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Kunnskap og varsling av isutbredelse og isfjell - «Barentshavet SØ» og «Jan Mayen»

Knowledge and Forecasts of Sea Ice Extent and Icebergs - “Barents Sea SE” and “Jan Mayen”

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Abstract

Meteorologisk institutt ble i 2012 gitt i oppdrag fra Olje- og energidepartementet om å utarbeide en rapport om isforhold i norske havområder med fokus på Barentshavet sørøst og Jan Mayen. En tilleggsstudie er gjennomført i løpet av 2014-2015. Historiske trender for isutbredelse blir analysert, og resultatene fra ulike klimamodeller for de neste 20 årene blir presentert. Informasjon om flerårig havis og isfjell i de to fokusområdene er også inkludert i rapporten.

Keywords
Climate, sea ice, icebergs, klima, havis, isfjell

Disciplinary signature

Responsible signature

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Meteorologisk institutt ble i 2012 gitt i oppdrag fra Olje- og energidepartementet om å utarbeide en rapport om isforhold i norske havområder med fokus på Barentshavet sørøst og Jan Mayen. En tilleggsstudie er gjennomført i løpet av 2014-2015. Historiske trender for isutbredelse blir analysert, og resultatene fra ulike klimamodeller for de neste 20 årene blir presentert. Informasjon om flerårig havis og isfjell i de to fokusområdene er også inkludert i rapporten.

In 2012 the Ministry of Petroleum and Energy tasked the Meteorological Institute with preparing a report on ice conditions in Norwegian waters focusing on the south-east Barents Sea and Jan Mayen. An additional study was conducted during 2014-2015. Historical trends for sea ice extent are analyzed, and the results from different climate models for the next 20 years presented. Information about the perennial sea ice and icebergs in the two areas of focus are also included in the report.

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1 Innledning / Introduction

Temaet isutbredelse har fått betydelig oppmerksomhet etter åpningen av Barentshavet SØ og den etterfølgende prosessen med utlysning av blokker i området.

For å øke kunnskapen om Barentshavet er det vurdert som hensiktsmessig å innhente mer kunnskap fra Meteorologisk institutt om enkelte forhold relatert til isutbredelse, og det foreliggende arbeidet er gjennomført i 2014 og 2015.

Hovedhensiktene med rapporten er å:

- Gi en faglig vurdering av datagrunnlaget som foreligger omkring isutbredelse.
- Angi historisk utvikling og dagens situasjon for isutbredelse.
- Vurdere forekomst av ulike typer (og alder) av is, inkludert isfjell.
- Gi en vurdering av trender i isutbredelse, på kort og lengre sikt.

Ice extent in the Nordic Seas has received considerable attention after the opening of the Barents Sea SE and subsequent process of awarding of blocks in the area.

To increase the knowledge about the Barents Sea it is considered appropriate to obtain more knowledge from the Norwegian Meteorological Institute about certain matters related to its extent, and the present work has been completed in 2014 and 2015.

The main objectives of this report are to:

- Give a scientific assessment of data that exist about sea ice extent in the region.
- Provide an overview of historical changes and current situation of ice cover.
- Assess the occurrence of various types (and age) of ice, including icebergs.
- Give an assessment of the future trends in sea ice extent, in the short and longer term.

2 Datagrunnlag / Data Background

2.1 Innledning

Denne delen av rapporten omhandler tilgjengeligheten av data fra ulike kilder. Det har vært en betydelig utvikling i måten data er samlet inn over tid.

To hovedtyper av data ble brukt:

a) iskart, der tolkning av isforholdene er gjort manuelt av en trenet analytiker fra et utvalg av datakilder. Dette har den fordelen at høye (<1 km) satellittbilder kan benyttes, og sammenligningen av forskjellige datakilder reduserer sannsynligheten for feil. Ulempene ved denne type data er at den er bare tilgjengelig så lenge en analytiker er til stede, og det er potensiale for feil på grunn av menneskelig bias.

b) OSI SAF, en metode for å automatisk kunne innhente haviskonsentrasjon fra lavoppløselig (12.5 eller 25 km) passiv-mikrobølge (PMW) satellittdata. Dette har den fordel at det er rutinemessig tilgjengelig, og eventuelle feil er konsistente. Denne typen satellittdata har et svakhet ved observasjon av sjøis i løpet av sommerens smelteperioder, nær iskanten, hvor iskonsentrasjonen typisk vil bli underestimert. Om sommeren kan feilmarginen bli opptil 15%.

Introduction

This section deals with the availability of data from various acquisition sources. There has been significant development in the way data has been collected over time.

Two main types of data were used:

a) Ice charts, where the ice conditions are interpreted manually by a trained analyst from a variety of data sources. This has the advantage that high (< 1km) resolution satellite images can be used, and the comparison of different data sources reduces the likelihood of error. The disadvantages of this type of data is that it is only available when there are analyst time to work on it, and there is potential for error due to human bias.

b) OSI SAF, a method of automatically deriving sea ice concentration from low (12.5 or 25 km) resolution passive microwave (PMW) satellite data. This has the advantage that it is available routinely and errors are consistent. This type of satellite data has an issue with sea ice observations during the summer melt period, and at the ice edge, typically underestimating the concentration of ice present. In summer this level of error can be up to 15%.

2.2 Iskart

Iskart har blitt rutinemessig produsert ved MET av den norske Istjenesten (NIS) siden vinteren 1969-1970. Før den tid ble det produsert på sporadisk basis fra 1933 og framover, med en pause på grunn av andre verdenskrig frem til 1963. Denne produksjonen fant sted på Isfjord Radio-stasjon på Svalbard. Tilgjengelig-gjøringen av optisk infrarøde (IR) satellittbilder har tillatt et større dekningsområde, men iskartene i de tidligste årene var fortsatt i stor grad supplert med observasjoner fra skip og fly.

Iskartdata benyttet i denne rapporten kan betraktes som data fra tre perioder hvor det foreligger data av ulik kvalitet. Disse er:

1) Fra januar 1967 til juni 1997

Iskart ble nedtegnet på papir på ukentlig basis, i utgangspunktet på bakgrunn av observasjoner fra skip og fly. Fra vinteren 1969/70 ble bilder fra IR-satellitter tilgjengelig. NIS var på den tiden plassett på METs hovedkontor i Oslo.

2) Fra juli 1997 til sommeren 2007

Iskart ble tegnet elektronisk ved hjelp av geografiske informasjonssystemer (GIS). GIS-programvaren var ESRI ArcView, og ble brukt fram til slutten av juni 2014. NIS ble flyttet til METs Tromsøkontor (Vervarslinga for nord-norge) og prduksjonen av iskart ble økt fra ukentlig til hver ukedag (unntatt offentlige helligdager). I løpet av denne tiden ble enkelte passiv-mikrobølge satellittdata (PMW) tilgjengelig. Disse ble tatt i bruk for å kartlegge haviskonsentrasjonen (SIC) da dette ga en fullstendig dekning av den Europeisk-Arktiske sektor i all slags vær, riktignok ved lav (25 kilometer) oppløsning.

Ice Charts

Ice charts have been produced routinely at MET by the Norwegian Ice Service (NIS) since the winter of 1969/70. Prior to that they were produced on a sporadic basis from 1933 onward, with a break due to the Second World War through to 1963, at the Isfjord Radio Station on Svalbard. The advent of optical infared (IR) satellite imagery allowed a wider area to be covered, but ice charts in the early years were still largely supplemented by observations from ships and aircraft.

The ice chart data used in this report can be regarded as three periods of differing quality. These are:

1) January 1967 to June 1997

Ice charts were drawn on paper on a weekly basis, initially using only ship and aircraft observations. From the winter of 1969/70 images from IR satellites became available. The NIS was based at the MET headquarters in Oslo.

2) July 1997 to summer 2007

Ice charts were drawn electronically using geographical information system (GIS) software. The GIS software was ESRI ArcView, and was used until the end of June 2014. The NIS was moved to the MET Tromsø office (Forecasting Division for Northern Norway) and the production frequency of ice charts increased from weekly to every weekday (excluding public holidays). During this time some passive microwave (PMW) satellite data, used to derive sea ice concentration (SIC), started to be used as this provided complete, all-weather coverage of the European Arctic sector, albeit at low (25 kilometre) resolution.

3) Sommeren 2007 til i dag

Ytterligere satellittdata fra satellitter utstyrt med syntetisk apertur radar (SAR) sensorer begynte å bli tatt i brukt. I første omgang var dette fra den kanadiske Radarsat-1-satellitten, men fra desember 2008 og oktober 2014 har hhv Radarsat-2 og europeiske Sentinel-1A blitt tatt i brukt. SAR er en aktiv mikrobølgesensor og produserer bilder på et 400-500 kilometer stort område, med en oppløsning på 100 meter eller mindre. Med de nyere typer SAR-satellitt, blir den utsendte radarenergien også mottatt tilbake av satellitten med horisontal eller vertikal polarisasjon. Med en horisontal faset overføring, vil en vertikal polarisasjon gi en vesentlig forbedret adskillelse av is og vann.

Iskartene viser seks iskonsentrasjon/ istyper (figur 2.1), og er lagret i et vektor format (ESRI Shapefile) som polygoner. For denne analysen, ble iskonsentrasjonsbilder med verdier tilsvarende de oppgitte iskartklassene (tabell 2.1) lagt på ved hjelp av en Lambert Azimuthal Equal Area (LAEA) kartprojeksjon (Proj4 string: +proj=laea +lat_0=73n +lon_0=0E + x_0=0 +y_0=0 +ellps=WGS84 +datum= WGS84) med reell skala på 73°N og en oppløsning av rutenettet på 1 kilometer. Denne informasjonen ble så brukt til å utlede kart med gjennomsnittlig, minimums- og maksimums isutbredelse med hhv 10, 40 og 70% iskonsentrasjon for periodene beskrevet i kapittel 3.

2.3 OSI SAF

Kart over Haviskonsentrasjon (SIC) i Arktis og Antarktis genereres automatisk av EUMETSAT Ocean and Sea Ice Satellite Application Facility (OSI SAF) High Latitude (HL) Processing Centre ved MET i Oslo. Satellittdata av lav oppløsning (25 kilometer) brukes som input, og dataene dekker perioden oktober 1978 fram til i dag.

3) Summer 2007 to present

Additional satellite data from satellites carrying synthetic aperture radar (SAR) sensors started to be used. Initially this was the Canadian RADARSAT-1 satellite, but from December 2008 and October 2014 the RADARSAT-2 and European Sentinel-1A satellites have been used. SAR is an active microwave sensor and produces images on a 400-500 kilometre wide swath at 100 metres or better resolution. With the new types of SAR satellite, the transmitted radar energy is also received back at the satellite as horizontally or vertically polarized. With a horizontally phased transmission, a vertical polarisation received image provides significantly improved ice and water discrimination.

The ice charts show six ice concentration/type classes (Figure 2.1), and are stored in a vector format (ESRI Shapefile) as polygons. For this analysis, ice concentration images with values corresponding to the ice chart classes (Table 2.1) were constructed using a Lambert Azimuthal Equal Area (LAEA) map projection (Proj4 string: +proj=laea +lat_0=73n +lon_0=0e +x_0=0 +y_0=0 +ellps=WGS84 +datum=WGS84) with true scale at 73°N and grid resolution of 1 kilometre. This data was then used to derive average, minimum and maximum extent maps at 10, 40 and 70% ice concentration for the periods described in Section 3.

OSI SAF

Sea ice concentration (SIC) maps for the Arctic and Antarctic are generated automatically by the EUMETSAT Ocean and Sea Ice Satellite Application Facility (OSI SAF) High Latitude (HL) Processing Centre at MET Norway in Oslo. Low resolution (25 kilometre) satellite data is used as input, and the data covers the period October 1978 to present.

SIC-verdier er utledet ved hjelp av en kombinasjon av to algoritmer; Bootstrap frekvensmodus algoritme (Comiso, 1986) for åpent vann og ved lave iskonsentrasjoner, og Bristol algoritme (Smith og Barrett, 1994) for is med høyere konsentrasjon.

SIC-data fra OSI SAF kan variere i kvalitet i forhold til hvilken periode som er dekket, først og fremst på grunn av hvilke satellittsensorer som var tilgjengelige. I de tilfeller hvor flere sensorer var tilgjengelig, ble ulike SIC-anslag kombinert vha en bayesiansk tilnærming for å gi en optimal SIC-verdi. De viktigste periodene med forskjellig sensordrift er:

1) Oktober 1987 til juli 1987

Informasjonen er basert utelukkende på Scanning Multichannel Microwave Radiometer (SMMR) sensoren.

2) Fra juli 1987 til oktober 2009

Dataene er basert på Special Sensor Microwave Imager (SSM / I), noen ganger fra flere satellitter.

3) Oktober 2009 til i dag

Dataene er basert på SIC fra både SSM/I og Special Sensor Microwave Imager Sounder (SSMIS) PMW radiometer sensorer.

OSI SAF produkter bruker en konservativ landmaske på minst 25 kilometer langs kysten. For å kunne sammenligne verdier for isutbredelse fra OSI SAF med

Table 2.1: Norwegian Ice Service ice concentration classes.

Ice Concentration Class	Range 10ths	Median Value %
Open Water	0 - 1	5
Very Open Drift Ice	1 - 4	25
Open Drift Ice	4 - 7	55
Close Drift Ice	7 - 9	80
Very Close Drift Ice	9 - 10	95
Fast Ice	10	100

SIC values are derived using a combination of two algorithms; the Bootstrap frequency mode algorithm (Comiso, 1986) for open water and low ice concentrations, and the Bristol algorithm (Smith and Barrett, 1994) for higher ice concentrations.

SIC data from OSI SAF can be vary in quality according to the period covered, primarily due to the satellite sensors available. Where multiple satellite sensors were available, SIC estimates were combined using a Bayesian approach to yield an optimal SIC value. The main periods of different satellite sensor operation are:

1) October 1987 to July 1987

Data is based solely on the Scanning Multichannel Microwave Radiometer (SMMR) sensor.

2) July 1987 to October 2009

Data is based on Special Sensor Microwave Imager (SSM/I), sometimes from multiple satellites.

3) October 2009 to present

Data is based on SIC from both SSM/I and Special Sensor Microwave Imager Sounder (SSMIS) PMW radiometer sensors.

OSI SAF products use a conservative land mask of at least 25 kilometres around coastline. Therefore to be able to compare OSI SAF sea ice extent values with those verdiene fra iskartene, må denne masken også være implementert i iskartene. For de to områdene av interesse, vil dette forholdet bare påvirke området rundt øya Jan Mayen.

Rådata fra OSI SAF kommer i en Polar Stereo-kartprojeksjon, som har blitt rotert 45 ° W og har en reell skala ved 70 ° N (figur 2.2). Dataene har derfor blitt reprojisert til Lambert Azimuthal Equal Area (LAEA) kartprojeksjon (Proj4 string: +proj=laea +lat_0=73n +lon_0=0E +x_0=0 +y_0=0 +ellps=WGS84 +datum=WGS84) med reell skala på 73°N og en oppløsning av rutenettet på 1 kilometer, noe som som også benyttes i iskartene. Denne informasjonen ble så brukt til å utlede gjennomsnittlig, minimums- og maksimums utbredelse for hhv 10, 40 og 70% iskonsentrasjon for periodene beskrevet i kapittel 3.

from ice charts, the ice charts must also have this mask applied. For the two areas of interest, the land mask issue only affects the area around Jan Mayen island.

Raw data from OSI SAF comes in a Polar Stereographic map projection, which has been rotated to 45°W and has a true scale at 70°N (Figure 2.2). Data was therefore reprojected to the Lambert Azimuthal Equal Area (LAEA) map projection (Proj4 string: +proj=laea +lat_0=73n +lon_0=0e +x_0=0 +y_0=0 +ellps=WGS84 +datum=WGS84) with true scale at 73°N and grid resolution of 1 kilometre as also used with the ice charts. This data was then used to derive average, minimum and maximum extent maps at 10, 40 and 70% ice concentration for the periods described in Section 3.

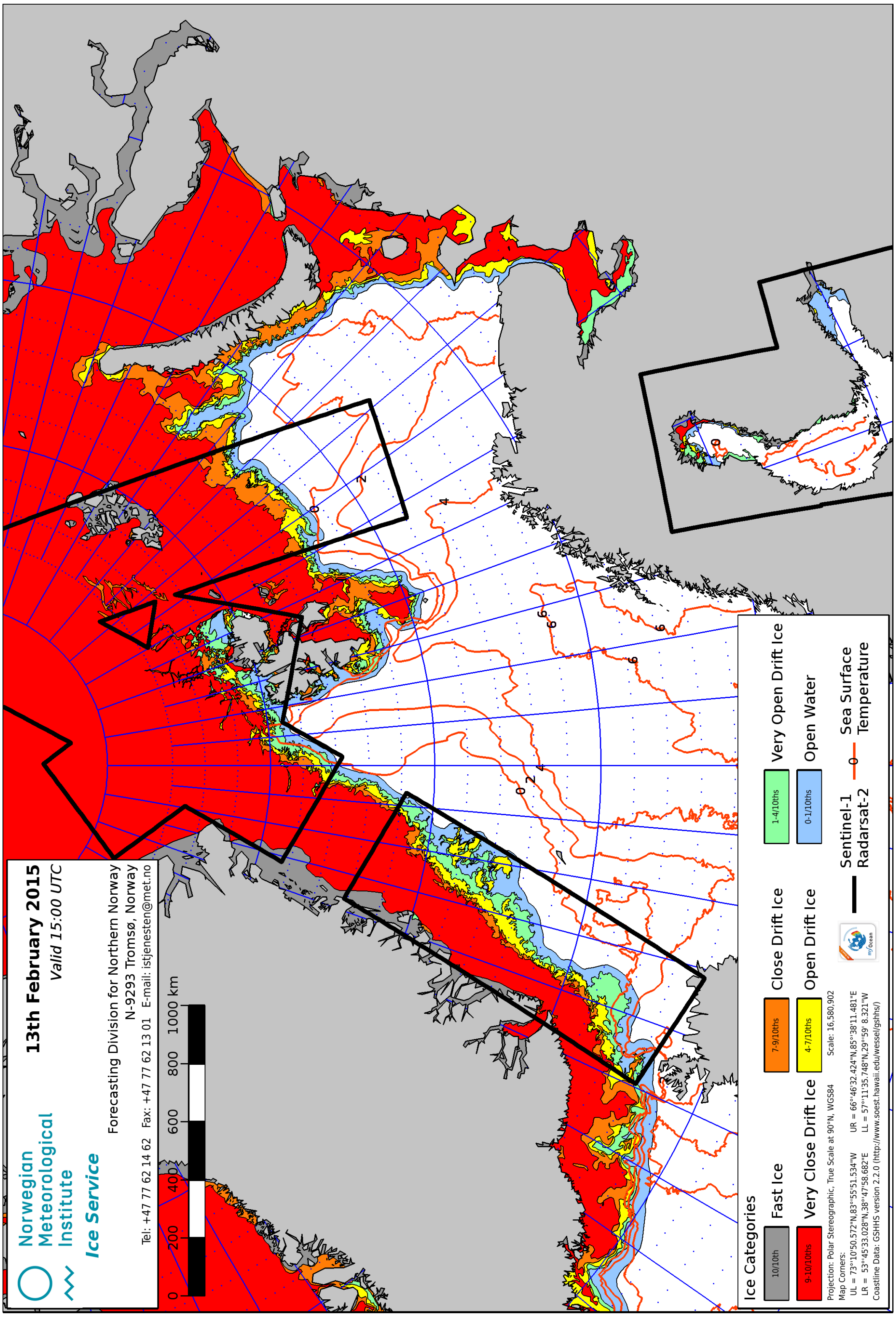


Figure 2.1: Example of typical Norwegian Ice Service ice chart showing concentration classes.

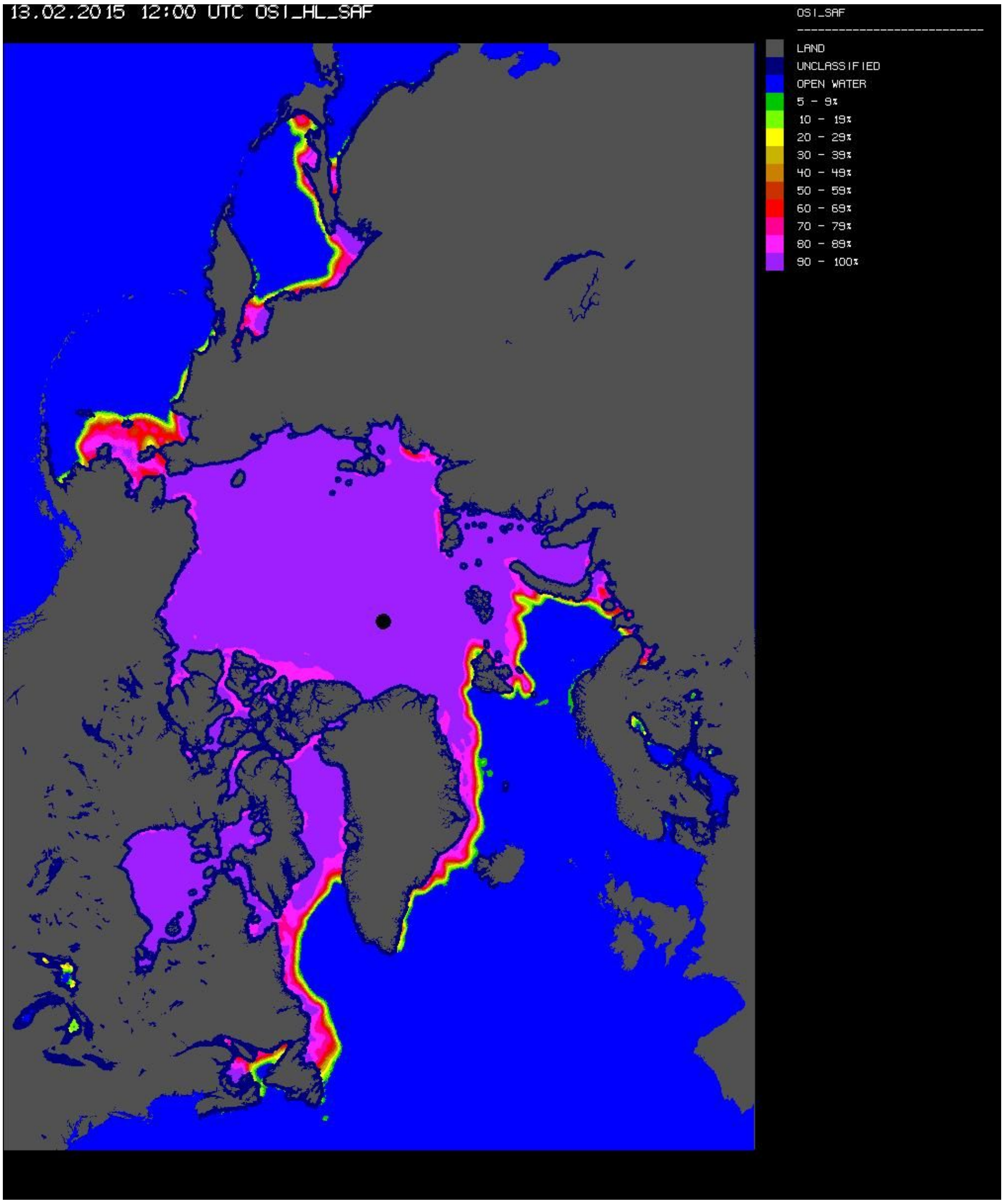


Figure 2.2: Example of OSI SAF sea ice concentration product for the Arctic.

3 Historisk Isutbredelse / Historical Ice Extent

3.1 Innledning

Som tidligere nevnt har utbredelse av havis blitt analysert for de to geografiske områdene Jan Mayen og det sørøstlige Barentshavet. Det er utarbeidet kart som viser månedlig havisminimum, -maksimum, og gjennomsnittlig utbredelsesgrad for disse områdene, som en del av et fullstendig datasett for de nordiske hav.

3.2 Analyserte perioder

Isutbredelse for hver enkelt måned i fem ulike perioder har blitt avledet ut fra iskart og OSI SAF SIC-data. Periodene ble valgt for å gi en god oversikt over forholdene i løpet av de siste 10 årene. I tillegg bidra til klimamodelllering (§ 5), beregning av siste 30-års klimatologiske gjennomsnitt, og som et komplett datasett. Periodene var:

1) 2004-09 (5 år)

Forrige 5-års periode.

2) 2010-14 (5 år)

Siste 5-årene.

3) 2004-14 (10 år)

Siste tiåret, kombinasjon av 1) og 2).

4) 1981-2010 (30 år)

Klimatologisk gjennomsnittlig periode.

5) 1967-2014 og 1978-2014

Komplett datasett for hhv iskart og OSI SAF data.

De gjennomsnittlige , minimums- og maksimums is grad er kartlagt ved hjelp av farge i figur 3.1.

Introduction

Sea ice extents were analysed for the two geographical areas, Jan Mayen and south-east Barents Sea, covered in the opening process. Maps are provided that show the monthly sea ice minimum, average and maximum extents for these areas in the context of the whole Nordic Seas area.

Analysis Periods

Ice extents for each month in five periods were derived from ice chart and OSIS AF SIC data. The periods were chosen to provide a good overview of conditions over the past 10 years, and leading into the climate model forecasts (Section 5), the last 30-year climatological average period, and the whole dataset. The periods were:

1)2004-09 (5 years)

Previous 5 year period.

2) 2010-14 (5 years)

Latest 5 year period.

3) 2004-14 (10 years)

Past decade, combination of 1) and 2).

4) 1981-2010 (30 years)

Climatological average period.

5) 1967 to 2014 and 1978 to 2014

Complete ice chart and OSI SAF datasets respectively.

The average, minimum and maximum ice extents are mapped using the colour in Figure 3.1.

3.3 Analyse etter måned

3.3.1 Januar

(Figur 3.2, 3.14 and 3.26)

Mens isdekket til tider har vært omfattende i «Barentshavet SØ» i perioden før 2004, hvor den nordlige halvdelen av området har vært dekket av is, har ikke konsentrasjonsnivået oversteget 10% i løpet av januar i noen periode de siste 10 årene.

I «Jan Mayen» området var delen av Grønlandshavet nord for øya Jan Mayen preget av en vinterlig tilvekst av ny is, noen ganger øst for 0°E meridianen, kjent som «Odden». Dette ble først beskrevet av Nansen (1906), men har i liten grad vært sett siden våren 1997 (Shuchman et al., 1998, Comiso et al., 2001). Iskonsentrasjonen i dette området var vanligvis mellom 10-40%.

3.3.2 Februar

(Figur 3.3, 3.15 og 3.27)

Isutbredelsen i de nordiske hav i løpet av februar er normalt fortsatt økende.

Som for januar, har området «Barentshavet SØ» vært upåvirket av havis i konsentrasjoner tettere enn 10% i løpet av de siste 10 årene.

Analysis By Month

January

(Figures 3.2, 3.14 and 3.26)

Whilst sea ice cover has on occasion been extensive in the “Barents Sea SE” during the period before 2004, with the northern half of the area being covered, it has not entered the area in concentrations of 10% or greater during January at any time over the past 10 years.

In the “Jan Mayen” area the region of the Greenland Sea north of Jan Mayen island was characterised by a winter protrusion of new ice sometimes out east of the 0°E meridian known as the “Odden” ice tongue. This was first reported by Nansen (1906) but has not been seen to any great extent since spring 1997 (Shuchman et al., 1998, Comiso et al., 2001). Ice concentrations in this area were typically between 10 – 40%.

February

(Figures 3.3, 3.15 and 3.27)

The ice extent in the Nordic Seas during February is normally still growing.

As for January, the “Barents Sea SE” area has been unaffected by sea ice in concentrations of 10% or greater during the past 10 years.

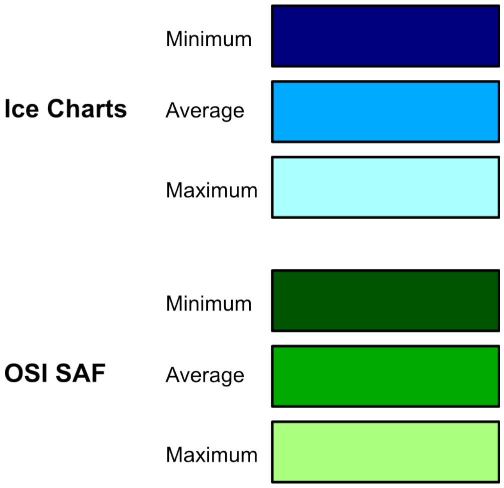


Figure 3.1: Legend for historical ice extent maps.

I «Jan Mayen-ommrådet» var isforholdene mer betydelig før 2005. I perioden 2005-09, forekom en iskonsentrasjon på 10% eller høyere i gjennomsnitt i den nordlige delen av området, og ikke i konsentrasjoner høyere enn 40%. Under den siste perioden, 2010-14, har det bare sporadisk kommet inn i området.

3.3.3 Mars

(Figures 3.4, 3.16 and 3.28)

Isutbredelsen i mars i De nordiske hav er en videreføring av veks ten sett i løpet av januar og februar. Mens isen var jevnlig til stede i begge områdene i perioden 1981-2014, og i perioden for det komplette datasettet sett under ett, er det bare av og til blitt observert i «Barentshavet SØ» i konsentrasjoner mindre enn 40% i løpet av de siste 10 årene.

I Løpet av de siste 10 årene er det fortsatt vanlig at iskanten «buler» østover og kommer inn i den nordligste delen av «Jan Mayen» området i løpet av mars, i konsentrasjoner mellom 10 og 40%. Av og til har isen nådd selve øya Jan Mayen i løpet av de siste 5 år (2010-14), med konsentrasjoner mellom 40 og 70%. Dette representerer en liten økning i isforholdene i forhold til de foregående fem år (2005-09), da isen ikke nådde øya. Is med mer enn 70% konsentrasjon er tidvis til stede i nordenden av området. Mars er vanligvis toppmåneden for isutbredelse i dette området.

3.3.4 April

(Figures 3.5, 3.17 and 3.29)

Isutbredelse i De nordiske hav fortsetter å vokse i løpet av april. Dette er vanligvis den måneden maksimal utredelse finner sted i «Barentshavet SØ», og is med 10-40% konsentrasjon er observert i det nordøstlige hjørnet av dette området i løpet av de seneste 5 år (2010-14). Før 2005 var det vanlig med et isdekke på 10 til 40% konsentrasjon i den nordlige delen av området, og tidvis var en større del av

In the “Jan Mayen” area ice was more extensive before 2005. In the period 2005-09, ice of 10% or greater concentration was on average occurring right at the northern part of the area, and not in concentrations greater than 40%. During the latter period 2010-14 it has only occasionally entered the area.

March

(Figures 3.4, 3.16 and 3.28)

The March ice extent in the Nordic Seas is a continuation of the growth seen during January and February. Whilst ice would have been regularly present in both areas during 1981-2014, and the whole dataset period, it only occasionally been observed in the “Barents Sea SE” area in concentrations less than 40% during the past 10 years.

It is still common during the past 10 years for the ice edge to bulge eastward and enter the northern end of the “Jan Mayen” area during March at concentrations between 10 and 40%. Occasionally the ice has approached Jan Mayen island itself during the past 5 years (2010-14), with some concentrations between 40 and 70%. This represents a slight increase in ice conditions over the preceding 5 years (2005-09) when ice did not approach the island. Ice at over 70% concentration is occasionally present in the north end of the area. March is typically the peak month for ice extent in this area.

April

(Figures 3.5, 3.17 and 3.29)

Ice extent in the Nordic Seas continues to grow during April. This is typically the month of maximum extent in the “Barents Sea SE” area and ice at 10 to 40% concentrations has been observed in the north-east corner of this area during the pasty 5 years (2010-14). Before 2005 it was common for the north-eastern part of the area to have ice cover at 10 to 40% concentration, and occasionally for a larger part of the area to be covered with ice området dekket av is med høyere konsentrasjon.

I «Jan Mayen» området er det en liten nedgang i isutbredelse i løpet av april. Iskonsentrasjonen er i området vanligvis 10 til 40%, hvor den nordlige delen av området av og til har konsentrasjon høyere enn 70%. Som for mars, var forholdene mer betydlige i perioden 2010-14 sammenlignet med 2005-09.

3.3.5 Mai

(Figur 3.6, 3.18 og 3.30)

I mai er det en ytterligere svak nedgang i isutbredelse i forhold til toppunktet. I «Barentshavet SØ» var det relativt vanlig med is i den nordlige delen av området. I de siste 10 årene har det ikke vært is i området, til tross for at isen de seneste 5 årene (2010-14) har beveget seg nærmere den nordlige kanten sammenlignet med perioden (2005-09).

Det er vanlig at iskanten vest for «Jan Mayen» området fortsatt varierer og potensielt befinner seg i området i løpet av mai med iskonsentrasjoner på mellom 10 og 40%. I løpet av de seneste 5 årene (2010-14) har det vært vanlig at is med konsentrasjon på 10% eller høyere, har befunnet seg langs den nordlige utkanten av området, hvor grensen for konsentrasjon på mer enn 40% har vært godt utenfor området.

3.3.6 Juni

(Figur 3.7, 3.19 og 3.31)

Mens isen tidligere tidvis har kommet inn i den nordøstlige delen av «Barentshavet SØ» i løpet av juni, har den ikke blitt observert nær området i løpet av de seneste 10 årene.

I «Jan Mayen» området ligger is med konsentrasjon mellom 10 og 40% vanligvis langs den nordlige utkanten av området. I løpet av de seneste fem årene (2010-14) har isen tidvis kommet inn i området i høyere konsentrasjoner, inkludert de på 70% eller

of greater concentration.

In the “Jan Mayen” area there is a slight decrease in ice extent during April. Ice concentrations are typically in the range 10 to 40%, with the north part of the area occasionally seeing a little ice of over 70% concentration. As for March, conditions during 2010-14 were slightly more severe than 2005-09.

May

(Figures 3.6, 3.18 and 3.30)

In May there is a further slight decline in ice extent from its peak. In the “Barents Sea SE” area ice used to occasionally occur over the northern part of the area. In the past 10 years ice has not occurred in the area, although in the past 5 years (2010-14) it has approached closer to the northern edge than the 5 years prior (2005-09).

It is common for the ice edge west of the “Jan Mayen” area to still be mobile and potentially enter the area during May with ice concentrations of between 10 and 40%. In the past 5 years (2010-14) it has usual for the edge of ice at concentrations of 10% or greater to lie along the northern edge of the area, with the edge of ice concentrations at 40% or greater lying well outside the area.

June

(Figures 3.7, 3.19 and 3.31)

Whilst sea ice used to occasionally enter the north-eastern part of the “Barents Sea SE” area during June, it has not been observed near the area during the past 10 years.

In the “Jan Mayen” area the edge of ice concentrations between 10 and 40% typically lies along the northern edge of the area. During the past 5 years (2010-14) ice has occasionally entered the area in higher concentrations, including those at 70% or mer, etter å ha blitt advektert ut fra hovediskanten av vestlige vinder. Området hvor isen har blitt observert har økt i 2010-14 til 11 900 km^2 fra 2600 km^2 i 2005-09.

3.3.7 Juli

(Figur 3.8, 3.20 and 3.32)

Et meget lite (63 km^2) område av is med 10 til 40% konsentrasjon ble i perioden 2005-09 observert i «Barentshavet SØ». For øvrig har iskanten befunnet seg godt utenfor dette området. Før 2005 var is med konsentrasjon på 10 til 40% tidvis til stede i den nordlige delen av området.

Isforhold for «Jan Mayen» området var lik de som ble observert i løpet av juni, igjen med isforhold noe mer betydelig i den seneste 5 års- perioden (2010-14) sammenlignet med den foregående 5 års-perioden (2005-09).

3.3.8 August

(Figur 3.9, 3.21 and 3.33)

Is har ikke blitt observert i området «Barentshavet SØ» i løpet av august for hele perioden dekket av iskart (1967-2014).

I «Jan Mayen» området har is med konsentrasjon på 40 til 70% drevet inn den nordlige delen av området i små mengder (917 km^2) med opp til 3.700 km^2 dekket av is som er tettere enn 10% konsentrasjon i perioden 2010-14. I perioden 2005-09 ble det ikke observert is i dette området, og maksimumsutbredelsen for is med konsentrasjon tettere enn 10% lå godt nord for området.

3.3.9 September

(Figur 3.10, 3.22 and 3.34)

September er vanligvis måneden hvor minimum isutbredelse opptrer i Arktis. Det har ikke blitt observert is verken i «Barentshavet SØ» eller «Jan Mayen» området i løpet av de seneste 10 årene. Før 2005 ble noe is med konsentrasjon lavere enn 70% sporadisk observert «Jan Mayen» området.

greater, having been advected out from the main ice edge by westerly winds. The area where ice has been observed has increased in 2010-14 to 11,900 km^2 from 2,600 km^2 in 2005-09.

Juli

(Figures 3.8, 3.20 and 3.32)

A very small (63 km^2) area of ice at 10 to 40% concentration was observed in the “Barents Sea SE” area during the period 2005-09. Otherwise the ice edge lay well outside this area. Before 2005 ice at 10 to 40% concentration was occasionally present over the northern part of the area.

Ice conditions for the “Jan Mayen” area were similar to those observed during June, again with ice condition in the latest 5 year period (2010-14) being more severe than observed during the previous 5 year period (2005-09).

August

(Figure 3.9, 3.21 and 3.33)

Ice has not been observed in the “Barents Sea SE” area during August for the whole period of the ice chart record (1967-2014).

In the “Jan Mayen” area ice at 40 to 70% concentrations has drifted into the northern part of the area in small quantities 917 km^2) with up to 3,700 km^2 of ice greater than 10% concentration during the period 2010-14. In the period 2005-09 no ice was observed in this area and the maximum extent of ice of 10% concentration or greater lay well to the north of the area.

September

(Figures 3.10, 3.22 and 3.34)

September is typically the month of minimum Arctic ice extent. No ice has been observed in either the “Barents Sea SE” or “Jan Mayen” area during the past 10 years. Prior to 2005 some ice at less than 70% concentration had been observed occasionally in the “Jan Mayen” area.

3.3.10 Oktober

(Figur 3.11, 3.23 and 3.35)

Det har ikke blitt observert is verken i «Barentshavet SØ» eller «Jan Mayen» området i oktober i løpet av de seneste 10 årene. Mellom 1981 og 2005 ble litt is med mindre enn 40% konsentrasjon sporadisk observert i den nordlige delen av «Jan Mayen» området. Før 1981 er det registreringer av mye større isutbredelse med konsentrasjoner høyere enn 70% i den nordlige delen av området.

3.3.11 November

(Figur 3.12, and 3.36)

Tilfrysningsperioden for de Nordiske hav starter vanligvis i november, men har stadig blitt forsinket de senere år. Is har ikke blitt observert i «Barentshavet SØ» i løpet av november de siste 10 år (2005-14). Før 2005 ble is med konsentrasjoner lavere enn 70% tidvis observert i den nordlige delen av området.

Is med konsentrasjon mellom 10 og 40% har blitt observert i den nordlige delen av «Jan Mayen» området. Til tross for at det ikke har vært så omfattende som før 2005, dekket det fremdeles 3900 km^2 i 2005-09 og 9900 km^2 i 2010-14. En liten del av isen (408 km^2) i perioden 2010-14 hadde en konsentrasjon på mellom 40 og 70%.

3.3.12 Desember

(Figur 3.13, 3.25 and 3.37

Det har ikke blitt observert is i «Barentshavet SØ» i løpet av desember de seneste 10 år (2005-14). Før 2005 ble is med konsentrasjon mindre enn 70% tidvis observert i den nordlige delen av området. Før 2005 ble is i konsentrasjoner mindre enn 70% tidvis observert i den nordlige delen av området.

October

(Figures 3.11, 3.23 and 3.35)

No ice has been observed in either the “Barents Sea SE” or “Jan Mayen” area in October during the past 10 years. Between 1981 and 2005 some ice at less than 40% concentration had been observed occasionally in the northern part of “Jan Mayen” area. Prior to 1981 there are records of much greater ice extent at concentrations greater than 70% in the northern part of the area.

November

(Figures 3.12, and 3.36)

The freeze-up period for the Nordic Seas usually starts in November, but has been increasingly delayed in recent years. No ice has been observed in the “Barents Sea SE” area during November during the past 10 years (2005-14). Prior to 2005 ice at concentrations less than 70% was occasionally observed in the northern part of the area.

Ice at 10 to 40% concentration has been observed in the northern part of the “Jan Mayen” area. Whilst not as extensive as prior to 2005, it still covered 3,900 km^2 in 2005-09 and 9,900 km^2 in 2010-14. A fraction of the ice (408 km^2) in 2010-14 was between 40 and 70% concentration.

December

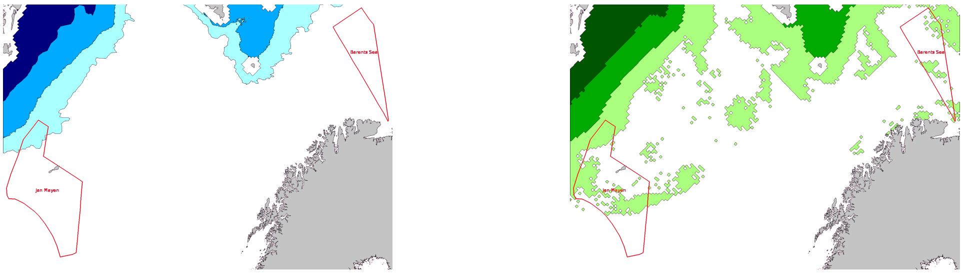
(Figures 3.13, 3.25 and 3.37)

No ice has been observed in the “Barents Sea SE” area during December during the past 10 years (2005-14). Prior to 2005 ice at concentrations less than 70% was occasionally observed in the northern part of the area. Prior to 2005 ice at concentrations less than 70% was occasionally observed in the northern part of the area.

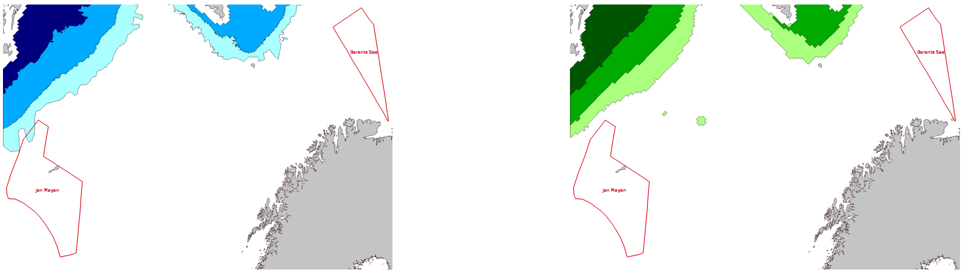
Is med konsentrasjon 70% eller høyere har nådd den nordvestlige kanten av «Jan Mayen» området i alle periodene bortsett fra 2005-09. Vanligvis vil inntrengning av is i området være begrenset, med et maksimum på 3900 km2 av is med konsentrasjon høyere enn 10% i løpet av perioden 2010-14. Dette er igjen en økning sammenlignet med perioden 2005-09 da bare 1400 km2 ble observert.

Ice of 70% or greater concentration has reached the north-western edge of the “Jan Mayen” area in all periods except 2005-09. Typically the incursion of ice into the area is limited, with a maximum of 3,900 km^2 of ice concentrations greater than 10% during the period 2010-14, again being an increase over the period 2005-09 when only 1,400 km^2 was observed.

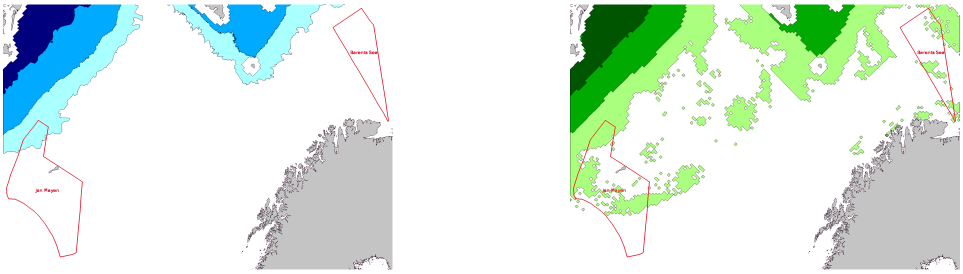
Ice Charts **OSI SAF**


a) 2005-09 (5 years)

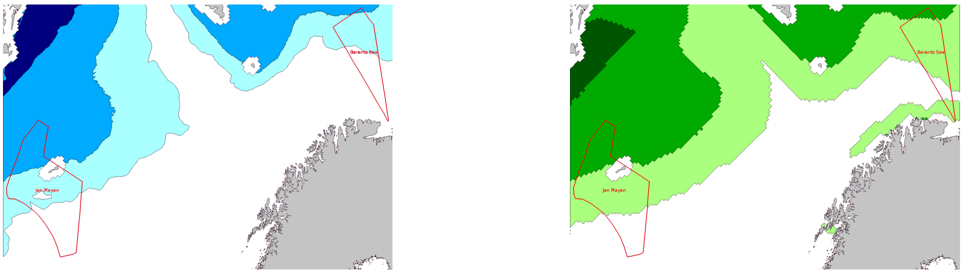
f) 2005-09 (5 years)


b) 2010-14 (5 years)

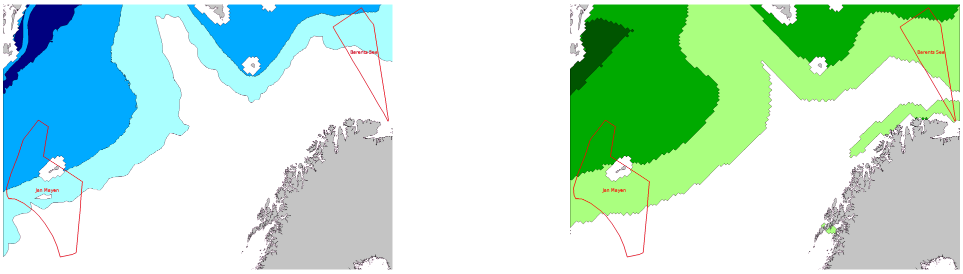
g) 2010-14 (5 years)


c) 2005-14 (10 years)

h) 2005-14 (10 years)


d) 1981-2014 (30 years)

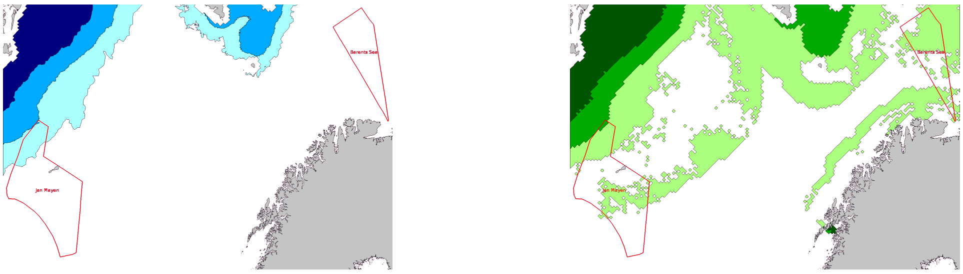
i) 1981-2014 (30 years)

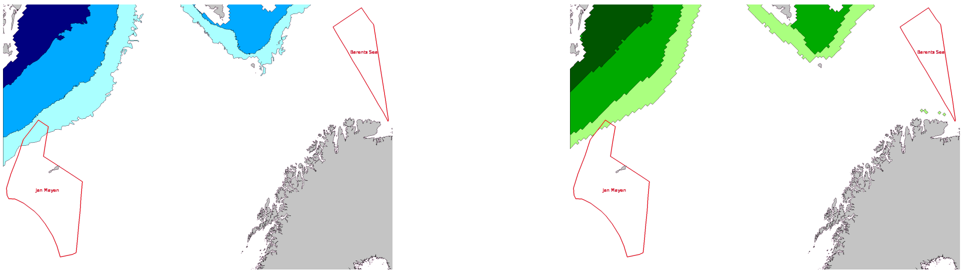

e) 1967-2014 (All Data)

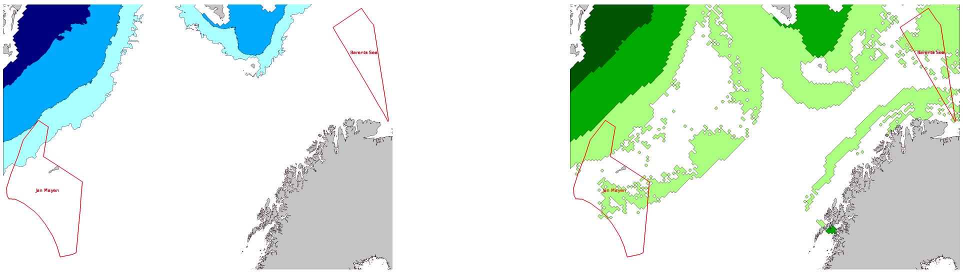
j) 1979-2014 (All Data)

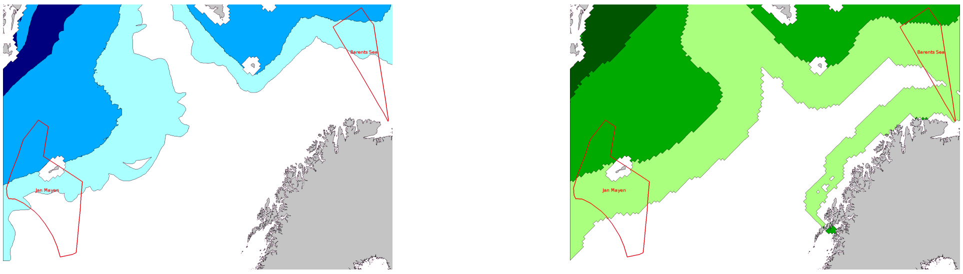
Figure 3.2: Historical ice conditions from ice charts and OSI SAF for JANUARY at 10% concentration.

Ice Charts **OSI SAF**


a) 2005-09 (5 years) f) 2005-09 (5 years)


b) 2010-14 (5 years) g) 2010-14 (5 years)


c) 2005-14 (10 years) h) 2005-14 (10 years)


d) 1981-2014 (30 years) i) 1981-2014 (30 years)

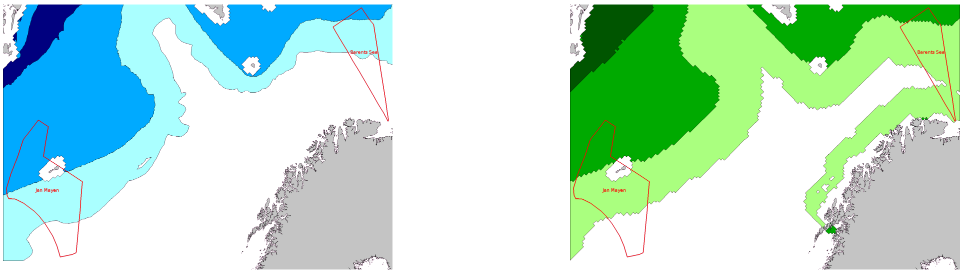
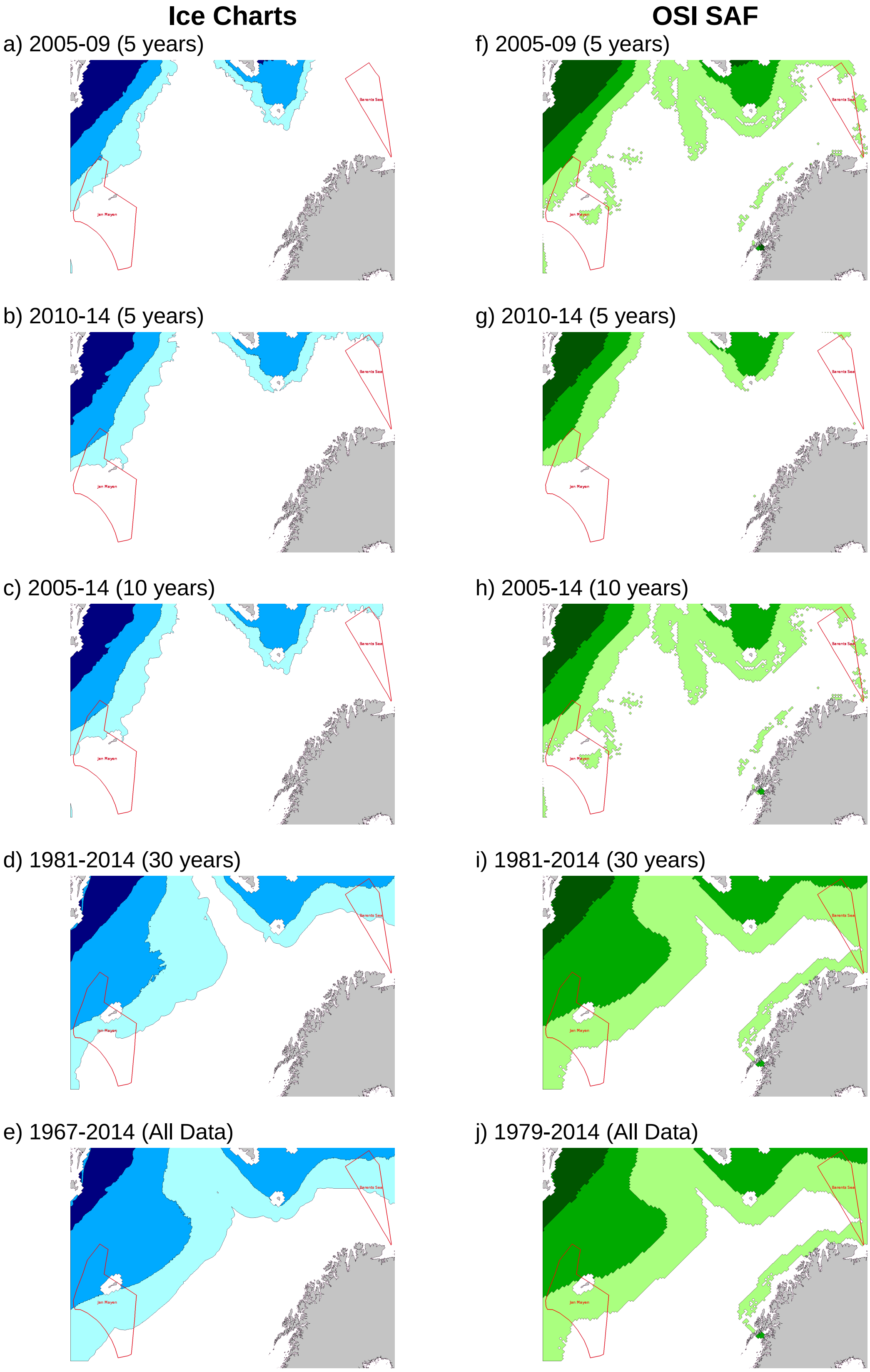

e) 1967-2014 (All Data) j) 1979-2014 (All Data)

Figure 3.3: Historical ice conditions from ice charts and OSI SAF for FEBRUARY at 10% concentration.



Ice Charts

OSI SAF

a) 2005-09 (5 years)

b) 2010-14 (5 years)

c) 2005-14 (10 years)

d) 1981-2014 (30 years)

e) 1967-2014 (All Data)

f) 2005-09 (5 years)

g) 2010-14 (5 years)

h) 2005-14 (10 years)

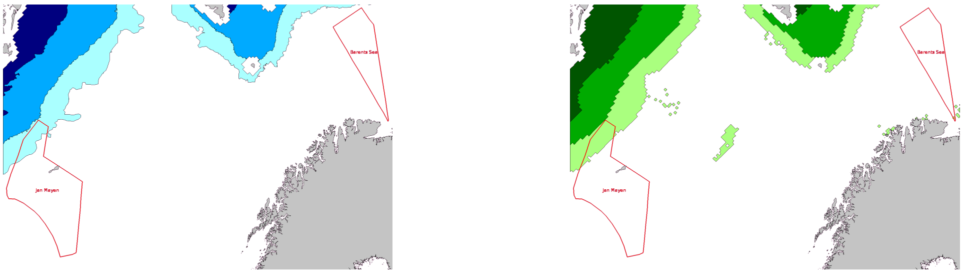
i) 1981-2014 (30 years)

j) 1979-2014 (All Data)

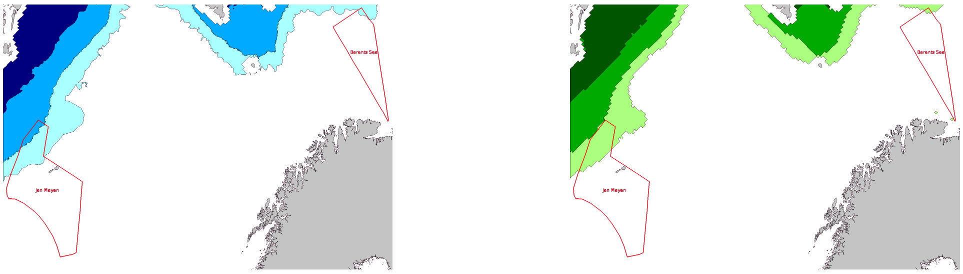
Figure 3.4: Historical ice conditions from ice charts and OSI SAF for MARCH at 10% concentration.

Ice Charts **OSI SAF**

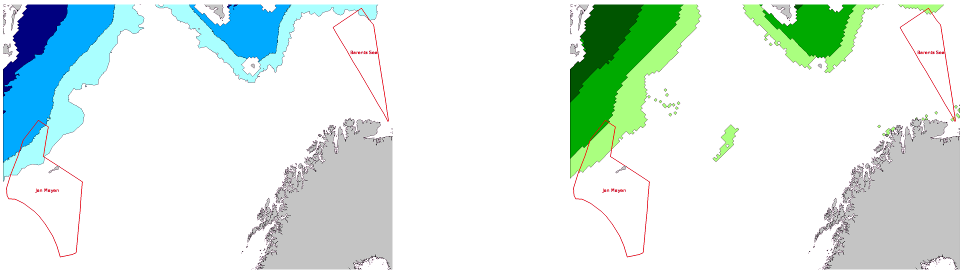
a) 2005-09 (5 years) f) 2005-09 (5 years)



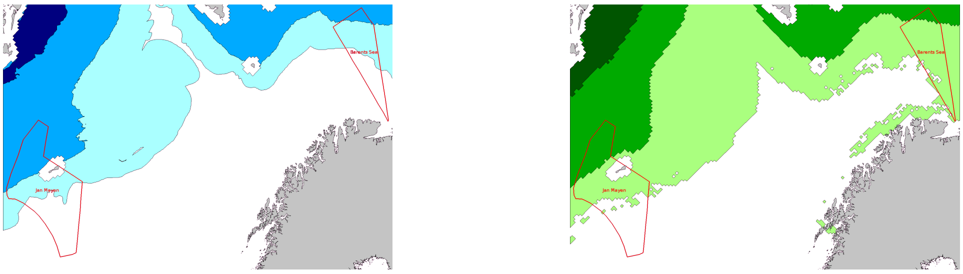
b) 2010-14 (5 years) g) 2010-14 (5 years)



c) 2005-14 (10 years) h) 2005-14 (10 years)



d) 1981-2014 (30 years) i) 1981-2014 (30 years)



e) 1967-2014 (All Data) j) 1979-2014 (All Data)

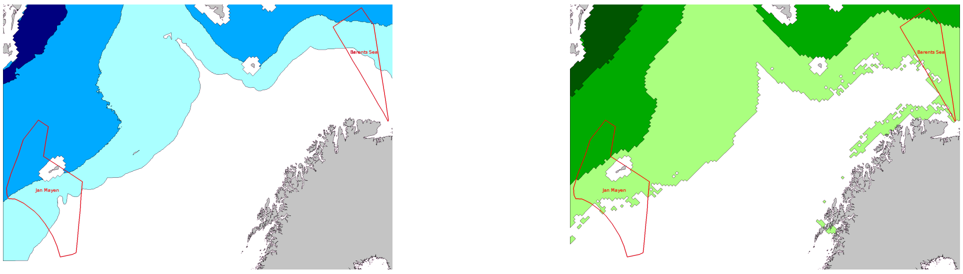
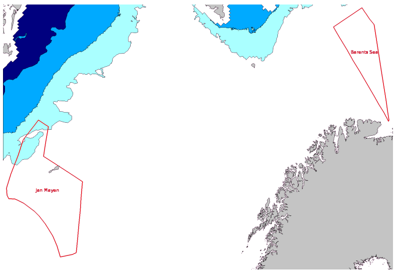


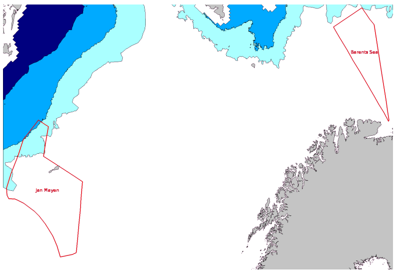
Figure 3.5: Historical ice conditions from ice charts and OSI SAF for APRIL at 10% concentration.

Ice Charts

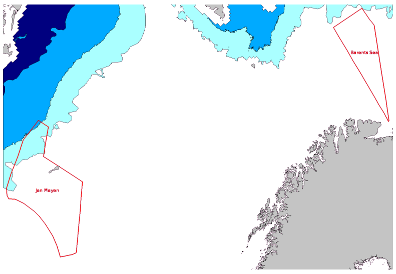
a) 2005-09 (5 years)



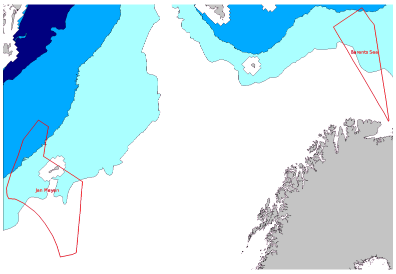
b) 2010-14 (5 years)



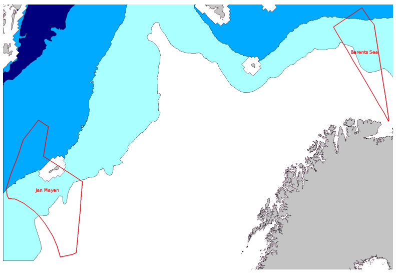
c) 2005-14 (10 years)



d) 1981-2014 (30 years)

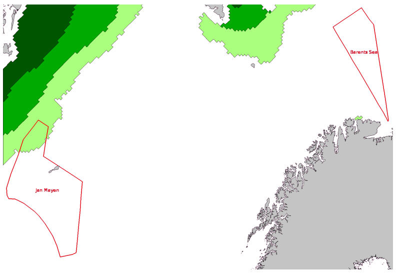


e) 1967-2014 (All Data)

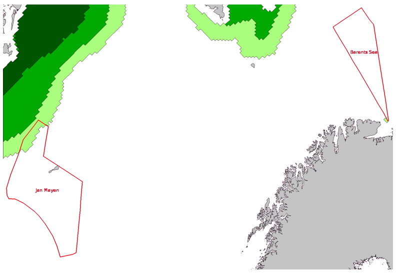


OSI SAF

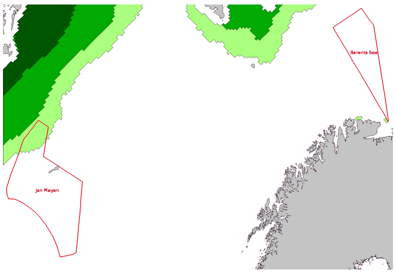
f) 2005-09 (5 years)



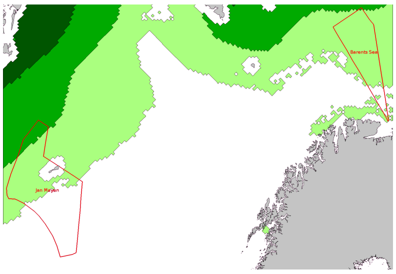
g) 2010-14 (5 years)



h) 2005-14 (10 years)



i) 1981-2014 (30 years)



j) 1979-2014 (All Data)

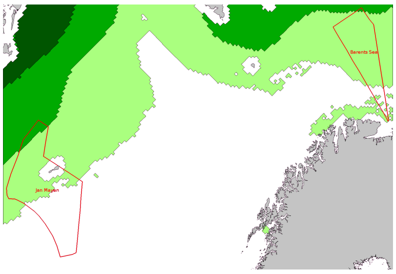


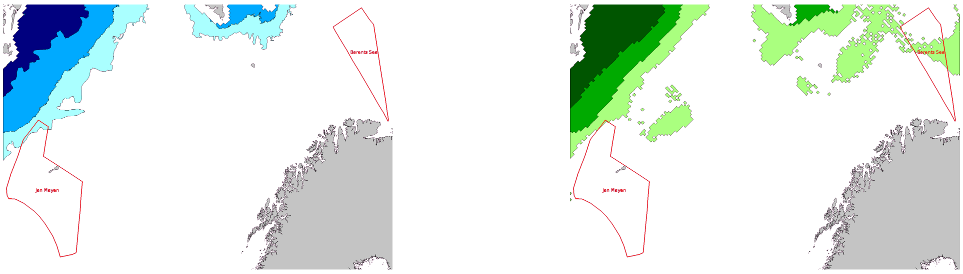
Figure 3.6: Historical ice conditions from ice charts and OSI SAF for MAY at 10% concentration.

Ice Charts

OSI SAF

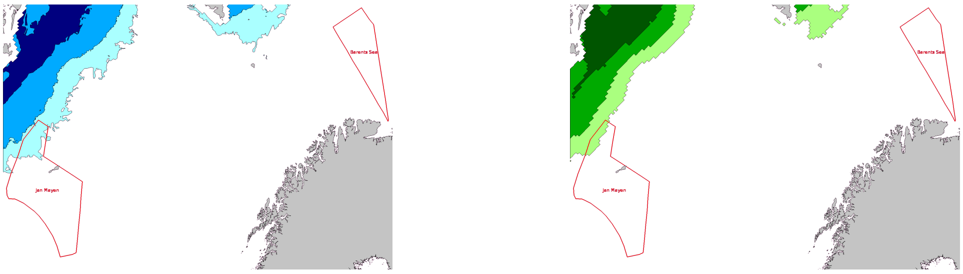
a) 2005-09 (5 years)

f) 2005-09 (5 years)



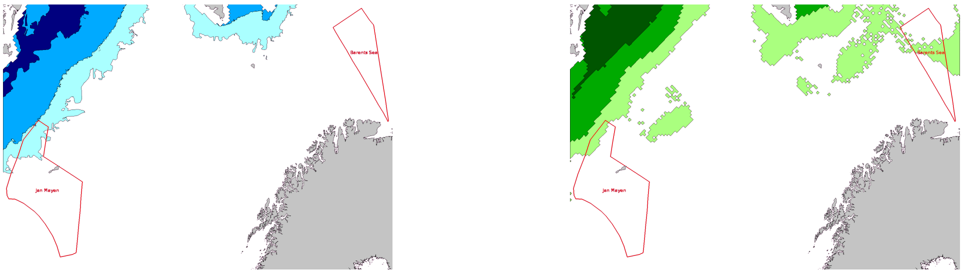
b) 2010-14 (5 years)

g) 2010-14 (5 years)



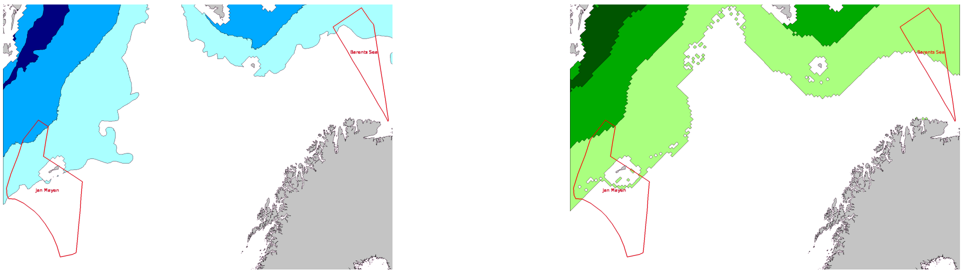
c) 2005-14 (10 years)

h) 2005-14 (10 years)



d) 1981-2014 (30 years)

i) 1981-2014 (30 years)



e) 1967-2014 (All Data)

j) 1979-2014 (All Data)

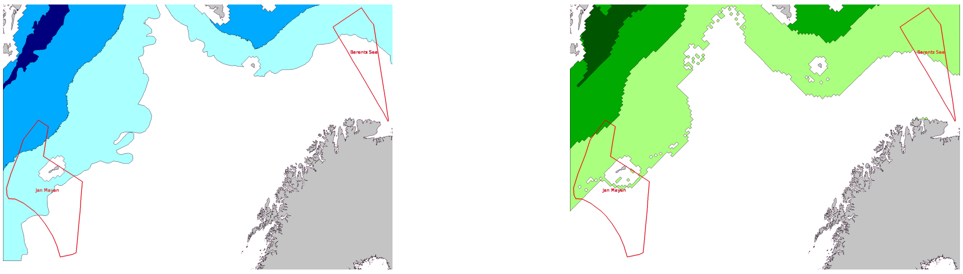
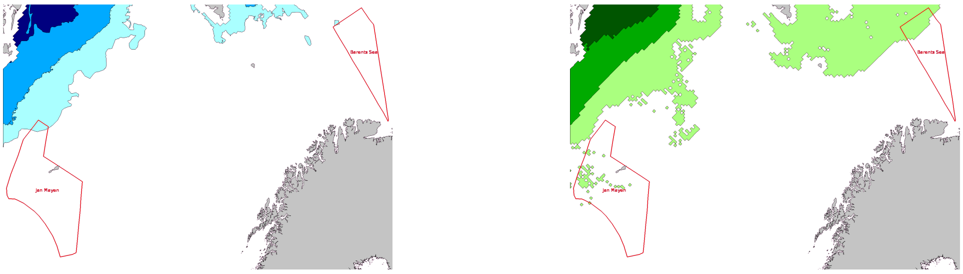


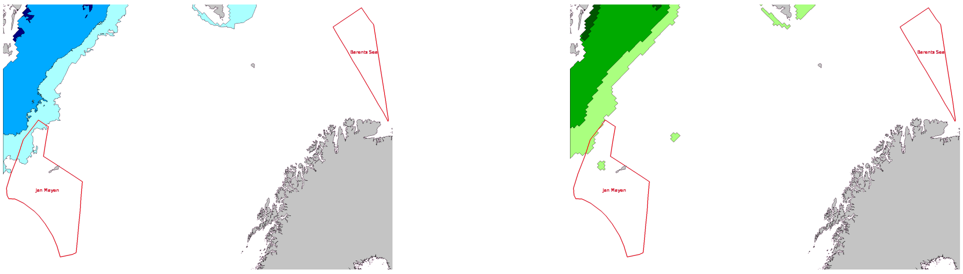
Figure 3.7: Historical ice conditions from ice charts and OSI SAF for JUNE at 10% concentration.

Ice Charts **OSI SAF**



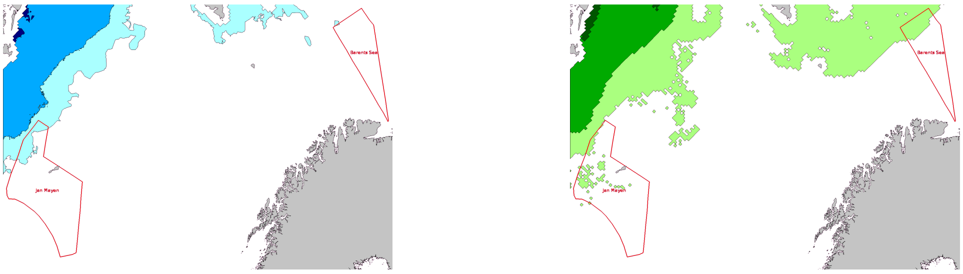
a) 2005-09 (5 years)

f) 2005-09 (5 years)



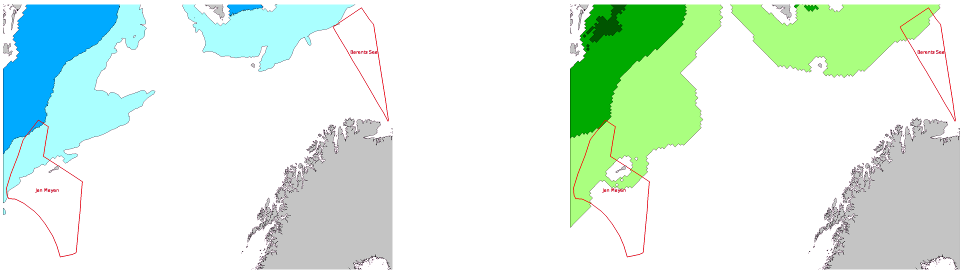
b) 2010-14 (5 years)

g) 2010-14 (5 years)



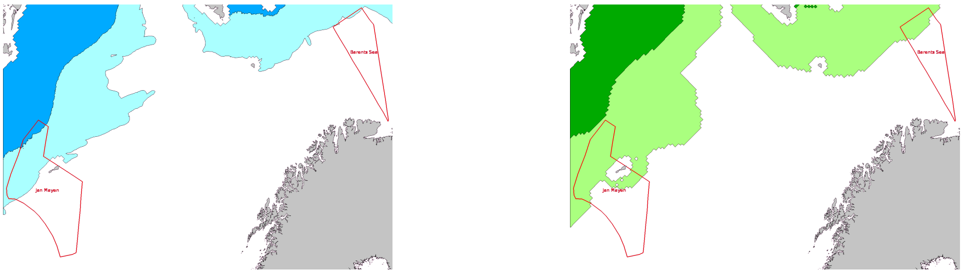
c) 2005-14 (10 years)

h) 2005-14 (10 years)



d) 1981-2014 (30 years)

i) 1981-2014 (30 years)



e) 1967-2014 (All Data)

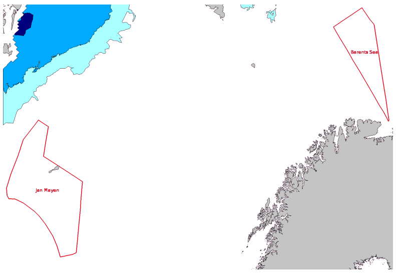
j) 1979-2014 (All Data)

Figure 3.8: Historical ice conditions from ice charts and OSI SAF for JULY at 10% concentration.

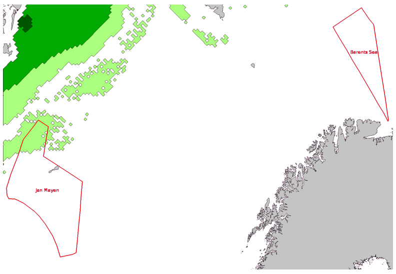
Ice Charts

OSI SAF

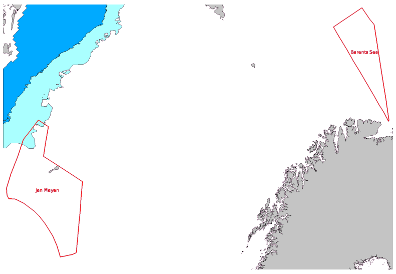
a) 2005-09 (5 years)



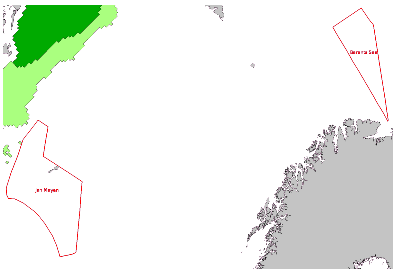
f) 2005-09 (5 years)



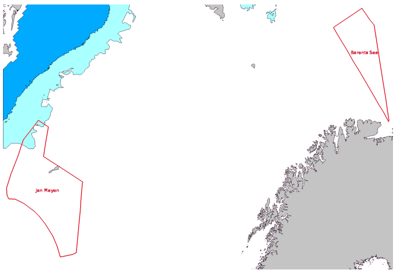
b) 2010-14 (5 years)



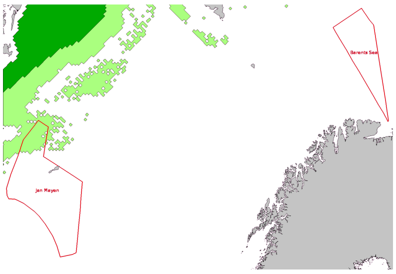
g) 2010-14 (5 years)



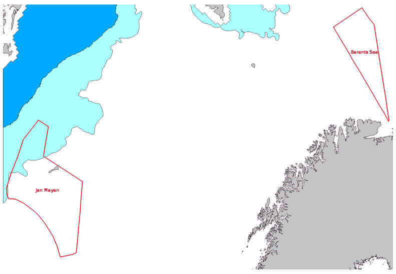
c) 2005-14 (10 years)



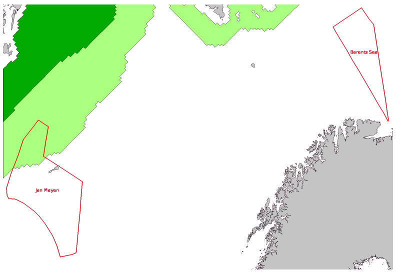
h) 2005-14 (10 years)



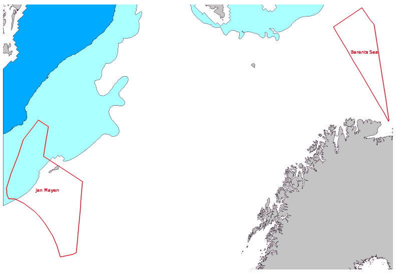
d) 1981-2014 (30 years)



i) 1981-2014 (30 years)



e) 1967-2014 (All Data)



j) 1979-2014 (All Data)

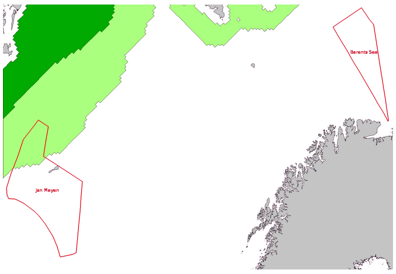
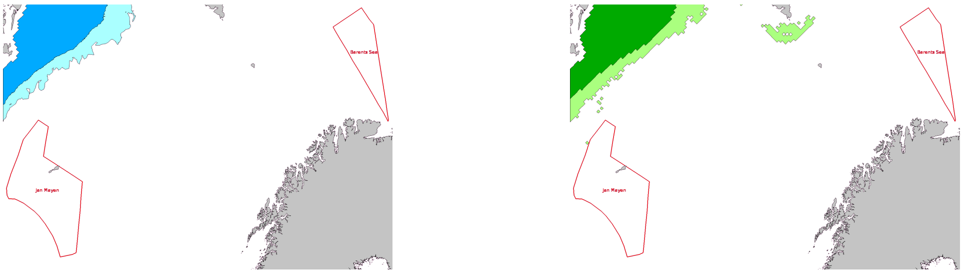


Figure 3.9: Historical ice conditions from ice charts and OSI SAF for AUGUST at 10% concentration.

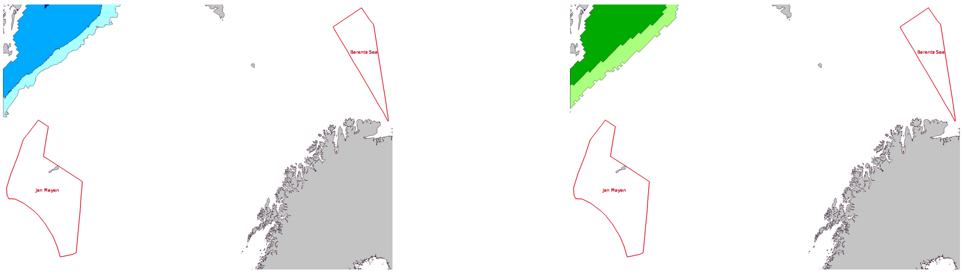
Ice Charts

OSI SAF



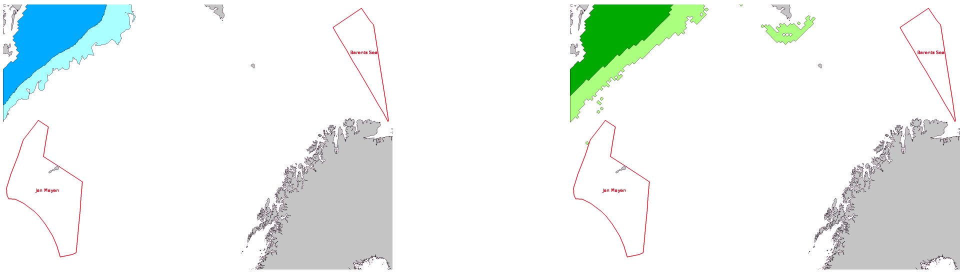
a) 2005-09 (5 years)

f) 2005-09 (5 years)



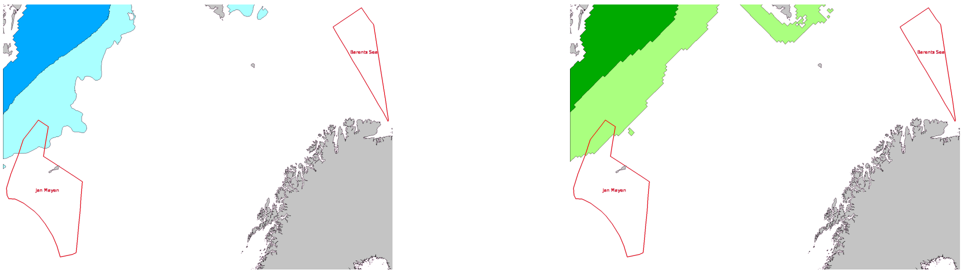
b) 2010-14 (5 years)

g) 2010-14 (5 years)



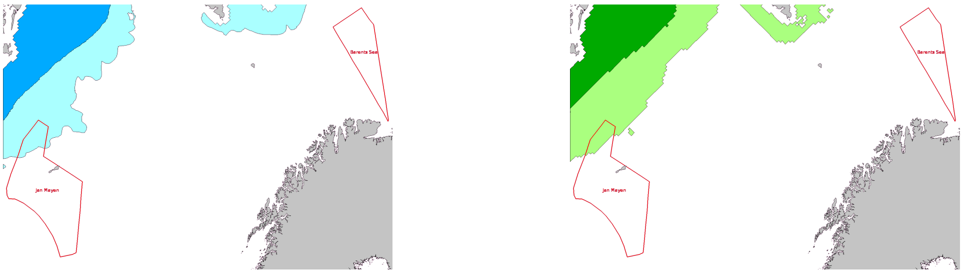
c) 2005-14 (10 years)

h) 2005-14 (10 years)



d) 1981-2014 (30 years)

i) 1981-2014 (30 years)



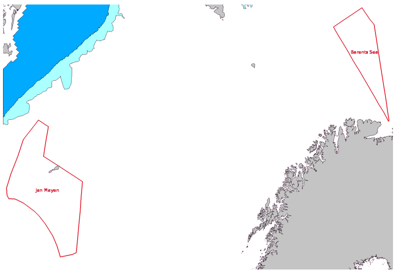
e) 1967-2014 (All Data)

j) 1979-2014 (All Data)

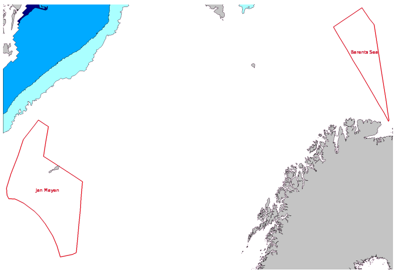
Figure 3.10: Historical ice conditions from ice charts and OSI SAF for SEPTEMBER at 10% concentration.

