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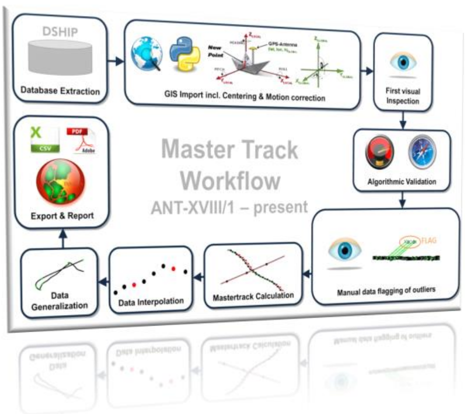
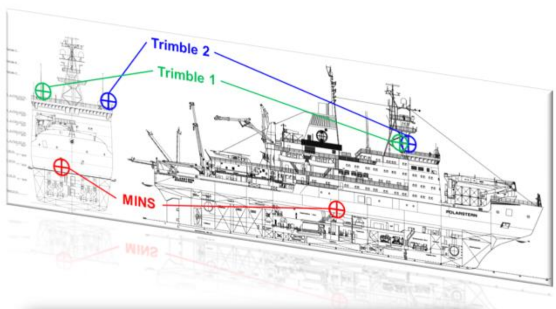
Processing Logbook

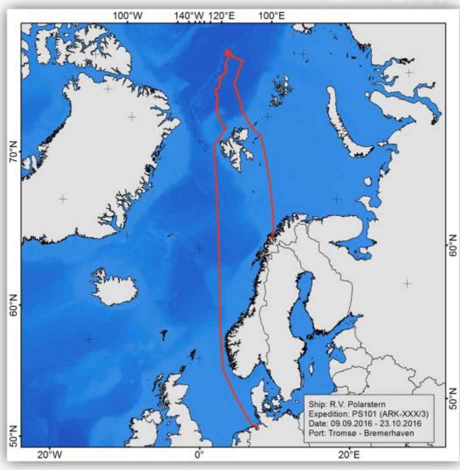
Master track creation RV "Polarstern"





	MINS		Trimble 1		Trimble 2	
Missing	62024	1.595%	61758	1.588%	61758	1.588%
Speed	1773	0.046%	5	0.000%	5	0.000%
Acceleration	890	0.023%	5	0.000%	5	0.000%
Course	678676	17.456%	1349234	34.703%	1218653	31.344%
Manually	0	0.000%	0	0.000%	0	0.000%

Sensor	Data points	Percentage
Total	3826800	98.428 %
MINS	618	0.016 %
Trimble 1	3826176	99.984 %
Trimble 2	0	0.000 %
Interpolated	6	0.000 %
Gaps	0	0.000 %



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Ref.: Processing_Logbook_RV_Polarstern.pdf	Vers.: 4	Date: 07/03/2017	Status: final

Content

1 Introduction

The Research Vessel (RV) Polarstern started her scientific operation on the 27th December 1982 with a transit cruise from Bremerhaven to Cape Town. Since then, 260 scientific cruises have been undertaken (as of December 2016).

For general route descriptions of the expeditions and for the description of taken samples or measured seabed structures, it is important to have positioning information as accurate as possible for the entire cruise.

During time, a wide variety of GPS sensors was installed on different locations at the ship and sometimes replaced by more advanced sensors after a while. Additionally, the ships navigation systems received positioning information from the GPS sensors and the data may be already filtered or the same "raw" data is stored as for the GPS sensor itself. Thus, these datasets like "System", NACOS and MINS also offer positioning information without having an own GPS antenna.

Additionally, the ships motion data like pitch, roll, heave and heading are recorded by different sensors over the time and with increasing quality. Together with the exact measured lever arm of the GPS antennas, the motion information can be used to project the received GPS signal to any location on the ship.

In an ideal case, the individual positions of all available GPS Sensors should unite at a single spot after centering and motion compensation. But due to effects like shadowing of the signal by ship components, general inaccuracy of the signal, faulty data transfer or other reasons, this is highly unlikely to happen.

The idea behind the so called "Mastertrack" is to use all available information of the sensors, additional motion data and sensor installation offsets (lever arms) to find the most likely position of the ship for every second of the cruise.

2 Data availability

Since its commissioning, the vessel RV Polarstern is equipped with several different positioning sensors which continuously record the position of the vessel during a cruise. Depending on the temporal resolution not validated position data of up to three sensors and, if available, ship motion data are extracted in one- or five-second intervals. Data source is the DAVIS SHIP data base (DSHIP, https://dship.awi.de), the data acquisition- and management system onboard, which allows the download of any raw data after the cruise via a web interface. Table 1 shows the data as availability until present.

Table 1: Overview of extractable Data from DSHIP

From	To	System	MINS	Ashtech	NACOS	Leica	Trimble 1	Trimble 2
ANT-I/1	ARK-II/1							
ARK-II/2	ARK-V/3b	X						
ANT-VII/1	ARK-IX/1b	X	(X)					
ARK-IX/2	ARK-XVI/2	X	(X)	X	X			
ANT-XVIII/1	present	X	X	X	X	X	X	X

X = GPS positioning, X = filtered / derived positioning, (X) = only motion data available

In this table, Ashtech, Leica and Trimble are genuine GPS-receivers. NACOS is the ship navigation system and offers filtered GPS-positioning data. The Marine Inertial Navigation System (MINS) is a motion sensor for measuring heading, roll, and pitch of the vessel and offers also only filtered navigation data which it receives from the GPS sensor Trimble 1. "System" denotes a dataset which is used as the "System position" during a cruise. Usually, this entry if filled with the "most reliable" positioning sensor. Since not all available data (according to DSHIP) offer valid values, or the entries are redundant, the useable data is summarized in Table 2.

Table 2: Overview of useable data

From	To	"System"	MINS	Ashtech	NACOS	Leica	Trimble 1	Trimble 2
ARK-II/2	ARK-IX/1b	X						
ARK-IX/2	ARK-XVI/2	(X)		X	X			
ANT-XVIII/1	present	(X)	X	X		X	X	X

In DSHIP, data is available from 1984-06-13T00:00:12, thus starting with the cruise ARK-II/2. Although MINS should be available from the cruise ANT-VII/1 (1988-09-15 – 1988-10-10), only motion data and no positioning information until the cruise ARK-IX/1b (1993-03-24 – 1993-04-18) is stored.

From ARK-IX/2, "System" is a copy / repetition of either of the other sensors / systems. It is not continuously traceable, which position is used as "System". Thus, "System" is only used for cruises until ARK-IX/1b due to the lack of alternative information.

From ARK-IX/2 to ARK-XVI/2, the "System" position is found to be almost always the same as the position derived from NACOS. However, sometimes, the latitude values differ but the longitudes remain the same. This leads to the decision, that "System" was omitted for the mastertrack creation.

Besides the data provided by DSHIP, already processed tracks from Parasound sub-bottom profiler survey are used to enhance the overall data quality if available.

From ANT-XVIII/1 until present, position information is taken from the two Trimble sensors and the Marine Inertial Navigation System (MINS). Only for one cruise (ARK-XIX/3b), the position information from Hydrosweep surveys are used due to lack of other positioning data for almost the whole cruise.

The following three Figures (Figure 1 to Figure 3) show the amount of available data for the available positioning sensors.

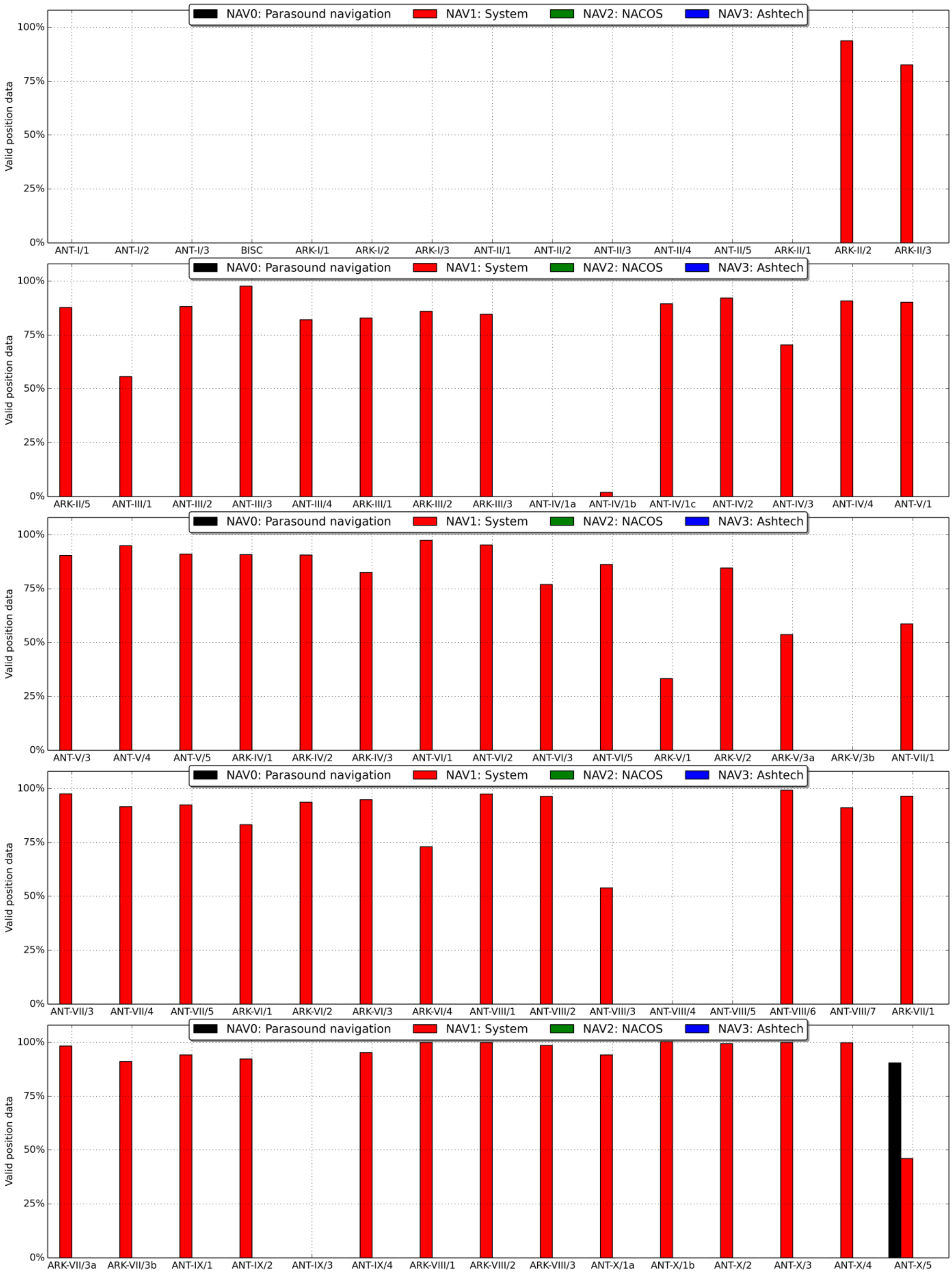

Figure 1: Data availability from ANT-I/1 – ANT-X/5

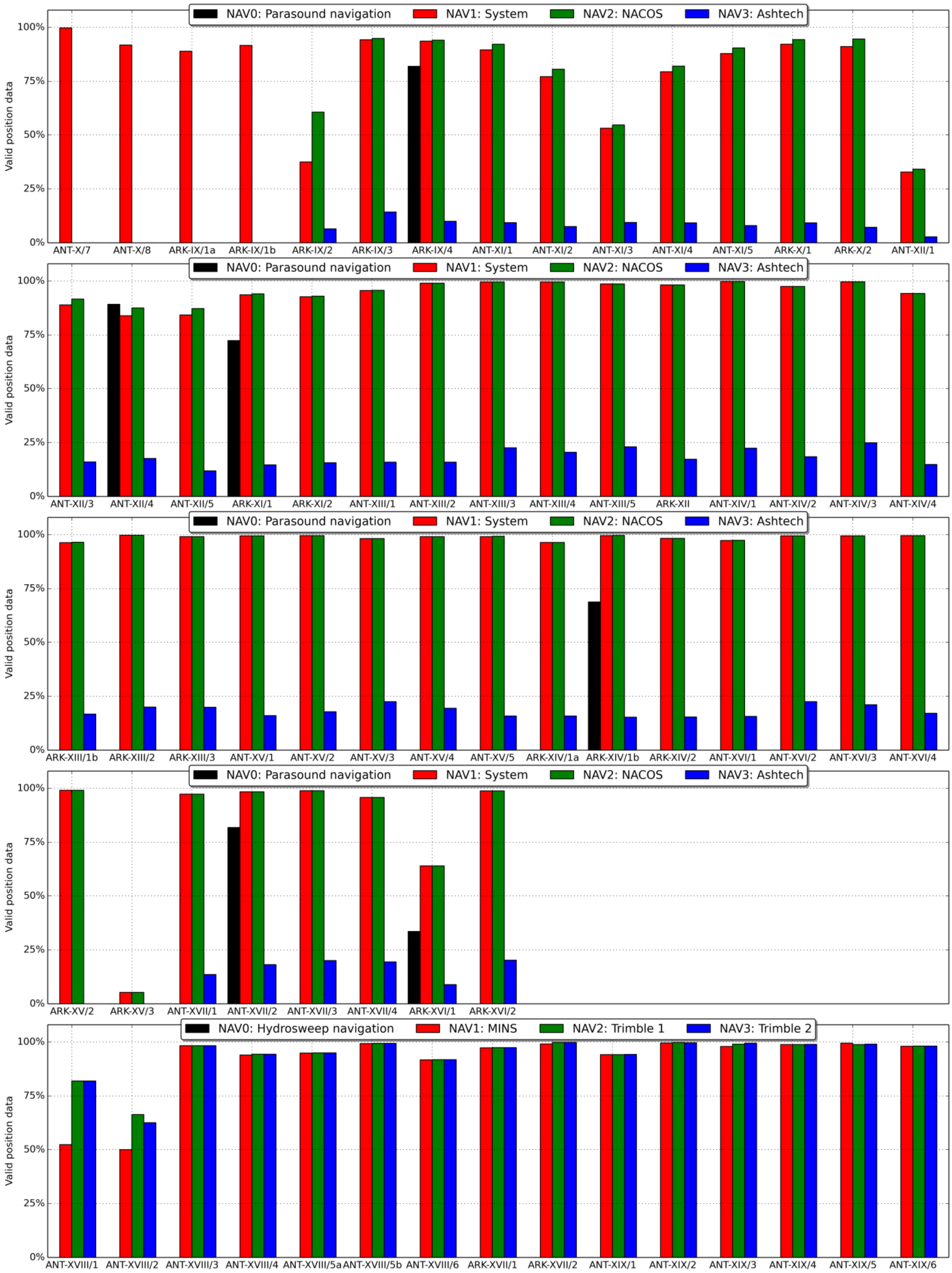

Figure 2: Data availability from ANT-X/7 – ANT-XIX/6

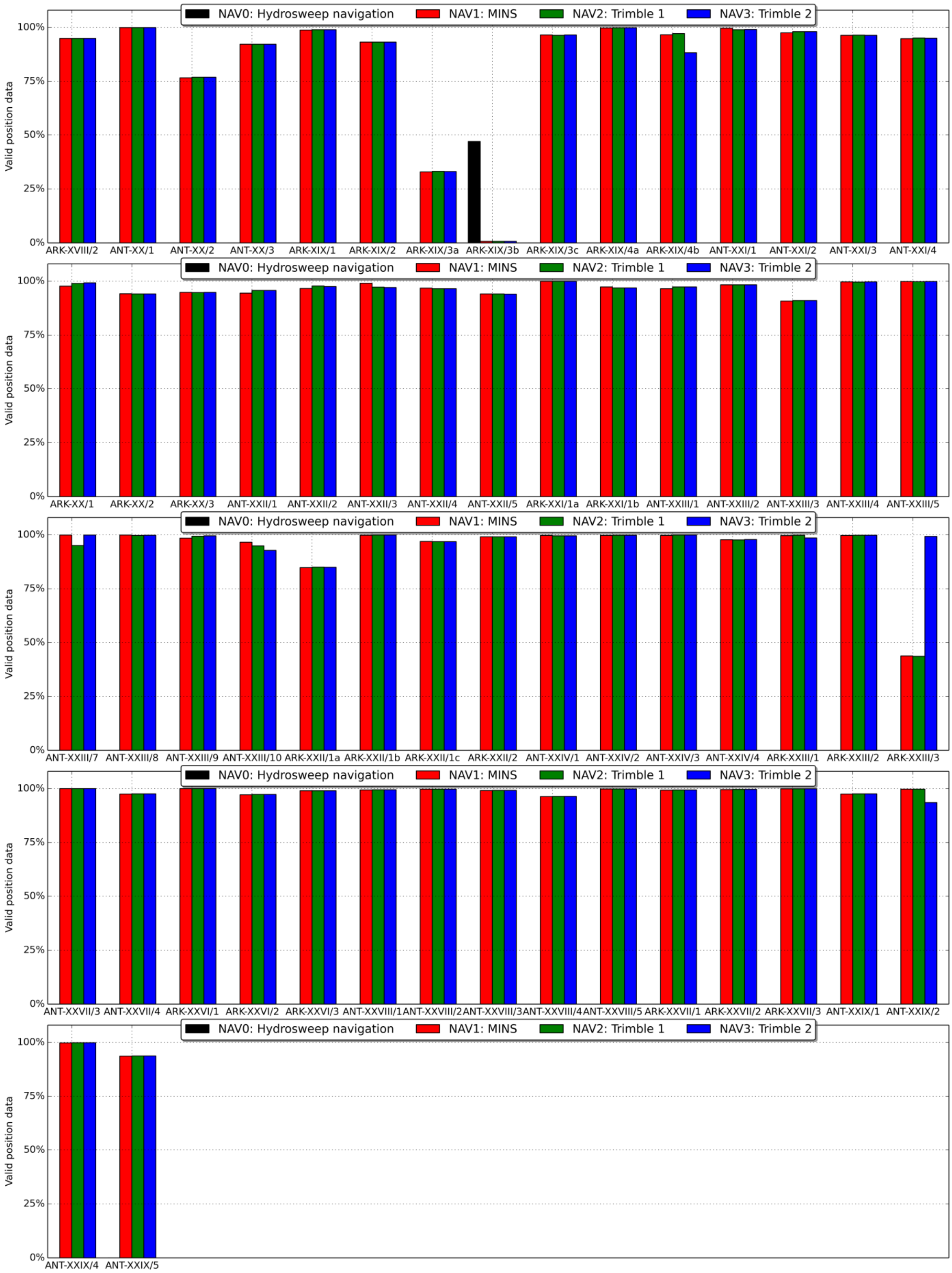

Figure 3: Data availability from ARK-XVIII/2 – ANT-XXIX/5

3 Workflow

Depending on the available positioning sensors and associated information like installation offsets and motion angles, there are three different workflows of data processing. The different steps of processing and validation are visualized in Figure 4 to Figure 6.

For the cruises ARK-II/2 to ARK-IX/1b, only "System" data is available in a five-second interval. Thus, no real "Mastertrack Calculation" is performed but a validation and interpolation of the existing datasets ().

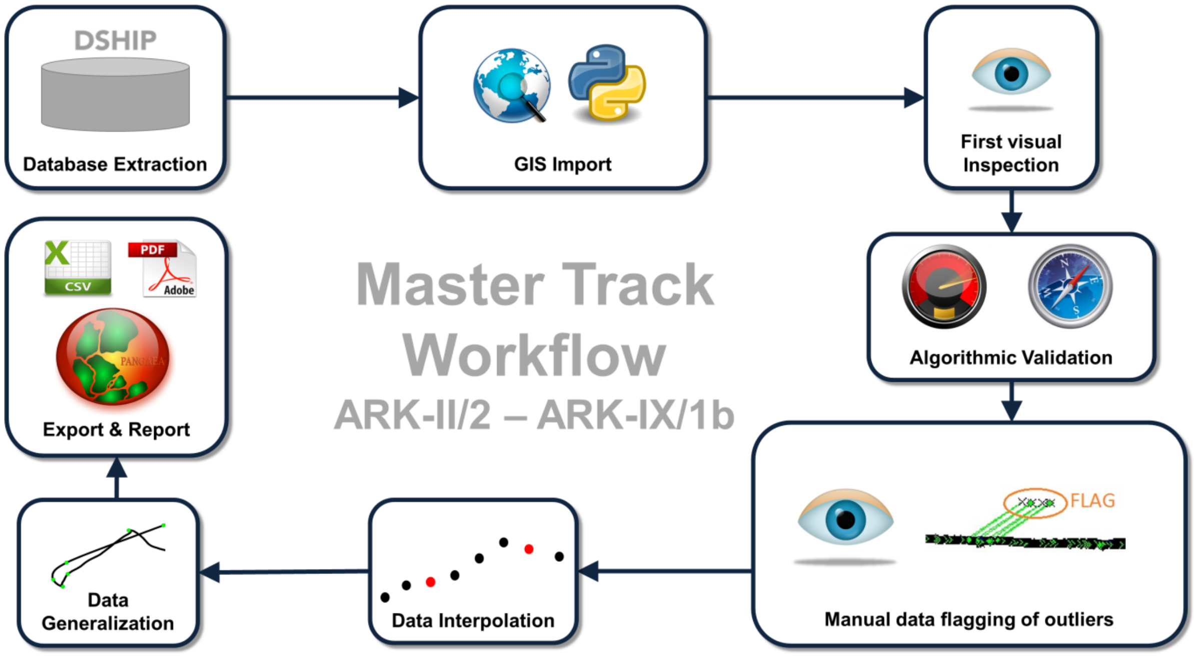

Figure 4: Workflow of master track data processing (ARK-II/2 – ARK-IX/1b)

The extracted positioning data are converted to ESRI point shapefiles and imported to ArcGIS for a first visual screening. Quality checks are performed using a ship's speed filter, an acceleration filter, and a filter of course alteration. Filtered positions are flagged. In addition, a manual check is performed to flag obvious outliers. The data is interpolated to a one-second interval for gaps up to a timespan of 60 seconds – that means at least 80% of the created master track positions are interpolated values for the cruises ARK-II/2 to ARK-IX/1b.

To reduce the amount of points for overview maps the master track is generalized by using the Ramer-Douglas-Peucker algorithm[12]. 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).

[1] Ramer, U. (1972). An iterative 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

For the cruises ARK-IX/2 to ARK-XVI/2, positioning information could be extracted from the sensors “System”, NACOS and Ashtech. However, no installation offsets of the GPS-antenna are known (Figure 5).

