Seasonal Atlas of Greenland Icebergs

This atlas shows the seasonal distribution of the icebergs – observed from space – in the waters around Greenland; it is a service developed- and provided by the SALIENSEAS project. The atlas is also available online in an interactive version at http://ocean.dmi.dk/salienseas. The atlas consists of a series of maps that displays iceberg statistics for each of the 52 weeks of the year. Note that the maps show statistics on icebergs detected in open-water only. This is due to the presence of rugged structures in the sea ice (such as ridges and rubble fields), that make iceberg-detection in sea-ice infested areas uncertain. The following sections give a brief description of the background and a guide to how the maps should be interpreted.

1. Background

Because of the polar darkness that prevails in the Arctic during long periods of the year; and because of frequent cloud cover, satellite based detection of icebergs at high latitudes requires radar based technology. With the launch of the Copernicus Sentinel-1A satellite in April 2014 and Sentinel-1B in April 2016, an unprecedented amount of Synthetic Aperture Radar (SAR) satellite imagery has been available within the recent years. The Danish Meteorological Institute (DMI) uses these data to monitor the amount of icebergs present in the Greenland Waters; and provides iceberg observations as a service in the Copernicus Marine Environment Monitoring Service (CMEMS). The maps shown in this atlas is a synthesis of these observations.

1.1 iceberg detection

Daily, DMI receives up to about 100 scenes of SAR imagery from the Sentinel-1 satellites. Together such 100 images cover more than ten million square kilometers and contain more than 35 billion pixels. Each pixel is analyzed by dedicated detection algorithms that decide whether the pixel constitutes a part of an iceberg.

The Sentinel-1 SAR instruments transmit radar signals towards the surface of the Earth in an oblique angle. Rugged objects with sharp edges – such as icebergs – reflect the signals in the direction back towards the radar sensor (see Figure 1C – the double bounce effect), which gives a strong return signal. In SAR imagery iceberg-pixels thus typically will appear brighter than the nearby surroundings (i.e. the background noise floor).

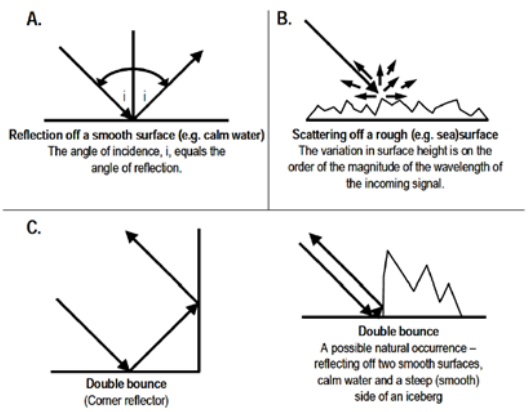

Figure 1. Radar signals - reflection and scattering off at the boundary of different surface types.

A: smooth surfaces basically act as mirrors, reflecting more or less the whole signal away from the radar sensor. Such surfaces therefore appear dark in radar imagery.
B: more rough surfaces scatter radar signals in all directions and thus a certain fraction of the signal returns to the satellite. These surfaces therefore appear somewhat brighter and grainier in the imagery.
C: larger objects with steep sides and sharp edges act as corner reflectors. Through the double bounce effect most of the radar signal returns to the satellite, and thus such objects typically appear very bright in SAR imagery.

However, Icebergs may take many forms with sizes ranging from a few tenths of meters to more than one kilometer (by definition an iceberg is a chunk of ice – larger than 15 m horizontal length – that has formed on land). Furthermore, other objects – typically ships – can be misjudged by the detection algorithm as false iceberg-targets. To cope with these issues the DMI detection algorithms are able to automatically adapt to work at different spatial scales and to analyze the shapes of the objects appearing in the imagery. Finally, because of limitations in the spatial resolution of the imagery, icebergs smaller than about 40-60 meters in horizontal length will not necessarily be detected.

Thus, in summary, the statistics in the maps in this atlas includes iceberg-targets observed in open-water, larger than about 50 meters in length; and the included targets have geometrical shapes making them likely to be *true* icebergs.

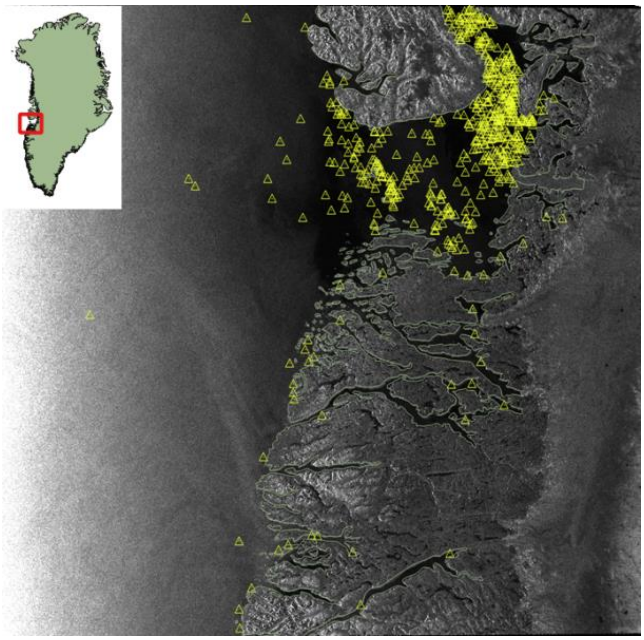

Figure 2. SAR imagery, Sentinel-1B 2019-09-02 20:54:19, Disko Area West Greenland with indications (yellow triangles) of detected icebergs.

2. Seasonal maps (pages 4-21) – interpretation of the statistics

To create mapped statistics the Greenland region is divided into grid-cells (squares) of 10 x 10 km. Each time a Sentinel-1 satellite scene covers a grid-cell, the number of detected icebergs present within that particular grid-cell is registered. The current version of iceberg-detection algorithms has been operational at DMI since the beginning of 2017, which means that the statistics at the current time of writing includes close to three years of observation – equivalent to more than 32,000 individual Sentinel-1 scenes. Thus, during these three years most of the thousands of 10x10 km grid-cells of the Greenland Waters were overpassed many times by the Sentinel-1 satellites. That is to say, that all of these grid-cells have their own time series of iceberg concentration – and thereby seasonal iceberg-statistics can be derived for each grid-cell. Figure 3 shows the coverage of Sentinel-1 acquired (in Extra Wide Swath mode) over the Greenland region during a four day period (2019-11-29 to 2019-12-03). For exemplification grid-cells covered by the scene acquired 2019-12-02 10:16:37 UTC are highlighted.

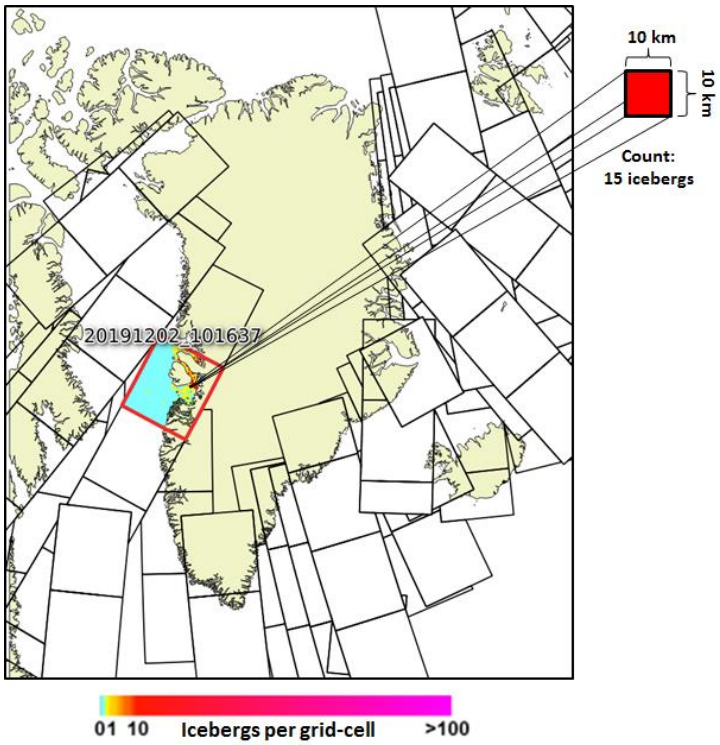

Figure 3. Coverage of Sentinel-1 A and B Extra Wide Swath Scenes during the period: 2019-11-29 to 2019-12-03. For exemplification the scene coverage (including the corresponding gridded iceberg concentration) acquired 2019-12-02 is highlighted.
The zoom-in is on a grid-cell situated in the inner Disko Bay in Central West Greenland, quite close to Jakobshavn Isbræ – the World's fastest moving glacier. Thus, at this satellite acquisition time 15 medium and large sized icebergs were present within that particular 10x10 km area.

Note that over time the many thousands of 10x10 km grid-cells of the Greenland Waters will be overpassed many times by the Sentinel-1 satellites during a multiyear period. That is to say, that all of these grid-cells have their own time series of iceberg concentration, and thereby seasonal iceberg-statistics can be derived for each grid-cell.
The statistical maps (pages 4-21) of this atlas show the number of icebergs expected to be present under various conditions in any region around Greenland at any time (week) of the year. The conditions Displayed are: few: (P16), normal (P50), and many (P84).

