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Canadian Magnetic Observatory Network Equivalent Currents for 13-14 March 1989

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Canadian Magnetic Observatory Network: Equivalent Currents for 13-14 March 1989

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ABSTRACT

Equivalent overhead electric currents are calculated for the magnetic field variations observed in Canada during the magnetic disturbance of 13-14 March 1989. Plots of these equivalent currents show the spatial variation at a particular instant in time and are a useful technique for studying the evolution of magnetic disturbances. Amongst other features, the plots indicate that the major magnetic field changes observed at the lower latitude observatories were produced by the rapid intensification of an in-situ current system, not by movement of a current system from higher latitudes. The high electric currents induced by these magnetic field variations were the cause of the power system problems experienced in Canada and the U.S. during this disturbance.

RESUMÉ

Les courants électriques équivalents sont calculés pour les variations du champ magnétique observées durant la perturbation magnétique du 13 - 14 Mars 1989. Les graphiques de ces courants équivalents montrent la variation spatiale à un moment particulier dans le temps. Cette technique est très utile pour étudier l'évolution des perturbations magnétiques. Parmi les autres avantages, les graphiques indiquent que les changements majeurs du champ magnétique, enregistrés dans les observatoires de latitude inférieure, étaient produits par une intensification rapide d'un système courant intérieur et non pas par le déplacement d'un système courant provenant de latitudes supérieures. Les forts courants induits par les variations du champ magnétique durant la perturbation étaient la cause des problèmes ressentis par les systèmes de distribution au Canada ainsi q'aux Etats-Unis.

Introduction

To monitor the magnetic field over Canada, the Geomagnetism Program of the Geophysics Division of the Geological Survey of Canada operates thirteen permanent magnetic observatories at the locations shown in Figure 1 (Jansen van Beek et al., 1986). At these sites measurements are made, at one minute intervals, of the geographic north (X) and east (Y) and vertical (Z) components of the magnetic field. Magnetic field variations away from the normal "quiet" level can be interpreted in terms of "equivalent" electric currents in the ionosphere 100 km above the observatory. Plots of these currents provide a record of the spatial variation at a particular instant in time that is complementary to the classical picture of the time variation at a particular location provided by a magnetogram.

During March 13 and 14, 1989, Canada, and the rest of the world, experienced a major magnetic disturbance which had serious consequences. This magnetic disturbance, one of the five most severe storms of the past fifty years produced a magnetic variation in Ottawa of over 2000 nT and a planetary magnetic index Ap value of 246. Electric currents induced in power lines by the magnetic field variations caused a blackout of the Hydro-Quebec power system (Czech, 1989) and burn out of power transformers in the eastern United States. Other effects of the magnetic storm included disruption of magnetic survey work, blackout of radio communications, and problems with satellite operation (Allen et al, 1989). In this report, equivalent current plots are presented to show the intensity, location, and extent of the magnetic disturbance across Canada.

Calculation of Equivalent Currents

During a magnetic disturbance large electric currents are produced by the interaction of the solar wind with the earth's magnetic field and can flow down to the ionosphere, 100 km above the surface of the earth. The fluctuating electric currents produce a varying magnetic field that, in turn, induces electric currents in the earth. These induced currents also produce a magnetic field and it is the combined magnetic field due to the external and internal currents that is observed at the earth's surface as a magnetic disturbance. For a layered earth, the internal currents produce a magnetic field that tends to increase the horizontal component and decrease the vertical component due to the external currents. However, in practice, the local geological structure near an observatory can produce induced current concentrations that further distort the recorded magnetic field. These distortions are particularly severe in the vertical component of the magnetic field making this unreliable for use in determining external currents. Thus for this work only the horizontal components of the magnetic field variation are used to produce an equivalent current that is located directly above the observatory.

To compute the equivalent currents for a particular geomagnetic disturbance, the magnetic variation is determined by subtracting a "quiet" level from each magnetic recording. The quiet level is determined by selecting a recent undisturbed time and calculating the average of the hourly means for that interval. To obtain the "external" part of this magnetic variation it is assumed, based on data presented by Chapman and Bartels (1940), that the "internal" part of the magnetic variation is 30% the size of the "external" part, and so to compensate for this the observed horizontal components are divided by the factor 1.3. The magnetic field produced by a line current I is given by

$$B = \frac{\mu I}{2\pi r} \qquad (1)$$

where r is the distance from the current, and $\mu = 4\pi.10^{-7}$ is the magnetic permeability. For an equivalent current 100 km vertically above the observatory, the magnitude in amps, and azimuth in degrees, are given in terms of the "external" magnetic variations X_e and Y_e, in nanoteslas, by

$$I = 500\sqrt{X_e^2 + Y_e^2} \qquad (2)$$

and

$$\theta = 90.0 + \tan^{-1}\left(\frac{Y_e}{X_e}\right) \qquad (3)$$

Equations (2) and (3) show that a southwards magnetic variation of 1000 nT has a westward equivalent overhead current of 500,000 amps.

It must be remembered that calculation is only made of an equivalent current. The actual current system responsible for high-latitude magnetic disturbances is comprised of not only ionospheric currents but also field-aligned currents connecting to current systems in the outer magnetosphere. These currents will be at a greater distance than an ionospheric current and so must be larger in order to produce the same magnetic disturbance. Also, in practice, the ionospheric current may be a sheet current with a width of several degrees of latitude and may not be directly over the observatory. Thus the overhead equivalent currents calculated give the minimum value of the electric current necessary to produce the observed magnetic disturbance.

Results

Equivalent current plots are presented for every 10 minutes from 00:00 March 13 (Day 72) to 11:50 March 14 (Day 73) to show the general evolution of the disturbance. In addition, equivalent current plots are produced for every minute during the intervals: 07:41-08:12, 11:01-12:00, 21:51-22:30 on March 13, and 01:01-01:32 on March 14, to show the development of particular substorms. All times given are in Universal Time (UT). The Canadian magnetic observatory network spans approximately five hours in local time ranging from 3.5 hours to 8.3 hours behind universal time. For example, at 18:00 UT Resolute (RES), Baker Lake (BLC) and Churchill (FCC) are approximately at noon, local time, with the more westerly observatories in the morning sector and the more easterly observatories in the afternoon sector.

The 10-minute plots show that the magnetic field was quiet for the first two hours of March 13 (day 72) and then moderately disturbed from 02:10 to 07:40 with current enhancements at 03:50 and 06:20. Between 07:40 and 07:50 there was a sudden intensification of the disturbance featuring a large westward equivalent current over the St. John's, Ottawa, Glenlea, and Meanook observatories, but with little disturbance at Victoria. This current moved polewards before decaying at 08:40 to 08:50. The field was comparatively quiet from 09:00 to 10:50. Plots for 11:00 and 11:10 show the eruption of a major current system across the southern-most stations extending from St. John's in the east to Victoria in the west. This system features equivalent currents close to one million amps before moving polewards between 11:30 and 11:40. A subsequent increase of this current at 12:10 to 12:30 shows that the focus of the equivalent current system has moved westward and the disturbances at St. John's and Ottawa are now relatively minor. From 13:30 onwards, the southern-most observatories show little activity but the equivalent current plots show that considerable activity continued at the higher latitude observatories until about 18:20, after which most observatories were quiet for a time.

From 19:50 on March 13 (day 72) a broad new disturbance started building. This disturbance produced similar equivalent currents at most observatories initially directed westward but rotating to the northwest by 00:30 of March 14 (day 73). From 00:30 to 01:10 the current system grew considerably smaller while at the northern stations it rotated to the north. Between 01:10 and 01:20 there is an eruption of a large new disturbance shown by a westward equivalent current at Ottawa of over 800,000 amps. This current system persists until 02:10 and is followed by a quiet period until 06:00. Between 06:00 and 06:10, on day 73, there is a sudden intensification of a westward current extending from St. John's, through Ottawa and Glenlea, to Meanook. This current persists until 06:30 and then moves poleward as shown by the increasing disturbance at Poste-de-la-Baleine and Churchill. From 07:40 onwards the field is comparatively quiet.

The evolution of the major disturbances can be seen in greater detail on the 1-minute plots. For example, the plots show that the major disturbances at 07:50 and 11:10 on March 13 and 01.20 on March 14 are produced by a sudden eruption of a westward current at the southern-most observatories. The current increases are seen to occur within a few minutes. These disturbances feature westward equivalent currents at lower latitudes and eastward equivalent currents at higher latitudes. However the disturbance between 21:51 and 22:30 on March 13 has equivalent currents pointed in a north-west direction over most of the country. During part of this time Victoria and Meanook show currents directed opposite to the general pattern, while at Ottawa large magnetic field fluctuations can be attributed to the changes in direction of a predominantly northwards equivalent current.

Conclusions

Equivalent current plots provide a useful picture of the magnetic activity recorded across the Canadian magnetic observatory network. Successive disturbances (see the plots for 07:50, 11:10, and 12:30) are seen to be produced by an equivalent current pattern featuring currents circulating clockwise round a focus that moves progressively westward. This apparent motion is due to the rotation of the earth, moving Canada eastward under the region of ionospheric currents on the nightside of the Earth.

A significant feature illustrated by the equivalent current plots is that the major disturbance at 07:45 UT (02.45 EST), is produced by a sudden eruption of a westward current, in-situ, at the southern-most observatories, not by the movement of a current from more northerly sites. It is this large and rapid change of the magnetic field that caused the extreme induced electric fields responsible for the blackout of the power system in Quebéc.

References

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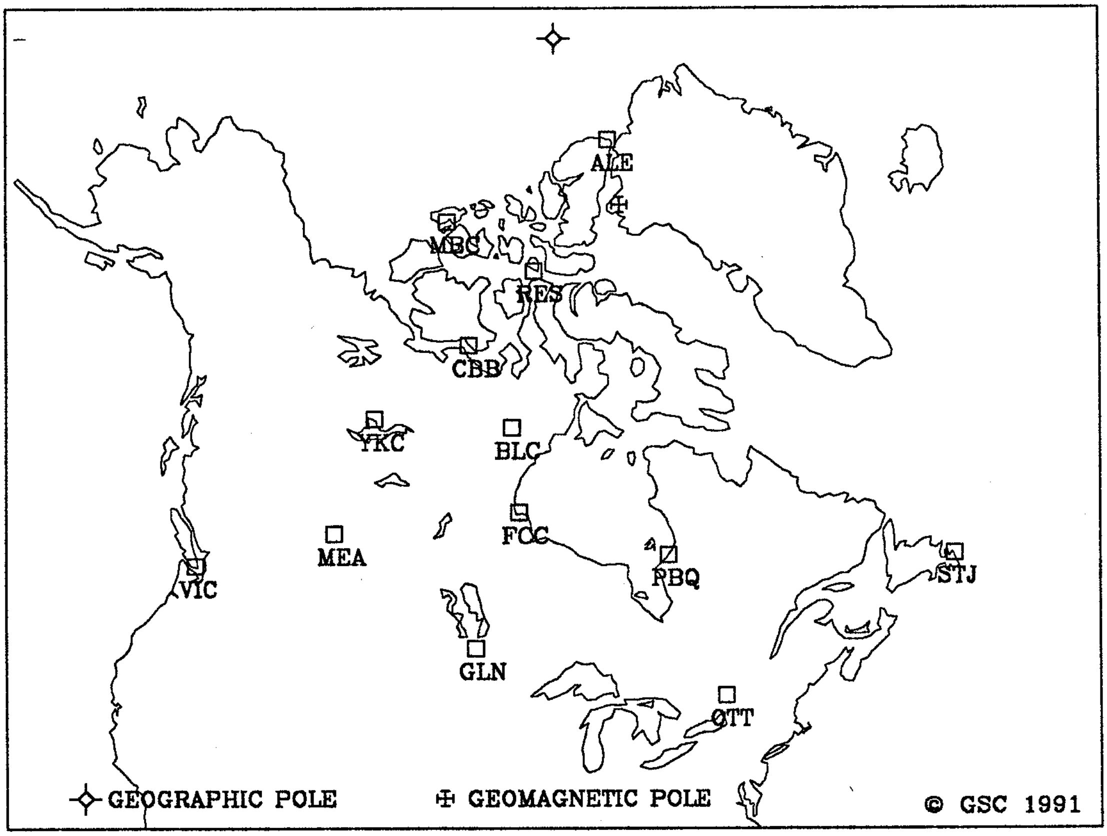


MAG	GEOGRAPHIC		GEOMAGNETIC		QUIET LEVELS: MAR 1989		
OBS	LAT	LONG	LAT	LONG	X(nT)	Y(nT)	Z(nT)
OTT	45.4	284.4	57.0	351.5	16601	−4140	54663
STJ	47.6	307.3	58.7	21.4	17235	−7495	49400
VIC	48.5	236.6	54.3	292.7	12651	4752	58079
GLN	49.6	262.9	59.5	323.0	17753	6674	52517
MEA	54.6	246.7	61.9	301.0	7802	89	60234
PBQ	55.3	282.2	66.8	347.2	4880	53	60286
FCC	58.8	265.9	68.8	322.5	2986	1117	59763
YKC	62.5	245.5	69.1	292.7	10360	−3575	58575
BLC	64.3	264.0	73.9	314.8	791	−864	58309
CBB	69.1	255.0	76.6	294.0	7971	3756	59849
RES	74.7	265.1	83.1	287.7	14249	1784	58306
MBC	76.2	240.6	79.1	255.4	985	−3925	55626
ALE	82.5	297.6	85.7	168.7	1297	1968	57990

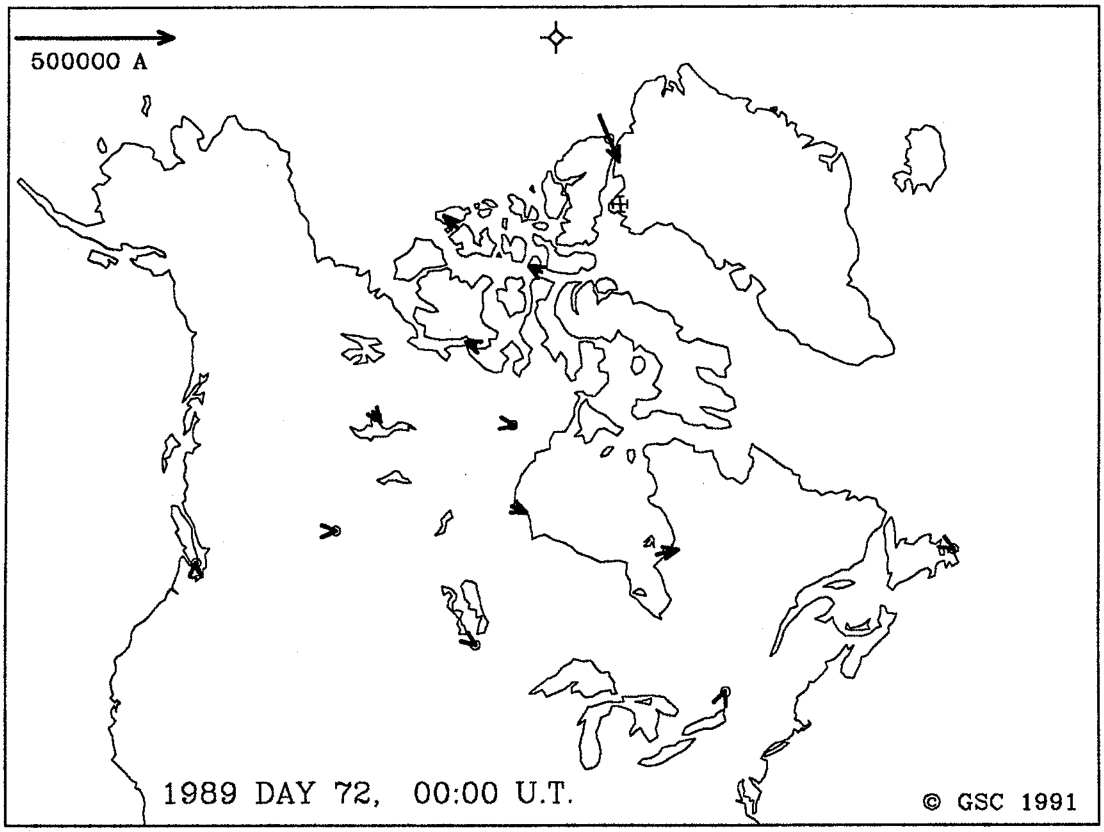
Figure 1. Canadian Magnetic Observatory Network

