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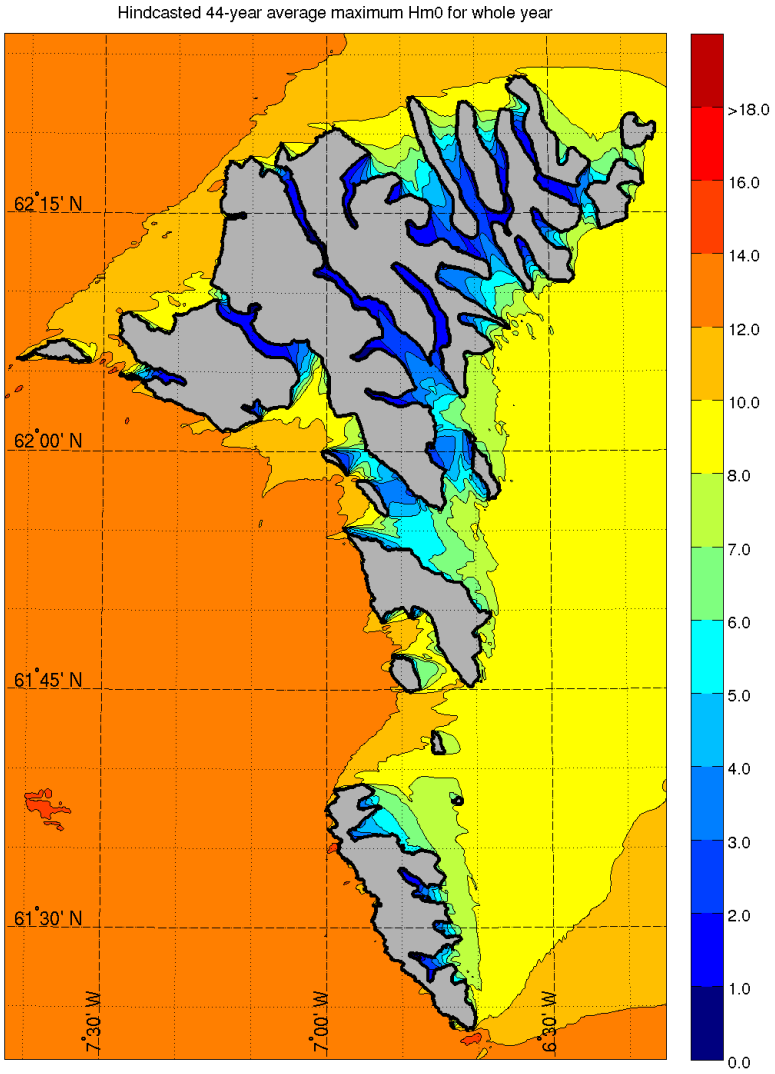
High resolution wave climate of the Faroe Islands

B. A. Niclasen & K. Simonsen



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High resolution Wave climate for the Faroe Islands

Bárður A. Niclasen and Knud Simonsen, June 2012

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Introduction

Located in the North East Atlantic the Faroe Islands are exposed to many deep low pressure systems. This exposure and the extended areas of open ocean surrounding the islands generate a quite severe wave climate. At the same time the faroese economy is primarily based on fishery and aquaculture.

A good understanding of the local wave climate is vital when extending present fish farming areas or when looking for potential new sites. For this reason the University of the Faroe Islands has been contracted to produce a new high-resolution wave climate information by the Aquaculture Research Station of the Faroes.

The primary objective of this report is to present the new results, while more technical and academical aspects of this investigation are left to a subsequent dedicated report.

Methodology

Below a very short description of the applied methods is given. More detailed information will be given in a dedicated report.

Historical record of the waves

In order to get reliable estimates of the local wave climate, we need detailed continuous historical information about the wave conditions. This information can either come from measurements or from numerical models. There exist offshore wave measurements on each (East, West, North and South) side of the Faroe Islands, which go back to early 1980'ties. Unfortunately investigations have shown (Niclasen and Simonsen, 2007) that the measurements seem significantly influenced by the durable but rigid mooring system used. On the positive side the investigations have also shown that the directional wave measurements south of the islands, spanning from 1999 to present, are trustworthy. Hereafter this location will be referred to as the South buoy.

All in all we have valuable wave data, but not enough to derive the long term directional local wave climate. For this reason we use hindcasted wave parameters from the DMI reanalysis wave model. The model has a spatial resolution of 10 km, using 32 frequencies and 24 directions. The parameters used are wind velocity at 10 meter height, significant wave height H_{m0}, mean wave period T_{m-10}, mean wave direction. The wave parameters are given for swell and wind-sea. The parameters are available at 1-hour intervals spanning from 1960 to 2003, both years included.

High resolution wave model

The wave parameters available from the DMI-reanalysis were compared against the measurements at the South buoy for the overlapping interval (1999-2003). The comparison showed that the DMI-reanalysis according to wave model standards, is accurate and well suited as forcing for a higher resolution model.

The wave model SWAN (Booij et al., 1996) is used for the high resolution transport and transformation of the DMI-reanalysis sea-state as it propagates from the model boundaries into the nearshore areas. Swell and wind sea are modeled separately and the total sea-state is regenerated in the post processing. As wave reflection from land is highly frequency dependent favoring low frequencies, only the swell cases were rerun with reflections included. As reflections must be added in a manual manner, reflecting boundaries are only added in areas thought to be of interest for the fish-farming industry. Investigations showed that parametric wave reflection formulas gave suspiciously high reflection coefficients, which were primarily sensitive to bottom/seaface permeability, which is unknown, and not so much on bottom slope, which at best can only be roughly approximated. Estimating wave reflections correctly is thus a highly site specific ad hoc process, and these model runs can only provide a first iteration of this process. As a first guess we use reflection coefficients of 0.5 (i.e. 25% of the wave energy is re-emitted into the wave field) along the specified stretches of coastline.

To be able to preform a 44-year high-resolution hindcast, some simplifying assumptions must be made. Here we have assumed that the Faroe Islands are small compared to the incoming variations in the wave and wind fields. Inspection of the spatial variations of the DMI-reanalysis fields, showed that on average this is a good approximation. This implies two important simplifications:

1) the wave model can be run in stationary mode
2) the offshore wave field is the same at all borders

The forcing sea state was determined to be the average sea state on the model border which had highest wave height and waves traveling into the model trough that border. Initially it was only planned to model the wave height and wave direction correctly and approximate the wave period, but tests showed that wave period was also quite important in some cases. It also turned out that wind speed correlation to wind-sea was improved by including wave period in the approximation. For this reason the wave period was included as a variable in the model runs as well. All forcing sea-states were binned into whole numbers in wave height and period and 15° intervals in wave direction. This was done for wind-sea and swell, and not only as initially planned, for total sea only. For this reason the initially planned less than 300 pre-calculated sea-state scenarios grew to over 4000.

Using the data from the South buoy and the overlapping interval with the DMI-reanalysis results, it was possible to eliminate bias and trend in the wave height predictions from the high resolution runs. In this manner the high resolution wave model provides reliable time series in all model points (although with some random error), which subsequently could be treated statistically in order to estimate the most likely extreme sea states in each model point.

Statistical treatment

Having constantly sampled 1-hour values, a time series length of 44-year years in each model point, and having almost 100% data coverage, the statistical treatment is somewhat simplified. Extreme-value theory tells us that having this much data at our hands we can reduce our investigation into looking at annual maxima, and the distribution of these maxima should follow the Gumbel distribution (e.g. Holthuijsen, 2007).

For this reason the annual-maxima approach is used in all model points and the 50-year and 10-year return values are calculated according to the best fitting Gumbel distribution. The only issue with this approach is that it does not provide an estimate of the maxima in an average year. This is instead done by taking the average over the annual maxima in the 44-year hindcast in each model point.

An alternative method to estimate the highest wave height in each point would simply be to find the largest value in each of the single point time series. As the hindcast spans 44-years, this value can be compared with the 50-year return value to see if there are any discrepancies. When the maximum from the 44-year hindcast is larger than the 50-year return value, this indicates that there is some severe storm (annual maximum value) in the hindcast which is a outlier compared to the distributions the other years. On the other hand if the 50-year return value is larger, this can indicate that several of the largest annual maxima are of similar size and the distribution extrapolates beyond this value.

Results

The primary concern is how large the waves can be expected to be, in average and extreme conditions. It is also important to know how these conditions vary during the different months of the year. For this reason the expected largest significant wave height H_{m0} is given for the whole year and each month individually as:

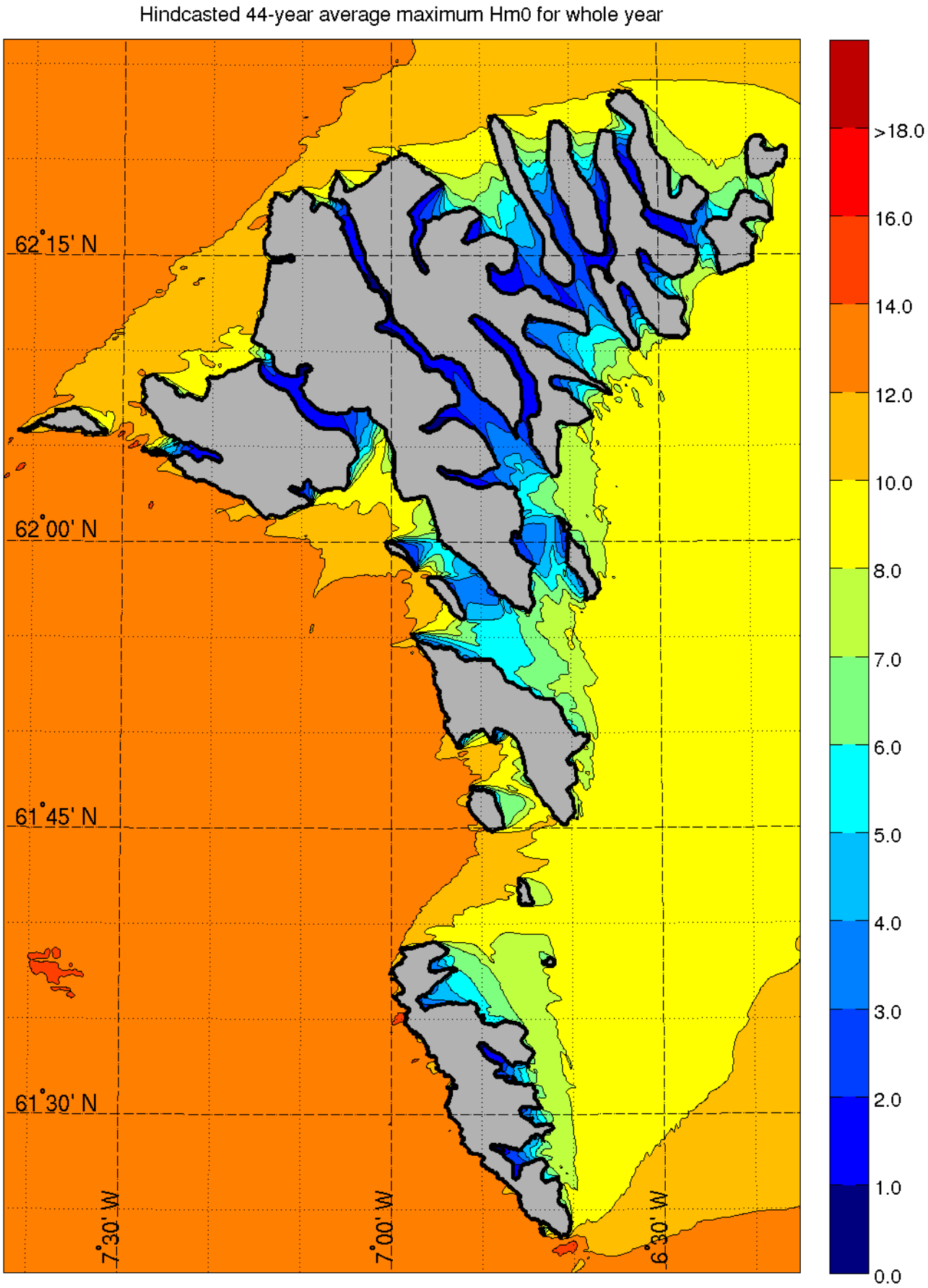
- H_{mean} the annual average of the largest H_{m0} modeled value during the 44-year hind-cast. This value therefore corresponds to the largest expected 1-hour H_{m0} value in an average year.
- H_{10} the statistically estimated largest 1-hour H_{m0} value during 10 years.
- H_{50} the statistically estimated largest 1-hour H_{m0} value during 50 years.
- H_{max} the largest H_{m0} modeled 1-hour H_{m0} value during the 44-year hind-cast.

The results are displayed for the whole model area in the following pages. The figures have the same color scale for wave height values in order to make the interpretation easier.

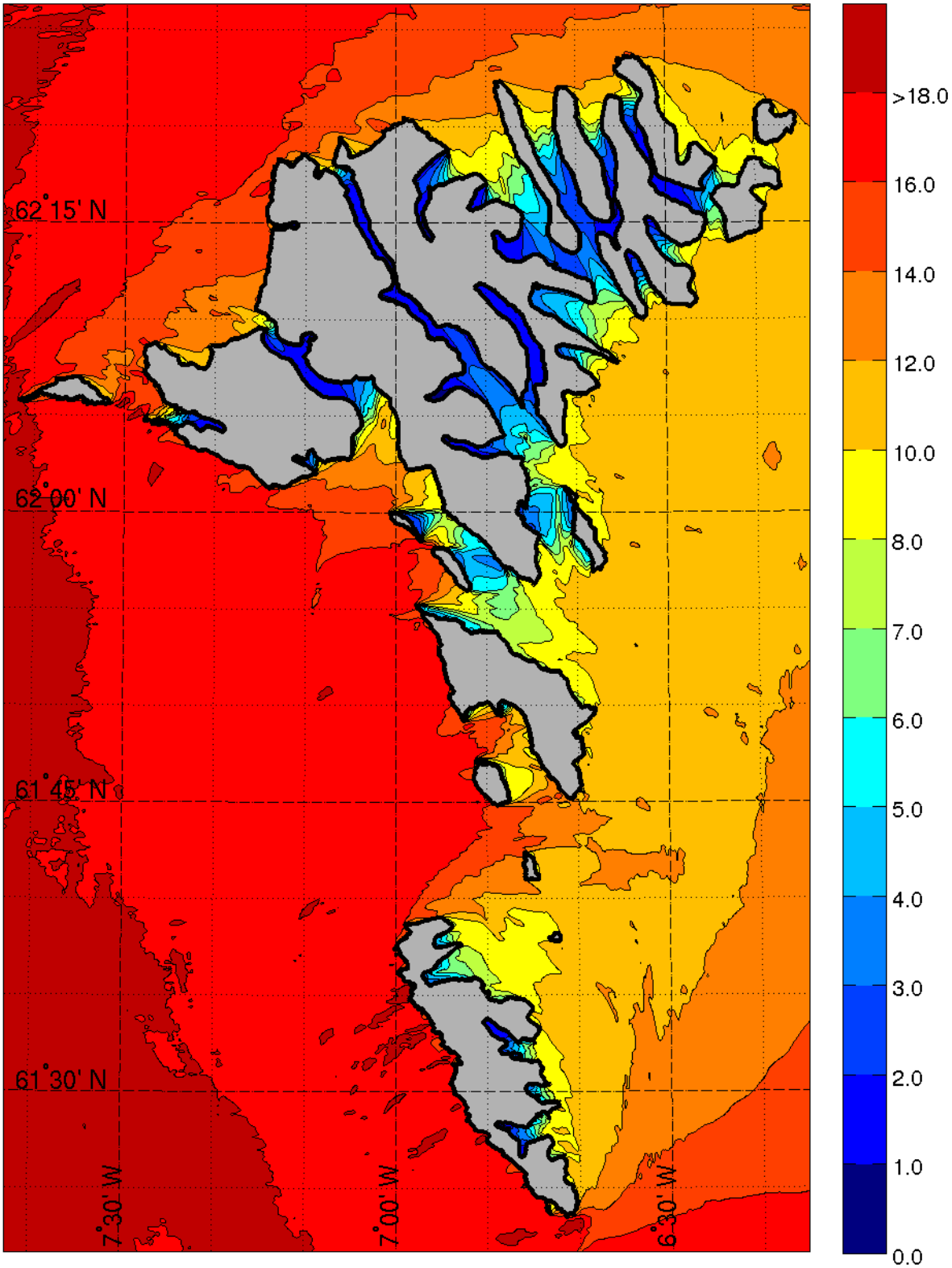
For those interested in small scale features such as the wave conditions in some specific location, the report is accompanied by a set of these same figures only in larger format. As the files are standard png-files any browser can be used to zoom in on the specific areas of interest. To make the results as easy to evaluate as possible, there is no interpolation and the model resolution is apparent (as squares) when zooming in.

On a large scale the differences of introducing reflections are quite limited, so these plots are not included in the report as the number of plots included would be doubled. These results are only given as the larger format pictures, suited for small scale investigations by zooming with a browser.

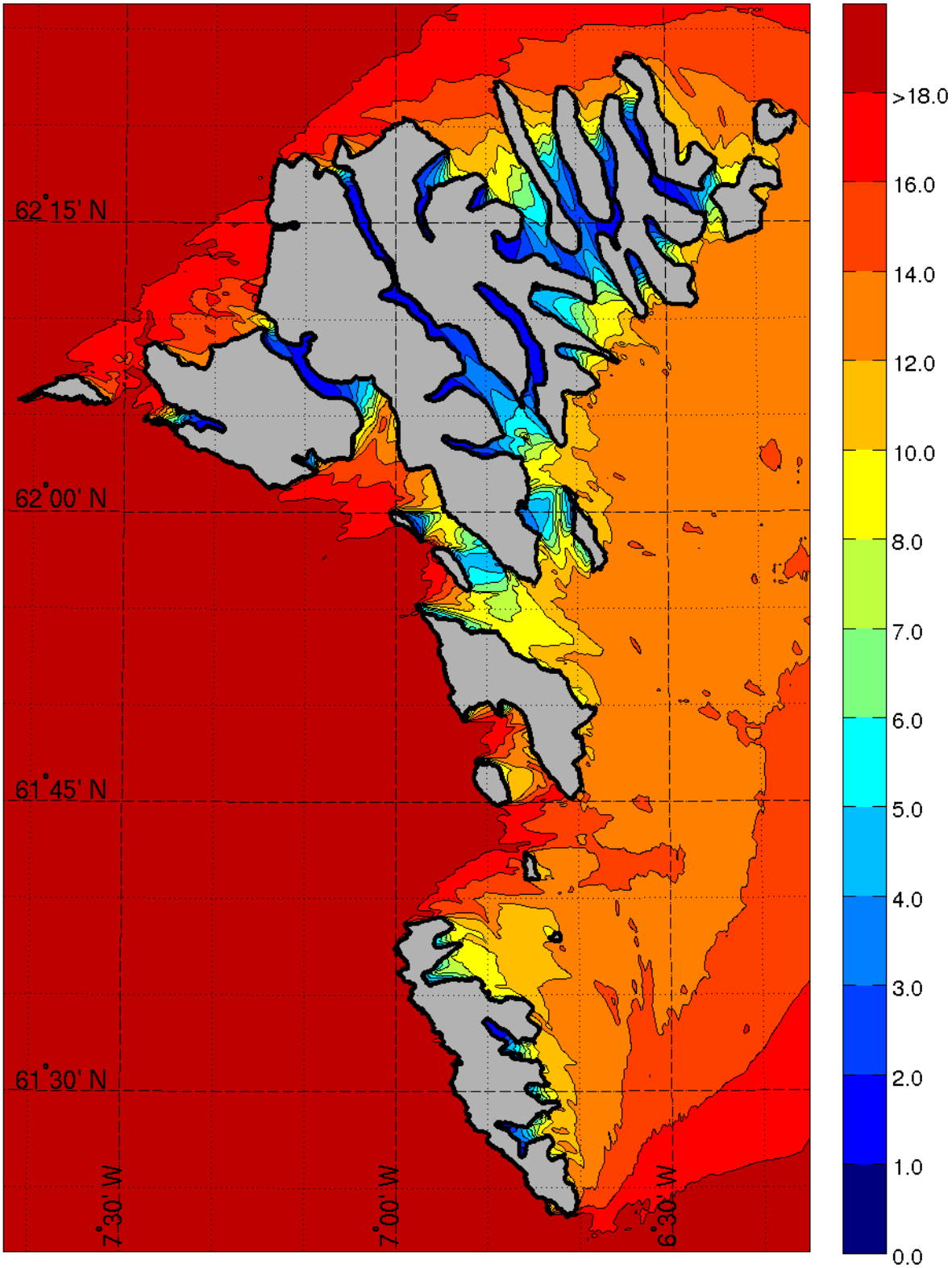
Statistics for the whole year



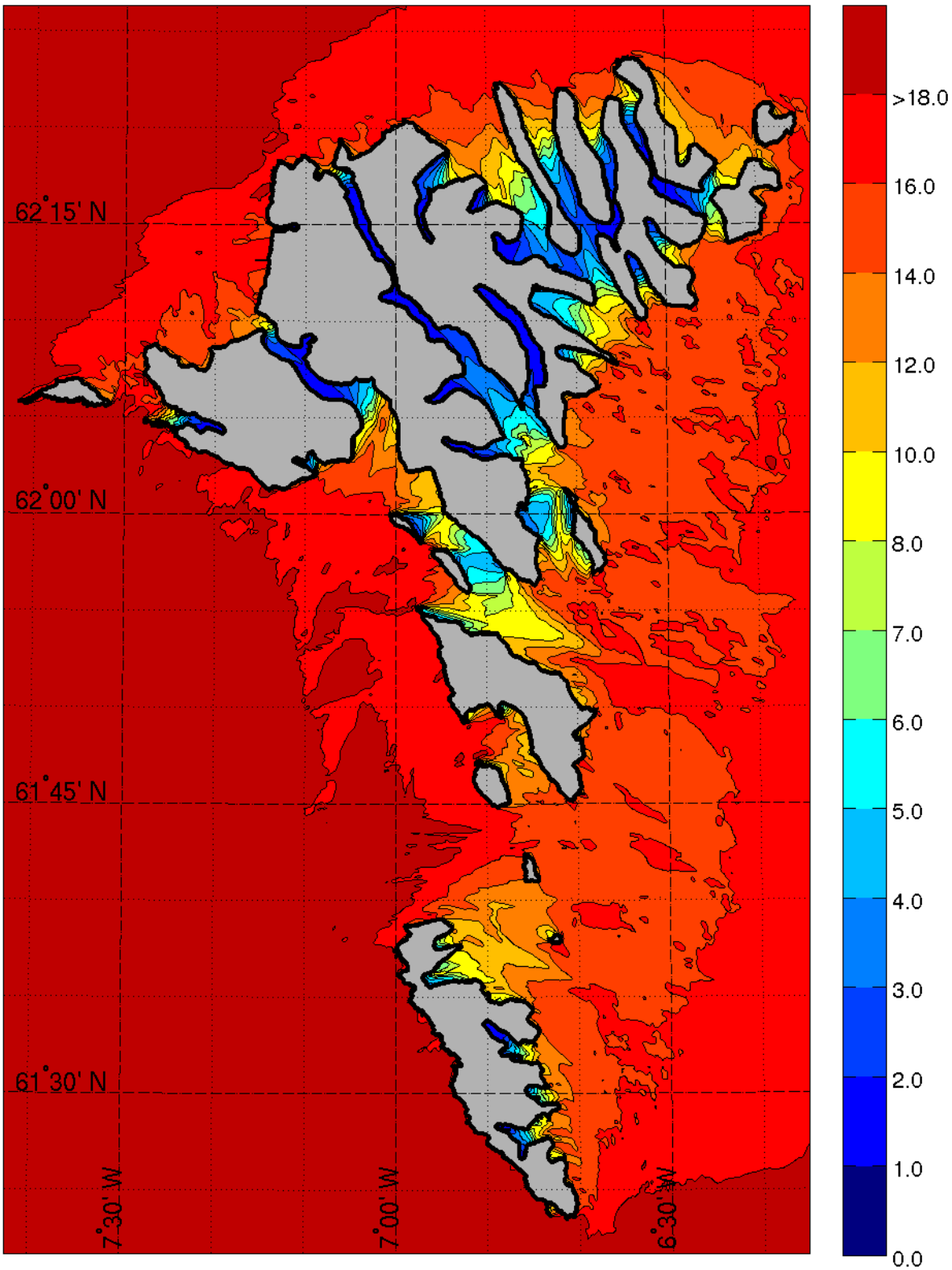
Estimated 10-year maximum Hm0 for whole year



