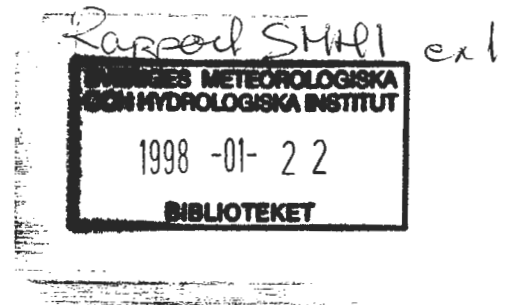


Validation of HIROMB during 1995-96

Lennart Funkquist and Patrik Ljungemyr



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AMERICAN METEOROLOGICAL SOCIETY
JOURNAL OF CLIMATE
VOLUME 18
NUMBER 1
JANUARY 2005
\$12.00

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Abstract

HIROMB (High Resolution Operational Model of the Baltic Sea) is the result of a combined effort between BSH (Bundesamt für Seeschifffahrt und Hydrographie) and SMHI (Swedish Meteorological and Hydrological Institute) aiming at a common operational model for the North Sea/Baltic Sea region. The present resolution is 3 nautical miles in the horizontal and 24 levels in the vertical and will increase with available computer capacity.

This report presents results from a continuous verification exercise, where model results are compared to observations of water level, surface temperature, ice thickness and salinity and temperature profiles. The times series data are taken from the period September-November 1996 while the ice thickness data are from November and December 1996 and the sea surface temperature data are taken from August, November and December 1996.

Introduction

HIROMB (High Resolution Operational Model of the Baltic Sea) is the result of a combined effort between BSH (Bundesamt für Seeschifffahrt und Hydrographie) and SMHI (Swedish Meteorological and Hydrological Institute). In its present form, the model is a modified version of the BSH operational model (Kleine, 1994) with identical boundaries to the North Atlantic. The cooperation started in summer 1994 when the model was set up at SMHI. The first operational runs started in the summer 1995 and since then the model has been running daily except for a limited number of periods when there were no meteorological input from the HIRLAM (atmospheric) model available because of computer problems. During the first months, some occasions with stability problems occurred, leading to a restart from the climatological fields.

This report presents results from a continuous verification exercise, where model results are compared to observations of water level, surface temperature, currents, ice thickness and salinity and temperature profiles. The times series data are taken from the period September-November 1996 while the ice thickness data are from November and December 1996 and the sea surface temperature data are taken from August, November and December 1996.

For a detailed description of the model, the reader is referred to a forthcoming report by Funkquist and Kleine.

Model configuration and forcing

In the Baltic Sea, a minimum resolution, which resolves the baroclinic Rossby radius, mesoscale eddies, internal waves and mixing, would be 500 m to 1 km in the horizontal and from 1 m for the pycnocline to 10 m for more inactive layers. However, in reality the resolution of the model has to be chosen in order to fit into the available computer memory and CPU-time. For the horizontal, this has resulted in a 12 nautical miles grid covering the whole North Sea and Baltic Sea region. East of 6 E, a 3 nautical miles grid for the Skagerrak, Kattegat, Belt Sea and Baltic Sea is nested into the larger grid. In the vertical, there is a variable resolution of 4 m for the mixed layer and gradually increasing to 60 m for the deeper layers.

In a first attempt to set up the model configuration, a horizontal grid of 1 nautical mile was nested into the 3 nautical miles grid with the boundary at the western part of the Skagerrak. That version also included the two largest lakes in Sweden, Lake Vänern and Lake Vättern, with a vertical resolution of 50 layers with 2 m resolution in the mixed layer. While this grid was impossible to fit into the computer, a subset containing only the lakes was extracted in order to test various lake-specific phenomena like seiches and lake-ice dynamics. The lake subset has also been tested operationally for a limited period of time.

The main forcing comes from an atmospheric model in the form of 10 m wind, sea surface pressure, 2 m temperature, 2m humidity and cloudiness. River runoff is specified for 73 rivers and 17 tidal constituents are specified at the open boundary to the Atlantic. HIROMB also consists of a NE Atlantic storm surge model, which gives the storm surge at the open boundary.

Validation

The validation is mainly done for the four parameters water level, sea surface temperature, surface salinity and ice thickness. Besides these, a few examples of salinity and temperature profiles will be compared with ship observations.

Water level

Water level data from 7 stations (see Table 1) have been chosen as representative of the model area. In general, the three northernmost stations have a similar response reflecting the large-scale pressure and wind-dependent variation in the Baltic Sea. Landsort is representative of the mean water volume in the Baltic Sea with a much smaller variation. Simrishamn has a similar response as the first three stations, but with an opposite sign. Viken and Göteborg both have a relatively strong tidal component and with the largest variation in sea level.

Table 1. Water level stations used for verification against model data.

Station	Longitude	Latitude
Furögrund	64°55'	21°14'
Ratan	64°00'	20°55'
Spikarna	62°22'	17°32'
Landsort	58°45'	17°52'
Simrishamn	55°33'	14°21'
Viken	56°09'	12°34'
Göteborg	57°41'	11°48'

As the datum for the computed water level depends on the initial density distribution and water level, there is no exactly defined value to be used in transforming the model data to the reference level used for the water level stations. Further, the steric effect caused by the density difference between stations in the southern and northern Baltic Sea may differ between the model state and real values, mainly because of wrong initial density field. Therefore, to exclude this effect, separate mean values for both the observed and the computed water level data were subtracted from each time series. First the mean values for September was picked out to be used for all subsequent months. However, due to a two days stop in September (18-19) and six days stop in October (17-22) when the model's water level was left at the old value, a marked difference at all stations was observed after the restart. Therefore it was considered necessary to redefine the mean values that should be subtracted. To summarize, the mean values for September have been used for both the September and October plots, while new mean values were used for the November plots. These problems could easily be removed if some kind of data assimilation procedure for water level was incorporated into the model. Then it also should be more meaningful

to look at the bias, a scalar error estimate that has not been addressed in the present study.

When comparing the time series one should have in mind that the model is forced by data from 12 to 36 hours forecast from the 55 km HIRLAM model. A limited validation study of the 10 m wind velocity in HIRLAM at Swedish coastal stations shows that for October-November the correlation range from 0.77 to 0.87 for forecasts up to 24 hours. However it is not straightforward to couple wind correlation to water level correlation, because the water level setup also depends on the sea level pressure, which probably gets a higher score in the HIRLAM forecast compared to wind velocity. There is also a dependence on variations in the density but it is only effective on a longer time scale.

In Figures 1-3 the observed water level is plotted against the computed one. In the middle of September there seems to have been problems with the data at Spikarna. Note also the different vertical scale for Landsort.

For September (Figure 1) the interruption of the model is evident from 12:00 the 17 to 12:00 the 19. It is also clear that this has the effect that there is a marked bias for the rest of the month. However, in all the Baltic Sea stations, the model seems to adjust to the real state after 8 days. This means that there should have been an increased outflow from the Baltic Sea in the model as at all the stations the bias is positive.

The difference at the Landsort station during days 6-9 and 13 may have been caused by a poorly forecasted wind which on these occasions happened to have a large local influence, but this can not be conclusive as no comparisons on observed and modelled wind are done on a routine basis. By studying available data from Falsterbo, it is although evident that HIRLAM has a relatively large error in the wind speed during both periods.

The dominant tide (M2) at Viken and Gothenburg is surprisingly well captured by the model, especially regarding the phase. After the restart the 19 September, it only takes a few cycles before the water level reach the right phase again.

The correlation for October (Table 2) is highly influenced by the one week's stop in the model run, but during this period the change in the water volume for the Baltic Sea is not as large as for the September stop. On the other hand there is an underestimate of the water volume that shows up at all Baltic Sea stations starting at the 6 to 7 October (Figure 2). From the 13 October the underestimate increases at the Bothnian Bay stations.

Notably for Viken and Gothenburg, is that the peak at the end of the month is almost perfectly forecasted.

For November when there were no interruptions, it is clear that the correlation (Table 2) has drastically increased. A further explanation is that the result of a subjective comparison of the observed and the HIRLAM winds, also gives a higher score for this month.

During 5-6 November a heavy storm caused an unusually high water level at Gothenburg (Figure 3). This is rather well captured by the model, though the difference is about 25 cm.

Table 2. Correlation coefficients for September-November 1996. An asterisk means that the observed data were missing. Note the low correlation at Spikarna for September due to errors in the observed values.

Station	September 1996	October 1996	November 1996
Furuögrund	0.86	0.87	*
Ratan	0.88	0.84	0.91
Spikarna	0.56	0.72	0.83
Landsort	0.40	0.52	*
Simrishamn	0.85	0.81	0.93
Viken	0.74	0.87	0.77
Göteborg	0.76	0.79	0.89

Vertical salinity and temperature profiles

Vertical profiles of salinity and temperature from the model results have been compared with measurements from U/F Argos at five locations during the June 1996 cruise (Table 3). It is obvious that the last initial stratification used for the model start (March 1996) at all these locations (Figures 4 and 5) is very weak or almost absent. Then a quantitative comparison between model data and observations should not be very fruitful. However, looking at the model results for June 1996, well established pycnoclines and thermoclines have developed and except for a thin surface layer, both salinity and temperature are very close to what has been observed.

The model temperature for stations BY15 and BY20 clearly shows the effect of the absence of a vertical density gradient in the initial data. The whole water column has been mixed during late winter resulting in too low temperatures below the summer thermocline. However, the thermocline is well developed and in agreement with observations though the surface layer (0-5 m) is too warm. At the Bornholm Deep, inflowing warmer water has started to reestablish the temperature stratification in the deep water. In general, a significant amount of heat has been lost from the Baltic Sea. For the Skagerrak and Kattegat stations the heat loss is smaller and the thermocline evolution seems to be limited by the halocline. The observed thermocline is deeper which probably is the result of non-local processes which will need longer time to create the observed vertical temperature structure. As long as there is no data assimilation in the model, the only way to correct for the temperature stratification error is to restart the model from more realistic initial data. This will in fact be done as new initial fields soon will be available as part of an analysis project at SMHI.

At the Gotland Deep and Fårö Deep stations, a weak halocline has been established at 10 m depth and the salinity has increased for the whole water column. At station BY5 (Bornholm Deep), the salinity of the bottom water has increased by almost 2 PSU because of inflowing salt water creating a halocline at a depth of 50 to 60 m. For the other two stations, the corresponding increase is between 0.2 and 0.6 PSU. Though

inflowing water has started to increase the deep water salinity at the Bornholm Deep, it will take too long to correct for the wrong initial data. The development of the halocline is much faster at the Skagerrak and Kattegat stations and for SK17 the salinity increase is about 3.5 PSU at 100 m depth. For all five stations the further development of salinity for July to September is marked with dashed lines. The gradually increase of bottom water salinity is most clearly seen at BY5 and SK17 which are more exposed for a continuous supply of more saline bottom water from the Arkona Sea and the North Sea. The new initial fields mentioned above will hopefully correct for the salinity error in the same way as for temperature.

Table 3. Geographical position for five vertical stations

Station	Longitude	Latitude
Gotland Deep (BT15)	20°03'	57°20'
Fåry Deep (BT20)	19°57'	58°35'
Bornholm Deep (BY5)	15°59'	58°80'
Kattegat (KA29)	56°40'	12°07'
Skagerrak (SK17)	58°16'	10°43.5'

Monthly means and standard deviation

Temperature and salinity

We have calculated the monthly means and standard deviations for surface temperature and surface salinity using the output fields from every 6th hour. This has been done for August and November 1996 (Figures 6 - 14). The August pictures show large temperature deviations (see Figure 10) along coastal areas where upwelling occurs and the largest deviation occurs outside the coast of Östergötland and along the southern coast of Norrland. The surface temperature deviation picture (Figure 11) shows smaller deviations in November and the largest deviations are around the coasts in the southwest and also at the very northern top of the Bay of Bothnia where the coastal water reaches zero degrees towards the end of November.

The mean salinity pictures (Figures 8 and 9) shows the large salinity differences between the North Sea and the Baltic Sea. The Baltic Current is visible and in november also the Norwegian Coastal Current. Some river outflows can be seen on the November picture because the river discharge has been added to the model after the end of August. The largest salinity deviations (Figure 12) in August 1996 can be seen in the Sound, the Great Belt and the Fehmarn Belt. The area northeast of Skagen also shows larger salinity deviations. In November there are not as large deviations as in August. The salinity deviations (Figure 13) are much smaller but if one changes the scale (Figure 14) there is a complex pattern with the largest deviations around the Swedish westcoast, near the outflows of some rivers and in shallow areas. The two surface salinity deviation pictures from November (Figures 13 and 14) also has some areas with zero salinity deviation and these areas appear as white spots (extra islands).

Water level and current

We also have calculated the monthly means and standard deviations for surface currents and water level for November 1996. The water level mean fields (Figure 15) show the Baltic Sea leaning towards the south with a water level difference of about 35 cm between the Bay of Bothnia and the Arcona basin and about 15 cm difference between the Arcona basin and the eastern North Sea. This is a combined effect of dominating southerly winds, inflow and river runoff and corresponds well to observations (Ekman and Mäkinen, 1996). The water level standard deviation (Figure 17) has a minimum in the middle of the Baltic Proper and a great maximum in the German Bight.

The current mean fields (Figure 16) show maximum currents in the southeastern Baltic Sea and in the North Sea and the prevailing direction is towards northeast. The current standard deviation for November (Figure 18) shows minimas around the coasts and in the Gulf of Finland and the Gulf of Riga. The maximas are in the German Bight, north of Denmark and also smaller maximas in the Baltic Sea inflow regions and in the southeastern part of the Baltic Sea.

Ice and temperature verification

The surface temperature and ice cover output fields from the HIROMB model was verified by eye during spring 1996 against the ice and SST-maps created by SMHI. The result was promising both for the temperature and ice case but when the ice began to melt the modelled ice was too thick and had a too high concentration. This has been considered by Ekhard Kleine and Lennart Funkquist who now has changed the ice model to allow for more ice deformation. This new part of the icemodel in HIROMB will be tested during the winter 96/97.

We have chosen the period 21 November until 19 December 1996 to show how the SST and the initial ice develops in the HIROMB model compared to observations. See figures 19 - 26.

The surface temperature fields from HIROMB (Figures 19b - 26b) show a very good accordance with the SST maps (Figures 19a - 26a) and the differences are rarely more than 1 degree in most areas but can be great in regions where HIROMB simulates upwelling which is not seen on the SST map.

The ice fields from HIROMB (Figures 21c - 26c) show a quite good accordance with the ice maps (Figures 21a - 26a) but have a tendency to form too much ice which can be seen on the figure from 19 December where the Gävle Bight and parts of the Northern Quark is ice covered by HIROMB but not on the ice map. The ice growth in the inner Gulf of Finland is though well simulated.

Closely related validation exercises

Validation exercise for the Kattegat and the Skagerrak

In 1994, the Nordic Council of Ministers (NMR) conducted a model intercomparison for the Skagerrak - Kattegat region consisting of 6 invited models. A horizontal grid of 5 km was assumed but with no restrictions on the vertical resolution. Three more or less artificial cases were considered where the first only dealt with wind-driven flow with closed boundaries, the second with no wind and specified in- and outflow and the third with both kinds of forcing.

As there were no real data or even a real situation available to compare with the test cases, the outcome of the exercise can be kept in a short summary. A general experience from the intercomparison was that the models responded similar to the applied forcing. Clear differences could be related to physical and numerical formulations in the models. Differences in the mixing parameters were also clear and some shortcomings of some models were noticed. The whole intercomparison is described in Gustafsson and Jönsson (1994) and the HIROMB application is reported in Funkquist (1996).

DYNOCS

DYNOCS (Dynamics of connected seas) is a MAST-II project concentrating on the flow characteristics in the seas that connect the North Sea and the Baltic Sea. It contains field measurements, process studies and numerical as well as laboratory modelling. In the numerical modelling part, three different type of models are applied in a local area bounded by the southern Kattegat and the eastern Bornholm Basin. One of the models is identical to HIROMB with the addition of a flow relaxation scheme for the open boundaries. The model is run for three different periods each lasting for about two weeks. Boundary and initial data is given by a regional model covering the North Sea and the Baltic Sea. There will be an intercomparison between all models as well as comparisons with field data.

At present, only data reports and a few data analysis reports are available. Results from the model exercise will be reported soon after the finish of the project, i.e. in March 1997.

Vänern and Vättern

With the aim to learn more about the BSH-model the lakes Vänern and Vättern have been set up as a 3D-model. There was already an existing grid with 1 nm resolution covering the Baltic Sea including Lake Vänern and Lake Vättern and the area covering these lakes were cut out to form a smaller grid with 98x98 horizontal gridpoint and 35 vertical levels with 2 meters resolution the first 27 layers and then increasing every second layer to 4, 6, 8 and 10 meters down to the maximum depth 110 meters (in Lake Vättern). The time step is 3 minutes and the discharge from the rivers Klarälven and Göta älv is considered. After some tests it was discovered that the grid was not complete, the western part of Lake Vänern was missing but the work to complete the grid has started and will be ready in the early 1997.

Temperature

The Vänern-Vättern model has been tested during the ice-free season and has also been tested as an operational model during June 1996. It uses HIRLAM-fields as input data and works stable without numerical problems. It has been verified against the SST-maps (which covers Vänern but not Vättern) from 960616 and 960620 which shows that the model surface temperature is up to 5 degrees too high. This implies that Lake Vänern is too quickly heated or the vertical diffusion is too low.

Seiches in lake Vättern

The barotropic part of the Vänern-Vättern model has been thoroughly investigated. The Lake Vättern is known for the seiches going in the north-south direction and there are measurements done by Bergsten 1926. In 1989 Björk and Lundberg did some measurements and found three north-south seiche modes which they also found in their calculations. We tried to find these periods, of which the 3-hour (179.5 min) period is by far the strongest, and with different methods we managed to find all three of them.

Lake Vättern has a length of 111 km in our model (with the narrow bay south of Askersund not included in the grid) and has a mean depth of about 40 meters. A seiche moves with the speed $v = \sqrt{g \cdot h} \sim 20.2$ m/s which means that a journey back and forth will take about 183 minutes. When the model was started with a tilted watersurface (in north-south direction) the 3 hour period is very clearly seen and is damped with a damping coefficient of about 30 hours. The 3 hour period is also easily found if the model is forced with a sinusshaped wind with a 3 hour period.

The second strongest period is 97 minutes but is 10 times weaker than the dominating 3 hour period. It can be found by either initiating the model with a ridge of water in the middle of the lake (as seen from east or west) or by forcing the model with a sinusshaped wind with a 97 minute period.

The 80.5 minute period is almost as strong as the 97 minute period and was found by forcing the model with a sinusshaped wind with a 80.5 minute period.

In the paper by Björk and Lundberg there were some measurements of the waterlevel in Jönköping (at the southern end of Lake Vättern) from 6-8 December 1985. In a test our model was forced by SYNOP-data every third hour from the Baltic database from 1. to 9. December but did not reproduce the measurement at all. The amplitudes were about the same size but in the simulation the 3 hour period dominated totally and there were no small timescale variations like in the observations. We tried to change the bottomfriction and other parameters in the model but without result. When we later added a random part and let the wind change every half an hour, instead of every third hour, the waterlevel answer was slightly better but there were no major difference.

Conclusions

A general conclusion from this validation is that the model results to a large extent suffer from the poor initial data, where the vertical stratification is too weak or almost

absent. This is well illustrated by the comparisons of vertical profiles. Consequently the vertical mixing has been too large leading to an excessive cooling of the Baltic Sea with implications on the start of the ice formation. However, since the last restart from initial data in March 1996, both thermoclines and haloclines have started to form and seem to continuously approach the observed structures, which means that the model, if run long enough, is capable of producing the Baltic Sea estuarine structure.

An SMHI oceanographic analysis project which ends in February 1997 will produce monthly values of gridded salinity and temperature data. Then it is most likely that the model performance will increase and more baroclinic features will appear in the model results.

Most of the water level variations are reproduced by the model and the correlation for November 1996 is in the range 0.77 to 0.93. Also the tidal component which dominates the stations in Kattegat and Skagerrak is right in phase and almost right in amplitude. The mean water level for November 1996 (Figure 15) agrees well with the corresponding data from observations.

Although the water level is well captured by the model, the performance could easily be increased by including a data assimilation routine. Then also the effect caused by a several days break in the simulation, which is well demonstrated in the October data, could be removed.

The surface salinity looks reasonably and the surface temperature is very close to observations. The ice results are rather good but there are some overestimation of the ice coverage which probably depends on the too cold deeper water caused by the absence of a halocline. The seiches in Lake Vättern are well simulated and all three measured seichmodes are seen in the model simulations but measured variations with much smaller timescale than 3 hours are not caught by the model.

Recommendations

This validation study clearly points at potential improvements that could be implemented in the model.

Realistic monthly means of temperature and salinity will be extracted to be used for initialization and operational control of the model. The analysis project mentioned in the validation section is a first step to solve this problem.

The weak mixing in the surface layer has to be corrected by looking for a possible error in the model code or modifying the turbulence model.

Data assimilation of water level could be incorporated by applying e.g. a variational method.

Concentration and thickness of ice only affects the surface layer and a suitable data assimilation method for these parameters should rather easily be implemented. As a consequence of changing the ice variables, the sea surface temperature also should be modified according to a suitable assimilation scheme.

So far, currents have not been validated to the same degree as other variables. This could be done by comparing to existing and future measurements and experimenting with the horizontal friction parameters.

At present, the light attenuation coefficient is held constant. But as there are significant variations both in time and space, this coefficient could be variable.

In the original setup of the model, the river runoff for all 73 rivers is constant in time. However, monthly mean values are available and will be transferred to the model.

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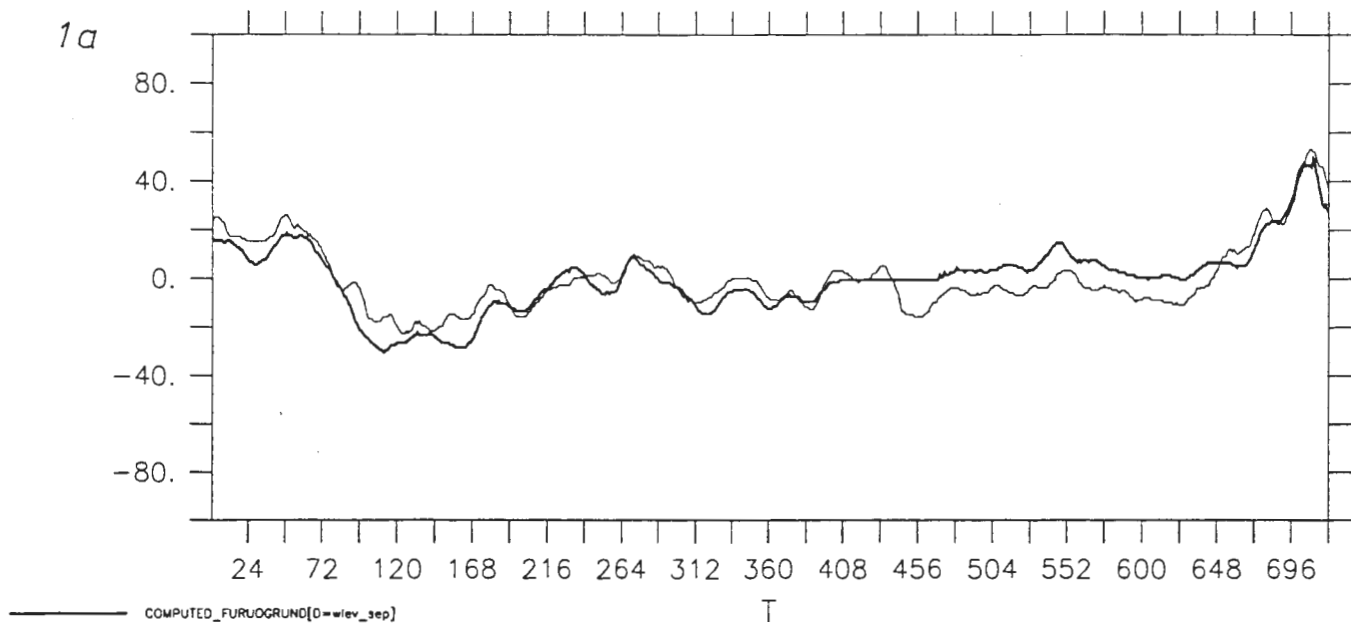
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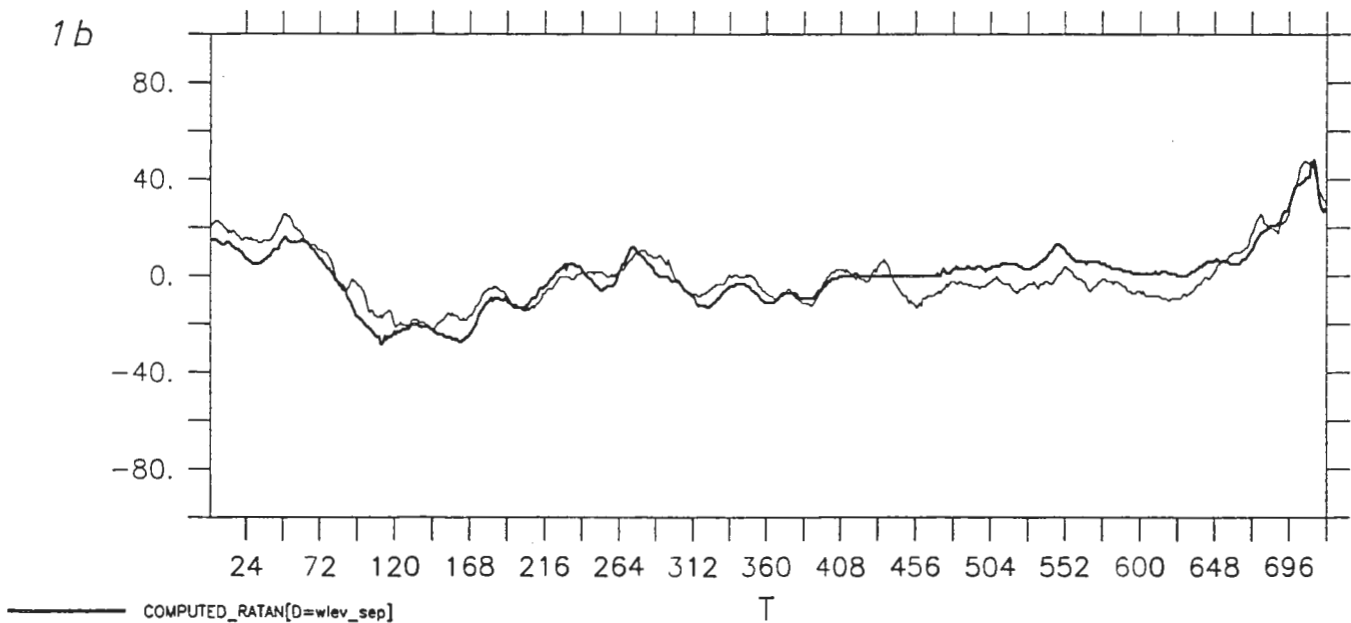
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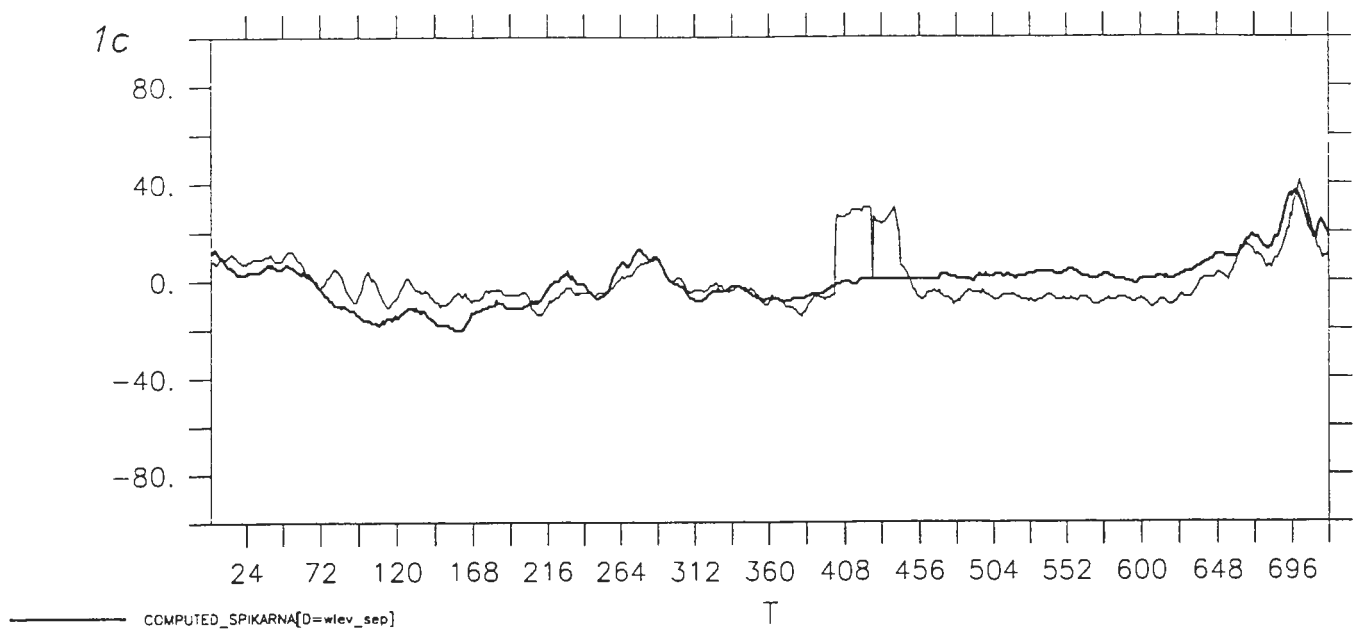