Equivalent Currents at 10 minute intervals

00:00 UT March 13 (Day 72) 1989

to

11:50 UT March 14 (Day 73) 1989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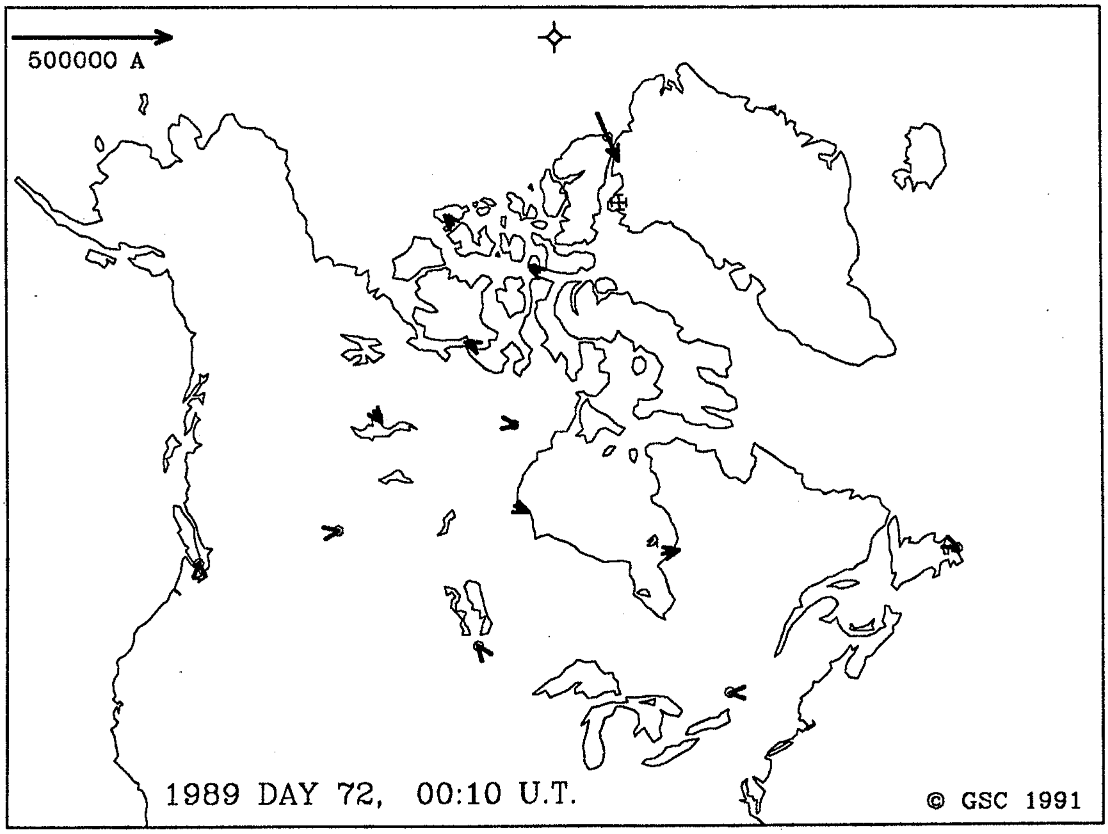
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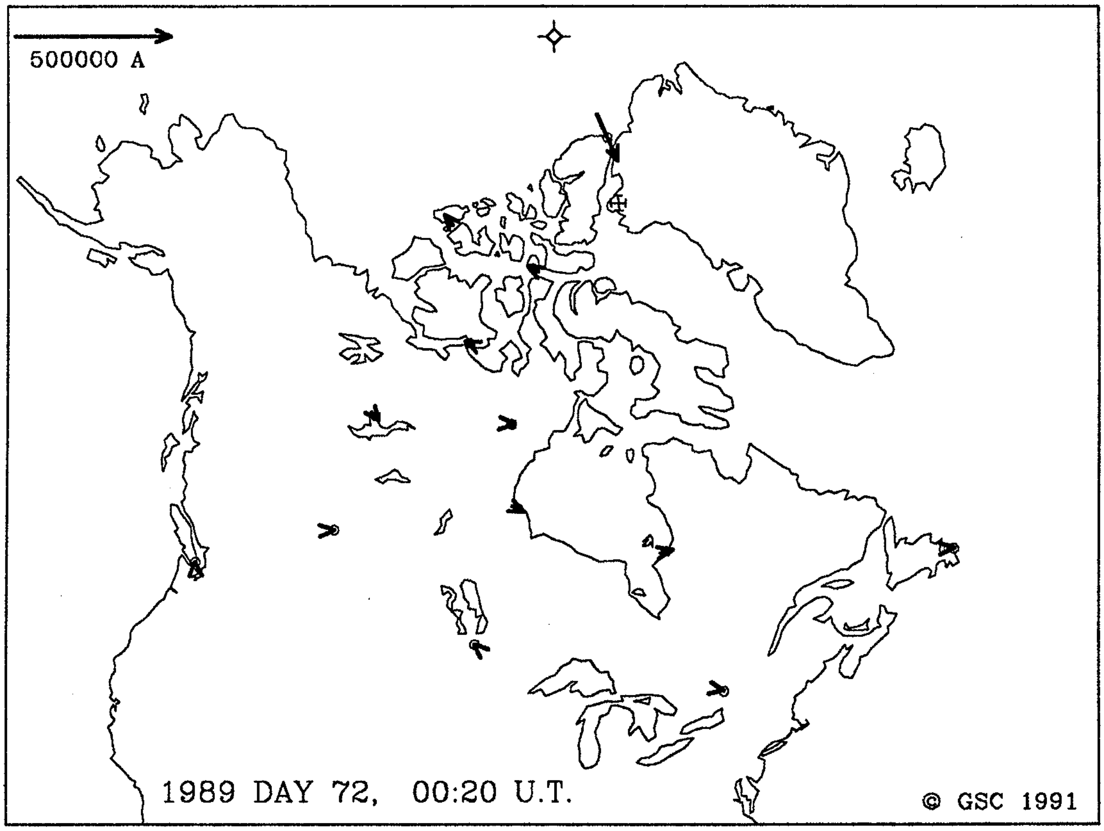
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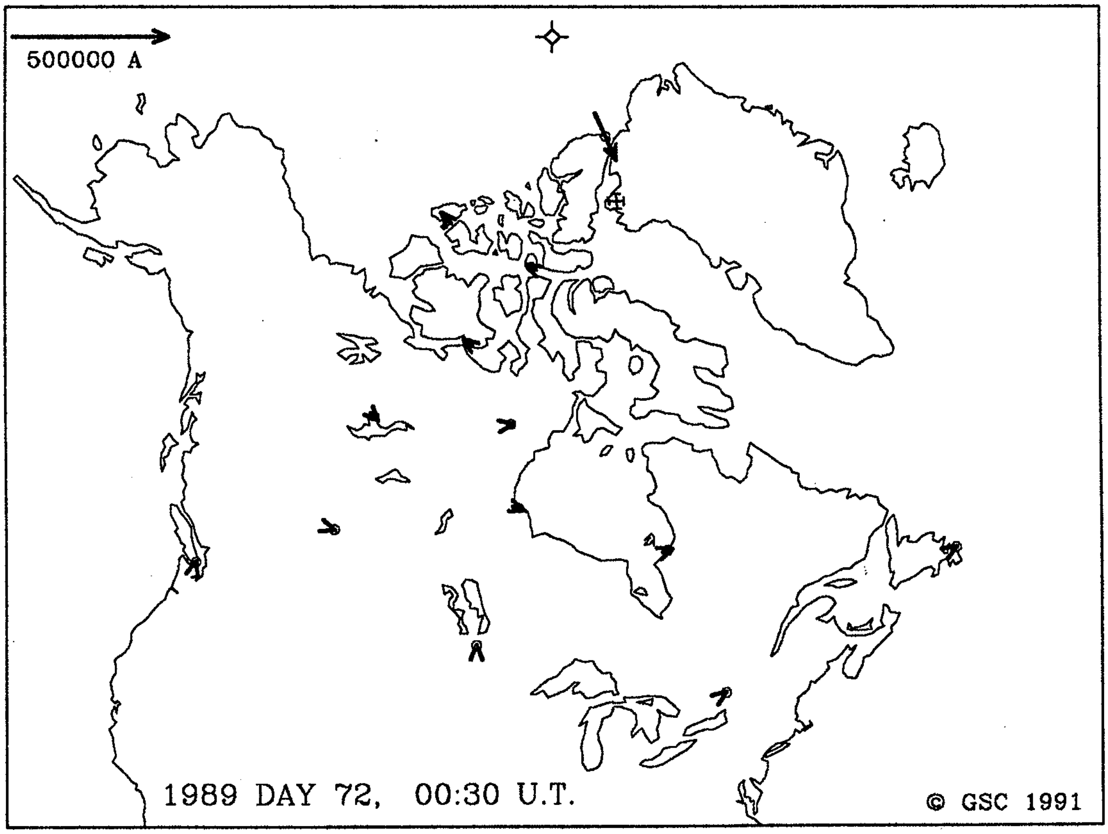
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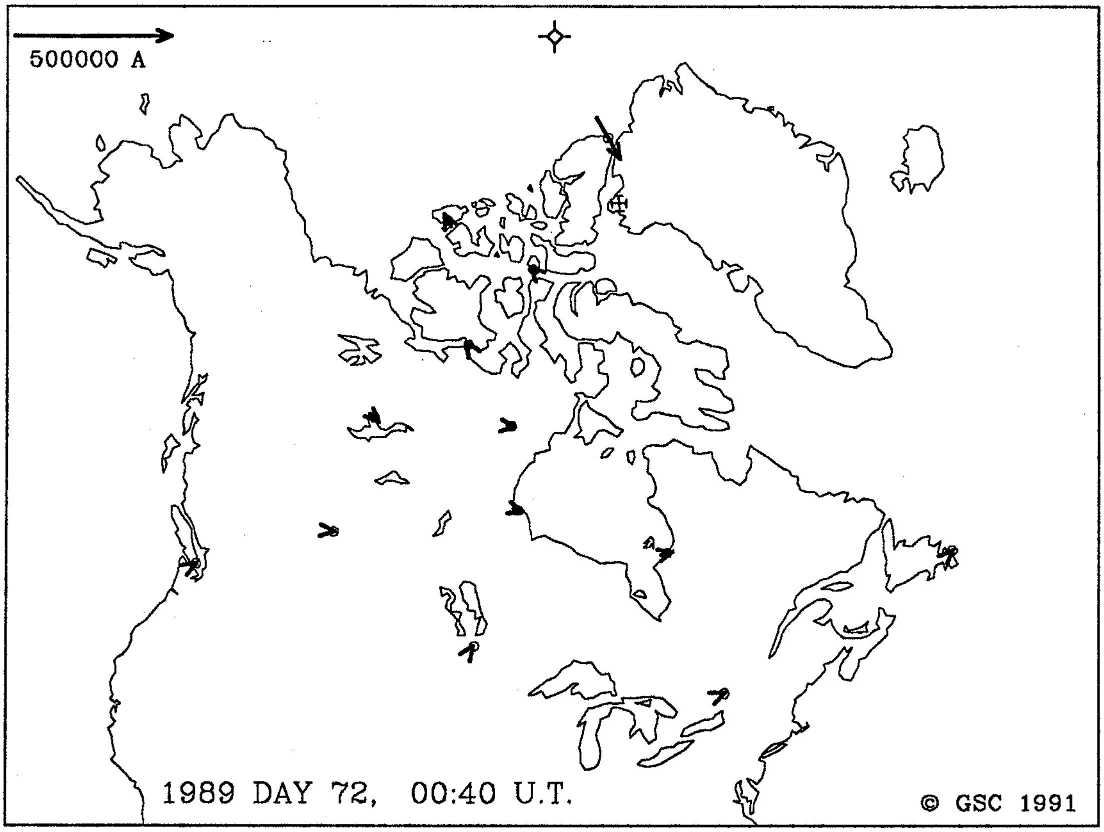
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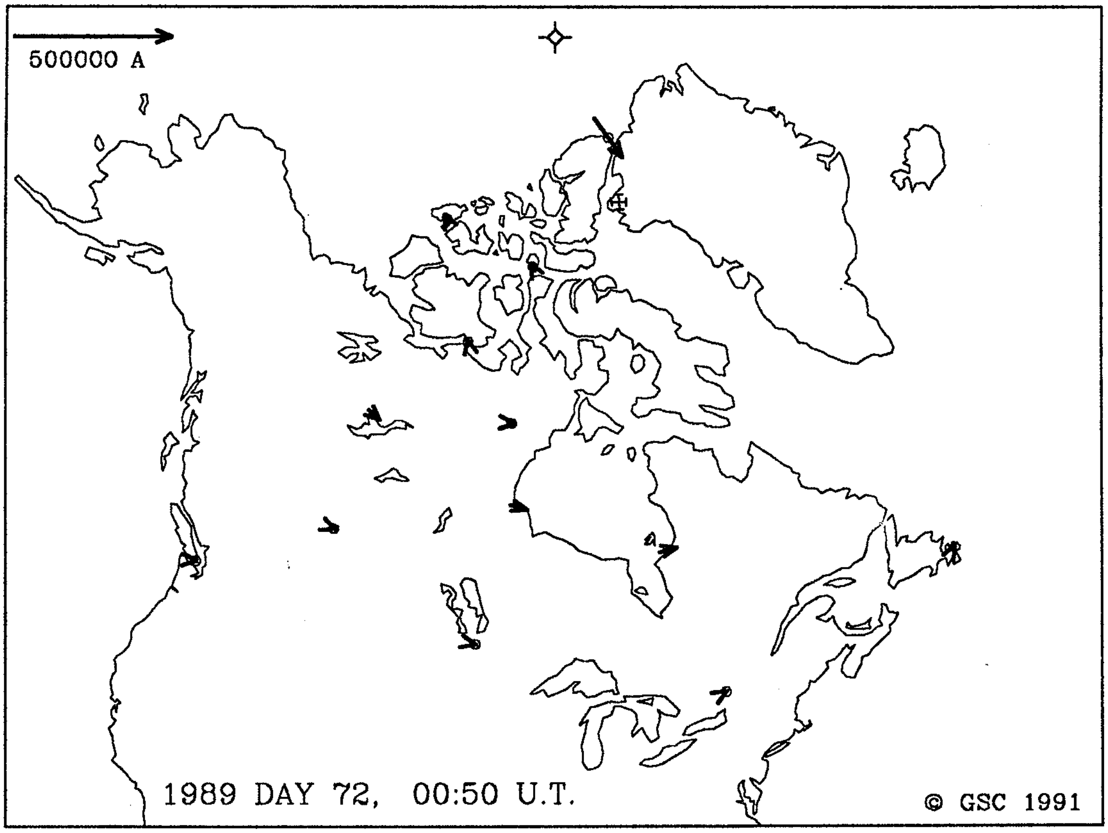
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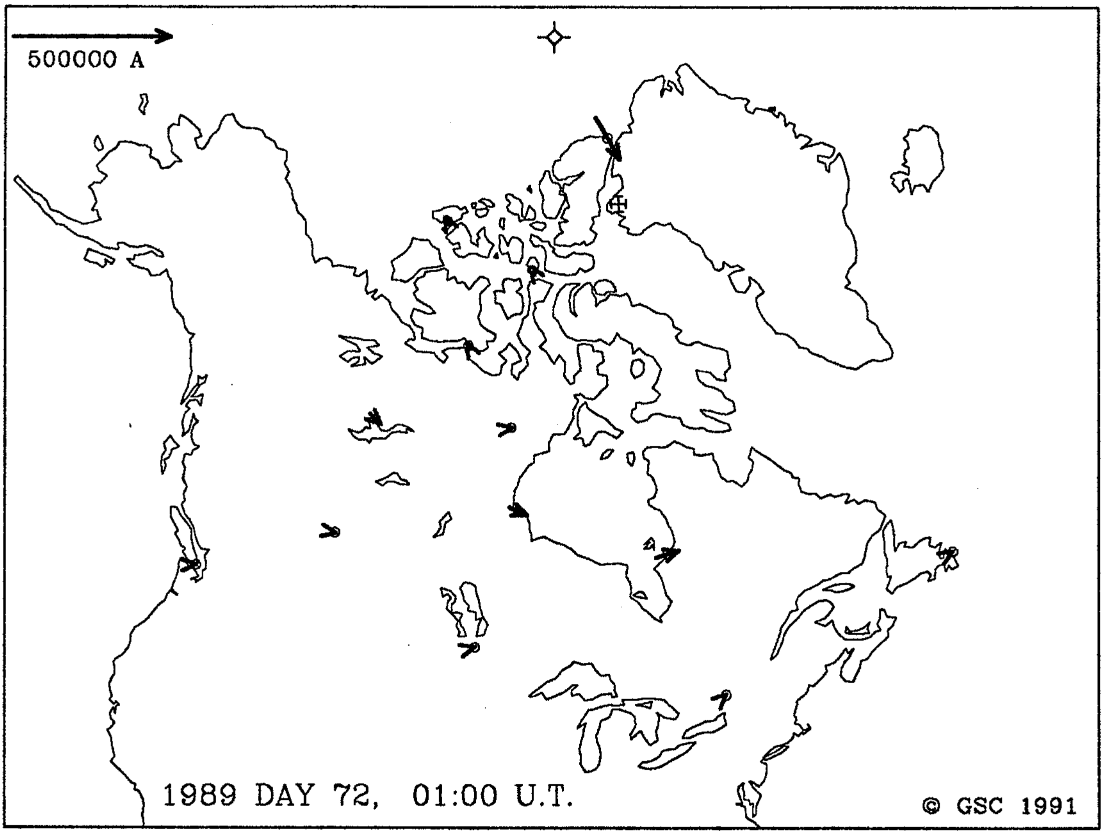
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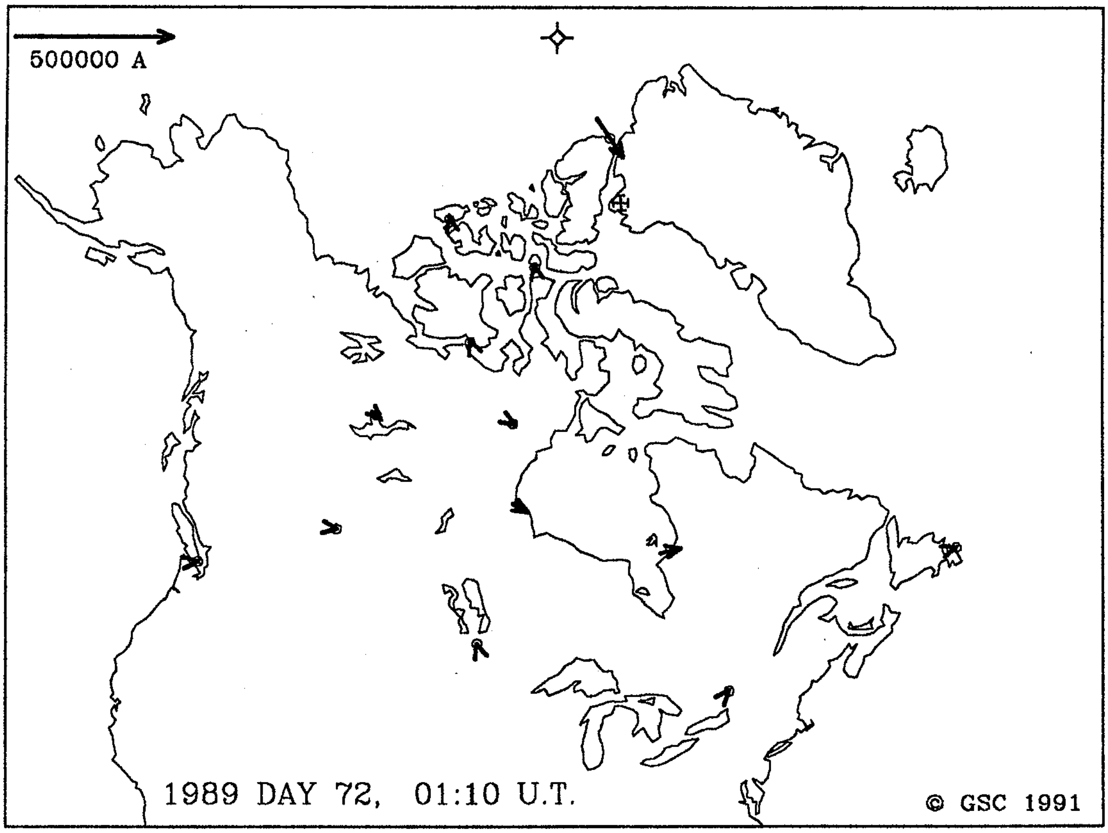
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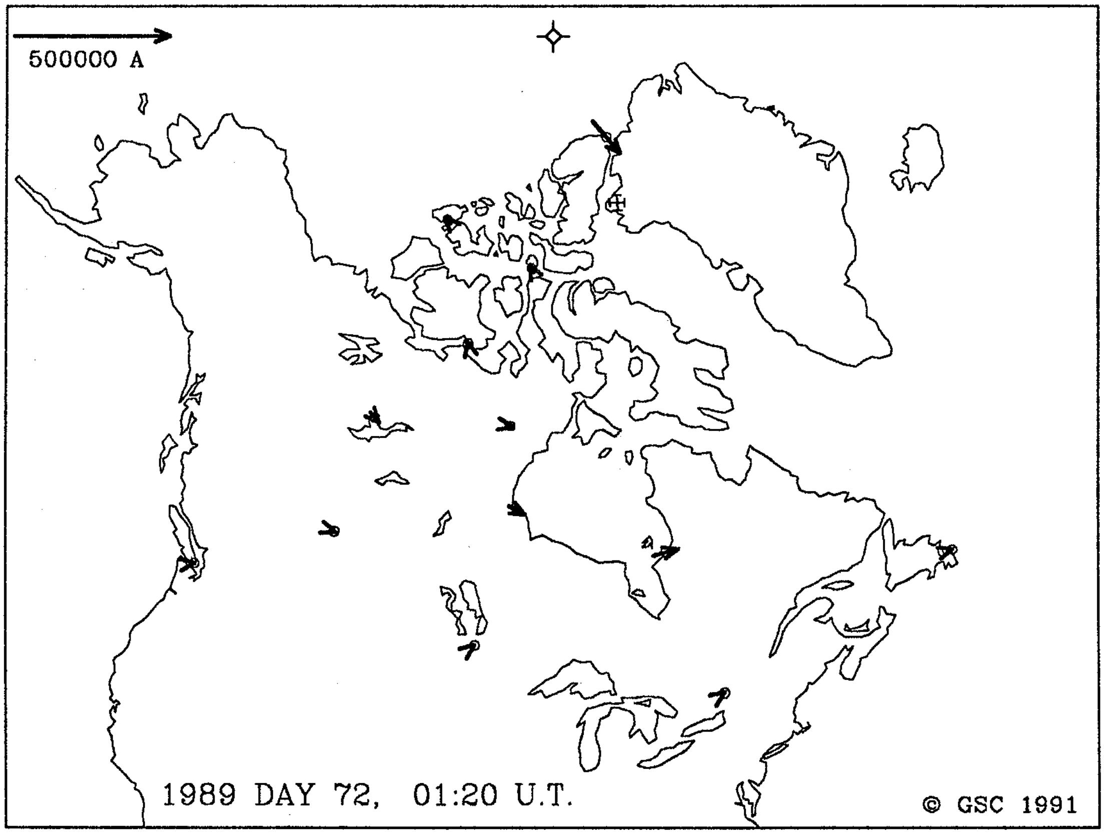
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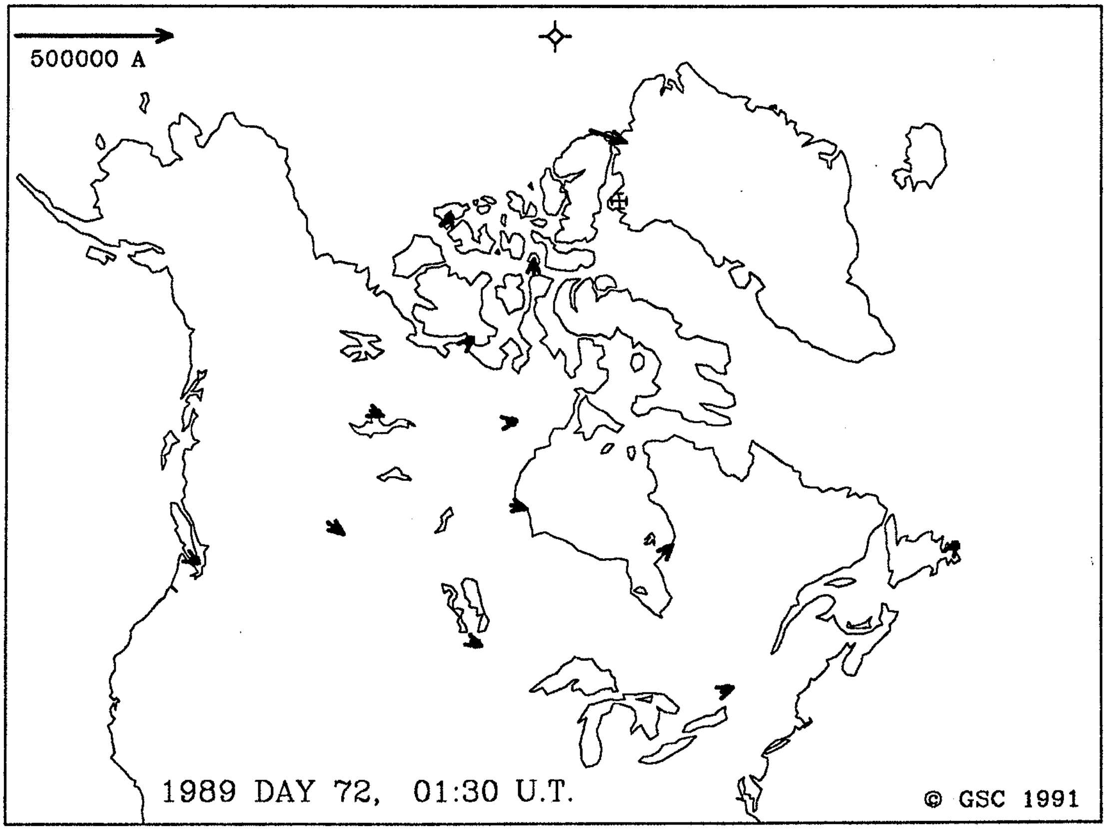
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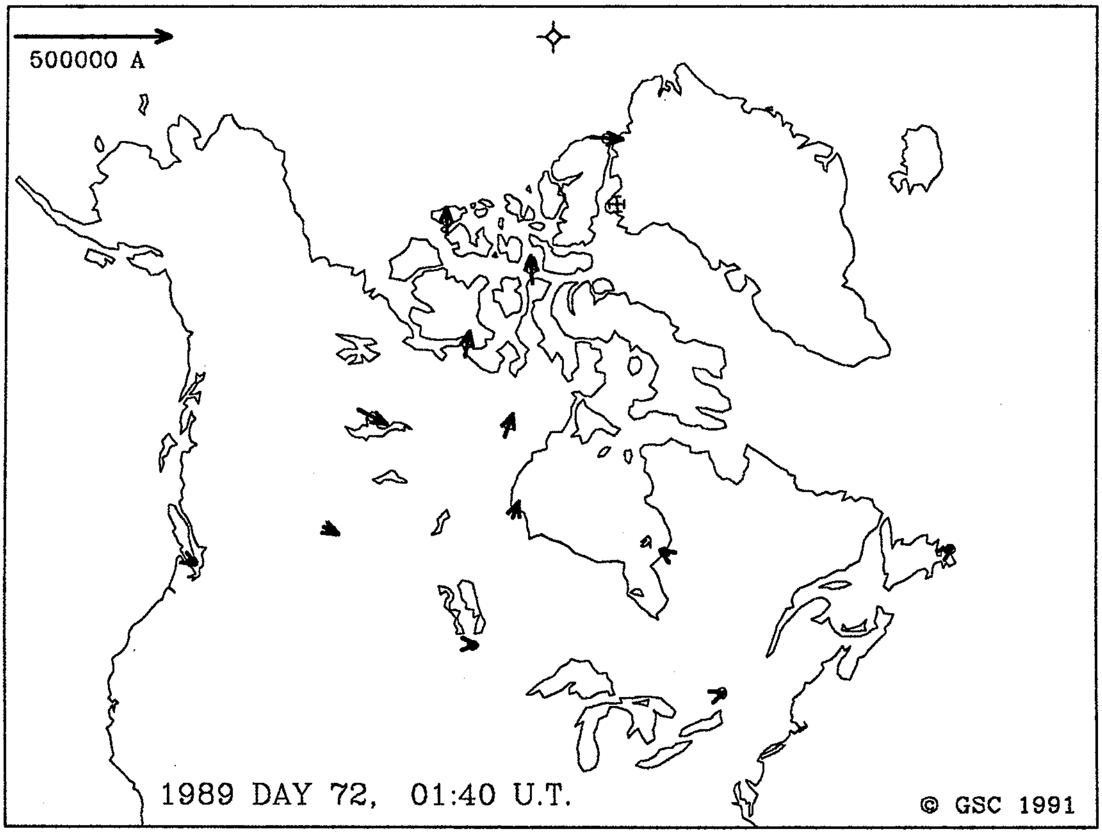
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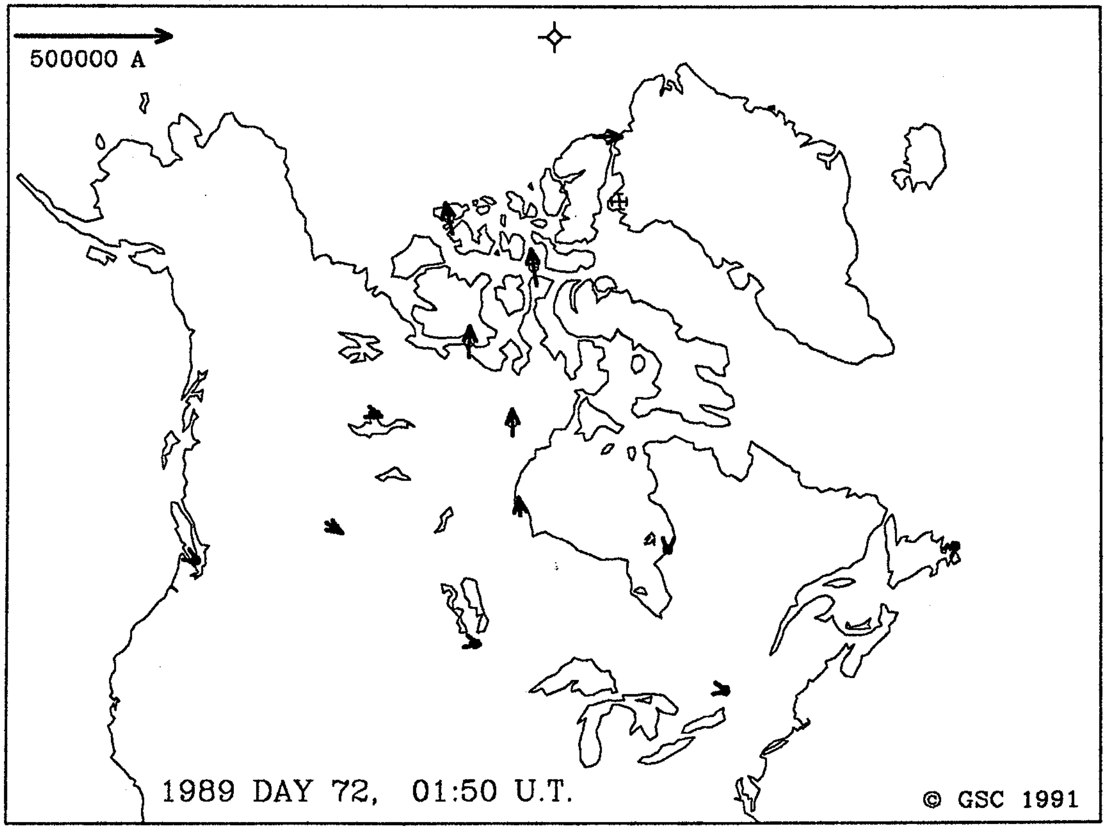
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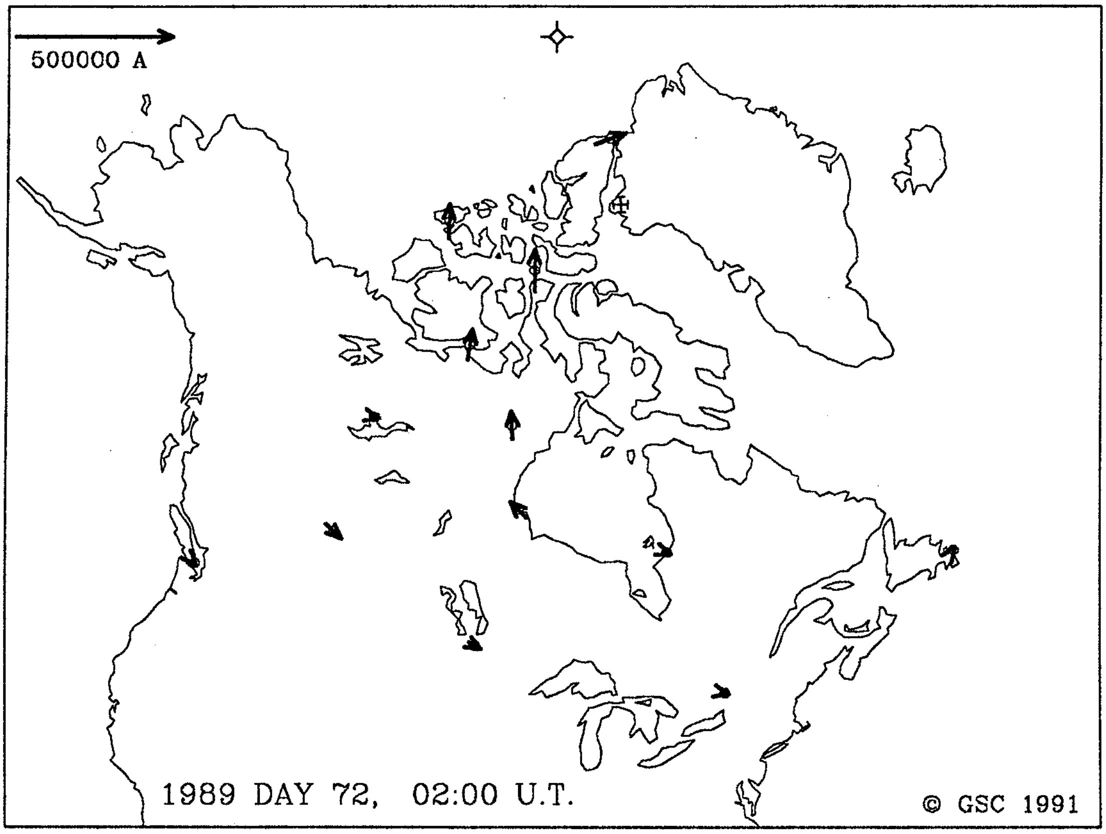
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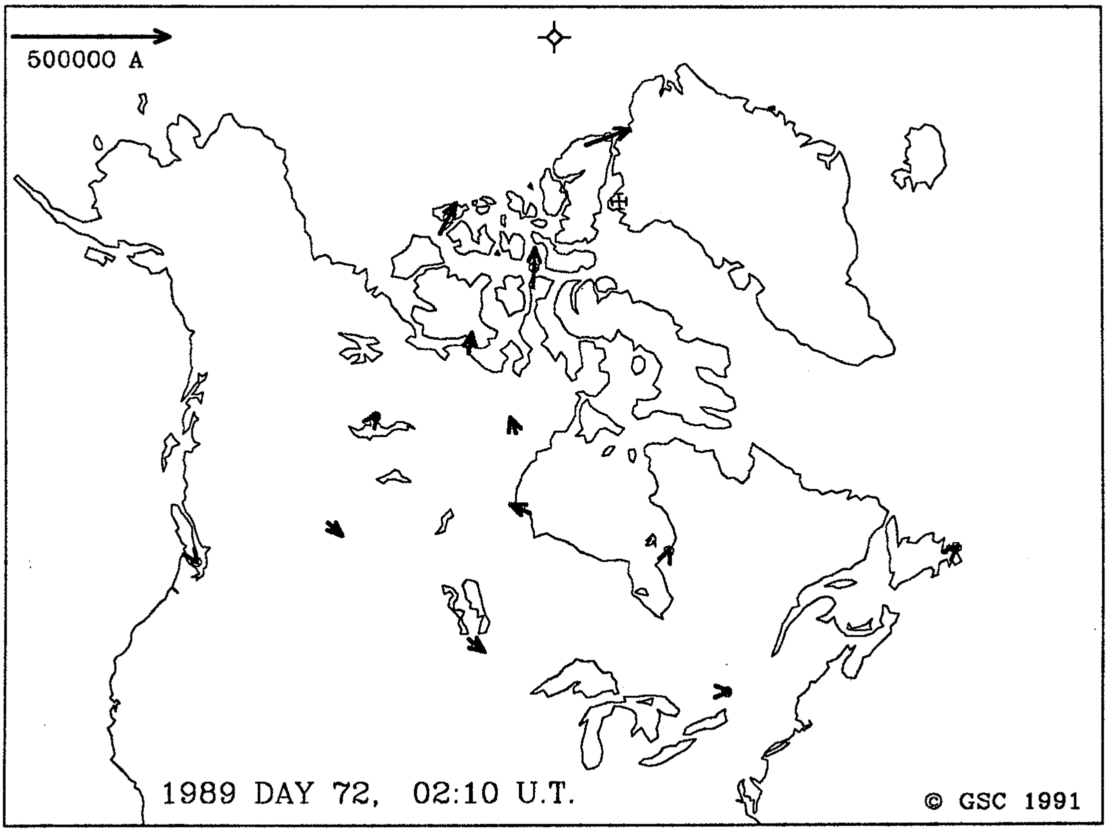
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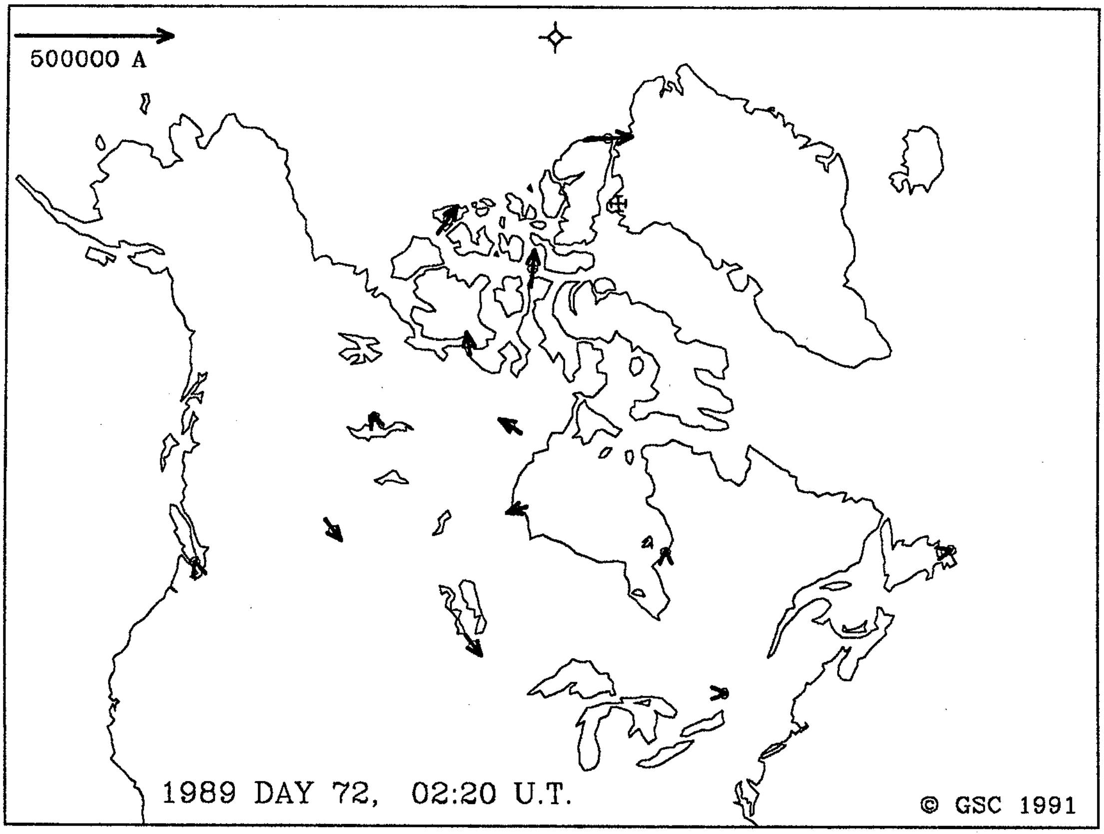
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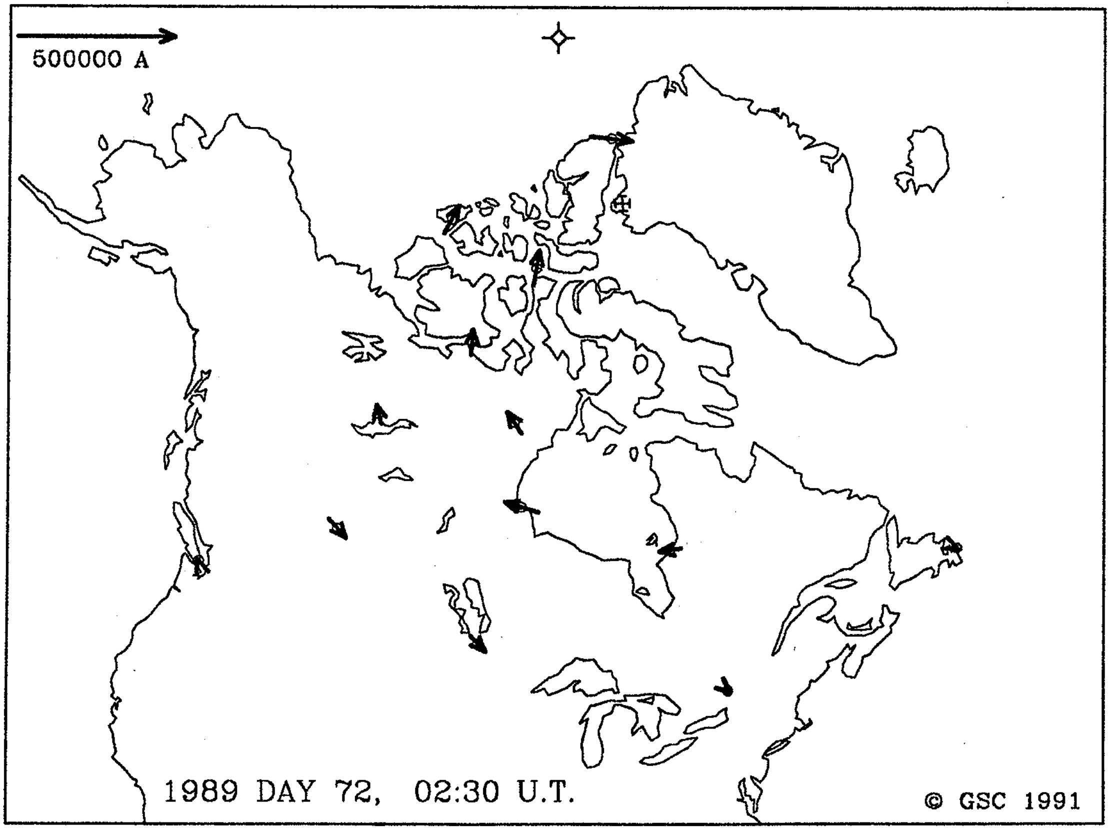
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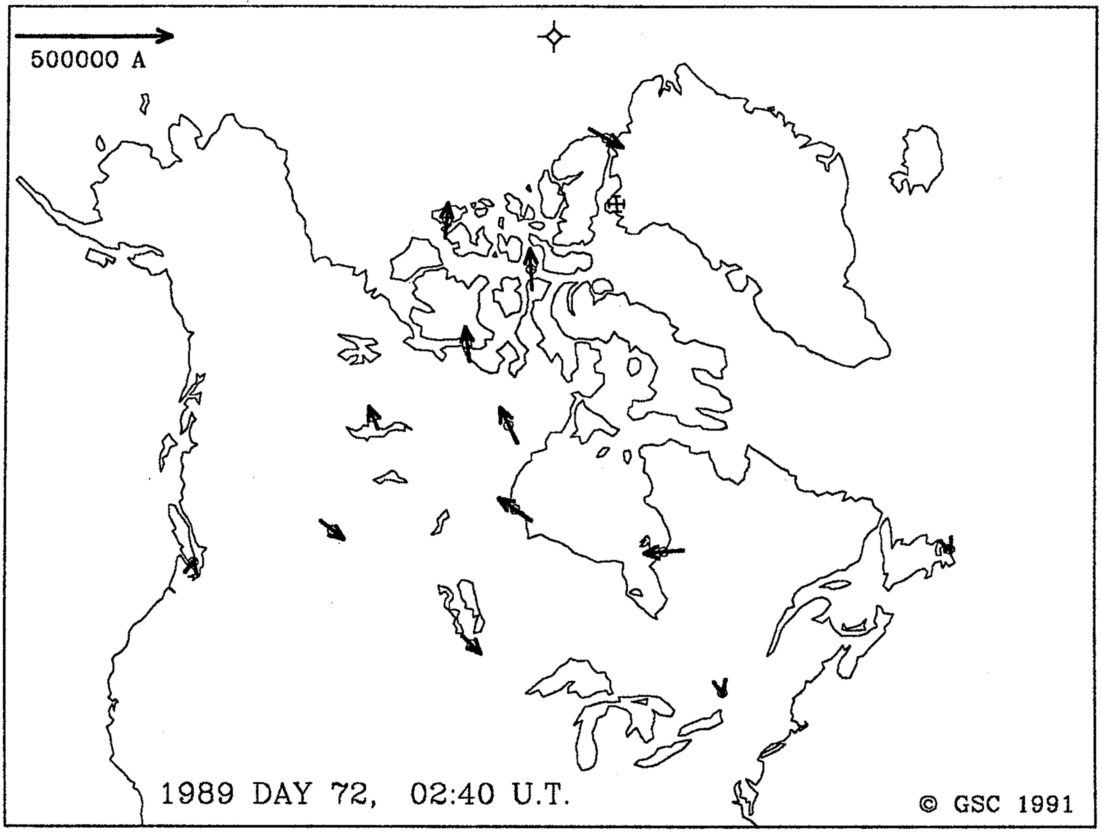
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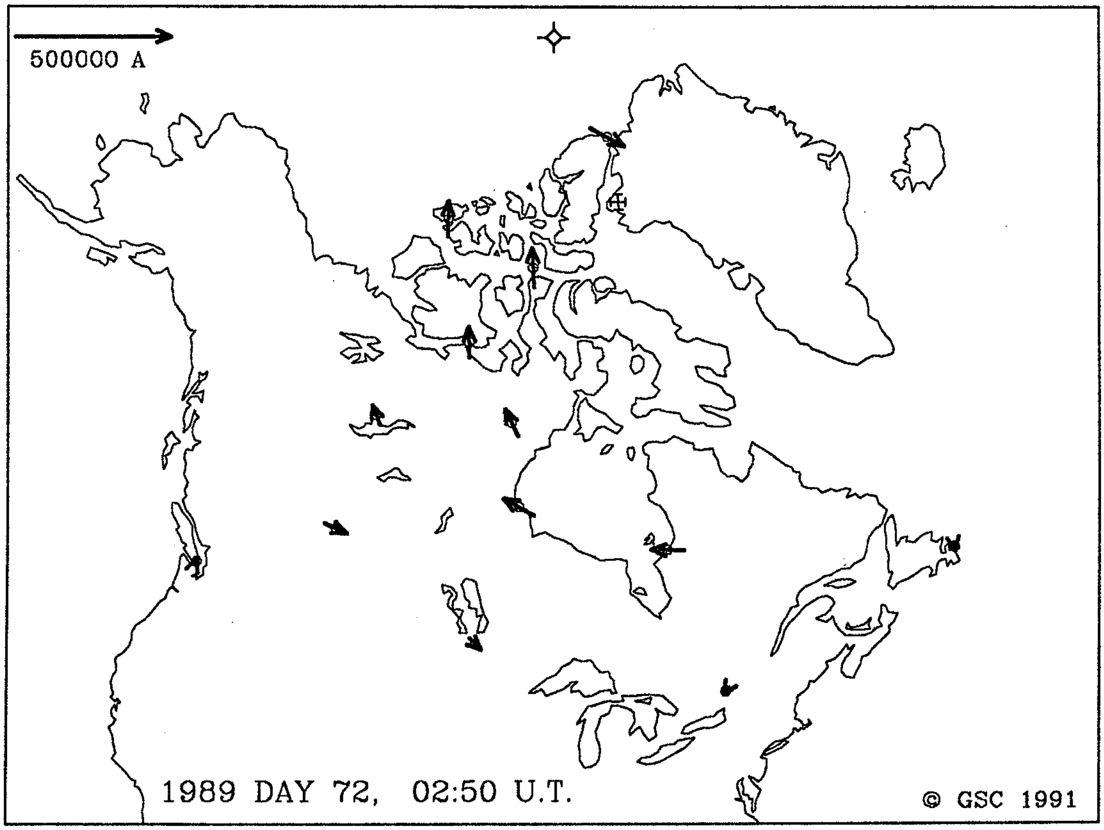
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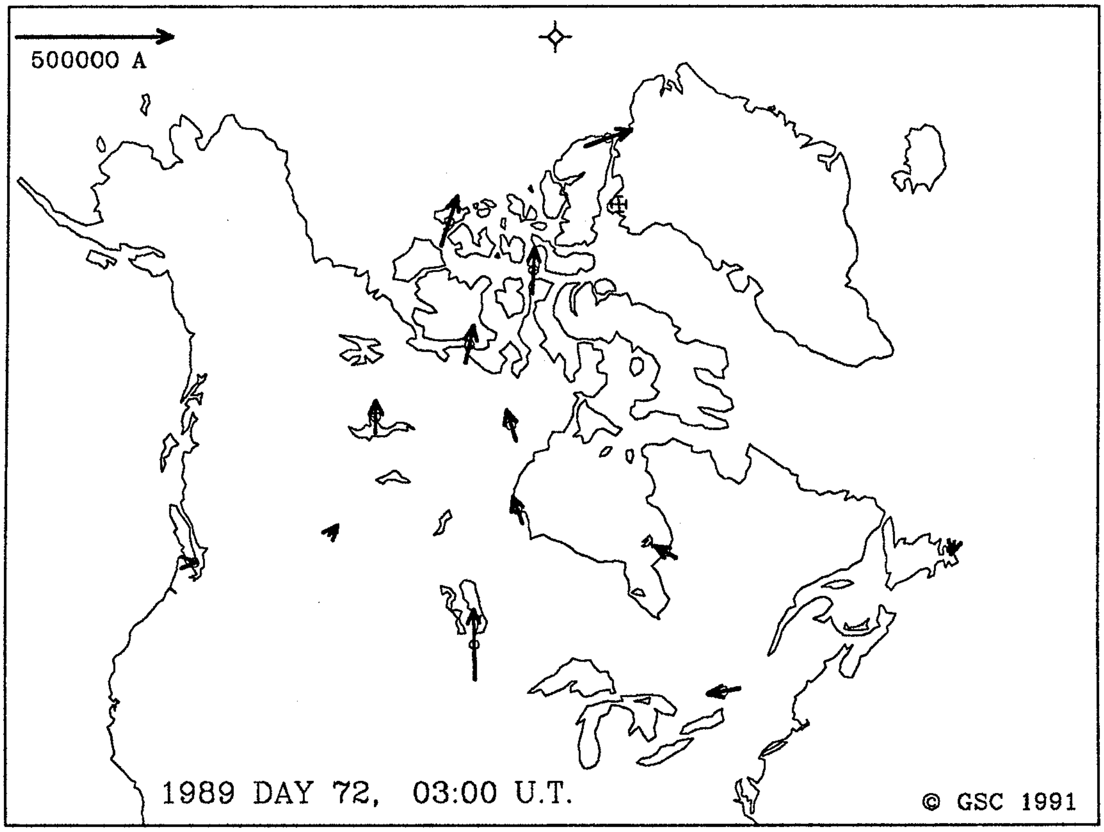
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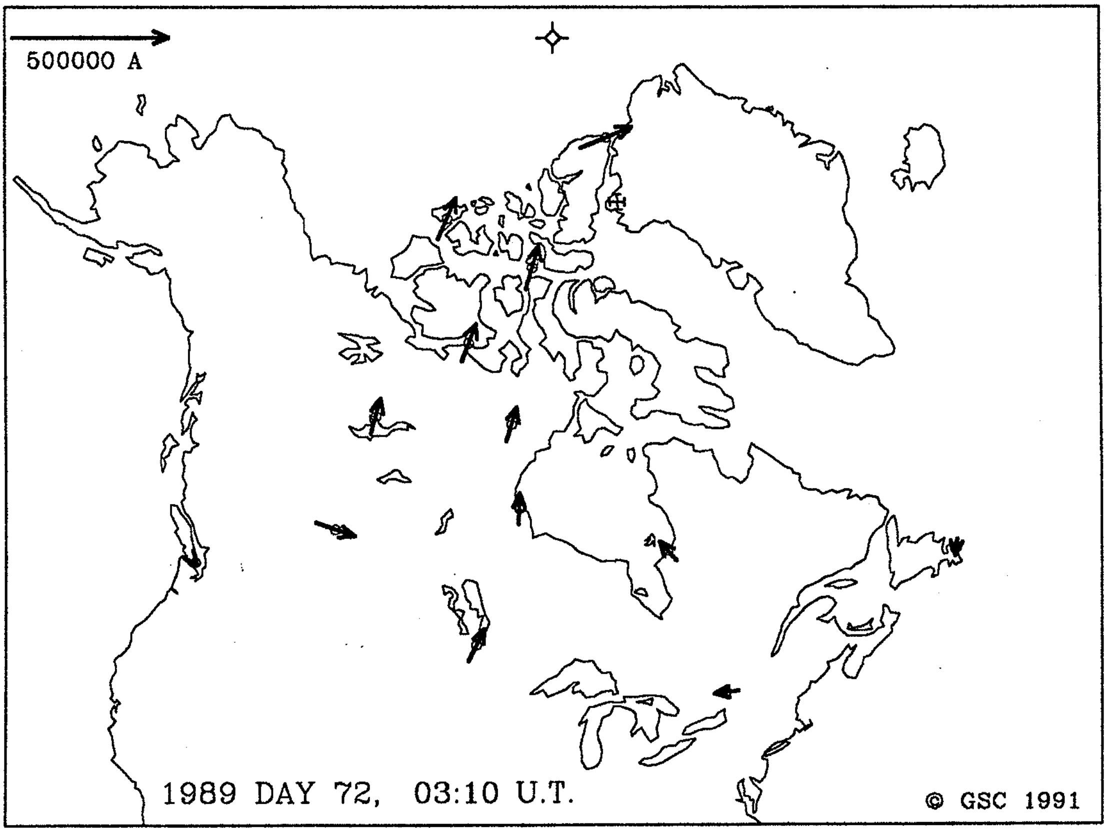
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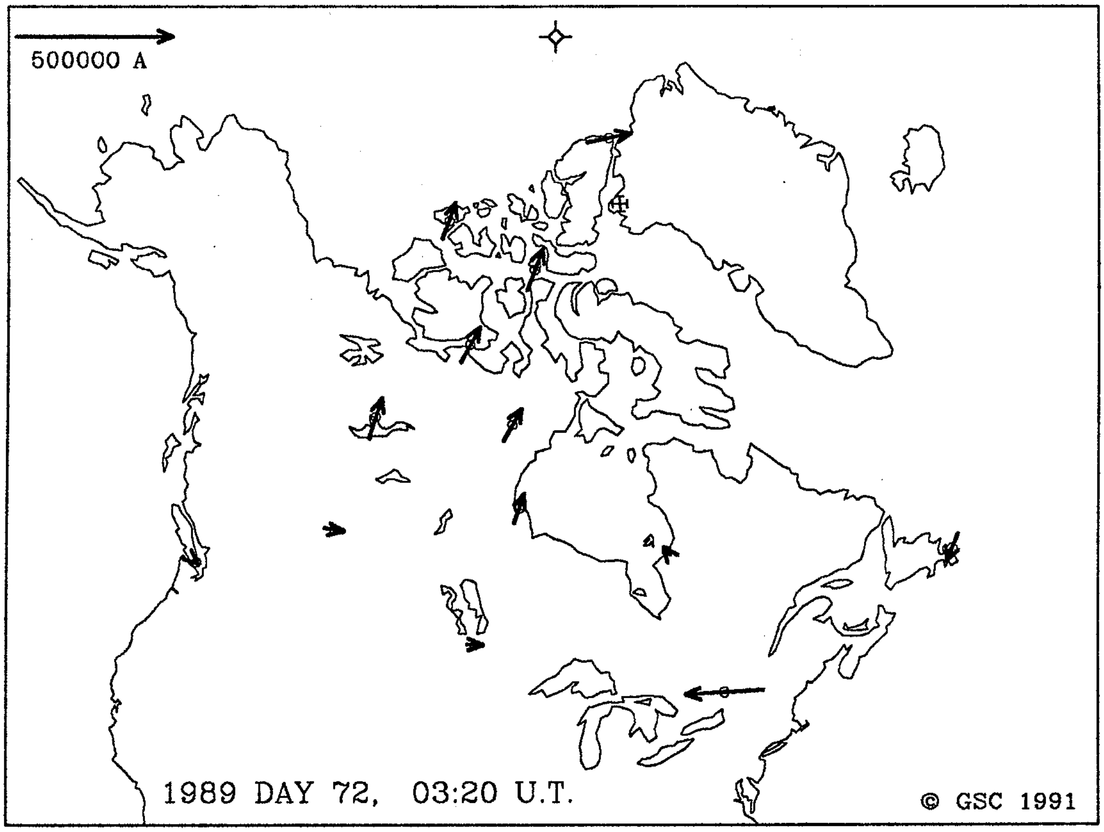
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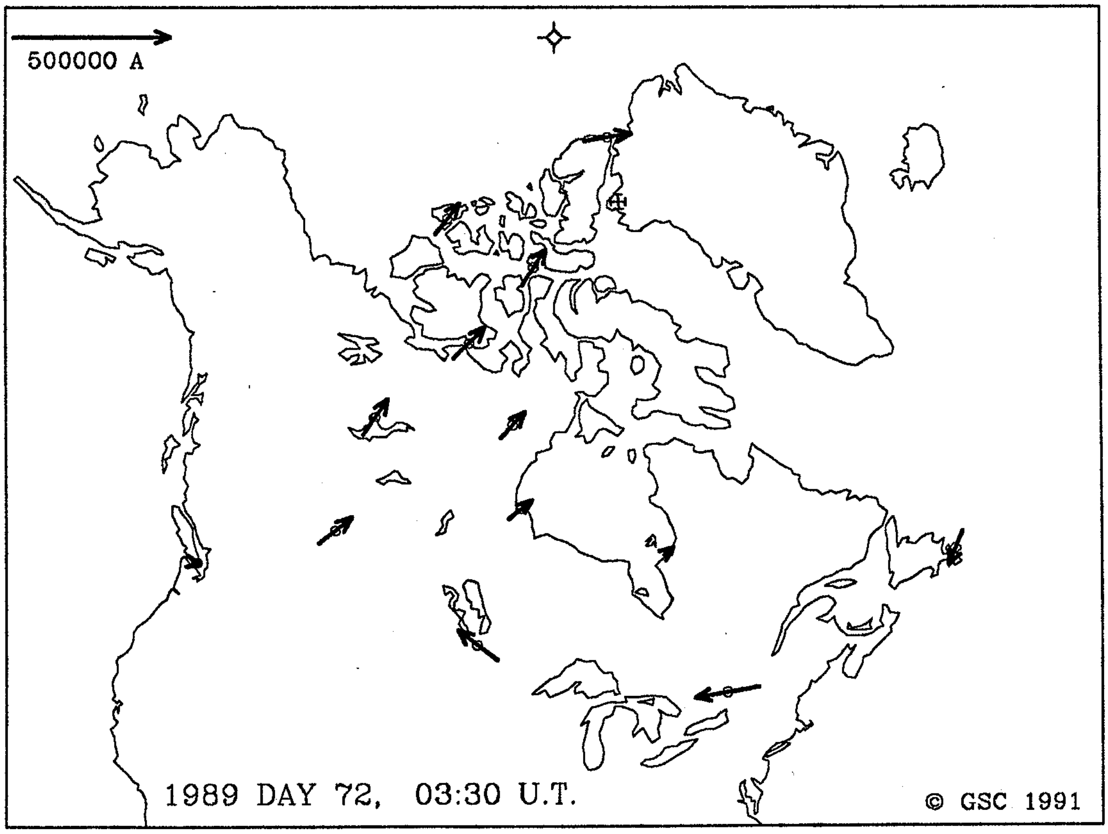
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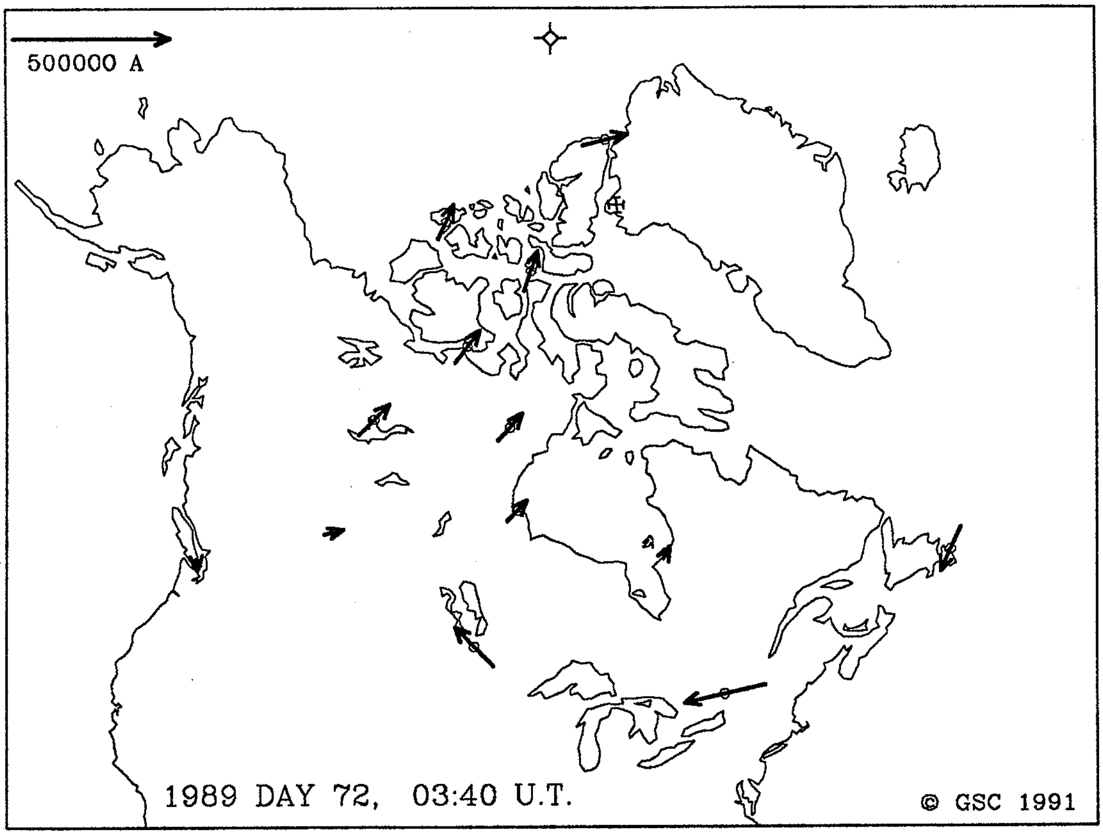
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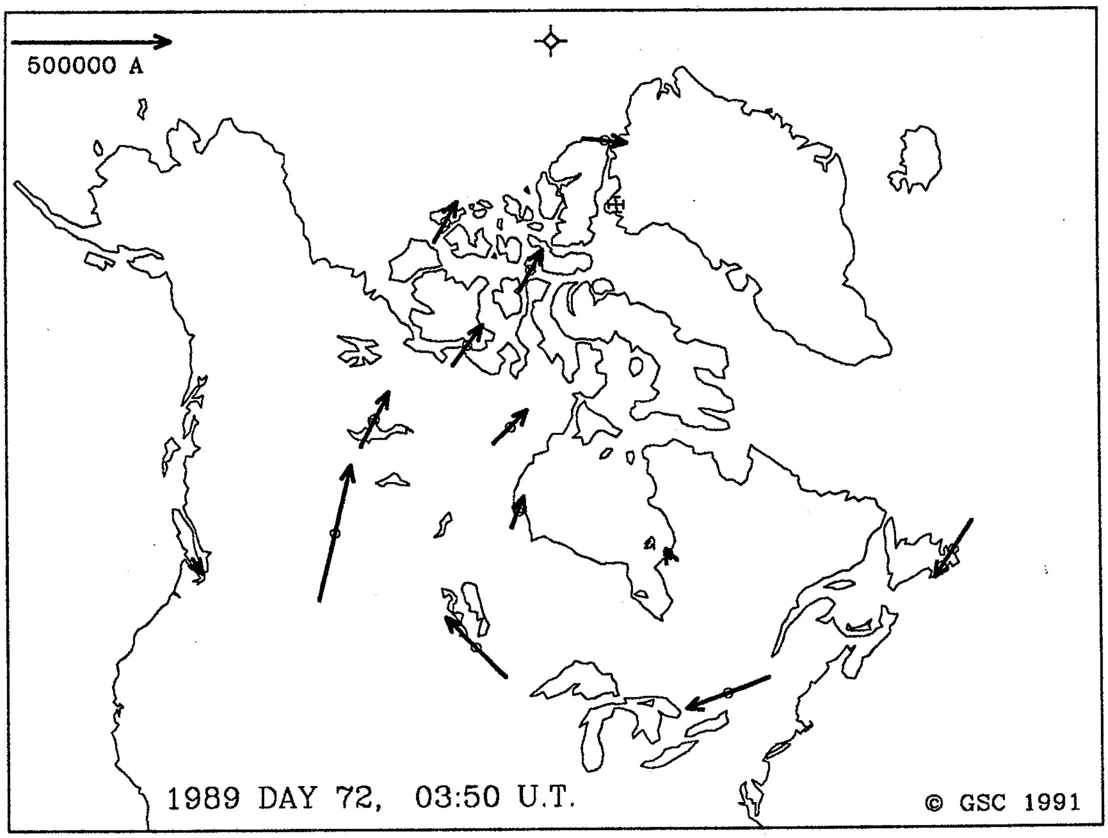
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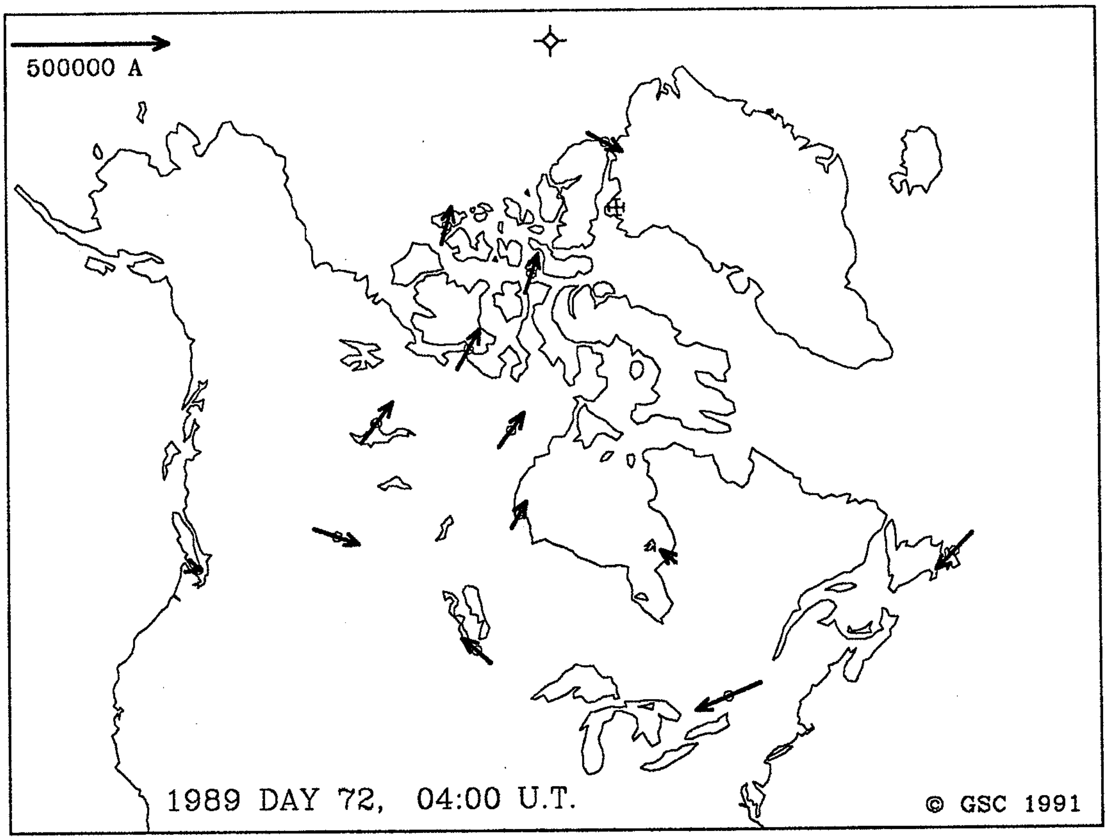
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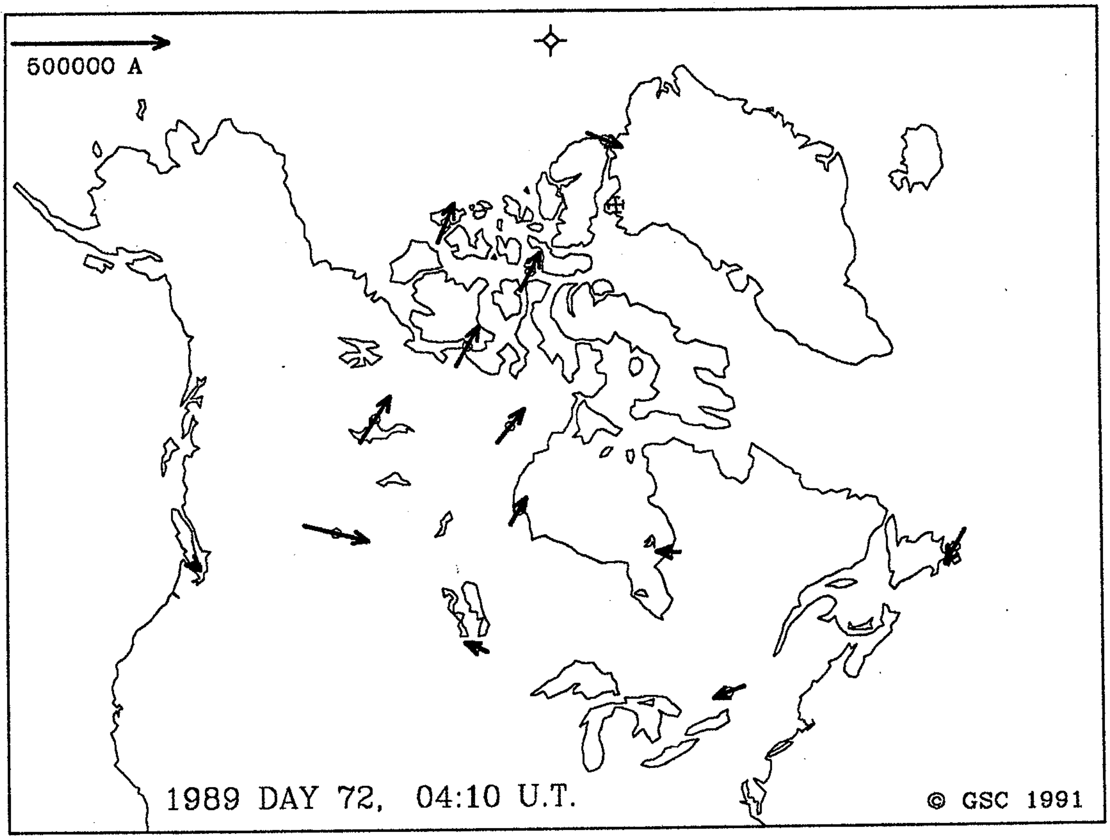
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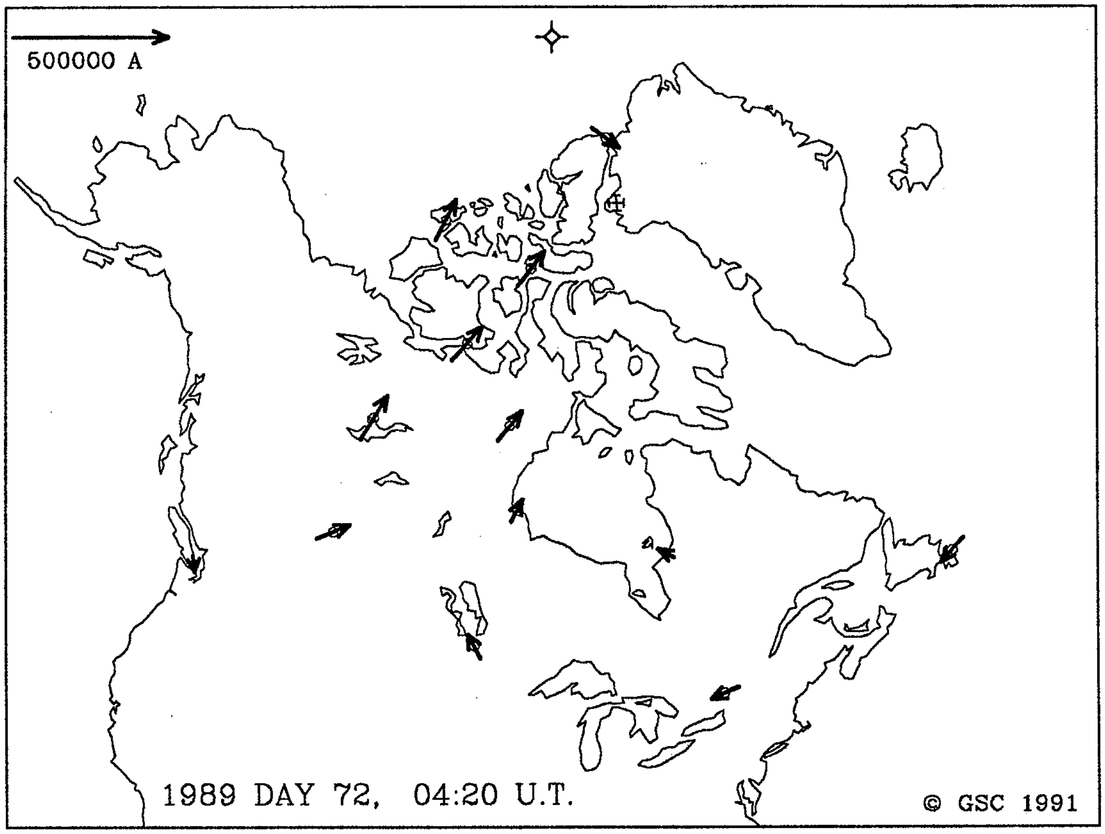