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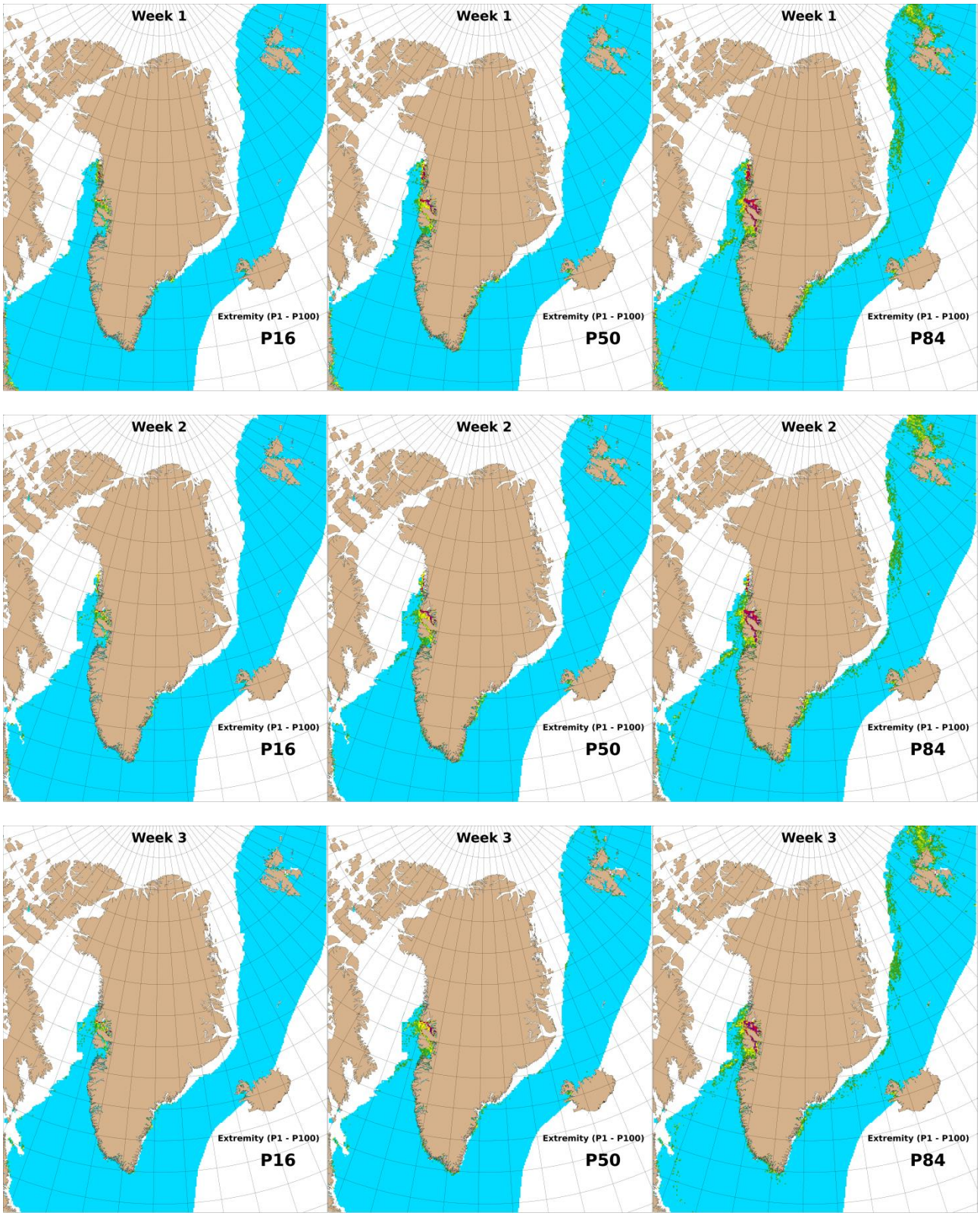
Note that it is (of course) highly unlikely to have the same conditions (e.g. P50) over the entire Greenland region at the same time. When interpreting the maps one should therefore focus at (zoom to) local areas of interest. In this regard it is recommended to use online version of the atlas at http://ocean.dmi.dk/salienseas. Here it is possible to select between week numbers and in more detail between different iceberg conditions. I.e. here all percentiles from P1 to P100 are available and it is also possible to zoom interactively in the maps.

Also note that in regions where sea-ice is present during long periods there will not be enough observations to derive valid statistics. In the maps statistically invalid areas are just white.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Extremity (P1 - P100)
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Week 2
Extremity (P1 - P100)
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Week 3
Extremity (P1 - P100)
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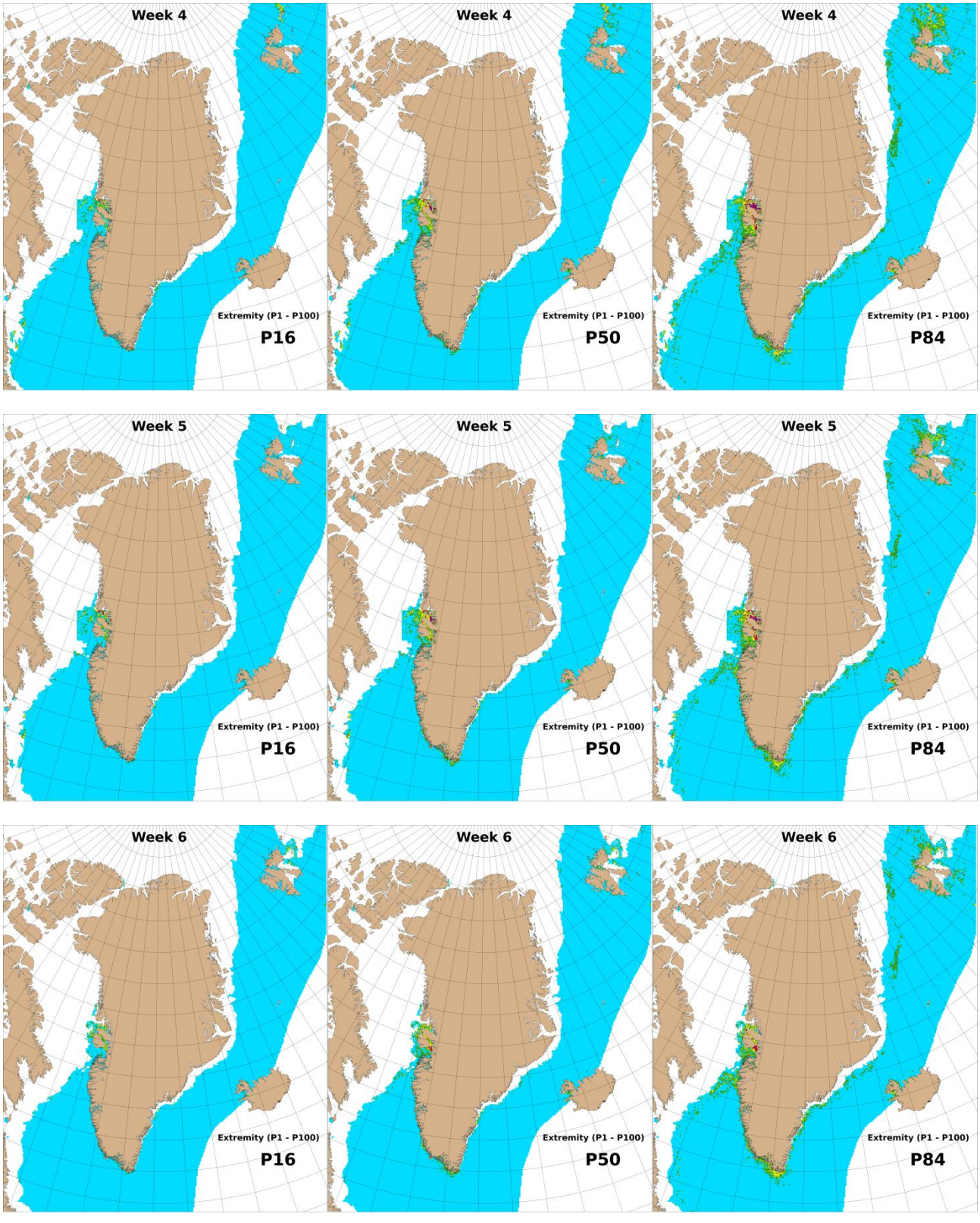
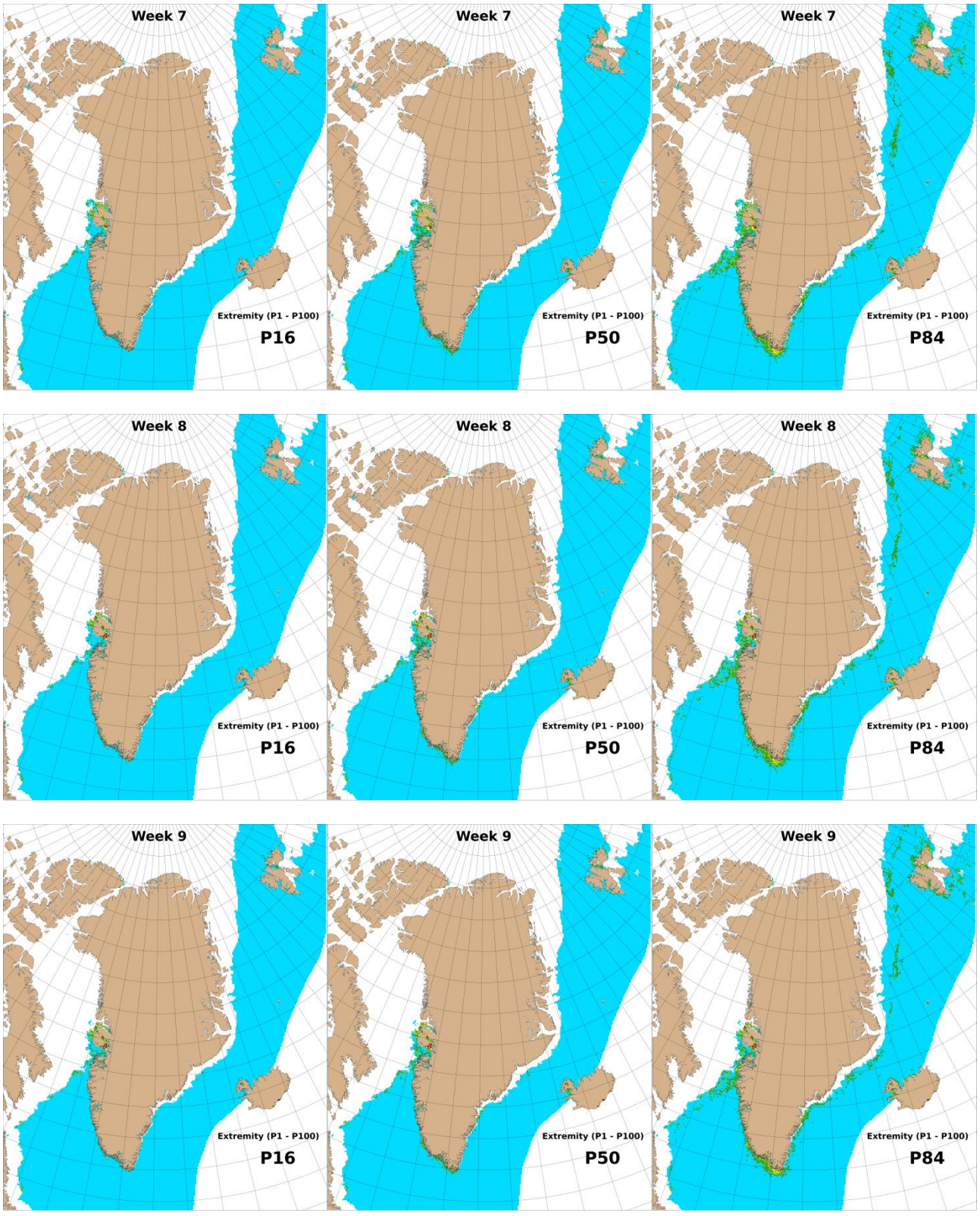
Icebergs per 10x10 km



