CODAR-observed currents off northern Taiwan

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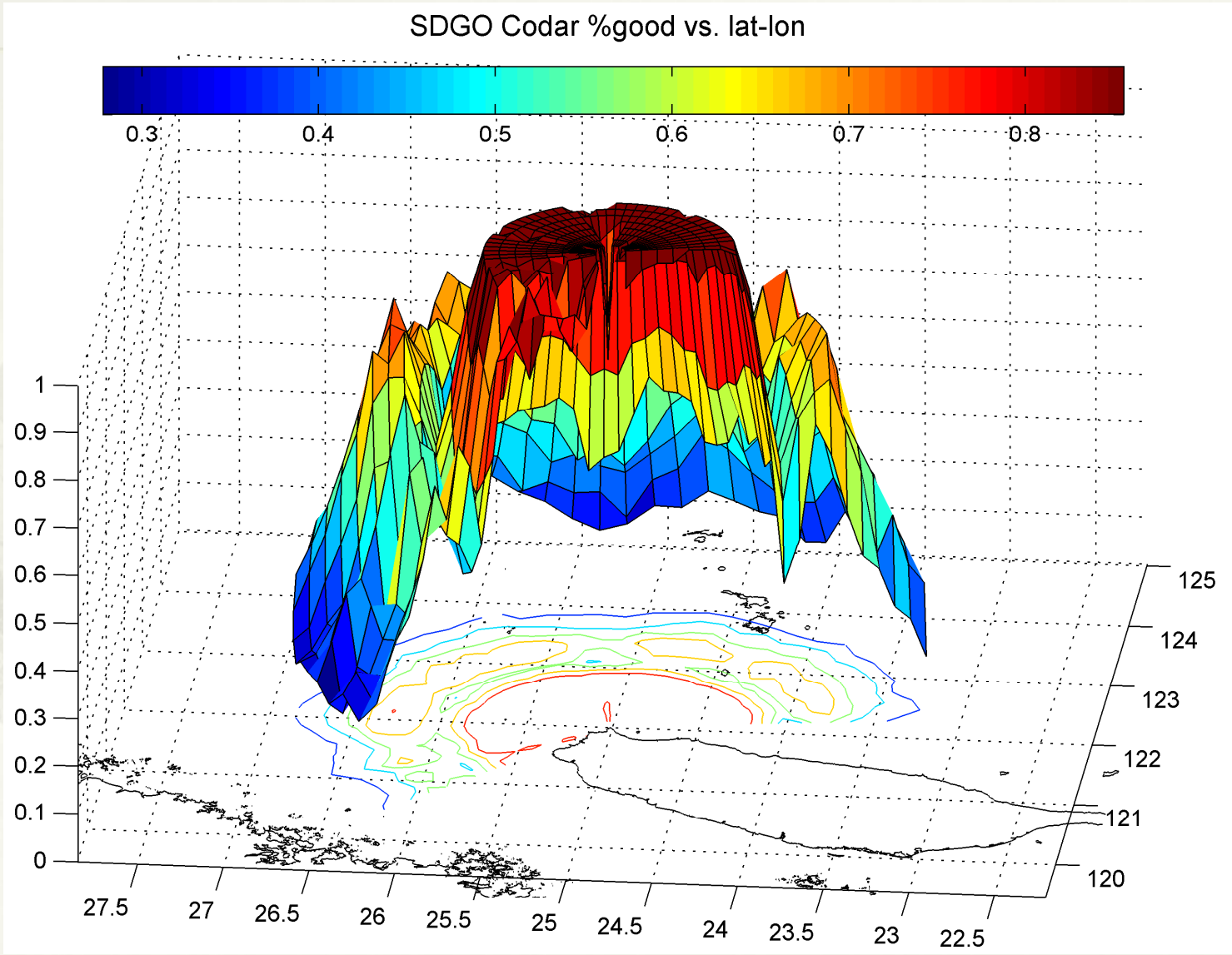
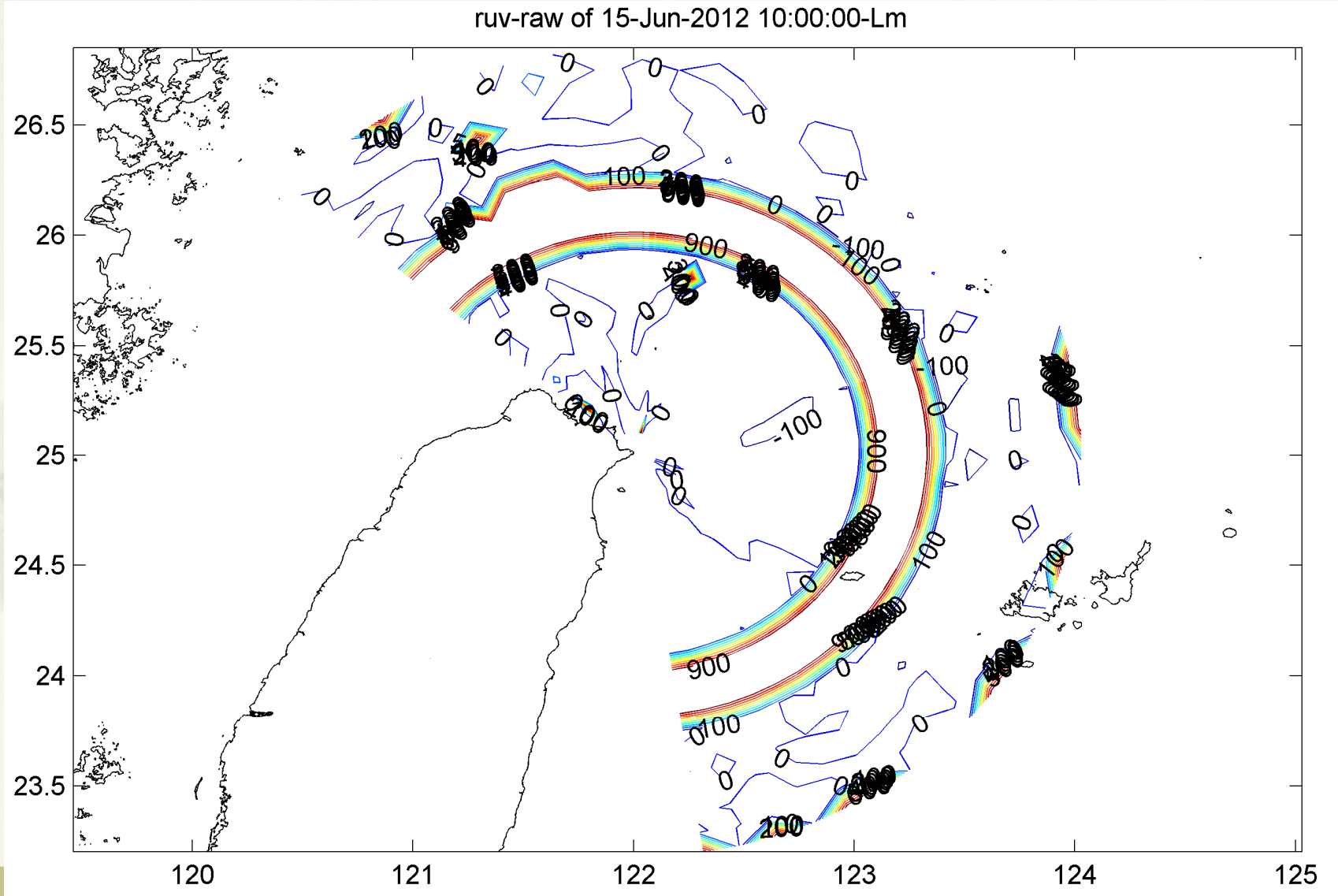
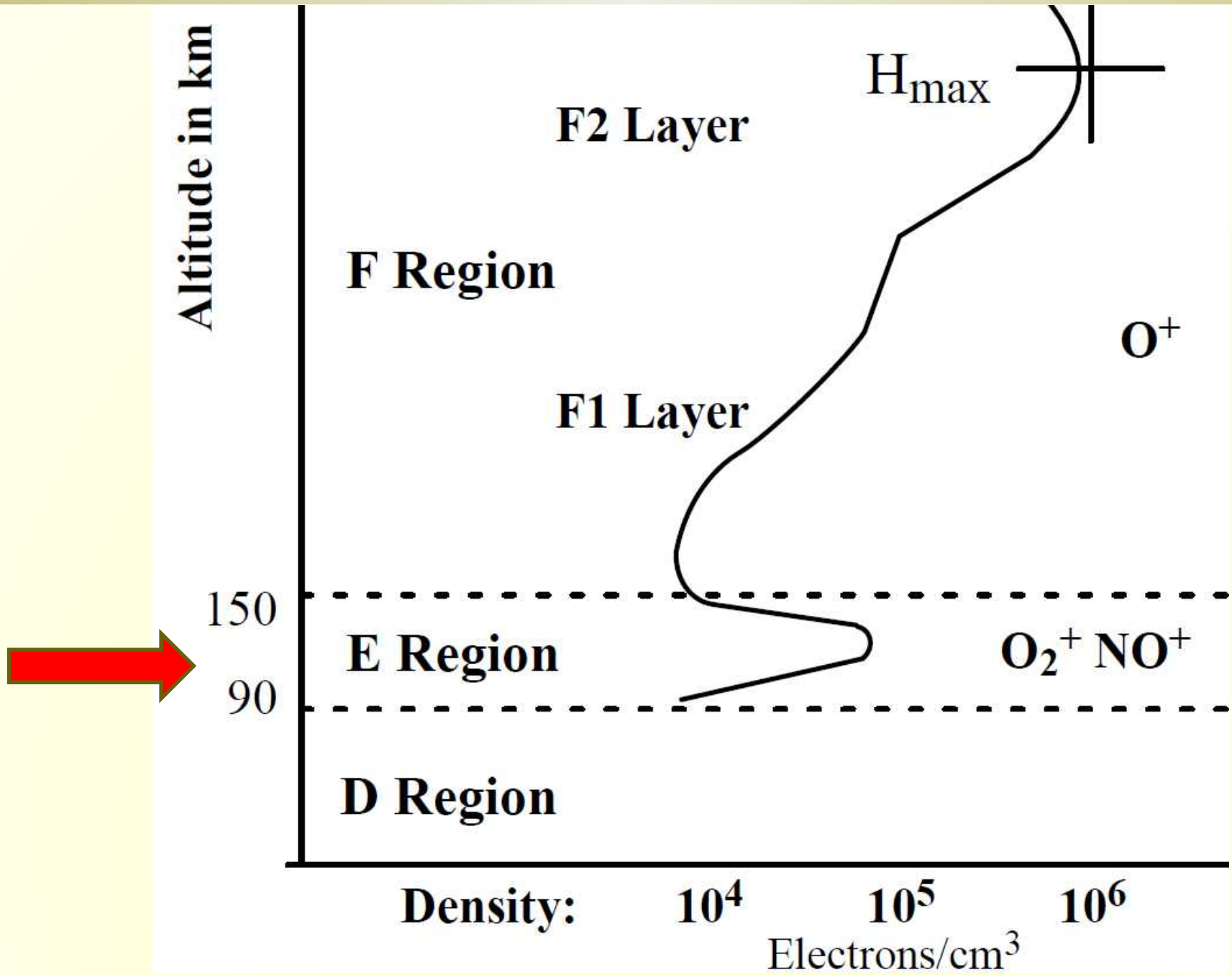
Coverage:10~100km and 140~180 km



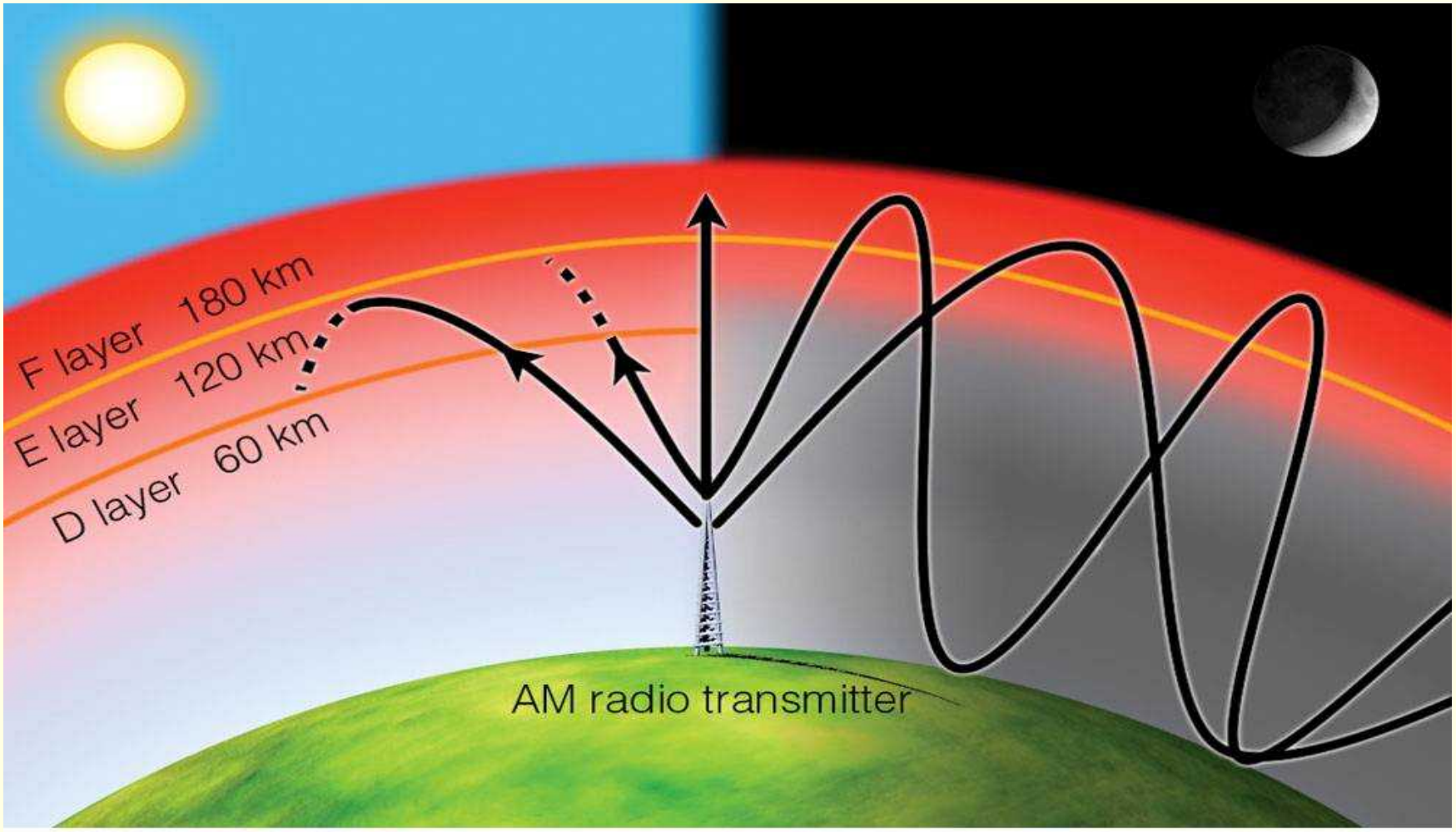
Codar ruv between deploying 4 RIAM buoys

