Preliminary progress of ocean surface current mapping system in Taiwan

WEN-SON CHIANG S-H CHEN

W-C YANG J-W LAI K-I LIN E-Y LIANG

TAIWAN OCEAN RESEARCH INSTITUTE,
NATIONAL APPLIED RESEARCH LABORATORIES,
TAIWAN

Outline

- Initiation of HFR network project
- Setup of HFR stations
- Instruments
- HFR data analysis
- Validations of HFR data
- Applications
  - **Ocean surface current pattern**
  - **Hindcast of drifter trajectories**
- Summary

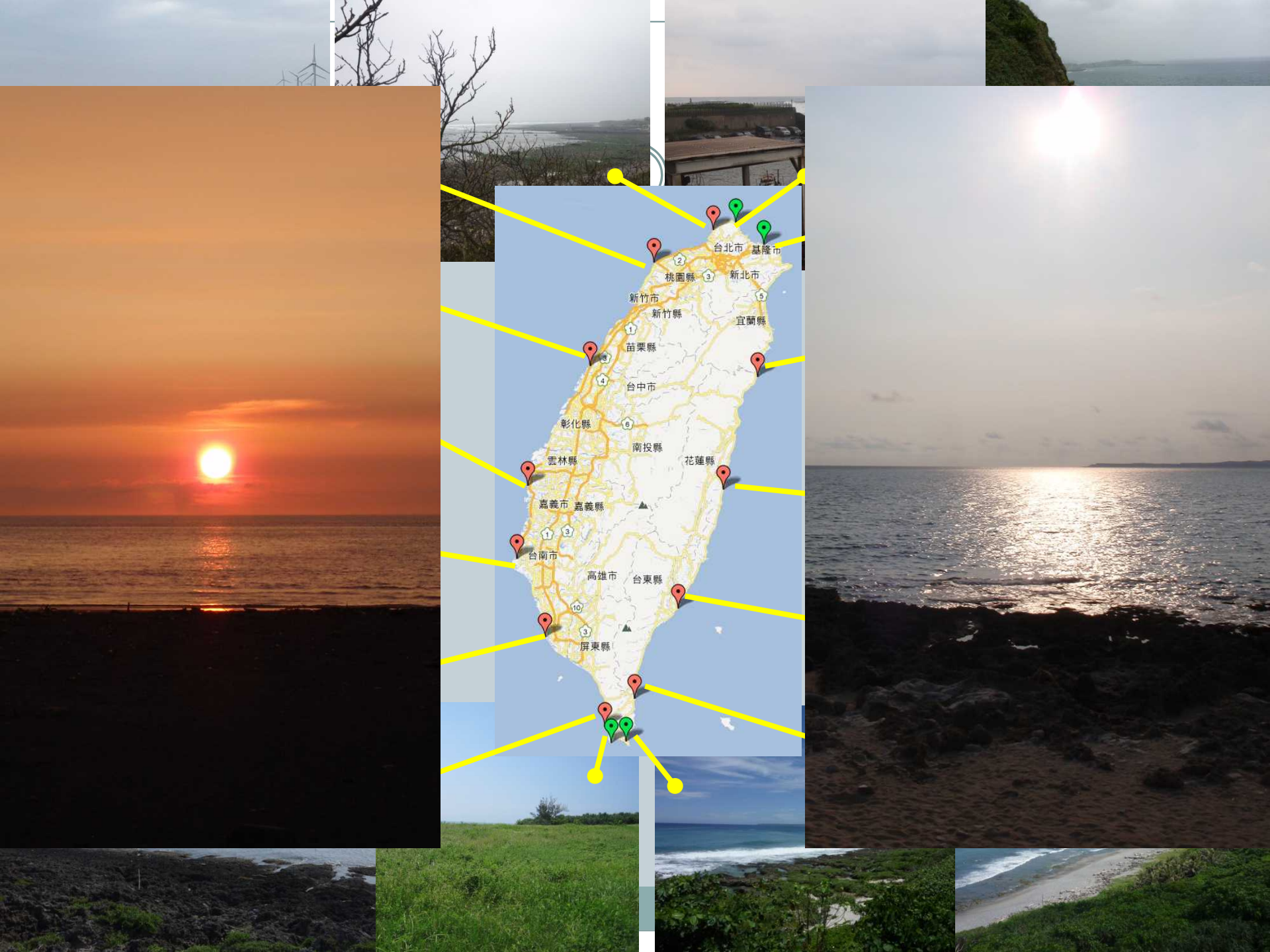
Introduction

- In 2006, a proposal submitted to NSC for construction of a HFR network around Taiwan.
- In 2008, TORI was founded and the construction of the HFR network was assigned as one of the missions.
- Budget: ~120 million NTD
- Man power: 4~5 full time staffs
- Time: 3 and half years
- In 2009, finished 3 stations
- In 2010, finished 7 stations
- In 2011, finished 5 stations

Site selection

Guide lines of site selection:

1. proximity to water
2. the area around the receive antenna should be kept clear
3. enough distance between antennas.
4. suitable distance between sites
5. power supply
6. internet service
7. security


台北市
基隆市
桃園縣
新北市
新竹市
新竹縣
宜蘭縣
苗栗縣
台中市
彰化縣
南投縣
雲林縣
花蓮縣
嘉義市
嘉義縣
台南市
高雄市
台東縣
屏東縣

Setup of antennas

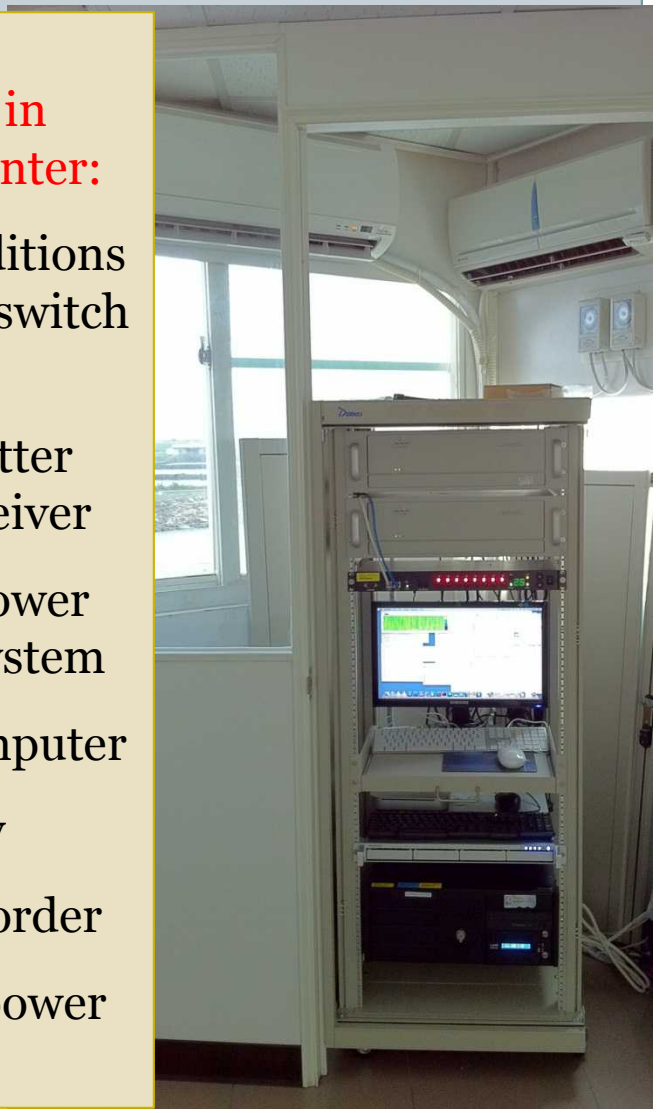
Once the potential sites had been selected. Before the construction, the most critical thing was to negotiate with owners of the land properties of radar sites:

- Coast guard
- Navy
- National companies
- Central and Local governments

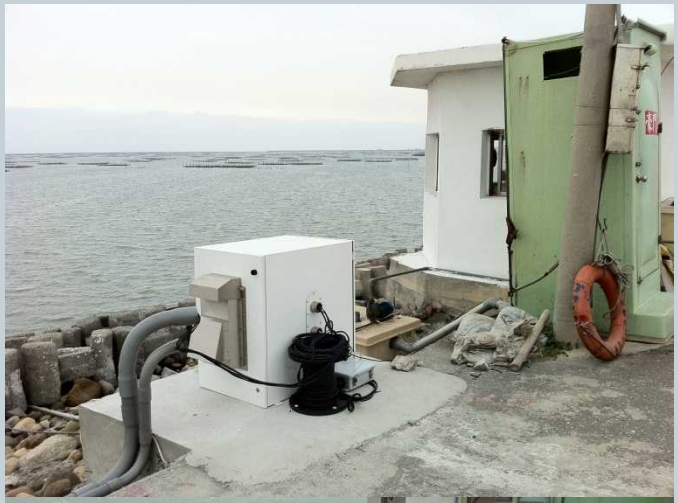
local control center

List of instruments in each local center:

- ✓ 2 air conditions and auto switch system
- ✓ a transmitter and a receiver
- ✓ remote power control system
- ✓ radar computer
- ✓ disk array
- ✓ video recorder
- ✓ 1.5 KVA power supply



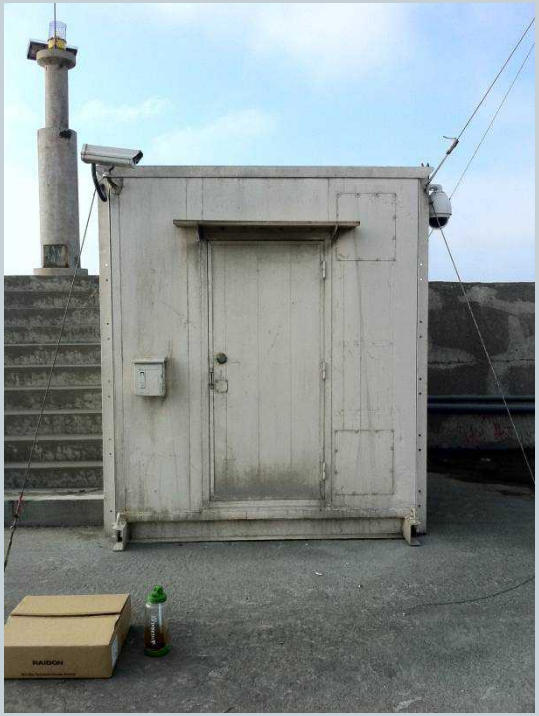
Types of local control center



Outdoor type rack with shielding

light steel frame

Types of local control center



Container

Bunker

Data Transmission

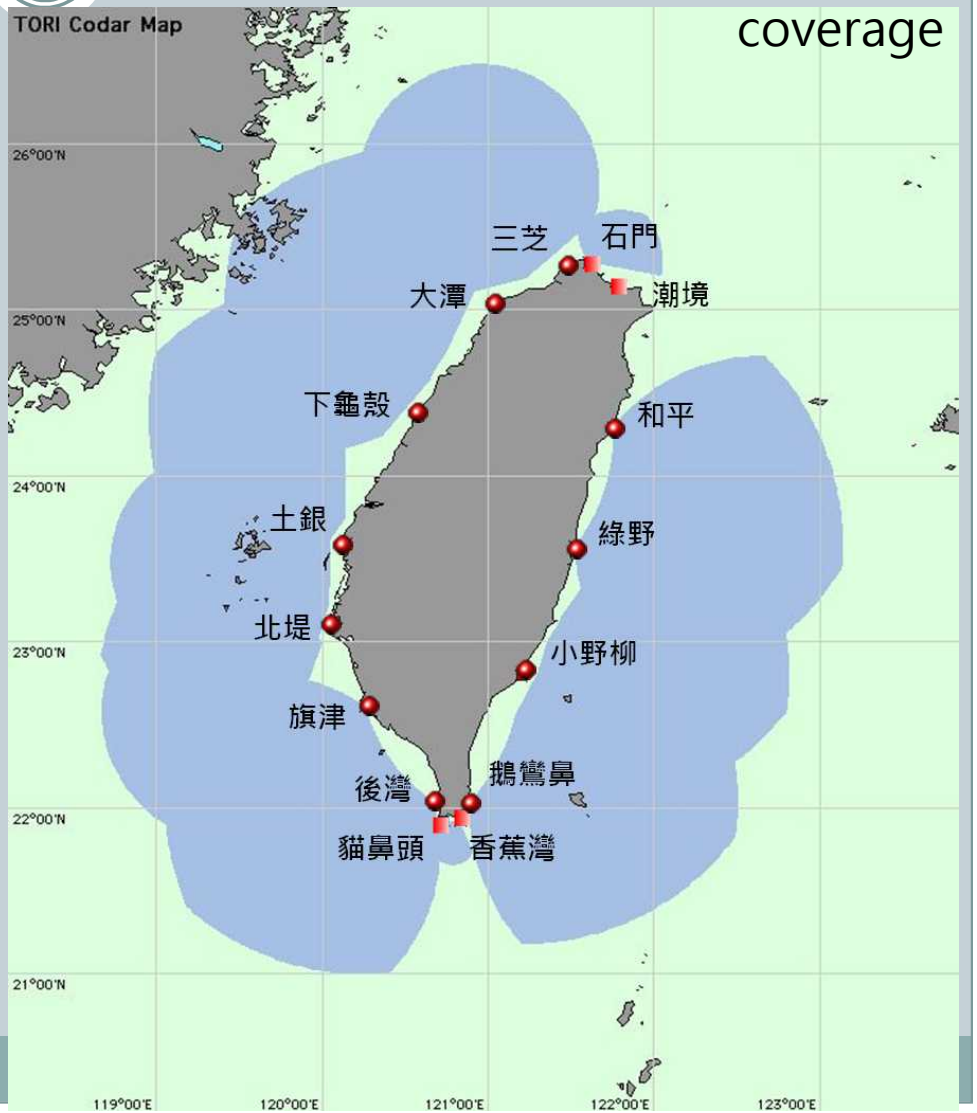
- Cabled Internet
- 3G wireless
- Microwave

Data: 75GB per day

Only small part of that is transmitted through internet.

coverage of HFR ocean surface currents

- red circles : long range sites
- red squares : standard sites
- shaded area :
  - 120km for the long range radars
  - 40km for the standard type radars



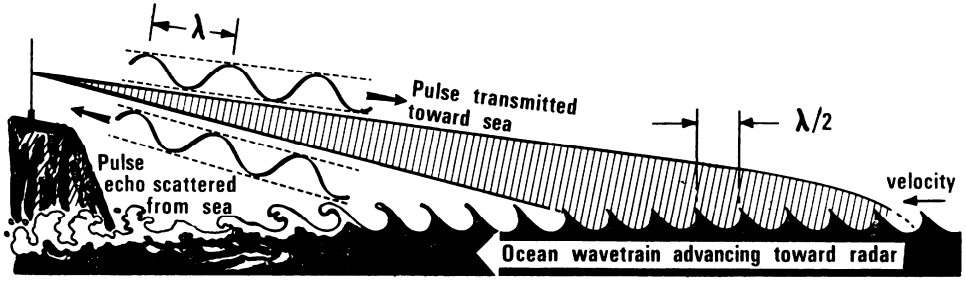
Parameters of each radar system

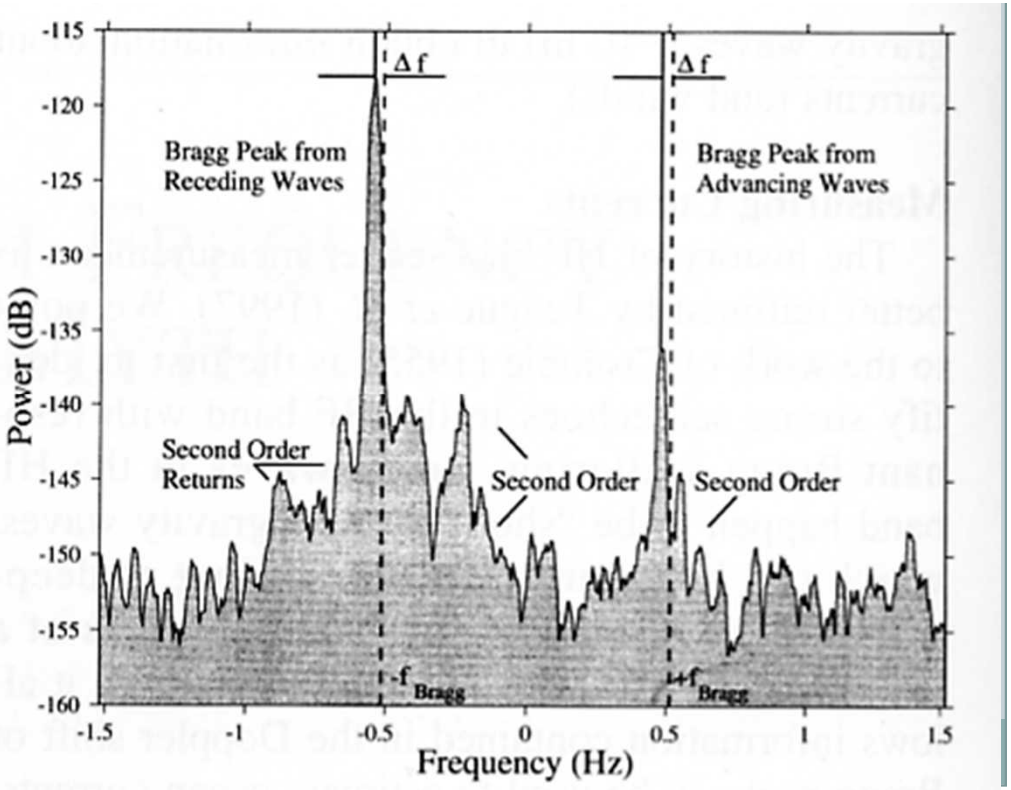
According to the hardware of the systems and the local environment, the following parameters were set for each radar site.