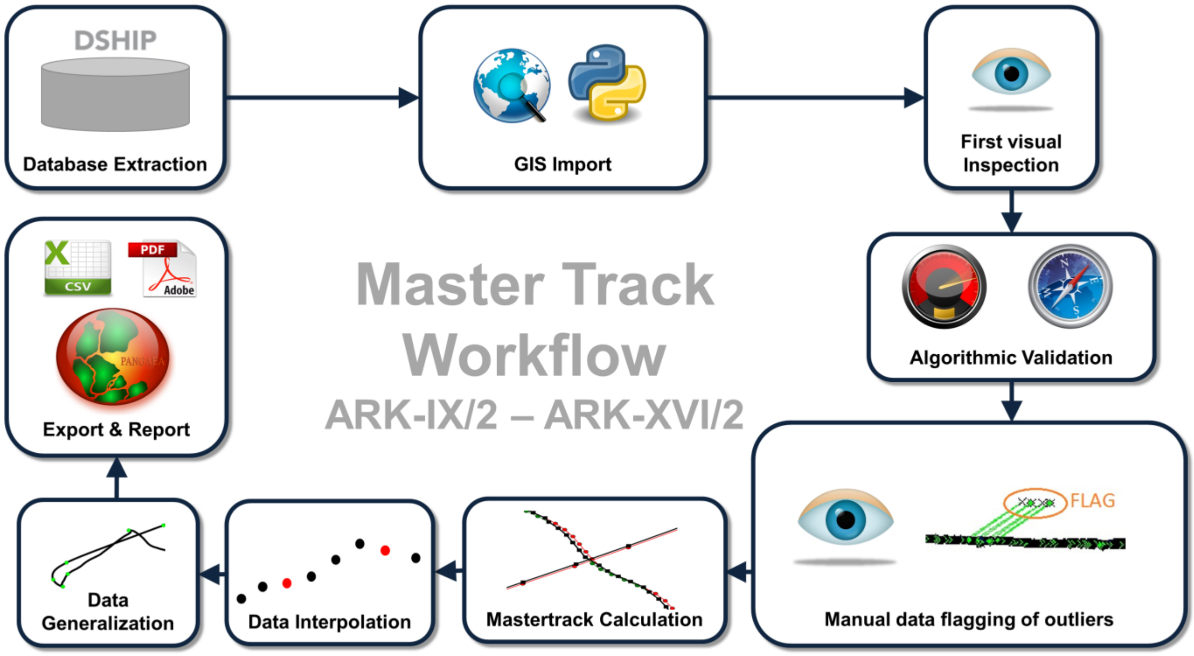

Figure 5: Workflow of master track data processing (ARK-IX/2 – ARK-XVI/2)

In contrast to the processing routine shown in Figure 4, positioning information is derived from three sensors. Hence, automatic and manual quality checks are performed for all three sensors. 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.

In Figure 6, the processing workflow from ANT-XVIII/1 until now is shown. Besides three position sensors (MINS, Trimble 1, and Trimble 2), also the installation offsets of the antennas are known. Together with the ship-motion data (angles of roll, pitch and heading), they are used to center the data from each position sensor to the destined master track origin with a rotation matrix.

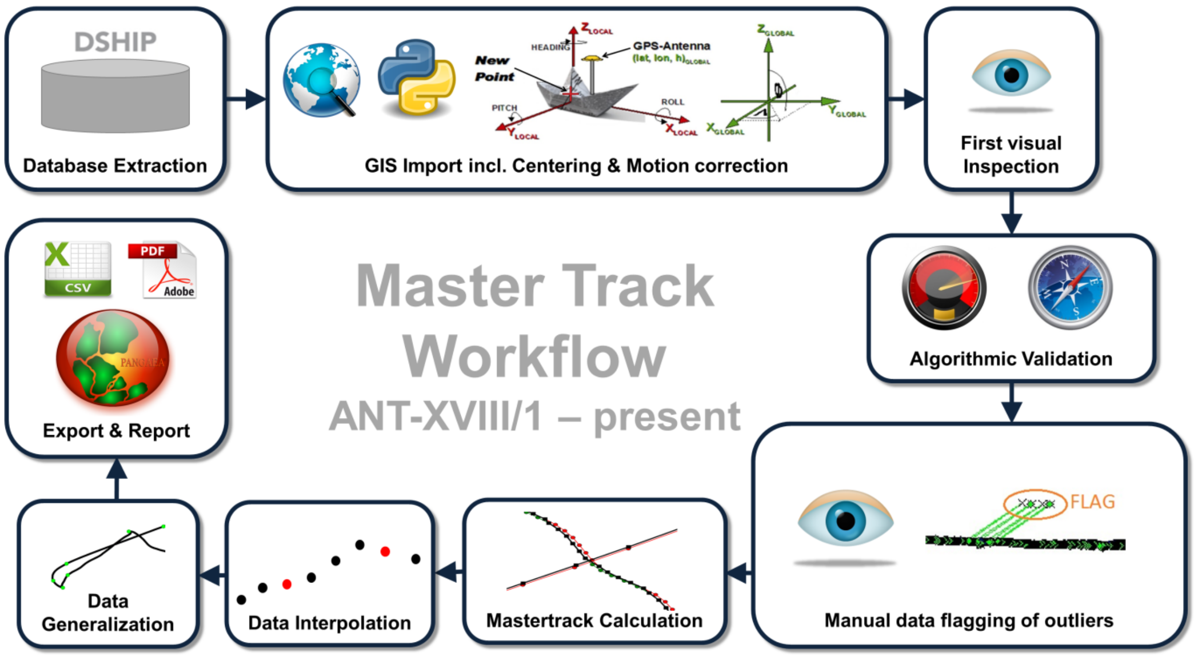

Figure 6: Workflow of master track data processing (ANT-XVIII/1 – present)

4 Sensor Configuration

Table 3 gives an overview of the sensors available for the cruises of the period 1984 – 2000. The corrected Parasound-Navigation is derived from the header-information of Parasound surveys and has been processed during previous assignments. If position information exits, this information is used for the master track creation.

Table 3: Sensor specifications ARK-V/1 – ARK-XVI/3

Sensor name	**System Position Information**, short: System
Description	Position information delivered to the system
Sensor name	**Navigation Automation Control System**, short: NACOS
Description	Navigation system of the ship
Sensor name	**Ashtech Z-12**, short: Ashtech
Description	GPS-Receiver
Sensor name	**Corrected Parasound-Navigation**, short: Parasound-NAV
Description	Already processed position information from Parasound navigation

From ANT-XVIII/1 on, the vessel RV Polarstern hosts three positioning sensors for scientific purposes. Figure 7 shows the locations of the sensors in the ship. The first positioning sensor is the motion sensor MINS which receives its reference positions from differential GPS (DGPS) Trimble 1 (Table 4).

Table 4: Sensor specifications of the MINS

Sensor name	**Raytheon Anschuetz MINS2**, short: MINS		
Description	Marine Inertial Navigation System with reference positions from Trimble DGPS		
Motion accuracy	± 0.02° roll, ± 0.02° pitch, ± 0.05° heading		
Installation point	Gravimeter room on F-Deck		
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

The second positioning sensor is the DGPS Trimble 1; its specifications are given below (Table 5).

Table 5: Sensor specifications of the Trimble 1 DGPS

Sensor name	**Trimble Marine SPS461 (1)**, short: Trimble 1		
Description	DGPS-Receiver, correction type DGPS RTCM 2.x, correction source DGPS Base via radio		
Position accuracy	Horizontal: ± 0.25 m + 1 ppm & Vertical: ± 0.50 m + 1 ppm		
Installation point	Observation deck (starboard)		
Offset from master track reference point to sensor installation point	X (Positive to bow) 22.777 m	Y (Positive to starboard) -5.460 m	Z (Positive upwards) 21.525 m

The third positioning sensor is the DGPS Trimble 2; its specifications are given below (Table 6).

Table 6: Sensor specifications of the Trimble 2 DGPS

Sensor name	**Trimble Marine SPS461 (2)**, short: Trimble 2		
Description	DGPS-Receiver, correction type DGPS RTCM 2.x, correction source DGPS Base via radio		
Position accuracy	Horizontal: ± 0.25 m + 1 ppm & Vertical: ± 0.50 m + 1 ppm		
Installation point	Observation deck (port)		
Offset from master track reference point to sensor installation point	X (Positive to bow) 16.527 m	Y (Positive to starboard) 12.408 m	Z (Positive upwards) 21.538 m

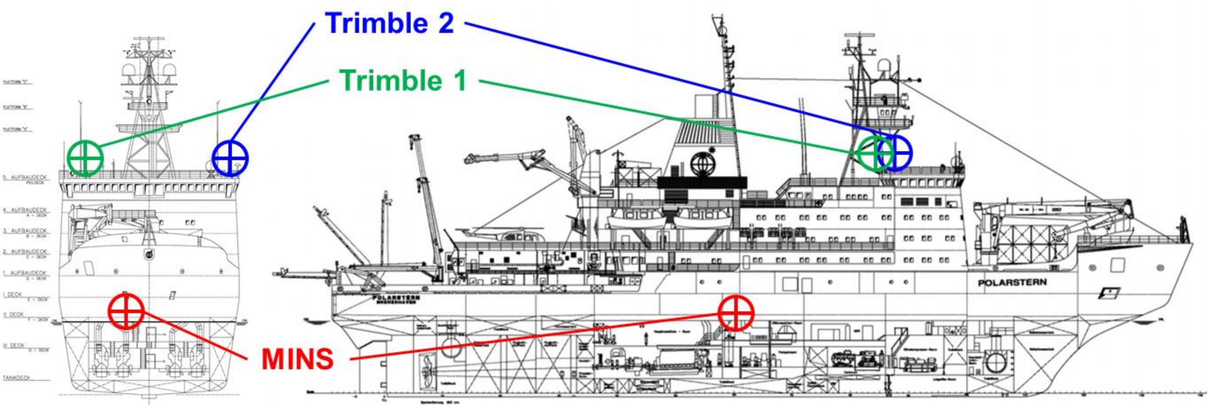

Figure 7: Locations of positioning sensors on RV *Polarstern*

5 Detected sources of error

The following is a description of typical errors that occurred in the records. The errors detected during the working step “Manual data flagging of outliers” are – as the name suggests – flagged manually accordingly if not other mentioned. Only if too many positions would be deleted, the errors are only described.

5.1 Errors of DSHIP extraction

While extracting data from the web version of DSHIP, there are already some sources of error:

- Valid data can be only extracted within the time ranges displayed as “Data Inventory of DAVIS-Ship FS Polarstern” on the website. The time spans outside these valid ranges are either filled up with “NaN”-values or the whole data extraction may fail.
- The positions can be assigned to the wrong timestamps. This issue can only be solved, if the GPS time is available.
- Specific problems are encountered for the cruises ARK-IX/2 to ARK-XIV/2:
    - The sensor Ashtech delivers extreme values like “6.173E+237” or “-2.41E+235” instead of the chosen placeholder of “9999999.9999999”.
    - The sensor NACOS contains invalid positions which are not labeled as errors. This applies to both Latitude and Longitude, and the locations can be 0.0°, 1.0°, or 127.0°.
    - The sensor “System” receives it positions from NACOS. Sometimes, only the Longitude is the same as NACOS, but Latitude differs and is not the same as Ashtech either.

5.2 Errors of the sensor "System"

The errors of the positioning data obtained from "System" can be summarized in eight groups:

- Wrong sign of latitude when crossing the equator (latitude remains positive until reaching -1.0 degree) and wrong sign of longitude when crossing the prime meridian (longitude remains positive until reaching -1.0 degree) (Figure 8). This error affects all cruises between ARK-II/2 and ARK-IX/1b and is corrected manually by changing the sign.

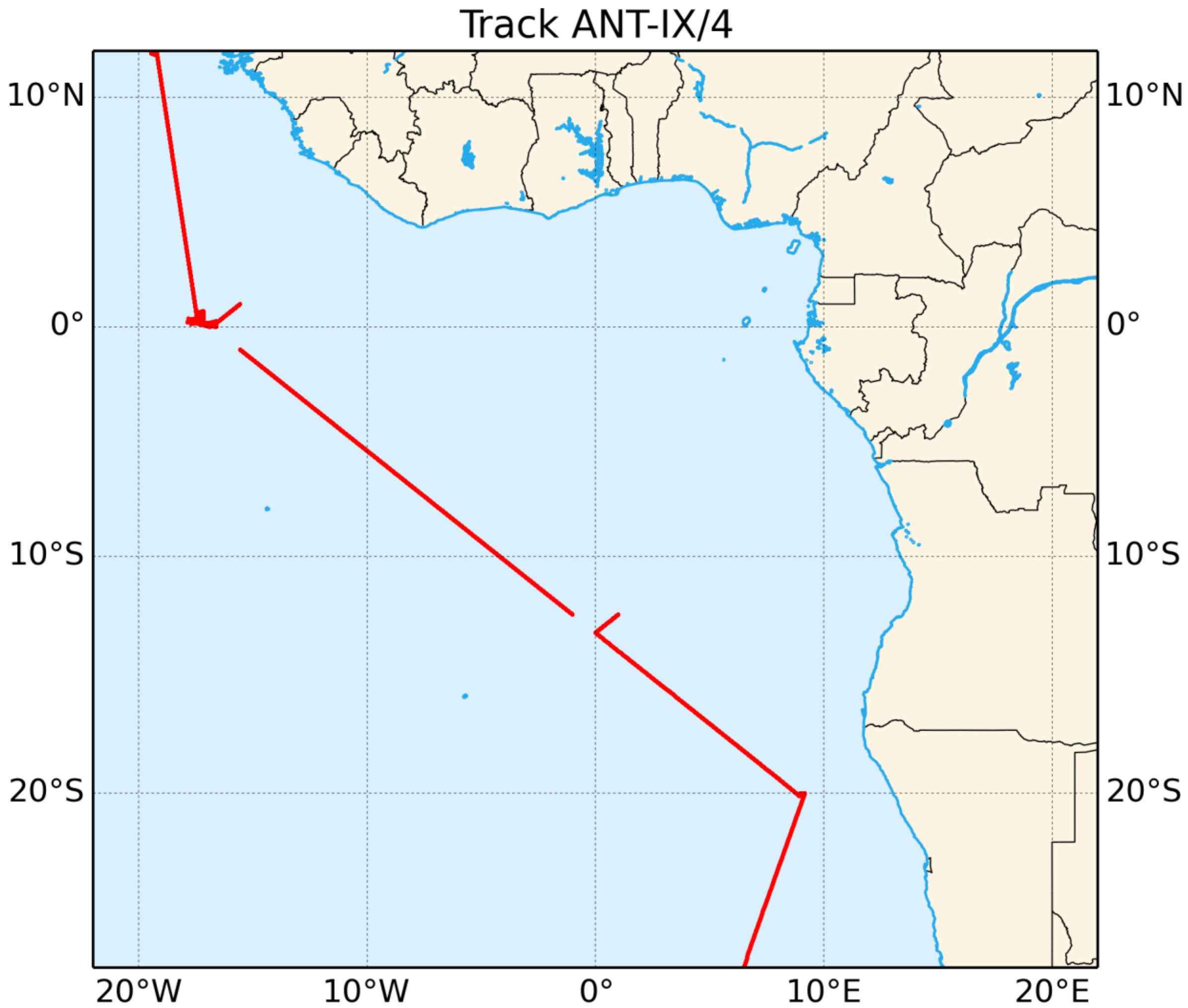

Figure 8: Example of wrong sign when crossing the equator and prime meridian

- Position-Jumps of Points to 0 degrees latitude and / or 0 degrees longitude (e.g. Figure 9)

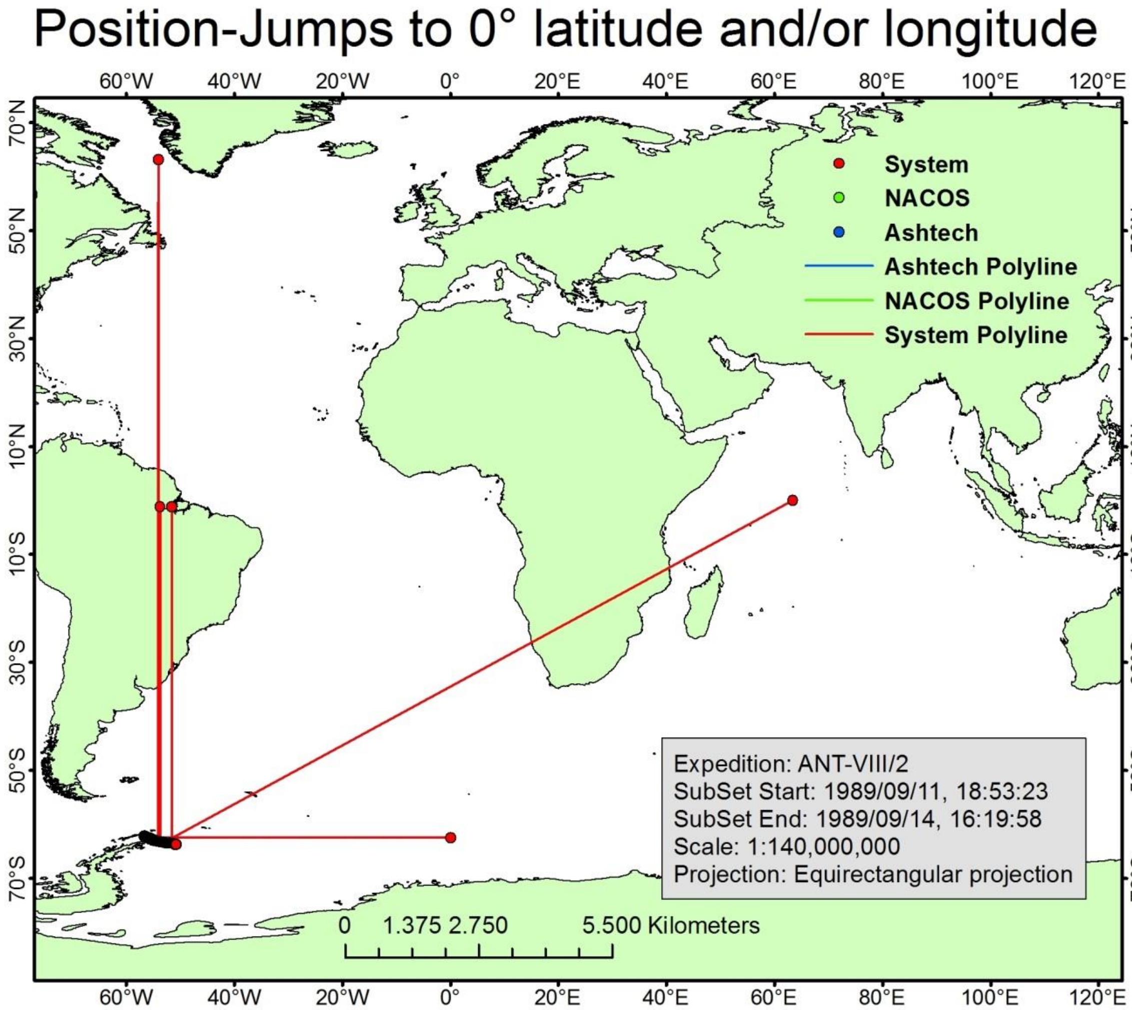

Figure 9: Data example from ANT-VIII/2

- Single outliers far away from the track (e.g. Figure 10)

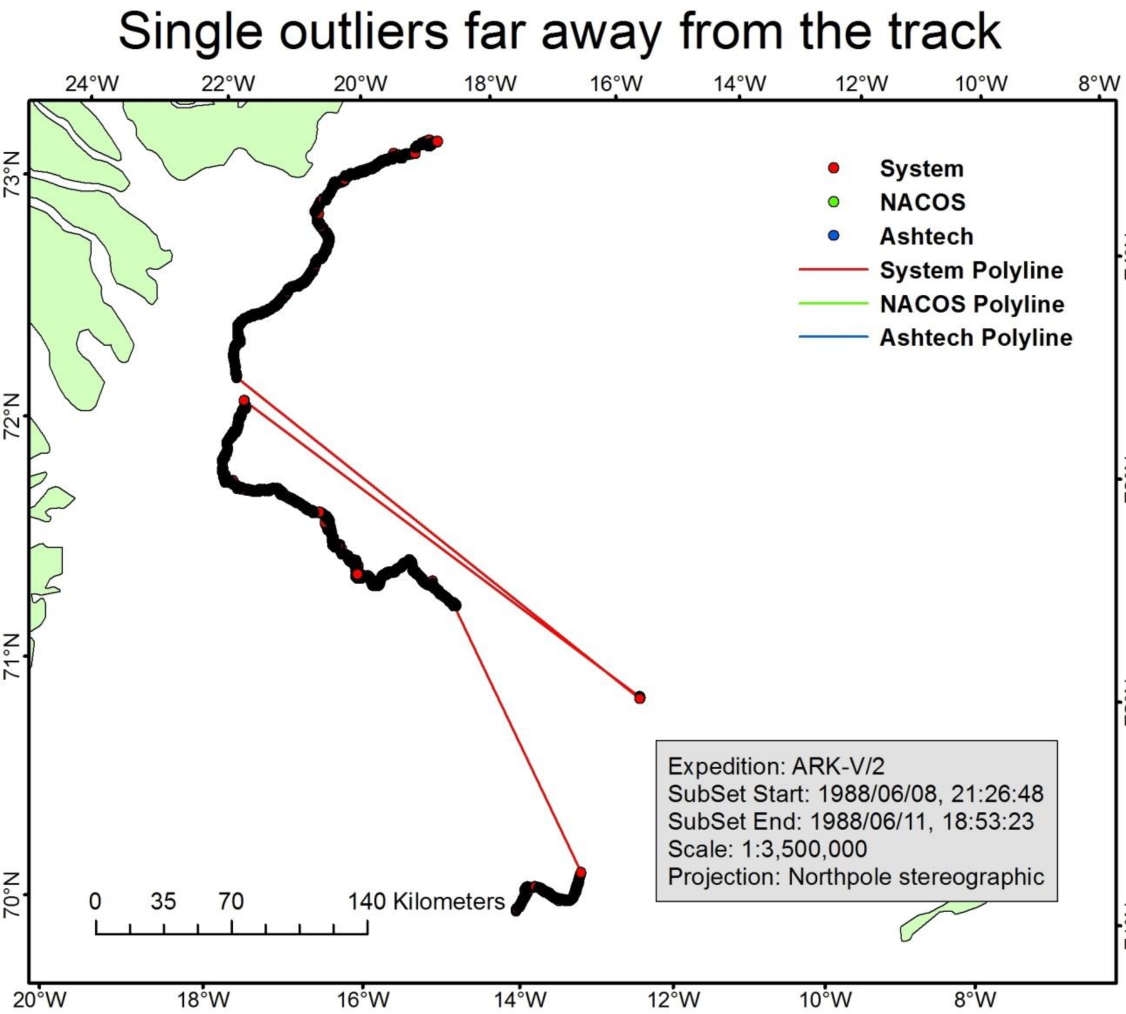

Figure 10: Data example from ARK-V/2

- Regular gaps in short periods of time (e.g. every 60 seconds in Figure 11), which were interpolated

