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Final Report to Svalbard Environmental Protection Fund

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Final Report 12/145 to Svalbard Environmental Protection Fund

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Preface

In the autumn of 2012 the Norwegian Polar Institute (NPI) applied and was allocated funding from the Svalbard Environmental Protection Fund for the project “Arctic fox spatial ecology related to harvest management” 12/145, and this is the final report for the project. The project was carried out by an international team consisting of researchers from the Norwegian Polar Institute with added expertise from the Université du Québec à Rimouski in Canada. The Canadian team has contributed with their experience - gathered during many years from ARGOS telemetry - of arctic foxes at Bylot Island in Arctic Canada.

We thank the Svalbard Environmental Protection Fund for financial support of the project. We also thank Tommy Sandal for help and expert knowledge during the field work and for his special competence in trapping and handling arctic foxes, and we thank Conrad Helgeland (NPI) for administrating and providing the ARGOS data at NPI.

Tromsø 30 December 2015

Eva Fuglei

Project Leader

Arctic fox fitted with a satellite collar. Photo: Tommy Sandal

Contents

Norwegian summary

Vi mangler i dag kunnskap om hvordan fjellrev på Svalbard bruker omgivelsene sine gjennom året og spesielt i periodene høst, vinter og vår. Hensikten med dette prosjektet har vært å undersøke fjellrevens romlige økologi (bevegelsesmønster gjennom året og forekomst av lange vandringer) for å kunne bidra med råd om anvendt forvaltning og for å utvikle den kunnskapsbaserte overvåkingen av høstede arter på Svalbard. Fjellrev på Svalbard fangstes årlig, og fangstsesongen varer fra 1. november til 15. mars. Jegerne har siden 1997 vært pålagt å rapportere fangstresultatet når fangstsesongen er over. Antall terreng det fangstes i har variert fra 23 til 50 siden 1997, men er i dag satt til å være 25 områder hvor hvert terreng er markert på kart tilgjengelig hos Sysselmannen på Svalbard. For å kunne gi kunnskapsbaserte råd om størrelsen på hvert fangstområde, samt den totale størrelsen på fangstområdene, har vi benyttet satellitt-telemetri for å studere fjellrevens romlige bevegelsesmønster gjennom året på Svalbard.

1. **De viktigste resultatene**

Resultatene fra prosjektet har vist at fjellrev om sommeren generelt benyttet mindre leveområder sammenlignet med høst og vinter. Fangstsesongen (1. november til 15. mars) sammenfalt med perioden som fjellrev beveget seg i større grad, selv om det var stor variasjon mellom individer, noe som gjorde det vanskelig å fange opp et entydig mønster. Gjennomsnittlig månedlig størrelse på leveområdene var 236,6 km^2, men de varierte fra 54,9 til 891,8 km^2. Størrelsen på overlapp mellom leveområdene og fangstområdene utgjorde 12,4 %. Fangstområdenes totale størrelse var på 998,8 km^2, og hvert fangstområde hadde en gjennomsnittlig størrelse på 39,9 km^2. Ingen av revene forlot Svalbard, og den lengste vandringsavstanden som ble gått i ett var 275 km. Kun to fjellrev vandret >250 km unna der de ble påmontert satellitt sender, mens de 20 andre revene holdt seg innenfor 90 km fra der de ble påmontert sender. I snitt beveget fjellrevene seg 6,6 km per dag. Variasjonen mellom individer var fra 0,5 km til 72,6 km per dag.

2. **Miljøgevinst**

Vi har gjennom dette prosjektet økt vår kunnskap om hvordan fjellrev bruker områdene sine gjennom året og bidratt med viktig informasjon som kan bidra til bedre forvaltning av denne arten på Svalbard. Dette prosjektet har styrket det faglige grunnlaget for å gi råd om antallet og størrelsen på fangstområdene som blir tildelt hver fangster.

3. **Forslag til tiltak**

Prosjektet gir ikke direkte grunnlag for konkrete tiltak, annet enn at nåværende antall og størrelser på fangstområder som brukes i den årlige fangsten av fjellrev på Svalbard ikke må endres uten en nøye evaluering av fjellrevbestandens status på Svalbard.

4. **Hva er viktig for miljøforvaltningen**

Resultatene fra prosjektet har gitt ny og viktig kunnskap om en høstet art, fjellrev på Svalbard, og resultatene kan brukes direkte av Sysselmannen på Svalbard i arbeidet med å vurdere og avgjøre størrelsen på det totale området det er lov å fangste i og størrelsen på hvert fangstområde som hver fangster kan sette opp fellene sine i.

5. **Oppfølging**

Fjellrev på Svalbard er en tallrik art med stor årlig variasjon i overvåkingsområdene som overlapper med fangstområdene. Fjellrev fangstes lokalt i stort antall, noe som påvirker fjellrevbestandens demografi og genetiske struktur betydelig, men uten at vi har fanget opp noen nedgang i bestandens størrelse. Klimaendringene skjer raskt i Arktis, og dette gir ukjente fremtidige effekter på arter og økosystemer. For å kunne fange opp mulige fremtidige endringer i bestandene og dokumentere samlede påvirkningsfaktorer (jakt, forstyrrelse, miljøgiftbelastning, klimaendringer, zoonoser) på fjellrev er det viktig med langsiktig adaptiv økosystembasert overvåking.

English summary

Today we lack knowledge of spatial movements of arctic foxes in Svalbard during autumn, winter and spring. The main objective of the present project was to investigate critical aspects of arctic fox spatial ecology (annual movements and long ranging behaviour) to provide applied management advice and to develop the knowledgebase for harvest management in Svalbard. Arctic foxes in Svalbard are annually harvested from November 1 to March 15, and since 1997 it is mandatory for hunters to obtain a hunting license and to report the result at the end of the hunting season. The number of hunting terrains has varied from 23 to 50 since 1997, but is now set to 25 and the area of each terrain is marked on a map available from the Governor of Svalbard. To provide better advice about the size of each trapping terrain and the total size of the area of trapping, we have used satellite telemetry to investigate the spatial scales and annual cycles of arctic fox movements in Svalbard.

1. **The most important results**

Our results showed that in general, foxes had smaller home ranges in summer compared to autumn and winter. The period of trapping (November 1 to March 15) seems to correspond to the period when arctic foxes are relatively mobile, although the large individual variation between foxes likely prevents a clear movement pattern. The average monthly home range size was 236.6 km^2, howevever with substantially variation between individuals, with home range sizes that ranged from 54.9 to 891.8 km^2. Individual home ranges and the trapping areas overlapped with 12.4 %. The trapping areas covered a total area of 998.8 km^2, with an average size of each trapping area of 39.9 km^2. No foxes moved out of the Svalbard archipelago, and the longest distance covered by any of the individuals was 275 km. Only two foxes moved >250 km away from their first position. The remaining 20 individuals all stayed within 90 km from their first location during the period they were satellite-tracked. Arctic foxes moved on average 6.6 km per day. The variation between individuals was large and varied from 0.5 km to 72.6 km per day.

2. **Environmental benefits**

The project has improved our knowledge of seasonal spatial ecology of the arctic fox and contributed with crucial information for the overall understanding and management of this species in Svalbard. This new knowledge will contribute directly towards improving the management of the arctic fox in Svalbard by making it possible to give advice regarding the size of the trapping area used by each fox trapper.

3. **Recommended actions**

Results from the project do not translate into direct, specific management actions. However, we recommend that the present number and sizes of the trapping areas used for the annual trapping of arctic foxes in Svalbard should not change without a careful evaluation of the status of the arctic fox population in Svalbard.

4. **Environmental management implications**

The results from the project have provided evidence-based new and important knowledge about a harvested species, the arctic fox, in Svalbard. The results of the project can be used directly by the Governor of Svalbard when deciding the size of the total trapping area and the area each hunter is allowed to use for trapping.

5. **Follow-up**

At present the arctic fox is an abundant species with large annual variations in the monitoring areas that overlap with the trapping areas. The harvesting pressure is high locally and exerts significant impacts on the demographic and genetic structure of the population, however there are no signs of a

decline in the population size. The changes in climate occur at a high speed in the Arctic with future unknown effects on species and ecosystems. Therefore, it is of importance to conduct long term adaptive ecosystem-based monitoring to be able to document possible future changes in abundance and cumulative effects of stressors (hunting, traffic, contaminants, climate change, zoonoses) on the arctic fox in Svalbard.

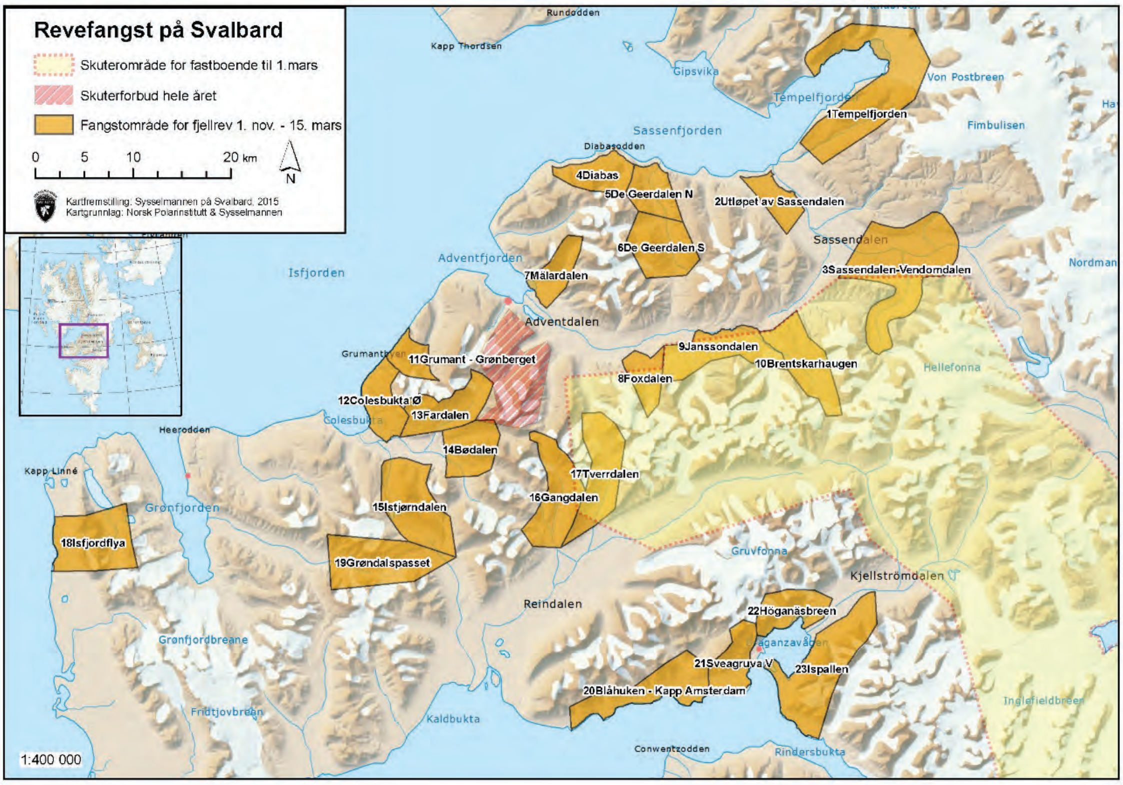
1 Introduction

1.1 Background

The Svalbard Environmental Protection Act (Ministry of Climate and Environment 2012) and the Regulations relating to harvesting of the fauna on Svalbard (The Governor of Svalbard 2013), allow residents to hunt outside the archipelago's protected areas provided that the total offtake does not have a significant impact on the population. The Svalbard Environmental Protection Act, section 24, states: "*The flora and fauna on land and in the sea shall be managed in such a manner that the natural productivity and diversity of species and their habitats are maintained, and Svalbard's natural wilderness is protected for future generations. Controlled and limited harvesting may take place within this framework*". The Regulations relating to harvesting of the fauna on Svalbard, section 5, say: "*All species of fauna, including their eggs, nests and lairs, are protected. Harvesting and collection of eggs and down are only permitted in accordance with provisions laid down in or under these regulations. Harvesting must not significantly alter the composition and development of the stocks in question*". This is further emphasized in "Miljøforvaltningens kunnskapsmatrise for Svalbard" which says that it is a goal to increase the knowledge related to harvest of arctic foxes (*Vulpes lagopus*). Thus, all animals in Svalbard are protected, although controlled and limited harvest is allowed for a few species. One of these species is the arctic fox that due to its excellent winter fur has been harvested in Svalbard for decades (Arlov 1996). Today the harvest represents an important recreational activity for local residents and a few trappers in Svalbard.

The majority of the harvest of arctic foxes occurs in Nordenskiöld Land and the hunting season lasts from 1 November to 15 March (http://www.sysselmannen.no/en/Residents/Hunting-and-Fishing/). Since 1997 it is mandatory for hunters to obtain a hunting license every year and report the result at the end of the hunting season. Due to increased interest for harvesting by the locals in Longyearbyen in 2007-2008, the number of licences increased from 25 to approximately 50 per trapping season. Because of the increased interest, the Governor of Svalbard (SMS) opened up for approving new terrains temporarily and decided to predefine each trapping terrain, and mark and number them on a map. Should one expand to include terrain outside the original trapping area this could have negative effects on the arctic fox population. The population in the original (so called "sink") trapping area needs immigrants from the outside (so called "source") area to maintain the population size (Pulliam 1988; Novaro et al. 2005). Based on unpublished monitoring data from the trapping areas between 2007 and 2009 we found that the number of juvenile foxes in the returned bags was higher than the number of juveniles produced in the areas after the number of trapping areas had been increased (Pers. com. E. Fuglei). In an earlier study financed by Svalbard Environmental protection Fund, we showed that harvest had significant effects on the demography (age and gender) and the genetic structure of the arctic fox population (Fuglei et al. 2013). As a consequence of hunting the proportion of young foxes in the population rose, and the increase was higher for females than for males, i.e. the proportion of older females in the population was significantly lower in hunted populations. However, we could not document any significant decreasing temporal trend in the population (Fuglei et al. 2013; Ims et al. 2014). The number of trapping terrains is now reduced to 25 (Figure 1). Each year before the trapping season starts, residents in Longyearbyen question the number and sizes of terrain available for harvesting of arctic fox, since the number of applicants over the last years (approximately 50) has reached twice the number of available terrains.

A.



B.

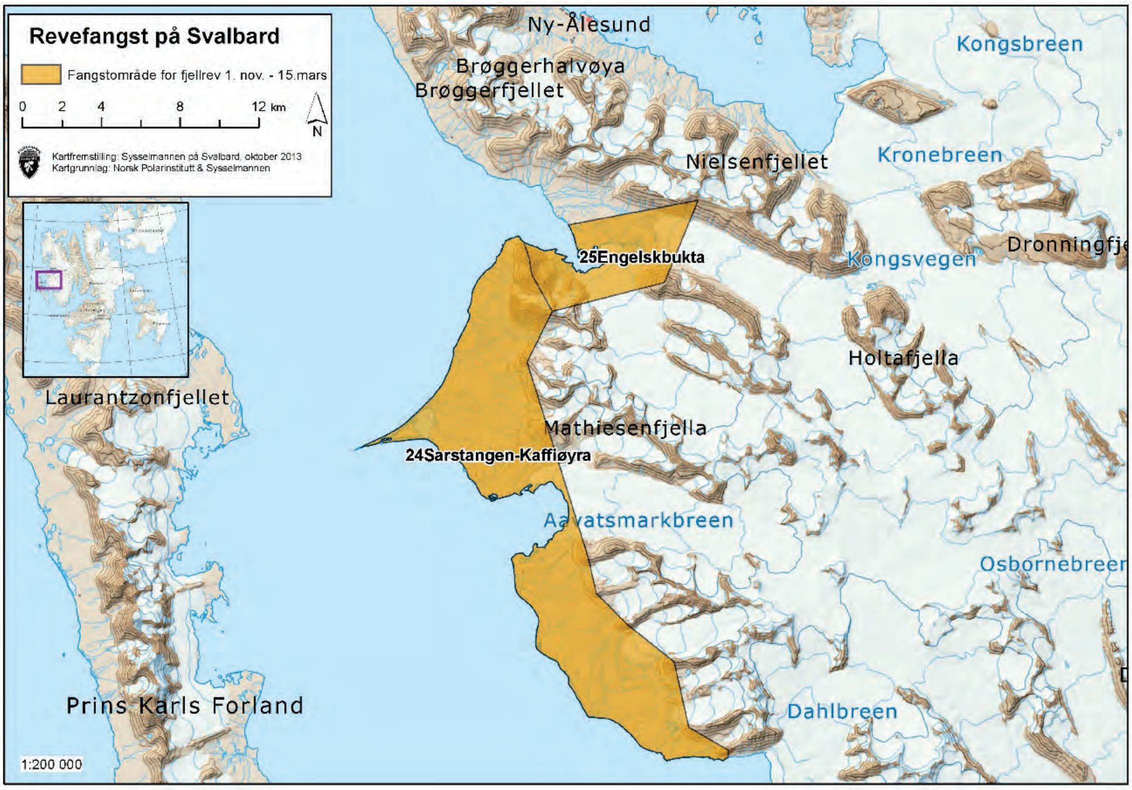


Figure 1 – Maps showing the 25 arctic fox *Vulpes lagopus* trapping terrains in Svalbard (from the Governor of Svalbard; http://www.sysselmannen.no/Documents/Sysselmannen_dok). Map A) showing the 23 terrains at Nordenskiöld Land and map B) the two terrains south of Ny-Ålesund.

