

Olga Pavlova and
Jan-Gunnar Winther

**SEA ICE
CONCENTRATION**
off Dronning Maud
Land, Antarctica



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Olga Pavlova and Jan-Gunnar Winther

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The Norwegian Polar Institute is Norway's main institution for research, monitoring and topographic mapping in Norwegian polar regions. The Institute also advises Norwegian authorities on matters concerning polar environmental management.

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Introduction

This project was undertaken by the Norwegian Polar Institute for the Norwegian Petroleum Directorate (Oljedirektoratet) as support for planning of marine geophysical surveys offshore from Dronning Maud Land (DML), Antarctica. The project was carried out by scientists Olga Pavlova and Jan-Gunnar Winther at the Norwegian Polar Institute under the direction of Morten Sand at the Norwegian Petroleum Directorate.

The main objectives of the project were to:

- a) calculate 10-day average historical (i.e., 1978-1996) sea ice concentrations off DML for the months of December through April
- b) identify the minimum and maximum sea ice extent occurring in the period 1978-1996
- c) present the above information graphically

Daily microwave satellite data covering the period 1978-1996 with 25 x 25 km spatial resolution were used as basis for this study (see text below for description of data set).

Data set

This work concerns analysis and visualization of the spatial and temporal variations of Antarctic sea ice using ice concentration data set acquired by microwave satellite sensors. Our results are based on the NASA Goddard Space Flight Center (GSFC) sea ice concentration data set in the polar stereographic projection with a grid of about 25 x 25 km, covering the period from

October 1978 through December 1996.

This data set currently includes daily and monthly averaged sea ice concentrations derived from NASA Nimbus-7 Scanning Multichannel Microwave Radiometer (SMMR) and Defense Meteorological Satellite Program (DMSP) -F8, -F11, and -F13 Special Sensor Microwave/Imager (SSM/I) daily brightness temperature. It is distributed by the National Snow and Ice Data Center (NSIDC). Information about the data set can be found at

<http://www-nsidc.colorado.edu/NSIDC/CATALOG/ENTRIES/nsi-0051.html>.

Spatial resolution and grid description

The sea ice concentration data provide coverage of the Southern Ocean projected on a polar stereographic grid. This polar stereographic projection specifies a projection plane (i.e., the grid) tangent to the earth at 70 degrees south. The planar grid is designed so that the grid cell at 70 degrees latitude is 25 km by 25 km. The polar stereographic formulae for converting between latitude/longitude and X-Y grid coordinates was taken from the map projections used by the U.S. Geological Survey (Snyder 1982). The origin of each grid point (i.e., X, Y) is the pole. The grid size is 332 rows by 316 columns. The first data value in the Southern Hemisphere files corresponds to -39.23 degrees latitude and 317.76 degrees longitude.

Temporal resolution

SMMR data were collected every other day (from 26 October 1978 through December 1987). Typically, there are at least 14 days of coverage per month. A major data gap in the SMMR data occurred in August 1982 and August 1984.

SSM/I data were collected daily (from December 1987 through December 1996). A major data gap in the SSM/I data occurred between 3 December 1987 and 13 January 1988.

Data range

Ice concentration is ranging from 0.0 to 1.0. Thus, a sea ice concentration of 0% (i.e., no sea ice present) is mapped as a value of 0.0 and a sea ice concentration of 100% is mapped as a value of 1.0. We have presented plots of both 0.05 (or 5%) and 0.10 (or 10%) resolution in sea ice concentration (see Appendices I, II and III).

Work description

The area of interest is limited to the area between 60 degrees east longitude and 60 degrees west longitude. Our investigations cover the five summer months from December through April. Temporal coverage is the time series of 19 years of sea ice concentration from 1978 to 1996.

To calculate 10-day average sea ice concentration fields we used gridded daily and every-

other-day sea ice concentration. This process was divided into two steps. First, we prepared 10-days average data for each of the five summer months for the whole series (i.e., 19 years). This 10-day average data were generated by averaging all the available daily (or every-other-day for SMMR) ice concentration data split in three periods per month. Second, we averaged these 19 fields for each individual 10-day period. Thus, we obtained one average field for each of the three 10-day periods for each of the five months, producing totally 15 fields of mean sea ice concentration. For reading and averaging these data a FORTRAN program was used.

For the selection of the absolute minimum and maximum sea ice extent for each 10-day period we used the following approach: we determined the minimum and maximum sea ice extent as the extreme situations occurring during 1978-1996 for a sea ice concentration of 10% and 5%, respectively, for the whole region. This means that we plotted when the minimum and maximum areas with sea ice concentration of 10% and 5% over our domain occurred. This further means that there might have been more extreme sea ice conditions at a particular position (or pixel) since we show the extreme situations as they occurred over the whole area. Plotting the extreme situations occurring at each grid point (or location) would probably produce a scattered border line and not give a sound physical reconstruction of extreme sea ice conditions. Therefore, we selected the four

(i. e., two for sea ice concentration of 10% and 5%, respectively) extreme days occurring during 1978-1996 (within each of the 10-day periods) in this region. We emphasize that such an approach of determination of minimum and maximum ice conditions depends on the region selected. This means that for another region the days of absolute minimum and maximum ice extent might be different. This work was done using FORTRAN as program language.

We prepared three versions of the fifteen 10-day average sea ice concentration; one with 10% resolution and two with 5% (one indicating every degree of latitude) in sea ice concentrations, respectively. The data behind the figures are identical for all three versions. Each of these figures presents the 10-day average of sea ice concentration and two solid lines that indicate the absolute minimum and maximum sea ice concentration of 10% (Appendix I) and 5% (Appendices II and III) for the 1978-1996 period.

It should be emphasized that the microwave emissivity of sea ice is affected by the ice thickness. When the ice cover is thin, the satellite-derived emissivity shows combined contributions from the underlying water and the ice, the contribution from the water decreasing with increasing ice thickness. This means that plots from early season (e.g., December) and late season (e.g., April) are not directly comparable. Thus, the plots from April overestimate

the problems for ship operations caused by sea ice compared to early in the season because the sea ice is thin. On the other hand, relevant for ship operations, in April air temperatures drop quickly and the potential for icing increases significantly.

As a tool to graphically display our results we used Golden Software SURFER Program.

References

Snyder, J.P. 1982: Map projections used by the U.S. Geological Survey. U.S. Geological Survey Bulletin 1532, 313 p.

Appendices

APPENDIX I 10-day average of sea ice concentrations (at 10% resolution) off Dronning Maud Land, Antarctica, for 1978-1996. The extreme situations for sea ice concentrations of 10% for 1978-1996 are also shown.

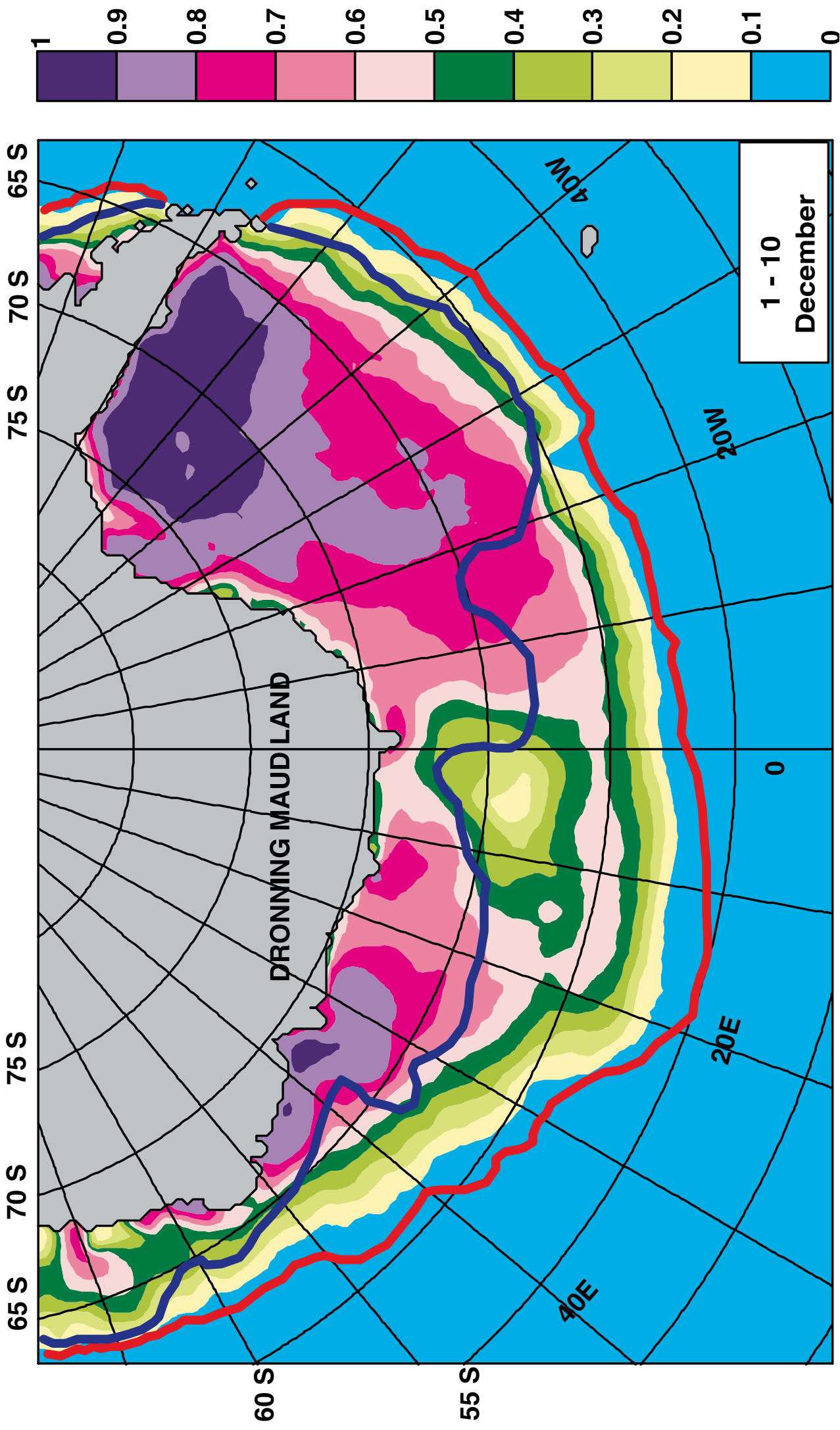


Fig. I-1

10 day average of Antarctic sea ice concentrations for 1978-1996. Solid lines indicate the absolute minimum (blue) and maximum (red) ice extent.

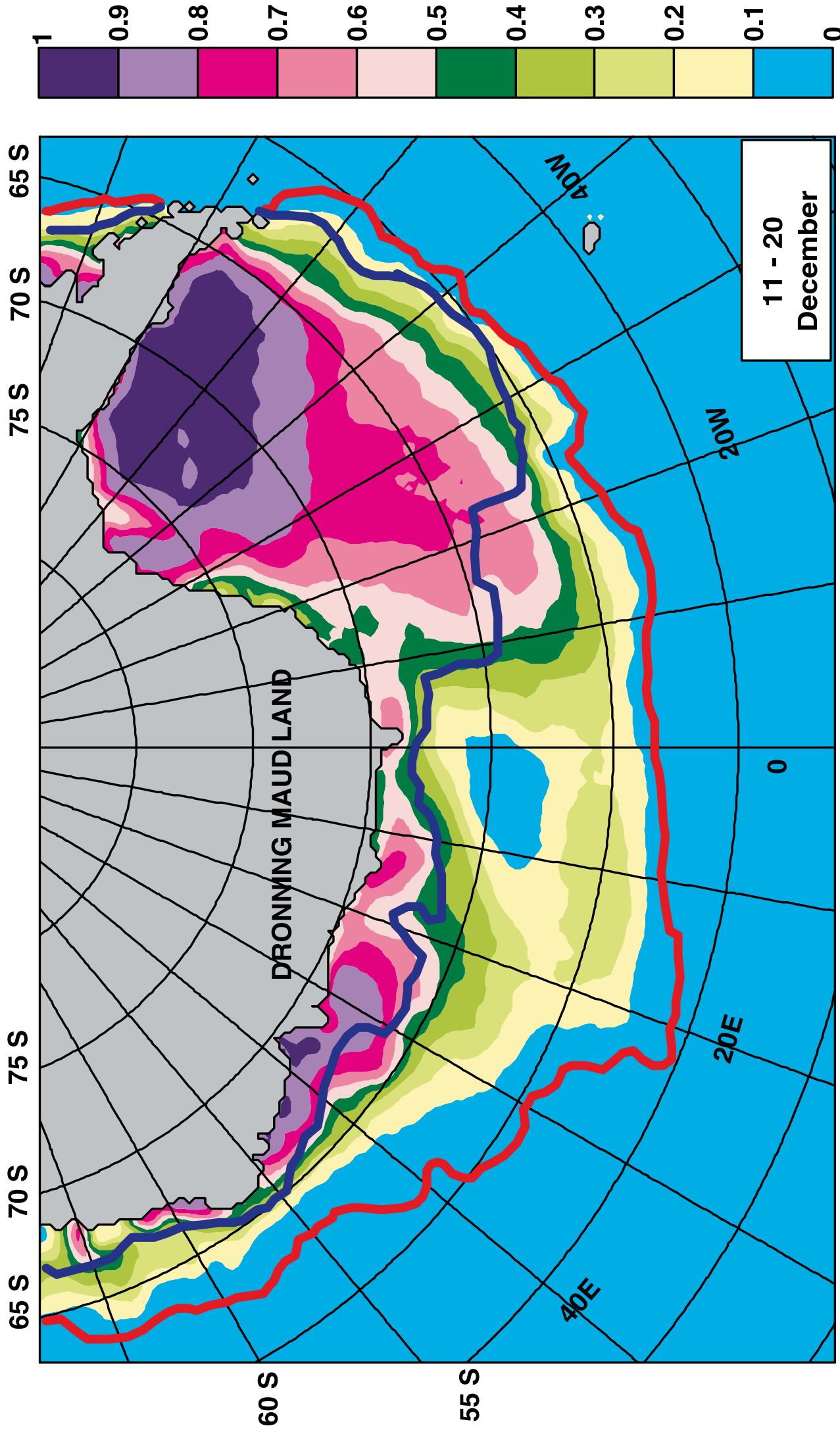


Fig. I-2
10 day average of Antarctic sea ice concentrations for 1978-1996. Solid lines indicate the absolute minimum (blue) and maximum (red) ice

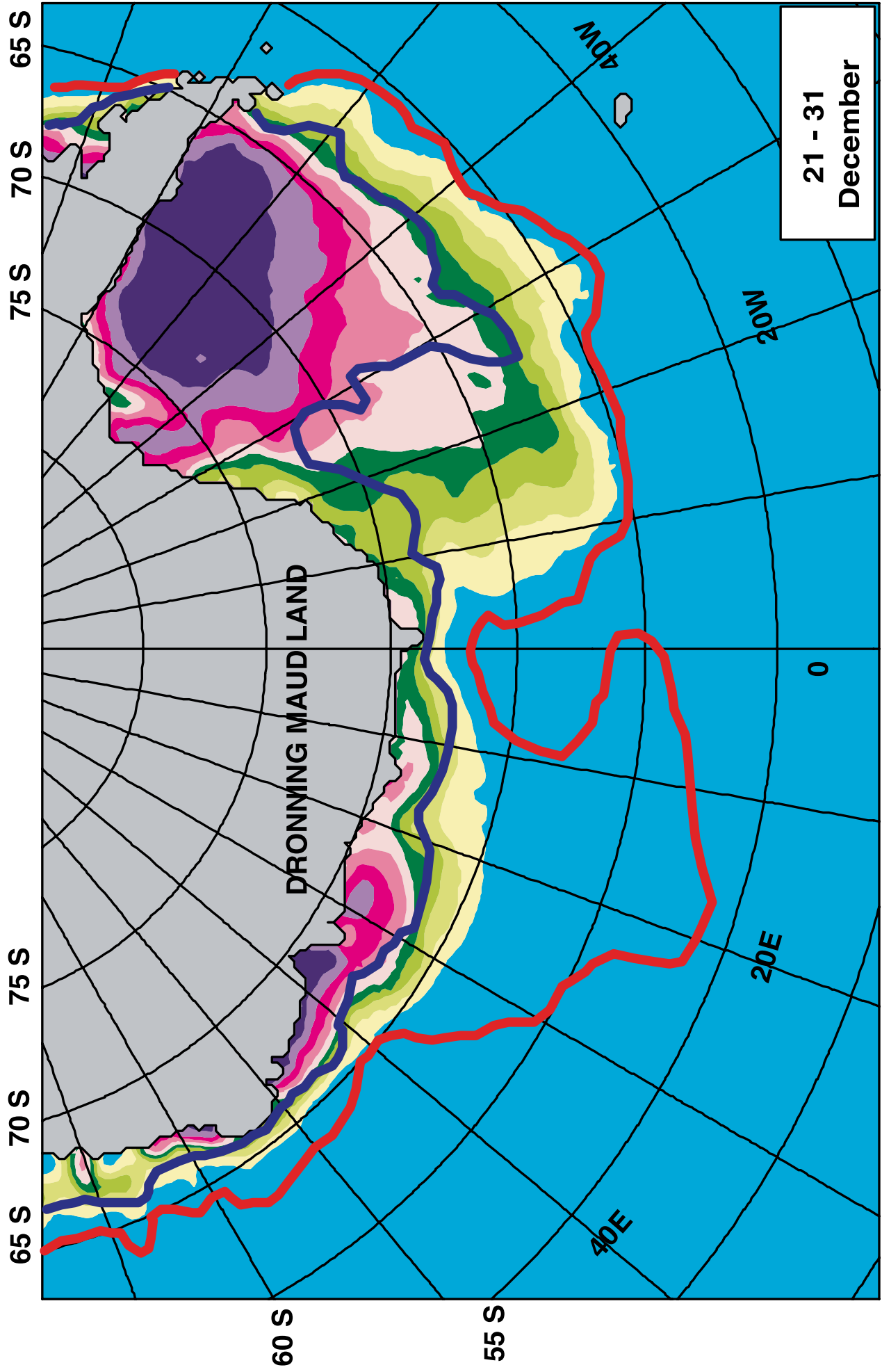


Fig. I-3
10 day average of Antarctic sea ice concentrations for 1978-1996. Solid lines indicate the absolute minimum (blue) and maximum (red) ice

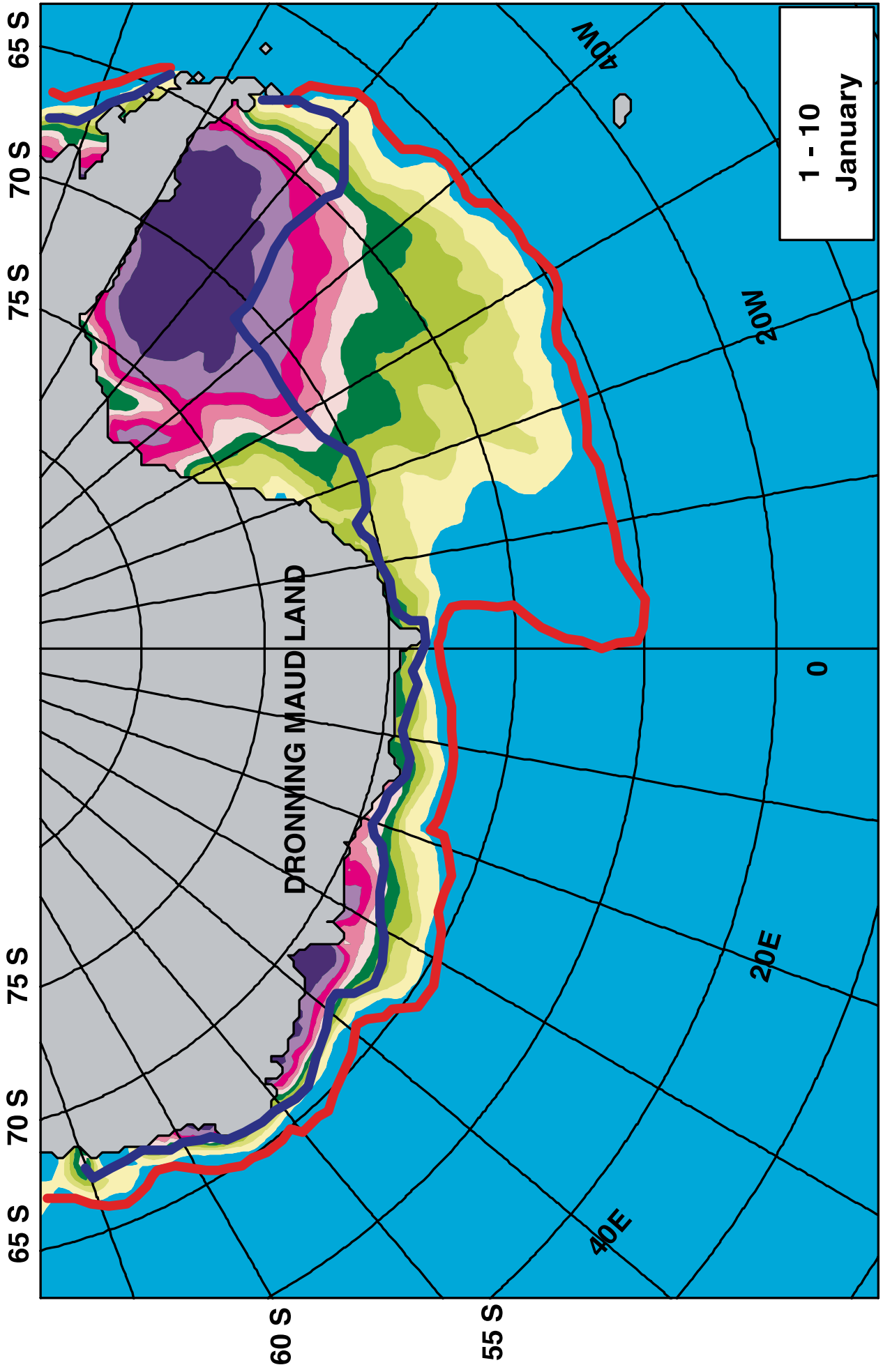


Fig. I-4
 10 day average of Antarctic sea ice concentrations for 1978-1996. Solid lines indicate the absolute minimum (blue) and maximum (red) ice

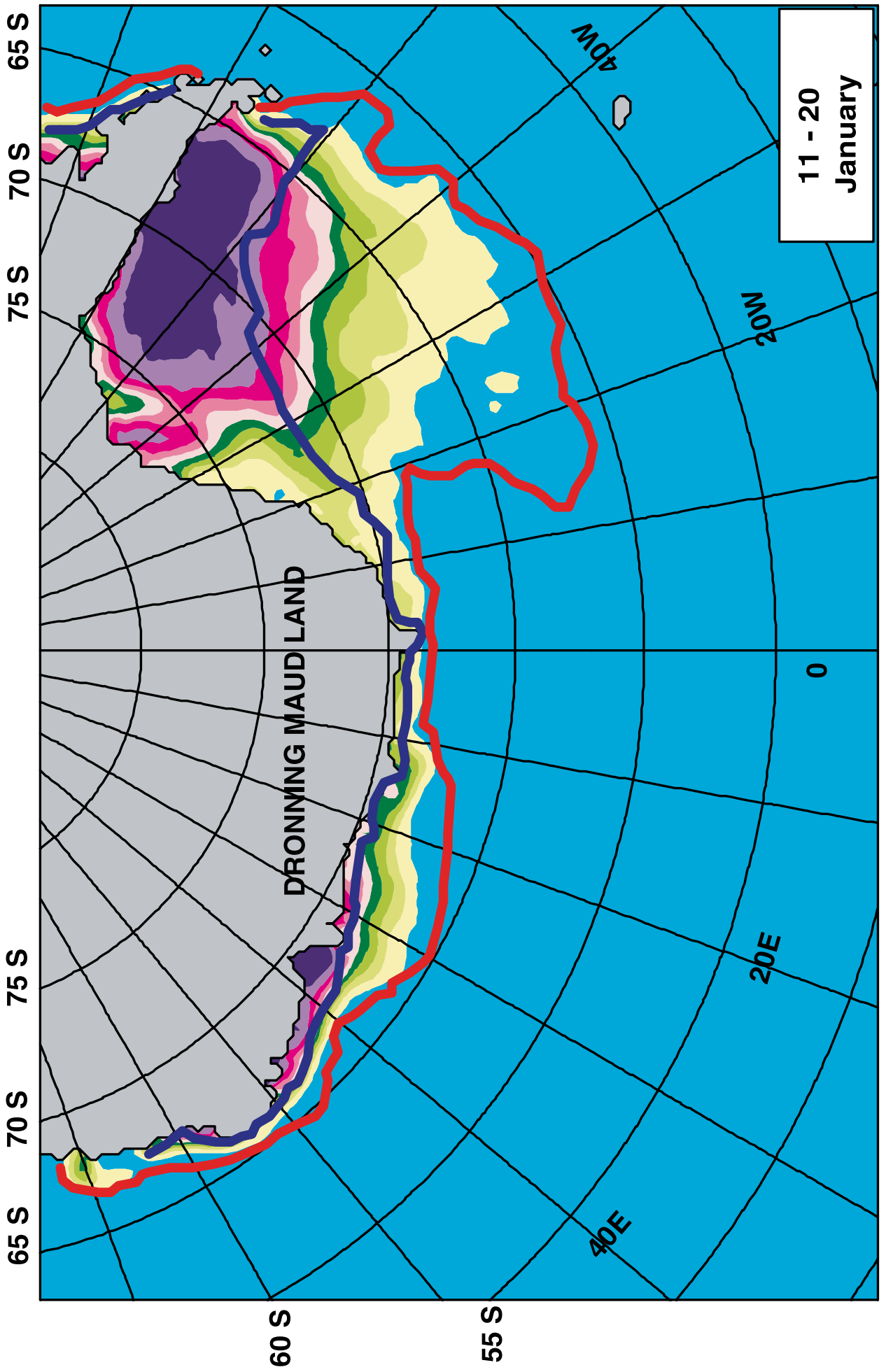


Fig. I-5

10 day average of Antarctic sea ice concentrations for 1978-1996. Solid lines indicate the absolute minimum (blue) and maximum (red) ice extent.

