10. HUMIDITY

10.1. Water vapour pressure

The annual course of water vapour pressure (VP), characterizing gaseous water resources in the air, shows typical variability at Hornsund that is tightly linked with the air temperature there (Table 18.24). This variability, which can be substantial over the course of a day and especially over successive days, remains very strongly suppressed in the annual records that are presented as monthly means.

Water vapour pressure attained the highest values in July when the monthly mean exceeded 7.2 hPa, and were slightly smaller in August. Both standard deviations and the range of observed variability show that there is the smallest variability of water vapour contents in these two months, (Table 10.1). The smooth minimum, differing little between particular months, occurred between December and April when mean monthly VP values ranged only from 2.5 to 2.8 hPa.

Table 10.1. Mean monthly water vapour pressure (hPa), its standard deviation (σ_n) and the lowest (Min) and the highest (Max) mean monthly VP at Hornsund, 1978–2009.

	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Mean	2.53	2.53	2.52	2.80	4.06	5.86	7.22	7.03	5.63	3.90	3.29	2,70
σ_n	0.88	0.66	0.71	0.83	0.45	0.39	0.26	0.34	0.74	0.73	1.01	0.96
Min	1.1	1.5	1.3	1.7	2.8	5,1	6.7	6.4	4.1	2.7	1.7	1.3
Max	5.0	3.8	4.2	5.3	5.0	6.5	7.9	7.8	7.6	6.3	5.5	5.2

Over the annual course (Fig. 10.1) increase of VP begins in May after the extended smooth minimum and lasts until July. It is rapid, quite straightforward and is characterized by a distinct decrease of the range of interannual variability. VP increase is strongest between May and June. This jump corresponds with the strong increase of air temperature in this period (Fig. 9.4). The period between July and December is characterized by the slower and more extended drop of VP and increase in its interannual variability.

Over the whole of Spitsbergen and its environs (Hopen, Björnöya) the monthly behaviour of VP is strongly correlated. In the winter VP was only insignificantly higher at Hornsund than at other stations further inland or to the north (Table 10.2). In the summer (July, August) these differences declined or VP even became slightly smaller at Hornsund than at Ny Ålesund or Longyearbyen. Such spatial distribution of water vapour above Spitsbergen faithfully reproduces the air temperature field and its variability. Especially big interannual variability of VP at Hornsund was evident in November and December, due to the effect of sea water that was still warm in the autumn and beginning of winter. The air masses warmer than the water, moving over Spitsbergen from the south are transformed above such water relatively slowly. Neither air temperature nor VP can fall below water temperature and maximum water vapour pressure at the water surface during transformation.

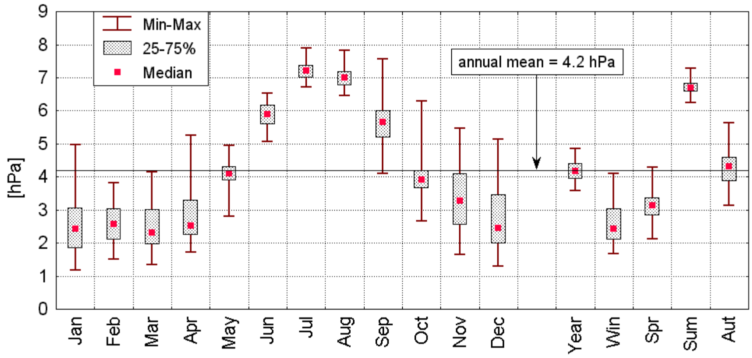

Fig. 10.1. Range of variability of mean monthly and seasonal water vapour pressure [hPa] at Hornsund, 1978–2009. Win – winter (DJF), Spr – spring (MAM), Sum – summer (JJA), Aut – autumn (SON).

Table 10.2. Comparison of mean multiannual values of water vapour pressure VP [hPa] at Hornsund and other Svalbard stations in 1978–2009.

