Processing Logbook

master track creation of RV "Heincke"

Contact:

FIELAX Gesellschaft für wissenschaftliche Datenverarbeitung mbH

Schleusenstraße 14, D-27568 Bremerhaven, GERMANY

Fon: +49 (0)471 30015-0, Fax: +49 (0)471 30015-22

Mail: info@fielax.de

Ref.:Processing_Logbook_RV_Heincke.pdf	Vers.: 1	Date: 22/06/2015	Status: final

Content

1 Introduction

The vessel RV Heincke is equipped with different positioning sensors which continuously record the position of the vessel during a cruise. However, these sensors vary in accuracy or they may fail completely for a certain time. Thus, all of them are compared and their accuracy is estimated to retrieve the most reliable and most probable position of the ship for each second of the cruise. This track can then be used as "master track" for the geographical positioning of further data.

2 Workflow

The different steps of processing and validation are visualized in Figure 1.

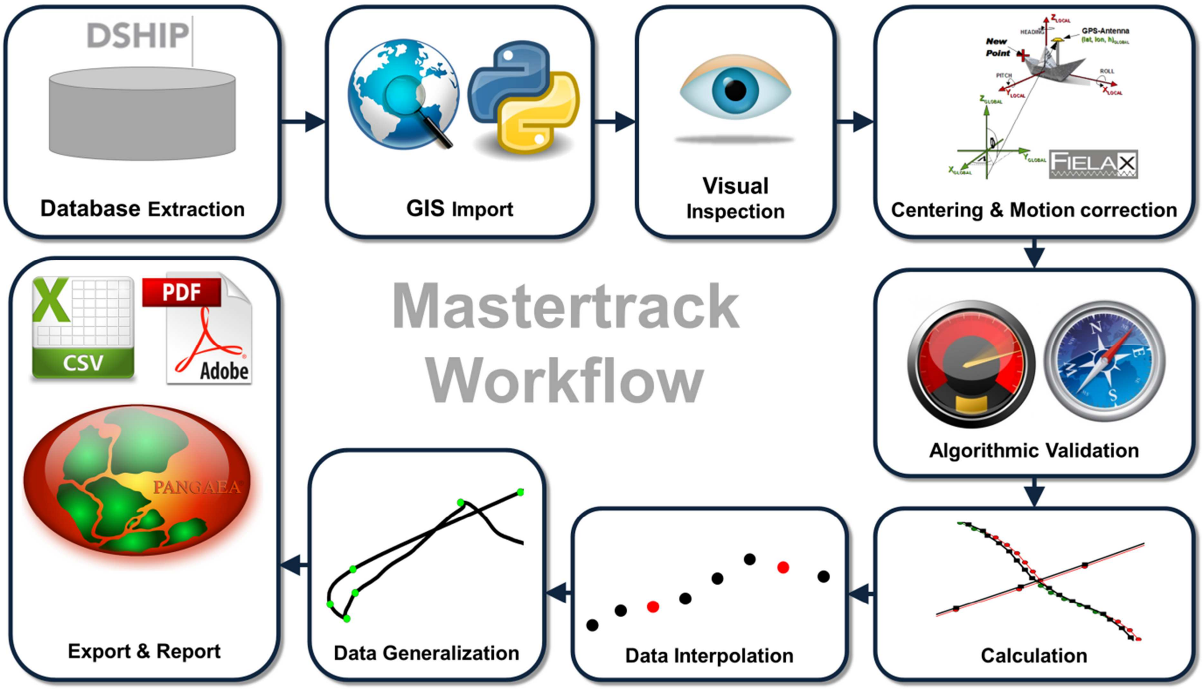

Figure 1: Workflow of master track data processing

Unvalidated data of up to three sensors and ship-motion data are extracted from the DAVIS SHIP data base (https://dship.awi.de) in a 1-second interval. They are converted to ESRI point shapefiles and imported to ArcGIS. A visual screening is performed to evaluate data quality and remove outliers manually. The position data from each position sensor are centered to the destined master track origin by applying ship-motion data (angles of roll, pitch and heading) and lever arms.

For all three resulting position tracks, a quality check is performed using a ship's speed filter and an acceleration filter. Filtered positions are flagged. In addition, a manual check is performed to flag obvious outliers. Those position tracks are combined to a single master track depending on a sensor priority list (by accuracy, reliability) and availability / applied exclusion of automatically or manually flagged data. Missing data up to a time span of 60 seconds are interpolated linearly.

Finally a master position track is created by use of a regression smoothing filter. The regression estimates the position of the subsequent point and compares that to the next position of each position sensor. The point that is closest to the estimated point is assigned to the master track. To reduce the amount of points for overview maps the master track is generalized by using the Ramer-Douglas-Peucker algorithm[1,2]. This algorithm returns only the most significant points from the track. Full master track and generalized master track are written to text files and imported to PANGAEA (http://www.pangaea.de).

3 Sensor Configuration

The vessel RV Heincke currently hosts three positioning sensors for scientific purposes. The first positioning sensor is the differential GPS (DGPS) Trimble; its specifications are given in Table 3.

Table 1: Sensor specifications of the Trimble DGPS

Sensor Name	**Trimble Marine SPS461**, short: Trimble		
Description	DGPS-Receiver, correction type DGPS RTCM 2.x, correction source DGPS Base via radio		
Accuracy	Horizontal: ± 0.25 m + 1 ppm & Vertical: ± 0.50 m + 1 ppm		
Installation point	Until HE379: Masttop; From HE380: Starboard railing above bridge deck		
Offset from master track reference point to sensor installation point	X (Positive to bow)	Y (Positive to starboard)	Z (Positive upwards)
		Until HE379	
	5.298 m	-0.034 m	22.297 m
		From HE380	
	5.044 m	6.788 m	11.489 m

Note:

The positioning sensor Trimble was moved from the position at the Masttop to its current position at the starboard railing above the bridge deck in May 2012 between the cruises HE379 and HE380.

The second positioning sensor is the GPS DEBEG, its specifications are given below (Table 2).

Table 2: Sensor specifications of the DEBEG GPS

Sensor Name	**DEBEG/Leica MX400**, short: DEBEG		
Description	GPS-Receiver for navigation purposes		
Accuracy	± 7 – 15 m		
Installation point	Observational Deck, fore rail		
Offset from master track reference point to sensor installation point	X (Positive to bow) 12.985 m	Y (Positive to starboard) 2.958 m	Z (Positive upwards) 11.328 m

[1] Ramer, U. (1972). An interative procedure for the polygonal approximation of plane curves. *Computer Graphics and Image Processing*, (1) 3, 244-256
[2] Douglas, D., & Peucker, T. (1973). Algorithms for the reduction of the number of points required to represent a digitized line or its caricature. *The Canadian Cartographer*, (10) 2, 112-122

The third positioning device is the motion sensor PHINS which receives its reference positions from the DGPS Trimble (Table 3).