No data regions are red-green contours of large numbers

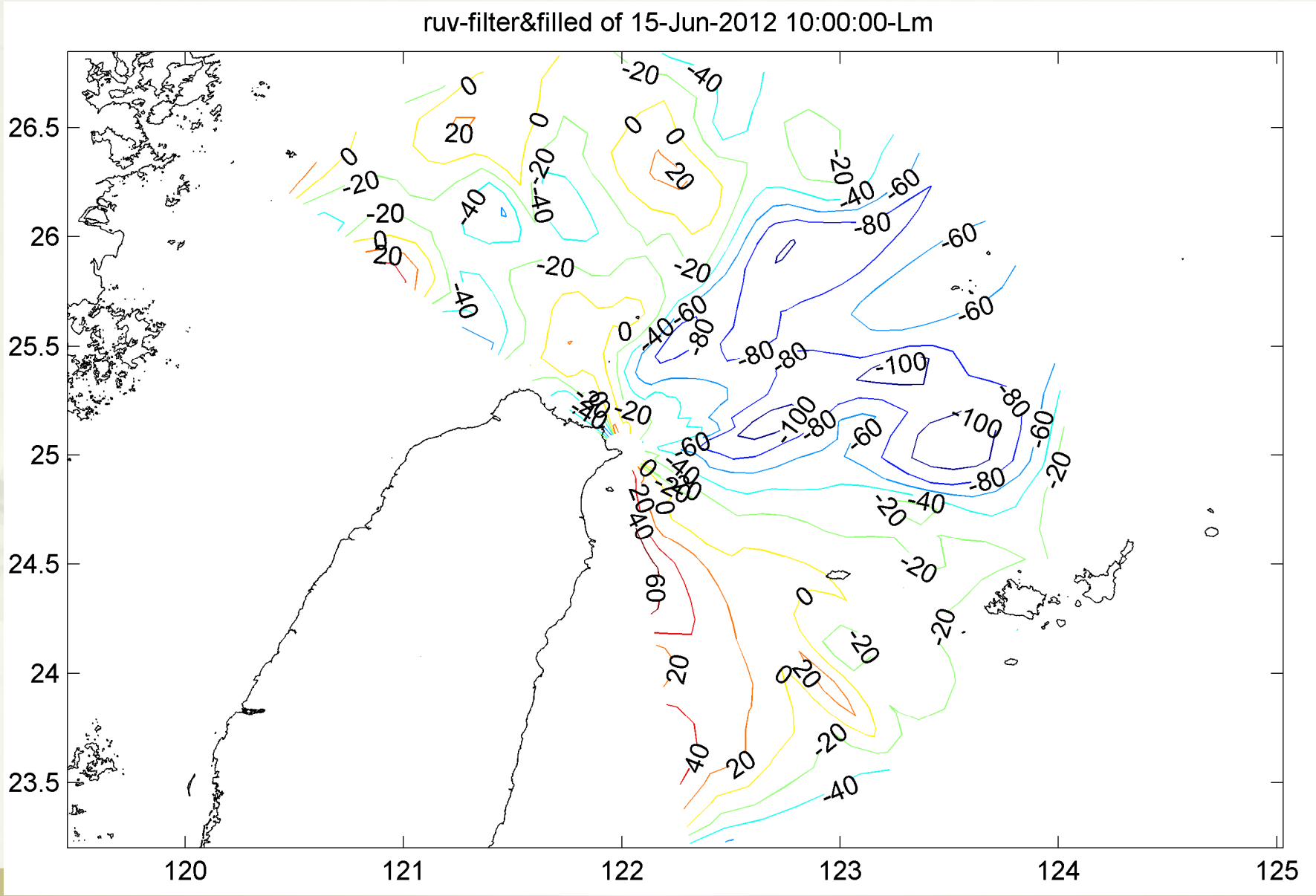



Altitude in km
H_{max}
F2 Layer
F Region
O^+
F1 Layer
150
E Region
O_2^+ NO^+
90
D Region
Density:
10^4
10^5
10^6
Electrons/cm^3

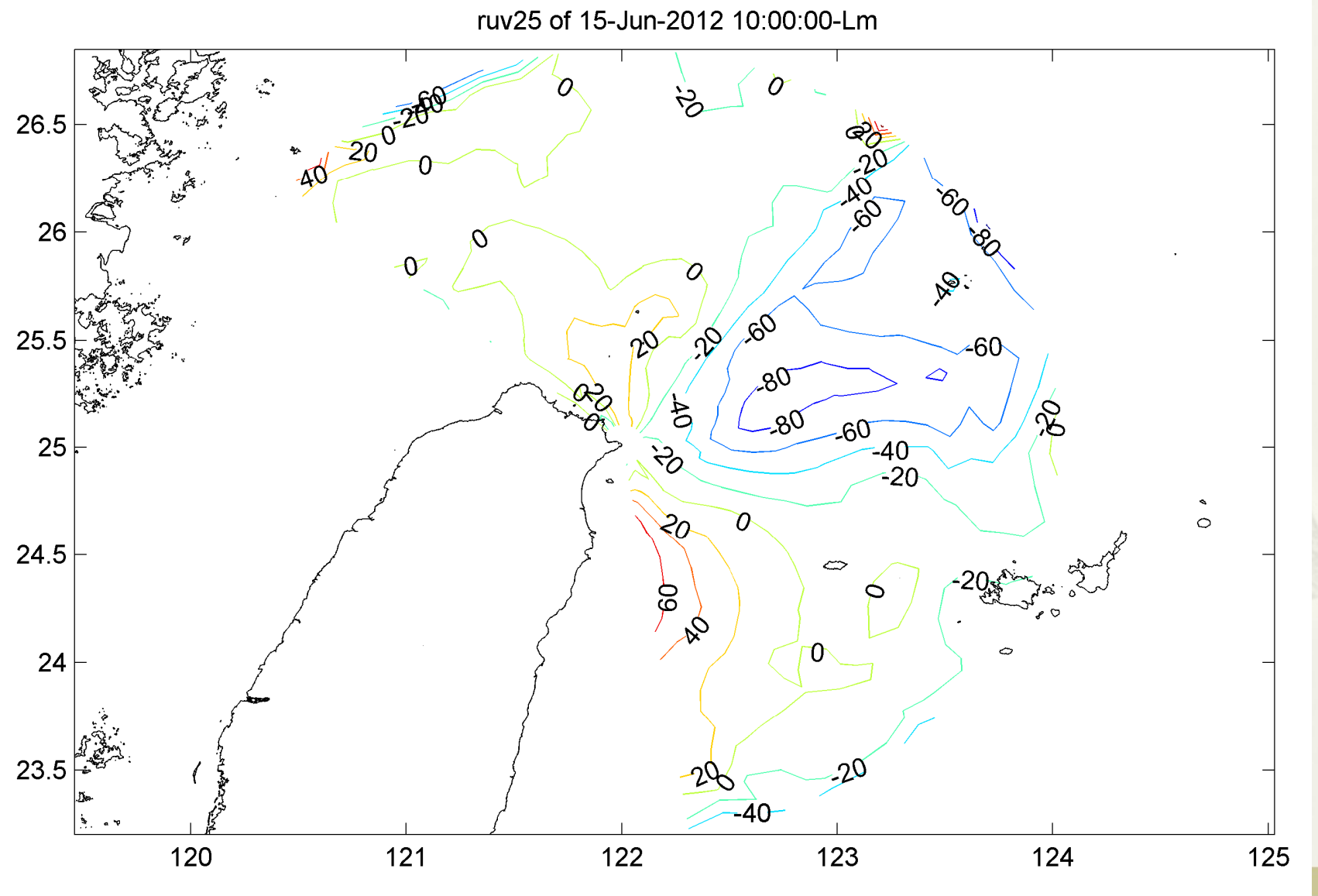
Radio waves from CODAR bounces above 180 km at night



Filtered and filled ruv field

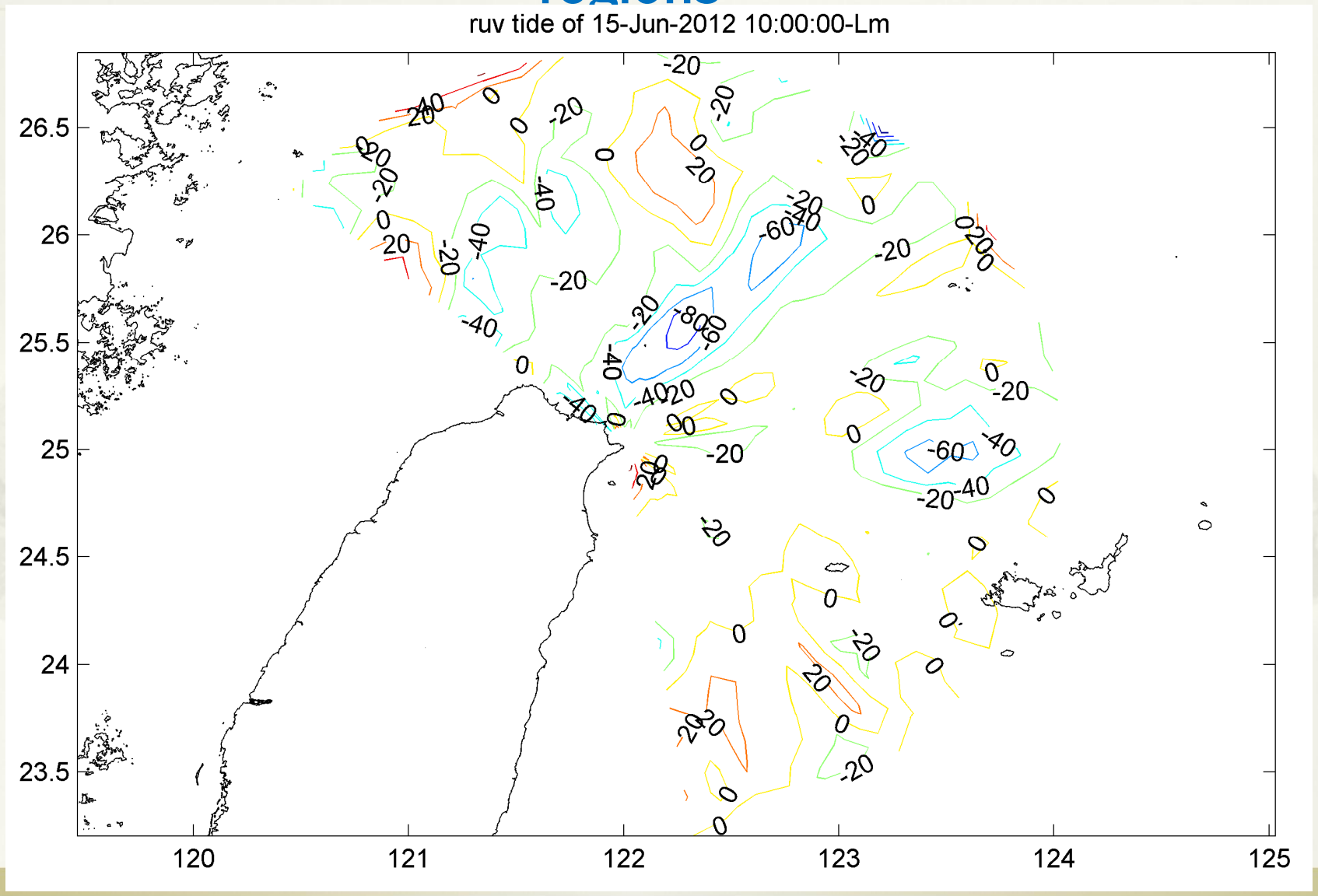


25-hour moving average of ruv



Tidal ruv @2012/6/15 10UTC

tidal ruv is large at shelf break and low %good regions



CODAR has been used more than 30 years, but its accuracy and meaning are constantly under discussion

verification with various buoys

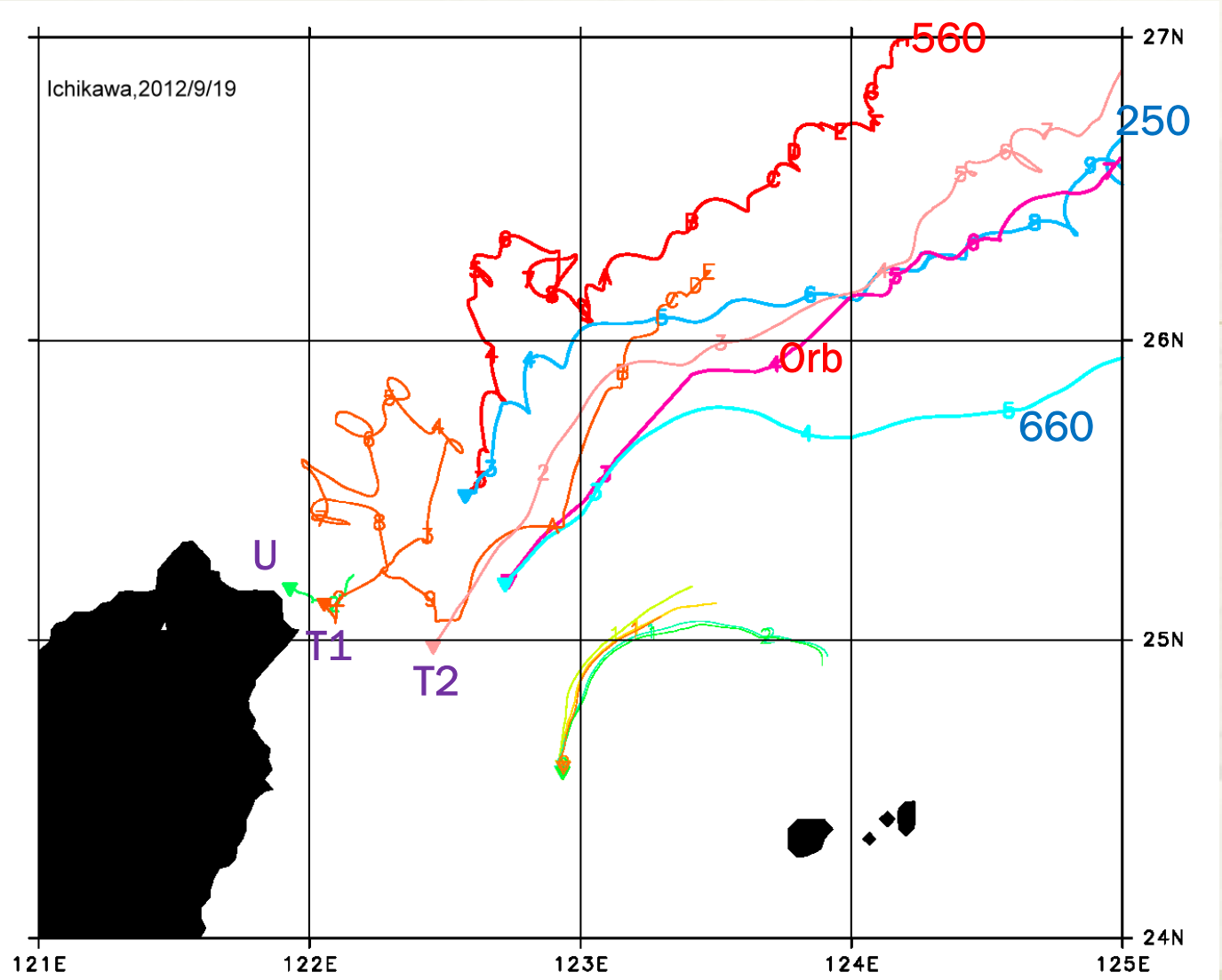
two buoys had drogue at 15 m depth

Three buoys had drogue near surface

Buoys deployed from OR-2

	Taipei time	depth	material	weight
NTU buoy	2012/6/14 10:00	0.5 m	holey bags	0.5 kg @ 1m
TORI-1	2012/6/14 10:38	0.2 m	holey bags	n
TORI-2	2012/6/14 14:16	0.2 m	holey bags	n
Iridium-3560	2012/6/15 14:50	x		
Iridium-5250	2012/6/15 14:46	15 m		
Iridium-1660	2012/6/15 19:27	15 m		
	2012/6/15			