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Ny Alesund *	2.0	2.0	2.1	2.5	3.9	5.9	7.5	6.9	5.2	3.3	2.7	2.2	4.0
Svalbard-Lufthavn*	1.9	1.9	2.0	2.4	3.7	5.6	7.3	7.0	5.2	3.3	2.7	2.2	3.8
Hornsund	**2.5**	**2.5**	**2.5**	**2.8**	**4.1**	**5.9**	**7.2**	**7.0**	**5.6**	**3.9**	**3.3**	**2.7**	**4.2**
Bjornoya *	3.7	3.7	3.9	4.2	5.2	6.6	8.1	8.2	7.1	5.3	4.5	3.8	5.4
Hopen *	2.9	2.6	2.7	3.0	4.1	5.6	6.8	7.1	6.1	4.5	3.6	2.8	4.3
Hornsund – Svalbard-Lufthavn	0.6	0.6	0.5	0.4	0.4	0.3	-0.1	0.0	0.4	0.6	0.6	0.5	0.4

* – data from the Norwegian Meteorological Institute (eKlima)

Advection of air masses colder than the water surface in turn creates exceptionally favourable conditions for intensification of evaporation from the still relatively warm seas surrounding Spitsbergen. In the autumn, each advection of air significantly cooler than the water results in a sudden increase of its temperature and water vapour content.

If in a given November or December there is exceptional inflow of air from the southern or western sectors or also from the opposite sectors, the result is a big difference of mean VP for the month. As the sea surface is cooling and the extent of open water is decreasing due to the development of sea ice cover, fluxes of heat and vapour from the sea surface decrease and as a result the water vapour content in the air decreases.

Covering of the sea surface by ice substantially changes both the potential for evaporation and other processes of transformation of air masses flowing over the frozen sea. From October to February there are highly statistically significant negative correlations between monthly VP at Hornsund and the area of sea ice on the Greenland Sea and the Barents and Kara Seas. Correlations between VP at Hornsund and sea ice area are stronger for ice cover on the Barents and Kara Seas (r= –0.70 in December, r = –0.72 in February), than on the Greenland Sea (r = –0.66 in December, r = –0.66 in February).

In November monthly changes of sea surface temperature (SST) on the body of water S–SW from the forefield of Hornsund (74–76°N, 14–16°E) explain around 13% of monthly VP variability at the station. In the same month, variability of sea ice area on the Greenland Sea explains ~26%, and ice on the Barents and Kara Seas ~22% of VP variation. In December variability of SST in the West Spitsbergen Current (76°N, 14°E) ceases to be crucial for the explanation of VP behaviour at Hornsund. The combined variation of sea ice area on the Greenland, Barents and Kara Seas explains more than half (51.8%) of VP variation at Hornsund.

The course of diurnal VP during a year displays much more complicated variability at Hornsund. The trends of diurnal VP in 1988, which was the coldest year in the history of observations at the station (annual mean –7.3°C) may be taken as an example here (Fig. 10.2). A big, and at times exceptionally big, interdiurnal variability of VP is clearly seen (Fig. 10.3) as well as the close association of VP changes with changes of air temperature. The character of changes clearly shows that both interdiurnal variability of VP and air temperature are steered by circulation processes at the synoptic scale.

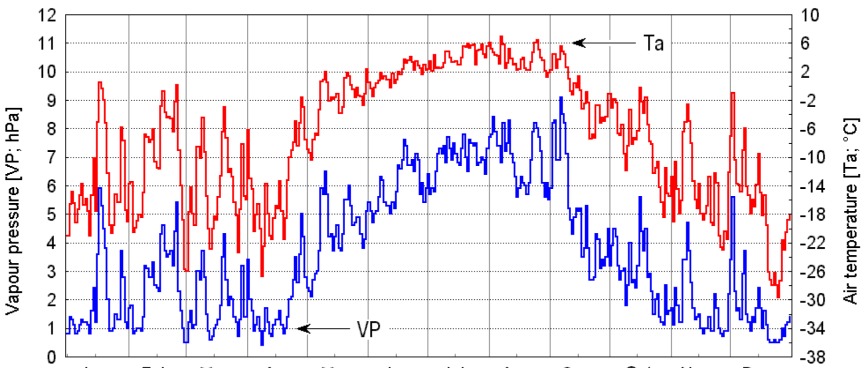

Fig. 10.2. The course of mean diurnal water vapour pressure (VP) and air temperature (Ta) in 1988.

