Arctic ice-ocean landfast ice

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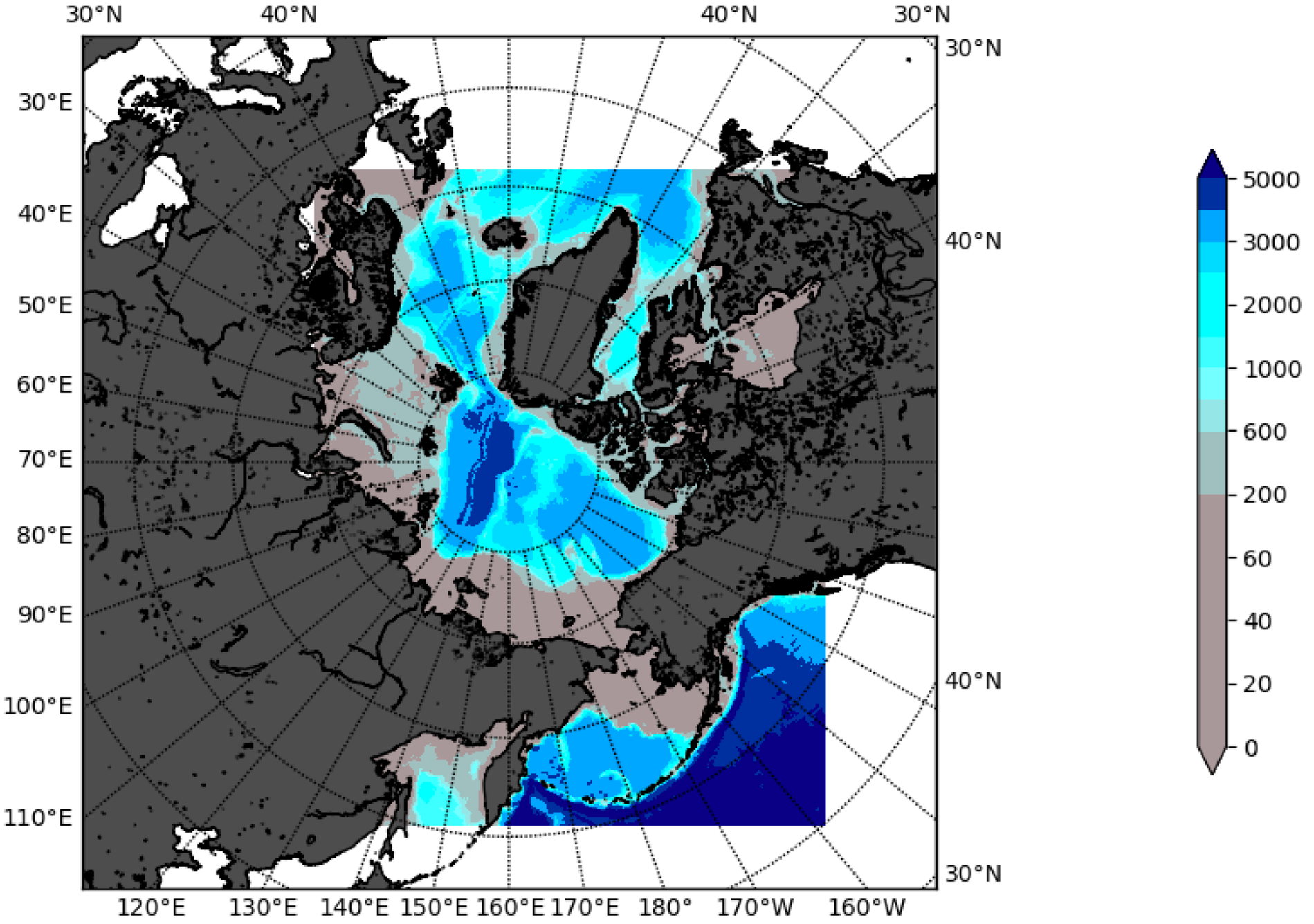
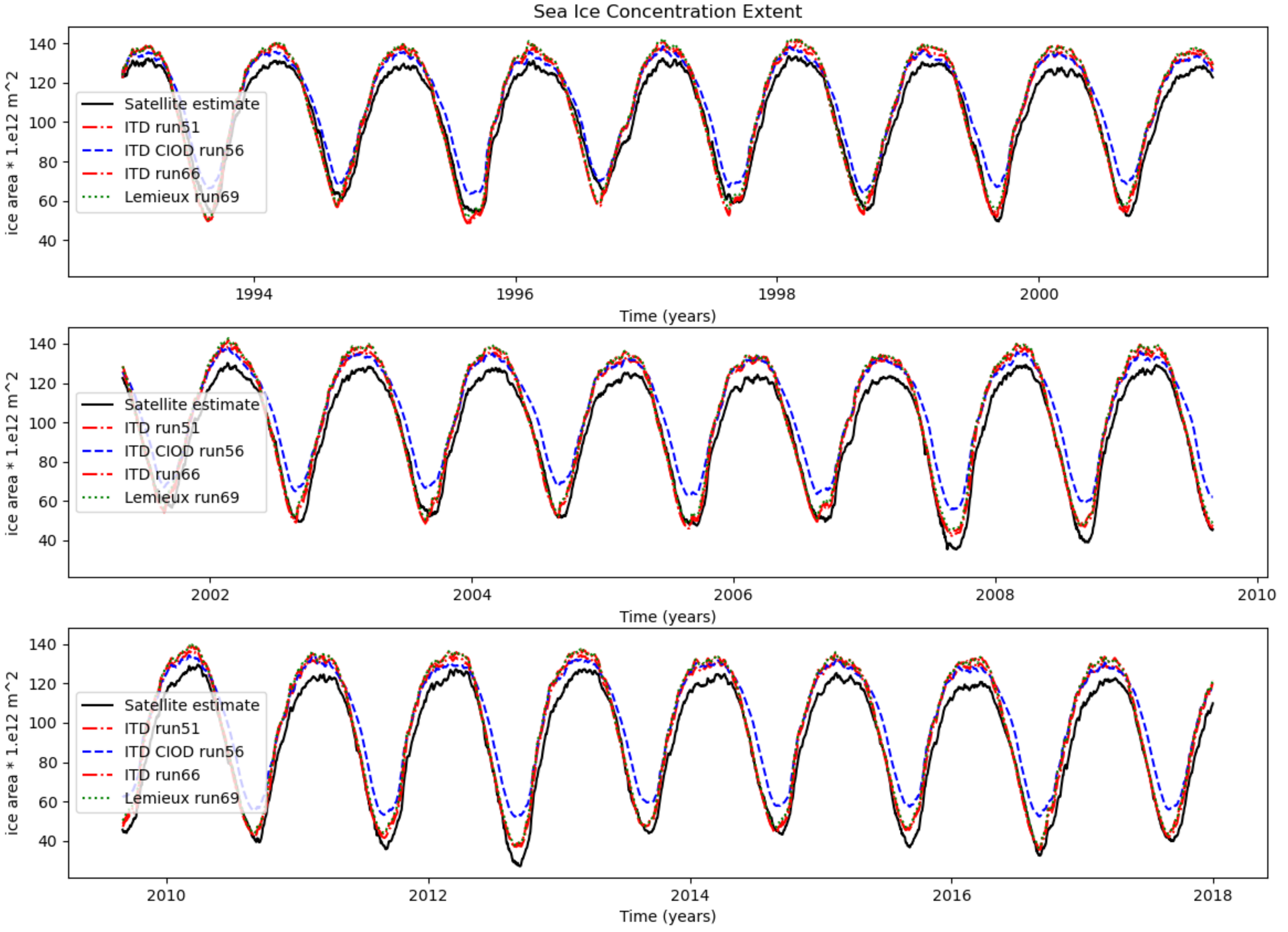
GFDL team
Andy Mahoney lab

