The Comparison Between the Coastal HF Radar Scanning and the DGPS Tracked Drifter Measurements for Ocean Currents
海岸雷達遙測與 DGPS 表層浮標追蹤測流之比較

Jian-Hwa Hu, Jai-Shing Lin,
胡 健 驊, 林 佳 興,
Department of Oceanography
National Taiwan Ocean University

Hsiao-Hua Chen, Hsien-Liang Tsai, Gen-Chen Liao
陳 曉 華, 蔡 顯 亮, 廖 建 成
Naval Weather Center, Republic of China

Abstract

The hourly realizations remotely obtained by the HF radar system on the shore were compared with the measurements of high accuracy DGPS tracked drifters for coastal tidal currents at north of Taiwan. Direct comparison made with single trajectory over few hours provided encouraging result, although experiment with more drifters is not done yet. Nevertheless, indirect method was preliminarily applied to simulate the Lagrangian progressive vector diagram from the Eulerian radar scanning data set and concluded as a valuable approach for further inspection.

I. Introduction

Ocean current observing method has been desired since ever and various devices or systems have been developed or under developing with more modern techniques. The common idea in doing this task must be that the approach be synoptic, namely, to observe a current field as soon as possible as a snapshot even over a wide flow domain horizontally and vertically to avoid any bias due to the variation of high frequency of the dynamical environment. Nevertheless, in fact, to grasp the current''s temporal variation is always also of significance. Any system may cover all of these requirements thus becomes highly wished, although none can reach yet. In the past two or three decades, satellite remote sensing has been viewed as a quite synoptic method if its skindeep measurement can be well related to the world below the sea surface and proved by a reliable approach. However, due to its globally scaled scanning design, the sampling rate and spatial resolution are not satisfactory for certain demands like for continuous coastal watch in a small time interval. Such a difficulty therefore leaves a space for other techniques, such as the HF radar scanning system for coastal purposes, to develope.

After Crombie (1955), the pioneer of the principle in applying the doppler effect of sea surface back-scattering of radar signals for ocean movements, the development of radar theory and technology in 1960s encouraged some to devote themselves to implement the hardwar and software engineerings of the system since 1970s as Barrick (1971), Stewart and Joy (1974), Barrick, Evans and Weber (1977), etc.. In the decade, the device named CODAR (Coastal Ocean Dynamics Application Radar) system using two sets of omni-directional antenna was developed in NOAA WPL (Wave Propagation Lab) of the US. The spectral method for data processing of the system was introduced by Lipa and Barrick (1983). Meanwhile, a different type of device named OSCR (Ocean Surface Current Radar) by using 100 m array of antenna was designed in England (Prandle and Ryder, 1985). Both of the two systems are running until present.

However, these two systems have been suffering from their inconsistency with other measurements of current observing techniques in field experiments (Prandle and Ryder, 1989; Holbrook and Frisch, 1981; Paduan and Rosenfeld, 1996), although in low frequency bands the radar observations had been proved qualified for further investigations. Otherwise, they all concluded the fault owing to the inequivalent type of measurings in the comparison, radar for very surface flows (1 m) while others for depths (10 m at least), therefore might not be able to justify the quality of the individual radar measurement (realization). Notwithstanding, without any adequate comparison, it would constrain the extent of application of such a potential equipment to, for example, the environmental study on the diffusion of coastal pollution and so forth. Here we will present what we have been trying to cope with this problem.

II. The experiment

1. HF radar system (CODAR)

Recently, the Naval Weather Center of the Republic of China (ROC-NWC) established a HF radar system of theCODAR product, SeaSonde, at northeast coast of Taiwan. The details about the system can be found in a recent paper by Paduan and Rosenfeld (1996). Basically, a complete system re-quires at least two sets of radar device with antenna located at two sites on the shore and separated at a proper distance, say 10-20 km apart according to the 50 km effective receiving range of the back-scatterings of the radar signals. The intersection of the radial components of the flows by two radar scanning circles of 50 km raduis provides current vectors on a grid format.

In the case at northeast of Taiwan (Fig.1a), three sites of radar devices were built to efficiently obtain a wider coverage of the coastal current region because of the geographic merit of the three capes just about 15 km apart as shown in Fig.1c. They are site A at Hopindao, site B at Cape Bi-Tou and site C at Cape San-Diao. Semicircles are drawn with a radius of 40 km with respect to the radar sites to intersect an area of ABCDEFGHA, in which current vectors were supposedly measured everywhere. In Fig.1c, current vectors were measured by radar signals from site A and site B only. Therefore, data area was ABIFGHA instead. Even though, some blank areas without vectors exist more or less, like where between A and J, K and F, due to higher noise level in data processing. This phenomenon also happened in other experiment (Paduan and Rosenfeld, 1996), is a problem not fully understood yet. Fig.1b shows an example when site C was working as well.