Home ranges (the regular area where an animal lives and travels) and more long-ranging, less frequent movements of arctic foxes vary with the predictability and abundance of their prey. Arctic foxes in general are territorial and monogamous, with home range sizes that may vary by a factor of 40 depending on habitat type and available food resources within their circumpolar distribution range (Eberhardt et al. 1982; Hersteinsson and Macdonald 1982; Frafjord and Prestrud 1992; Angerbjörn et al. 1997; Anthony 1997; Eide et al. 2004). In Svalbard we have knowledge about foxes' home range sizes in summer only, where reproducing arctic foxes are resident and defend summer home ranges that vary between 4 and 60 km^2 (Eide et al. 2004). Arctic foxes with a den in prey-rich coastal areas had the smallest home ranges (10±5,6 km^2) while medium home ranges (23±4,2 km^2) occurred at den sites further from the coast, more inside the rich river valleys, where geese and reindeer are the main food. The largest home ranges (52±8,4 km^2) were found in poorer river valleys where only reindeer are main prey (Eide et al. 2004). During autumn and winter, arctic fox pairs can switch to a more nomadic behaviour, presumably in search of food when such is scarce (Pamperin et al. 2008; Tarroux et al. 2010; Lai et al. 2015). No work has previously been done on the Svalbard arctic foxes' spatial ecology during autumn and winter. Knowledge about their home ranges and movements during the winter period should constitute essential baseline information when deciding specific management action for harvesting the species. These parameters (movement rates and distances covered) will therefore help deciding at which spatial scale the management and monitoring can be optimally implemented (i.e. size of trapping areas). To be able to give knowledge-based advice to the management about the terrain size for harvesting, we need data on home ranges and movements during the trapping season.

In Svalbard we lack knowledge about arctic foxes' movements during autumn, winter and spring which coincide with the trapping season. Satellite telemetry has proven to be an efficient, reliable, and well tested method to collect movement data on long-ranging animals that are otherwise impossible to track by other means (Pamperin et al. 2008; Tarroux et al. 2010, Lai et al. 2015). In this study we use satellite collars to investigate the spatial scales and annual cycles of arctic fox movement in Svalbard.

1.2 Objectives for the project

Main objective

To investigate critical aspects of arctic fox spatial ecology (annual movements and long ranging behaviour) to provide applied management advice and further develop the knowledge-base for harvest management.

Secondary objectives

- To produce maps and estimates of locations and straight line movements of arctic foxes that can be used to estimate home range sizes over the entire year.
- To provide estimates of the frequency of large scale movements throughout the year, which are directly related to the size of the trapping areas.
- To provide estimates of the daily distances that can potentially be covered by roving foxes during all seasons.

2 Methods

2.1 Study species and area

Arctic foxes in Svalbard are abundant although the population size varies significantly between years and there are no obvious long-term trends in the areas that are annually monitored (Ims et al. 2014). The number of occupied dens are monitored annually in two main areas (Brøggerhalvøya and Adventdalen-Sassendalen) and the variation in reproduction has been shown to mainly be driven by availability of dead reindeer or carcasses during winter (Eide et al. 2012, Hansen et al. 2013). Other important food resources are increasing populations of arctic breeding geese, sea bird colonies and marine subsidies as seals (Fuglei et al. 2003, Eide et al. 2012, Ims et al. 2014). The monitoring areas overlap with the trapping areas (MOSJ). The harvesting pressure is locally high and has a significant impact on the demographic and genetic structure of the actic fox population (Fuglei et al. 2013). However, we have not been able to document harvest as a negative factor on the population size (Fuglei et al. 2013, Ims et al. 2014).

We captured foxes on both sides of the fjord Van Mijenfjorden on Nordenskiöld Land and Nathorst land (77,78°N; 15,41°E), Spitsbergen, south of the hunting and trapping areas, in order to avoid that foxes are captured during the regular annual harvest.

2.2 Satellite tracking

We fitted a total of 23 arctic foxes (15 females and 8 males) with satellite transmitters (four foxes in 2012, six in 2013 of which three collars were reused from 2012 after three of the satellite foxes were trapped during the annual harvest, seven in 2014 and six in 2015). Foxes were captured by using a Swiss snare system consisting of a springmounted plastic-coated foot snare (Nybakk et al. 1996; Eide et al. 2004) mounted on a modified padded leg-hold trap system (Victor No. 1 Soft-Catch® padded leg-hold trap; www.oneidavictortraps.com/softcatchtraps.html). The trapping system demanded continuous observations from a distance of 250-400 m with a telescope or binocluar, and when a fox was trapped it was removed from the trap within < 5 min. The foxes were sexed, weighted, ear tagged, age estimated by the wearing of the teeth to juvenile or adult, and fitted with a 115 g KIWISAT 303 ARGOS collar (ARGOS 2011; biotrack Ltd, http://www.biotrack.co.uk/). The collars weighed approximately 4 % of the foxes' body mass, and the handling time took approximately 15-20 min from a fox was trapped until it was released. All trapping methods and handling of the animals were approved in accordance with the principles and guidelines of the Norwegian Animal Welfare Act, with permission from the National Animal Research Authority of Norway. All necessary permits for conducting the fieldwork were obtained from the Governor of Svalbard.

Each collar had an Argos Platform Transmitter Terminal (PTT) with a repetition rate of 60 seconds and it transmitted daily for a 3-hour period between 14:00 and 17:00 GMT (corresponding to 15:00–18:00 local time; ARGOS 2011). Each Argos PTT was equipped with a temperature sensor, which we could use, along with the movement data, to monitor the status (alive, with temperatures higher than expected temperatures; dead, temperature close to ambient temperatures). The average number of locations (± SD) obtained per day per animal was 3.1 ± 1.6, whereas the average number of transmitting days per animal (± SD) was 600 ± 582. A few individuals (N = 6) died of unknown causes before their PTTs stopped transmitting. One collar (#145026) partly failed providing us only with low quality location data (i.e. LC A, B, or Z; see below). Data from this individual were thus not used.

To have a suitable level of accuracy for the analyses, we only kept positions with a Location Class 3, 2 and 1, corresponding respectively to positioning errors having a 68% probability of being <250 m, < 500 m, and < 1,500 m (CLS 2011). We removed all positions with a Location Class 0, A, B, and Z, corresponding to large (>1,500 m) or unquantifiable positioning errors (CLS 2011). Coordinates were projected in the *Universal Transverse Mercator* Zone 33N, and we filtered the obtained Argos data using recursive routines in software R.3.2.2 (R Development Core Team 2015) to exclude locations resulting in unrealistic speed and distance values (> 6 km h^{-1} cruising speed, with possible 15-min acceleration bouts of 15 km h^{-1}). The total number of locations obtained per individual and per season (as defined below) is shown in Table 1. In order to avoid any bias due to potential differences in sampling frequency among individuals we kept only one location per day for all individuals tracked when estimating home range sizes (methods below). We have previously evaluated Argos telemetry accuracy on Bylot Island in the High Canadian Arctic, and reported some of the lowest published errors for this system (Christin et al. 2015), likely due to increased satellite coverage at high latitudes.

2.3 Specification of the scientific method

All data analyses and mapping were performed in R.3.2.2 (R Development Core Team 2015).

Home range estimation – Kernel density utilization distributions (UDs) were used to estimate the area of individual home ranges, using package *adehabitatHR* (Calenge et al. 2009). Home ranges were calculated at two temporal scales, seasonally (for all individuals and years pooled; Figure 2) and monthly (per individual; Table 2). Monthly individual home range areas were estimated at the 95% Kernel UD level, and thus represent the area where the probability of sighting a given individual during a given month is 95% (Table 2). Three seasons were defined as follow:

- Summer (from 1 May to 31 August): breeding arctic foxes are rearing pups.
- Autumn (from 1 September to 30 November): arctic foxes are not caring for their pups any longer, but cannot leave the Svalbard area, as the sea ice has usually not formed.
- Winter (from 1 December to 30 April): sea ice has generally formed and allows arctic foxes to undertake long-range movements.

Long range movements – The occurrence of long range movement was investigated through the computation of a Net Displacement Metric (NDM). The NDM is defined, for each location along a given track, as the straight-line distance between that location and the first location for that track. In other words, this index measures the net displacement that has been achieved by an individual since the first day it has been satellite-tracked. Temporal variation in individual NDMs through time allowed us to investigate the occurrence of long-range movements throughout the tracking period (Figure 5).

Trapping areas – Trapping areas are shown in Figure 1. At present there are a total of 25 trapping areas provided by the Governor of Svalbard for harvesting arctic foxes in Svalbard. Each area is predefined and marked on a map available from the Governor of Svalbard's home page (www.sysselmannen.no/Tilreisende/Kart-og-GPS). The overall area of trapping areas combined covers 998.8 km^2 (mean ± SD = 39.9 ± 23.8 km^2). In order to evaluate the use of the trapping areas by arctic foxes, we calculated the proportion of the monthly home range (i.e. 95% Kernel UD, as defined above) that overlapped one or several of the trapping areas for each individual (Table 2). The overlap was computed only for the months from November to March, i.e. when trapping occurs.

Table 1 – Number of Argos locations per season and individual, for arctic foxes *Vulpes lagopus* tracked in Svalbard during three consecutive years. Data shown here were obtained after speed filtering (see Methods).

		fox 001	fox 002	fox 003	fox 004	fox 005	fox 006	fox 007	fox 008	fox 009	fox 010	fox 011	fox 012	fox 013	fox 014	fox 015	fox 016	fox 017	fox 018	fox 019	fox 020	fox 022	fox 023
2012	**Autumn**	378	282	357	383	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Winter	-	299	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2013	**Summer**	-	-	-	-	50	20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Autumn	-	-	-	-	478	382	56	91	241	358	-	-	-	-	-	-	-	-	-	-	-	-
	Winter	-	-	-	-	411	-	-	-	389	384	-	-	-	-	-	-	-	-	-	-	-	-
2014	**Summer**	-	-	-	-	457	-	-	-	37	421	-	-	-	-	-	-	-	-	-	-	-	-
	Autumn	-	-	-	-	392	-	-	-	5	327	128	314	398	42	295	277	317	-	-	-	-	-
	Winter	-	-	-	-	117	-	-	-	-	210	-	56	19	-	380	73	-	-	-	-	-	-
2015	**Summer**	-	-	-	-	-	-	-	-	-	337	-	-	-	-	486	-	-	-	-	-	-	-
	Autumn	-	-	-	-	-	-	-	-	-	195	-	-	-	-	393	-	-	49	117	10	75	87

3 Results and discussion

This is the first time that adult arctic foxes in Svalbard have been fitted with satellite tags. Out of the 23 tagged foxes, one had a collar (#145026) that partly failed, providing us only with low quality data location (i.e. LC A, B, or Z) that could not be used. Individual tracking of foxes documented large space use variations between individuals, and home range sizes, during the year. We also describe large inter-individual variation regarding the occurrence and amplitude of long-range movements throughout the year. We found that generally foxes had slightly smaller home ranges in summer compared to autumn and winter (Figure 3), although this did not apply to all individuals. The period of trapping (November 1 to March 15) seems to correspond with the period when arctic foxes are relatively more mobile, although the large individual variations likely prevented the emergence of a clear pattern (Figures 3, 4, and 5).

3.1 Home range size

The average estimated monthly home range size of arctic foxes in Svalbard was 236.6 km^2 (range = 54.9; 891.8]). The overall home range area used by artic foxes varied substantially through time (Figure 4), although there was no clear seasonal pattern (Figure 2). There seemed to be a slight increase in spread of the intensively used areas in winter (Figure 2). At the individual scale, we found substantial variation in home range size, both within individuals (i.e. temporal variation) and among individuals (Table 2 and Figure 3). The monthly individual home ranges did usually not overlap with the trapping areas (Table 2). However, when there was an overlap, it represented on average 12.4 % (range = [0.1; 39.1]) of the area of a given home range.

Table 2 – Estimated monthly home range areas of arctic foxes *Vulpes lagopus* satellite-tracked in Svalbard. Home range area estimates are based on Kernel density UDs at 95%, (see Methods). The percentage overlap indicates the proportion of the monthly home range that overlaps with one or several of the harvesting areas (see Fig. 1).

ID	year	month	Home range area (km^2)	% overlap
fox001	2012	sep	126.2	-
		oct	67.5	-
		nov	147.9	0.0
		dec	68.1	0.0
fox002	2012	sep	143.5	-
		oct	161.8	-
		nov	253.5	0.0
		dec	76.5	0.0
	2013	jan	70.1	0.0
		feb	72.2	0.0
		mar	196.6	0.0
		apr	107.5	0.0
fox003	2012	sep	76.5	-
		oct	346.8	-
		nov	362.2	0.0
		dec	115.6	0.0
fox004	2012	sep	70.2	-
		oct	374.1	-
		nov	173	39.1
		dec	166.9	36.2
fox005	2013	aug	90.5	-
		sep	181.9	-
		oct	195.6	-
		nov	254.1	16.5
		dec	346.7	13.8
	2014	jan	277.5	5.5
		feb	382.8	7.1
		mar	187.7	0.0
		apr	227.5	-
		mai	429.6	-
		jun	134.3	-
		jul	190.5	-
		aug	246.2	-
		sep	209.5	-
		oct	267.8	-
		nov	322.1	5.6
		dec	228.7	0.0
	2015	jan	205.4	13.1
		feb	149.1	0.0
fox006	2013	aug	108	-
		sep	126.5	-
		oct	212.4	-
		nov	115.3	37.8
fox007	2013	sep	68.7	-
fox008	2013	sep	171.4	-
	2013	oct	324.8	-
fox009	2013	sep	159.4	-
		oct	173.3	-
		nov	211.4	0.0
		dec	351.8	0.0
	2014	jan	203.8	0.0
		feb	216.6	0.0
		mar	724.7	7.0
		apr	615.1	-
		mai	214.8	-
fox010	2013	oct	248.5	-
		nov	213.3	5.1
		dec	891.8	0.1
	2014	jan	132.9	0.0
		feb	98.4	0.0
		mar	274.4	0.0
		apr	498.3	-
		mai	210.7	-
		jun	645.5	-
		jul	549	-
		aug	263	-
		sep	239.4	-
		oct	143.8	-
		nov	129.8	0.0
		dec	232.4	0.0
	2015	jan	336.1	0.0
		feb	165.7	0.0
		mar	150.8	0.0
		apr	768.6	-
		mai	423.8	-
		jun	369.2	-
		jul	401.2	-
		aug	313.7	-
		sep	333.8	-

ID	year	month	Home range area (km^2)	% overlap
fox010	2015	oct	419.1	-
(continued)		nov	314.6	0.0
fox011	2014	sep	310.6	-
	2014	oct	259.6	-
fox012	2014	sep	153	-
		oct	179.9	-
		nov	358	0.0
		dec	337.7	0.0
	2015	jan	530.5	0.8
fox013	2014	sep	189.4	-
		oct	165.5	-
		nov	170.1	0.0
		dec	95.7	0.0
	2015	jan	54.9	0.0
fox014	2014	sep	62	-
	2014	oct	63.4	-
fox015	2014	oct	131.8	-
		nov	193.1	5.3
		dec	134.8	0.0
	2015	jan	199	3.1
		feb	165.5	0.0
		mar	502.2	0.2
		apr	659.1	-
		mai	301.7	-
		jun	187	-
		jul	306.1	-
		aug	223.7	-
		sep	351.2	-
		oct	316.3	-
		nov	239.9	0.0
		dec	120	0.0

ID	year	month	Home range area (km^2)	% overlap
fox016	2014	sep	73.2	-
		oct	131.8	-
		nov	136	0.0
		dec	122.4	0.0
	2015	jan	104.7	0.0
		feb	99.5	0.0
fox017	2014	sep	204.1	-
		oct	205.4	-
		nov	330.9	0.0
		dec	154.3	0.0
fox018	2015	oct	70	-
		nov	189.2	0.0
		dec	104.9	0.0
fox019	2015	oct	234.2	-
		nov	334.7	27.9
		dec	169.8	9.0
fox020	2015	nov	187.7	0.0
fox022	2015	nov	228.3	0.0
		dec	164.9	0.0
fox023	2015	nov	244.7	1.7
		dec	68.2	0.0

