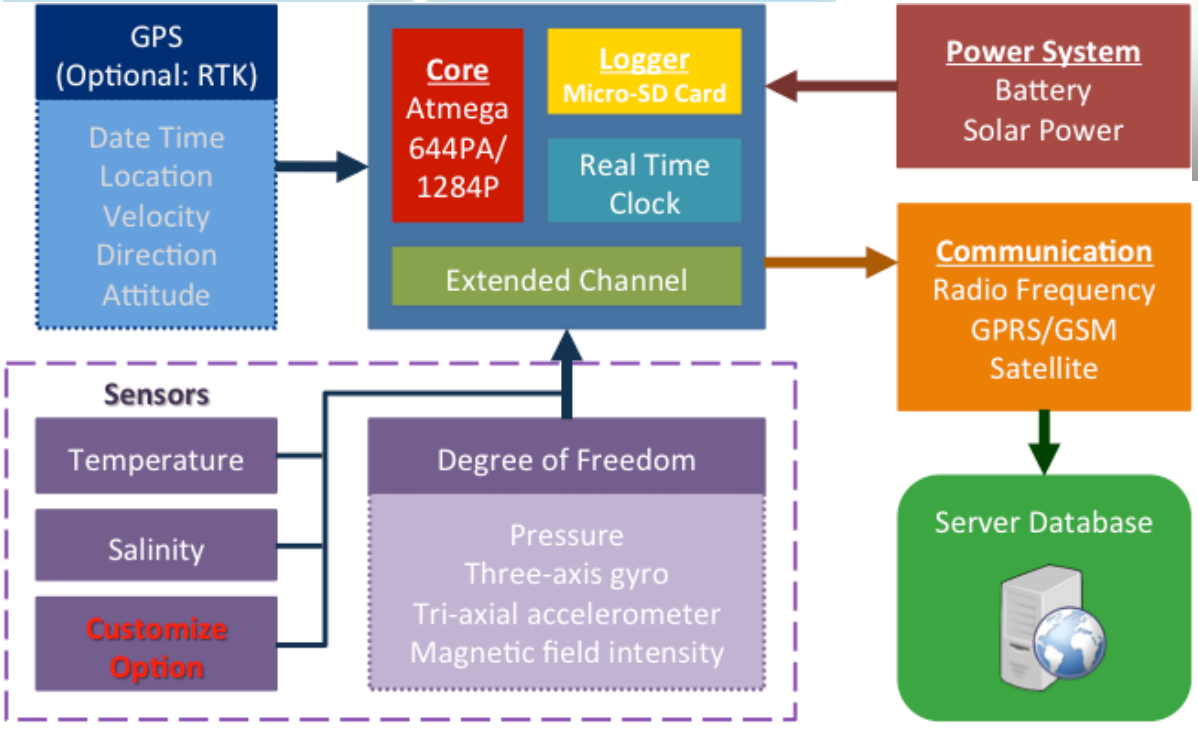


GNSS Tracking drifters

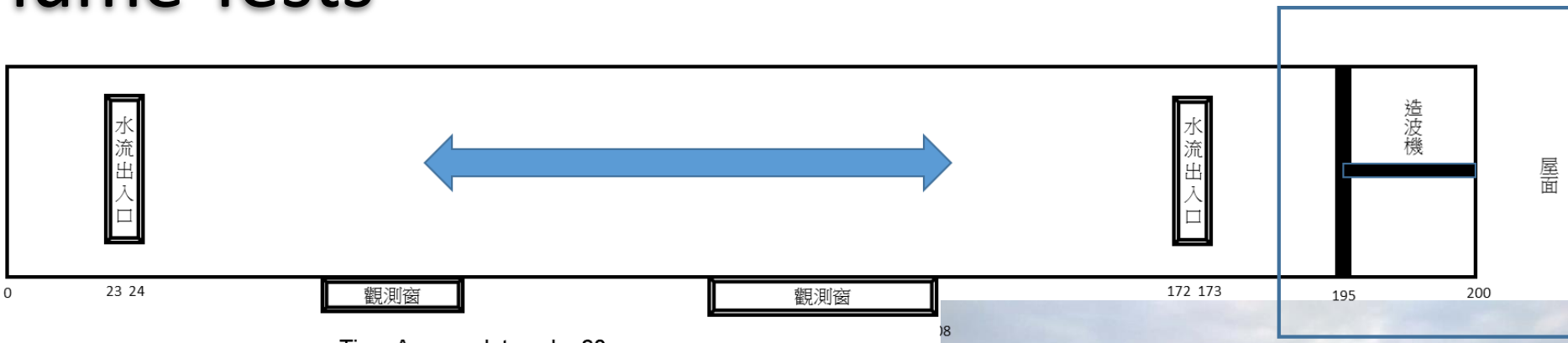
Biodegradable聚己內酯(PCL)外殼

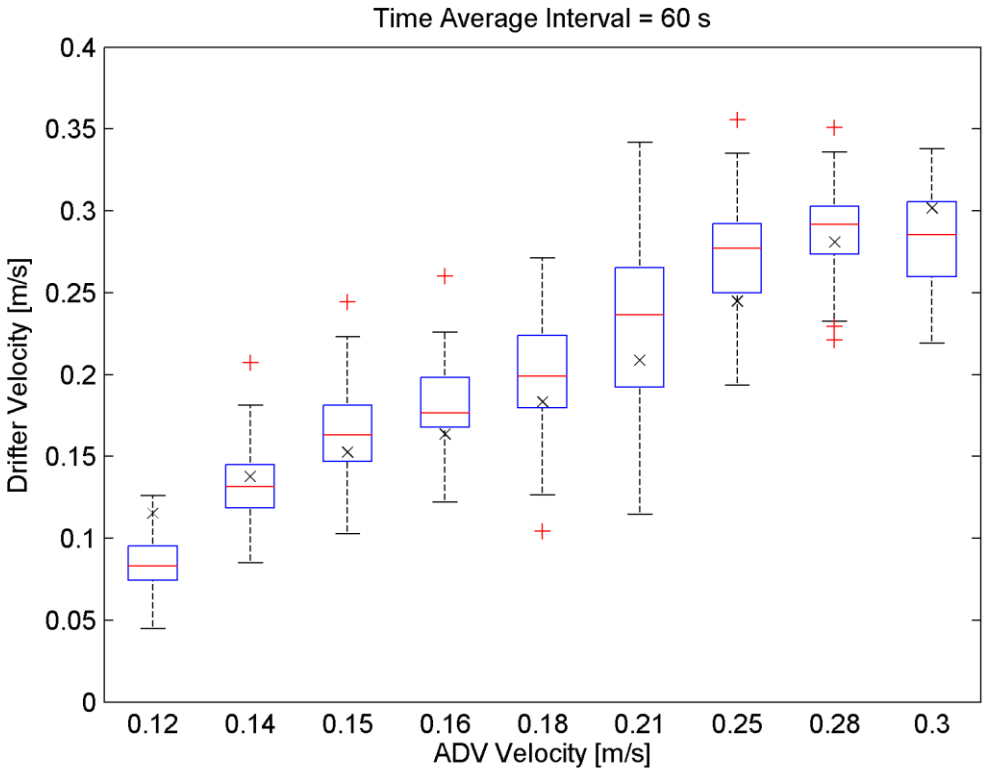




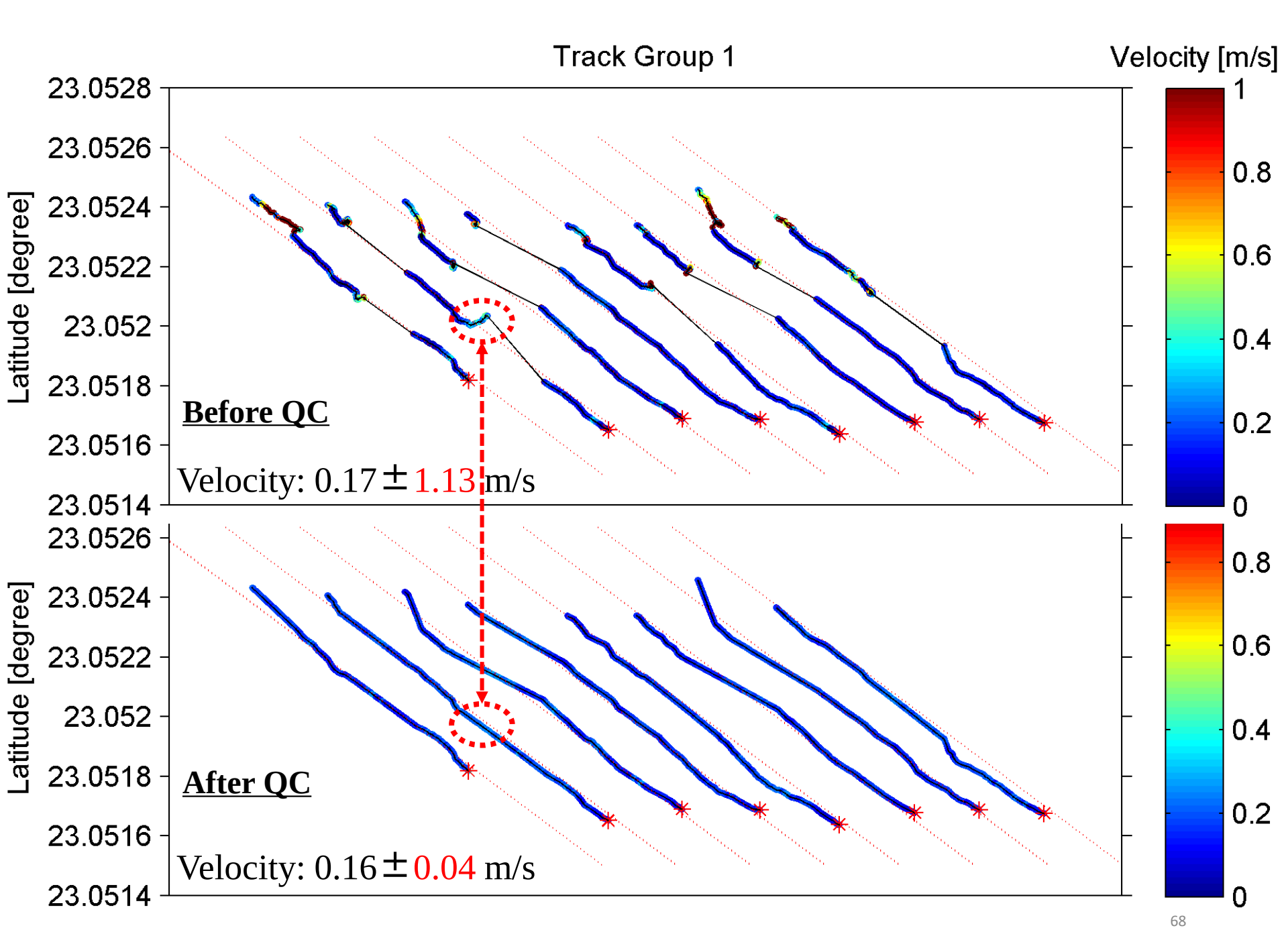


Flume Tests

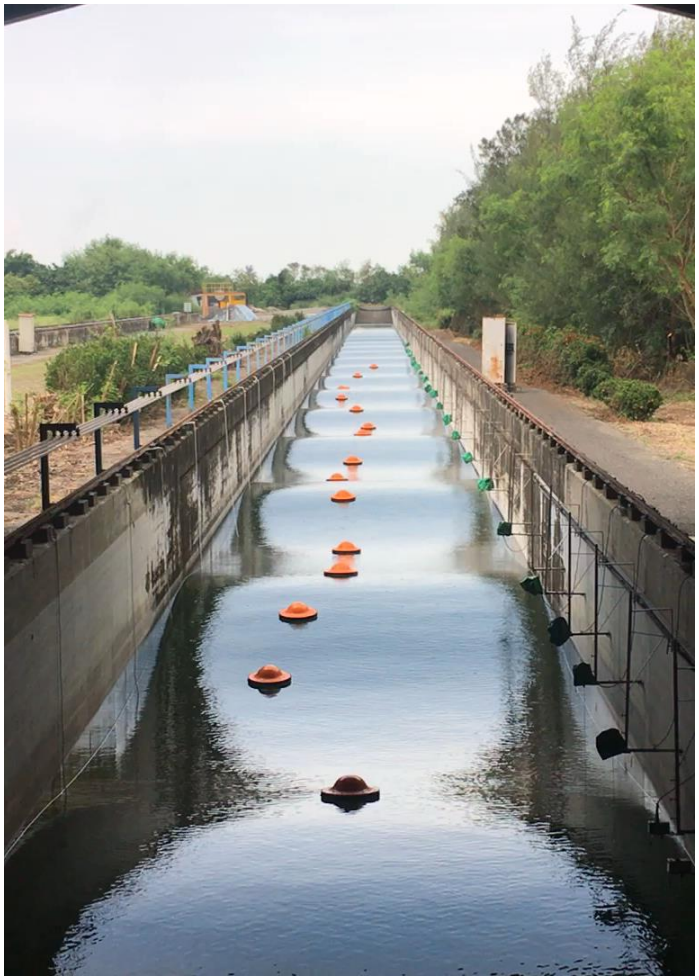




ADV (m/s)	0.12	0.14	0.15	0.16	0.18	0.21	0.25	0.28	0.30
Bias %	28	4	8	8	9	13	12	5	5

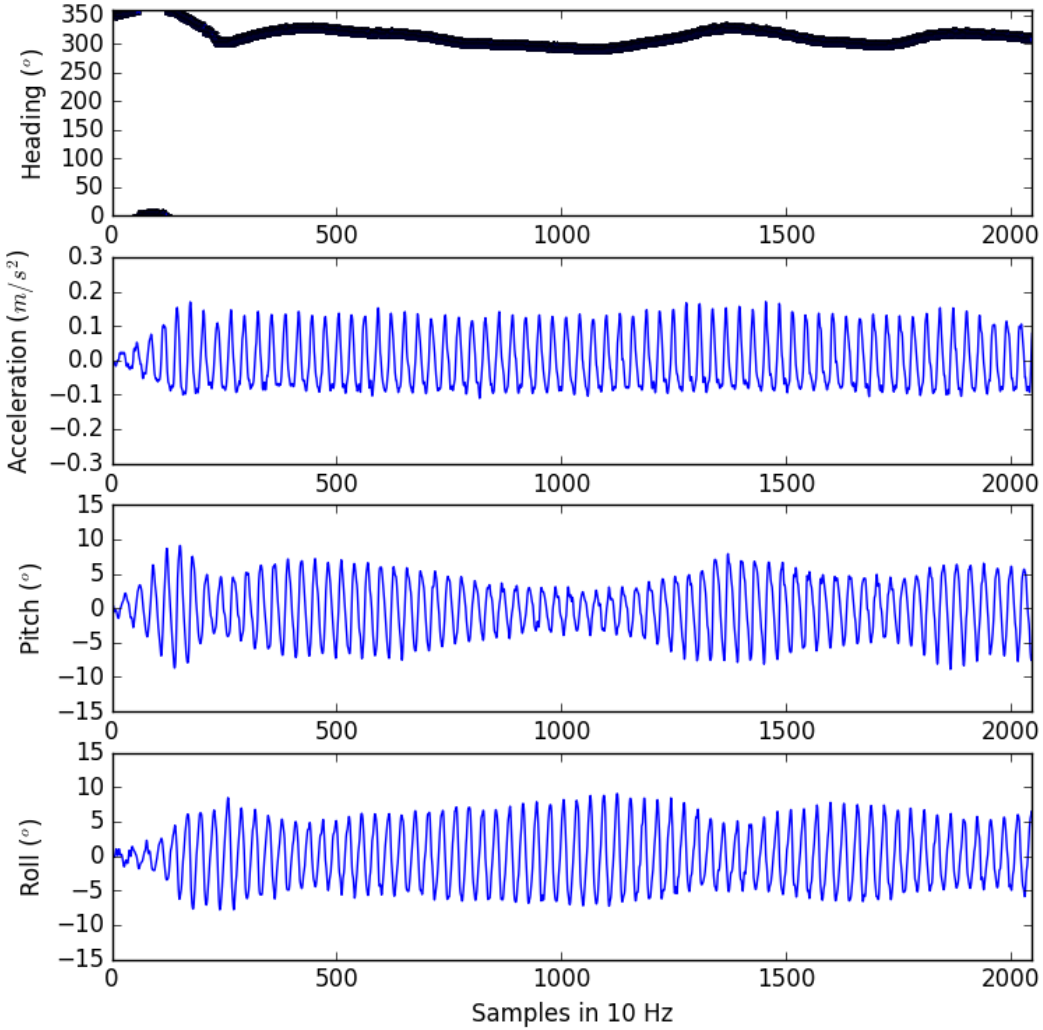

Track Group 1
Velocity [m/s]
Latitude [degree]
23.0528
23.0526
23.0524
23.0522
23.052
23.0518
23.0516
23.0514
1
0.8
0.6
0.4
0.2
0
Before QC
Velocity: 0.17 ± 1.13 m/s
After QC
Velocity: 0.16 ± 0.04 m/s

Flume Test for Wave measurement



Regular wave ($H_{1/3}$:80cm, T_p:3sec)

Data processing



The significant wave height (H_s, unit: m) and mean period (T_m, unit: second) were calculated based on the following equations:

$$H_s = 3.8\sqrt{m_0} \qquad T_m = \sqrt{\frac{m_0}{m_2}}$$

where m_0 and m_2 are zeroth-moment and second-moment of wave displacement spectrum, respectively:

$$m_n = \int S_{\eta-a}(f)\,f^n\,df$$

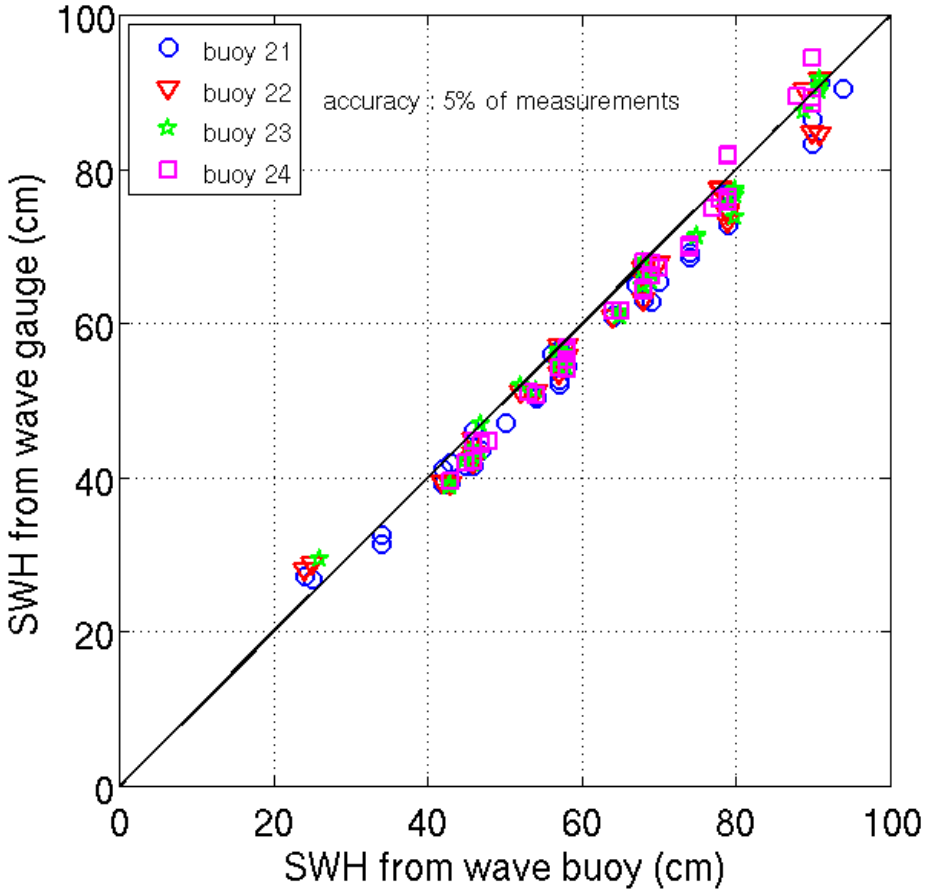
where

$$S_{\eta-a}(f) = 2\frac{\Delta t}{L}\left|X_a\right|^2\frac{1}{f^4}$$

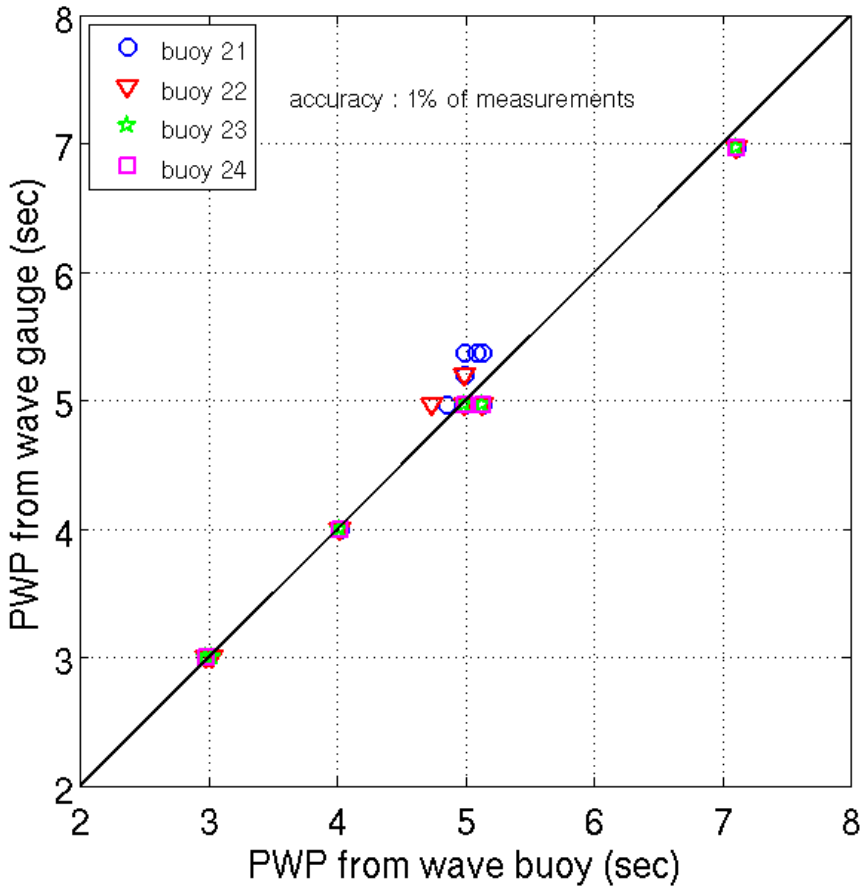
where Δt = sampling interval, L = count of data, X_a = Discrete Fourier Transform of vertical acceleration.

