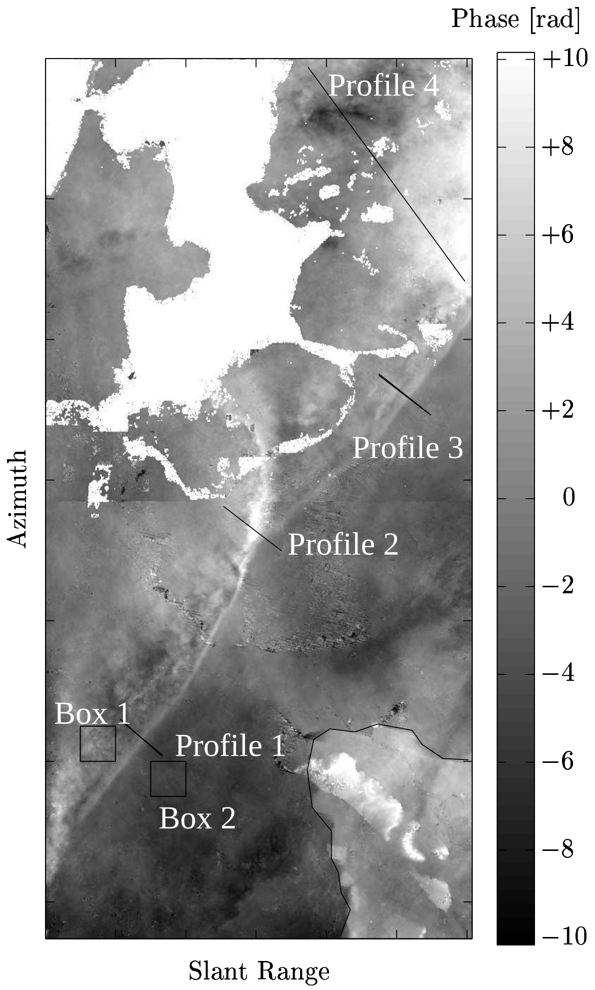


Figure 5.115 *Unwrapped differential interferogram fa2*

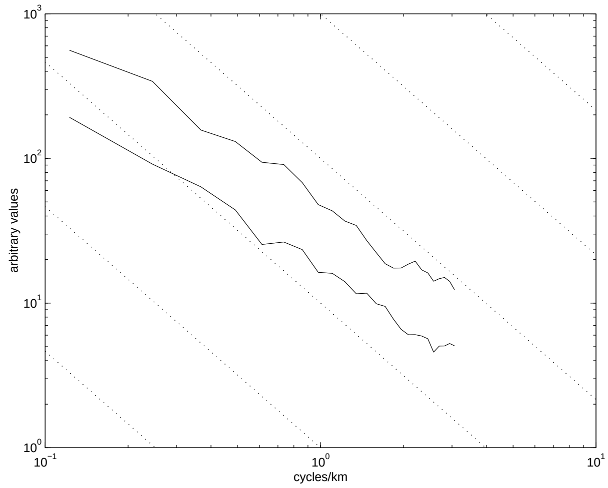


Figure 5.116 *Rotationally averaged spectrum for the two boxes, left and right of the wave crest in fa2. The upper line corresponds with the box left of the crest.*

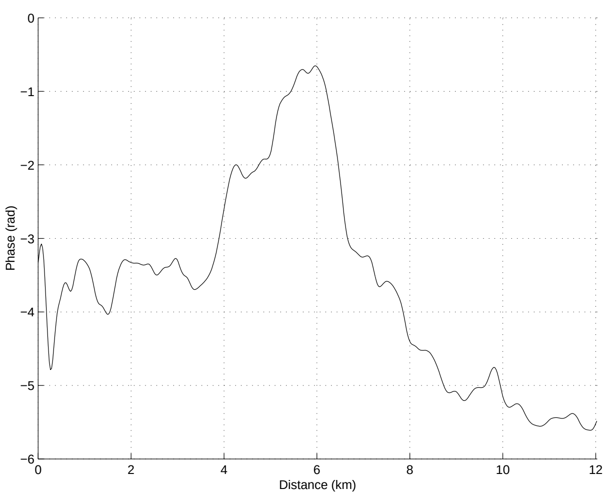


Figure 5.117 *Profile 1 of fa2*

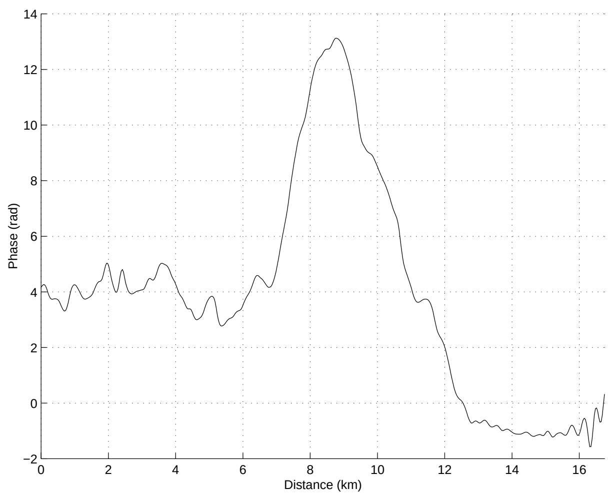


Figure 5.118 *Profile 2 of fa2*

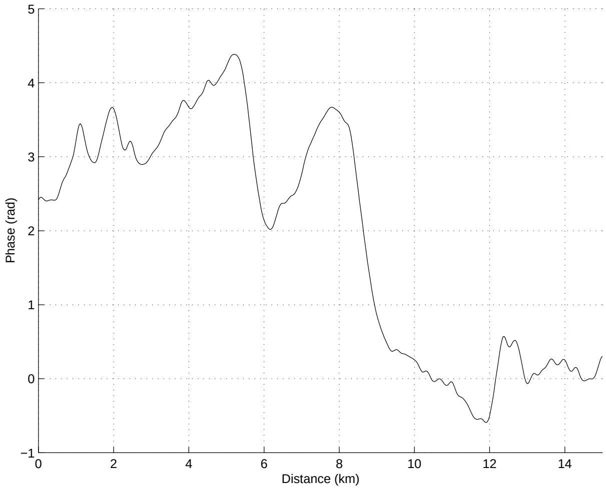


Figure 5.119 *Profile 3 of fa2*

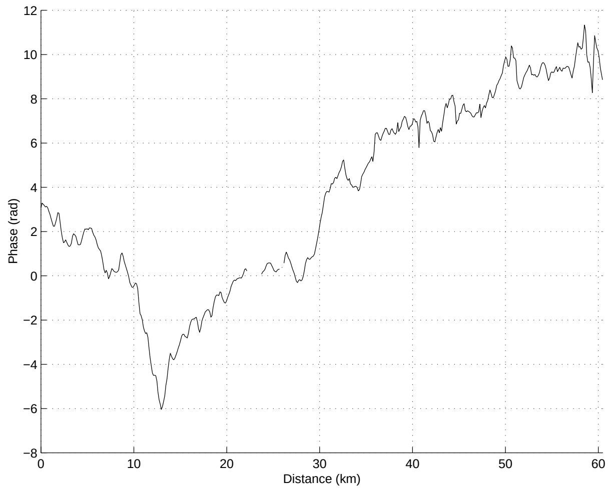


Figure 5.120 *Profile 4 of fa2*

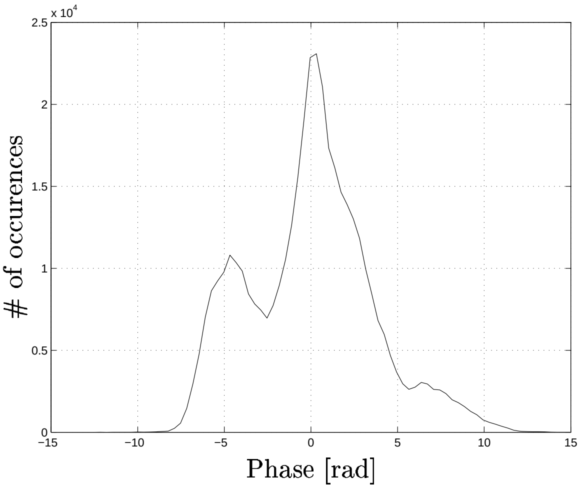


Figure 5.121 *Histogram of major part of interferogram fa2. The two Gaussians are the result of the average difference between the phase at the left side of the diagonal crest and at the right side.*

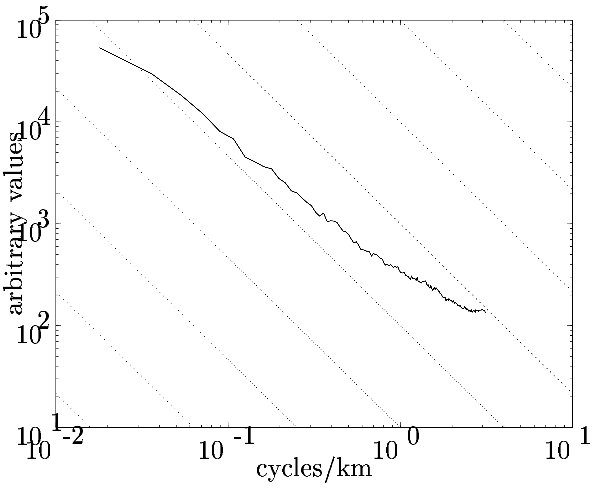


Figure 5.122 *Rotationally averaged spectrum of fa2. The upper line is found for an area around the crest, at the lower part of the interferogram. The lower line results from an analysis of the upper right part of the image.*

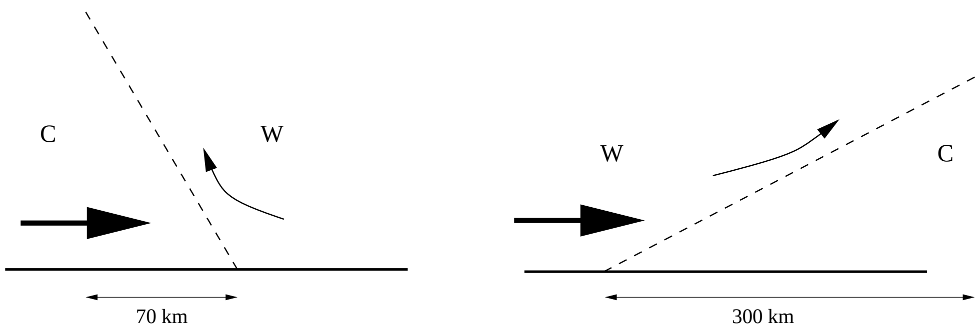


Figure 5.123 *The average gradient for a cold front is 1/70, which is much steeper compared to a warm front, with an average gradient of 1/300*

The wave top (position of the occlusion point) is just over Friesland. The cold front has a northeast-southwest orientation. The cold front could be a split-level cold front, see figure 5.130. The synoptic weather features are rain, showers and thunderstorms.