Surface buoys were deployed to verify HF Radar data

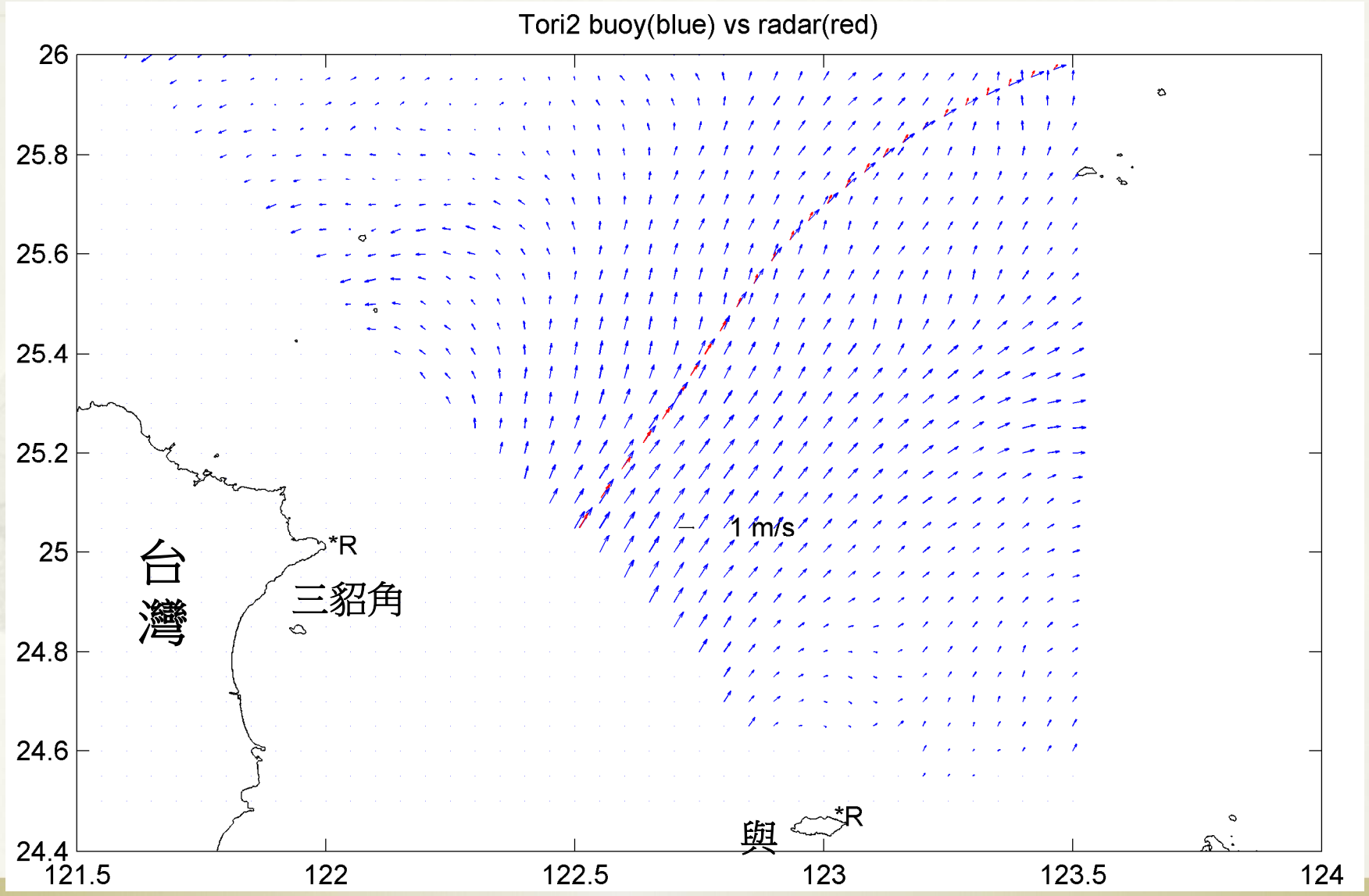


Blue tracks are buoys (250, 660) with drogue@15m

2 buoys (560, Orb) had no drogue co-start with blue track

3 buoys (U, T1 T2, near tw) had drogue at 0.2m ~ 0.5 m

Track of TORI-2 buoy (drogue@0.2m)
TUV from two radar stations



Statistics on ruv of codar & ruv of buoy

ruv from measured AP agrees better with buoy data

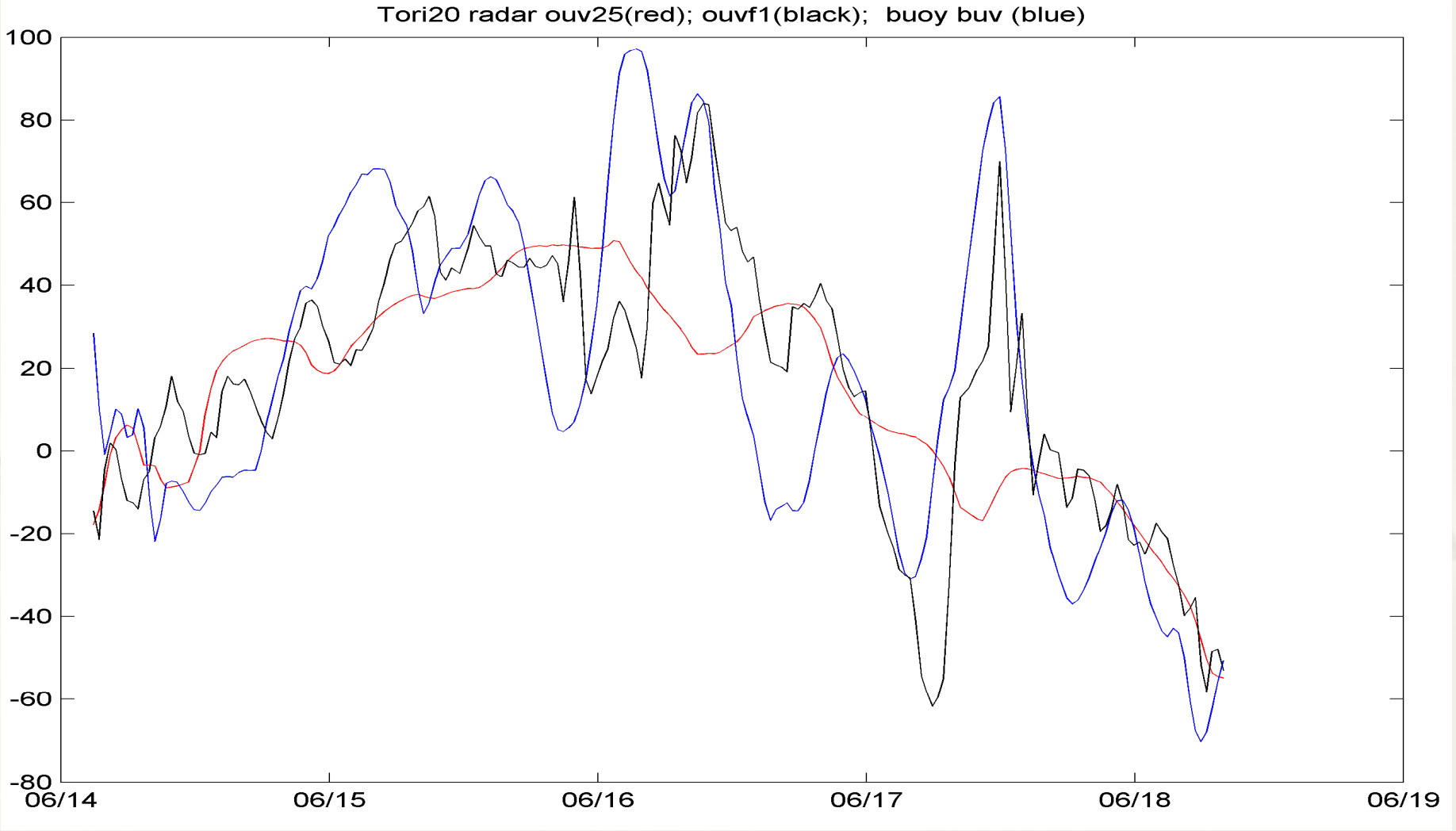
ruv	γ_{codar}(best=1), ratio (best=1), bias (cm/s) (small is better)			
	ideal AP	measured AP	ideal AP	measured AP
	raw	raw	LLP	LLP
NTU buoy	0.665 0.451 7.8	0.879 0.618 2.0	0.664 0.510 5.1	0.897 0.688 -3.6
TORI-1	0.596 0.504 -0.20	0.744 0.602 6.3	0.604 0.797 -4.2	0.715 1.049 -4.6
TORI-2	0.392 0.407 9.2	0.584 0.624 1.3	0.624 1.548 -96.5	0.723 1.919 -124.6
Iridium-3560	0.406 0.422 14.2	0.518 0.484 20.6	0.225 0.686 7.0	0.235 0.732 12.0
Iridium-5250	-0.011 -0.011 35.7	-0.004 -0.003 42.1	-0.335 -0.650 63.8	-0.385 -0.691 71.8
Iridium-1660	-0.024 -0.021 40.8	0.366 0.387 8.2	0.586 1.551 -112.2	0.614 1.789 -125.7
Orbcomm	0.595 0.433 2.6	0.828 0.768 -22.1	0.769 1.140 -73.8	0.774 1.171 -67.4

Statistics on ruv of codar & buoy

comparing raw data of ruv is better than 25-hr mean LLP

best	ruv γ_{codar}(best=1), ratio (best=1), bias (cm/s) (small is better)					
2nd		measured AP			measured AP	
		raw			LLP	
NTU buoy	0.5	0.879	0.618	2.0	0.897	0.688 -3.6
TORI-1	0.2	0.744	0.602	6.3	0.715	1.049 -4.6
TORI-2	0.2	0.584	0.624	1.3	Too far	0.723 1.919 -124.6
Iridium-3560	0	0.518	0.484	20.6	Wind?	0.235 0.732 12.0
Iridium-5250	15	-0.004	-0.003	42.1		-0.385 -0.691 71.8
Iridium-1660	15	0.366	0.387	8.2	Too far	0.614 1.789 -125.7
Orbcomm	0	0.828	0.768	-22.1	Wind?	0.774 1.171 -67.4

Outward speed of Tori-1 buoy (blue), codar_hour (black), codar_25hr (red)



Conclusion (1) on buoy experiment

1. The correlation between CODAR ruv and buoy ruv is
   worst for drogue at 15 m depth;
   better with no drogue
   best with drogue at 0.2 ~ 0.5 m; high correlation, low bias

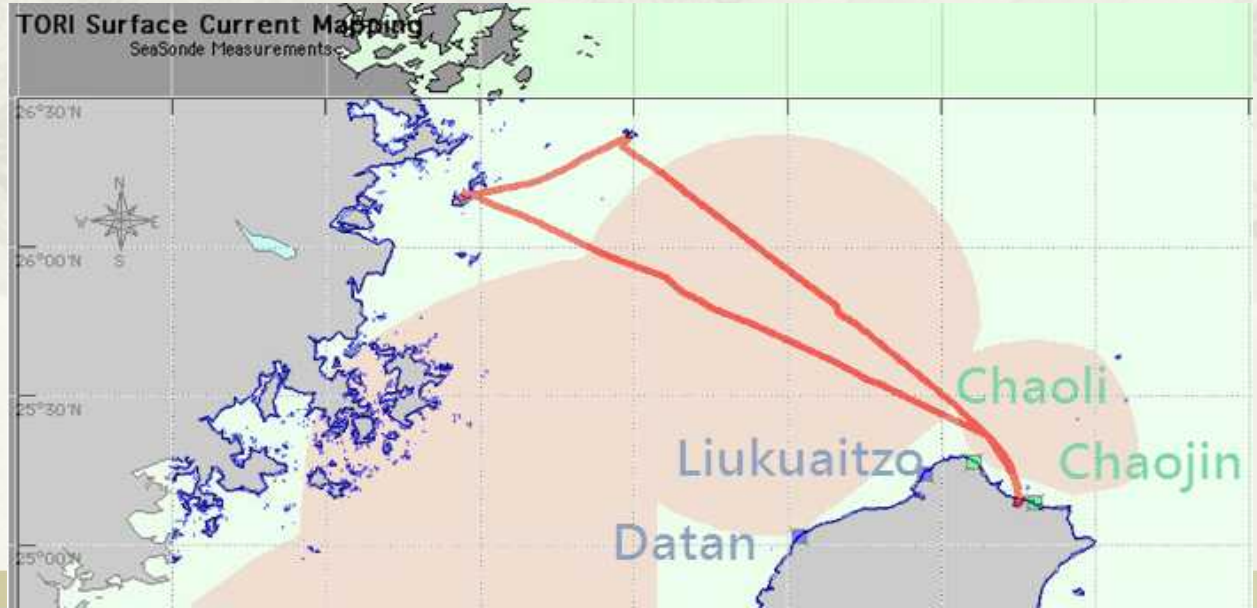
2. Comparing raw data is better than comparing 25-hr mean data;
   probably due to insufficient length of data for 25-hr smoothing

3. Wind effect on buoy without drogue may deteriorate their
   correlation with CODAR ruv;

4. Buoy data is point-wise instant data, while CODAR data is 3 hour
   mean and 10 km by 5-degree azimuth average data;
   they are intrinsically different, therefore they will never be the
   same

2012/3/21~4/21 Ferry ADCP observed current velocity in Taiwan Strait

* Taima ferry ADCP (ship track)
  * 300 kHz bin size:2m 1st bin Mid:-5m
* TORI CODAR stations at LIUK & DATN)
  * 4.5 MHz Long range