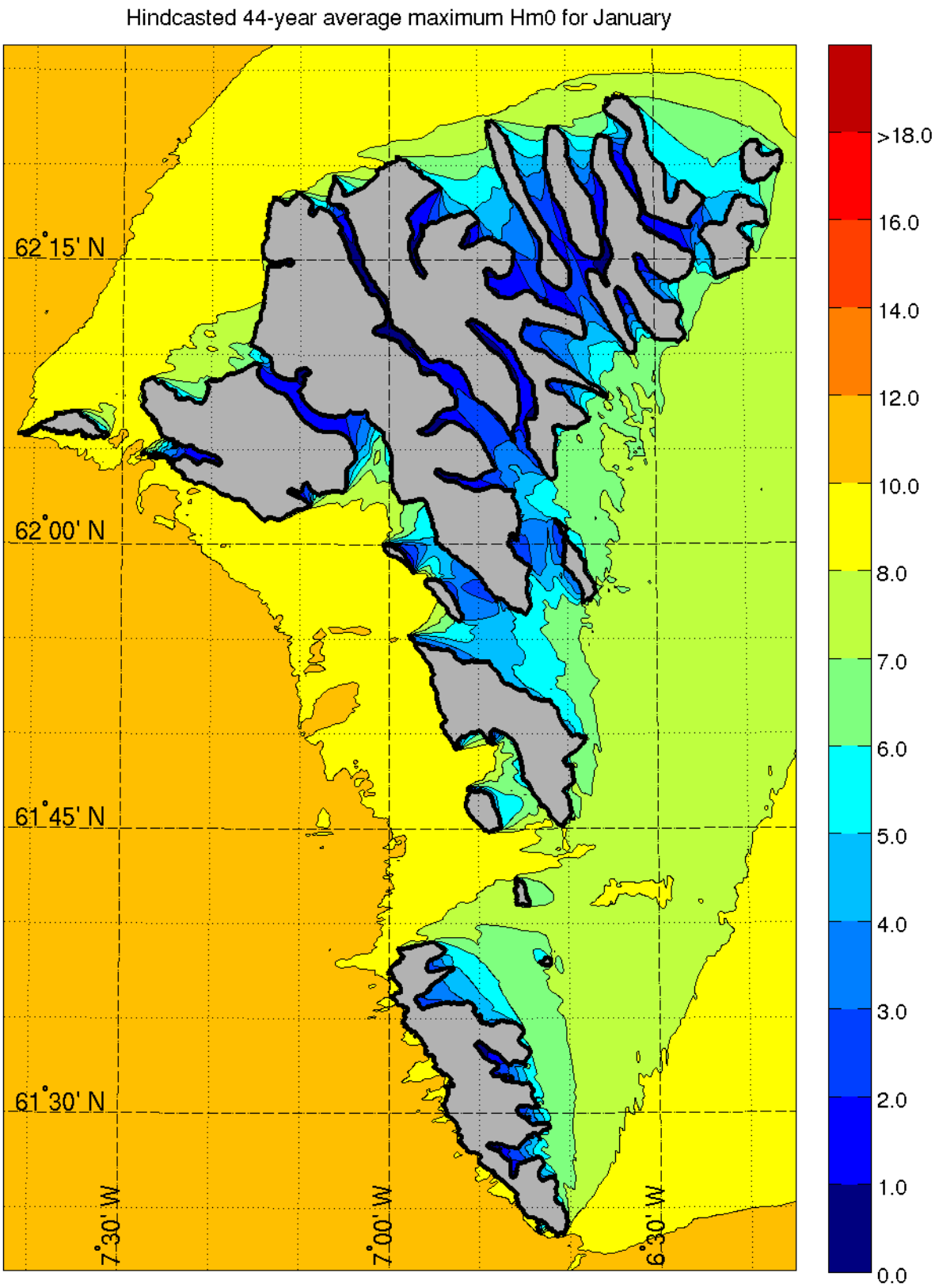
Estimated 50-year maximum Hm0 for whole year



Hindcasted 44-year maximum Hm0 for whole year



Statistics for January



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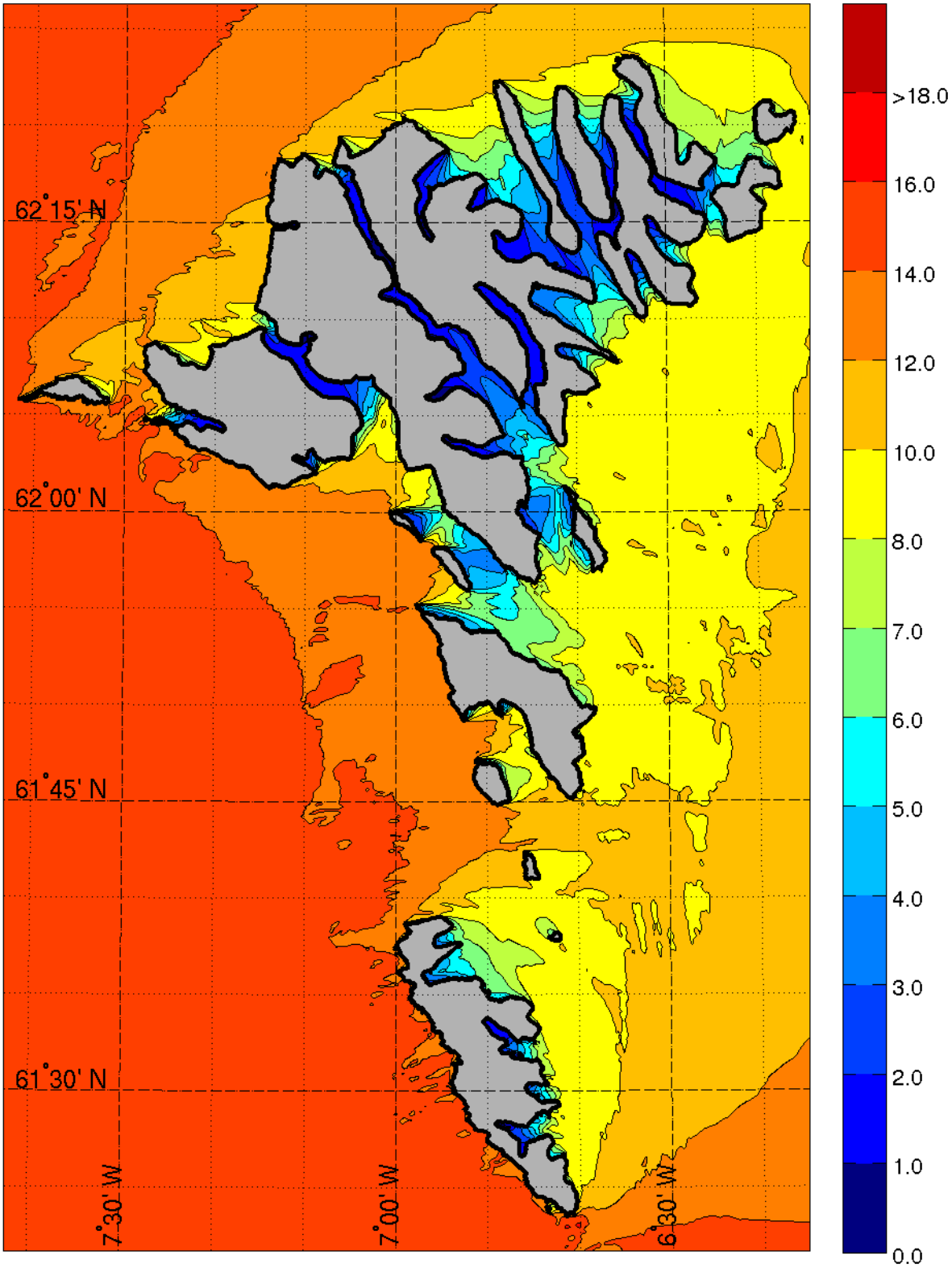

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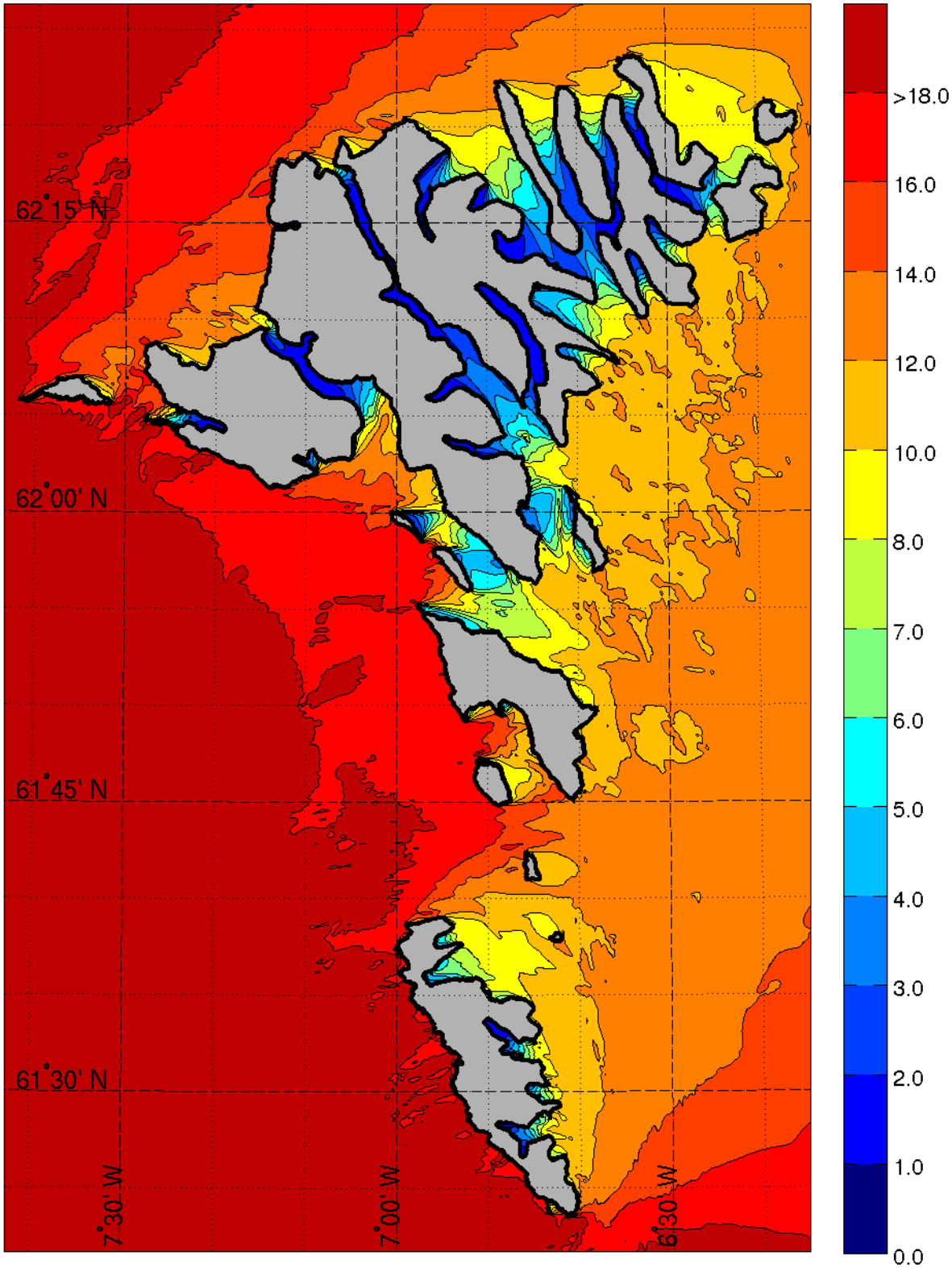

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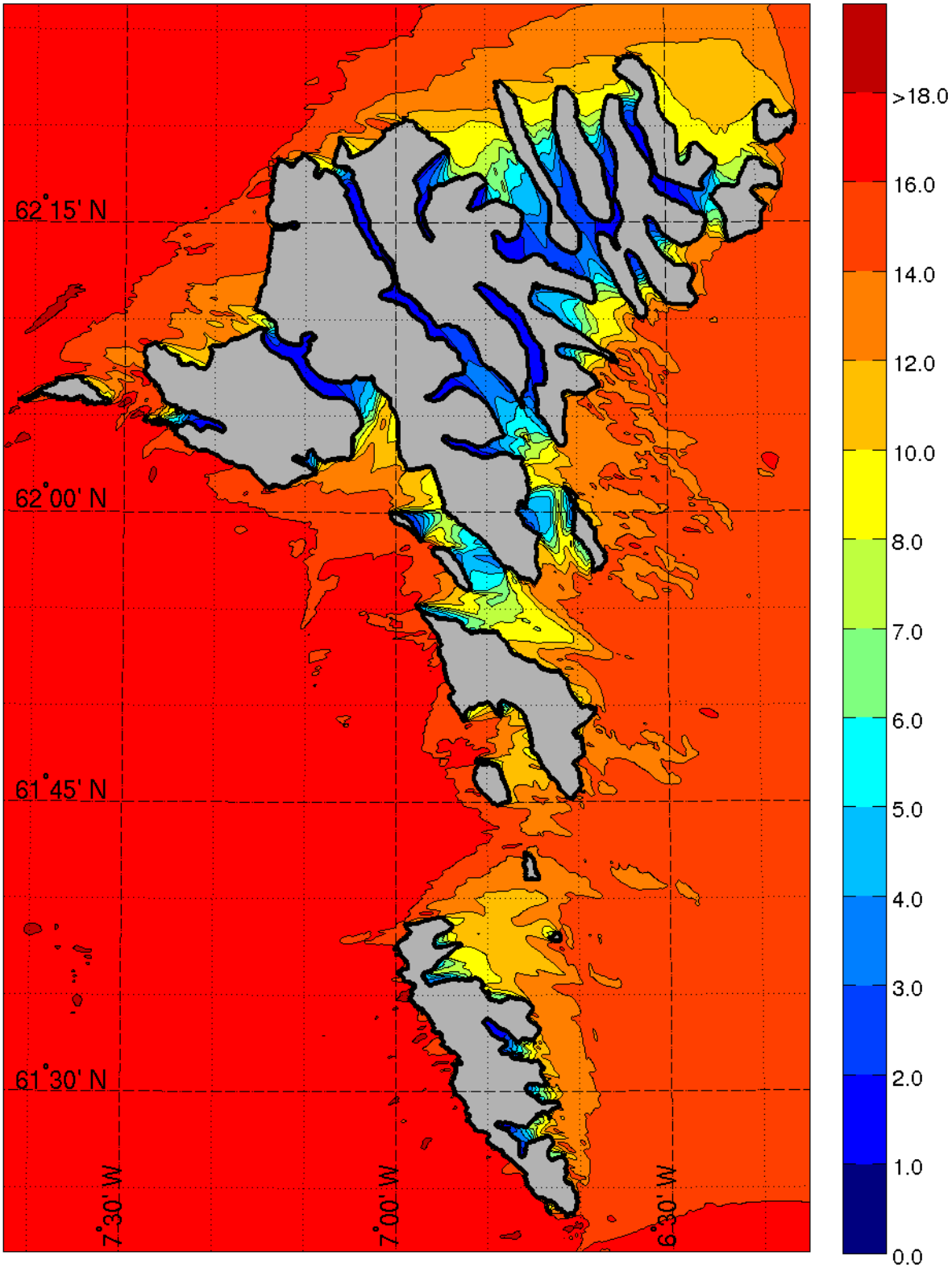

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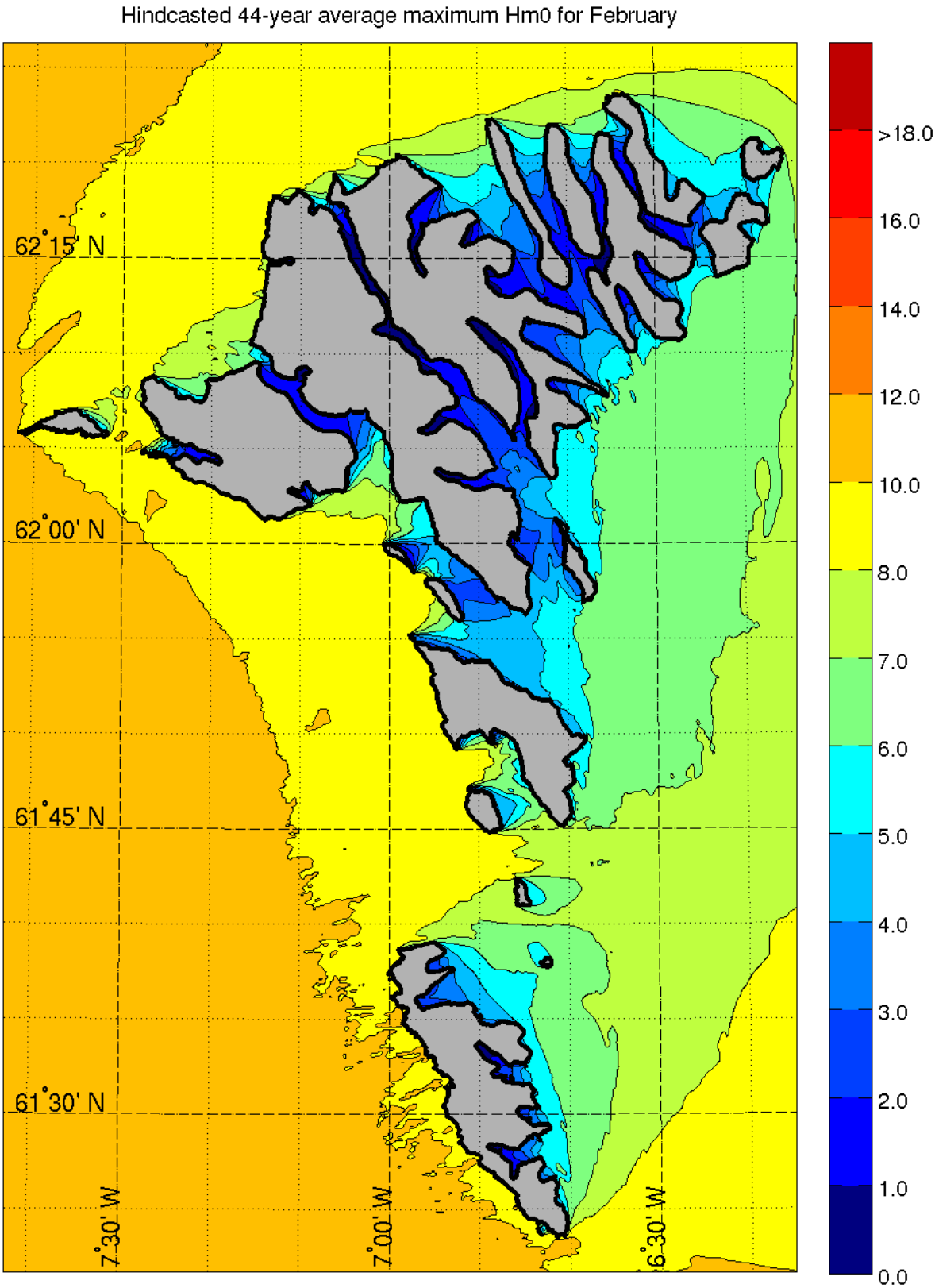

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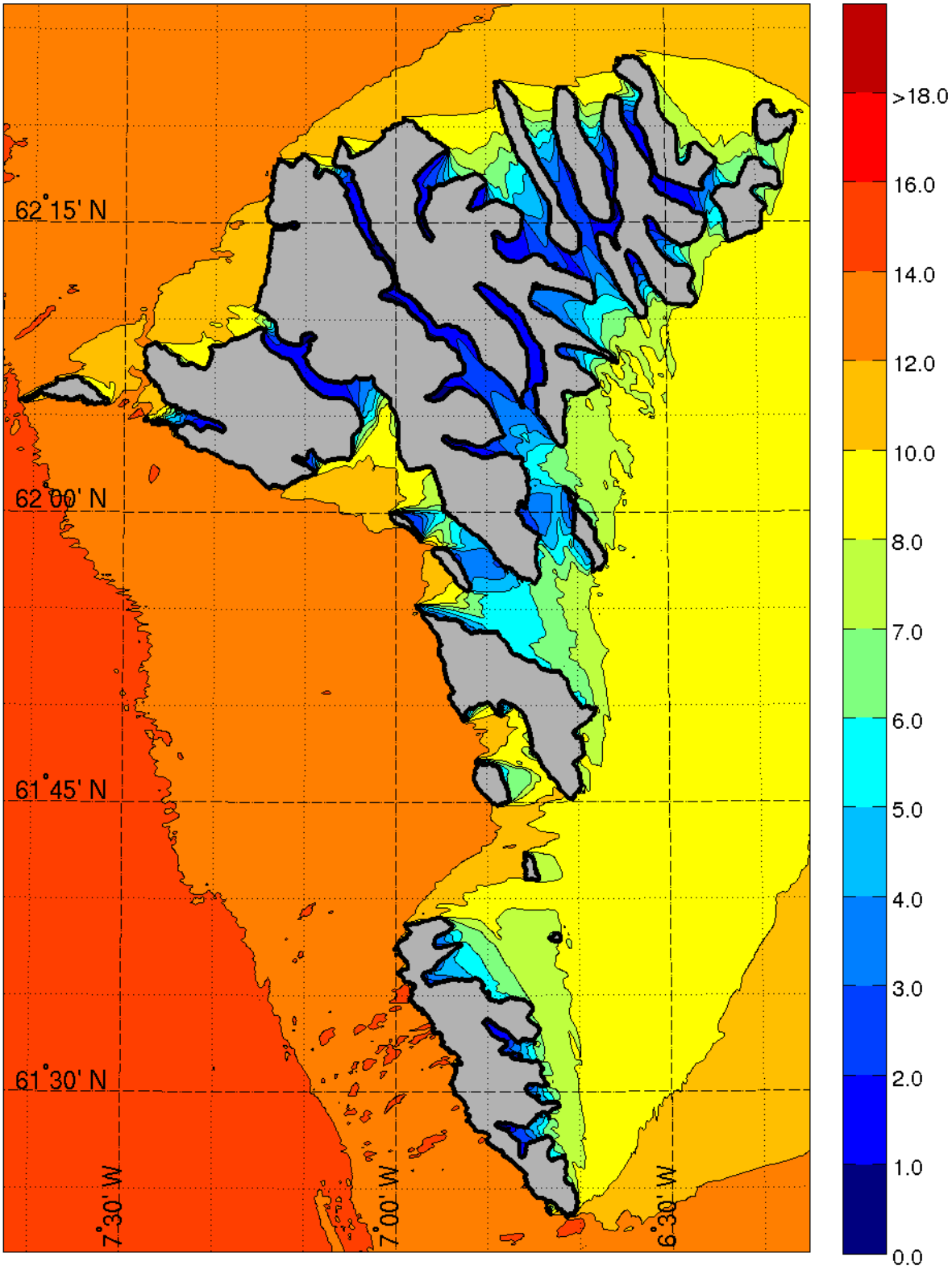

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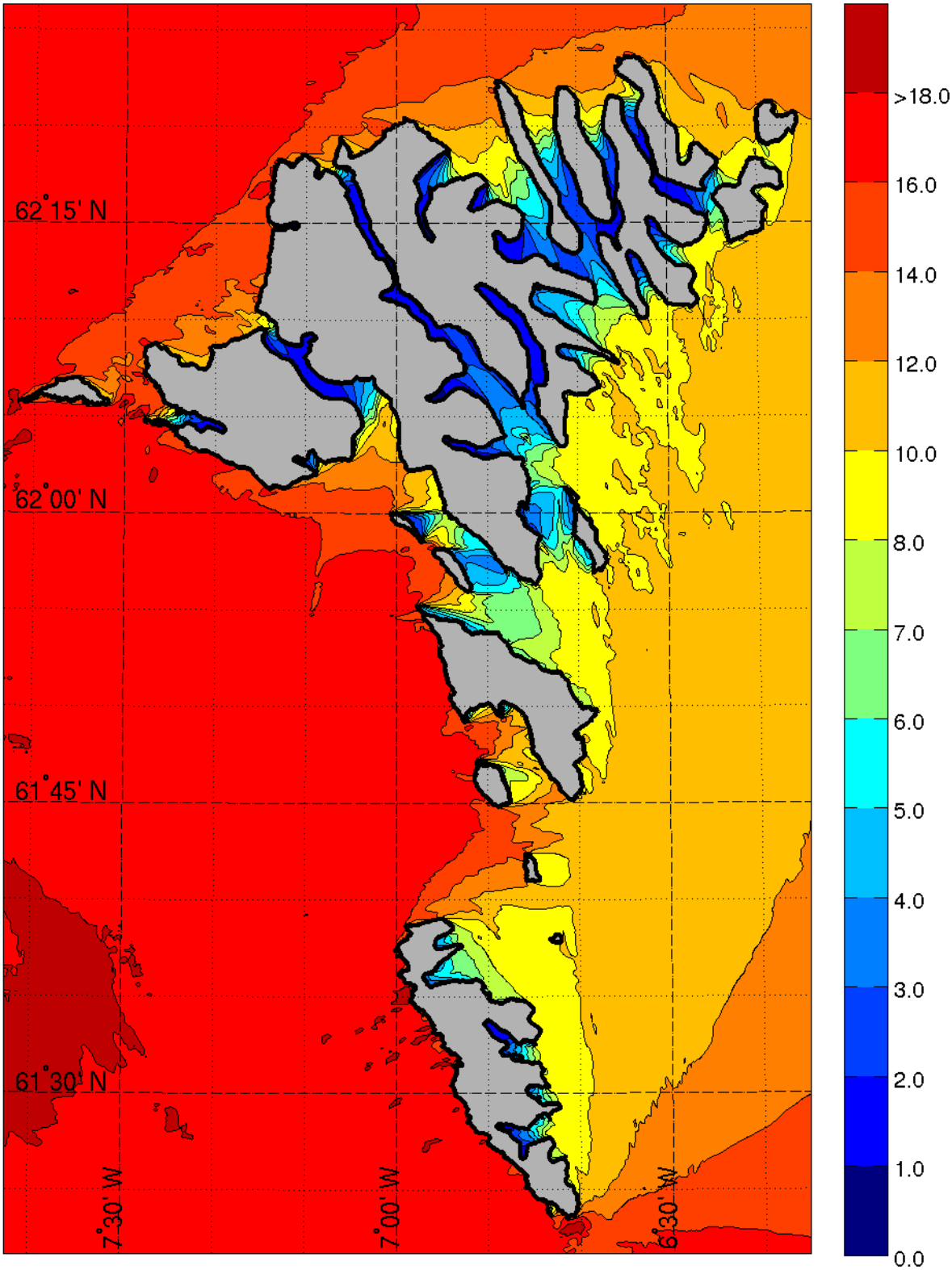