Water level at Furuogrund (sep 96)

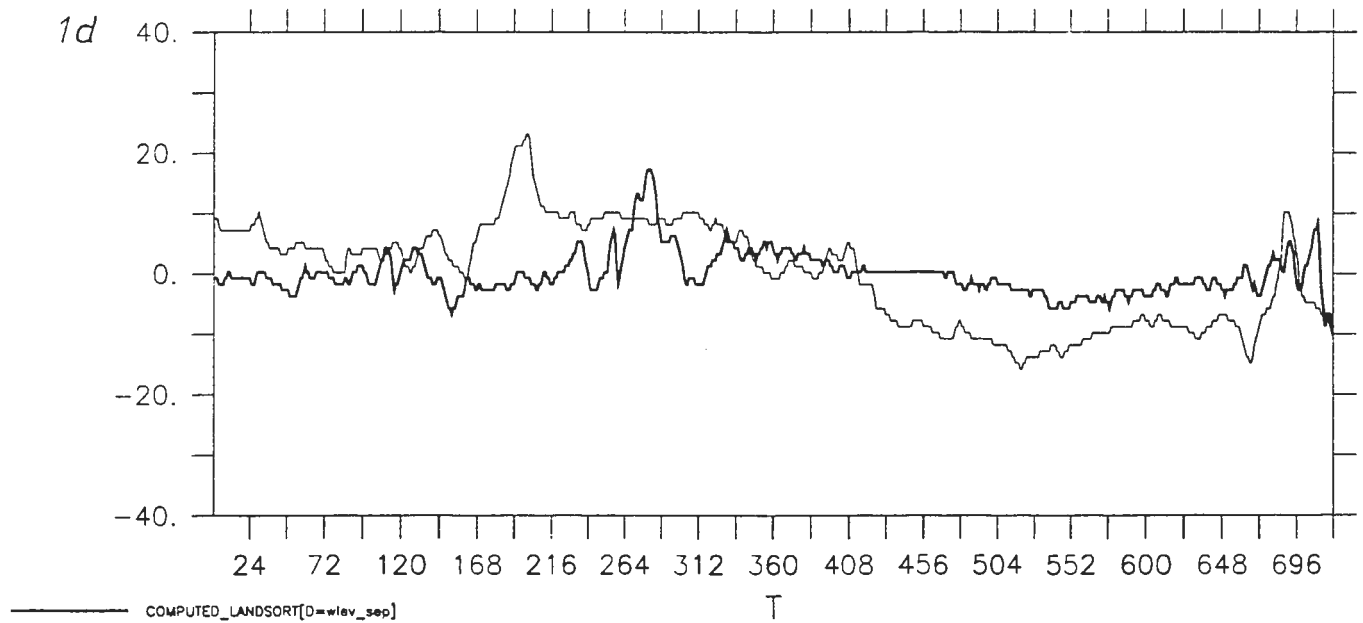


Water level at Ratan (sep 96)

Figure 1. Computed and measured water level at 7 stations for September 1996

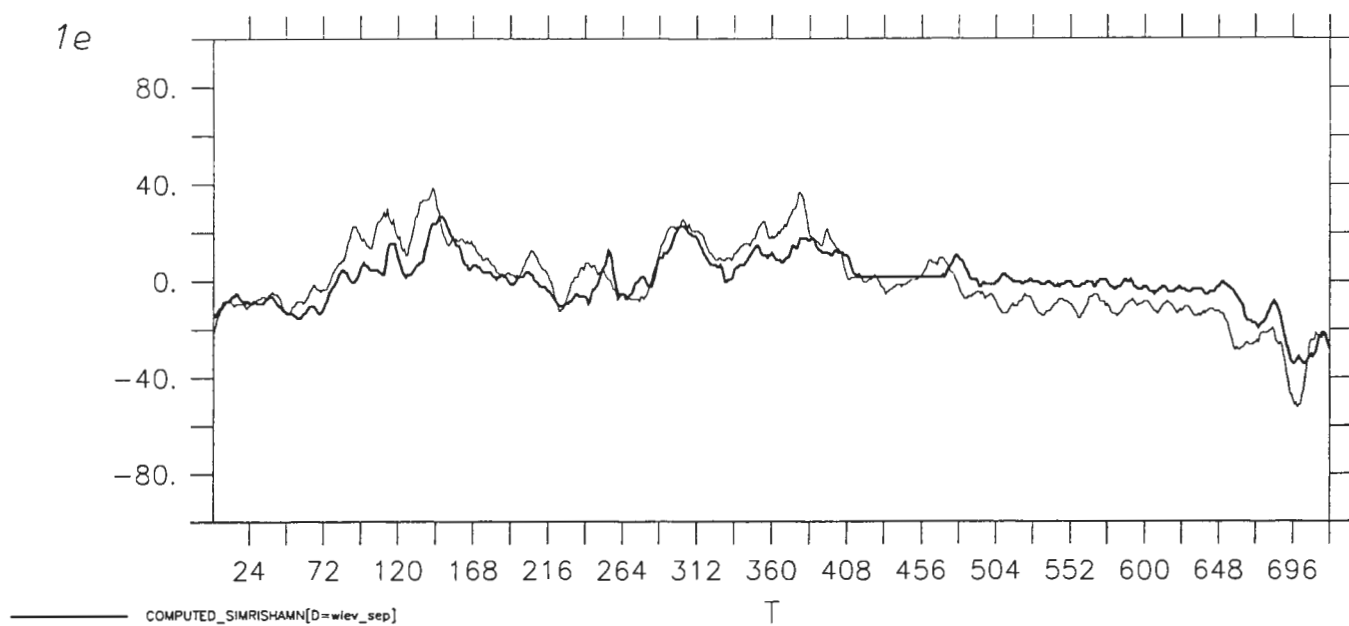


Water level at Spikarna (sep 96)

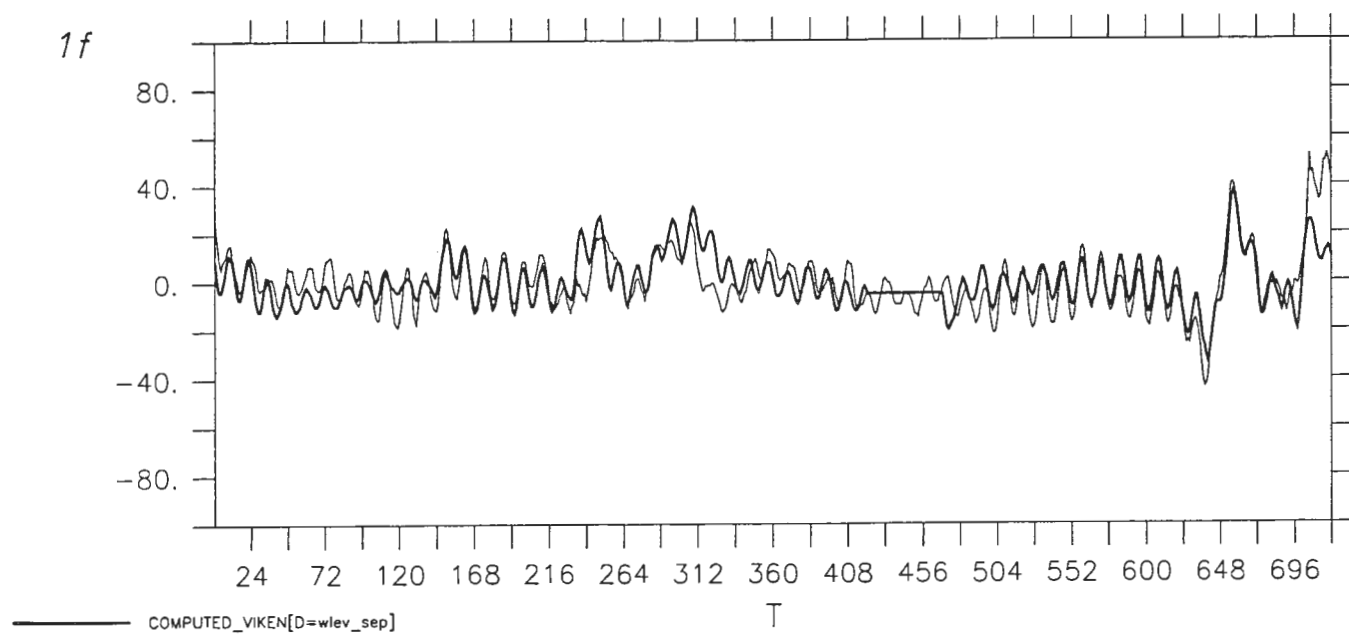


Water level at Landsort (sep 96)

Figure 1. Computed and measured water level at 7 stations for September 1996

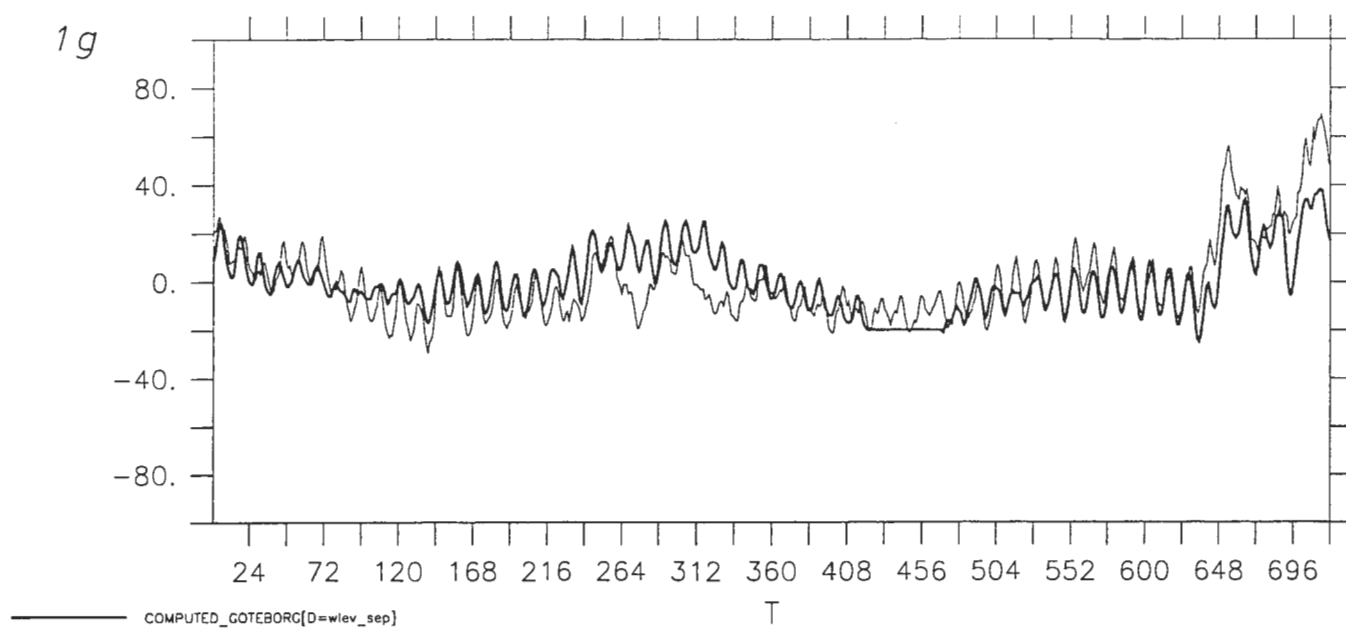


Water level at Simrishamn (sep 96)



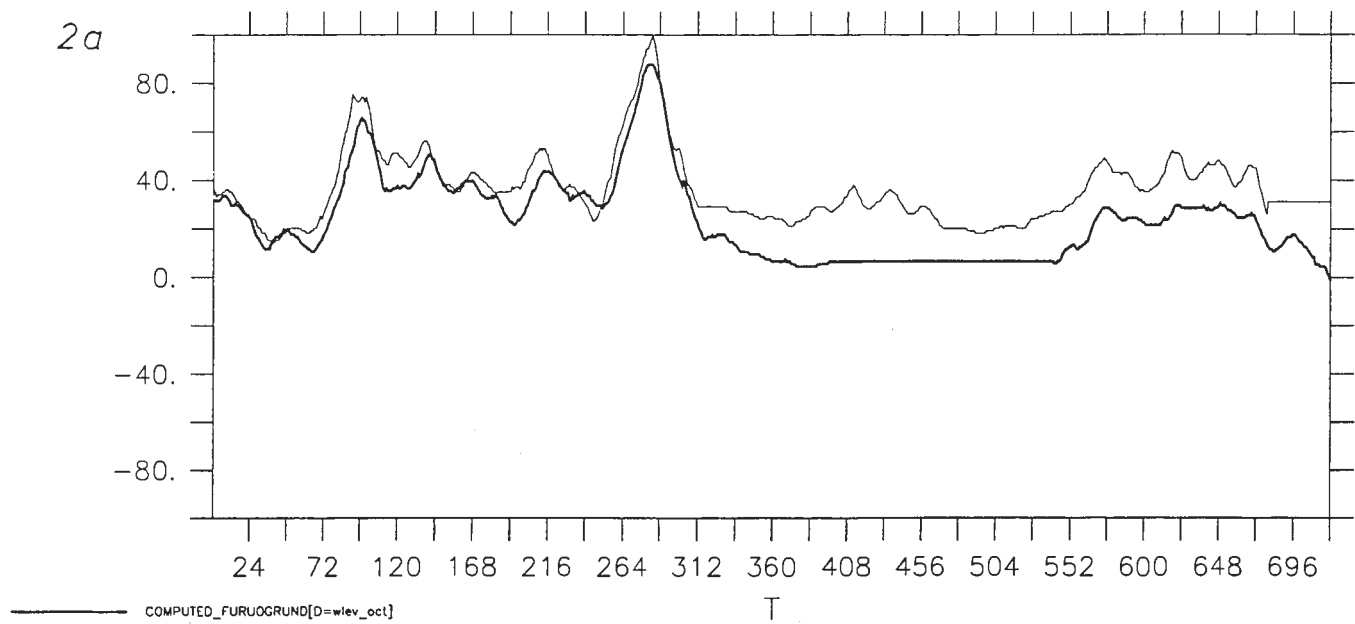
Water level at Viken (sep 96)

Figure 1. Computed and measured water level at 7 stations for September 1996

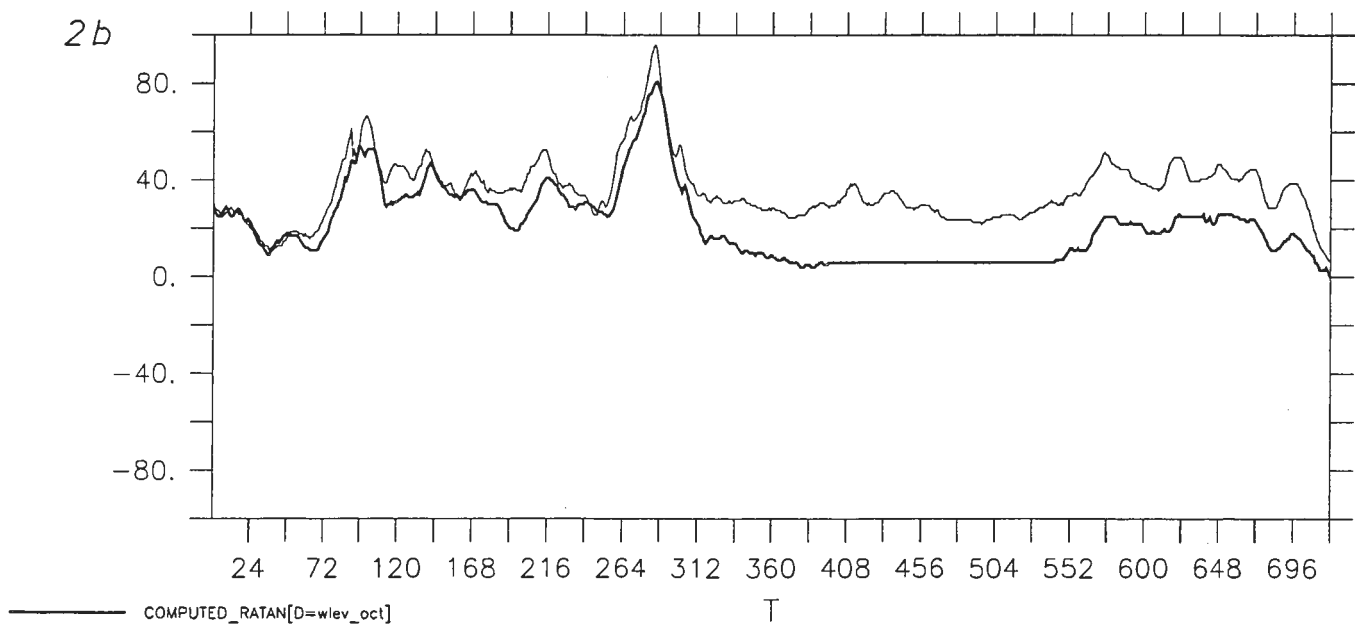


Water level at Goteborg (sep 96)

Figure 1. Computed and measured water level at 7 stations for September 1996

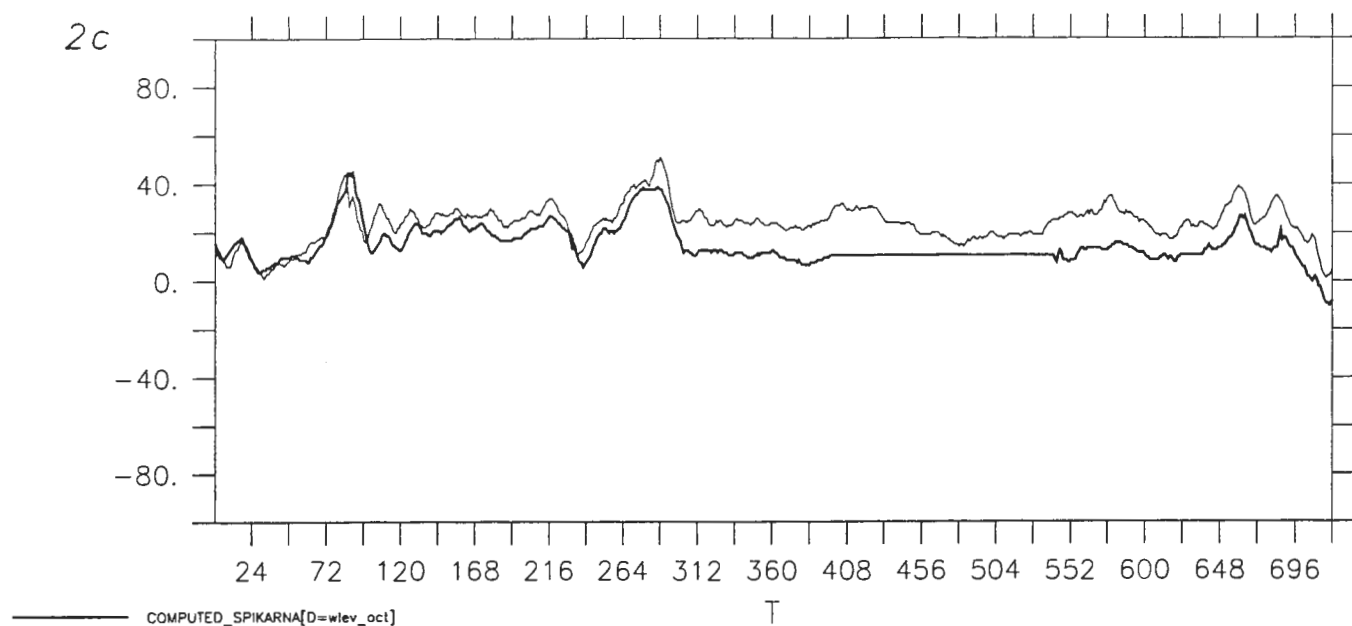


Water level at Furuogrund (oct 96)

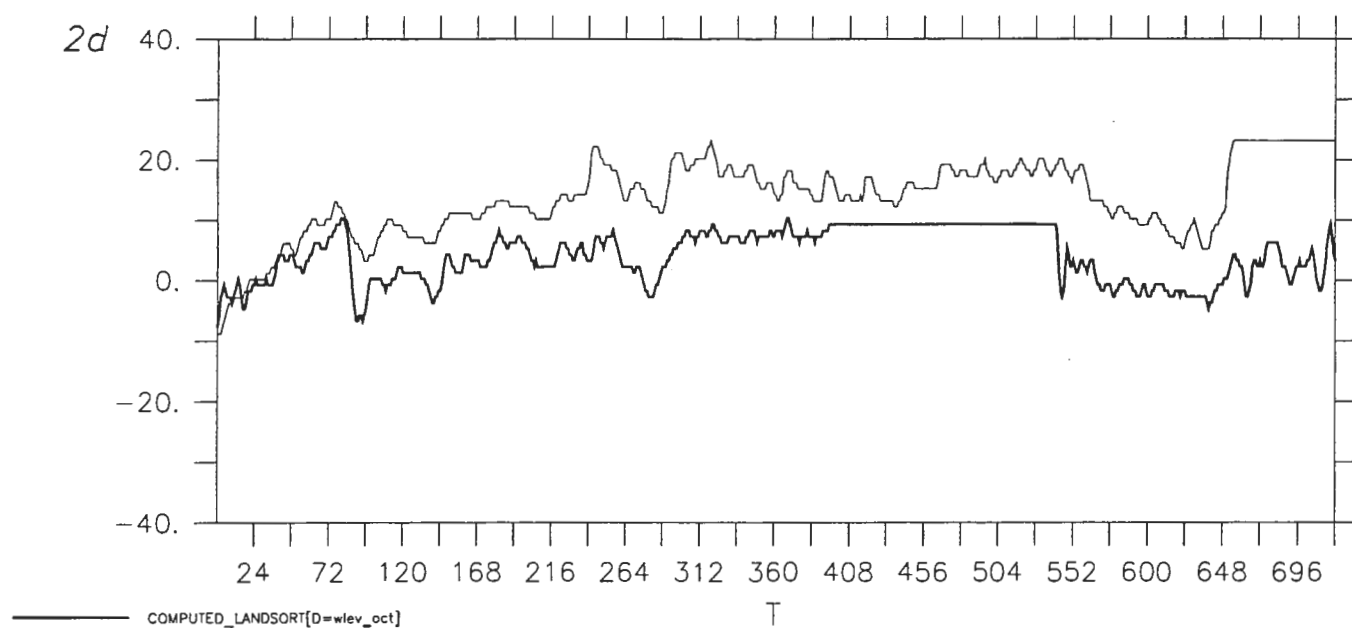


Water level at Ratan (oct 96)

