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Study Reliability of the Information About the CPA and TCPA Indicated by the Ship's AIS

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ABSTRACT: According to the IMO recommendation when the target data from AIS and radar tracking are both available and the association criteria are fulfilled such that the AIS and radar information are considered as for one physical target, then as a default condition in radar equipment, the AIS target symbol and the alphanumerical AIS target data should be automatically selected and displayed only. The article presents research conducted in real conditions on the reliability of information presented by the ship's AIS about the passing distance with the other vessel equipped with AIS and time to pass it by comparing data from the AIS with that presented by ARPA.

1 INTRODUCTION

Introducing of automatic identification system (AIS) on sea going vessels changes significantly possibility of maintaining a proper look-out, particularly in restricted visibility. According to the recommendation of the Resolution A.1106(29) „Revised guidelines for the operational use of shipborne automatic identification systems (AIS)" adopted by International Maritime Organisation (IMO) on 2 December 2015, the AIS may be recommended as an anti-collision device in due time and its introducing has not impact on the Rule 19 "Conduct of vessels in restricted visibility" of the International Regulations for the Preventing Collision at Sea (COLREG) and its interpretation. Nevertheless, AIS may be used to assist in collision avoidance decision-making as an additional source of information which supports radar and radar tracking aids, by assisting in [Resolution A.1106(29)]:

- Identification of targets by name, call sign, ship type and an navigational status;
- Presentation of targets heading;
- Immediate identification of manoeuvres performed by targets; and
- More accurate presentation of the targets courses and speeds over ground and rate of turn.

But also, if the target data from AIS and radar tracking are both available and the association criteria (position, motion, etc.) are fulfilled such that the AIS and radar information are considered as one physical target, then as a default condition in radar equipment, the AIS target symbol and the alphanumerical AIS target data should be automatically selected and displayed [Resolution MSC,192(79)].

Two basic parameters needed to assess the risk of collision in meeting situation at sea are passing distance and passing time called closest point of approach (CPA) and time to the closest point of approach (TCPA). AIS calculates their values on the basis of information on courses over ground and speeds over ground and the positions of the own vessel and opposite object, indicated by receivers of the satellite navigation system (actually mainly GPS or DGPS) connected to the onboard AIS. Due to that

AIS indication should be more accurate and reliable than values of the CPA and TCPA ascertained on the basis of radar tracking and presented by automatic radar plotting aids (ARPA) and automatic tracking aids (ATA). There are available publications comparing the accuracy of the position, course and speed presented by the AIS and radar plotting aids [Wawruch 2008]. But it is still an open question the accuracy and reliability of information about the CPA and TCPA indicated by AIS as compared with the accuracy of their values calculated on the basis of radar tracking.

The measurements reported in this article were carried out to find the answer to this question.

2 DESCRIPTION OF THE MEASUREMENTS

The measurements were carried out in real (not simulated) conditions during the sea voyages of ships listed in Table 1 and presented in Figures 1 and 2, using installed on these vessels AIS and radar equipment mentioned in this table too. JRC is the abbreviation of Japan Radio Company Ltd. Weather conditions during the tests describes the state of the sea, expressed in degrees of the Douglas scale in the last column of Table 2.

Table 1. Ships on which tests were carried out [Wesłowski 2016, Wilczyński 2016]

Data	Magdalena Odendorff	Pampero
Ship's type	Bulk carrier	LPG tanker
Gross Tonnage	106884	46789
Length [m]	299.9	226,0 m
Service speed [kn/m/s]	15.6/8,0	16.7/8,6
Utilised radar equipment / manufacturer	JMA-9132-SA, JMA-9122-9XA / JRC	JMA-9172-SA, JMA-9122-9XA /JRC
Utilised AIS / manufacturer	JHS-183 / JRC	JHS-183 / JRC

Figure 1. Bulk carrier "Magdalena Oldendorff" [www.google.pl/search?q=magdalena+oldendorff+ship&rlz]

Figure 2. LPG carrier "Pampero" [www.vesselfinder.com/pl/vessels/PAMPERO-IMO-9689548-MMSI-538006047]

The measurements were carried out for 38 meeting situations with vessels listed in Table 2. The terms used in this table mean:

- T - type of the ship:
  - B - bulk carrier;
  - C - container vessel;
  - CS - cargo ship;
  - F - ferry boat;
  - FV - fishing vessel;
  - P - passenger ship; and
  - T - tanker;
- L - the length of the vessel presented on the website;
- CPA_{mean} - the average value of the CPA during the measurement;
- MS - meeting situation:
  - 1 - overtaking;
  - 2 - head-on situation; and
  - 3 - crossing situation;
- S - sea state expressed in degrees of the Douglas scale, sw means swell.

In each test were recorded simultaneously every 30 seconds, indicated by ARPA and AIS following parameters of the observed vessel:

- Bearing and distance;
- Course and speed; and
- CPA and TCPA.

As the units of distance and speed are officially used in maritime navigation nautical miles (M) and knots (kn), and AIS and ARPA present values of the CPA and speed in these units. Due to that, values of CPA and speed are expressed in figures in nautical miles (M) and knots (kn), and CPA_{mean} and speed in Table 2 in nautical miles and kilometres and in knots and m/s (1M=1852 m; 1 knot=1 M/h).

