Oceanographic Radars in Korea

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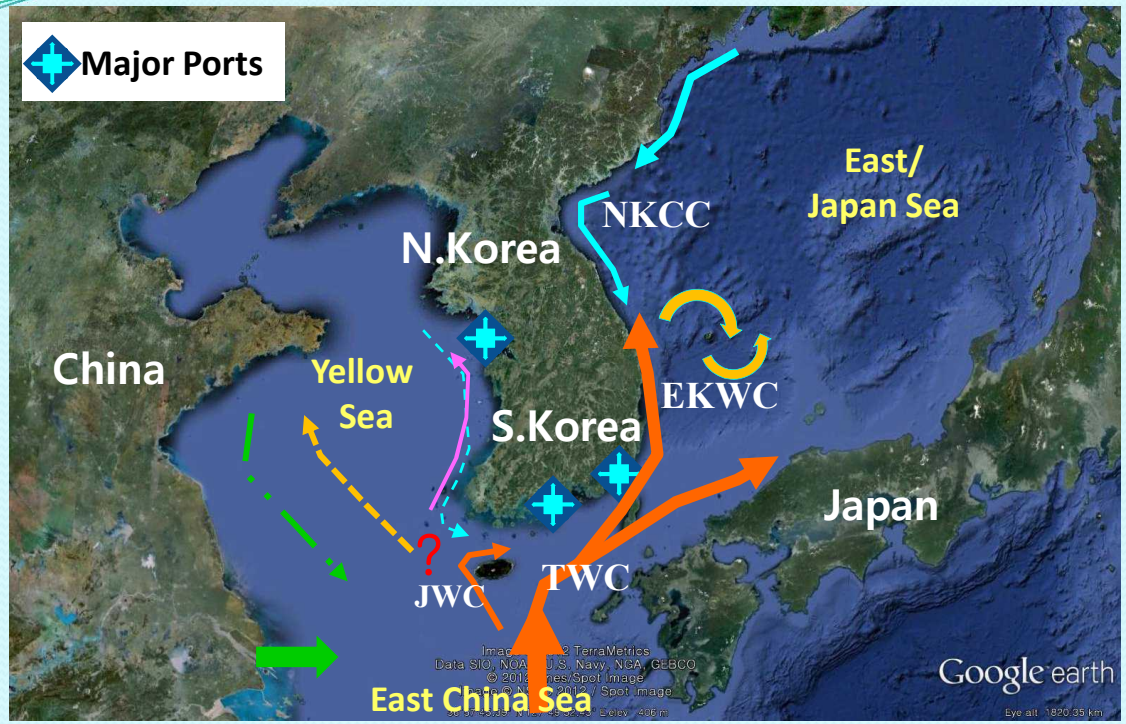
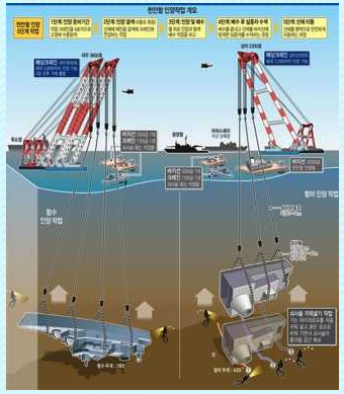
Outline

1. **Background and Brief History**
2. **Radar Systems and Sites**
3. **Major Scientific Results**
   (KNU, KORDI and KHOA)
4. **Activities & Future Plans of Radar Community**

1. Background and History





❖ **Research & Public Demands for Oceanographic Radar Network Development**

Scientific demand: current system & variations

YS : **weak and variable circulation** but **strong tidal currents** off the west coast of Korea

EJS : **strong boundary currents** such as EKWC and NKCC with active eddies in polar front region

KS and ECS : **TWC, JWC** pass into the YS and EJS

Public demand: Operational Application

- Heavy traffics of transport in major ports
- Naval activities near NLL area (CheonAn warship)
- Frequent oil spill accidents (Herbei Sprits II, 2009)
- Large coastal developments in the west coast
- Increase of coastal leisure activity, pollution, fisheries

Brief History

- 1992: SeaSonde radar trial test near the Keum River Estuary (CORDAR)
- 1999: 1st operation by Prof. Jae-Chul Lee (Pukyong National University)
- 2002: KNU measured current off N. Saemangeum Dyke (SD) by HF radars
- 2003-2004: KHOA measured surface currents for Incheon port transport
- 2004: KHOA began to construct Yeosu site for GwangYang port transport
- 2006: SNU begun HF radar operation in east coast of Korea
- 2008: KORDI added 2 radars in S. SD region, cooperating with KNU
- 2010: KORDI measured the JWC in Jeju Strait by 2 Seasonde units
- 2011: KHOA constructed Busan New Port site with triple nested 6 radars
- 2011 (Nov. 4th): KORF (Korea Ocean Radar Forum) was founded
- 2012 : MIT installed 2 phased-array type (WERA) radars in the east coast
- 2012 (May 17-18th): 1st ORCA meeting in Seoul, organized by KORF

2. Radar Systems and Sites

❖ **25 ocean radar systems in Korea (5Mhz: 1, 13Mhz: 7, 25 MHz:13, VHF 4)**

Owner	Site	Radar No	Freq.	BW	Range	△ t	Main purpose
KHOA	YB	2	44 MHz	300 kHz	15 km	0.5 hr	**Operational** for shipping & navigational safety
		2	25 MHz	200 kHz	30 km	0.5 hr	
	BNP	2	44 MHz	500 kHz	9 km	1 hr	**Operational** for shipping & navigational safety
		2	25 MHz	150 kHz	30 km	1 hr	
		2	13 MHz	50 kHz	90 km	1 hr	Monitoring of **TWC**
	BRI	2	25 MHz	150 kHz	30 km	1 hr	**Operational** for **naval activity (NLL)**
KNU & KIOST	KRE	3	25 MHz	100 kHz	45 km	1 hr	Monitoring of current changes **plumes from river and dyke sluices**
	SD	2	25 MHz	100 kHz	45 km	1 hr	
KIOST	JS	2	13 MHz	50 kHz	90 km	1 hr	**Jeju Warm Current** monitoring
SNU	ECS	3	13 MHz	50 kHz	90 km	1 hr	**EKWC & NKCC** mapping
		1	5 MHz	30 kHz	150 km	1 hr	Frequency and **operation test**
MIT*	ECM	2	25 MHz	150 kHz	50 km	0.5 hr	Current and **wave** mapping **(WERA Phased Array system)**

KHOA: Korea Hydrographic and Oceanographic Administration

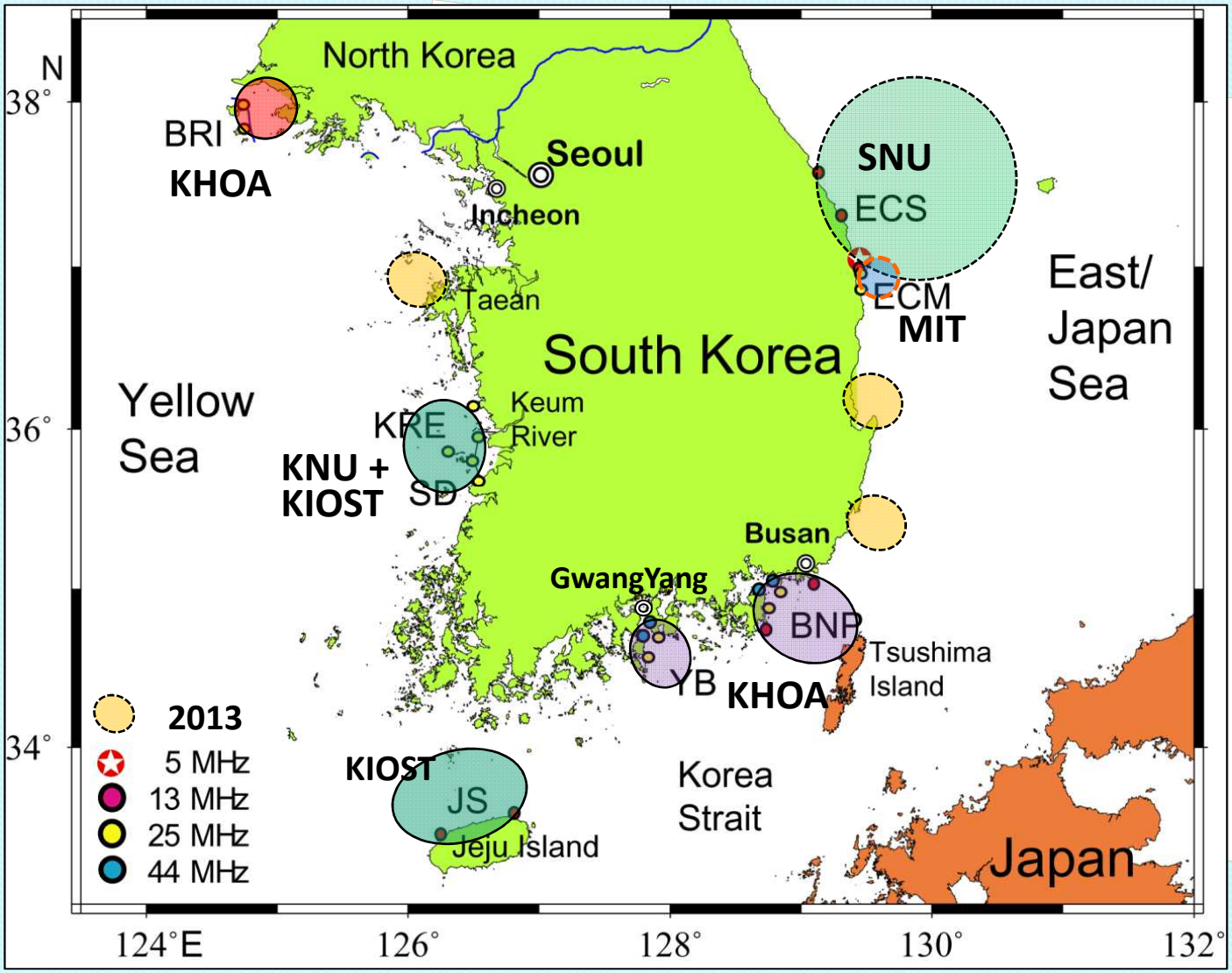
KIOST: Korea Institute of Ocean Science and Technology (Old name is KORDI)

KNU: Kunsan National University, **SNU:** Seoul National University

MIT: Marine Information Technology Co.

TWC: Tsushima Warm Current, **EKWC:** East Korean Warm Current, **NKCC:** North Korean Cold Current

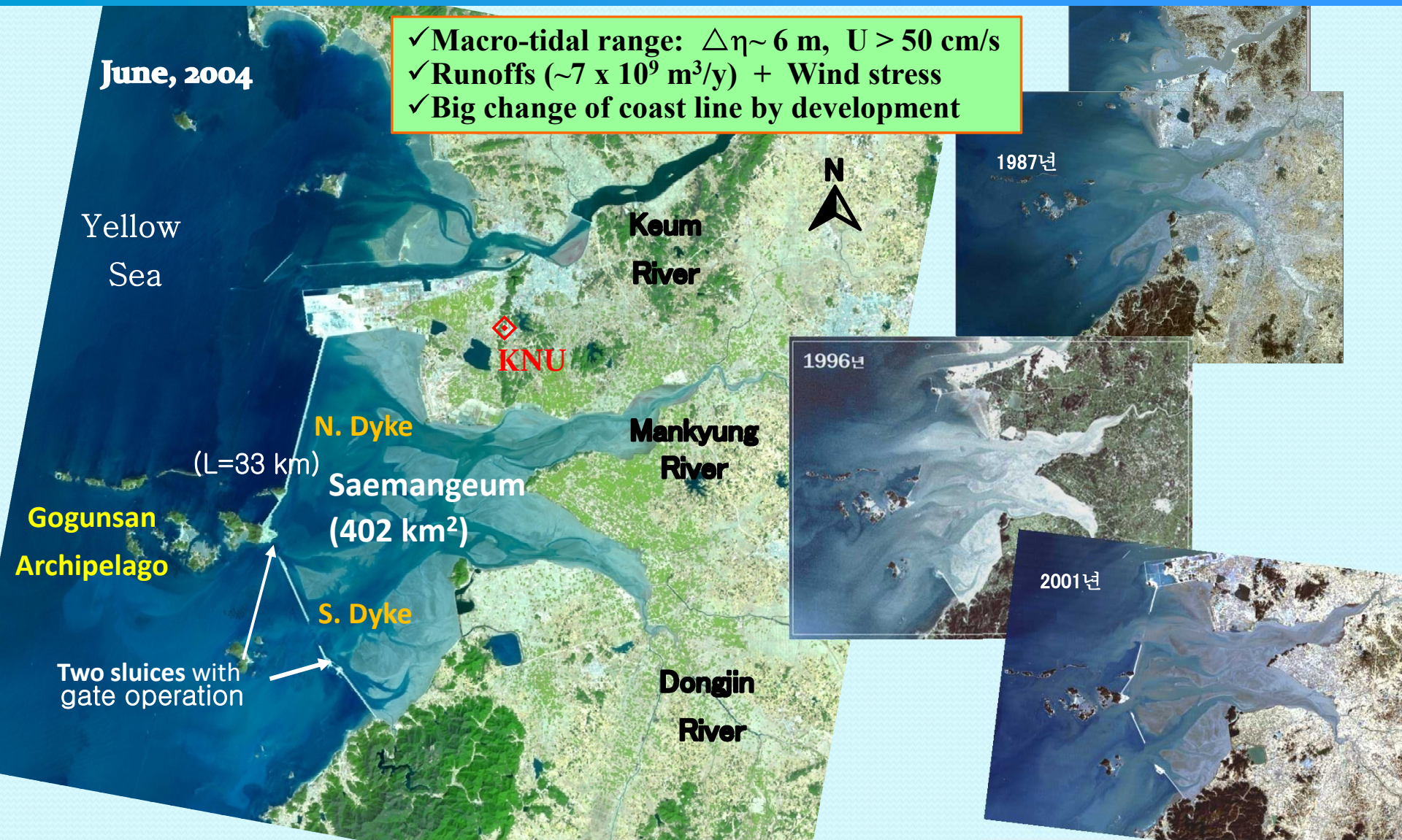
❖ Locations of 25 radar stations in Korea (2012)



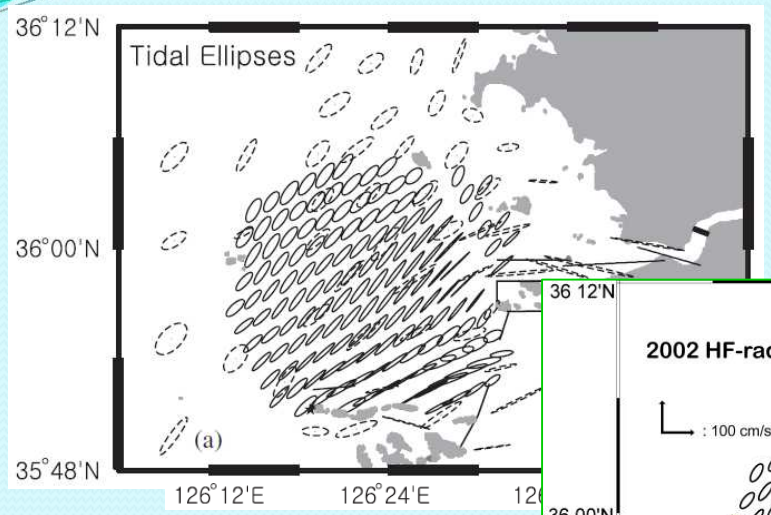
- Each network except for KRE and SD sites gathers and archives data individually.
- The current maps are provided near real-time by KHOA and KNU Web sites.

