

# OBSERVATIONS AND PHOTOGRAPHIC MEASUREMENTS OF MOTHER OF PEARL CLOUDS OVER SCANDINAVIA 1930—1938

## SECOND PART

BY *CARL STØRMER*

(Institute of Theoretical Astrophysics, Blindern, Oslo, Norway).

(Manuscript received Jan. 19, 1940.)

**Summary.** In this second and final part are given the results of the photographic measurements of the mother of pearl clouds seen from Oslo on February 19th and 20th, 1932, and on February 6th, 1934, with a series of other photographs and observations.

The mean height in the night of February 19th—20th, 23.2 km, was notably lower than the mean from the afternoon before, 24.8 km.

An observation of a corona round the moon that night gave for the diameter of the cloud-droplets about 0.0025 mm.

The velocity of the clouds on February 19th was small, of the order 10 m per second towards SE; during the following night the velocity was still smaller.

The mean height for the clouds on February 6th,

1934, was 24.7 km and the velocity from 10 to 20 m per second towards S or SE.

Of special interest were some wavy cirrus clouds at about 12 km beneath the mother of pearl clouds. The length of half a wave was about 20 km and the difference in height between bottom and crest from 1 to 2 km. They were almost stationary.

On February 16th, 1934, Mr. Einbu at Dombaas measured the velocity of mother of pearl clouds at 15<sup>h</sup> to be as high as about 70 to 90 meters per second, a velocity of the same order as that I found for the clouds on December 30th, 1926.

In the last section a diagram is given of the measurements of heights from 1926 to 1934, in all 1122, with means for each date.

## Introduction.

In a paper<sup>1</sup> with the same title the results of the observations and measurements of mother of pearl clouds over Scandinavia including February 1, 1932, has been given in detail.

In this paper the report is continued and, in particular, the results from the very extensive material

from February 19—20, 1932, and February 6—7, 1934, are given in detail. Most of the material has been worked out by my assistant Olav Egeberg and the figures and sketches have been made by him and by my assistant Nicolai Herlofson.

## CHAPTER 1.

### Mother of Pearl Clouds on February 19th, 1932.

#### 1. The Clouds in the Afternoon of February 19th.

On this day there was a meteorological situation favourable for nacreous clouds. (See section 17.) In Oslo we had föhn-wind and clear weather and I watched the sky very carefully. At about 16<sup>h</sup> M. E. T.<sup>2</sup> I discovered the first of the mother of pearl clouds and

immediately warned my aurora stations Oslo Observatory, Oscarsborg, Kongsberg and Tømte. I also telephoned to Captain Ween of the Geographical Survey and to the people of the firm Nerlien, asking them to take pictures and moving picture film in natural colours.

At about 16<sup>h</sup> 20<sup>m</sup> the stations were in order. Before sunset (17<sup>h</sup> 14<sup>m</sup>) the sky was so bright that my aurora cameras could not be used; pictures were therefore taken with other cameras.

<sup>1</sup> Geof. Publikasjoner, Vol. XII, No. 11, Oslo 1939.

<sup>2</sup> In this paper the time is always M. E. T. mean time of Central Europe, (12 M. E. T. = 11 G. M. T.).

Table 1.

No.	St.	M. E. T.	Ex.	Ref.	Remarks	No.	St.	M. E. T.	Ex.	Ref.	Remarks
Obs.	C	16.55.00		Landsc.	Sketch in colour.	46	C-O	18.18.38	2	Landsc.	Diffuse clouds in NW.
1*	—>—	17.09.17		—>—	Taken with ordin. camera.	47	O	.19.10	2	—>—	Small cloud in W.
2*	—>—	.09.57		—>—	—>—	51	—>—	.24.06	2	—>—	Cloud in NW.
3*	—>—	.10.37		—>—	—>—	52	C-O-K <sub>3</sub>	.26.57	5	—>—	2 small clouds in W.
4*	—>—	.12.47		—>—	—>—	53	C-O-K <sub>3</sub>	.27.25	5	—>—	The same.
5*	—>—	.13.25		—>—	—>—	54	C-O-K <sub>3</sub>	.28.30	6	—>—	Cloud in NW.
1	C-O-T	.14.46	1	—>—	Nos. 1—20 is an inter- esting series of mother of pearl clouds in W.	55	C-K <sub>3</sub>	.29.27	6	Cyg.Lyr.	—>—
2	—>—	.15.30	1	—>—		56	C-O-K <sub>3</sub>	.30.29	7	Landsc.	Small clouds in W
3	C-O	.16.04	2	—>—		60	C-O	.34.06	9	Cyg.	Cloud in NW.
4	—>—	.16.29	1	—>—		61	C-O-K <sub>3</sub> -T	.35.57	9	Cyg.	—>—
5	C-O-T	.18.17	2	—>—		63	C-O-T	.38.46	9	Cyg.Peg.	—>—
6	—>—	.18.55	2	—>—		64	C-O-K <sub>3</sub> -T	.39.53	10	Cyg.Lyr.	—>—
7	C-O	.19.29	3	—>—		65	C-O-T	.41.12	15	Peg	Another cloud in W.
8	—>—	.20.02	2	—>—		66	C-O-T	.42.32	9	Peg Lyr.	The same.
9	C	.22.02	2	—>—		68	C-O	.45.00	12	Peg.Cyg.	—>—
10	C-O	.22.29	2	—>—		69	C-O-T	.46.23	11	Cyg.Peg.	Cloud in NW.
12	—>—	.23.17	3	—>—		70	C-O-K <sub>3</sub>	.47.23	18	Peg.	Small cloud in W.
13	—>—	.24.23	1	—>—		72	C-O-K <sub>3</sub>	.49.47	22	Cyg Lyr.	Cloud in NW.
14	—>—	.24.53	1	—>—		73	C-O-K <sub>3</sub>	.51.28	20	Peg.	Same as No. 70.
15	—>—	.25.09	2	—>—		74	C-O-K <sub>3</sub> -T	.52.53	17	Cyg.Lyr.	Cloud in NW.
16	—>—	.25.47	5	—>—		75	C-O-K <sub>3</sub> -T	.53.39	23	Cyg.Lyr.	—>—
6*	C	.28.17		—>—	Taken with a common camera.	76	C-O-K <sub>3</sub>	.54.41	26	Peg.	Same as No. 70.
7*	—>—	.28.47		—>—	—>—	77	C-O-K <sub>3</sub> -T	.55.48	31	Cyg.Lyr.	Cloud in NW.
19	C-O	.31.38	1	—>—		78	C-O-K <sub>3</sub>	.56.44	31	Peg.	Same as No. 70
20	—>—	.32.03	1	—>—		79	C-O-K <sub>3</sub> -T	.58.23	30	Peg.Cyg.Lyr.	Cloud in NW.
21	—>—	.52.16	1	—>—	Small blue cloud.	80	C-O-K <sub>3</sub>	.59.24	22	Peg.Psc.	Same as No. 70.
24	—>—	.54.36	1	—>—	—>—	81	C-O-K <sub>3</sub>	19.00.49	30	Peg.Cyg.Lyr.	Cloud in NW.
28	—>—	.58.25	1	—>—	—>—	83	C-O-K <sub>3</sub> -T	.03.01	39	Peg.Cyg.	—>—
29	—>—	.59.41	1	—>—	—>—	85	C-O-K <sub>3</sub> -T	.07.26	35	Peg.	—>—
30	—>—	18.00.16	1	—>—	—>—	86	C-O	.09.16	30	Peg.	Cloud in W.
34	—>—	.04.35	1	—>—	—>—	87	C-O-K <sub>3</sub>	.10.21	22	Cyg.Lyr.	Cloud in NW.
38	—>—	.10.26	1	—>—	—>—	88	C-O-K <sub>3</sub>	.11.36	28	Cyg.Lyr.	—>—
						89	C-O-K <sub>3</sub>	.12.26	31	Peg.	Cloud in W.
						94	C-K <sub>3</sub>	.20.02	25	Cyg.	Cloud in NW.

At the stations the following persons were working:

- (C) Oslo: Tvester, Sandøy, my two sons Per and Christian Fredrik Størmer and myself.
- (O) Oscarsborg: Bakøy.
- (K<sub>3</sub>) Kongsberg: Oddleiv Busengdal.
- (T) Tømte: Albert and Egil Tømte.

The base lines used had the following length and orientation (azimuth  $a_0$  of second station seen from principal station, reckoned from S towards W).

Base line	Length	$a_0$
O -C	27.36 km	192° 93
O -T	73.73 "	199 .95
C -T	46.68 "	204 .13
C -K <sub>3</sub>	65.16 "	65 .62
K <sub>3</sub> -T	104.81 "	227 .53

The first 20 double pictures were taken on pancromatic plates with filter, the following on Sonja plates.

In Table 1 is given a list of the observations and photographs used in chronological order, the headings are the same as the corresponding ones in the first part<sup>1</sup>:

## 2. Height Measurements of the Clouds Photographed on Pancromatic Plates.

The first 20 sets of pictures were taken on pancromatic plates with red filter, because the sky was still so bright that no stars were visible. Reference points were found in the landscape. As these reference points were taken far away from the optical centre, the measurements are not so good in spite of the big parallax, up to 30 degrees. The measurements with the longest base line O-T are probably the best ones. The plates have been measured and height and situation taken out graphically by the improved methods

<sup>1</sup> Geofysiske Publikasjoner, Vol. XII, No. 11, p. 14.

Table 2.

Measurements of Mother of Pearl Clouds on February 19th, 1932.

No.	St.	P	p	h	a	H	D	Mean height	No.	St.	P	p	h	a	H	D	Mean height					
1	O-C	1	18.2	19.8	83.7	24.3	66	24.3			4	36.6	16.0	104.0	25.7	87						
		2	15.6	16.2	87.4	24.7	83				7	28.4	18.3	74.0	23.0	68						
		3	13.3	12.7	91.4	24.7	105				8	27.3	14.6	82.0	24.2	90						
		5	14.5	15.6	80.4	24.5	85				6	O-C	1	24.2	23.5	100.6		24.0	54	24.0		
		7	23.9	22.9	100.9	24.0	56						2	17.9	16.4	103.8		24.5	81			
		8	18.6	16.9	103.3	24.2	78						5	22.2	18.7	123.0		23.4	68			
		9	20.4	17.9	107.8	23.6	72						6	25.2	21.6	126.0		23.9	59			
	O-T	1	33.8	19.8	83.7	23.9	65	24.2		7			O-C	1	22.3	20.6		102.1	23.6		60	23.1
		2	31.4	16.2	87.4	24.3	82							2	19.3	16.5		103.9	22.7		75	
		3	23.3	12.7	91.4	24.5	105							3	26.3	23.3		108.1	22.9		52	
		4	27.2	18.2	72.8	23.9	71				4	19.5		16.4	108.1	22.8		76				
		5	23.1	15.6	80.4	23.8	83				5	22.0		18.8	123.4	23.8		69				
		6	26.6	12.5	87.8	24.7	107				10	O-C		1	24.6	23.3		101.0	23.4	54	23.3	
		7	45.6	22.9	100.9	24.0	56							2	22.4	20.4		102.3	23.3	62		
8	38.8	16.9	103.3	24.6	79	3	19.9	16.9	104.9	22.8			73									
C-T	1	15.5	16.5	65.1	23.8	78	24.2	4	18.7	15.8			107.3	22.8	79							
	2	15.4	14.3	71.5	24.5	93		5	20.7	18.4			107.4	23.8	70							
	3	14.7	11.6	78.0	24.7	115		6	24.7	22.3			106.2	23.4	56							
	a	21.4	25.5	64.6	23.8	49		12	O-C	1			23.2	22.7	101.3	24.6	58	24.3				
	b	21.9	21.5	73.1	23.6	59				2	19.8	18.6	103.3	24.6	72							
	c	19.8	15.6	84.7	25.4	88				3	20.4	18.5	107.3	24.3	71							
	d	17.5	17.4	69.6	23.9	75				4	22.0	19.5	120.5	24.6	68							
2	O-C	1	18.0	19.9	84.0	24.7	67			24.9	5	21.9	18.4	122.4	23.5	69						
		2	15.3	15.7	88.2	24.9	86				13	C-O	1	8.5	7.7	73.4			25.4	170	24.5	
		3	14.2	13.9	90.2	24.6	96						2	8.6	8.0	70.5			25.4	165		
		4	12.4	11.8	92.9	25.1	115	3	15.9				13.7	79.5	24.2	96						
		5	13.8	14.6	83.0	24.9	92	4	16.7				14.4	76.1	24.0	91						
		7	23.0	22.4	101.7	24.5	59	5	22.2				18.8	78.8	23.7	68						
		8	20.5	19.7	102.5	24.9	68	14	O-C				1	19.8	17.5	106.7		23.7	73	24.3		
		9	19.1	17.9	103.0	24.6	75						2	20.3	18.6	110.2		24.8	72			
		10	17.5	16.4	103.5	25.0	83				3	21.6	19.4	109.9	24.2	67						
		11	19.3	18.1	109.6	25.4	76				4	23.2	20.5	109.1	23.4	62						
		12	22.3	21.1	109.3	25.2	64				5	20.5	18.5	104.5	23.8	70						
		13	22.3	22.3	106.4	25.0	60				6	21.6	20.6	102.3	24.4	64						
		14	23.2	22.3	106.4	25.0	60				7	24.4	24.5	99.7	24.5	53						
		O-T	1	33.4	19.9	84.0	24.4	66	24.2		8	17.1	16.3	102.3	25.3	84						
4	27.5		11.8	92.9	24.3	111	9	15.9		14.8	96.1	24.1	89									
7	45.5		22.4	101.7	23.8	57	10	8.5		8.4	81.8	25.4	158									
10	38.5		16.4	103.5	24.2	80	11	22.3		20.5	107.1	24.2	64									
3	O-C		1	18.5	16.5	108.0	24.3	80		23.5	12	25.8	23.5	107.1	23.4	53						
			2	25.9	22.3	108.5	22.5	54			15	C-O	1	9.0	7.7	73.1		23.9	161	24.1		
			3	24.3	23.0	101.6	23.6	55					2	9.0	8.0	70.1		24.2	158			
		4	18.1	16.5	103.7	24.4	80	3	15.6				13.8	79.6	23.5	98						
		5	14.9	14.1	89.6	23.6	90	4	16.5				14.4	76.2	24.3	92						
		6	14.0	12.3	92.1	22.8	100	5	17.8				15.6	83.5	24.6	85						
		4	O-C	1	18.9	16.4	107.6	23.6	78				23.8	6	22.2	18.9		79.2	23.9		68	
				2	24.5	22.5	107.8	24.1	57					16	O-C	5		20.6	19.1		107.0	
				3	23.5	22.4	101.7	24.1	58		6	22.0				20.6		106.8	24.6	65		
				4	18.4	16.4	103.7	23.8	79		7	24.2				22.7		107.2	24.3	57		
				5	14.5	13.9	90.0	23.9	94		8	25.3				22.5		109.5	23.3	55		
				6	13.3	12.1	92.4	23.8	106		9	21.4				19.5		109.7	24.5	68		
				7	22.4	20.4	109.4	24.3	64		10	29.8				26.3		126.5	24.3	49		
		8	23.6	20.3	114.7	23.4	62	11	24.1		21.3	123.0	24.5			62						
5	O-T	9	27.3	26.3	101.8	23.5	47	24.4	12	30.7	25.9	128.6	23.5	47								
		10	27.9	26.5	106.3	23.9	47		13	22.4	19.4	122.8	24.1	67								
		11	21.6	18.3	114.4	23.3	69		14	25.7	22.2	128.5	24.1	58								
		12	22.7	20.0	119.7	24.4	66		15	22.1	18.9	125.9	23.8	68								
		III	1	34.2	21.3	81.1	23.5		59	24.4												
			2	30.1	15.6	87.6	25.1		87													
			3	27.7	12.4	91.5	24.7		108													
			3	45.6	23.5	101.3	24.4		55													

Table 2 (Cont.)

No.	St.	P	p	h	a	H	D	Mean height	No.	St.	P	p	h	a	H	D	Mean height	
20	O-C	1	29.4	25.6	118.9	23.4	48	23.6				5	27.4	24.1	122.8	24.1	53	
		2	22.7	20.0	115.7	24.1	65					6	30.7	26.2	127.5	23.6	47	
		3	25.3	22.3	110.1	23.2	56					7	27.2	33.8	124.5	23.2	54	
		4	31.1	26.6	124.9	23.4	46					8	25.6	22.0	126.2	24.0	58	

recently published.<sup>1</sup> The work has been done by my assistant Olav Egeberg.

In Table 2 the results are given in chronological order. As in "First Part" the headings have the following meaning:

- No. gives the current number of the set.
- St. is the base line, the main station is given by the first letter, the secondary station by the second one.
- P is the point chosen on the cloud.
- p is the parallax.
- h is the height over the horizon of the chosen point.
- a is the azimuth, reckoned from south westwards of the same.
- H is the height of the chosen point.
- D is the distance from the main station to the projection of the same point on the Earth's surface.

All angles in degrees, all lengths in kilometers.

Among the pictures the following are of special interest:

*Pictures 1, C-O-T, 17<sup>h</sup> 14<sup>m</sup> 46<sup>s</sup> M. E. T.*

As a control we have measured a series of the points with different base lines O-C, O-T and C-T. Nos. 1, 2, 3 gave the heights:

P	O-C	O-T	C-T	Mean
1	24.3	23.9	23.8	24.00
2	24.7	24.3	24.5	24.50
3	24.7	24.5	24.7	24.63

<sup>1</sup> Carl Størmø: Some Results regarding Height and Spectra of Auroræ over Southern Norway during 1936, Geof. Publ., Vol. XII, No. 7, p. 6.

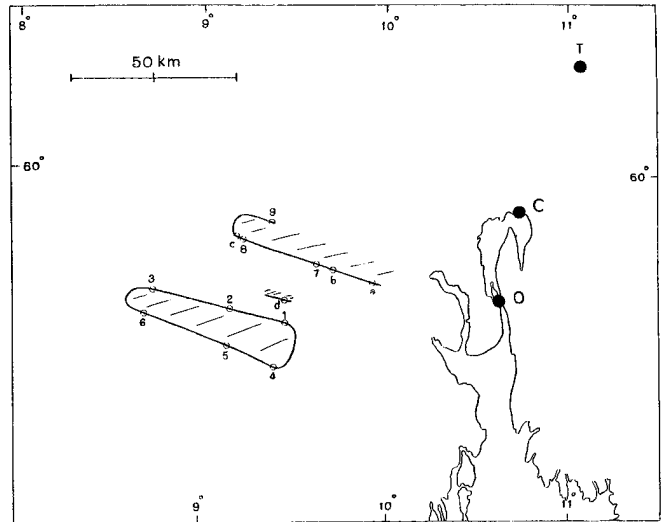


Fig. 1. Geographical Situation of the Mother of Pearl Clouds on February 19th, 1932, 17<sup>h</sup> 14<sup>m</sup> 46<sup>s</sup> M. E. T. (Pictures No. 1.)

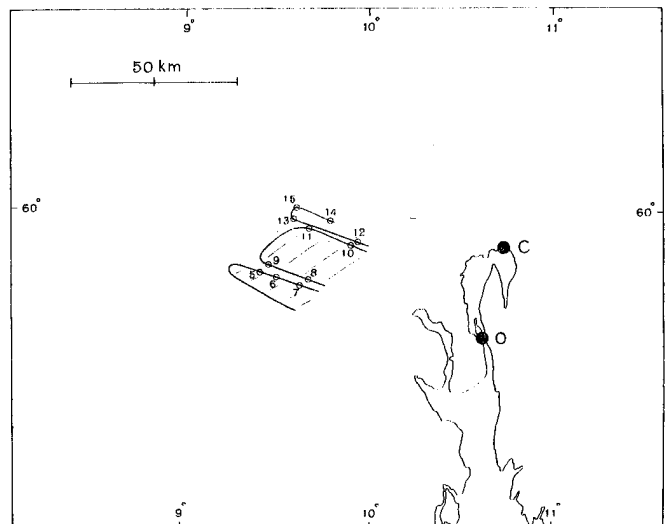


Fig. 2. Geographical Situation of the Mother of Pearl Clouds on February 19th, 1932, 17<sup>h</sup> 25<sup>m</sup> 47<sup>s</sup> M. E. T. (Pictures No. 16.)

As seen, the agreement is fairly good.

The sketches<sup>1</sup> are given on Pl. I. In fig. 1 is seen the geographical situation.

The Tømte picture is reproduced on Pl. V because it shows how the mother of pearl cloud continues as a weaker tail to the left.

*Pictures 16, O-C, 17<sup>h</sup> 25<sup>m</sup> 47<sup>s</sup> M. E. T.*

This is a very interesting picture giving the same mean height as picture No. 1. The sketches

<sup>1</sup> The reference points in the landscape are indicated by crosses.

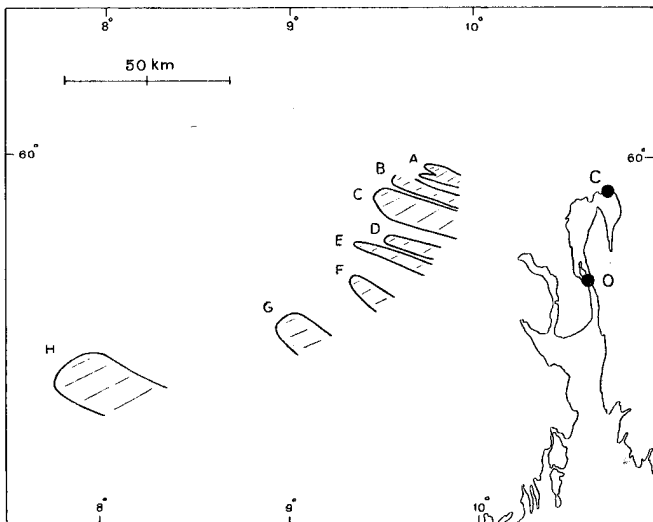


Fig. 3. Geographical Situation of the Mother of Pearl Clouds on February 19th, 1932 17<sup>h</sup> 32<sup>m</sup> 3<sup>s</sup> M. E. T. (Pictures No. 20.)