Table 2. Observed ships [Wesłowski 2016, Wilczyński 2016]

No	Name	T	L [m]	Speed [kn / m/s]	CPA_{mean} [M/km]	MS	S
1	APL Vancuver	C	328	19.2/9.9	10.1/18.8	2	4
2	Belgian Express	C	180	13.0/6.7	0.7/1.3	1	4
3	Bulk Switzerland	B	289	9.5/4.9	17.0/31.5	3	5
4	Cap San Marco	C	333	20.0/10.3	2.5/4.7	3	4
5	Carnival Valor	P	292	18.2/9.4	2.8/5.2	3	4
6	Caroline Maersk	C	347	19.0/9.8	2.9/5.4	1	5
7	China Peace	B	289	0/0	4.4/8.1	1	3
8	Cosco Jinggangshan	B	177	10.0/5.1	3.0/5.5	2	5
9	F.D. Gennaro Aurilia	B	225	12.0/6.2	7.7/14.2	1	3
10	Four Wind	T	249	12.0/6.2	0.9/1.6	3	4
11	Free Neptune	CS	185	11.5/5.9	9.5/17.6	3	2
12	Horncap	C	153	14.5/7.5	2.7/5.0	3	3
13	HSC	B	289	11.6/6.0	5.5/10.1	2	3
14	Hua San	T	333	14.0/7.2	3.1/5.8	3	4
15	Hyundai Unity	C	294	13.3/6.8	9.2/17.0	1	3
16	Jacamar Arrow	B	199	14.0/7.2	1.1/2.1	2	5
17	JS Columbia	B	199	14.4/7.4	5.3/9.8	3	2
18	Lena River	T	290	0	0.7/1.3	1	2
19	Maersk Cape Coast	C	249	15.0/7.7	2.1/3.8	2	1
20	Mount Nevis	B	290	7.0/3.6	1.7/3.1	2	7
21	MSC Rachele	C	334	19.5/10.0	3.6/6.7	3	5
22	NCC Danah	T	183	13.5/6.9	2.9/5.4	3	7
23	New Harmony	T	333	14.5/7.4	3.1/5.8	1	6
24	NYK Altair	C	333	14.1/7.3	6.0/11.1	2	4
25	Ocean Trader	CS	180	11.1/5.7	15.7/29.0	1	4
26	OOCL Korea	C	366	15.8/8.1	1.5/2.7	3	sw
27	Port Shanghai	B	190	10.0/5.1	2.2/4.1	2	5
28	Regio Mar	FV	21	8.0/4.1	2.4/4.4	1	2
29	Samoa	B	225	12.0/6.2	2.1/3.9	1	5
30	SCL Basilea	CS	140	14.2/7.3	9.5/17.7	2	3

31 Southern Narwhal	T	135	13.0/6.7	1.3/2.4	3	4
32 Spirit of Britain	F	213	23.5/12.1	8.3/15.3	3	3
33 Stolt Puffin	T	100	10.2/5.2	7.4/13.8	1	3
34 Stolt Puffin	T	100	10.2/5.2	5.7/10.6	1	3
35 Suez Vasilis	T	274	14.0/7.2	1.4/2.6	1	4
36 Tian Zhu Feng	B	225	10.8/5.6	10.0/18.5	1	7
37 Unique Brilliance	B	288	Variable	2.1/3.8	1	6
38 Varamo	C	166	25.3/13.0	1.3/2.4	2	4

In all cases, observed ship was tracked by ARPA for at least 5 minutes before the start of registration and both vessels (own and opposite) did not take at this time any manoeuvres. Each series consisted of 30 registrations. In 5 meeting situations one vessel was staying at anchor: own ship in situations No: 6, 23 and 37, observed in situations No: 7 and 18. In other cases, during the registration:

- Own ship altered her course while observed vessel was proceeding with steady course and speed (situations No: 20, 22 and 34);
- Own ship was proceeding with steady course and speed and observed vessel altered its course (situations No: 10, 14, 31 and 33);
- Both vessels altered their courses (situation 30); and
- Both vessels were sailing on steady courses and with steady speeds (situations No: 1-5, 8, 9, 11-13, 15-17, 19, 21, 22, 24, 25-28, 32, 35, 36 and 38).

3 DISCUSSION OF TESTS RESULTS

Described tests were conducted in order to check whether, when data from AIS and radar tracking are both available and the association criteria are fulfilled, the person in command and manoeuvring the ship (captain or watchkeeping officer) can rely on values of CPA and TCPA of other vessels available from AIS only. The amount of the measurements is small and makes it impossible to determine any statistical relationships but allows formulating some general observations.

There were observed by AIS and tracked by ARPA ships of different sizes, from the small fishing vessel to large container ships and tankers, staying at anchor and proceeding with different speeds in different meeting situations and different weather conditions, including stormy weather, passing own ship at different CPA, between 0.7 M (1.3 km) and 17.0 M (31.5 km).

Onboard AIS receives, at predetermined time intervals, the indications of GPS or DGPS receiver, gyrocompass, speed measuring device and rate of turn indicator when connected to the unit on the opposite ship, and knowing the position, course and speed of own vessel calculates CPA and TCPA of that opposite ship. Due to that it should detect and indicate changes of CPA and TCPA caused by manoeuvres of the own ship and/or opposite vessel faster than ARPA calculating current values of these two parameters on the basis of the radar detection and tracking. The tests performed confirmed the validity of this view. As shown in the Figures 3, 4, 6 and 7, in all series of measurements during which the own and/or opposite ship manoeuvred, AIS pointed changes in the CPA and TCPA faster than ARPA.

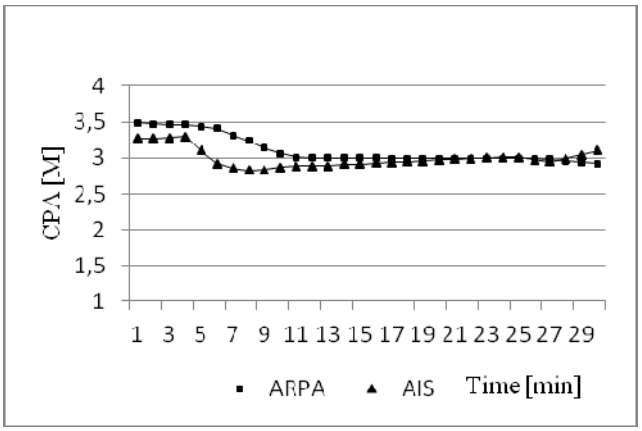

Figure 3. Presented by AIS and ARPA information on CPA of the container vessel "Caroline Maersk" altering course for 16° (situation No 6, own ship at anchor, sea state 5) [Wesołowski 2016]