3. Major Scientific Results

3.1. Keum River Estuary & Saemangeum Dyke [KNU + KIOST]



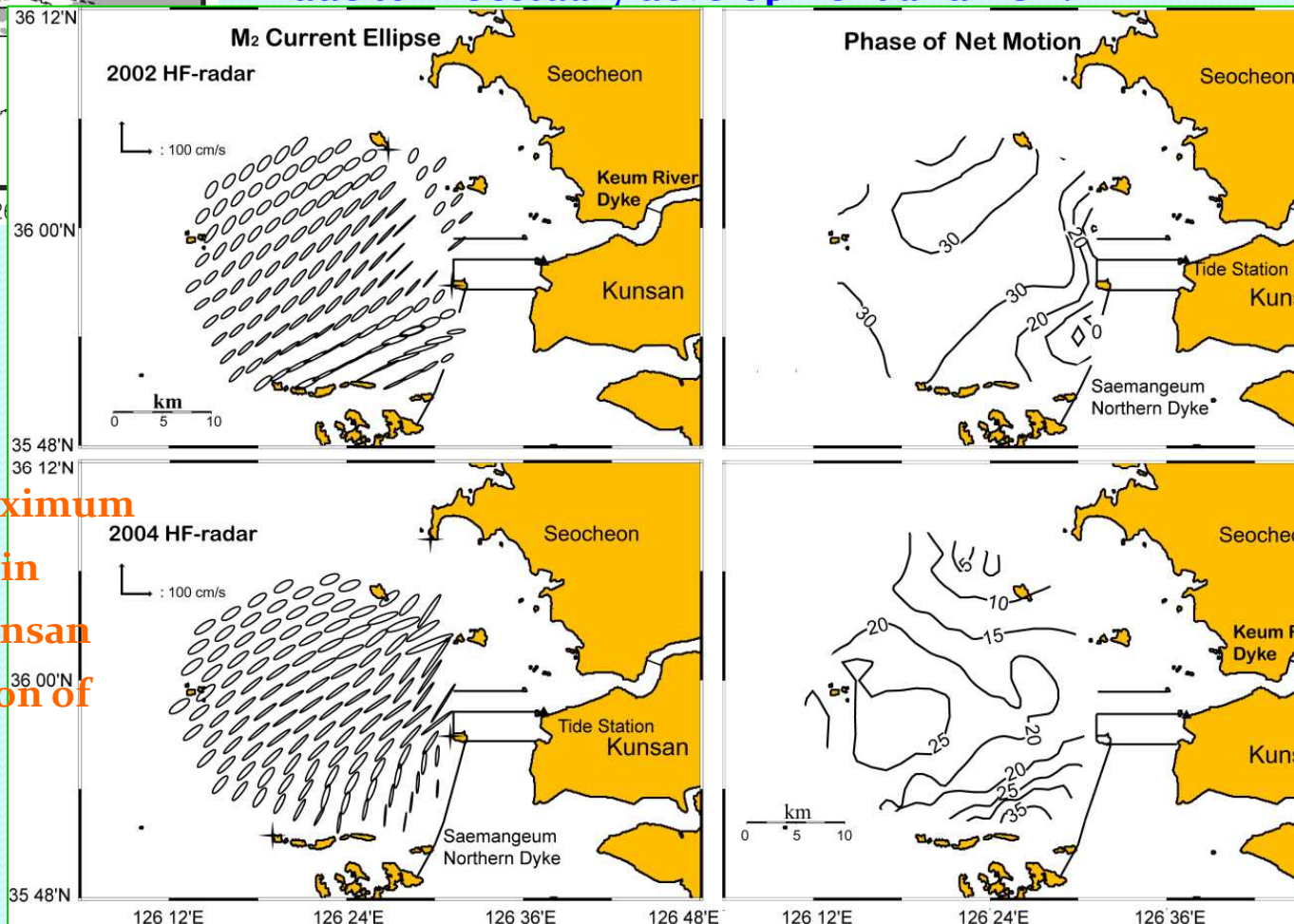
● M_2 tidal current change by the northern Saemangeum dyke construction



Dashed lie: Conventional (RCM9, ADCP) observations by KHOA before 1992

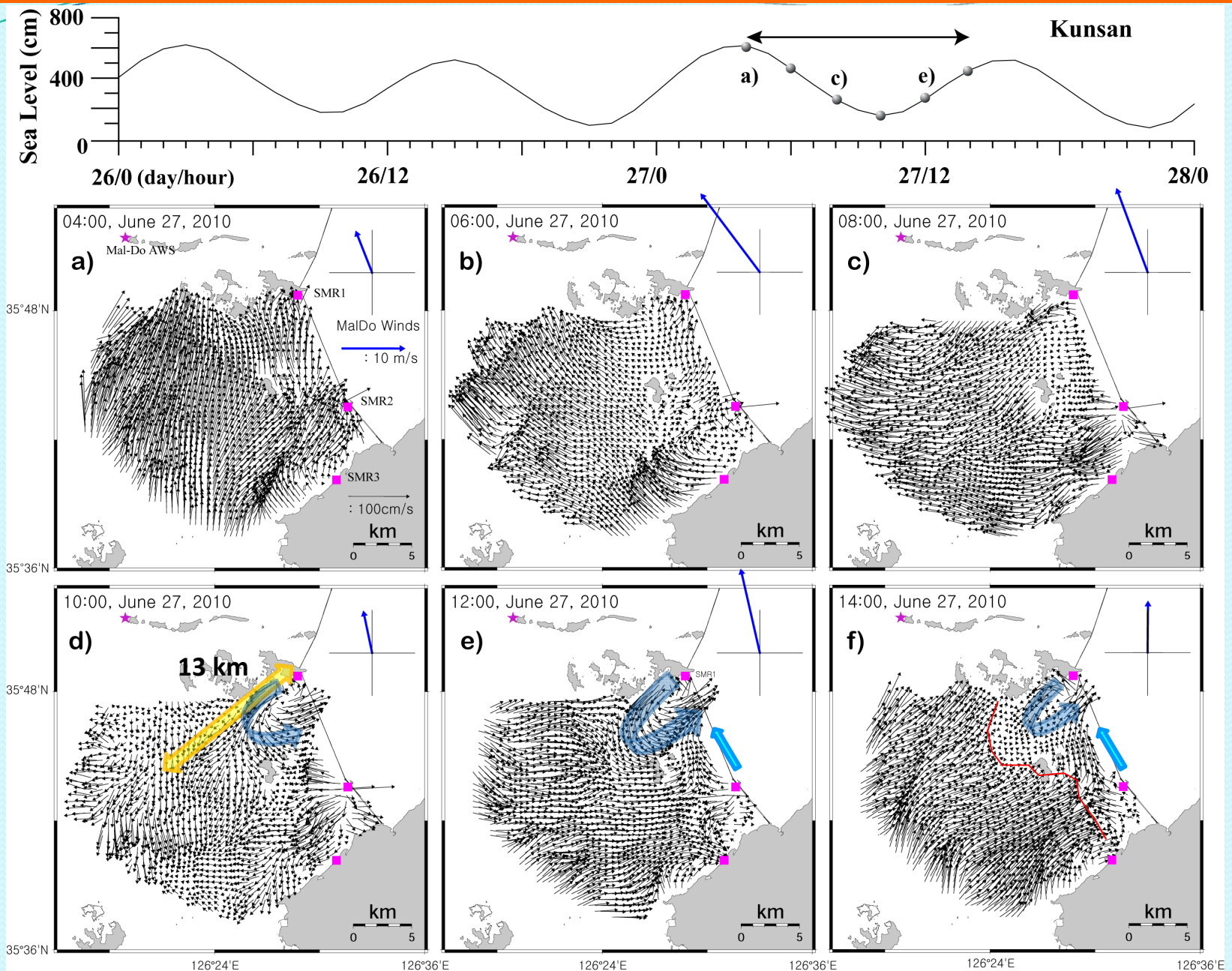
Solid line: HF radar observation in 2002 (son et al. 2007)

➡Significant tidal current change around KR mouth due to KR estuary development and NSD.

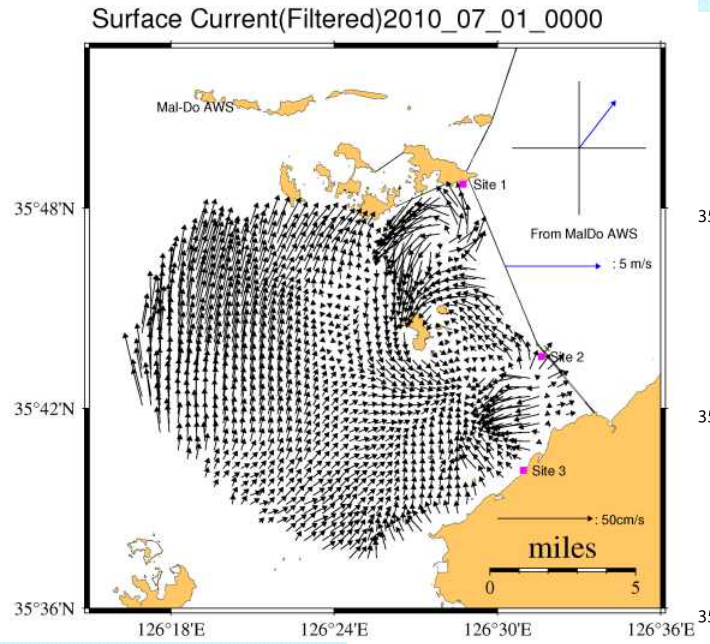


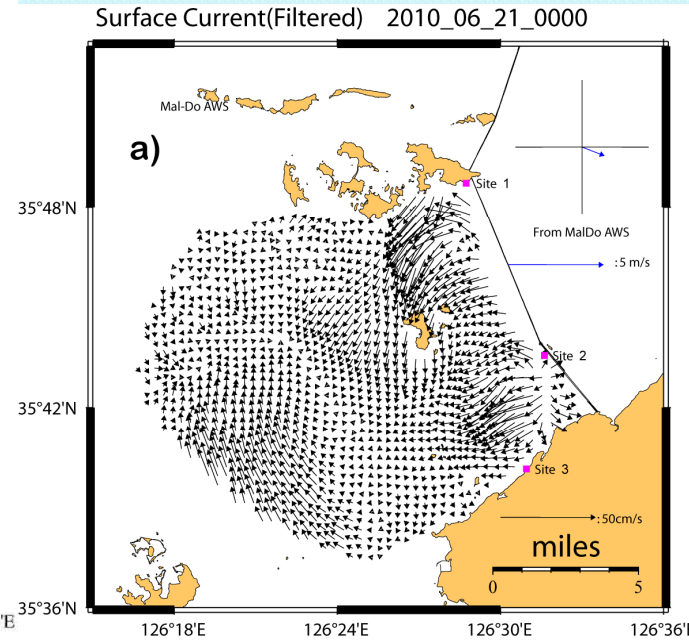
⇨Direction and time of maximum tidal current changes in large area north of Gugunsan archipelago by completion of N. Dyke in 2004 (Kim et al. 2006)

● Surface current variation off the southern dyke (June 2010, all gates were opened)



● Response of subtidal surface current to wind and outflow plume in summer 2010





- **Southerly wind : Onshore current, Eddies of outflow, along-dyke flow**
- **Westerly wind : blocks plume extension**

➢ **Large Discharge events**

+ Easterly winds :