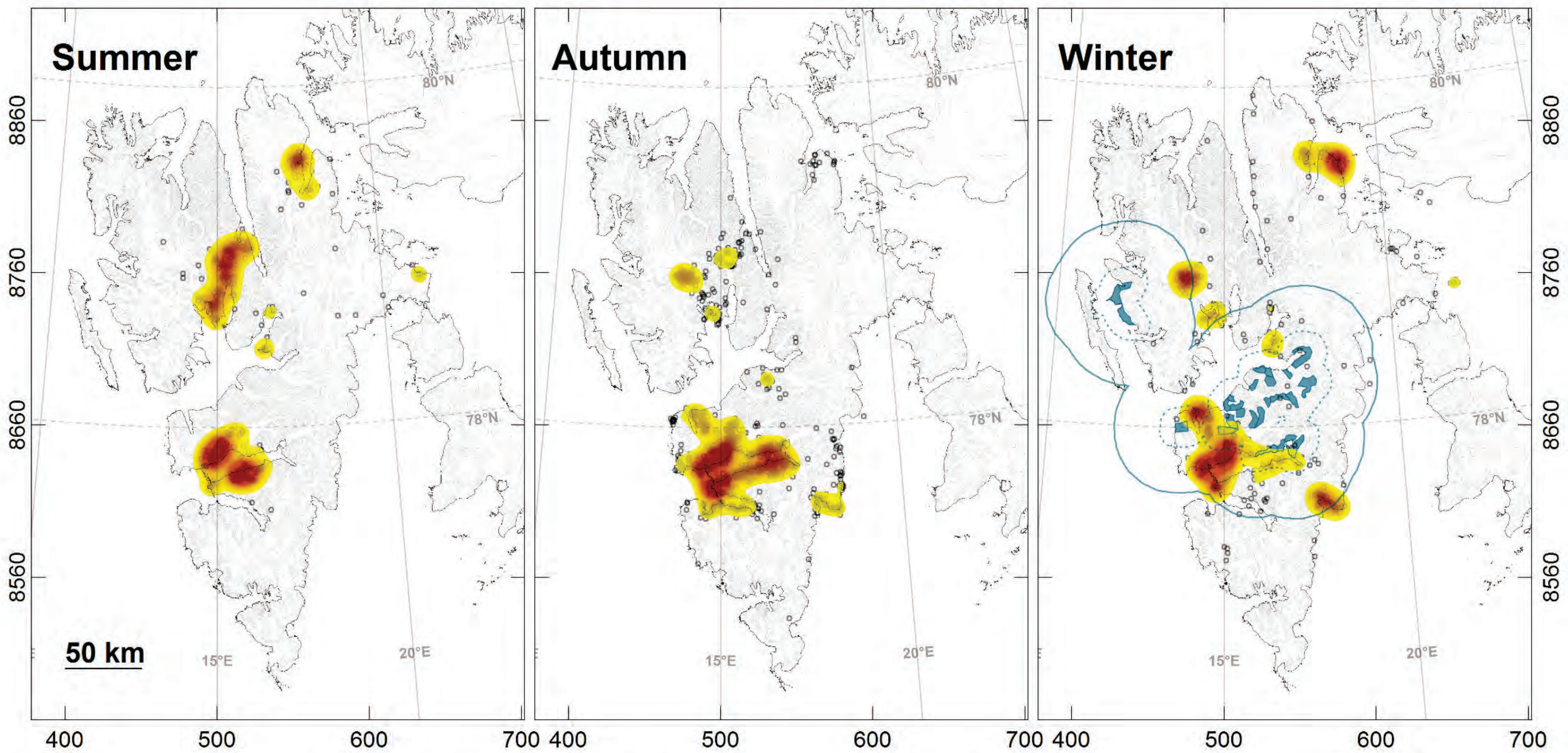
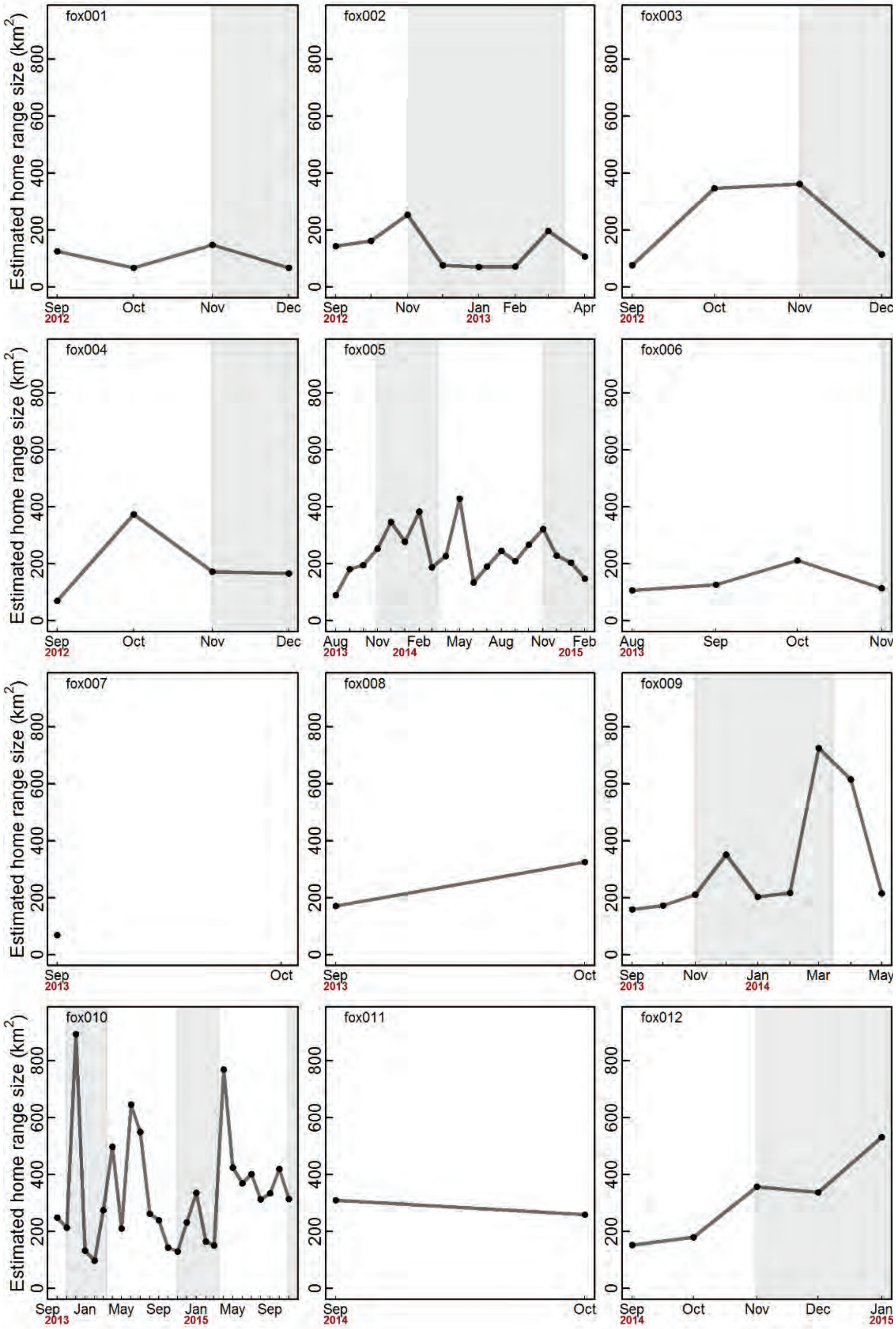


Figure 2 – Seasonal overview of the space use patterns of arctic foxes satellite-tracked in Svalbard. Maps show the density distributions of daily locations of all arctic foxes *Vulpes lagopus* tracked in Svalbard during the summer, autumn, and winter periods. Data were pooled over several years (2012-2015). Map projection is UTM 33N and projected coordinates are shown along each axis in km. Empty circles represent the Argos locations of individual arctic foxes. Red (yellow) colours indicate higher (lower) probability of observation within a given area during the period considered, based on the Kernel Utilization Distributions calculated at the 95% level for all individuals pooled together per season. In winter, the blue polygons represent the areas where harvesting occurs. The potential areas of attraction around harvesting areas, based on the detection range of arctic foxes (Lai et al. 2015), are represented with blue lines (10 km range, dashed line; 40 km range, continuous line).


fox001
fox002
fox003
fox004
fox005
fox006
fox007
fox008
fox009
fox010
fox011
fox012
Estimated home range size (km²)
0
200
400
600
800
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Aug
2012
2013
2014
2015

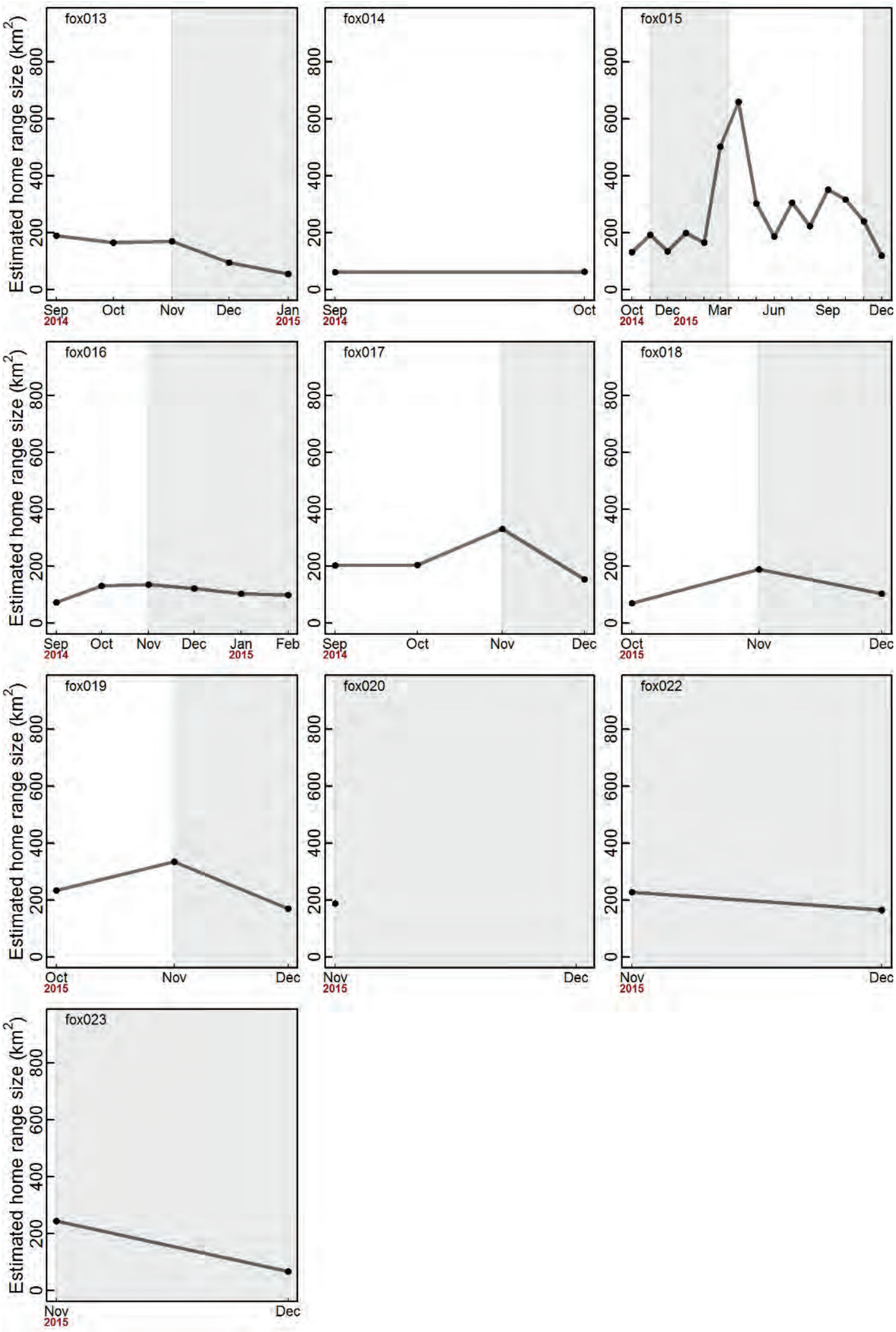


Figure 3 – Temporal variation in estimated home range size (95% Kernel Utilization Distributions) of individual arctic foxes *Vulpes lagopus* satellite-tracked in Svalbard. The shaded areas indicate the periods when harvesting (fox trapping) is allowed. Individual # fox021 is not represented on this figure, due to lack of good-quality location data. Note that the scales vary among subplots.

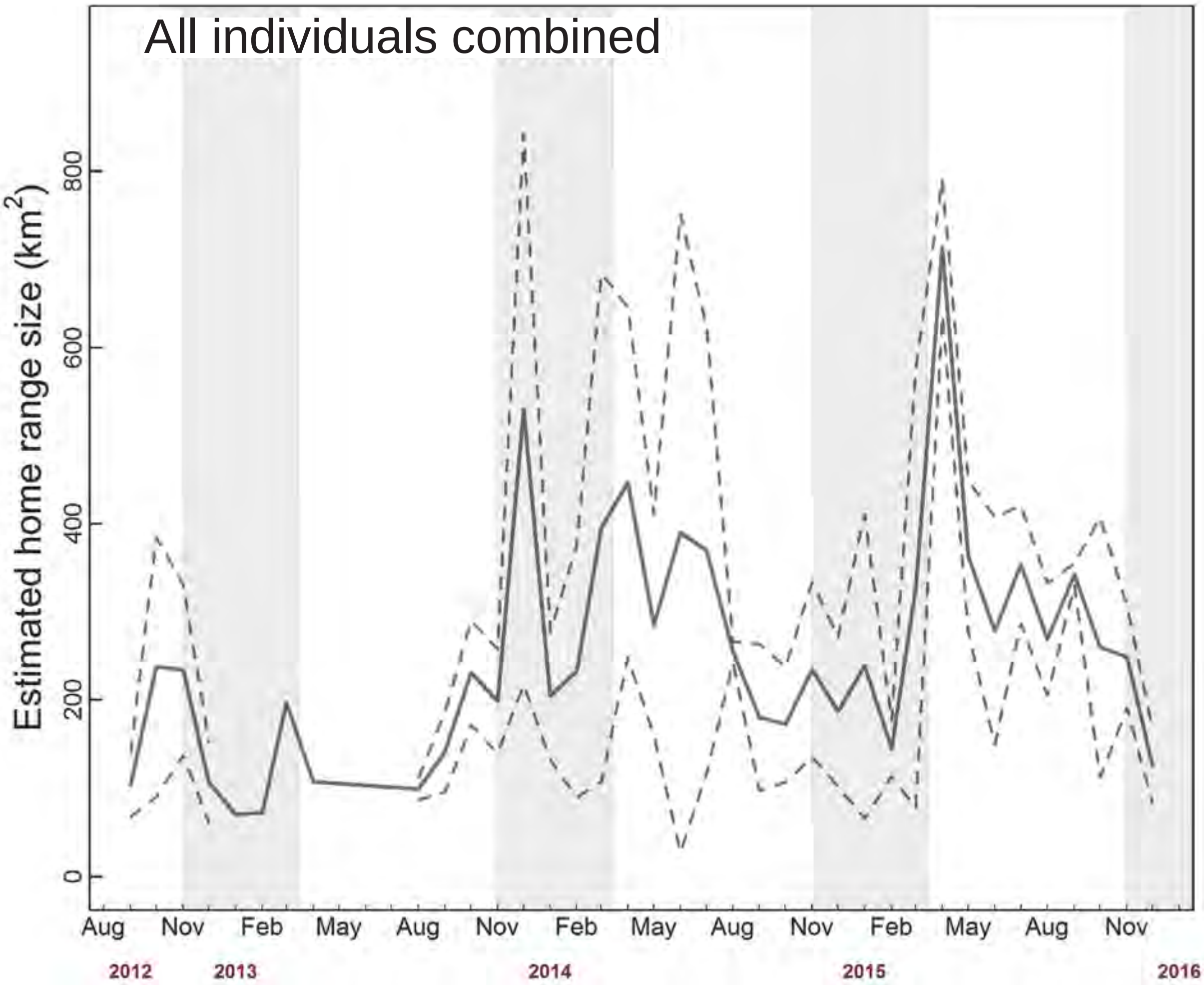


Figure 4 – Temporal variation in the average (± SD, dashed lines) estimated home range size for all individuals combined. Home range size was estimated by calculating the 95% Kernel Utilization Distributions individually, and then averaging these values monthly.

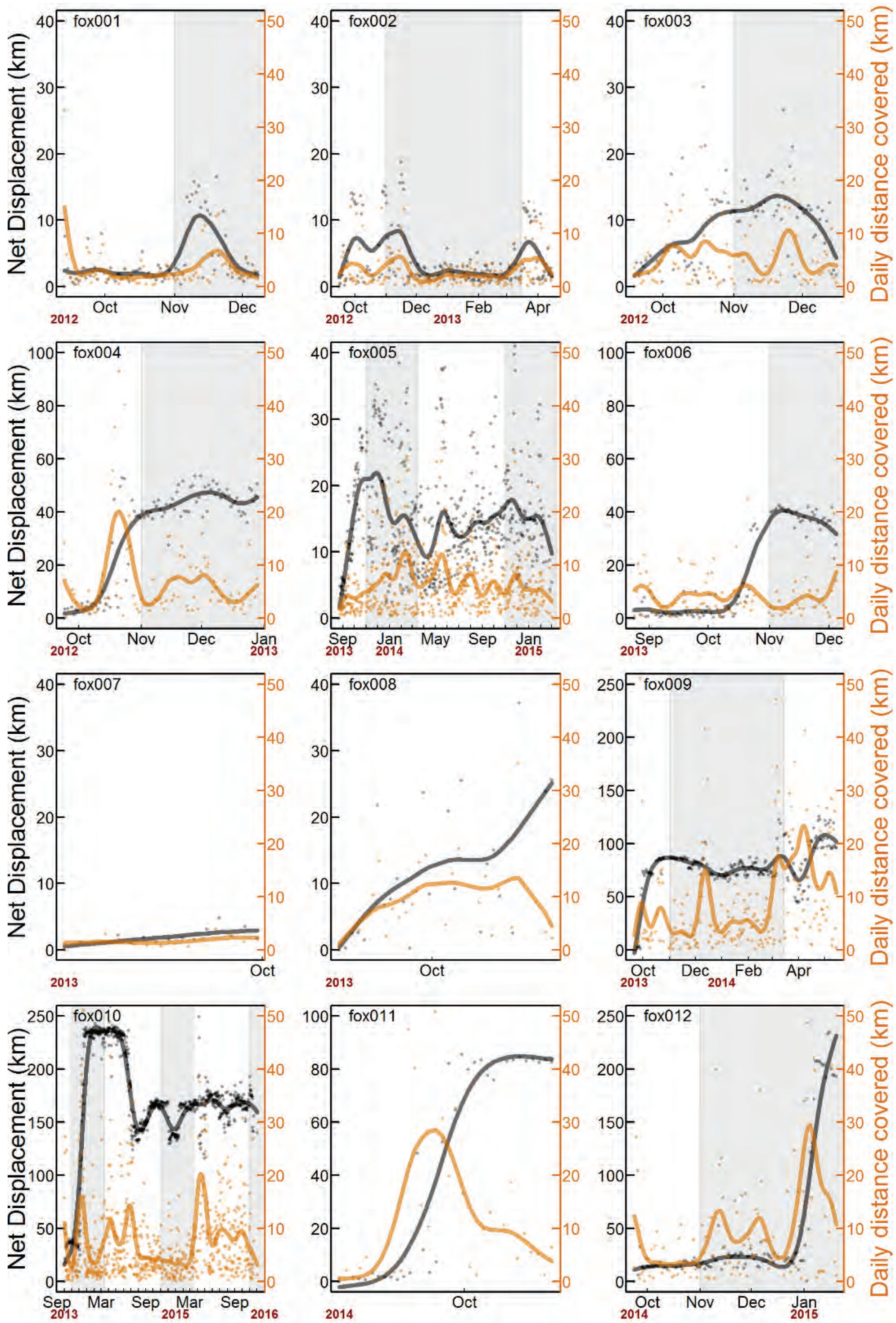
3.2 Estimated frequencies of long-range movements

Based on the 22 successfully satellite-tracked individuals, we found no evidence so far for the occurrence of long-range movements, i.e. movements that would have led some individuals to leave the Svalbard archipelago area. The longest distance covered by an individual was 275 km (fox # 010; Figure 5). Only two individuals (fox # 010 and fox # 012; Figure 5), moved >250 km away from their first position. The remaining 20 individuals all stayed within 90 km from their first location during the tracking period. We found large individual variation in movement patterns: some individuals remained within their original home range for long time periods (e.g., fox # 001, fox # 002, and fox # 016; Figure 5), while others seemingly established new home ranges remotely situated from their original home range (e.g., fox # 009, fox # 010, and fox # 016; Figure 5). Finally, some individuals had very large day-to-day variation in Net Displacement Metric (NDM; e.g. fox # 005; Figure 5), meaning they travelled a lot back and forth, without ever going extremely far.