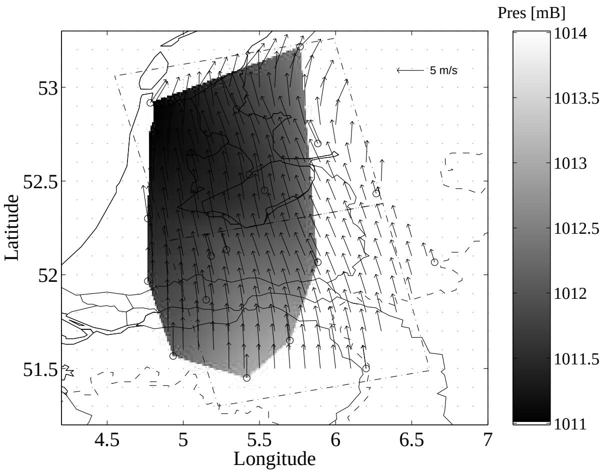


Figure 5.124 *Pressure and surface wind field fa2, day 1,21:00 UTC*

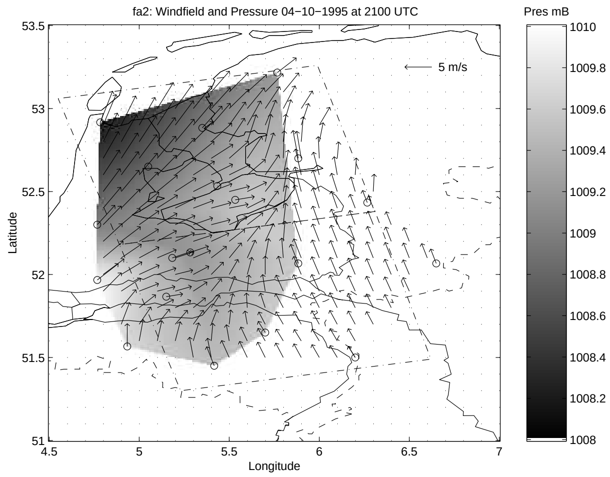


Figure 5.125 *Pressure and surface wind field fa2, day 2, 21:00 UTC*

At day 2, the weather charts of 12:00 UTC (daily overviews), indicate that the cold front is still situated over the southeastern part of the Netherlands. Northwest of the front, our research area , there still some showers and rain. A second cold front is approaching behind the first one. It is probably this second cold front which is located over the Netherlands at the time of the SAR acquisitions.

The weather radar image of the first day indicates a thunderstorm over Friesland with cloud tops at 8 km. The position of the showers at the first day, see figure 5.126, corresponds closely with the position of the negative phase anomaly in the interferogram. De Kooy also has a thunderstorm with tops on 8 km. The second day, figure 5.127 the weather radar shows a large sickle shaped form of rain over Flevoland. This sickle is also clearly visible in the interferogram. The cloud cover consists of layered clouds with embedded cumulonimbus.

At day 1, a large part of the synoptic stations is still situated at the warm side of the cold front. De Kooy and Leeuwarden are at the warm side of the front. At 10:00 UTC, De Kooy reports lightning, but no rain. It has rained, however, 4.4 mm in the last hour. Leeuwarden has a thunderstorm, with 5.3 mm precipitation and a visibility of 1800 m, which is very low. Lelystad has 0.1 mm precipitation. At 11:00 UTC, De Kooy reports a thunderstorm with rain and wind from the south-southeast. Also Schiphol reports rain. Leeuwarden reports a heavy thunderstorm, with 13.2 mm precipitation, and southwestern wind! Eindhoven observes rain in the distance. There is a changing cloud cover in the area, see table 5.18. Cloud cover observations at 21:00 UTC show cumulonimbus clouds over the middle and northern part of the area, with additional stratocumulus and altocumulus. The southern stations report altocumulus and cirrus. There is southwestern wind at higher altitudes, and southeastern wind at surface level, according to the radiosonde observations. At 22:00 UTC, cumulonimbus clouds are observed in the north. In the south of the Netherlands it looks like nothing is happening.

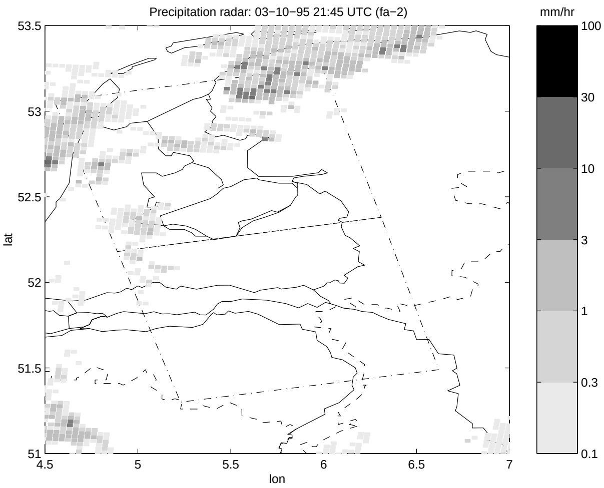


Figure 5.126 *Weather radar fa2, day 1*

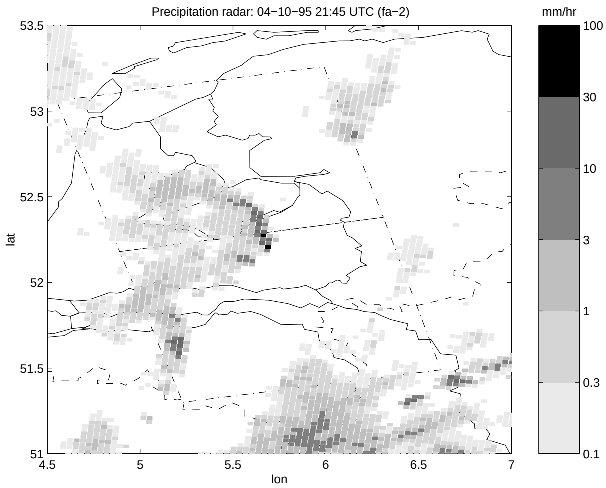


Figure 5.127 *Weather radar fa2, day 2*

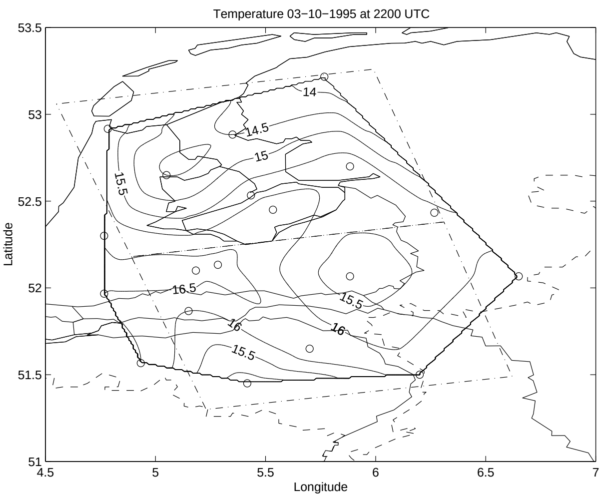


Figure 5.128 *Temperature contours fa2, day 1*

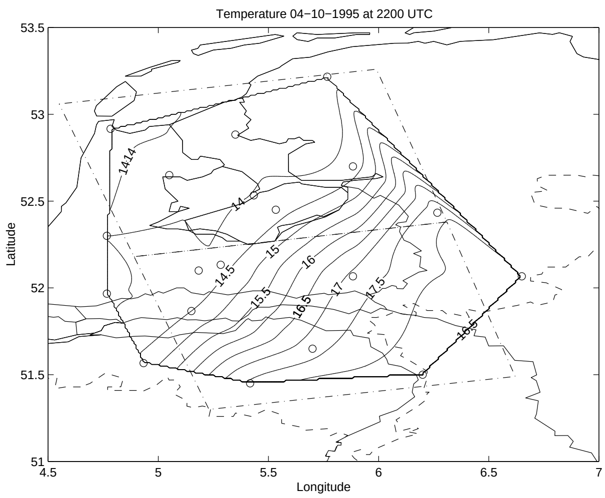


Figure 5.129 *Temperature contours fa2, day 2*

The synoptic data at day 2, 21:00 UTC, list for De Kooy light rain and southern winds and for Schiphol light rain. Houtrib has had a light shower in the last hour. Leeuwarden reports drizzle. In the south, the stations have seen lightning, but did not have precipitation. The front has moved now, over the south-east of the Netherlands. The wind in that area is south-east, between 230–260 degrees. The northwest part of the Netherlands indicate wind from the southwest!

Cloud observations at day 2, 21:00 UTC, indicate cumulonimbus over Amsterdam, stratocumulus over the center of the area, and altocumulus at the southeast. At 22:00 UTC, there was a thunderstorm in the southwest. The total cloud cover was 7/8–8/8. There are no more cumulonimbus clouds observed between 21:00 and 22:00.

5.5.2.3 Conclusions

The data indicate clearly that the wave crest in the interferogram is closely related with the cold front. Figure 5.130 describes this configuration. The left subfigure gives a side-view of the split-level cold front. At some altitude, there is a south-western wind, according to the radiosonde. At surface level up to 1800 m the wind is more south to south-east (synoptic data). The frontal plane (the diagonal line in the right subfigure) is splitting up, and the 'height-cold front' is moving towards the north-east. The 'surface cold front' is nearly stationary. Behind the height-cold front the air dries up: in the De Bilt radiosonde we observe the dry part of the profile between 2 and 5 km. The air below and above this region has a relative humidity of 100%. The right subfigure shows the two combined interferograms, with the front depicted as the fat dashed line. We divide the area in three parts: Part I is behind the front, part II is the warm sector, and part III is the frontal zone. At day 2, area II is warmer (17–18°C) , more humid, and has more low and layered clouds than area I, where it is colder (14°C) , and there are higher clouds. The temperature differences are clearly notable from the synoptic data. In area III, a higher pressure is expected just behind the frontal zone, where there is also a sudden drop of temperature.