Table 3: Sensor specifications of the PHINS motion sensor

Sensor Name	**IXSEA PHINS III**, short: PHINS		
Description	Inertial Navigation system with reference positions from Trimble DGPS		
Position Accuracy	± 0.5 – 3.0 m		
Motion Accuracy	± 0.01° roll, ± 0.01° pitch, ± 0.05 ° heading		
Installation point	Electrician's workshop, close to COG		
Offset from master track reference point to sensor installation point	X (Positive to bow) 0.0 m	Y (Positive to starboard) 0.0 m	Z (Positive upwards) 0.0 m

This device delivered motion information of the pitch, the roll and the heading angles of the ship since HE308 (2009-07-28 – 2009-08-06), and positions since HE316 (2010-01-27 – 2010-02-06). Before these dates, only information about the heading of the ship was available from the gyrocompass at the bridge, which was used for the centering of the GPS data.

Figure 2 shows the locations of the sensors in the ship, the coordinates are given relative to the reference point at the aft keel (indicted in Figure 2).

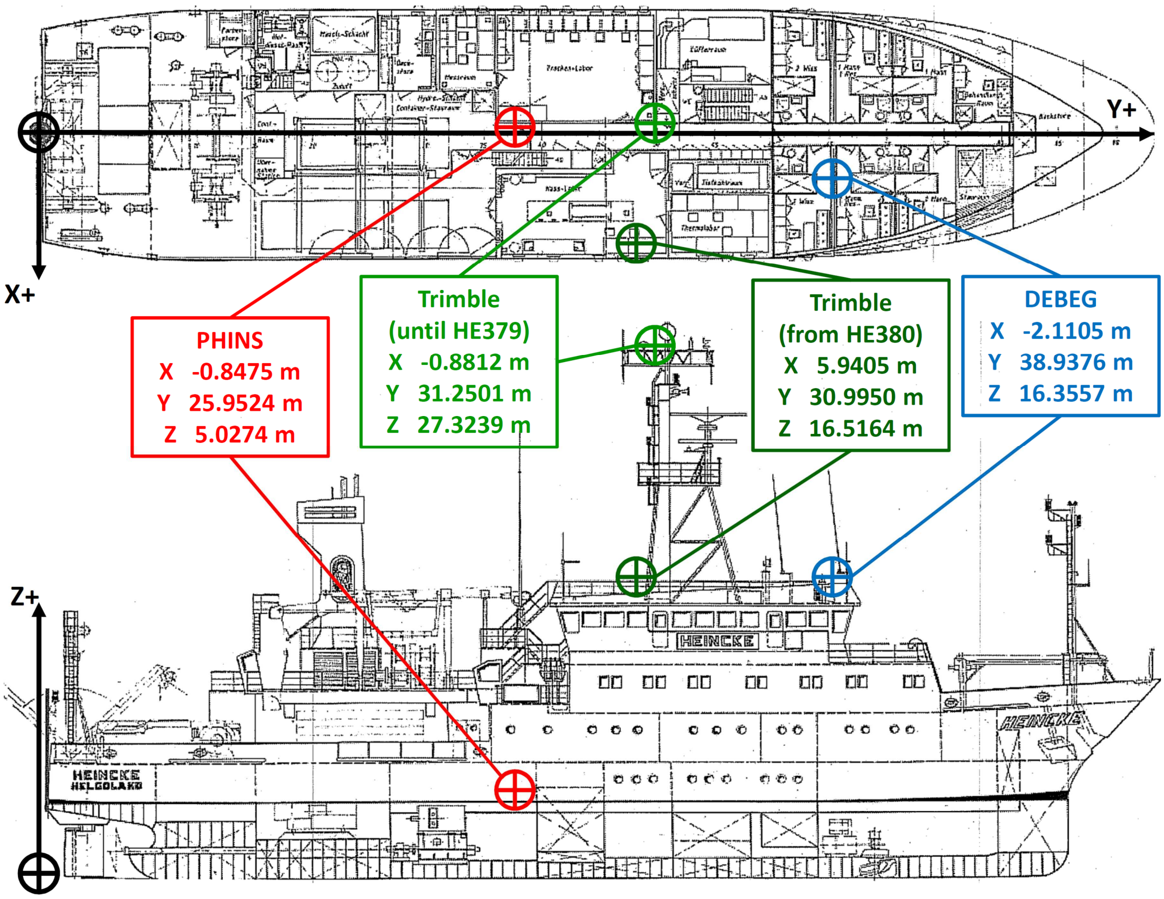

Figure 2: Locations of positioning sensors on RV Heincke

4 Extracted Data

Navigation data of RV Heincke were extracted from the DAVIS SHIP data base (dship.awi.de) for the period 2005-2013. Since data is available from 2005-03-03 15:00:00, the extracted cruises start with HE222A (2005-03-02 – 2005-03-13) and end with HE404 (2013-06-20 – 2013-07-25). For these cruises, unvalidated data of all available positioning sensors and ship-motion data were extracted in 1- second interval (Table 4).

Table 4: Available cruises per year

Year	Amount	Cruises
2005	22	HE222A, HE222B, HE223, HE224, HE225, HE226, HE228, HE229, HE230, HE231, HE232, HE233B, HE234, HE235, HE236, HE237, HE238, HE239, HE240, HE241, HE242/1, HE242/2
2006	17	HE244, HE248, HE249, HE250, HE251, HE252, HE254, HE255, HE256, HE257, HE258, HE259, HE260, HE261, HE262, HE263/1, HE263/2
2007	11	HE265, HE266/1, HE266/2, HE267, HE268, HE269, HE270, HE271, HE272, HE273, HE274
2008	15	HE283, HE284, HE285, HE287, HE288, HE289, HE290, HE291, HE292/1, HE292/2, HE293, HE294, HE295, HE296, HE297
2009	20	HE298, HE299, HE300, HE301, HE302, HE303, HE304, HE305, HE306/1, HE306/2, HE307, HE308, HE309, HE310, HE311, HE312/1, HE312/2, HE313, HE314, HE315
2010	29	HE316, HE317, HE318, HE319, HE320, HE321, HE322, HE323, HE324, HE325, HE326, HE327, HE328, HE329, HE330, HE331, HE332, HE333, HE334, HE336, HE337, HE338, HE339, HE340, HE341, HE342, HE343, HE344, HE345
2011	28	HE346, HE347, HE348, HE349, HE350, HE351, HE352/1, HE352/2, HE353, HE354, HE355/1, HE355/2, HE356/1, HE356/2, HE357, HE358, HE359, HE360, HE361, HE362, HE363, HE364, HE365, HE366, HE367, HE368, HE369, HE370
2012	23	HE371, HE372, HE373, HE374, HE375, HE376, HE377, HE378, HE379, HE380, HE381, HE382/1, HE382/2, HE383, HE384, HE385, HE386, HE387, HE388, HE389, HE390, HE391, HE392
2013	13	HE393, HE394, HE395/1, HE395/2, HE396, HE397, HE398, HE399, HE400, HE401, HE402, HE403, HE404
Total 178 cruises		

5 Processing Logbook

5.1 First processing step: Data quality and manual flagging

The extracted data are converted to ESRI point shapefiles and imported to a GIS. The position data from each position sensor are centered to the destined master track origin by applying ship-motion data (angles roll, pitch, and heading) and lever arms. For all position tracks, a quality check is performed using a ship's speed filter, an acceleration filter, and a change of course-filter. Visual screening is then performed to evaluate data quality and to remove outliers manually. Filtered positions are flagged and are omitted in the master track creation.