Ice Charts

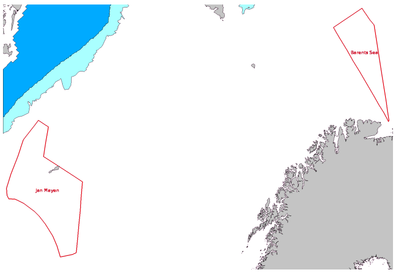
a) 2005-09 (5 years)



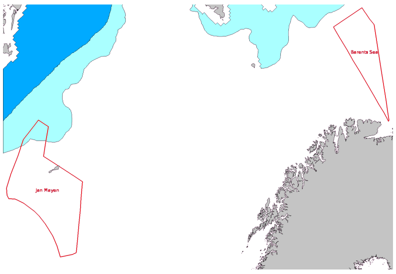
b) 2010-14 (5 years)



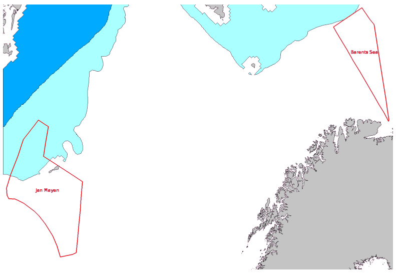
c) 2005-14 (10 years)



d) 1981-2014 (30 years)

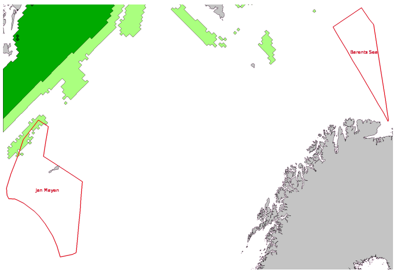


e) 1967-2014 (All Data)

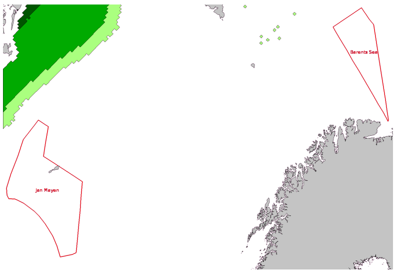


OSI SAF

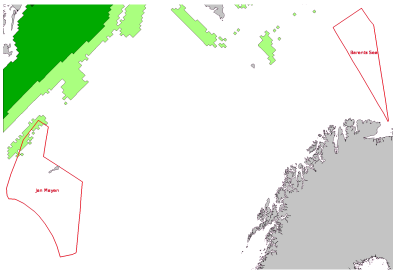
f) 2005-09 (5 years)



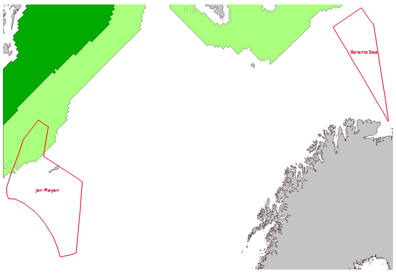
g) 2010-14 (5 years)



h) 2005-14 (10 years)



i) 1981-2014 (30 years)



j) 1979-2014 (All Data)

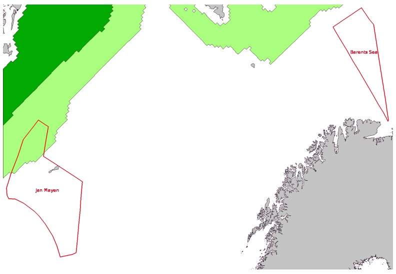
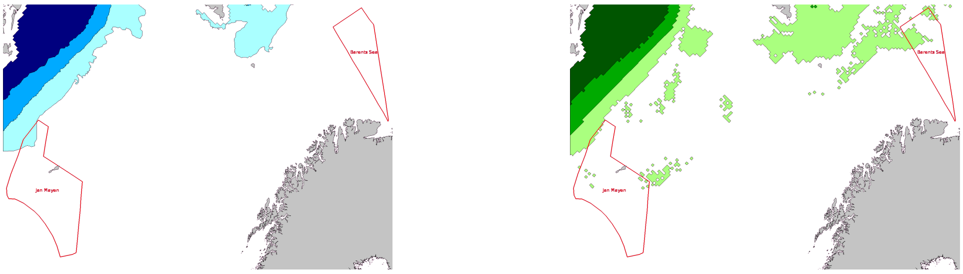


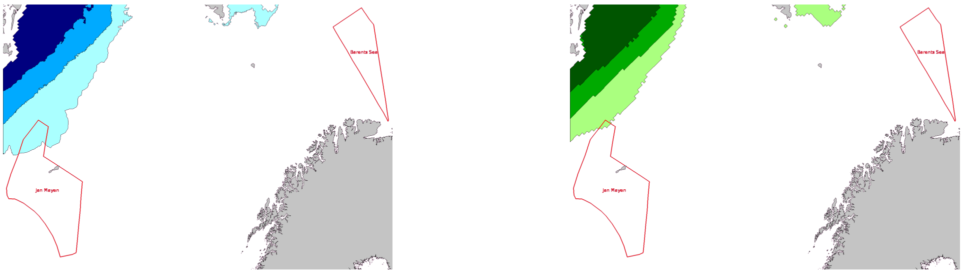
Figure 3.11: Historical ice conditions from ice charts and OSI SAF for OCTOBER at 10% concentration.

Ice Charts **OSI SAF**

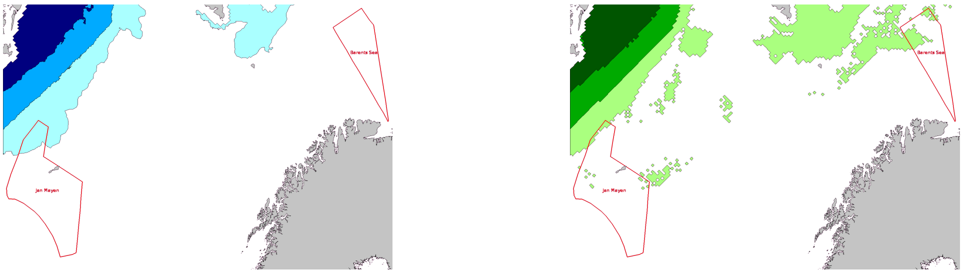
a) 2005-09 (5 years) f) 2005-09 (5 years)



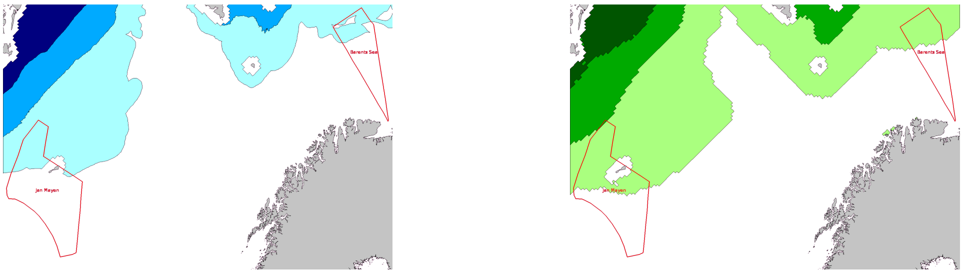
b) 2010-14 (5 years) g) 2010-14 (5 years)



c) 2005-14 (10 years) h) 2005-14 (10 years)



d) 1981-2014 (30 years) i) 1981-2014 (30 years)



e) 1967-2014 (All Data) j) 1979-2014 (All Data)

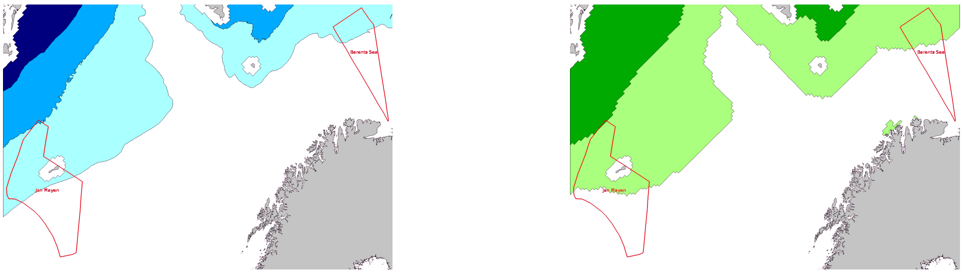
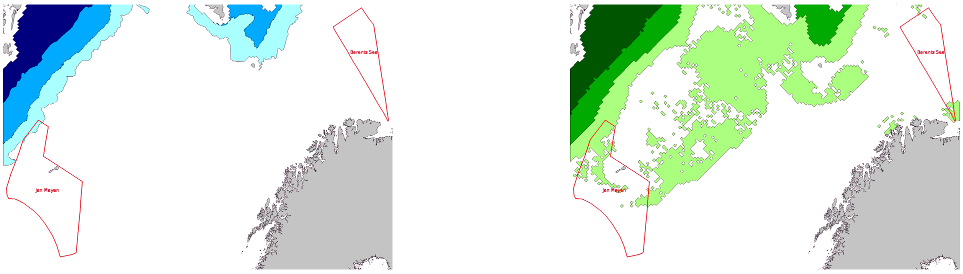
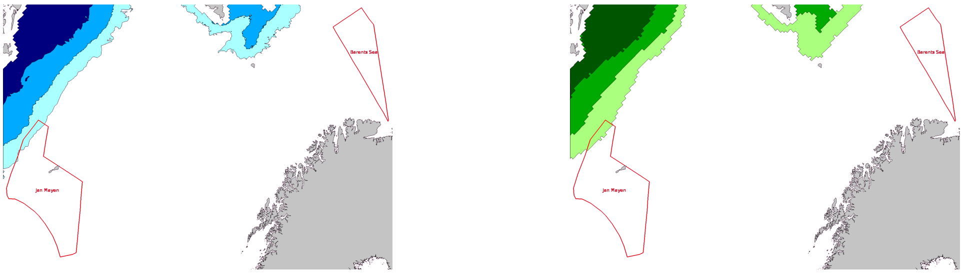
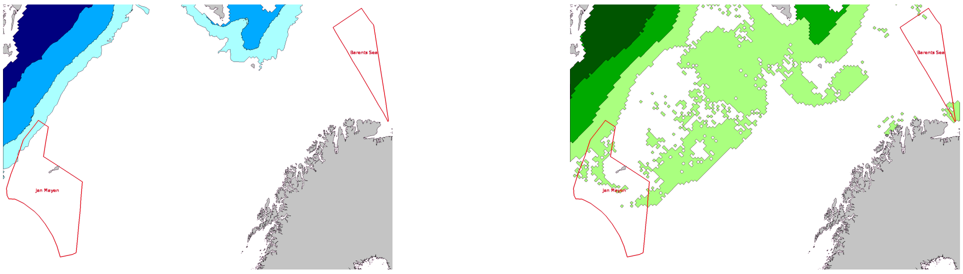


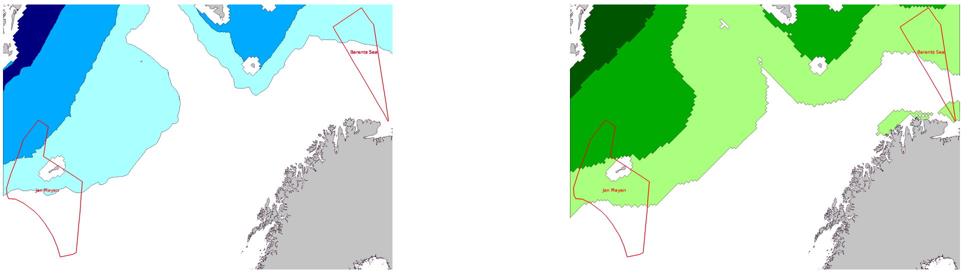
Figure 3.12: Historical ice conditions from ice charts and OSI SAF for NOVEMBER at 10% concentration.

Ice Charts **OSI SAF**


a) 2005-09 (5 years)
f) 2005-09 (5 years)


b) 2010-14 (5 years)
g) 2010-14 (5 years)


c) 2005-14 (10 years)
h) 2005-14 (10 years)


d) 1981-2014 (30 years)
i) 1981-2014 (30 years)

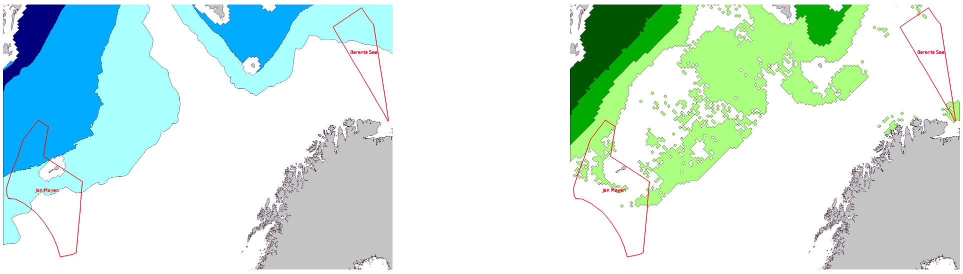
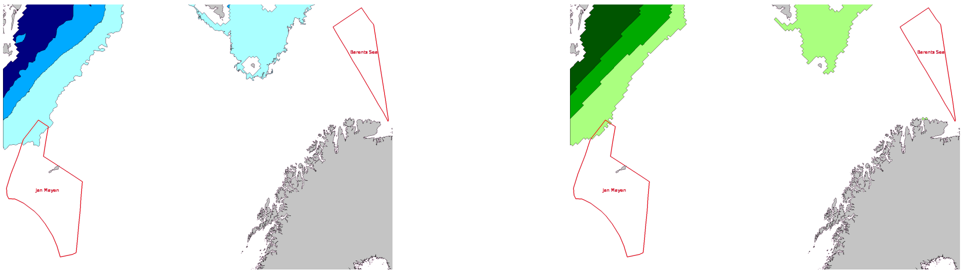

e) 1967-2014 (All Data)
j) 1979-2014 (All Data)

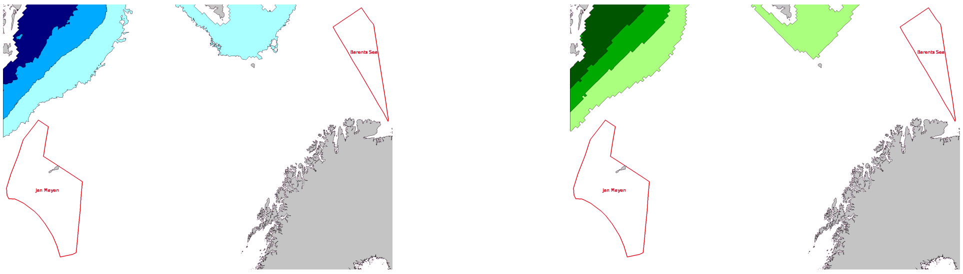
Figure 3.13: Historical ice conditions from ice charts and OSI SAF for DECEMBER at 10% concentration.

Ice Charts

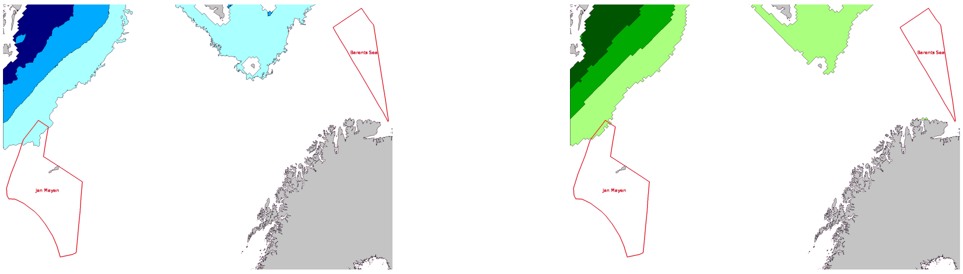
OSI SAF


a) 2005-09 (5 years)

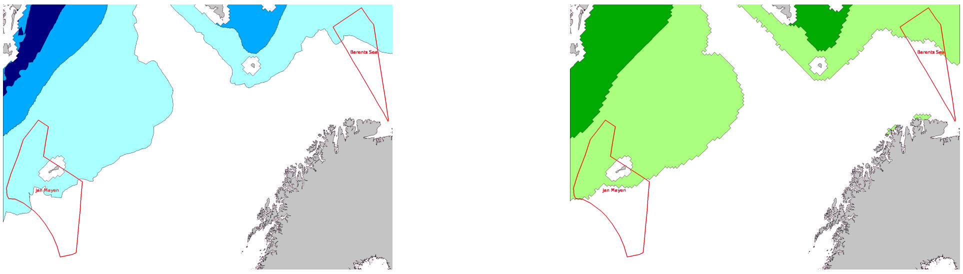
f) 2005-09 (5 years)


b) 2010-14 (5 years)

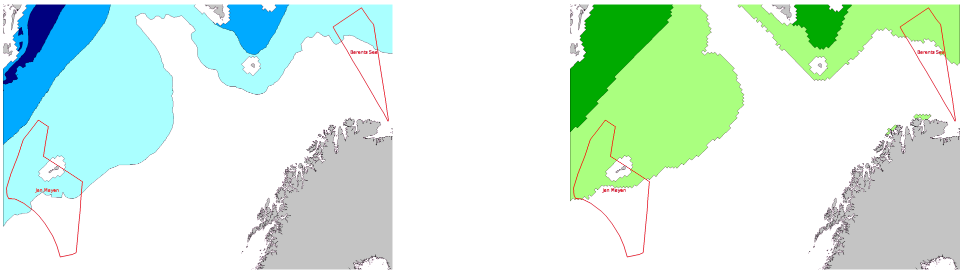
g) 2010-14 (5 years)


c) 2005-14 (10 years)

h) 2005-14 (10 years)


d) 1981-2014 (30 years)

i) 1981-2014 (30 years)

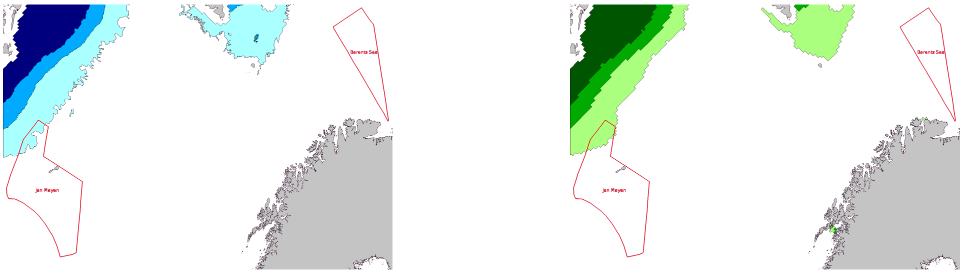

e) 1967-2014 (All Data)

j) 1979-2014 (All Data)

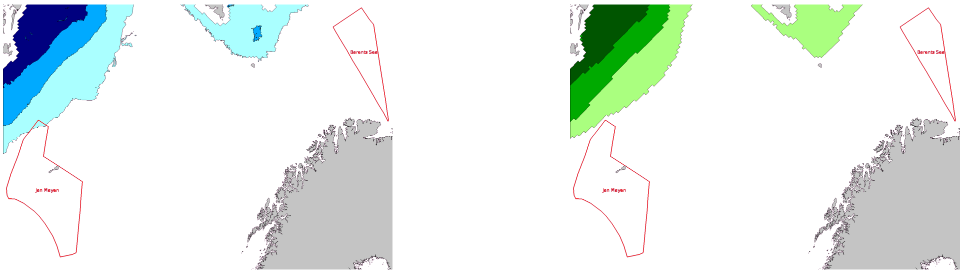
Figure 3.14: Historical ice conditions from ice charts and OSI SAF for JANUARY at 40% concentration.

Ice Charts **OSI SAF**

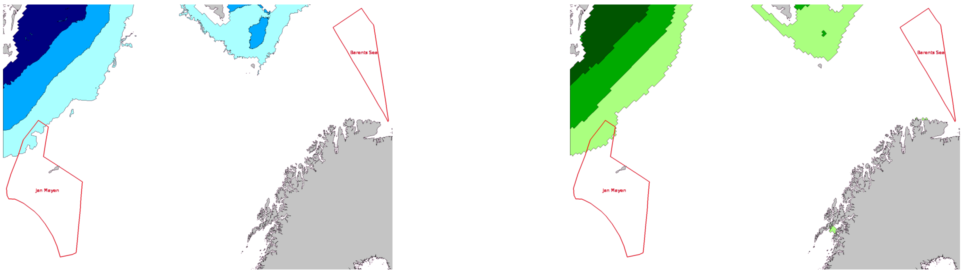
a) 2005-09 (5 years) f) 2005-09 (5 years)



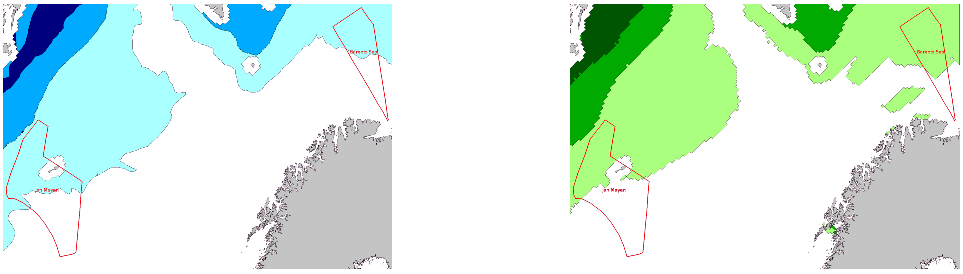
b) 2010-14 (5 years) g) 2010-14 (5 years)



c) 2005-14 (10 years) h) 2005-14 (10 years)



d) 1981-2014 (30 years) i) 1981-2014 (30 years)



e) 1967-2014 (All Data) j) 1979-2014 (All Data)

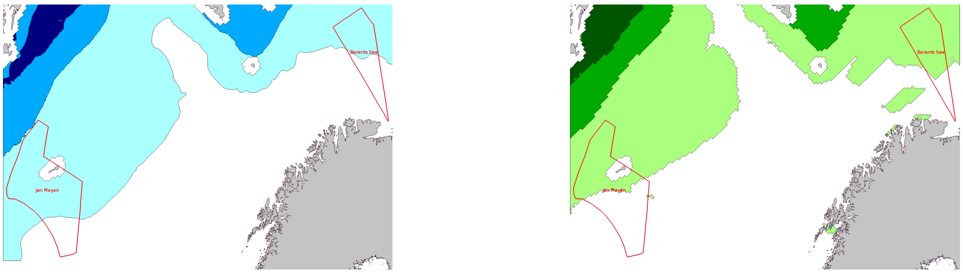
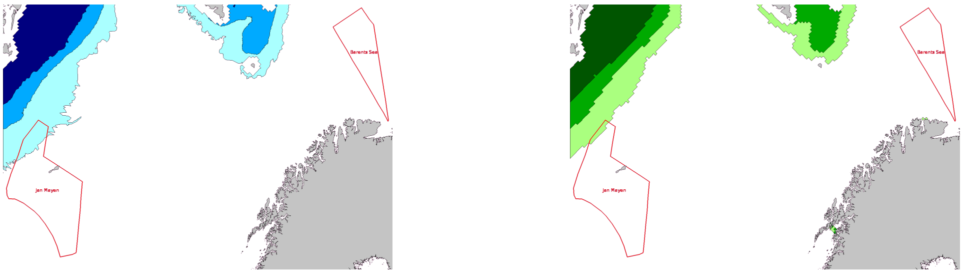


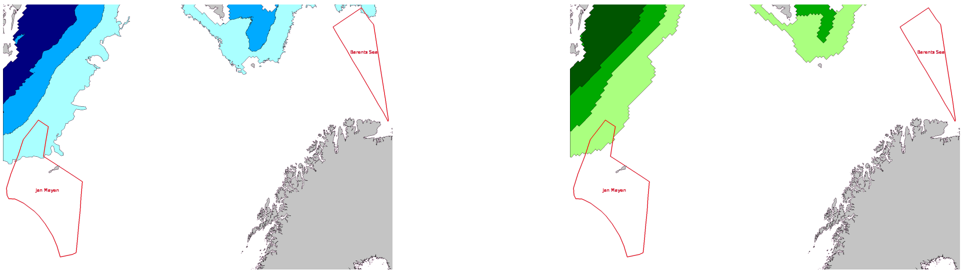
Figure 3.15: Historical ice conditions from ice charts and OSI SAF for FEBRUARY at 40% concentration.

Ice Charts **OSI SAF**

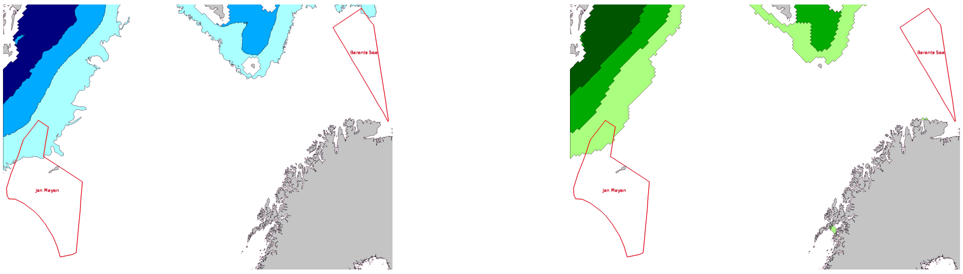
a) 2005-09 (5 years) f) 2005-09 (5 years)



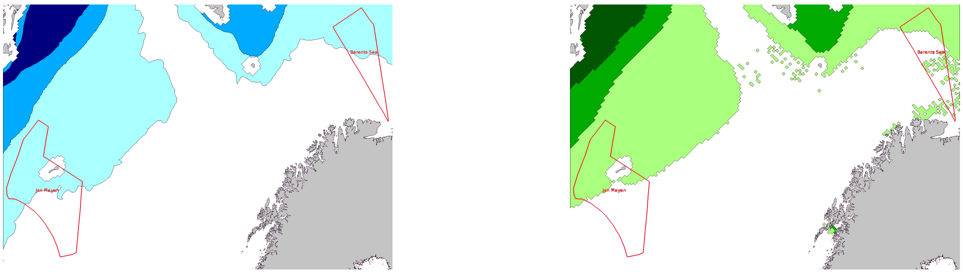
b) 2010-14 (5 years) g) 2010-14 (5 years)



c) 2005-14 (10 years) h) 2005-14 (10 years)



d) 1981-2014 (30 years) i) 1981-2014 (30 years)



e) 1967-2014 (All Data) j) 1979-2014 (All Data)

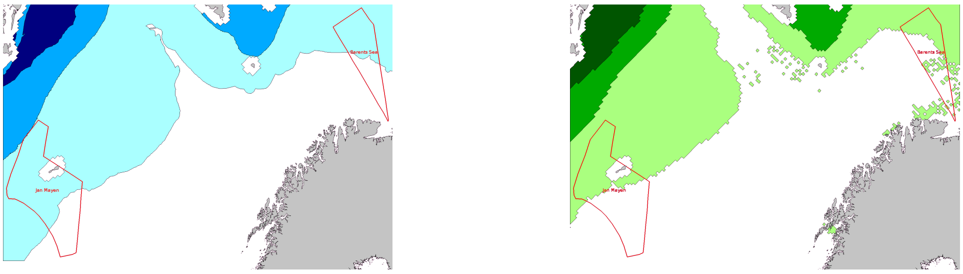
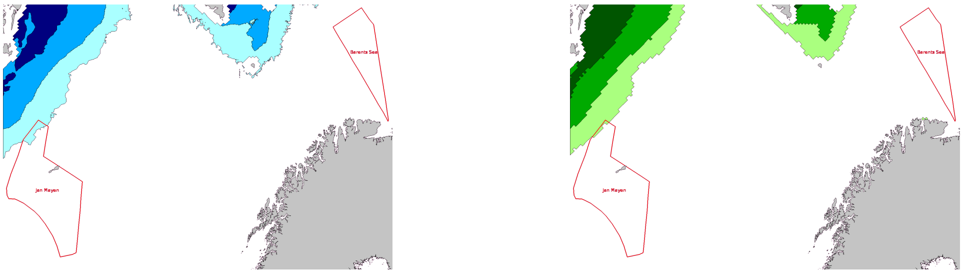


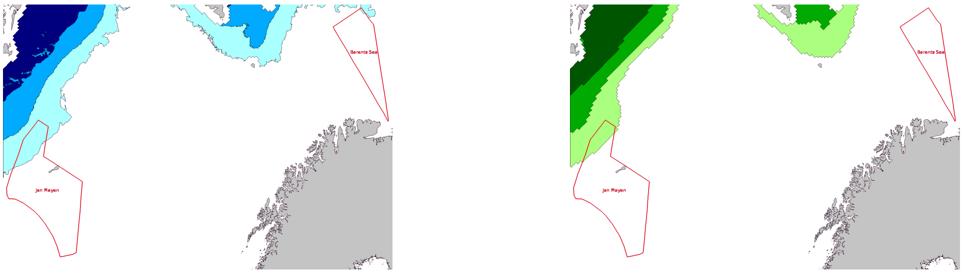
Figure 3.16: Historical ice conditions from ice charts and OSI SAF for MARCH at 40% concentration.

Ice Charts **OSI SAF**

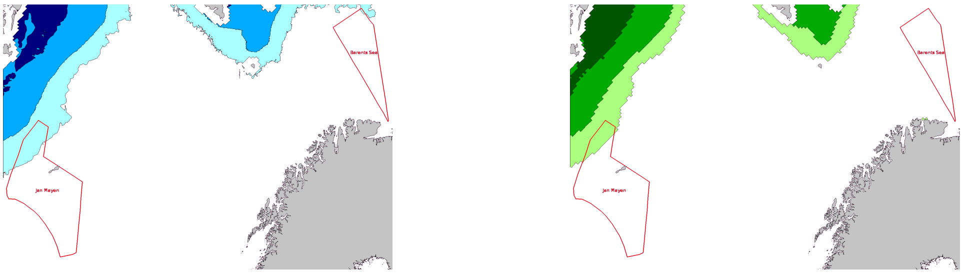
a) 2005-09 (5 years) f) 2005-09 (5 years)



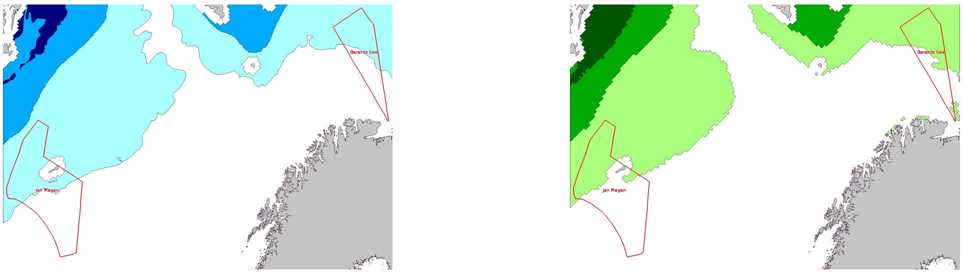
b) 2010-14 (5 years) g) 2010-14 (5 years)



c) 2005-14 (10 years) h) 2005-14 (10 years)



d) 1981-2014 (30 years) i) 1981-2014 (30 years)



e) 1967-2014 (All Data) j) 1979-2014 (All Data)

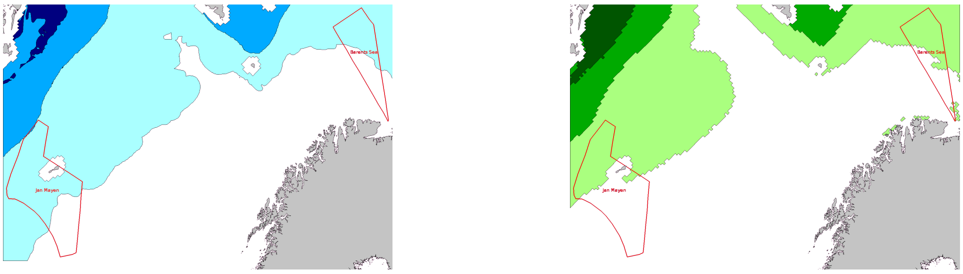
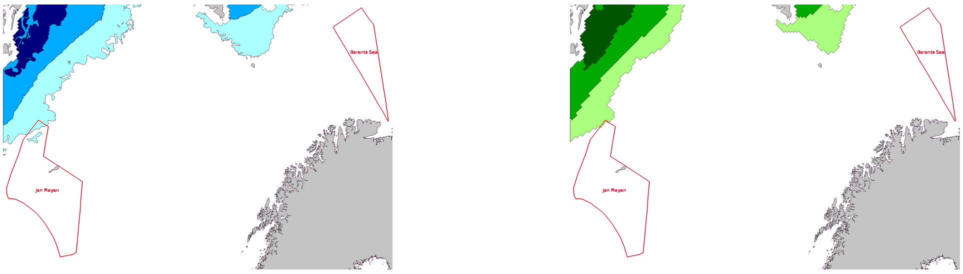


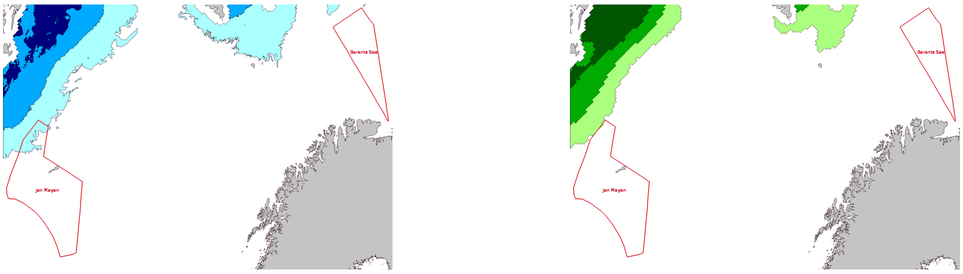
Figure 3.17: Historical ice conditions from ice charts and OSI SAF for APRIL at 40% concentration.

Ice Charts **OSI SAF**

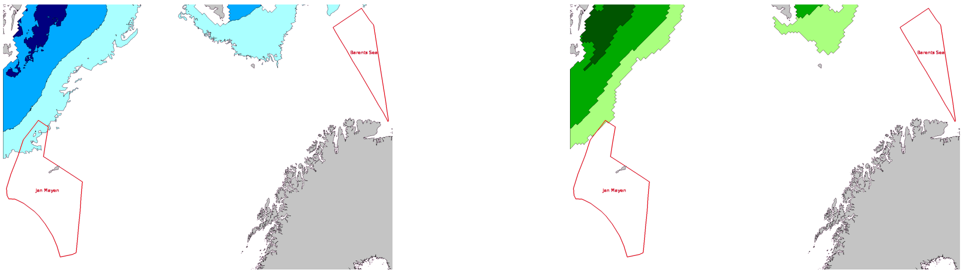
a) 2005-09 (5 years) f) 2005-09 (5 years)



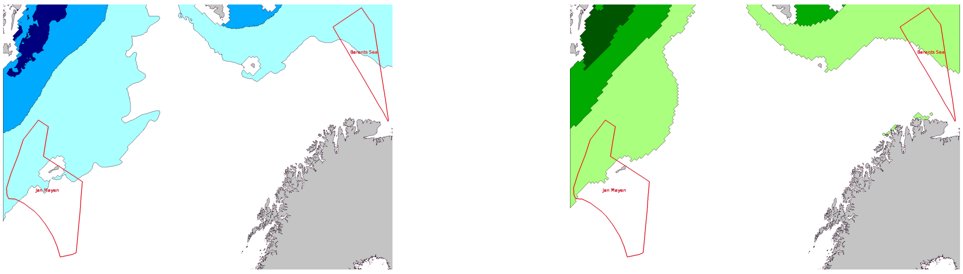
b) 2010-14 (5 years) g) 2010-14 (5 years)



c) 2005-14 (10 years) h) 2005-14 (10 years)



d) 1981-2014 (30 years) i) 1981-2014 (30 years)



e) 1967-2014 (All Data) j) 1979-2014 (All Data)

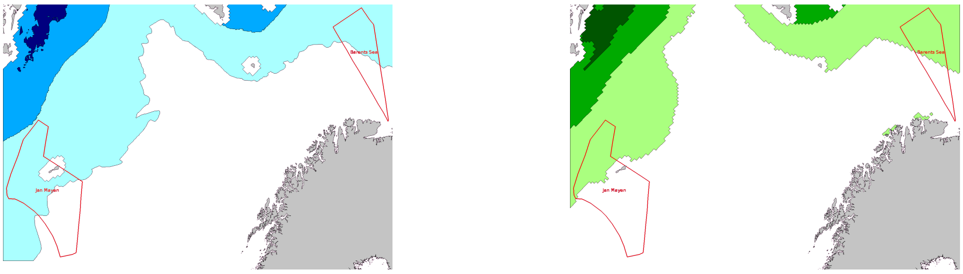
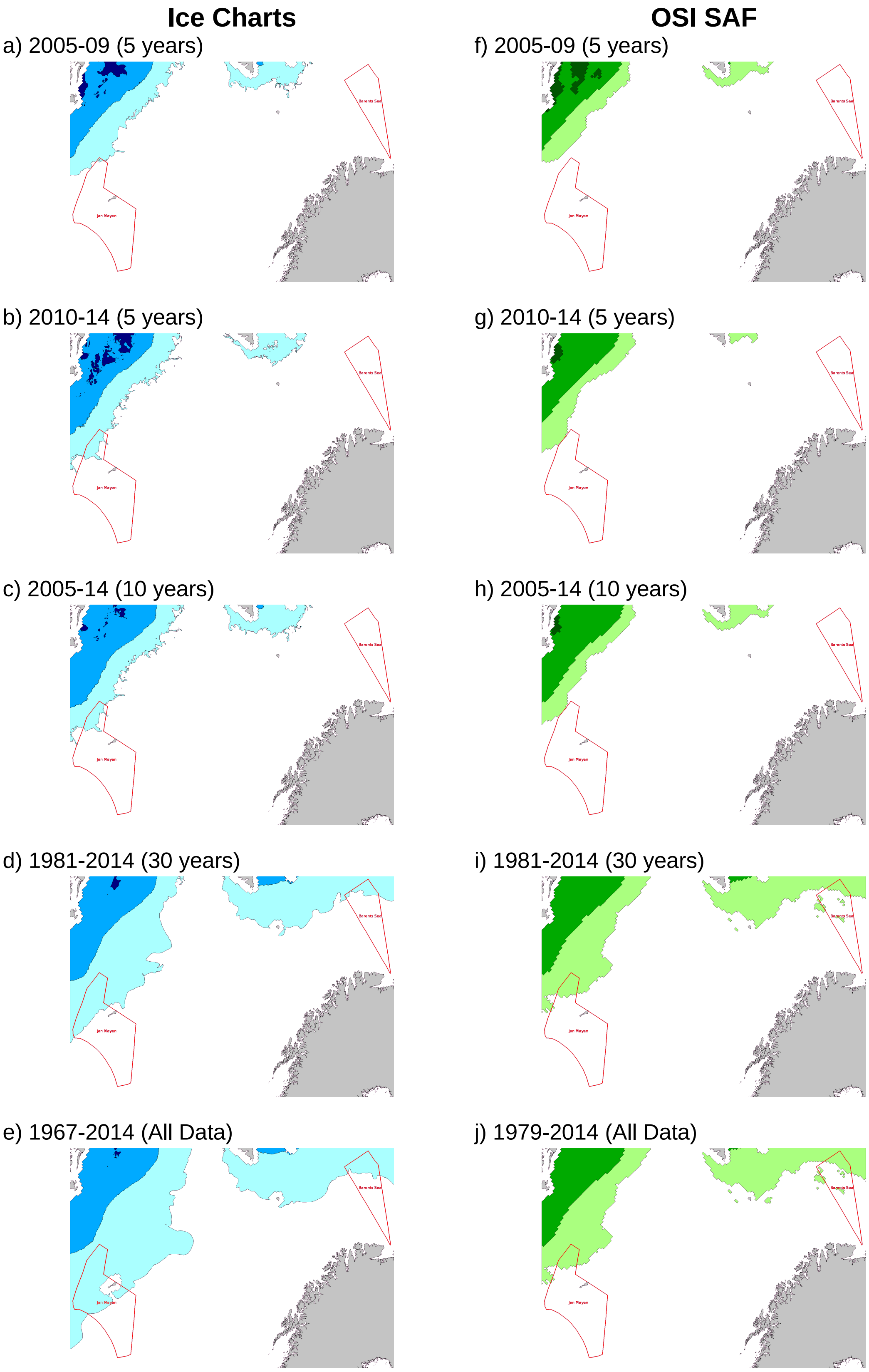


Figure 3.18: Historical ice conditions from ice charts and OSI SAF for MAY at 40% concentration.



Ice Charts

OSI SAF

a) 2005-09 (5 years)

f) 2005-09 (5 years)

b) 2010-14 (5 years)

g) 2010-14 (5 years)

c) 2005-14 (10 years)

h) 2005-14 (10 years)

d) 1981-2014 (30 years)

i) 1981-2014 (30 years)

e) 1967-2014 (All Data)

j) 1979-2014 (All Data)

Figure 3.19: Historical ice conditions from ice charts and OSI SAF for JUNE at 40% concentration.

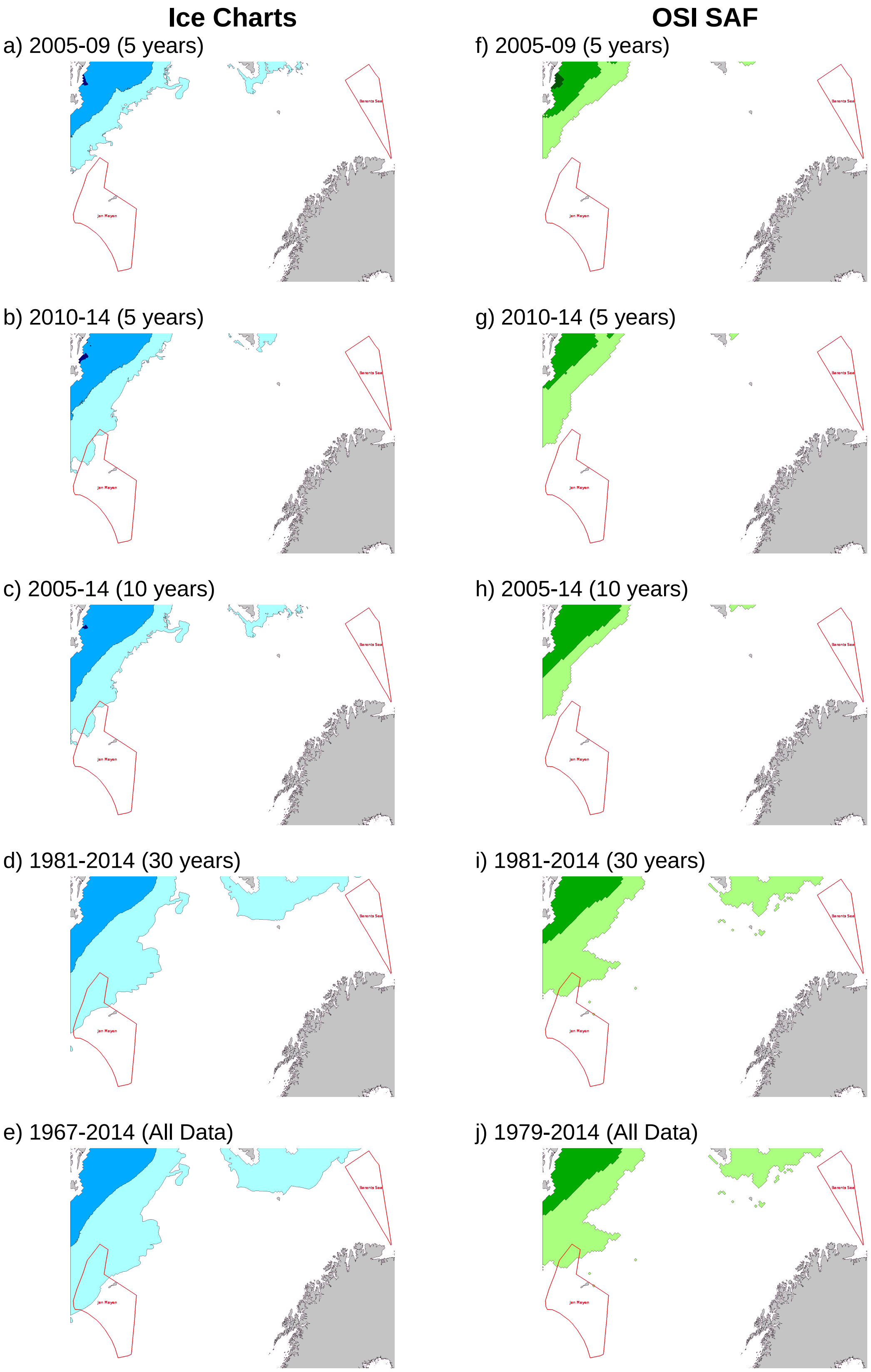
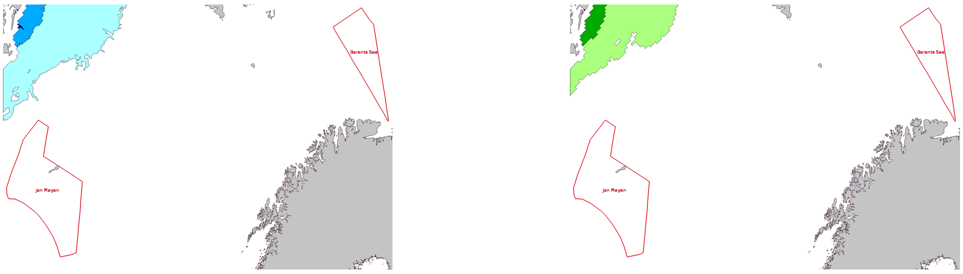
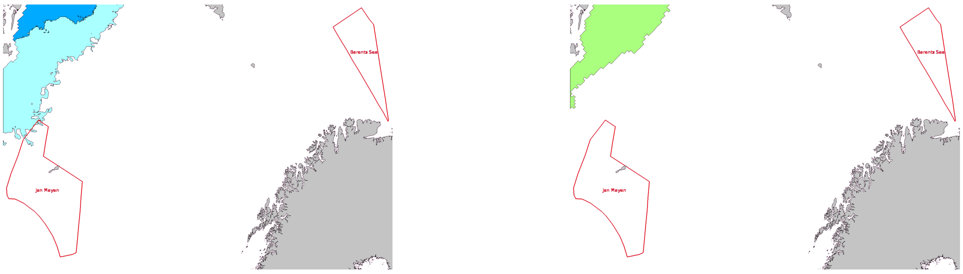


Figure 3.20: Historical ice conditions from ice charts and OSI SAF for JULY at 40% concentration.

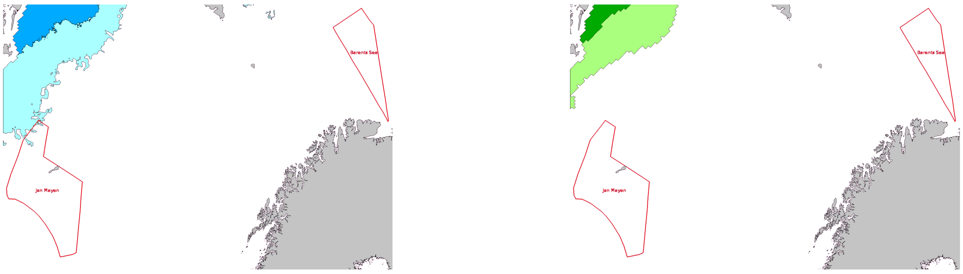
Ice Charts **OSI SAF**


a) 2005-09 (5 years)

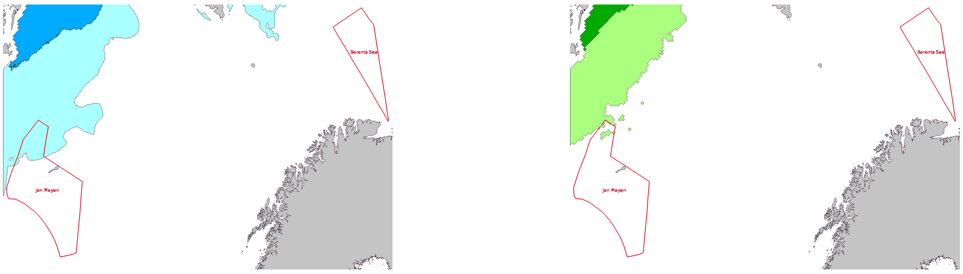
f) 2005-09 (5 years)


b) 2010-14 (5 years)

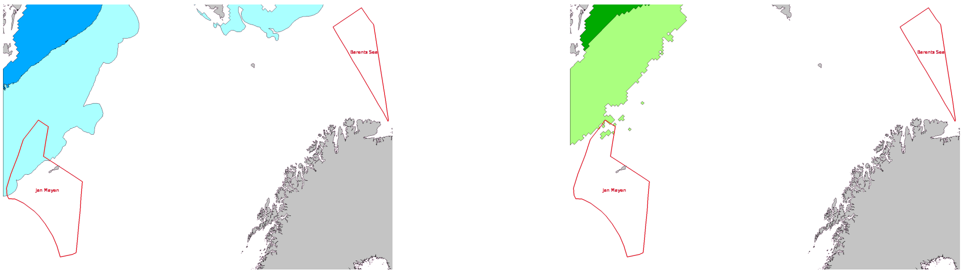
g) 2010-14 (5 years)


c) 2005-14 (10 years)

h) 2005-14 (10 years)


d) 1981-2014 (30 years)

i) 1981-2014 (30 years)

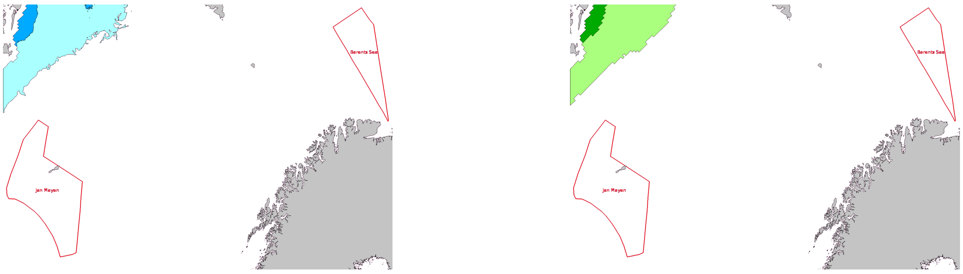

e) 1967-2014 (All Data)

j) 1979-2014 (All Data)

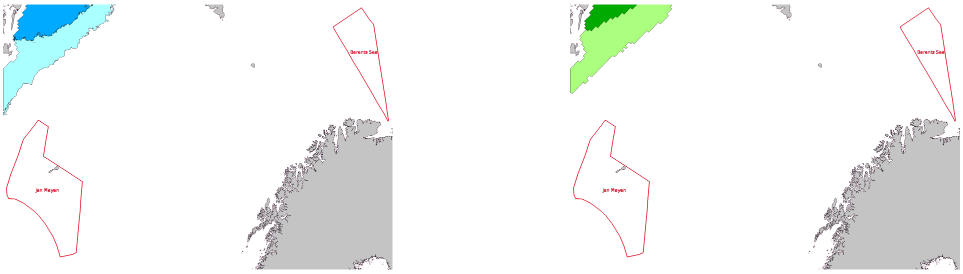
Figure 3.21: Historical ice conditions from ice charts and OSI SAF for AUGUST at 40% concentration.

Ice Charts **OSI SAF**

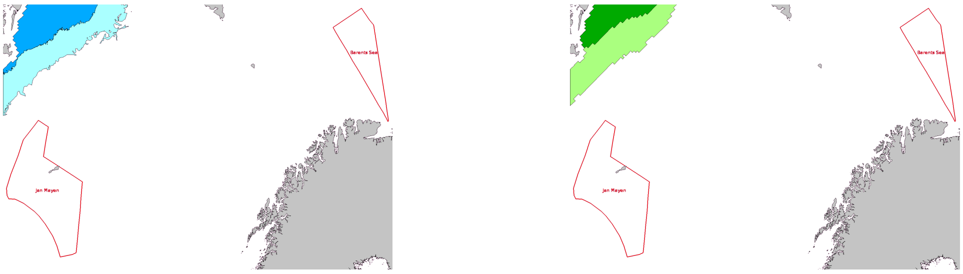
a) 2005-09 (5 years) f) 2005-09 (5 years)



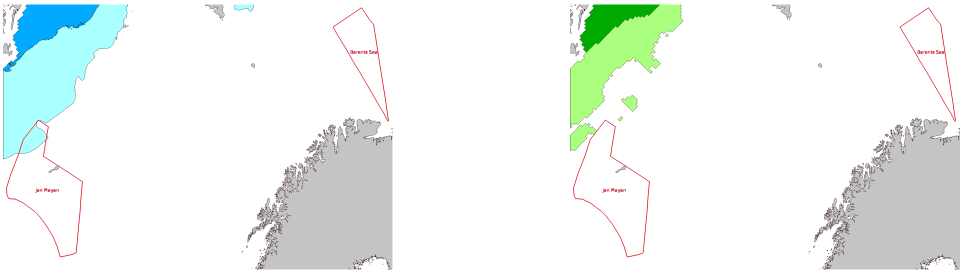
b) 2010-14 (5 years) g) 2010-14 (5 years)



c) 2005-14 (10 years) h) 2005-14 (10 years)



d) 1981-2014 (30 years) i) 1981-2014 (30 years)



e) 1967-2014 (All Data) j) 1979-2014 (All Data)

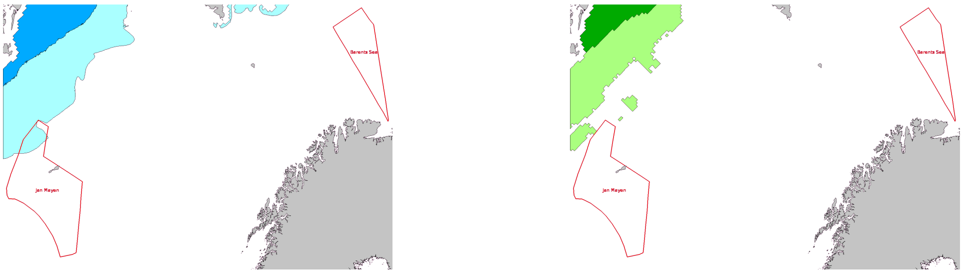
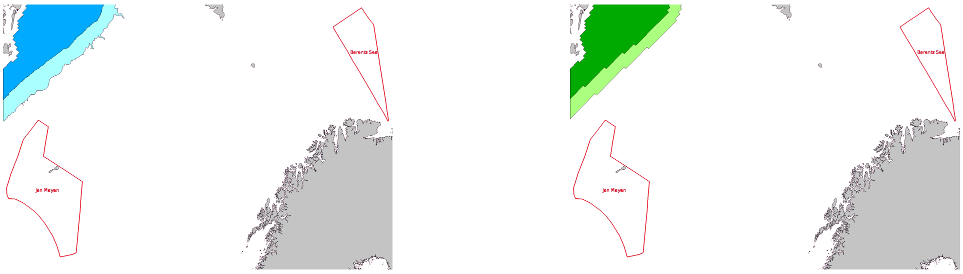


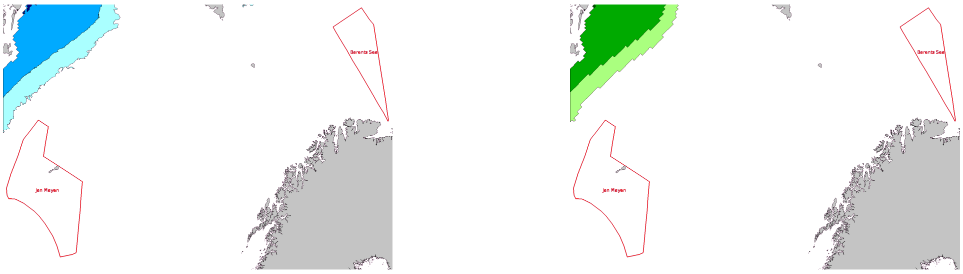
Figure 3.22: Historical ice conditions from ice charts and OSI SAF for SEPTEMBER at 40% concentration.

Ice Charts **OSI SAF**

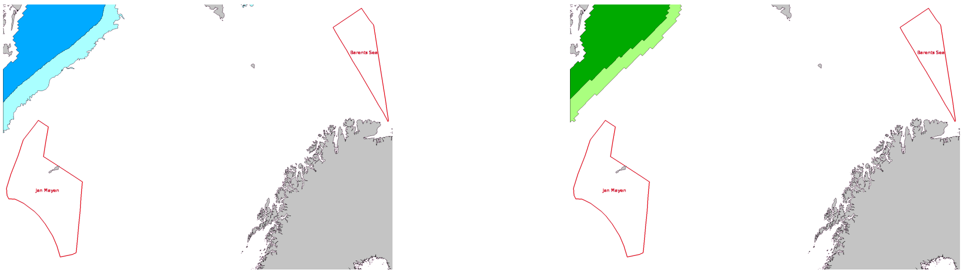
a) 2005-09 (5 years) f) 2005-09 (5 years)



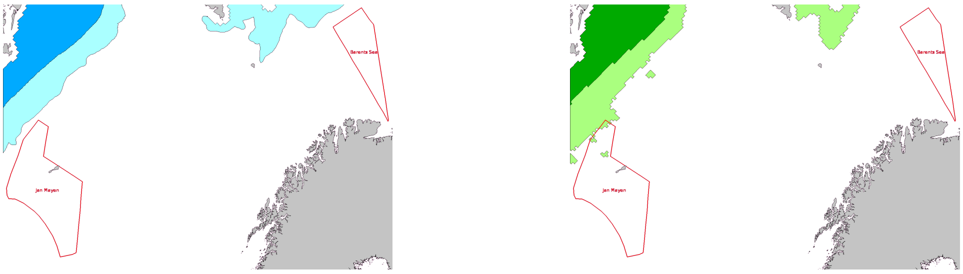
b) 2010-14 (5 years) g) 2010-14 (5 years)



c) 2005-14 (10 years) h) 2005-14 (10 years)



d) 1981-2014 (30 years) i) 1981-2014 (30 years)



e) 1967-2014 (All Data) j) 1979-2014 (All Data)

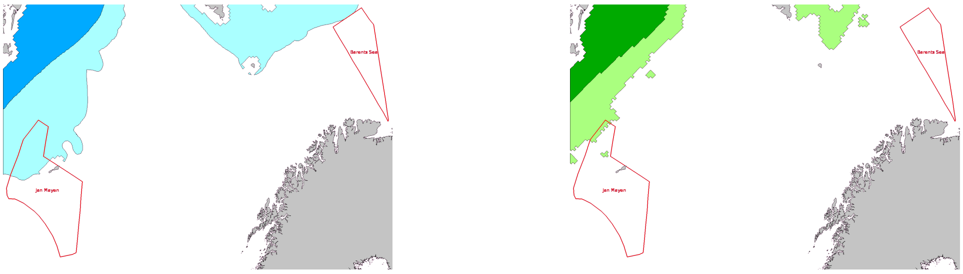
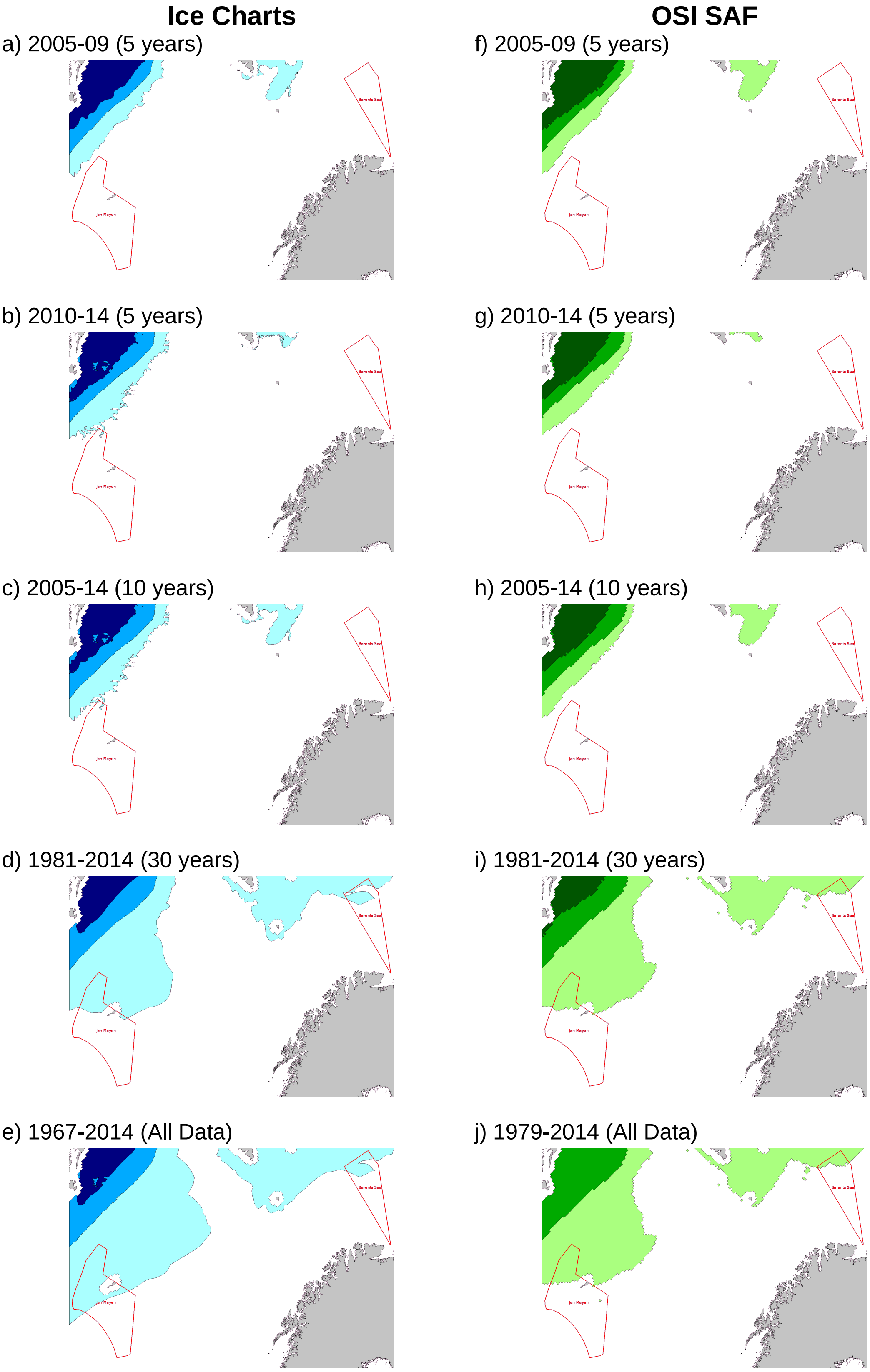


Figure 3.23: Historical ice conditions from ice charts and OSI SAF for OCTOBER at 40% concentration.



Ice Charts

OSI SAF

a) 2005-09 (5 years)

f) 2005-09 (5 years)

b) 2010-14 (5 years)

g) 2010-14 (5 years)

c) 2005-14 (10 years)

h) 2005-14 (10 years)

d) 1981-2014 (30 years)

i) 1981-2014 (30 years)

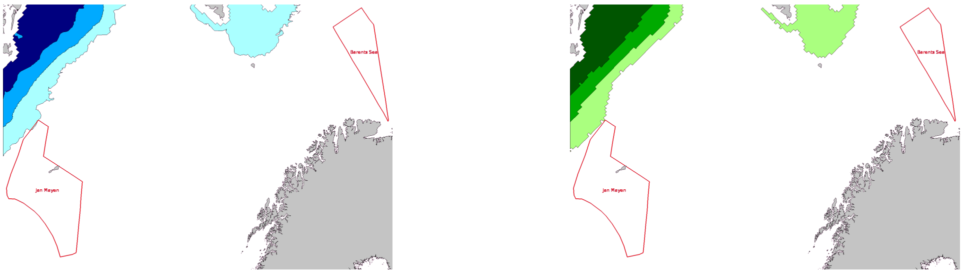
e) 1967-2014 (All Data)

j) 1979-2014 (All Data)

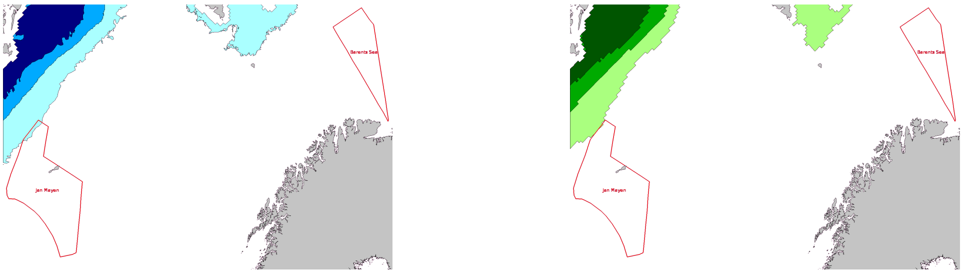
Figure 3.24: Historical ice conditions from ice charts and OSI SAF for NOVEMBER at 40% concentration.

Ice Charts **OSI SAF**

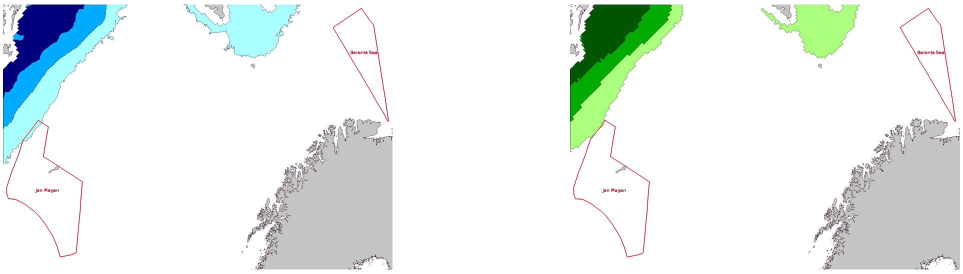
a) 2005-09 (5 years) f) 2005-09 (5 years)



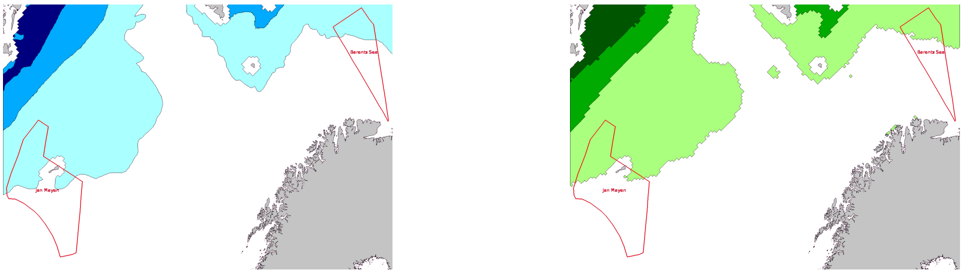
b) 2010-14 (5 years) g) 2010-14 (5 years)



c) 2005-14 (10 years) h) 2005-14 (10 years)



d) 1981-2014 (30 years) i) 1981-2014 (30 years)



e) 1967-2014 (All Data) j) 1979-2014 (All Data)

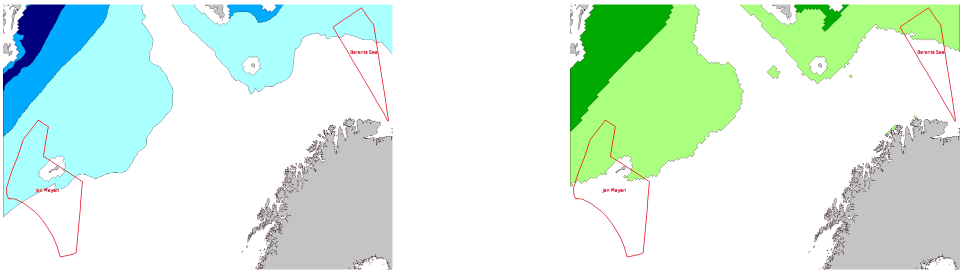
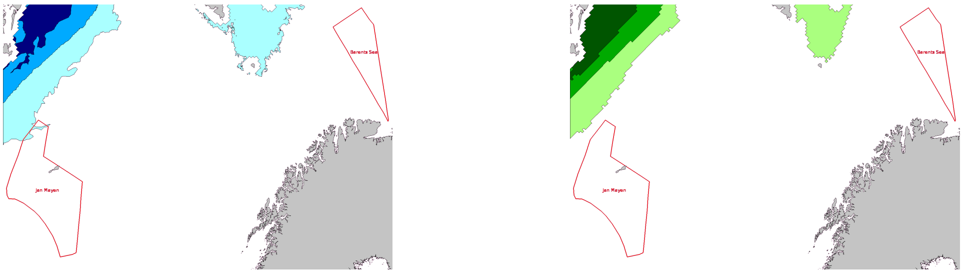
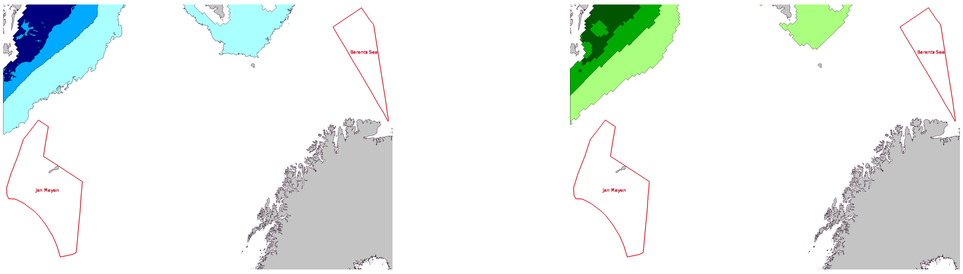


Figure 3.25: Historical ice conditions from ice charts and OSI SAF for DECEMBER at 40% concentration.

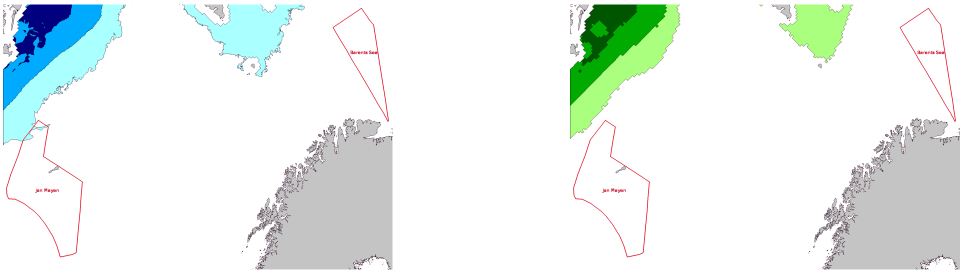
Ice Charts **OSI SAF**



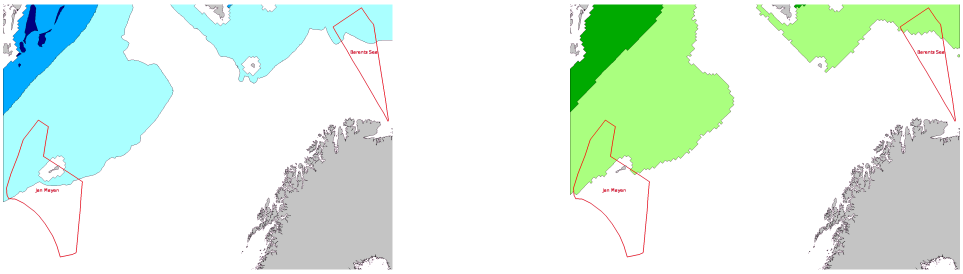
a) 2005-09 (5 years) f) 2005-09 (5 years)



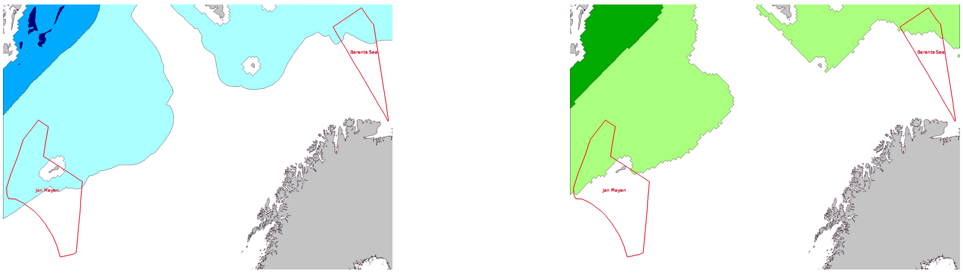
b) 2010-14 (5 years) g) 2010-14 (5 years)



c) 2005-14 (10 years) h) 2005-14 (10 years)



d) 1981-2014 (30 years) i) 1981-2014 (30 years)

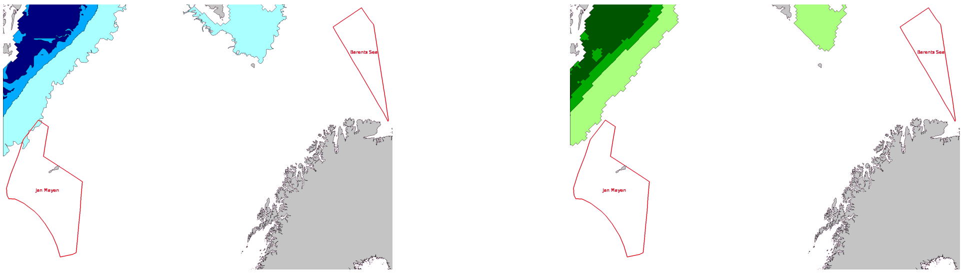


e) 1967-2014 (All Data) j) 1979-2014 (All Data)

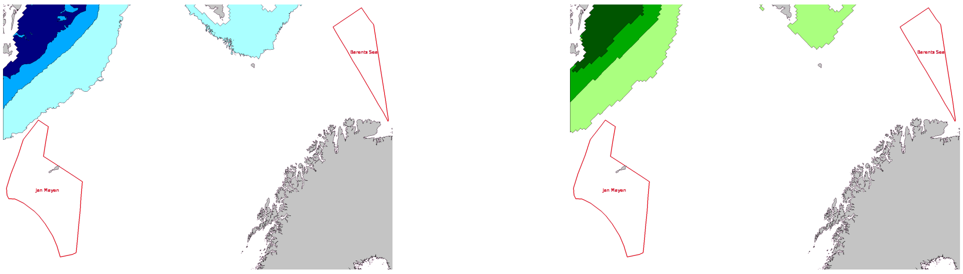
Figure 3.26: Historical ice conditions from ice charts and OSI SAF for JANUARY at 70% concentration.

Ice Charts **OSI SAF**

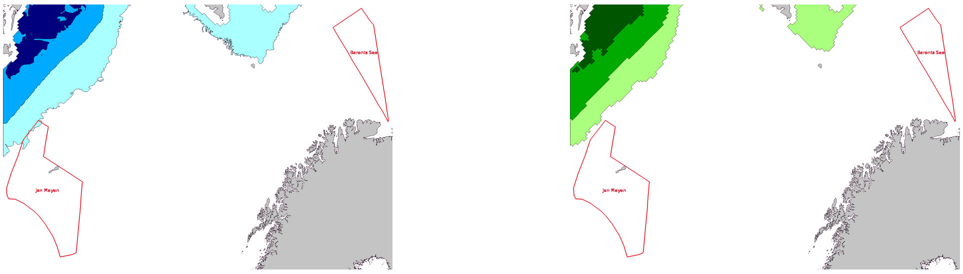
a) 2005-09 (5 years) f) 2005-09 (5 years)



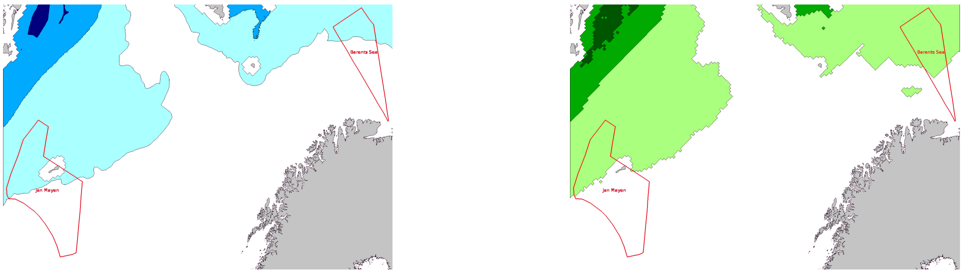
b) 2010-14 (5 years) g) 2010-14 (5 years)



c) 2005-14 (10 years) h) 2005-14 (10 years)



d) 1981-2014 (30 years) i) 1981-2014 (30 years)



e) 1967-2014 (All Data) j) 1979-2014 (All Data)

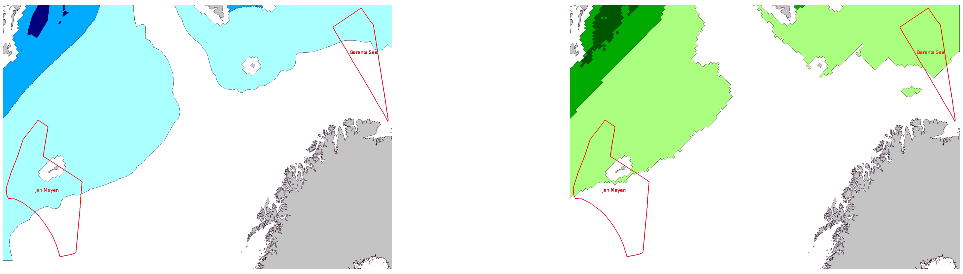
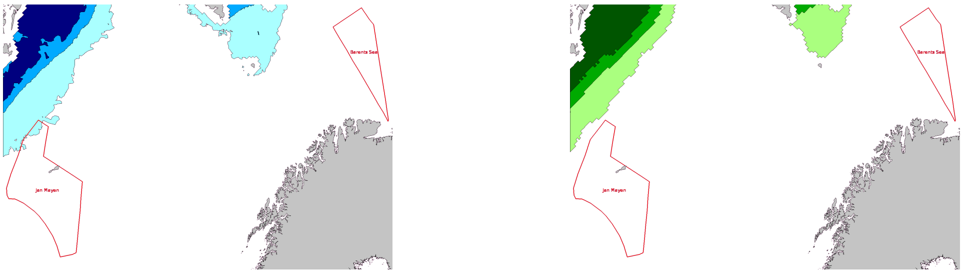
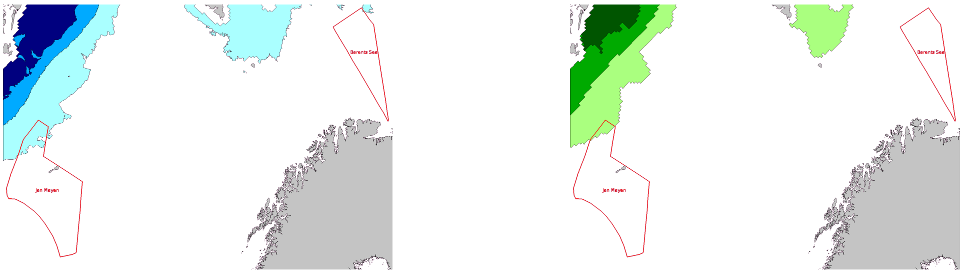


Figure 3.27: Historical ice conditions from ice charts and OSI SAF for FEBRUARY at 70% concentration.

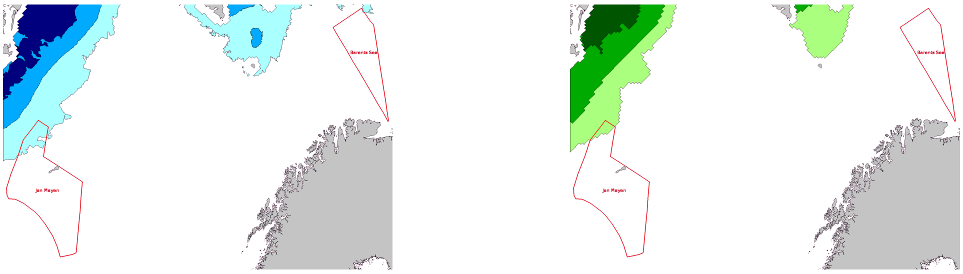
Ice Charts **OSI SAF**



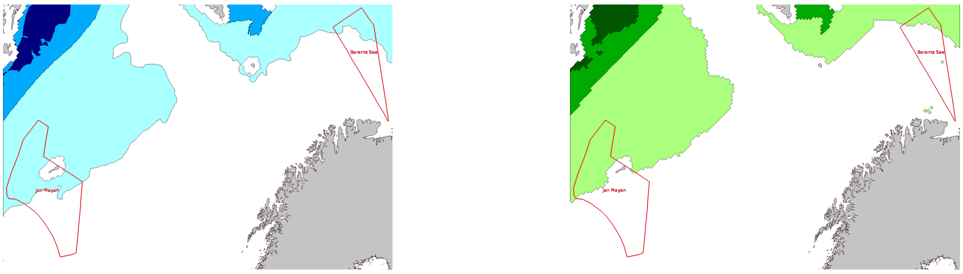
a) 2005-09 (5 years) f) 2005-09 (5 years)



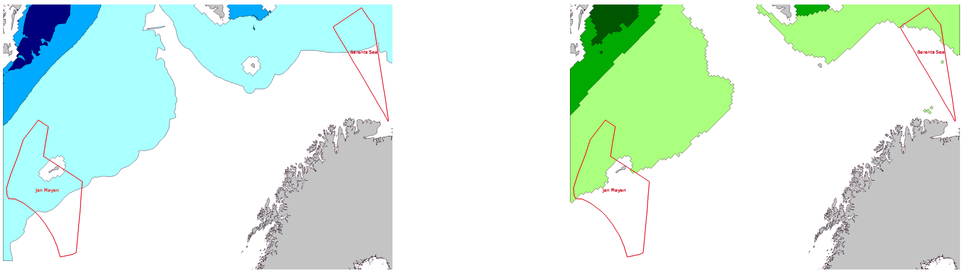
b) 2010-14 (5 years) g) 2010-14 (5 years)



c) 2005-14 (10 years) h) 2005-14 (10 years)



d) 1981-2014 (30 years) i) 1981-2014 (30 years)

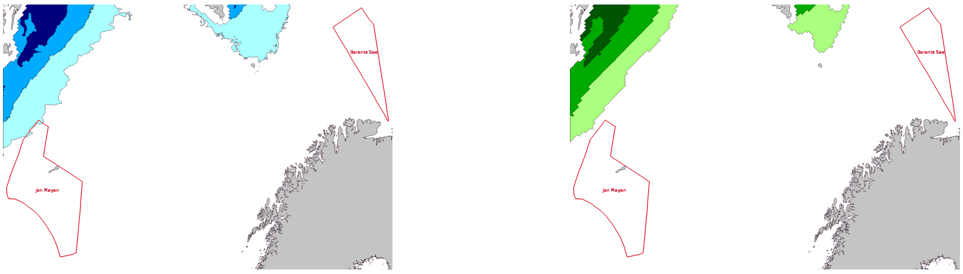


e) 1967-2014 (All Data) j) 1979-2014 (All Data)

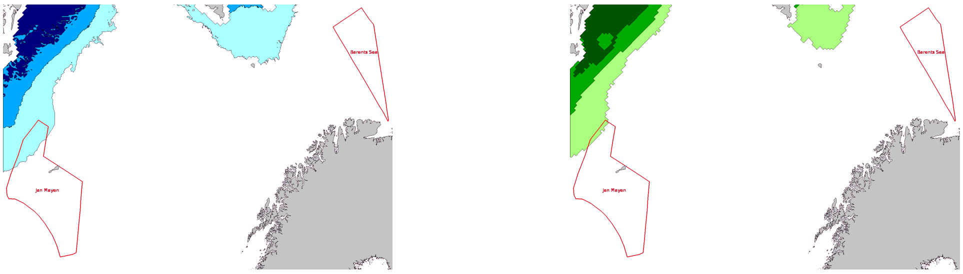
Figure 3.28: Historical ice conditions from ice charts and OSI SAF for MARCH at 70% concentration.