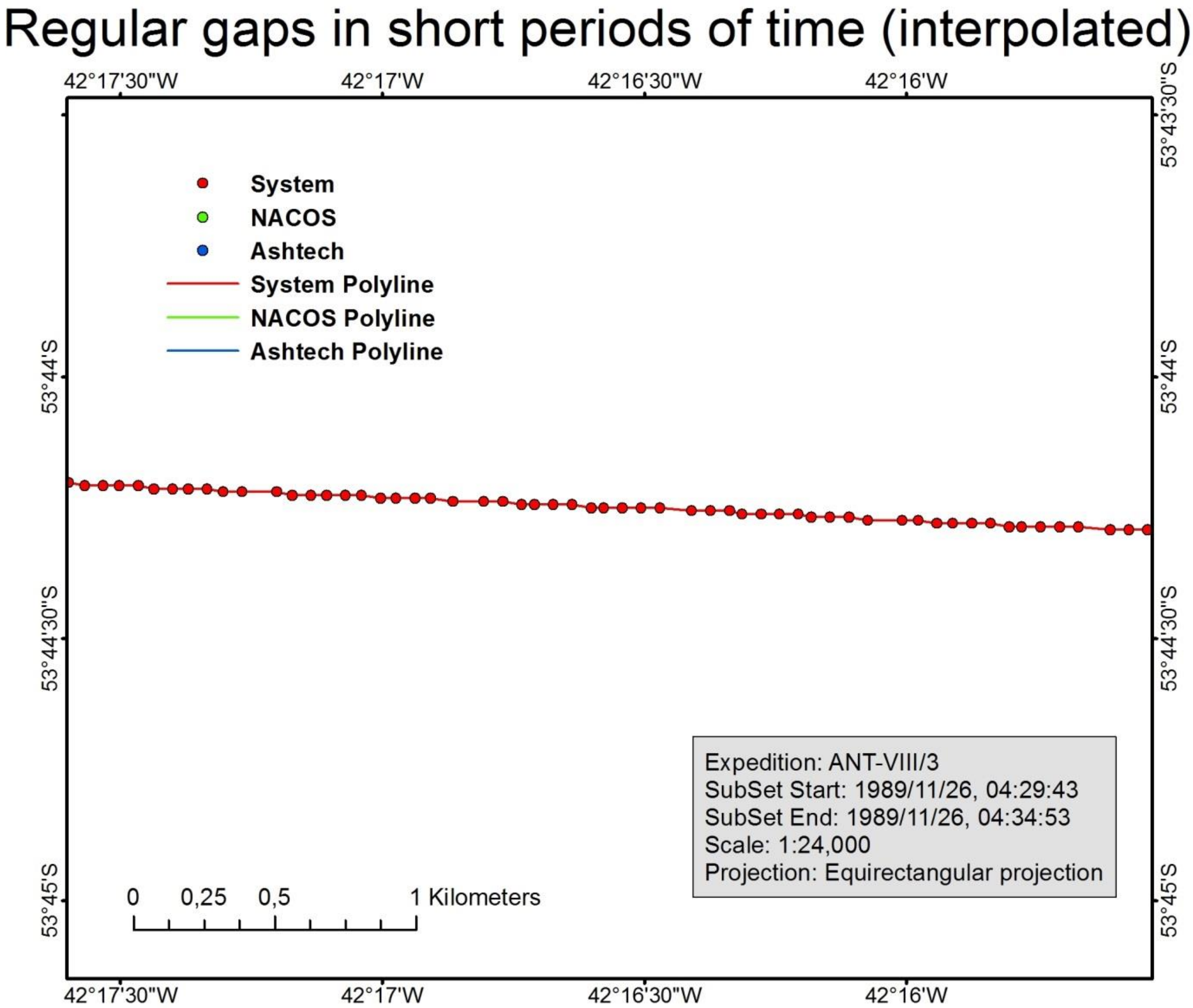

Figure 11: Data example from ANT-VIII/3

- Position jumps where the actual track is unknown (e.g. Figure 12). These points were not flagged when the actual track is not known.

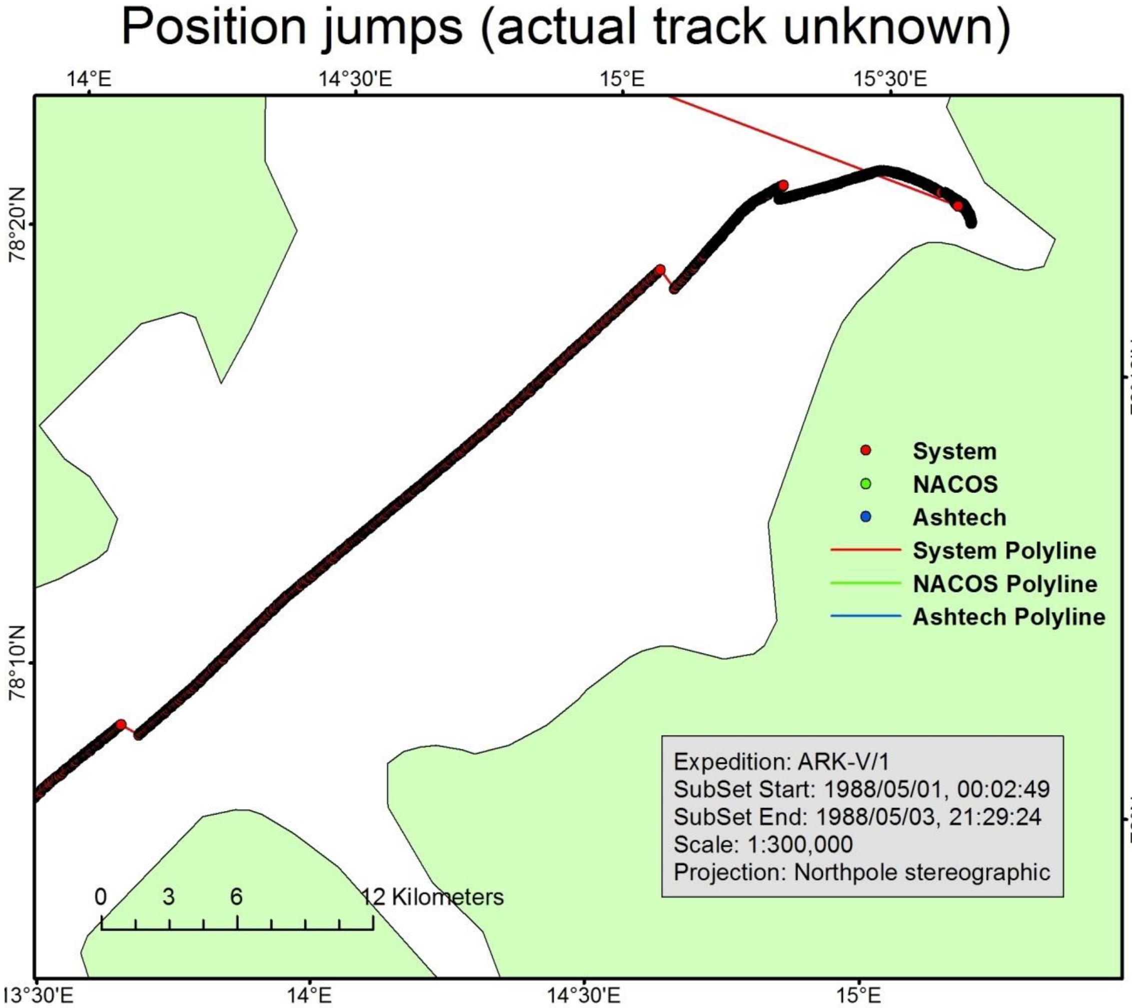

Figure 12: Data example from ARK-V/1

- Completely invalid track (track drifts away while ship is – according to the Ashtech positions – stationary) (e.g. Figure 13)

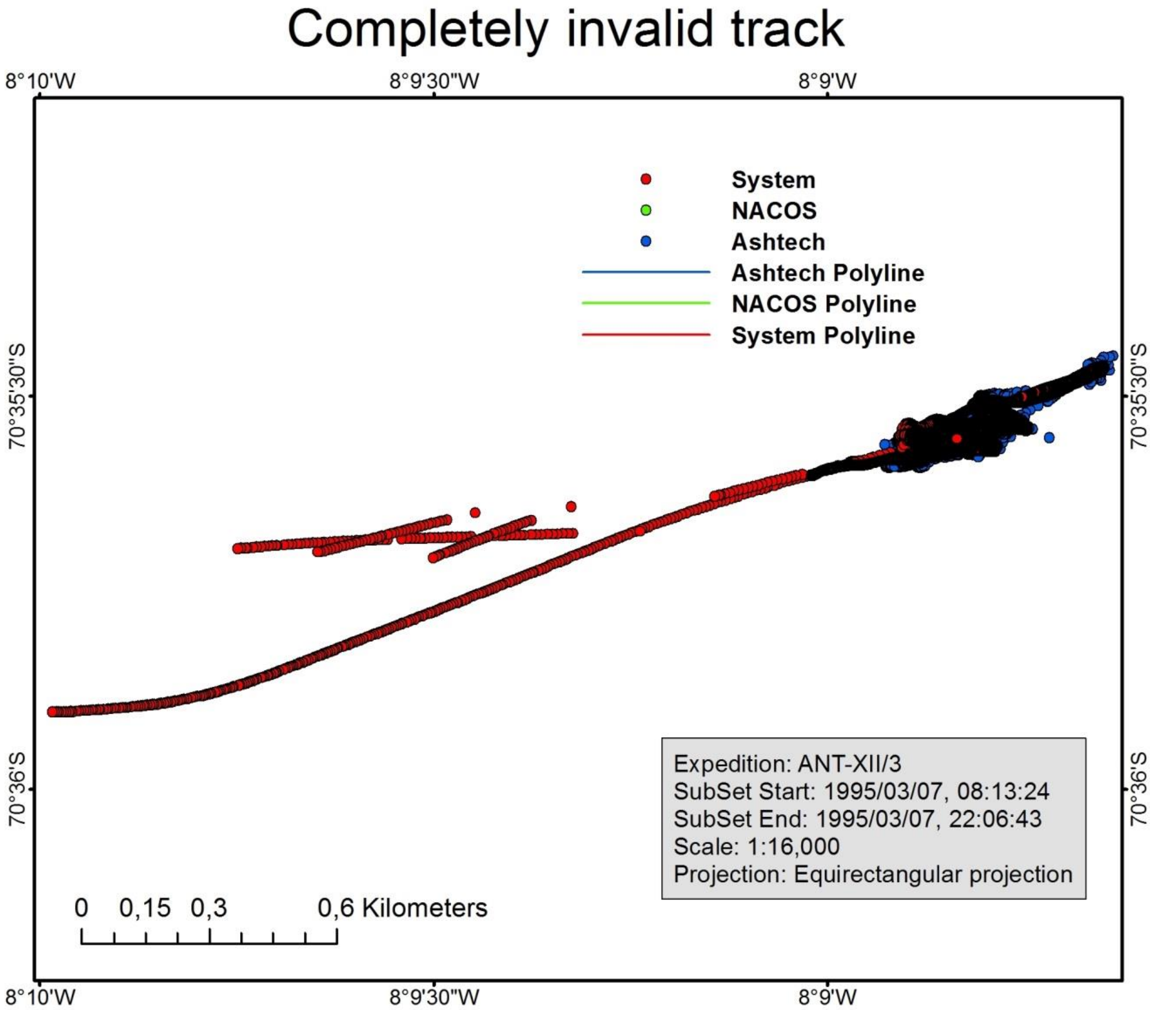

Figure 13: Data example from ANT-XII/3

- Points are drifting away from the track, return and drift away again (e.g. Figure 14). Positions are flagged if the remaining sensors show reliable positions.

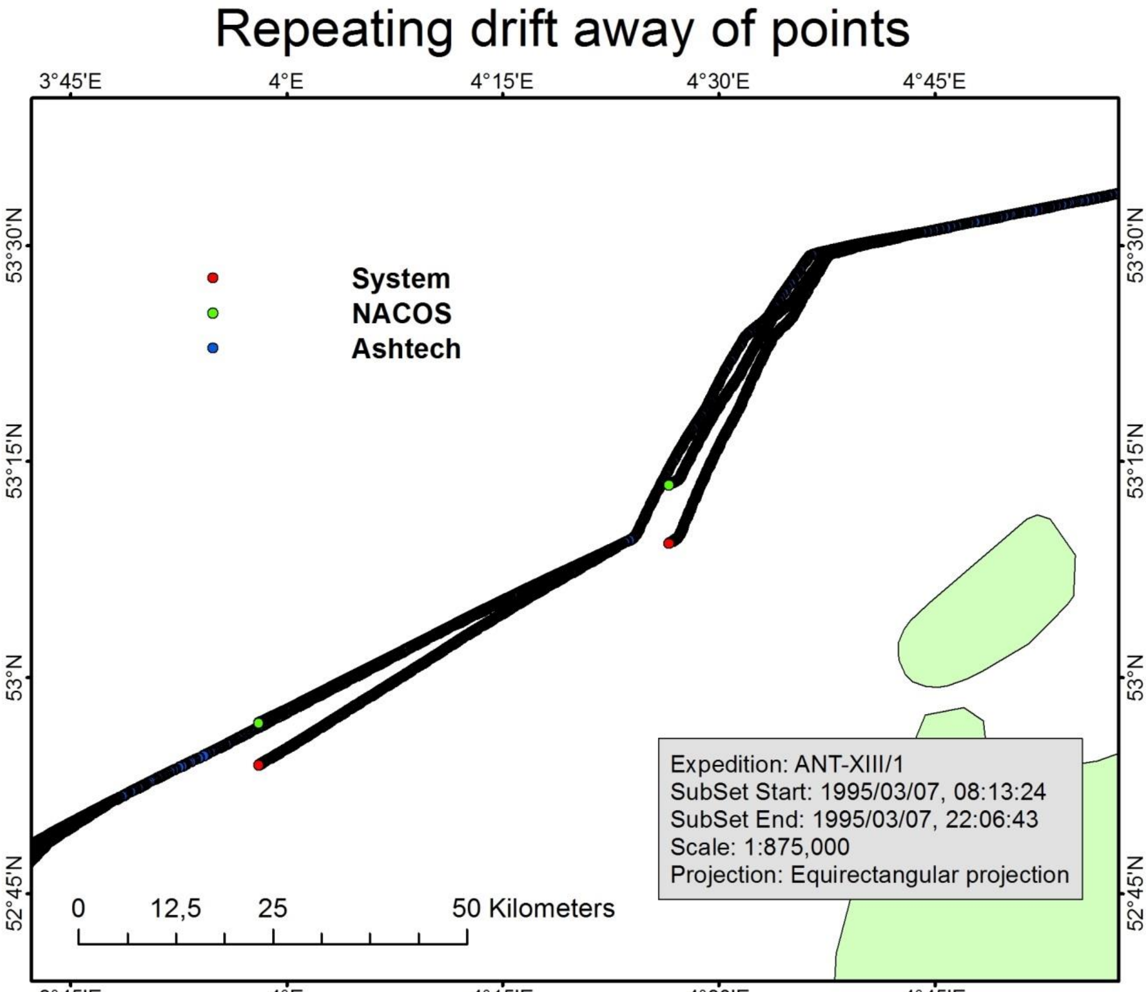

Figure 14: Data example from ANT-XIII/1

- Jumps back to former positions of the track (e.g. Figure 15)

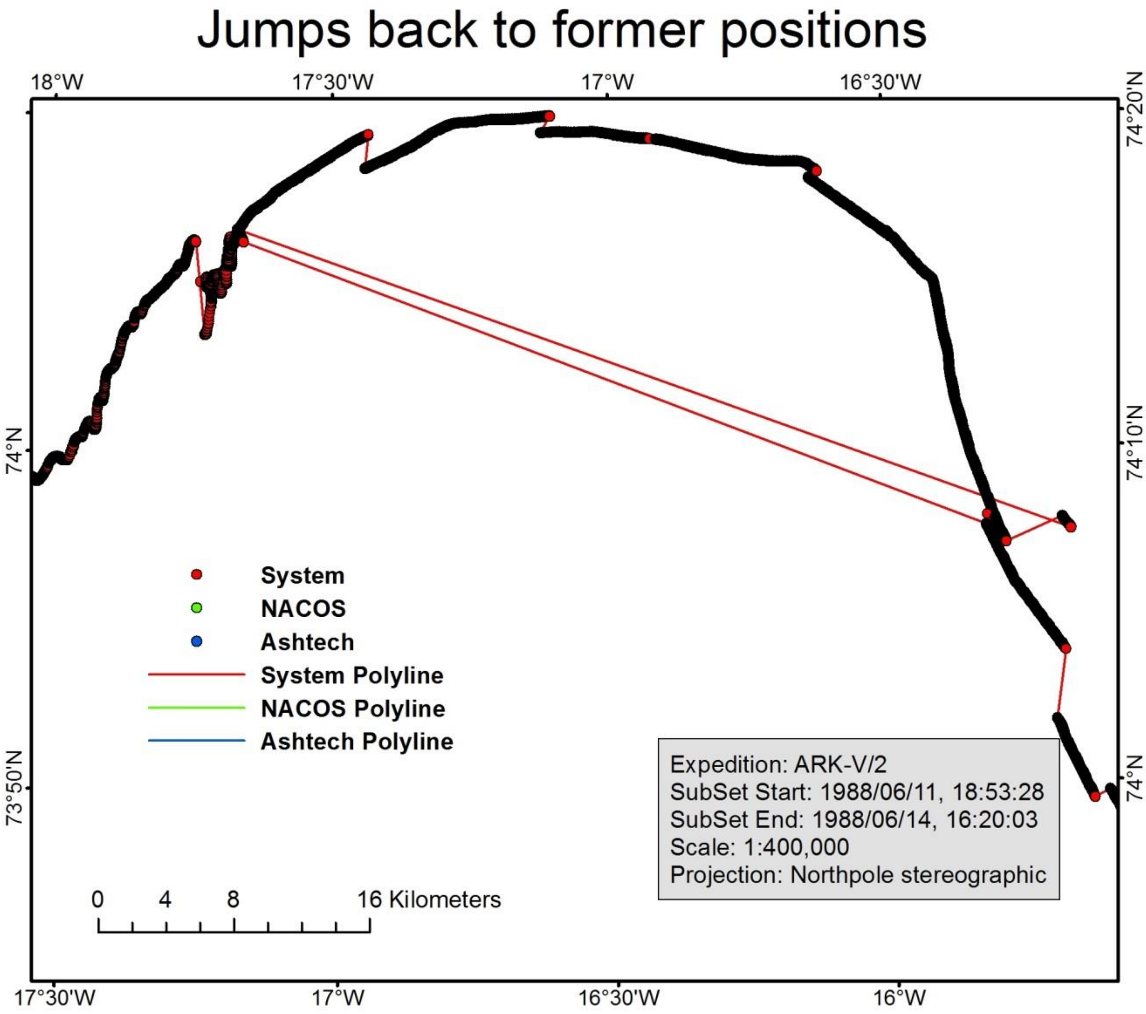

Figure 15: Data example from ARK-V/2

5.3 Errors of the sensor NACOS

The errors of the navigation device NACOS are the same as from “System”, only one additional specific error was found:

- Constant offsets of points parallel to the track (e.g. Figure 16). Here, “System” receives the Longitude from NACOS, but not the Latitude.

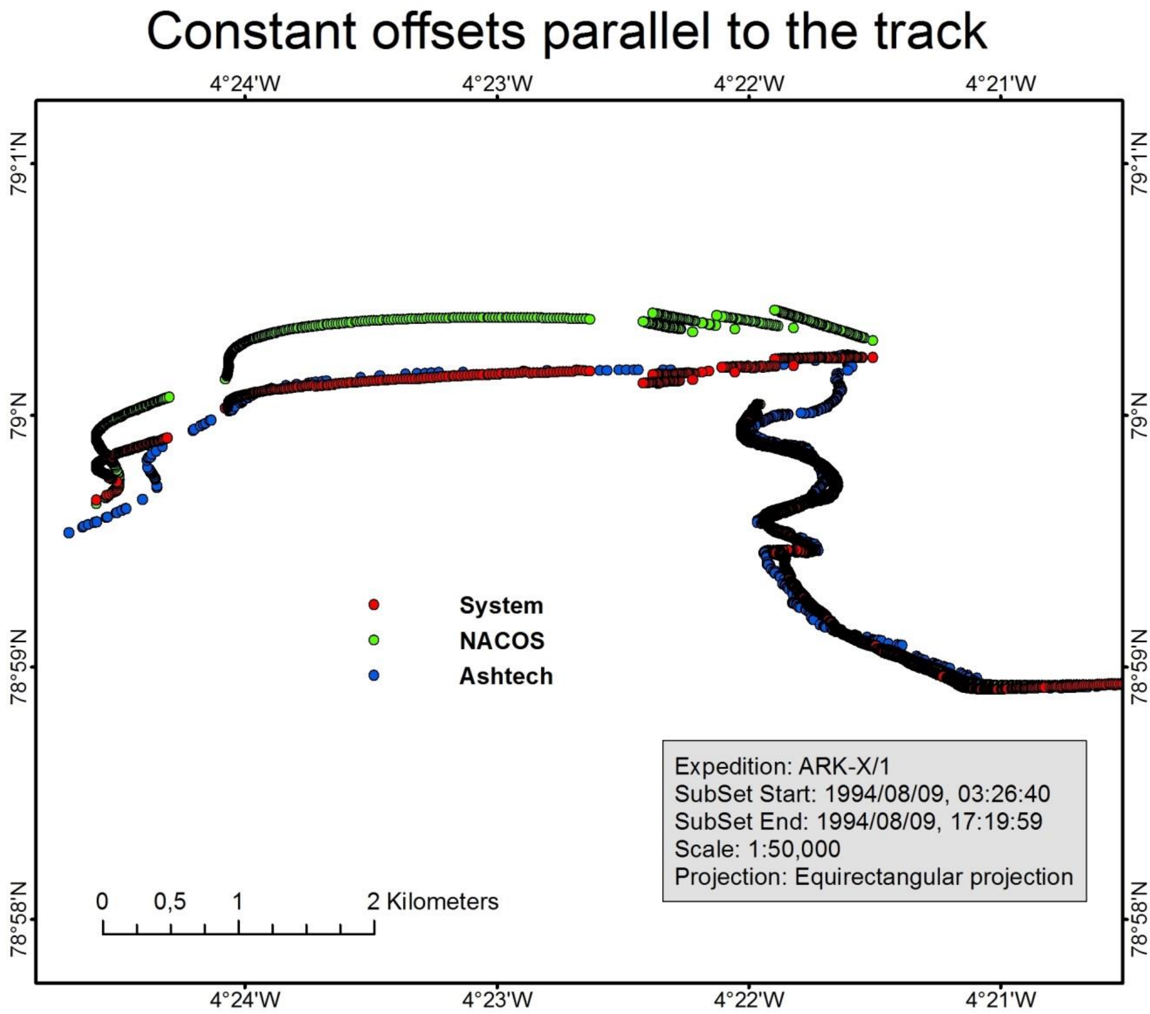

Figure 16: Data example from ARK-X/1

5.4 Errors of the sensor Ashtech

The errors of GPS Ashtech can be summarized in eight groups:

- Groups of positions next to the track with changing offsets (e.g. Figure 17)