For each position sensor, an average percentage of good values of the extracted data is calculated taking into account the missing datapoints, the automatically, and the manually flagged points. This results in a recommendation for the sensor priority used for the subsequent master track generation.

The following figures show the availability of the data extracted from the DAVIS SHIP data base for all processed cruises. As can be seen in Figure 3 to Figure 6, the position sensor PHINS was only available from HE316 onwards.

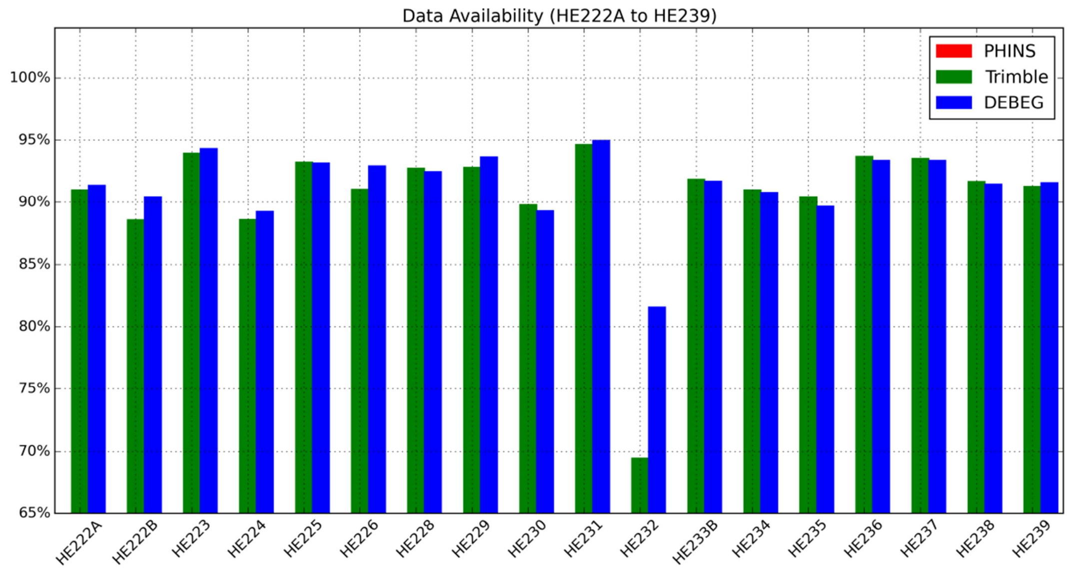

Figure 3: Data availability for the cruises HE222A – HE239

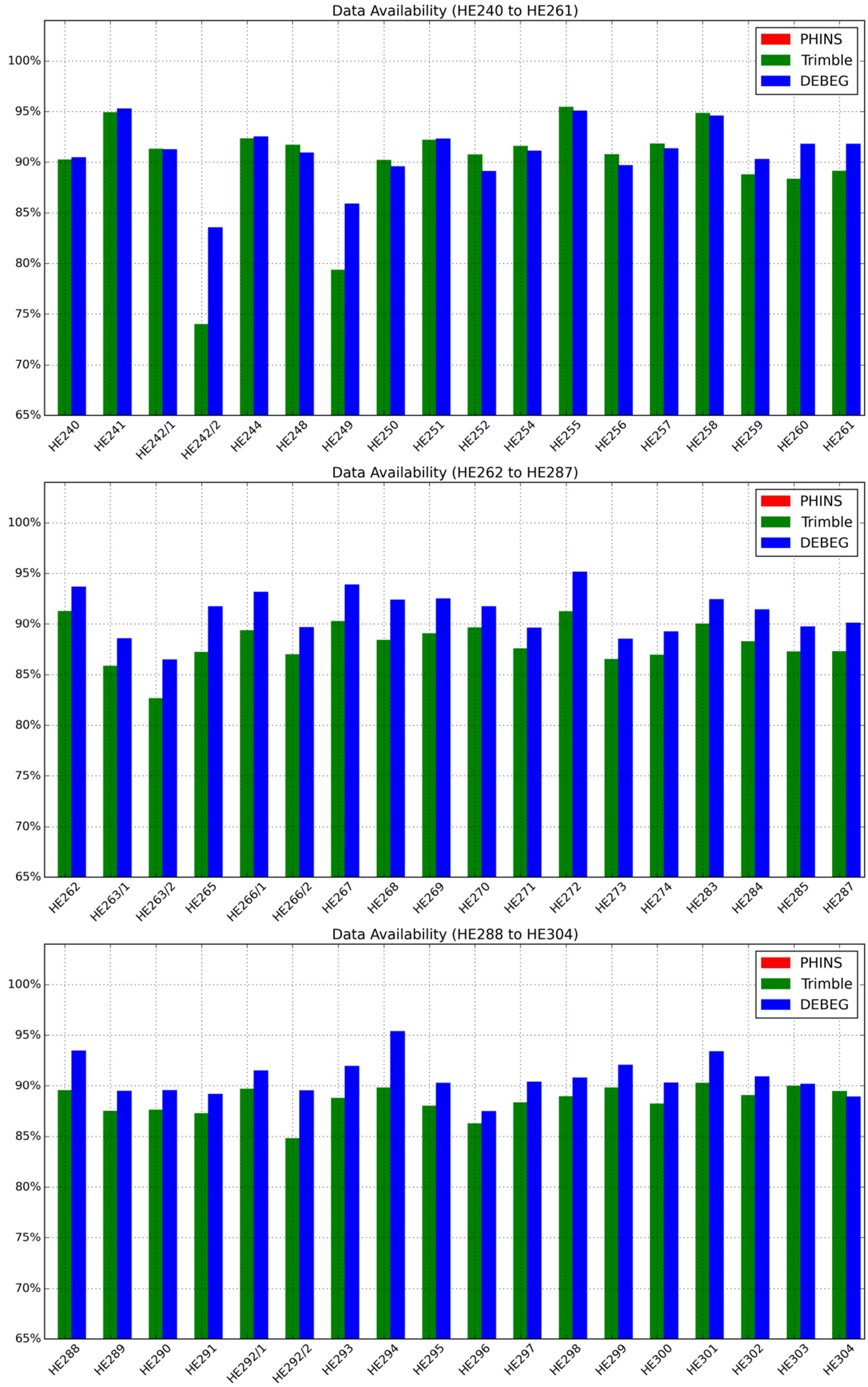

Figure 4: Data availability for the cruises HE240 – HE304