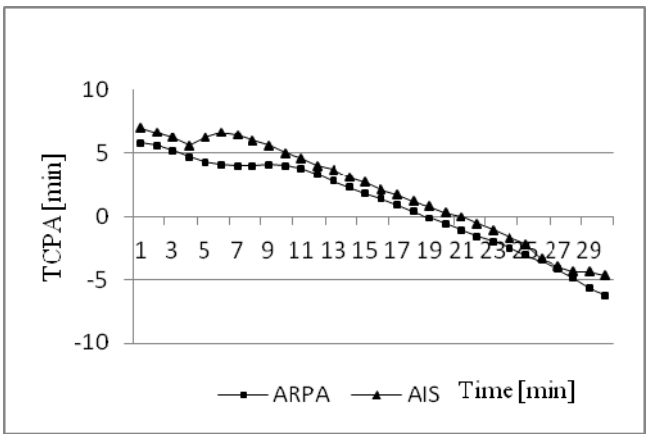

Figure 4. Presented by AIS and ARPA information on TCPA of the container vessel "Caroline Maersk" altering course for 16° (situation No 6, own ship at anchor, sea state 5) [Wesołowski 2016]

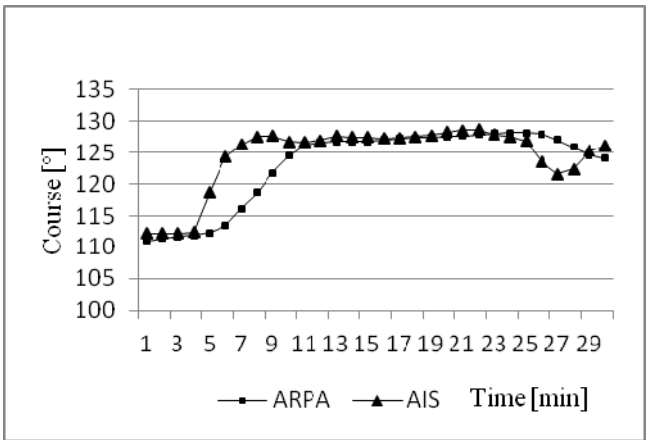

Figure 5. Presented by AIS and ARPA information on course of the container vessel "Caroline Maersk" (situation No 6, own ship at anchor, sea state 5) [Wesołowski 2016]

Presented in Figures 3 and 4 faster indication of new values of CPA and TCPA were achieved due to the earlier detection of the opposite ship course alteration by AIS than by ARPA (Figure 5).

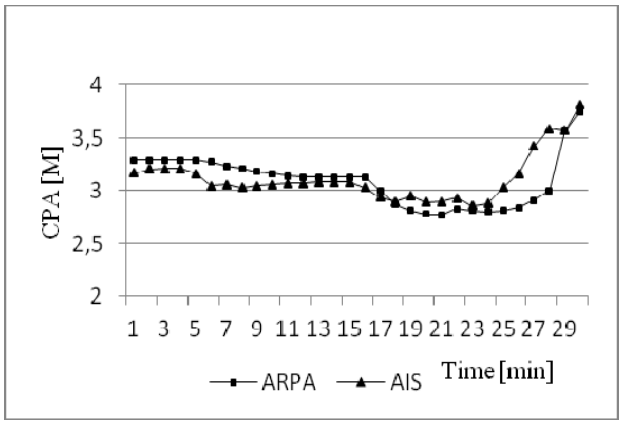

Figure 6. Presented by AIS and ARPA information on CPA of the tanker "New Harmony" altering twice its course (situation No 23, own ship at anchor, sea state 6) [Wesołowski 2016]

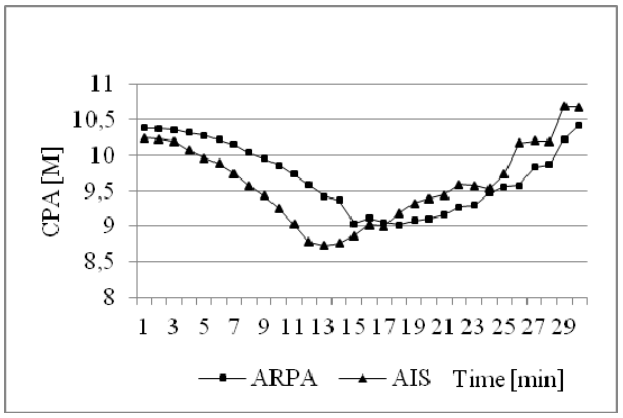

Figure 7. Presented by AIS and ARPA information on CPA of the cargo ship "SCL Basilea" (situation No 30, both vessels were altering their courses during the measurement, sea state 3) [Wilczyński 2016]

In all cases, information on the CPA and TCPA presented by the AIS for vessels proceeding with steady course and speed was at least as stable as the values of these parameters indicated by the ARPA. Figures 8 and 9 show exemplary graphs of changes of CPA and TCPA as a function of time in the test No. 38. They demonstrate that the accuracy of information shown by AIS about the CPA and TCPA of observed vessel may depend on the number of position reports (AIS messages) received from that vessel.

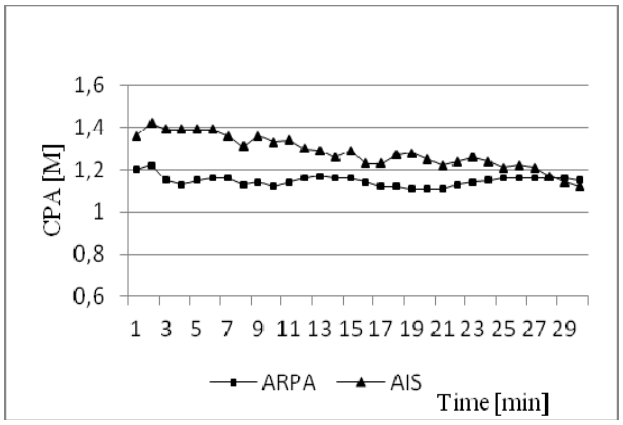

Figure 8. Presented by AIS and ARPA information on CPA of the container vessel "Varamo" (situation No 38, own ship and "Varamo" were proceeding with steady courses and speeds, sea state 4) [Wesołowski 2016]