Site	Frequency (MHz)	Band Width (kHz)	Resolution (Km)	Measure Range(km)	Bearing (azimuth)
LUYE	4.58	15 → 40	10 → 3.75	180	59-191
SHIA	4.58	15 → 40	10 → 3.75	180	26-186
HOPE	4.58	15 → 40	10 → 3.75	180	26-196
LIUK	4.58	15 → 40	10 → 3.75	150	235-0
DATN	4.58	15 → 40	10 → 3.75	150	57-195
TUTL	4.58	15 → 40	10 → 3.75	160	252-2
CIHO	4.58	15 → 40	10 → 3.75	170	151-331
HOWN	4.58	15 → 40	10 → 3.75	160	192-327
PETI	4.58	15 → 40	10 → 3.75	150	221-332
TWIN	4.58	15 → 40	10 → 3.75	180	224-349
SUHI	4.58	15 → 40	10 → 3.75	180	178-48
LILY	13.425	100	1.5	70	320-110
CIAO	13.425	100	1.5	60	359-4
MABT	24.3	100	1.5	40	112-256
BABY	24.3	100	1.5	40	177-253

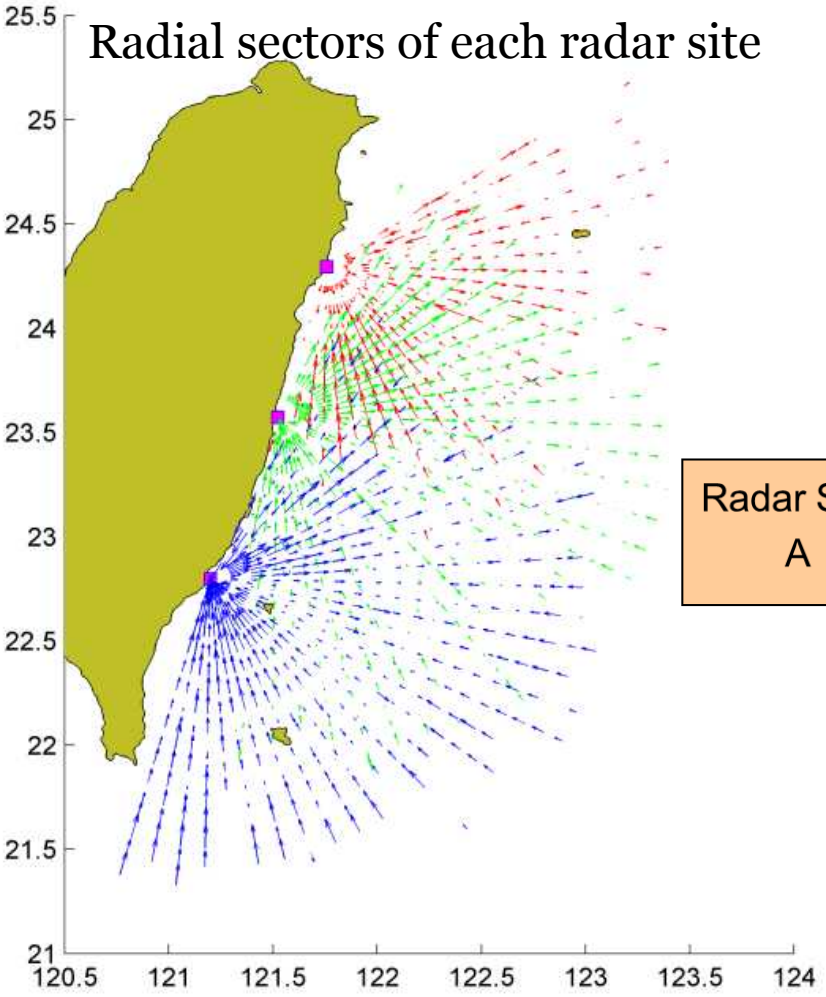
Theoretical background of HFR

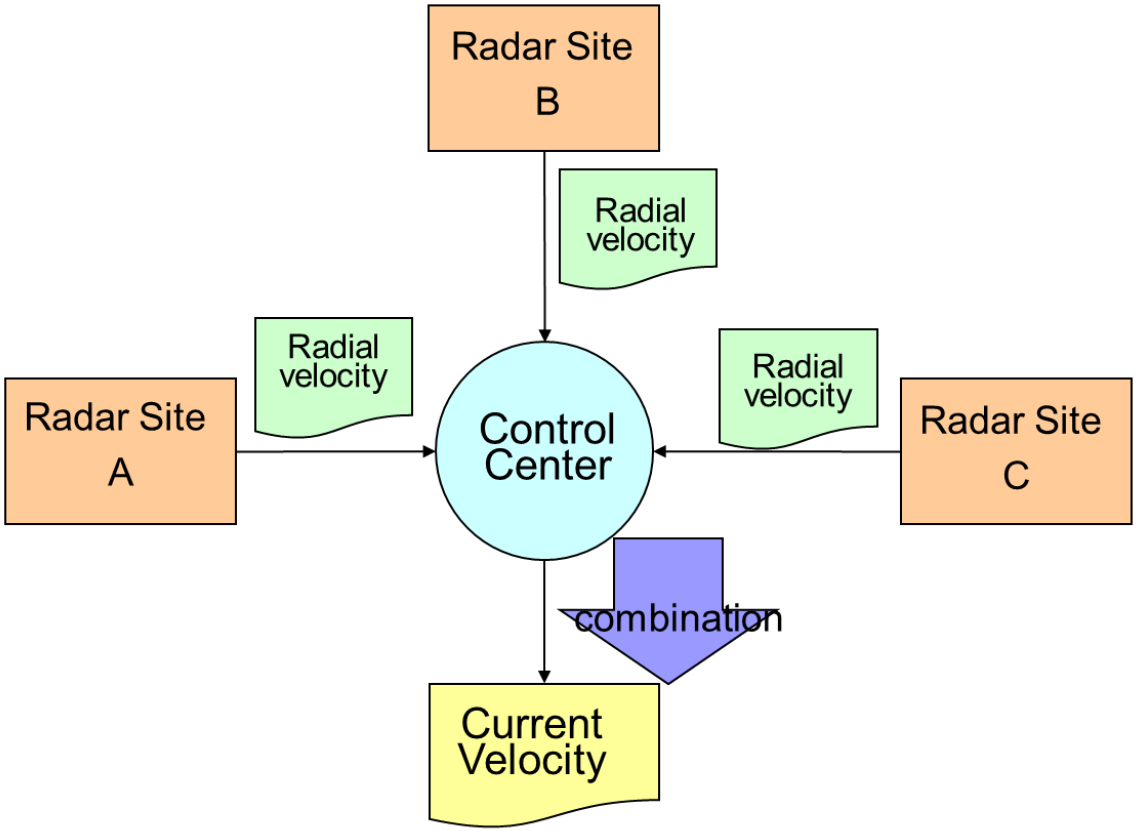
- Bragg scattering off the ocean surface
- Doppler Effect
- $f_D = 2\,V/\lambda$
- $V = c + U$
- Linear wave : $c = \sqrt{g\lambda_\omega / 2\pi}$
- Velocity can be estimated from frequency shift based on the returned signal spectrum. According to linear wave theory, the phase velocity was separated from ocean current





Concept of Velocity combination





Parameters of Data Analysis

radial

- Clean radial(> **260 cm/s depends on each site)**
- Radial grid(dR=10(2)km; dD=5deg)
- Radial interpolation

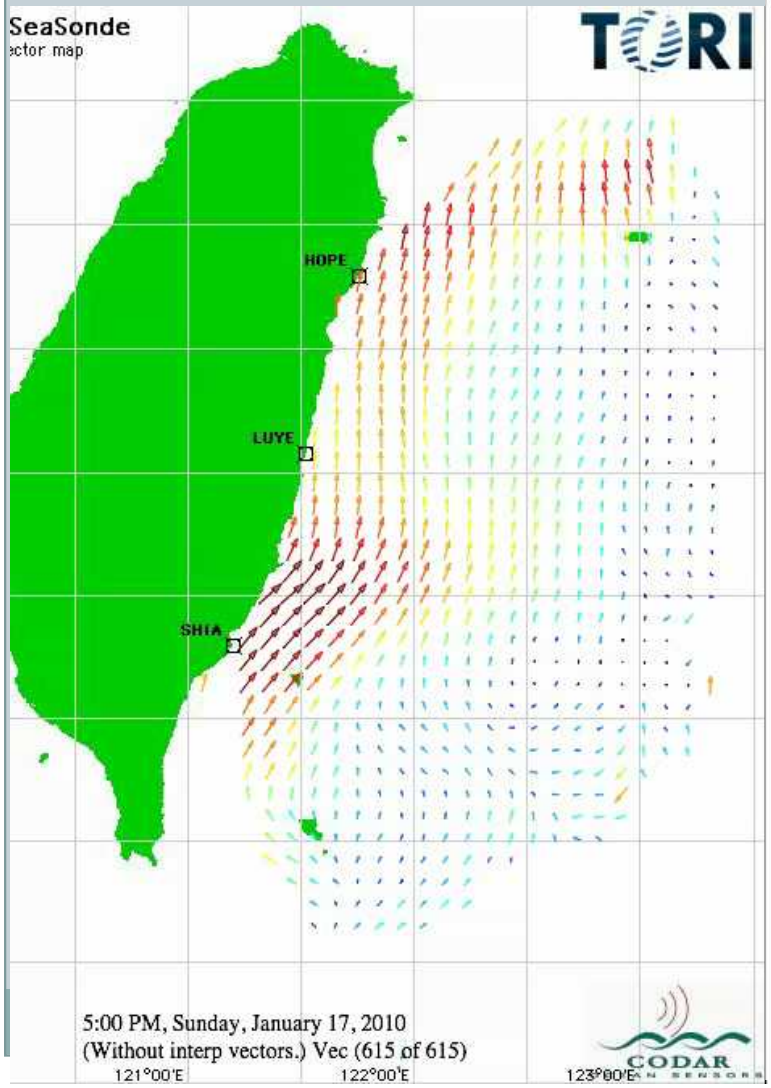
total

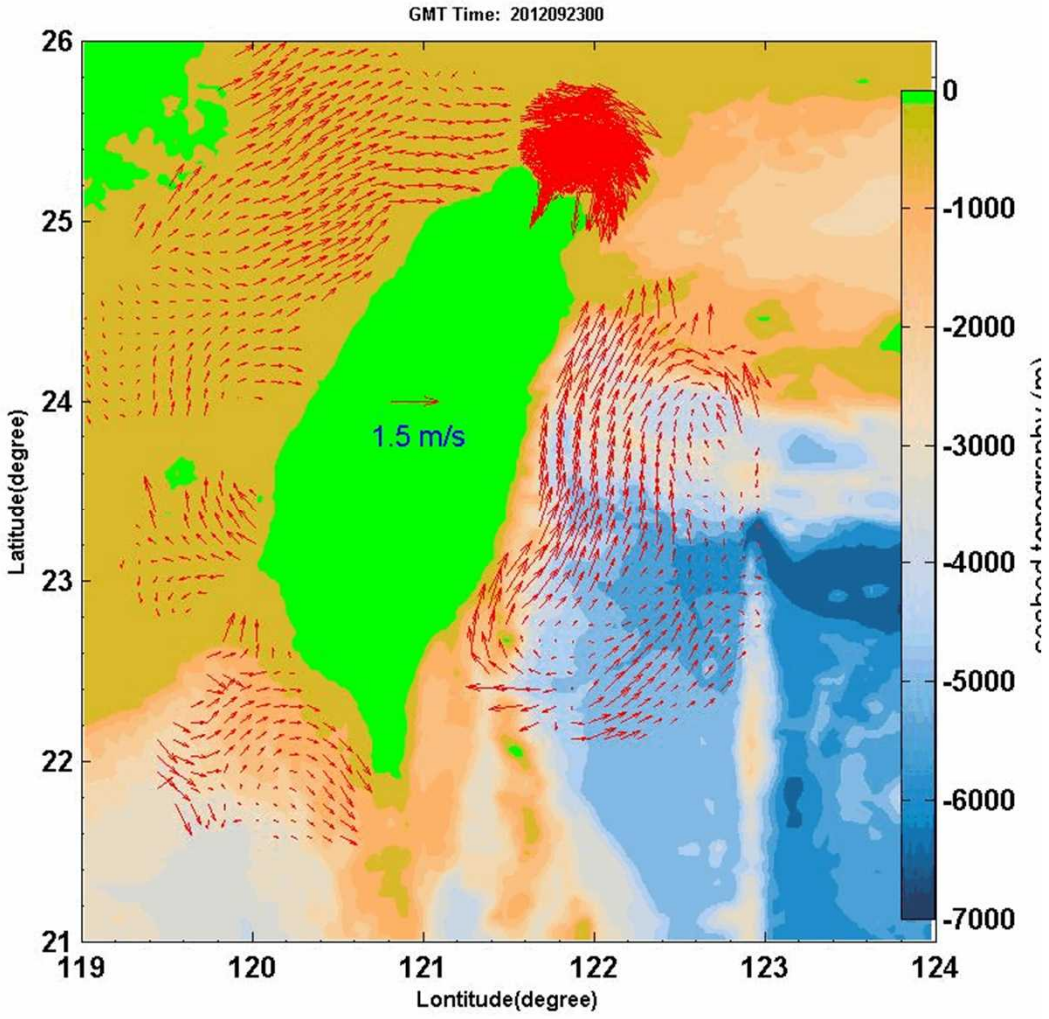
- define total grid (**0.1 degree)**
- exclude the total grids out of the bearing
- search radial vector for each total grid (Dist < 15km)
- **at least 2 sites and 3 radial vectors for combination of total velocity**
- GDOP >1.25 (30 < cross angle <150)
- Least square method

smooth

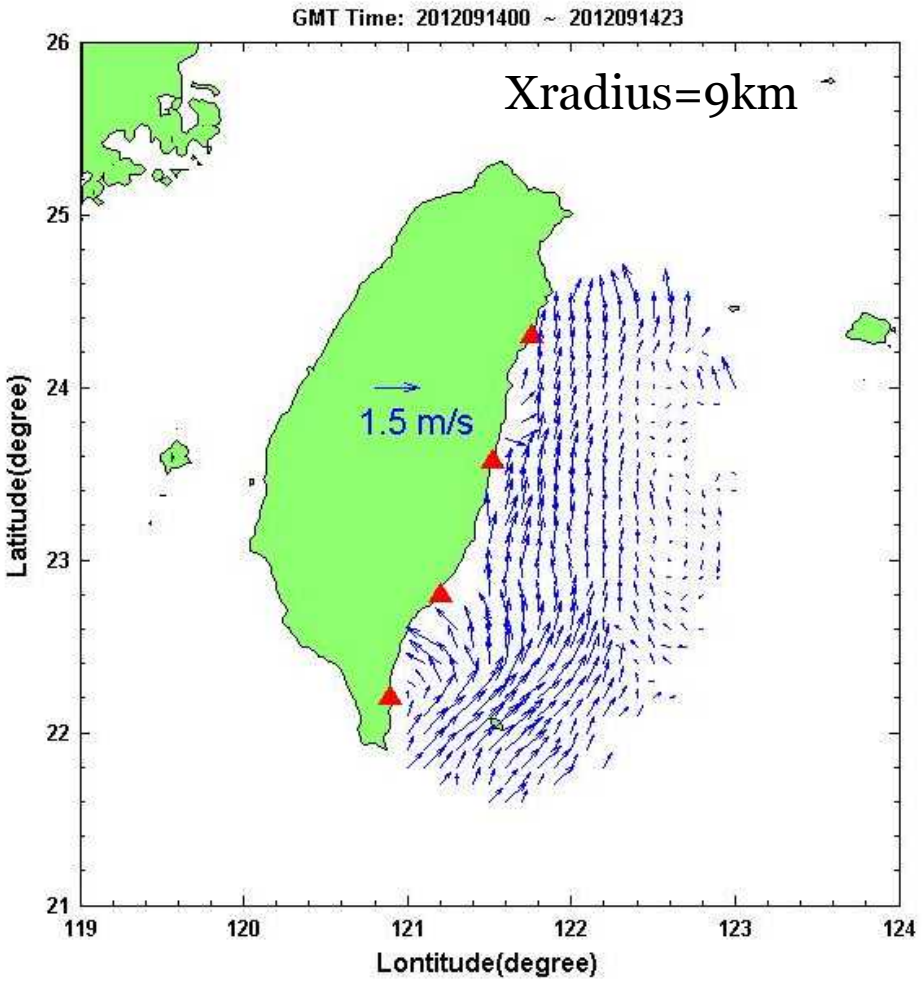
- Spatial interpolation
- Temporal interpolation