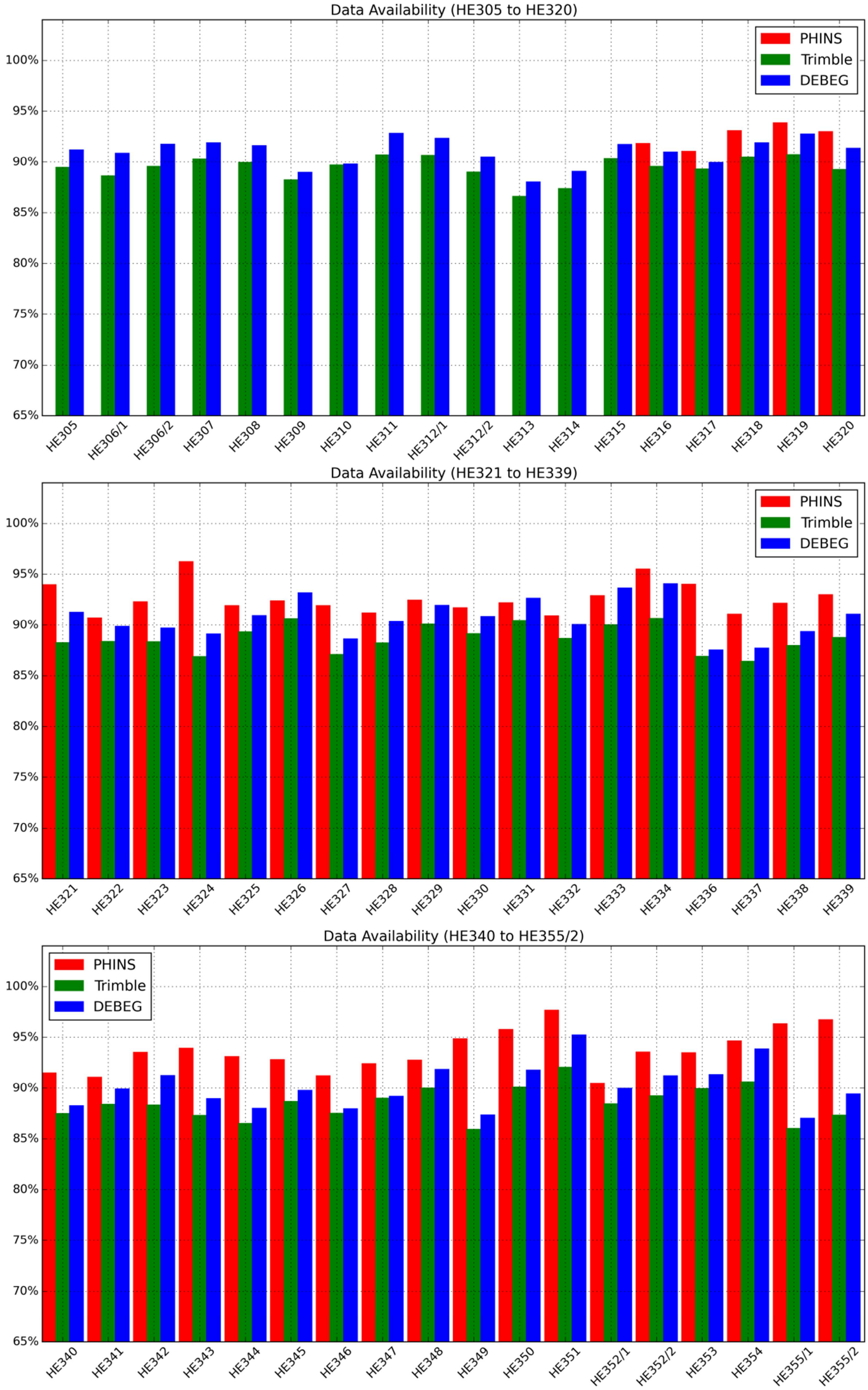

Figure 5: Data availability for the cruises HE305 – HE355/2

Figure 6: Data availability for the cruises HE356/1 – HE404

5.3 Typical errors in the dataset

DGPS Trimble

The errors of DGPS Trimble can be summarized in seven groups:

- Single outliers or a small group of points located next to the track with a constant offset (e. g. Figure 7)

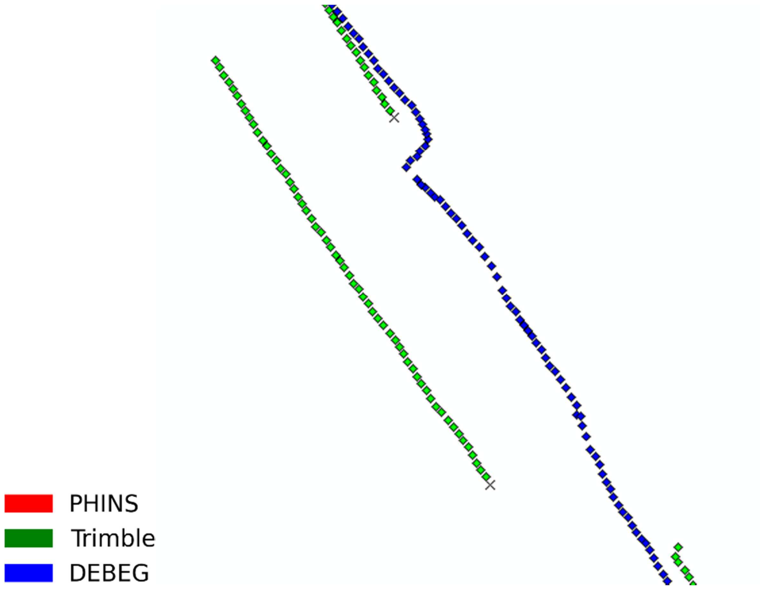

Figure 7: Error example from HE294

- A clustering of points in the vicinity of curves (e. g. Figure 8)

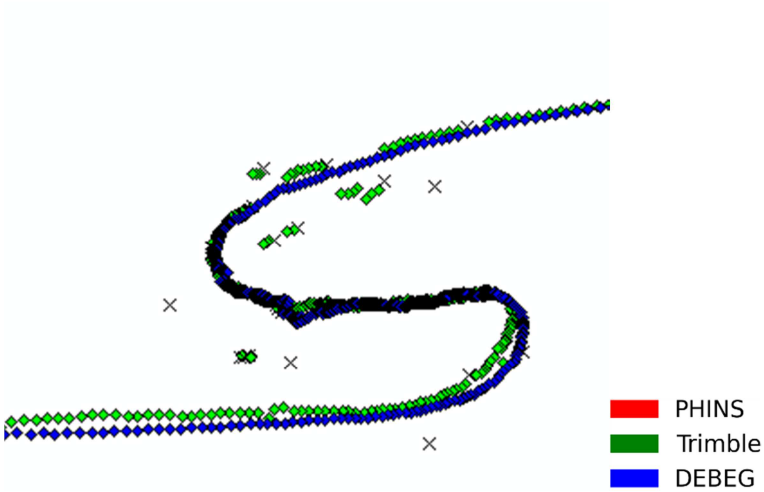

Figure 8: Error example from HE272

- A larger group of points is located next to the track over a longer period (e. g. Figure 9)