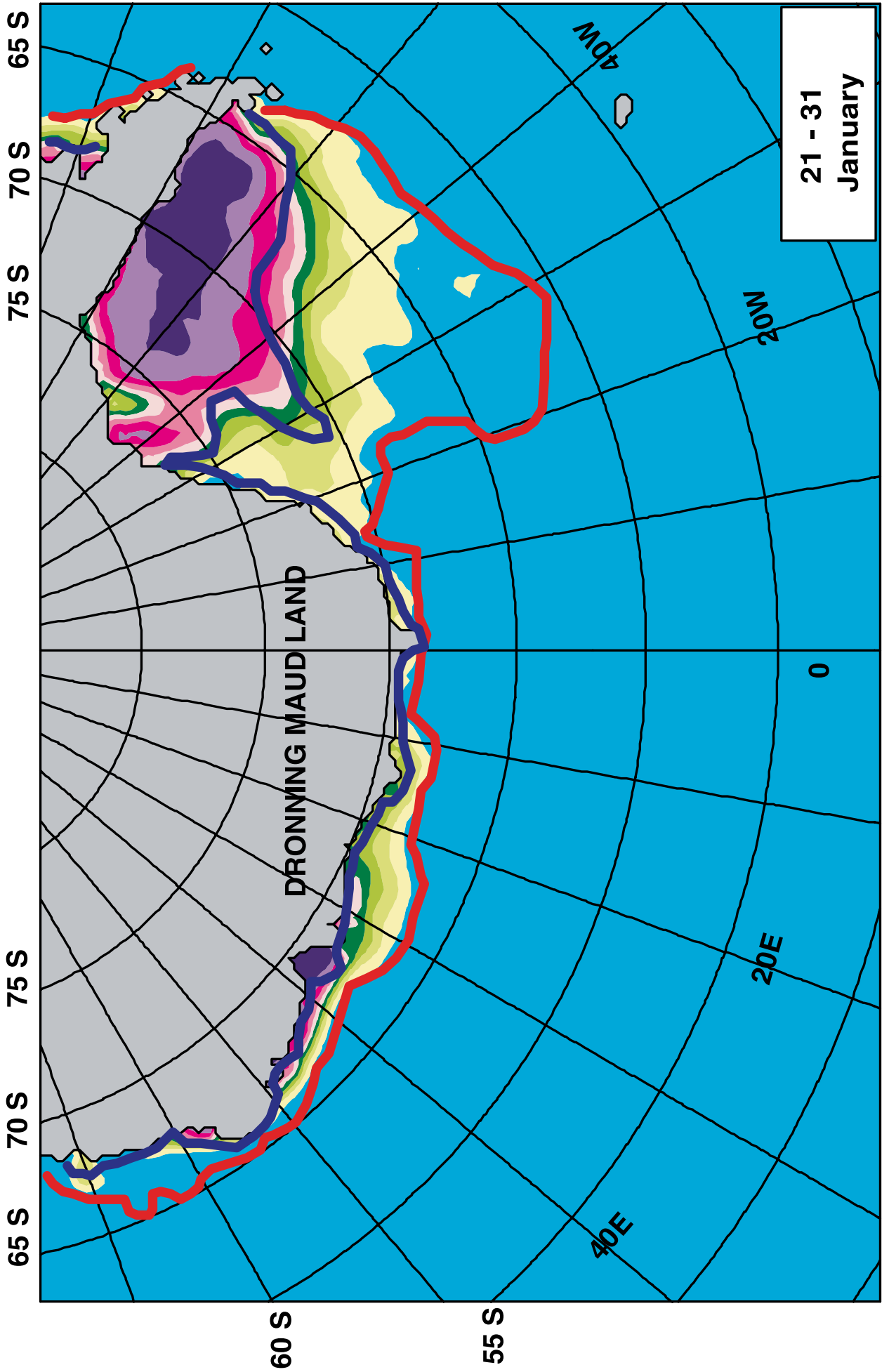


Fig. I-6

10 day average of Antarctic sea ice concentrations for 1978-1996. Solid lines indicate the absolute minimum (blue) and maximum (red) ice extent.

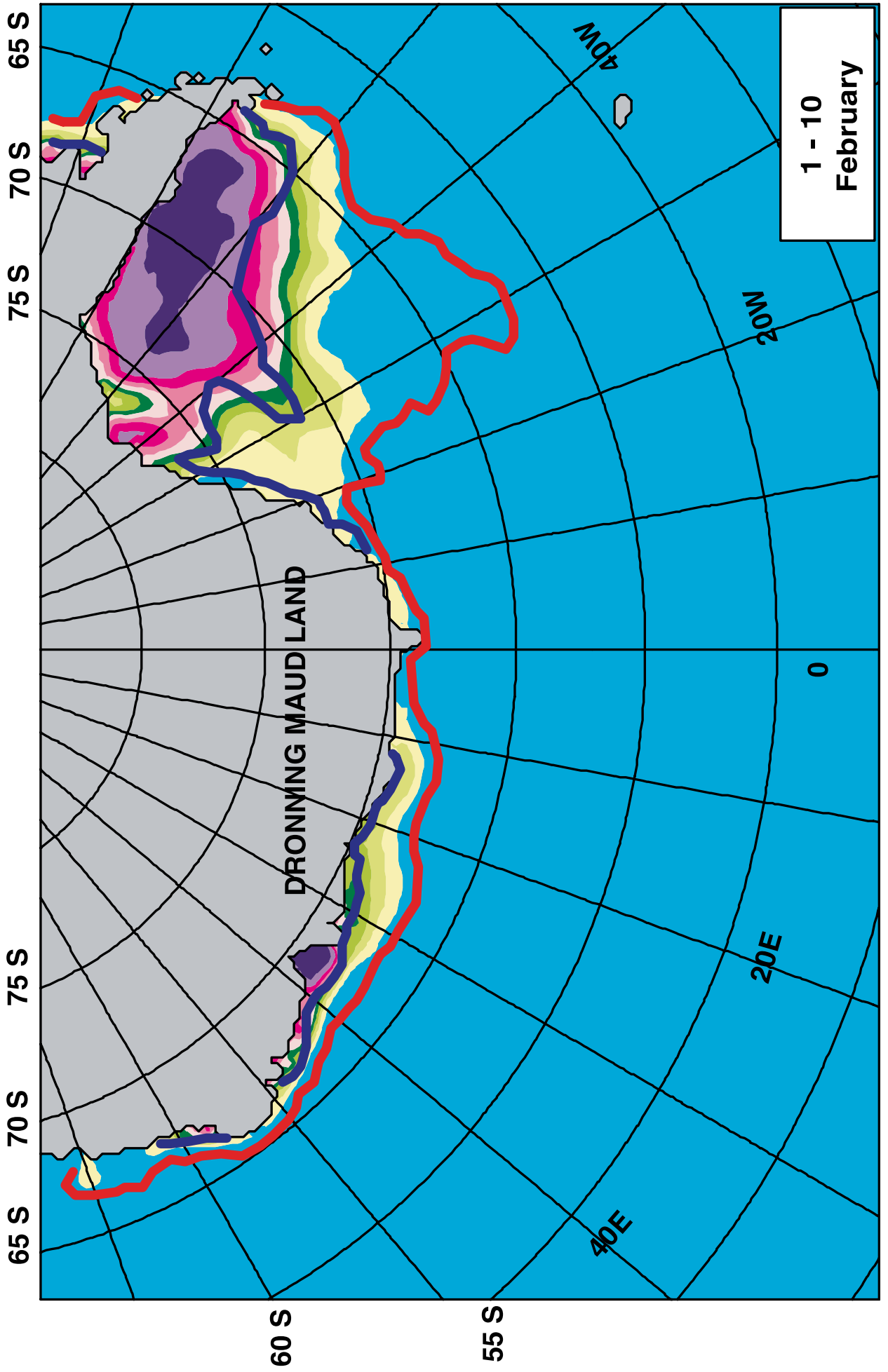


Fig. I-7

10 day average of Antarctic sea ice concentrations for 1978-1996. Solid lines indicate the absolute minimum (blue) and maximum (red) ice

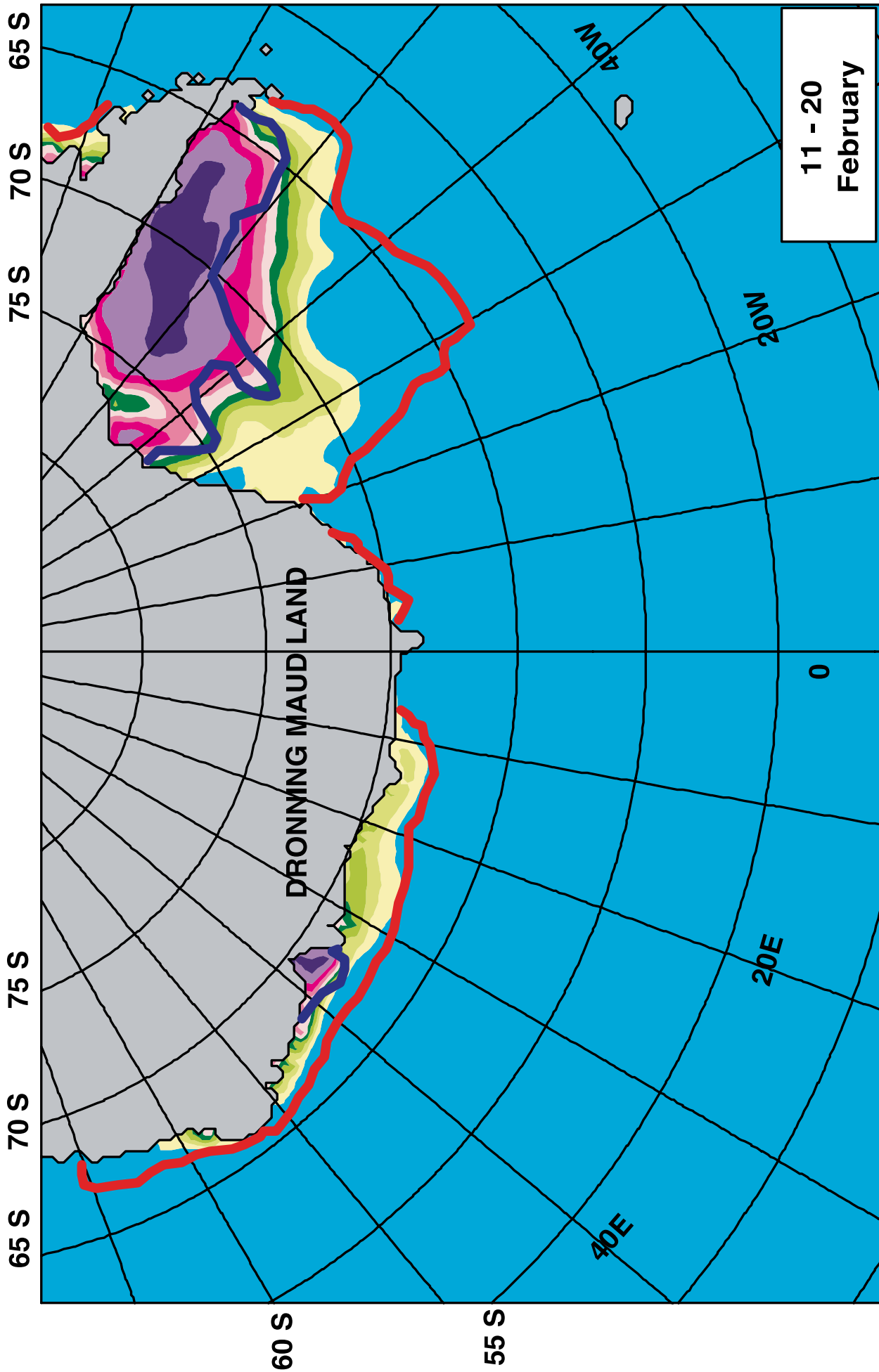


Fig. I-8

10 day average of Antarctic sea ice concentrations for 1978-1996. Solid lines indicate the absolute minimum (blue) and maximum (red) ice

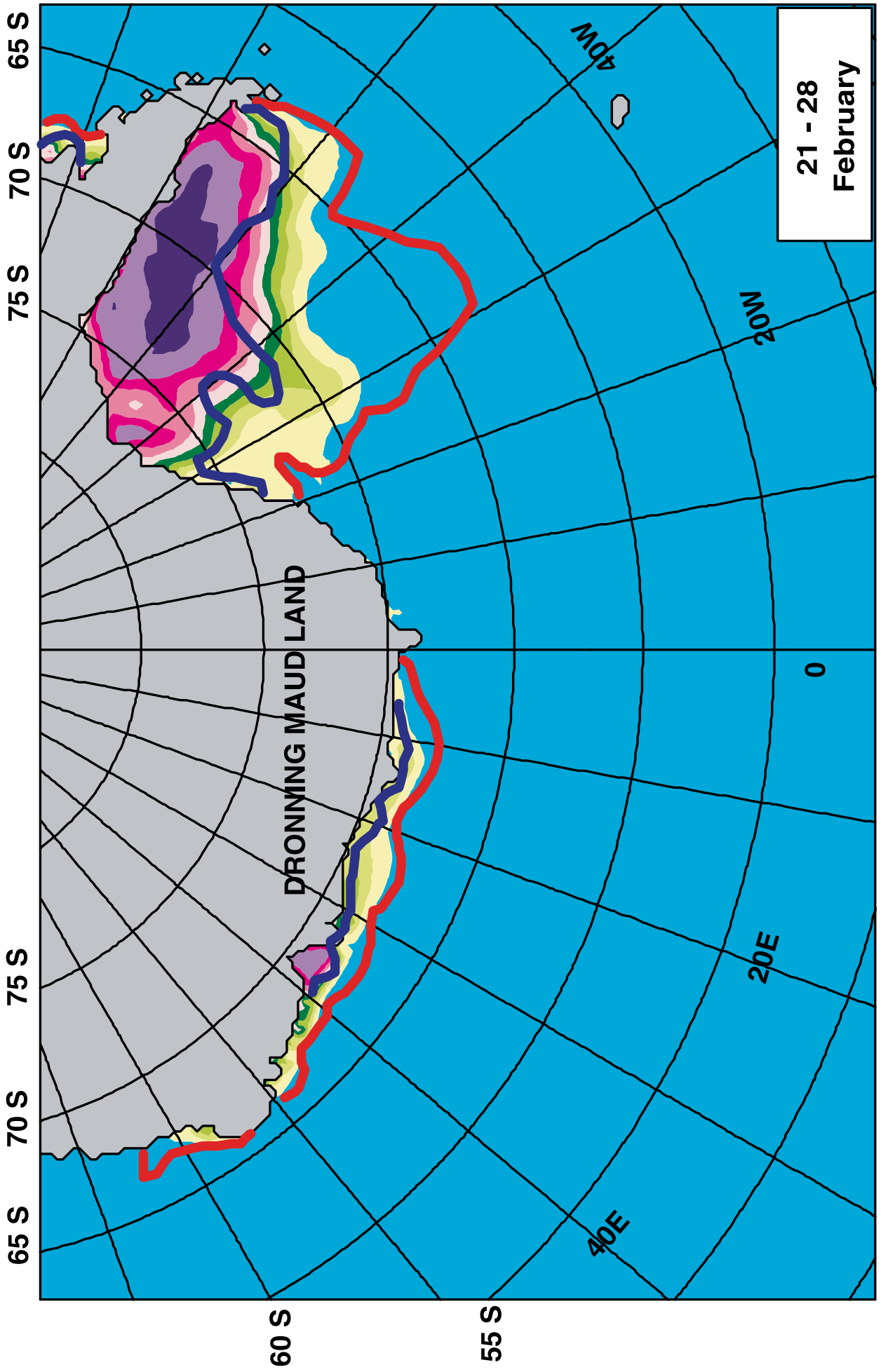


Fig. I-9
10 day average of Antarctic sea ice concentrations for 1978-1996. Solid lines indicate the absolute minimum (blue) and maximum (red) ice extent.

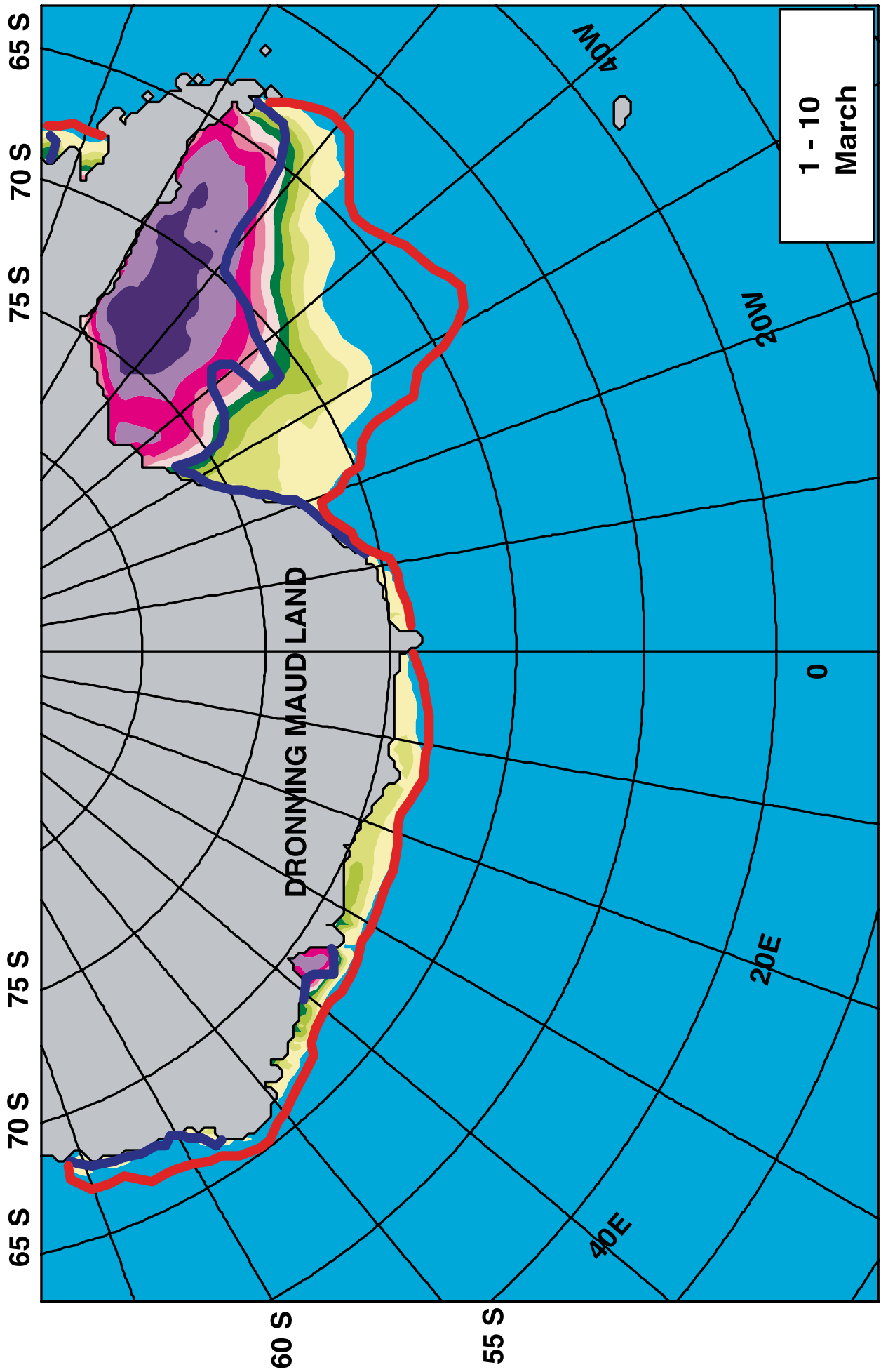


Fig. I-10

10 day average of Antarctic sea ice concentrations for 1978-1996. Solid lines indicate the absolute minimum (blue) and maximum (red) ice extent.

