KNMI-Publication; 226

HISKLIM 14

Data acquisition and keypunching codes for marine meteorological observations at the Royal Netherlands Meteorological Institute, 1854 – 1968

Hendrik Wallbrink and Frits Koek

De Bilt, 2010

KNMI-Publication 226

HISKLIM-14

De Bilt, 2010

PO Box 201
3730 AE De Bilt
Wilhelminalaan 10
De Bilt
The Netherlands
http://www.knmi.nl
Telephone +31(0)30-220 69 11
Telefax +31(0)30-221 04 07

Authors: H. Wallbrink, F.B. Koek

The KNMI-program HISKLIM aims at making historical land and sea climate data from Dutch sources physically accessible, with the highest possible time resolution and quality. The program started in 2000 and will run 5 to 10 years.

HISKLIM-1	Het KNMI-programma HISKLIM (HIStorisch KLIMaat) / T. Brandsma, F.B. Koek, H. Wallbrink en G.P. Können. (also KNMI-publication 191)
HISKLIM-2	Gang van zaken 1940-48 rond de 20.000 zoekgeraakte scheepsjournalen / H. Wallbrink en F.B. Koek. (also KNMI-publication 192)
HISKLIM-3	Historische maritieme windschalen tot 1947 / H. Wallbrink en F.B. Koek. (Memorandum)
HISKLIM-4	Onbekende weersymbolen in oude Extract-Journalen (1826-1865). / H. Wallbrink en F.B. Koek. (Memorandum)
HISKLIM-5	CLIWOC, Multilingual Meteorological Dictionary; an English-Spanish-Dutch-French dictionary of wind force terms used by mariners from 1750-1850 (also KNMI-publication 205)
HISKLIM-6	DIGISTAD (DIGitaliseren STADswaterkantoor). H.W. Riepma. (Memorandum)
HISKLIM-7	Parallel air temperature measurements at the KNMI-terrain in De Bilt (the Netherlands) May 2003–April 2005, Interim report. / T. Brandsma. (also KNMI-publication 207)
HISKLIM-8	Hisklim COADS, Final report. / H. Wallbrink and F.B. Koek. (also KNMI-publication 210)
HISKLIM-9	DIGISTAD, Disclosure of the hourly meteorological observations of the Amsterdam City Water Office 1784-1963, Final report. / H. Wallbrink and T. Brandsma. (also KNMI-publication 220)
HISKLIM-10	Report on meteorological observations at Willemstad, Curaçao, during the period 1910-1946. / P.V.J. Girigori. (Memorandum)
HISKLIM-11	The US Maury collection metadata 1796-1861. / H. Wallbrink, F.B. Koek and T. Brandsma (also KNMI-publication 225)
HISKLIM-12	Historical maritime wind scales until 1947. / H. Wallbrink and F.B. Koek. (translation and update of Hisklim 3; Memorandum)
HISKLIM-13	Historical wind speed equivalents of the Beaufort scale, 1850-1950. / H. Wallbrink and F.B. Koek. (Memorandum)

● ● ● ●

Contents

Preface

In his last year at KNMI, before his retirement, Hendrik Wallbrink worked hard on this publication, but was not able to finish it. After Wallbrink's departure, Frits Koek took over and completed it.

Hendrik Wallbrink

A chronological review of Dutch historical marine meteorological codes and logbook instructions is presented for worldwide ships' observations covering the period 1854-1982. In order to rescue the metadata of these observations, punch card formats that were used to process the observations mechanically, and codes for reproduction of the data are described. In addition some background information about the process of digitizing the observations is given.

Introduction

Halfway the 19th century, the American lieutenant Matthew Fontaine Maury (see Figure d) was the first who organised an attempt to collect weather observations from the world's oceans. Using meteorological and oceanographic information reported in the ships' logbooks, he was able to compile climatological *Wind and Current Charts* of the various oceans (Maury, 1851). With the help of these monthly climatological charts, the so-called *Pilot Charts*, the average duration of the ocean passages of sailing ships reduced dramatically. The Netherlands showed a growing interest in these charts. The Dutch Navy officer Marin Henry Jansen (see Figure a) travelled to America in 1852 to meet Maury in Washington. Maury and Jansen became good friends and discussed the possibilities to exchange American Pilot Charts for Dutch marine observations. Once back in the Netherlands, Jansen took several steps to encourage Dutch ship owners and captains to use this American system (Van Driest, 1946).

Collecting and processing marine observations started in the Netherlands after the establishment of the KNMI (Royal Netherlands Meteorological Institute) on 31 January 1854. In order to compile climatological atlases for the world's oceans, originally the ships' observations were processed manually, i.e. the observations were written in separate monthly registers arranged by latitude and longitude. Because of the steadily increasing number of logbooks, from 1923 onwards the data was punched and processed mechanically with the help of keypunch, sorting and tabulating machines. Before World War II, the observations were punched on 45-columns punch cards. After WW2, on 80-columns punch cards. From 1968 until 1981 all the available keypunched data were archived on magnetic tape. Keypunching ended at KNMI in 1982.

Apparently, historical metadata of the meteorological and oceanographic observations were not recorded. They can only be retrieved with the help of original ship logbooks and by researching the available historical documentation. Unfortunately, at the end of WW2, the German occupier took possession of nearly all meteorological ship logbooks and punch cards that were kept at KNMI. Approximately 20,000 logbooks and 8 million punch cards were transported to Germany. After WW2 only the punch cards were retrieved, fortunately in good condition. Regrettably, the meteorological ship logbooks are still missing (Wallbrink and Koek, 2001). By chance, a small collection of 128 logbooks (1851-1860) were hidden safely during the war and were not confiscated by the Germans. With the help of these rescued logbooks, it was possible to retrieve in what way the original logbooks were *marked-off*[1] for keypunching, and which corrections had been applied on the instrumental observations. The greater part of all the logbooks, including the rescued logbooks, was keypunched between 1936 and 1941, using comparable mark-off procedures and keypunching codes.

[1] Marking-off (or in Dutch: "afperken") was a procedure used to instruct the key punchers. The mark-off personnel used red or blue pencils, e.g. to indicate which columns and/or records were to be skipped. Also other helpful information for the punch personnel was added to the logbook pages (see Figure g).

The Universeel Extract-Journaal

Approximately one year before the first Maritime Meteorological Conference at Brussels in August-September 1853, Jansen prepared a concept meteorological ship logbook. The Dutch Minister of War ordered that the Dutch Navy ships were to make meteorological observations on a regular base. The first concept of the meteorological logbook was given to the Dutch Navy frigates *Prins van Oranje* and *Palembang*, to be tested while at sea. Thanks to an early return of both frigates to the Netherlands, the meteorological logbooks could be presented at the Brussels Conference in 1853. Both logbooks contributed significantly to the final design of the international meteorological logbook called the *Abstract Logbook*, or in Dutch: *Universeel Extract-Journaal* (KNMI, 1885).

From February 1854, almost immediately after the establishment of the KNMI, the *Universeel Extract-Journaal* was widely spread among the Dutch ocean-going fleet. The *Commissie ter bevordering van het onderzoek naar de verschijnsele op den oceaan* ("Commission to promote research into the phenomena at sea") at Rotterdam, was willing to act on behalf of KNMI. At the first public meeting of this commission, on 28 February 1854, a number of ship owners agreed to supply instruments and to carry out observations on board of their ships:

Amsterdam:	Louis Bienfait & Zn., Boissevain & Cie., Boissevain en Kooy, A.L. Harpen & Zn., Frakranen & Zn., Luder & Van Geuns, L. Blaauw;
Rotterdam:	C. Vlierboom & Zn., A. Van Hoboken & Zn., W. Ruys, E. Suermont & Zn., Joost Van Vollenhoven, H. Van Rijckevoorsel, D. Dunlop, C. Balguerie & Zn., Mees & Moens, M.P. Keteler, Hudig & Blokhuizen, Reuchlin, Moll & Dutilh, Van Hoey Smyth;
Dordrecht:	Mr. A. Blussé, 't Hooft, Deking Dura;
Alblasserdam:	Murk Lels;
Zwolle:	Doyer, Kalff;
Middelburg:	Fokker.

On 10 January 1855, the Amsterdam ship *Willem le Clerq* was the first ship to return a fully completed logbook to KNMI (KNMI, 1885: 14).

Instruction To Observers

Initially, instructions to the observers were presented in separate small booklets in a series called "*Het Universeel Extract-Journaal met Verklaring ten gebruike van de Nederlandse zeelieden*" (see Figure b). These booklets were issued by KNMI and published between 1853 and 1889 in six editions (KNMI, 1853, 1856, 1859, 1866, 1874 and 1889). Later, between 1897 and 1937, the instructions to the observers were printed on the first pages of the various models of the meteorological logbook. After 1937, the instructions appeared again in separate booklets series called "*Handleiding voor het verrichten van meteorologische waarnemingen op zee*" (KNMI, 1937, 1949 and 1958), and "*Voorschriften voor het bijhouden van het meteorologisch journaal, druk 1947; Toelichtingen voor het verzenden van het Internationaal Scheepsweerrapport; Correctie-, herleidings- en psychrometertabellen*" (KNMI, 1947).

The ships' nautical officers were responsible for keeping the meteorological logbook. At the nautical schools, they learned how to observe the weather, during their regular two years training.

Logbook Modifications

Since its original design, the Dutch meteorological logbook changed only in some minor details. Initially, KNMI complied with the (impractical) instructions agreed at the Brussels Conference of 1853 (Buys Ballot, 1853), because only under this condition KNMI was likely to get the Maury publications for free. As soon as KNMI received enough logbooks to perform their own statistics, the original *Universeel Extract-Journaal* was slightly modified by Professor Buys Ballot (see Figure c). It was replaced by the *Meteorologisch Journaal* and to be used by the Dutch Royal Navy. A more straightforward version, called the *Extract-Journaal*, was to be used by the merchant marine. This version had a reduced number of columns (KNMI, 1853). The observers were not asked anymore to determine for instance the salinity or the humidity (Buys Ballot, 1882: 77). The Dutch modifications were accepted officially during the "International Maritime Conference" at London in 1873.

In order to obtain Maury's Pilot Charts free of charge, Dutch men-of-war had to complete all the 24 columns in the *Meteorologisch Journaal*, while the Dutch merchant ships only had to complete 14 columns in the *Extract-Journaal*. However, in the Dutch merchant marine it was all the same common practice to fill in all 24 columns (see Table 1).

Column	Dutch Royal Navy *Meteorologisch Journaal*	Dutch Merchant Trade *Extract-Journaal*
1	Date (according to Civil Time[1])	Date (according to Civil Time)
2	Hour	Hour
3	Observed latitude	Latitude
4	Latitude by Dead Reckoning[2]	
5	Observed longitude	Longitude
6	Longitude by Dead Reckoning	
7	Current direction	Current direction
8	Current speed	Current speed
9	Observed compass error	Observed compass error
10	Wind direction	Wind direction
11	Wind force	Wind force
12	Barometer reading	Barometer reading
13	Barometer's attached thermometer	
14	Thermometer dry bulb	Thermometer dry bulb
15	Thermometer wet bulb	
16	Shape and directions of the clouds	
17	Brightness of the sky	
18	Hours fog (A), hours rain (B), hours snow (C), hours hail (D)	
19	Sea state	
20	Sea surface temperature	Sea surface temperature
21	Sea water density	
22	Water temperature at depth	Water temperature at depth
23	Weather	
24	Remarks	Remarks

Table 1. *Dutch meteorological logbooks 1854-1874*

Logbook Instructions Period 1854-1897

In the explanatory notes in the *Instructions to the Observers* is written that on the first pages of the logbook the following information is to be recorded:

- The ship's type, the name and the flag of the ship;
- The captain's name;
- Is the ship built of wood or iron and how much iron is on board?
- The names of the places that were visited successively;
- The first meridian used for the determination of the geographical longitude;
- The corrections in use for the different instruments;
- The deviation table of the magnetic compass.

Also which instruments the ship carried and where the instruments were placed was to be recorded. In case of damage, the type of the replaced instrument and the place where it was exchanged should be added.

[1] Civil time is the time where the day is reckoned between midnight and the following midnight.
[2] Dead Reckoning is the process of estimating one's current position based upon a previously determined position, or fix, and advancing that position based upon known or estimated speeds over elapsed time, and course.

Parameter	Instructions
Current set and drift	True direction in which the current is moving, reported in whole compass points. Current set in tenths of nautical miles over the last 24 hours.
Wind force and direction	Most prevailing wind during the last part (8 hours) of the day. True direction where the wind comes from, reported in whole compass points. Wind force conform the Beaufort scale as given inside the logbook. After 1898, observation of wind force and direction at the time of observation, took place on even hours.
Air pressure (see also Appendix E)	Uncorrected in tenths of millimetres. Corrected temperature of the attached thermometer should be recorded in the logbook.
Dry and wet bulb temperature	Corrected temperature. Celsius, Fahrenheit or Réaumur scale. For temperatures observed during a shower or rain, the character 'B' was written before the observed values.
Sea surface temperature and water temperature from several depths	Corrected bucket temperature. During calms, a corrected water temperature from depths of 25, 50 and 100 fathoms was requested once per day.
Density of seawater	Corrected areometer (see Figure e) reading.
Shape and direction of the clouds	Different cloud shapes similar to the table given inside the logbook. True direction. Upper and lower cloud levels. Prior to 1898: direction where the clouds are heading. After 1-1-1898: direction where the clouds come from.
Brightness of the sky (transparency of the atmosphere)	Numerical scale 0-10. Prior to 1879: 10 = cloudless, 0 = overcast. After 1-1-1879: 10 = overcast, 0 = cloudless.
Hours of fog, rain, snow or hail	Hours of fog (A), rain (B), snow (C) or hail (D) in one part (8 hours) of the day. Underlining indicates the intensity of the phenomenon.
State of the sea	Only reported when the sea state deviated from the normal ocean sea state. True direction where the waves or swell come from.
Weather	Optional written text, e.g. serene, bleak, sultry, chilly, muggy, etc.
Remarks	All remarks and observations which do not fit the logbook columns, e.g. hurricanes, waterspouts, thunderstorms, red fog, sea ice, birds, fishes, insects, etc.

Table 2. *Logbook instructions for marine meteorological observations 1854-1938 (KNMI, 1866)*

From 1879 onward, the "total cloud cover" was reported instead of the "brightness of the sky". Subtracting the brightness number from 10, transforms the numbers from "brightness" to "cloud cover", for observations prior to 1879.

Observations of sea state started in 1883. Prior to 1883 the state of the sea was defined by subjective jargon only and no scale numbers were given. Swell observations started in 1922 (see Appendix D).

Sea temperature observations at depth were usually not taken because there were no appropriate instruments. Moreover, the (sailing) ships had to be stopped for making reliable depth observations, causing unacceptable time delays.

Logbook Instructions Period 1898-1940

A new model logbook, KNMI model 704, was issued in 1898. Instructions to observers were now printed on the first pages inside the logbook instead of in a separate booklet. All information referring to compasses was not recorded in these logbooks.

Seawater density observations were carried out until 1898 with the help of an areometer (or aerometer, hydrometer, salinometer; see Figure e). After 1898 the observations were no longer required, due to inaccuracy of the instruments on board.

Wet bulb temperature observations interrupted in 1908, also due to lack of available accurate instruments. The observations continued after WW2 with help of the sling psychrometer.

From 1922 the International scale for visibility was used.

Scale numbers for fog and visibility, in use from 1922-1947			
Code	Original Dutch text	English translation	Visibility limits
0	Zeer dikke mist	Dense fog	≤ 50 metres
1	Dikke mist	Thick fog	50 - 200m
2	Mist	Fog	200 - 500m
3	Mistig	Moderate fog	500m - 0.5 nautical mile (Nm)
4	Nevelig	Mist or Haze, or very poor visibility	0.5 - 1 Nm
5	Slecht zicht	Poor visibility	1 - 2 Nm
6	Matig zicht	Moderate visibility	2 - 5 Nm
7	Vrij goed zicht	Good visibility	5 - 10 Nm
8	Helder zicht	Very good visibility	10 - 30 Nm
9	Buitengewoon helder zicht	Excellent visibility	≥ 30 Nm

Table 3. *International scale of visibility, as printed in 1937 (KNMI, 1937: 60)*

Observations of swell started in 1922 according to a combined sea and swell scale that was introduced by the International Meteorological Committee London, 1921 (IMC, 1922); (see Appendix D). Because the scale did not satisfy, it was modified in 1929 according to the "Douglas Sea and Swell Scale", adopted by the International Meteorological Conference at Copenhagen in 1929 (CMI, 1930). From 1927, the direction of the sea waves was not requested anymore. Assumed was that sea and wind directions were the same. The swell direction is defined as the direction from where the swell waves come.

