The synoptic data at day 1 report around 10:00 UTC light and moderate showers. At 11:00 UTC, the rain front has moved a little further to the southeast. The showery precipitation gives rise to local differences in the rain intensities. Cloud reports all include cumulonimbus with a cloud base of approximately 500 m.

At day 2, the atmosphere is very unstable. There is a north-northwest flow and there is not much sunshine. The relative warm water of the North Sea in combination with the cold polar air results in lots of showers. The weather radar indicates these, sometimes at the same spots as day 1. All stations report cumulonimbus clouds and showers, although the showers are now more widespread than on day 1. The positions of the flake-structures in the weather radar seem to match the shower structure.

Station	#	UTC	Day	Level 1	Level 2	Level 3
De Kooij	235	1000	1	1/8, St, 250	3/8, Cb, 500	
Schiphol	240	1000	1	1/8, St, 250	3/8, Cu, 400	6/8, Sc, 1600
De Bilt	260	1000	1	2/8, Cu, 400	5/8, Cu, 500	5/8, Sc, 1600
Soesterberg	265	1000	1	4/8, Cu, 400	6/8, Sc, 500	
Deelen	275	1000	1	1/8, St, 200	3/8, St, 300	6/8, Sc, 450
De Kooij	235	1100	1	1/8, Cu, 500	3/8, Cu, 650	7/8, Ci, 8300
Schiphol	240	1100	1	1/8, St, 250	3/8, Cb, 500	
De Bilt	260	1100	1	1/8, Cu, 350	3/8, Cu, 500	7/8, Sc, 1600
Soesterberg	265	1100	1	4/8, Cu, 400	7/8, Sc, 3000	
Deelen	275	1100	1	2/8, St, 300	1/8, Cb, 450	5/8, Sc, 3000
De Kooij	235	1000	2	3/8, Cb, 600	3/8, Cu, 750	6/8, Ci, 6600
Schiphol	240	1000	2	1/8, St, 250	4/8, Cb, 400	
De Bilt	260	1000	2	1/8, Cu, 400	2/8, Cb, 650	7/8, Ac, 3300
Soesterberg	265	1000	2	1/8, Cu, 650	3/8, Sc, 1600	5/8, Ac, 3000
Deelen	275	1000	2	1/8, Cu, 700	5/8, Ac, 3000	5/8, Ci, 8300
De Kooij	235	1100	2	2/8, Cb, 600	4/8, Ci, 6600	
Schiphol	240	1100	2	1/8, Cb, 400	3/8, Cu, 500	7/8, Ci, 6600
De Bilt	260	1100	2	1/8, Cu, 500	3/8, Cb, 650	5/8, Ac, 3300
Soesterberg	265	1100	2	2/8, Cu, 650	3/8, Sc, 1600	5/8, Ci, 8300
Deelen	275	1100	2	1/8, Cu, 400	4/8, Ac, 3000	5/8, Ci, 8300

Table 5.13 *Cloud observations fd4: 16-11/17-11-1995. The observations give the amount of cloud cover (okta), the type of cloud, and the cloud base at 3 levels. Height is given in meters.*

5.4.4.3 Conclusions

The correspondence between the shower patterns from the weather radar and the phase distortion in the interferogram points at rain, associated with higher cumulonimbus clouds, as the main cause of the phase variation.

5.4.5 Analysis of interferogram fd5

Interferogram fd5 was acquired at December 21 and 22, 1995, at 10:35:07 UTC, or 11:35:07 LT. SAR frame number 2547, for ERS-1 orbit 23185, and ERS-2 orbit 3512. The parallel baseline is 62 m, the perpendicular baseline 173 m. Phase unwrapping is performed using the minimal cost flow algorithm (Costantini, 1996).

5.4.5.1 Observations

Interferogram fd5, figure 5.80, has relatively small disturbances, up to 1–1.5 rad. Extraction of the topographic phase, which dominates the unwrapped phase in figure 5.81 results in the differential interferogram, see figure 5.82. Since only a small part of the $[-\pi, +\pi]$ range is used, figure 5.83 shows a scaled-up version of the differential interferogram. The disturbances are mainly lineated features running horizontally over Noord-Holland, and small isolated "humps" over the Noord-oostpolder , Flevoland, and the right side of the image.

The histogram in figure 5.84 reveals the small variance, the rms value is 0.7 rad. The rotationally averaged spectrum in figure 5.85 deviates considerably from the $-5/3$ power law lines.

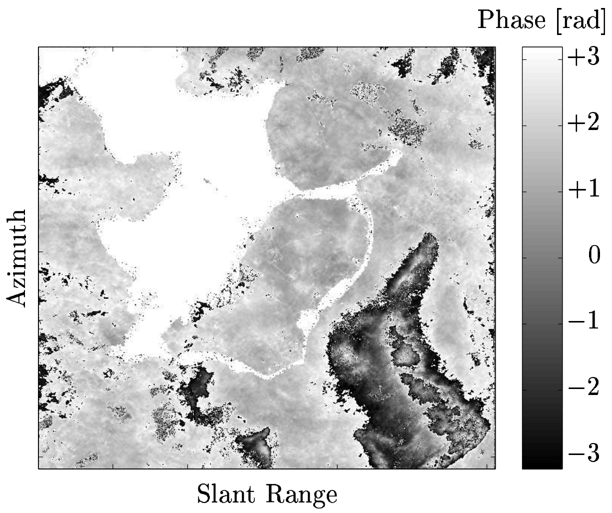

Figure 5.80 *Interferogram fd5*

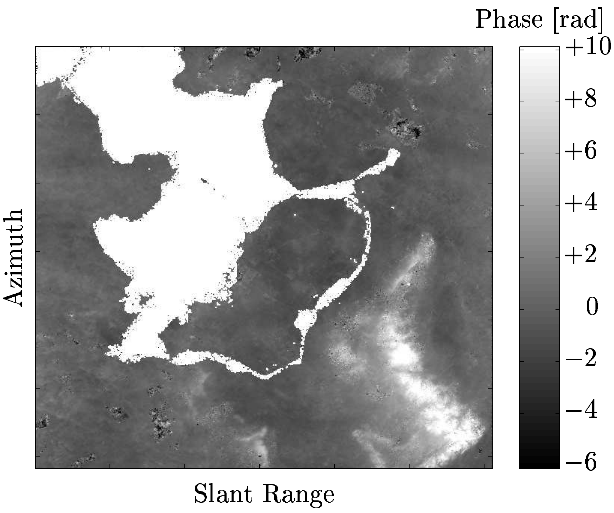

Figure 5.81 *Unwrapped interferogram fd5*

5.4.5.2 Interpretation

The differential interferogram, figure 5.83, is quite undisturbed, ranging from -2 to 1 rad. From the SAR intensity images ice cover over the IJsselmeer is observed.

At day 1, the weather radar does not show precipitation in the area. From Meteosat we find that there are only high and middle level clouds, mostly cirrus. The synoptic data show high relative humidities, and haziness: a reduced visibility to 2–5 km at 10:00, increasing to 6–13 km at 11:00 UTC. The wind is southeast. The current meteorological situation can be called a *frontal jam*, which consists of the weak remains of different frontal systems. In terms of cloud cover we find 6/8–8/8 cover for the whole area, with only middle and high level clouds, see table 5.14. The surface wind field is shown in figure 5.86.

At day 2, the weather radar indicates a large homogeneous rain field with embedded Cb's