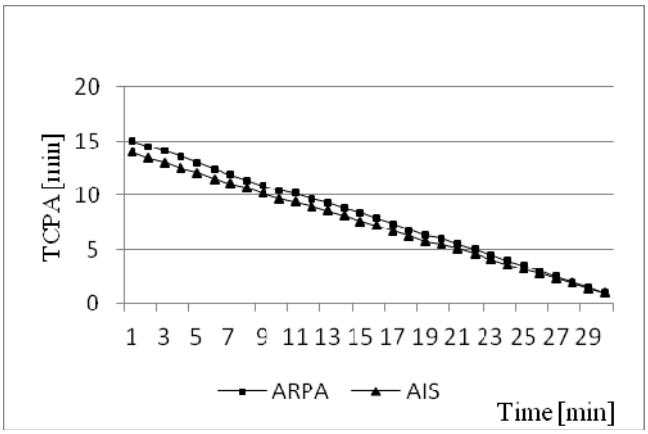

Figure 9. Presented by AIS and ARPA information on TCPA of the container vessel "Varamo" (situation No 38, own ship and "Varamo" were proceeding with steady courses and speeds, sea state 4) [Wesołowski 2016]

Often AIS presented measured parameters more accurately and much more stable than ARPA (Figures 10-14).

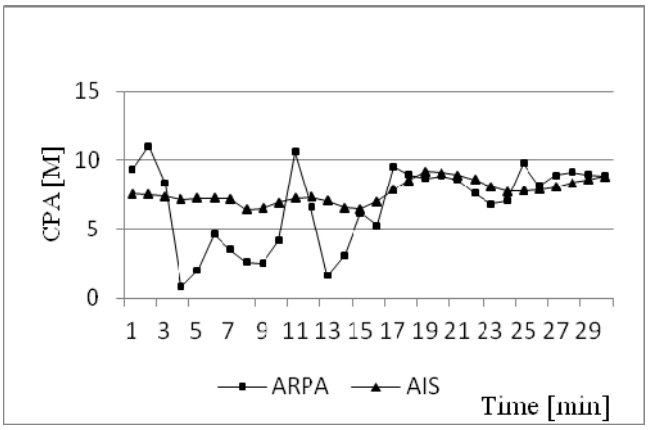

Figure 10. Presented by AIS and ARPA information on CPA of the bulk carrier "F.D. Gennaro Aurilia" (situation No 9, own ship and "F.D. Gennaro Aurilia" were proceeding with steady courses and speeds, sea state 3) [Wesołowski 2016]

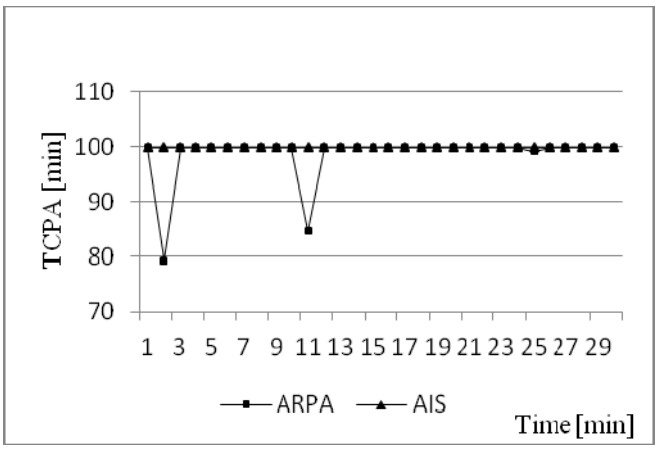

Figure 11. Presented by AIS and ARPA information on TCPA of the bulk carrier "F.D. Gennaro Aurilia" (situation No 9, own ship and "F.D. Gennaro Aurilia" were proceeding with steady courses and speeds, sea state 3) [Wesołowski 2016]

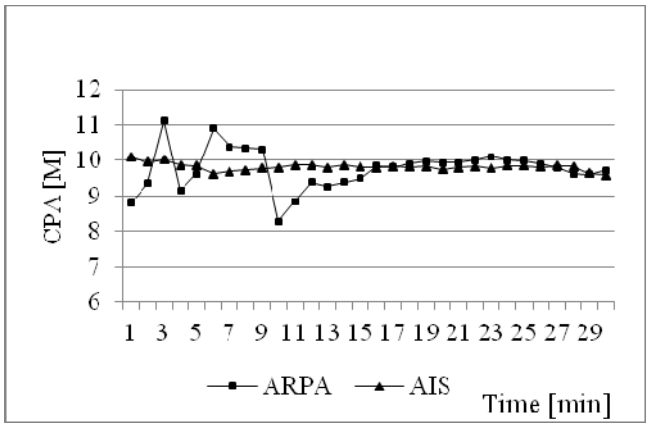

Figure 12. Presented by AIS and ARPA information on CPA of the container vessel "APL Vancouver" (situation No 1, own ship and "APL Vancouver" were proceeding with steady courses and speeds, sea state 4) [Wilczyński 2016]

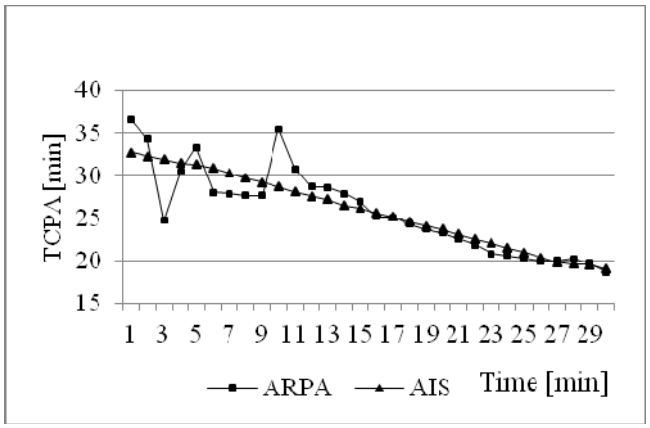

Figure 13. Presented by AIS and ARPA information on TCPA of the container vessel "APL Vancouver" (situation No 1, own ship and "APL Vancouver" were proceeding with steady courses and speeds, sea state 4) [Wilczyński 2016]

The higher accuracy and stability of CPA and TCPA indicated by the AIS in the absence of the own and opposite ships' manoeuvres is due to the greater accuracy and stability of information about the opposite ship's course and speed (Figures 14-17).