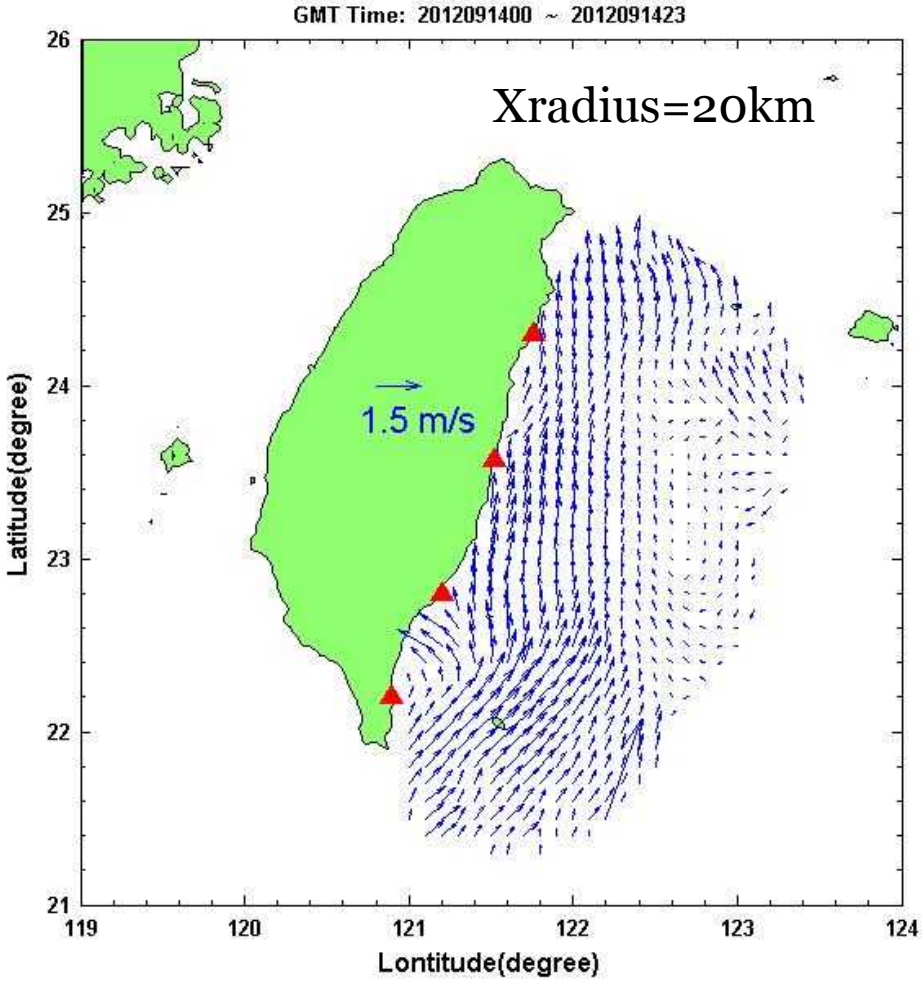
Total velocity





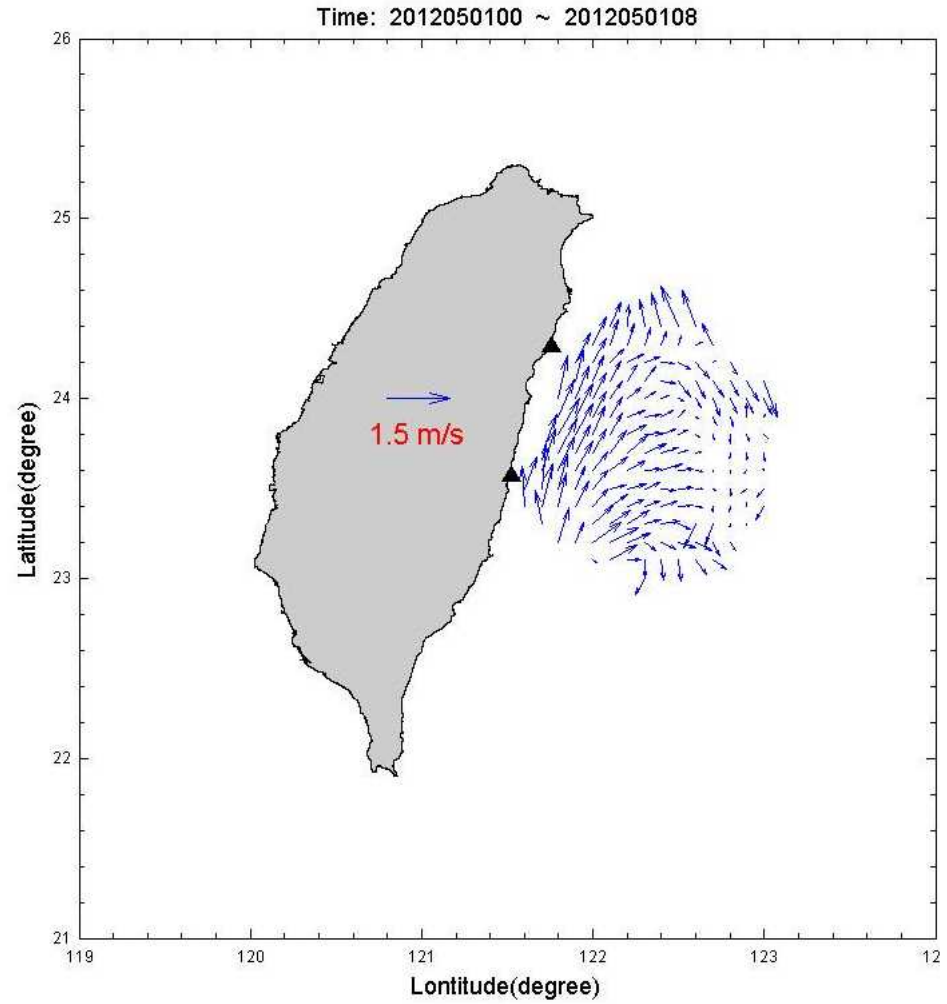
Search range effect

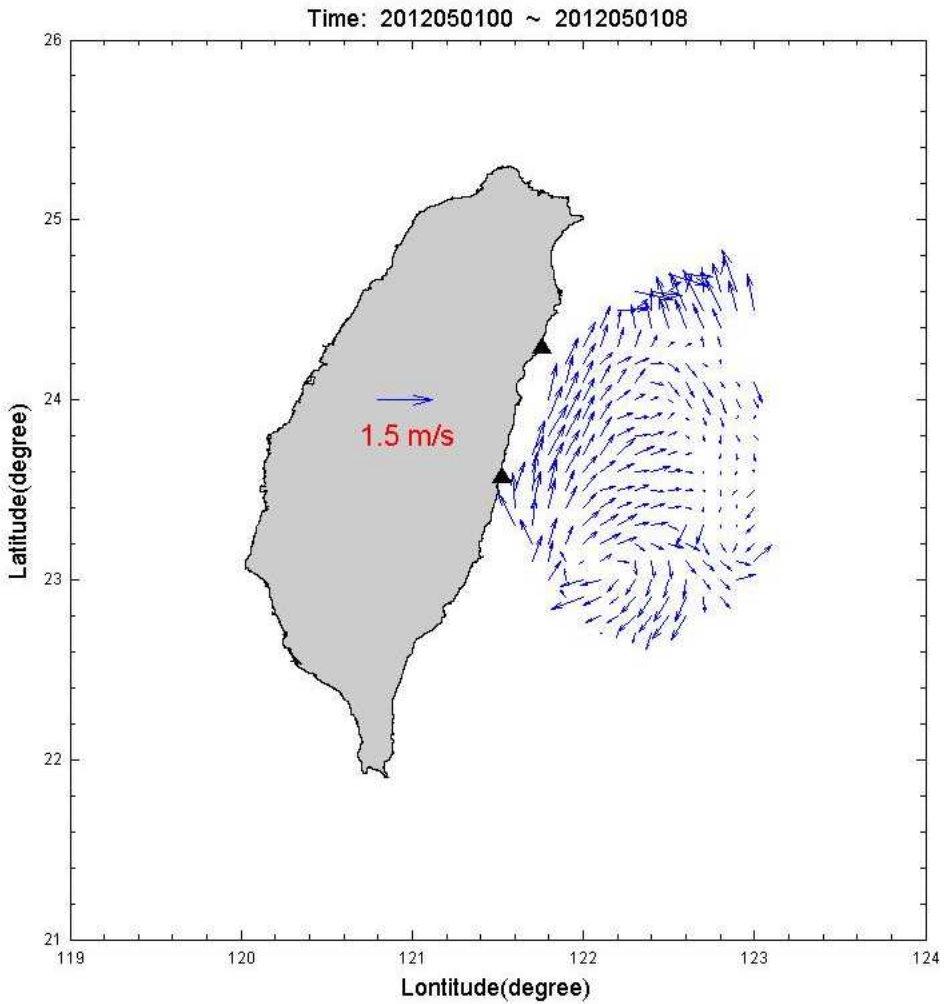




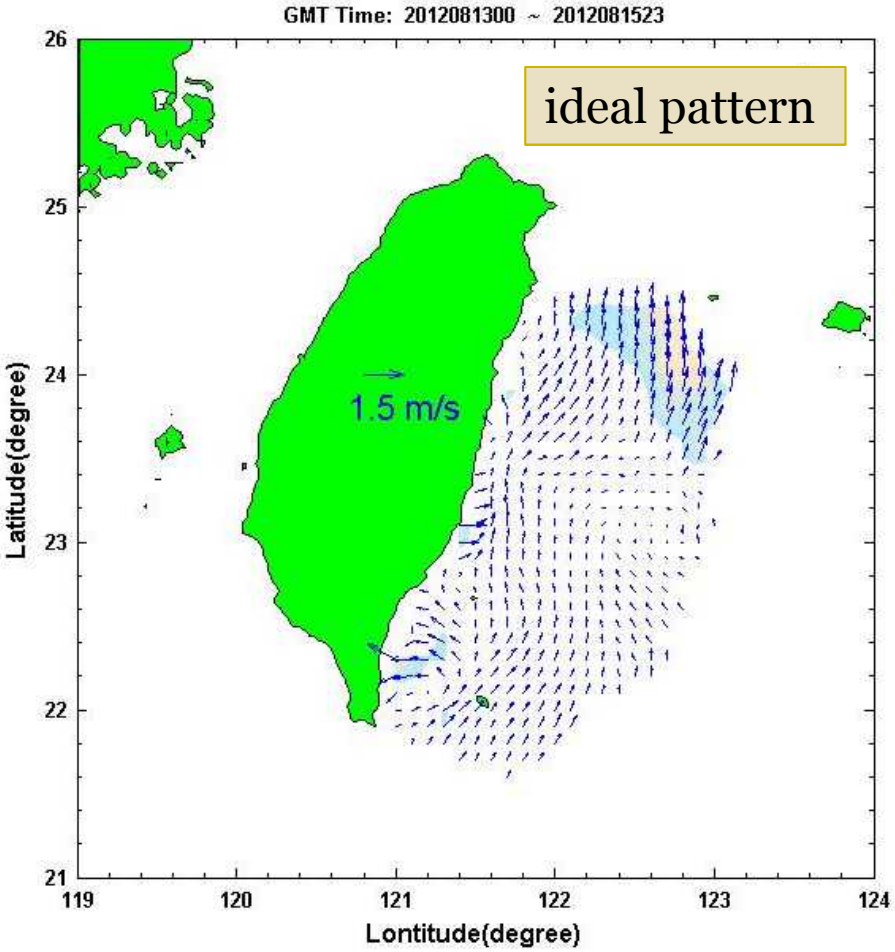
Geometric dilution of position(GDOP) effect

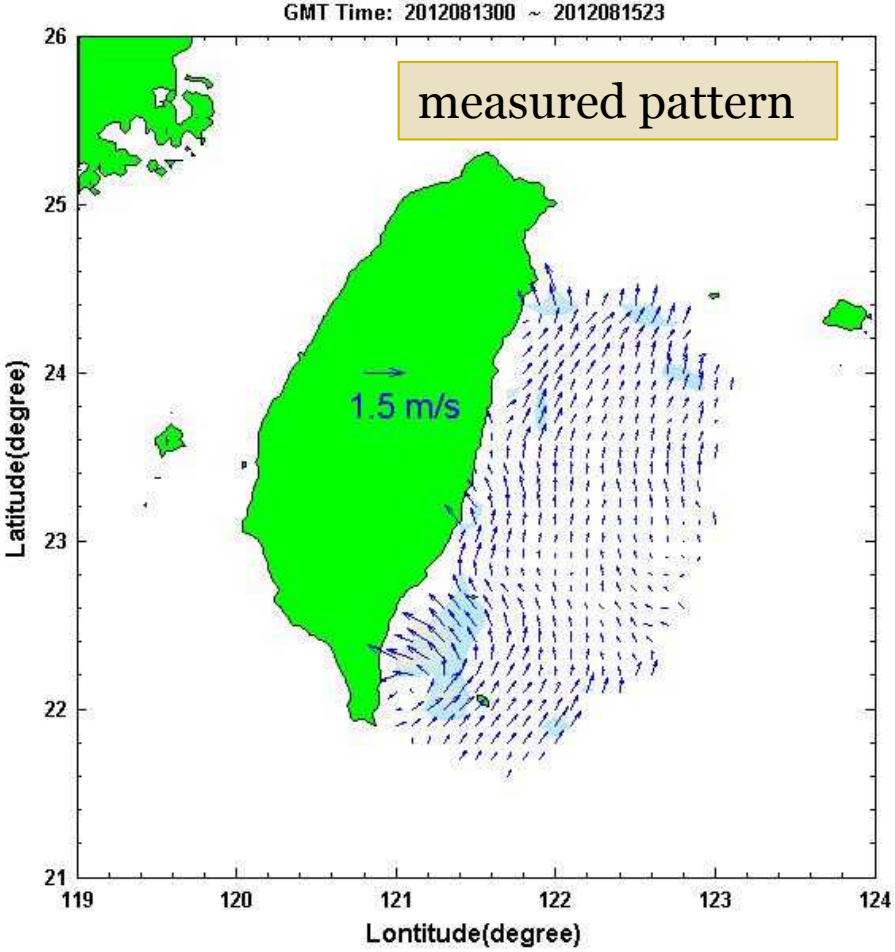
- GDOP: 1.25 (cross angle between 30~150 degree), left
  GDOP: 1.00 (cross angle between 20~160 degree), right





Comparison between ideal and measured pattern





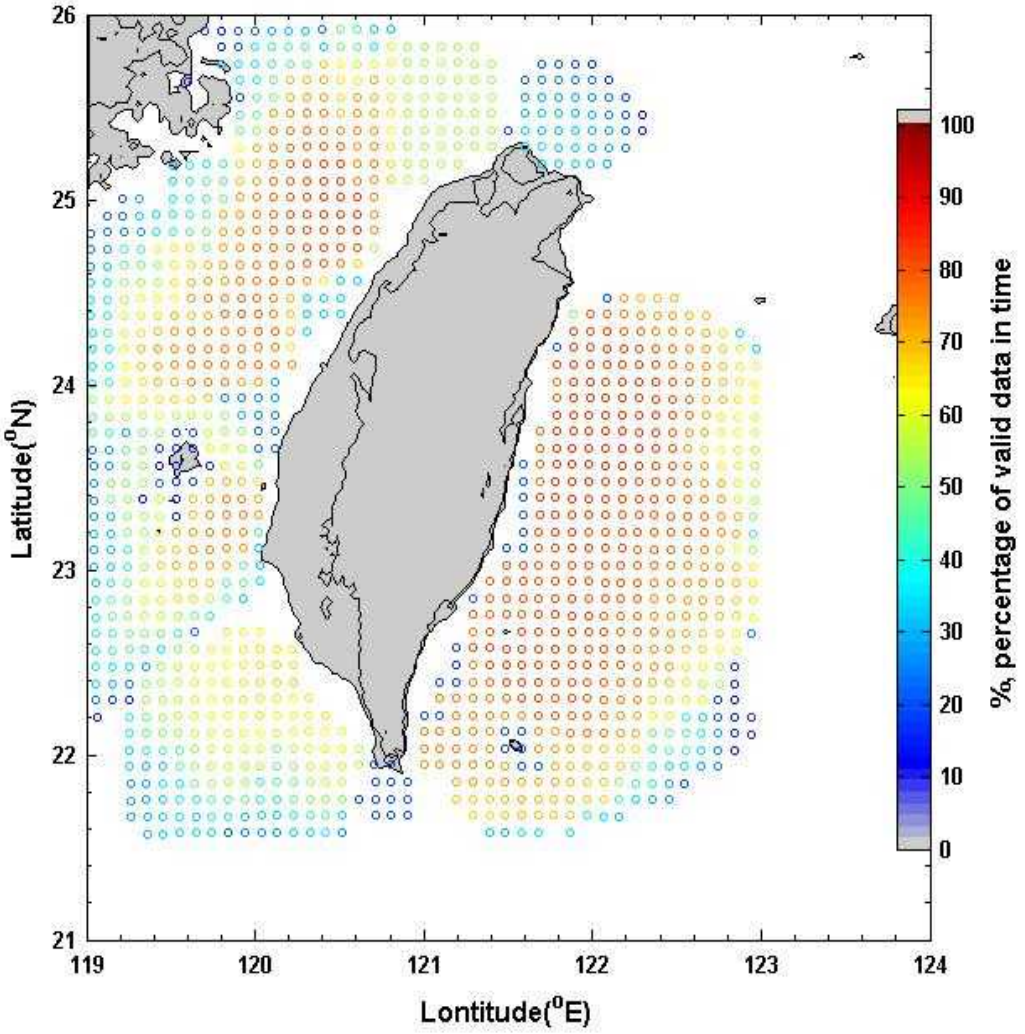
Parameters of total velocity Analysis

A series of experiments were conducted and the results were discussed. Finally, the following parameters were used for combination of the radial velocities.