Icebergs per 10x10 km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Week 8
Extremity (P1 - P100)
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Week 9
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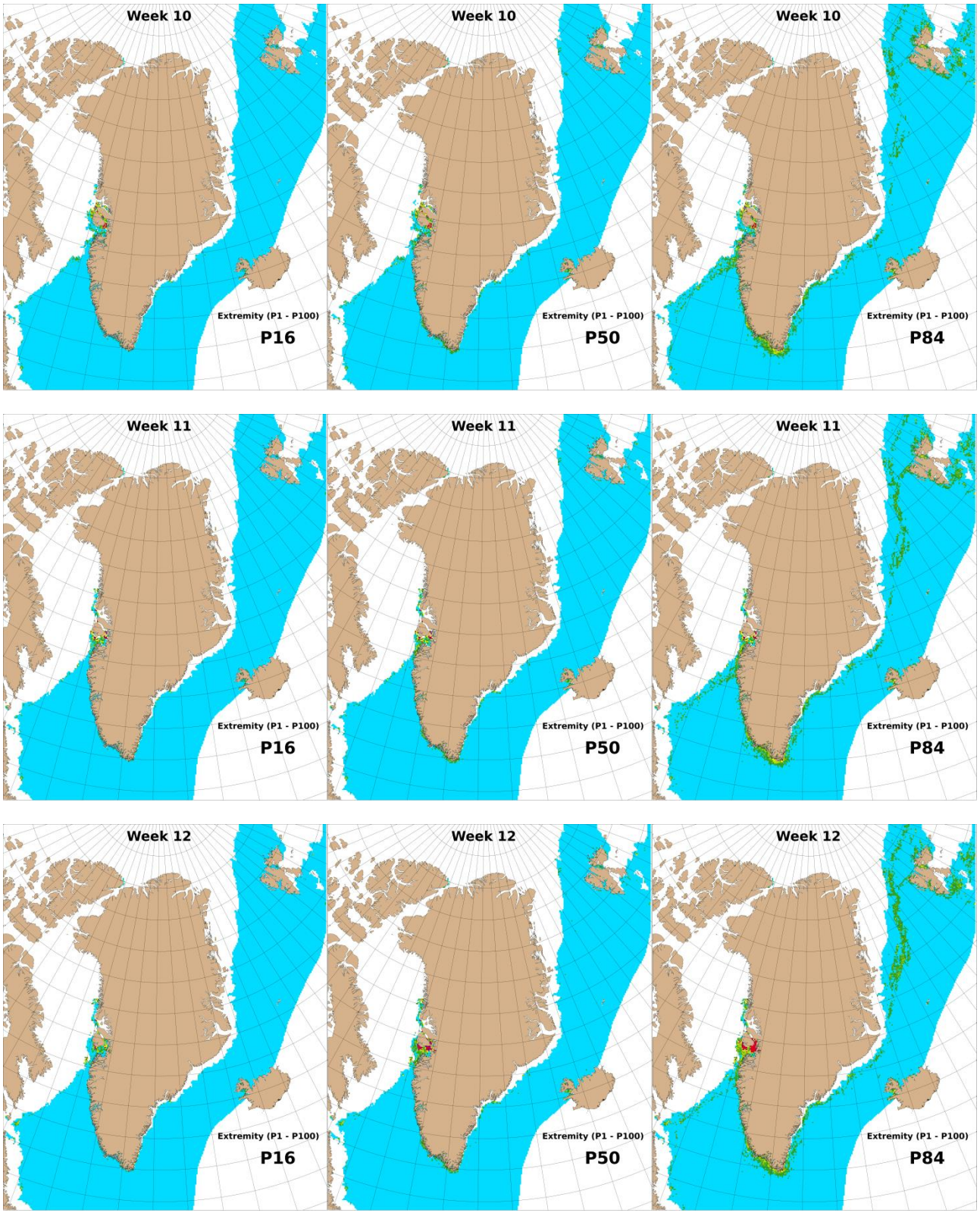
Icebergs per 10x10 km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Extremity (P1 - P100)
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Extremity (P1 - P100)
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Week 11
Extremity (P1 - P100)