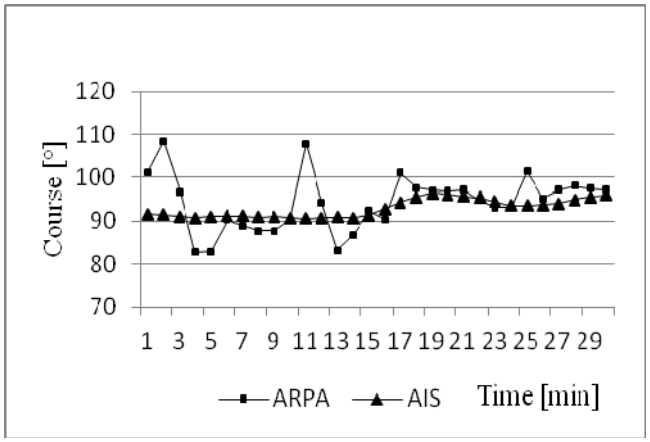

Figure 14. Presented by AIS and ARPA information on the course of the bulk carrier "F.D. Gennaro Aurilia" (situation No 9, own ship and "F.D. Gennaro Aurilia" were proceeding with steady courses and speeds, sea state 3) [Wesołowski 2016]

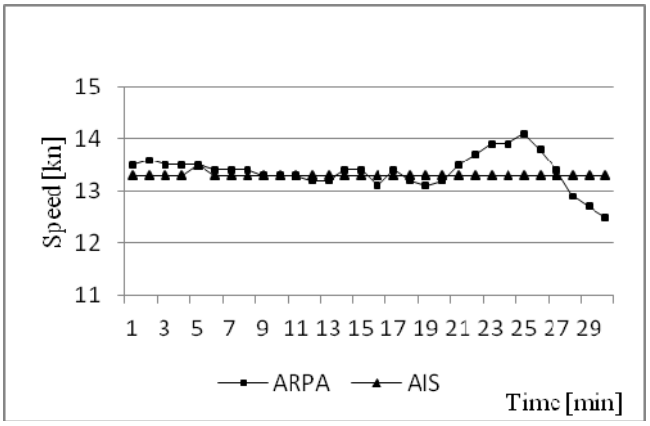

Figure 15. Presented by AIS and ARPA information on the speed of the bulk carrier "F.D. Gennaro Aurilia" (situation No 9, own ship and "F.D. Gennaro Aurilia" were proceeding with steady courses and speeds, sea state 3) [Wesołowski 2016]

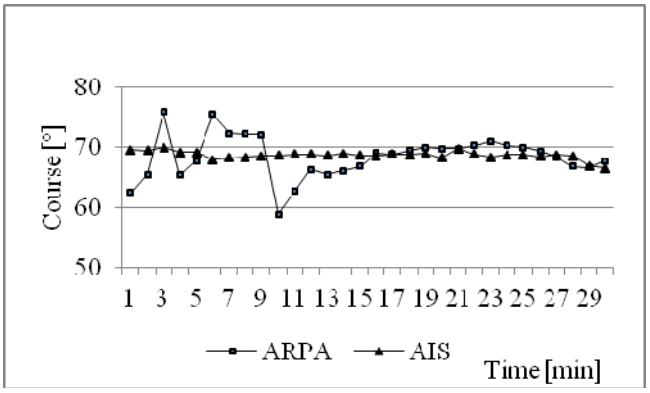

Figure 16. Presented by AIS and ARPA information on the course of the container vessel "APL Vancouver" (situation No 1, own ship and "APL Vancouver" were proceeding with steady courses and speeds, sea state 4) [Wilczyński 2016]

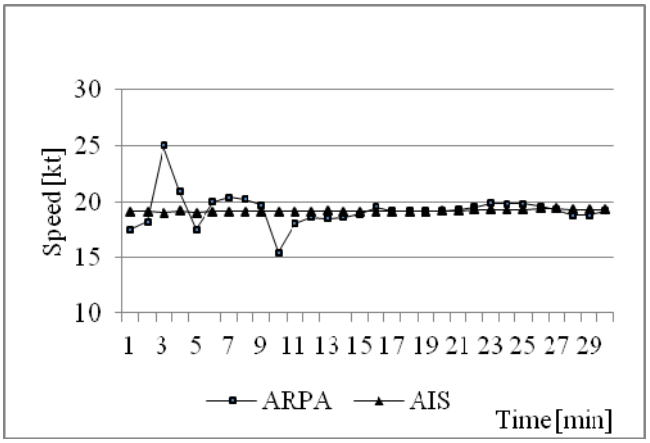

Figure 17. Presented by AIS and ARPA information on the speed of the container vessel "APL Vancouver" (situation No 1, own ship and "APL Vancouver" were proceeding with steady courses and speeds, sea state 4) [Wilczyński 2016]

Sometimes AIS presents values of described ships meeting parameters, mainly CPA, in an unstable manner (Fig. 18). The reason for this may be a small stability of the AIS information about the course and/or speed of the opposite vessel (Fig. 19, 20).

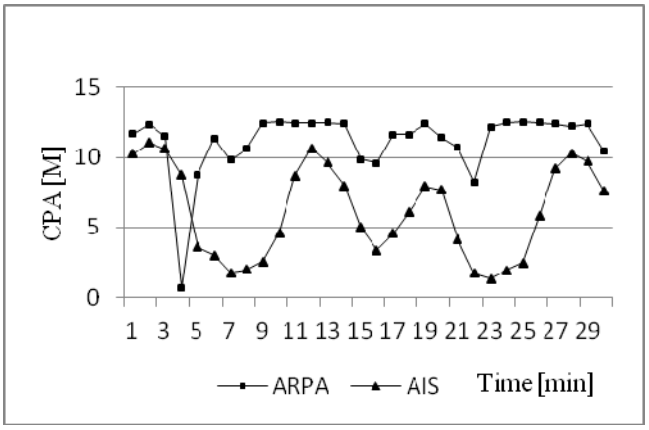

Figure 18. Presented by AIS and ARPA information on CPA of the container vessel "NYK Altair" (situation No 24, own ship and "NYK Altair" were proceeding with steady courses and speeds, sea state 4) [Wilczyński 2016]

