PICES-2017 Annual Meeting
Vladivostok, Russia

An analysis of dynamical factors influencing 2013 giant jellyfish bloom near Qinhuangdao in the Bohai Sea

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2017.09

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1. Introduction on jellyfish disaster

Due to the global change and human activities, great changes have taken place in the structure and function of marine ecosystem. The occurrence frequency and disaster category of large jellyfish increase continuously (Brodeur et al.,1999; Mills, 2011; Nagai, 2003; Greve, 1994) . The jellyfish disaster has seriously affected the offshore marine fisheries, coastal industry, coastal tourism and marine ecosystem.

1. Introduction on jellyfish disaster

Due to the global change and human activities, great changes have taken place in the structure and function of marine ecosystem. The occurrence frequency and disaster category of large jellyfish increase continuously.

Since 2008, the number of jellyfish near Hebei Province has increased year by year, which has seriously affected fishery resources and safety of beach swimmers. In 2013, giant jellyfish bloomed near Qinhuangdao and the beach visitors were stung frequently. According to incomplete statistics, more than 1000 people were stung and a child was stung to death by Nemopilema nomurai.

Giant jellyfish in an aggregation near Qianshui Bay,

Their medusa or larvae were not observed during the previous winter and spring, yet mature jellyfish (bell diameter 60–100 cm) can be found in summer in Qinhuangdao(Zheng et al.,2014)

Jellyfish in the coastal water of Qinhuangdao

Rhopilema esculentum Kishinouye

Rhopilema esculentum

non-local type

Aurelia aurita

local type

mainly distribute in Bay, replenish themselves and complete their life history

In July 2013, N. nomurai appeared near Qinhuangdao, then grew rapidly, and matured with diameters from 60 to 100cm.

In August 2012 , giant jellyfish decreased from central Bohai Bay to offshore of Luanhe River and could not be found in the coastal waters of Qinhuangdao.

In August 2013, jellyfish in Bohai Bay was obviously less than that in August 2012, while that was quite different scenario from Jingtang Port to Qinhuangdao coastal waters. In other words, in 2013, jellyfish bloomed in the coastal waters off Qinhuangdao, while it did not occur in 2012.

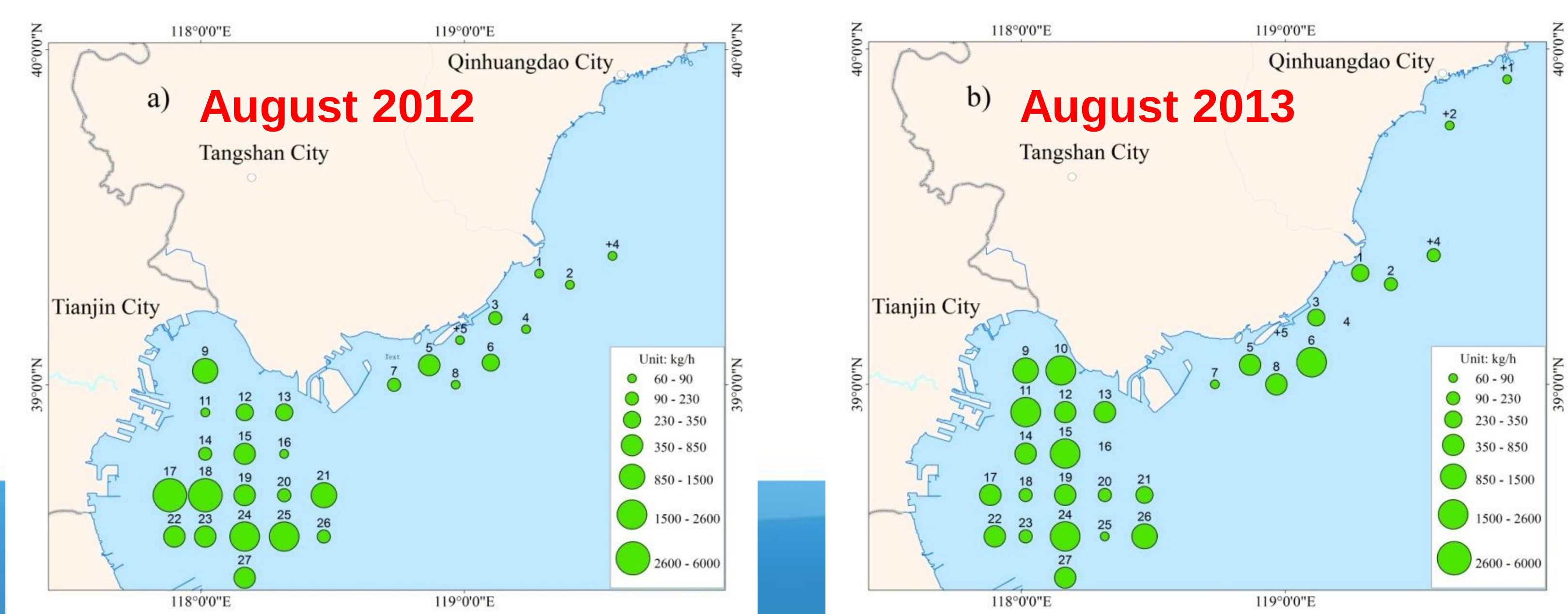
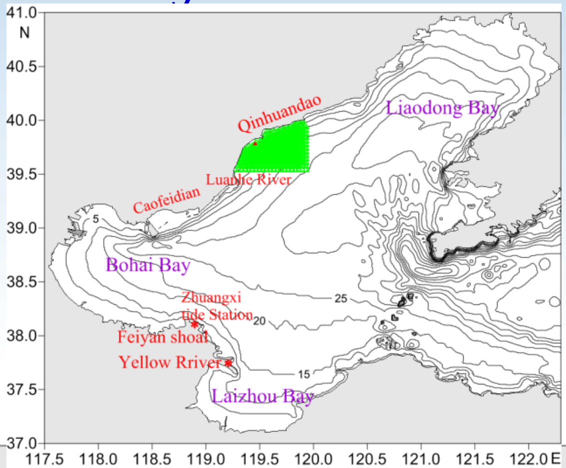


Fig. Net number of N. nomurai (unit: kg/hour) in Hebei Province offshore in August 2012(left) and 2013(right).

2. Introduction on possible source of Jellyfish

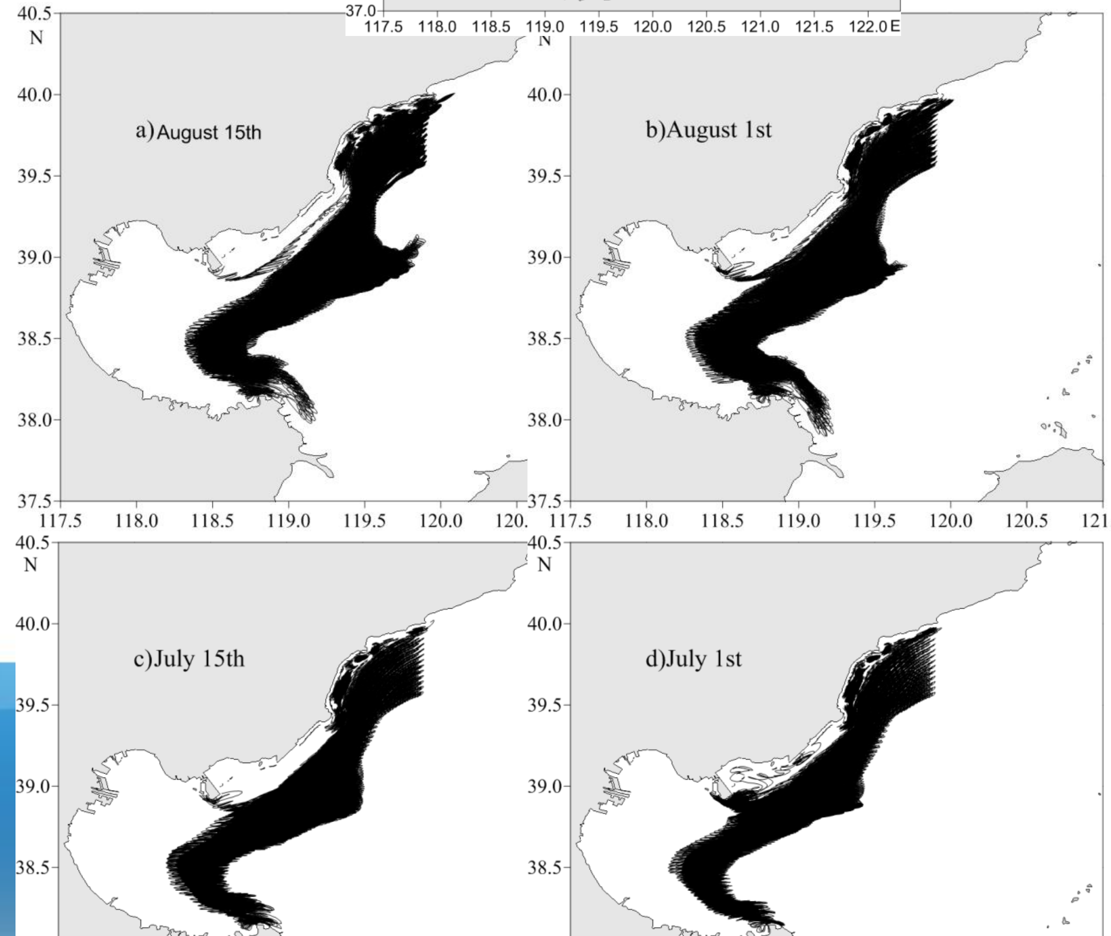
Wu L, Wu X, Bai T. Comprehensive analysis of the origin of giant jellyfish near Qinhuangdao in summer[J]. Chinese Journal of Oceanology & Limnology, 2016:1-9.