2. DGPS drifter

As mentioned above, the fact that CODAR system was never evidenced to provide relevant realizations about a flow field was due to that no other proper equipments might inspect and calibrate them, neither in depth nor in simutaneously horizontal coverage. To track many drifters which were attached with surface drogue for measuring surface currents and evenly spread over the radar scanning area thus was considered since ever. However, positioning those drifters accurately and frequently was not quite simply attainable.

For the past two decades, the ARGOS system has been used, according to the principle of doppler effect, to fix positions of moving object which carries transmitter to regularly send signals with ID code or other sensor data to satellites. Nevertheless, due to the satellite orbiting motion, there could be only few fixings per day, not offering enough data in the time scale, one hour, of the CODAR measurement. Be-sides, the uncertainty of ARGOS fixing of 300-500 m is somewhat big for deriving current vector if the speed is not significant.

The recent progress in satellite position fixing technique was the popularity of the so-called GPS (Global Positioning System). In which, satellites transmit information while they are navigating for the GPS engine board carried by moving object on earth to compute the position of the object at a rate as once per second. Its general error is about 50-150 m. The even modern skill by applying the real-time deviations of a base GPS recording from its real position to correct the GPS data of a moving object may astonishingly reduce the error down to 1 m. Such a electronic system is called DGPS (differential GPS).

We thus employed the DGPS to drifter and call it the DGPS drifter (Hu *et al.*, 1995). Fig.2 illustrates the device with 1 m depth cross-van drogue, just good to measure currents of 1 m depth as CODAR does. The drifter carries GPS and sends its data by radio at a desired rate. The radio power is 50 watts, allowing a base 50 km away on shore being able to receive its signals, again just matching the CODAR effective range.

3. field experiments

In the past year after the NWC CODAR started running, we had tried to conduct drifter experiment several times. Unfortunately, since this was the first year for NWC and the local technician to handle the CODAR system, it had been terminated or broken down for a long period of months from time to time by various reasons including a super typhoon, while the reserved R/V schedule could not be easily changed accordingly, turning out none complete experiment with 5-10 DGPS drifters and CODAR observations conducted simutaneously being successful.

Nevertheless, several times of drifter experiments were still done over the coastal region. Fig.3 shows trajectory of one drifter in the experiment. A careful study on this trajectory by looking at when turnings occurred (not shown in here), together with many other trajectories, indicating the field was characterized by strong tidal currents along a NW-SE elongately ellipitical path. More about this can be found in Lin (1996), also agreeing with the earlier model result by Li (1987).

III. Direct comparison

Nevertheless, there was one experiment on November 27 of 1995 to have 4 hours of one drifter conducted before the weather suddenly changed, during when the CODAR system performed properly as well. Fig.4 shows both of the two kinds of data. (Still unfortunately, the realizations at 3 pm and 4 pm were missing.) Carefully inspecting the CODAR vectors of where the drifter passed, an encouraging agreement between them was seen, both showed a flow from north to the south (slightly to the southeast).

We are not to show the details of the comparison with their speeds and flow directions because they are not statistically meaningful under the circumstances of so few data being applied. In fact, the more interesting phenomenon is that the time series of the CODAR realizations illustrates the gradual hori-zontal flow pattern variation under the tide mechanism, while the immediate question would be that whether it is true or not because some of them looks really bizarre as those at noon time and 1 pm. We are even not sure if though we had drifters spread out in the region might allow us to directly compare their results in such a complicated flow field over the hours.

IV. Indirect comparison (PVD)

Due to the fact that we have no enough data at present to do direct comparing between CODAR and drifter measurements, and also, even though we had, we suspect that a piece by piece direct comparison of single vector with a segment of trajectory be substantial, as done by Paduan and Rosenfeld (1996), with ARGOS drifters but transmitting better GPS data. An idea to use a reverse way thus arose if we could simulate all possible Lagrangian behavior of the field from the Eulerian CODAR observations and examined the qseudo-trajectories in statistics with drifter experiment, the piecewise disagreements might be ignorable.