Ice Charts **OSI SAF**

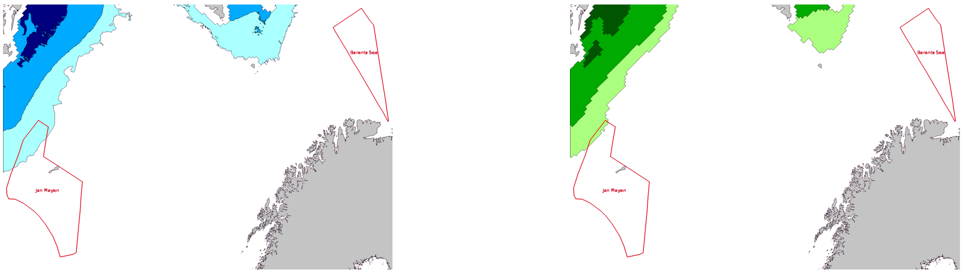
a) 2005-09 (5 years) f) 2005-09 (5 years)



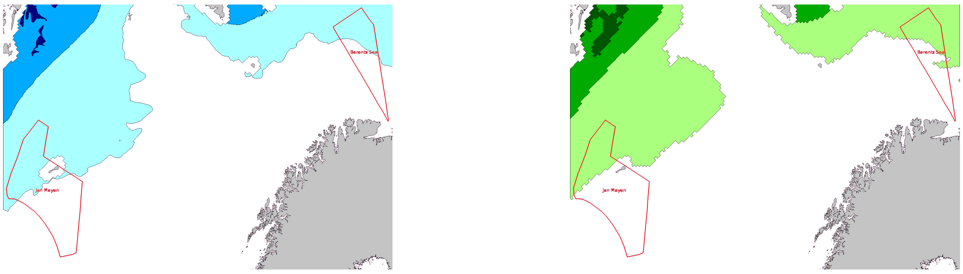
b) 2010-14 (5 years) g) 2010-14 (5 years)



c) 2005-14 (10 years) h) 2005-14 (10 years)



d) 1981-2014 (30 years) i) 1981-2014 (30 years)



e) 1967-2014 (All Data) j) 1979-2014 (All Data)

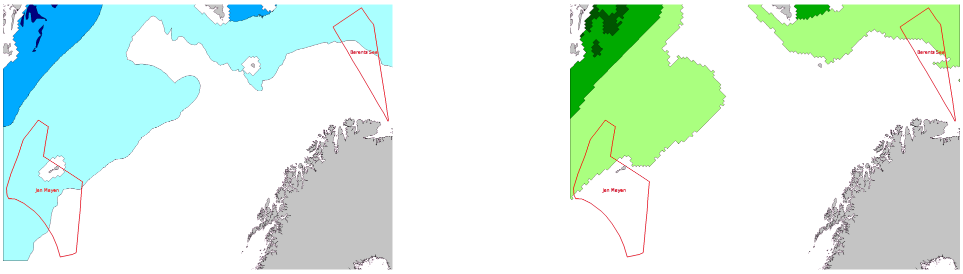
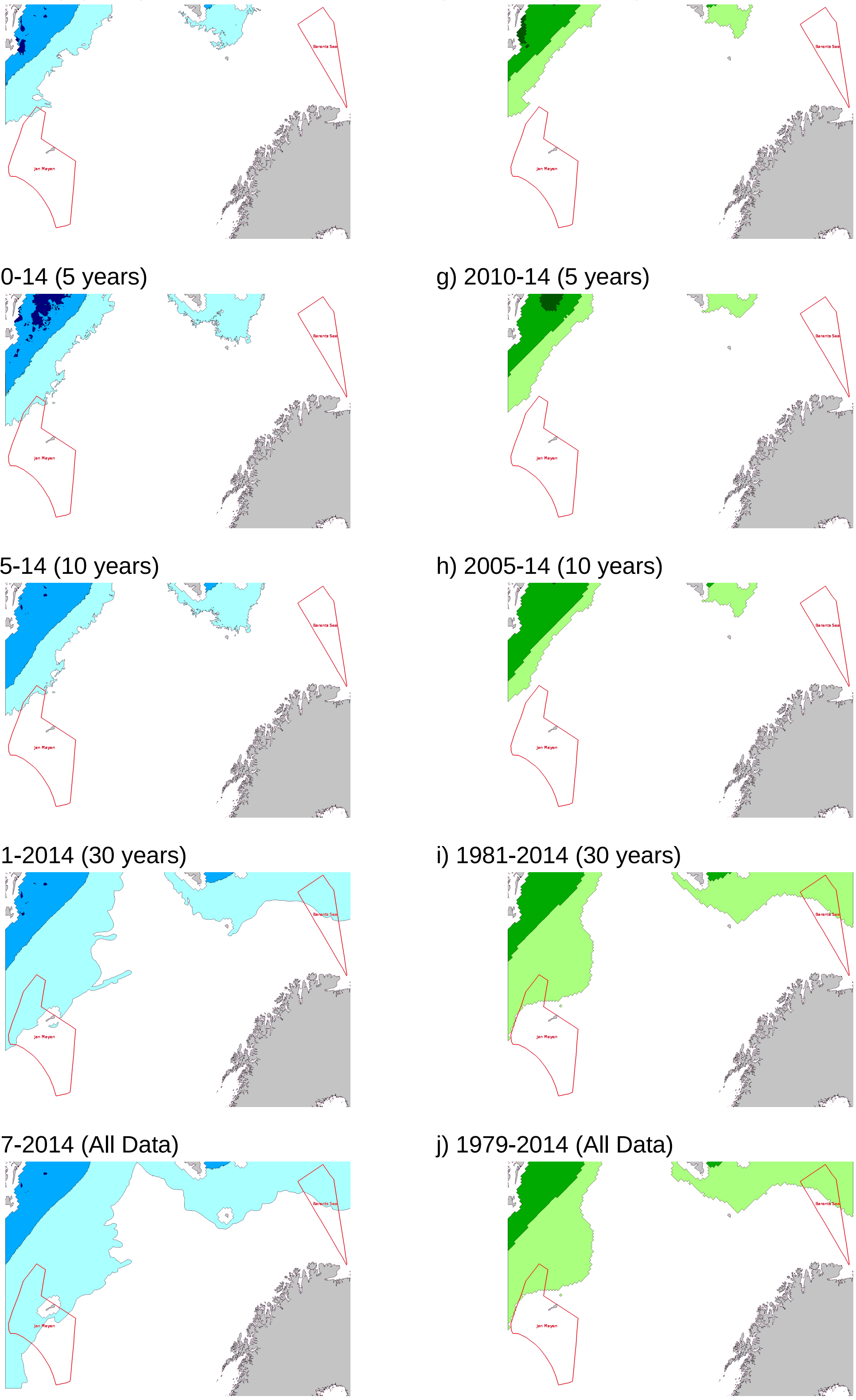


Figure 3.29: Historical ice conditions from ice charts and OSI SAF for APRIL at 70% concentration.



Ice Charts

OSI SAF

a) 2005-09 (5 years)

b) 2010-14 (5 years)

c) 2005-14 (10 years)

d) 1981-2014 (30 years)

e) 1967-2014 (All Data)

f) 2005-09 (5 years)

g) 2010-14 (5 years)

h) 2005-14 (10 years)

i) 1981-2014 (30 years)

j) 1979-2014 (All Data)

Figure 3.30: Historical ice conditions from ice charts and OSI SAF for MAY at 70% concentration.

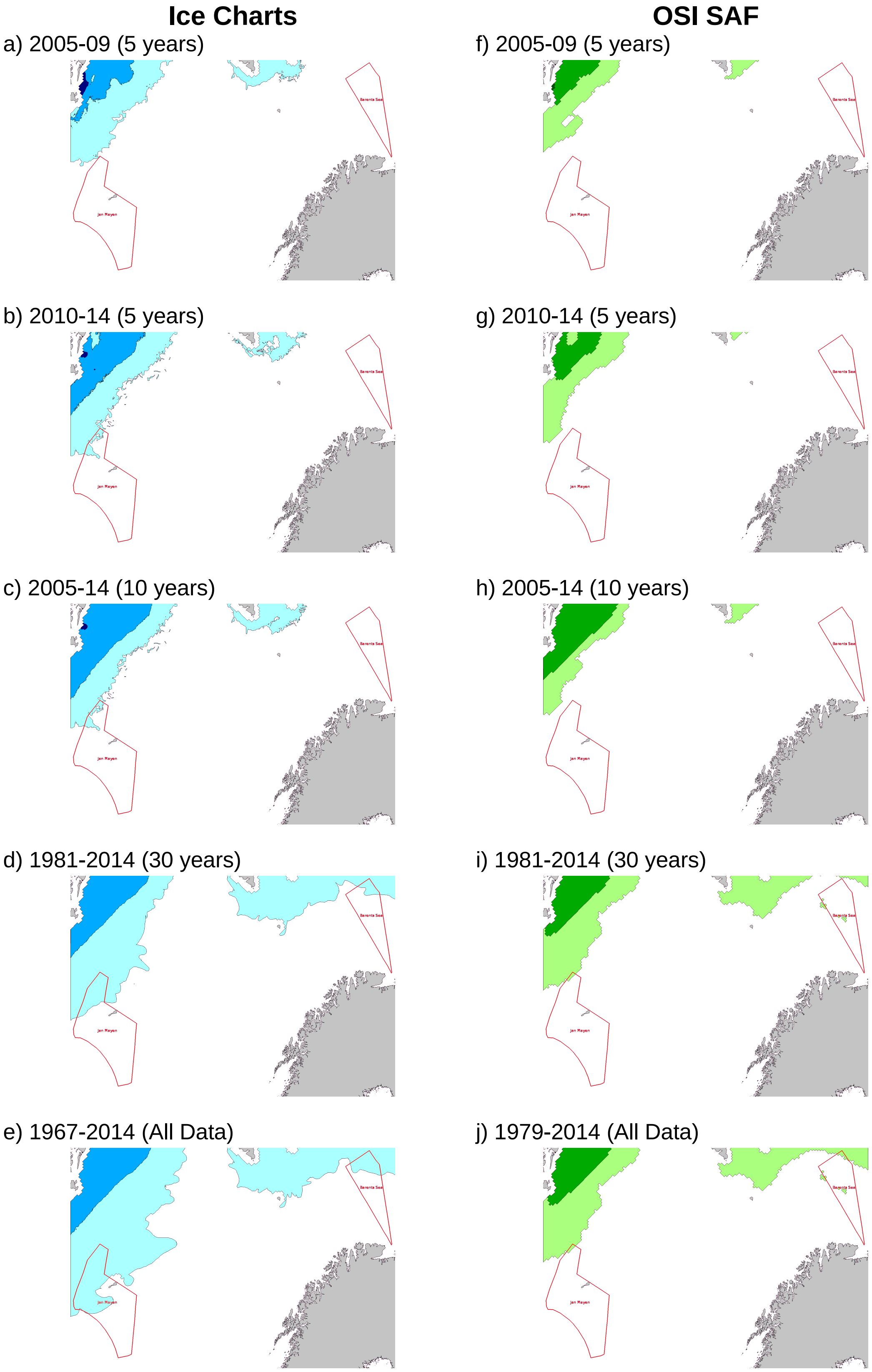
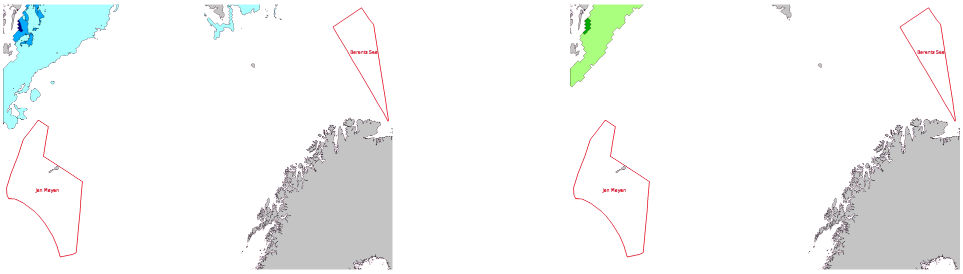
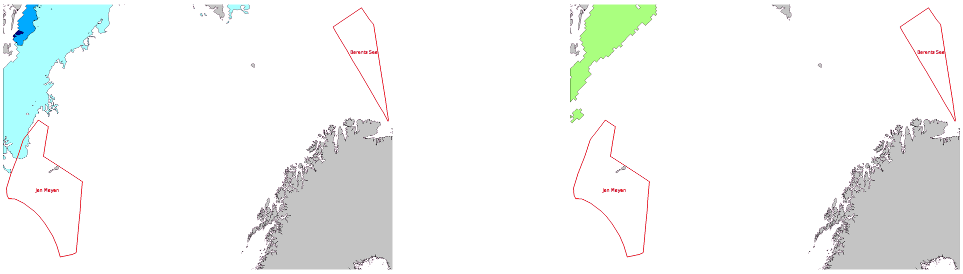


Figure 3.31: Historical ice conditions from ice charts and OSI SAF for JUNE at 70% concentration.

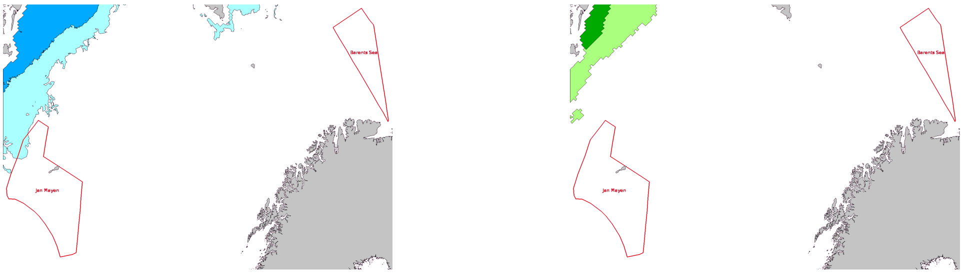
Ice Charts **OSI SAF**


a) 2005-09 (5 years)

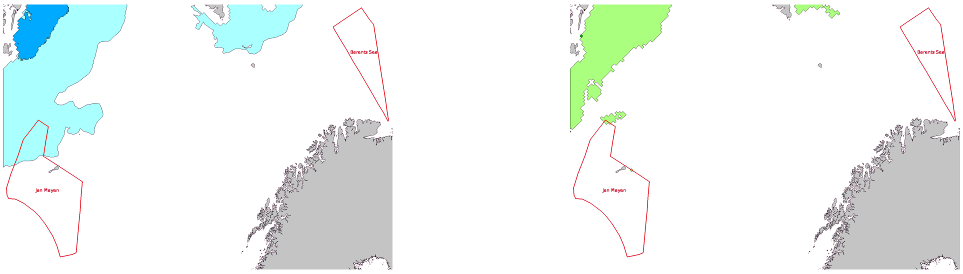
f) 2005-09 (5 years)


b) 2010-14 (5 years)

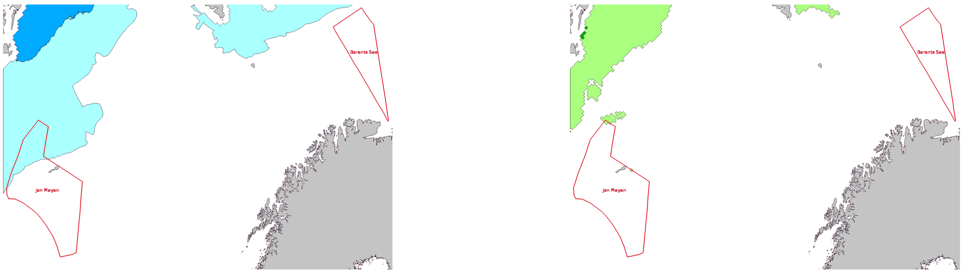
g) 2010-14 (5 years)


c) 2005-14 (10 years)

h) 2005-14 (10 years)


d) 1981-2014 (30 years)

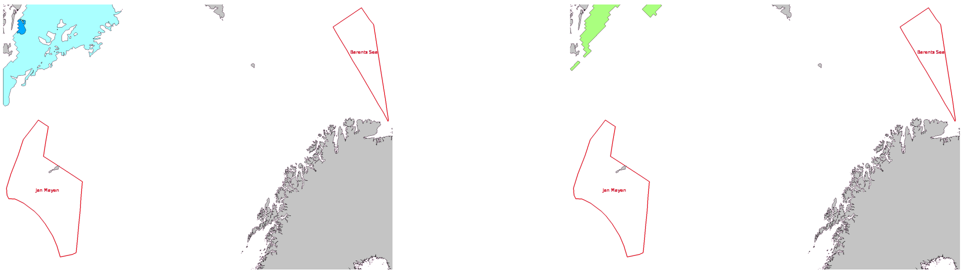
i) 1981-2014 (30 years)

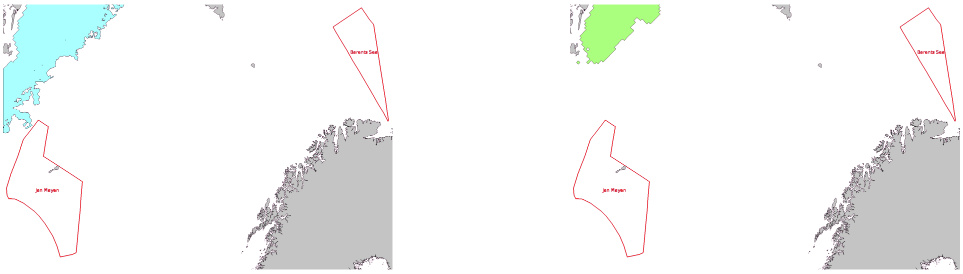

e) 1967-2014 (All Data)

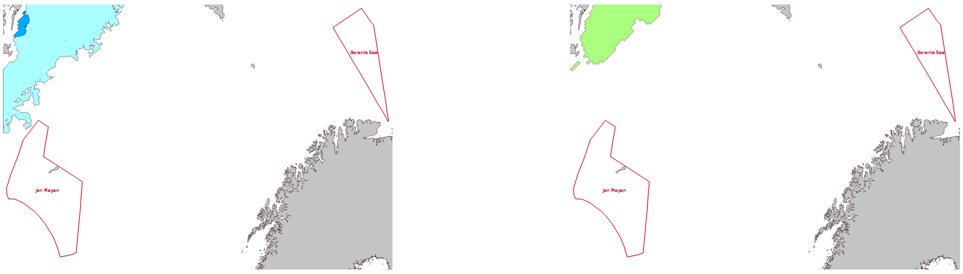
j) 1979-2014 (All Data)

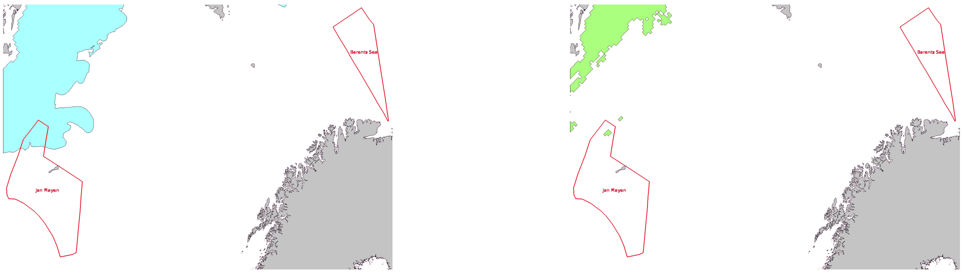
Figure 3.32: Historical ice conditions from ice charts and OSI SAF for JULY at 70% concentration.

Ice Charts **OSI SAF**


a) 2005-09 (5 years)
f) 2005-09 (5 years)


b) 2010-14 (5 years)
g) 2010-14 (5 years)


c) 2005-14 (10 years)
h) 2005-14 (10 years)


d) 1981-2014 (30 years)
i) 1981-2014 (30 years)

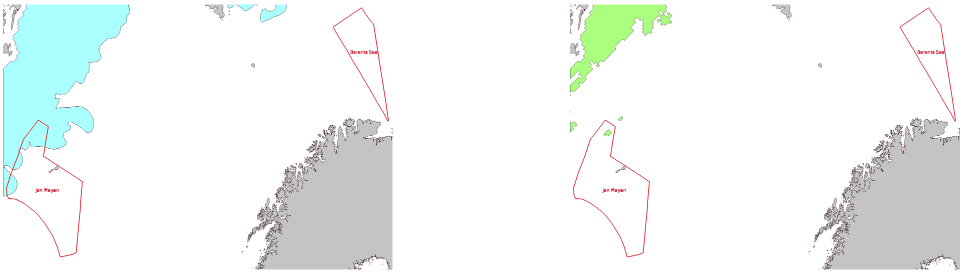

e) 1967-2014 (All Data)
j) 1979-2014 (All Data)

Figure 3.33: Historical ice conditions from ice charts and OSI SAF for AUGUST at 70% concentration.

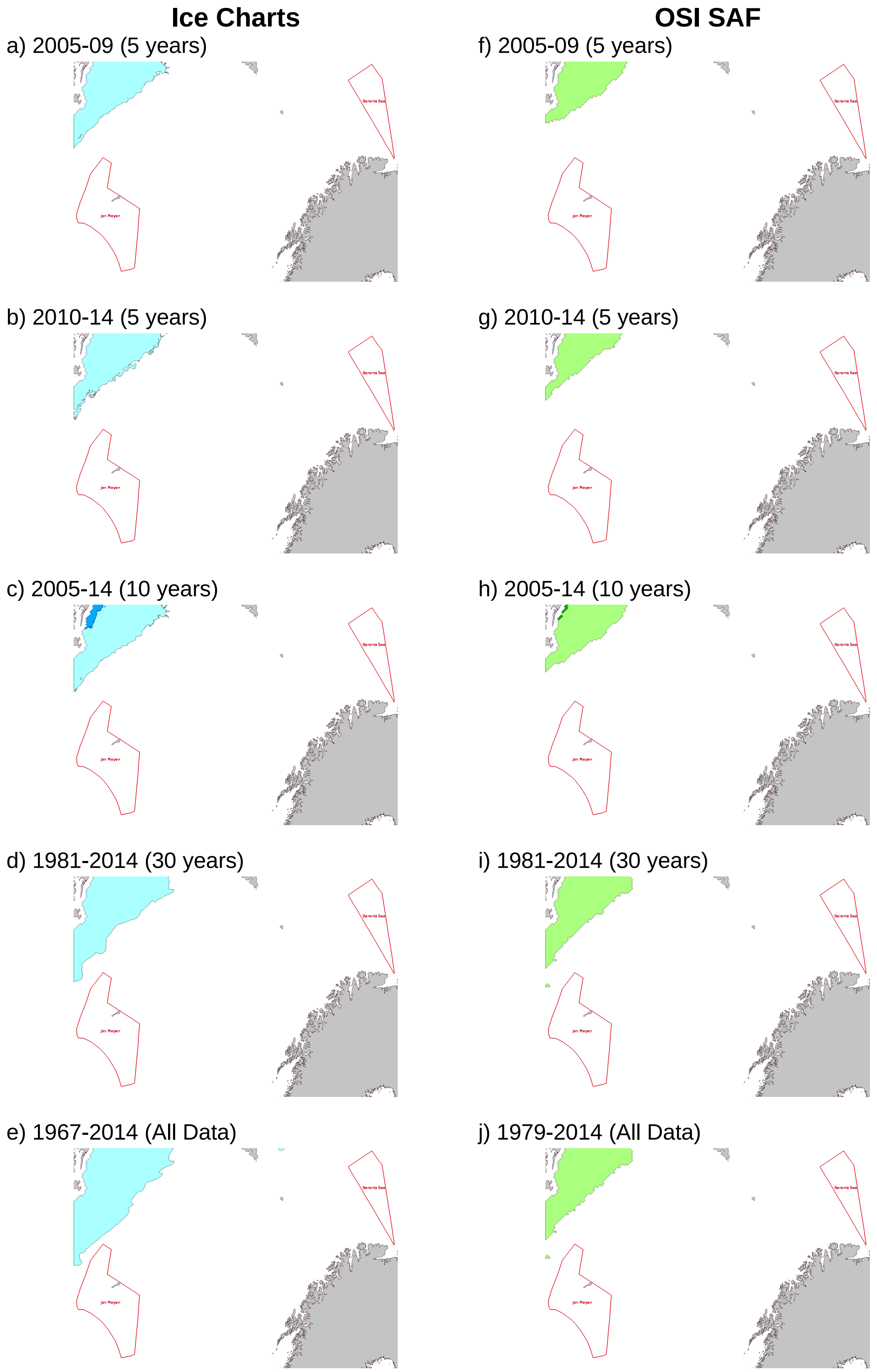
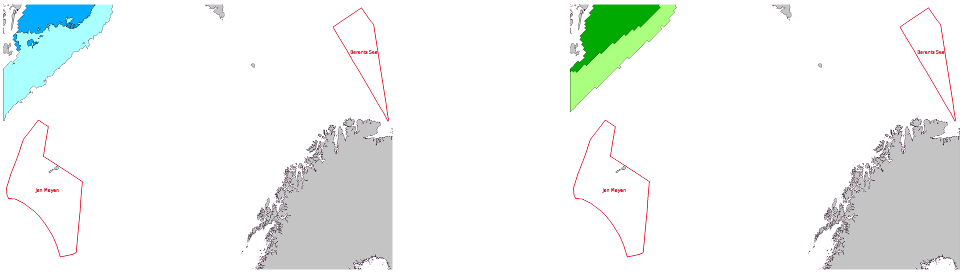


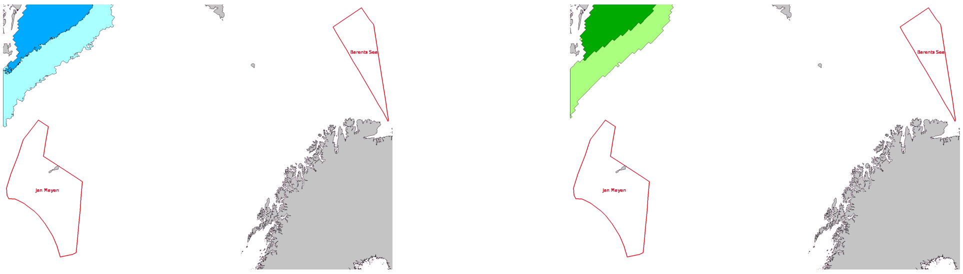
Figure 3.34: Historical ice conditions from ice charts and OSI SAF for SEPTEMBER at 70% concentration.

Ice Charts

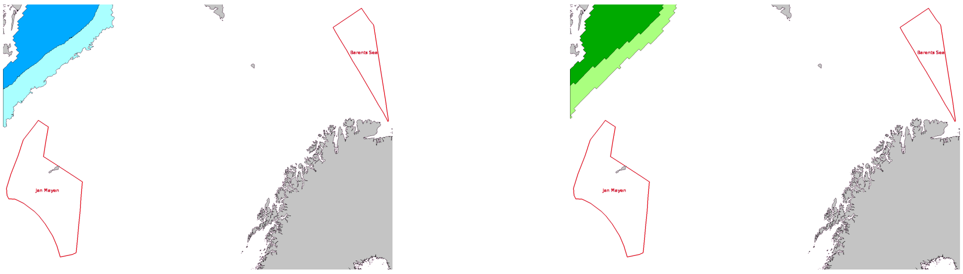
OSI SAF


a) 2005-09 (5 years)

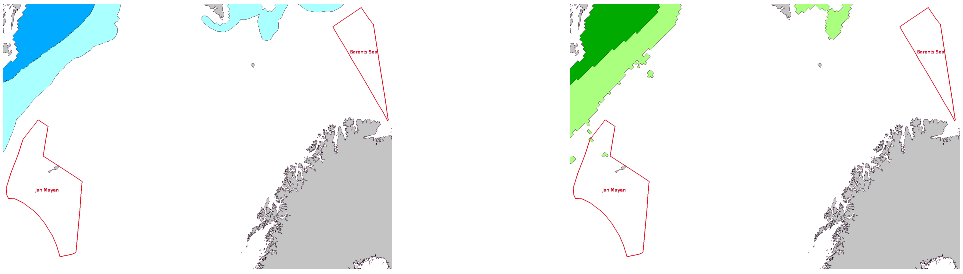
f) 2005-09 (5 years)


b) 2010-14 (5 years)

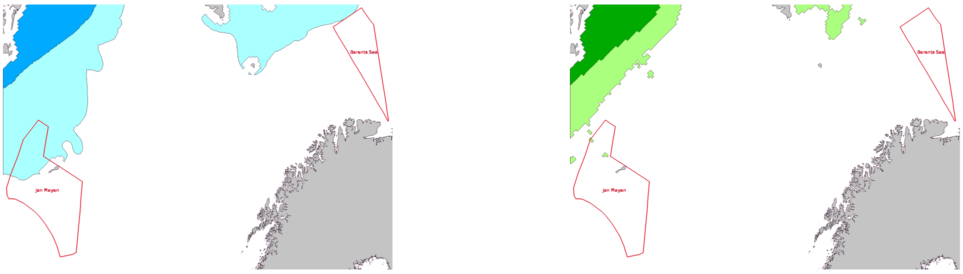
g) 2010-14 (5 years)


c) 2005-14 (10 years)

h) 2005-14 (10 years)


d) 1981-2014 (30 years)

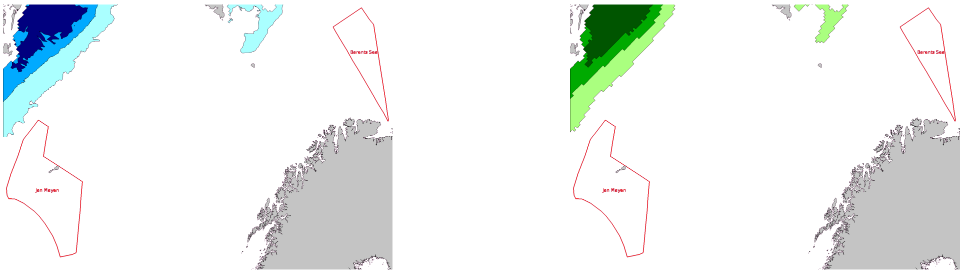
i) 1981-2014 (30 years)


e) 1967-2014 (All Data)

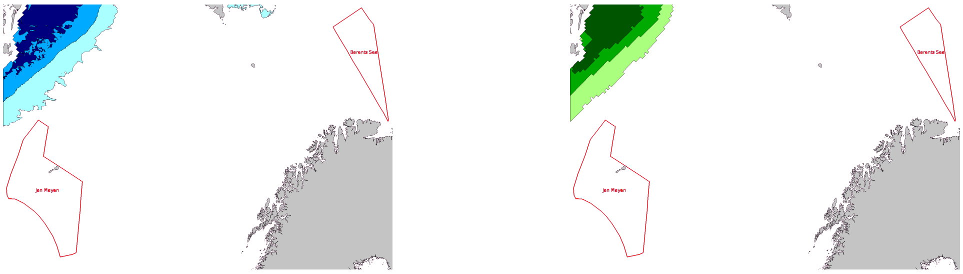
j) 1979-2014 (All Data)

Figure 3.35: Historical ice conditions from ice charts and OSI SAF for OCTOBER at 70% concentration.

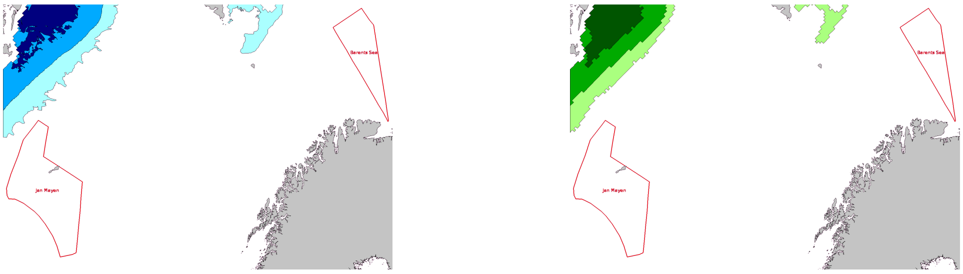
Ice Charts **OSI SAF**



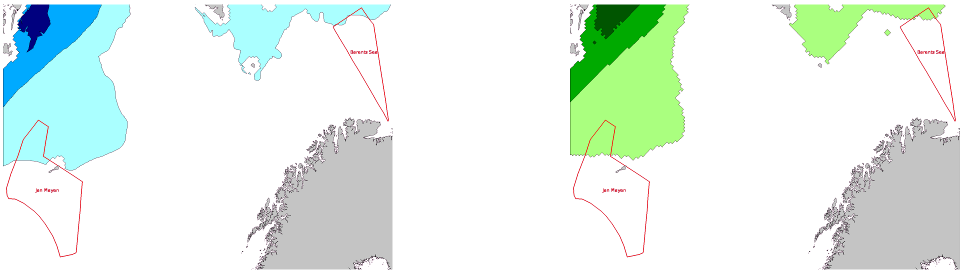
a) 2005-09 (5 years) f) 2005-09 (5 years)



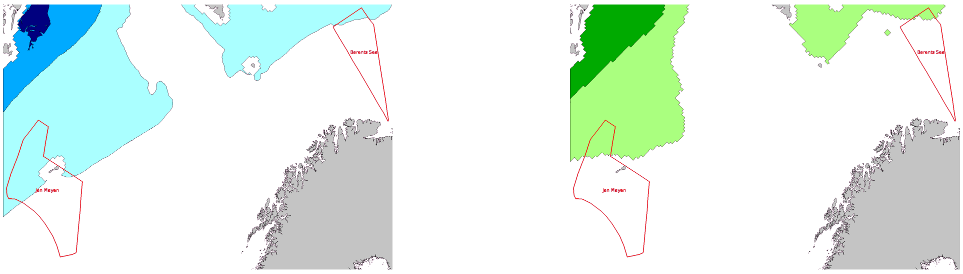
b) 2010-14 (5 years) g) 2010-14 (5 years)



c) 2005-14 (10 years) h) 2005-14 (10 years)

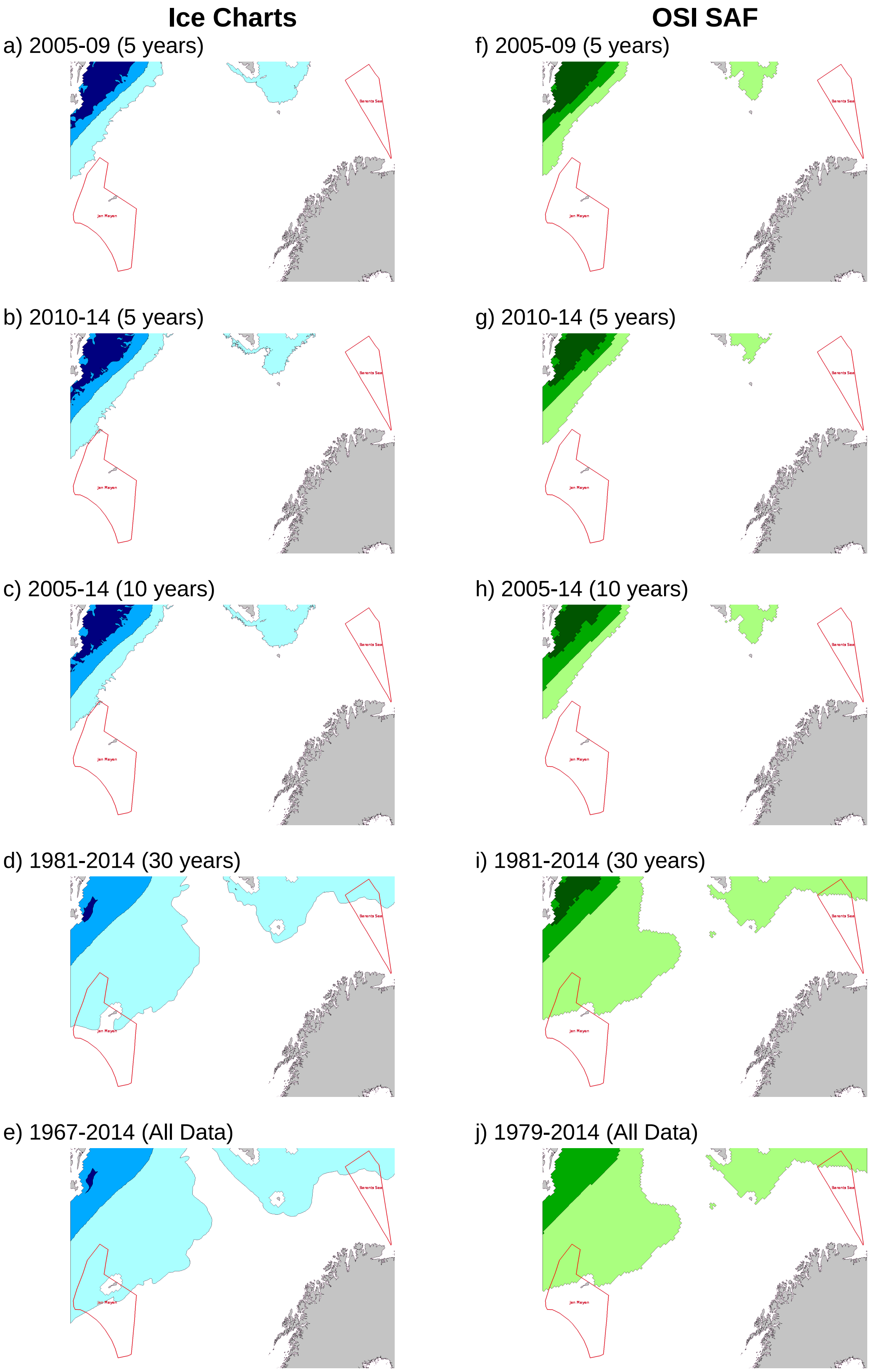


d) 1981-2014 (30 years) i) 1981-2014 (30 years)



e) 1967-2014 (All Data) j) 1979-2014 (All Data)

Figure 3.36: Historical ice conditions from ice charts and OSI SAF for NOVEMBER at 70% concentration.



a) 2005-09 (5 years)

f) 2005-09 (5 years)

b) 2010-14 (5 years)

g) 2010-14 (5 years)

c) 2005-14 (10 years)

h) 2005-14 (10 years)

d) 1981-2014 (30 years)

i) 1981-2014 (30 years)

e) 1967-2014 (All Data)

j) 1979-2014 (All Data)

Figure 3.37: Historical ice conditions from ice charts and OSI SAF for DECEMBER at 70% concentration.

4 Sesongprognosemodeller / Seasonal Forecast Models

4.1 Innledning

Denne delen beskriver sesongvise prognosemodeller for sjøis utviklet av NIS.

For områdetberegningen omkring Svalbard er det brukt en boks med 72-85 grader nordlig bredde, 0-40 grader østlig lengde, OSI SAFs landmaske kommer til fradrag.

4.2 Weka programvare

Prognosemodellsystemet på NIS bruker Weka programvare (http://www.cs.waikato.ac.nz/ml/weka/) for å utlede enkle empiriske prognoser for isutbredelse rundt Svalbard, med prognose-lengde opp til 12 måneder.

Tidsseriekomponeneten til denne program-varen tar flere parametre, og beregner beste tilpasning for disse parametrene for flere ulike forsinkelser (lags). Vektingen av beste tilpasning for ulike parametre brukes så for å utlede en prognosemodell.

4.3 Enkel empirisk prognosemodell

Den enkle empiriske prognosemodellen (SEFM) henter et utvalg månedlige parametre observert i perioden fra januar 1967 fram til i dag, og bruker Weka til å bestemme den beste kombinasjonen av disse, med etterslep, slik at det passer den observerte månedlige isutbredelsen for Svalbard.

Introduction

This section describes the seasonal sea ice forecast models developed by the NIS.

The Svalbard sea ice area used is a box 72-85 degrees North Latitude, 0-40 degrees East Longitude, minus the OSI SAF land mask.

Weka Software

The seasonal forecast model system at NIS uses Weka data mining software (http://www.cs.waikato.ac.nz/ml/weka/) to derive simple empirical forecasts of the sea ice extent around Svalbard up to 12 months in advance.

The time series component of this software takes any number of parameters, and investigates the best fit of these to a desired parameter at differing lags. The weighting of the best fits of these parameters in then used to derive a forecast model.

Simple Empirical Forecast Model

The Simple Empirical Forecast Model (SEFM) takes an number of monthly parameters observed over the period January 1967 to present and uses Weka to determine the best combination of these, with lags, to fit the observed monthly Svalbard sea ice extent.

Parametrene er:

Arctic Oscillation (AO) Indeks

Månedlige gjennomsnittsverdier fra januar 1950 er lastet ned fra NOAA NCEP (http://www.cpc.ncep.noaa.gov/products/precip/CWlink/daily_ao_index/ao.shtml)

AO (også referert til som Northern Annular Mode/Northern Hemisphere Annular Mode (NAM)) er en indeks som brukes for å beskrive det dominerende mønsteret av ikke-sesongavhengige trykkanomalier i Arktis, versus motsatte anomalier i Atlanterhavet og Stillehavets sektorer ved 37 -45 ° N (Thompson et al 1998). Som forskjeller i lufttrykk driver vinden på jordas overflate, vil svingninger og trender i AO påvirke havisens bevegelse over Arktis, og særlig hvor mye isen er drevet mot kysten av Svalbard (Rigor et al. 2002).

Lufttrykket i Framstredet og lufttrykket i Barentshavet

I tillegg til AO, er lufttrykket i havnivå nær Svalbard vurdert i forhold til lokasjoner i Framstredet (10°W 80°N) og Barentshavet (20°E 73°N). Begrunnelsen for innlemmelse av disse parametrene er observasjon (Vinje, 2001) at havis fluks i Framstredet er lineært relatert til trykkforskjellen mellom disse to stedene.

Data om havnivå er hentet fra NOAA NCEP-NCAR reanalyse (http://www.esrl.noaa.gov/psd/data/reanalysis/reanalysis.shtml).

SST på NV Svalbard, Bjørnøya, og Island-Storbritannia

Havoverflatetemperatur (SST) gir en indikasjon på varmetransport fra lavere breddegrader til Svalbard og potensiale til å smelte isen. SST er hentet fra tre steder, NV Svalbard (10°E 79°N), Norge-Bjørnøya (19,45 °E 72,42°N), og Island-Storbritannia (349,7°E 63,42°N). Data blir hentet fra NOAAs Extended Reconstructed Sea Surface Temperature (SST) V3b.

The parameters include:

Arctic Oscillation (AO) Index

Monthly mean values from January 1950 downloaded from NOAA NCEP (http://www.cpc.ncep.noaa.gov/products/precip/CWlink/daily_ao_index/ao.shtml)

The AO (also referred to as the Northern Annular Mode/Northern Hemisphere Annular Mode (NAM) is an index of the dominant pattern of non-seasonal sea-level pressure anomalies in the Arctic, versus opposite anomalies in the Atlantic and Pacific sectors at 37-45°N (Thompson et al 1998). As SLP differences drive surface winds, fluctuations and trends in the AO affect sea ice motion across the Arctic and in particular how much ice is driven against the coast of Svalbard (Rigor et al. 2002).

Pressure Fram Strait and Pressure Barents Sea

In addition to the AO, sea level pressure local to Svalbard is assessed at Fram Strait (10°W 80°N) and Barents Sea (20°E 73°N) locations respectively. The rationale for the inclusion of these parameters is the observation (Vinje, 2001) that Fram Strait sea ice flux is linearly related to the pressure difference between these two locations.

Data on sea level pressure is obtained from the NOAA NCEP-NCAR Reanalysis (http://www.esrl.noaa.gov/psd/data/reanalysis/reanalysis.shtml).

SST at NW Svalbard, Norway-Bear Island, and Iceland-UK

Sea surface temperature (SST) provides an indication of heat transport from lower latitudes to Svalbard and the potential to melt sea ice. SST is obtained from 3 locations, NW Svalbard (10°E 79°N), Norway-Bear Island (19.45°E 72.42°N), and Iceland-UK (349.7°E 63.42°N). Data is derived from the NOAA Extended Reconstructed Sea Surface Temperature (SST) V3b (http://www.esrl.noaa.gov/psd/data/gridded/data.noaa.ersst.html).

Solflekktall

Langsiktige klimaendringer er påvirket av solaktivitet og antropogene aktiviteter. Av disse har solaktivitet i form av solflekktall en 11-års syklus, som videre kan ha innflytelse på en periodevise svigninger med varighet på 5-6 år som man kan se i iskartene rundt Svalbard. Et forhold mellom solens sykluser og arktisk isutbredelse ble først satt i hypotese av Bray (1968) og rapportert av Lamb (1977) (p.446). Forholdet har også nylig blitt brukt av Hill et al 2012, for havisen i farvannene omkring Newfoundland.

Månedlige gjennomsnittstall for solflekkaktivitet er hentet fra NASA MSFC Royal Greenwich Observatory og US Air Force Solar Optical Observing Network dataset (http://solarscience.msfc.nasa.gov/SunspotCycle.shtml). Disse gir en prognose opp til slutten av 2019.

4.4 Ensemble prognosemodell

En ensemble prognosemodell (EFM) benytter data fra ECMWF Long Range (sesong) værprognose (http://www.ecmwf.int/en/forecasts/charts/seasonal/mean-sea-level-pressure-public-charts-long-range-forecast). Denne gir månedlige gjennomsnittsverdier for 40 forskjellige kjøringer (ensembler) fra modellen med en prognoselengde på opptil 6 måneder.

I denne første versjonen ble kun trykket i havnivået for Framstredet og Barentshavet brukt for kommende måneder ved hjelp av denne modellen. På lengre sikt ønsker MET også å avlede indeksverdien for den arktiske oscillasjonen (AO) og SST-verdier fra dette datasettet.

(http://www.esrl.noaa.gov/psd/data/gridded/data.noaa.ersst.html).

Sun spot numbers

Long term climate changes are affected by solar activity and anthropogenic activities. Of these, solar activity in the form of sunspot numbers has an 11-year cycle that may have an influence on an 5-6 year periodicity seen in ice chart extents around Svalbard. A relationship between solar cycles and Arctic sea ice extent was first hypothesised by Bray (1968) and reported by Lamb (1977) (p.446). The relationship has also been used recently by Hill et al 2012, for sea ice in waters around Newfoundland.

Monthly mean sunspot numbers are derived from NASA MSFC Royal Greenwich Observatory and US Air Force Solar Optical Observing Network dataset (http://solarscience.msfc.nasa.gov/SunspotCycle.shtml). In addition these provide a prediction up to the end of 2019.

Ensemble Forecast Model

The Ensemble Forecast Model (EFM) utilises data from the ECMWF Long Range (Seasonal) forecast (http://www.ecmwf.int/en/forecasts/charts/seasonal/mean-sea-level-pressure-public-charts-long-range-forecast). This provides monthly average values for 40 different runs (ensembles) of the model for up to 6 months in advance.

In this initial version, only the Fram Strait and Barents Sea sea-level pressure were set for future months using this model. Longer-term MET Norway would like to also derive the Arctic Oscillation (AO) index value, and SST values from this dataset.

40 ulike utfall er produsert vba Weka. Siden trykket for Framstredet og Barentshavet er hentet fra ECMWF-modellen vil dette begrense rekkevidden av prognosene og gi en rekke mulige variasjoner for hver måned.

4.5 Resultater

Utgangsplott fra den enkle empiriske modellen og ensemble prognosemodellen er vist hhv i figur 4.1 and 4.2.

Figur 4.1 viser månedlig gjennomsnittlig isutbredelse omkring Svalbard de seneste 12 månedene, fulgt av prognosen for de neste 12 månedene. Erfaringer med å kjøre denne modellen over flere år har vist at mens den forblir stabil under vanlige forhold, kan store endringer i de observerte verdier for en enkelt måned resultere i en stor variasjon i den påfølgende prognosen.

Ensemble prognosemodellen ble satt opp i løpet av dette prosjektet, og har ennå ikke kjørt lenge nok til å gjøre noen observasjoner på hvordan den leverer. Figur 4.2 viser gjennomsnittlig isutbredelse omkring Svalbard de seneste 12 månedene, etterfulgt av ensemble-prognosen for de neste 6 månedene med verdiene gjennomsnitt, median og fordeling. Lengden på prognosen er begrenset av tilgjengeligheten av ECMWF data.

4.6 Fremtidig utvikling

En rekke forbedringer er planlagt for begge modellene. Disse er:

- Beregning av egne AO-indeksverdier basert på NOAA NCEP-NCAR reanalyse og ECMWF EFM data. Dette vil gjøre verdiene konsistente med verdiene for lufttrykk i havnivået.

40 different predictions are produced using Weka. Since the Fram Strait and Barents Sea sea-level pressure are set by the ECMWF model this restricts the range of forecast results and provides a range of possible variability for each month.

Results

Output plots from the Simple Empirical Forecast Model and Ensemble Forecast Model are shown in Figures 4.1 and 4.2 respectively.

Figure 4.1 shows the previous 12 months of monthly average Svalbard ice extent followed by the forecast for the next 12 months. Experience with running this model over a number of years has shown that whilst it remains stable under typical conditions, large changes in the observed conditions for a single month can result in a wide variation in the following forecast.

The Ensemble Forecast Model was set up during the course of this project and has yet to be run long enough to make any observations as to how it performs. Figure 4.2 shows the previous 12 months of monthly average Svalbard ice extent followed by the ensemble forecast for the next 6 months as a mean and median average, and as a range. The length of the forecast is limited by the availability of ECMWF data.

Future development

A number of improvements are planned for both models. These are:

- Calculation of own Arctic Oscillation index values based on NOAA NCEP-NCAR Reanalysis and ECMWF EFM data. This will make the values consistent with those for sea level pressure.

- Inkludering av ECMWF EFM havoverflatetemperatur (SST) data. Denne informasjonen er tilgjengelig, men hentes for øyeblikket ikke av MET. Inkludering av disse dataene vil videre forbedre de enkelte ensemble-medlemmenes resultater.

- Inclusion of ECMWF EFM sea surface temperature (SST) data. This data is available but not currently accessed by MET Norway. Inclusion of this data would further refine the individual ensemble member results.

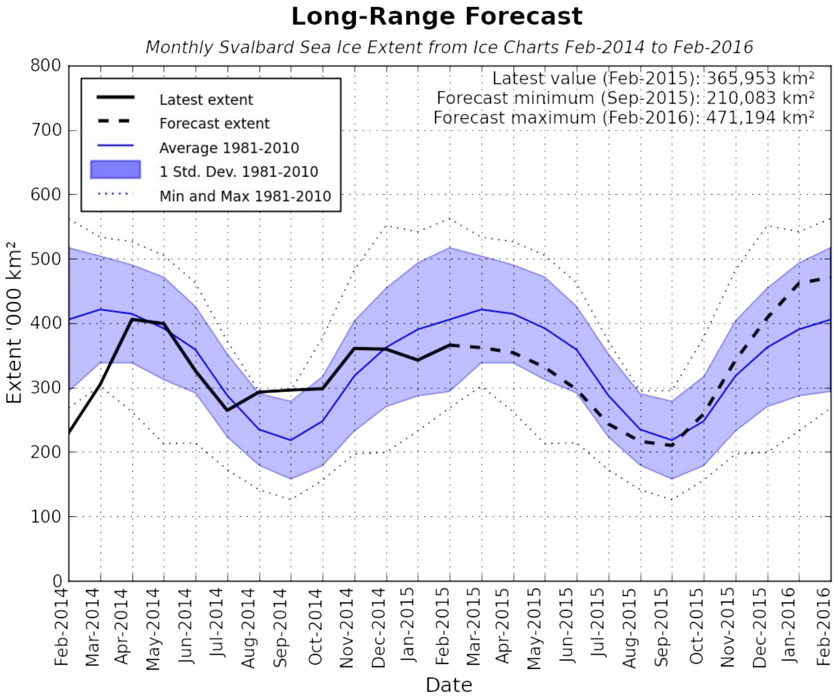


Figure 4.1: Forecast from March 2015 for the Simple Empirical Forecast Model.

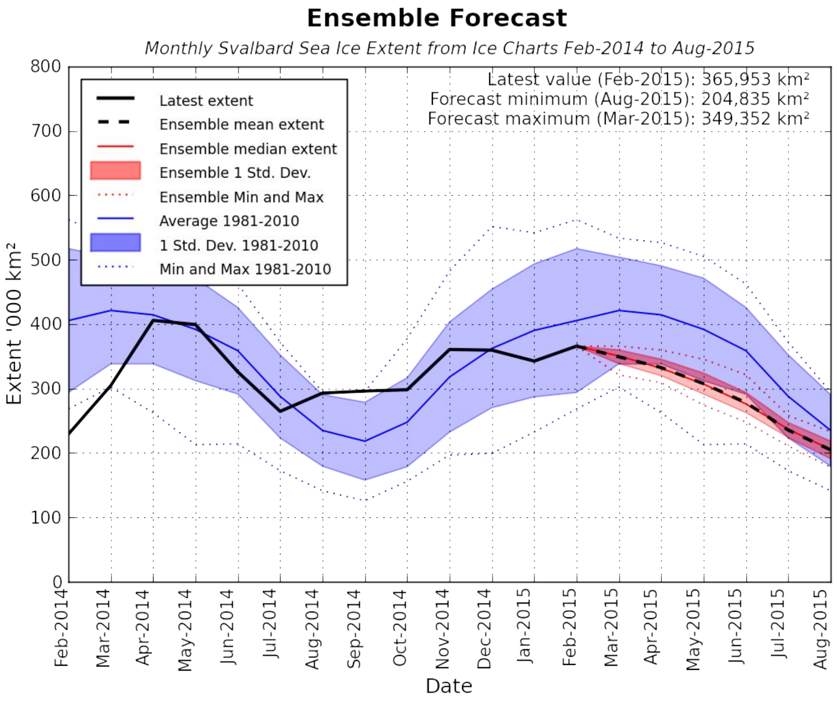


Figure 4.2: Forecast from March 2015 for the Ensemble Forecast Model.

5 Klimaprognoser fra CMIP modell data / Climate Forecasts from CMIP5 Model Data

5.1 Innledning

Denne delen beskriver hvordan klimamodellene som brukes i IPCC AR5-rapporten beskriver endringer i isforholdene i de 2 interesseområdene, samt det videre Nordiske hav, i perioden 2015-2035.

5.2 ACCESS-prosjektresultater for CMIP5 data

Denne rapporten er basert på klimamodelleringsresultater fra the Coupled Model Intercomparison Project phase 5 (CMIP5) climate models MPI-ESM-LR, GFDL_CM3, og NorESM, nedlastet fra the Earth System Grid - Center for Enabling Technologies (ESG-CET) hos:

http://pcmdi9.llnl.gov/esgf-web-fe/

Følgende modellkjøringer vektla enten utelukkende CO2-pådriv eller pådriv basert på observasjoner og the Representative Concentration Pathway (RCP) scenarios (Giorgetta, et al, 2013).

Giorgetta et al, 2013 beskrev hvordan klimamodellresultatene bygger på egenskaper knyttet til global oppvarming og faktorer knyttet til historisk påvirkning. Faktorene knyttet til global oppvarming fra 1850 og 2080- 2100 omfatter et bredt spekter av temperaturer, fra 1.5C i henhold til RCP 2,6 og til 4.4C under det høyere RCP 8.5. De menneskeskapte karbonpådrivene er også lavere på RCP2.6 og høyere på RCP8.5. Men disse sterke tropiske karbonkildene som finnes i RCP2.6- og RCP8.5-eksperimentene er nesten fraværende i RCP4.5t, noe som kan forklares ved skogplanting i scenariet RCP4.5.

Introduction

This section reviews how climate models used in the IPCC AR5 report see sea ice conditions changing in the 2 areas of interest, and the wider Nordic Seas, during the period 2015 to 2035.

ACCESS Project outcomes for CMIP5 data

This report is based on climate model outcomes from the Coupled Model Intercomparison Project phase 5 (CMIP5) climate models MPI-ESM-LR, GFDL_CM3, and NorESM downloaded from the Earth System Grid - Center for Enabling Technologies (ESG-CET) at:

http://pcmdi9.llnl.gov/esgf-web-fe/

The following model runs either idealized CO2-only forcing or forcings based on observations and the Representative Concentration Pathway (RCP) scenarios (Giorgetta, et al, 2013).

Giorgetta et al, 2013 described how model climate feedback outputs are driven by properties integral to global warming and factors related to historical forcings. Global warming conditions from 1850 and 2080-2100 include a wide range of temperatures from 1.5C under RCP 2.6 to 4.4C under the higher RCP 8.5. The anthropogenic carbon forcings are also lower at RCP2.6 and the highest being at RCP8.5. However, these strong tropical carbon sources found in the RCP2.6 and RCP8.5 experiments are almost absent in the RCP4.5 experiment, which can be explained by reforestation in the RCP4.5 scenario.

I tillegg til deres robuste potensiale til å representere historiske og fremtidige globale miljøforhold, ble MPI-ESM-LR, GFDL-CM3, og NorESM valgt basert på gode resultater fra ACCESS prosjektet "D1.51 – Results of Arctic ocean-sea ice downscaling runs validated and documented ". De fleste modeller er ikke i stand til å beskrive historiske og fremtidige isforhold på grunn av det faktum at vinterens sjøis er sterkt påvirket av posisjonen til den nordatlantiske strømmen i det respektive havområdet dekket av modellen (Riemann -Campe, 2014). Dermed er det vanskelig å simulere den korrekte posisjon av denne strømmen over lange perioder, enten det er Hindcast, nåværende, eller prognostisert. Som nevnt i ACCESS D1.51-rapporten har flere studier analysert den arktiske sjøis-fordelingen i CMIP5 modeller (til stede i rapporten), hvor enkelte modeller ble identifisert som bedre enn andre til å simulere denne fordelingen av sjøis. Tretti modeller ble sammenlignet i områder av spesiell interesse for ressursutvinning i henhold til ACCESS-partnere, dette inkluderer deler av Karahavet, Vest-Grønland og nordlige og sørlige Barentshavet. Bestemmende for om en modell rangeres som god, avgjøres av hvor godt den har fungeret historisk, og brukes så på framtidige prognoser basert på disse forutsetningene. Totalt sett presterte MPI-ESM-LR-modellen mest konsistent for alle områdene og virker å være den optimale modellen for å kunne representere globale forhold. GFDL-CM3 ble rangert nest best i sammenligningen. Til tross for at NorESM ikke ble rangert høyest, utkonkurrerte den ca 80% av de andre modellene og ga konsistente resultater (Riemann-Campe, et al., 2014).

In addition to their robust potential to represent historical and future global environmental conditions, the MPI-ESM-LR, GFDL-CM3, and NorESM were selected based on good outcomes from the ACCESS project “D1.51 – Results of Arctic ocean-sea ice downscaling runs validated and documented.” Most models are unable to represent historical and future sea ice conditions due to the fact that winter sea-ice extent is strongly influenced by the position of the North Atlantic current in the respective ocean part of the model (Riemann-Campe, 2014). Thus it is difficult to simulate the correct position of this current over long periods, whether it be Hindcast, present, or forecast. As stated in the ACCESS D1.51 report, Several studies have analysed the Arctic sea-ice distributions in CMIP5 models (found in the report), in which individual models were identified that simulate the distribution of sea-ice better than others. Thirty models were compared in areas of specific interest to resource extraction according to ACCESS partners, that include parts of the Kara Sea, West Greenland and north and southern Barents Sea region. The gauge of a good model is determined on how well it performs in the past, and applied to forecasts based upon these assumptions. Overall, the MPI-ESM-LR model performed the most consistent for all areas and suggested to be the optimal model to represent global conditions. The GFDL-CM3 was ranked second best in comparison. The NorESM, though wasn't ranked the highest, outperformed approximately 80% of the other models and presented consistent results in its ranking (Riemann-Campe, et al., 2014).

5.3 MPI-ESM-LR

MPI-ESM kobler atmosfære, hav og landoverflate gjennom utveksling av energi, momentum, vann og viktige sporgasser slik som karbondioksid. Dette er spesielt viktig for havisen fordi den innbefatter den atmosfæriske modellenkomponenten ECHAM6 (Stevens et al., 2013, the modelled climate variability (Giorgetta et al., 2013), the tuning of MPI-ESM (Mauritsen et al., 2012), the impact of sea-ice melt ponds (Roeckner et al., 2012), og the ocean model MPIOM (Jungclaus et al., 2013) (Notz, et al., 2013)) Hav er representert som en del av dette modellsystem både innenfor ECHAM6 og innenfor MPIOM, med hensikt å frambringe overflatetemperatur og albedo i konsistens med utviklingen av den atmosfæriske tilstand på hvert tidstrinn (Notz et al, 2013). Oppdateringen av istykkelsen og havis-dynamikk føres innenfor den "fullstendige" havis-delmodellen som utgjør en del av havmodellen MPIOM. I tillegg er MPI-ESM-LR en fullstendig termodynamisk modell som er basert på 'Hibler 1979 sea ice rheolog', som er en robust modell som inkluderer karakterisktika for istykkelse og oseanisk varmetap for Polhavet (Hibler, 1979). MPI-ESM-LR har vært brukt i sammenlignende modellberegninger i regi av CMIP5, som utgjør det tyske bidraget til den femte hovedrapporten fra FNs klimapanel on Climate Change (IPCC) AR5.

5.4 GFDL-CM3

Geophysical Fluid Dynamics Laboratory (GFDL), en del av the National Oceanic and Atmospheric Administration (NOAA), utviklet GFDL_CM3-modellen for å studere problem-stillinger vedrørende klimavariasjoner og endringer på sesong- til hundreårsskala, og er fokusert på den atmosfæriske komponenten ved bruk av the Atmospheric Model Intercomparison Project (AMIP) (Griffies, et al., 2011 and Delworth, et al., 2006).

MPI-ESM-LR

The MPI-ESM couples the atmosphere, ocean and land surface through the exchange of energy, momentum, water and important trace gases such as carbon dioxide. This one is particularly important for sea ice because it contains the atmospheric model component ECHAM6 (Stevens et al., 2013, the modelled climate variability (Giorgetta et al., 2013), the tuning of MPI-ESM (Mauritsen et al., 2012), the impact of sea-ice melt ponds (Roeckner et al., 2012), and the ocean model MPIOM (Jungclaus et al., 2013) (Notz, et al., 2013). Sea ice is represented as part of this model system both within ECHAM6 and within MPIOM in order to provide at each atmospheric time-step surface temperature and albedo consistent with the evolution of the atmospheric state (Notz et al, 2013). The update of ice thickness and sea-ice dynamics are carried out within the ‘‘full’’ sea-ice submodel that forms part of ocean model MPIOM. Additionally, the MPI-ESM-LR is a full thermodynamic model that is based on Hibler, 1979 sea ice rheology which is a robust model that includes ice thickness characteristics and oceanic heat losses for the Arctic Ocean (Hibler, 1979). The MPI-ESM-LR has been used for comparative model calculations in the context of CMIP5, which constitute the German contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) AR5.

GFDL-CM3

The Geophysical Fluid Dynamics Laboratory (GFDL) of the National Oceanic and Atmospheric Administration (NOAA) developed the GFDL_CM3 model to study issues of climate variability and change on seasonal to centennial time scales and is focused on the atmosphere component with the use of the Atmospheric Model Intercomparison Project (AMIP) (Griffies, et al., 2011 and Delworth, et al., 2006).

Formålet med GFDL-CM3-modellen var at det er ment å realistisk simulere en rekke fenomener, fra svingninger fra dag til dag og stormer på synoptisk skala, til klimaendringer over århundrer (Griffies et al., 2011). Selv om modellen innlemmer biogeokjemi, landvegetasjon og en interaktiv karbonsyklus, inkluderer den også aerosol-sky interaksjoner, kjemi-klima interaksjoner og koblinger mellom troposfæren og stratosfæren. Hav- og sjøismodellene hadde ikke forandret seg mye fra tidligere versjoner, med unntak av GFDL-CM3-modellen som har hatt en større netto inngang av varme til havet og viser en økt forekomst av oppvarming. Gitt at den kjører lengre enn tidligere GFDL-modeller, er den nærmere en tilstand av likevekt. I tillegg er albedo innstilt lysere mhp is og snø-på-is, så den er forventet å representere mer realistiske alternativer. Dette blir også brukt til eksperimentell sesongvarsling og simulering av globale klimaendringer. GFDL Climate Model versjon 3 (CM3) har bidratt til IPCC femte hovedrapport (AR5).

5.5 NorESM

Det norske Earth System Model (ESM) - NorESM ble utviklet som et nasjonalt koordinert bidrag, organisert gjennom EarthClim og finansiert av Forskningsrådet. Dens styrker er spesielt nyttig for høye breddegrader og polare strøk. Den er basert på Community Climate System Model (CCSM) og Community Earth System Model (CESM), modeller fra the National Center for Atmospheric Research (NCAR) i USA. CCSM-modellen kombinerer koblede komponenter som består av en atmosfærisk modell (Community Atmosphere Model), en landoverflatemodell (Community Land Model), en havmodell (Parallel Ocean Program), og en havismodell (Community Sea Ice Model). CESM regnes som en omfattende klimamodell som inkorporerer hovedkomponentene i klimasystemet. Dette er et unikt system der de enkelte arbeids-

The purpose of the GFDL-CM3 model was that it is meant to realistically simulate a range of phenomena from diurnal-scale fluctuations and synoptic-scale storms to multicentury climate change (Griffies et al., 2011). Though it does incorporate the biogeochemistry, land vegetation, and interactive carbon cycle, it also includes aerosol-cloud interactions, chemistry-climate interactions, and links between the troposphere and stratosphere. The ocean and sea ice models hadn't changed much from earlier versions except the GFDL-CM3 model has a larger net input of heat to the ocean and shows an increased rate of warming. Given that it is running longer than previous GFDL models, it is closer to its equilibrium state. Additionally, the albedos are tuned brighter with ice and snow-on-ice so it is expected to represent more realistic settings. This is also being applied to experimental seasonal forecasting and the simulation of global climate change. The GFDL Climate Model version 3 (CM3) contributed to the IPCC Fifth Assessment Report (AR5).

NorESM

The Norwegian community Earth System Model (ESM) NorESM was developed as a nationally coordinated effort, organised through EarthClim, funded by the Reseach Council of Norway. Its strength is particularly useful for high latitudes, and polar climates. It is based on the Community Climate System Model (CCSM) and Community Earth System Model (CESM) models from the National Center for Atmospheric Research (NCAR) in the United States. The CCSM model combines coupled components consisting of an atmospheric model (Community Atmosphere Model), a land-surface model (Community Land Model), an ocean model (Parallel Ocean Program), and a sea ice model (Community Sea Ice Model). The CESM is considered a comprehensive climate model that incorporates the principle components of the climate system. This is a gruppene arbeide for fininnstille de enkelte parametrene i separate modeller som: Atmosfære, biokjemi, klimakjem, klima-variabilitet og -endring, is over land, hav, paleoklima, polarklima, samfunnsmessige dimensjoner, og software-utvikling. Selv om NorESM ligner på CCSM og CESM, inkluderer den også et robust skjema for samhandlingen mellom kjemi, aerosol, sky og stråling i atmosfæremodellen (CAM4-Oslo), samt den isopyknisk koordinere havet modell utviklet i Bergen og som har sitt opphav fra den Miami Isopycnic Coordinate Ocean Model MICOM); the HAMburg Ocean Carbon Cycle (HAMOCC) modell utviklet ved Max-Plank-Institute for Meteorology, Hamburg, og tilpasset dens rammeverk. Dette er også viktig fordi den er mer følsom for klimasensitivitet og gir et sterkere fokus på bidrag fra karbonkretsløpet. NorESM har bidratt til et nødvendig mangfold blant klimamodellene, noe som er inkludert i den femte hovedrapporten fra FNs klimapanel.

5.6 Analyserte perioder

Isutbredelse for hver måned i fire femårsperioder, sammenfallende med historiske dataanalyse (§ 3), ble hentet fra de tre settene av klimamodellresultater. Periodene var:

1) 2015-2019 (5 år)
2) 2020-2024 (5 år)
3) 2025-2029 (5 år)
4) 2030-2034 (5 år)

Gjennomsnittlige verdier, samt minimums- og maksimums isutbredelse er kartlagt ved hjelp av paletten i figur 5.1

unique system in which individual working groups work to tune the individual parameters in separate models such as: Atmosphere , Biogeochemistry, chemistry climate, climate variability & change, land ice, land, ocean, paleoclimate, polar climate, societal dimensions, and software engineering. Though the NorESM is similar to the CCSM and CESM, it also includes a robust chemistry-aerosol-cloud -radiation interaction scheme in the atmosphere model (CAM4-Oslo), as well as the isopycnic coordinate ocean model developed in Bergen and originating from the Miami Isopycnic Coordinate Ocean Model MICOM);the HAMburg Ocean Carbon Cycle (HAMOCC) model developed at the Max-Plank-Institute for Meteorology, Hamburg and adapted to the isopycnic ocean model framework. This is also important because it is more sensitive to climate sensitivity and provides a stronger focus on the carbon cycle feedback. The NorESM contributed to needed climate model diversity included in the Fifth Assessment Report of the IPCC.

Analysis Periods

Ice extents for each month in four five-year periods, following from the historical data analysis (Section 3), were derived from the three sets of climate model results. The periods were:

1) 2015-2019 (5 years)
2) 2020-2024 (5 years)
3) 2025-2029 (5 years)
4) 2030-2034 (5 years)

The average, minimum and maximum ice extents are mapped using the colour in Figure 5.1

5.7 Månedlig analyse

5.7.1 Januar

(RCP45 figur 5.2, 5.14 og 5.26,
RCP85 figur 5.38, 5.50 og 5.62)

Alle tre klimamodeller viser svært liten endring i isutbredelsen i januar i løpet av de neste 20 årene, og liten forskjell mellom scenariene RCP45 og RCP85r. MPI-modellen har en høyere detaljgrad, så det er lettere å sammenligne mot faktiske iskart og OSI-SAF-kart.

5.7.2 Februar

(RCP45 figur 5.3, 5.15 og 5.27.
RCP85 figur 5.39, 5.51 og 5.62)

Svært liten forskjell i isforholdene i februar i løpet av de neste 20 årene når sammenligner scenariene RCP45 og RCP85.

Analysis By Month

January

(RCP45 Figures 5.2, 5.14 and 5.26,
RCP85 Figures 5.38, 5.50 and 5.62)

All three climate models show very little change in January ice extents over the next 20 years and little difference between RCP45 and RCP85 scenarios. The MPI model has a greater detail, so is easier to compare against the ice chart and OSI SAF maps of actual extents.

February

(RCP45 Figures 5.3, 5.15 and 5.27,
RCP85 Figures 5.39, 5.51 and 5.62)

Very little change in February ice conditions over the next 20 years between RCP45 and RCP85 scenarios.

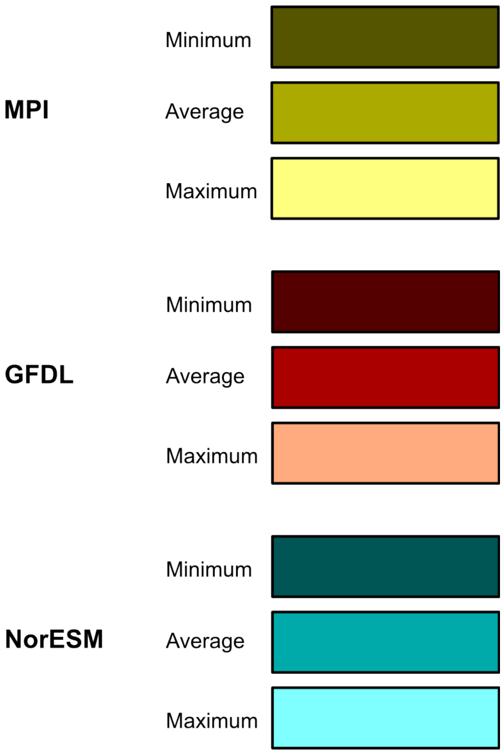


Figure 5.1: Legend for climate model average, minimum, and maximum maps.

5.7.3 Mars

(RCP45 figur 5.4, 5.16 og 5.28,
RCP85 figur 5.40, 5.52 og 5.64)

Beregningene for mars viser en svak nedgang fra observerte forhold i 2005-09 og 2010-14 (figur 3.4, 3.16 og 3.28). Denne reduksjonen er noe større i henhold til RCP85. GFDL viser et bredere spekter av utbredelse i henhold til RCP85 sammenlignet med RCP45, og økende grad i både RCP45 og RCP85 gjennom tid. Dette indikerer muligens problemer ved parametriseringen av havis i denne modellen.

5.7.4 April

(RCP45 figur 5.5, 5.17 og 5.29,
RCP85 figur 5.41, 5.53 og 5.65)

Modellresultatene fra MPI og NorESM for april viser minkende havisutbredelse både i RCP45 og RCP85. Denne tilbaketrekkingen er særlig markert i Barentshavet. Resultatene synes også å indikere en nedgang på 2020-tallet og en delvis oppgang i isutbredelse igjen i 2030-34.

5.7.5 Mai

(RCP45 figur 5.6, 5.18 og 5.30,
RCP85 figur 5.42, 5.54 og 5.66)

En liten nedgang i isutbredelse er observert i resultatene for mai. MPI-modellen for RCP45 synes å indikere en alvorlig periode for kystisen på Øst-Grønland i perioden 2025-29, hvor denne isen potensielt kan nå inn i Jan Mayen-området. NorESM-Modellen viser igjen en delvis reetablering av isforholdene i Barentshavet i løpet av 2030-34.

5.7.6 Juni

(RCP45 figur 5.7, 5.19 og 5.31,
RCP85 figur 5.43, 5.55 og 5.67)

Resultatene for juni indikerer en liten nedgang i forhold til dagens observerte forhold (figur 3.7, 3.19 og 3.31).

March

(RCP45 Figures 5.4, 5.16 and 5.28,
RCP85 Figures 5.40, 5.52 and 5.64)

The March results show a slight decrease from observed conditions in 2005-09 and2010-14 (Figures 3.4, 3.16, and 3.28). This decrease is slightly greater under RCP85. GFDL shows a wider range of extent under RCP85 than RCP45, and increasing extents on both RCP45 and RCP85 through time, possibly indicating some sea ice parameterisation problem in this model.

April

(RCP45 Figures 5.5, 5.17 and 5.29,
RCP85 Figures 5.41, 5.53 and 5.65)

The MPI and NorESM model results for April show decreasing sea ice extents both in RCP45 and RCP85. This retreat is particularly pronounced in the Barents Sea. The results also seem to indicate a decline in the 202's and a partial recovery in sea ice extent in 2030-34.

May

(RCP45 Figures 5.6, 5.18 and 5.30,
RCP85 Figures 5.42, 5.54 and 5.66)

A small decline in sea ice extent is observed in the results for May. The MPI model for RCP45 appears to indicate a severe 2025-29 period on the east Greenland coastal ice, and this ice potentially entering the Jan Mayen area. The NorESM model again indicates a partial recovery of sea ice conditions in the Barents Sea during 2030-34.

June

(RCP45 Figures 5.7, 5.19 and 5.31,
RCP85 Figures 5.43, 5.55 and 5.67)

The June results again indicate a small decline over current observed conditions (Figures 3.7, 3.19 and 3.31).

5.7.7 Juli

(RCP45 figur 5.8, 5.20 og 5.32,
RCP85 figur 5.44, 5.56 og 5.68)

Alle modellene viser en nedgang i isutbredelse i løpet av juli, og isutbredelsen i GFDL-modellen begynner å virke mer realistisk. I NorESM-modellen synes det å være en svak oppgang i isforholdene rundt sørlige delen av Svalbard i RCP85 scenarioet.

5.7.8 August

(RCP45 figur 5.9, 5.21 og 5.33,
RCP85 figur 5.45, 5.57 og 5.69)

NorESM Modellen viser svært liten endring fra observerte forhold (figur 3.9, 3.21 og 3.33), MPI-modellen indikerer en svak nedgang, og GFDL-modellen en sterk nedgang.

5.7.9 September

(RCP45 figur 5.10, 5.22 og 5.34,
RCP85 figur 5.46, 5.58 og 5.70)

Septemberresultatene for samtlige tre modeller er lik de for august.

5.7.10 Oktober

(RCP45 figur 5.11, 5.23 og 5.35,
RCP85 figur 5.47, 5.59 og 5.71)

I oktober synes NorESM-resultatene mest i samsvar med gjeldende observasjoner (figur 3.11, 3.23 og 3.35). MPI-Modellen viser nedgang i isdekket i både RCP45- og RCP85 scenarioet. GFDL-modellene indikerer en nedgang i perioden 2025-29, deretter en delvis oppgang igjen i 2030-34 i RCP45-scenarioet, men opprettholder isutbredelsen under RCP85 scenarioet.

July

(RCP45 Figures 5.8, 5.20 and 5.32,
RCP85 Figures 5.44, 5.56 and 5.68)

All the models show a decline in sea ice extent during July, and GFDL ice extents start to look more realistic. In the NorESM model, there appears to be a slight recovery in ice conditions around the south of Svalbard in the RCP85 scenario.

August

(RCP45 Figures 5.9, 5.21 and 5.33,
RCP85 Figures 5.45, 5.57 and 5.69)

The NorESM model shows very little change from observed conditions (Figures 3.9, 3.21 and 3.33), the MPI model a sliight decline, and the GFDL model a strong decline.

September

(RCP45 Figures 5.10, 5.22 and 5.34,
RCP85 Figures 5.46, 5.58 and 5.70)

The September results for all three models are similar to those of August.

October

(RCP45 Figures 5.11, 5.23 and 5.35,
RCP85 Figures 5.47, 5.59 and 5.71)

In October, the NorESM model results appear most consistent with current observations (Figures 3.11, 3.23 and 3.35). The MPI model shows decrease in ice cover in both RCP45 and RCP85 scenarios. The GFDL models shows a decline to the 2025-29 period, then a partial recovery in 2030-34, in RCP45, but maintained ice extents under the RCP85 scenario.

5.7.11 November

(RCP45 figur 5.12, 5.24 og 5.36,
RCP85 figur 5.48, 5.60 og 5.72)

Alle modellene viser en nedgang i forhold til aktuell isutbredelse (figur 3.12, 3.24 og 3.36), men det er uenighet mellom de ulike modellene hvorvidt RCP45 eller RCP85 vil ha størst effekt.

5.7.12 Desember

(RCP45 figur 5.13, 5.25 og 5.37,
RCP85 figur 5.49, 5.61 og 5.73)

Modellene viser et minkende isdekke i desember, hvor NorESM antyder en mulig delvis gjenoppretting i 2030-34.

November

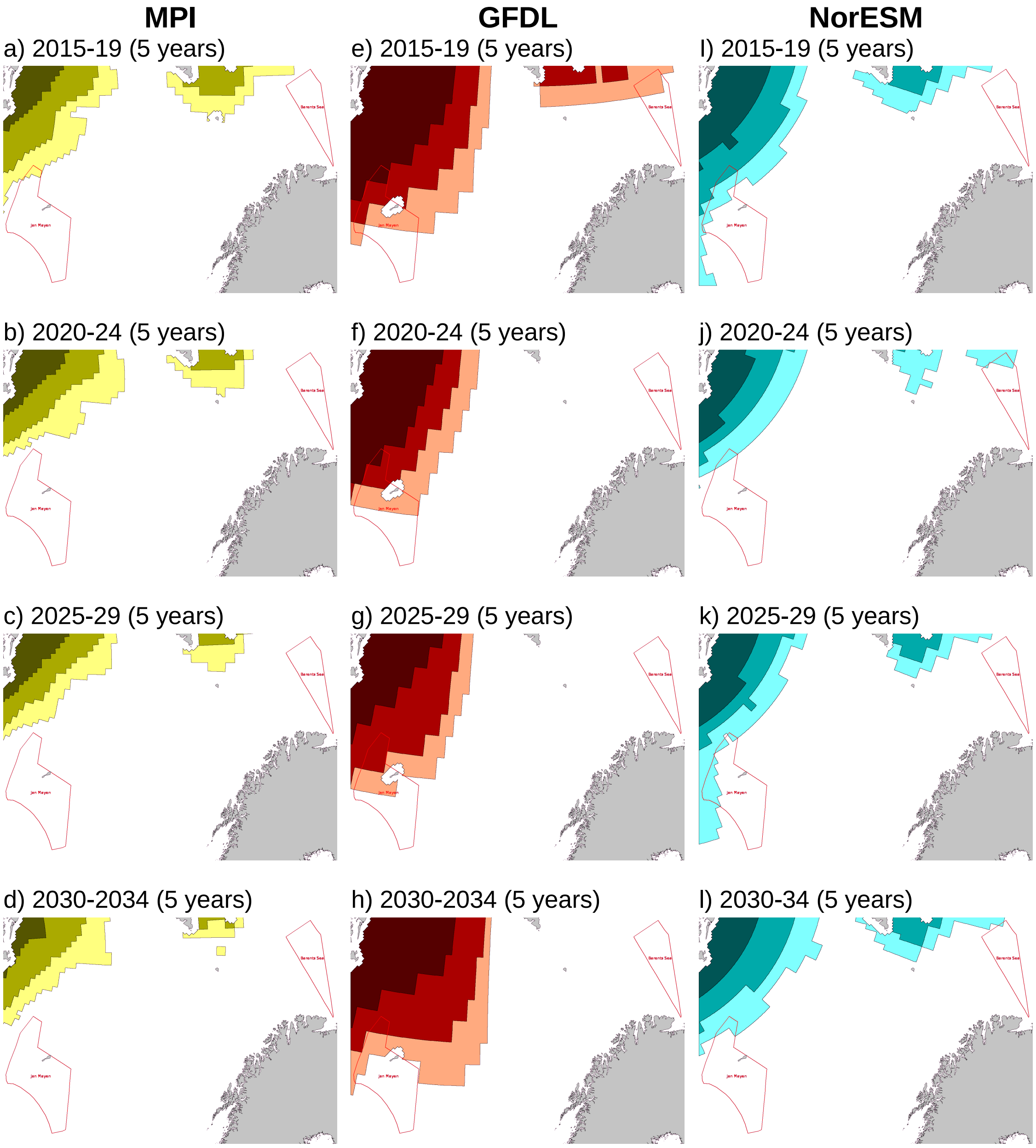
(RCP45 Figures 5.12, 5.24 and 5.36,
RCP85 Figures 5.48, 5.60 and 5.72)

All the models show a decrease on current ice extents (Figures 3.12, 3.24 and 3.36) but there is disagreement between the models as to whether RCP45 or RCP85 will have more of an effect.