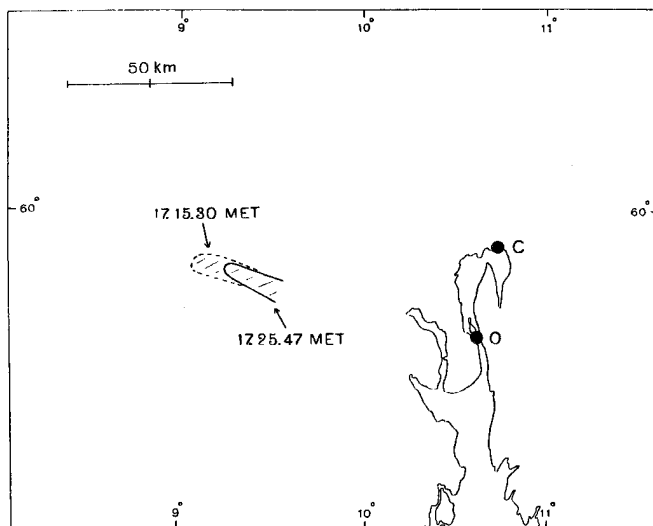


Fig. 4. Geographical Situation for determining Velocity. (Pictures O 2 and O 16.)

are seen on Pl. I. In fig. 2 the geographical situation is seen.

*Pictures 20, O-C, 17<sup>h</sup> 32<sup>m</sup> 3<sup>s</sup> M. E. T.*

These are the last pictures of the series taken on pancromatic plates with red filter. See Pl. I and V.

On the Oslo picture is seen a long series of almost parallel clouds. Assuming everywhere the height to be 23.6 km, we have found their geographical position, which is given in fig. 3.

When we take the mean of all the 125 heights found for these 20 first sets we get 24.1 km.

A diagram compared with corresponding diagrams of other clouds the same evening, is given in section 5.

### 3. Velocity of the Mother of Pearl Clouds Found from Pictures O 2 and O 16.

We have made an attempt to find the velocity of the mother of pearl clouds from the first 20 sets of pictures. As the displacement was parallel to the longest borders of the clouds, it was difficult to find suitable pictures. The best ones were O 2 (17<sup>h</sup> 15<sup>m</sup> 30<sup>s</sup>) and O 16 (17<sup>h</sup> 25<sup>m</sup> 47<sup>s</sup>). In fig. 4 the geographical situation of the measured cloud is seen. The result was a velocity in the indicated direction of 12.9 meters pr. second, towards ESE. See also section 4.

### 4. The Other Pictures of the Afternoon 19th February 1932.

On Table 3 are seen the height measurements for the rest of the pictures taken on Sonja EW plates. To these measurements we may add the following remarks. Pictures Nos. 21, 24, 29 and 30 were of a small cloud in the west; they seemed to give greater heights than the first pictures No. 1 to No. 20. In fact, the mean height for the four pictures measured was 25.6 km. The sketches of the pictures C-O 21 are seen on Pl. I and the geographical situation in fig. 5.

From the two pictures C 21 and C 30 we have tried to find the velocity of the clouds. Taking the mid-point of each of the two small clouds, we find a displacement of 5500 meters in 480 seconds, that is, a velocity of 11.5 meters pr. second. The direction of displacement was along the two small clouds, that is towards SSW.

Next comes a long series of faint diffuse pictures which gave such uncertain results that they have been dropped here.

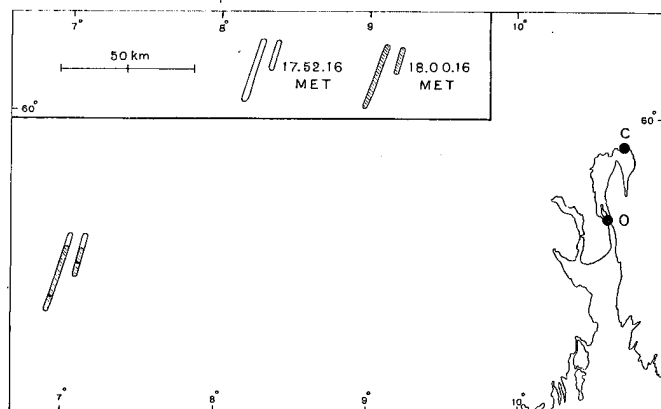


Fig. 5. Geographical Situation for determining Velocity.  
(Pictures C 21 and C 30.)

*C-O No. 52, 18<sup>h</sup> 26<sup>m</sup> 57<sup>s</sup> M. E. T.*

Two small clouds in WSW. Only the upper one has been measured. The next set, No. 53, is of the same cloud.

*O-C No. 54, 18<sup>h</sup> 28<sup>m</sup> 30<sup>s</sup> M. E. T.*

This is the first set of an interesting cloud to the NW of Oslo, photographed many times during the following hour. (Sets Nos. 54, 55, 60, 61, 63, 64, 69, 72, 74, 75, 79, 81, 83, 85, 87, 88.)

Among the sets we have selected the 16 best for height measuring, as seen in Table 3. 86 points were measured and gave a mean height equal to 25.9 km.

In section 5 is seen a corresponding diagram of the sets measured; we give some selections:

*No. 64, C-T and K<sub>3</sub>-T, 18<sup>h</sup> 39<sup>m</sup> 53<sup>s</sup> M. E. T.*

Photographs were taken simultaneously from the 4 stations C, O, T and K<sub>3</sub>. The O-picture was not good but the other three were excellent. As seen from Table 3, the measurements of the same points give fairly good agreement, except for points where the outlines of the cloud on the K<sub>3</sub>-picture are diffuse and blurred.

The mean height measured with the two base lines C-T and K<sub>3</sub>-T are 26.1 and 26.0 km.

On Pl. I are seen the sketches and on Pl. VI the pictures taken from Oslo and Tømte.

Fig. 6 gives the geographical situation.

*No. 69, C-T, 18<sup>h</sup> 46<sup>m</sup> 23<sup>s</sup> M. E. T.*

This is also a very good set. The cloud has changed a little in detail in the seven minutes since picture No. 64. The sketches are seen on Pl. II, the pictures on Pl. VII.

Among the rest of the pictures of this cloud, set No. 79 is interesting. In fact, the measurements

with the long base lines K<sub>3</sub>-T and C-T give for point 1 almost coinciding heights 26.1 and 26.3 km, and for point 2 the heights 24.7 and 24.4 km showing that these points must have a difference in height of 1.5 to 2 km, probably corresponding to the upper and the lower part of the cloud.

We have tried to discover any motion of the cloud. From the Tømte pictures it seems as if the cloud has moved but the displacement is too small to warrant any quantitative measurements. The only thing we can say is that the motion seems to have been towards S or SE.

Among the rest of the pictures of other clouds, there are 2 sets, Nos. 65 and 66, of great interest. The parallaxes are great and give very good results, stars being identified on all pictures. The heights vary between 23.4 and 24.7 km with mean about 24.1. The sketches of both sets are seen on Pl. II.

Among the rest of the pictures Nos. 70, 78, 80, 86 and 89 are of a small cloud to the west of Oslo. But the small parallax does not give such good results as for the other clouds.

## 5. Comparison of Heights of the Different Groups of Clouds.

As will be seen from the preceding tables, we have measured different groups of clouds this evening and it is of interest to consider the distribution of height of these groups.

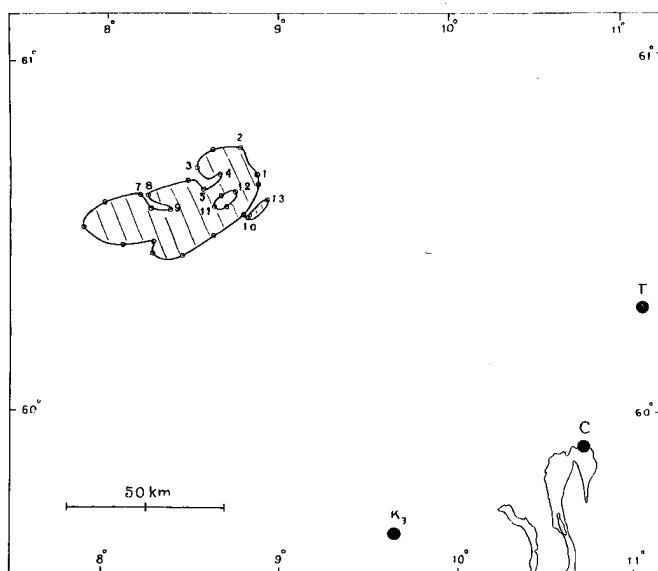


Fig. 6. Geographical Situation of the Mother of Pearl Cloud on February 19th, 1932, 18<sup>h</sup> 39<sup>m</sup> 53<sup>s</sup> M. E. T. (Pictures No. 64).

Table 3.

Continued Measurements

No.	St.	P	p	h	a	H	D	Mean height	No.	St.	P	p	h	a	H	D	Mean height					
21	C-O	1	7.3	6.4	81.4	26.5	206	25.5			4	47.3	11.2	155.3	25.3	120						
		2	7.3	6.2	78.7	25.6	204				5	46.5	11.4	152.3	25.5	119						
		3	7.2	6.1	81.5	25.9	209				7	39.7	10.5	144.2	26.6	134						
		4	7.2	5.9	78.4	24.7	206				8	40.4	10.6	145.1	26.6	133						
		5	7.1	5.9	76.7	24.9	207				9	42.4	11.4	146.7	27.1	126						
24	C-O	1	7.7	6.3	80.9	24.7	196	25.2			10	52.4	12.9	156.4	25.5	106						
		2	7.5	6.4	80.7	25.8	201				11	46.8	12.0	152.3	26.5	118						
											12	48.6	11.8	156.5	26.0	118						
29	O-C	1	7.6	6.8	87.5	25.4	189	25.8			65	C-T	1	31.9	24.3	95.0		23.9	52	24.0		
		2	6.9	6.6	82.0	26.3	200						2	30.3	21.7	96.9		23.9	59			
30	O-C	1	7.3	6.8	87.5	26.5	196	26.5					3	30.1	21.6	96.2		23.8	59			
													4	31.7	24.2	94.2		23.8	52			
									5	26.8			19.5	94.2	24.6	68						
									6	29.3			23.1	91.7	24.4	56						
52	C-O	1	8.5	7.5	77.1	25.5	175	24.8	7	30.6			21.0	100.1	24.1	62						
		2	8.8	7.5	74.2	24.1	166		8	35.2			25.7	99.0	23.4	48						
53	C-O	1	9.0	7.6	77.0	24.3	165	24.3	66	C-O			1	29.3	27.5	98.4	23.5	45	24.1			
		2	8.7	7.5	74.1	24.4	168						2	26.4	24.5	99.0	23.7	51				
54	O-C	2	8.6	8.7	141.1	26.2	157	26.2					3	22.0	20.6	98.9	24.7	65				
													4	24.5	22.3	91.0	24.6	59				
											I	28.7	20.0	97.7	24.2	65						
											II	31.0	23.6	95.2	24.3	55						
55	C-K <sub>3</sub>	1	28.4	9.7	131.7	24.4	134	25.8			III	32.8	27.0	92.7	24.3	47						
		2	27.4	10.0	127.7	26.1	139				IV	28.5	19.9	96.7	23.9	65						
		3	22.9	8.7	121.3	26.9	161				V	30.7	23.4	94.3	24.1	55						
60	O-C	1	8.8	8.3	131.5	26.4	165	26.6			VI	32.6	26.9	91.8	24.1	47						
		2	8.9	8.7	131.1	27.4	164				68	C-O	1	21.9	19.4	96.9	23.7	66		23.6		
		3	8.6	8.3	130.3	27.3	171						2	24.0	21.7	98.0	23.7	59				
		4	9.2	7.8	125.8	24.7	164		3	27.0			24.6	98.2	23.3	50						
		5	8.9	8.4	124.9	27.4	169		69	C-T			1	18.3	9.9	116.0	26.0	140	25.7			
						2	17.9	9.5					117.7	25.9	144							
						3	17.5	9.1			119.3	25.7	149									
						4	16.2	8.3			120.6	26.0	162									
						5	17.1	8.8			120.1	25.6	153									
61	C-T	6	17.3	9.1	121.5	26.3	152	25.9	6	20.2	9.8	131.4	24.4	132								
		7	17.8	9.3	121.4	26.0	147		7	19.8	10.5	131.7	26.5	135								
		9	18.8	10.3	117.5	26.5	137		8	20.9	10.9	130.6	26.0	128								
		11	19.5	10.3	129.3	26.4	137		9	20.0	10.3	127.1	25.6	133								
		12	19.3	10.0	126.3	25.8	137		70	C-O	1	7.1	5.9	75.8	24.7	206	24.7					
		63	C-T	1	16.0	8.5	120.9				26.8	164	72	C-K <sub>3</sub>	1	24.4		8.7	121.0	25.3	152	25.7
				2	17.3	8.9	122.1				25.8	152			2	24.4		9.1	121.3	26.4	153	
				3	19.8	9.9	131.3				25.1	135			3	23.7		8.8	120.2	26.2	156	
				4	19.5	10.6	132.3				27.1	136			4	23.0		8.4	120.4	25.8	160	
				5	18.6	9.7	125.5				26.0	142			6	22.0		8.0	116.0	25.2	163	
				6	18.8	9.9	126.9				26.3	141			7	24.6		9.1	115.4	25.5	148	
		64	C-T	1	20.0	10.5	132.4				26.2	133	26.1	74	C-K <sub>3</sub>	2		28.2	10.3	131.5	26.0	135
2	19.4			9.9	131.6	25.6	138	3			21.3	8.7				113.3		25.5	165			
3	18.8			9.3	127.2	24.9	141	4			20.6	8.0				113.6		26.4	170			
5	19.1			9.8	125.1	25.5	138	75			C-K <sub>3</sub>	1				29.8		11.2	131.2	26.6	127	26.1
7	16.2			8.5	121.0	26.4	112					3		22.1	8.5	113.7		26.2	161			
8	16.5			8.8	121.7	26.8	159		4	20.7		7.7		114.3	25.5	171						
9	17.8			9.4	122.5	26.3	148		78	C-O		1		6.6	5.7	71.9	25.1	214	25.1			
10	20.2			11.0	123.9	26.7	130															
11	19.3			10.3	124.9	26.4	165															
12	20.5			10.5	128.5	25.4	129															
13	21.8			11.6	129.3	26.3	121															
14	17.1			9.8	116.6	26.3	142															
K <sub>3</sub> -T	K <sub>3</sub> -T			1	48.3	11.6	160.4	26.8	123	26.0	79	K <sub>3</sub> -T		1	49.3	11.7	159.4	26.1	119	25.4		
				2	47.6	10.7	159.5	25.1	125					2	48.8	10.9	159.1	24.7	120			
		3	44.8	10.7	152.9	25.5	126	C-T	1				20.6	10.9	130.7	26.3	129	25.1				





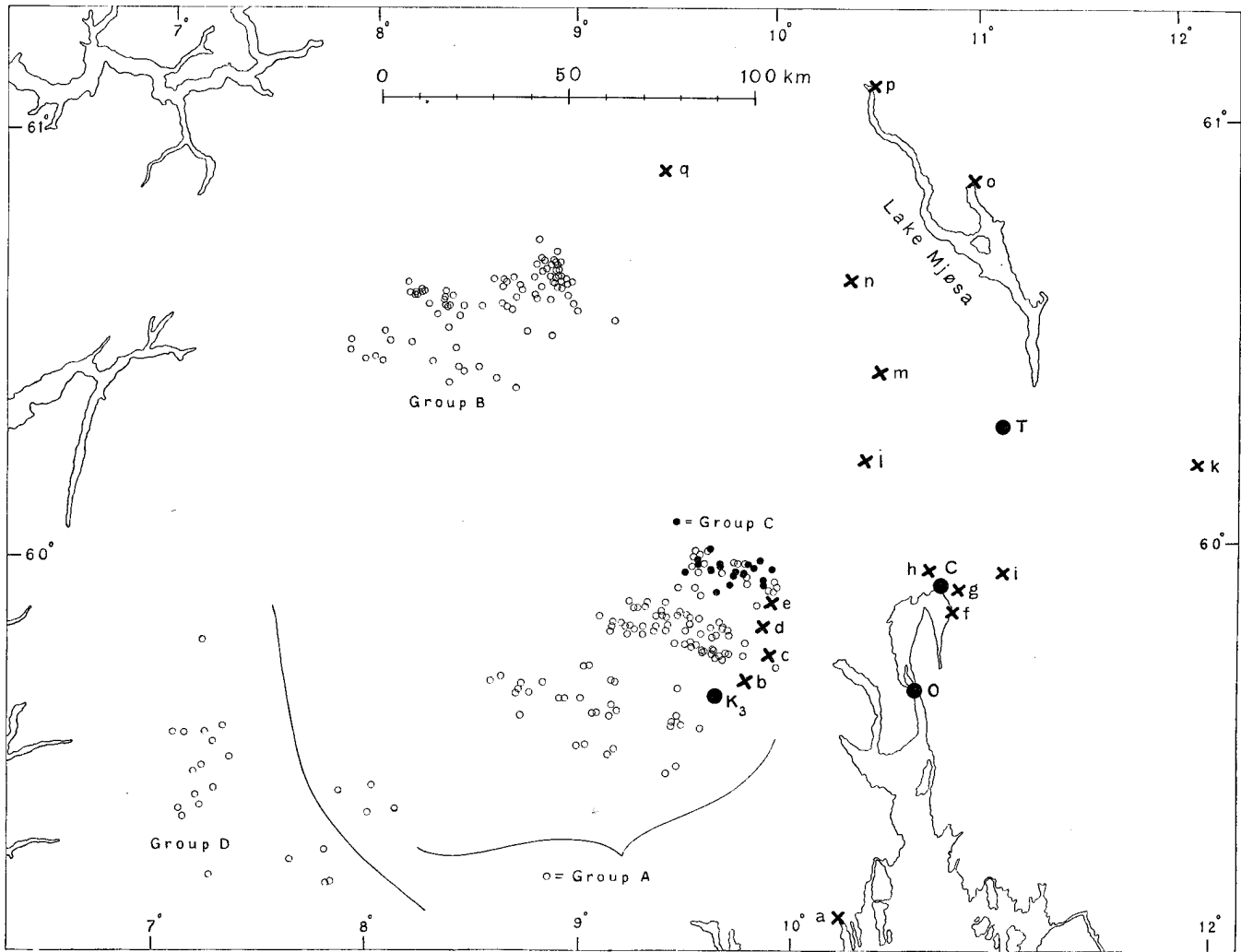


Fig. 7. Geographical Situation of the Groups A, B, C and D of Mother of Pearl Clouds on February 19th, 1932.

Clouds	Film	Taken by	Place	Number of single pictures
Group A	codac colour	Gihbsson	Nordstrand <sup>1</sup>	1975
Group D (blue small cloud)	codac	Schjerven	(Amundrud <sup>2</sup> Jevnaker (60° 13', 10° 23' E))	129
Group A	—>—	—>—	—>—	96
Group D (blue cloud)	—>—	—>—	—>—	106
Group B	—>—	—>—	—>—	133
Group D	—>—	—>—	—>—	593

Captain Ween had also measured some of these clouds and as the outlines of the clouds are better

<sup>1</sup> Marked on fig. 7 with letter f.

<sup>2</sup> Marked on fig. 7 with letter l.

defined than those of the mother of pearl clouds the measurements are very good, the mean of the 27 measurements gave about 2.9 km.

As to the velocity of the clouds, we have measured the displacement from pictures 13 to 15, that is for 46 seconds. As a mean of 6 measurements we found about 21 meters per second normal in the direction of sight. The direction is difficult to give; it was most probably towards SE. At the meteorological station in Oslo, the velocity of the föhn wind at 14<sup>h</sup> on February 19th was about 11 meters per second towards ESE. At 19<sup>h</sup>, however, it had become quite calm, no wind at all.

### 8. The Moving Picture Films.

Of the nacreous clouds, moving picture films were taken on small film of 16 mm breadth (see the table to the left).

I have viewed the performance of these films. The colours are clearly seen, but could have been much better. As to the ordinary film taken by Mr. Schjerven, the small blue cloud shines very brightly behind the lower fracto-cumulus clouds, which are seen drifting rapidly towards SE, sometimes going over the blue cloud and obscuring it.

### 9. Photographs in Natural Colours.

4 photographs were taken of the clouds of group A, by the photographer, mr. Simonsen of the firm Nerlien. The photographs are rather dark, but by a strong electric light illumination from behind the colours can be very distinctly seen.

### 10. Single Photographs Taken from Oslo.

From 17<sup>h</sup> 9<sup>m</sup> till 17<sup>h</sup> 29<sup>m</sup> I took from the station Oslo 7 photographs, 1\*, 2\*...7\*, with a common camera. Pancromatic plates with red filter were used. See Table 1. Two of these photographs are reproduced on Pl. VIII. The clouds belong to group A.

Another photograph, on pancromatic plates with red filter, taken later towards W by my son Per Størmer and from the same place, is reproduced on Pl. IX. Of special interest on this picture is the small cloud low in the west and consisting of 3 horizontal streaks (group D). This picture was published in 1932<sup>1</sup>.

### 11. Observations and Photographs from Other Places in South Norway.

As on January 29th the same year, a long series of reports was received, with sketches and photographs. Some of the most interesting are given here the letters a, b, c... are written on fig. 7 at the observers positions.

a. Mr. *Dag Heyerdal*, Sandefjord (latitude 59°.1, longitude 10°.2 E. Grw.) says:

"I herewith send you 4 sketches in colours, taken every 5 minutes from 17<sup>h</sup> 55<sup>m</sup> to 18<sup>h</sup> 10<sup>m</sup> on Friday February 19th.

I happened to see the beautiful display of colours and as I had read about nacreous clouds in

the newspapers I got interested and climbed the observation tower of the Navigation School — (I am a teacher at Sandefjord public naval school).