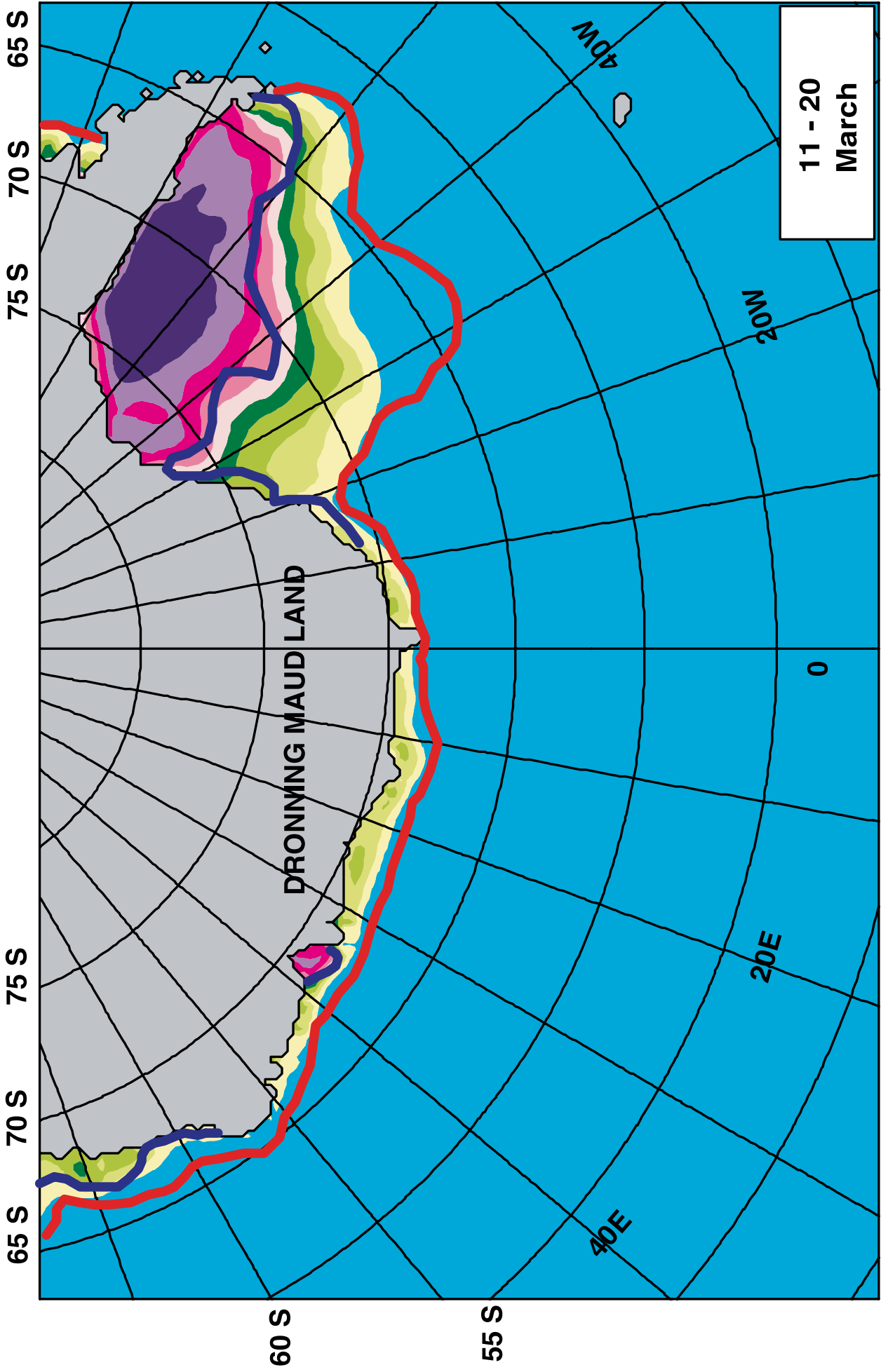


Fig. I-11

10 day average of Antarctic sea ice concentrations for 1978-1996. Solid lines indicate the absolute minimum (blue) and maximum (red) ice extent.

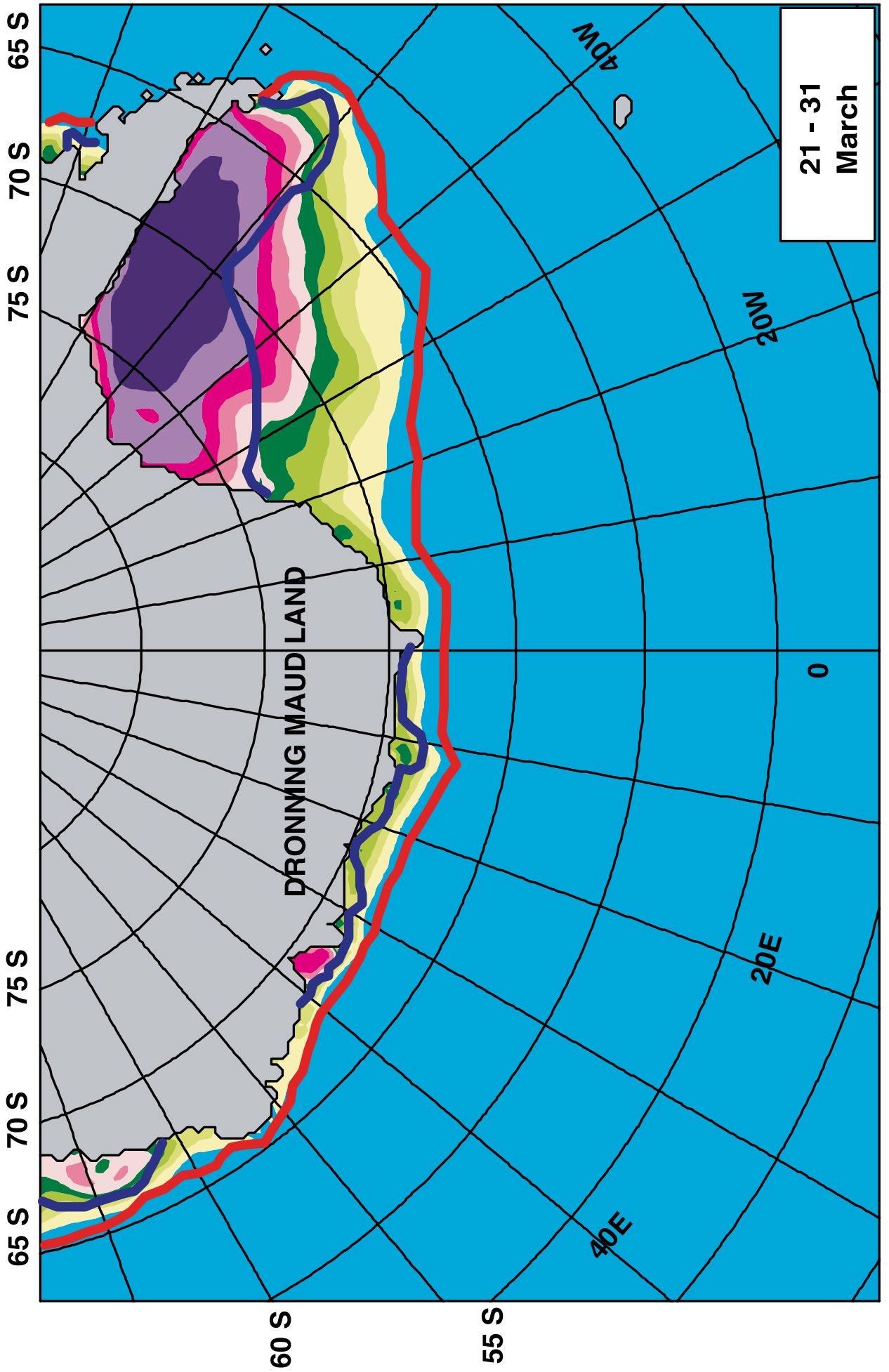


Fig. I-12

10 day average of Antarctic sea ice concentrations for 1978-1996. Solid lines indicate the absolute minimum (blue) and maximum (red) ice extent.

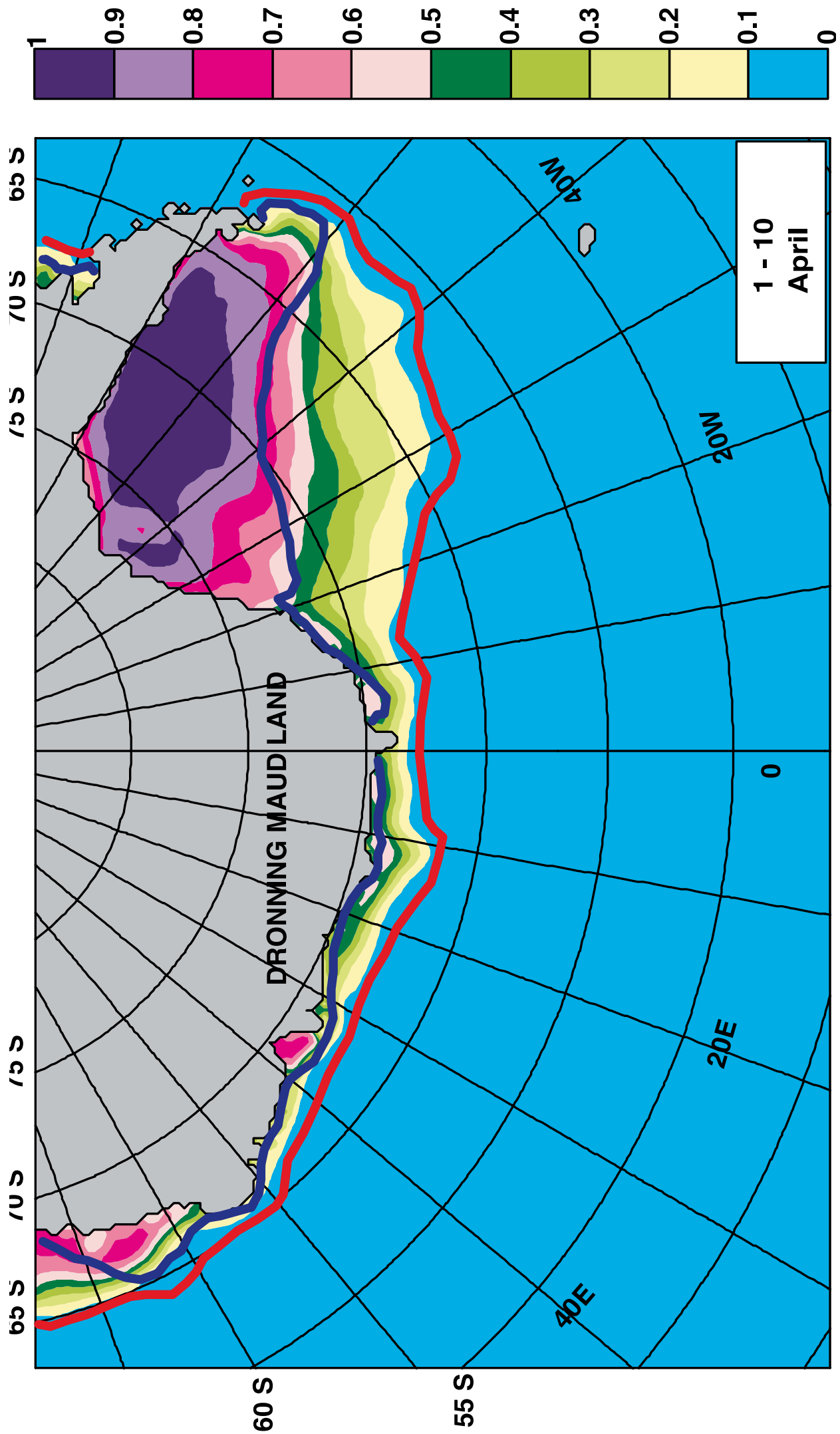


Fig. I-13

10 day average of Antarctic sea ice concentrations for 1978-1996. Solid lines indicate the absolute minimum (blue) and maximum (red) ice

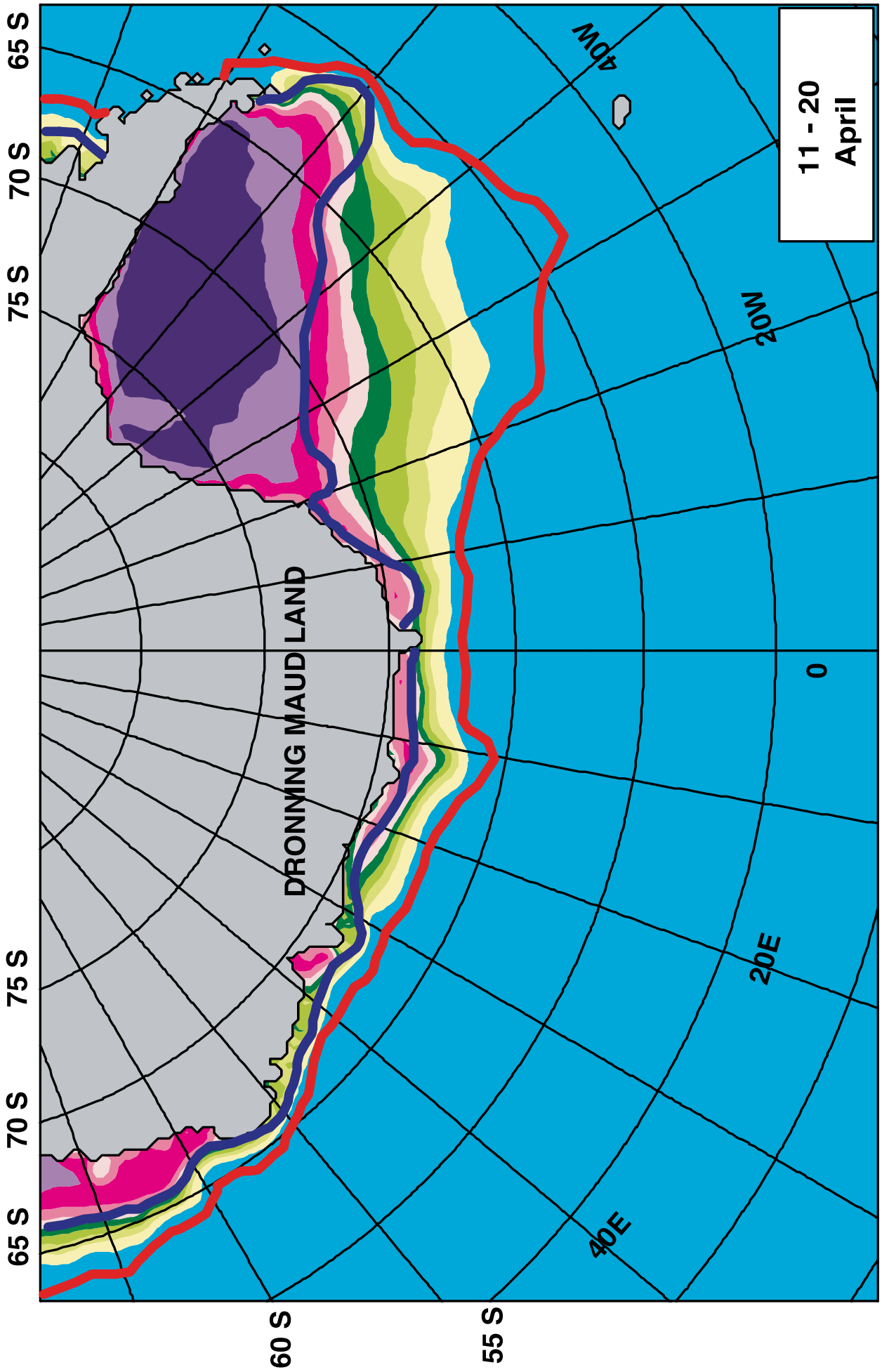


Fig. I-14

10 day average of Antarctic sea ice concentrations for 1978-1996. Solid lines indicate the absolute minimum (blue) and maximum (red) ice

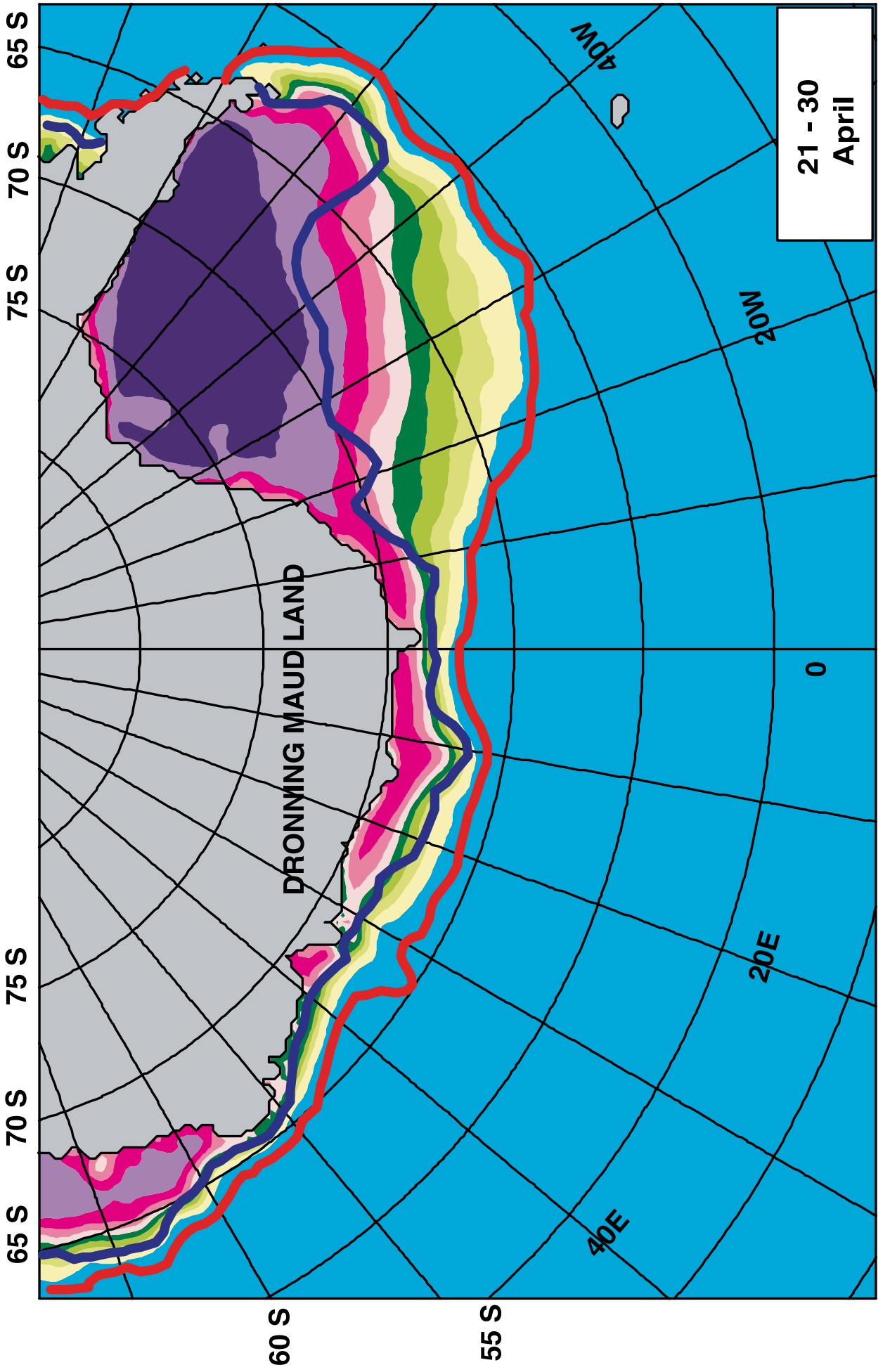


Fig. I-15

10 day average of Antarctic sea ice concentrations for 1978-1996. Solid lines indicate the absolute minimum (blue) and maximum (red) ice extent.

APPENDIX II 10-day average of sea ice concentrations (at 5% resolution) off Dronning Maud Land, Antarctica, for 1978-1996. The extreme situations for sea ice concentrations of 5% for 1978-1996 are also shown.