December

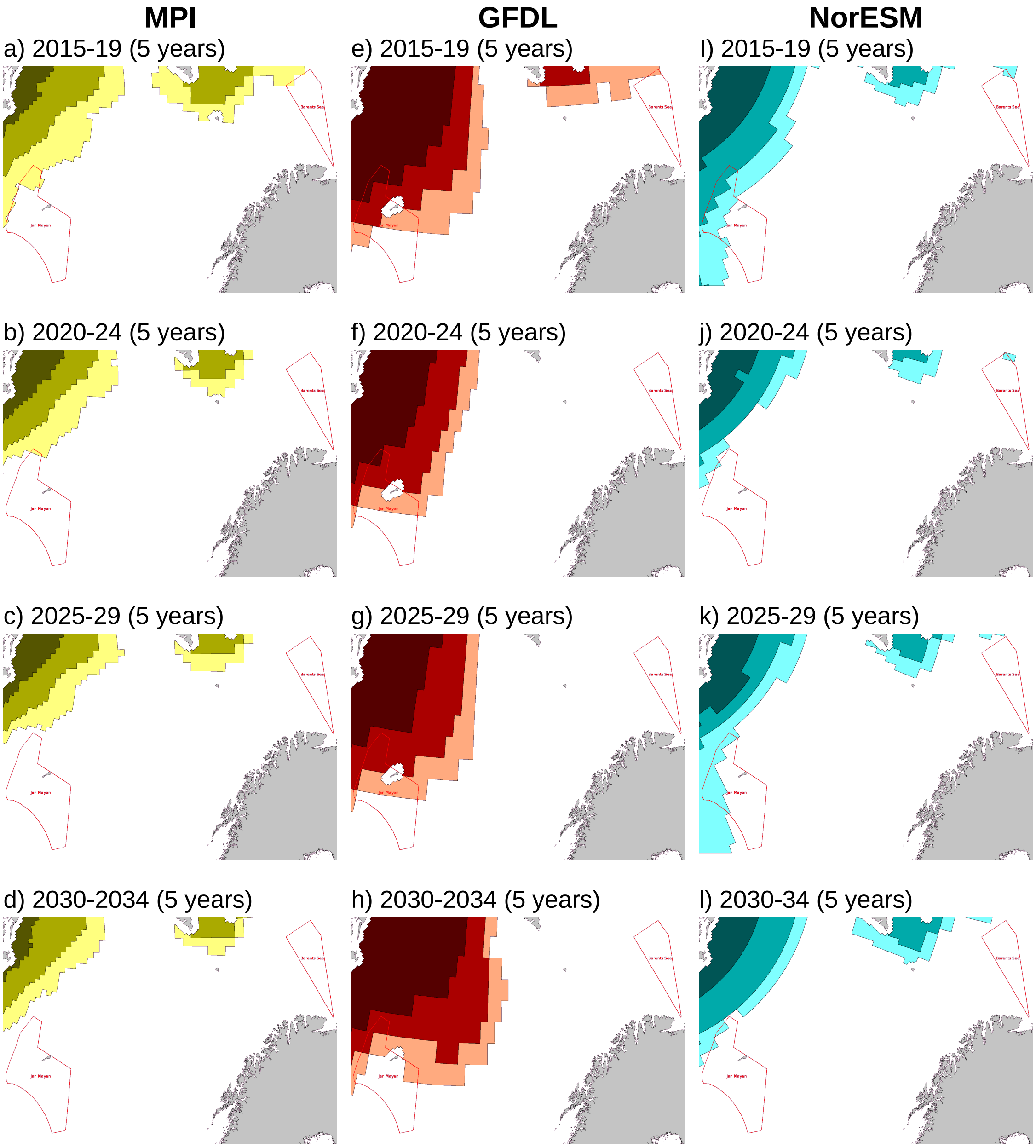
(RCP45 Figures 5.13, 5.25 and 5.37,
RCP85 Figures 5.49, 5.61 and 5.73)

The models show a decreasing ice cover in December, with NorESM predicting a possible partial recovery in the 2030-34 period.



a) 2015-19 (5 years)
e) 2015-19 (5 years)
I) 2015-19 (5 years)
b) 2020-24 (5 years)
f) 2020-24 (5 years)
j) 2020-24 (5 years)
c) 2025-29 (5 years)
g) 2025-29 (5 years)
k) 2025-29 (5 years)
d) 2030-2034 (5 years)
h) 2030-2034 (5 years)
l) 2030-34 (5 years)

Figure 5.2: CMIP model forecasts for JANUARY at 10% ice concentration under emissions scenario RCP45.



MPI

a) 2015-19 (5 years)

b) 2020-24 (5 years)

c) 2025-29 (5 years)

d) 2030-2034 (5 years)

GFDL

e) 2015-19 (5 years)

f) 2020-24 (5 years)

g) 2025-29 (5 years)

h) 2030-2034 (5 years)

NorESM

I) 2015-19 (5 years)

j) 2020-24 (5 years)

k) 2025-29 (5 years)

l) 2030-34 (5 years)

Figure 5.3: CMIP model forecasts for FEBRUARY at 10% ice concentration under emissions scenario RCP45.

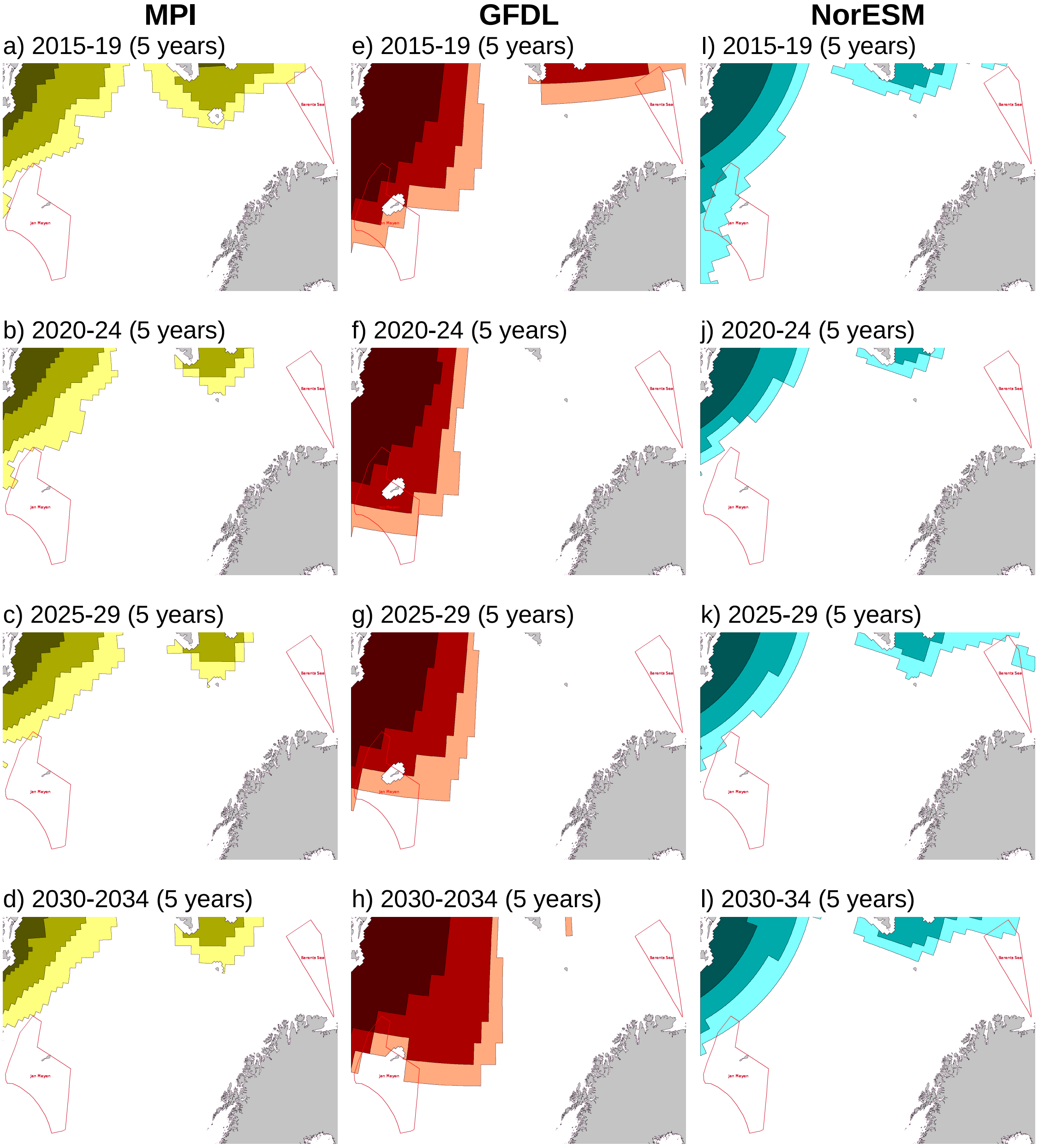
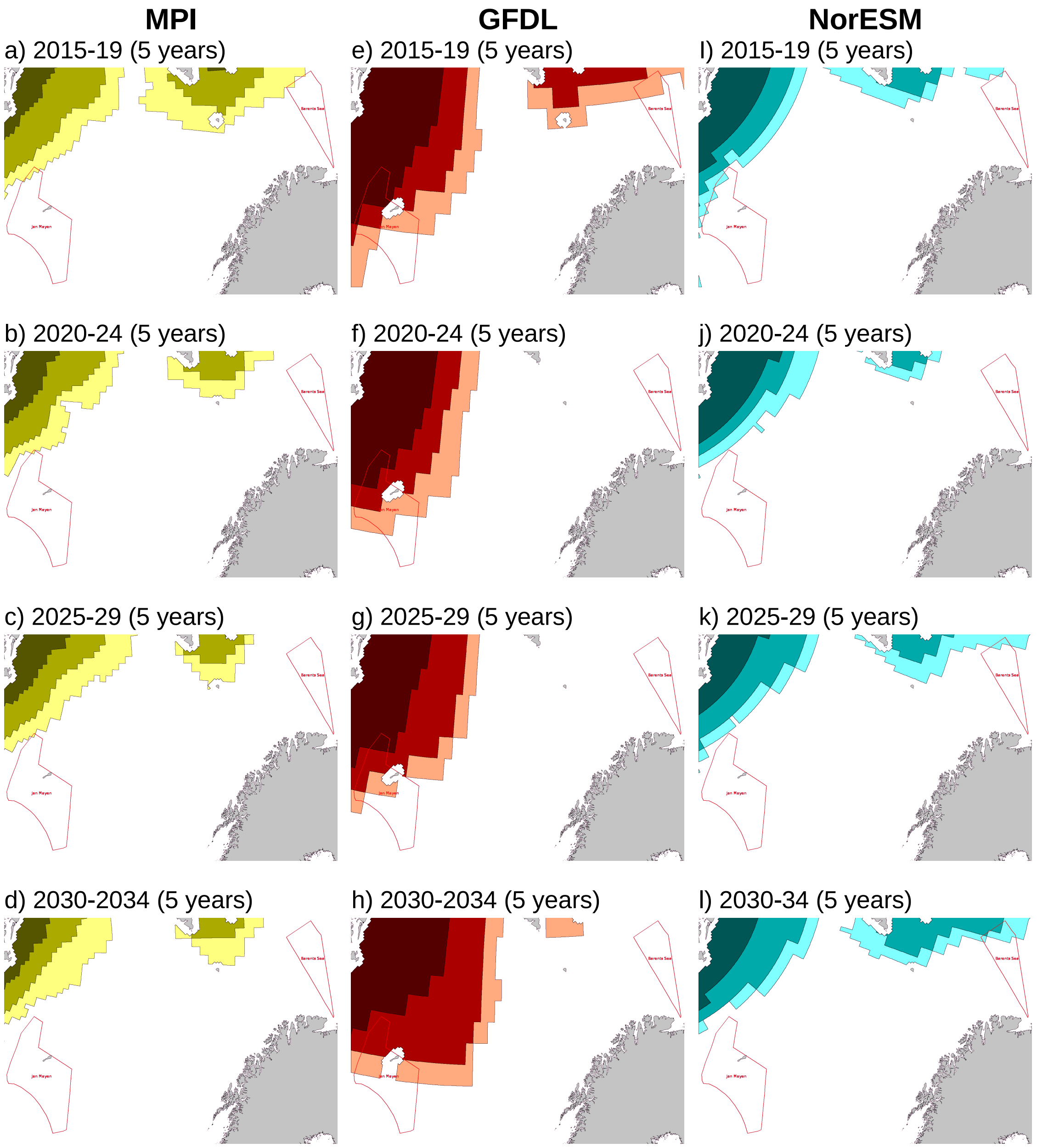


Figure 5.4: CMIP model forecasts for MARCH at 10% ice concentration under emissions scenario RCP45.



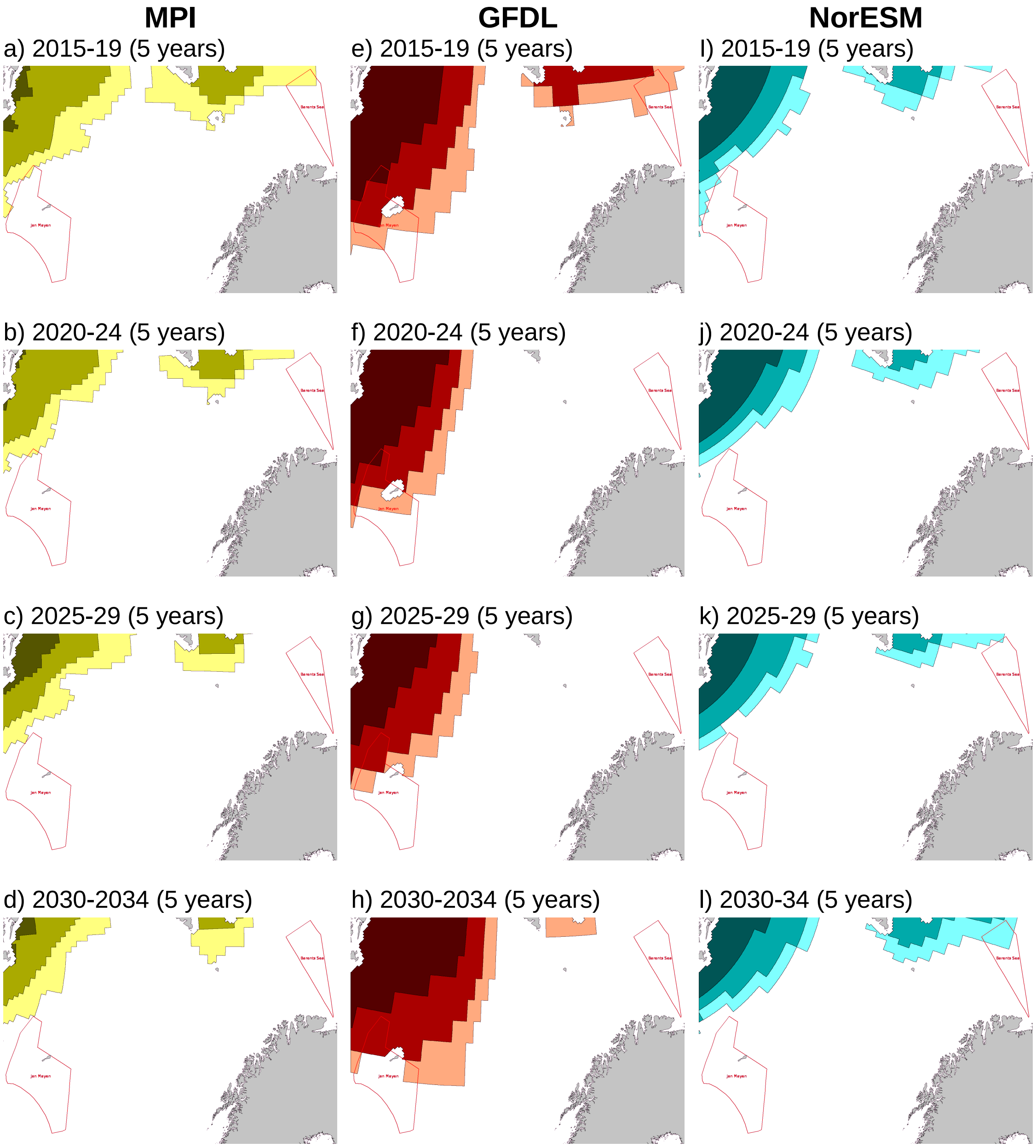
a) 2015-19 (5 years)
e) 2015-19 (5 years)
I) 2015-19 (5 years)

b) 2020-24 (5 years)
f) 2020-24 (5 years)
j) 2020-24 (5 years)

c) 2025-29 (5 years)
g) 2025-29 (5 years)
k) 2025-29 (5 years)

d) 2030-2034 (5 years)
h) 2030-2034 (5 years)
l) 2030-34 (5 years)

Figure 5.5: CMIP model forecasts for APRIL at 10% ice concentration under emissions scenario RCP45.



a) 2015-19 (5 years)
e) 2015-19 (5 years)
I) 2015-19 (5 years)
b) 2020-24 (5 years)
f) 2020-24 (5 years)
j) 2020-24 (5 years)
c) 2025-29 (5 years)
g) 2025-29 (5 years)
k) 2025-29 (5 years)
d) 2030-2034 (5 years)
h) 2030-2034 (5 years)
l) 2030-34 (5 years)

Figure 5.6: CMIP model forecasts for MAY at 10% ice concentration under emissions scenario RCP45.

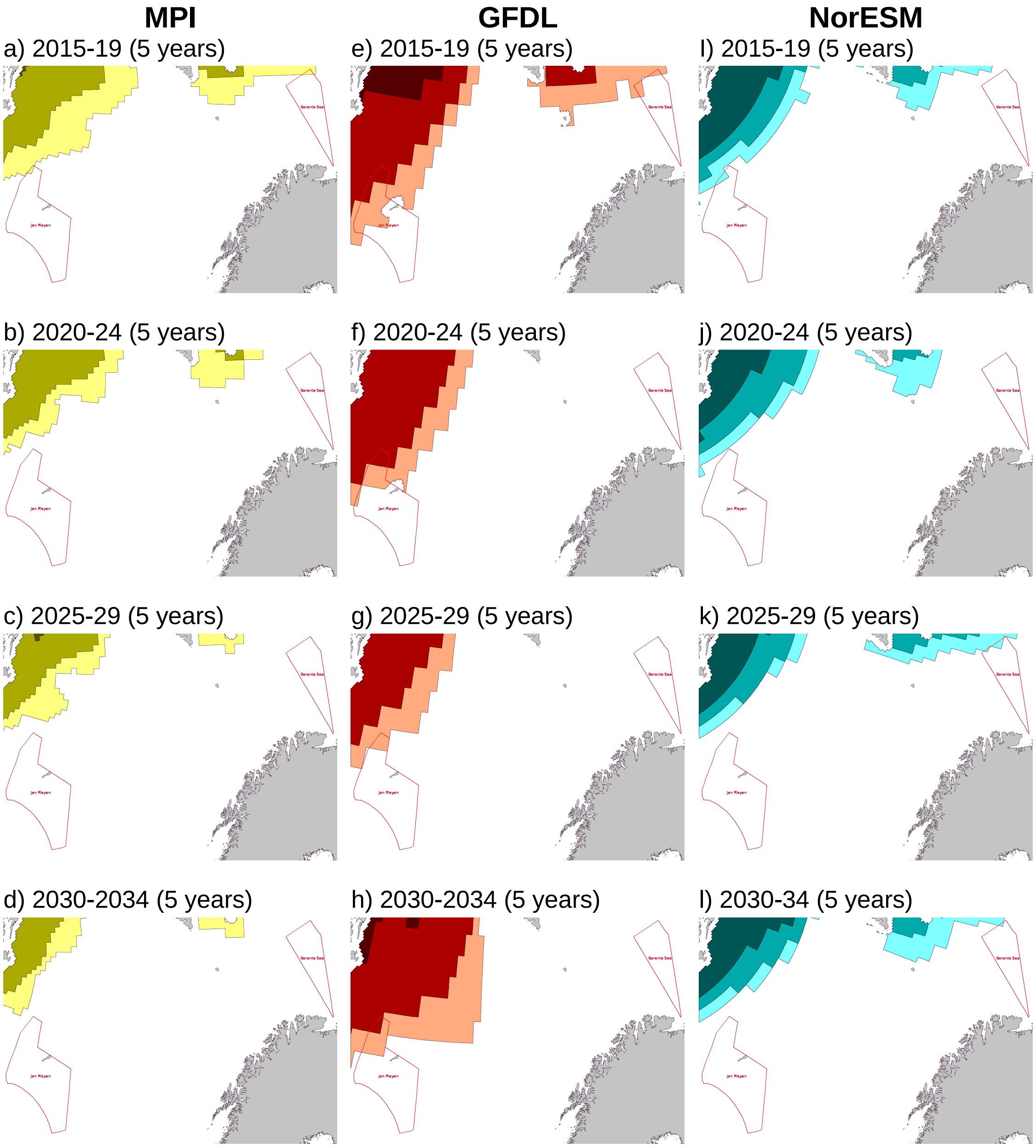
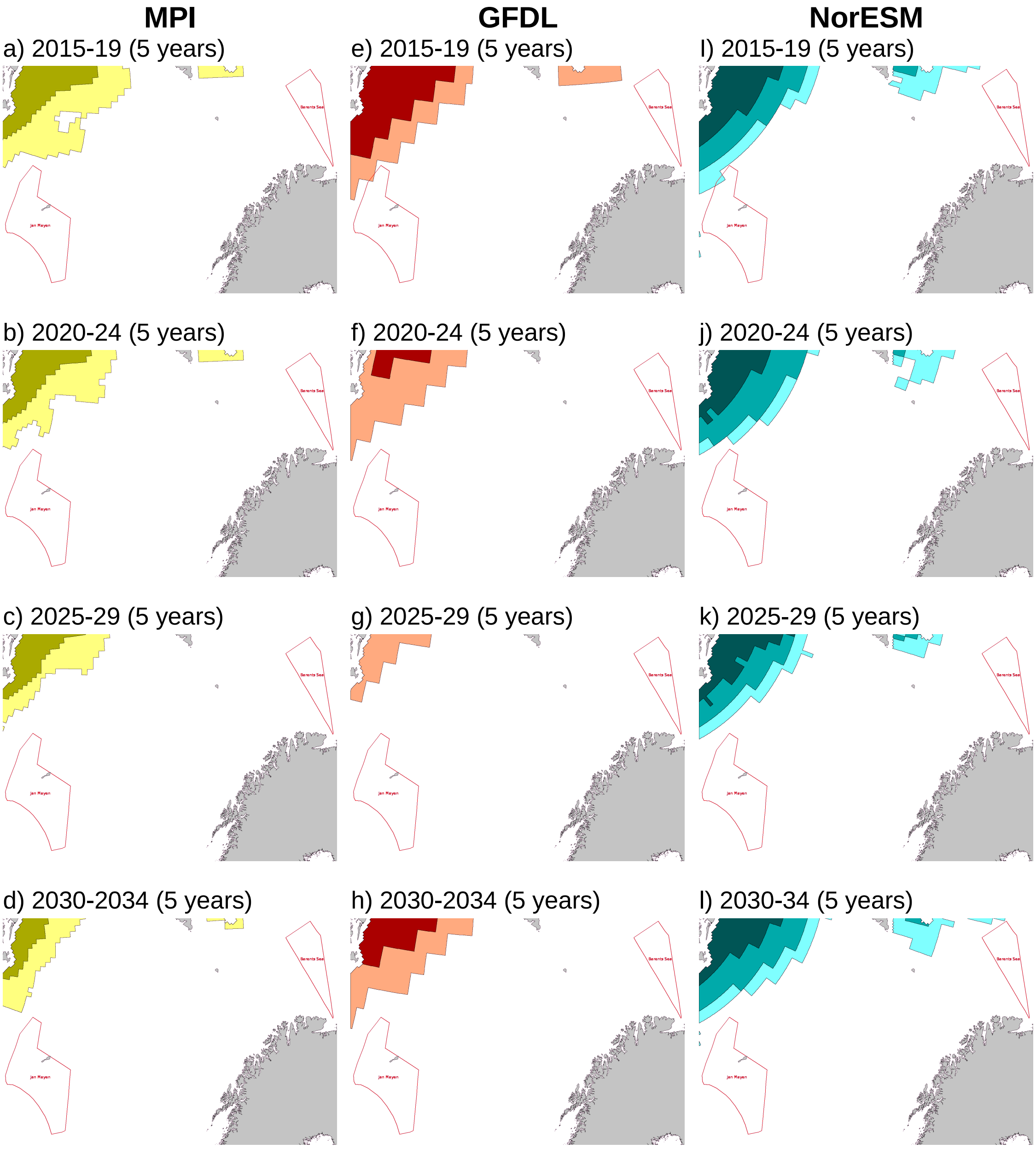


Figure 5.7: CMIP model forecasts for JUNE at 10% ice concentration under emissions scenario RCP45.



MPI

GFDL

NorESM

a) 2015-19 (5 years)

e) 2015-19 (5 years)

I) 2015-19 (5 years)

b) 2020-24 (5 years)

f) 2020-24 (5 years)

j) 2020-24 (5 years)

c) 2025-29 (5 years)

g) 2025-29 (5 years)

k) 2025-29 (5 years)

d) 2030-2034 (5 years)

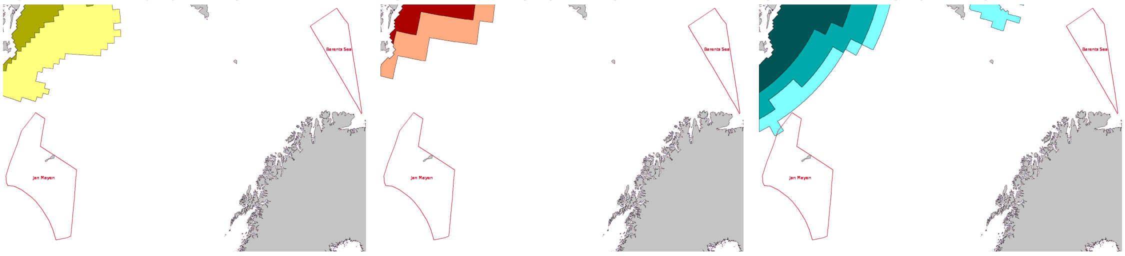
h) 2030-2034 (5 years)

l) 2030-34 (5 years)

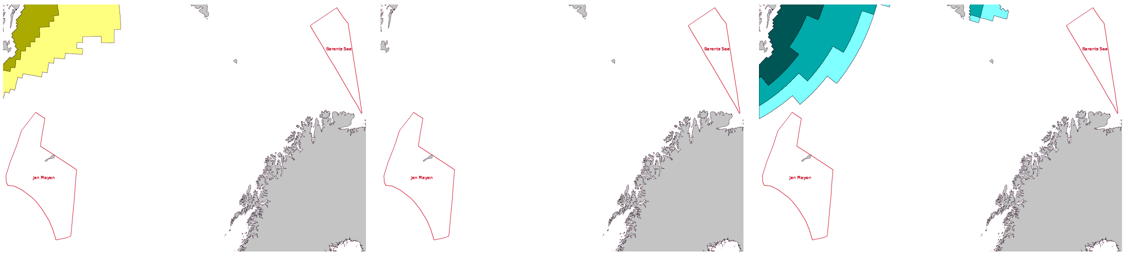
Figure 5.8: CMIP model forecasts for JULY at 10% ice concentration under emissions scenario RCP45.

MPI **GFDL** **NorESM**

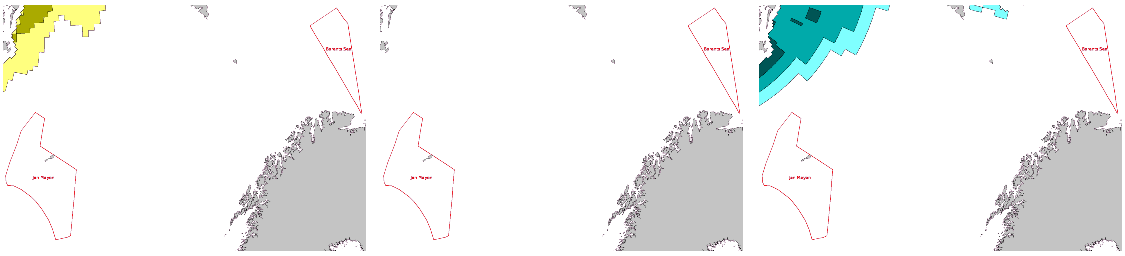
a) 2015-19 (5 years) e) 2015-19 (5 years) I) 2015-19 (5 years)



b) 2020-24 (5 years) f) 2020-24 (5 years) j) 2020-24 (5 years)



c) 2025-29 (5 years) g) 2025-29 (5 years) k) 2025-29 (5 years)



d) 2030-2034 (5 years) h) 2030-2034 (5 years) l) 2030-34 (5 years)

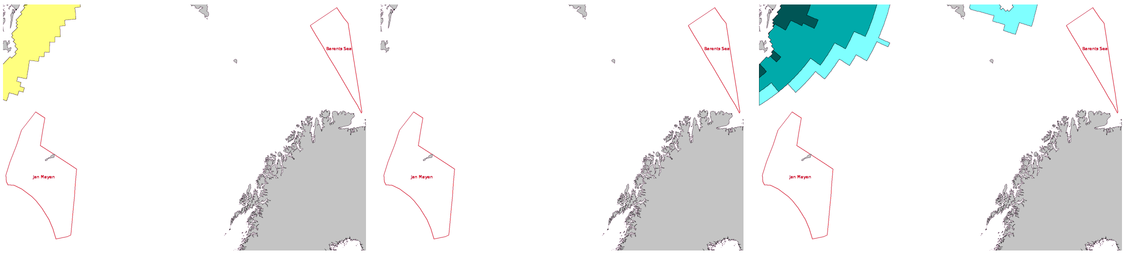
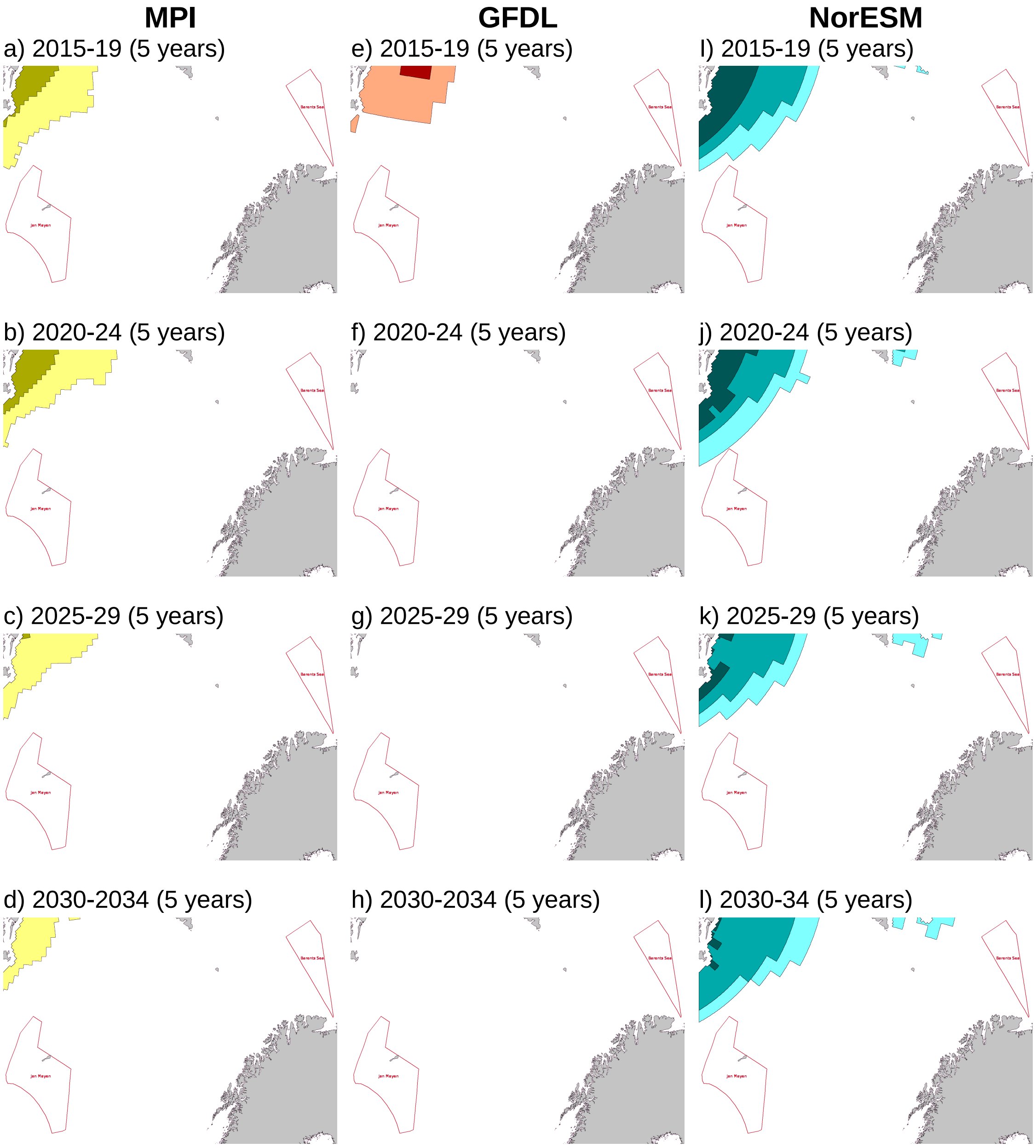


Figure 5.9: CMIP model forecasts for AUGUST at 10% ice concentration under emissions scenario RCP45.



a) 2015-19 (5 years)
e) 2015-19 (5 years)
I) 2015-19 (5 years)

b) 2020-24 (5 years)
f) 2020-24 (5 years)
j) 2020-24 (5 years)

c) 2025-29 (5 years)
g) 2025-29 (5 years)
k) 2025-29 (5 years)

d) 2030-2034 (5 years)
h) 2030-2034 (5 years)
l) 2030-34 (5 years)

Figure 5.10: CMIP model forecasts for SEPTEMBER at 10% ice concentration under emissions scenario RCP45.

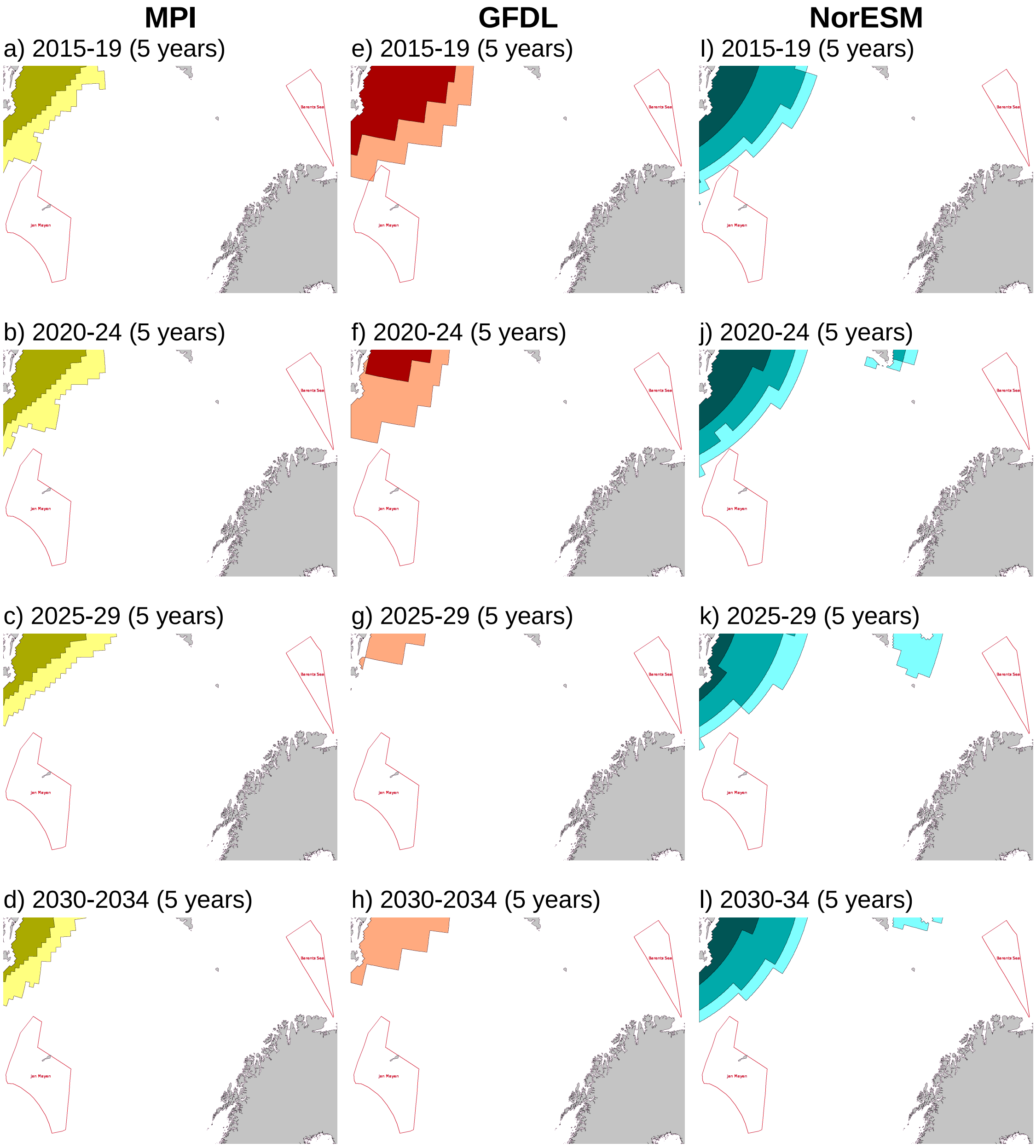
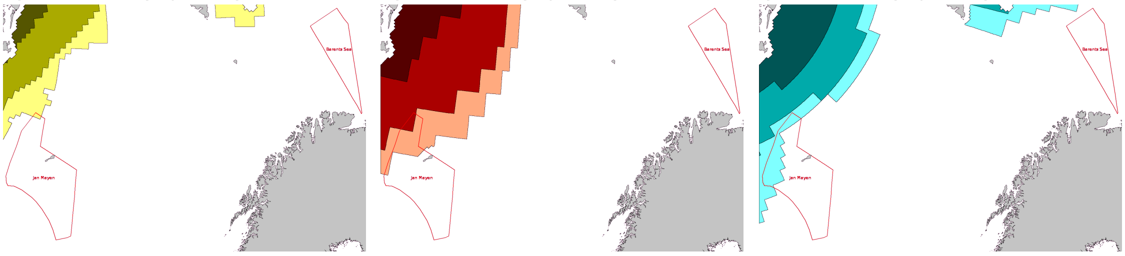


Figure 5.11: CMIP model forecasts for OCTOBER at 10% ice concentration under emissions scenario RCP45.

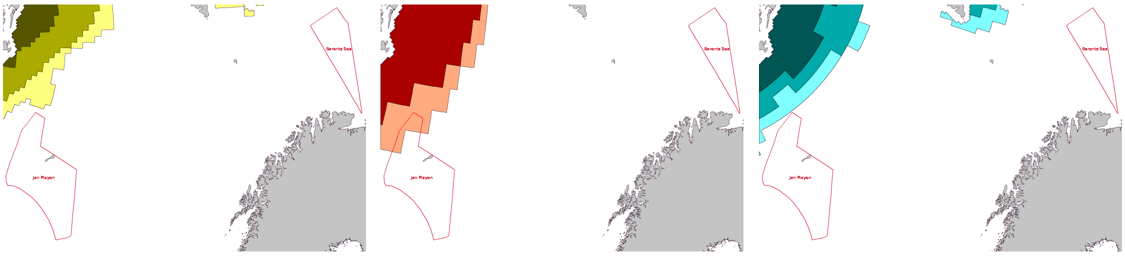
MPI **GFDL** **NorESM**



a) 2015-19 (5 years)

e) 2015-19 (5 years)

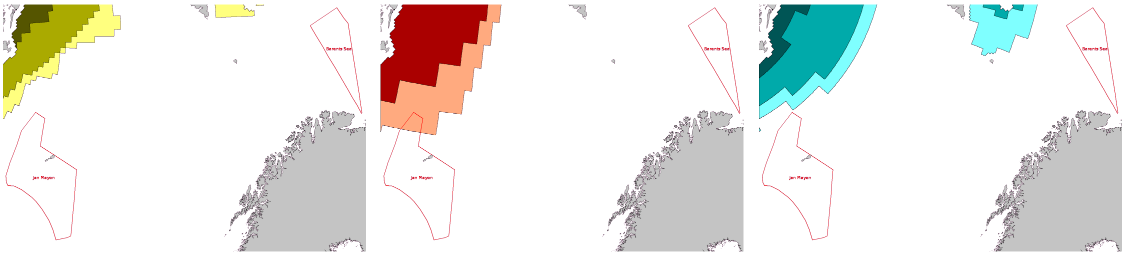
I) 2015-19 (5 years)



b) 2020-24 (5 years)

f) 2020-24 (5 years)

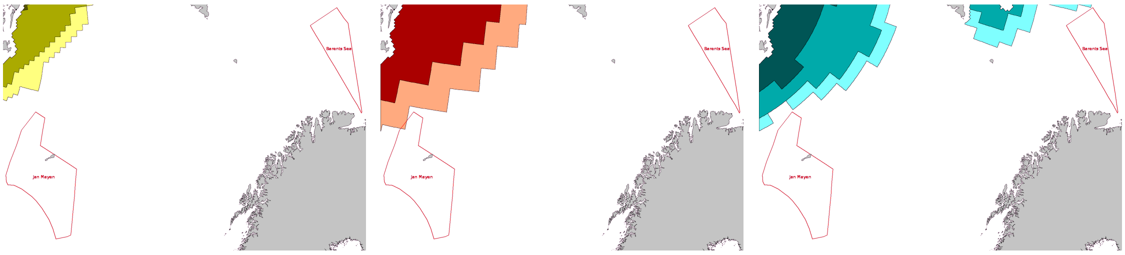
j) 2020-24 (5 years)



c) 2025-29 (5 years)

g) 2025-29 (5 years)

k) 2025-29 (5 years)



d) 2030-2034 (5 years)

h) 2030-2034 (5 years)

l) 2030-34 (5 years)

Figure 5.12: CMIP model forecasts for NOVEMBER at 10% ice concentration under emissions scenario RCP45.

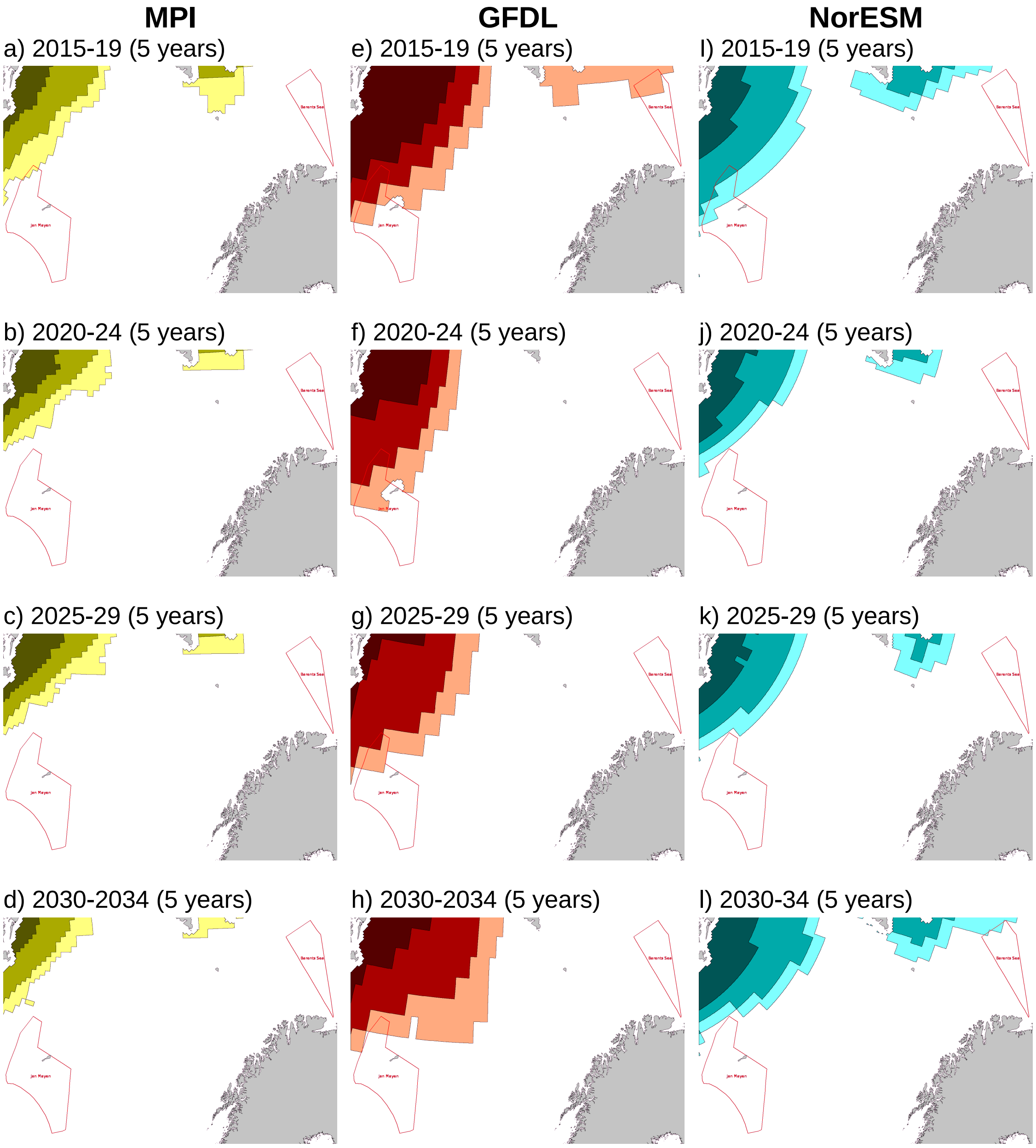


Figure 5.13: CMIP model forecasts for DECEMBER at 10% ice concentration under emissions scenario RCP45.

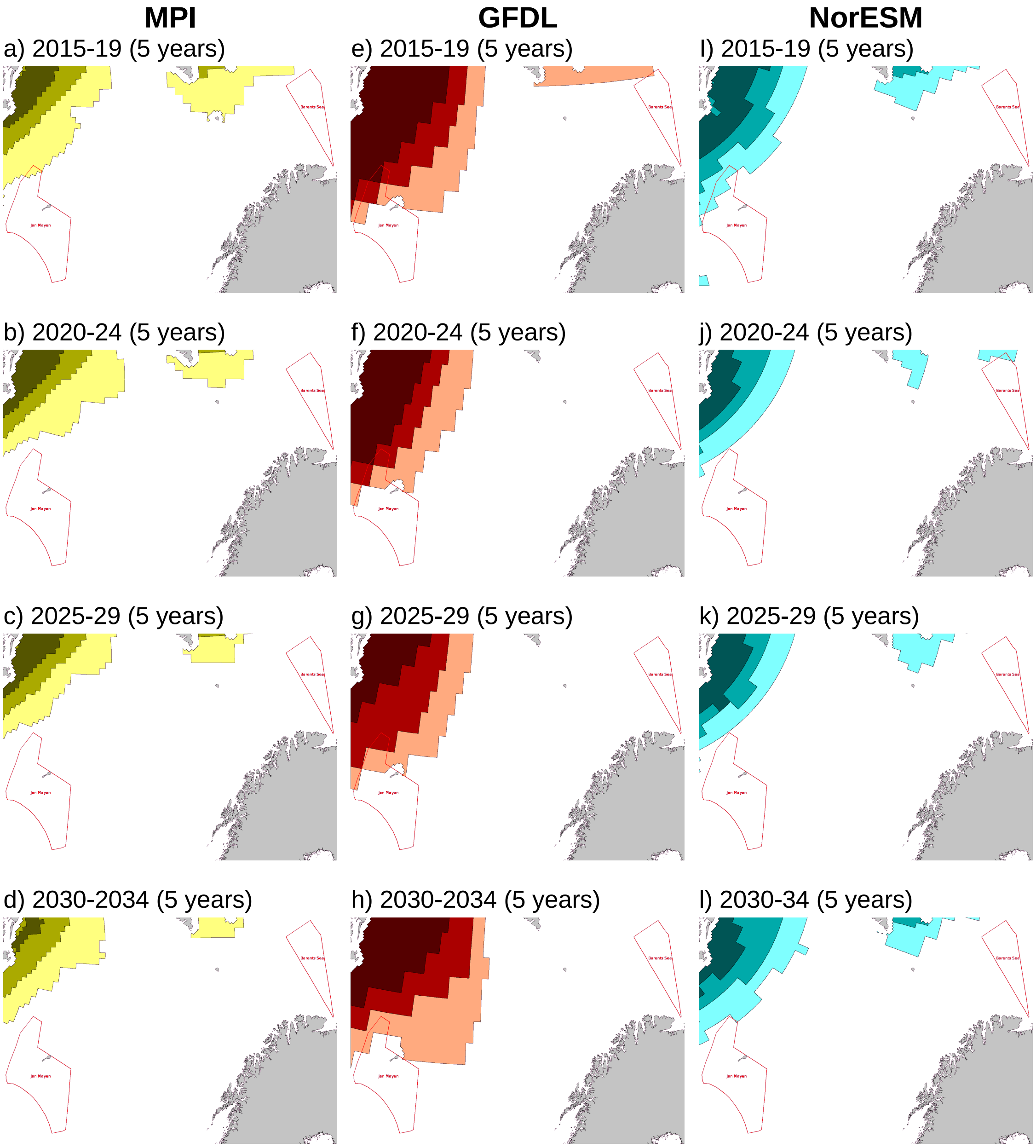


Figure 5.14: CMIP model forecasts for JANUARY at 40% ice concentration under emissions scenario RCP45.

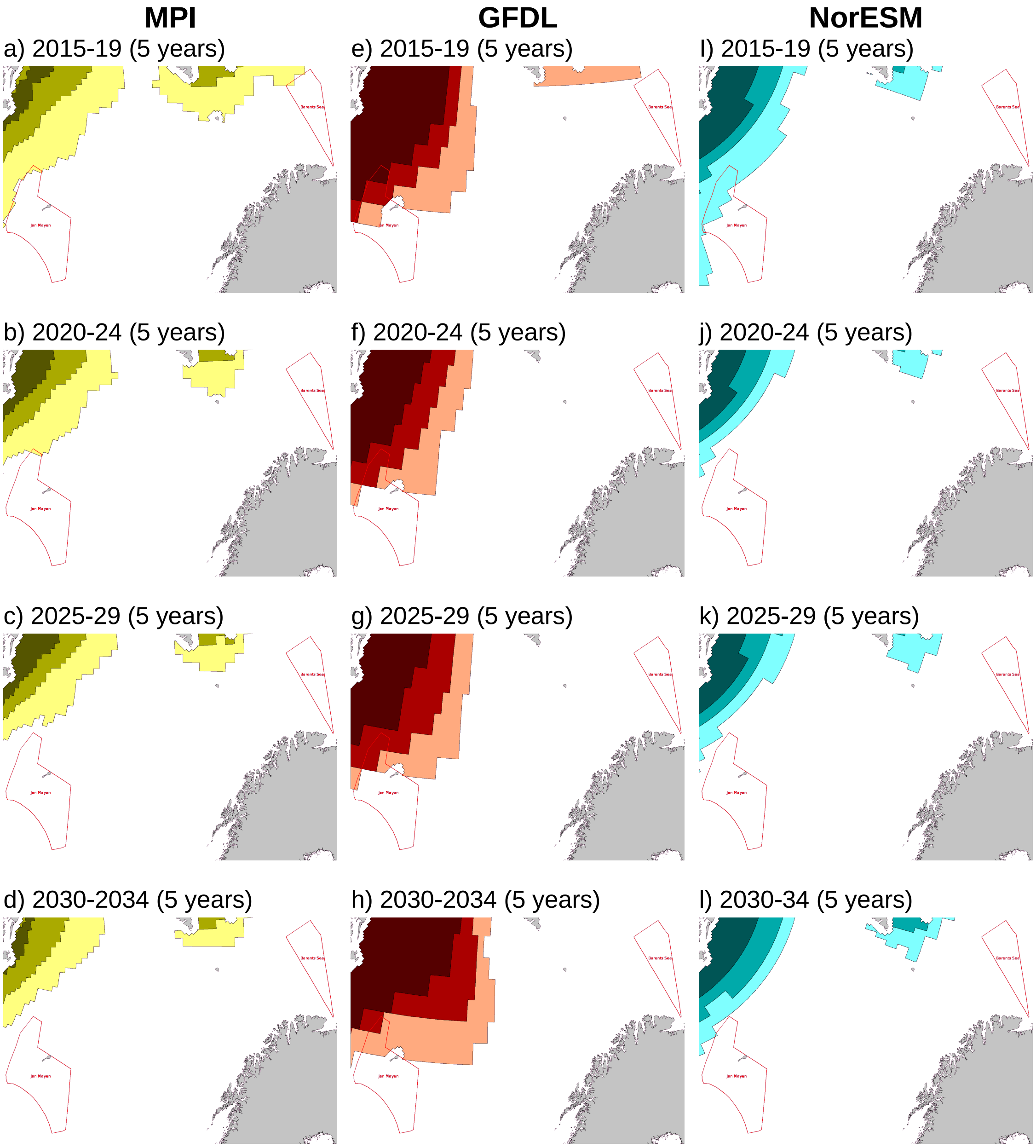
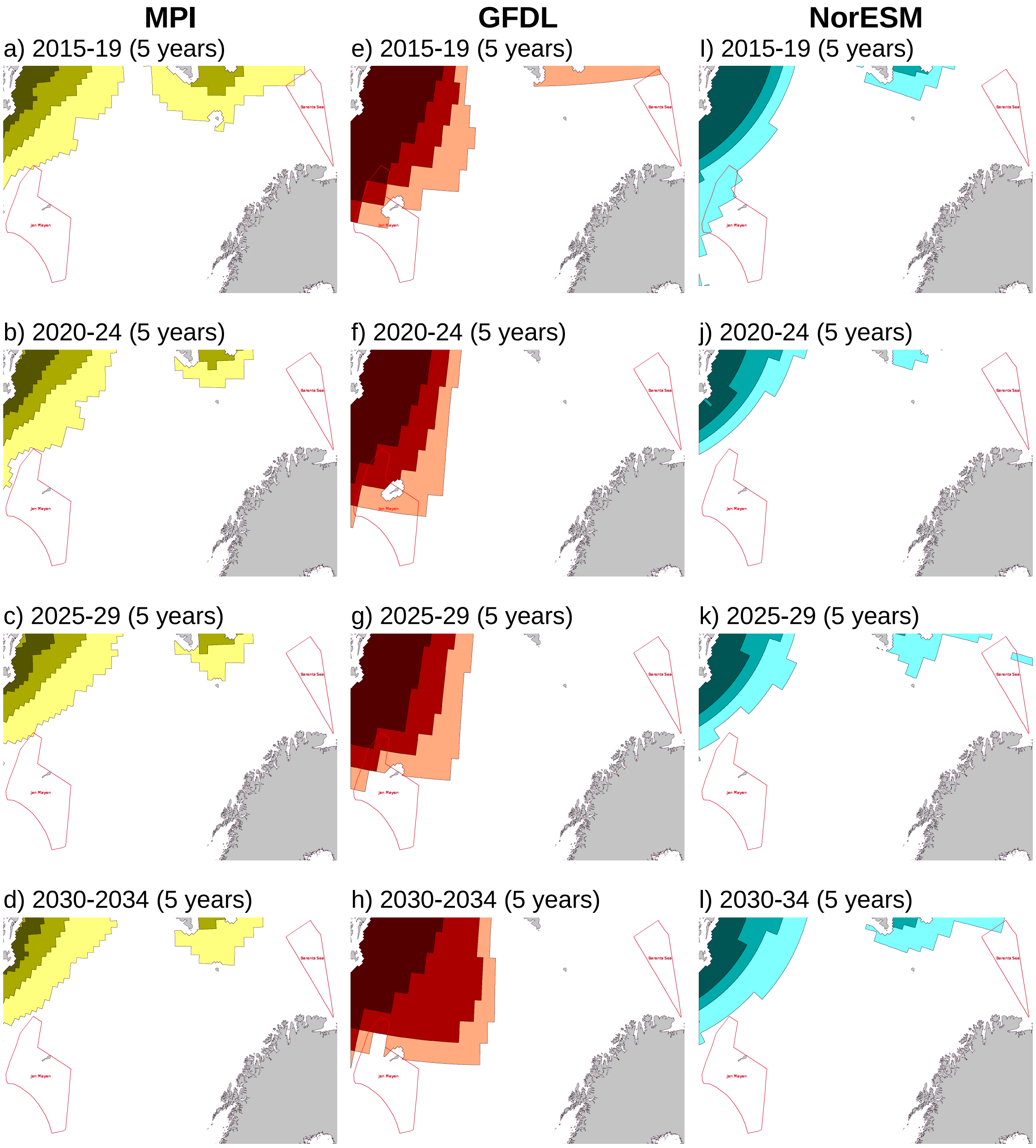


Figure 5.15: CMIP model forecasts for FEBRUARY at 40% ice concentration under emissions scenario RCP45.



a) 2015-19 (5 years)
b) 2020-24 (5 years)
c) 2025-29 (5 years)
d) 2030-2034 (5 years)
e) 2015-19 (5 years)
f) 2020-24 (5 years)
g) 2025-29 (5 years)
h) 2030-2034 (5 years)
I) 2015-19 (5 years)
j) 2020-24 (5 years)
k) 2025-29 (5 years)
l) 2030-34 (5 years)

Figure 5.16: CMIP model forecasts for MARCH at 40% ice concentration under emissions scenario RCP45.

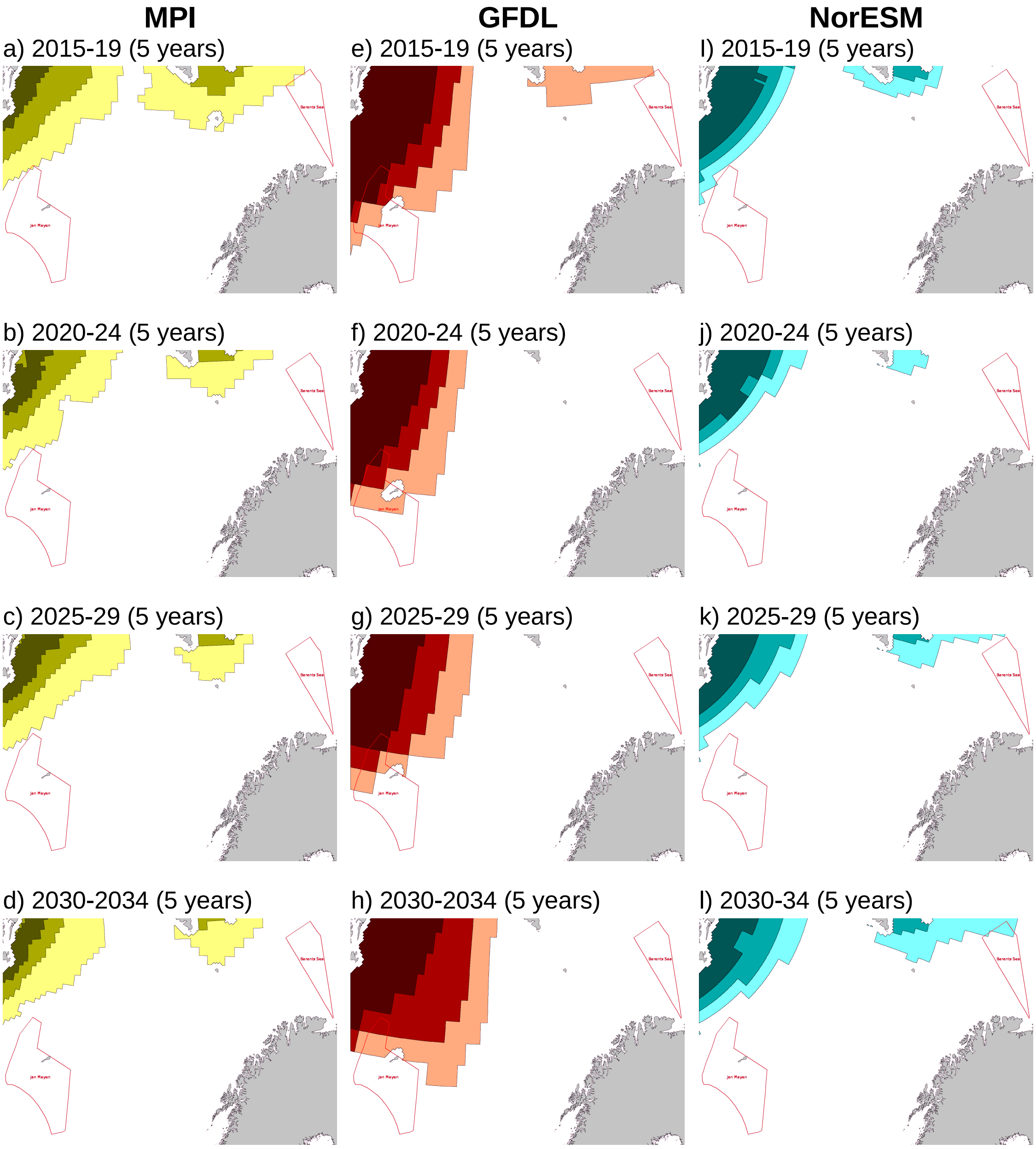
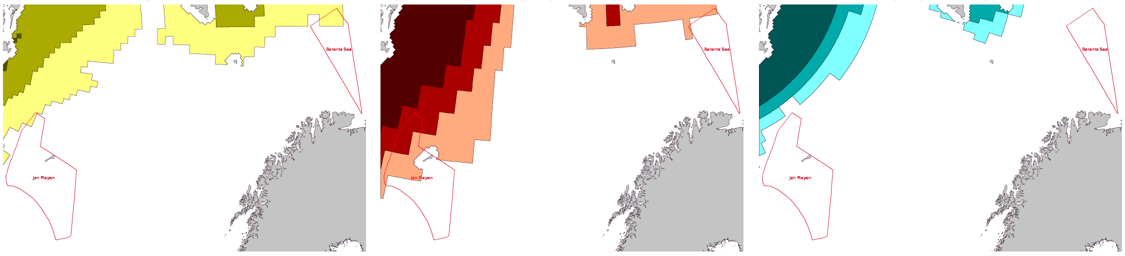


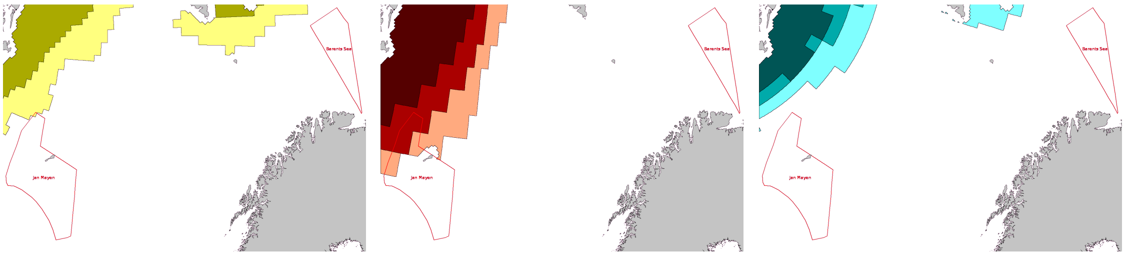
Figure 5.17: CMIP model forecasts for APRIL at 40% ice concentration under emissions scenario RCP45.

MPI **GFDL** **NorESM**

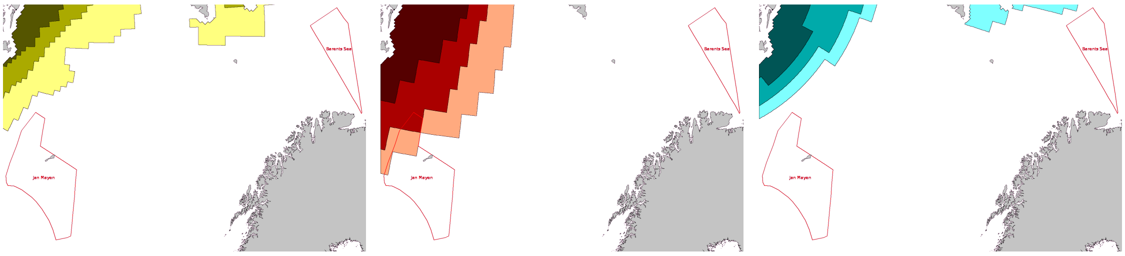
a) 2015-19 (5 years) e) 2015-19 (5 years) I) 2015-19 (5 years)



b) 2020-24 (5 years) f) 2020-24 (5 years) j) 2020-24 (5 years)



c) 2025-29 (5 years) g) 2025-29 (5 years) k) 2025-29 (5 years)



d) 2030-2034 (5 years) h) 2030-2034 (5 years) l) 2030-34 (5 years)

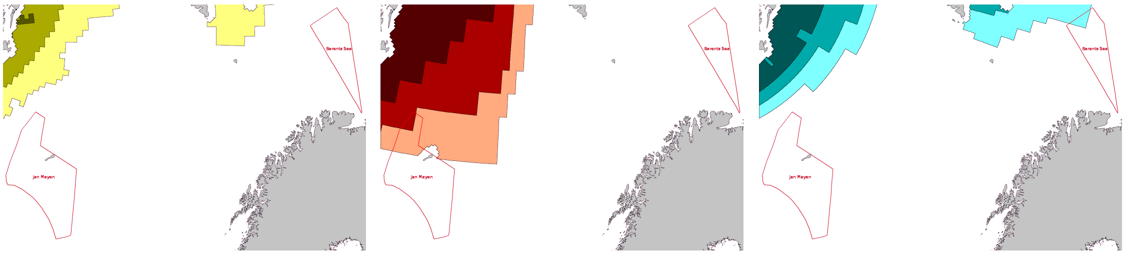
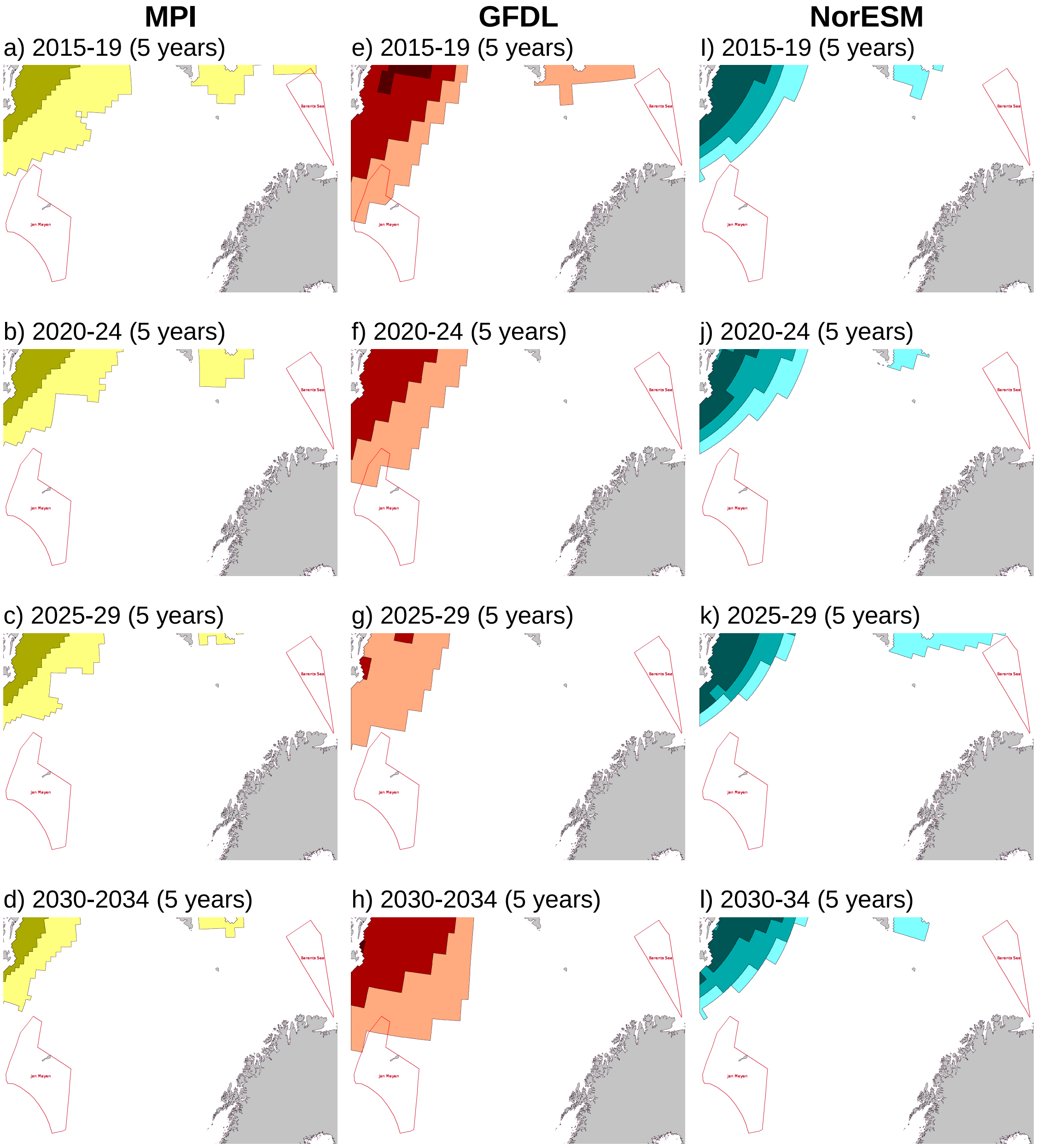


Figure 5.18: CMIP model forecasts for MAY at 40% ice concentration under emissions scenario RCP45.



MPI

GFDL

NorESM

a) 2015-19 (5 years)

e) 2015-19 (5 years)

I) 2015-19 (5 years)

b) 2020-24 (5 years)

f) 2020-24 (5 years)

j) 2020-24 (5 years)

c) 2025-29 (5 years)

g) 2025-29 (5 years)

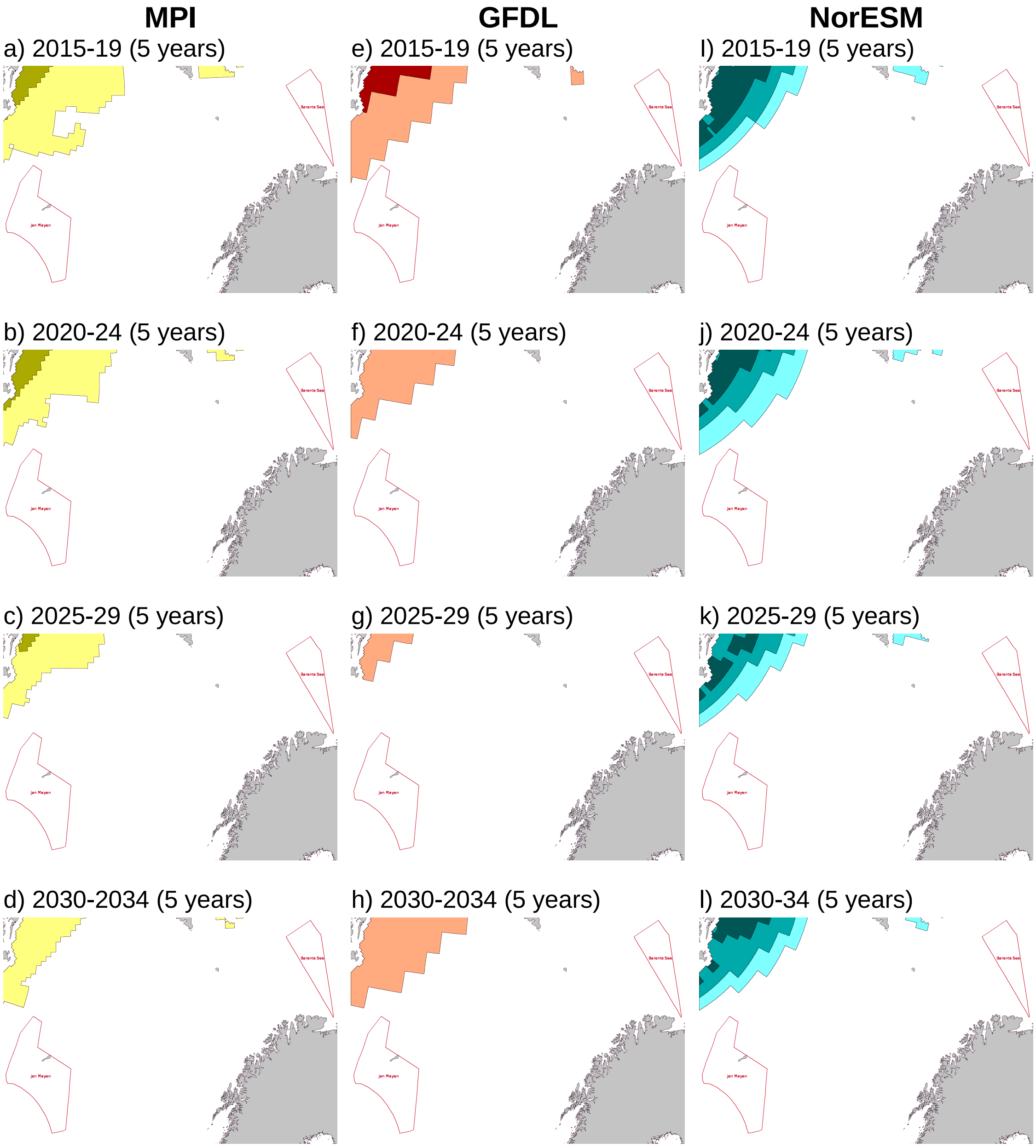
k) 2025-29 (5 years)

d) 2030-2034 (5 years)

h) 2030-2034 (5 years)

l) 2030-34 (5 years)

Figure 5.19: CMIP model forecasts for JUNE at 40% ice concentration under emissions scenario RCP45.



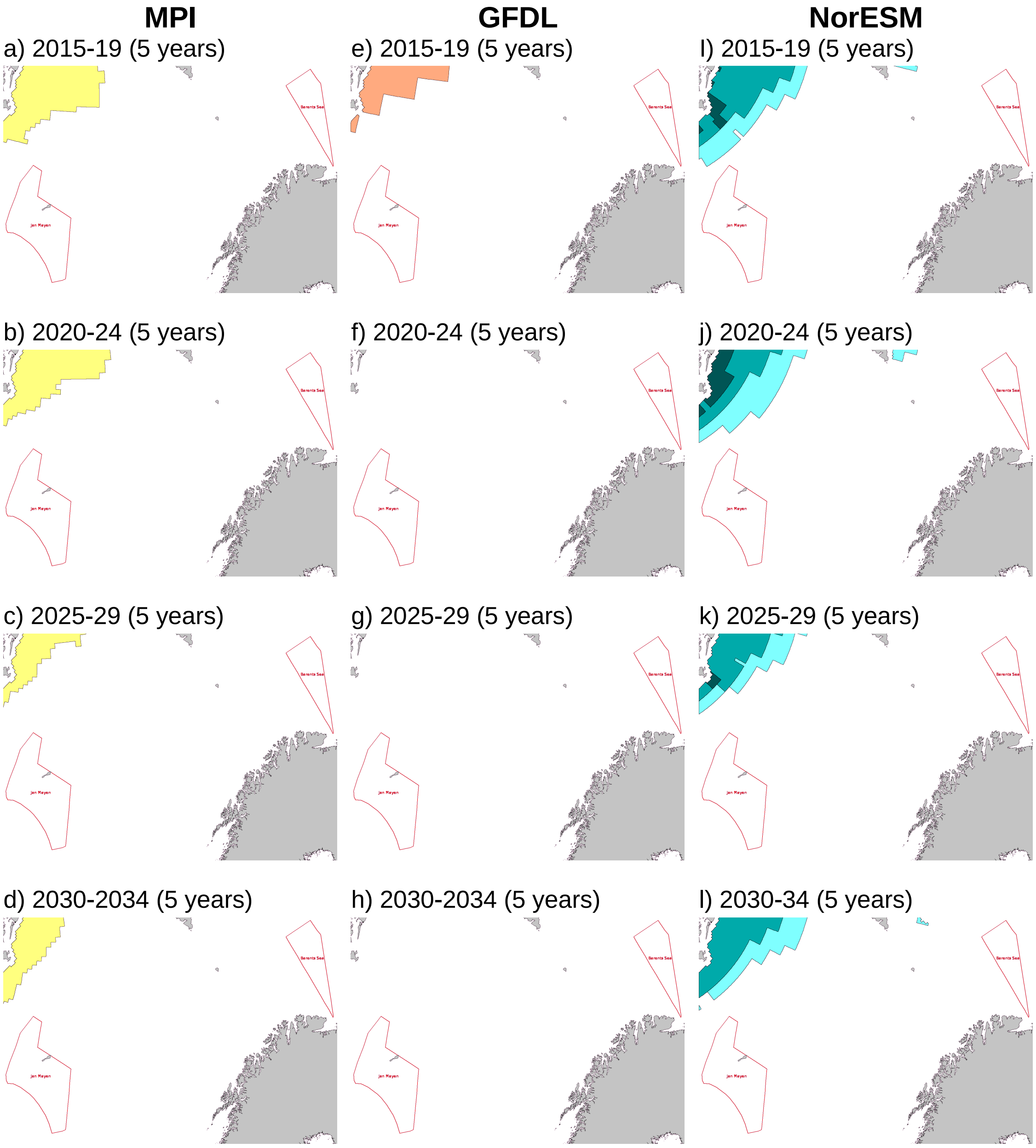
a) 2015-19 (5 years)
e) 2015-19 (5 years)
I) 2015-19 (5 years)

b) 2020-24 (5 years)
f) 2020-24 (5 years)
j) 2020-24 (5 years)

c) 2025-29 (5 years)
g) 2025-29 (5 years)
k) 2025-29 (5 years)

d) 2030-2034 (5 years)
h) 2030-2034 (5 years)
l) 2030-34 (5 years)

Figure 5.20: CMIP model forecasts for JULY at 40% ice concentration under emissions scenario RCP45.



a) 2015-19 (5 years)

b) 2020-24 (5 years)

c) 2025-29 (5 years)

d) 2030-2034 (5 years)

e) 2015-19 (5 years)

f) 2020-24 (5 years)

g) 2025-29 (5 years)

h) 2030-2034 (5 years)

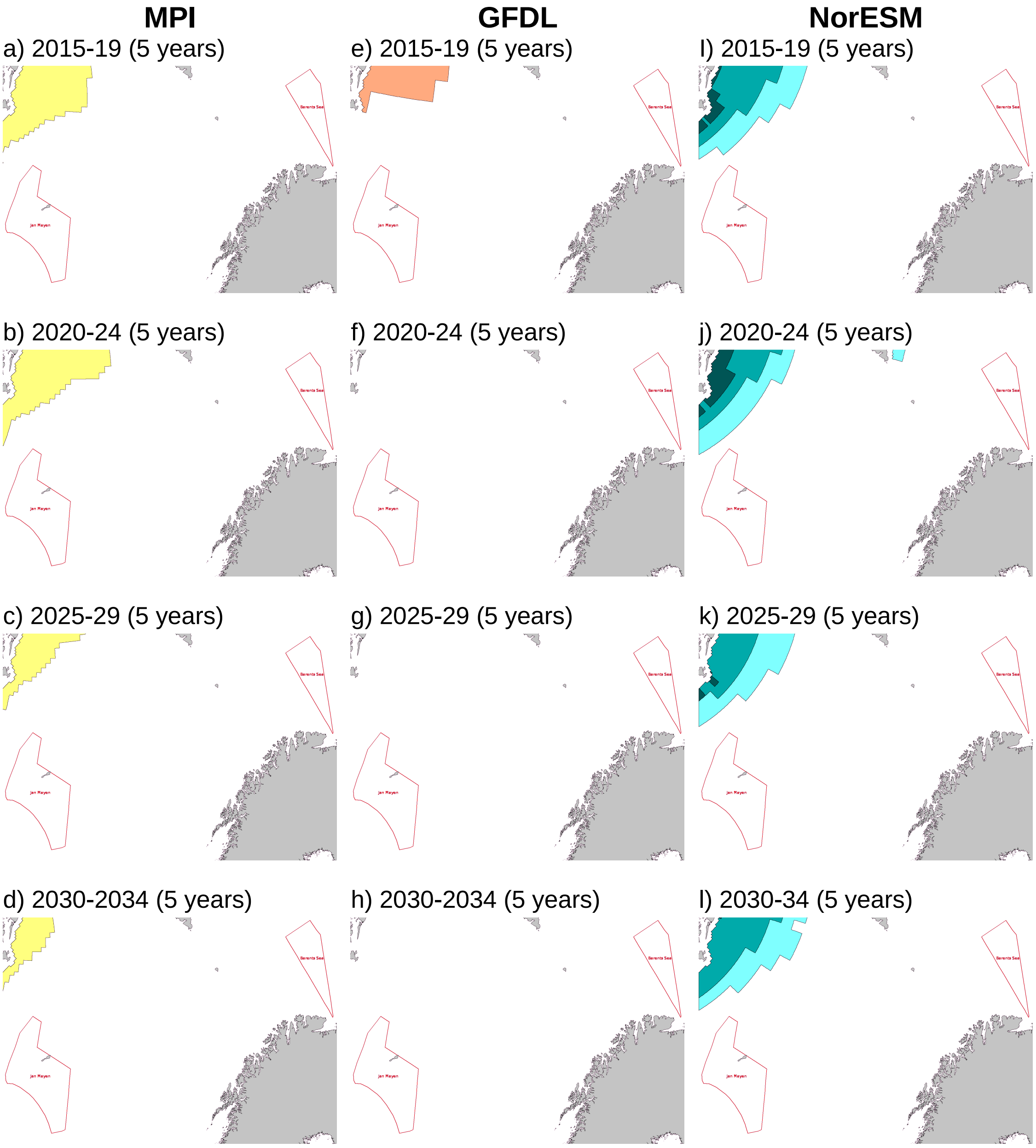
I) 2015-19 (5 years)

j) 2020-24 (5 years)

k) 2025-29 (5 years)

l) 2030-34 (5 years)

Figure 5.21: CMIP model forecasts for AUGUST at 40% ice concentration under emissions scenario RCP45.