There I made the following observations: close to the eastern horizon lay a bank of clouds, and from W to SW two banks of stratus clouds near the horizon. Everywhere else the sky was fine and clear without any clouds except the mother of pearl ones mentioned above.

Using a sextant I made the following measurements. Height to the lower border of the lowest cloud 17° 20'. Horizontal extension of the cloud formation 10°, from N 50° W to N 60° W. The red colour was strongest along the outer borders and then following in concentric belts, orange, yellow, green and blue. The blue colour as seen from the sketch 18<sup>h</sup> 10<sup>m</sup> was at that time very strong like a horizontal line.

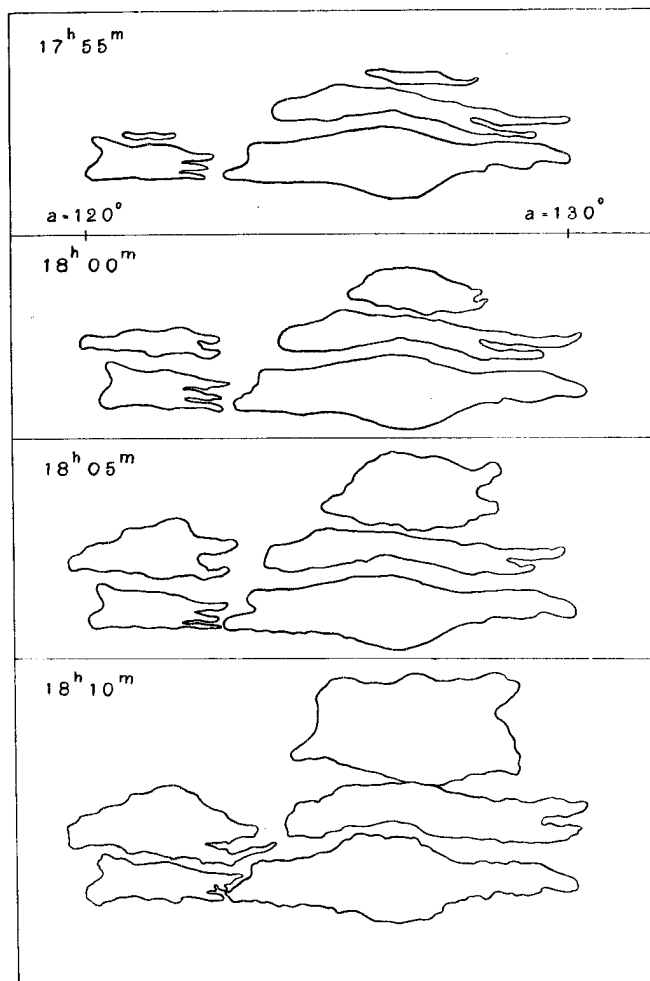


Fig. 9. Sketches of Mother of Pearl Clouds on February 19th 1932, by Mr. Heyerdal.

<sup>1</sup> *Carl Størmer*: Mother of Pearl Clouds over Scandinavia in January and February 1932, Quarterly Journ. of the Royal Meteorological Society, Vol. LVIII, p. 307—309, 1932. (Fig. 2).



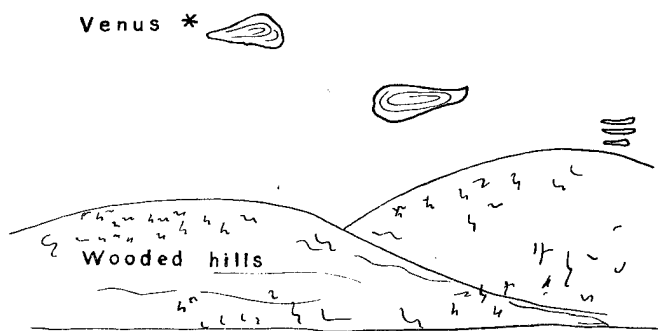


Fig. 12. Sketches of Mother of Pearl Clouds on February 19th, by Mr. Torkildsen.

changed to regions of light red, blue and green, like mother of pearl. The regions followed the outlines of the cloud as concentric bands. This lasted about 15 minutes. Then the cloud became red and disappeared. Just before, a new cloud appeared in the vicinity of the first, showing a quite dazzling blue white colour like melted silver.<sup>1</sup> After 15 to 20 minutes the colour of this cloud changed to mother of pearl and at last it became very intensely red.

d. *Engineer Asbjørn Torkildsen* writes February 19th:

"In accordance with your appeal in the newspapers about mother of pearl clouds, I have pleasure in sending you my observations of this afternoon.

I was driving from Vikersund to Drammen, on the eastern side of Drammenselven to Skotselven where the road turns toward west. I then saw a cloud in the western sky which I observed from its beginning. A grey mist-like patch without colours developed rapidly into a cloud of dazzling colours. In the middle it was red, around this was a belt of violet and an outer border was yellow-green. The colours were beautiful and very pure, like the colours of the sun's spectrum.

To the left of this cloud was a bright star.<sup>2</sup> Close to the right of this star a new cloud appeared and lower down, another, in the same manner as before, but the colours of these two were not so beautiful. Successively the two last clouds melted together to a new cloud to the right and a little lower than the star. The time was now 17<sup>h</sup> 45<sup>m</sup> and from the moment I first saw the clouds 5 minutes had gone.

Looking upwards, I saw up to zenith several traces of similar developments.

<sup>1</sup> This must have been the blue cloud mentioned on several occasions in the foregoing sections.

<sup>2</sup> This must have been Venus.

On my further drive, I passed the bridge over Skotselv and arrived at Bakke Church (59° 8', 9° 9') where I stopped to make new observations. The colours of the first clouds had by now faded, but lower down to the right 3 new clouds had appeared like horizontal streaks, shining very intensely in bright yellow and green colours. They had melted together and were still shining bright in yellow, red and violet.

At 18<sup>h</sup> the first clouds had disappeared.

In zenith there was a deep red cloud like a hand growing brighter, getting stripes in yellow and violet and then disappearing.

The western sky then shone very brightly in yellow-green colour and with indications of mother of pearl clouds up to zenith but the clouds did not develop the bright colours before.

I had never seen mother of pearl clouds before, but I have a big shell which a sailor brought me from the Galapagos Islands, and the beautiful colours of this shell lead me to believe that I had seen mother of pearl clouds this afternoon".

It seems to me very probable that the 3 small clouds to the right in this sketch are the same as those seen on the upper photograph on Pl. IX.

e. *Mr. Alex Buhs*, a dentist, sent a photograph from Modum (59° 9', 10° 0'), taken at 17<sup>h</sup> 56<sup>m</sup> of the same small blue clouds which were photographed simultaneously from stations C and O between 16<sup>h</sup> 52<sup>m</sup> and 17<sup>h</sup> (See Table 1).

f. The place marked on the map fig. 7 with this letter is the position of the moving picture camera used by *Mr. Gihbsson* and mentioned in section 8.

g. From *Dr. Dedichen*, Østre Aker (59° 9', 10° 8'), near Oslo, I got 3 good photographs taken from 17<sup>h</sup> 10<sup>m</sup> to 17<sup>h</sup> 25<sup>m</sup> of the clouds of group A, but as they are of the same cloud as on Pl. IX, lower picture, they are not reproduced here.

h. From *Mr. Gunnar Holmsen of the Geological Survey*, Oslo, I got some most wonderful photographs taken, the first at 17<sup>h</sup> 15<sup>m</sup>, see Pl. IX lowest picture, the second at 17<sup>h</sup> 29<sup>m</sup>, from his house Villa Joldia, Skådalen (60° 0', 10° 7'), near Oslo. From the form of the clouds and from the time, it is clear that these are the clouds of group A, whose height was determined by simultaneous pictures from Oslo, Oscarsborg and Tømte.

i. *Tormod Sund*, (a school teacher), Lillestrøm (60° 0', 11° 1') east of Oslo sent me a very fine photograph of the same clouds of group A. The time is

not observed, but from the picture C 20 taken from my station Oslo it is clear that the time must have been about 17<sup>h</sup> 32<sup>m</sup>.

k. *Mr. Gunnar Bagli* also, from Kongsvinger (60°.2, 12°.0) took a photograph at 17<sup>h</sup> 10<sup>m</sup> of the easily recognisable main clouds of group A. He says that the cloud first shone in all the colours of the spectrum and after an hour became red.

l. From *Mr. E. J. Schjerven* (firm Nerlien), the same who took the film (see section 8) I got 3 most beautiful photographs, taken at 18<sup>h</sup>, 18<sup>h</sup> 3<sup>m</sup> and 18<sup>h</sup> 12<sup>m</sup> from the farm Amundrud (60°13' N, 10°23' E. Grw.) of which the two last mentioned are reproduced on Pl. X.

On the first one, taken at 18<sup>h</sup> 3<sup>m</sup> is seen the characteristic cloud B (section 5) and the direction indicated on the map agrees with this. He says that this cloud was visible 17<sup>h</sup> 45<sup>m</sup> to 18<sup>h</sup> 30<sup>m</sup>.

On the last one, taken at 18<sup>h</sup> 12<sup>m</sup>, the shining divided cloud in SW, (blue cloud of group D) is clearly seen behind the dark fracto-cumulus clouds driving towards S.

m. *Astrid Støren*, writes from Brandbu (60°.4, 10°.5), Hadeland:

"The most wonderful mother of pearl clouds of unique beauty and colour were observed here at Brandbu, Hadeland, at about 17<sup>h</sup> 30<sup>m</sup>. Two shell-like not very big clouds towards west. These had the most pure colour — rose, yellow-green and bright violet — like the finest mother of pearl. More to SW there was a flat shining stripe, bright yellow and yellow-green with porcelain-blue colour along the upper border; the cloud was quite dazzling like silver. Still more to SW and lower down was a greater, oval cloud, more reddish and with the colours of the spectrum in bent stripes. It was marvellous! Later at 21.30 the wind was strong and increasing to a little hurricane at 3<sup>h</sup> in the night".

The two clouds seen due west must have been the clouds B and in this position they must have shown fine prismatic colours as also observed. The other clouds probably belonged to the group A.

n. *Mr. J. A. Linnerud*, Ringelia (60°.6, 10°.3), Søndre Land, also observed the two clouds in W. They melted together at 18<sup>h</sup>, when they had a red colour like fire. Later at 18.30 the colour was more violet.

o. *M. G. Hegre* sent me from Brummunddalen (60°.9, 10°.9) measurements of direction towards and height over the horizon of two mother of pearl clouds

at 17<sup>h</sup> 55<sup>m</sup>. The measurements are in excellent agreement with the height and situation of clouds of group B, seen to the NW of Oslo.

p. Similar good measurements of the same clouds were sent from *Mr. J. Dobloug*, Lillehammer (61°.1, 10°.5).

He says among other things:

"I took the measurements at 17<sup>h</sup>. At that time there was an upper and bigger oval cloud, yellow in the middle and with colours on each side which through several transitions went over to blue violet. Under this cloud was a small horizontal one, yellow in the middle and blue violet on both sides. The wind was rather strong from the north and with several lower clouds drifting southwards. The mother of pearl clouds, however, remained in the same place all the time".

Then came his measurements which agree with the position of the clouds B.

q. *Mr. Bredok Eriksen* sent from Aurdal (60°.9, 9°.4), Valdres, a series of observations of the same clouds. He observed that from 17.25 to 17.57 there were two clouds which at 17.58 melted to one, and that a bright star, probably Venus, was in the middle of the cloud at 18.22. The cloud disappeared at 18.45. The colours were at their finest from 17.40 — 18.00.

At the moment 18<sup>h</sup> 22<sup>m</sup> the height of Venus was about 19° and azimuth 62° which fits in well with the position of the clouds B.

## CHAPTER 2.

### Mother of Pearl Clouds during the Night 19—20 February 1932.

#### 12. Mother of Pearl Clouds Illuminated by the Moon.

In the afternoon of 19th February work ended at 20<sup>h</sup> 25<sup>m</sup> when the last traces of the mother of pearl clouds seemed to have disappeared.

I did not imagine that the clouds might appear during the night, but at 22<sup>h</sup> my youngest son Christian Fredrik told me that he had just observed the clouds again. I hurried to the Observatory, but by then they had already disappeared. I therefore went home to bed. My son Per, however, coming home from a party, woke me up at about 1<sup>h</sup> and said there were mother of pearl clouds in red and green colours illuminated by the moon. I immediately went to the

Table 5.

No.	MET.	Ex.	Ref. Const.	Remarks	No.	MET.	Ex.	Ref. Const.	Remarks
14	2h 52 <sup>m</sup> 59 <sup>s</sup>	9	Per.	Feeble stripe	40	3h 48 <sup>m</sup> 42 <sup>s</sup>	9	Aur.Per.	Good
18	> 56 20	24	Aur.Tau.Per.	—>—	41	> 49 54	13	Aur.Per.	—>—
19	> 57 27	18	Per.	Good	44	> 49 22	15	Leo.Gem.	—>—
21	> 59 46	20	Per.	Feeble	45	> 50 49	14	Leo.Gem.	—>—
24	3 06 22	16	Aur.Per.	—>—	46	> 55 34	14	Leo.Gem.	—>—
25	> 23 26	16	Aur.Per.Gem.	—>—	48	5 03 53	4	Aur.Gem.	Feeble
27	> 26 13	24	—>—	—>—	50	> 09 33	11	Aur.Gem.UMa.	—>—
28	> 27 19	25	Cas.	—>—	51	> 10 31	5	Aur.Gem.	—>—
31	> 31 06	11	Aur.Per.	Very good	52	> 11 23	9	Aur.Gem.	—>—
32	> 31 57	17	Aur.	Good	53	> 36 33	18	Leo.UMa.	—>—
33	> 32 35	22	Aur.Per.	Feeble	54	> 37 58	11	Leo.Uma.	—>—
35	> 35 04	19	Aur.Gem.	Red and green colours	55	> 39 28	13	Leo.UMa.	—>—
36	> 35 51	20	Aur.Gem.Tau.		56	6 03 32	24	Leo.UMa.	—>—
38	> 45 11	11	Aur.Gem.Per.	Diffuse	57	> 04 25	15	Leo.UMa.	—>—
39	> 46 02	10	Aur.Gem.	—>—					

window and looked out. There could be no doubt. Rather far away from the moon, big clouds shone in red and green colours in broad belts over the clouds.

I immediately telephoned to my stations Oslo Observatory (C) and Oscarsborg (O) to get ready for work as soon as possible. Accompanied by my son Per, I then hurried to the Observatory to get everything ready. As assistant there, I had Mr. Sandøy and at Oscarsborg, Mr. Bakøy.

At 2<sup>h</sup> 30<sup>m</sup> the photographic work began and 75 sets of simultaneous pictures were taken from the two stations. Of these, only 22 were good enough for height measuring. The clouds were all over the sky as diffuse mist-like patches which at a distance of 30° to 40° from the moon showed distinct colours in red and green.

Before sunrise some very small mother of pearl clouds were seen near the horizon in E, but no height measurements succeeded.

On Table 5 are seen the successful sets with remarks.

**13. The Height Measurements.**

The collected material was provisionally measured and calculated by my assistant Falch and myself in 1932, and, later, more systematically and carefully, by Mr. Egeberg in 1938—39. On account of the feeble contrast between the clouds and the moonlit sky the measurements were rather difficult. On the other hand, the clouds were higher in the sky which gave great parallaxes.

In Table 6 the results are seen. For all pictures C is the main station and O is the secondary one.

To these measurements we would add the following remarks:

*C-O 19, 2<sup>h</sup> 57<sup>m</sup> 27<sup>s</sup> MET. Mean height 23.9 km.*

This is a rather good set. Two stripes are very easily recognised on each picture.

*C-O 31, 3<sup>h</sup> 31<sup>m</sup> 06<sup>s</sup> MET. Mean height 24.2 km.*

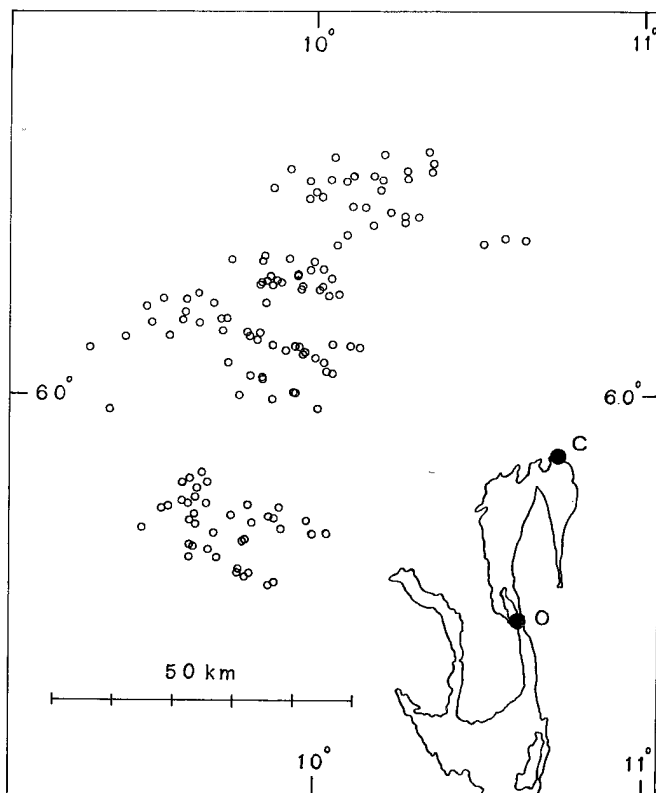


Fig. 13. Geographical Situation of all the measured Points of the Mother of Pearl Clouds in the Night 19th--20th February 1932.



Table 6 (Cont.)

No.	P	p	h	a	H	D	Mean height	No.	P	p	h	a	H	D	Mean height
52	6	28.6	27.7	112.0	21.8	41	23.3	55	1	29.0	22.9	69.5	22.1	52	22.8
	7	30.4	29.9	109.9	22.2	39			2	25.9	21.1	74.9	22.9	58	
	1	27.6	25.9	102.5	23.1	47			5	26.8	22.3	83.0	23.0	55	
	2	25.2	23.9	102.1	23.5	52			6	31.6	26.5	78.8	23.1	46	
53	1	25.0	21.4	74.8	23.8	60	23.0	56	1	29.3	23.9	65.9	22.8	51	22.9
	2	24.7	20.2	78.6	22.9	61			2	27.6	22.5	70.9	22.9	54	
	3	23.0	18.8	82.4	22.9	66			3	24.3	20.7	76.9	23.8	62	
	5	30.7	25.9	78.7	23.3	47			4	27.4	22.2	80.3	22.6	54	
	6	34.0	27.1	75.1	22.2	43			5	30.6	25.6	77.8	23.1	48	
										6	36.0	28.9	71.3	22.4	
54	1	27.1	22.1	71.4	22.9	55	23.7	57	1	28.5	23.9	66.6	23.3	52	22.8
	2	24.7	20.5	77.5	23.2	61			2	26.9	22.3	71.0	23.2	57	
	3	22.0	19.1	81.6	24.2	68			3	25.8	21.1	74.0	22.9	58	
	4	24.7	21.5	85.2	24.0	60			4	29.2	22.9	78.3	21.9	51	
	5	28.7	25.1	82.5	24.0	50			5	31.6	25.1	75.4	22.2	47	
								6	34.0	28.4	73.1	23.2	42		

Mean of all heights 23.2 km.

This is very good and refers to clouds other than No. 19.

*C-O 32, 3<sup>h</sup> 31<sup>m</sup> 57<sup>s</sup> MET.*

Point 1 belongs to the former cloud C-O 31 and the height measurement 24.7 km agrees with this. The other points refer to other clouds to the right of this one, and which seem to lie about 1 km lower. See sketches Pl. II.

*C-O 41, 3<sup>h</sup> 49<sup>m</sup> 54<sup>s</sup> MET.* Mean height 22.5 km.

This set is very good and gives a very reliable height measurement. Sketches are seen on Pl. II.

*C-O 53, 5<sup>h</sup> 36<sup>m</sup> 33<sup>s</sup> MET.* Mean height 23.0 km.

Also a good set. On the Oscarsborg picture, the cloud is close to the moon which makes it shine intensely. See Pl. II and III.

*C-O 55 5<sup>h</sup> 39<sup>m</sup> 28<sup>s</sup> MET.* Mean height 22.8 km.

The same cloud, see Pl. III.

*C-O 56, 6<sup>h</sup> 03<sup>m</sup> 32<sup>s</sup> MET.* Mean height 22.9 km.

The geographical situation of all the measured points are seen on fig. 13.

#### 14. The Heights of the Mother of Pearl Clouds during the Night 19—20 February as compared with those of the Afternoon, the 19th.

It is most interesting to compare to height during the night with the heights of the afternoon before. In Fig. 14 are seen the statistics of all measured heights of the two occasions. It is evident from this diagram that the clouds have dropped during the night from the mean height of 24.8 km to the mean

23.2 km, that is, about 1.5 km. Probably the most reliable set No. 41, at 3<sup>h</sup> 49<sup>m</sup> 54<sup>s</sup> gives even a mean height of 22.5, with lowest point down to 21.7 km.

This tendency of sinking with time was also indicated on the diagram Fig. 6 in the report on the Mother of Pearl Clouds 13 January 1929.<sup>1</sup>

#### 15. Attempt to Find the Velocity of the Clouds.

The clouds showed very little displacement and the determination of velocity is therefore very difficult. Mr. Egeberg has made the following attempts:

O-19 to O-24. No quantitative result. Only a displacement towards SE.

C-39, C-40 to C-41. Displacement probably towards SE or E. From C-40 to C-41 a velocity of 10 metres per second was found.

C-54 to C-56. Velocity of 5.9 metres per second towards SE.

O-53 to O-57. 6.6 metres towards SE or E.

O-53 to O-55. 8.6 » » » »

#### 16. Observations of a Corona round the Moon and Resulting Magnitude of the Droplets of the Clouds.

During the work, at about 3<sup>h</sup> 45<sup>m</sup>, I made an interesting observation. A rather homogeneous mother of pearl cloud happened to be just to the right of

<sup>1</sup> Carl Størmær: Höhe und Farbenverteilung der Perlmutterwolken, Geof. Publ., Vol. IX, No. 4.