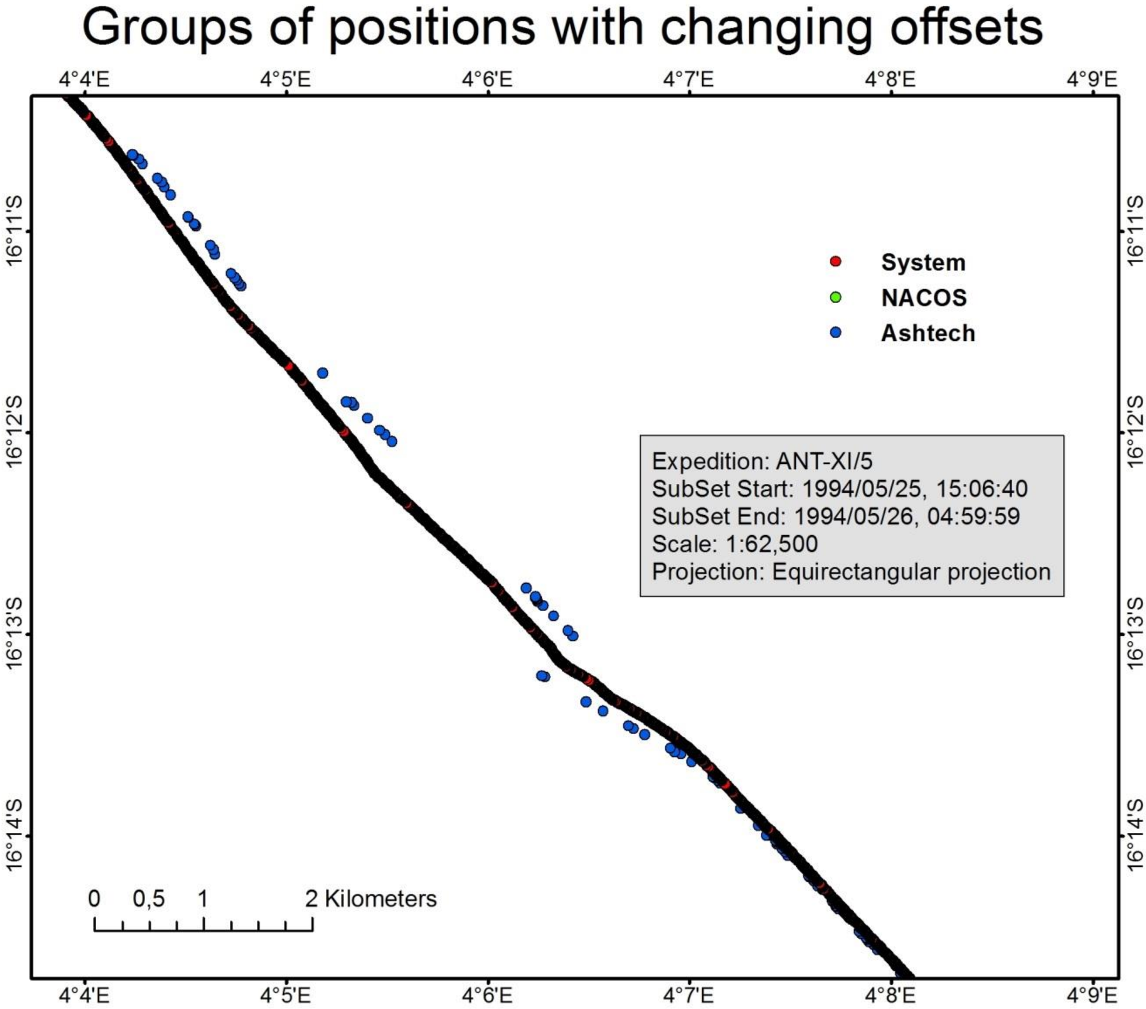

Figure 17: Data example from ANT-XI/5

- Large amount of points at 0 degree latitude and / or 0 degree longitude (e.g. Figure 18) or at invalid coordinates

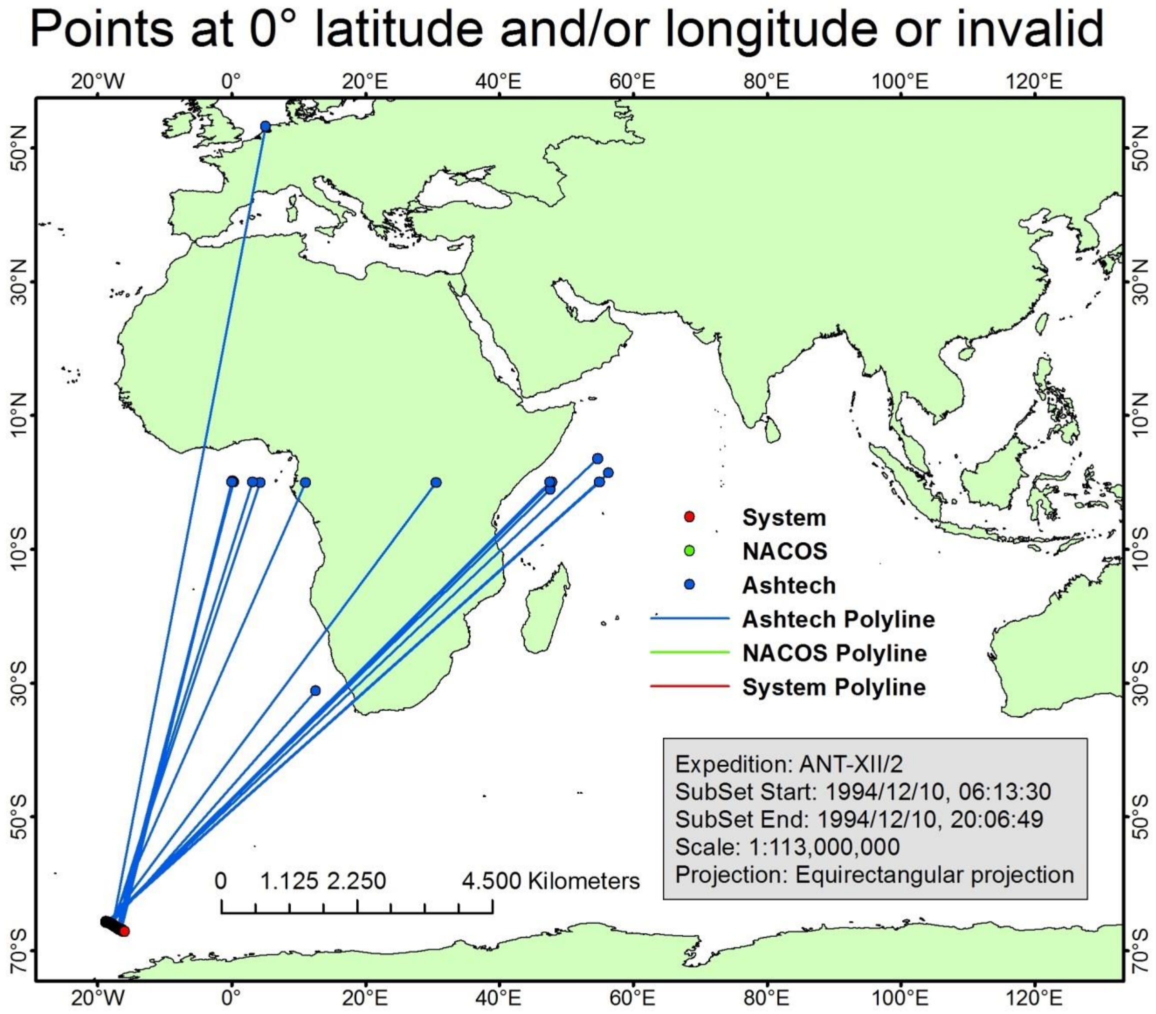

Figure 18: Data example from ANT-XII/2

- Single outliers next to the track (e.g. Figure 19)

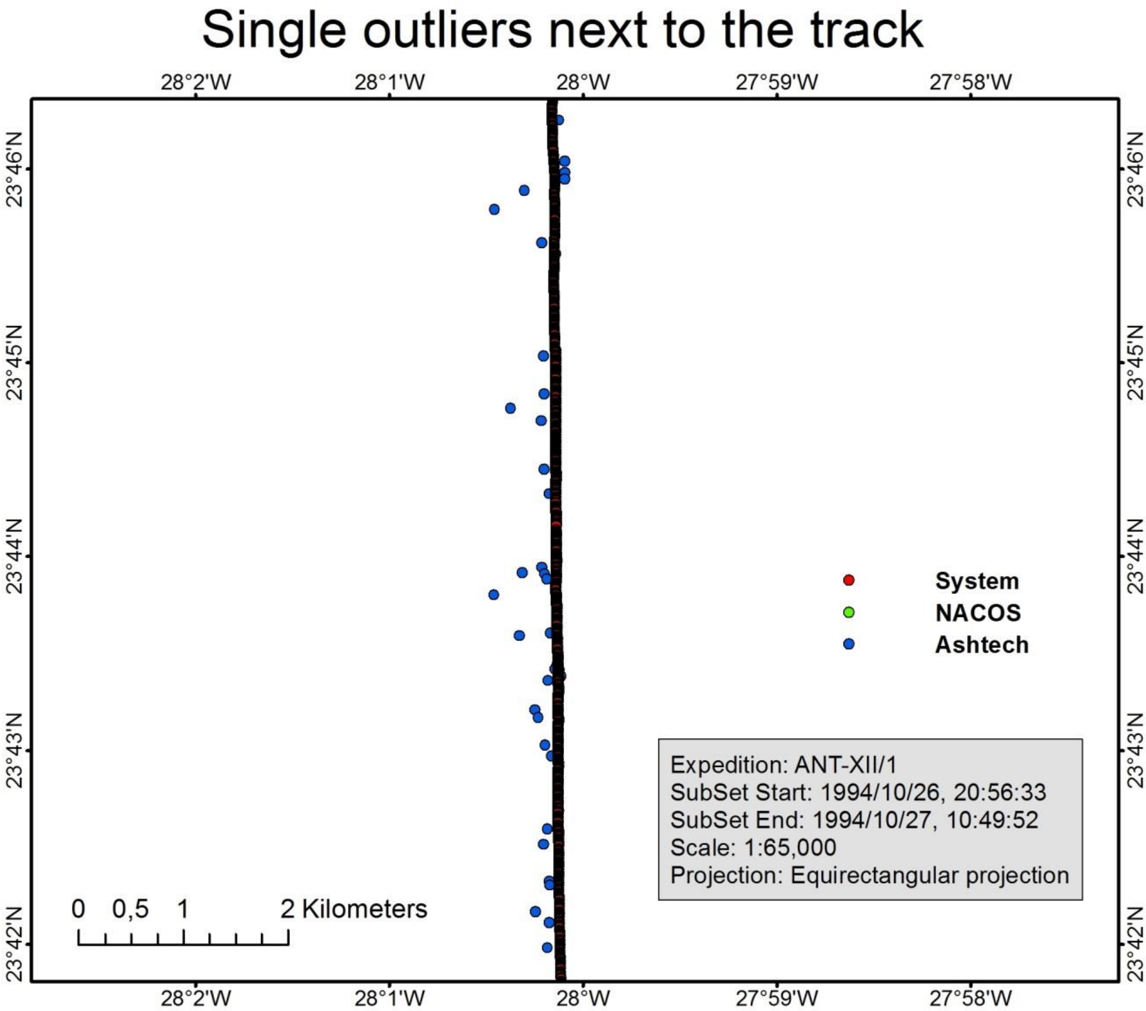

Figure 19: Data example from ANT-XII/1

- Regular offset next to the track (e.g. Figure 20). The blue dots of Ashtech also show the general lower data availability and the amount of gaps compared to the other two sensors.

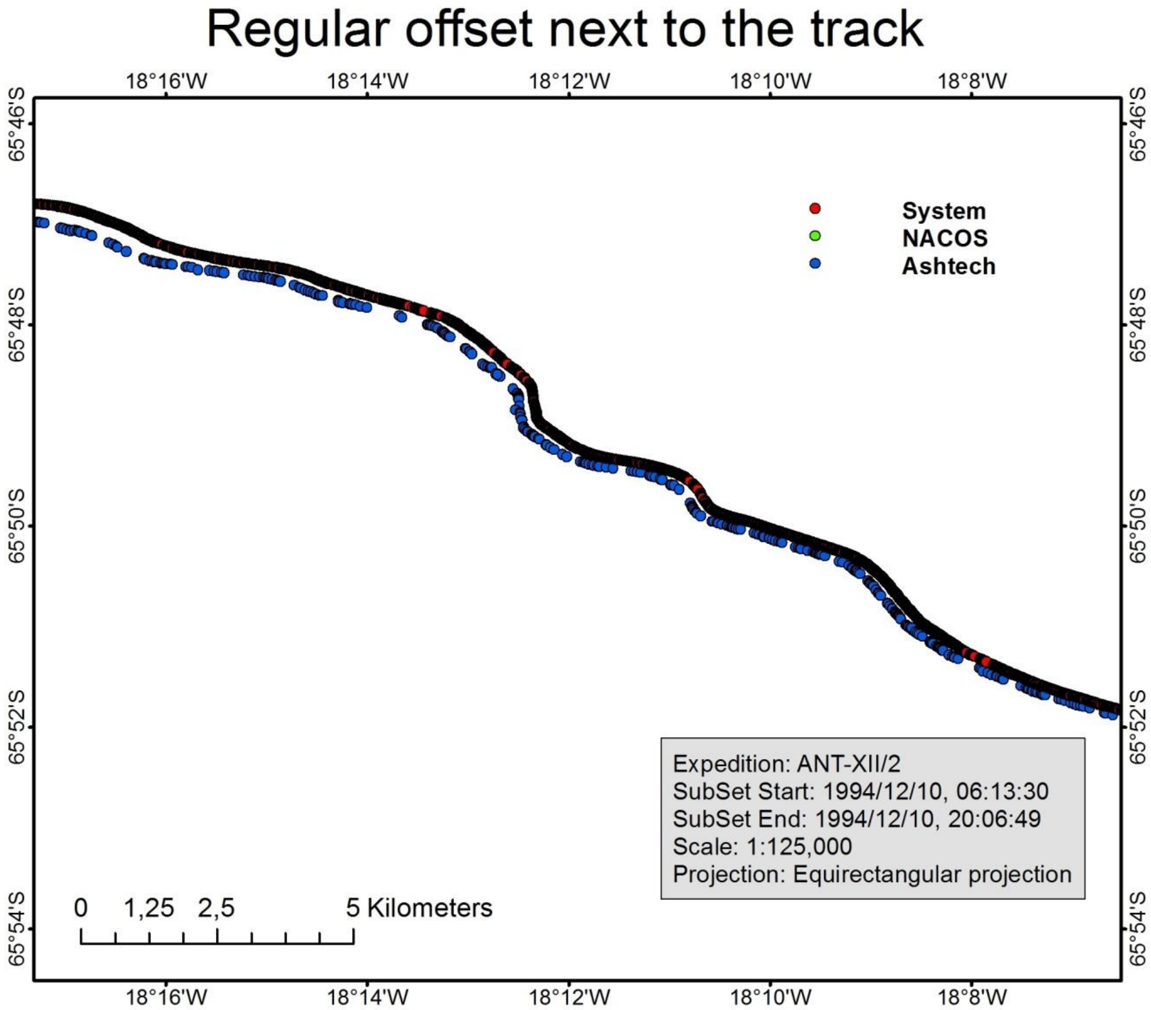

Figure 20: Data example from ANT-XII/2

- Regular gaps in short periods of time (e.g. Figure 21) which were interpolated.

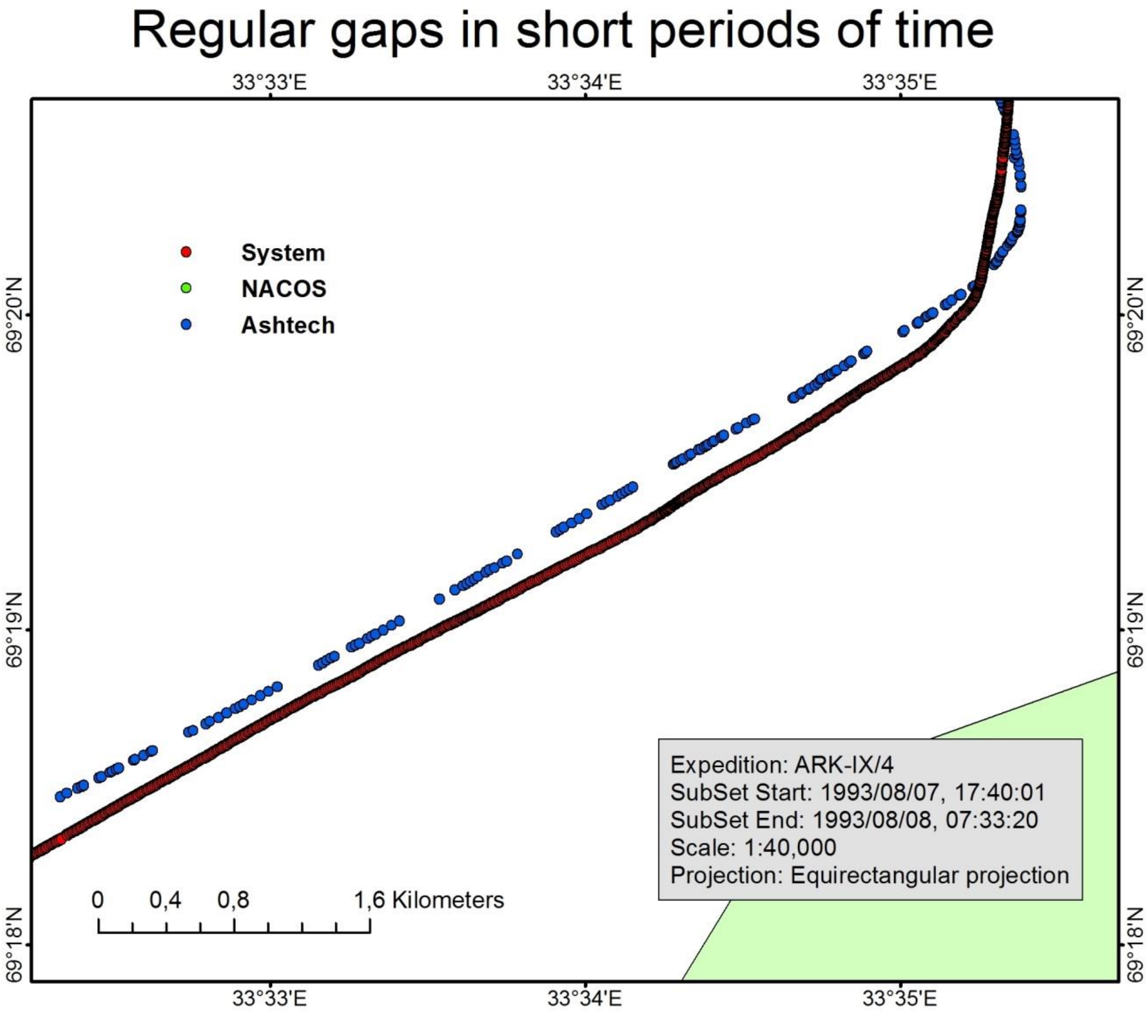

Figure 21: Data example from ARK-IX/4

- Track-change over a short period of time (e.g. Figure 22)

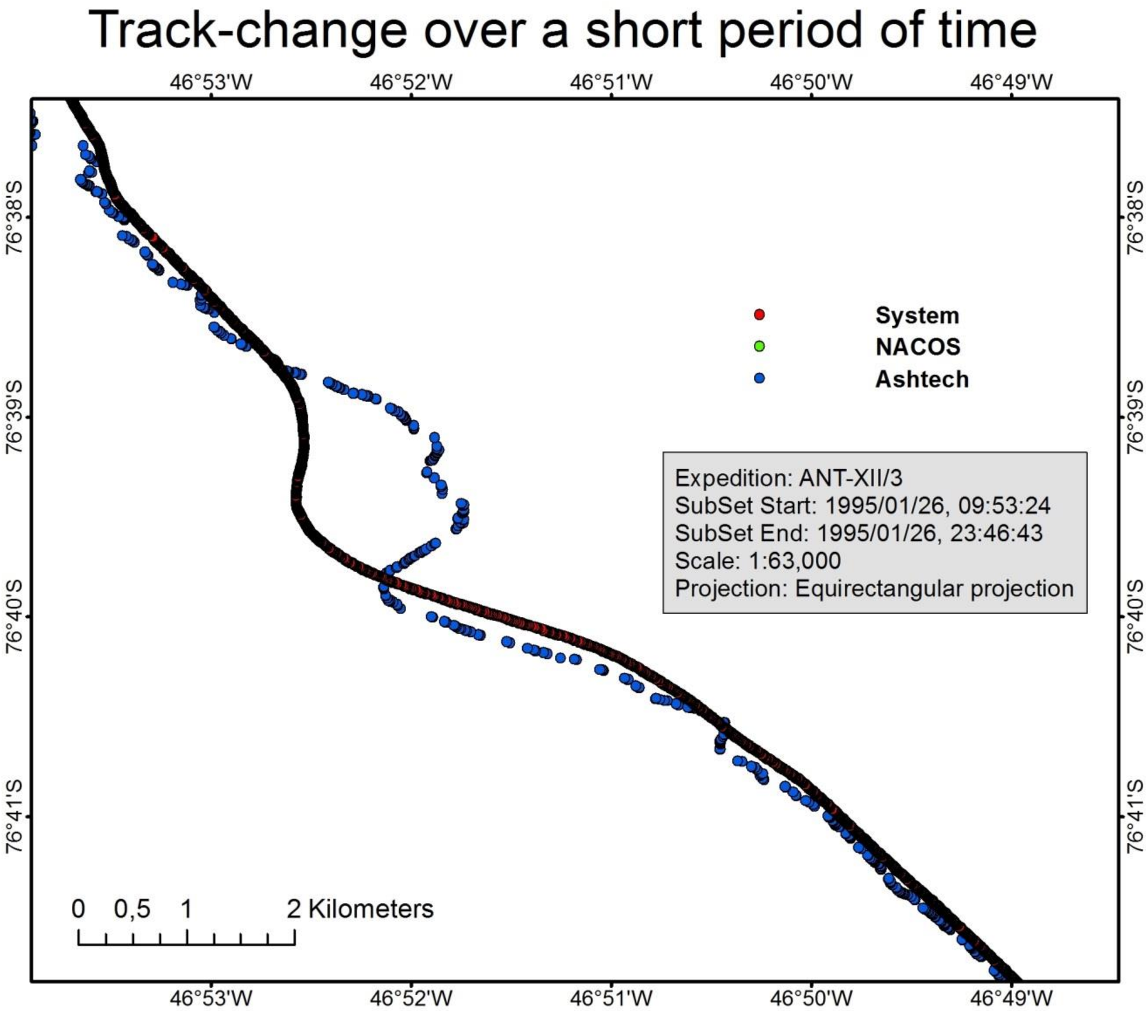

Figure 22: Data example from ANT-XII/3

- Scattering positions along the track (e.g. Figure 23), this errors will be mostly detected by the automatic filters, but also flagged manually if detected.