Figure 2. Computed and measured water level at 7 stations for October 1996

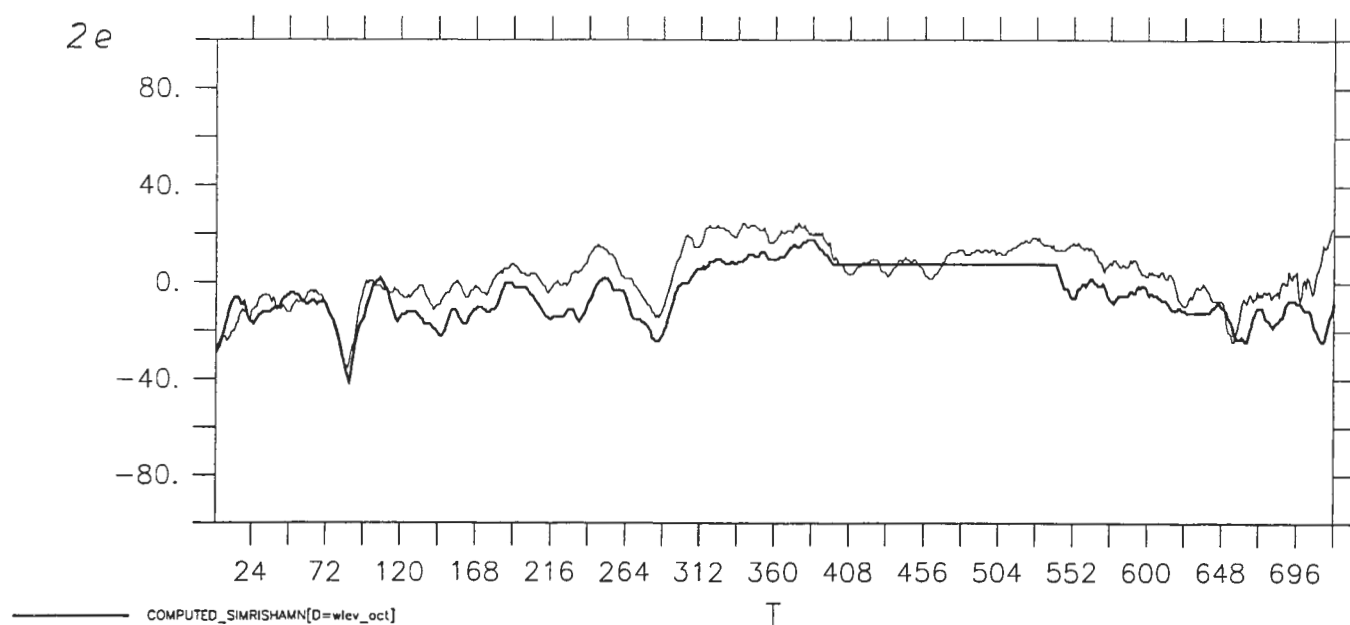


Water level at Spikarna (oct 96)

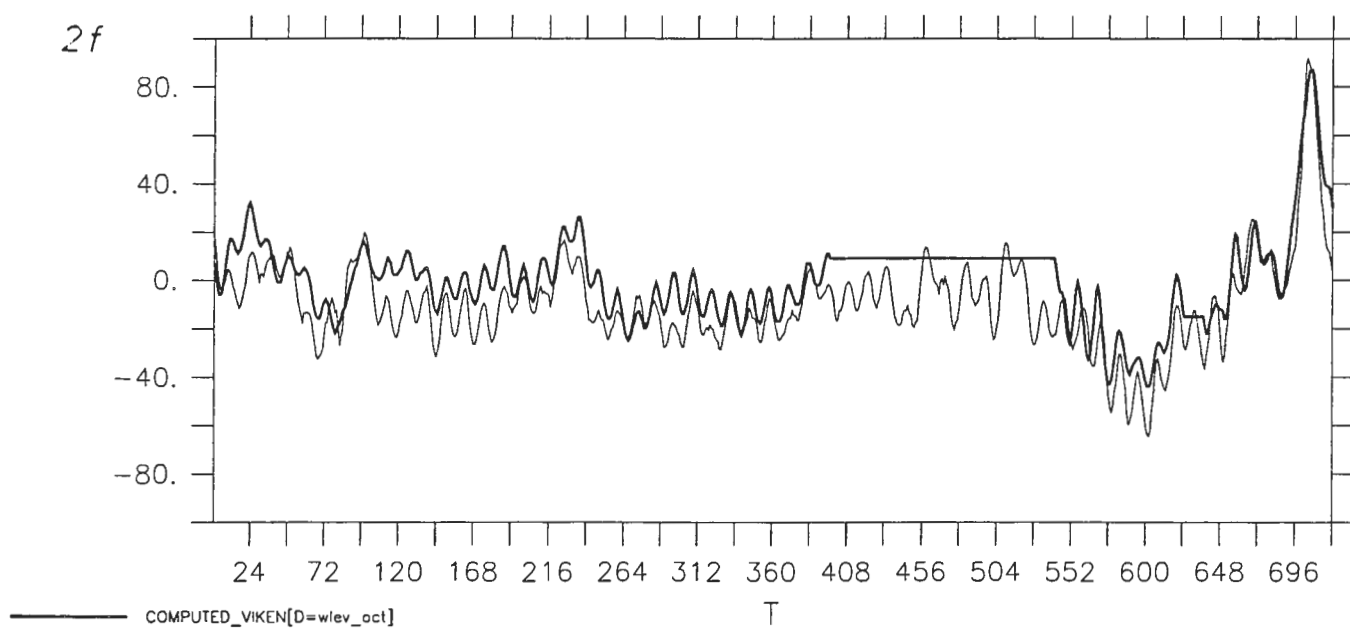


Water level at Landsort (oct 96)

Figure 2. Computed and measured water level at 7 stations for October 1996

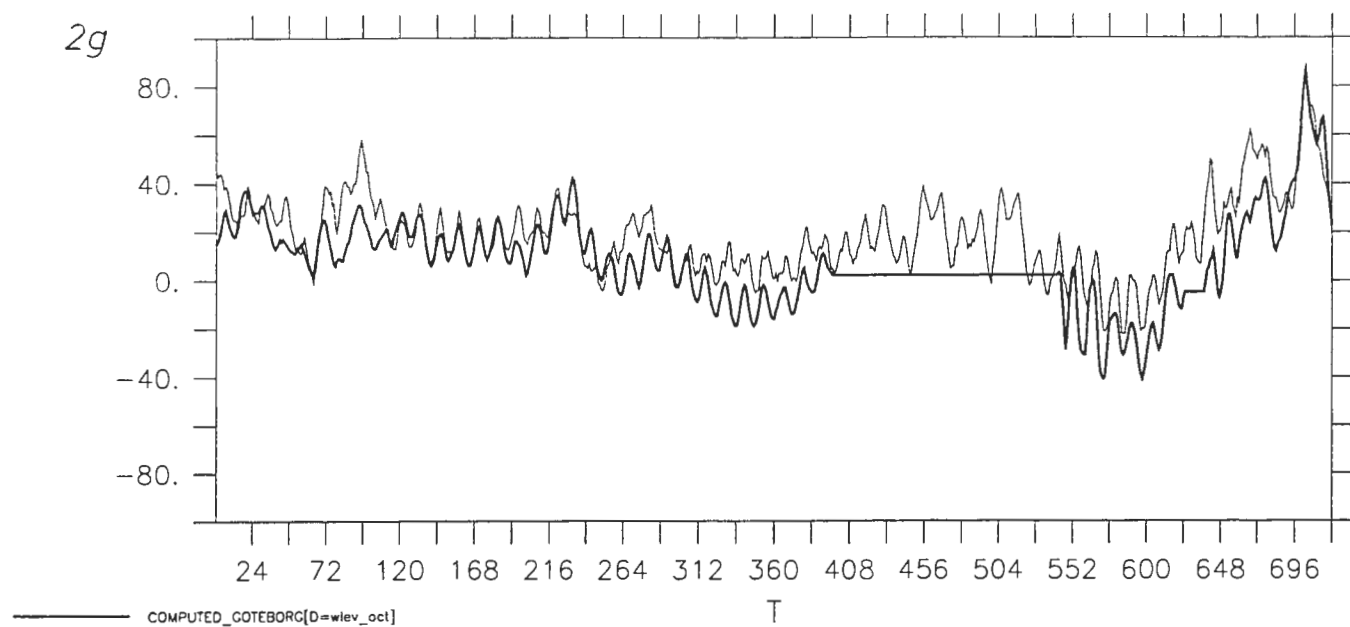


Water level at Simrishamn (oct 96)



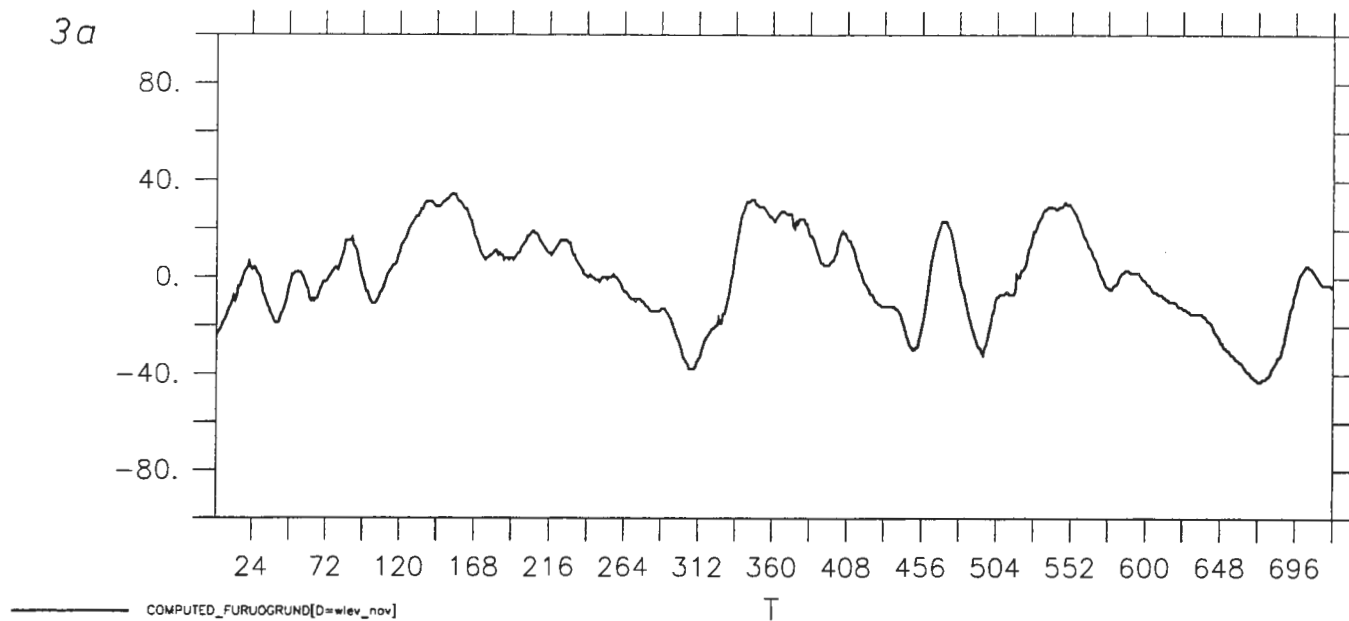
Water level at Viken (oct 96)

Figure 2. Computed and measured water level at 7 stations for October 1996

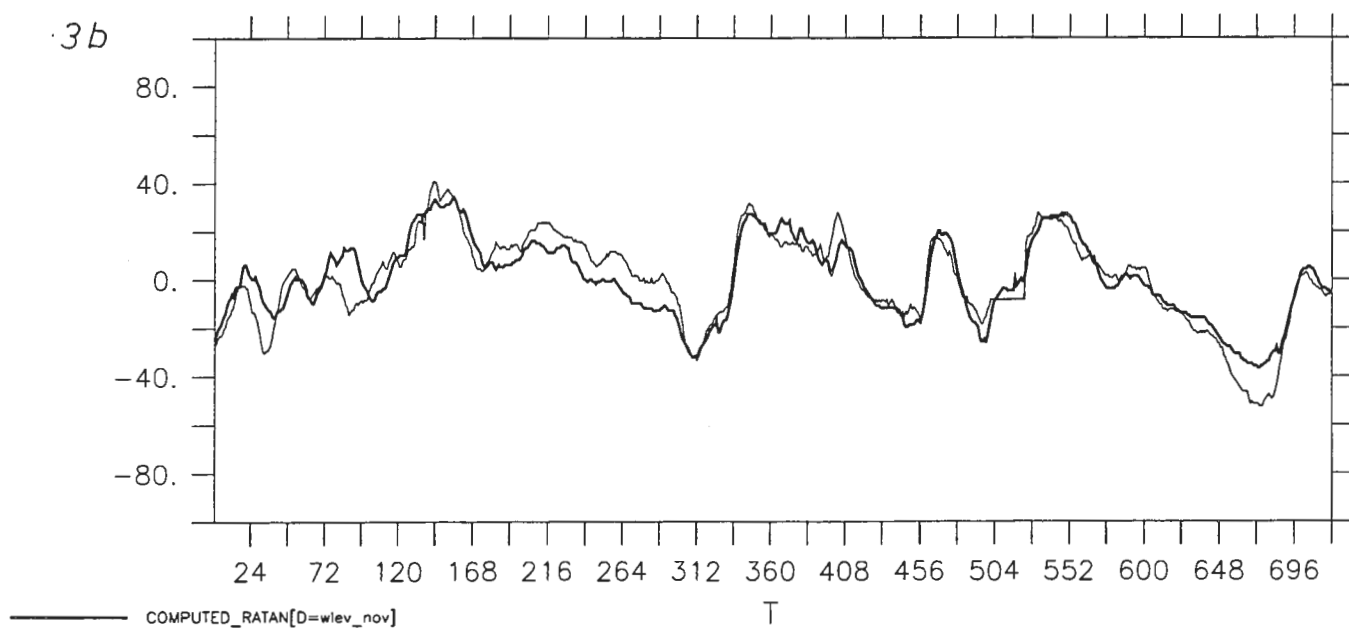


Water level at Goteborg (oct 96)

Figure 2. Computed and measured water level at 7 stations for October 1996

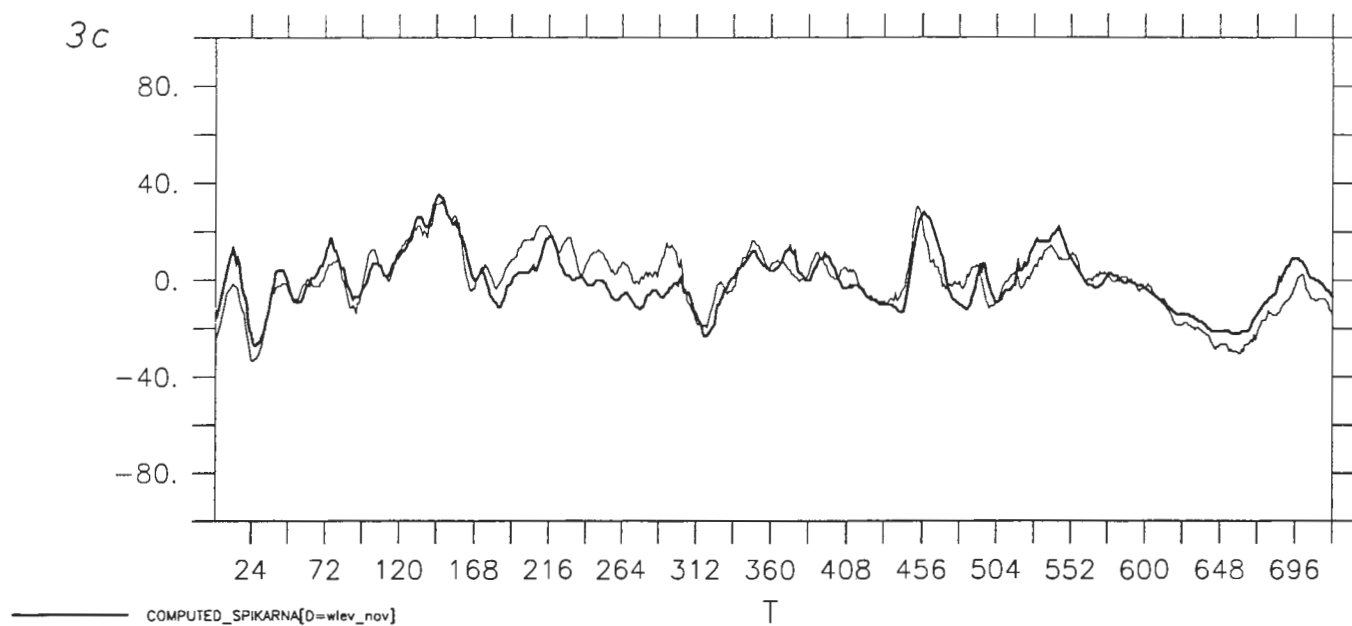


Water level at Furuogrund (Nov 96)

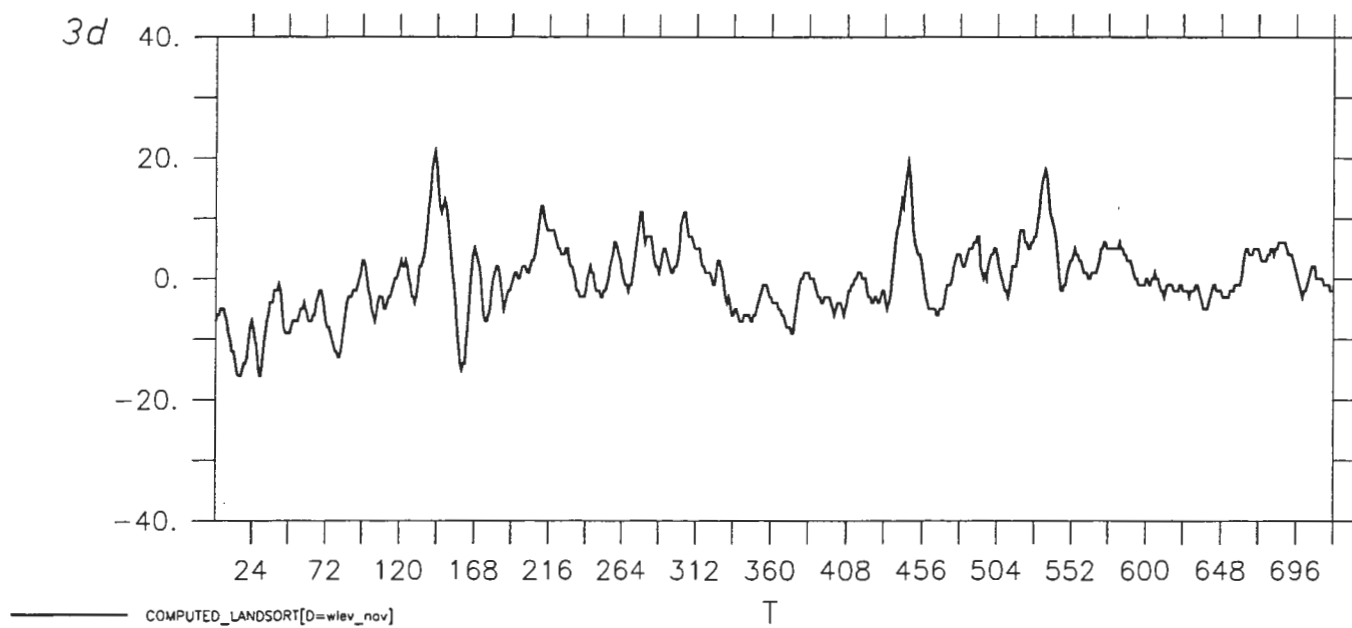


Water level at Ratan (Nov 96)

Figure 3. Computed and measured water level at 7 stations for November 1996

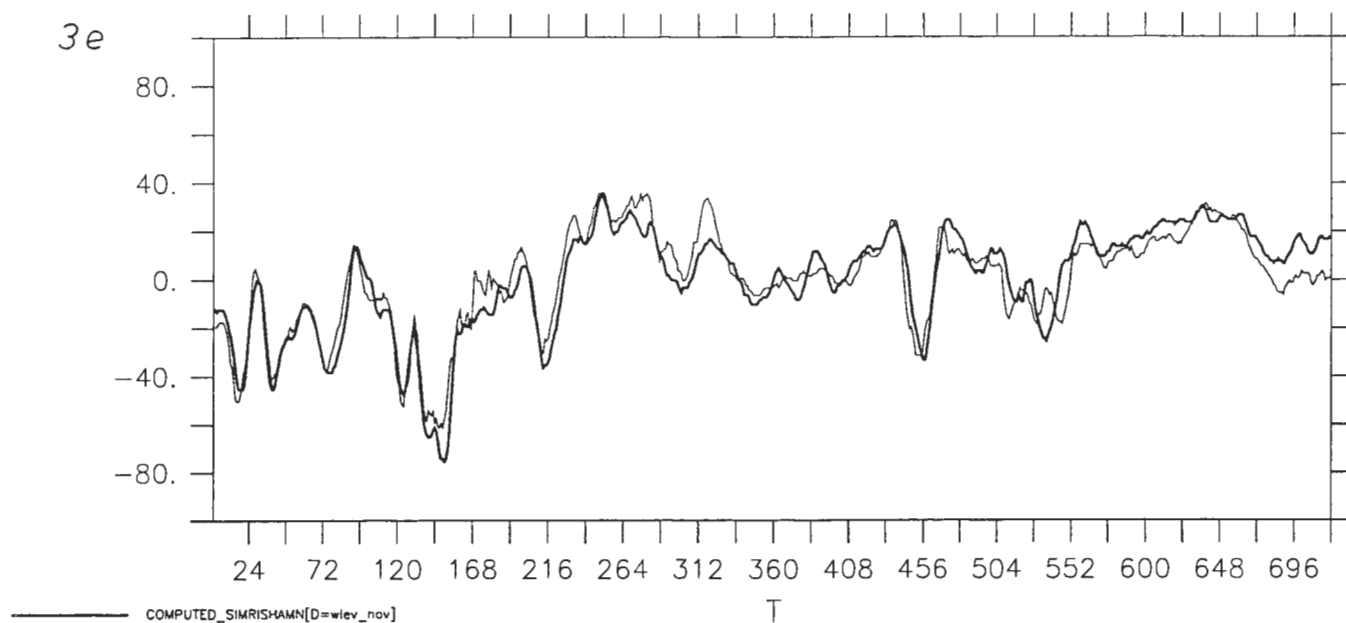


Water level at Spikarna (Nov 96)

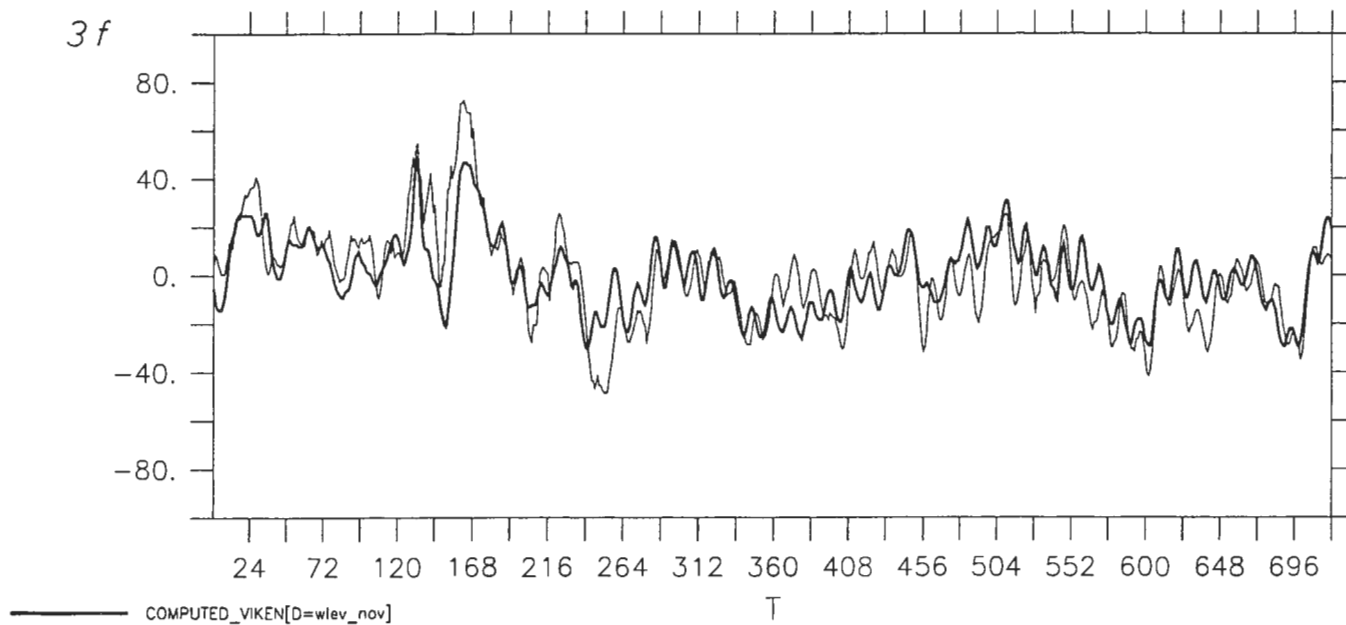


Water level at Landsort (Nov 96)

Figure 3. Computed and measured water level at 7 stations for November 1996

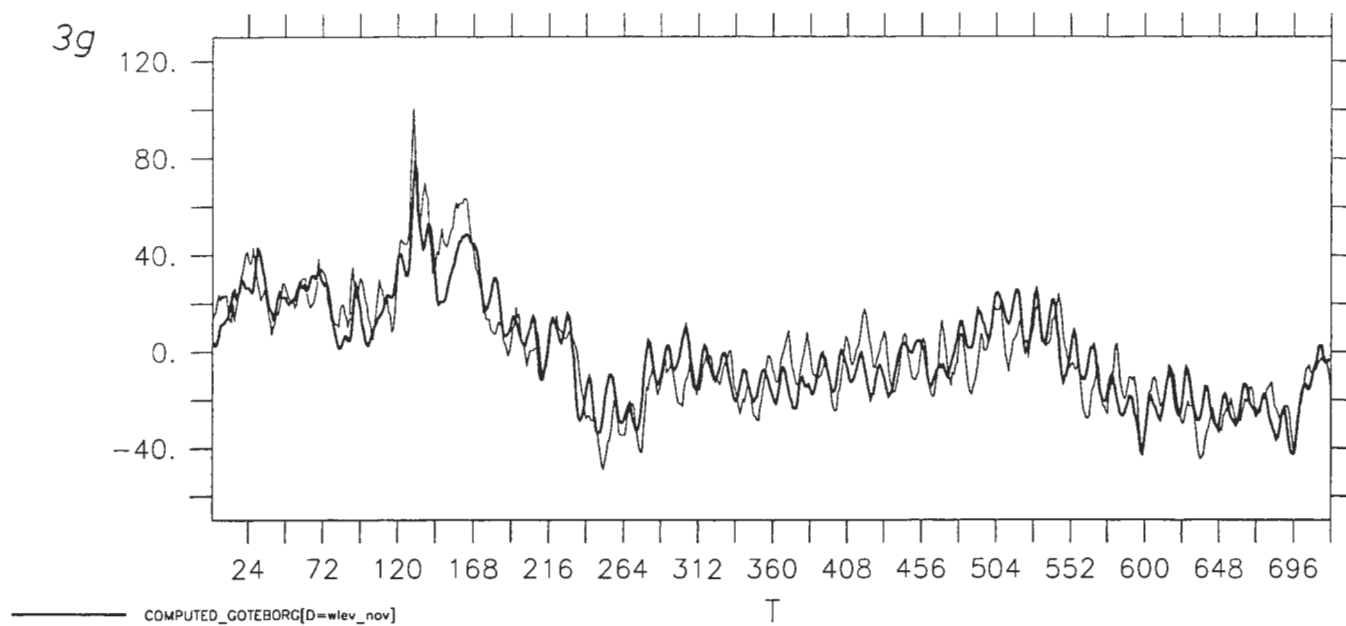


Water level at Simrishamn (Nov 96)