Ferry $\underline{U}_{ADCP}$ in Taiwan Strait, 2012/3/21~4/21

ADCP 1st bin $\underline{U}$

↓

$\underline{U}_{adcp}$ =
1 hr average of $\underline{U}$

↓

D=1 hr ship track

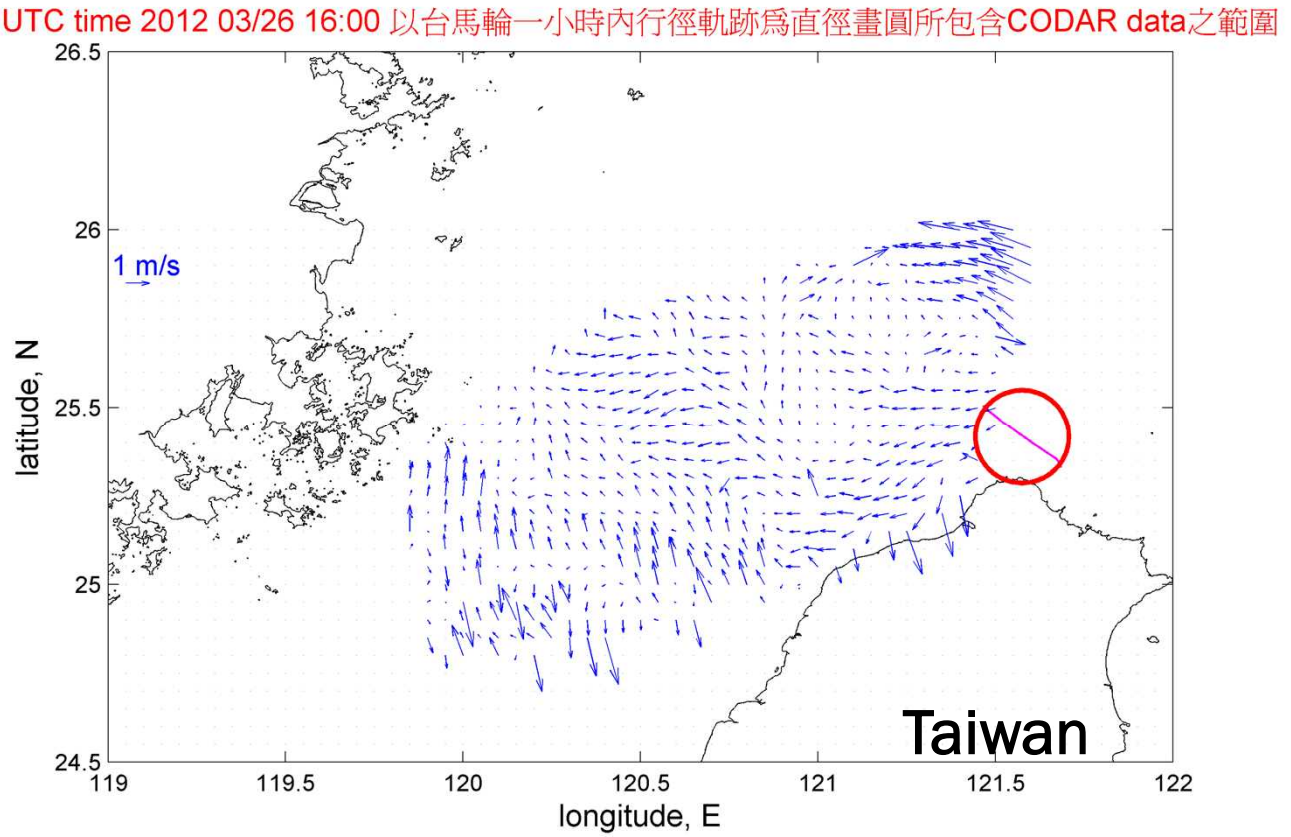
A circle with dia. D

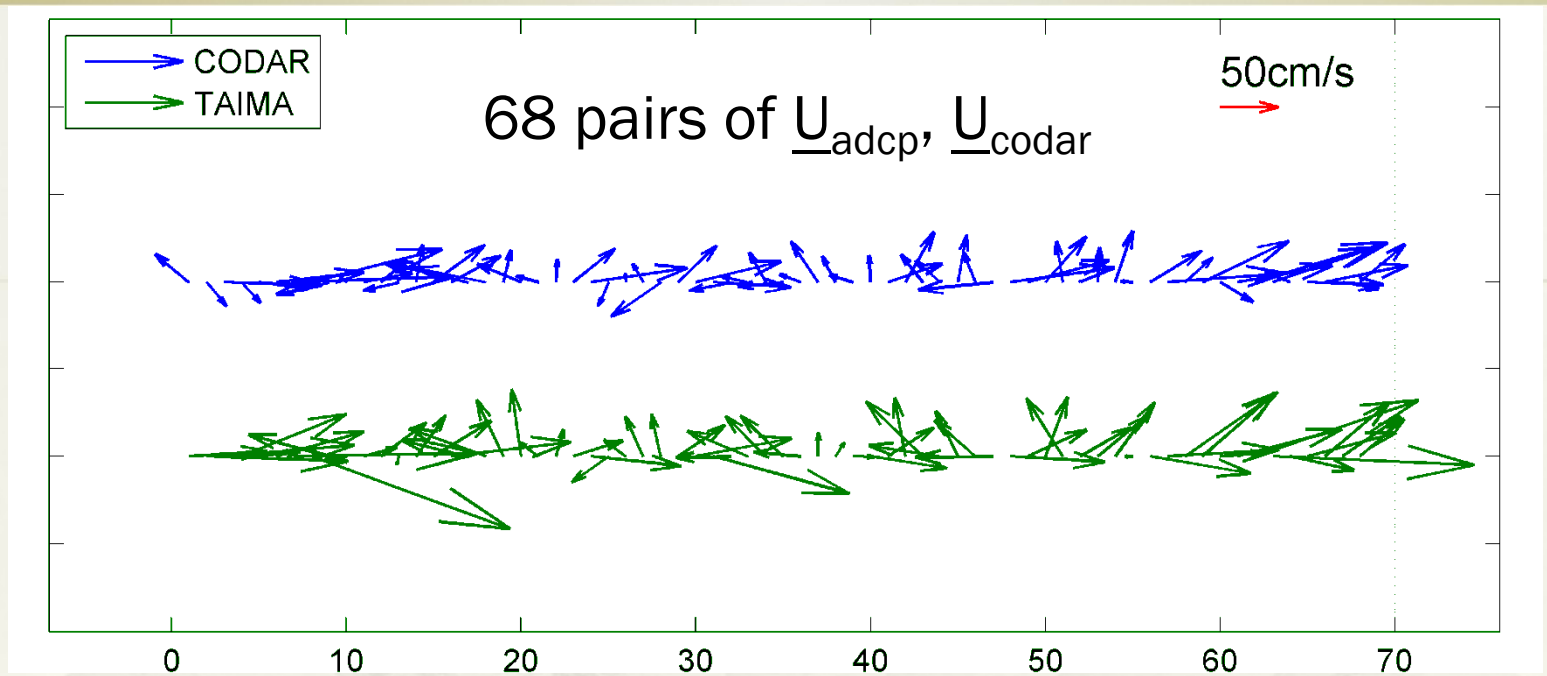
↓

$\underline{U}_{codar}$ = 1 hr average of CODAR data

↓

Compare $\underline{U}_{adcp}$, $\underline{U}_{codar}$

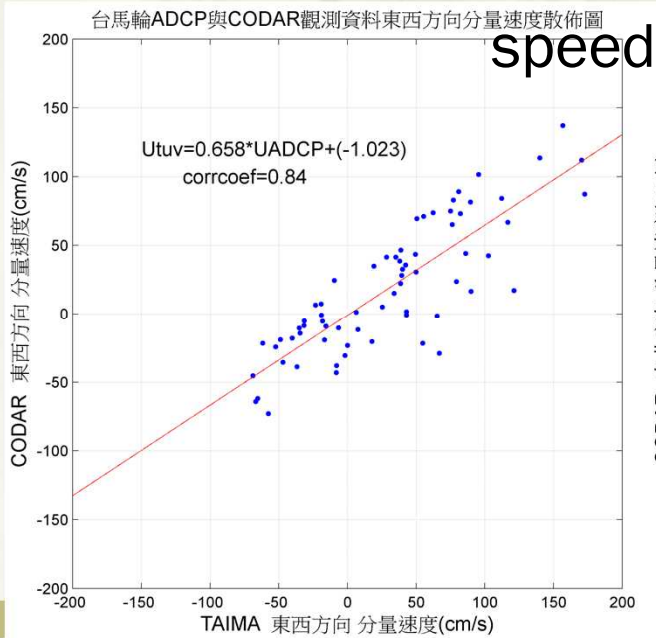


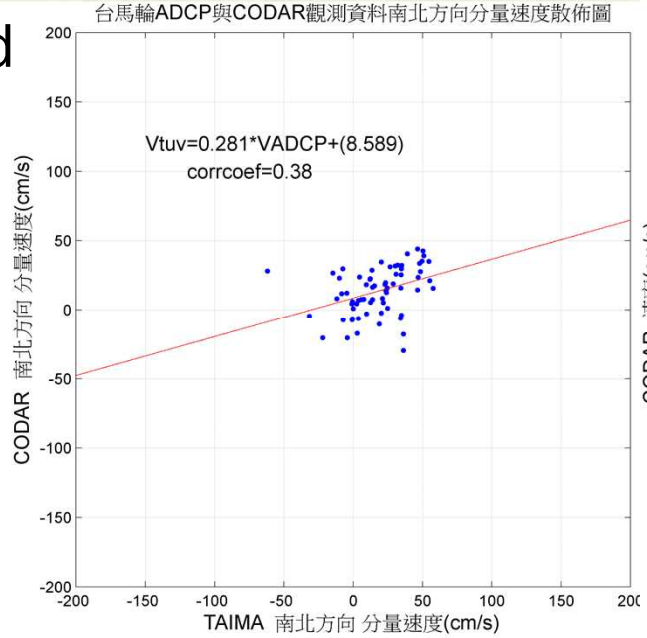


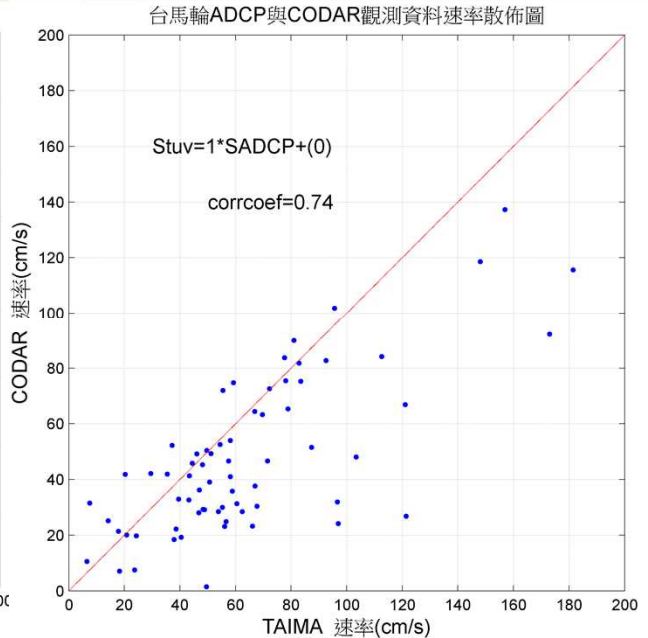
East u

North, v

speed





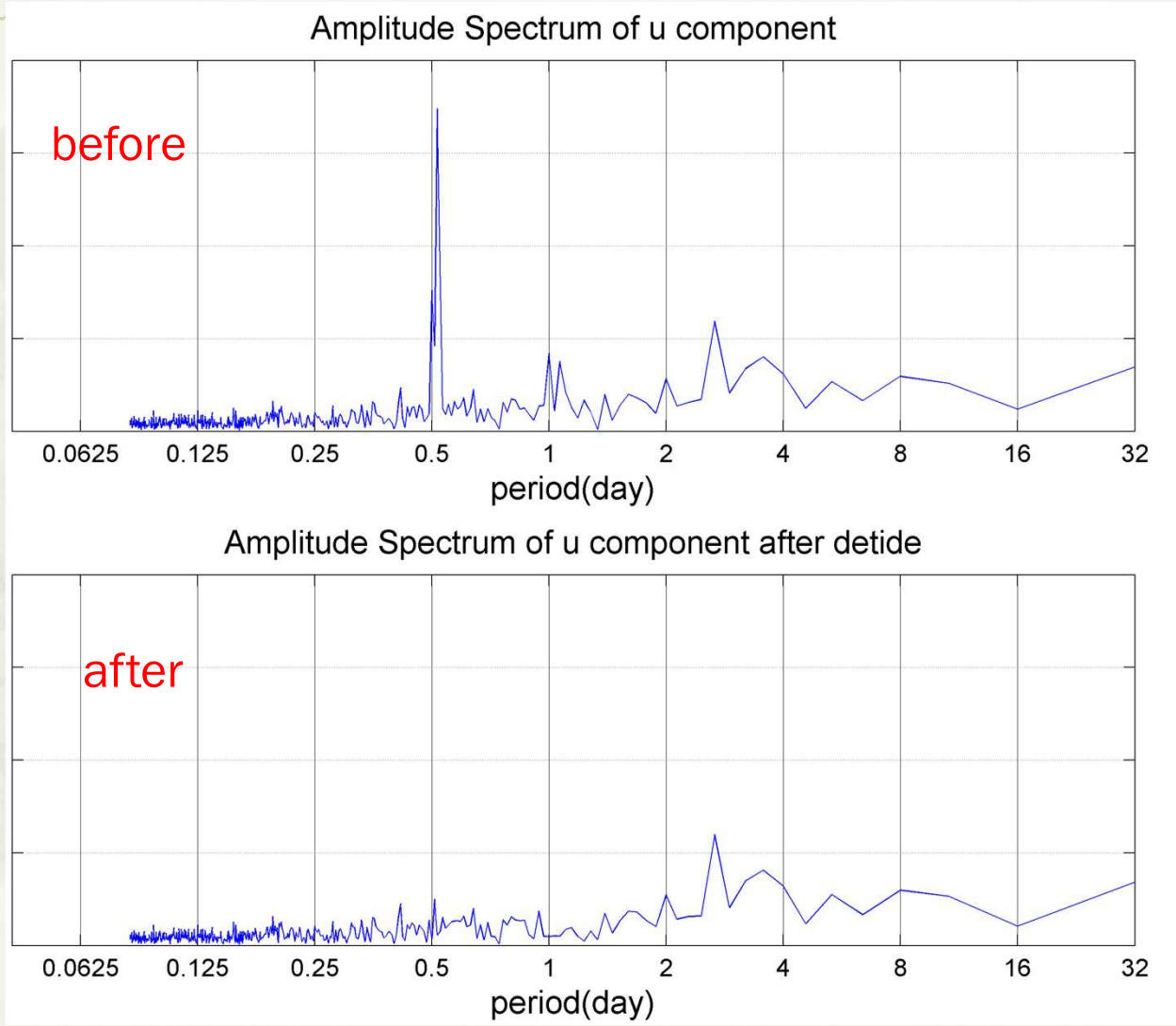


Ferry $\underline{U}_{ADCP}$ in Taiwan Strait, 2012/3/21~4/21