Easterly wind enhances plume extension current

b) Precipitation > 70 mm/day

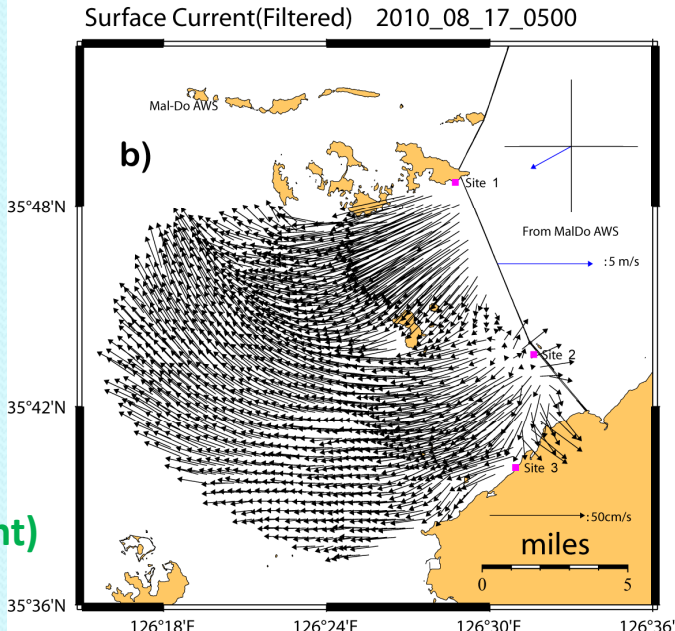
Wind factor for SAC ~ 7%

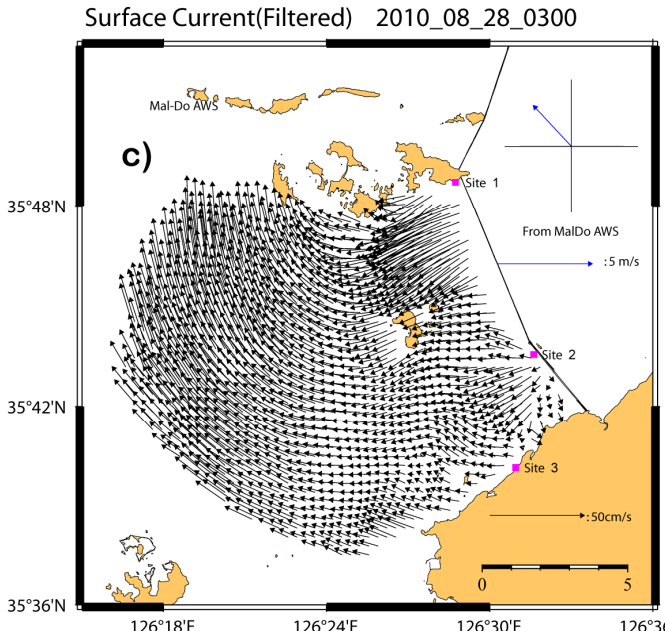
Max. speed ~ 50 cm/s

c) Precipitation < 20 mm/day

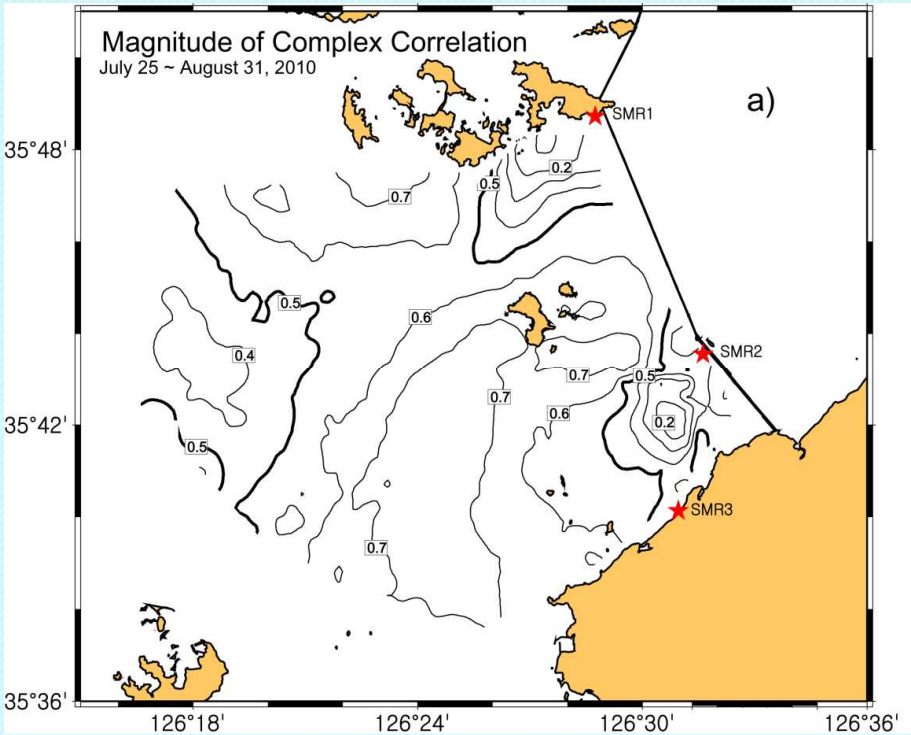
Wind factor for SAC ~ 4%

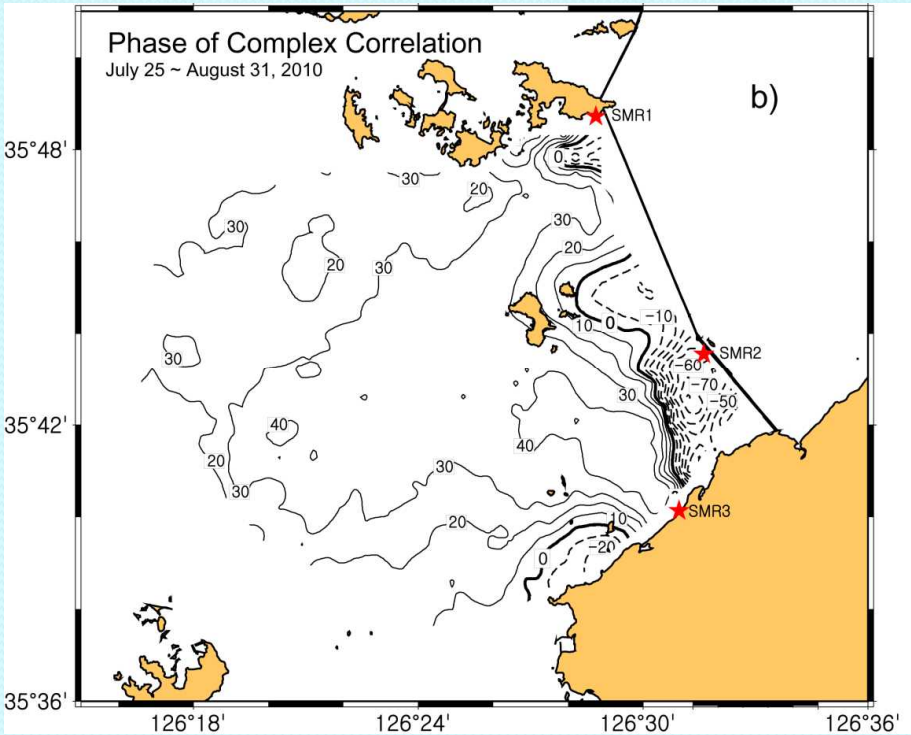
(SAC: spatially averaged current)





● Complex Correlation between wind and subtidal frequency current vectors



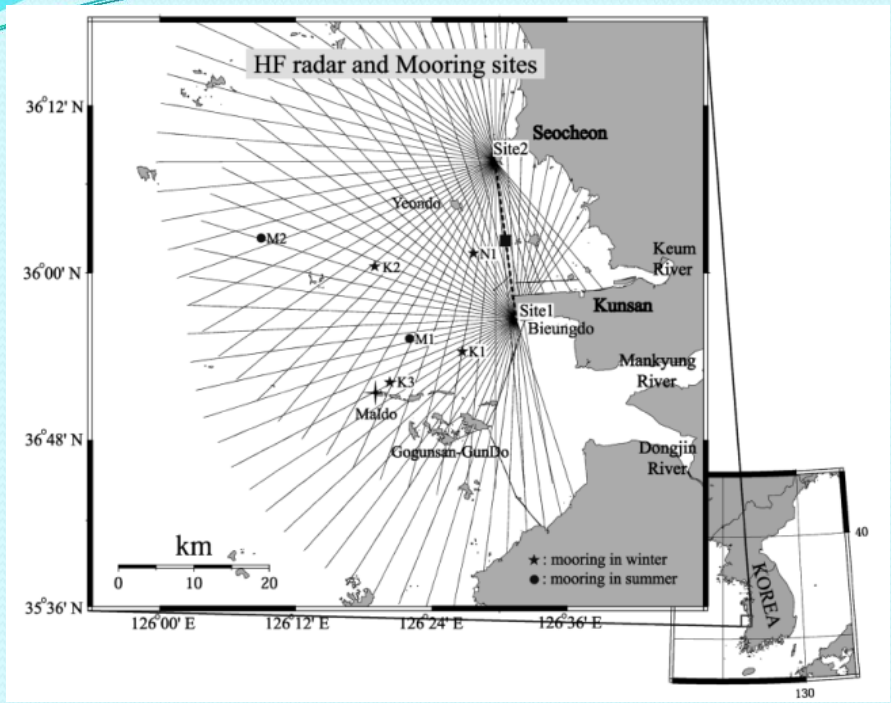


Correlation Coefficient
(time lag < 2 hrs)

Deflection Angle of Current to Wind
(solid line (positive): to the right of wind)

Off the Saemangeum Dyke after the dyke completion in summer

● Radar-derived current verification (Lee et al. 2008)



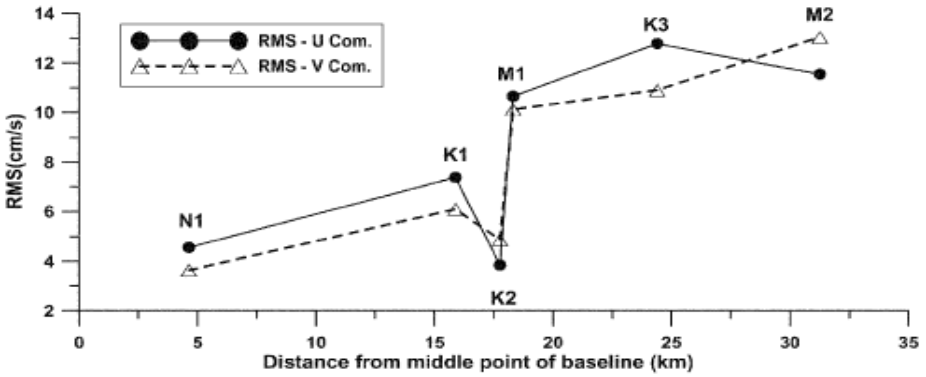
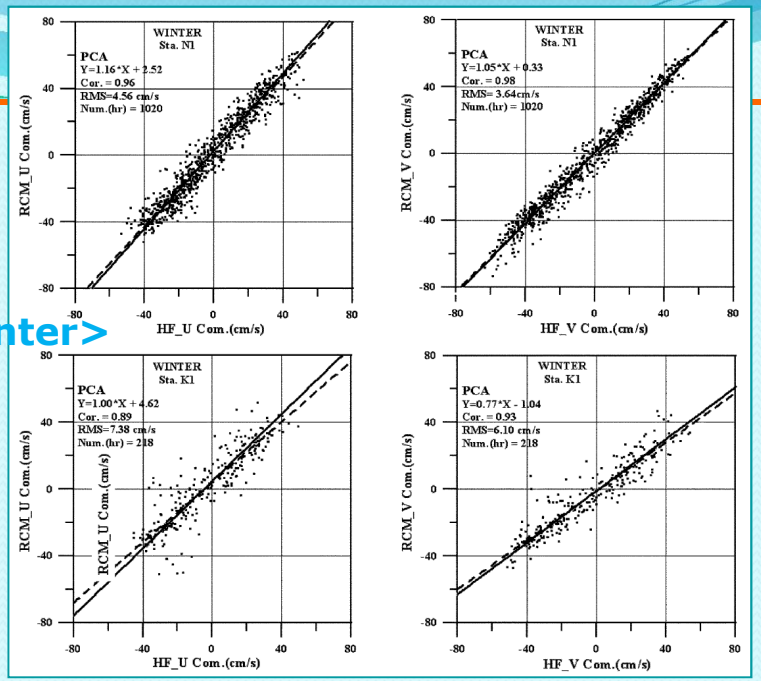


Fig. 5. Variations of RMS deviation as a function of distance from middle point of base line.

<Winter>



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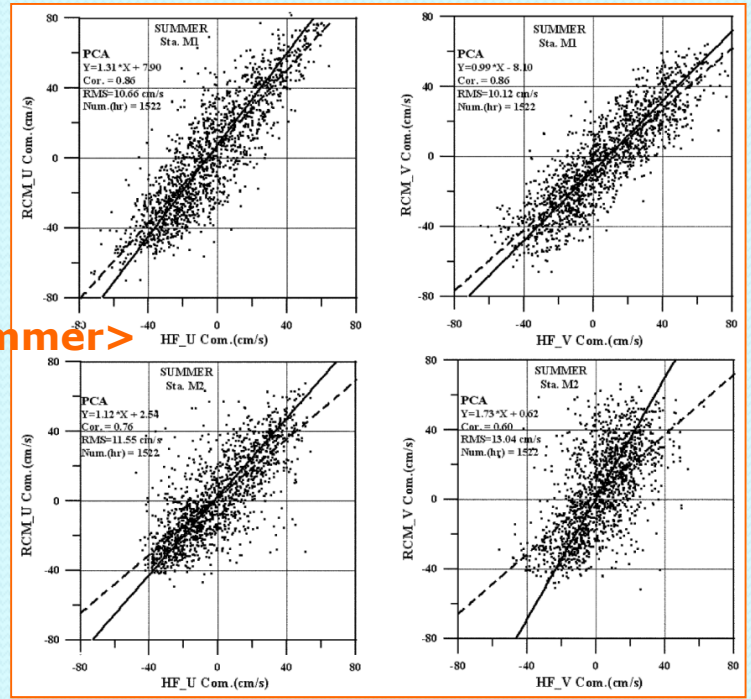
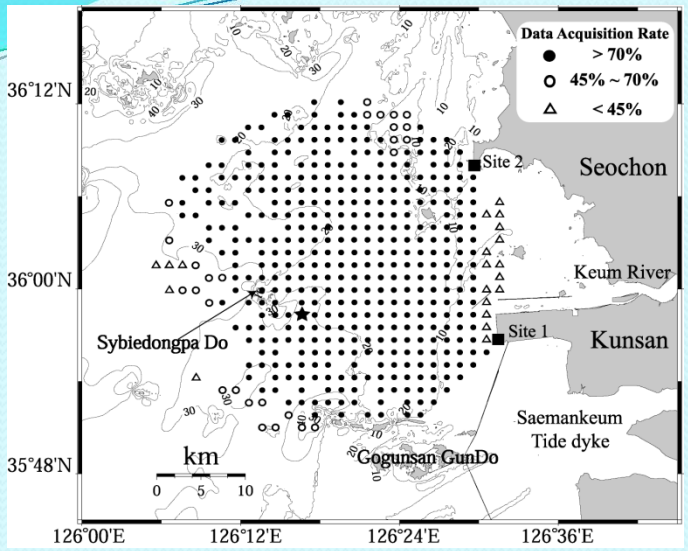
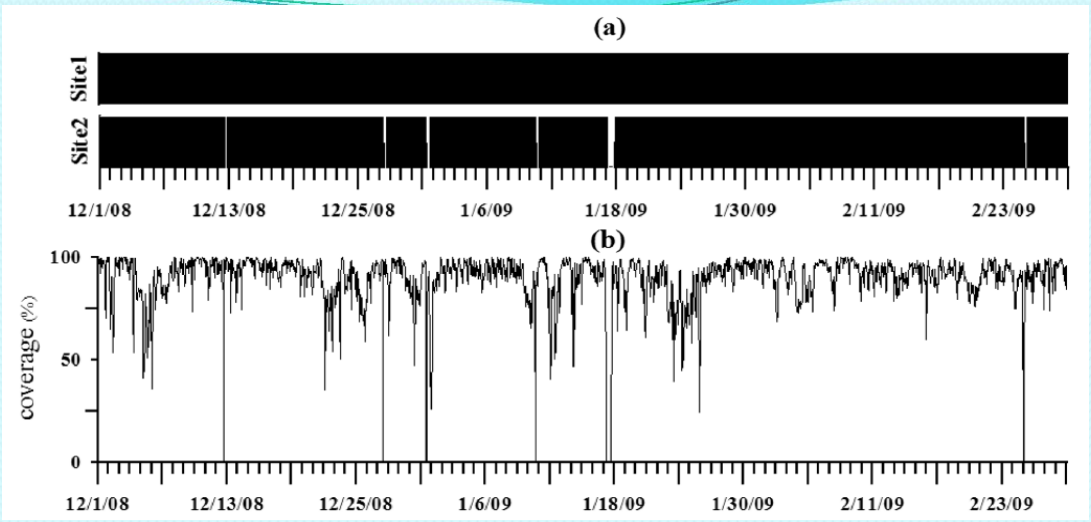