Even if these movements were of rather limited amplitude, with regard to distances arctic foxes can potentially cover, they were sufficient to generate some overlap between arctic fox home range areas and the trapping areas in Svalbard (see previous section and Table 2). They also desmonstrate the remarkable mobility of this species, even at relatively smaller spatial scale, i.e. <50 km.

3.3 Estimated daily distances covered by roving foxes

Arctic foxes moved on average 6.6 km daily (range = [0.5; 72.6]). Temporal variation in daily distances covered by arctic foxes is shown in Figure 5. Similarly to temporal variation in NDM and home range sizes, we found no clear pattern in temporal variation of daily distances covered. The monthly movements of all arctic foxes satellite-tracked from September 2012 to December 2015 can be seen on 37 maps presented in Appendix Figure A1.


fox001
fox002
fox003
fox004
fox005
fox006
fox007
fox008
fox009
fox010
fox011
fox012
Net Displacement (km)
Daily distance covered (km)
2012
2013
2014
2015
2016
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May

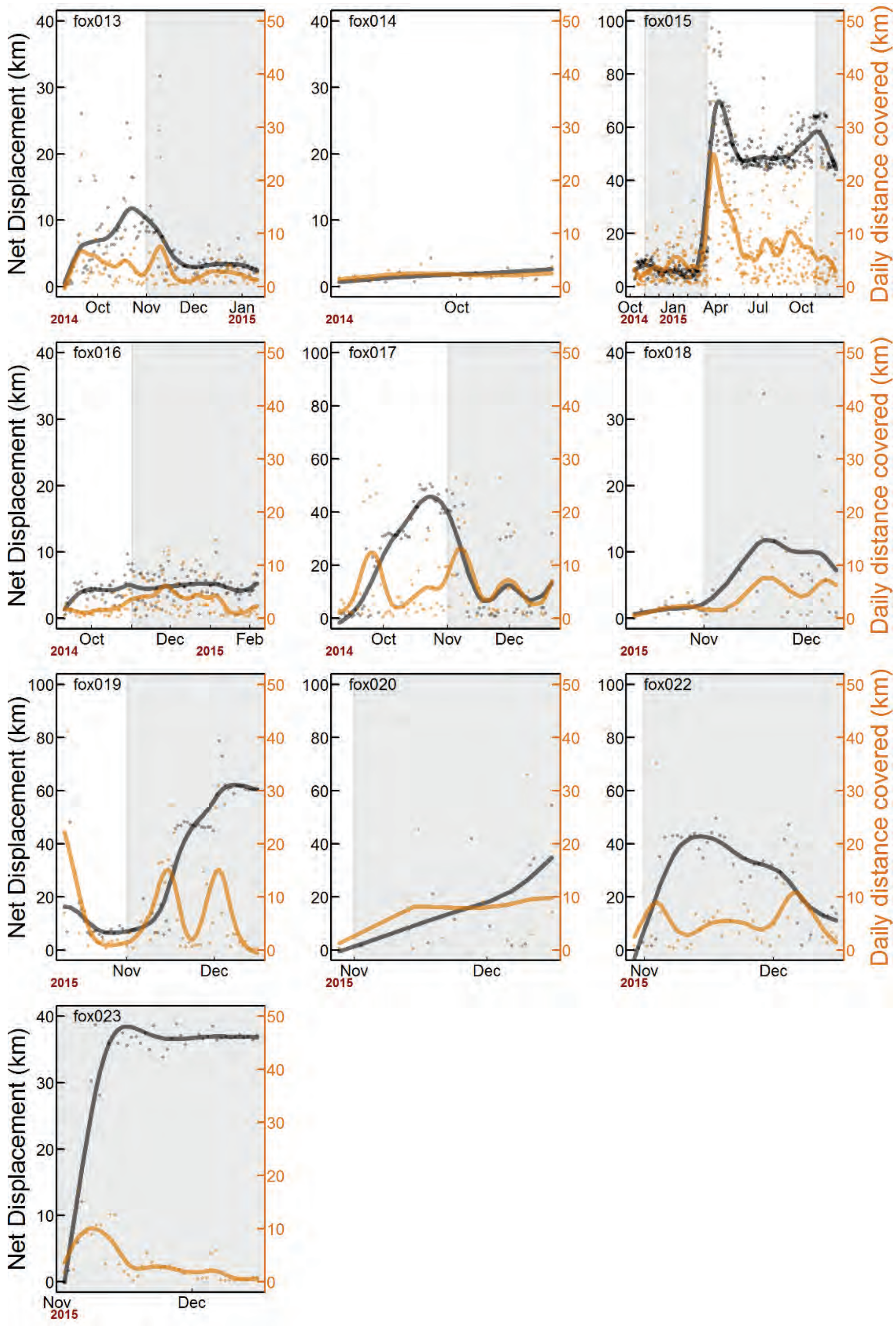


Figure 5 – Long-range movements and daily distances covered by individual arctic foxes *Vulpes lagopus* satellite-tracked in Svalbard. Each sub-plot shows the temporal variation in the Net Displacement Metric (NDM; left hand Y-axis) and in daily distance covered (right hand Y-axis) (see Methods for details). Curves are moving averages (loess smoothers) which are presented only for descriptive purposes, both for the NDM (black) and for the daily distance covered (orange). The shaded areas indicate the periods when harvesting (fox trapping) is allowed. Individual # fox021 is not represented, due to lack of good-quality location data. Note that the scales vary among subplots.

3.4 Concluding remarks

The project has improved our knowledge of seasonal spatial ecology (autumn, winter and spring) of the arctic fox and contributed essential information for the overall understanding and management of this species in Svalbard.

There were huge variations between individual home range sizes which ranged from 54,9 to 891,8 km^2. Daily fox movements ranged from 0.5 to 72.6 km, and the longest movement distance was 275 km. No foxes left Spitsbergen during the tracking period. To avoid trapping of satellite collared foxes, we deployed satellite collars on foxes south of the trapping areas. Still - three of the satellite foxes were captured in the annual trapping, however, we got back the satellite tag and were able to re-use the collar. The 25 trapping areas cover a total area of 998,8 km^2, with an average size of each trapping area of 39.9 km^2. The trappers use baited traps with ptarmigan heads, reinder meat or fat, or other smelly food to allure foxes to the traps. From the Canadian Arctic it is shown that arctic foxes can detect a potential food supply on a distance that varies between 10 and 40 km (Lai et al. 2015). Based on the home range sizes, the movements made by the foxes in the present study, and the potential detection distances for arctic foxes for baited traps, indicate that it is likely that arctic foxes can move in from areas quite far away from the trapping areas. Good reproduction areas outside the trapping terrains which provide juveniles that can migrate over large areas (Ehrich et al. 2012) will act as “source areas” of importance for maintaining the arctic fox population in the trapped areas (“sink areas”).

The huge variation in home range sizes both within and among individuals, as well as variation in movements in the present study made it difficult to detect clear patterns in space use. Therefore we suggest to increase the number of satellite collared foxes in Svalbard in the future to improve the exisitng data on spatial movements of arctic foxes.

Despite uncertainties in our results, we have enough documentation to recommend that the present number and sizes of the trapping areas used in the annual trapping of arctic foxes in Svalbard should not change or increase in number or size. Due to both the high mobility and detection range of arctic foxes, trapping areas have the potential to attract individuals from a much larger area than they actually cover.

Picture of a female arctic fox fitted with a satellite collar. Photo: E. Fuglei; Reconyx photobox

4 References

Angerbjörn A, Ströman J, Becker D. 1997. Home range patterns in arctic foxes in Sweden. J Wildl Res, 2: 9-14.

Anthony RM. 1997. Home ranges and movements of arctic fox (*Alopex lagopus*) in western Alaska. Arctic, 50: 147-157

ARGOS 2011. Argos User's manual. http://www.argos-system.org/web/en/76-user-s-manual.php. Accessed 01 November 2011

Arlov TB. 1996. Svalbards historie. H. Aschehough & Co. (W. Nygaard), Oslo, Norway.

Calenge C, Dray S, Royer-Carenzi M. 2009. The concept of animals' trajectories from a data analysis perspective. Ecol Inform 4:34-41,

Christin S, St-Laurent M-H, Berteaux D. 2015. Evaluation of Argos Telemetry Accuracy in the High-Arctic and Implications for the Estimation of Home-Range Size. PLoS ONE 10(11).

CLS 2011. Argos user's manual. Accessed on the internet at http://www.argos-system.org/manual/ on 01 November 2011.

Eberhardt LE, Hanson WC, Bengtson JL, Garrot RA, Hanson EE. 1982. Arctic fox home range characteristics in an oil development area. J Wildl Manag, 46: 132-138.

Ehrich D, Carmichael LE, Fuglei E. 2012. Age dependent genetic structure in arctic foxes in Svalbard. Polar Biol 35(1): 53-62.

Eide NE, Jepsen JU, Prestrud P. 2004. Spatial organization of reproductive arctic foxes Alopex lagopus: responses to changes in spatial and temporal availability of prey. J Anim Ecol 73: 1056-1068.

Eide NE, Stien A, Prestrud P, Yoccoz NG, Fuglei E. 2012. Reproductive responses to spatial and temporal prey availability in a coastal arctic fox population. J Anim Ecol 81: 640-648.

Frafjord K, Prestrud P. 1992. Home range and movements of arctic foxes Alopex lagopus in Svalbard. Polar Biol, 12: 519-526.

Fuglei E, Øritsland NA, Prestrud P. 2003. Local variation in arctic fox abundance on Svalbard, Norway. Polar Biol 26: 93-98.

Fuglei E, Meldrum EA, Ehrich D. 2013. Effekt av fangst – fjellrev på Svalbard. Sluttrapport til Svalbards Miljøvernfond, 30 sider.

Hansen BB, Grøtan V, Aanes R, Sæther B-E, Stien A, Fuglei E, Ims RA, Yoccoz NG, Pedersen ÅØ. 2013. Climate Events Synchronize the Dynamics of a Resident Vertebrate Community in the High Arctic. Science 339: 313-315.

Hersteinsson P, Macdonald DW. 1982. Some comparisons between red and arctic foxes *Vulpes vulpes* and *Alopex lagopus* as revealed by radio tracking. Proc Royal Soc Lond, 49: 259-288.

Ims RA, Alsos IG, Fuglei E, Pedersen ÅØ, Yoccoz NG. 2014. An assessment of MOSJ – The state of the terrestrial environment in Svalbard. Norwegian Polar Institute, Report Series no. 144, p 42.

Lai S, Bêty J, Berteaux D. 2015. Spatio-temporal hotspots of satellite-tracked arctic foxes reveal a large detection range in a mammalian predator. Movem Ecol 3:37.

Ministry of Climate and Environment. 2012. Svalbard Environmental Protection Act http://www.sysselmannen.no/Documents/Sysselmannen_dok/English/Legacy/LOV-2001-06-15-79%20Svalbardmilj%c3%b8vern_2012_eng.pdf

MOSJ, Environmental Monitoring of Svalbard and Jan Mayen (http://www.mosj.no/en/).

Novaro AJ, Funes MC, Walker S. 2005. An emoirical test of source-sink dynamics induced by hunting. J Appl Ecol 42: 910-920.

Nybakk K, Kjørstad M, Overskaug K, Kvam T, Linnell JDC, Andersen R, Berntsen F. 1996. Experiences with live-capture and radio collaring of lynx (*Lynx lynx*) in Norway. Fauna Norw Ser A, 17: 17-26.

Pamperin NJ, Follmann EH, Person BT. 2008. Sea-ice use by arctic foxes in northern Alaska. Polar Biol 31(11): 1421-1426.

Pulliam HR 1988. Source, sinks, and population regulation. Am Nat 132: 652-661.

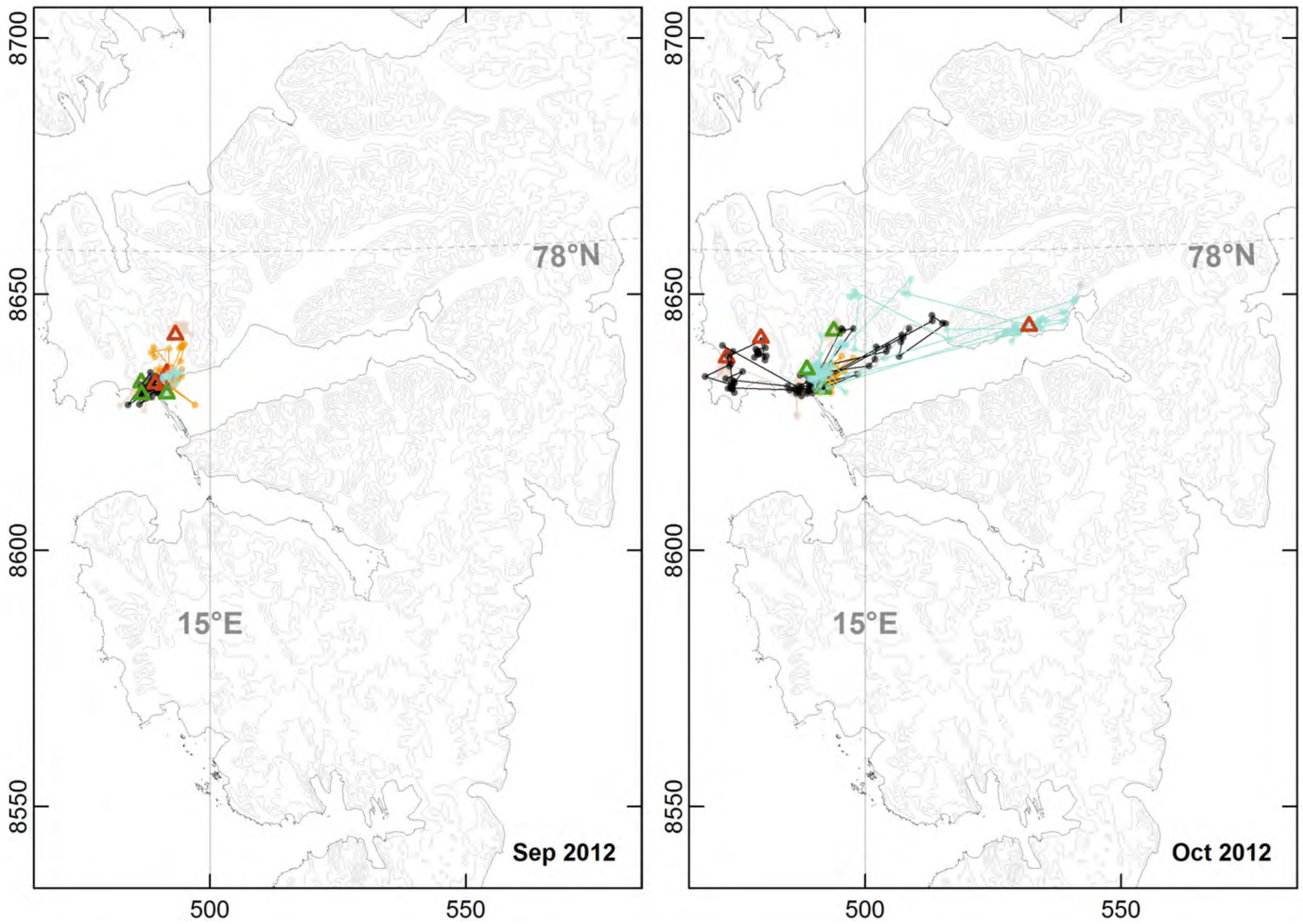
R Development Core Team. 2015. R: a language and environment for statistical computing. In: R Foundation for Statistical Computing (ed), Vienna, Austria.