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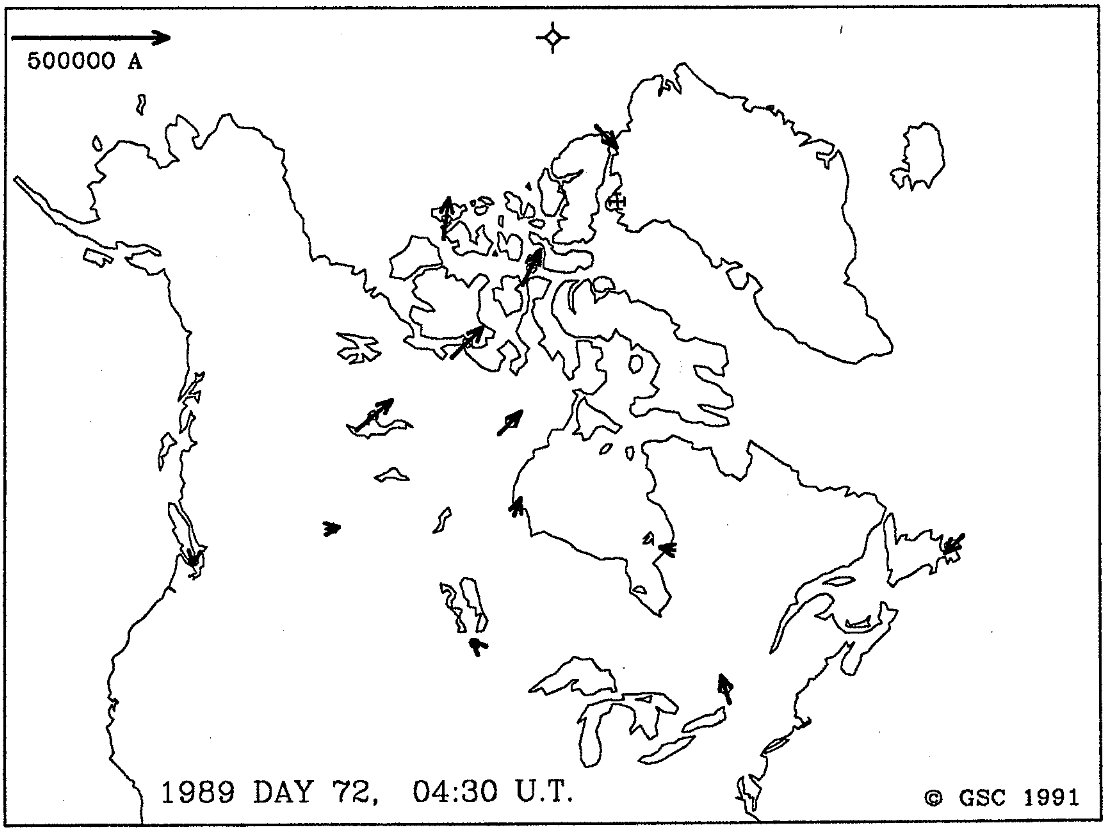