● Data gap filling: Objective Interpolation (Kim et al. 2007, Hwang et al. 2010)





Objective mapping to fill up data gap

(Kim et al. 2007; Hwang et al. 2011)

1. Using Sample Covariance

$\underline{D} = (COV_{dm})^T (COV_{dd})^{-1} \underline{d}$

$\underline{d}$: the observed demeaned current vectors,

$COV_{dm} = C(x, x')$; covariance of observed currents

$COV_{dd} = C(x, x') + R$,

$R = \lambda^2 I$; regulation matrix

$\lambda^2 = 49$ cm^2/s^2 was used (10% of averaged COV_{dm})

- Expected uncertainty of $\underline{D}$ ~ 7 cm/s

2. Using Smoothed (homogeneous) Covariance with localization

$$\overline{\rho}(\Delta X) = \frac{\Sigma_{\forall X} N(X, X+\Delta X)\rho(X, X+\Delta X)}{\Sigma_{\forall X} N(X, X+\Delta X)} = \begin{bmatrix} \overline{\rho_{uu}} & \overline{\rho_{uv}} \\ \overline{\rho_{vu}} & \overline{\rho_{vv}} \end{bmatrix}$$

Sample Mean Correl. Coeff.

$$C_{sm}(X, X') = \overline{\rho}(\Delta X)\overline{\sigma}(X)\overline{\sigma}(X')$$

$$C^G_{sm}(X, X') = G(\Delta X) \cdot C_{sm}$$

$$\overline{\sigma}(\mathbf{x}) = \begin{bmatrix} \overline{\sigma}_u(\mathbf{x}) \\ \overline{\sigma}_v(\mathbf{x}) \end{bmatrix}$$

Sample Mean STD

where $G = \exp\{-[(\Delta X)^2 + (\Delta Y)^2]/2k^2\}$ is Gaussian Function

3. Using Fitted mean Covariance (for correlation coeff.)

$$C_{ft}(X, X') = f(\Delta X)\overline{\sigma}(X)\overline{\sigma}(X')$$

where $f(\Delta X) = \exp[-[a(\Delta X)^2 + b(\Delta X)(\Delta Y) + c(\Delta Y)^2]^d]$

is a fitting function of sample mean correl. coeff.

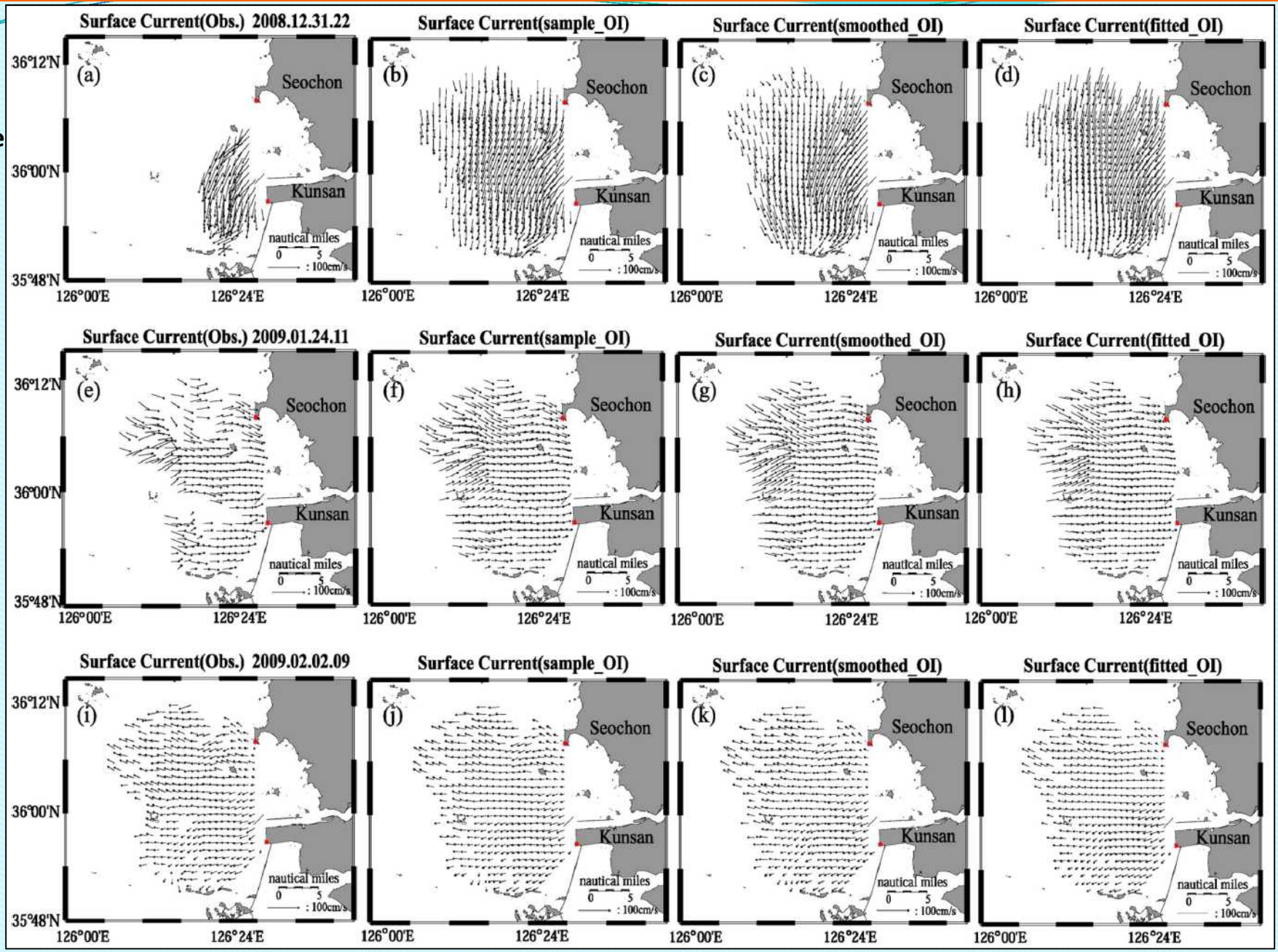
● Examples of Objective Mapping

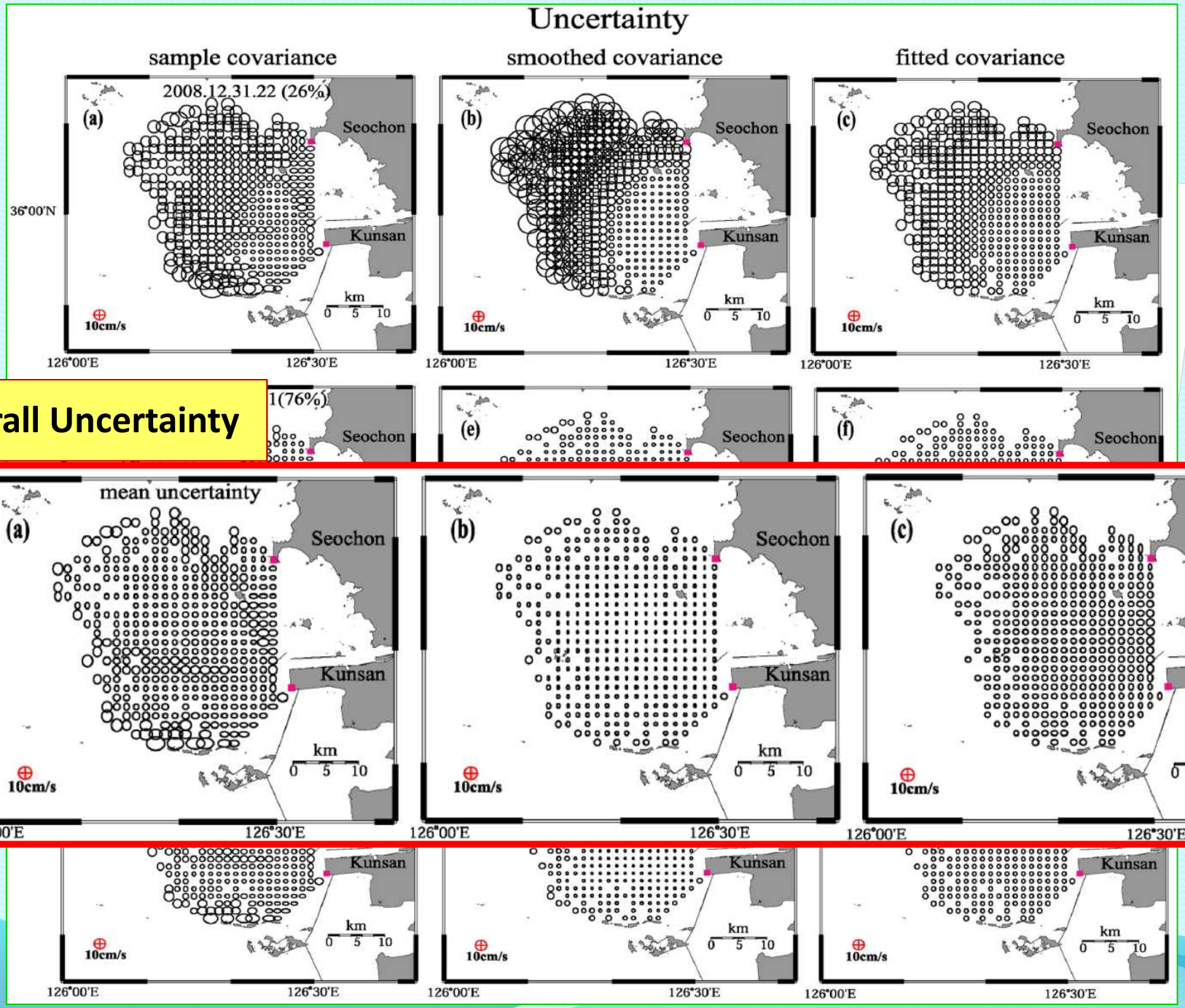
Spatial Coverage

26%

76%

90%

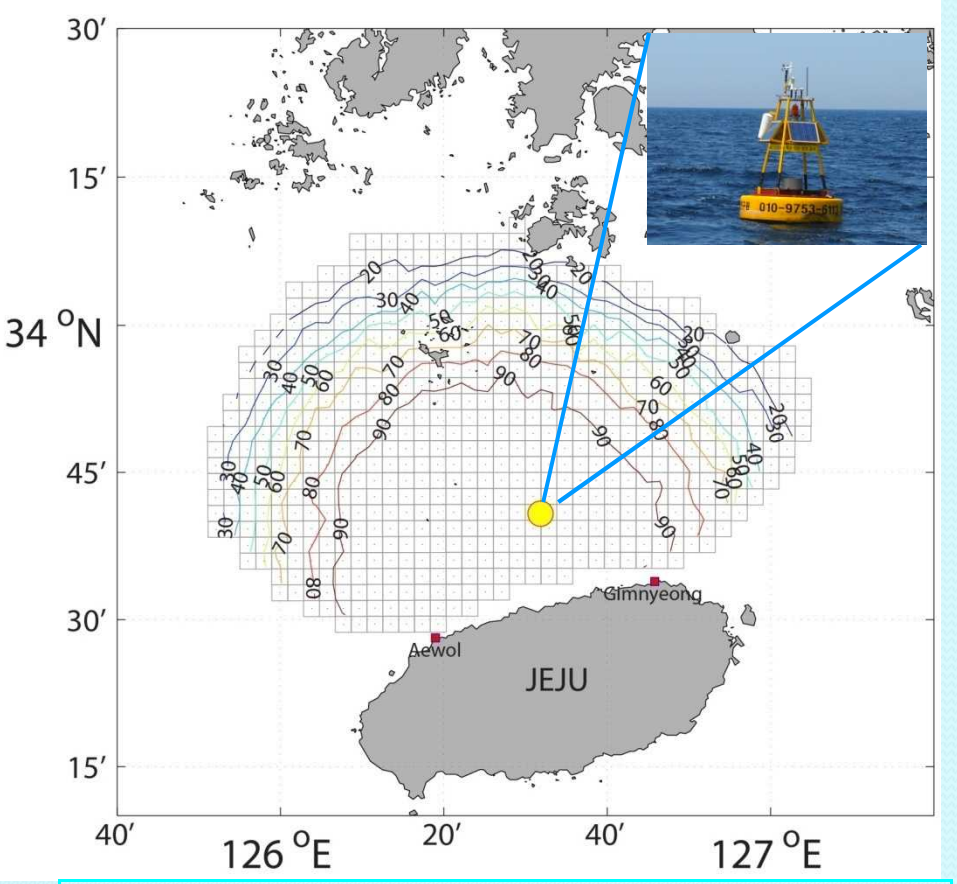



Uncertainty
sample covariance
smoothed covariance
fitted covariance
2008.12.31.22 (26%)
(a)
(b)
(c)
(e)
(f)
Seochon
Kunsan
36°00'N
126°00'E
126°30'E
km
0 5 10
10cm/s
Overall Uncertainty
mean uncertainty