Inter-comparisons of wave parameters in Flume tests

RMSE: 0.04m



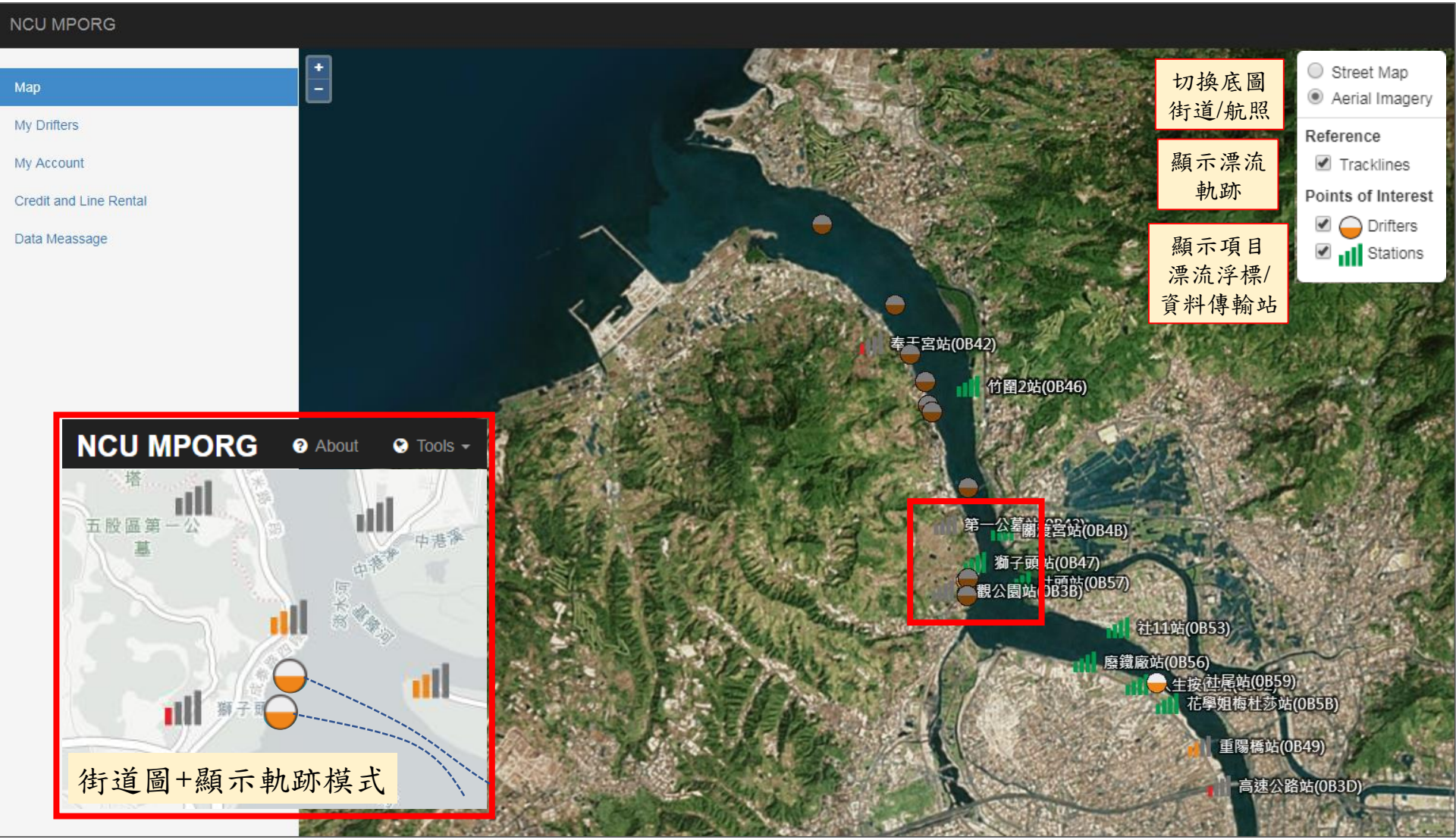
RMSE: 0.1s



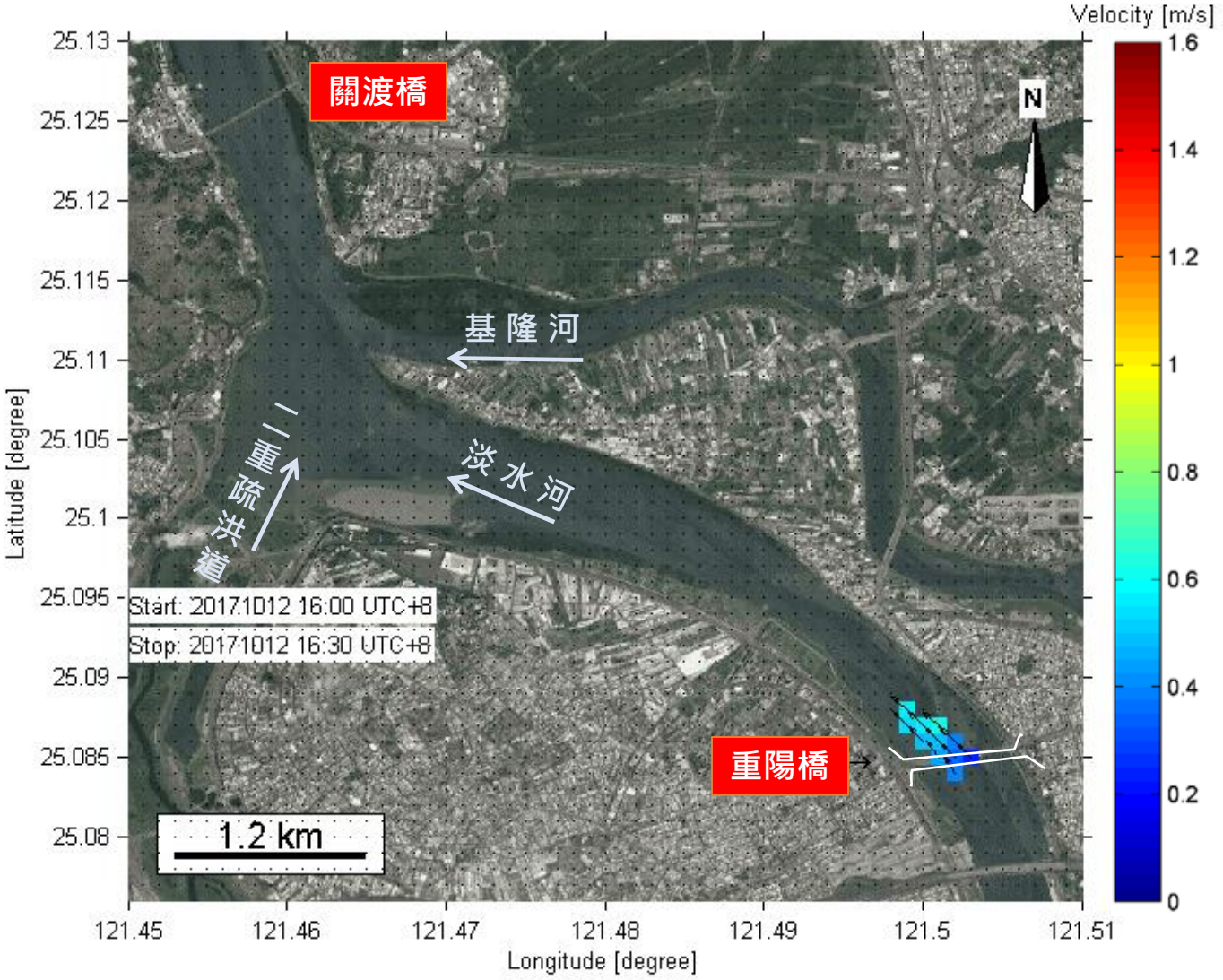
Big: Density=0.54, UTV=1.077 m/s

Small: Density=0.76, UTV=0.715 m/s

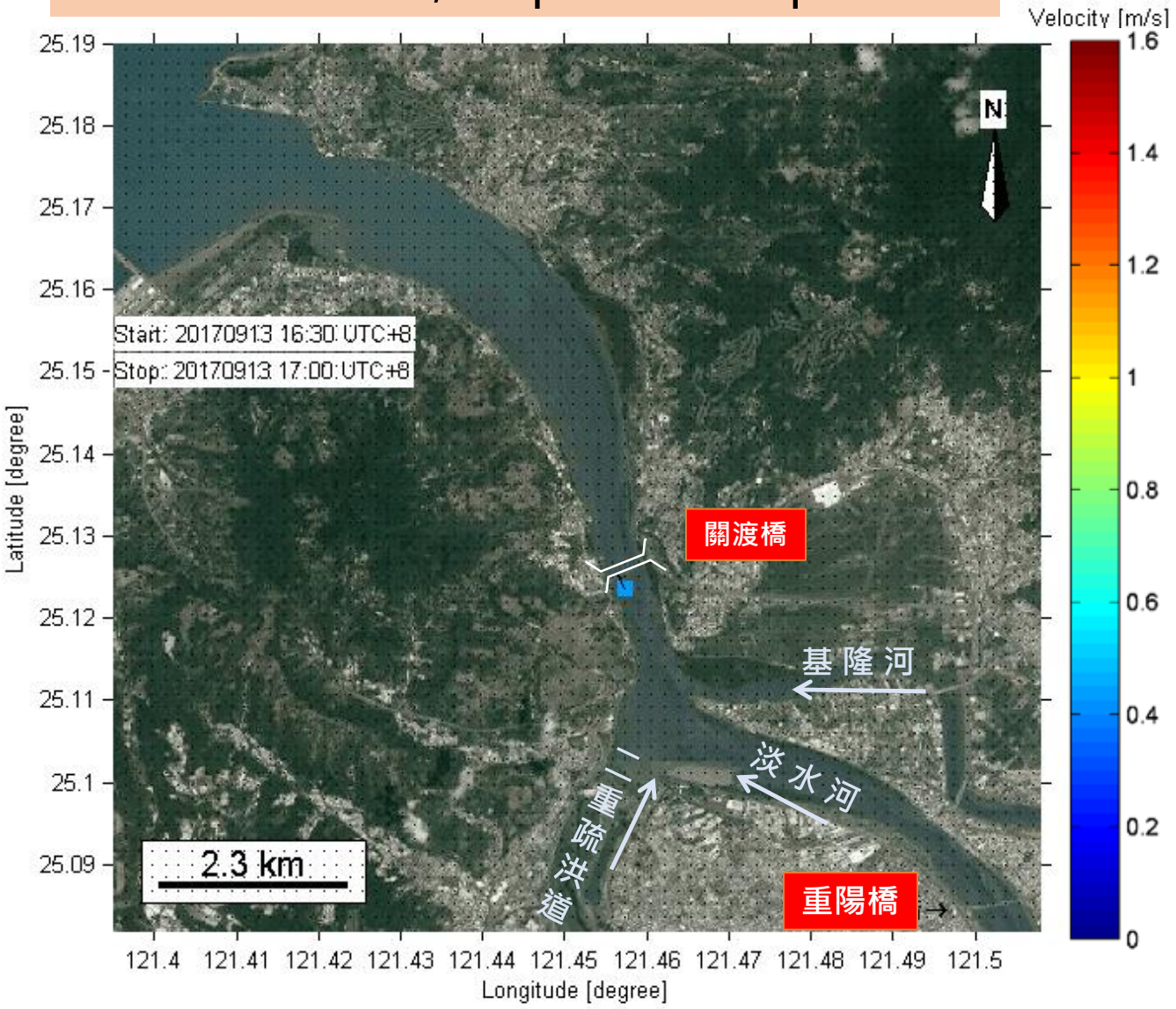
Danshuei River Experiment



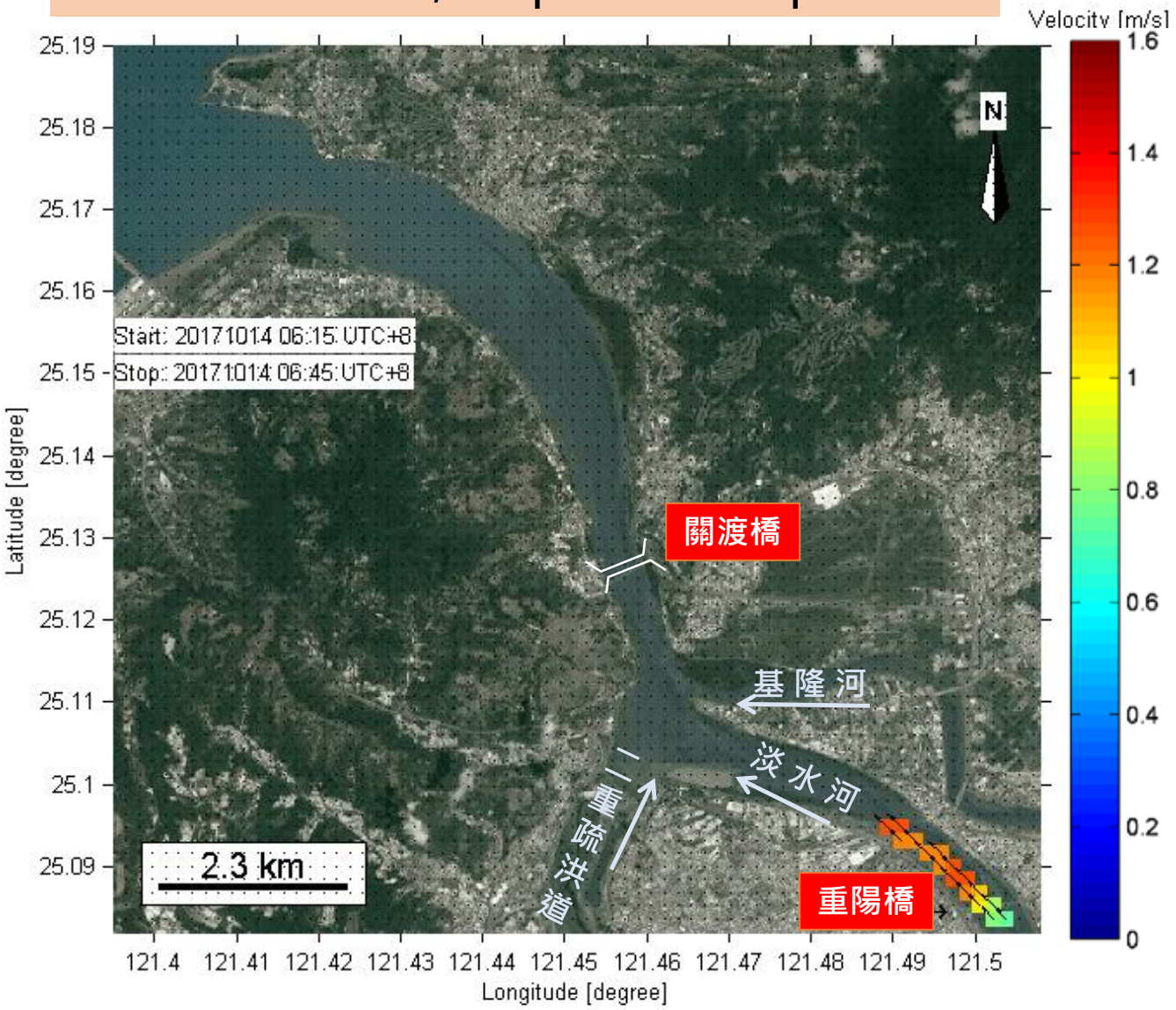
TamShui River, Taipei Metropolitan