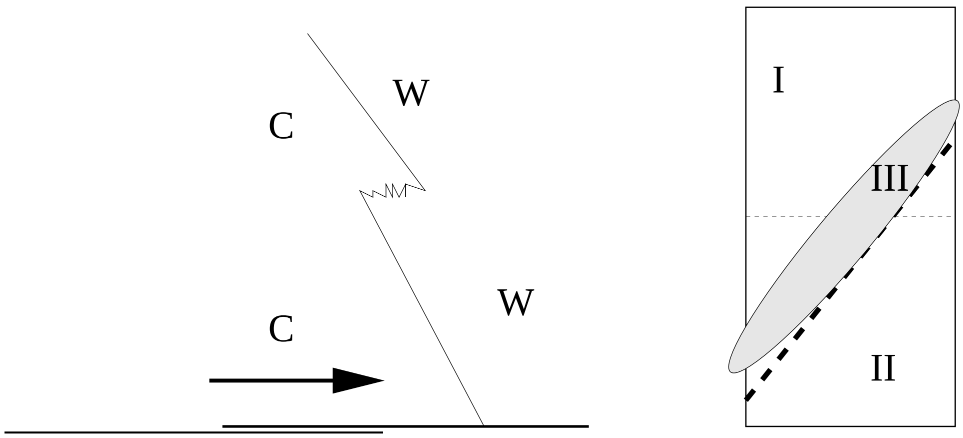


Figure 5.130 *A split-level front. The surface front is nearly stationary, the upper-level front is pushed forward by winds at this altitude. The right figure shows the location of the crest, see the text for the discussion on the three areas.*

The hypotheses of relating the features in the interferogram to a frontal system seems to be confirmed by the meteorological feature of the split-level front with a high intensity of precipitation (thunderstorms) and a remarkable drying out of a layer behind the upper level cold front.

Station	#	UTC	Day	Level 1	Level 2	Level 3
De Kooij	235	2100	1	1/8, St, 200	1/8, Cb, 500	7/8, Sc, 900
						7/8, Ac, 3000
Schiphol	240	2100	1	1/8, Cb, 1300	3/8, Sc, 3000	7/8, Ci, 6600
De Bilt	260	2100	1	6/8, Sc, 1600		
Soesterberg	265	2100	1	3/8, Sc, 1000	6/8, Sc, 1600	7/8, Ac, 3300
Leeuwarden	270	2100	1	3/8, St, 200	2/8, Cb, 400	4/8, Sc, 650
						6/8, Sc, 1500
Deelen	275	2100	1	3/8, Sc, 1600	5/8, Ci, 8300	
Gilze-Rijen	350	2100	1	1/8, Ac, 3300	3/8, Ci, 8300	
Eindhoven	370	2100	1	1/8, Cu, 1400	4/8, Ac, 3300	7/8, Ci, 8300
Volkel	375	2100	1	4/8, Sc, 1000	6/8, Ci, 8300	
De Kooij	235	2200	1	1/8, Cu, 1000	4/8, Ac, 3000	7/8, Ac, 3300
Schiphol	240	2200	1	1/8, Sc, 1300	3/8, Ac, 3000	7/8, Ci, 6600
De Bilt	260	2200	1	6/8, Sc, 1600		
Soesterberg	265	2200	1	3/8, Sc, 1600	4/8, Ac, 3000	6/8, Ac, 3300
Leeuwarden	270	2200	1	1/8, Cb, 500	5/8, Sc, 750	7/8, Sc, 1300
Deelen	275	2200	1	2/8, Sc, 1600		
Gilze-Rijen	350	2200	1	2/8, Ac, 3300		
Eindhoven	370	2200	1	2/8, Ac, 3300		
Volkel	375	2200	1	2/8, Ac, 3300		
De Kooij	235	2100	2	1/8, Cu, 1200	6/8, Ac, 3000	8/8, Ac, 3000
Schiphol	240	2100	2	2/8, Cb, 800	5/8, Sc, 1300	
De Bilt	260	2100	2	4/8, Sc, 1100	4/8, Ac, 3300	
Soesterberg	265	2100	2	3/8, Cu, 800		
Leeuwarden	270	2100	2	1/8, Cu, 900	4/8, Sc, 1100	6/8, Sc, 3000
Deelen	275	2100	2	1/8, Ac, 3000	3/8, Ac, 3300	7/8, Ci, 8300
Gilze-Rijen	350	2100	2	1/8, Cu, 300	5/8, Ac, 3000	7/8, Ci, 8300
Eindhoven	370	2100	2	2/8, Ac, 3000	6/8, Ci, 8300	
Volkel	375	2100	2	3/8, Ac, 3000	5/8, Ac, 3300	
De Kooij	235	2200	2	1/8, Cu, 1200	5/8, Ac, 3000	8/8, Ac, 3000
Schiphol	240	2200	2	1/8, Cu, 800	7/8, Ac, 3000	
De Bilt	260	2200	2	8/8, Sc, 1000		
Soesterberg	265	2200	2	1/8, Cu, 700	3/8, Sc, 3000	8/8, Ac, 3000
Leeuwarden	270	2200	2	1/8, Sc, 1200	5/8, Sc, 1600	7/8, Ac, 3300
Deelen	275	2200	2	3/8, Ac, 3000	5/8, Ac, 3300	7/8, Ci, 8300
Gilze-Rijen	350	2200	2	1/8, Sc, 1100	5/8, Ac, 3000	8/8, Ac, 3300
Eindhoven	370	2200	2	3/8, Ac, 3000	7/8, Ac, 3300	
Volkel	375	2200	2	4/8, Ac, 3000	7/8, Ac, 3300	

Table 5.18 *Cloud observations fa2: 03-10/04-10-1995. 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.*

5.5.3 Analysis of interferogram fa3

Interferogram fa3 was acquired at March 26 and 27, 1996, at 21:41:05 UTC (22:41:05 LT). SAR frame numbers 1053 and 1035 are used, for ERS-1 orbit 24566, and ERS-2 orbit 4893. The parallel baseline is −21 and −21 m, the perpendicular baseline −32 and −33 m, for the southern and northern image respectively. The method of Ghiglia and Romero (1994) is used for the phase unwrapping.

5.5.3.1 Observations

After correcting for possible orbit errors in interferogram fa3—mainly a first order tilt in slant range direction—an exceptionally strong phase ramp remains at the lower part of the southern interferogram, see figure 5.131 and figure 5.132. The ramp is covering

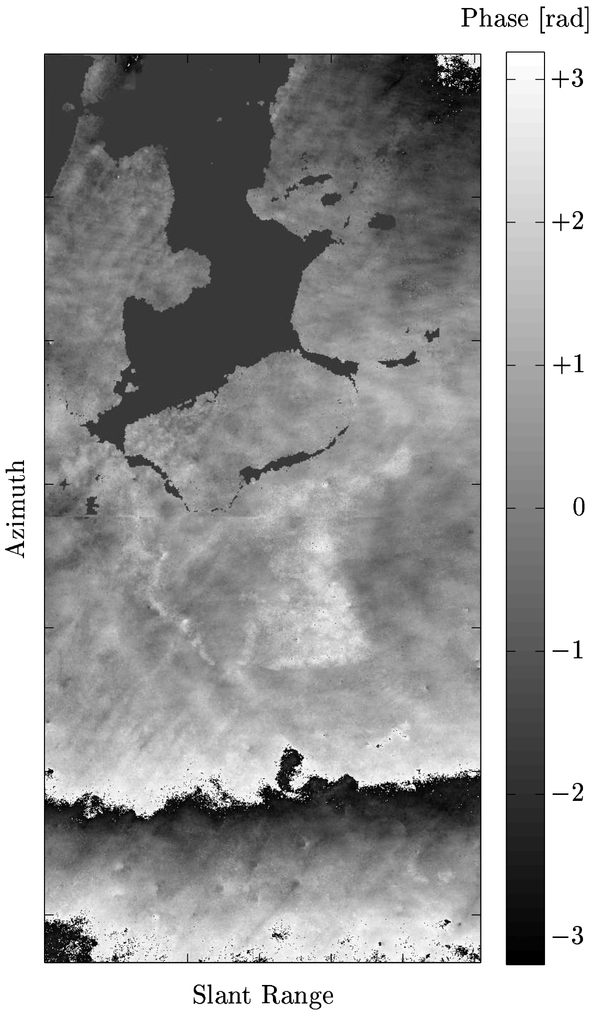


Figure 5.131 *Interferogram fa3*

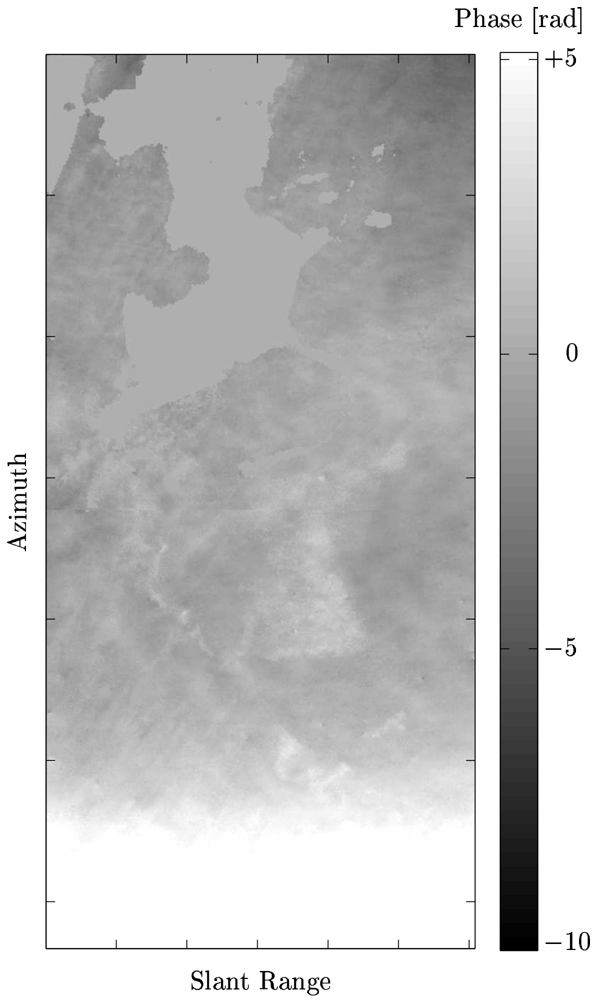


Figure 5.132 *Unwrapped interferogram fa3*

1.5 fringe. Since the effect is only covering the lower half of the interferogram, orbit errors seem unlikely to cause this, especially because the top interferogram does not show this effect at all. Tests with independently calculated precise orbits of DEOS-TUD and DLR-GFZ yielded identical results. On the other hand, the effect seems to be very systematic, and can be modeled well using a third degree polynomial over the lower parts of the lower image, see figure 5.133. Therefore the assumption that it is purely of atmospheric origin