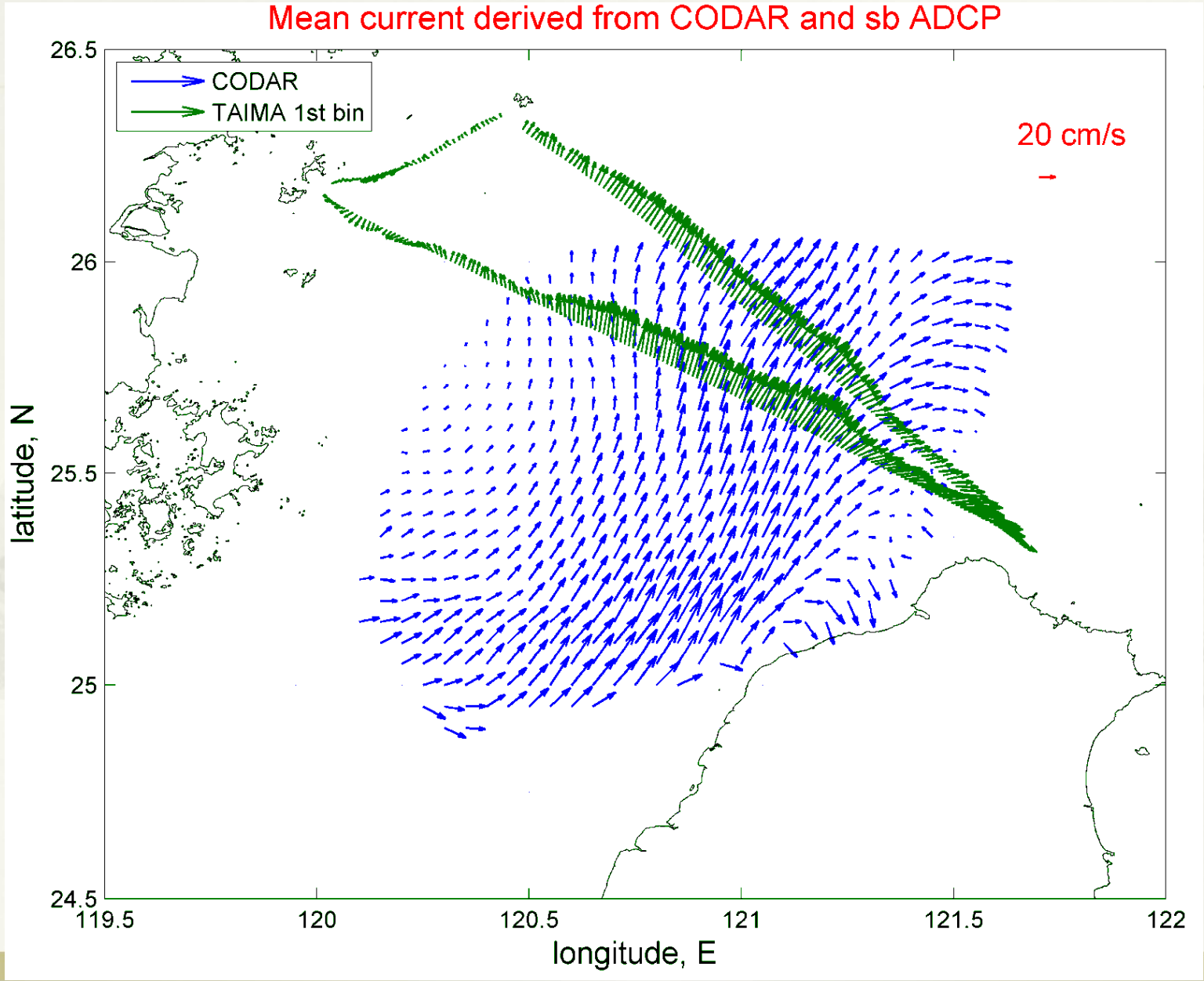
* Detide

$\underline{U}_{adcp}$, is detided with TPXO BT tidal model (Egbert et al., 2002; they use altimeter data of TOPEX /Poseidon to derive the regional tidal constituents)

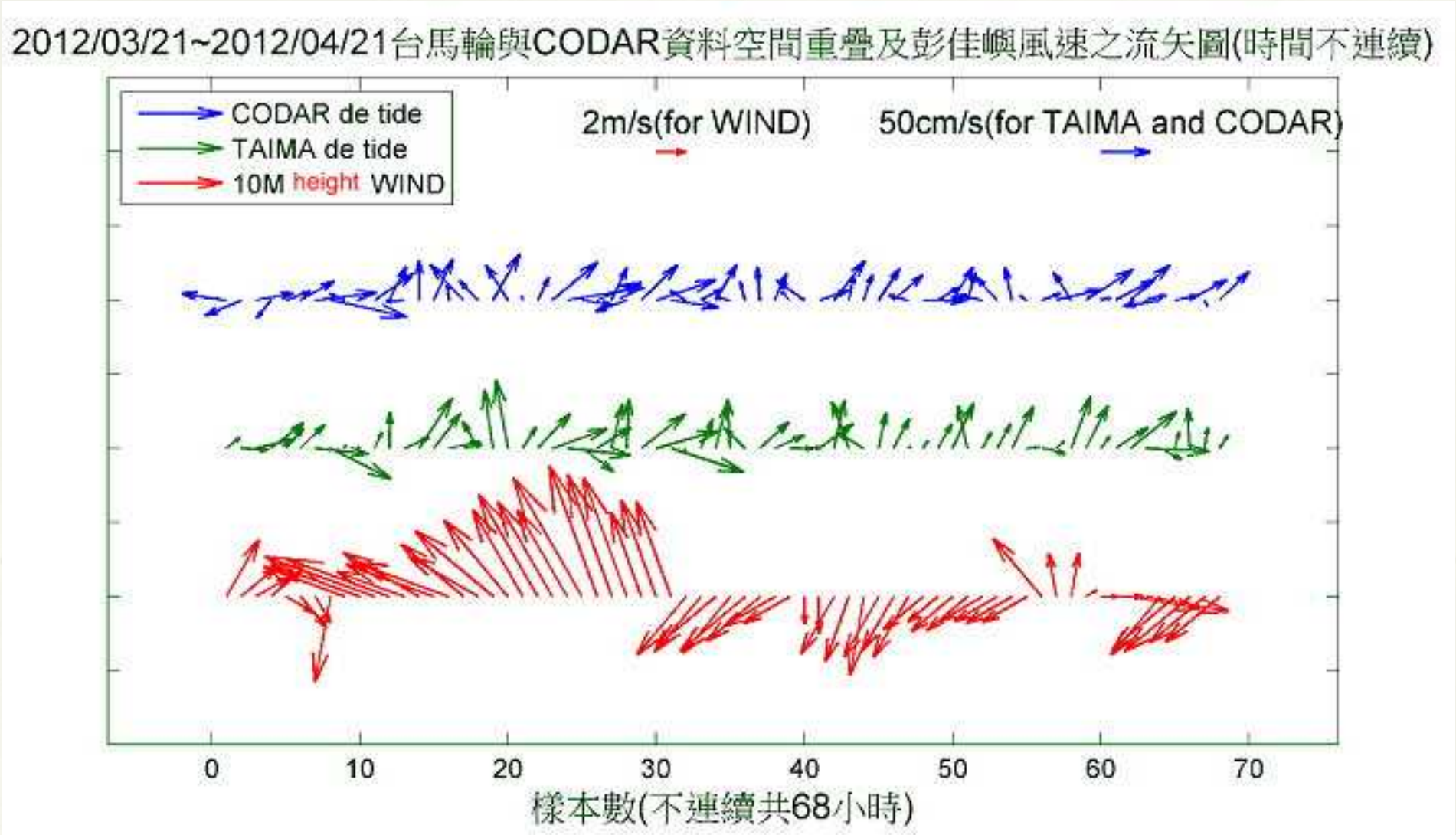
$\underline{U}_{codar}$ is detided with t_tide.m (Pawlowicz et al.)



Ferry $\underline{U}_{ADCP}$ in Taiwan Strait, 2012/3/21~4/21



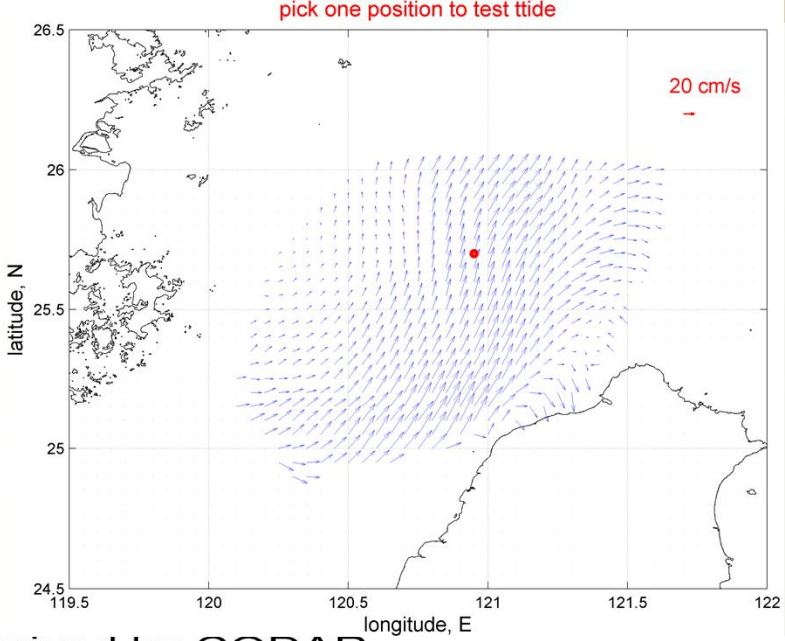
Ferry $\underline{U}_{ADCP}$ in Taiwan Strait, 2012/3/21~4/21

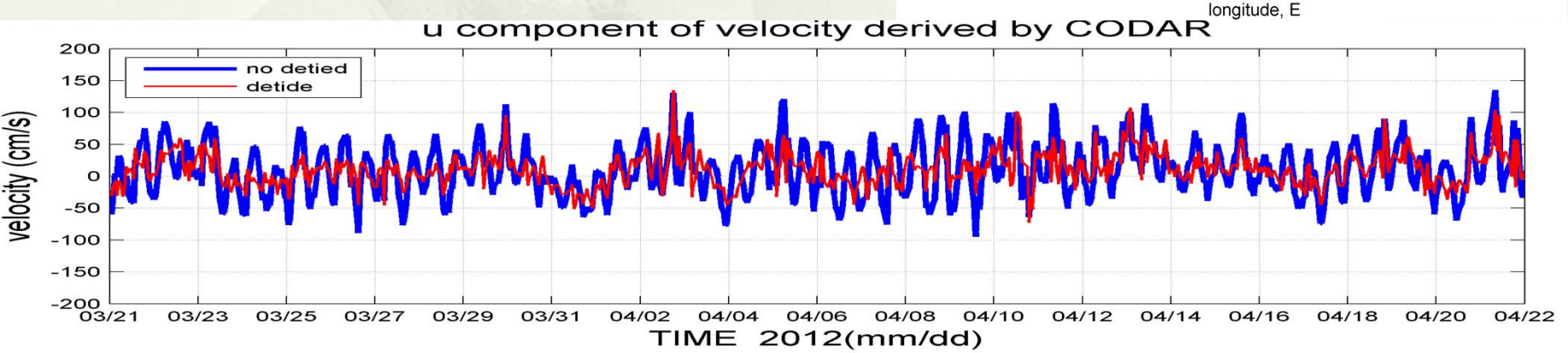


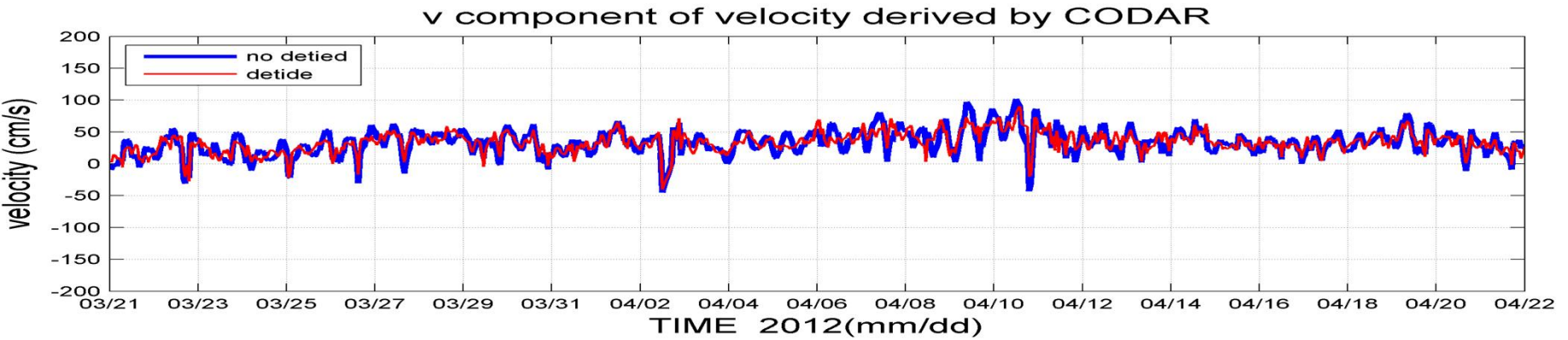
Ferry U_{ADCP} in Taiwan Strait, 2012/3/21~4/21