Support by BOEM, NOAA
Computers by UAF, NOAA

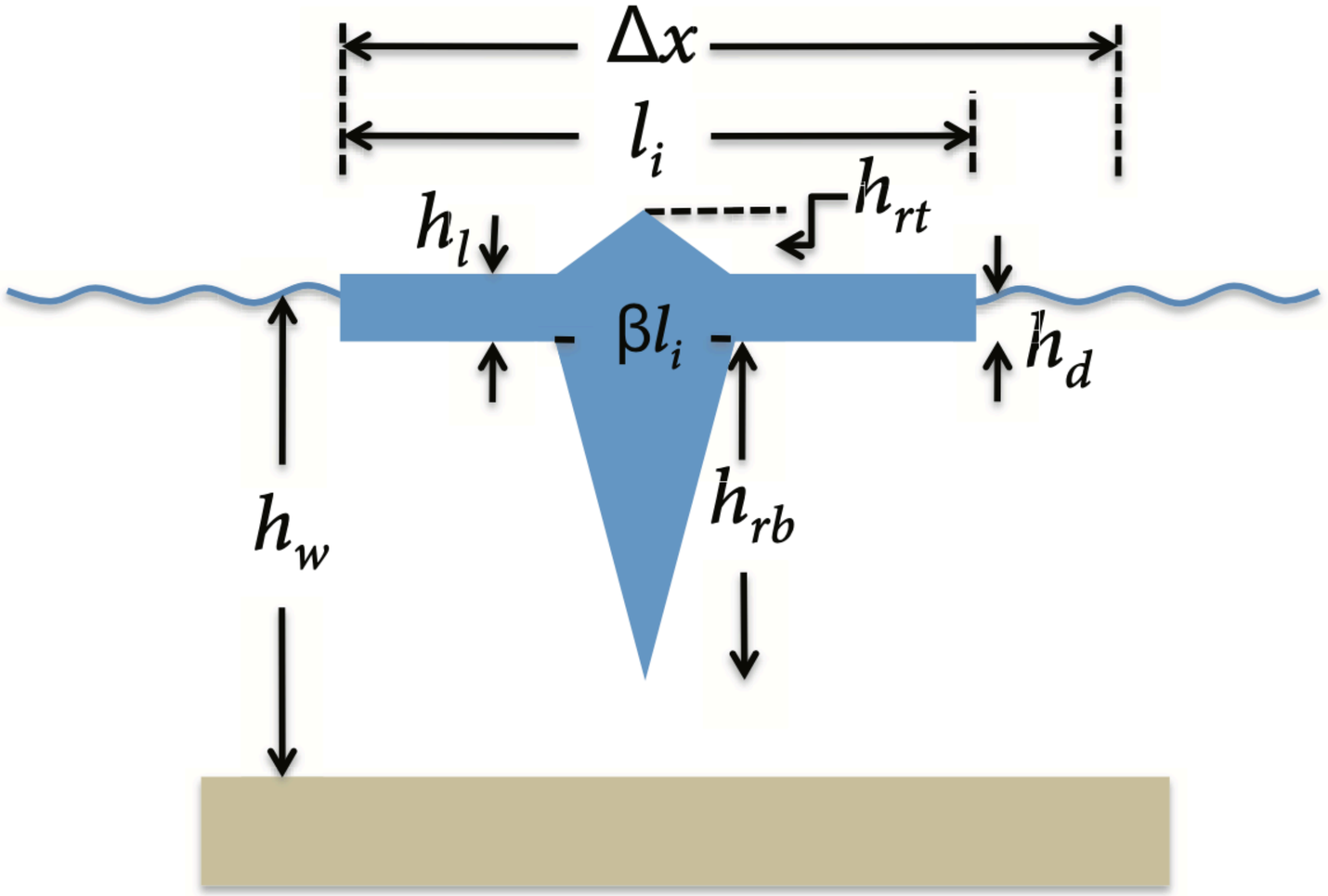

30°N
40°N
40°N
30°N
30°E
40°E
50°E
60°E
70°E
80°E
90°E
100°E
110°E
30°N
40°N
40°N
30°N
120°E
130°E
140°E
150°E
160°E
170°E
180°
170°W
160°W
5000
3000
2000
1000
600
200
60
40
20
0

Pan-Arctic domain

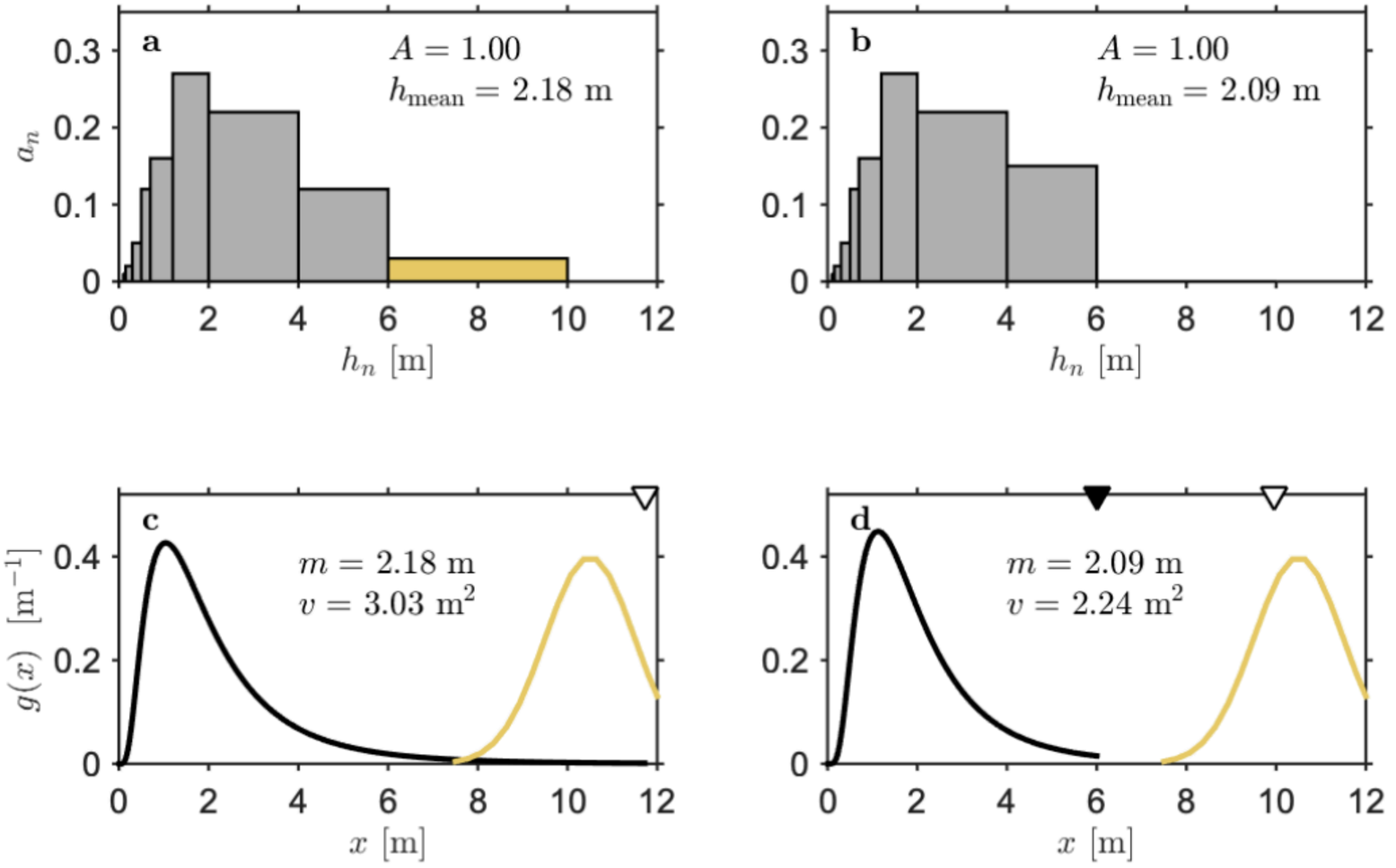
- MOM6 ocean, SIS2 ice, Icepack ridging
- 12 km resolution
- JRA55-do atmospheric forcing
- Open boundary conditions from GLORYS
- 75 vertical z-star levels in ocean
- A combined GLOFAS-Hill river runoff
- Tides from OBCs and body forces
- COBALT BGC tracers
- A landfast ice parameterization (Dupont, 2022)
- Ten sea-ice categories
- Focus on the years 1993-2019


Sea Ice Concentration Extent
ice area * 1.e12 m^2
Time (years)
Satellite estimate
ITD run51
ITD CIOD run56
ITD run66
Lemieux run69
140
120
100
80
60
40
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018