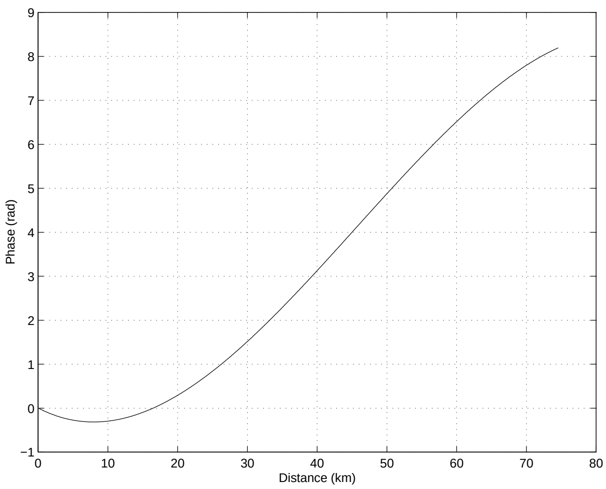


Figure 5.133 *The third degree polynomial ramp, which was extracted from the lower side of interferogram fa3*

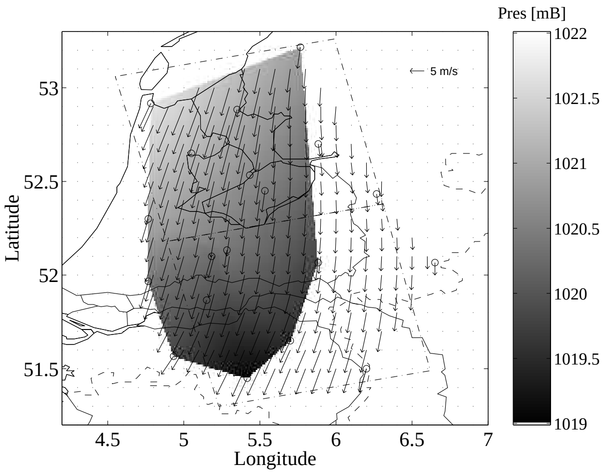


Figure 5.134 *Pressure and surface wind field fa3, day 1, 22:00, showing a change from north to northwest over the interferogram area.*

raises some questions as well. For this reason, both the original differential interferogram (figure 5.135) is shown, as well as a version in which the ramp is modeled by a third degree polynomial, and extracted from the interferogram, see figure 5.136.

Whereas in the uncorrected version the ramp dominates the behavior of the interferometric phase, the corrected version shows much more detail, and low amplitude phase effects. A histogram of combined parts of the interferogram, not including the ramp area, is shown in figure 5.137. A rotationally averaged spectrum is shown in figure 5.138. Note that this spectrum is calculated over a relatively large region, enabling longer wavelengths to be present in the plot. The curve deviates considerably from the $-5/3$ gradient, indicated by the dotted lines.

An overall rms value, including the ramp area, of 2.5 rad was found. More localized statistics were checked as well for this interferogram. An area of 24×24 km in Noord-Holland had only small phase deviations with Gaussian characteristics, and an rms of 0.36 rad. An area of the same size in the east of the Netherlands had an rms of 0.46 rad, in the north 0.68 rad, and in the west 0.46 rad.

5.5.3.2 Interpretation

Observed phase variations include slight humps, a strong third order gradient, and waves in the south-western part of the image. In the water of the IJsselmeer, wind strokes are visible. These wind strokes are probably connected with the waves in the southern image, wind rolls, causing moisture streets under the subsidence inversion, see Hanssen et al. (1998a) for a more elaborate discussion. The strong gradient in the southern image can be related with a frontal zone.

From the Meteosat WV channel, figure 5.140 it may be concluded that at day 1, 21:30 UTC, there is a jet stream flowing over the Netherlands, at about 10 km height. However, this is not confirmed by the radiosondes of De Bilt and Emden: at day 1 there are thick cirrus layers, cirrostratus, but the wind speed at higher levels is not very high. Still,

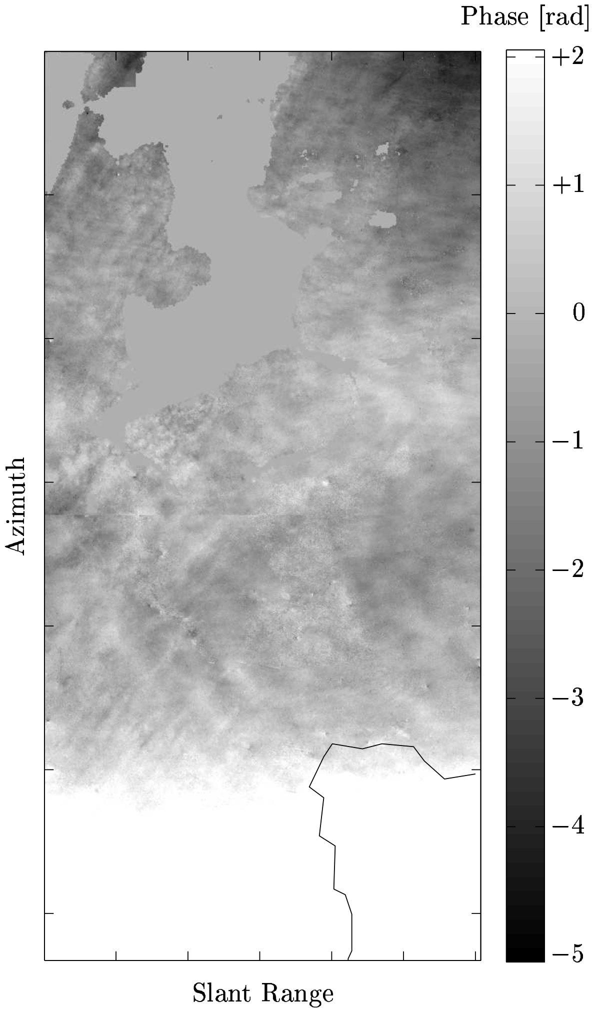


Figure 5.135 Unwrapped differential interferogram fa3, topographic phase is eliminated

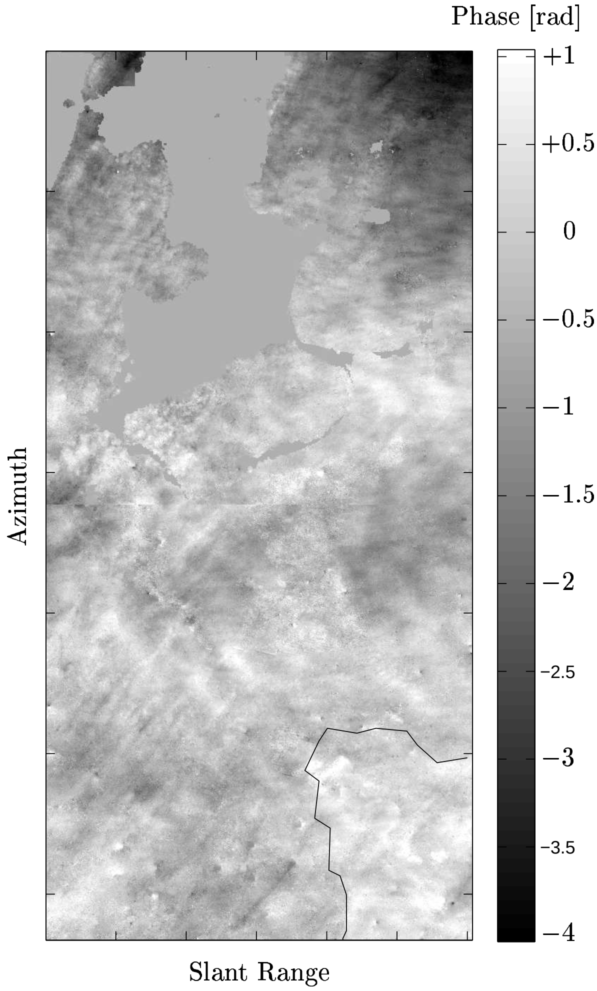


Figure 5.136 Unwrapped differential interferogram fa3, after elimination of the ramp

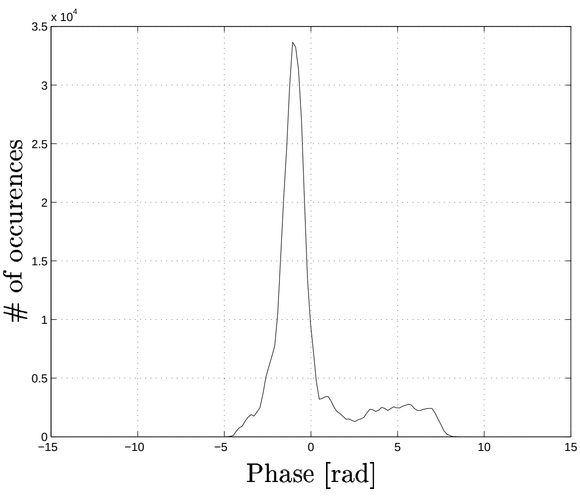


Figure 5.137 Histogram of a major part of interferogram fa3

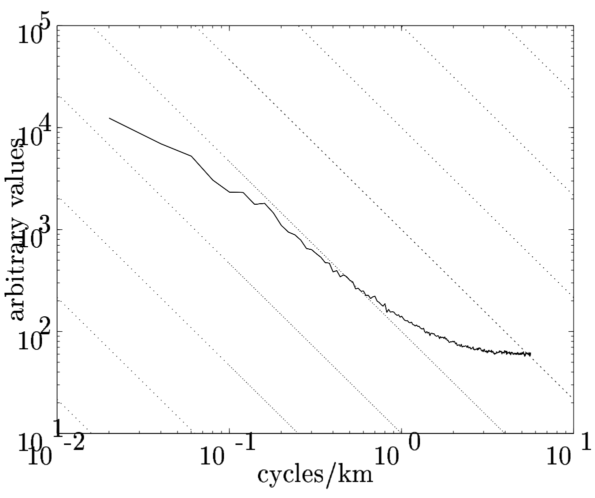


Figure 5.138 Rotationally averaged spectrum of fa3

there is a lot of water vapor available at higher levels. The extension of a ridge of high pressure provides subsidence and that's the reason why the WV-image of the Meteosat gives a dry stroke in the Netherlands. Note that the pixels in the water vapor image yield the integrated water vapor content of the troposphere at a certain position. This could be an explanation for the strong gradient in the southern interferogram. The water vapor instrument measures the absorption spectrum of water vapor from the top of the troposphere down to approximately 3 km.