	Resolution (Km)	Radials around each grid point. (km)	Maximun current velocity (cm/s)	GDOP (^{O})
ALML (Long Range)	10	20	200	30
SOUTH (Standard)	1.5	2	180	30
NORTH (Standard)	1.5	2	180	30

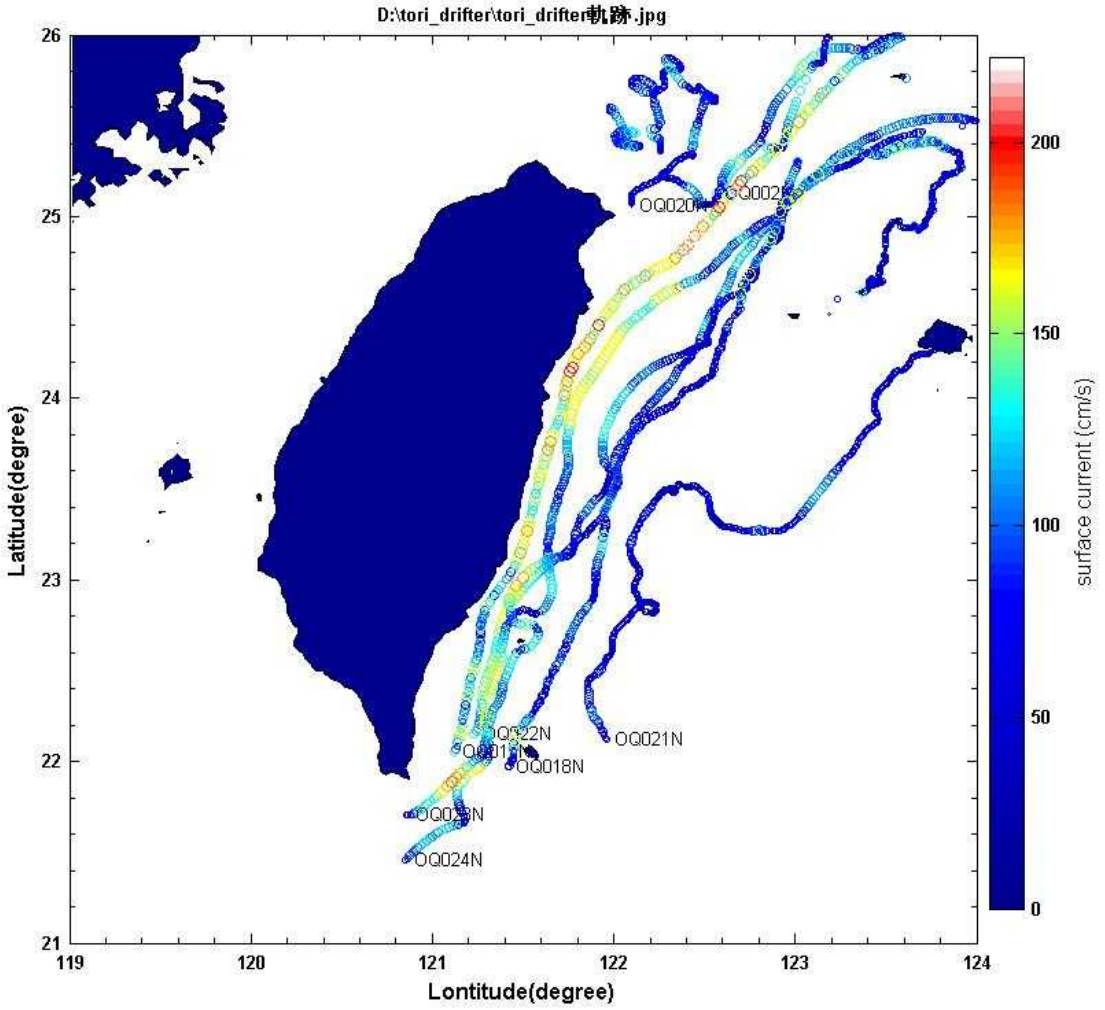
coverage of good data percentage

coverage of good data percentage based on data from the Jan. 1 and Nov. 30 in 2012



Validation of HFR surface currents

Totally, 8 drifters were deployed in 2012, which trajectories are shown on the right panel.

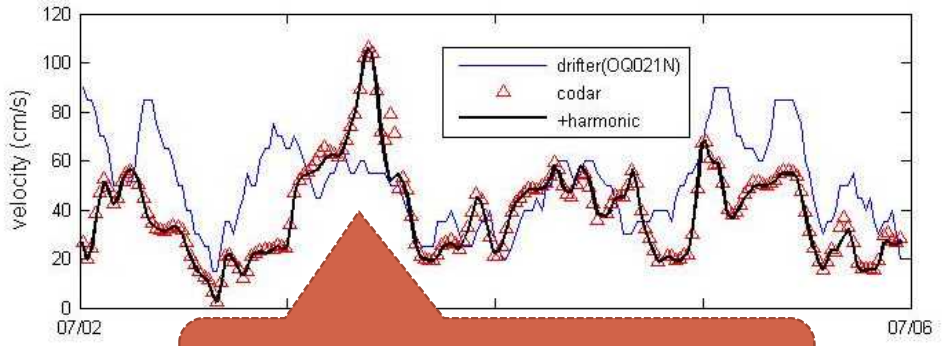


summary of the deployed drifters

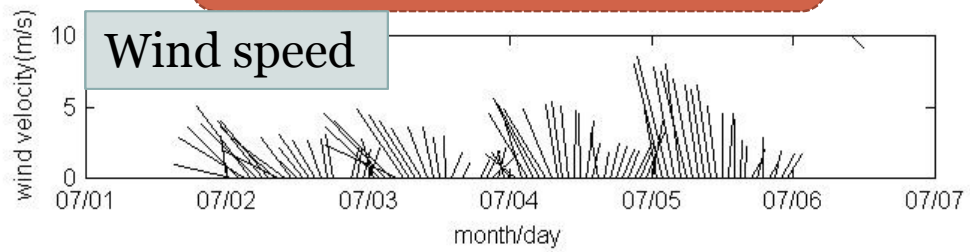
The time period showed here indicated the simulation period of drifter trajectories based on HFR currents.

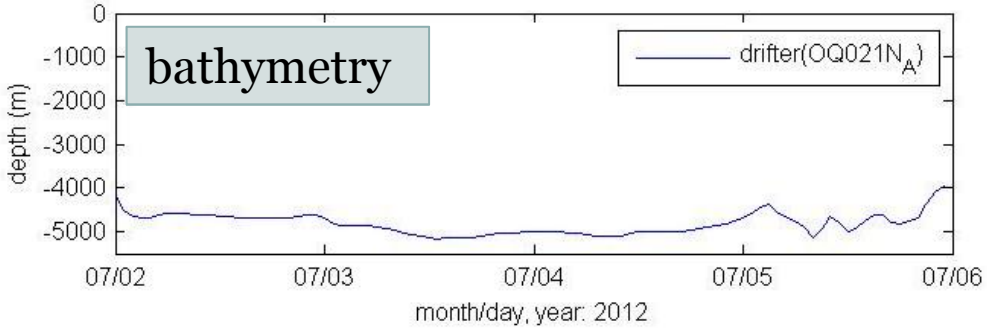
drifter	deploy time (mm-dd hr)	initial °E	initial °N	recovery (mm-dd hr)	recovery ° E	recovery ° N
OQ021N	07-02 00	121.8627	22.3449	07-06 23	122.5136	23.4607
OQ022N	07-02 00	121.2695	22.2860	07-04 23	122.2879	24.0603
OQ023N	07-03 12	121.2906	22.0951	07-06 12	122.0288	23.9806
OQ024N	07-04 00	121.3126	22.0649	07-06 23	122.1905	24.4983
OQ017N	09-08 17	121.1700	22.2415	09-10 23	121.9666	24.4740
OQ018N	09-09 00	121.5240	22.2307	09-11 18	122.0543	23.7600

Comparisons of measured and estimated velocity drifter OQ021N

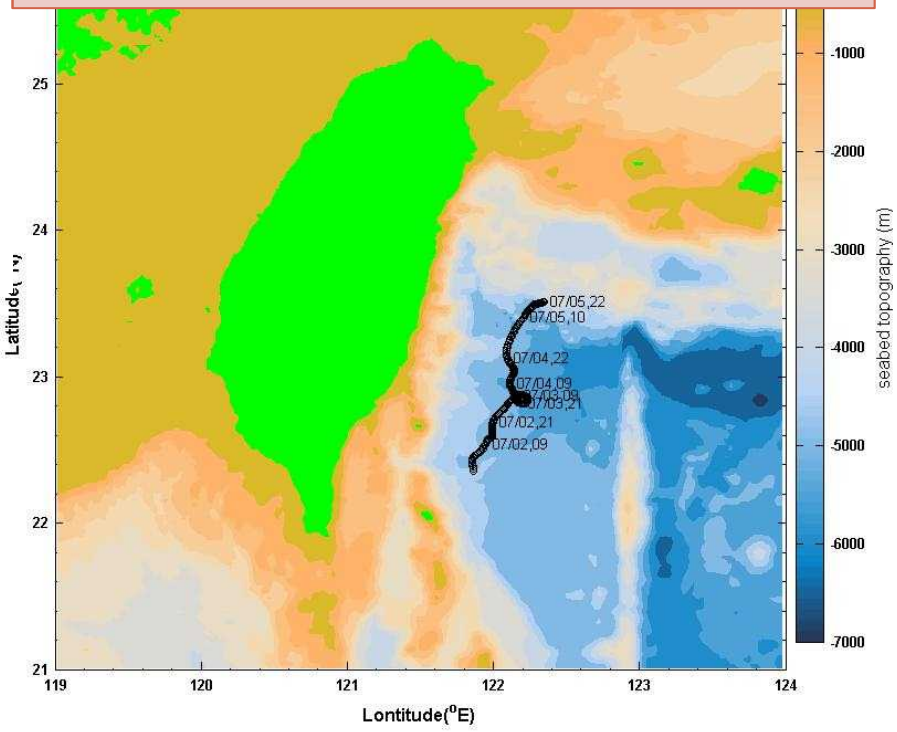


experienced a small scale flow circulation



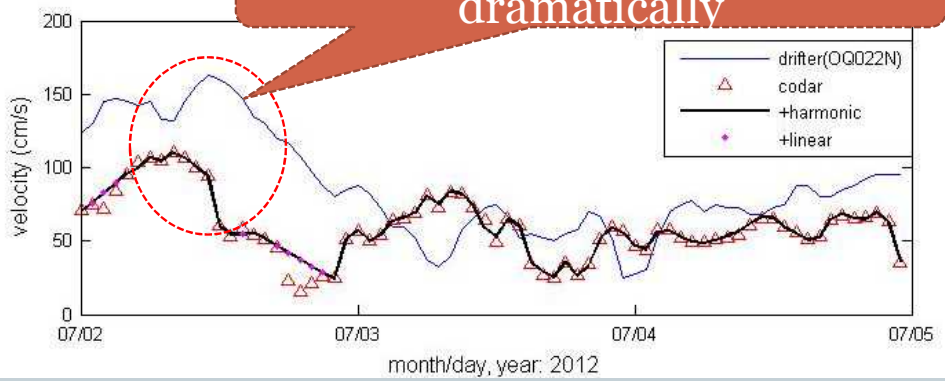


- **Drifted to northeastern direction driven by the Kuroshio**
- **A periodic velocity oscillation due to wind forcing**
- **Curved trajectory affected by the eddy transportation**

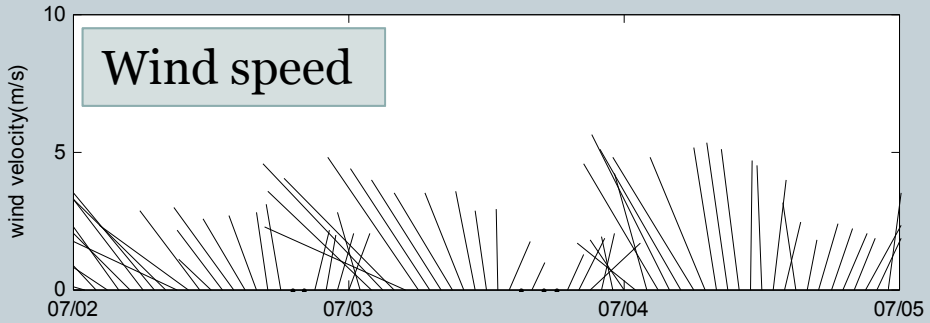


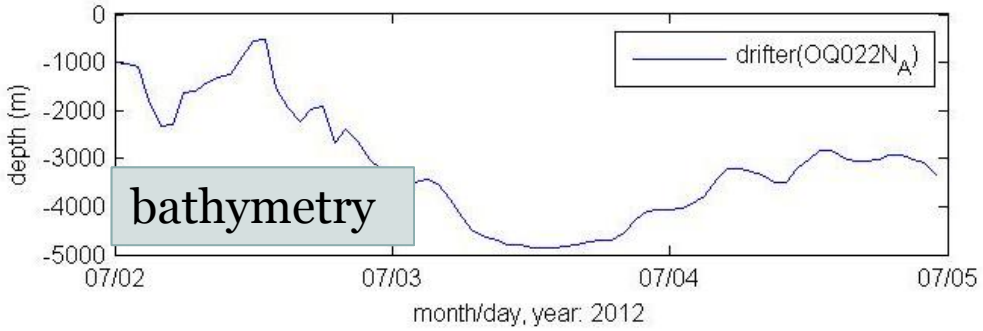
Comparisons of measured and estimated velocity drifter OQ022N

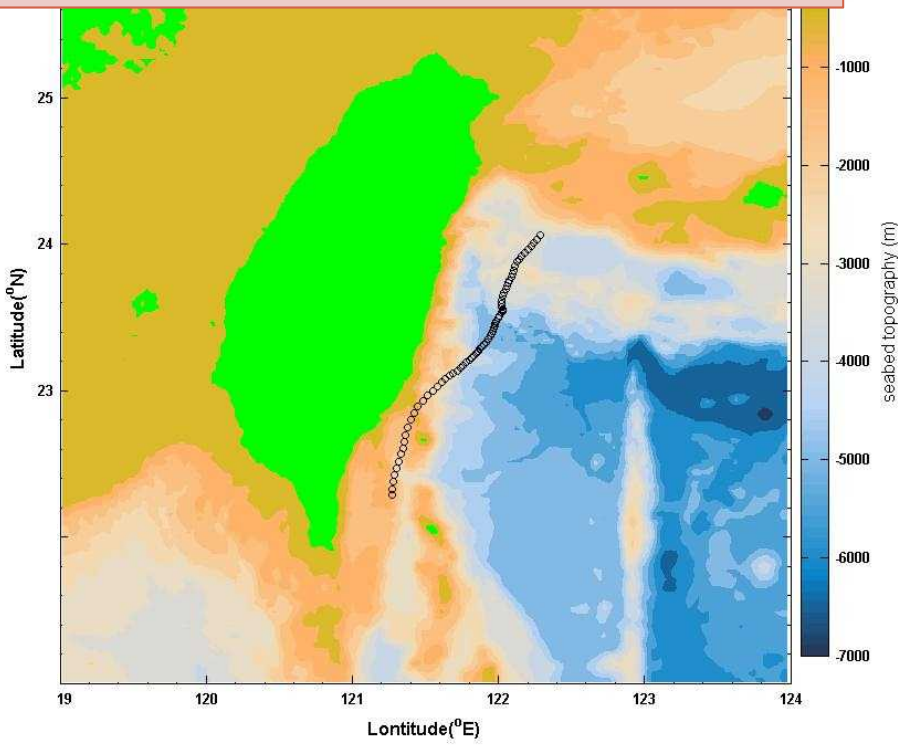
topography change dramatically



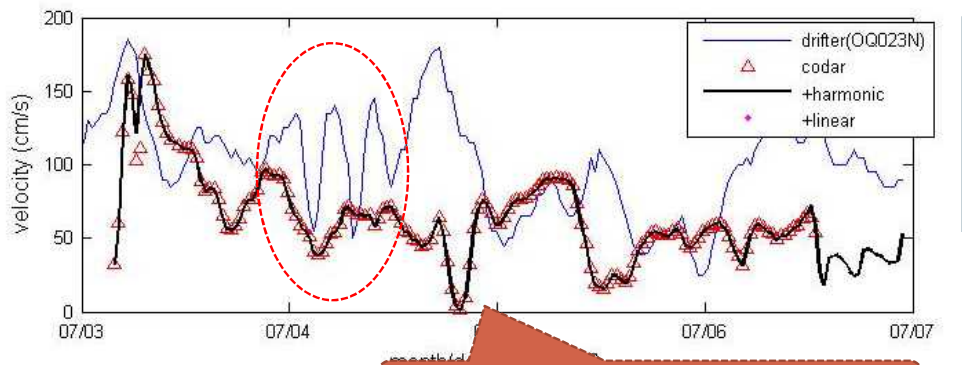
- **Drifted to northeastern direction driven by the Kuroshio**
- **Large velocity difference was found due to decreasing water depth**