Ship Weather Reports

After the invention of the telegraph and telex, KNMI was also able to receive ships' weather reports. Around 1913, KNMI received 100-150 of these reports by cablegram on a daily base. Despite the proposal of the Copenhagen Conference in 1929, to transmit synoptical radio messages 4 times a day at 00, 06, 12 and 18 GMT (Greenwich Mean Time, or UTC), the observational times in the Dutch logbook remained unchanged until WW2. The observation times, i.e. six times per day at the end of each watch at local time,

remained unaffected until the end of 1938. The received ships' weather reports were not keypunched and were kept separate from the meteorological logbook observations.

Observations from ships equipped with accurately calibrated instruments (selected ships, weatherships, lightships), were distinguished from observations carried out by ships of which the instruments were not inspected by a meteorological service. However, basically all Dutch ships that kept a meteorological logbook was treated as a selected ship (KNMI, 1949a).

Observations During The Period 1940-1949

No meteorological logbooks were kept on Dutch ships during WW2. By order of the authorities it was prohibited to keep a logbook from which the ship's location and course might be determined afterwards (KNMI, 1945). Ship's weather reports were stopped between 6 October 1939 and 1 November 1945. The first post-war logbook was received at KNMI in November 1945. During the period 1945-1949 a total of 312 logbooks were received. The post-war numbering of the logbooks stayed in connection with the pre-war logbook numbering.

Processing The Observations Mechanically

Originally, the ships' observations were processed manually in order to compile climatological atlases of the world's oceans. The observations were written in separate month lists, ordered by latitude and longitude. All the observations for one "Marsden square" (10° latitude x 10° longitude square – see Figure f) and a unit of time (1 month) were collected and written down in these so called "Registers".

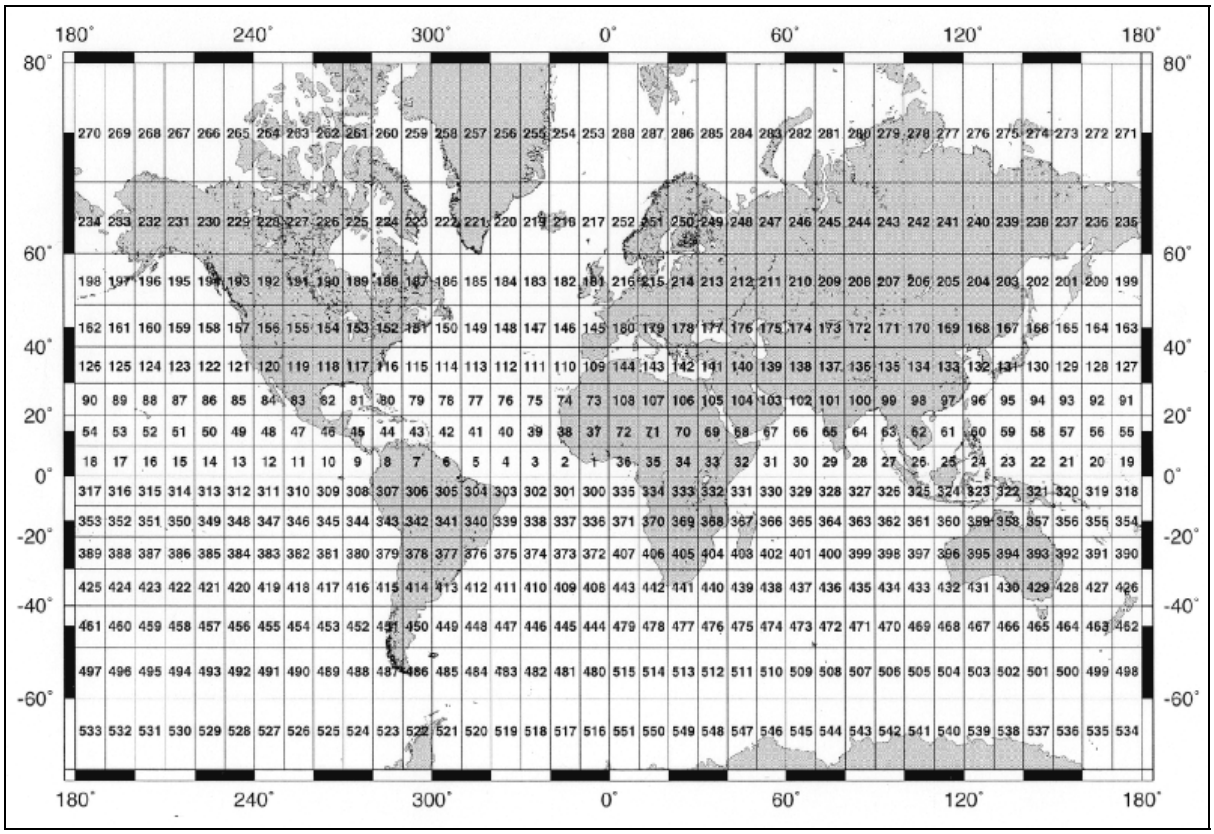

Figure f. *Assignment of Marsden square numbers. Image derived from: <http://www.ofcm.gov/fmh3/text/appen-e3.htm> [13 Jan 2010]*

Next, the data per register was analyzed statistically. Due to the steadily increasing number of observations, in the long run this method was not practical anymore. Following the British Meteorological Office in London, where keypunching and processing of ships' observations mechanically started in 1920, KNMI decided to choose for the same mechanical approach. From 1923 onwards, the observations were processed automatically with the help of sorting and tabulating machines. Before WW2 the observations were punched on 45-columns punch cards, after the war on 80-columns punch cards (see Appendix A). From 1968 until 1981 the keypunched data was converted to magnetic tape and analyzed with the help of computer programs. Keypunching at KNMI ended in 1982.

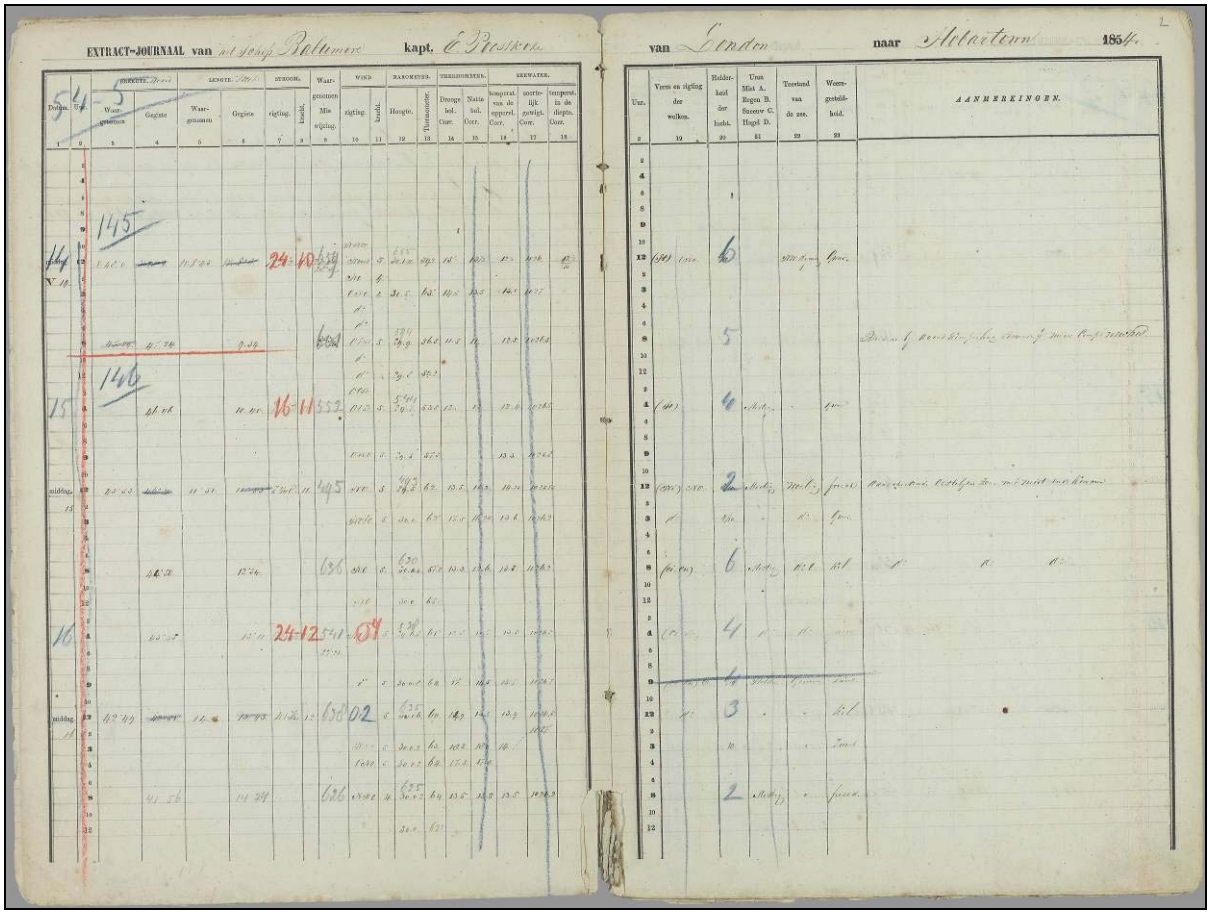

Figure g. *Example of the "marking-off" with red and blue pencils*

Keypunching 1923-1945

1923: During April, a first experiment took place at KNMI with keypunching and mechanical processing approximately 5,000 observations from Marsden square number 149 (40°N – 50°N and 40°W – 50°W), covering the months of June, July and August. The keypunch, sorting and tabulating machines used, were Hollerith-system machines. In August, KNMI purchased three Hollerith keypunch machines and the necessary punch cards. Keypunching started with steamship observations from the Atlantic Ocean covering the months June, July and August. At the end of the year, approximately 80,000 punch cards were punched.

1924: Punching of the (other) steamship observations ended at the end of April 1924. The total number of punch cards added up to 150,000. Through a company from Amsterdam (Fles & Co.), a contract was made with the Hollerith's Tabulating Machine Company to rent one sorting and one tabulating machine for the period of one year. These machines started working on 1 October.

1925: Keypunching of the Indian Ocean observations covering the months December-January-February, ended in March. The rent of the processing machines expired 1 October. Further processing continued with an electrical Powers keypunch-, sorting- and tabulating machine.

1926: Mid March, keypunching Atlantic Ocean observations covering the months of September-October-November started. During this year 183,000 punch cards were punched.

1927: Keypunching observations from the Atlantic Ocean for the other months continued. This was done as far as 1925. At the end of 1927, keypunching all steamship logbooks back to 1895 was almost finished. During this year a total of 274,000 punch cards were punched.

1928: During this year, 134,000 punch cards were punched.

1929: From Dutch meteorological logbooks 183,000 cards were punched, of which 38,000 from the Indian Ocean and 145,000 from the Chinese Sea and Pacific Ocean. In addition 14,000 punch cards with observations from foreign ships, to be used for the Atlantic Ocean atlas, were punched.

1930: 190,000 Records with observations from the Chinese Sea and the Pacific Ocean from Dutch meteorological logbooks were punched.

1931: From Dutch meteorological logbooks, 63,000 cards from the Chinese Sea and the Pacific Ocean were punched.

1932: Mechanical processing of the Chinese Sea and Pacific Ocean observations continued. About 2,600 sea surface temperature observations were punched. These were reported by ships from the Dutch company "Koninklijke Pakketvaart Maatschappij" during the period 1925-1931. They were received at the "Koninklijk Magnetisch en Meteorologisch Observatorium" at Batavia, Dutch East Indies (now Jakarta, Indonesia).

1933: Mechanical processing of the Chinese Sea and Pacific Ocean observations continued. Additionally, 7,490 German observations of air pressure, temperatures, cloudiness, winds and currents were punched. Also 1,012 synoptical observations, reported off Celebes (now Sulawesi) during the period 1930-1932, were punched and processed. 1,452 Observations from ship logbooks from April-September 1933 were punched. From French logbooks, 3,317 reports of air pressure, temperatures, winds and currents were punched. However, compared to the Dutch observations, the French air pressure observations showed differences to such an extent, that they were not included in the atlas.

1934: Processing of the data for the Chinese Sea and Pacific Ocean continued. At the end of September, punching observations from Dutch logbooks resumed. A number of 44,000 punch cards of observations from 1931 were produced.

1935: This year 168,000 punch cards from Dutch logbooks were punched, including the remaining observations of 1931 and a part of the observations of 1932. Because of an increase of staff, KNMI was able to start check-punching[1] the punch cards from 25 May onwards. The "Nederlandse Spoorwegen" (Dutch Rail) at Utrecht supplied 2 check punching machines for use at KNMI.

1936: From Dutch and some Swedish logbooks, 767,000 cards were punched, including the remaining observations of 1932, 1933 and 1934. Furthermore all available observations from area 0°S – 60°S and 90°E – 170°W (roughly the Australian waters), covering the period 1854-1935, were processed. Under the Dutch Minister for Social Services and Employment, Marcus Slingenberg, an agreement was made with the councils of Utrecht, Amsterdam and Hilversum, to appoint 4 unemployed ship officers and 8 office clerks at KNMI for one year. The appointment started 4 May 1936. The selected unemployed people were not allowed to work longer than one year at KNMI. The auditor's office of the "Nederlandse Spoorwegen" at Utrecht supplied 1 electrical and 1 hand punch machine together with 4 check punch machines for use at KNMI.

[1] Check-punching (Dutch: "contrôleponsen") was a procedure where an observation was typed for the second time, while the original punched card was read in the check punch machine. If a difference showed up, it was signalled to the typist and the error could be fixed.

1937: This year 876,000 punch cards were produced, including the years 1937 (almost entirely), 1936, 1935, 1930, 1929, 1928, 1927 (partly), 1855 and 1854. The total number of punch cards also included the observations from the "Snellius expedition", some British ocean current observations, and Danish ships' observations. The arrangement to appoint unemployed personnel, ordered by the Dutch Minister for Social Services and Employment, remained valid.

1938: Backlog punching of logbooks. This year 790,000 cards were punched, including the remaining observations of 1937 and 1927 backwards until 1917, and 1916 (partly). This pile of punch cards also included 6,000 German observations for the atlas of the Australian waters. All the appointed unemployed personnel were changed. The number of appointments increased to 7 unemployed ship officers and 8 unemployed office clerks.

1939: Backlog punching of logbooks. This year 827,000 punch cards were produced, including the observations of 1938 (delayed received old model logbooks), and the remaining 1916 observations backwards to 1900. The number of punch cards also included 130,000 German punch cards for the atlas of the Australian waters. Swedish logbooks were marked-off and were also punched. Again the appointed unemployed personnel were changed. The Powers sorting machine, received from the "Post-, Cheque en Girodienst" in 1925, was replaced by a Kamadex machine due to wear and tear.

17 Boxes, containing 1,000 meteorological logbooks, together with mark-off instructions, were sent to the KNMI branch office in Rotterdam on 27 November 1939.

1940: Until the start of WW2 in the Netherlands, 128 ship meteorological logbooks were received. Backlog punching of logbooks continued. This year 108,800 cards were punched. All observations from Dutch ships, covering the years 1874-1899. Additionally 34,000 German observations, 6,000 swell observations and 25,000 rain gauge observations were punched.

Swedish logbooks were marked-off. The mark-off people distinguished between sailing ship logbooks and steam ship logbooks in the usual mark-off procedures. The latter took less time to mark-off.