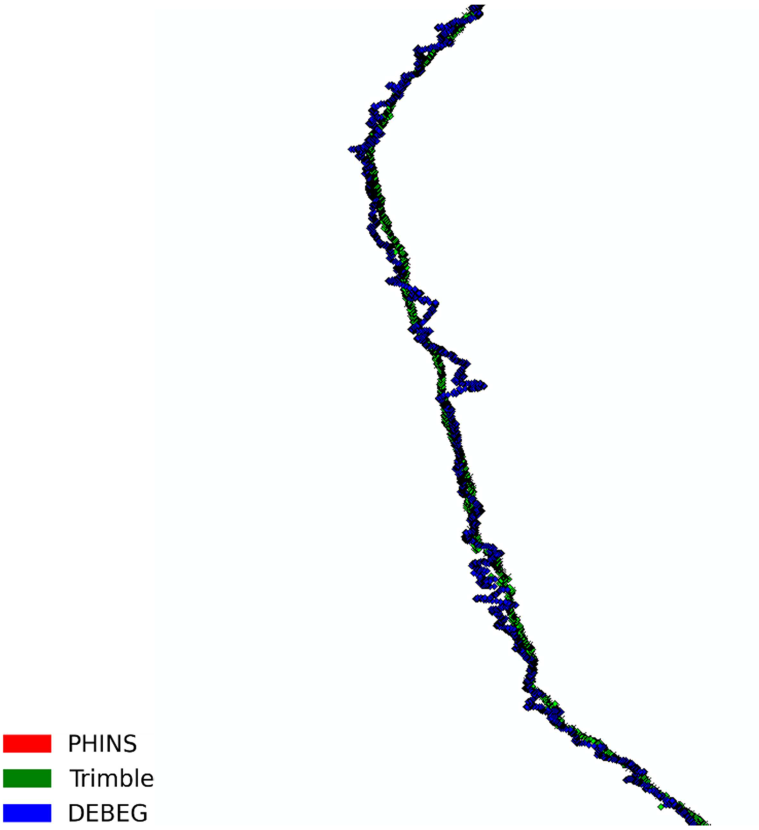

Figure 9: Error example from HE288

- Regular offsets after missing positions (e. g. Figure 10)

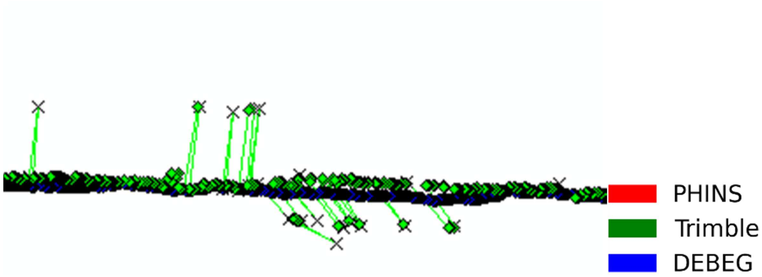

Figure 10: Error example from HE239

- Large set of points are close to the track with constant offsets but they change very rapidly their offsets (e. g. Figure 11)

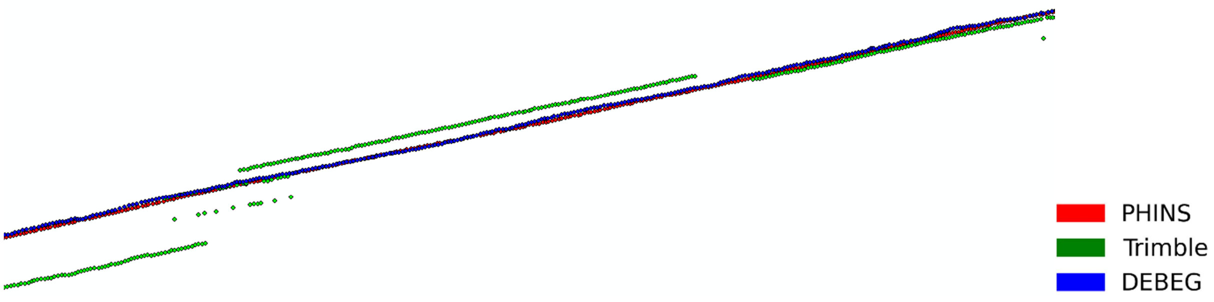

Figure 11: Error example from HE328

- The data may become very noisy and a clear track is no longer recognizable (e. g. Figure 12)

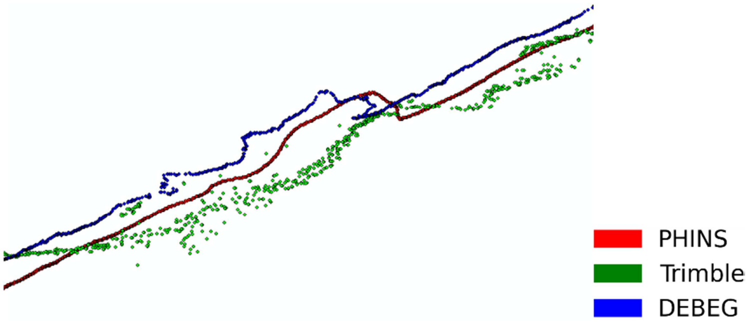

Figure 12: Error example from HE330

- Constant offsets in curves (e. g. Figure 13)