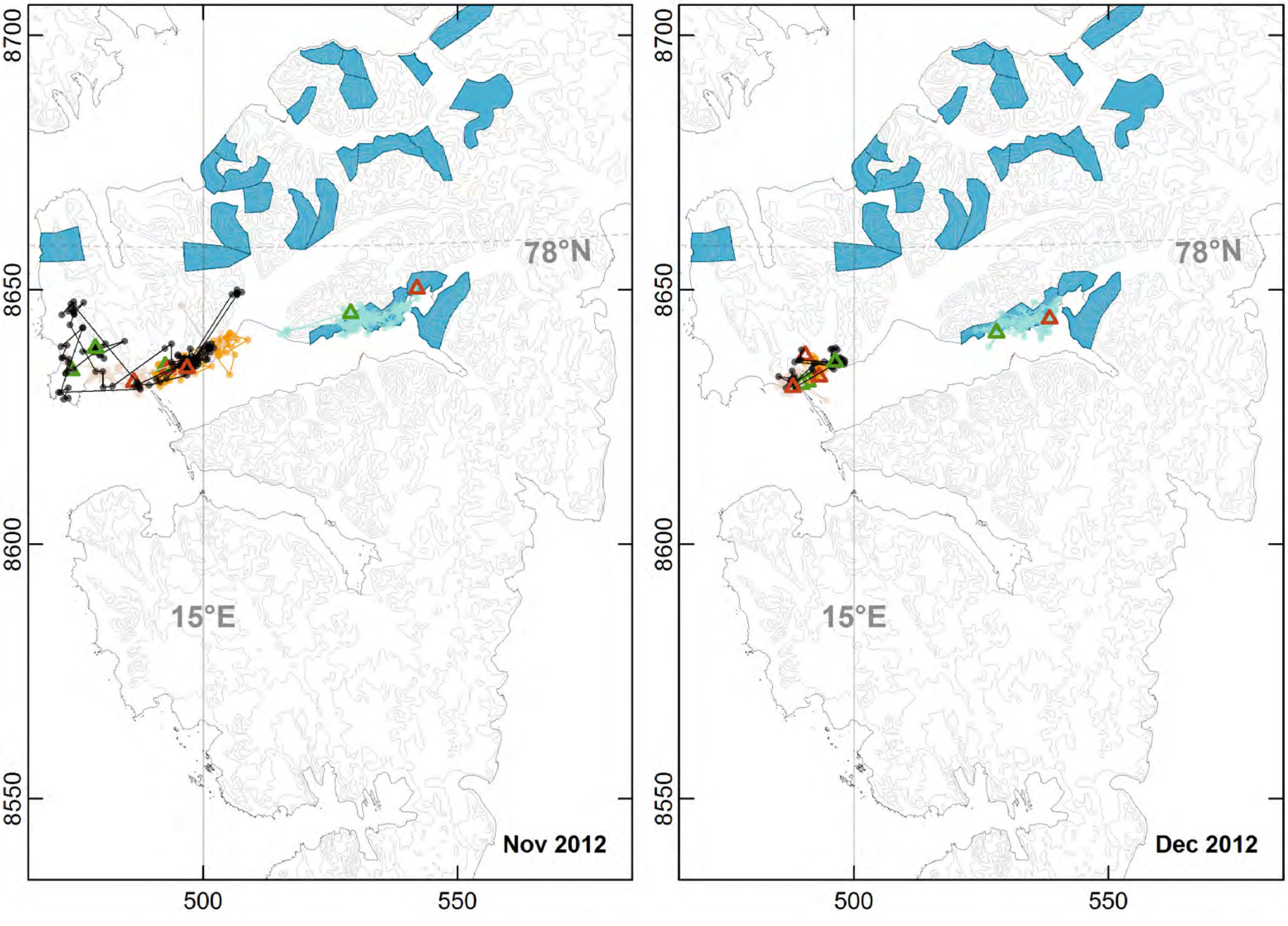
The Governor of Svalbard. 2013. Regulations relating to harvesting of the fauna on Svalbard (http://www.sysselmannen.no/Documents/Sysselmannen_dok/English/Regulations/Regulations_FOR-2002-06-24-712_Hosting_Svalbard_2009_eng__2__8hmdY.pdf)

Tarroux A, Berteaux D, Bety J. 2010. Northern nomads: ability for extensive movements in adult arctic foxes. Polar Biol 33: 1021-1026.

Appendix

Figure A1 – Monthly movements of arctic foxes satellite-tracked in Svalbard, from September 2012 to December 2015 (shown on 37 maps). Green and red triangles indicate the first and last position for a given individual respectively. Some months are missing, owing to absence of data. Each individual was attributed a unique colour for easier reference on successive maps. Argos tracking data were filtered in order to exclude unlikely locations (see methods for details). Map projection is UTM 33N (WGS84).

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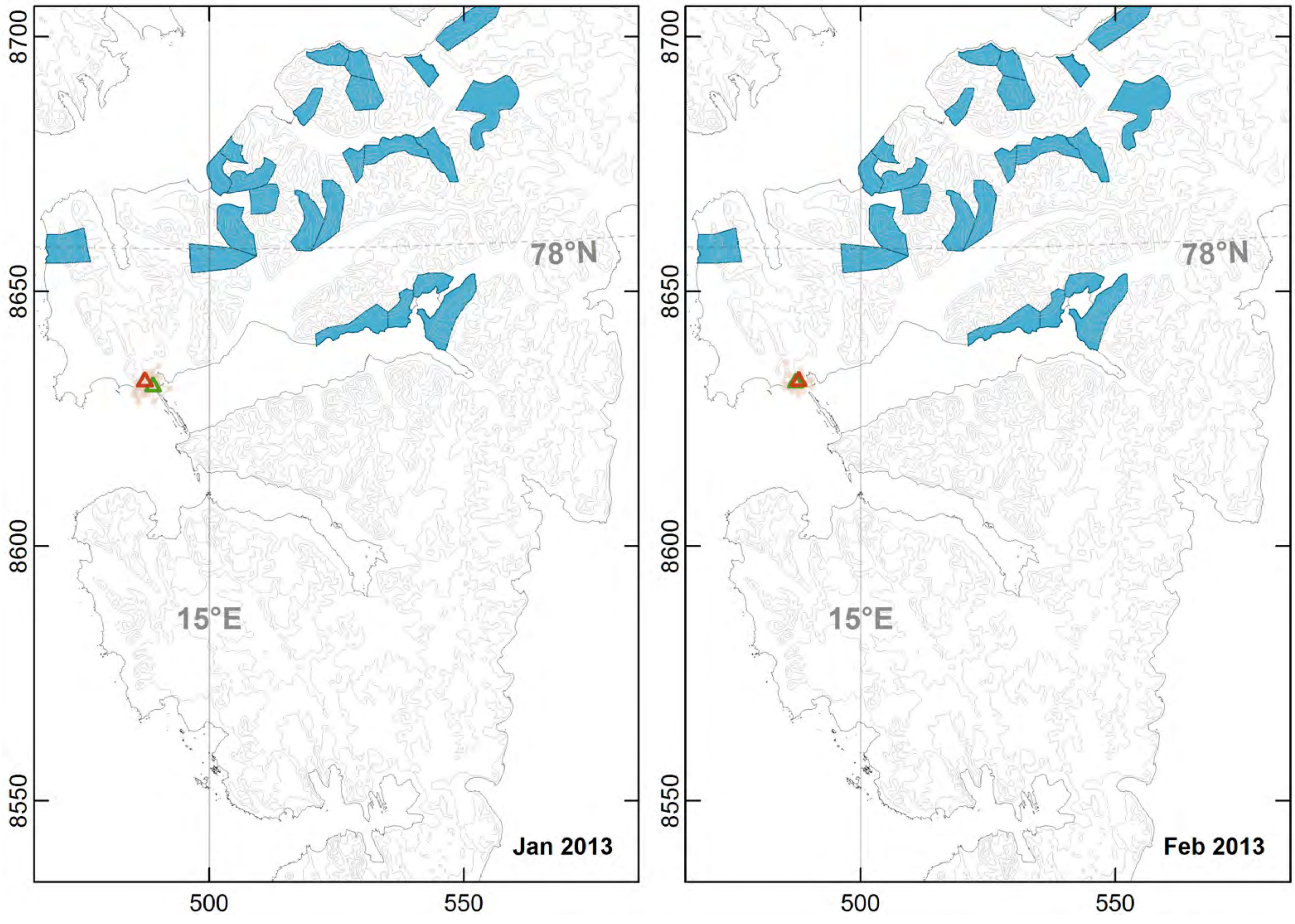
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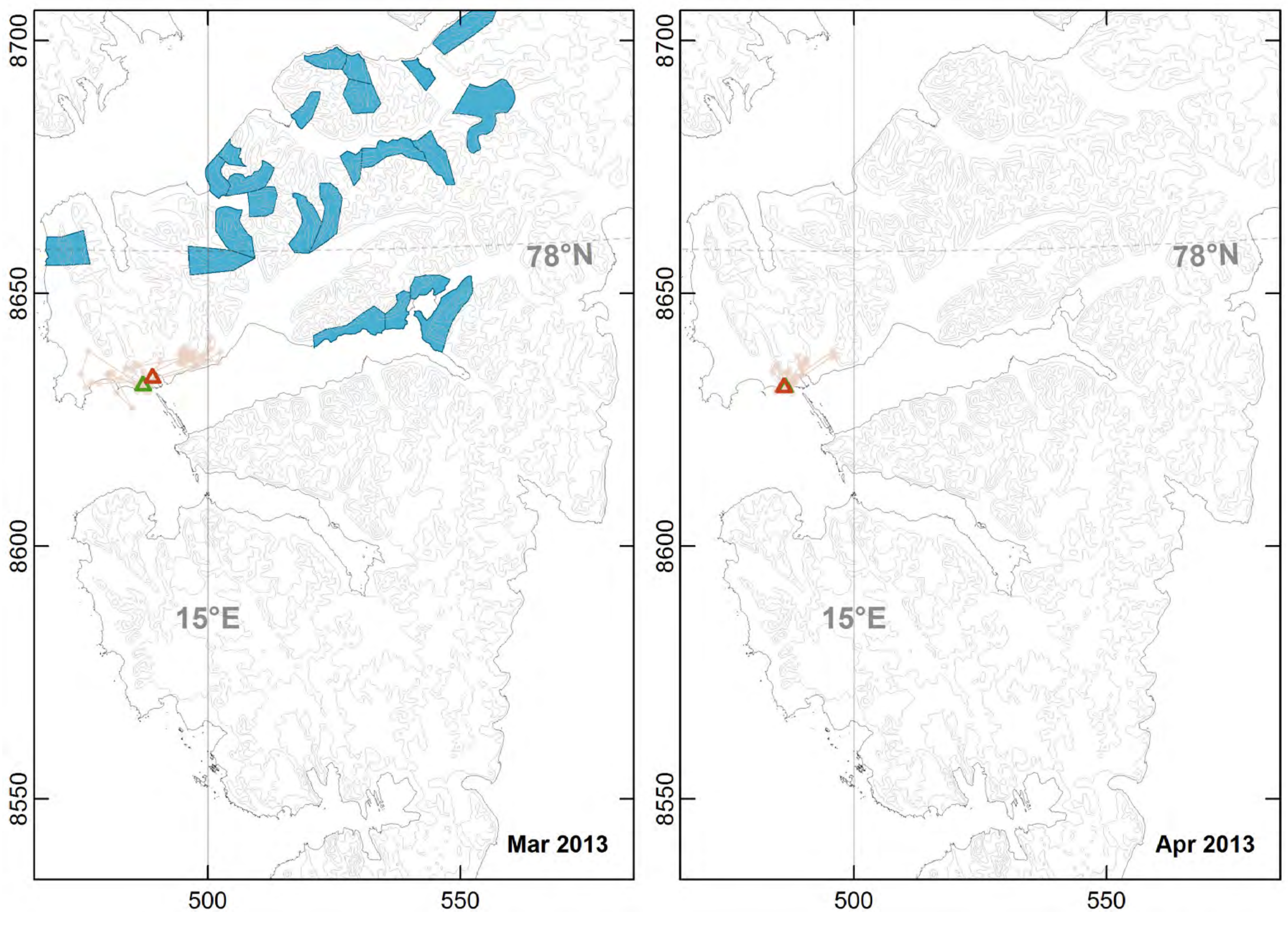
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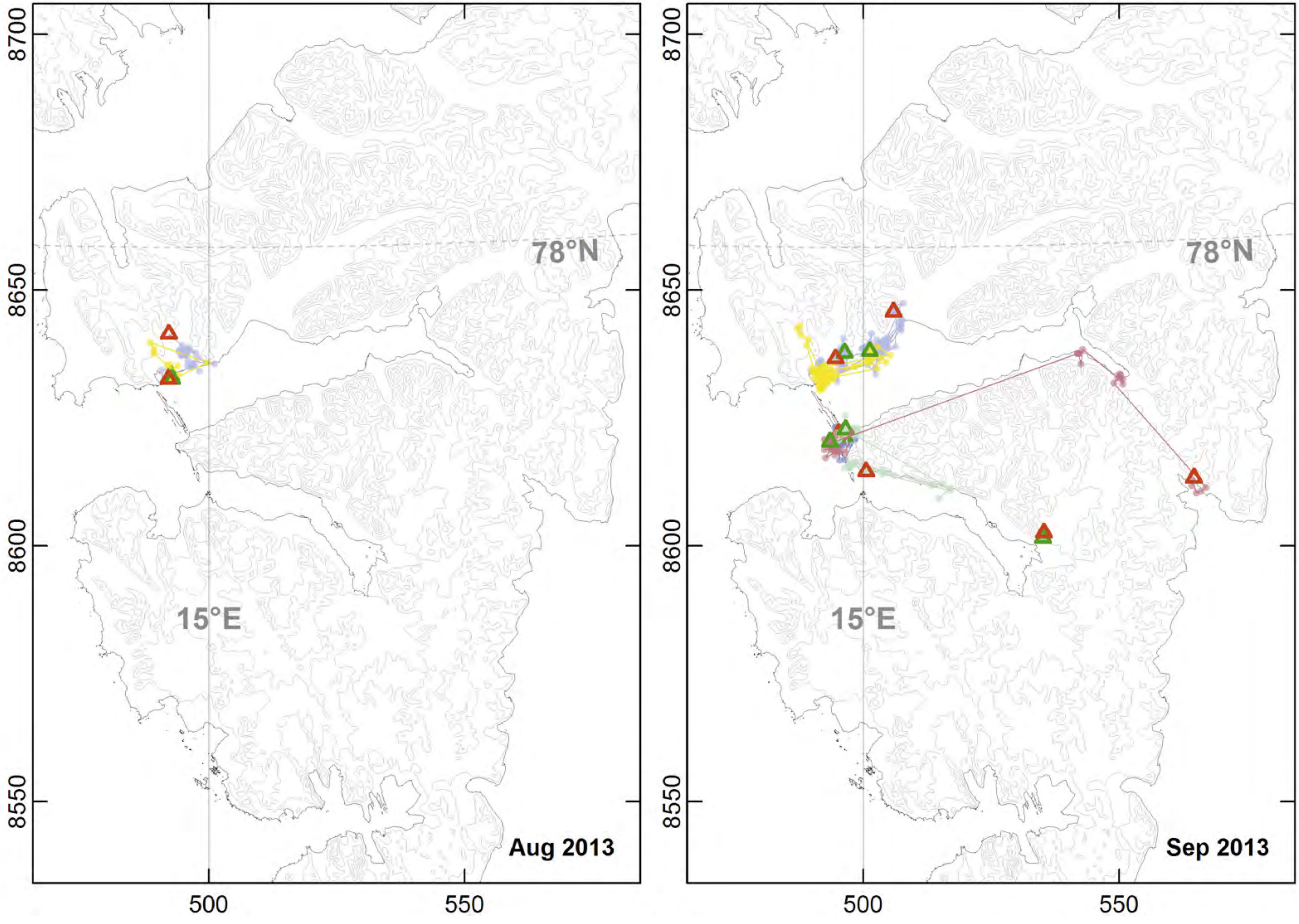
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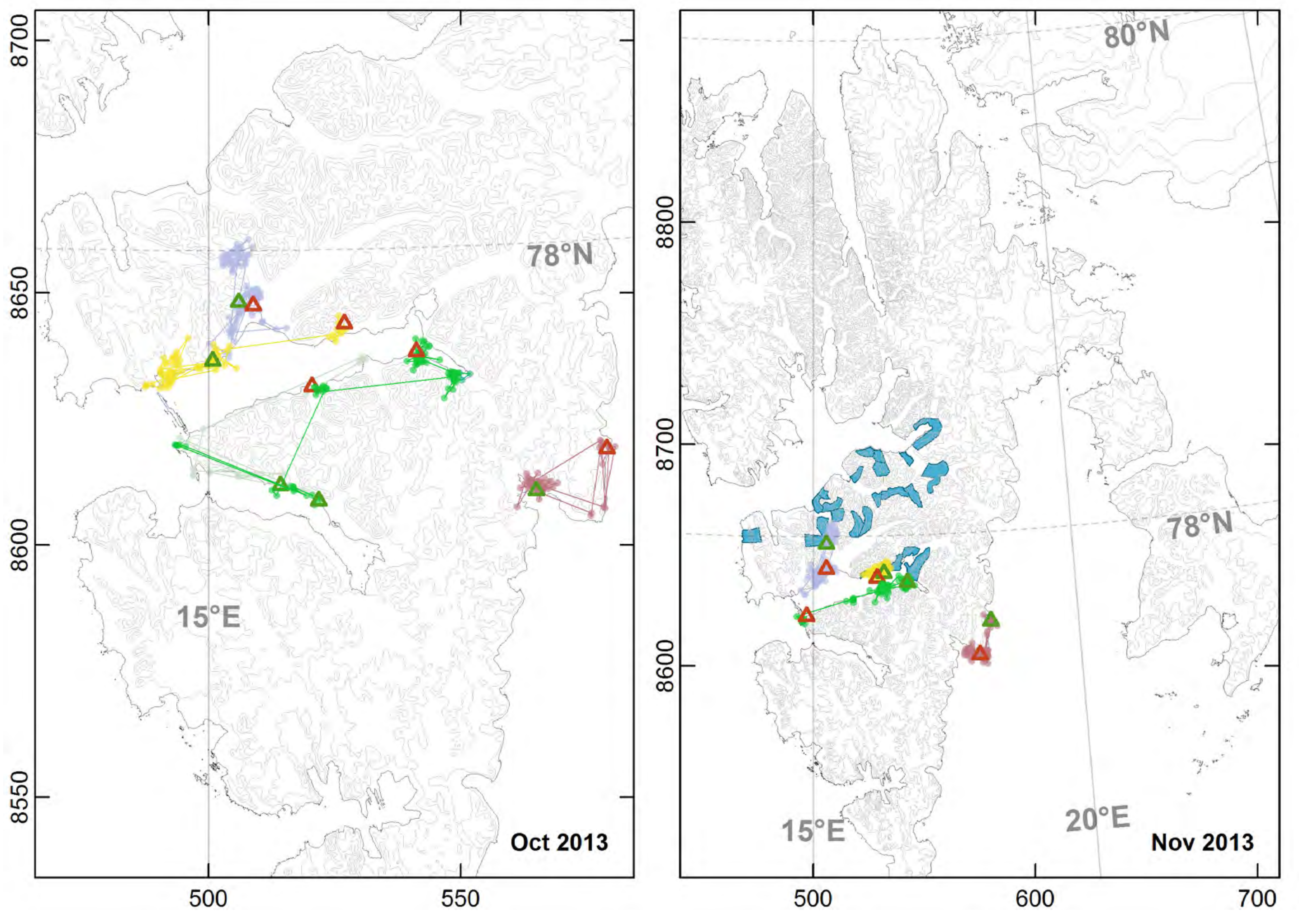
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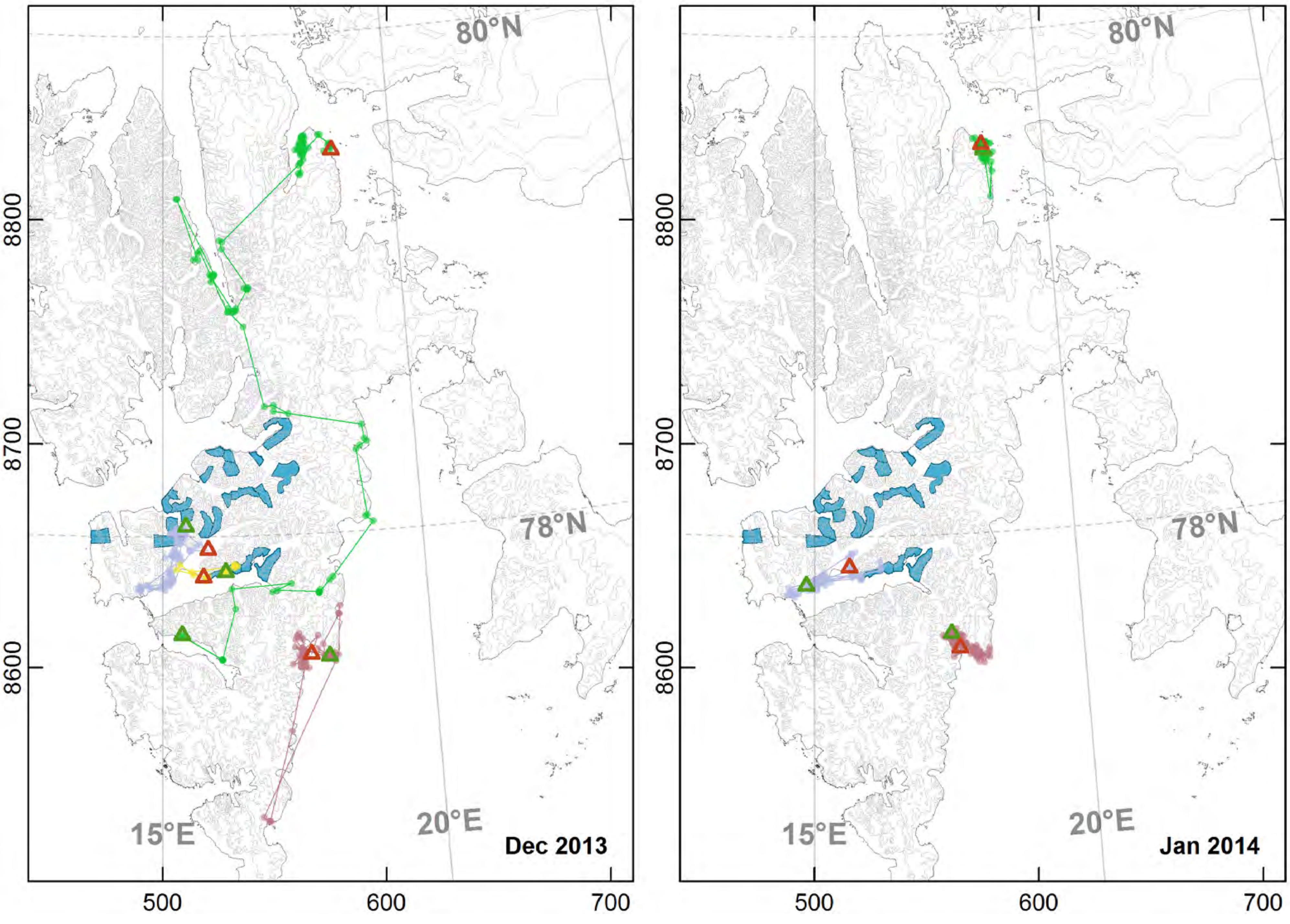