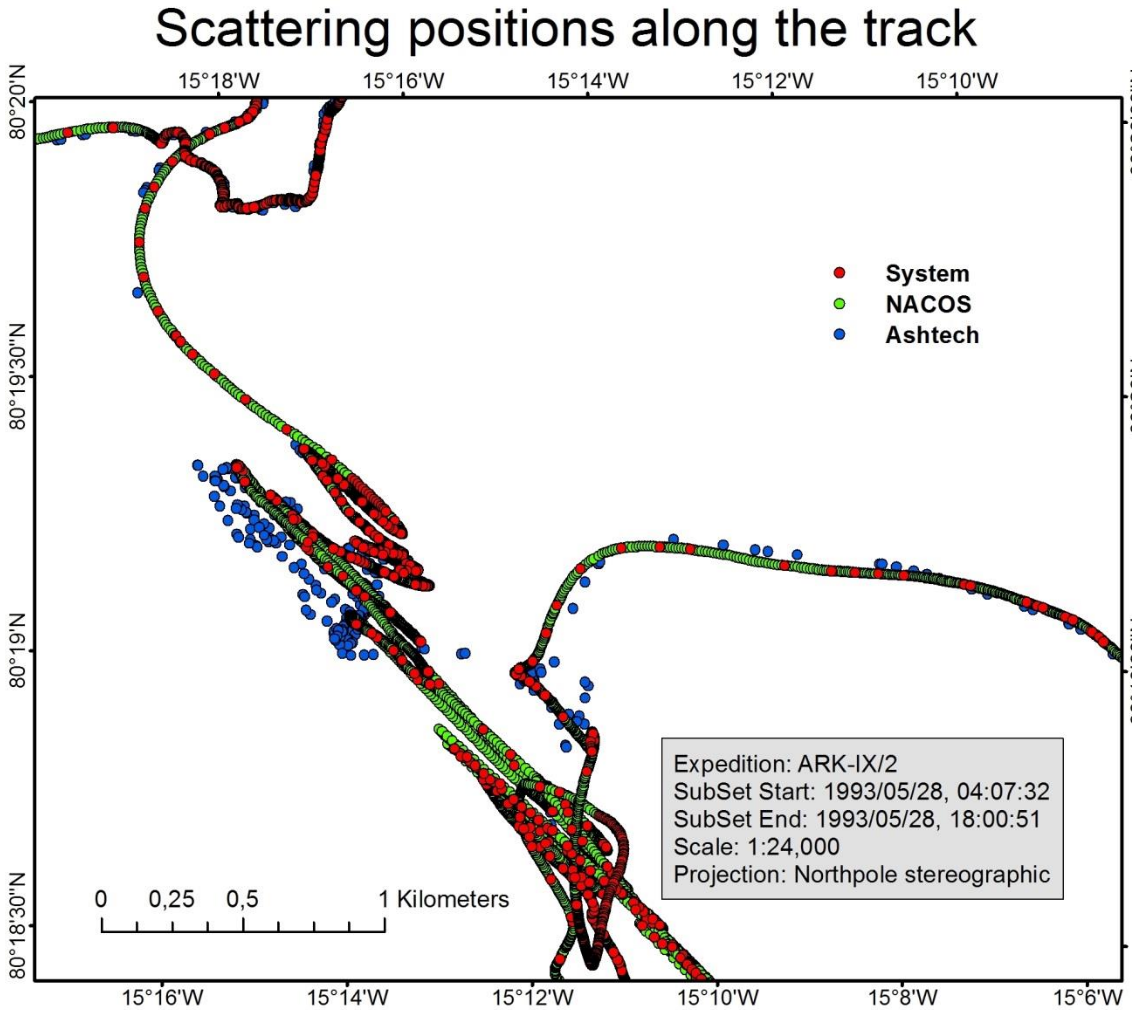

Figure 23: Data example from ARK-IX/2

- Points are drifting away from the track before gaps (e.g. Figure 24)

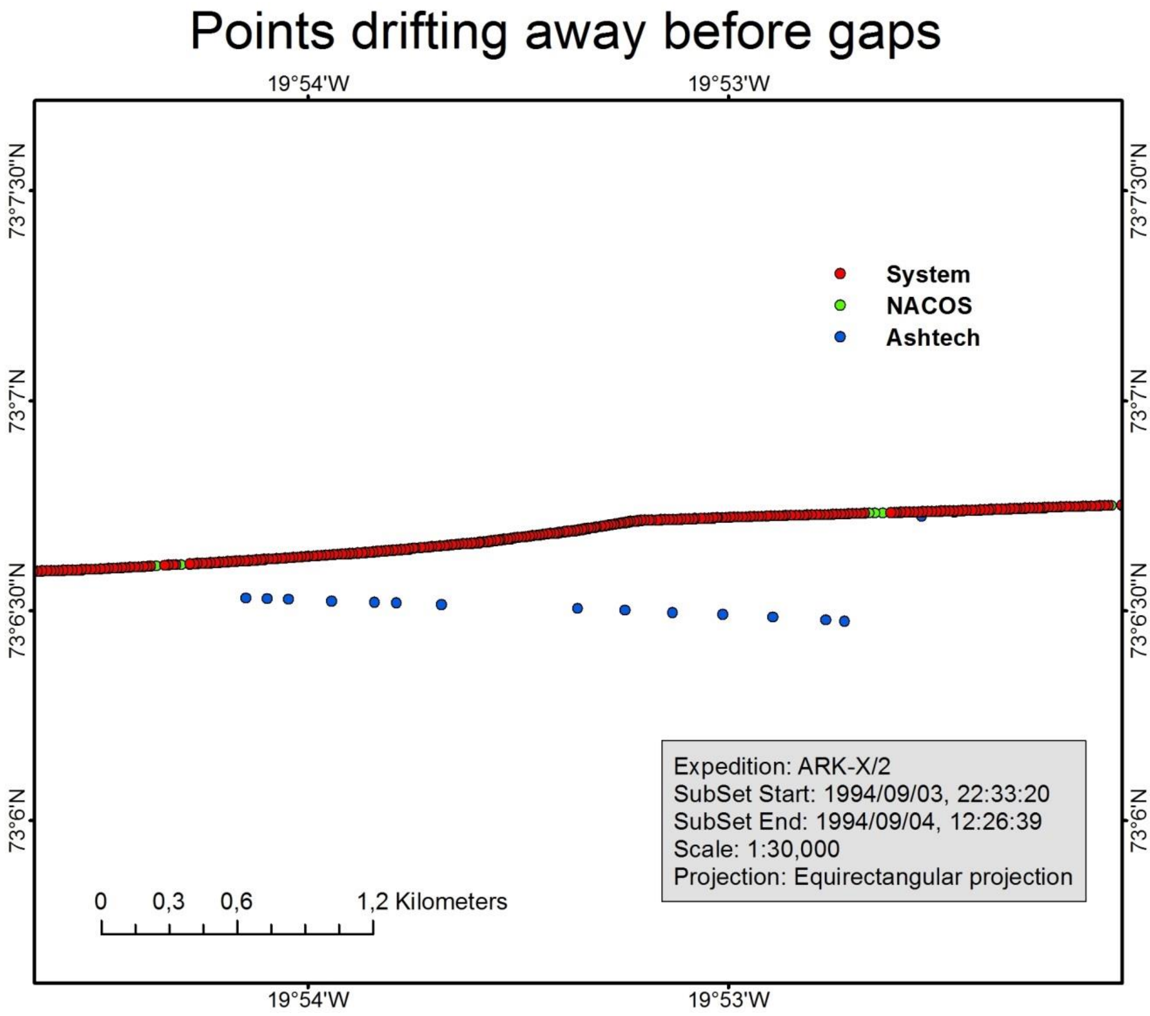

Figure 24: Data example from ARK-X/2

5.5 Errors of the sensor MINS

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

- Constant offset between MINS and Trimble 1 / 2 orientated parallel to track (e.g. Figure 25). The offset between MINS and Trimble 1 / 2 can be up to hundreds of meters, occasionally a few kilometers. If the offset is too big, and the Trimble data seem more reliable, the track of MINS will be flagged manually.

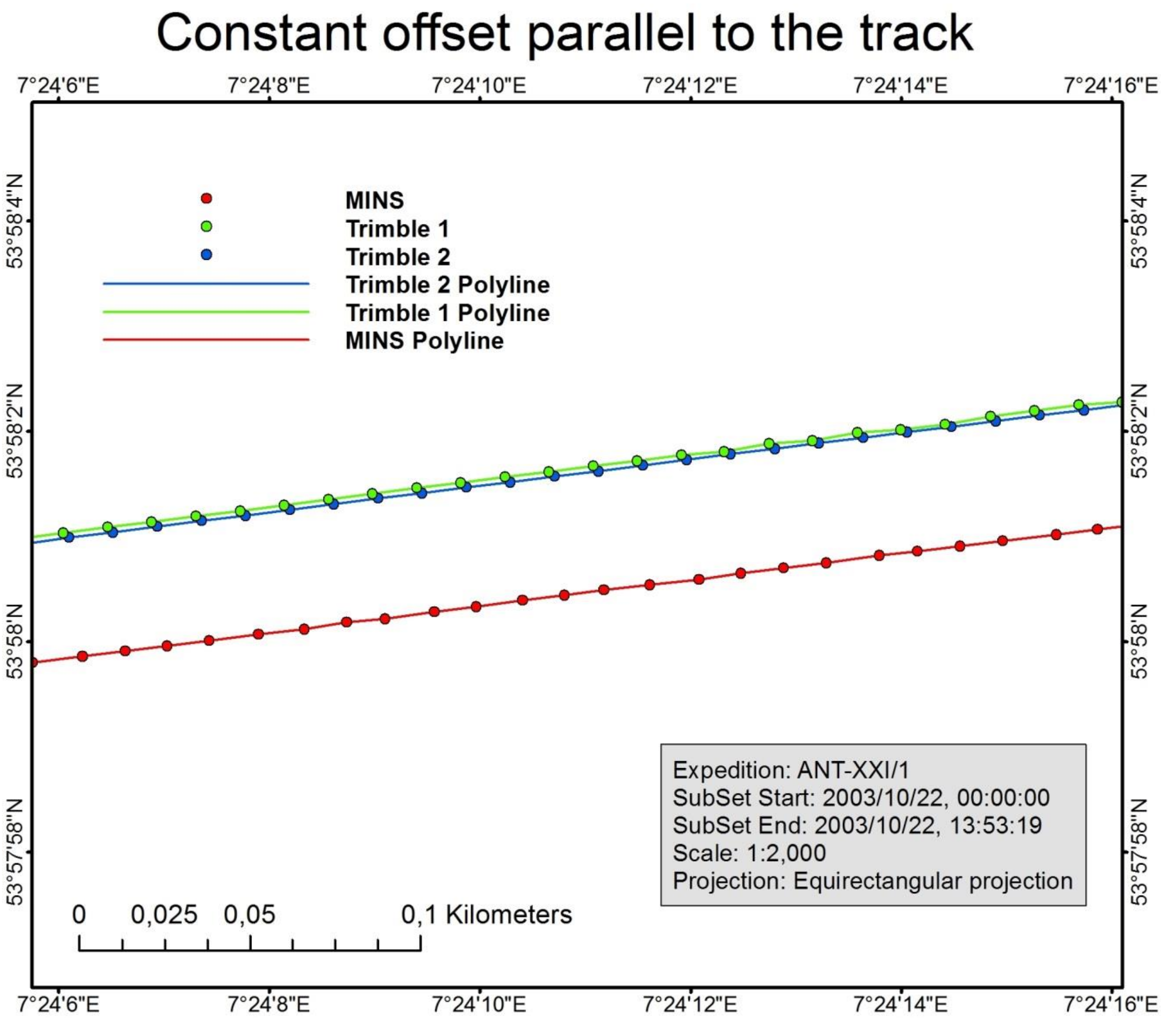

Figure 25: Data example from ANT-XXI/1

- Increasing offset between MINS and Trimble 1 / 2 in curves (e.g. Figure 24). During course change the track recorded by the MINS tends to drift away compared to the track recorded by Trimble 1 / 2. This is due to the Kalman filtering of the MINS.

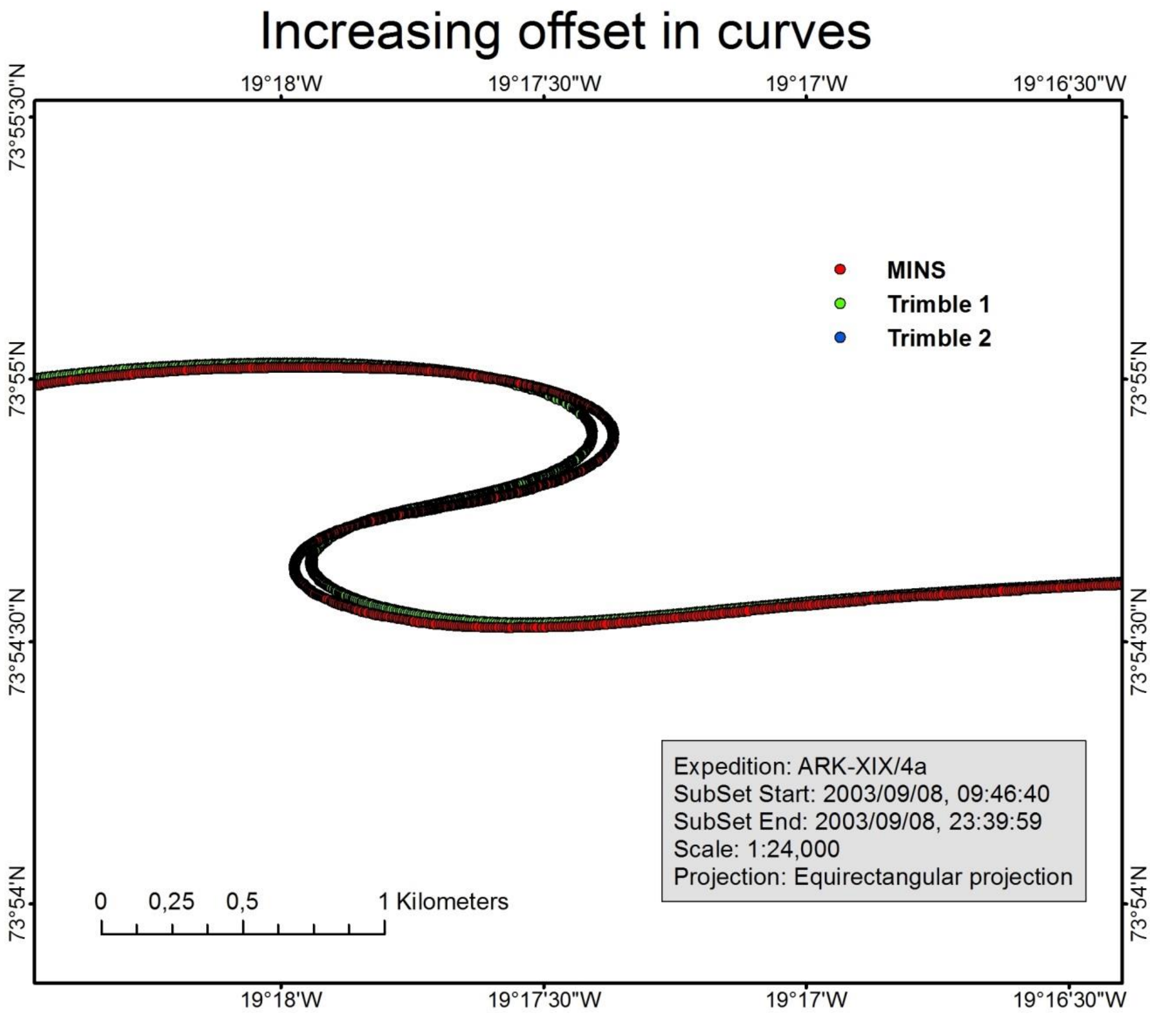

Figure 26: Data example from ARK-XIX/4a

* Missing data over larger distances (e.g. Figure 27). The data gaps can be tens of kilometers long. In Figure 27, the data gaps seem to occur in a regular interval. However, also other data gaps without showing this regularity where found in the datasets. If the gaps are within one minute, they are interpolated.

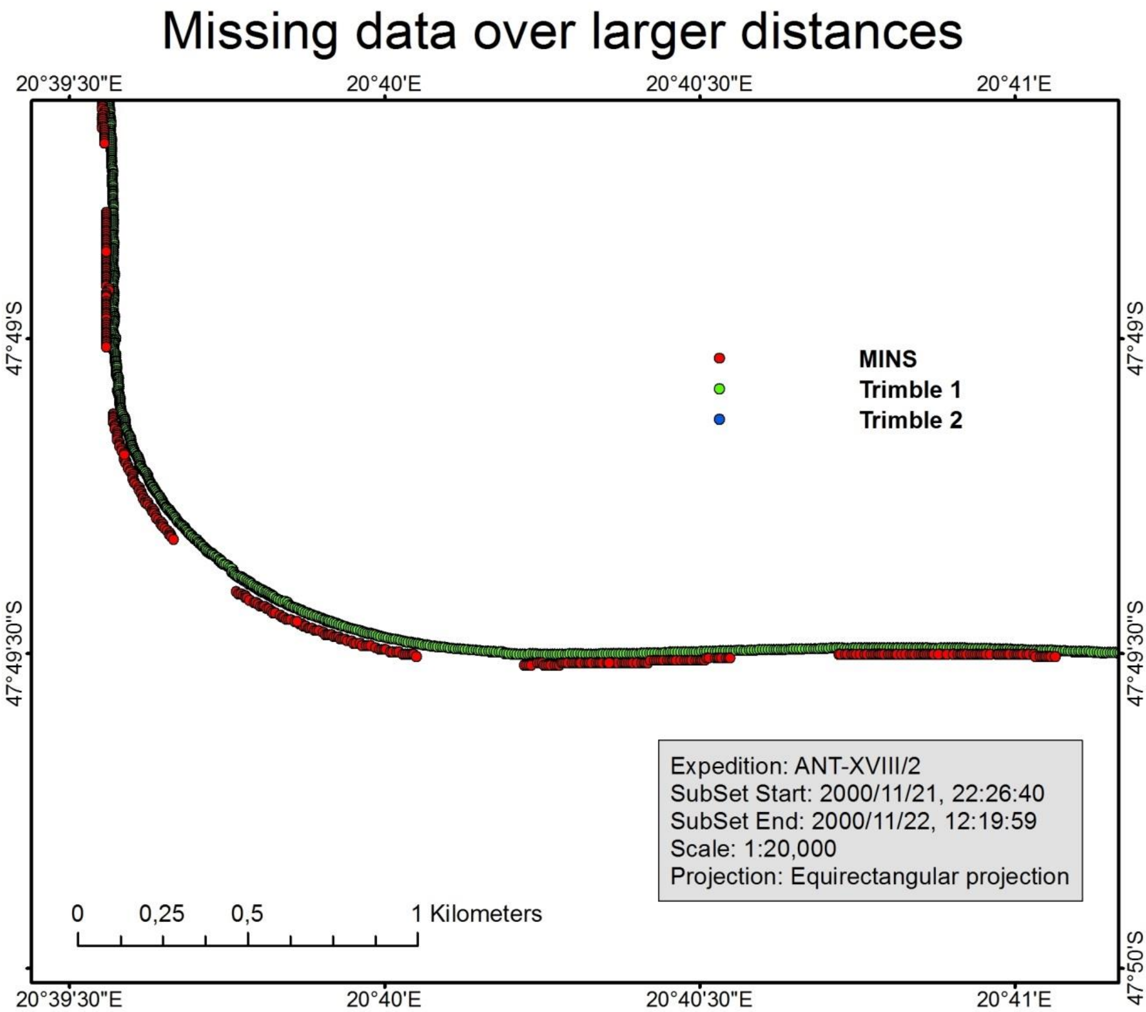

Figure 27: Data example from ANT-XVIII/2

- False single positions with a regular interval and pattern (e.g. Figure 28). Occasionally the data recorded by the MINS have position errors with a regular interval.

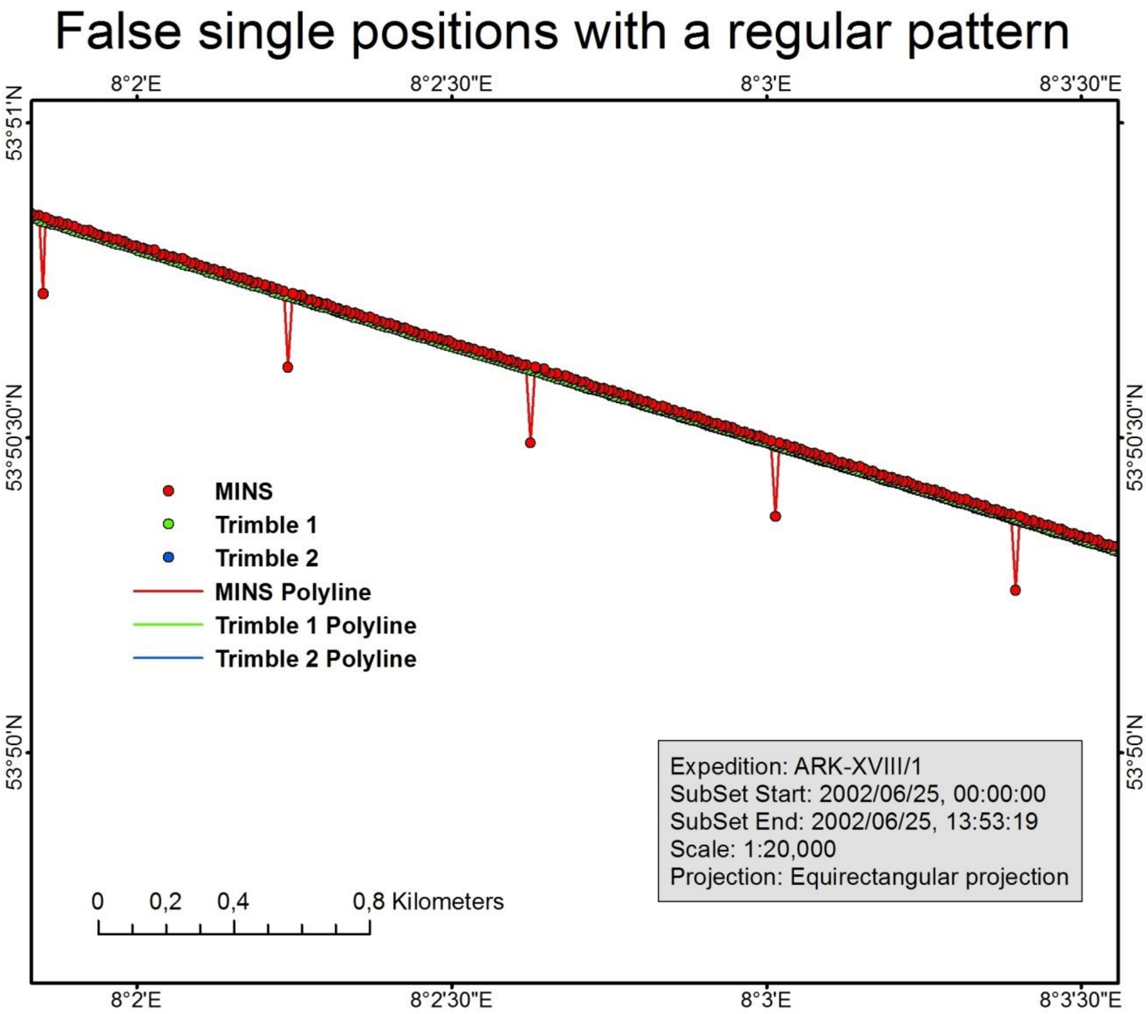

Figure 28: Data example from ARK-XVIII/1

- Single outliers with east-west orientation (6° longitude jumps) (e.g. Figure 29). Outliers are located with an offset of 6° to the east and to the west of the track. This error is caused by incorrect UTM coordinate transformations. The centered accumulation of data points are true data.