- CODAR vs wind data

LON 120.95 LAT 25.7

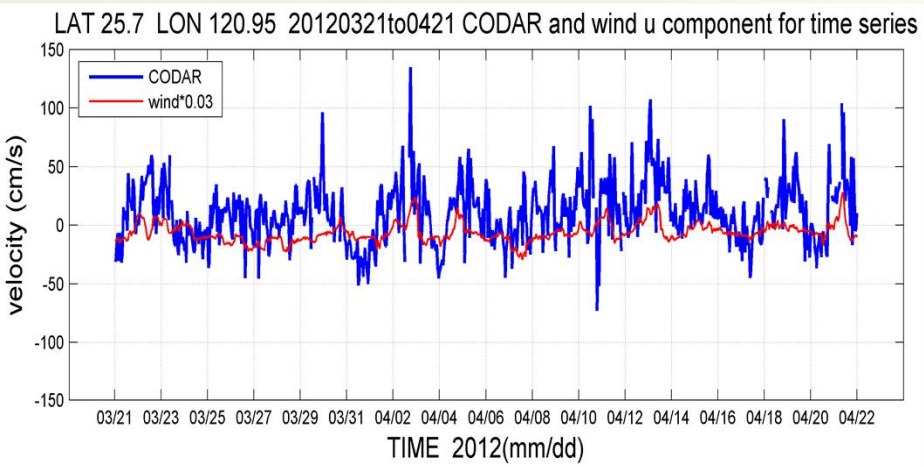


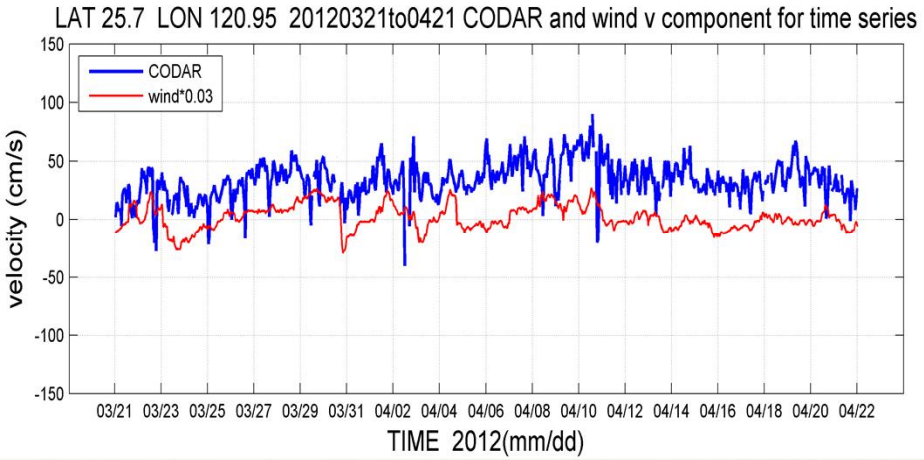




Ferry $\underline{U}_{ADCP}$ in Taiwan Strait, 2012/3/21~4/21

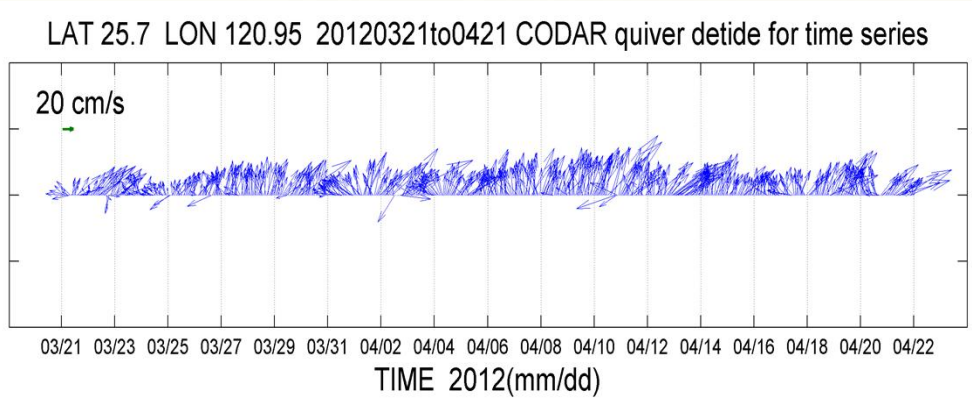
East velocity

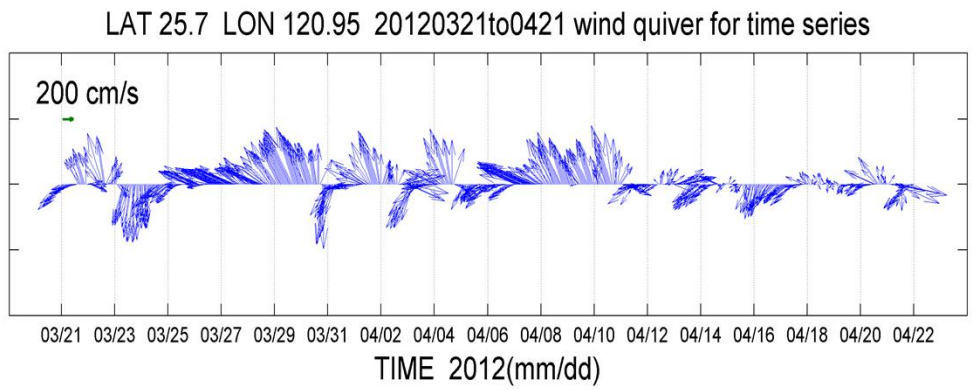




North velocity

U from CODAR

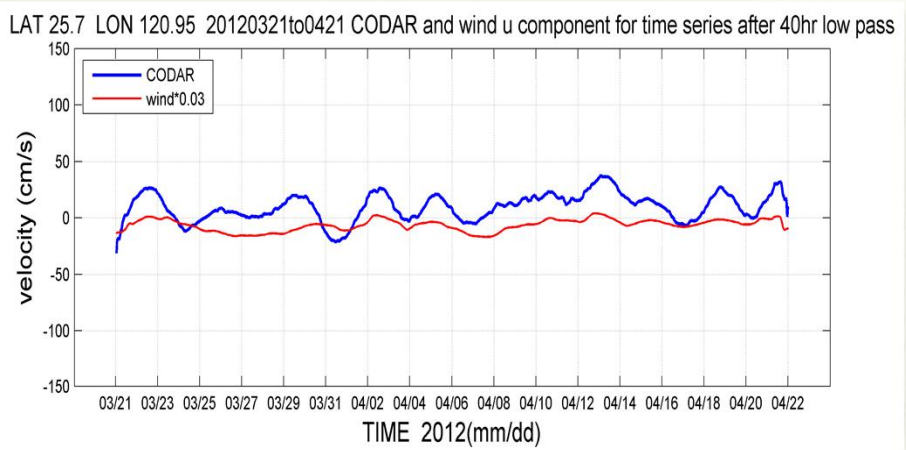


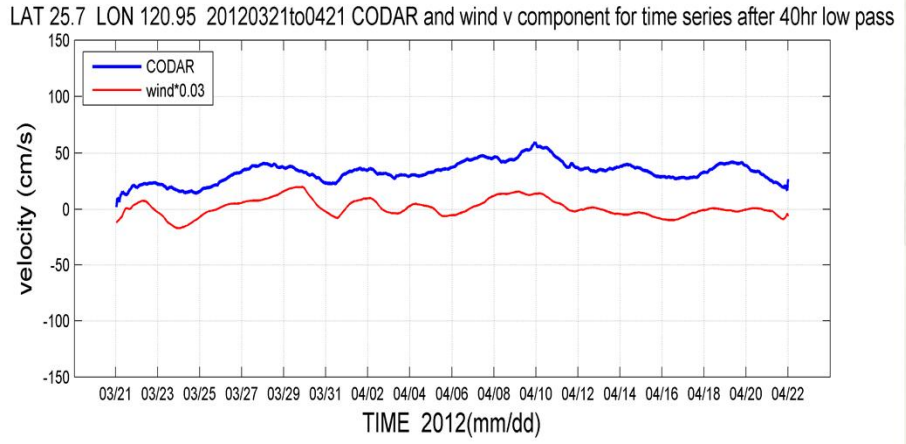


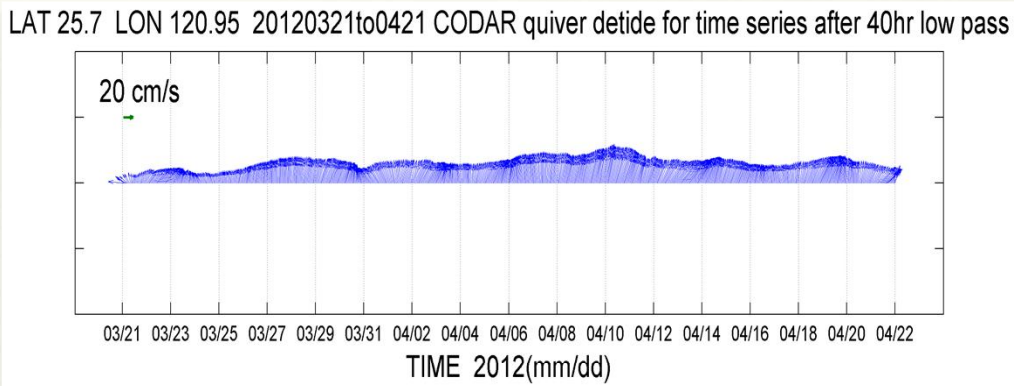
Wind velocity

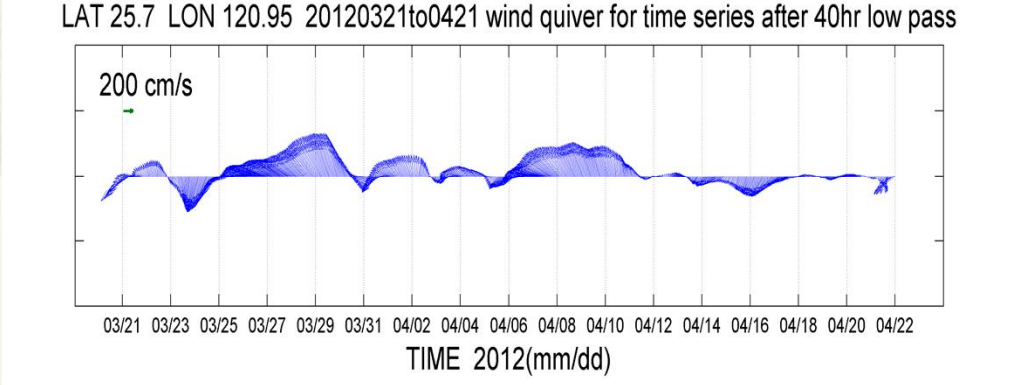
Ferry $\underline{U}_{ADCP}$ in Taiwan Strait, 2012/3/21~4/21

With 40 hour low low pass





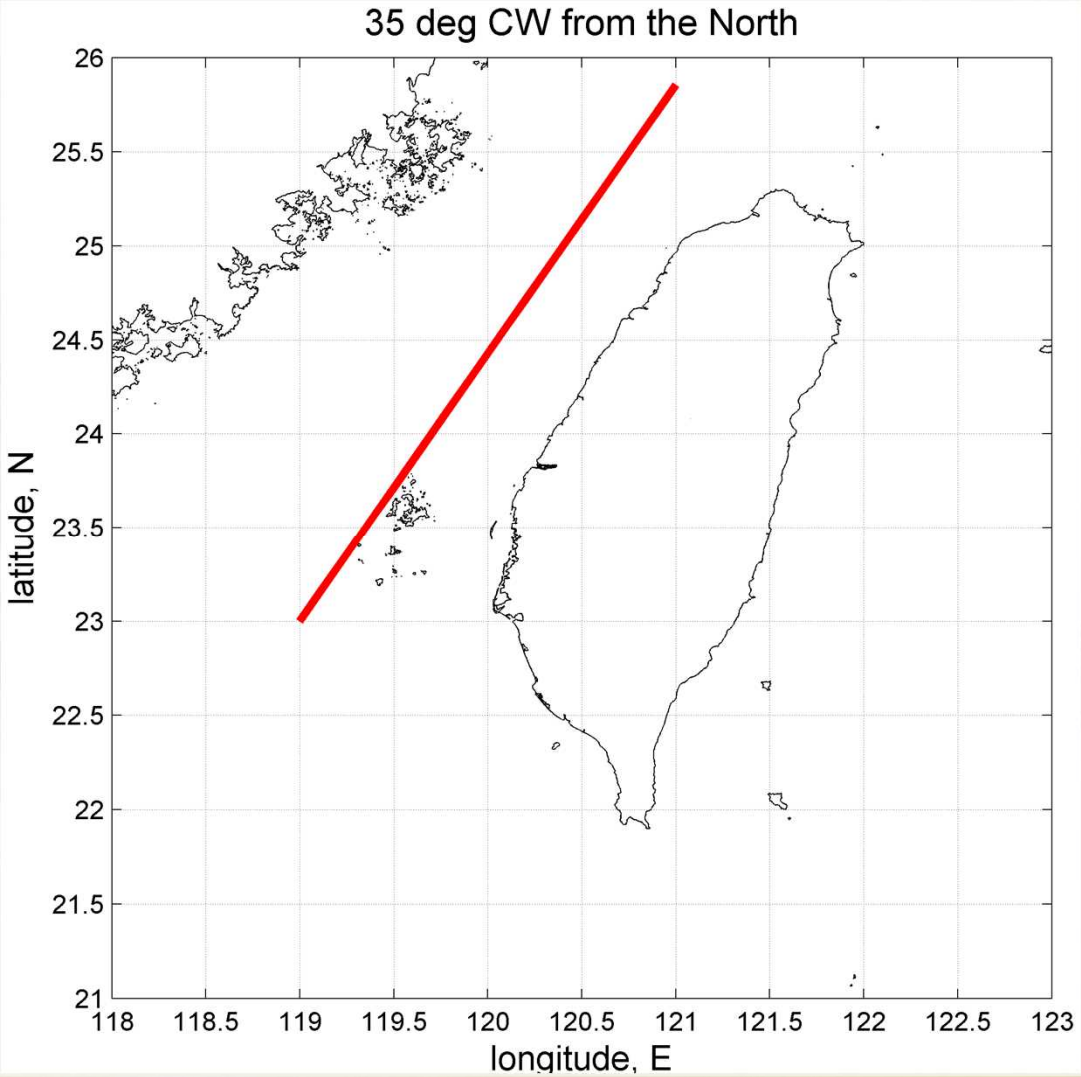




Ferry $\underline{U}_{ADCP}$ in Taiwan Strait, 2012/3/21~4/21

Volume transport Q through Taiwan Strait has good correlation with the along-strait (35 degree clockwise from North) wind W_{as};

compare the along-strait current velocity U_{as} with W_{as}



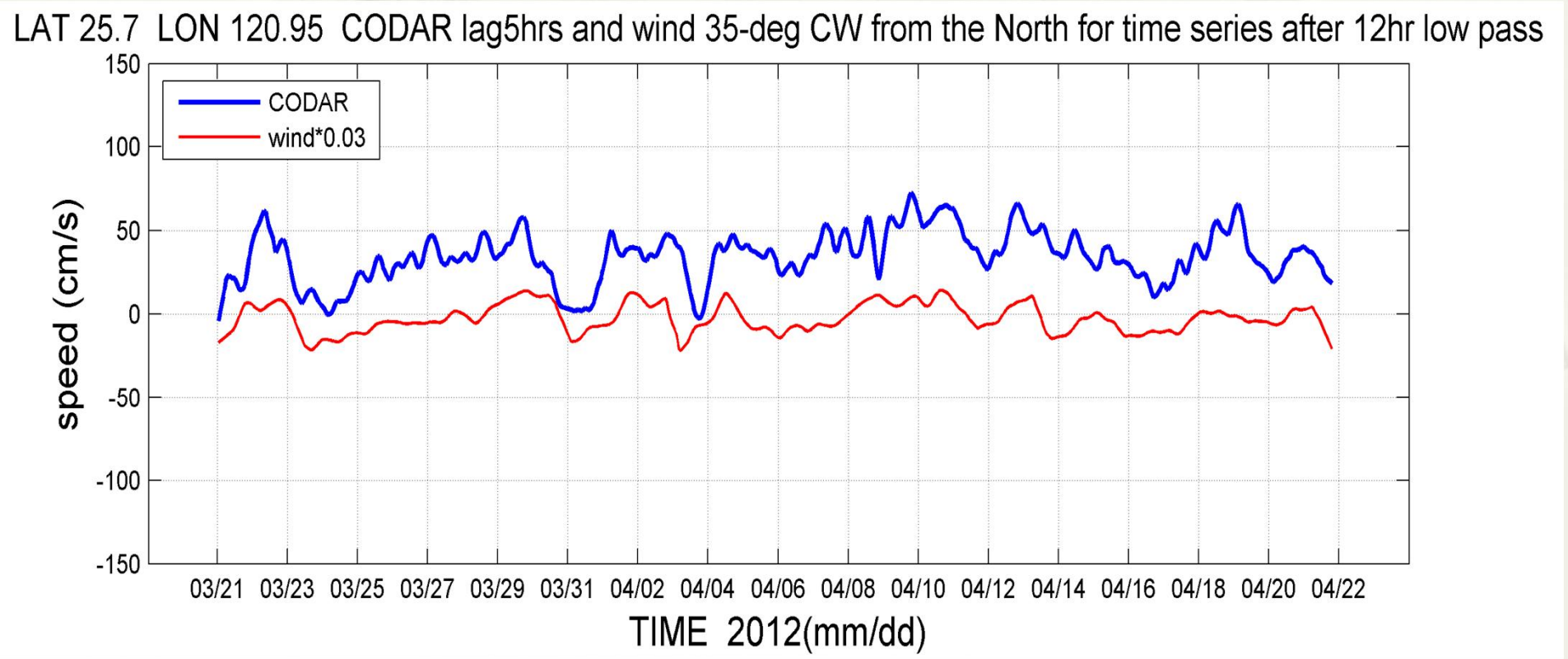
Ferry U_{ADCP} in Taiwan Strait, 2012/3/21~4/21

Correlation between U_{as} and W_{as} as a function of lag time (hour)