Simulated results showed that passive particles released in surface waters at different dates during the summer had consistent trajectories.

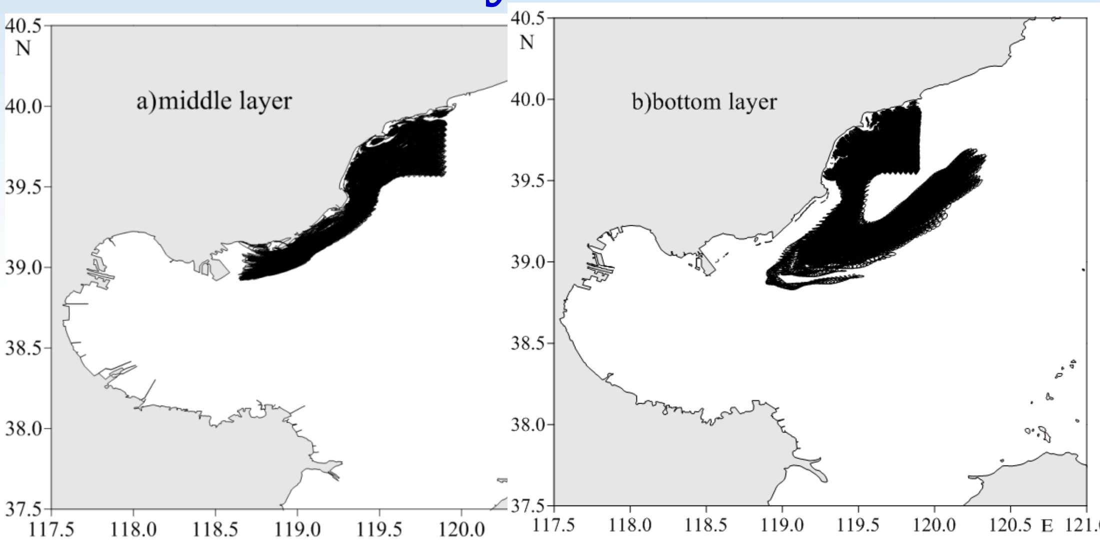
Particles released at the sea surface on August 1 and 15 could be traced back to the center of Bohai Sea and to waters between Feiyan Shoal and the new Yellow River estuary.

Particles released on July 1 and 15 could also be traced back to the center of the Bohai Sea and to waters between Feiyan Shoal and only to Zhuangxi tide station.

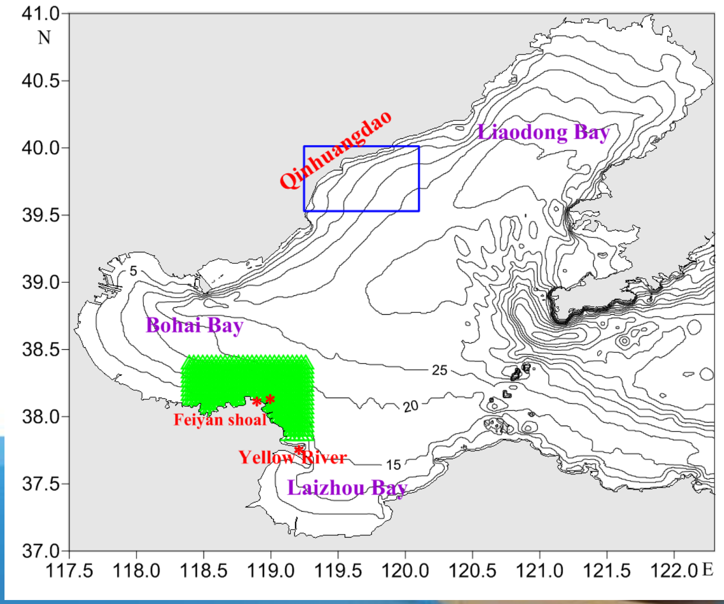


2. Introduction on possible source of Jellyfish

However, none of the particles released in the middle and bottom water layers could be traced back to those areas.



Based on the results of numerical simulations, distribution characteristics of seafloor sediments, and observational data for giant jellyfish in the region, we suggest that waters between Feiyan Shoal and the new Yellow River estuary are the likely origin of giant jellyfish observed near Qinhuangdao in summer.



2. Introduction on possible source of Jellyfish

The life cycle of giant jellyfish is complex and the temperature functions are unclear for the life stages.

The purpose of this study

- **reveal the major roles played by dynamical factors such as wind, circulation and temperature in the interannual variation of jellyfish bloom and distribution**

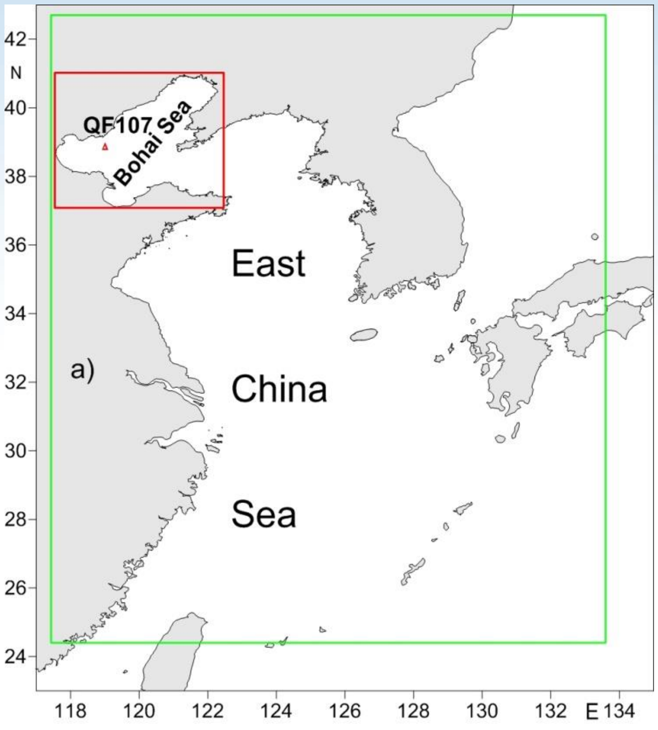
by using a particle-tracking model on the aggregation of giant jellyfish in 2013.

