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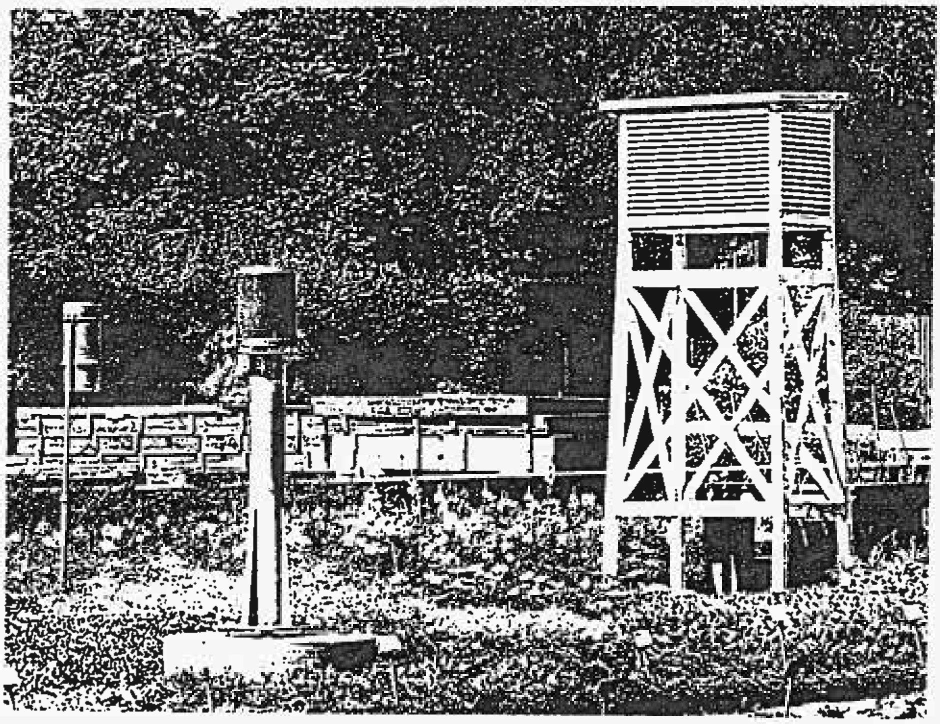
TECHNICAL REPORT

94-20

THE NORTH ATLANTIC CLIMATOLOGICAL DATASET
(NACD)

Summary of Meta data from NACD-stations in Denmark, Greenland and the Faroe Islands 1872-1994.

Marie Louise Brandt



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Preface

In 1993 I applied for a job at the Danish Meteorological Institute, keen on learning something new and bringing experience from map-making, cadastral administration, teaching, tourist information and guiding. I was attracted by the prospect of investigation. I have done this kind of a job before, but an inquiring mind still looks for a new happy hunting ground.

At the moment 6 reports have been made, thoroughly examining the history of all the Danish climatological NACD-stations, including all points of source discrepances, the level of knowledge and lack of documentation, the potential sources of error etc. Due to the authors liking of quotations, the discussion and interpretation was written in Danish, but now a comprehensive view will be presented to an international group of readers.

Obviously the meta data-pool should be staked concerning matters like relocation, replacement of instruments, innovation of calculating methods and formulas etc. since these factors are expected to cause significant modifications of the observed data. Apparently the rather logic "data-series-breakers" mentioned above might not always be sufficient, and further investigation has to be carried out, but how? Even if all sources were at hand we do not know exactly what we are looking for.

The co-operation between data processing and meta data collection is essential. Using various statistical tools a "break" or a "double-break" can be detected, and the diagnosis is to be found consulting the meta data investigator. The data series might be homogenised as soon as reasonable causes of breaks are given.

This report deals with subjects proved to cause breaks as well as more undetermined data-break causes. Furthermore an outline will be presented of methods, instruments, observing conditions and manners of the Danish meteorological establishment over the last 120-240 years.

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October 1994, Marie Louise Brandt.

1. Introduction.

The Danish Meteorological Institute was founded 1872 with a very small staff. Captain N. Hoffmeyer was the head manager, Poul la Cour the assistant manager and besides that a few other people were attached (a clerk, a delivery boy and a cleaner).

The assistant manager (later the head of the Climatological Department as the Institute enlarged) was the caretaker of setting up meteorological stations, inspection visits, instruction of observers as well as regulary revision of observed data. The weather maps worked out by Hoffmeyer, the head manager, were very recognized at that time, and both men were members of meteorological commissions and participated in meetings of The International Meteorological Committee.

A letter from the assistant manager to the head manager is source to our knowledge of barometer cleaning and height measurements, but few detailed descriptions of methods and observing conditions have been found.

According to the 1873 International Congress of Meteorologists resoluted classification Denmark was (in 1874) covered by 8 Second Order Stations, 27 Third Order Stations and 82 sites of precipitation measurement. The North Atlantic area was covered by 7 Second Order Stations (Greenland 3, Iceland 3 and the Faroe Islands 1), 4 Second Order Stations (Greenland 1, the Faroe Islands 3) and 4 wind observation sites (Iceland 1, the Faroe Islands 3). The number of stations has increased ever since.

The sample of NACD-stations have been selected partly from the point of view of location, but the claim for complete series and reliable observations is urgent.

The creation a homogeneous climatological dataset depend on complete knowledge of observation conditions. The methods of observing have changed due to innovation of instruments, exposure methods etc. and the observation site has been moved several times since the initiation of the data series.

Meta data is the knowledge of data origin, or more precisely, the data behind data. The aim of collecting meta data is to create an image of data-emerging at any time and place. This means a file of all aspects that might influence the observations. Type and replacement of instruments, adjusting, repair or cleaning, relocation as well as the observers training, care and precision and the ability of calculating and adjusting the raw-data by the staff of The Meteorological Institute are all part of the meta data sphere.

So the meta data concept covers solid elements that can be described precisely (type of instruments, replacements etc.) as well as rather spiritual elements (mental abilities of human beings).

No one should doubt that description of the "solid" elements can be difficult, due to lack of detailed sources and documentation, but treating the various mental abilities might be even more complicated.

Daily observations of pressure at 8 am, 2 pm and 9 pm (local time) are filed on lists delivered monthly by the observers. Normally the observers notebook (prime source) is lost, and so are other prime sources like covering letters from observers and correspondence between observers and DMI-staff.

The series of journals (instrument registers, journals of correspondence and parcels/mail items) are not intact, and records known to contain essential information have been lost.

Some "instructions for observers" (rough drafts as well as copies) have been left over, but most of them are undated, and the collections are not complete. Still the remains contain useful information.

Very few inspection reports have survived. Of course all habits of every day observing and data processing practice have never been described neither 100 years ago nor nowadays.

This leaves the investigator of meta data with an immense jig-saw puzzle. Every piece of information, even what might seem to be unimportant by a first glance, has to fit somewhere. As far as the whole image is not quite sharp, nothing is useless.

The meta data image is linked up from scattered pieces, but no chain is stronger than the weakest link. Collecting meta data takes time, lots of fruitless searching and lots of thrilling detection. The best method is perseverance.

2. Observation sites and relocations.

The Danish contribution to the NACD-project includes a number of observation sites in Greenland, the Faroe Islands and Denmark. Some of the generel information is valid for stations in Iceland as well (at least untill World War I). The sites are listed below (table 1) and exposed on maps (figure 1 and 2).

Each observer was equipped with a mercury barometer, a screen with 4 thermometers (dry, wet, minimum and maximum), a rain and snow gauge with graduated glasses, a flagpole with pennant, a lantern and a notebook for entering the readings at 8, 14 and 21 o'clock each day.

For the purpose of weather forecast and storm warnings the readings were corrected by the observer and telegraphed at once to Copenhagen as well as customers in England, Norway etc. The NACD-data, however, comes from lists delivered monthly by the

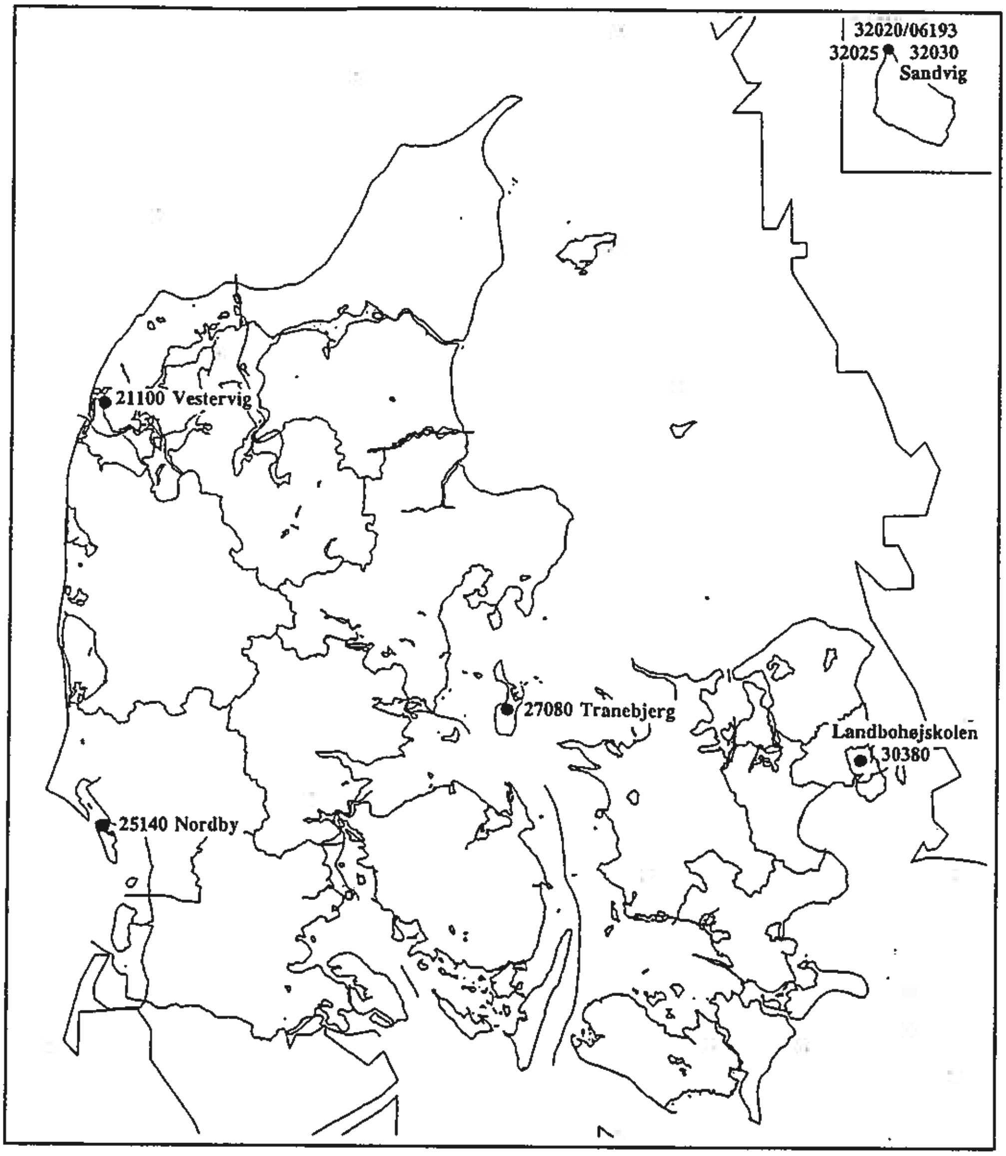

Fig. 1. Location of observing sites in Denmark. Source: DMI.

observer. These lists contain the readings copied from the observer's notebook, and all revision, correction (instrumental error etc.) and calculation af mean monthly values was carried out by the staff at the Meteorological Institute.

By occupation the observers of the 1870s were teachers (Fanø, Sandvig and Tórshavn), a captain (Vestervig) and a doctor (Tranebjerg) but later on all kind of professions enabling the pursuit of meteorological observing were represented (chemist, postmaster, bookseller, clockmaster, carpenter, tailor, hairdresser and savings bank manager). However the schoolmaster was the most frequent occupation, and only one family of observers are known to be farmers.

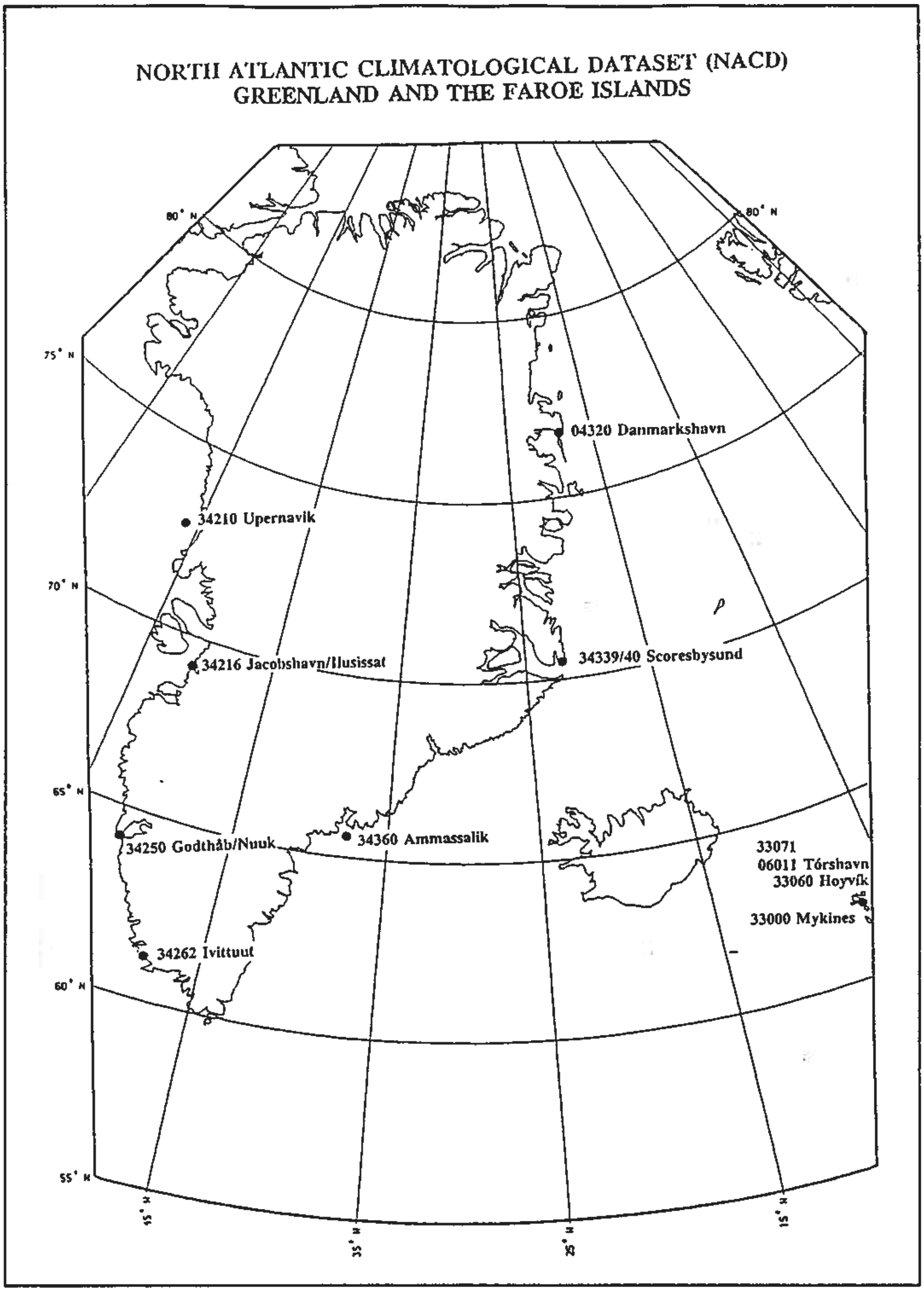

Fig. 2. Location of stations in Greenland and the Faroe Islands. Source: DMI.

Table 1 shows the number of relocations. Although the Fanø station has moved 9 times, all sites have been identified, whereas the dwellings of some observers in Sandvig and Tranebjerg are on dispute.