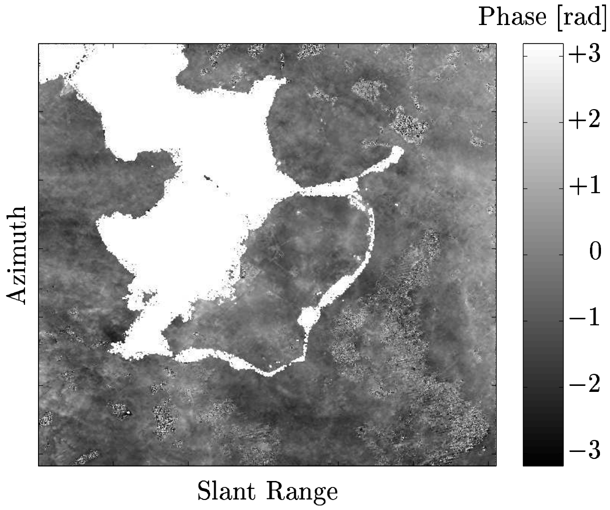

Figure 5.82 *Differential interferogram fd5, in the [−π, +π] range.*

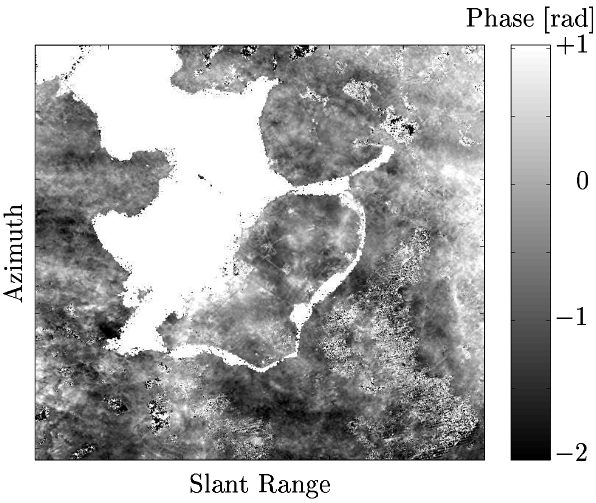

Figure 5.83 *Unwrapped differential interferogram fd5*

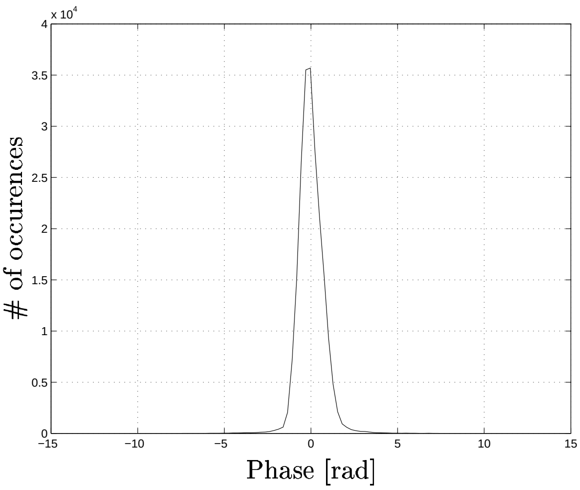

Figure 5.84 *Histogram of a major part of interferogram fd5*

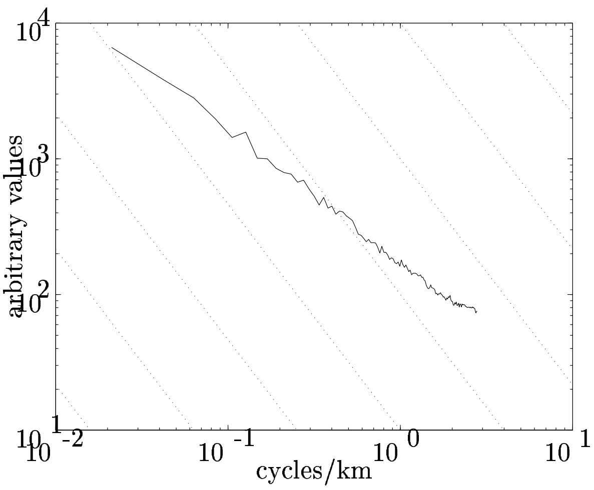

Figure 5.85 *Rotationally averaged spectrum of interferogram fd5*

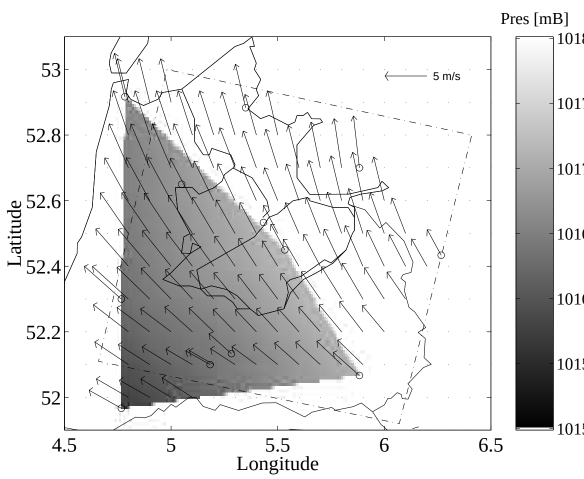

Figure 5.86 *Pressure and surface wind field fd5, day 1, 11:00 UTC*

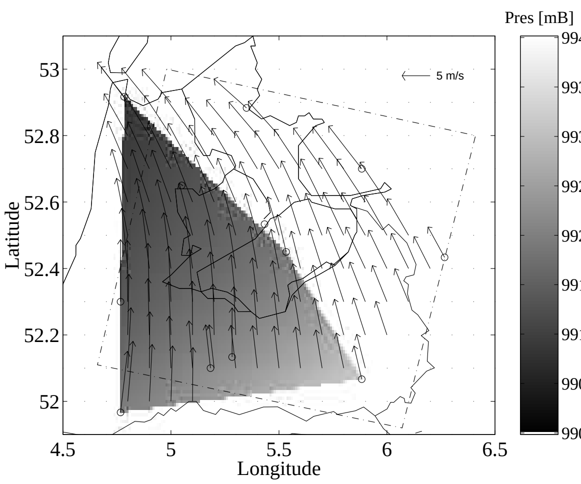

Figure 5.87 *Pressure and surface wind field fd5, day 2, 11:00 UTC*

with tops up to 7 km. This field is covering the whole interferogram. The high tops of the *embedded cumulonimbus* clouds are located over Noord-Holland and southwest Friesland in the interferogram. All synoptic stations indicate medium precipitation in the last hour at 10:00 UTC: 1.8–3.9 mm/hr. This is *homogeneous rain*: all stations report more or less the same. Therefore the effect in the differential interferogram may be small. All stations report 100% relative humidity. At the image acquisition time, it was raining for at least two hours continuously. Cloud cover was 8/8 at 70–100 m. Temperatures were just above the freezing level. The satellite imagery from AVHRR and Meteosat shows a layered, thick cloud cover with sometimes holes in the cirrus layer. The surface wind field is shown in figure 5.87.

Station	#	UTC	Day	Level 1	Level 2	Level 3
De Kooij	235	1000	1	1/8, Cu, 800	5/8, Ac, 3300	7/8, Ci, 8300
Schiphol	240	1000	1	5/8, Ac, 3300	6/8, Ci, 6600	
De Bilt	260	1000	1	2/8, Ac, 3300	7/8, Ci, 8300	
Soesterberg	265	1000	1	2/8, Ac, 3300	5/8, Cs, 6600	5/8, Ci, 8300
Deelen	275	1000	1	1/8, Ac, 3300	7/8, Ci, 8300	
De Kooij	235	1100	1	1/8, Sc, 1000	3/8, Ci, 6600	7/8, Ci, 8300
Schiphol	240	1100	1	1/8, Ac, 3000	6/8, Ac, 3300	8/8, Cs, 8300
De Bilt	260	1100	1	4/8, Ci, 8300	8/8, Cs, 8300	
Soesterberg	265	1100	1	2/8, Ac, 3300	6/8, Cs, 6600	5/8, Ci, 8300
Deelen	275	1100	1	5/8, Ci, 6600	7/8, Ci, 8300	
De Kooij	235	1000	2	2/8, St, 0	7/8, St, 50	7/8, St, 100
Schiphol	240	1000	2	1/8, St, 0	7/8, St, 100	7/8, St, 200
De Bilt	260	1000	2	8/8, St, 0		
Soesterberg	265	1000	2	5/8, St, 100	8/8, St, 200	
Deelen	275	1000	2	5/8, St, 50	8/8, St, 150	
De Kooij	235	1100	2	6/8, St, 50	7/8, St, 100	7/8, St, 200
Schiphol	240	1100	2	3/8, St, 0	7/8, St, 100	8/8, St, 100
De Bilt	260	1100	2	6/8, St, 100	8/8, St, 300	
Soesterberg	265	1100	2	4/8, St, 100	8/8, St, 150	
Deelen	275	1100	2	8/8, St, 50		

Table 5.14 *Cloud observations fd5: 21-12/22-12-1995. The observations give the amount of cloud cover (okta), the type of cloud, and the cloud base at 3 levels. Height is given in meters.*

5.4.5.3 Conclusions

The small phase variations (the humps) in the interferogram are considered to be caused by variations in humidity and rain rates, especially during the second acquisition. The linear horizontal patterns over Noord-Holland align with the wind direction of day 2.

5.4.6 Analysis of interferogram fd6

Interferogram fd6 was acquired at April 4 and 5, 1996, at 10:34:55 UTC (12:34:55 LT). SAR frame number 2547, for ERS-1 orbit 24688, and ERS-2 orbit 5015. The parallel baseline is 26 m, the perpendicular baseline 59 m. Phase unwrapping is performed using the method of Ghiglia and Romero (1994).

5.4.6.1 Observations

Interferogram fd6 is characterized by an organized diagonal wave pattern, covering the whole image, see figure 5.88. Phase unwrapping leads to the absolute interferogram, shown in figure 5.89. The differential interferogram in figure 5.91, where the topographic effect is eliminated, has only small phase variations, with an rms of 0.53 rad, see the histogram in figure 5.94. Although the wave pattern is clearly anisotropic, and therefore this assumption of Kolmogorovs turbulence theory is not fulfilled, a radial averaged spectrum is shown in figure 5.95. A closer look at extraction A in the absolute differential interferogram gives a clear view of the wave pattern, see figure 5.92, and the Radon transform in figure 5.93 indicates the azimuth strike of the waves (125 degrees counterclockwise from the azimuth axis) and the wavelength of 700 m.