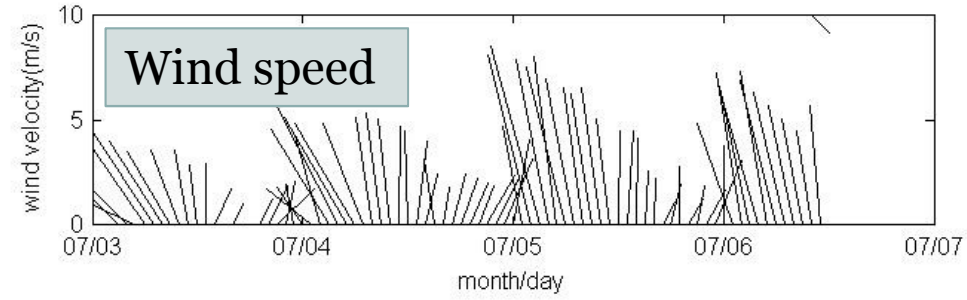


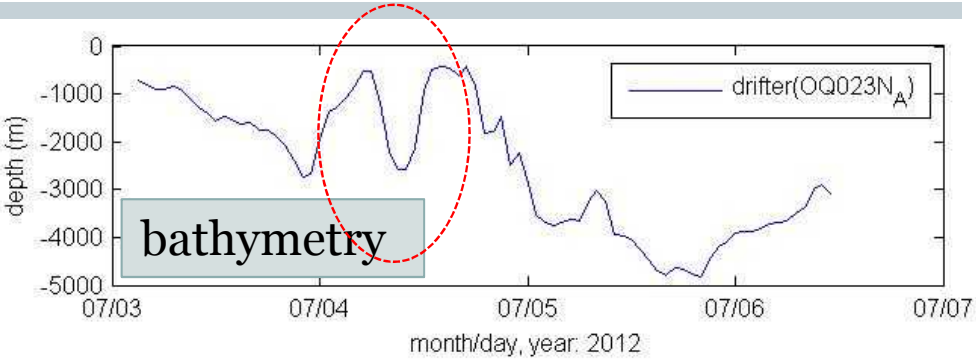


Comparisons of measured and estimated velocity drifter OQ023N

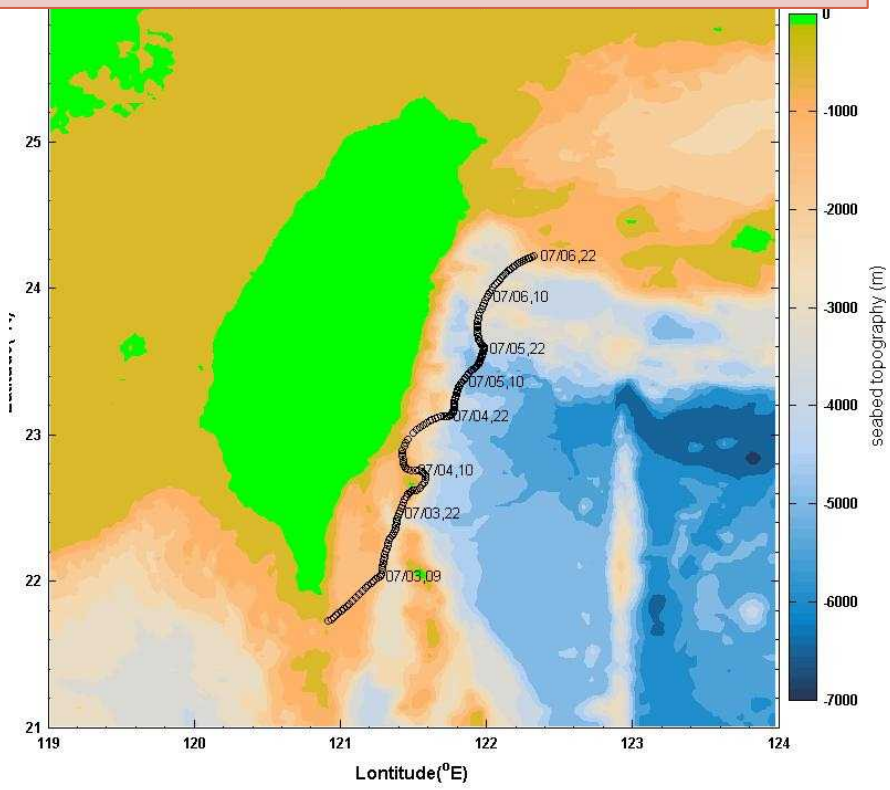


near the Green Island





- Drifted to northeastern direction driven by the Kuroshio
- High frequency velocity oscillation was found near the trench. HFR can not reveal the high frequency speed variation in time.



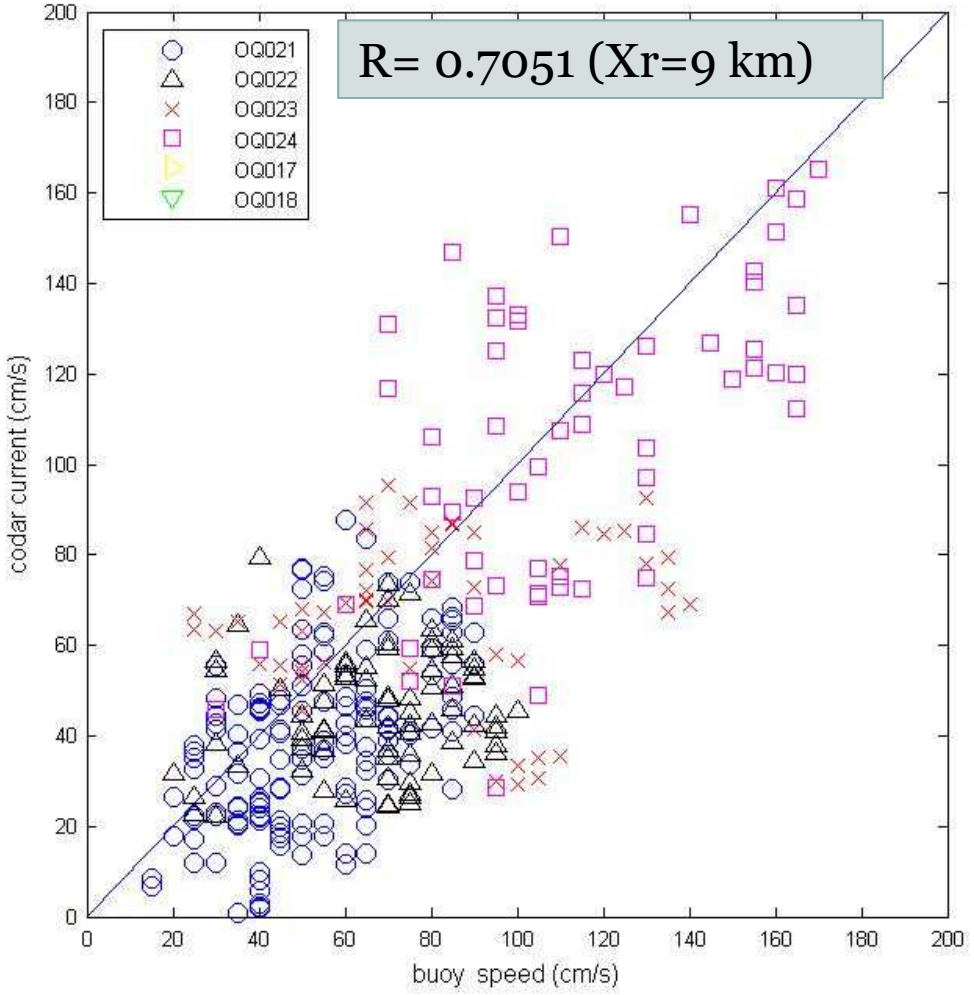
Comparisons of velocities at drifter locations

Consider only the "measured" data

- generally fall along the line of unit slope
- some uncertainties as represented by scattering of the data points
- HFR velocities were weaker

? reasons

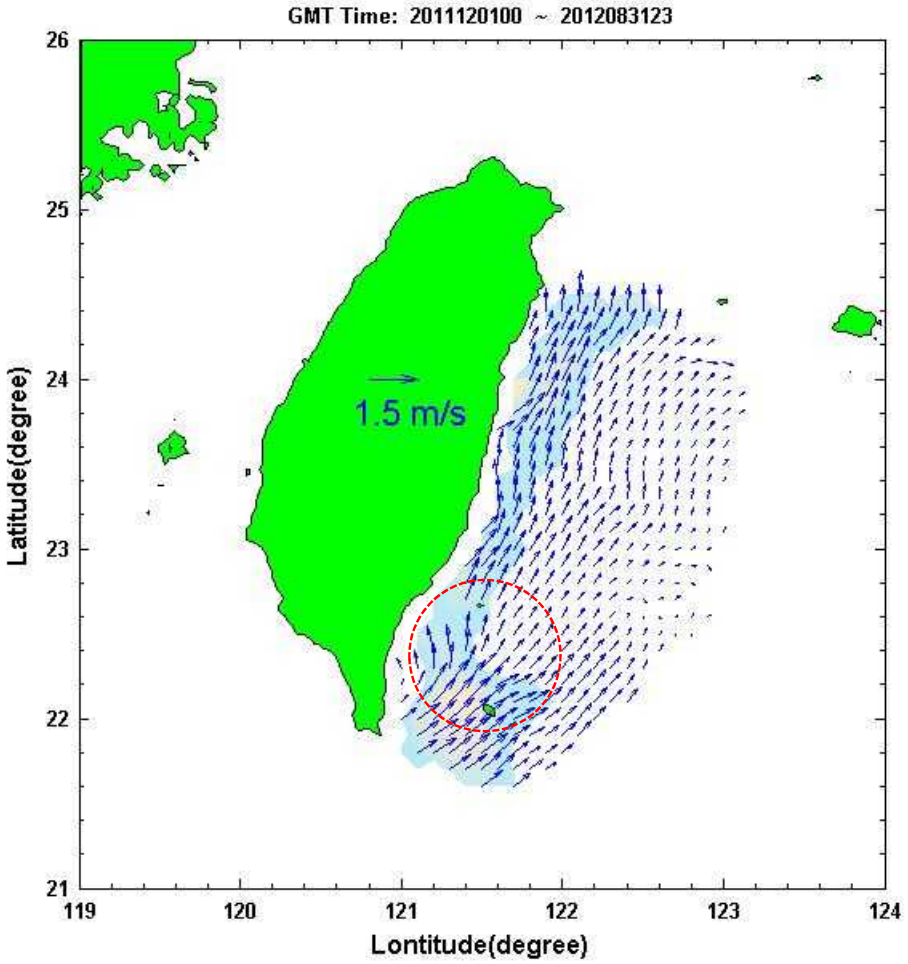
- ✓ Different system
- ✓ Uncertainty
- ✓ error



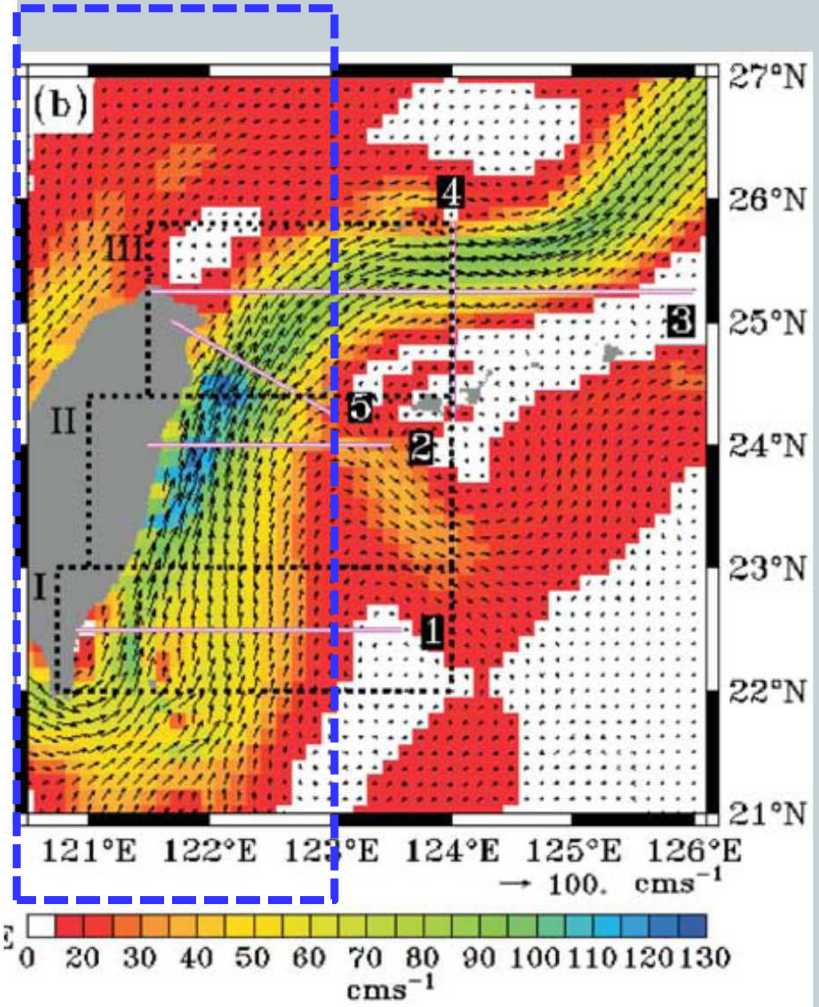
Experiences learned form these experiments

- Limitation of the spatial resolution small scale eddy can not be resolved.
- High frequency oscillations of velocity due to the dramatic change of bathymetry was not found in HFR currents.
- Surface currents derived based on HFRs was generally weaker than that of drifters, especially at the region where the dramatic change of bathymetry was found.

Application
ocean surface current off eastern Taiwan

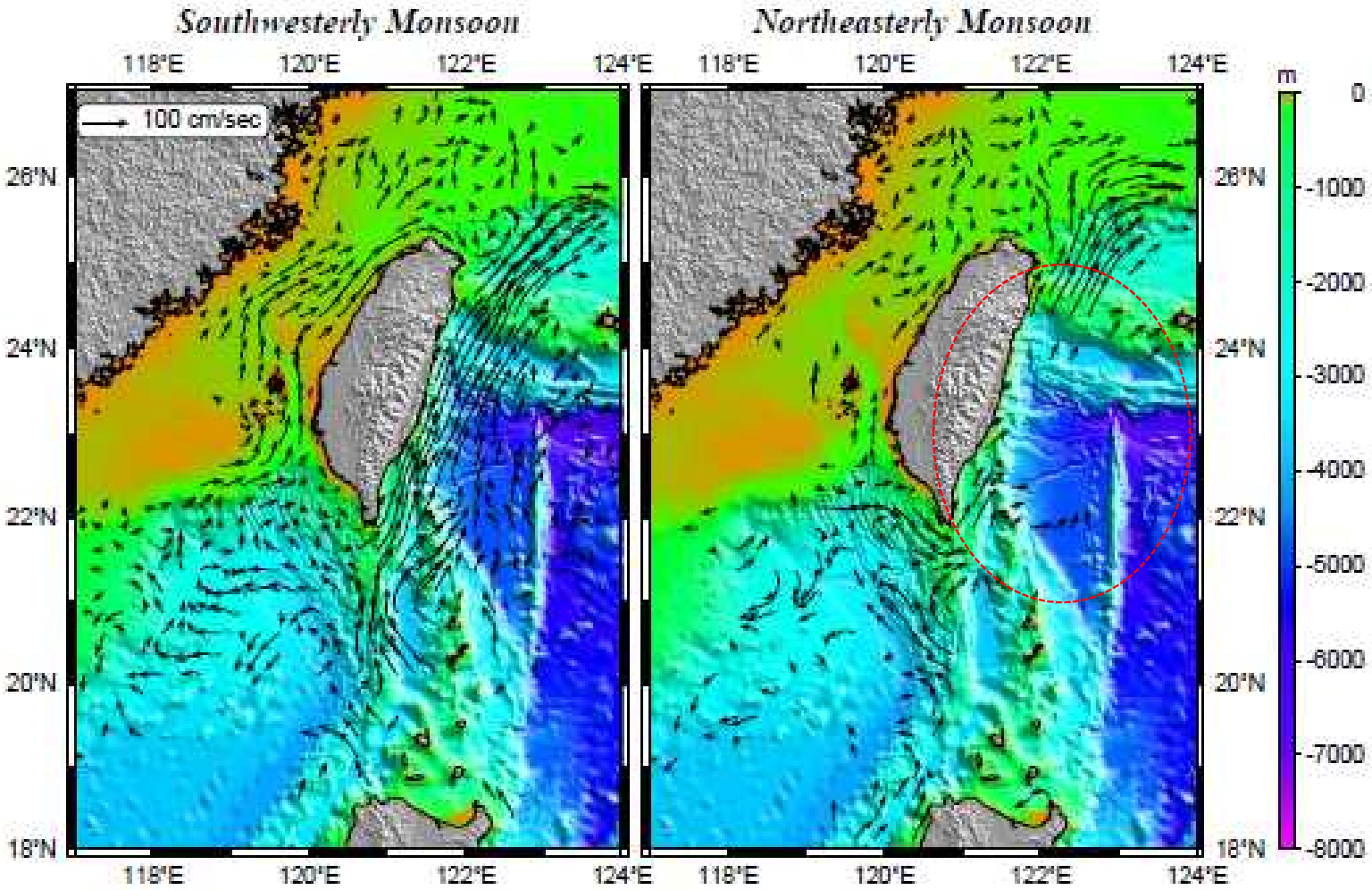


Codar results: Dec. 2011 ~ Jul. 2012



Hsin et al.(2008)