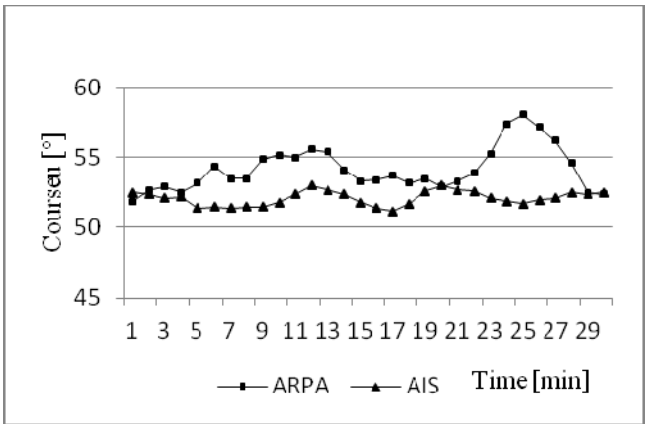

Figure 19. Presented by AIS and ARPA information on the course of the container vessel "NYK Altair" (situation No 24, own ship and "NYK Altair" were proceeding with steady courses and speeds, sea state 4) [Wilczyński 2016]

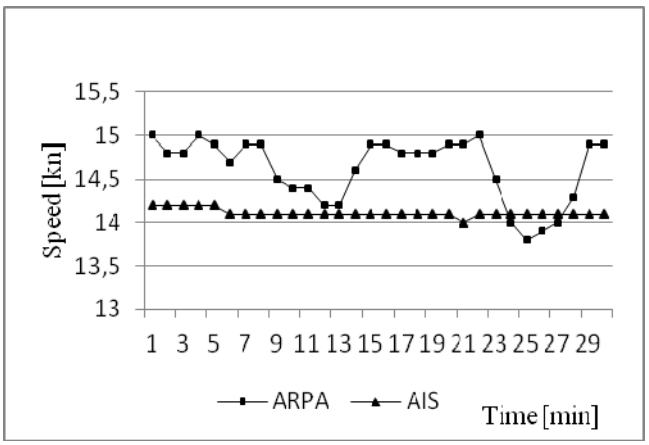

Figure 20. Presented by AIS and ARPA information on the speed of the container vessel "NYK Altair" (situation No 24, own ship and "NYK Altair" were proceeding with steady courses and speeds, sea state 4) [Wilczyński 2016]

AIS advantages become apparent during the observation of vessels at anchorage when slewing of ship at anchor affects the low accuracy of data about CPA, TCPA, course and speed of that ship received from radar tracking. It may be seen in Figures 21-24 presenting the information on bulk carrier "China Peace" staying at anchor, shown by AIS and ARPA on ship approaching the anchorage from the distance of 15 M (27.8 km).

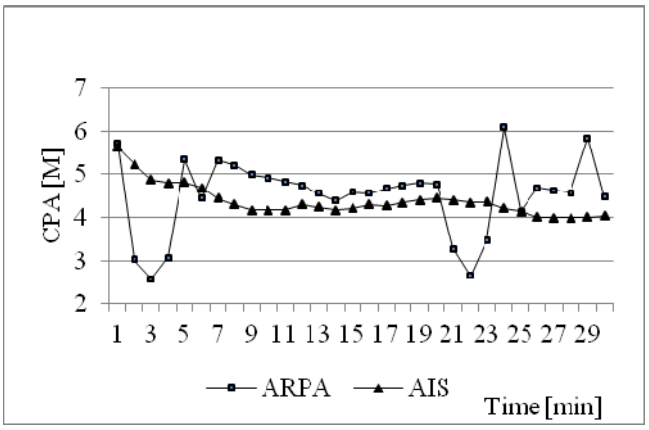

Figure 21. Presented by AIS and ARPA information on CPA of the bulk carrier "China Peace" staying at anchor (situation No 7, own ship was proceeding with steady course and speed, sea state 3) [Wilczyński 2016]

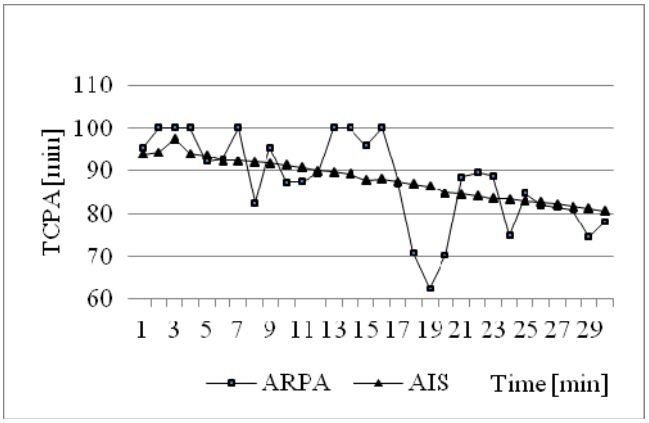

Figure 22. Presented by AIS and ARPA information on TCPA of the bulk carrier "China Peace" staying at anchor (situation No 7, own ship was proceeding with steady course and speed, sea state 3) [Wilczyński 2016]

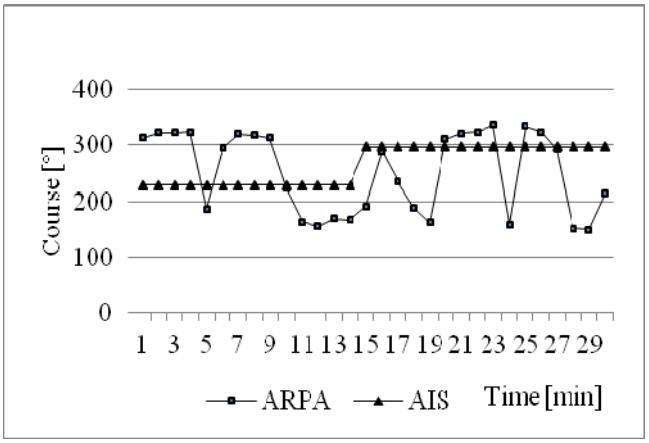

Figure 23. Presented by AIS and ARPA information on the course of the bulk carrier "China Peace" staying at anchor (situation No 7, own ship was proceeding with steady course and speed, sea state 3) [Wilczyński 2016]