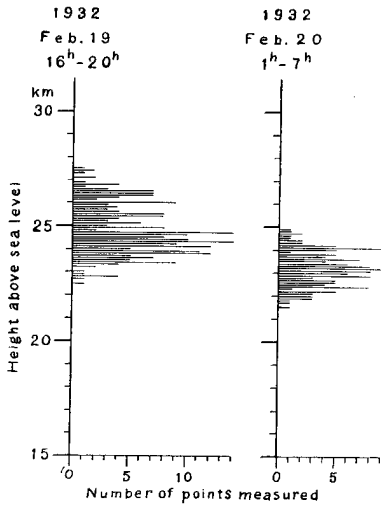


Fig. 14. Heights of Mother of Pearl Clouds during the Night of 19th—20th February 1932 as compared with the Heights of the Clouds on the Afternoon the 19th February.

the moon and in this cloud there was a corona like those seen round the moon when it shines through thin clouds consisting of drops of water. The inner field of the corona had a lilac yellow colour and then came a part of a red ring beginning between Castor and Pollux to the right of the moon. The outer radius of that ring was not observed. The angular distance from the moon to the inner border of the ring was  $15^\circ$  and then the outer radius probably  $18^\circ$  or more. This gives, according to meteorological optics,<sup>1</sup> diameters of the small droplets not exceeding 0.0025 mm, considerably less than for lower clouds.

**17. Weather Maps Corresponding to the Occurrence of the Mother of Pearl Clouds on 19—20 February 1932.**

Mr. Christensen has also drawn the weather maps for February 19th, 14<sup>h</sup> and 19<sup>h</sup> and for February 20th, 7<sup>h</sup>, reproduced on fig. 15, 16, and 17.

To this he has added the following remarks:

“In the days round 20th February 1932, the meteorological conditions were determined by a high pressure with centre W of Scotland and a very intense occurrence of cyclones in a belt stretching from southern Greenland over Jan Mayen, Bear Island and further towards SE. Between this belt and the high pressure

<sup>1</sup> Pernter-Exner: Meteorologische Optik, Zweite Auflage, 2. Kap. Wien und Leipzig 1922. Doubts regarding the allowance of the application of these results for very small drops are expressed in a paper *Note on the optical methods of measuring the size of small water drops*, by John G. Wilson, Proceedings of the Cambridge Philosoph. Soc, Vol. 32, Part 1, p. 493, 1936.

was a strong north-western current of unstable air. Instability showers occurred along the whole Norwegian coast from Bergen to Ingøy; this situation became well accentuated after the passage of the cold front. The Föhn on the lee side of the mountains was at that time well developed. The type of weather along the Norwegian coast and east of the mountains as well as the meteorological situation in general was in these days very similar to the conditions at the end of January the same year when mother of pearl clouds were observed.

CHAPTER 3.

**Mother of Pearl Clouds in 1934.**

**18. Reports from the 20th January till the 5th February 1934.**

On 20th January very fine clouds were observed in northern Norway. *Magnus Os*, a school-teacher at Offersøy, Salten ( $68^\circ.3$ ,  $15^\circ.6$ ) writes:

“Today, 20th January, at 9<sup>h</sup> I observed some small almond-shaped mother of pearl clouds in SE. The pressure in Offersøy had risen very rapidly this forenoon. It began at 3<sup>h</sup> in the night and at 8<sup>h</sup> the tendency was 8.6 mb. This morning the sky was covered by big cumulus clouds giving from time to time showers of snow. But at 9<sup>h</sup> a break in the lower clouds was seen and in this some small almond-shaped mother of pearl clouds, and a more irregular formation of such clouds. But about 10<sup>h</sup> the clouds

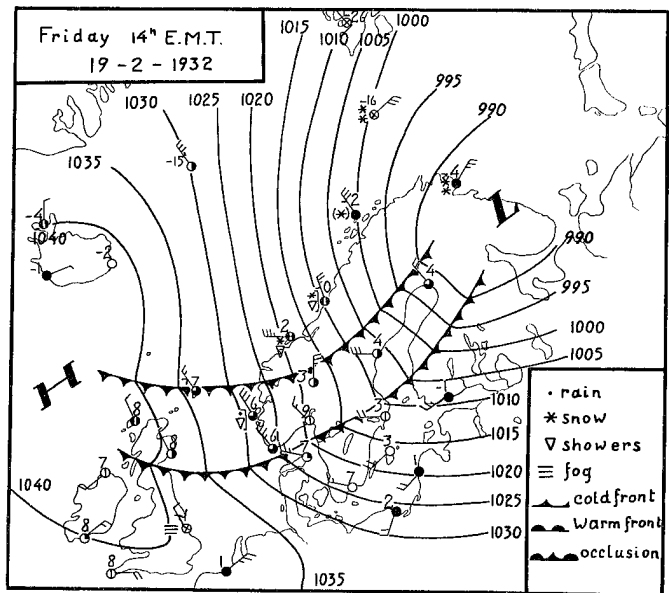


Fig. 15. Weather Map on February 19th, at 14<sup>h</sup>.

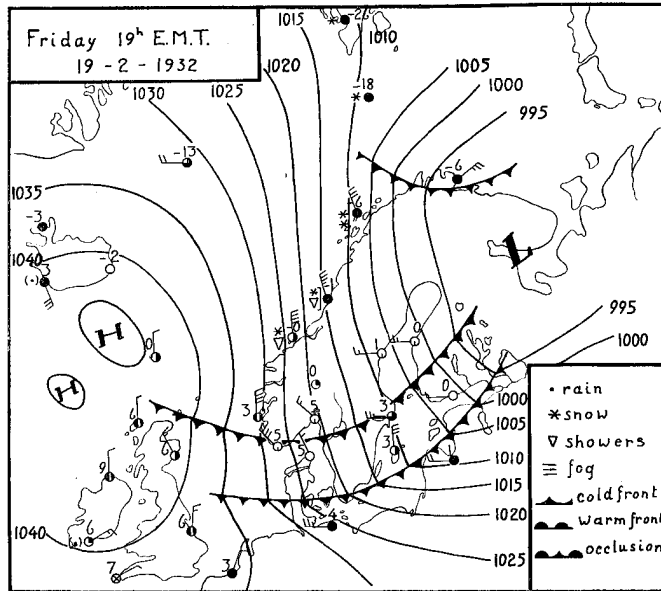


Fig. 16. The same at 19<sup>h</sup>.

were shining in a clear sky, and now no doubt was possible. The irregular part had disappeared and the two almond-shaped clouds were clearly seen: the first toward SE to S; it was about  $8^\circ$  over the horizon. The length was  $4^\circ$  and the breadth  $2^\circ$ . The colours had the following distribution: In the middle, deep red, then in concentric layers light red, yellow, and round the border, light blue. The second cloud was in SSE and at the same elevation as the first. In this cloud the colours were not so distinct. In the middle it was deep red and along the border, light red. Between these clouds there were some very small stripes and dots of mother of pearl clouds.

The shining colours of the clouds were essentially different from the colours of the lower sunlit clouds.

At 10<sup>h</sup> 30<sup>m</sup> the clouds were hidden behind big shower clouds, but at 11<sup>h</sup> 10<sup>m</sup> they were again visible for 10 minutes. But now they were much fainter on account of the daylight. Later they were hidden again."

The report was accompanied by a coloured sketch.

Another report of mother of pearl clouds was received from Mr. *Jacob Knutsen*, Fjeldnes ( $68^\circ.4$ ,  $16^\circ.0$ ), near Lødingen.

In the adjacent parts of Sweden the clouds were also observed. In fact, from the meteorological office in Stockholm (Statens Meteorologisk-Hydrografiska Anstalt) I got a copy of some observations made by Mr. *A. Forsén* at Kalixfors railway station ( $67^\circ.7$ ,  $20^\circ.2$ ), Jukkasjärvi in Norrbotten. He says:

"At 2 o'clock on Saturday afternoon a mother of pearl cloud was quite suddenly shining over Kiru-

navaara. By its exceptional beauty and colours the cloud made a most effective contrast to the grey wintry sky with driving banks of low clouds. Such clouds have earlier been observed in Västerbotten and sometimes in Kiruna, but this phenomenon probably exceeded all earlier cases by its gorgeous splendour".

From January 23th the two following reports are of interest:

*Erling Labukt* (teacher) from Storsteinnes in Balsfjord ( $69^\circ.2$ ,  $19^\circ.4$  near Tromsø writes:

"On 23rd January I saw from Glimt school on the east side of Sagelvvatn in Balsfjord, some marvellous mother of pearl clouds in S and SSE at about 12<sup>h</sup> 10<sup>m</sup>. I took a photograph of the clouds which I send you. (See Pl. XIV.) The mark on the right side gives the azimuth of the sun at 12<sup>h</sup>. It points to the smaller cloud which was the most intense of the clouds. To the left is seen the most beautiful, a series of colours arranged from left to right and with the sharpest boundaries between them and the right end. The colours were arranged as on the sketch fig. 18. It was a severe gale from SW and dark rain clouds passed over the mother of pearl clouds several times. At 12<sup>h</sup> 35<sup>m</sup> it became quite overcast with rain and later snow."

From *Martin Enge* (teacher), Fauske ( $67^\circ.3$ ,  $15^\circ.4$ ), I received the following report:

"Thinking that it may perhaps interest you, I beg to inform you that I observed some very beautiful mother of pearl clouds towards SE from a class

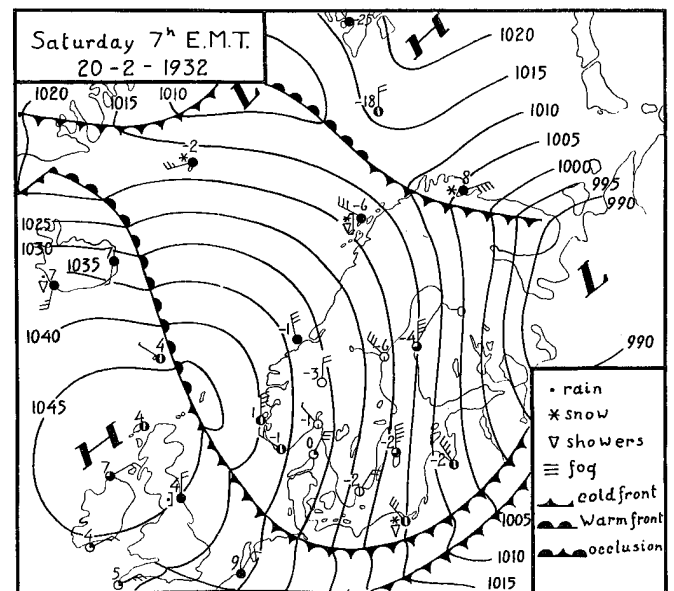


Fig. 17. The same on February 20th at 7<sup>h</sup>.

room in our school. The sky was almost covered by low irregular shower clouds but in SE there was a break in the clouds and here the mother of pearl clouds were visible. I immediately asked a boy clever at drawing to make sketches of the clouds. These sketches which were made every 5 minutes from 9<sup>h</sup> 5<sup>m</sup> to 9<sup>h</sup> 35<sup>m</sup> follow."

Then comes a description which permits finding of the height and azimuth of the clouds, if desirable. The coloured sketches show the rapid changes of the mother of pearl clouds.

On the next day, January 24, the mother of pearl clouds were again observed in northern Norway. The observer Mr. *Digre* at the meteorological station Ingøy (71°.1, 24°.0) in Finnmark, says that between 8<sup>h</sup> and 10<sup>h</sup> about one tenth of the sky towards S and SE was covered by mother of pearl clouds. From Vardø (70°.3, 31°.1) Mr. *Alf Leifseth* sends a more complete report as follows:

"I beg to inform you that I saw a mother of pearl cloud from Vardø on January 24th, 1934. I am sorry I had no time to take a photograph as I saw it only for half an hour from 1<sup>h</sup> 30<sup>m</sup> to 2<sup>h</sup>.

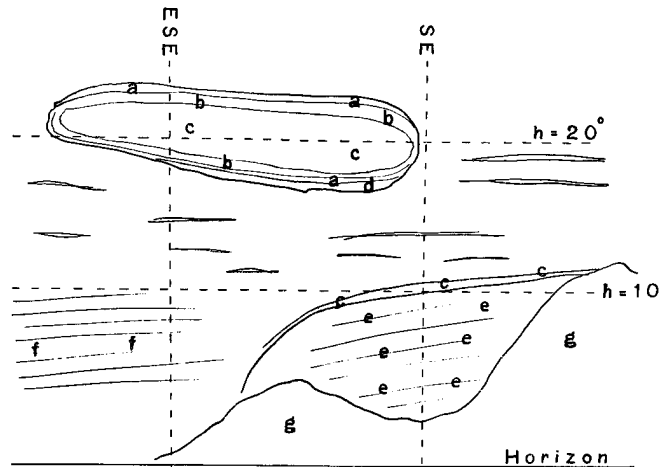
The cloud had the form of an almond and was visible at a rather high elevation above the horizon in W to SW. The outer border was violet to pure blue. Then came a belt of yellow-red with transitions to deep pink and dark red. Then a belt of red-green towards green. I have never seen more beautiful combination of colours. The cloud was shining intensely especially in blue and lilac."

A new period of fine nacreous clouds began on February 1, first in northern Norway and later more southwards, over Oslo. It is remarkable that in 1932 an analogous development occurred with clouds visible first in northern Norway and a couple of days later in Oslo.

The first report came from Mr. *Digre*, Ingøy, saying that mother of pearl clouds were again visible from Ingøy in SE from 8<sup>h</sup> to 11<sup>h</sup>. At the same time they had a hurricane with wind velocity up to 60 m per second, in good accordance with the traditions among the old fishermen there, who remember similar coincidences earlier and who for that reason call the clouds hurricane clouds.



Fig. 18. Distribution of Colours on Mother of Pearl Clouds from Balsfjord, 23rd January 1934.



a. pale red. b. light blue. c. yellow red. d. pale blue.  
e. intense blue. f. diffuse yellow red. g. cumulus clouds.

Fig. 19. Mother of Pearl Clouds from Offersøy, on February 3rd, 1934.

On February 2 they were again visible from Ingøy. Mr. *Digre* says:

"I saw them from 8<sup>h</sup> to 9<sup>h</sup> till they were covered by shower clouds. From 15.30—16.00 they were again visible in great masses in SSE. It is impossible to describe their splendour. They showed all the colours of the spectrum and were at some places shining like a sun."

The next day, February 3rd, mother of pearl clouds were seen not only in the northern Norway but also more to the south in Salten and Helgeland.

The first report, sent me by Mr. *Thrane*, chief of the meteorological service in Tromsø, comes from an observer *Petter Moe* at Myken (66°.6, 13°.2). He says:

"The 3rd February from 8.20 to 8.30 we looked at the sky in E—SE and probably observed mother of pearl clouds. The colours were more numerous and much purer than the colours of the rainbow... We have never before seen such a splendid and divinely beautiful sight."

*Magnus Os*, (teacher) Offersøy (68°.3, 15°.6) in Salten again sent me his observations with a sketch which is reproduced on fig. 19. He says:

"Also today, 3rd February, I had the pleasure of observing mother of pearl clouds. Already before 8<sup>h</sup> this morning a suspicious bank of shining clouds was seen in SE, but as the colours were only red yellow, I thought them to be only cirrus clouds illuminated by the sun. But at 8.30 the colours began

to be more varied with patches of pure blue. I therefore became more and more convinced that they were mother of pearl clouds.

At 9.25 I looked at them again. In the direction SE there was a rather big cloud with fine colours, as seen on the sketch. Nearer the horizon was an intensely shining blue cloud and here and there stripes of other coloured clouds as seen on the sketch. From this moment the clouds changed rapidly. The big cloud diminished and dissolved ultimately in horizontal stripes. At 10<sup>h</sup> only a diffusely shining stripe remained, which together with the other clouds stretched from E to S with their upper border at about 10° to 12° over the horizon. But over the sun in SE we had still the blue cloud with red yellow patches along the upper border.

At 10<sup>h</sup> 45<sup>m</sup> the sky became overcast and no more coloured clouds were visible."

Another report was sent me from *Edv. Walvig*, Meløy, Northern Helgeland, (66°.9, 13° .5), of very fine blue violet mother of pearl clouds in SE between 8<sup>h</sup> and 8<sup>h</sup> 30<sup>m</sup>.

The 5th February, mother of pearl clouds were again reported from Ingøy in SSW.

#### 19. Report from G. A. Clarke on Mother of Pearl Clouds seen at Aberdeen on the 5th and 6th of February.

It is most interesting to note that mother of pearl clouds also occurred in Scotland at the same time as in Norway. In fact, in a letter to me from Mr. *G. A. Clarke* of the Aberdeen Meteorological Office, dated February 9th, 1934, he sent the following most interesting report.

"Throughout the night of February 4th the sky at Aberdeen had gradually cleared, and on the morning of the 5th the day had dawned with a strongly green-tinted sky, in which a band of deep-red Cirrostratus lay down along the eastern horizon. Temperature had fallen to 31° F. during the night but at 7<sup>h</sup> it stood at 34° F. A light south-westerly wind was blowing and the temperature rose steadily, eventually reaching 52° F. in the afternoon. During the morning the sky had been about two-tenths covered with very slight Cirrus and Cu-st. in lines and patches, but after 13<sup>h</sup> Alto-cumulus made its appearance and gradually increased in quantity from three-tenths at 15<sup>h</sup> to five-tenths by 18<sup>h</sup>. The A-cu was present in detached patches and bands, very slightly lenticular in arrangement, and was intermixed with some

stray wisps of cloud at levels somewhat different from that of the main cloud, and partly above and partly below the latter. Still farther above this cloud (which in places resembled Ci-cu.), at 15<sup>h</sup> some very small patches of shining cloud were noticed, and were kept under observation because of their brilliant irisation. By 16<sup>h</sup> their number had apparently increased, and, though observation was much impeded by the presence of the A-cu, it was nevertheless possible to maintain a fair watch on their development. These shining clouds were confined to an area of the westward sky between azimuths 200° and 330°, and a theodolite measurement gave the elevation of the highest one visible as 36° at the moment when the sun's disc was touching the south-western horizon, i. e. about 16<sup>h</sup> 30<sup>m</sup>.

But, since some of these clouds, visible at the same time, were situated well to the north of west (azimuth 300°) and at almost the same elevation, their angular distance from the sun must have been between 70° and 80°. It was therefore obvious that the colouring was not the usual irisation seen sometimes on the intermediate cloud-layers within limits much nearer to the sun's position, but that the clouds were in fact the nacreous high-level clouds called "Perlmutter Wolken" by Prof. Carl Størmer of Oslo<sup>1</sup>, who has studied them extensively in Norway.

The individual clouds exhibited all the characteristics mentioned in Størmer's paper: "Höhe und Farbenverteilungen der Perlmutter-Wolken" — *Geofysiske Publikasjoner*, Vol. IX, No. 4, so far as appearance, variation, and colours were concerned, but of course I was unable to make any height-determination.

At 15<sup>h</sup> the clouds nearest to the sun's position showed intense colours, prominent amongst which was a very cold clear "electric-blue" tint, whose intensity far exceeded that of any of the other tints, and which seemed to be present chiefly on the upper edges of the clouds. The larger masses of the clouds were situated about azimuth 270° to 290°, and at an elevation of 20°—30°, and had a pale milky hue, called blue-grey by Størmer, until about 16<sup>h</sup> 30<sup>m</sup>, after which they became tinted with pale rose-pink, violet and green, in the customary "contour" pattern, having in the meantime either (1) actually moved southwards to about azimuth 260°, or (2) developed in that direction while dispersing at their northern

<sup>1</sup> This name was introduced long before by the late Professor H. Mohn.

extremities, much after the manner of the internal changes seen in the ordinary lenticular clouds. The nacreous clouds themselves were decidedly lenticular in form, but continuous observation of the individual clouds was seriously interrupted by the presence of the lower A-cu. cloud sheets which tended to increase in quantity.

After sunset the lower clouds (A-cu.) assumed very brilliant orange to crimson colouring from about 16<sup>h</sup> 45<sup>m</sup> until at least 17<sup>h</sup> 30<sup>m</sup>; at about 17<sup>h</sup> the rose-red colour spread right across the sky to the eastern horizon, the whole sky thus appearing tinted in varying shades of red at the same time.

As the sunset colours faded and the A-cu. became dark and grey, the mother of pearl clouds shone out more brilliantly and sharply, and showed more red and yellowish-green than formerly, with brownish and violet here and there. I hoped to obtain a photograph of them when the sky became dark enough but unfortunately the A-cu. cloud now began rapidly to overspread the western sky in the region where the chief group of these nacreous clouds lay, and I was disappointed. The last view I had of these beautiful clouds was at 18<sup>h</sup> 30<sup>m</sup> when one single small perfectly lenticular cloud was shining with a flame-like colour in the dark twilight sky, close to the edge of the A-cu. layer which soon advanced and hid the cloud from view.

It is worthy of note, too, that on the evening of the next day, Tuesday 6th February, a very fine display of sunset colouring was again seen on the under surface of a widely extended A-cu. to A-st. cloud sheet, which had covered eight to nine-tenths of the sky all day, leaving a narrow band of clear sky along the western horizon. Low in the N. W. where the edge of this cloud-sheet thinned out and became striated, three small lenticular mother of pearl clouds were seen for a short time shining blue-white above the lower layer.

During both the 5th and 6th February the surface wind was chiefly S.W.ly, very variable in force, and somewhat squally and gusty. The A-cu. and Ci-cu. clouds moved steadily from W. Temperature was high for the time of year, 47° F. to 52° F. during day-time, and the usual local slight föhn effect was noticeable. The mother of pearl clouds, as mentioned above, seemed to be moving from either N. or N. N. E., but this is not certain because of the great difficulty of proper observation."