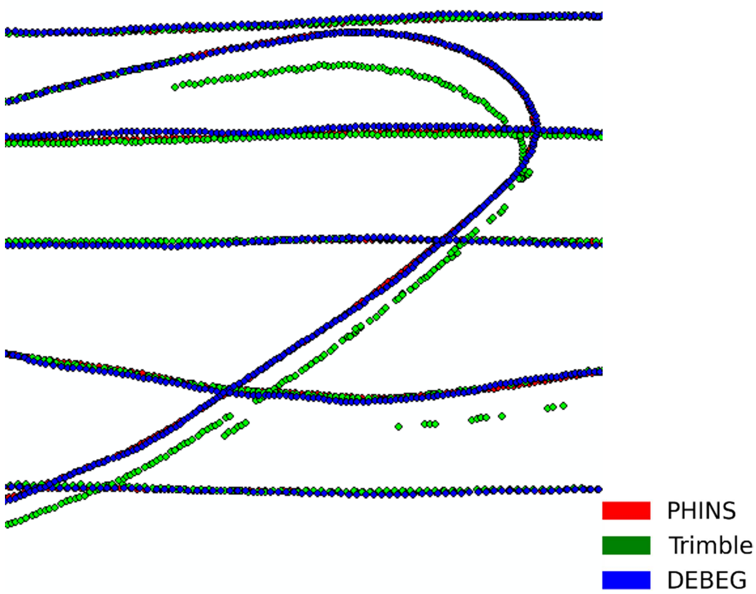

Figure 13: Error example from HE349

- Frozen GPS positions over a long period (e. g. Figure 14) of 4.5 hours

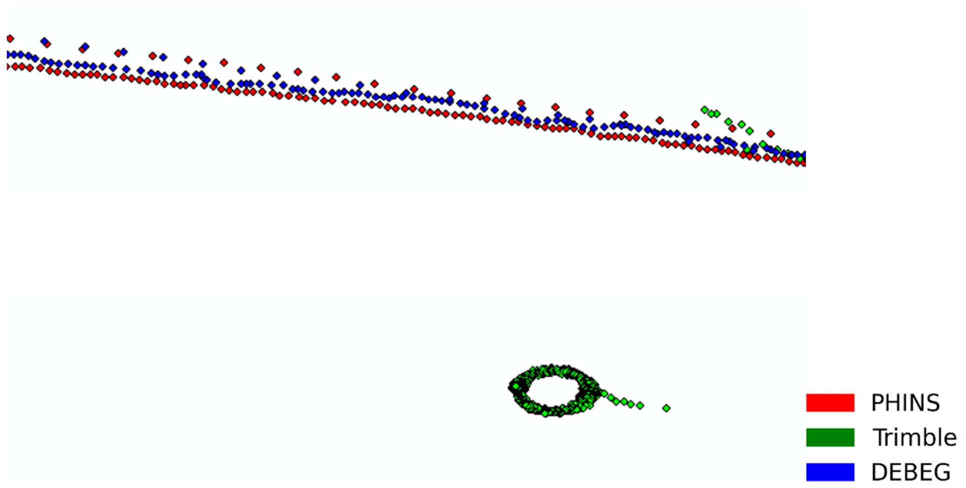

Figure 14: Error example from HE321/2

GPS DEBEG

The errors of the GPS DEBEG can be summarized in six groups:

- Slightly meandering along the straight Track of Trimble (e. g. Figure 15)

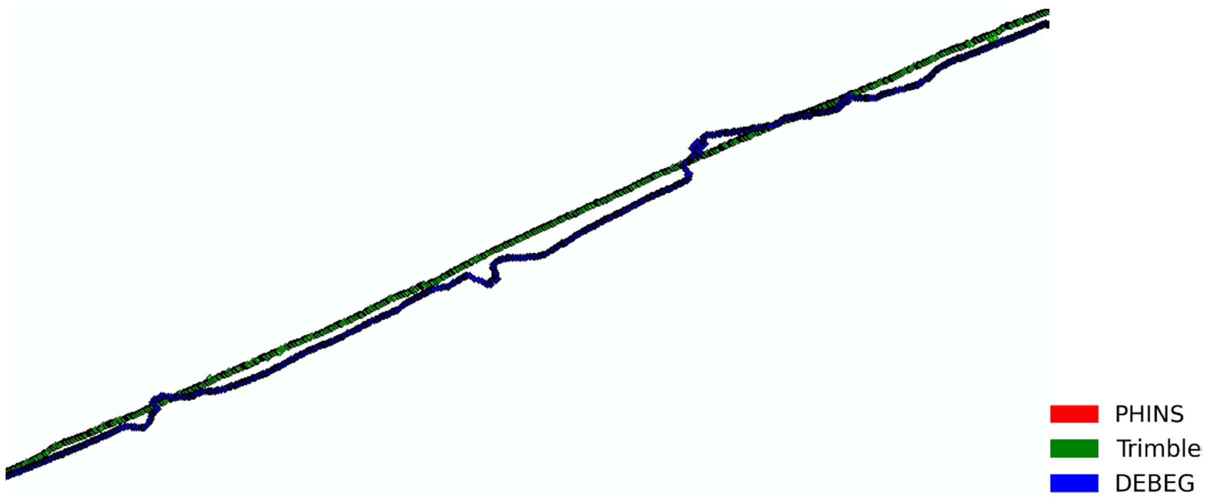

Figure 15: Error example from HE273

- Very noisy meandering along the straight Track of Trimble (e. g. Figure 16)

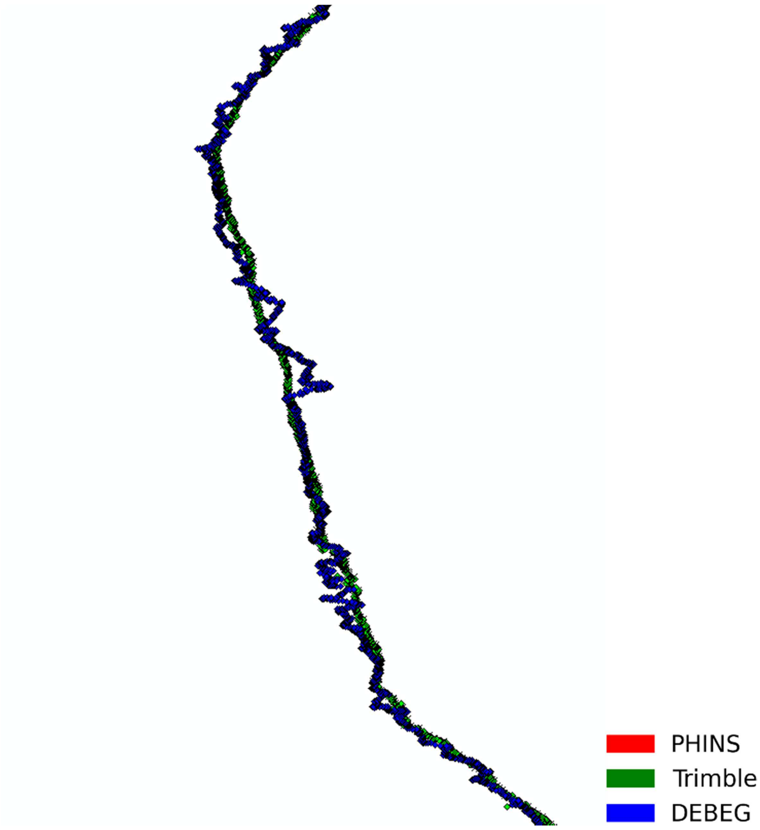

Figure 16: Error example from HE288

- Offsets occur suddenly and disappear after a short time (e. g. Figure 17)

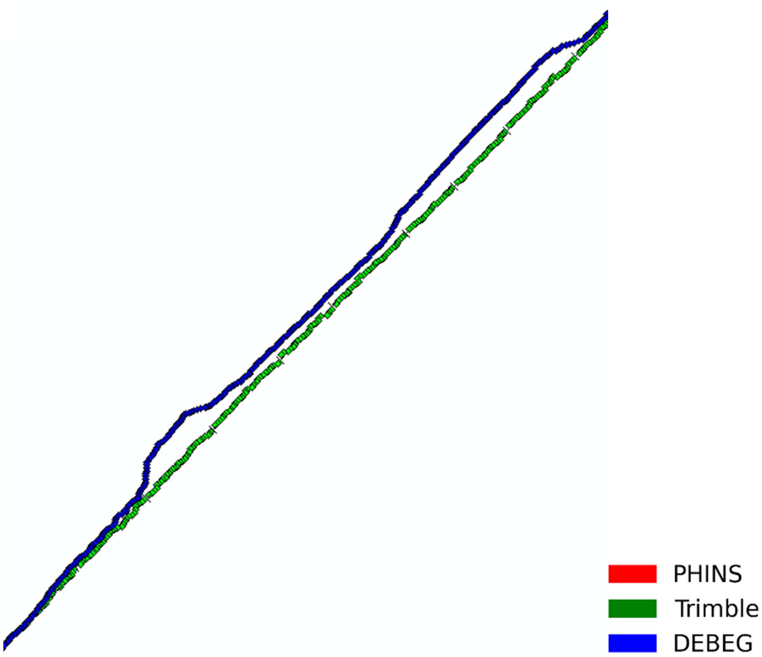

Figure 17: Error example from HE287

- An increasing drift away from the track (e. g. Figure 18)