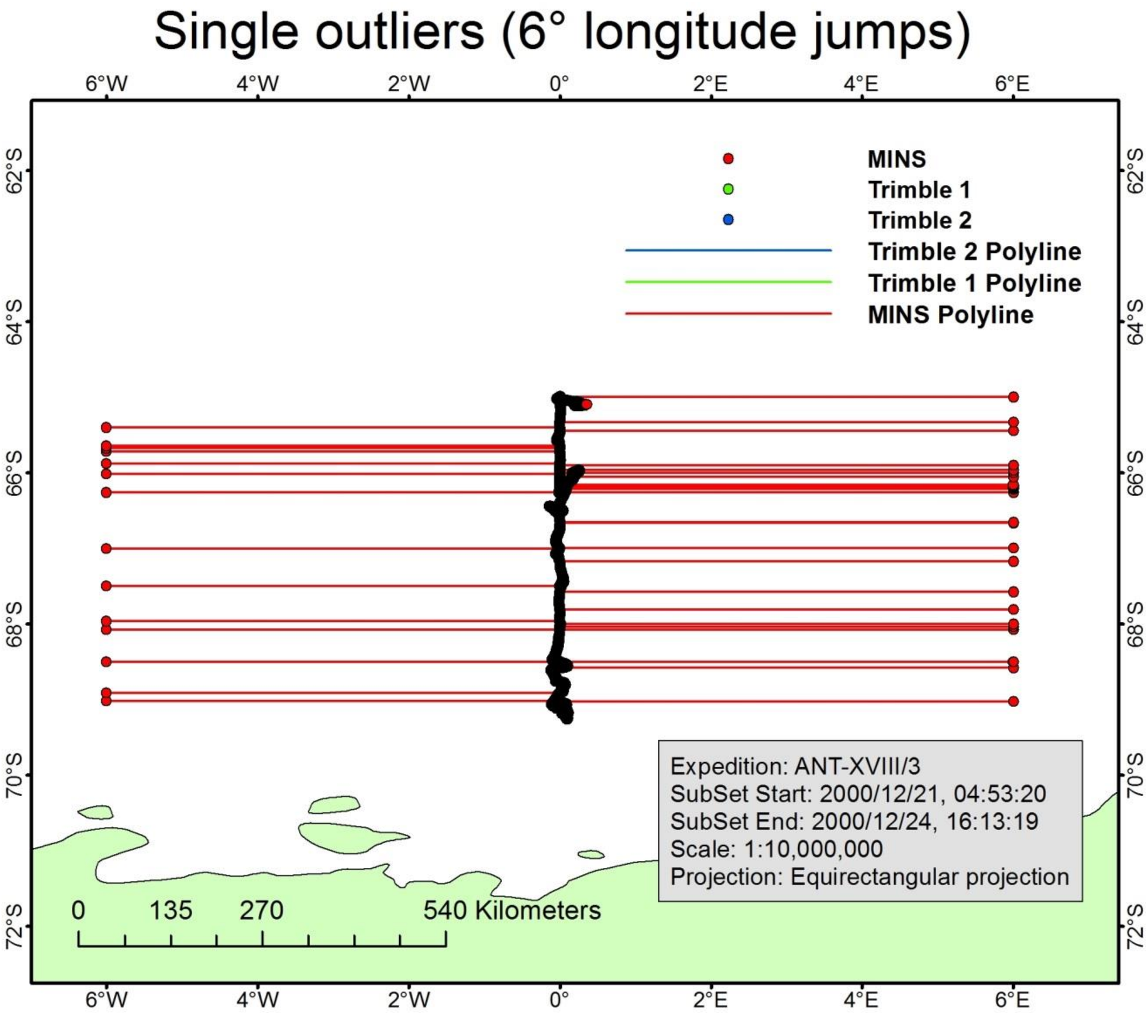

Figure 29 Data example from ANT-XVIII/3

- Group of data points located distant to the track (e.g. Figure 30). The offset between both groups of data points measures 45.5 kilometers in this example. Data points to the right are true data. Data points to the left are false data.

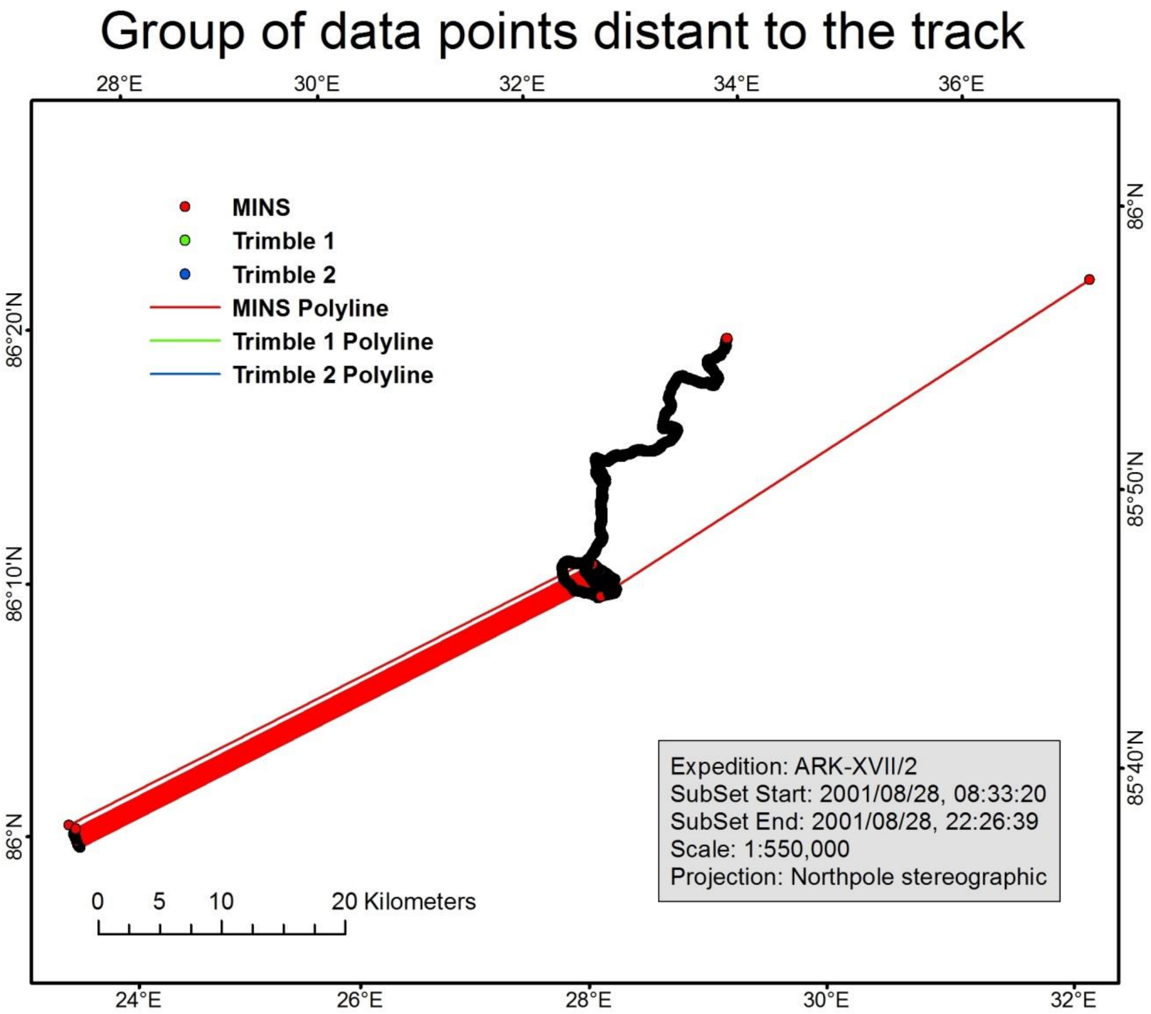

Figure 30: Data example from ARK-XVII/2

- Zig-zag-pattern of data points (e.g. Figure 31)

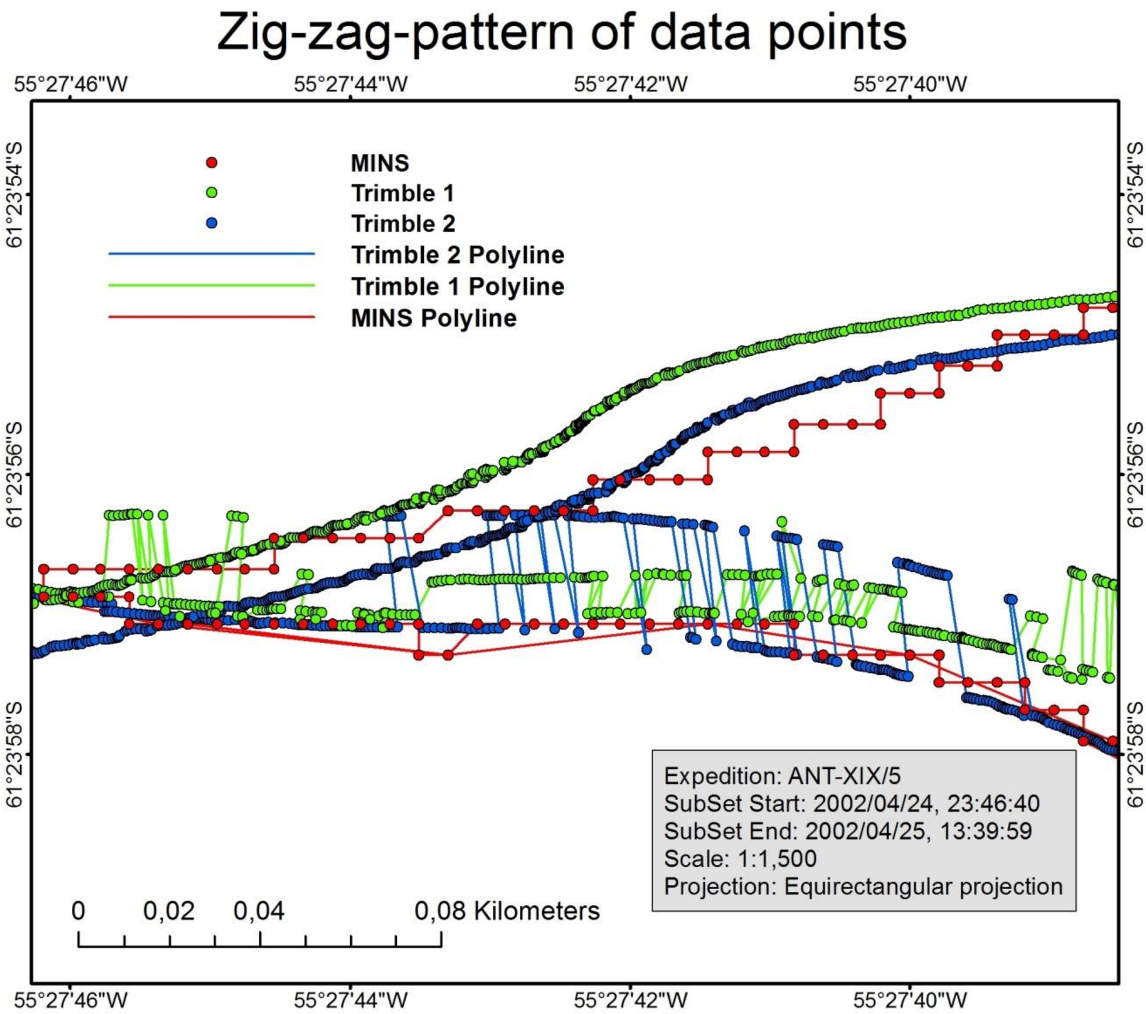

Figure 31 Data example from ANT-XIX/5

- Jump of data point resulting in an ongoing offset of the dataset (e.g. Figure 32). The sudden jump of the MINS data causes an ongoing offset to the Trimble 1 data.

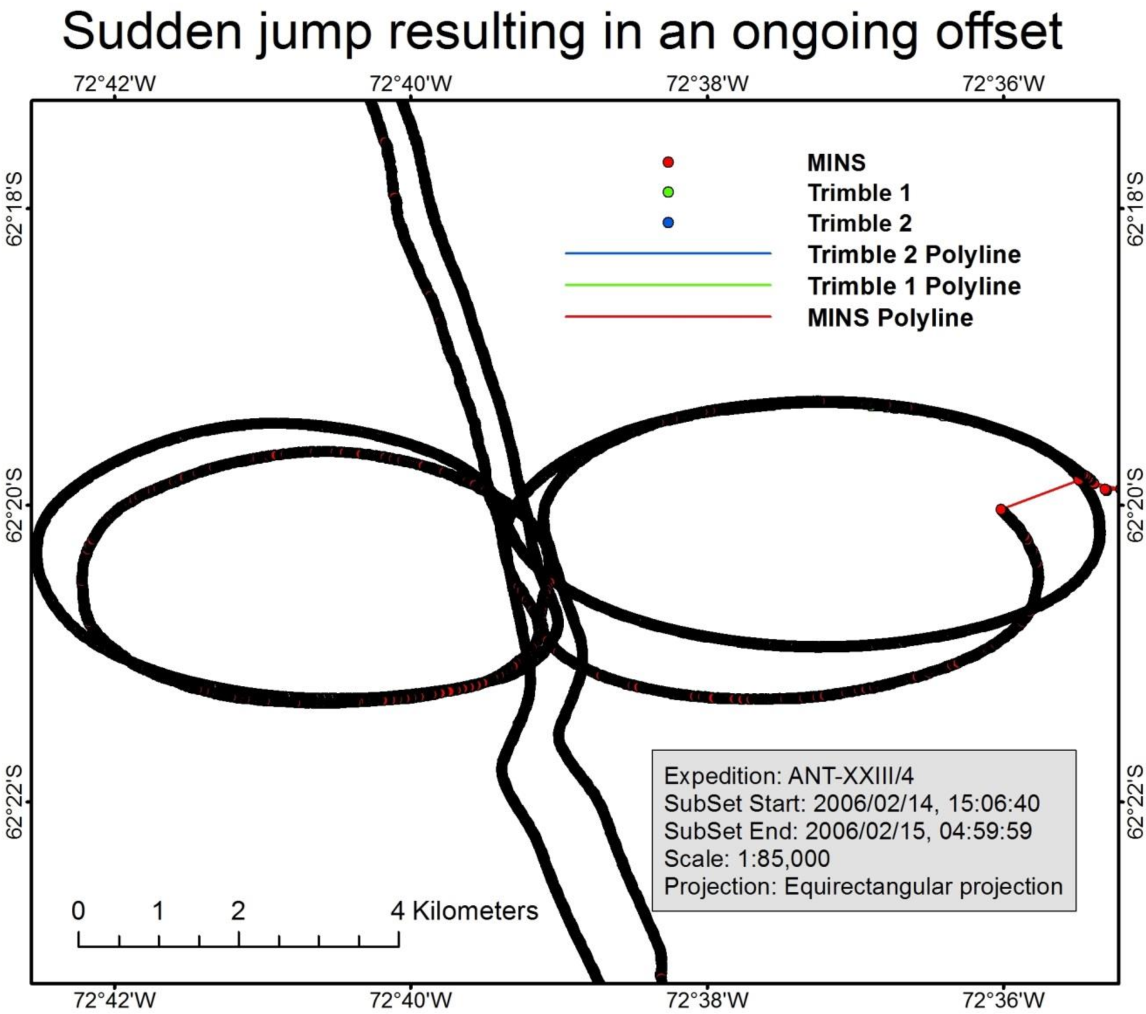

Figure 32: Data example from ANT-XXIII/4

- Random offsets for a certain track compared to Trimble data without obvious pattern (e.g. Figure 33)

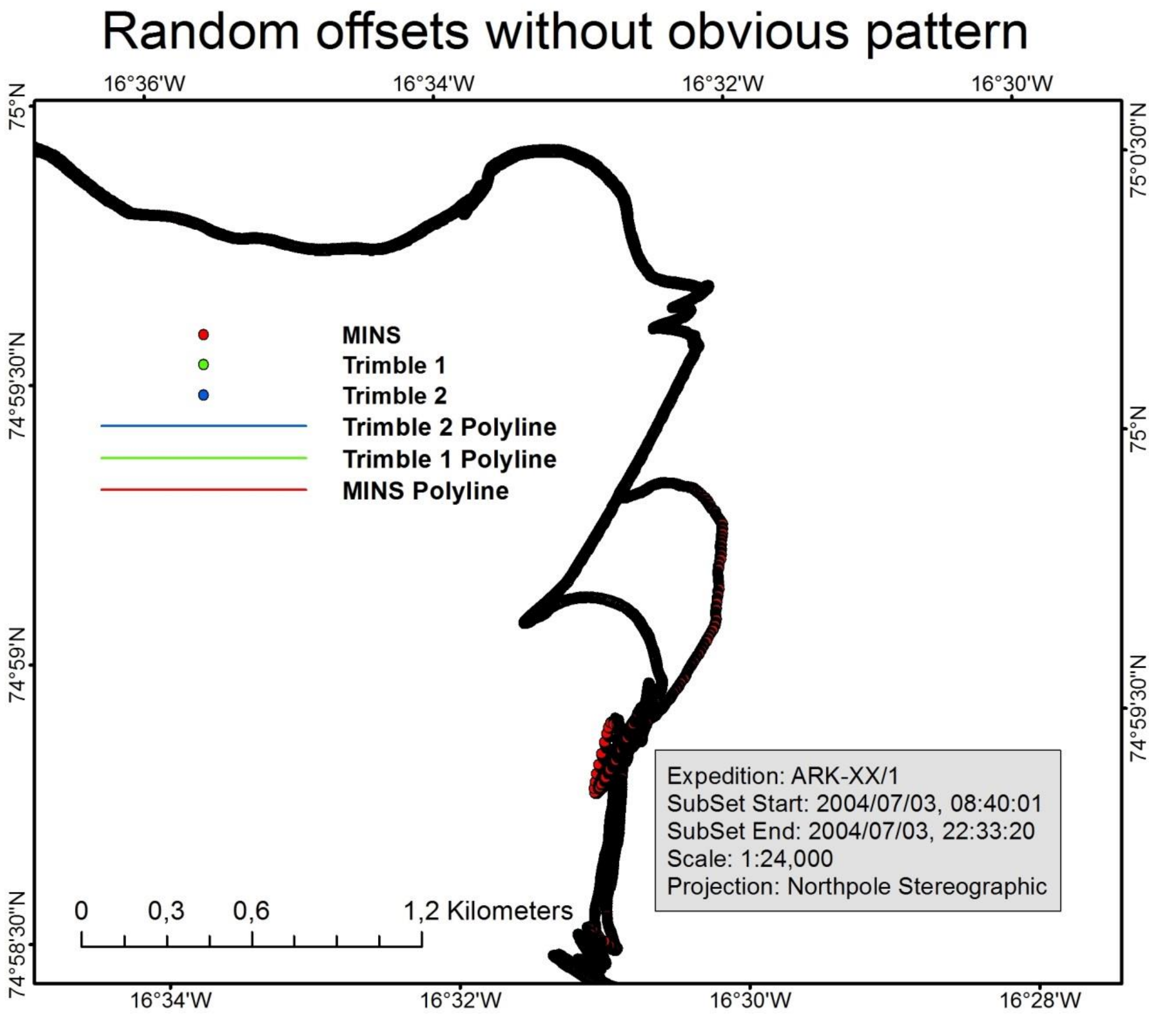

Figure 33: Data example from ARK-XX/1

5.6 Errors of the sensor Trimble 1

The errors of the DGPS Trimble 1 can be summarized in five groups:

- False single positions with a regular interval and pattern (e.g. Figure 34). This error is due to lacking motion information for this position, which prohibits centering. In this example, the deviation between the main track of Trimble 1 and the false data points is 48 meters

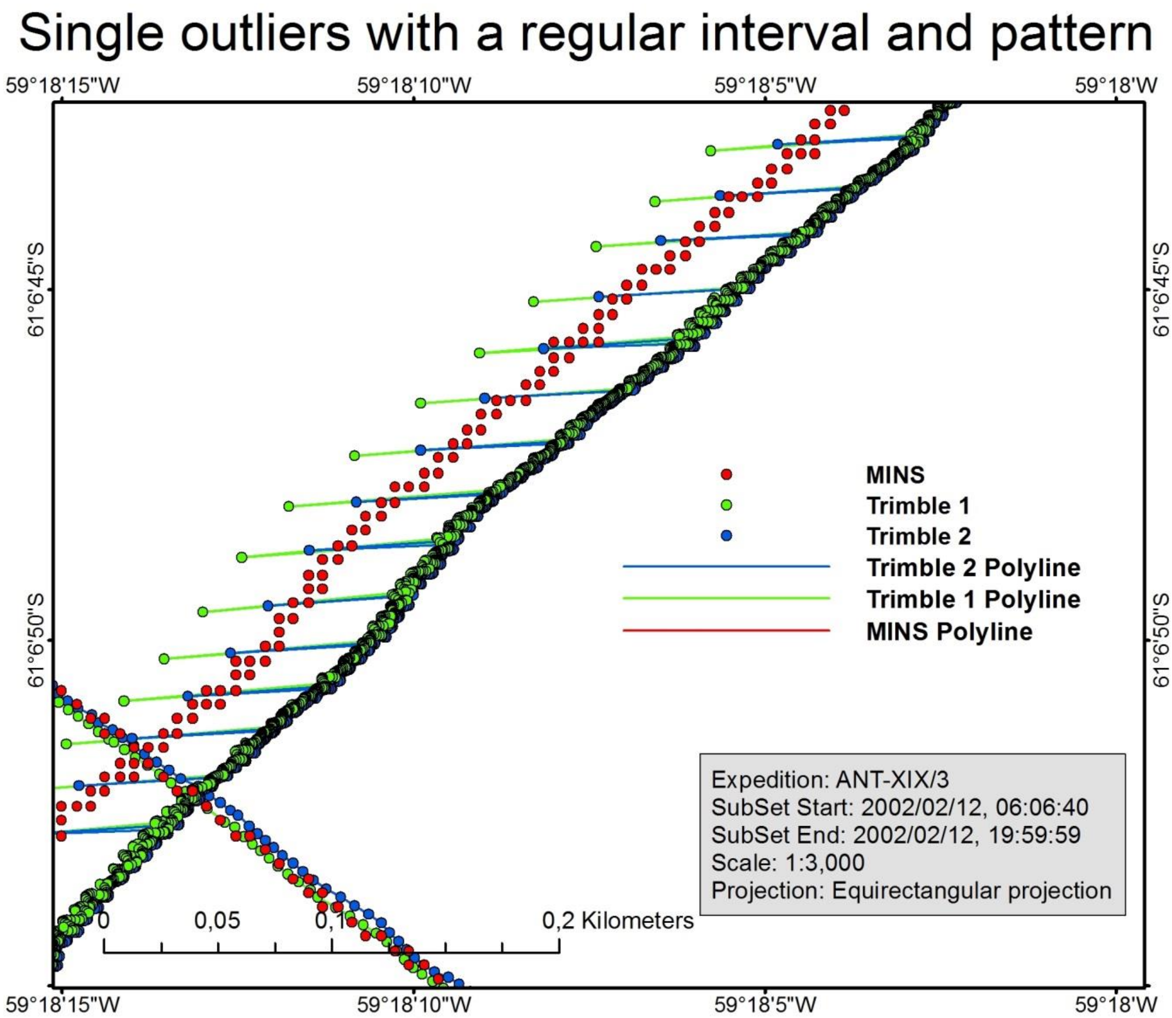

Figure 34: Data example from ANT-XIX/3

- Meandering data (e.g. Figure 35)