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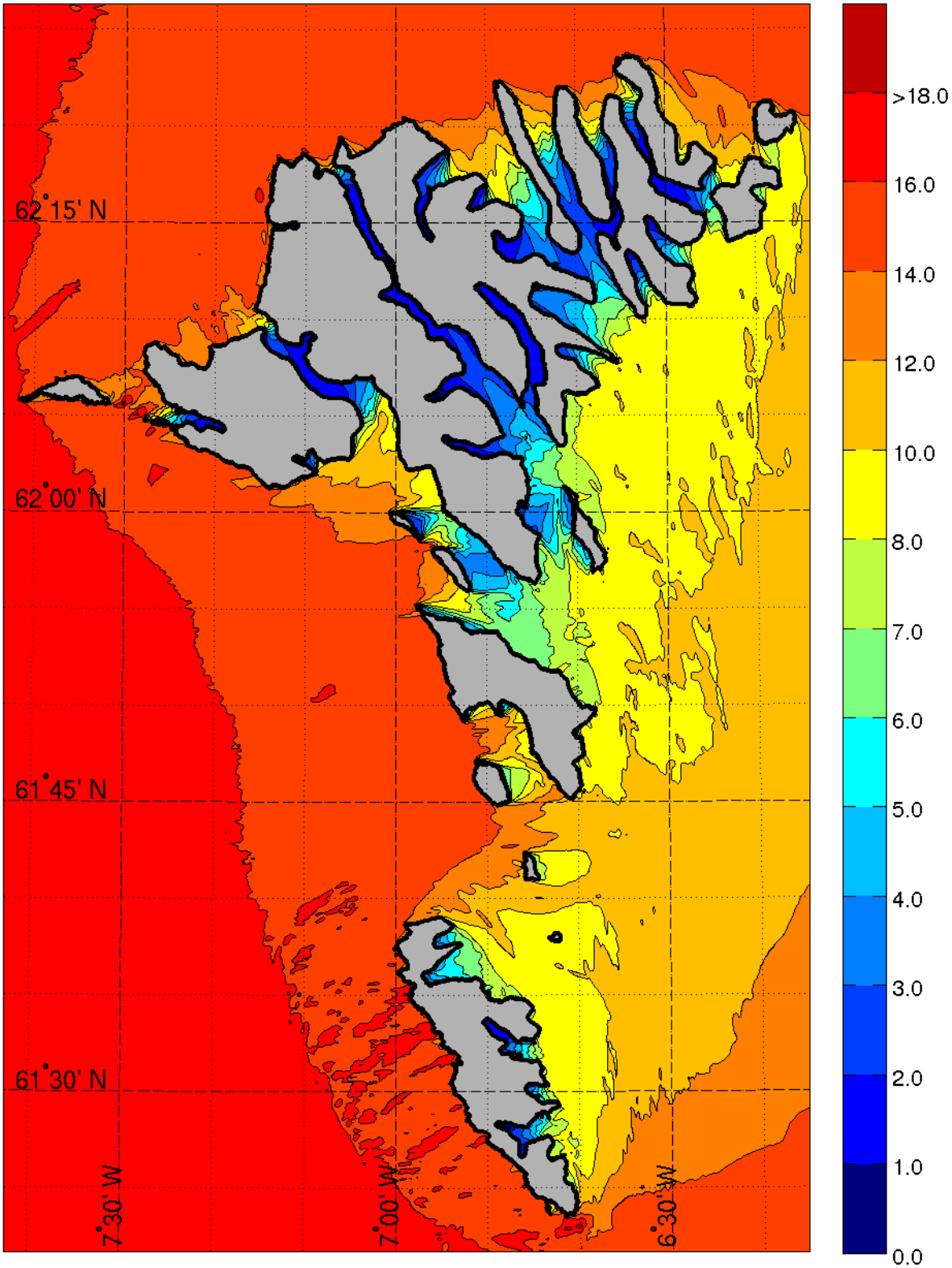

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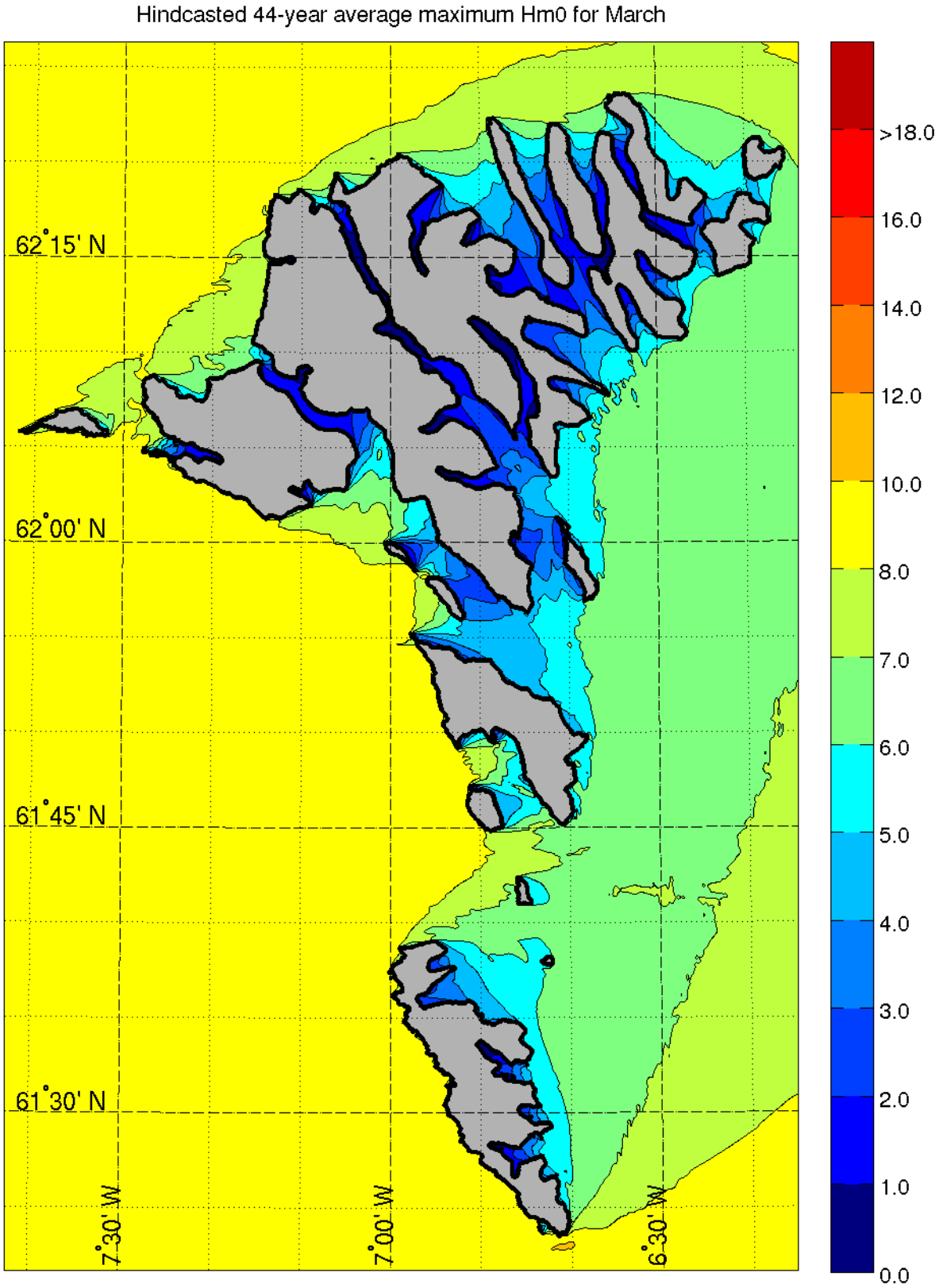

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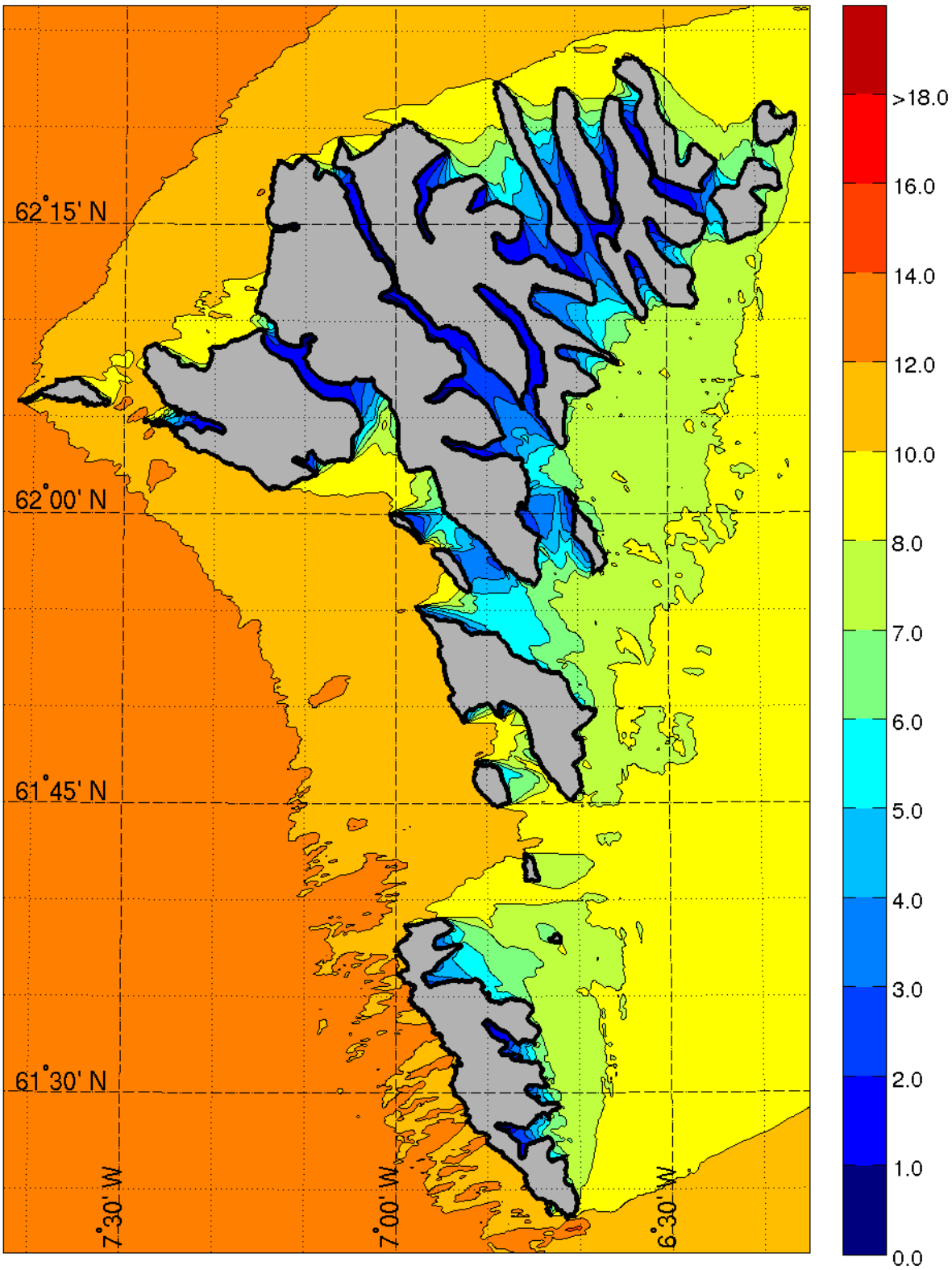

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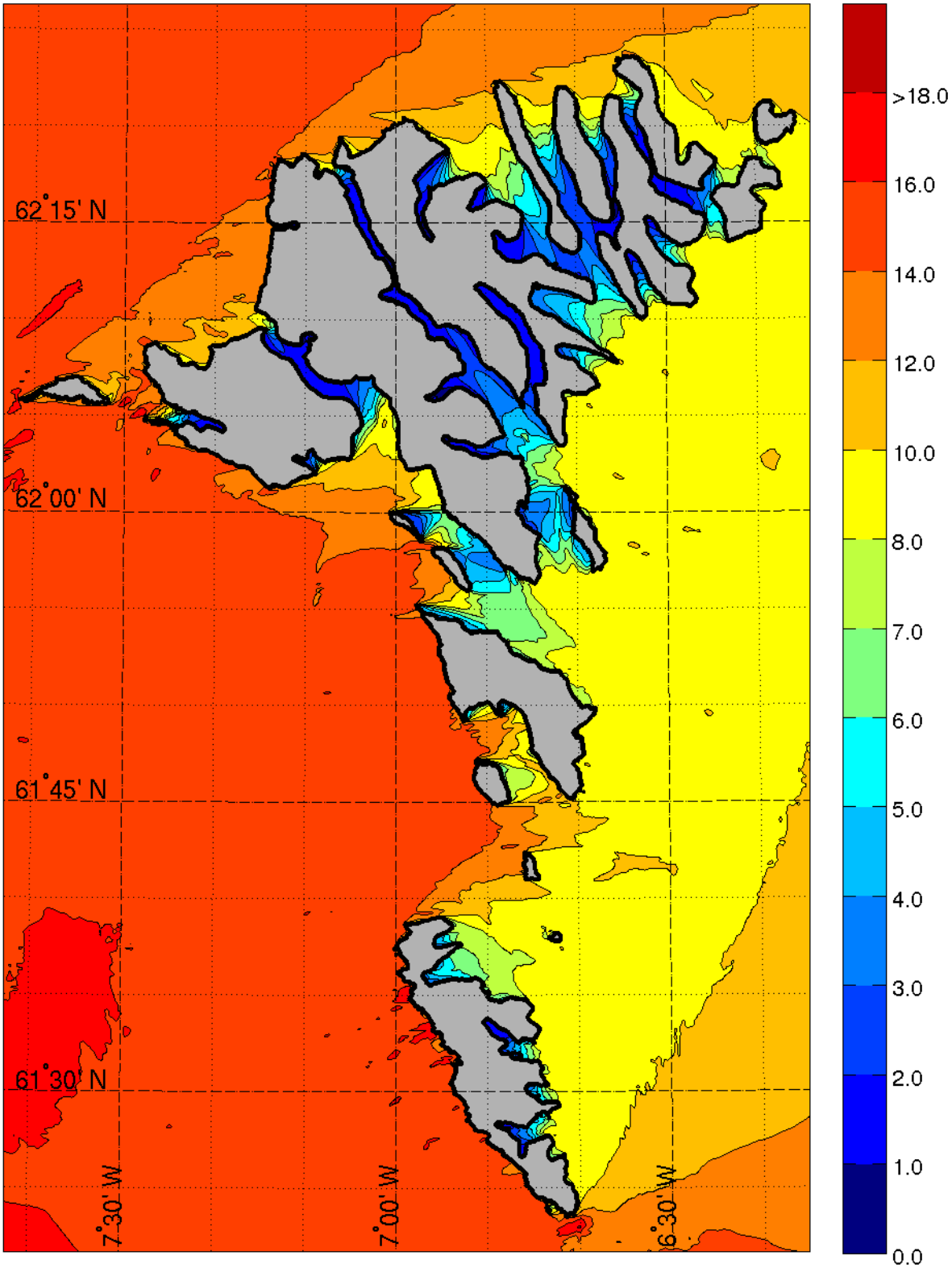

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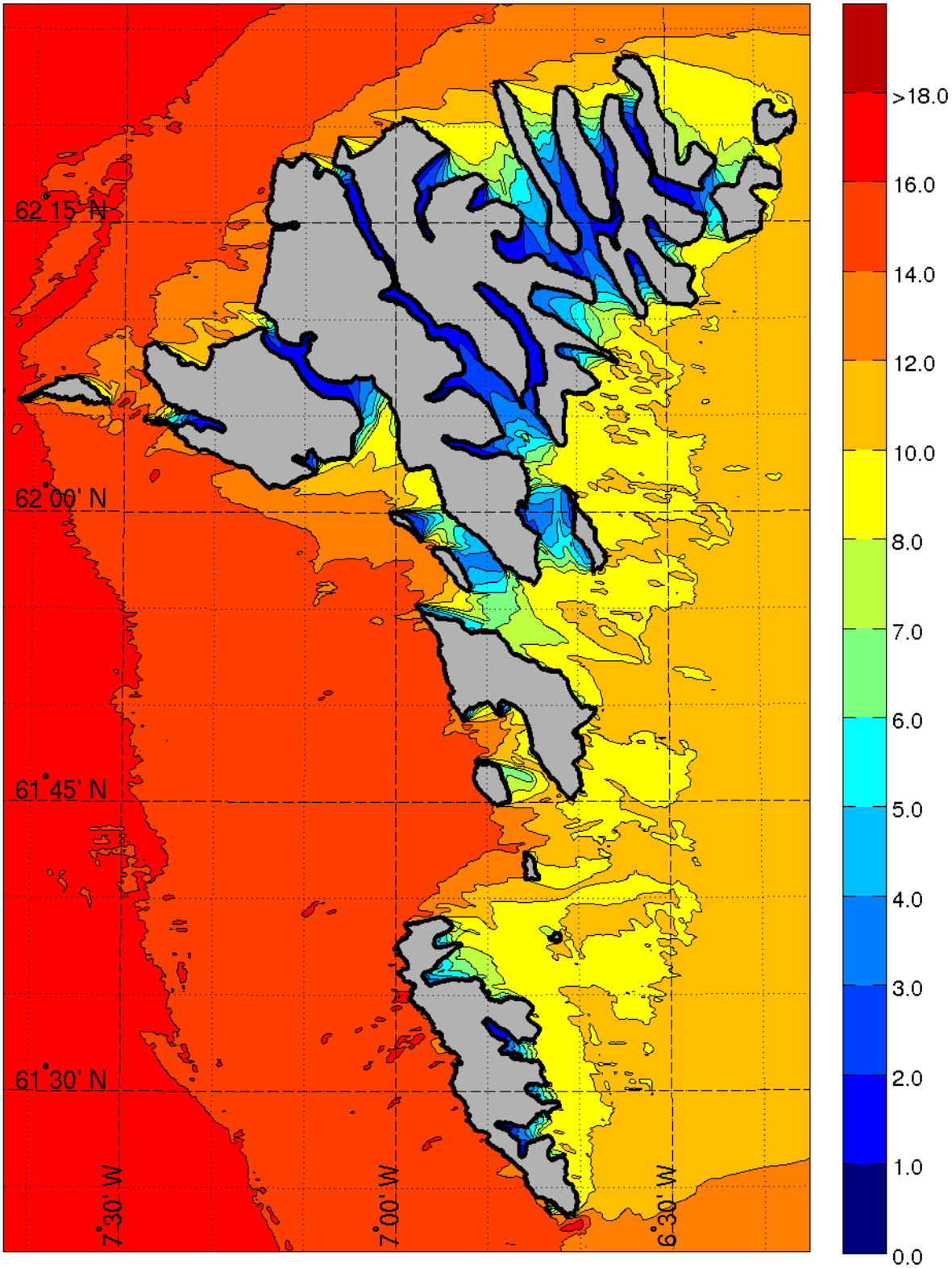

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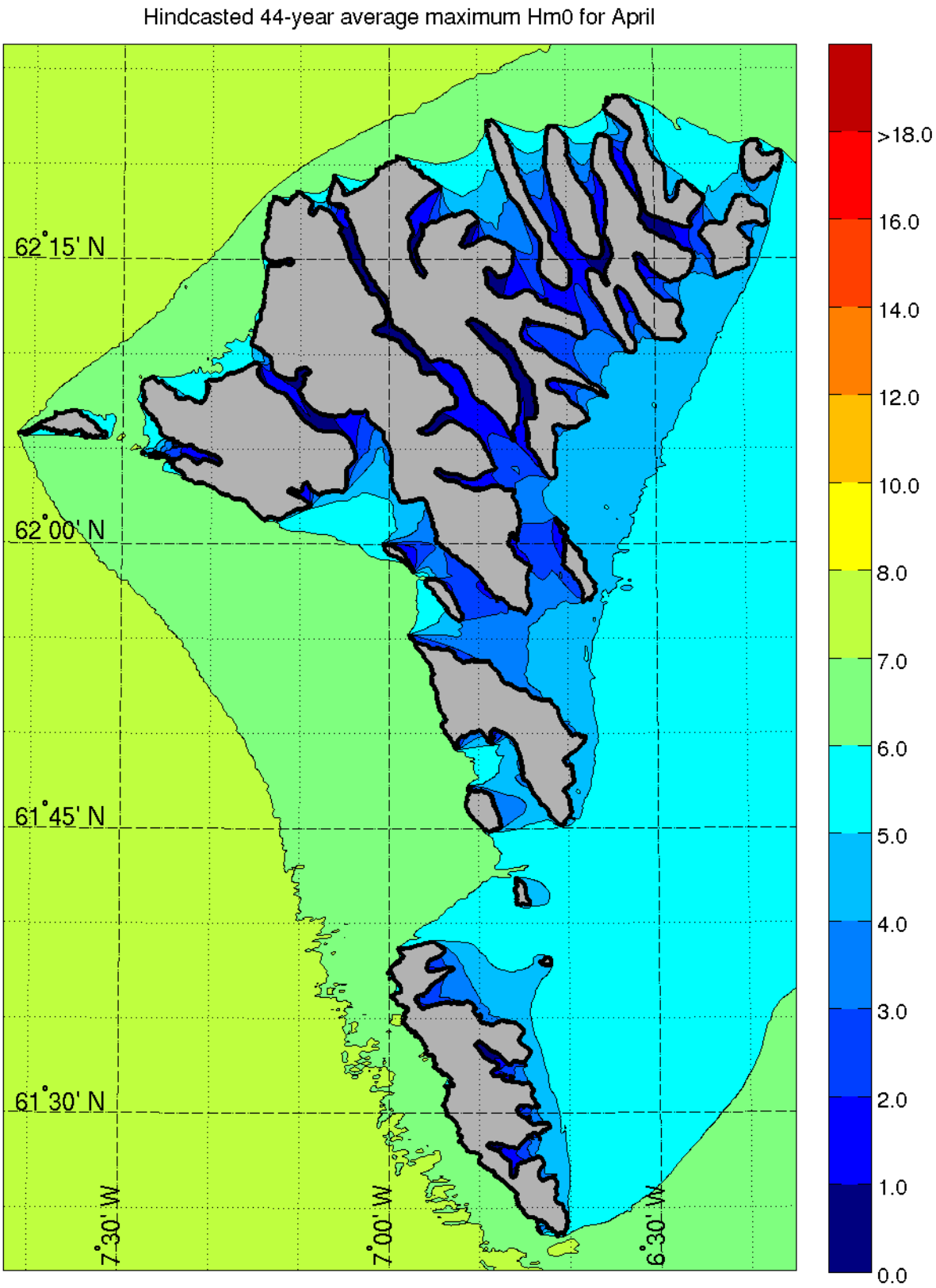

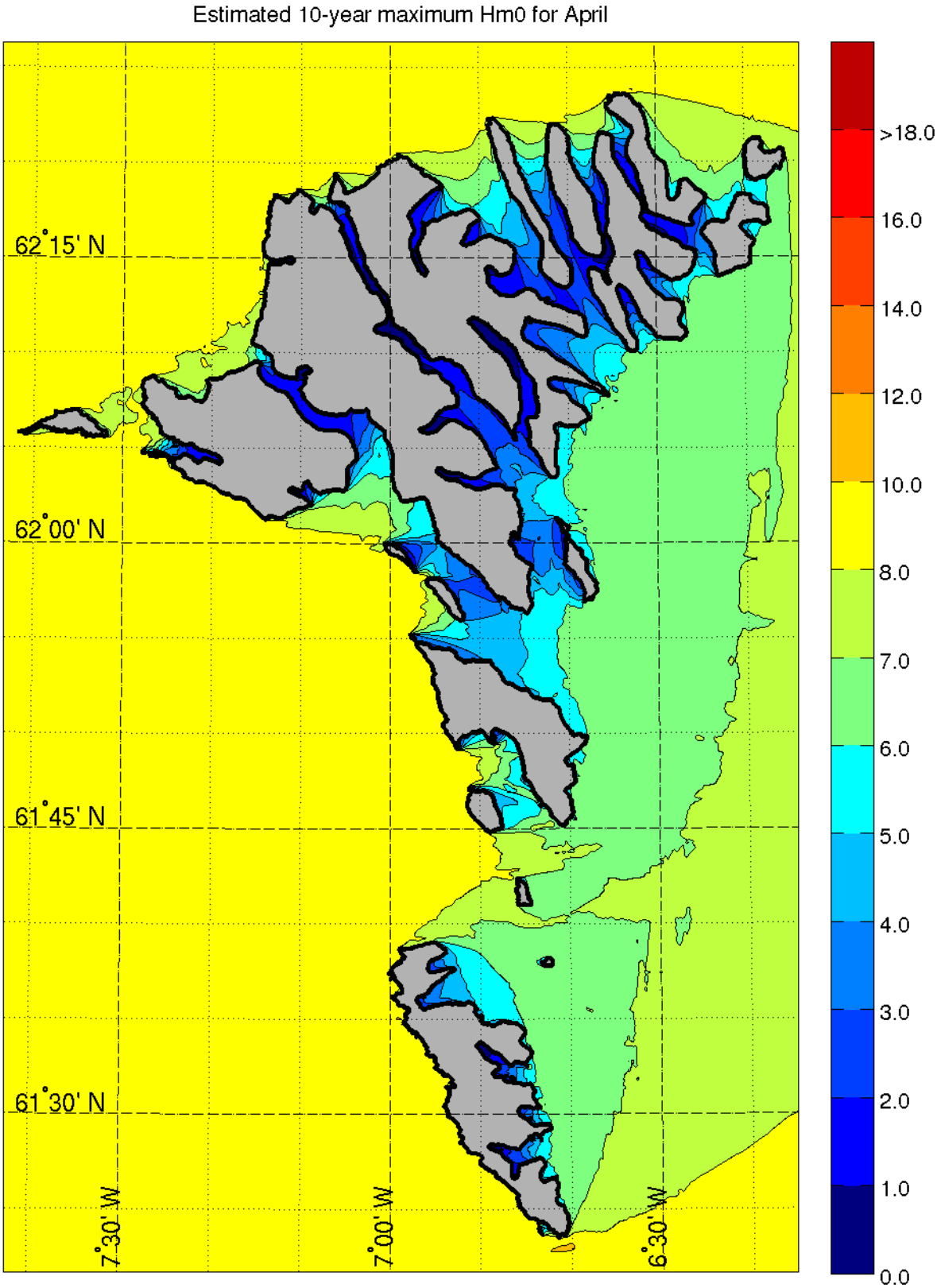
Estimated 10-year maximum Hm0 for April
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62°00' N
61°45' N
61°30' N
7°30' W
7°00' W
6°30' W
>18.0
16.0
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12.0
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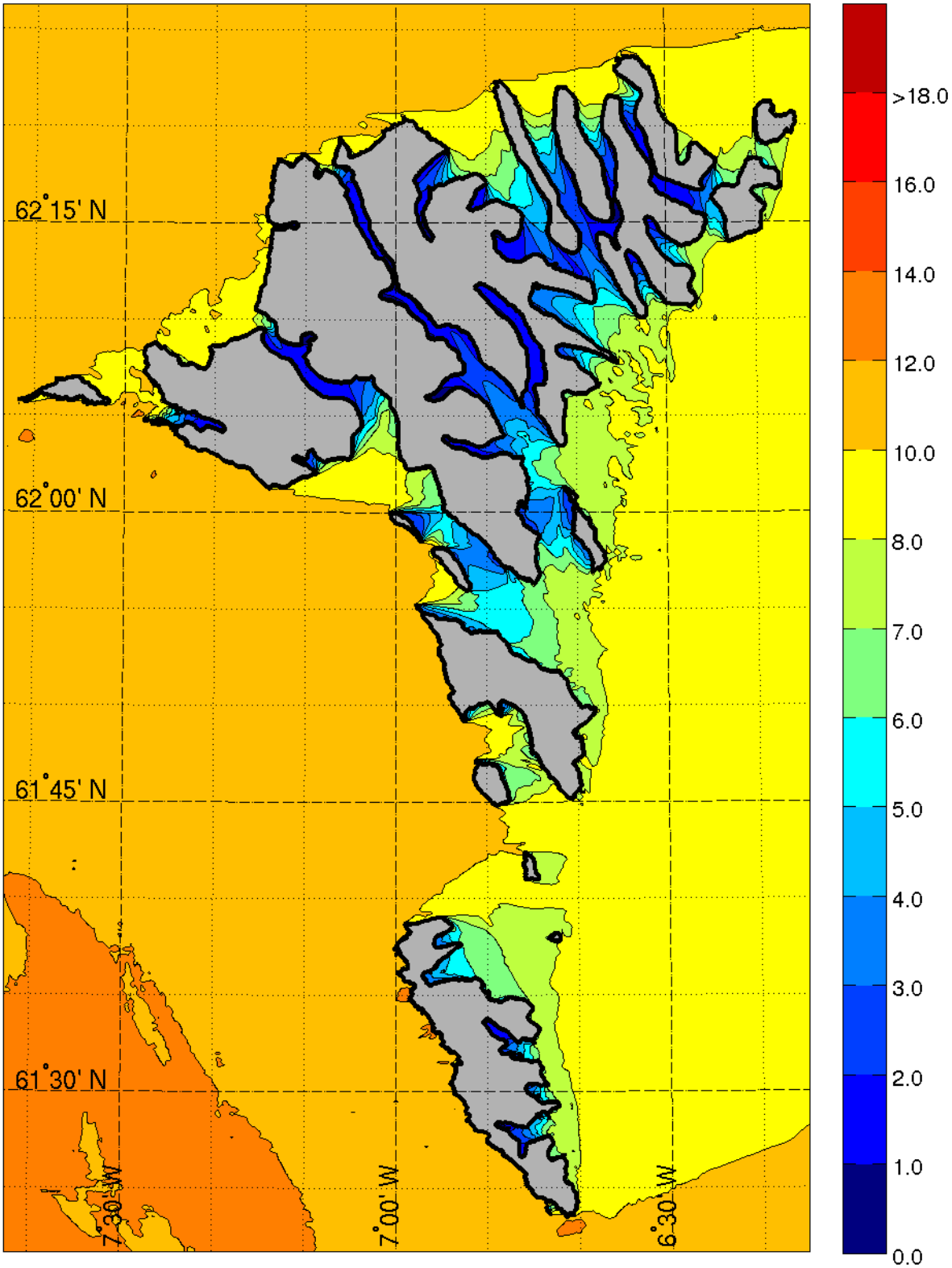