3.2 Jeju Strait [KIOST]

● Jeju Warm Current Observation

- HF radar in Jeju Strait
  - 13 MHz HF-Radar (SeaSonde)
    Aewol: 13.415MHz
    Kimnyung: 13.470MHz
    (Band width: 50kHz)
  - Max range: 80 km
  - Range resolution: 3 km
  - Angular resolution: 5 deg.
  - Time interval : 60 minute
- Temporal coverage
  - More than 80% in range of 60km
- ADCP mooring for validation
  - 300kHz ADCP

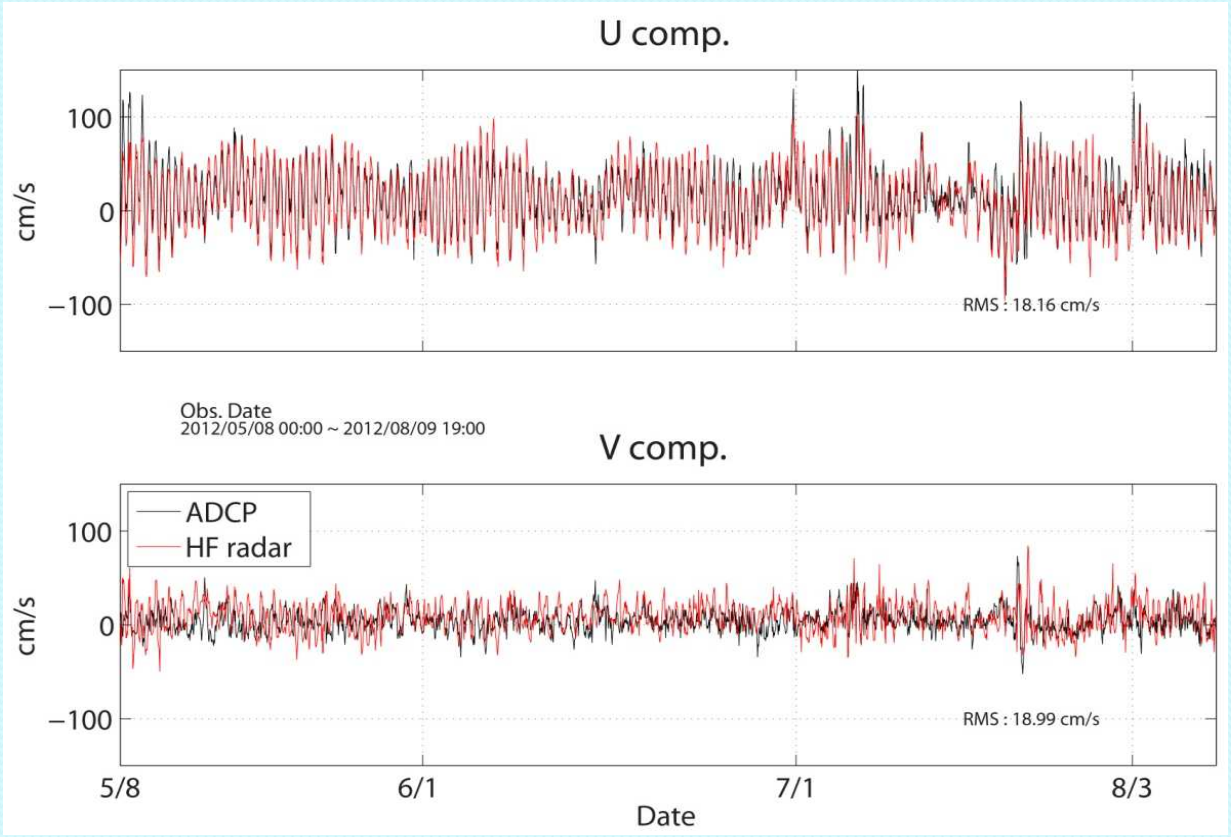


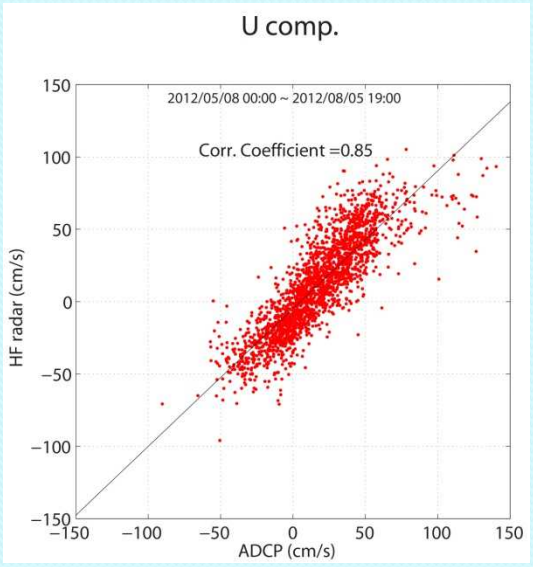
HF radar sites and percent temporal coverage

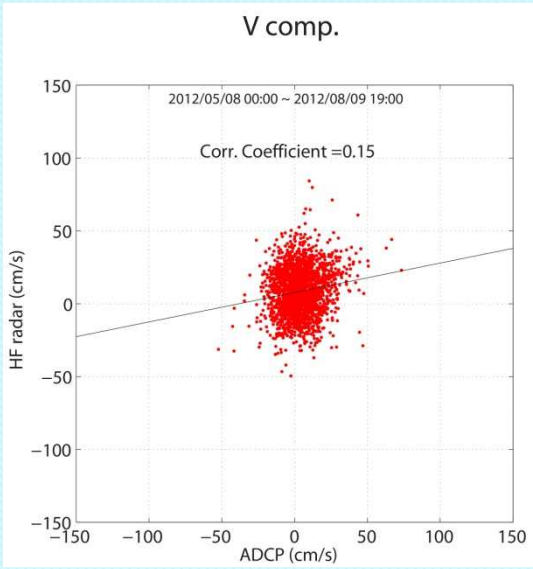
● Validation of HF-Radar

◇ Comparison with buoy-moored ADCP

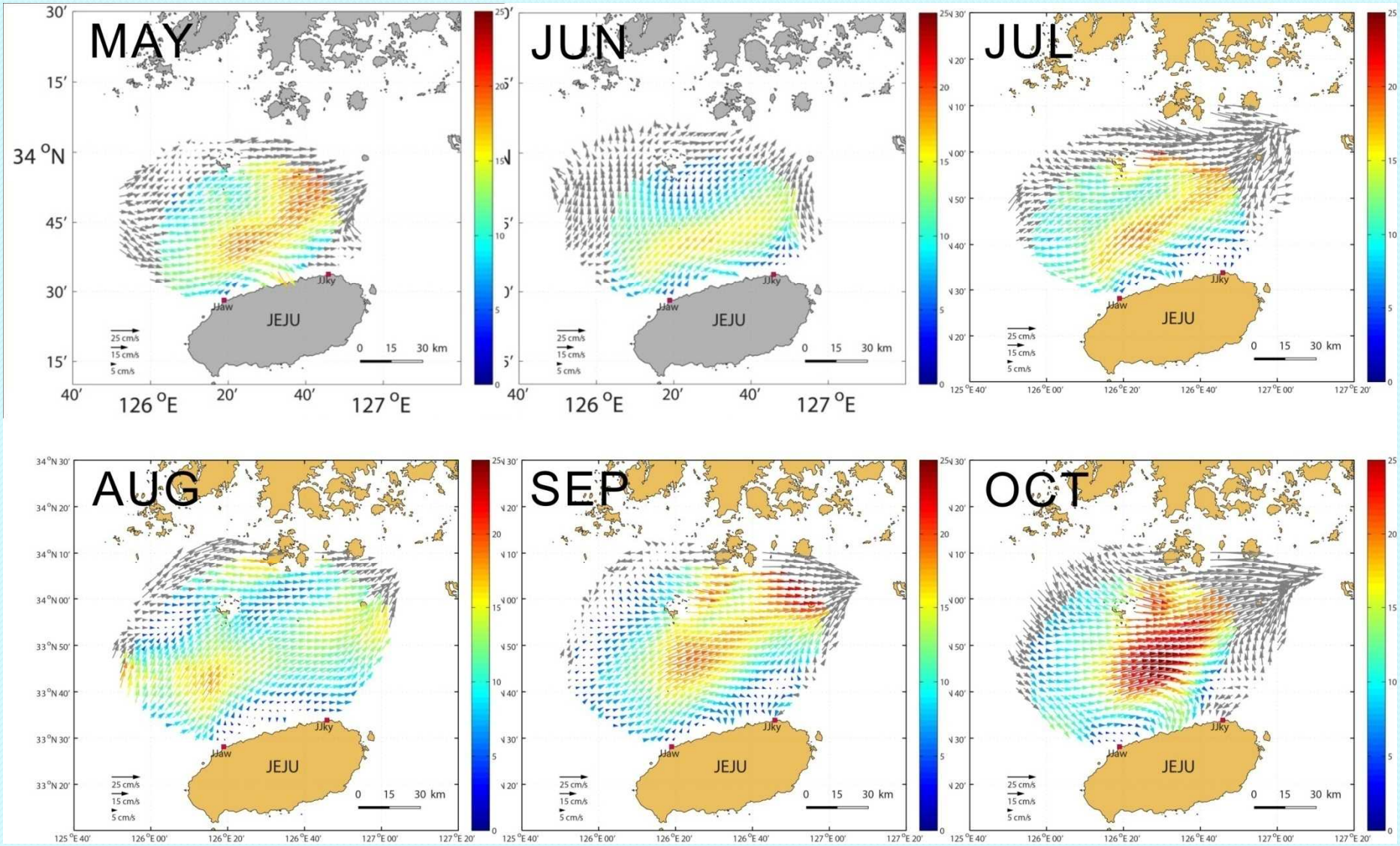
- Correlation coeff. : u-comp: 0.85, v-comp: 0.15
- RMS difference : u: 18.16 cm/s, v: 18.99 cm/s







Monthly Mean Surface Current 2012

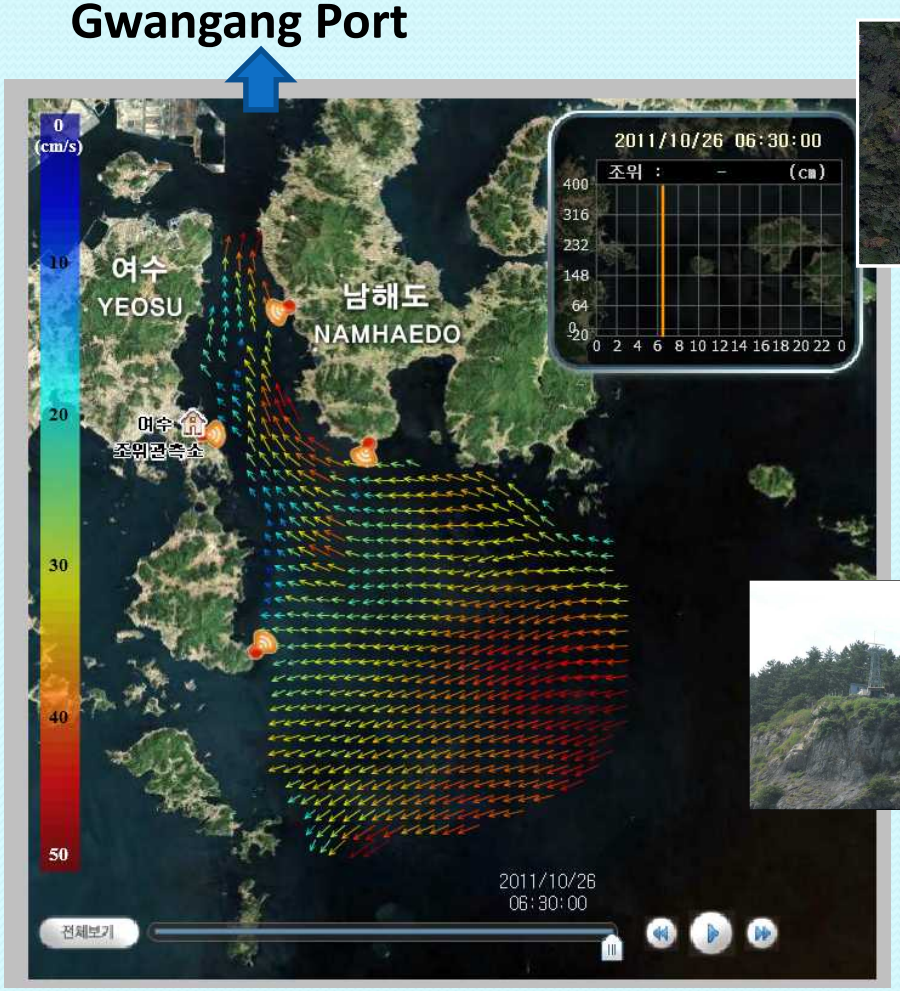


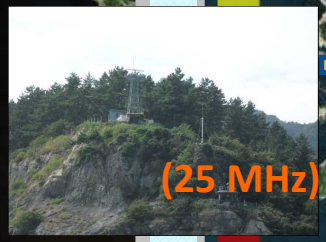
3.3 Yeosu Bay and Busan New Port sites [KHOA]

- **Yeosu Bay (YB site) : Operational to support the navigation & transport (GwangYang Port)**

Gwangang Port

(Yeosu Expo)