Station number	Name	Present position	Start date	No. of relocations	Notes
21100	Vestervig	55°46'N 8°19'E DK	18730603	6	
25140	Nordby, Fanø	55°27'N 8°24'E DK	18710723	9	
27080	Tranebjerg	55°50'N 10°36'E DK	18380101	6	
30380	Landbohøjskolen/ Copenhagen	55°41'N 12°33'E DK	17510101	3	
32020/ 06193	Hammer Odde Fyr	55°18'N 14°46'E DK	19530301	-	Lighthouse
32025	Hammeren Fyr	55°17'N 14°47'E DK	18800121	-	Lighthouse
32030	Sandvig	55°17'N 14°48'E DK	18721111	2-3	1872 site unknown
33060	Hoyvík	62°3'N 6°45'W F	19210601	-	Experimental center
33071	Tórshavn	62°3'N 6°44'W F	18720912	3	
06011	Tórshavn	62°1'N 6°46'W F	19060801	4	Telegraph office
33000	Mykines Fyr	62°6'N 7°40'W F	19110101	-	Lighthouse
34210	Upernavik	72°47'N 58°20'W G	18730901	5	
34216	Jacobshavn/ Ilusissat	69°13'N 50°55'W G	18730601	6-7	
34250	Godthåb/Nuuk	64°11'N 51°46'W G	18730901	6-7	
34262	Ivittuut	61°12'N 48°11'W G	18661001	4-5	
34339/40	Scoresbysund	70°29'N 21°58'W G	19241025		
34360	Ammasalik	65°37'N 37°16'W G	18841001	7	
04320	Danmarkshavn	76°46'N 18°46'W G	19580101		

Table 1. The Danish NACD stations. (DK=Denmark, F=Faroe Islands, G=Greenland)

Environmental changes.

The effect of environmental change throughout more than 240 years of observing must not be neglected. The local climate might be influenced by urbanization, but if some perhaps at this moment unrecognized laws of climatological variation should be discovered, all expected and well-known external effects must be pointed out.

The hitherto obtained knowledge of Danish station history is far from able to comply with this ambitious request. The influence from growing trees, hedges and bushes can not be proved, and more abrupt effects like the cut down of trees and hedges are proved by sheer luck: The turn up of significant different photos within a short space of time.

The building of houses in the neighbourhood might be detected by consulting cadastral departments or building authorities, but these are time-consuming investigations.

It seems as if we need to rely on the MI-inspectors' ability to replace and relocate the instruments into environments not very unlike the former sites. A more detailed study of station environments will be presented below.

The Copenhagen time-series.

The series of weather observations started 1751 at the top of Rundetårn in Copenhagen. Rundetårn was built as an observatory in 1640 by the Danish king Christian IV, and astronomers like Ole Rømer (1644-1710) and Peder Horrebow (1679-1764) were observing from the top of this rather unique spiral ramp tower. The height is 36 m above street level and 43 m above sea level.

Since the thermometer was inside the observatory during the first 16 years of observing these readings could not tell the true air temperature. From 1768 the thermometer was placed northfacing outside the building at the top of the tower, and so the temperature series start in 1768 whereas the wind observations began 1751.

From 1818 the Copenhagen weather observations came from Botanisk Have (the Botanical Gardens). In the years of 1778-1874 the Botanical Garden was situated behind Charlottenborg at the SE side of Kongens Nytorv, the garden being less than 300 meters from the quays.

In June 1860 a meteorological observation site was established at Landbohøjskolen (today: The Royal Veterinary and Agricultural University) under the guidance of the Meteorological Committee of the Agricultural Society.

Figure 3 is a map of Copenhagen build-up areas in the 18th century. Rundetårn is situated in the older part of the city and the Botanical Gardens to the NE of the castle. Landbohøjskolen was founded in 1858 about 1,5 km west of the city border.

Until 1852 the city was enclosed by ramparts. The lines of demarcation, forming a 500-1000 meter build-banned zone outside the ramparts, had forced the citizens to build apartment houses of up to five floors, but nevertheless the city became more and more overcrowded. In 1852 the military power had to sacrifice the external defences to comply with the need for urban expansion.

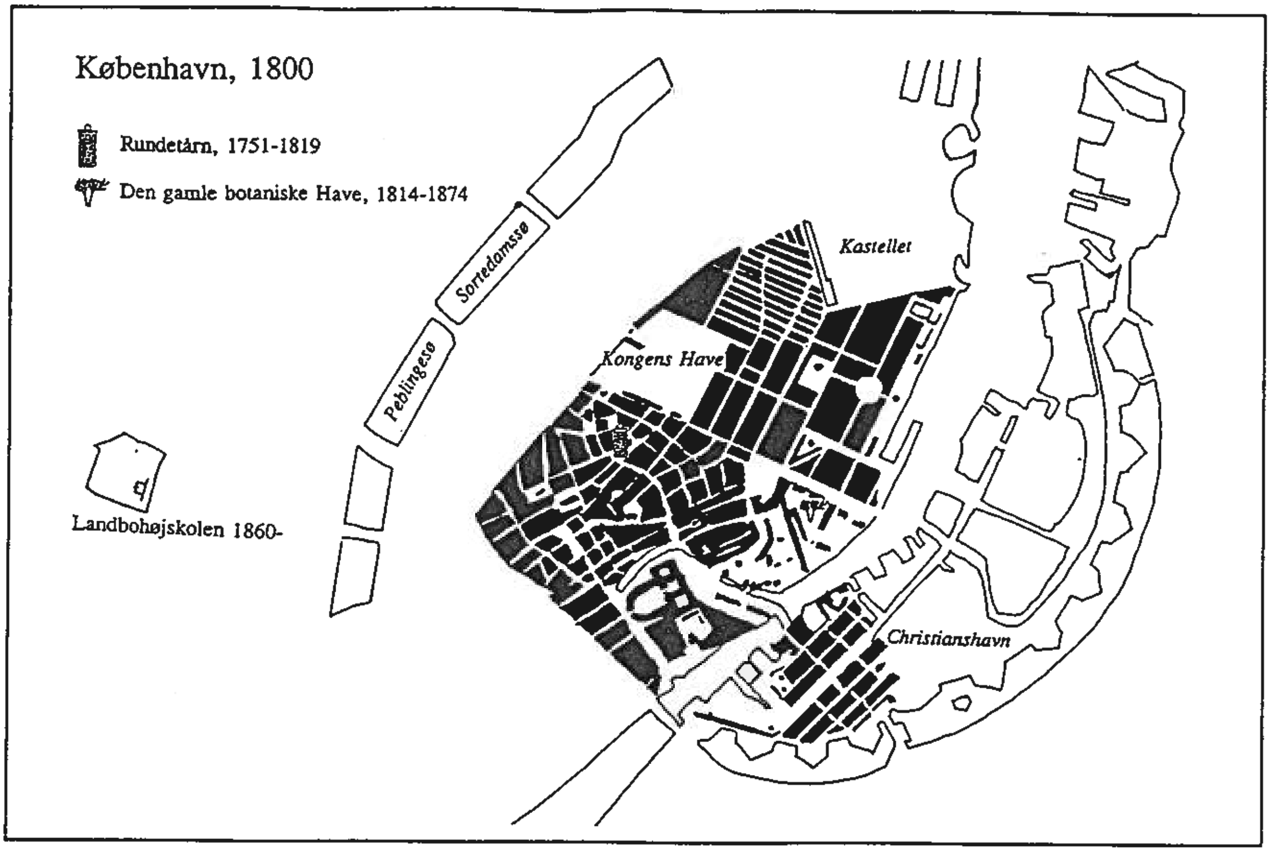

Fig. 3. Build-up areas of Copenhagen in the 18th century. Until 1852 the city was enclosed by ramparts and a demarcation zone. The location of Rundetårn is marked by a tower and the Botanical Garden by a tree a few hundred meter from the harbour. Landbohøjskolen was founded 1,5 km west of the town border. MLB 1994.

For the first two or three decades the building activity was moderate and the rural atmosphere was preserved. In the 1880s however, block after block, street after street of five or six-storey high apartment houses were thrown up. The later slum areas of Nørrebro and Vesterbro with stretches of small flats and narrow courtyards were formed in these years. Yet still in the late 19th century the surroundings of Landbohøjskolen were more or less open land, although a residential neighbourhood of cottages and villas grow up in the 1890s.

Today Landbohøjskolen is entirely surrounded by urban buildings, but still the villas remain part of the neighbourhood.

The provincial stations.

For the first two decades the stations at Fanø (25140 Nordby) and in Western Jutland (21100 Vestervig) were situated in open-land areas.

The observer at Fanø lived in a newly built house on a strech of open land between the church and the small harbour of Odden. Fanø is a very flat tidal area island, and in 1872 there were no trees in sight of the observer's house (reported by the observer in a letter, referring to the wind force scale).

In Vestervig the first observer, a captain, lived on a farm outside Vestervig. The surrounding areas were fields, and apart from the small farmhouse gardens this part of Jutland seemed to be rather in the lacking of trees or forests at the time. In 1879 the station was moved to the school near the open-land sited church and vicarage 1 km. to the north of Vestervig.

Later on the stations of Nordby and Vestervig were moved into the village areas. The 27080 Tranebjerg and 32030 Sandvig climatological stations were located in the villages from the start.

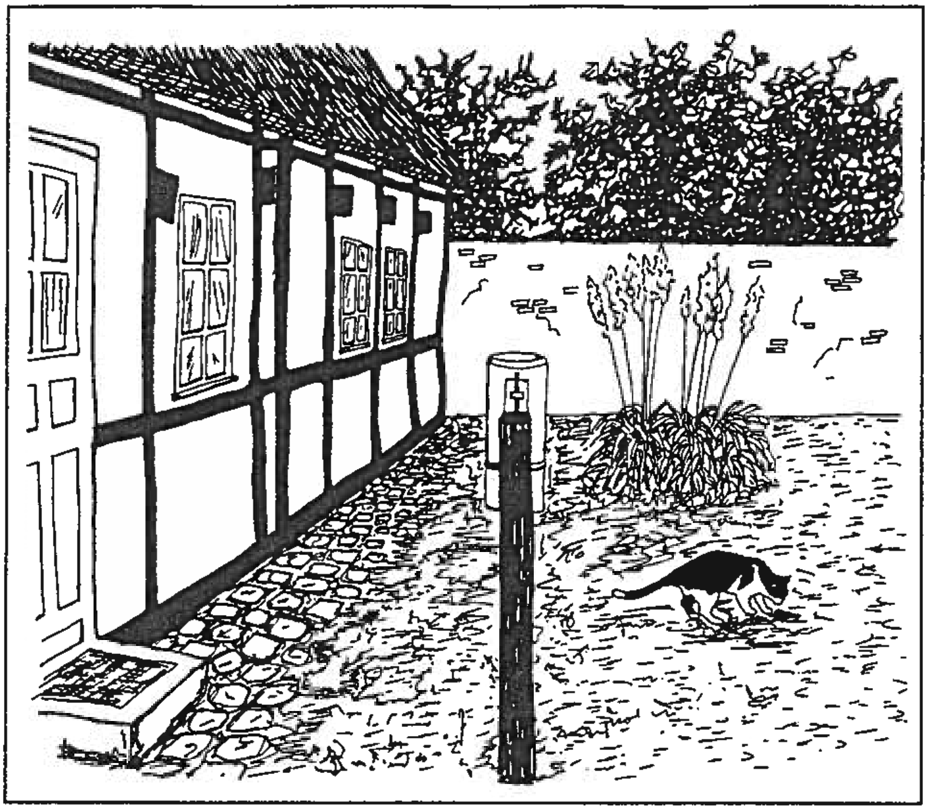

Fig. 4. Hellmann gauge outside a half-timbered house in Tranebjerg, 1971. MLB 1994.

To describe these small parish villages with their nice gardens, often overcrowded with small fruit trees and lots of berry-bushes and flower beds, might be like reading a tourist leaflet, but some photos from rural stations seem to leave very small room for thermometer screens and rain gauges. Figure 4 is far less overgrown than most of the photos, but the house is like the original parish village one-floor houses of Denmark, and at least the picture might give an image.

The villages of Nordby, Vestervig, Tranebjerg and the small market town of Sandvig (the smallest borough of Denmark) each had less than 400 inhabitants in the late 19th century. Of course the number has increased in the 20th century, but still they are villages (with less than 2000 inhabitants). Sometimes the climatological station was sited near the edge of the village and sometimes closer to the center, enclosed by small houses and gardens, but still today they are not very far away from the open land.

Investigations of environmental changes have been carried out using series of topographic and cadastral maps. The growing of each village has been described in the DMI Technical Reports (no. 94-13 to 94-17), but details like the cut down of trees and hedges that might influence the catch-efficiency of the rain gauge can hardly be proved.

The Faroe Islands and Greenland.

Unlike most of the Danish countryside areas the environments of the Faroe Islands and Greenland are free from grown-up trees and thick-growing bushes. Furthermore the concept of gardens enclosing the house with flower-beds and bushes are very uncommon in these northern regions. This means that the environments of the climatological stations are more windy and far less enclosed and sheltered than the stations of the Danish parish village.

In Greenland and the Faroe Islands the overall cover of the soil is grass, and snow cover is far more often observed here than in Denmark. The typical "bygd" looks like coloured wooden houses scattered about the lush green areas surrounded by rocks or cliffs, and the open sea or a deep fjord just below the settlement. These environments have not changed very much during the last century.

3. Climatological elements.

Pressure.

Since 1872 all Danish and North Atlantic stations have been observing pressure three times daily using a mercury barometer with an attached thermometer.

At the Danish Meteorological Institute the readings were revised and prepared for publishing. The published data were reduced to 0°C but not to sea level, and the barometer level (Hb) was published in the Meteorological Yearbook for the benefit of the readers. Unfortunately these Hb-values are sometimes very far from being true.

At the 1891 Munich Meeting of the International Meteorological Committee the latitude correction was resolved, and the publishing of latitude corrected data was introduced by the Danish Meteorological Institute from January 1st, 1893.

The mercury barometer.

The observers were supplied with a mercury barometer for pressure readings. Besides some observers had an aneroid barometer or a barograph. The mercury barometer was compared with a normal barometer, sometimes even tested in a metal pressure box. The deviation was noted and a table for temperature corrections was made.

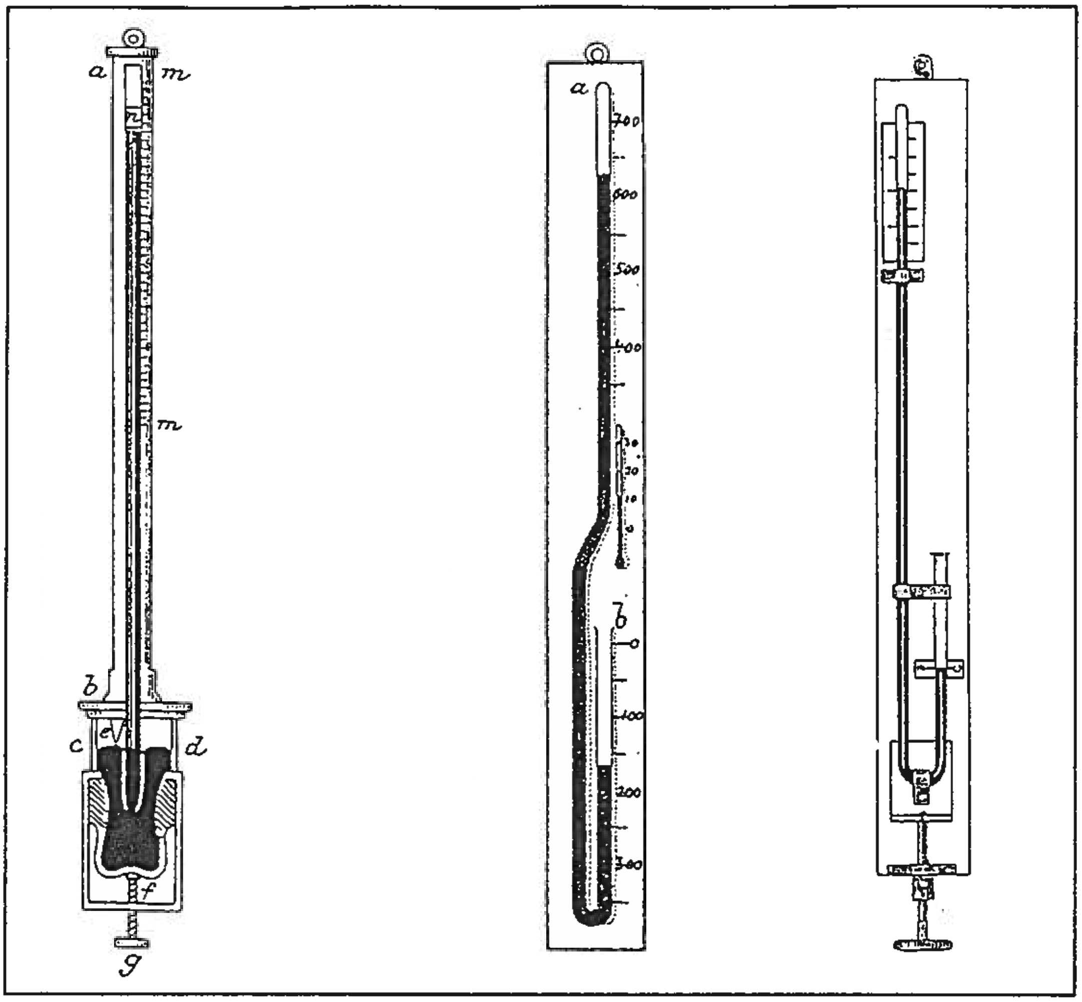

Fig. 5. Adjustable cistern barometer and siphon barometer. Source: H. Mohn: Meteorologi, Kristiania 1903 p. 46 & 48, A. Paulsen: Meteorologi og Geografi, Kbh. 1886 p. 25.