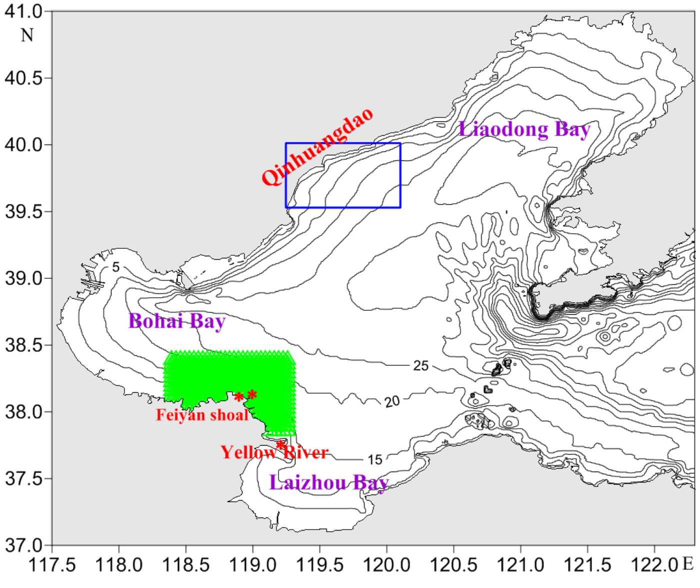
3. Model setup and validation

Model configuration

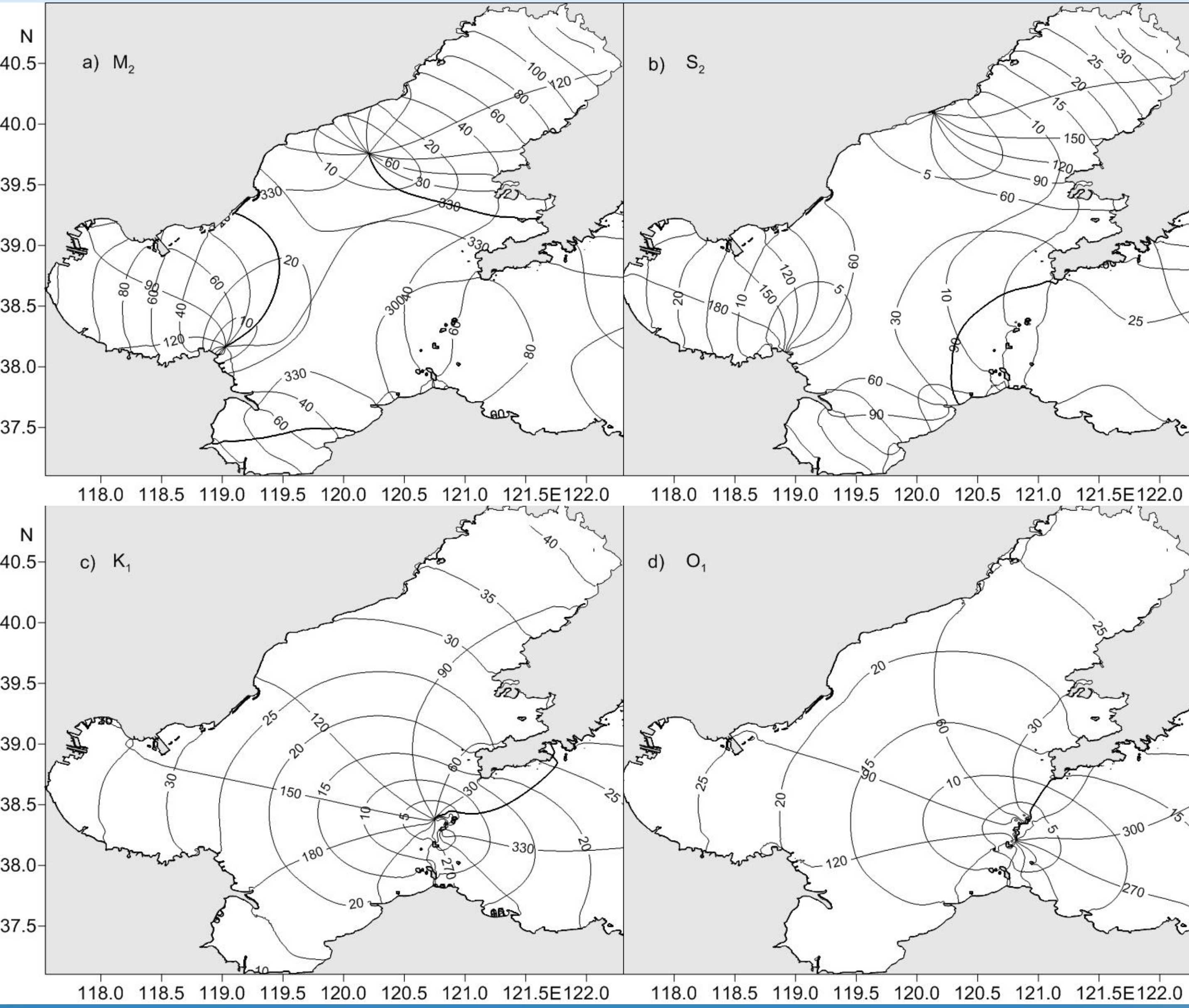
ROMS

- **Multi-layer nested**
  - **Northwestern Pacific**
  - **East China Sea**
  - **Bohai Sea**
- **Meteorological forcing and initial and boundary conditions for the big-region model were setup according to numerical experiments.**
- **M_2, S_2, N_2, K_2, K_1 ,O_1, P_1, Q_1 sub-tides**
- **Lagrangian particle-tracking method**



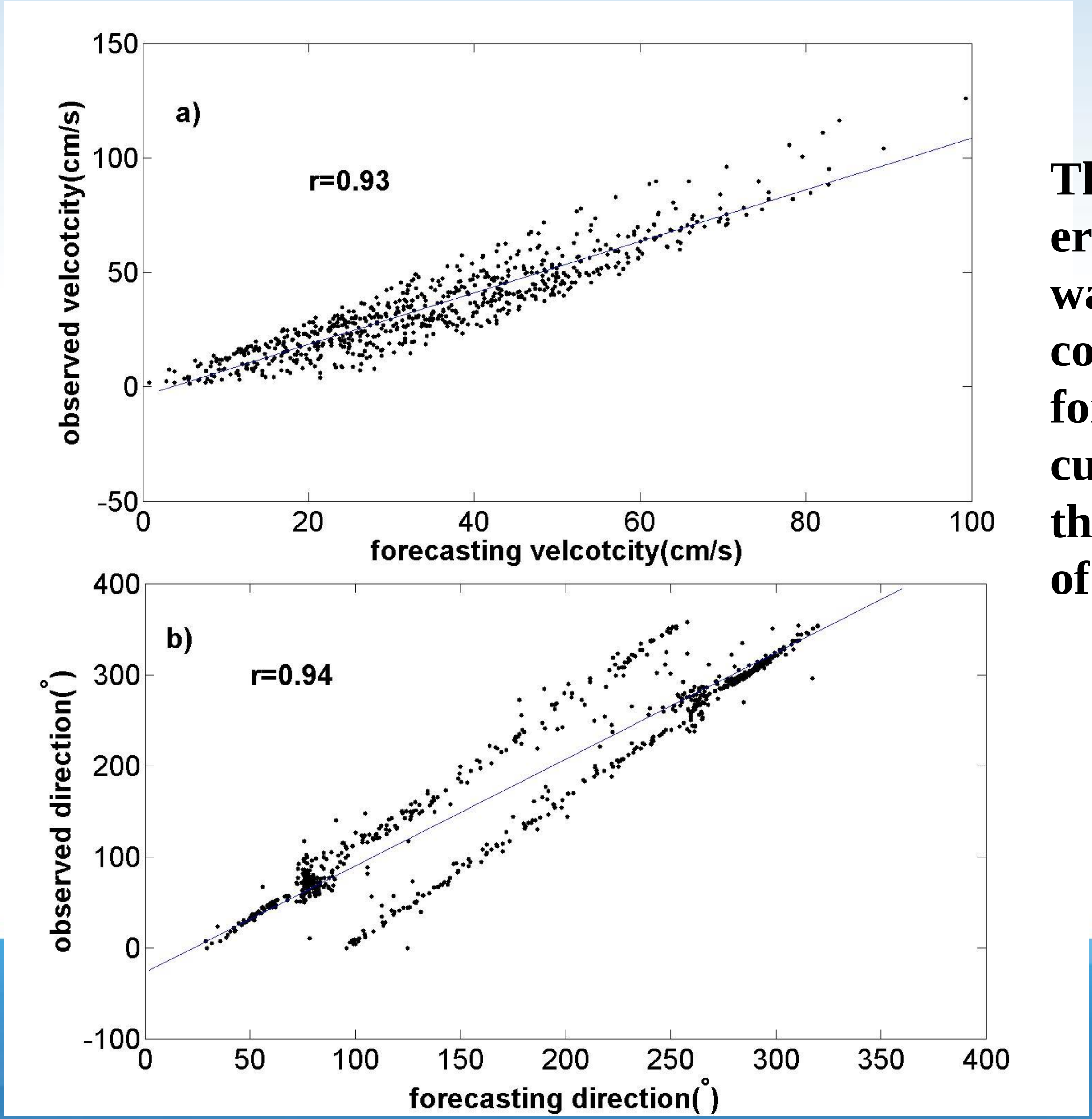


Model validation



simulated amplitudes and phases of four subtides agree fairly well with the observation.