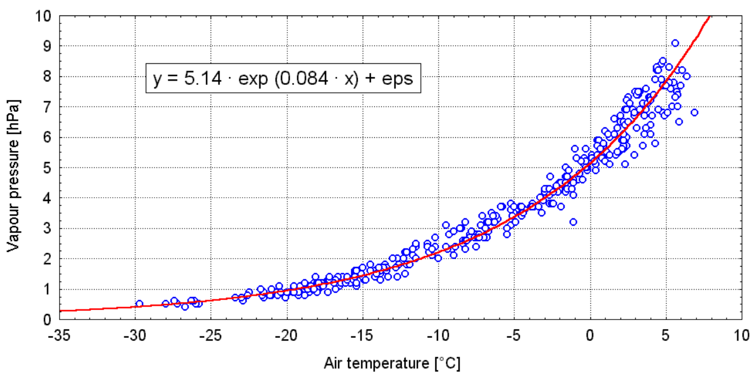

Fig.10.3. Correlation between changes of mean diurnal water vapour pressure [hPa] and mean diurnal air temperature at Hornsund in 1988.

The main flux of water vapour arrives over Hornsund, and generally over Spitsbergen, with advections of air masses from the southern sector. Associations between this direction as well as intensity of advection and amounts of water vapour in the air over Hornsund are manifested by the highly significant correlations between the Niedźwiedź S index of circulation and VP, at the scale of monthly means for almost the entire year (Table 10.3).

Advection from the southern sector (positive values of S index) brings air masses forming or transforming over the North Atlantic, the Norwegian Sea, or the Barents Sea, which are relatively warm and humid masses of marine air. On the contrary the inflow of air masses from the northern sector (negative values of S index), with which is connected inflow of masses PAk in the winter, PAk or PAm in the summer, leads to rapid decrease of air temperature and drop of VP.

Table 10.3. Correlation coefficients (r) between monthly VP at Hornsund and monthly values of the Niedźwiedź S index of circulation, and its statistical significance (p) in 1978-2009. Coefficients that are statistically significant are shown in bold.

	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
r	**0.75**	**0.43**	**0.61**	**0.81**	**0.39**	0.11	**0.42**	**0.47**	**0.77**	**0.76**	**0.86**	**0.88**
p	0.000	0.014	0.000	0,000	0.034	0.577	0.022	0.008	0.000	0.000	0.000	0.000

Statistically significant correlations between VP at Hornsund and the Niedźwiedź W index are limited to the period November – December – January (r equal: 0.48, 0.45 and 0.38, respectively) as well as March and June. Correlations are positive, meaning that VP increases together with the intensification of inflow of air from above the Greenland Sea (inflow from the west – positive value of W index). Inflow of increased amounts of water vapour together with advection from the western sector is restricted, as mentioned earlier, first of all to the period in which there are favourable conditions for strong evaporation from the surface of the Greenland Sea (November, December). One may note that positive correlation coefficients in the same months mean that increase of frequency of advection from the east (negative values of W index) must lead to decrease of water vapour resources in the air. Even at times when the northern part of the Barents Sea is not yet covered with the sea ice, foehn processes on the eastern, windward coast of the island decrease water vapour resources in the air in the region of the Hornsund station.