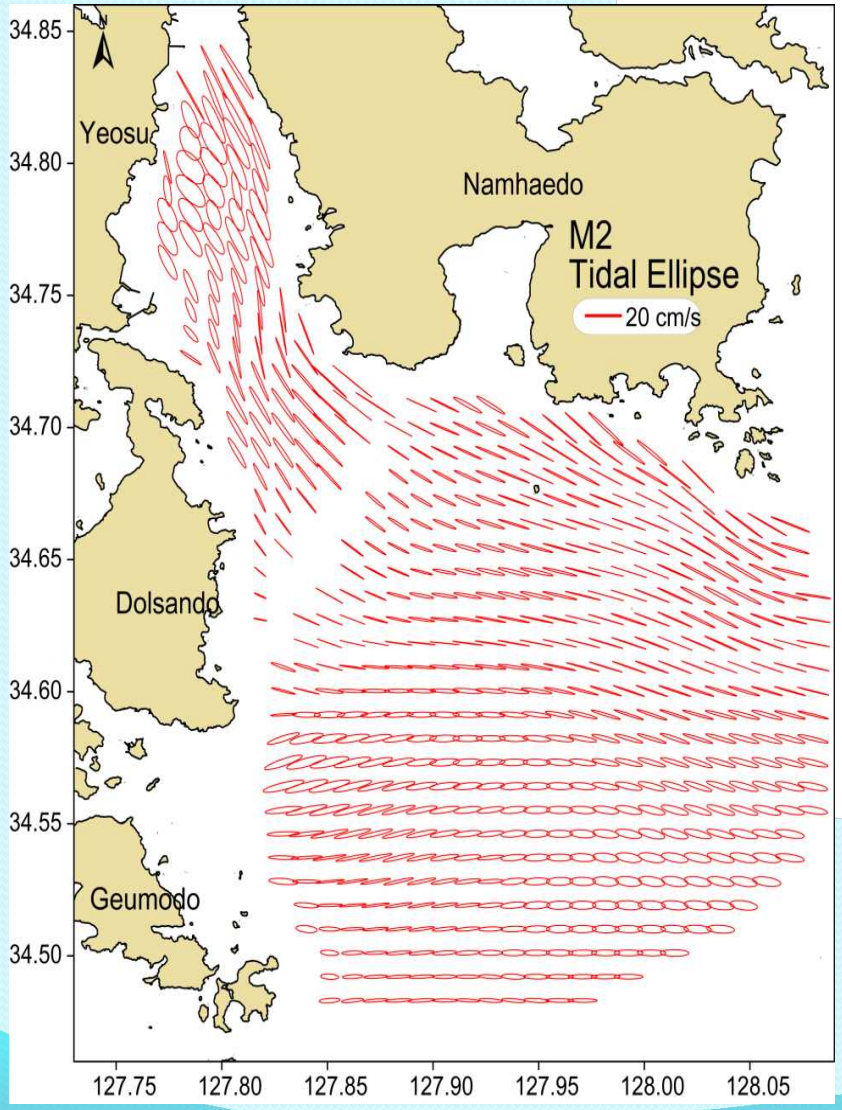
Flooding current

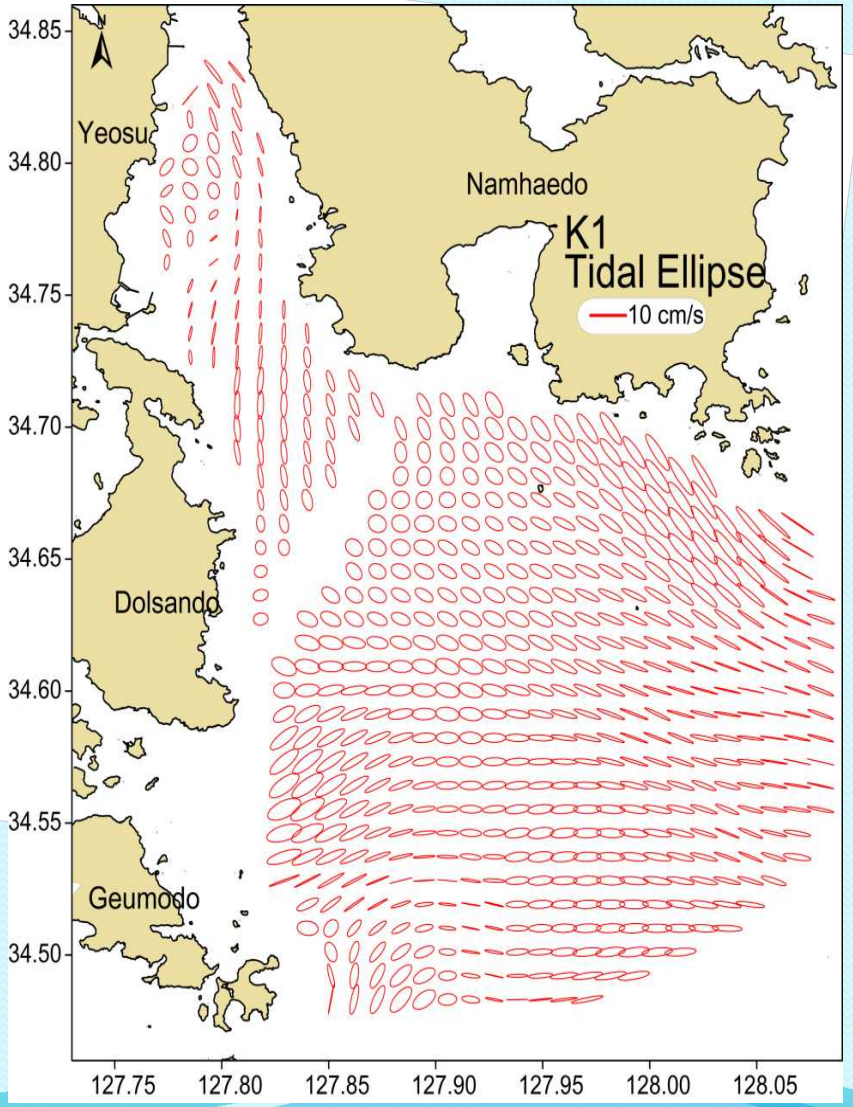
Ebbing current

(http://www.khoa.go.kr/koofs/kor/observation/obs_real_map.asp)

✓ **Tidal Current Ellipses**

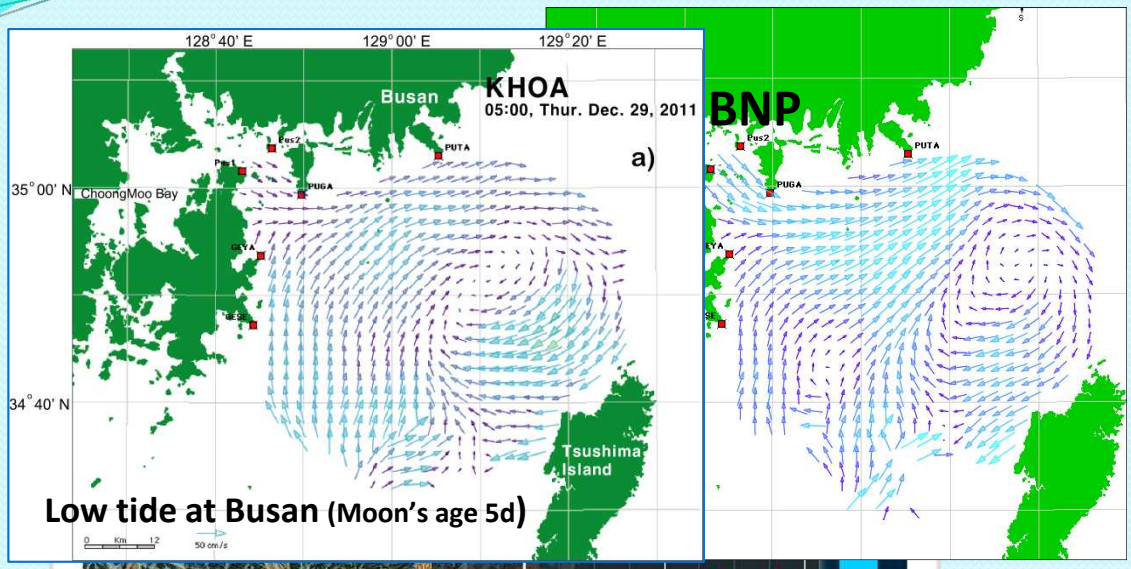
➢ **Trajectory**

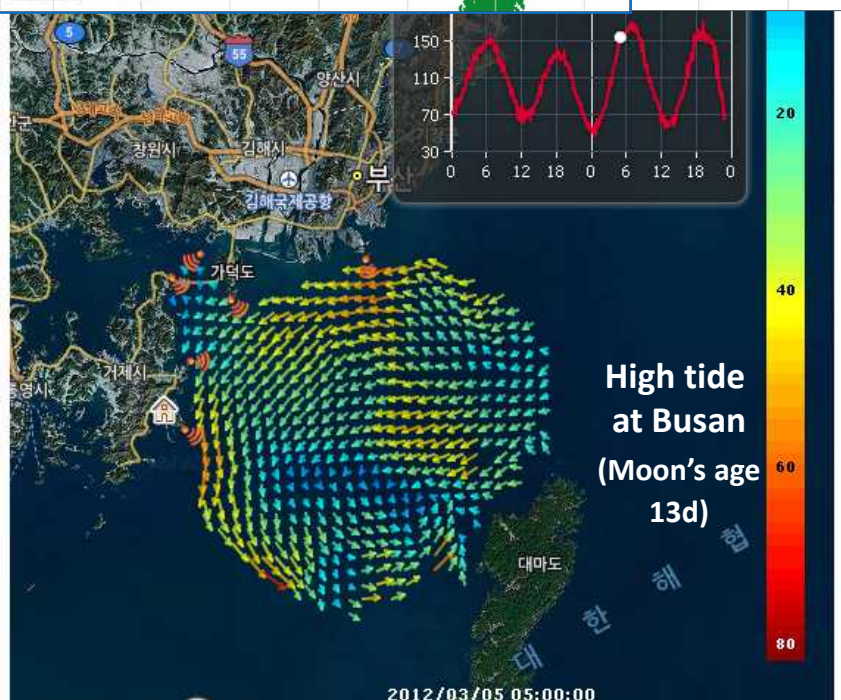


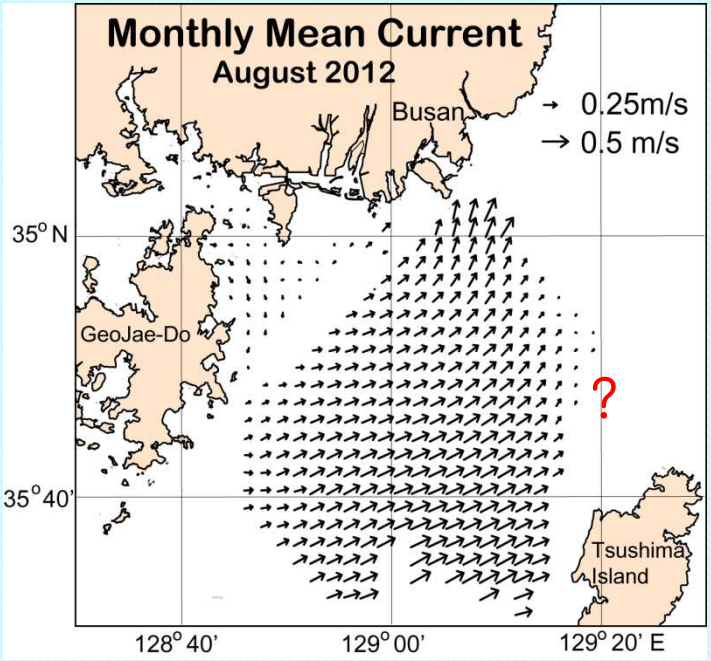


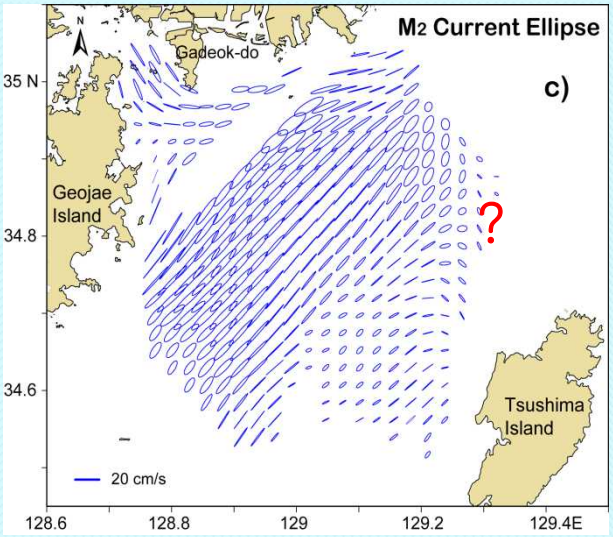
● Busan New Port and Korea Channel (BNP site, triple multi-static, 44, 25, 13 MHz) :

Operational for navigation & transport + Monitoring of TWC







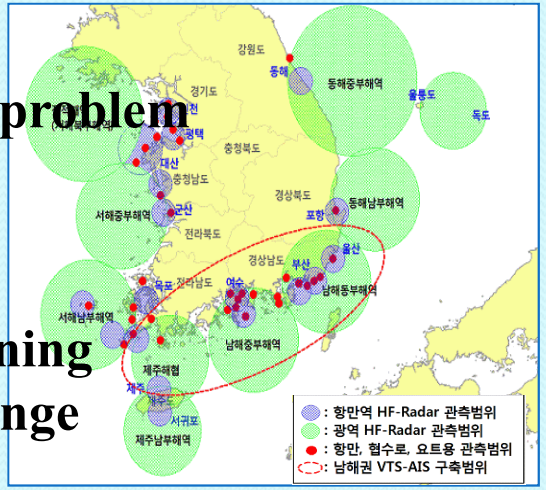


4. Radar community Activities & Future Plan

- **KORF (Korea Ocean Radar Forum)**
  - **1st ORCA, May 17-18, Seoul, Korea**
  - **Special edition of OSJ (Mar. 2013)**
  - **Annual Meeting for Scientist**

- **KHOA**
  - **Adding 2-4 radars/year to increase spatial coverage of current measurement**