Lemieux Landfast Ice Parameterization

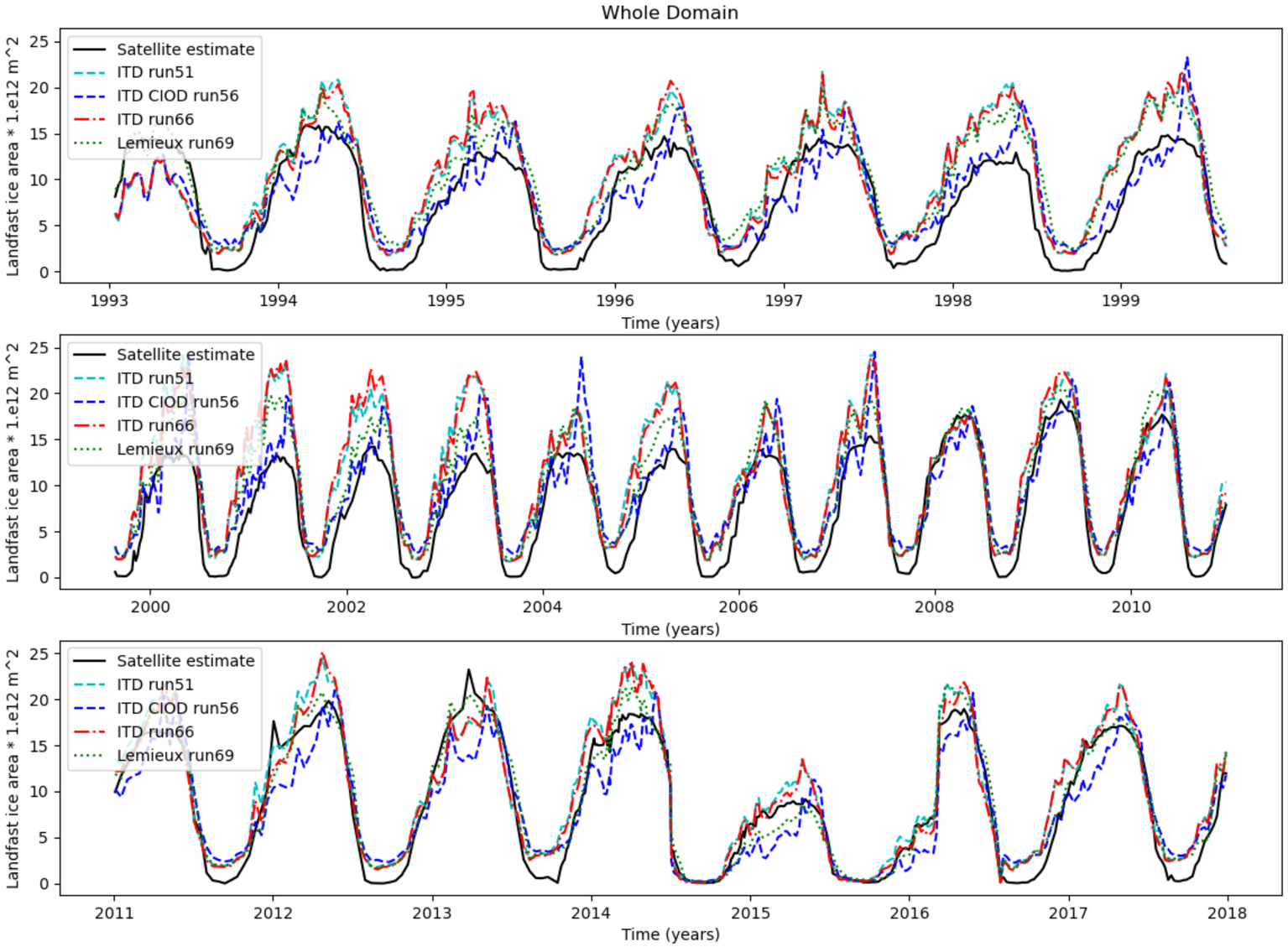


Probabilistic (ITD) Landfast Ice



Landfast Ice Extent

Large scale - 25 km Canadian product