10.2. Relative humidity

The mean annual relative humidity (RH) at Hornsund is large, 79.4% (σ_n = 1.96). The lowest annual mean was 75.7% (2003), the highest 82.9% (1994). Mean interannual variability of humidity is minimum (1.98%), close to precision of the measurement of RH (±2%).

The course of monthly RH shows a weakly outlined annual cycle (Fig. 10.4). Between December and April the limit of upper quartile was located at the 80% level while medians were in the range from 75 to 78%. Between April and July mean monthly RH increased, reaching the maximum in July and August (Table 10.4). Differences between mean monthly RH in July and August are not statistically significant. Weakly differentiated minima in the annual course of RH were in October-November from the upper quartile values, or in December from the median and the lower quartile. Firm assignment of minimum RH in the annual cycle is risky because statistical differences between various measures characterizing humidity are irrelevant. Analysis of clusterings (Ward method, Euclid's distances) distinguishes two clusters, the first including June, July, August and

September and the second the remaining months of the year. In this second cluster two sub-clusters may be distinguished: one encompassing October, November and December and the second including January, February, March, April and May. In such a depiction the period between June and September clearly stands out with its greater humidity, and the period with lesser humidity (October-May), in which period with the lowest RH (October-December) is weakly differentiated.

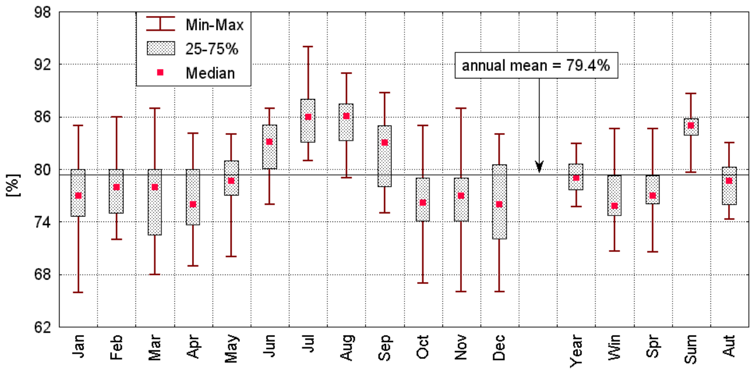

Fig. 10.4. The range of variability of monthly mean relative humidity [%] at Hornsund in 1978–2009. Win – winter (DJF), Spr – spring (MAM), Sum – summer (JJA), Aut – autumn (SON).

Table 10.4. Mean monthly relative humidity (%), standard deviations (σ_n), minimum (Min) and maximum (Max) monthly values of relative humidity at Hornsund in 1978-2009.

	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Mean	76.6	77.5	77.0	76.7	78.6	82.7	85.9	85.7	81.9	76.5	76.3	75.9
σ_n	4.6	3.7	5.0	4.1	3.6	3.2	3.1	2.7	3.9	3.9	4.8	5.0
Min	66	72	68	69	70	76	81	79	75	67	66	66
Max	85	86	87	84	84	87	94	91	89	85	87	84

Relative humidity in the range 80–85% is characteristic of the fully developed marine air masses. Mean monthly values given in Table 10.4 fit to this range or are only slightly lower. This shows that over Hornsund, on average in all months, only slightly transformed masses of marine air or fresh masses of marine air are dominant. In comparison with other principal Svalbard stations, Hornsund is characterized by increased RH throughout the year (Table 10.5). However, in all months of the year RH at Hornsund is lower than at the stations located on the coasts of small islands (Björnöya, Hopen).

Monthly values of RH at Hornsund (Table 18.25) show associations with a number of climatic parameters (Table 10.6). RH shows the strongest, and all-year association with water vapour pressure. The correlations are the strongest between September and December (from r = 0.83 in September to r = 0.71 in December). Such associations are obvious – the greater the VP, generally the greater is RH, especially during each drop of the air temperature.

Associations of RH with air temperature are positive and significant between September and January and in March and April. This shows on RH increases together with increase of air temperature

Table 10.5. Comparison of mean multiannual values of relative humidity [%] at Hornsund and Svalbard stations in 1978-2009.