In this paper, we present our very preliminary result in such a method using an extremely simple approach. First of all, we selected a chunk of CODAR data series over 30 hours with least missing in time and in space. Fig.5 shows 24 hours of them. Visualizing these series may not obtain a clear idea how a drifter would have gone within the region. We then interpolated the missing data as much as possilbe spatially and temporally. In time, in order to solve the problem that, over the high speed area, a moving point might qseudo-Lagrangianly ski straightforward too far to catch the curve flow in real, we thus made the time series in a time interval of 20 minutes instead. Then we arbitraily chose a starting grid point in the CODAR dara region, calculated where it would arrive in 20 minutes. Found the velocity from the grid point the closest to continue its moving. We call this result the progressive vector diagram (PVD).

Fig.6c is one of the results. Fig.6a and b indicate where this PVD equivalently located. The qseudo-Lagrangian trajectory exhibits a NW-SE elongately ellipitical path again, as we've already learnt from others (see above). Numbers marked in Fig.6c are local time as marked in Fig.5. We then compare the speeds along the PVD in Fig.6e and the tide record at Keelung Harbor (near the west side of Panel (b)) in Fig.6d, it is seen that the to and fro PVD is exactly the tidal current with magnitudes of speeds very reasonable according to our experiences over the region (Lin, 1996).

V. Conclusions

The shore-based HF radar scannig device CODAR for current measnurement (also for waves) is a very powful equipment to stand against bad weather or sea condition or fishing activities for a long-term real-time synoptic observation. It actually is not a modern concept, but until present, with insufficient confidence for scientists to use it, just because it has been so hard to examine its output. It is already shown that the low frequency band of the data is good enough for further investigations, however, the individual realizations hold even the key for more science and applications. We have been doing both the direct and indirect comparisons between the precise DGPS drifter and CODAR measurements and the very preliminary results are so fruitful and encouraging. We will continue such a task with more complete field experiments and develope a more sophisticated, therefore of higher fidelity qseudo-Lagrangian PVD method for further statistical study. Besides, a new powerful field device, ADP, a mini ADCP of high frequency signal to acoustically measure very surface 1 m flows can be employed for this purpose. This will be our next tasks.

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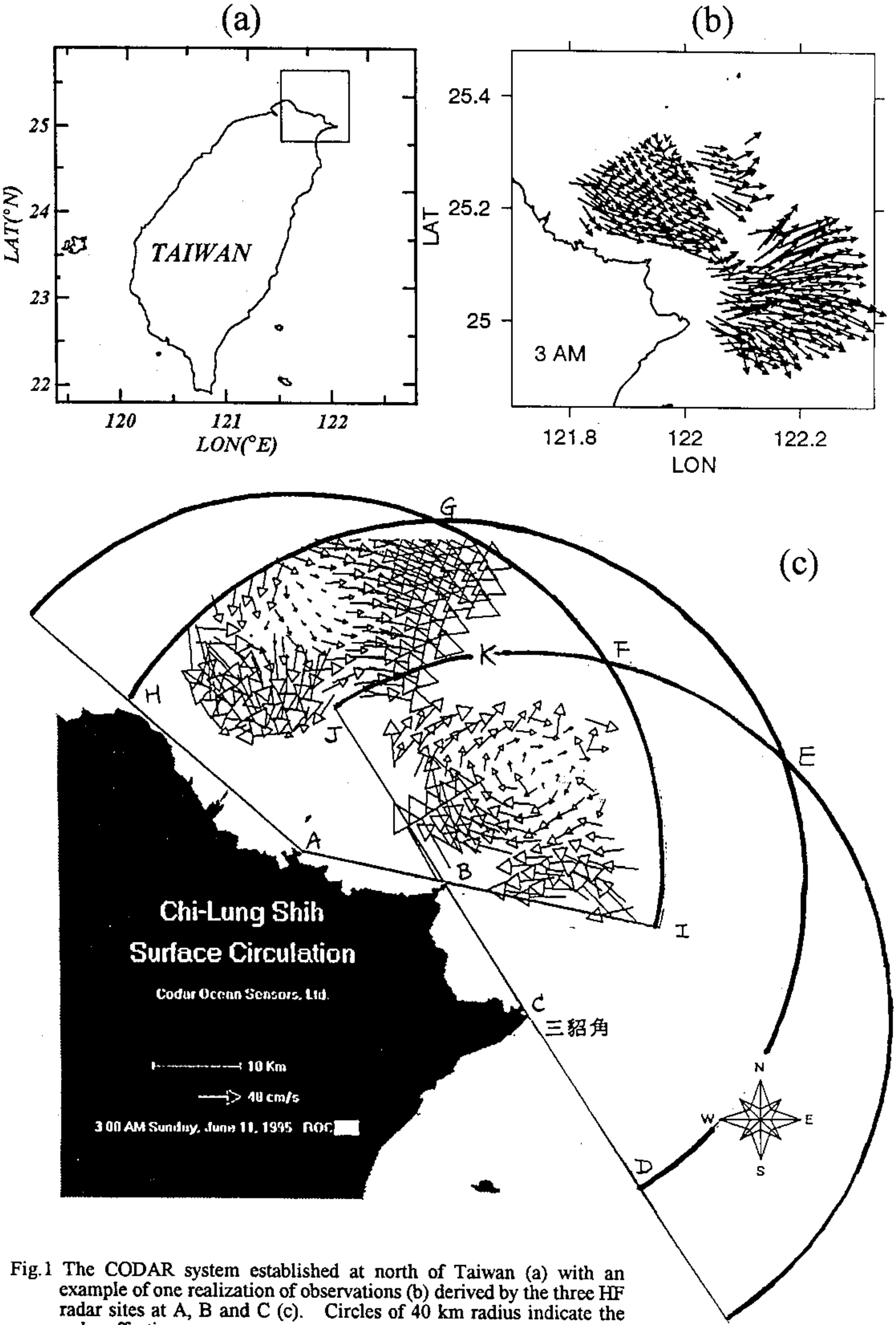