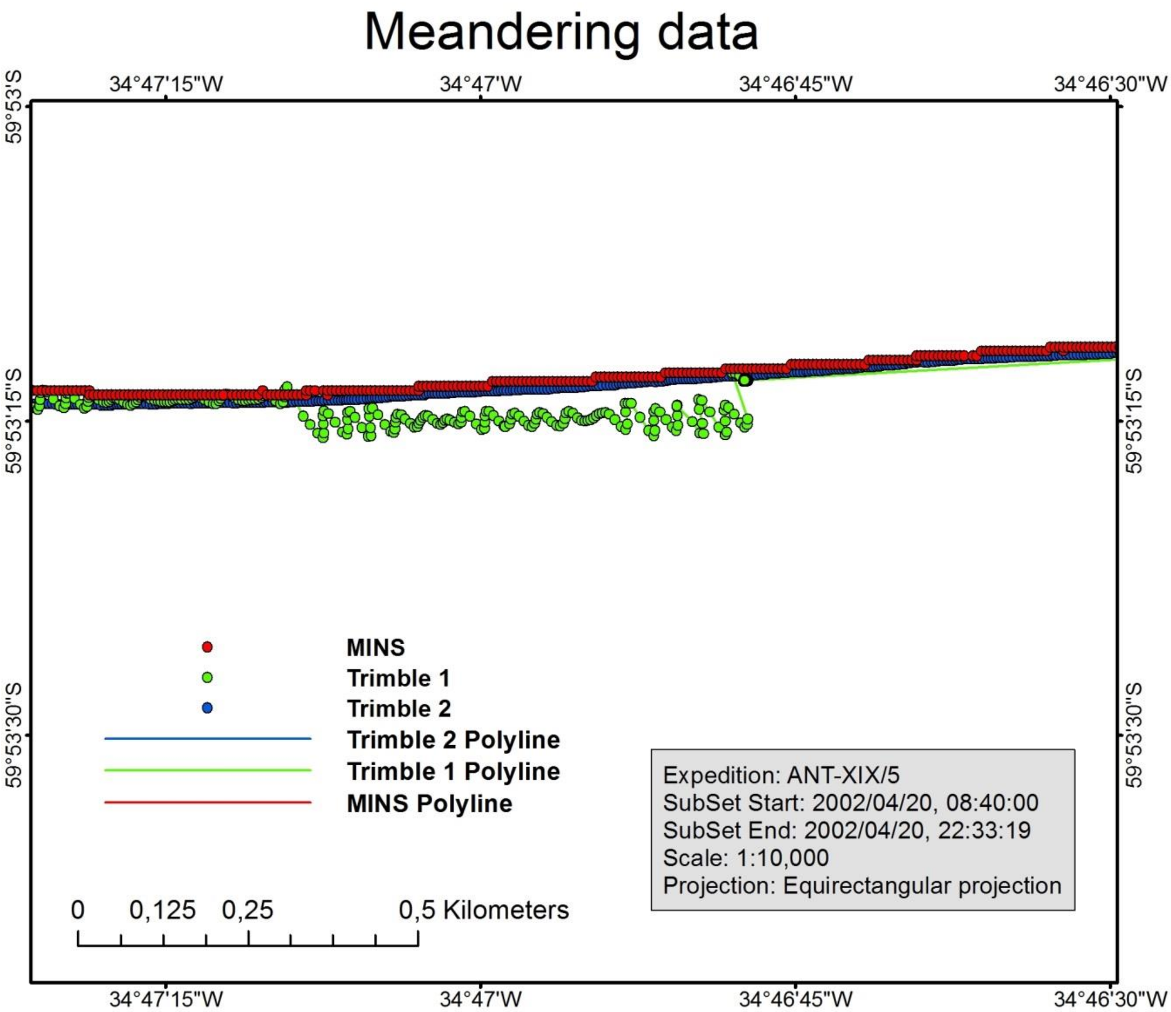

Figure 35: Data examples from ANT-XIX/5

- Data points are stagnating at the same positions for several seconds (e.g. Figure 36).

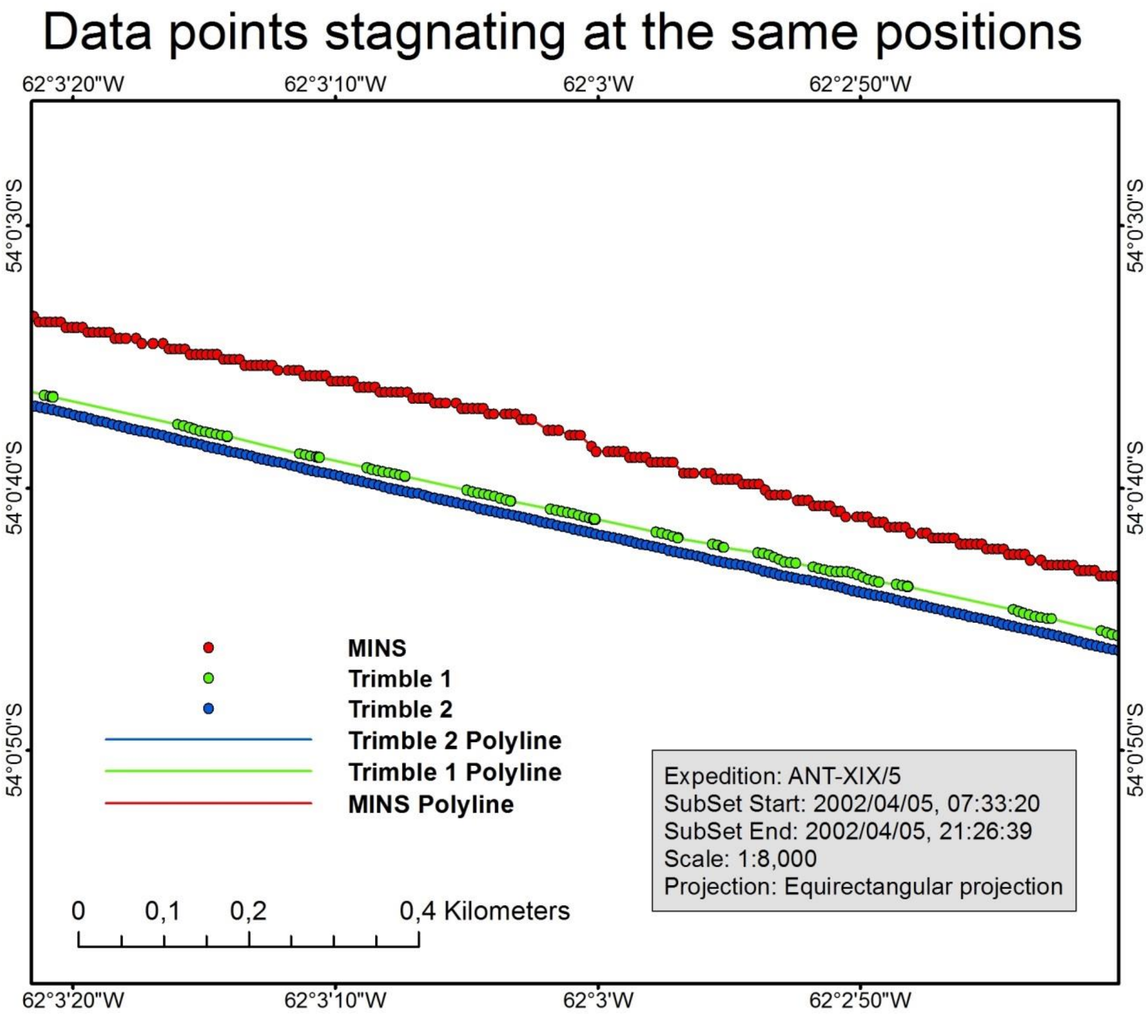

Figure 36: Data example from ANT-XIX/5

- Random offsets compared to Trimble 2 / MINS data without clearly visible pattern (e.g. Figure 37).

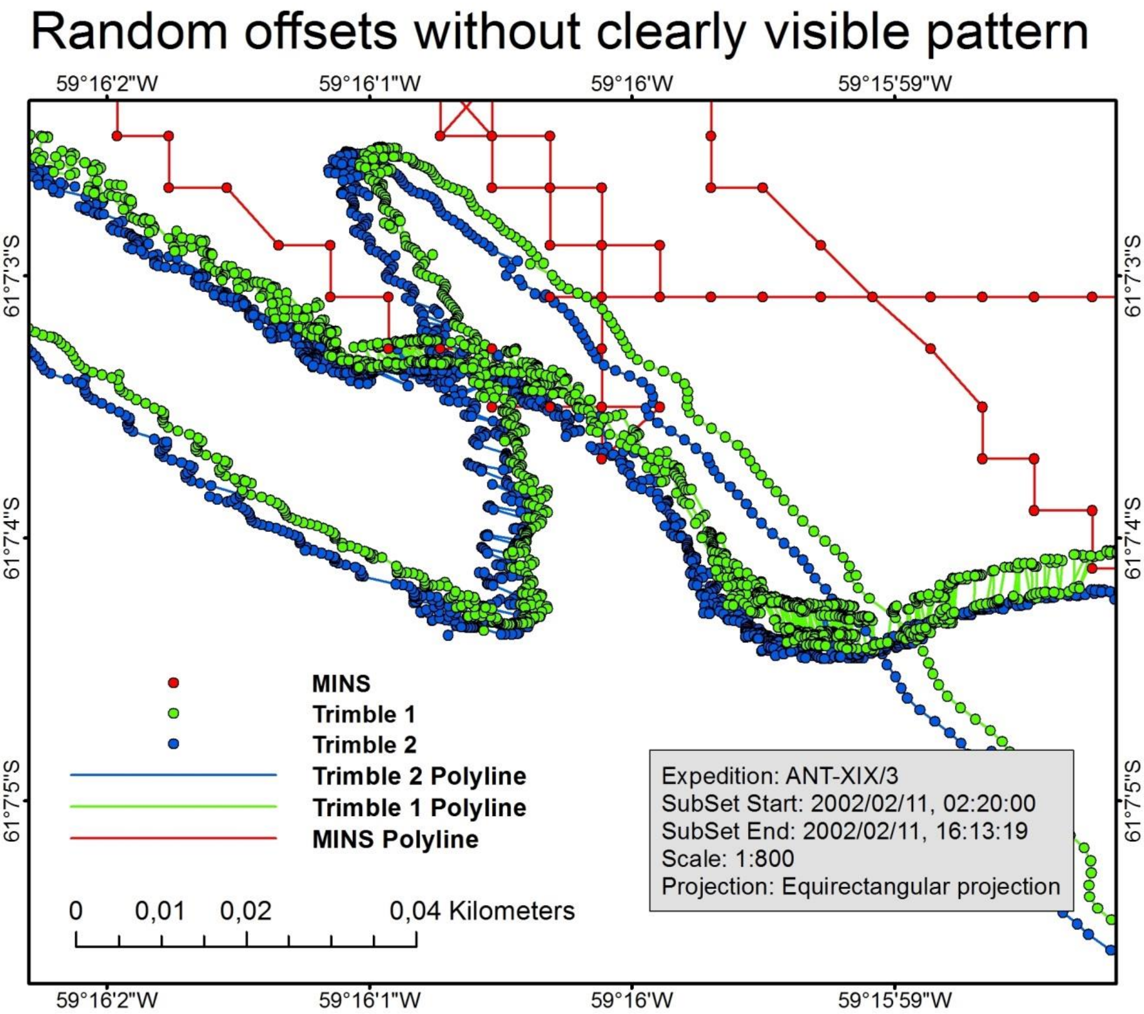

Figure 37: Data example from ANT-XIX/3

- Track drift away (e.g. Figure 38)

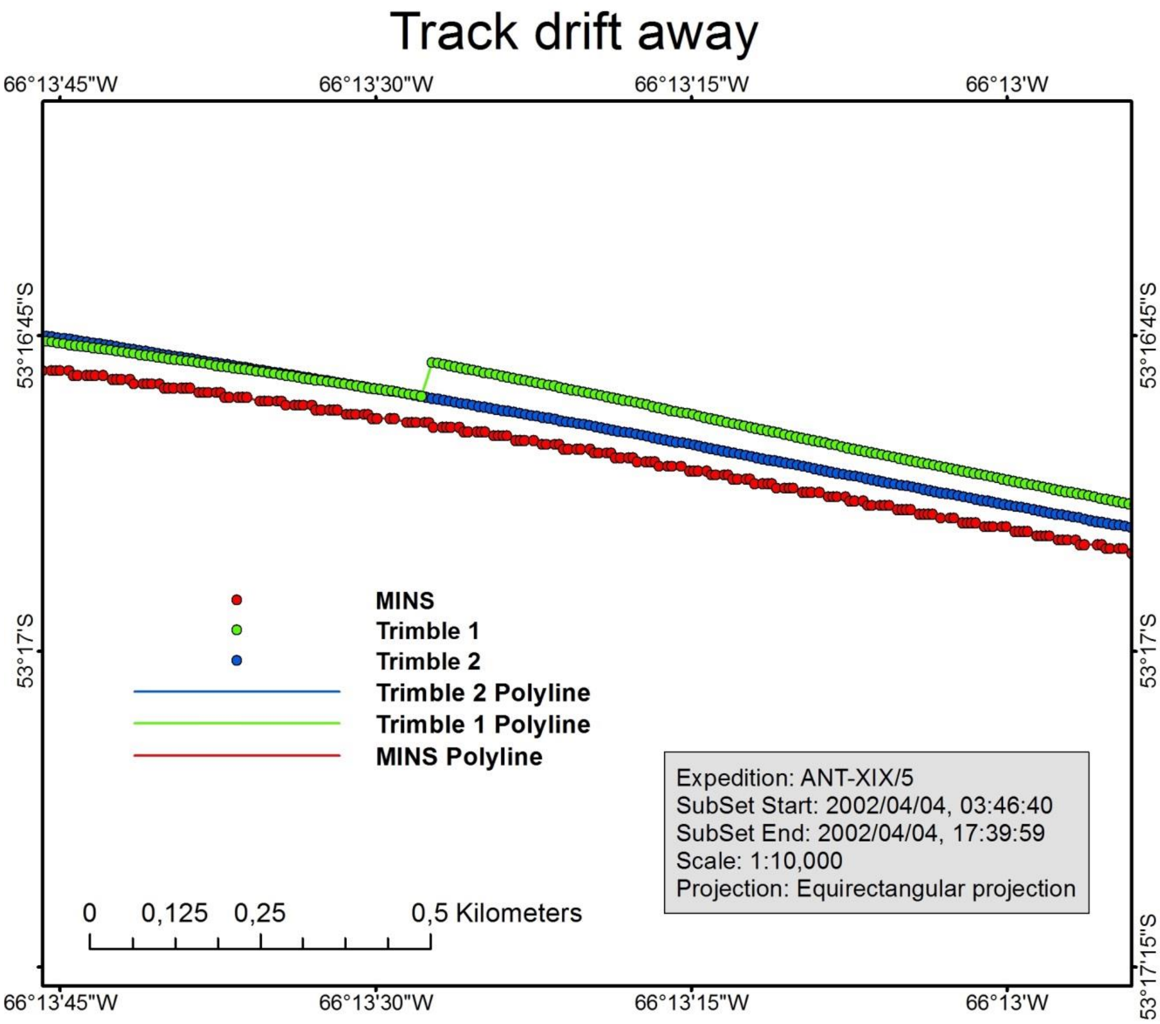

Figure 38: Data examples from ANT-XIX/5

5.7 Errors of the sensor Trimble 2

The errors of DGPS Trimble 2 can be summarized in four groups:

- Regular offset of small groups of position data due to missing motion data (e.g. Figure 39)

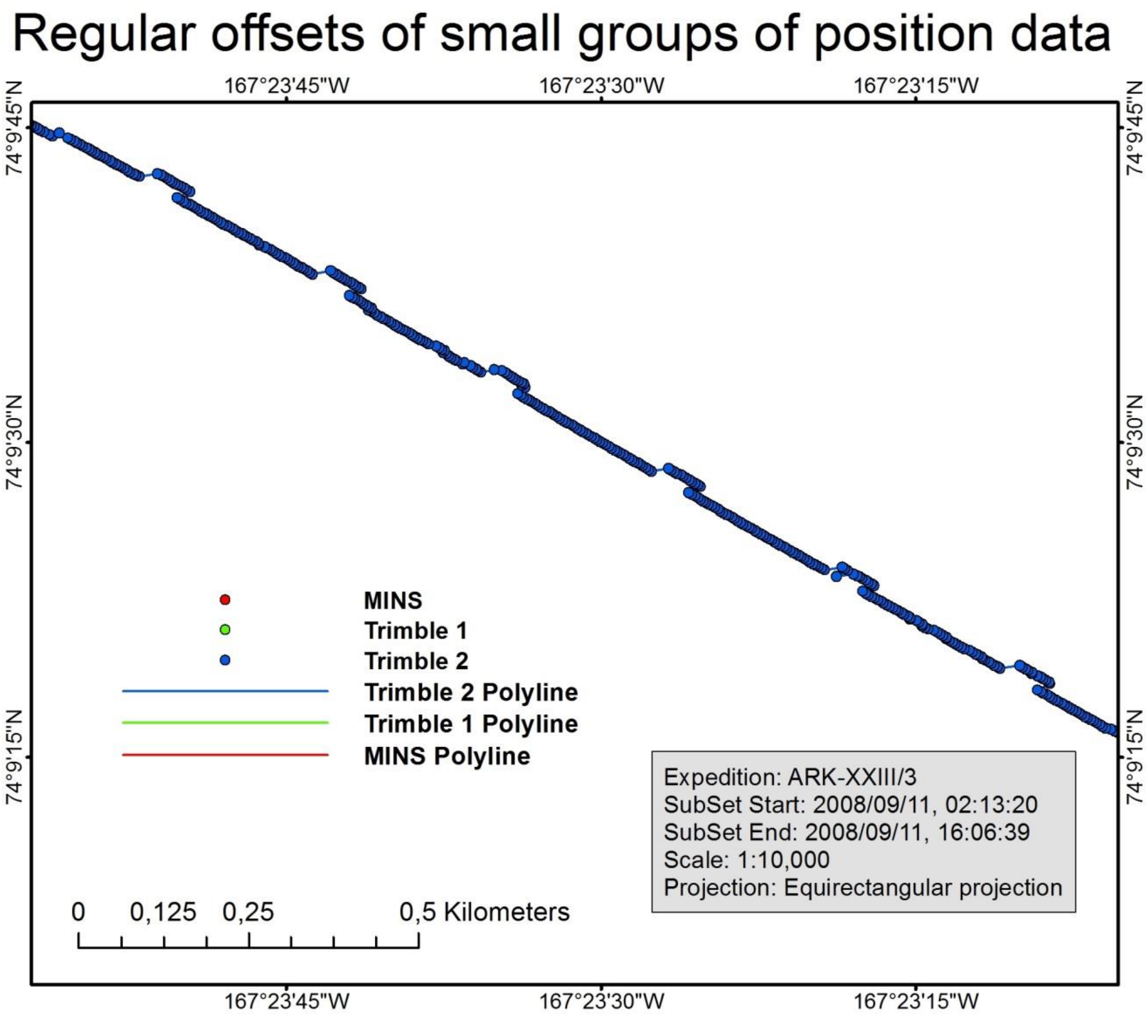

Figure 39: Data example from ARK-XXIII/3

- Missing data over larger distances (e.g. Figure 40).

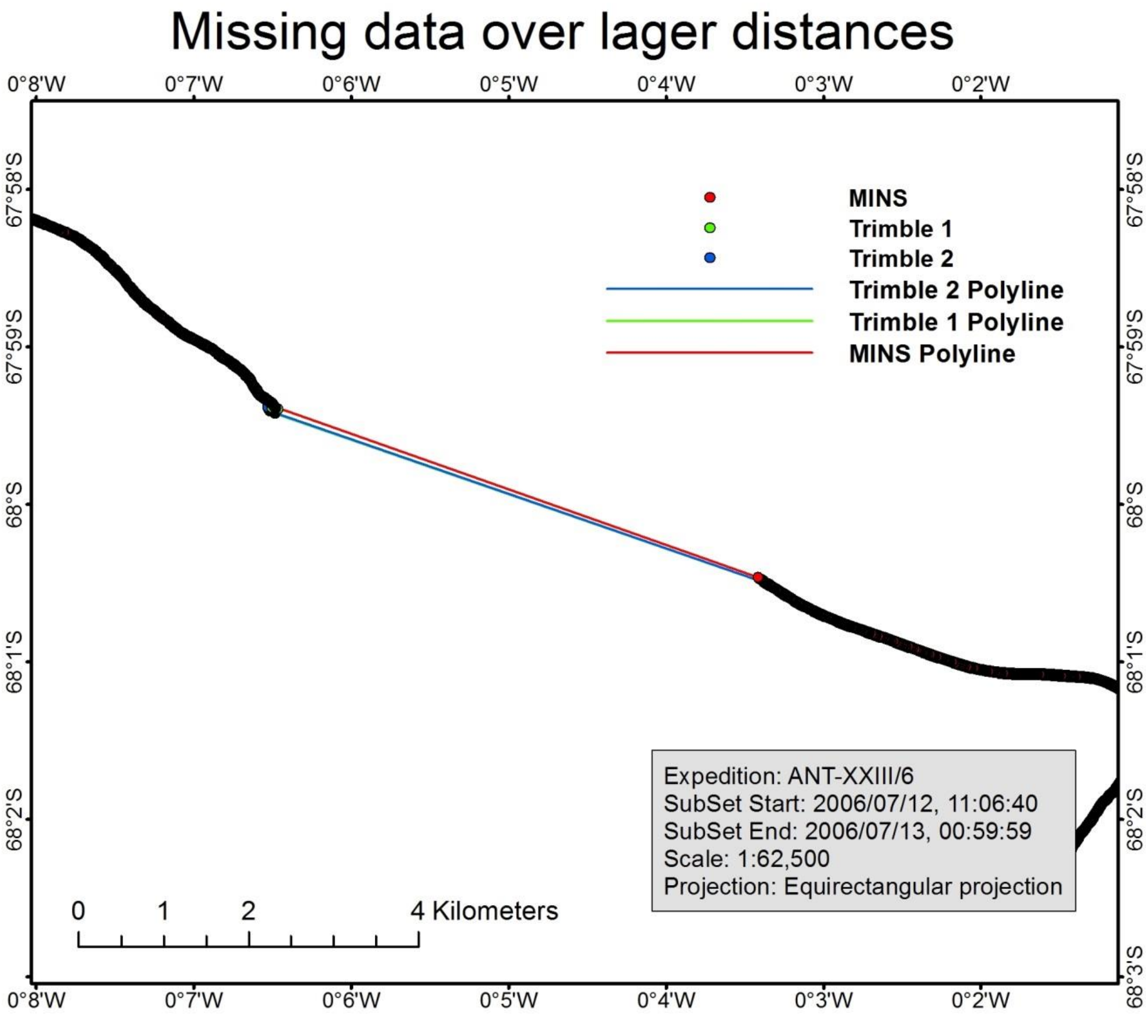

Figure 40: Data example from ANT-XXIII/6

- Single outliers (e.g. Figure 41).