Station	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
Ny Alesund *	72.4	74.8	74.6	73.8	76.0	81.0	83.2	82.3	79.6	73.6	71.9	71.6	75.8
Svalbard-Lufthavn *	73.0	73.7	73.7	73.0	72.4	72.9	75.1	76.5	75.4	73.2	73.1	73.0	73.8
Hornsund	**76.6**	**77.5**	**77.0**	**76.7**	**78.6**	**82.7**	**85.9**	**85.7**	**81.9**	**76.5**	**76.3**	**75.9**	**79.4**
Bjornöya *	87.1	88.3	88.4	87.0	86.7	89.0	91.7	91.0	89.2	84.3	86.4	86.8	88.1
Hopen *	85.8	86.5	86.2	85.0	84.6	89.1	91.5	91.3	88.1	85.5	88.0	86.5	87.5
Hornsund – Svalbard-Lufthavn	3.6	3.8	4.0	3.7	6.2	9.8	10.8	9.0	6.5	3.3	3.2	2.9	5.6

* – data from the Norwegian Meteorological Institute (eKlima).

and is a reflection of the Hornsund thermohygrometric advection regime. In July and August these associations change sign to negative, reflecting the predominance of radiation factors over advection factors in the thermohygrometric regime in these months. Positive correlations of RH with total cloudiness in July and August and negative correlations with sunshine duration confirm such an interpretation. At the same time the advective factor (see July in Table 10.6) also plays an important role in development of RH variability. It is proved by the statistically significant positive correlation of RH with the S index in July and elevated (although not exceeding the limit of statistical significance) correlation coefficient of RH with W index of circulation (r = 0.34, p = 0.070).

Table 10.6. Associations between monthly relative humidity (RH) and monthly air temperature (T_m), water vapour pressure (VP), cloudiness (N), sunshine duration (SS) and the Niedźwiedź indices of meridional circulation (S) and zonal circulation (W) in 1978–2009. Correlation coefficients significant at $p < 0.05$ are shown in bold. # – the lack of insolation in this month (polar night).

Element	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
T_m	**0.55**	0.28	**0.64**	**0.53**	0.28	0.06	**–0.51**	–0.11	**0.65**	**0.59**	**0.64**	**0.61**
VP	**0.61**	**0.43**	**0.74**	**0.66**	**0.63**	**0.63**	**0.49**	**0.56**	**0.83**	**0.76**	**0.76**	**0.71**
N	**0.52**	0.22	**0.57**	**0.49**	**0.46**	**0.52**	**0.62**	**0.55**	**0.62**	**0.63**	**0.64**	**0.73**
SS	#	–0.01	**–0.47**	**–0.63**	**–0.56**	**–0.58**	**–0.61**	**–0.60**	**–0.63**	–0.16	#	#
S	**0.53**	0.19	**0.52**	**0.58**	**0.63**	0.27	**0.46**	0.25	**0.69**	**0.59**	**0.76**	**0.66**
W	0.08	0.21	0.26	–0.08	–0.05	0.28	0.34	**0.45**	0.30	0.23	**0.50**	**0.45**

The associations of RH with cloudiness are very regular. In all months of the year except February these associations are statistically significant. They are clearly stronger in the second half of the year, between July and December, particularly in December (r = 0.73), already in the polar night. Influence of variability of cloudiness on development of RH variability is multifaceted and intermediate. No one single mechanism explaining this statistical correlation can be found.

Statistically significant negative correlations between RH and insolation are of similar strength over the whole period (r from –0.47 to –0.63) after the Sun appears over horizon and reaches greater than a few degrees in height and the day becomes longer (between March and September). Extending the duration of insolation causes increase of the air temperature, which leads to the drop of RH. In this case intermediate influence of variability of cloudiness on the development of variability of air humidity is evident.