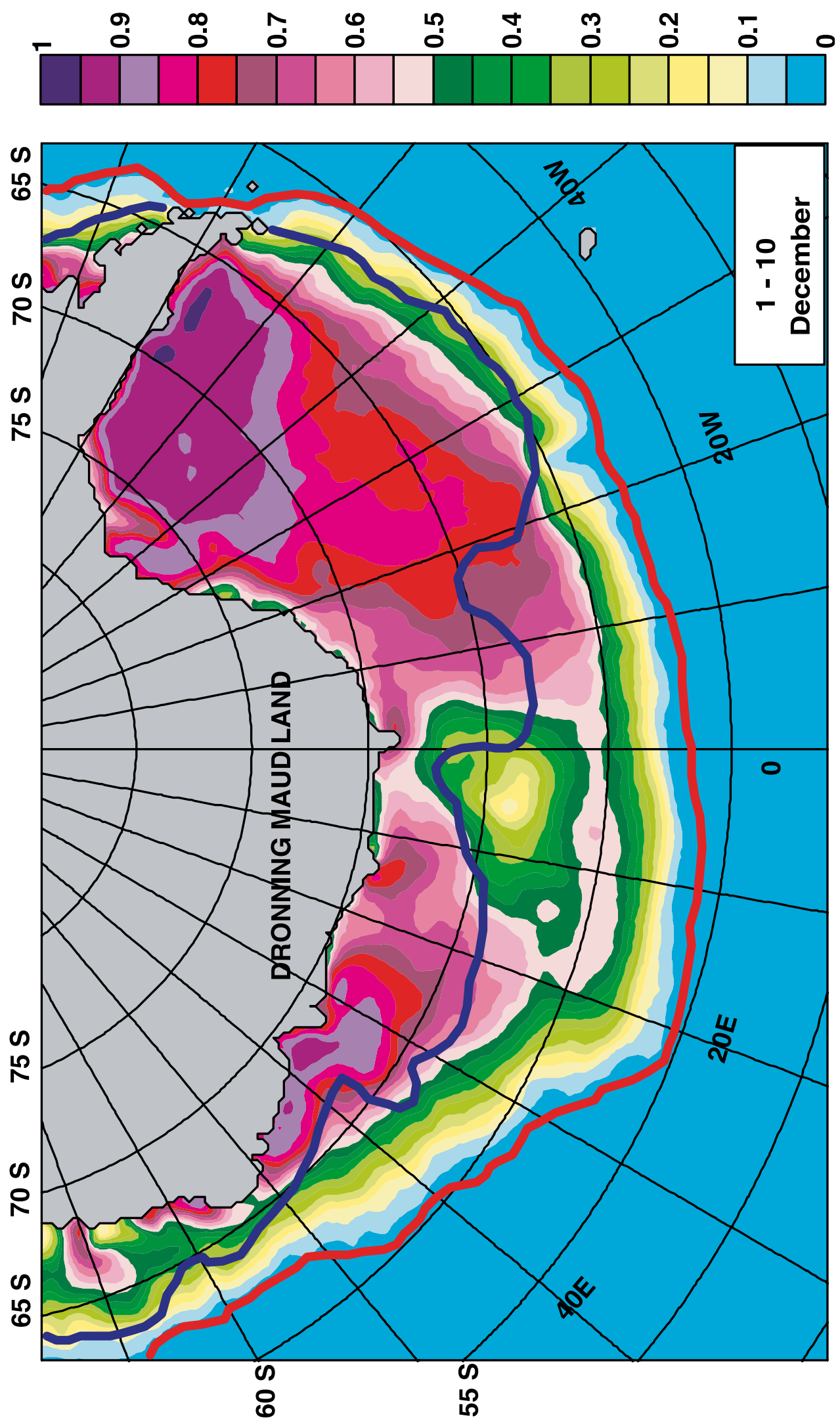


Fig. II-1
10 day average of Antarctic sea ice concentrations for 1978-1996. Solid lines indicate the absolute minimum (blue) and maximum (red) ice

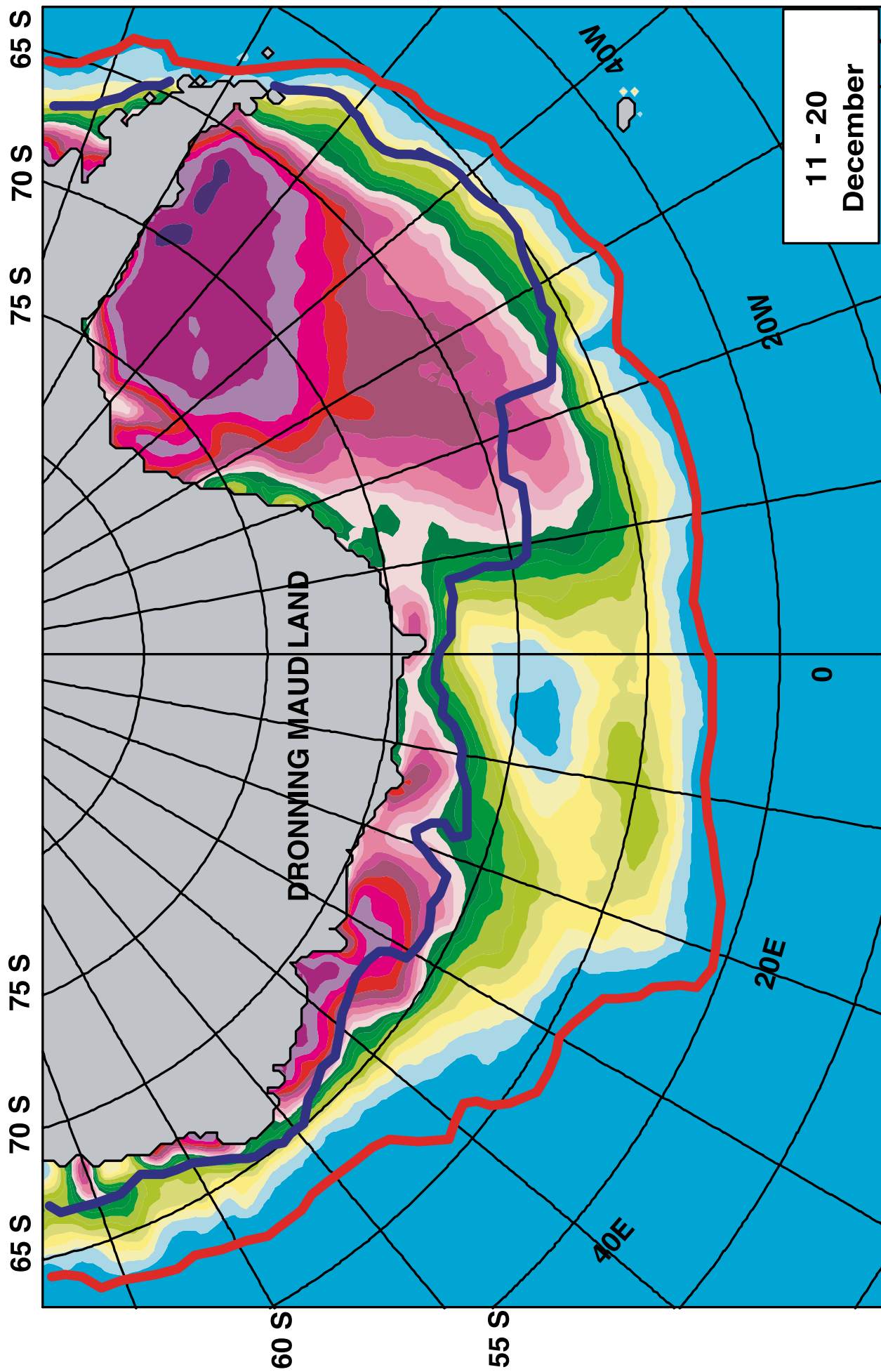


Fig. II-2
10 day average of Antarctic sea ice concentrations for 1978-1996. Solid lines indicate the absolute minimum (blue) and maximum (red) ice

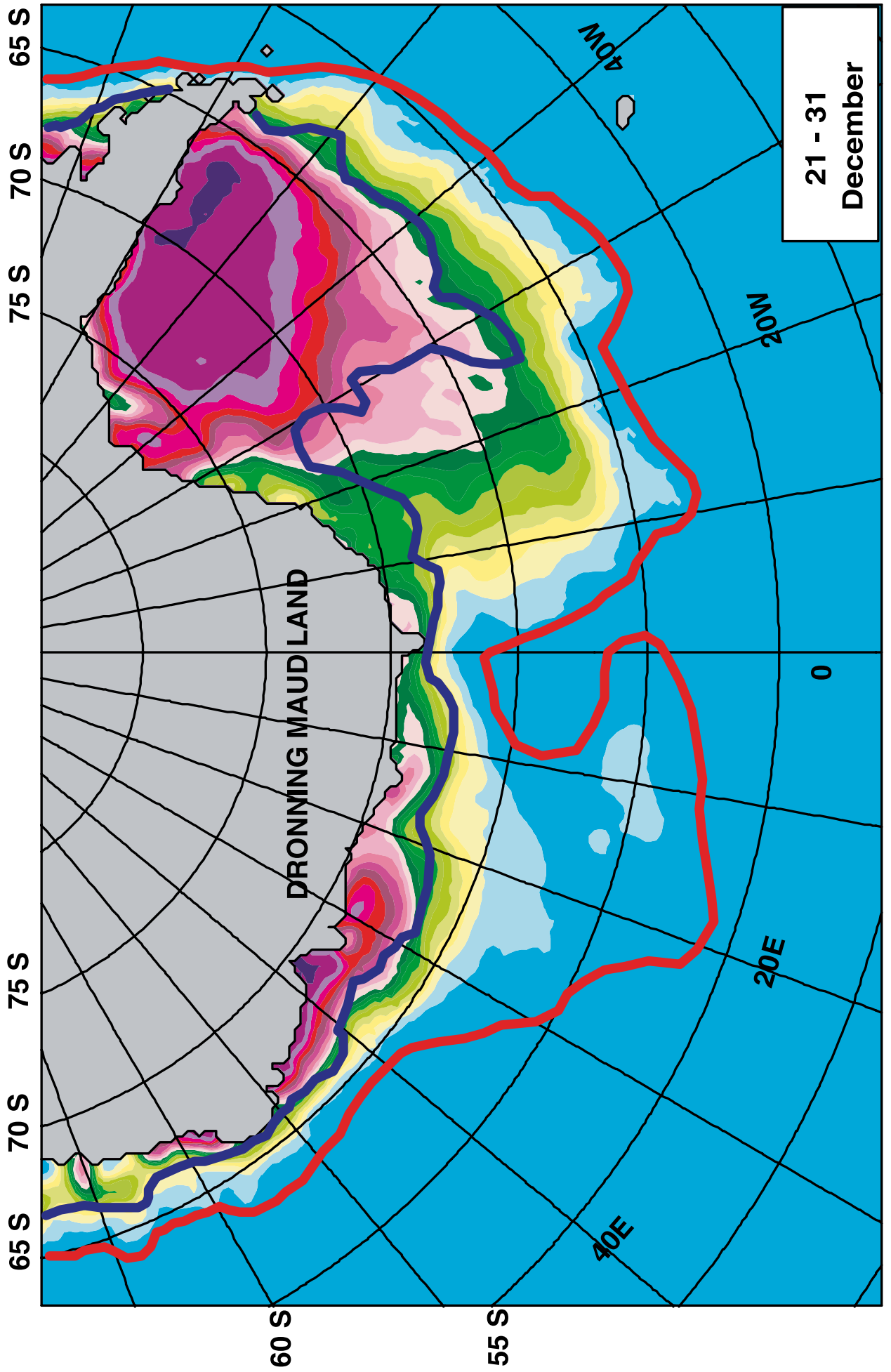


Fig. II-3

10 day average of Antarctic sea ice concentrations for 1978-1996. Solid lines indicate the absolute minimum (blue) and maximum (red) ice extent.

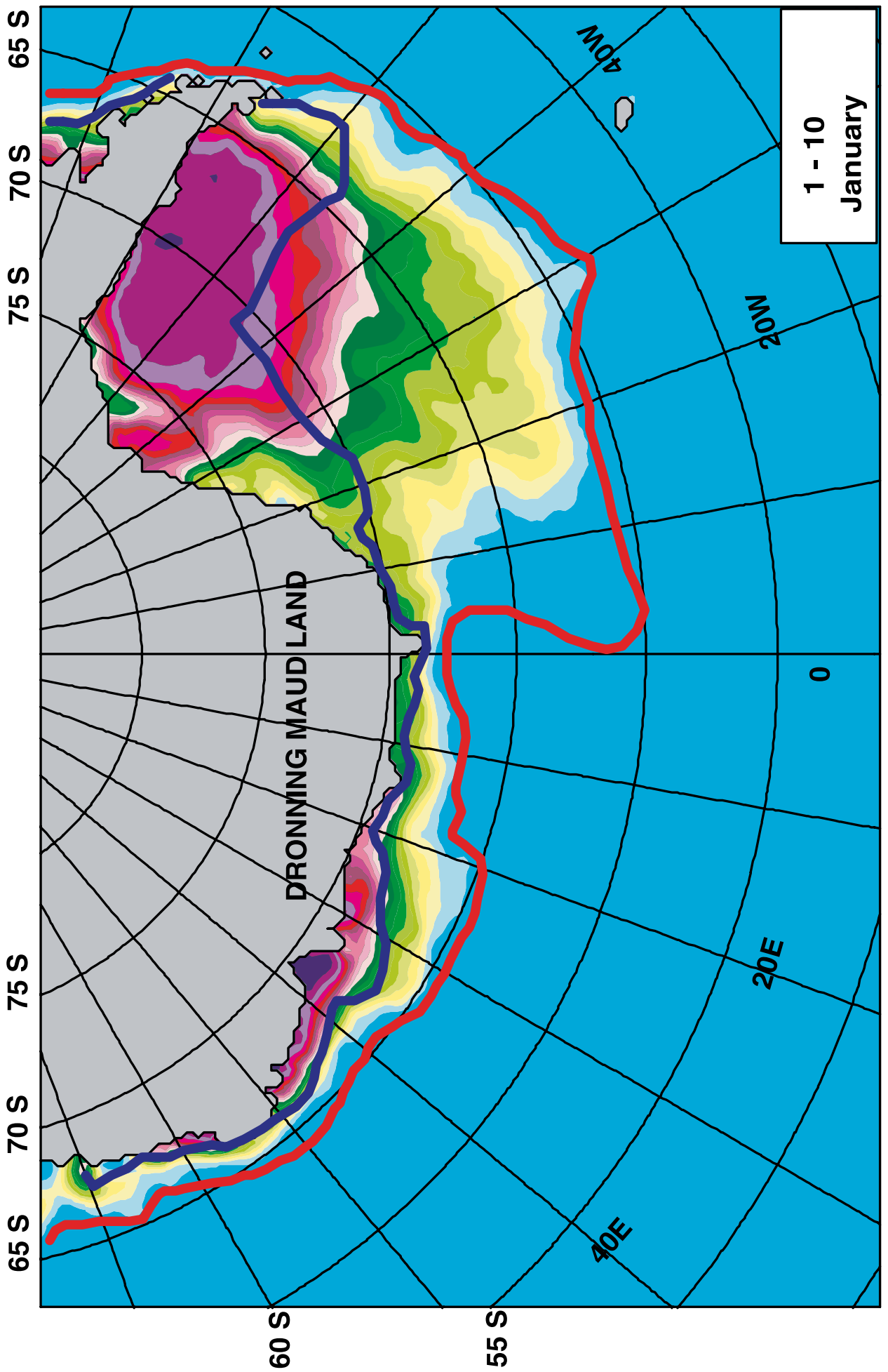


Fig. II-4
 10 day average of Antarctic sea ice concentrations for 1978-1996. Solid lines indicate the absolute minimum (blue) and maximum (red) ice extent.

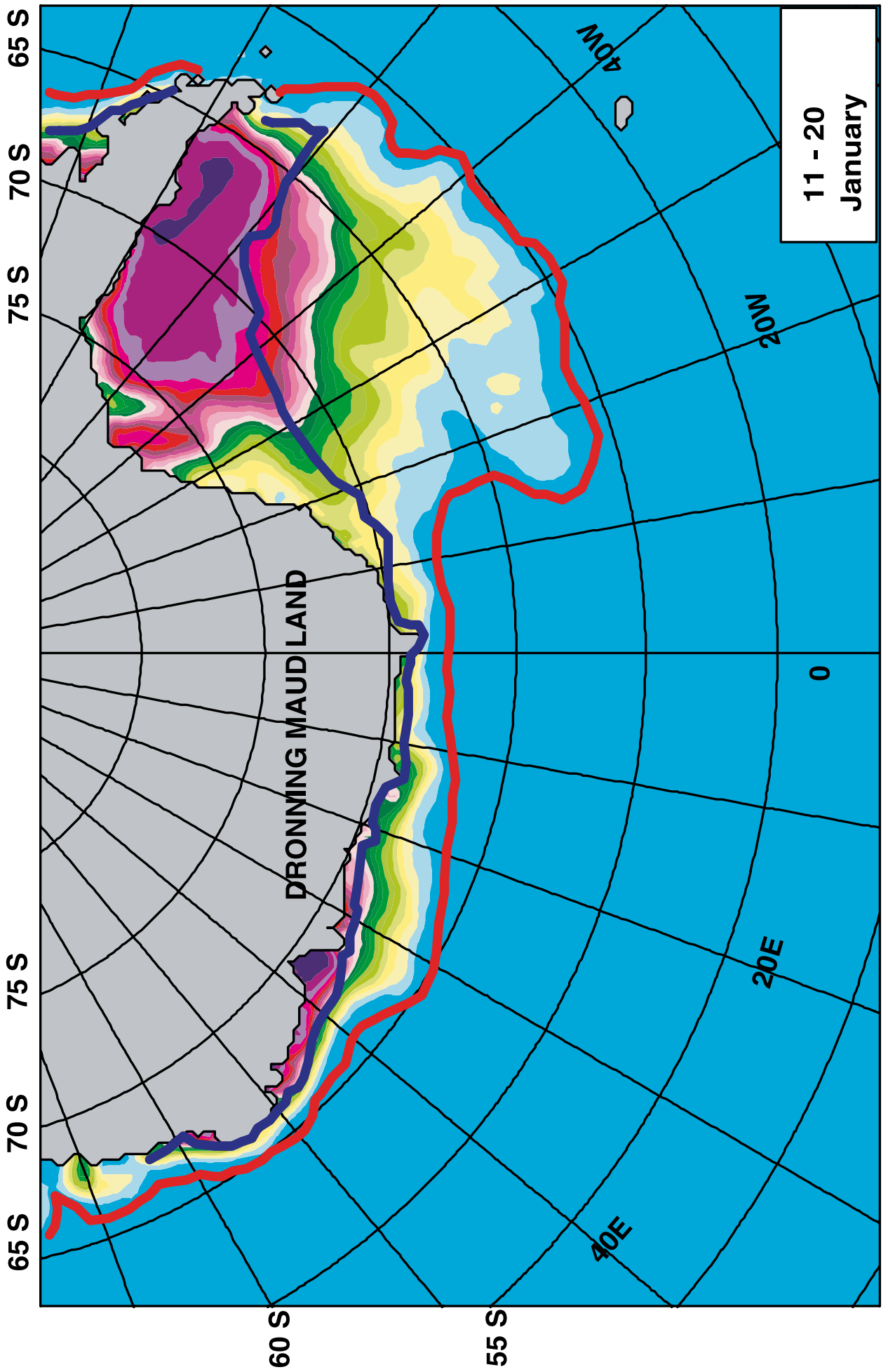


Fig. II-5
10 day average of Antarctic sea ice concentrations for 1978-1996. Solid lines indicate the absolute minimum (blue) and maximum (red) ice

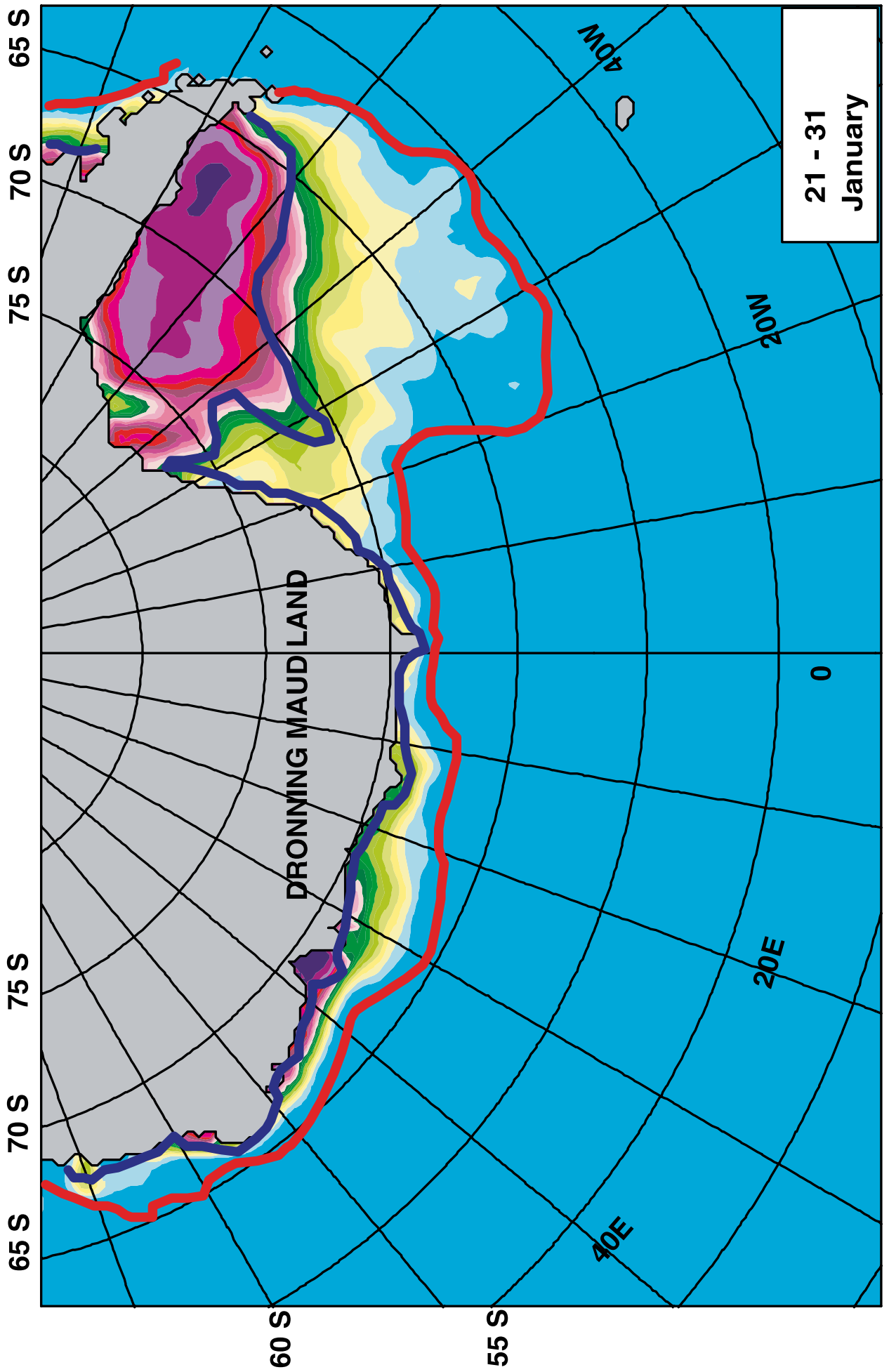


Fig. II-6

10 day average of Antarctic sea ice concentrations for 1978-1996. Solid lines indicate the absolute minimum (blue) and maximum (red) ice extent.

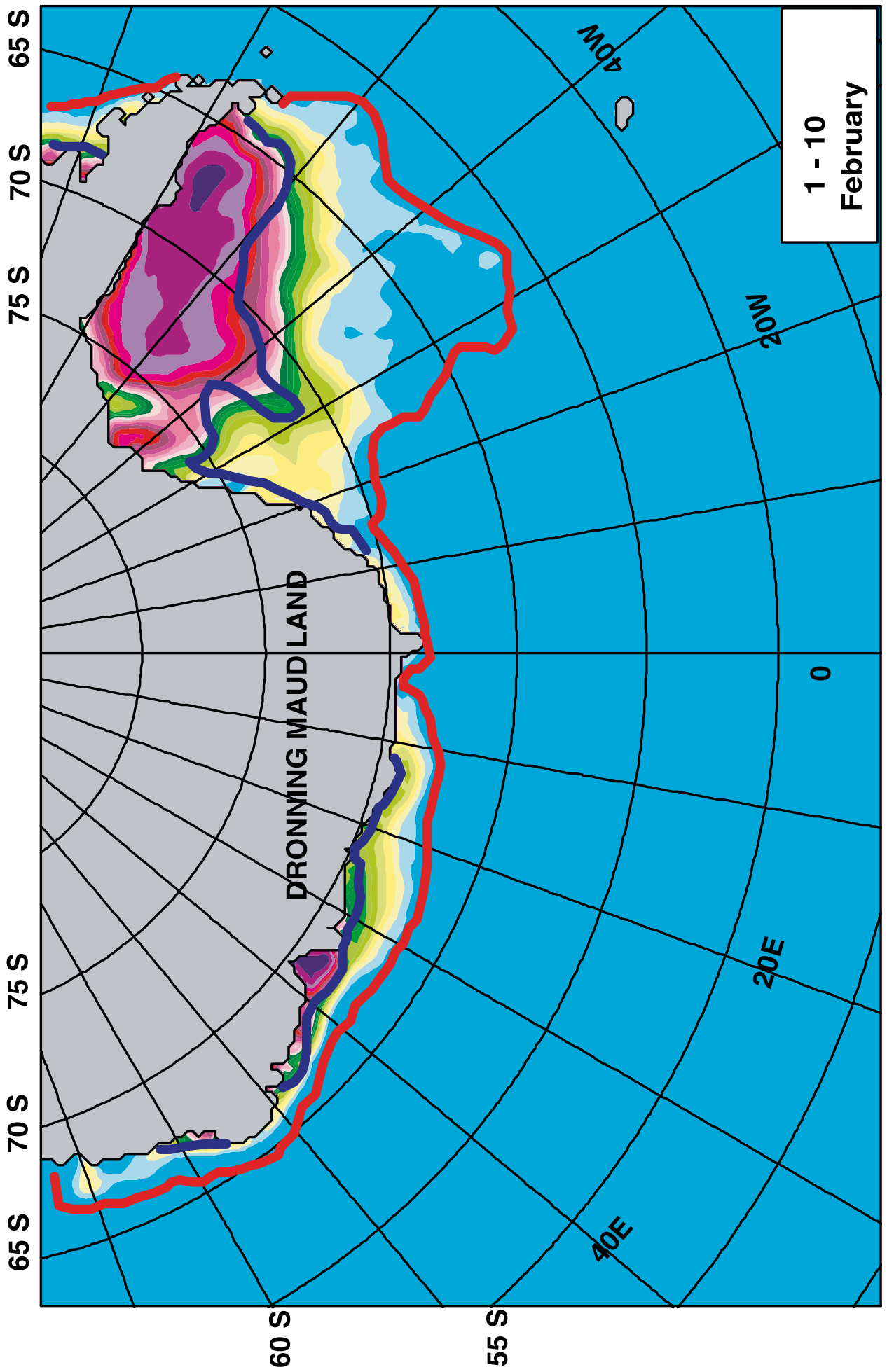


Fig. II-7

10 day average of Antarctic sea ice concentrations for 1978-1996. Solid lines indicate the absolute minimum (blue) and maximum (red) ice extent.