Water level at Viken (Nov 96)

Figure 3. Computed and measured water level at 7 stations for November 1996



Water level at Goteborg (Nov 96)

Figure 3. Computed and measured water level at 7 stations for November 1996

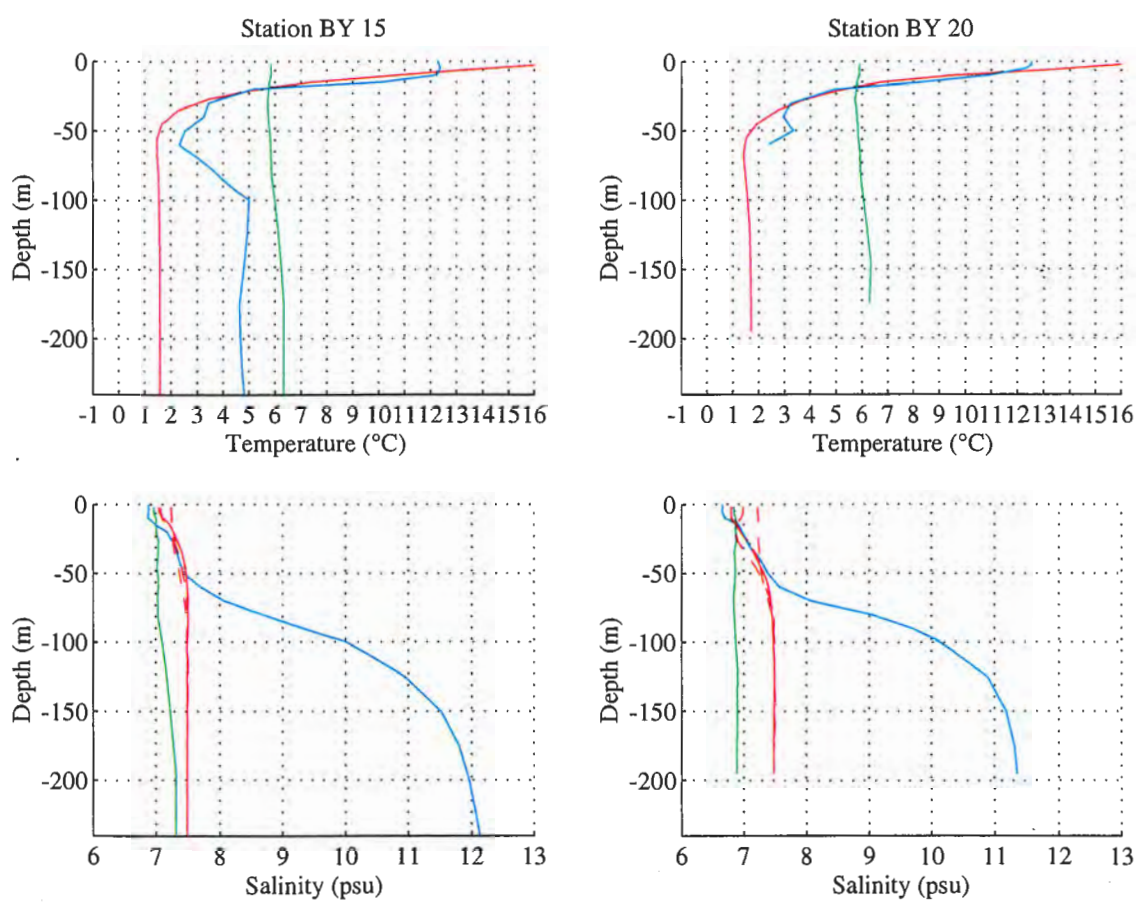


Figure 4.a: Temperature and salinity data: initial-green, calculated-red and observed-blue from June 26 1996, whereas the red dashed lines is from July, August and September 24.

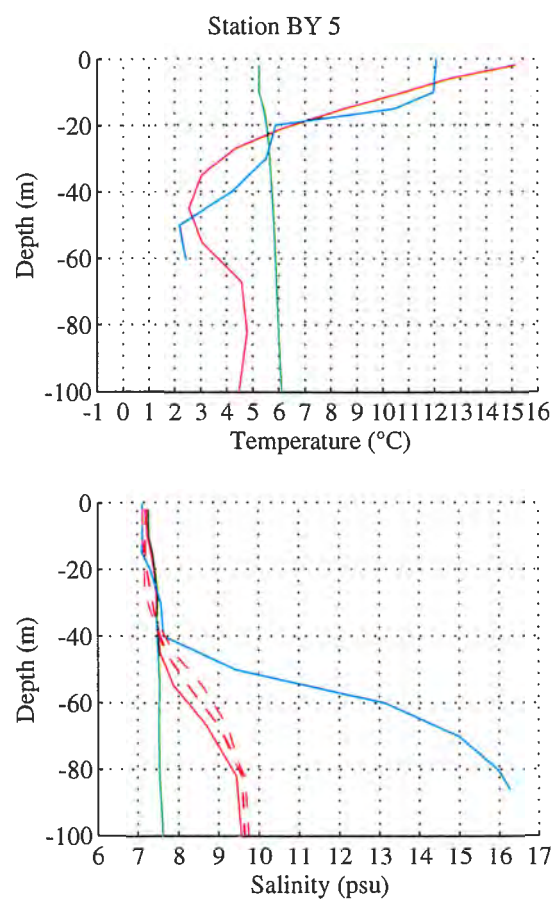


Figure 4.b: Temperature and salinity data: initial-green, calculated-red and observed-blue from June 26 1996, whereas red dashed lines are from July, August and September 24.

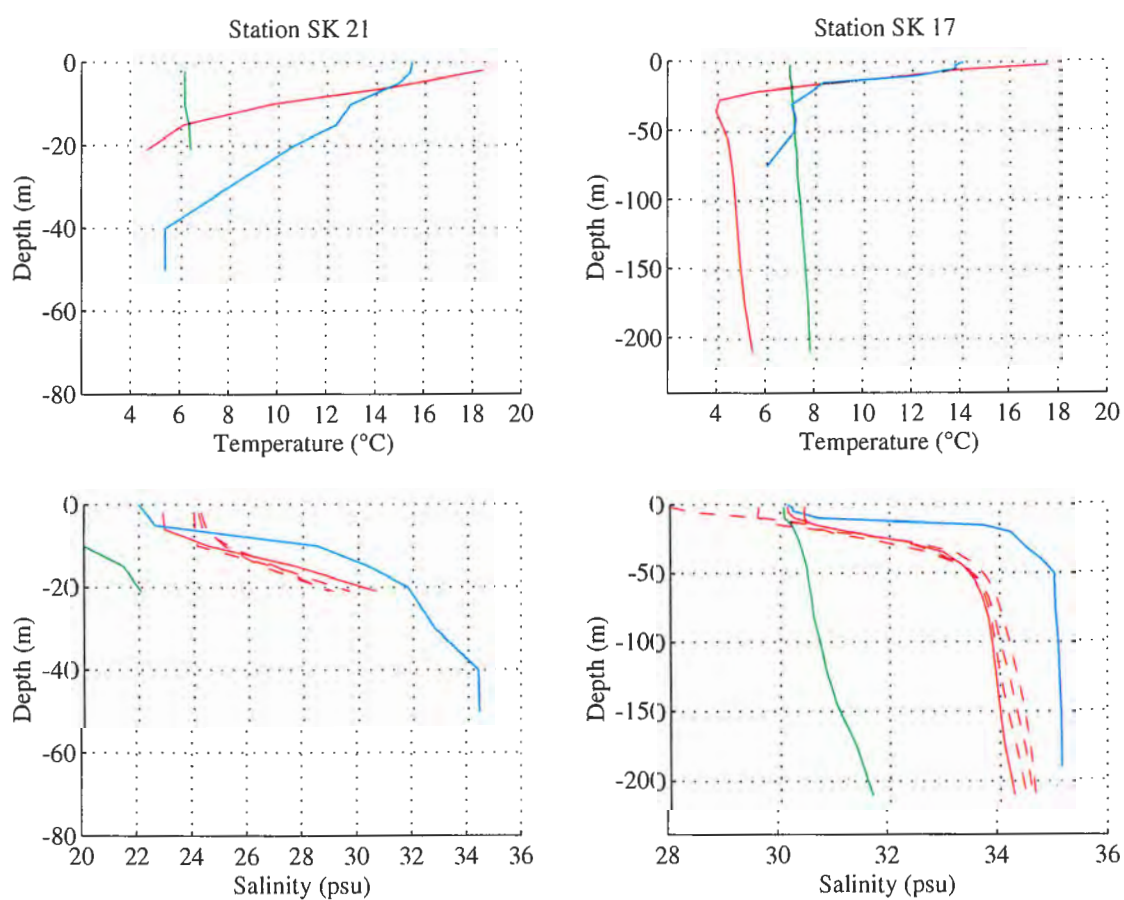


Figure 5: Temperature and salinity data: initial-green, calculated-red and observed-blue from June 26 1996, whereas the red dashed lines are from July, August and September 24.

HIROMB mean surface-temperature August 1996

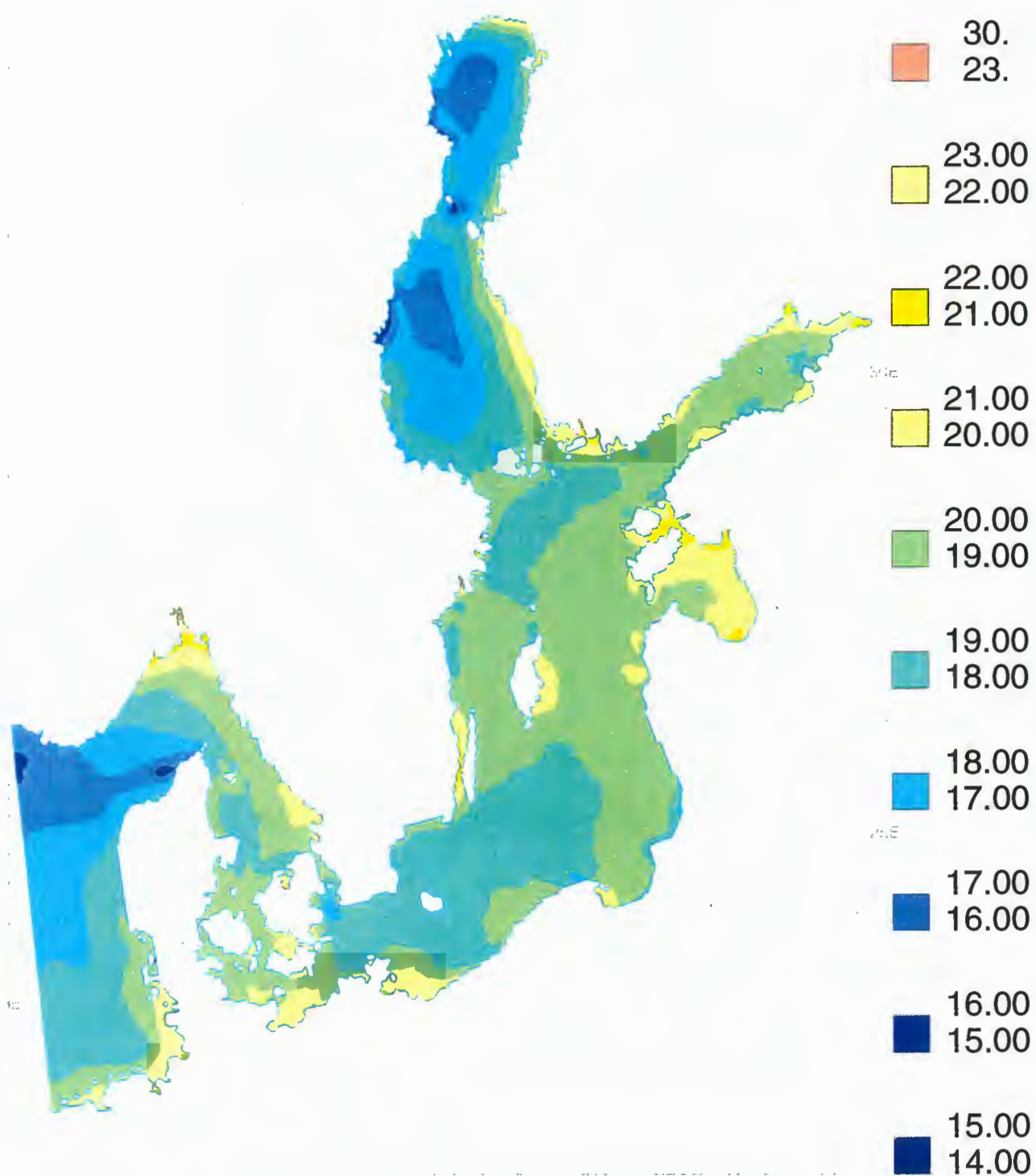


Figure 6. Mean surface temperature (colourscale, °C), august 1996

HIROMB mean surface-temperature November 1996

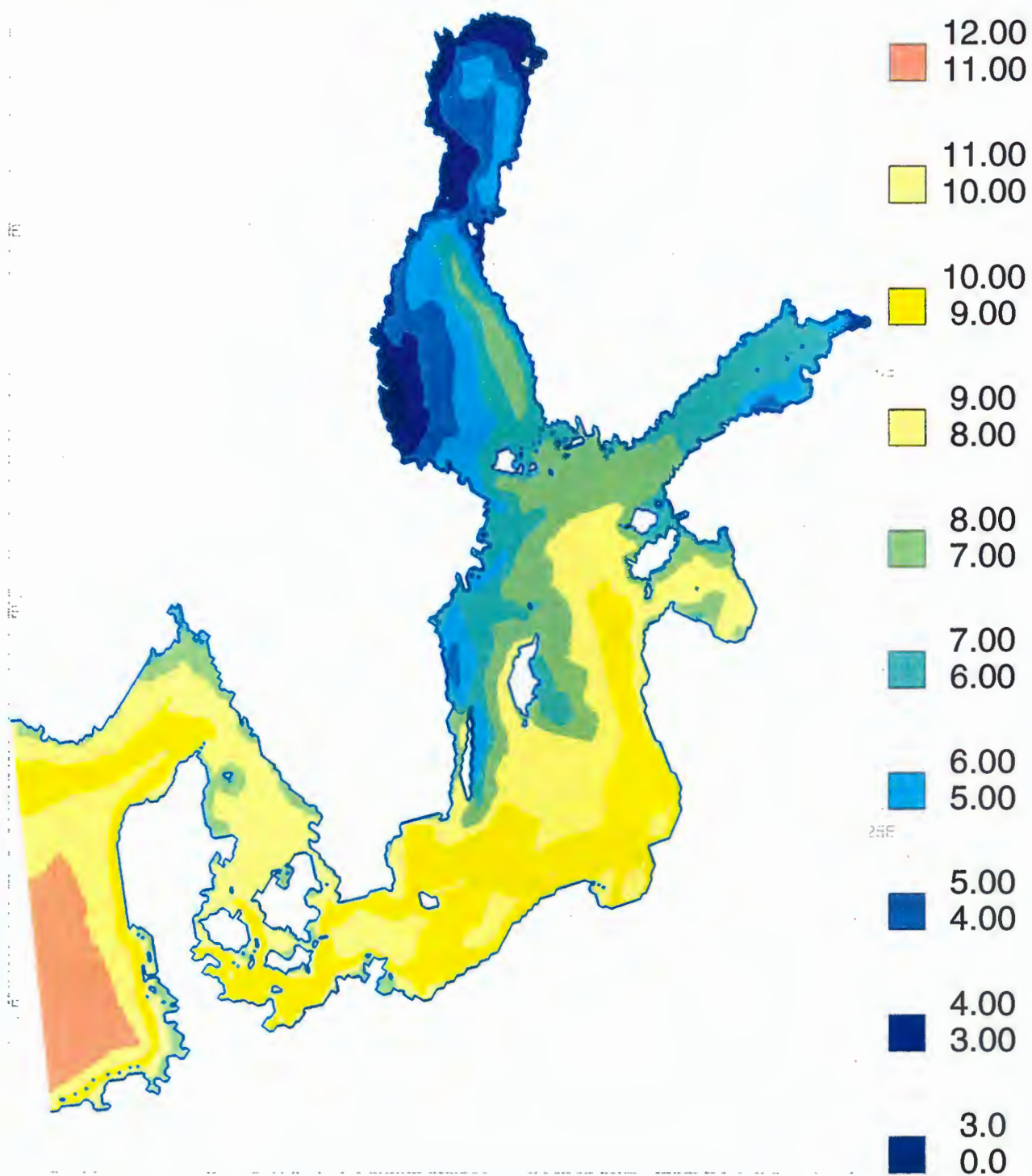


Figure 7. Mean surface temperature (colourscale, °C), november 1996

HIROMB mean surface-salinity August 1996

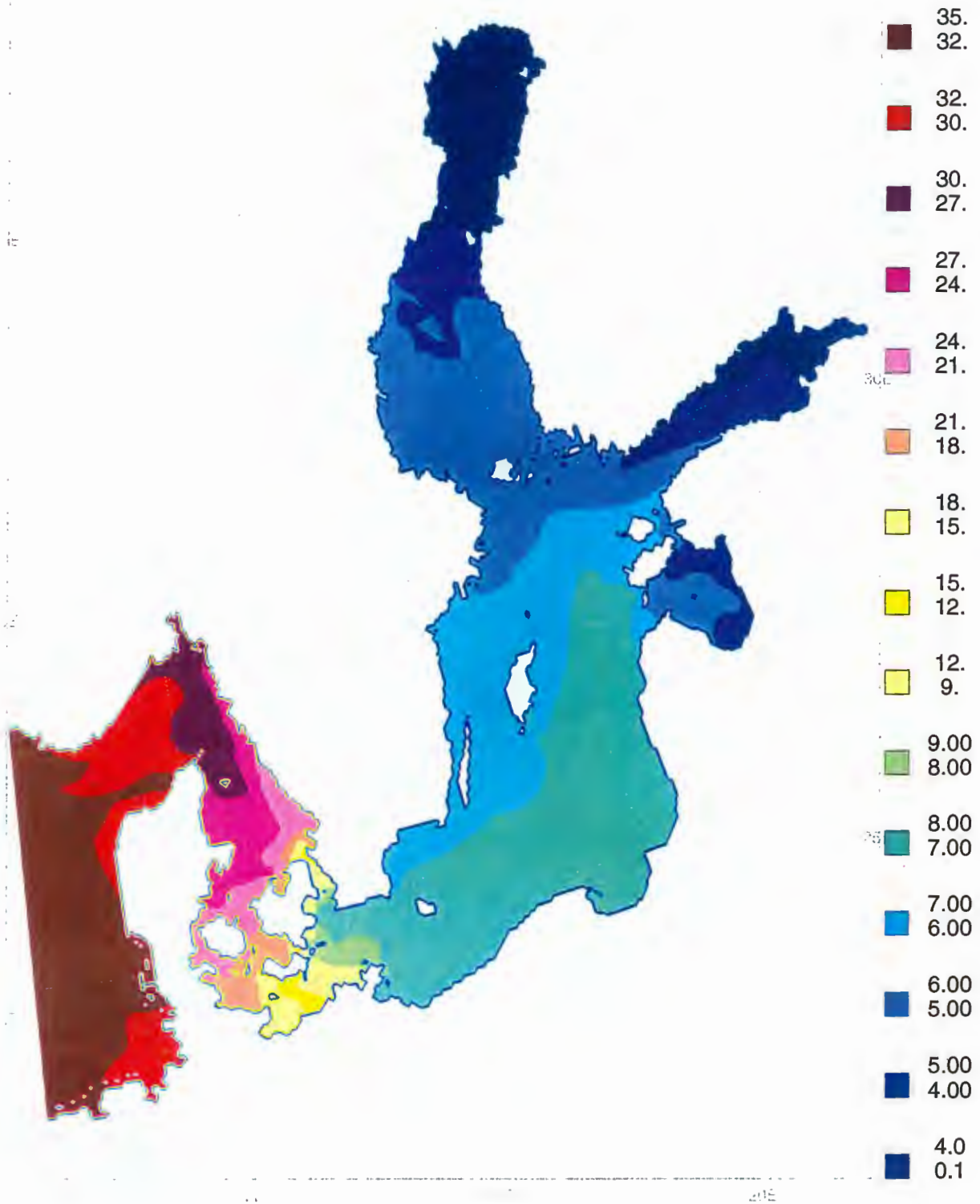


Figure 8. Mean surface salinity, august 1996

HIROMB mean surface-salinity November 1996

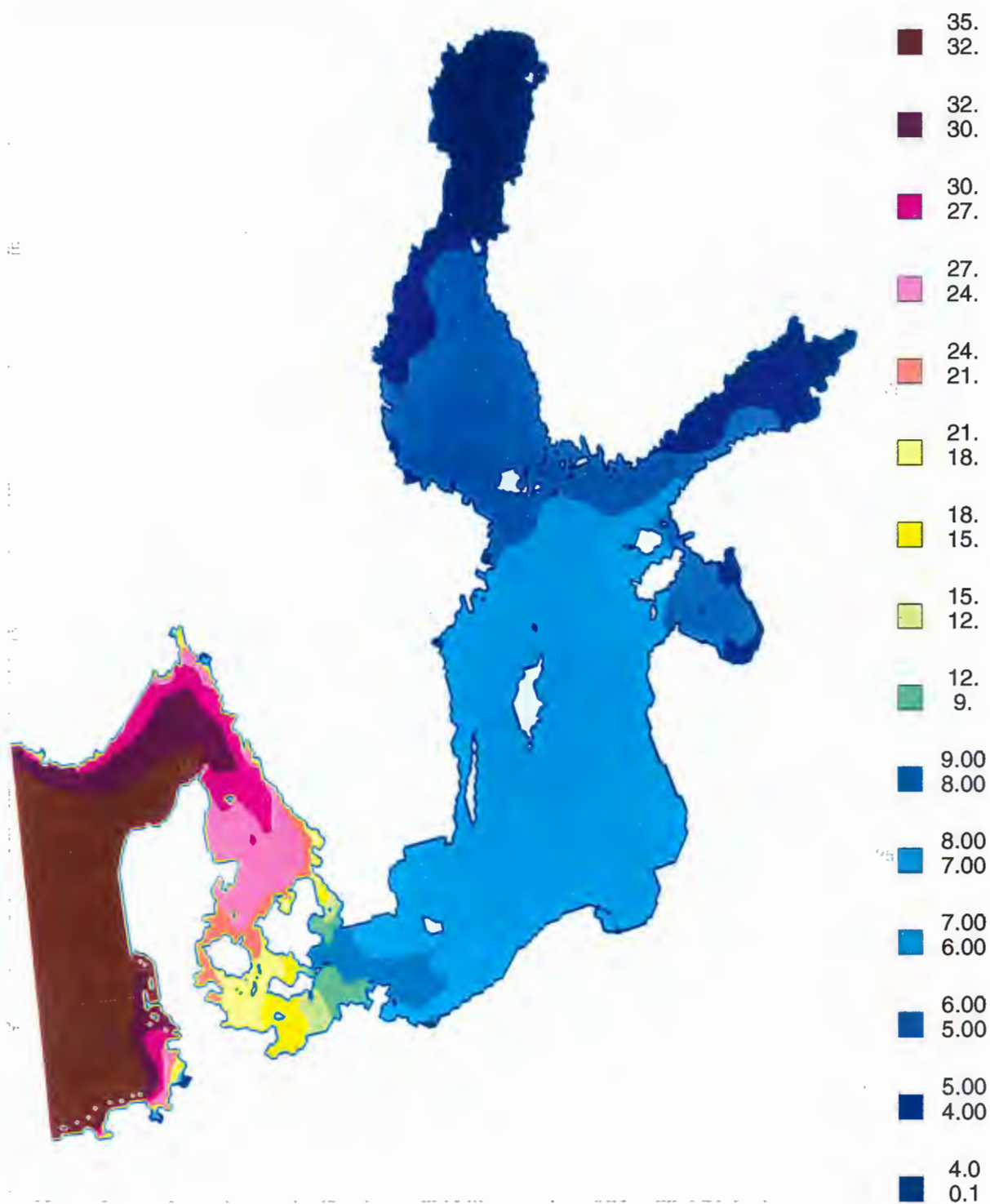


Figure 9. Mean surface salinity, november 1996

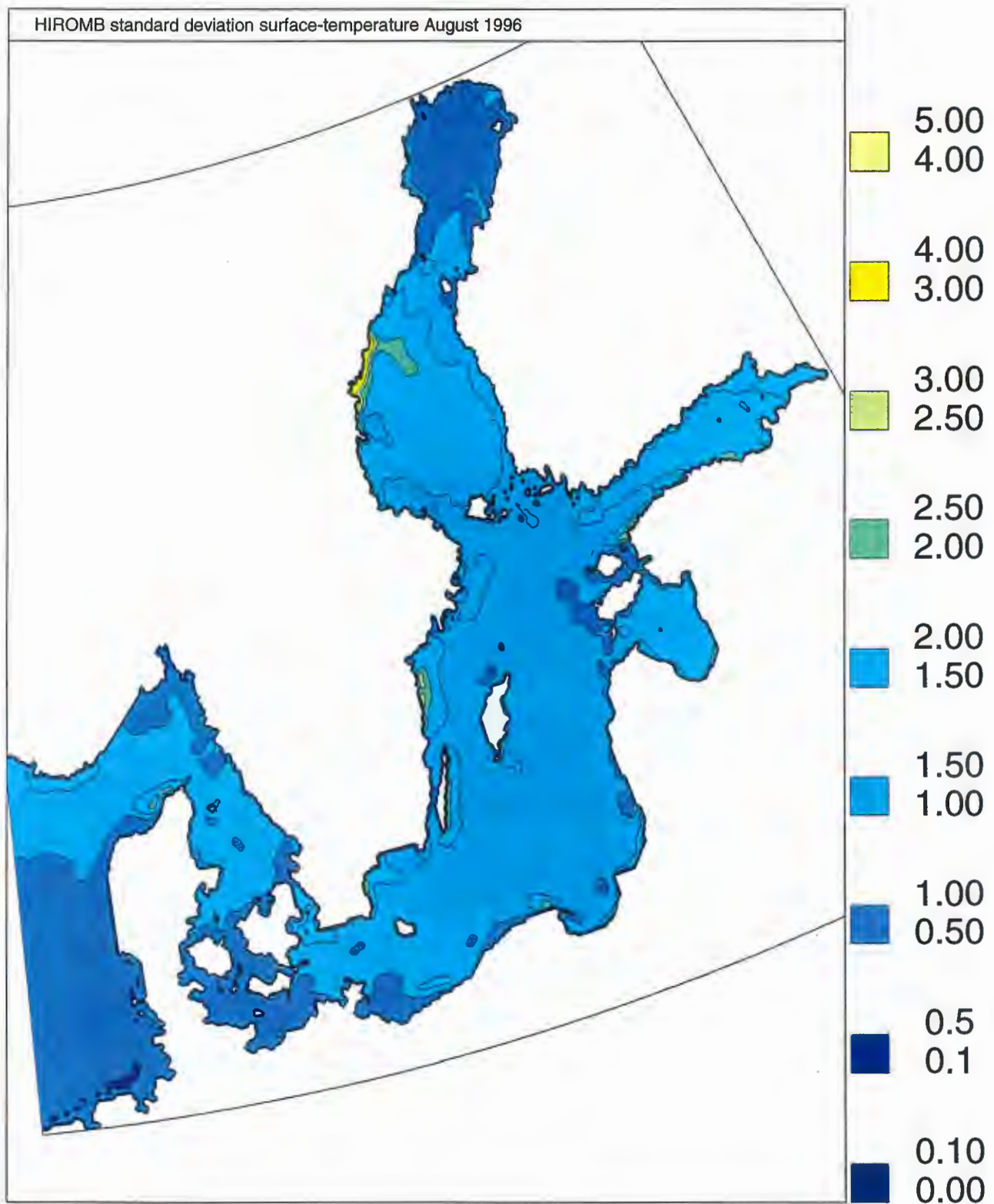


Figure 10. Standard deviation, surface temperature (colourscale, °C), august 1996