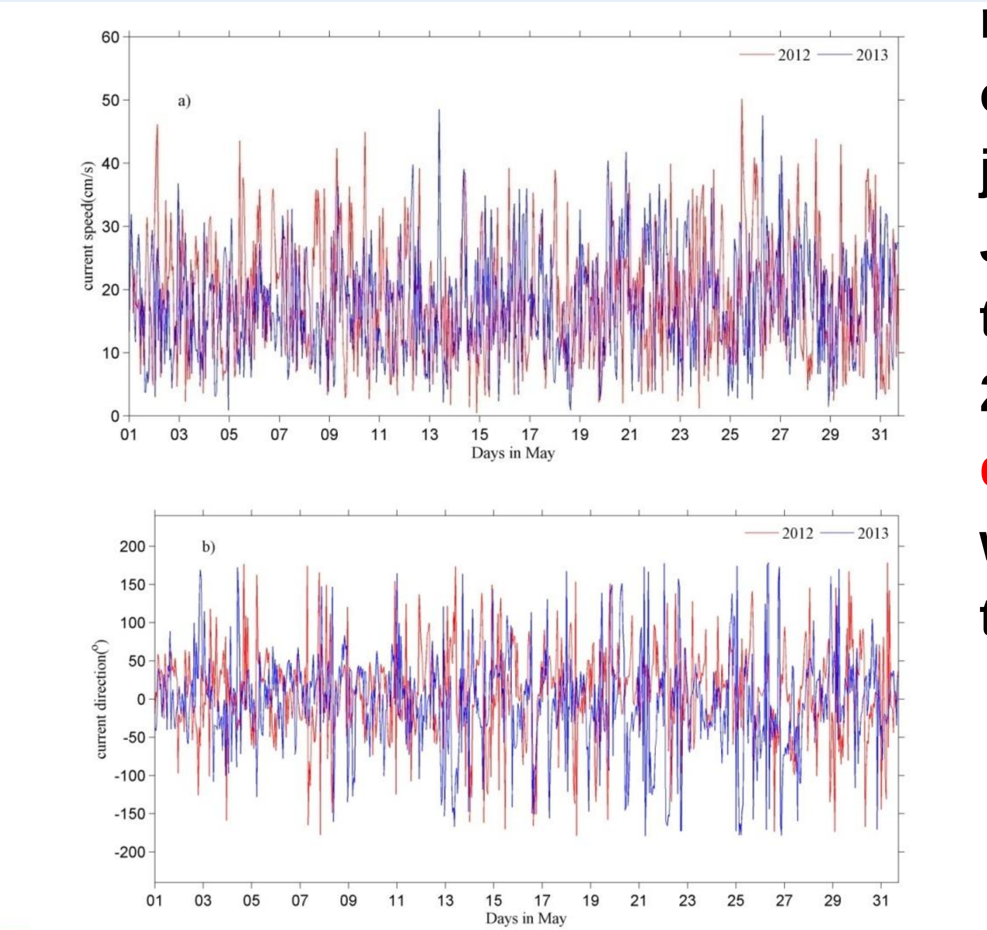
Model validation



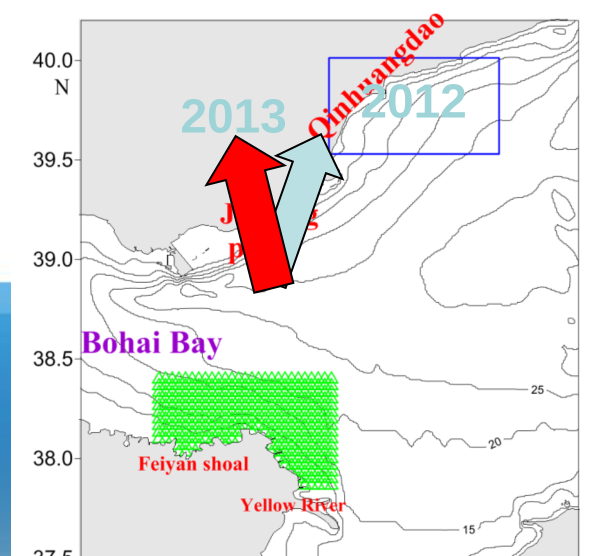
The relative forecasted errors of the current speed was less than 15% with a correlation of 0.94, and forecasted errors of the current direction was less than 14° with a correlation of 0.96 for buoy QF107

4. Analysis on dynamic factors

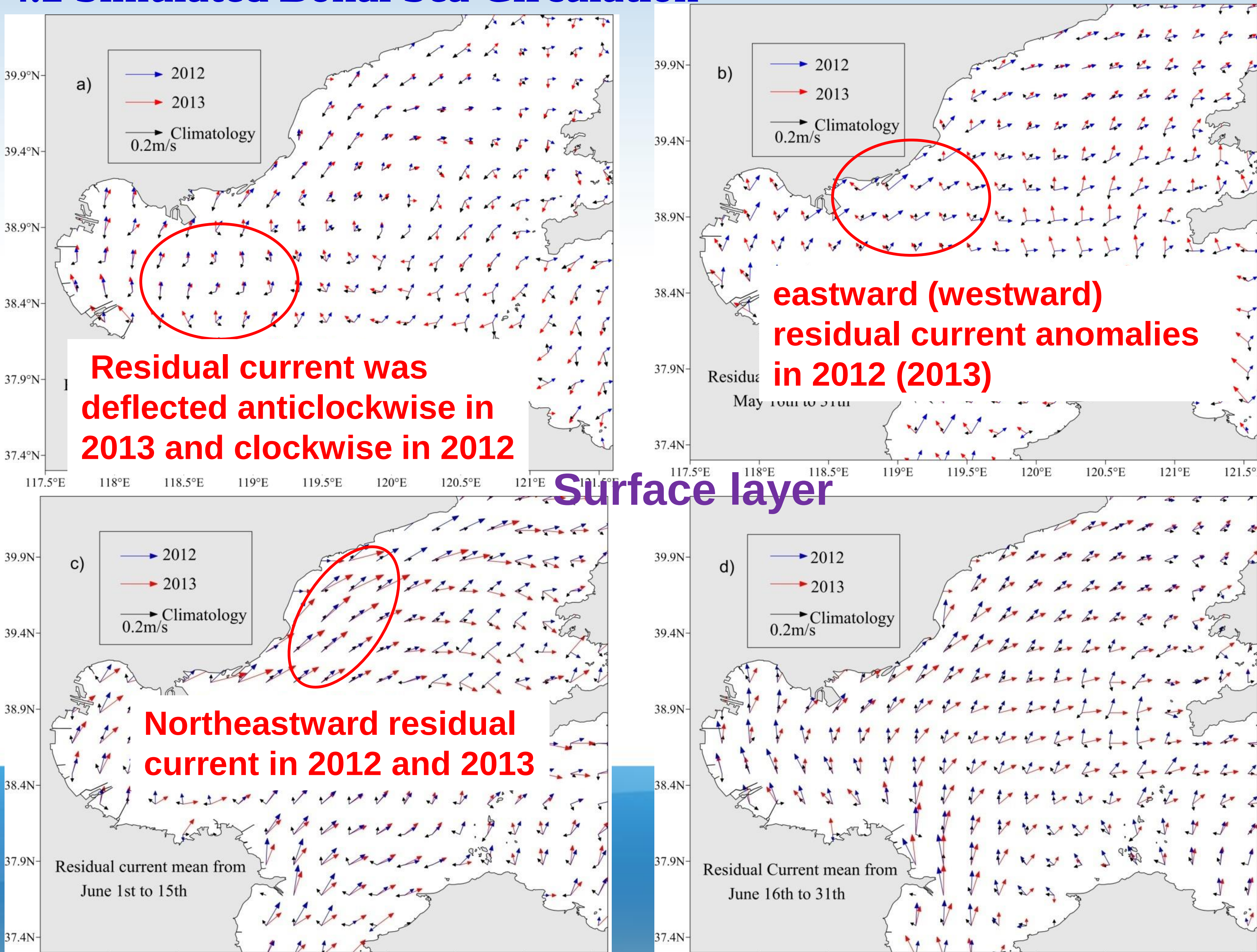
4.1 Residual current south of Jingtang Port