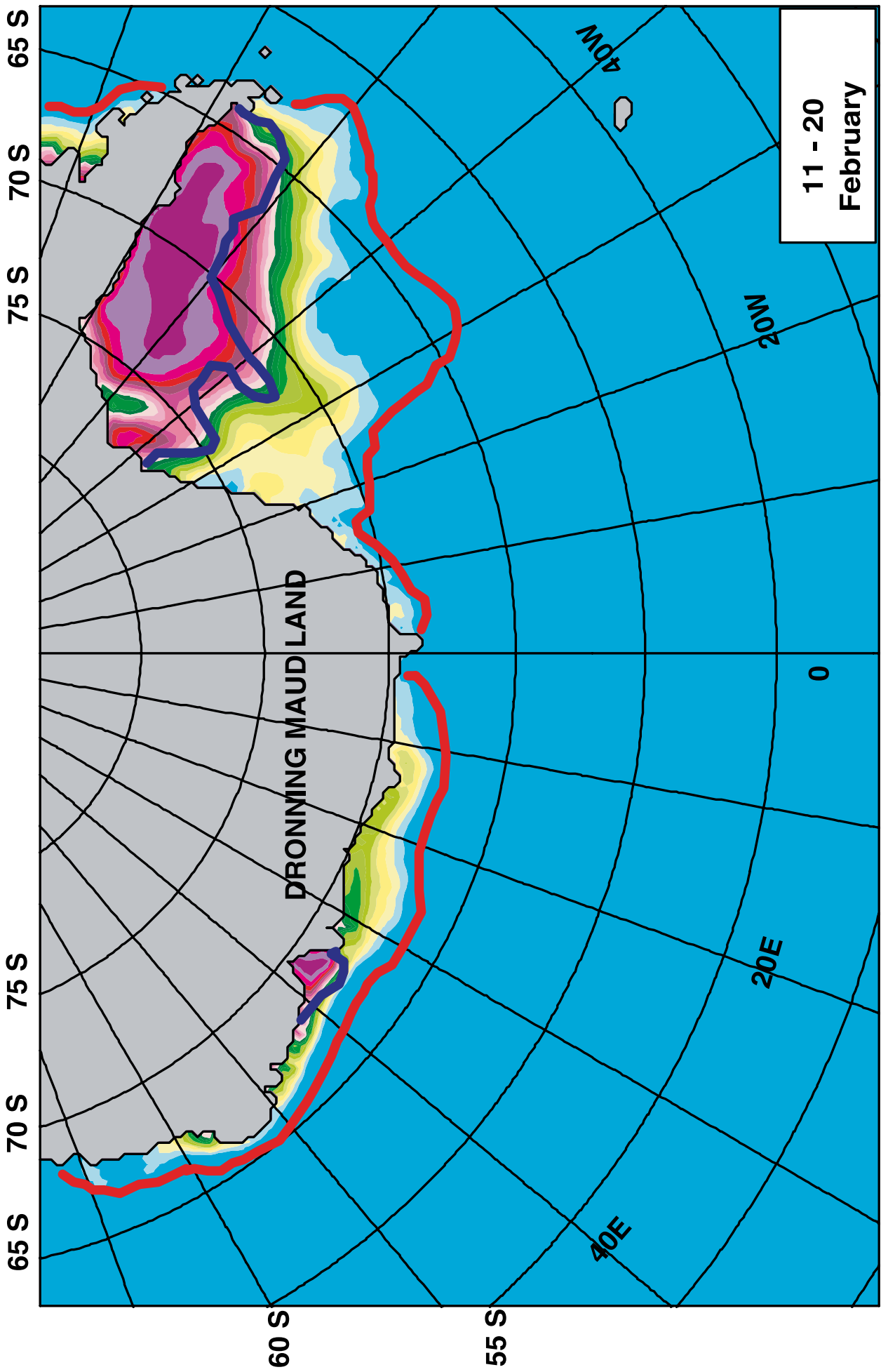


Fig. II-8

10 day average of Antarctic sea ice concentrations for 1978-1996. Solid lines indicate the absolute minimum (blue) and maximum (red) ice

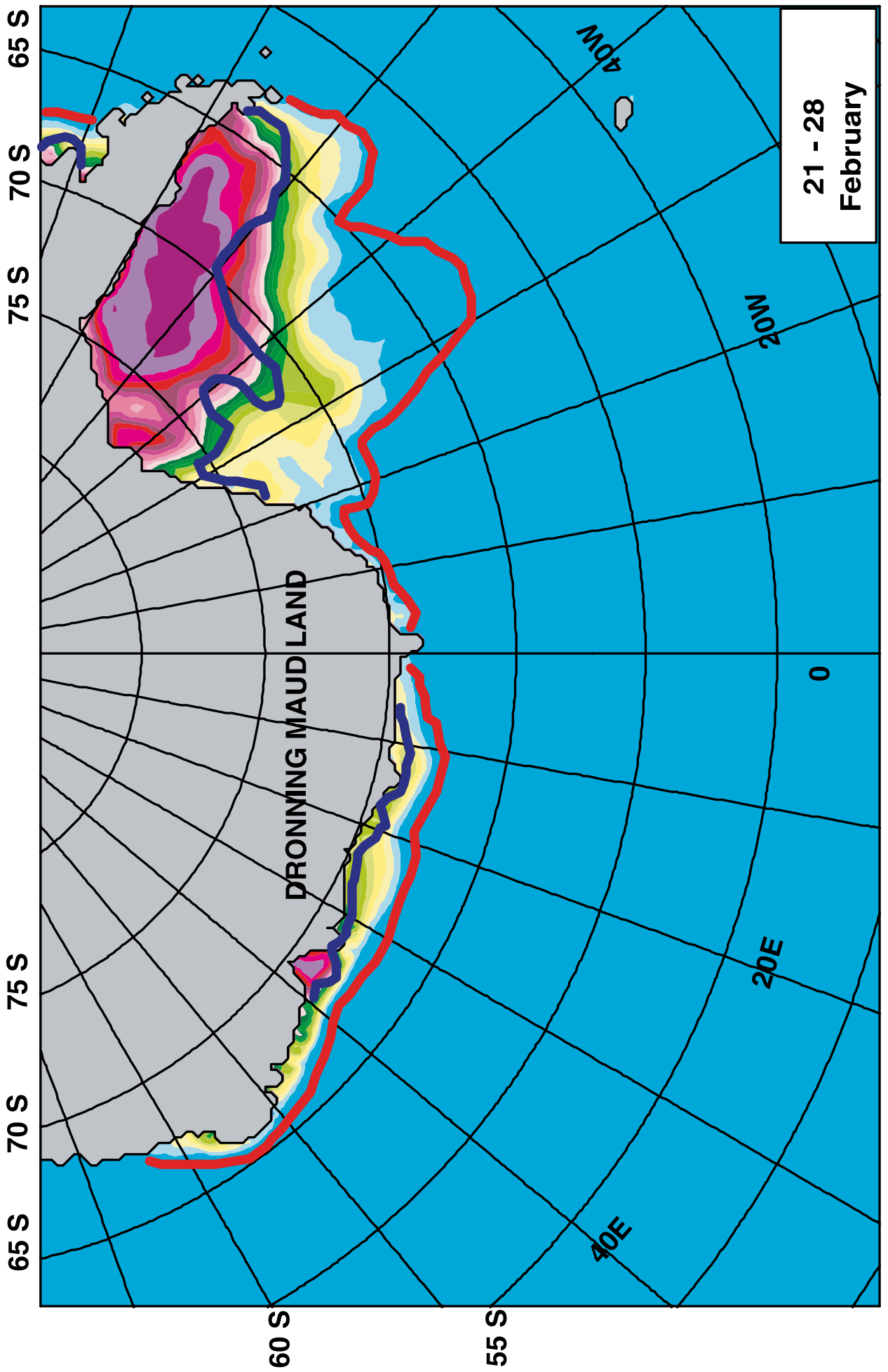


Fig. II-9
10 day average of Antarctic sea ice concentrations for 1978-1996. Solid lines indicate the absolute minimum (blue) and maximum (red) ice

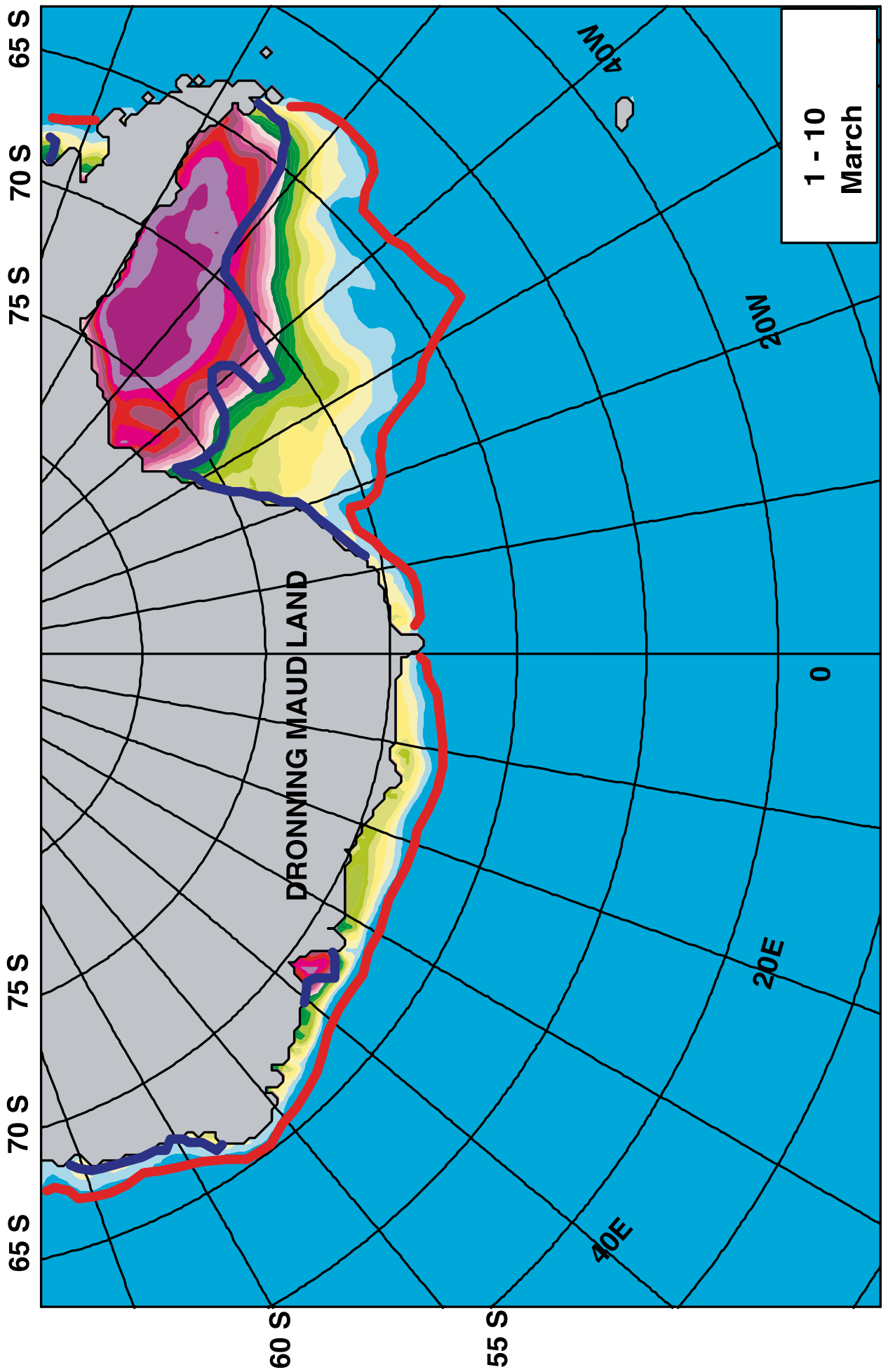


Fig. II-10
10 day average of Antarctic sea ice concentrations for 1978-1996. Solid lines indicate the absolute minimum (blue) and maximum (red) ice extent.

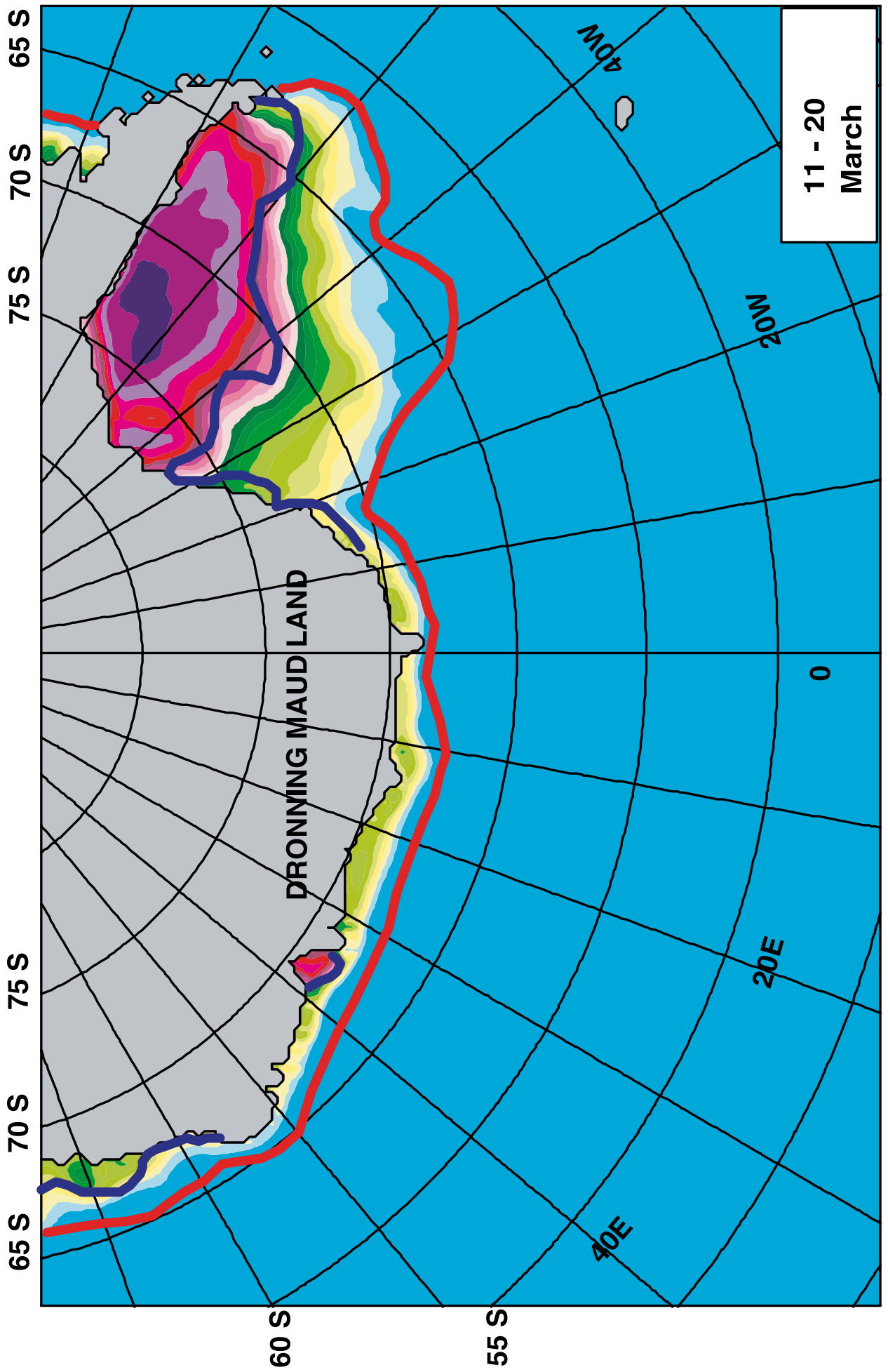


Fig. II-11

10 day average of Antarctic sea ice concentrations for 1978-1996. Solid lines indicate the absolute minimum (blue) and maximum (red) ice

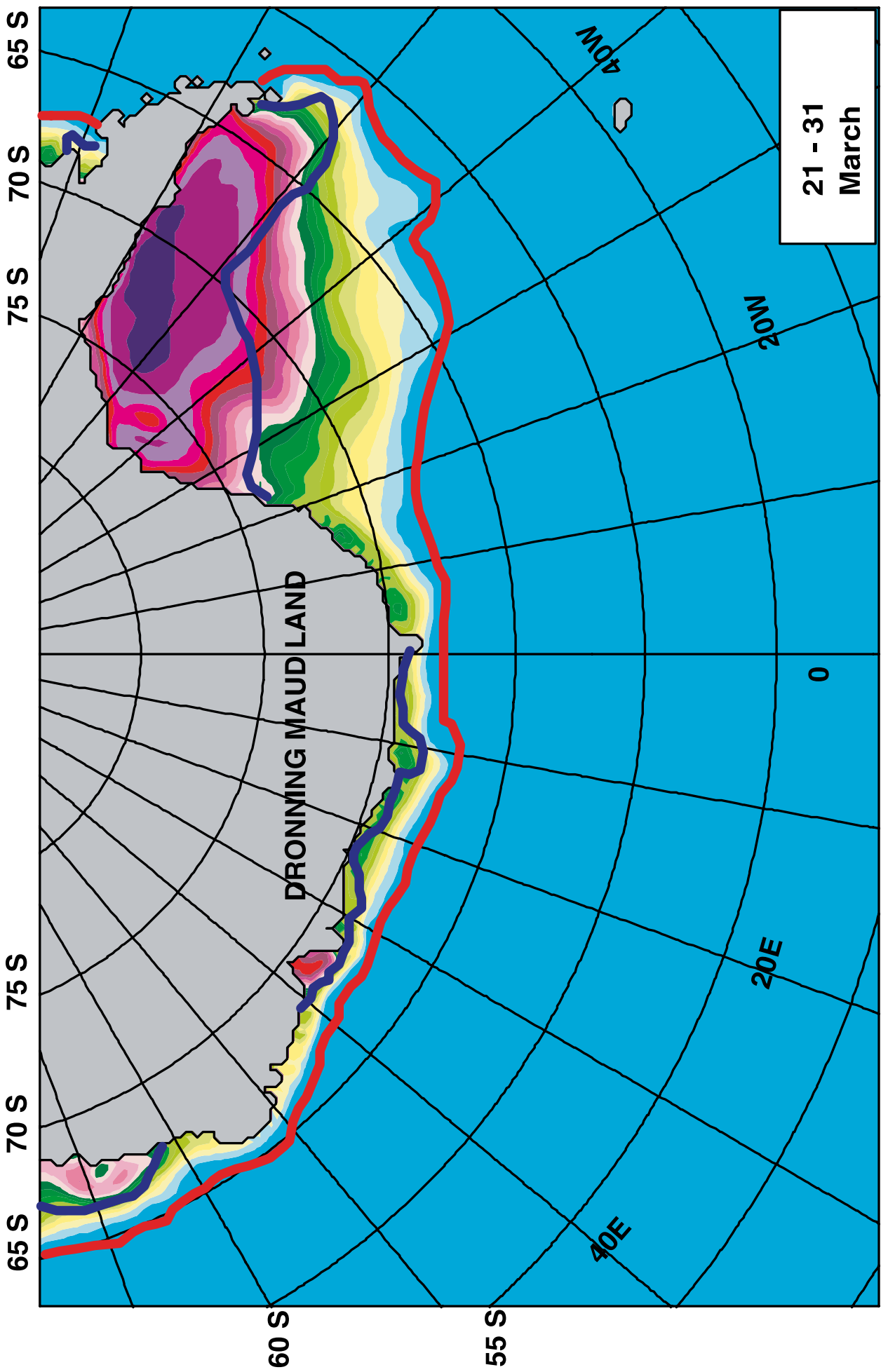


Fig. II-12
10 day average of Antarctic sea ice concentrations for 1978-1996. Solid lines indicate the absolute minimum (blue) and maximum (red) ice

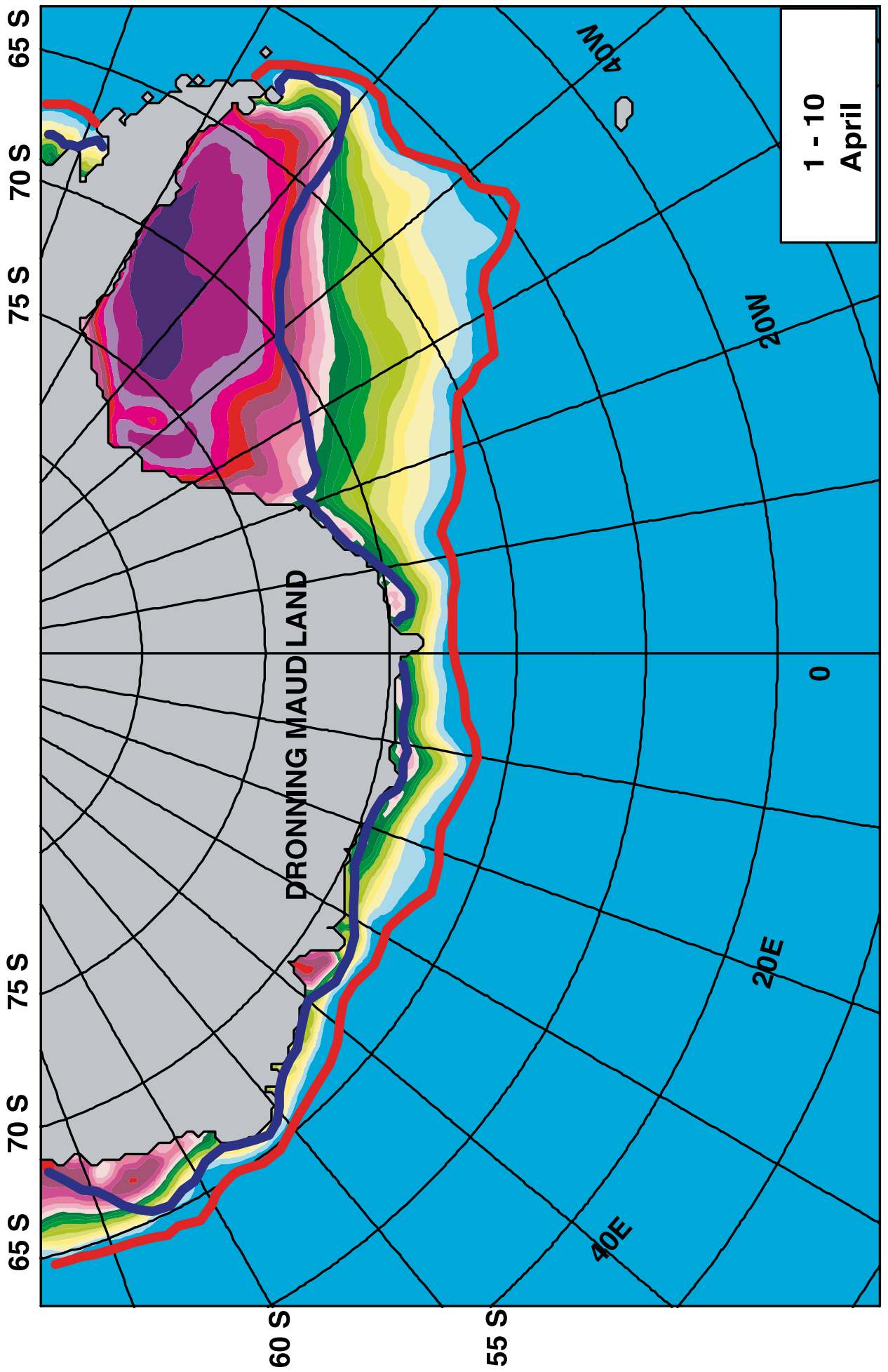


Fig. II-13

10 day average of Antarctic sea ice concentrations for 1978-1996. Solid lines indicate the absolute minimum (blue) and maximum (red) ice