MPI

GFDL

NorESM

a) 2015-19 (5 years)

e) 2015-19 (5 years)

I) 2015-19 (5 years)

b) 2020-24 (5 years)

f) 2020-24 (5 years)

j) 2020-24 (5 years)

c) 2025-29 (5 years)

g) 2025-29 (5 years)

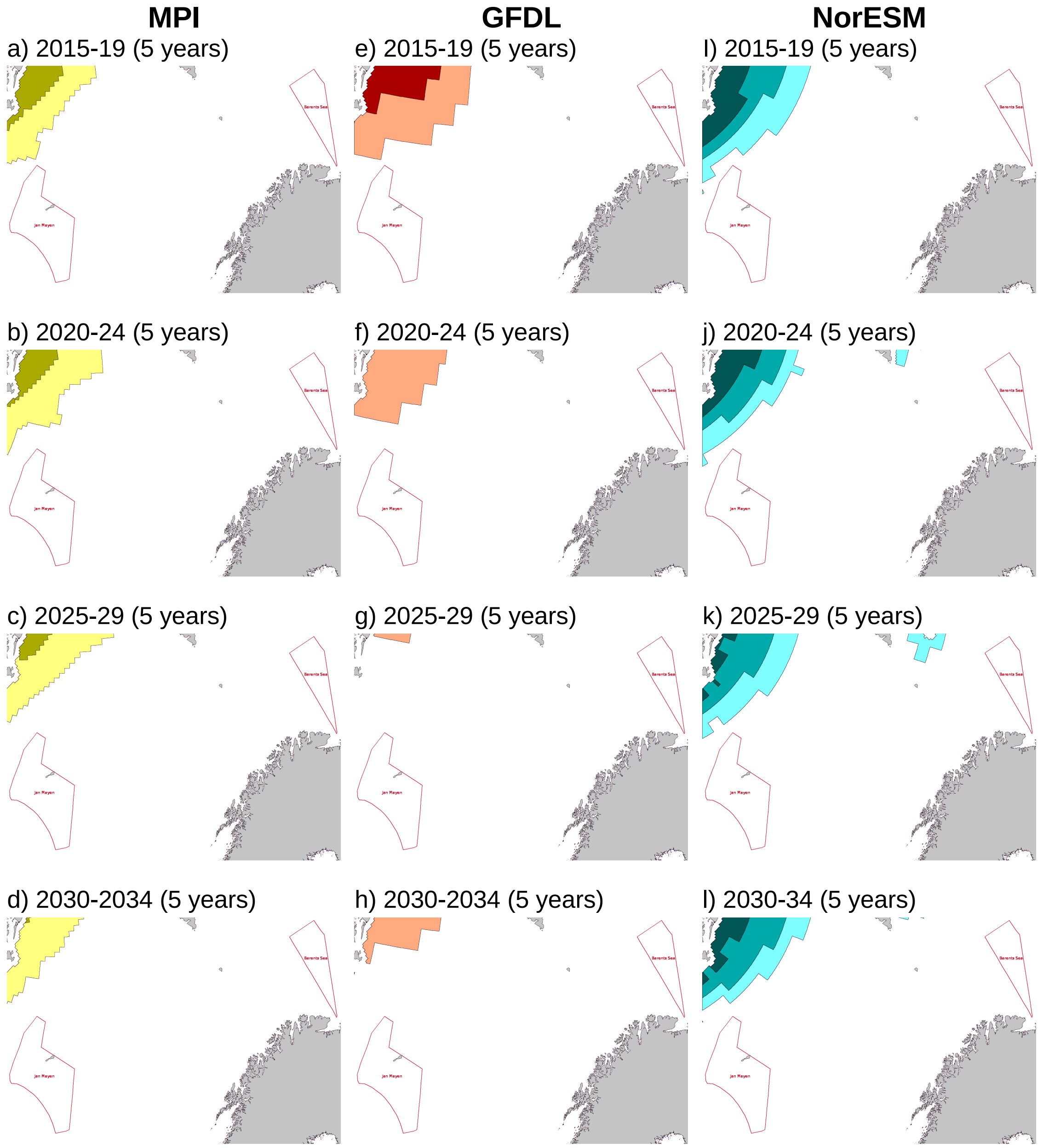
k) 2025-29 (5 years)

d) 2030-2034 (5 years)

h) 2030-2034 (5 years)

l) 2030-34 (5 years)

Figure 5.22: CMIP model forecasts for SEPTEMBER at 40% ice concentration under emissions scenario RCP45.



MPI

GFDL

NorESM

a) 2015-19 (5 years)

e) 2015-19 (5 years)

I) 2015-19 (5 years)

b) 2020-24 (5 years)

f) 2020-24 (5 years)

j) 2020-24 (5 years)

c) 2025-29 (5 years)

g) 2025-29 (5 years)

k) 2025-29 (5 years)

d) 2030-2034 (5 years)

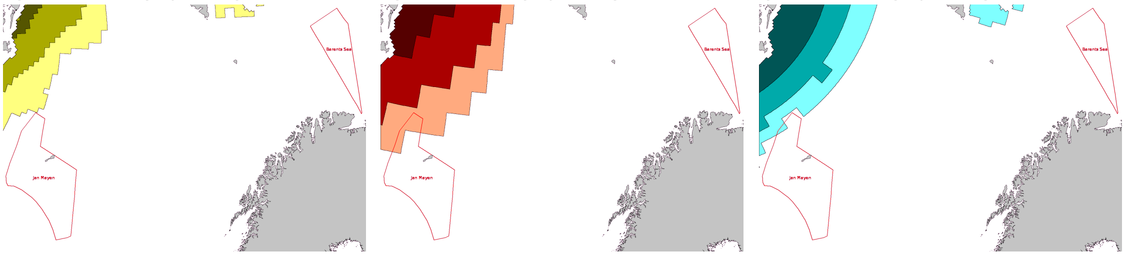
h) 2030-2034 (5 years)

l) 2030-34 (5 years)

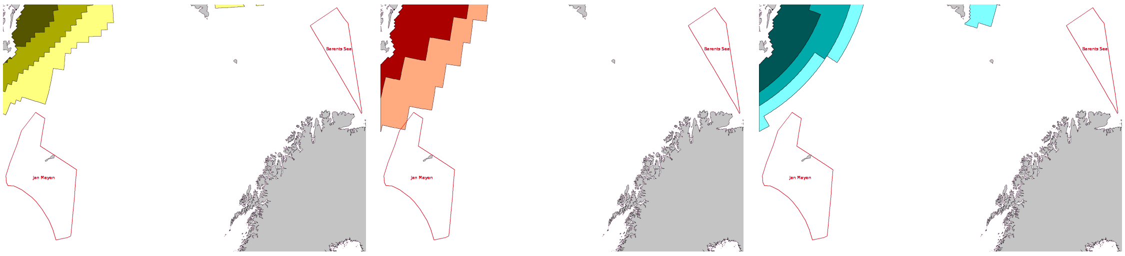
Figure 5.23: CMIP model forecasts for OCTOBER at 40% ice concentration under emissions scenario RCP45.

MPI **GFDL** **NorESM**

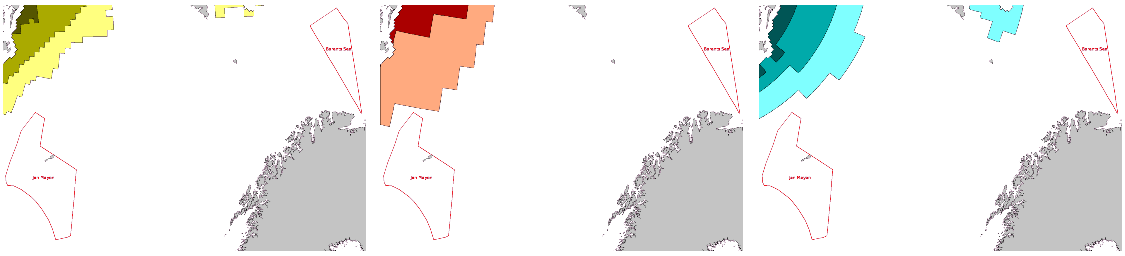
a) 2015-19 (5 years) e) 2015-19 (5 years) l) 2015-19 (5 years)



b) 2020-24 (5 years) f) 2020-24 (5 years) j) 2020-24 (5 years)



c) 2025-29 (5 years) g) 2025-29 (5 years) k) 2025-29 (5 years)



d) 2030-2034 (5 years) h) 2030-2034 (5 years) l) 2030-34 (5 years)

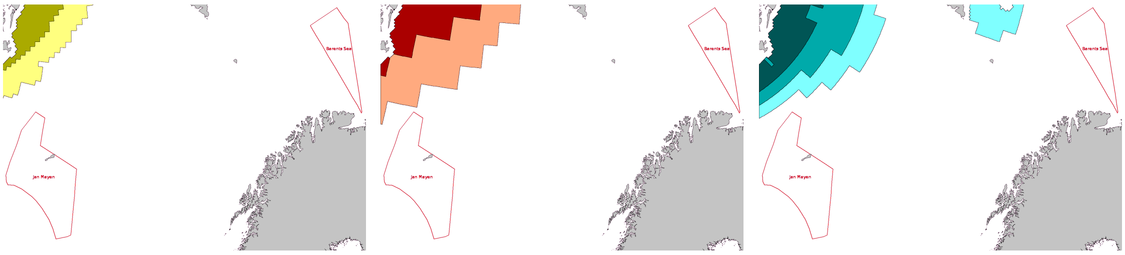
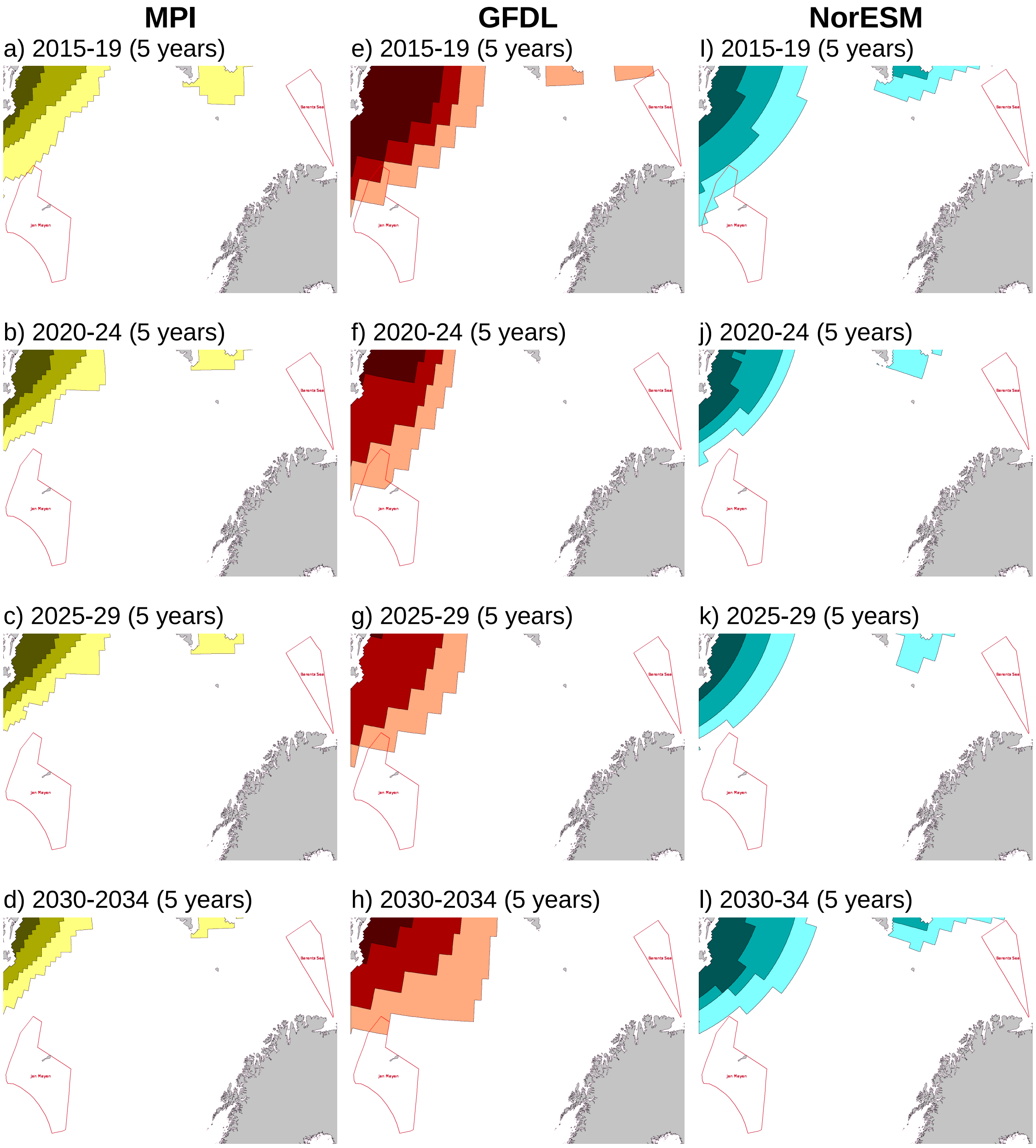


Figure 5.24: CMIP model forecasts for NOVEMBER at 40% ice concentration under emissions scenario RCP45.



a) 2015-19 (5 years)
e) 2015-19 (5 years)
I) 2015-19 (5 years)

b) 2020-24 (5 years)
f) 2020-24 (5 years)
j) 2020-24 (5 years)

c) 2025-29 (5 years)
g) 2025-29 (5 years)
k) 2025-29 (5 years)

d) 2030-2034 (5 years)
h) 2030-2034 (5 years)
l) 2030-34 (5 years)

Figure 5.25: CMIP model forecasts for DECEMBER at 40% ice concentration under emissions scenario RCP45.

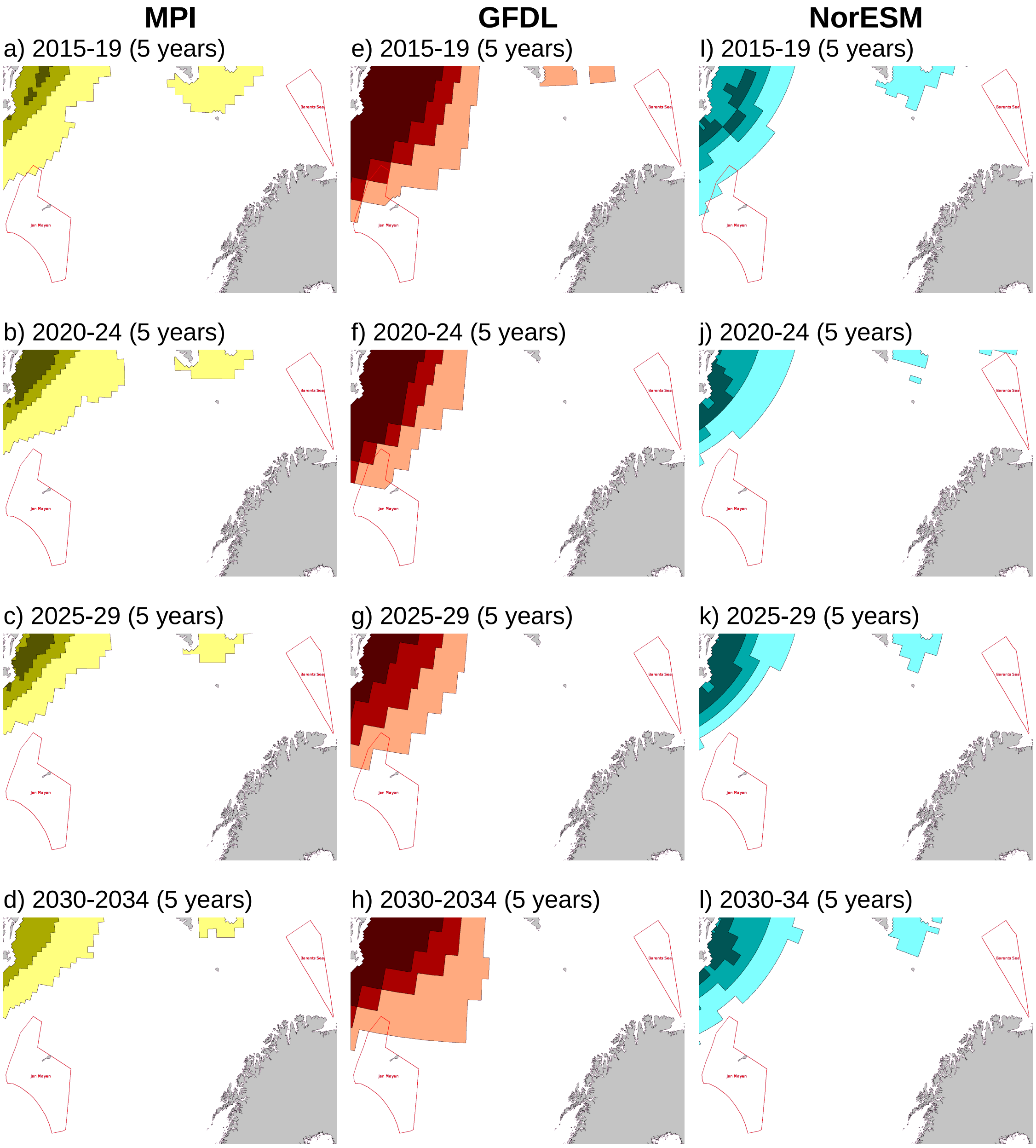
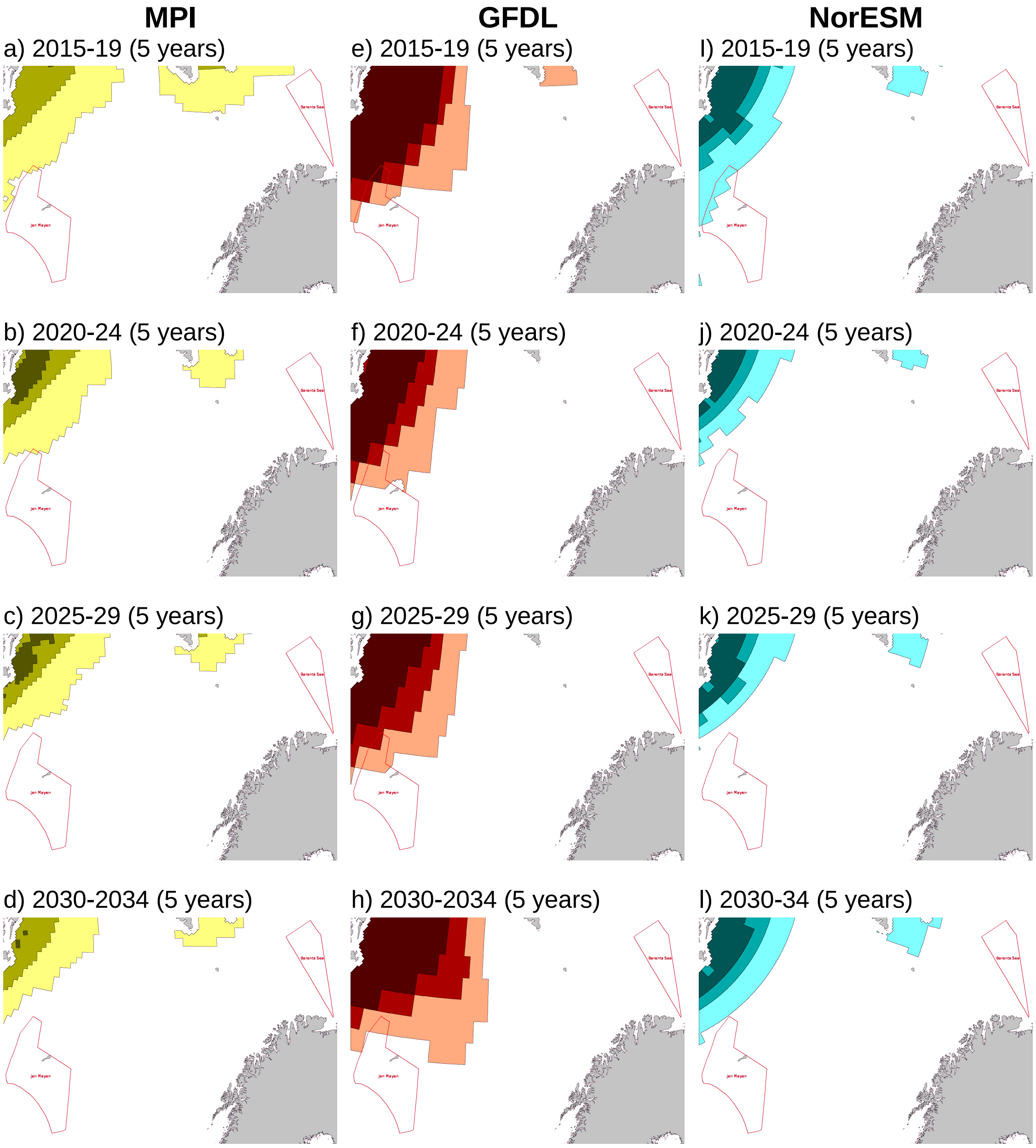
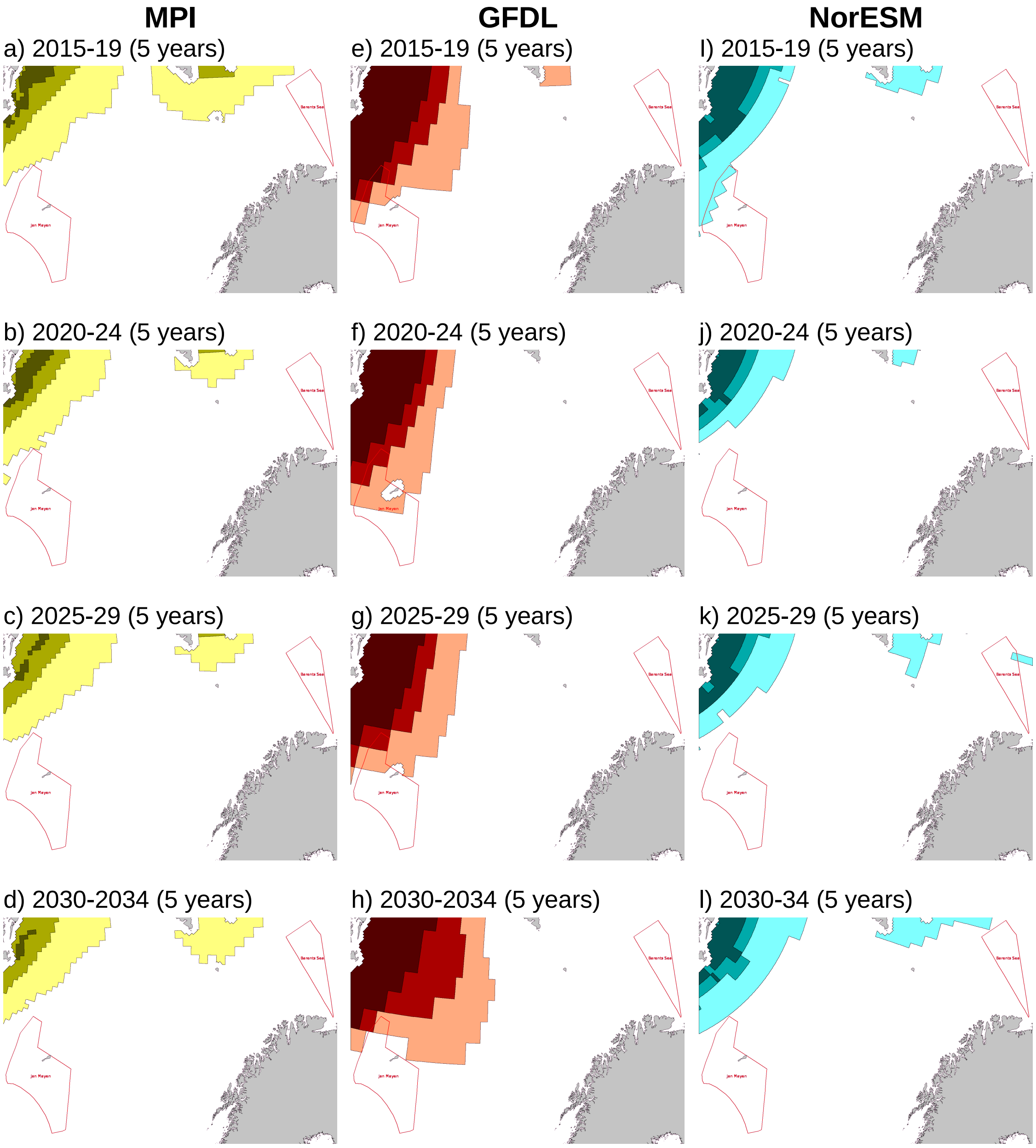


Figure 5.26: CMIP model forecasts for JANUARY at 70% ice concentration under emissions scenario RCP45.



a) 2015-19 (5 years)
e) 2015-19 (5 years)
I) 2015-19 (5 years)
b) 2020-24 (5 years)
f) 2020-24 (5 years)
j) 2020-24 (5 years)
c) 2025-29 (5 years)
g) 2025-29 (5 years)
k) 2025-29 (5 years)
d) 2030-2034 (5 years)
h) 2030-2034 (5 years)
l) 2030-34 (5 years)

Figure 5.27: CMIP model forecasts for FEBRUARY at 70% ice concentration under emissions scenario RCP45.



MPI

GFDL

NorESM

a) 2015-19 (5 years)

e) 2015-19 (5 years)

I) 2015-19 (5 years)

b) 2020-24 (5 years)

f) 2020-24 (5 years)

j) 2020-24 (5 years)

c) 2025-29 (5 years)

g) 2025-29 (5 years)

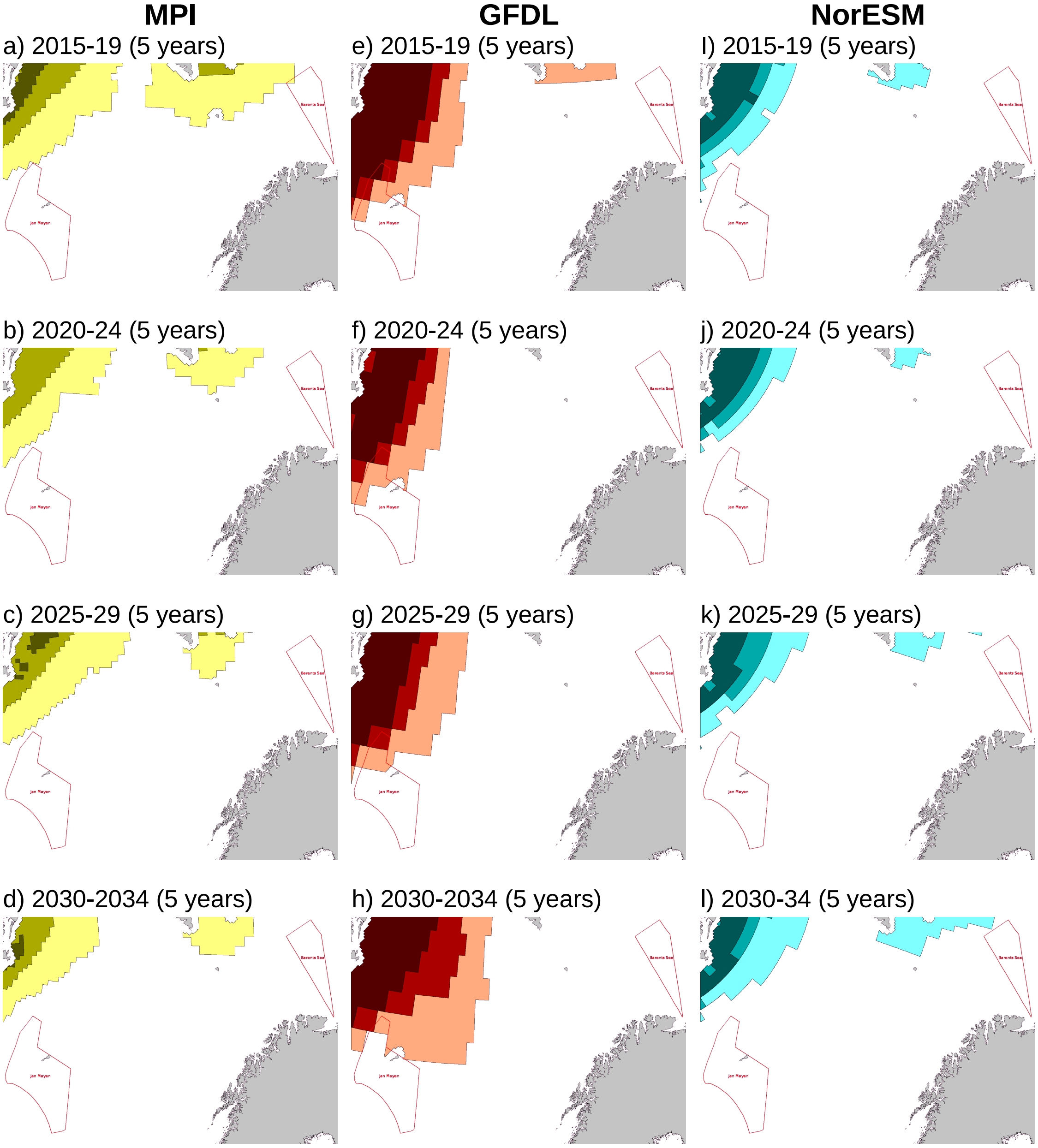
k) 2025-29 (5 years)

d) 2030-2034 (5 years)

h) 2030-2034 (5 years)

l) 2030-34 (5 years)

Figure 5.28: CMIP model forecasts for MARCH at 70% ice concentration under emissions scenario RCP45.



a) 2015-19 (5 years)
e) 2015-19 (5 years)
I) 2015-19 (5 years)
b) 2020-24 (5 years)
f) 2020-24 (5 years)
j) 2020-24 (5 years)
c) 2025-29 (5 years)
g) 2025-29 (5 years)
k) 2025-29 (5 years)
d) 2030-2034 (5 years)
h) 2030-2034 (5 years)
l) 2030-34 (5 years)

Figure 5.29: CMIP model forecasts for APRIL at 70% ice concentration under emissions scenario RCP45.

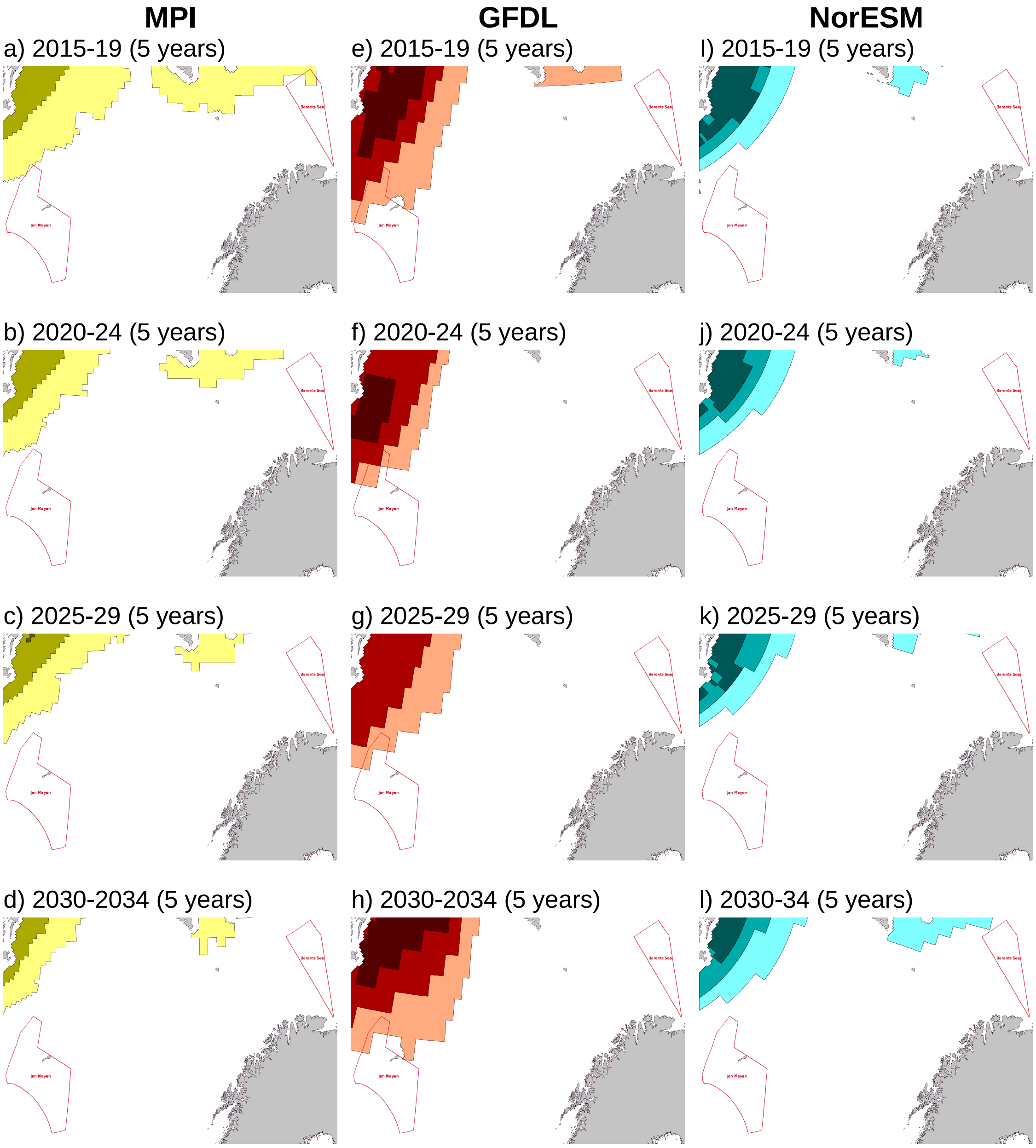


Figure 5.30: CMIP model forecasts for MAY at 70% ice concentration under emissions scenario RCP45.

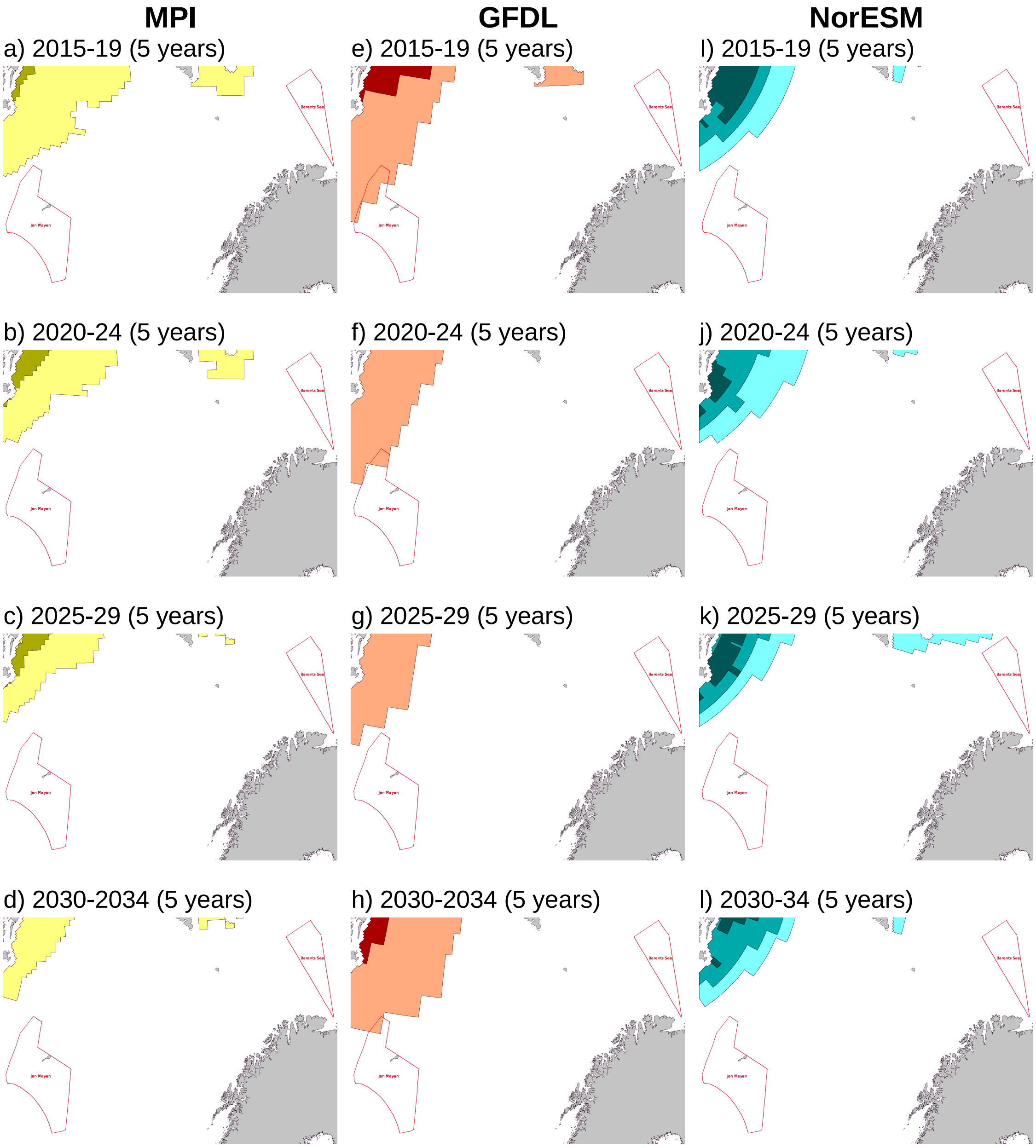
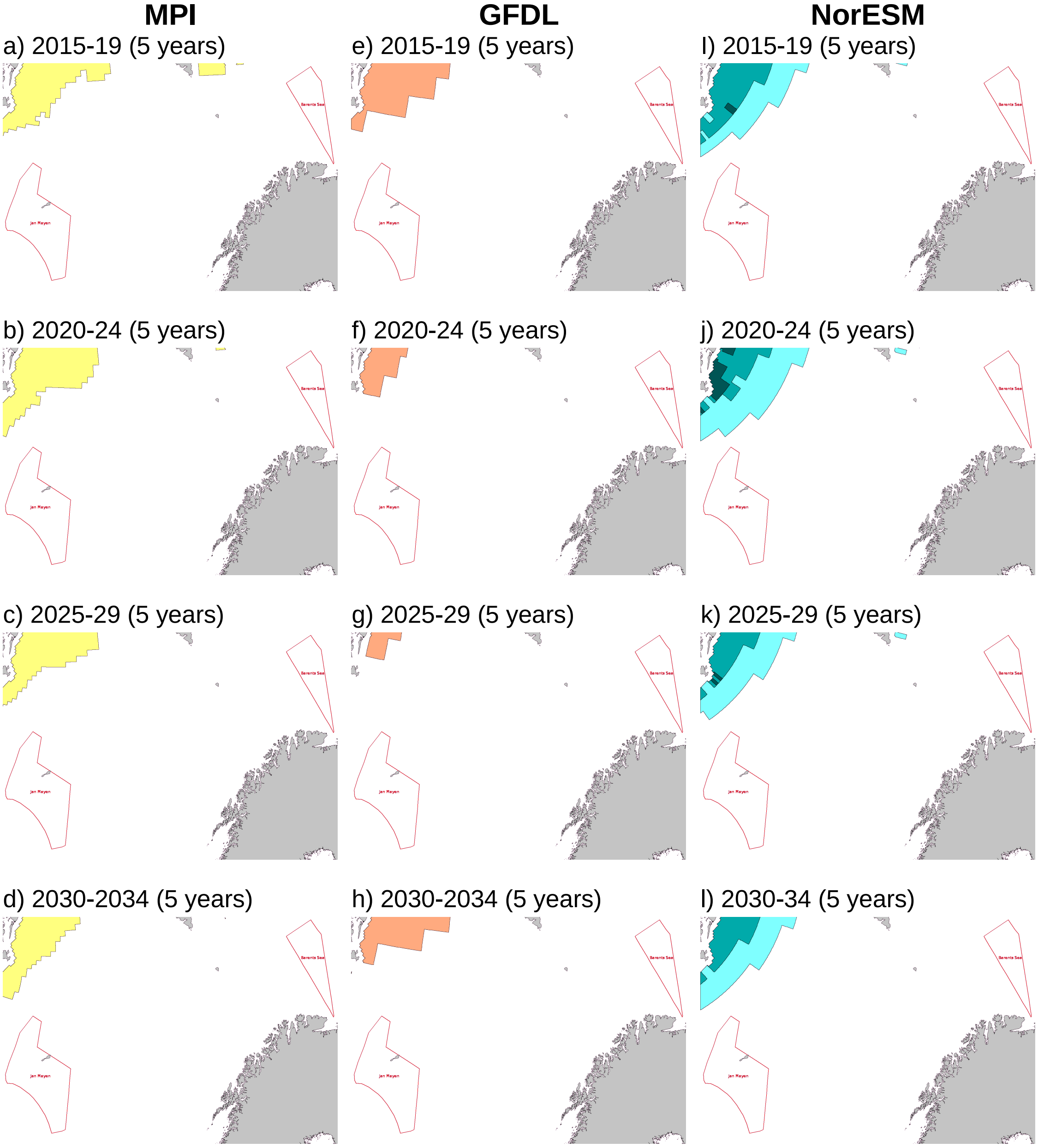


Figure 5.31: CMIP model forecasts for JUNE at 70% ice concentration under emissions scenario RCP45.



MPI

GFDL

NorESM

a) 2015-19 (5 years)

e) 2015-19 (5 years)

I) 2015-19 (5 years)

b) 2020-24 (5 years)

f) 2020-24 (5 years)

j) 2020-24 (5 years)

c) 2025-29 (5 years)

g) 2025-29 (5 years)

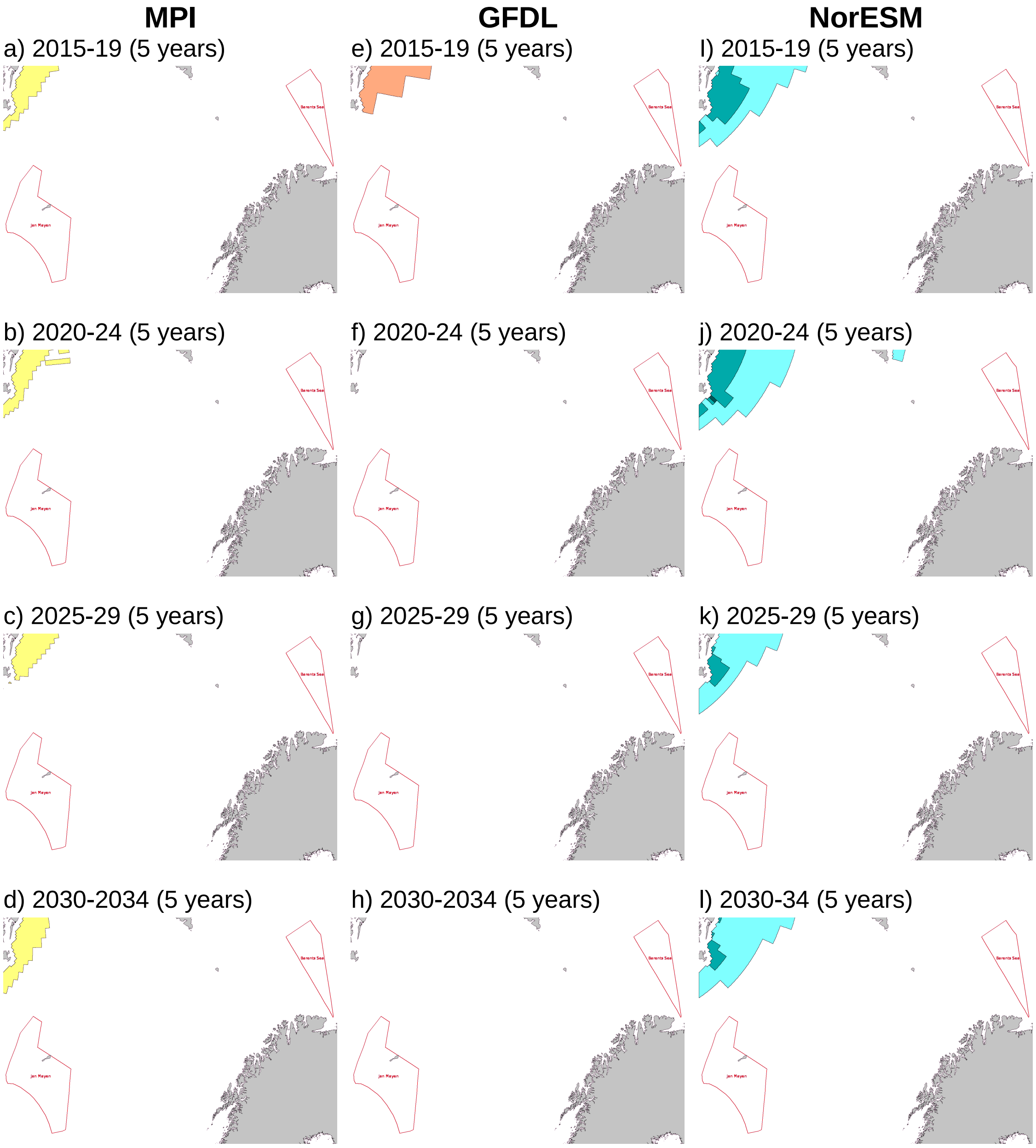
k) 2025-29 (5 years)

d) 2030-2034 (5 years)

h) 2030-2034 (5 years)

l) 2030-34 (5 years)

Figure 5.32: CMIP model forecasts for JULY at 70% ice concentration under emissions scenario RCP45.



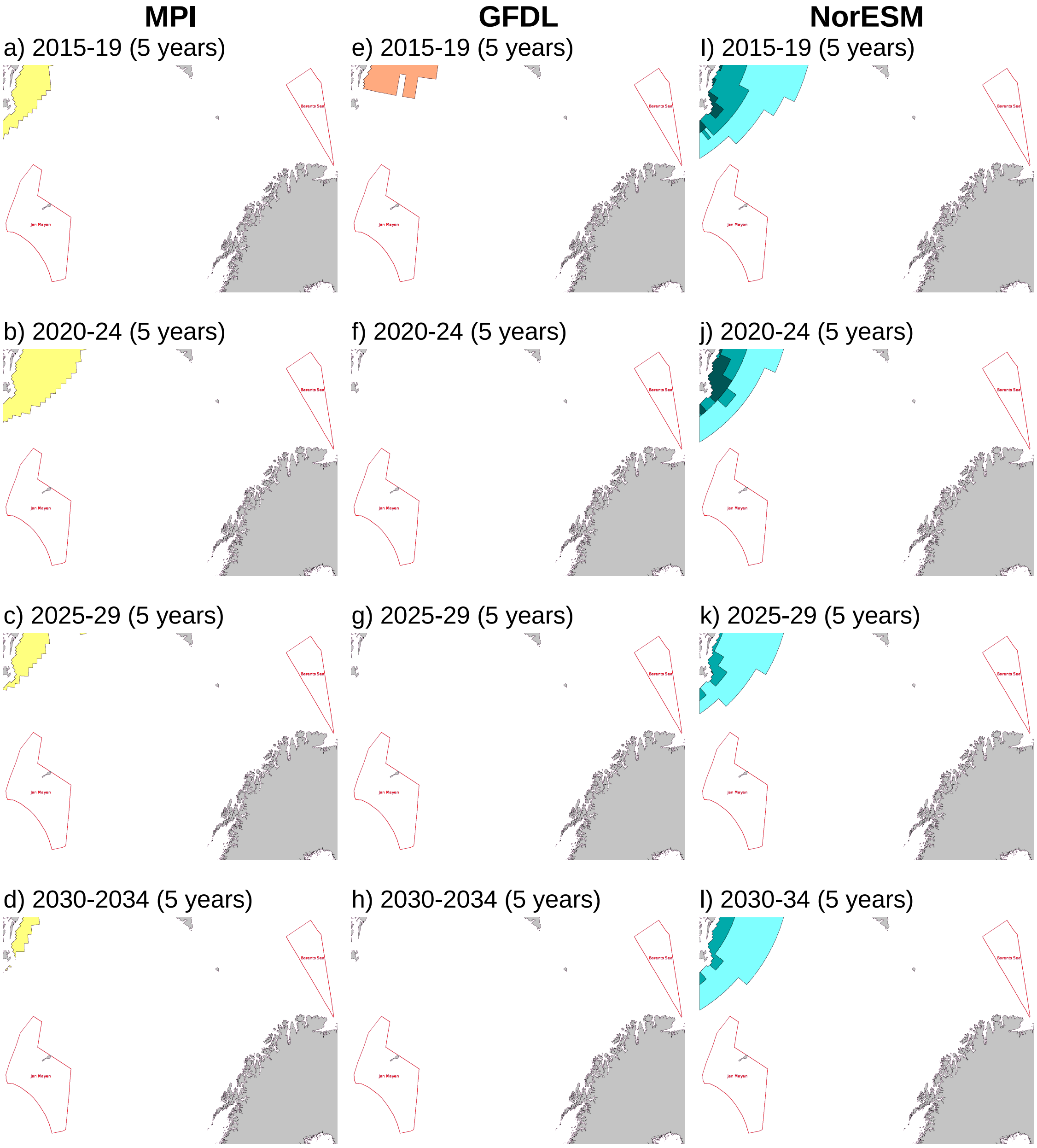
a) 2015-19 (5 years)
e) 2015-19 (5 years)
I) 2015-19 (5 years)

b) 2020-24 (5 years)
f) 2020-24 (5 years)
j) 2020-24 (5 years)

c) 2025-29 (5 years)
g) 2025-29 (5 years)
k) 2025-29 (5 years)

d) 2030-2034 (5 years)
h) 2030-2034 (5 years)
l) 2030-34 (5 years)

Figure 5.33: CMIP model forecasts for AUGUST at 70% ice concentration under emissions scenario RCP45.



a) 2015-19 (5 years)
b) 2020-24 (5 years)
c) 2025-29 (5 years)
d) 2030-2034 (5 years)
e) 2015-19 (5 years)
f) 2020-24 (5 years)
g) 2025-29 (5 years)
h) 2030-2034 (5 years)
l) 2015-19 (5 years)
j) 2020-24 (5 years)
k) 2025-29 (5 years)
l) 2030-34 (5 years)

Figure 5.34: CMIP model forecasts for SEPTEMBER at 70% ice concentration under emissions scenario RCP45.

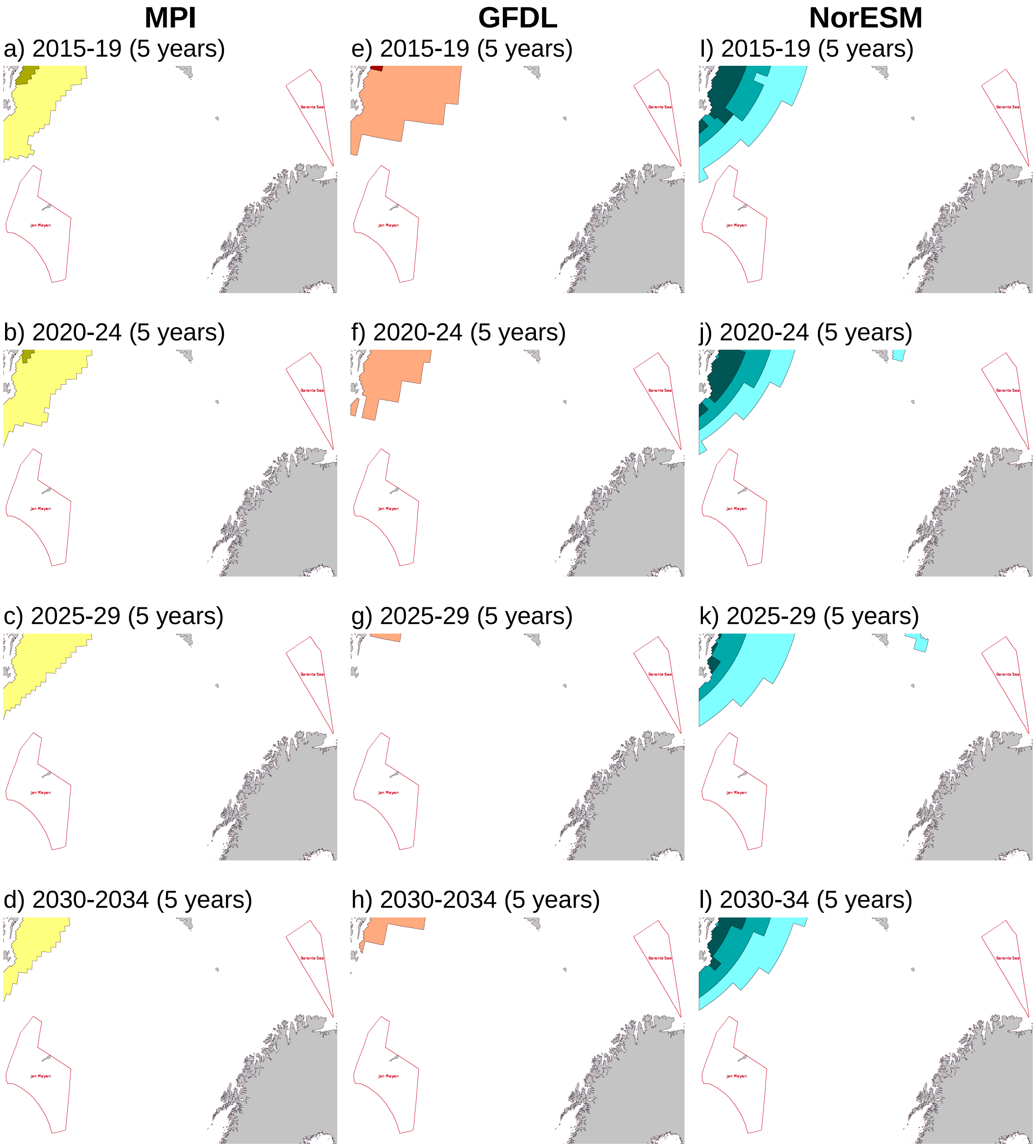


Figure 5.35: CMIP model forecasts for OCTOBER at 70% ice concentration under emissions scenario RCP45.

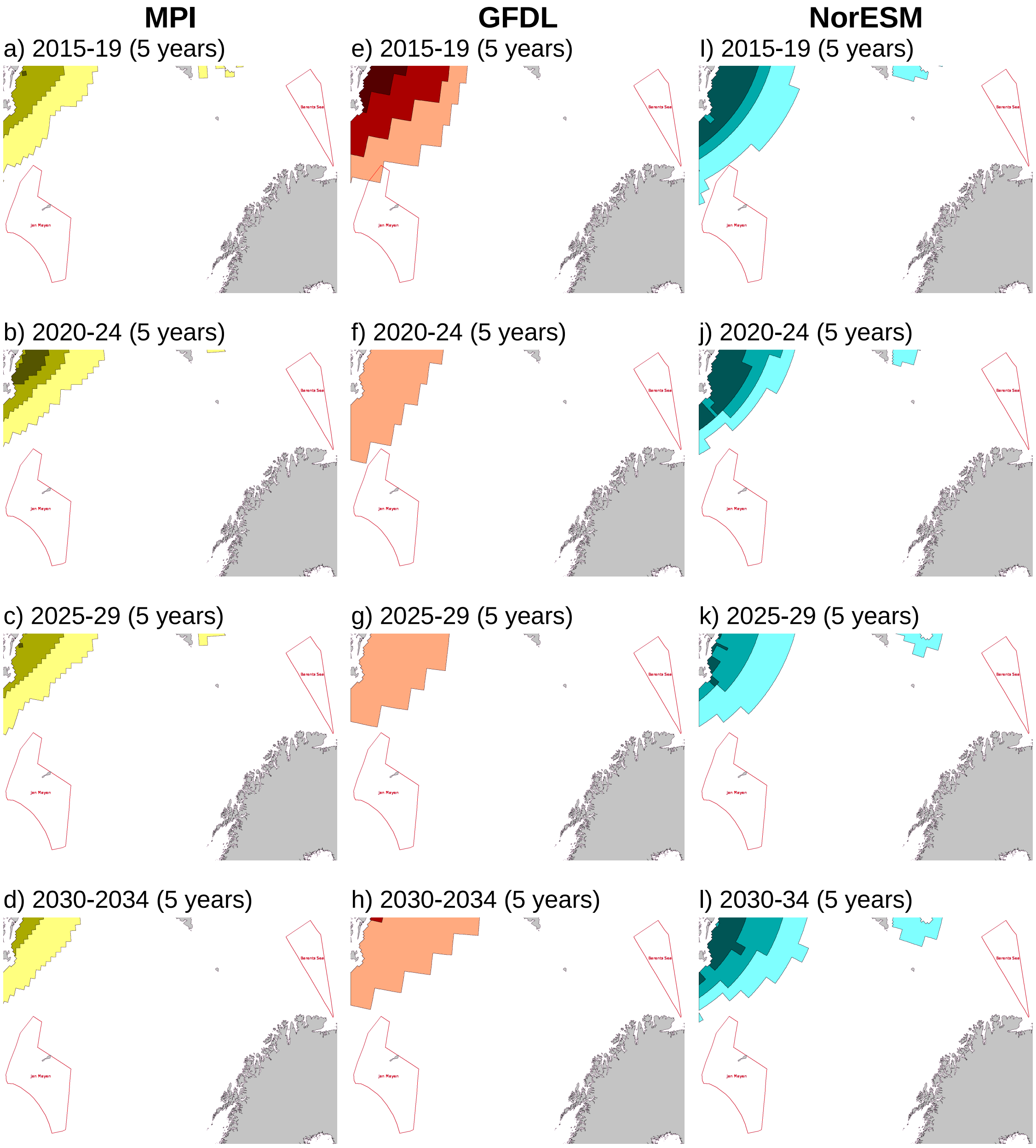


Figure 5.36: CMIP model forecasts for NOVEMBER at 70% ice concentration under emissions scenario RCP45.

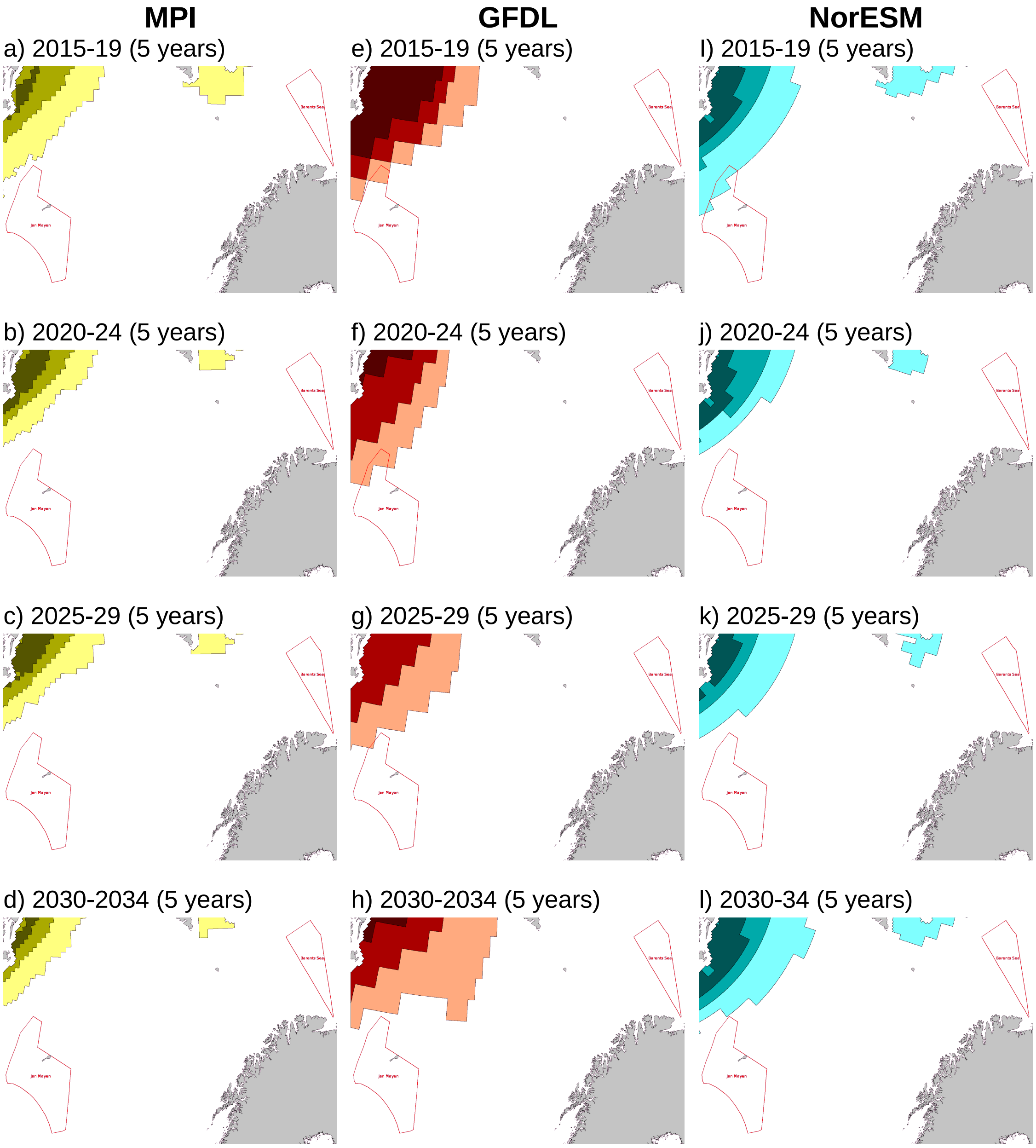


Figure 5.37: CMIP model forecasts for DECEMBER at 70% ice concentration under emissions scenario RCP45.

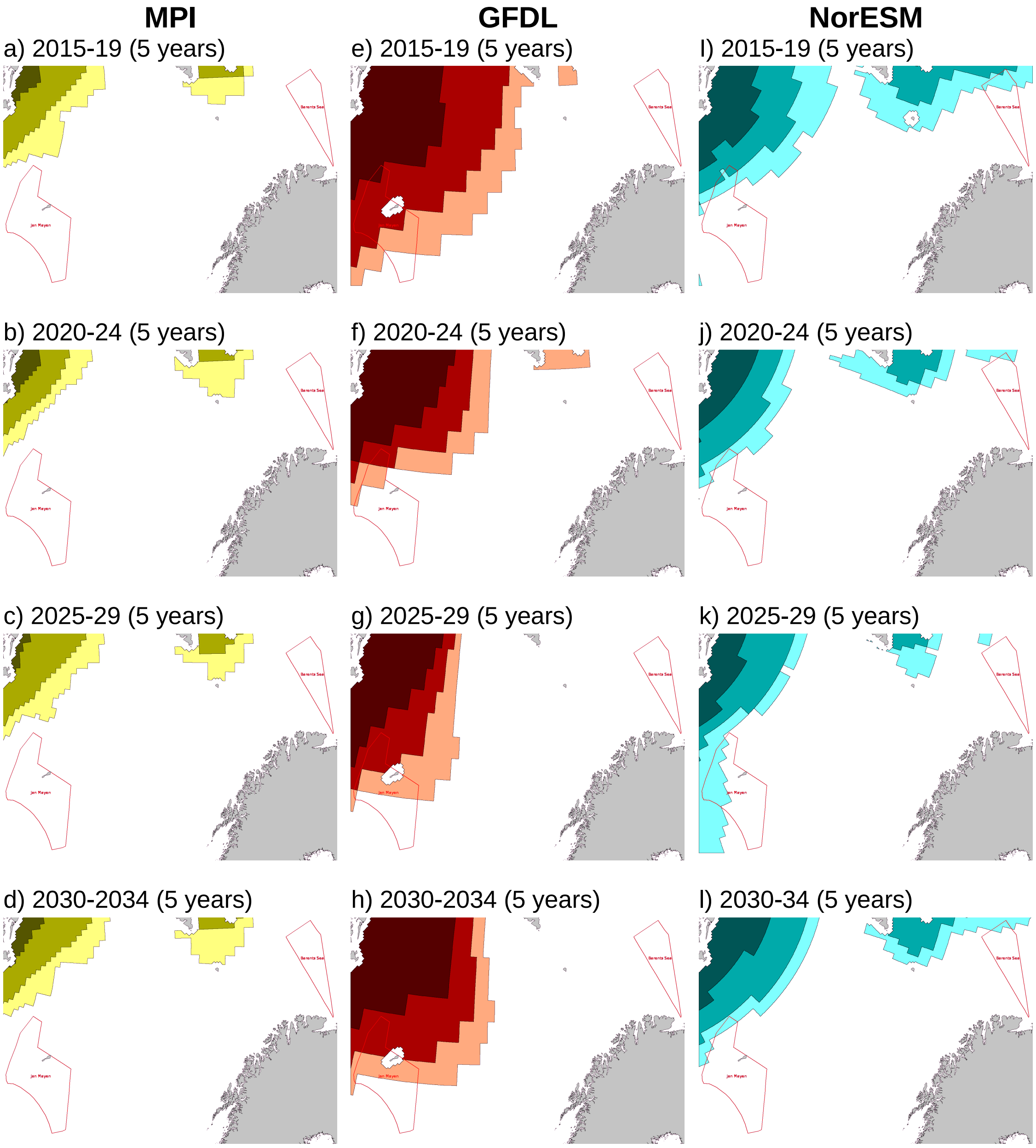
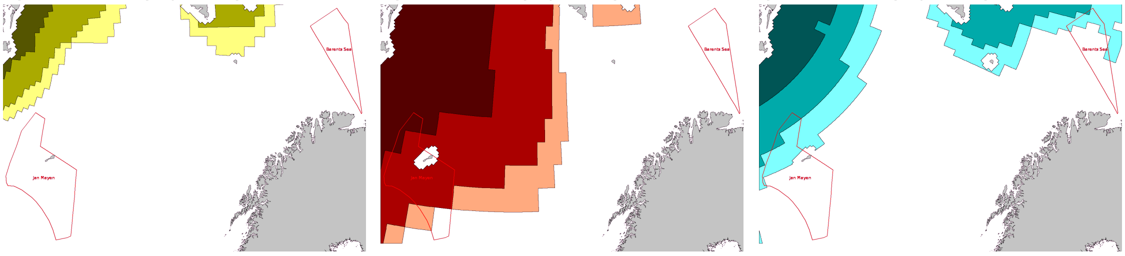


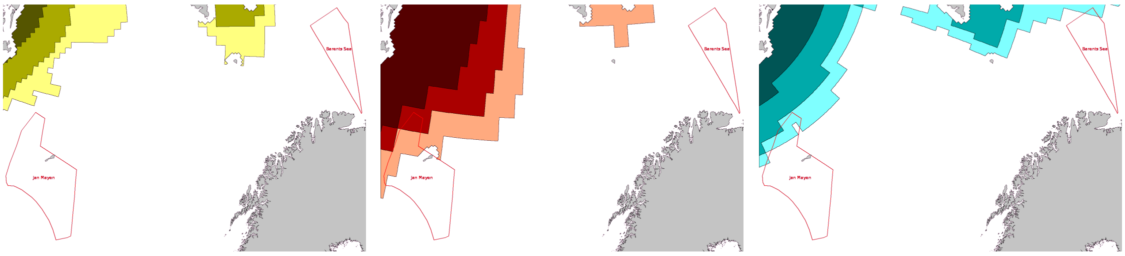
Figure 5.38: CMIP model forecasts for JANUARY at 10% ice concentration under emissions scenario RCP85.

MPI GFDL NorESM

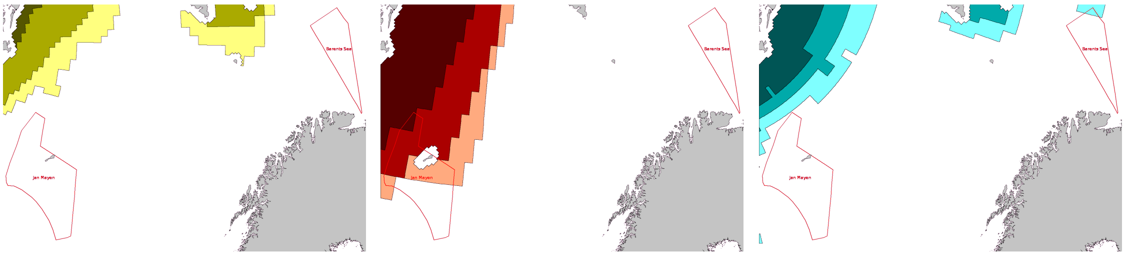
a) 2015-19 (5 years) e) 2015-19 (5 years) I) 2015-19 (5 years)



b) 2020-24 (5 years) f) 2020-24 (5 years) j) 2020-24 (5 years)



c) 2025-29 (5 years) g) 2025-29 (5 years) k) 2025-29 (5 years)



d) 2030-2034 (5 years) h) 2030-2034 (5 years) l) 2030-34 (5 years)

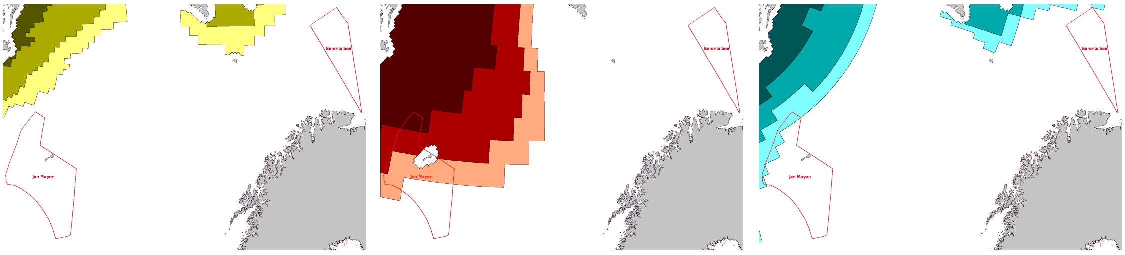


Figure 5.39: CMIP model forecasts for FEBRUARY at 10% ice concentration under emissions scenario RCP85.

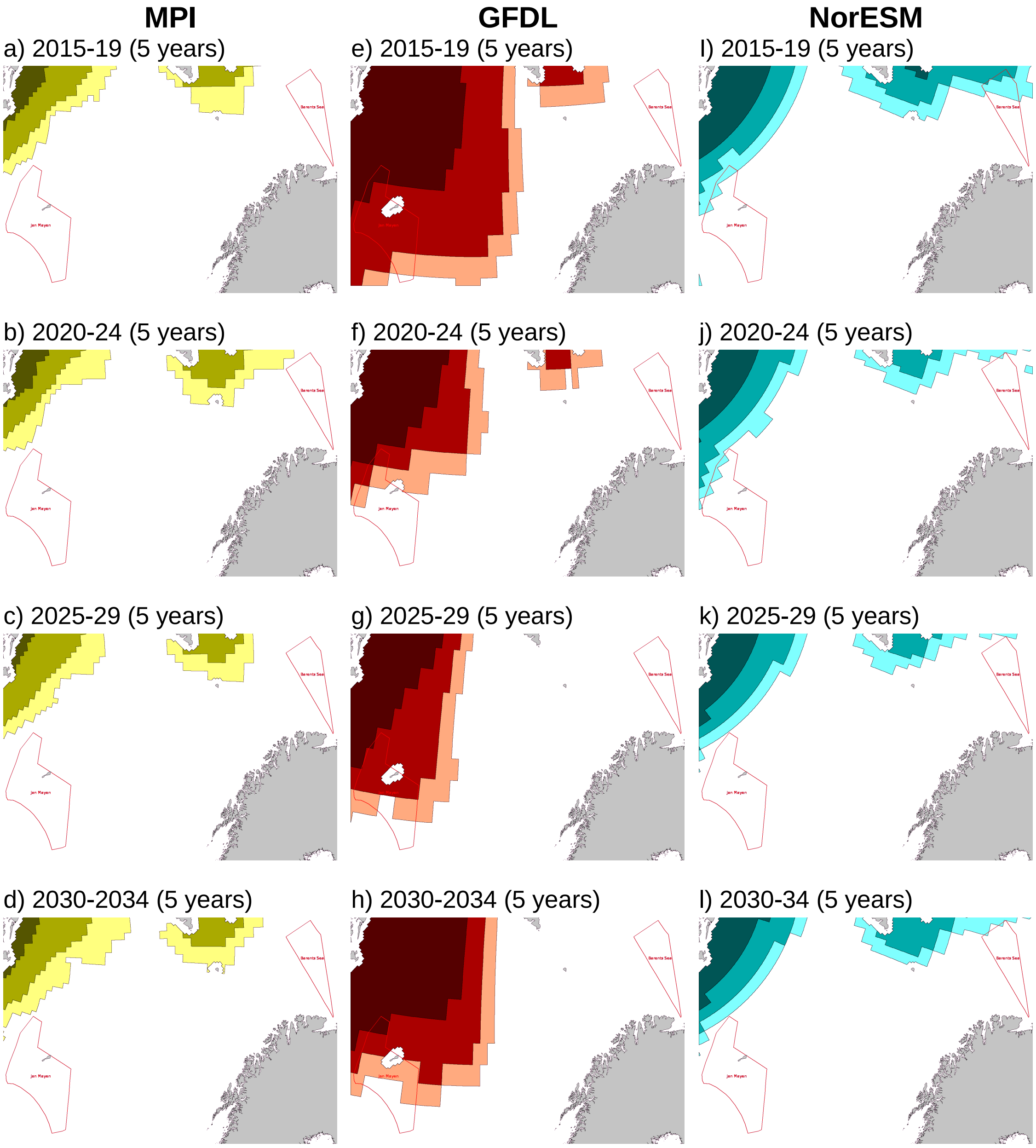
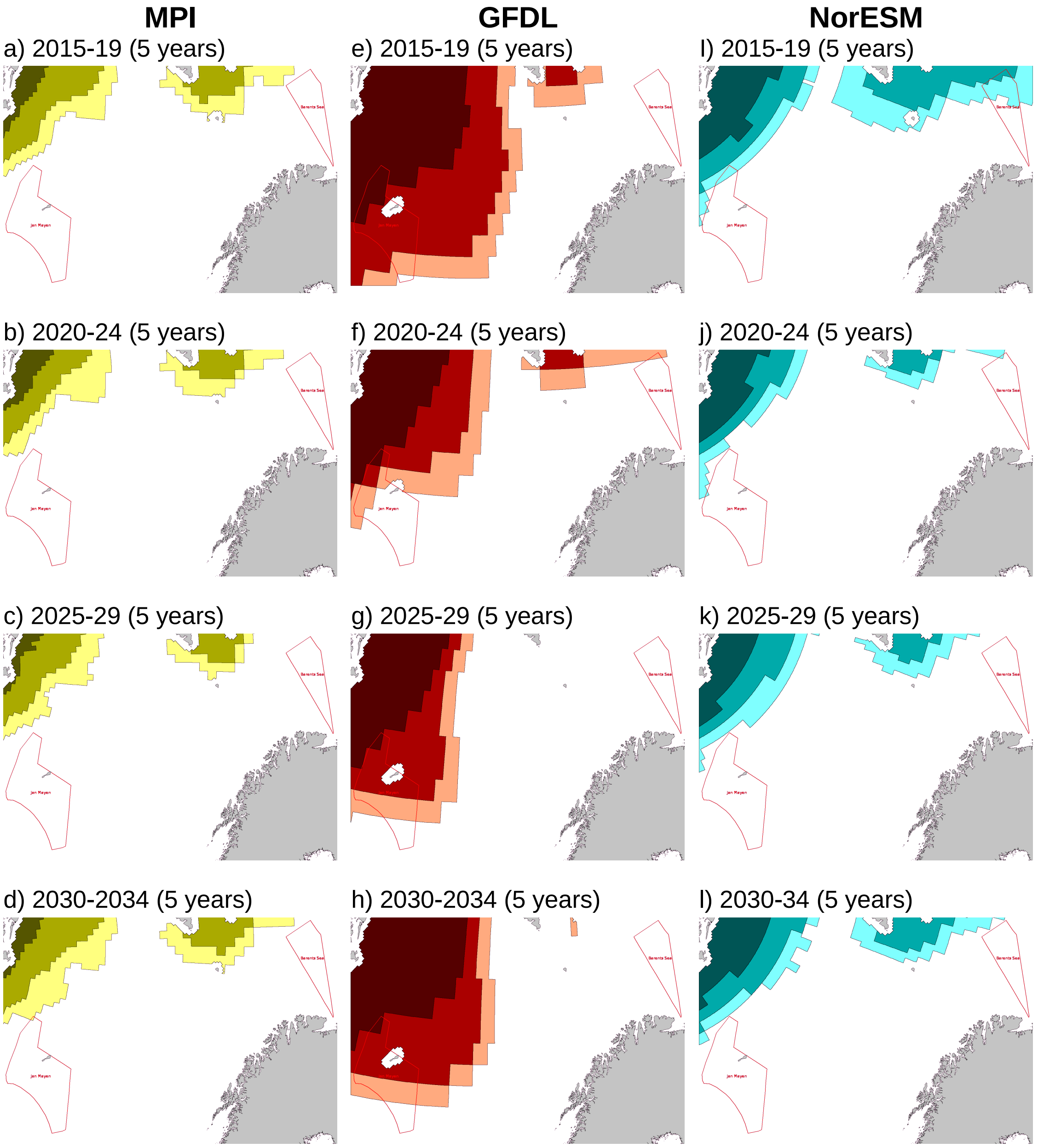


Figure 5.40: CMIP model forecasts for MARCH at 10% ice concentration under emissions scenario RCP85.



a) 2015-19 (5 years)
e) 2015-19 (5 years)
l) 2015-19 (5 years)

b) 2020-24 (5 years)
f) 2020-24 (5 years)
j) 2020-24 (5 years)

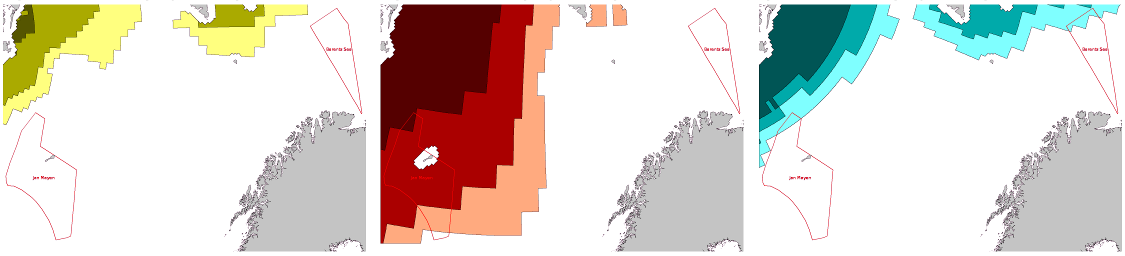
c) 2025-29 (5 years)
g) 2025-29 (5 years)
k) 2025-29 (5 years)

d) 2030-2034 (5 years)
h) 2030-2034 (5 years)
l) 2030-34 (5 years)

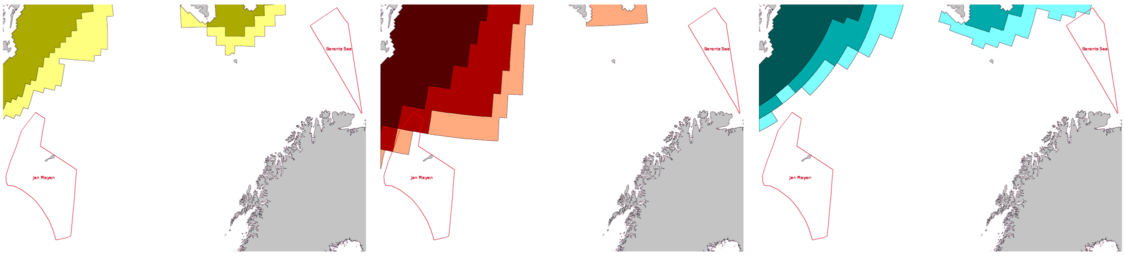
Figure 5.41: CMIP model forecasts for APRIL at 10% ice concentration under emissions scenario RCP85.