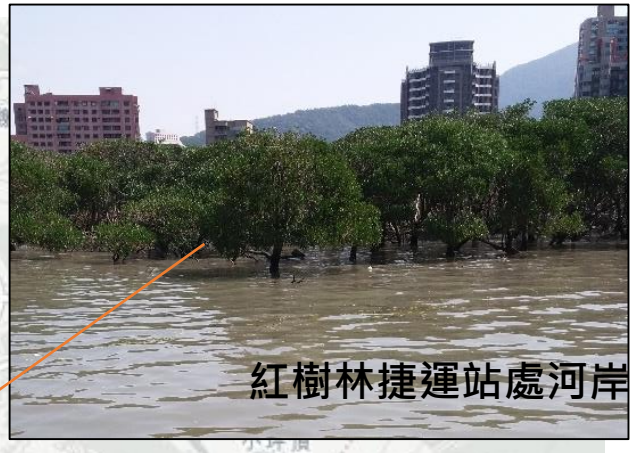
TamShui River, Taipei Metropolitan



TamShui River, Taipei Metropolitan



統計重陽橋下游最後擱淺位置狀況，河道變化與匯流處是擱淺主要發生地區



20% Into Ocean

5%

11%

淡水河

13%

11%

河道變寬

關渡橋

18%

河道匯流

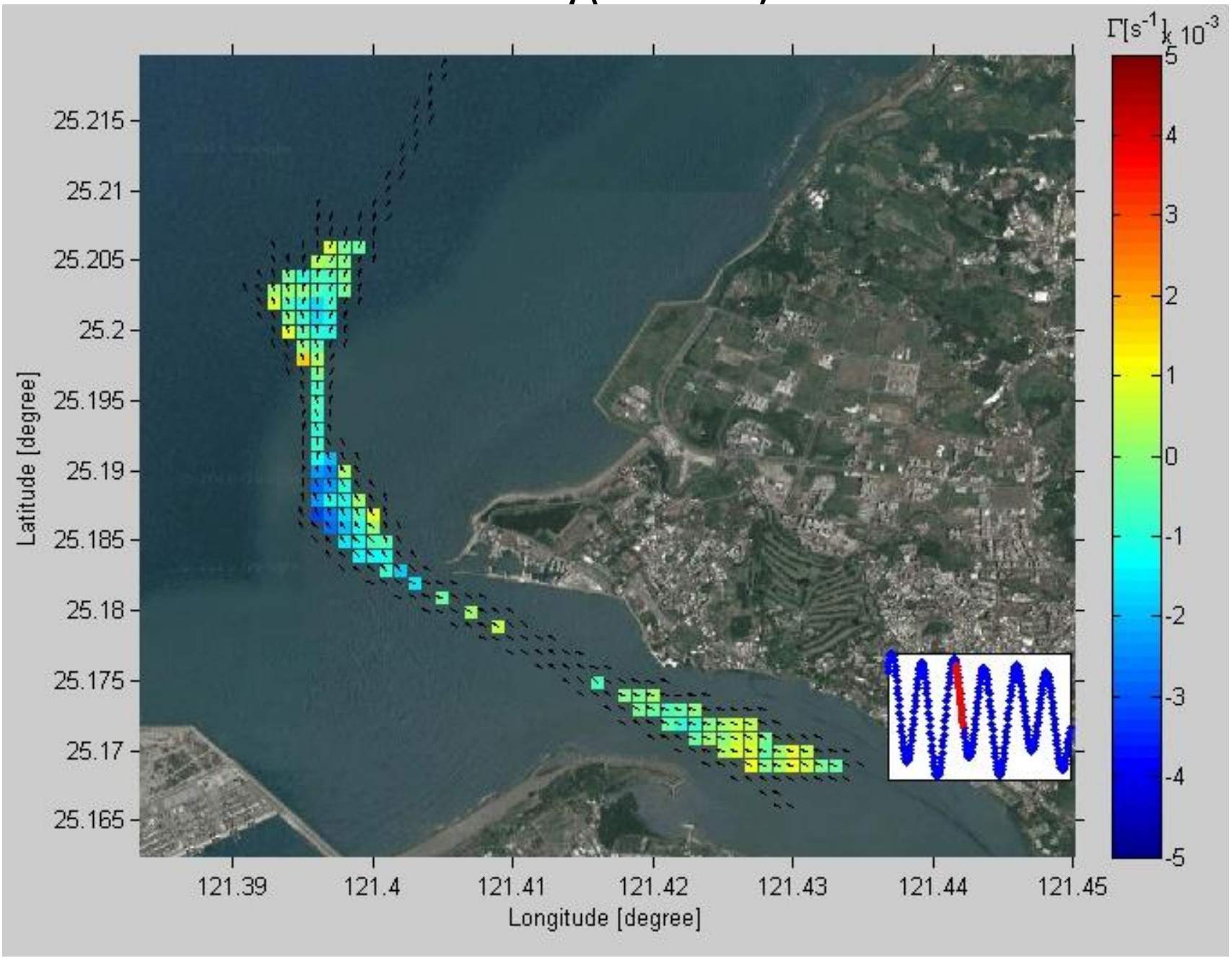
8%

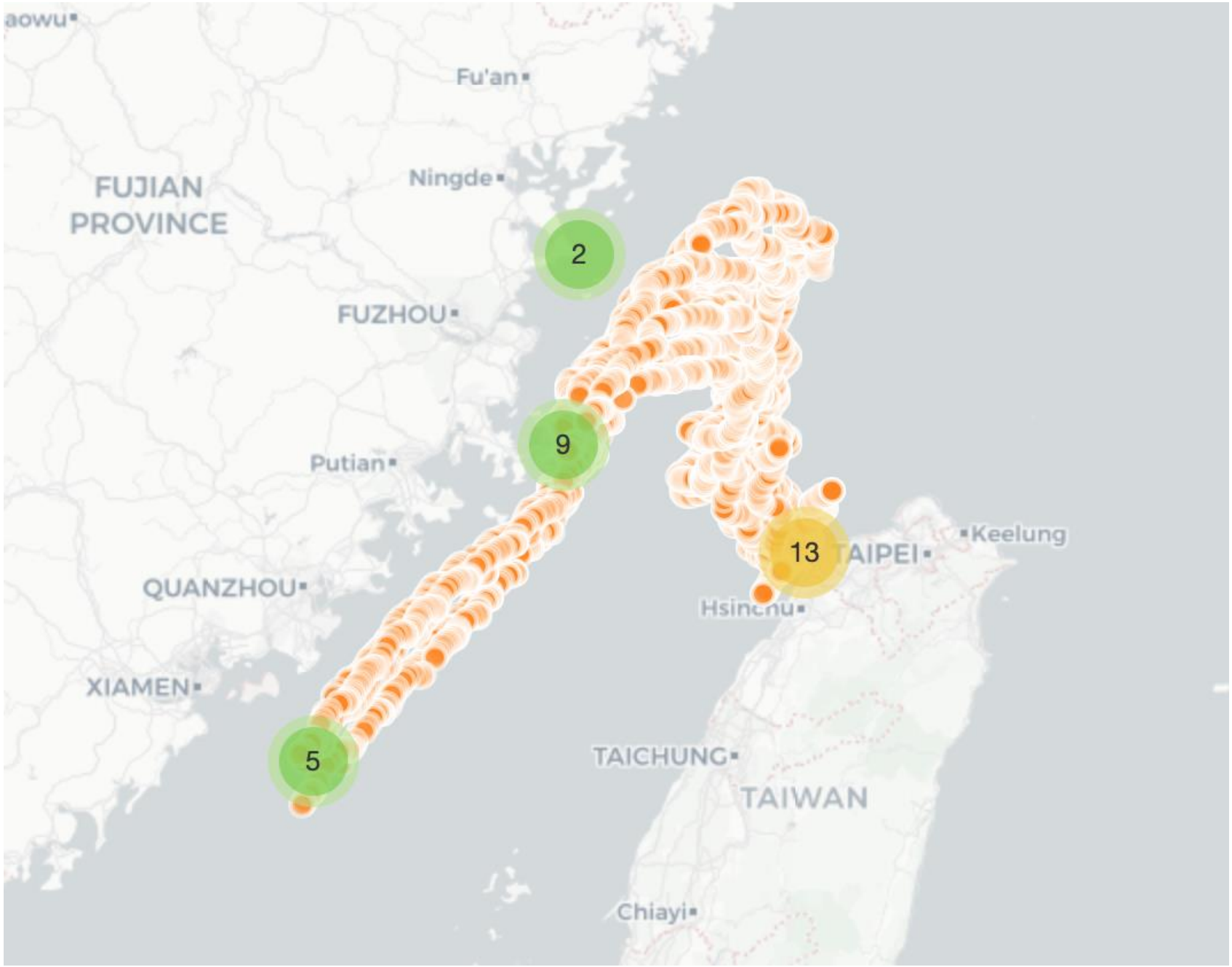
8%

6%

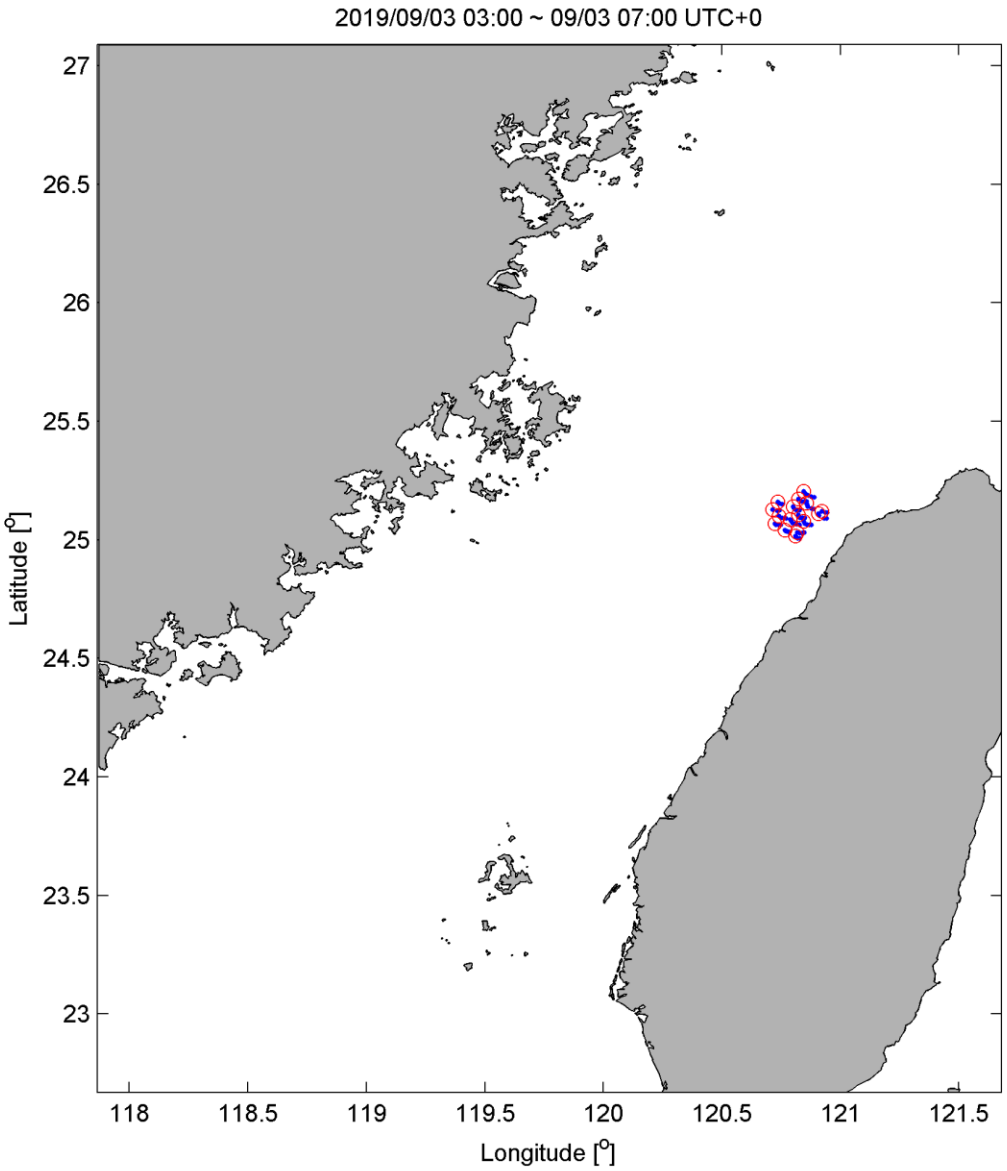
重陽橋

Vorticity (2016.10.06)

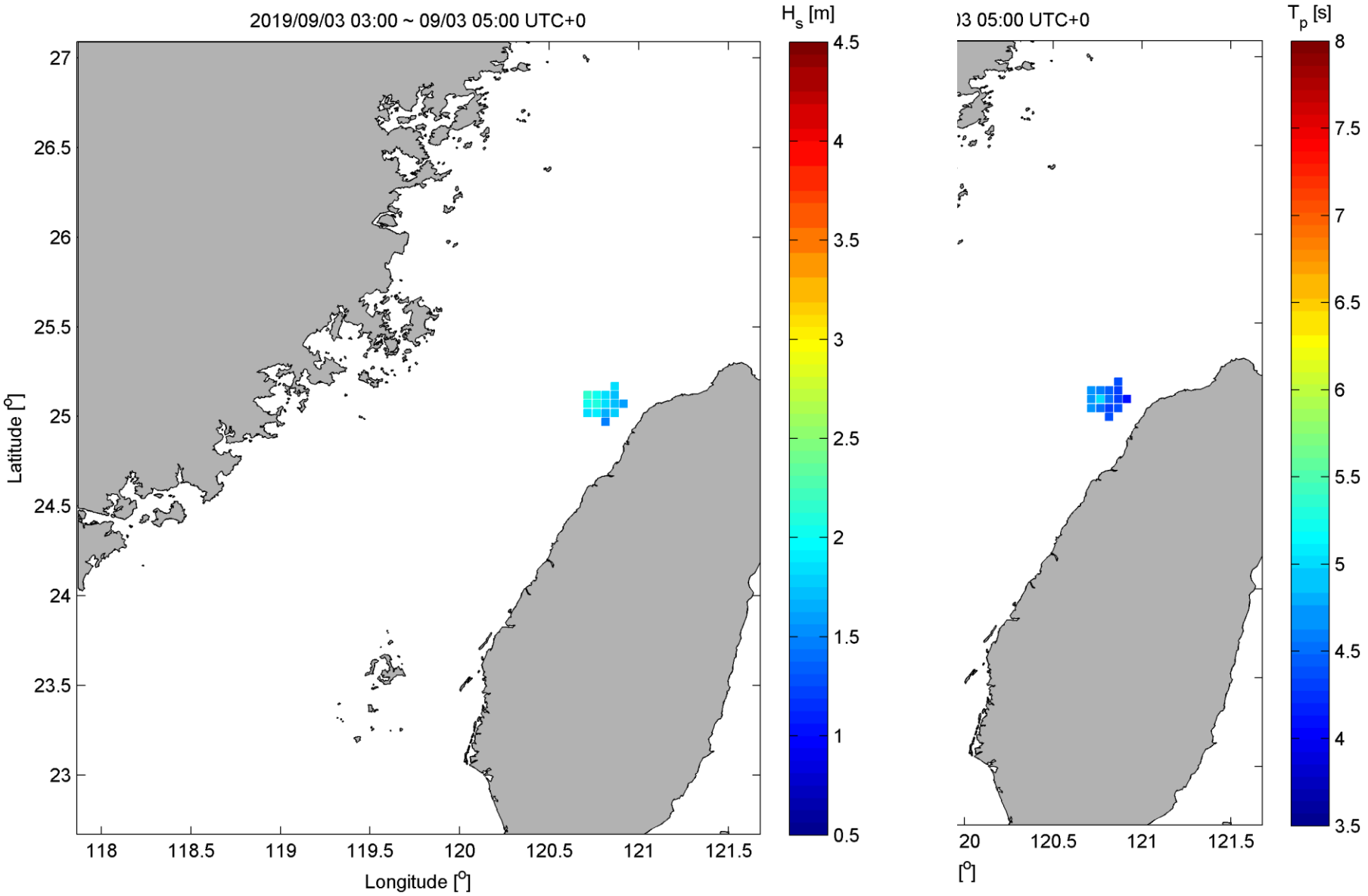



aowu
Fu'an
FUJIAN
PROVINCE
Ningde
2
FUZHOU
9
Putian
13
TAIPEI
Keelung
QUANZHOU
Hsinchu
XIAMEN
5
TAICHUNG
TAIWAN
Chiayi

Field measurements in the Taiwan strait



- Duration: from 2019/09/03 till now (still alive on ocean)
- Number of drifters: 22
- Observation scenario: drift + Wave +Wind
- Sampling frequency: 20 Hz
- Measurement duration: ~8 min
- Measurement interval: 30 min