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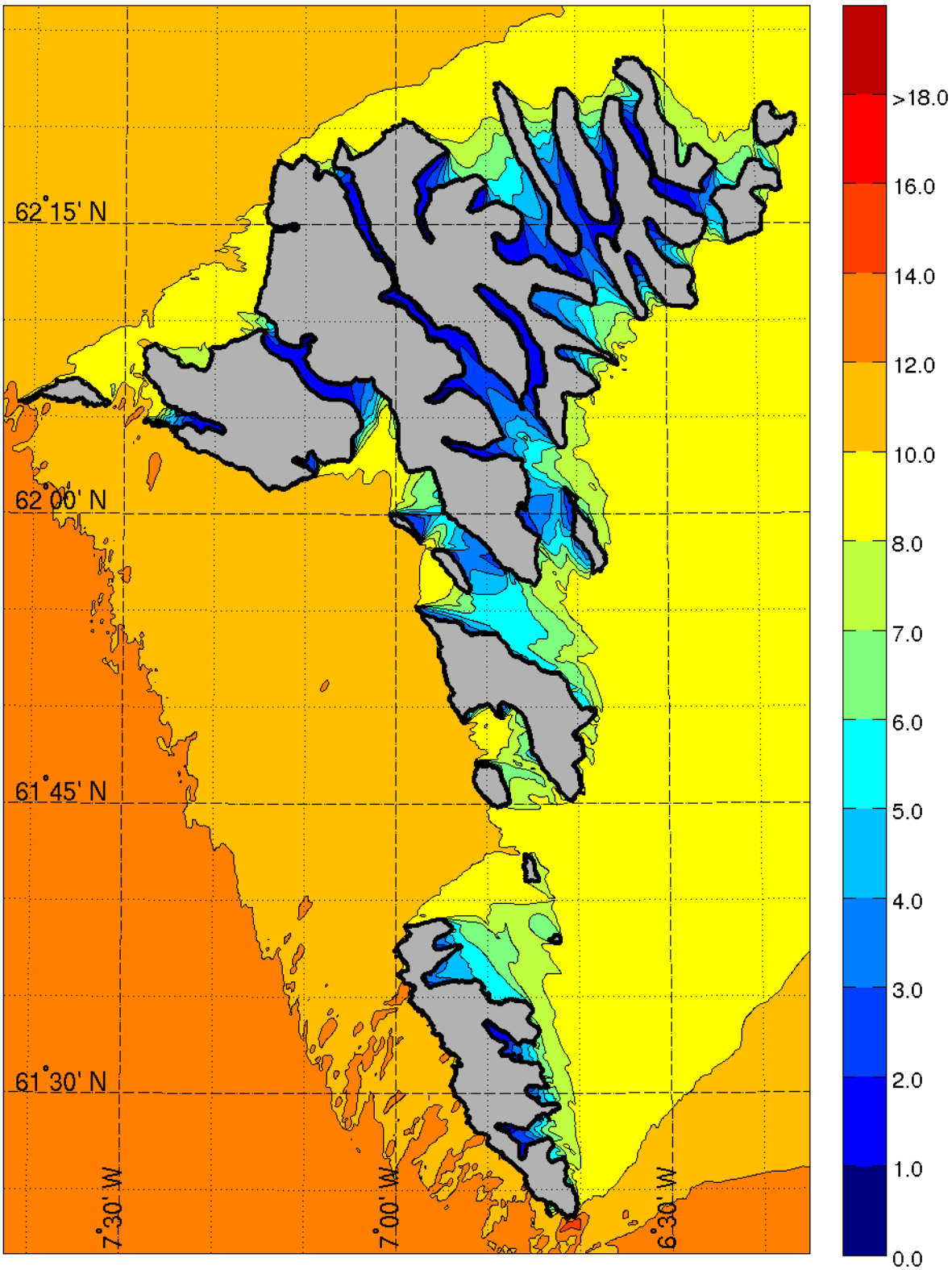

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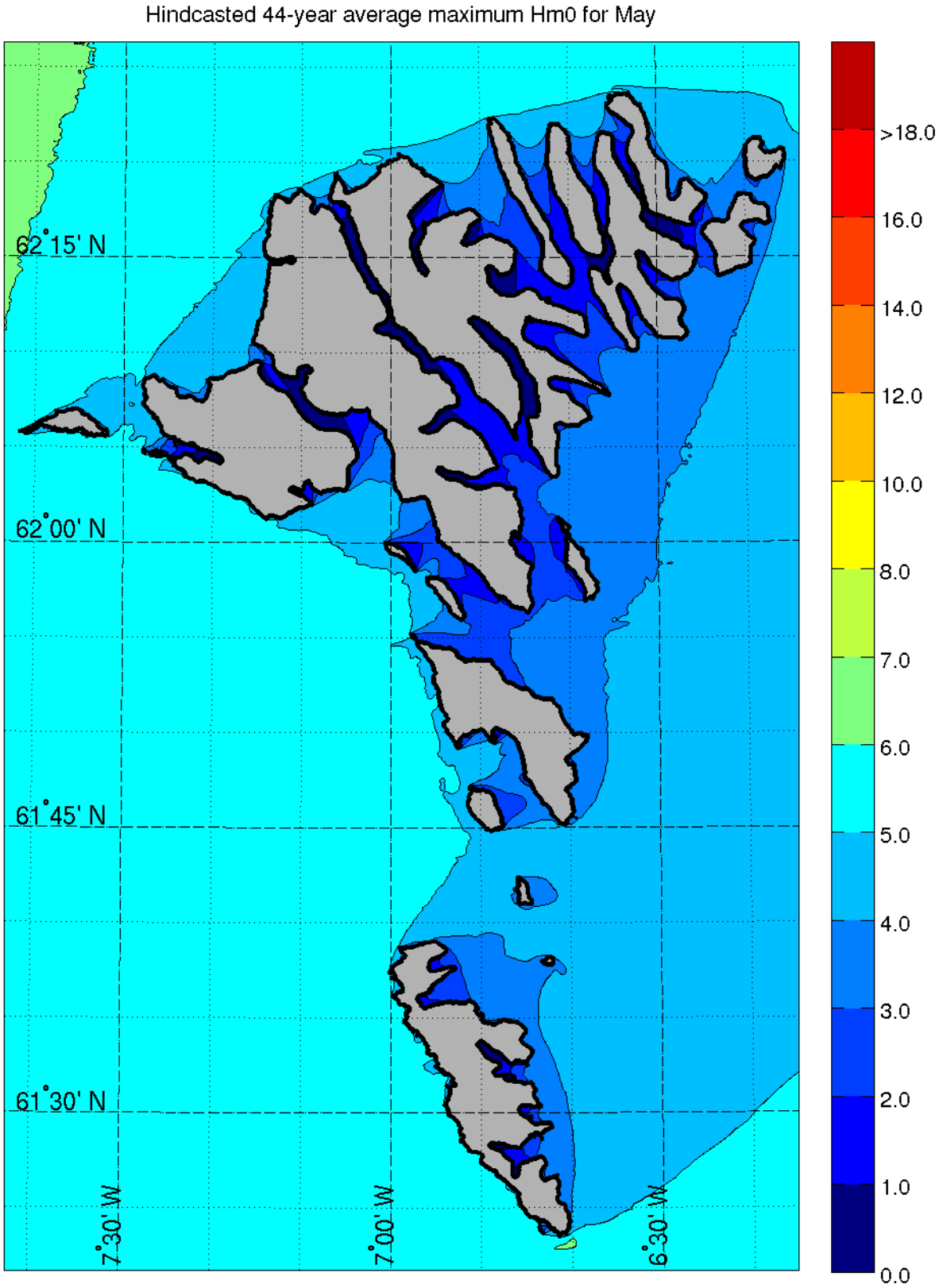

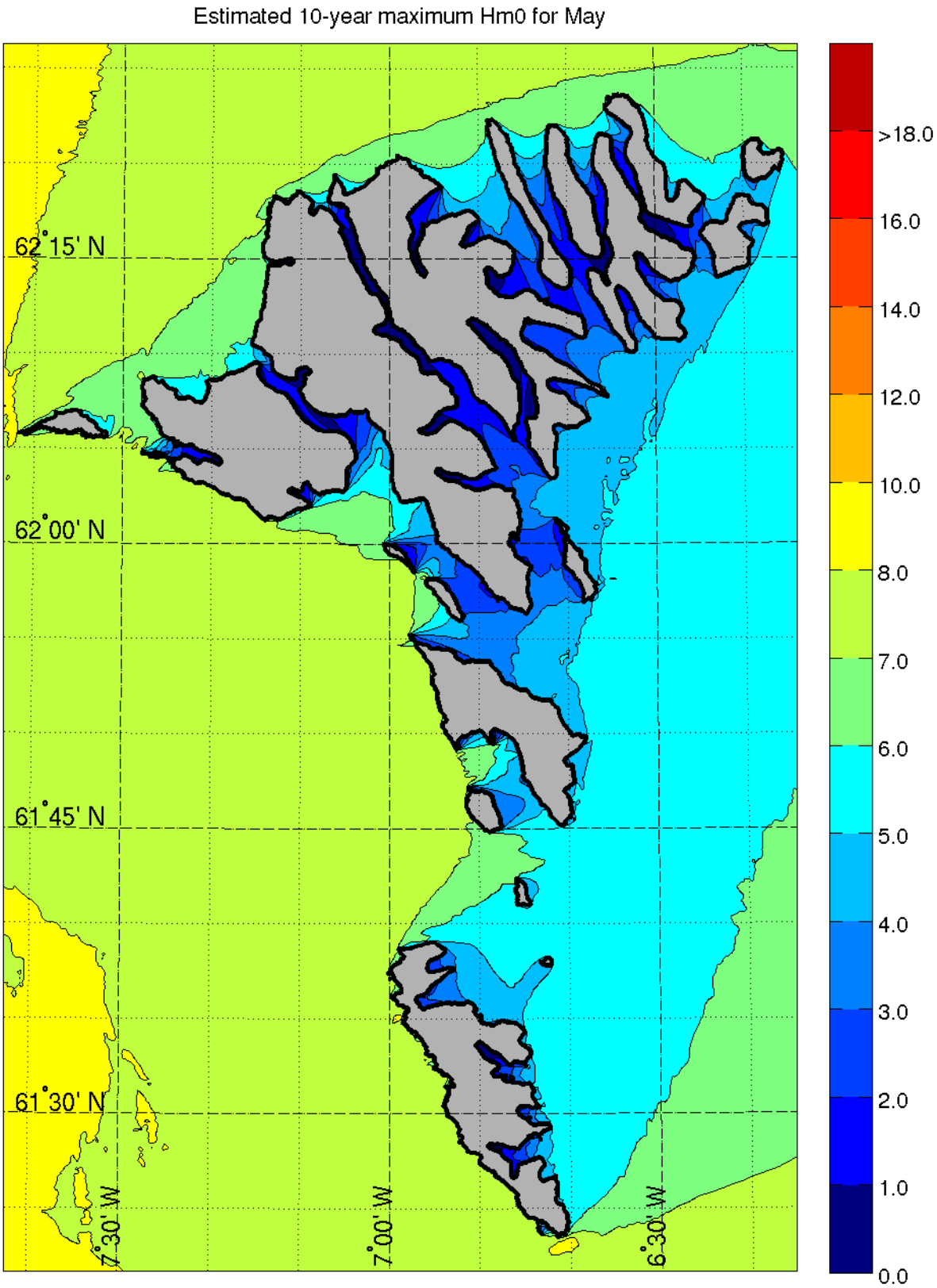
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61°45' N
61°30' N
7°30' W
7°00' W
6°30' W
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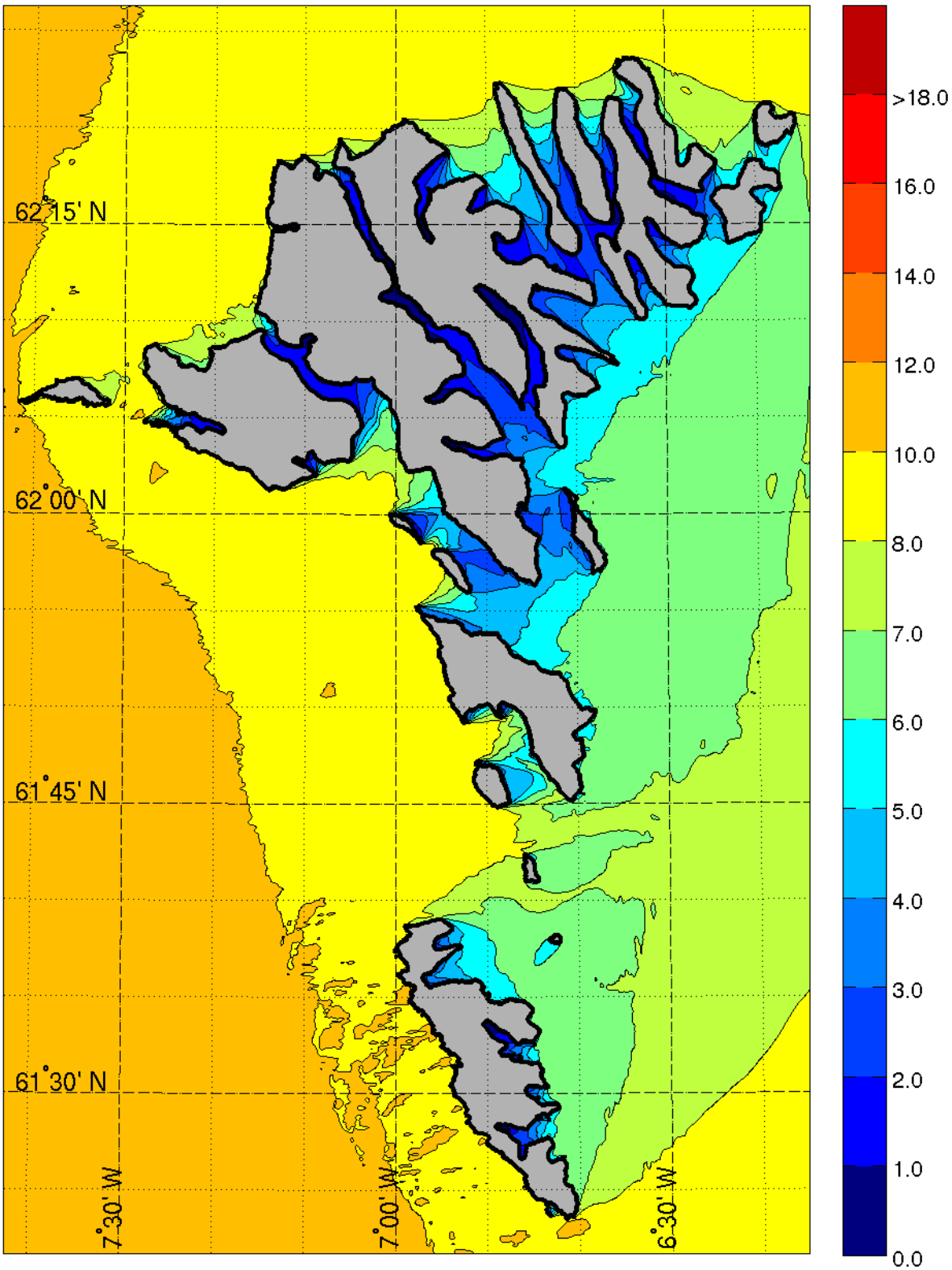
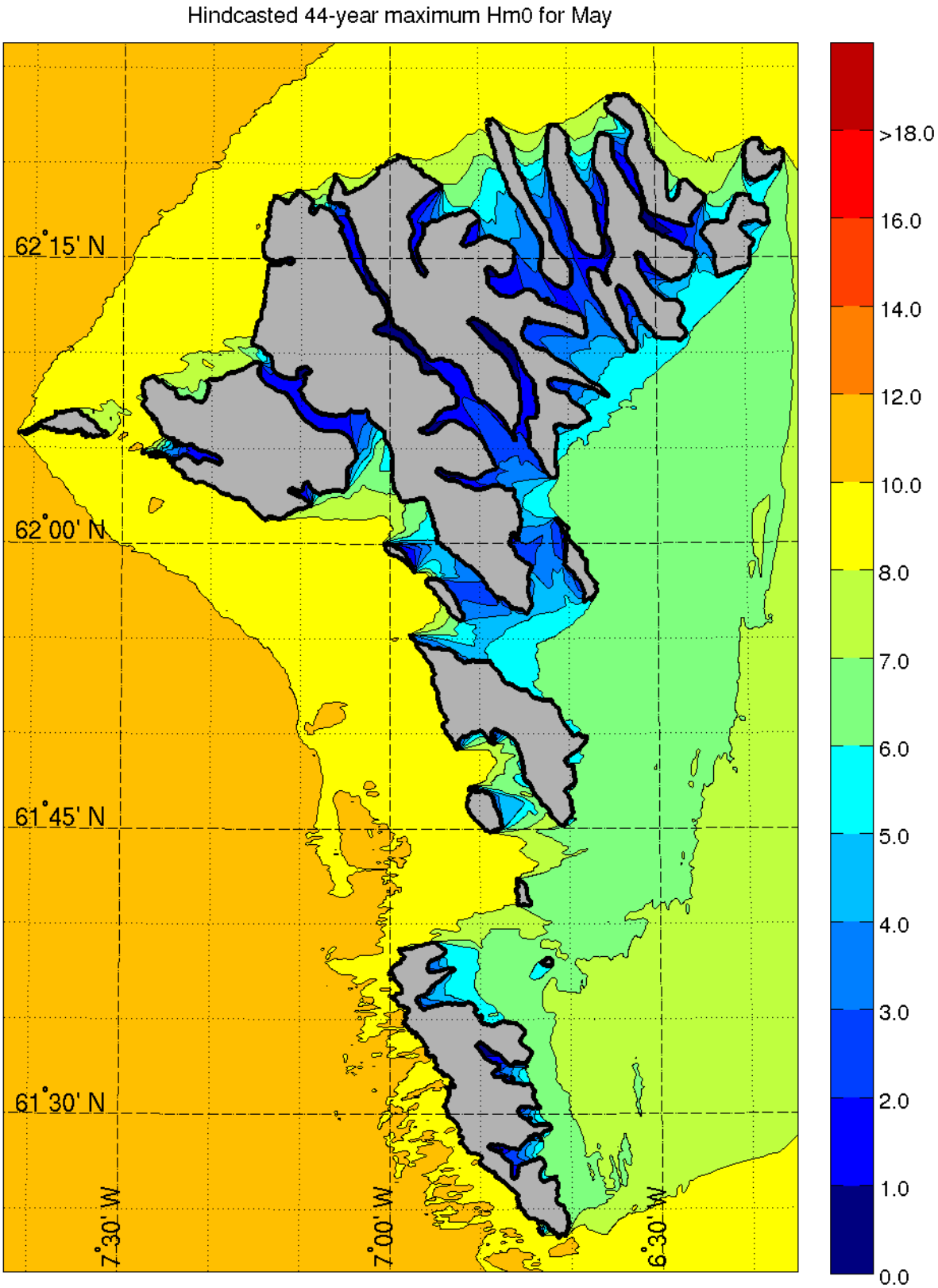
Estimated 50-year maximum Hm0 for May