The arrangement for unemployed personnel ordered by the Dutch Minister for Social Services and Employment remained valid. In addition to this, a new deal was made with the council of Rotterdam implying that from 9 September, 10 unemployed ship officers were appointed at the Rotterdam branch office and 3 unemployed ship officers and 8 unemployed office clerks at KNMI in De Bilt.

1941: No new logbooks were received. Backlog punching of logbooks only. A total number of 960,000 cards were punched.

On 30 April 1941, punching and check punching of the Swedish logbooks was completed.

Punching identification marks into punch cards that contained foreign observations finished 11 June 1941.

Marking-off of the Dutch logbooks from the period 1854-1938 finished at KNMI in De Bilt on 29 April 1941 and in Rotterdam on 30 April 1941.

Punching of all Dutch ships' data covering the period 1854-1938, completed on 1 November 1941. The employment for the keypunchers appointed by the Dutch Minister for Social Services and Employment ended the same date. For the keypunchers the employment started 4 May 1936 and ended 1 November 1941.

1942: Three boxes containing 48 sailing ship logbooks were sent to the prison of Utrecht for repairs and rebinding. They returned the same year.
More observations from German ships were punched for the Atlas of the Australian waters.
The employment for the mark-off people appointed by the Dutch Minister for Social Services and Employment, ended 31 December 1942.

1943: In January, a German meteorologist was stationed at KNMI and stress and conflicts increased. On 31 May 1943 the punching of the new model logbooks onto 80-columns punch cards started. Due to differing ideas with the Germans present at KNMI, Director of the "Afdeling Zeevaart" (Sailing Department), H. Keyser, was fired in July.

1944: From 28 February 1944, only records from German logbooks were punched. All other activities stopped. On 4 September 1944 all punching and check punching activities were brought to an end.
The General Director of KNMI, Dr. H.G. Cannegieter, decided to start the punching activities again on 9 October 1944. On 18 December 1944 the German occupant confiscated all the KNMI punching machines and carried them away to Germany (Wallbrink and Koek, 2001).

1945: Due to the missing punching machines, keypunching was impossible this year. KNMI closed on 26 March 1945 and resumed service on 14 May 1945.

Keypunching After World War II

Keypunching was not resumed at KNMI immediately after WW2. The general expectation was that a new, 80-column international punch code would be published soon. However, the so-called 'Washington Code', proposed by the International Conferences at Toronto and Washington in 1947, was not adopted until 1949.

In 1946, the International Meteorological Conference in Paris adopted a new code for ship's observations with the expectation that the code could be effective in 1947. At KNMI, a new logbook edition, model 753, based on this code, was developed and supplied to the Dutch ships. These meteorological logbooks were to be filled in 4 times per day, following UTC. Ocean current observations were to be reported 6 times per day, according to local ship time. However, this so called 'Paris Code' never was officially introduced. The International Meteorological Conference in Washington 1947 adopted another universal code for both land stations and ship observations. The 'Washington Code' came into force on 1 January 1949. The Dutch logbook edition based on the 'Paris Code' was withdrawn. Meanwhile, a new logbook edition (model 754), based on the International Meteorological Conference of Copenhagen 1948, was supplied to the Dutch ships in 1948. From now on, until 1962, the logbooks included a separate loose-leaf meteorological notepad in UTC and a bound ocean current logbook that followed local ship time.

KNMI supplied different editions of logbooks that were based on different codes. During the period 1938-1949 also different 80-columns punch codes were in use. Originally the pre-war logbooks (model 704, editions 1938 and 1939) were punched according to KNMI 80-columns punch code 01, which is a combination of meteorological and current observations on the same punch card. Later the 80-columns punch code 01 cards were reproduced onto two different 80-columns punch codes to separate the meteorological and the current observations, and to fit the observations into KNMI 80-columns punch code 08.

Punch Codes 07-17-19 Meteorological ship observations 4 times per day, 1938-1949

A part of the 80-columns punch cards (code 01), the ones containing observations from the Indian Ocean, was duplicated on 24,000 80-columns punch cards, code 07. The remaining 82,000 cards, with observations from other oceans, were reproduced on 80-columns punch cards, code 17.

- Punch code 07 – Meteorological observations Indian Ocean.
- Punch code 17 – Meteorological observations remaining ocean areas.
- Punch code 19 – Ocean current observations.

Punch Codes 03-14 Meteorological ship observations 6 times per day

If the observations from logbook model 704 (printed in 1938 and 1939) had not already been punched according to punch code 01, they were now punched according to:

- Punch code 14 – Meteorological ship observations.
- Punch code 03 – Currents observations.

Punch Codes 15-16 Meteorological ship observations 6 times per day, 1947-1949

Logbook edition 1947 Combination of Meteorological and Currents logbook.
Model 753 Punch code 15 – Meteorological ship observations.
Model 753 Punch code 03 – Current observations.

Logbook edition 1948
Model 754 Punch code 16 – Meteorological ship observations.
Model 755 Punch code 03 – Current observations.

Logbook edition 1949-1961 Meteorological logbooks.
Logbook edition 1961-1970 Meteorological logbooks.
Logbook edition 1971-1982 Meteorological logbooks.

The marine 45-columns punch cards covering the period 1854-1938, were reproduced onto 80-columns punch cards, using KNMI punch code 28 (see Appendix D).

During the punch card conversion to magnetic tape in 1968, only punch codes 07, 14, 15, 16 and 17 were reproduced. Punch code 01 was removed.

Punch code 08 modifications

Meteorological ship logbooks:
1 January 1949 - 30 June 1957: code 08
30 June 1957 - 31 December 1957: code 08a

1 January 1958 - January 1968: code 08b
After 1968: code 08c

Swedish Logbooks

In Stockholm, Sweden, a new department of marine meteorology (Nautisk Meteorologiska Byrån) was established in 1878. The Swedish institute did not receive enough logbooks to carry out proper statistical calculations per 10°x10° Marsden square. The director of the Swedish institute, Dr. Malmberg, called in the help of KNMI to process the Swedish observations in the Netherlands, together with the Dutch observations. A total of 592 Swedish logbooks were received between 1879 and 1921, and approximately 220,500 punch cards were punched at KNMI. Copies of the Swedish logbooks were also sent to Hamburg and London (KNMI, 1878). All Swedish logbooks stored at KNMI, were lost at the end of WW2.

Chronological Review Of Logbook Editions And Corresponding Keypunch Codes

Year	Punch card or tape	Ship logbook, Model	KNMI Punch Code	Remarks
1854	Handwritten registers (collection books)	*Universeel Extract-Journaal*		6 times daily at the end of each watch. Local time. The new day started at midnight (watch 6 = 00 hours of the new day).
1898	Handwritten registers (collection books)	Model 704		
1923	Handwritten registers. First test with a Hollerith keypunch machine	Model 704	Code 01	Marsden square 149. Month June, July and August.
1924	45-columns punch card	Model 704	Code 01	Additional British observations were punched.
1925	45-columns punch card. Powers keypunch, sorting and tabulating machines purchased from the "Post-, Cheque en Girodienst."	Model 704	Code 02	Additional observations from France and Germany were keypunched.
1931	45-columns punch card. All Hollerith Code 01 cards reproduced to Powers Code 02 punch cards	Model 704	Code 02	Code 02 used until 1 January 1931.
1931	45-columns punch card	Model 704	Code 07	Code 07 used from 1 January 1931 until 1937.
1935	45-columns punch card	Model 704	Code 02 and Code 07	Introduction of punch card verification by check punching.
1940 ↯ 1945	During WW2, all Dutch marine meteorological observations were cancelled. Keypunching continued. November 1941: all Dutch ships' observations covering the period 1854-1938 are punched and check-punched on 45-columns punch cards.			

Table 4. *Punching of Dutch marine meteorological observations 1854-1982, pre-WW2 ship's logbooks*

Year	Punch card or tape	Ship log	KNMI Code	Remarks
1946	80-columns punch card	Model 704, issue 1938 and 1939	Code 01	6 Times daily. Ship's local time.
	80-columns punch card. Reproduction Code 01 cards to 80-columns punch cards.		Code 07 Code 17	Day and Watch similar to Code 01.
	80-columns punch card. Meteorological observations Code 01. Ocean current observations conform code 03 rounded to whole hours ship's time.	Model 704, issue 1938 and 1939	Code 14 Code 03	6 Times daily. Ship's local time. The new day starts at watch 1 = 04 hours (Code 14).
1947	80-columns punch card. Adaptation from 'Paris Code' observations to International Code 08. Current observations, until 1962, in local time conform Code 03.	Model 753, issue 1947	Code 15 Code 03	4 Times daily at 00, 06, 12 and 18 UTC.
1948	80-columns punch card. Adaptation Copenhagen code observations to international Code 08. Current logbooks, model 755, until 1962 conform ship's local time.	Model 754, issue 1948; Model 755, issue 1948.	Code 16 Code 03	4 Times daily at 00, 08, 12 and 18 UTC. Model 754 = loose-leaf logbook.
1949	80-columns punch card. International 'Washington Code', Code 08. In use from 1 January 1949.	Model 756, issue 1949	Code 08 until 1968	4 Times daily at 00, 08, 12 and 18 UTC.
1951 ↯ 1953	ICOADS[1] deck 193. Ship's observations punched on 45-columns punch cards from the period 1854-1938 were reproduced to 80-columns punch cards on behalf of the US Weather Bureau from 1951 until 1953.		IBM card No. A11831	6 Times daily UTC. The new day starts at watch 6 or 00 hours of the day beginning.
1953	80-columns punch card.	Model 777, issue 1953	Code 08 until 1968	4 Times daily at 00, 08, 12, en 18 UTC. The new day starts at midnight.
1955	80-columns punch card.	Model 784, 792	Code 08 until 1968	First, respectively second edition
1957	80-columns punch card.	Model 800, issue 1957	Code 08 until 1968	Idem

[1] In September 2002 the name COADS (Comprehensive Ocean-Atmosphere Data Set) was replaced by ICOADS (International Comprehensive Ocean-Atmosphere Data Set)

Year	Punch card or tape	Ship log	KNMI Code	Remarks
1958	80-columns punch card.	Model 802, issue 1958	Code 08 until 1968	Idem
1959	80-columns punch card.	Model 802, issue 1959, 1960	Code 08 until 1968	Idem
1961	80-columns punch card.	Model 805, issue 1961	Code 08 until 1968	Idem
1962	80-columns punch card. Current logbook issued in 1962.	Model 807	Code 03	Local time
1961 ↯ 1963	80-columns punch card. All 45-columns punch cards 1854-1938 re-produced to 80-columns punch card.		Code 28	Local time. Watch conform 45-columns Code 02. Marsden square transferred to Q, La, Lo (octant, latitude and longitude). Air pressure converted to millibar (hectoPascal).
1965	80-columns punch card. Current logbook issued in 1964.	Model 808	Code 03	Rounded to whole hours UTC.
1968	80-columns punch card. "Selected Ships".	Model 815, issue 1968	Code 08	Starts 1 January 1968. UTC.
1968	Magnetic Tape. Reproducing 80-columns punch cards to KNMI standard 120-character tape format.		120-character	Codes 07, 14, 15, 16 en 17 are converted to magnetic tape. Code 01 was rejected.
1981	Magnetic Tape. Checking, correcting and cleaning the Code 28 data tapes 1854-1938.		120-character	Errors were introduced.
1982	Keypunching at KNMI ended			

Table 5. *Punching of Dutch marine meteorological observations 1854-1982, post-WW2 ships' logbooks: November 1945-1949 (~300 logbooks)*

Figure i. *Punch card typists at work at KNMI, punching the ships' logbooks*

Reproduction Of 45-Columns Punch Cards (Code 28)

Because the 45-columns cards could not be processed with the newly bought Bull and Kamadex sorting and tabulating machines, the cards had to be reproduced onto 80-columns punch cards. During the years 1963-1966, all available marine 45-columns punch cards covering the period 1854-1938 were duplicated on 80-columns punch cards according to KNMI punch code 28 (see Appendix D). The 80-columns punch cards were provided by different manufactures such as Bull (France), Hollerith (United Kingdom), and IBM (USA). Punching holes on these cards were usually rectangular in shape while the 45-columns punch cards had round punching holes. Together with the Dutch ship observations, also ship observations from other countries (Sweden, Germany, England, Australia, America, Denmark and France) were reproduced at KNMI. The cards were copied with the help of a Gamma (an electronic computer) and a reproducing punching machine named PRD (Perforatrice, Reproductrice, Duplicatrice) by Bull, purchased in 1960. The reading of the cards was done by metal brushes that made electrical contact through the holes in the card – the card being the insulator – with a copper pressure roll. Unfortunately, during the reproduction, many errors were introduced by these brushes. Punch holes and dust, always appearing at the same place, caused a burn on the pressure roll, generating an erroneous electrical pulse.

During the reproduction, the Marsden squares were converted to octant, latitude, longitude, and the air pressure was transformed from millimetres to millibars/hectoPascal. Also the gravity correction was applied. Many incorrect, duplicate or incomplete values were generated during this reproduction process (Broersma, 1981; De Hart, 1972).

Missing values in the 45-columns cards were also missing in code 28. Because of this, many errors were generated in e.g. the air-water temperature difference parameter:

air temperature:	18.0°
water temperature:	Missing
air-water temperature difference:	18.0°

Reproduction Of 80-Columns Punch Cards (120-Character)

During the period mid 1969 - ultimo 1969, approximately 22 million punch cards, including all marine series, were transferred to magnetic tape. The job was done by the RCC, "Rijks Computer Centrum" on behalf of KNMI. Because of understaffing of KNMI personnel, together with the installation of an EL-X8 computer, there was no time left to pay sufficient attention to this project. The data was simply dumped on tape (De Hart, 1972). Later, back in 1981, during cleaning and reproduction of the magnetic tape to the KNMI 120-character format, it appeared that approximately 10% of the observations contained errors (Broersma, 1981).

KNMI 45-Columns Punch Card Codes

During the period when 45-columns punch cards were handled, the following codes were used. These are codes that were used for marine purposes only. There were more departments at KNMI that used punch cards, but they are not discussed here.

Code	45-columns punch cards (round punch holes)
1	General punch code for Dutch ships' observations punched on Hollerith punch cards. All cards are reproduced to code 02 Powers-system (see Appendix B).
2	General punch code for Dutch ships' observations, until 1 January 1931 (see Appendix B).
3	Observations for KNMI Publication No. 107. Contribution from USA and Australia.
4	Observations for KNMI Publication No. 107. Contribution from Germany and Denmark.
5	Trial calculations with tidal observations.
6	Synoptical observations Chinese Sea, 1930-1932.
7	General punch code for Dutch ships' observations dating from 1 January 1931 and later, punched on Powers punch cards (see Appendix C).
8	Lightship observations.
9	Observations for KNMI Publication No. 119, "Typhoon statistics" (Keyser, 1938).
10	Rain gauge observations.
11	International swell observations, 1938.
12	Surface salinity, temperature and density observations.
13	American observations from Australian waters, 1932.
14	Circulation water inlet temperature.
15	British ocean current observations Indian Ocean for the reprint of the Indian Ocean Atlas.

Table 6. *KNMI 45-columns punch card codes, see Appendix A, B and C (KNMI, 1941)*

KNMI 80-Columns Punch Card Codes

Following are the 80-columns marine punch card codes that were used at KNMI. These punch cards followed the 45-columns punch cards and were later superseded by magnetic tape.