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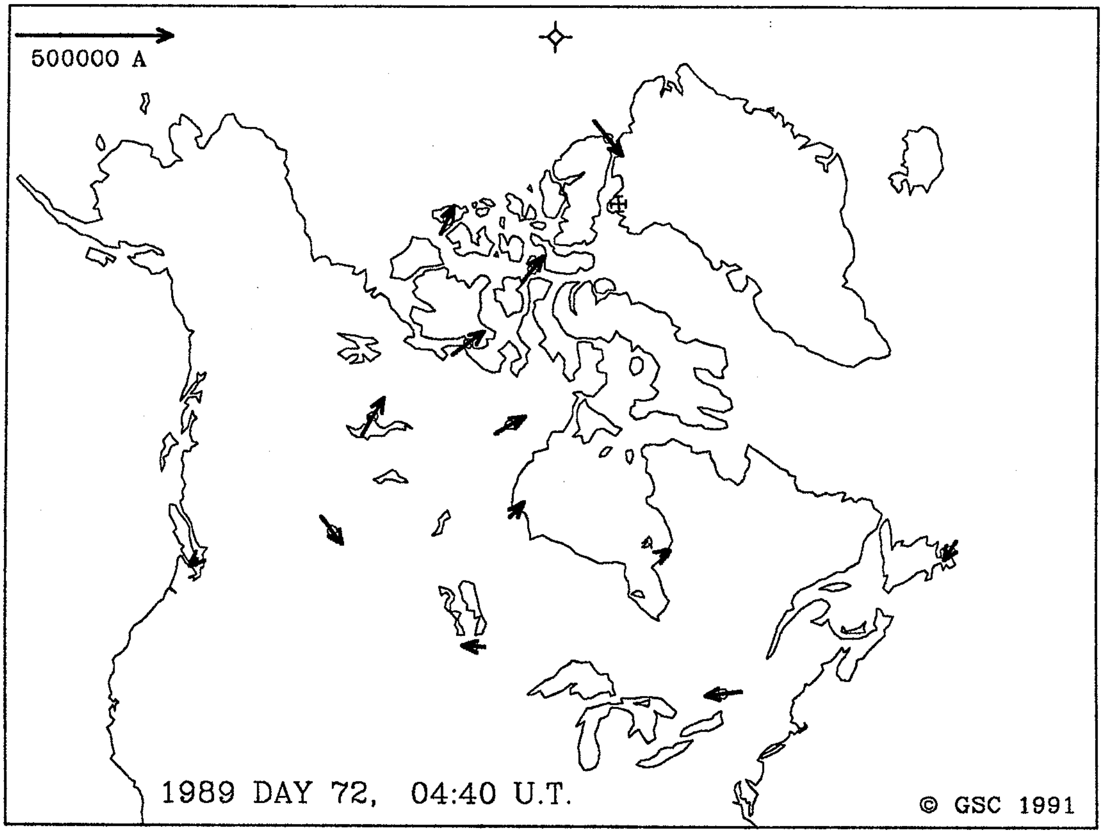
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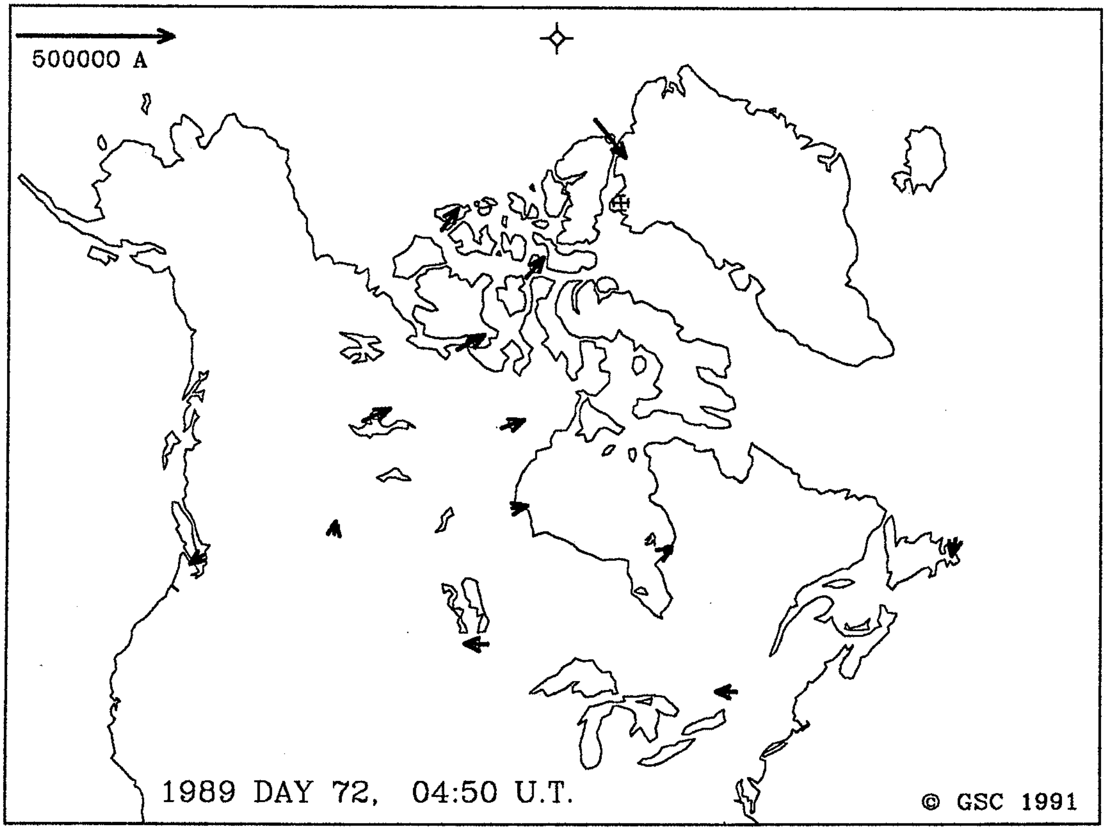
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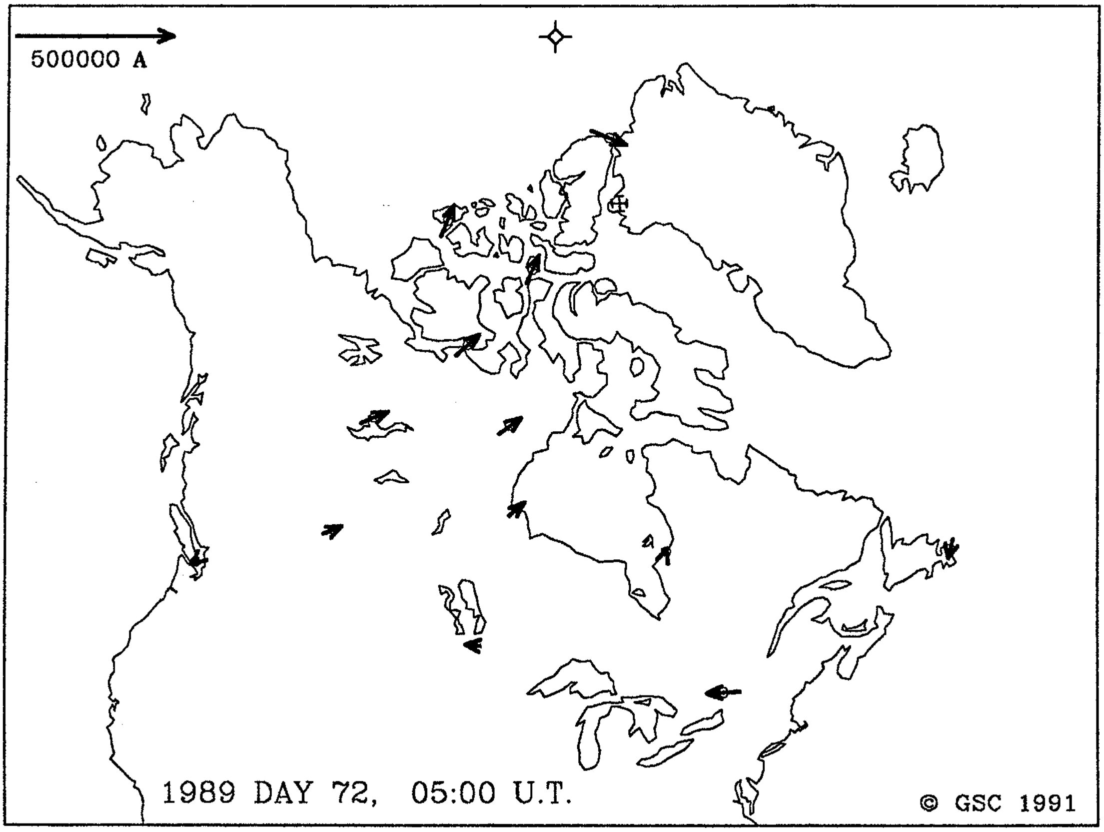
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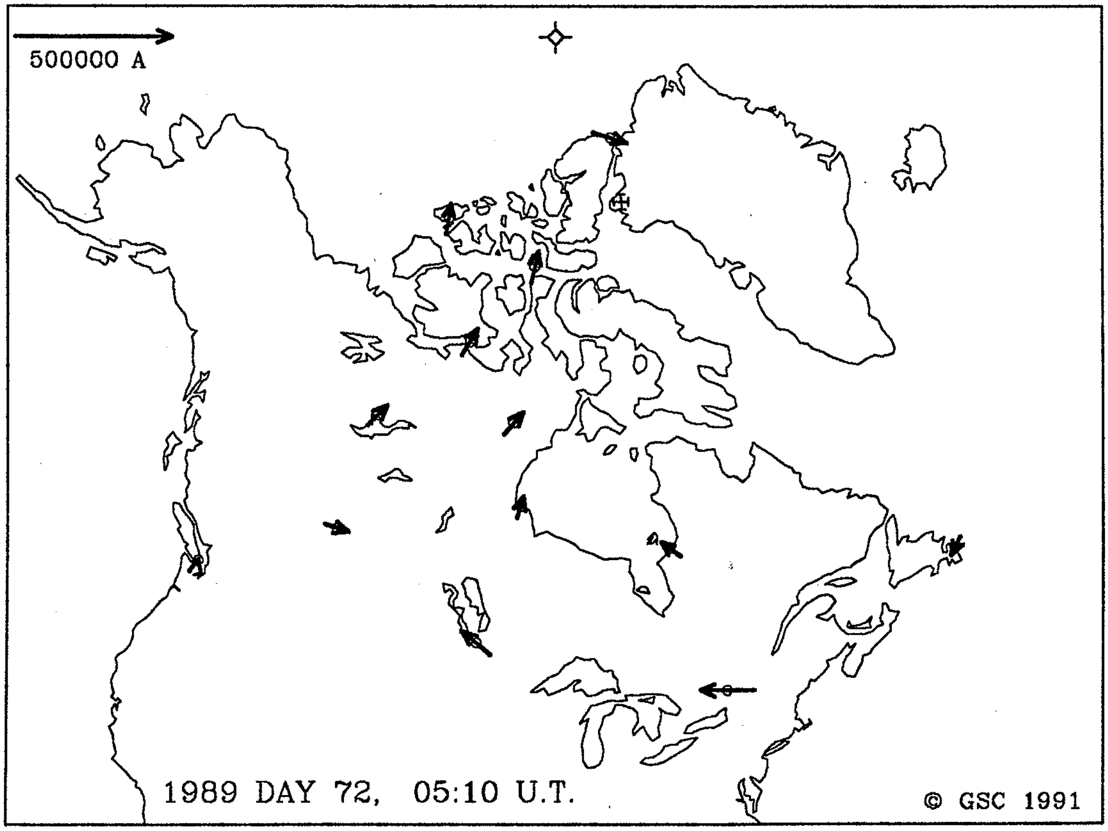
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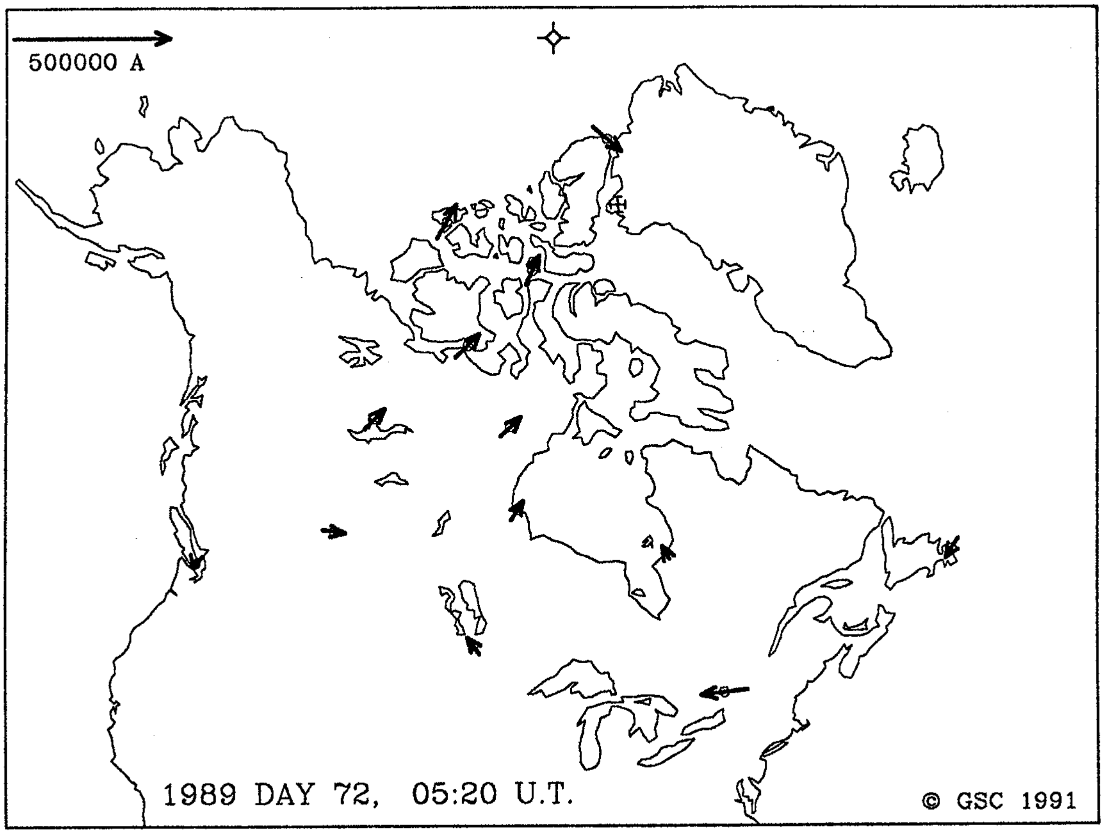
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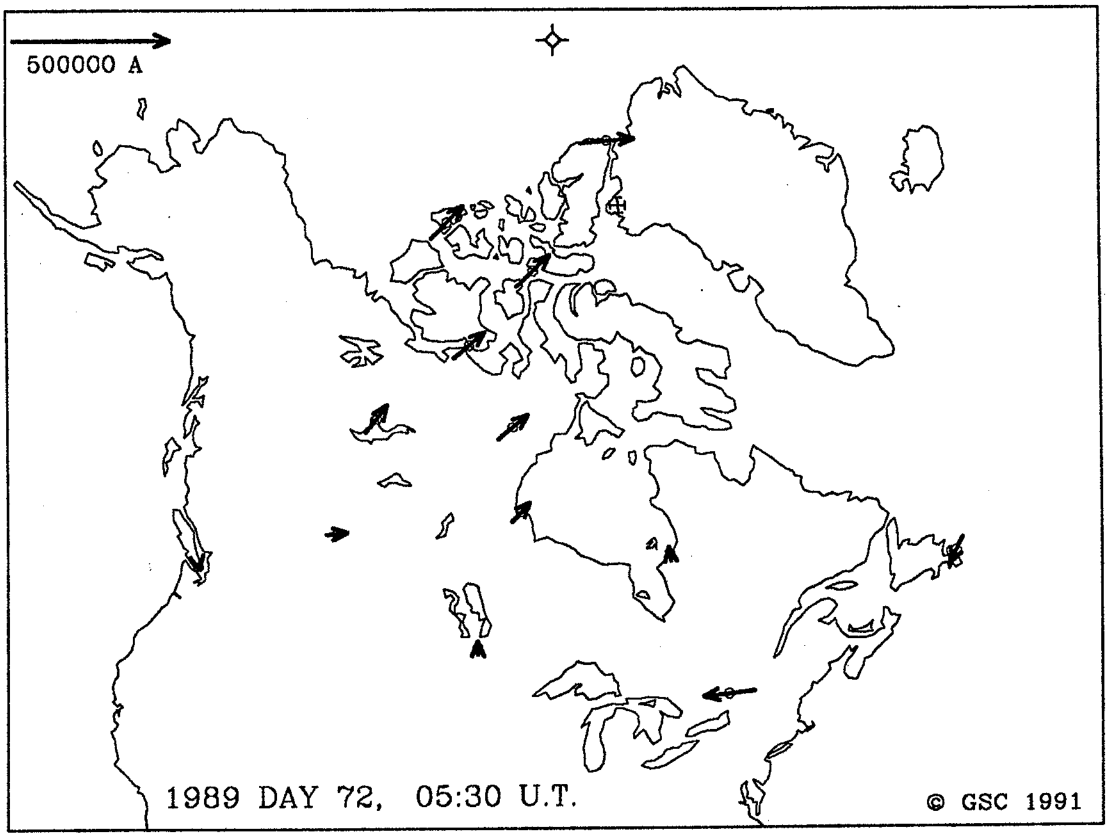
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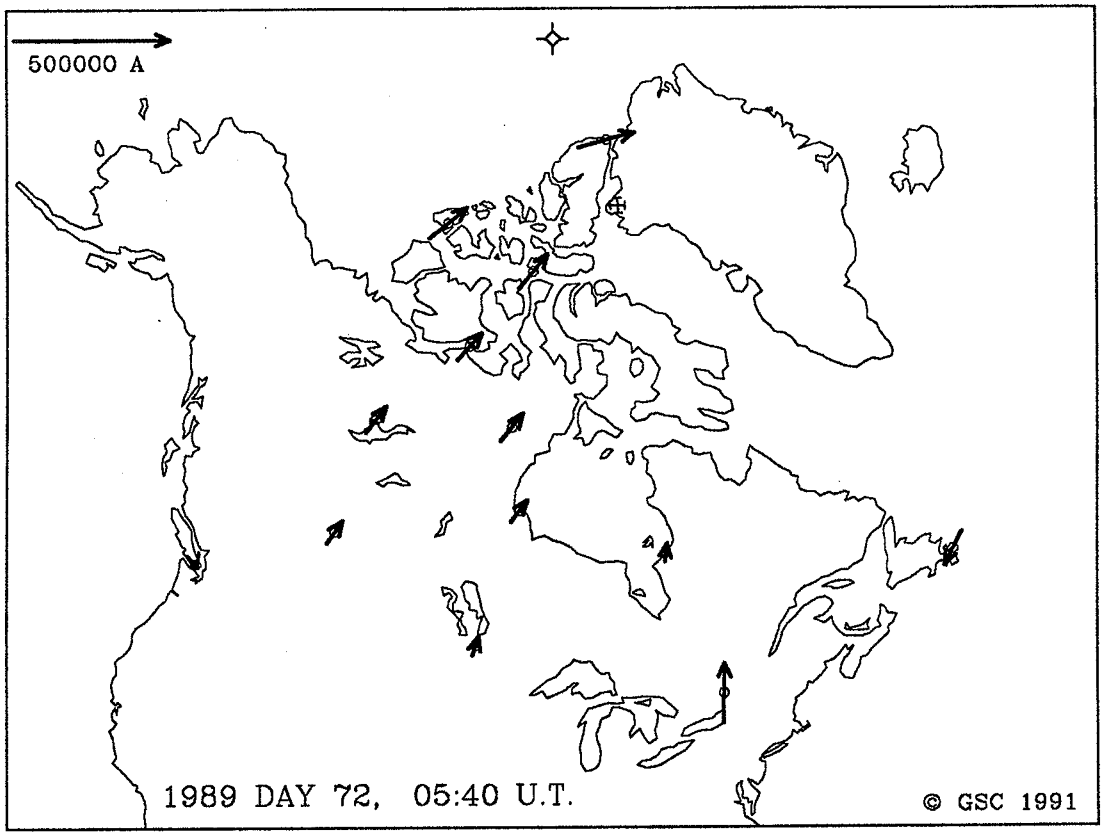
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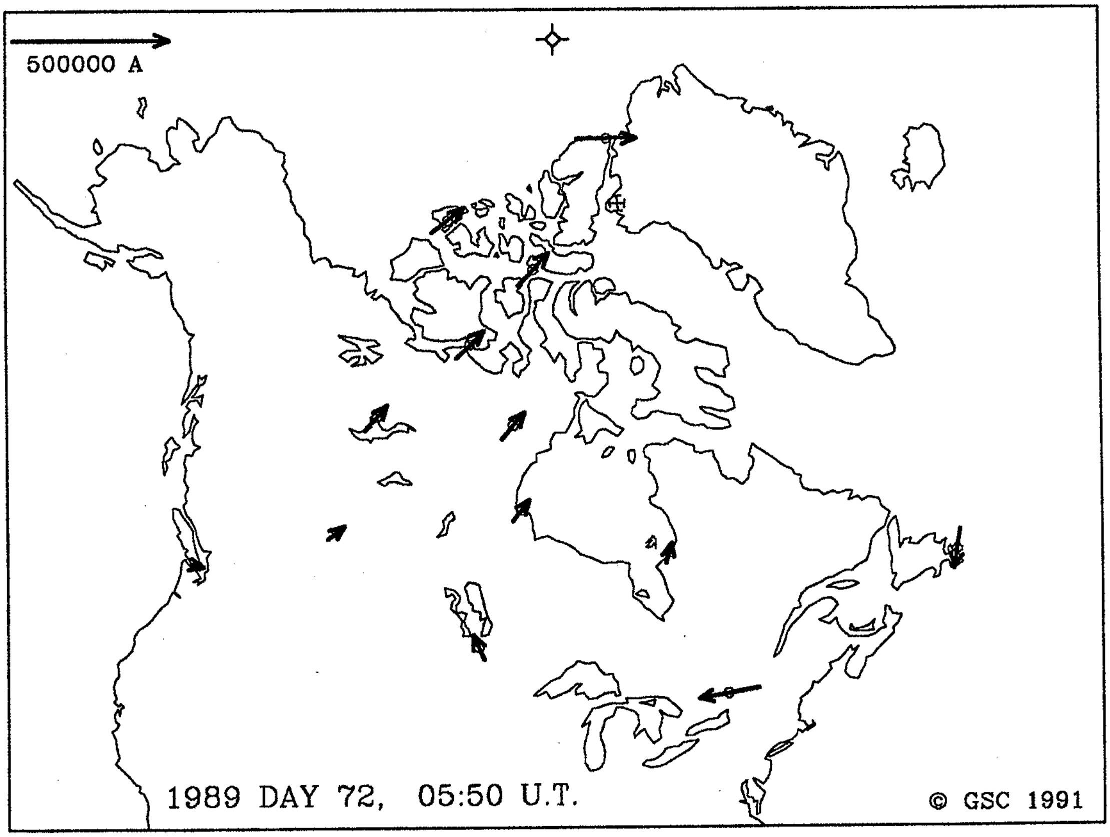
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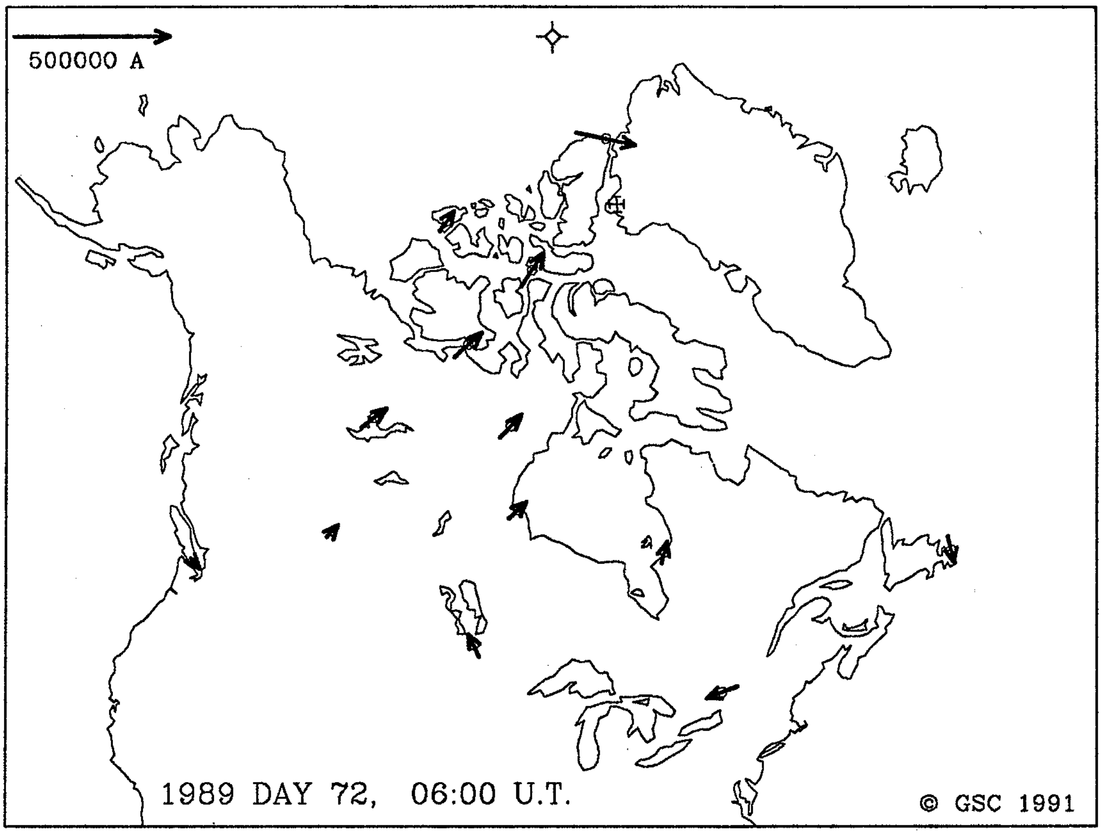
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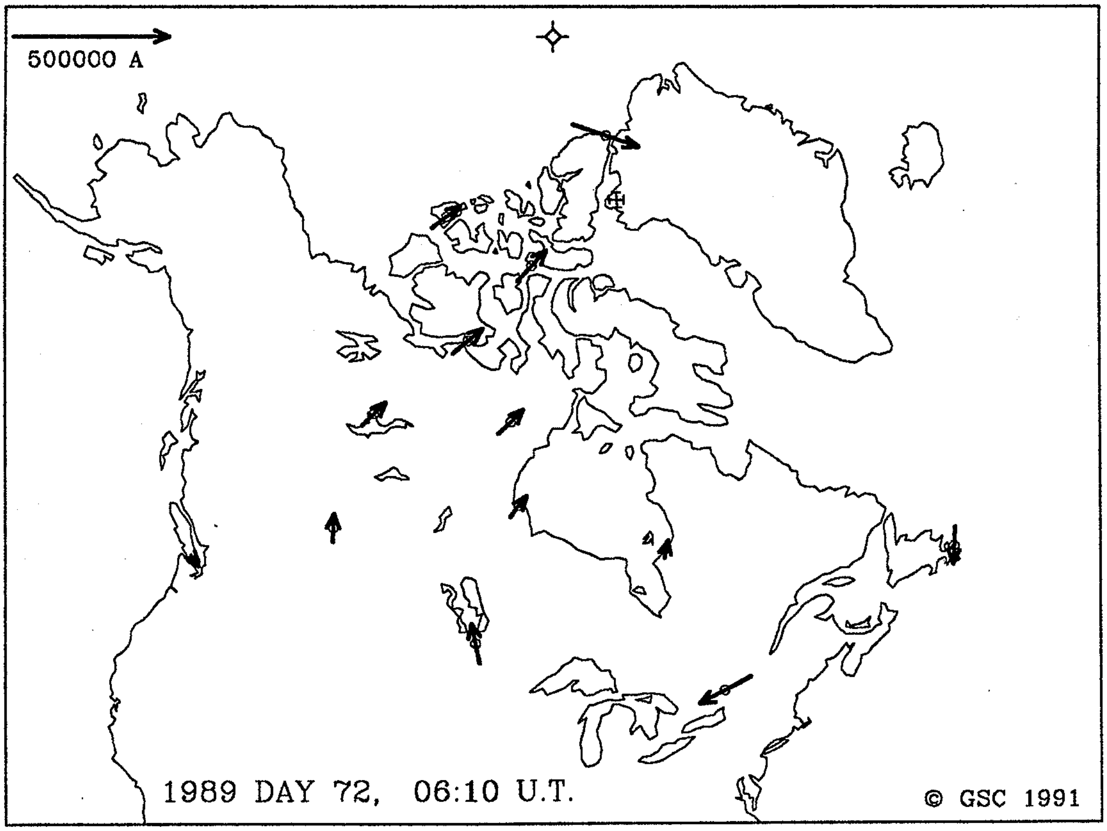
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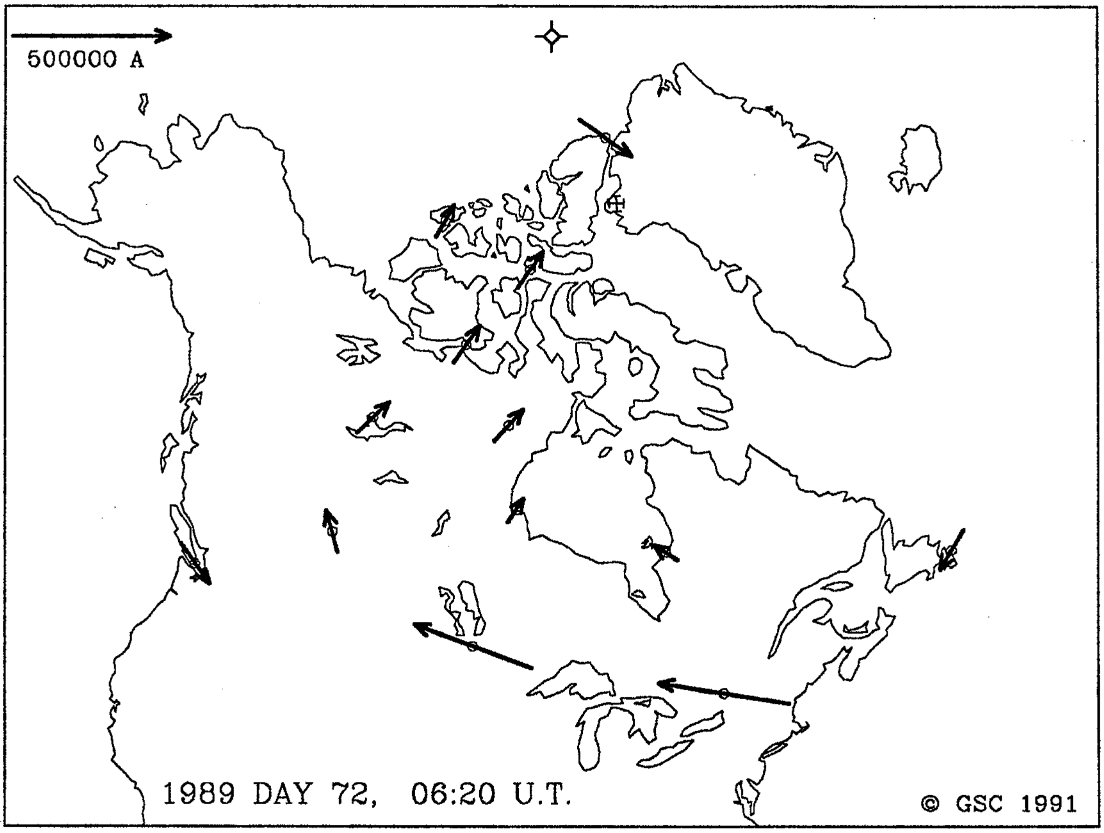
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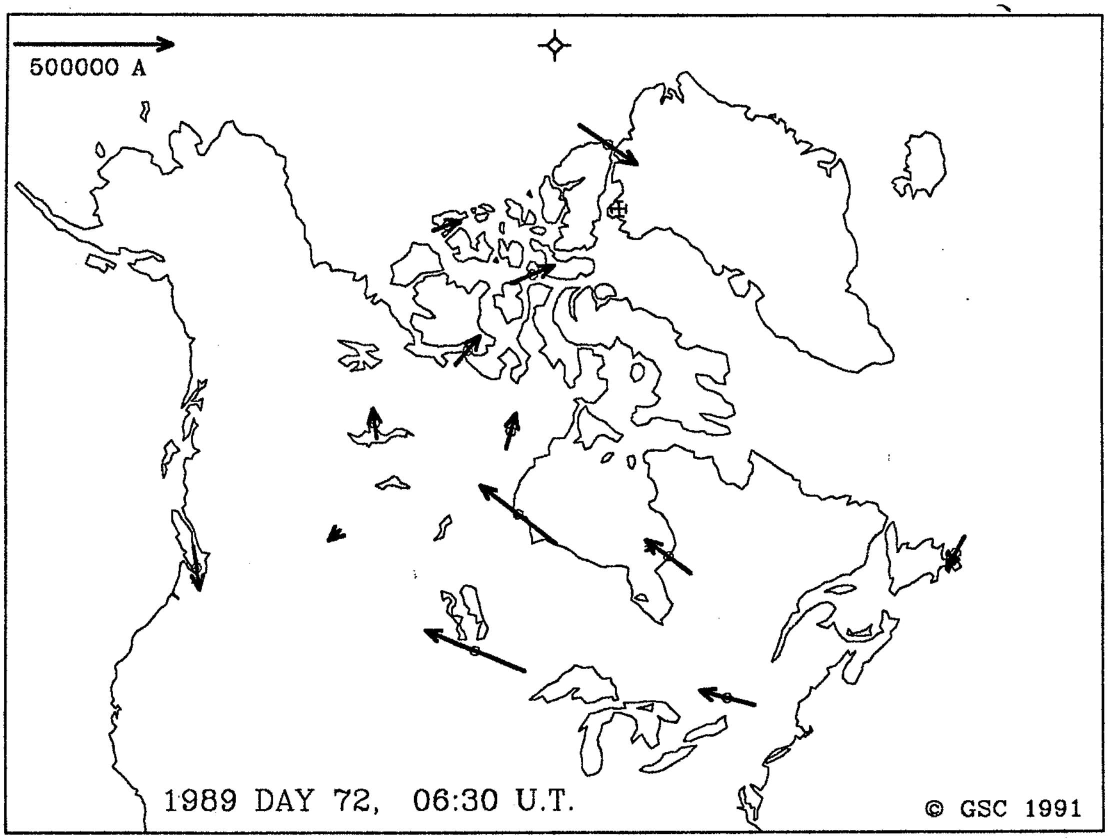
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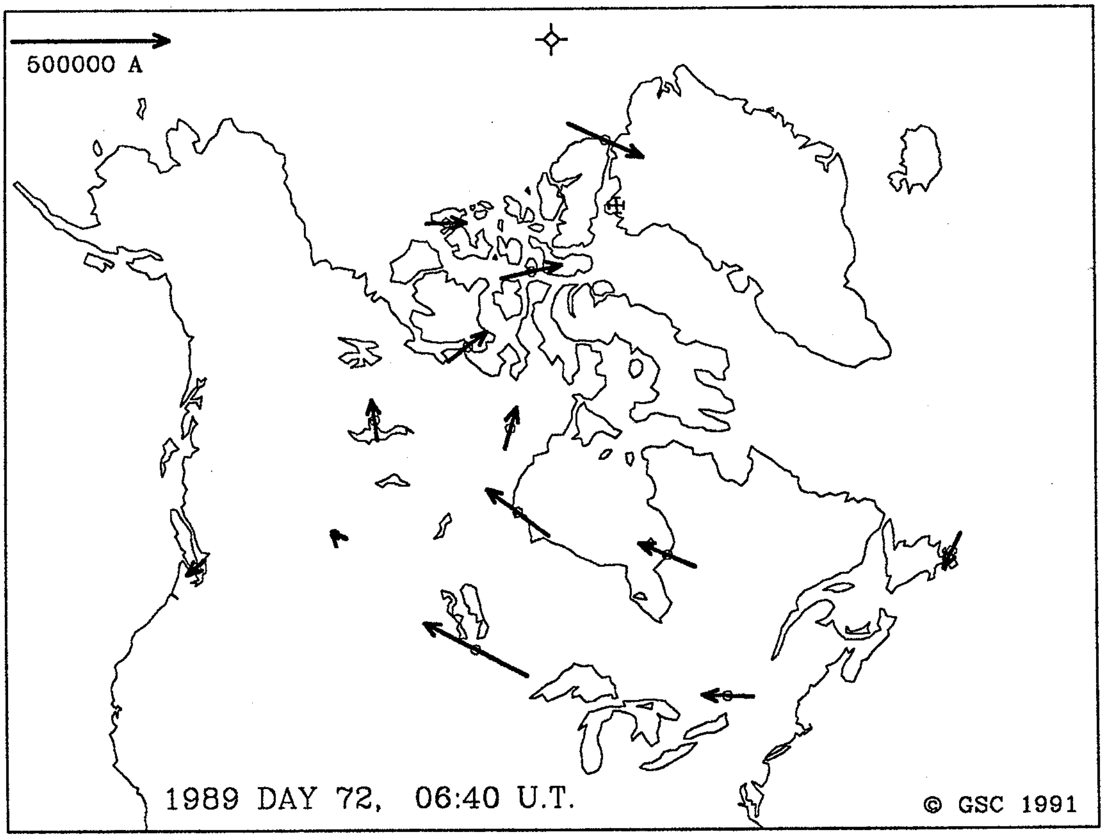
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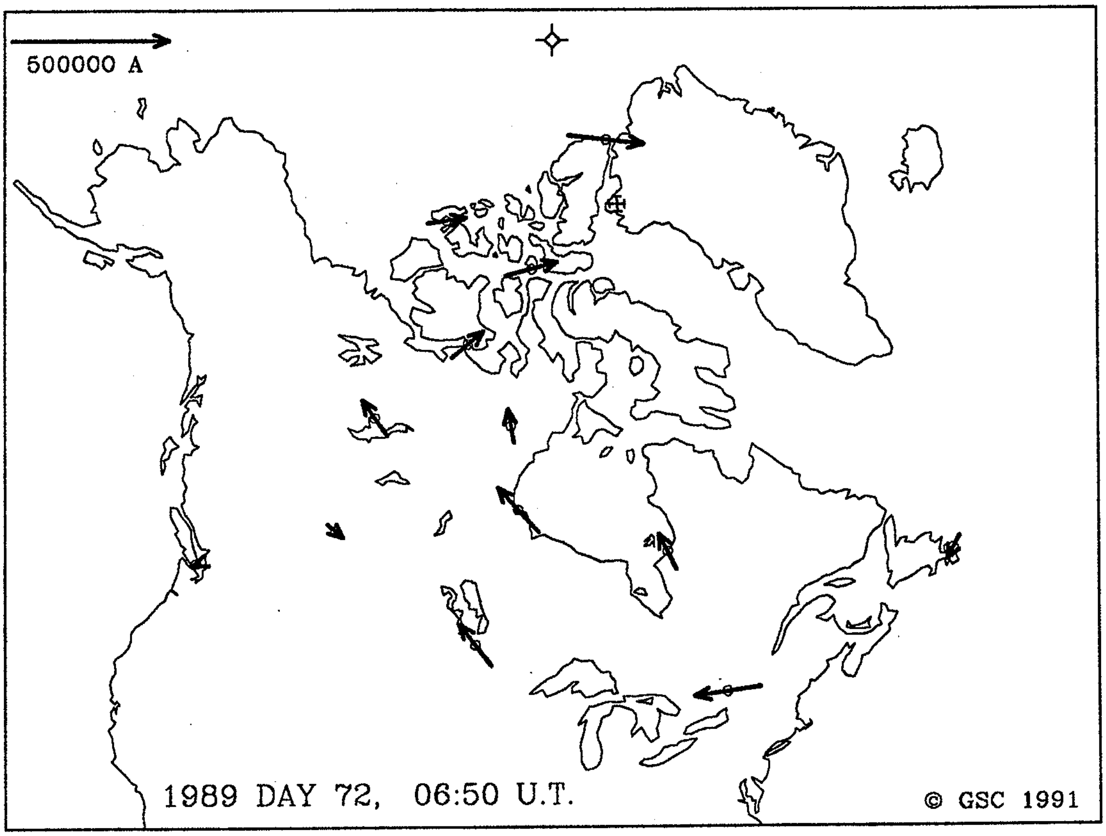
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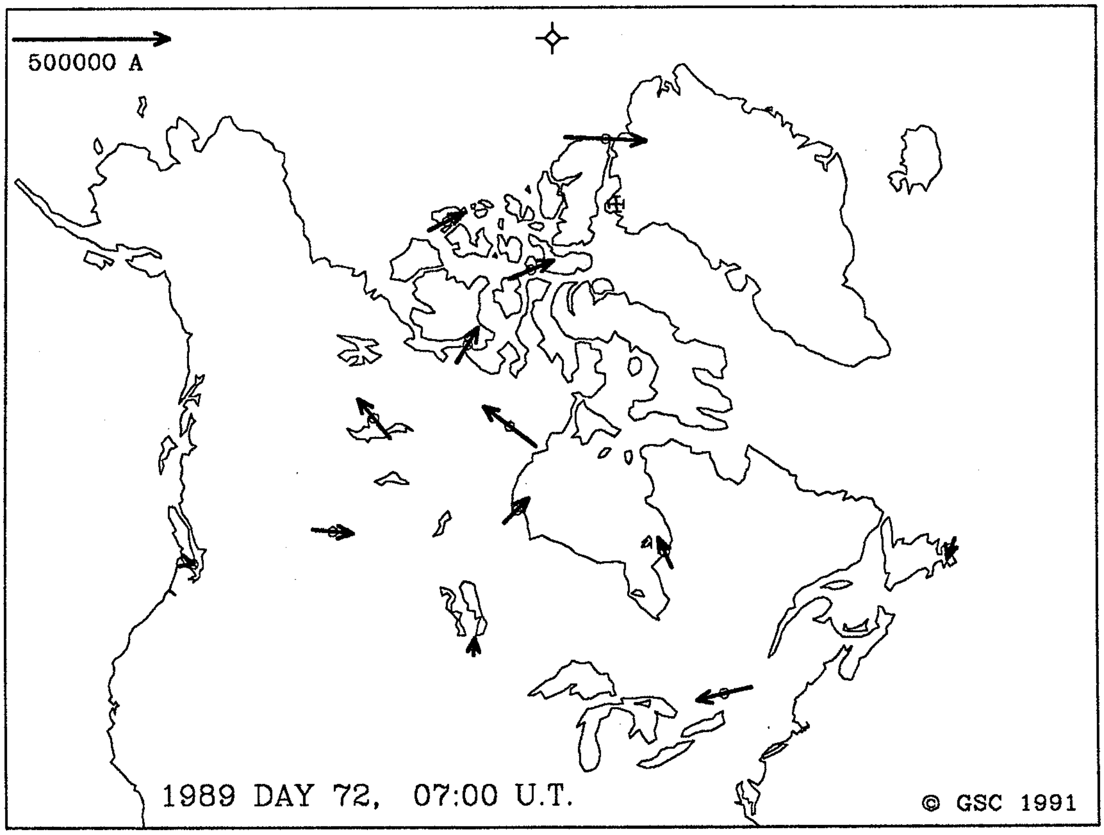
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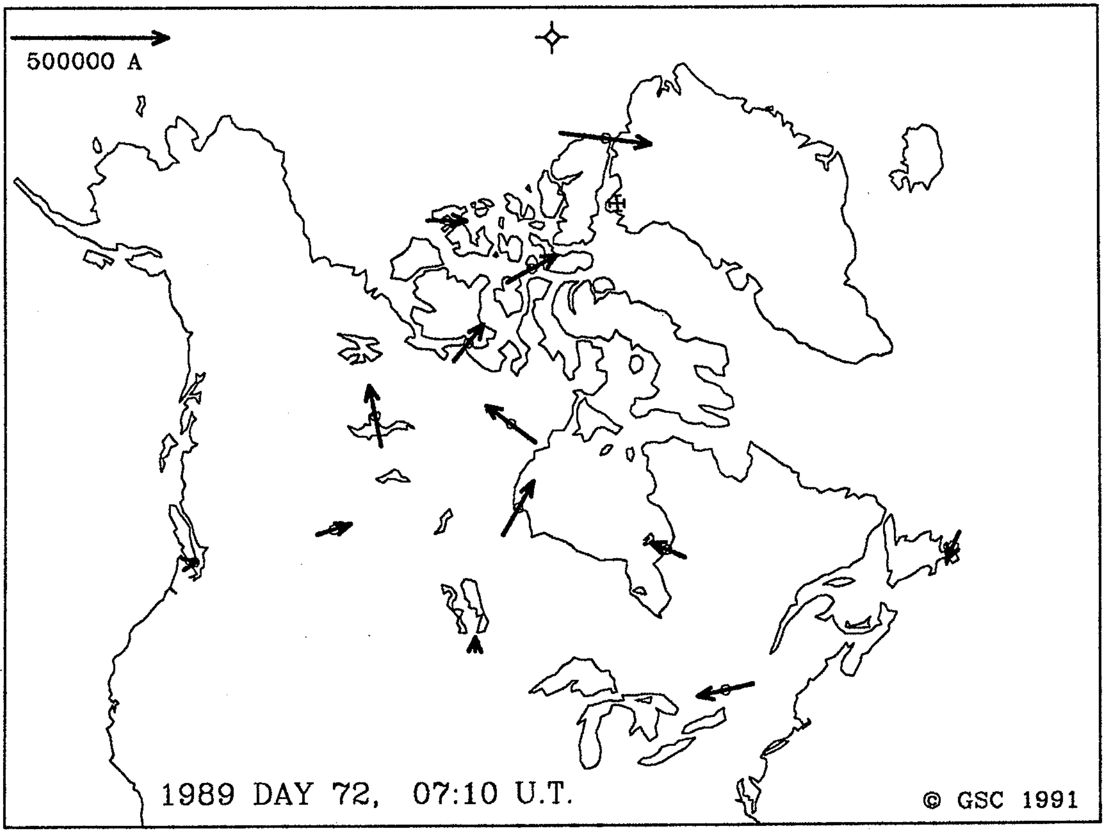
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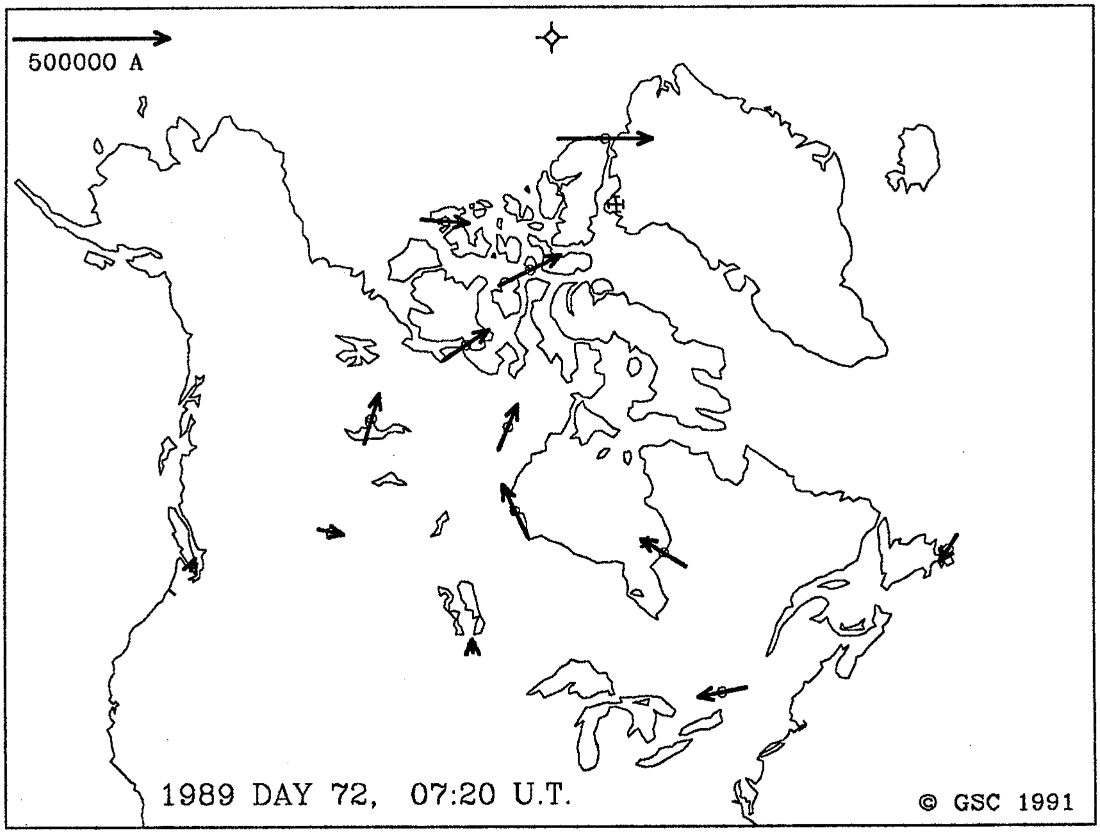