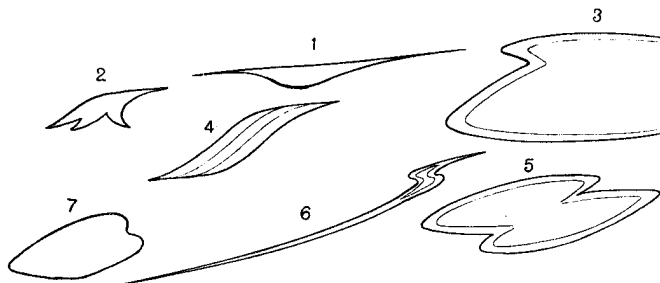


Fig. 20. Types of Mother of Pearl Clouds observed by Mr. Clarke from Aberdeen on 5th and 6th February 1934.

Mr. Clarke also sent me a coloured sketch with a detailed description of the clouds, seen in Fig. 20, and his description was as follows:

No. 1 was the most striking of the clouds in regard to colour-intensity. It was of an intensely brilliant pale "electric" blue at the upper edge shaded to a blue-green at the lower edge. It maintained the blue-green colour as long as observed but with gradually diminishing intensity till it was hidden from view by lower A-cu. clouds.

No. 2. Bright green upper edge shading through yellow to reddish-orange — became blue-green at upper edge and yellow-green at lower edge later.

No. 3 was the most distant from the sun's disc; the cloud was at first a faint blue-grey, but later became tinged with rose-pink round its edges nearest to the sun.

No. 4. A very vivid and sharply defined cloud, showing little or no change of shape. At first brilliant green with sharply defined centre of bright yellow. changing later into yellow with orange-red central band.

No. 5. A twin lenticular mass — very beautifully coloured — almost as through the central area (C) of each mass were situated *below* the edge (E).

The colour separation was *sharp*. The E portion shaded rose-pink at sunward edge to blue-green at their edge — while the C portion was blue-green to yellow-green. Further changes in these colours could not be observed because of lower A-cu. covering them.

No. 6. A long stripe — yellow orange with reddish-orange centre stripe at bend — changing to green-yellow with yellow centre.

No. 7. Seen only for a short time — reddish-pink edge, then brownish-red, with violet-brown centre.

Table 7.

No.	St.	MET	Ex.	Ref. Const.	Remarks	No.	St.	MET	Ex.	Ref. Const.	Remarks
2	C-O-T	16 <sup>h</sup> 56 <sup>m</sup> 24 <sup>s</sup>	2 <sup>s</sup>	Landscape	Also cirrus clouds and fracto-cumulus clouds.	20	O-C	17 <sup>h</sup> 16 <sup>m</sup> 02 <sup>s</sup>	4 <sup>s</sup>	Landscape	Cirrus measured.
3	C-O-T	> 57 59	2	—>—	Lower clouds also measured.	21	O-C-T	> 17 24	4	—>—	—>—
4	C-O-T	> 58 54	2	—>—	—>—	22	O-C-T	> 18 48	7	—>—	—>—
5	C-O-T	> 59 22	2	—>—	—>—	23	C-O	> 19 46	5	—>—	Only cirrus measured.
6	C-O-T	17 00 21	2	—>—	—>—	24	C-O-T	> 20 58	6	—>—	—>—
9	O-C	> 04 35	3	—>—	—>—	25	O-C-T	> 22 18	7	—>—	—>—
10	O-C	> 04 52	1	—>—	—>—	26	O-C	> 23 22	4	—>—	—>—
11	O-C	> 05 19	2	—>—	—>—	30	O-C	> 33 07	8	—>—	Cirrus measured.
12	O-C	> 05 37	1	—>—	—>—	41	K <sub>4</sub> -C-O	18 26 54	15	Peg.Aql.	—>—
14	O-C	> 07 36	2	—>—	—>—	42	K <sub>4</sub> -C-O	> 30 19	15	Peg.Psc.	—>—
16	O-C	> 11 14	2	—>—	—>—	43	K <sub>4</sub> -C-O	> 31 05	12	Peg.	—>—
17	O-C	> 13 22	2	—>—	Only cirrus measured.	44	O-C	> 32 13	15	Peg.Aql.	—>—
18	O-C	> 14 06	5	—>—	—>—	45	K <sub>4</sub> -C	> 35 16	16	Peg.Aql.	—>—
						46	K <sub>4</sub> -C	> 36 01	18	Psc.Aql.	—>—

## 20. Photographic Work on the Mother of Pearl Clouds on February 6th, 1934.

On February 6th, the same day when mother of pearl clouds were seen at Aberdeen, we had a fine display of such clouds in Oslo. Warm weather and föhnwind led me to suspect such clouds and in the afternoon they appeared in the western sky. I warned my aurora stations and at 16<sup>h</sup> 20<sup>m</sup>; Oslo, Oscarsborg and Tømte got in order and were connected by state telephone lines. Later at 17.30 the station Kongsberg came in.

In Oslo I was myself at the station, with Mr. Tveter, Mr. Sandøy and Mr. Anda as helpers. Also my son Per Størmøer took a series of photographs and Mr. Simonsen from the firm Nerlien succeeded in taking a series of pictures in natural colours. The assistant at Oscarsborg was Mr. Bakøy, at Tømte, Mr. Albert and Egil Tømte, and at Kongsberg Mr. O. Busengdal. During the work, the mother of pearl clouds often shone through lower clouds, but on account of their intensity their outlines could be fixed very well.

In Table 7 is seen a list of the pictures which succeeded well. The headings have the same meaning as in Part I.

No. means the current number of the set of pictures.

St. are the stations from which the photographs were taken simultaneously. Here C means Oslo Observatory, O Oscarsborg, T Tømte and K<sub>4</sub> Kongsberg.

Station K had been removed to another place in the town Kongsberg and is now indicated by K<sub>4</sub> instead of K<sub>g</sub>.

MET Middle European time for the middle of the exposure.

Ex. means the exposure.

The meaning of the rest of the headings is clear. In the list are only given the photographs used for the height measurements.

## 21. The Results of the Height Measurements.

The photographs have been measured out with very great care by my excellent assistant Olaf Egeberg during the winter 1938—39. Some cases had already been measured in 1934, but have been measured anew in 1939 with greater exactitude.

Together with the mother of pearl clouds, other low clouds have also been measured and will be mentioned (in section) later.

In Table 8, the results are seen for the mother of pearl clouds; the headings have the same meaning as in Table 2.

*Picture No. 6, O-C and O-T, 17<sup>h</sup> 00<sup>m</sup> 21<sup>s</sup> MET.*

The same mother of pearl clouds can easily be recognized on all 3 pictures, as seen on Pl. III and XI. The mean height 25.0 and 25.2 km for measurements with the two base lines O-C and O-T are in good agreement.

Table 8.

Measurements of Mother of Pearl Clouds in the Afternoon of February 6th, 1934.

No.	St.	P	p	h	a	H	D	Mean height	No.	St.	P	p	h	a	H	D	Mean height						
2	O-C	1	11.0	10.4	93.9	25.7	132	26.2			5	8.5	7.8	86.9	25.0	166							
		2	11.2	10.8	92.4	25.8	128				6	10.8	10.5	83.7	24.3	124							
		3	7.2	6.8	86.1	26.6	197				7	15.6	15.4	90.9	24.6	87							
		4	6.8	6.8	80.1	26.9	199																
3	O-C	1	10.9	10.1	93.4	25.2	133	25.4	21	O-C	4	11.2	10.3	89.3	24.1	125	24.5						
		2	11.5	11.2	90.2	25.5	122				5	12.0	10.9	94.1	24.4	120							
		3	10.5	10.1	88.3	25.3	133				7	8.9	8.0	86.8	24.3	157							
		4	7.7	7.0	86.7	25.5	185				8	10.8	9.9	94.0	25.0	134							
	C-T	1	13.2	9.4	82.3	25.6	144	24.8		O-T	a	25.5	10.4	96.1	24.9	130	24.3						
		3	12.7	9.1	77.7	24.0	139				b	26.0	10.7	95.3	24.9	125							
											d	40.0	16.6	104.3	23.4	77							
4	O-C	1	11.0	10.3	93.2	25.4	131	25.0	22	O-C	1	6.8	6.9	78.4	26.6	195	25.6						
		2	11.4	10.5	94.2	24.9	127				2	6.8	6.3	84.0	26.2	205							
		3	10.6	10.4	88.4	25.7	132				3	7.4	6.8	87.5	26.1	193							
		4	11.0	10.7	87.4	25.1	126				4	8.6	7.8	86.1	24.6	163							
		5	7.2	6.8	79.9	25.2	187				5	9.7	9.6	83.5	25.2	139							
		6	6.8	6.0	78.4	23.6	195				6	9.5	9.2	84.5	25.1	144							
5	O-C	1	11.1	10.5	94.3	25.7	131	25.6			7	10.2	10.4	85.0	26.1	134							
		2	11.3	10.7	92.5	25.4	127				8	9.7	9.4	88.7	25.9	146							
		3	10.3	10.3	88.3	26.3	136				9	11.6	11.0	94.4	25.6	125							
		4	11.6	11.2	89.7	25.1	120				10	10.4	10.0	93.6	26.3	140							
6	O-C	1	11.2	10.3	92.9	24.8	129	25.0			14	16.1	15.5	93.5	24.5	86							
		2	11.3	10.7	91.9	25.3	126				15	16.3	15.7	95.9	24.8	86							
		3	10.5	10.3	88.0	25.7	133				9	26.1	11.0	94.5	25.3	123							
		4	7.3	6.9	86.1	24.3	95				10	24.0	10.0	93.8	25.4	136							
		7	11.7	11.2	90.3	25.0	119				15	34.0	15.6	95.9	24.6	85							
											16	25.5	10.4	95.7	25.2	129							
		O-T	1	24.2	10.3	92.9	25.8	133	25.2	24	C-O	1	11.2	9.8	84.2	25.2	136	25.6					
			2	25.1	10.7	91.9	24.9	125				2	10.4	9.2	84.1	25.4	147						
			3	23.2	10.3	88.0	25.1	131				3	10.3	9.5	79.7	26.3	146						
			7	25.3	11.2	90.3	25.0	120				4	10.5	9.6	76.0	25.5	141						
9	O-C	1	12.8	14.8	73.9	24.4	90	25.0			5	8.2	7.3	78.1	25.9	181							
		2	11.4	14.1	66.0	23.6	91				6	14.3	13.3	75.4	25.4	104							
		4	5.9	6.9	67.3	26.9	197				a	23.7	9.5	93.8	24.8	138							
											b	24.9	10.5	94.6	25.5	130							
10	O-C	1	12.8	14.7	73.9	24.2	91	24.9	25	O-C	1	11.9	10.3	94.8	25.1	130	24.8						
		2	11.8	14.1	66.7	22.8	88				2	10.9	9.8	94.0	24.6	133							
		3	15.4	20.0	69.7	24.7	66				3	11.0	10.2	90.4	24.6	129							
		4	6.0	6.9	67.3	26.4	193				O-T	1	23.6	9.9	93.6	25.9		139	25.9				
		5	6.4	8.8	53.6	23.1	138					26	O-C	1	11.6	10.5		94.2		24.5	125	24.7	
		7	6.3	7.3	66.0	25.7	180							3	10.8	10.3		89.8		25.2	131		
		8	5.1	5.9	65.0	27.1	223				4			9.7	9.1	85.1		24.5	142				
		9	4.9	5.6	63.1	26.1	226				5			8.6	7.8	85.4		24.3	162				
		11	5.3	6.8	56.0	24.3	180				6			7.1	6.8	78.0		25.0	186				
		13	5.0	5.9	59.4	24.8	206																
		11	O-C	1	13.0	14.5	74.0				23.6	88	23.6	30	O-C	2		11.5	11.0	94.2	25.7	126	25.7
				2	17.9	20.2	78.3				23.5	63											
		12	O-C	1	12.8	14.5	74.2				24.1	90	24.5	41	K <sub>1</sub> -O	1		6.4	16.8	88.0	25.2	80	24.6
2	11.6			14.1	66.3	23.4	89	2	7.0	17.4	85.7	24.7				76							
4	15.5			19.9	69.3	24.0	65	3	7.1	16.2	80.5	24.3				81							
5	6.0			6.9	67.2	26.4	194	4	7.7	18.8	91.0	24.6				70							
14	O-C	1	13.2	15.2	74.0	24.3	87	24.6			6	8.1	16.6	77.2	24.1	78							
		2	17.3	21.1	78.7	25.8	66				9	6.9	17.7	87.6	25.5	77							
		4	12.0	14.9	66.3	23.7	86				10	3.0	9.8	84.5	25.0	135							
											11	2.9	8.9	83.6	23.4	138							
16	O-C	2	12.4	14.6	73.3	25.0	93	24.9		K <sub>1</sub> -C	1	12.0	16.8	88.0	25.0	80	24.6						
		3	11.2	14.5	65.7	24.8	93				2	11.7	17.4	85.7	24.9	77							
20	O-C	3	8.6	3.8	77.9	24.7	150	24.6			3	9.5	16.2	80.5	24.1	80							
		4									4	14.6	18.8	91.0	24.3	69							

Table 8 (Cont.).

No.	St.	P	p	h	a	H	D	Mean height	No.	St.	P	p	h	a	H	D	Mean height
42	K <sub>4</sub> -O	5	13.2	19.9	85.0	24.3	65	24.5	K <sub>4</sub> -C	11	8.0	17.0	78.1	24.4	77	24.3	
		6	8.9	16.6	77.2	24.0	78			14	11.7	20.3	70.7	24.9	66		
		7	12.0	19.4	82.5	24.6	68			15	9.5	20.0	78.8	24.8	66		
		8	11.2	19.5	79.3	24.3	67			16	8.7	18.7	79.6	24.5	70		
		9	12.4	17.7	87.6	25.3	77			17	3.0	9.8	84.6	24.7	133		
		10	6.6	9.8	84.5	25.6	138			18	2.8	9.2	84.9	23.7	135		
		11	6.1	8.9	83.6	24.4	143			1	14.6	19.3	90.4	24.4	68		
		1	8.7	20.2	91.8	24.2	64			2	14.0	20.1	86.8	24.0	64		
		2	8.7	20.3	89.0	24.3	64			3	13.2	20.0	84.6	23.9	64		
		3	9.0	20.0	82.7	24.2	65			4	15.0	20.0	90.4	24.6	66		
		4	9.7	20.0	78.2	24.5	66			5	14.3	20.7	86.7	24.3	63		
	5	11.1	20.2	73.8	24.3	63	6	13.4		20.6	84.4	24.4	63				
	6	8.1	19.4	90.6	24.4	67	7	12.2		17.1	87.9	24.9	78				
	7	8.3	19.7	88.1	24.4	67	8	11.7		17.5	85.3	24.4	75				
	8	7.0	17.7	88.9	24.6	75	9	12.1		18.0	86.4	25.4	76				
	9	7.6	18.3	86.3	23.9	70	11	9.3		17.0	78.1	24.0	76				
	10	6.5	16.9	87.7	24.7	79	12	7.9		16.6	73.4	24.5	80				
	11	7.1	17.6	85.6	24.6	75	15	11.4		20.0	78.8	24.3	65				
	12	7.8	17.0	78.8	24.4	77	16	10.9	18.7	79.6	23.6	68					
	13	8.0	16.7	76.7	24.8	80	17	6.9	9.8	84.6	24.3	136					
14	8.9	16.7	72.9	25.2	81	18	6.8	9.2	84.9	23.4	134						
15	8.5	14.7	70.1	25.4	93	44	O-C	1	10.6	10.5	83.8	24.8	127	24.4			
16	7.6	12.3	69.4	24.6	107			3	9.5	9.6	78.6	24.6	136				
17	3.0	9.8	84.6	24.4	132			4	7.2	7.3	72.5	24.4	171				
18	2.6	9.1	85.1	24.9	144			5	12.1	11.1	90.9	24.1	116				
19	7.8	17.6	81.0	24.1	74			7	11.2	10.2	89.8	24.1	126				
20	12.3	20.3	69.4	24.2	64			45	K <sub>4</sub> -C	1	10.9	20.1	77.5		24.8	66	24.2
1	15.9	20.2	91.8	24.0	63					2	10.2	20.7	69.9		24.3	63	
2	14.8	20.3	89.0	24.4	64	3	10.3			20.7	60.2	24.6	63				
3	12.6	20.0	82.7	24.3	65	4	8.4			16.4	76.6	24.6	81				
4	11.2	20.0	78.2	24.4	66	5	7.9			17.5	69.2	24.3	75				
5	10.4	20.2	73.8	24.4	65	6	6.0			14.7	66.5	23.8	87				
6	14.8	19.4	90.6	24.3	67	7	5.3			13.4	69.3	24.3	98				
7	14.0	19.7	88.1	24.7	67	8	5.5			13.8	67.9	23.9	93				
8	12.9	17.7	88.9	25.0	76	9	4.8			12.5	69.0	24.0	103				
9	12.5	18.3	86.3	24.7	73	10	3.6			10.6	63.4	24.0	121				
10	12.1	16.9	87.7	24.6	78	11	4.7			10.2	56.0	23.8	124				
11	11.7	17.6	85.6	25.1	77	12	6.8			9.4	46.4	23.9	134				
12	9.3	17.0	78.8	25.1	79	46	K <sub>4</sub> -C			1	10.5	20.3	75.8	25.4	67	24.6	
13	8.8	16.7	76.7	24.0	77					2	10.0	20.9	68.5	25.0	64		
14	7.9	16.7	72.9	24.7	80					3	10.3	20.7	60.2	24.4	63		
15	6.2	14.7	70.1	24.6	90					4	8.0	16.3	75.9	25.2	83		
16	4.8	12.3	69.4	23.6	103			5	7.8	17.6	68.0	24.6	75				
43	K <sub>4</sub> -O	1	8.2	19.3	90.4			23.8	66	24.2	6	8.2	18.0	61.0	25.0		75
		2	8.7	20.1	86.8			24.0	64		7	5.7	14.5	67.1	24.9		93
		3	8.9	20.0	84.6			23.8	64		8	6.5	15.1	60.6	24.6		88
		4	8.6	20.0	90.4	24.0	64	9	5.6		13.9	67.5	23.5	91			
		5	9.1	20.7	86.7	24.3	63	10	5.3		12.4	58.5	24.0	104			
		6	9.2	20.6	84.4	24.1	63	11	3.6		10.3	61.9	24.1	124			
		7	6.8	17.1	87.9	24.2	75	12	5.2		9.7	52.5	24.8	135			
		8	7.2	17.5	85.3	24.1	74										
		9	7.4	18.0	86.4	24.1	72										
		10	8.0	17.8	80.1	24.5	74										

Picture No. 12, O-C, 17<sup>h</sup> 05<sup>m</sup> 37<sup>s</sup> MET.

Successful pictures at both stations. The intensely shining, thread structured mother of pearl clouds easily recognized on both pictures. See Pl. III.

Picture No. 20, O-C, 17<sup>h</sup> 16<sup>m</sup> 02<sup>s</sup> MET.

Very fine set, both of the mother of pearl clouds and of the lower clouds (see section 24). The sky becomes now darker and the mother of pearl clouds shine brighter against the darker background. See Pl. IV.



*Picture No. 21, O-C-T, 17<sup>h</sup> 17<sup>m</sup> 24<sup>s</sup> MET.*

Also a very fine set giving excellent agreement between the measures with the two base lines O-C and O-T, as seen on Table 8. The pictures have been published earlier in a paper by director Jaumotte on mother of pearl clouds<sup>1</sup>.

*Picture No. 22, O-C-T, 17<sup>h</sup> 18<sup>m</sup> 48<sup>s</sup> MET.*

Also a good set; probably the measurements with base line O-T are the best on account of the large parallax. The sketches are reproduced on Pl. IV, the pictures on Pl. XII.

All the pictures, Nos. 1 to 30 have been measured by means of reference point in the landscape except in some cases where Venus was visible on the plates. The following numbers, however, have been measured by reference stars among the clouds and the results are therefore much more reliable for these last pictures. This is also evident from the comparison between the measurements with base lines K<sub>4</sub>-O and K<sub>4</sub>-C of the same points. We only mention two of the best.

*Picture No. 42, K<sub>4</sub>-C-O, 18<sup>h</sup> 30<sup>m</sup> 19<sup>s</sup> MET.*

A long series of points are measured and the results must be considered as fairly good. Sketches are seen on Pl. IV and the pictures from O and K on Pl. XIV.

*Pictures No. 43, K<sub>4</sub>-C-O, 18<sup>h</sup> 31<sup>m</sup> 05<sup>s</sup> MET.*

These also gave a long series of good height measurements. See Pl. IV.

## 22. Statistics of the Height Distribution and the Geographical Situation of the Measured Clouds.

As before, we have also this time enumerated the distribution of individual heights and drawn a corresponding diagram, which is seen in Fig. 21. The mean of all individual heights is 24,7 km. The last pictures Nos. 41, 42, 43, 44, 45 and 46, where stars are reference points, show very little variation in the heights as seen on the same fig. The mean is here 24,4 km.

The geographical situation is seen in Fig. 22 where all the points measured are marked by small circles. On the same map are seen the situation of

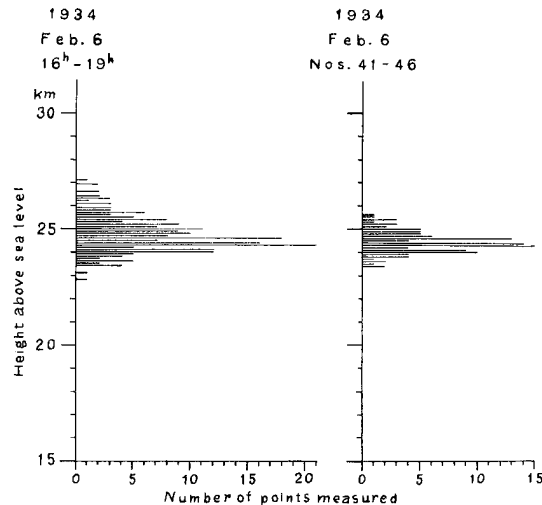


Fig. 21. Height Distribution of Mother of Pearl Clouds on February 6th, 1934.

the wavy cirrus clouds, the points of which are marked by crosses.