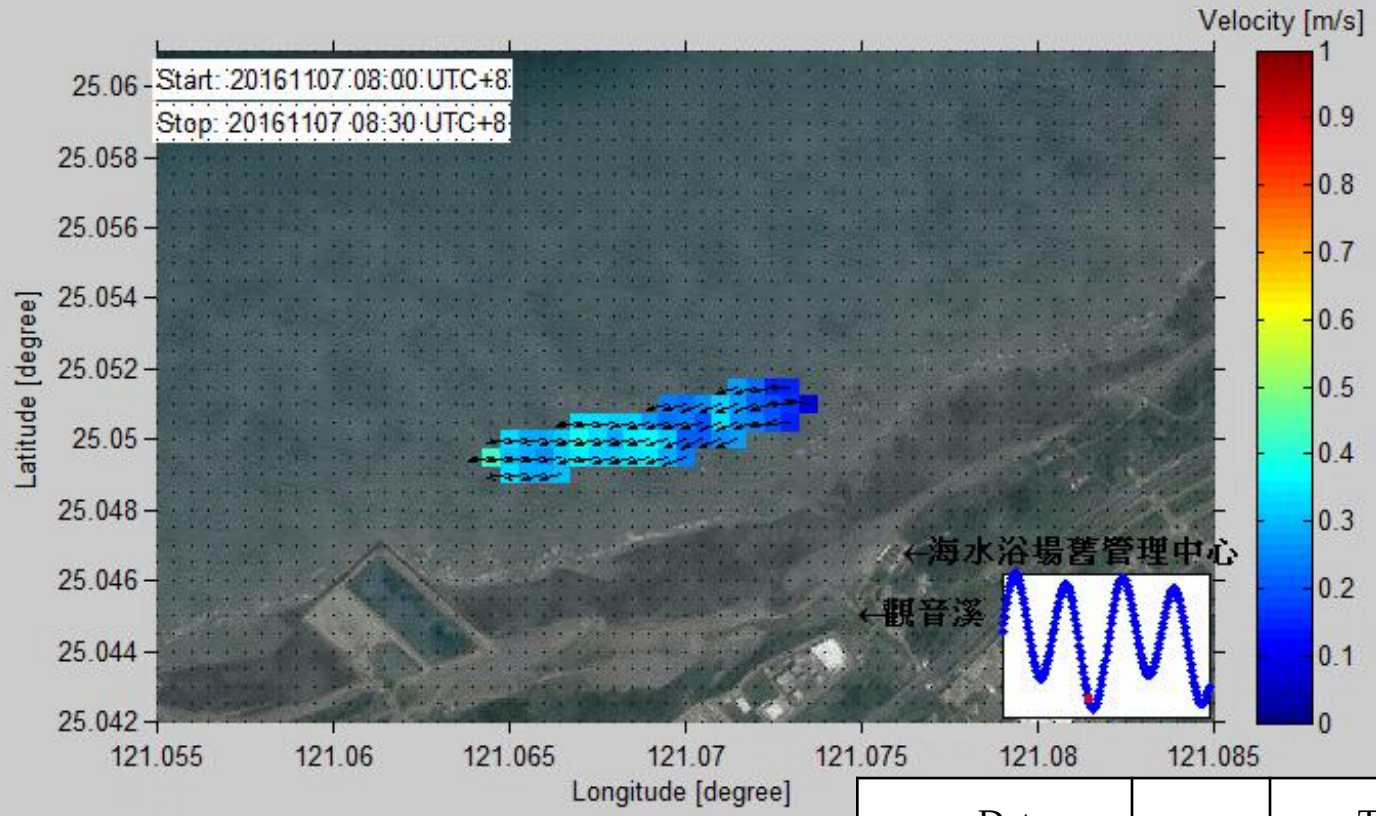

2019/09/03 03:00 ~ 09/03 05:00 UTC+0
)3 05:00 UTC+0
H_s [m]
T_p [s]
Latitude [°]
Longitude [°]
[°]
27
26.5
26
25.5
25
24.5
24
23.5
23
118
118.5
119
119.5
120
120.5
121
121.5
20
4.5
4
3.5
3
2.5
2
1.5
1
0.5
8
7.5
7
6.5
6
5.5
5
4.5
4
3.5

More Questions:

Under which nearshore hydrodynamic conditions, plastic marine debris will be stranded on the beach?

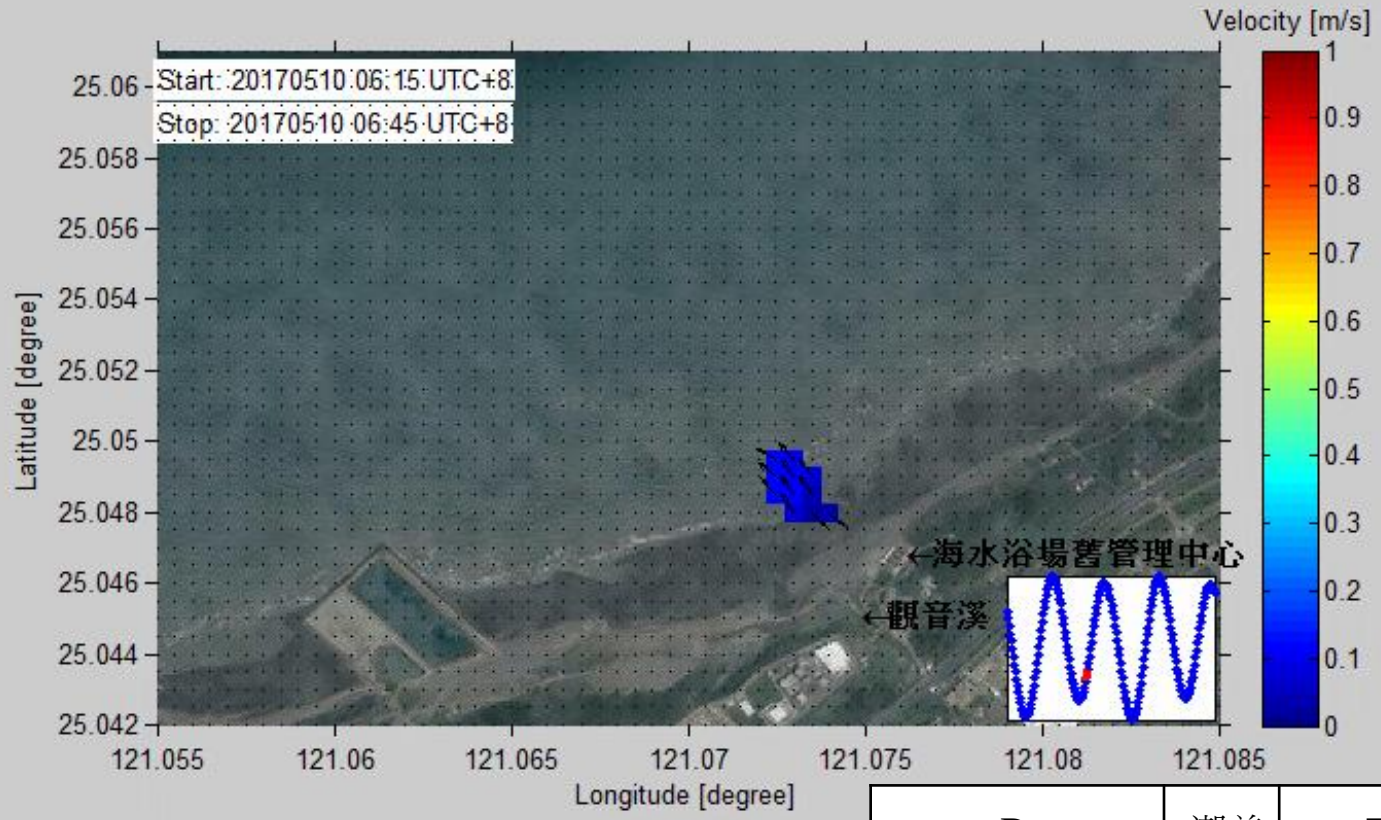
Drifters can do more…

Coastal Zone Experiment 1



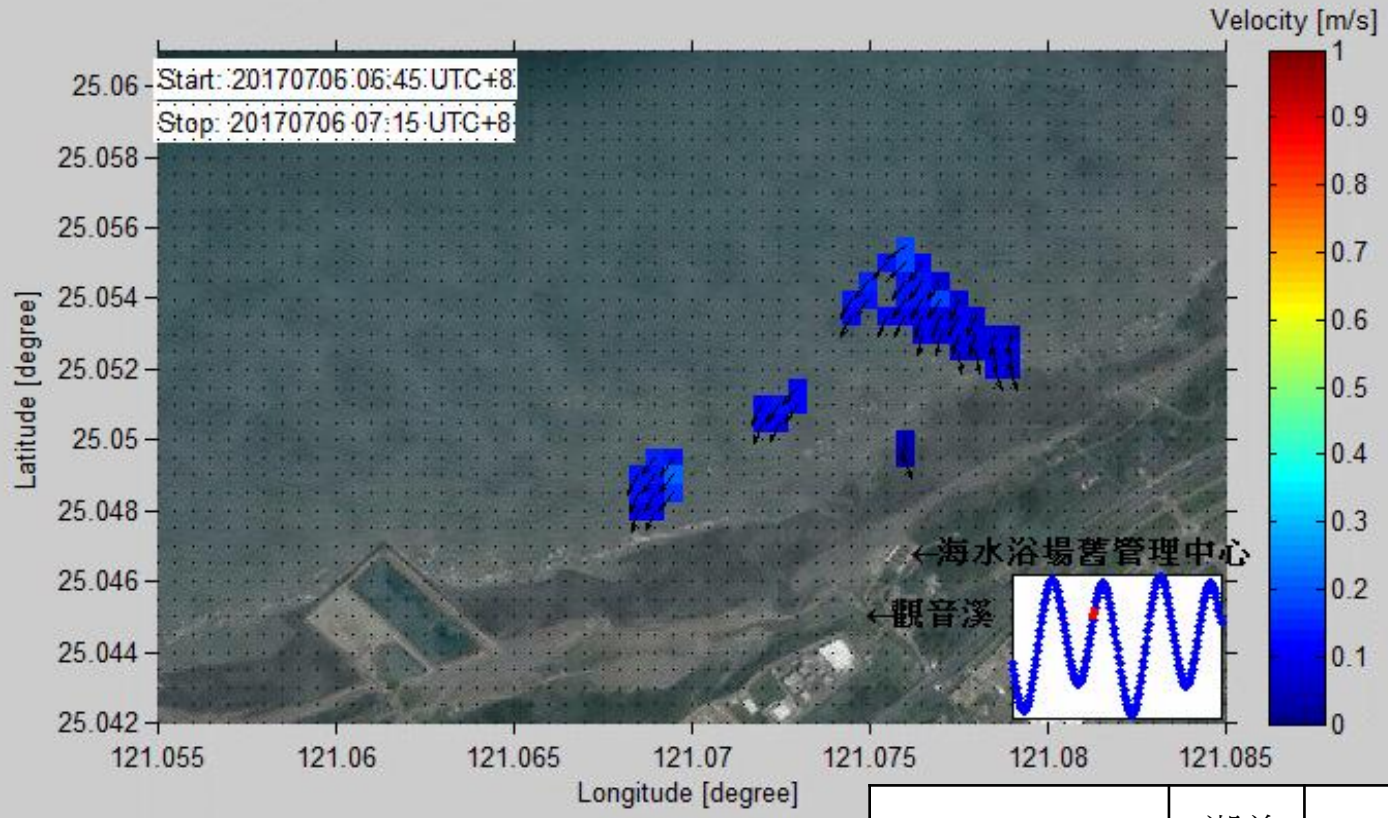
Date		Tide	Time	潮位(cm) Ele.
11/07 (星期一) 農曆 10/08	Spring	Flood	02:11	103
		Ebb	09:11	-132
		Flood	15:11	-113
		Ebb	22:11	-78
日出/日中/日落	06：07 // 11：40 // 17：12			