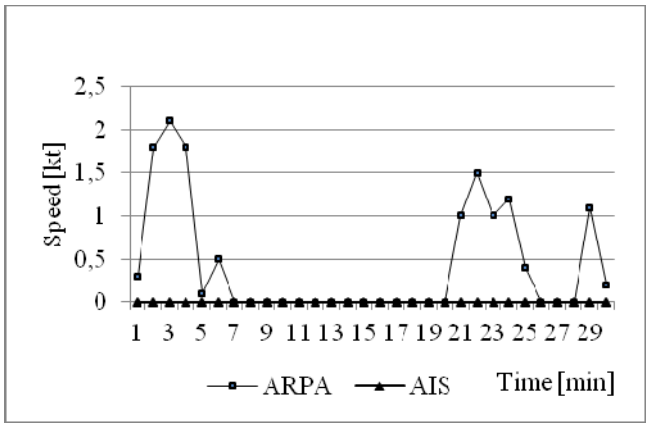

Figure 24. Presented by AIS and ARPA information on the speed of the bulk carrier "China Peace" staying at anchor (situation No 7, own ship was proceeding with steady course and speed, sea state 3) [Wilczyński 2016]

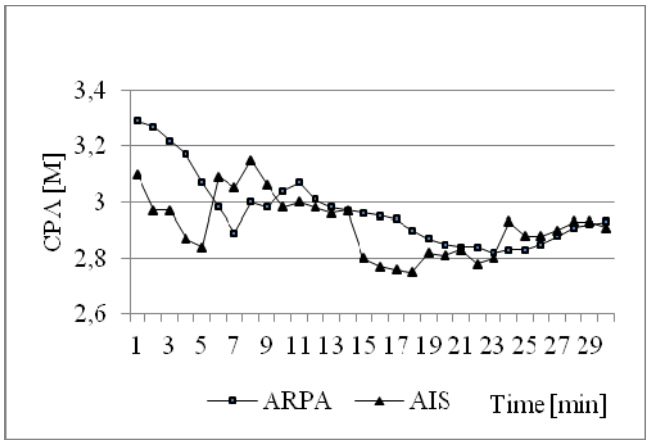

Figure 25. Presented by AIS and ARPA information on CPA of the tanker "NCC Danah" (situation No 22, own ship and "NCC Danah" were proceeding with steady courses and speeds, sea state 7) [Wilczyński 2016]

Another problem is the issue of the accuracy of data presented by the AIS in adverse weather conditions. As shown in Figures 25 and 26 the accuracy and stability of data presented by AIS may be on the same level or even worse than the accuracy and stability of ARPA data. The reason of that are unstable instantaneous values of the course and/or speed of observed vessel indicated by AIS (Figures 27 and 28). In Figures 25-28 are presented data about tanker "NCC Danah" sailing on the crossing course in heavy storm (sea state 7 degrees of the Douglas scale).

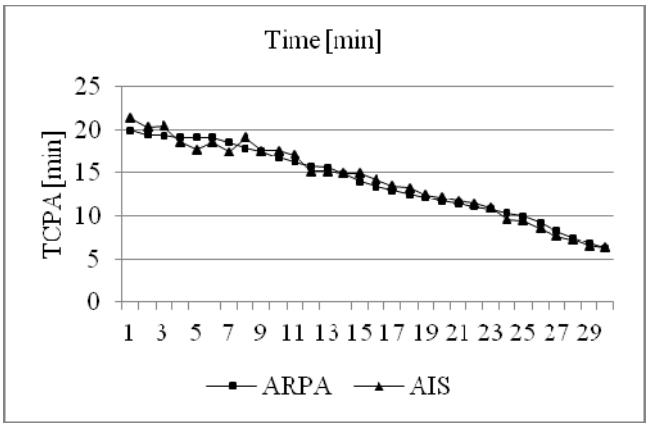

Figure 26. Presented by AIS and ARPA information on TCPA of the tanker "NCC Danah" (situation No 22, own ship and "NCC Danah" were proceeding with steady courses and speeds, sea state 7) [Wilczyński 2016]

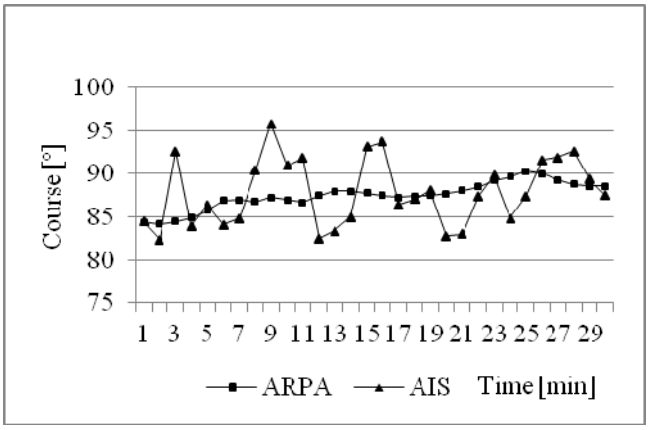

Figure 27. Presented by AIS and ARPA information on course of the tanker "NCC Danah" (situation No 22, own ship and "NCC Danah" were proceeding with steady courses and speeds, sea state 7) [Wilczyński 2016]