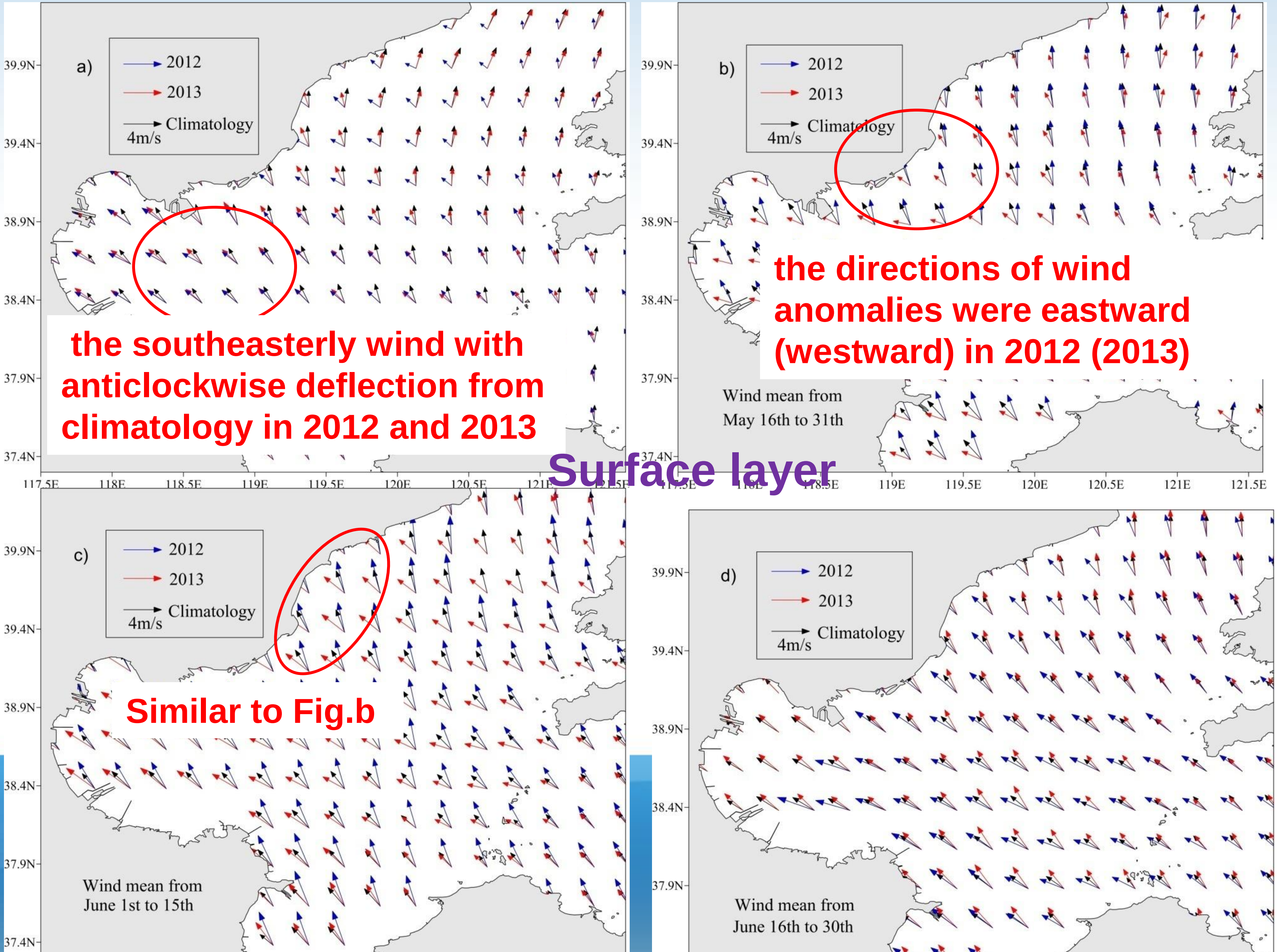
numerical simulation and observation show that the jellyfish reached south of Jingtang Port in mid-late May. the averaged velocity in 2013 was larger than that in 2012, direction leaning to northwest, which could advect the jellyfish towards Jingtang Port.



4.2 Simulated Bohai Sea Circulation



4.3 Bohai Sea wind

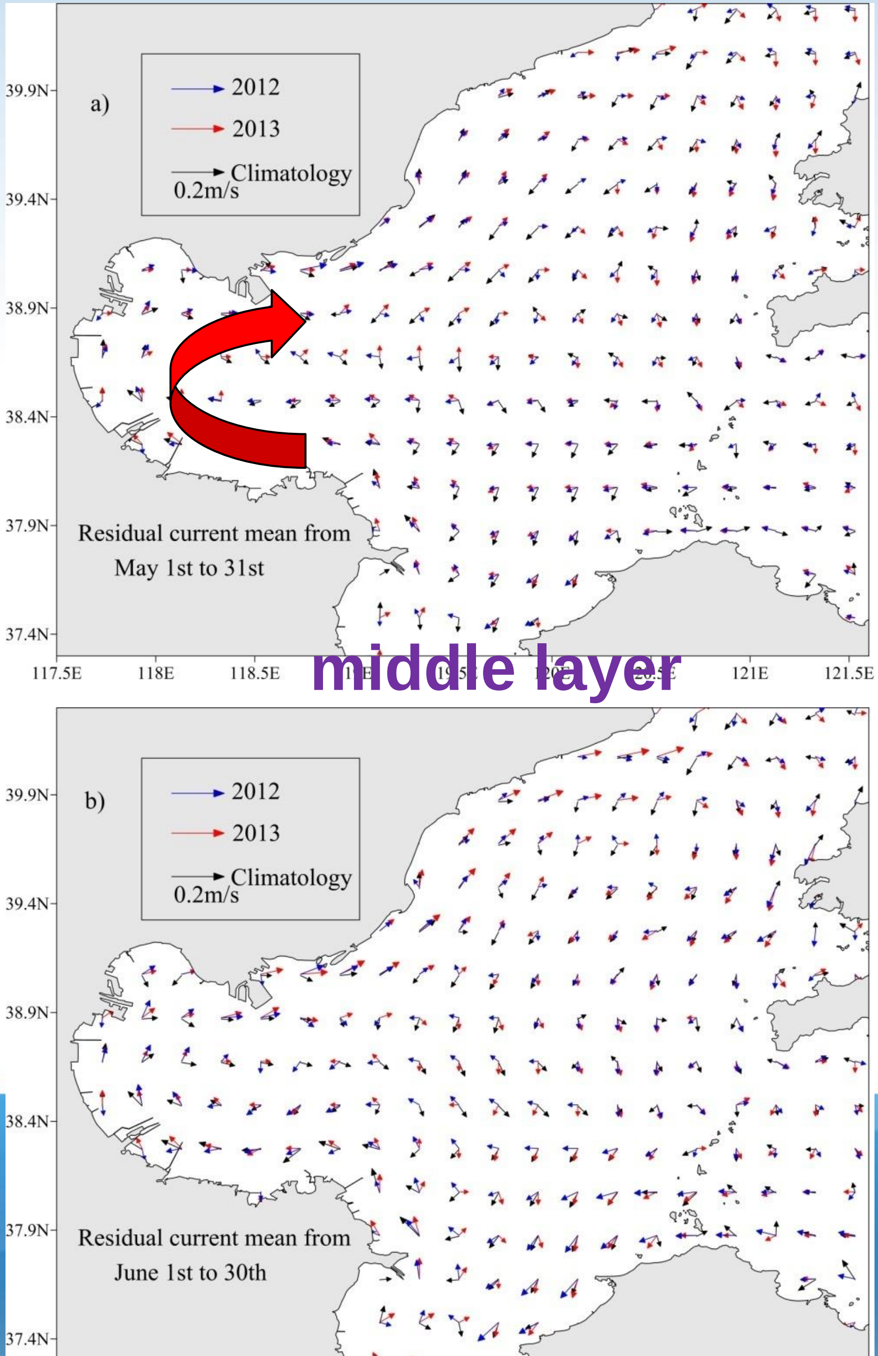


the southeasterly wind with anticlockwise deflection from climatology in 2012 and 2013

the directions of wind anomalies were eastward (westward) in 2012 (2013)

Surface layer

Similar to Fig.b



In May, there was mostly anticyclonic circulation in Bohai Bay with westward current in the southern part and eastward current in the northern part, which was deflected anticlockwise relative to that in surface.