Lag (hr) ¥ month	1	2	3	4	5	6	7	8	9	10	11	12
0	NaN	0.35	0.34	0.41	0.36	0.42	0.46	0.52	0.54	0.57	0.58	0.59
1	NaN	0.35	0.34	0.41	0.37	0.44	0.47	0.54	0.55	0.58	0.59	0.61
2	NaN	0.35	0.34	0.42	0.38	0.44	0.48	0.55	0.57	0.59	0.60	0.62
3	NaN	0.35	0.34	0.42	0.39	0.45	0.49	0.56	0.58	0.60	0.61	0.63
4	NaN	0.35	0.33	0.42	0.40	0.45	0.49	0.56	0.58	0.61	0.62	0.64
5	NaN	0.34	0.33	0.42	0.39	0.45	0.49	0.56	0.59	0.61	0.62	0.64
6	NaN	0.34	0.33	0.42	0.40	0.45	0.50	0.57	0.59	0.61	0.63	0.64
7	NaN	0.34	0.33	0.42	0.40	0.45	0.49	0.56	0.59	0.61	0.62	0.64
8	NaN	0.34	0.33	0.42	0.40	0.46	0.51	0.56	0.58	0.60	0.62	0.63
9	NaN	0.35	0.34	0.42	0.40	0.46	0.50	0.56	0.58	0.60	0.61	0.63
10	NaN	0.36	0.34	0.42	0.40	0.46	0.49	0.55	0.57	0.59	0.60	0.62
11	NaN	0.35	0.34	0.42	0.40	0.46	0.49	0.54	0.56	0.58	0.59	0.60
12	NaN	0.34	0.33	0.41	0.40	0.45	0.48	0.52	0.54	0.56	0.57	0.58

Ferry $\underline{U}_{ADCP}$ in Taiwan Strait, 2012/3/21~4/21

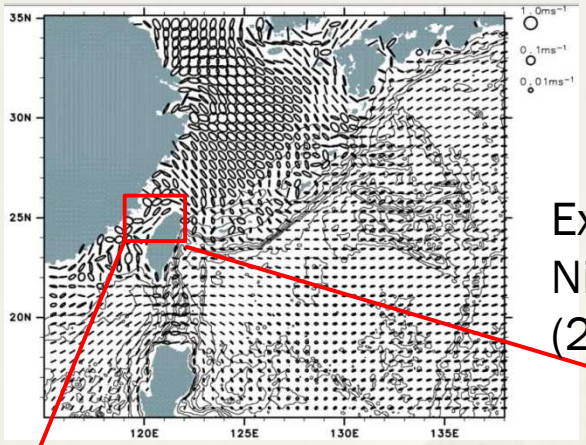
Tidal current in Taiwan Strait is dominated by semi-diurnal tide, the following show that after 12-hr moving average, the wind is slightly ahead of the current from CODAR data



Tidal analysis

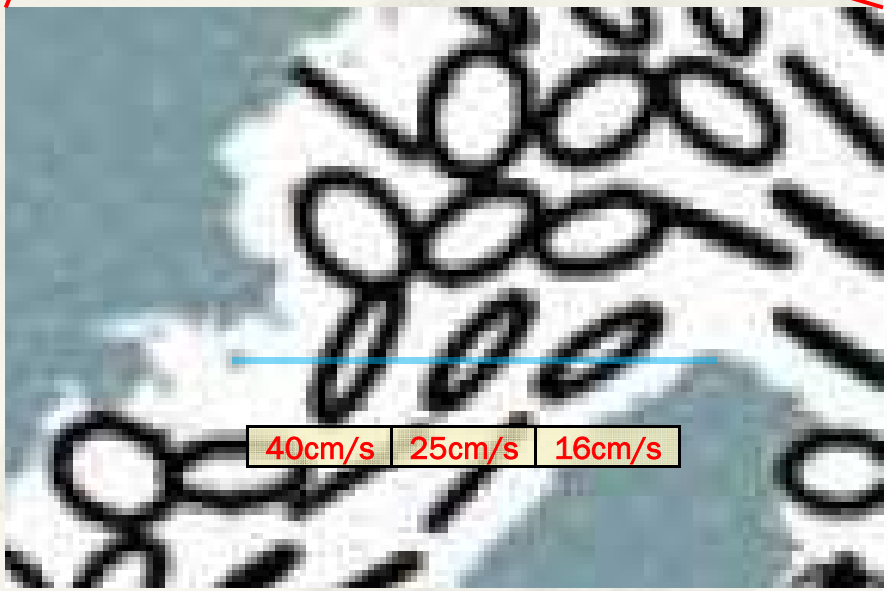
- Mean current varies with the wind and general circulation;
  noises are unpredictable
- Only tidal current that is nearly invariable through out the year
- Comparing the tidal ellipse (amplitude and phase) of tidal constituents is a good measure on the accuracy and reliability of the current velocity from CODAR

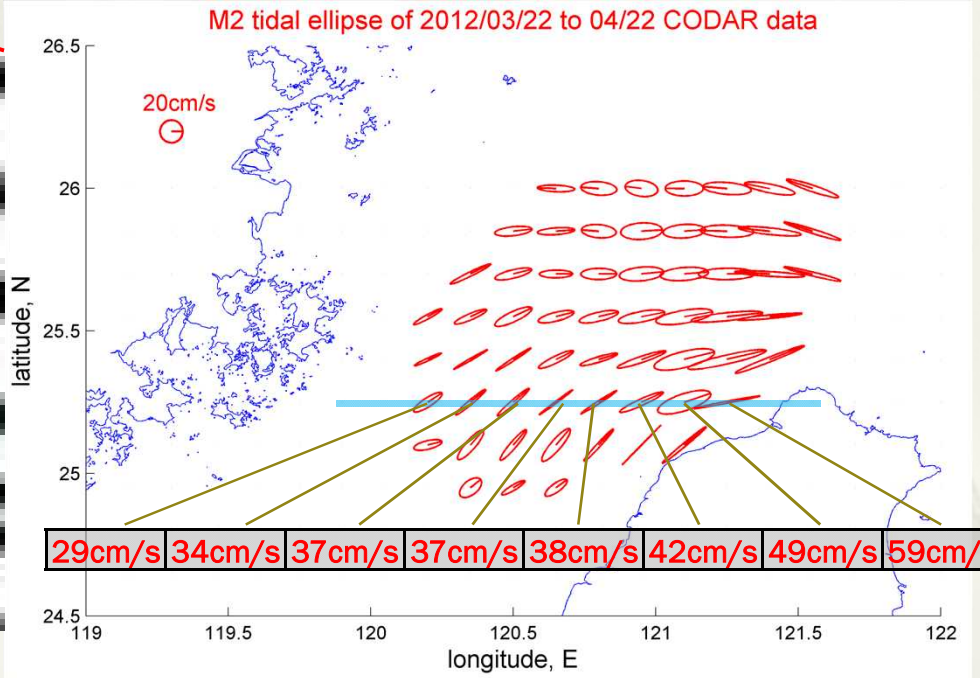
Ferry $\underline{U}_{ADCP}$ in Taiwan Strait, 2012/3/21~4/21



Extract from Niwa & Hibiya (2004)

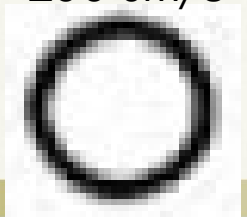
M2 tidal ellipse from CODAR and from tidal model



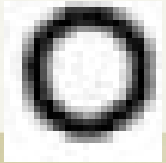


M2 tidal ellipse from CODAR data

100 cm/s



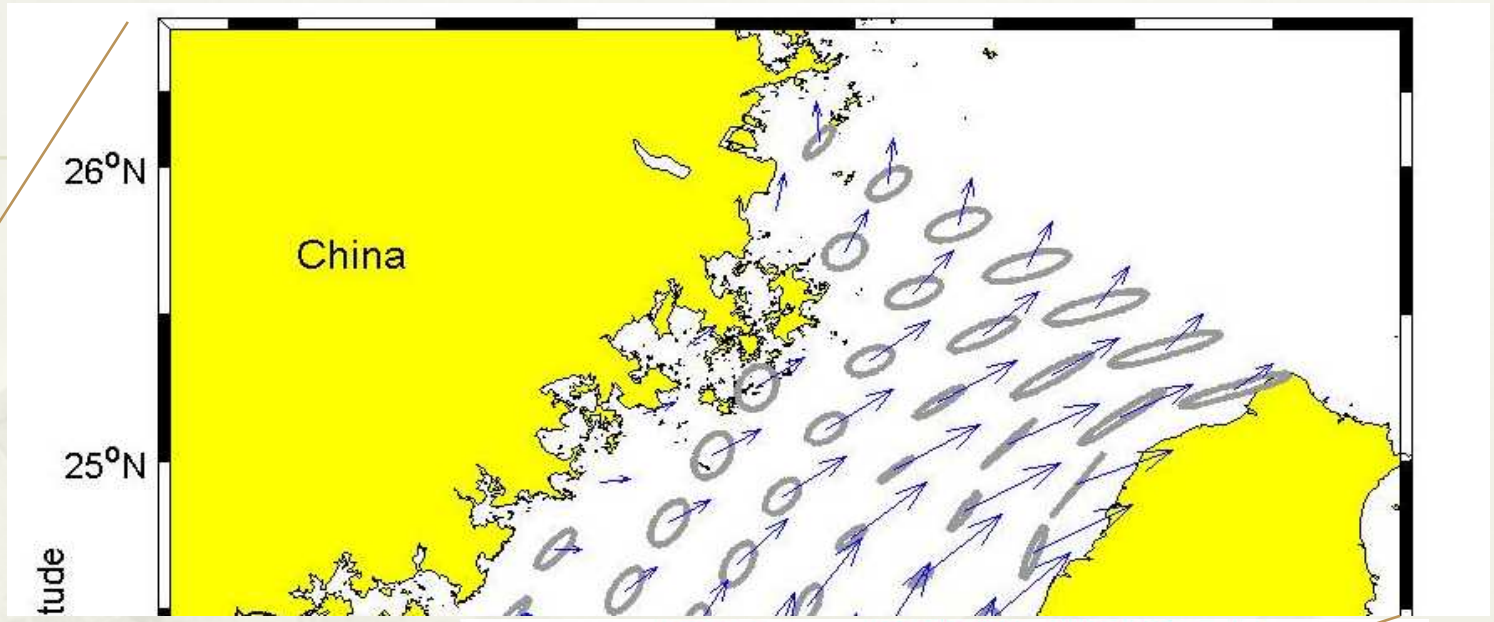
10 cm/s



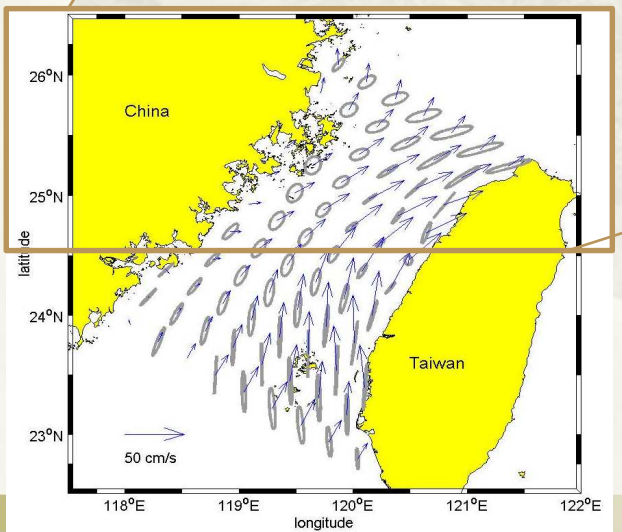
1 cm/s

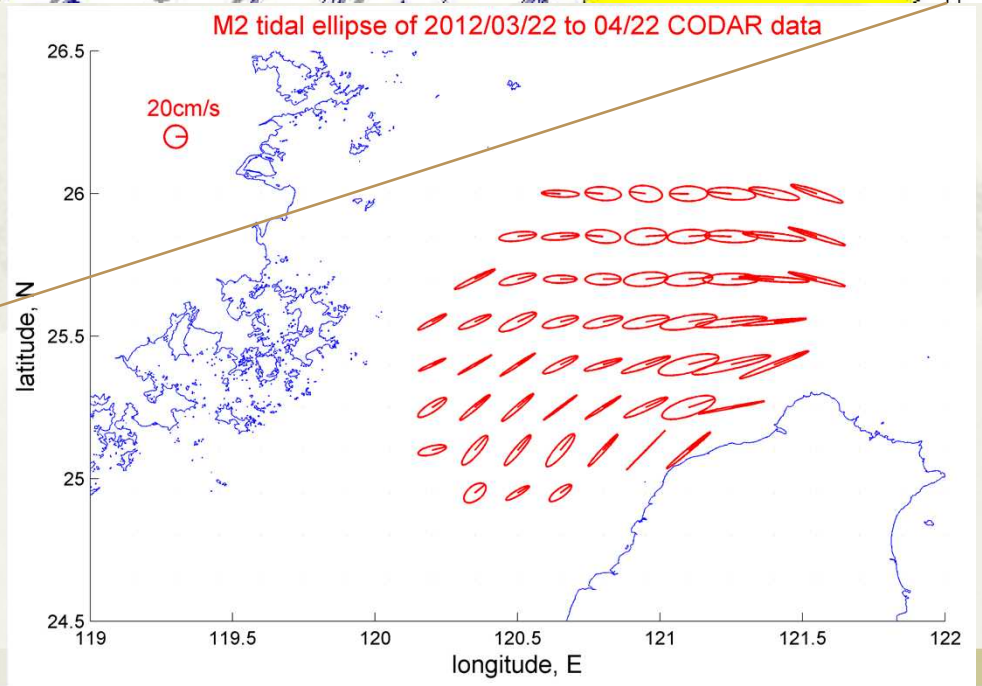
Ferry $\underline{U}_{ADCP}$ in Taiwan Strait, 2012/3/21~4/21