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Week 12
Extremity (P1 - P100)
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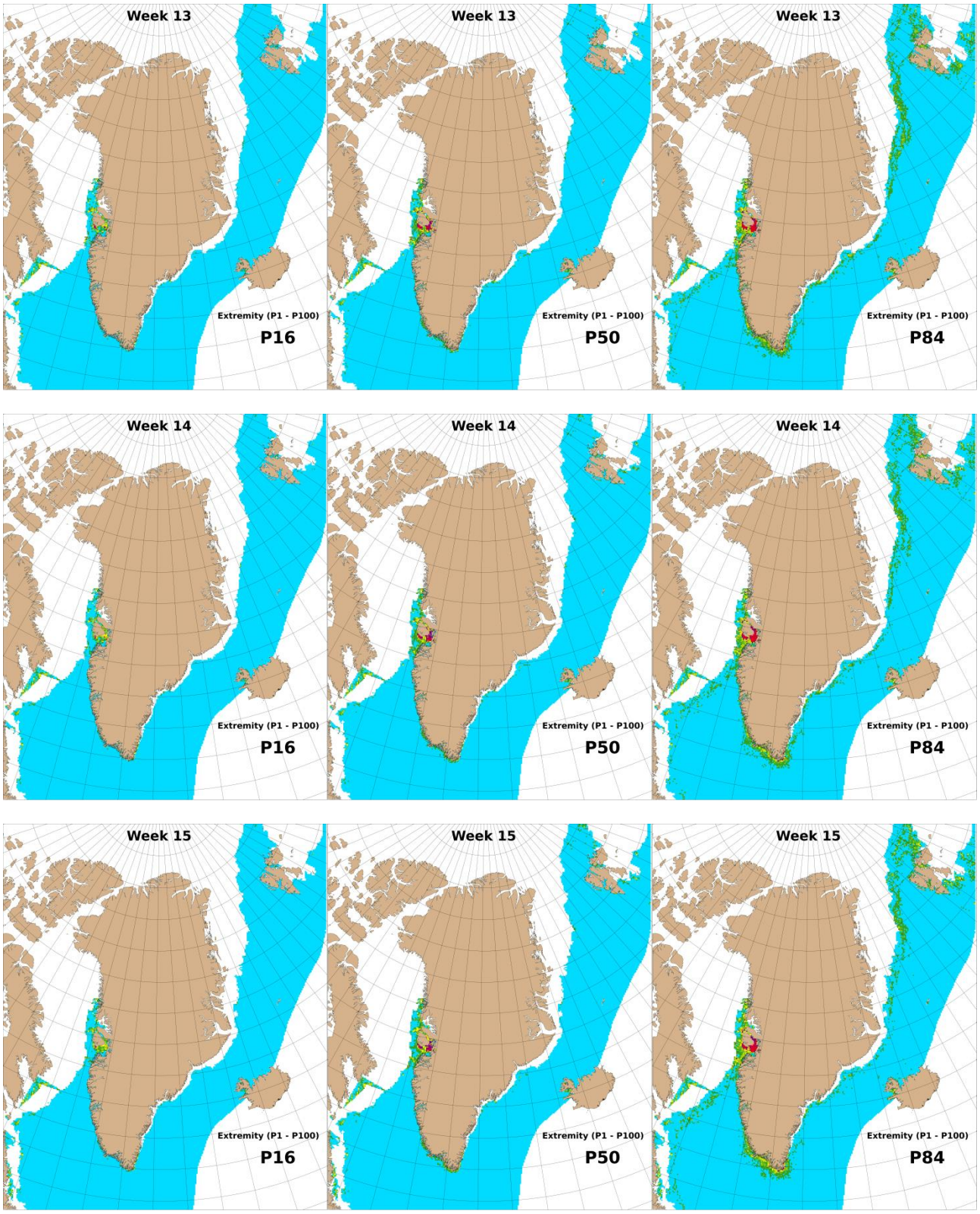
Icebergs per 10x10 km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Extremity (P1 - P100)
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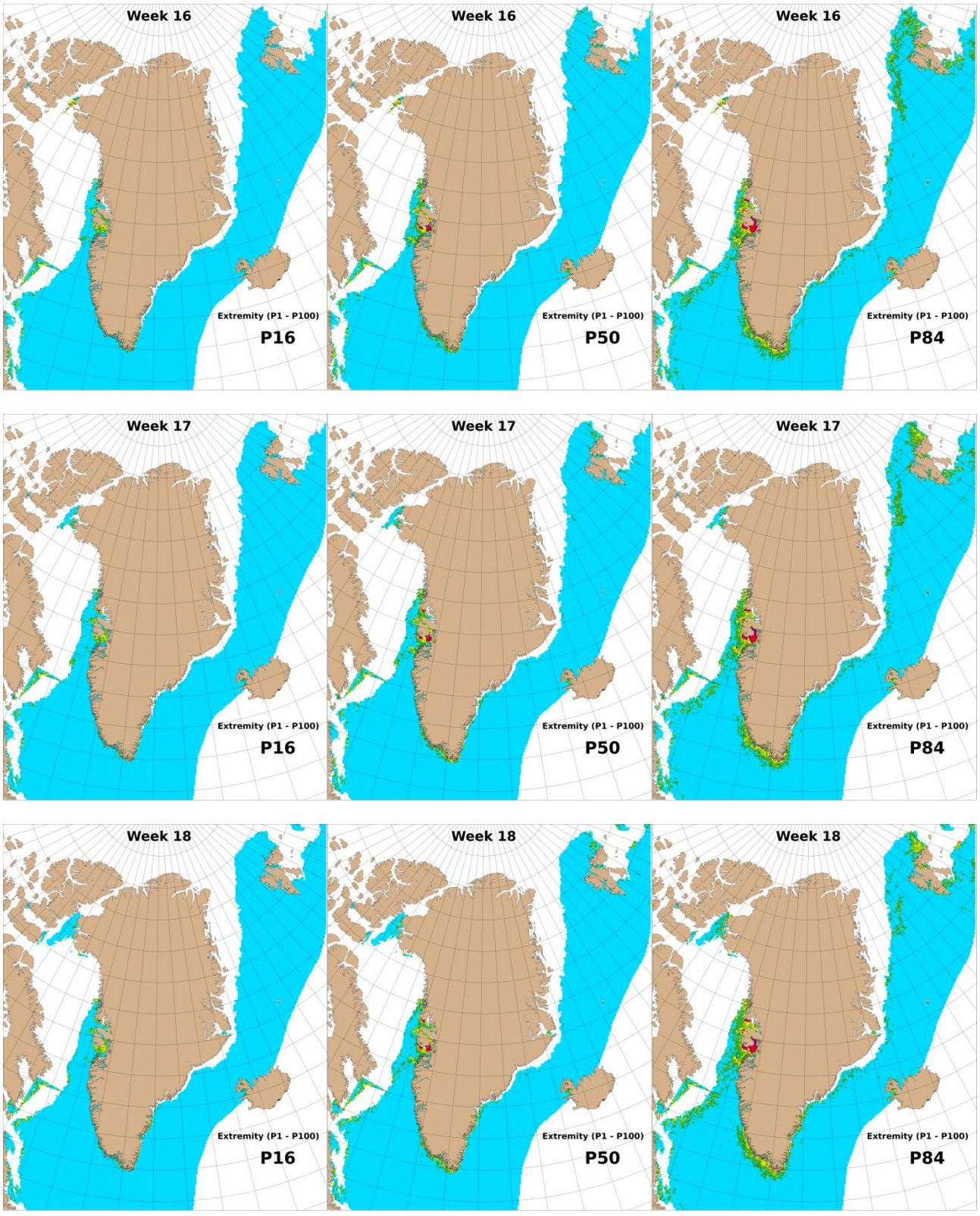
Icebergs per 10x10 km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Extremity (P1 - P100)
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Week 18
Extremity (P1 - P100)