Fig.1 The CODAR system established at north of Taiwan (a) with an example of one realization of observations (b) derived by the three HF radar sites at A, B and C (c). Circles of 40 km radius indicate the radar effective range.

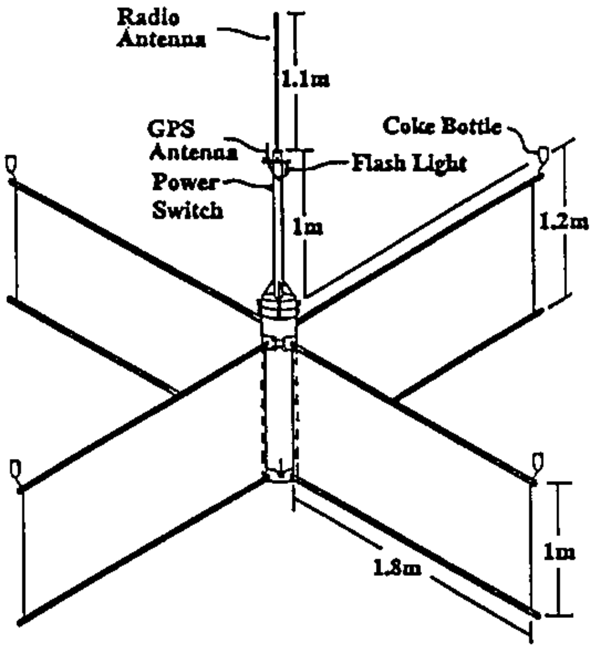

Fig.2 The schematic diagram of a GPS drifter attached with cross-vane drogue for 1 m depth. For details, see Hu *et al.* (1995).