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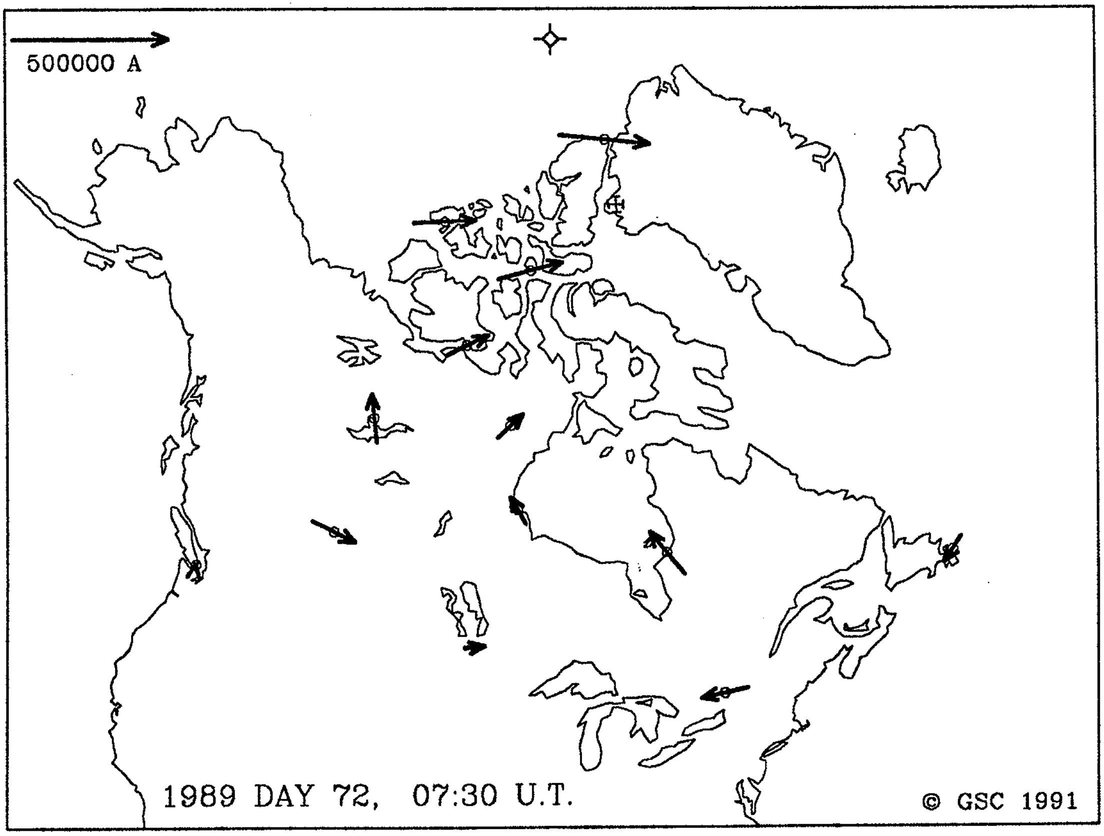
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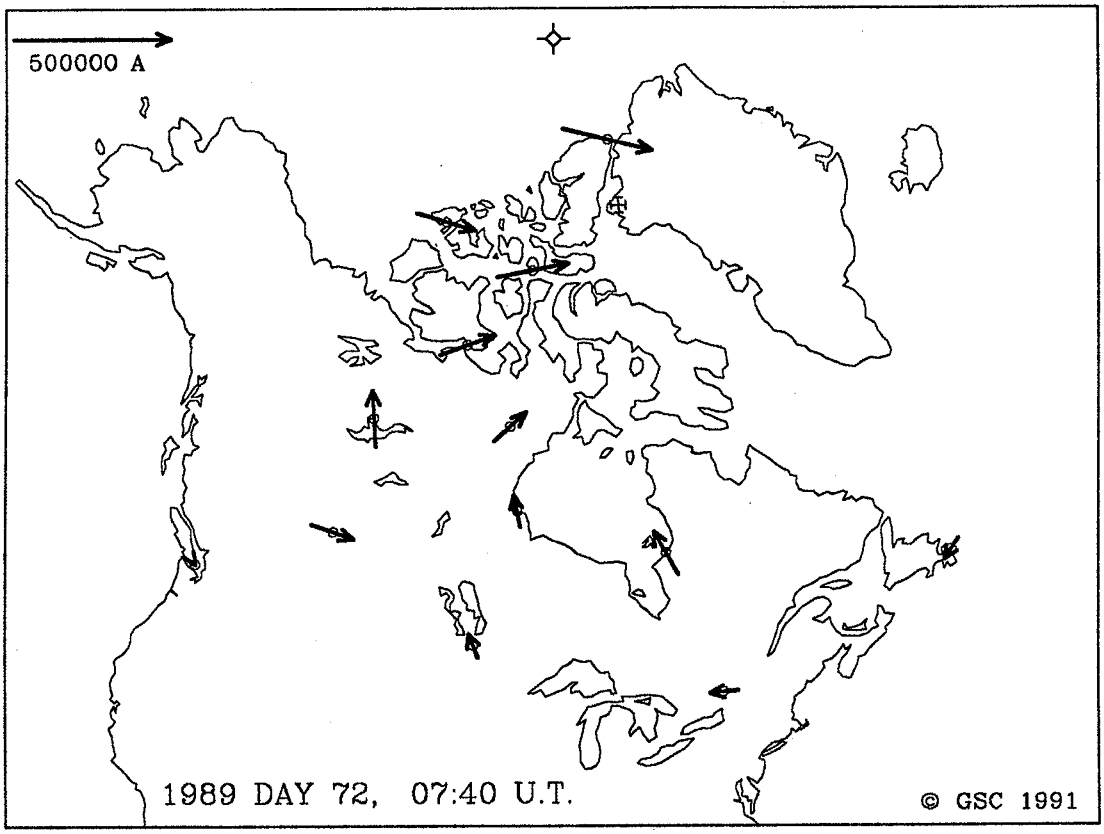
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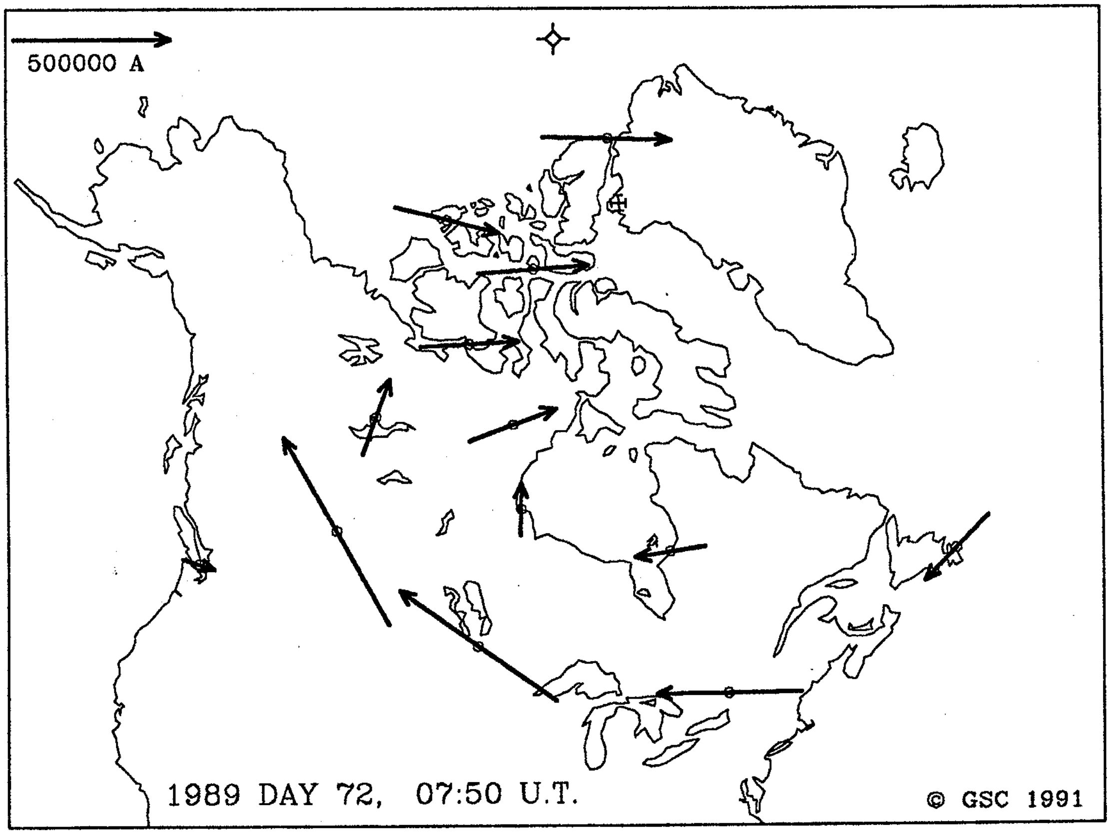
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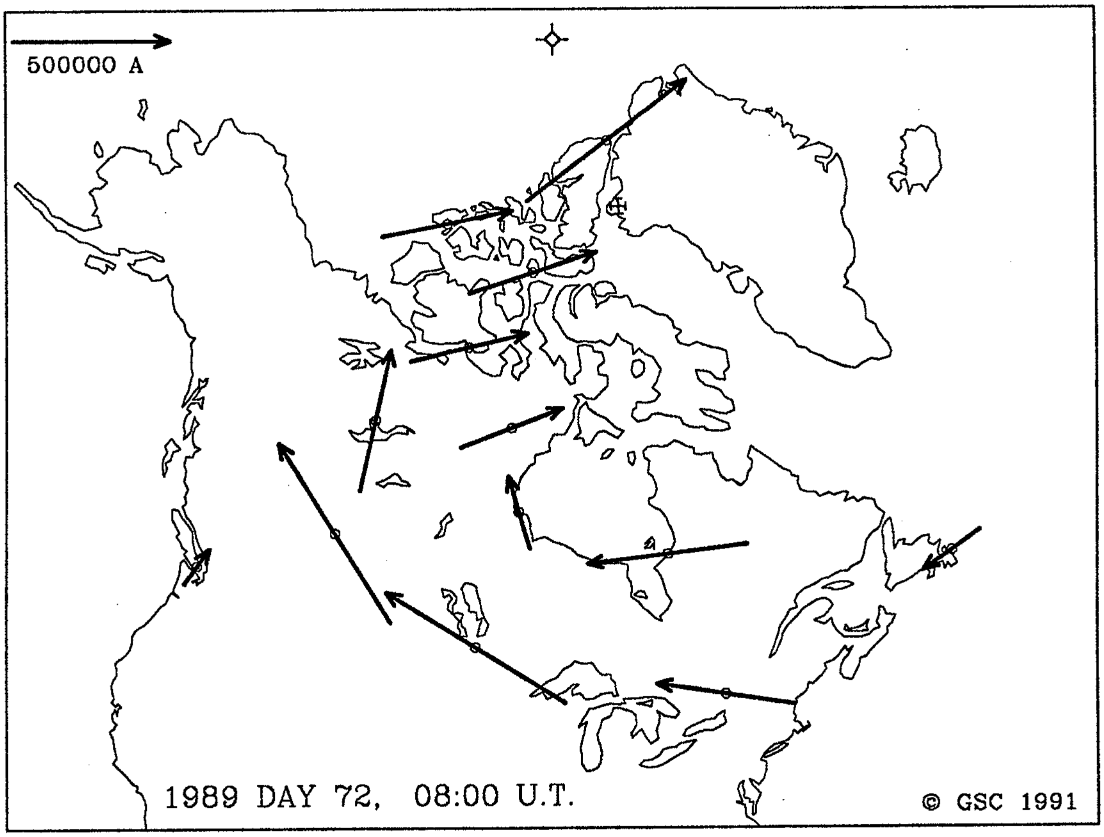
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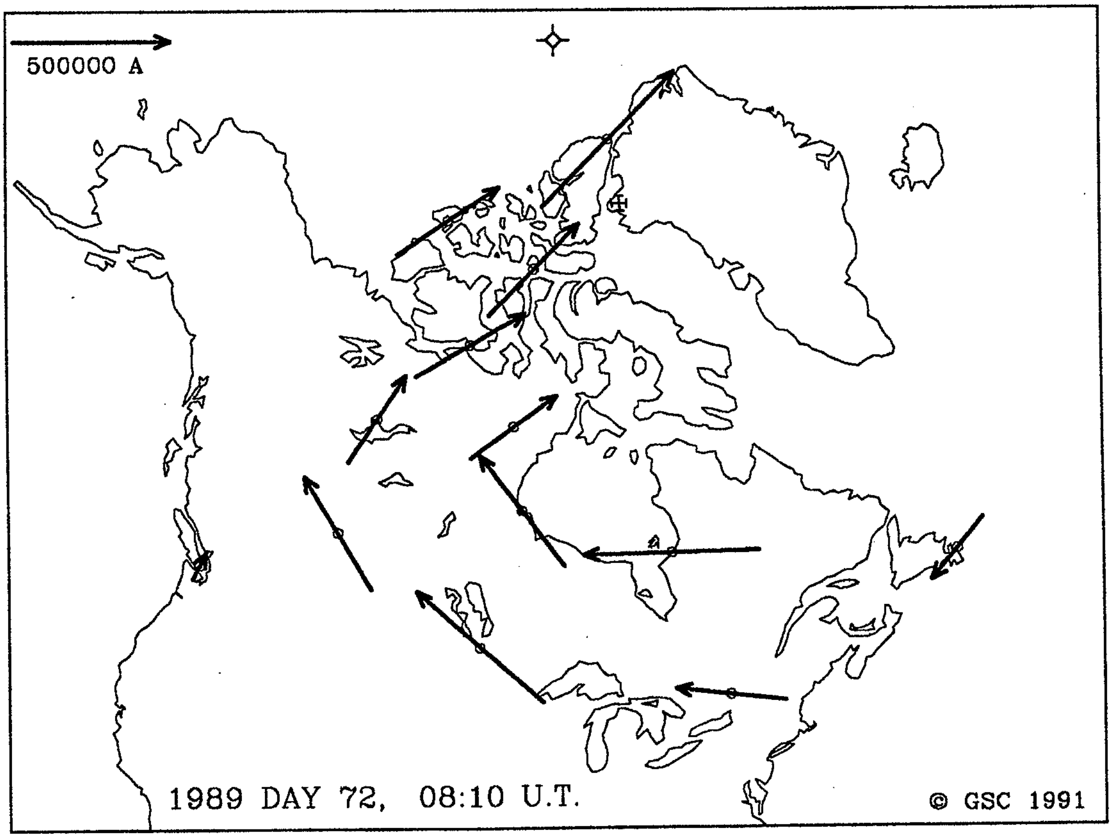
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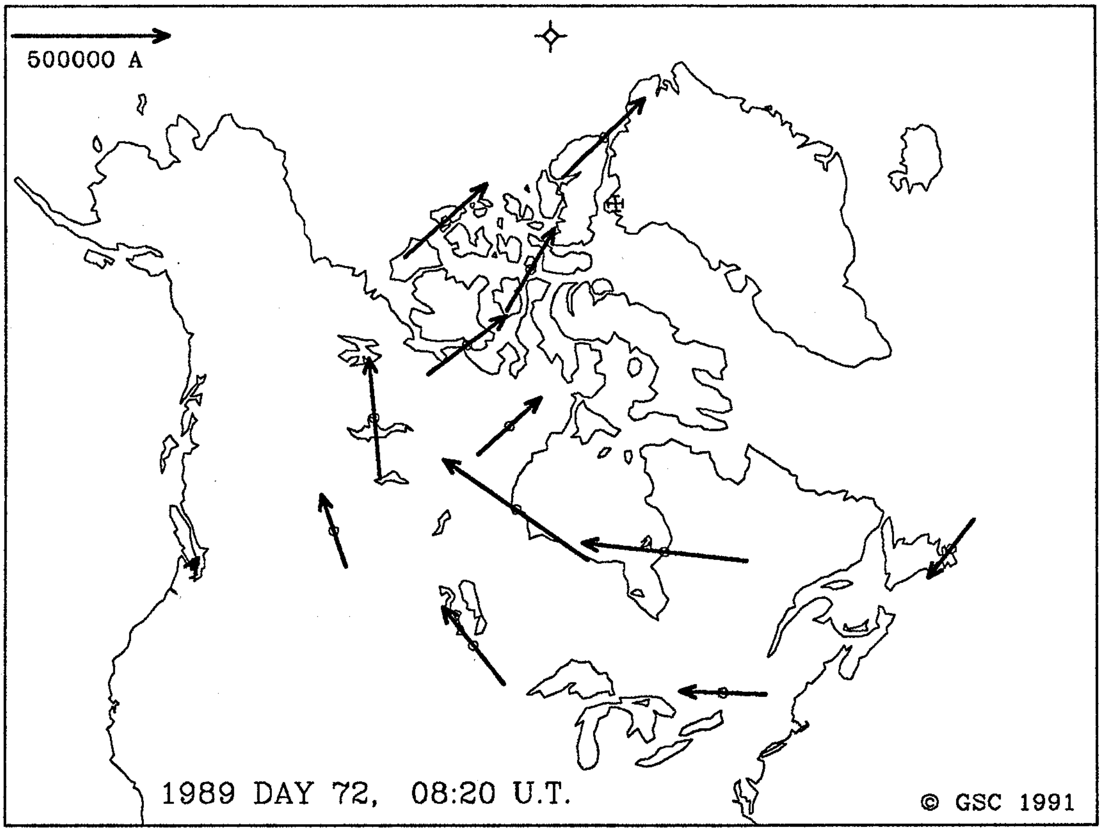
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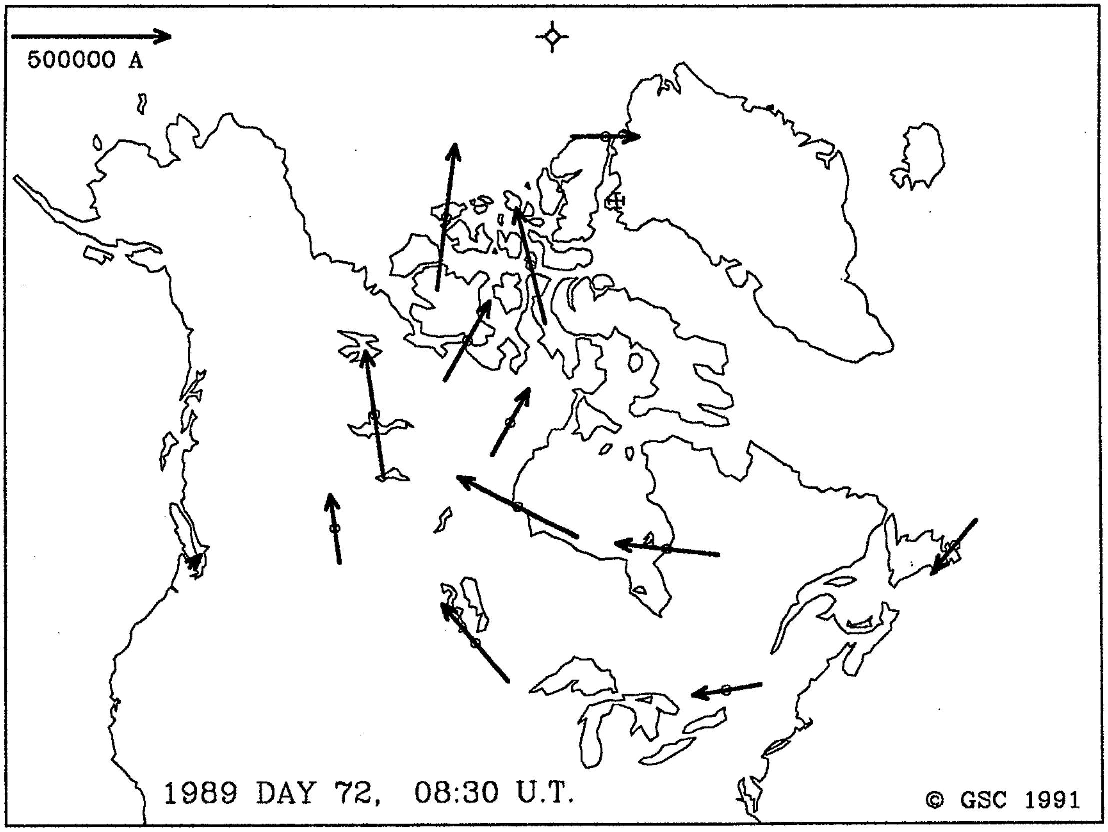
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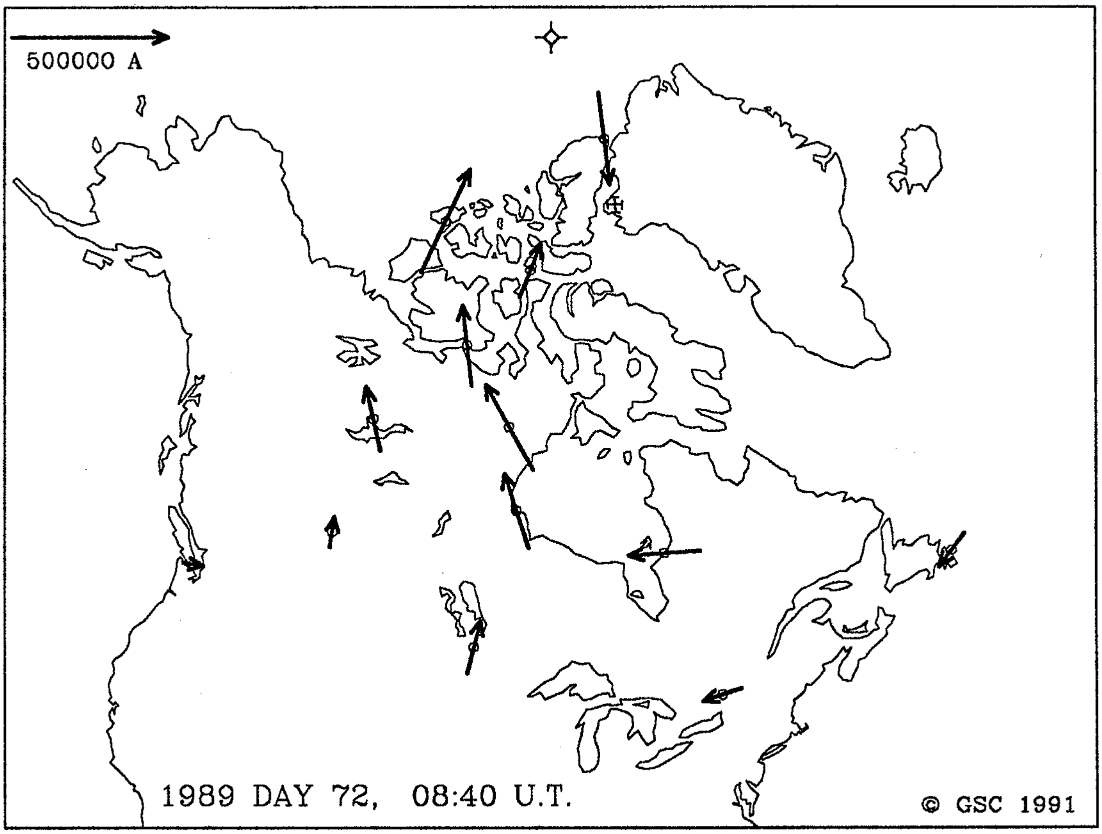
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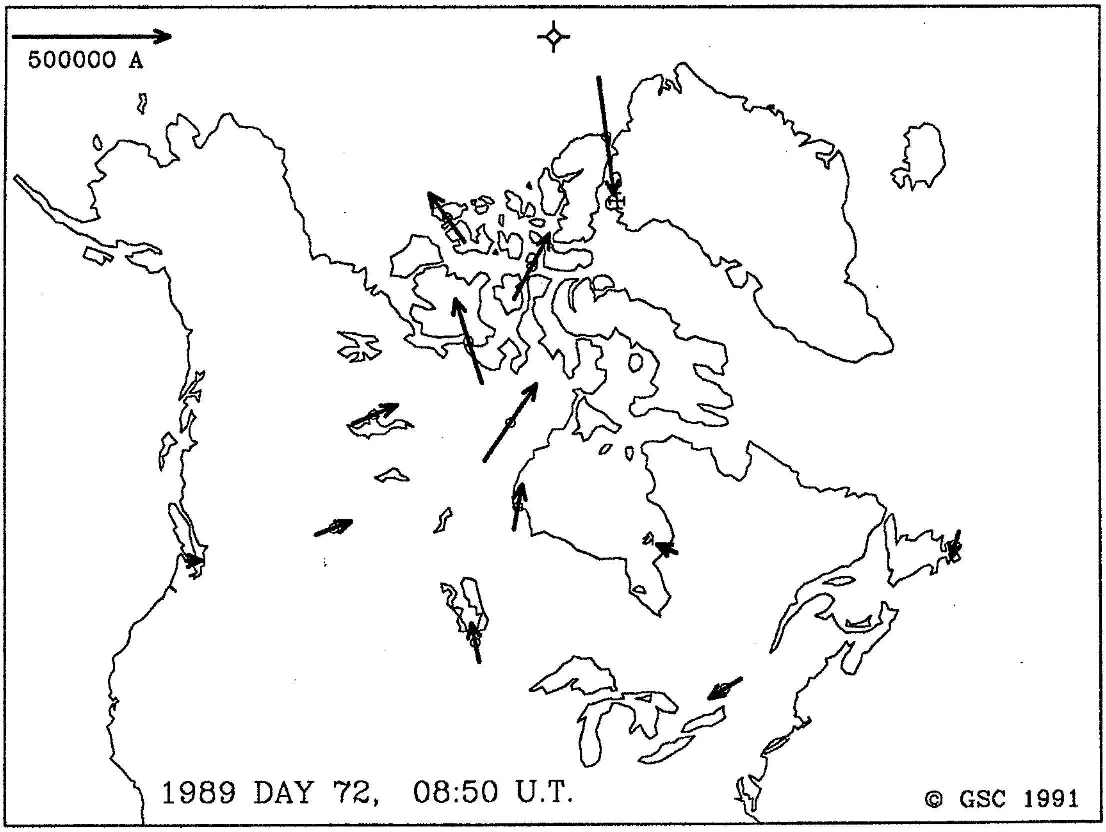
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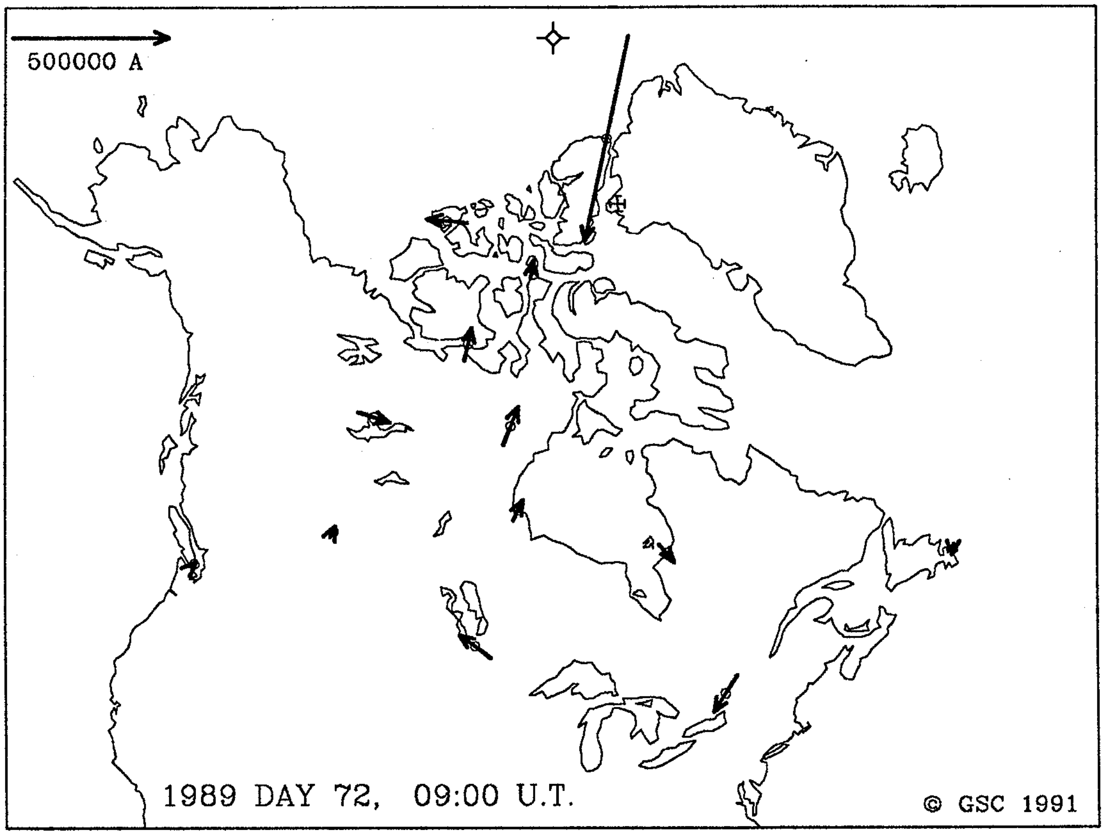
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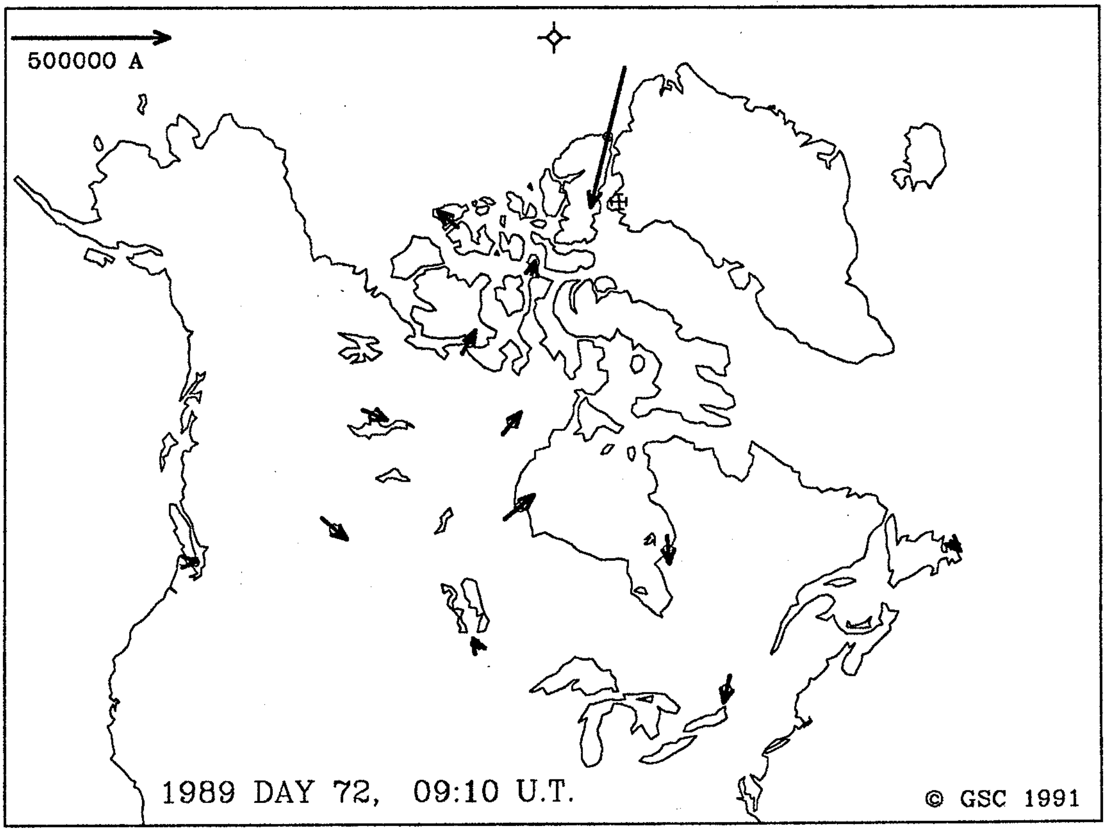
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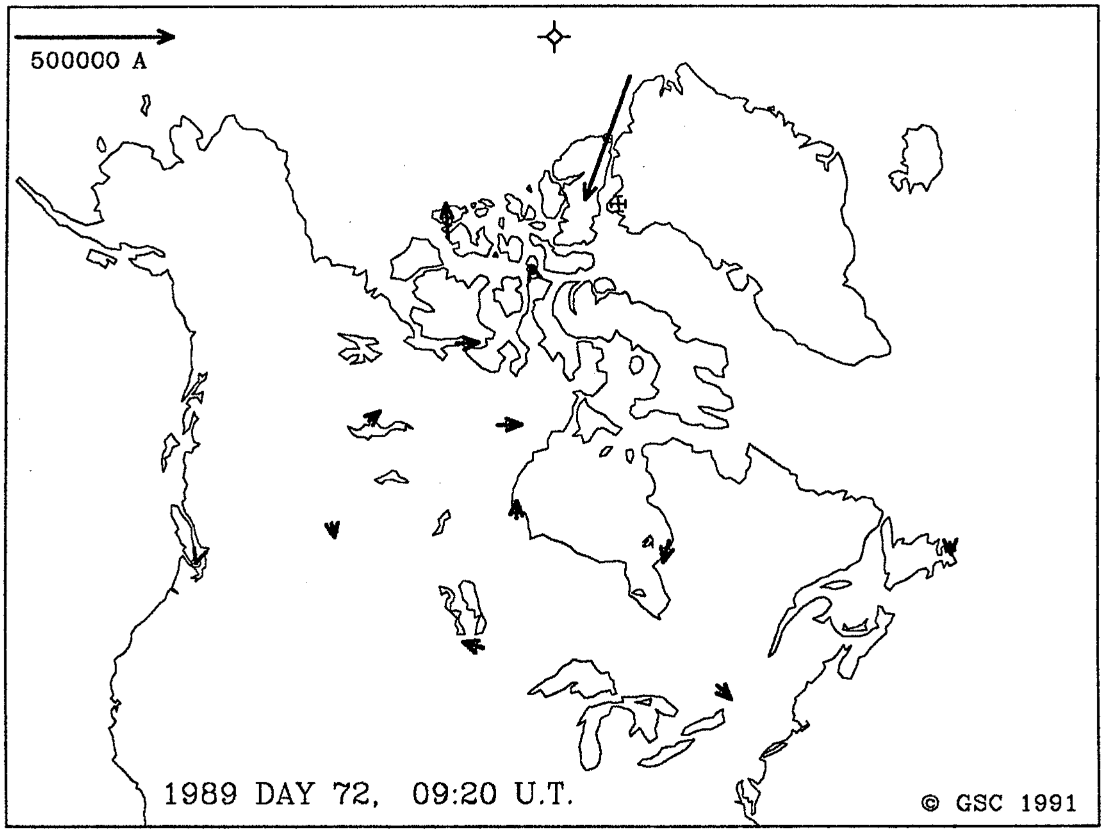
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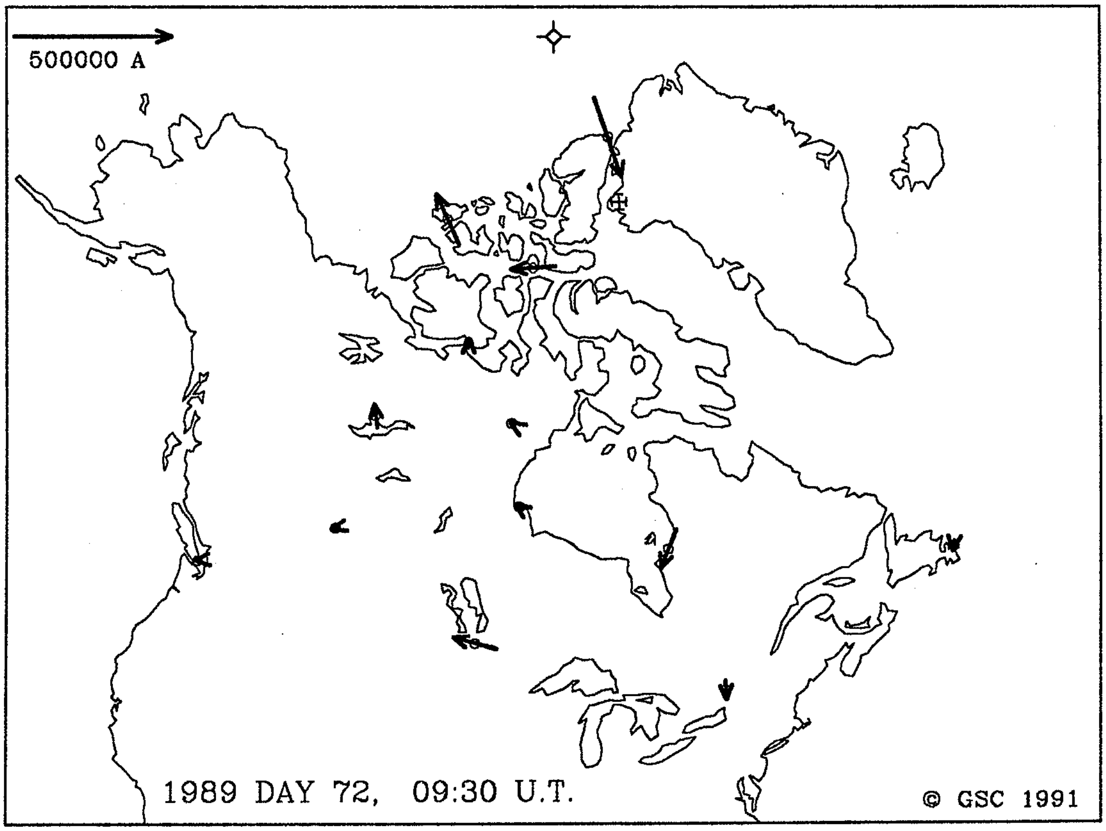
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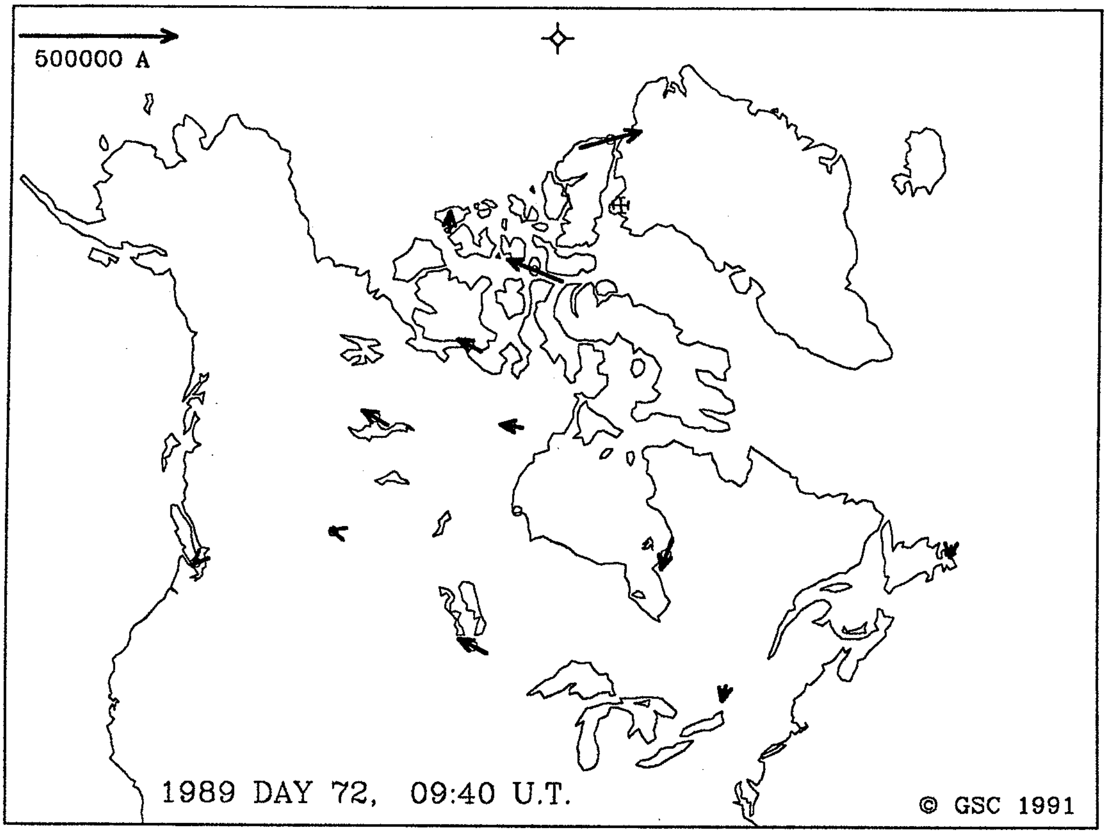
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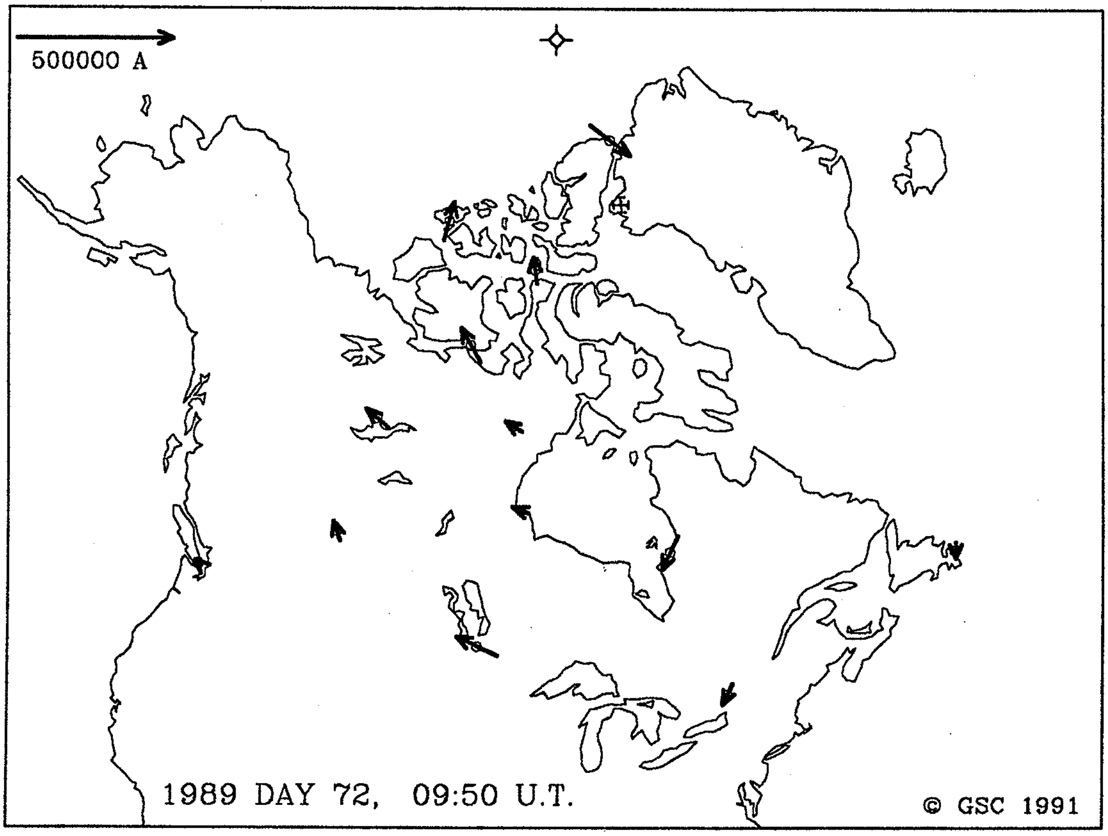
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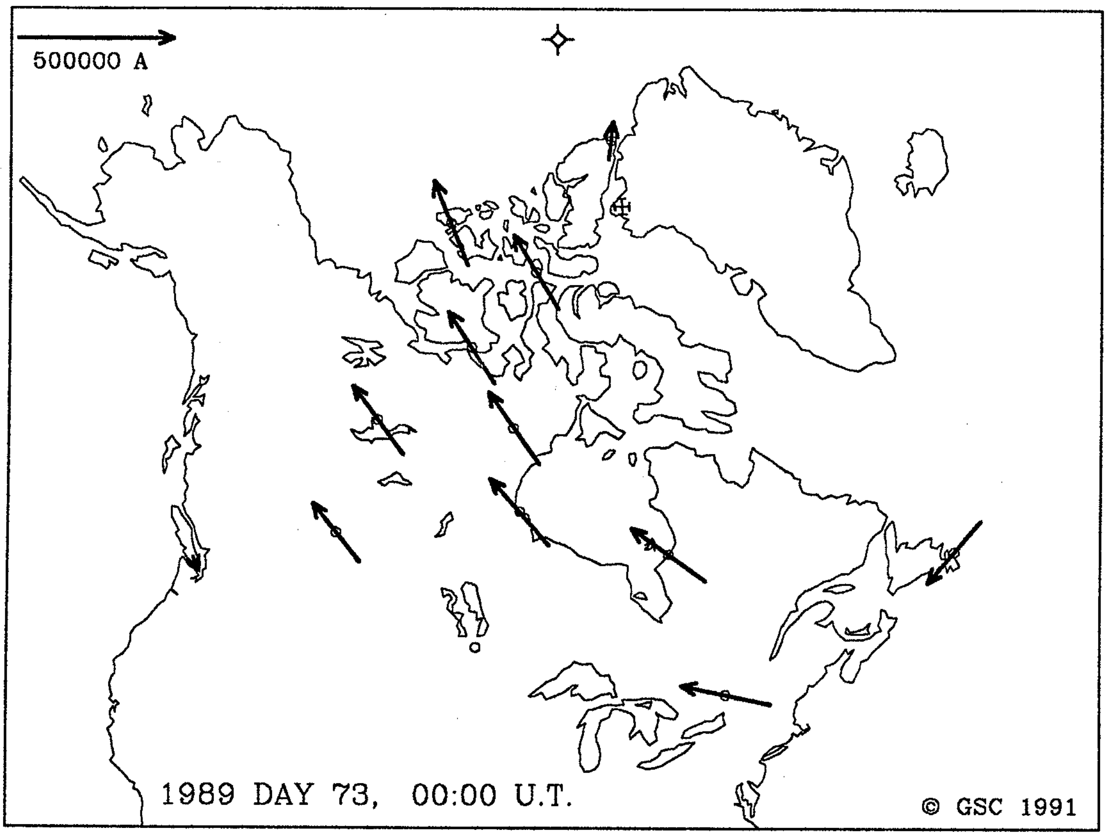