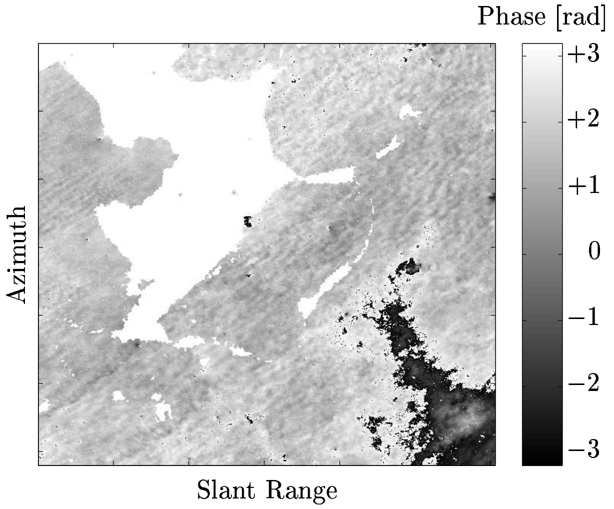

Figure 5.88 *Interferogram fd6*

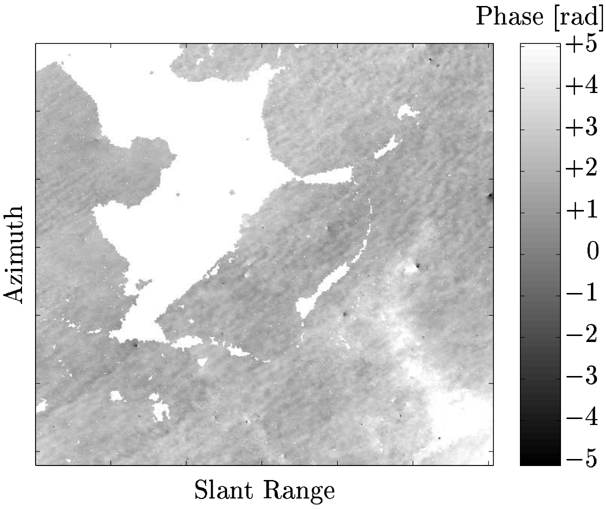

Figure 5.89 *Unwrapped interferogram fd6*

5.4.6.2 Interpretation

A pattern of small waves is observed, with a wavelength of 2 km. Two hypotheses hold for this situation. The first is that the waves are cloud streets, the second assumes that it is connected with moisture under an inversion. When there is vertical circulation in the layer under the inversion, moisture could heap up in the upward moving air. The horizontal diameter of such a upward moving cell is estimated to be approximately equal to the height of the inversion.

At the time of the first image acquisition, the Netherlands are in a high pressure zone. Unfortunately no Meteosat data were available. AVHRR imagery showed no visible clouds. The weather radar did not show any precipitation at both days. At station De Kooy the observers indicated haze, all other stations had good visibility. The air was dry at ground level: relative humidities around 50–60% The wind direction at surface level was east-northeast, and visibility was better than 10 km. It was totally unclouded, although

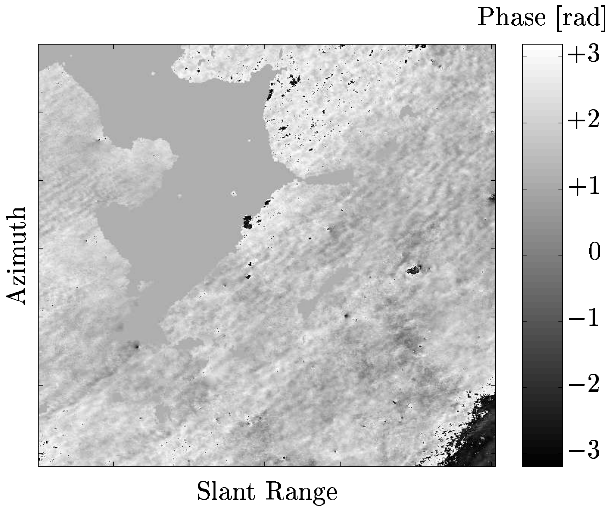

Figure 5.90 *Wrapped differential interferogram fd6*

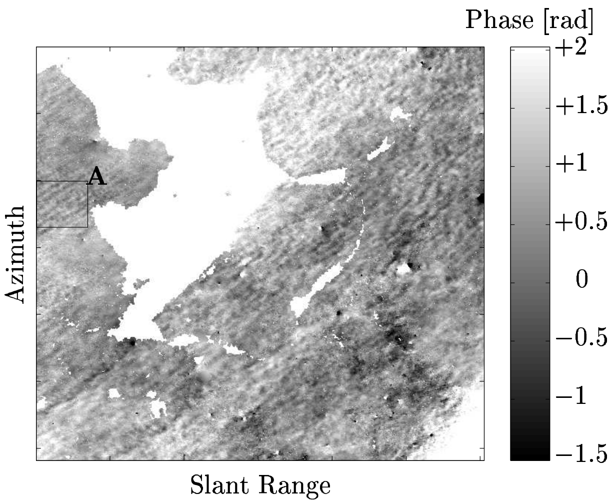

Figure 5.91 *Unwrapped differential interferogram fd6*

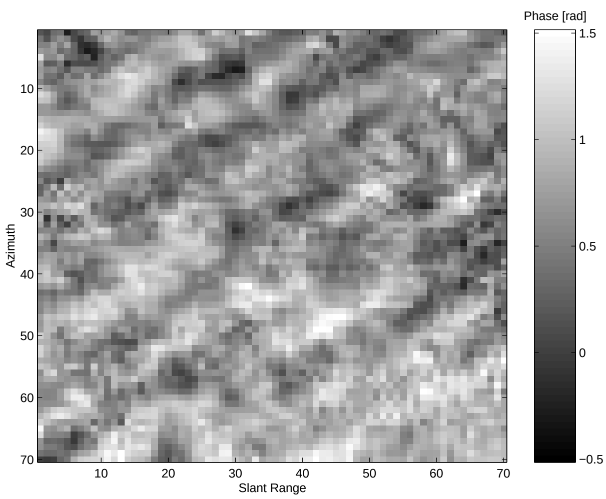

Figure 5.92 *Extraction A of the absolute phase of differential interferogram fd6 in figure 5.91*

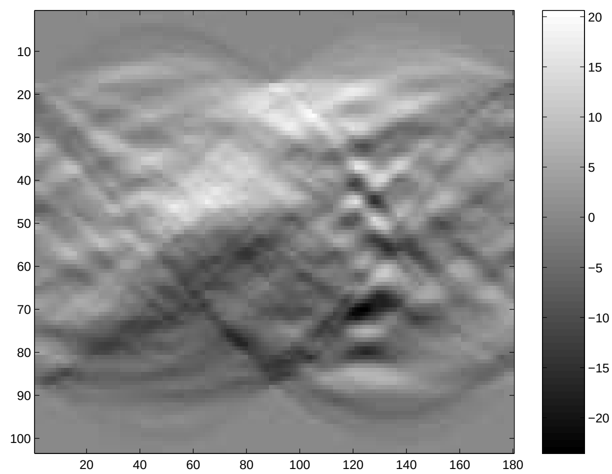

Figure 5.93 *Radon transform of extraction A, showing strong intensity variations at angles of 125 degrees.*

station Deelen reported 6/8 altocumulus at 11:00 UTC. A strong inversion is observed from the radiosonde data, with the inversion base at 2200 m. The wind is backing from the surface (east-northeast) to under the inversion (north-northeast), and is then suddenly veering 90 degrees to east-southeast! This can be labeled as directional wind shear. Surface wind velocities are around 6–8 m/s.

At the second day the weather was cold and dry. There was a fair amount of wind from east-northeast, and according to AVHRR and synoptic data, there was some more cirrus cloud cover, see also table 5.15. The radiosonde profile indicated an inversion at 1000 m. Wind direction (east–east-northeast) and speed did not change considerably over height. Surface wind velocities are equal to the first day, around 6–8 m/s.

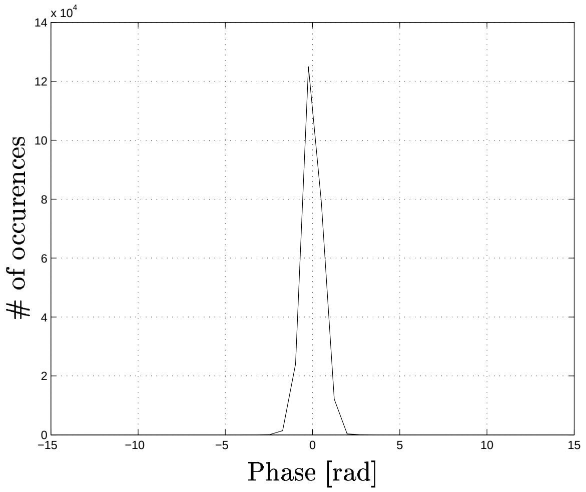

Figure 5.94 *Histogram of a major part of interferogram fd6*

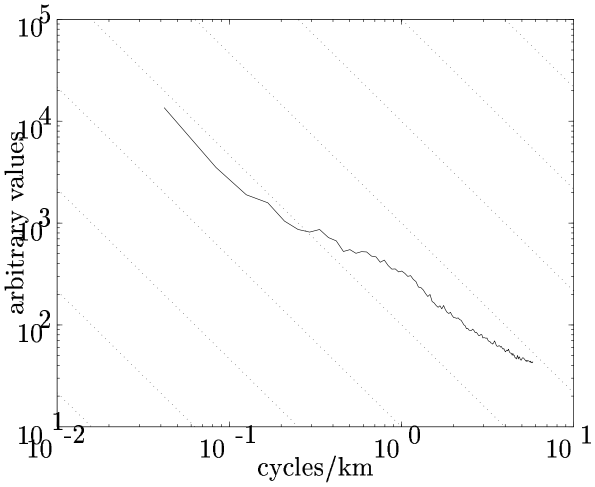

Figure 5.95 *Rotationally averaged spectrum of interferogram fd6*

Station	#	UTC	Day	Level 1	Level 2
De Kooij	235	1000	1		
Schiphol	240	1000	1		
De Bilt	260	1000	1		
Soesterberg	265	1000	1		
Deelen	275	1000	1		
De Kooij	235	1100	1		
Schiphol	240	1100	1		
De Bilt	260	1100	1		
Soesterberg	265	1100	1		
Deelen	275	1100	1	6/8, Ac, 3000 m	
De Kooij	235	1000	2	1/8, Ci, 8300 m	
Schiphol	240	1000	2	2/8, Ci, 8300 m	
De Bilt	260	1000	2	5/8, Ci, 8300 m	
Soesterberg	265	1000	2	6/8, Ci, 10000 m	
Deelen	275	1000	2	6/8, Ci, 8300 m	
De Kooij	235	1100	2	1/8, Ci, 8300 m	
Schiphol	240	1100	2	2/8, Ci, 8300 m	
De Bilt	260	1100	2	1/8, Cu, 1300 m	6/8, Ci, 8300 m
Soesterberg	265	1100	2	6/8, Ci, 8300 m	
Deelen	275	1100	2	7/8, Ci, 8300 m	

Table 5.15 *Cloud observations fd6: 04-04/05-04-1996. The observations give the amount of cloud cover (okta), the type of cloud, and the cloud base at 2 levels.*

5.4.6.3 Conclusions

The stripes in the interferogram have a north to northeast direction. Two explanations are: (1) directional wind shear at day 1 due to the sudden change in wind direction around the inversion, (2) moisture streets due to moisture circulation under the inversion. Due to the fact that the waves are bulged, which is not expected for a plain wave phenomenon, the moisture street hypothesis seems to be more likely.