1996

HIROMB standard deviation surface-salinity August 1996

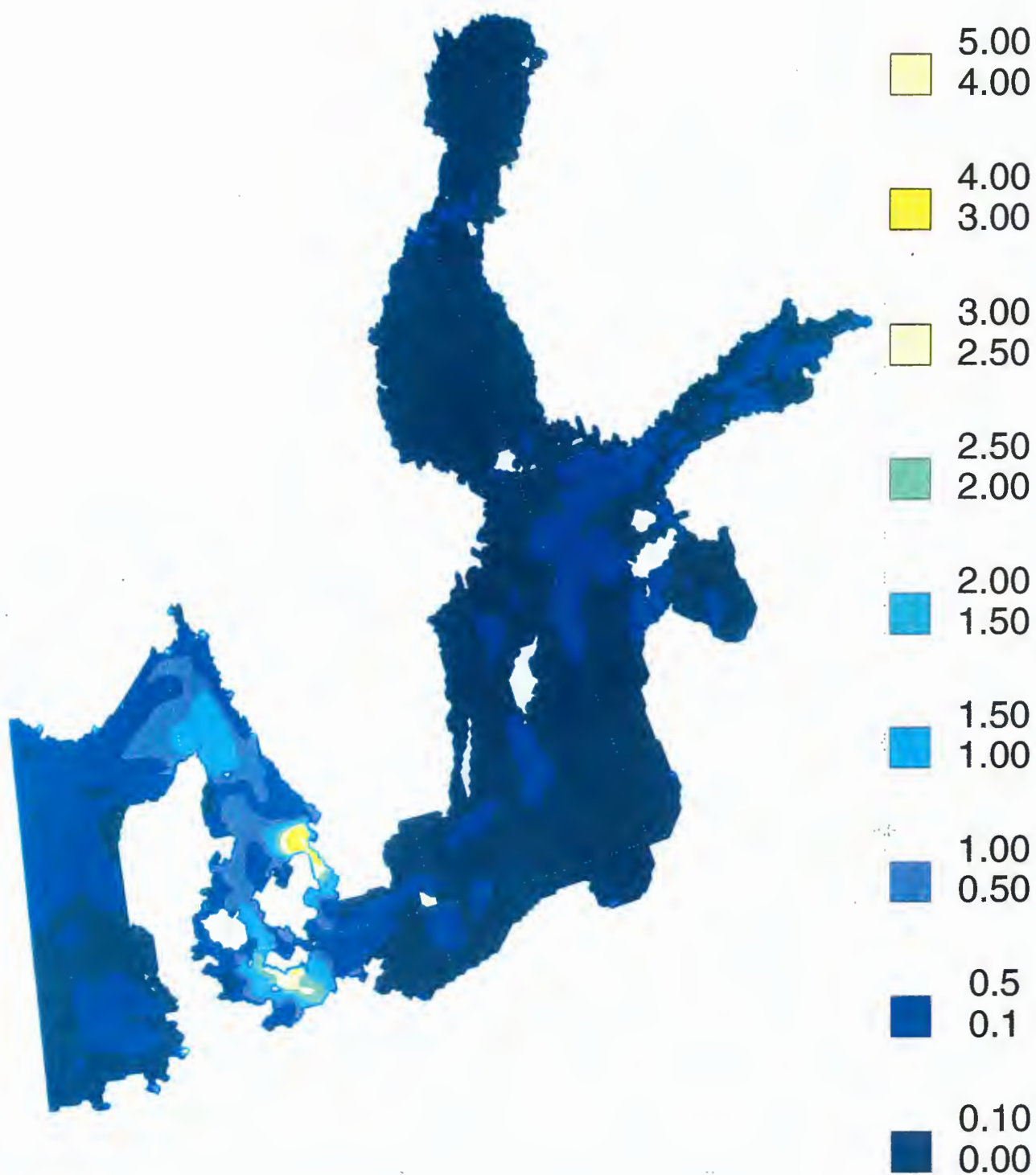


Figure 12. Standard deviation, surface salinity, august 1996

HIROMB standard deviation surface-salinity November 1996

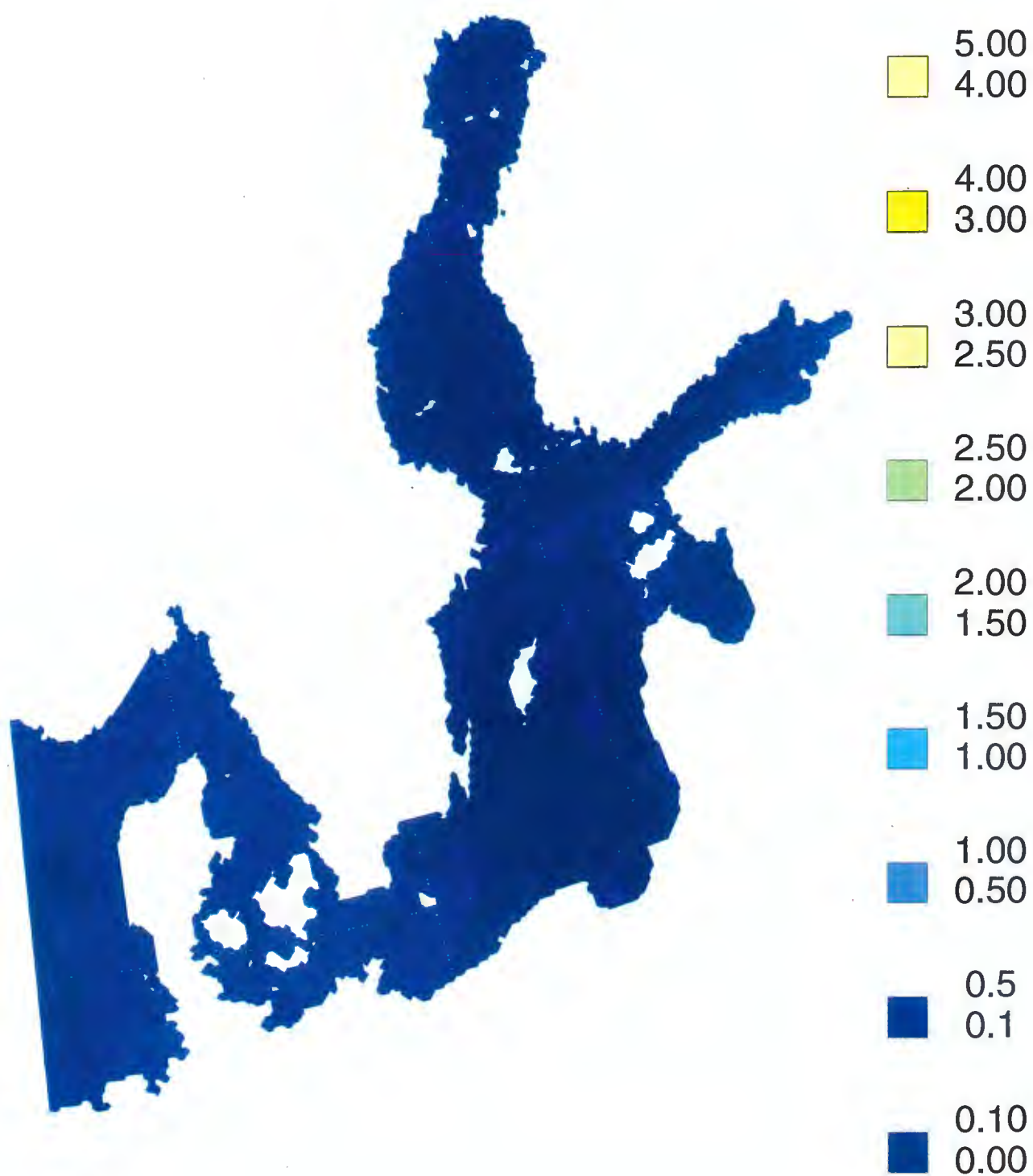


Figure 13. Standard deviation, surface salinity, november 1996

HIROMB standard deviation surface-salinity November 1996

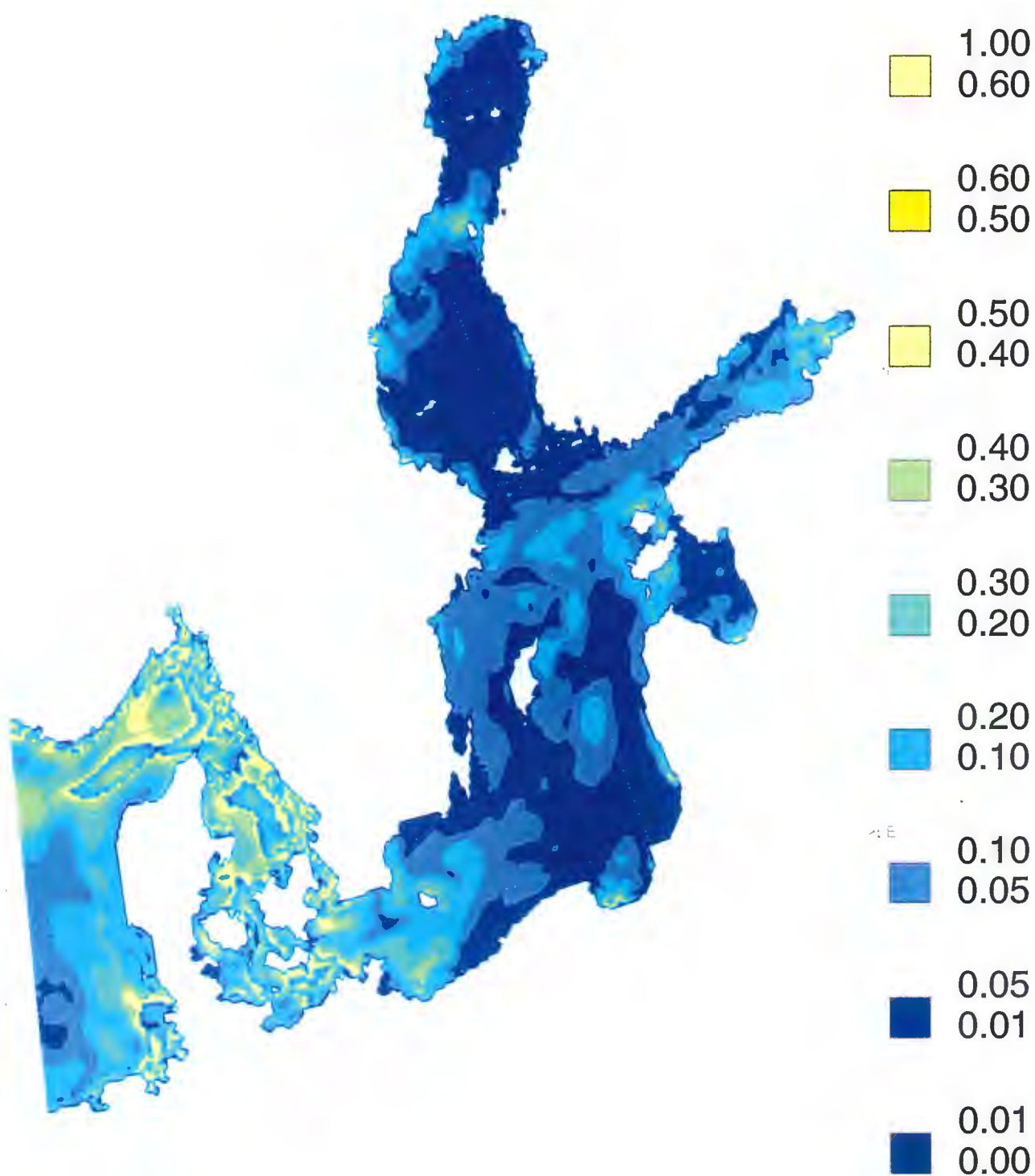


Figure 14. Standard deviation, surface salinity, november 1996 (finer scale)