In the 1870s the most common type in Denmark, the Faroe Islands and Greenland was the adjustable cistern barometer, but in the late 19th and through the 20th century a compensated scale barometer, often mentioned as "Adie for Land Stations" or just

"English barometer", perhaps more or less constructed like the Kew type barometer, became more widespread. Types like siphon barometer and marine barometer are mentioned in the files, but mostly for special purpose or short-time replacement.

Figure 5 shows the principles sketch of the cistern and siphon mercury barometer types as they were exposed in textbooks of meteorology from the late 19th century. H. Mohn, from the Norwegian Meteorological Institute, wrote a textbook (published 1872) which was translated to several languages (German, Russian, Italian, Spanish, French, Polish and Finnish) and this book was rendered to the Danish main station observers. The book may give us an idea of the observer's level of knowledge concerning the aim of measurements and the most common instructions of daily instrument handling.

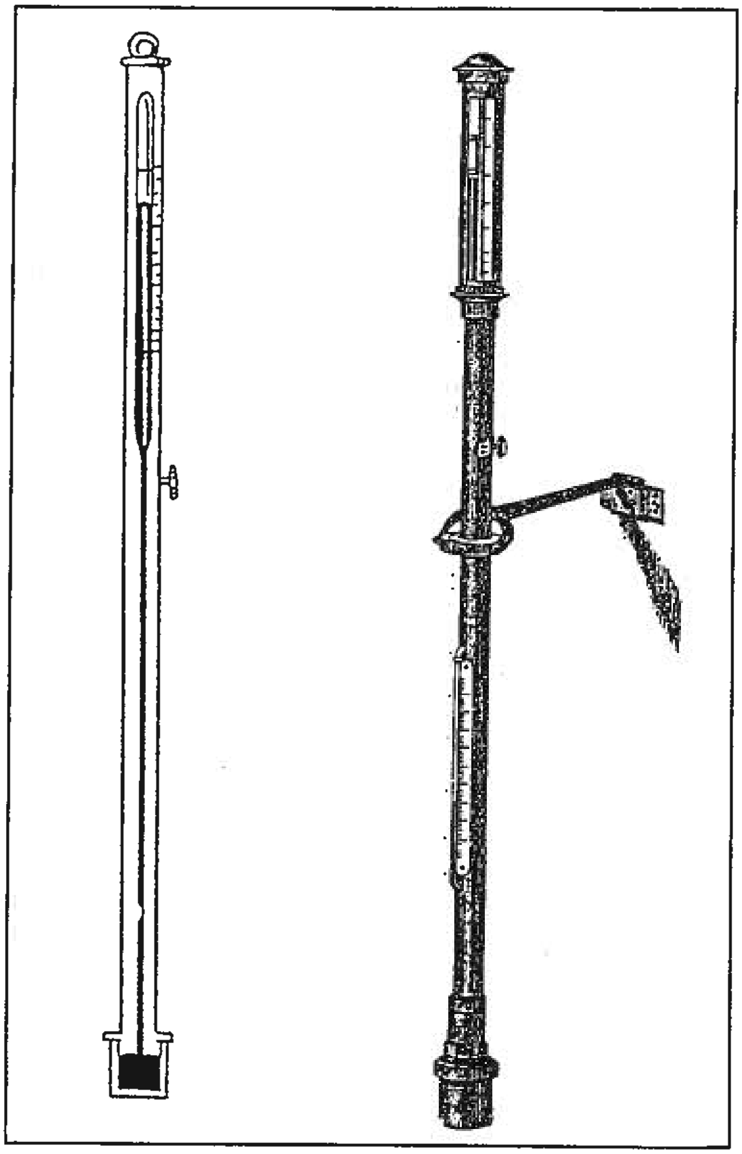

Fig. 6. Marine barometer, Kew pattern. Source: H. Mohn: Meteorologi, Kristiania 1903 p. 49 & R.H.Scott: Elementary Meteorology, London 1883 p. 74.

"Travel barometers", a concept used in 19th century inspection reports, are probably Fortin or Kappler cistern barometers. These are most suitable for travelling, as the leather bag can be pressed up until both tube and cistern are filled with mercury to prevent from intrusion of air during transport.

Occasionally the "travel barometer" was used for estimating height of a station above sea level. At letter, dated 1880 from the assistant director of the Danish Meteorological Institute V. Willaume-Jantzen, refers to an inspection visit in Vestervig at a station located on a school 25 m above sea level. Jantzen and the observer, a local teacher, read the pressure 3 times using the travel barometer in a tripod cardanic suspension, before walking down to the sea (an inlet at Nissum Bredning). 15 Danish inches (about 40 cm) above "daily water lewel" another 3 readings were done and the height was calculated. The result differed 70 cm from the levelling done by the local surveyor. The assistant director was quite satisfied with this experiment, and later on levelling by a surveyor does not seem to be the common method of height determination.

In the 1920s and 30s several Danish files mention the station barometer as an "English barometer", some of which are known to be Kew barometers delivered by Negretti-Zambra or Adie in London.

The instrument invented by Mr. P. Adie in 1854, for use at sea, is commonly known as the Kew barometer. The marine barometer is characterized by a constriction in the tube in order to damp out pumping (oscillations of the mercury caused by movements of the ship). The extreme length of the scale is marked on the instrument, but instead of laying off the true measurements on it the inches or millimeters are shortened from the upper part downwards in proportion to the relative sizes of the diameters of the tube and cistern.

As mentioned in an English textbook (R.H.Scott, 1883) the Kew barometer was coming more and more into use every day, and the Danish observers seem to have received Kew type barometers from the late 19th century replacing the Fortin adjustable cistern barometer. Figure 6 shows the marine barometer, Kew pattern.

Figure 7 shows the Lambrecht model of station barometer used in Denmark, the Faroe Islands and Greenland in the 20th century. These pictures, to some extend used for teaching and instructing observers, are picked from a catalogue of instruments, unfortunately undated and anonymous, but certainly dating before 1948.

Figure 7 is a compensated scale barometer, the scale constructed like the scale of the marine barometer. Similar to the marine and Kew type barometer, the mercury tube of the station barometer is constricted and furthermore supplied with an air trap.

The station barometer (cardanic suspension) was inert to movements. An instruction dated 1910 for the station "North Star Bay" says:

"If the barometer is moved from vertical position, you must wait 4-5 minutes before reading to let the mercury repose."

A vernier scale was used for reading since 1872. A very enthusiastic observer in Nordby, Fanø has described his endeavour teaching a 50 years old housekeeper reading the barometer and using the vernier scale.

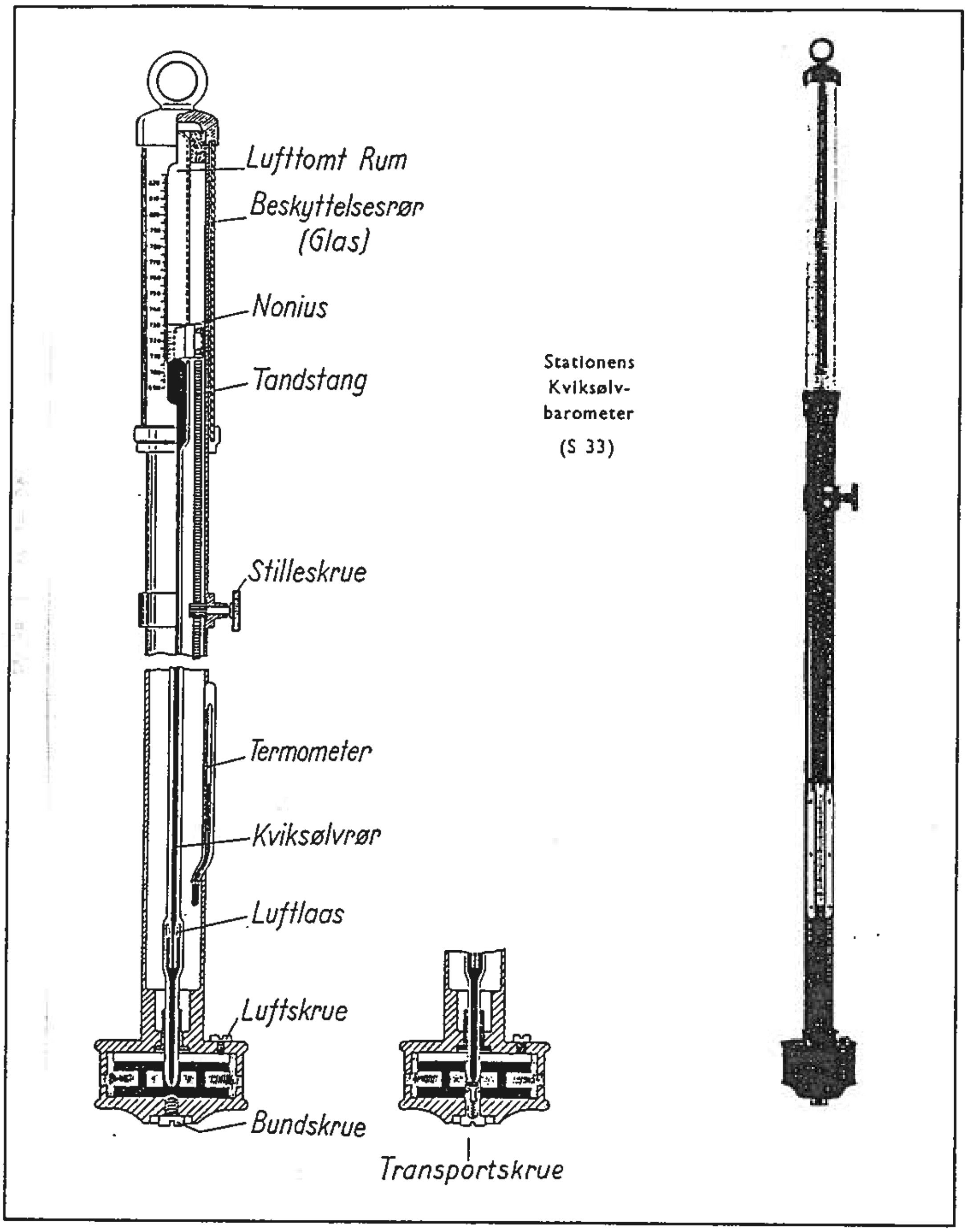

Fig. 7. Compensated scale barometer used by observers in the 20th century, replacing the Fortin or Kappler cistern barometer. Source: Undated and anonymous catalogue.

Heights.

Information about barometer altitude is urgent for the aim of correct calculation of sea level pressure. This request has been offered a great deal of time and attention, but still some barometer levels are rather disputed.

The Danish Meteorological Yearbook has been published annually since 1873. As pressure data were not reduced to sea level it might sound easy to make a complete list of Hb-values (Hb=barometer level) from the series of yearbooks. This was done for a start, but very soon it became obvious that the Hb-values recorded in the yearbook were not quite correct. Still we are forced to rely on the yearbook information if we can not find more reliable sources, but somehow we need to examine the Hb-values by other methods of investigation.

The knowledge of barometer altitude has been obtained from different sources. Occasionally levelling was done by a land surveyor, but more often it was done by the MI-staff. A trial of altitude measurement by using a barometer was described in a letter, and topographic maps might have been used as well.

The levelling carried out by an experienced land surveyor must be the best source of information. This was requested in 1974 to deal with some problematic pressure data from Tórshavn, and 5 barometer sites were levelled by Matrikulstovan (the local cadastral department) within an accuracy of 10 cm.

Apart from this well documented survey it seems as if the MI-inspectors had themselves done most of the levelling. At least nothing about paying surveyors was listed in the 1872-1875 account-books (the years of establishing the climatological stations).

On the other hand Generalstaben (the General Staff, the authors of the Danish Topographic map survey) was asked for information about altitude fixed points in 1872. In spring 1873 the assistant manager had done some sort of levelling between the observer's house and the nearest fixed point. In Fanø, however, he was doubtful if he had found the correct site of the altitude point at the SE corner of the church (the discrepancy was 0.7 meter!)

The method of levelling by using a barometer was described in a letter from the assistant manager in Vestervig 1880. This has been mentioned earlier in the report, and the barometer method differed from the survey by 0.7 m. Jantzen was quite satisfied with this result.

Although a barometer level error of 70 cm seems to be accepted by the meteorological authorities, one become amazed by reading an unchanged barometer level of 25.0 m in the Meteorological Yearbook record of Vestervig 1879-1924, in spite of several well-proved barometer relocations in those years.

So the use of topographic maps has been considered. The contour lines of large scale topographic maps (1:25.000 and 1:20.000) have been studied and the level of observer's houses are estimated. By this method it has been proved, that the base levels of the houses were up to 6 meter below the dubious 25.0 meter Hb-value.

Of course this examination can not lead to any true Hb-values, but the outcome has been discussed in the reports.

Potential errors.

The potential barometer altitude errors have already been stated, but some further sources of error will now be presented.

One source of error was caused by intrusion of air into the barometer tube during transport. Nothing could be done about this, except replacing the barometer by the next inspection visit.

By working out the reports I was wondering how the MI-staff were able to control pressure readings, enabling them to detect instrumental errors. Some series of unexplained instrumental corrections have been applied on the pressure data of Vestervig and Tranebjerg.

Since Tranebjerg is situated right in the middle of Denmark (when you are looking at a map) it seems obvious that the construction of isobar maps might be the key. This was to be explored.

On December 22nd, 1876, the assistant manager Jantzen has imposed a barometer correction of +1.8 mm "*since the Samsø barometer seems to read too low*". According to the Correspondence Journal he hadn't received any letters or messages from Samsø (not even a Christmas card), and nothing is mentioned about inspection travels.

As mentioned in the introduction, the head master of MI, captain N. Hoffmeyer, was very acknowledged for his compilation of daily weather maps. Figure 8 shows the Hoffmeyer maps of December the 21st and 22nd, but the Samsø pressure is without the Jantzen correction mentioned above. The 750 mm isobar is curling south of Fanø and to the north through Samsø, since the Samsø sea level pressure was 1 mm below the Fanø value.

In order to compile a more detailed isobar map the 8 am. readings are listed in table 2.

Figure 9 shows isobar maps produced with table 2-listed values. The upper map is without the +1.8 mm correction for Samsø and the lower with this correction. It seems as if the +1.8 mm correction will smooth out the course of the 750 mm isobar.

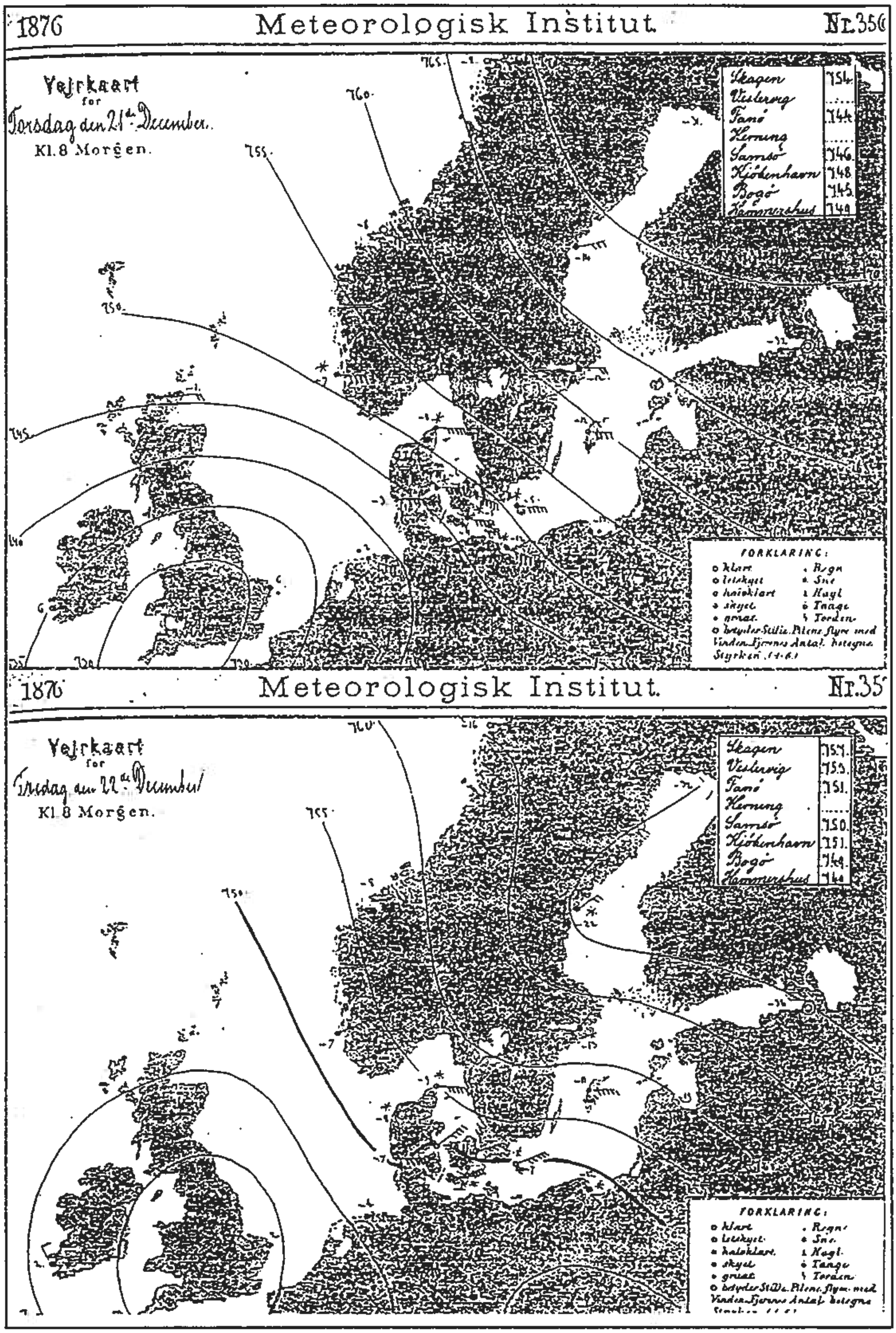

Fig. 8. Weather maps for 1876, December 21st and 22nd. Compiled By N. Hoffmeyer. Source: DMI.