Coastal Zone Experiment 2



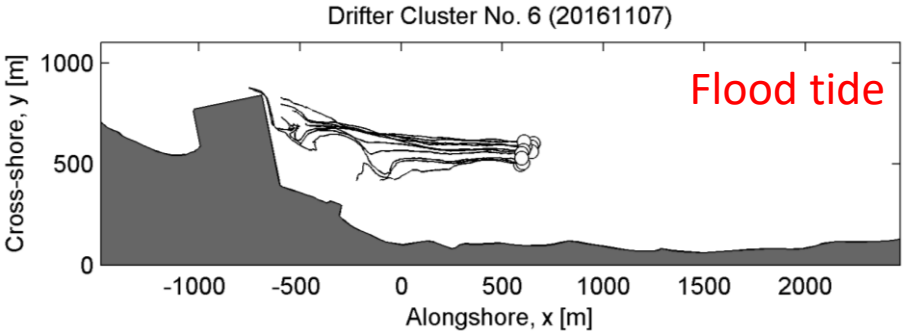
Date	潮差	Tide	Time	潮位(cm) Ele.
05/10 (星期三) 農曆 04/15	Neap	Ebb	04:59	-99
		Flood	10:39	136
		Ebb	17:16	-134
		Flood	23:08	146
日出/日中/日落	05：06 // 11：53 // 18：41			

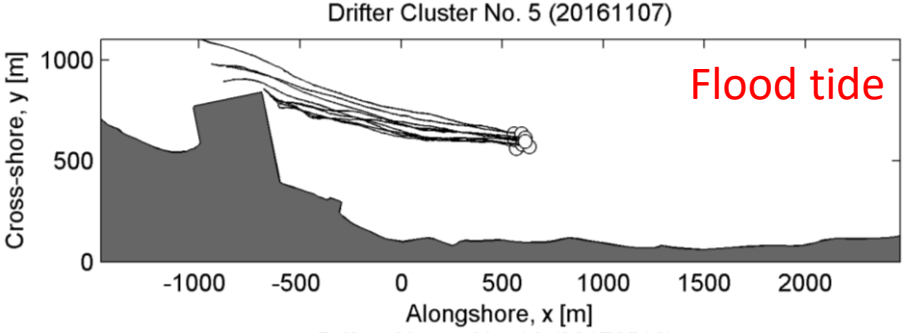
Coastal Zone Experiment 3

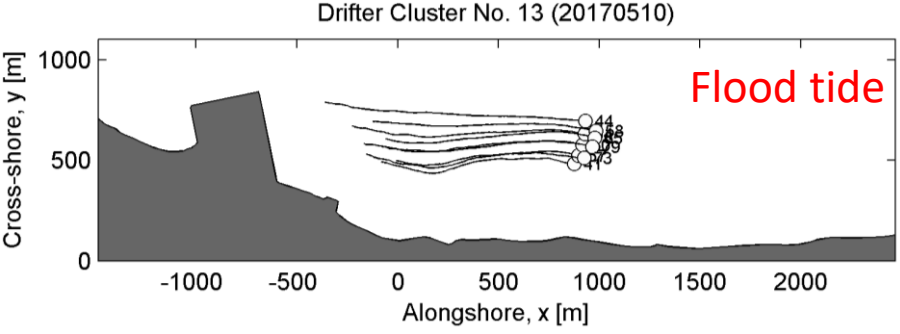


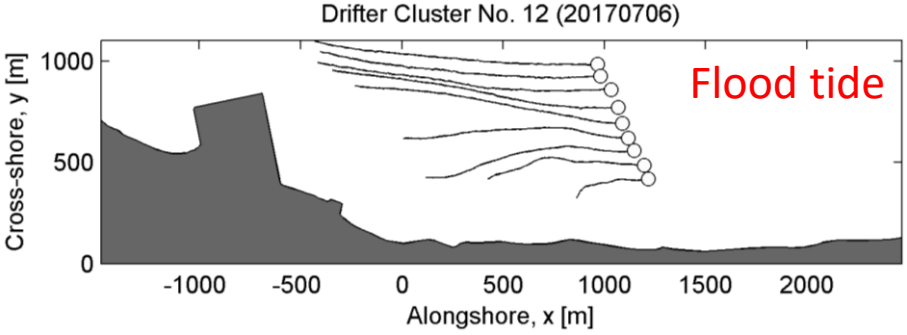
Date	潮差	Tide	Time	潮位(cm) Ele.
07/06 (星期四) 農曆 06/13	Spring	Ebb	03:14	-55
		Flood	08:59	120
		Ebb	15:42	-107
		Flood	22:04	128
日出/日中/日落	05：06 // 11：53 // 18：41			

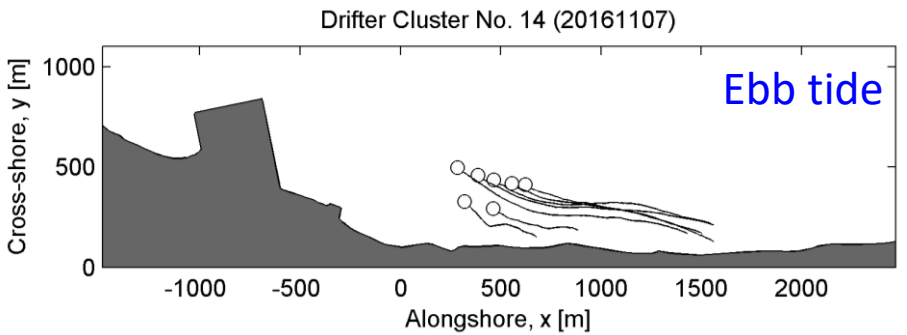
Marine Debris

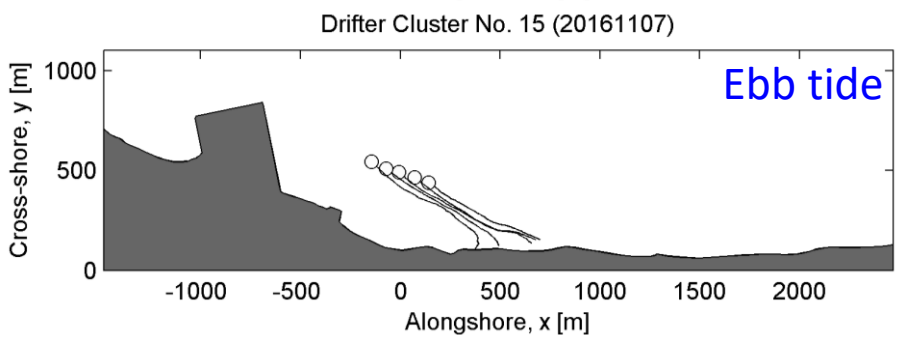


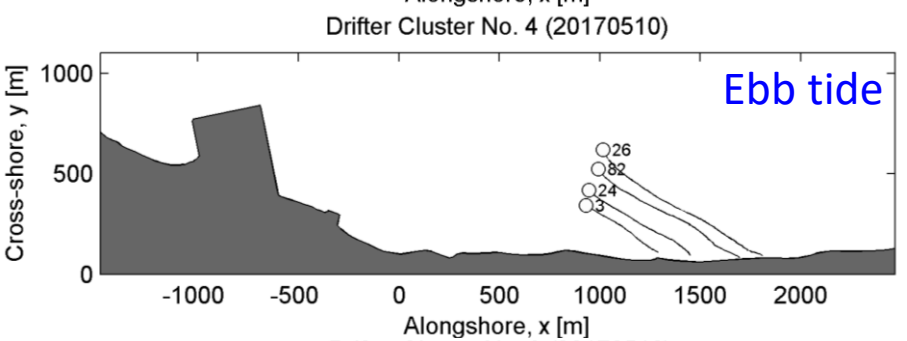


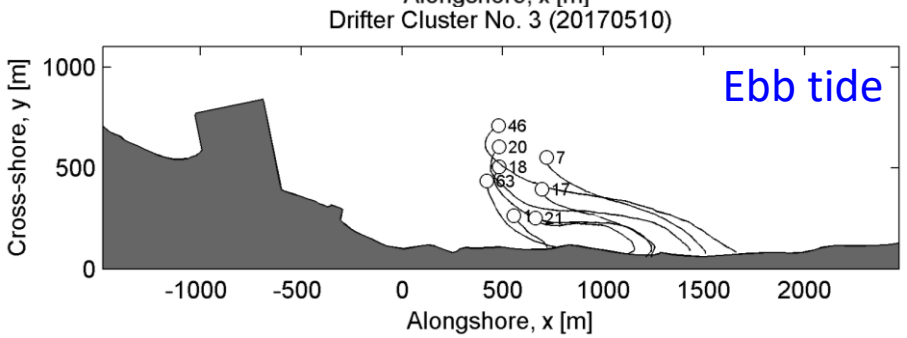












Concluding Remarks

- Currently, two of the major threatens of global scale to Human induced by anthropogenic effects,
  - **Climate Change**
  - **Plastic Debris/Microplastic**
- The pathways and fluxes of Plastic debris/Microplastic from source to sink are unclear, neither their transports among atmosphere, ocean and land. Nevertheless, it is strongly associated with water and driven by water cycle.
- Scientists, Researchers, Engineers and Policy-makers from Water Sphere research and management are encouraged to contribute to this field.