At day 1, a cold front has recently passed from the north. During the passage of the front there are several cloud layers, middle to heigh clouds, but there is no precipitation. There is advection of cold air.

At day 2, the Meteosat IR channel indicates cold cirrus clouds over the North Sea. Cloud cover has moved towards the south.

The synoptic data at day 1, 21:00, show there is a north-northeastern wind: 7.7–10 m/s, see figure 5.134. There is only few cloud cover, only Volkel (375) and Eindhoven (370) report more than 2/8 octa. In Leeuwarden the temperature is below zero, in all other stations it is 2–3°C. The most observed cloud type is stratocumulus, with a coverage of 2/8–3/8 octa. Note that there is more cloud cover reported over the southern part of the image, just as expected from the interferogram. There is no precipitation. At 22:00 UTC, the cloud conditions are similar, with no precipitation.

At day 2, the situation is almost similar: The rain radar shows no true precipitation signal, only some erroneous scattering. This was a very 'nice' day, regarding the time of the year. The wind direction was west in De Kooy and north in Schiphol. There was, however, not much wind. The visibility was very good. Cloud cover at 21:00 UTC was 7/8 in total, see table 5.19: with stratocumulus in the northeast and cirrus in the northern part of the area. The higher clouds that are visible in the Meteosat IR image are already observed as the first signs of a warm front, which is invading the northwest of the Netherlands the next day.

5.5.3.3 Conclusions

The strong gradient of more than a full cycle in the south of the interferogram seems to be very systematic, which raises some doubt if it is caused by atmosphere or if it is, e.g., a processing error. However, based on the Meteosat observations of integrated water vapor, combined with synoptic cloud observations and the direction of the cold front at day 1, the gradient can be explained sufficiently as a gradient in integrated water vapor.

Observed wind strokes over the IJsselmeer, the synoptic wind direction observations, and the direction of the waves in the southern part of the interferogram reveal the same direction. The interferometric effects are probably caused by the distribution of moisture in boundary layer rolls.

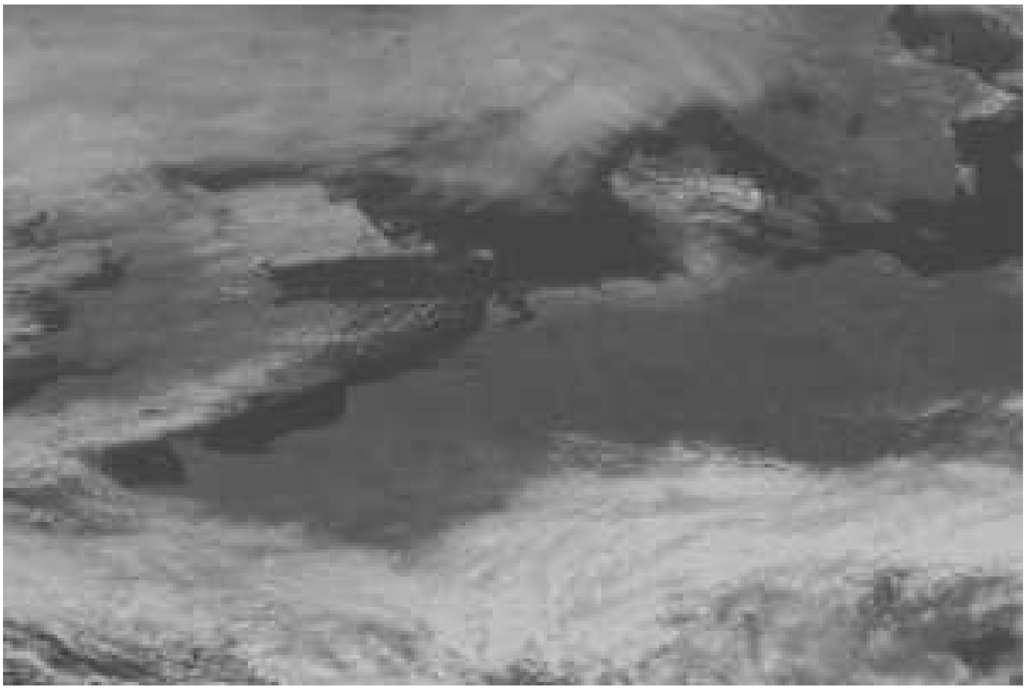


Figure 5.139 *Meteosat visual channel fa3, day 2. This image serves as an orientation tool for the water vapor gradient in figure 5.140*

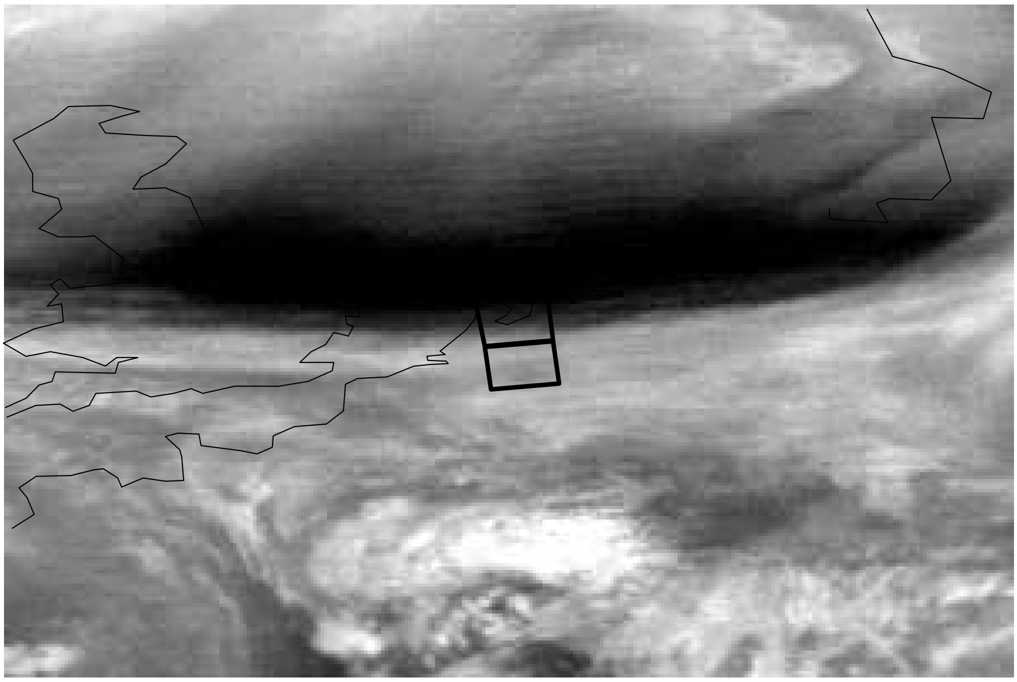


Figure 5.140 *Meteosat water vapor channel fa3, day 1, 21:30 UTC. A strong increase in integrated water vapor can be observed over the south of the Netherlands. Refer to figure 5.139 for orientation. The two rectangles indicate the position of the interferogram.*

Station	#	UTC	Day	Level 1	Level 2	Level 3
De Kooij	235	2100	1	2/8, Sc, 700		
Schiphol	240	2100	1	1/8, Sc, 1000	3/8, Sc, 1200	
De Bilt	260	2100	1	5/8, Sc, 1500		
Soesterberg	265	2100	1	1/8, Sc, 1100	3/8, Sc, 1300	
Leeuwarden	270	2100	1	1/8, Sc, 1100		
Deelen	275	2100	1			
Gilze-Rijen	350	2100	1	1/8, Cu, 500	3/8, Sc, 900	7/8, Sc, 1100
Eindhoven	370	2100	1	8/8, Sc, 1100		
Volkel	375	2100	1	3/8, Sc, 1300	6/8, Sc, 3000	
De Kooij	235	2200	1	2/8, Sc, 800		
Schiphol	240	2200	1	2/8, Sc, 1000	6/8, Sc, 1200	
De Bilt	260	2200	1	1/8, Cu, 650	4/8, Sc, 1500	
Soesterberg	265	2200	1	1/8, Sc, 1000	3/8, Sc, 1200	
Leeuwarden	270	2200	1	1/8, Sc, 1100		
Deelen	275	2200	1			
Gilze-Rijen	350	2200	1	3/8, Sc, 1000	7/8, Sc, 1400	
Eindhoven	370	2200	1	8/8, Sc, 1100		
Volkel	375	2200	1	4/8, Cu, 1300		
De Kooij	235	2100	2	5/8, Ci, 8300		
Schiphol	240	2100	2	2/8, Ci, 8300		
De Bilt	260	2100	2	1/8, Ci, 8300		
Soesterberg	265	2100	2	1/8, Ci, 8300		
Leeuwarden	270	2100	2	4/8, Sc, 1300	7/8, Ci, 8300	
Deelen	275	2100	2			
Gilze-Rijen	350	2100	2	1/8, Ci, 8300		
Eindhoven	370	2100	2	2/8, Ci, 8300		
Volkel	375	2100	2			
De Kooij	235	2200	2	5/8, Cs, 6600	7/8, Ci, 8300	
Schiphol	240	2200	2	7/8, Cs, 8300		
De Bilt	260	2200	2	6/8, Ci, 8300		
Soesterberg	265	2200	2	3/8, Ci, 8300		
Leeuwarden	270	2200	2	1/8, Sc, 1300	5/8, Ac, 3300	8/8, Ci, 8300
Deelen	275	2200	2			
Gilze-Rijen	350	2200	2	1/8, Ci, 8300		
Eindhoven	370	2200	2	1/8, Ci, 8300		
Volkel	375	2200	2			

Table 5.19 *Cloud observations fa3: 26-03/27-03-1996. 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.*

5.5.4 Analysis of interferogram fa4

Interferogram fa4 was acquired at April 30 and May 1, 1996, at 21:41:04 UTC, or 23:41:04 LT. SAR frame number 1053 and 1035, for ERS-1 orbit 25067, ERS-2 orbit 5394. The parallel baseline is -30 and -31 m, the perpendicular baseline -57 and -59 m, for the southern and the northern image respectively. Phase unwrapping was performed using the method of Ghiglia and Romero (1994).