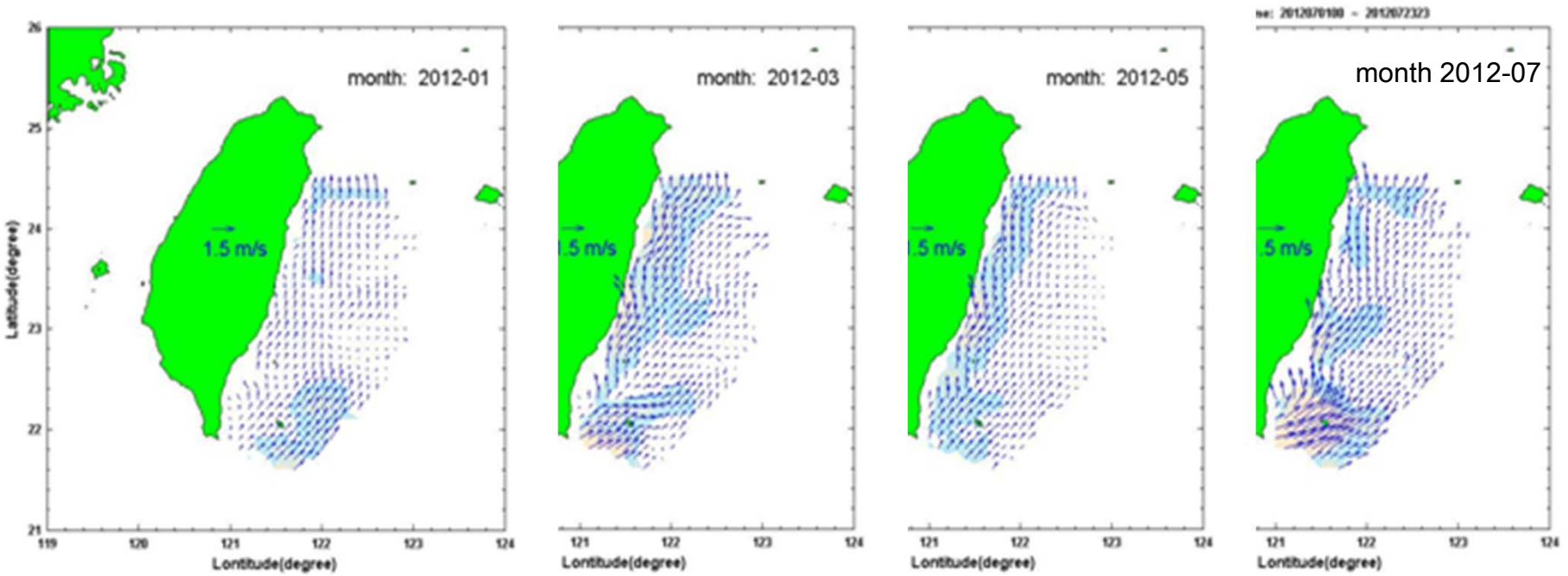
Seasonal Cycle
data measured during 1991-2000



Liang et al., Deep Sea Research II, Vol. 50, 2003

Seasonal variation of ocean surface current off eastern Taiwan

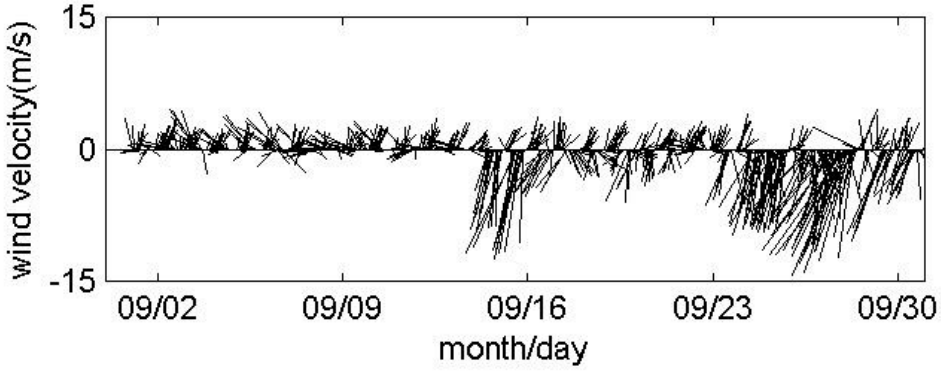
- The Kuroshio flows along the east coast of Taiwan and splits into two branches.
- One branch flows northward follows the east coastline of Taiwan. The other goes northeastward through OGC into the basin of Pacific Ocean. Flow strength of the two branches varies in time.

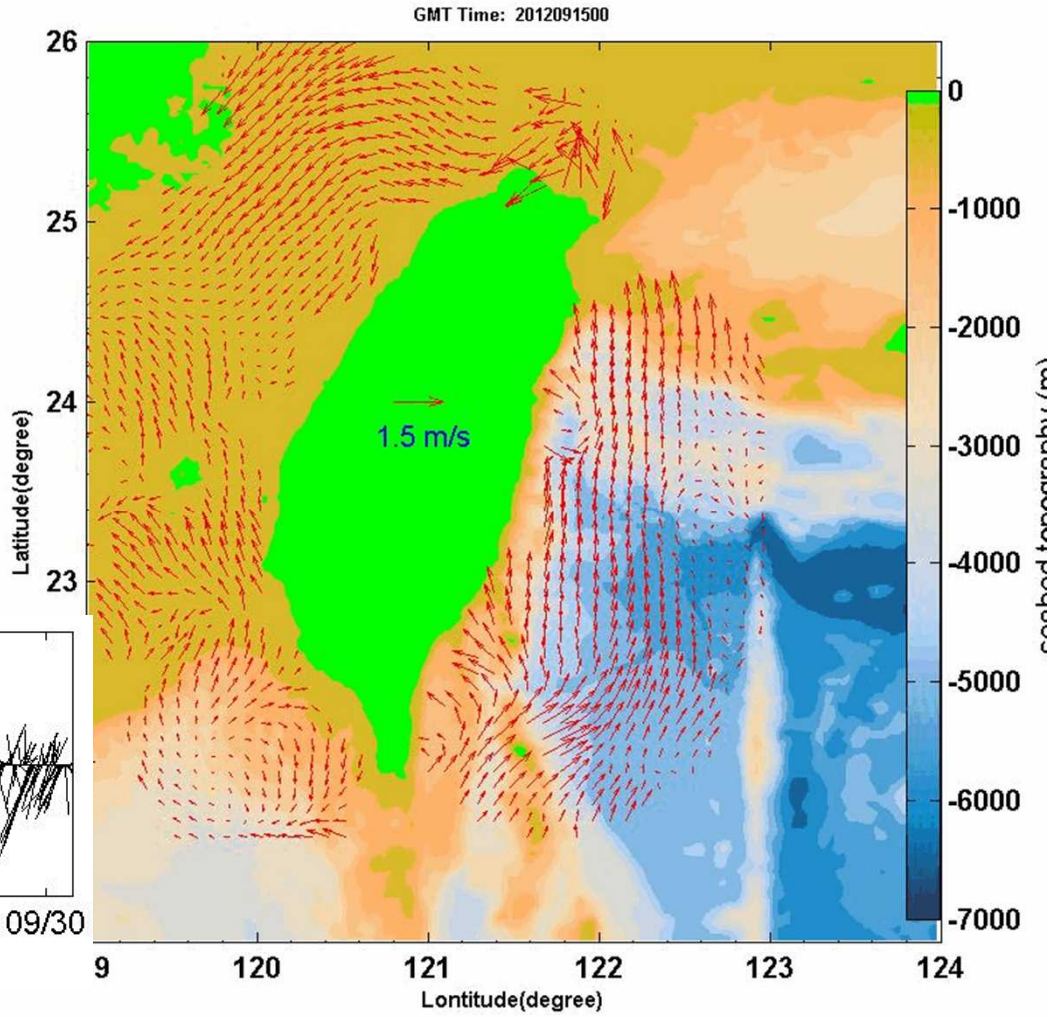


Monthly mean current (a)Jan. (b)Mar. (c)May (d)July

Detide currents

- The low frequency currents were derived by a low-pass filter (>33Hr).
- The variation of low frequency currents versus time was shown on the right figure.
- Demonstrated the wind driven current on the ocean surface.

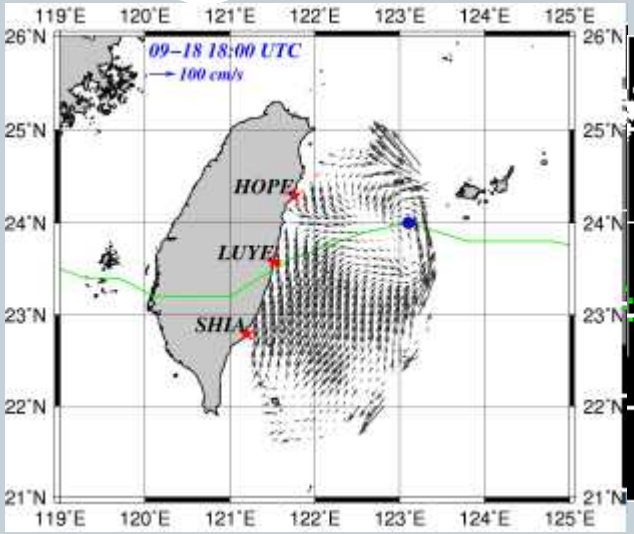


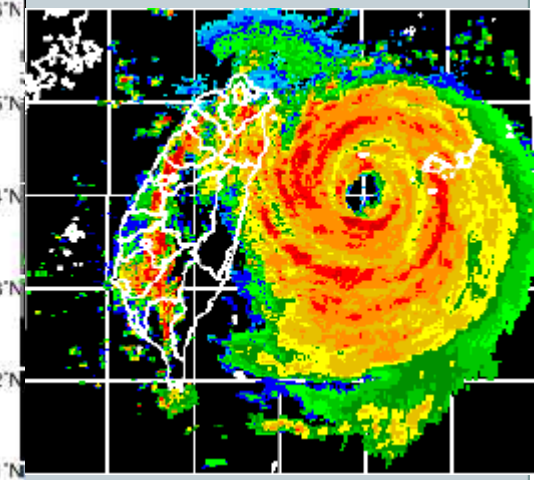


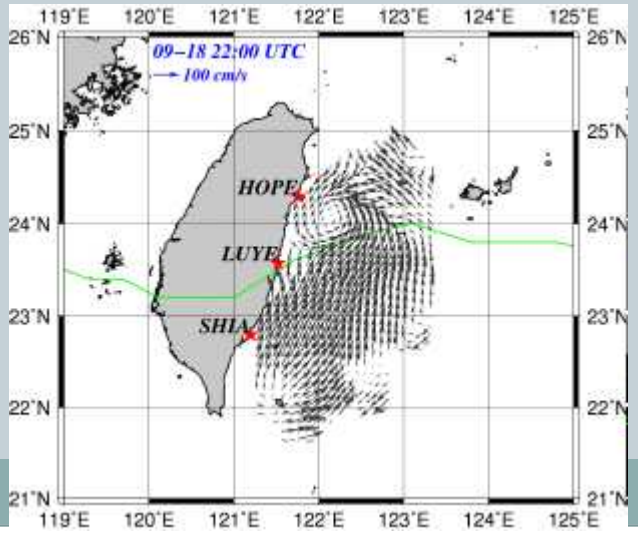
Application
ocean surface currents induced by a typhoon event

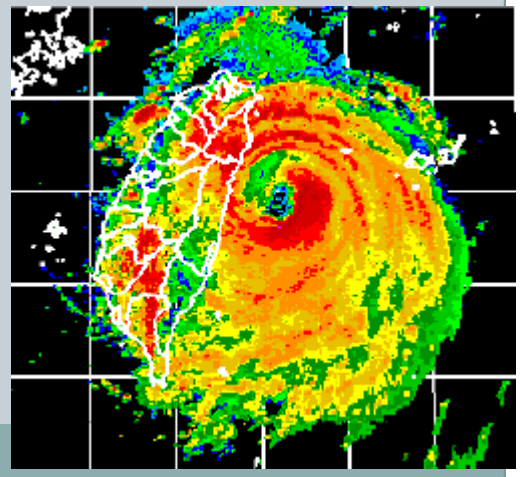
Left column:
hourly current velocity field
Right column:
weather radar images

The figures revealed the variations of ocean surface current pattern corresponded to the movement of the typhoon, which indicated the potential use of HFR currents to the study of air-sea interaction induced by typhoon events.









Application
Hindcast of drifter trajectories

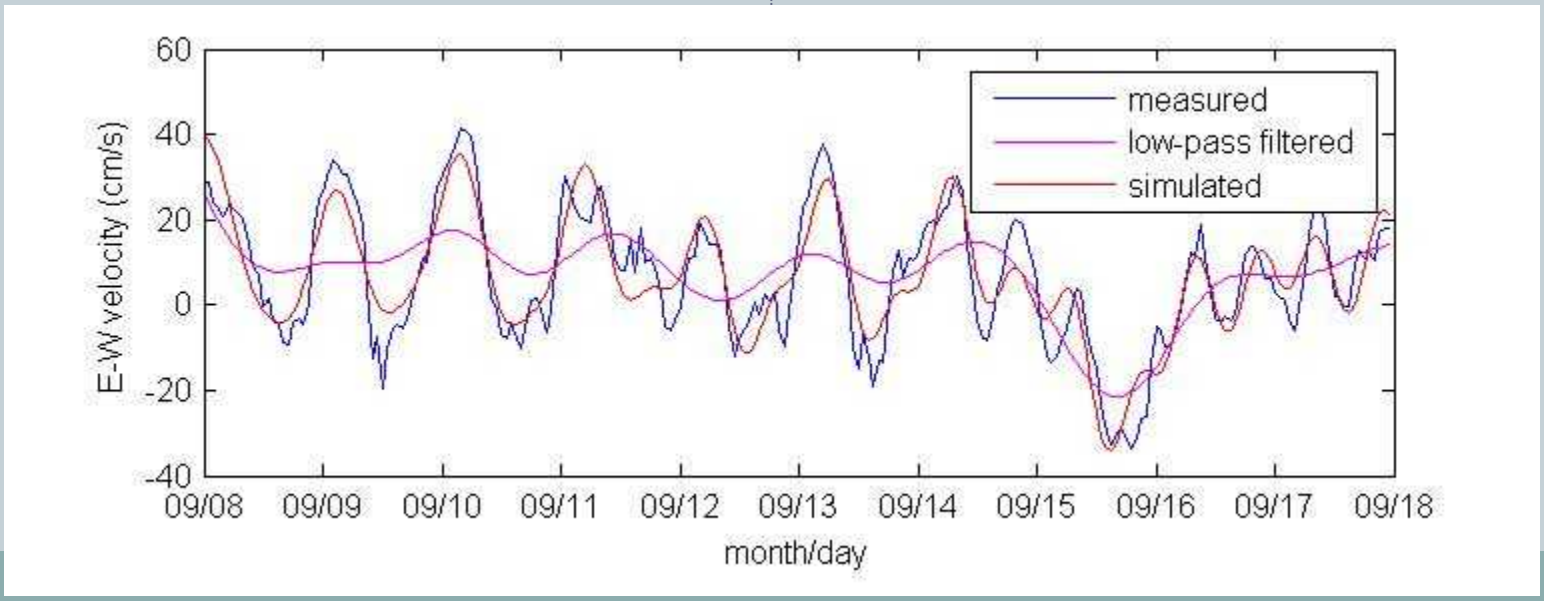
Method

- The drifter trajectories were divided into 24-hour segments overlapped by 12 hours, which resulted in a total 32 independent sample tracks within the study area.
- The measured surface current is decomposed into a tidal and a non-tidal components.
- Non-tidal component is estimated by a low-pass filter.
- Least-square harmonic analysis is used to compute the amplitude and phase of largest five tidal constituents.
- The composition of the low-pass filtered current and tidal current was used to make 24-hour trajectory hindcasting.