Code	80-columns punch cards, rectangular punching holes
01	Used for keypunching Dutch ships' observations from the logbook model 704, issued 1938-1939.
02	Used for keypunching international swell observations (14-19 November 1938).
03	Used for keypunching meteorological and oceanographical observations from Dutch ocean current logbooks. Punch cards are marked "STROOMJOURNAAL".
04	Used for keypunching British meteorological observations (reproduced) to 80-columns punch cards marked "ENGELSE METEOR. WAARN.".
05	Used for 45-columns German meteorological observations (reproduced) to 80-columns "German" punch cards. KNMI codes 05, 06, 07 and 17 were keypunched on cards marked "DUITSE METEOR. WAARN.".
06	Used for reproducing 45-columns German punch cards from the Indian Ocean, to 80-columns "German" punch cards. KNMI codes 05, 06, 07 and 17 were keypunched on cards marked "DUITSE METEOR. WAARN.".
07	Used for reproducing 80-columns Dutch punch cards (code 01) from the Indian Ocean, to 80-columns "German" punch cards. KNMI cards with punch codes 05, 06, 07 and 17 were punched on cards marked "DUITSE METEOR. WAARN.".
08	Used for Dutch ships' logbooks model 756, conform the International 'Washington Code' issued 1949. Sometimes marked "METEO JOURNAAL".
08x	Used for records from Dutch ships' logbooks kept on board "SHIGY" ships during the International Geophysical Year (01-07-1957 until 31-12-1958) and later. Meteorological logbook KNMI-03-00520
08r	Used for ship logbooks kept on board Dutch fishing ships during the International Geophysical Year (01-07-1957 until 31-12-1958) and later. Meteorological logbook KNMI-IV-Model 793.
09	Used for keypunching records with more than one wave group in the ship logbook model 756, punched conform code 08, issue 1949.
09 Changed	Used for keypunching records with a second swell system observed next to the dominant swell system. Punched together with wind waves (2nd supplement), conform code 08 or code 13.
10	Used for keypunching a second swell system observed together with a dominant swell system. Punched together with wind waves conform the 1st supplement of code 11.
11	Used for keypunching observations from Dutch lightships (North Sea), conform code 08, issue 1949.
12	Used for keypunching observations from the weathership *Aer Mas* conform code 08, issue 1949.
13	Used for keypunching observations from the Dutch ocean station weatherships, model 759, issue 1949, conform code 08. Marked "WEATHERSHIP".
14	Used for keypunching the not yet punched observations from logbook model 704, issue 1938-1939, to agree as much as possible with code 08.
15	Used for keypunching observations from logbook model 753, issue 1947, to agree as much as possible with code 08.
16	Used for keypunching of observations from logbook model 754, issue 1948, to agree as much as possible with code 08.

Code	80-columns punch cards, rectangular punching holes
17	Used for reproducing 80-columns Dutch punch cards punched conform code 01, to 80-columns "German" punch cards. The observations from the Indian Ocean are punched conform code 07. KNMI codes 05, 06, 07 and 17 were punched on cards marked "DUITSE METEOR. WAARN."
18	Used for keypunching German ocean current observations from the Mediterranean, received at KNMI on 1 October 1951.
19	Used for keypunching ocean current observations reproduced from code 01.
20	Used for observations from ships in the southern hemisphere. Dutch observations were excluded. Punch cards were received from the South African Weather Bureau: "Weerburo Pretoria".
21	Used for keypunching lightship observations of the years 1886-1940.
22	Used for keypunching precipitation observations from the Indian Ocean.
23	Used for keypunching observations from "Auxiliary ships".
28	Reproduced 45-columns cards to 80-columns cards, 1854-1938 (see Appendix D).
40	Used for keypunching oceanographic observations. Cards with no header label.
41	Used for keypunching wind and salinity observations from Dutch lightships.
42 – 46	Used for ICES (Hydro Cards), see "Reproduction For ICES".
47	Used for keypunching wave height observations from Dutch lightships.
49	Additional cards for ocean current observations.

Table 7. *KNMI 80-columns punch card codes (see Appendix A and D)*

Reproduction For The US Weather Bureau

ICOADS Deck 193 (International Comprehensive Ocean Atmosphere Data Set)

The US Weather Bureau, Washington, asked the Dutch Ministry of Transport and Public Works in 1950, to reproduce all marine meteorological punch cards covering the period 1854-1938 (KNMI, 1950a). The punch cards were requested as part of an increasing interest in marine climatology to supplement the German and British decks in the earlier years (ICOADS, 1954). The reproduction costs, for the account of the US Weather Bureau, were estimated at approximately *f* 66,000 (Dutch Guilders), not including transport costs to the USA.

1951: For the US Weather Bureau, 5,515,000 punch cards from several oceans were reproduced from 45-columns punch cards (KNMI punch codes 02 and 07) to 80-columns IBM No. A11831 punch cards (KNMI, 1951a).

1952: Again for the US Weather Bureau, 1,044,000 punch cards from several oceans were reproduced from 45-columns punch cards (KNMI punch codes 02 and 07) to 80-columns IBM No. A11831 punch cards. During the first five months of 1952 an employee of the Amsterdam company "Internationale Bedrijfsmachine Maatschappij" did the punch job at KNMI (KNMI, 1952).

1953: The remaining punch cards were reproduced. A total of 6,601,000 punch cards were sent to the USA.

1954: At the US Weather Bureau, reproduction on a slightly revised punch card (IBM No. 809691) was accomplished. The Dutch data was stored as ICOADS Deck 193. Due to errors, while reproducing the Dutch data on film (Tape Data Family-11, or TDF-11), only 6,415,147 records, including 538 block parity header records, remained.

Erroneous Dutch Observations 1800-1807 In Deck 193

According to ICOADS, Dutch Deck 193 includes 50 data records prior to 1854, all from the period 1800-1807. It turned out that in the original punched data, the year characters (4:5) from 45 data records were corrupted. Instead of "01" the character read "*1". The same error appeared in 1800, "*8" and in 1804, "*4". Probably something went wrong during the conversion from the original Dutch format to the ICOADS TDF-11 format or LMR format. In one case the original year characters read "81", what should have been 1881. In another case we found two (near) duplicates on the cdrom. One incorrect (&7) and one correct, 77 = 1877.

Two cases from 1801 did not match either and we were unable to trace the duplicate on the cdrom sent by ICOADS to KNMI, recently. It is, however, very unlikely observations prior to 1854 were punched at KNMI.

Currents, Lightship And Weathership Observations

In 1955, the US Navy Hydrographic Office, Washington, requested KNMI to reproduce a part of the Dutch ocean current, lightship and weathership (KNMI, 1955). Reproduced were:

- Currents observations from 1939-1954: 76,000 punch cards;
- Dutch lightship observations 1910-1939: 22,000 punch cards;
- Dutch lightship observations 1949-1954: 52,250 punch cards;
- Dutch weathership observations: 51,800 punch cards.

The reproduction of the punch cards for the US Navy Hydrographic Office was completed by the RMA ("Rijkscentrale voor Mechanische Administratie") in The Hague, in 1955.

ICOADS Deck 189

In 1956, the US Weather Bureau, Washington asked KNMI to reproduce all available Dutch marine meteorological observations from 1938 onwards. These observations were an extension of ICOADS Deck 193, that covered the period 1854 – 1938. The period of record for Deck 189 is January 1939 – December 1939 and September 1945 – June 1955. The missing period (January 1940 – August 1945) was during WW2, when the Germans occupied the Netherlands and during which no observations at sea were made. Reproduction was carried out by the RMA on IBM No. A11651 punch cards. The volume of this deck is 262,945 punch cards. No Pacific Ocean data was included.

The periods 1939 and September 1945 – December 1954 were punched according to the International 'Washington Code' of 1949. The period January 1955 – June 1955 was punched according to the new International code of 1955.

Air pressure units were recorded in millibars/hectoPascal, reduced to sea level, corrected for temperature, and corrected for gravity.

Historical Sea Surface Temperature Data Project 1860-1960

The Historical Sea Surface Temperature Data (HSSTD) Project was set up originally to collect all available sea surface temperature records held by the major maritime nations for the period 1860-1960. Later it was decided to include also other parameters like air pressure, air temperature, cloud amount, wind direction and wind force, and to publish monthly summaries. At KNMI this project was identified as CII 69-3, and was pulled by Mr. B.M. Kamp and Dr. C.G. Korevaar, between 1971 and 1977 (Korevaar, 1982).
The starting year 1860 was chosen because at that time most of the maritime nations were able to collect the meteorological data according to the Brussels Conference. The final year 1960 was chosen because from that year on, another International project started, i.e. the Marine Climatological Summaries Scheme (MCSS).

Dutch Pacific Data In HSST Format

Dutch Pacific data taken after 1939 and covering the periods December 1939 and September 1945 – June 1955, were sent to America (NOAA, Asheville NC) in 1974. The data was stored on one magnetic tape (KNMI, 1974). Although KNMI was asked to write the tape in USA sub format, it was written in the HSST 46-character format. The Dutch

46-character format differs only from the original USA sub format by the first five characters, giving Hour/Month/Day and country of origin in the header of the tape. Flags, indicating suspect values, were not included. The suspect values found while creating the tape, were doubtful to such an extent that it was decided to reject all these values.

HSSTD Exchange

The HSST data for the Dutch "Responsible Areas" (Indian Ocean and Mediterranean) were sent by KNMI to Mr. R.G. Quayle, NOAA, Asheville NC, 28801 USA, at 15-08-1977 on 17 basic observational tapes and one summary tape.

The HSST 46-character format was used to exchange the data. A concept format description of the summary tape was written by B.J. Painting in 1980. The official WMO Technical Document appeared in 1985 (WMO, 1985)

HSSTD Chronology

1971: Preparations were made for the exchange of observations with the participating countries: USA, UK and Germany.

1972: Processing the raw data tape files for the HSSTD project was contracted to the "Voorraad Administratie Centrum" of the Royal Dutch Air force (KLu).

1973: Sorting, temporary raw quality control and the elimination of duplicates from the data files was finished this year.

1974: The HSST data to be supplied by the Netherlands, are forwarded to Germany and the USA

1975: At KNMI, the HSST data from the USA and Germany were received.

1976: All foreign observations from the Indian Ocean and the Mediterranean are now available at KNMI and quality controlled (see flags in the exchange format). Consensus was achieved about the format of the summary tapes, the time schedule and the way of publishing.

1977: 17 Basic observational tapes and one summary tape for the Dutch areas of responsibility were sent to the USA (Mr. R.G. Quayle), Germany (Dr. Höfflich) and the UK (Mr. Painting) (KNMI, 1977). The basic tapes had no labels and were written in 9-track, 800 bpi, EBCDIC characters. The record length was 46 and the block size 4,140 bytes. For the summary tape the record length was 232 characters and the block size 2320 bytes.

The records with decade 92 and year 999 were summaries of individual monthly means (for months with more than 9 observations). The records with decade 91 and year 999 were summaries of all individual observations.

Quality Control Procedures For The HSST Data By The Netherlands

(Extracted from WMO, 1985: Annex III-5, Attachment C).

1. Exact duplicate observations have been eliminated.
2. Observations with impossible positions (e.g. over land) have been eliminated.
3. *Temperatures*

   For each 10 degrees square monthly lower and upper limits have been determined using the Netherlands climatological atlases for the Mediterranean (KNMI, 1957), Red Sea (KNMI, 1949b), Indian Ocean (KNMI, 1950b) and the China Sea (KNMI, 1936).

Temperatures outside these limits have been rejected. For determining, for example, the lower limit in a certain ten degrees square for a certain month first the lowest mean value of the temperature in the square (mostly occurring at the pole-ward boundary) was determined. Next from this value 4 times the standard deviation was subtracted. For the determination of the upper limits a same procedure was followed.

Moreover sea surface temperatures below -2°C were eliminated.

4. *Air pressure*
   Pressures below 920 hPa and above 1050 hPa have been eliminated.
5. *Wind*
   Wind directions other than 000-360 and 990 (variable) have been eliminated.
   If the wind direction was 000 and the wind speed more than 1.0 m/s or if the wind direction was 990 and the wind speed more than 5.0 m/s then both were eliminated. Estimated wind speeds of more than 32.3 m/s have been deleted.

HSSTD Air Pressure

The HSSTD sea level pressure observations were corrected for gravity. During the years 1961-1963 the 45-columns punch cards covering the period 1854-1938, were reproduced to 80-columns punch cards according to KNMI punch code 28 (see Appendix D). At the same time the barometer readings were converted from millimetres (45-columns cards) to millibars (80-columns cards). The HSST air pressure in millibars was corrected for temperature, reduced to sea level, and corrected for gravity. For the gravity correction at mean sea level at latitude φ, the following WMO formula was used:

$$G(\varphi, 0) = 980.665 \times (1 - 0.0026373 \times \cos(2\varphi) + 0.0000059 \times \cos^2(2\varphi)).$$

Before 1954 the gravity constant read 980.616 at latitude 45°00'00". After 1954 the constant read 980.665 at latitude 45°32'40". It is possible that the choice of the gravity constant generated a 0.1 hPa difference in air pressure.

HSSTD Wind

The estimated wind force in Beaufort was converted to m/s according to the CMM-IV scale. This consideration is explained in WMO report No. 3 "Reports on Marine Science Affairs" (WMO, 1970).

HSSTD Sea Surface Temperatures

For the HSSTD project only SST's measured with the bucket method were used.

Reproduction For ICES

KNMI punched Dutch oceanographic observations from weatherships, lightships and research vessels for the International Council for Exploration of the Sea (ICES). For each hydrographic station, a Hydro Master Card was punched, and additionally a Hydro Depth Card for each observational depth of the hydrographic station. The Hydro Master Card was also used as Hydro Surface Card.

For each Bathythermograph (BT) station, a BT Master Card and a BT Detail Card were punched. Chemical observations, i.e. phosphate or oxygen observations, were not carried out.

The "Manual on ICES Oceanographic Punch Cards" (Lund, 1973) gives the layouts for the different ICES codes.

ICES code 01 = KNMI punch code 42 (Hydro Master Card)
For each oceanographic observation made with the help of Nansen water bottles, the general hydrographic and meteorological data is given.

ICES code 02 = KNMI punch code 43 (Hydro Surface Card)
The data for each oceanographic surface station is given.

ICES code 03 = KNMI punch code 44 (Hydro Depth Card)
For each oceanographic observation depth the oceanographical data is given. The cards also include the simultaneous surface observation.

ICES code 04 = KNMI punch code 45 (BT Master Card)
The general hydrographical and meteorological data belonging to each BT station is given.

ICES code 05 = KNMI punch code 46 (BT Detail Card)
The derived temperature at standard depths for each BT station is given.

00 – 49	*Research and other ships under way or groups of such vessels*
00	Weatherships: en route Hook of Holland – OWS Alpha
01	Batavier Line: en route Hook of Holland – London
02	Hollandse Stoomboot Maatschappij (HSM): en route IJmuiden – London
03	HSM: en route IJmuiden – Hull
04	HSM: en route IJmuiden – Scotland;
05	Weatherships: en route Hook of Holland – OWS India
06	Weatherships: en route Hook of Holland – OWS Juliet
07	Weatherships: en route Hook of Holland – OWS Kilo
08	Weatherships: en route Hook of Holland – OWS Mike
09	HSM: en route IJmuiden – English Channel
10	Royal Navy ships
11	Fishing research vessels (RIVO)
12	Ships sailing for KNMI
50 – 59	*Ocean Weather Stations (OWS)*
50	OWS Alpha
51	OWS Bravo
52	OWS Charlie
53	OWS Delta
54	OWS Echo
55	OWS India
56	OWS Juliet
57	OWS Kilo
58	OWS Mike
60 – 79	*Lightships or other permanent stations near the coast*
60	Noord-Hinder
61	Goeree
62	Texel
63	Terschellingerbank
80 – 89	*Drifting buoys*
90 – 99	*Moored buoys*

Table 8. *Ship code numbers, columns 3 and 4 of the ICES codes 01-05 (KNMI punch codes 42-46), used to indicate Dutch regular shipping lines, research vessels, Ocean Weather Stations, lightships and buoy data*

Abbreviations

bpi	Bytes per inch
BT	Bathythermograph
CMI	Comité Météorologique International
CMM	Commission on Marine Meteorology
EBCDIC	Extended Binary Coded Decimal Interchange Code
GMT	Greenwich Mean Time
HSM	Hollandse Stoomboot Maatschappij
HSSTD	Historical Sea Surface Temperature Data
ICES	International Council for Exploration of the Sea
ICOADS	International Comprehensive Ocean-Atmosphere Data Set
IMC	International Meteorological Committee
KNMI	Koninklijk Nederlands Meteorologisch Instituut (Royal Netherlands Meteorological Institute)
La	Latitude
LMR	Long Marine Reports
Lo	Longitude
MCSS	Marine Climatological Summaries Scheme
NOAA	National Oceanic and Atmospheric Administration
OWS	Ocean Weather Station
Q	Octant on the globe
RIVO	Rijks Instituut voor Visserij Onderzoek
RMA	Rijkscentrale voor Mechanische Administratie
SST	Sea Surface Temperature
TDF	Tape Data Family
UTC	Universal Time Coordinated
WMO	World Meteorological Organization
WW2	Second World War

Recommended Publications And References

In the following list the references used in this publication are listed together with recommended interesting publications (marked *). KNMI being a Dutch institute caused that many occurrences are written in native Dutch.