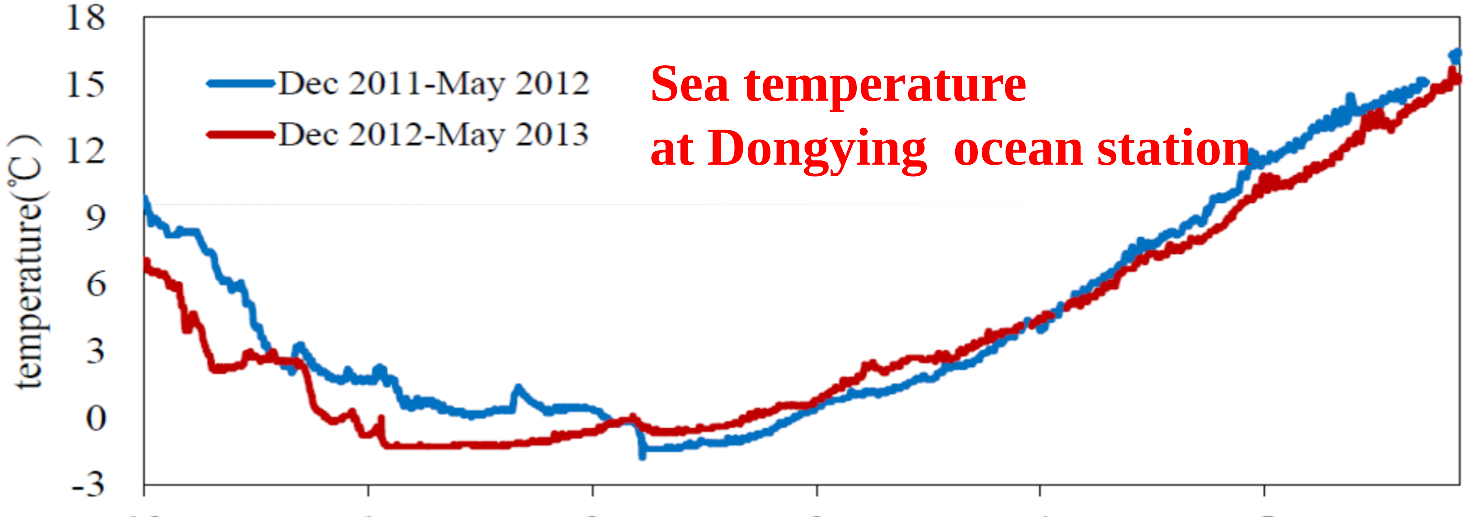
Especially, in 2013, the current in the southern part was north by west, and the current in the northern part was northeastward. In June, the anticyclonic circulation became stronger in Bohai Bay, and there was relatively stronger current near Luanhe River

4.4 Sea temperature in potential source of jellyfish

According to the studies of Sun (2012), the key factors influencing jellyfish bloom are temperature stimulation and food supply. Bottom water temperature of 10~15° C zone is a critical temperature for the strobilation of N. nomurai and Rhopilema esculentum.

- Sea temperature in winter of 2011 and spring of 2012 was generally lower than that in winter of 2012 and spring of 2013.
- water was warmer earlier in the spring of 2012 than that of 2013, and the duration of 10-15° C was the same for both years.

→ Therefore, in the condition of sufficient bait, sea temperature in 2012 was more conducive to jellyfish bloom than that in 2013.

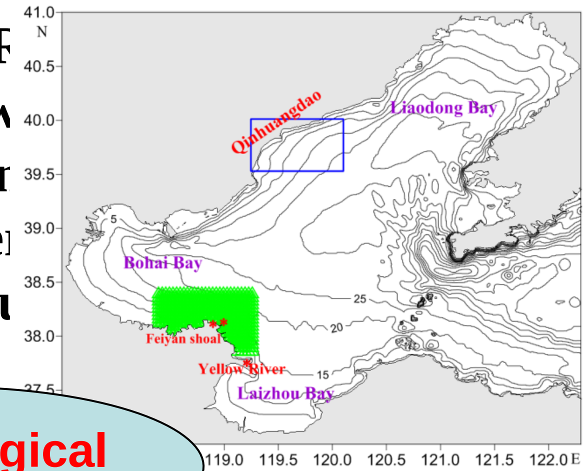


5.Simulation results of giant jellyfish

Numerical experiments

According to the studies of Sun (2012), the key factors influencing jellyfish bloom are temperature stimulation and food supply. Bottom water temperature of 10~15° C zone is a critical temperature for the strobilation of N. nomurai and Rhopilema esculentum.

According to observation, waters near Yellow R temperature in May. Eight numerical experiments w consideration of different meteorological and marin boundary conditions, releasing time and releasing laye of jellyfish particles released from the source were simu

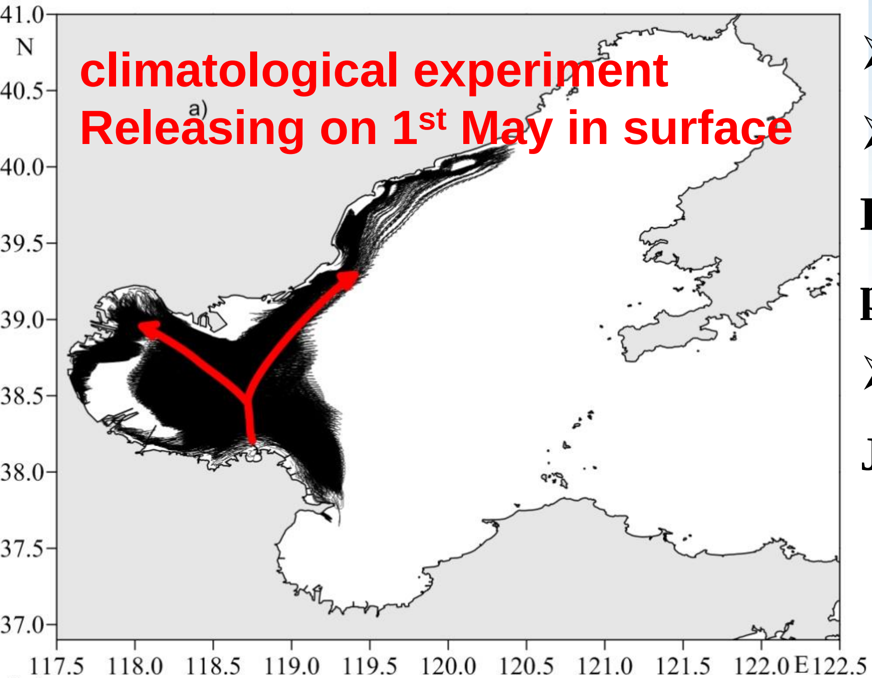


climatological experiment

Table 1
Design of numerical experiments.