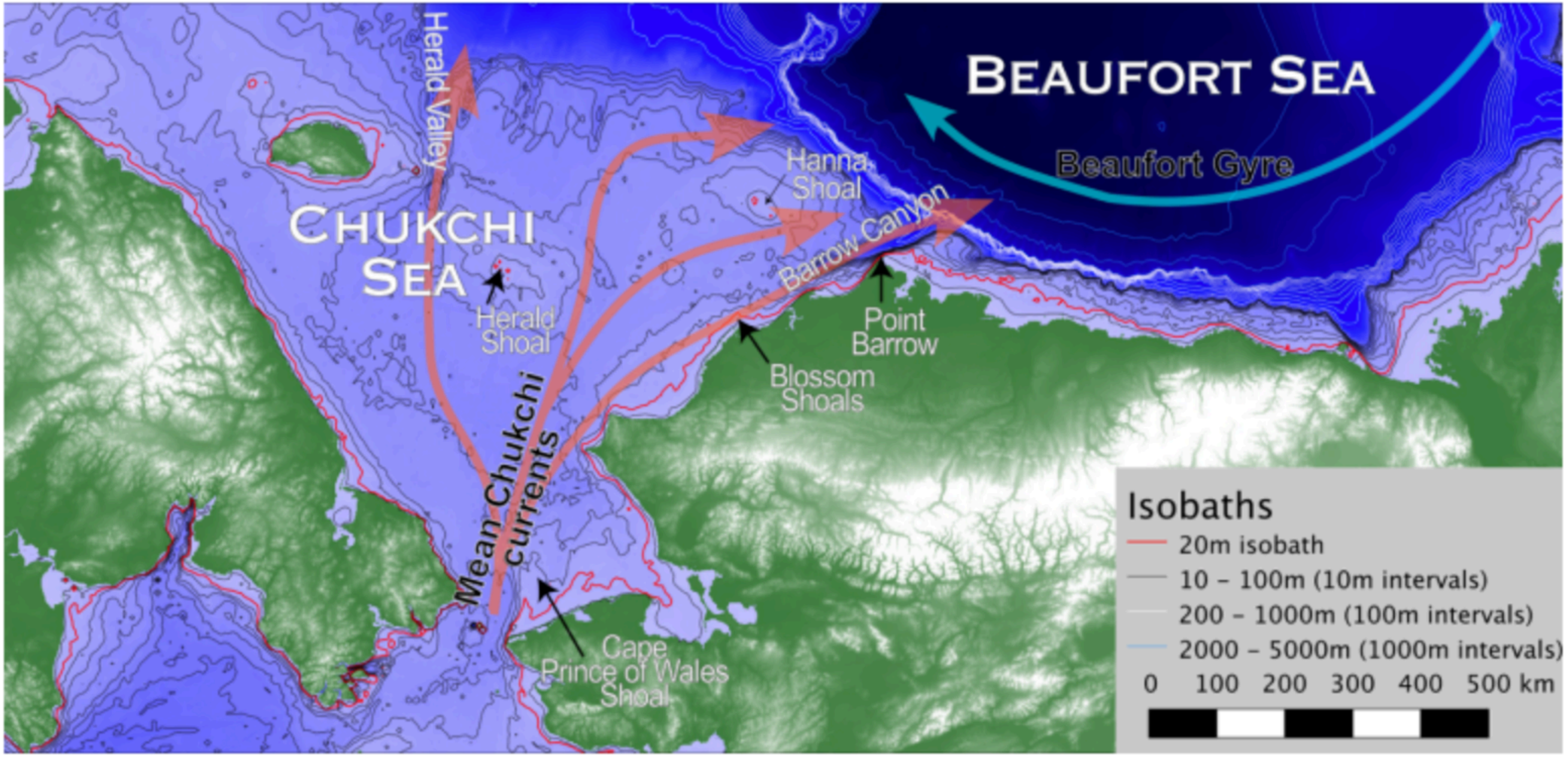
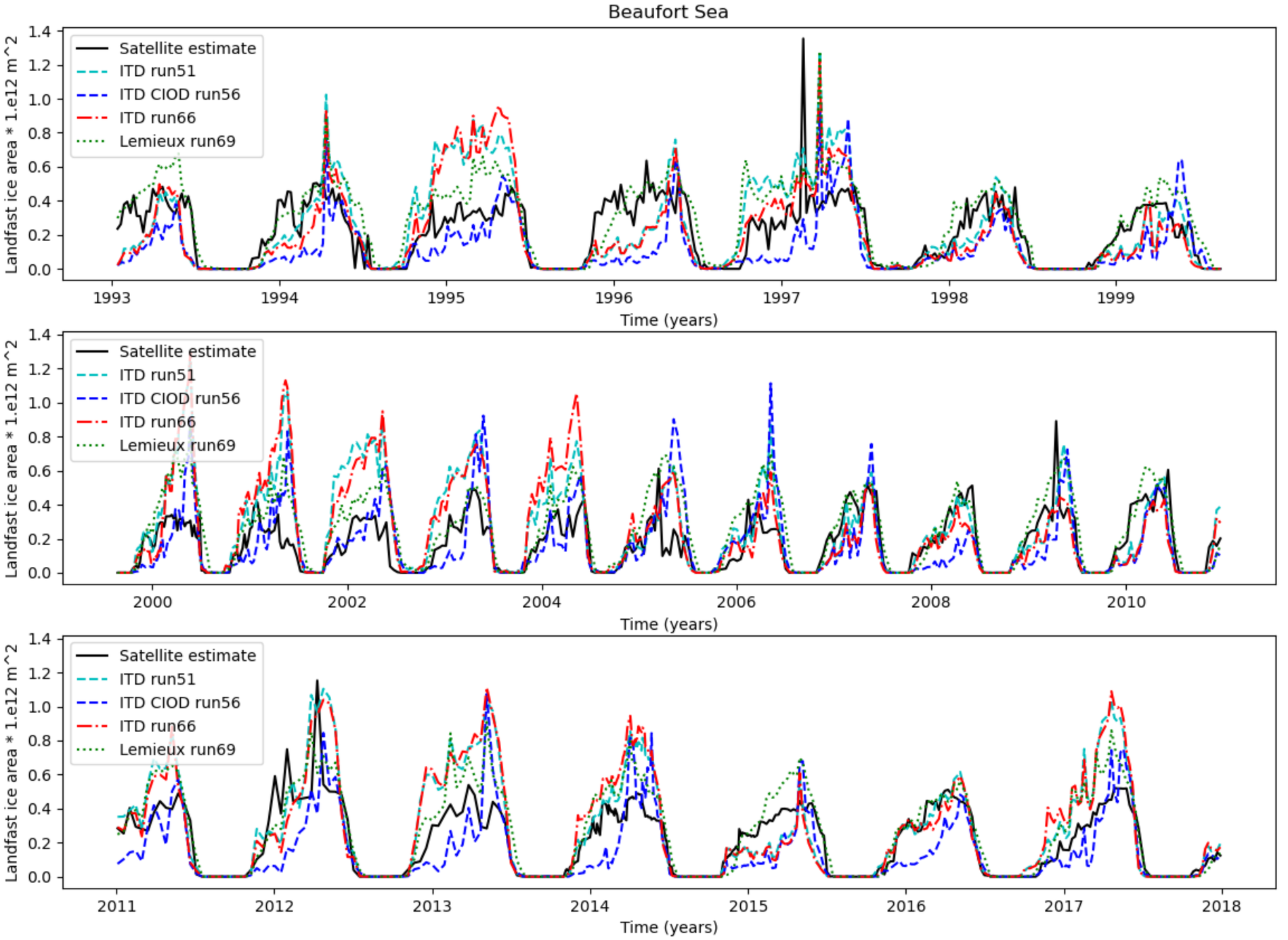
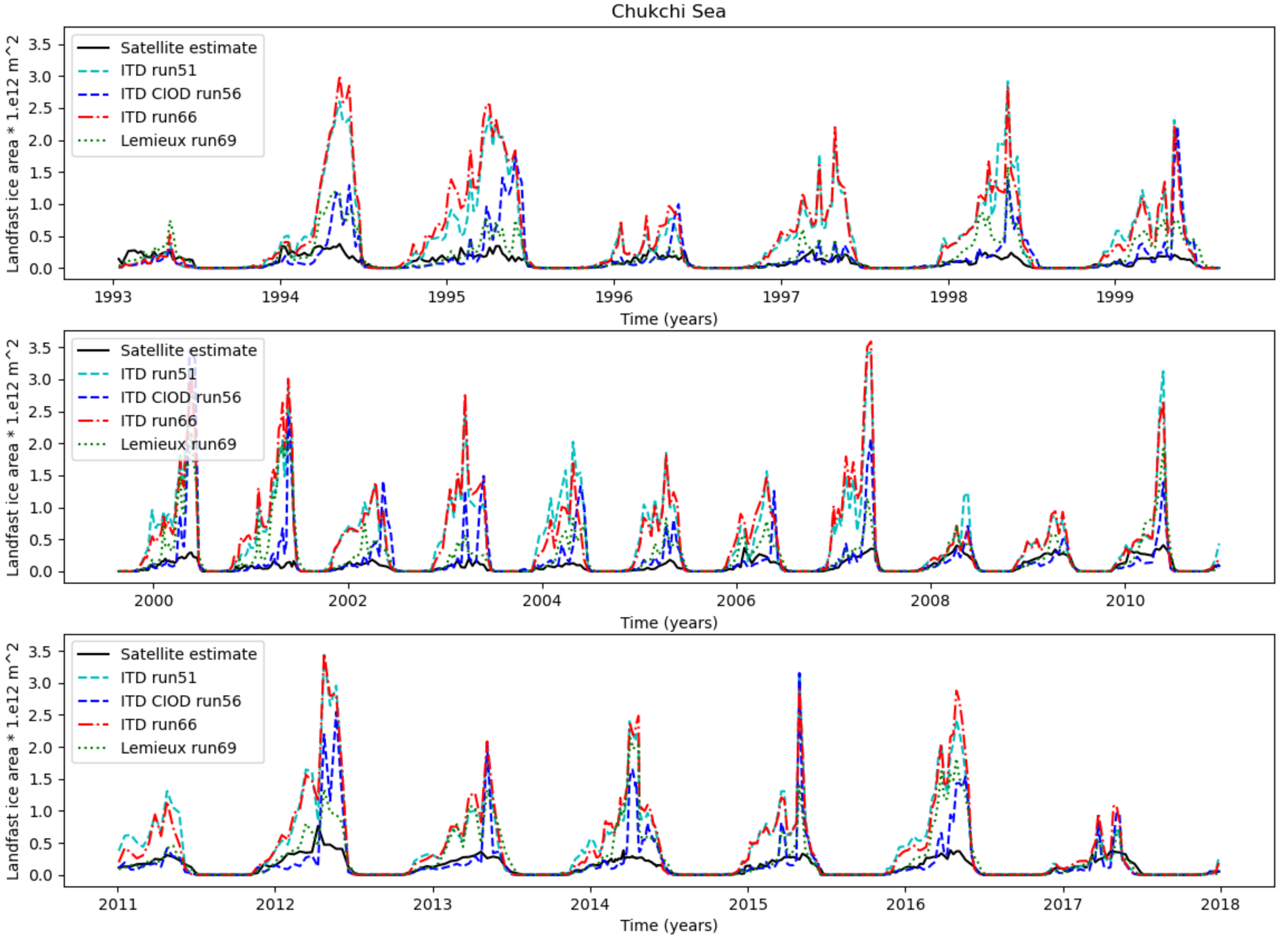
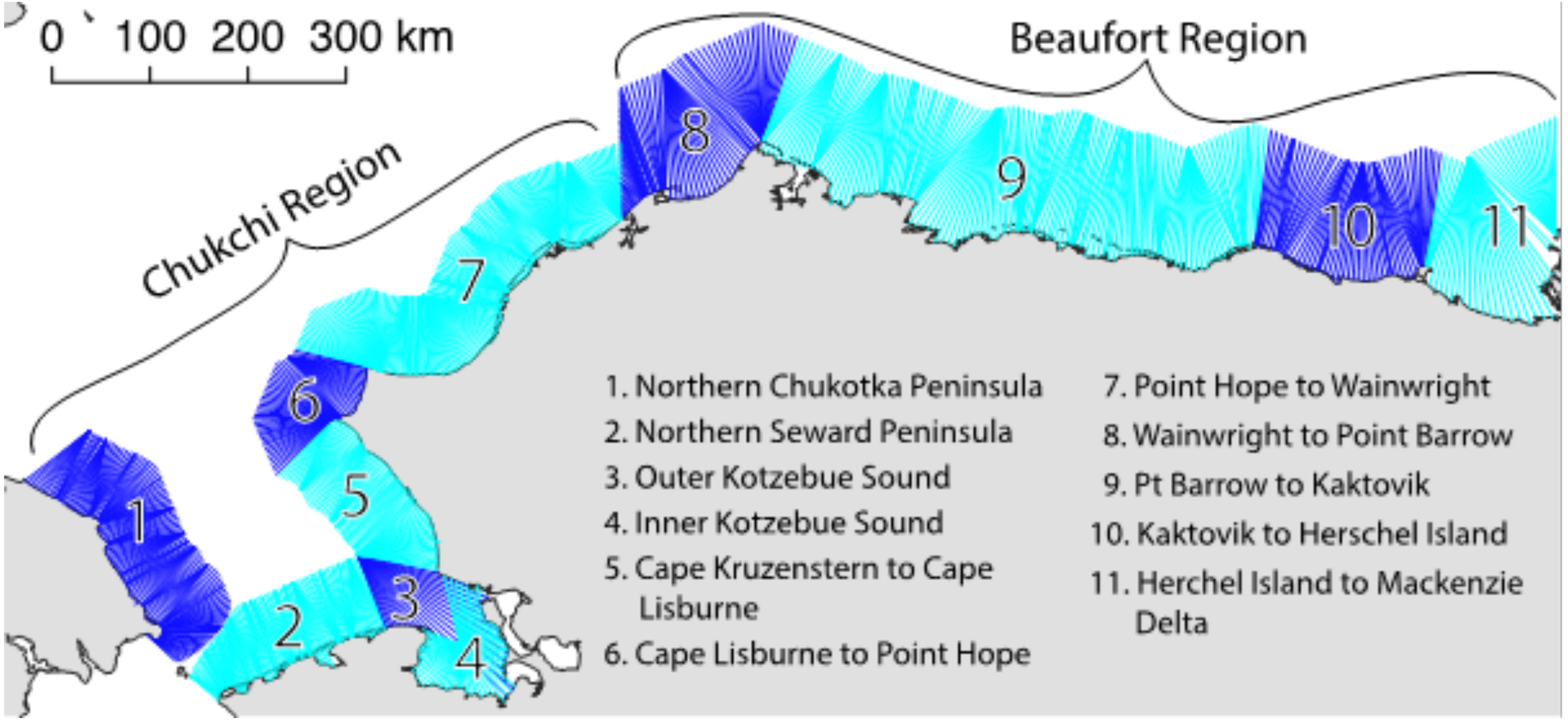