*Andrau, K.F.R. (1861): *Onderzoekingen met den Zeethermometer, als uitkomsten van wetenschap en ervaring, aangaande winden en zeestroomen in sommige gedeelten van den Indischen Oceaan*. KNMI Publication No. 24. Utrecht. Kemink en Zoon, 183pp.

*Andrau, K.F.R. (1877): *Maandelijkse zeilaanwijzingen van het Kanaal naar Java, als uitkomsten van wetenschap en ervaring aangaande winden en zeestroomen in sommige gedeelten van den Oceaan*. KNMI Publication No. 21. Utrecht: Kemink en Zoon, 124pp + plates.

*Brandsma, T., F.B. Koek, H. Wallbrink and G.P. Können (2000): *Het KNMI-programma HISKLIM (HIStorisch KLIMaat)*. HISKLIM 1. KNMI Publication No. 191, ISBN 9036921813; De Bilt, 71pp.

Broersma, R. (1981): *Internal communication*. 25 August 1981.

Buys Ballot, C.H.D. (1853): *Uitkomsten van Wetenschap en Ervaring aangaande winden en zeestromingen in sommige gedeelten van de oceaan benevens Verslag van de Conferentie te Brussel*. KNMI. Utrecht: Kemink en Zoon.

*Buys Ballot, C.H.D. (1855): *De waarnemingen van de temperatuur van het zeewater nuttig voor de zeevaart, vooral ter verkrijging van eene betere kennis aangaande de stroomen van den oceaan*. KNMI Publication No. 10. Rotterdam: P.M. Bazendijk, 36pp.

*Buys Ballot, C.H.D. (1872): *Suggestions on a uniform system of meteorological observations*. KNMI publication No. 37. Utrecht: Printing office "The Industry", K.A. Manssen.

*Buys Ballot, C.H.D. (1873): *A sequel to the "Suggestions on a uniform system of meteorological observations"*. KNMI Publication No. 38. Utrecht: Printing office "The Industry", K.A. Manssen.

Buys Ballot, C.H.D. (1882): *Beredeneerd register op de werken van het KNMI tot 1882*. KNMI Publication No. 58a. Utrecht: Kemink & Zoon, 91pp.

CMI (1930): *Procès-verbaux des Séances de la Conférence Internationale des Directeurs, du Comité Météorologique International et de Diverses Commissions à Copenhague, Septembre 1929*. Secrétariat du Comité Météorologique International, Publication No. 3. Utrecht: Kemink & Zoon N.V., 401pp.

*François, J.P.A. (1854): *Het Extract-Journaal toegelicht*. Rotterdam: P.M. Bazendijk, 16pp + plate.

De Hart (1972): *Internal Communication*. 12 December 1972.

*De Zee (1926): *Nieuw druk van het meteorologisch journaal*. De Zee, **48**, 97-98.

*De Zee (1930): *Schaal voor deining in het meteorologisch journaal*. De Zee, **52**, p664.

Gallé, P.H. (1908): *Mededelingen van de Afdeeling "Oceanografie en Maritieme Meteorologie" van het Meteorologisch Instituut: Stroomen; Wind; Herleide druk van den dampkring*. De Zee, **30**, 309-314.

ICOADS (1954): *Reference Manual 193 Dutch Marine Obs*. HQ, Air Weather Service, Data Control Division Weather Bureau, Climatological Services Division, [13 Jan 2010], <http://icoads.noaa.gov/reclaim/pdf/dck193.pdf>.

IMC (1922): *International Meteorological Committee, Report of the Eleventh Ordinary Meeting, 1921, London*. M.O. No. 248. London: HMSO, 128pp.

*Jansen, M.H. (1853): *Het stroomen van den oceaan, een veld van onderzoek voor den zeethermometer*. Amsterdam: G. Hulst van Keulen, 54pp.

*Keyser, H. (1929): *Wenken aan journaalhouders*. De Zee, **51**, 251-252.

*Keyser, H. (1930a): *De Internationale Meteorologische Conferentie van 1929 te Kopenhagen, met enkele van hare gevolgen voor de uitzending van meteorologische gegevens door landstations en door schepen*. De Zee, **52**, 121-135.
*Keyser, H. (1930b): *Weerberichten van schepen aan landstations en aan schepen*. De Zee, **52**, 665-666.
*Keyser, H. (1936): *Oceanografische en meteorologische waarnemingen in de Chineesche Zeeën en in het westelijke gedeelte van den Noord Stillen Oceaan*. De Zee, **58**, 9-15 & 596-598.
KNMI (1853): *Het Universeel Extract-Journaal met Verklaring ten gebruike van de Nederlandse zeelieden.* KNMI Publication No. 6, 1st Edition. Utrecht: Kemink en Zoon, 44p.
KNMI (1856): *Het Universeel Extract-Journaal met Verklaring ten gebruike van de Nederlandsche zeelieden.* KNMI Publication No. 6, 2nd Edition.
KNMI (1859): *Het Universeel Extract-Journaal met Verklaring ten gebruike van de Nederlandsche zeelieden.* KNMI Publication No. 6, 3rd Edition. Utrecht.
KNMI (1866): *Het Universeel Extract-Journaal met Verklaring ten gebruike van de Nederlandsche zeelieden*. KNMI Publication No. 6, 4th Edition. Utrecht: J.G. Broese, 111pp.
KNMI (1874): *Het Universeel Extract-Journaal met Verklaring ten gebruike van de Nederlandsche zeelieden.* KNMI Publication No. 6, 5th Edition. 61pp.
KNMI (1878): *Verslag van de werkzaamheden van het KNMI, verrigt van 1 Junij 1877 tot 31 Mei 1878*. Jaarverslagen KNMI 1860-1900, KNMI signature II.r.71.
KNMI (1885): *Jaarlijksche Verslagen van de 2de afdeling, afdeeling zeevaart*. KNMI signature II.r.71.
KNMI (1889): *Het Universeel Extract-Journaal met Verklaring ten gebruike van de Nederlandsche zeelieden.* KNMI Publication No. 6, 6th Edition. Utrecht: Stoom Boek- en Steendrukkerij "de Industrie", J. van Druten. 50pp.
*KNMI (1935): *Oceanographic and meteorological observations in the China Sea and in the Western Part of the North Pacific Ocean: I - Monthly charts for January-June*. KNMI Publication No. 115, 46pp.
KNMI (1936): *Oceanographic and meteorological observations in the China Sea and in the Western Part of the North Pacific Ocean: II - Monthly charts for July-December*. KNMI Publication No. 115. 's-Gravenhage: Rijksuitgeverij, 48pp.
KNMI (1937): *Handleiding voor het verrichten van meteorologische waarnemingen op zee*, KNMI Publication No. 118. 's-Gravenhage: Algemeene Landsdrukkerij, 115pp.
KNMI (1941): *Gegevens betreffende het archief maritiem meteorologische waarnemingen op ponskaarten (45 rijen) volgens het Hollerith- en Powerssysteem*. Preliminary Edition, KNMI Publication No. 123. 's-Gravenhage: Algemeene Landsdrukkerij, 57pp.
KNMI (1945): *Jaarverslag 1945*. KNMI Signature II.r.71, 39pp.
KNMI (1947): *Voorschriften voor het bijhouden van het meteorologisch journaal, druk 1947; Toelichtingen voor het verzenden van het Internationaal Scheepsweerrapport; Correctie-, herleidings- en psychrometertabellen*. KNMI Publication No. 128, 48pp.
*KNMI (1948): *Voorschriften voor het bijhouden van het meteorologisch journaal, druk 1948; Correctie-, herleidings- en psychrometertabellen*. KNMI Publication No. 128a, 26pp.
KNMI (1949a): *Handleiding voor het verrichten van meteorologische waarnemingen op zee.* KNMI Publication No. 118a. 's-Gravenhage: Staatsdrukkerij- en Uitgeverijbedrijf, p12.
KNMI (1949b): *Red Sea and Gulf of Aden. Oceanographic and meteorological data.* KNMI Publication No. 129. 's-Gravenhage: Staatsdrukkerij- en Uitgeverijbedrijf, 26pp.
KNMI (1950a): *Jaarverslag 1950*. Verslag omtrent de toestand en de werkzaamheden van het KNMI, te De Bilt, gedurende het jaar 1950. KNMI Signature II.r.71, 21pp.
KNMI (1950b): *Indian Ocean. Oceanographic and meteorological data. I - Text, II - Charts.* KNMI Publication No. 135. 's-Gravenhage: Staatsuitgeverij, 31pp & 48pp.

KNMI (1951a): *Jaarverslag 1951*. Verslag van den Hoofddirecteur van het KNMI gedurende het jaar 1951. KNMI Signatuur II.r.71, 43pp.
KNMI (1952): *Jaarverslag 1952*. Verslag van den Hoofddirecteur van het KNMI gedurende het jaar 1951. KNMI Signatuur II.r.71, 58pp.
KNMI (1955): *Jaarverslag 1955*. KNMI Signature II.r.71a, 33pp.
KNMI (1957): The Mediterranean. *Oceanographic and meteorological data*. KNMI Publication No. 138. 's-Gravenhage: Staatsdrukkerij- en Uitgeverijbedrijf, 91pp.
KNMI (1958): *Handleiding voor het verrichten van meteorologische waarnemingen op zee*. KNMI Publication No. 118b. 's-Gravenhage: Staatsdrukkerij- en Uitgeverijbedrijf, 131pp.
KNMI (1974): *letter D531x1*, rec. ref. 5109/23160, 7 May 1974.
KNMI (1977): *letter ref. 22713*, code 61.19.9, 15 August 1977.
*KNMI (1981): *Handleiding voor het verrichten van meteorologische waarnemingen op zee*. KNMI Publication No. 118d. 's-Gravenhage: Staatsuitgeverij.
Korevaar, C.G. (1982): *Historical sea surface temperature data (HSSTD) project*. KNMI Technical Report No. 12, 29pp.
Lund, C. (1973): *Manual on ICES Oceanographic Punch Cards*. Third edition, Denmark.
*Maury, M.F. (1848): *Abstract Log for the Use of American Navigators*. Prepared under the direction of Commodore Lewis Warrington, Chief of the Bureau of Ordnance and Hydrography, by authority of Hon. John Y. Mason, Secretary of the Navy, by Lieut. M.F. Maury, U.S. Navy, Superintendent National Observatory. Washington: C. Alexander, Printer, 10pp of Explanations. [Available within the US Maury Collection].
Maury, M.F. (1851). *Explanations and Sailing Directions to Accompany the Wind and Current Charts*. 3rd Ed., C. Alexander, Printer, Washington, 315 pp. + plates.
*Maury, M.F. (1852). *Explanations and Sailing Directions to Accompany the Wind and Current Charts*, approved by Charles Morris, and published by authority of William A. Graham. Washington: C. Alexander.
* Maury, M.F. (1854). *Explanations and Sailing Directions to Accompany the Wind and Current Charts*. 6th Ed., E.C. and J. Biddle, Philadelphia, 772 pp. + plates.
*Maury, M.F. (1855). *Explanations and Sailing Directions to Accompany the Wind and Current Charts*. 7th Ed., E.C. and J. Biddle, Philadelphia, 869 pp. + plates.
*Maury, M.F. (1858): *Explanations and Sailing Directions to Accompany the Wind and Current Charts*. 8th Ed., Vol. 1, W.A. Harris, printer, Washington, 383 pp. + plates.
*Maury, M.F. (1859): *Explanations and Sailing Directions to Accompany the Wind and Current Charts*. 8th Ed., Vol. 2, W.A. Harris, printer, Washington, 874 pp. + plates.
*Neumayer, G. (1879): Report on the "*Conduct of marine meteorology in Germany" and the agreements reached between the Royal Netherlands Meteorological Institute in Utrecht and the German Marine Observatory regarding the publication of the results of maritime meteorology, delivered to the Second International Meteorological Congress in Rome*. Hamburg, 26pp + images [UK Met Office Translation No.1631].
*Smith, H.T. (1937): *The extraction and compilation of marine meteorological data by mechanical Methods*. Marine Observer, **XIV** No. 125, 16-20.
Van Driest, J.C. (1946): *Het ontstaan van de afdeling Maritieme Meteorologie en Oceanografie van het Kon. Ned. Meteor. Instituut*. De Zee, **67**, 134-138.
*Van Riel, P.M. (1921): *Nauwkeurigheid der Meteorologische Journalen, 1920*. De Zee, **43**, De Zee, 17-20.
*Van Riel, P.M. (1922): *De bewerking der gegevens uit de meteorologische Journalen op het Kon. Ned. Meteor. Instituut te De Bilt*. De Zee, **44**, 429-438.
*Van Riel, P.M. (1923a): *Het waarnemingsmateriaal van schepen en de mechanische bewerking daarvan*. De Zee, **45**, 642-649.

*Van Riel, P.M. (1923b): *De Internationale Meteorologische Conferentie te Utrecht, September 1923*. De Zee, **45**, 724-731.
*Van Riel, P.M. (1927): *Internationale Meteorologie*. De Zee, **49**, 161-165.
Wallbrink H. and F.B. Koek (2001): *Gang van zaken 1940-48 rond de 20.000 zoekgeraakte scheepsjournalen*. HISKLIM 2. KNMI publication No. 192, 21pp.
*WMO (1960): *Guide des Pratiques Climatologiques*. WMO No. 100 TP. 44. Geneva: Secretariat WMO.
WMO (1970):*The Beaufort Scale of Wind Force (Technical and operational aspects)*. Report No. 3, Reports on Marine Science Affairs. Geneva: Secretariat WMO, 22pp.
WMO (1985): *User's guide to the data and summaries of the Historical Sea Surface Temperature Data project.* Marine Meteorology and Related Oceanographic Activities Report No. 13. WMO/TD-No. 36. Geneva: Secretariat WMO, 41pp.

Appendix A, KNMI Punch Cards

This appendix shows several examples of original punch cards. The images are all at 85% of the original card size.