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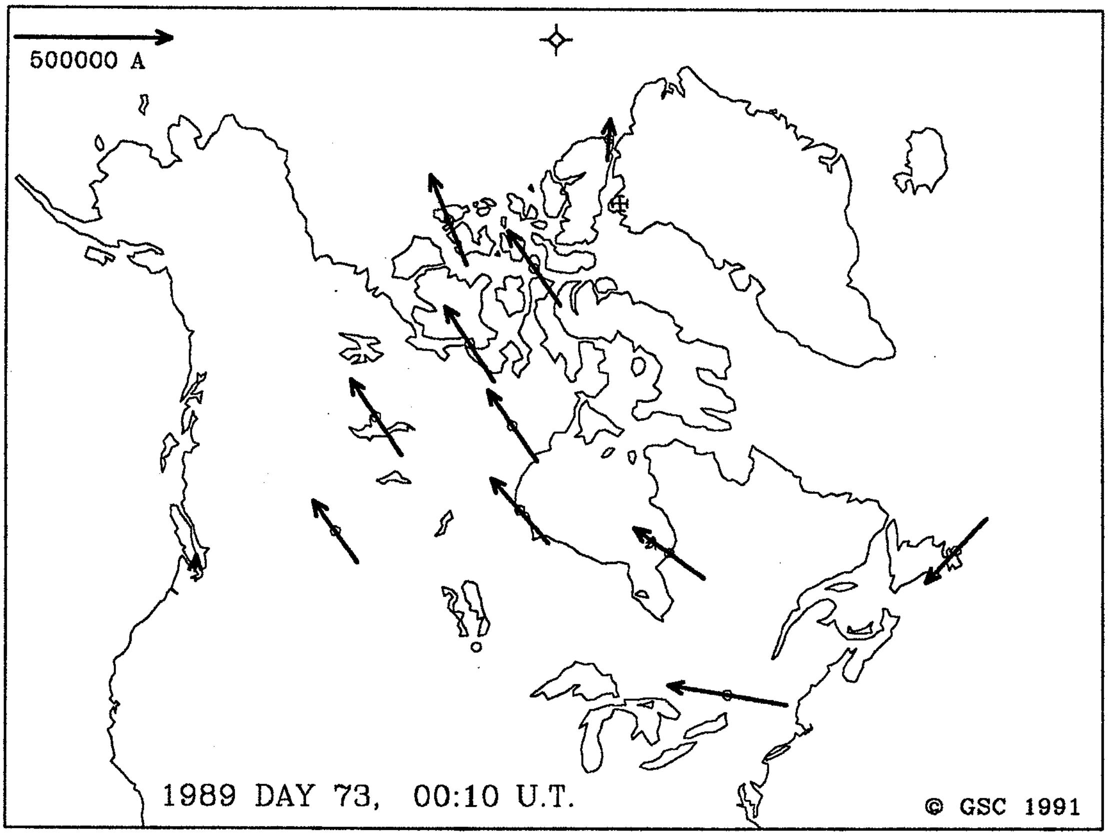