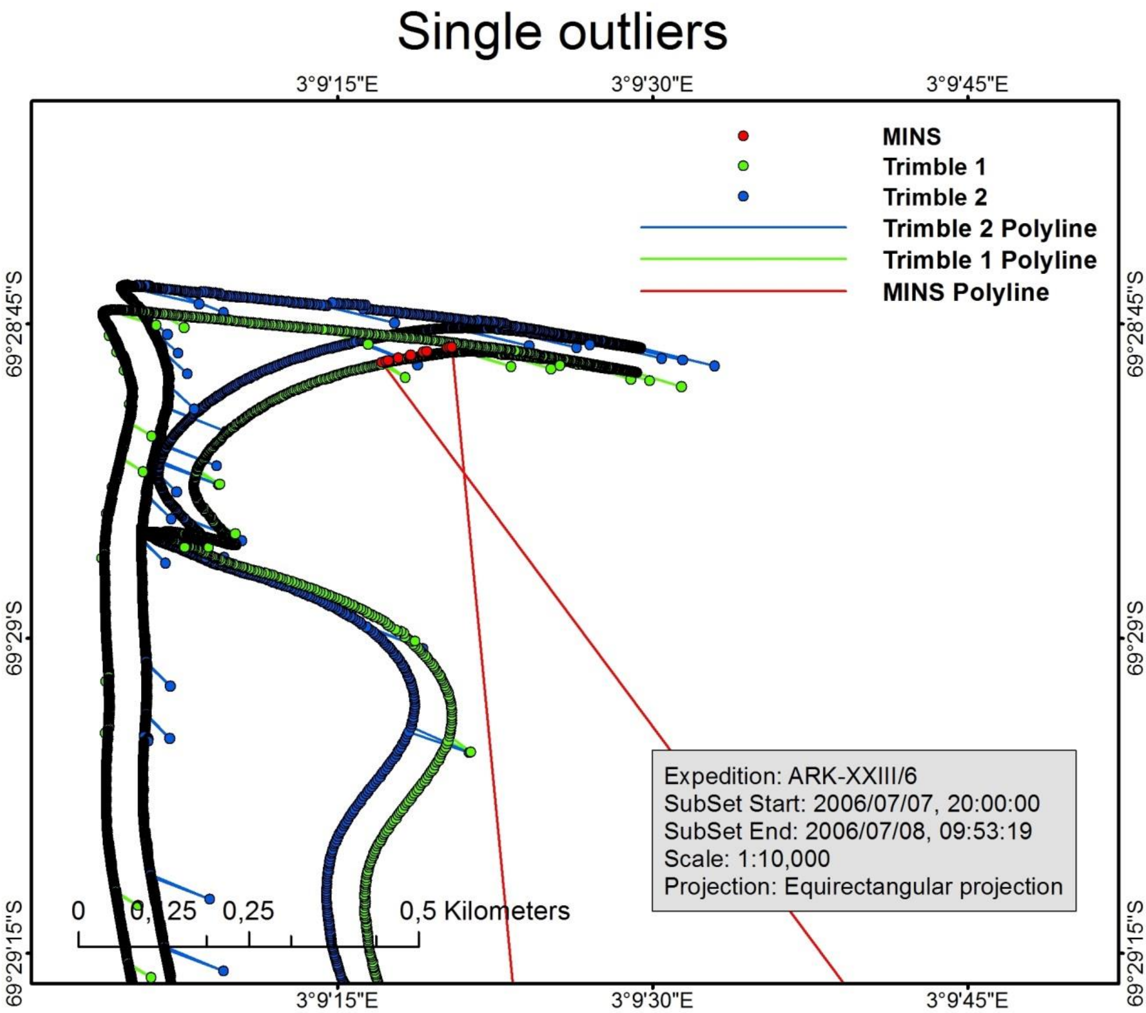

Figure 41: Data example from ANT-XXIII/6

- Jump of data points due to missing motion data (e.g. Figure 42).

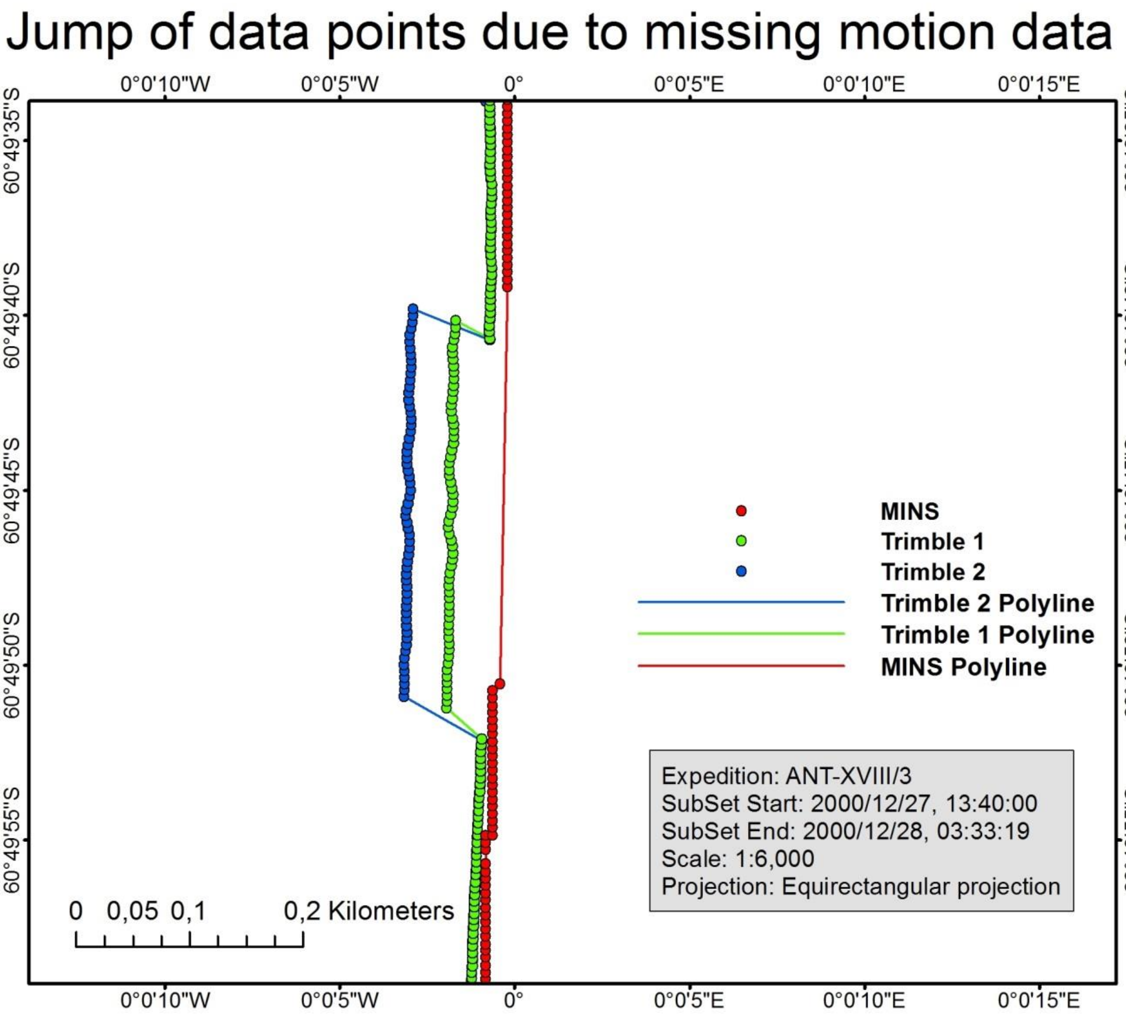

Figure 42: Data example from ANT-XVIII/3

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 is applied for all cruises. The availability of raw position data is also shown in Figure 1 to Figure 3.

$$raw_{score} = \left(\frac{available_{NAV1} + available_{NAV2} + available_{NAV3}}{datapoints}\right)/3 \quad (1)$$

Secondly, the arithmetic mean of all flagged datapoints is calculated for all automatic filters and the manual inspection. The equation 2 is applied for all cruises.

$$flagging_{score} = \left(\frac{\overline{flagged_{NAV1}} + \overline{flagged_{NAV2}} + \overline{flagged_{NAV3}}}{datapoints}\right)/3 \quad (2)$$

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 ARK-II/2 to ANT-XXIX/5, the following score-values were calculated (Table 7). A value of 100 means a perfect dataset. The color coding is stretched to the following values (Figure 43):

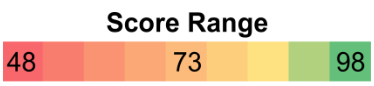

Figure 43: Color bar for Table 7

Table 7: Calculated score-values for all processed Polarstern cruises

Cruise	Score	Cruise	Score	Cruise	Score	Cruise	Score	Cruise	Score
ARK-II/2	68	ARK-VIII/7	64	ARK-XIII/5	88	ARK-XIX/4	94	ARK-XXII/2	97
ARK-II/3	66	ARK-VII/1	66	ARK-XII/	88	ARK-XIX/5	92	ARK-XXIV/1	97
ARK-II/4	64	ARK-VII/2	67	ARK-XIV/1	90	ARK-XIX/6	93	ARK-XXIV/2	86
ARK-II/5	63	ARK-VII/3a	68	ARK-XIV/2	85	ARK-XVIII/1	89	ARK-XXIV/3	90
ARK-III/1	60	ARK-VII/3b	66	ARK-XIV/3	90	ARK-XVIII/2	98	ARK-XXIV/4	96
ARK-III/2	64	ARK-IX/1	64	ARK-XIV/4	87	ARK-XX/1	97	ARK-XXIII/1	92
ARK-III/3	65	ARK-IX/2	66	ARK-XIII/1a	88	ARK-XX/2	81	ARK-XXIII/2	95
ARK-III/4	60	ARK-IX/4	63	ARK-XIII/1b	86	ARK-XX/3	95	ARK-XXIII/3	87
ARK-III/1	65	ARK-VIII/1	67	ARK-XIII/2	89	ARK-XIX/1	94	ARK-XXV/1	92
ARK-III/2	65	ARK-VIII/2	68	ARK-XIII/3	89	ARK-XIX/2	94	ARK-XXV/2	95
ARK-III/3	66	ARK-VIII/3	65	ARK-XV/1	89	ARK-XIX/3a	54	ARK-XXV/3	93
ARK-IV/1b	53	ARK-X/1a	64	ARK-XV/2	89	ARK-XIX/3b	48	ARK-XXV/4	90
ARK-IV/1c	61	ARK-X/1b	65	ARK-XV/3	89	ARK-XIX/3c	92	ARK-XXV/5	96
ARK-IV/2	61	ARK-X/2	66	ARK-XV/4	88	ARK-XIX/4a	97	ARK-XXIV/1	94
ARK-IV/3	63	ARK-X/3	66	ARK-XV/5	88	ARK-XIX/4b	92	ARK-XXIV/2	88
ARK-IV/4	64	ARK-X/4	67	ARK-XIV/1a	87	ARK-XXI/1	98	ARK-XXIV/3	95
ARK-V/1	63	ARK-X/5	89	ARK-XIV/1b	79	ARK-XXI/2	97	ARK-XXVI/1	96
ARK-V/3	64	ARK-X/6	65	ARK-XIV/2	87	ARK-XXI/3	91	ARK-XXVI/2	90
ARK-V/4	64	ARK-X/7	67	ARK-XVI/1	89	ARK-XXI/4	95	ARK-XXVI/3	97
ARK-V/5	62	ARK-X/8	62	ARK-XVI/2	88	ARK-XXI/5	96	ARK-XXVI/4	95
ARK-IV/1	64	ARK-IX/1a	68	ARK-XVI/3	89	ARK-XX/1	95	ARK-XXV/1	91
ARK-IV/2	64	ARK-IX/1b	67	ARK-XVI/4	88	ARK-XX/2	95	ARK-XXV/2	90
ARK-IV/3	67	ARK-IX/2	53	ARK-XV/1	86	ARK-XX/3	97	ARK-XXV/3	96
ARK-VI/1	62	ARK-IX/3	86	ARK-XV/2	86	ARK-XXII/1	95	ARK-XXVII/1	98
ARK-VI/2	63	ARK-IX/4	87	ARK-XV/3	64	ARK-XXII/2	96	ARK-XXVII/2	92
ARK-VI/3	63	ARK-XI/1	84	ARK-XVII/1	86	ARK-XXII/3	91	ARK-XXVII/3	95
ARK-VI/5	59	ARK-XI/2	77	ARK-XVII/2	89	ARK-XXII/4	97	ARK-XXVII/4	96
ARK-V/1	64	ARK-XI/3	76	ARK-XVII/3	89	ARK-XXII/5	96	ARK-XXVI/1	94
ARK-V/2	65	ARK-XI/4	80	ARK-XVII/4	88	ARK-XXI/1a	97	ARK-XXVI/2	87
ARK-V/3a	63	ARK-XI/5	84	ARK-XVI/1	81	ARK-XXI/1b	92	ARK-XXVI/3	95
ARK-VII/1	64	ARK-X/1	85	ARK-XVI/2	88	ARK-XXIII/1	96	ARK-XXVIII/1	96
ARK-VII/2	66	ARK-X/2	85	ARK-XVIII/1	88	ARK-XXIII/2	97	ARK-XXVIII/2	94
ARK-VII/3	66	ARK-XII/1	71	ARK-XVIII/2	73	ARK-XXIII/3	90	ARK-XXVIII/3	87
ARK-VII/4	65	ARK-XII/2	73	ARK-XVIII/3	93	ARK-XXIII/4	96	ARK-XXVIII/4	94
ARK-VII/5	64	ARK-XII/3	84	ARK-XVIII/4	95	ARK-XXIII/5	94	ARK-XXVIII/5	95
ARK-VI/1	66	ARK-XII/4	85	ARK-XVIII/5a	97	ARK-XXIII/6	98	ARK-XXVII/1	93
ARK-VI/2	67	ARK-XII/5	81	ARK-XVIII/5b	95	ARK-XXIII/7	97	ARK-XXVII/2	90
ARK-VI/3	69	ARK-XI/1	80	ARK-XVIII/6	93	ARK-XXIII/8	97	ARK-XXVII/3	95
ARK-VI/4	65	ARK-XI/2	86	ARK-XVII/1	96	ARK-XXIII/9	96	ARK-XXIX/1	97
ARK-VIII/1	64	ARK-XIII/1	87	ARK-XVII/2	98	ARK-XXIII/10	96	ARK-XXIX/2	93
ARK-VIII/2	67	ARK-XIII/2	89	ARK-XIX/1	97	ARK-XXII/1a	93	ARK-XXIX/3	94
ARK-VIII/3	62	ARK-XIII/3	89	ARK-XIX/2	97	ARK-XXII/1b	86	ARK-XXIX/4	94
ARK-VIII/6	66	ARK-XIII/4	89	ARK-XIX/3	88	ARK-XXII/1c	90	ARK-XXIX/5	95

7 Data delivery and processing reports

The delivered mastertracks are available in one-second-resolution, as a generalized track and in ten-minute-resolution (extracted by PANGAEA). An overview with the links to all processed tracks is available via the "Cruise reports – Polarstern" page of the digital data library PANGAEA (https://www.pangaea.de/expeditions/cr.php/Polarstern).

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

8 Appendix

8.1 Extracted Data

Year	#	Available Cruises	Missing Cruises
1983	10		ANT-I/1, ANT-I/2, ANT-I/3, BISC, ARK-I/1, ARK-I/2, ARK-I/3, ANT-II/1, ANT-II/2, ANT-II/3
1984	9	ARK-II/2, ARK-II/3, ARK-II/4, ARK-II/5, ANT-III/1, ANT-III/2	ANT-II/4, ANT-II/5, ARK-II/1
1985	9	ANT-III/3, ANT-III/4, ARK-III/1, ARK-III/2, ARK-III/3, ANT-IV/1b, ANT-IV/1c, ANT-IV/2	ANT-IV/1a
1986	5	ANT-IV/3, ANT-IV/4, ANT-V/1, ANT-V/3	ANT-V/2
1987	7	ANT-V/4, ANT-V/5, ARK-IV/1, ARK-IV/2, ARK-IV/3, ANT-VI/1, ANT-VI/2	
1988	8	ANT-VI/3, ANT-VI/5, ARK-V/1, ARK-V/2, ARK-V/3a, ARK-V/3b, ANT-VII/1, ANT-VII/2	
1989	11	ANT-VII/3, ANT-VII/4, ANT-VII/5, ARK-VI/1, ARK-VI/2, ARK-VI/3, ARK-VI/4, ANT-VIII/1, ANT-VIII/2, ANT-VIII/3	ANT-VIII/4
1990	9	ANT-VIII/6, ANT-VIII/7, ARK-VII/1, ARK-VII/2, ARK-VII/3a, ARK-VII/3b, ANT-IX/1, ANT-IX/2	ANT-VIII/5
1991	6	ANT-IX/4, ARK-VIII/1, ARK-VIII/2, ARK-VIII/3, ANT-X/1a	ANT-IX/3
1992	6	ANT-X/1b, ANT-X/2, ANT-X/3, ANT-X/4, ANT-X/5, ANT-X/6	
1993	8	ANT-X/7, ANT-X/8, ARK-IX/1a, ARK-IX/1b, ARK-IX/2, ARK-IX/3, ARK-IX/4, ANT-XI/1	
1994	7	ANT-XI/2, ANT-XI/3, ANT-XI/4, ANT-XI/5, ARK-X/1, ARK-X/2, ANT-XII/1	
1995	7	ANT-XII/2, ANT-XII/3, ANT-XII/4, ANT-XII/5, ARK-XI/1, ARK-XI/2, ANT-XIII/1	
1996	6	ANT-XIII/2, ANT-XIII/3, ANT-XIII/4, ANT-XIII/5, ARK-XII, ANT-XIV/1	
1997	8	ANT-XIV/2, ANT-XIV/3, ANT-XIV/4, ARK-XIII/1a, ARK-XIII/1b, ARK-XIII/2, ARK-XIII/3, ANT-XV/1	
1998	7	ANT-XV/2, ANT-XV/3, ANT-XV/4, ANT-XV/5, ARK-XIV/1a, ARK-XIV/1b, ARK-XIV/2	
1999	7	ANT-XVI/1, ANT-XVI/2, ANT-XVI/3, ANT-XVI/4, ARK-XV/1, ARK-XV/2, ARK-XV/3	
2000	8	ANT-XVII/1, ANT-XVII/2, ANT-XVII/3, ANT-XVII/4, ARK-XVI/1, ARK-XVI/2, ANT-XVIII/1, ANT-XVIII/2	
2001	8	ANT-XVIII/3, ANT-XVIII/4, ANT-XVIII/5a, ANT-XVIII/5b, ANT-XVIII/6, ARK-XVII/1, ARK-XVII/2, ANT-XIX/1	
2002	8	ANT-XIX/2, ANT-XIX/3, ANT-XIX/4, ANT-XIX/5, ANT-XIX/6, ARK-XVIII/1, ARK-XVIII/2, ANT-XX/1	
2003	10	ANT-XX/2, ANT-XX/3, ARK-XIX/1, ARK-XIX/2, ARK-XIX/3a, ARK-XIX/3b, ARK-XIX/3c, ARK-XIX/4a, ARK-XIX/4b, ANT-XXI/1	
2004	8	ANT-XXI/2, ANT-XXI/3, ANT-XXI/4, ANT-XXI/5, ARK-XX/2, ARK-XX/3, ANT-XXII/1	ARK-XX/1
2005	7	ANT-XXII/2, ANT-XXII/3, ANT-XXII/4, ANT-XXII/5, ARK-XXI/1a, ARK-XXI/1b, ANT-XXIII/1	
2006	6	ANT-XXIII/2, ANT-XXIII/3, ANT-XXIII/4, ANT-XXIII/5, ANT-XXIII/6, ANT-XXIII/7	
Continuation on next page			

Year	#	Available Cruises	Missing Cruises
2007	8	ANT-XXIII/8, ANT-XXIII/9, ANT-XXIII/10, ARK-XXII/1a, ARK-XXII/1b, ARK-XXII/1c, ARK-XXII/2, ANT-XXIV/1	
2008	7	ANT-XXIV/2, ANT-XXIV/3, ANT-XXIV/4, ARK-XXIII/1, ARK-XXIII/2, ARK-XXIII/3, ANT-XXV/1	
2009	8	ANT-XXV/2, ANT-XXV/3, ANT-XXV/4, ANT-XXV/5, ARK-XXIV/1, ARK-XXIV/2, ARK-XXIV/3, ANT-XXVI/1	
2010	7	ANT-XXVI/2, ANT-XXVI/3, ANT-XXVI/4, ARK-XXV/1, ARK-XXV/2, ARK-XXV/3, ANT-XXVII/1	
2011	7	ANT-XXVII/2, ANT-XXVII/3, ANT-XXVII/4, ARK-XXVI/1, ARK-XXVI/2, ARK-XXVI/3, ANT-XXVIII/1	
2012	8	ANT-XXVIII/2, ANT-XXVIII/3, ANT-XXVIII/4, ANT-XXVIII/5, ARK-XXVII/1, ARK-XXVII/2, ARK-XXVII/3, ANT-XXIX/1	
2013	7	ANT-XXIX/2, ANT-XXIX/3, ANT-XXIX/4, ANT-XXIX/5, ANT-XXIX/6, ANT-XXIX/7, ANT-XXIX/8	
2014	7	PS82, PS83, PS85, PS86, PS87, PS88.1, PS88.2	
2015	8	PS89, PS90, PS92, PS93.1, PS93.2, PS94, PS95.1, PS95.2	
2016	8	PS96, PS97, PS98, PS99.1, PS99.2, PS100, PS101	PS102
Total: 260 Cruises (240 available, 20 missing in DSHIP)			