MPI **GFDL** **NorESM**

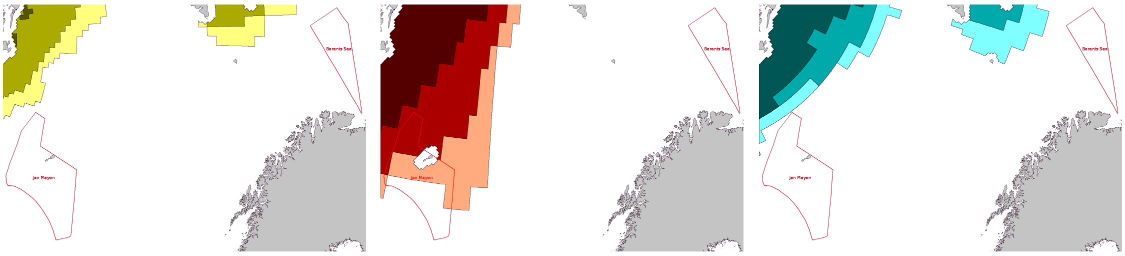
a) 2015-19 (5 years) e) 2015-19 (5 years) I) 2015-19 (5 years)



b) 2020-24 (5 years) f) 2020-24 (5 years) j) 2020-24 (5 years)



c) 2025-29 (5 years) g) 2025-29 (5 years) k) 2025-29 (5 years)



d) 2030-2034 (5 years) h) 2030-2034 (5 years) l) 2030-34 (5 years)

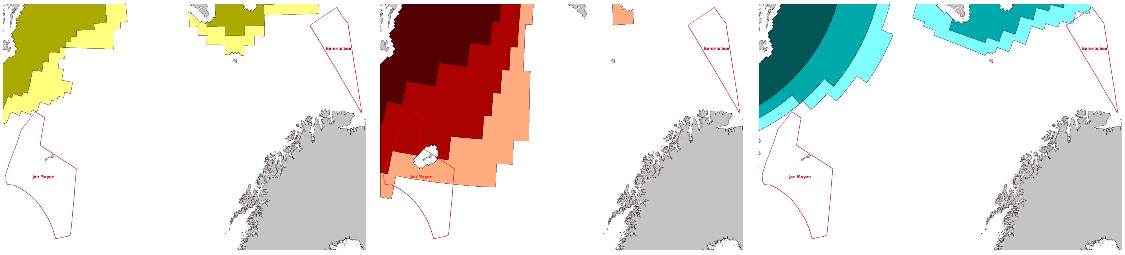
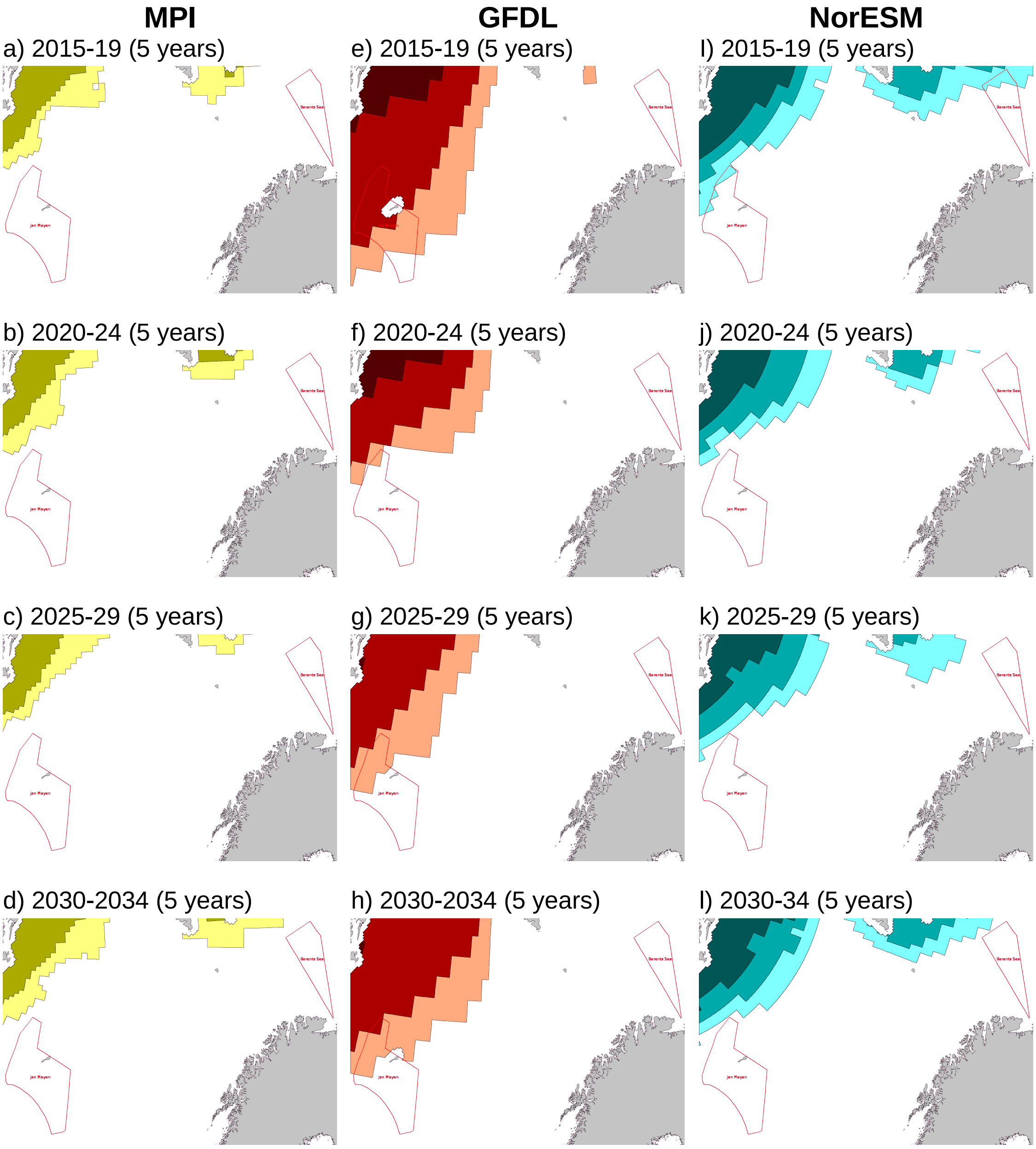


Figure 5.42: CMIP model forecasts for MAY at 10% ice concentration under emissions scenario RCP85.



a) 2015-19 (5 years)
e) 2015-19 (5 years)
I) 2015-19 (5 years)

b) 2020-24 (5 years)
f) 2020-24 (5 years)
j) 2020-24 (5 years)

c) 2025-29 (5 years)
g) 2025-29 (5 years)
k) 2025-29 (5 years)

d) 2030-2034 (5 years)
h) 2030-2034 (5 years)
l) 2030-34 (5 years)

Figure 5.43: CMIP model forecasts for JUNE at 10% ice concentration under emissions scenario RCP85.

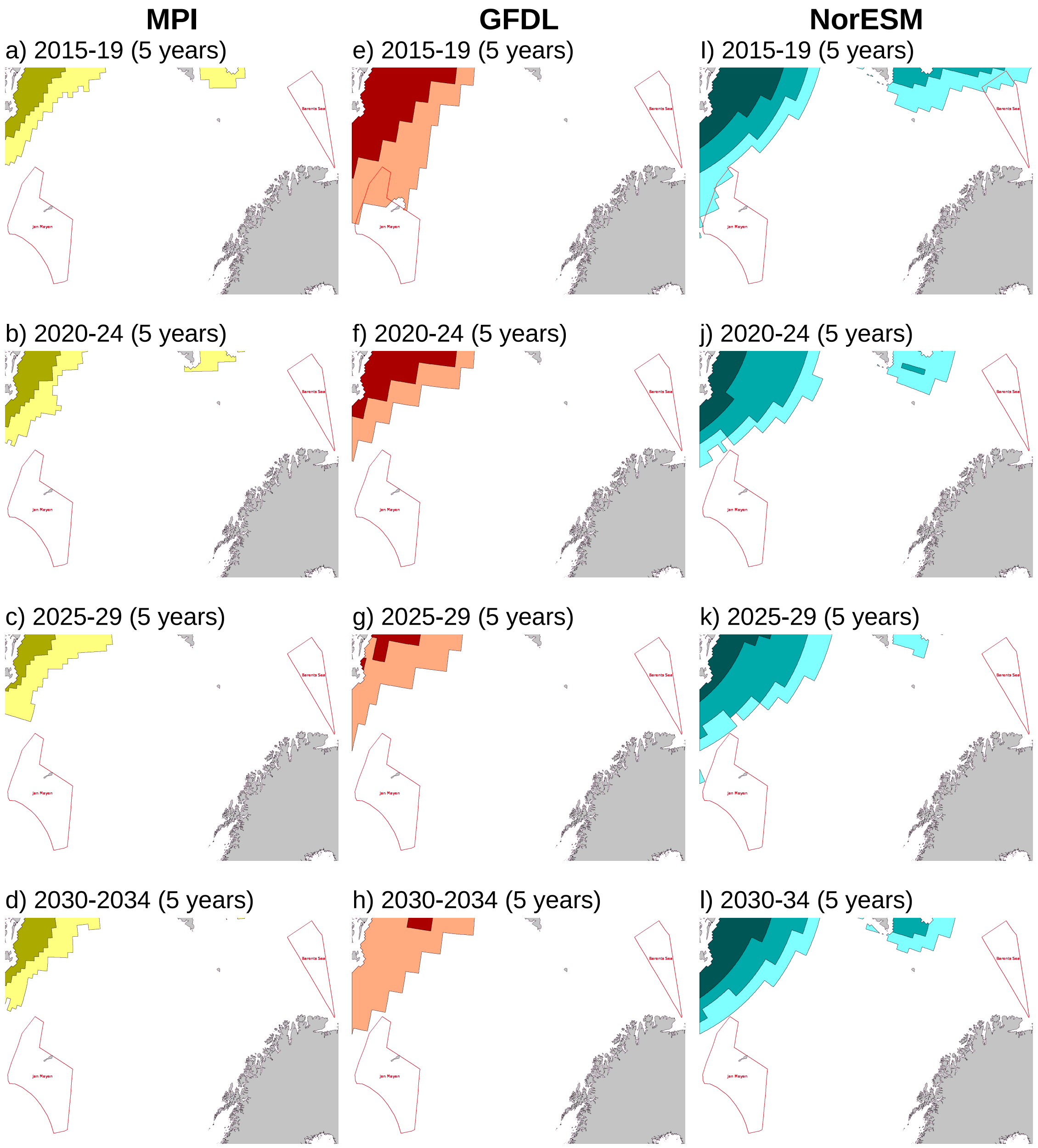


Figure 5.44: CMIP model forecasts for JULY at 10% ice concentration under emissions scenario RCP85.

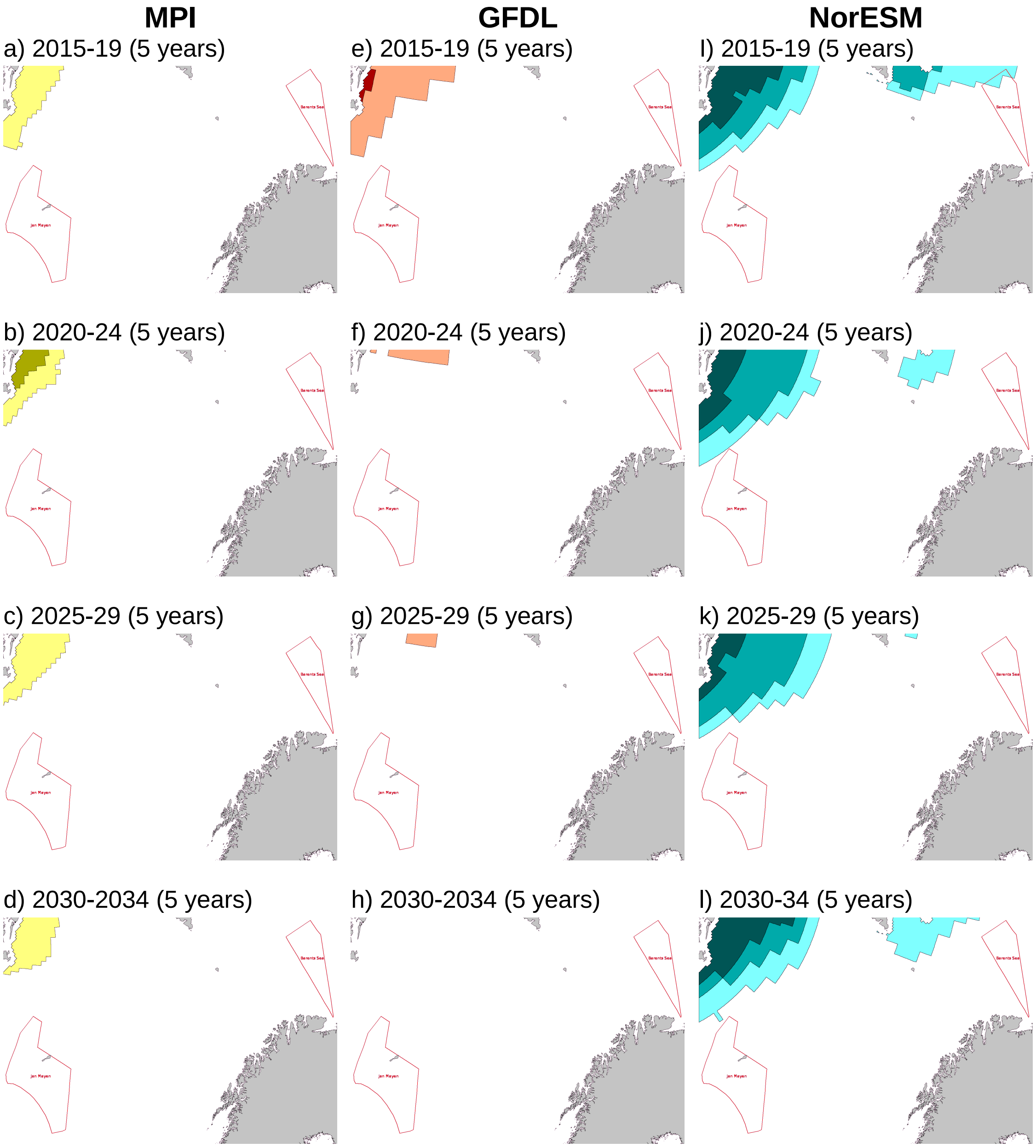


Figure 5.45: CMIP model forecasts for AUGUST at 10% ice concentration under emissions scenario RCP85.

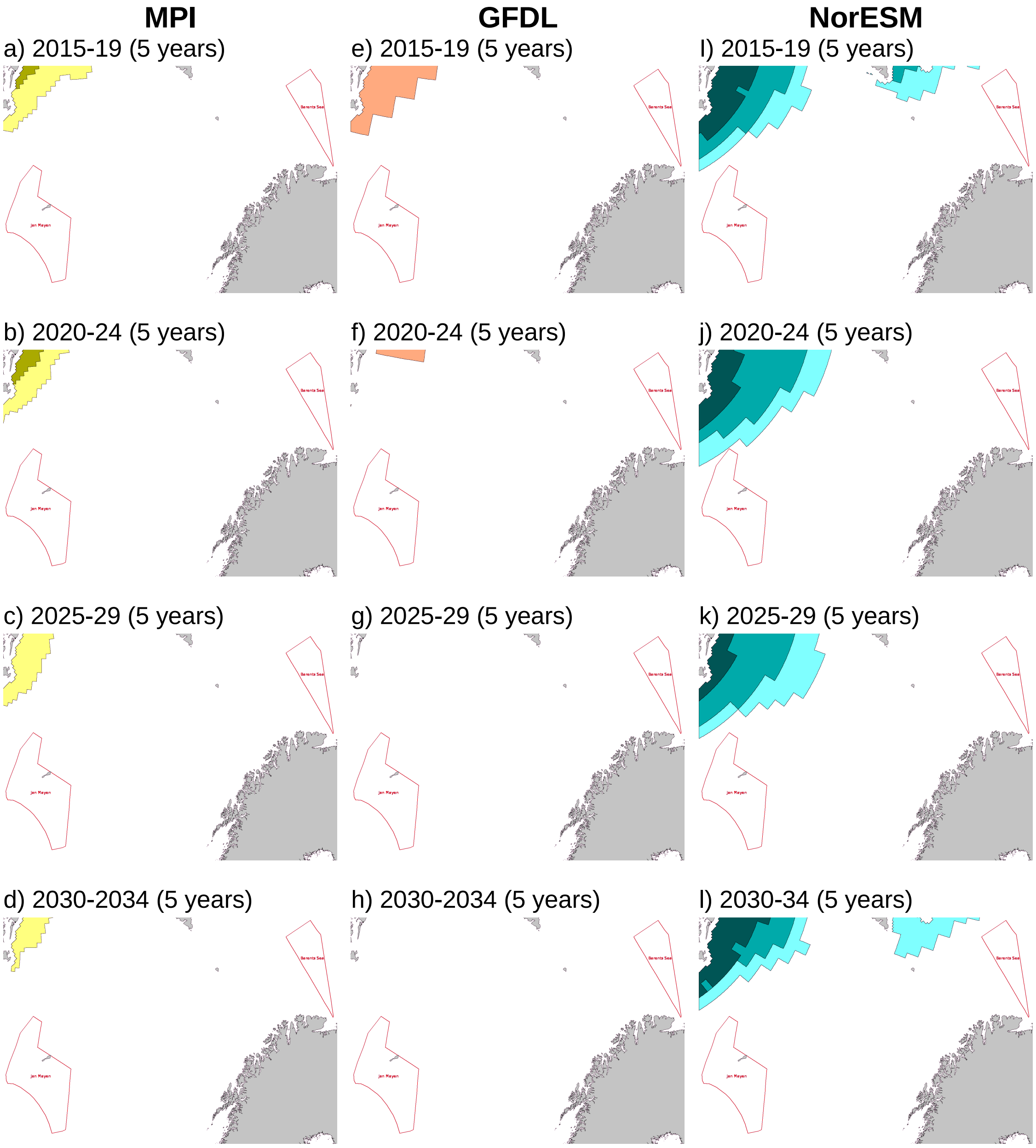


Figure 5.46: CMIP model forecasts for SEPTEMBER at 10% ice concentration under emissions scenario RCP85.

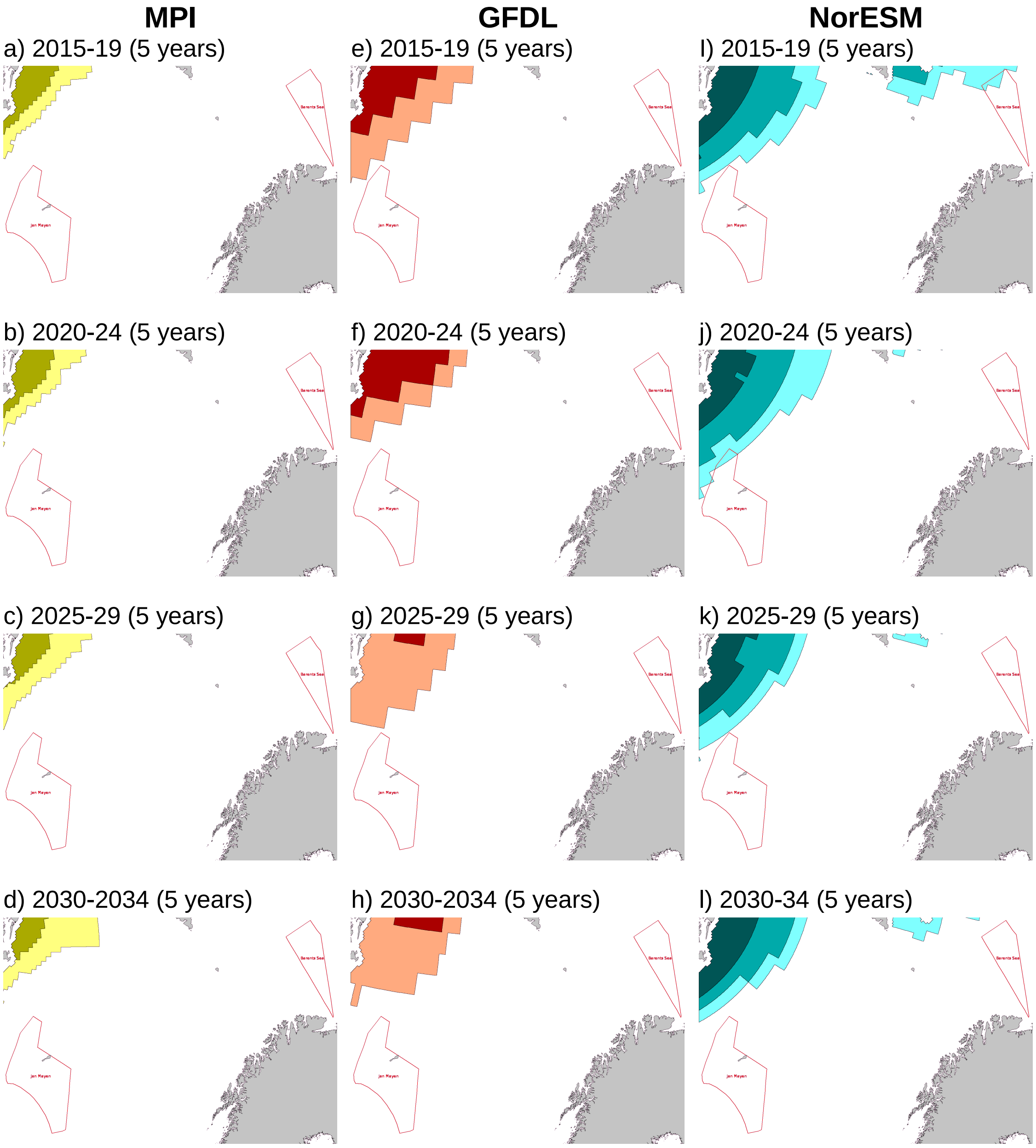


Figure 5.47: CMIP model forecasts for OCTOBER at 10% ice concentration under emissions scenario RCP85.

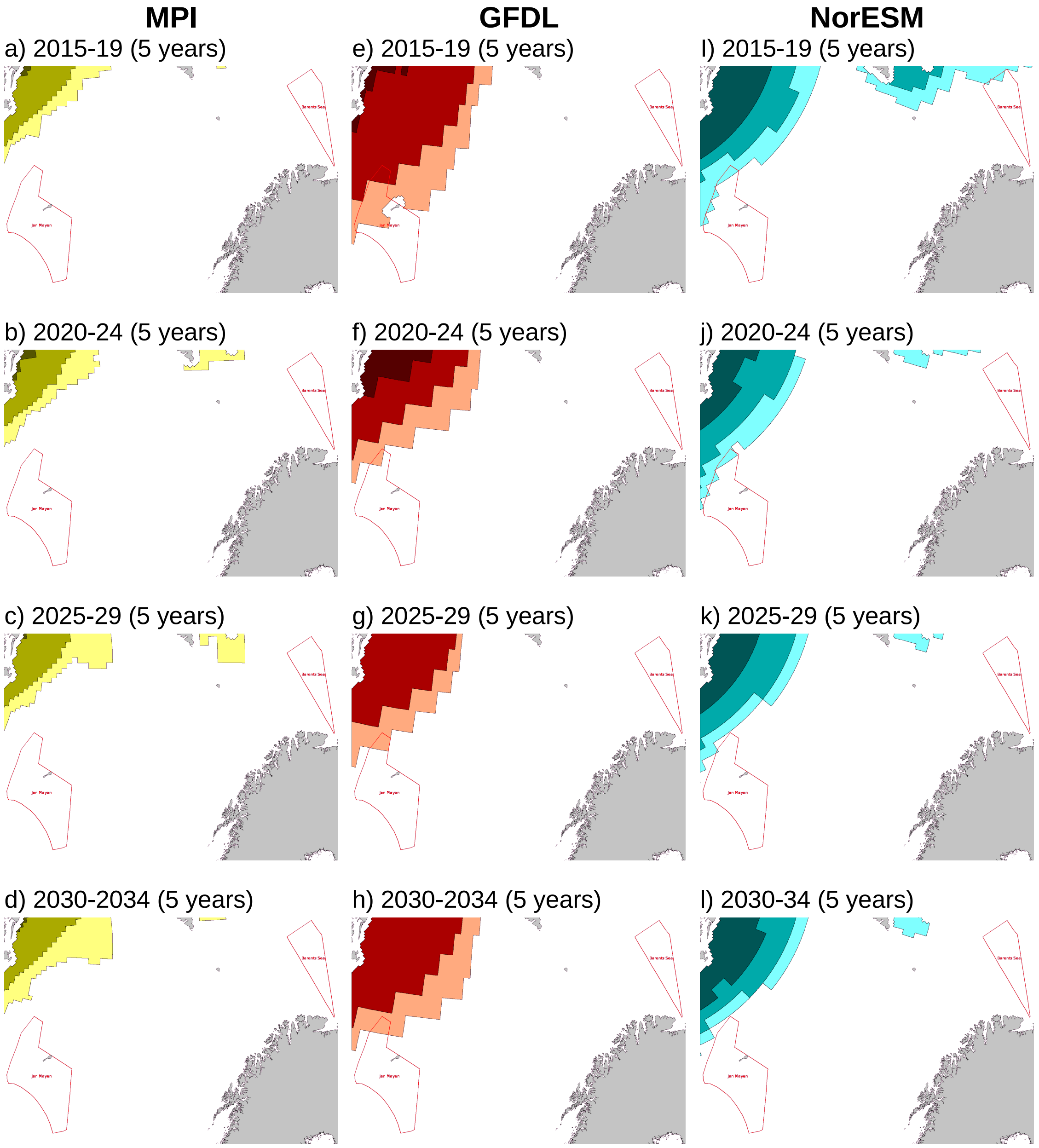
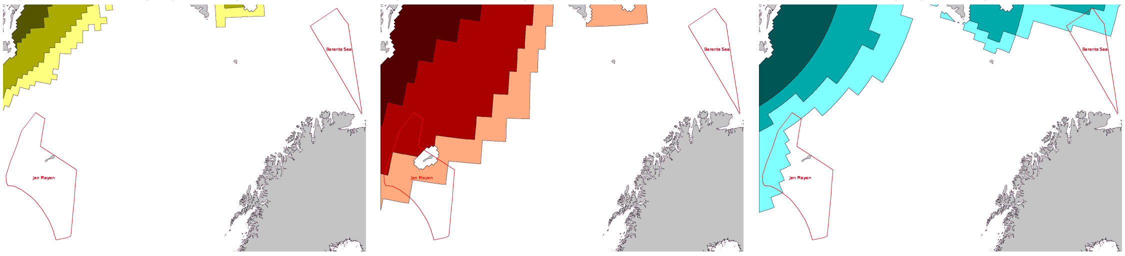


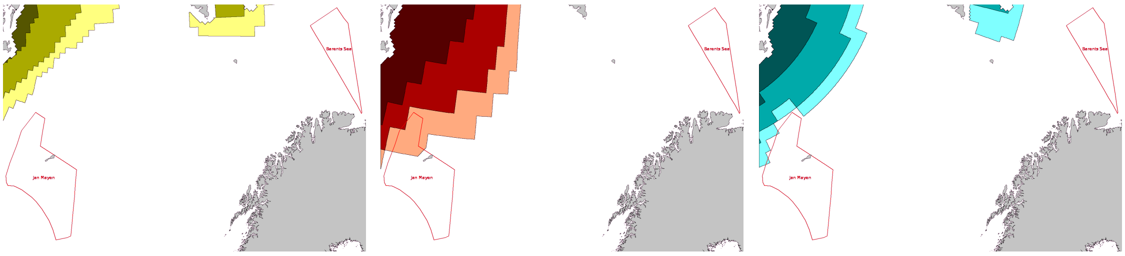
Figure 5.48: CMIP model forecasts for NOVEMBER at 10% ice concentration under emissions scenario RCP85.

MPI **GFDL** **NorESM**

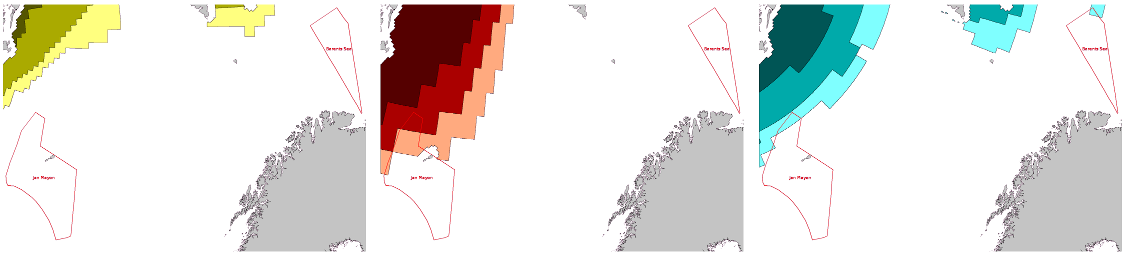
a) 2015-19 (5 years) e) 2015-19 (5 years) l) 2015-19 (5 years)



b) 2020-24 (5 years) f) 2020-24 (5 years) j) 2020-24 (5 years)



c) 2025-29 (5 years) g) 2025-29 (5 years) k) 2025-29 (5 years)



d) 2030-2034 (5 years) h) 2030-2034 (5 years) l) 2030-34 (5 years)

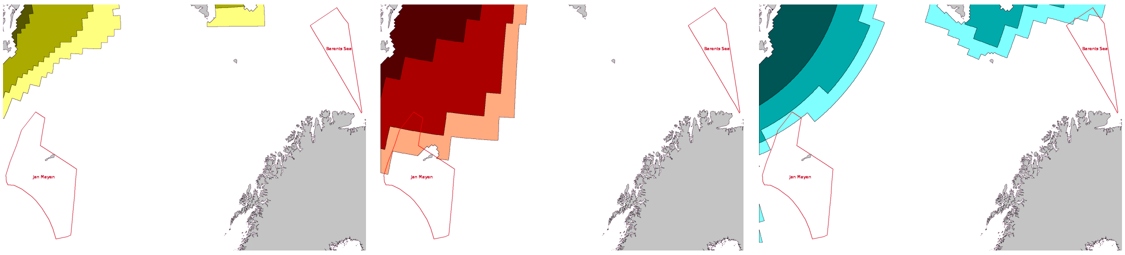


Figure 5.49: CMIP model forecasts for DECEMBER at 10% ice concentration under emissions scenario RCP85.

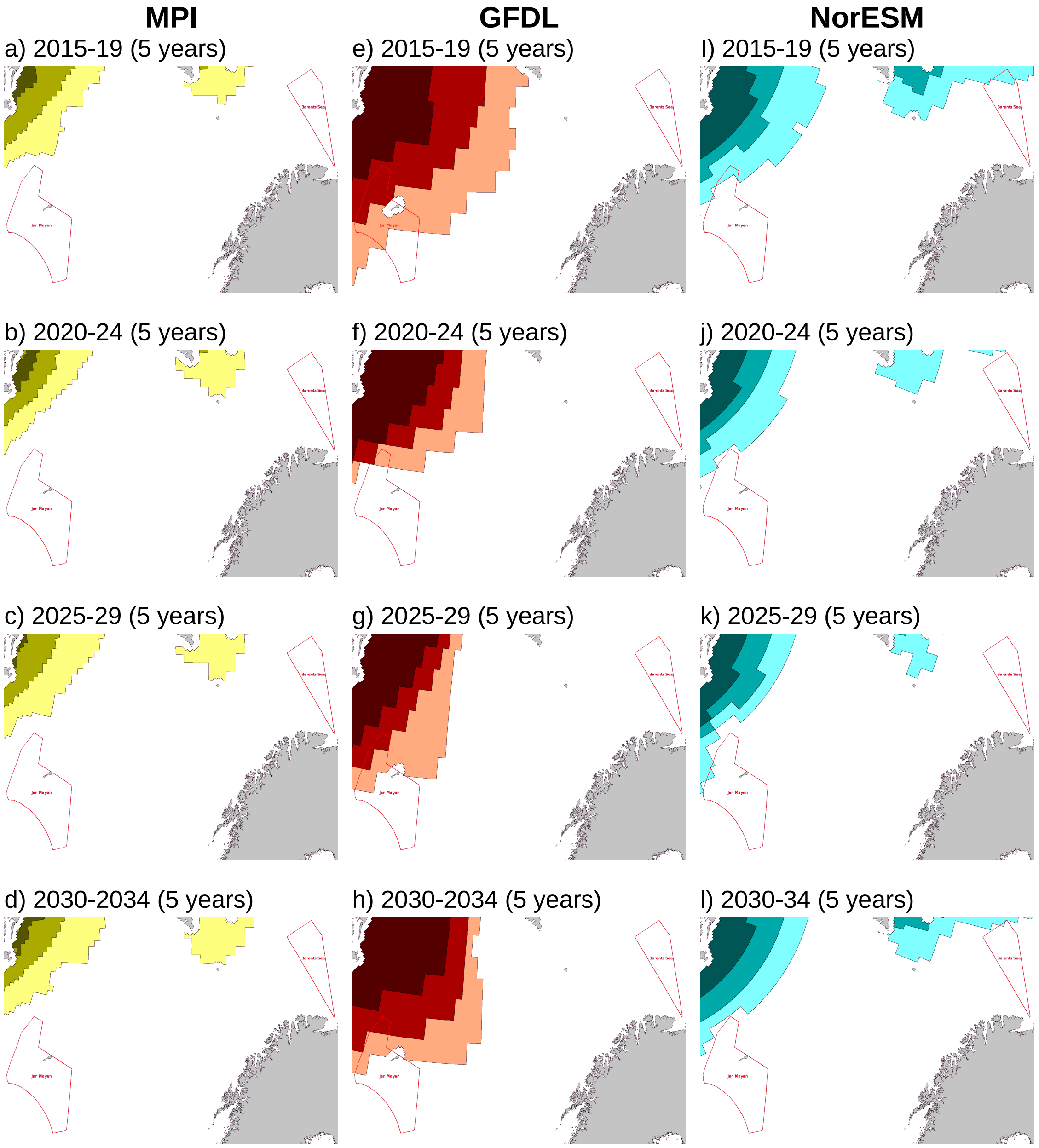
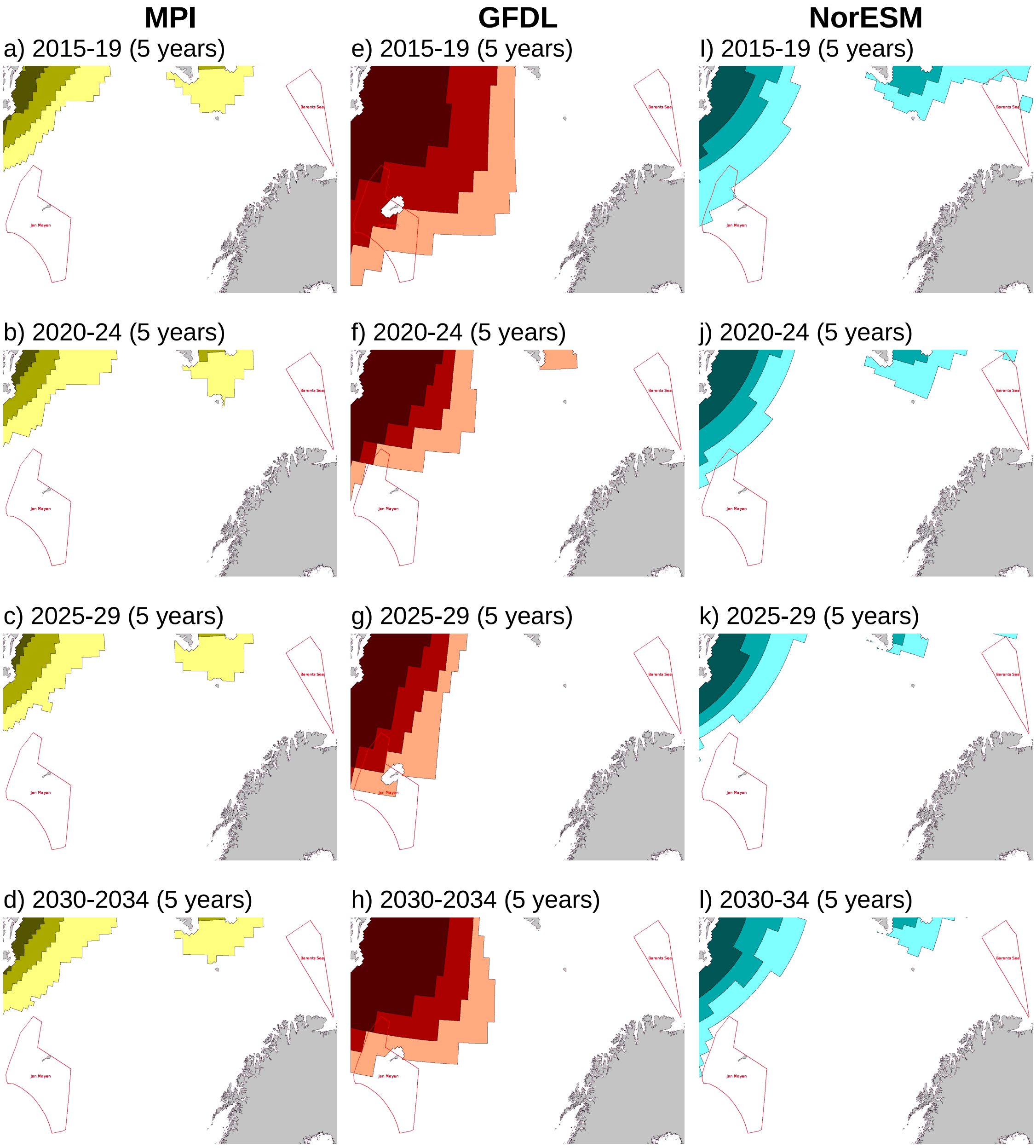
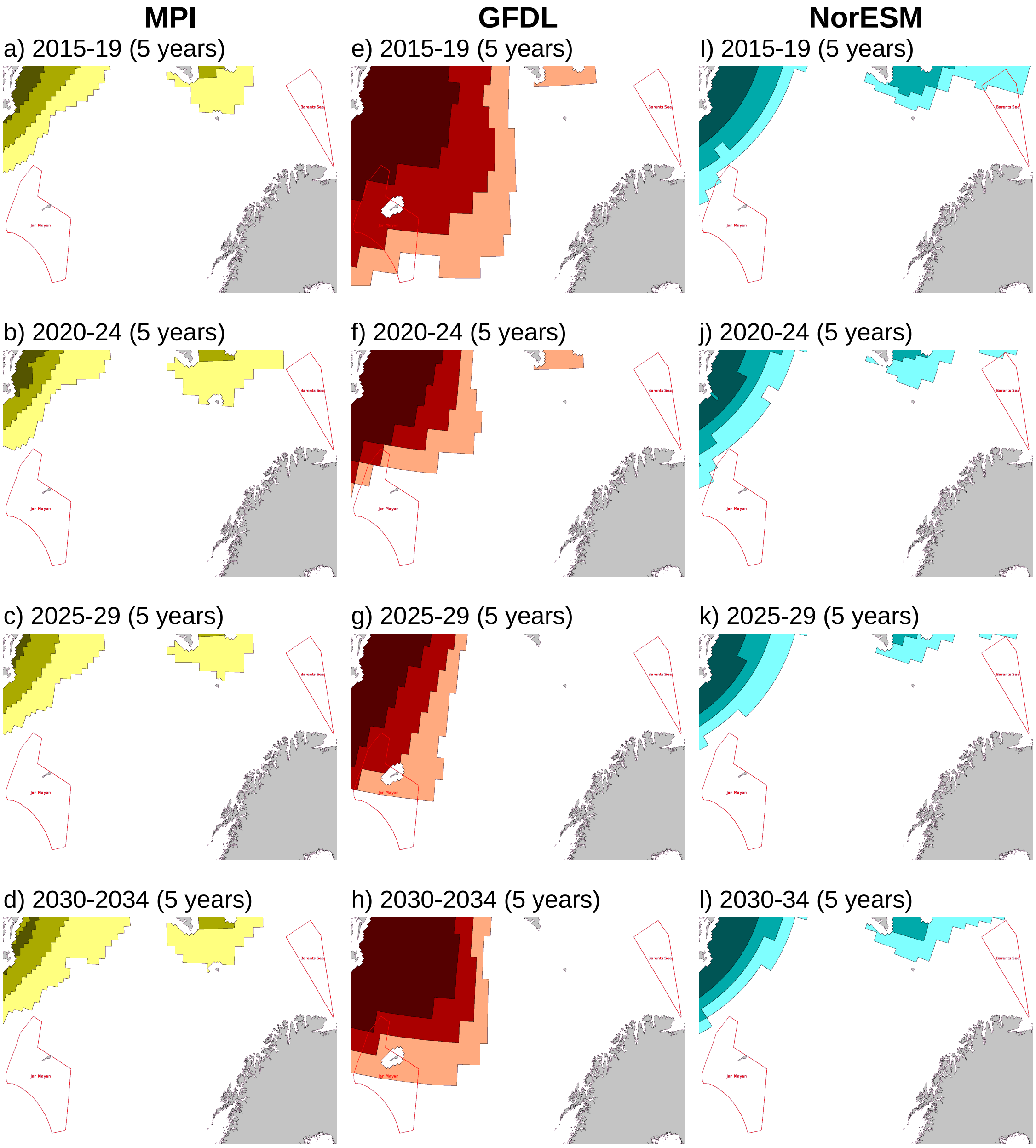


Figure 5.50: CMIP model forecasts for JANUARY at 40% ice concentration under emissions scenario RCP85.



a) 2015-19 (5 years)
e) 2015-19 (5 years)
I) 2015-19 (5 years)
b) 2020-24 (5 years)
f) 2020-24 (5 years)
j) 2020-24 (5 years)
c) 2025-29 (5 years)
g) 2025-29 (5 years)
k) 2025-29 (5 years)
d) 2030-2034 (5 years)
h) 2030-2034 (5 years)
l) 2030-34 (5 years)

Figure 5.51: CMIP model forecasts for FEBRUARY at 40% ice concentration under emissions scenario RCP85.



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d) 2030-2034 (5 years)
e) 2015-19 (5 years)
f) 2020-24 (5 years)
g) 2025-29 (5 years)
h) 2030-2034 (5 years)
I) 2015-19 (5 years)
j) 2020-24 (5 years)
k) 2025-29 (5 years)
l) 2030-34 (5 years)

Figure 5.52: CMIP model forecasts for MARCH at 40% ice concentration under emissions scenario RCP85.

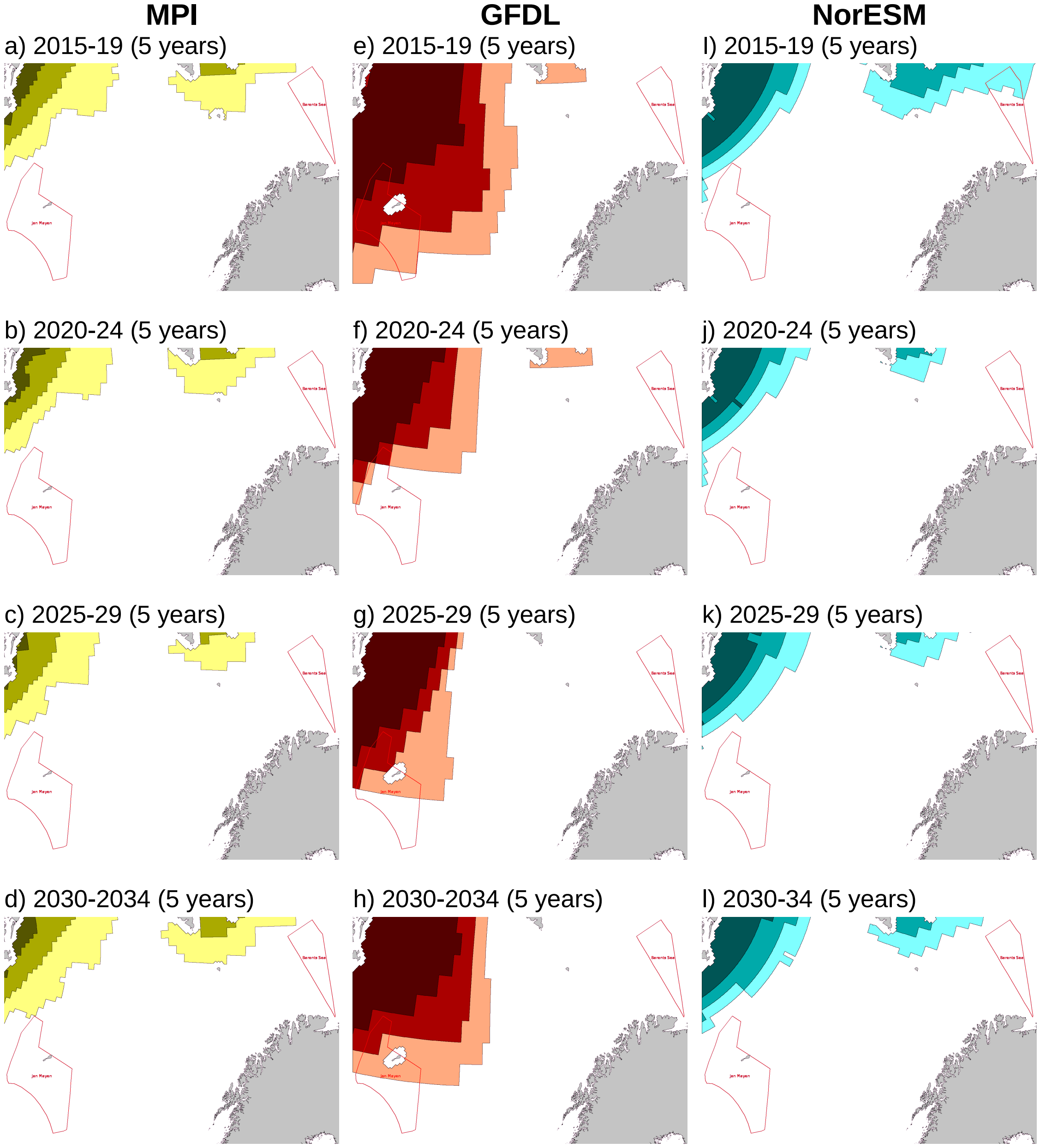


Figure 5.53: CMIP model forecasts for APRIL at 40% ice concentration under emissions scenario RCP85.

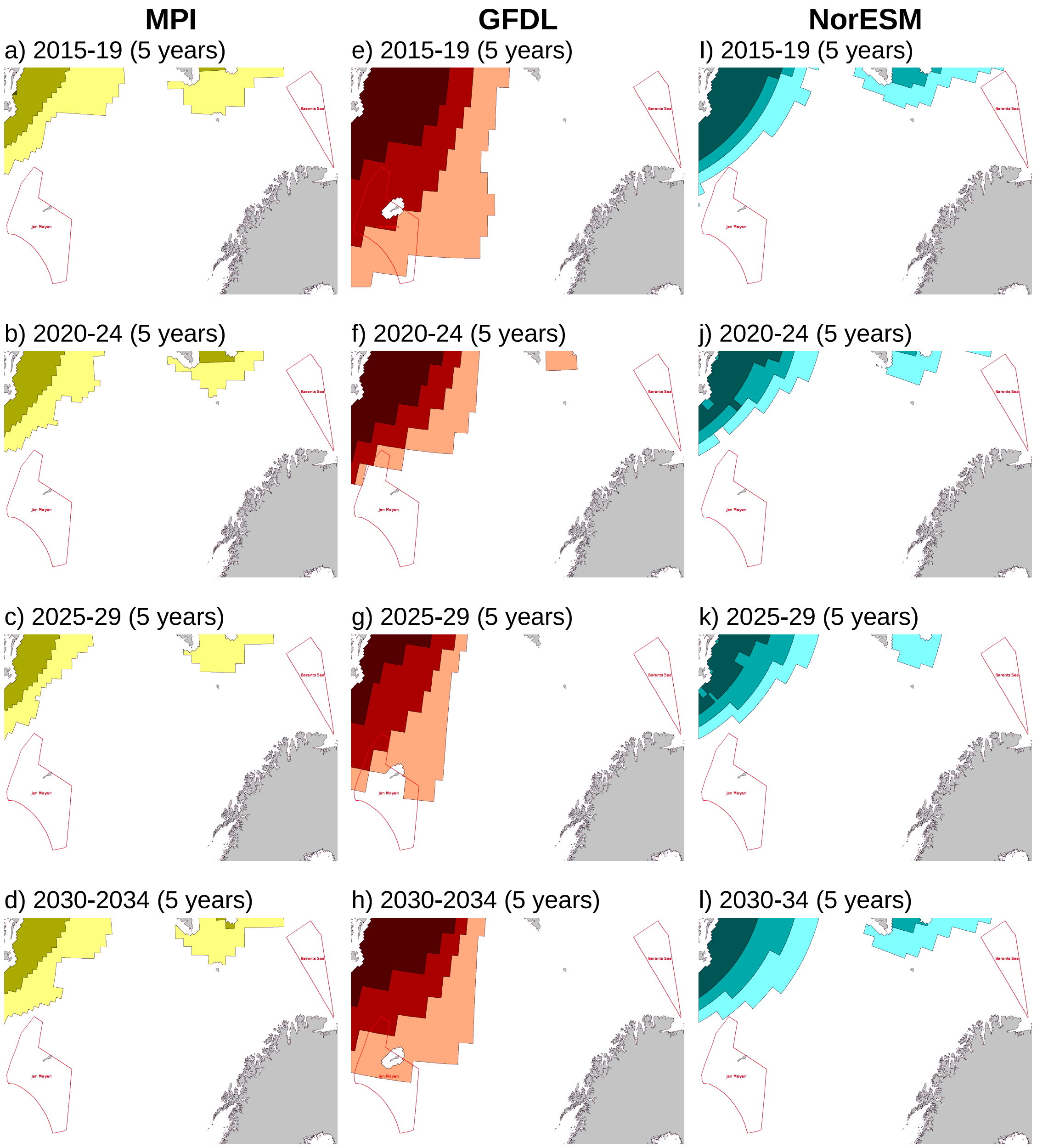
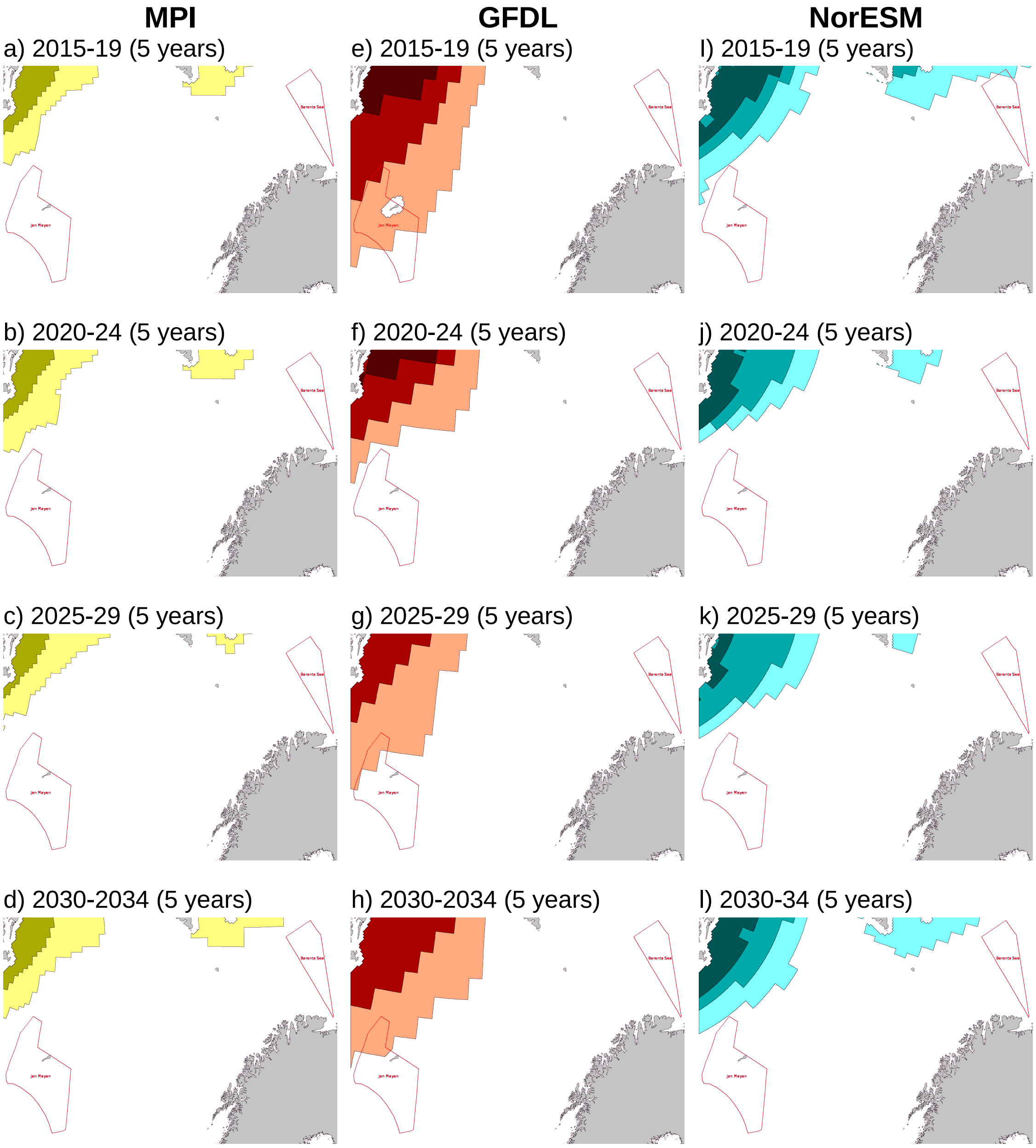


Figure 5.54: CMIP model forecasts for MAY at 40% ice concentration under emissions scenario RCP85.



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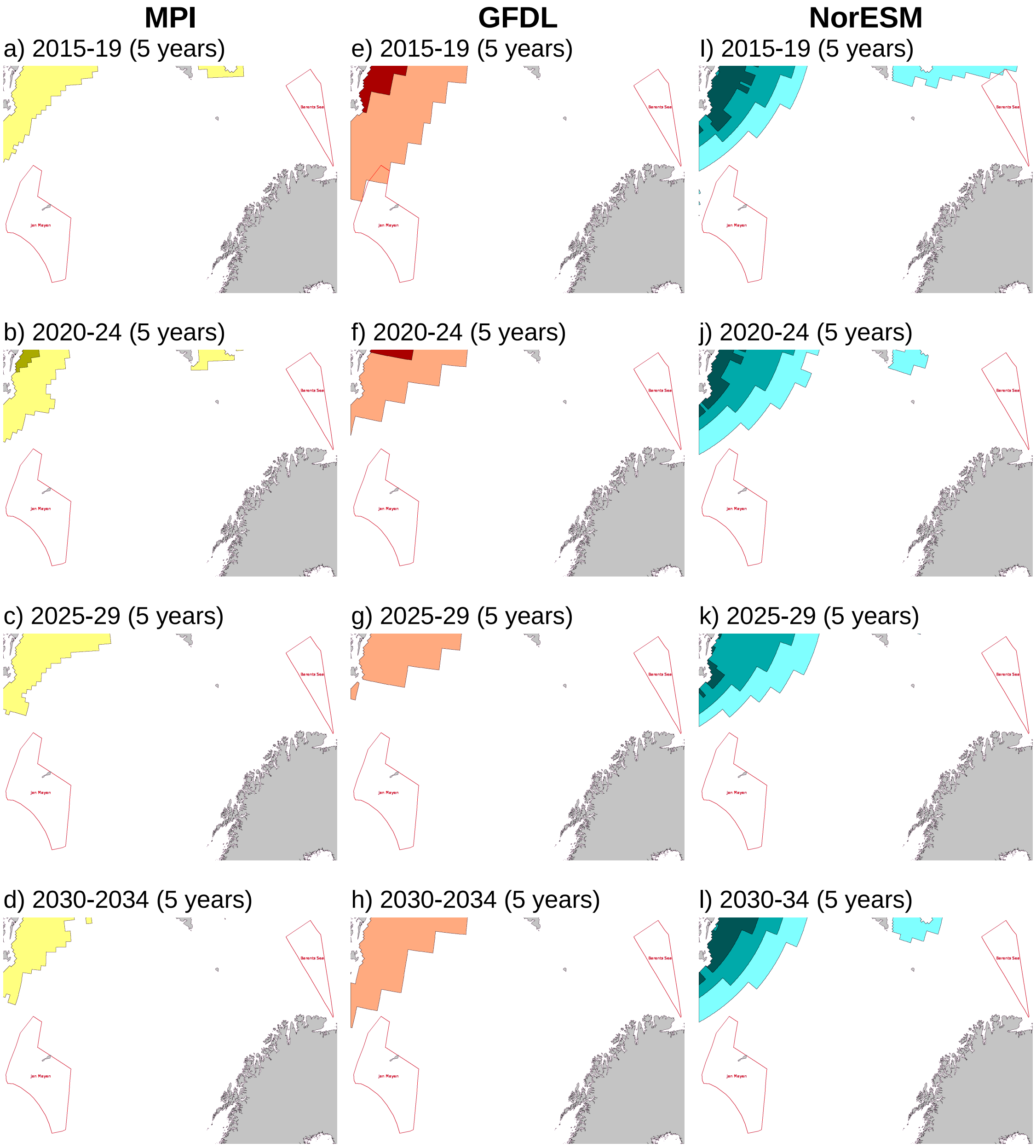
e) 2015-19 (5 years)
I) 2015-19 (5 years)

b) 2020-24 (5 years)
f) 2020-24 (5 years)
j) 2020-24 (5 years)

c) 2025-29 (5 years)
g) 2025-29 (5 years)
k) 2025-29 (5 years)

d) 2030-2034 (5 years)
h) 2030-2034 (5 years)
l) 2030-34 (5 years)

Figure 5.55: CMIP model forecasts for JUNE at 40% ice concentration under emissions scenario RCP85.



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e) 2015-19 (5 years)
I) 2015-19 (5 years)
b) 2020-24 (5 years)
f) 2020-24 (5 years)
j) 2020-24 (5 years)
c) 2025-29 (5 years)
g) 2025-29 (5 years)
k) 2025-29 (5 years)
d) 2030-2034 (5 years)
h) 2030-2034 (5 years)
l) 2030-34 (5 years)

Figure 5.56: CMIP model forecasts for JULY at 40% ice concentration under emissions scenario RCP85.

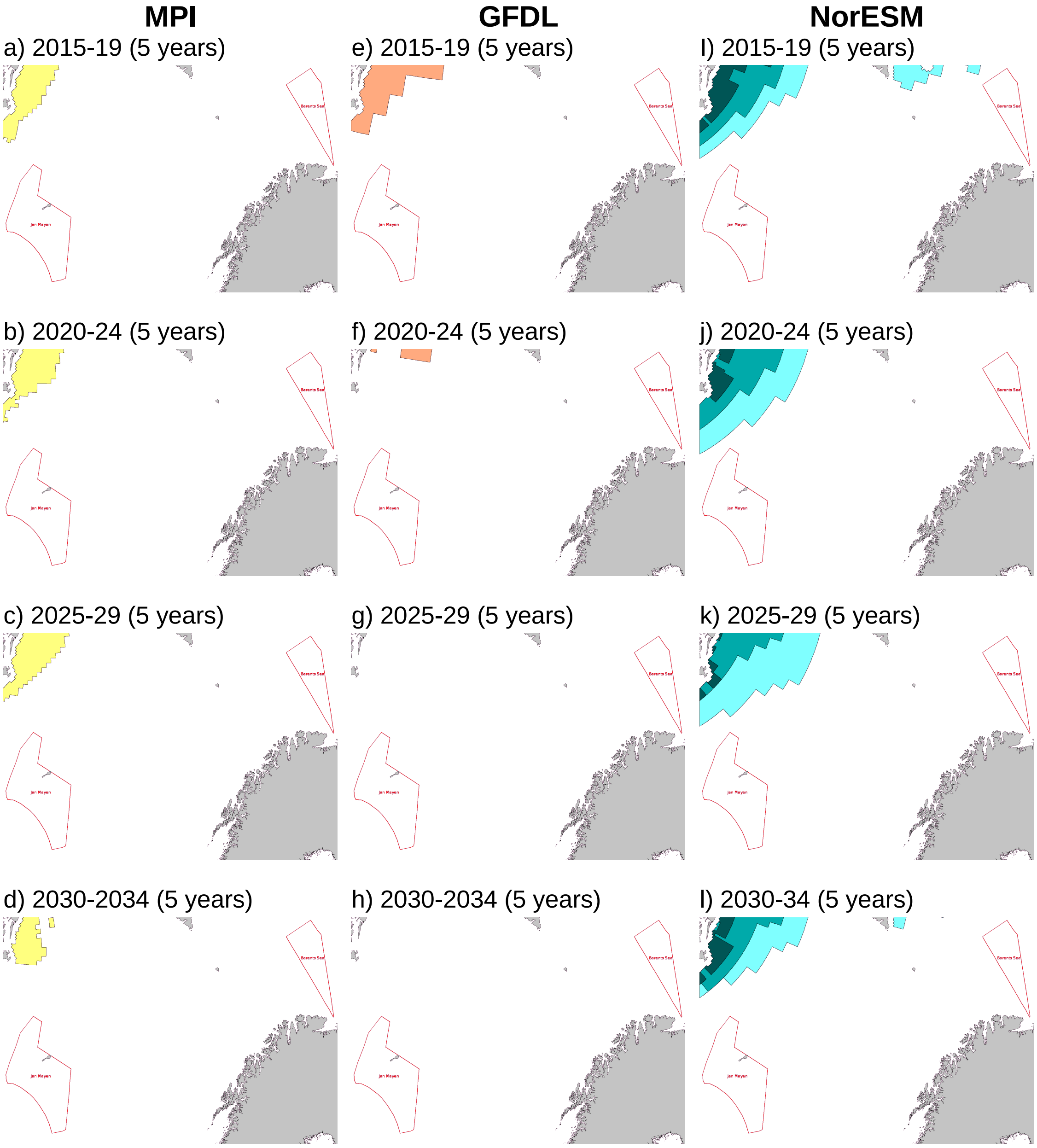


Figure 5.57: CMIP model forecasts for AUGUST at 40% ice concentration under emissions scenario RCP85.

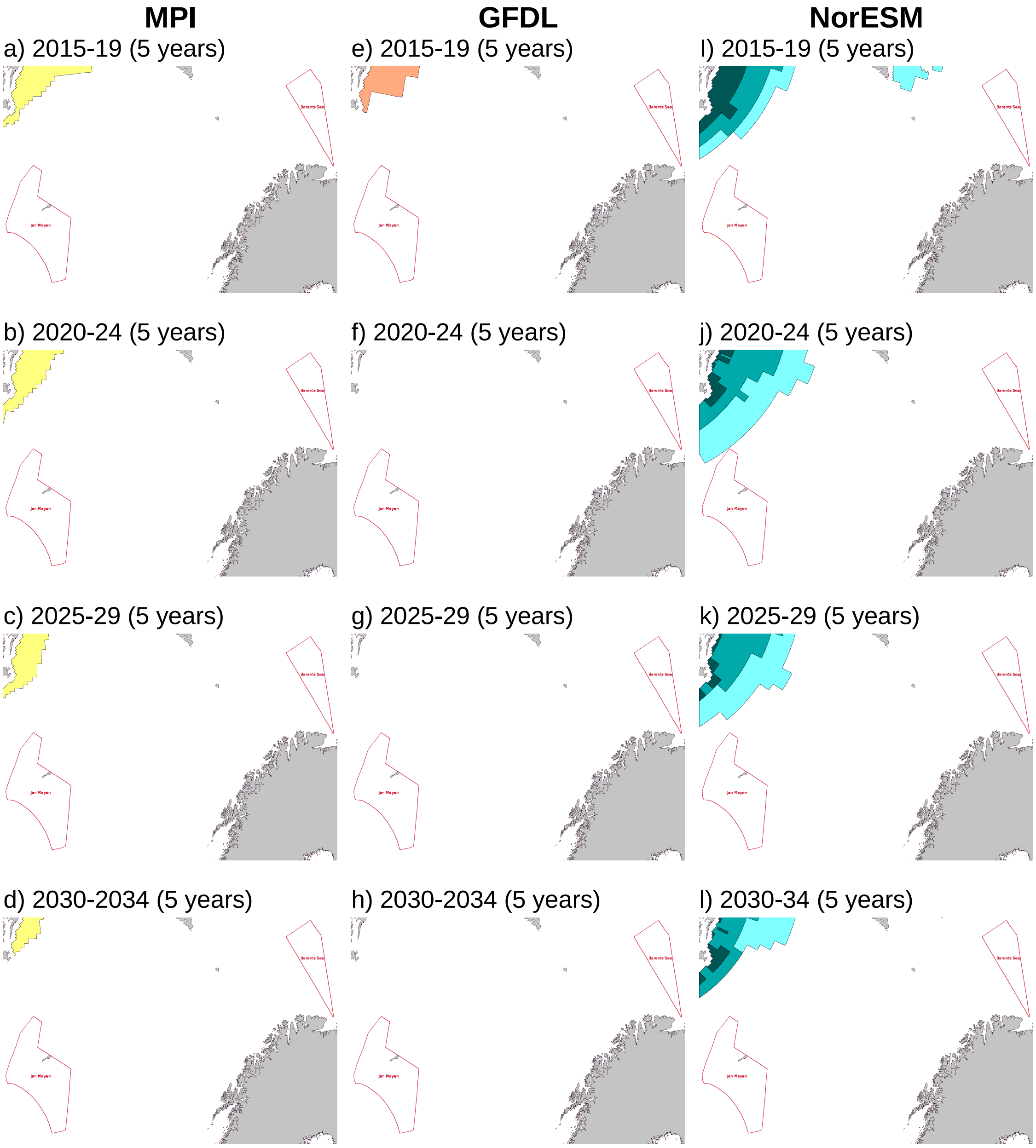
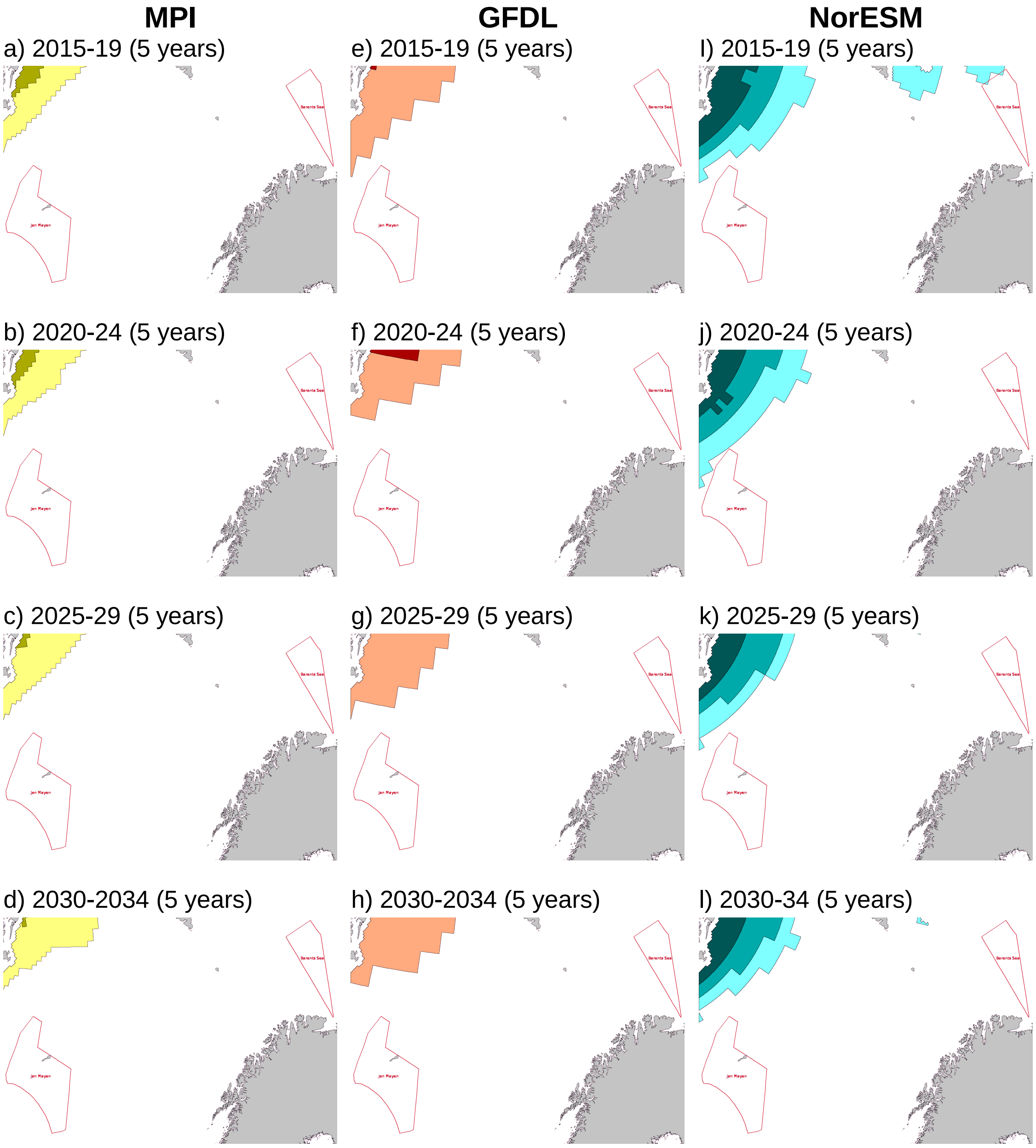


Figure 5.58: CMIP model forecasts for SEPTEMBER at 40% ice concentration under emissions scenario RCP85.



MPI

GFDL

NorESM

a) 2015-19 (5 years)

e) 2015-19 (5 years)

I) 2015-19 (5 years)

b) 2020-24 (5 years)

f) 2020-24 (5 years)

j) 2020-24 (5 years)

c) 2025-29 (5 years)

g) 2025-29 (5 years)

k) 2025-29 (5 years)

d) 2030-2034 (5 years)

h) 2030-2034 (5 years)

l) 2030-34 (5 years)

Figure 5.59: CMIP model forecasts for OCTOBER at 40% ice concentration under emissions scenario RCP85.

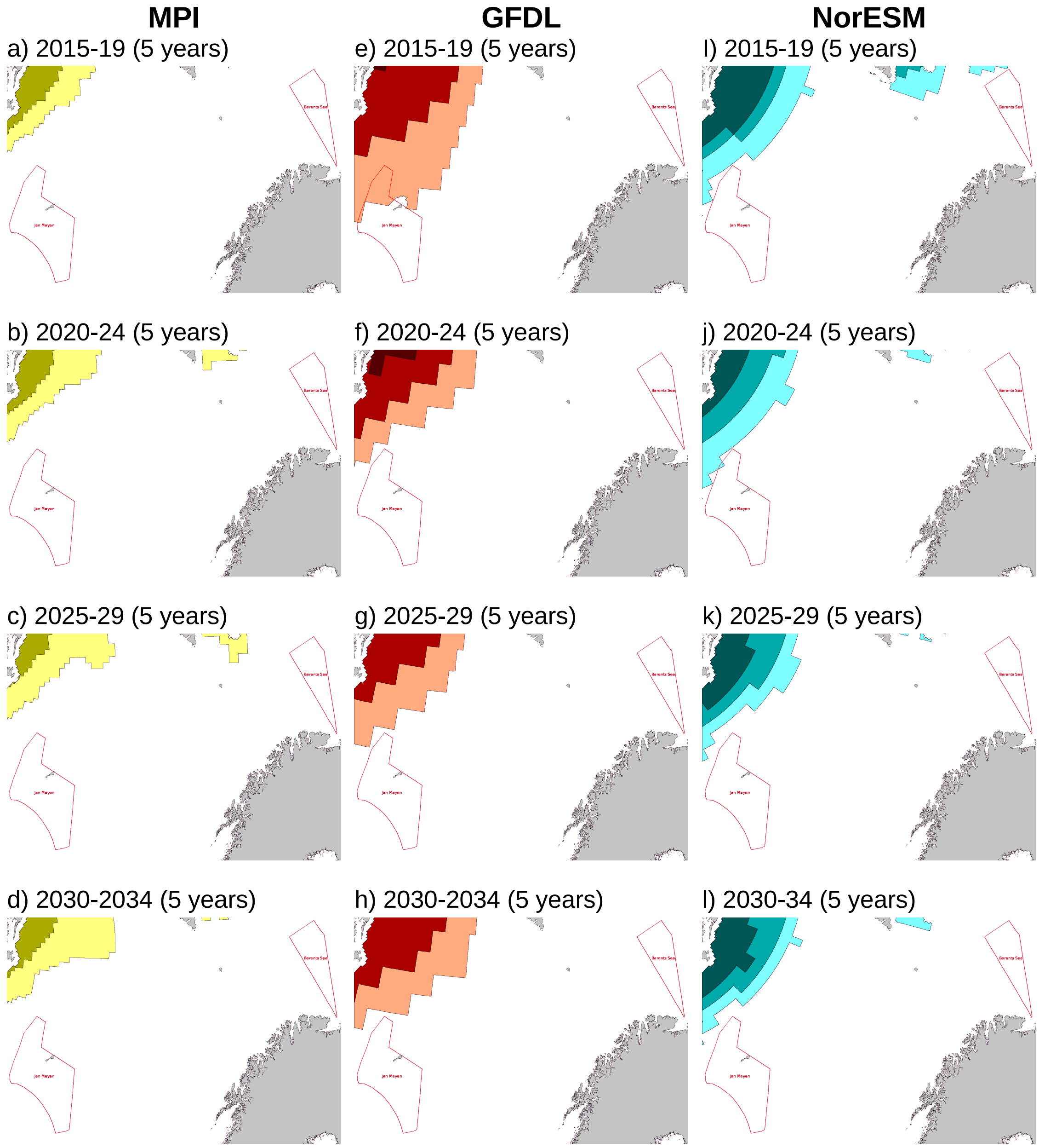
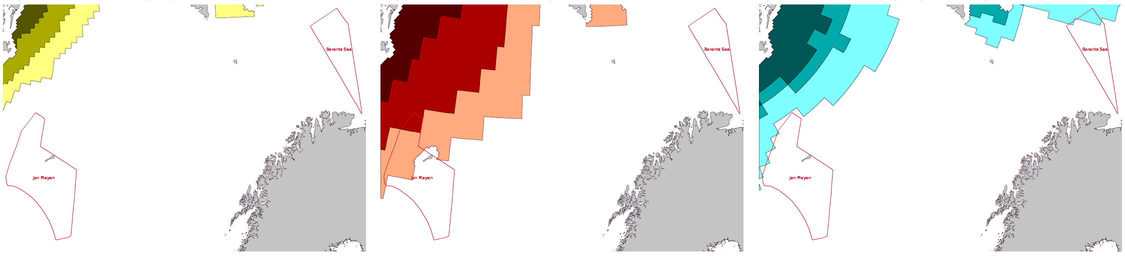


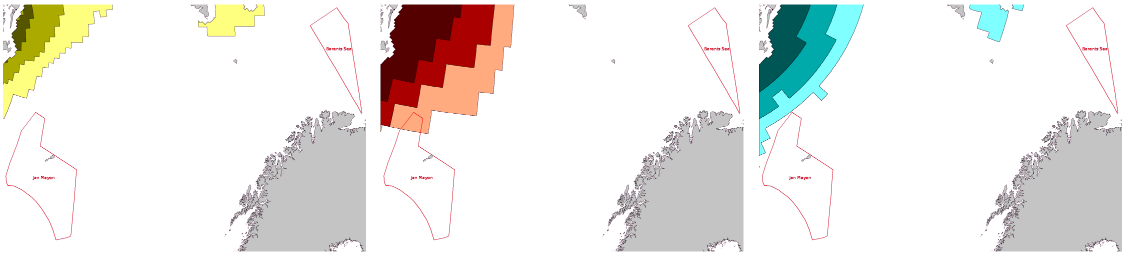
Figure 5.60: CMIP model forecasts for NOVEMBER at 40% ice concentration under emissions scenario RCP85.

MPI GFDL NorESM

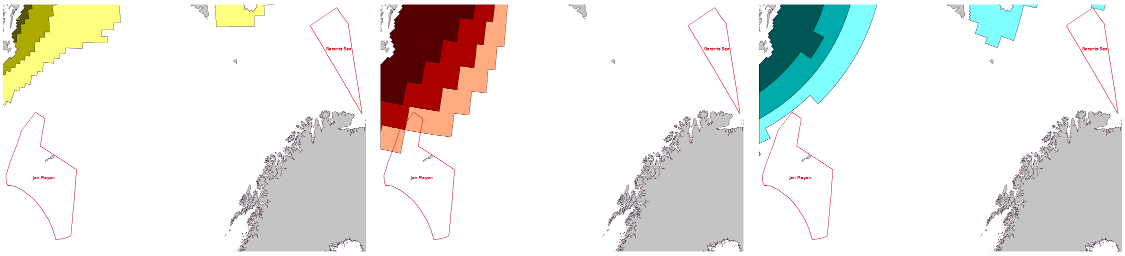
a) 2015-19 (5 years) e) 2015-19 (5 years) I) 2015-19 (5 years)



b) 2020-24 (5 years) f) 2020-24 (5 years) j) 2020-24 (5 years)



c) 2025-29 (5 years) g) 2025-29 (5 years) k) 2025-29 (5 years)



d) 2030-2034 (5 years) h) 2030-2034 (5 years) l) 2030-34 (5 years)

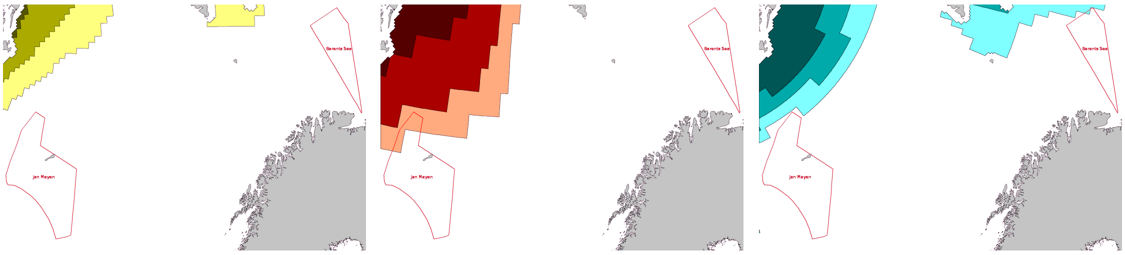


Figure 5.61: CMIP model forecasts for DECEMBER at 40% ice concentration under emissions scenario RCP85.

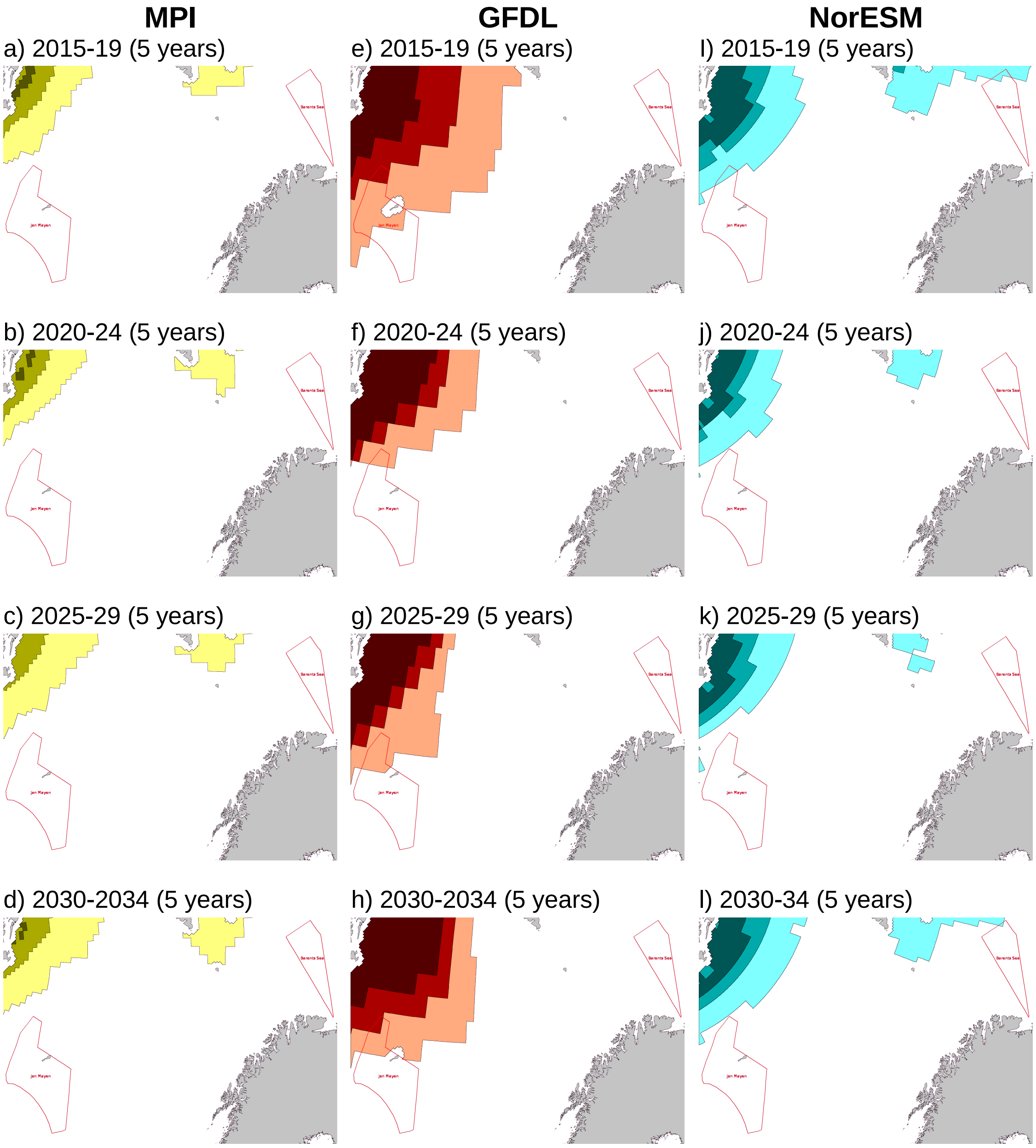


Figure 5.62: CMIP model forecasts for JANUARY at 70% ice concentration under emissions scenario RCP85.