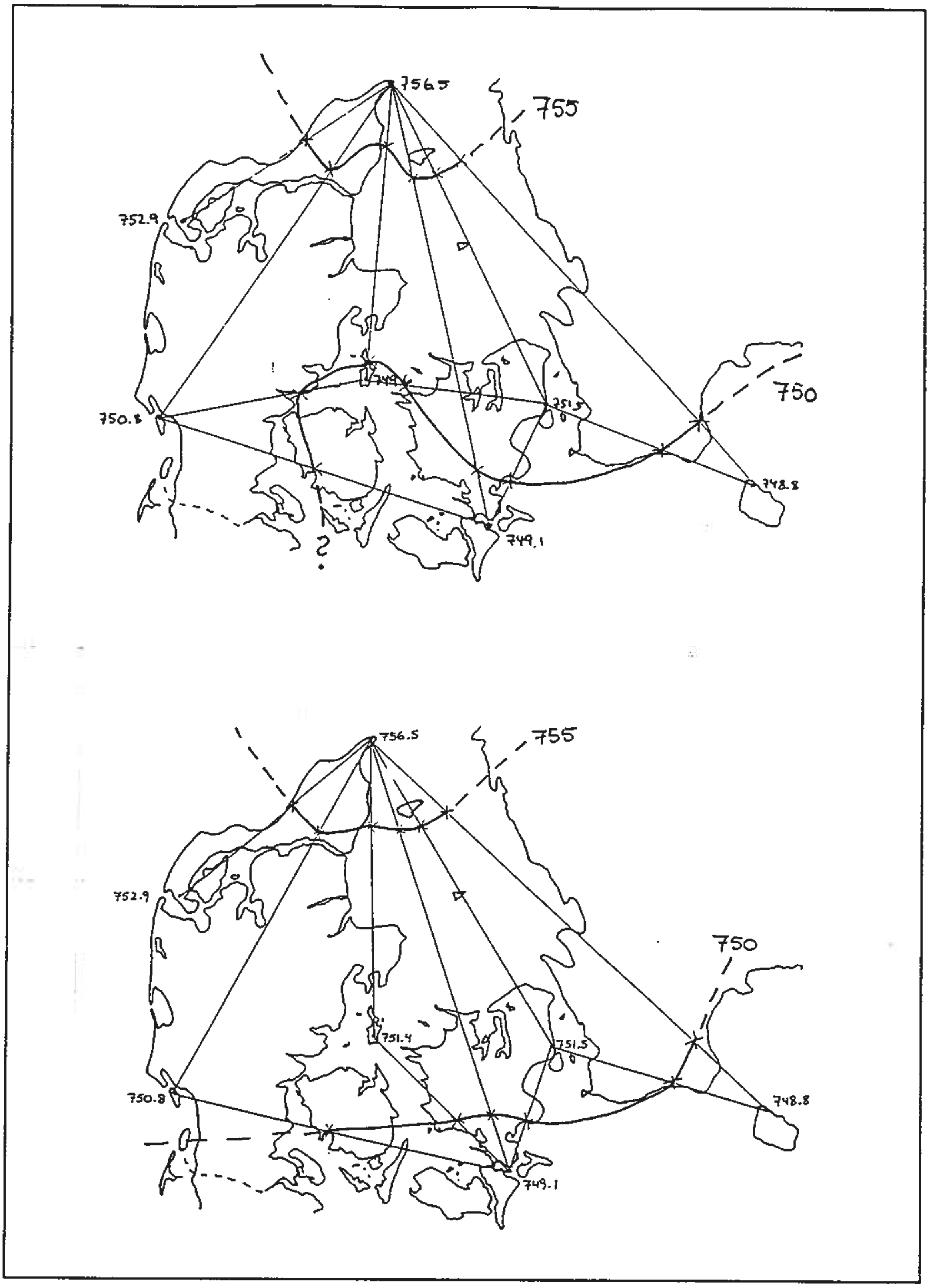

Fig. 9. Isobar maps of December 22nd, compiled by MLB. The upper map is without Jantzens corrections (like the Hoffmeyer map), and the lower with +1.8 mm correction for Samsø.

We still don't know if this method was used by Jantzen in 1876. Furthermore the correction was imposed on all pressure readings for the rest of the month.

Since the Jantzen correction can smooth out the curves on December 22nd, what happens to another day of December, for example the 30th?

Station	Hb, meter	Pressure at 8 am. Dec. 21st	Temperature at 8 am. Dec. 21st	Sea level pressure Dec. 21st	Pressure at 8 am. Dec. 22nd	Temperature at 8 am. Dec. 22nd	Sea level pressure Dec. 22nd
Skagen	3,1	753,5	-8,1	753,8	756,2	-8,9	756,5
Vestervig	47,4	743,1	-7,0	747,5	748,3	-8,4	752,9
Fanø	5,5	743,0	-2,9	743,5	750,3	-6,4	750,8
Samsø	16,8	744,9	-3,9	746,5	748,8*)	-7,7	749,6*)
Copenhagen	13,3	747,0	-5,4	748,3	750,2	-7,4	751,5
Bogø	26,7	743,0	-4,0	745,5	746,6	-6,1	749,1
Sandvig	15,1	747,8	-4,5	749,2	747,4	-6,5	748,8

*) These are uncorrected values. The corrected values should be added 1,8 mm, i.e. 749,8 and 751,4 mm.

Table 2. Barometer readings and sea level pressure for December 21st and 22nd, 1876.

Figure 10 shows the Hoffmeyer map and the "Jantzen-corrected" map on December 30th. The 750 isobar line is curling across Denmark in two quite different manners.

So some of the corrections applied by the MI-staff are still unexplained. The Samsø barometer had caused a lot of trouble in those years, it was cleaned, replaced and even tested through a period of double barometer readings (one Fortin barometer no. 13 and one "double-barometer" no. 2).

In 1881 it was replaced by a new barometer, Adie no. C 599.

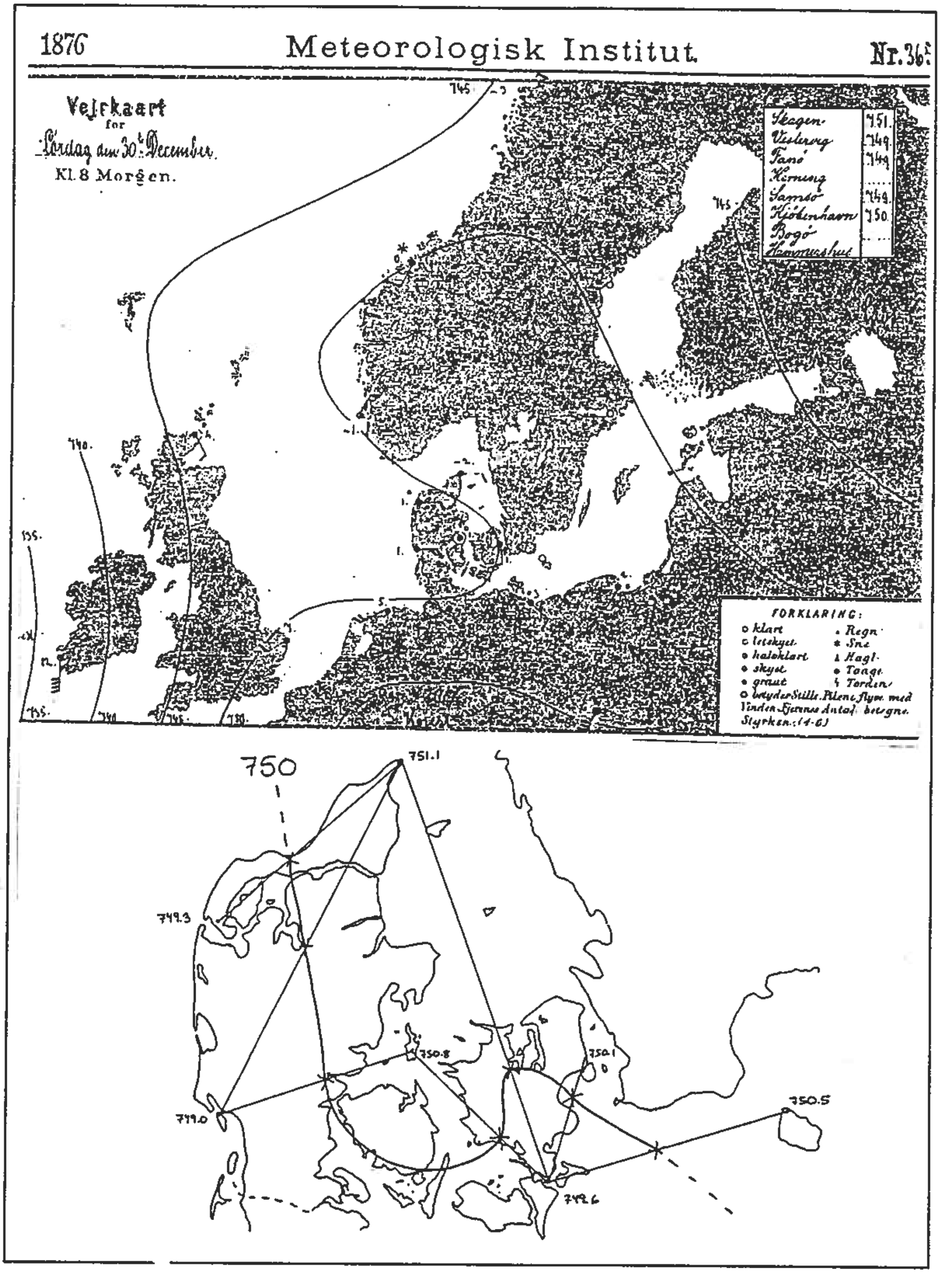

Fig. 10. Hoffmeyer map and corrected map for December 30th, 1876. The lover map was compiled with a correction of +1.8 for the Samsø values. The outcome is quite different! Source: DMI and MLB 1994.

Temperature.

The temperature has been recorded using 4 types of thermometers: Dry, wet, minimum and maximum. Except for the station in Copenhagen, Landbohøjskolen, the instruments were shelteret by a cage. Between 1913 and 1928 most of the Danish climatological stations were equipped with a Stevenson screen, and this event normally caused a break in the temperature series.

Instruments and replacement frequency.

The first dry and wet bulp thermometers are described in the 1872 Instrumental Journal. They were delivered by various instrument makers, the scales were graduated into 1/5°C and the negative degrees were complement to 100. This means that -2.4° was read on the scale as 97.6°C.

station number	Name	Bar.	T	Tw	Tn	Tx	Notes
21100	Vestervig	5	4	11	18	33	
25140	Nordby, Fanø	9	4	3	5	20	
27080	Tranebjerg	6-7	10	11	7	14	
30380	Landbohøjskolen/ Copenhagen	?	7	8	19	26	barometer information unstated
32025	Hammeren Fyr	1	3	-	11	12	started 1880
32030	Sandvig	2	4	4	7	15	
33060	Hoyvík	4	3	3	13	22	started 1921
33071	Tórshavn	5	1	3	3	3	stopped 1925
33000	Mykines Fyr	-	1	-	2	5	started 1911

Table 3. The approximate number of replacements of barometer (Bar.), dry thermometer (T), wet bulp thermometer (Tw), maximum thermometer (Tx) and minimum thermometer (Tn) in the period 1872-1972. Source: MLB/DMI.

The manufacturer is rarely noticed, but Nissen, Geissler and Åderman instruments have been used.

The index-thermometers were shorter than today and less fine graduated.

The minimum thermometers were manufactured by Geissler or Nissen and they were resting horizontally on the back wall of the cage or in a mobile axis stand.

Most of the older maximum thermometers were vertical, at least until the introduction of the Stevenson screen. Some vertical maximum thermometers were unreliable as the index might slide down. The maximum thermometers were manufactured by Nissen, Jacob, Adie, Negretti-Zambra, Geissler and Fuess.

All instruments were tested before rendered to the observer and the instrument errors were noted in a journal. Since the correction might change (perhaps due to a contraction of recently blown glass tubes) the observer was ordered to probe the zero point by embracing the thermometer bulp with a melting snowball.

The frequency of replacement has been examined as far as possible. Table 3 is a summary of replacements in the 1872-1972 century. The Greenland stations are not listed since no studies have been carried through.

The open shelter.

Instruments for temperature records should be exposed to let their readings give the true air temperature. Of course the instruments should be sheltered from direct sun and rain or snow, but further sources of error are radiation from the surrounding objects.

A sort of open shelter was used for thermometer exposure at Landbohøjskolen in Copenhagen at least in the late 19th century and perhaps until the replacement by a Stevenson screen in 1919. The open exposure was not recommended by the Meteorological Institute, but the observations at Landbohøjskolen, starting 12 years before the establishment of the Meteorological Institute, was under the authority of the Royal Danish Agricultural Society.

No photographs or drawings of the open shelter has been found, but a description in the 1876 Meteorological Yearbook gives some information about proportions:

> "... a double plank-shelter, shaped like a horseshoe and opening north. The internal size of the shelter is 0.7 meter wide and 0.5 meter deep; the height is 1.6 meter and the lower edge is 0.2 meter above the surface of earth. The top is partly covered by oblique slats. The bulps are 1 meter above surface and and 0.15-0.25 meter in front of the back wall (south wall)" (Meteorological Yearbook 1876 p. XIV).

This description was written in Danish, but surely the phrase "oblique slats" sound as odd in Danish as in English. So the description of the roof is rather insufficient, but a reconstruction has been sketched in figure 11.

The open shelter was standing at Landbohøjskolen, Copenhagen at least in 1860-95. The temperature series shows some disturbances without any satisfactory explanations, but no replacements of exposure methods has been documentated until the mounting of a

Stevenson screen in 1919. The institution erected a number of buildings in the 1880s and 90s and the shelter might have been moved several times, but nothing is specifically mentioned in the files.