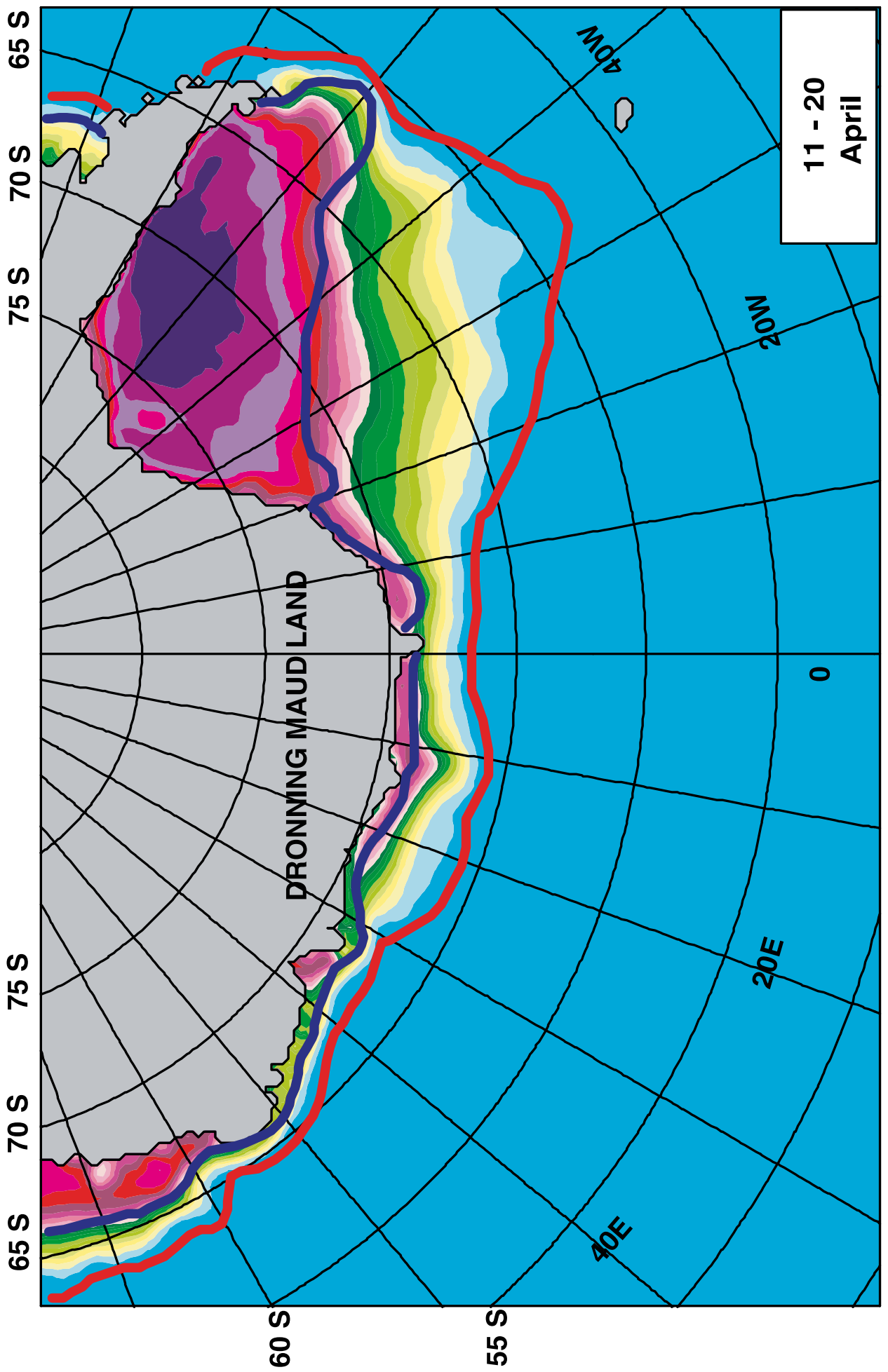


Fig. II-14

10 day average of Antarctic sea ice concentrations for 1978-1996. Solid lines indicate the absolute minimum (blue) and maximum (red) ice extent.

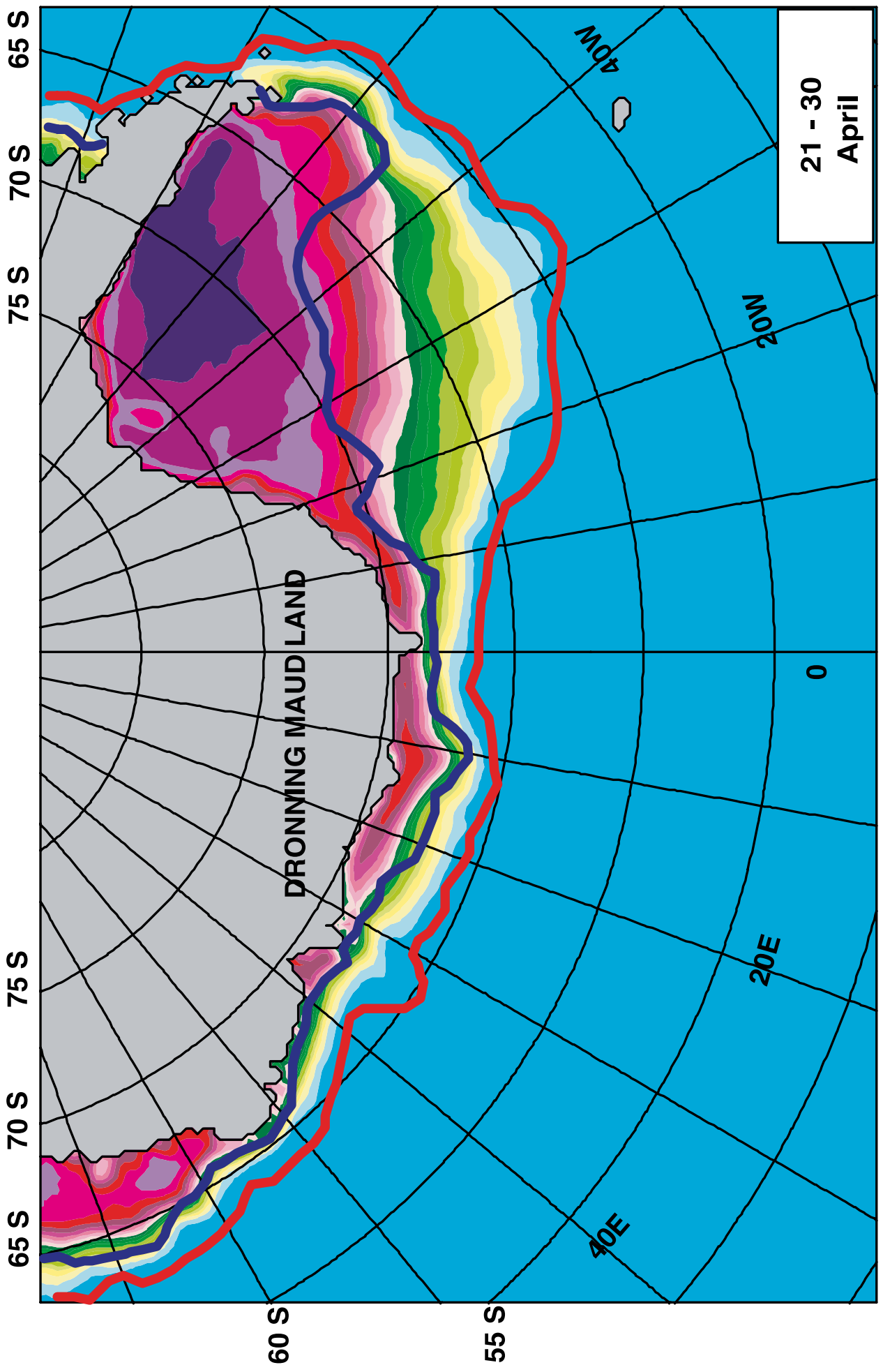


Fig. II-15

10 day average of Antarctic sea ice concentrations for 1978-1996. Solid lines indicate the absolute minimum (blue) and maximum (red) ice extent.

APPENDIX III 10-day average of sea ice concentrations (at 5% resolution – every degree of latitude is indicated) off Dronning Maud Land, Antarctica, for 1978-1996. The extreme situations for sea ice concentrations of 5% for 1978-1996 are also shown.

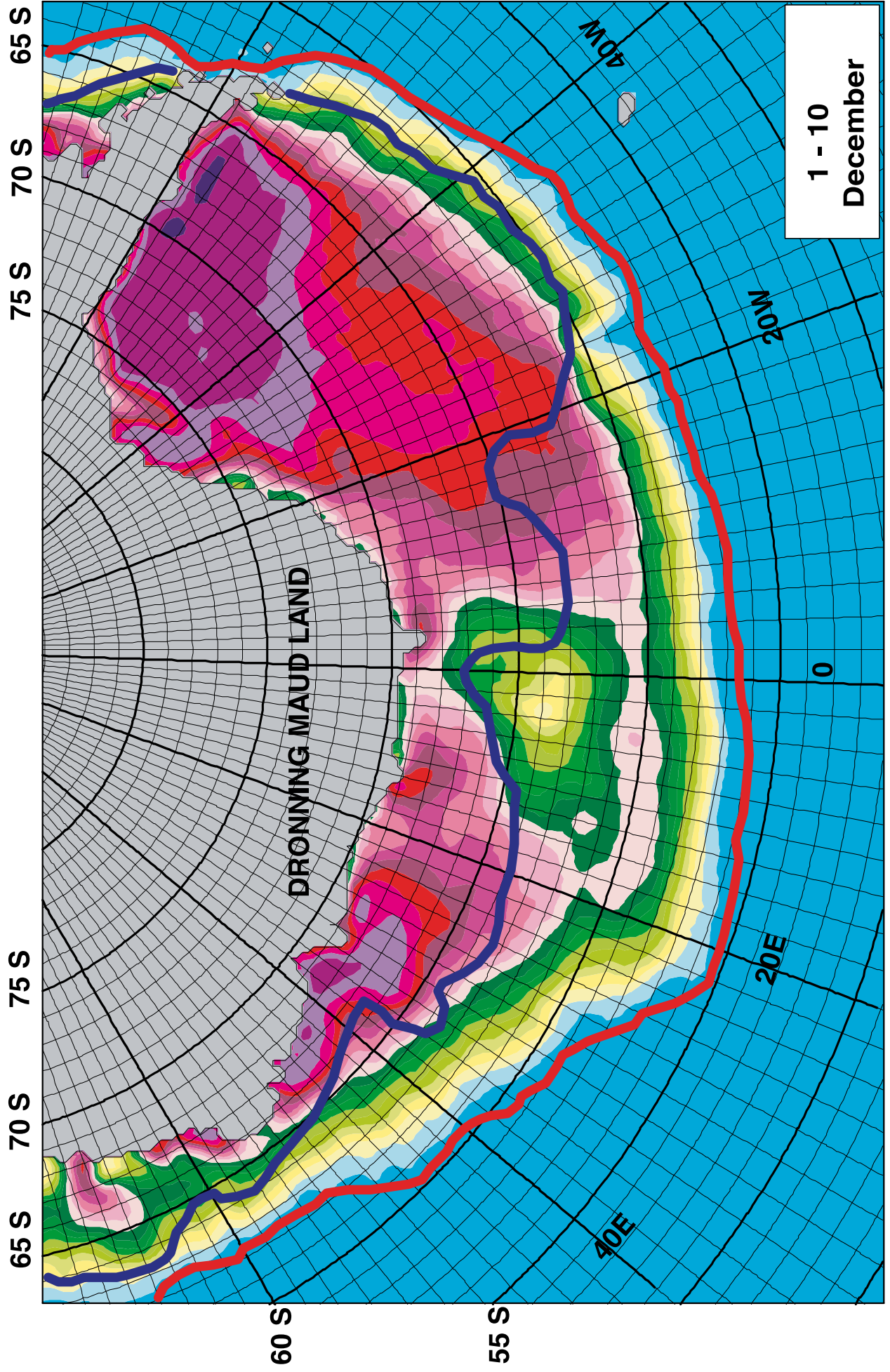


Fig. III-1
10 day average of Antarctic sea ice concentrations for 1978-1996. Solid lines indicate the absolute minimum (blue) and maximum (red) ice extent.

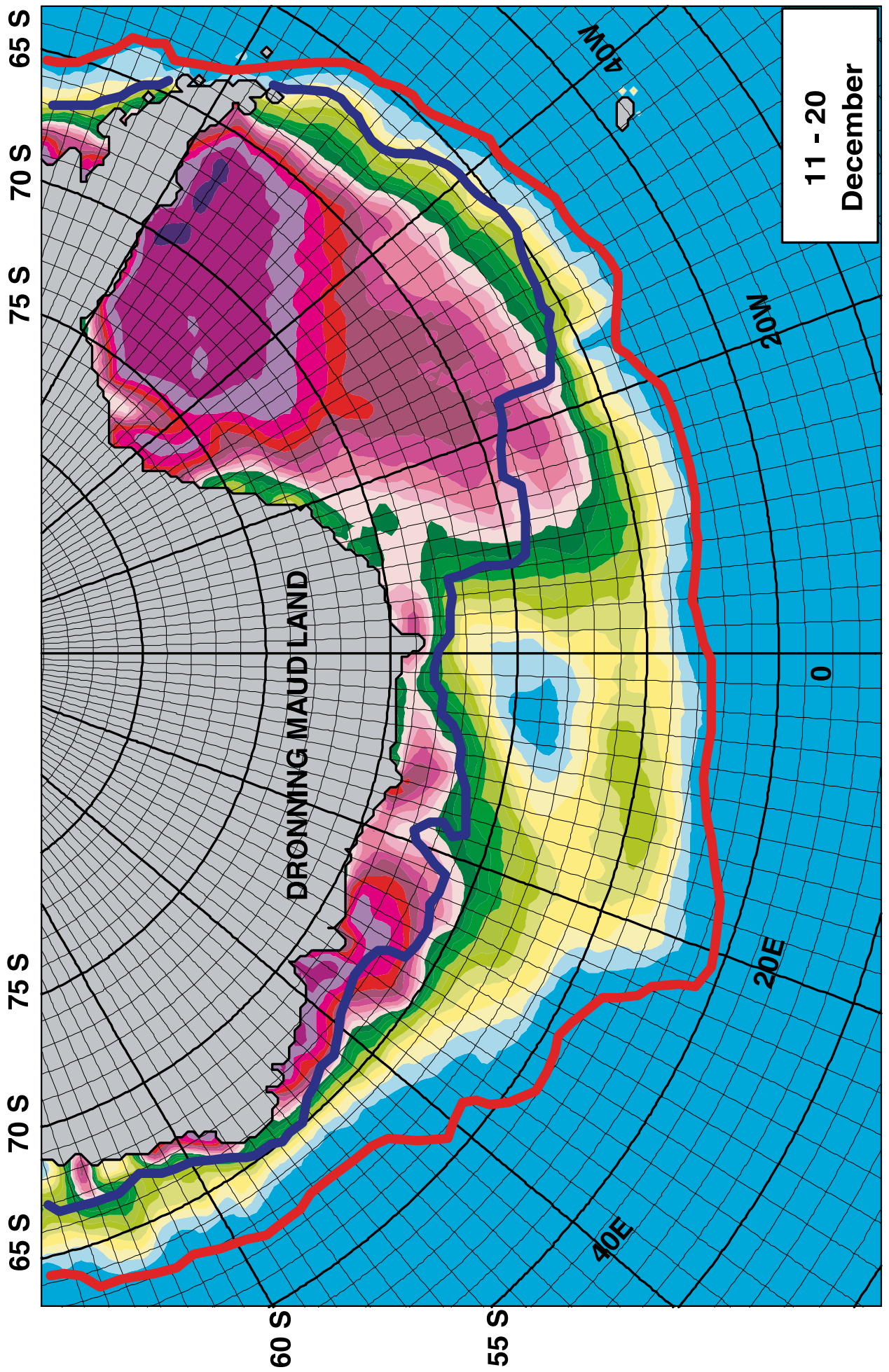


Fig. III-2
 10 day average of Antarctic sea ice concentrations for 1978-1996. Solid lines indicate the absolute minimum (blue) and maximum (red) ice extent.

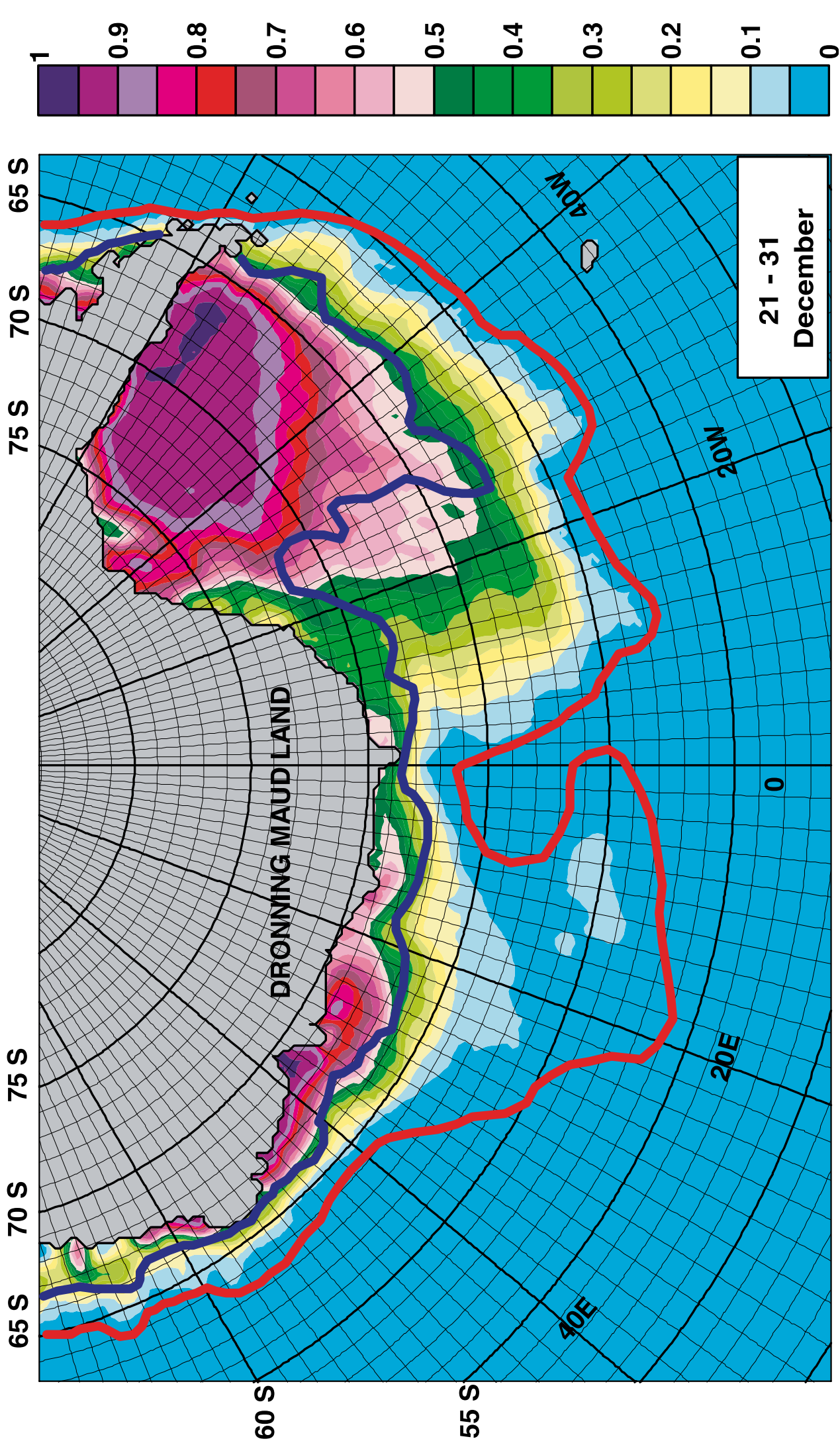


Fig. III-3
10 day average of Antarctic sea ice concentrations for 1978-1996. Solid lines indicate the absolute minimum (blue) and maximum (red) ice extent.