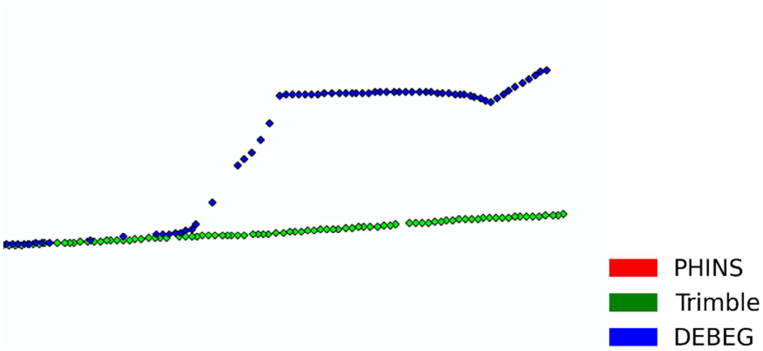

Figure 18: Error example from HE303

- Meandering around the track that disappears (e. g. Figure 19)

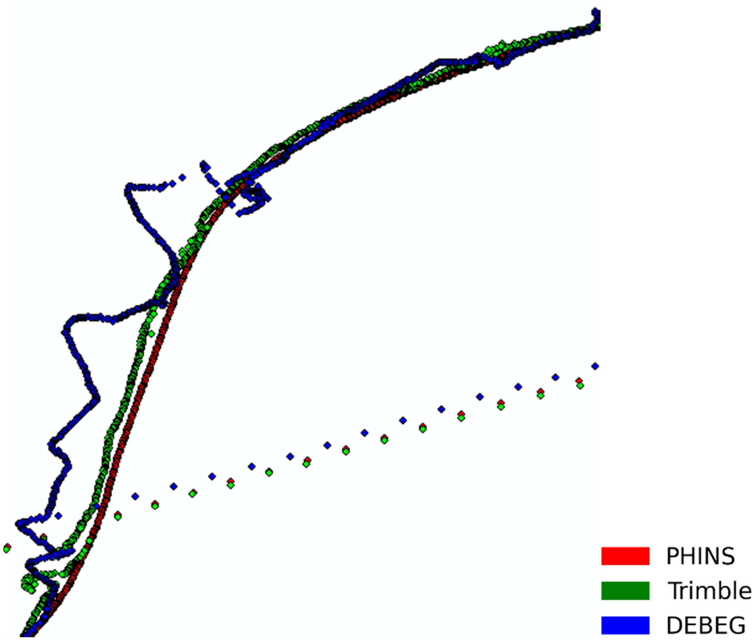

Figure 19: Error example from HE326

- Slightly meandering around the track where Trimble delivers noisy data (e. g. Figure 20)

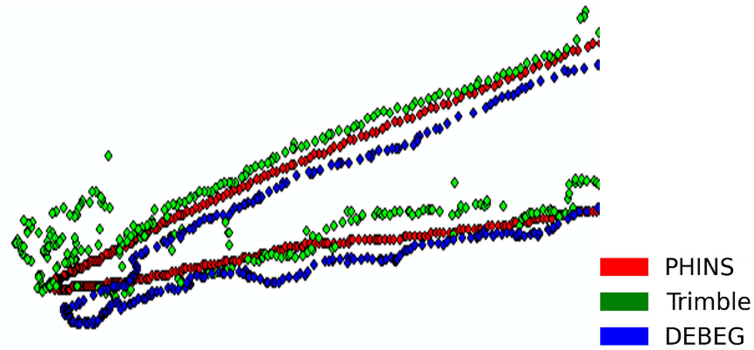

Figure 20: Error example from HE327

Motion sensor PHINS

The PHINS delivered positions are of very good quality, hence only isolated outliers are detected during smooth track (in HE321/2, see Figure 14)

5.4 Hierarchical groups of cruises

The availability / absence of PHINS data is the primary hierarchical subdivision of the whole cruises dataset. The second subdivision relates to the sensor priority which is used for the generation of the master.

The third level refers to the applied filters. Outliers are marked manually and with automated filters. However, if too high percentages of points are flagged by the automated filters, they are not used for the master track creation. A threshold of 10% is used for the speed filter, and 5% for the acceleration- and course-change-filter, respectively. Altogether, 10 groups are defined (Table 5).

Table 5: Processing groups

<table>
<tr><th rowspan="2">Group</th><th rowspan="2">Sensors</th><th rowspan="2">Sensor priority</th><th colspan="4">Used filters</th><th rowspan="2">Cruises</th></tr>
<tr><th>Manually</th><th>Speed</th><th>Acceleration</th><th>Course change</th></tr>
<tr><td>1</td><td rowspan="6">PHINS not available</td><td rowspan="2">Trimble, DEBEG</td><td>X</td><td>X</td><td></td><td></td><td>HE273, HE287, HE288</td></tr>
<tr><td>2</td><td>X</td><td>X</td><td>X</td><td></td><td>HE293</td></tr>
<tr><td>3</td><td rowspan="4">DEBEG, Trimble</td><td>X</td><td></td><td></td><td></td><td>HE265</td></tr>
<tr><td>4</td><td>X</td><td>X</td><td></td><td></td><td>HE259, HE260, HE261, HE262, HE263/1, HE266/1, HE266/2, HE267, HE268, HE269, HE270, HE271, HE272, HE274, HE284, HE285, HE289, HE290, HE291, HE292/1, HE292/2, HE294, HE295, HE296, HE297, HE298, HE299, HE300, HE302, HE303, HE304, HE305, HE306/1, HE306/2, HE307, HE308, HE309, HE310, HE311,HE312/1, HE312/2, HE313, HE314</td></tr>
<tr><td>5</td><td>X</td><td>X</td><td>X</td><td></td><td>HE222A, HE222B, HE223, HE224, HE225, HE226, HE227, HE228, HE229, HE230, HE231, HE233B, HE234, HE235, HE236, HE237, HE238, HE239, HE240, HE241, HE242/1, HE242/2, HE244, HE248, HE249, HE250, HE251, HE252, HE253, HE254, HE255, HE256, HE257, HE258, HE263/2, HE283, HE301, HE315</td></tr>
<tr><td>6</td><td>X</td><td>X</td><td>X</td><td>X</td><td>HE232</td></tr>
<tr><td>7</td><td rowspan="4">PHINS available</td><td rowspan="2">PHINS, DEBEG, Trimble</td><td>X</td><td>X</td><td></td><td></td><td>HE316, HE317, HE318, HE319, HE320, HE321, HE322, HE323, HE324, HE325, HE326, HE327, HE328, HE329, HE330, HE331, HE332, HE333, HE334, HE335, HE336, HE337, HE338, HE339, HE340, HE341, HE342, HE343, HE344, HE345, HE346, HE347, HE348, HE349, HE350, HE351, HE352/1, HE352/2, HE353, HE354, HE356/1, HE356/2, HE357, HE358, HE359, HE360, HE361, HE362, HE363, HE364, HE365, HE366, HE367, HE368, HE369, HE370</td></tr>
<tr><td>8</td><td>X</td><td>X</td><td>X</td><td></td><td>HE355/1, HE355/2</td></tr>
<tr><td>9</td><td rowspan="2">PHINS, Trimble, DEBEG</td><td>X</td><td>X</td><td></td><td></td><td>HE371, HE372, HE373, HE374, HE375, HE376, HE377, HE378, HE379, HE380, HE381, HE382/1, HE382/2, HE383, HE384, HE386, HE387, HE388, HE389, HE390, HE391, HE392, HE393, HE394, HE395/1, HE395/2, HE396, HE397, HE398, HE399, HE400, HE401, HE402, HE403, HE404</td></tr>
<tr><td>10</td><td>X</td><td>X</td><td>X</td><td></td><td>HE385</td></tr>
</table>