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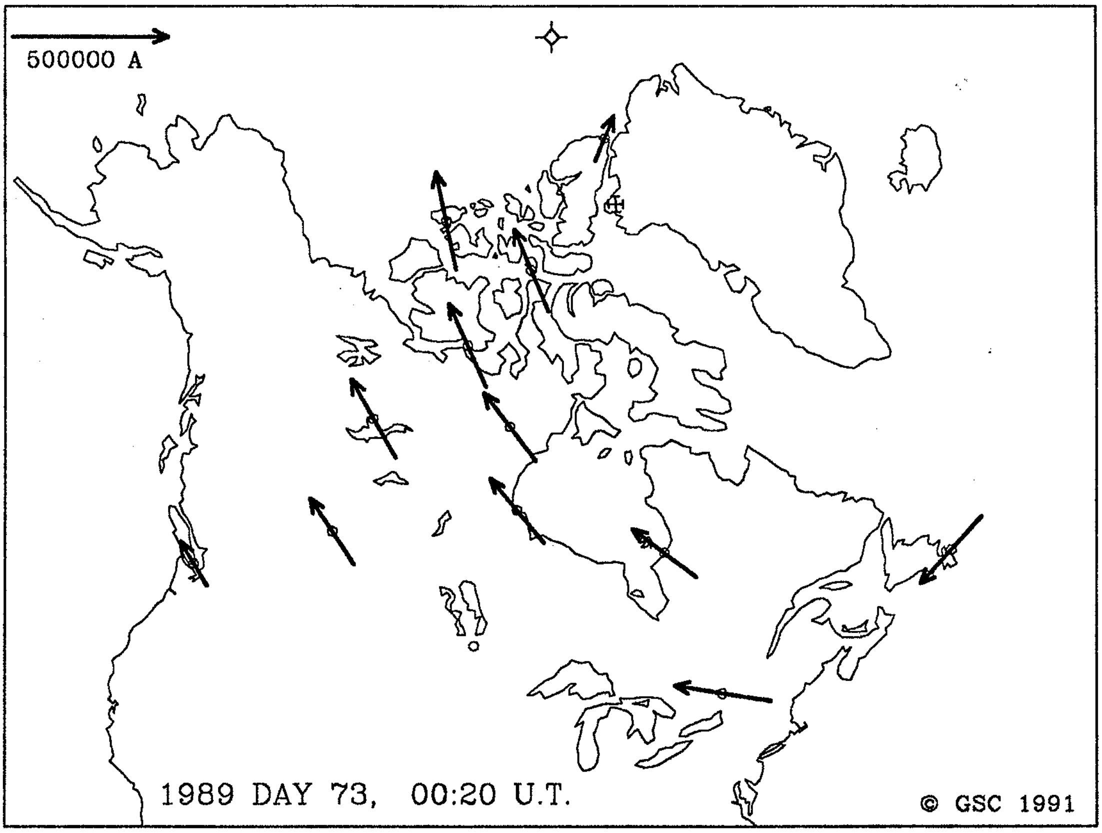
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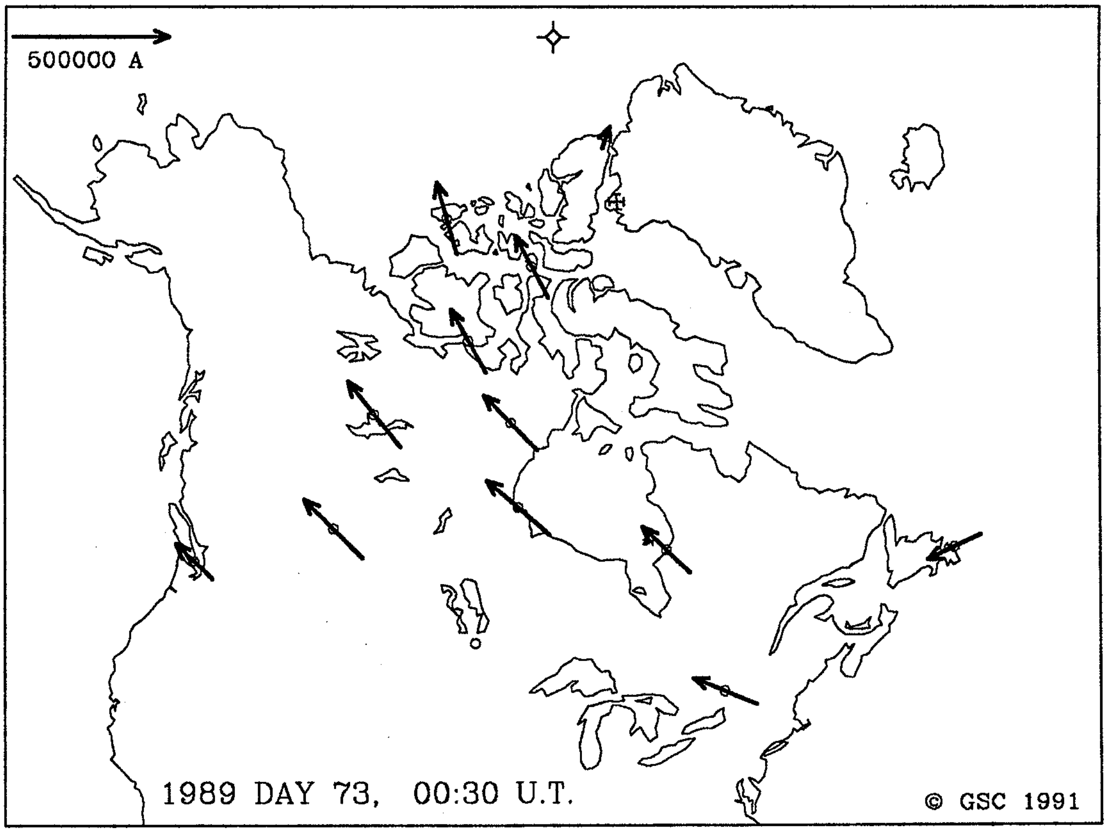
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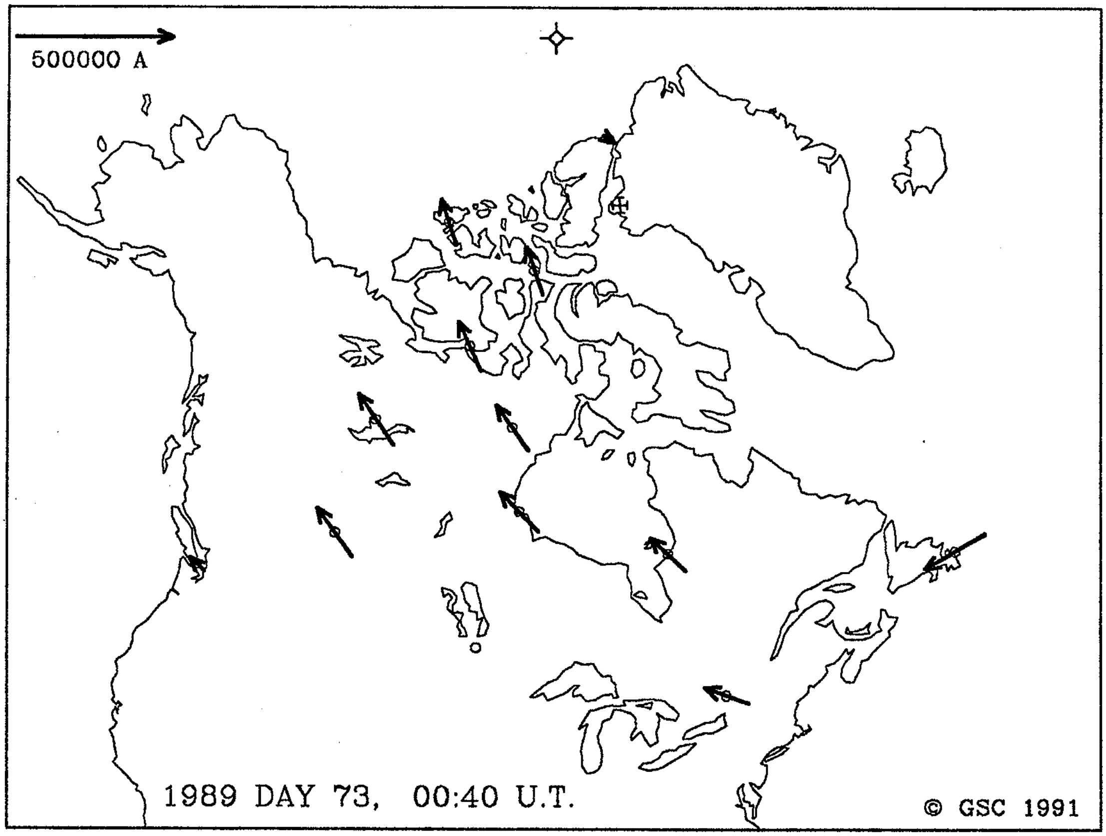
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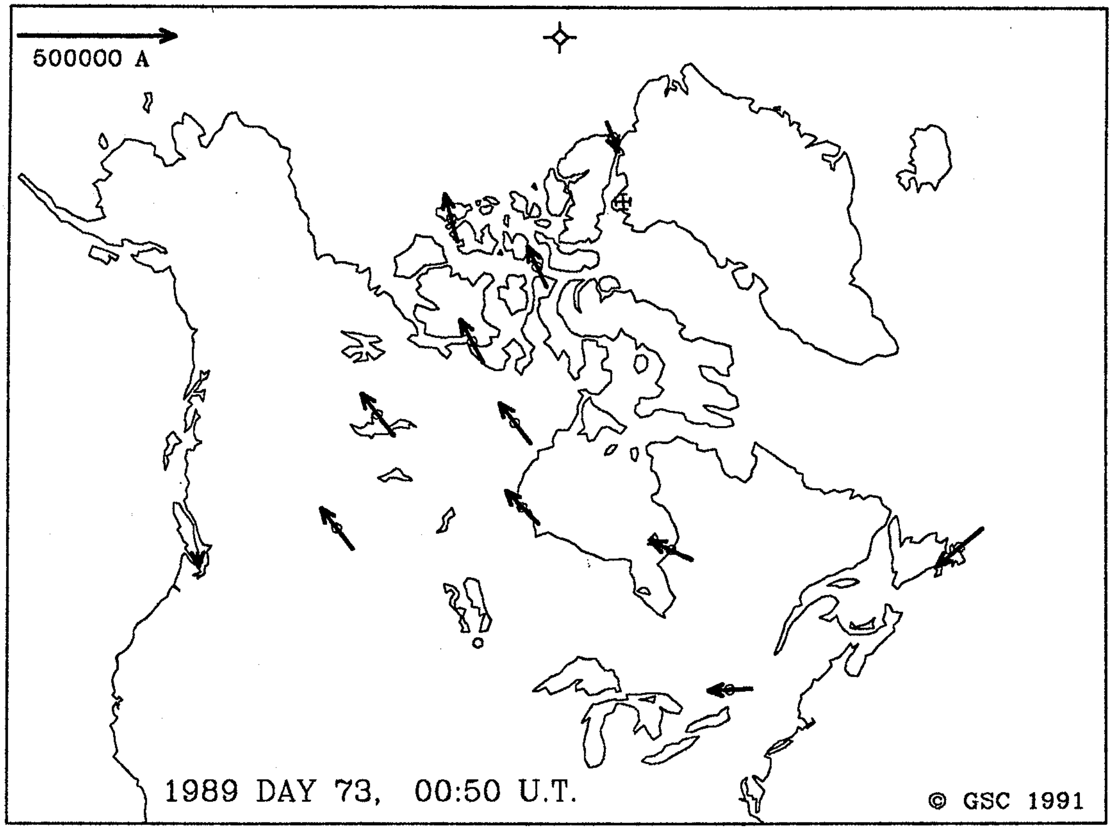
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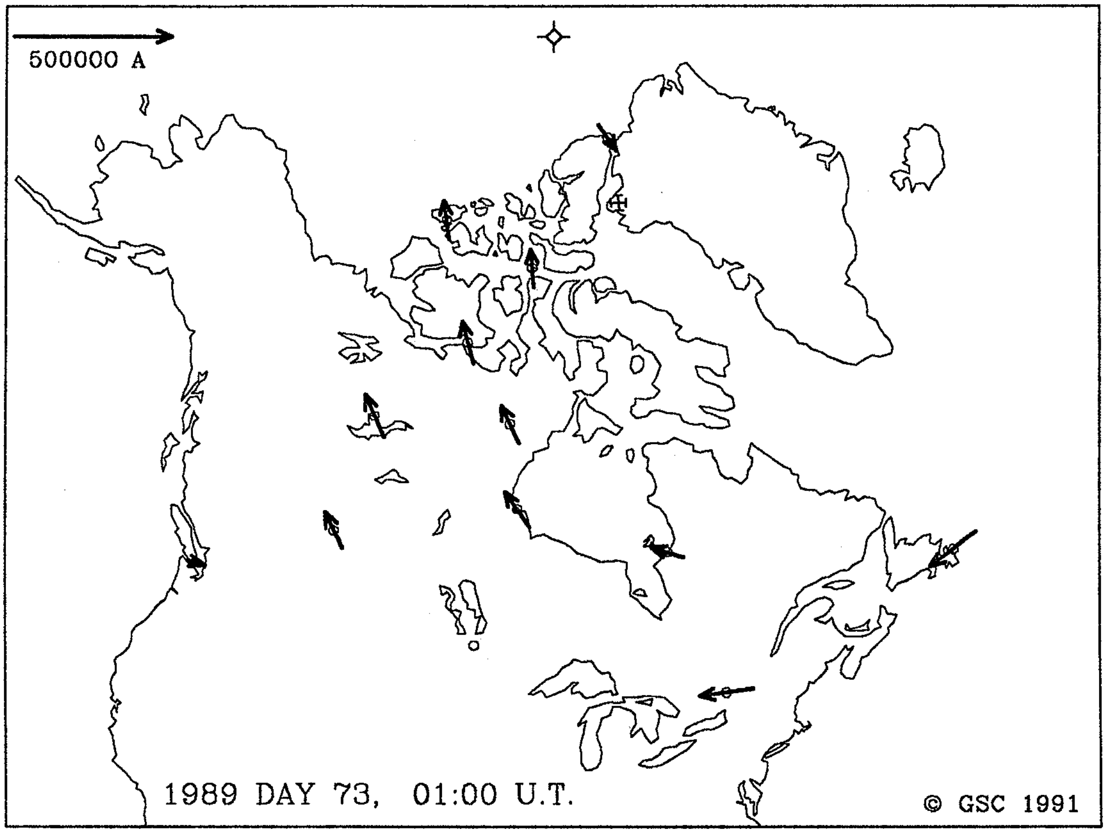
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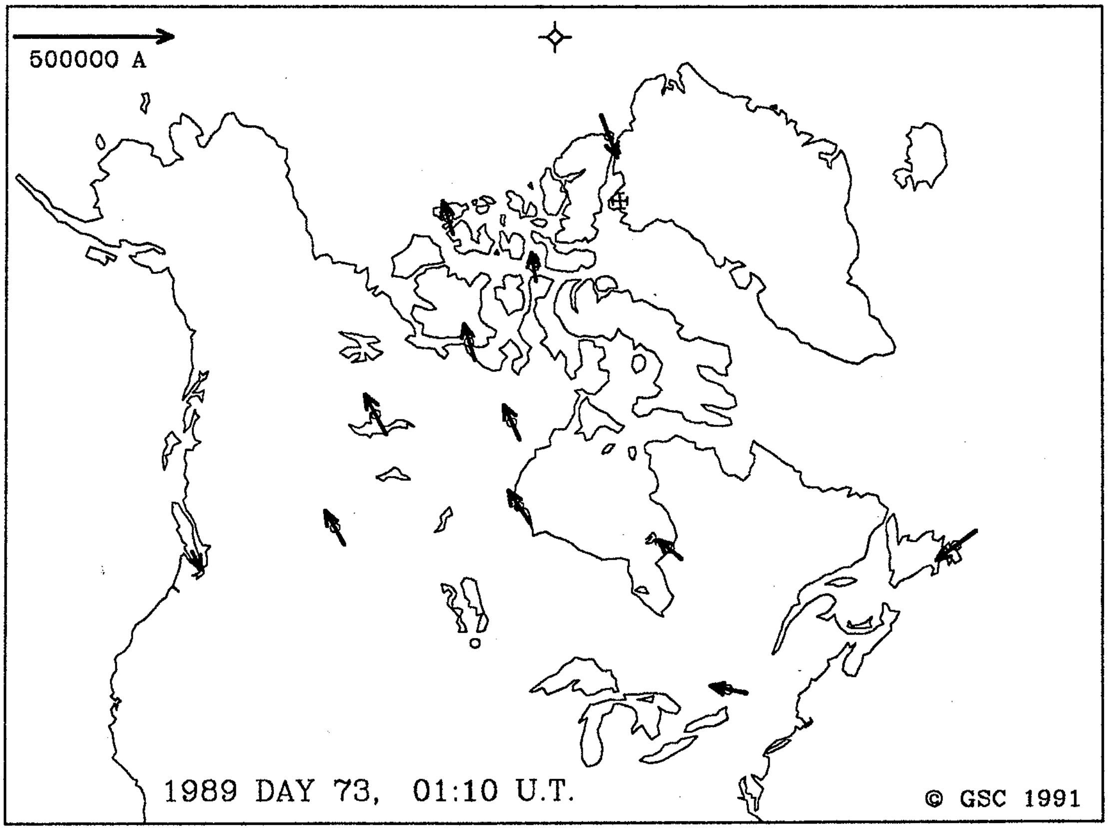
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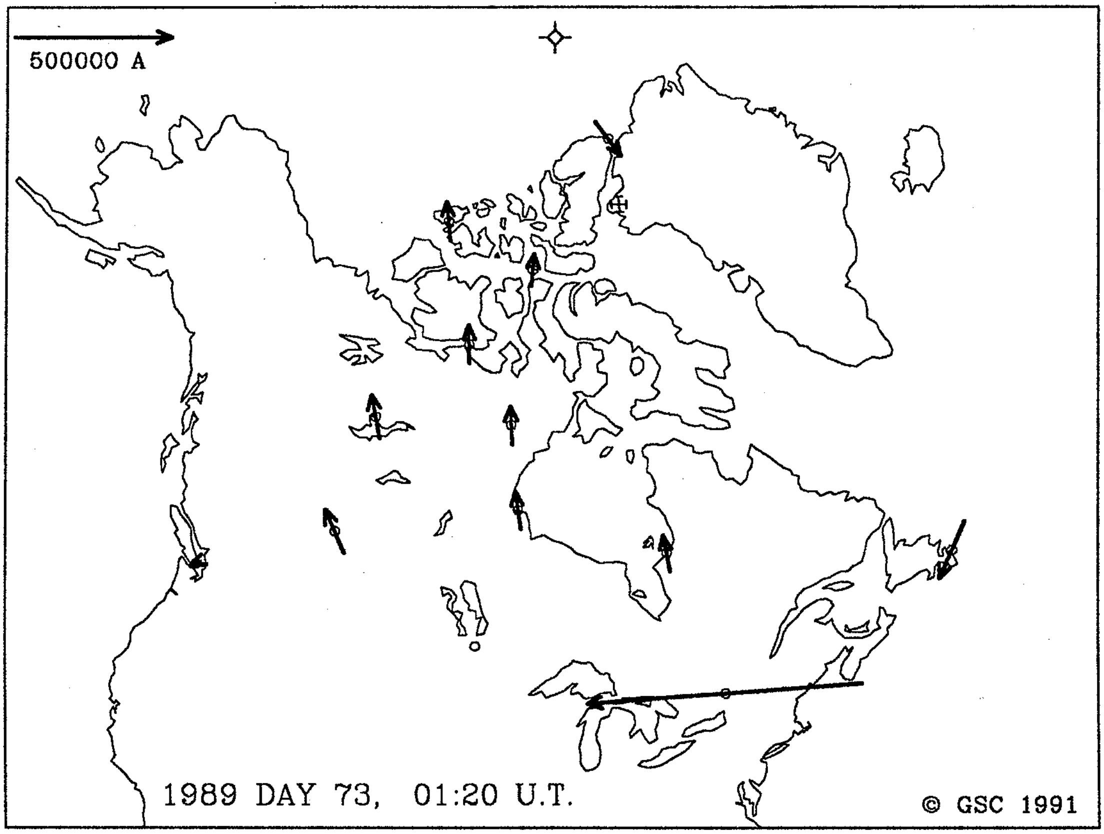
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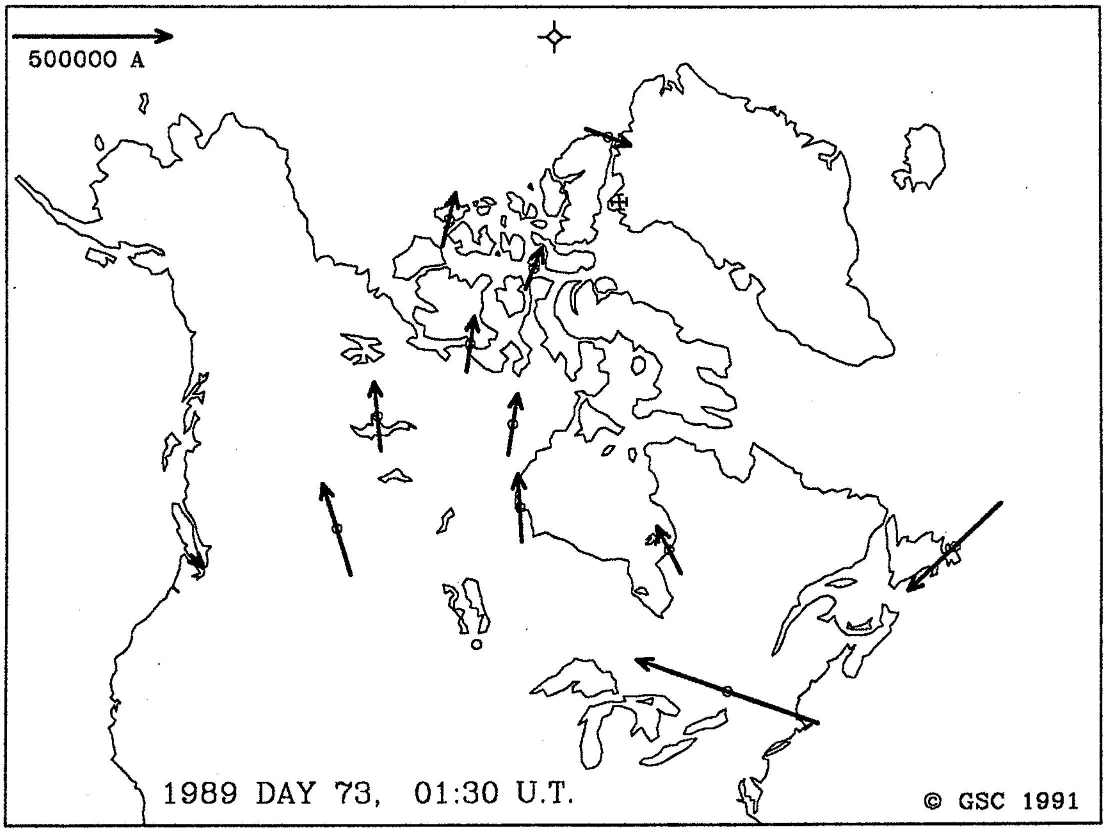
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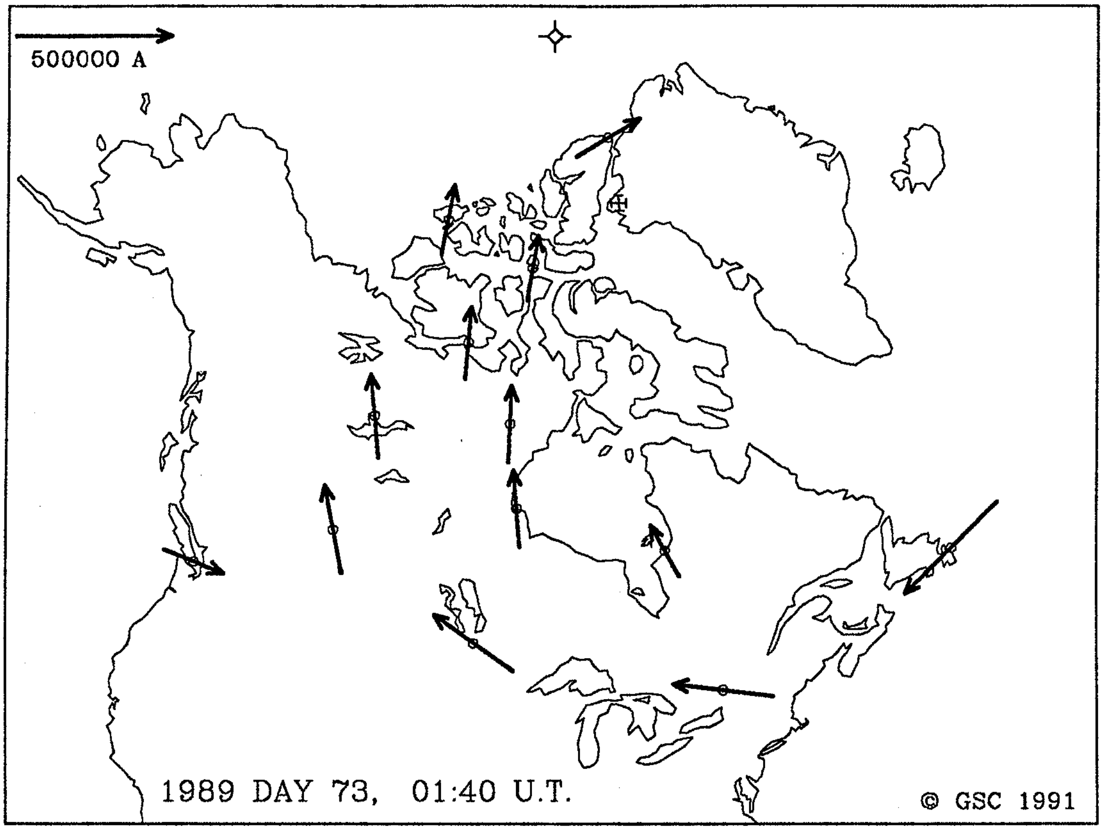
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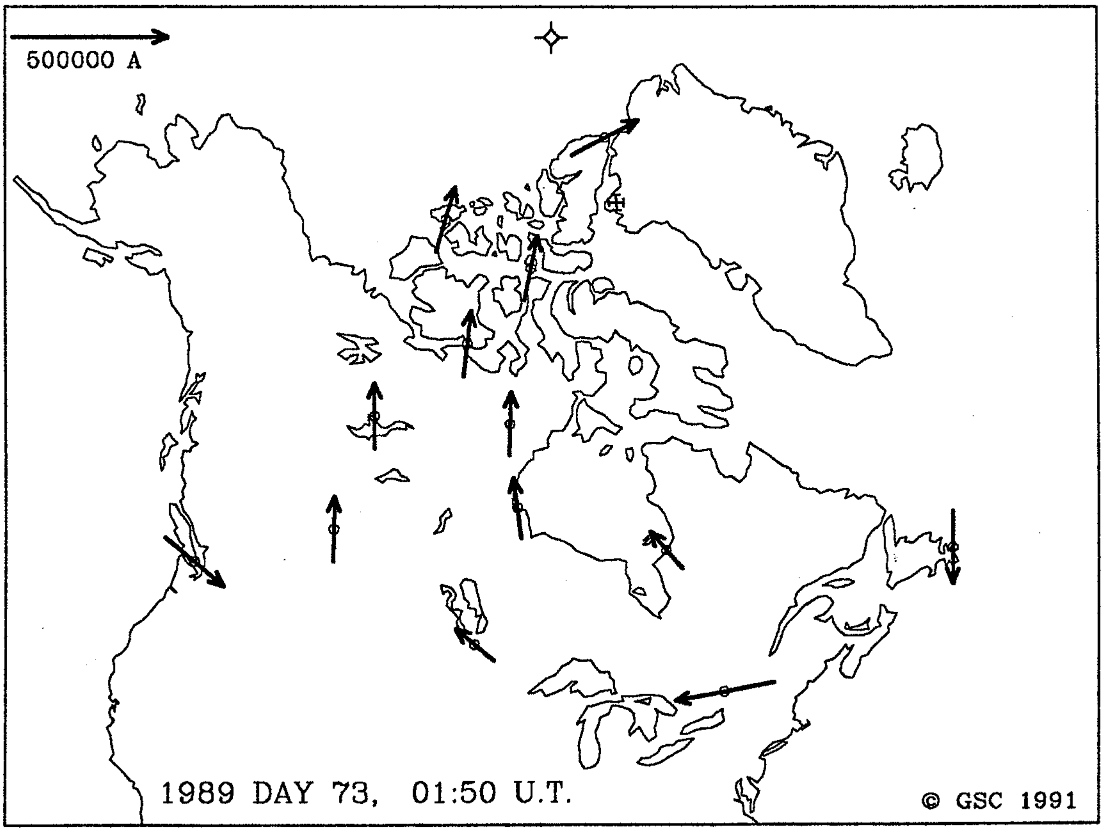
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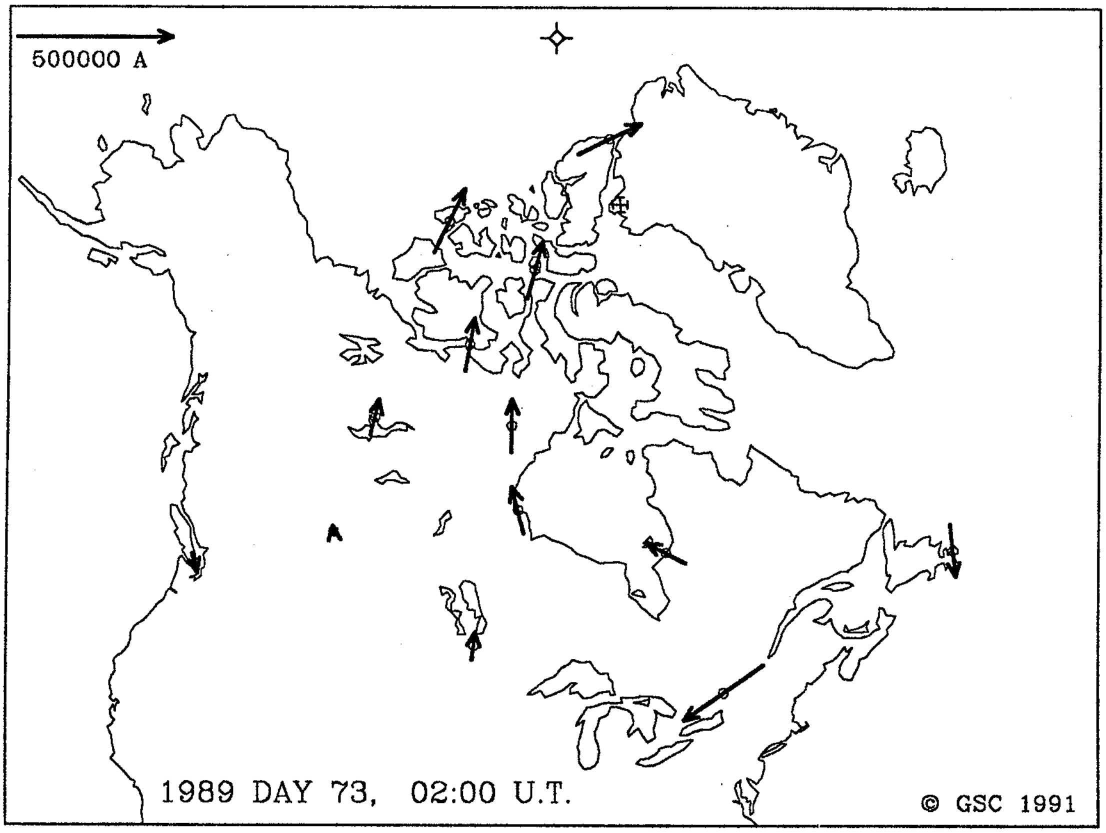
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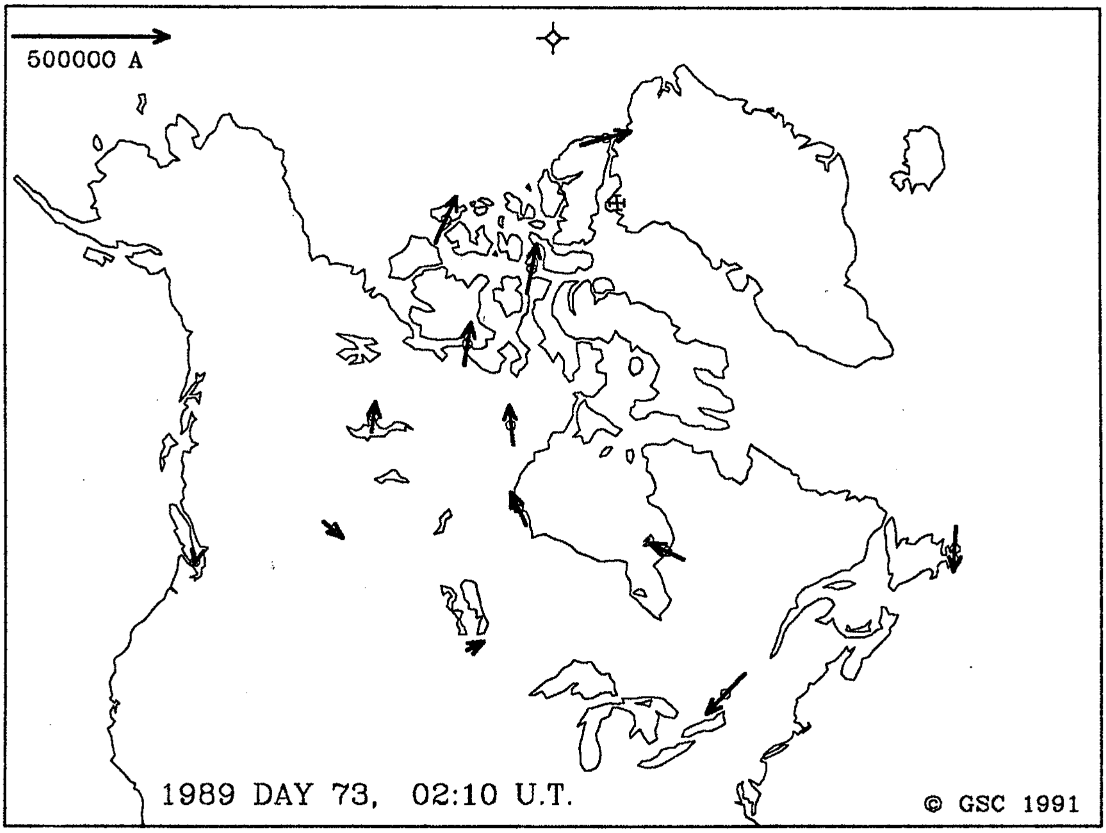
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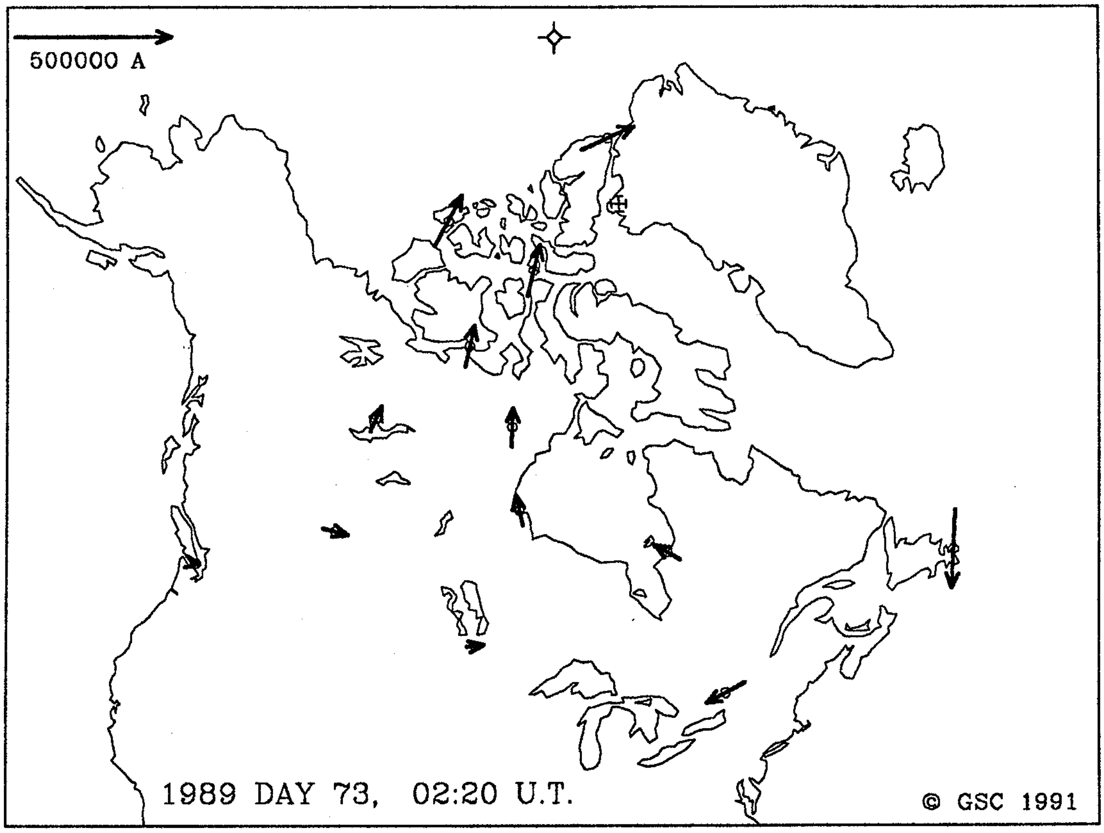
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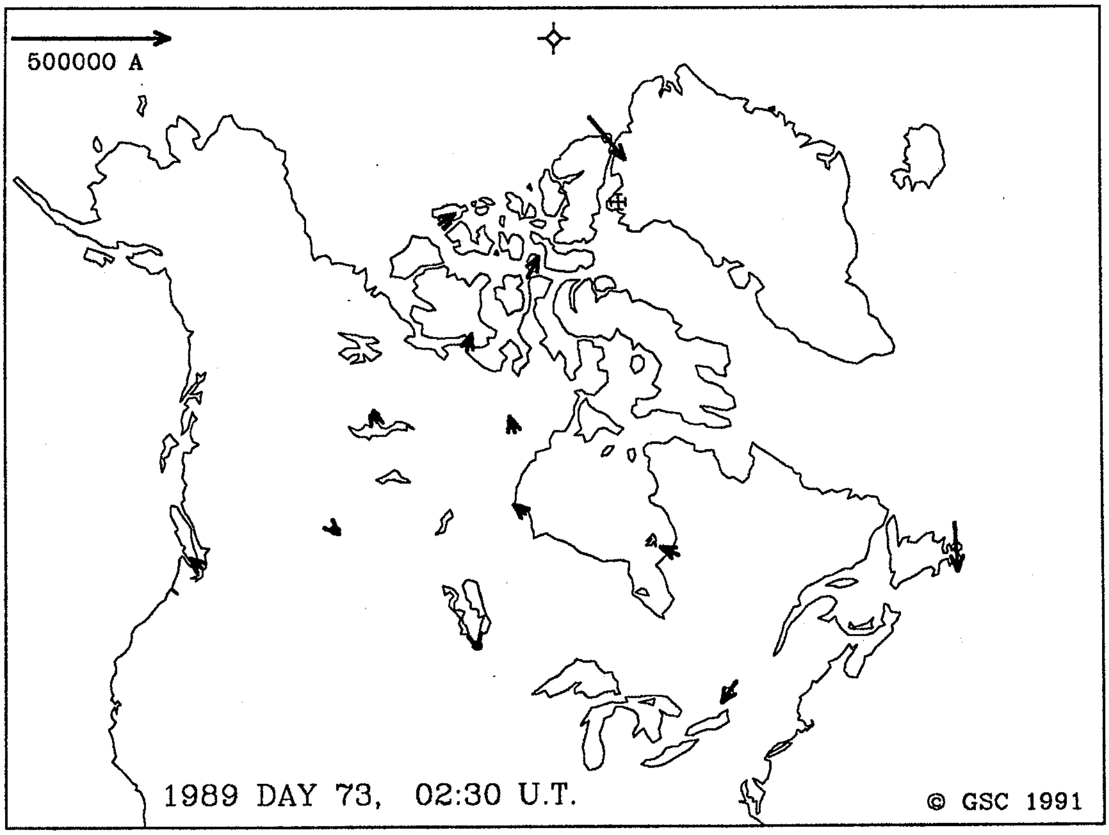
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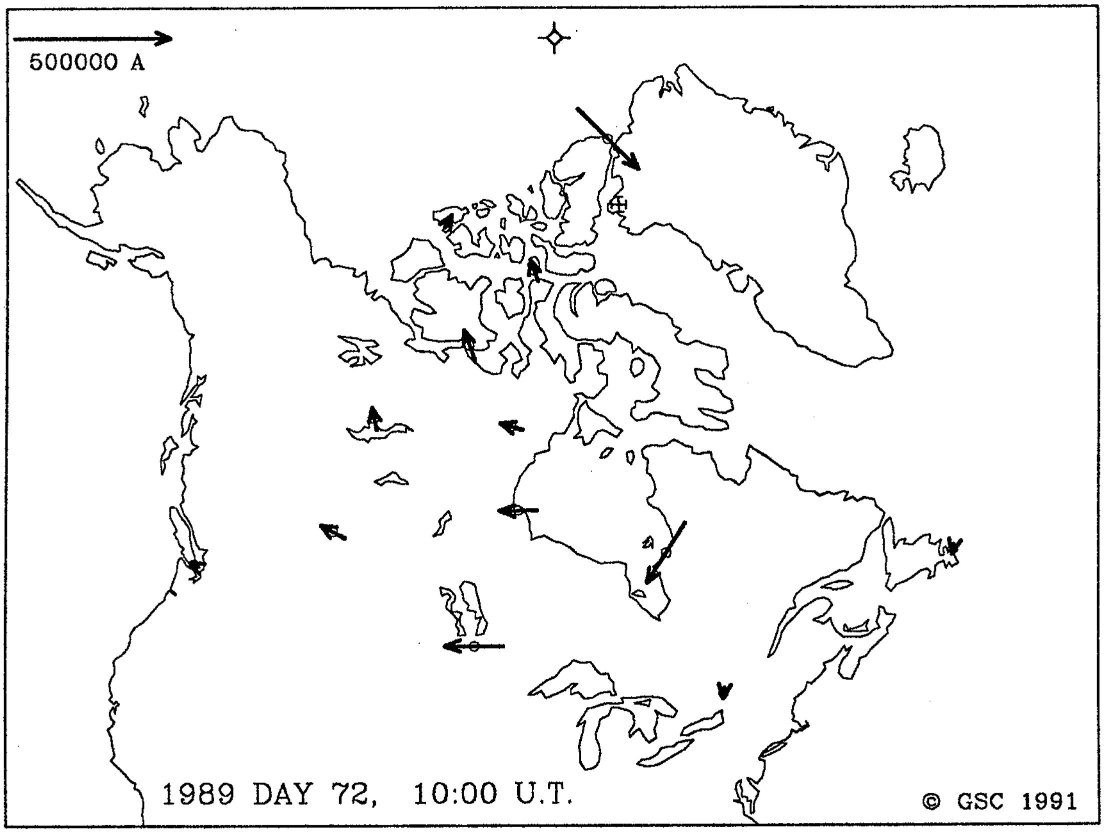
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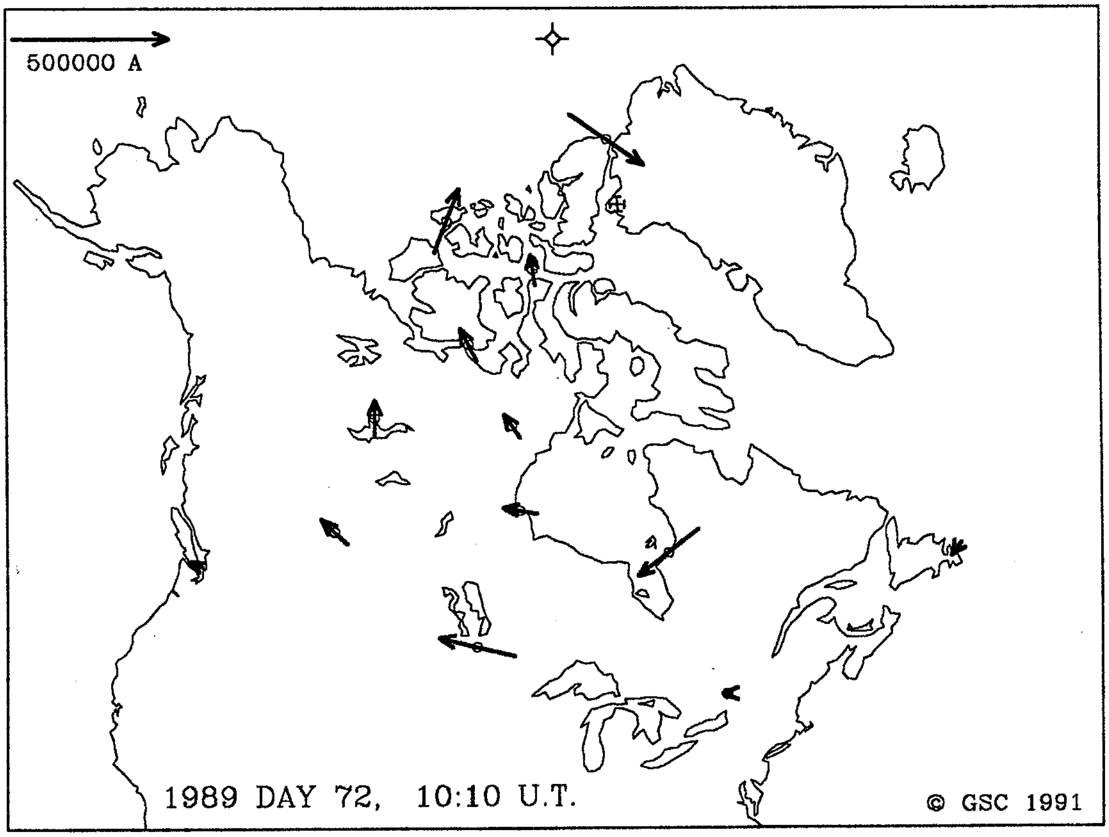
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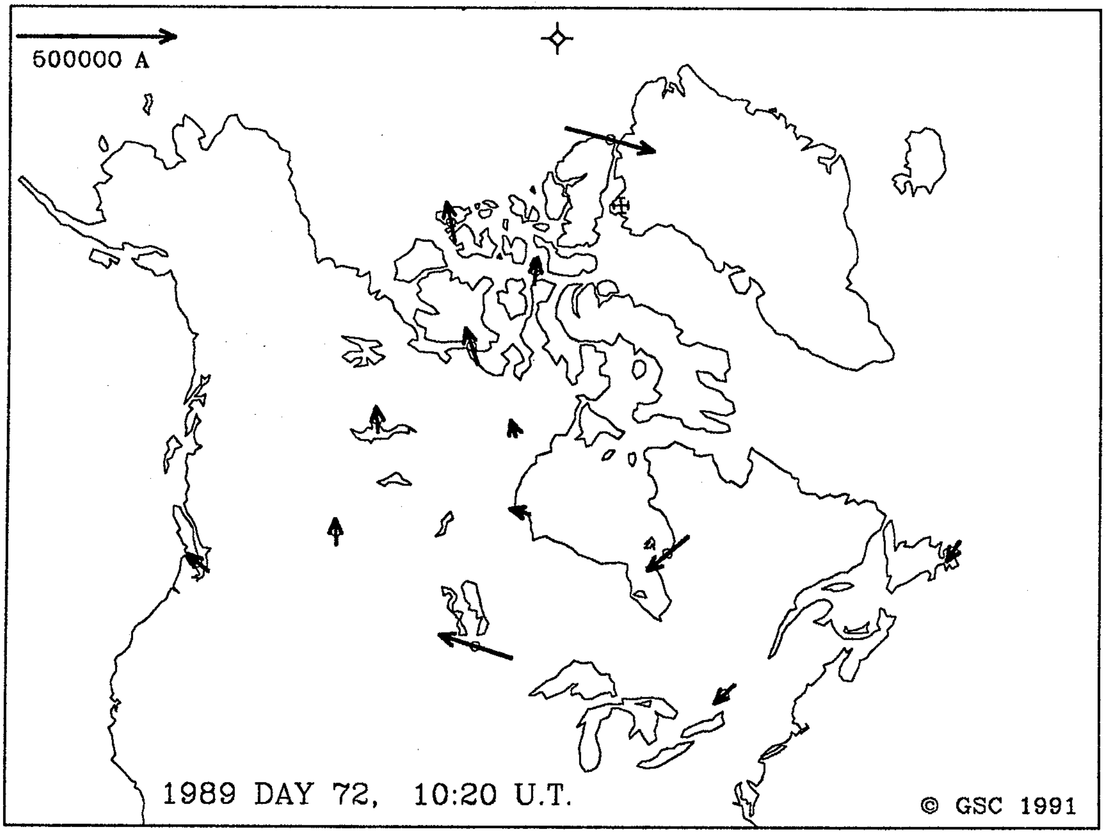
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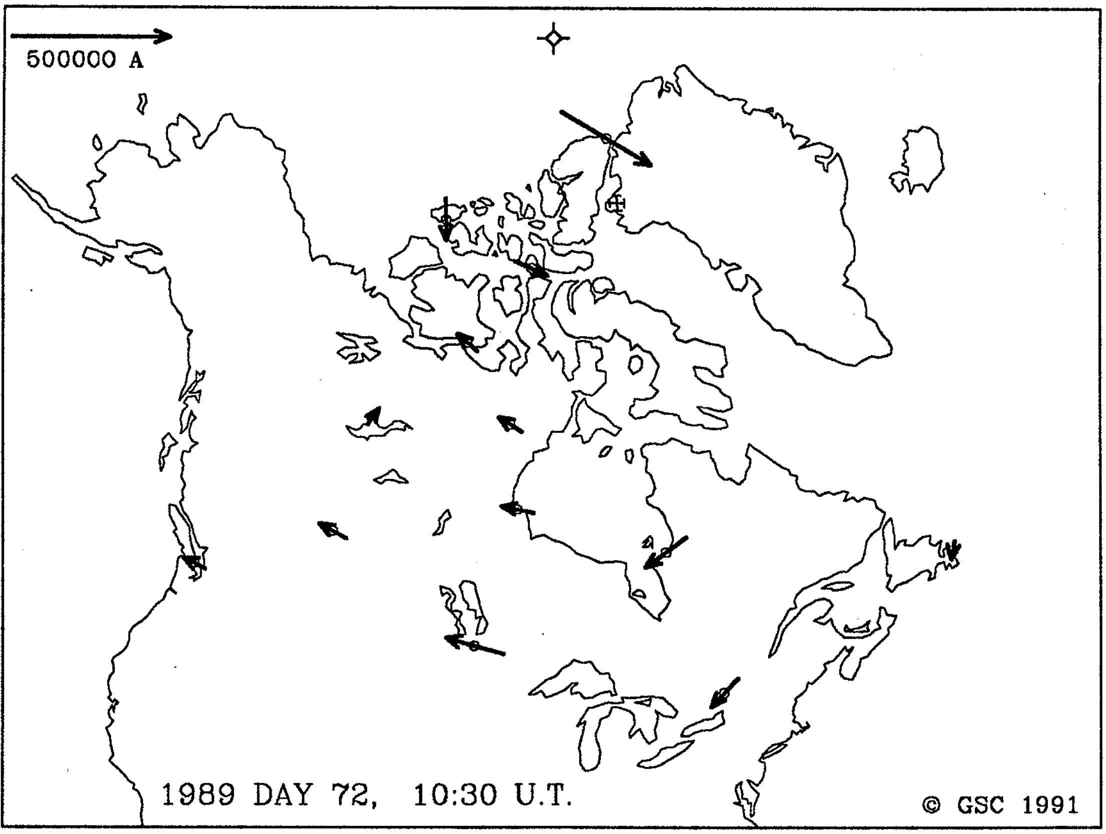
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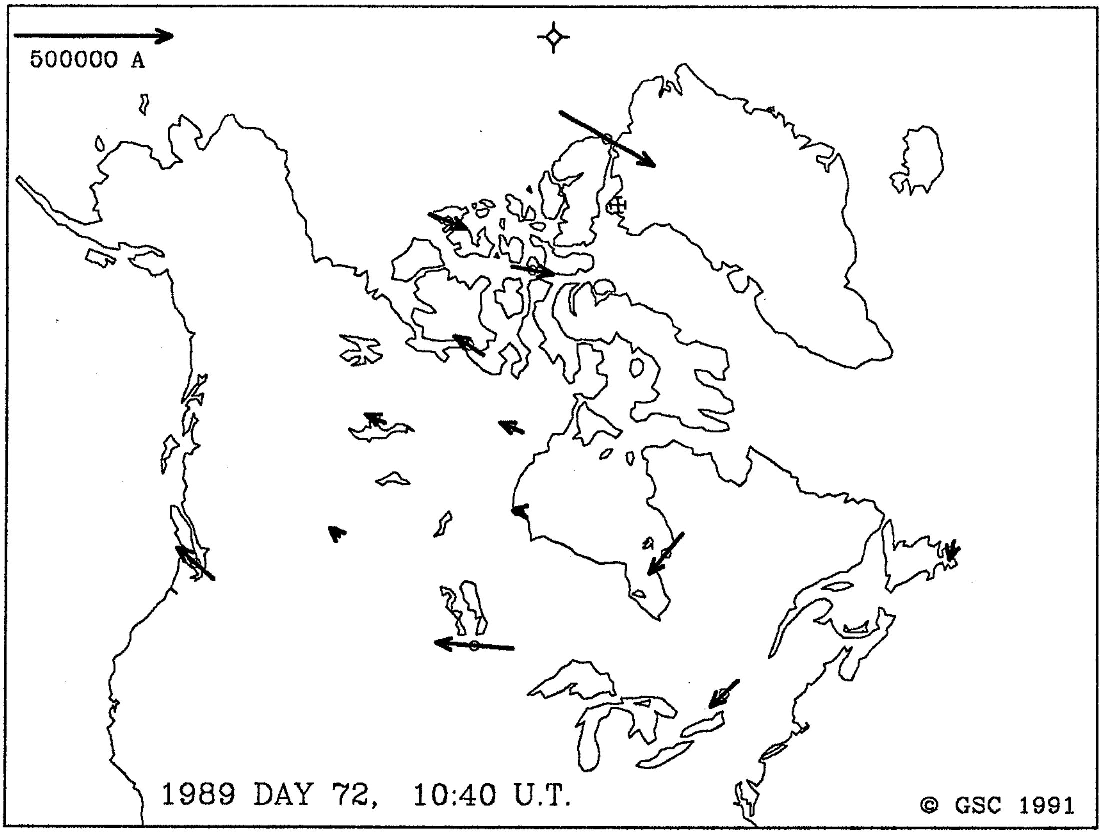
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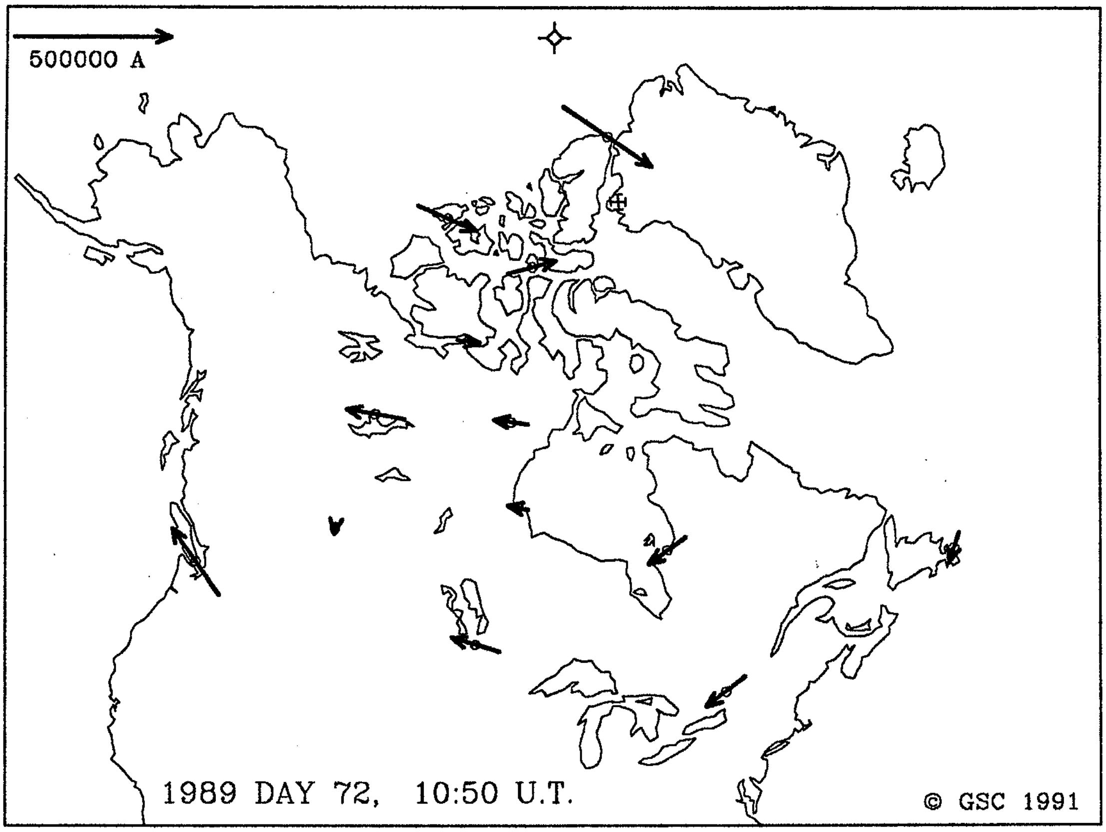
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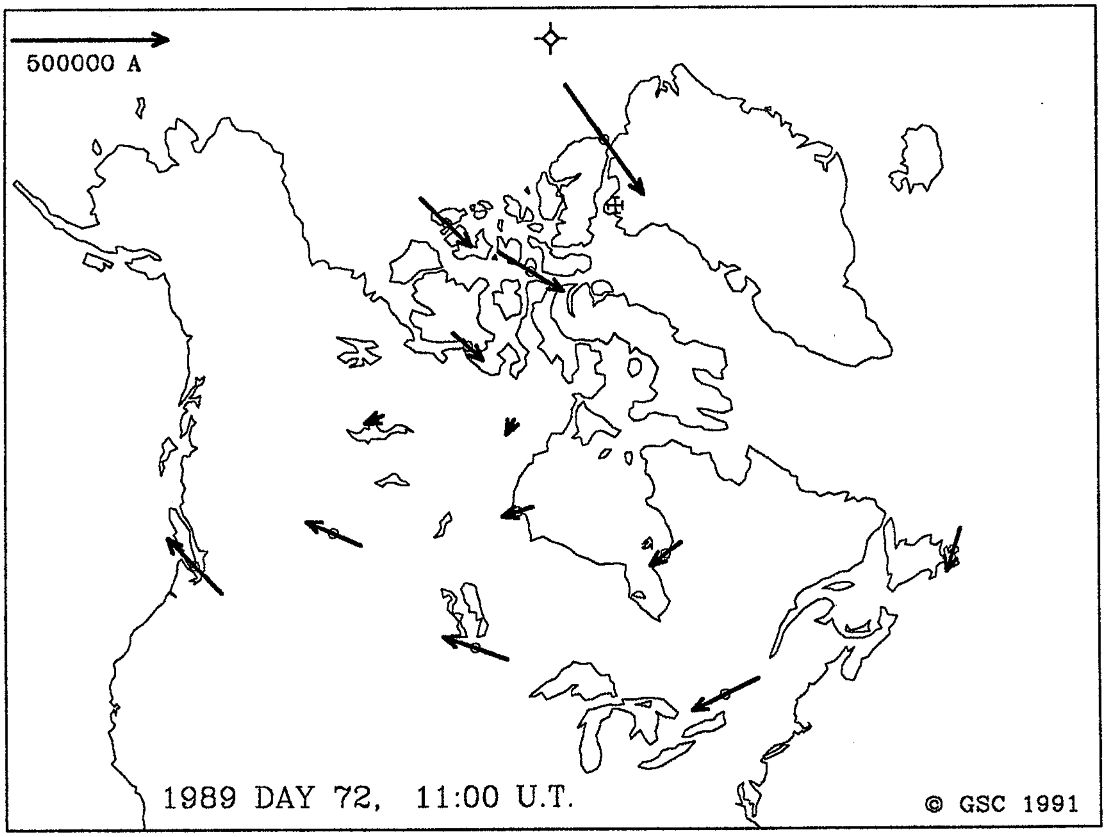