Application
Hindcast of drifter trajectories

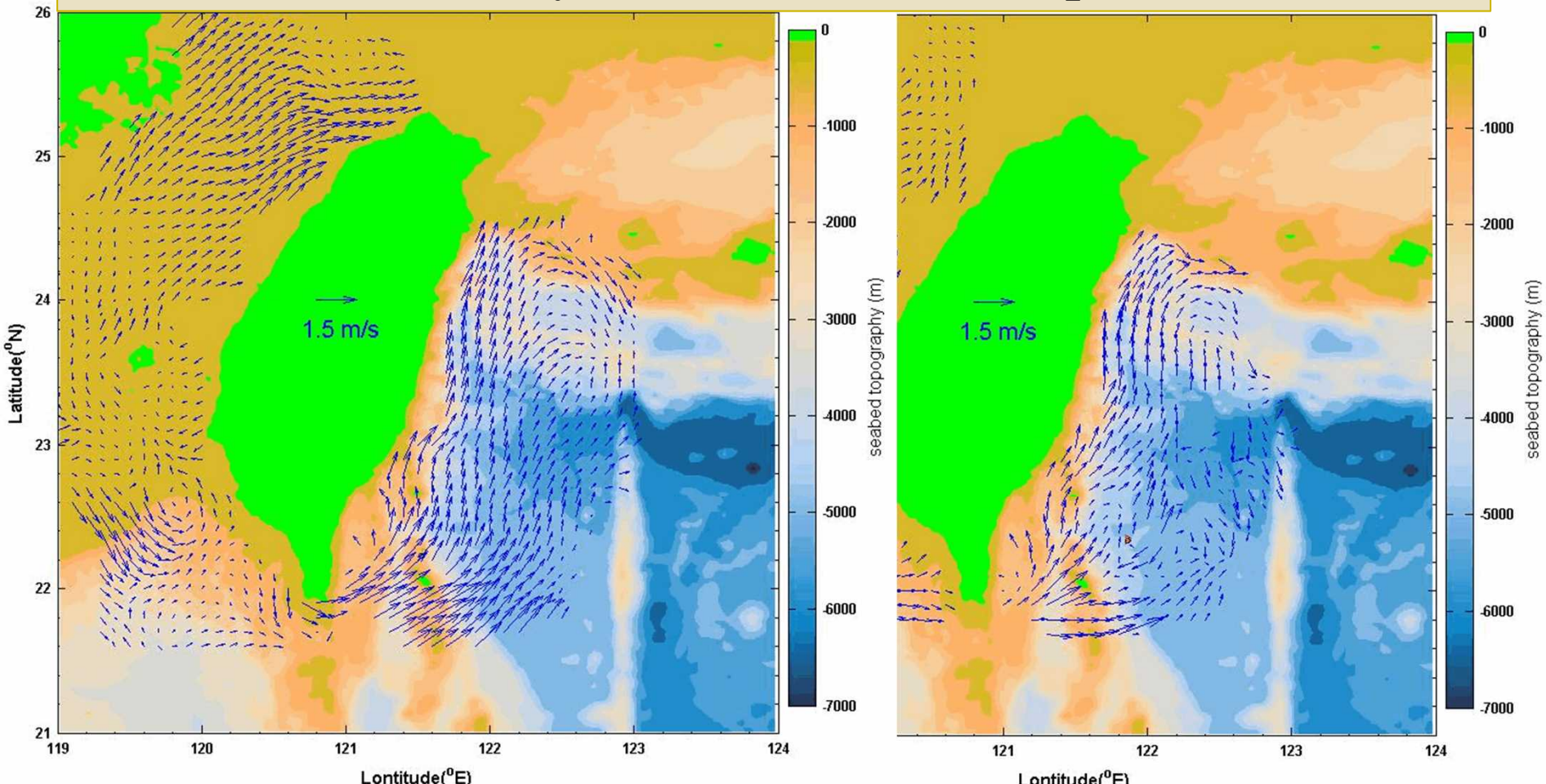
The measured surface current is decomposed into a tidal and a non-tidal components.

- Non-tidal component is estimated by a low-pass filter.
- Least-square harmonic analysis is used to compute the amplitude and phase of largest five tidal constituents.



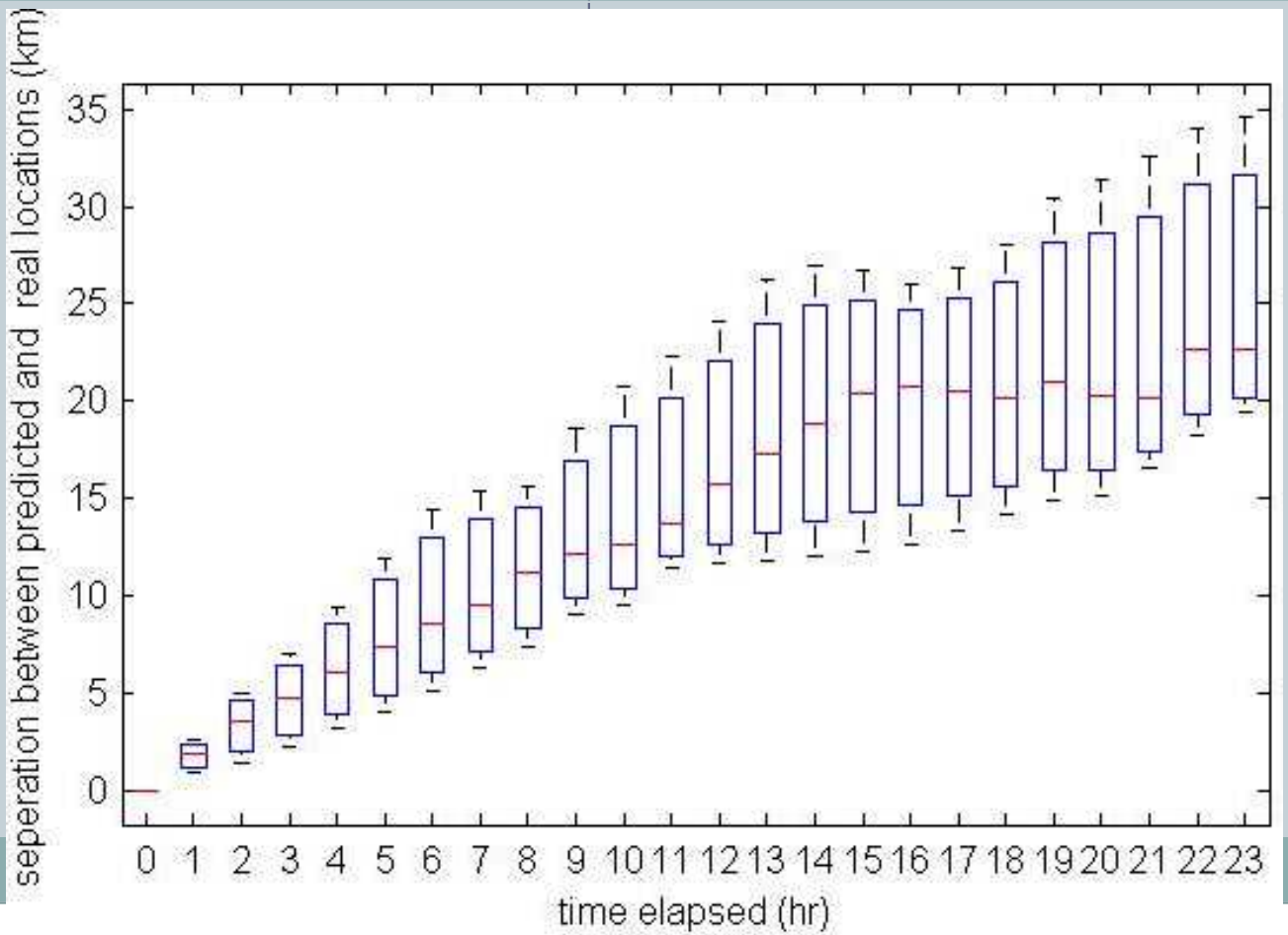
Comparisons of predicted and drifter trajectories

- The drifter trajectory represented by the black line and the predicted is colored red
- The surface velocity field at each time step is shown.



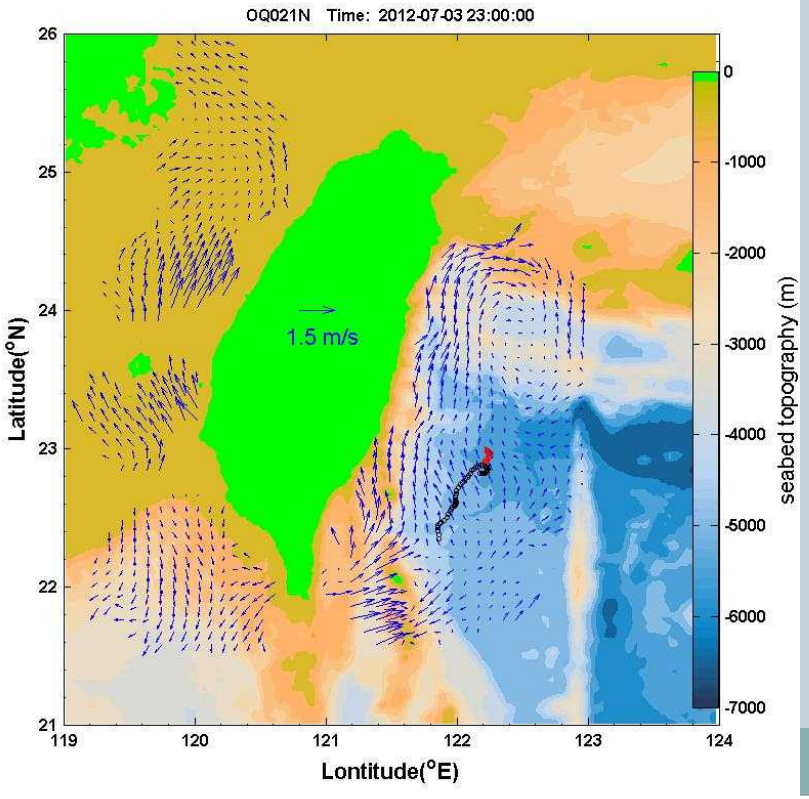
Separations between predicted and real locations

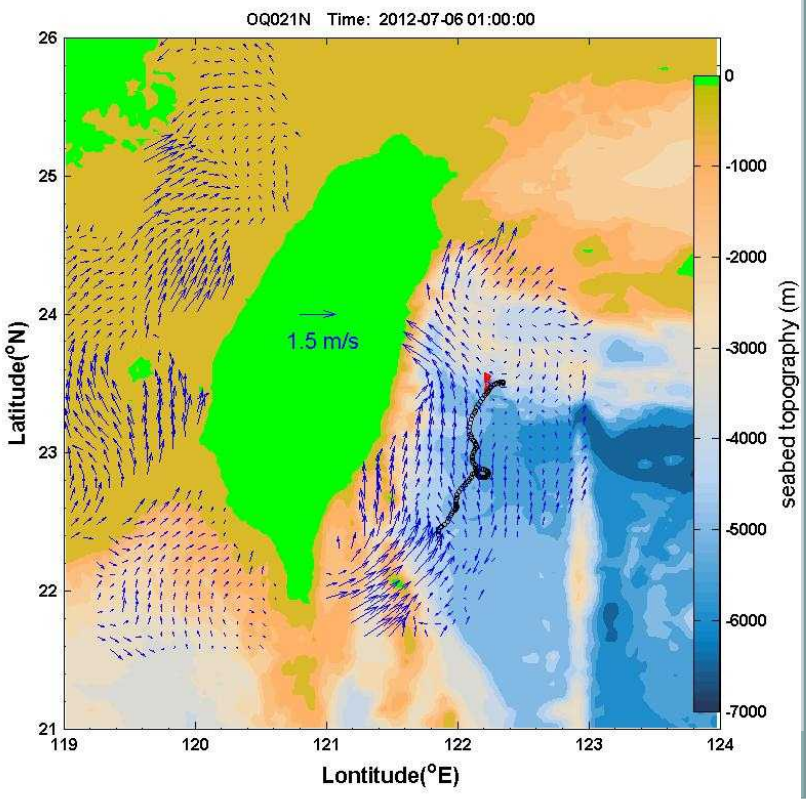
- The mean separation increases with time elapsed until ~20km where it levels off.
- Separation fast increases at some specific locations.



Discussions on separation

The separation is highly dependent on environmental conditions. In this study, the complicated flow structure was observed due to the strong Kuroshio (~1m/s) interacted with the dramatically changed topography and the eddy transportation from Pacific ocean.





Conclusions

- After three and half years efforts, TORI had successfully installed 15 HFR systems around Taiwan. HFR mapped ocean surface currents provided the valuable information for the understanding of ocean environment, especially for the extreme conditions such as the strong NE monsoon period and typhoon events.
- The ocean surface currents derived by HFR had been validated by the deployment of drifters and the results were comparable to those of previous studies, which confirmed the reliability of TORI's HFR systems.
- Some applications had been demonstrated, although detailed investigations need to be done before solid conclusions can be made.

Real time flow field shows online

http://med.tori.org.tw/CODAR/

- CODAR 資料庫 »
- 時間序列資料
- 48小時內流場動畫 »
- 環台資料測試 »
- 連絡資訊

Visitors
4,562 5
289 4
250 3
41 3
18 2
9 2
20,636 pageviews
FLAG Counter

目前位於：海洋環境資料庫 - CODAR 資料庫 >> 首頁

CODAR 資料庫

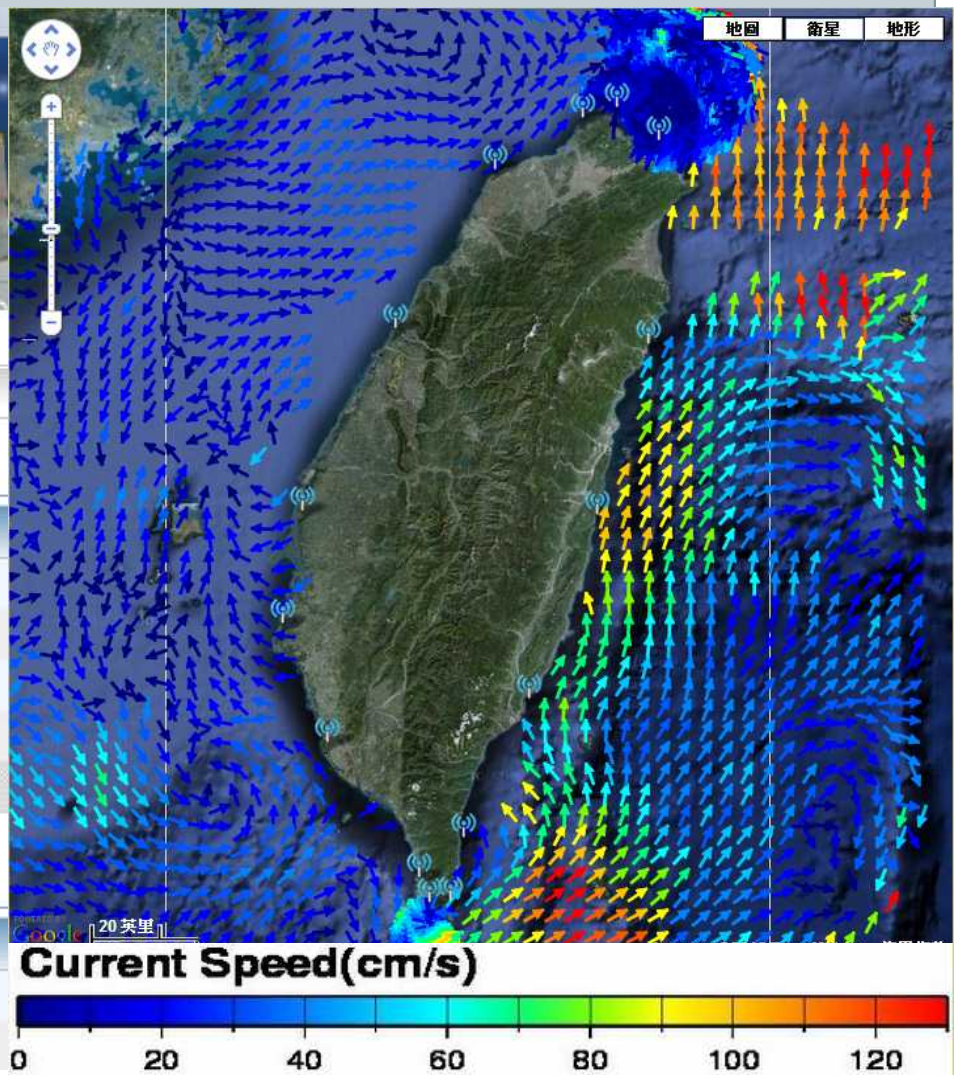
CODAR 資料統計

年度	資料數量
2009	1902
2010	8582
2011	7913
2012	6972

共 4 個年度 25369 筆資料

資料更新紀錄

日期	資料數量
2012-10-21	18
2012-10-20	24

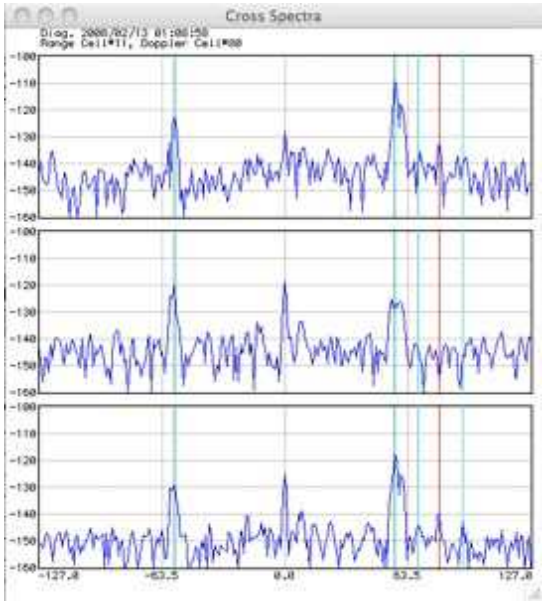


THANK YOU FOR YOUR PAY ATTANTION !