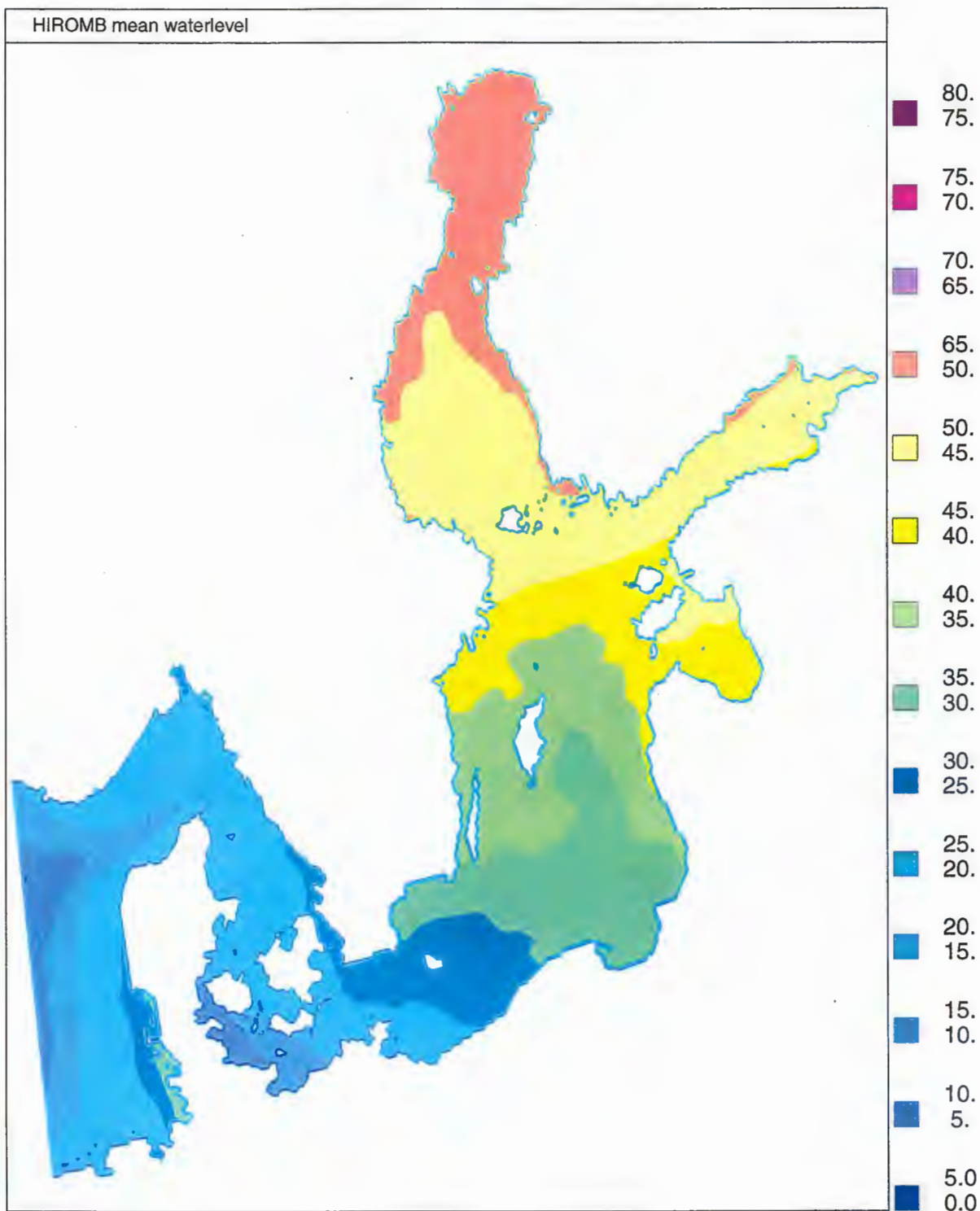


Figure 15. Mean waterlevel, november 1996

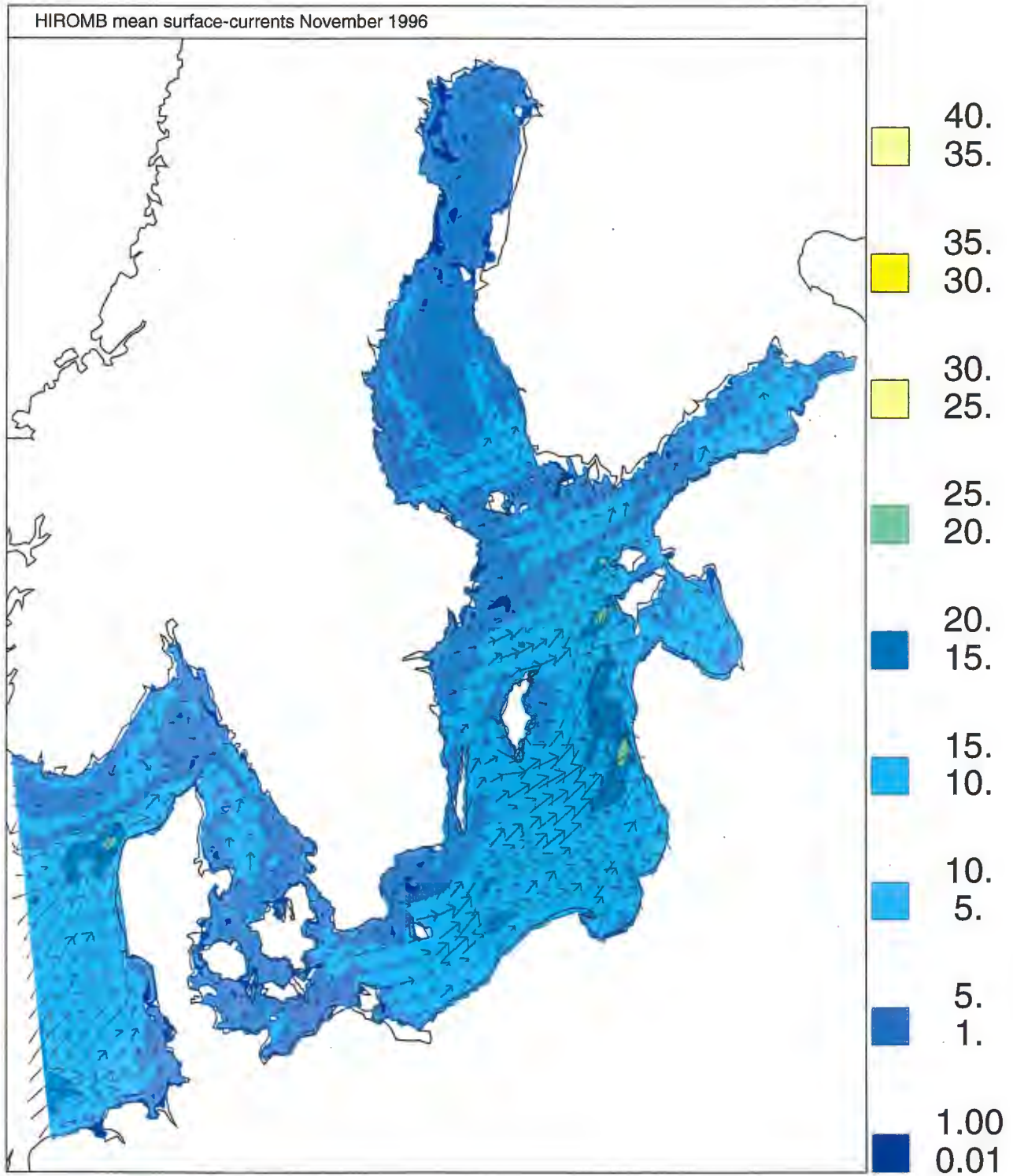


Figure 16. Mean surface current (every 5th arrow), november 1996

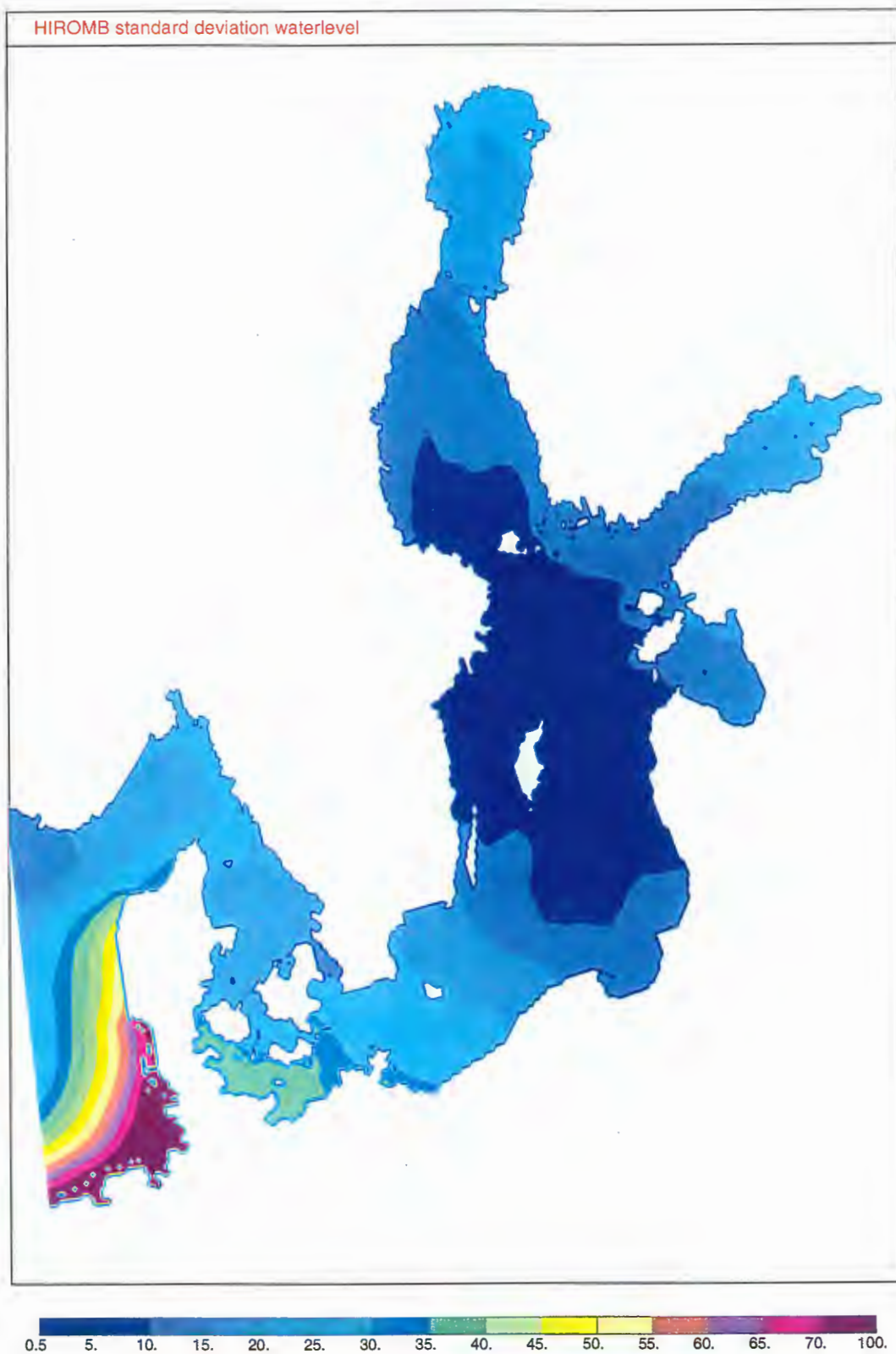


Figure 17. Standard deviation, waterlevel, november 1996

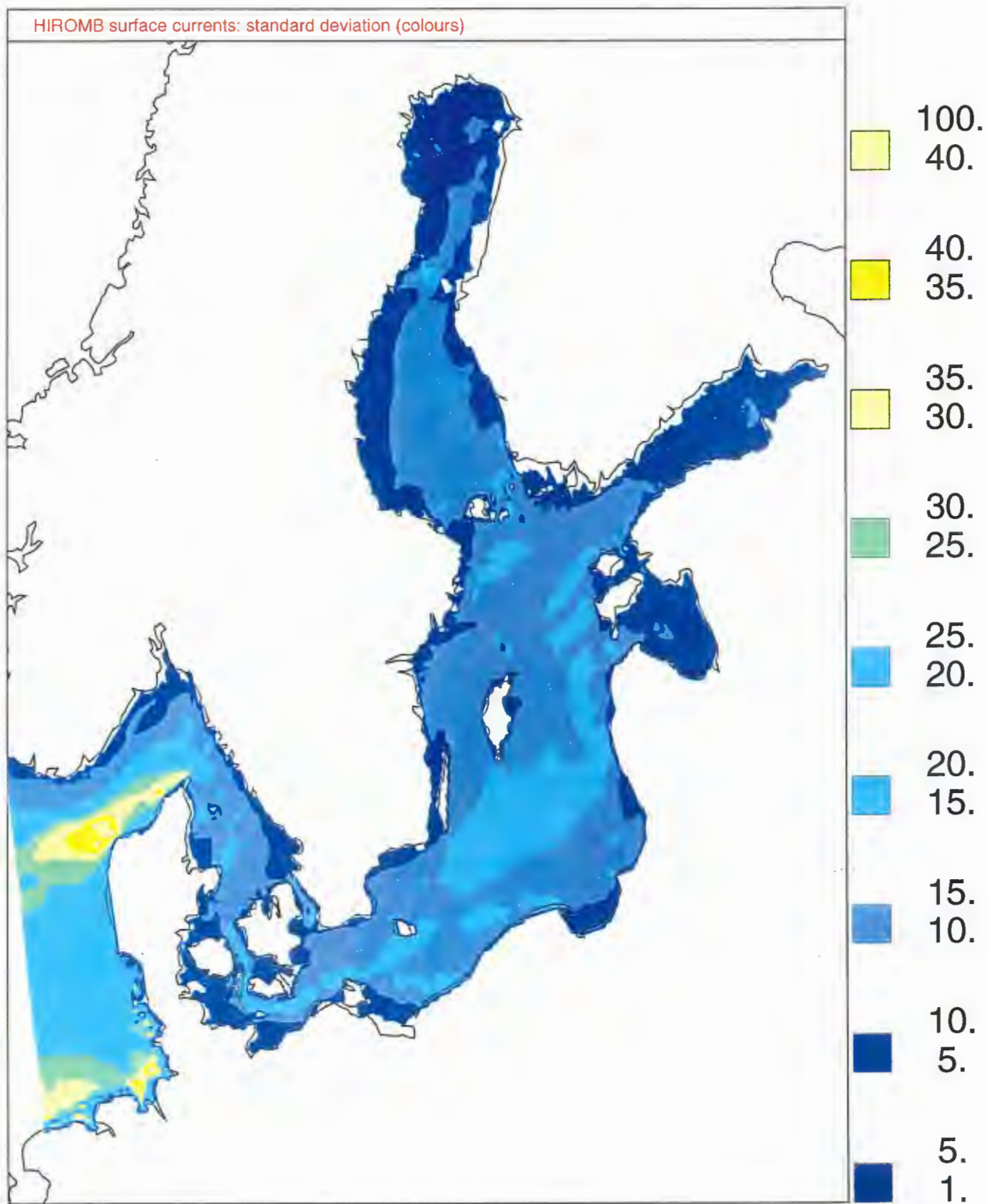


Figure 18. Standard deviation, surface current, november 1996

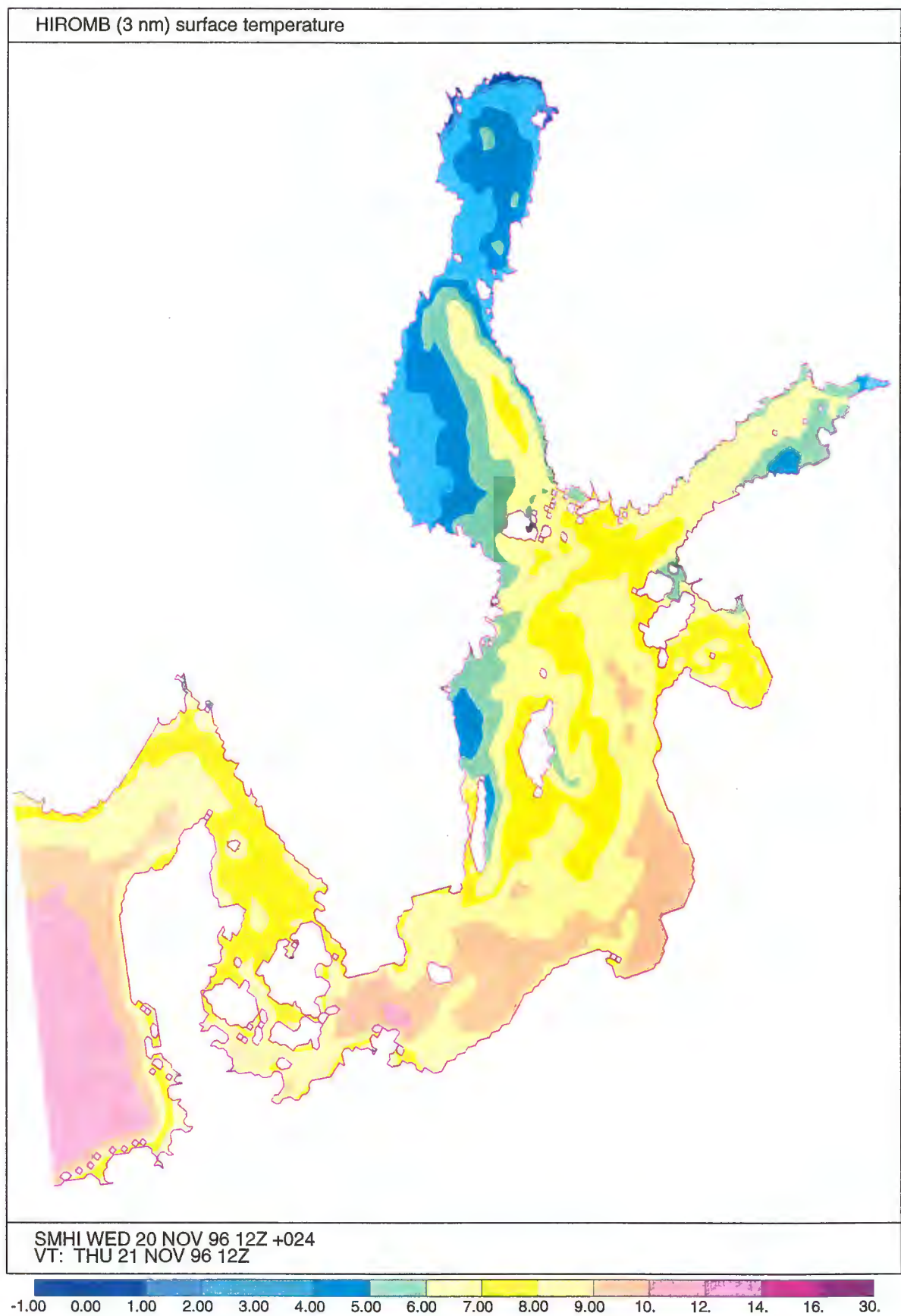


Figure 19b. HIROMB SST field from 21. november

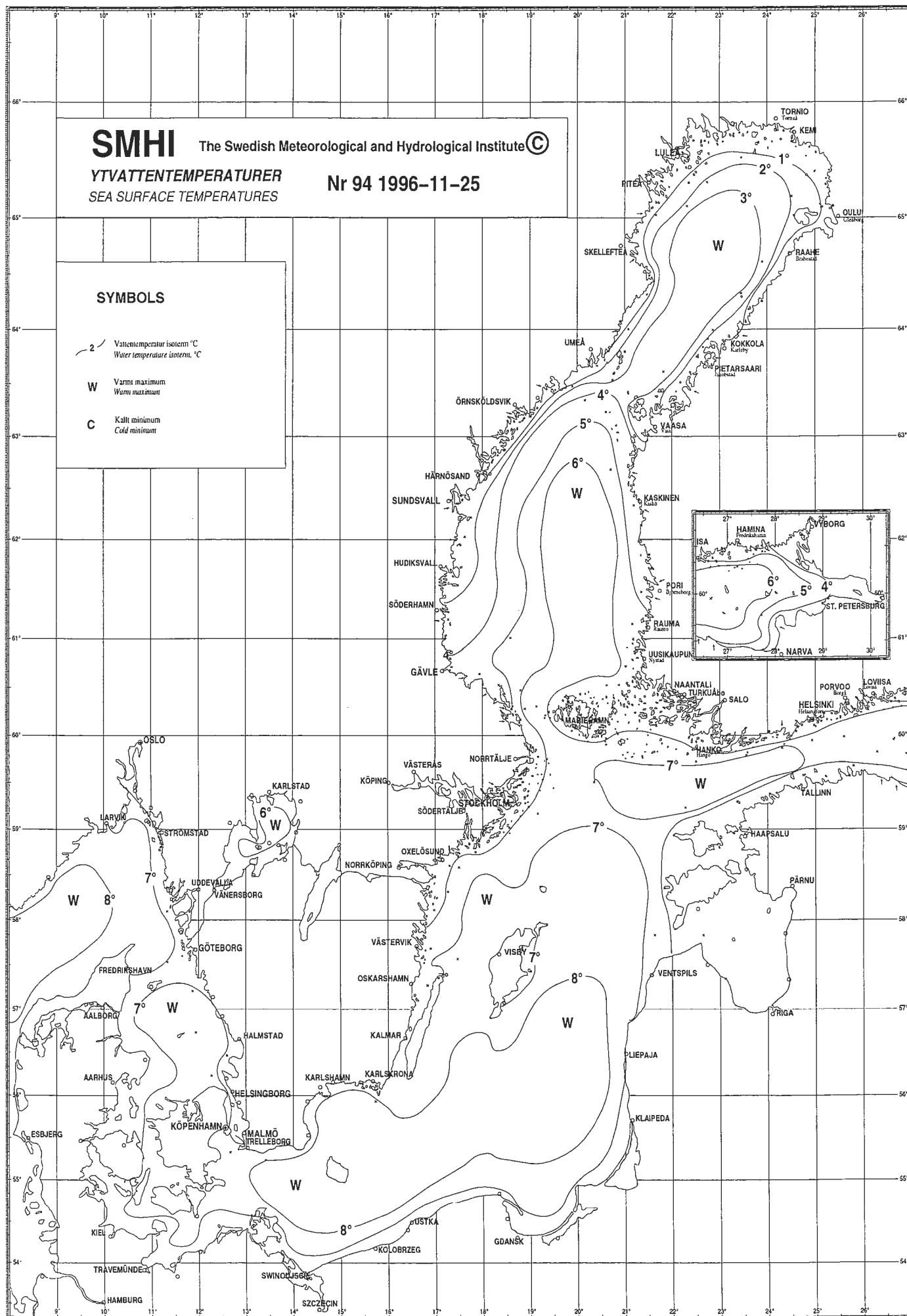


Figure 20a. SST and ice map from 25. november

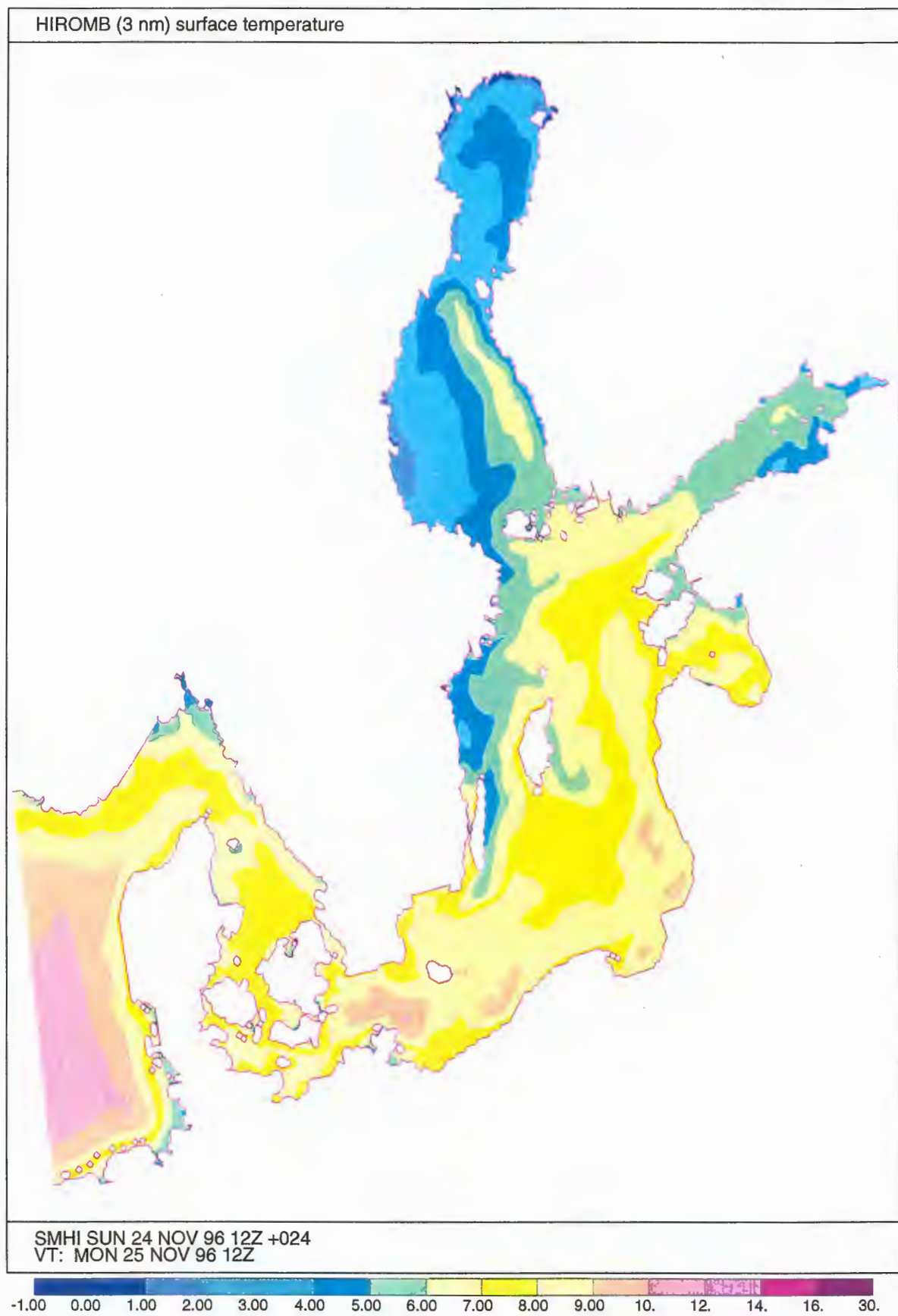


Figure 20b. HIROMB SST field from 25. november