Figure 1-1: The bathymetry of the Chukchi and Beaufort Seas based on the Alaska Regional Digital Elevation Model (ARDEM), compiled by Danielson et al. [2015]. The red contour indicates the location of the 20 m isobath. Colored arrows are schematic representations of mean surface currents, from Weingartner [2005]


Beaufort Sea
Satellite estimate
ITD run51
ITD CIOD run56
ITD run66
Lemieux run69
Landfast ice area * 1.e12 m^2
Time (years)
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1993
1994
1995
1996
1997
1998
1999
2000
2002
2004
2006
2008
2010
2011
2012
2013
2014
2015
2016
2017
2018


Chukchi Sea
Satellite estimate
ITD run51
ITD CIOD run56
ITD run66
Lemieux run69
Landfast ice area * 1.e12 m^2
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
1993
1994
1995
1996
1997
1998
1999
Time (years)
2000
2002
2004
2006
2008
2010
2011
2012
2013
2014
2015
2016
2017
2018

Mahoney's Landfast Ice Products



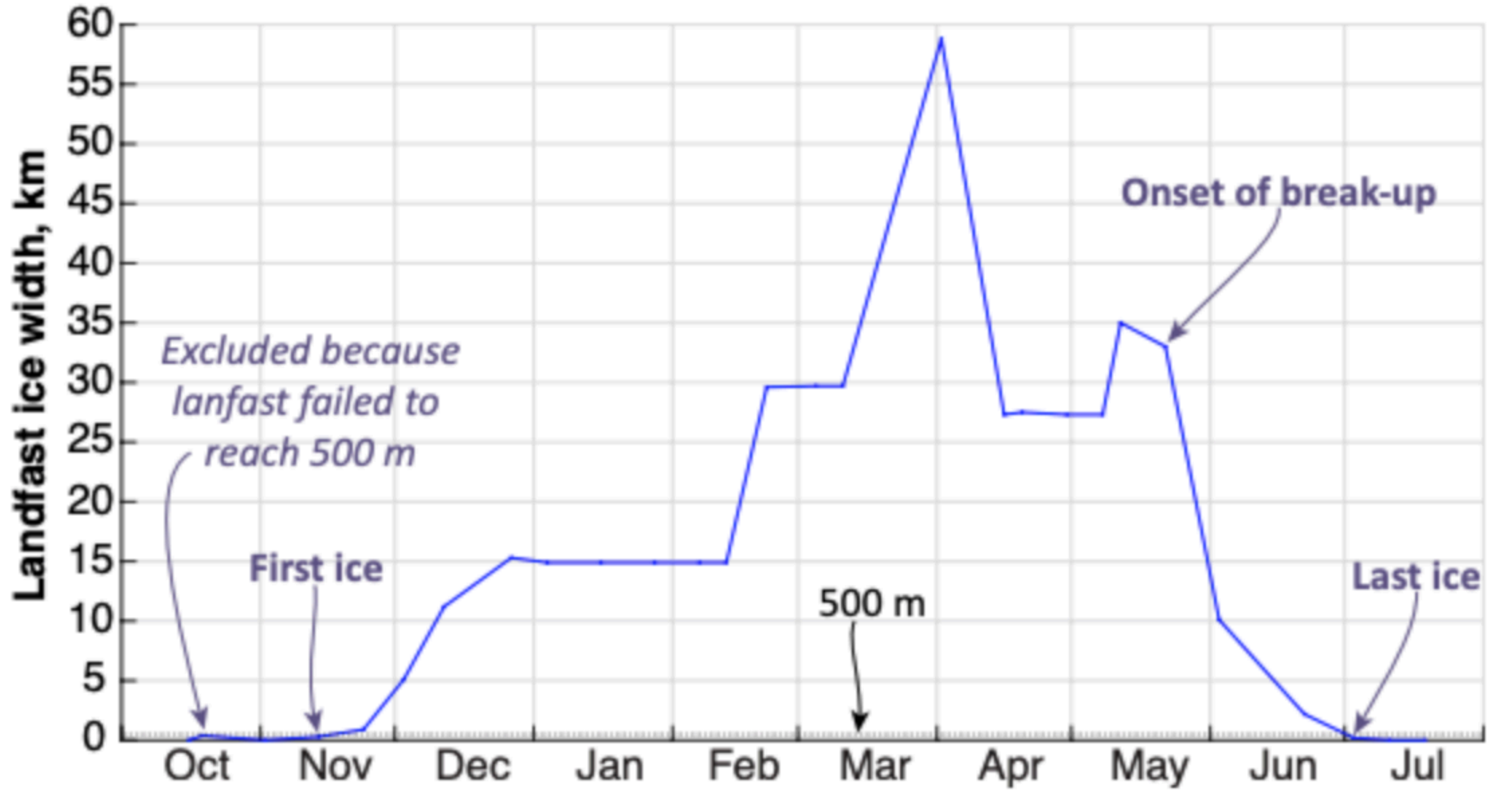


Figure 2-2: One annual cycle of landfast ice width at a location in the Beaufort Sea, illustrating the definition of the three key events (first ice, break-up, and last ice).

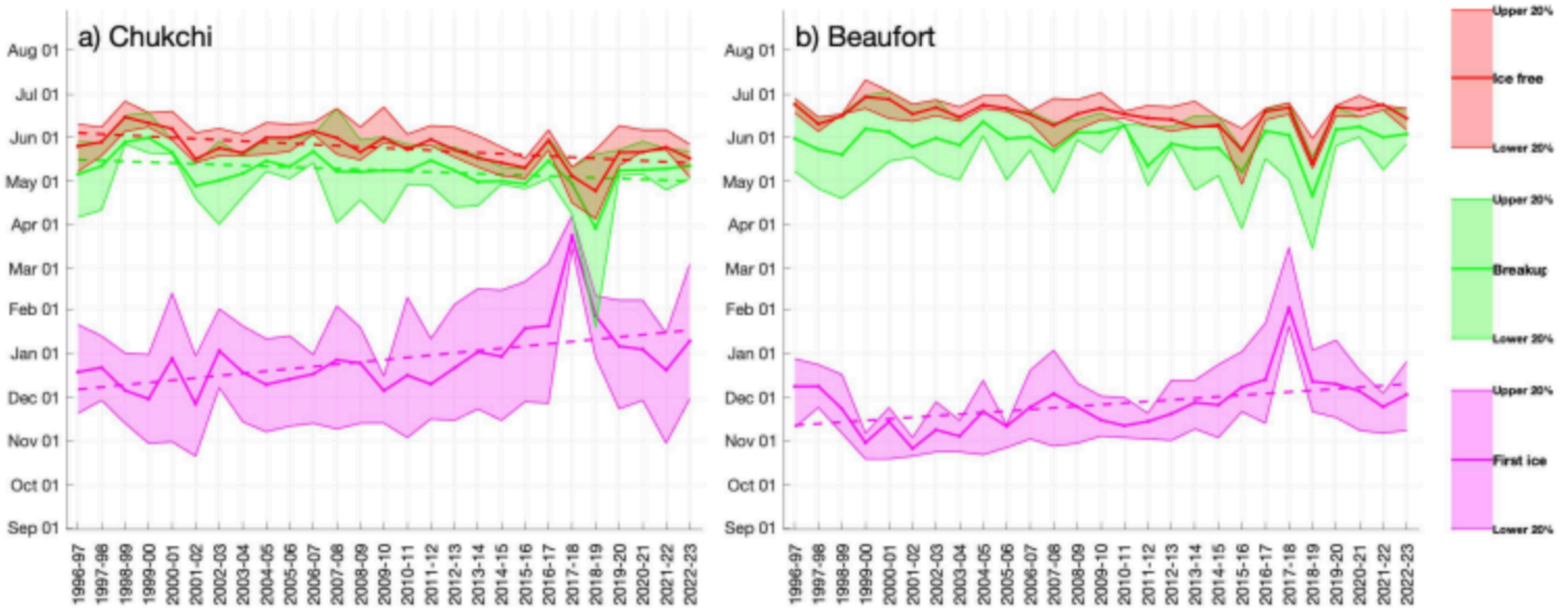


Figure 4-3: Timeseries of mean occurrence date for each key event in the landfast ice cycle over the period of 1996-2023 calculated for a) the Chukchi region and b) the Beaufort region. Dashed lines indicated a statistically significant (P-value < 0.05) trend in the event date.