The cirrus clouds are almost vertically under the mother of pearl clouds, and their height is about half the height of the latter (see section 24).

## 23. Determination of Velocity of the Mother of Pearl Clouds on February 6th, 1934.

This time it was also rather difficult to determine the velocity. Mr. Egeberg who made that attempt chose first the two pictures O 21 and O 24. The right end of a small cloud at 8° over the horizon showed a displacement from azimuth 86° 8' to azimuth 85° 7'. Supposing the height to be 24.5 km this gave a velocity of about 14 meters per second in a SE-ly direction. An attempt with pictures O 21 and O 26 gave 18 meters and with pictures O 41 and O 42 about 10 meters in southerly direction. But all these determinations are very doubtful and only give the order of magnitude of the velocity.

## 24. The Wavy Cirrus Clouds beneath the Mother of Pearl Clouds.

On a series of pictures of the mother of pearl clouds are also seen, near the horizon, some most interesting wave formed clouds. We have compared all the pictures of these clouds very carefully to see if we could discover any motion, but they seemed

<sup>1</sup> J. Jaumotte: Transformations thermodynamiques de la stratosphère et nuages nacrés. Institut Royal Météorologique, Memoires Vol. V, Bruxelles 1936, Fig. 22. In that paper 7th February is erroneously written for the date of the clouds (p. 41).



Table 9.

*Height of Cirrus Clouds beneath the Mother of Pearl Clouds.*

No.	St.	P	p	h	a	H	D
9	O-C	3	9.2	4.5	77.3	12.5	139
10	O-C	6	9.2	4.4	77.5	12.3	139
14	O-C	3	7.7	4.2	69.4	13.3	153
16	O-C	I	7.4	4.0	68.6	13.0	158
		II	7.6	3.6	76.8	13.1	171
			7.5	3.5	72.0	12.0	164
17	O-C	1	10.9	5.0	86.4	12.5	127
		2	8.9	4.0	86.6	13.1	158
		3	7.5	2.8	86.8	12.3	191
18	O-C	1	11.0	5.0	86.3	12.1	124
		2	9.4	4.0	87.0	12.3	150
		4	7.1	2.8	86.3	13.1	202
20	O-C	1	11.6	5.0	86.4	11.6	119
		2	9.9	4.0	86.7	11.6	142
		3	7.5	2.8	86.6	12.2	191
21	O-C	1	11.9	5.0	86.3	11.3	115
		2	9.7	4.1	86.4	12.1	145
		3	7.8	2.8	86.7	11.6	183
23	C-O	1	8.3	2.9	69.8	11.0	172
		2	7.7	2.8	69.2	11.5	183
		3	7.5	2.7	68.9	11.5	187
30	O-C	1	20.0	6.8	105.4	9.6	76
		3	17.5	8.5	89.3	12.0	77

Mean height 12,1 km.

shape so rapidly that no determination of velocity was possible. Their height, however, could easily be determined. In Table 10 is seen the result; the mean height was 1.9 km.

## 26. Single Photographs taken from Oslo and Neighbourhood.

During the simultaneous work at the stations, some pictures were taken independently from Oslo Observatory by my son Per Størmer and myself. Pancromatic films and plates with red filter were used.

On Pl. XV two of the pictures are seen. The upper one, taken by P. Størmer towards the upper part of the clouds at about 16<sup>h</sup> 47<sup>m</sup> very well shows the fine structure of the clouds rather different from the structure on former occasions.

The lower one, also taken by P. Størmer, at 17<sup>h</sup> and at the same time as C-O-T No. 6, shows very

Table 10.

*Height of lower Fracto-Cumulus Clouds.*

No.	St.	P	p	h	a	H	D
2	O-C	6	31.4	2.8	93.8	2.0	40
		7	32.3	2.9	97.4	2.0	40
3	O-C	5	33.2	3.0	95.7	2.0	38
5	O-C	5	33.9	2.9	101.5	2.0	40
6	O-C	5	31.4	2.7	95.5	1.9	41
		6	33.2	2.6	101.1	1.9	41
20	O-C	8	32.5	2.8	95.5	1.9	39
		9	33.3	2.7	98.0	1.8	39
		10	33.5	2.9	98.5	2.0	39
21	O-C	9	33.4	2.7	96.3	1.8	38
		10	33.5	2.9	96.8	1.9	38
		11	34.7	2.9	101.3	2.0	39
22	O-C	11	33.4	2.7	97.9	1.8	39
		12	33.1	2.9	98.4	2.0	40
		13	33.2	2.6	100.3	1.8	41

Mean height 1.9 km.

well the shining clouds lower down as well as the wavy cirrus clouds nearer to the horizon. The 3 small mother of pearl clouds like 3 waves in the middle to the right, were measured from the 3 stations C, O, and T, point 1, 2 and 7, and were lying between 24.8 and 25.9 km. above the earth.

From Nordstrand (latitude 59°51'.6, longitude 10°47'.3) about 7 km S of Oslo, Mr. Gihbsson took a series of 12 very good Leica pictures from 17<sup>h</sup> 15<sup>m</sup> to 17<sup>h</sup> 45<sup>m</sup>. On Pl. XVI one of them, taken about 17<sup>h</sup> 20<sup>m</sup> is reproduced. The wavy cirrus clouds are beautifully seen and the shining mother of pearl clouds above them.

## 27. Single and Moving Pictures, in Natural Colours.

Among the pictures in natural colours taken from Oslo Observatory by Mr. Simonsen, one picture was very fine. It was taken at about 17<sup>h</sup>.

From Nordstrand Mr. Gihbsson also took a moving picture film in natural colours, on Kodac colour small film. This film was also taken about 17 o'clock and shows very beautifully the western sky after sunset with the lower clouds grey or red and the mother of pearl clouds shining in different prismatic colours through them. The film which is 15.25 meters

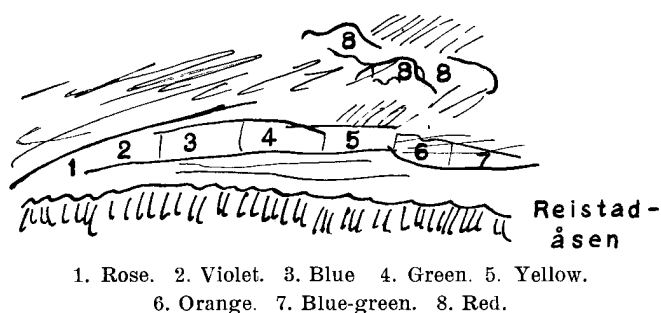


Fig. 24. Sketch of Mother of Pearl Clouds seen from Lillehammer on February 6th, 1934.

long contains about 1980 single pictures. The wave formed high cirrus clouds are also most interesting on this film.

## 28. Visual Observations and Photographs from Other places in South Norway.

My indefatigable assistant Olaf Hassel also took a series of photographs with corresponding observations of the mother of pearl clouds. We have reproduced one, taken at 18<sup>h</sup> 23<sup>m</sup> (Pl. XIV).

Among the other about 30 observations, a series came from Kristiansand (58°.2, 8°.0). One of them from Mr. *Thv. Skaar* is given below:

"This evening at about 17<sup>h</sup> 15<sup>m</sup> I saw clouds in W with colours so beautiful that I have never seen anything like it. To the left the clouds were stretching a good deal southwards. In W was a region with very strong mother of pearl colours. Under this region and to the right of it the sky seemed quite clear but had a very strange colour, as if one looked at the sky through a dirty grey-brown glass."

Mrs. *Sigrid Undset* writes from Bjerkebæk near Lillehammer:

"This evening at about 17<sup>h</sup> I observed clouds which may have been mother of pearl clouds. During the night we had strong wind from S or SW and the wind continued to blow during the day but not so strong. After sunset the sky was covered by a thin veil of grey yellow wind-clouds. Some minutes before 17<sup>h</sup> I saw in breaks of these clouds, distant clouds with mother of pearl colours but the rest of them were hidden by the wind-clouds. Some of the upper ones had a long upper border of rose-red to rose-violet. Lower down along the mountain ridge, there was a long break and in this a cloud with all the colours from rose, rose-violet to intense

blue, then green, yellow, orange and lastly blue-green, as on the sketch. Further to the south, one could see in a break of the clouds a field which was shining "electric-blue". The whole was visible only 10–15 minutes, until hidden by the lower clouds".

Coloured sketches and observations were also sent from a series of other places in southern Norway but they do not add anything essentially new to that already given above.

## 29. Mother of Pearl Clouds on February 7, 1934.

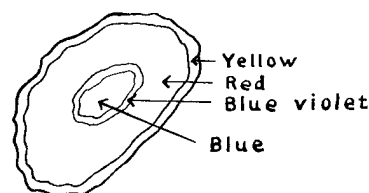
As it was probable that the mother of pearl clouds would also appear next morning the 7th February, I watched from Oslo Observatory the eastern sky before sunrise and in spite of smoky air a series of mother of pearl clouds shone through the smoke of the town in SE and S. I took some pictures on ultra red plates with ultra red filter at 8<sup>h</sup> 33<sup>m</sup> before the sun had appeared over the slopes of Ekeberg SE of Oslo, but they did not succeed very well. I had no telephonic connection with the other stations and therefore no height determinations were made. During the day, I several times saw thin mother of pearl clouds near the sun, but no photographs were taken. After sunset, mother of pearl clouds were not seen.

From several parts of southern Norway I got reports, among which the following may be of interest.

From *Olaf Hassel*, Darbu: a series of photographs and sketches with detailed descriptions. He says: "To-day I awoke at 4<sup>h</sup> 35<sup>m</sup> and looked for clouds round the half-moon. The moon was in the middle of a big blue-green cloud with red-violet border on the right side. I immediately went up and took 18 pictures of the clouds from 4<sup>h</sup> 53<sup>m</sup> to 6<sup>h</sup> 48<sup>m</sup>". Later, he took 34 pictures till 9<sup>h</sup>. At noon he observed thin and diffuse mother of pearl clouds 10° to 30° from the sun, with feeble colours. But after sunset no coloured clouds were seen.

Mr. *Helmuth Rosenthal*, Oslo, also observed the mother of pearl clouds at noon. He saw them first at 12<sup>h</sup> 10<sup>m</sup> and took a good picture of them at 12<sup>h</sup>

Fig. 25. Mother of Pearl Clouds seen from Aas on February 7th, 1934, at 12<sup>h</sup> 35<sup>m</sup>.



30<sup>m</sup> (se Pl. XVI). They faded at 12<sup>h</sup> 45<sup>m</sup> and at 1<sup>h</sup> they could hardly be seen any longer. The photographed clouds were not far from the sun, which was hidden behind the roof of the house.

Docent *Olaf Egeberg Traaen* has sent me the following interesting report from Norges Landbruks-høiskole, Aas (59°.7, 10°.8):

"I was in my laboratory facing south and west. I first saw a red very strongly shining cloud in south. Along the border it was yellow, then came a broad concentric ring of red and then an inner thin blue violet border. The centre of the cloud had the colour of the sky; see fig. 25.

The intensity of the colours increased till 12<sup>h</sup> 30<sup>m</sup> and then rapidly decreased till 12<sup>h</sup> 50<sup>m</sup>, when the whole cloud was white. Some feeble red colours were also seen up to the left of this cloud. The cloud was first oval, then after 12<sup>h</sup> 30<sup>m</sup> like an oblique triangle with red colour all over and lastly as a long white stripe forming an angle of 45° with the horizon. During this deformation the center of the cloud was almost stationary. No other clouds were seen. At 12<sup>h</sup> 30<sup>m</sup> the lower part of the cloud had the same height as the sun and the distance between the center of the cloud and the sun was about 15°. The vertical length of the cloud was about 5½ degree, the lower border 18½, the upper 24° over the horizon.

I saw no more clouds before 13<sup>h</sup> 55<sup>m</sup>. At that moment a similar cloud was seen in south with exactly the same distribution of colours as on the cloud 12<sup>h</sup> 35<sup>m</sup>.

The axis of the cloud made about 30° with the horizon. The colours were strong at 13<sup>h</sup> 55<sup>m</sup>, decreased about 14<sup>h</sup>, grew very strong at 14<sup>h</sup> 5<sup>m</sup>, decreased slowly till 14<sup>h</sup> 15<sup>m</sup> when the cloud became white all over. Up to the left of this cloud was another triangular red cloud and to the right and nearer the cloud a smaller one, which also for a time was red. The height of the cloud was from 15° (lower border) to 20°.7 (upper border) over the horizon. The horizontal extension was about 15° and the center of the cloud was very nearly due south".

In connection with the very exact observations from Docent Trøen the following is most interesting because it gives data to find the probable height of the cloud at 13<sup>h</sup> 55<sup>m</sup>.



Fig. 26. Cloud at 13<sup>h</sup> 55<sup>m</sup>, from the same Place.

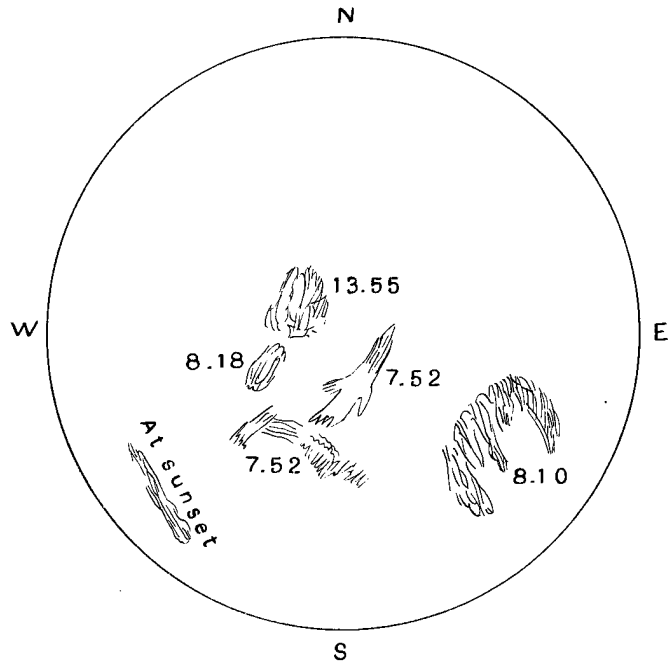


Fig. 27. Mother of Pearl Clouds on February 7th, seen from Bølingshavn.

*Mrs. Dr. Lundevall* writes from Bølingshavn (59°1, 11°.1):

"The 7th February the sky here was completely clear. The sun rose over the forest in SE at 8<sup>h</sup> 34<sup>m</sup>. At 7<sup>h</sup> 52<sup>m</sup> I observed a gorgeous cloud, near the middle of the heaven, a little to the south (see fig. 27).

This cloud persisted till 8<sup>h</sup> 18<sup>m</sup> when it faded but a new cloud suddenly appeared close to it and whit the same most beautiful colours. This last one faded rapidly and disappeared when the sun rose.

At the same time I observed in SE lower down a big extremely beautiful cloud with stronger colours than the other clouds. The time was then 8<sup>h</sup> 10<sup>m</sup>.

At 13<sup>h</sup> 55<sup>m</sup> I suddenly observed a big, fine cloud near zenith with delicate colours. At that time the sky was quite clear without other clouds. This cloud lasted about 15 minutes. (See fig. 27.)

At sunset the sky was covered by thin clouds. I then observed a single long white cloud (see fig. 27), but the western part showed beautiful but faint mother of pearl colours."

It is probable that Mr. Traaen at Aas and Mrs. Lundevall at Bølingshavn saw the same cloud at 13<sup>h</sup> 55<sup>m</sup>. Bølingshavn is situated about 69 km to the south of Aas and, according to the directions to the cloud seen from the two places, the height will be of the order of 21 km, which is too



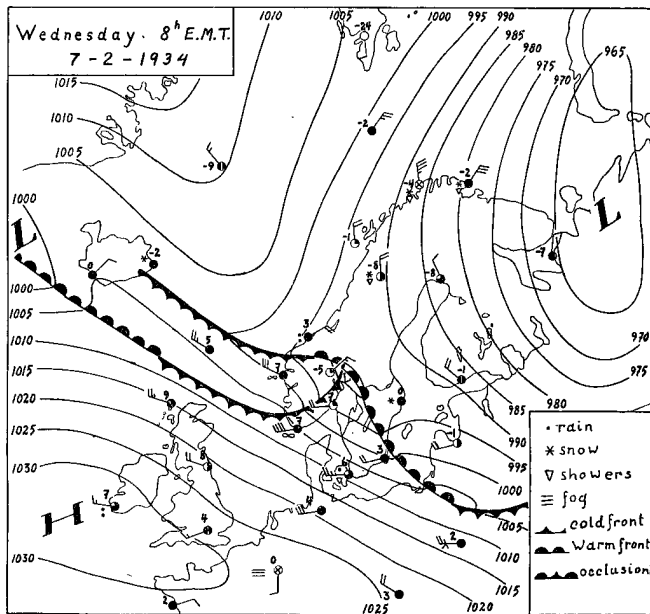


Fig. 30. The same on February 7th at 8h.

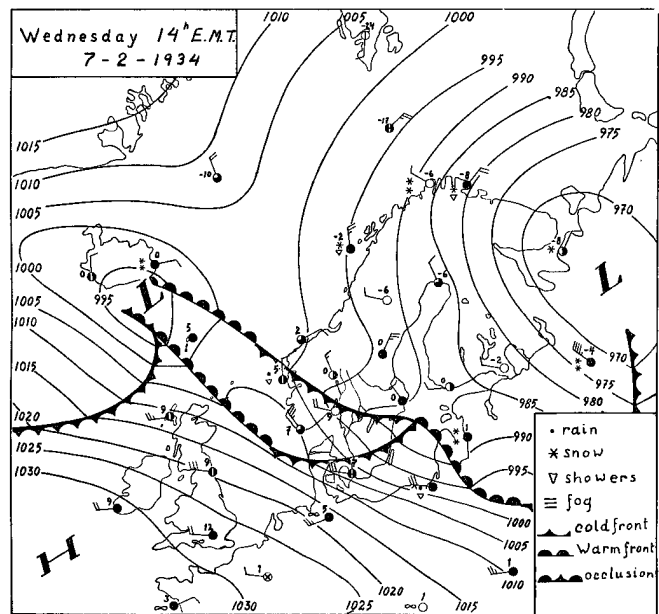


Fig. 31. The same at 14h.

At 14<sup>h</sup> on the 7th a new cyclone appears over Iceland on its way eastwards. On account of the neutral belt between this cyclone and the preceding one now centred over the White Sea, the NW current still decreases in force and turns successively towards NE with increasing cloudiness over Eastern Norway.

### 32. Mother of Pearl Clouds during the Rest of 1934.

I spent the days 14—18 February at my aurora station Tømte. The weather was clear and warm with a föhnwind from W and NW and I expected to see mother of pearl clouds. The sky on February 14th and 16th had also some tendency for these clouds, with blue white undulated background after sunset. I did not see any, but got telephone calls and telegrams from several other places that mother of pearl clouds were observed.

We here only give one interesting report from the astronomer, Einbu at Dombaas ( $62^{\circ}.1$ ,  $9^{\circ}.1$ ):

“On February 16th about 15<sup>h</sup> the mother of pearl clouds were of exceptional beauty. As they were moving I measured their velocity by means of a small instrument for that purpose. Assuming the height to be 25 km, the velocity was found to be 90 meters per second, towards ESE. With a height of 20 km, the velocity would be 71 meters.

This is only approximate because the height over the horizon was small.

The clouds had stripes normal to the direction of drift, that is, stripes orientated about N-S.

The temperature was high both on February 16th and 17th. At the time of the clouds it was about  $10^{\circ}$  Centigrade with föhnwind from NW. The mother of pearl clouds gave a splendid spectacle I shall never forget.”

What is remarkable in Mr. Einbu's report is the great velocity he found for the clouds. Only on one occasion, have I observed such a great velocity, namely for the clouds on December 30, 1926,<sup>1</sup> where I found a velocity of 76 m per second, also towards ESE.

## CHAPTER 4.

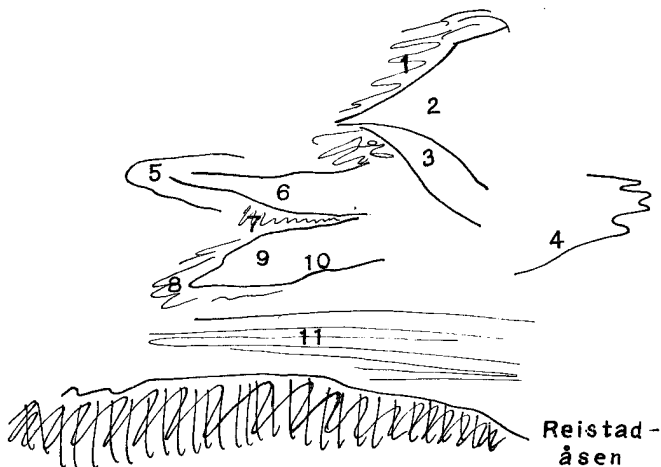
### Mother of Pearl Clouds since 1934. Concluding Remarks.

#### 33. Clouds from the Beginning of 1935, to the End of 1938.

From Dr. Keränen, Helsingfors, I received a letter as follows:

“I send you some observations on mother of pearl clouds observed in January 1935 in Finland. A Danish physician, Dr. Justesen, who was visiting Lappland this winter, wrote to me some time ago: “On January 8th at 8<sup>h</sup> when I was driving in sledge from Vuotso ( $68^{\circ}.1$ ,  $27^{\circ}.0$ ), I suddenly observed a

<sup>1</sup> Geofysiske Publikasjoner, Vol. V, No. 2, 1927.



- |                                 |                  |
|---------------------------------|------------------|
| 1. Violet.                      | 5. Orange.       |
| 2. Pale bluegreen.              | 6. Yellow green. |
| 3. Yellow white.                | 7. Violet.       |
| 4. Violet.                      | 8. Orange.       |
| 9. Yellow green.                |                  |
| 10. Golden.                     |                  |
| 11. Rust-orange<br>frost smoke. |                  |

Fig. 32. Mother of Pearl Clouds seen from Lillehammer on January 15th, 1935.

remarkable cloud in NW, about 75° over the horizon. I have never seen anything like it. It had the form of a band shining like mother of pearl end with spectral colours along the borders. After half an hour the cloud dissolved and vanished."