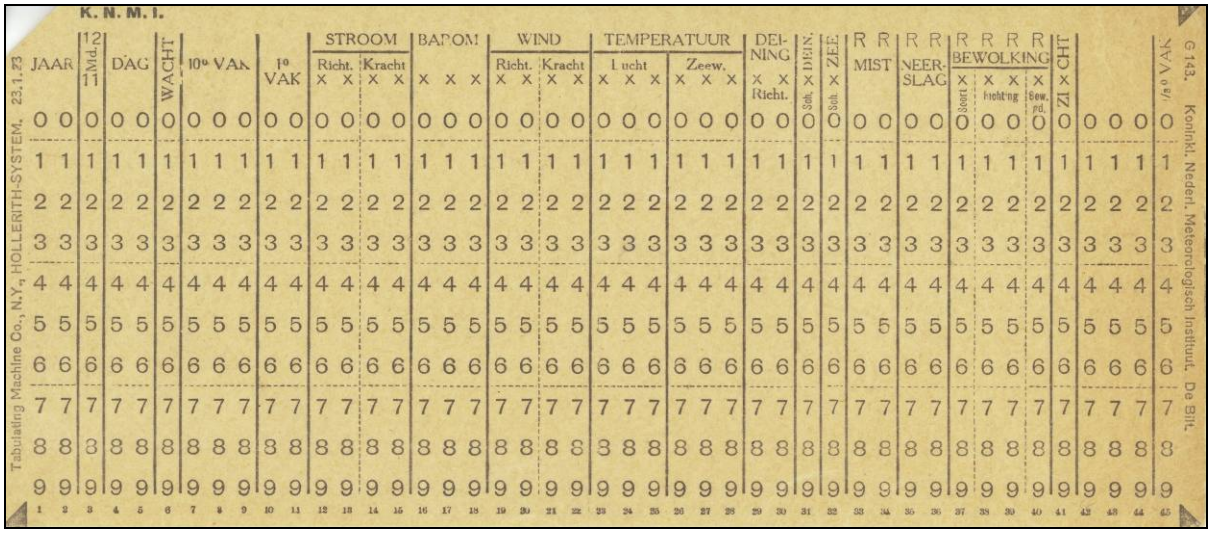

Figure A/a. *KNMI 45-columns Hollerith punch card (round punch holes) code 01. Note: column 45 gives a ⅓° square number to be able to report a more accurate position, e.g. when the ship is in harbour or at anchor, while still making observations*

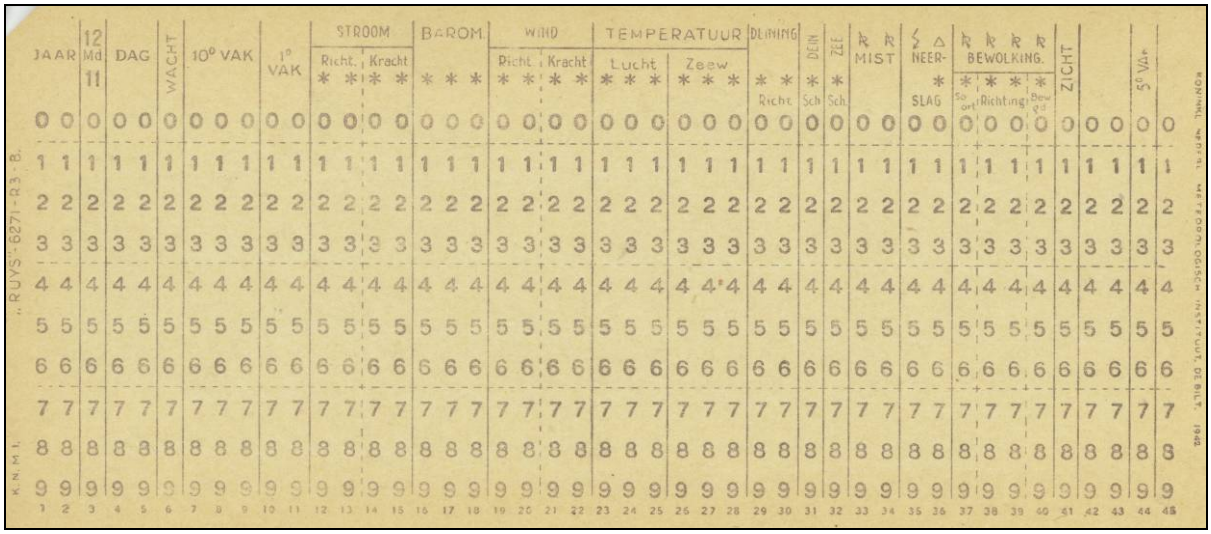

Figure A/b. *KNMI 45-columns Powers punch card (round punch holes) code 02 for observations 1854-1930 and code 07 for observations 1931-1938*

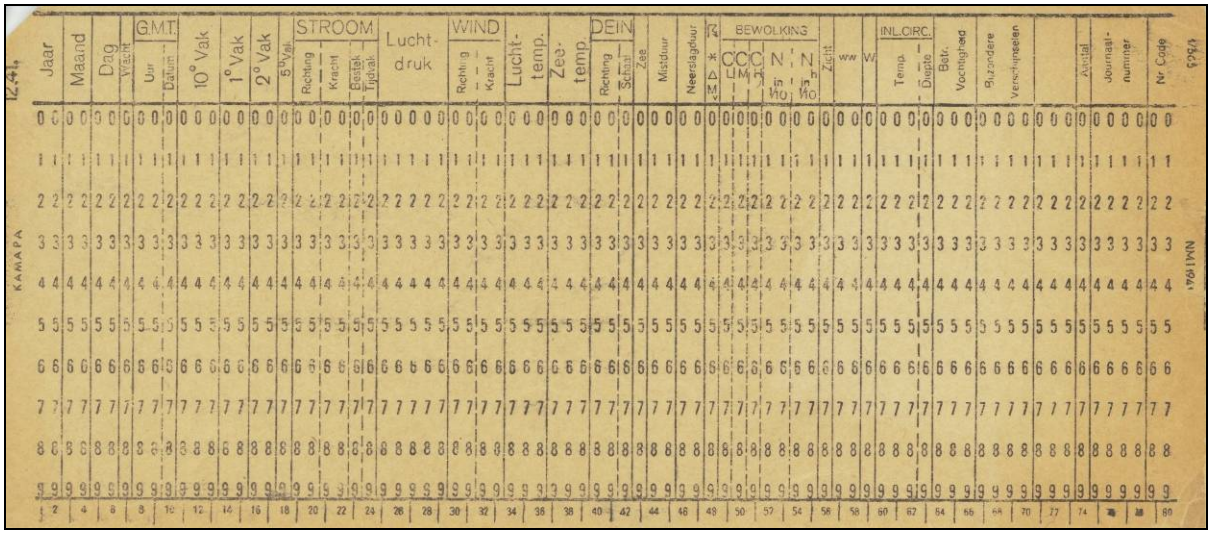

Figure A/c. *KNMI 80-columns punch code 01, 1938 and 1939*

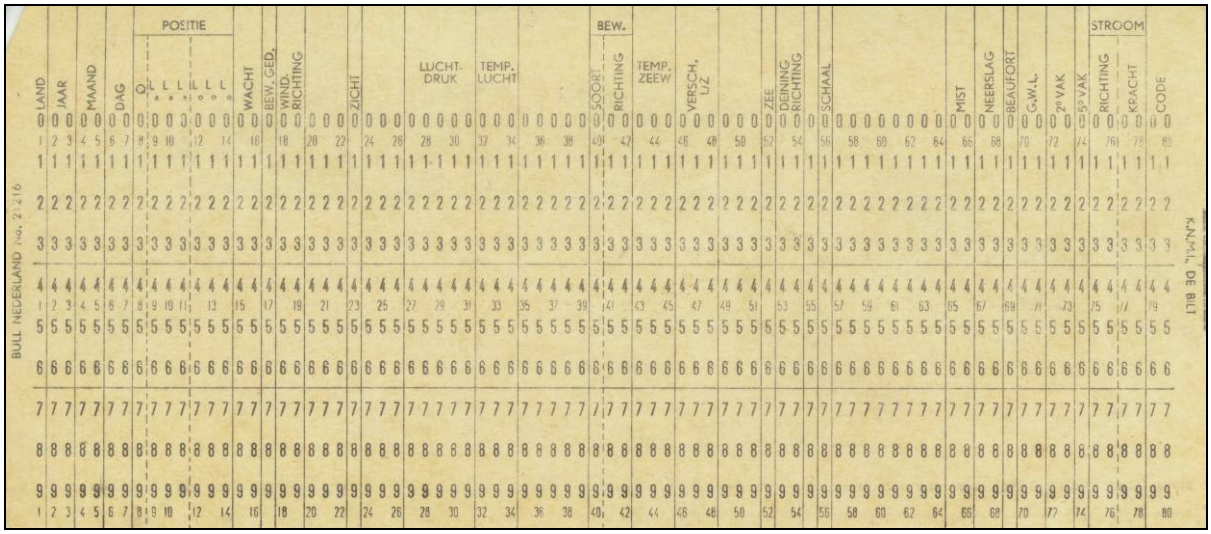

Figure A/d. *KNMI 80-columns Bull punch card code 28*

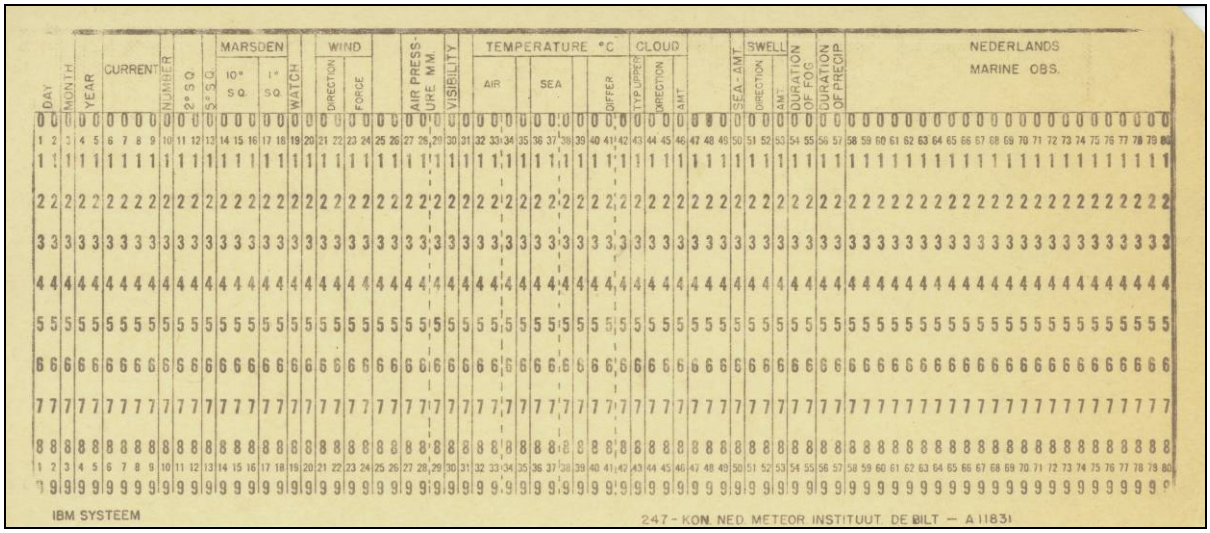

Figure A/e. *KNMI 80-columns punch card, Deck 193, designed for the US Weather Bureau (ICOADS), 1953*

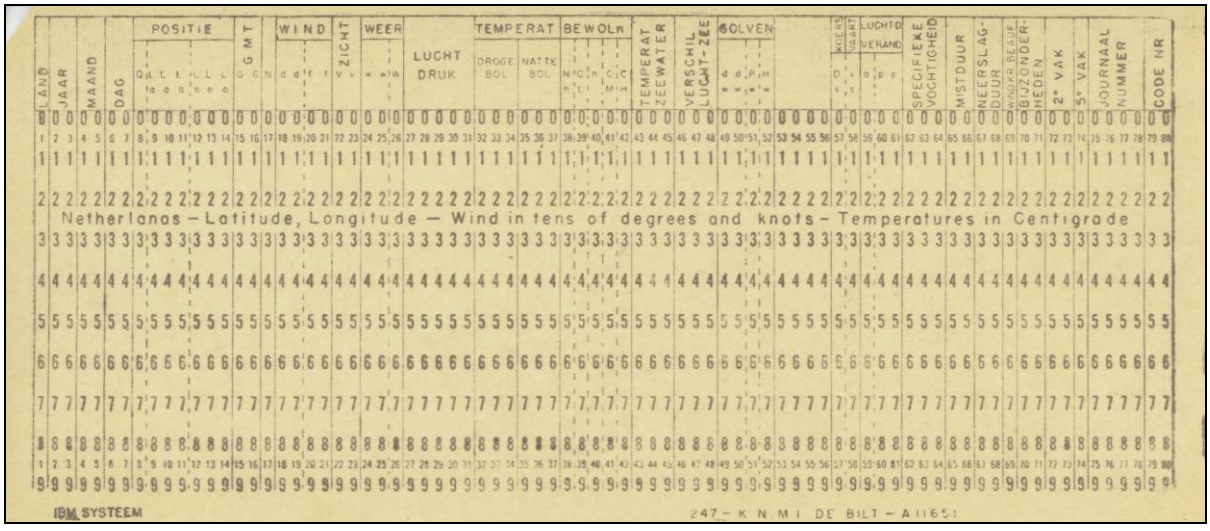

Figure A/f. *KNMI 80-columns punch card code 08 ('Washington Code'), 1949*

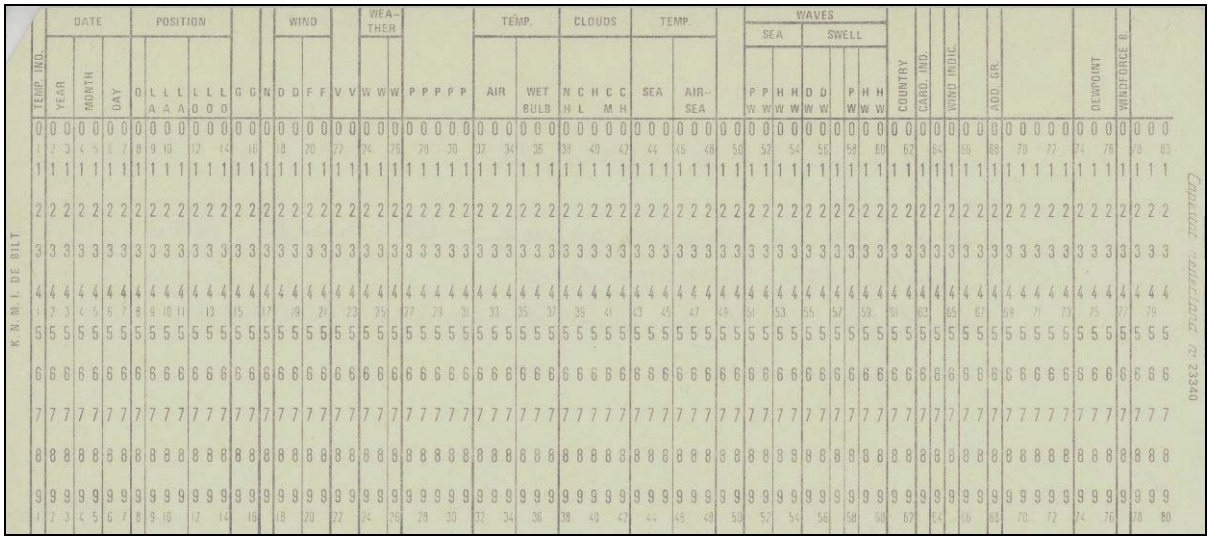

Figure A/g. *International Maritime Meteorological Punch card (IMMP), used from 1968 onwards for selected ships' observations*

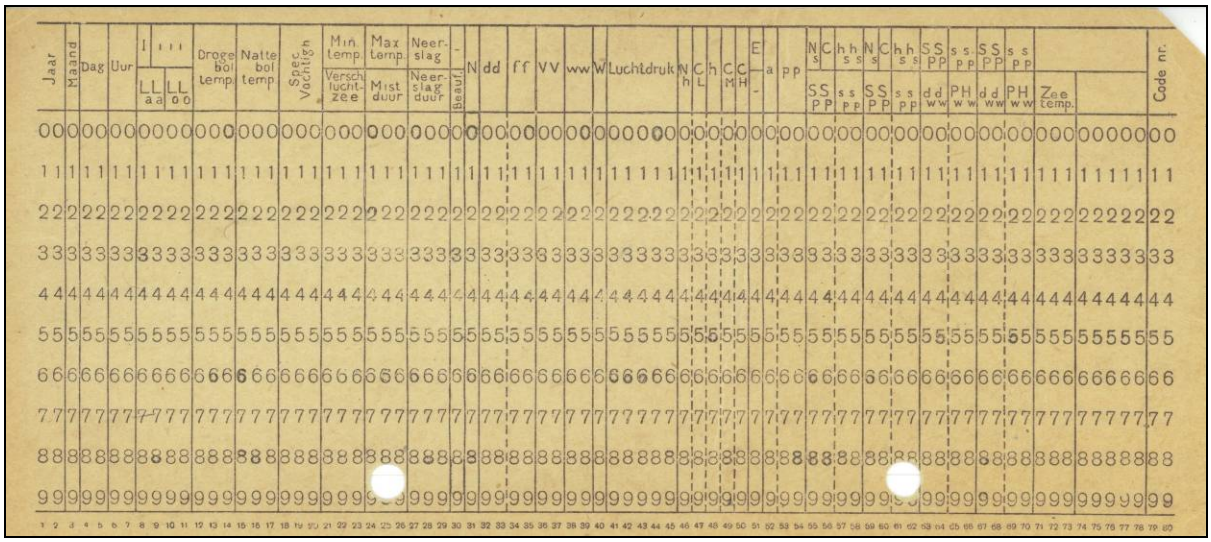

Figure A/h. *KNMI 80-columns punch card code 11, used for lightships' meteorological observations*