5.4.7 Analysis of interferogram fd7

Interferogram fd7 was acquired at June 13 and 14, 1996, at 10:35:04 UTC (12:35:04 LT). SAR frame number 2547, for ERS-1 orbit 25690, and ERS-2 orbit 6017. The parallel baseline is 45 m, the perpendicular baseline 77 m. Phase unwrapping is performed using the minimal cost flow algorithm (Costantini, 1996). There were no precise state vectors available for the ERS-1 orbit, which made a manual correction for the orbit errors necessary.

5.4.7.1 Observations

Interferogram fd7 has phase variations of two phase cycles, see figure 5.96 for the interferogram, and figure 5.97 for the unwrapped interferogram. The differential interferogram, shown in figure 5.99, reveals that although some topography caused this phase variation, the maximum variation is still two phase cycles. The rms of the variation is 1.7 rad, see the histogram in figure 5.100. The signature of the variation varies from small waves in the upper left corner of the interferogram to artifacts with larger dimensions (max. diameter around 20 km) over Flevoland and in the lower right corner. The rotationally averages log-log spectrum in figure 5.101 shows a $-5/3$ power law for wavelengths between 400 m and 3.3 km, and between 15 and 30 km.

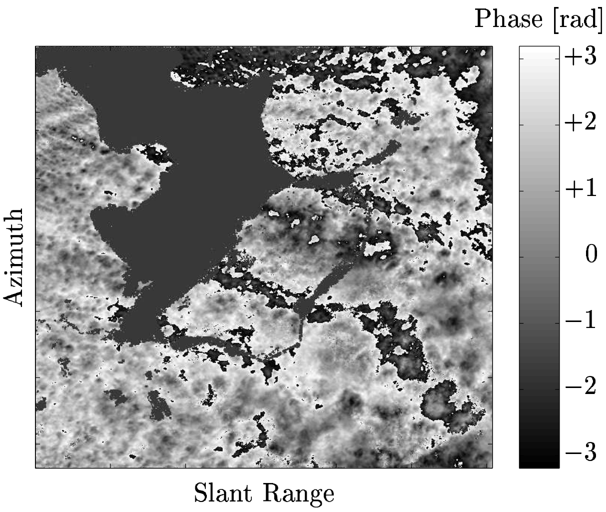

Figure 5.96 *Interferogram fd7*

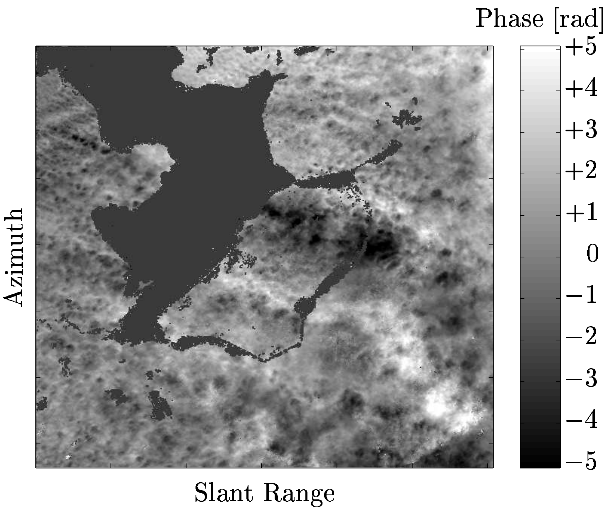

Figure 5.97 *Unwrapped interferogram fd7*

5.4.7.2 Interpretation

The pattern of phase behavior shows clearly small laminar structures in the west which grow more turbulent in diameter and magnitude towards the east. This corresponds clearly with the prevailing wind direction, see figure 5.102. NOAA's AVHRR shows at day 1 northwestern winds, with cloud streets which grow bigger, starting just after reaching the coast. The cloud street patterns can be clearly associated with the phase variation in the interferograms. The Meteosat visual channel shows the same type of cloud patterns, though with less resolution. The synoptic data of day 1 indicate cumulus clouds. The relative humidity lies between 40–50% and temperatures vary between 16–19°C.

At day 2, there is a weak cold front over the Netherlands. There are some cumuli, combined with stratocumulus and cirrus. Relative humidity is 50–60%, temperature 13–16°C. AVHRR confirms these observations.