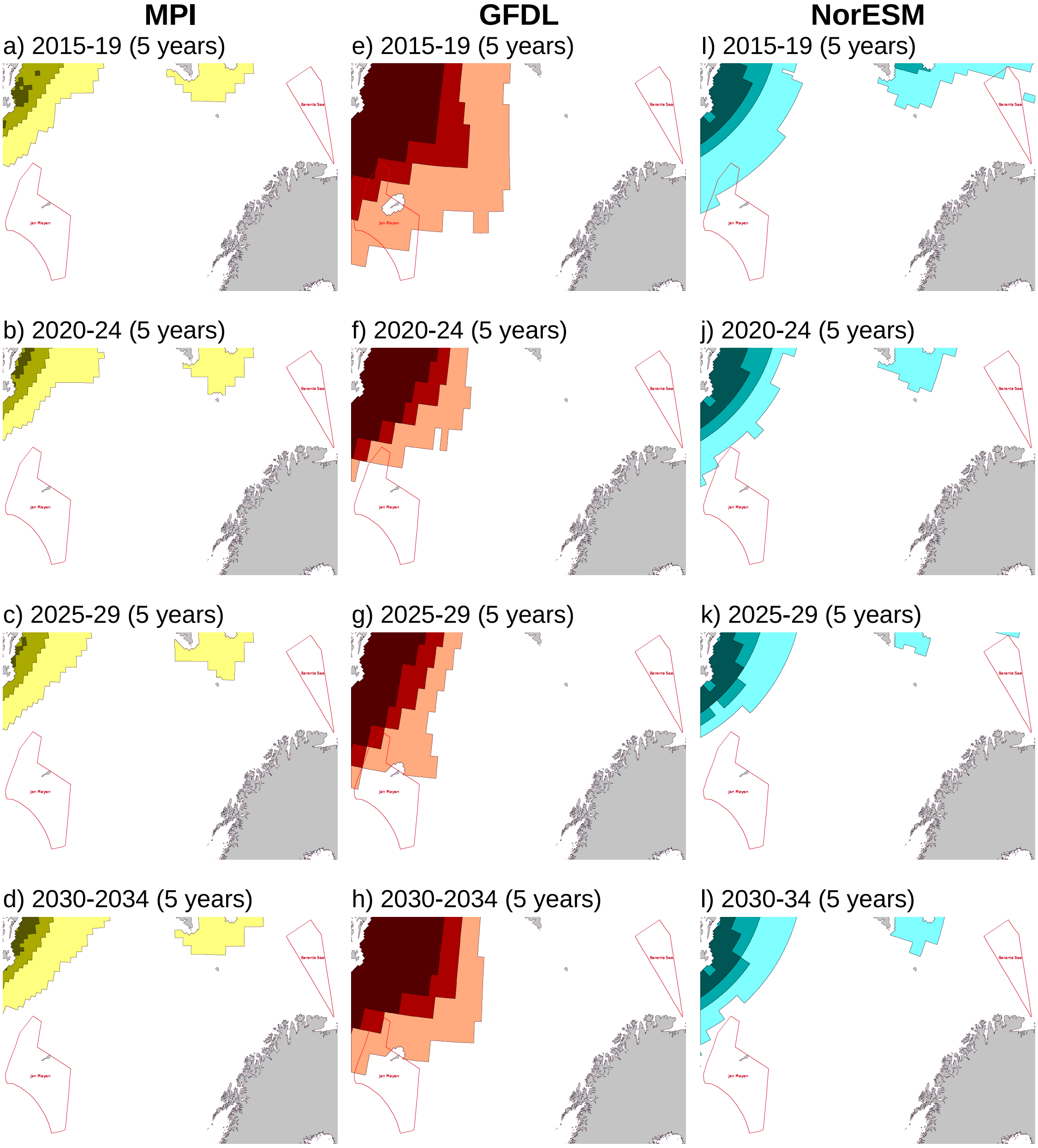
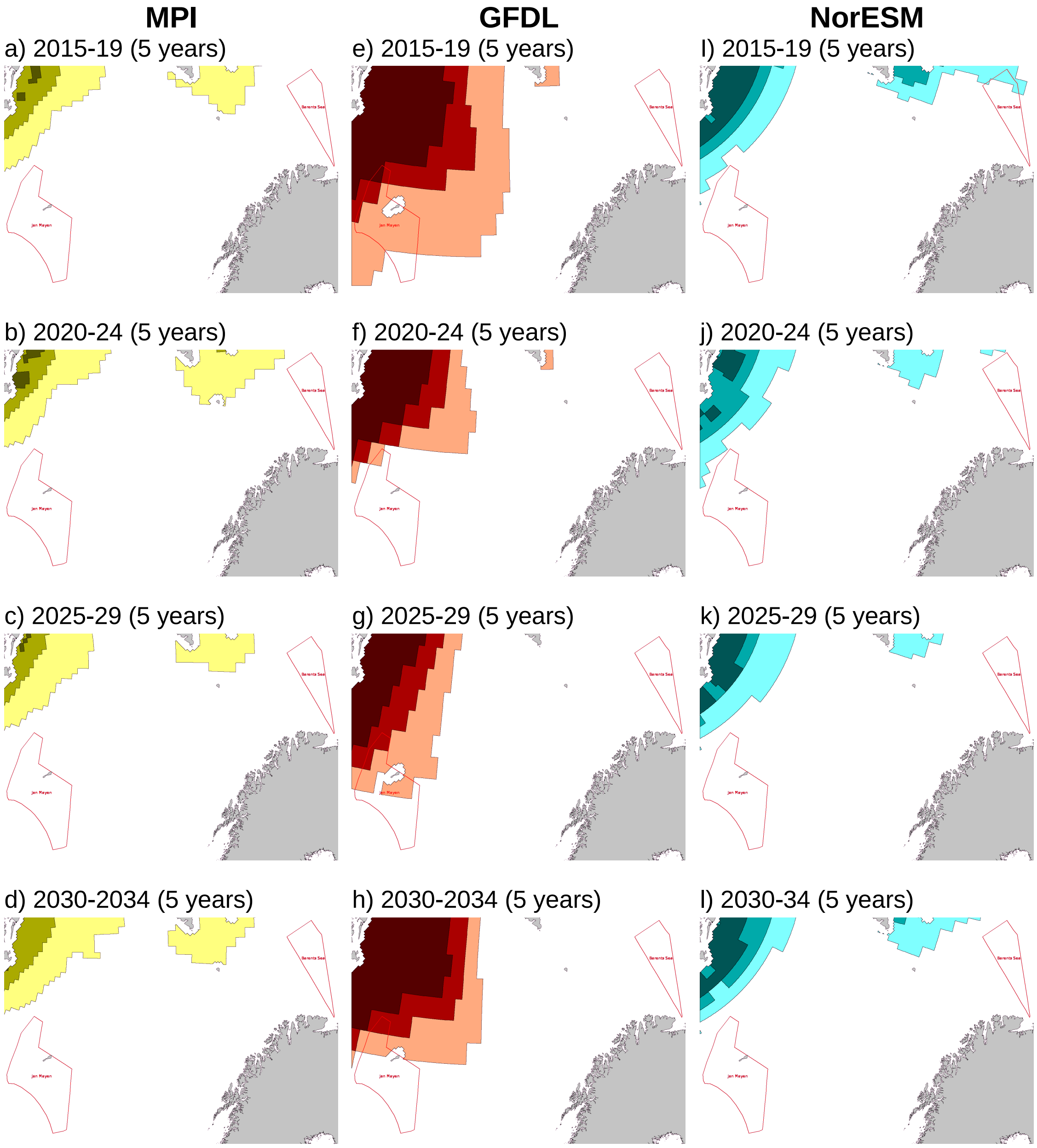


Figure 5.63: CMIP model forecasts for FEBRUARY at 70% ice concentration under emissions scenario RCP85.



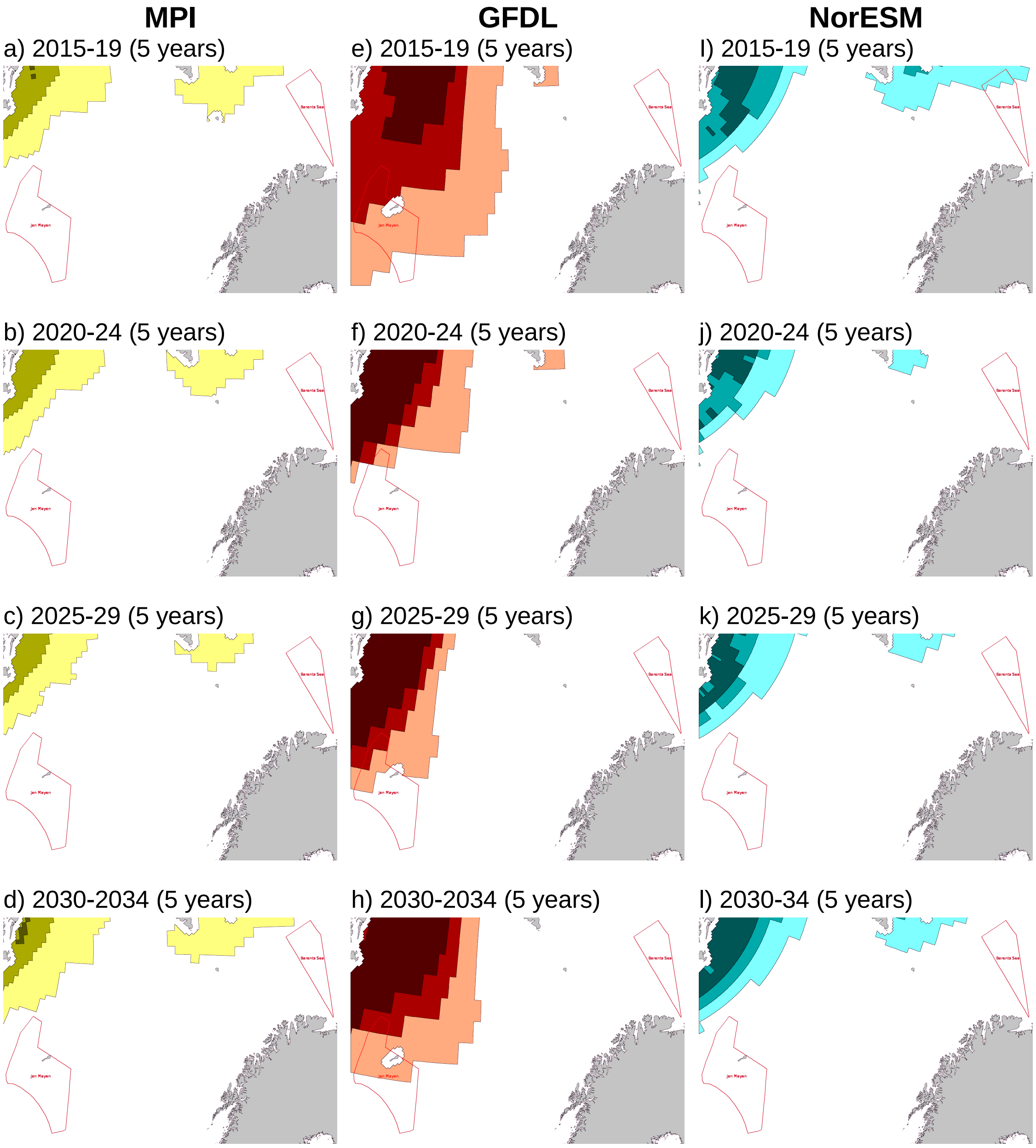
a) 2015-19 (5 years)
e) 2015-19 (5 years)
I) 2015-19 (5 years)

b) 2020-24 (5 years)
f) 2020-24 (5 years)
j) 2020-24 (5 years)

c) 2025-29 (5 years)
g) 2025-29 (5 years)
k) 2025-29 (5 years)

d) 2030-2034 (5 years)
h) 2030-2034 (5 years)
l) 2030-34 (5 years)

Figure 5.64: CMIP model forecasts for MARCH at 70% ice concentration under emissions scenario RCP85.



MPI

GFDL

NorESM

a) 2015-19 (5 years)

e) 2015-19 (5 years)

I) 2015-19 (5 years)

b) 2020-24 (5 years)

f) 2020-24 (5 years)

j) 2020-24 (5 years)

c) 2025-29 (5 years)

g) 2025-29 (5 years)

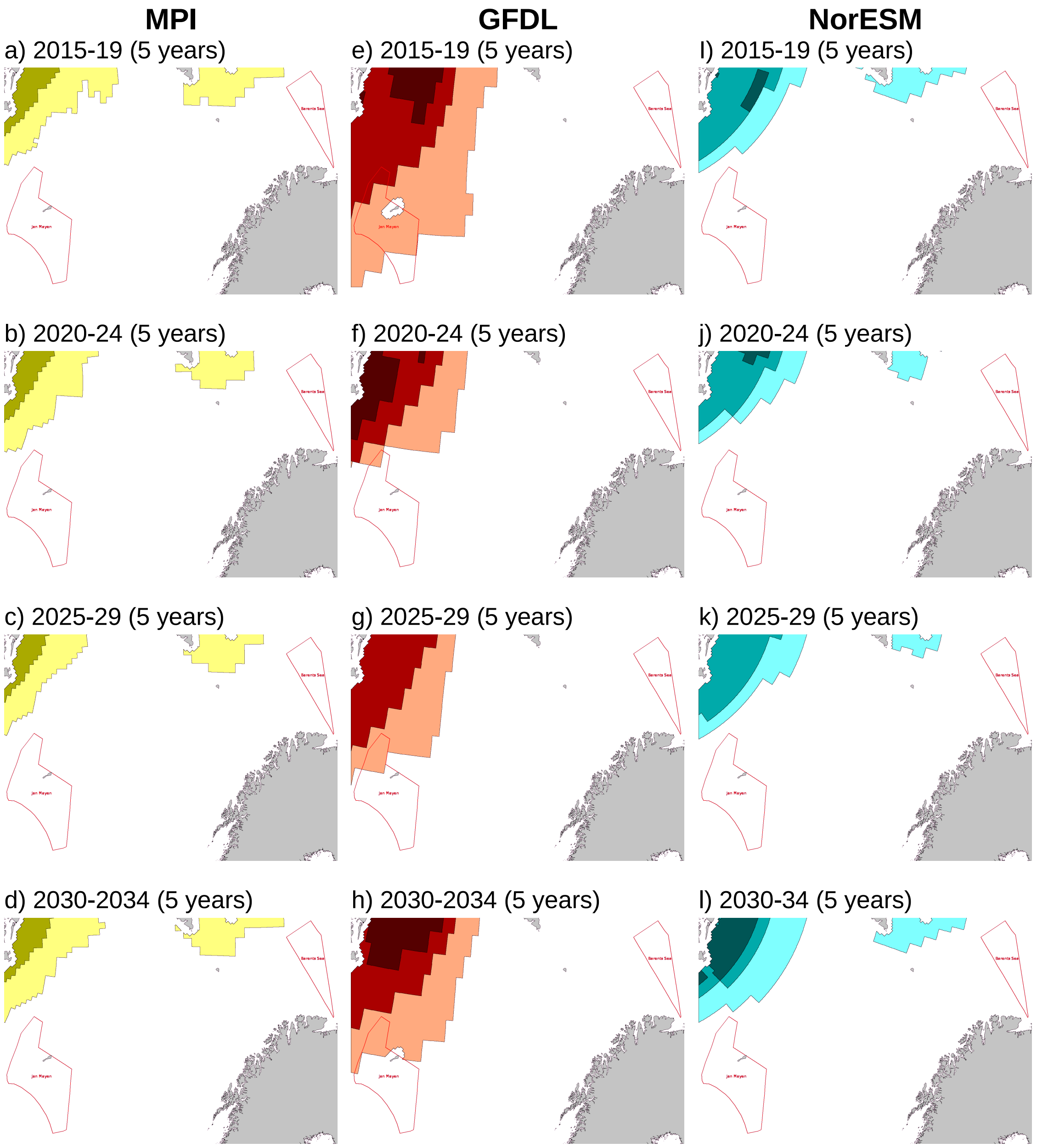
k) 2025-29 (5 years)

d) 2030-2034 (5 years)

h) 2030-2034 (5 years)

l) 2030-34 (5 years)

Figure 5.65: CMIP model forecasts for APRIL at 70% ice concentration under emissions scenario RCP85.



MPI

a) 2015-19 (5 years)

b) 2020-24 (5 years)

c) 2025-29 (5 years)

d) 2030-2034 (5 years)

GFDL

e) 2015-19 (5 years)

f) 2020-24 (5 years)

g) 2025-29 (5 years)

h) 2030-2034 (5 years)

NorESM

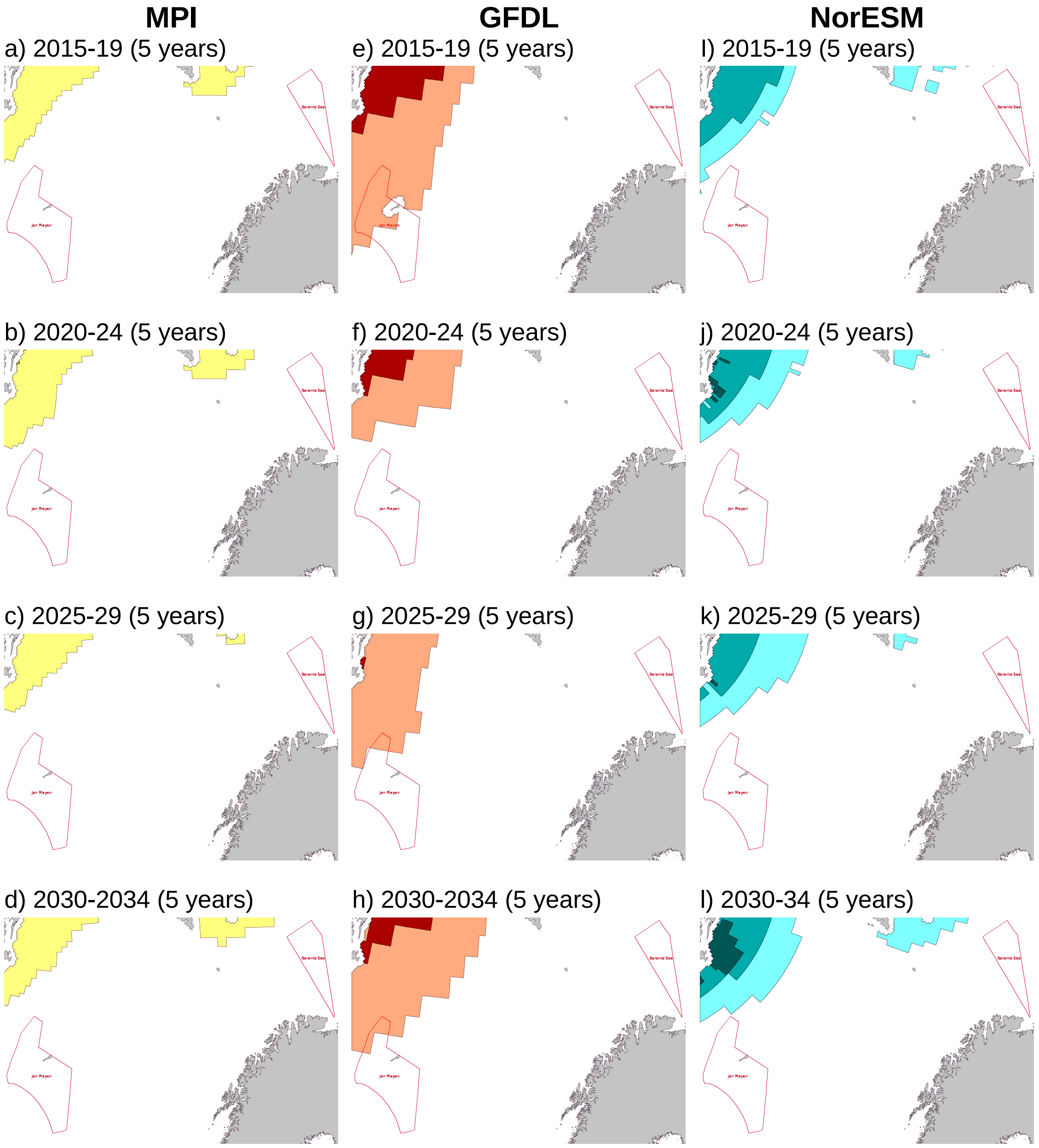
I) 2015-19 (5 years)

j) 2020-24 (5 years)

k) 2025-29 (5 years)

l) 2030-34 (5 years)

Figure 5.66: CMIP model forecasts for MAY at 70% ice concentration under emissions scenario RCP85.



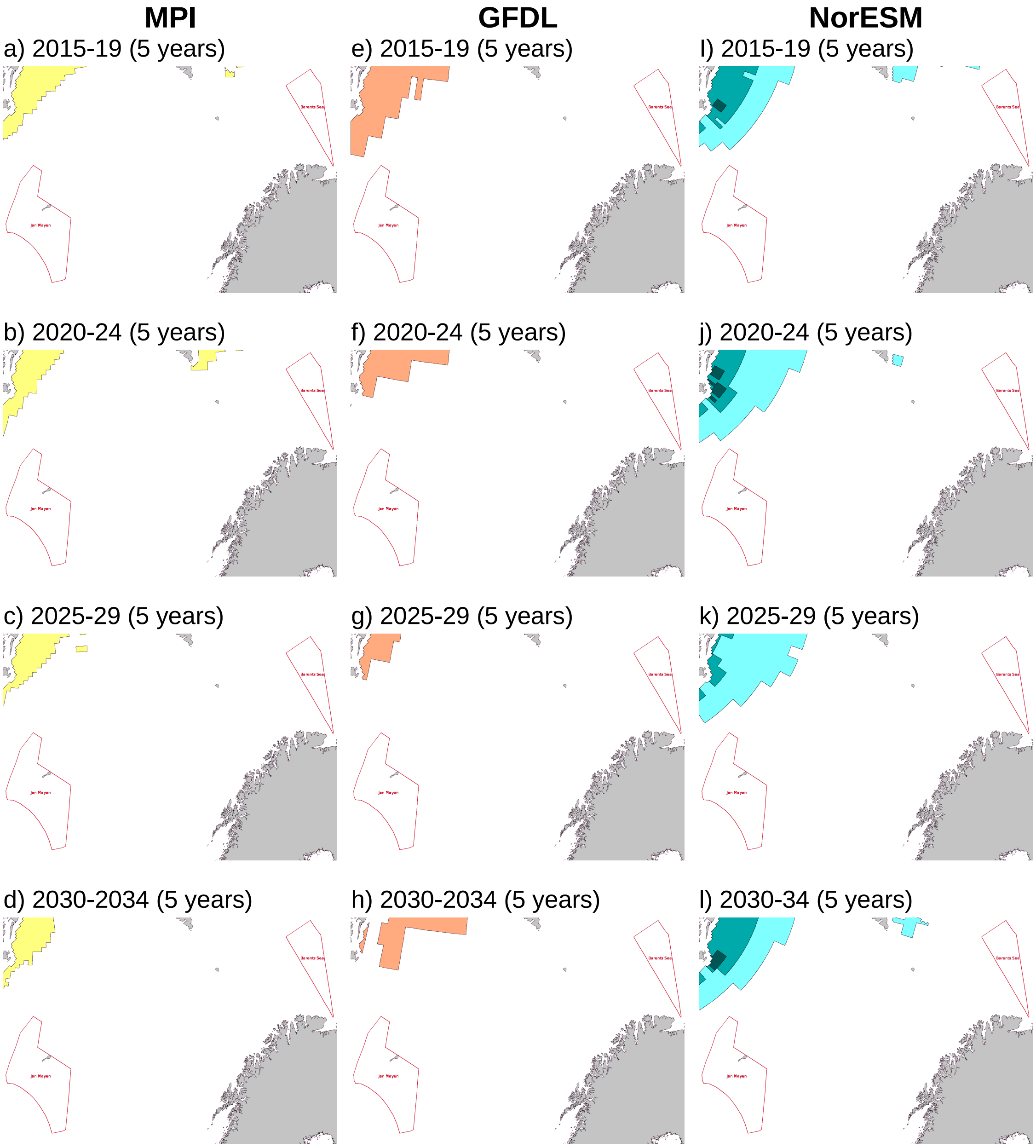
a) 2015-19 (5 years)
e) 2015-19 (5 years)
I) 2015-19 (5 years)

b) 2020-24 (5 years)
f) 2020-24 (5 years)
j) 2020-24 (5 years)

c) 2025-29 (5 years)
g) 2025-29 (5 years)
k) 2025-29 (5 years)

d) 2030-2034 (5 years)
h) 2030-2034 (5 years)
l) 2030-34 (5 years)

Figure 5.67: CMIP model forecasts for JUNE at 70% ice concentration under emissions scenario RCP85.



a) 2015-19 (5 years)
b) 2020-24 (5 years)
c) 2025-29 (5 years)
d) 2030-2034 (5 years)
e) 2015-19 (5 years)
f) 2020-24 (5 years)
g) 2025-29 (5 years)
h) 2030-2034 (5 years)
I) 2015-19 (5 years)
j) 2020-24 (5 years)
k) 2025-29 (5 years)
l) 2030-34 (5 years)

Figure 5.68: CMIP model forecasts for JULY at 70% ice concentration under emissions scenario RCP85.

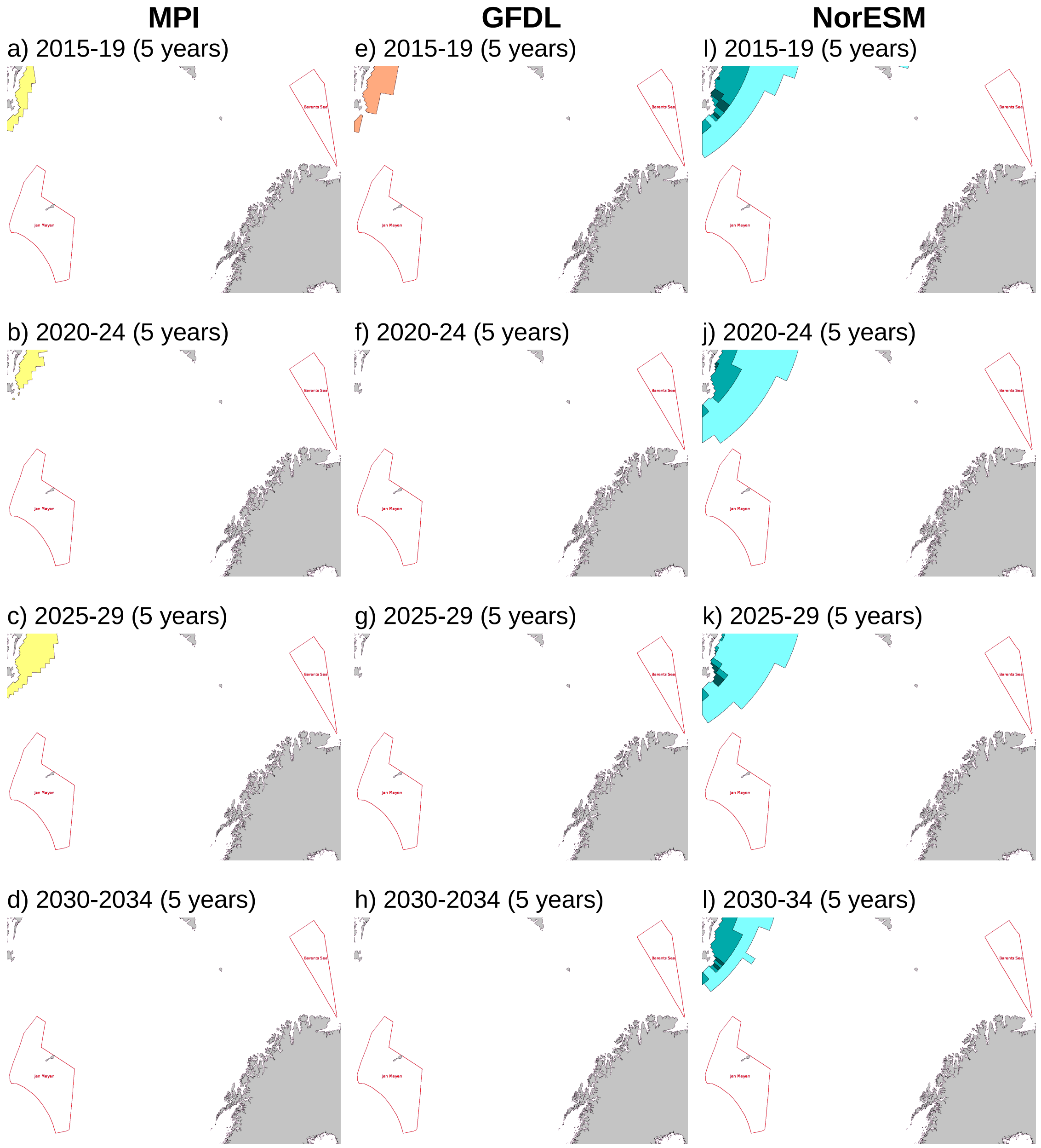
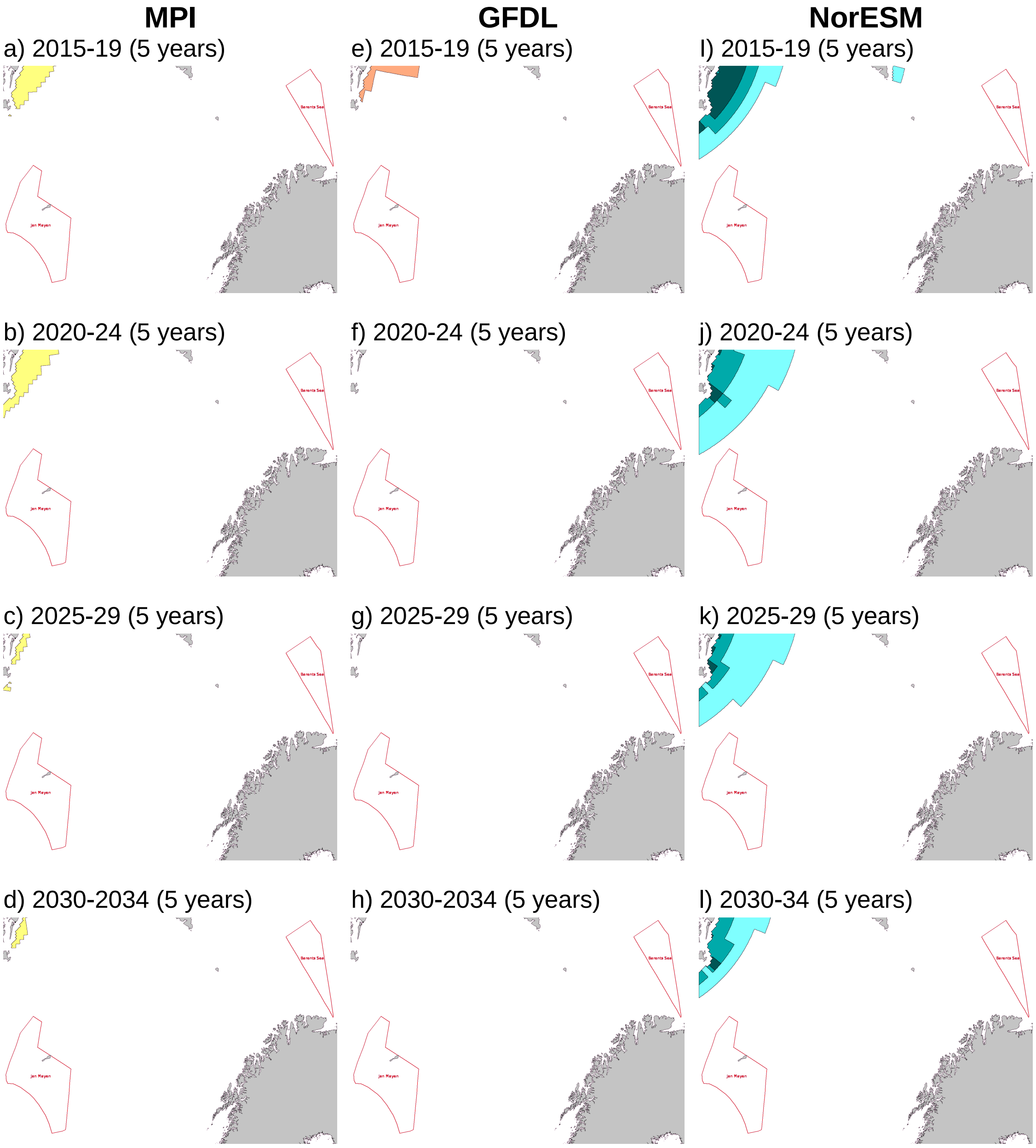
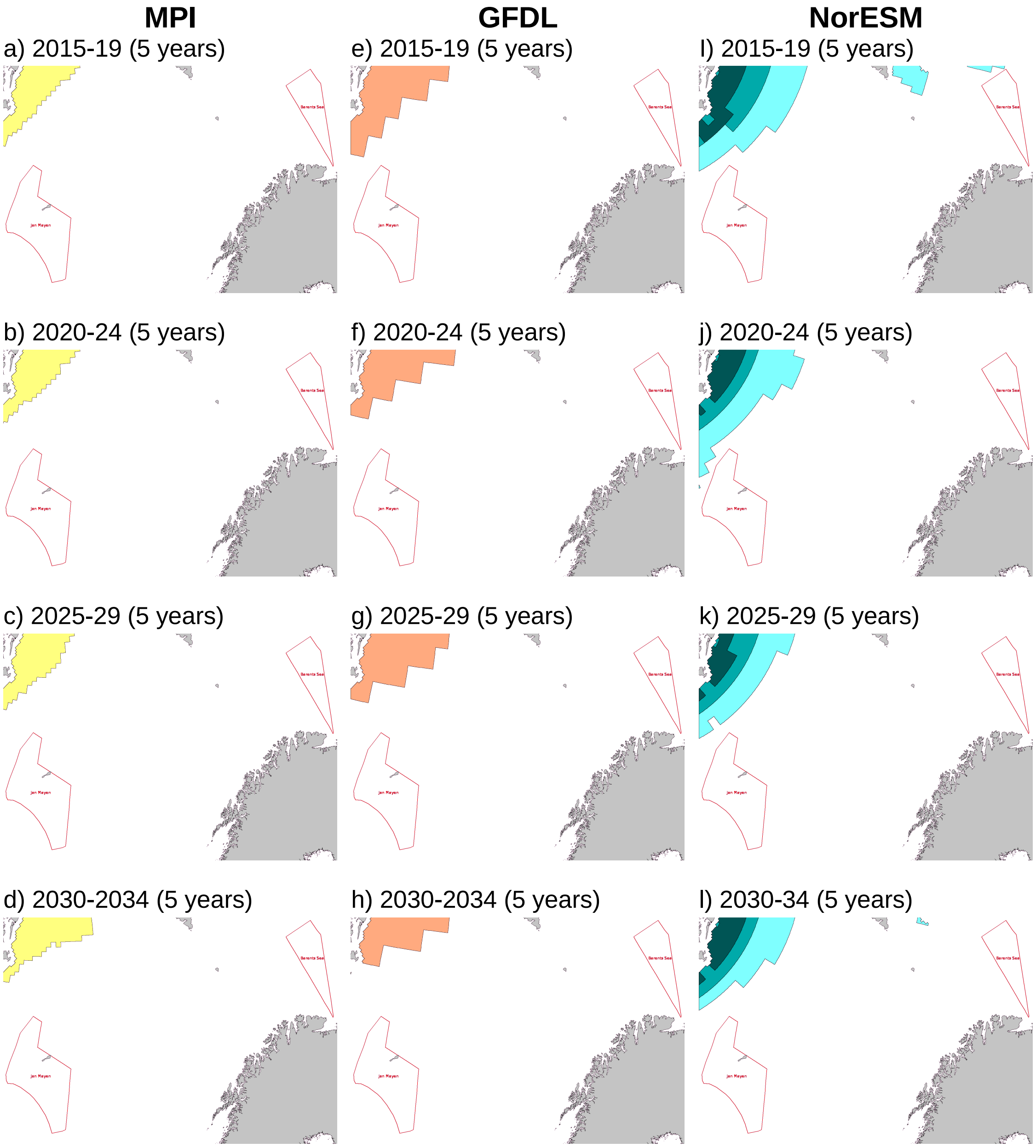


Figure 5.69: CMIP model forecasts for AUGUST at 70% ice concentration under emissions scenario RCP85.



a) 2015-19 (5 years)
b) 2020-24 (5 years)
c) 2025-29 (5 years)
d) 2030-2034 (5 years)
e) 2015-19 (5 years)
f) 2020-24 (5 years)
g) 2025-29 (5 years)
h) 2030-2034 (5 years)
I) 2015-19 (5 years)
j) 2020-24 (5 years)
k) 2025-29 (5 years)
l) 2030-34 (5 years)

Figure 5.70: CMIP model forecasts for SEPTEMBER at 70% ice concentration under emissions scenario RCP85.



MPI

GFDL

NorESM

a) 2015-19 (5 years)

e) 2015-19 (5 years)

I) 2015-19 (5 years)

b) 2020-24 (5 years)

f) 2020-24 (5 years)

j) 2020-24 (5 years)

c) 2025-29 (5 years)

g) 2025-29 (5 years)

k) 2025-29 (5 years)

d) 2030-2034 (5 years)

h) 2030-2034 (5 years)

l) 2030-34 (5 years)

Figure 5.71: CMIP model forecasts for OCTOBER at 70% ice concentration under emissions scenario RCP85.

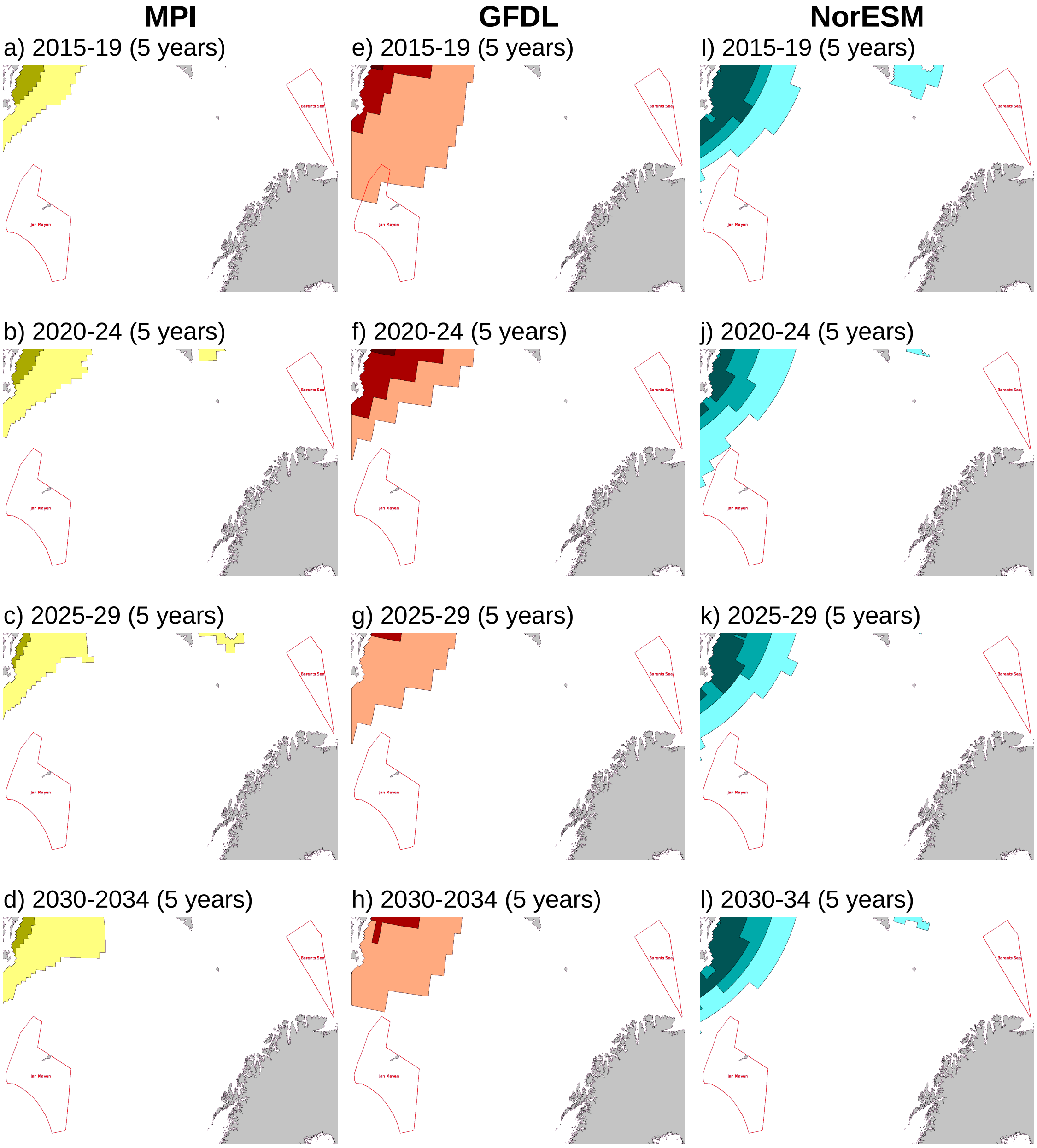


Figure 5.72: CMIP model forecasts for NOVEMBER at 70% ice concentration under emissions scenario RCP85.

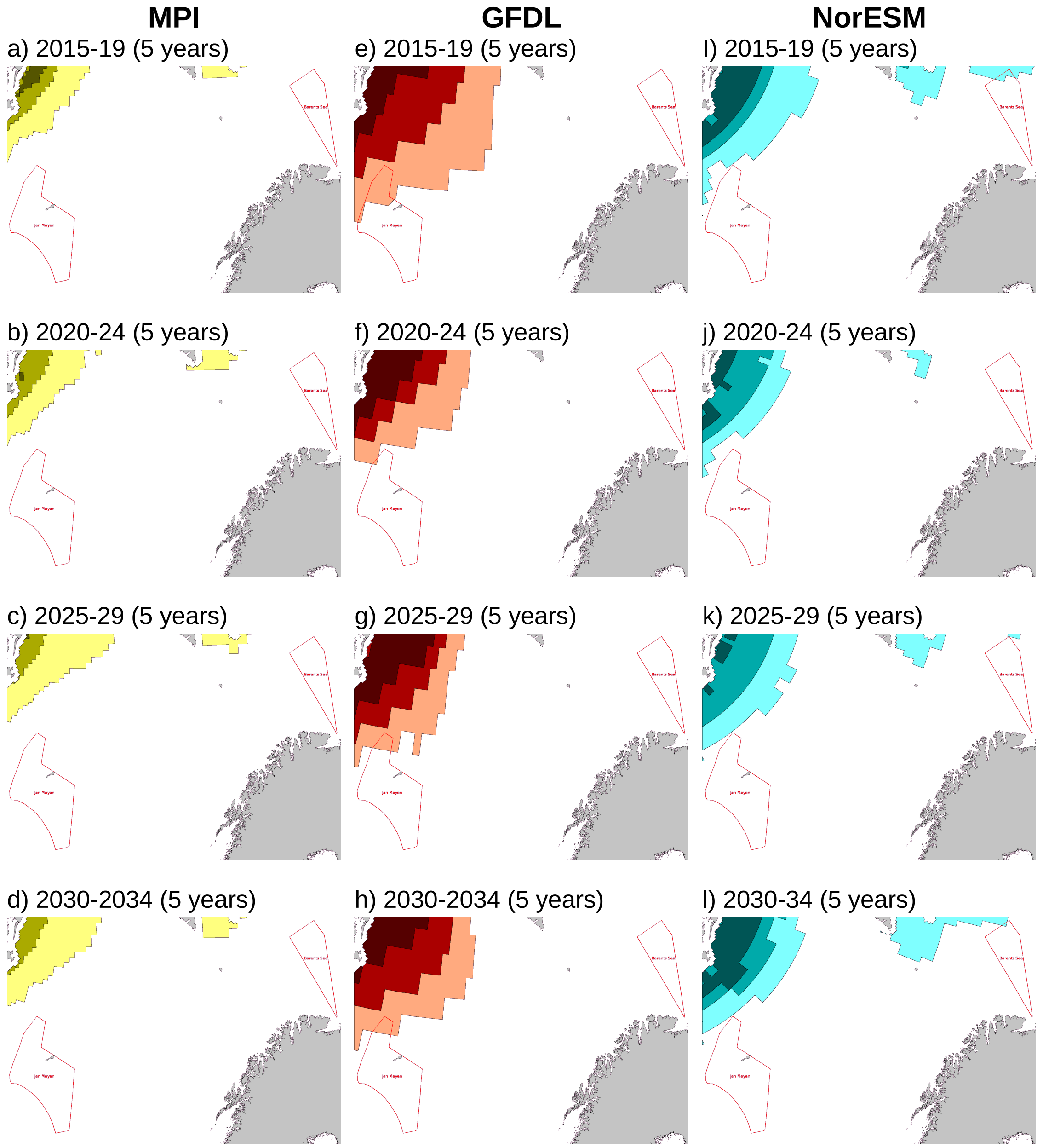


Figure 5.73: CMIP model forecasts for DECEMBER at 70% ice concentration under emissions scenario RCP85.

6 Flerårıs / Multi-Year Sea Ice

6.1 Innledning

Historiske observasjoner fra "special sensor microwave/imager-sensoren" (SSM / I) fra satelittene innenfor Defence Meteorological Satellite Program (DMSP), samt fra sensoren scanning-multi-channel-microwave-radiometer (SMMR) på NIMBUS-7-satelliten, har passive mikrobølge-observasjoner vist at overflatetemperatur er sterkere korrelert til havisens endringer og at atmosfærisk sirkulasjon sterkt påvirker driften av havis (Comiso, 2002). Sammen med pådriv fra havet påvirker disse faktorene flerårsisens utbredelse og tilbaketrekning. En generell god beksrivelse av sjøisens endringer i Polhavet ble oppsummert i Comiso, 2002 og Comiso, 2012. Her benyttes passive mikrobølger til å vurdere utviklingen av minimum isutbredelse i årene 1979-2011 og har re-evaluert både utbredelsen og tilbaketrekningen i årene 1979 -2010 med den hensikt å nyttiggjøre seg av tilgjengeligheten av Advanced Microwave Scanning Radiometer for Earth Observing System (AMSR-E) 36- GHz TB data på horisontale og vertikale polariseringer og 89-GHz TB på en vertikal polariseringing. Gevinsten av flere enn to kanaler innen passive mikrobølger, gir et mer robust datasett fordi det bedrer adskillelsen av førsteårsis og flerårsis sammenlignet med tidligere brukte scatterometer-data (Comiso, 2012). De første endringene avbildet mellom 1979-2000 viste at utbredelsen av arktisk flerårig havis avtar med en hastighet på -12,2% og -13,5% / tiår (Comiso, 2002). Det er viktig å merke seg at denne tidligere studien av isutbredelse evaluerte gammel is, altså is som har overlevd lengre enn flerårsis.

Introduction

Historical observations from the special sensor microwave/imager (SSM/I) on board the Defence Meteorological Satellite Program (DMSP) series of satellites, as well as the scanning multi- channel microwave radiometer (SMMR) on the NIMBUS-7 satellite passive microwave observations have shown surface temperature is more strongly correlated to sea ice cover changes and atmospheric circulation strongly influences sea ice drift (Comiso, 2002). Together, these with ocean forcings affect multi-year ice expanse and retreat. A general good overview of sea ice changes in the Arctic Ocean were summarized in Comiso, 2002 and Comiso, 2012 which used passive microwaves to evaluate the trend of the minimum ice extent from 1979-2011 and re-evaluated both the extent and retreat for 1979-2010 in order to take advantage of the addition of the Advanced Microwave Scanning Radiometer for Earth Observing System (AMSR-E) 36- GHz TB data at horizontal and vertical polarizations and 89-GHz TB at a vertical polarization. The addition of more than two channels in the passive microwave provides a more robust dataset because it improves the discrimination between first-year ice and multi-year ice better than previously used scatterometer data (Comiso, 2012). Initial changes depicted between 1979-2000 showed that the area of Arctic perennial sea ice is declining at a rate of -12.2% and -13.5 %/decade (Comiso, 2002). It is important to note that this previous sea ice extent study evaluated perennial ice which is ice that lasts longer than multi-year ice.

Når man ser på de seneste trendene innen havisens tilbakegang og utbredelse i Comiso, 2012, synes det som om endringer i sommerens smelteperioder synes å være mer ekstrem, spesielt mellom årene 2007-2010. De største forskjellene skjedde normalt mot slutten av sommeren, representert i Beauforthavet, Siberian Sea, Laptev-, og Barentshavet. I perioden 1981-2011 avtok flerårsisens omfang og utbredelse fra -15,6% og -17,5% ± 2,4% per tiår, men i perioden 2000-2010 i gjennomsnitt mellom -15,6 til -15,2 x 106 når man sammenligner alle konsentrasjonsalgoritmene (Comiso, 2012).

6.2 Flerårsisen i Framstredet og Grønlandshavet

Tabell 6.1 definerer tykkelses-parametere for ulike typer is og er nyttig når man beskriver trender i havistykkelsen.

When looking at recent trends in sea ice retreat and extent in Comiso, 2012, changes during the summer sea ice extent decline appeared to be more extreme, especially between the years 2007-2010. The largest differences normally occurred towards the end of the summer and were represented in the Beaufort, Siberian, Laptev, and Barents Seas. From 1981-2011 the trends in multi-year ice extent and area were decreasing from -15.6% and -17.5% ± 2.4% per decade, however, from 2000-2010 averaged between -15.6 to -15.2 x 106 when comparing all concentration algorithms (Comiso, 2012).

Multi-Year Ice in the Fram Strait and Greenland Sea

Table 6.1 defines the thickness parameters for different ice types and will be helpful when describing sea ice thickness trends.

Table 6.1: WMO sea ice stage of development categories and associated thicknesses.

Ice Types	Thickness (cm)
New ice-frazil, grease, slush, shuga	0 - 10
Nilas	0 - 10
Young	10 - 30
Gray	10 - 15
Gray-white	15 - 30
First-year	30 - 200
Thin first-year	30 - 70
Medium first-year	70 - 120
Thick first-year	120 - 200
Multi-Year	> 200

Mest sjøis i Arktis blir transportert ut av Polhavet via Framstredet, som regnes som en av de største avløp i ferskvannsbalansen i Arktis (Schmith og Hansen, 2003). Dette er ytterligere forsterket av noen flerårige episoder med smelting av flerårsisen i Beaufort Gyre før den går ut i Polhavet. Mens havisen beveger seg gjennom Framstredet langs Østgrønlandstrømmen (EGC) går den vanligvis i en sørvestlig bane mot Kapp Farvel og Labaradorhavet (Kwok, et al., 2004). I løpet av desember og januar kan det komme så langt som Cape Farewell, men bare for korte perioder. Porten til Framstredet ligger på ca 81°N mellom nordøst-Grønland og den nordvestlige tuppen av Svalbard, noe som dekker en avstand på ~ 40 km. Utløpet inneholder ca 15% av havisen i Polhavet og kan også eksporteres gjennom Framstredet i de nordiske hav som legger opp til ca 25% av den totale arktiske ferskvannstrømmen (Spreen, mfl .. 2009). Selv om nyere observasjoner har vist Arktis tynnes, vil variasjoner i havisen (dvs. volum, konsentrasjon og tykkelse), samt miljøforhold (atmosfære, saltholdighet, og pådriv fra havet) gjøre det vanskelig å fullt ut gi noen nøyaktighet på den eksakte ruten for flerårsisen når den går inn i de nordiske hav, spesielt så langt sør som Jan Mayen som ligger på ~ 71 ° N, 8 ° W (Kwok et al., 2009 og Kwok og Rothrock, 2009). Men vi kan gi informasjon om tidligere trender knyttet til isens fluks gjennom passasjer i Barents- og Norskehavet, og bruke denne informasjonen til å utlede sannsynligheten for at flerårsisen strømmer inn i Grønlandshavet og ut til de nordiske hav på lavere breddegrader.

Most sea ice in the Arctic is transported out of the Arctic Ocean via the Fram Strait, which is considered one of the largest drains in the freshwater balance in the Arctic (Schmith and Hansen, 2003). This is further amplified by some multi-year ice melting events in the Beaufort Gyre before before exiting the Arctic Ocean. As sea ice moves through the Fram Strait along East Greenland Current (EGC) it usually travels in a southwest trajectory towards Cape Farewell and the Labarador Sea (Kwok, et al., 2004). During December and January it can reach as far as Cape Farewell but only remains for short periods. The gate of the Fram Strait lies at approximately 81°N between the northeast Greenland and the Northwestern tip of Svalbard which covers a distance of ~40 km. The outflow contains approximately 15% of the sea ice mass of the Arctic Ocean and can also be exported through Fram Strait into the Nordic Seas which adds up to about 25% of the total Arctic freshwater outflow (Spreen, et al.. 2009). Though recent observations have shown Arctic is thinning, variations in the sea ice cover (i.e. volume, concentration, and thickness), as well as environmental conditions (atmosphere, salinity stratification in the sea and ocean forcings) make it difficult to fully provide any accuracy on the exact route of multi-year ice going into the Nordic Seas, especially as far south as Jan Mayen which lies at ~71°N, 8°W (Kwok et al., 2009 and Kwok and Rothrock, 2009). However, we can provide information on previous trends associated with the ice flux through passageways into the Barents and Nordic Seas and use this information to infer the likelihood of multi-year ice flowing into the Greenland Sea and out to the Nordic Seas at lower latitudes.

Is som går ned gjennom Grønlandshavet fra Arktis og nordøst-Grønland, er omsluttet av en veldefinert iskant (Miz) som normalt inneholder tynnere istyper som issørpe/småis og pannekakeis. Tykkere is i denne regionen er sterkt knyttet til havet og atmosfæriske påvirkninger og har en tendens til å bryte opp raskere i mindre is-typer på grunn av disse regionale pådrivene mens de fortsetter sørover langs Øst-Grønland. Oppbrytningen av havisen har da en tendens til å forårsake at flerårsisen og førsteårsis har en tilsvarende radiometrisk signatur. Avhengig av intensiteten av EGC og regionale lavtrykk fra Framstredet eller de som dannes fra den østlige kysten av Grønland, kan isen nå southvest-regionen av Grønland. Dette er også kjent som "Storis" (Schmith, og Hansen, 2003) . Kjennskapen til "Storis" er mer kjent enn feomenet for Øst-Grønland på grunn av skipsloggbøker. Imidlertid ble minimums- og maksimumsgraden for isutbredelselangs Øst-Grønland i 1966-1975 illustrert i Vinje, 1977. Her vises det til at grensen for maksimumet normalt ikke kommer forbi 10 ° W, og beveger seg østover.

Selv om informasjon om havisens volum og tykkelse er tilgjengelig fra oppoverpekende sonar (ULS) og kombinert-havmodeller, gir de fortsatt ikke god nok konsistens sammenlignet med passiv-mikrobølge, i å gi et best mulig anslag på isens eksport i Framstredet, inkludert sin mellomårlige variabilitet (Schmith og Hansen, 2003). En 29-årig serie, evaluert fra Kwok 2009, brukte passive mikrobølgedata fra 37-GHz kanalen til SMMR og SSM / I radiometers, og 89 GHz AMSR og konstruerte en bane for hvilke typer ispartikler som strømmet ut fra Framstredet. De fant at av drenering fra det vestlige Polhavet og nord for Grønland, eksporteres mesteparten av den tykkere havisen ned Framstredet til Grønlandshavet. Frekvensen av tynning is i Arktis ble antatt å øke, deretter tilrettelegge for en økning i eksporten av flerårsis (Lindsay

Ice travelling down through the Greenland Sea from the Arctic and northeast Greenland are enclosed in a well defined Marginal Ice Zone (MIZ) which normally contains thinner ice types such as brash, pancakes, and frazil. Thicker ice in this region is heavily susceptible to ocean and atmospheric influences and tend to break up faster into smaller ice types due to these regional forcings, as they continue southward along east Greenland. The sea ice break up then tends to cause multi-year ice and first year ice to have similar radiometric signatures. Depending on the intensity of the EGC and regional lows from the Fram Strait or those that formed from the eastern coast of Greenland, the ice can reach the Southwest region of Greenland, also known as the 'Storis' (Schmith, and Hansen, 2003). Information on the 'storis' is more well-known than that of east Greenland due to shipping logbooks. However, the ice edge minimum and maximum extent along east Greenland during 1966-1975 was illustrated in Vinje, 1977 and shows the maximum edge does not normally reach past 10°W moving eastward.

Though information on sea ice volume and thickness are available from upward looking sonar (ULS) and coupled-ocean models, respectively, they still do not provide enough continuity as passive microwave in giving the most correct estimate of ice export in the Fram Strait, including its interannual variability (Schmith and Hansen, 2003). A 29-year record evaluated from Kwok, 2009 used passive microwave data from the 37-GHz channel of the SMMR and SSM/I radiometers, and 89 GHz AMSR and constructed a trajectory of what types of ice particles exit from the Fram Strait gate. They found the drainage from the western Arctic Ocean and north of Greenland exported most of its thicker sea ice down Fram Strait to the Greenland Sea. The rate of thinning ice in the Arctic was postulated to increase, subsequently facilitating an increase in the og Zhang, 2005). Hypotesen kan understøttes ved bruk av ULS-istykkelse- data fra 1991-1999, som viser en samlet reduksjon av flerårig istykkelse på 0,55 m, og en vinterlig reduksjon på 0,42 m (Kwok, 2004 og Kwok, 2009). Denne kortere serien synes også å sammenfalle med Rothrock et al. (2008) sin estimering av 1,25 m nedgang for hele Arktis. Her benyttes en lengre 25-årig serie (1975 og 2000) for isens undersjøiske del for det meste av det sentrale Polhavet (Kwok, 2009). Til tross for dette, ser det ut til at havisvolumet og området for iseksport ikke har endret seg vesentlig, når man analyserer årene 2003-2008 sammenlignet med 1990-tallet (Spreen, 2009). Tidligere tidsserier samlet i dette dokumentet antyder totalt sett lite bevegelse av flerårig is utenfor EGC eller bort fra Grønland. Med fortynning av istype og oppbrytning av isflak under transporten gjennom EGC, vil gjenværende flerårsis som eventuelt måtte bryte opp og flyte østover utenfor EGC, bare eksistere for en kort stund før den brytes videre opp og smelter mens den driver lengre bort fra ismassen og MIZ.

6.3 Flerårsisen i Barentshavet

En viktig funksjon som gjør Barentshavet unikt sammenlignet med andre sibirske randhav, er at den aldri er helt dekket av is, og etter å ha nådd den maksimale isutbredelsen i april, vil iskanten (eller Miz) trekke nordover og gi en isfri sommer (Johannessen, et. al 2007). Utstrømming av havisen i Barentshavet har sitt opphav mellom Svalbard og Franz Josef Land (S-FJL) og mellom Franz Josef Land og Severnaya Semlja (FJL-SZ), inn i Barentshavet (Kwok, 2009). Trender i passiv-mikrobølgedata beskrevet for Framstredet i dette dokumentet, samt å se på flerårige kombinerte is-havmodeller (Comiso, 2012 og Kwok, et al. 2005), kan brukes til å beregne muligheten for flerårsis i Barentsregionen. Utstrømming av havisen i Barentshavet er

export of multi-year ice (Lindsay and Zhang, 2005). This hypothesis may be supported with the use of ULS ice thickness data from 1991-1999, which showed an overall decrease of multi-year ice thickness distributions of 0.55 m and a winter decrease of 0.42 m (Kwok, 2004 and Kwok, 2009). This shorter record also seems to coincide with Rothrock et al. (2008) estimation of 1.25m decrease for the whole Arctic using the longer 25-yr record (1975 and 2000) of submarine ice draft of mostly the central Arctic Ocean (Kwok, 2009). Despite this, it appears sea ice volume and area export analysed from 2003-2008 compared to the 1990's have not changed significantly (Spreen, 2009). Overall, previous time series collated in this document suggests little multi-year ices flows outside the EGC or away from the Greenland coast. Additionally, with the thinning of ice-types and break up of ice floes during transit through the EGC, any remaining multi-year ice that happens to break off and flow eastward outside of the EGC, may only exist for a short duration before it is further broken up and melted as it drifts further from the ice pack and MIZ.

Multi-Year Ice in the Barents Sea

An important feature that makes the Barents Sea unique from other Siberian Shelf seas is that is is never completely ice-covered and after reaching the maximum ice extent in April, the ice edge (or MIZ)t retreats northward for an ice-free summer (Johannessen, et. Al 2007). The outflow of sea ice into the Barents Sea originate between Svalbard and Fraz Josef Land (S–FJL) and between Franz Josef Land and Severnaya Zemlya (FJL–SZ), into the Barents Sea (Kwok, 2009). Passive microwave trends described for the Fram Strait in this document can be used to asses the possibility of multi-year ice in the Barents region, as well as looking at multiple year coupled ice ocean models (Comiso, 2012 and Kwok, et al. 2005). The outflow of sea ice into stort sett drevet av vind, spesielt nordavind, i tillegg til istykkelsen i områdene nær S-FJL, og gjennom dypvannstrømmene i Atlanterhavet (Kwok et al., 2005). Comiso 2012, illustrerte hvordan dekket av gammel is har trukket seg systematisk tilbake, spesielt i Beauforthavet, Siberian Sea, Laptevhavet og Barentshavet og viser at en stor del av disse områdene er fri for flerårsis gjennom hele året. I tillegg viser passiv mikrøbølge at utbredelsen av flerårsis viser tidels endringer i retrett og økende trender i arktisk overflatetemperatur er økende. Denne trenden var spesielt dominerende i Baffin Bay og Barentshavet, noe som korrelerer med tilbaketrekkingen av flerårsis i disse regionene. Gitt at havisen ble analysert bare i de kalde og tørre månedene (november-april), er isens signatur relativt stabil og viser en sterk kontrast fra førsteårsis og flerårsis (Comiso, 2012). Utbredelsen av flerårsis fra passiv-mikrobølgedata er likt det som er funnet med scatterometerdata med høyere oppløsning fra samme tidsrom. Ifølge Johannessen et al., 2007, blir iskantens posisjon bestemt av Nordkappstrømmen, hvor det varme vannet forhindrer at havis brer seg i nærheten av 20-30°E lengdegrader, og iskantens posisjon varierer mellom 80°N ved havisens minimum, til 74°N på det høyeste. Vanligvis viser studier av utbredelsen av flerårsis at isen ikke synes å dannes eller opprettholdes sør for Franz Josef Land. Uten nøyaktig kunnskap om havisens drift, er det vanskelig og med sikkerhet kunne anslå hvor langt flerårsisen vil reise utenfor sin normale bane fordi små endringer skjer fra år til år. Det er mulig at noe flerårsis kan drive inn i Barentshavet og rundt Jan Mayen, men det har imidlertid vært lite is (generelt) nær begge områdene i de siste tiårene, og den generelle trenden i disse måleperiodene er negative for begge regioner.

the Barents Sea is mostly driven by wind forcings, particularly northerly winds, and sea ice thicknesses in the areas next to the S-FJL, and through flow of the Atlantic dense water (Kwok et al., 2005). Comiso, 2012 illustrated how the perennial ice cover has been retreating systematically, especially in the Beaufort, Siberian, Laptev, and Barents Seas and show a great deal of these areas are even multi-year ice free throughout the year. Additionally, sea ice multi-year ice extent from passive microwaves are showing decadal changes in sea ice retreat and escalating Arctic surface temperature trends are larger with each increasing decade beginning from 1979 - 2010. This trend was especially dominant in the Baffin Bay and Barents Sea which correlates with multi-year sea ice retreats in these regions. Given that the sea ice was analysed only during the cold and dry months (November – April), the ice signature is relatively stable and shows a strong contrast from first-year and multi-year ice (Comiso, 2012). The multi-year ice extent from passive microwave data are similar to what is found with higher resolution scatterometer data from the same time. According to Johannessen et al., 2007, the ice edge position is determined by the Nordkapp Current and the warm current prevents sea ice spreading in the vicinity of 20-30°E longitudes and the ice edge position varies between 80°N at the sea ice minimum to 74°N at the maximum. Generally, studies on sea ice multi-year ice extent do not appear to form or sustain below Franz Josef Land. Without accurate sea ice drift information it is difficult to confidently predict how far multi-year ice will travel off its normal trajectory because small changes happen from year to year. It is possible that some multiyear ice can drift into the Barents Sea and around Jan Mayen, however, there has been little ice (in general) near both areas in recent decades and the overall trend throughout these measurement periods is negative for both regions.

7 Isfjell / Icebergs

7.1 Overvåking av Isfjell

Mesteparten av isfjellovervåkingen rundt Grønland er gjort med bruk av Synthetic Aperture Radar (SAR), supplert med noen visuelle og infrarøde data fra MODIS og AVHRR. Et regionalt produkt for konsentrasjon av isfjell omkring Grønland er gjort tilgjengelig av EUs MyOcean-prosjekt, og produsert av det danske meteorologiske institutt (DMI).

I de senere årene har DMI overvåket isfjell med automatisk prosessert Radarsat-1 og -2 ScanSAR wide images, med en Constant False Alarm Rate (CFAR)-algoritme for å detektere objekter i åpent vann. Dette er brukt ved å filtrere ut havis ved hjelp AMSR-2, hvor alle objekter senere blir konvertert til tettheter i er rutenett på 10x10 km, og så lagt ut på MyOceans dataserver som kan finnes på: http://www.myocean.eu/. Samlet betyr dette at hvis et gitt mål (backscatter-verdi eller pixel) avviker vesentlig fra støyen fra bak-

Monitoring for Icebergs

The majority of iceberg monitoring around Greenland is done with the use of Synthetic Aperture Radar (SAR), supplemented with some and visual and infrared data from MODIS and AVHRR. A regional Greenland iceberg concentration product is provided by the EU MyOcean project and produced by the Danish Meteorological Institute (DMI).

In recent years, DMI has monitored icebergs with automatically processed RADARSAT-1 and -2 ScanSAR Wide images using a Constant False Alarm Rate (CFAR) algorithm to detect open water targets. This is applied by filtering out sea ice using AMSR-2 and subsequently all targets are converted to densities in a 10x10 km grid and posted on the MyOcean data server which can be found at: http://www.myocean.eu/. Overall this means that if a given target (backscatter value or pixel) deviates significantly from the back-

Table 7.1: Details of MyOcean iceberg concentration product.

Description	The iceberg product describes iceberg concentration as number of icebergs counted within 10x10 km grid cells. The product is derived by applying a Constant False Alarm Rate (CFAR) algorithm on data from Synthetic Aperture Radar (SAR)satellite sensors.
Product Identifier	SEAICE_ARC_SEAICE_L4_NRT_OBSERVATIONS_011_007
Web Site	http://www.myocean.eu/

grunnstøyen, er det klassifisert som et isfjell. De fleste isfjell er sett på den vestlige delen av Grønland, på grunn av mønsteret av dominerende strømninger, batymetri, og avstanden til kalvende isbreer. Ifølge DMI er det er ikke mye data tilgjengelig om breis i Grønlandshavet nær Jan Mayen. Ytterligere informasjon om DMIs isfjell-tracking kan finnes på:

http://myocean.met.no/SIW-TAC/doc/myo-wp14-siw-dmi-arc-seaice_berg-obs-validation_latest.pdf

7.2 Isfjell i litteraturen

Wadhams (1986) rapporterer at isfjell er sjeldne i Østgrønlandstrømmen, vest av "Jan Mayen-området", på grunn av en rekke faktorer:

- Landfast is langs kysten av Øst-Grønland begrenser de periodene når breene kan kalve til en kort sesong (ca. juli-september).
- Grunner eller ugunstige vind og strømforhold vil bidra til å holde isfjellene nær sine opprinnelige breer. I en typisk estuarin vannsirkulasjon i en fjord, er utadrennende vann nær overflaten kompensert av en langsomgående dyp strøm inn fjorden. Isfjell påvirkes mer av den dype innoverrettede strømmen enn den grunne og rask utovergående strømmen nær overflaten. Fjorder med en gyral sirkulasjon vil dermed produsere isfjell lettere. Dette betyr at Scoresbysundet og Kong Oscars Fjord er de mest produktive isfjellkildene. Isfjell som kommer ut fra disse blir med i Østgrønlandstrømmen og drives sørover, vekk fra "Jan Mayen-området".

ground noise, it is classified as an iceberg. Most icebergs are seen on the western part of Greenland due to the pattern of dominant currents, the bathymetry, and the distance to calving glaciers. According to DMI, there is not much data available about glacial ice in the Greenland Sea near to Jan Mayen. Additional information on the DMI iceberg tracking can be found at: http://myocean.met.no/SIW-TAC/doc/myo-wp14-siw-dmi-arc-seaice_berg-obs-validation_latest.pdf

Icebergs in the literature

Wadhams (1986) reports that icebergs rare in the East Greenland Current, to the west of the “Jan Mayen” area, because of a number of factors:

- Landfast ice along the East Greenland coast limits the periods when glaciers can discharge icebergs to a brief season (approximately July to September).
- Grounding or adverse winds and currents keep the icebergs to their glaciers of origin. In a typical estuarine water circulation in a fjord, outward-flowing water at the surface is compensated by a slow deep current moving into the fjord. Icebergs are affected more by the deep inward flowing current than the shallow and rapid outward flowing current at the surface. Fjords with a gyral circulation thus produce icebergs more readily. Thus Scoresby Sund and Kong Oscars Fjord are the most productive icebergs sources. Icebergs coming out from these join the East Greenland current and are swept southward, away from the “Jan Mayen” area.

Zubov (1943) og Abramov (1996) beskriver og kartlegger følgende isfjellkilder som kan påvirke enten «Barentshavet SØ» eller «Jan Mayen» området:

- Kvitøya - Dette gir bare enkelte små isfjell.
- Franz Josef Land - En viktig kilde.
- Nordlige Novaja Semlja.

De fleste isfjell fra disse kildene ser ut til å gå på grunn i Barents- eller Karahavet (Gaard et al., 1983).

Wadhams (1986) mener at et ekte isfjell som kommer ut av den Transpolare Driftstrømmen og inn i Østgrønlandstrømmen er en sjelden hendelse. Dog, seks små isfjell ble observert og fotografert under en helikopter- undersøkelse fra den svenske isbryteren Ymer ved iskanten nær øst-Grønland, på ca 79°10'N, 1°E 23. august 1980. Mer sannsynlig vurderes de lave tabularformede isfjellene av Wadhams til å være isøyer. Disse er produsert av følgende kilder, og er mer sannsynlig å forekomme i «Barentshavet SE» og «Jan Mayen» området:

- Nordøst-Grønland, spesielt isfronten i Nioghalvfjerds Fjorden ved 79°N.
- Nordaustlandet
- Edgeøya

Abramov (1996) forsøker å kartlegge utbredelsen av isfjell i Barentshavet ved hjelp av flyobservasjoner fra Sovjet-tiden (1933-1991). Han bemerker også at isbreene omkring Barenthavet, altså kildene til isfjellene, trakk seg tilbake, og dermed at antallet potensielle opphav til isfjell ville være redusert. Videre at isbreene, særlig på Svalbard, var utsatt for sig/utglidning. Et toppunkt for produksjonen av isfjell i Barentshavet ble antatt å være 1987-1991. Dette sammenfaller med perioden til den andre store kilden til observasjoner av isfjell i Barentshavet, Ice Data Acquisition Program (IDAP) 1986-1994 (Løset og Carstens, 1996; Spring, 1994).

Zubov (1943) and Abramov (1996) describe and map the following iceberg sources that could affect either the “Barents Sea SE” or “Jan Mayen” areas:

- Kvitøya – This produces only a few small small icebergs.
- Franz Josef Land – A major source.
- Northern Novaya Zemlya.

Most icebergs from these sources appear to go aground in the Barents or Kara Seas (Overgaard et al., 1983).

Wadhams (1986) considers that a true iceberg emerging from the Trans-Polar Drift Stream into the East Greenland Current is a rare event. However six small icebergs were observed and photographed during a helicopter survey from the Swedish icebreaker *Ymer* at the east-Greenland ice edge at about 79°10'N, 1°E on 23 August 1980. More likely are the low tabular icebergs considered by Wadhams to be ice islands. These are produced by the following sources, and are more likely to be encountered in the “”Barents Sea SE” and “Jan Mayen” areas:

- Northeast Greenland, particularly the ice front in Nioghalvfjerds Fjorden at 79°N.
- Nordaustlandet
- Edgeøya

Abramov (1996) attempts to map iceberg distribution in the Barents Sea using Soviet-era (1933-91) aerial reconnaissance observations. He also notes that the source glaciers around the Barents Sea were retreating, thus reducing the number of potential iceberg sources, and that the glaciers, particularly on Svalbard were subject to surging. A peak period for Barents Sea iceberg production was considered to be 1987-1991. This coincides with the period of the other major source of Barents Sea iceberg observations, the Ice Data Acquisition Program (IDAP) 1986-94 (Løset and Carstens, 1996; Spring, 1994).

8 Syntese / Synthesis

8.1 Innledning

Forskjellen mellom observasjoner og modeller vises best ved en serie av grafer som viser isutstrekning i fem års perioder fra 2005 til 2034. Disse viser at MPI og NorESM modeller produsere bart resultat, mens GFDL modellen lider av urealistiske isgrad.

MPI og NorESM uenig i at MPI prognoser en nedgang i isutbredelse og NorESM ser noen bedring fra 2025. Denne økningen er mer uttalt i urealistisk isutbredelse av GFDL

På grunn av uenighet mellom modellene, er det umulig å gi et endelig svar på de forventede fremtidige isforholdene i «Barentshavet SØ» og «Jan Mayen» områder.

Introduction

The difference between observations and models is best shown by a series of graphs showing the ice extents in 5 year periods from 2005 to 2034. These show that MPI and NorESM models produce feasible result, whilst the GFDL model suffers from unrealistic ice extents.

The MPI and NorESM disagree in that MPI forecasts a decline in sea ice extent and NorESM sees some recovery from 2025. This increase is more pronounced in the unrealistic ice extent of GFDL.

Because of the disagreement between the models, it is impossible to give a definitive answer as to the expected future sea ice conditions in the “Barents Sea SE” and “Jan Mayen” areas.

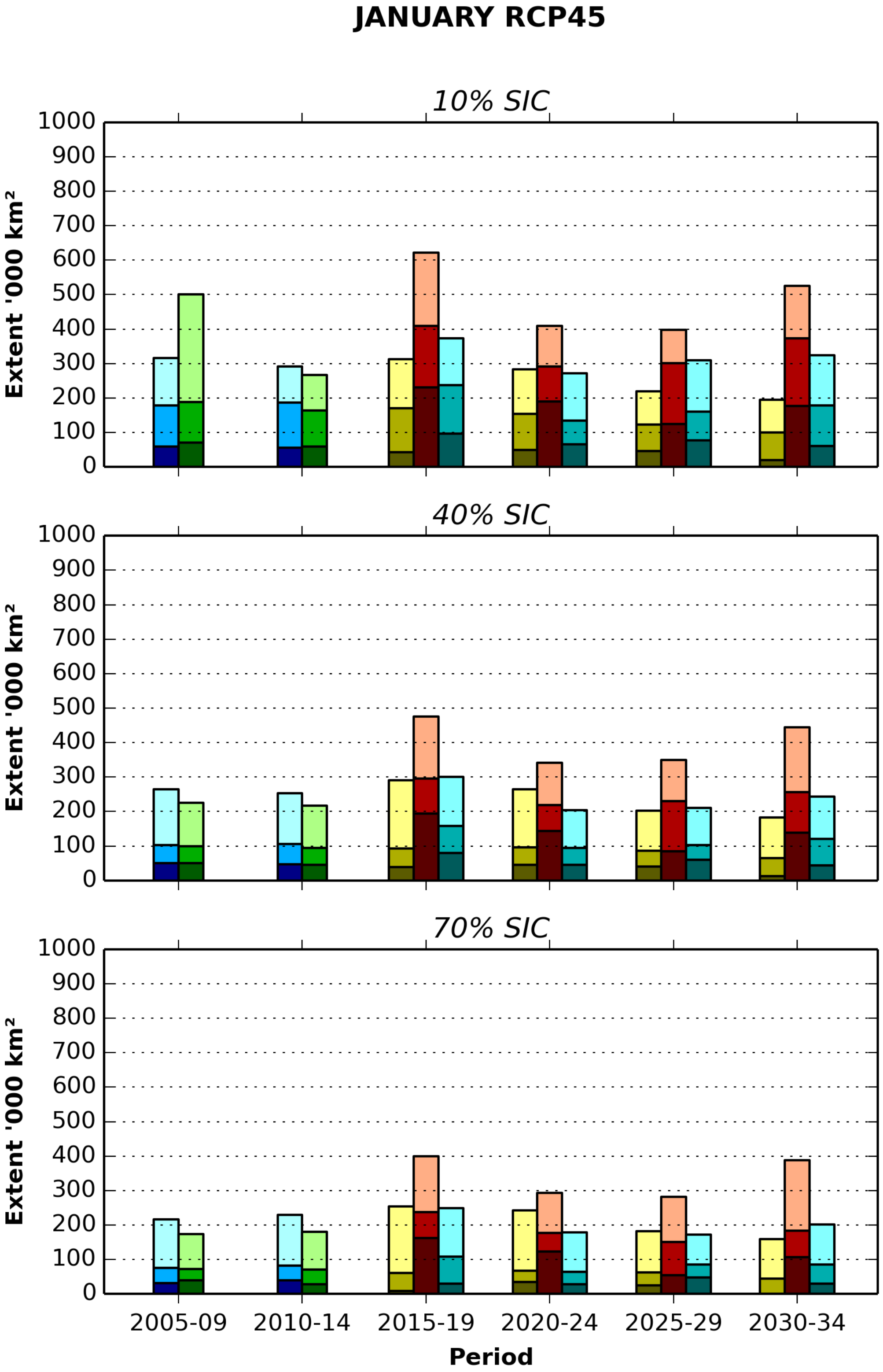


Figure 8.1: 5-year period ice extents from ice charts, OSI SAF, and climate models for JANUARY in the Nordic Seas under the RCP45 scenario.

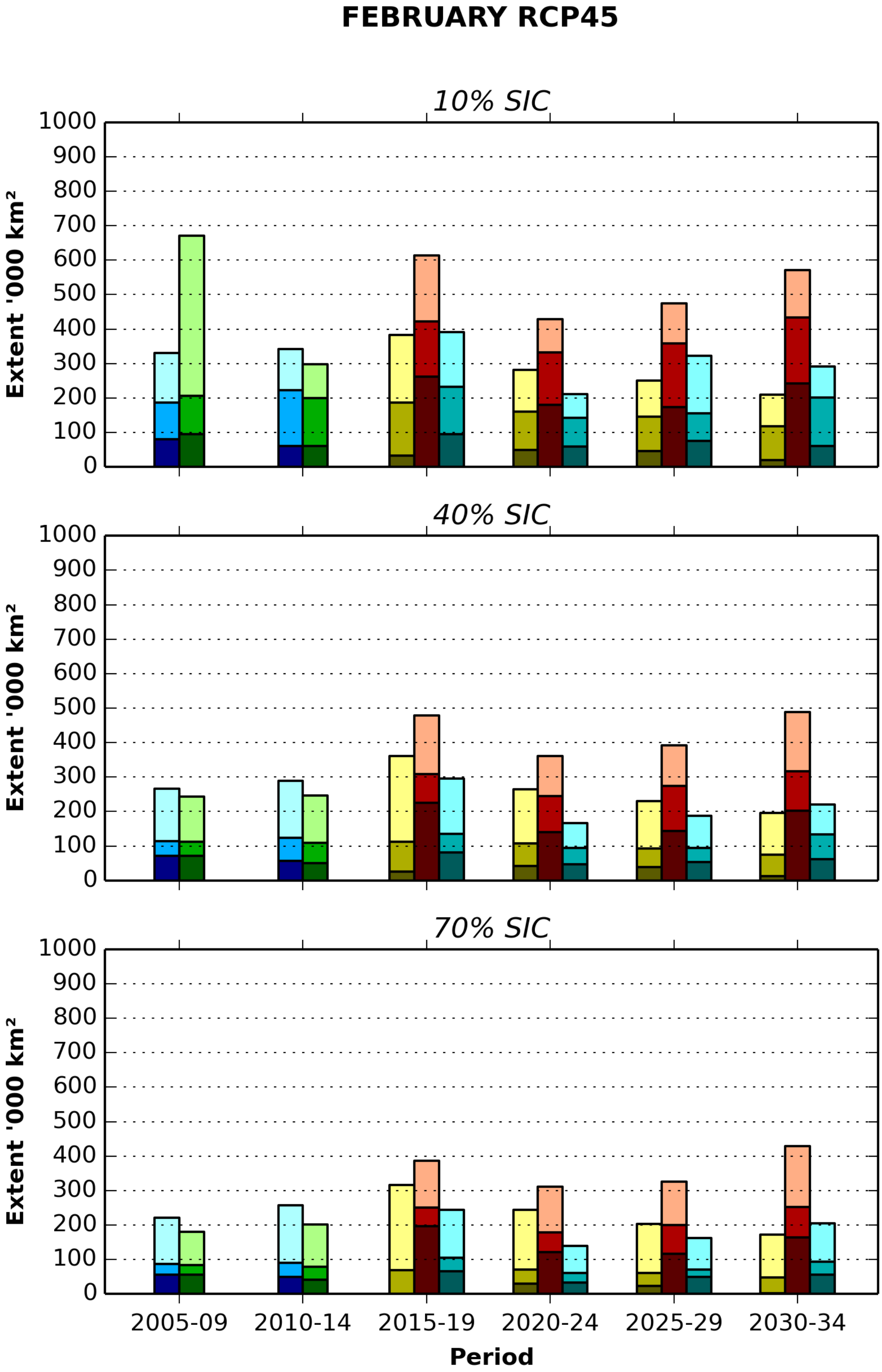


Figure 8.2: 5-year period ice extents from ice charts, OSI SAF, and climate models for FEBRUARY in the Nordic Seas under the RCP45 scenario.

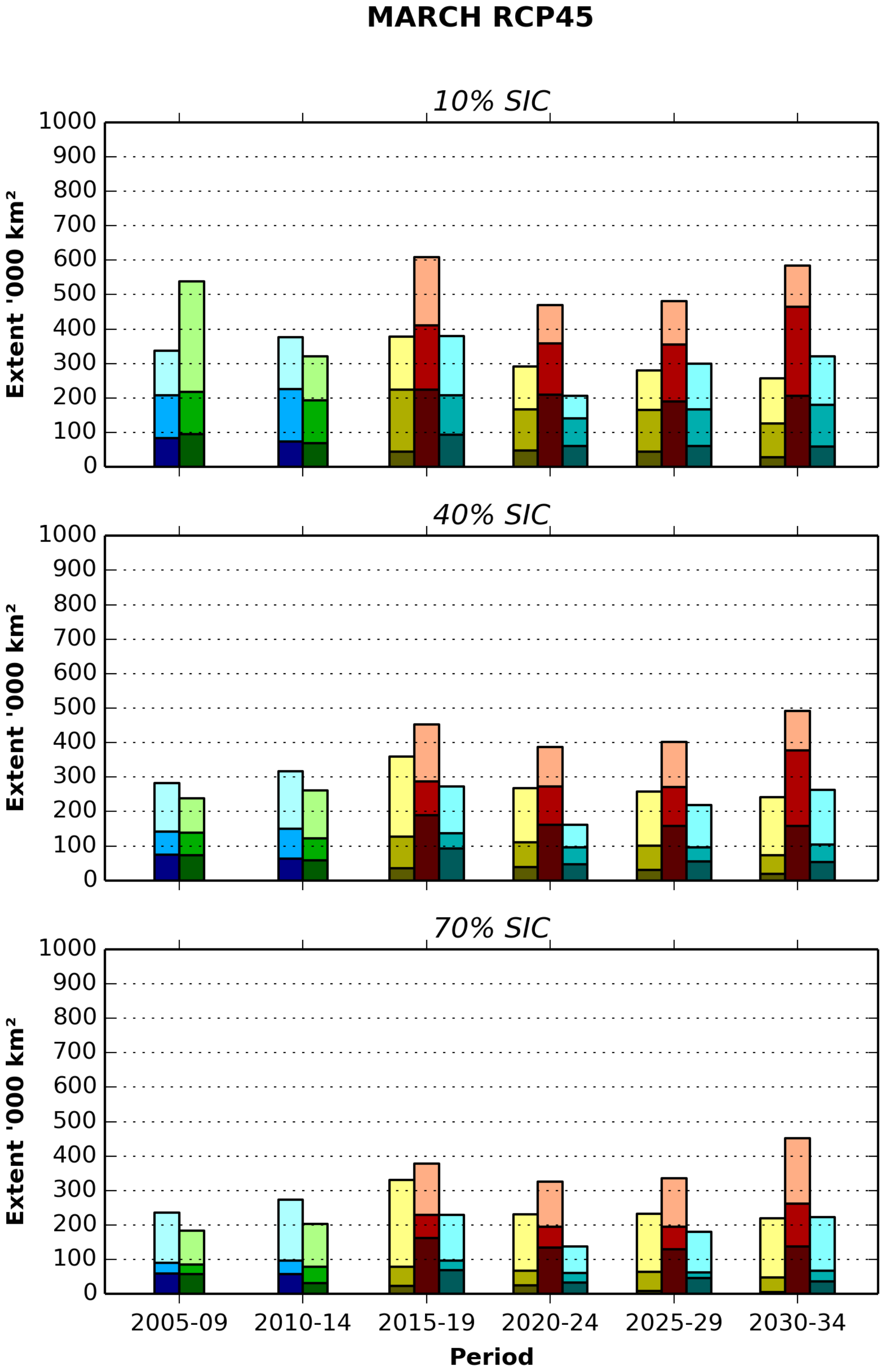


Figure 8.3: 5-year period ice extents from ice charts, OSI SAF, and climate models for MARCH in the Nordic Seas under the RCP45 scenario.