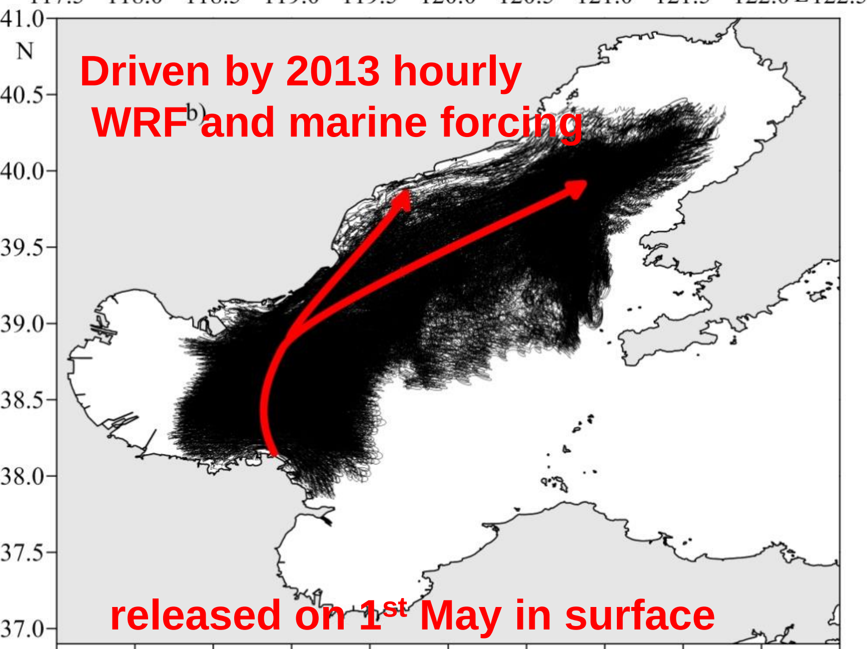
Exp.	Wind & heat/salt flux	Initial and boundary condition	Tides	Releasing time	Releasing layer
1	QSCAT/ASCAT, monthly	SODA for large- region model, tidal boundary forcing in small-region model	Yes	May 1, 2013	Surface
2	2013 WRF, hourly	2013 HYCOM + NCODA for large-region model, 2013 tidal boundary forcing in small-region model	Yes	May 1, 2013	Surface
3	2012 WRF, hourly	2012 HYCOM + NCODA for large-region model, 2012 tidal boundary forcing in small-region model	Yes	May 1, 2012	Surface
4	Same as 2	Same as 2	Yes	May 15, 2013	Surface
5	Same as 2	Same as 2	Yes	June 1, 2013	Surface
6	Same as 1	Same as 1	Yes	May 1, 2013	Mid-layer
7	Same as 2	Same as 2	Yes	May 1, 2013	Mid-layer
8	Same as 3	Same as 3	Yes	May 1, 2012	Mid-layer

5. Study on simulated trajectories



- ➢Move northward
- ➢Move northeastward and reached northeastern Bohai Bay, then moved northeastward and passed Luanhe River
- ➢reached the waters near Qinhuangdao in late July

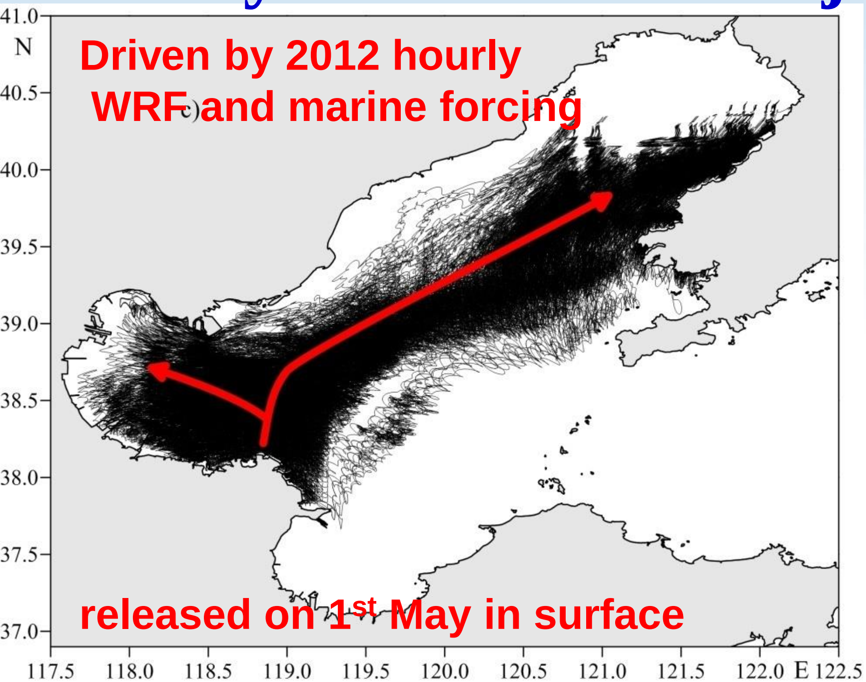
113 (34%) particles reached Qinhuangdao.

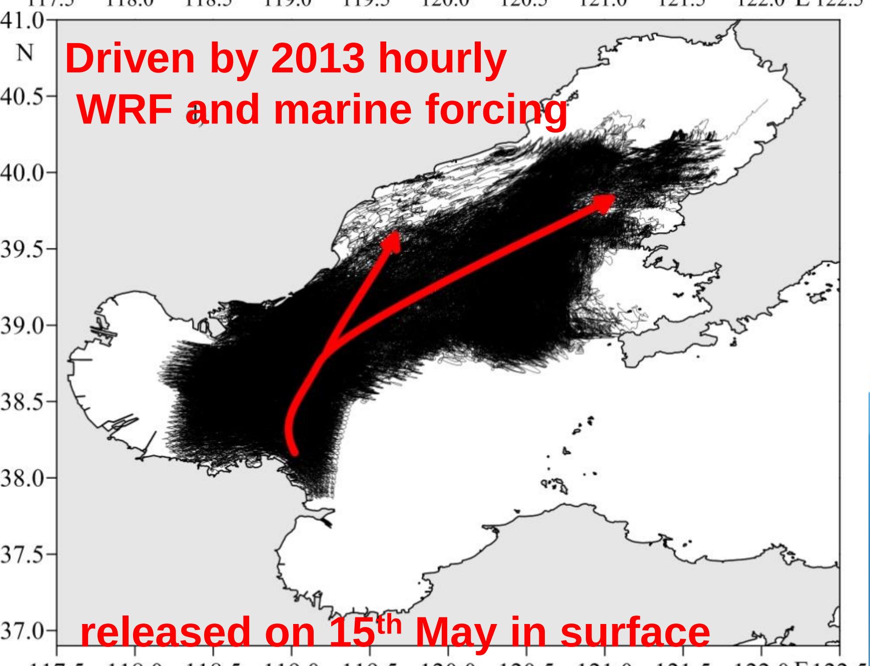


most particles moved northwestward with the influence of westward wind and residual current anomalies relative to the climatology and reached Jingtang Port in late May; moved northeastward, passed Luanhe River and reached Qinhuangdao in July.

190 (60%) particles influenced Qinhuangdao

5. Study on simulated trajectories





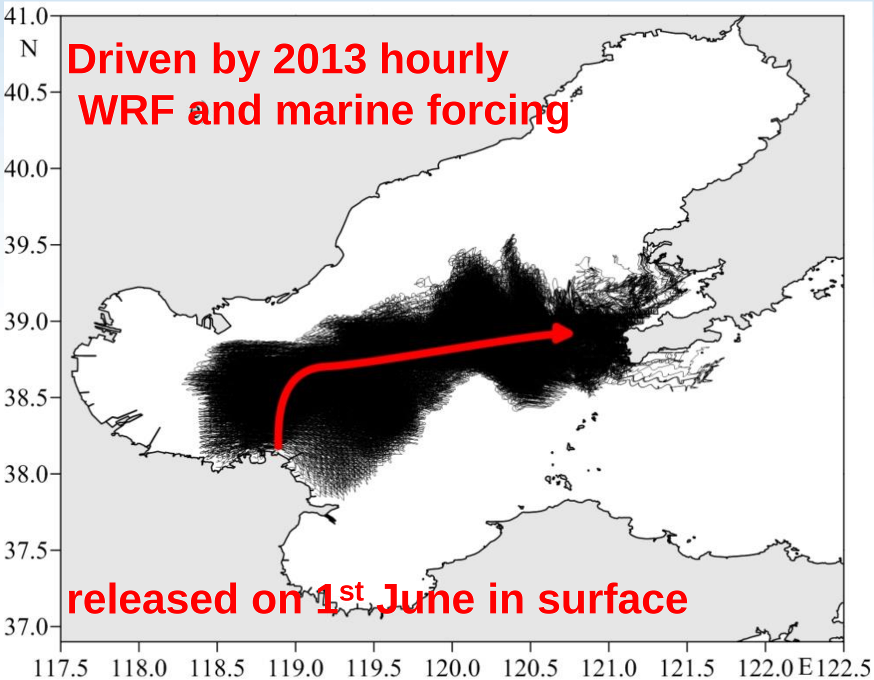
- part of particles in southeastern Bohai Bay moved northwestward
  the other part moved northward
- during the second half of May most particles driven by the anomalous eastward current moved north-northeastward, and did not aggregate near JingtangPort.