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61°45' N
61°30' N
7°30' W
7°00' W
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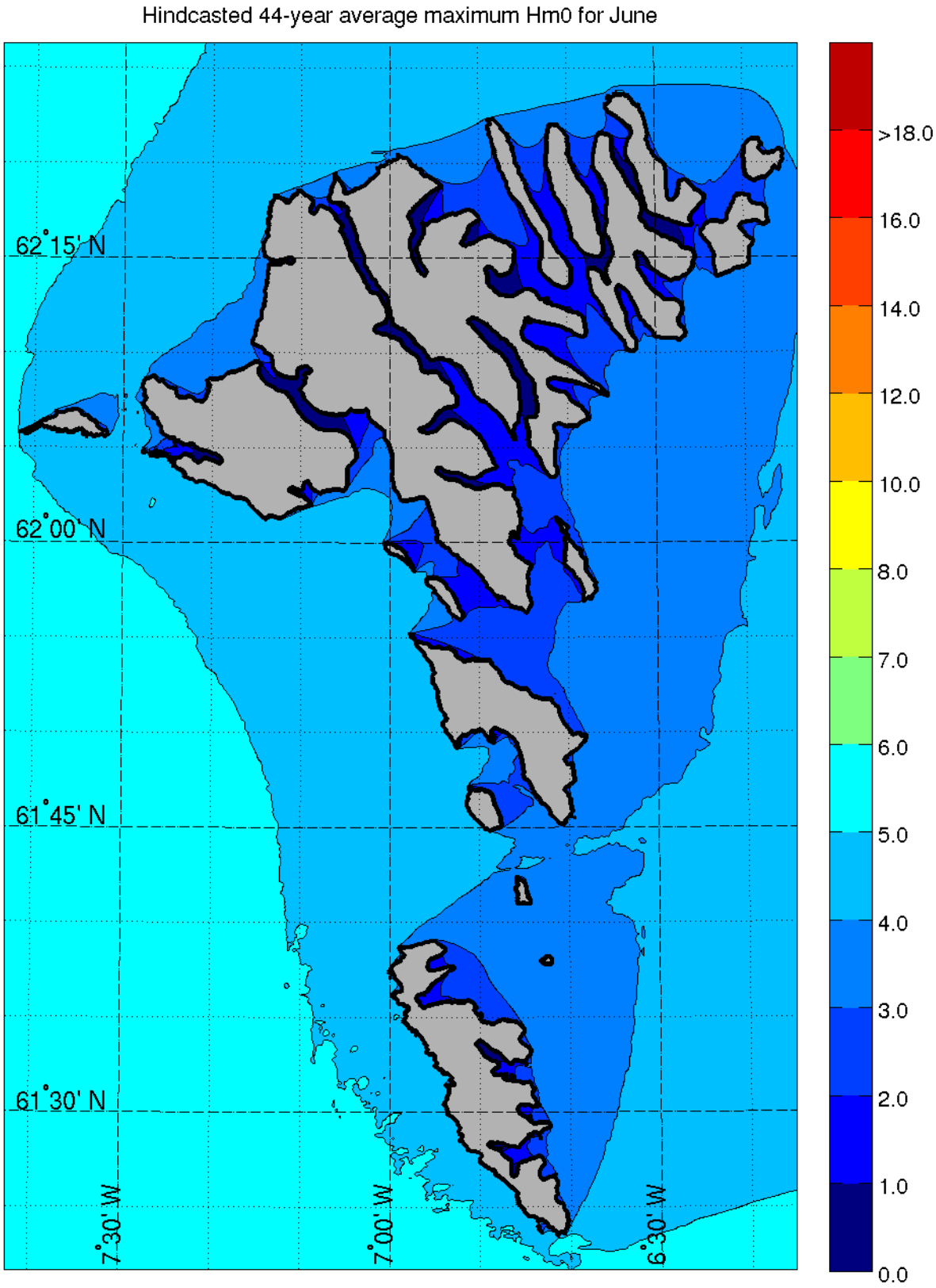
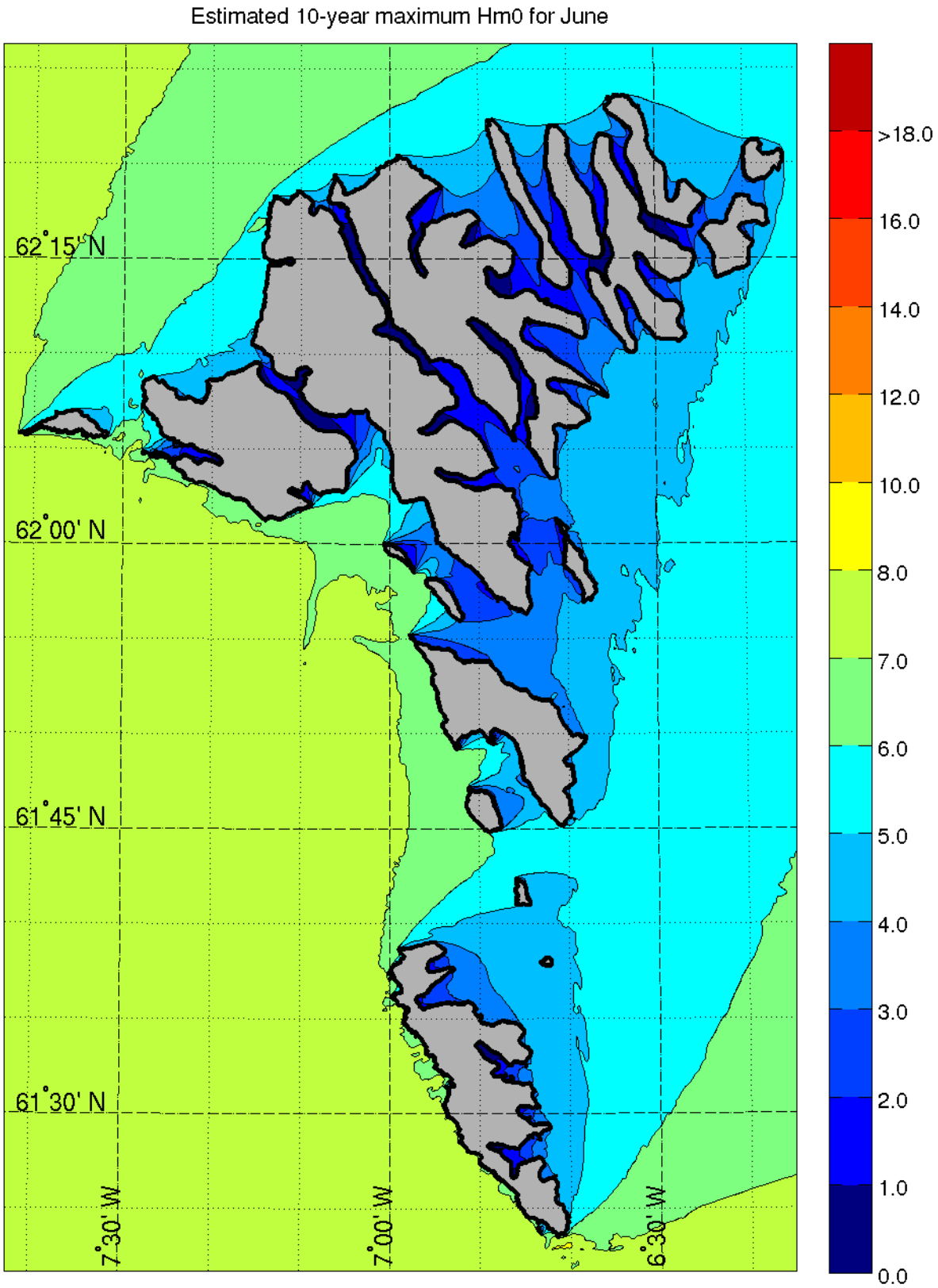
Statistics for June

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6°30' W
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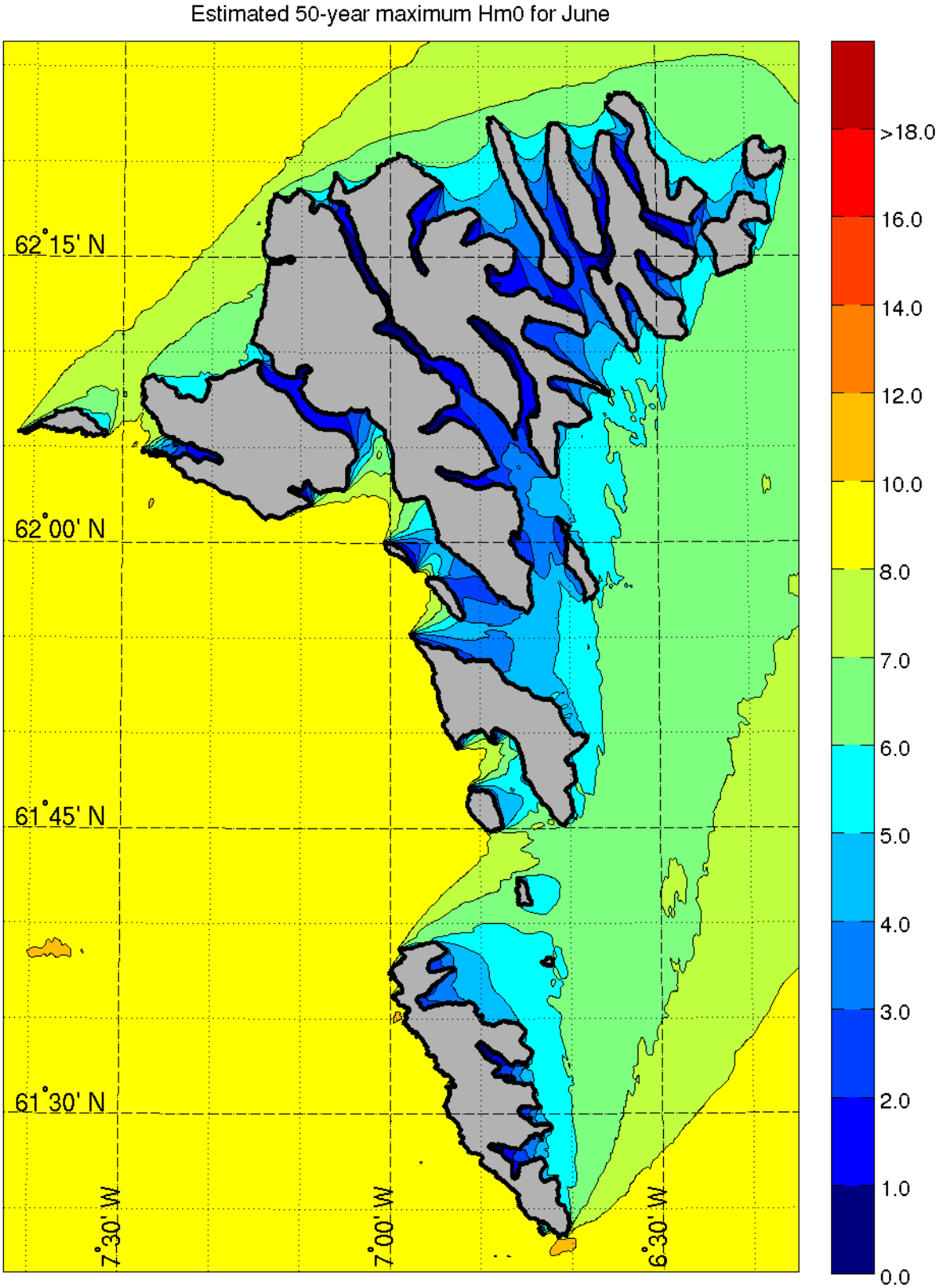
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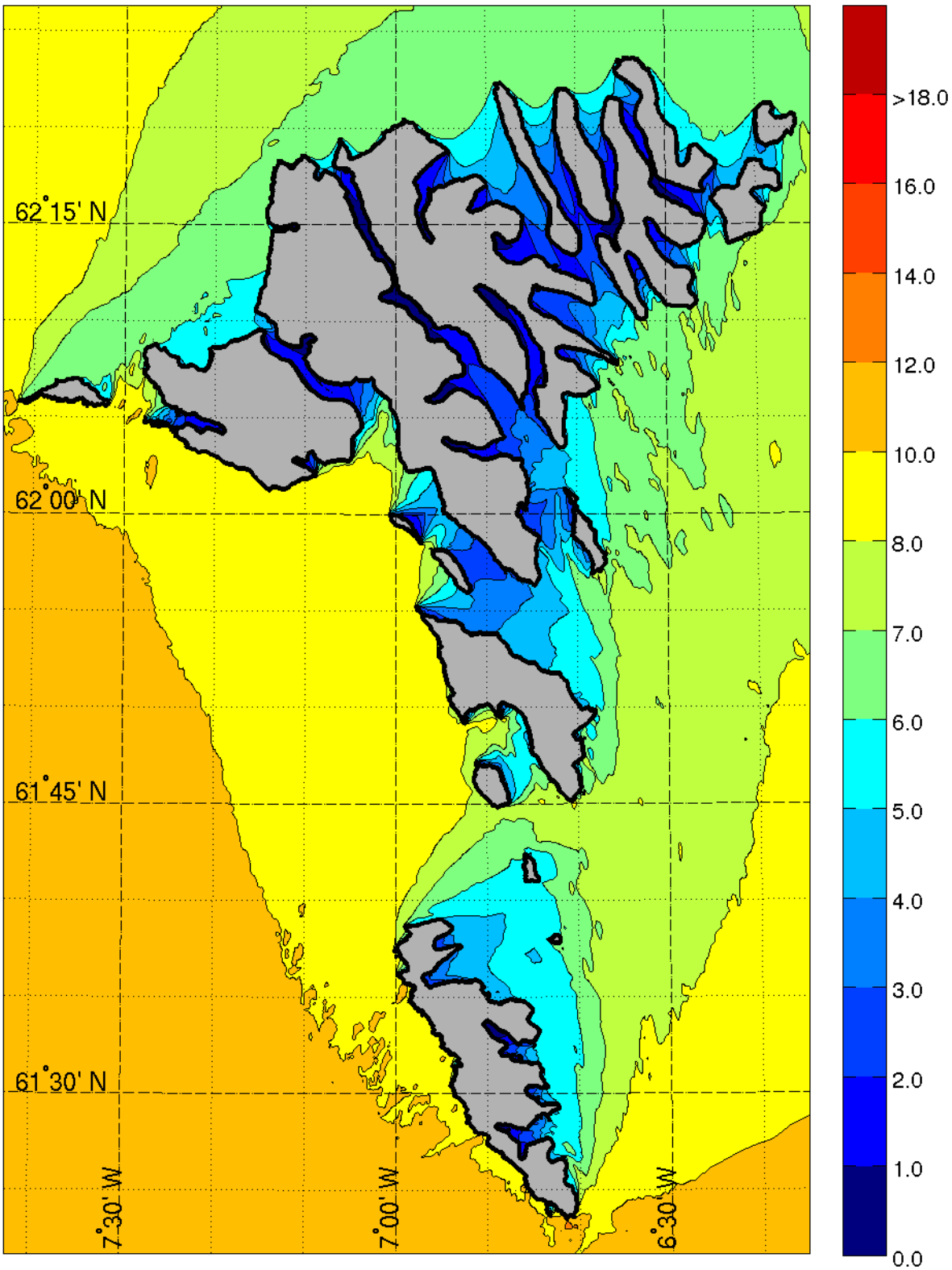
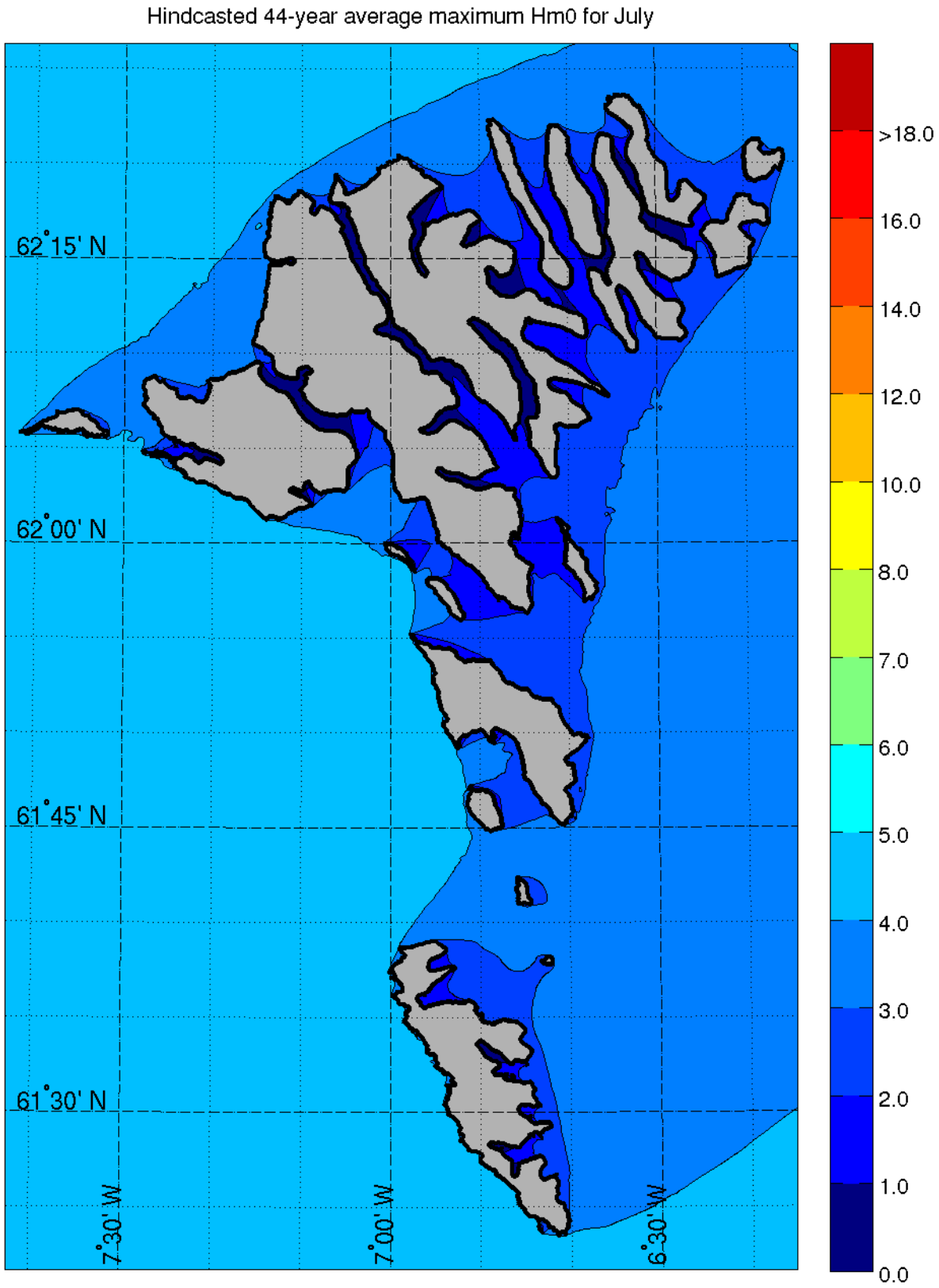
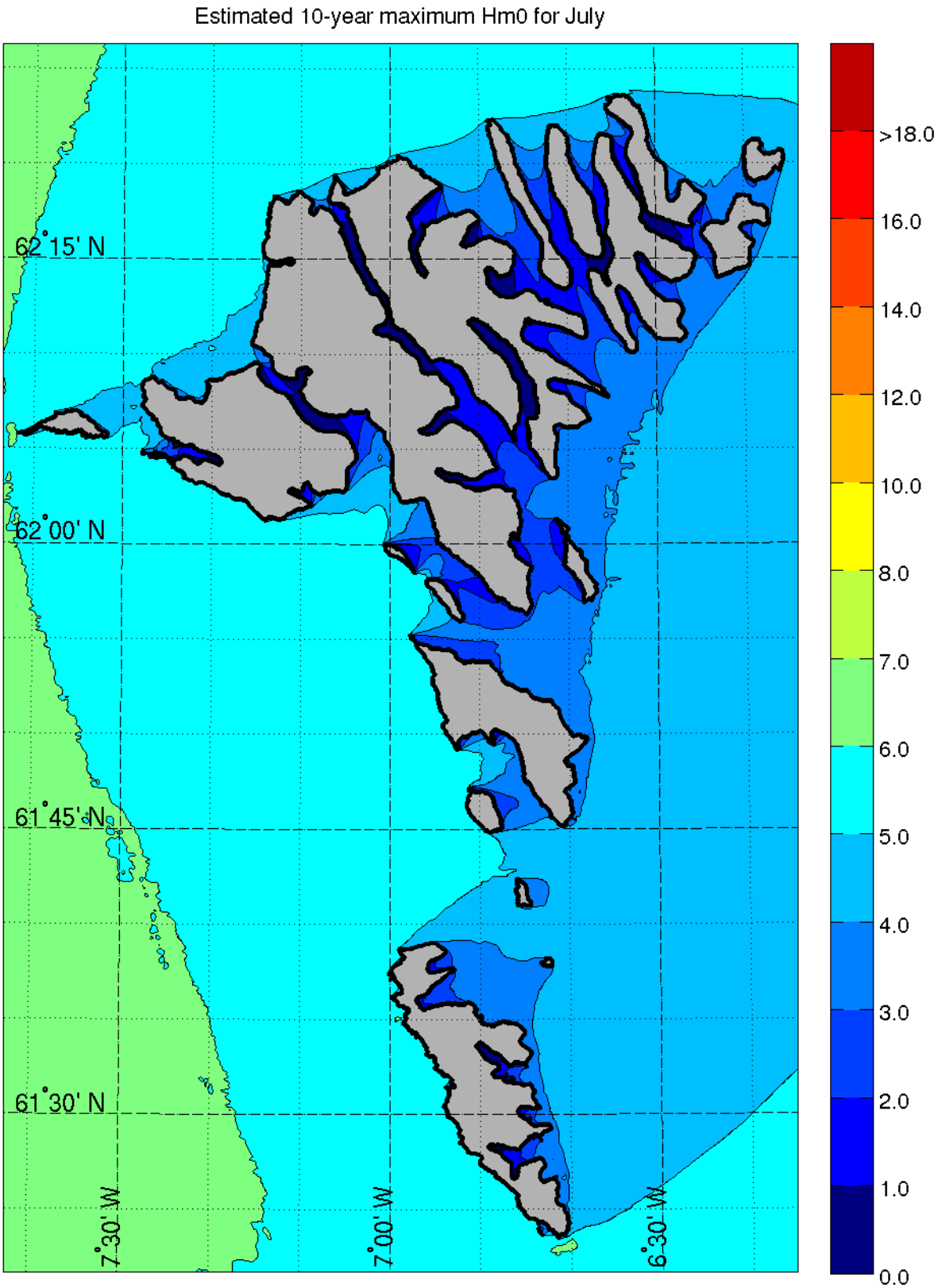
Hindcasted 44-year maximum Hm0 for June



Statistics for July

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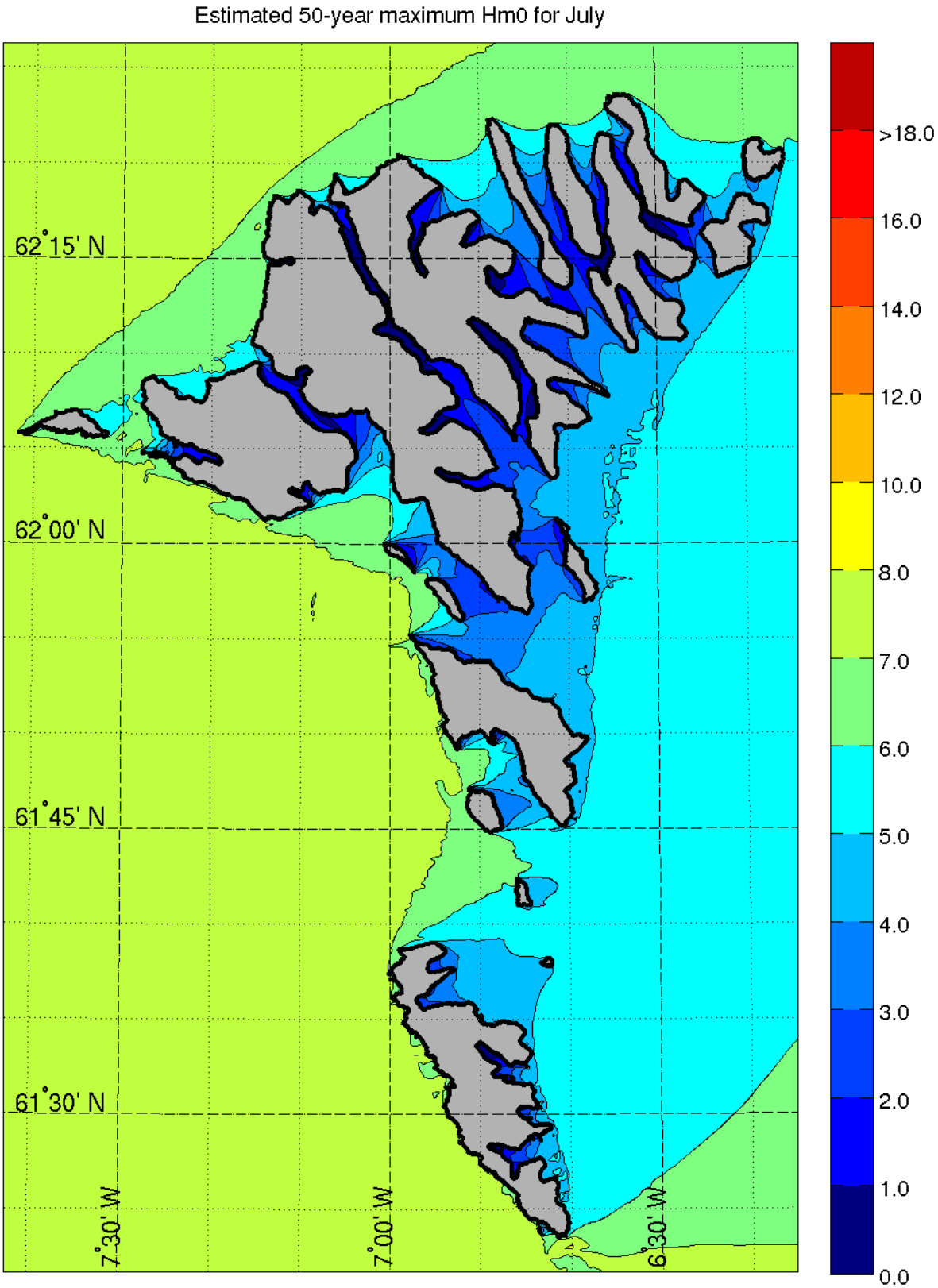
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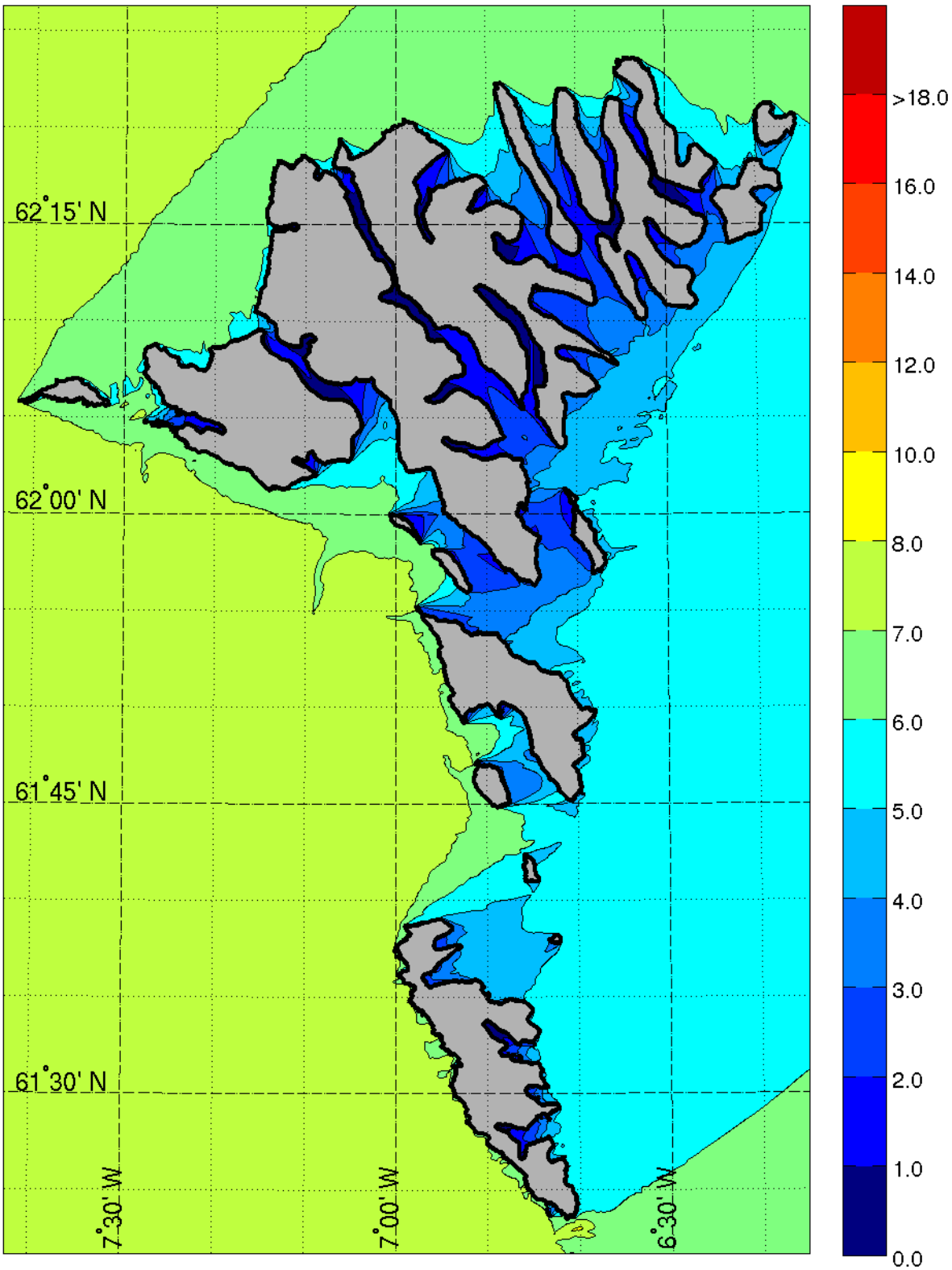
Hindcasted 44-year maximum Hm0 for July