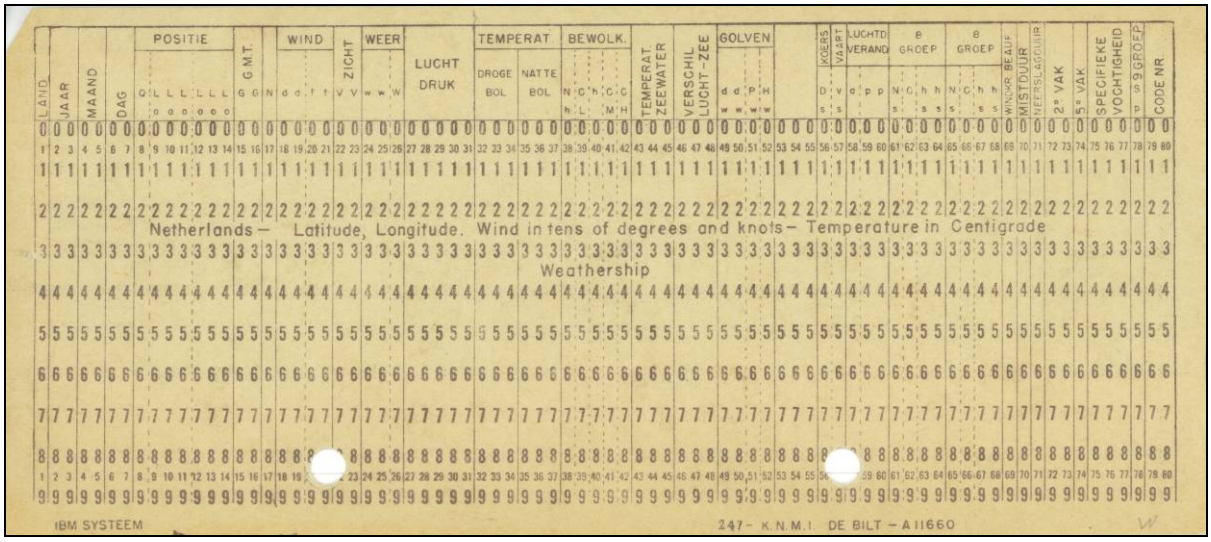

Figure A/i. *KNMI 80-columns punch card code 13, used for weathership observations, logbook model 759*

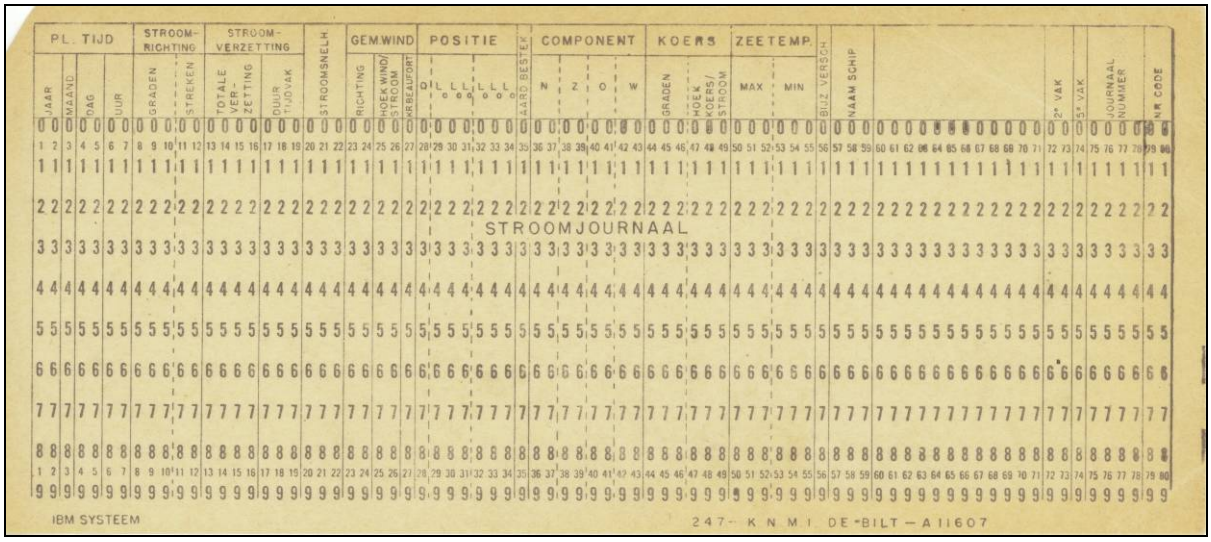

Figure A/j. *KNMI 80-columns punch card code 03, used for currents observations*

Appendix B, Punch Card Code 01 And 02 (Prior To January 1931)

Initially, Dutch ships' observations were punched on 45-columns Hollerith cards (round punch holes) according to KNMI punch code 01. This code was used only during a very short period. Because of the thickness of the paper punch cards, the Hollerith card was slightly different from the Powers punch card, and it was not possible to process both, Hollerith and Powers cards, on the same machine. Therefore, KNMI switched to the Powers punch cards in 1925. Later, prior to 1931, all the code 01 Hollerith punch cards were reproduced onto KNMI code 02 Powers punch cards.

KNMI punch code 01 differs from KNMI punch code 02 in column 45 only (see Figure A/a and Figure A/b). The use of this column was to specify a more accurate position within the 1° x 1° square if the ship was at anchor or stayed in port while making observations (see Figure B/a). In that case column 45 specifies a position within a ⅓° square. For ships underway, this method of specifying a more accurate location was never punched (KNMI, 1941).

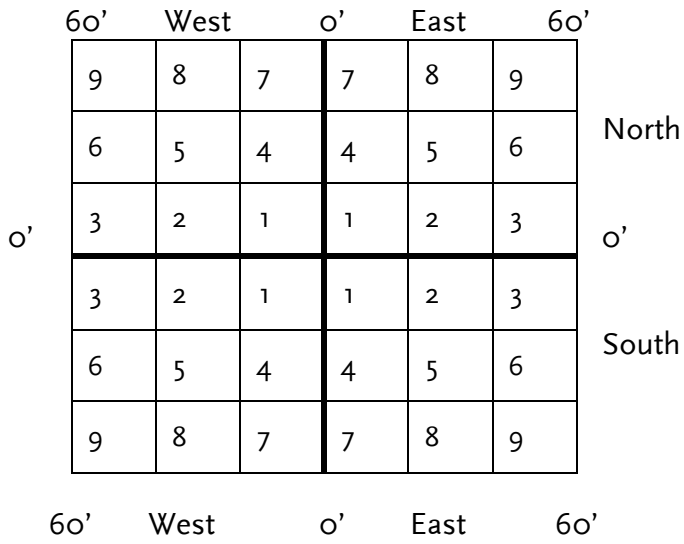

Figure B/a. *Example of four 1°x1° squares (60' x 60'), each in a different quadrant on the globe. Within each 1° x 1° square, the numbering is different. The given number is used in code 02, column 45.*

KNMI punch card code 02

Column	Element	Remarks
1-2	Year	Only last two digits; numbers 00-99
3	Month	1-9: January-September 0: October; the other months were possible to punch in one column using the overpunch[1] method. 11 + 1: November 12 + 2: December
4-5	Day	Numbers 01–31. All times are in ship's time (or local time)
6	Watch	1: 4:00 a.m. 4: 4:00 p.m. 2: 8:00 a.m. 5: 8:00 p.m. 3: noon 6: midnight 6 is punched for midnight or 00 hours of the day beginning.
7-9	10° Square	Marsden square numbers 001-551.
10-11	1° Square	Marsden sub square numbers 00–99. One degree squares are numbered by unit positions for the 1° latitude and the 1° longitude. Example: 3**8**°12'N. 6**5**°24'W is 1° x 1° square **85**
12-13	Current direction	Current direction in the way it is moving. Numbers 00-32 rounded to 2 compass points as much in rotation clockwise and anticlockwise. 00 = no current
14-15	Current speed	Nautical miles per day. Numbers 00–99. 99 for all currents ≥ 99. The real value has been written on the punch card.
16-18	Air pressure	Tens, units and tenths of millimetres omitting the initial 7. Corrected for temperature and reduced to mean sea level but not corrected for gravity.
19-20	Wind direction	Direction where the wind comes from. Numbers 00–32 rounded to 2 compass points as much in rotation clockwise and anticlockwise. 00 = calm.
21-22	Wind force	According to Beaufort scale. Numbers 00–12.
23-25	Air temperature	Tens of degrees Celsius. For negative temperatures -50° is added. Example: -1.8° = 518
26-28	Sea temperature	Tens of degrees Celsius. For negative temperatures -50° is added. Example: -1.8° = 518
29-30	Swell direction	Numbers 00-32. 00 = no swell or confused swell together with sea scale number 4 or 9.
31	Swell scale number	Digits 0-9 conform to the international code "Swell in the open sea". See logbook modifications 1898-1938. In use since the Meteorological logbook edition 1922. Before the swell was not punched.
32	Sea scale number	Numbers 0-9. See logbook modifications 1854-1897
33-34	Duration of fog	Numbers 00-16, number of quarters per watch. Numbers 50-66 give the duration of desert dust (Red Fog). Fog patches in quarters of the fog duration. Example: 04 = 4 hours of fog patches.

[1] A punch card basically has 10 rows, used for the digits 0-9. In addition to these ten rows it was possible to punch a hole in two extra rows, above the normal ten. These extra punch rows were called "overpunch rows" (Dutch: "bovenponsingen") and were indicated in the punch instructions with resp. 11 and 12 (topmost), X and Y or x and R. Combining the digits 0-9 with one overpunch expanded the possibilities of the punch card codes. Normally it was only possible to enter a digit 0-9 in one column, now, with the overpunch rows, it was possible e.g. to enter the month in one column, instead of in two.

35-36	Duration of precipitation	Numbers 00-16, number of quarters per watch. A = fog, B = rain, C = snow, D = hail. Is snow is accompanying precipitation 11 of column 36 is punched and for hail 12 of column 36. In case of thunderstorms 12 of column 35 is punched.
37	Upper air clouds type	Digits 1-5. 1 = Cirrus, 2 = Cirrostratus, 3 = Cirrocumulus, 4 = Altocumulus, 5 = Altostratus.
38-39	Upper air clouds direction	Numbers 00-32. Direction where the clouds come from. 00 = no movement. In case of different cloud types only the cloud type and direction which has the lowest scale number is punched. If no direction is observed also the cloud type is not punched.
40	Cloud amount	Cloud amount in tenths, digits 0-9 and overpunch 12, indicating overcast; 0 = cloudless, 10 = overcast. Each card contains a cloud amount figure, often obtained by interpolation.
41	Visibility	Digits 0-9 conform to the international code "Horizontal visibility from ships at sea". See logbook modifications 1898-1938. In use since the Meteorological logbook edition 1922. Before the visibility was not punched.
42-43	2° square	According Marsden square chart, numbers 01-25.
44	5° square	According Marsden square chart, digits 1-4.
45		All cards were punched with 1 in this column. Cards with air pressure, air temperature and sea temperature also were overpunched 12. Punch cards with one or more of the above mentioned parameters missing are punched 1 only. Punch cards from Swedish logbooks are additional overpunched 11.

Table B/1. *KNMI punch code 02 for 45-columns cards*

Remarks

- Logbook observations with fog (A) and rain (B) all through the watch, were punched 2 hours of fog and 2 hours of rain;
- Punch cards from Swedish logbooks did not contain fog and precipitation observations;
- Except for ocean currents, precipitation and fog the punched observations give the logbook observations the way they were noted at the end of each watch;
- Logbook observations where air pressure, temperatures and ocean currents are missing, were not punched;
- Marking-off of the logbooks for description of the sky (see Table B/2).

Logbook description (sometimes archaic Dutch)	Cloud type	Punched number
Heldere lucht		0 or 1
Afklarende lucht na wolkdrijvende lucht (van 5 naar 2)	Cirrus	2
Ligte bewolkte lucht	Cirrus	3
Ligte wolkdrijvende lucht	Cirro-cumulus	3
Wolkdrijvende lucht	Cumulus	4 or 5
Afklarende lucht na betrokken lucht (10 naar 5)	Cirro-cumulus	5
Buiige afklarende lucht	Cirro-stratus	5
	Cirro-stratus	6
	Cirro-cumulus	6
Dampige en wolkdrijvende lucht	Stratus	7
Bewolkte lucht	Cumulus	8
Dampige lucht	Strato-cumulus	8
Wolkdrijvend buiige lucht		8
Min of meer betrokken lucht		9
Iets afklarende dikke lucht		9
Dikke (regenachtige) lucht	Strato-cumulus	10
Betrokken lucht	Nimbus	10
Zware regen; Buiige lucht	Stratus	10
Afwisselend bewolkte en buiige lucht		10

Table B/2. *Marking-off instructions for the description of the sky*

Appendix C, Punch Card Code 07 (After January 1931)

The 45-columns KNMI Powers punch code 07 is similar to punch code 02 (see Appendix B) except current direction, wind direction, air temperature, sea temperature, swell direction and the swell scale number.

Column	Element	Remark
12-13	Current direction (flowing towards)	02-32, 99 02 = NNE, 16 = S, 32 = N 99 = No current (instead of 00)
19-20	Wind direction	02-32, 99 02 = NNE, 16 = S, 32 = N 99 = Calm (instead of 00)
23-25	Air temperature	When temperature is negative, -50 is added to the observation and the result is punched as a positive value; e.g. -1.8° is punched as 518. Freezing point 0.0° is punched 001
26-28	Sea temperature	When temperature is negative, -50 is added to the observation and the result is punched as a positive value; e.g. -1.8° is punched as 518. Freezing point 0.0° is punched 001
29-30	Swell direction	02-33, 99 02 = NNE, 16 = S, 32 = N 33 = confused swell, scale number (column 31) = 9 99 = swell scale number 0
31	Swell scale number	According to the International code of Copenhagen, 1929; this code is used in the logbooks for observations after 1 January 1931

Table C/1. *KNMI punch code 07, columns that differs slightly from KNMI punch code 02*

Appendix D, Punch Card Code 28

All marine 45-columns punch cards, covering the period 1854-1938, were reproduced onto 80-columns KNMI punch cards according to KNMI punch code 28.

Column	Element	Remarks		
1	Country of origin	Numbers 0-9, if necessary combined with an x or R overpunch, giving 30 possibilities. The Netherlands = 0		
2-3	Year	Last two digits, e.g. 1923 = 23		
4-5	Month	Numbers 01-12; Jan = 01, Dec = 12, etc.		
6-7	Day	Numbers 01-31		
8	Octant of the globe: Q	Northern Latitude	0	00° W – 90° W
			1	90° W – 180° W
			2	180° E – 90° E
			3	90° E – 00° E
		Southern Latitude	5	00° W – 90° W
			6	90° W – 180° W
			7	180° E – 90° E
			8	90° E – 00° E
9-10	Latitude	LaLa; whole degrees. In connection with Q		
11		Not used		
12-13	Longitude	LoLo; whole degrees. In connection with Q		
14		Not used		
15-16	Watch	Numbers 1-6. The hour at which the observation was made. 1 = 4 am, 2 = 8 am, 3 = noon, 4 = 4 pm, 5 = 8 pm, 6 = mid-night or 00 hours of the day beginning. Note: column 15 is usually blank.		
17	Total Cloud Amount: N	N in tenths. Numbers 0-9 and number 12 (overpunch) for N = 10. Clear sky = 0; overcast = 10. Always a value, if necessary inter-polated. Conform 45-columns punch card codes 02 (<1931) and code 07 (≥1931)		
18-19	Wind direction	DD Numbers 00-32 rounded to 2 compass points, and 99. Direction from which the wind blows. Calm = 00 (KNMI code 02); Calm = 99 (KNMI code 07); Missing values are blank. Conform 45-columns punch card codes 02 (<1931) and code 07 (≥1931)		
20-22		Not used		
23	Horizontal visibility	Numbers 0-9 and number 12 (overpunch) meaning fog patches. Conform 45-columns punch card codes 02 (<1931) and code 07 (≥1931)		
24-26		Not used		
27-31	Air pressure	Sea level pressure in 0.1 hPa. Corrected for index, temperature, height above sea level and gravity. Conform 80-columns punch card code 08 (<1968).		
32-34	Air temperature	Dry bulb temperature in tenths. Numbers 000-450. For negative numbers there is an 11 over-punch in column 32. Missing values are blank. Conform 80-columns punch card code 08 (<1968).		