Review of diurnal and other short-term cycles of RH shows that in reality range of RH changes may be of significant magnitude in some periods. Recorded maximum values of RH are, of course, 100%. Occurrence of such values happens in a few to a few dozen instances during a year. These are evident every year both in the course of diurnal means and in short term observations. During a year, minimum values of RH sporadically fall to 22–39% (Table 18.26). Drops of humidity to around 55–50% in diurnal means are recorded every year, but intense drops of RH below 50% are rare. There are years in which such low diurnal values are not recorded (Fig. 10.5). Such cases in longer term observations are quite numerous but are in general short- lived (Fig. 10.6).

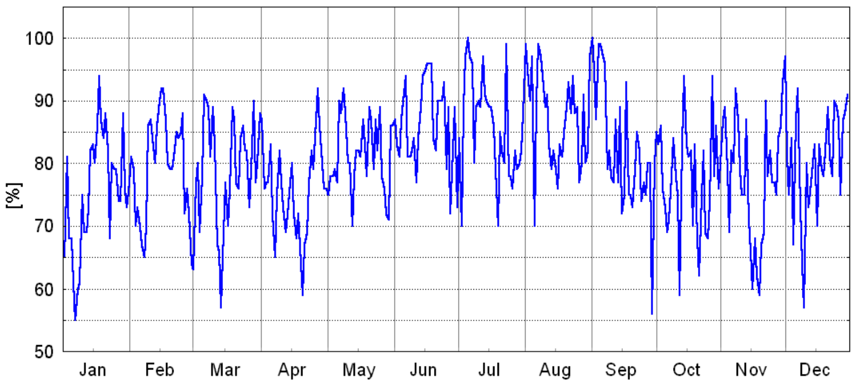

Fig. 10.5. The course of mean diurnal relative humidity RH [%] at Hornsund in 1988.

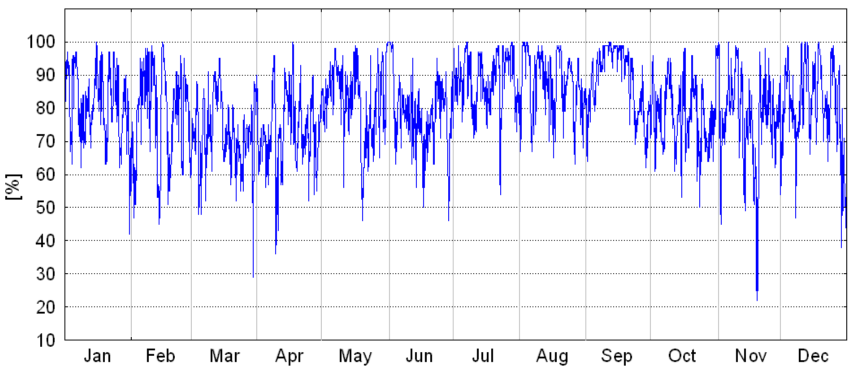

Fig. 10.6. The course of term observations of relative humidity HR [%] at Hornsund in 2008.

Intense drops of RH are observed both in warm and cold seasons of the year, during the polar day and the polar night. Detailed analysis of cases of intense drops using data from the middle term observations showed that there are different causes; generalizing one may distinguish three types of situations in which short-term intense drops of RH[1] take place at Hornsund. The first

[1] After elimination of cases in which there are evident errors in the notation of observations in Meteorological Yearbooks (most often printing e.g. 7 instead of 78, 38 instead of 83, 8 instead of 68, etc.).

type of situation occurs most often during a polar night, at sudden and rapid advections of very strongly cooled air. It occurs more seldom in the same conditions in the period when there are both day and night time conditions; drop of RH then follows a drop of air temperature. However, when RH reaches minimum value temperature slightly increases (for 2–3°C) at times. Cloudiness in general decreases together with the drop of air temperature and humidity. Later, lower cloudiness is maintained while RH increases and air temperature continues to drop. Such situations, unquestionably in most cases, occur with low winds from an easterly direction, often also when wind from the east temporarily changes to the north-east or the north (Fig. 10.7). In the each case however, the velocity of such winds is small (1–5 m·s^{-1}). Both during a polar night and in the period in which there is both day and night, such drops of RH may occur at random times of day (Fig. 10.8); in extreme cases during a polar night, they may last to over two days (e.g. on 14–17 November 2005).