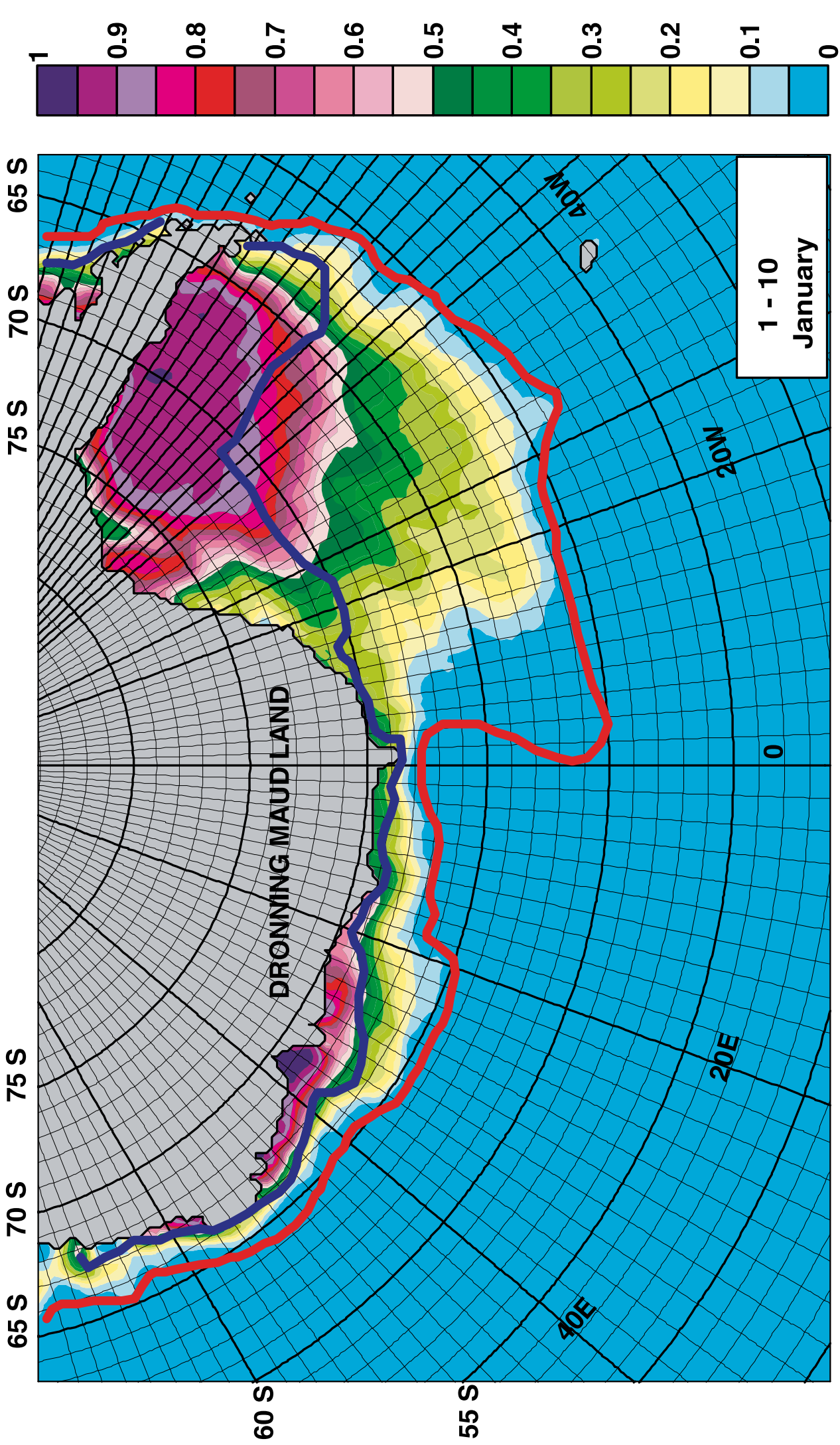


Fig. III-4

10 day average of Antarctic sea ice concentrations for 1978-1996. Solid lines indicate the absolute minimum (blue) and maximum (red) ice extent.

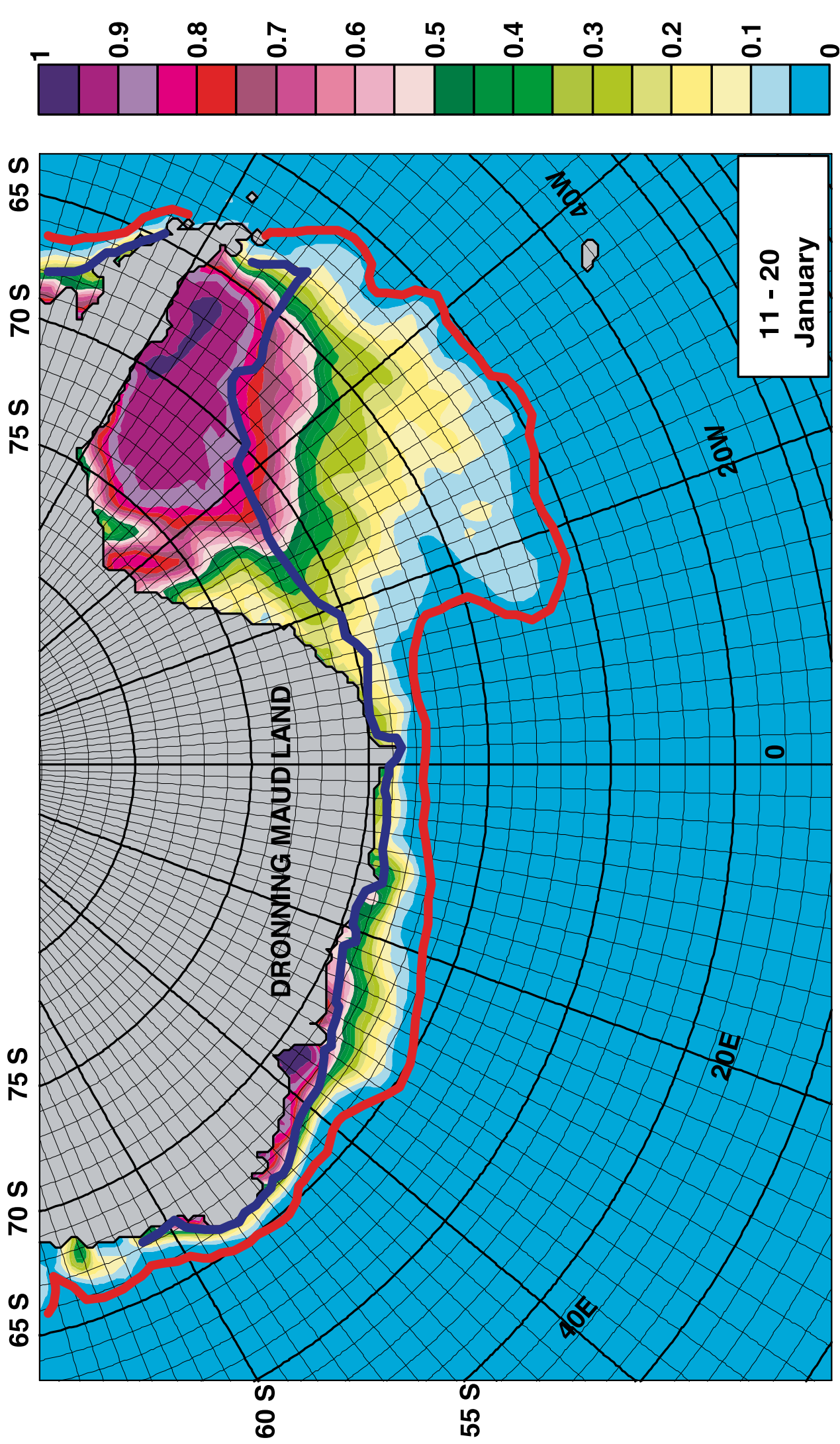


Fig. III-5
10 day average of Antarctic sea ice concentrations for 1978-1996. Solid lines indicate the absolute minimum (blue) and maximum (red) ice extent.

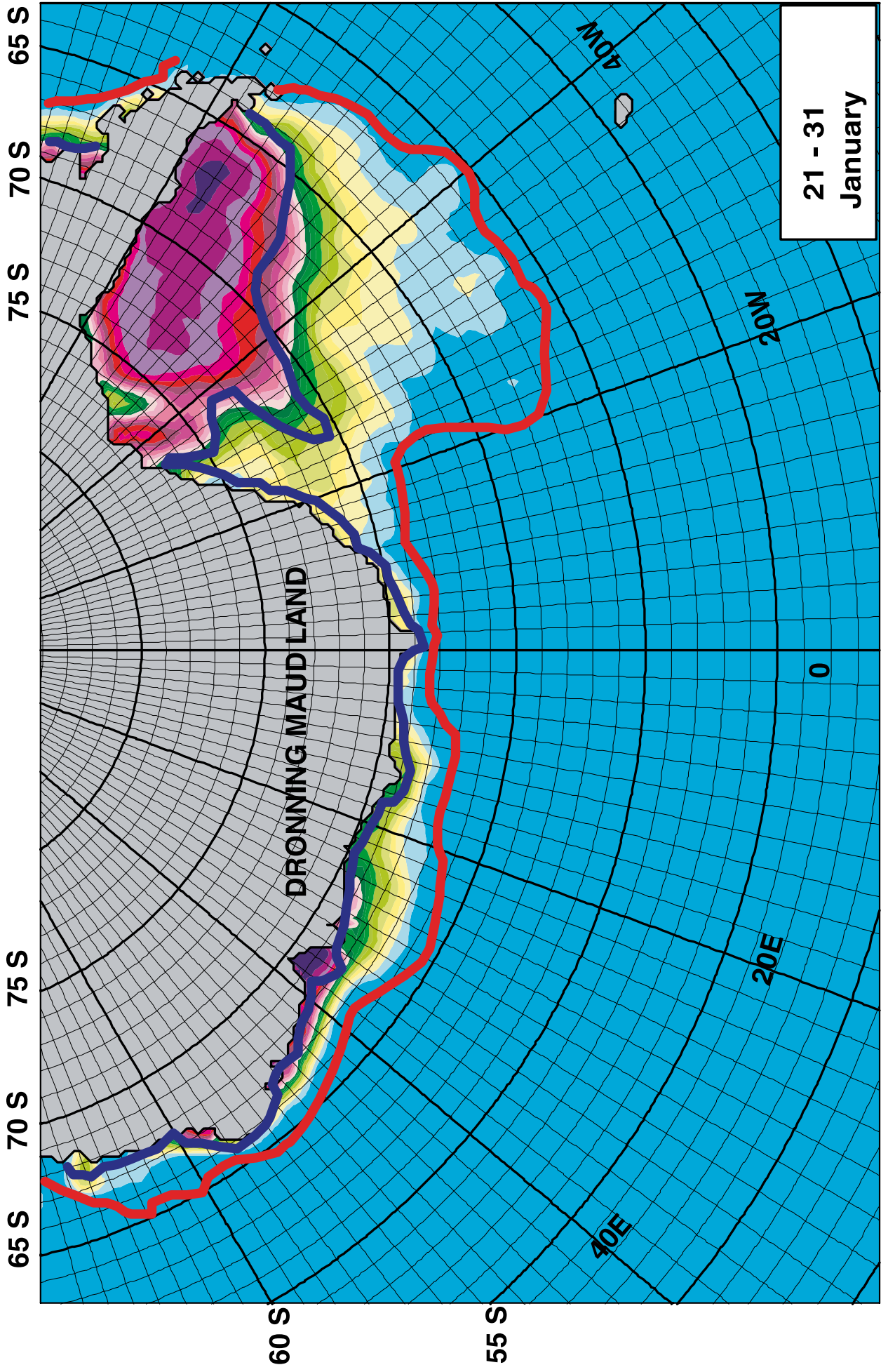


Fig. III-6

10 day average of Antarctic sea ice concentrations for 1978-1996. Solid lines indicate the absolute minimum (blue) and maximum (red) ice extent.

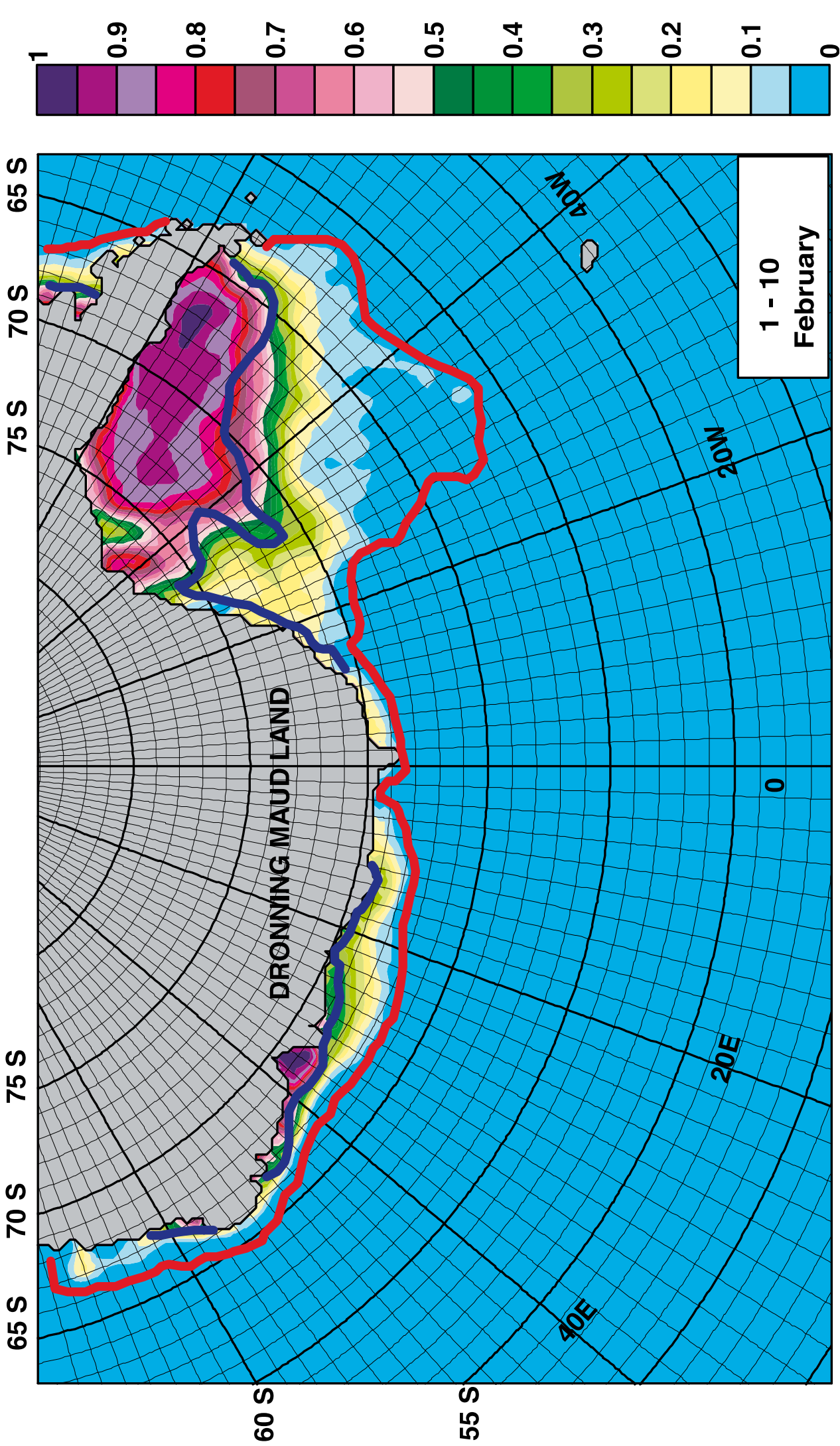


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10 day average of Antarctic sea ice concentrations for 1978-1996. Solid lines indicate the absolute minimum (blue) and maximum (red) ice extent.

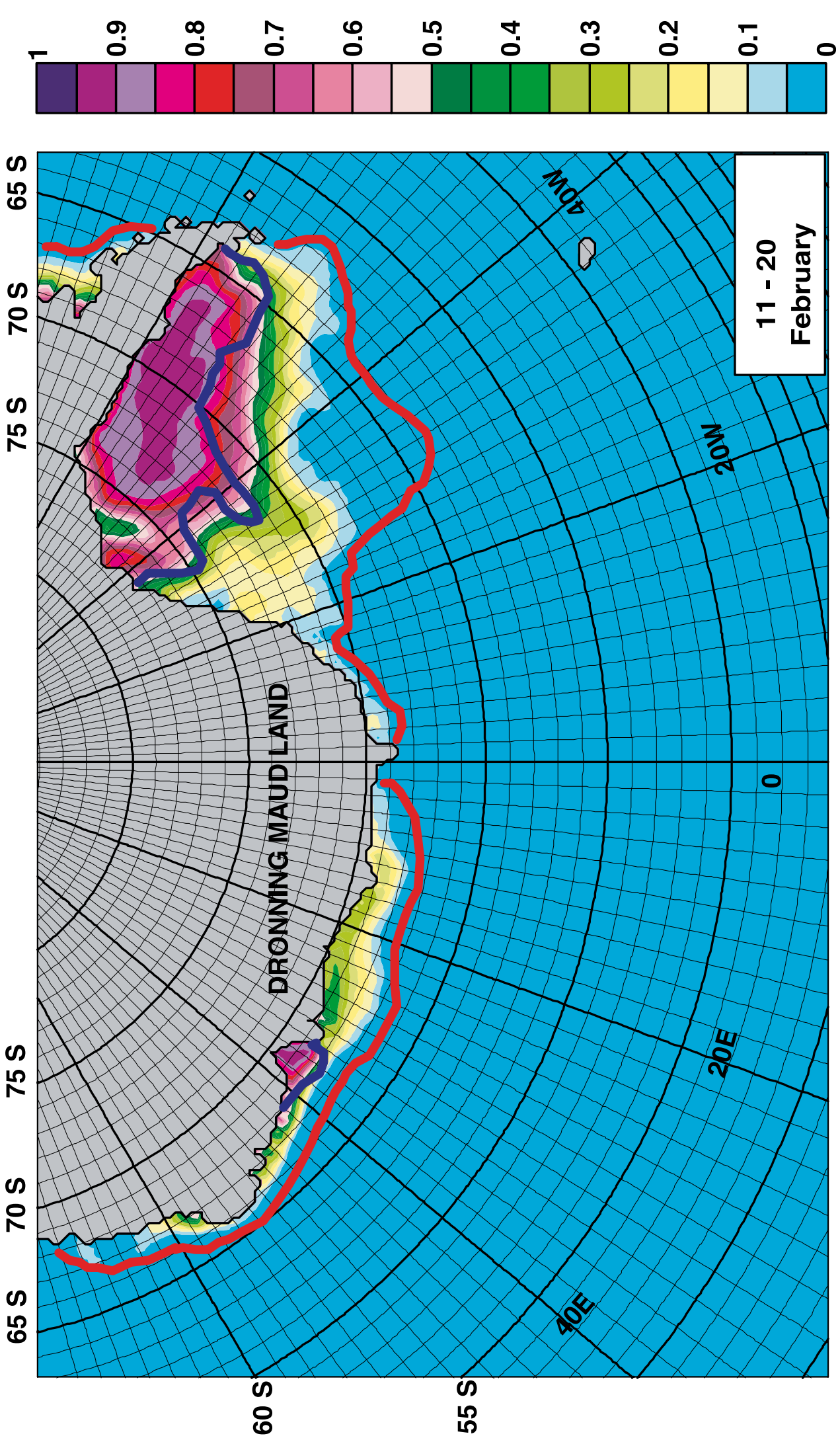


Fig. III-8

10 day average of Antarctic sea ice concentrations for 1978-1996. Solid lines indicate the absolute minimum (blue) and maximum (red) ice

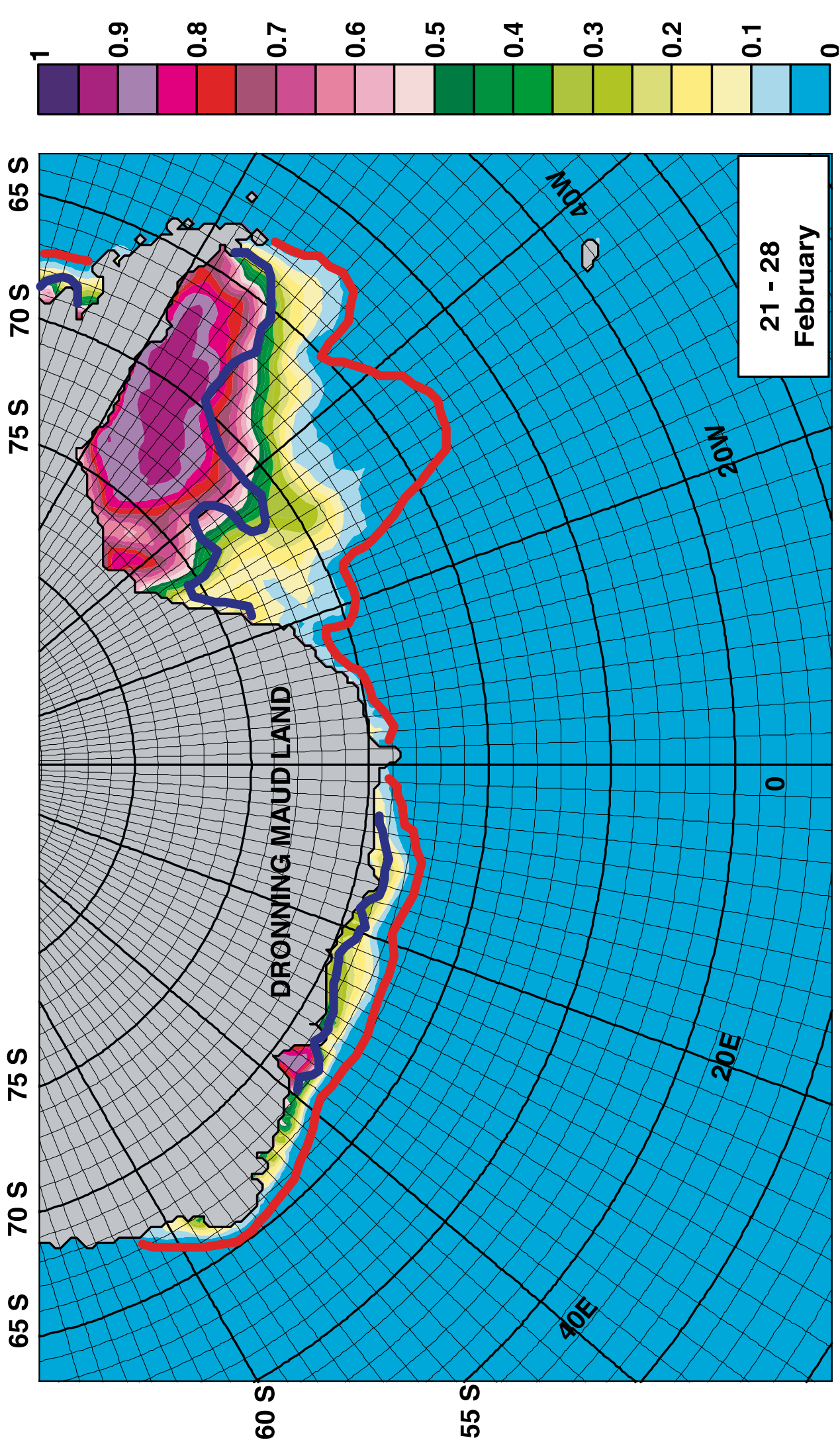


Fig. III-9
10 day average of Antarctic sea ice concentrations for 1978-1996. Solid lines indicate the absolute minimum (blue) and maximum (red) ice extent.