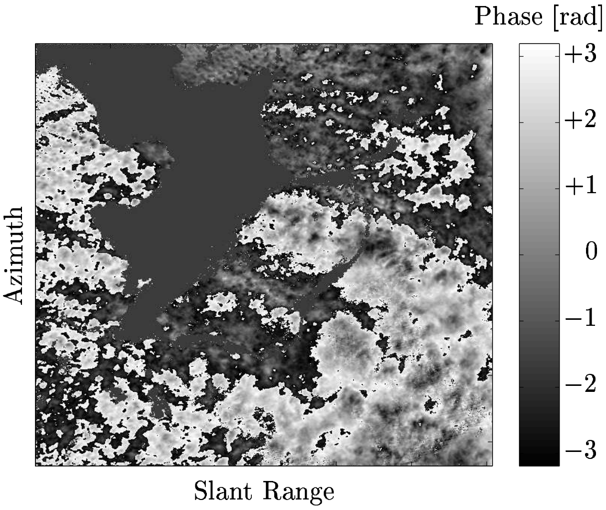

Figure 5.98 *Wrapped differential interferogram fd7*

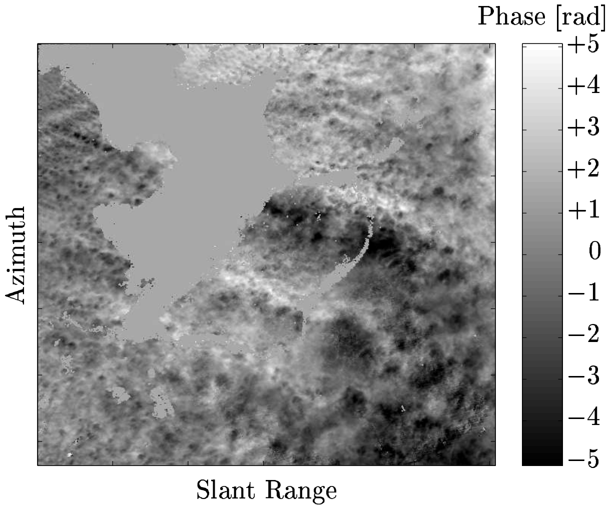

Figure 5.99 *Unwrapped differential interferogram fd7*

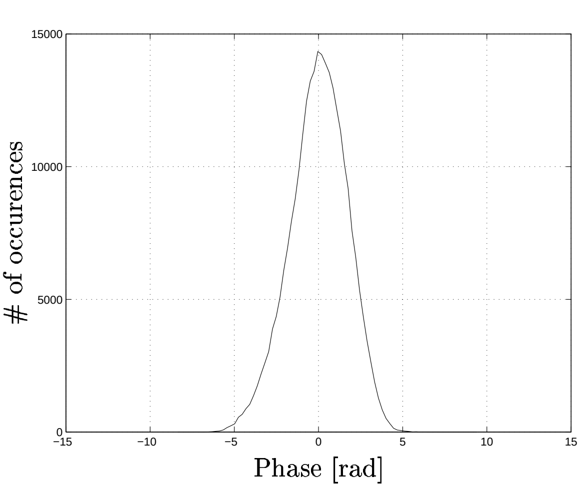

Figure 5.100 *Histogram of a major part of interferogram fd7*

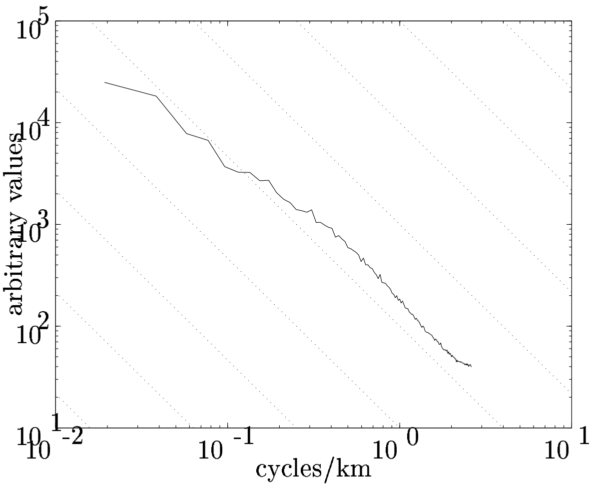

Figure 5.101 *Rotationally averaged spectrum of interferogram fd7*

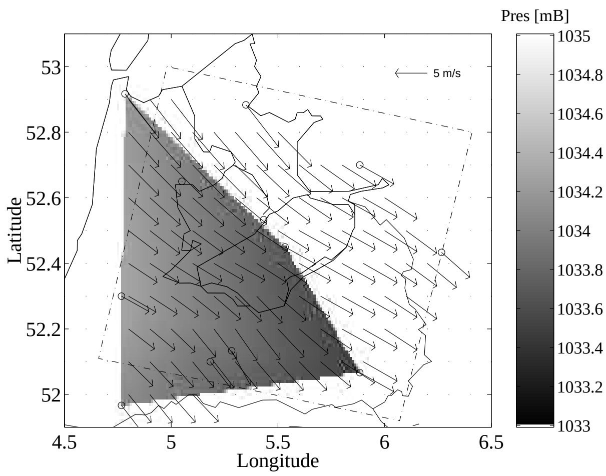

Figure 5.102 *Pressure and surface wind field fd7, day 1*

The inversion height in De Bilt at day 1 is 2000 m, and 1200 m at day 2. On the first day the cloud layer under the inversion is not very thick yet, the second day it clearly gets thicker. We see from the radiosondes that there must be a cirrus layer over Emden. From the synoptic data we see that this is also reported in De Bilt.

Station	#	UTC	Day	Level 1	Level 2	Level 3
De Kooij	235	1000	1	1/8, Cu, 650		
Schiphol	240	1000	1	2/8, Cu, 1300		
De Bilt	260	1000	1	3/8, Cu, 1100		
Soesterberg	265	1000	1	3/8, Cu, 1500		
Deelen	275	1000	1	5/8, Cu, 1600		
De Kooij	235	1100	1	1/8, Cu, 650		
Schiphol	240	1100	1	2/8, Cu, 1400		
De Bilt	260	1100	1	3/8, Cu, 1100		
Soesterberg	265	1100	1	4/8, Cu, 1600		
Deelen	275	1100	1	3/8, Cu, 1600	3/8, Sc, 3000	
De Kooij	235	1000	2	2/8, Cu, 800	5/8, Cu, 1300	
Schiphol	240	1000	2	2/8, Cu, 1000	6/8, Sc, 1300	
De Bilt	260	1000	2	6/8, Cu, 1000	5/8, Ci, 8300	
Soesterberg	265	1000	2	2/8, Cu, 1200		
Deelen	275	1000	2	2/8, Cu, 1000	7/8, Sc, 1300	
De Kooij	235	1100	2	2/8, Cu, 850	6/8, Cu, 1300	
Schiphol	240	1100	2	1/8, Cu, 800	3/8, Cu, 1000	6/8, Sc, 1300
De Bilt	260	1100	2	3/8, Cu, 1000		
Soesterberg	265	1100	2	2/8, Cu, 1200	5/8, Sc, 1500	
Deelen	275	1100	2	2/8, Cu, 1000	6/8, Sc, 1400	

Table 5.16 *Cloud observations fd7: 13-06/14-06-1996. The observations give the amount of cloud cover (okta), the type of cloud, and the cloud base at 3 levels. Height is given in meters.*

5.4.7.3 Conclusions

Based on the AVHRR observations of day 1, the wind speed and direction, and the radiosonde data, it is clear that the phase variation in the differential interferogram is caused by cloud streets, transporting moisture from the North-Sea to the inland. The observed low relative humidities at the surface indicate that the moisture variations occur at some height, presumably just below the inversion height.

5.5 Analysis Flevoland ascending

The interferograms *Flevoland ascending-north* and *Flevoland ascending-south* cover a large part of the Netherlands. Since the Flevoland polder is situated near the center of the combined interferograms, both areas are referred to by that name. The northern image just extends from the first of the *Frisian islands*, *Texel*, in the north-west, to the *Veluwe* hills in the south-east. A 30 km long dike, the *Afsluitdijk*, spans the distance between the provinces *Noord-Holland* and *Friesland*, at the west and east side of the *IJsselmeer* respectively. The southern image covers a land area with the provinces *Utrecht*, *Gelderland*, *Overijssel* and *Limburg*, as well as a part of Germany, see figure 5.103.

A large number of synoptic stations is used for the analysis of the interferograms. These stations are listed in figure 5.103. More or less regularly divided over the area, cloud observations are available from civil and military air fields, and the main meteorological station in *De Bilt*. Radiosonde observations are available from the De Bilt station and from the Belgian station *Ukkel* and the German station *Emden*, shown in figure 3.1.

Apart from topographic heights in the *Veluwe* area, some topography can be found in the eastern and south-eastern parts of interferogram area *fa-s*, and in the German areas in the interferogram. Since no reference elevation model was available from the German areas, this area is not included in the analysis.

5.5.1 Analysis of interferogram fa1

Interferogram fa1 was acquired at August 29 and 30, 1995, at 21:41:08 UTC, equivalent to 23:41:08 LT. SAR frame numbers 1053 and 1035 are used, for ERS-1 orbit 21560, and ERS-2 orbit 1887. The parallel baseline changed from -30 to -31 m, the perpendicular baseline from -79 to -80 m, for the southern and northern image respectively. The phase unwrapping is performed using the minimal cost flow algorithm (Costantini, 1996).

5.5.1.1 Observations

Interferogram fa1, see figure 5.104, is combined of two SAR frames, taken directly after each other in the same orbit. The frames were fitted together to form one, 100×200 km frame. This larger area gives some more specific detail of a different scale of atmospheric phenomena. Unwrapping of the interferogram gives figure 5.106. The phase varies over a range of a little more than one cycle, and a large "ridge" seems to cross the interferogram in the azimuth direction. Elimination of the topographic phase is performed in the differential interferogram, see figure 5.106. Note that the used reference DEM did not cover the whole area: the lower right corner, delimited by the line in the figure, still has some topographic phase signatures. This area is excluded from further analysis.

Characteristic of this differential interferogram is the ridge along azimuth direction, which affects the lower part as well as the upper part of the interferogram. Furthermore, small wave features are observed at different small areas in the interferogram. The wave direction is more or less in azimuth direction (-16 degrees w.r.t. the north), the wavelength is around 1 km, and the amplitude is less than 2 rad. A strong isolated artifact is located in the upper left part of the interferogram. A zoom of this area is shown in figure 5.107. This is a very localized artifact—it fits within a rectangle of 8×16 km—with a maximum phase difference of 8 rad (1.3 phase cycles). A horizontal cross section of this phenomenon is plotted in figure 5.108.

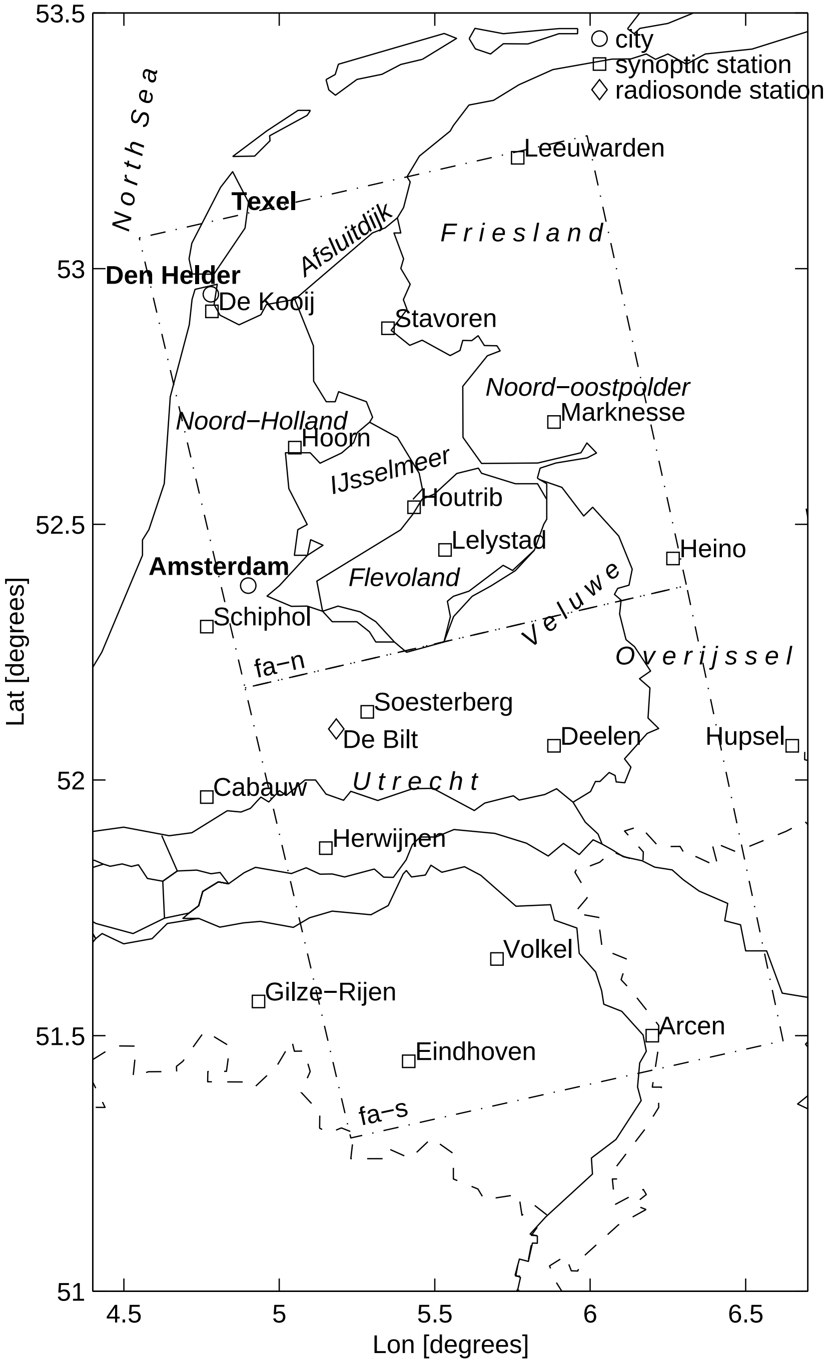

Figure 5.103 *Map of the area for the combined interferograms Flevoland ascending, showing the position of the synoptic and radiosonde stations with some relevant topographical information, referred to in the text.*