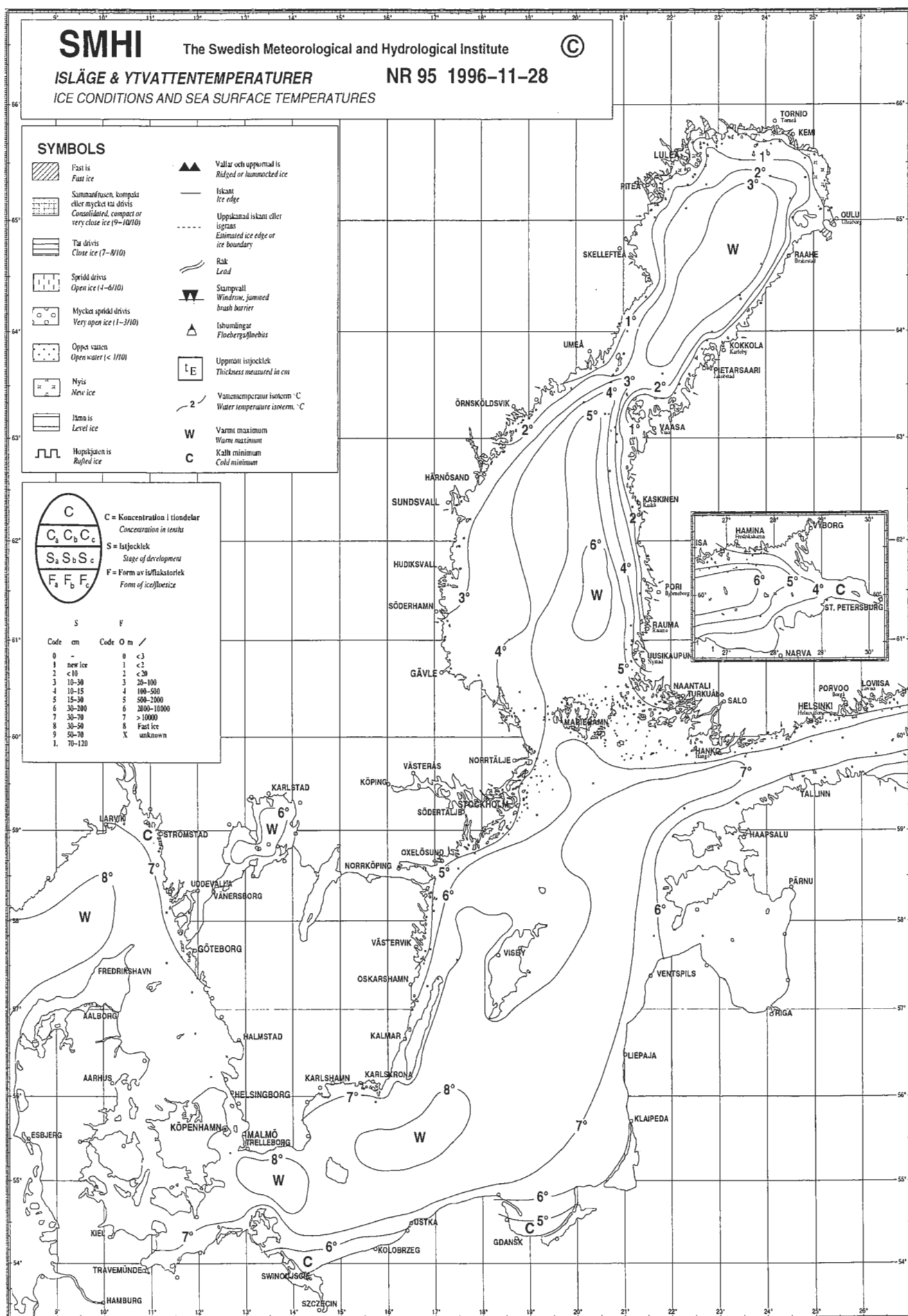


Figure 21a. SST and ice map from 28. november

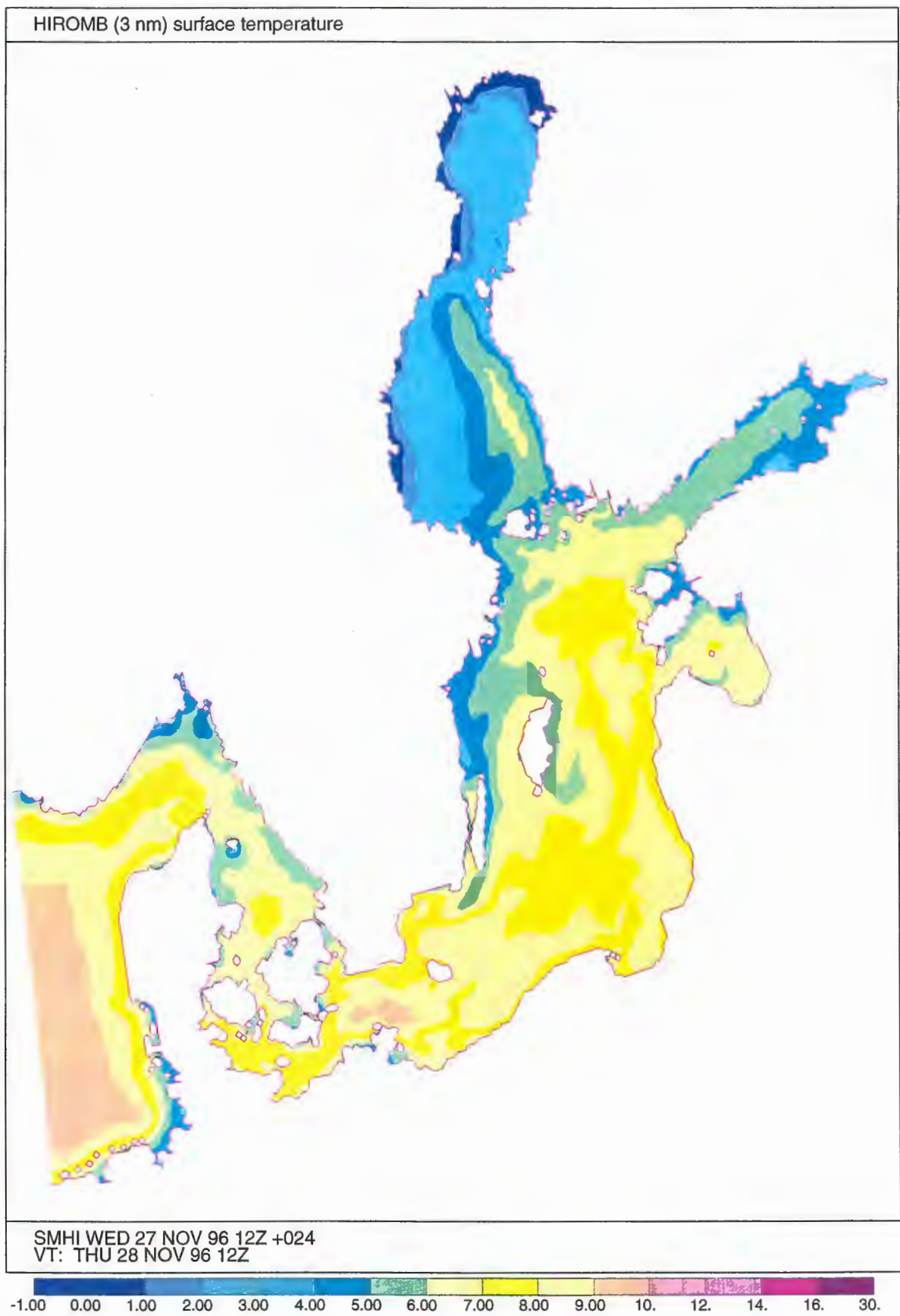


Figure 21b. HIROMB SST field from 28. november

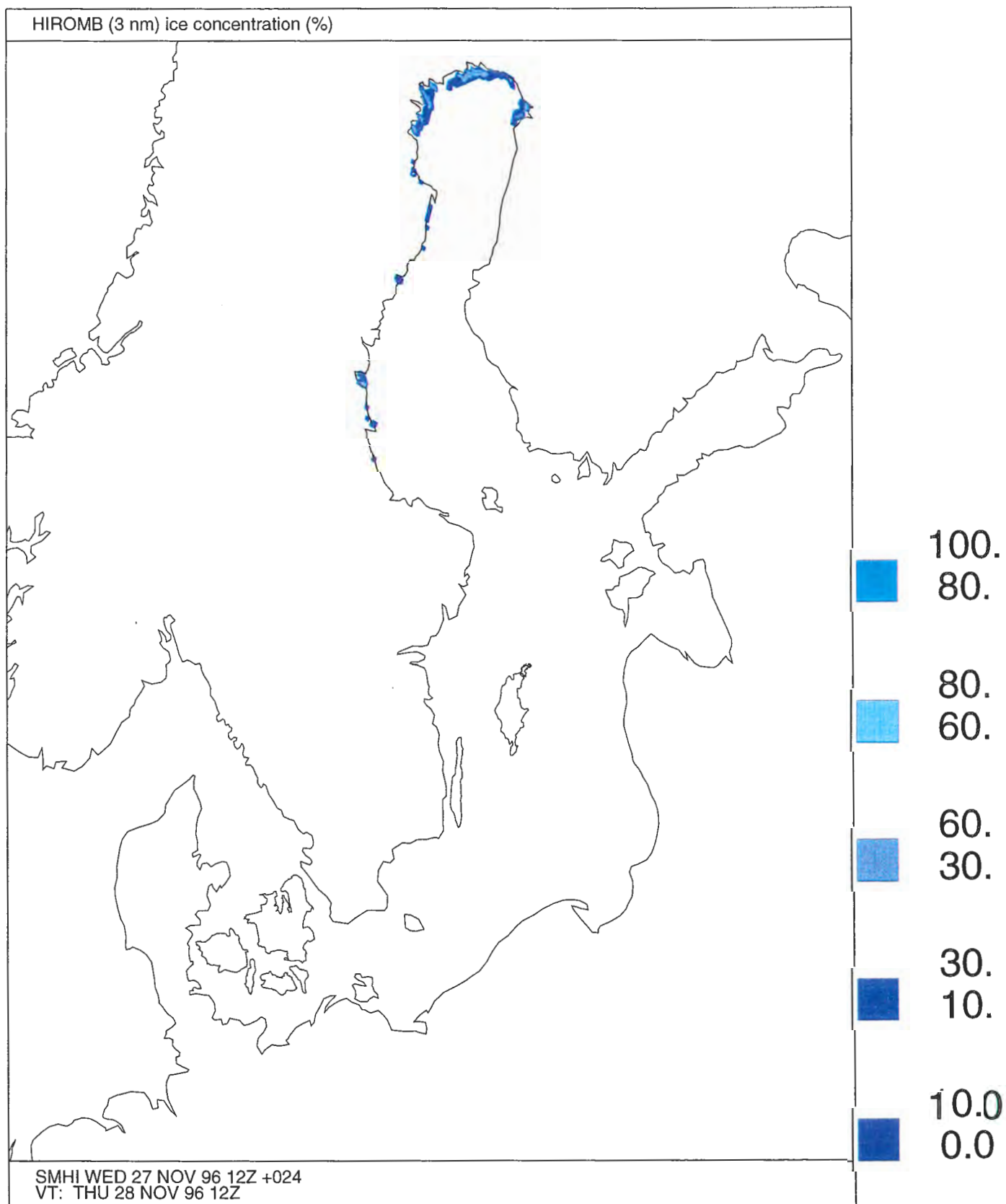


Figure 21c. HIROMB ice field from 28. november

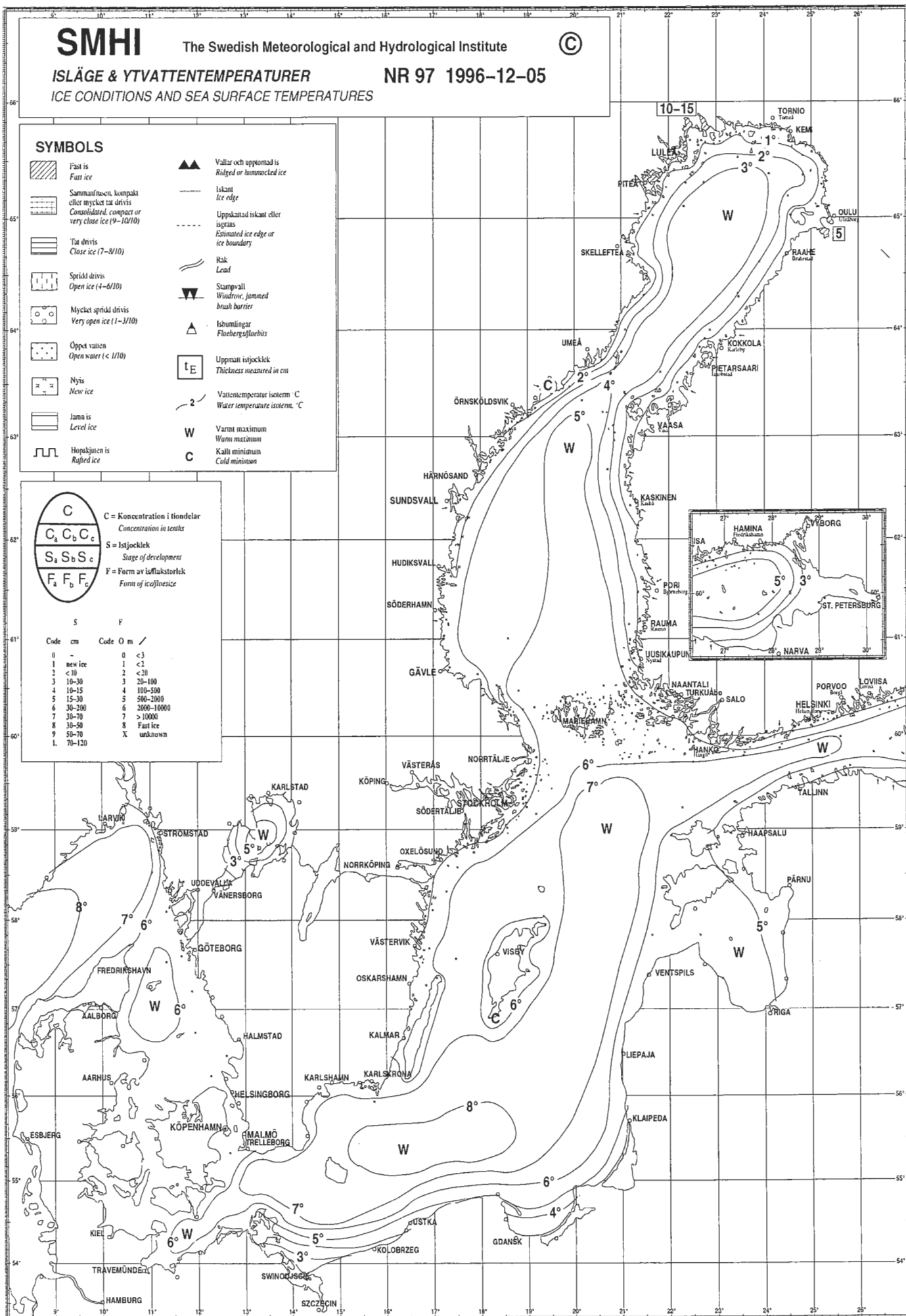


Figure 22a. SST and ice map from 5. december

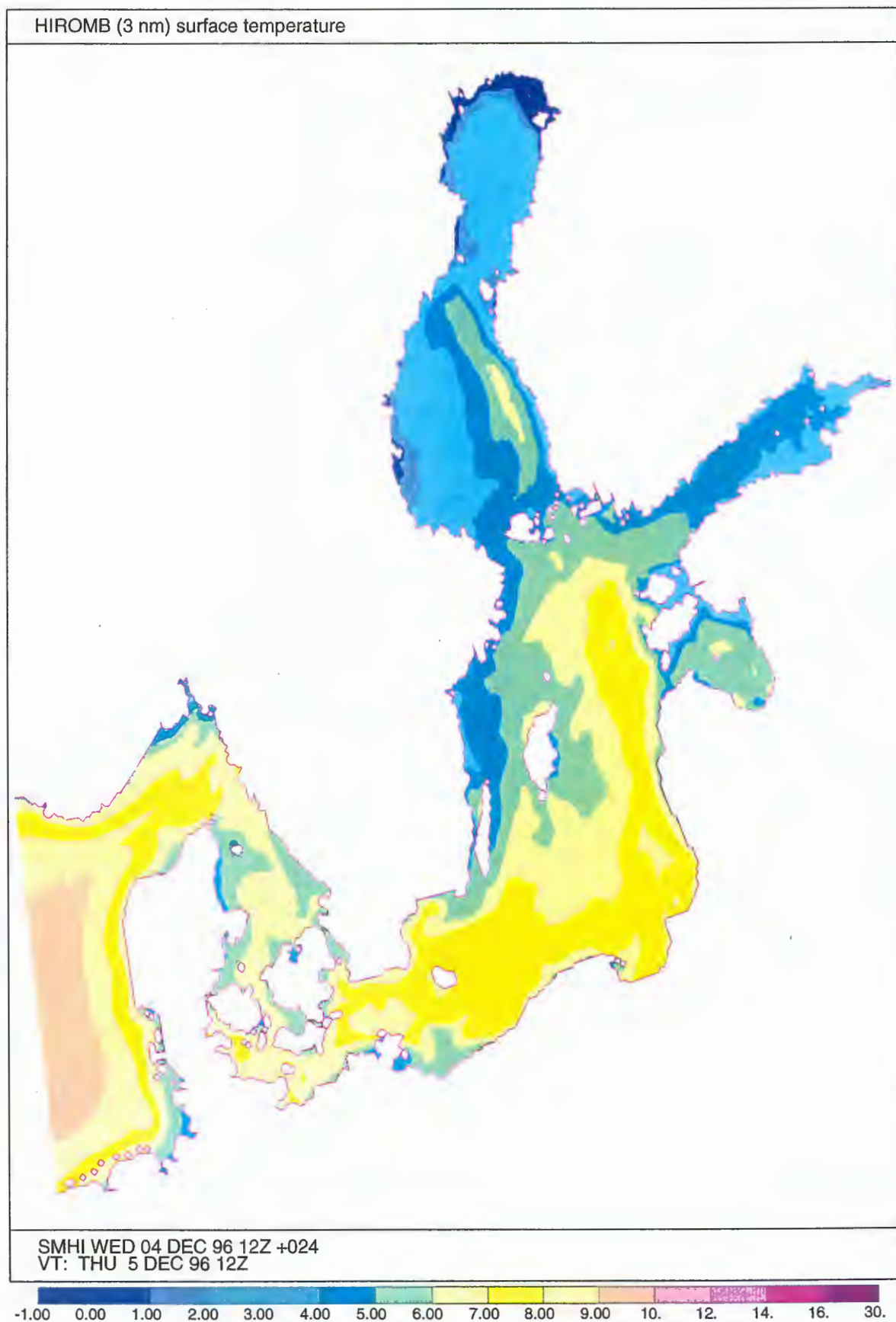


Figure 22b. HIROMB SST field from 5. december

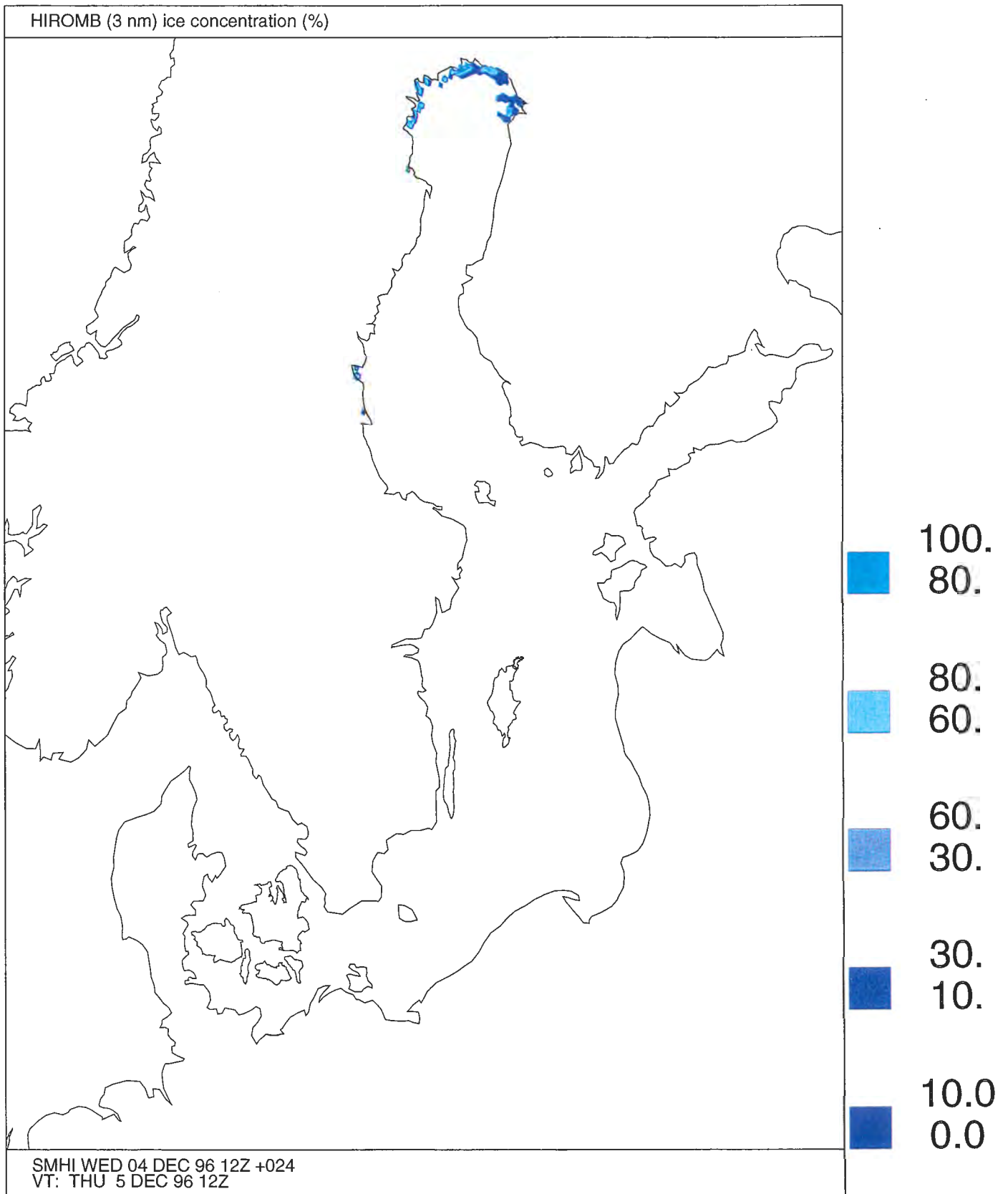


Figure 22c. HIROMB ice field from 5. december

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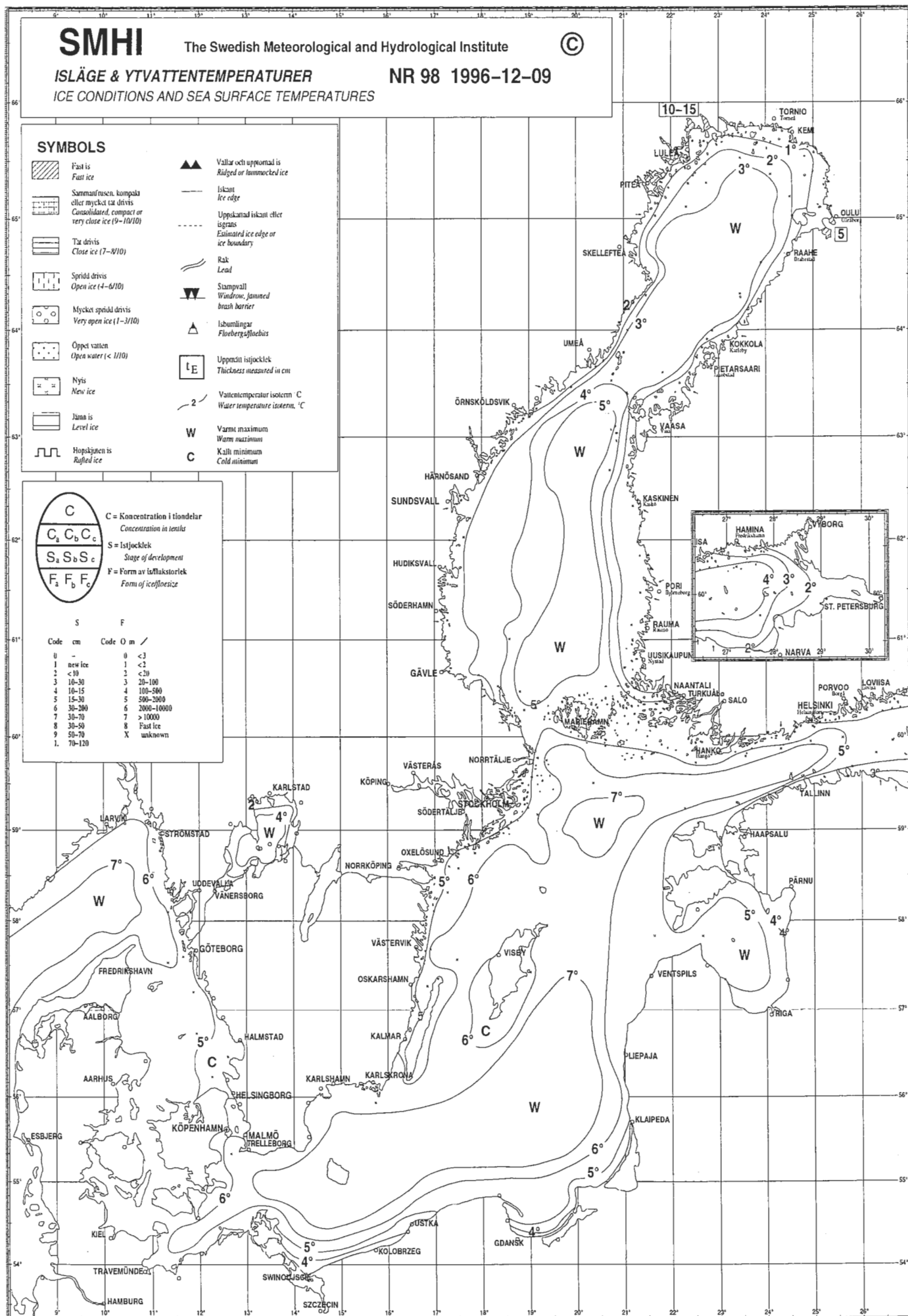