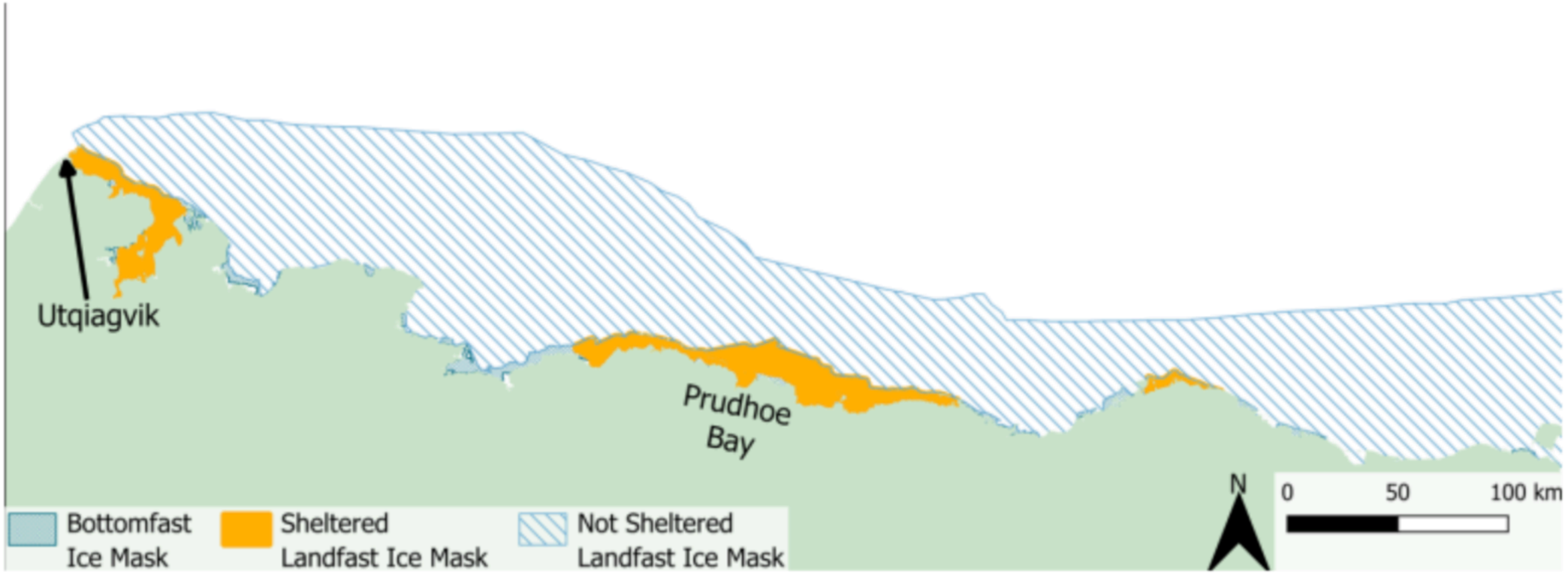


Figure 2-5: Spatial extent of bottomfast, sheltered, and not sheltered landfast ice masks

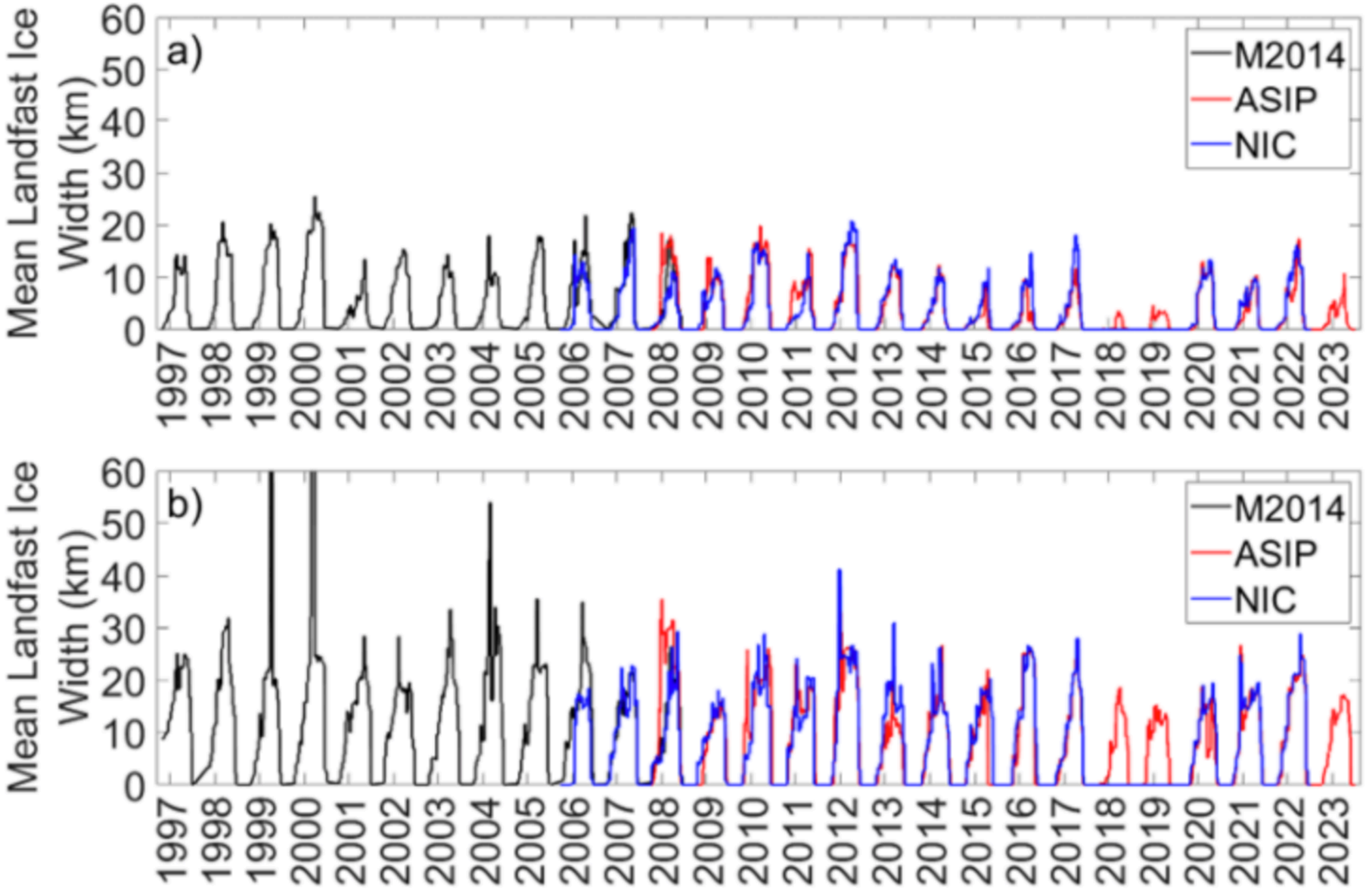


Figure 3-3: Time series of mean landfast ice width in the a) Chukchi and b) Beaufort regions for all seasons. each dataset: for M2014 (black), ASIP (red), and NIC (blue). For this comparison, all datasets are interpolated to daily resolution, while the ASIP and NIC datasets also have a 20-day running minimum applied.