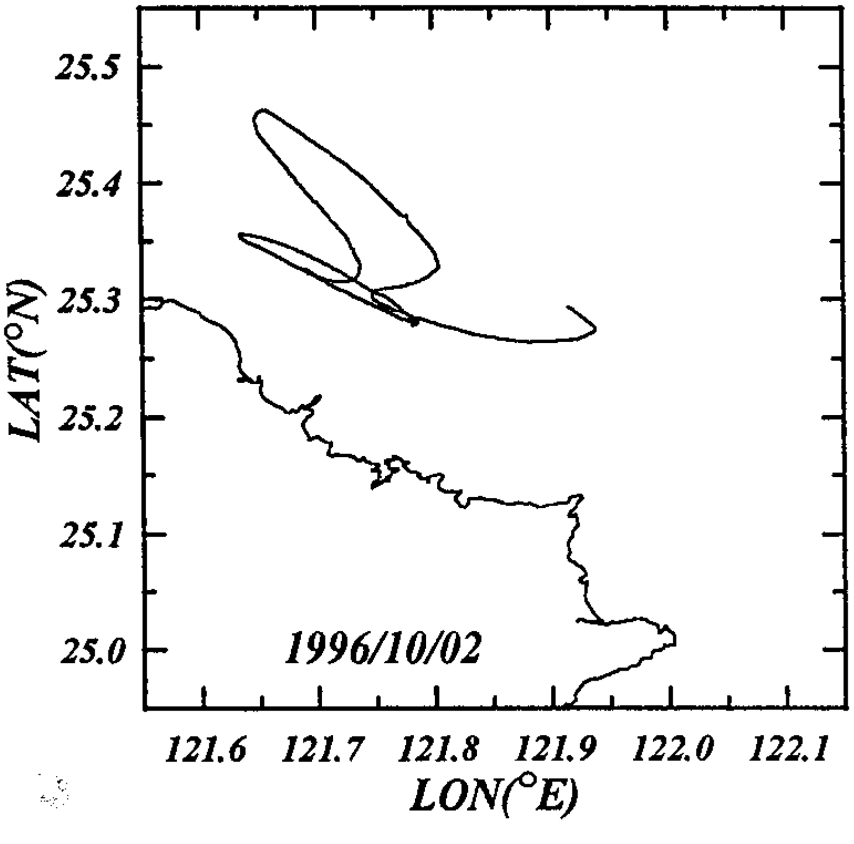

Fig.3 The trajectory of one DGPS drifter during a 25 hours experiment at north of Taiwan.