The overall phase statistics of the differential interferogram are analyzed, producing the histogram shown in figure 5.109. The overall rms is 2 rad. Note that the histogram is slightly divided as a consequence of lacking phase information over water areas. The rotationally averaged spectrum is shown in figure 5.110. The overall angle of the spectrum is not parallel with the $-5/3$ lines, although for wavelengths between 10 and 25 km it is nearly at this angle.

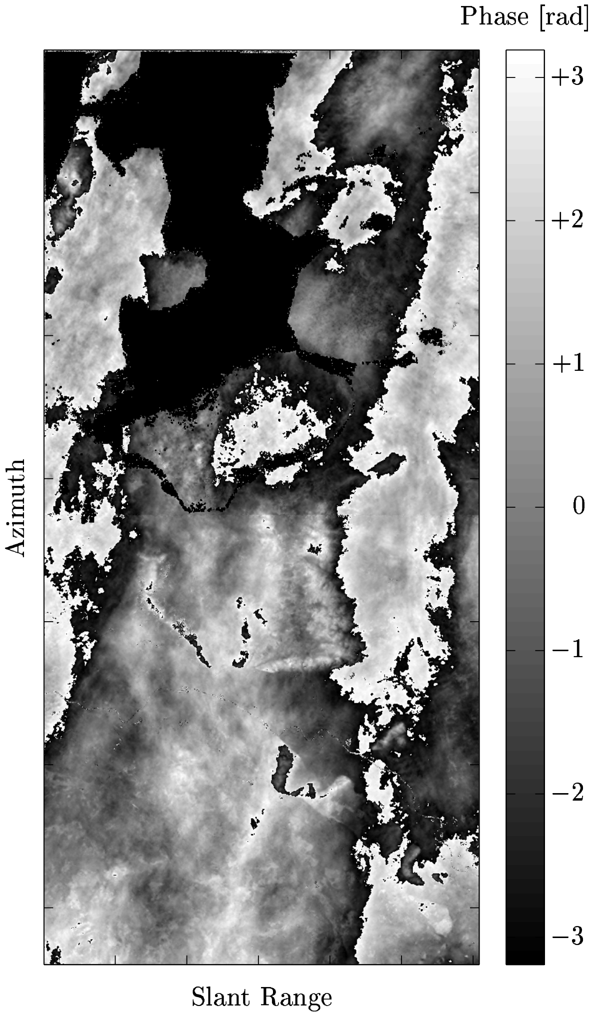

Figure 5.104 *Interferogram fa1*

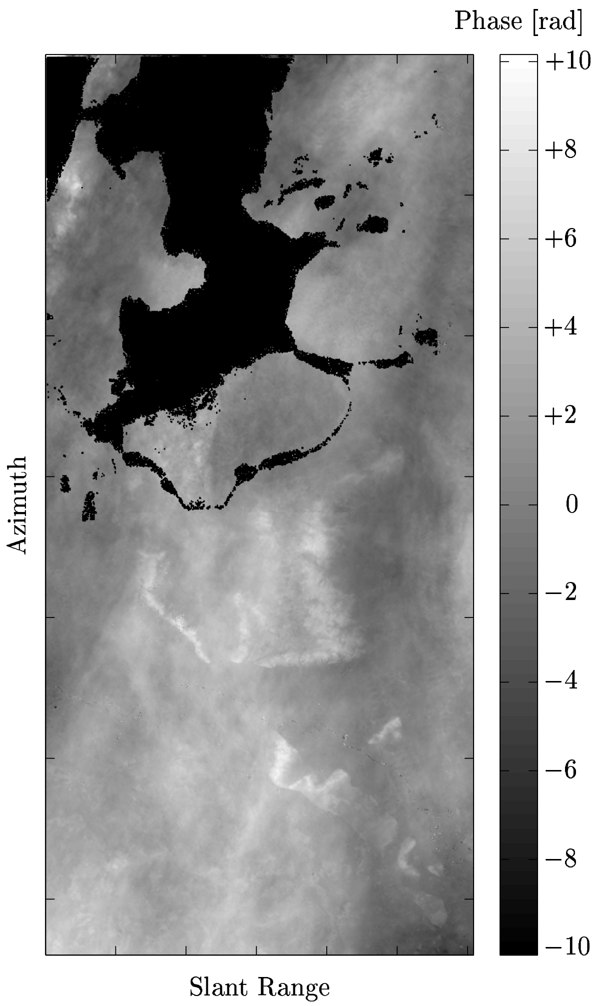

Figure 5.105 *Unwrapped interferogram fa1*

5.5.1.2 Interpretation

Possible atmospheric observations in this area include (1) the ridge in azimuth direction, (2) a localized anomaly in the north-western part of the interferogram, under the city of Den Helder, (3) a band of decreased coherence over Noord-Holland (not shown here), (4) footprints over water areas of active rain cells in the intensity image of day 2, and (5) some “humps” in the southern interferogram.

AVHRR imagery is not available for the times of the SAR acquisitions, which are acquired late in the evening. Images of 3–4 hours earlier show some broken cumulus clouds at day 1, and a warm front connected with a band of cloud cover approaching from the northwest at day 2.

At day 1, there is a northwesterly flow behind a cold front passage, in which showers are