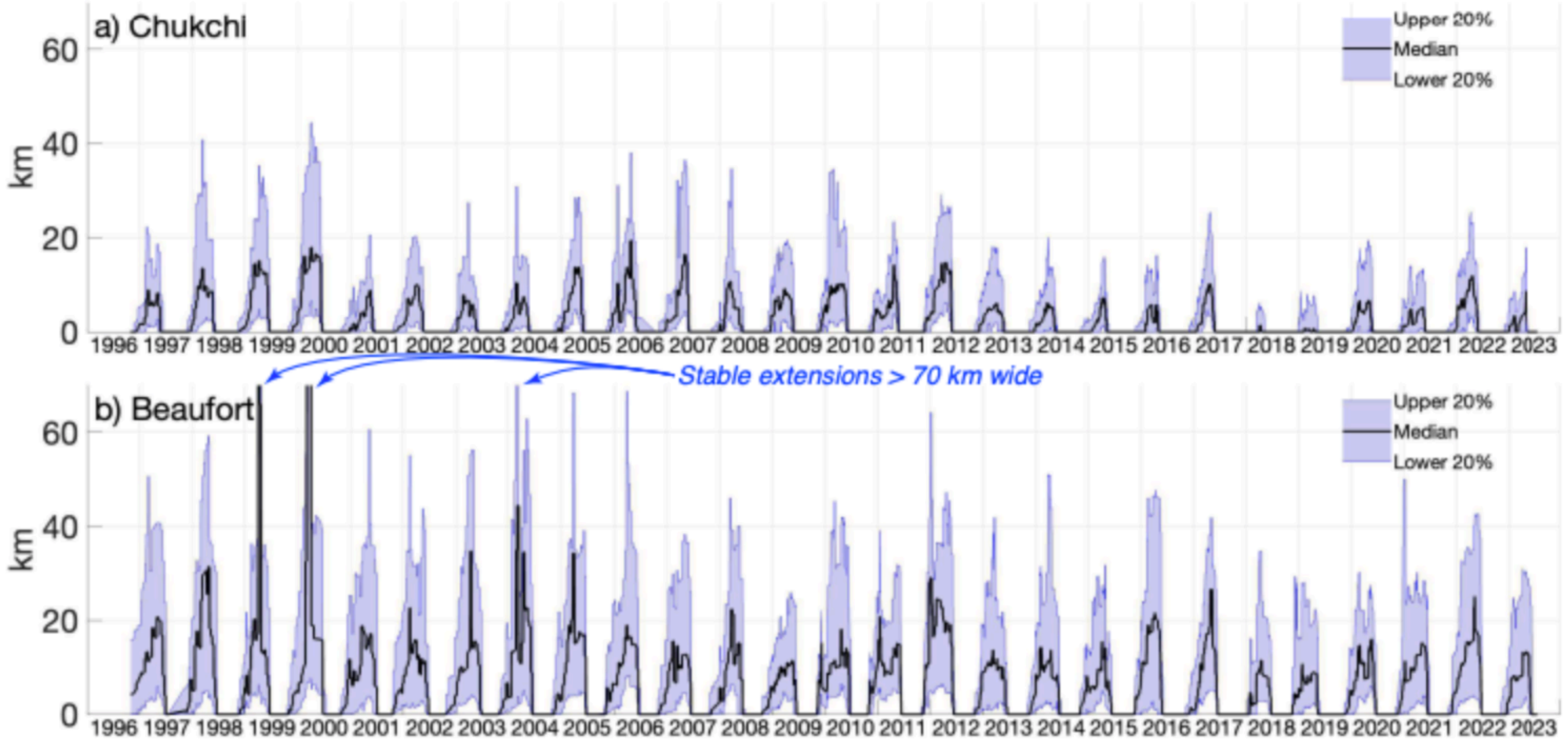


Figure 3-4: Regional mean landfast ice width in the a) Chukchi and b) Beaufort regions. The shaded regions represent the spatial variability in daily landfast ice width in each regions. Note full width of stable extensions that occurred in the Beauofrt Sea in 1999, 2000, and 2004 extend beyond the limit of the y-axis.

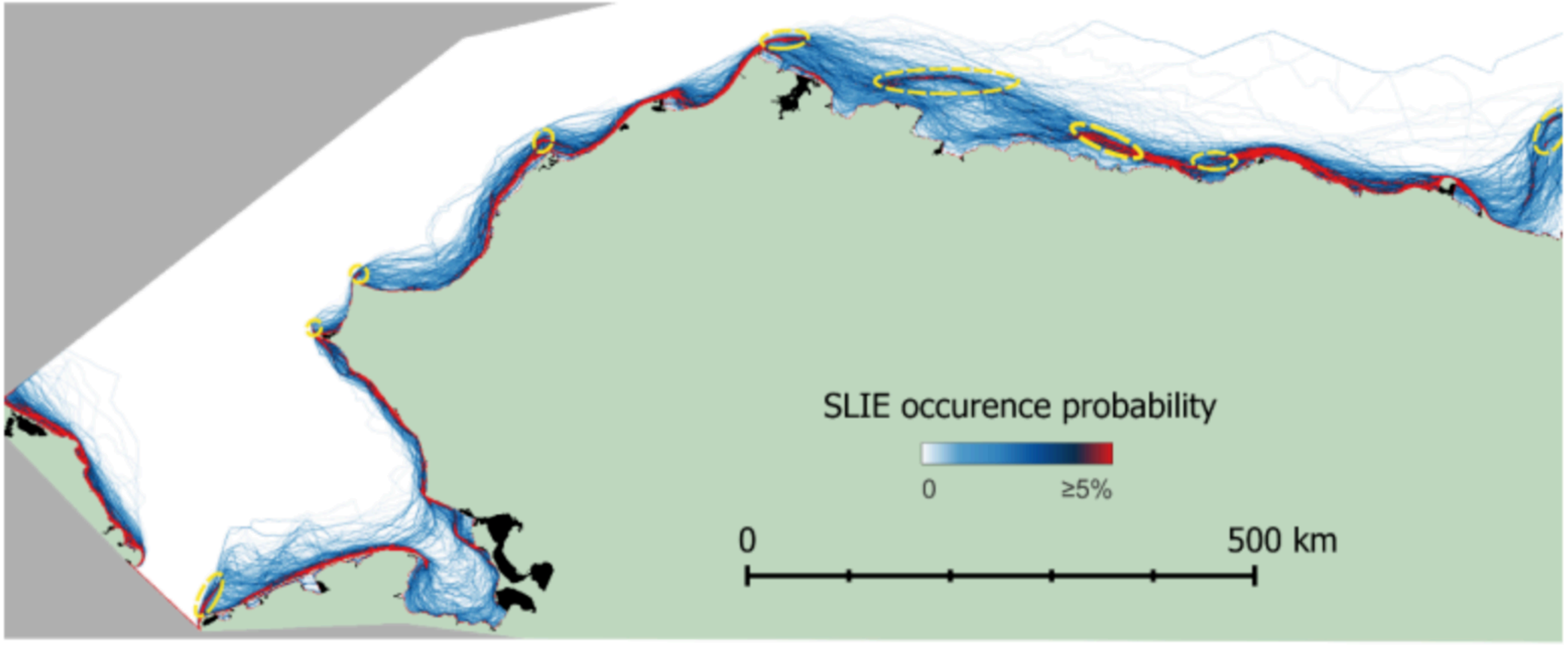


Figure 3-5: All SLIEs delineated from the period 1996-2023 stacks so the color value of a line indicated the probability of the SLIE lying within 500 m of a given point between October and July. A near continuous dark blue zone indicates where the SLIE commonly stabilizes. Dashed yellow ellipses highlight the location of nodes some distance from the coast where the SLIE occurs with greater frequency, and which indicate probable locations of recurring grounded ice features.

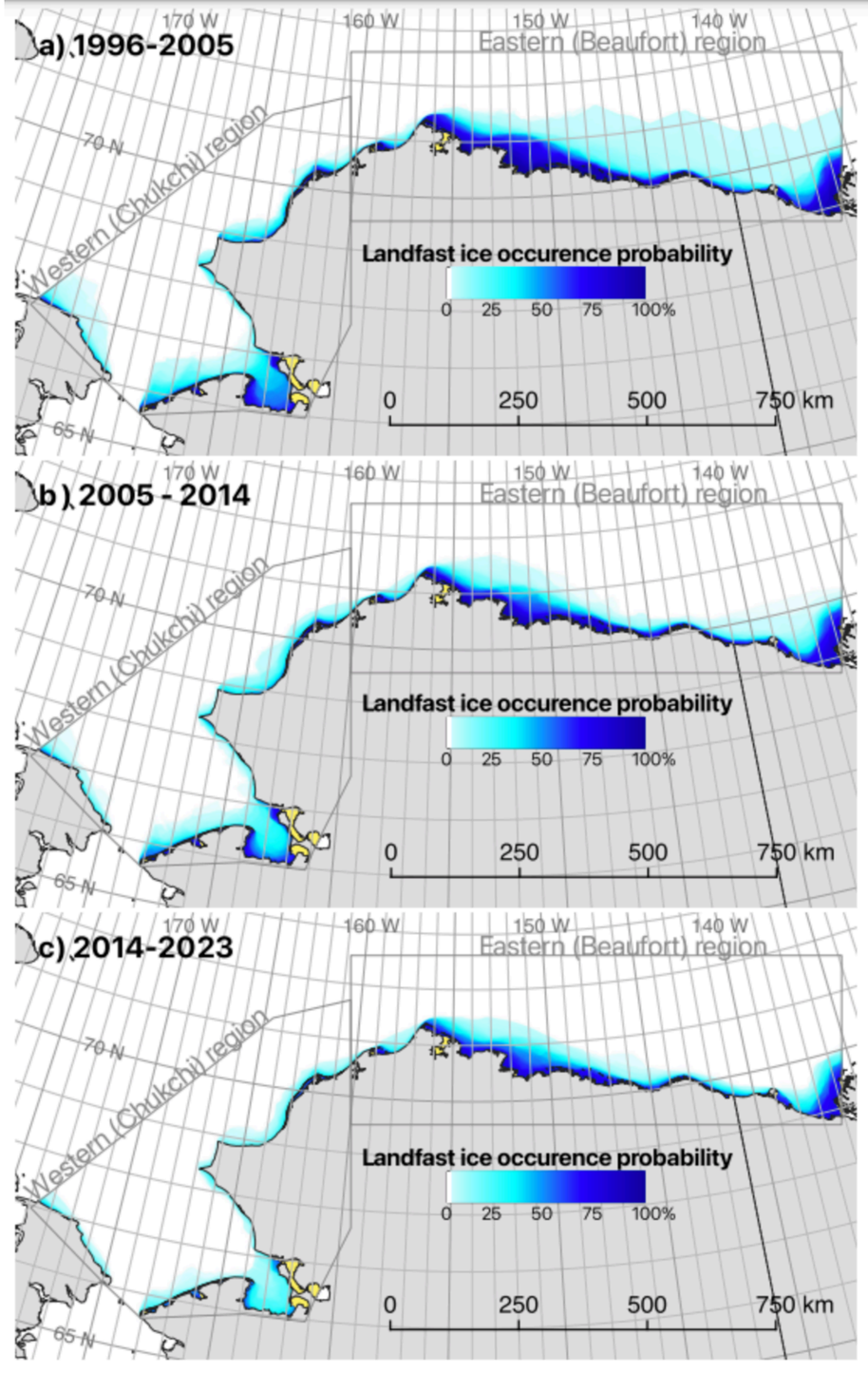


Figure 3-6: The extent of landfast ice shoreward of the SLIE stacked for each year in the EM2024 dataset (1996-2023), such that the shade of blue represents the fraction of the annual cycle (October-July) for which that area was occupied by landfast sea ice. White areas indicate where landfast ice was never observed was never observed.