The day before, our observer in Kuopio had seen similar clouds. This observer had together with me observed mother of pearl clouds in Kuopio some years ago, and his observations are therefore probably reliable.

The 8th January I was near Kajaani and saw again such clouds in SW after noon."

Two days later, January 10th, Mr. D. Chalonge from Paris who visited Abisko (68°.4, 18°.8) for scientific researches happened to take a fine photo of mother of pearl clouds. See Pl. XVI. It was taken towards S on the 10th January at 10<sup>h</sup> 15<sup>m</sup>. Exposure 5 minutes.

On January 15th mother of pearl clouds were again observed at Lillehammer by Mrs. Sigrid Undset. She writes:

To-day 15<sup>h</sup> 15<sup>m</sup> we observed mother of pearl clouds from here. I enclose a sketch giving the colours (fig. 32).

The clouds seem rather pale, shining through frost smoke. To the north of this group over the hill Reistadaasen, SW, 1 streak towards S according to measurement on a compass made by my son, there seemed to be big crowds of mother of pearl clouds shining in violet and rosa behind a thin stratus of lower clouds. The clouds had probable been visible some time before I saw them and lasted to about 16<sup>h</sup>."

Another very careful observation of the same clouds seen from Lillehammer, was sent me from Mr. Nordstrøm; he says:

"The clouds were seen after sunset low in SW, see sketch fig. 33, made at 15<sup>h</sup> 25<sup>m</sup>:"

The numbers have the following meaning:

- |          |               |
|----------|---------------|
| 1 green  | 4 yellow grey |
| 2 violet | 5 orange.     |
| 3 blue   |               |

The height and azimuth of the points a, b, c, d were

Point	Height	Azimuth
a	9°.2	48°
b	8.7	43
c	10.0	54
d	11.6	48

On January 20th mother of pearl clouds were again observed, this time from Trondheim (63°.4, 10°.4) by Mr. Bernhard Bakken, from Dombaas by Mr. Einbu and from Darbu by Mr. Hassel.

The next day, January 21st, I got telephone calls from Hadeland and from Hønefoss (60°.2, 10°.3) regarding beautiful mother of pearl clouds about sunset. In Oslo, the sky was foggy with clouds. They were seen, however, at my station Kongsberg.

January 22nd: Mr. Einbu writes from Dombaas that the clouds were of exceptional beauty from 14<sup>h</sup> to 17<sup>h</sup>. He measured their drift again but found

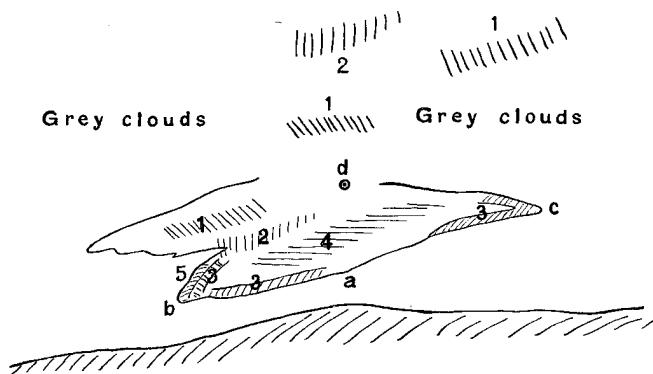


Fig. 33. Some Clouds sketched by another Observer.



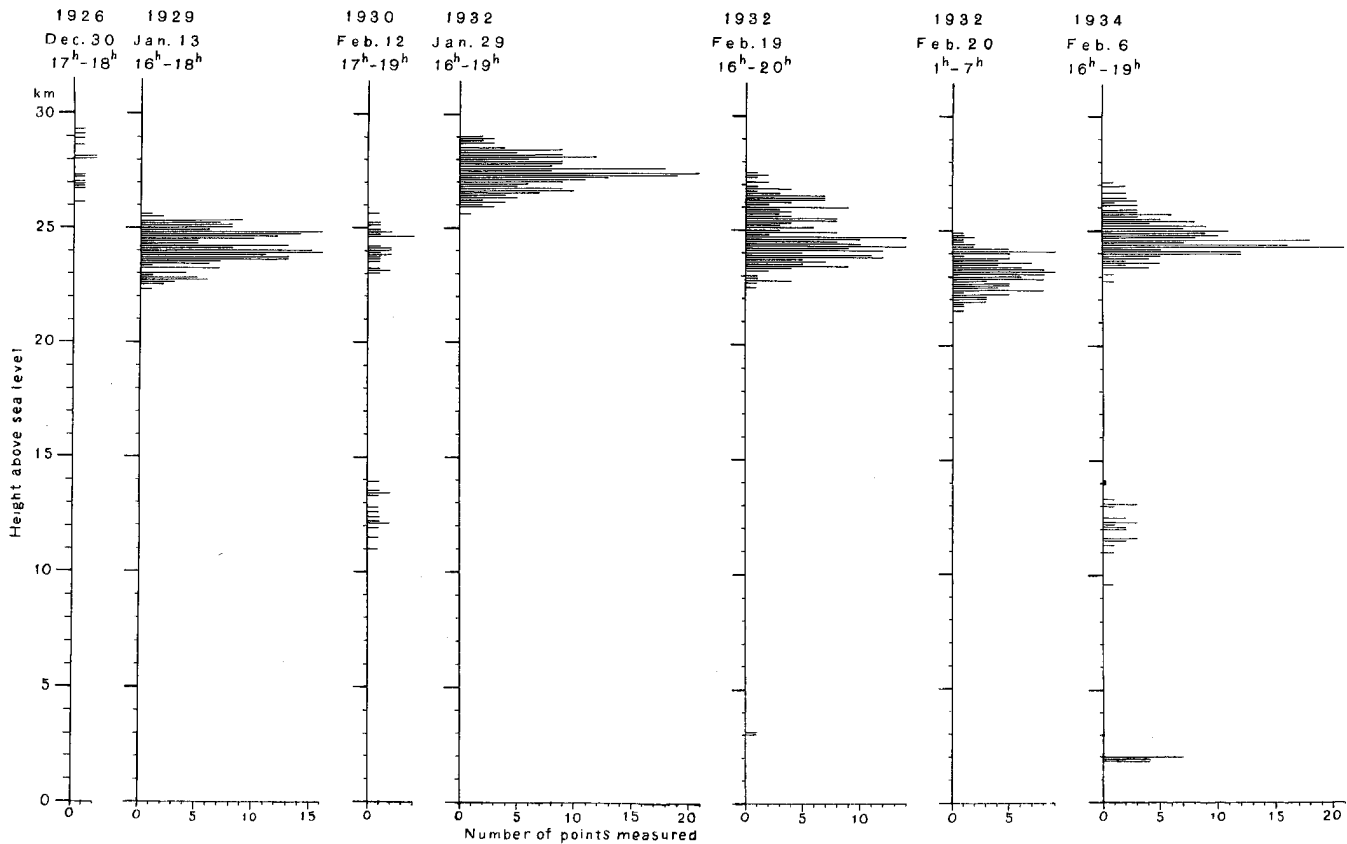


Fig. 34. Comparison of Height Measurements of Mother of Pearl Clouds and lower Clouds from 1926—1934.

that they were quite stationary for a whole hour. Mr. Klomstad writes from Kvam south of Dombaas, that the clouds were quite gorgeous.

From *Martin Ekre*, an engineer, Foldals Verk ( $62^{\circ}.2$ ,  $10^{\circ}.0$ ) I got an interesting letter from which the height of the clouds can be approximately found. He says that a fine mother of pearl cloud was observed in SW at  $16^h 30^m$  simultaneously by Director Aasgaard at Foldals Verk and by his fiancée at Hjerkin ( $62^{\circ}.3$ ,  $9^{\circ}.6$ ), 23 km to the north west of Foldals Verk. From the observations which were not very exact, he found for the height a mean of 21 km, of the right order, but of course very approximate.

The rest of the observations including those of the year 1938 do not give any new information of interest.

#### 34. Summary of all the Height Measurements and Concluding Remarks.

It may be of interest to give a graphical representation of all our height measurements of mother of pearl clouds, including those earlier published. This

has been done on the diagram fig. 34 where also the measurements of the associated lower clouds are given. As before, we have chosen as abscissa the number of cases with given height and as ordinate the height in kilometers. The date and time is given for each appearance. In the Table 11 are seen the results summarized.

As concluding remarks to these results of the observations and measurements of mother of pearl clouds since 1926, it may be of interest to point out what we intend to do in the future if such clouds should appear again.

Of primary importance is the knowledge of the temperature, humidity and so on of the higher atmosphere during the appearance of the clouds. For this purpose we have in the last 3 years had 12 registering balloons ready for ascent and shall continue to do so till the clouds appear again. They will be sent up from the Meteorological Observatory at Aas, 26 km south of Oslo. At the same time telegrams will be sent to some other similar stations in Norway and abroad.

Table 11.  
*Summary of Height Measurements 1926—34.*

	1926 Dec. 30	1929 Jan. 13	1930 Febr. 12	1932 Jan. 29	1932 Febr. 19	1932 Febr. 20	1934 Febr. 6	Total
Mother of Pearl Clouds								
Number of sets.....	2	38	7	42	44	29	24	186
» » points....	15	235	23	238	253	138	215	1122
Mean height .....	27.7	24.1	24.0	27.4	24.8	23.2	24.7	-
Cirrus Clouds								
Number of sets.....	-	-	8	-	-	-	10	18
» » points....	-	-	14	-	-	-	23	37
Mean height .....	-	-	-	-	-	-	12.1	-
Fracto-Cumulus Clouds								
Number of sets.....	-	-	-	-	2	-	7	9
» » points....	-	-	-	-	2	-	15	17
Mean height .....	-	-	-	-	3.1	-	1.9	-

For the closer study of the colours of the clouds, series of pictures in natural colours will be taken, in particular moving picture series with one picture each second. This will also be done with an ordinary film. If we then show this film on a screen with ordinary speed the very slow changes can easily

be studied in the same manner as, for instance, the german meteorologist *Mügge* has done for common clouds.<sup>1</sup>

Besides this, the ordinary work with photographic height-measurements and collection of observations will be continued.

#### Errata:

In the first part<sup>2</sup> I have noticed the following errata which are rectified here:

*p. 5:* The note on January 15, 1935, shall be replaced by the following:

February 15: Nacreous clouds at 15<sup>h</sup> — 15<sup>h</sup> 30<sup>m</sup> from Abisko by Mr. Chalonge.

<sup>1</sup> *R. Mügge:* Wolken in Bewegung. Meteor. Zeitschrift, Vol. 54, p. 81, March 1937.

March 10: Interesting nacreous clouds seen at 15<sup>h</sup> 30<sup>m</sup> to 16<sup>h</sup> from Abisko towards SE, about 30° over the horizon.

*p. 11:* Instead of Miss Honny Lynge, a school-teacher read "a school girl".

*p. 33:* Instead of: "About 8<sup>h</sup> the clouds in NE" read "About 8<sup>h</sup> the clouds in E."

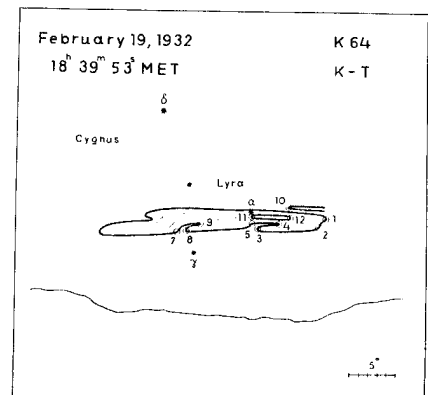
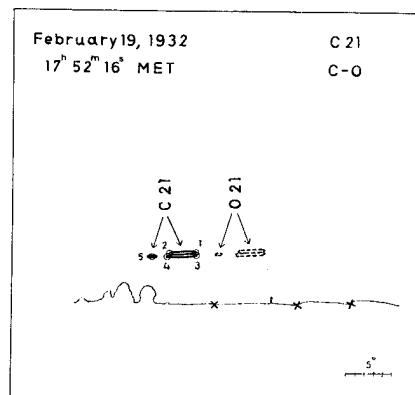
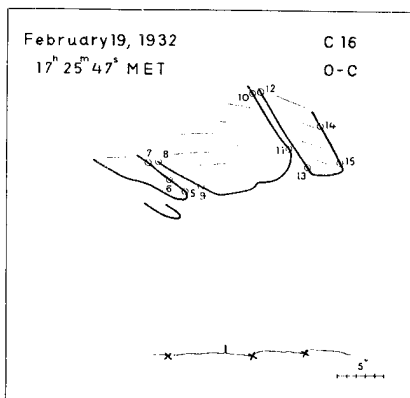
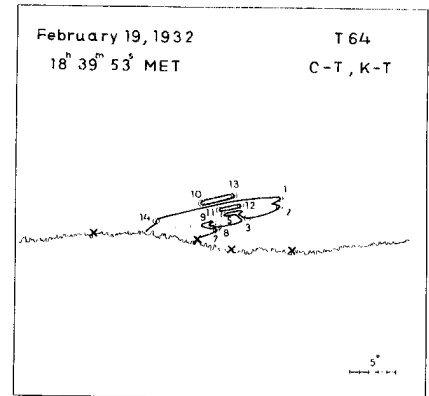
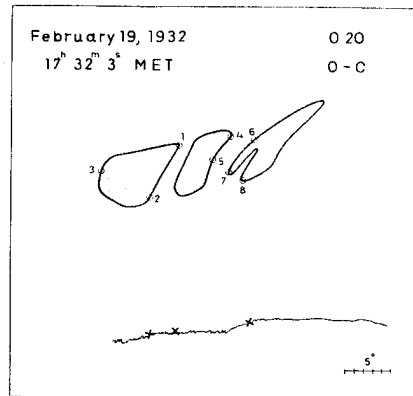
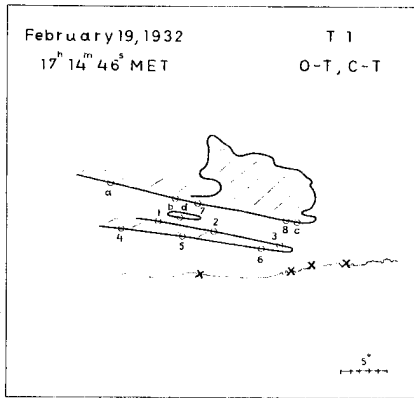
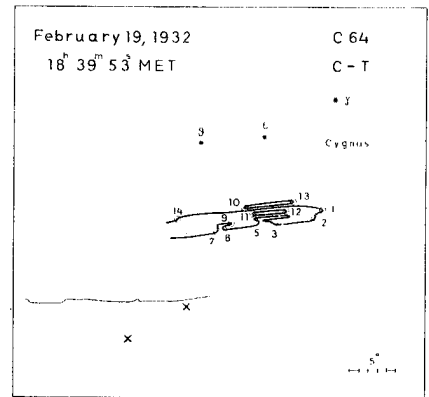
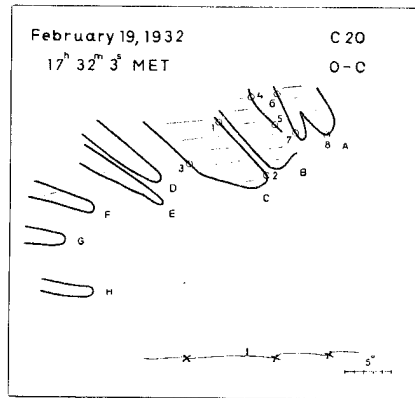
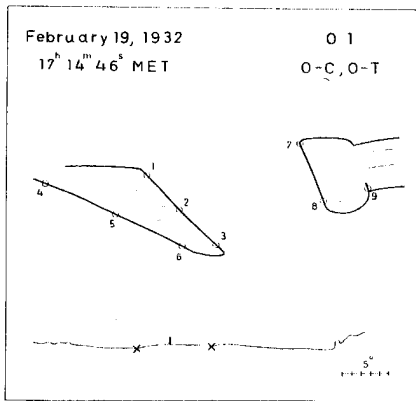
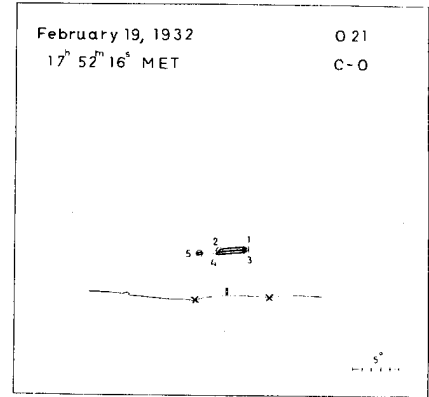
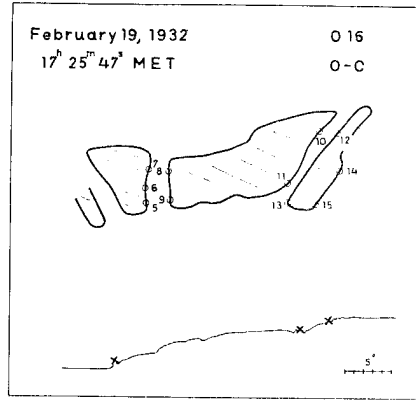
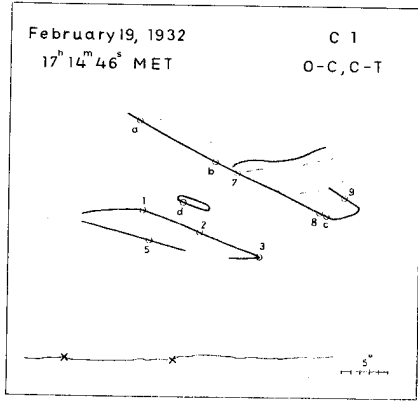
<sup>2</sup> Geofysiske Publikasjoner, Vol. XII, No. 11, 1939.

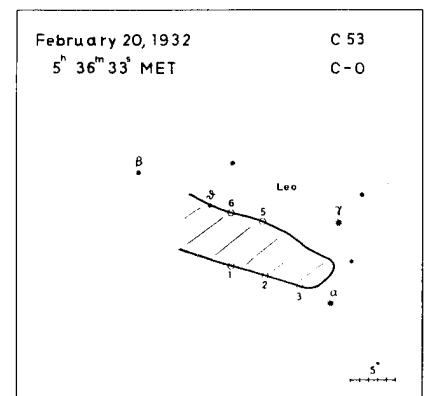
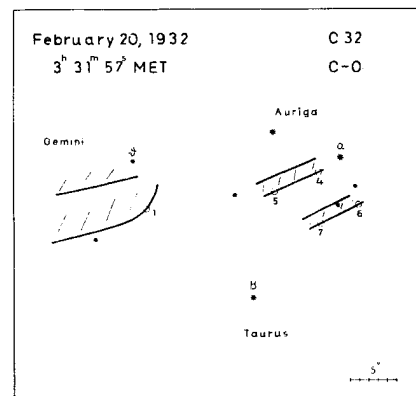
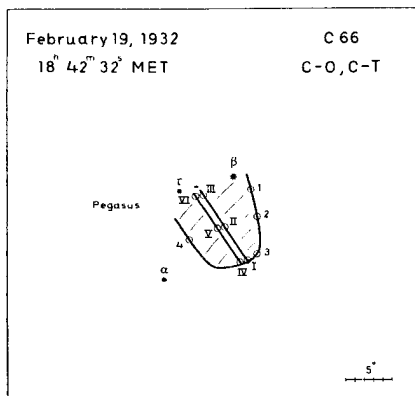
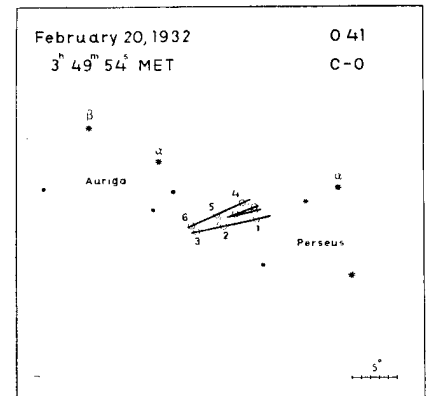
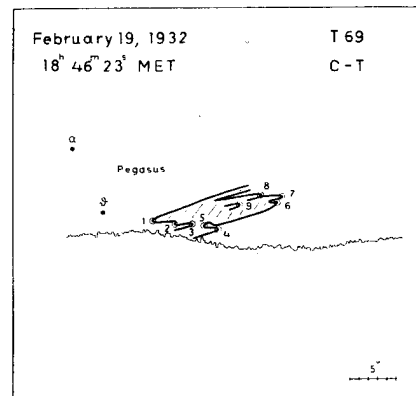
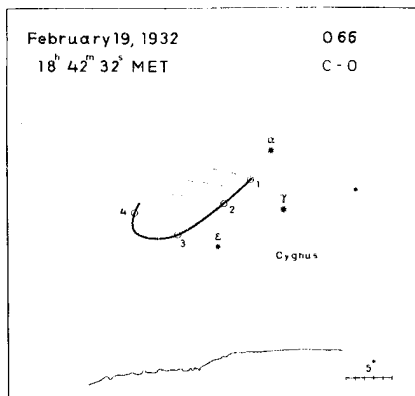
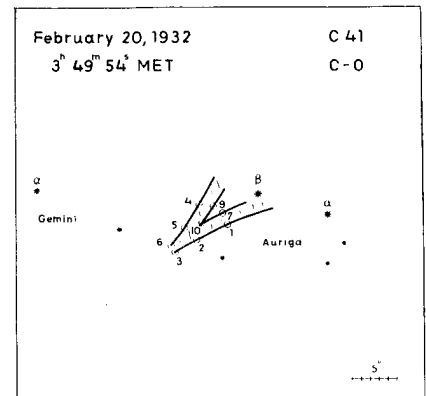
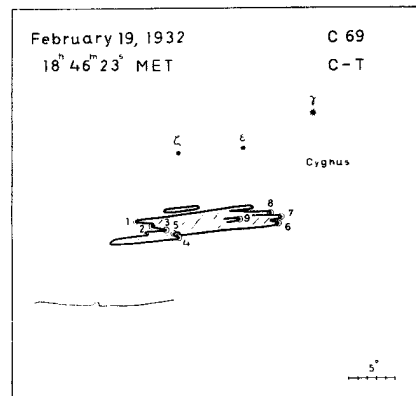
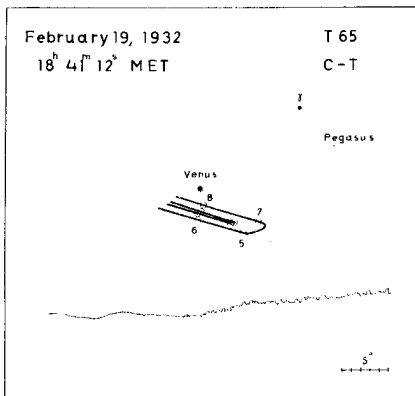
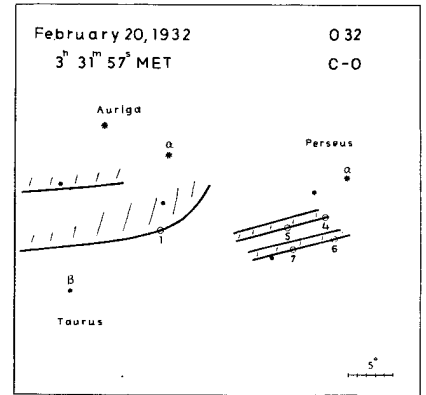
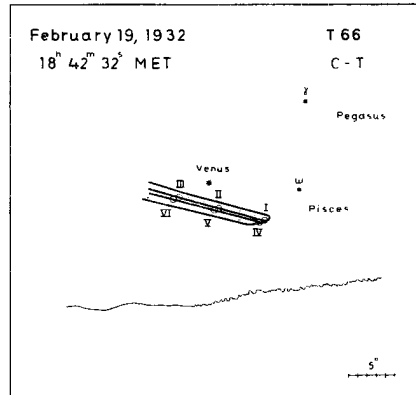
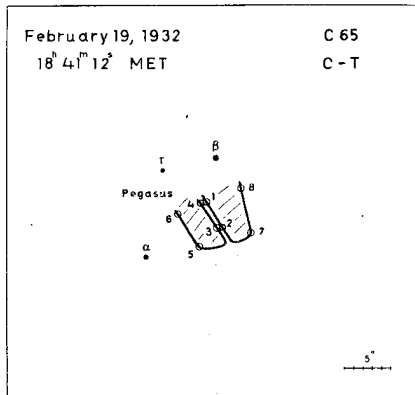
## CONTENTS