• only 18 (6%) particles influenced the waters near Qinhuangdao

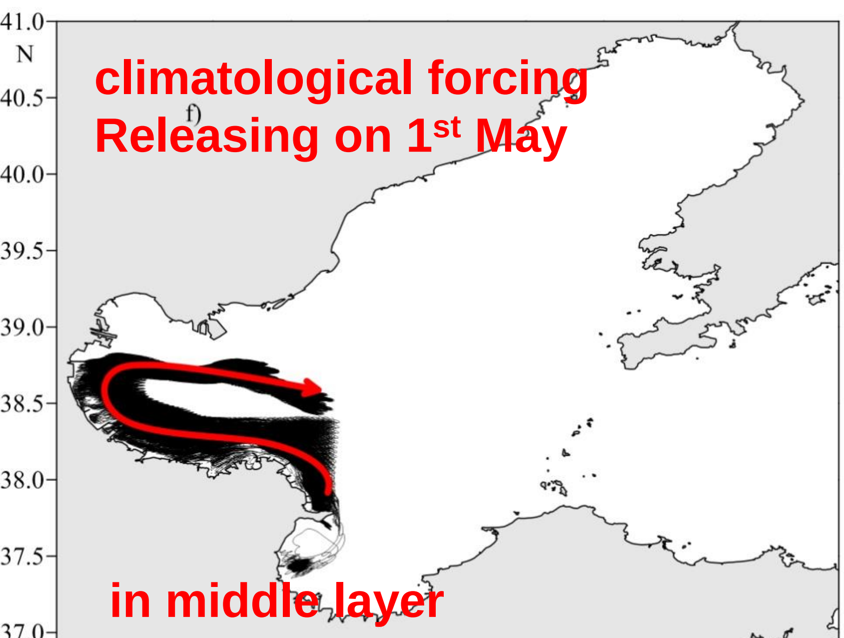
generally similar to those on 1st May 2013.

Since the particles released 15 days later for short time, only 144(44%) particles influenced the waters near Qinhuangdao.

5. Study on simulated trajectories

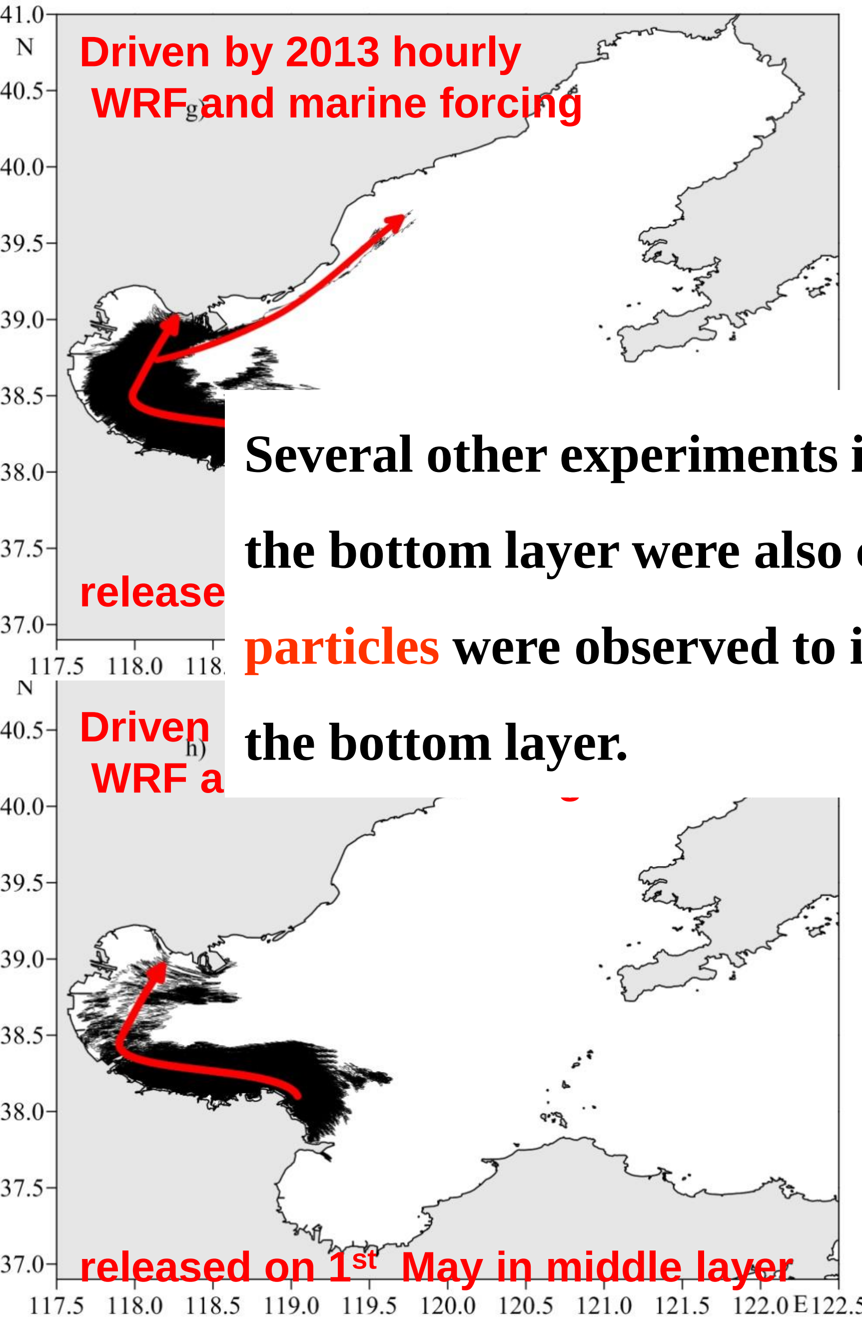


- Since the particles released 30 days later, moved northward for very short time and arrived at central Bohai Bay;
- part of the particles moved northeastward with the influence of northeastward current.
- **No particles** influenced the waters near Qinhuangdao.



- Influenced by the anticyclonic circulation with small current speed in Bohai Bay in middle layer
- the particles moved westward parallel to the coast of southern Bohai Bay, then part of particles reached the waters near Tianjin, and then moved eastward
- **no particles** influenced Qinhuangdao

5. Study on simulated trajectories



- ➢ in May most particles moved westward with westward current.
- ➢ In June and July, some particles moved northward, reached and stopped near waters south of Caofeidian
- ➢ only few particles (no more than 1%) moved

Several other experiments in which particles were released at the bottom layer were also conducted. In these experiments, no particles were observed to impact the waters near Qinhuangdao at the bottom layer.

no particles influenced the waters near Qinhuangdao

6. Conclusions

1) **In surface layer, jellyfish drift is jointly driven by the surface wind and surface current.**

The major difference between the 2013 bloom and 2012 non-bloom cases is that the wind field and the residual current pattern favored the bloom in 2013, but not in 2012.

In particular, the residual current pattern (or northwestward by north direction) in northeastern Bohai Bay was critical in advecting the jellyfish northward to the waters of Qinhuangdao in 2013, while in 2012, the northeastward current advected the jellyfish off the coast of Qinhuangdao toward northeastern Liaodong Bay.

6. Conclusions

2) Since the residual current velocity weakened and anticlockwise deflected with depth, few (no) jellyfish particles released at the middle (bottom) layer reached the waters off Qinhuangdao, most particles retained in Bohai Bay by the weak anticyclonic residual circulation.

3) If there were adequate bait, sea temperature in 2012 was more suitable for jellyfish bloom than that in 2013. However, there was no aggregation of giant jellyfish near Qinhuangdao in 2012.

Hence, the wind and surface current pattern (or direction) in the Bohai Sea (especially in the northeastern Bohai Bay during the second half of May) was more important than the sea temperature for the jellyfish bloom near Qinhuangdao.

Thank you！

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Wu L, Wang J, Gao S, et al. An analysis of dynamical factors influencing 2013 giant jellyfish bloom near Qinhuangdao in the Bohai Sea, China [J]. Estuarine Coastal & Shelf Science, 2016, 185,141-151.