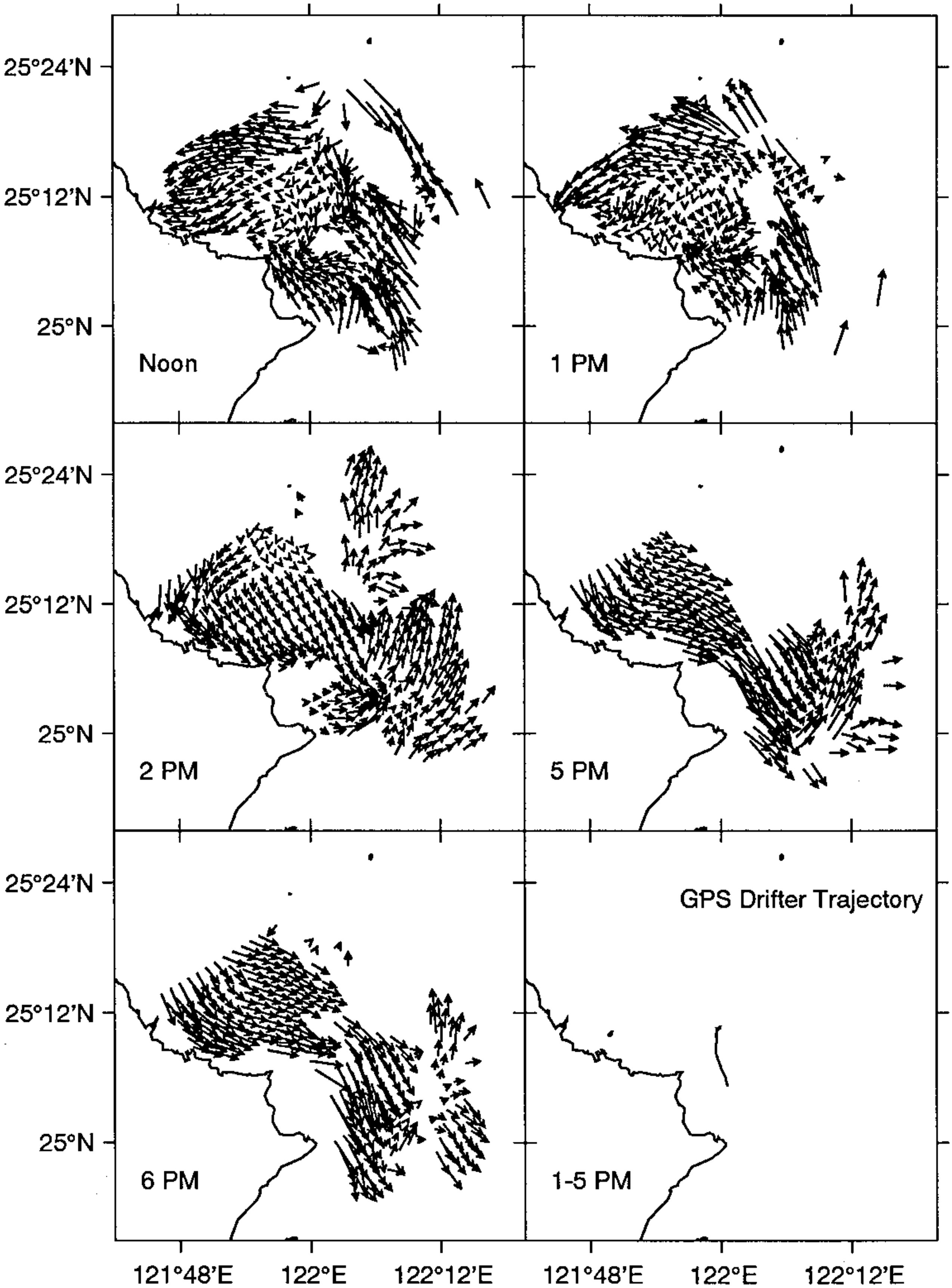

Fig.4 CODAR and one DGPS drifter measurements over five hours on November 27, 1995.

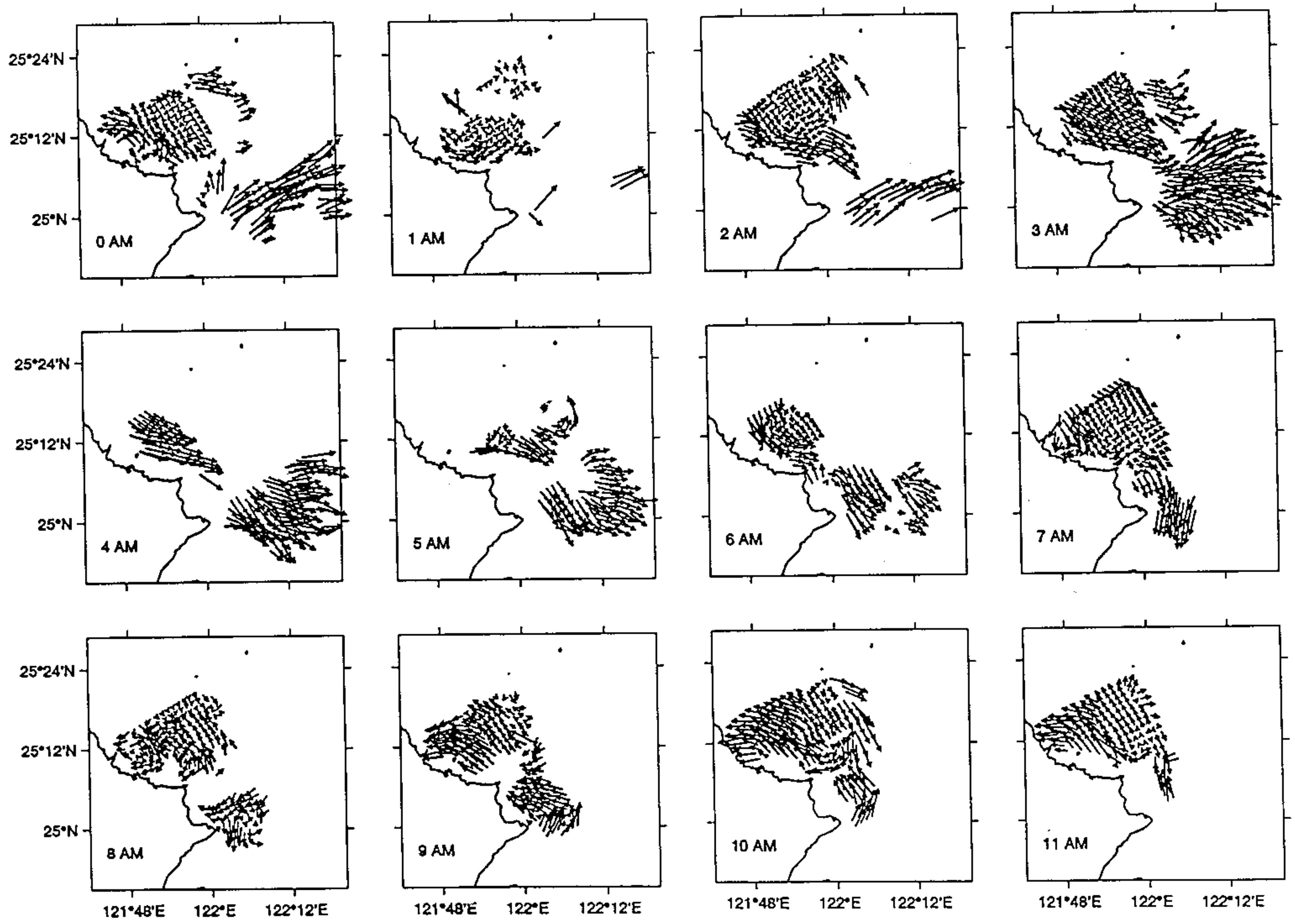

Fig.5 (Continued).