5.5.4.1 Observations

In interferogram fa4, shown in figure 5.141, two fringes can be observed. Phase unwrapping produces the unwrapped interferogram, as shown in figure 5.142. The main topography is removed using the reference DEM, and after correcting for the main linear phase ramps in slant range and azimuth direction, the differential interferogram is obtained, as shown in figure 5.143. It is clear that the main disturbance in this interferogram consists of a large anomaly which extends from the south of the lower image to well into the upper image, half way in Flevoland. Furthermore, there is a negative disturbance in the upper left of the image, and a positive one in the middle of the left side.

The histogram over the major part of the differential interferogram is shown in figure 5.145. The overall rms value is 1.3 rad. Figure 5.146 shows the rotationally averaged spectrum, which follows the $-5/3$ gradient for wavelengths between 8 and 25 km.

5.5.4.2 Interpretation

There are disturbances along the coast, and there is an extended anomaly over Flevoland, starting at the southern image. In the coherence image (not shown here), loss of coherence is observed along the coast and in Friesland.

Day 1 is an extension of a ridge of high pressure, which should not yield much weather activity. However, at day 2 a weak cold front located over the eastern part of the Netherlands, is moving to the west. Precipitation associated with this cold front may have influence on the interferogram.

At day 1 the weather radar does not give any signal in our test area. At day 2, however, it is clearly visible how a large band with precipitation correlates with the “intrusion” over Utrecht and Flevoland, cf. figure 5.144. This rain band can be described as *showery precipitation*, associated with a weak cold front with not very large cumulonimbus clouds, cloud tops are observed up to 5 km. Note that even the curvature in the southern interferogram correlates very well with the curvature in the image of the weather radar of day 2.

The synoptic observations day 1 indicate that there is a considerable amount of cloud cover and good visibility. At 21:00 there is mostly stratocumulus and high altocumulus, see table 5.20. In the center of the area, altocumulus and cirrus are observed. The southern stations observe stratocumulus and altocumulus.

At day 2, 21:00 UTC, some precipitation is reported in Leeuwarden. The other stations did not have much precipitation. At 22:00 UTC, Leeuwarden had light rain and Volkel had a small shower.

There seems to be a contradiction here between the weather radar at day 2, and the synoptic observations at that day. It is, however, likely that the precipitation that is seen by the radar does not reach the surface. Volkel, e.g., does not have much rain. Thus,

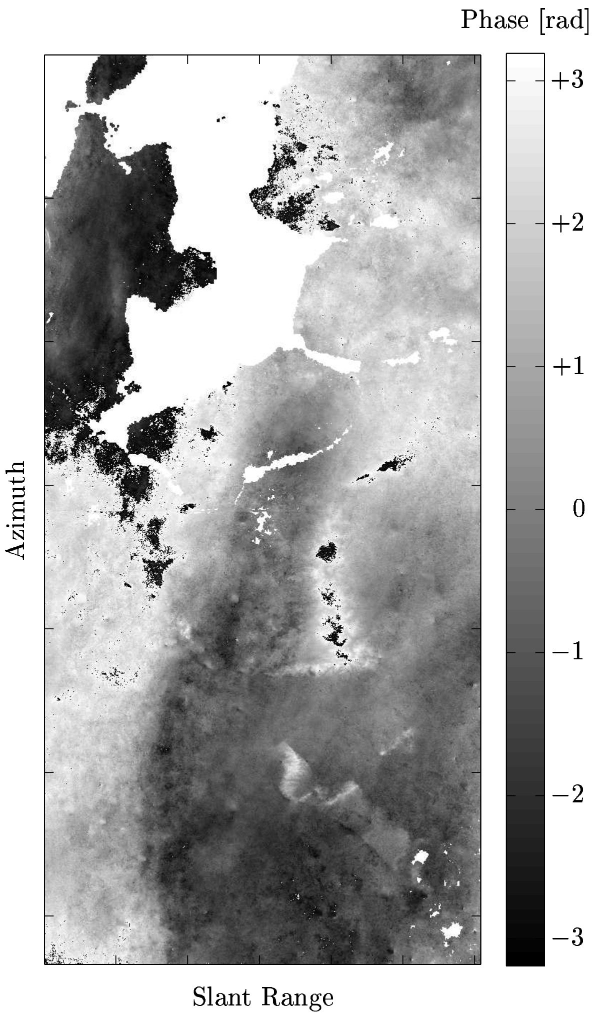


Figure 5.141 *Interferogram fa4*

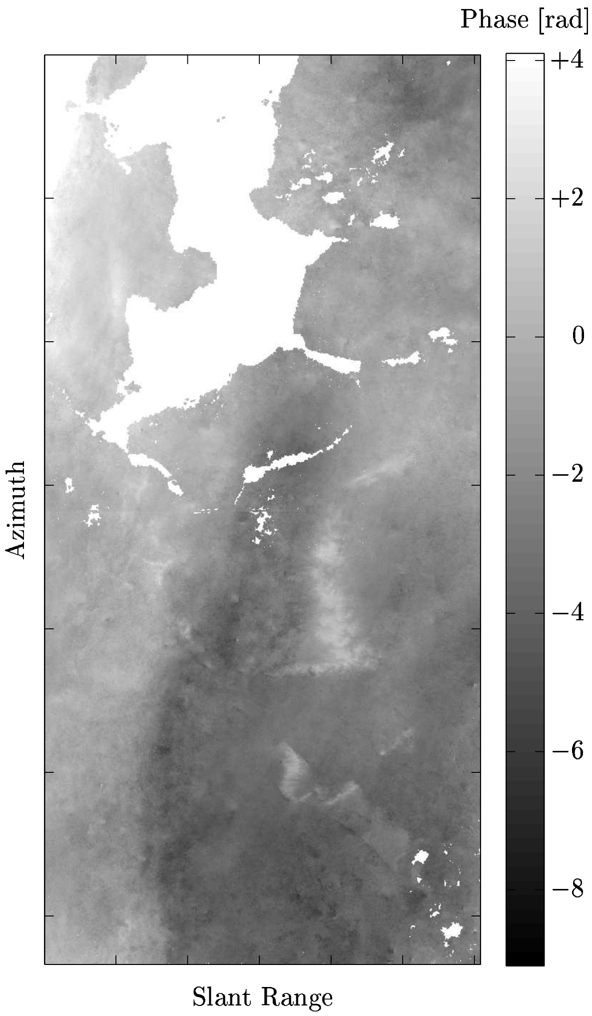


Figure 5.142 *Unwrapped interferogram fa4*

the precipitation evaporates before it reaches the surface. The layer between 3000 meter height and just above surface is dry according to the radiosondes. Above this dry layer there is a layer of about 2 km thickness which is very wet. The precipitation is falling from this layer through the dry layer beneath. This causes the relative humidities at the stations "under" the precipitation to be very high: between 85 and 100%.

Reported cloud cover at day 2, 21:00 UTC, included an almost complete (8/8) cloud cover over the whole area, mainly stratocumulus.

5.5.4.3 Conclusions

The strong correlation between the distribution of precipitation (possibly evaporating rain) and phase delay in the interferogram identifies the origin of the atmospheric artifacts. Note that also the loss of coherence over Friesland corresponds clearly with the areas of precipitation. Although outside the scope of this study, it can therefore be concluded that atmospheric artifacts can also increase increase the noise level of interferograms.