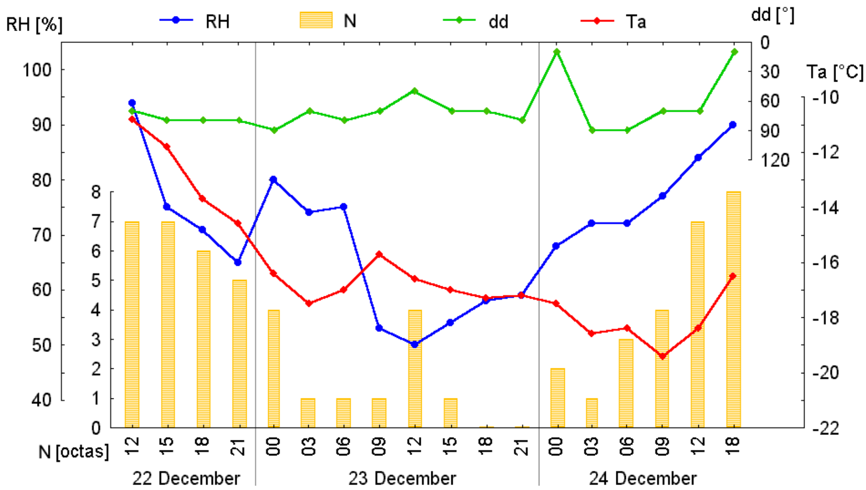

Fig. 10.7. Changes of relative humidity (RH; %) and air temperature (Ta; °C) during the term observations on 22–24 December 1993 at Hornsund. N – cloudiness [octas], dd – wind direction [°].

The second type of situation in which there are intense drops of RH at the Hornsund station occurs during the polar day or during a day in the period when night is already relatively short. For occurrence of RH decrease, cloudiness should be small already from the morning hours. If during such a day there is a clear decrease of wind speed (to 0–3 m·s^{-1}), increase of air temperature follows, which is accompanied by the strong fall of RH. The drop occurs as a rule in the afternoon or early evening (15–18 GMT[2]). Together with change of the height and azimuth of the Sun, in the evening and night RH increases rapidly even if little cloudiness still applies (Fig. 10.9).

Appearance of the first and the second type of rapid drops of humidity is connected as a rule with high or elevated atmospheric pressure recorded at the station. Both types of situation of rapid drop of RH have nothing in common with the foehn phenomena.

[2] LST of the Hornsund station is GMT + 1 hour.