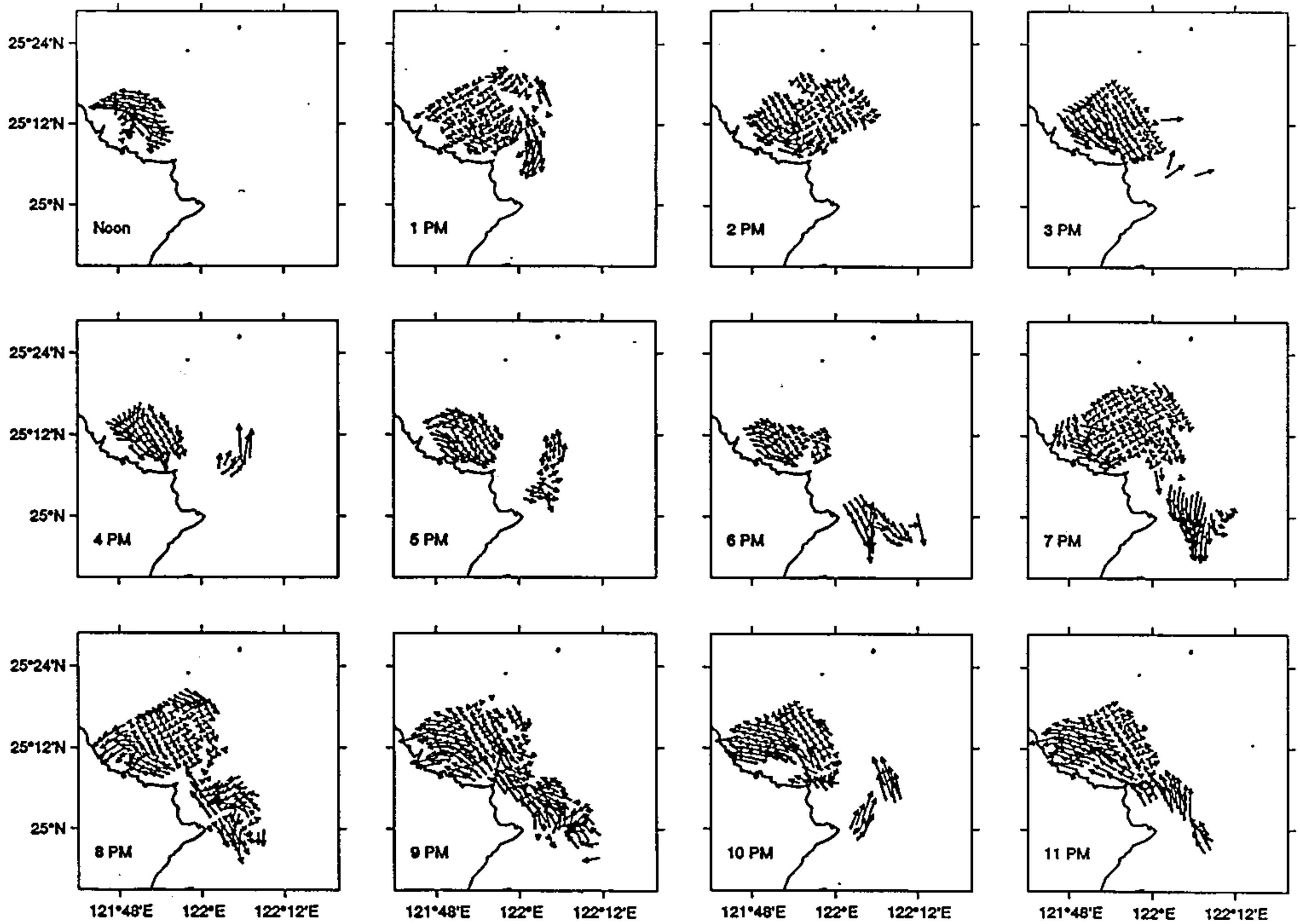

Fig.5 Realizations of CODAR measurements arbitrarily selected for the progressive vector diagram analysis.