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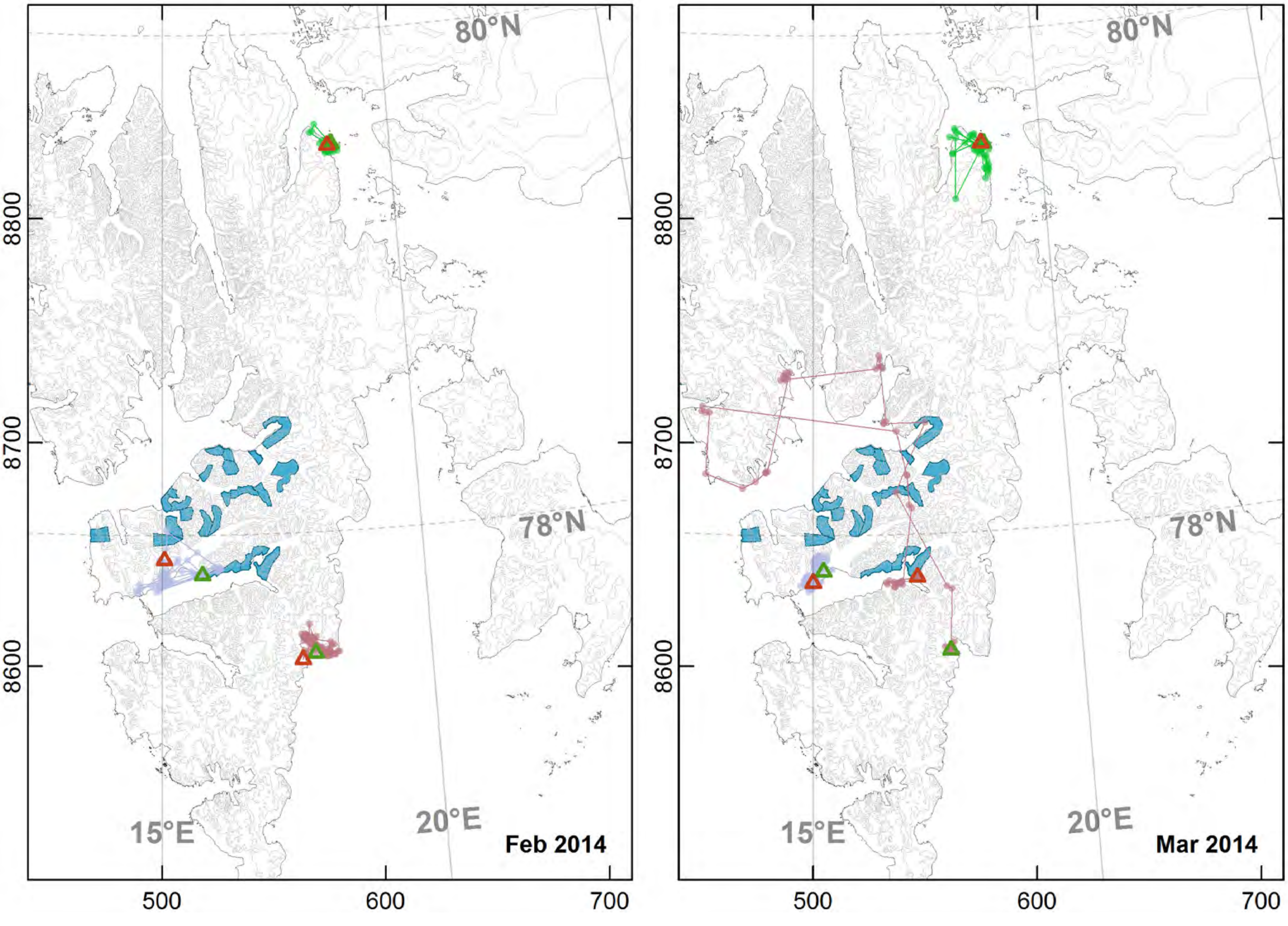

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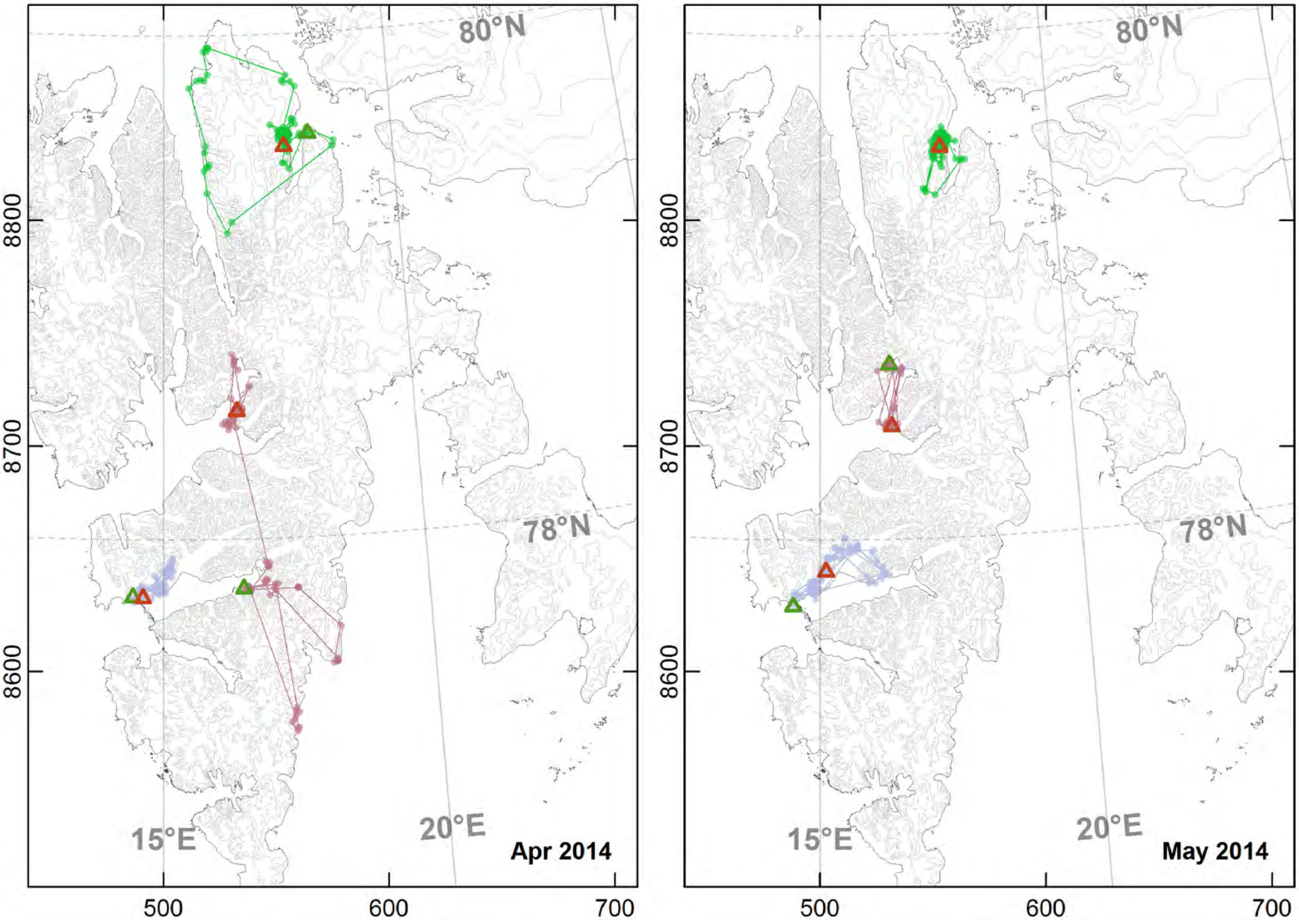

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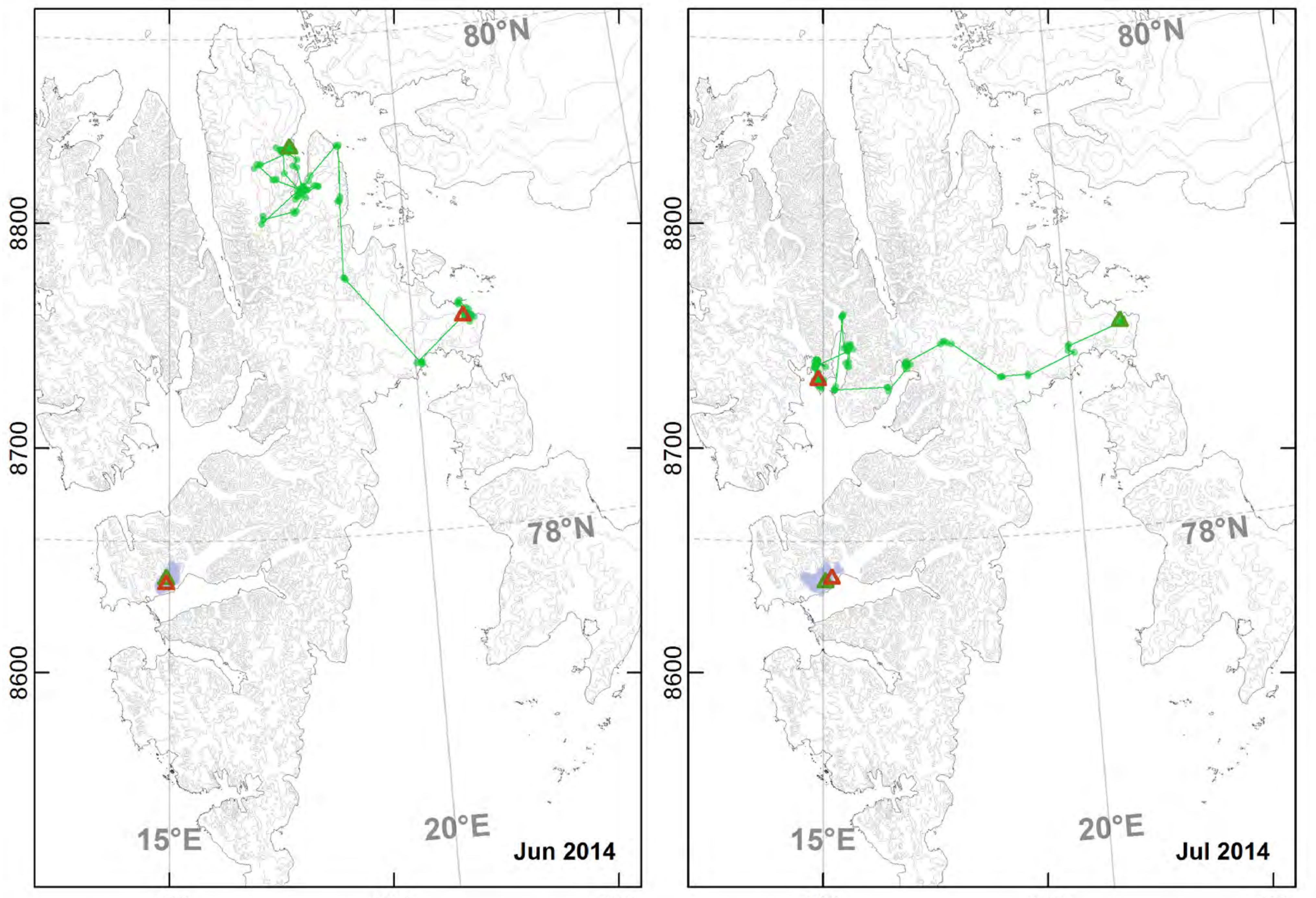