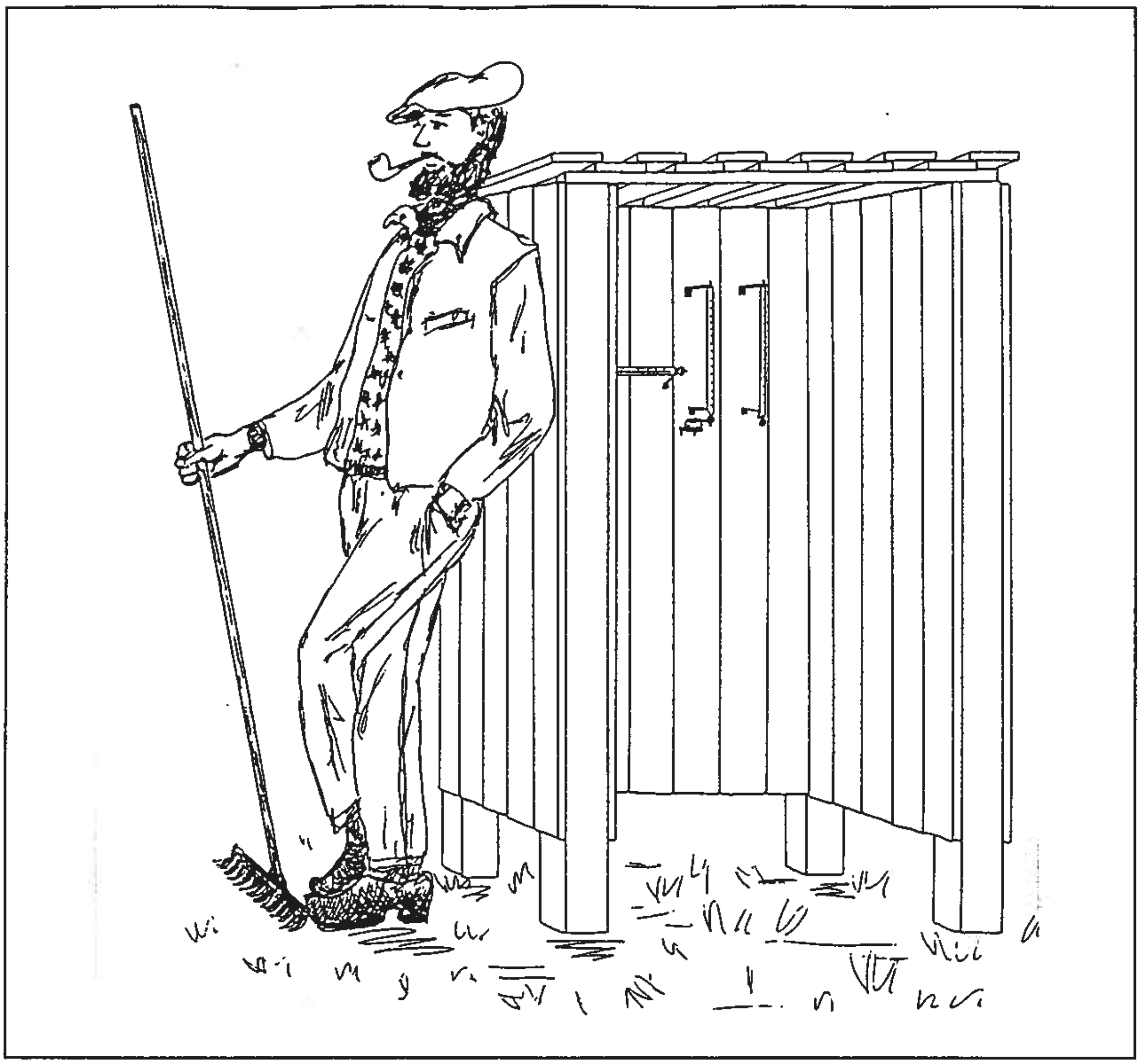

Fig. 11. Reconstruction of open shelter at Landbohøjskolen. The roof is obviously not quite like the description. Source: Meteorological Yearbook 1876. MLB 1994.

Observations in 25140 Nordby, Fanø was carried out under the authority of the Royal Danish Agricultural Society from 1871 to October 1872 and the thermometers were exposed to open air until the delivering of a louvred wall cage from the Meteorological Institute.

The window cage.

First some vague notes referring to a "window cage" was rejected. Being very concerned about the thermometer corrections and the zero point probes the image of a MI-inspector mounting a screen outside a window seemed like nonsense.

Nevertheless this kind of exposure was described by H. Mohn from the Norvegian Meteorological Institute in his 1872 textbook. So the contingency of the window cage exposure had to be considered.

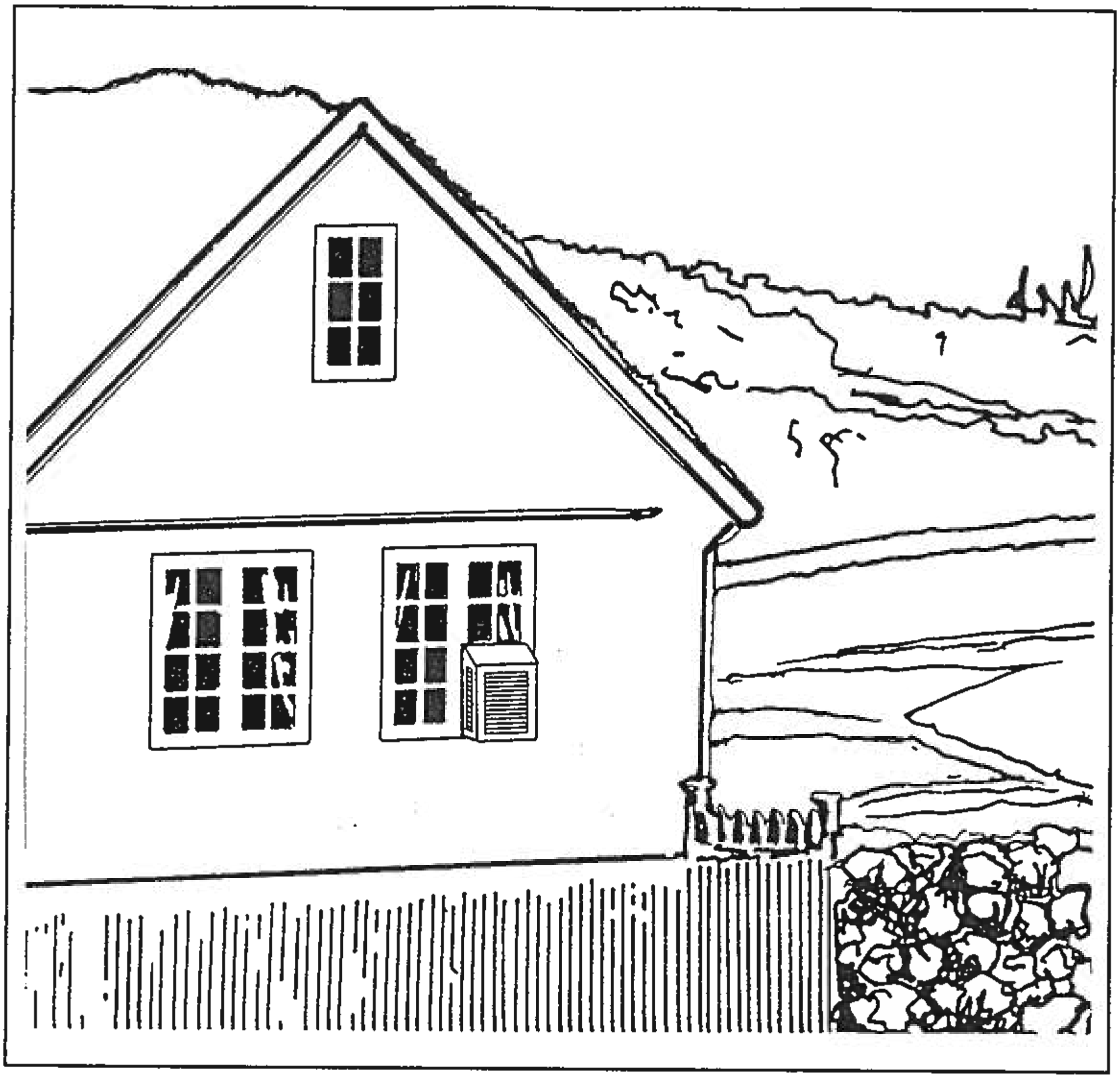

Fig. 12. Tórshavn Realskole with a window cage 1872. The school is seen from the north. A louvred window cage has been imposed on a photo dated 1865. The school was a black painted wooden building, but the black colour is not pasted on this picture. MLB 1994.

There are several clues leading to the fact, that window cages were mounted in 33071 Torshavn Skole, 27080 Tranebjerg and 32020 Sandvig from the start, whereas 25140 Nordby and 21100 Vestervig were equipped with wall cages.

The thermometer cages are described in the "1872 Instrumental Journal", but few of them were pictured. The window cage was louvred with a sloping roof and inside equipped with some brass strings for fixing the thermometers and a back plank for fastening the index thermometer. The size was not mentioned, but presumably each cage was adjusted to the proportions of the window.

Since we have photos showing louvred wall cages from Upernavik and Tórshavn it is easy to adapt this image to the windows of Tórshavn Realskole. This has been done in figure 12.

Tórshavn Realskole, today a booksellers store, was photographed in 1865. It is sited right to the north of the church and it was, and still is, a black painted wooden building.

A garden was laid out to the west of the school, not a very common phenomenon in the Faroe Islands, but the senior master, Louis Bergh, came from Denmark. There were no grown-up trees around in those days, but today there are some trees surrounding the building.

Tranebjerg and Sandvig in Denmark both had window cages. Possibly the cage in Tranebjerg was moved to a wall in spring 1874 or in summer 1876, the evidence may show up during homogenisation of the temperature series.

In Sandvig the window cage exposure was witnessed by a letter dating October 31st, 1875, from the third observer, but no evidence of a relocation of the station is seen until December 1905. Actually we do not know the exact position of the Sandvig station in the years of 1872-1905.

Figure 13 is pure fiction. A north facing window cage is seen from the study of the doctor in Tranebjerg 1872. Outside his garden fence was open land. Wet, dry and minimum temperature were observed since December 1872, and maximum temperature since April 1874, but the vertical maximun thermometer was placed in a "single" thermometer cage (to be described later).

From the observer's point of view it might be attractive to study the temperature just by looking through the window. As explained by Mohn (1872) the cage opened with the window, but either it has to be open at one side or some other way of enabling the observer to handle the instruments (adjusting the minimum thermometer and moisting the wet bulp thermometer) must be considered.

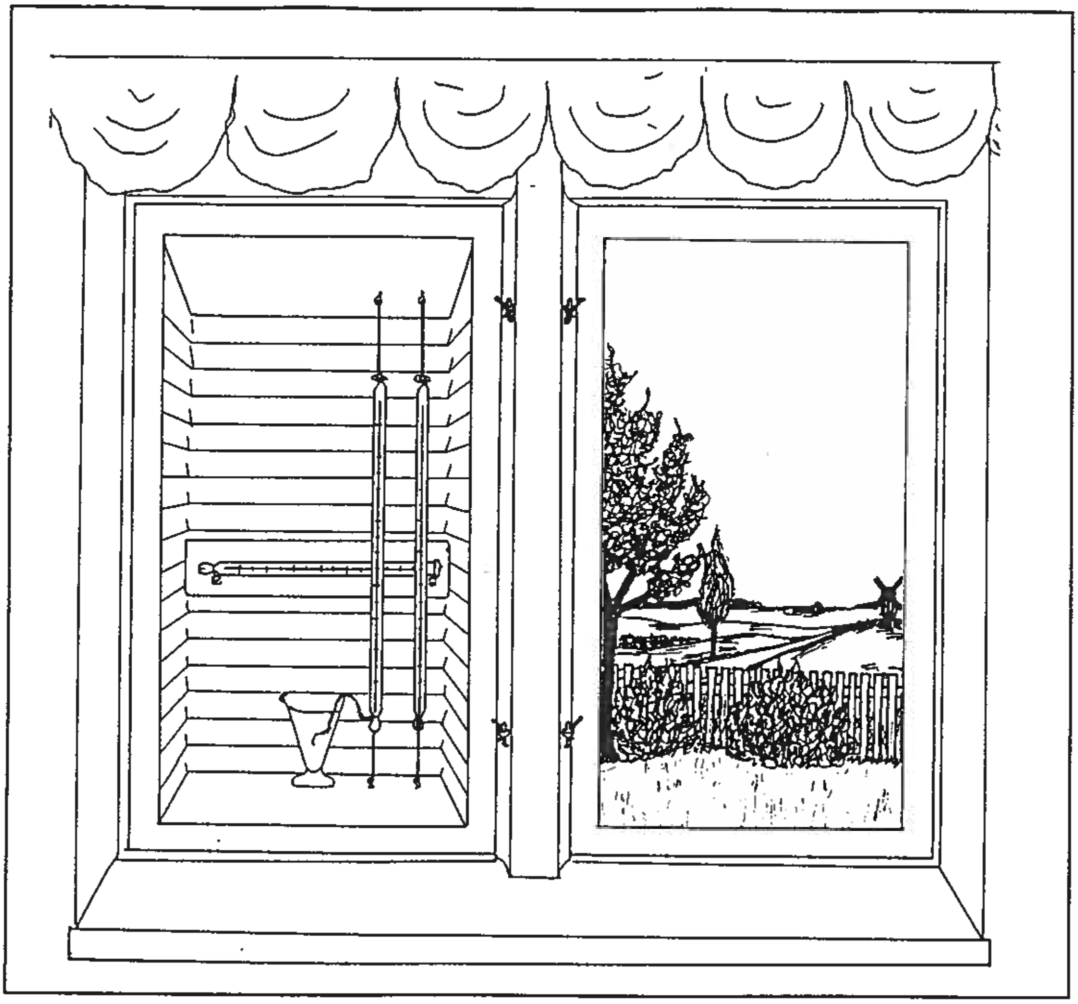

Fig. 13. An image of a window cage seen from inside a house. MLB 1994.

The front of the cage might open downwards or sidewards; this could not be seen on either of the photos.

The rather damaged photo from Tórshavn 1909 shows a small louvred cage in profile, and the contours are represented in figure 14. This is the image imposed on the window in figure 12. In fact the 1909 Tórshavn photo showed two louvred cages mounted on either side of a "henhouse", presumably sheltering the Rung automatic thermograph. The station was no longer at the school, but the louvred cages were moved to the third observer's house in 1907.

The photo is too damaged to be reproduced in this report; no negatives could be found and the only known copies are found in Rigsarkivet, Copenhagen. The photo was taken by Dan la Cour on an inspection visit to Tórshavn on his way to Iceland.

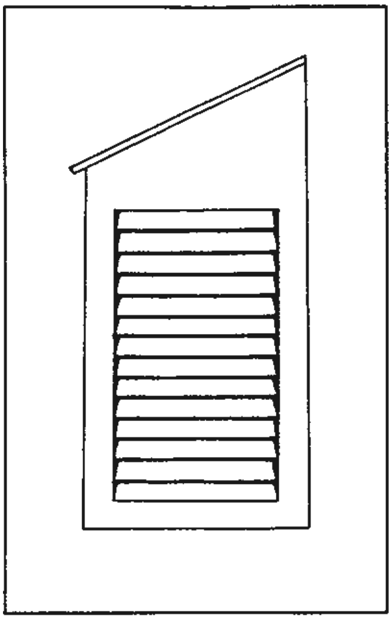

Fig. 14. Contours of a louvred cage in Tórshavn 1909. MLB 1994.

The louvred wall cage.

In 1872 the main stations were equipped with thermometer screens mounted on a window or on a north facing wall. Unfortunately we have very few photos and no drawings showing this type of thermometer exposure. A photo from Upernavik 1923 shows a louvred cabinet with a sloping roof. Figure 14 shows a sketch based on this photo.

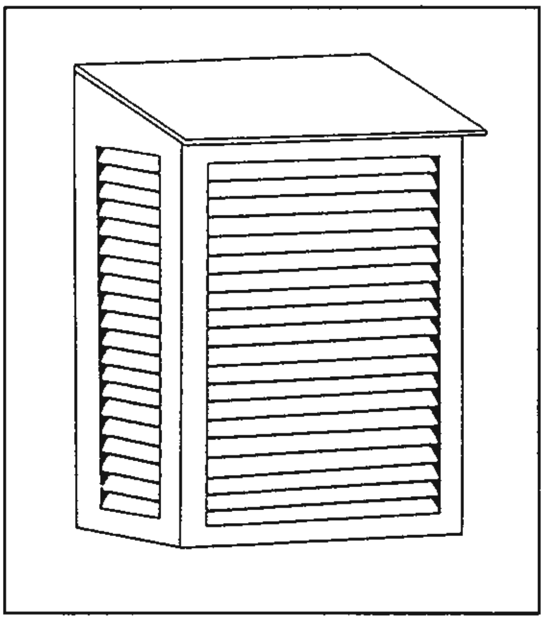

Fig. 15. Louvred wall cage. The sketch is based on at photo from Upernavik 1923. MLB 1994.

The 1872 Instrumental Journal describes the louvred wall cage like the window cage, but some of the wall cages are even designated by size. The inside proportions of cage no. 12 were: 18 1/4" x 11" x 8" and of no. 22: 20" x 13" x 9" (Danish inches).

Using a double louvred construction (figure 16) for the sides and the front of the cabinet the inside and outside proportions are presented in table 4.

Table 4.	inside	proportions	outside	proportions
	cage no. 12	cage no. 22	cage no. 12	cage no 22
height, cm	47.7	52.3	50.7	55.3
width, cm	28.8	35.3	37.8	44.3
depth, cm	20.9	23.5	26.9	29.5

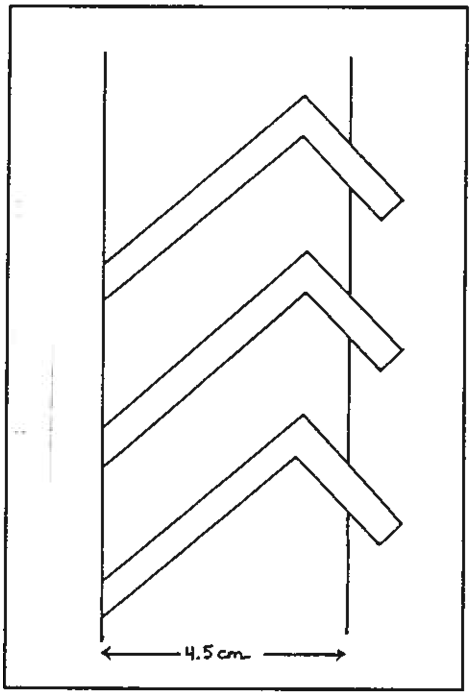

Fig. 16. Profile of a 1960 mounted louvred screen. MLB 1994.