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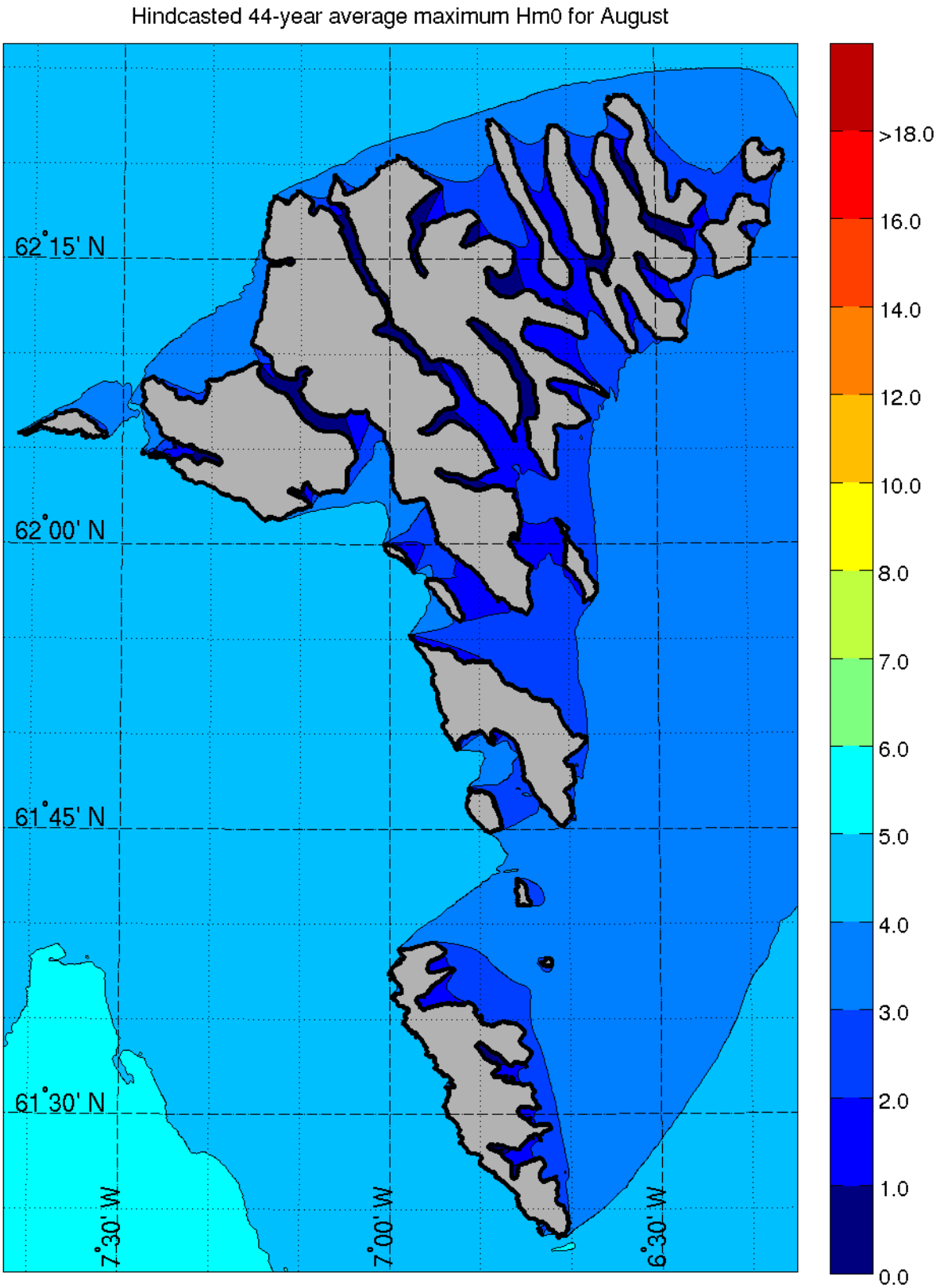

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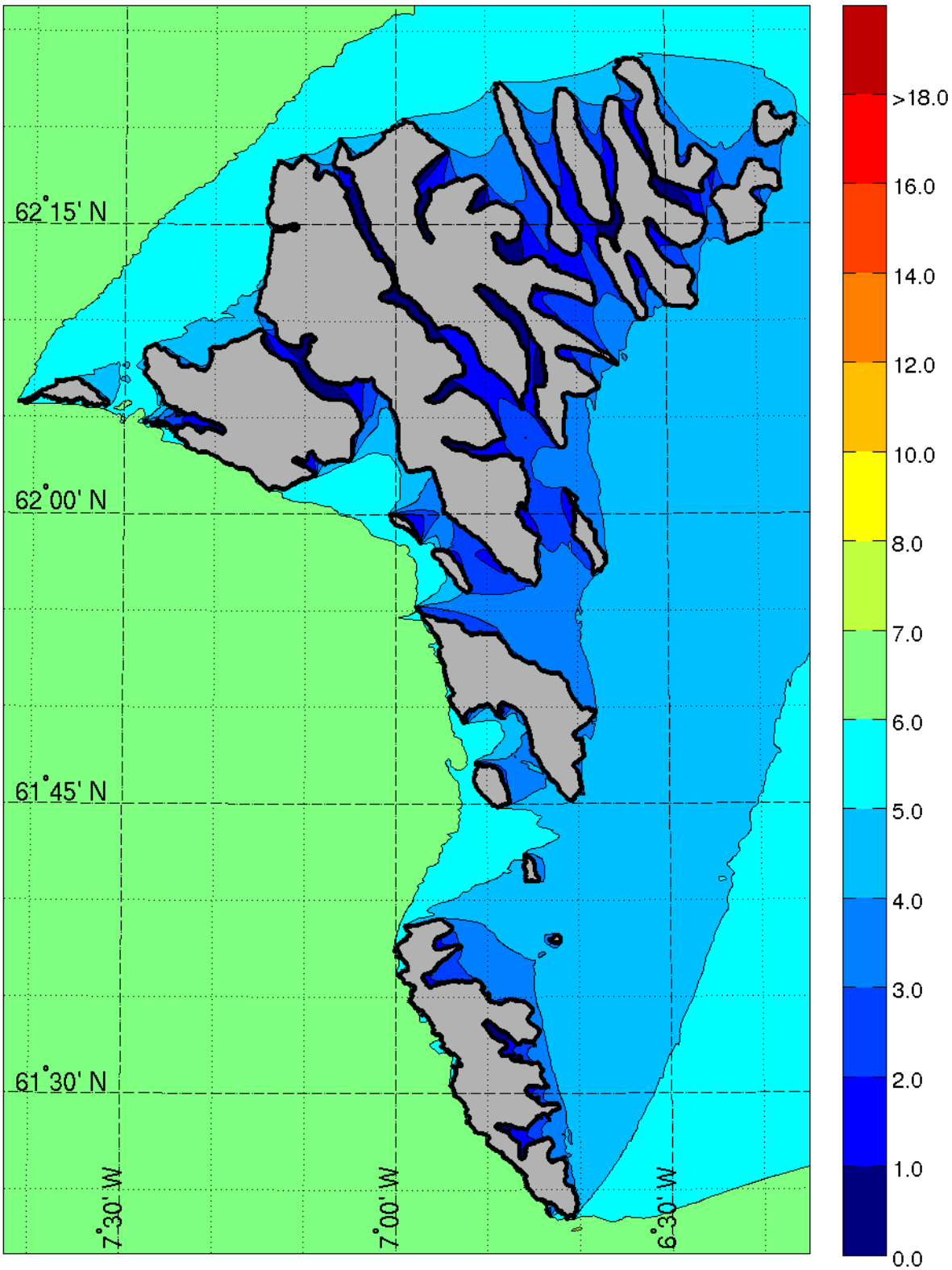
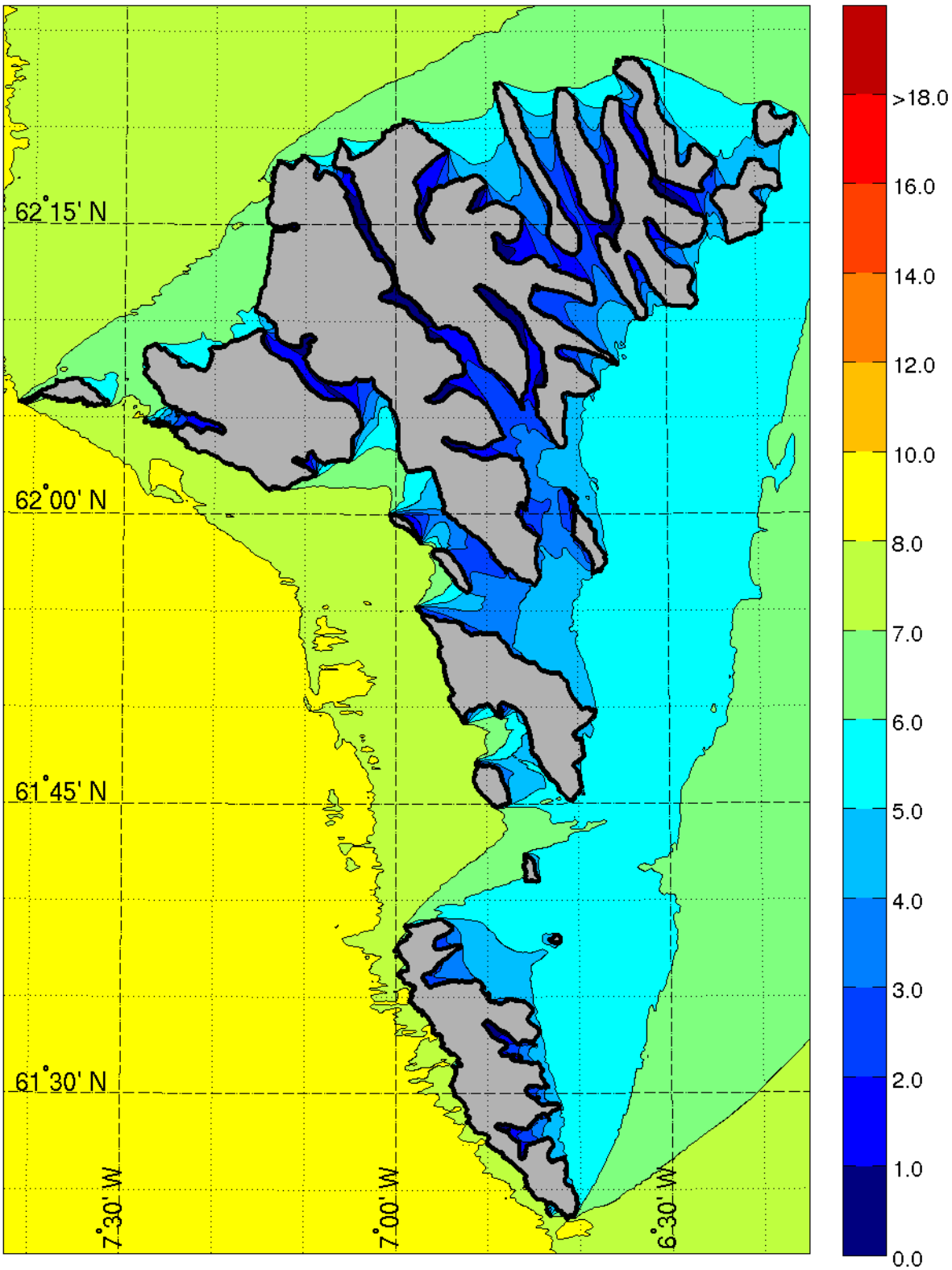
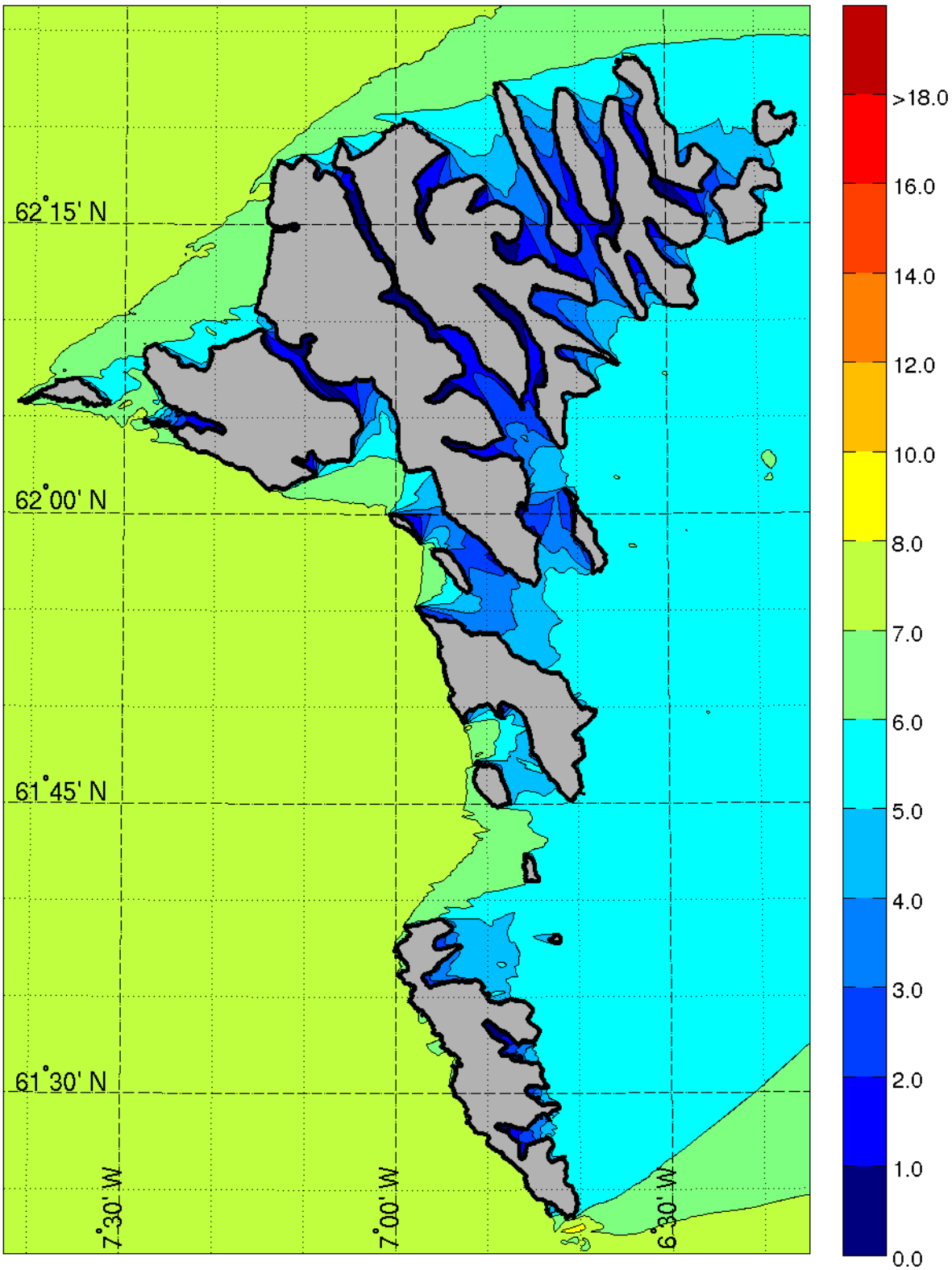


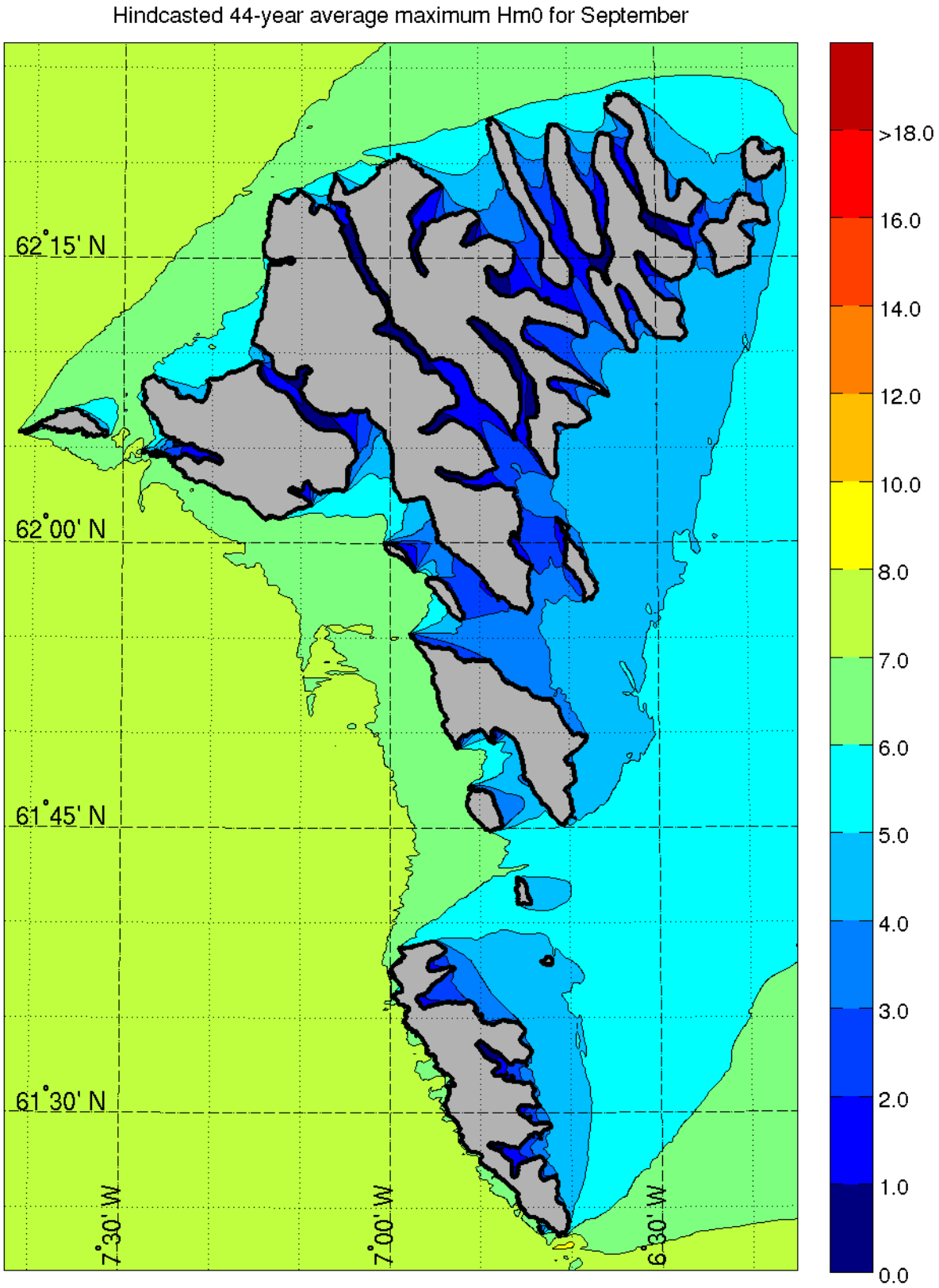
Estimated 50-year maximum Hm0 for August



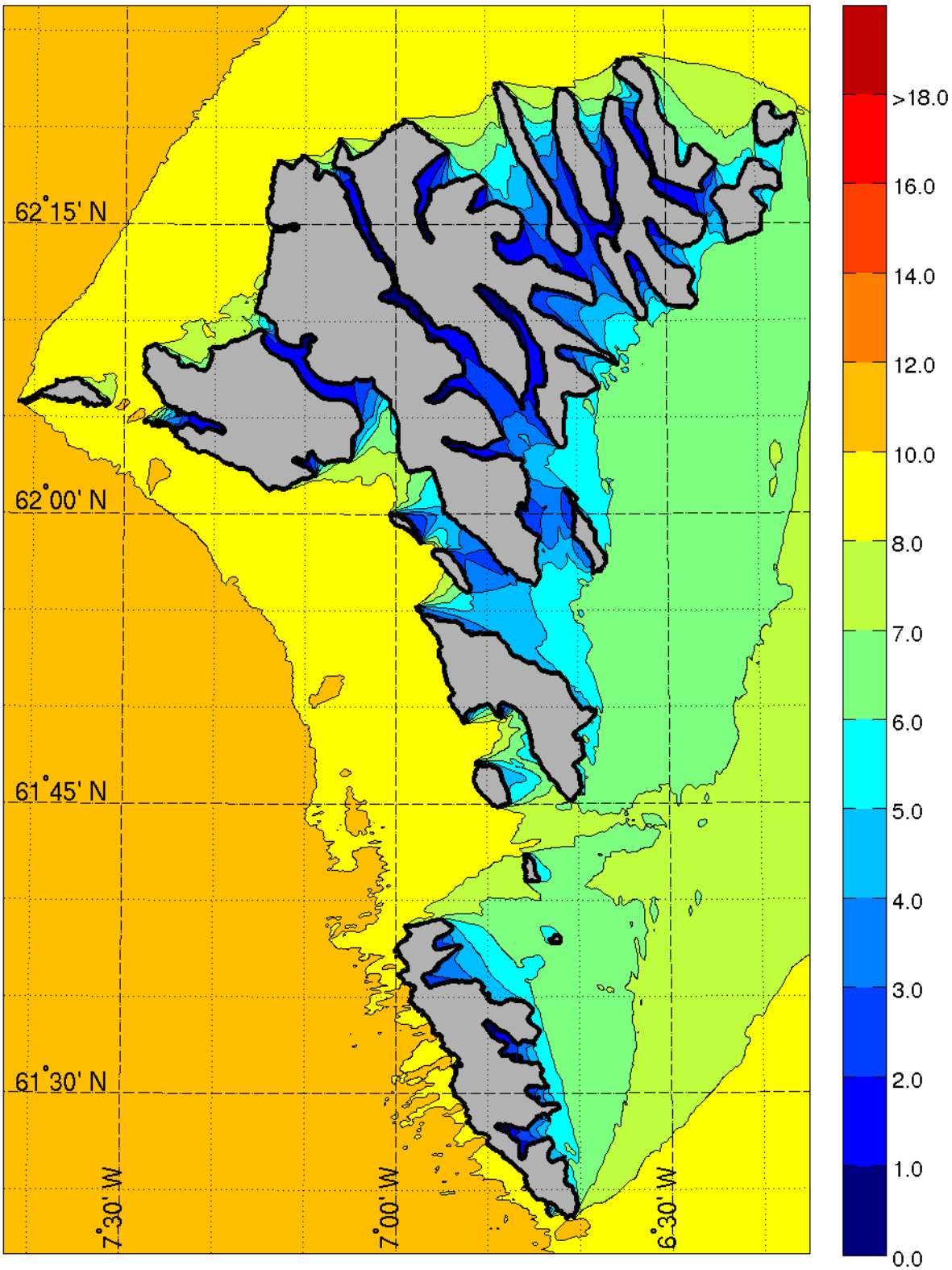
Hindcasted 44-year maximum Hm0 for August