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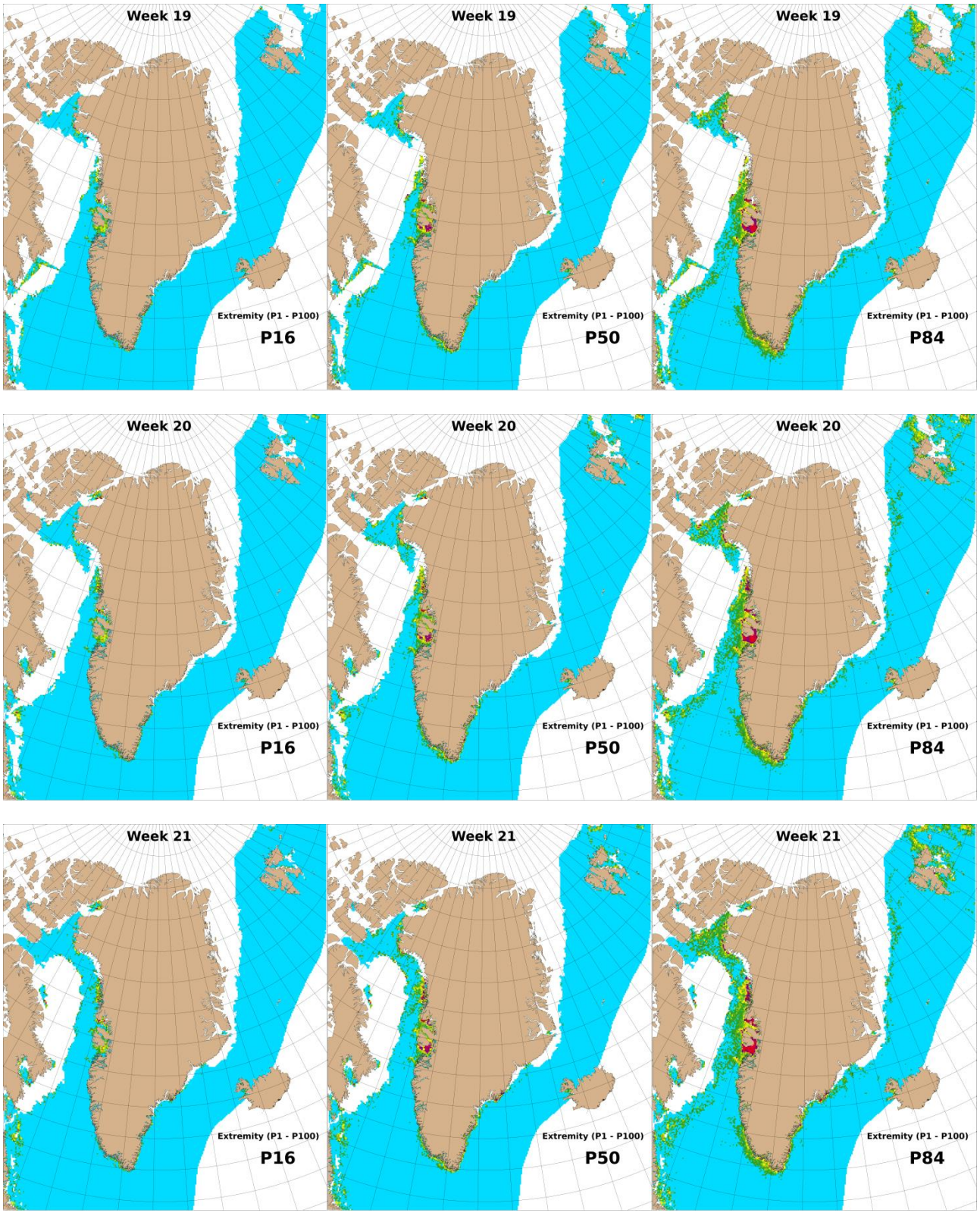
Icebergs per 10x10 km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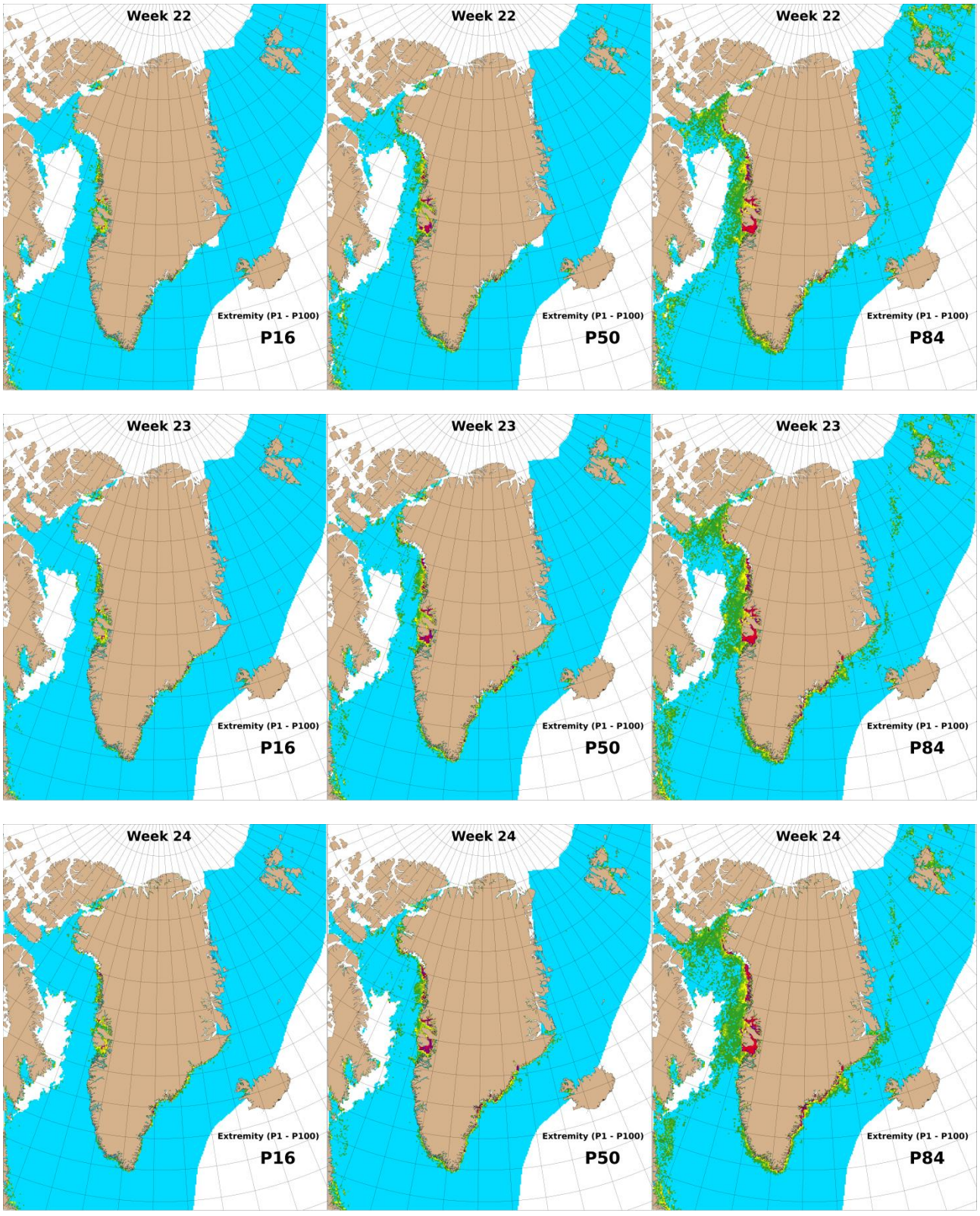
Icebergs per 10x10 km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Week 24
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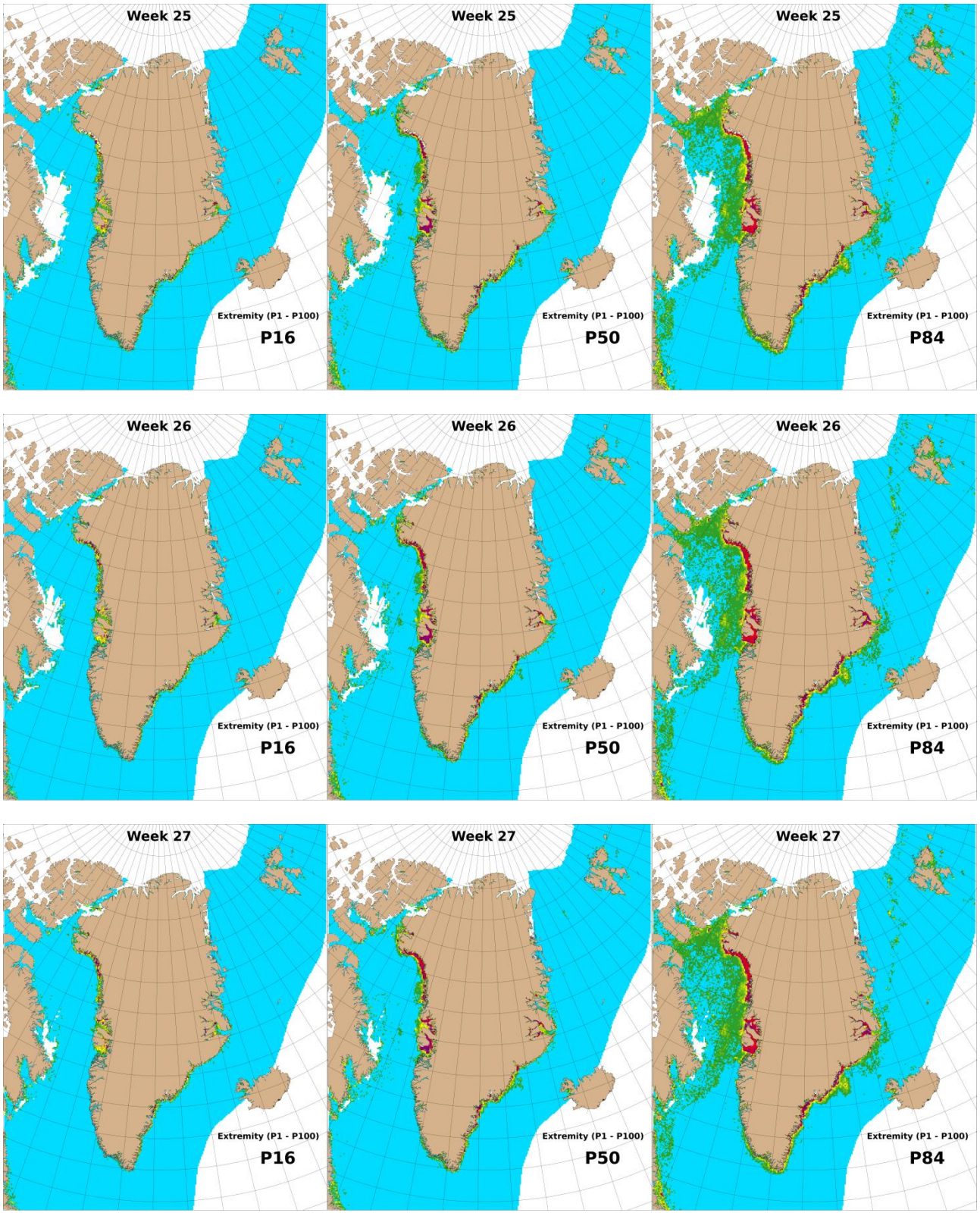
Icebergs per 10x10 km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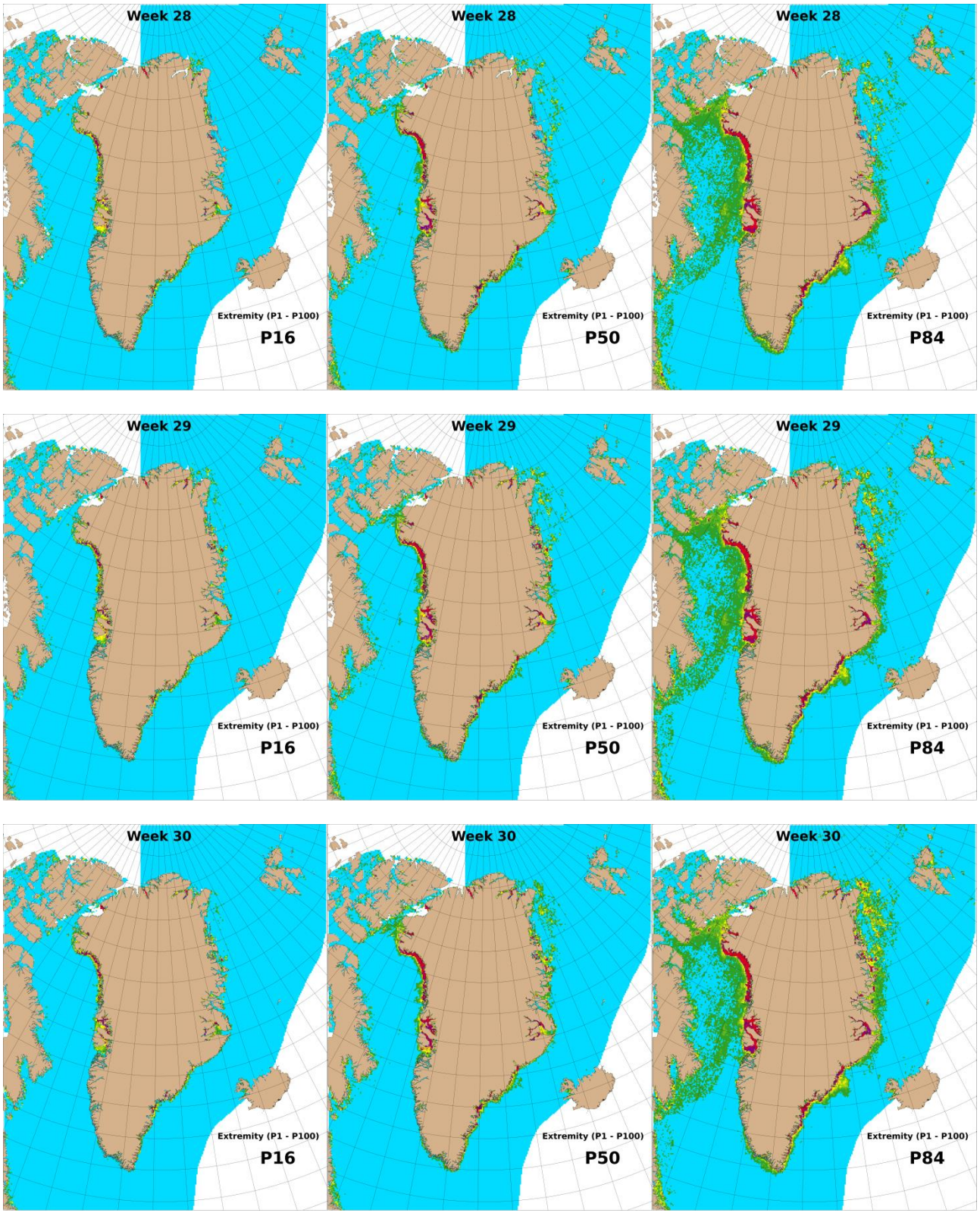
Icebergs per 10x10 km