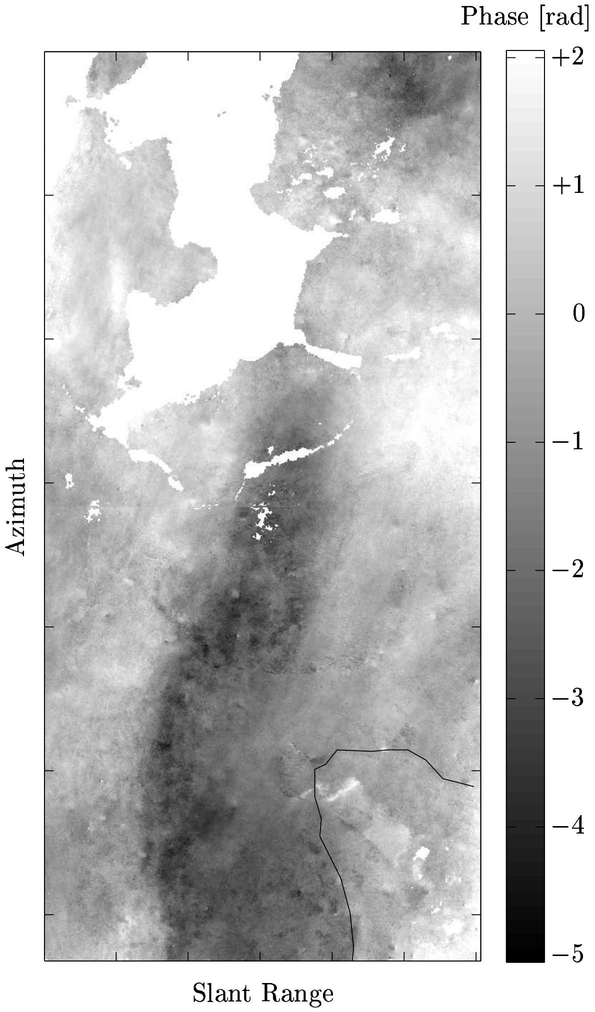


Figure 5.143 *Unwrapped differential interferogram fa4*

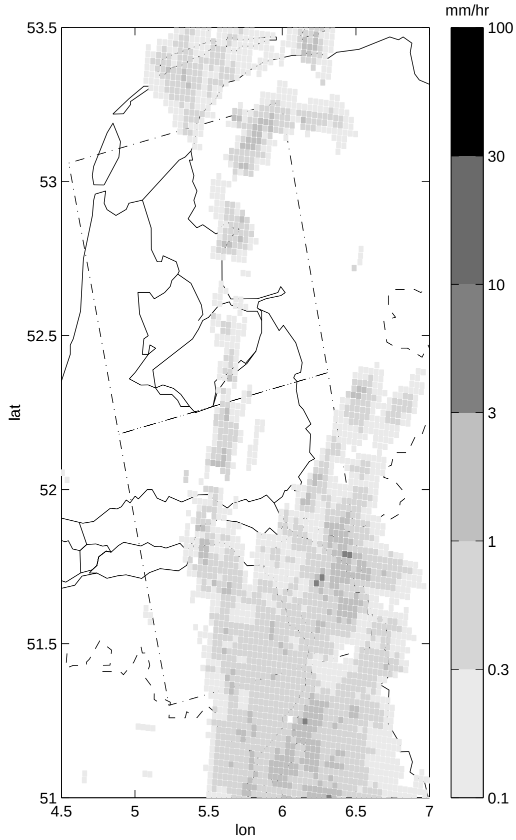


Figure 5.144 *Weather radar for interferogram fa4, day 2, 21:45 UTC*

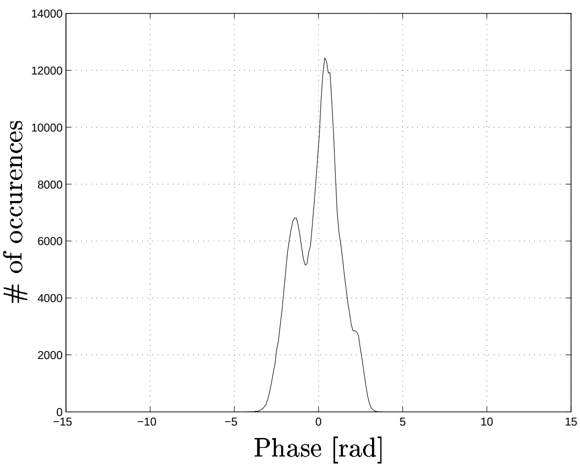


Figure 5.145 *Histogram of a major part of interferogram fa4*

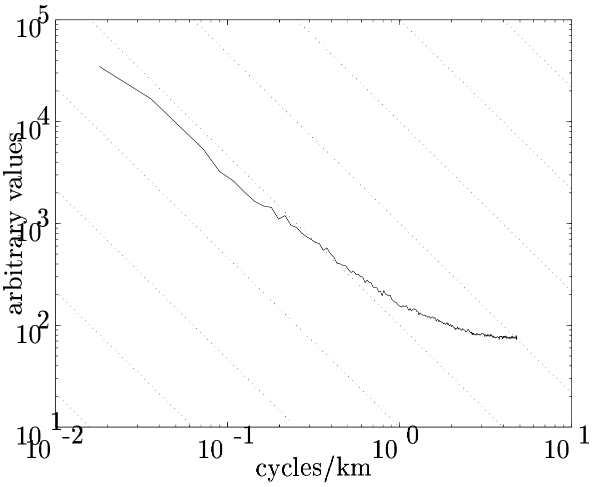


Figure 5.146 *Rotationally averaged spectrum of interferogram fa4*

Station	#	UTC	Day	Level 1	Level 2	Level 3
De Kooij	235	2100	1	3/8, Sc, 3000	6/8, Ac, 3000	
Schiphol	240	2100	1	4/8, Ac, 3000	6/8, Ci, 8300	
De Bilt	260	2100	1	6/8, Ac, 3000	8/8, Ac, 3300	
Soesterberg	265	2100	1	7/8, Ac, 3000		
Leeuwarden	270	2100	1	2/8, Sc, 3000	7/8, Ac, 3000	
Deelen	275	2100	1			
Gilze-Rijen	350	2100	1	7/8, Ac, 3000		
Eindhoven	370	2100	1	7/8, Sc, 3000		
Volkel	375	2100	1	7/8, Ac, 3000		
De Kooij	235	2200	1	2/8, Sc, 3000	3/8, Ac, 3000	6/8, Ac, 3300
Schiphol	240	2200	1	2/8, Ac, 3000	3/8, Ci, 8300	
De Bilt	260	2200	1	3/8, Ac, 3000		
Soesterberg	265	2200	1	6/8, Ac, 3000		
Leeuwarden	270	2200	1	4/8, Sc, 3000	6/8, Sc, 3000	8/8, Ac, 3000
Deelen	275	2200	1			
Gilze-Rijen	350	2200	1	6/8, Ac, 3000		
Eindhoven	370	2200	1	7/8, Sc, 3000		
Volkel	375	2200	1	4/8, Ac, 3000	7/8, Ac, 3000	
De Kooij	235	2100	2	1/8, Ac, 3000	7/8, As, 3300	8/8, Ci, 8300
Schiphol	240	2100	2	1/8, Ac, 3000	6/8, Ci, 8300	
De Bilt	260	2100	2	3/8, Ac, 3000	7/8, Ci, 8300	
Soesterberg	265	2100	2	1/8, Ac, 3000	7/8, Ac, 3300	
Leeuwarden	270	2100	2	8/8, Sc, 3000		
Deelen	275	2100	2			
Gilze-Rijen	350	2100	2	3/8, Ac, 3000	6/8, Ci, 8300	
Eindhoven	370	2100	2	4/8, Ac, 3300	7/8, Ci, 8300	
Volkel	375	2100	2	2/8, Sc, 1600	8/8, Sc, 3000	
De Kooij	235	2200	2	2/8, Ac, 3000	4/8, As, 3300	8/8, Ci, 8300
Schiphol	240	2200	2	1/8, Ac, 3000	6/8, Ac, 3300	7/8, Ci, 8300
De Bilt	260	2200	2	2/8, Sc, 3000	5/8, Ac, 3000	7/8, Ci, 8300
Soesterberg	265	2200	2	1/8, Ac, 3000	3/8, Ac, 3300	7/8, Ci, 6600
Leeuwarden	270	2200	2	8/8, Sc, 1600		
Deelen	275	2200	2			
Gilze-Rijen	350	2200	2	1/8, Sc, 1600	6/8, Ac, 3000	
Eindhoven	370	2200	2	4/8, Sc, 1600	7/8, Ac, 3300	
Volkel	375	2200	2	2/8, Cb, 1300	6/8, Sc, 1600	

Table 5.20 *Cloud observations fa4: 30-04/01-05-1996. 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.*

5.5.5 Analysis of interferogram fa5

Interferogram fa5 was acquired at June 4 and 5, 1996, at 21:41:00 UTC (23:41:00 LT). SAR frame numbers 1053 and 1035 are used, for ERS-1 orbit 25568, and ERS-2 orbit 5895. The parallel baseline is −34 and −35 m, the perpendicular baseline −88 and −89 m, for the southern and the northern image respectively. The phase unwrapping is performed using the algorithm of Ghiglia and Romero (1994).

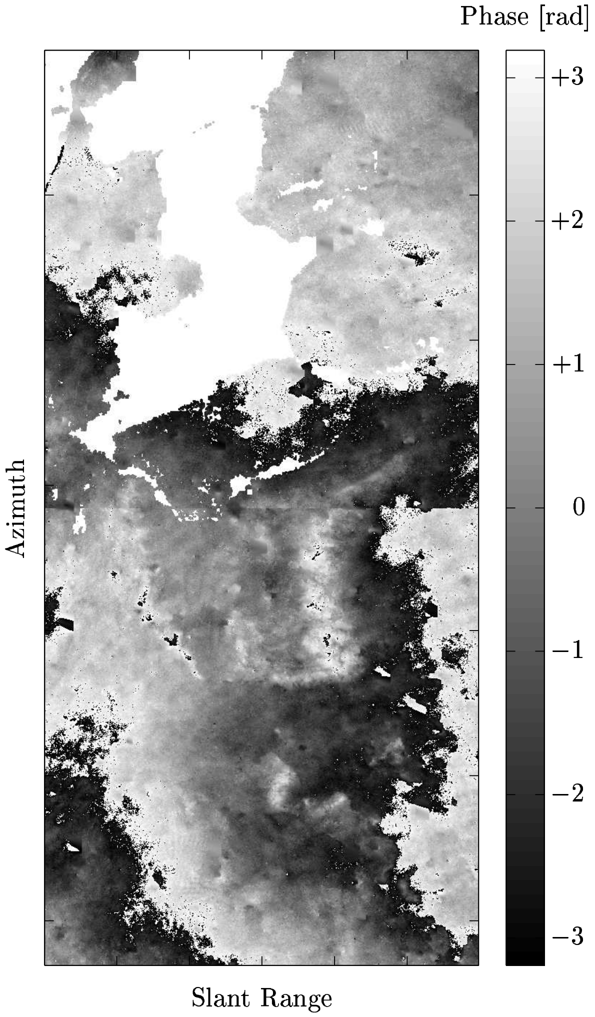


Figure 5.147 *Interferogram fa5*

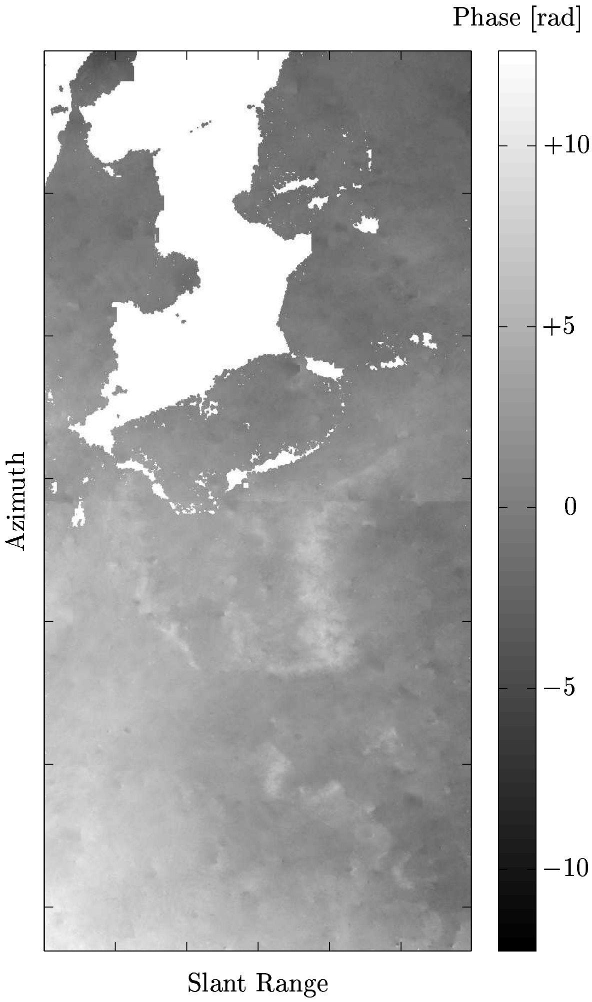
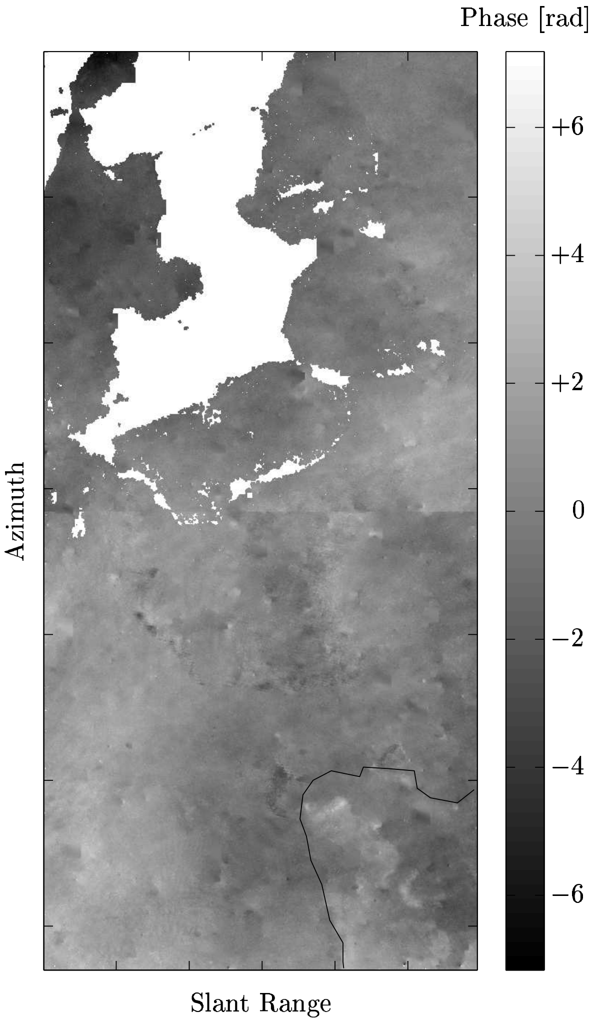