- **ETRI**
  - **HF frequency allocation & Field survey for inference problem**



❖ Future Plan

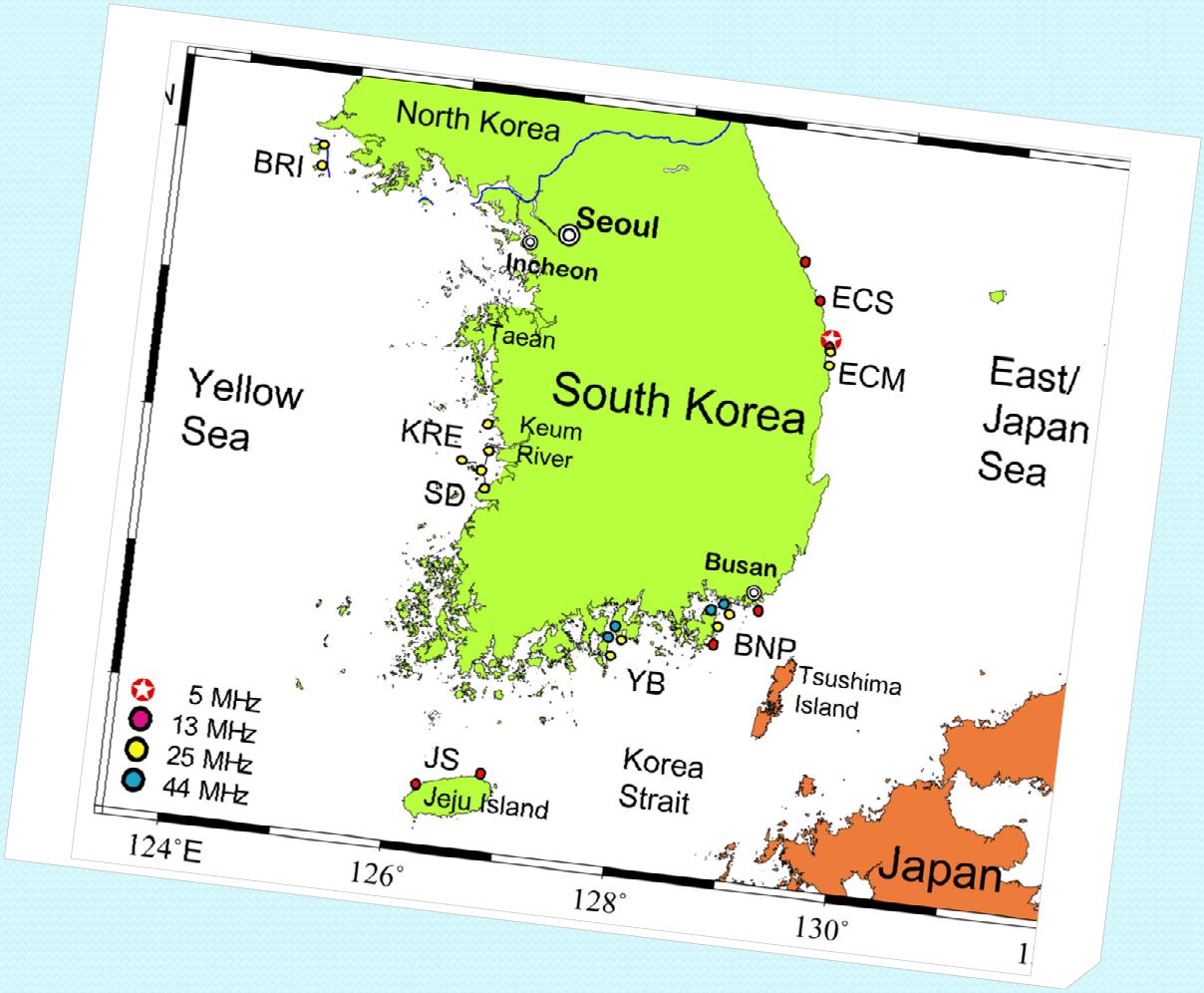
✓ **Workshop to foster Tech. community and student training**

✓ **Establish Nation-wide HF radar Network with long range**
+ Data Portal

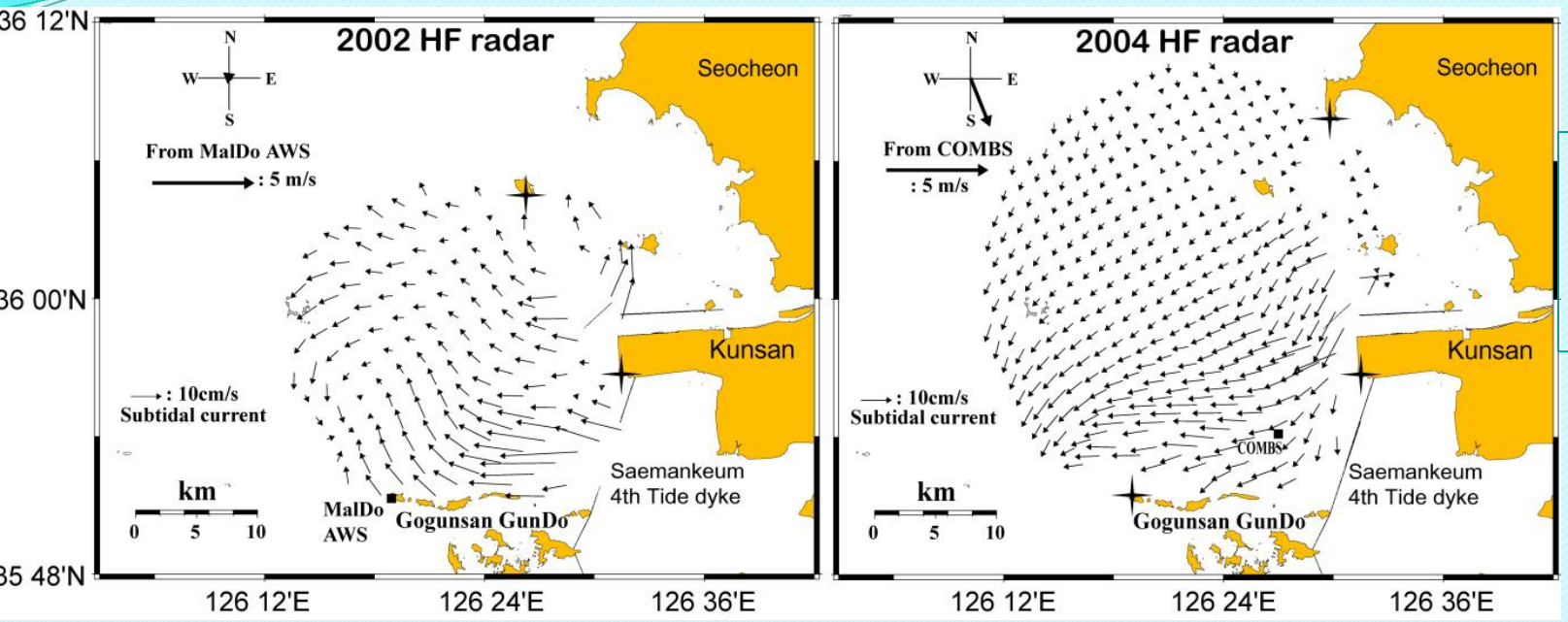
✓ **Development of software program for operational and emergency response**

Thank You for Your Attention !

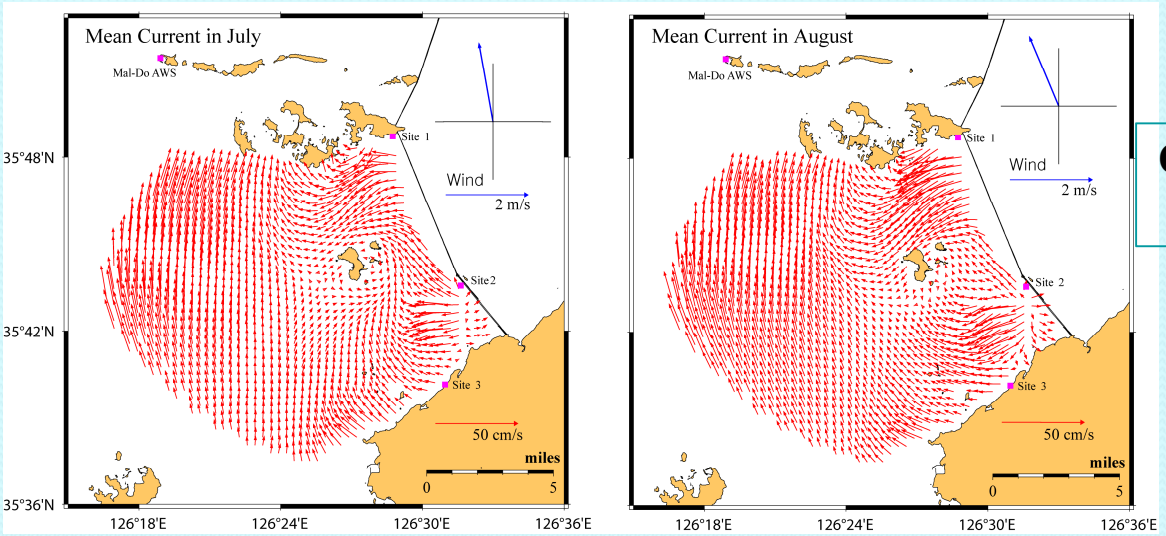
Questions and Comments !



● Mean Surface Current by Wind + Outflow plumes + Coast line change

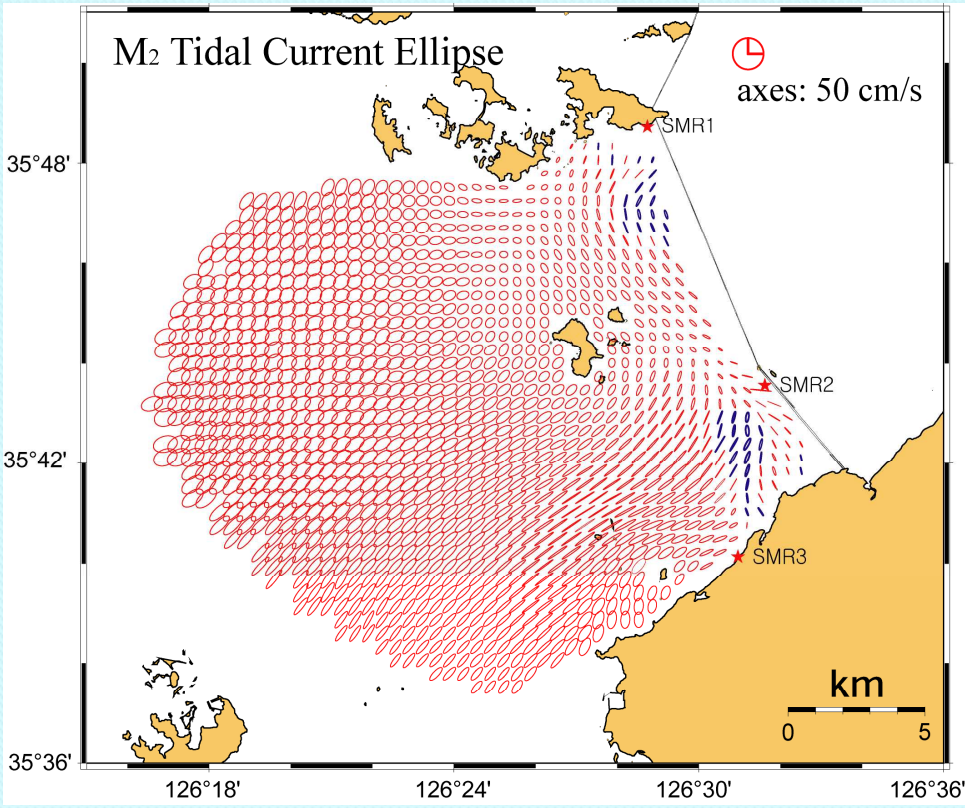


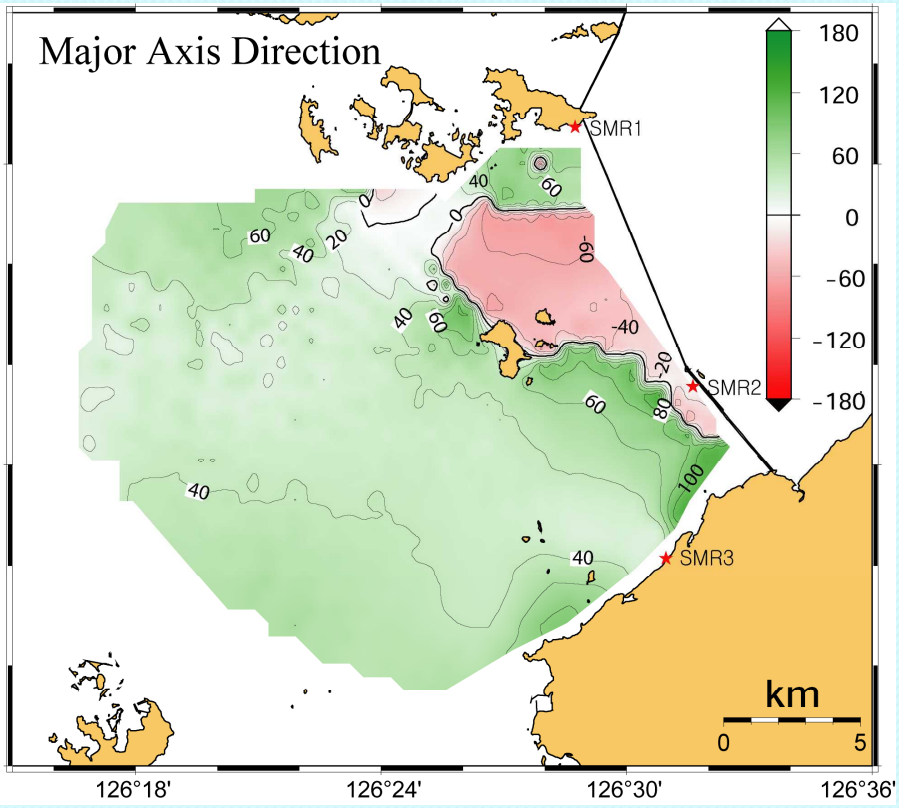
Off Keum River estuary in July 2002, October 2004