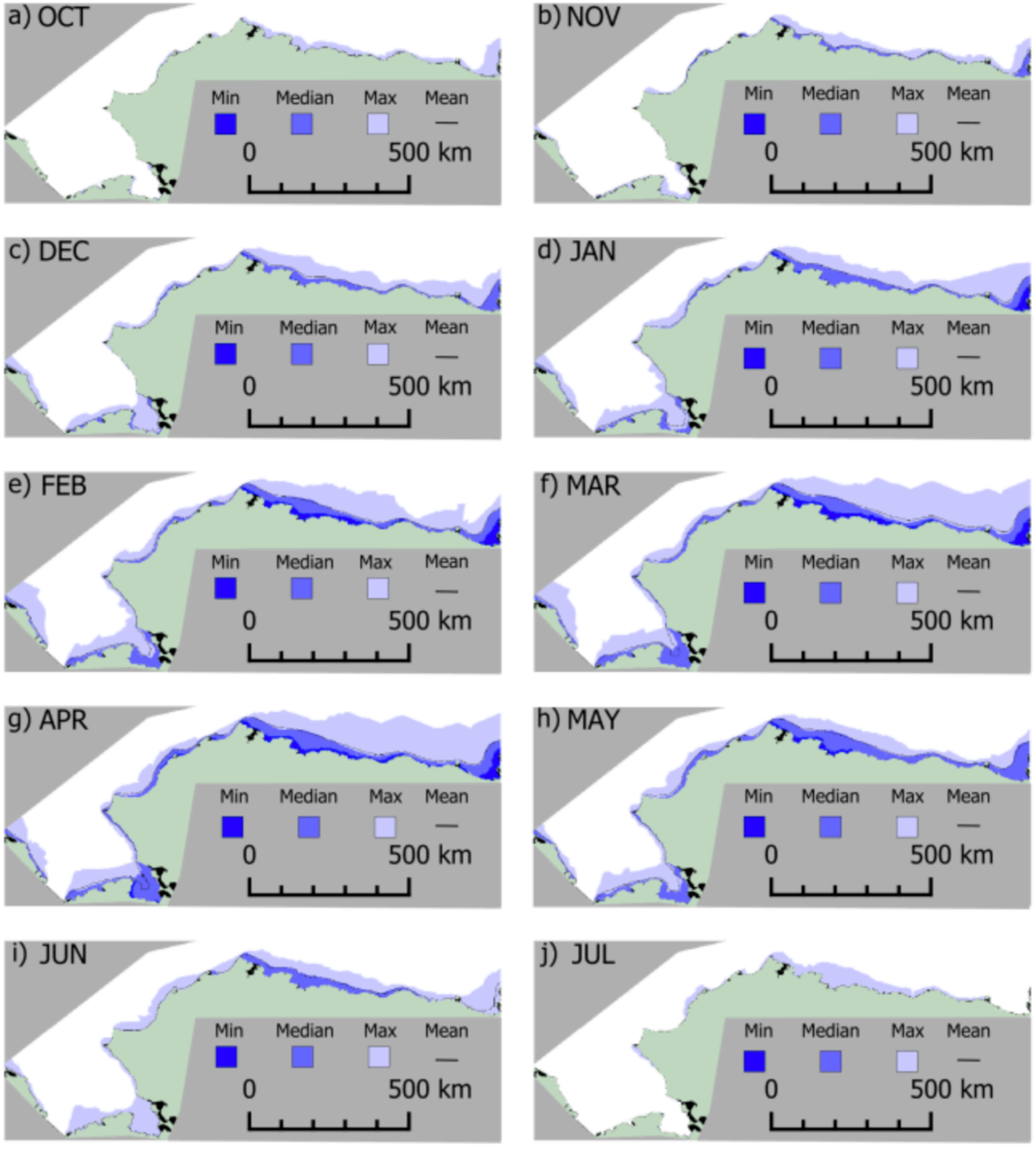


Figure 3-7: Minimum, median, maximum, and mean monthly mean landfast sea ice extents showing the change in landfast ice distribution in the study area through the annual cycle. See text for details on calculating these SLIE positions.

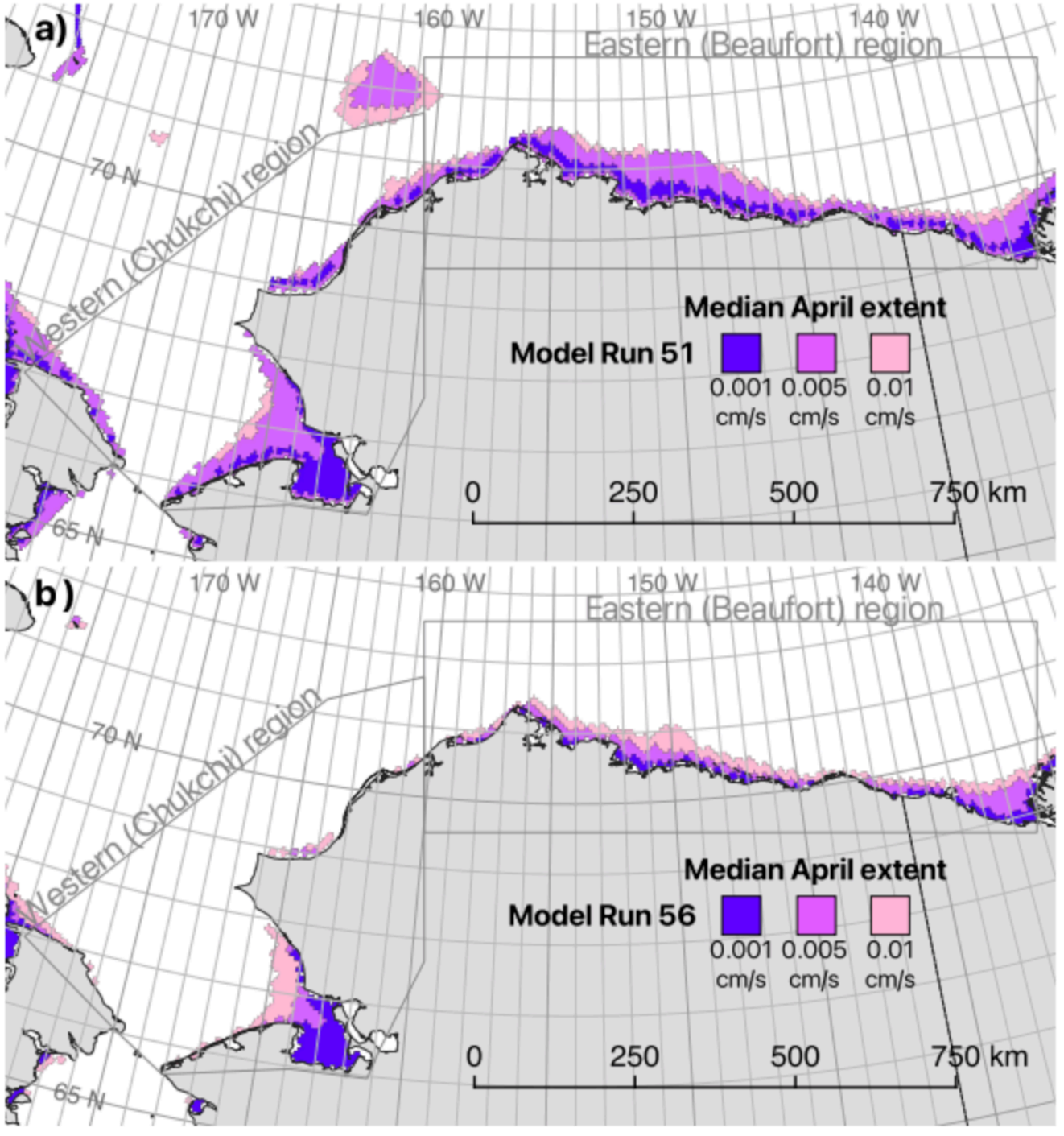


Figure 3-29: Median April landfast ice extent derived from the MOM6-SI22 model from a) run 51 and b) run 56. In both model runs, we use three different ice velocity thresholds is listed in Table 2-6.

Landfast Ice Summary

- There are some excellent sources of data to compare to, especially in the Beaufort and Chukchi Seas:
- https://seaice.alaska.edu/gi/projects/landfast/
- The model can capture some of the landfast ice features with these parameterizations
- Some sensitivity to the definition of landfast ice in the model - Lemieux chose 0.0005 m/s over a two-week average
- Compared to the 500 m scale of the Radarsat and other observations, 12km resolution isn’t sufficient for getting the timing of first/last landfast ice