TORI welcome any kind of cooperation

Flow diagram of data processing

1024 sample @ 1Hz



Time-Series data
FFT

Range-Series
FFT

Cross Spectra
File(CS)

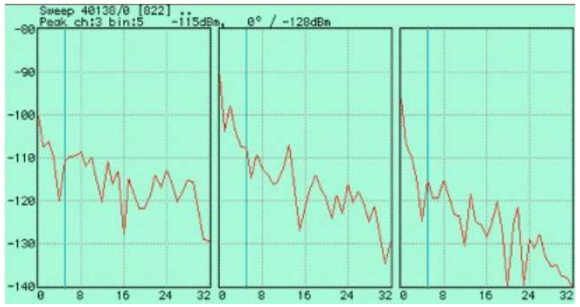
Cross Spectra Short
Time File(CSS)

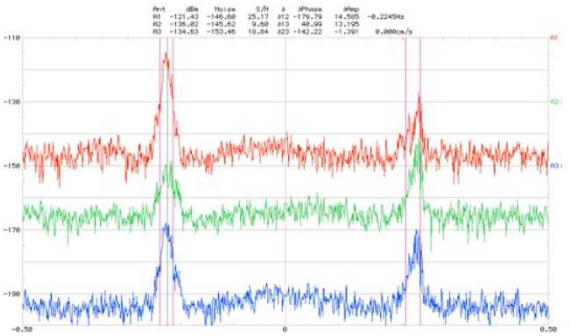
Spectral to Radial

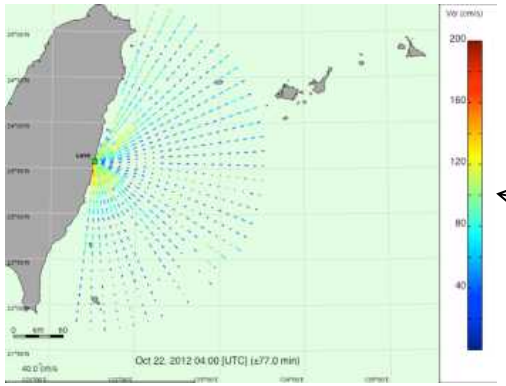
Radial Vector file

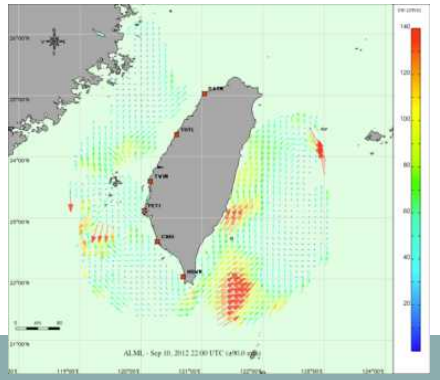
Total file

Echo Strength VS. Range



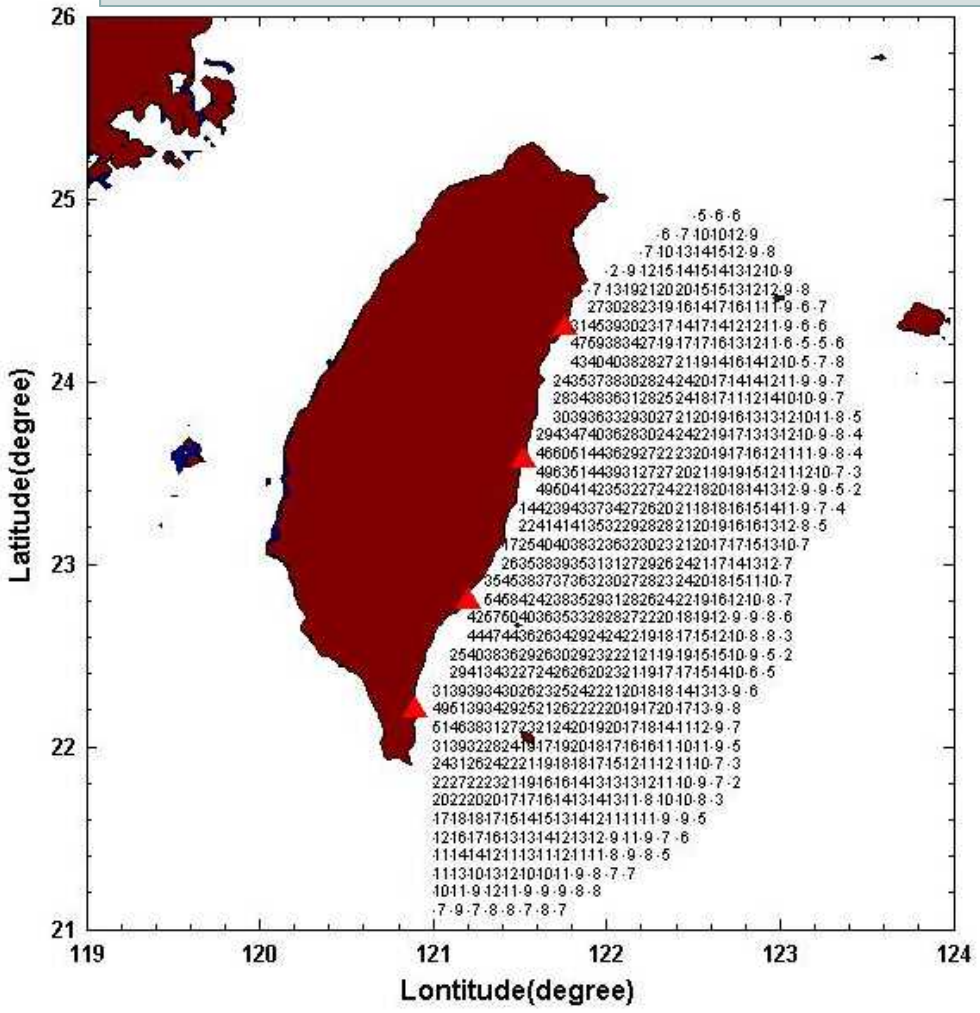


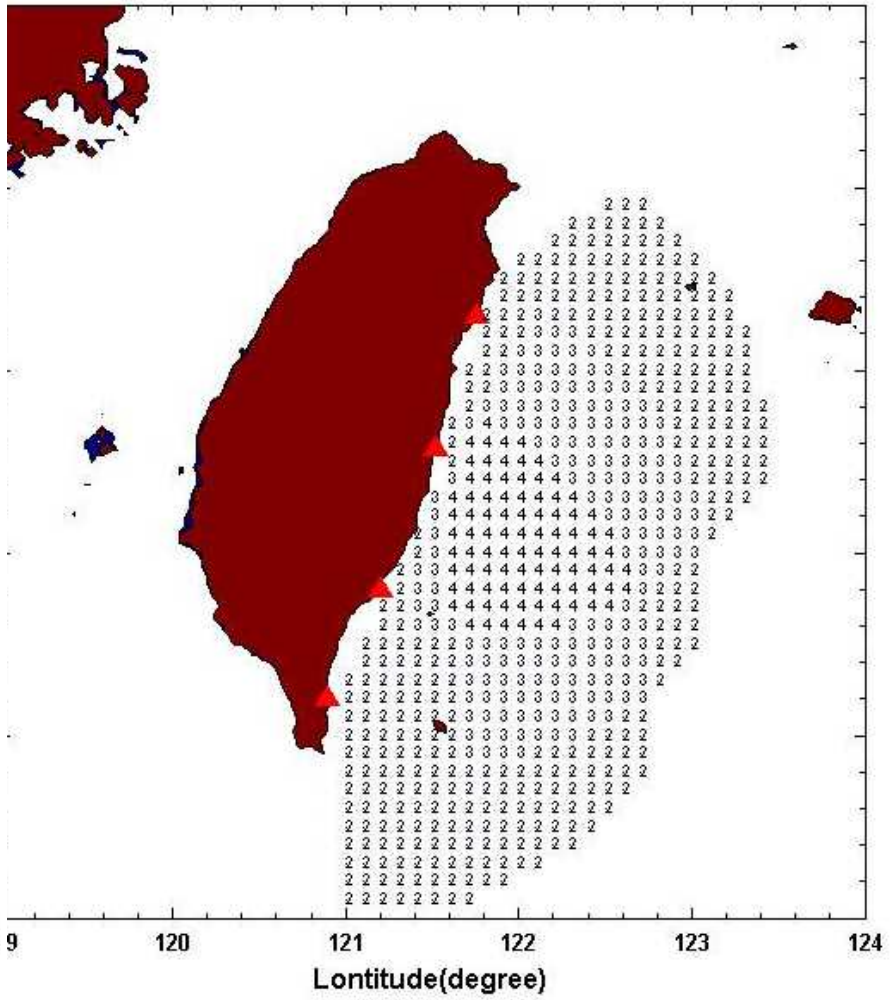




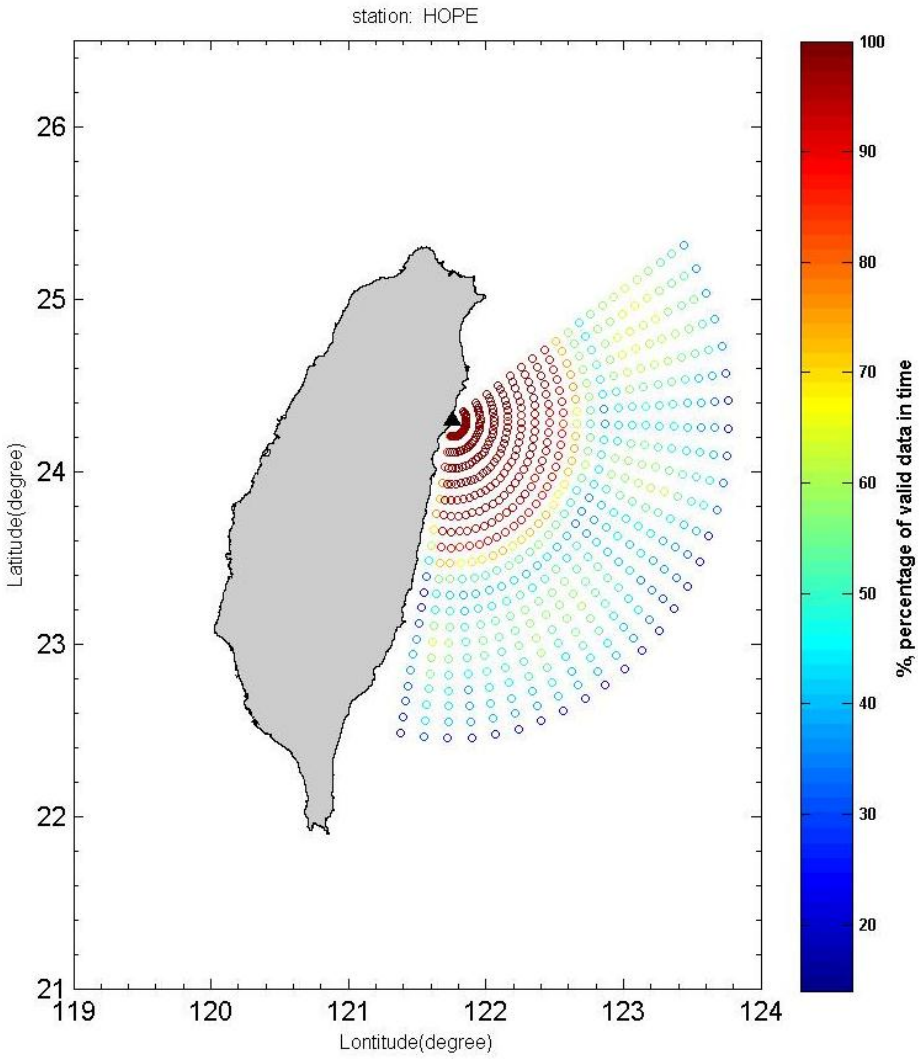
Requirements of Velocity combination

- radial vectors for at least two sites
- at least 3 radial vectors for each grid

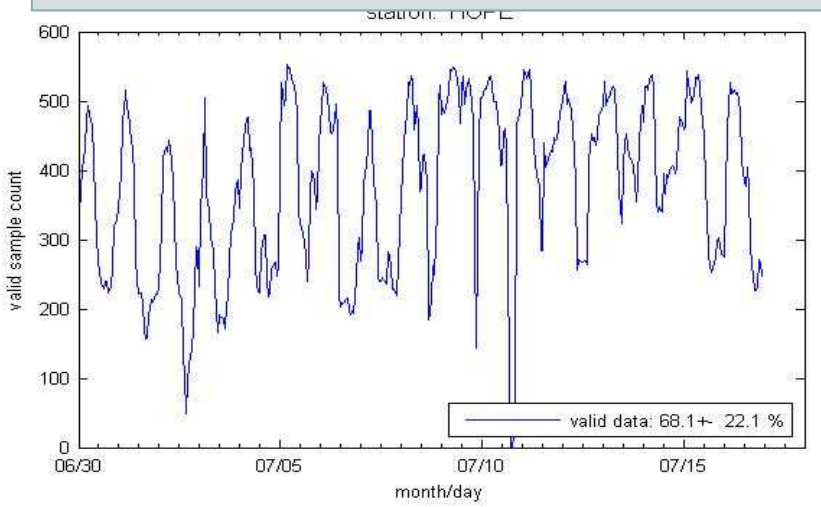




Coverage of radial velocity in time and space

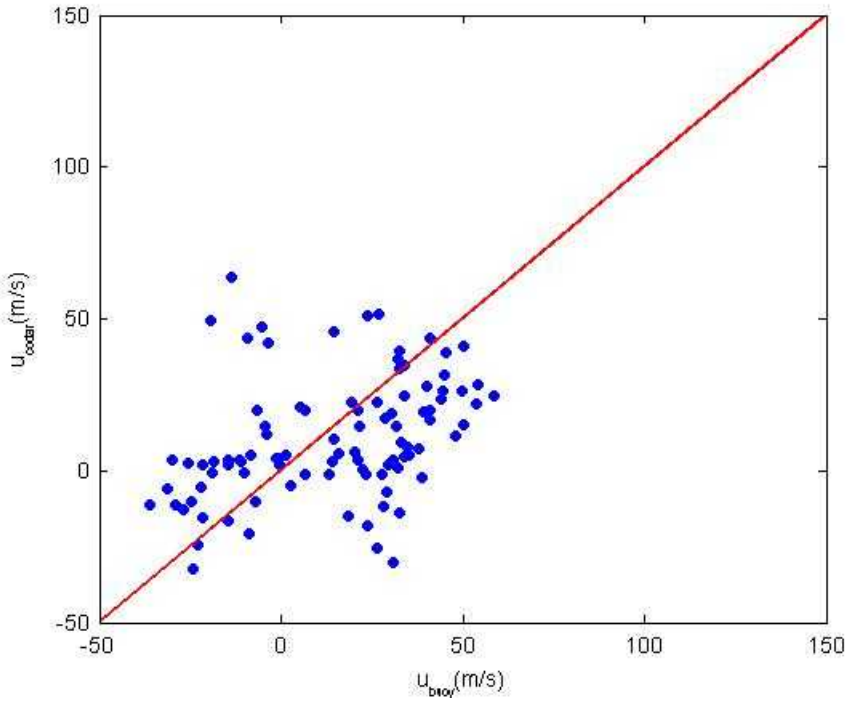


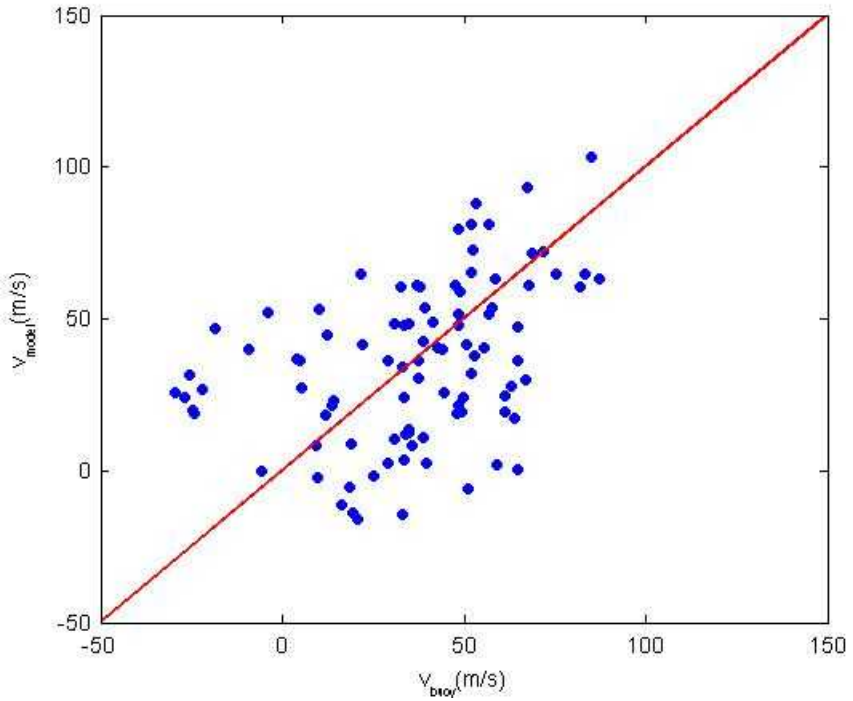
- Generally, valid sample decreases with increasing range, except a low value at ~100km (left figure).
- A periodic range fluctuation in time was found (bottom figure).



U & V OQ021N_A

- The drifter experienced a small scale eddy at the afternoon of July 3, which flow field can not be reasonably resolved due to the limitation of spatial resolution of long range CODAR.





U & V OQ022N_A

- In 2 July, the drifter moves closer to the eastern coast driven by southeasterly wind. There exists a ridge on the seabed and induced to speeding up of the drifter. At the same time, HFR velocity also exhibits an increasing trend but peak velocity is lower than that of the drifter. It could be reasoned to the smoothing operation of HFR velocity in time and space but the drifter velocity is defined at a point.