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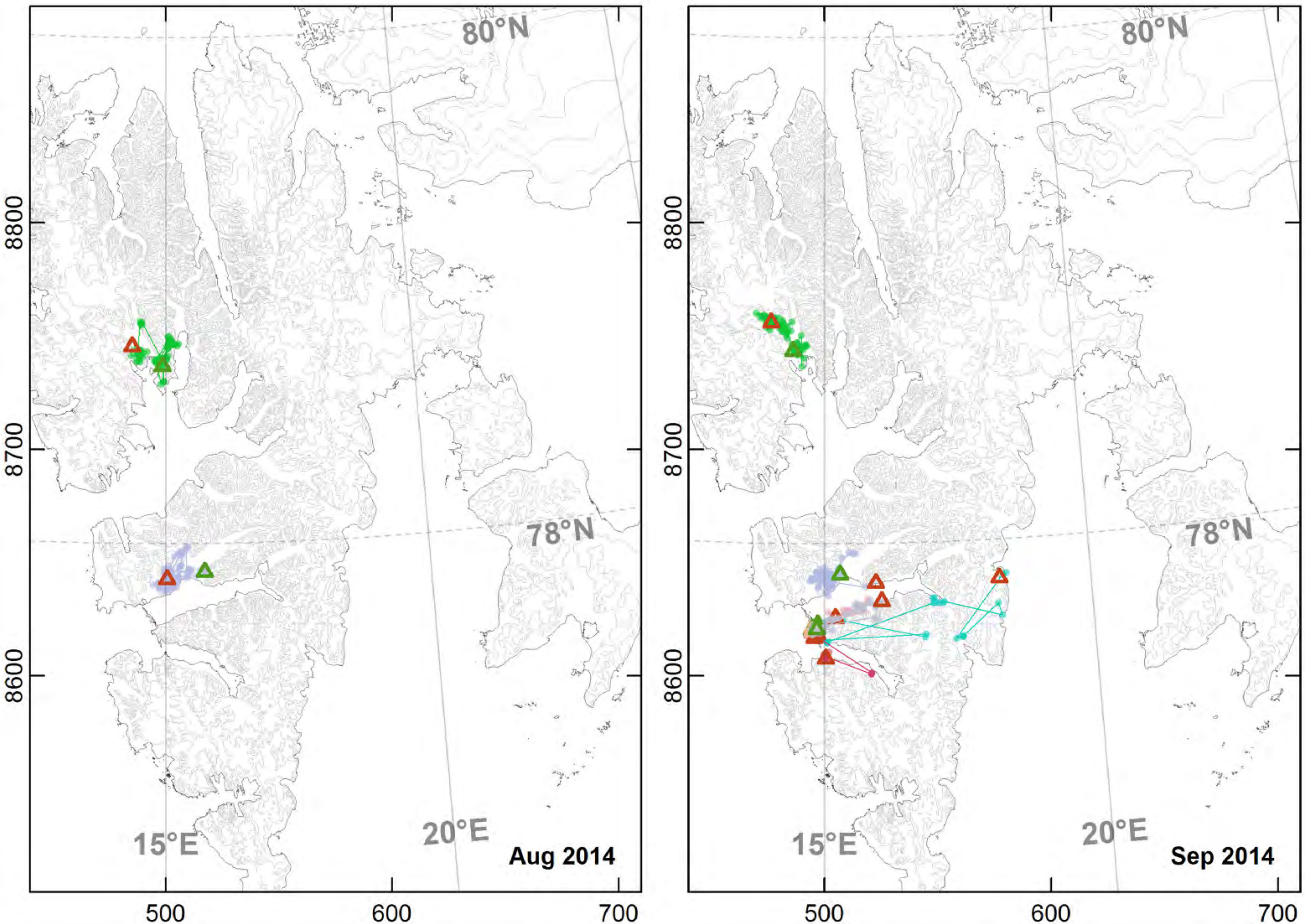
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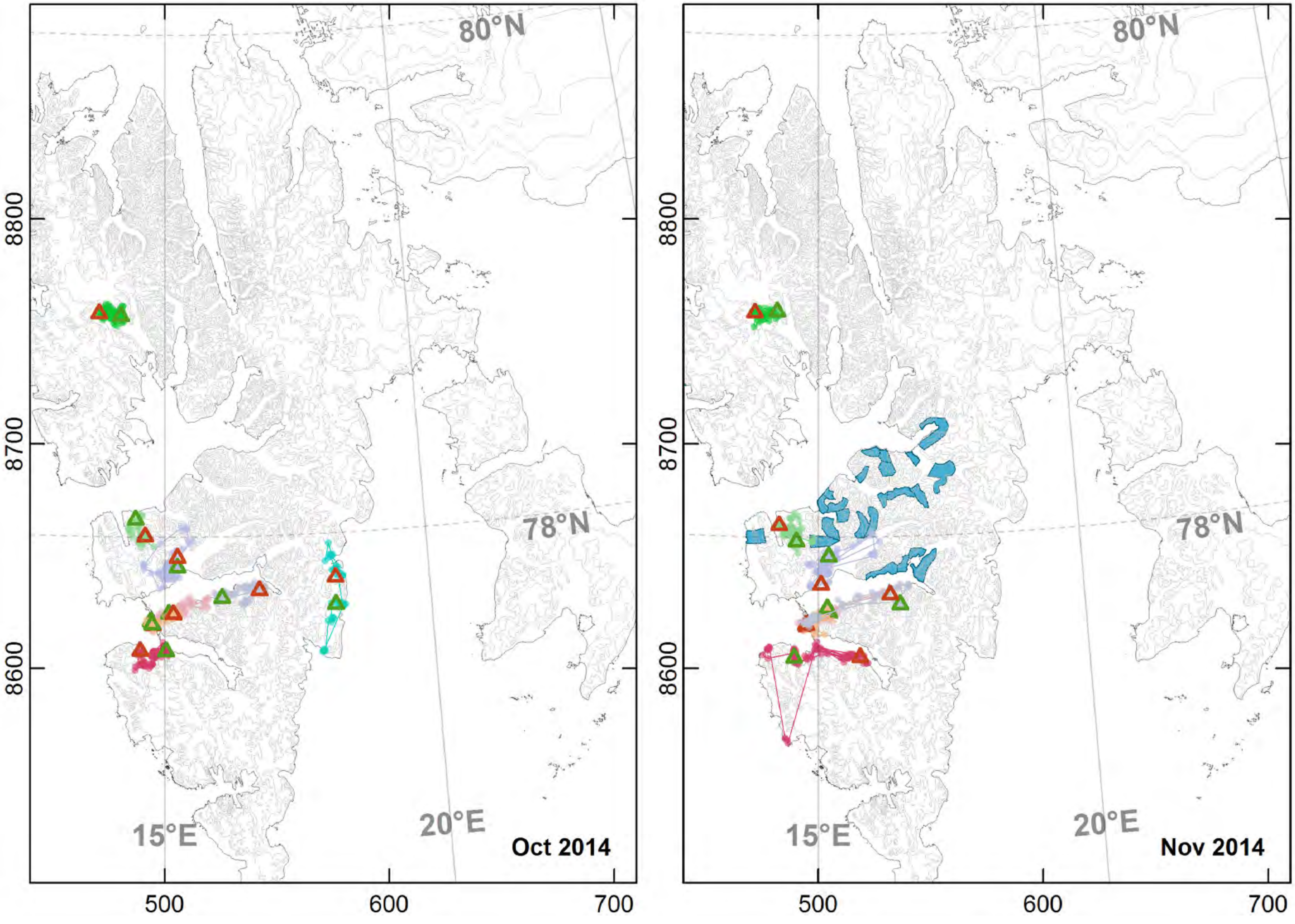

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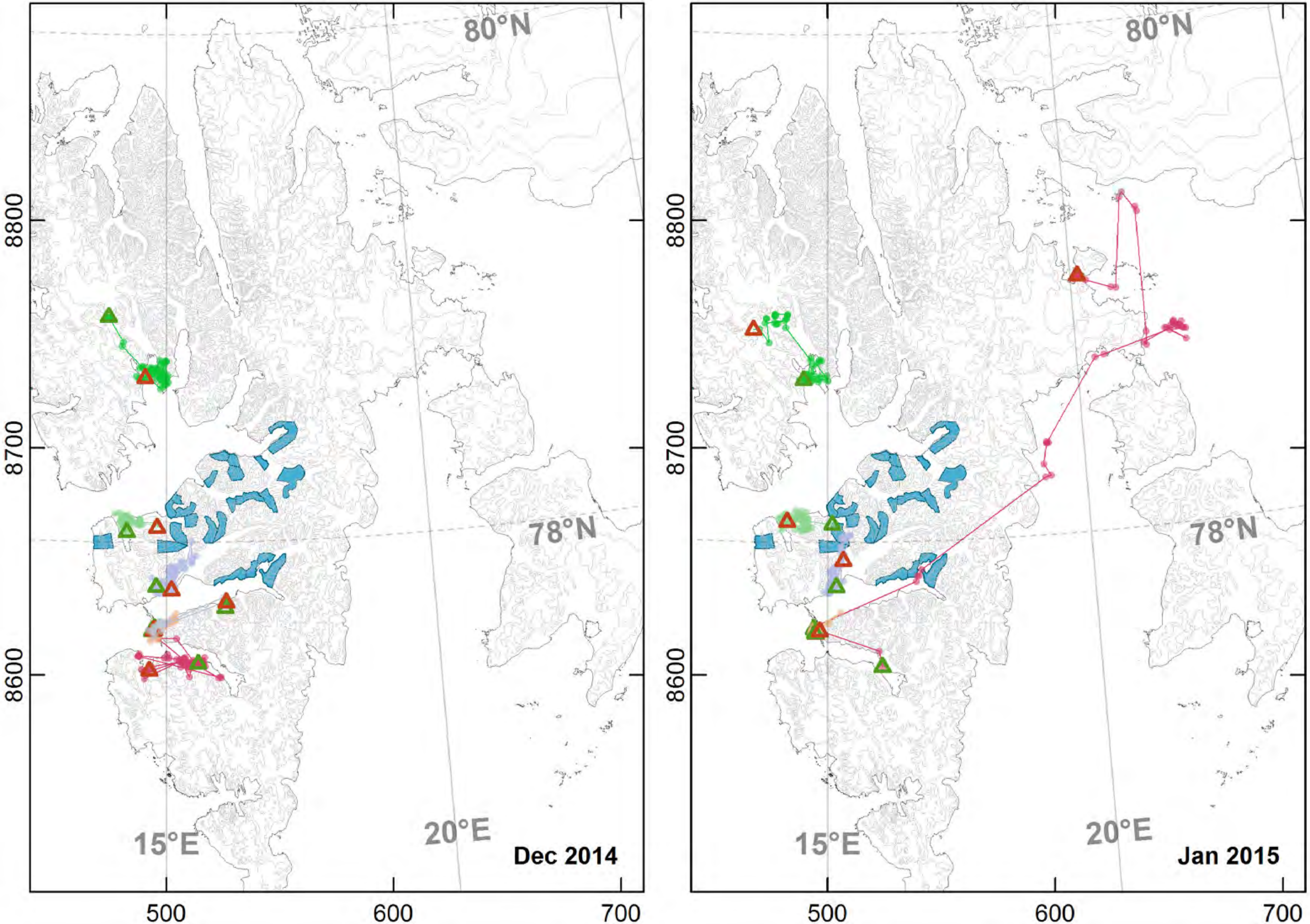
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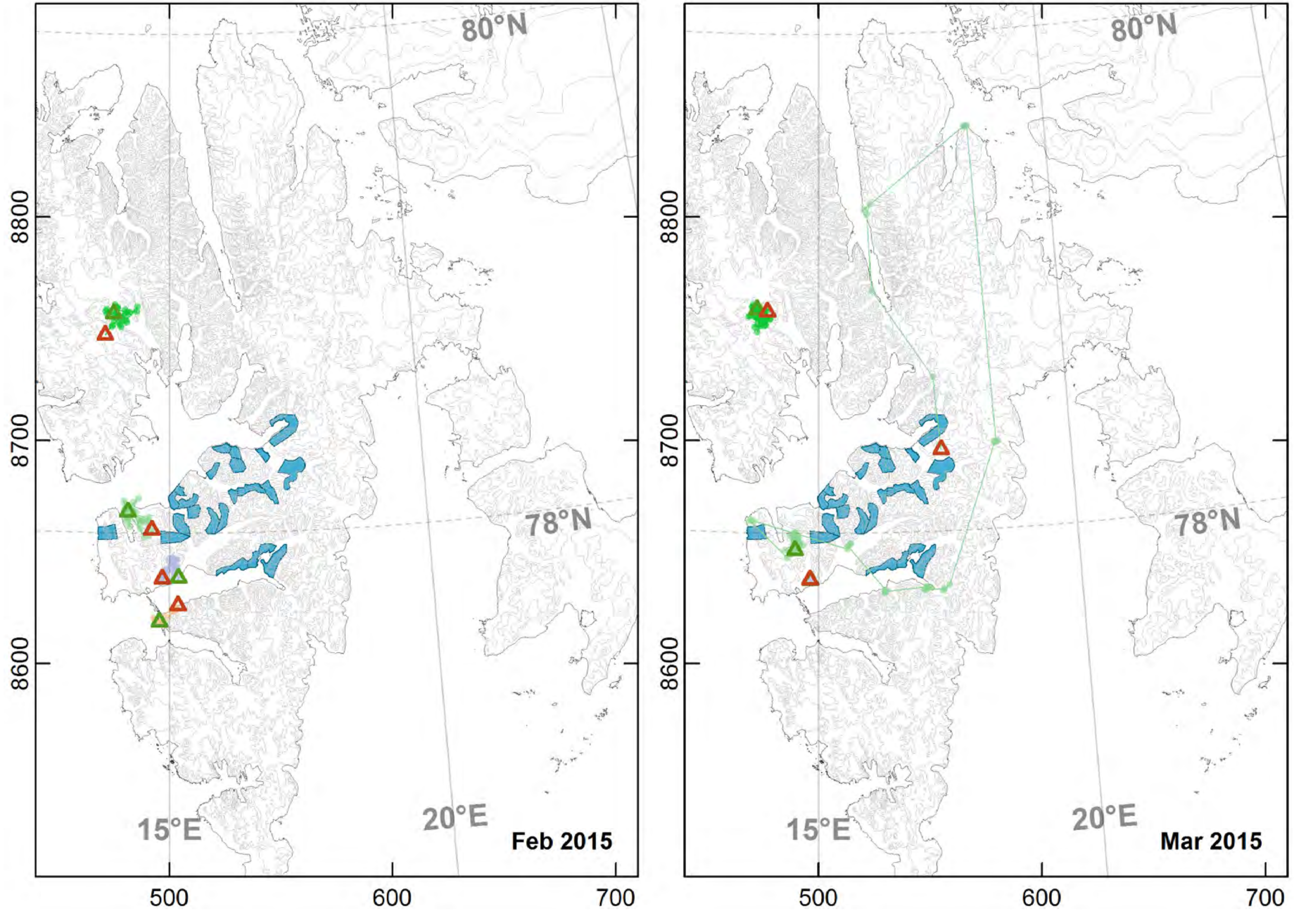
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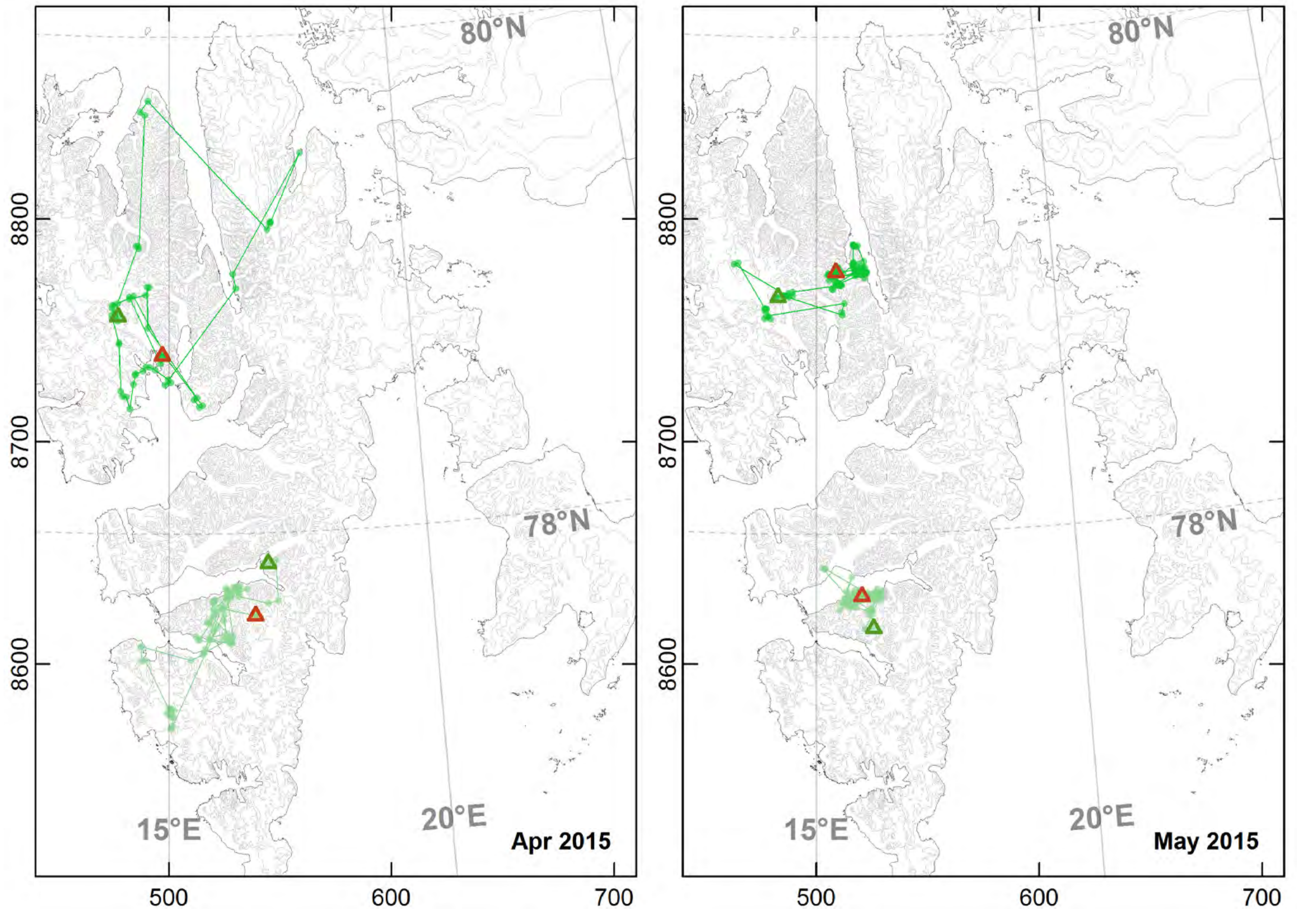
Mar 2015