35-39		Not used
40	Upper air cloud type	1 = Cirrus; 2 = Cirrostratus; 3 = Cirrocumulus; 4 = Altocumulus; 5 = Altostratus. Conform 45-columns punch card codes 02 (<1931) and code 07 (≥1931)
41-42	Upper air cloud direction	Numbers 00-32. Direction from which the clouds are moving. 00 = no movement, 02 = NNE, etc. 16 = South, 32 = North. Conform 45-columns punch card codes 02 (<1931) and code 07 (≥1931)
43-45	Sea surface temperature	SST in tenths. Numbers 000-450. For negative numbers there is an 11 overpunch in column 43. Missing values are blank. Conform 80-columns punch card code 08 (<1968).
46-48	Air-sea temperature difference	In tenths. Positive when TDry ≥ SST Negative when TDry < SST, overpunch 11 in column 46. Missing values are blank. Conform 80-columns punch card code 08 (<1968).
49-51		Not used
52	Sea	Wind waves. See Table D/2. Since 1883 always a value, if necessary interpolated. Conform 45-columns punch card codes 02 (<1931) and code 07 (≥1931)
53-54	Swell direction	Numbers 00-32. Direction from which the swell is coming. 00 = no swell, 02 = NNE, 16 = S, 32 = N. 00 is also punched if swell scale numbers 0, 4, 5 and 9 were logged. Conform 45-columns punch card codes 02 (<1931) and code 07 (≥1931)
55	Blank	Not used
56	Swell	See Table D/3 and Table D/4. In use since 1922. Conform 45-columns punch card codes 02 (<1931) and code 07 (≥1931)
57-60		Not used
61-64		Not used
65-66	Duration of fog	Quarters of an hour per watch. Numbers 00–16. Conform 45-columns punch card codes 02 (<1931) and code 07 (≥1931)
67-68	Duration of precipitation	Quarters of an hour per watch. Numbers 00–16. Conform 45-columns punch card codes 02 (<1931) and code 07 (≥1931)
69	Wind force	Wind force according to the Beaufort scale. Numbers 00-12.
70-71	GWL	*Gross Wetter Lage* numbers 1-29. Not used for ship observations.
72-73	2° square	According Marsden square chart. Numbers 01-25. Squares are always oriented so that the lowest number is nearest to the intersection of the Greenwich meridian and the Equator.
74	5° square	According Marsden square chart. Numbers 1-4. Squares are always oriented so that the lowest number is nearest to the intersection of the Greenwich meridian and the Equator.

75-76	Current set	Numbers 00-32 rounded to 2 compass points. Direction to which the current is moving. 00 = no current, 02 = NNE, etc. 16 = South, 32 = North. 99 = no currents (code 07). Conform 45-columns punch card codes 02 (<1931) and code 07 (≥1931)
77-78	Current drift	Nautical miles per twenty-four hours. Numbers 00-99. Drift > 99 is punched 99. Conform 45-columns punch card codes 02 (<1931) and code 07 (≥1931)
79-80	Code number	Always 28

Table D/1. *The 80-columns KNMI punch card code 28*

Scale numbers for sea state, 1883-1941		
Number	**Sea (Dutch)**	**Sea**
0	Vlak	Calm
1	Kabbelend	Smooth
2	Licht golvend	Slight
3	Golvend	Moderate
4	Zee	Rough
5	Aanschietende zee	Very rough
6	Wilde zee	High
7	Hoge zee	Very high
8	Zeer hoge zee	Precipitous
9	Buitengewoon hoge en wilde zee	Confused

Table D/2. *Scale numbers for sea state in use 1883-1947*

Combined scale for sea and swell 1921– 1930			
Code	**Swell (Dutch)**	**Swell**	**Concurrent sea**
0	Geen of lichte deining	No or slight swell	and sea smooth to moderate
1	Matige deining	Moderate swell	
2	Hoge deining	Heavy swell	
3	Lange vlakke deining	Long, low swell	
4	Dooreenlopende deining	Confused swell	
5	Geen of lichte deining	No or slight swell	and sea rough
6	Matige deining	Moderate swell	
7	Hoge deining	Heavy swell	
8	Lange vlakke deining	Long, low swell	
9	Dooreenlopende deining	Confused swell	

Table D/3. *Scale numbers for swell state to be used until 31 December 1930*

Code	Swell (Dutch)		Swell
0	Geen deining		No swell
1	< 2 m	Lage, korte of matig lange deining	Low swell, short or average length
2	< 2 m	Lage, lange deining	Low swell, long
3	2-4 m	Matig hoge korte deining	Moderate swell, short
4	2-4 m	Matig hoge, matig lange deining	Moderate swell, average length
5	2-4 m	Matig hoge, lange deining	Moderate swell, long
6	> 4 m	Hoge korte deining	Heavy swell, short
7	> 4 m	Hoge matig lange deining	Heavy swell, average length
8	> 4 m	Hoge lange deining	Heavy swell, long
9	Dooreenlopende, verwarde deining		Confused swell

Table D/4. *Swell scale numbers for swell state to be used from 1 January 1931*

Appendix E, Dutch Marine Barometers

The mercury barometer

Prior to 1939, the Dutch marine mercurial barometers were equipped with a scale that was graduated in millimetres (or inches) mercury (Hg). Both, the reading of the barometer and the reading of the attached thermometer (Celsius or Fahrenheit) were noted in their original units in the ships' logbooks. The International Meteorological Conference at Copenhagen introduced the unit millibars/hectoPascal instead of inches or millimetres Hg in 1929. The Netherlands switched over from millimetres Hg to millibars as one of the last countries in Europe, in October 1938 (Keyser, 1939). From that time on, KNMI supplied ships with a "standard" marine mercurial barometer, equipped with a scale graduated in millibars.

Before 1938 the design and construction of the ships' mercury barometers was left completely to the manufacturer. At the purchase of a mercury barometer, shipping companies and captains did not mention any particular requirements on the capacity and diameter of the capillary glass tube. Basically the only demands were a constricted glass tube, to avoid "pumping" of the mercury by the ship's movements, and an accompanying reasonable lagging time of the barometer. Several brands of mercurial barometers with different barometer capacities can be found on board of the Dutch merchant fleet. The most common brands were: "*H. Olland*", "*W.C. Olland*" and "*L.J. Harri*", all with a capacity of 24 and "*G. de Koningh*" with a capacity of 45. Due to accidents during the voyage, for instance breaking of the glass tube in stormy weather, also English Kew Pattern Marine mercurial barometers, acquired abroad, were found on several Dutch ships.

The aneroid barometer

The aneroid barometer was invented in 1843. At KNMI, aneroid barometer readings were not allowed for regular ship observations until 1955. Even if the mercurial barometer was out of order it was not allowed to use the aneroid barometer instead (KNMI, 1937: 29). The ship aneroid barometers were considered unreliable because they regularly showed an erratic behaviour due to temperature changes that affected the levers and springs inside the instrument. An exception was made for instruments manufactured in the factory of Naudet (former Vidi) in Paris. They were treated as more reliable (KNMI, 1889). However, the aneroid barometer observations were not punched at KNMI.

Regulations for the marine mercury barometer as prescribed in 1853

- The barometer should be gimballed;
- The glass tube should be vacuous;
- The mercury should be clear of any air bubbles;
- The glass tube should be constricted;
- The barometer should not be exposed to direct sunlight.

Barometric corrections

Mercurial barometer readings prior to 1938 should be corrected for:

- Temperature correction;
- Capacity correction;
- Capillarity correction;
- Height correction;
- Index correction;
- Gravity (latitude) correction.

Aneroid barometers are only corrected for index and height above sea level. Difference of gravity does not affect the measurement, and the instruments are compensated for temperature.

Temperature correction (mm)

From way back, the formula used for calculating the temperature correction (Tcor) is:

$$\text{Tcor} = \frac{(\alpha - \beta)}{(1 + \alpha t) \times (t \times b)}$$

or by approximation

$$\text{Tcor} = -(\alpha - \beta) t \times b$$

α = cubic expansion coefficient: 182×10^{-6}
β = linear expansion coefficient: 19×10^{-6}
t = temperature of the mercury and the graduation scale
b = barometer reading

During the second part of the 19th century the temperature correction was calculated in two parts, one for the expansion of the scale and one for the expansion of the mercury.

The temperature correction tables used in the first half of the 20th century, before 1938, were calculated by using the formula for approximation. However, this formula is only correct for some specific types of barometers. For mercury barometers with reduced graduation, i.e. all ships' mercury barometers, the formula is not exactly correct. In 1939 it was decided that an extra correction of 4% on average had to be applied to the existing temperature corrections (Keyser, 1940). In the tropics this meant a rise of a few tenths of a millibar/hectoPascal.

Capacity or cistern correction (mm)

The relation between the diameter of the mercury in the cistern around the tube and the diameter of the mercury in the tube at the top of the mercury column is called the capacity.

$$\text{Capacity correction} = \frac{\text{reading - neutral point}}{\text{capacity}}$$

The neutral point of the barometer is the reading at a temperature of 0° Celsius, where point zero of the graduation is equal to the mercury level in the cistern. The sign of the correction determines how the correction is to be applied. Both capacity and neutral point should have been noted at the first pages of the ship's logbook.

Capillarity correction (mm)

The fine capillary glass tube of the barometer causes a depression of the mercury level in the tube, causing a reading of the barometer that is too low. The size of the error depends on the diameter of the glass tube. Glass tubes with a diameter less than 6mm were not allowed on Dutch ships.

Diameter (mm)	Correction (mm)
10.0	+0.42
9.5	+0.47
9.0	+0.53
8.5	+0.60
8.0	+0.68
7.5	+0.77
7.0	+0.88
6.5	+1.00
6.0	+1.14

Source: Bouvard. Mém. de l'Acad. Roy. des Scienc. de l'Inst. de France. t. VII, p. 332.

In the 20th century, the correction became more or less constant for barometers with a diameter of the glass tube of more than 6mm (1922) or 8mm (1940), and allowance could be made for them in the process of construction. If the capillarity is considered as constant it is included in the index correction (KNMI branch office). In other cases it is recorded at the first pages of the ships' logbook.

The metal protected mercury barometers of the brand "H. Olland", in use at the Dutch Navy, do not need to be corrected for capacity and capillarity. The capacity and capillarity correction have already been taken care of in the graduation of the scale.

Height correction (mm)

The specific gravity of mercury is approximately 10,500 times bigger than the specific gravity of air.

Height correction = 1 millimetre for each 10,500 millimetres

For each meter this is equal to approximately 0.09mm or 0.12 mbar. The correction is not constant due to the changing draft of the ship.

Index correction (mm)

The index correction is caused by instrumental errors, mostly related to the positioning of point zero on the graduation. To determine the errors, the barometer is compared to a standard barometer of which the errors are accurately known. This was always done at

KNMI or at one of its branch offices. The difference between the two barometers is called the index correction. Inexperienced use or negligent treatment of the barometer may change the index correction; therefore additional inspectional observations are necessary. Inspectional observations against reliable instruments were done in the Netherlands at Amsterdam, Rotterdam, Den Helder, and Vlissingen and in the Dutch East Indies (now Indonesia) at Tandjung Priok – Batavia (Nautical Institute of the KPM) and Surabaya (Naval yard).

It was not allowed to determine a new index correction, based upon inspectional observations made onboard the ship. Re-verification of the index correction was only possible at the branch offices, respectively at the Nautical Institute or the Naval yard. Index corrections established in foreign (English) ports sometimes already include height - and latitude (gravity) corrections (adjusted fiducial temperature).

Gravity or latitude correction (mm)

Before to the introduction of the millibar graduation scale, in October 1938, the latitude correction was not applied at KNMI. All barometer readings expressed in millimetres or inches were adjusted to "Adjusted Pressure", which is the reading of the mercury barometer, corrected for index (including capacity and capillarity), temperature (0°C) and height above sea level. The adjusted pressure was also punched. This was done to make the "hurricane navigation" for the seamen easier (Van Hasselt, 1884). In those days the mariners were only interested in the deviation from the mean air pressure in certain, hurricane sensitive, areas. In meteorological atlases, issued by KNMI (Atlantic and Indian Ocean), the air pressure was not corrected for gravity. Consequently the sailors did not have to apply a latitude correction and for that reason inaccurate navigation did not bother them in determining the barometer's deviation.

The unit conversion from millimetres to millibars was done at KNMI between 1950 and 1968 during the reproduction of the 45-columns punch cards to 80-columns punch cards according to KNMI code 28. During the reproduction the latitude correction was also applied.

The theoretical value ($g\varphi, 0$) of the gravitational acceleration at mean sea level at latitude φ is established by the following formula:

$$G(\varphi,0) = 980.616\ (1 - 0.0026373 \times \cos(2\varphi) + 0.0000059 \times \cos^2(2\varphi))\ \text{in cm/s}^2$$

Considering:
The earth is shaped as given in the International Ellipsoid of Reference.

Flattening at the poles: $f = \frac{1}{297}$

$a = 6{,}378{,}388.0$ meter

The standard value 980.616 cm/s² was chosen as the most representative value at 45° latitude according to the International Association of Geodesy (1950). Nowadays the standard constant 980.665 cm/s² is used, which is derived from the theoretical gravitational acceleration at sea level at 45°32'40" latitude.

The barometer corrections was applied afterwards at KNMI and the corrected reading was noted into the logbooks by the mark-off people in a free separate column. Random tests showed that the barometer corrections were applied properly and that the gravity correction was not applied.

Reliability of Dutch marine mercurial barometer readings

During the years 1934, 1935 and 1936, all Dutch meteorological logbook keeping ships in the ports of Amsterdam and Rotterdam have performed check readings (Keyser, 1935; De Zee, 1936 and 1937).

From all these check readings (1,149) the corrected reading is on the average 0.27 hPa too high. This is probably caused by the construction of the tube. A mercurial barometer, however carefully used, may happen to be brought out of the vertical when read, and thus will give too high a reading. This error disappears only after several minutes (Keyser, 1949). The absolute average deviation from the actual pressure reads 0.40 hPa.

References (For Appendix E)

De Zee (1936): *Contrôle-barometerwaarnemingen in 1935*. De Zee, **58**, 231-234.

De Zee (1937): *Contrôle-barometerwaarnemingen in 1936*. De Zee, **59**, 289-290.

KNMI (1889): *Het Universeel Extract-Journaal met Verklaring ten gebruike van de Nederlandsche zeelieden. KNMI Publication No. 6, 6th Edition*. Utrecht: Stoom Boek- en Steendrukkerij "de Industrie", J. van Druten.

KNMI (1937): *Handleiding voor het verrichten van meteorologische waarnemingen op zee*, KNMI Publication No. 118.'s-Gravenhage: Algemeene Landsdrukkerij, 115pp.

KNMI (1941): *Gegevens betreffende het archief maritiem meteorologische waarnemingen op ponskaarten (45 rijen) volgens het Hollerith- en Powerssysteem*. Preliminary Edition, KNMI Publication No. 123. 's-Gravenhage: Algemeene Landsdrukkerij, 57pp.

Keyser, H. (1935): *Contrôle barometerwaarnemingen, bedoeld op blz. 1 van het meteorologische journaal*. De Zee, **57**, 190-193.

Keyser, H. (1940): *Eenige nieuwe aanteekeningen omtrent den scheepskwikbarometer*. De Zee, **62**, 145-154.

Keyser, H. (1949): *Over de fouten bij een kwikbarometer met vernauwde buis indien de luchtdrukking verandering ondergaat*. KNMI Publication No. 111-5. 's-Gravenhage: Staatdrukkerij- en Uitgeverijbedrijf, 14pp.

Van Hasselt, W. (1884): *Het nut van den Barometer voor den zeeman*. De Zee, **6**, 249-258, 317-327, 437-454.