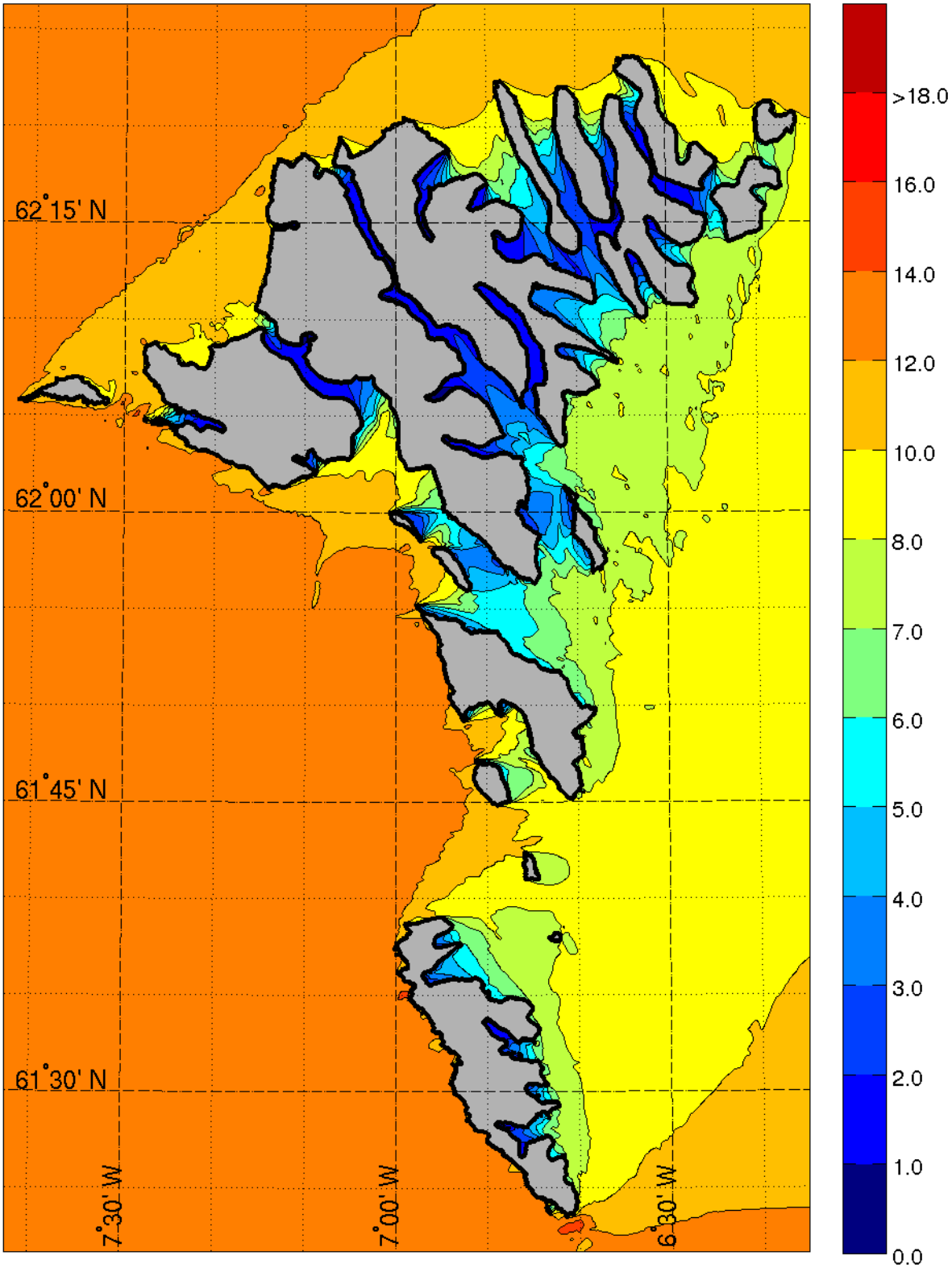
Statistics for September



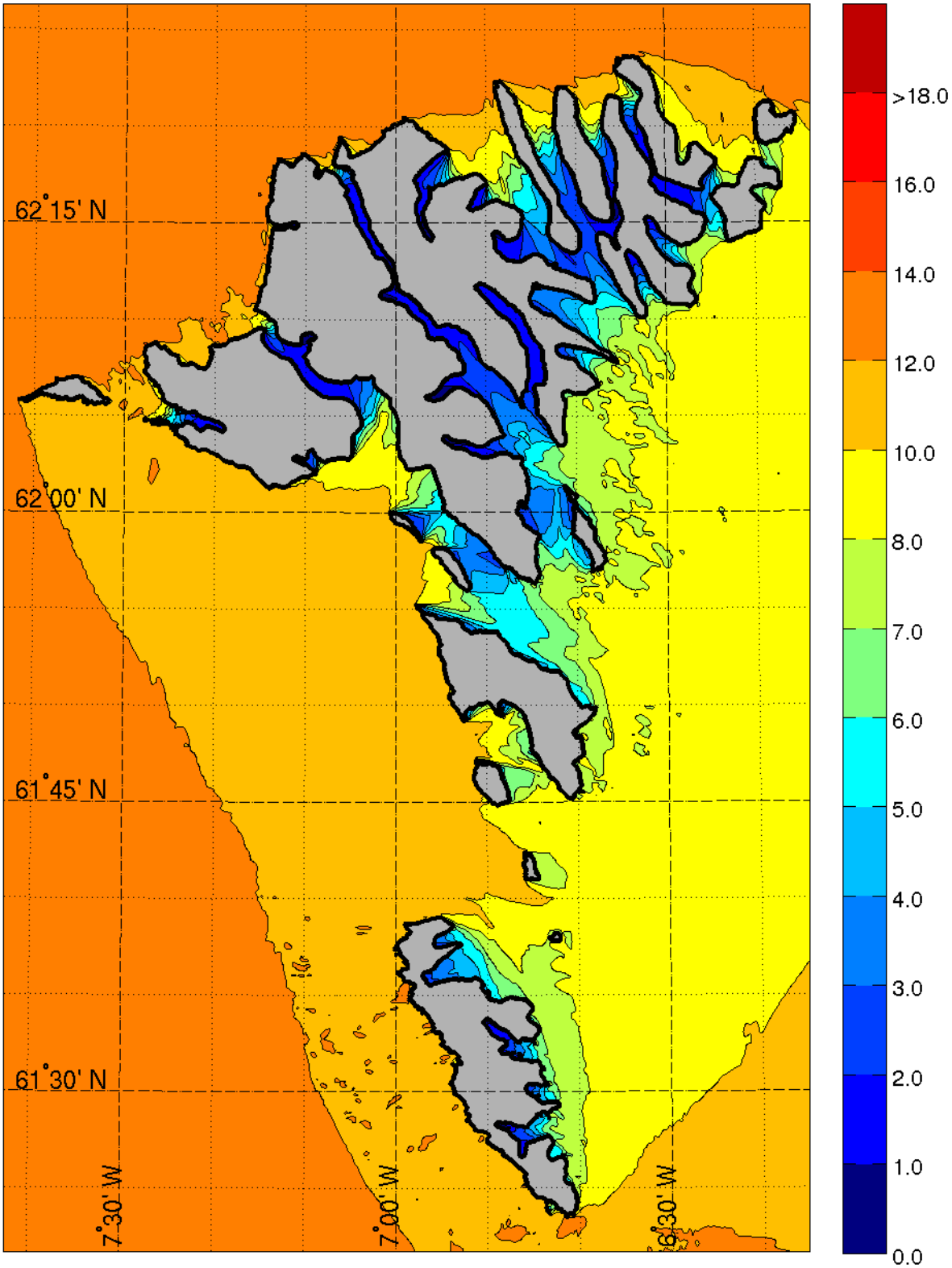
Estimated 10-year maximum Hm0 for September



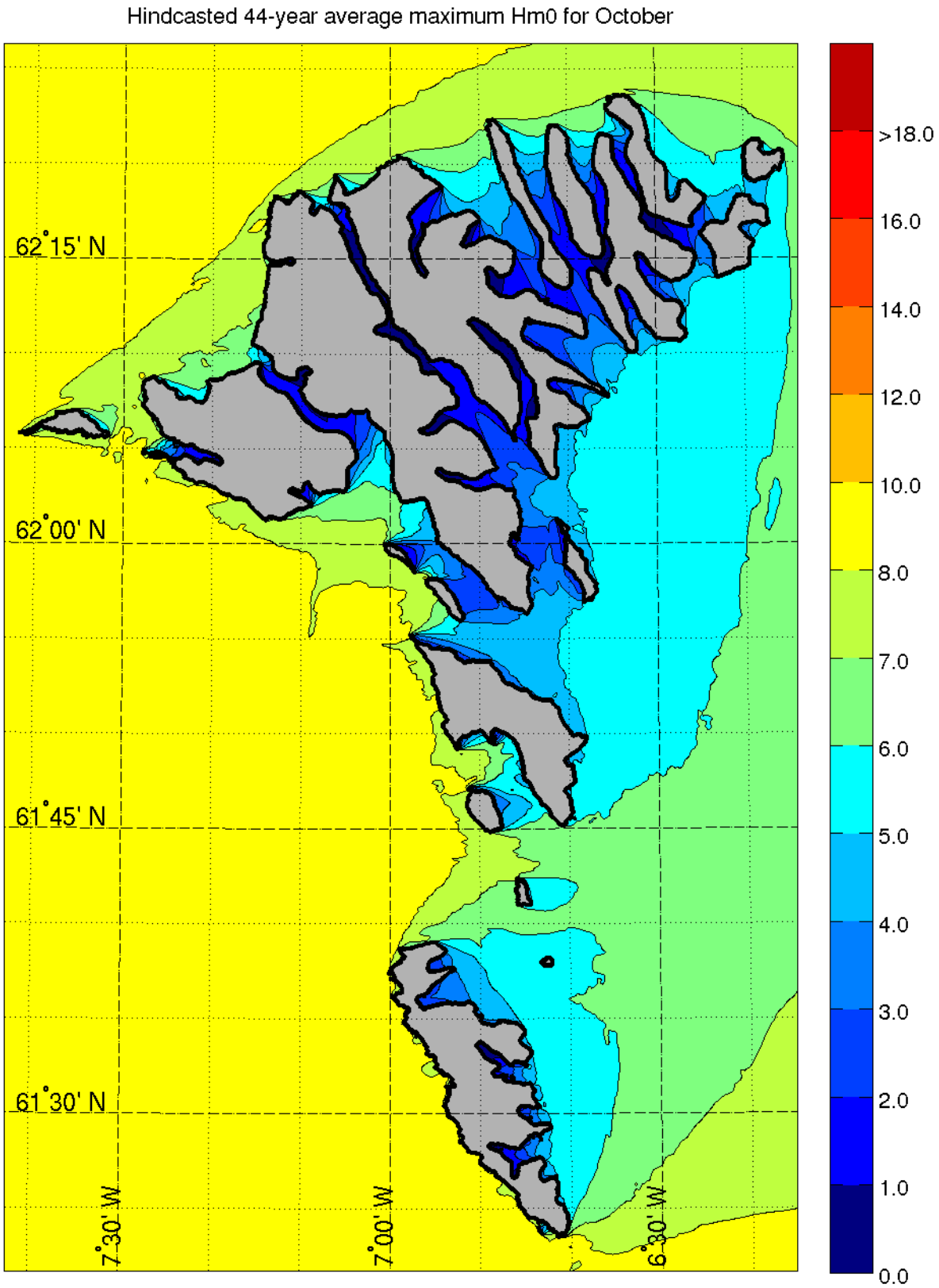
Estimated 50-year maximum Hm0 for September



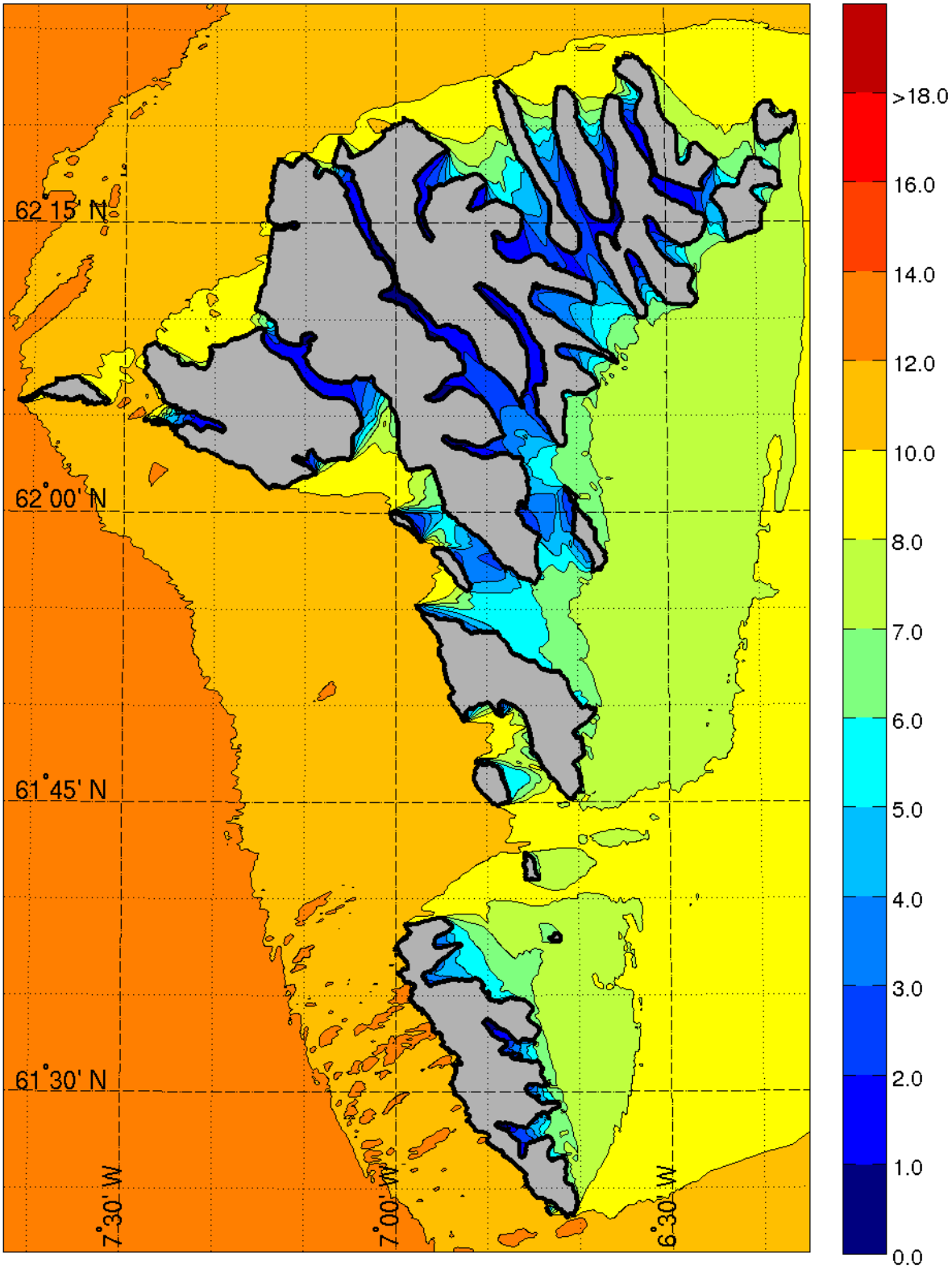
Hindcasted 44-year maximum Hm0 for September



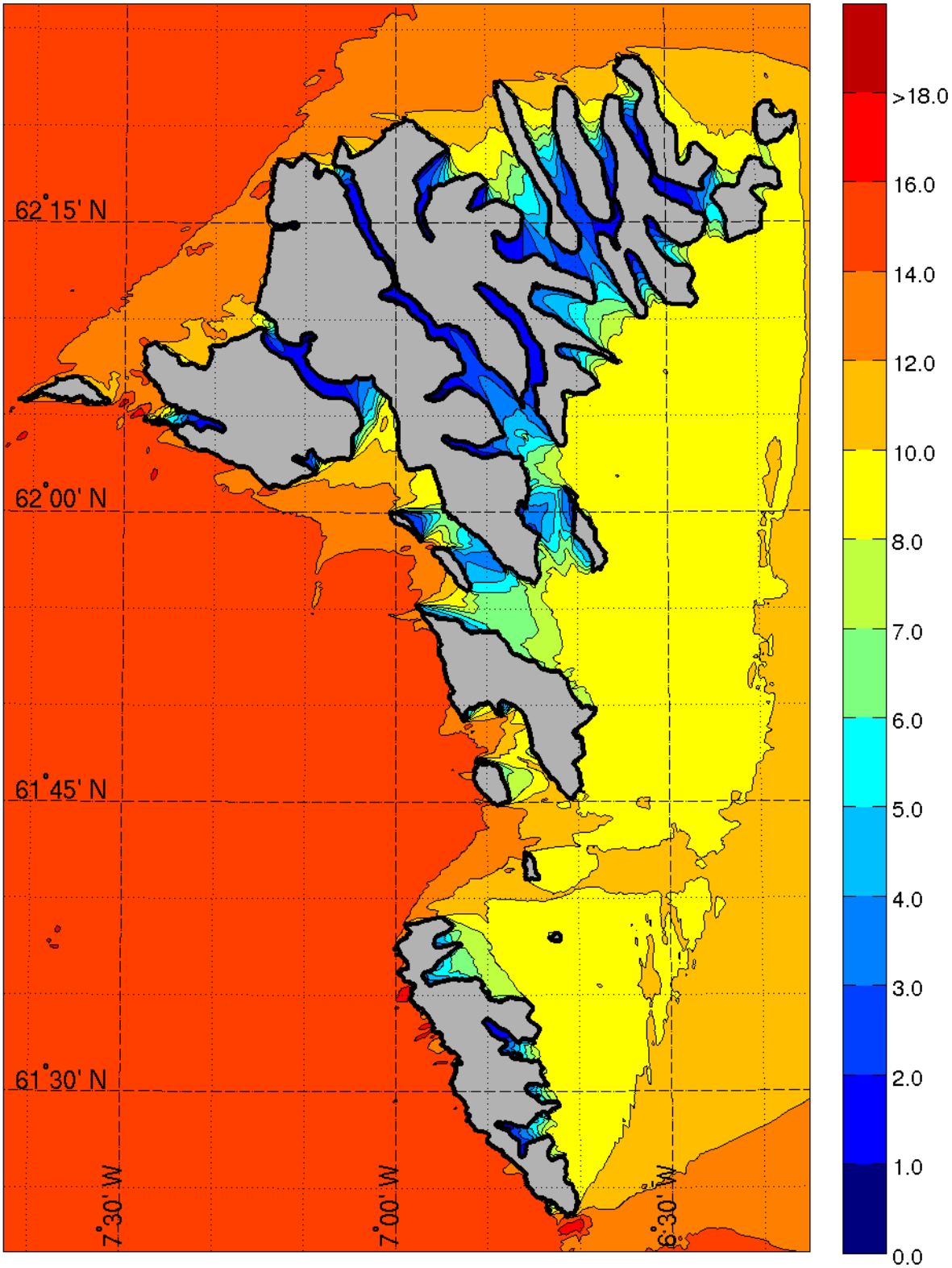
Statistics for October



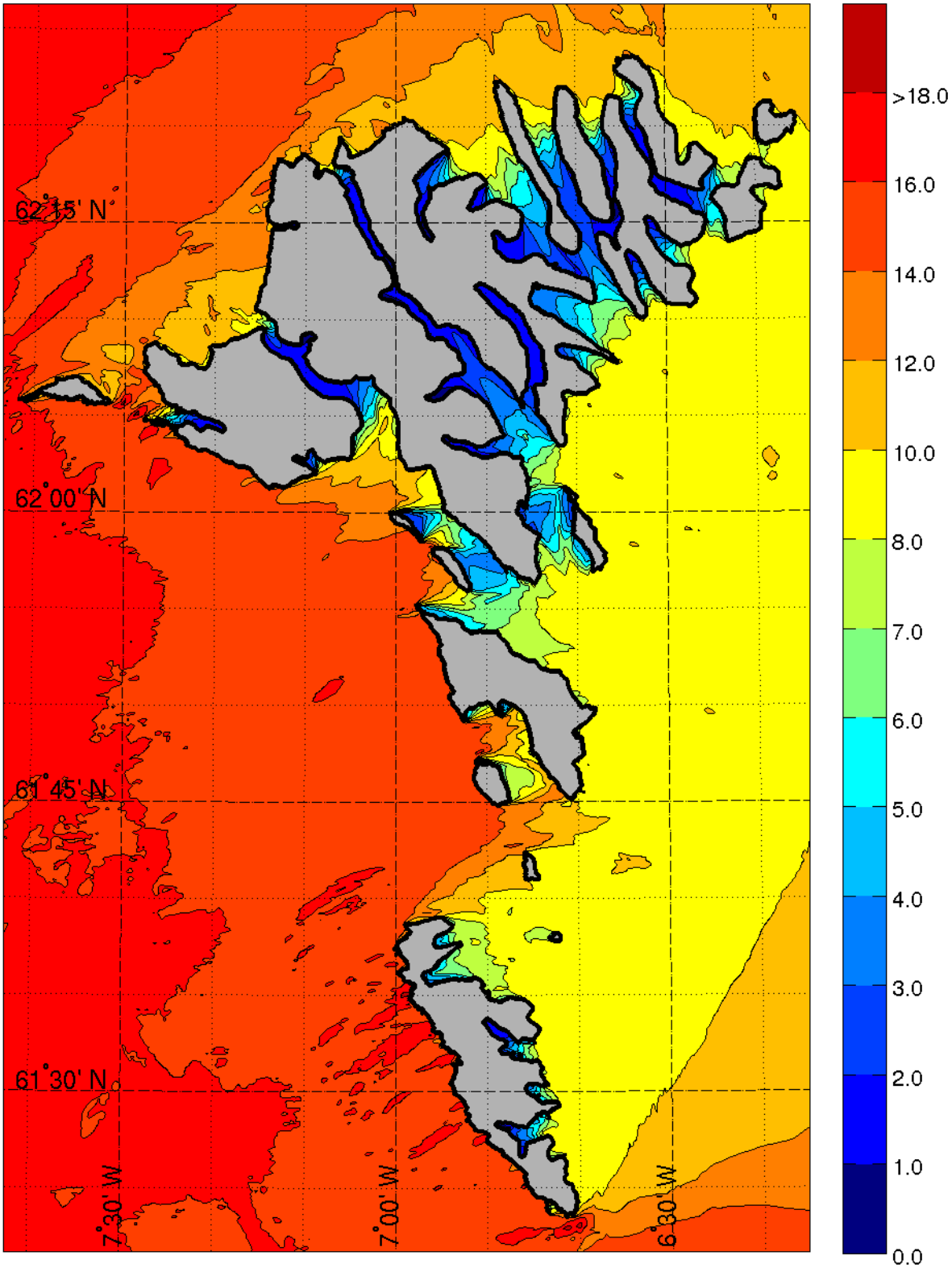
Estimated 10-year maximum Hm0 for October



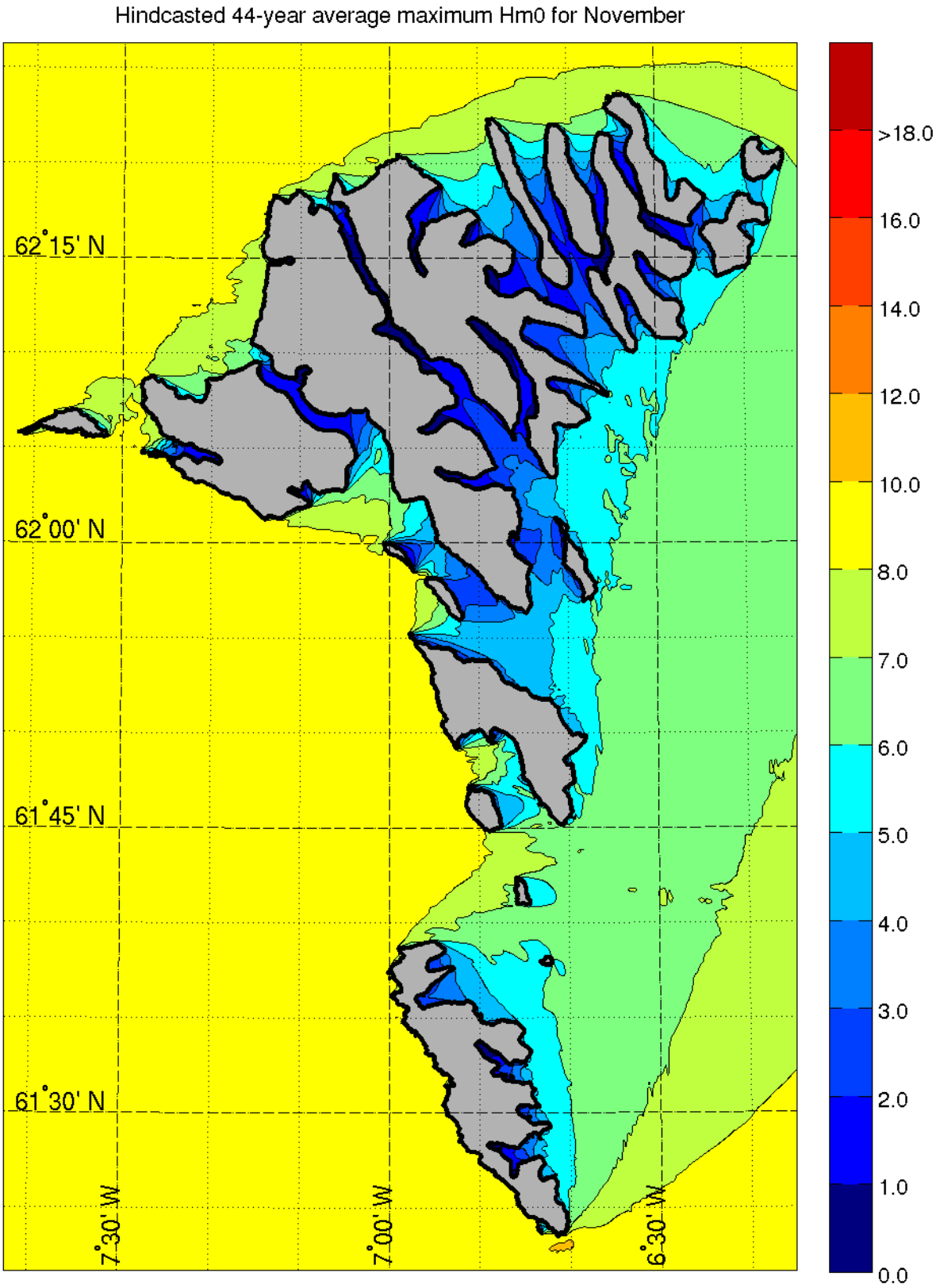
Estimated 50-year maximum Hm0 for October