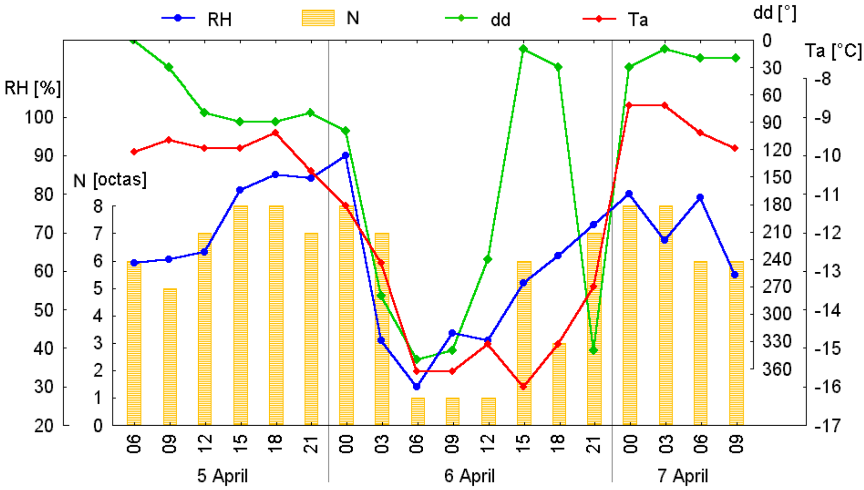

Fig. 10.8. Changes of relative humidity (RH; %) and air temperature (Ta; °C) during short term observations on 5–7 April 1999 at Hornsund. N – cloudiness [octas], dd – wind direction [°].

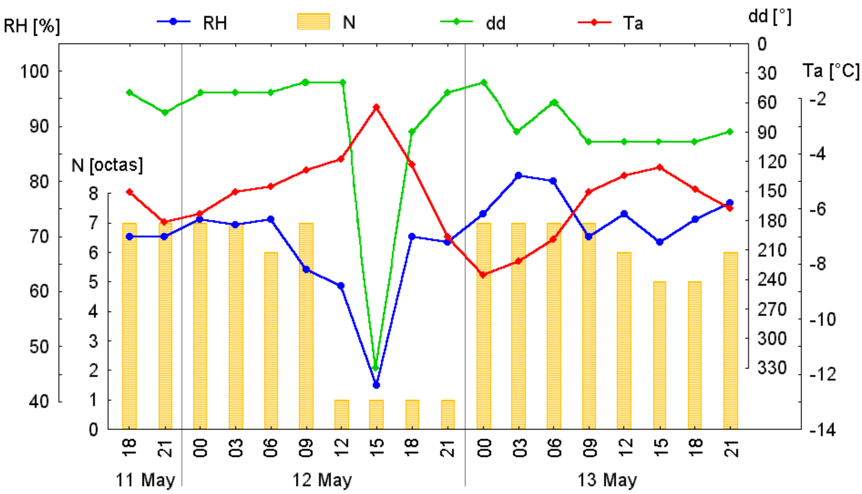

Fig. 10.9. Changes of relative humidity (RH; %) and air temperature (Ta;°C) during term observations on 11–13 May, 1993 at Hornsund. N – cloudiness [octas], dd – wind direction [°].

The third type of situation, in which we may assert that decrease of humidity is connected with the typical foehn effect, is exceptionally rare in a review of short term observations at the Hornsund station. Its occurrence is limited to just a few documented cases in the complete 30 years period of research. Increases of air temperature together with the drop of RH to 50–40%, at increased wind velocity (6–12 m·s^{-1}) from the northern sector are characteristic in these situations. Cloudiness is in general moderate in these cases, at times big (N from 4 to 7). Such a state is some discord with the common opinions on the role of foehn winds in the development of the thermohygrometric regime at Hornsund. Perhaps such opinions are correct in those areas close to the Hornsund station (e.g. the Werenskiold Glacier, upper parts of the Hans Glacier) where suitable topographic conditions exist for the development of foehn effects, with winds from the eastern sector dominating in these areas. However, these opinions are not confirmed by the observational data at the station.

Explanation of the causes leading to the occurrence of drops of humidity of the first type, which are accompanied by the drop of air temperature, is difficult. Most probably such situations are connected with the flow of strongly cooled air (at the small cloudiness) from the highest parts of the Hans Glacier, i.e. occurrence of katabatic winds in the lower sector of this glacier. Strongly cooled air flowing down warms adiabatically in such conditions, which should lead to an additional drop of its RH. Next this air also spreads out on the marine terrace on which the station is located, causing there simultaneously decrease of temperature (see Nowosielski 2004, p. 16). Reliable confirmation of this hypothesis requires conducting some not very complicated topoclimatic research. Genesis of RH drop of the second type is simple; in conditions of strong insolation of the marine terrace and concurrent lowering of wind speed, temperatures in boundary layer of the air increase causing decrease of humidity.