Now these two cages can be pictured. Figure 17 and 18 are sketches based on the image from the two mentioned photos and the sizes from table 4. The sloping of the roof and the number of slats are in between the Tórshavn cage (14 slats) and the Upernavik cage (20 slats).

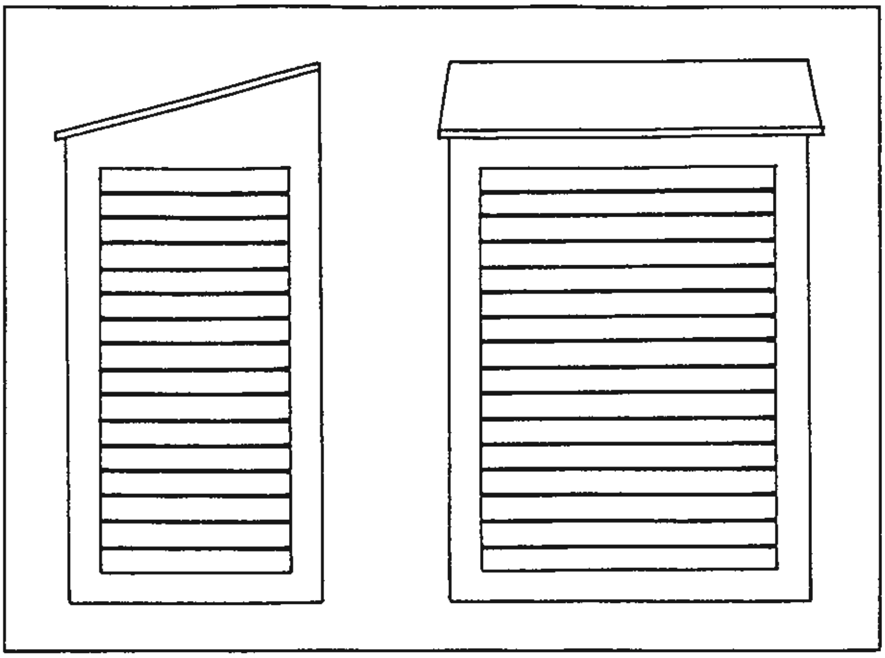

Fig. 17. Louvred wall cage no. 12, reconstruction. The proportions are (50.7 x 37.8 x 26.9) cm, there are 16 slats and the roof is sloping 17°. MLB 1994.

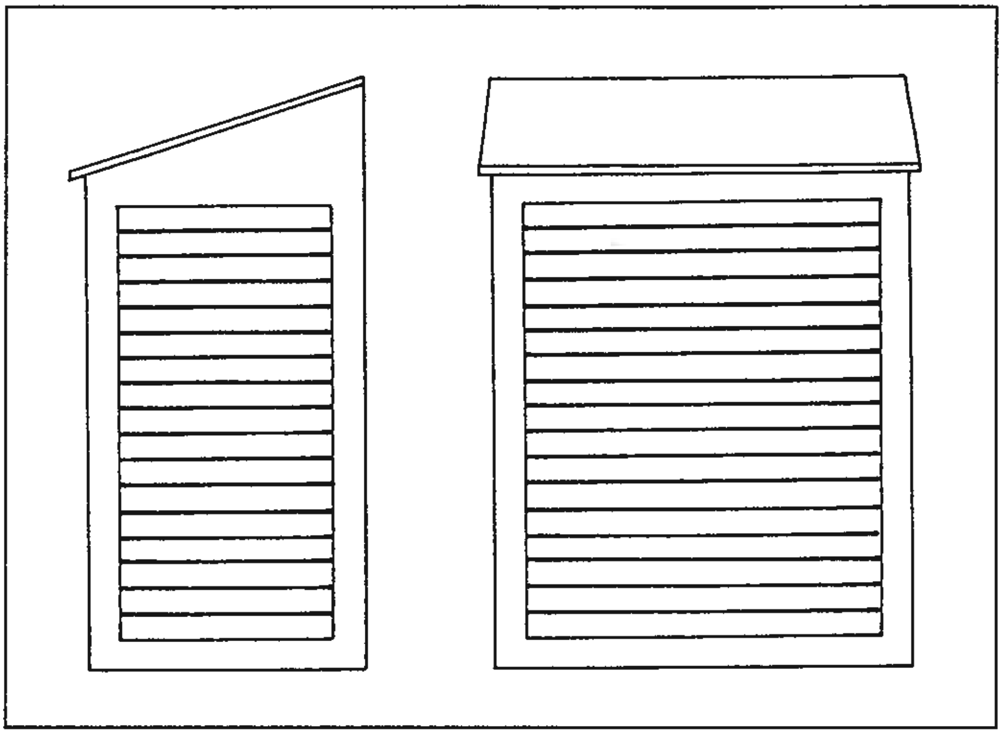

Fig. 18. Louvred wall cage no. 22, reconstruction. The proportions are (55.3 x 44.3 x 29.5) cm, there are 17 slats and the roof is sloping 17°. MLB 1994.

The "single" and "double" wall cage.

The 1874 Meteorological Yearbook gives some information about thermometer cages, and it is announced that a main station was equipped with a "capacious louvred screen" whereas other climatological stations had smaller cages with a front window. This type of cage (figure 19) was pictured in the 1874 Yearbook.

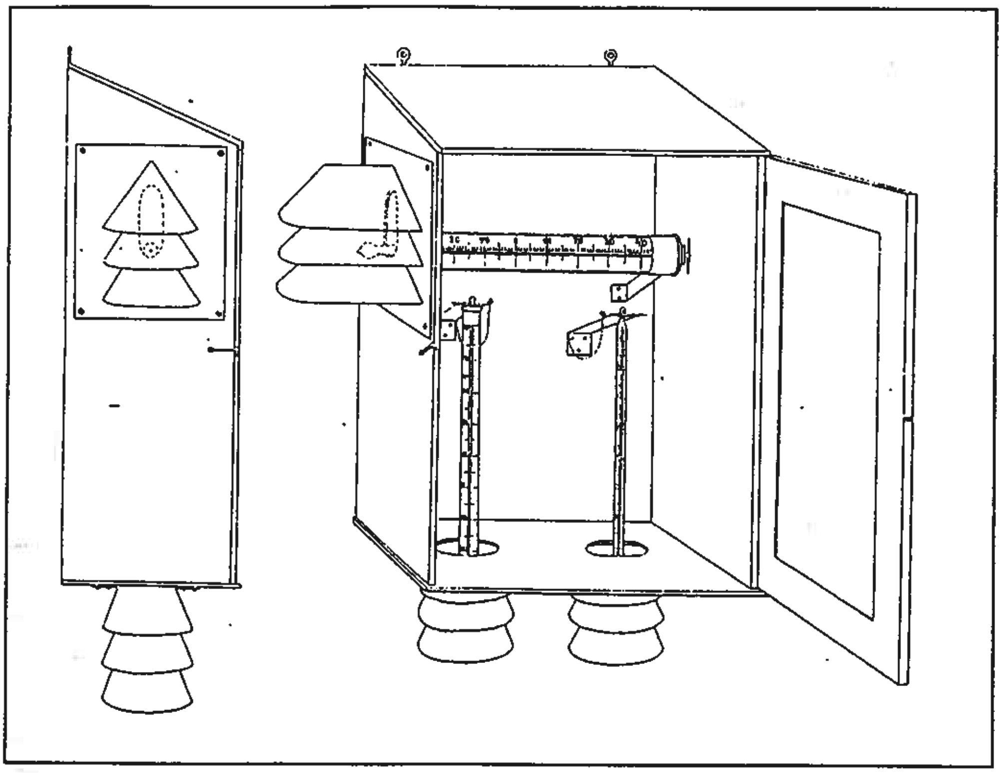

Fig. 19. A "double" thermometer cage with minimum, vertical maximum and dry bulp thermometers. Source: Meteorological Yearbook 1874 p. VII.

Comparing this figure with the 1872 Instrumental Journal descriptions it is noticed, that two or even three sizes of cages were used. The sizes are mentioned as "single", "double" and "triple" cages according to the number of holes in the bottom of the cage. A triple cage was mounted outside the Meteorological Institute and besides only one station (Vamdrup) was equipped with a triple cage. Although the cage in figure 18 gives room for three instruments it is not a triple cage, since it is proportioned for only two holes in the bottom.

The holes were meant to give the air access to the bulps below a shelter of zinc wings.

A photo, beyond any doubt showing a single and a double cage in Grimstadir, Iceland, was taken by Dan la Cour on his 1909 inspection visit. Furthermore a couple of undated photos have been found showing a double cage hanging on a brick wall.

With the average size of a Danish brick being 5.2 cm in height and using the scale mentioned on the 1874 Yearbook picture, the estimated proportions of single and double cages can be presented in table 5.

Table 5. (estimated sizes)	Double cage M.Y. 1874	Double cage Grimstadir 1909	Single cage Grimstadir 1909	Double cage on brick wall (photo)
Front side height (cm)	41.6	42.3	42.3	41.4
Back side height (cm)	48.8	48.2	48.2	-
Width (cm)	31.2	31.0	17.4	31.4
Depth (cm)	16.8	-	-	-
Roof sloping	22°	(22°)	(22°)	-

According to some instructions for observers (from the 1880s), the single cage was used for safe keeping the instrument during transport. The transformation of the cage, the fitting of the sheltering zinc wings, the arrangement of the thermometer and the hanging of the cage was described.

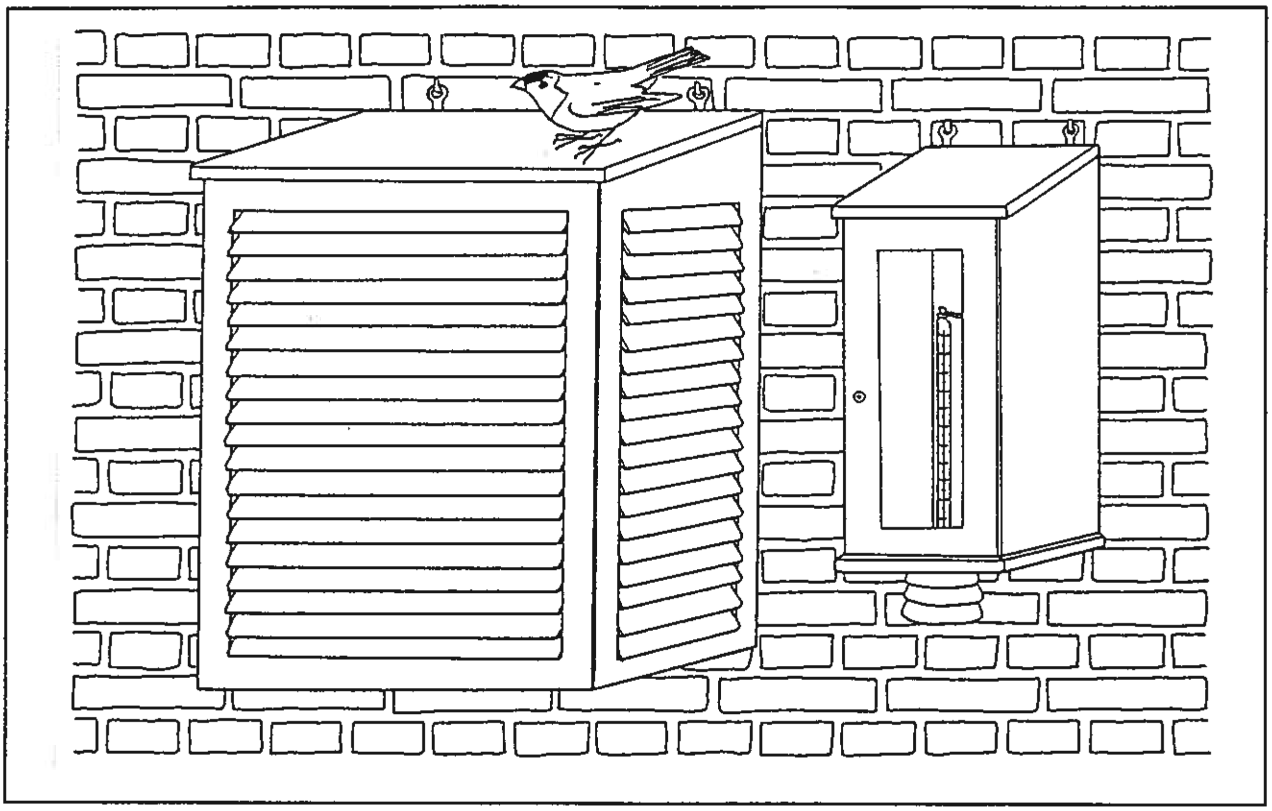

Fig. 20. A louvred wall screen no. 22 and a single cage, Vestervig 1874. MLB 1994.

A vertical maximum thermometer and a single cage were in 1874 sent to Tranebjerg as well as to Vestervig, Nordby and Sandvig.

On the four mentioned stations the louvred screens (either on windows or on walls) were supplemented with a single cage exposure for vertical maximum thermometers since 1874.

Figure 20 shows what might have been the exposure of thermometers in Vestervig 1874. The inside and estimated outside proportions of the louvred wall screen no. 22 are known (table 4) and the single cage size is mentioned in table 5. The 5.2 cm high bricks are shown as a scale; the Vestervig farmhouse might have been plastered or perhaps it was a half-timbered house in those days.

A double cage was used in Nordby, Fanø for experiments in 1881 (a west wall exposure to be compared with the north wall louvred screen), but in Vestervig two double cages seem to replace the former thermometer exposure in 1892.

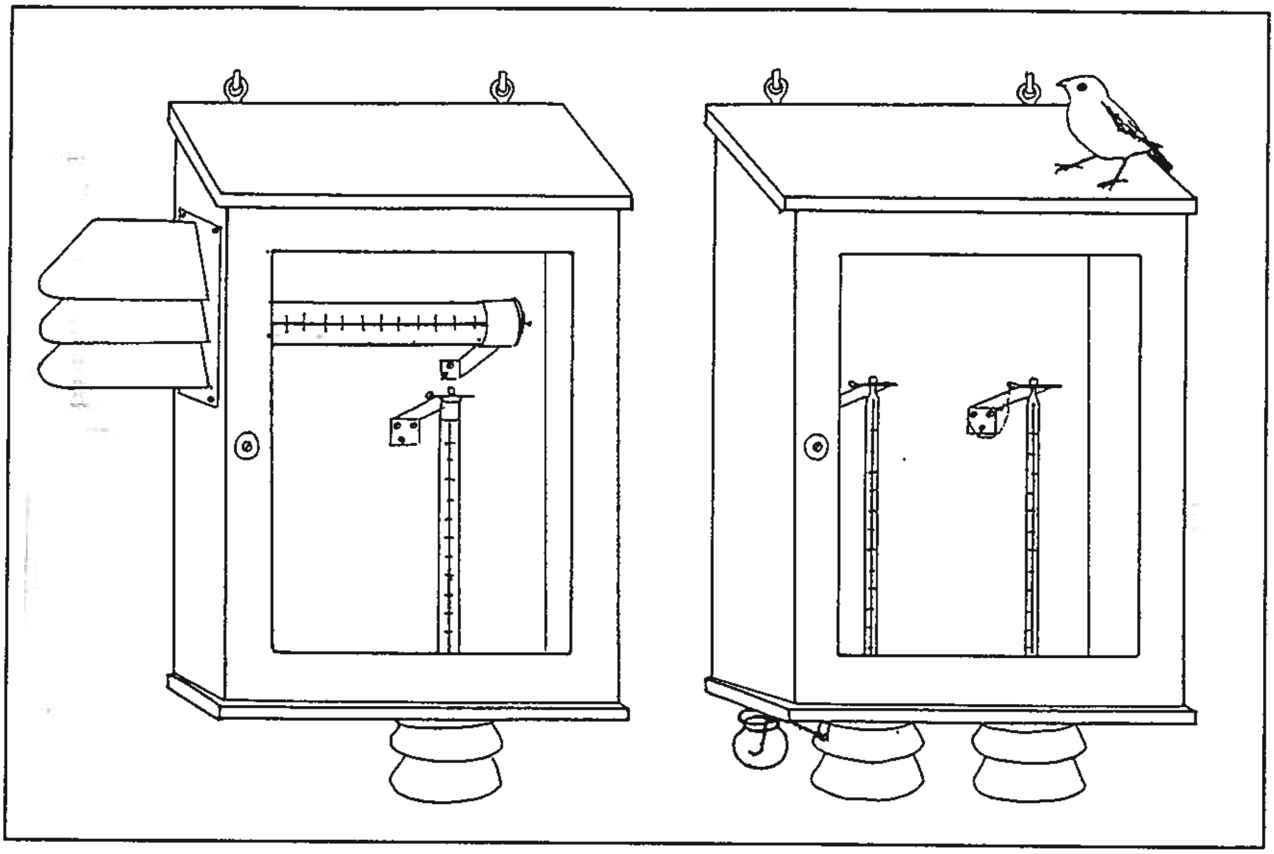

Fig. 21. Two double cages, Vestervig 1892-1924. MLB 1994.