Figure 23a. SST and ice map from 9. december

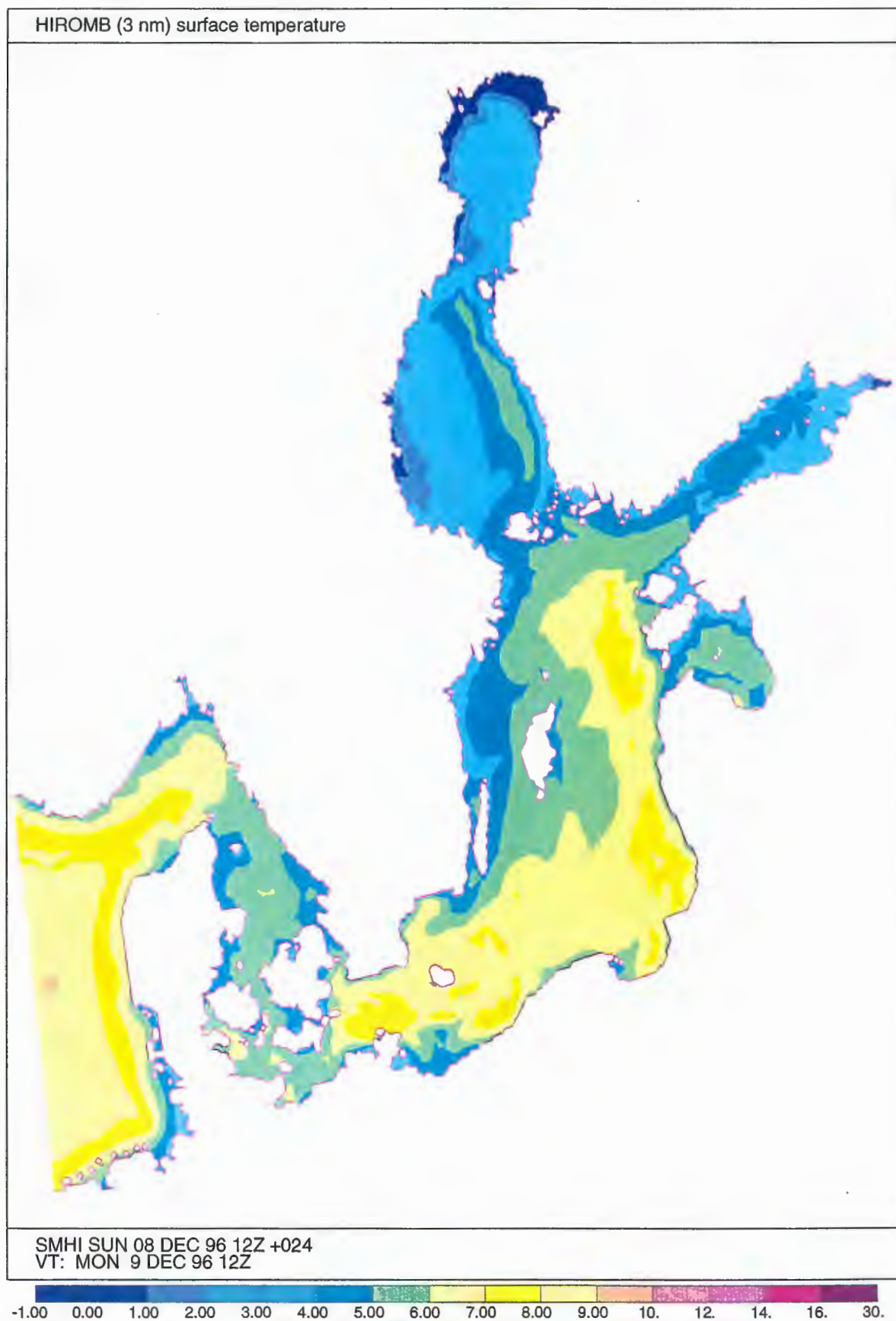


Figure 23b. HIROMB SST field from 9. december

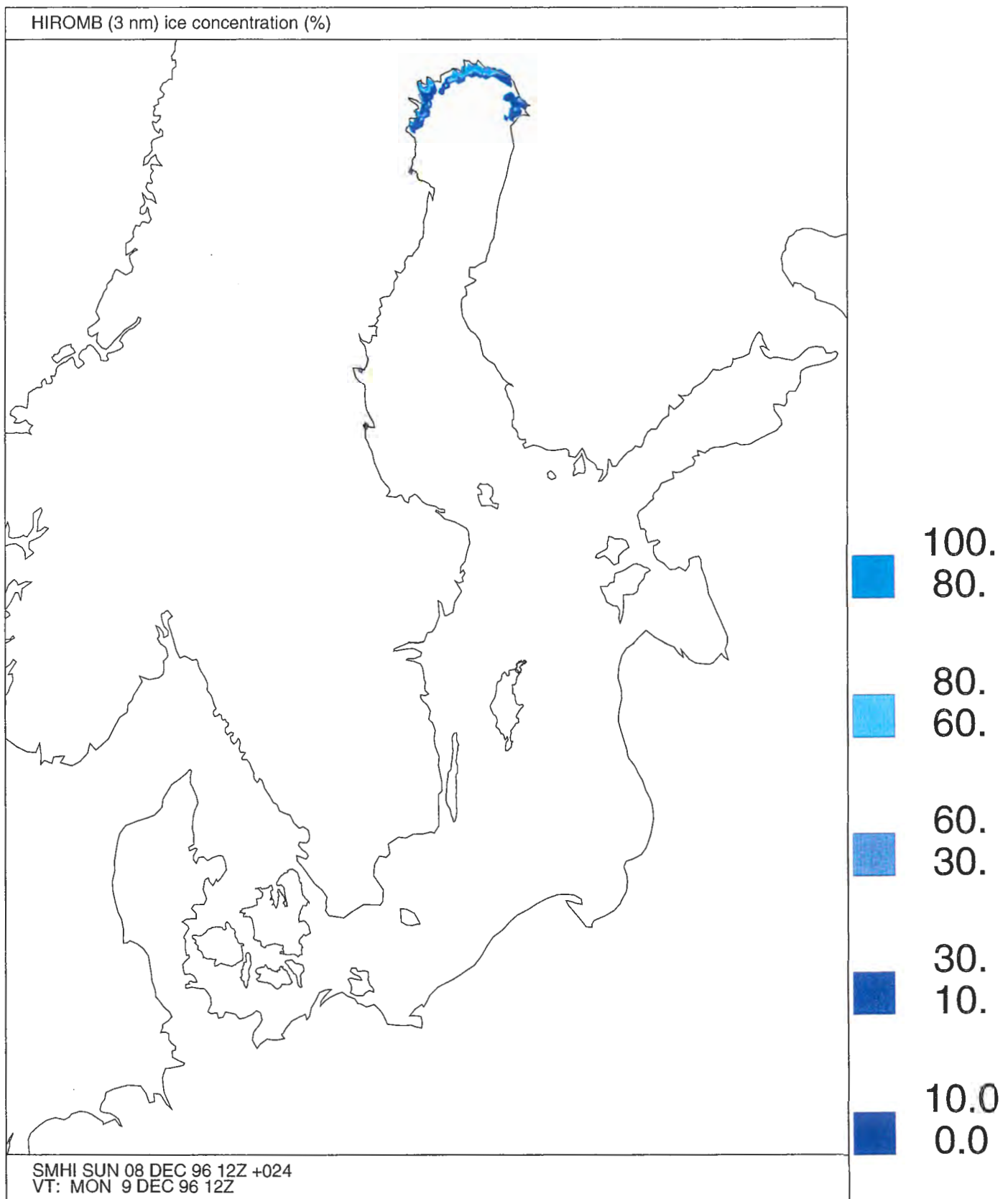


Figure 23c. HIROMB ice field from 9. december

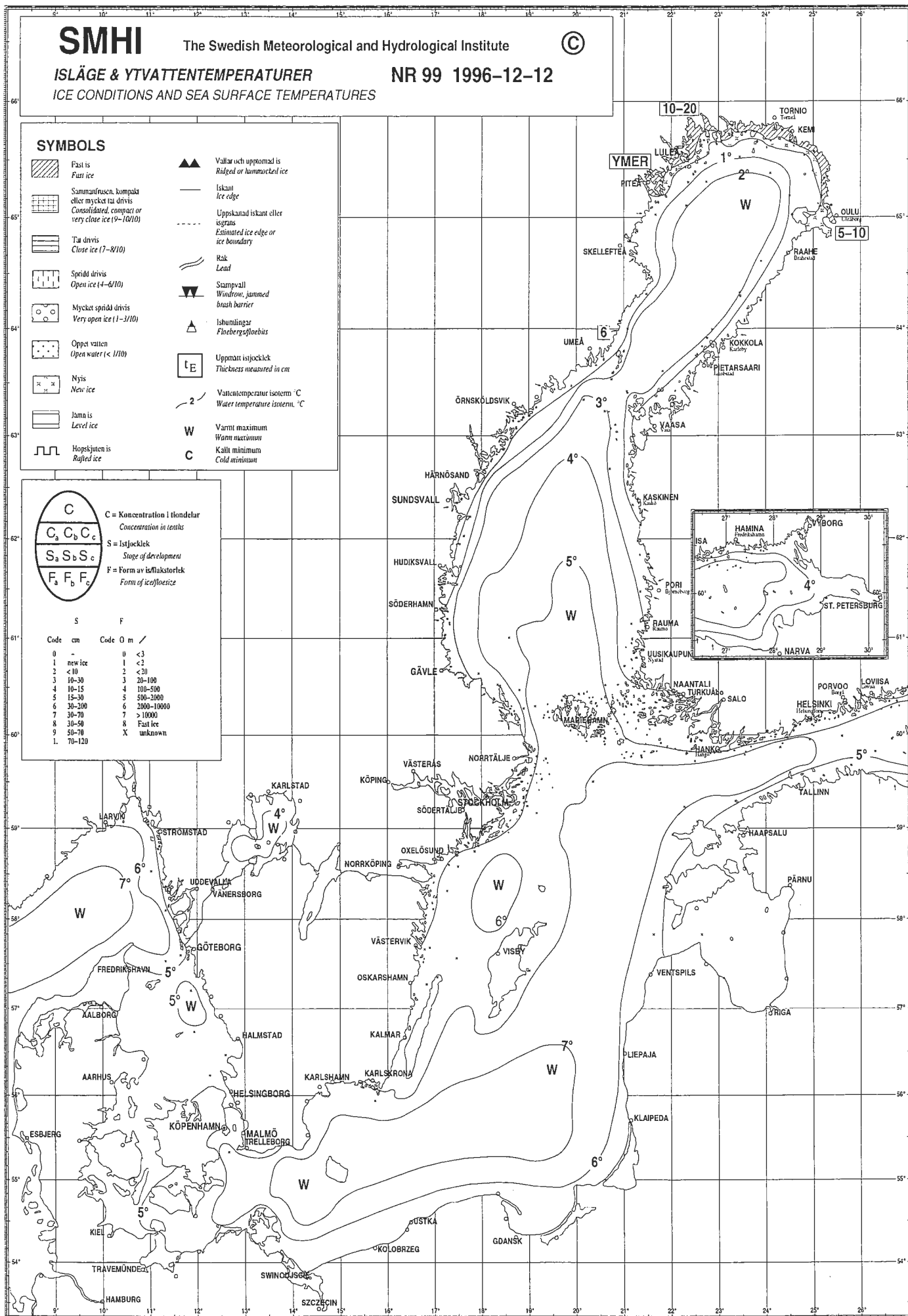


Figure 24a. SST and ice map from 12. december

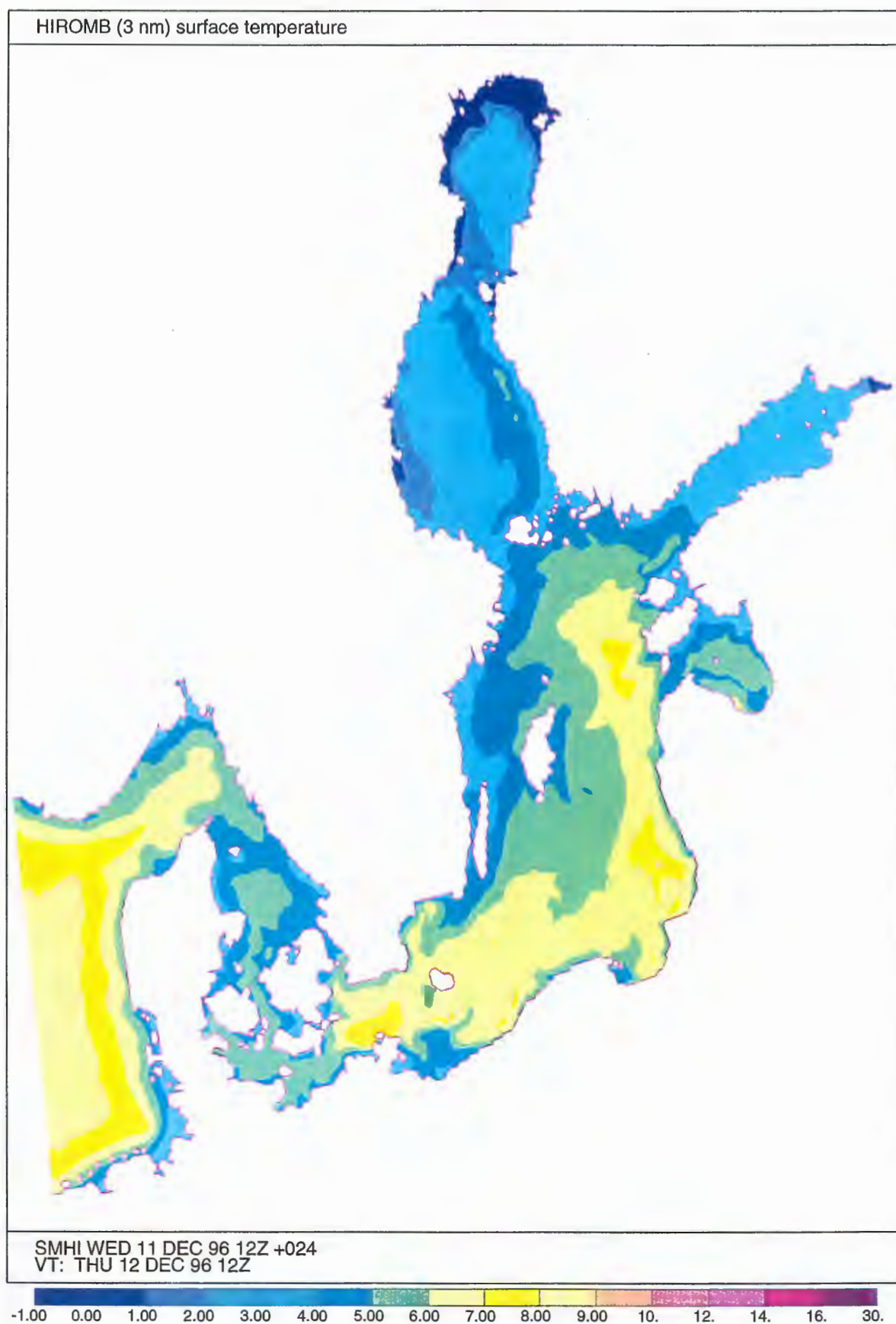


Figure 24b. HIROMB SST field from 12. december

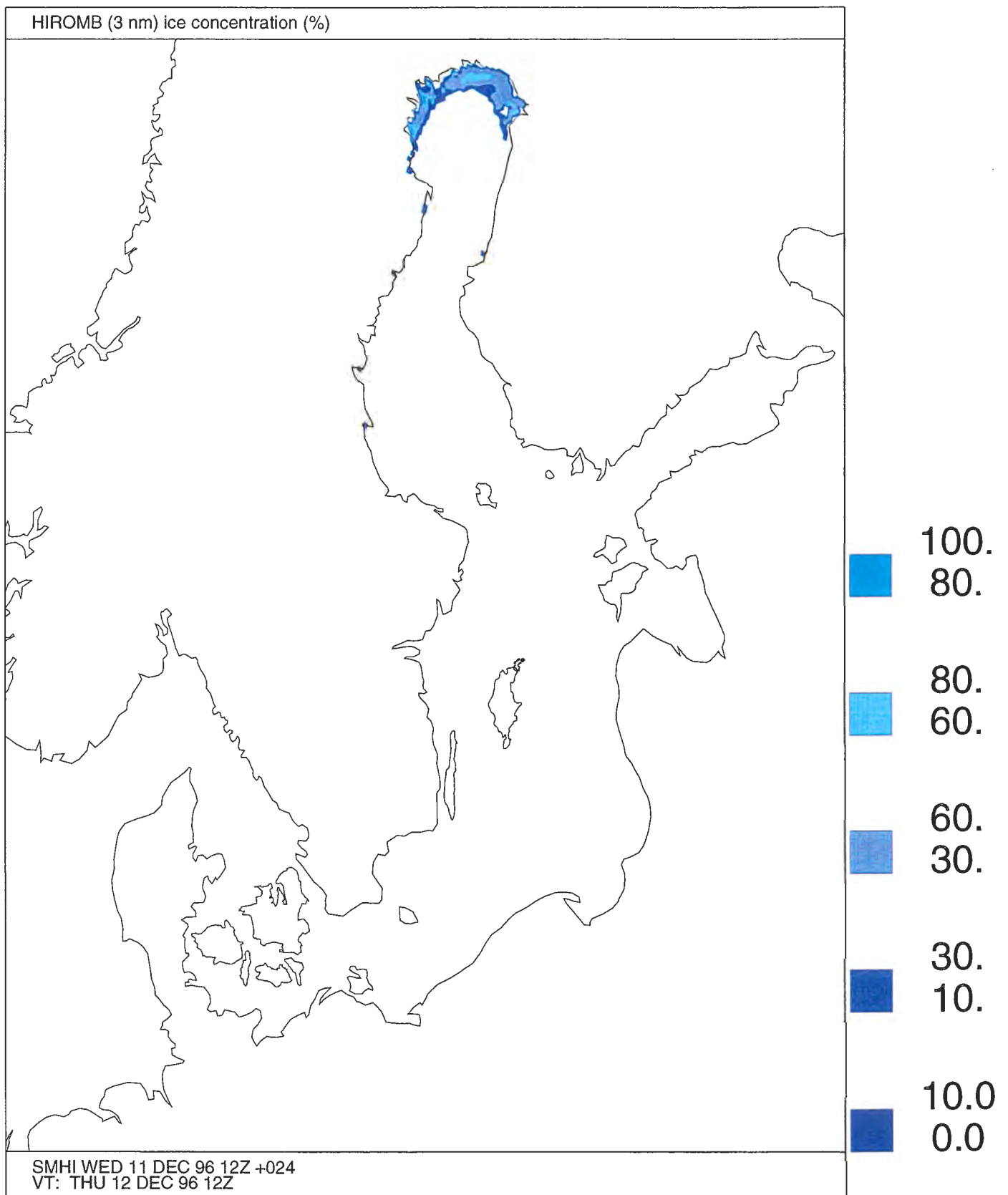


Figure 24c. HIROMB ice field from 12. december

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**ISLÄGE & YTVATTENTEMPERATURER****NR 100 1996-12-16**

ICE CONDITIONS AND SEA SURFACE TEMPERATURES

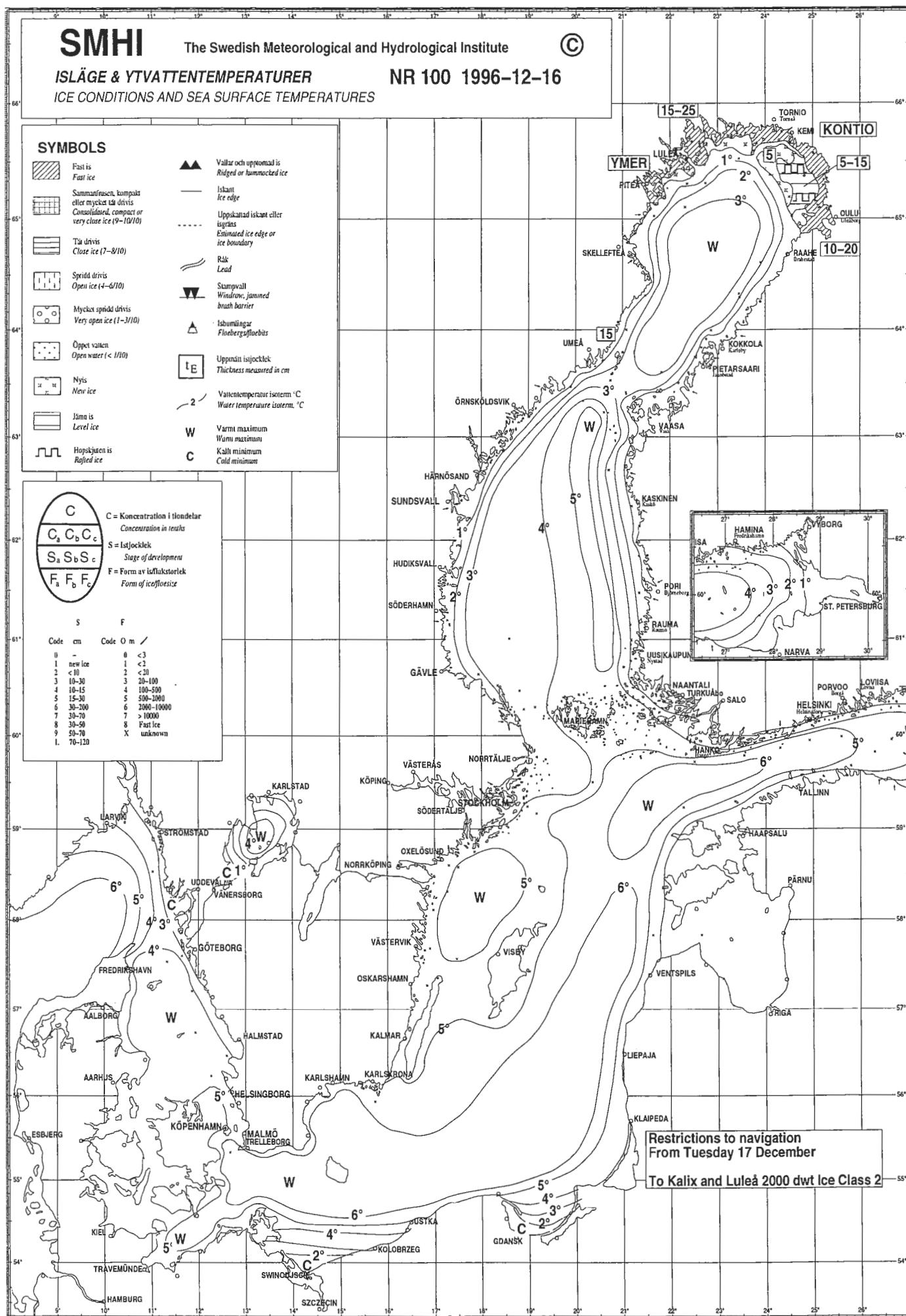


Figure 25a. SST and ice map from 16. december

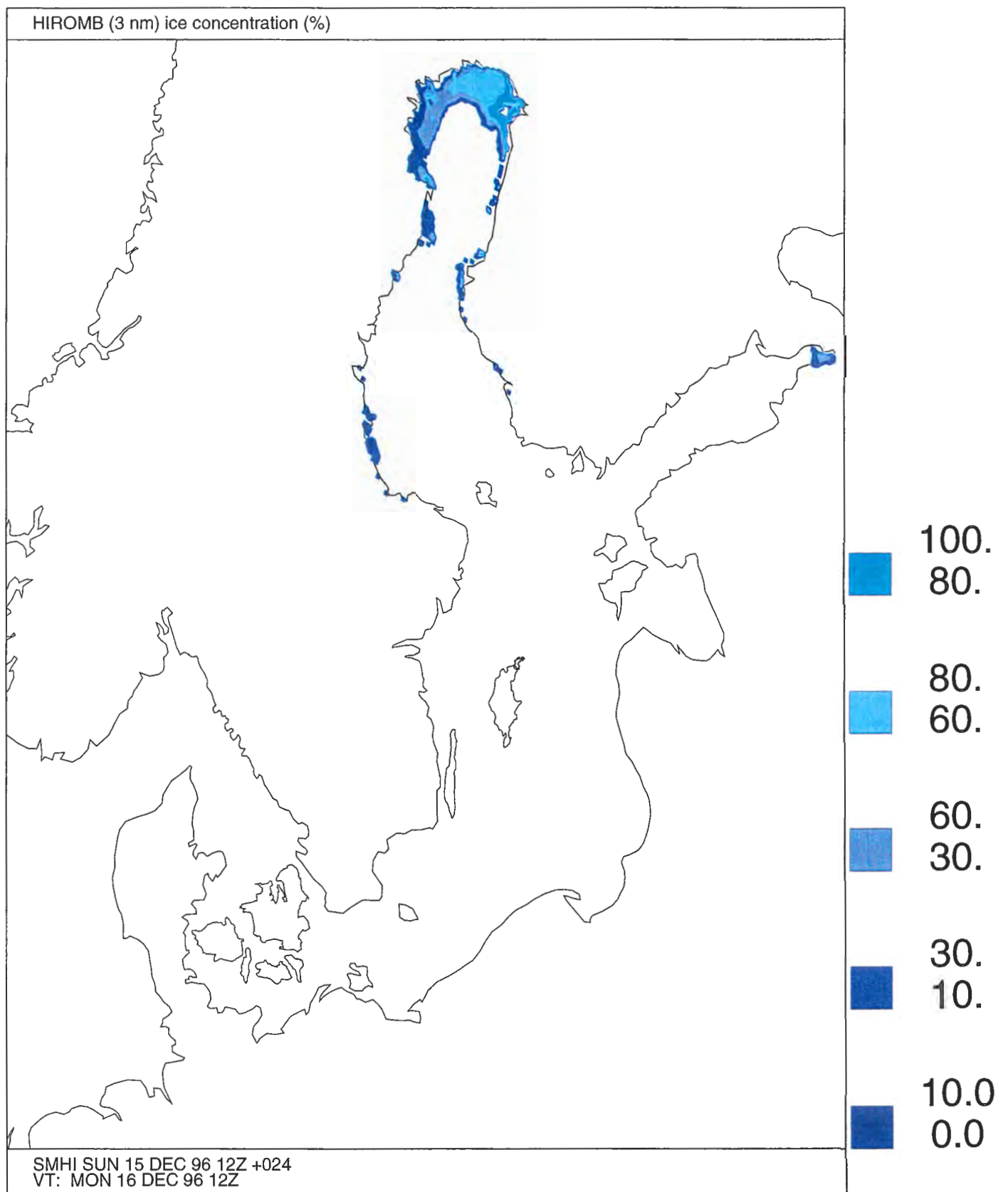


Figure 25c. HIROMB ice field from 16. december

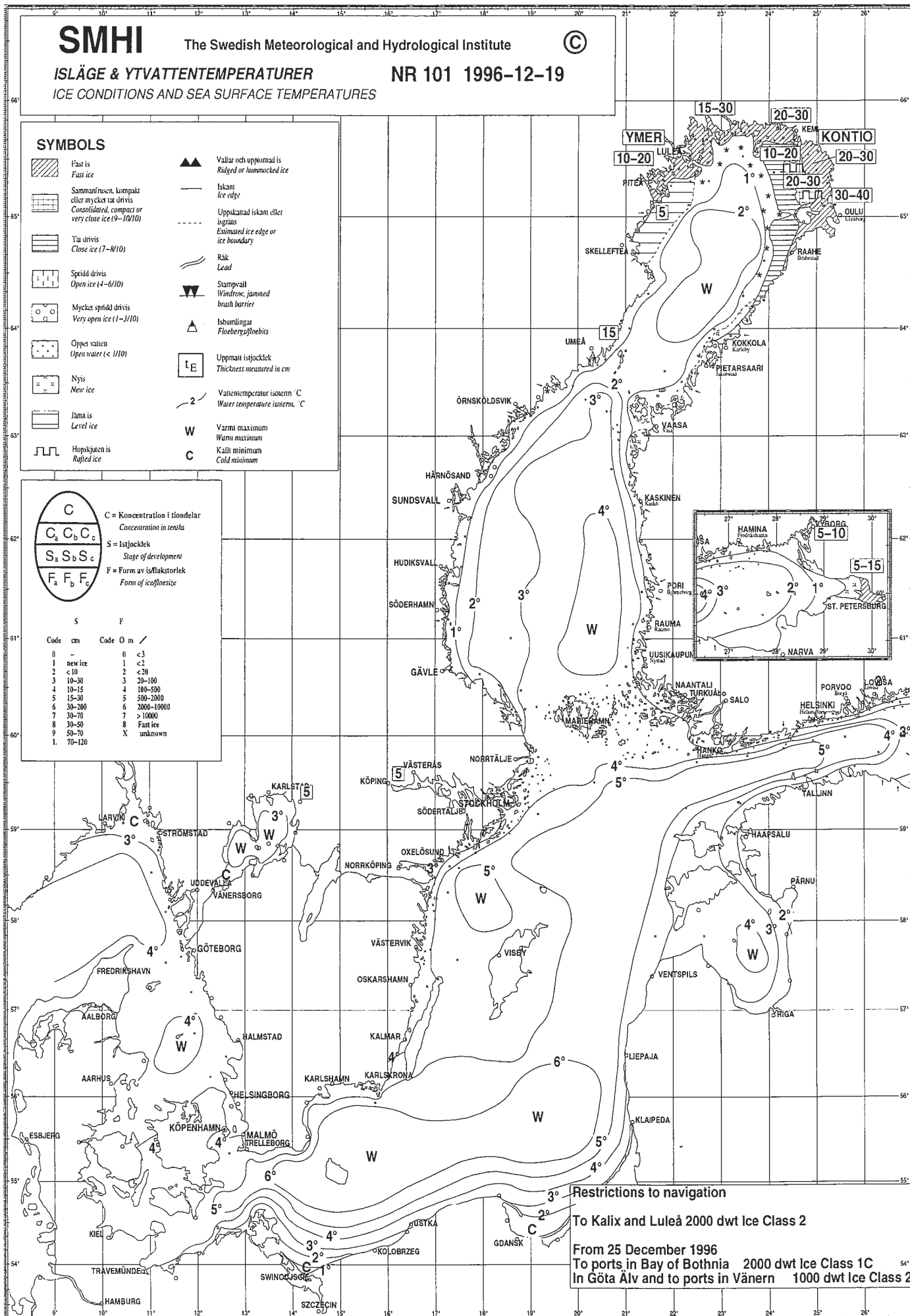


Figure 26a. SST and ice map from 19. december

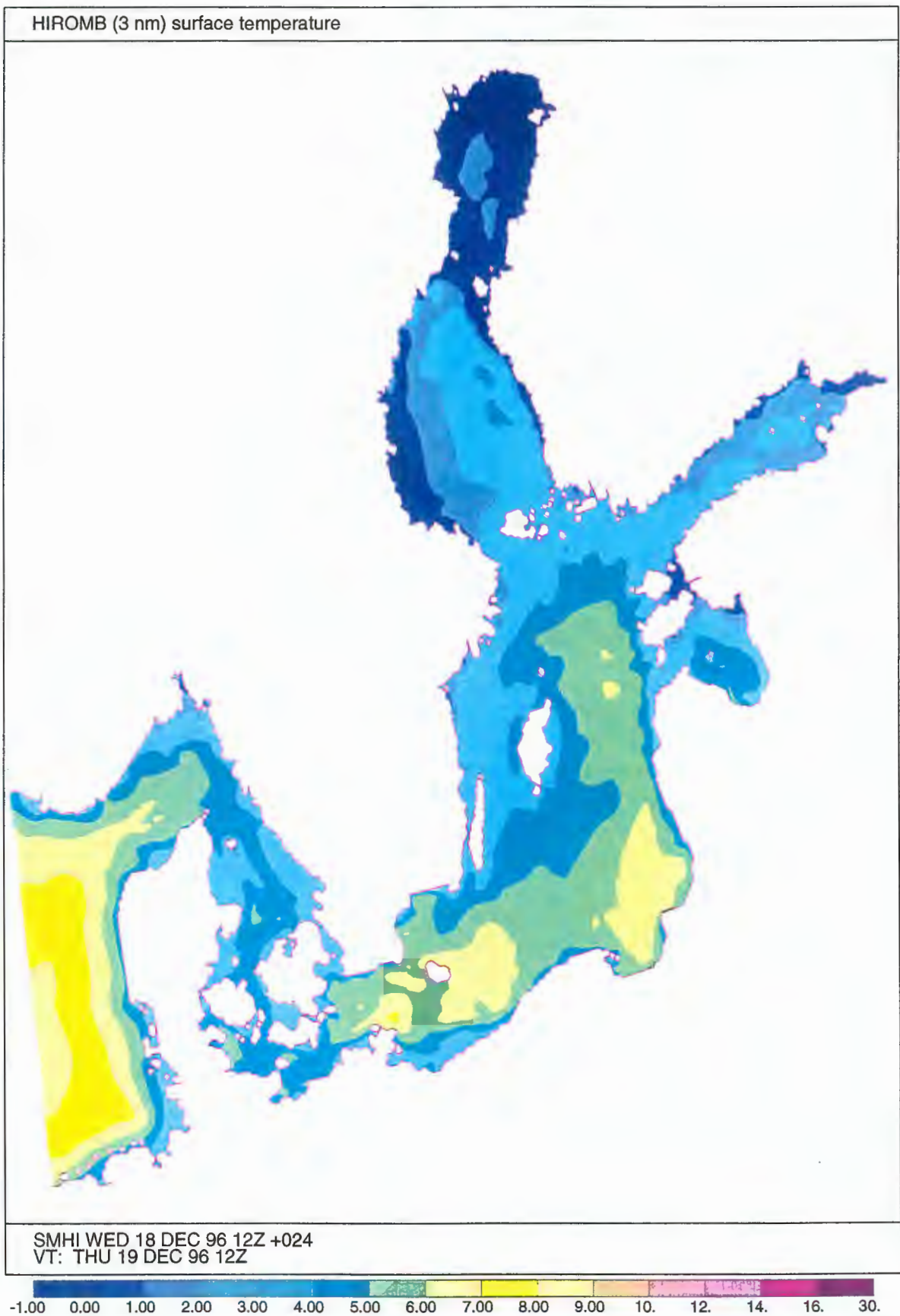


Figure 26b. HIROMB SST field from 19. december

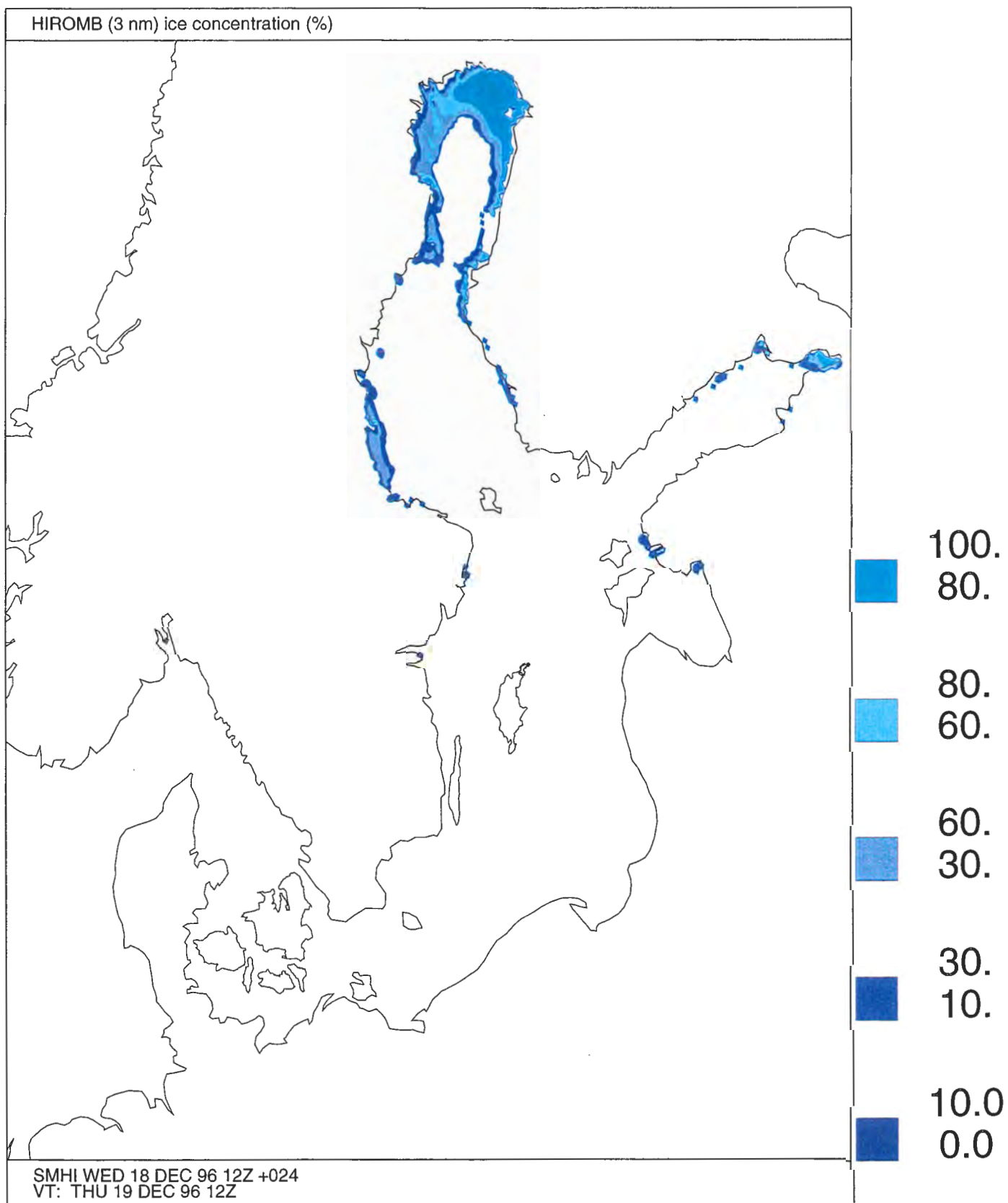


Figure 26c. HIROMB ice field from 19. december

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