M2 tidal ellipse from historical VM-ADCP data

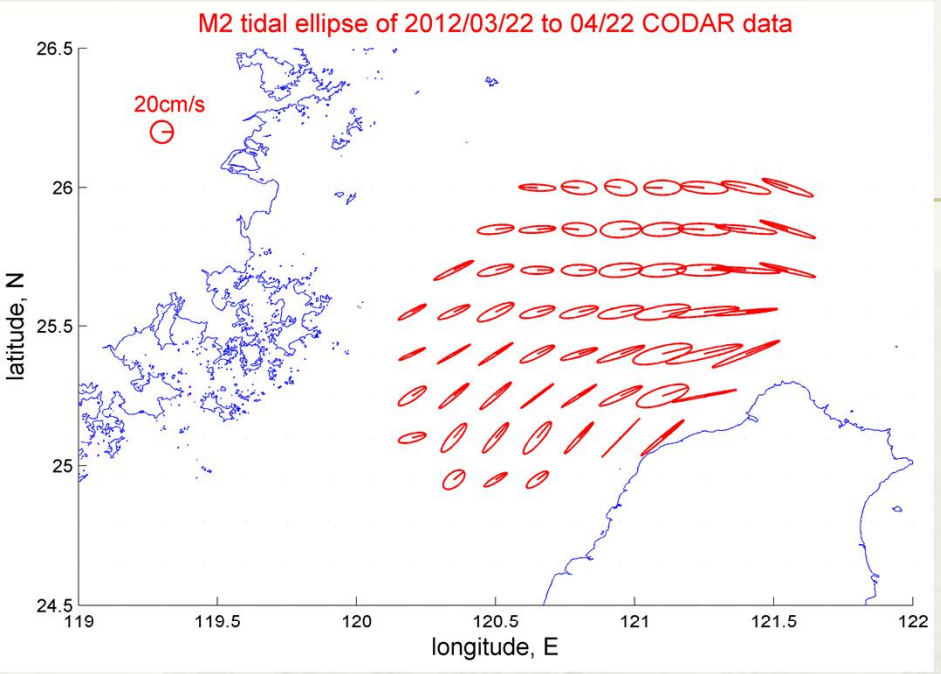


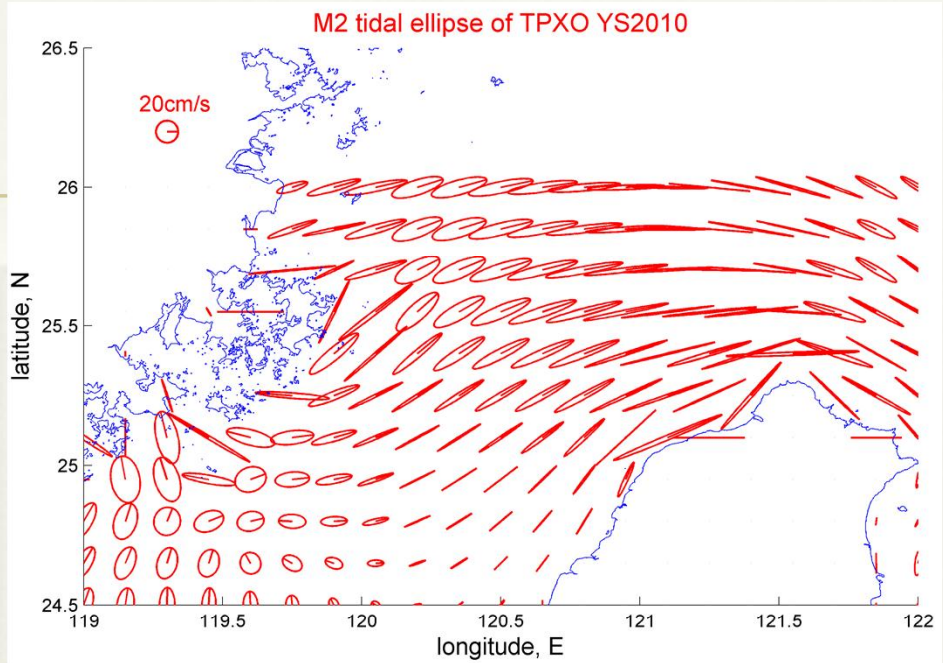
半日潮潮流橢圓(Wang et al.)

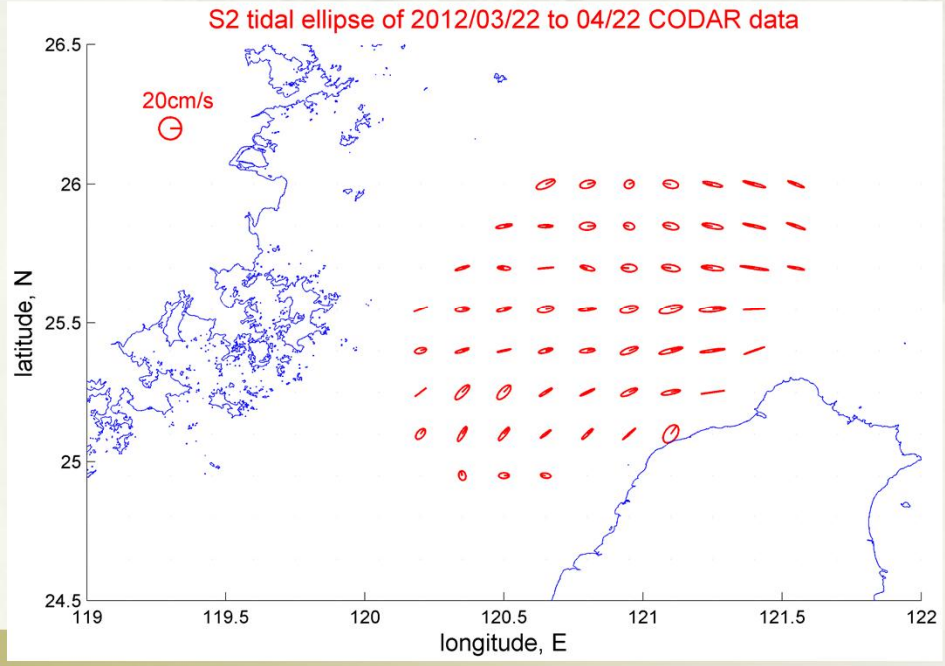


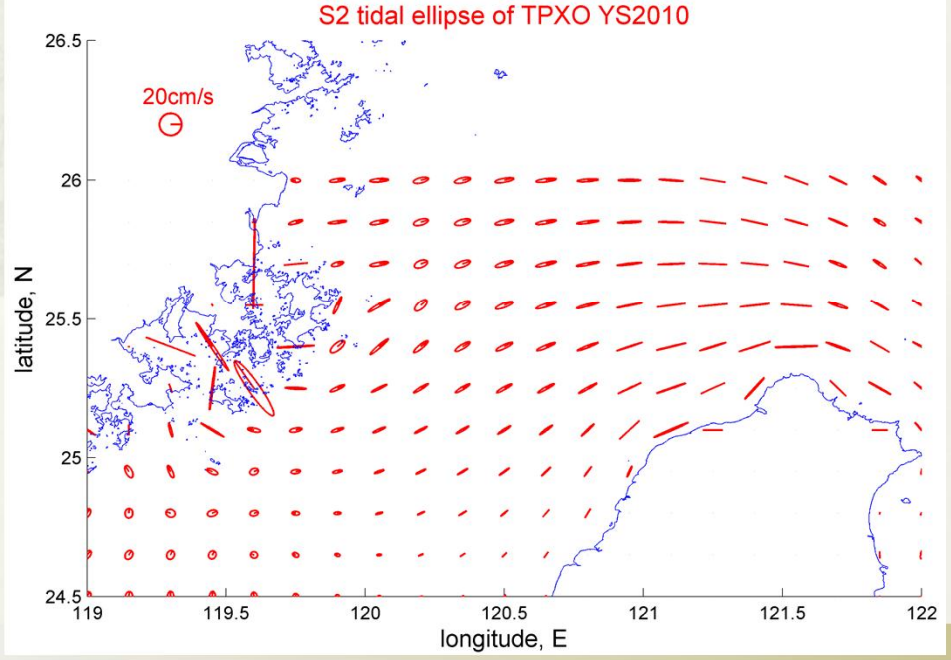


M2 & S2 tidal ellipses from CODAR data and from TPXO BT tidal model

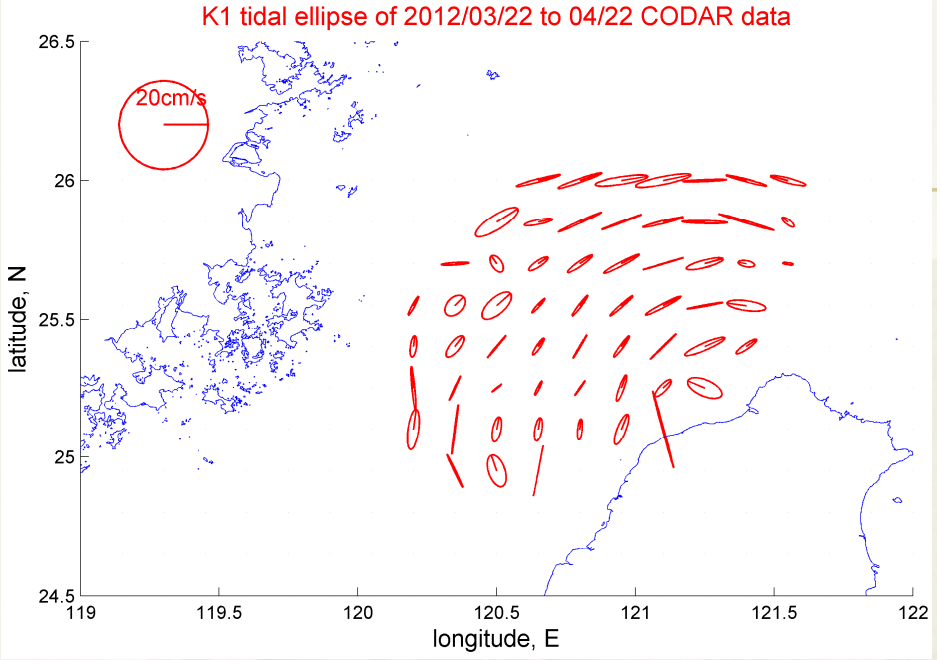


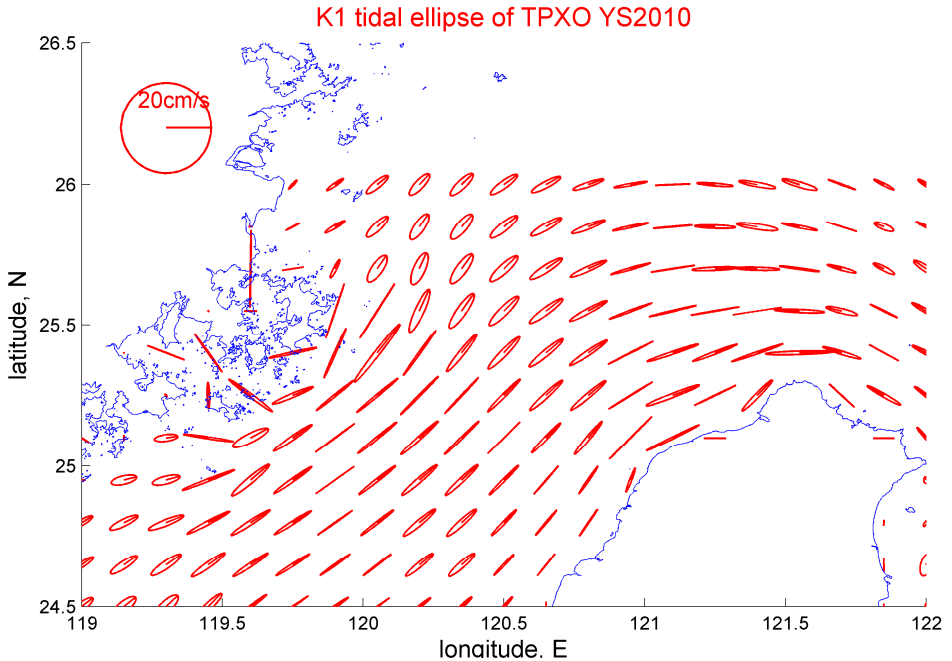


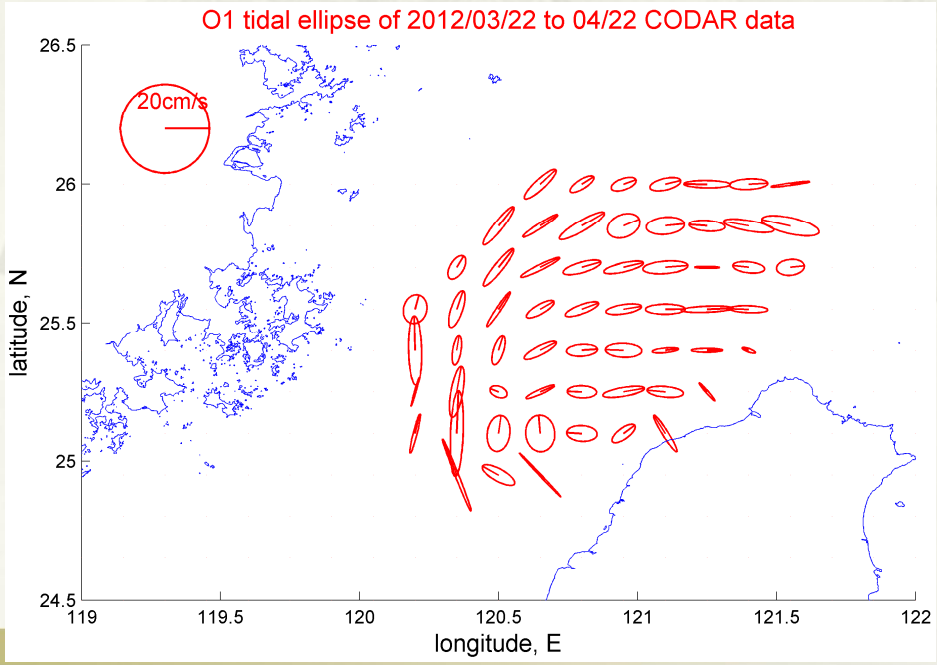


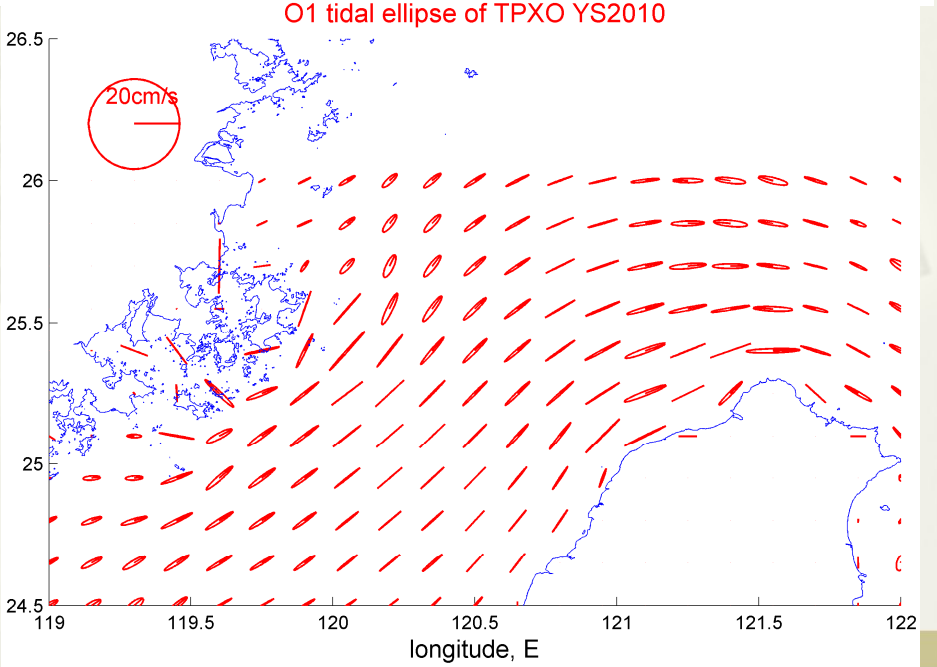


K1 & O1 tidal ellipses from CODAR data and from TPXO BT tidal model









Conclusions (2)

* Above analysis shows that
  (a) similar large scale velocity pattern for $\underline{U}_{adcp}$ and $\underline{U}_{codar}$;

  (b) the similarity decreases if comparison is on point by point;

  (c) because CODAR measures the surface current, $\underline{U}_{codar}$ varies closely with the wind changes

* CODAR-tuv responses to the wind forcing with 3.5~6 hour lag

* The CODAR-derived tidal constituents are consistent with
  numerical models (Hibiya et al., 2004),
  historical VM-ADCP data (Wang et al., 2003), and
  TPXO BT model on satellite altimeter data (Egbert et al., 2002)