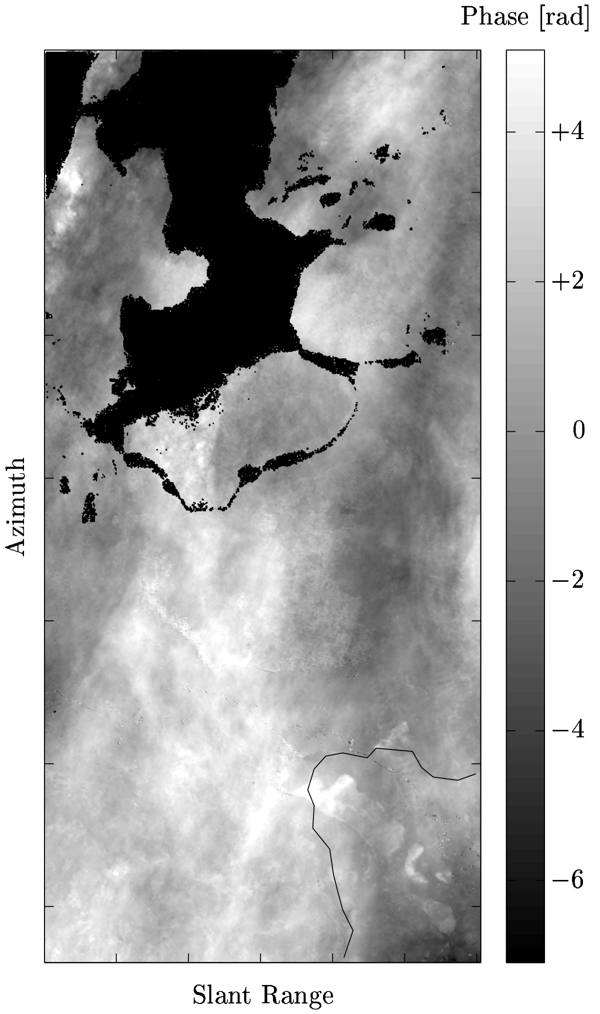

Figure 5.106 *Unwrapped differential interferogram fa1*

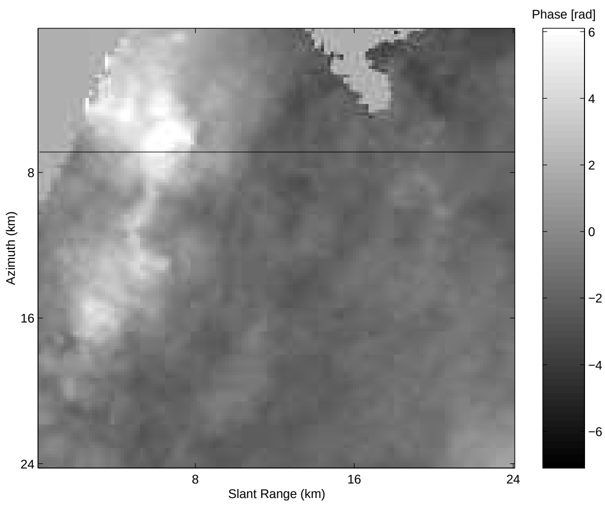

Figure 5.107 *Extraction of the selected part of interferogram fa1*

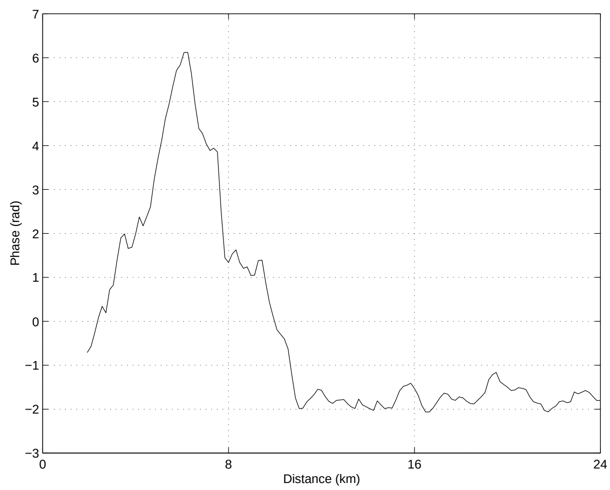

Figure 5.108 *Horizontal cross section of the anomaly in figure 5.107*

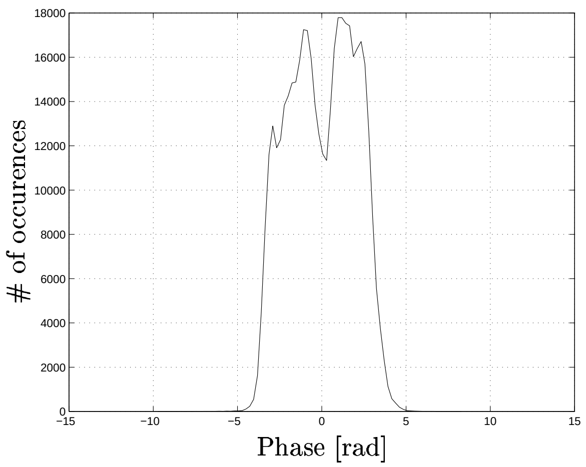

Figure 5.109 *Histogram of a major part of interferogram fa1*

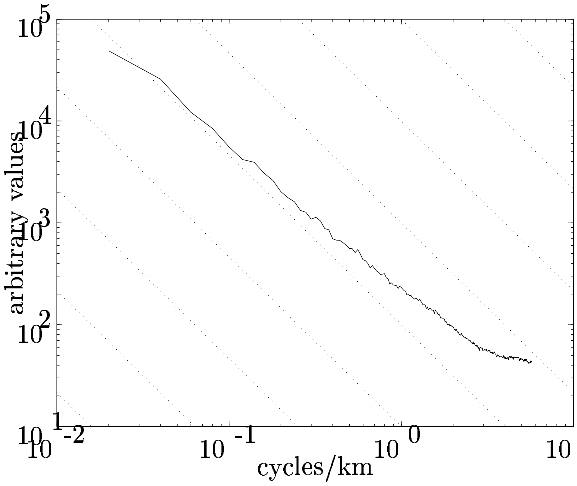

Figure 5.110 *Rotationally averaged spectrum of interferogram fa1*

likely, coming from the North-Sea. Behind the front, in the area of the interferogram, there is advection of unstable, polar air. It is the end of August, late in the evening: therefore the sea is still quite warm which may cause showers in the coastal areas in the evening. As a result, some cumulonimbus clouds are expected. The probability of showers is decreasing from the northwestern to the southeastern part of the image.

The weather radar for the first day, see figure 5.111, indicates isolated showers over Noord-Holland, over the Afsluitdijk, and over Zuid-Flevoland, with heights up to 4.5 km. These are also visible in the interferogram. A comparison of the weather radar with the southern interferogram is hard to perform, since only very small and localized rain signals are detected by the radar. At day 1, De Kooij reports a shower, northwestern winds, a relative humidity of 80% and a temperature of 10–14°C. Most of the synoptic stations report cumulus,stratocumulus, and altocumulus, see table 5.17. Note that the localized artifact under Den Helder is identified in shape as well as in magnitude as a rain cell by the weather radar.

Since the local artifact has the same phase sign as the “ridge” over the whole image, this is either a delay effect at day 1, or a relative advance in day 2. This last option is true when there is an area with, e.g., less moisture inside a relatively homogeneous area with more moisture. This seems not very likely in this case.

At day 2 there is still advection of cold air in the lower layers of the atmosphere. The extension of a ridge of high pressure over the Netherlands provides subsidence at higher levels.[5] There are a few showers, according to weather radar observations, only in the southwestern part of the country. The cloud cover varies quite strong, and there is good visibility (> 15 km). Some stations, such as Amsterdam and Gilze-Rijen, have had a shower. Stations in the northwest report cumulus clouds, in the center stratocumulus, and in the south stratocumulus and cumulonimbus, see table 5.17. It is likely that at the time of the SAR acquisition most of the area is dry; only Amsterdam could have had a light shower.

[5]Subsidence causes downward movements in which the air dries out and the temperature increases, which makes the atmosphere less unstable. In this case the subsidence inversion at day 2 is at 4500 m.

Station	#	UTC	Day	Level 1	Level 2	Level 3
De Kooij	235	2100	1	1/8, Cu, 800		
Schiphol	240	2100	1	1/8, Cu, 1100	4/8, Sc, 1600	
De Bilt	260	2100	1	1/8, Cu, 900		
Soesterberg	265	2100	1	3/8, Sc, 1600	3/8, Ac, 3000	
Leeuwarden	270	2100	1	1/8, Cu, 1300		
Deelen	275	2100	1	1/8, Ac, 3000		
Gilze-Rijen	350	2100	1	1/8, Cu, 1600	3/8, Ac, 3000	
Eindhoven	370	2100	1	2/8, Sc, 1600		
Volkel	375	2100	1	5/8, Ac, 3000		
De Kooij	235	2200	1	1/8, Cu, 900	3/8, Ac, 3000	
Schiphol	240	2200	1	1/8, Cb, 1000	4/8, Sc, 3000	
De Bilt	260	2200	1	1/8, Sc, 1400	3/8, Ac, 3000	
Soesterberg	265	2200	1	1/8, Sc, 1300	5/8, Ac, 3000	
Leeuwarden	270	2200	1	1/8, Cu, 1300		
Deelen	275	2200	1	1/8, Ac, 3000		
Gilze-Rijen	350	2200	1	1/8, Cb, 1100	3/8, Ac, 3000	
Eindhoven	370	2200	1	2/8, Cu, 1600	3/8, Ac, 3000	
Volkel	375	2200	1	4/8, Ac, 3000		
De Kooij	235	2100	2	1/8, Cu, 650	7/8, Sc, 1500	
Schiphol	240	2100	2	2/8, Cu, 1000	7/8, Sc, 1600	
De Bilt	260	2100	2	3/8, Sc, 1500		
Soesterberg	265	2100	2	1/8, Sc, 1600	3/8, Ci, 8300	
Leeuwarden	270	2100	2	1/8, Cu, 1000		
Deelen	275	2100	2	1/8, Ac, 3300		
Gilze-Rijen	350	2100	2	1/8, Sc, 1600	3/8, Sc, 3000	
Eindhoven	370	2100	2	1/8, Sc, 3000		
Volkel	375	2100	2	1/8, Cu, 1600		
De Kooij	235	2200	2	1/8, Cu, 800	3/8, Sc, 1100	6/8, Sc, 1600
Schiphol	240	2200	2	1/8, Cu, 800	7/8, Sc, 1300	
De Bilt	260	2200	2	1/8, Cu, 800	7/8, Sc, 1600	
Soesterberg	265	2200	2	4/8, Sc, 3000	5/8, Ci, 8300	
Leeuwarden	270	2200	2	1/8, Sc, 1600		
Deelen	275	2200	2	1/8, Ac, 3300		
Gilze-Rijen	350	2200	2	1/8, Cu, 800	1/8, Cb, 900	3/8, Sc, 1100 5/8, Ac,3000
Eindhoven	370	2200	2	1/8, Sc, 3000		
Volkel	375	2200	2	2/8, Cu, 1000		

Table 5.17 *Cloud observations fa1: 29-08/30-08-1995. The observations give the amount of cloud cover (okta), the type of cloud, and the cloud base at 3 or 4 levels. Height is given in meters.*

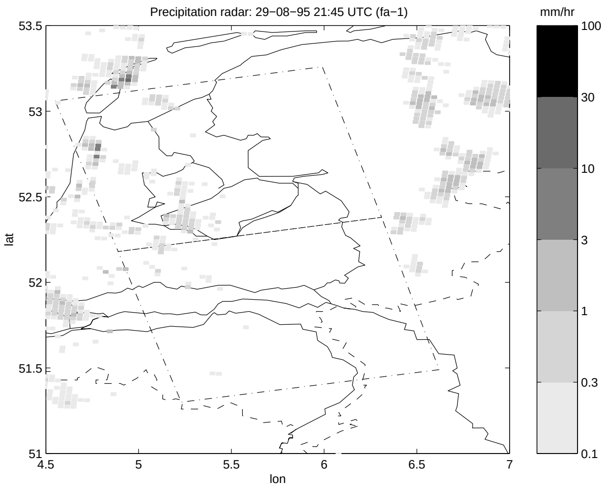

Figure 5.111 Weather radar image for interferogram fa1

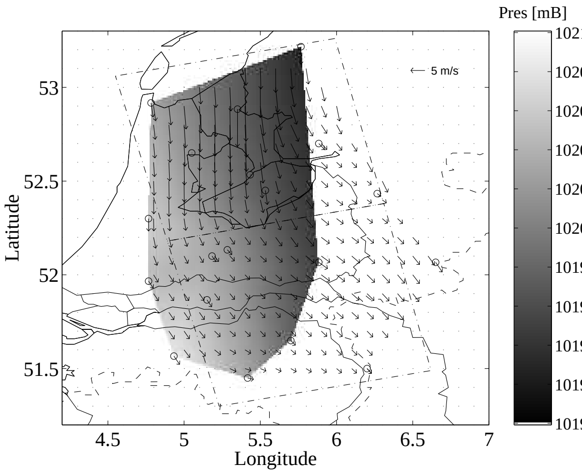

Figure 5.112 Pressure and surface wind field fa1, day 1

5.5.1.3 Conclusions

The local anomalies in the interferogram fit very well with showers at day 1. This also harmonizes with the derived meteorological situation. Based on its orientation, the ridge could be part of the warm front at day 2. However, in that case it should be a decrease in refractivity, which seems unlikely based on the relative homogeneity of the surrounding phase. The alignment of the ridge with the surface wind field at day 1, makes an explanation in terms of a field of increased humidity more likely. In this field, precipitation occurs at some parts.