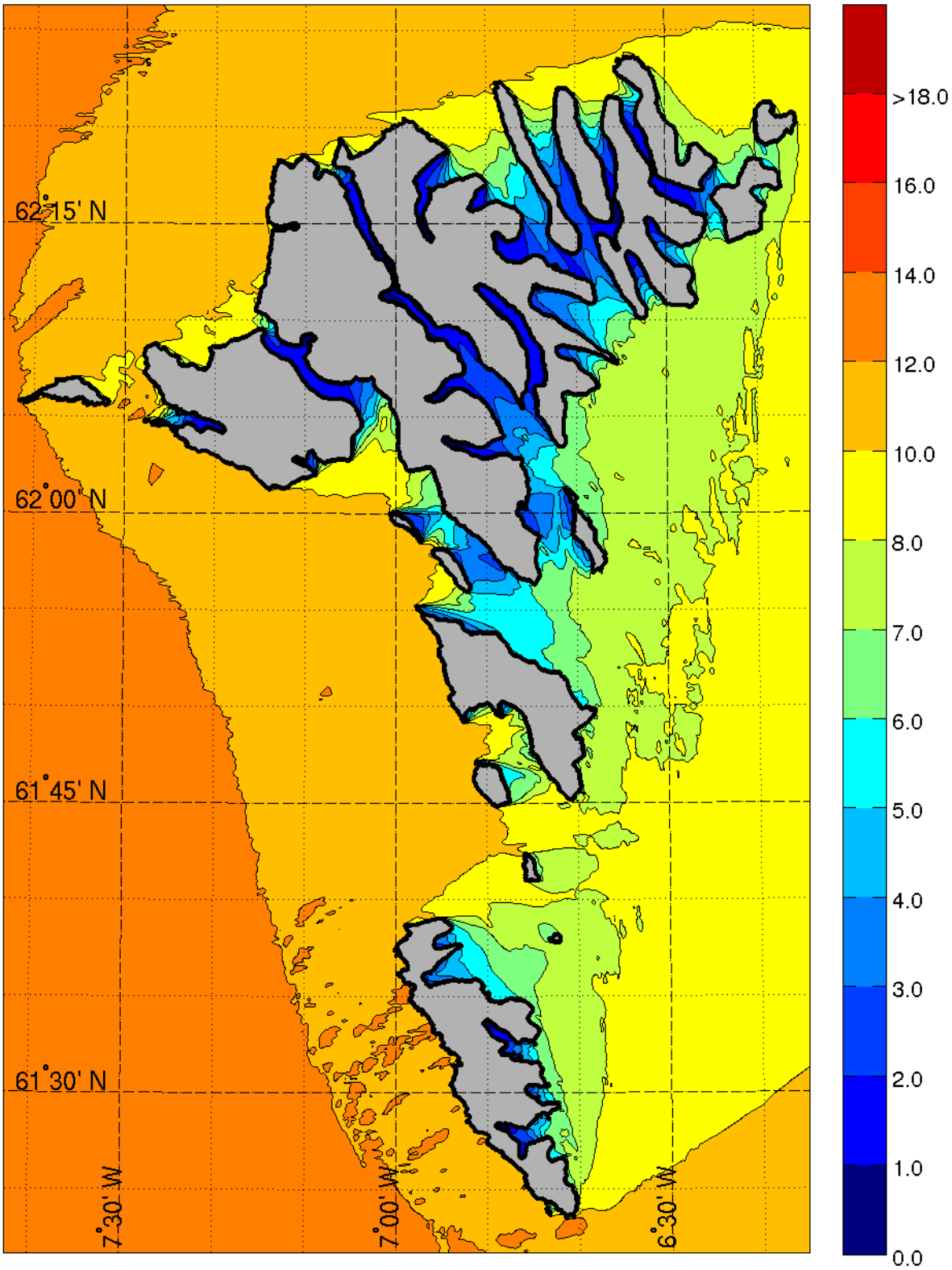
Hindcasted 44-year maximum Hm0 for October



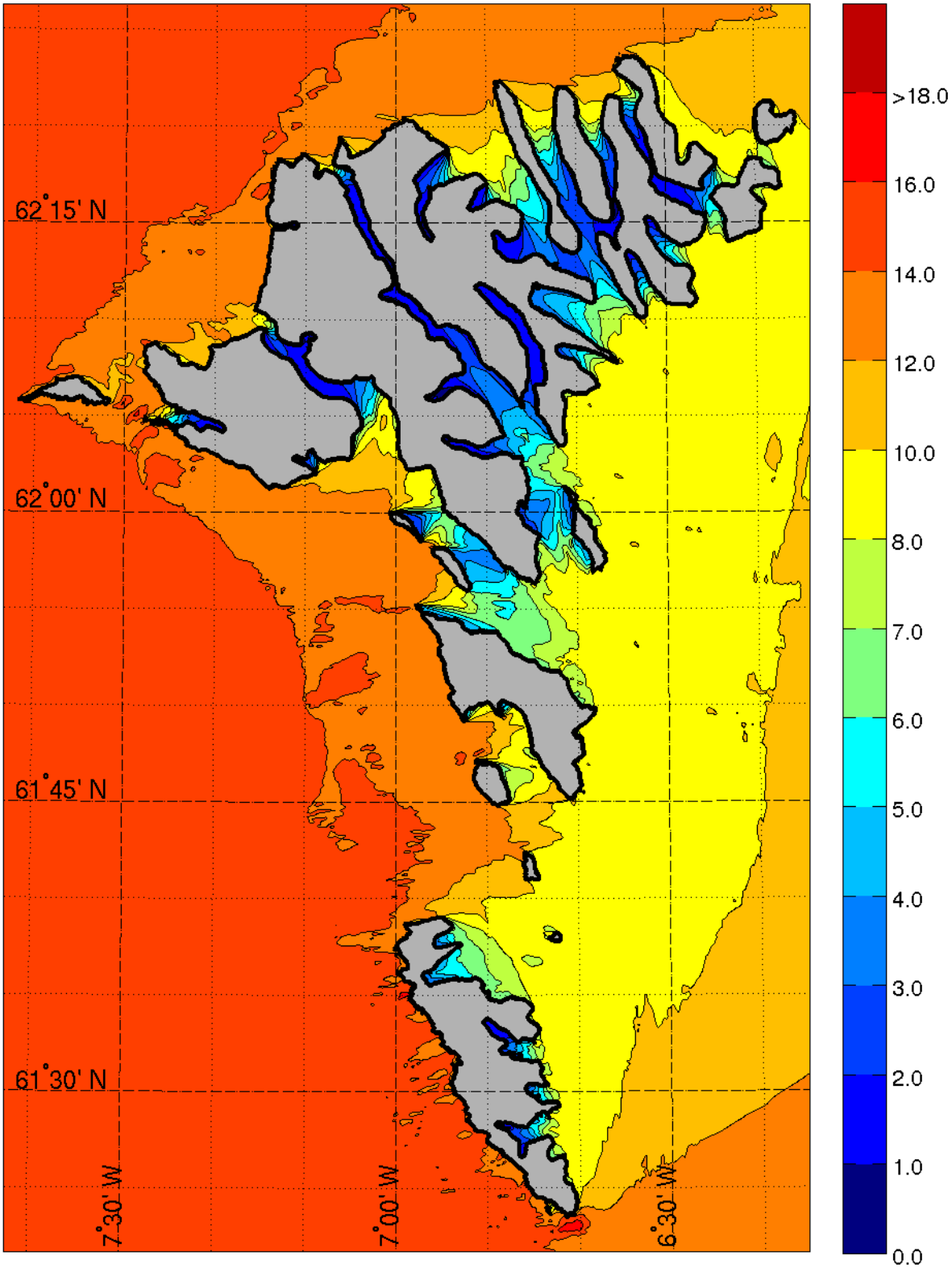
Statistics for November



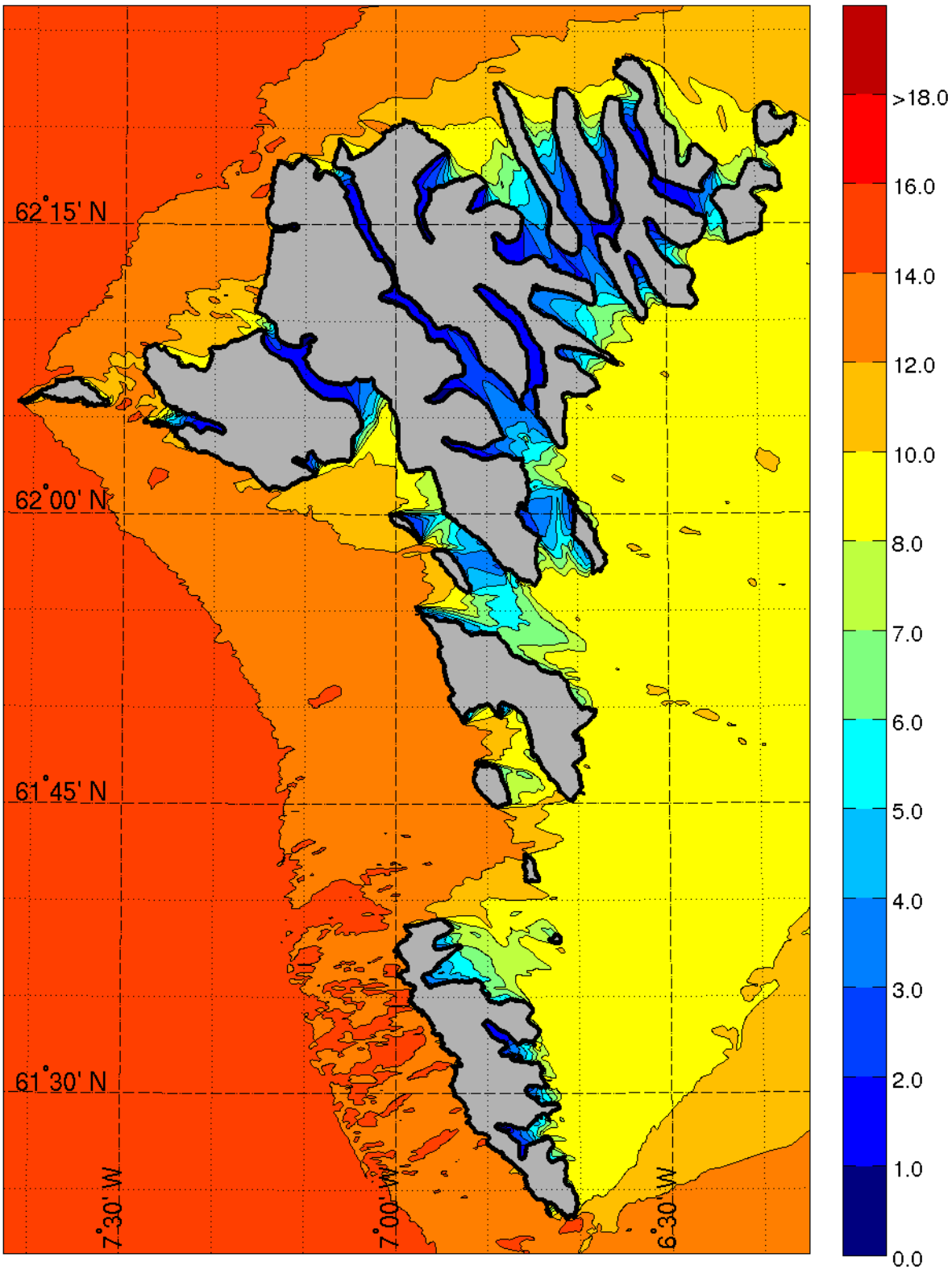
Estimated 10-year maximum Hm0 for November



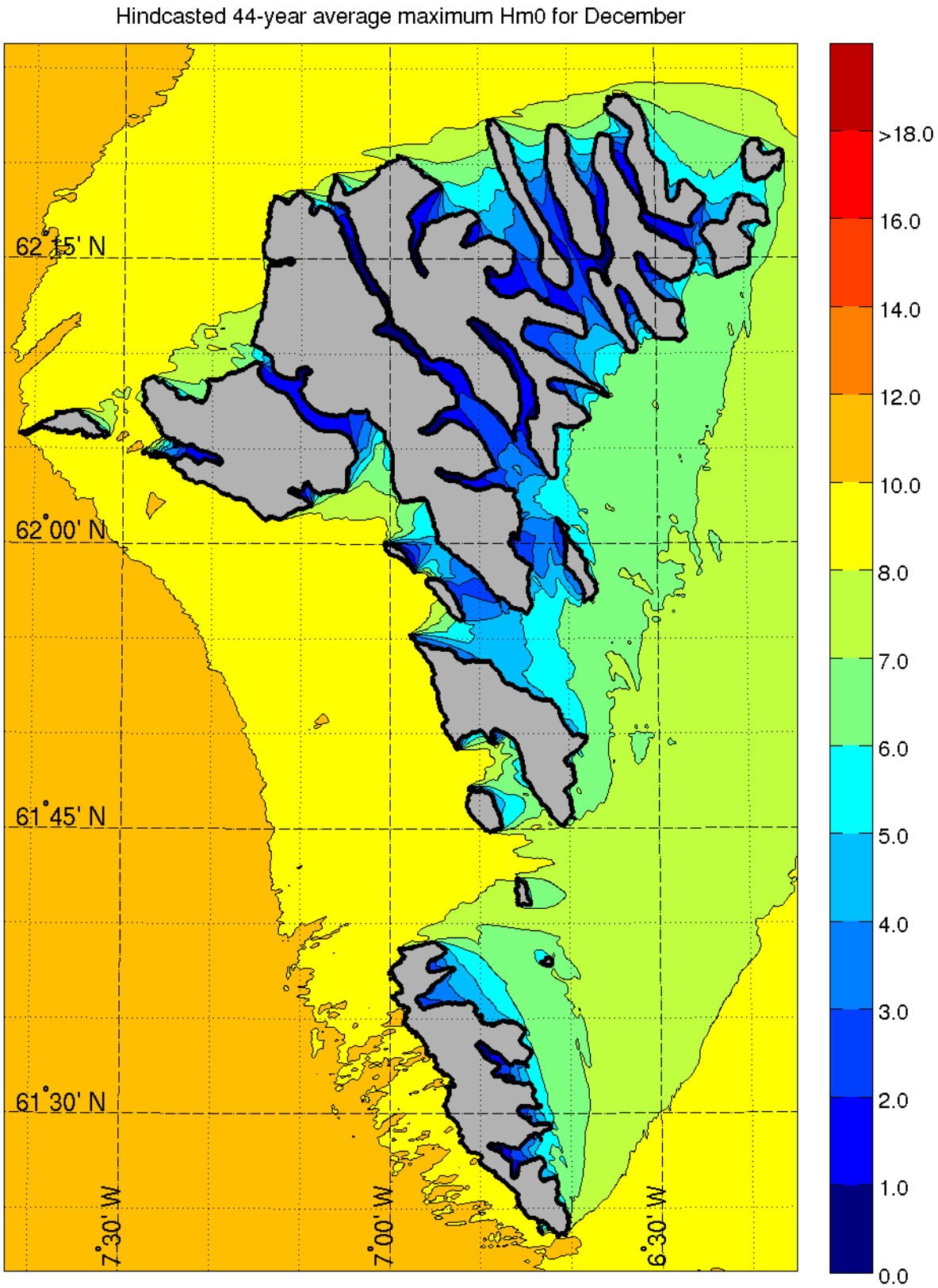
Estimated 50-year maximum Hm0 for November



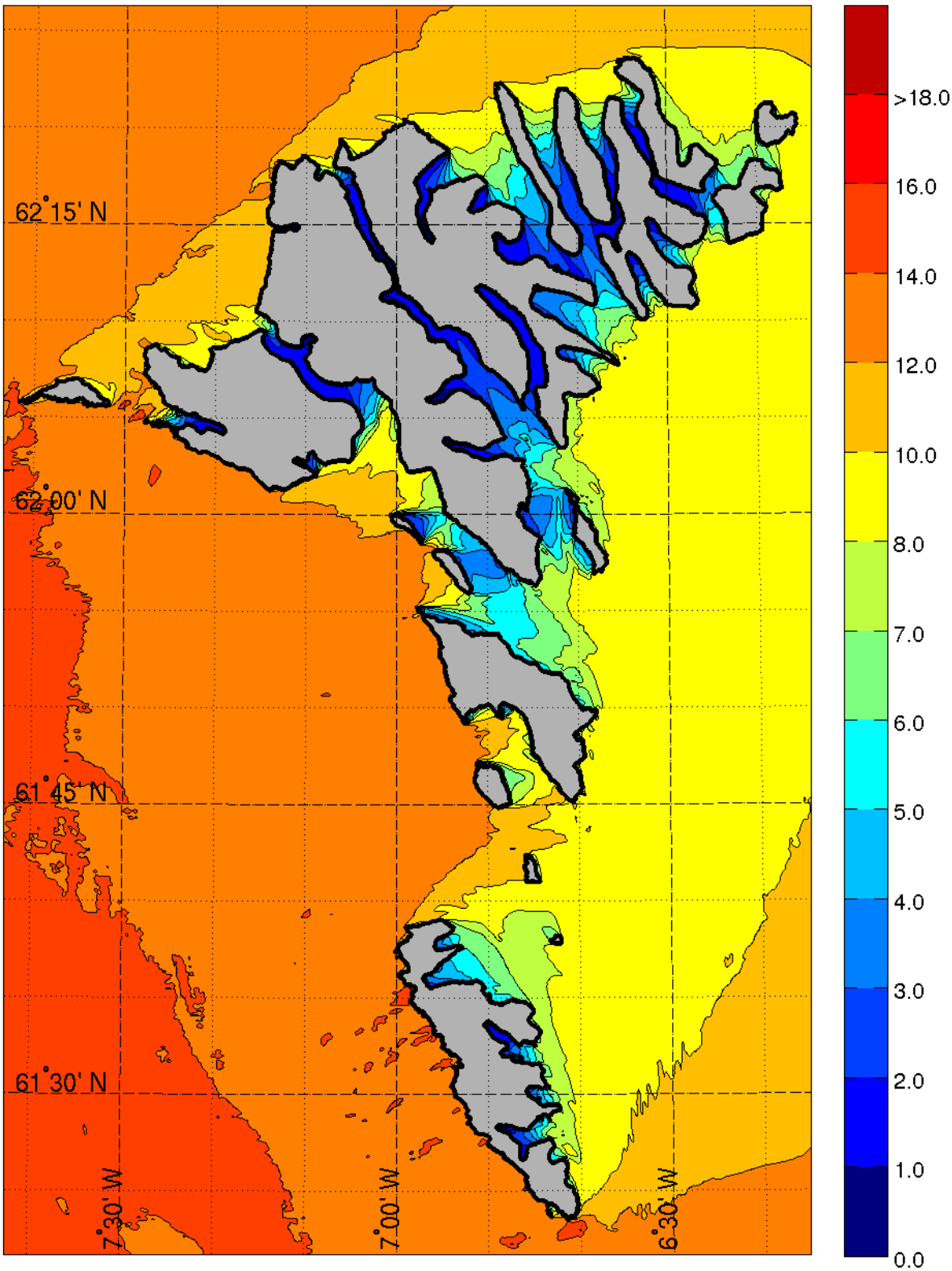
Hindcasted 44-year maximum Hm0 for November



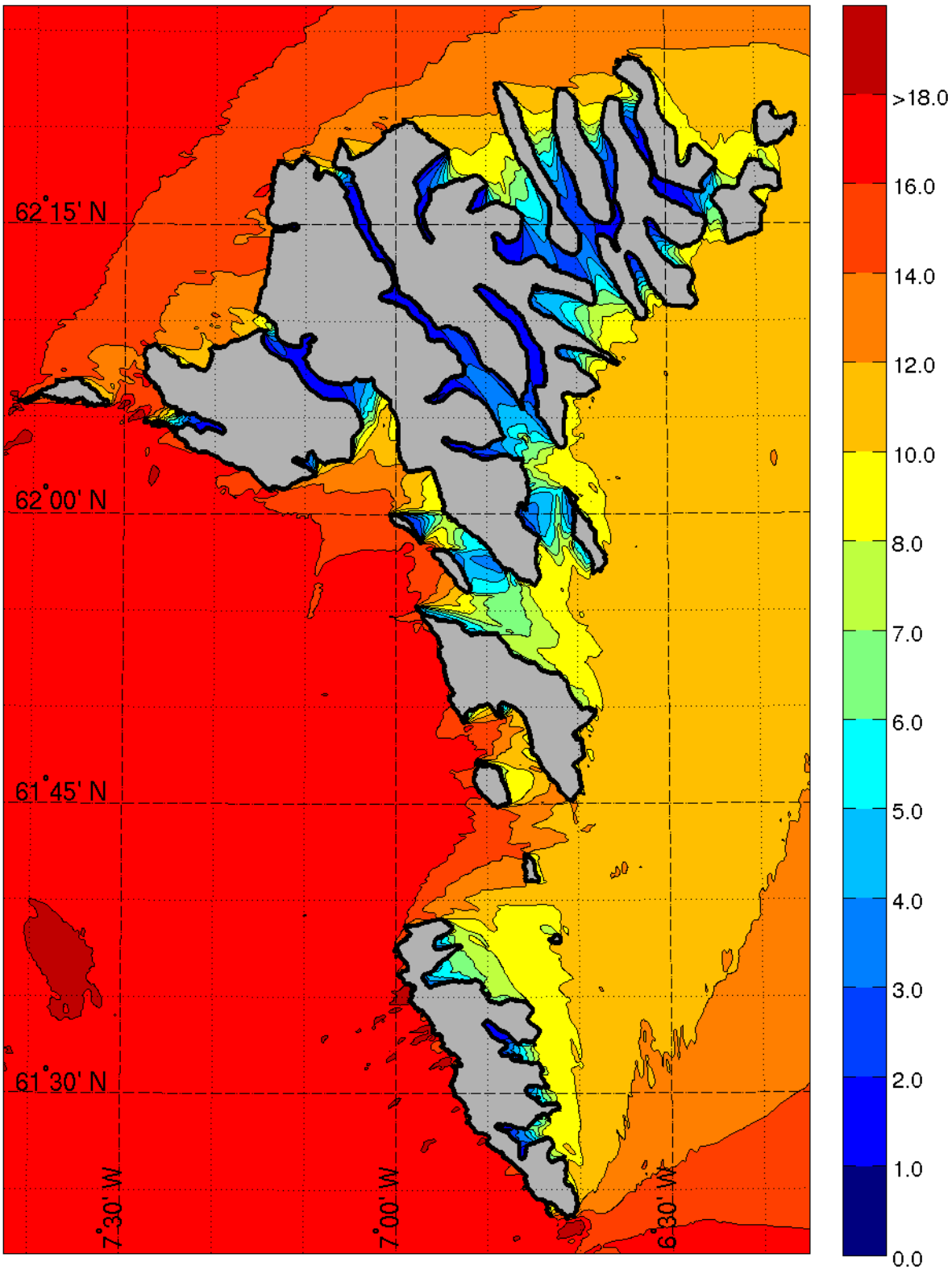
Statistics for December



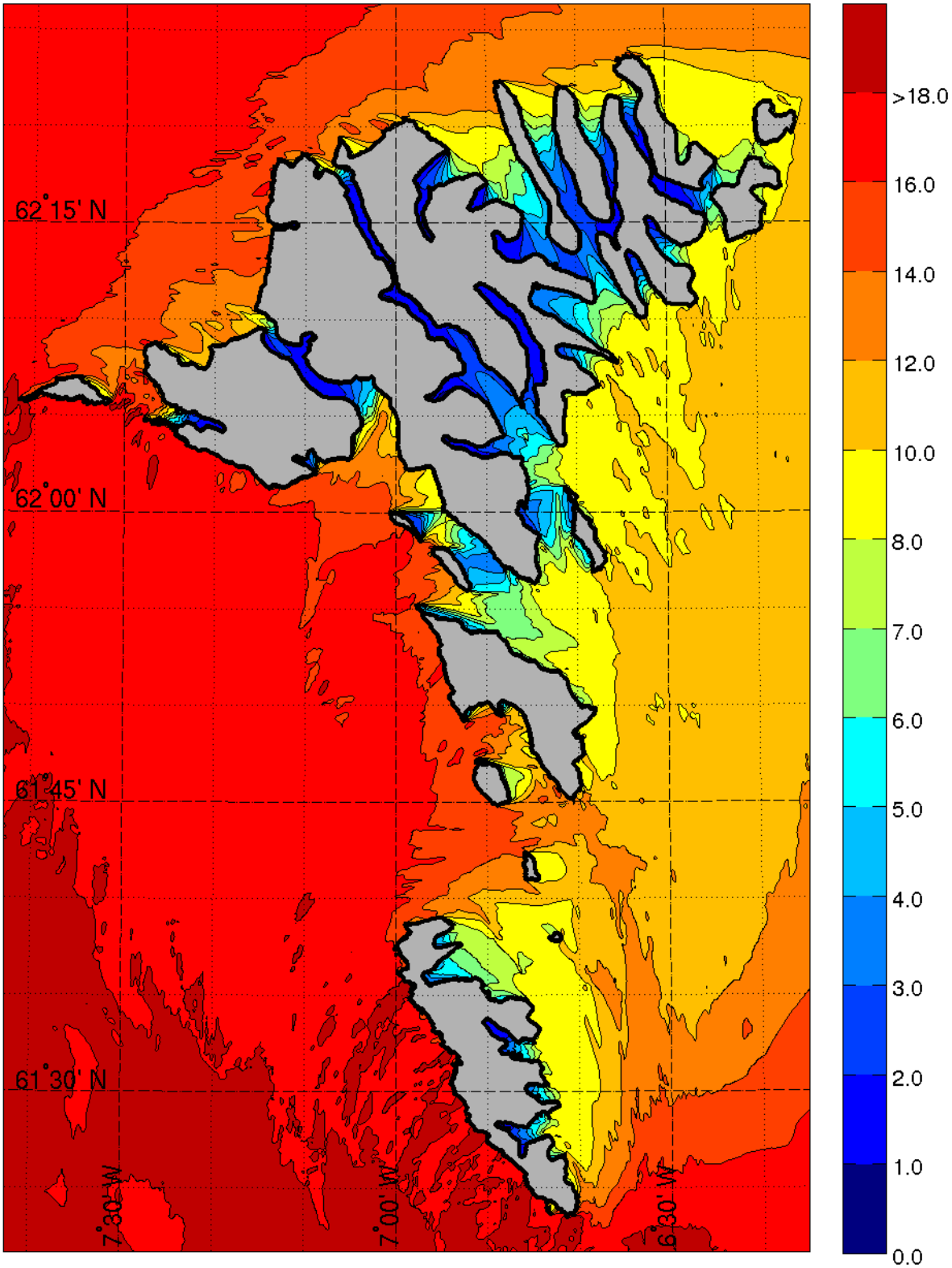
Estimated 10-year maximum Hm0 for December



Estimated 50-year maximum Hm0 for December



Hindcasted 44-year maximum Hm0 for December



References

- Booij, N. Holthuijsen, L.H., Ris , R.C. The SWAN wave model for shallow water . Proceedings of 24th International Conference on Coastal Engineering, Orlando, vol. 1 (1996), pp. 668–676

- Holthuijsen, L. H. Waves in Oceanic and Coastal Waters . Cambridge University Press, 2007.

- Niclasen, B. A. and Simonsen, K. 2007. Note on wave parameters from moored wave buoys. Applied Ocean Research 29: 231-238.