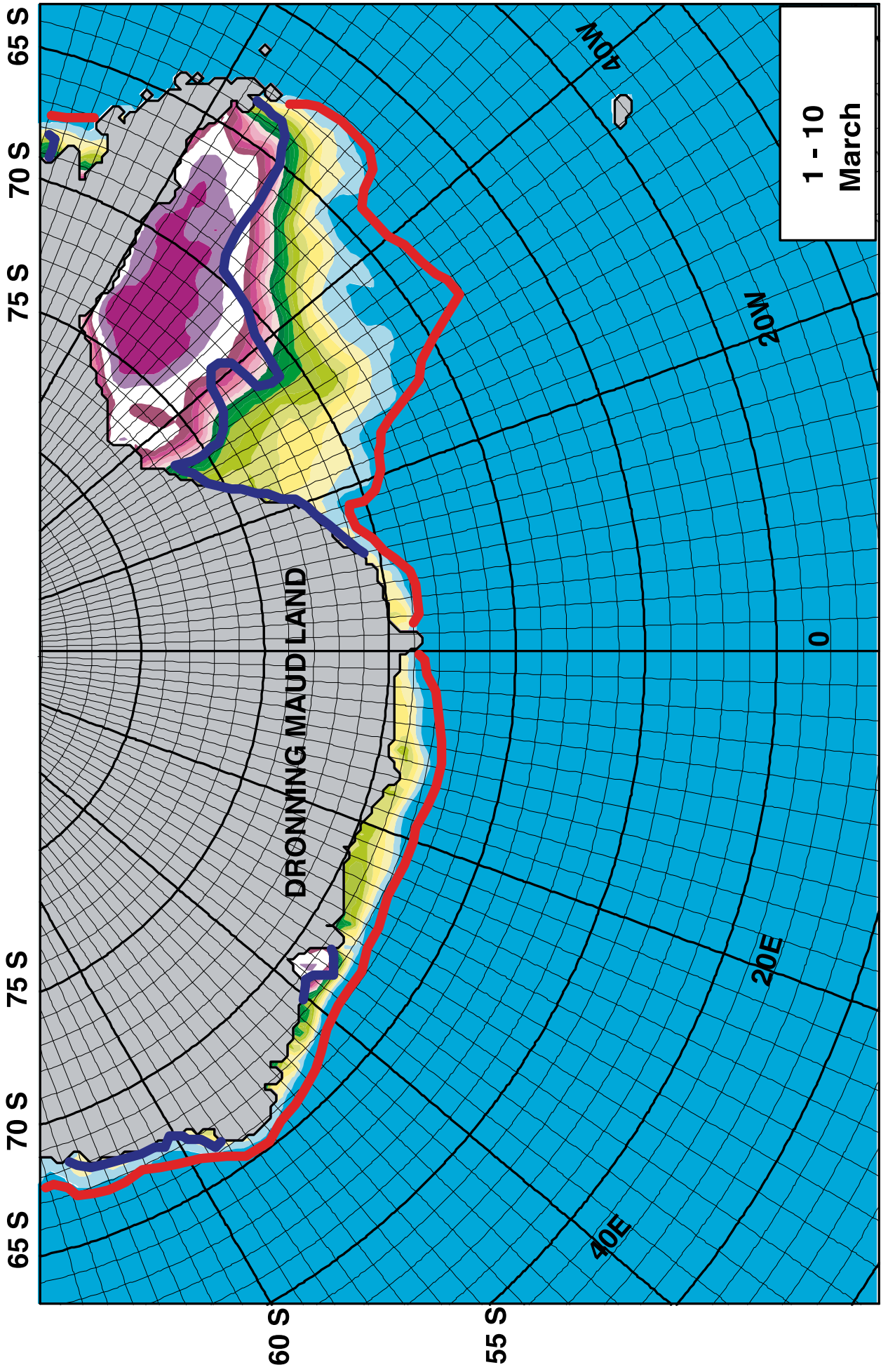


Fig. III-10
10 day average of Antarctic sea ice concentrations for 1978-1996. Solid lines indicate the absolute minimum (blue) and maximum (red) ice

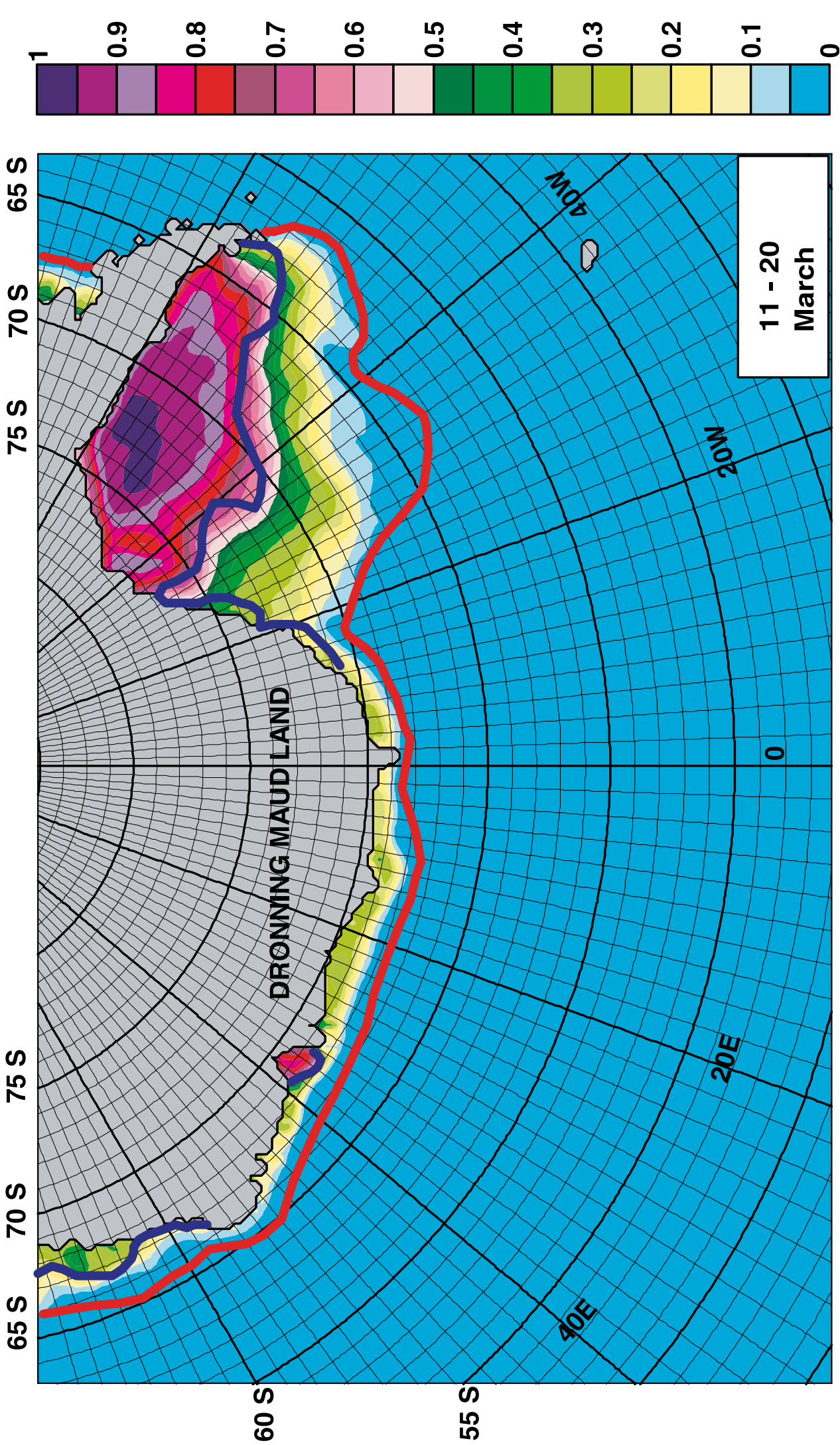


Fig. III-11
10 day average of Antarctic sea ice concentrations for 1978-1996. Solid lines indicate the absolute minimum (blue) and maximum (red) ice extent.

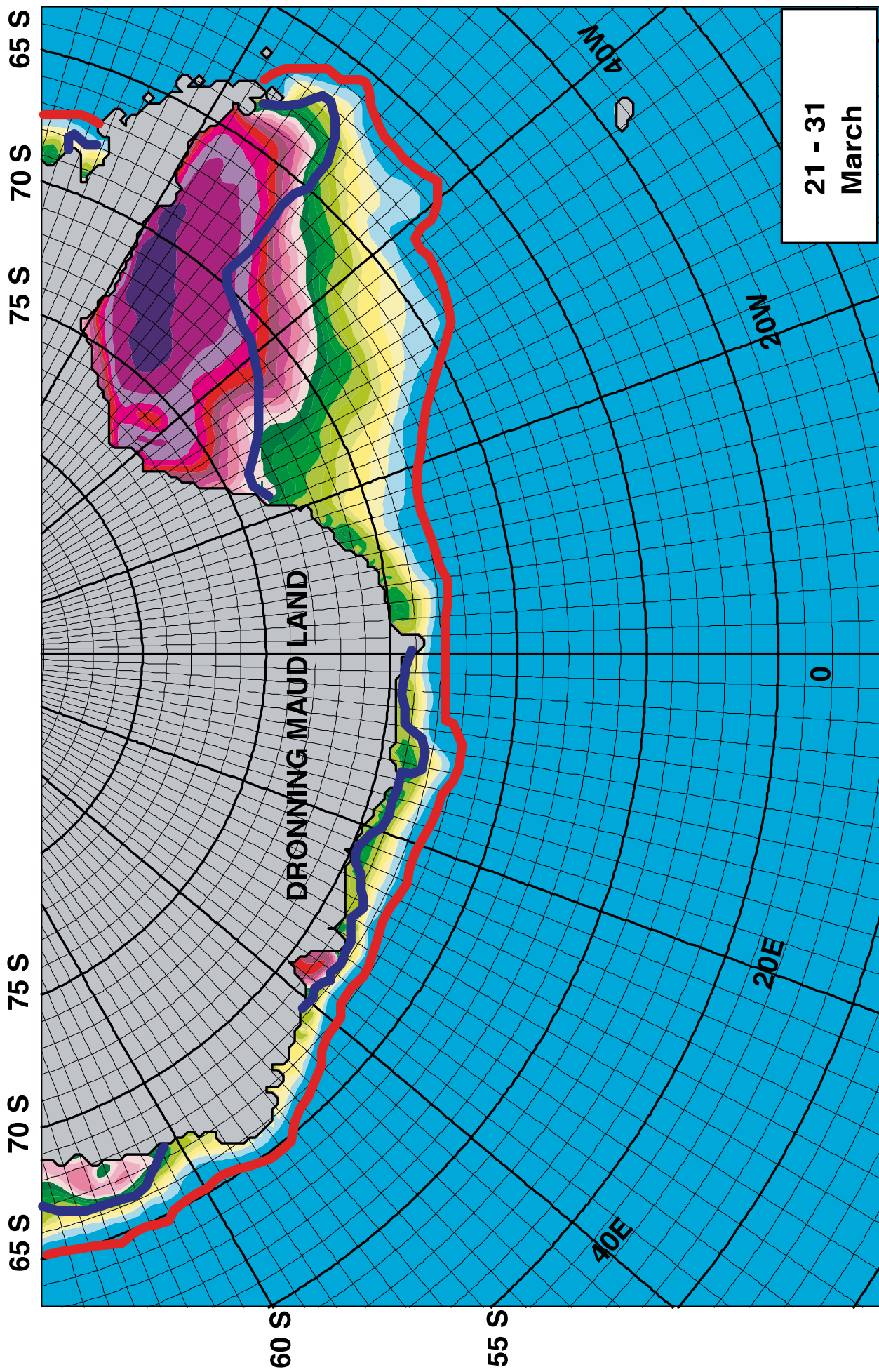


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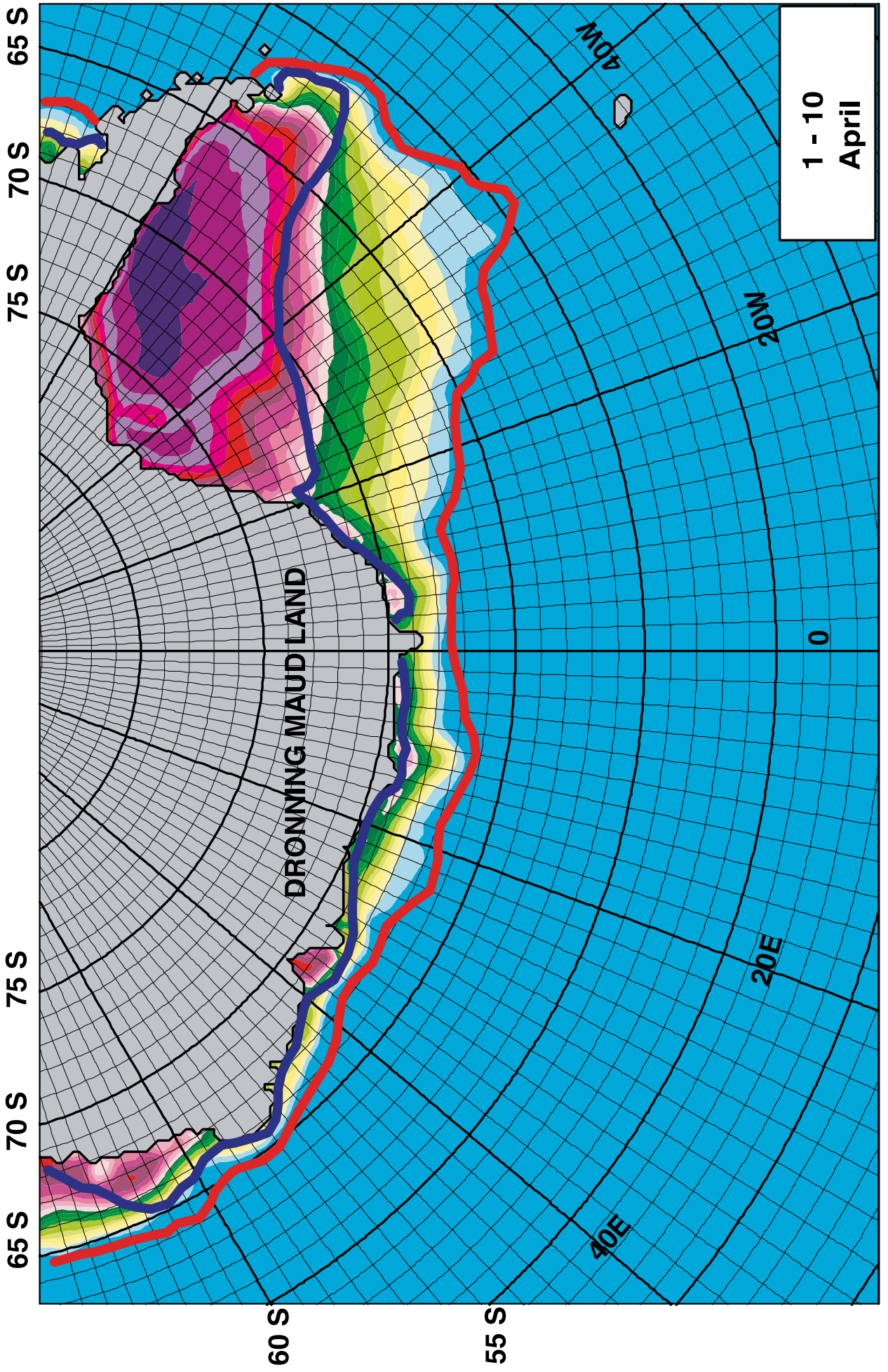


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10 day average of Antarctic sea ice concentrations for 1978-1996. Solid lines indicate the absolute minimum (blue) and maximum (red) ice extent.

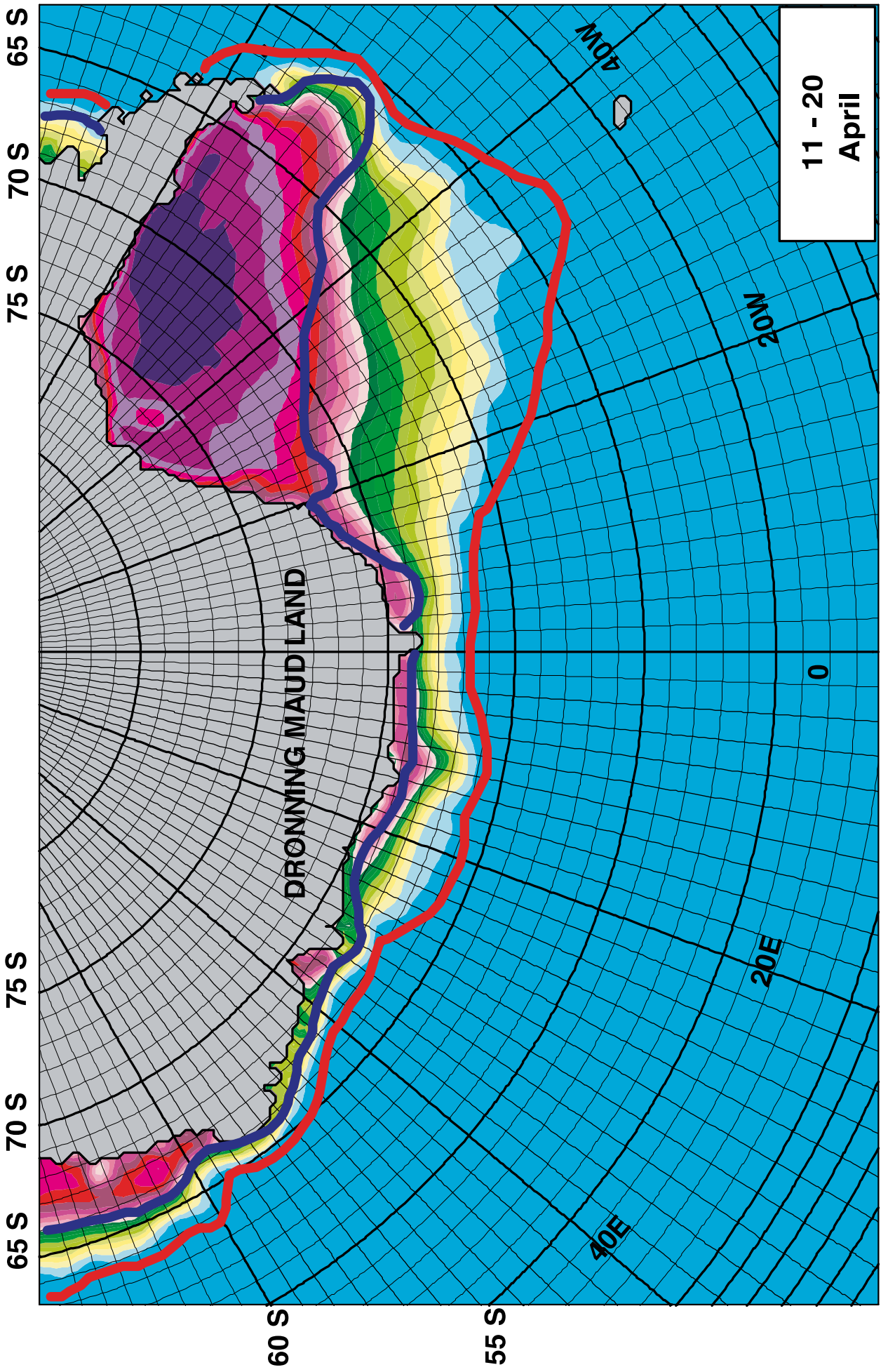


Fig. III-14

10 day average of Antarctic sea ice concentrations for 1978-1996. Solid lines indicate the absolute minimum (blue) and maximum (red) ice extent.

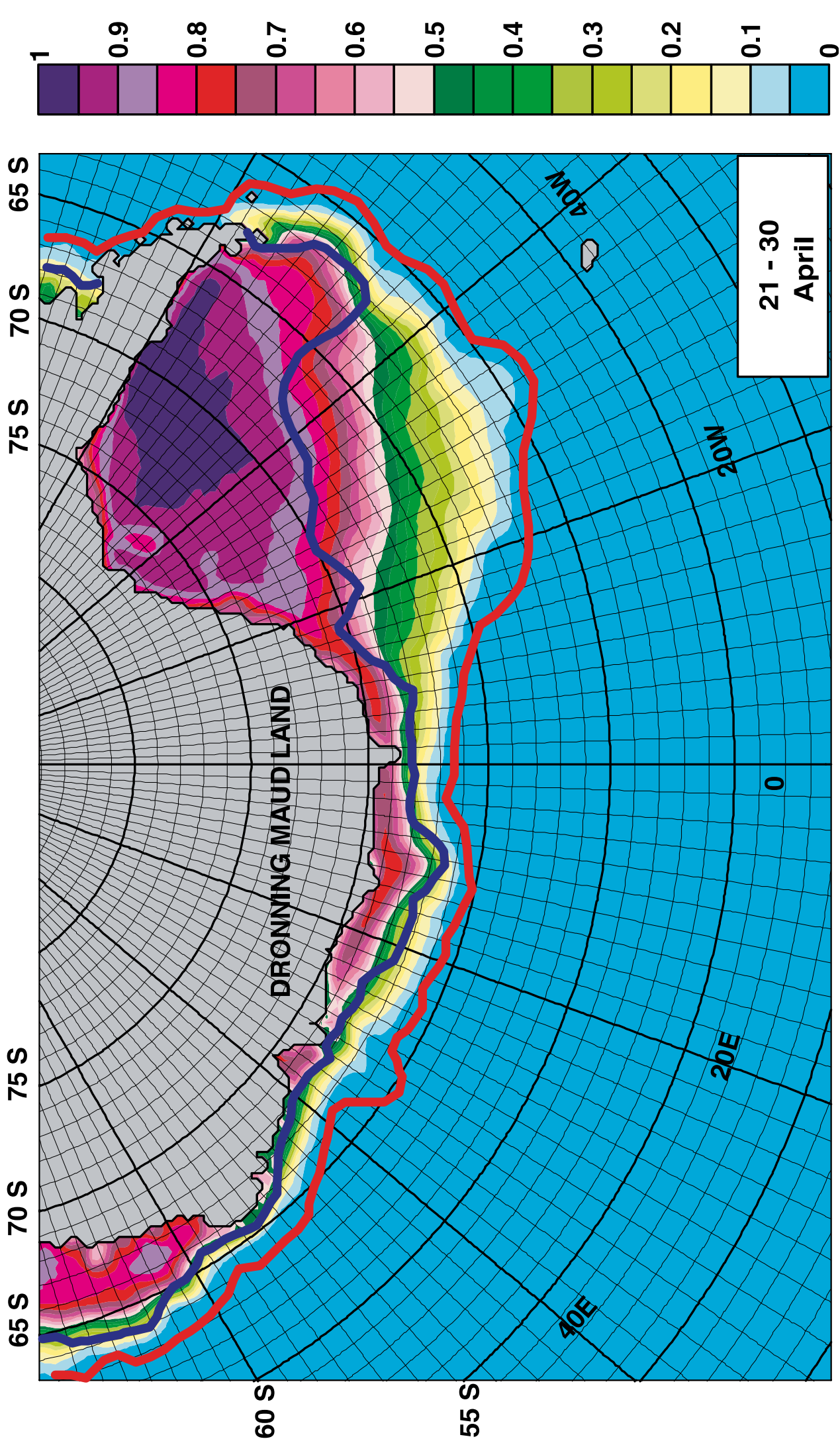


Fig. III-15
10 day average of Antarctic sea ice concentrations for 1978-1996. Solid lines indicate the absolute minimum (blue) and maximum (red) ice extent.