6 Scores

6.1 Calculation

In order to evaluate the quality of a created master track, a single score-value is calculated using the raw dataset, the automated and manual filters flagging, and the resulting master track.

First, the mean percentage of existing data is calculated for all useable navigation sensors. The equation 1.1 is applied for all cruises until HE315, from cruise HE316 onwards, equation 1.2 is used. The availability of raw position data is also shown in Figure 3 to Figure 6.

$$raw_{score} = \left(\frac{available_{Trimble} + available_{DEBEG}}{datapoints}\right)/2 \quad (1.1)$$

$$raw_{score} = \left(\frac{available_{PHINS} + available_{Trimble} + available_{DEBEG}}{datapoints}\right)/3 \quad (1.2)$$

Secondly, the arithmetic mean of all flagged datapoints is calculated for all automatic filters and the manual inspection. Again, the equation 2.1 is applied for all cruises up to HE315, the equation 2.2 for latter cruises.

$$flagging_{score} = \left(\frac{\overline{flagged_{Trimble}} + \overline{flagged_{DEBEG}}}{datapoints}\right)/2 \quad (2.1)$$

$$flagging_{score} = \left(\frac{\overline{flagged_{PHINS}} + \overline{flagged_{Trimble}} + \overline{flagged_{DEBEG}}}{datapoints}\right)/3 \quad (2.2)$$

The value of all valid and non-interpolated track-positions is calculated (3). This is done including also gaps and interpolated values of the final master track.

$$track_{score} = 1 - \frac{interpolated\ points + gaps + datapoints - points\ in\ track}{datapoints} \quad (3)$$

The single score-value is then derived calculating the mean of these three values scaled from 0 to 100 (4).

$$score = \frac{raw_{score} + (1 - flagging_{score}) + track_{score}}{3} * 100 \quad (4)$$

6.2 Resulting score-values

For the cruises HE222A to HE404, the following score-values were calculated (Table 6). A value of 100 means a perfect dataset.

Table 6: Calculated score-values for all processed Heincke cruises

cruise	score	cruise	score	cruise	score	cruise	score	cruise	score	cruise	score
HE222A	96	HE254	96	HE292/1	95	HE319	96	HE350	96	HE377	96
HE222B	89	HE255	98	HE292/2	84	HE320	95	HE351	97	HE378	96
HE223	97	HE256	96	HE293	93	HE321	95	HE352/1	95	HE379	96
HE224	91	HE257	96	HE294	96	HE322	95	HE352/2	95	HE380	95
HE225	97	HE258	98	HE295	95	HE323	95	HE353	95	HE381	95
HE226	90	HE259	95	HE296	94	HE324	94	HE354	96	HE382/1	95
HE227	97	HE260	95	HE297	95	HE325	95	HE355/1	94	HE382/2	96
HE228	97	HE261	95	HE298	95	HE326	96	HE355/2	94	HE383	96
HE229	97	HE262	96	HE299	95	HE327	94	HE356/1	96	HE384	96
HE230	94	HE263/1	94	HE300	95	HE328	95	HE356/2	96	HE385	82
HE231	98	HE263/2	79	HE301	96	HE329	96	HE357	96	HE386	98
HE232	40	HE265	94	HE302	95	HE330	95	HE358	95	HE387	96
HE233B	96	HE266/1	95	HE303	95	HE331	96	HE359	95	HE388	97
HE234	96	HE266/2	94	HE304	94	HE332	95	HE360	96	HE389	96
HE235	95	HE267	96	HE305	95	HE333	96	HE361	94	HE390	97
HE236	97	HE268	95	HE306/1	95	HE334	96	HE362	94	HE391	96
HE237	97	HE269	95	HE306/2	95	HE336	94	HE363	95	HE392	98
HE238	96	HE270	95	HE307	96	HE337	94	HE364	96	HE393	97
HE239	96	HE271	94	HE308	95	HE338	94	HE365	95	HE394	98
HE240	96	HE272	96	HE309	94	HE339	95	HE366	94	HE395/1	95
HE241	98	HE273	94	HE310	95	HE340	94	HE367	95	HE395/2	96
HE242/1	96	HE274	94	HE311	96	HE341	95	HE368	95	HE396	97
HE242/2	53	HE283	96	HE312/1	96	HE342	95	HE369	95	HE397	97
HE244	95	HE284	93	HE312/2	95	HE343	94	HE370	95	HE398	96
HE248	94	HE285	94	HE313	92	HE344	94	HE371	96	HE399	96
HE249	64	HE287	93	HE314	94	HE345	95	HE372	98	HE400	97
HE250	95	HE288	96	HE315	96	HE346	94	HE373	97	HE401	91
HE251	96	HE289	94	HE316	95	HE347	95	HE374	97	HE402	96
HE252	95	HE290	94	HE317	95	HE348	96	HE375	96	HE403	98
HE253	97	HE291	94	HE318	96	HE349	93	HE376	95	HE404	96

7 Reports

For each processed cruise, a report is created and uploaded to the electronic Publication Information Center (ePIC; http://epic.awi.de). These reports include all metadata of the cruise (duration, harbors, and start/end of extracted DSHIP-data) and all information of the used navigation sensors.

Besides this, the report gives detailed descriptions of the data quality, the result of automated and manual filtering, the settings of the master track creation (sensor priority and filters) and the composition of the created track.

Additionally, the generalized track is shown on an included map, and the calculated score value is given.