A double cage with a minimum and a vertical maximum thermometer was brought to Sandvig on an inspection visit 1876, and the lighthouses of 32025 Hammeren Fyr and 33000 Mykines Fyr were both equipped with double cages from the start.

The Stevenson screen.

The replacement from the louvred screens and wall cages to the Stevenson screens started before World War I. This replacement certainly leads to a "break point" in the temperature series. The Stevenson screen was situated at some distance from the observer's house, whereas the cages were much more influenced by heating or radiation from the house walls and windows.

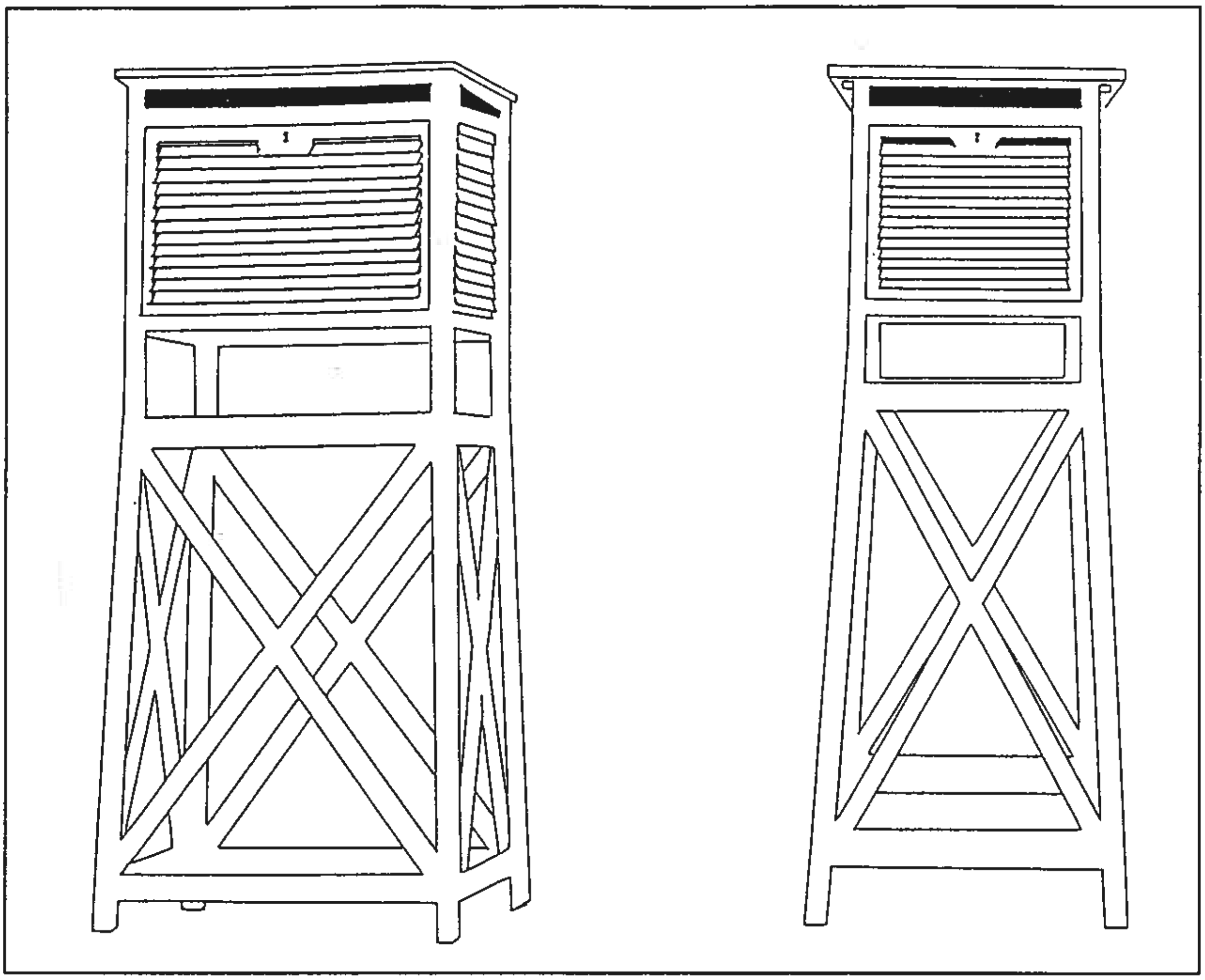

Fig. 22. Two Stevenson screens of various sizes erected after World War II. The sketches are based on photos. MLB 1994.

In Sandvig the Stevenson screen replaced the former exposure in 1913 at the address of a teacher, who had been observing since 1905, presumably in the same house.

The latest replacement was in Nordby, Fanø in 1928. The replacement took place at the same time as the take over of a new observer, so simultaneously it was a replacement of exposure and a relocation of site.

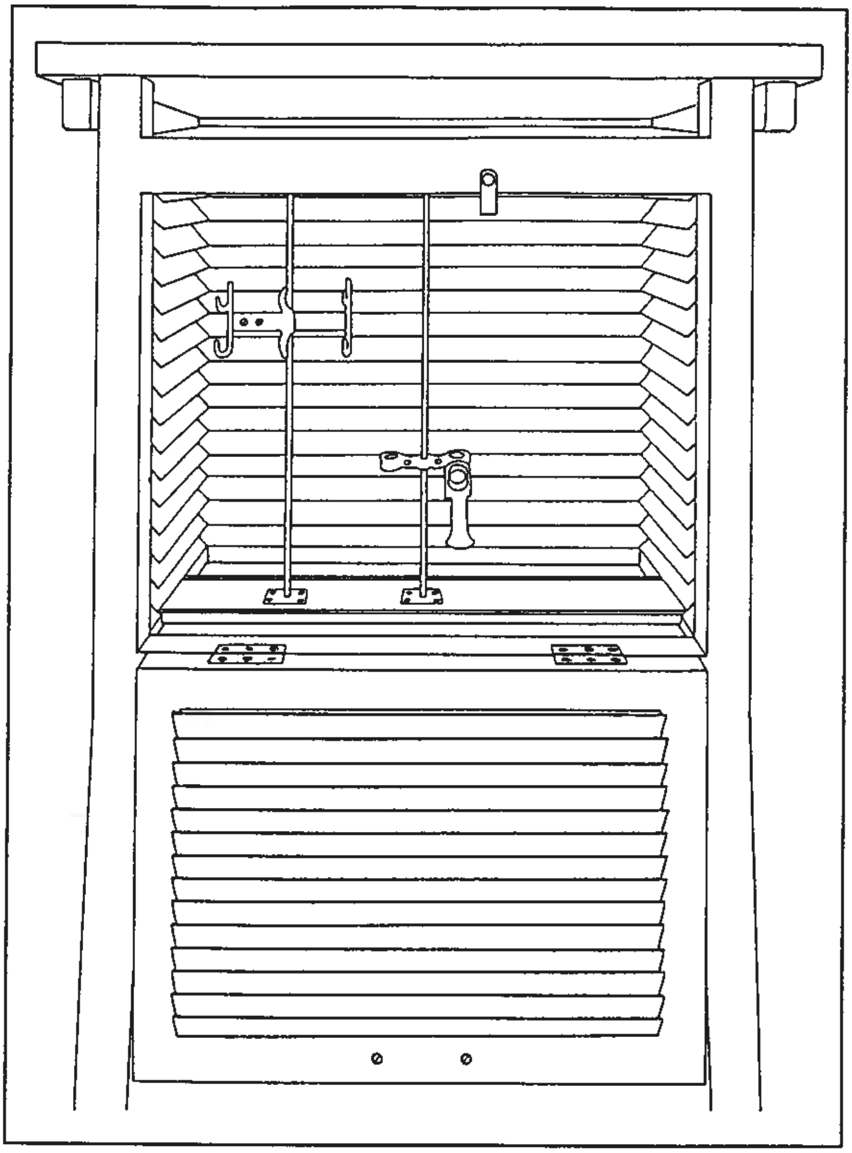

Fig. 23. Stevenson screen from Vandel, mounted in the 1960s. MLB 1994.

The first models of Stevenson screens have not been pictured, nor even is the size mentioned in any file, but apparently none of them have lasted for more than 40 years. In the late 1940s the Stevenson screens were renewed and today we have photos showing some of these screens. Figure 22 is sketches based on two different photos, showing screens of various sizes with the front sides opening downwards.

Figure 23 is a screen erected in Vandel in the 1960s and renewed in 1994. This screen was rather damaged, but before scrapping it, the screen was measured and a fairly true proportioned sketch was constructed. Of course the instruments were removed, but the left-over stands still show the arrangement of the four thermometers.

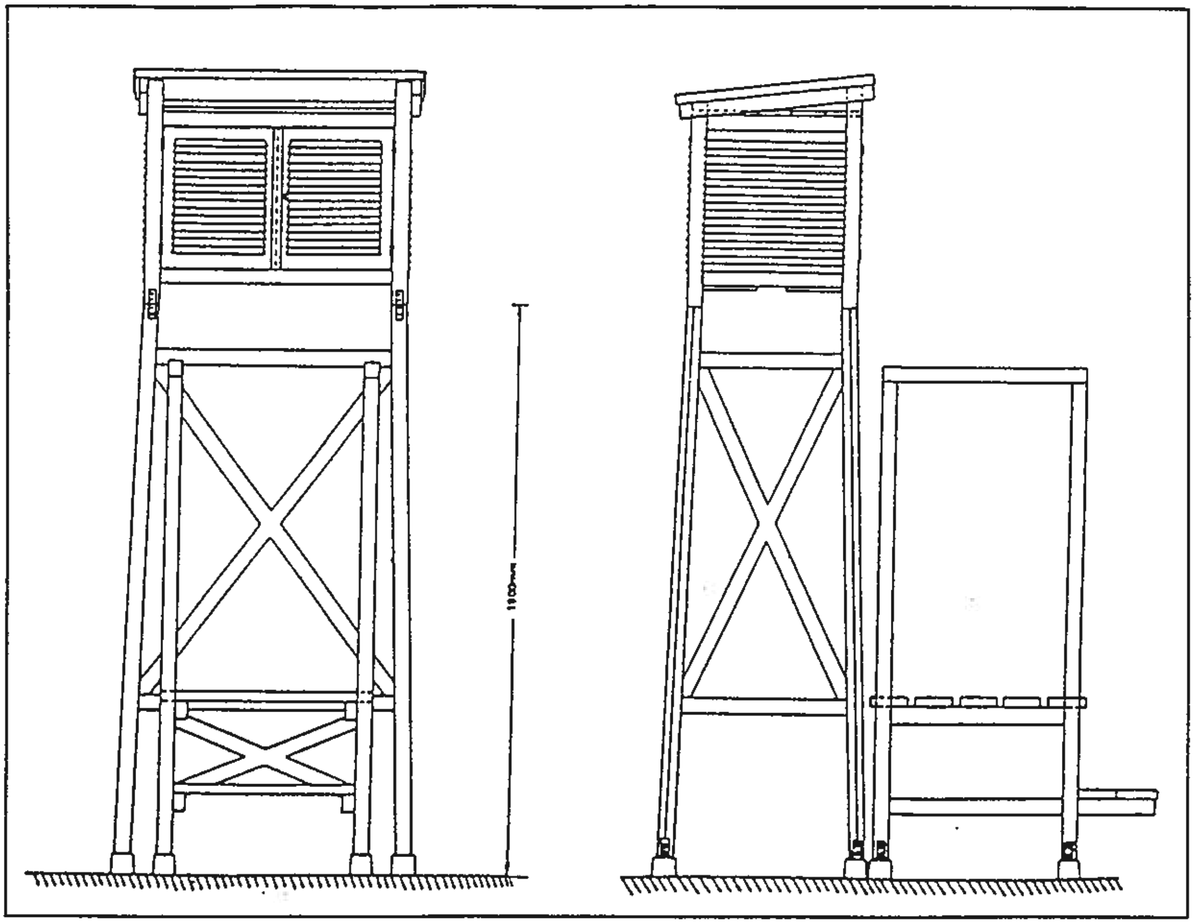

Fig. 24. The 1971 Stevenson screen model. Source: DMI/Materialforvaltningen.

In 1971 a new model of a Stevenson screen was constructed at the Danish Meteorological Institute. This screen in bigger than the former ones and it has two sideward opening front gates. The screen is pictured in figure 24.

Precipitation.

According to Scott (1882) the concept of precipitation covers such phenomena as dew, fog, mist and clouds as well as rain, snow and hail. Any attempt to measure e.g. the amount of dew quantitatively must be very difficult, but rain, snow and hail being in the liquid or solid state when falling are measured in gauges.

A rain gauge consists of a funnel to catch the rain and a bottle to receive and collect it. The water is always measured in a graduated glass, which shows the true millimeter for the aperture of the gauge. Inside the funnel is a delivery-tube, bent like a V shape in order to prevent evaporation from the receiver below.

The most widespread rain gauge in Denmark, the Faroe Islands, Greenland and Iceland before World War I was the rain gauge constructed by N.J.Fjord from the Royal Danish Agricultural Society. This gauge is shown in figure 25, and the Danish Meteorological Institute still has one specimen left.

Some years before World War I the Hellmann precipitation gauge was introduced, and between 1910 and 1925 this model was distributed to the Danish and North Atlantic stations.

The Fjord rain gauge and the snow gauge.

The Fjord rain gauge was solely made for measuring rain, but it was as well used for snow-measuring (will be described later).

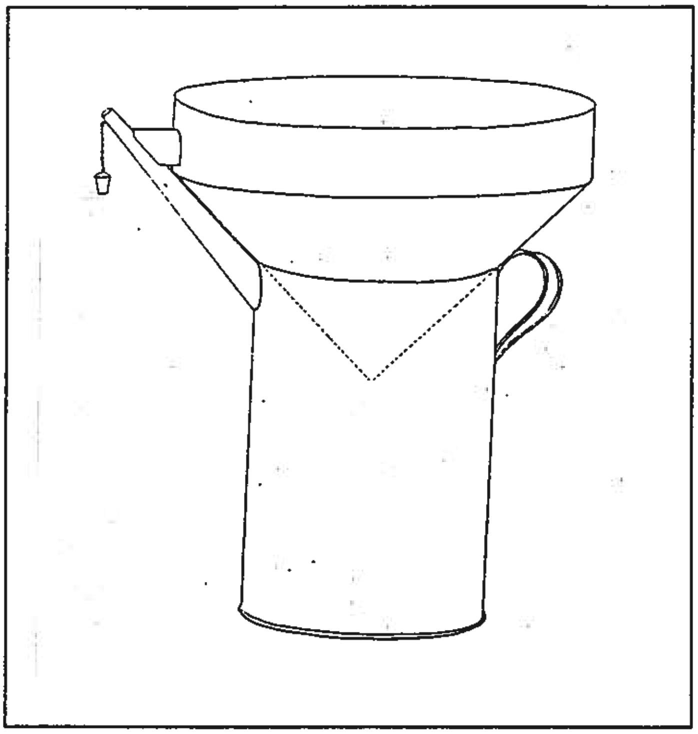

Fig. 25. Rain gauge constructed by N.J.Fjord.
Source: Meteorological yearbook 1874 p. VI.

A separate snow gauge was delivered by the Meteorological Institute to the observers of the main stations and both gauges were fixed in some 2 m high stands.

The gauges are known to be rather wide with an aperture of 1000 cm^2 (the diameters were 35.68 cm) but the looking of the stands as they appear on a 1909 photo from Tórshavn are quite astonishing (figure 26).

Some 1880-date observing instructions describe the assembling of the rain and snow gauge stands. After studying these instructions as well as the 1909 photos a reconstruction has been made (figure 27).

The stands of both gauges were made out of four bars assembled with a cross and four wedges. The Tórshavn snow gauge stand (a funnel, a drum and four bars) looks rather awkward, but we know that only the gauges were sent and the stands were made in Tórshavn by the local carpenter.