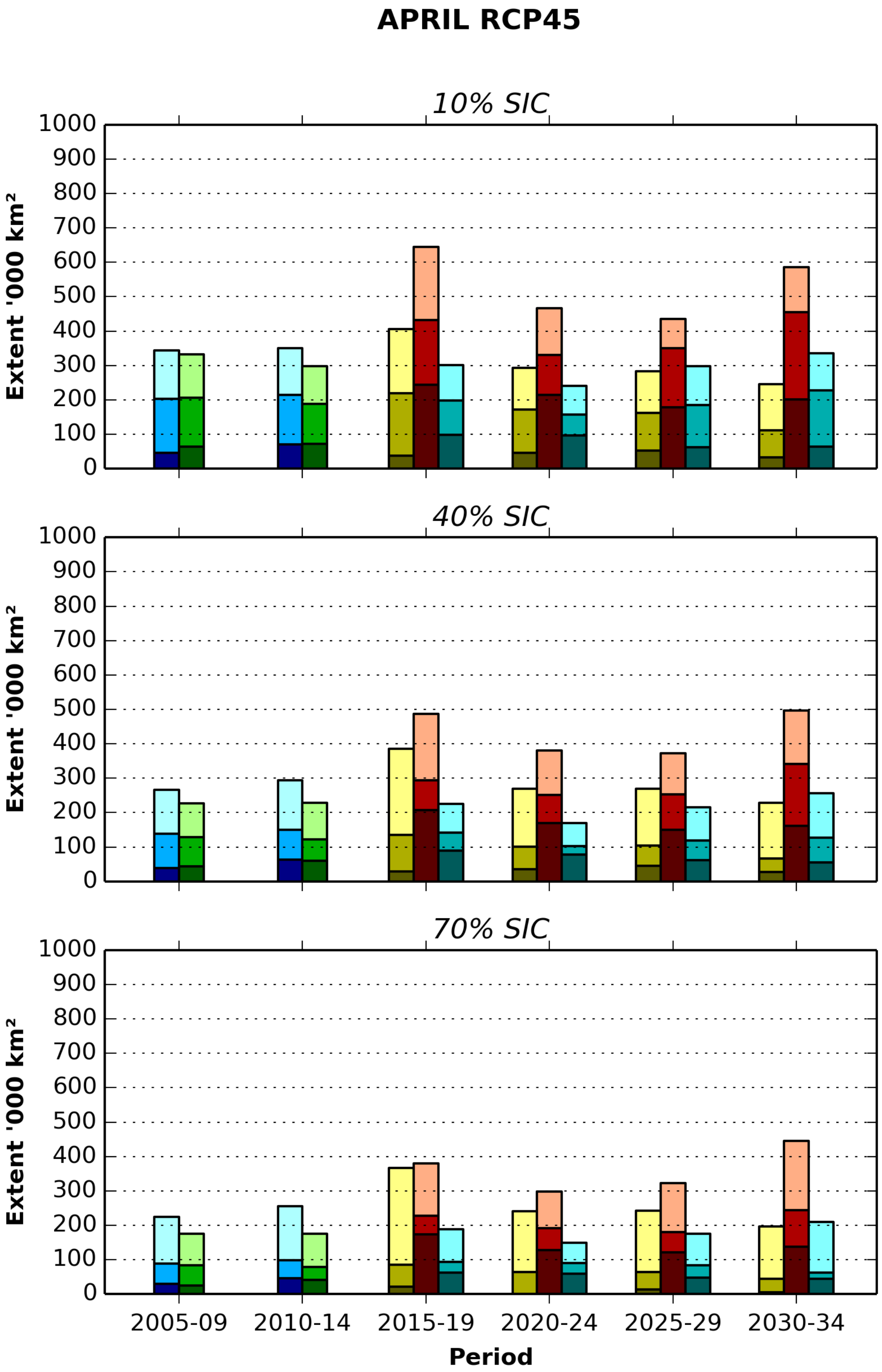


Figure 8.4: 5-year period ice extents from ice charts, OSI SAF, and climate models for APRIL in the Nordic Seas under the RCP45 scenario

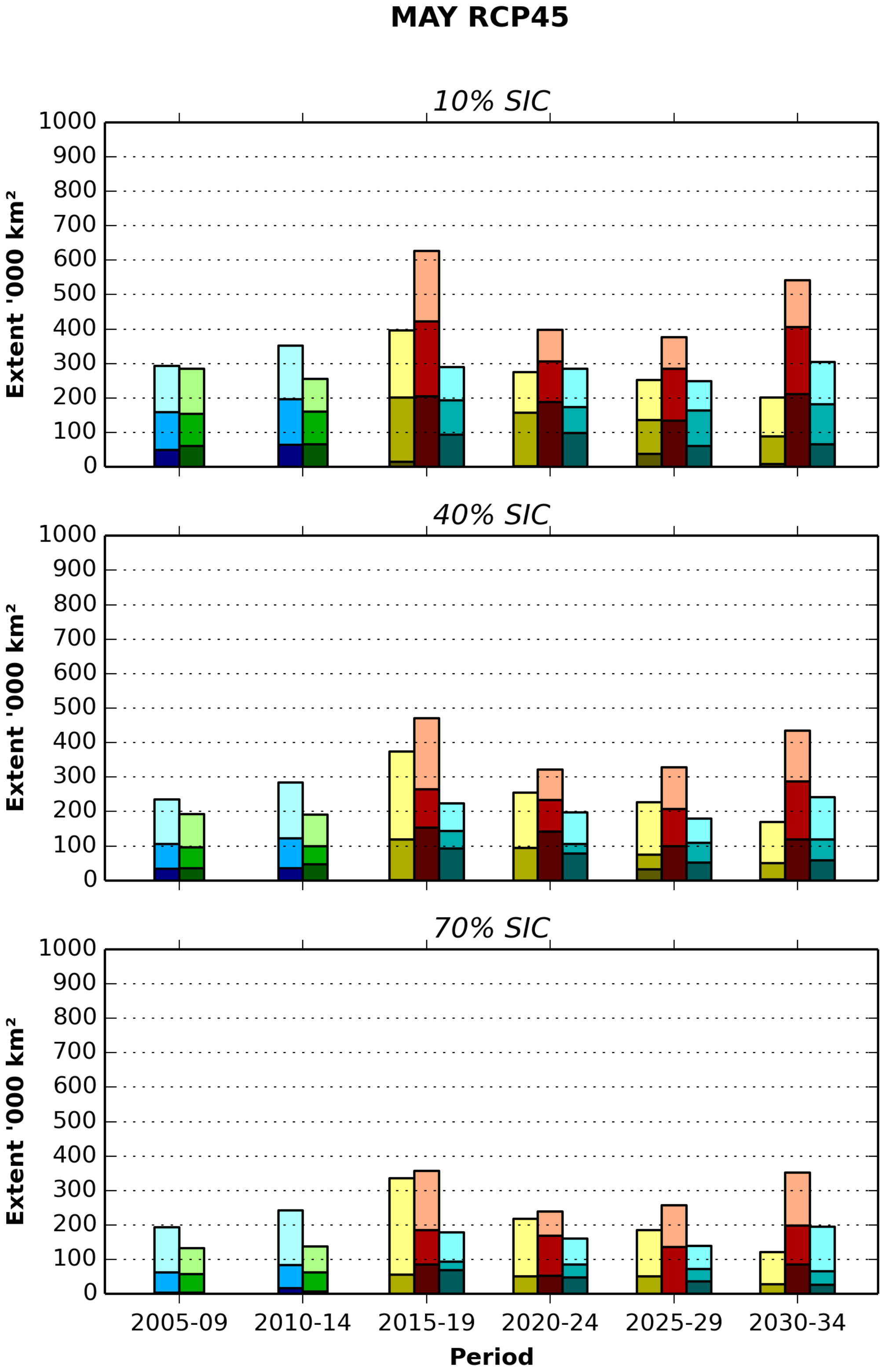


Figure 8.5: 5-year period ice extents from ice charts, OSI SAF, and climate models for MAY in the Nordic Seas under the RCP45 scenario

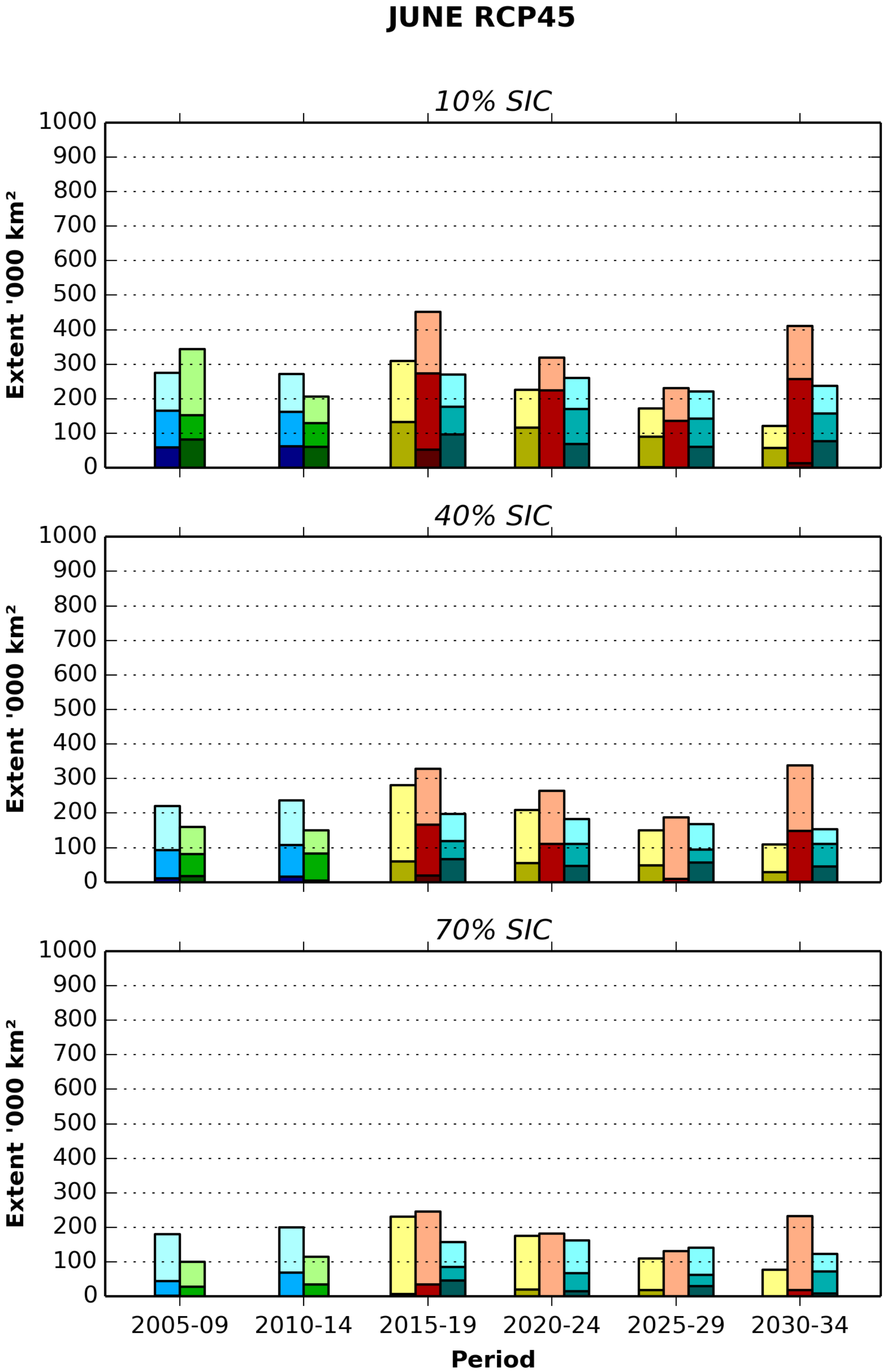


Figure 8.6: 5-year period ice extents from ice charts, OSI SAF, and climate models for JUNE in the Nordic Seas under the RCP45 scenario

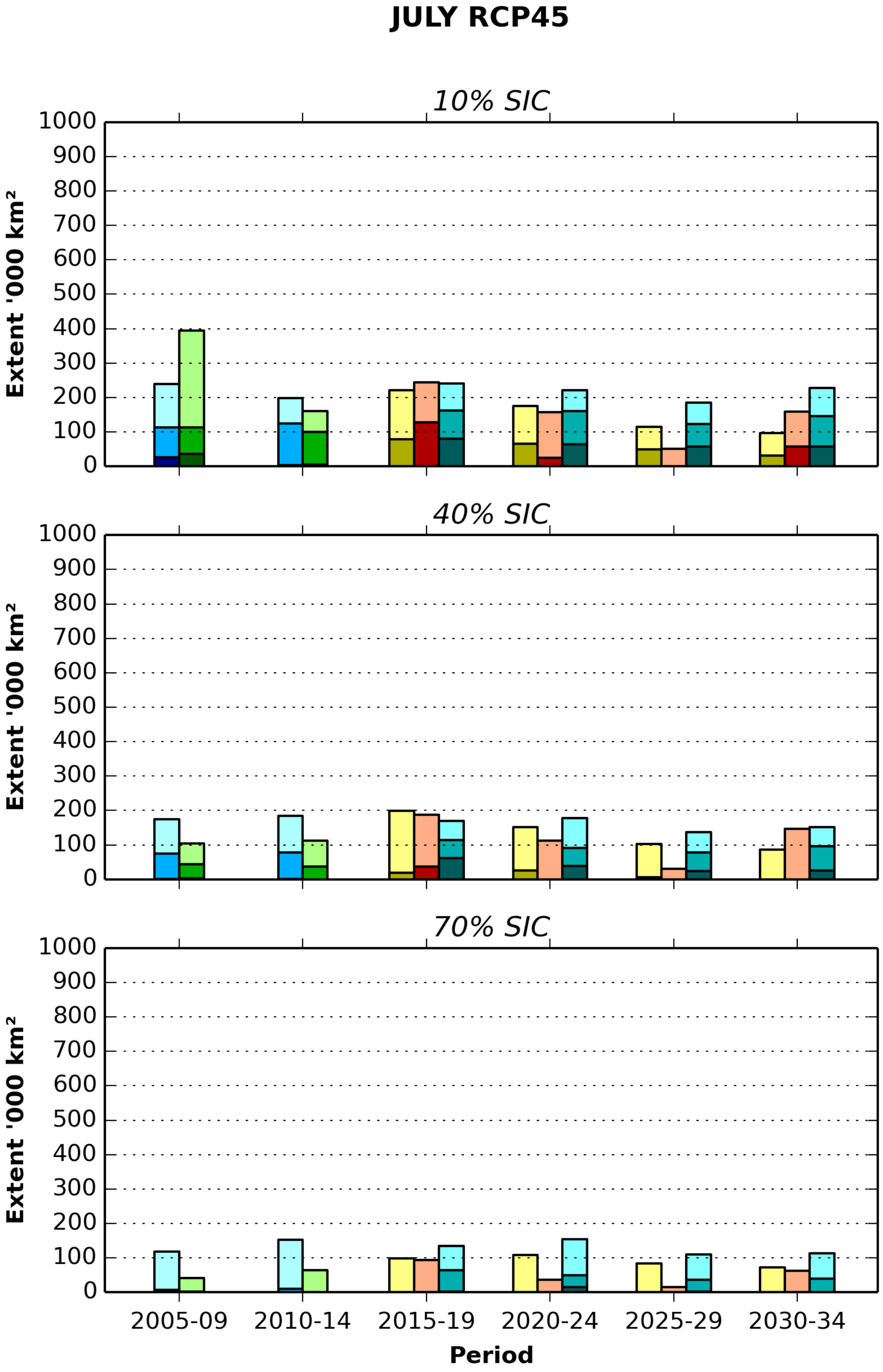


Figure 8.7: 5-year period ice extents from ice charts, OSI SAF, and climate models for JULY in the Nordic Seas under the RCP45 scenario

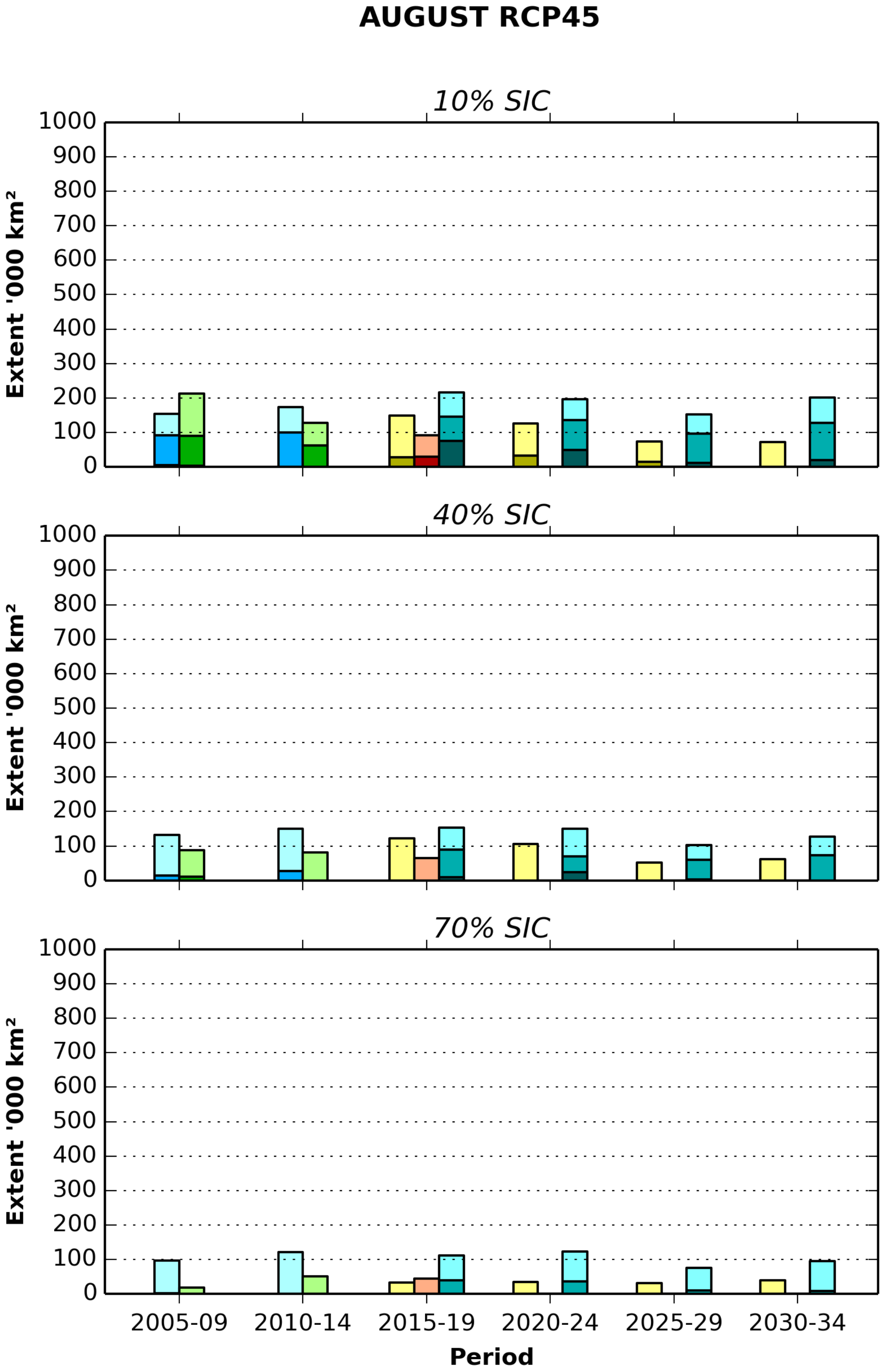


Figure 8.8: 5-year period ice extents from ice charts, OSI SAF, and climate models for AUGUST in the Nordic Seas under the RCP45 scenario

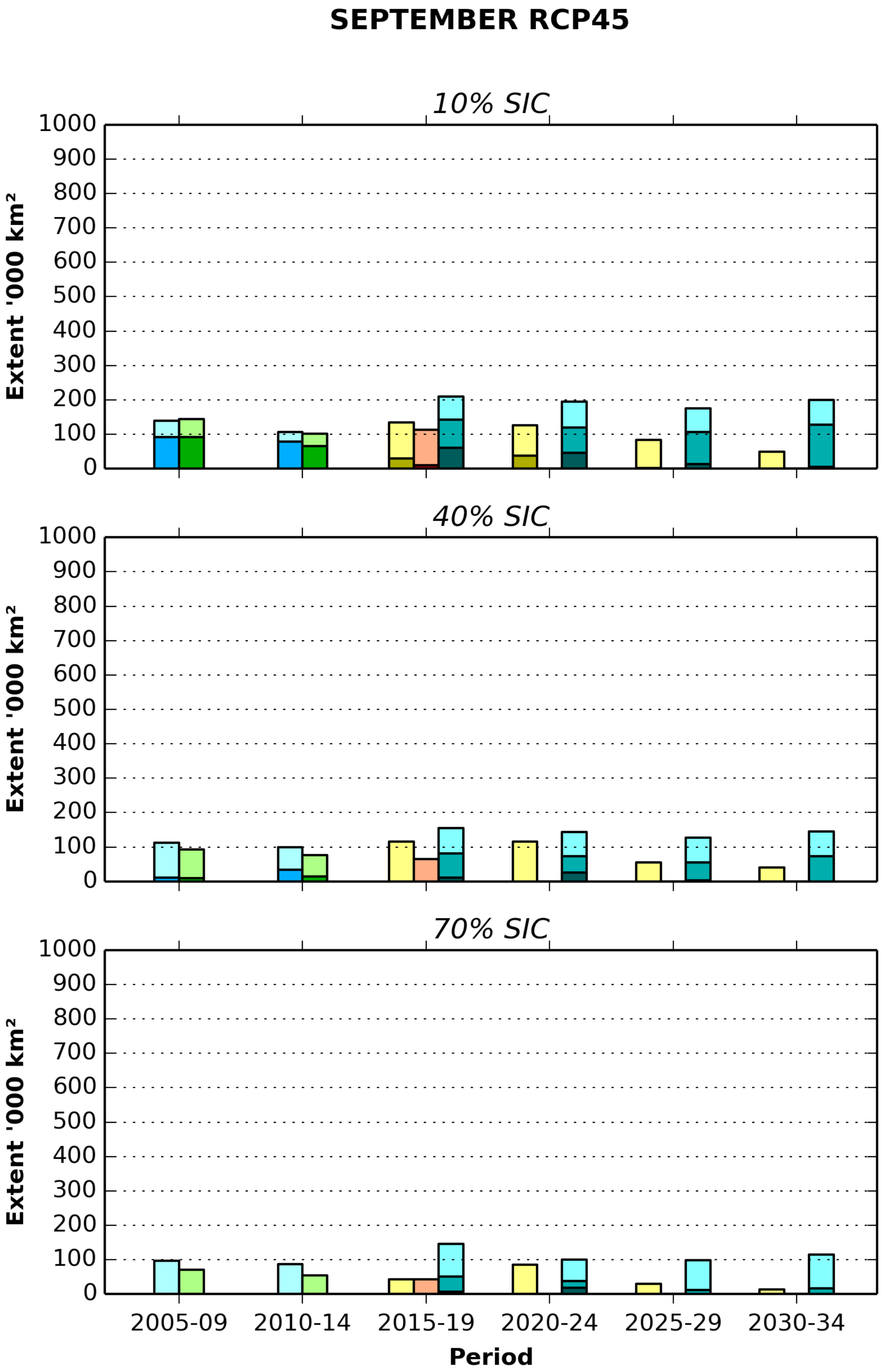


Figure 8.9: 5-year period ice extents from ice charts, OSI SAF, and climate models for SEPTEMBER in the Nordic Seas under the RCP45 scenario

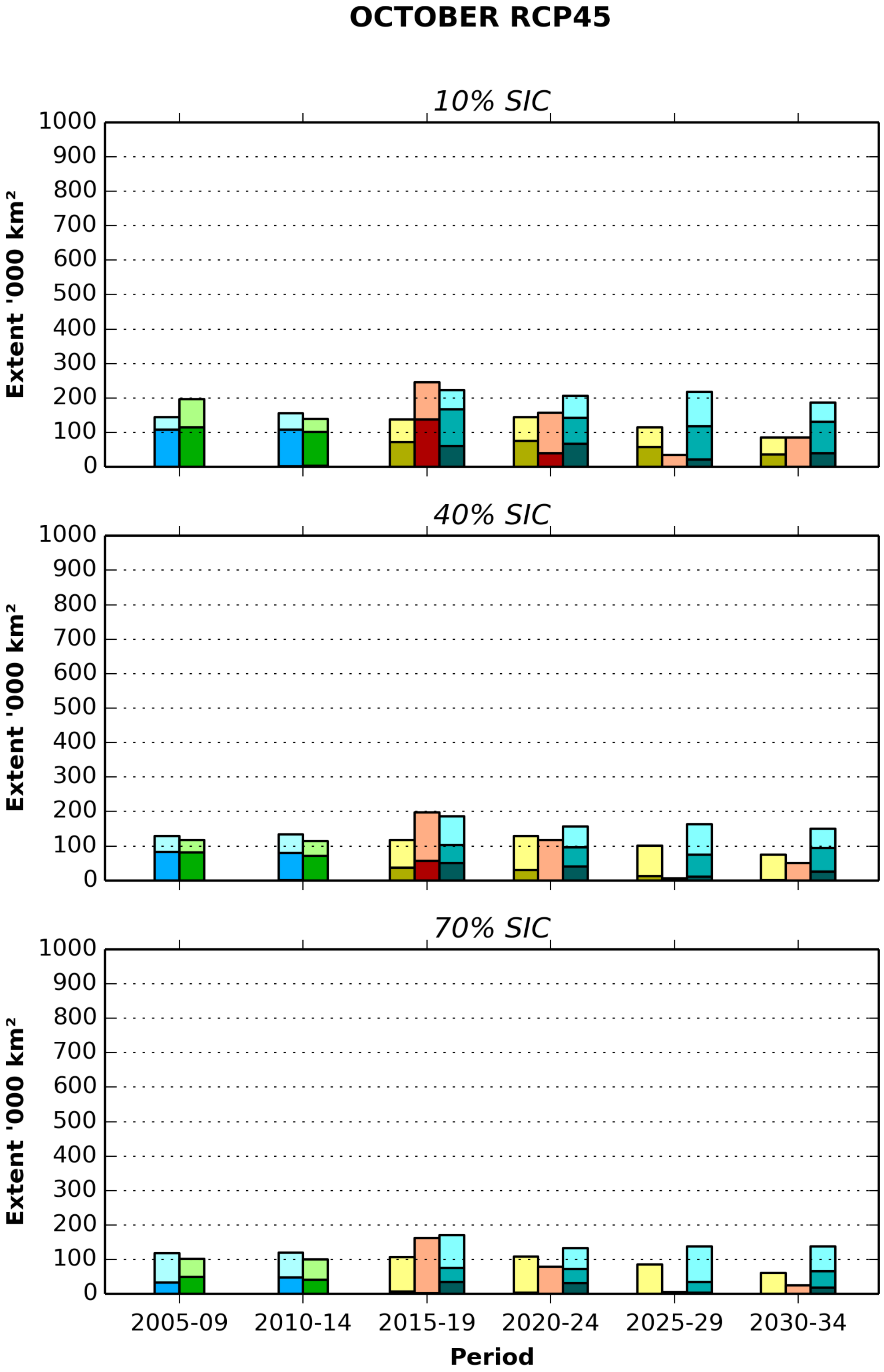


Figure 8.10: 5-year period ice extents from ice charts, OSI SAF, and climate models for OCTOBER in the Nordic Seas under the RCP45 scenario

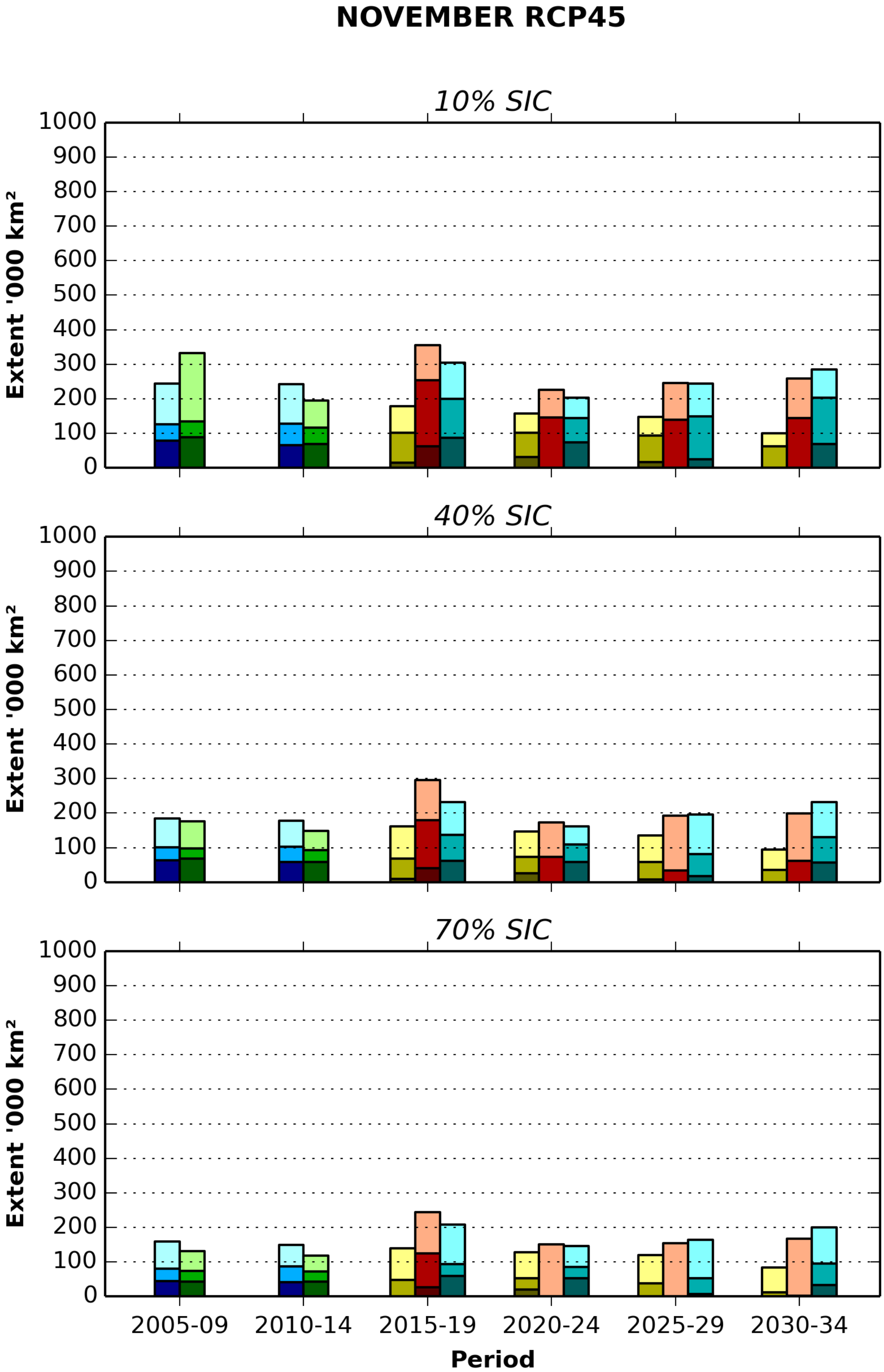


Figure 8.11: 5-year period ice extents from ice charts, OSI SAF, and climate models for NOVEMBER in the Nordic Seas under the RCP45 scenario

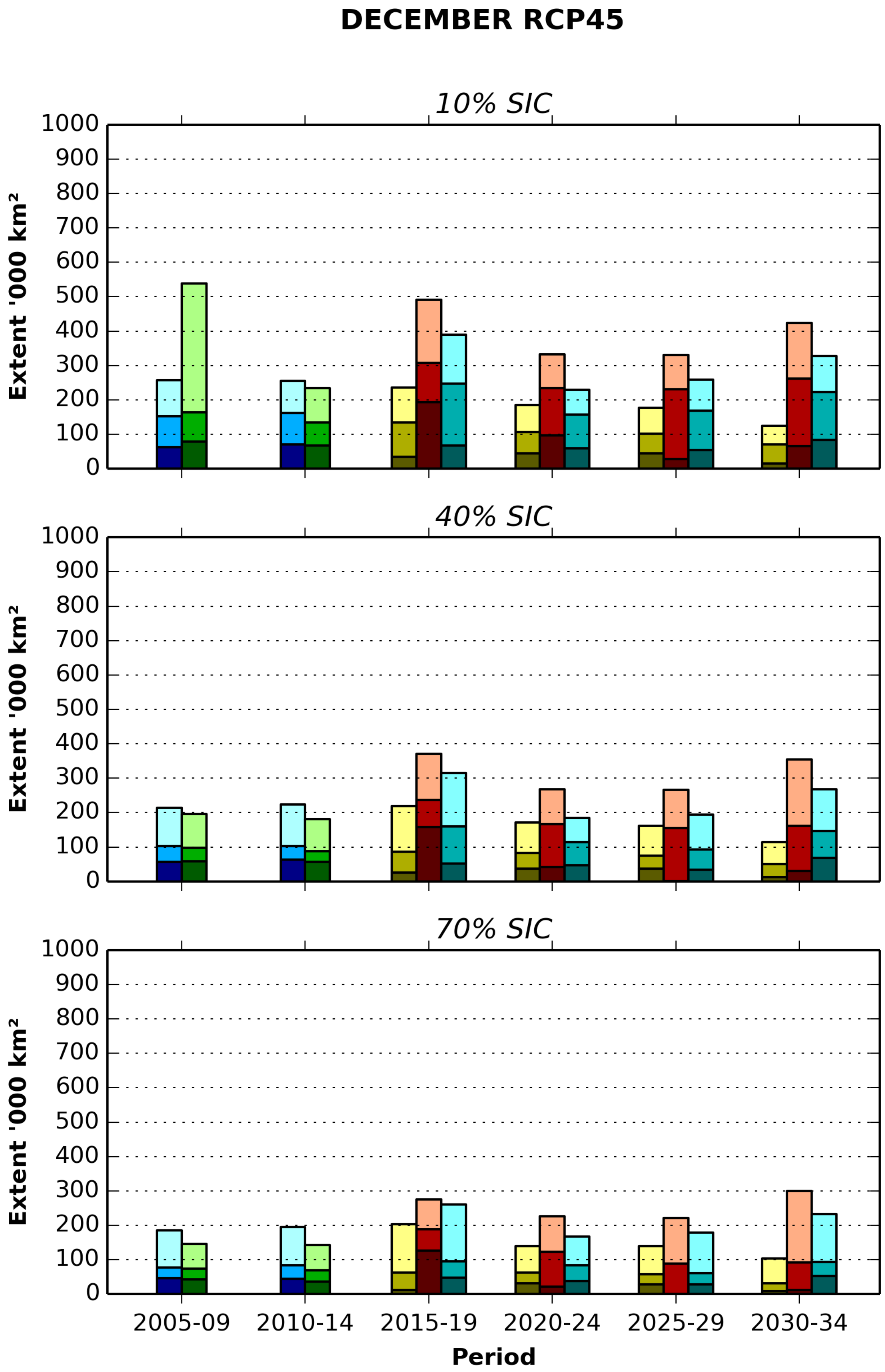


Figure 8.12: 5-year period ice extents from ice charts, OSI SAF, and climate models for DECEMBER in the Nordic Seas under the RCP45 scenario

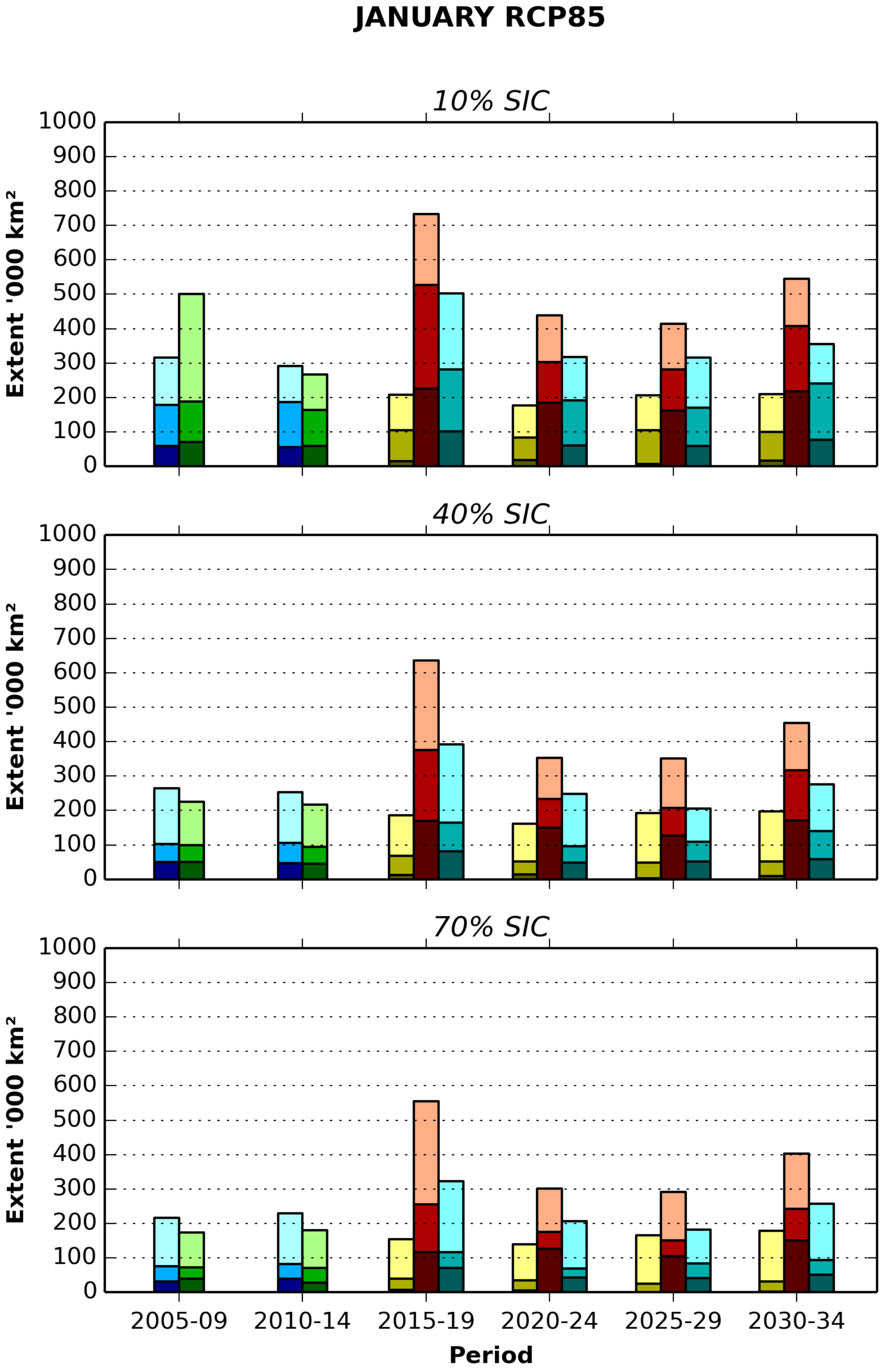


Figure 8.13: 5-year period ice extents from ice charts, OSI SAF, and climate models for JANUARY in the Nordic Seas under the RCP85 scenario.

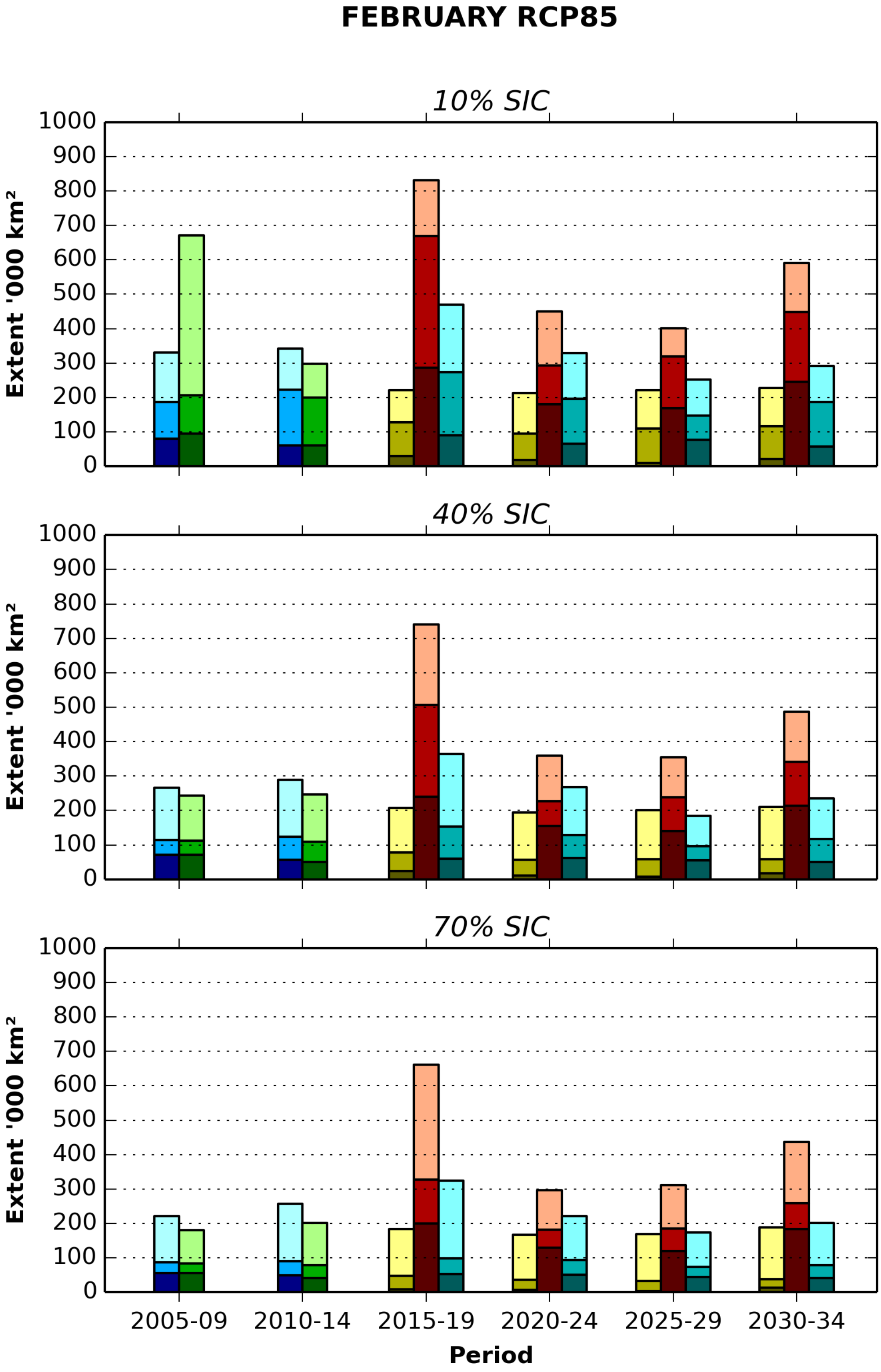


Figure 8.14: 5-year period ice extents from ice charts, OSI SAF, and climate models for FEBRUARY in the Nordic Seas under the RCP85 scenario.

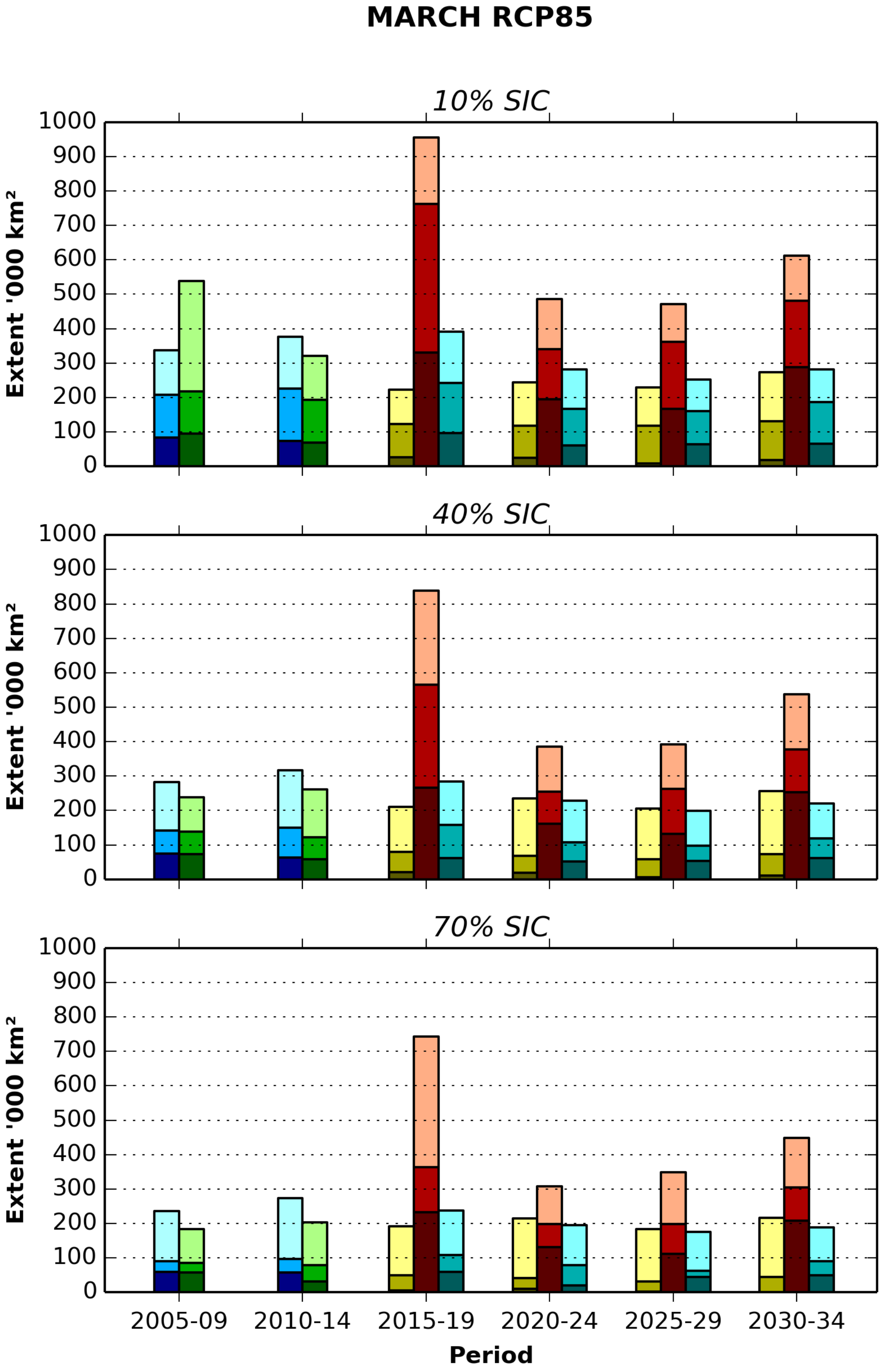


Figure 8.15: 5-year period ice extents from ice charts, OSI SAF, and climate models for MARCH in the Nordic Seas under the RCP85 scenario.

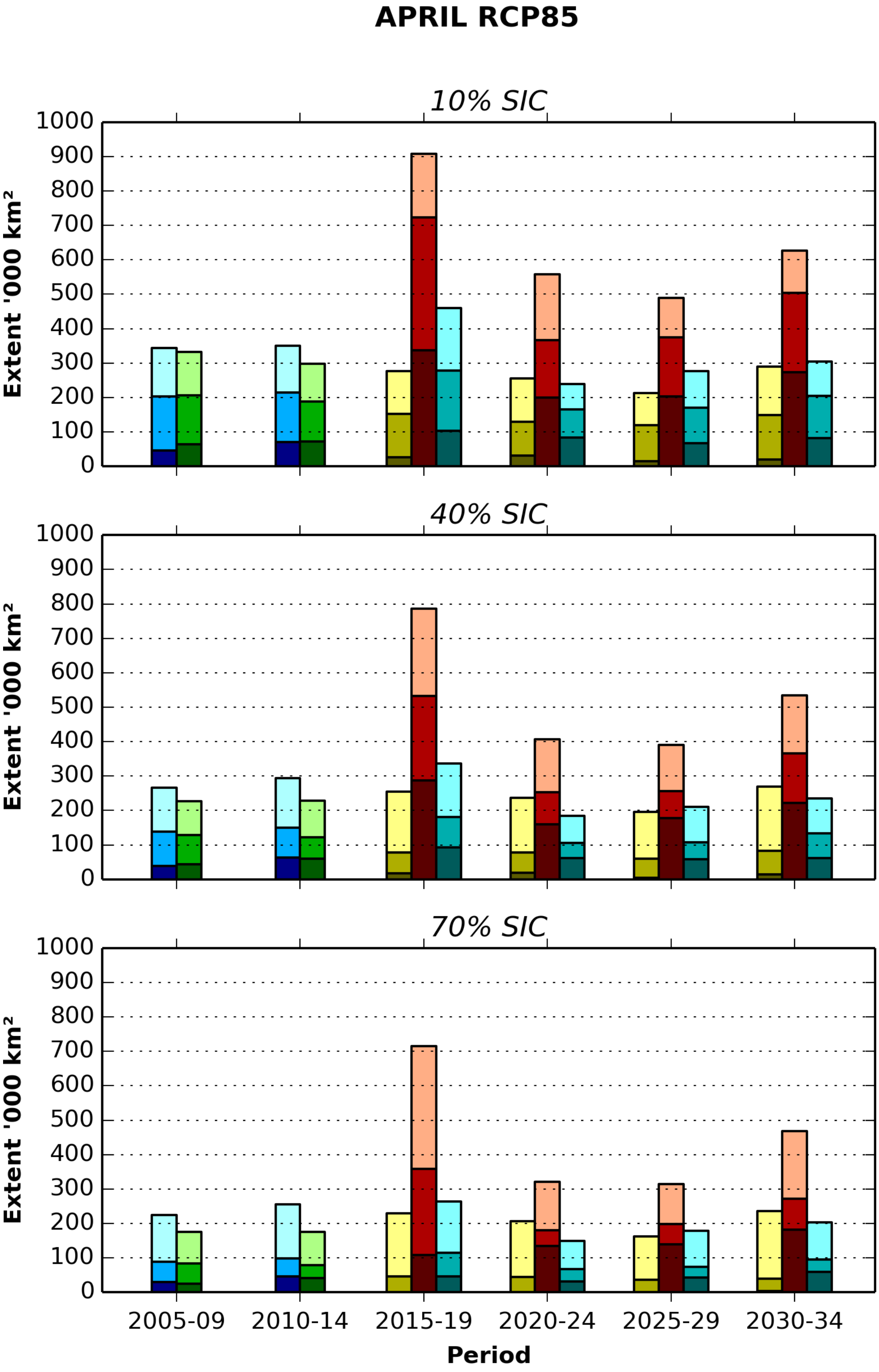


Figure 8.16: 5-year period ice extents from ice charts, OSI SAF, and climate models for APRIL in the Nordic Seas under the RCP85 scenario.

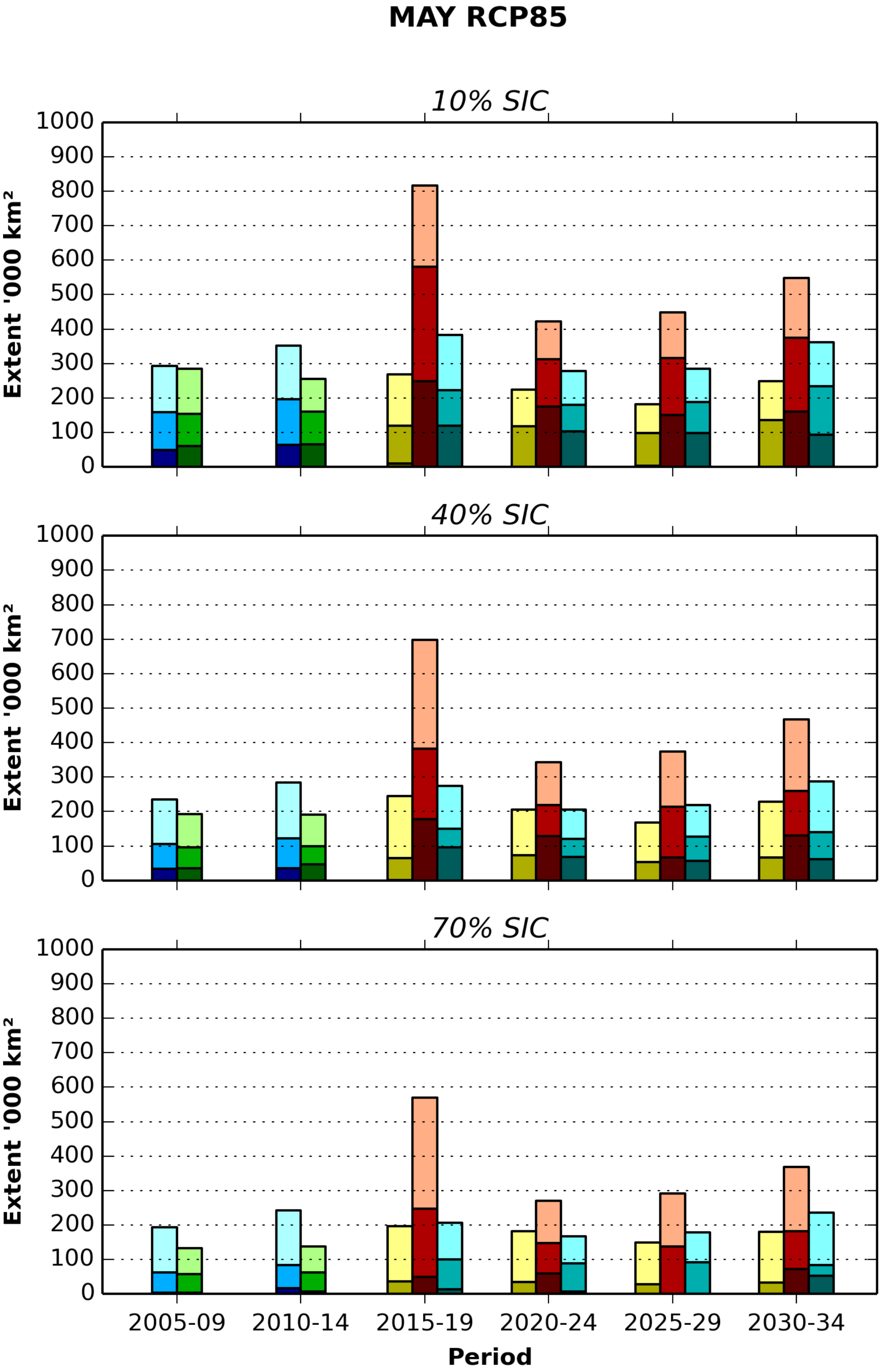


Figure 8.17: 5-year period ice extents from ice charts, OSI SAF, and climate models for MAY in the Nordic Seas under the RCP85 scenario.

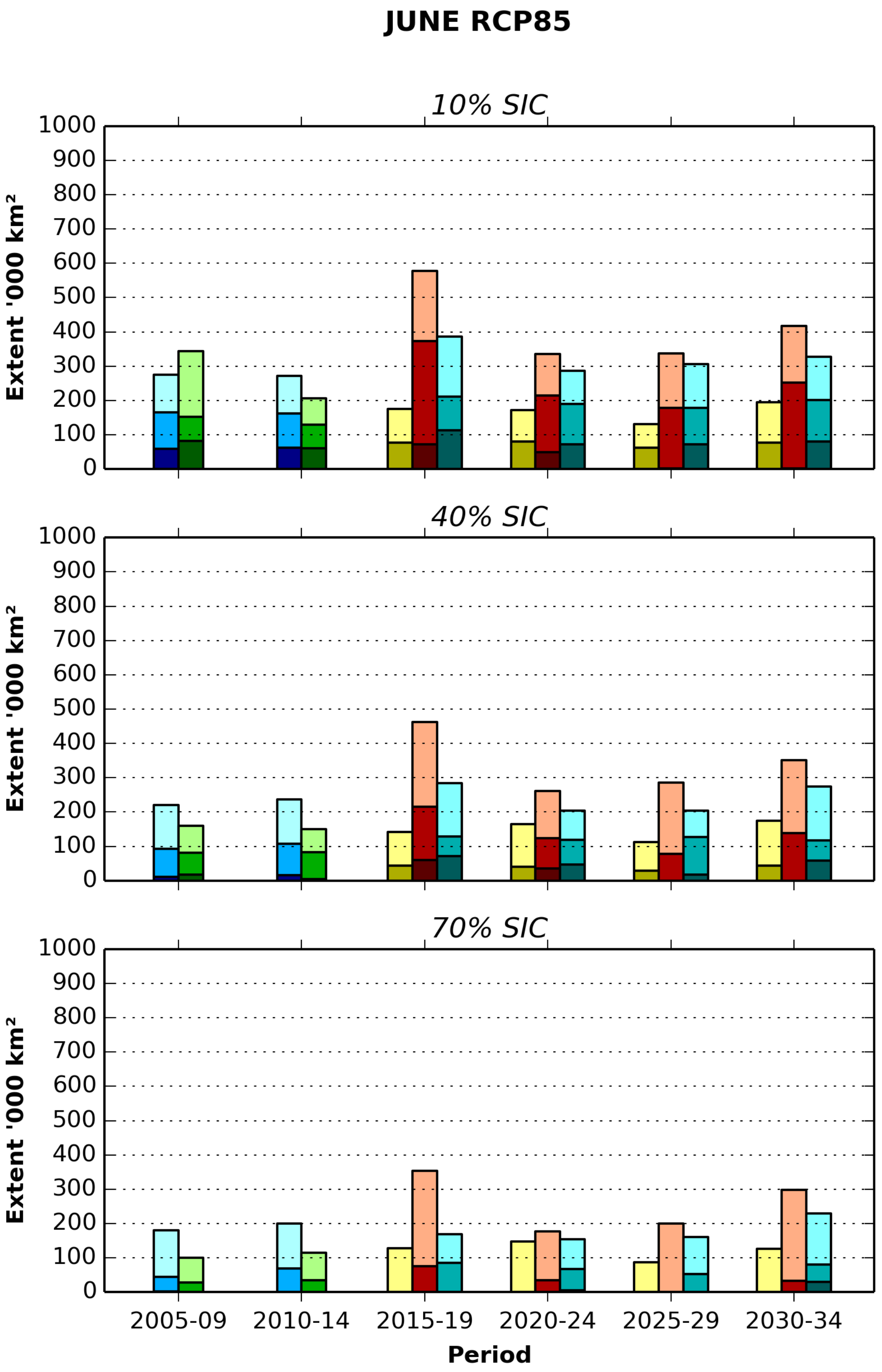


Figure 8.18: 5-year period ice extents from ice charts, OSI SAF, and climate models for JUNE in the Nordic Seas under the RCP85 scenario.

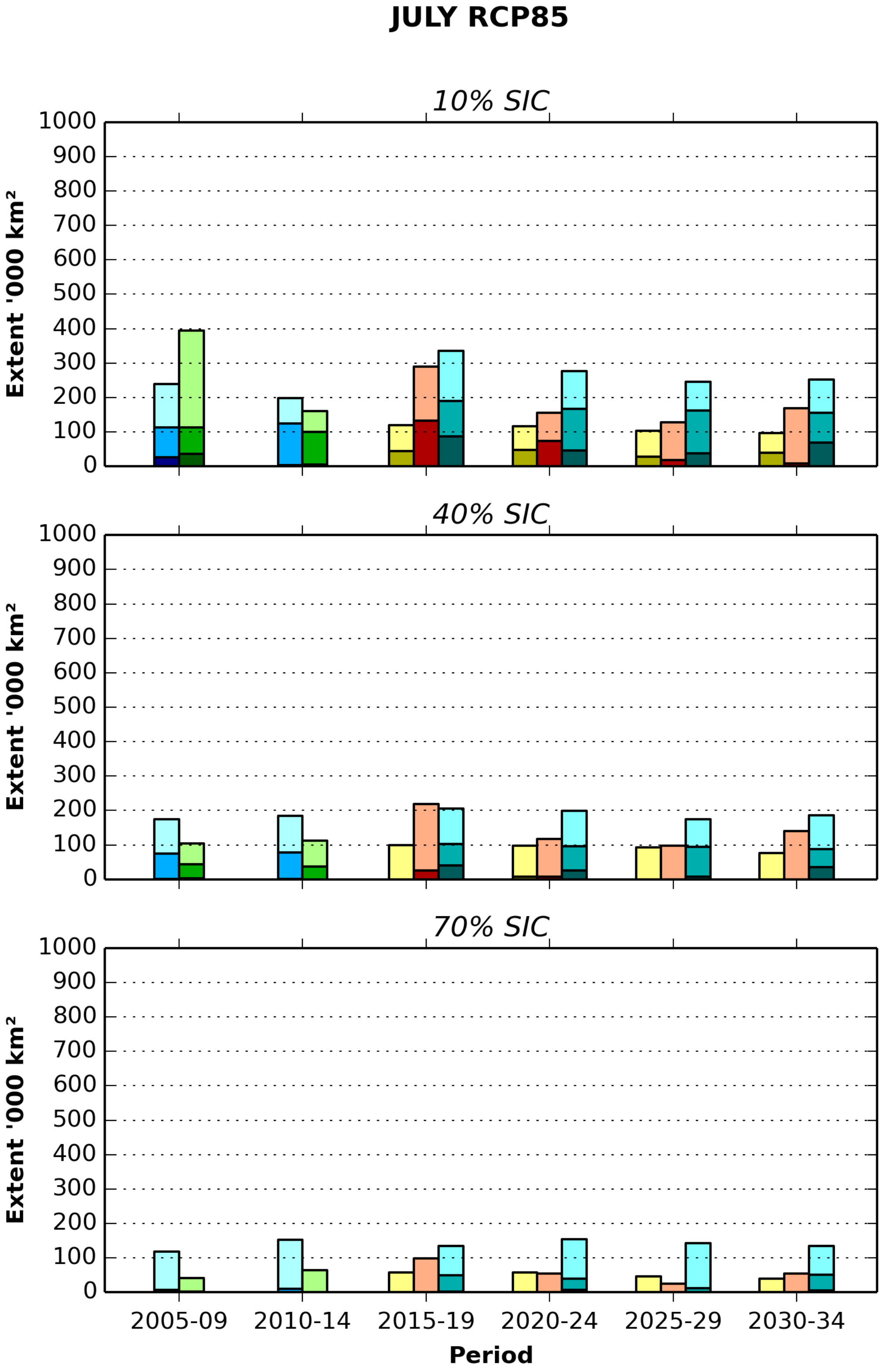


Figure 8.19: 5-year period ice extents from ice charts, OSI SAF, and climate models for JULY in the Nordic Seas under the RCP85 scenario.

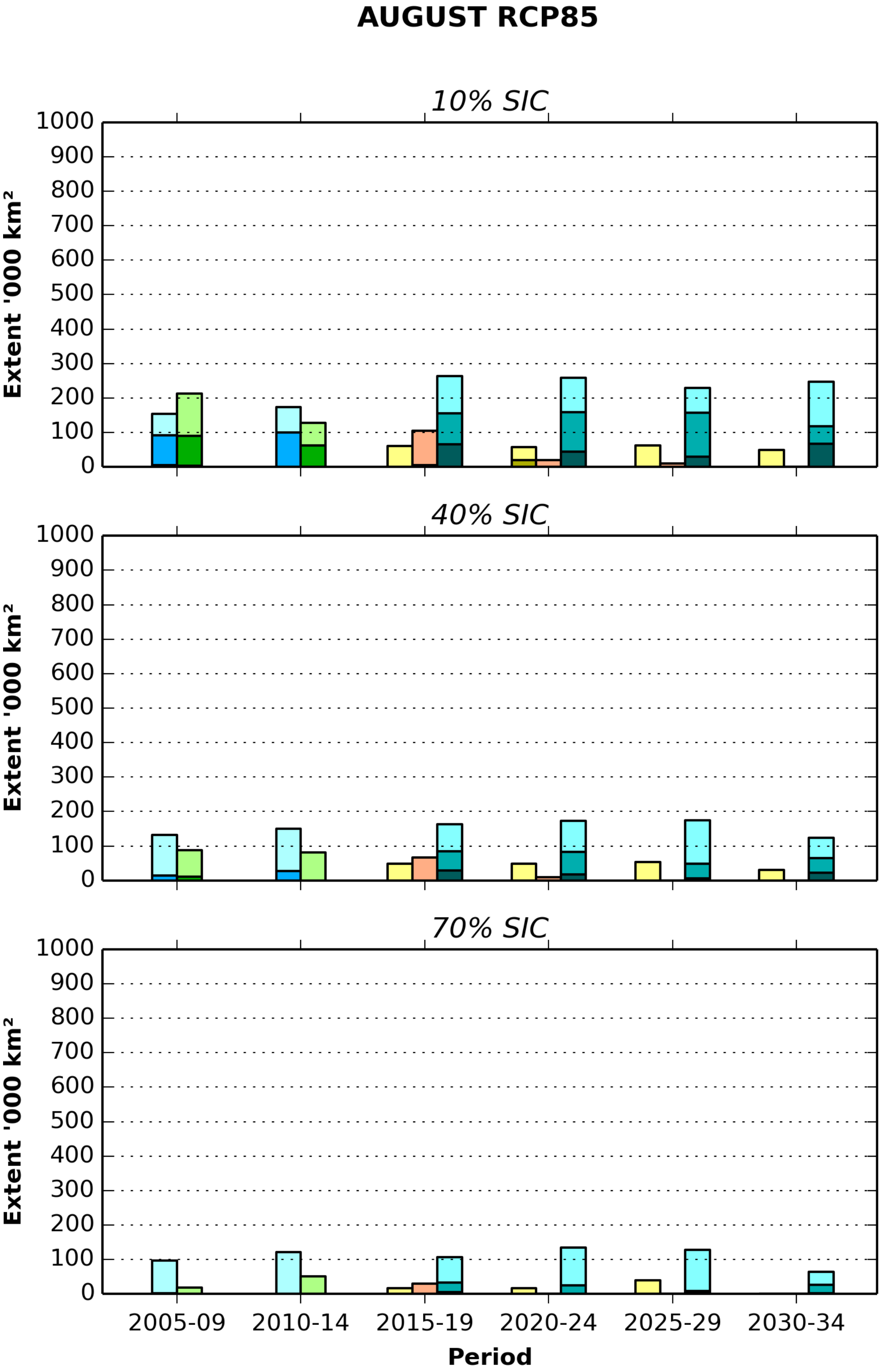


Figure 8.20: 5-year period ice extents from ice charts, OSI SAF, and climate models for AUGUST in the Nordic Seas under the RCP85 scenario.

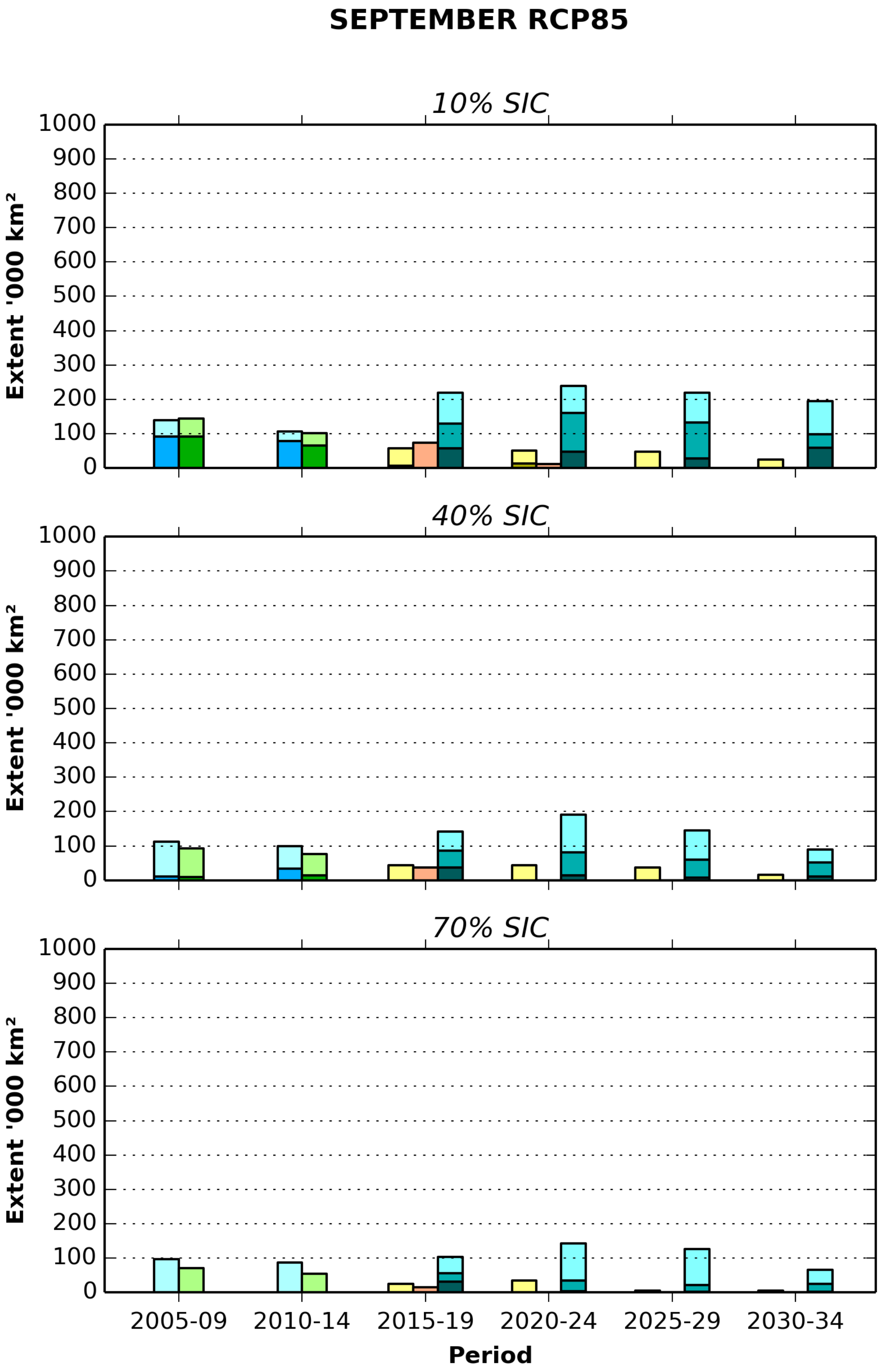


Figure 8.21: 5-year period ice extents from ice charts, OSI SAF, and climate models for SEPTEMBER in the Nordic Seas under the RCP85 scenario.

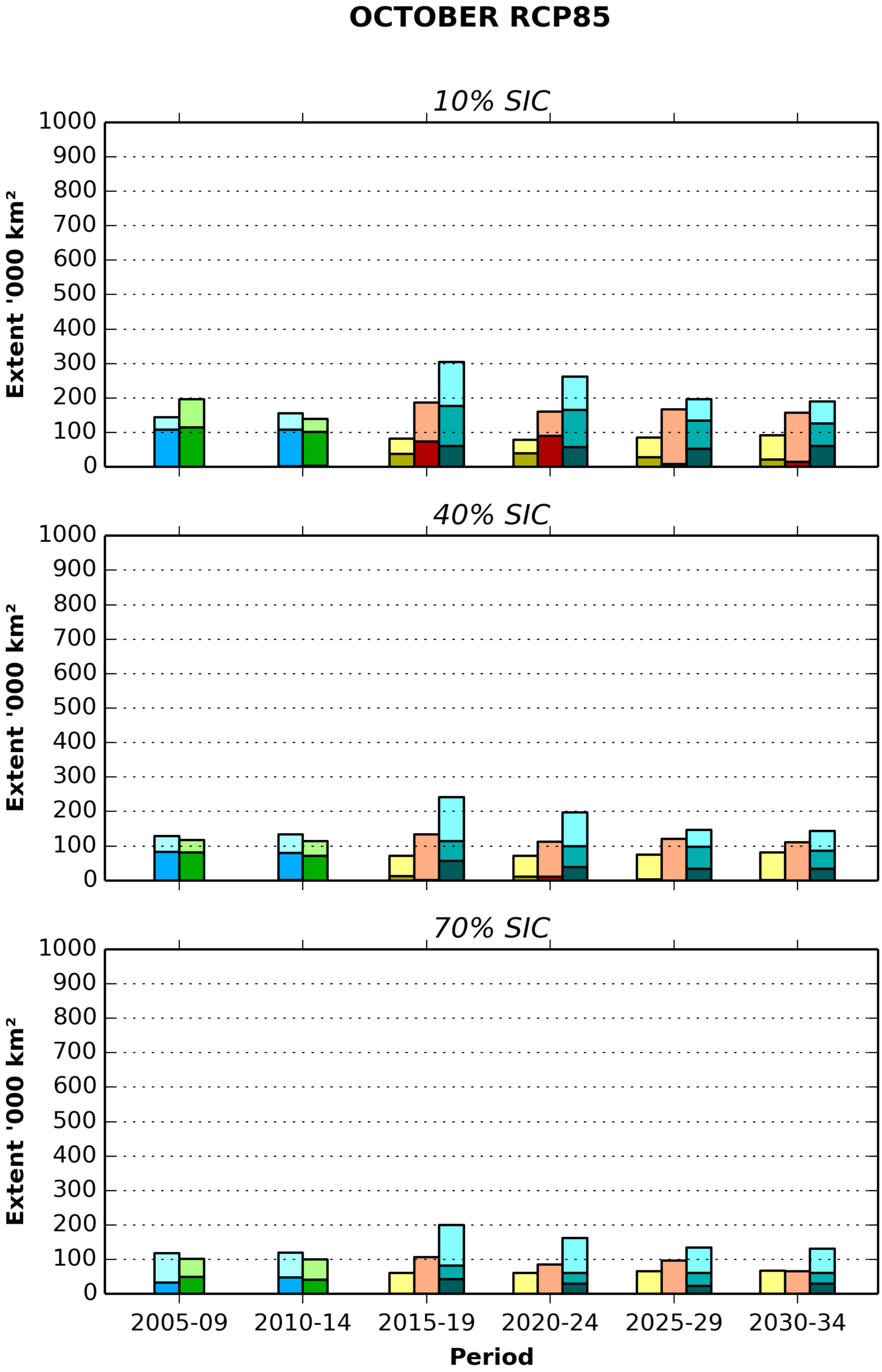


Figure 8.22: 5-year period ice extents from ice charts, OSI SAF, and climate models for OCTOBER in the Nordic Seas under the RCP85 scenario.

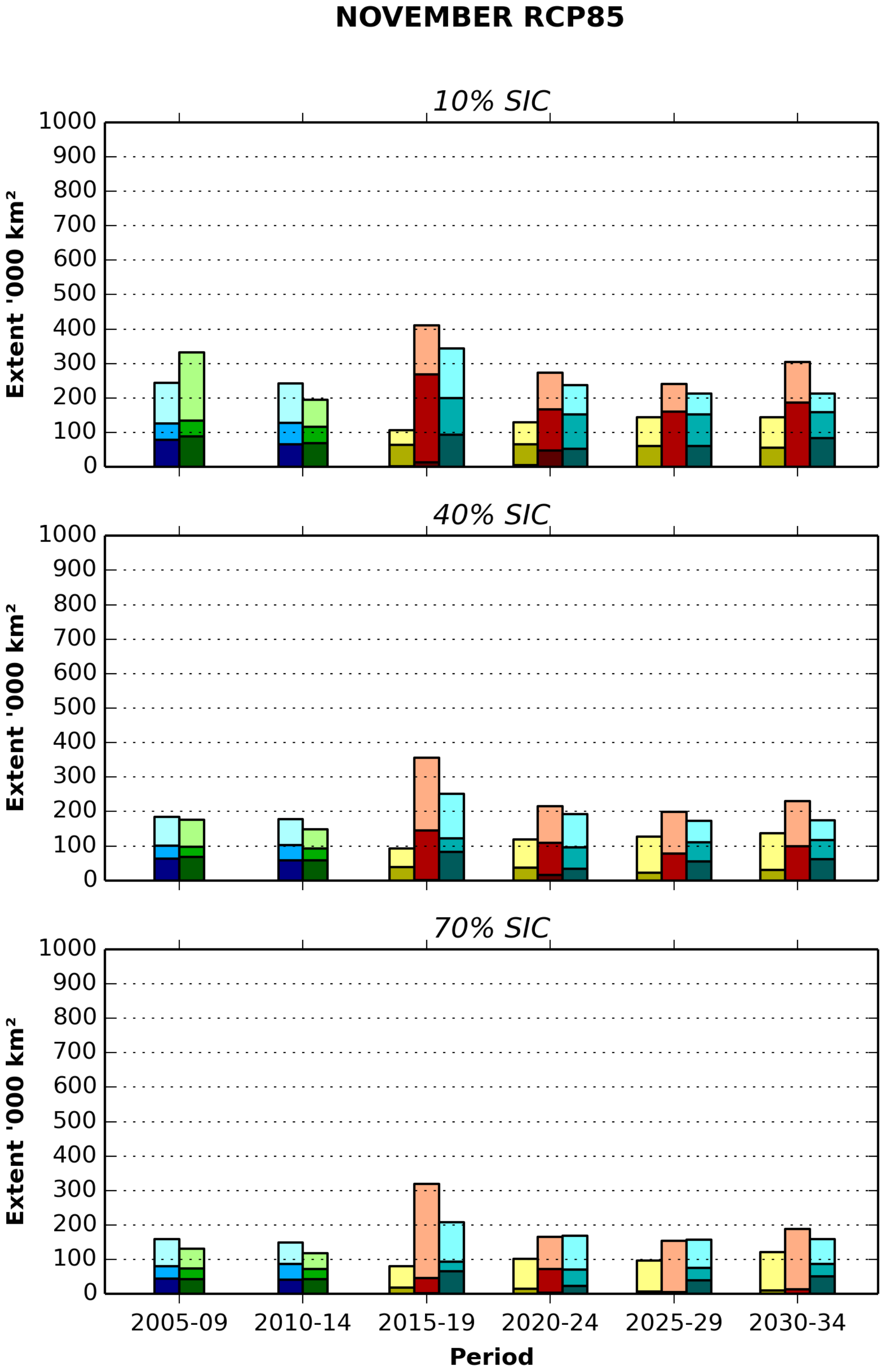


Figure 8.23: 5-year period ice extents from ice charts, OSI SAF, and climate models for NOVEMBER in the Nordic Seas under the RCP85 scenario.

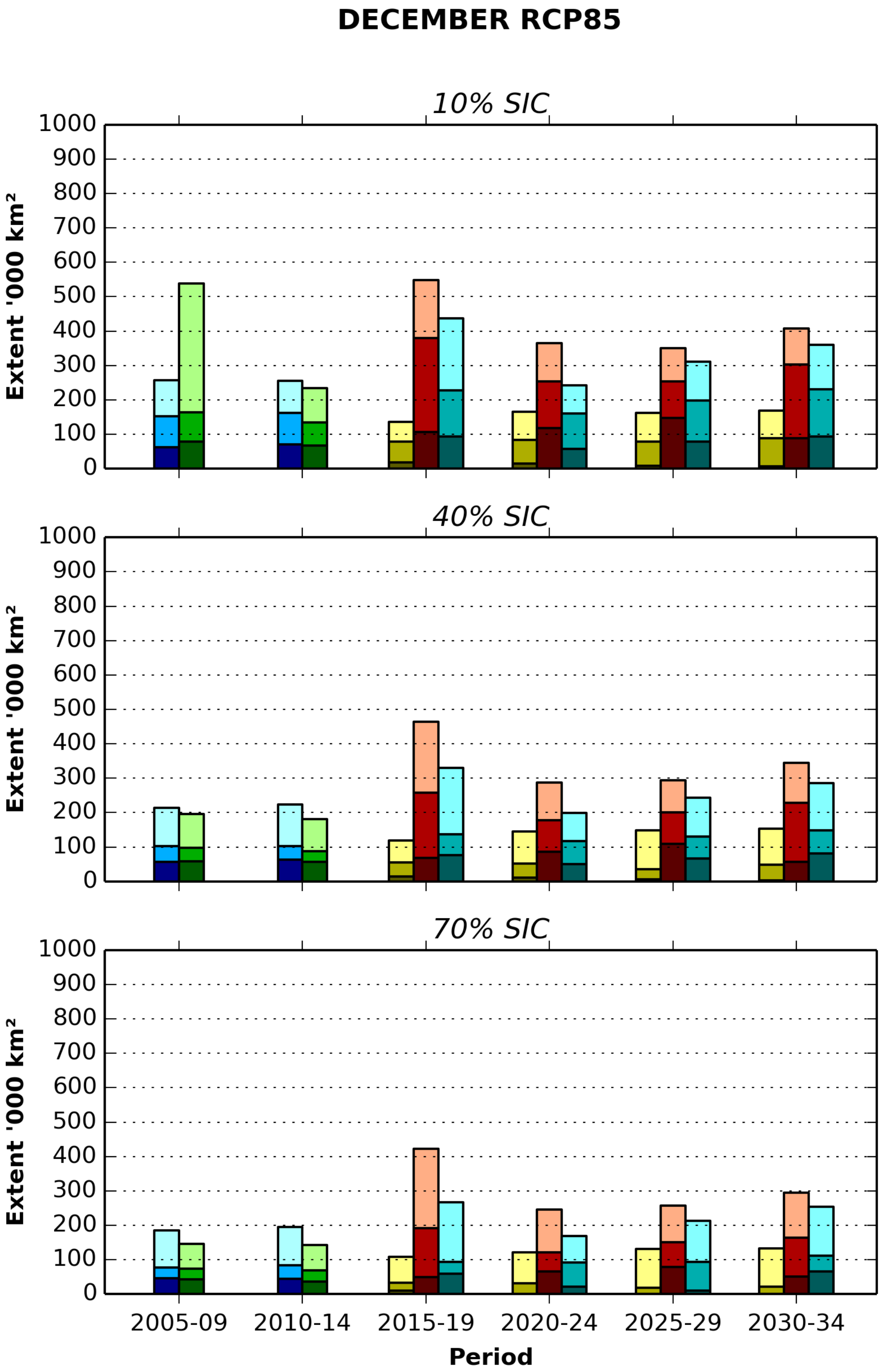


Figure 8.24: 5-year period ice extents from ice charts, OSI SAF, and climate models for DECEMBER in the Nordic Seas under the RCP85 scenario.

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