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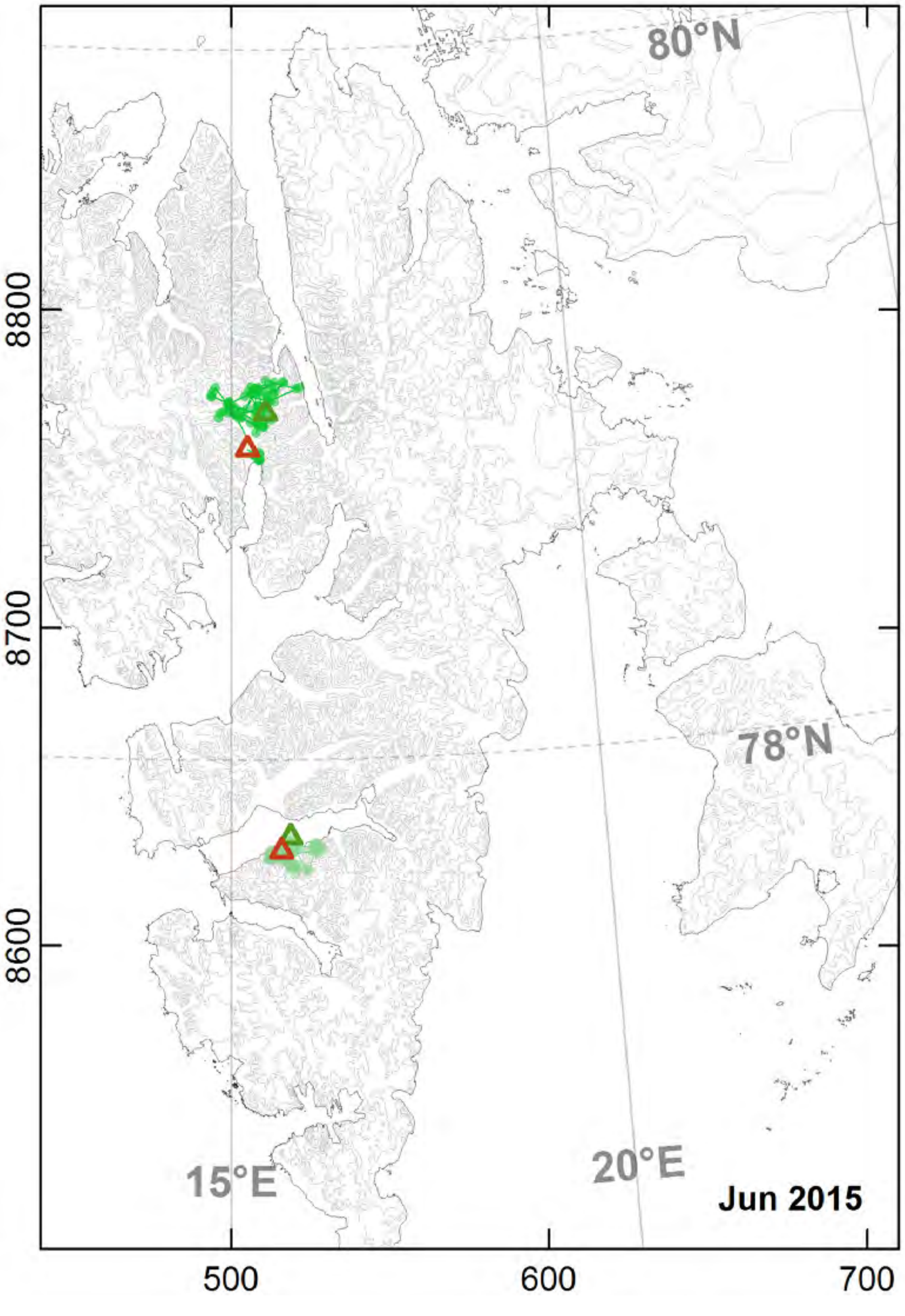
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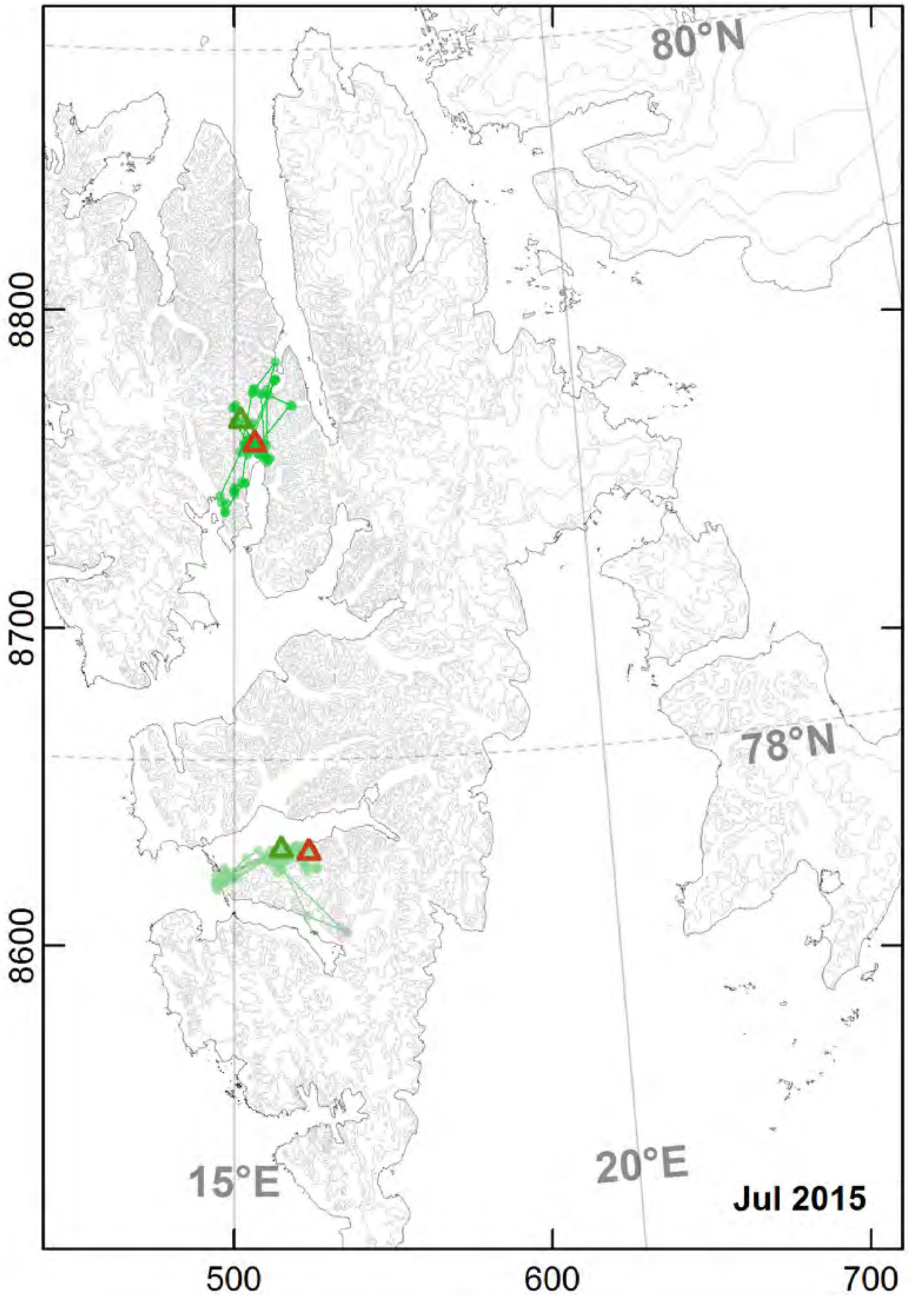
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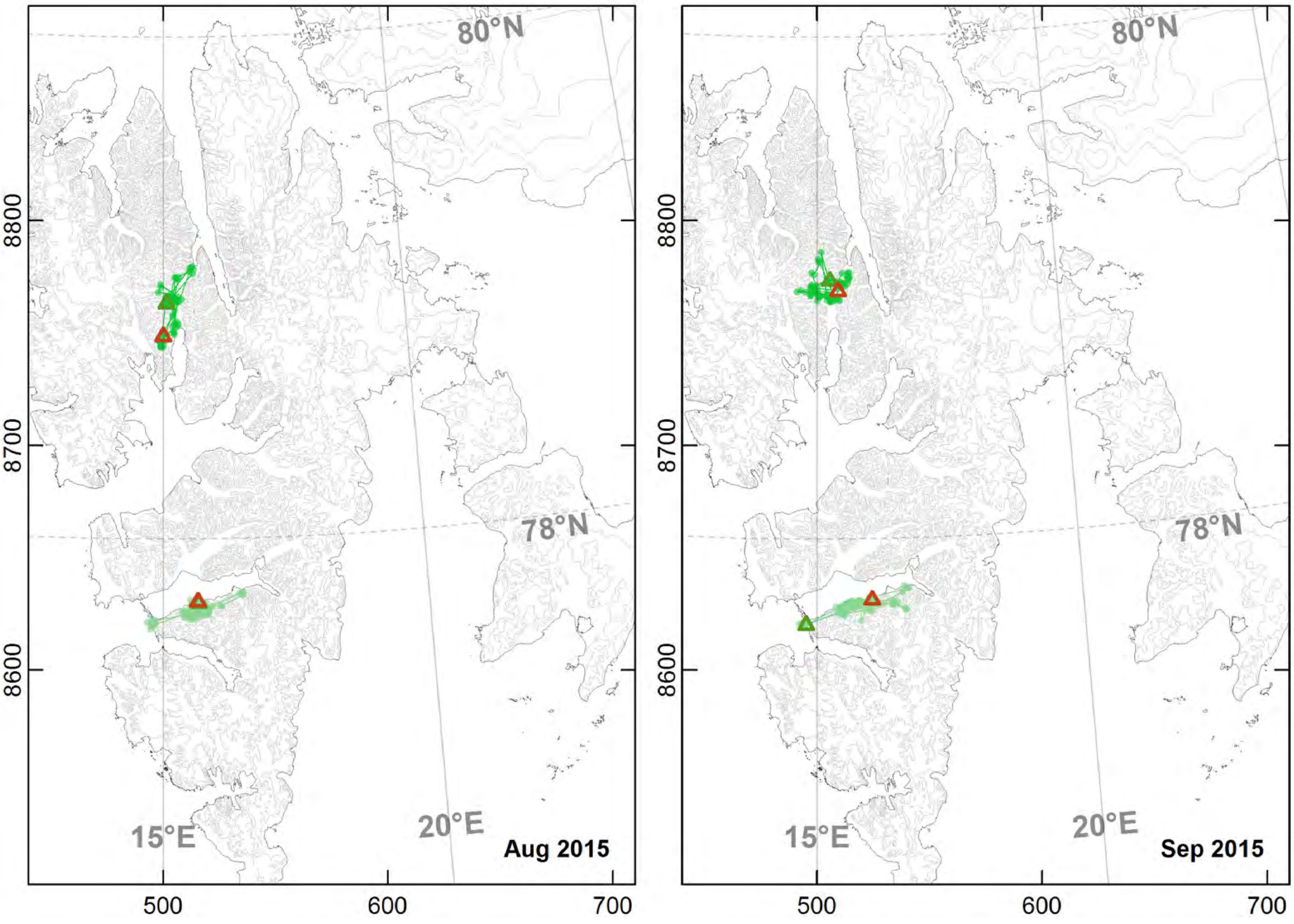
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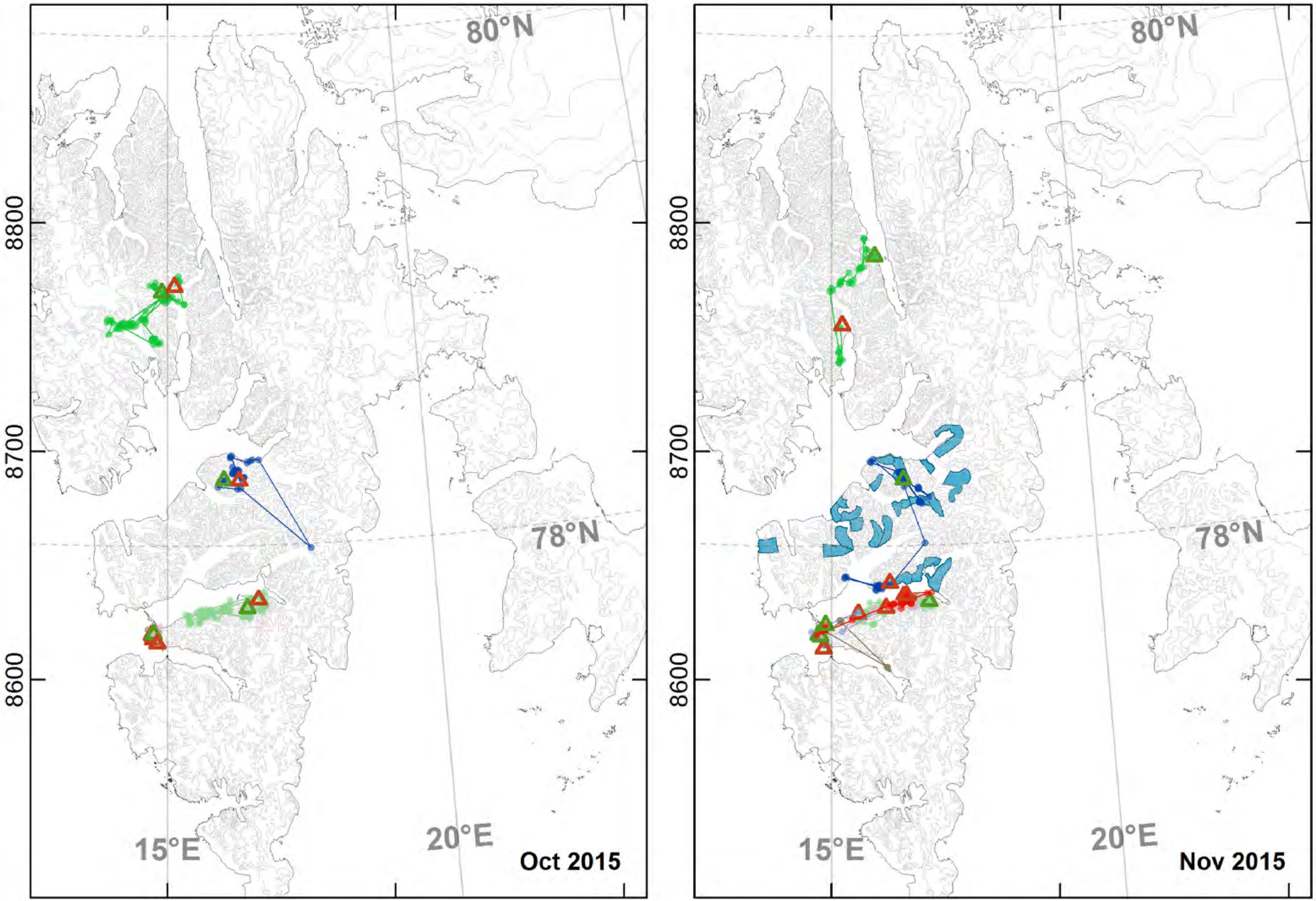

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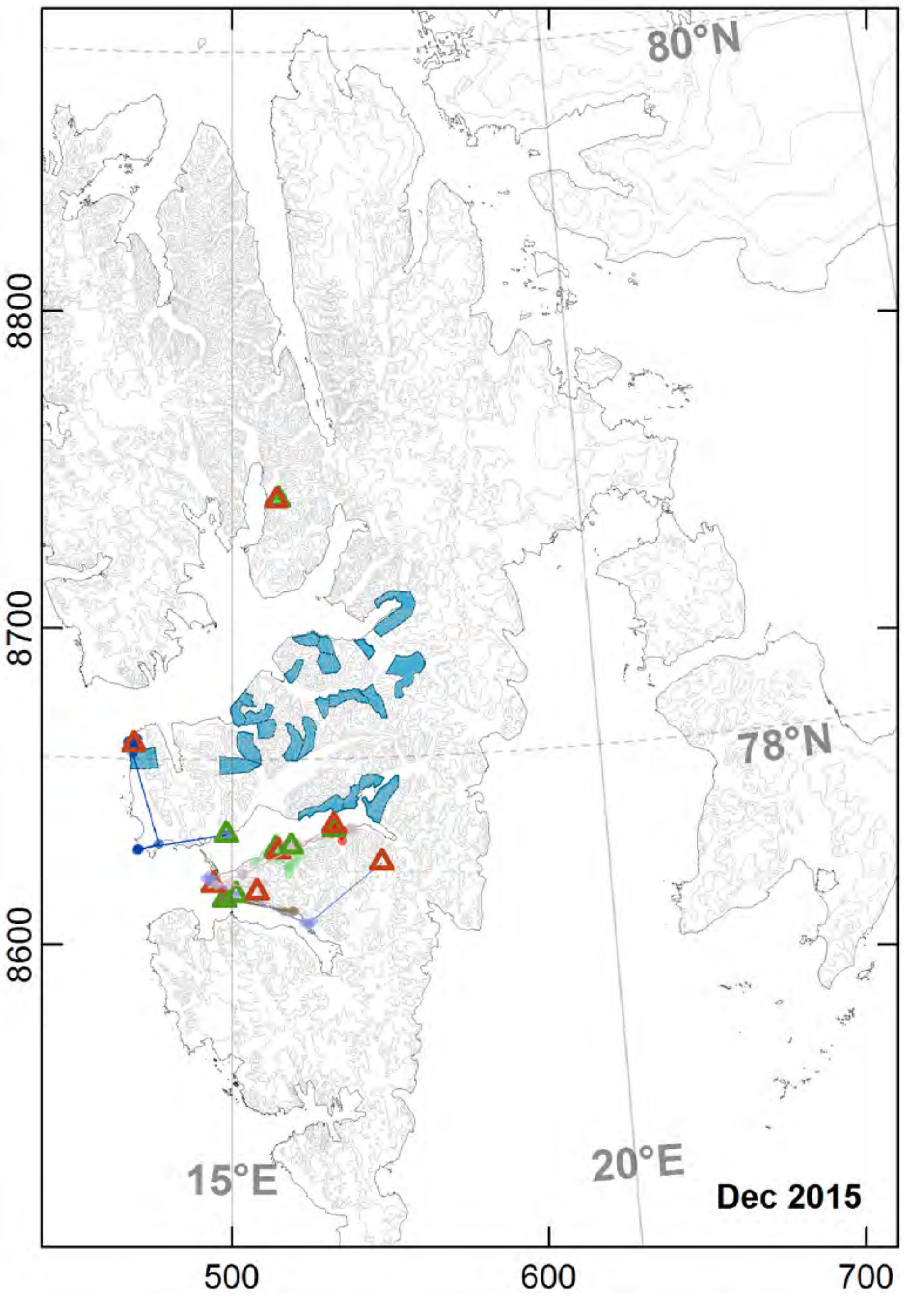
600
700


80°N
78°N
15°E
20°E
Dec 2015
8800
8700
8600
500
600
700

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