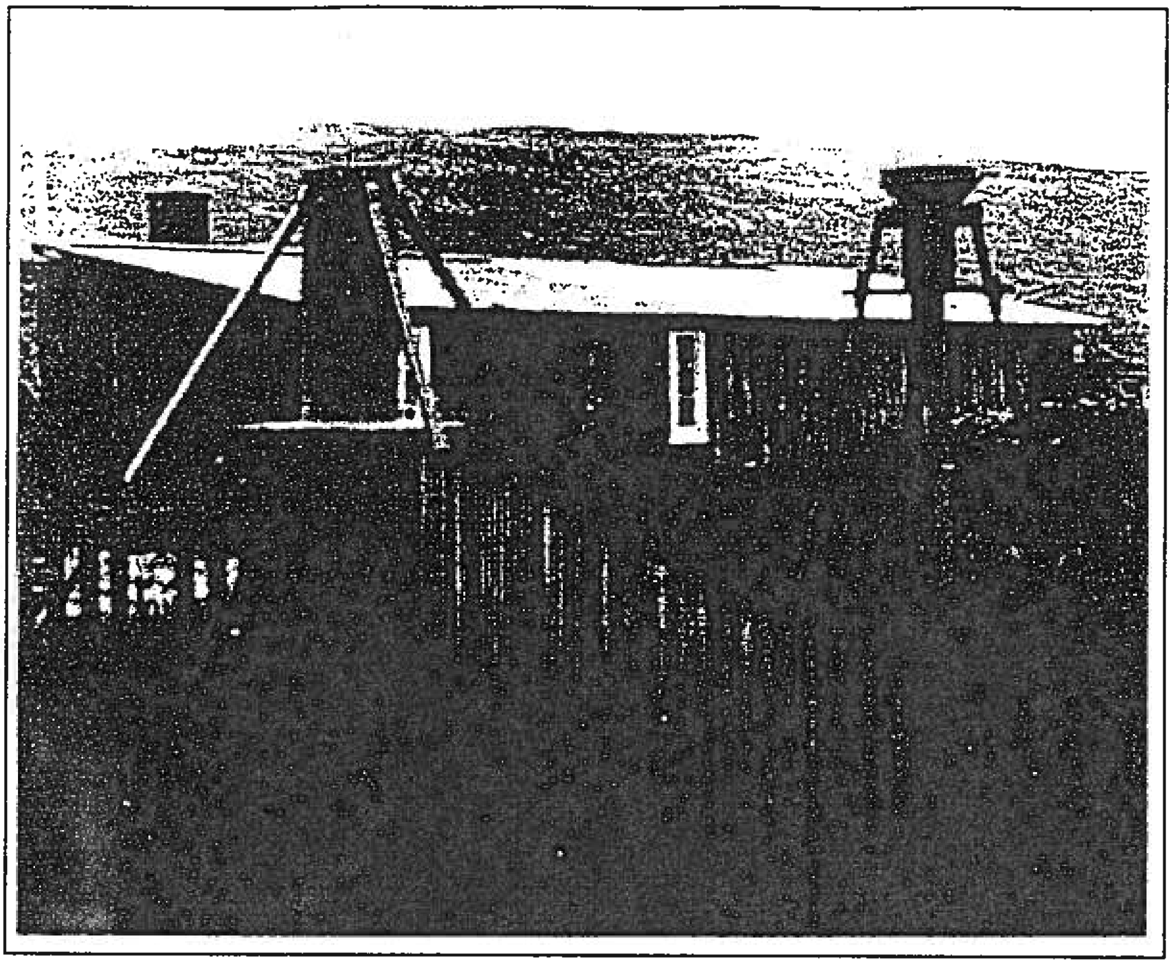

Fig. 26. Snow and rain gauges in Tórshavn 1909. The picture was taken on an inspection visit by Dan la Cour on his way to Iceland. Source: Rigsarkivet, Copenhagen; 1956 MI, E 103, Sag no. 11.

According to the 1880 instructions the Fjord gauge was resting in a square frame and the snow gauge funnel was hooked in the square frame from below. In a 1871 letter from the observer in Nordby the snow gauge was described like this:

> "... I cannot consider the snow gauge to be a useful apparatus..."
> (N.A.Lauridsen, Fanø, August 27th 1871 to N.J.Fjord).

Perhaps the staff at the Meteorological Institute took some note of these considerations, at least some additional instructions for snow measuring were distributed in 1880.

The observers were ordered to put the rain gauge upside down in a place with an average cover of snow. Lifting the gauge, the enclosed layer of snow could be carried away, melted and measured.

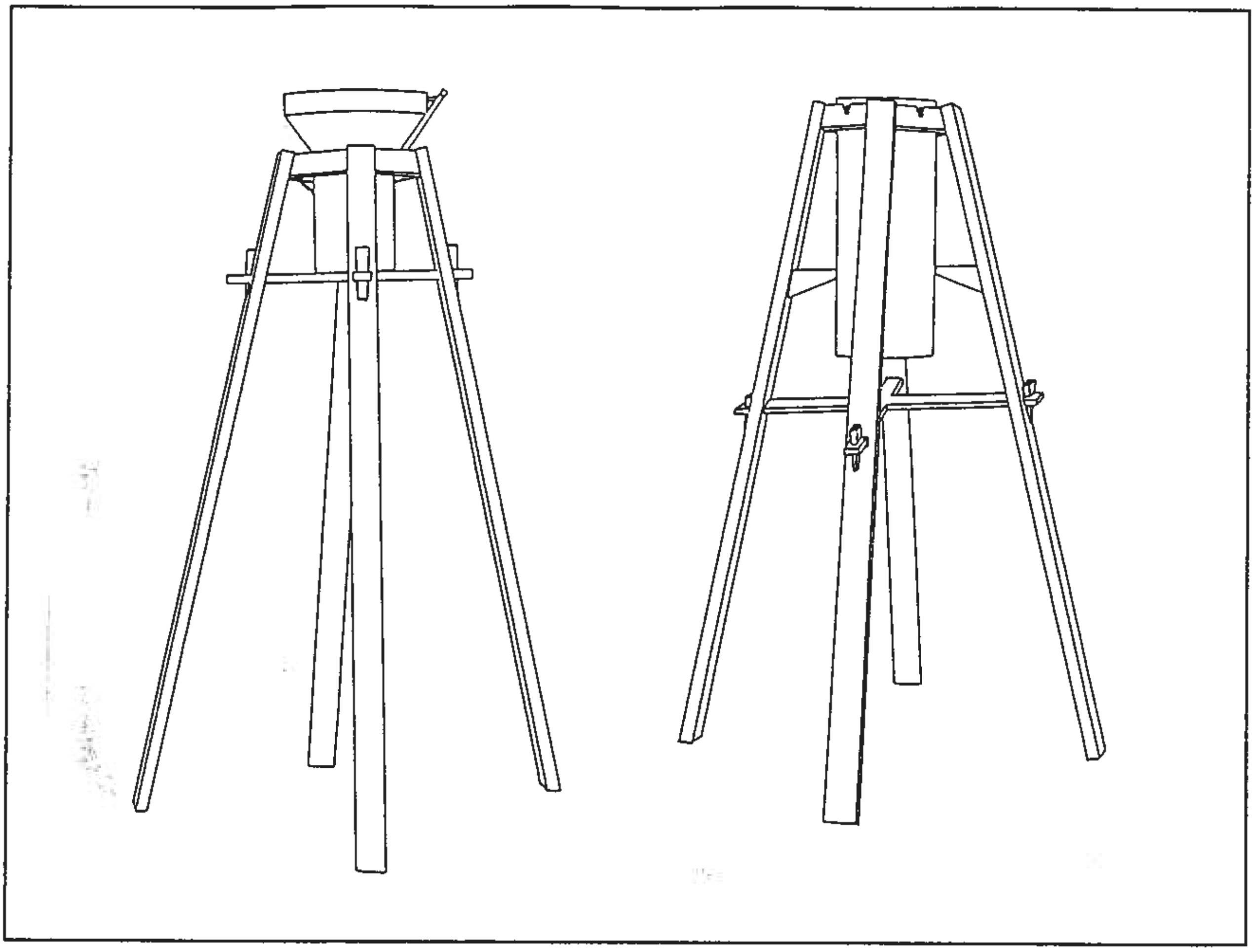

Fig. 27. N.J.Fjord rain gauge and snow gauge. Reconstruction MLB 1994.

Since the funnel of the Fjord gauge is only 6 cm high this method was less useful in the Northern Atlantic areas. A "rim for snow measuring" was sent to Iceland, presumably to be used like the upside-down snow gauge.

The Hellmann precipitation gauge.

The Fjord gauge and the snow gauge were replaced by the Hellmann precipitation gauge in the years of 1910-18.

The Hellmann gauge was less wide, the aperture being 200 cm², and the funnel taller enabling the gauge to collect snow, often supplied with a "cross" (two metal strips in right angles concentric with the funnel axis) to prevent the snow from being blown out.

The Hellmann precipitation gauge was mounted on a pole 1.5 m above the surface of the earth, and since the 1970s a lawn stand has been introduced for erecting the gauge. Figure 28 shows both types.

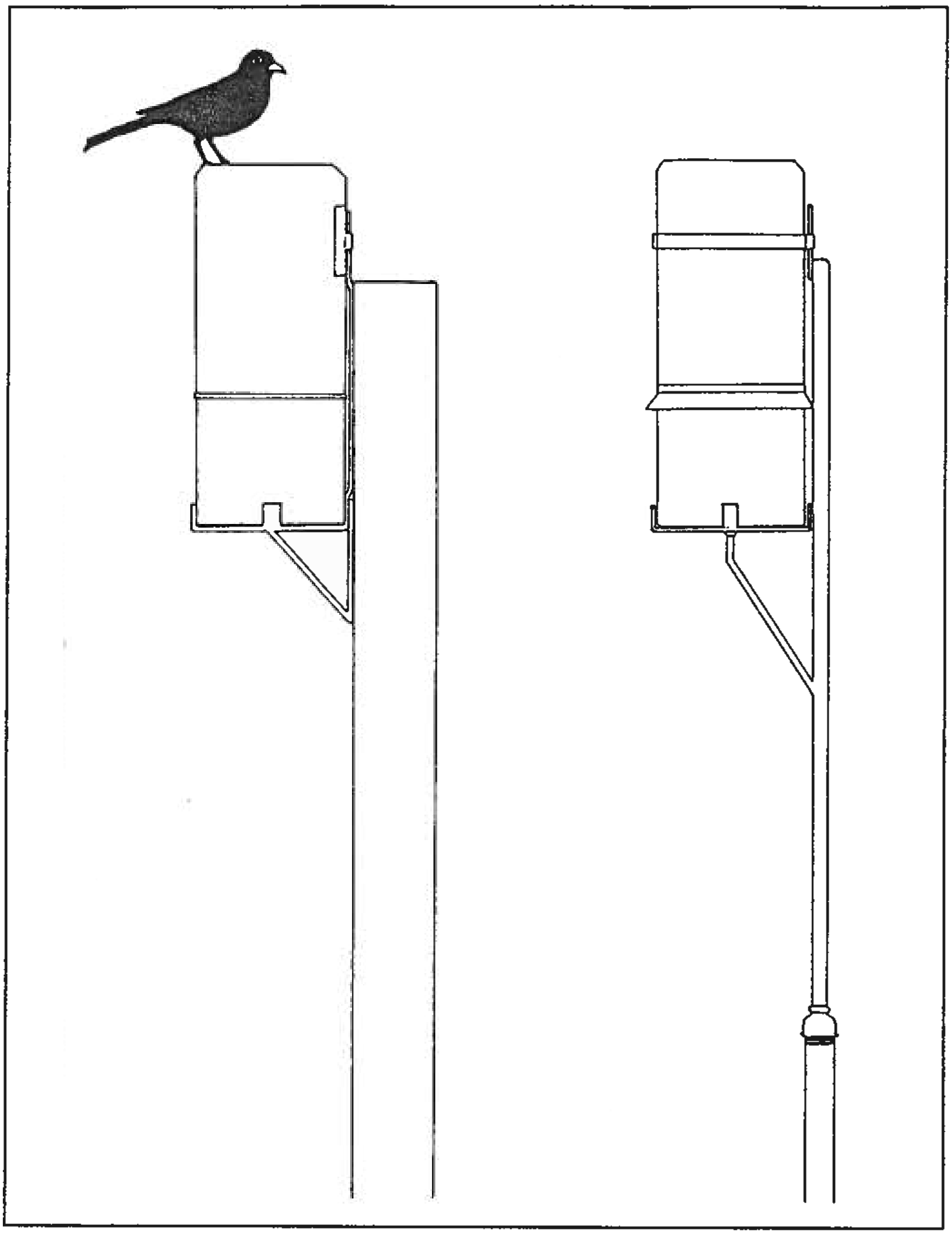

Fig. 28. Hellmann precipitation gauge on a pole and on a lawn stand. MLB 1994.

The Nipher's shield has been used at some Danish stations, but today this shield is solely used in Greenland.

The 1994 DMI-model of a Hellmann precipitation gauge is measured and sketched in fairly true proportions in figure 29.

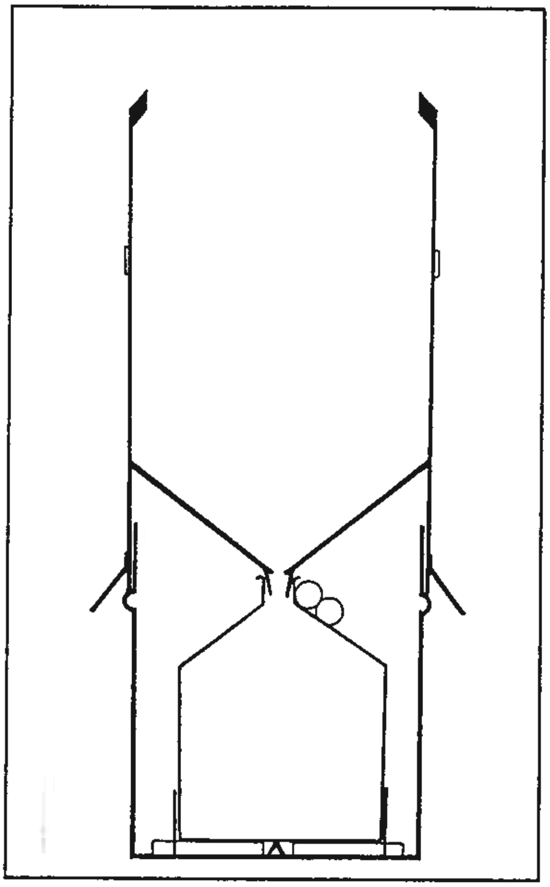

Fig. 29. Principle sketch of the 1994 Hellmann model, used by the Danish Meteorological Institute. The gauge is measured and constructed in fairly true proportions. MLB 1994.

The Tórshavn synoptic station was supplied with a Hellmann Pluviograph from 1923-1943, replaced by a Snowdon rain gauge W5000/1, 127 cm^2 from the Royal Air Force in 1943-1962.

Cloud cover and wind measurements.

The amount of cloud cover was estimated according to a scale, 0-10 (0 = clear sky, 10 = entirely overcast). Fog gives the appearance of an overcast sky (10 of the scale) if the observer is entirely enclosed and cannot see any blue sky. Of course these observations are rough personal estimates, which need proper training and instructions to be accomplished.

In 1952 a new scale, 0-8, was introduced in Denmark and the Faroe Islands, but some of the Greenland stations altered to the new scale more than 10 years later.

This change of scale may very well cause some disturbance of the series.

The wind direction was estimated using a flag pole and a pennant, and the direction was recorded as true course.

The wind speed was estimated according to a 0-6 scale, but on January 1st, 1912 the Beaufort scale 0-12 was introduced. The Beaufort scale was modified in December 1943 and again in 1954, so the scale was displaced.

Anemometers and wind velocity recorders have been used at some of the synoptic stations, but not very far back in time. So most of the records of wind speed are based on estimated values.

Outline of "break points".

Some events are proved to cause "break points" in the time series such as replacement from wall cage to Stevenson screen. The introduction of the 200 cm² Hellmann gauge replacing the 1000 cm² Fjord gauge presumably causes disturbance of the precipitation series. The approximate dates of these events are listed in table 6.

Table 6. Station number	Name	Fjord gauge replaced by Hellmann	Stevenson screen mounted	Notes
21100	Vestervig	about 1915	192407	
25140	Fanø	about 1913	192808	
27080	Tranebjerg	191109	191908	
30380	Landbohøjskolen/ Copenhagen	before 1922	191909	
32025	Hammeren Fyr	191109	-	Double thermometer cage
32030	Sandvig	191109	191309	
33071	Tórshavn	191907	-	Louvred wall cage/henhouse
34210	Upernavik	192309	-	
34216	Jacobshavn/ Ilusissat	192308	-	
34250	Godthåb/Nuuk	192110	195104	
34262	Ivittuut	192108	192209	
35360	Ammassalik	192010	-	

APPENDIX I

List of figures

APPENDIX II

List of reference publications

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