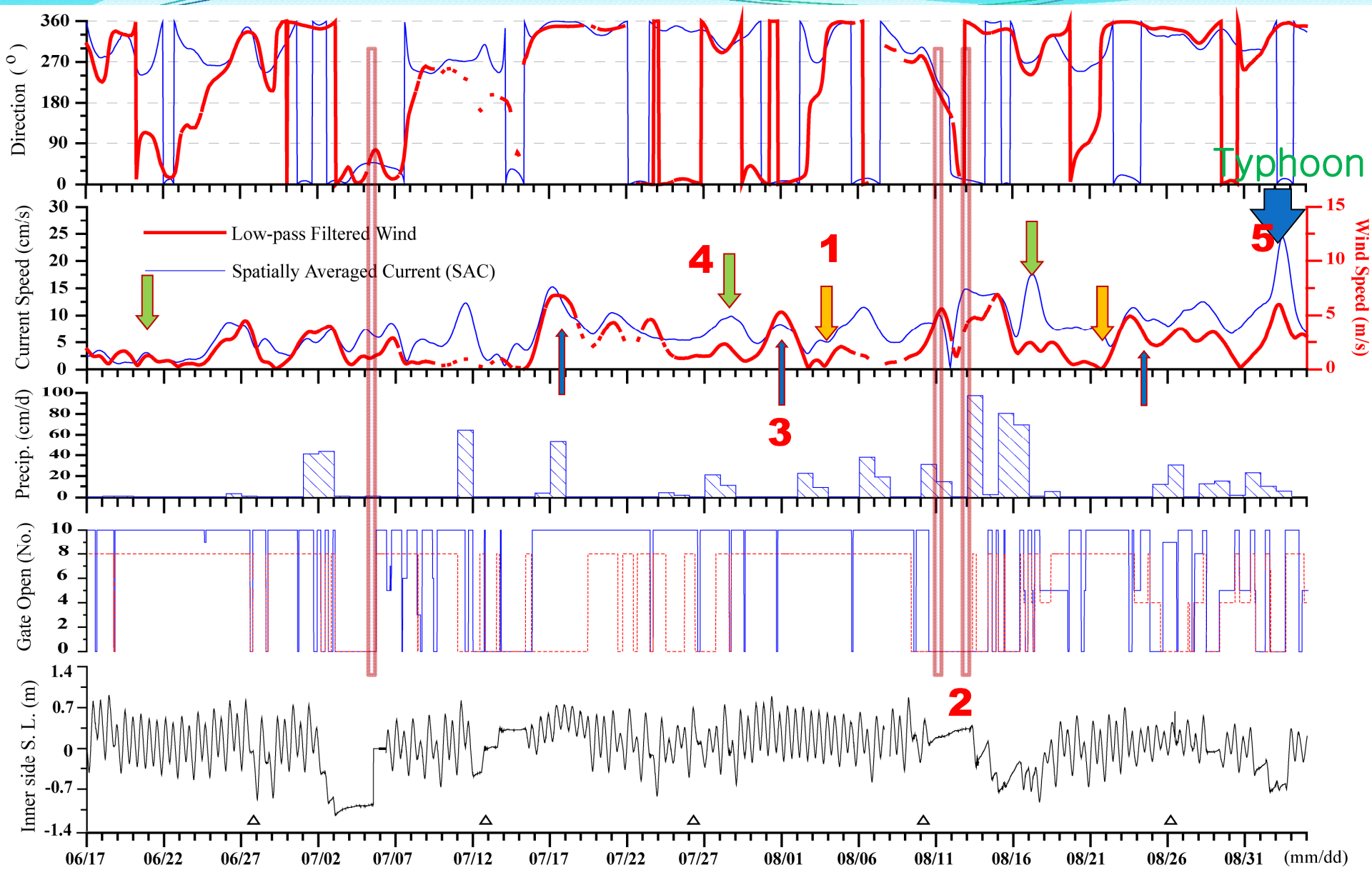
Off the Southern Dyke in summer 2010

➢ M_2 Tidal Current Ellipse

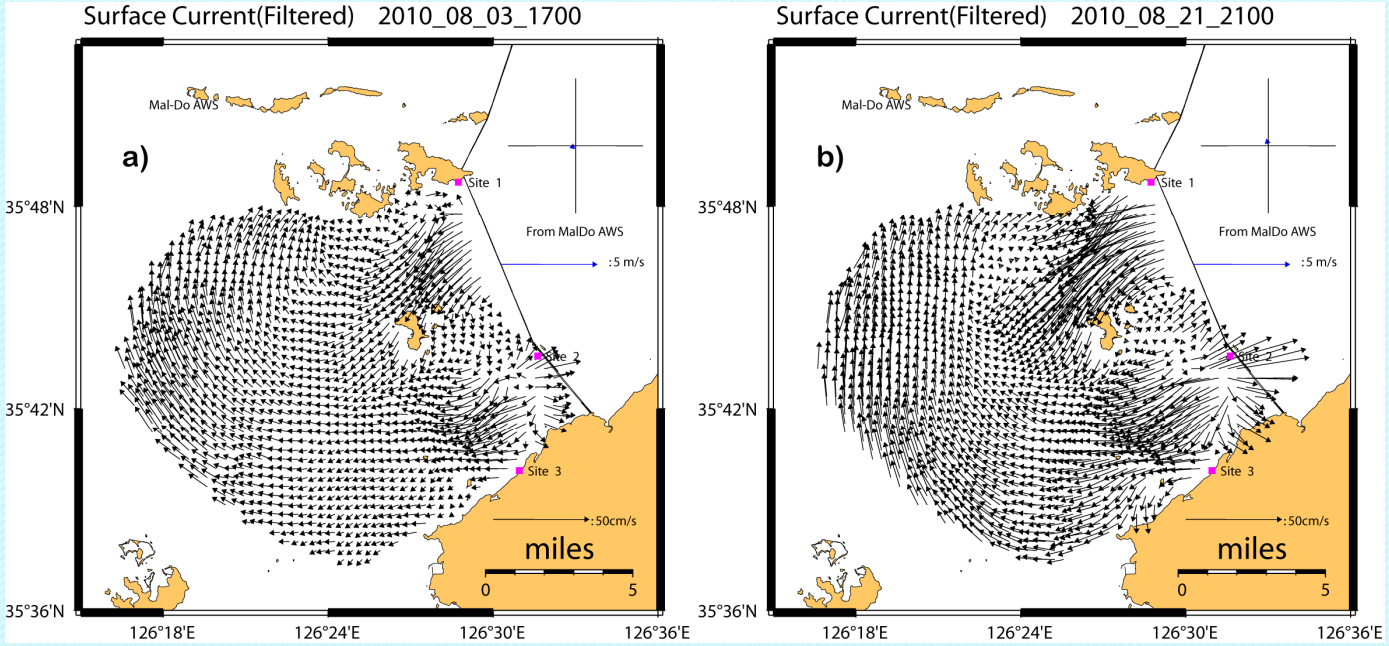




➢ Subtidal Currents

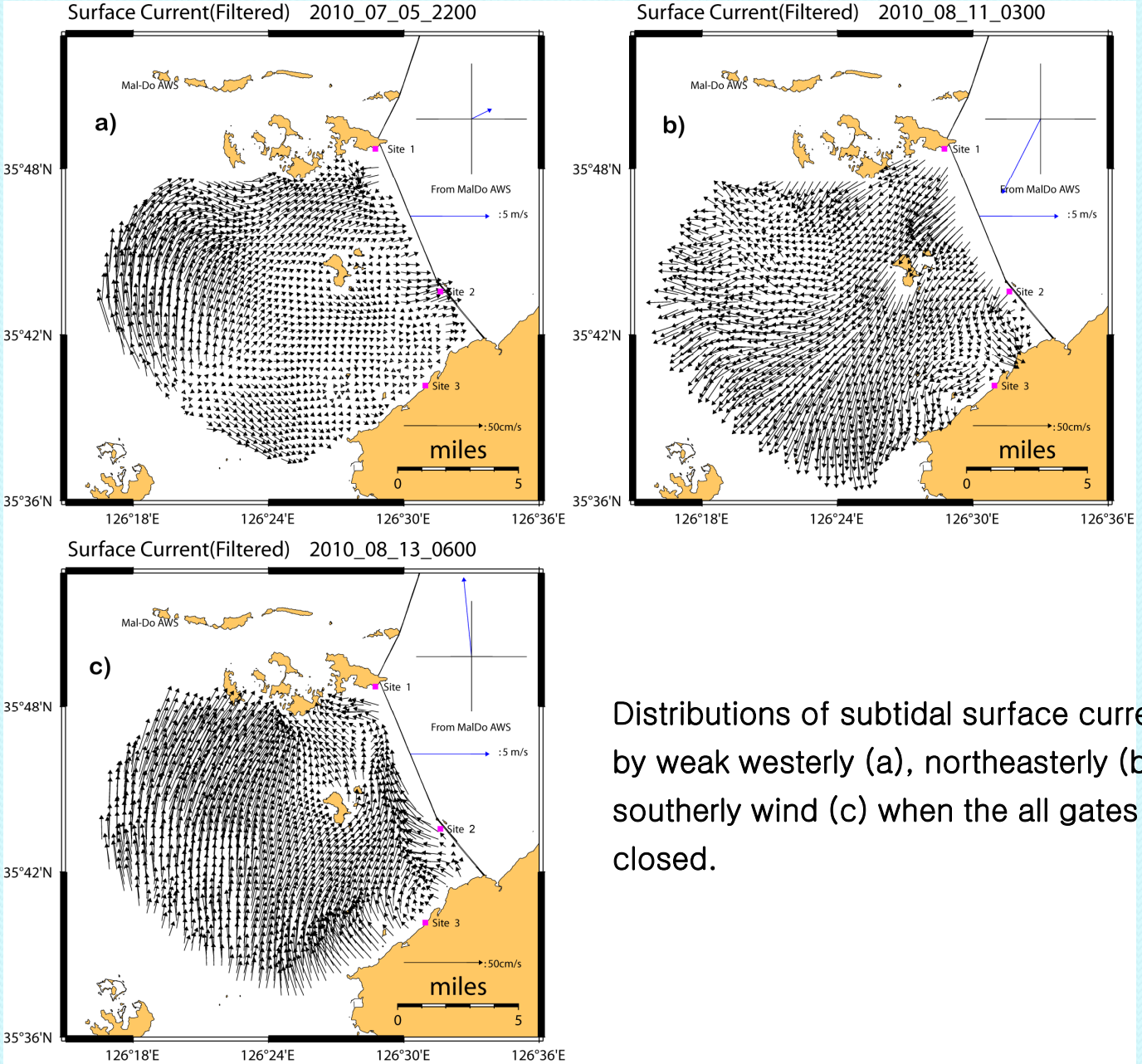


1) Effect of outflows when no winds



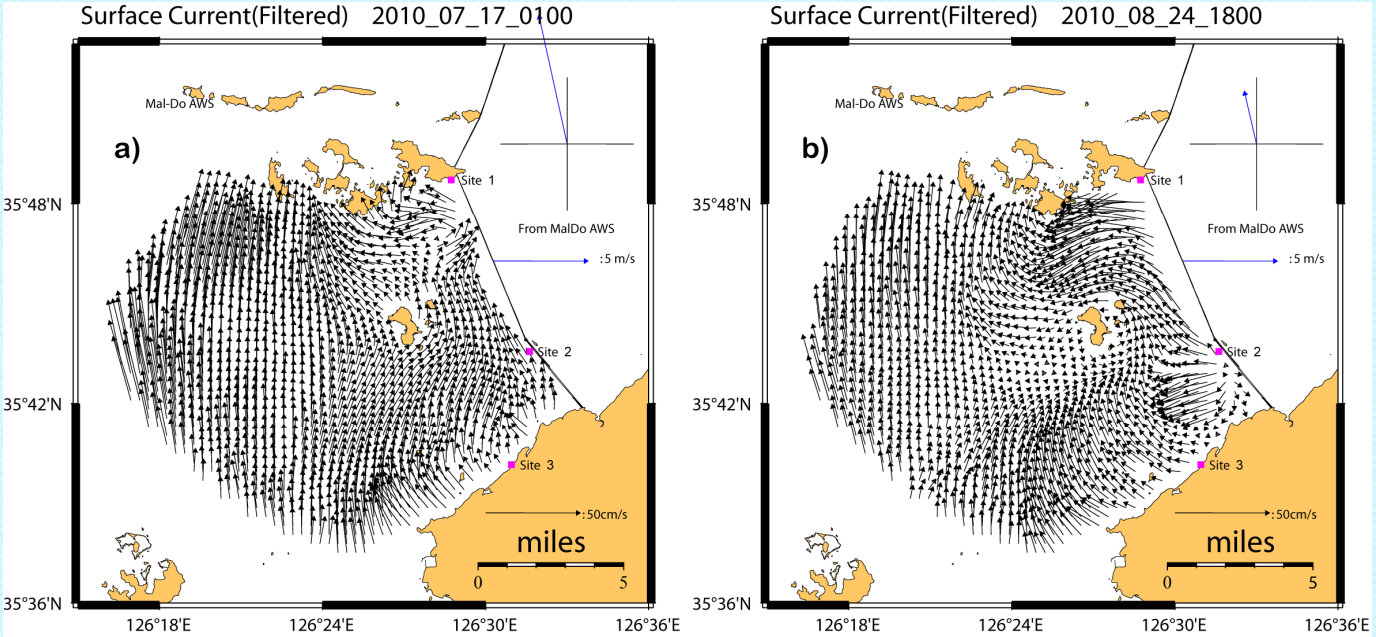
- Outflow inertia appears in 10 ~13 km from the sluices.
- Outflows contributed to the northward current development in the outer bay.

2) Effect of wind forcing when no discharge



Distributions of subtidal surface current driven by weak westerly (a), northeasterly (b) and southerly wind (c) when the all gates were closed.

3) Effects of Southerly Winds + Outflows



a) Shinsi: all open
Garyeok: close

b) Shinsi: all open
Garyeok: ½ close

c) Shinsi: all open
Garyeok: all open