Figure 5.148 *Unwrapped interferogram fa5*

5.5.5.1 Observations

In figure 5.147 and 5.148, the relative phase and the absolute phase of interferogram fa5 are shown respectively. There is still a strong phase ramp of 2 fringes over the interferogram. Remaining phase unwrapping residues cause localized errors over especially the lower image. The differential interferogram is shown in figure 5.149. Both the topographic phase, and the linear phase ramp in azimuth and range direction are corrected for. Phase fluctuations in the differential interferogram vary between −4 and 3 rad over the whole image. Anomalies are observed over the island Texel in the upper left part of the image, just right of Flevoland, and in the lower left part of the image. Small waves can be found in parts of the upper right quadrant of the image, see figure 5.150. The wavelength is typically 1 km, with an amplitude of 0.8 rad. The waves are aligned with an angle of

−22 degrees with respect to the azimuth direction, which is 232 degrees with respect to the north. The histogram of the differential interferogram is shown in figure 5.151. The overall rms value is 1.2 rad. Figure 5.152 shows the rotationally averaged spectrum. The overall curve does not follow the −5/3 gradient.



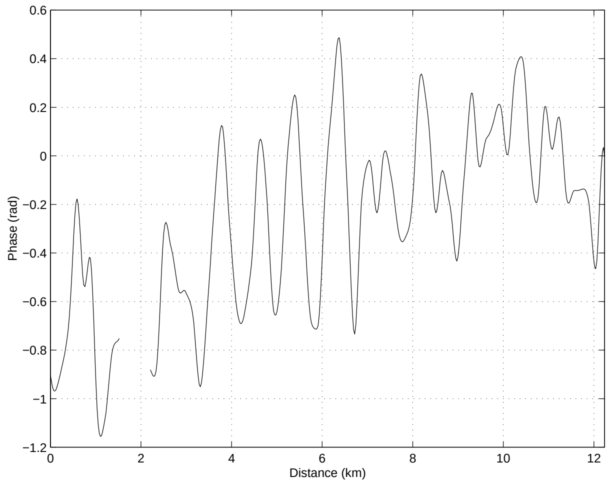


Figure 5.149 *Unwrapped differential interferogram fa5*

Figure 5.150 *A cross section in the upper right part of the image*

5.5.5.2 Interpretation

The observations include wave effects over Friesland nearly perpendicular to the wind direction, anomalous areas over Noord-Holland, humps and spots in both images, and wave effects (rolls) parallel to the wind direction over the Noord-oostpolder and Overijssel.

The days during which the SAR images were acquired were characterized by the passage of a cold front in a high pressure zone. The cold front, however, did not have strong effects: there was no precipitation and there were very few clouds. Cloud cover varied from 1–4 octa cirrus.

The weather radar did not indicate anything at both days (the second days there was some scatter noise). From the Meteosat infrared channel not much cloud cover is found. From the radiosondes we find and inversion at 1200 m at day 1 and at 1000 m at day 2. This could explain the wave effects.

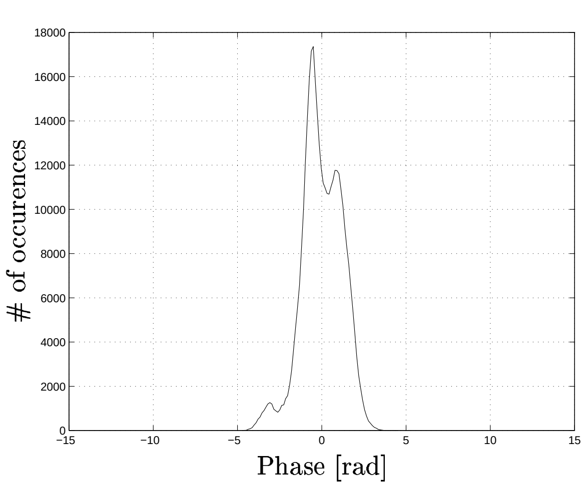


Figure 5.151 *Histogram of a major part of interferogram fa5*

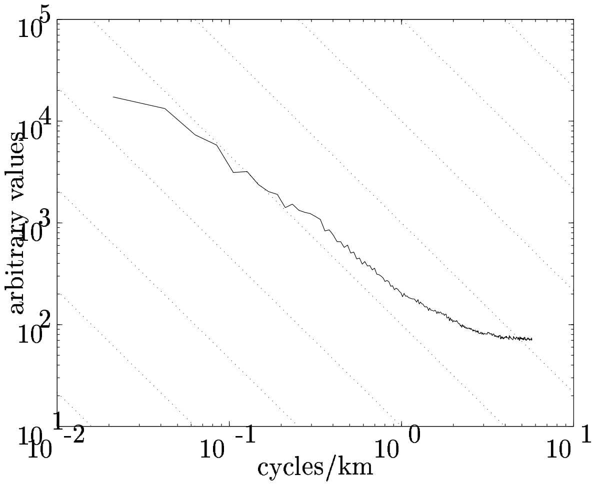


Figure 5.152 *Rotationally averaged spectrum of interferogram fa5*

In the northern image area, gravity waves are observed over Friesland, especially at the first day. In the southern image gravity waves can be found west of the Veluwe, especially the second day. The waves are perpendicular to the wind direction.

At day 1, 21:00 UTC there was shallow fog (radiation fog) at De Kooy. Therefore there is at that time only very few cloud cover. Note that the wind direction in De Kooy is 330 degrees, and in Schiphol 50 degrees. This indicates that the axis of the high pressure zone is in between! There is, however, not much wind. At 22:00 UTC it is almost calm and nearly cloudless. Leeuwarden indicates haze, with a visibility of 8 km. Almost all stations report 1/8–2/8 cirrus. De Kooy has some altocumulus.

At day 2, all stations report 1/8–4/8 cirrus, therefore there is also almost no real cloud cover. Both De Kooy and Leeuwarden indicate haze, with a visibility of 7 km. There is almost no wind, from eastern direction (90–110 degrees). Meteosat infrared observations indicate almost no clouds at both days.

5.5.5.3 Conclusions

The features in interferogram may find there origin in the presents of an subsidence inversion, below which some moisture can be trapped. The observed waves with a wavelength of around 1 km are presumably gravity waves at the inversion altitude.

Station	#	UTC	Day	Level 1
De Kooij	235	2100	1	1/8, Ac, 3300 m
Schiphol	240	2100	1	3/8, Ci, 8300 m
De Bilt	260	2100	1	1/8, Ci, 8300 m
Soesterberg	265	2100	1	1/8, Cc, 8300 m
Leeuwarden	270	2100	1	1/8, Ci, 8300 m
Deelen	275	2100	1	
Gilze-Rijen	350	2100	1	2/8, Ci, 8300 m
Eindhoven	370	2100	1	1/8, Ci, 8300 m
Volkel	375	2100	1	1/8, Ci, 8300 m
De Kooij	235	2200	1	1/8, Ac, 3300 m
Schiphol	240	2200	1	1/8, Ci, 8300 m
De Bilt	260	2200	1	
Soesterberg	265	2200	1	1/8, Ci, 8300 m
Leeuwarden	270	2200	1	1/8, Ci, 8300 m
Deelen	275	2200	1	
Gilze-Rijen	350	2200	1	1/8, Ci, 8300 m
Eindhoven	370	2200	1	1/8, Ci, 8300 m
Volkel	375	2200	1	
De Kooij	235	2100	2	4/8, Ci, 8300 m
Schiphol	240	2100	2	1/8, Ci, 8300 m
De Bilt	260	2100	2	3/8, Ci, 8300 m
Soesterberg	265	2100	2	3/8, Ci, 8300 m
Leeuwarden	270	2100	2	5/8, Ci, 8300 m
Deelen	275	2100	2	
Gilze-Rijen	350	2100	2	3/8, Ci, 8300 m
Eindhoven	370	2100	2	1/8, Ci, 8300 m
Volkel	375	2100	2	1/8, Ci, 10000 m
De Kooij	235	2200	2	3/8, Ci, 8300 m
Schiphol	240	2200	2	1/8, Ci, 8300 m
De Bilt	260	2200	2	2/8, Ci, 8300 m
Soesterberg	265	2200	2	3/8, Ci, 8300 m
Leeuwarden	270	2200	2	4/8, Ci, 8300 m
Deelen	275	2200	2	
Gilze-Rijen	350	2200	2	2/8, Ci, 8300 m
Eindhoven	370	2200	2	1/8, Ci, 8300 m
Volkel	375	2200	2	1/8, Ci, 10000 m

Table 5.21 *Cloud observations fa5: 04-06/05-06-1996. The observations give the amount of cloud cover (okta), the type of cloud, and the cloud base at 1 level.*