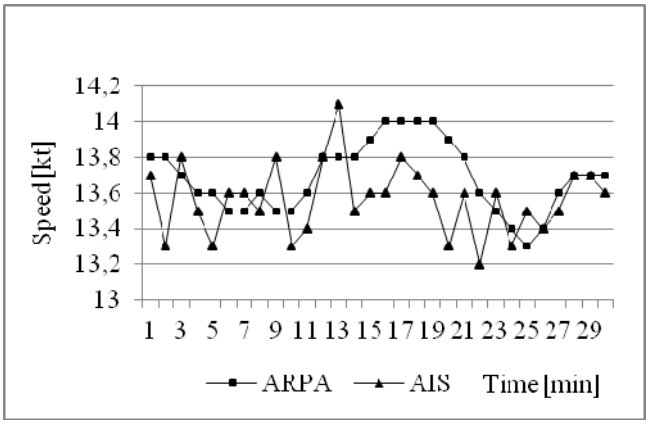

Figure 28. Presented by AIS and ARPA information on speed of the tanker "NCC Danah" (situation No 22, own ship and "NCC Danah" were proceeding with steady courses and speeds, sea state 7) [Wilczyński 2016]

Similarly, the problem with accuracy and stability of information presented by shipborne AIS about the CPA and TCPA appears in the case of a high swell. It may be seen in Figures 29-32 showing CPA, TCPA, course and speed of container vessel "OOCL Korea" sailing on the crossing course in the condition of high swell.

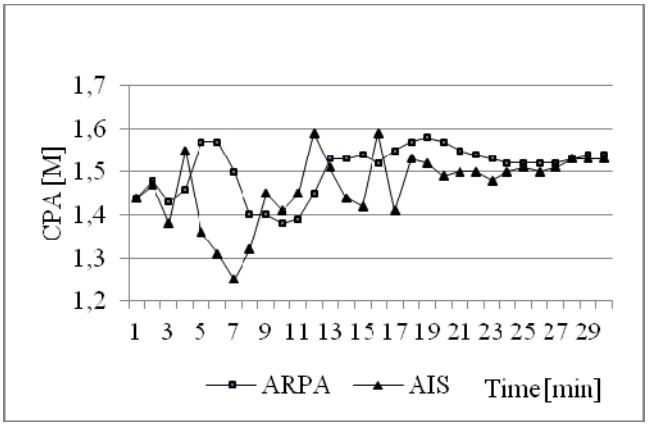

Figure 29. Presented by AIS and ARPA information on CPA of the container vessel "OOCL Korea" (situation No 26, own ship and "OOCL Korea" were proceeding with steady courses and speeds, high swell) [Wilczyński 2016]

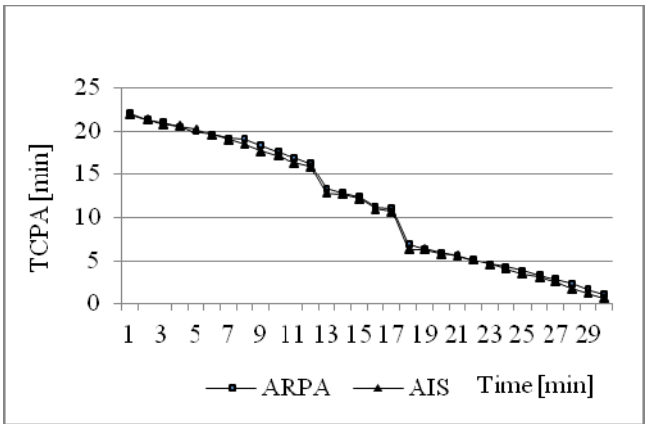

Figure 30. Presented by AIS and ARPA information on TCPA of the container vessel "OOCL Korea" (situation No 26, own ship and "OOCL Korea" were proceeding with steady courses and speeds, high swell) [Wilczyński 2016]

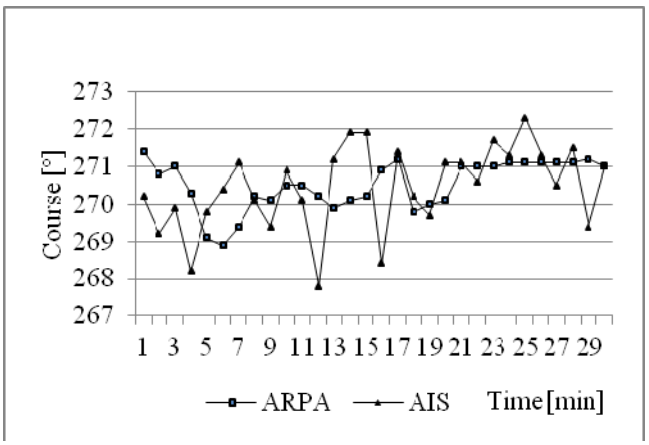

Figure 31. Presented by AIS and ARPA information on the course of the container vessel "OOCL Korea" (situation No 26, own ship and "OOCL Korea" were proceeding with steady courses and speeds, high swell) [Wilczyński 2016]

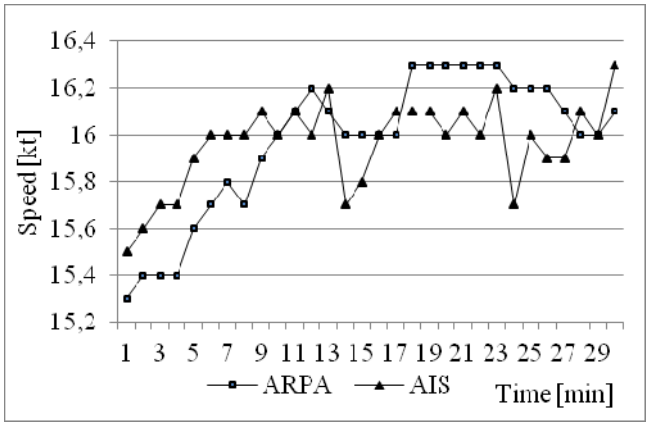

Figure 32. Presented by AIS and ARPA information on the speed of the container vessel "OOCL Korea" (situation No 26, own ship and "OOCL Korea" were proceeding with steady courses and speeds, high swell) [Wilczyński 2016]

4 CONCLUSIONS

The tests carried out have shown that information presented by AIS about the CPA and TCPA of other vessels is at least as accurate and stable over time as the values of these parameters indicated by ARPA. AIS shows data often more stable and precisely, for example in the case of ships at anchor. The problem requiring further research is the accuracy of the information, mainly about the CPA, presented by the ship's AIS in adverse weather conditions.

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