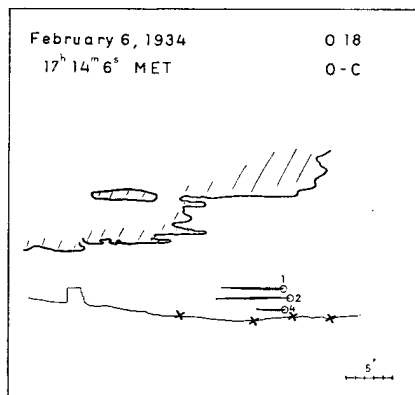
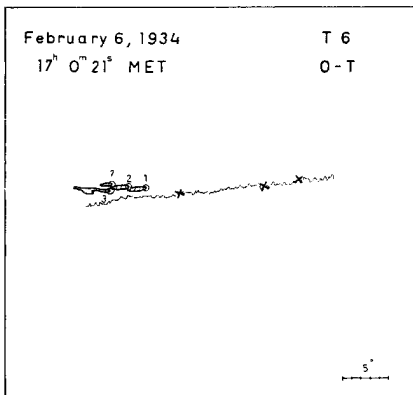
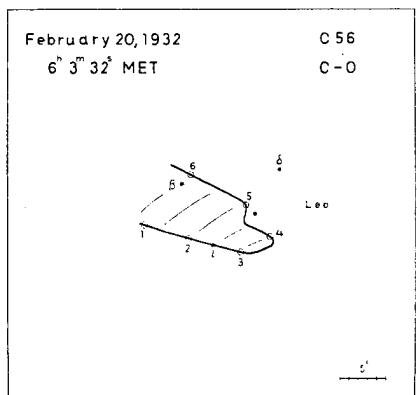
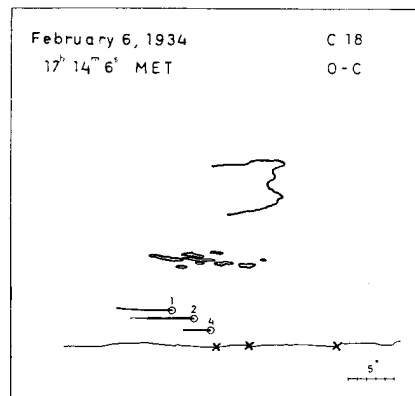
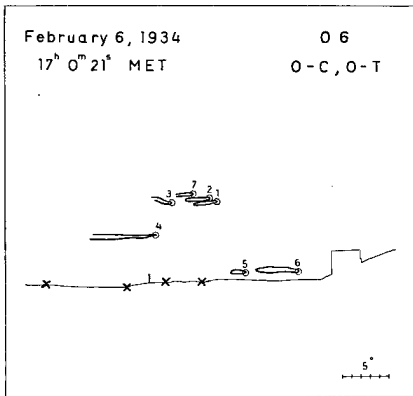
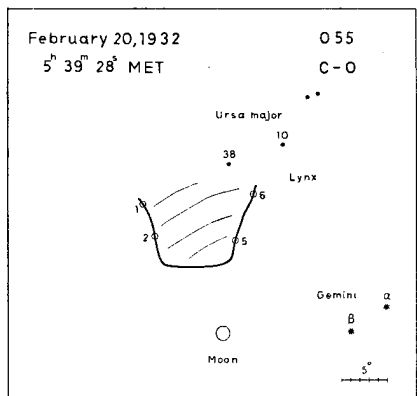
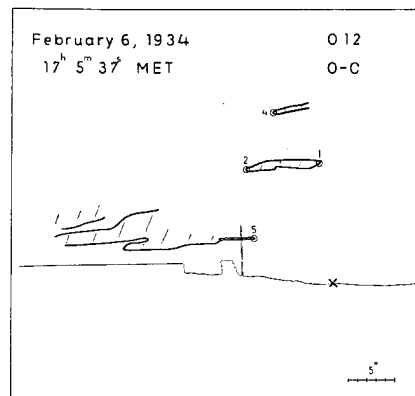
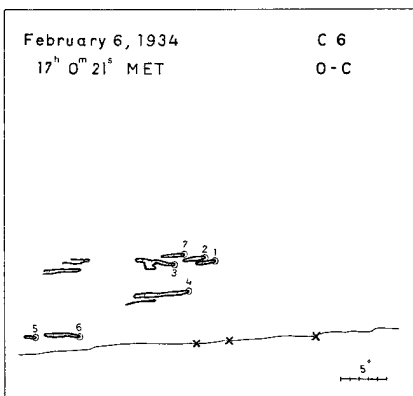
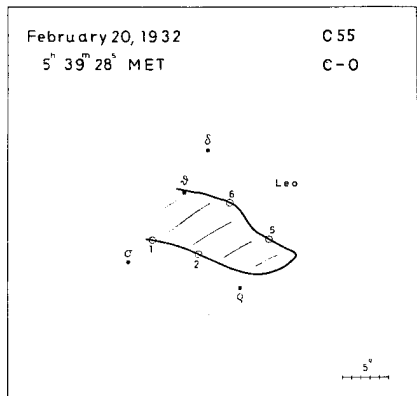
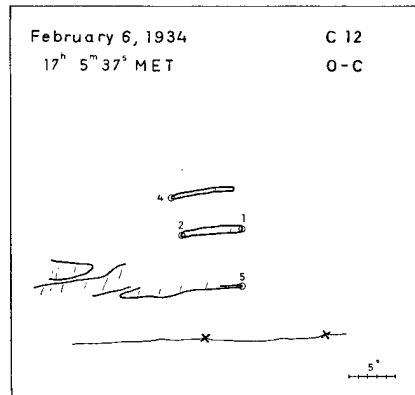
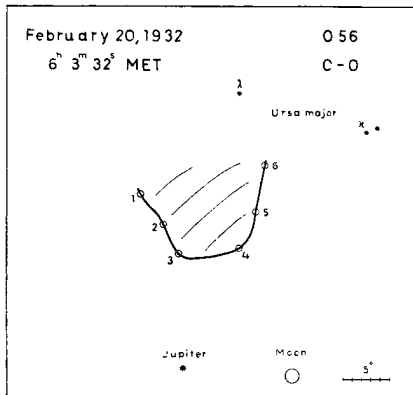
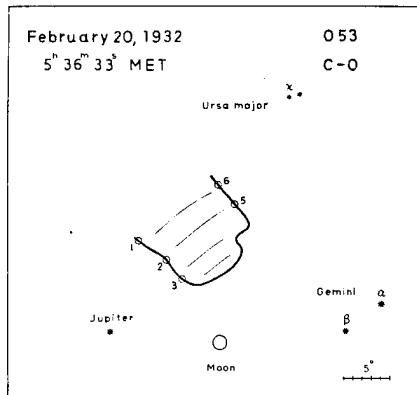
	Page		Page
Summary .....	3	Chapter 3. Mother of Pearl Clouds in 1934 .....	19
Introduction .....	3	18. Reports from the 20th January till the 5th February 1934 .....	19
Chapter 1. Mother of Pearl Clouds on February 19th, 1932 .....	3	19. Report from G. A. Clarke on Mother of Pearl Clouds seen at Aberdeen on the 5th and 6th of February .....	22
1. The Clouds in the Afternoon of February 19th	3	20. Photographic Work on the Mother of Pearl Clouds on February 6th 1934 .....	24
2. Height Measurements of Clouds Photographed on Pancromatic Plates .....	4	21. The Results of the Height Measurements .....	24
3. Velocity of the Mother of Pearl Clouds Found from Pictures O 2 and O 16 .....	7	22. Statistics of the Height Distribution and Geo- graphical Situation of the Measured Clouds	27
4. The Other Pictures of the Afternoon 19th Fe- bruary 1932 .....	7	23. Determination of Velocity of the Mother of Pearl Clouds on February 6th, 1934 .....	27
5. Comparison of Height of the Different Groups of Clouds .....	8	24. The Wavy Cirrus Clouds beneath the Mother of Pearl Clouds .....	27
6. The Photogrammetric Measurements of Captain Ween .....	10	25. Lower Fracto-Cumulus Clouds drifting SE-wards	28
7. Measurements of the Lower Fracto-Cumulus Clouds Drifting South-Eastwards .....	10	26. Single Photographs taken from Oslo and Neigh- bourhood .....	29
8. The Moving Picture Films .....	11	27. Single and Moving Pictures, in Natural Colours	29
9. Photographs in Natural Colours .....	12	28. Visual Observations and Photographs from Other Places in South Norway .....	30
10. Single Photographs Taken from Oslo .....	12	29. Mother of Pearl Clouds on February 7, 1934	30
11. Observations and Photographs from Other Places in South Norway .....	12	30. The Conditions in the Stratosphere at 17 <sup>h</sup> the 7th February 1934 .....	32
Chapter 2. Mother of Pearl Clouds during the Night 19th—20th February 1932 .....	15	31. Weather Maps on February 6th and 7th, 1934	32
12. Mother of Pearl Clouds Illuminated by the Moon .....	15	32. Mother of Pearl Clouds during the Rest of 1934 .....	33
13. The Height Measurements .....	16	Chapter 4. Mother of Pearl Clouds since 1934. Concluding Remarks .....	33
14. The Heights of the Mother of Pearl Clouds during the Night 19—20 February as Com- pared with those of the Afternoon, the 19th	18	33. Clouds from the Beginning of 1935, to the End of 1938 .....	33
15. Attempt to Find the Velocity of the Clouds ..	18	34. Summary of all the Height Measurements and Concluding Remarks .....	35
16. Observations of a Corona round the Moon and Resulting Magnitude of the Droplets of the Clouds .....	18	Errata .....	36
17. Weather Maps Corresponding to the Occurrence of the Mother of Pearl Clouds on 19—20 February 1932 .....	19		

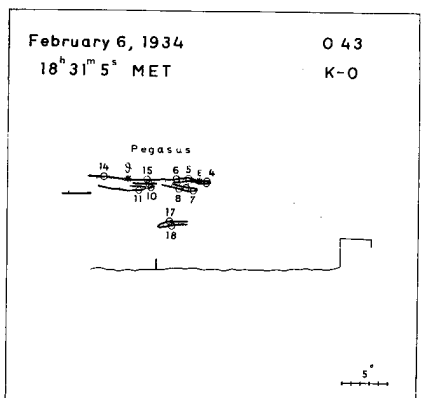
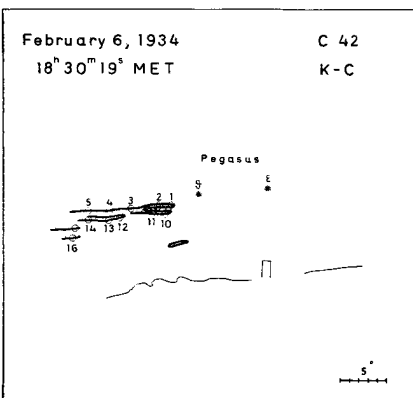
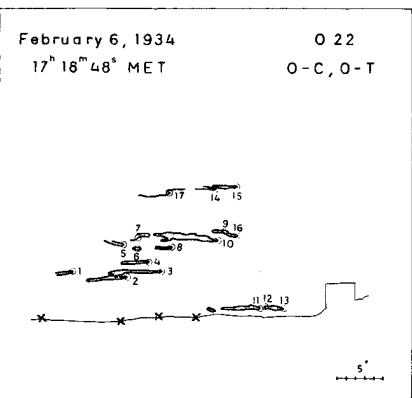
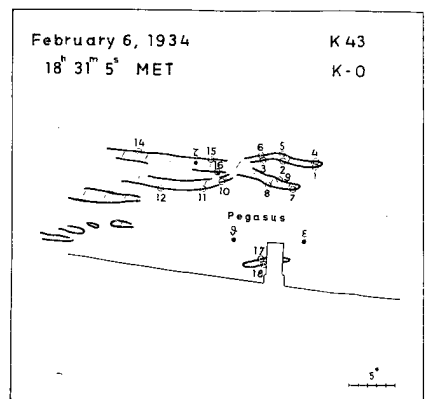
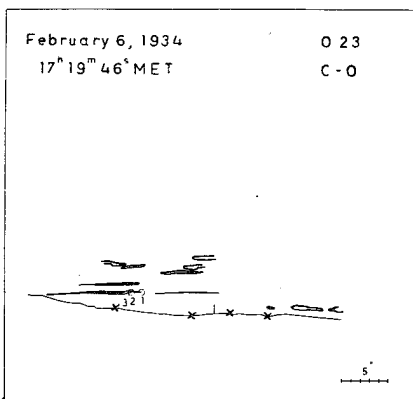
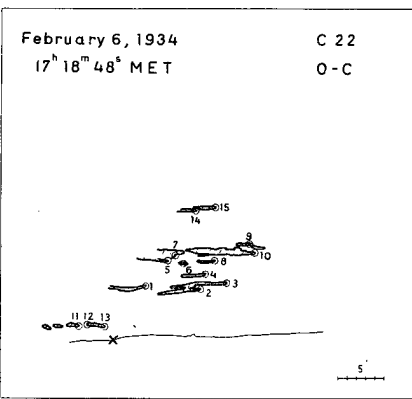
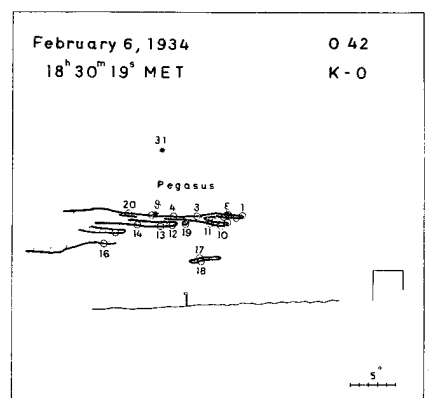
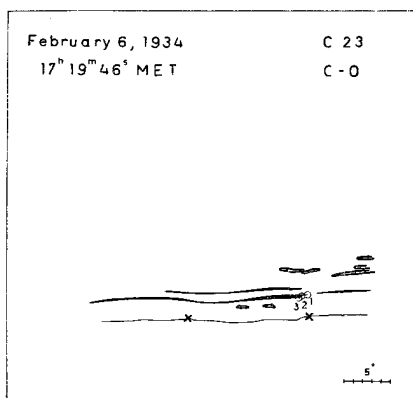
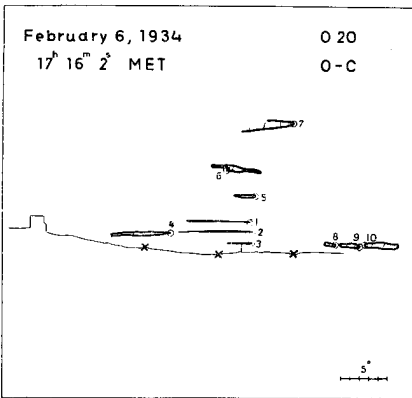
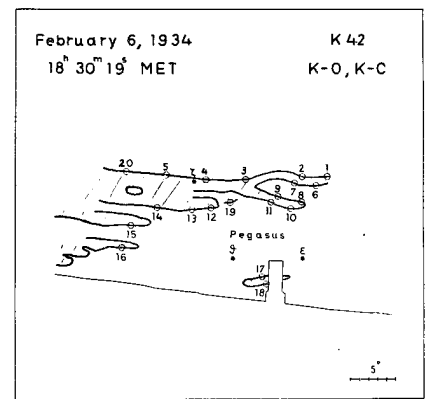
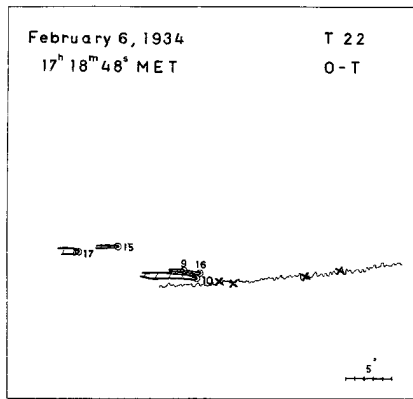
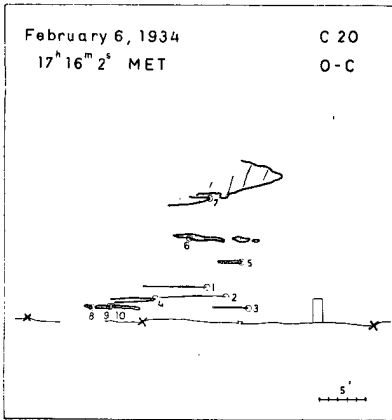
Printed May 30th, 1940.

A. W. BROGGERS BOKTRYKKERI A/S













Mother of pearl clouds on February 19th, 1932, 17<sup>h</sup> 14<sup>m</sup> 46<sup>s</sup> MET, from Temte (T 1).



Mother of pearl clouds on February 19th, 1932, 17<sup>h</sup> 32<sup>m</sup> 03<sup>s</sup> MET, from Oslo (C 20).



Mother of pearl cloud on February 19th, 18<sup>h</sup> 30<sup>m</sup> 53<sup>s</sup> MET, from Oslo (C 64).



The same from Tønte (T 64).



Mother of pearl cloud on February 19th, 18<sup>h</sup> 46<sup>m</sup> 23<sup>s</sup> MET, from Oslo (C 69).



The same from Tømtø (T 69).



Mother of pearl clouds on February 19th, 17<sup>h</sup> 13<sup>m</sup> 25<sup>s</sup> MET, from Oslo.



Mother of pearl clouds on February 19th, 17<sup>h</sup> 28<sup>m</sup> 17<sup>s</sup> MET, from Oslo.



Mother of pearl clouds on February 19th, from Oslo (phot. Per Størmer).



Mother of pearl clouds on February 19th, 17<sup>h</sup> 15<sup>m</sup> from Skådalen (phot. G. Holmsen).



Mother of pearl clouds on February 19th, 18<sup>h</sup> 3<sup>o</sup>, taken from Amundrud (phot. E. J. Schjerven).



Mother of pearl clouds on February 19th, 18<sup>h</sup> 12<sup>m</sup>, taken from the same place by the same.  
The town Hønefoss is situated in the foreground.



Mother of pearl clouds on February 6th, 1934, 17<sup>h</sup> 0<sup>m</sup> 21<sup>s</sup>, taken from Oslo (C 6).



The same from Oscarborg (O 6).



The same from Tomte (T 6).



Mother of pearl clouds on February 6th, 17<sup>h</sup> 48<sup>m</sup> 48<sup>s</sup>, from Oscarsborg (O 22).



The same from Oslo (C 22).



The same from Tente (T 22).





Mother of pearl clouds on February 6th at 17<sup>h</sup> 19<sup>m</sup> 46<sup>s</sup> MET from Oscarsborg (O 23).



The same from Oslo. The wavy cirrus clouds beneath the mother of pearl clouds well seen (C 23).



Mother of pearl clouds from Balsfjord near Tromsø, January 23rd, 1934 (phot. Labukt).



Mother of pearl clouds from Kongsberg on February 6th, 1934, 18<sup>h</sup> 30<sup>m</sup> 19<sup>s</sup> MET (K 42).



The same from Oscarsborg (O 42).



The same from Darbu at 18<sup>h</sup> 23<sup>m</sup> 37<sup>s</sup> MET (phot. Olaf Hassel).



Mother of pearl clouds from Oslo February 6th, 1934, 16<sup>h</sup> 47<sup>m</sup> MET (phot. Per Størmer).



Mother of pearl clouds from Oslo February 6th, 1934, 17<sup>h</sup> 0<sup>m</sup> MET (phot. Per Størmer).