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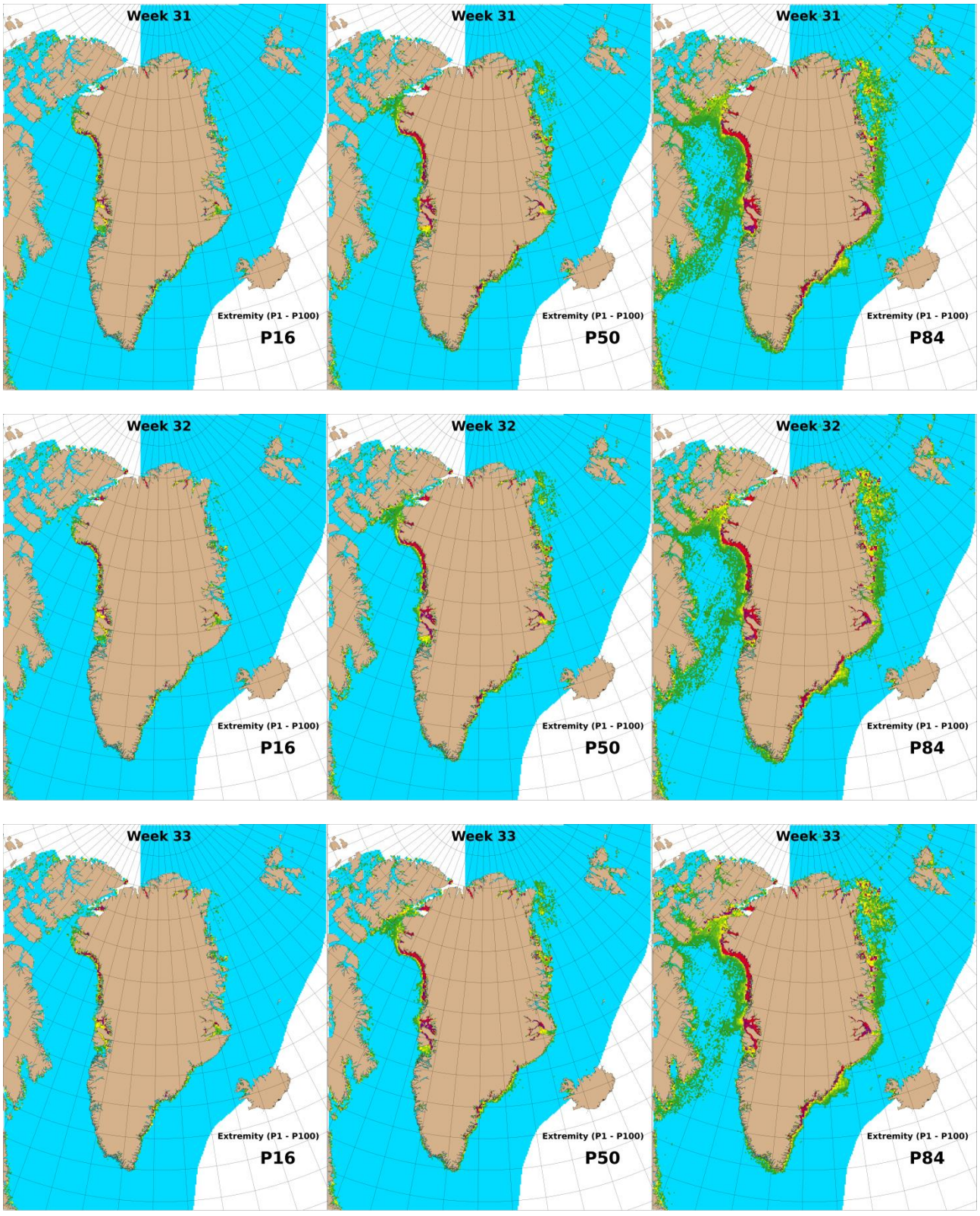
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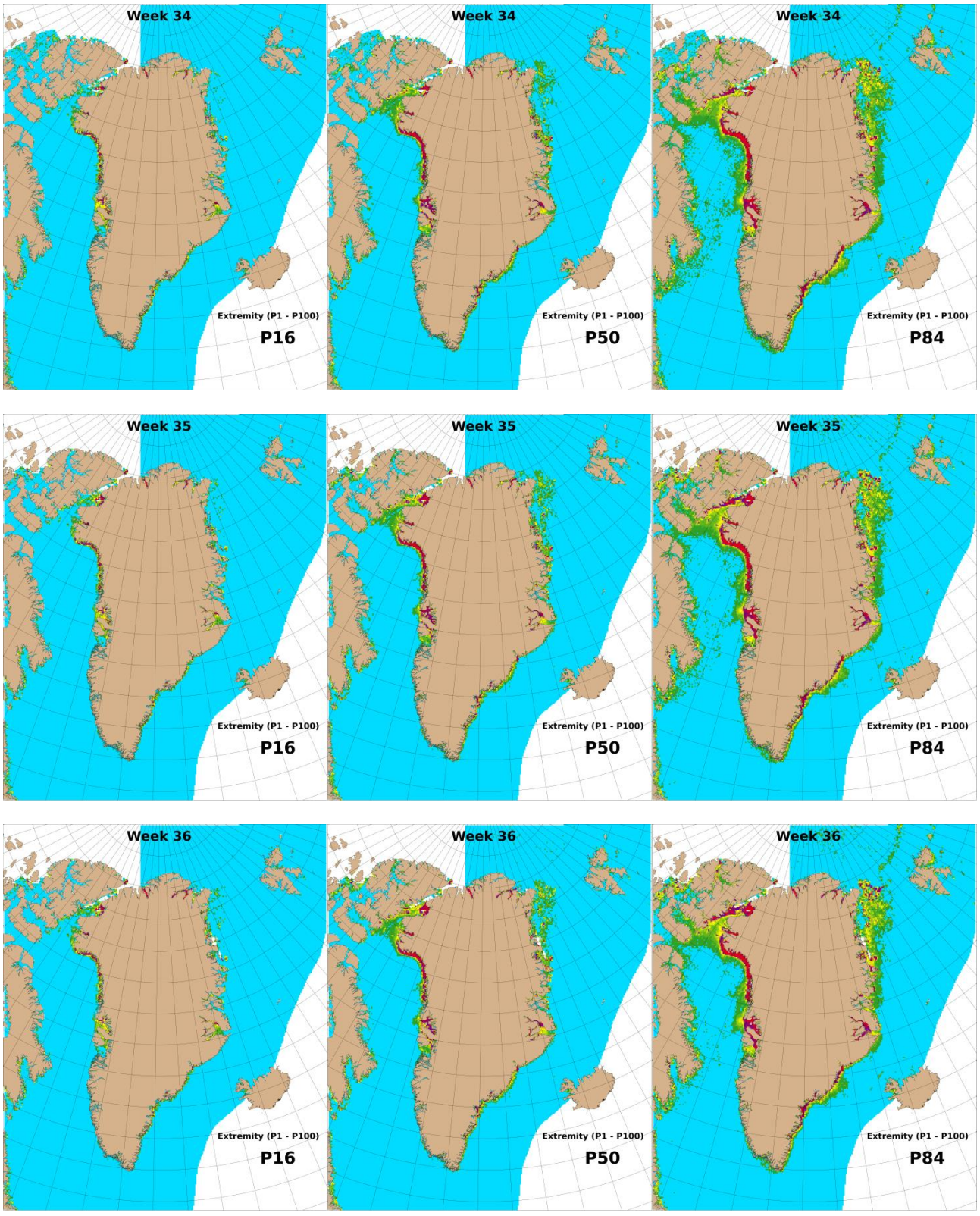
Icebergs per 10x10 km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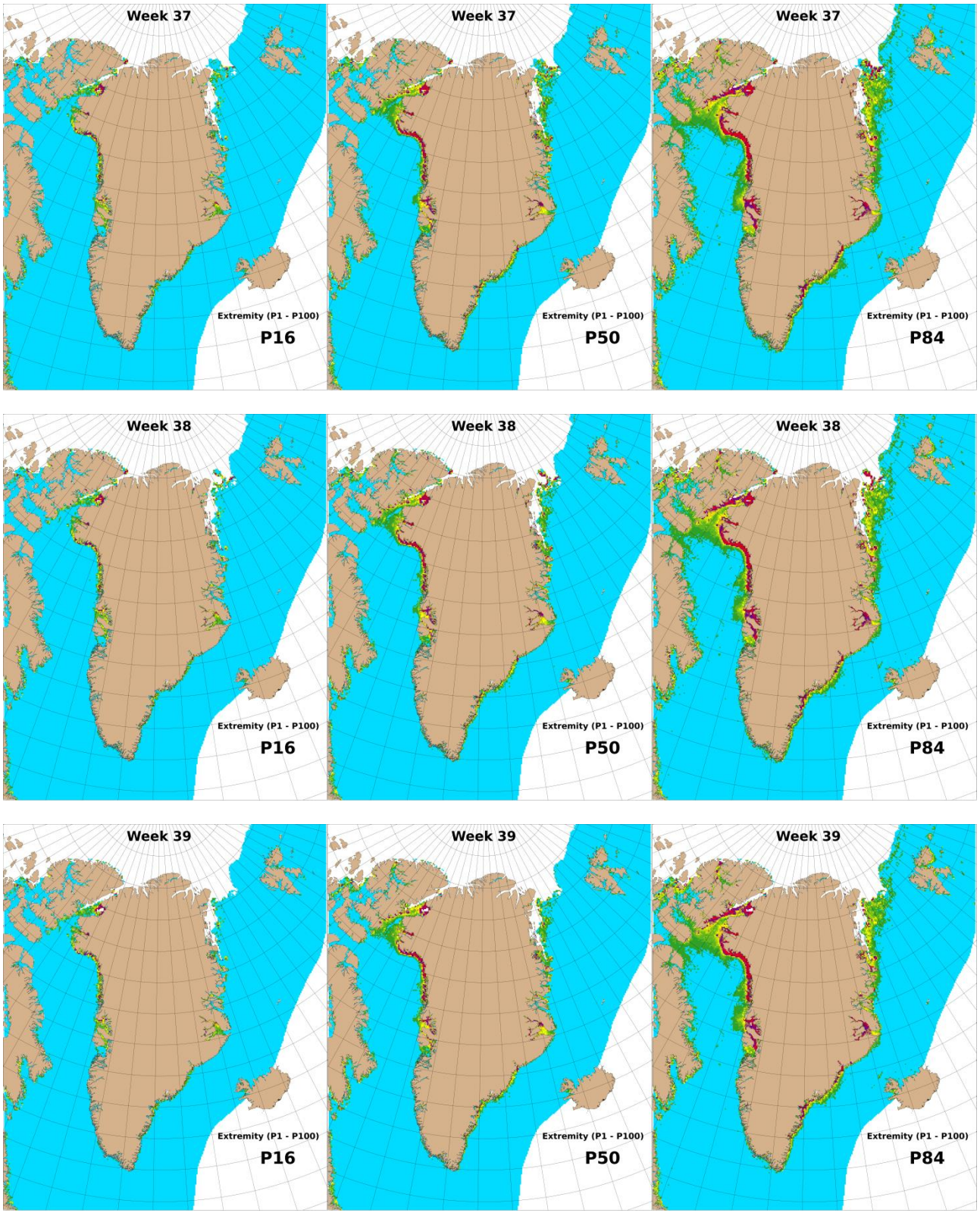