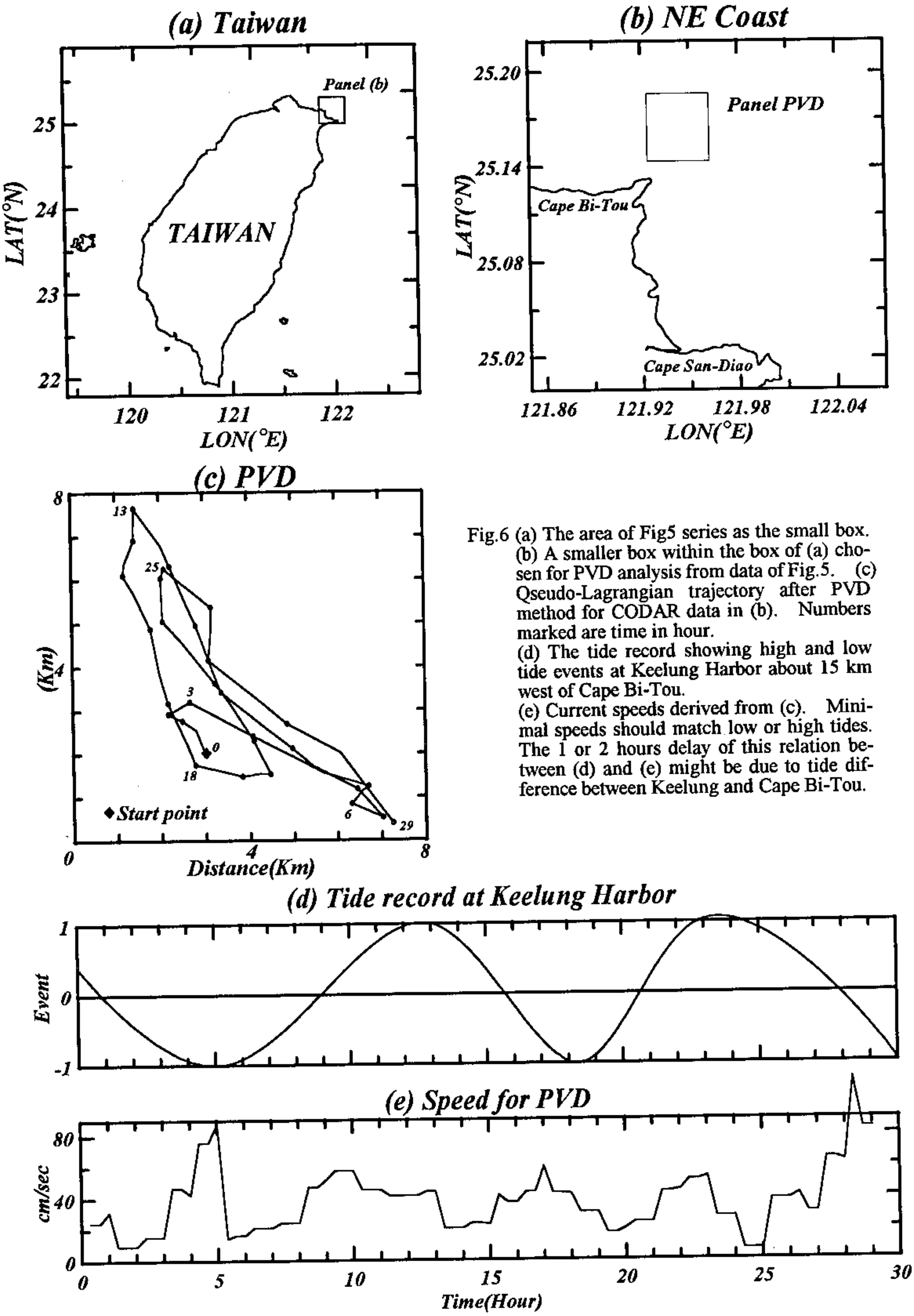

Fig.6 (a) The area of Fig5 series as the small box. (b) A smaller box within the box of (a) chosen for PVD analysis from data of Fig.5. (c) Qseudo-Lagrangian trajectory after PVD method for CODAR data in (b). Numbers marked are time in hour.
(d) The tide record showing high and low tide events at Keelung Harbor about 15 km west of Cape Bi-Tou.
(e) Current speeds derived from (c). Minimal speeds should match low or high tides. The 1 or 2 hours delay of this relation between (d) and (e) might be due to tide difference between Keelung and Cape Bi-Tou.