5.5.2 Analysis of interferogram fa2

Interferogram fa2 was acquired at October 3 and 4, 1995, at 21:41:14 UTC (22:41:14 LT). SAR frame numbers are 1053 and 1035, for ERS-1 orbit 22061, and ERS-2 orbit 2388. The parallel baseline is 144 and 146 m, the perpendicular baseline 385 and 393 m, for the southern and the northern image respectively. The phase unwrapping is performed using the minimal cost flow algorithm (Costantini, 1996).

5.5.2.1 Observations

Interferogram fa2 in figure 5.113 is again a composition of two neighboring SLC scenes. The whole interferogram shows several fringes, not only at the expected topographic features. Particularly striking is the diagonal line or wave crest, which is crossing both original images. The unwrapped interferogram in figure 5.114 is somewhat easier to interpret. Due to the cut-off boundaries of the used color scale, topography is clearly visible in the center and lower left of the image. In the differential interferogram, figure 5.115, this topography has been removed using the reference DEM, up to the lower right corner, which was not covered by the elevation model.

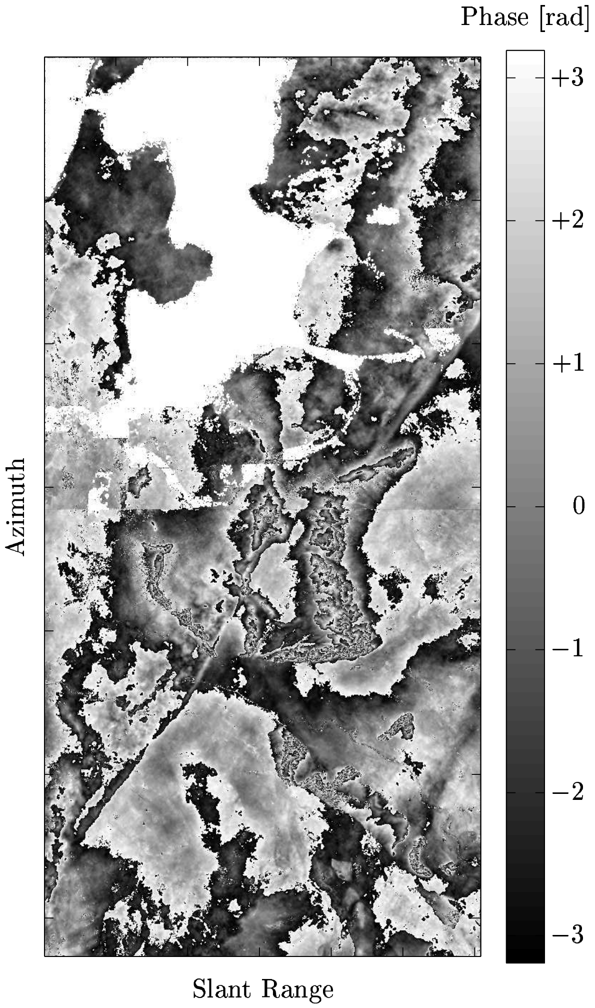

Figure 5.113 *Interferogram fa2*

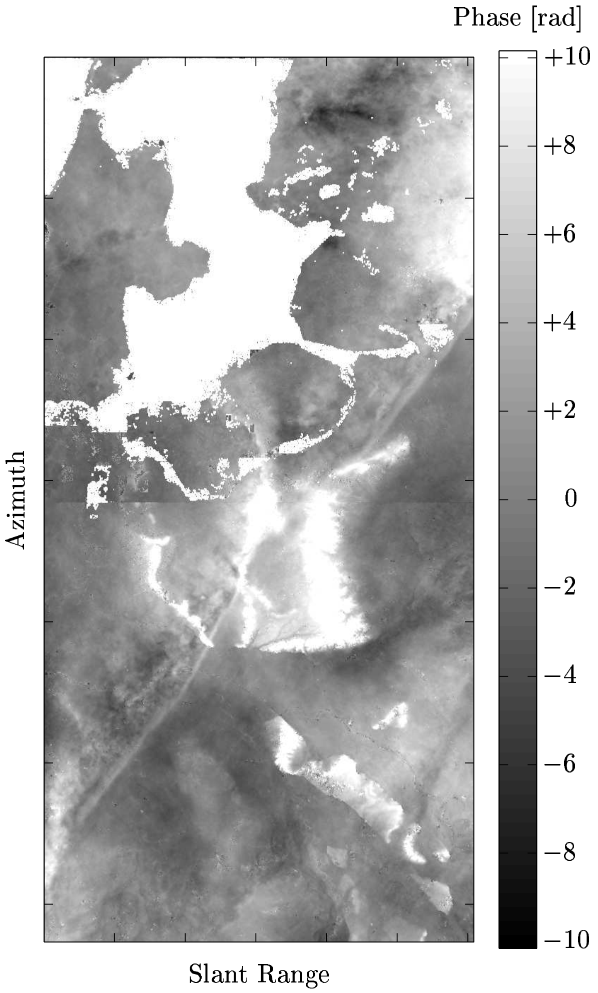

Figure 5.114 *Unwrapped interferogram fa2*

In the differential interferogram, the most prominent feature is the white diagonal crest, corresponding with a very local increase in absolute phase. In the lower part of this crest, the side left of the crest seems to have some stronger phase turbulence when compared to the right side. Two boxes, located at both side of the crest, indicated in figure 5.115 are analyzed using the rotationally averaged spectrum, see figure 5.116. Box 1 is at the left side of the crest, box 2 at the right side. It can be concluded that both lines have the same orientation, although the stronger amplitude differences in the left box result in a vertical shift of the line in the spectrum.

Some cross sections of the crest are shown in figures 5.117, 5.118, and 5.119. In profile 1, the lowest indicated in figure 5.115, the crest has an amplitude which is 3 rad higher than the average left side of the profile, and 5 rad higher than the right side. The wave crest itself is approximately 4 km wide. In the middle of the interferogram, the crest seems to split into two branches. The main branch deviates towards the left side of the image, and forms a curl. Profile 2 in figure 5.118 shows a cross section of this middle part of the crest, where it has the largest amplitude, and starts deviating towards the left side of the image. The maximum amplitude of the wave is here 13.1 rad. The difference with the left side the the profile is 9 rad, and with the right side of the profile even 14 rad! The width of the wave is 5 km. The second branch continues in the same direction as the lower part, accompanied at the left side by a parallel second wave crest. A third profile, in this area, is shown in figure 5.119. The maximum of the tops is 4.3 and 3.7 rad, while there is still the difference with the left side of the profile (1 rad) is smaller than the difference with the right side (4 rad). The width of both wave crests is approximately 2 km.

Apart from this wave crest phenomenon, still rather large phase deviations characterize the northern parts of the interferogram. A larger cross section over this area, profile 4, is shown in figure 5.120. In these parts, phase variations of 15 rad take place, where the anomalies have a typical diameter of 10 km.

The histogram of the total image, shown in figure 5.121, gives a wide spread curve, consisting of two main peaks. Most of the interferometric phase is located in a range of 18 rad. The rms value of this distribution is 3.6 rad, although it could be argued that the rms values of the two main Gaussians in the histogram would be less.

The rotational averaged spectral lines for two parts of the interferogram are shown in figure 5.122. The lower line is found for an area in the lower part of the interferogram, and includes the crest. This line deviates from the $-5/3$ slope, apart from a small range of long wavelengths. The upper line results from an area in the upper right corner of the interferogram, where the phase variation is quite strong. This line closely follows the $-5/3$ slope, for almost all wavelengths between 500 m and 30 km.

5.5.2.2 Interpretation

There are local anomalies in both images. A dominant wave crest crosses both images from the northeast to the southwest. It is only a couple of kilometers wide.In the upper right part of the interferogram there is also anomalous undulation.

The crest is related to the cold front which passes over the Netherlands. Since the average tangent of the angle of a cold front is 1/70, horizontal changes occur over relatively short distances when compared with a warm front, see figure 5.123. There can suddenly be less precipitation when the front passes over. This phenomenon is a Narrow Cold-Frontal Rainband (NCFR), or *line convection*, (Parsons, 1992).

The weather charts at day 1 show a curve in a polar front, which is moving over the area.