Icebergs per 10x10 km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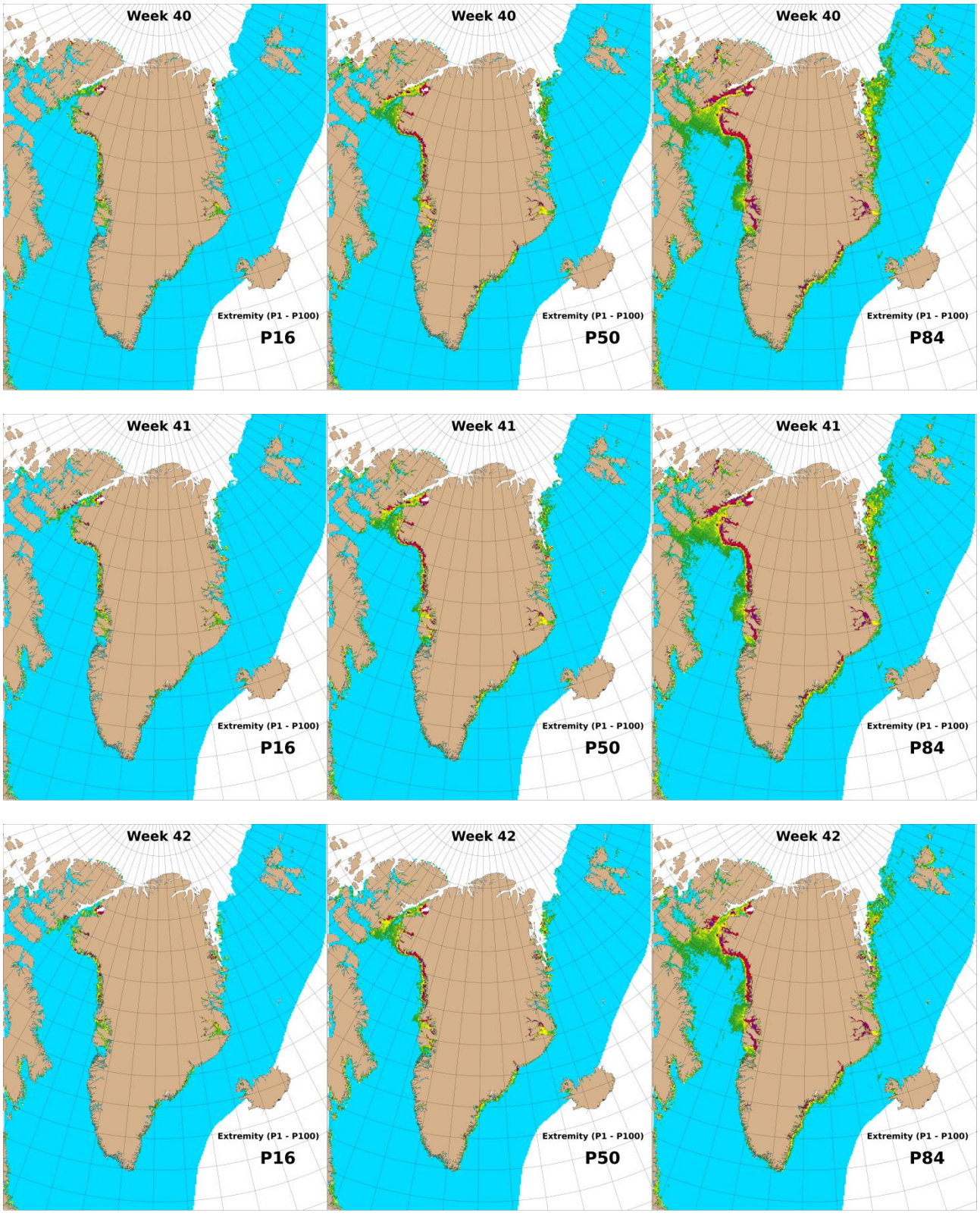
Icebergs per 10x10 km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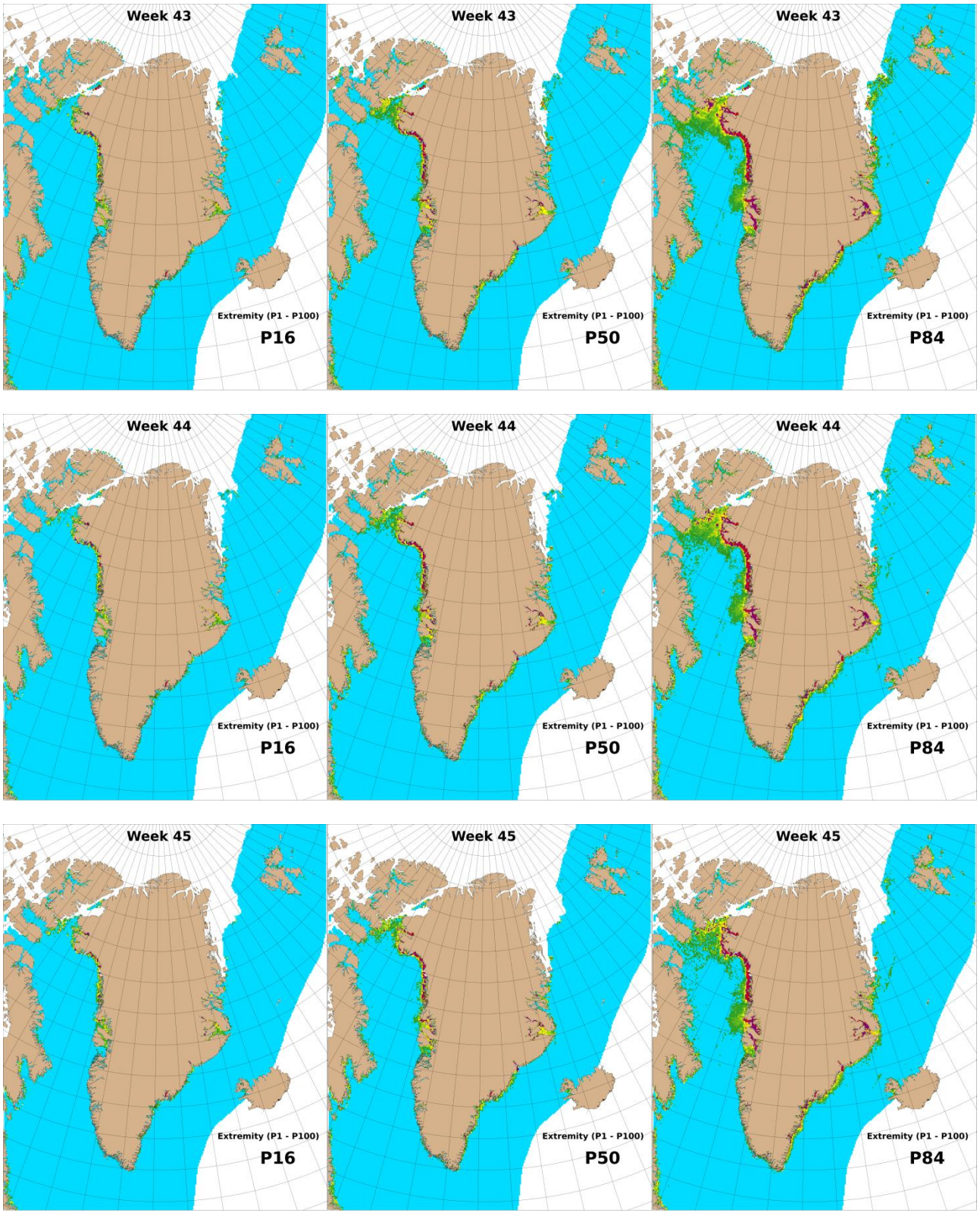
Icebergs per 10x10 km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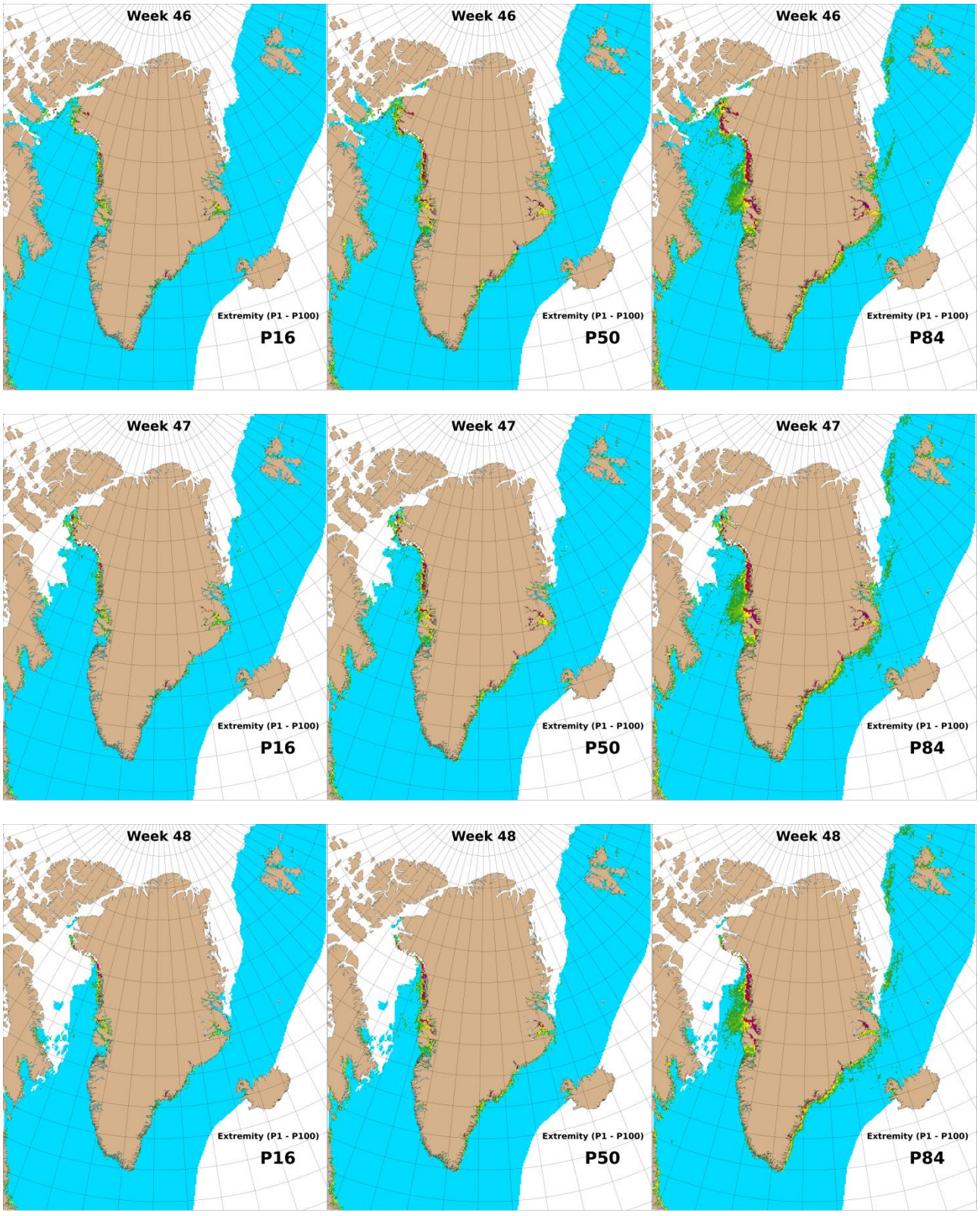
Icebergs per 10x10 km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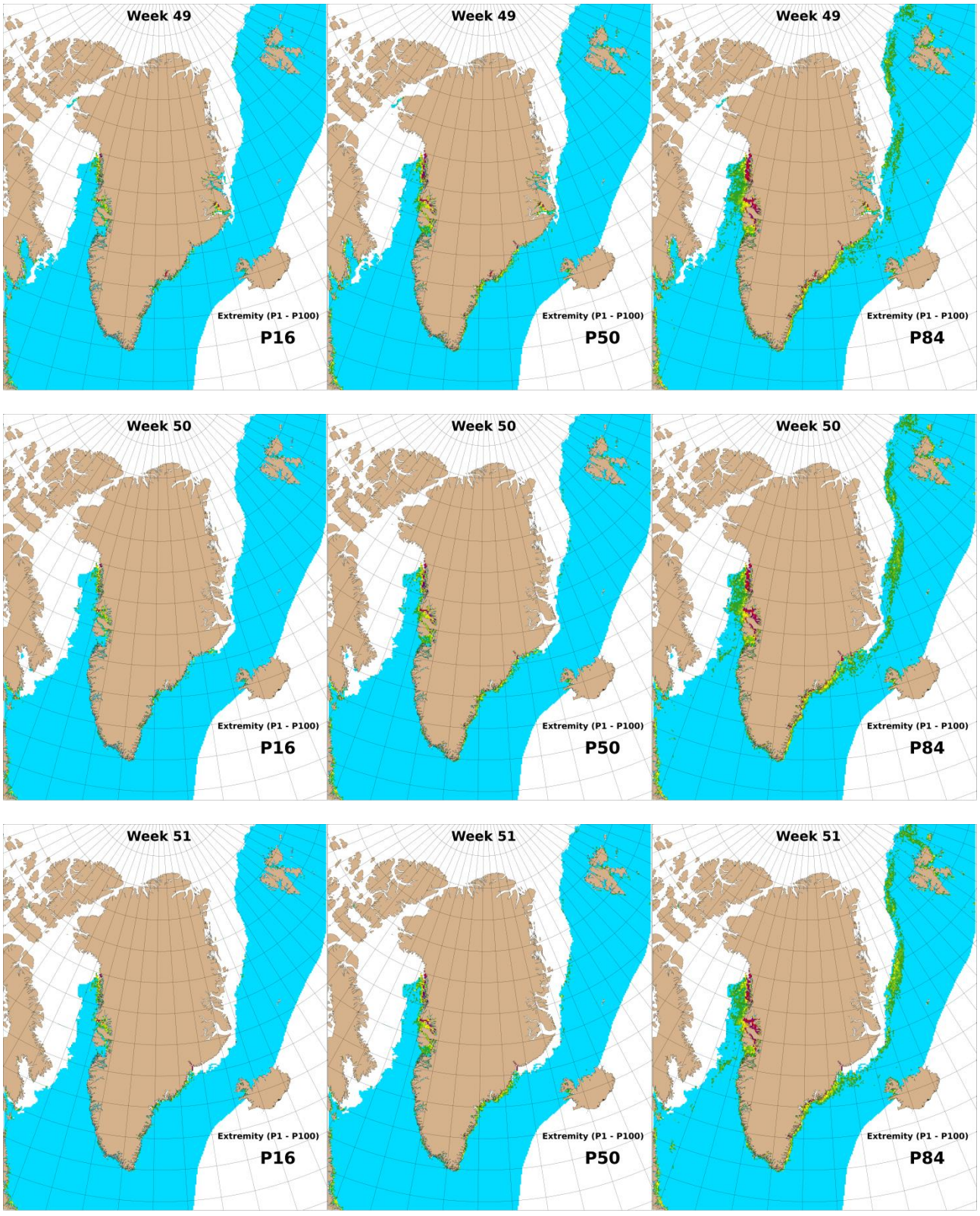
Icebergs per 10x10 km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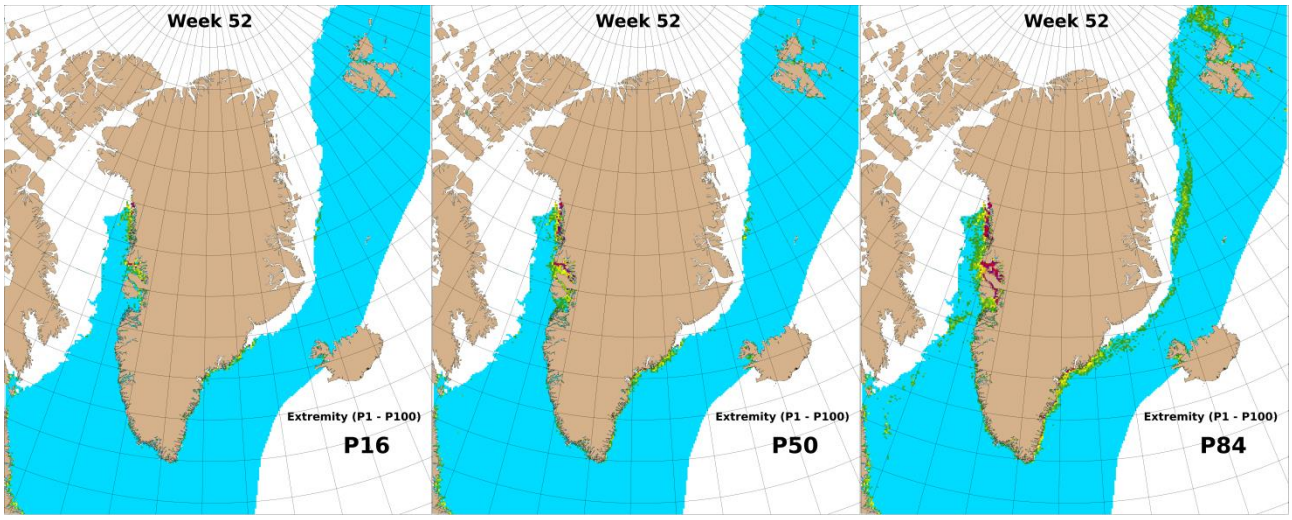
Icebergs per 10x10 km



Icebergs per 10x10 km