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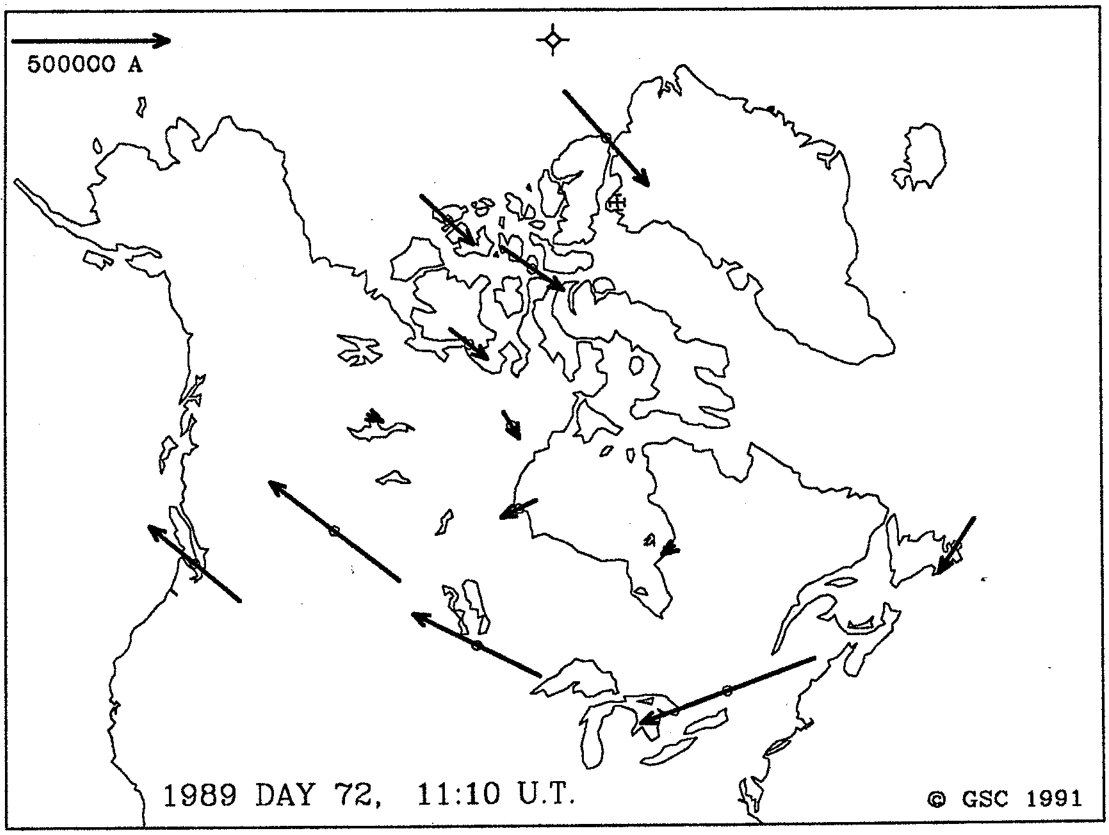
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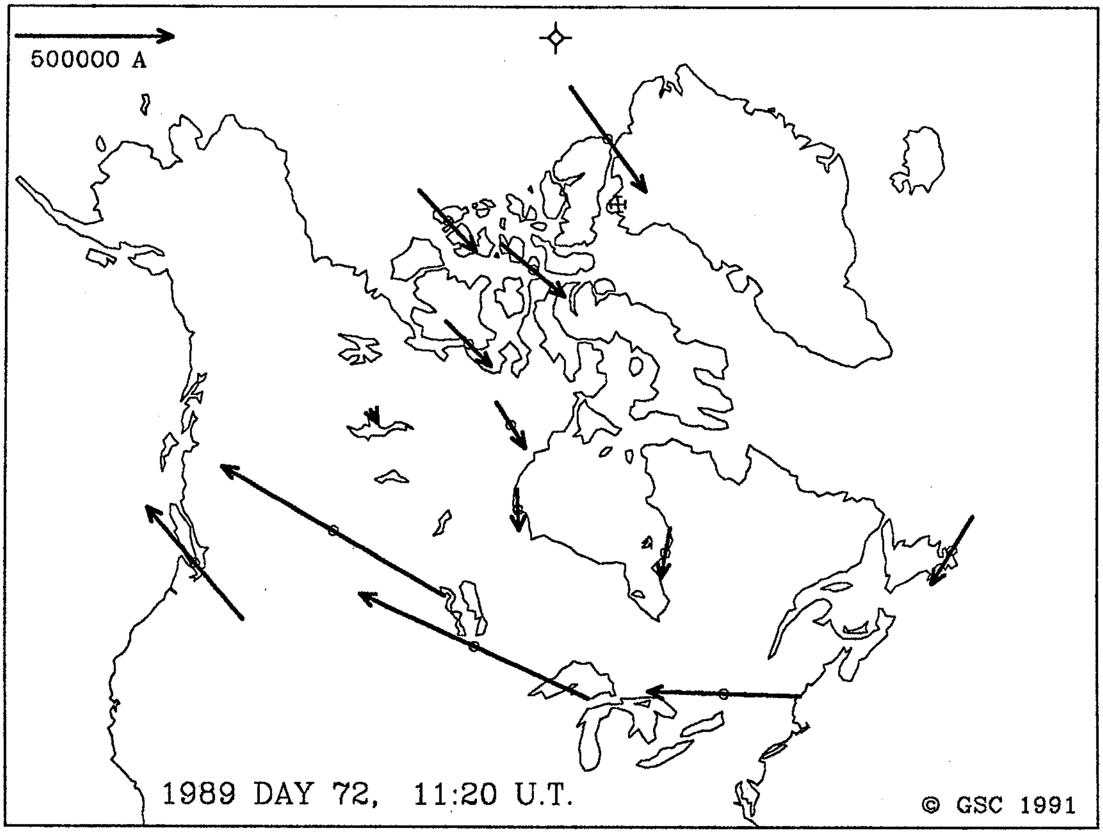
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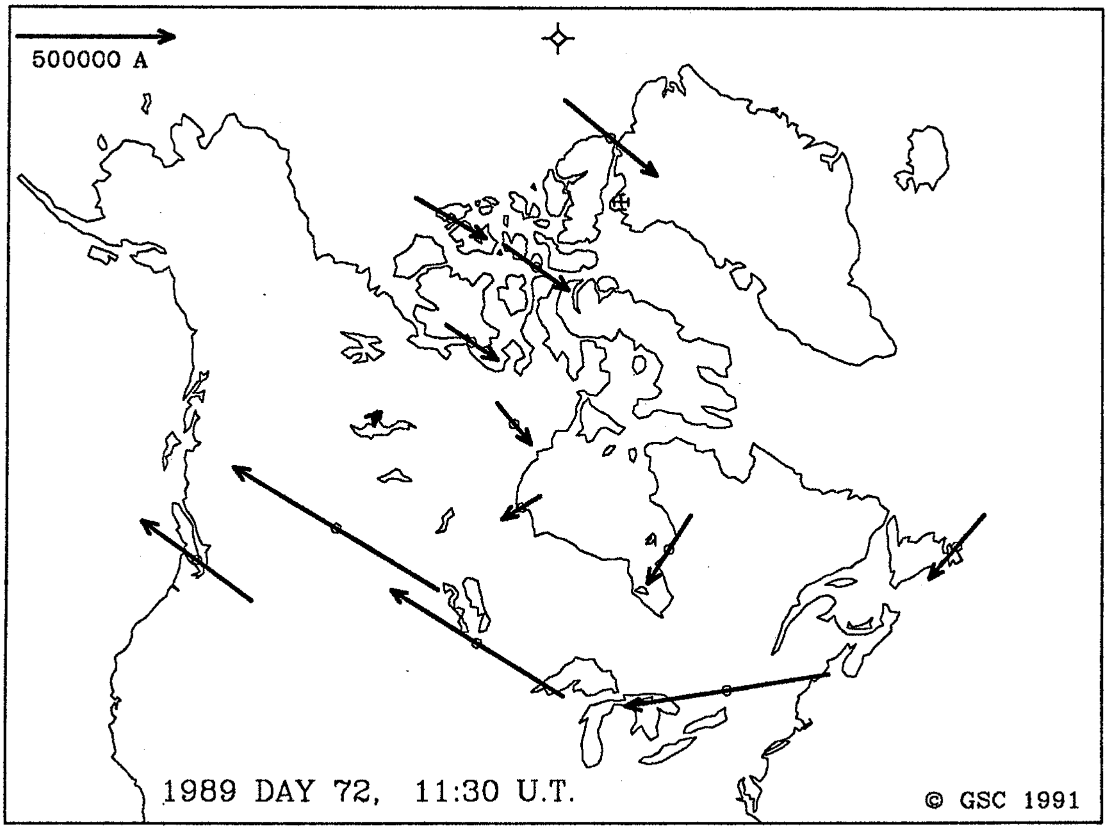
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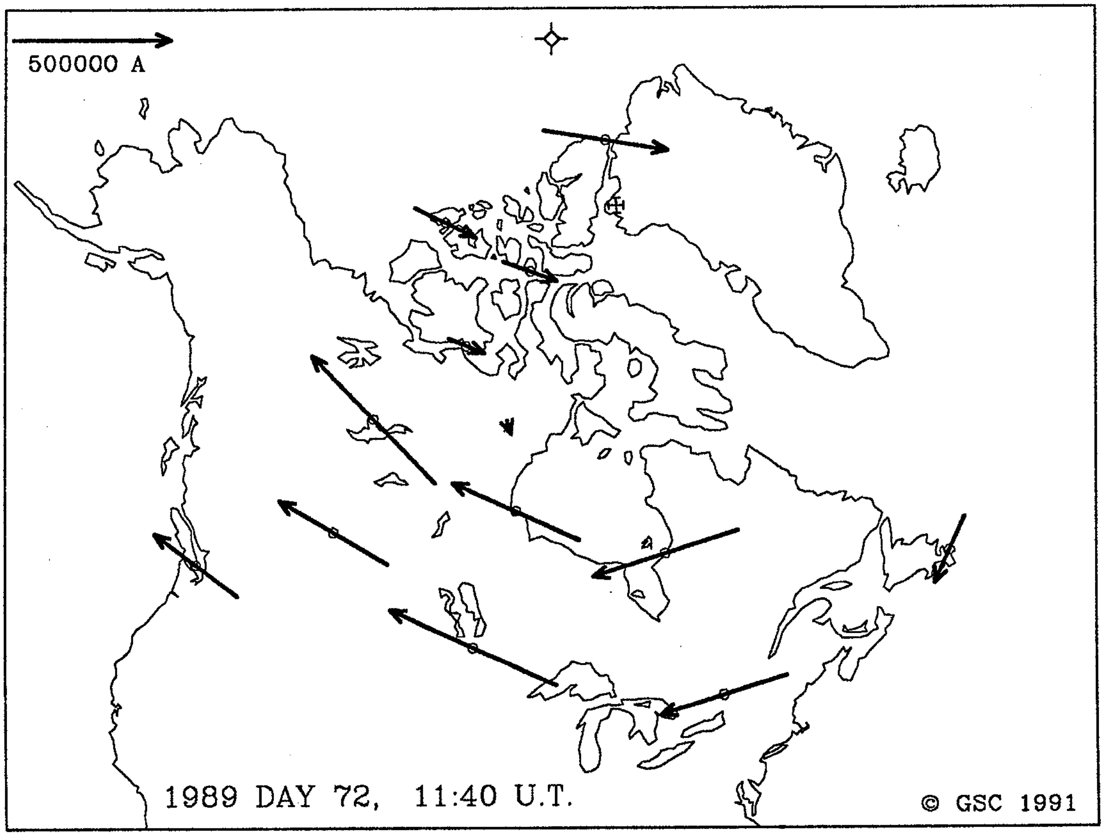
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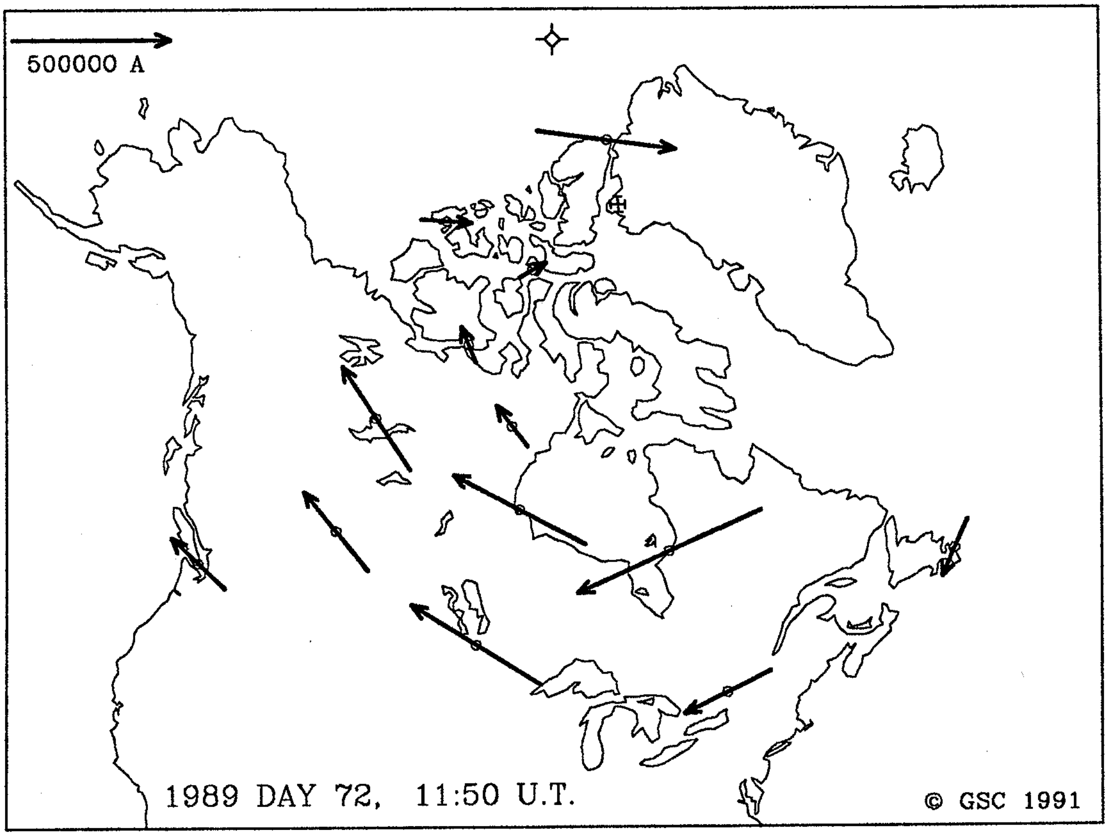
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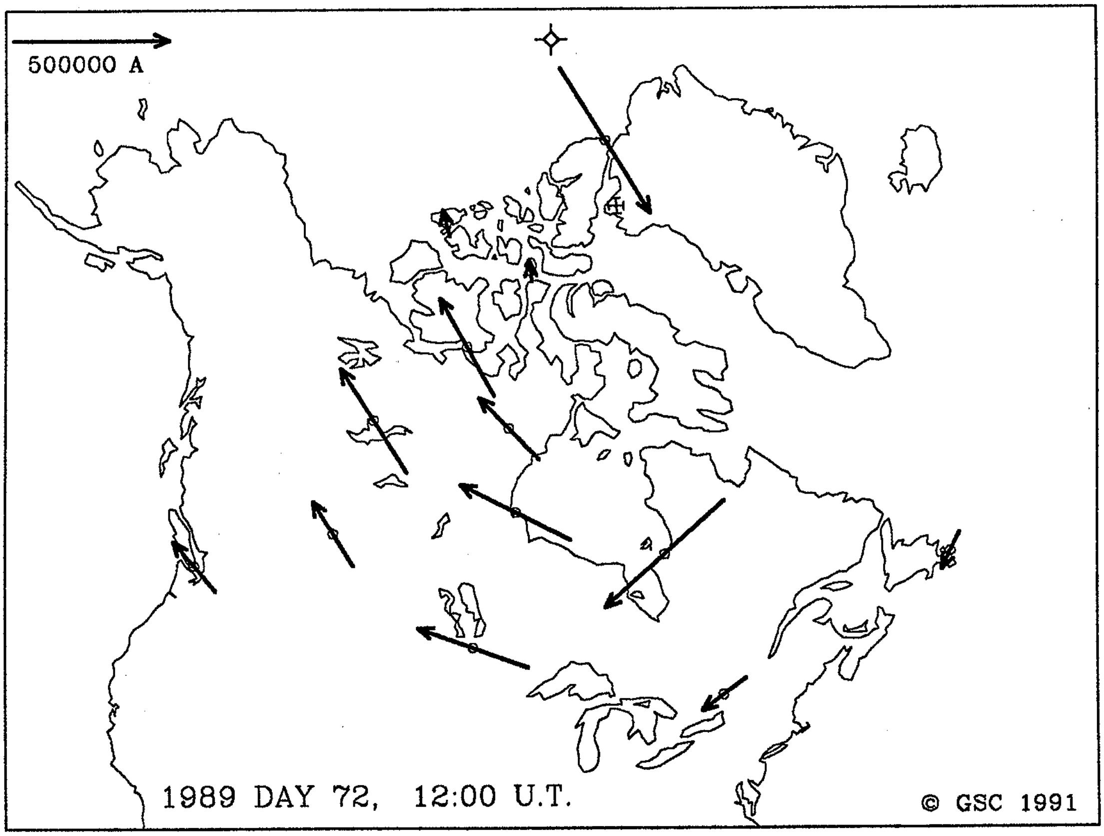
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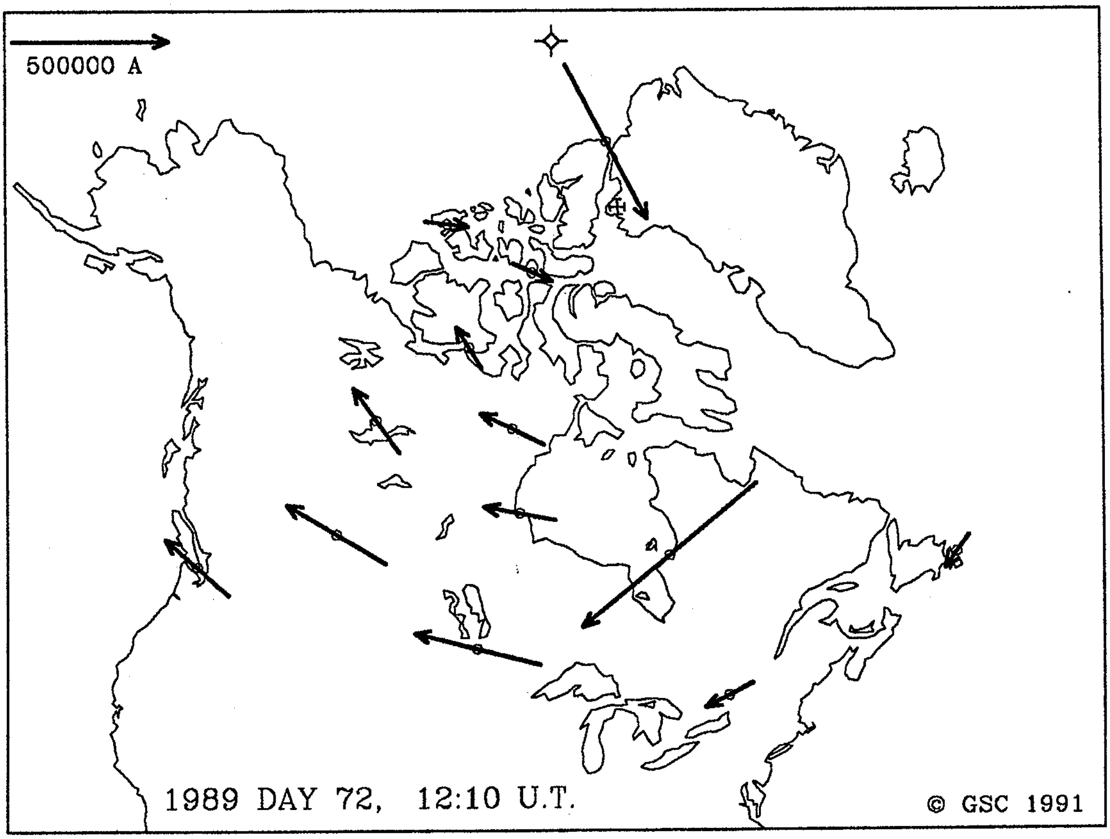
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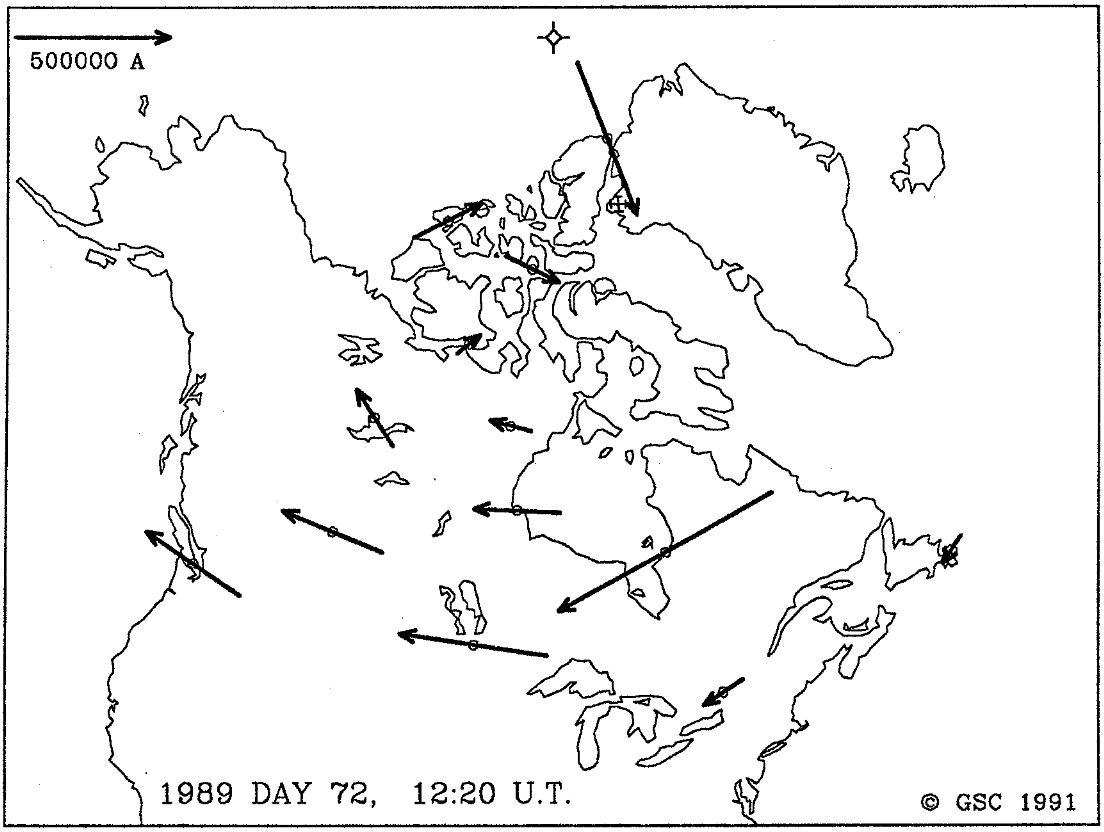
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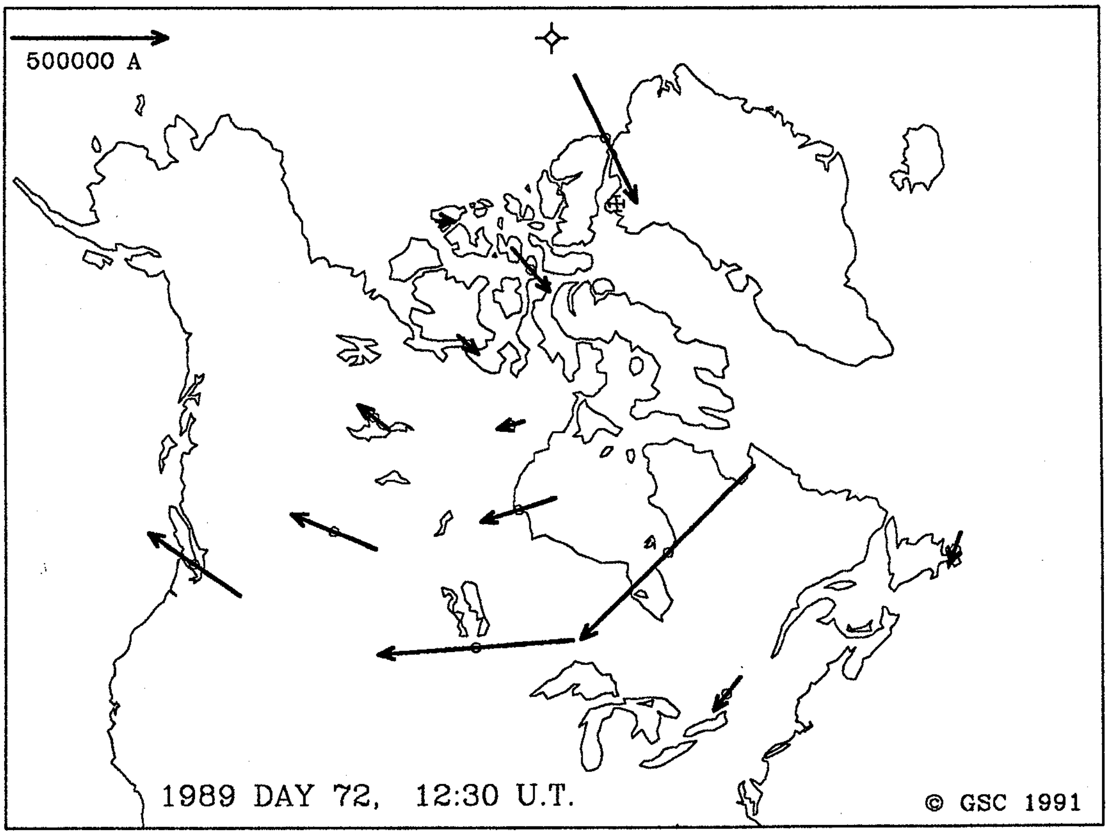
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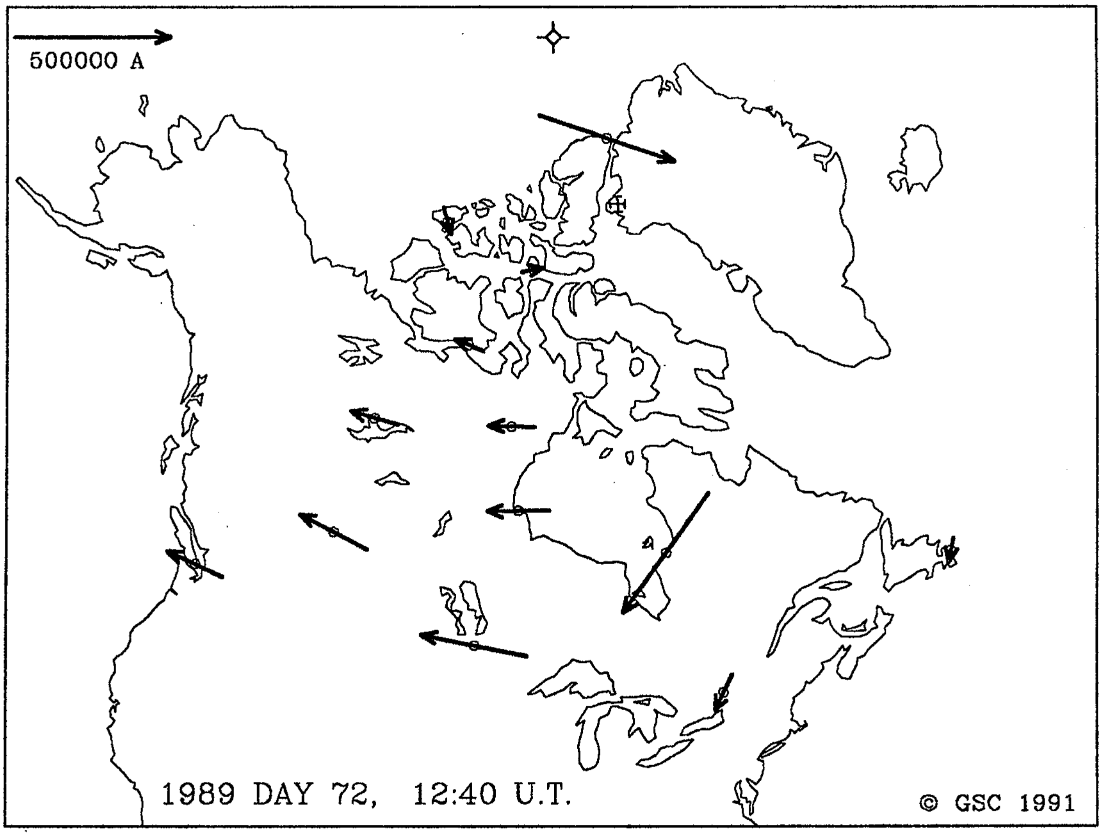
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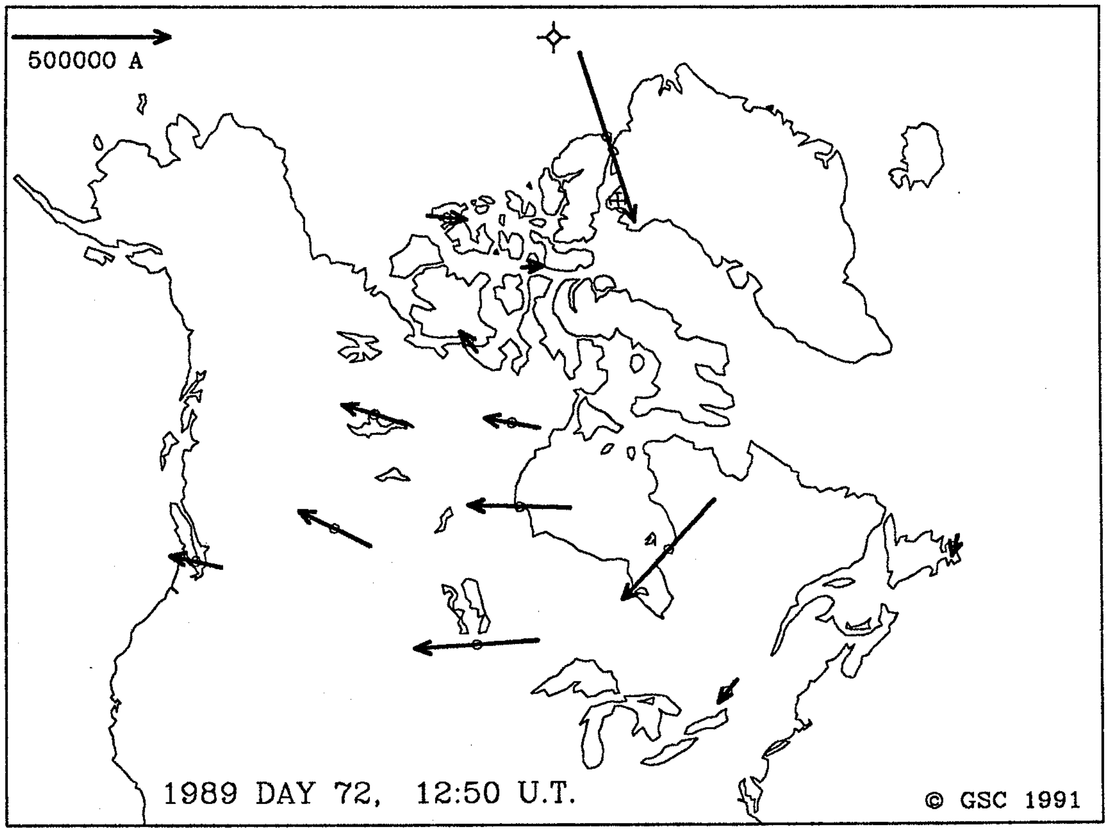
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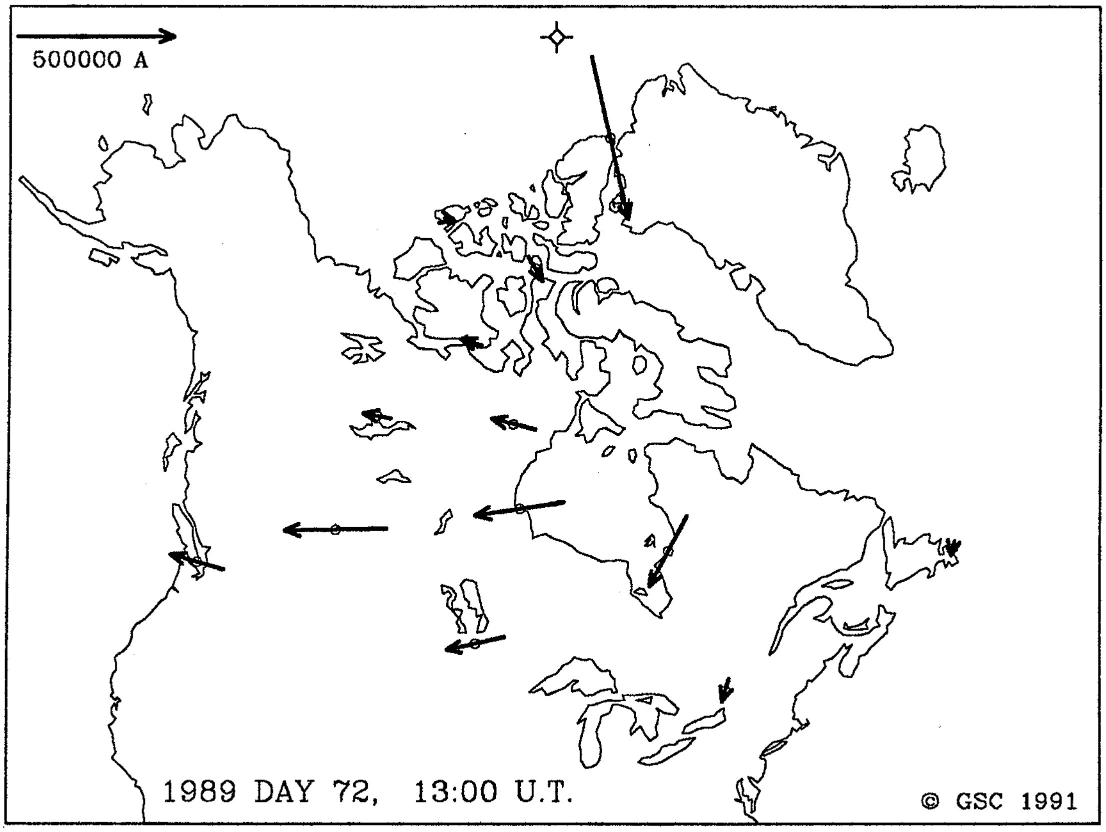
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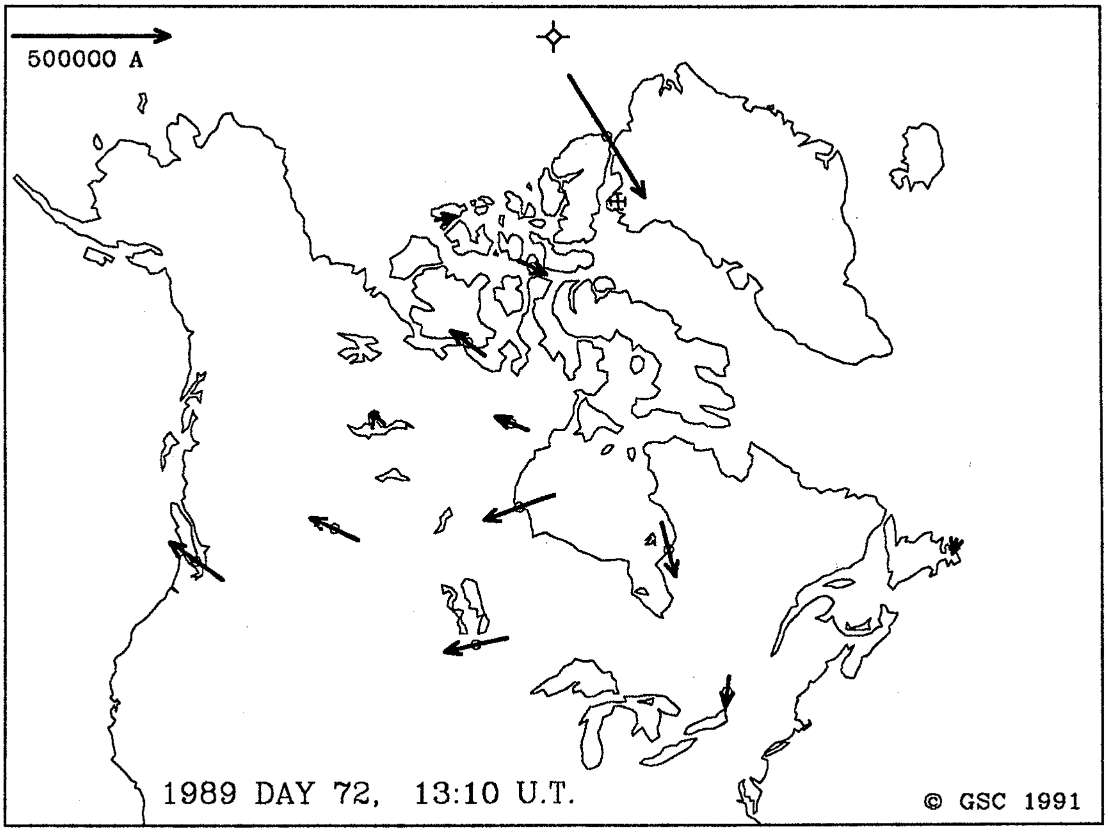
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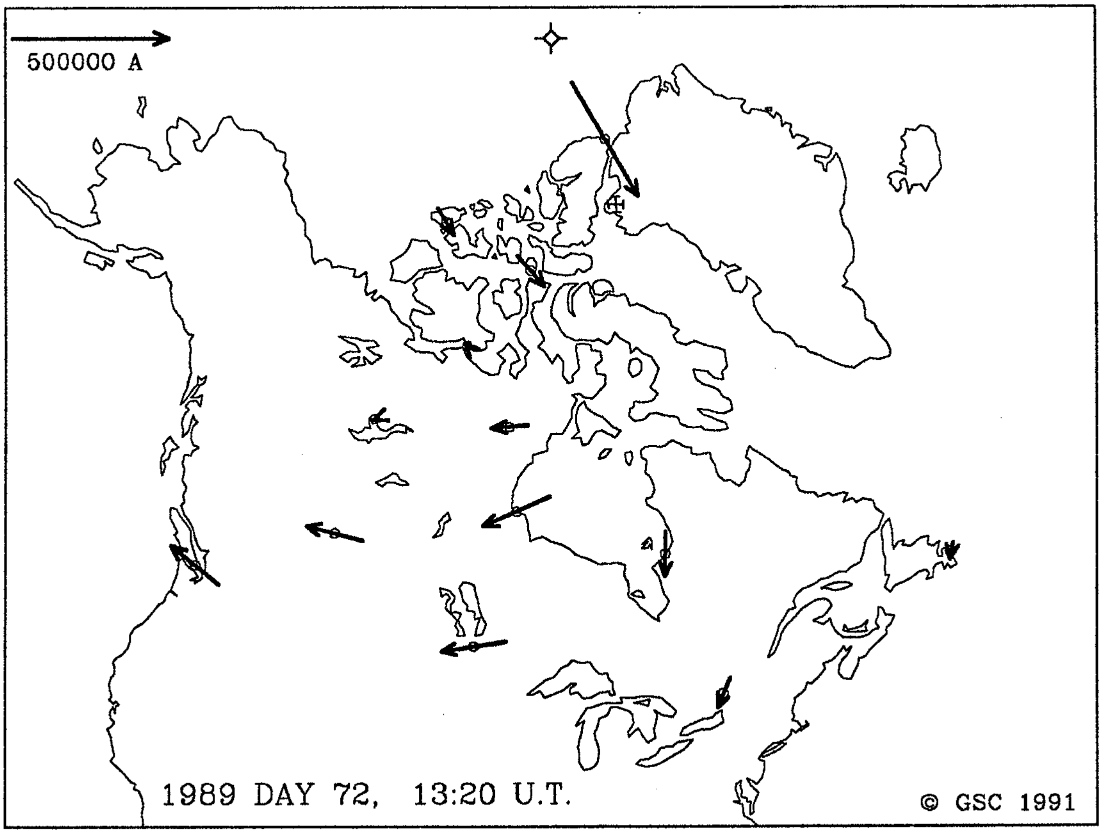
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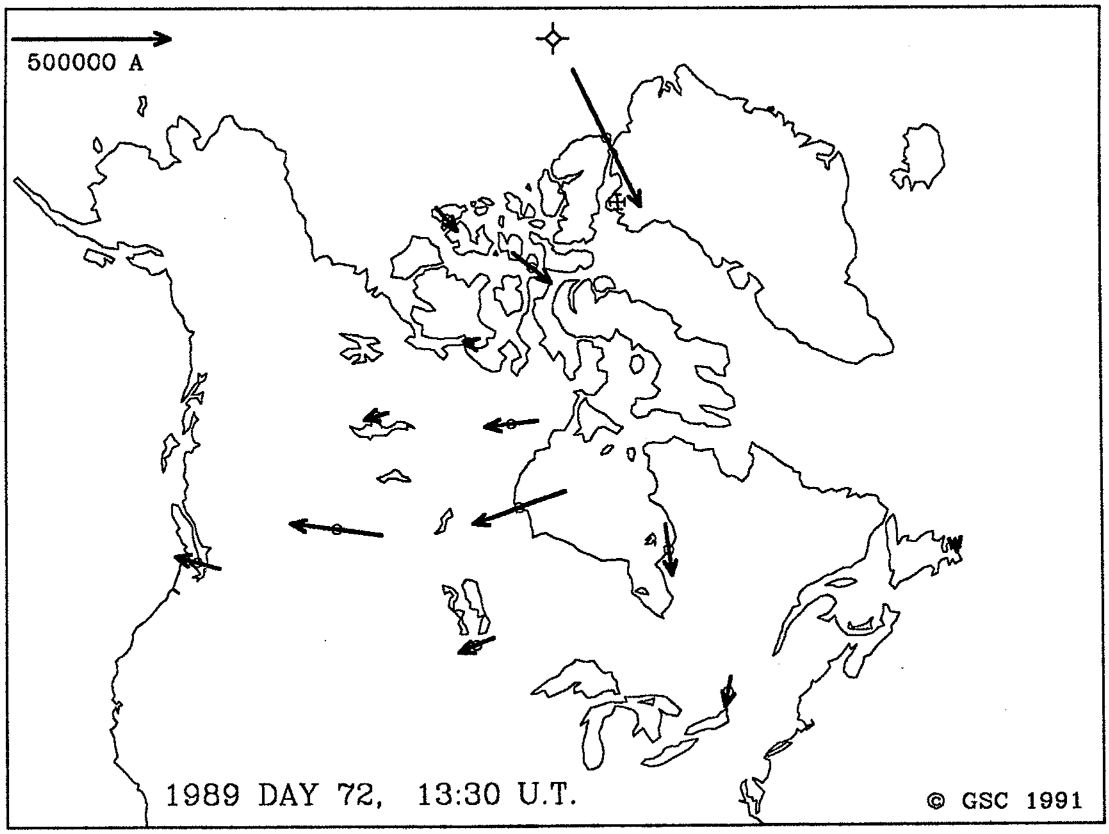
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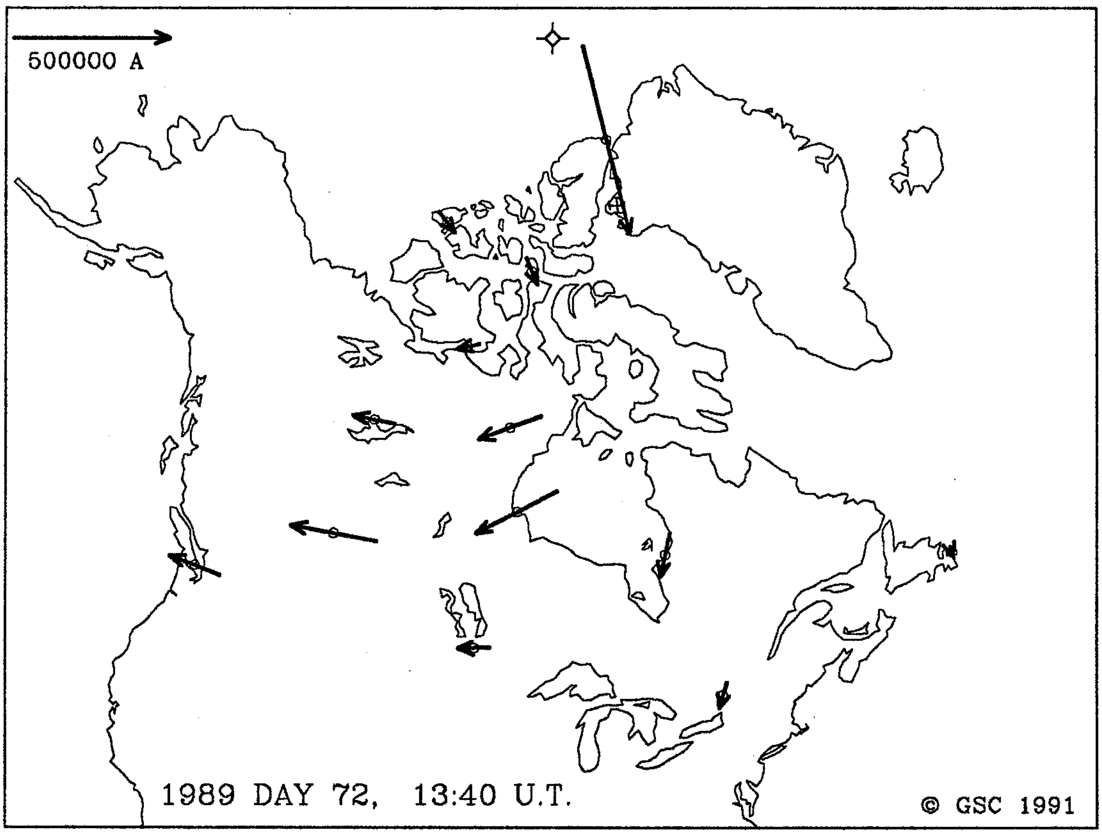
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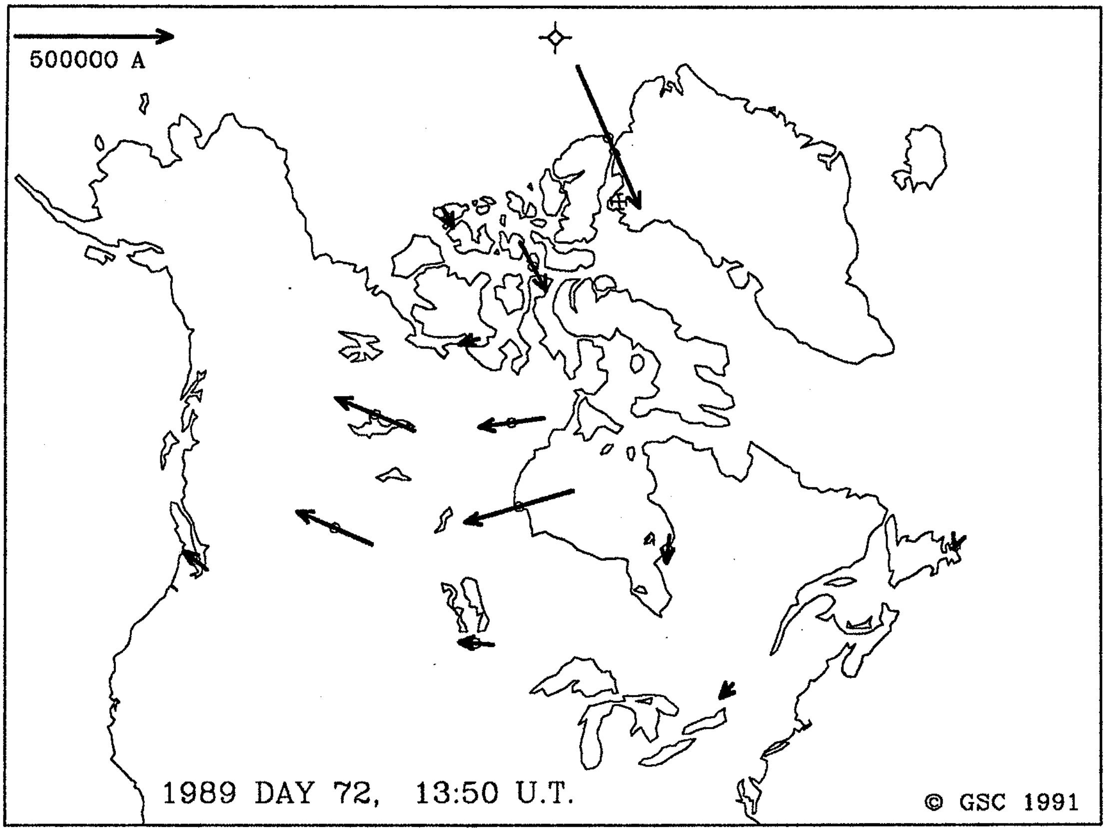
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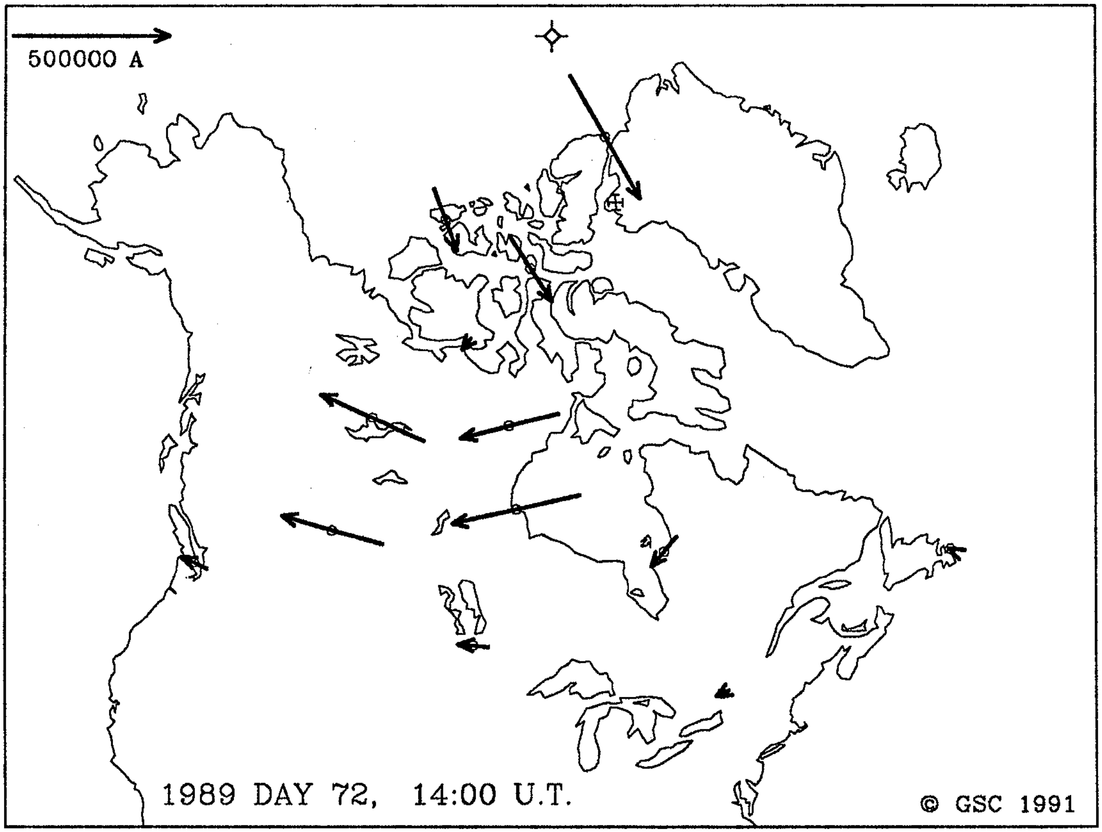
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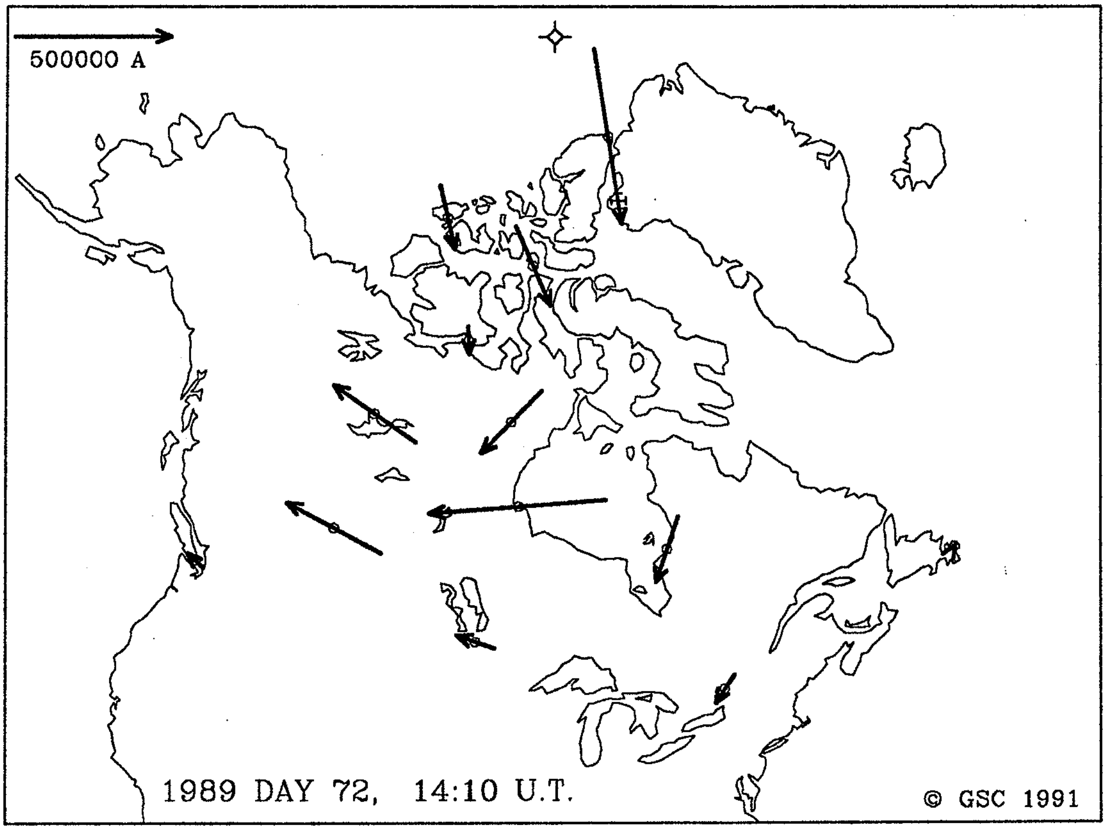
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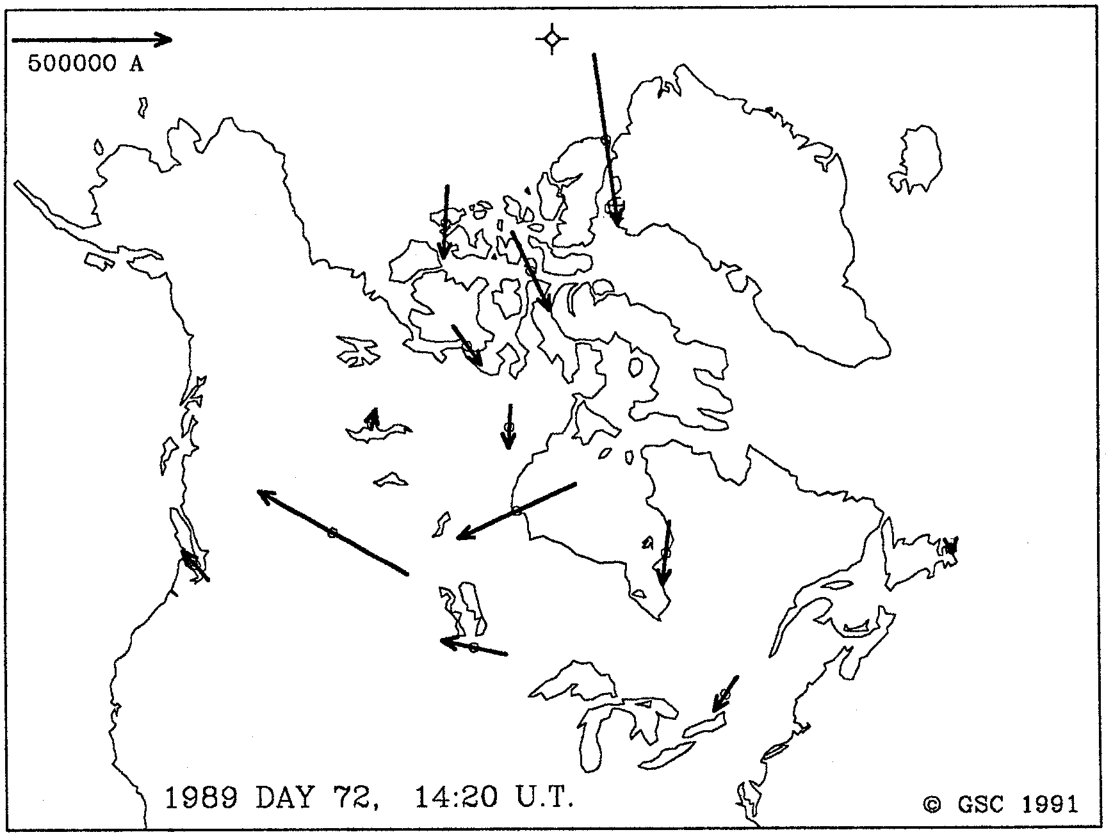
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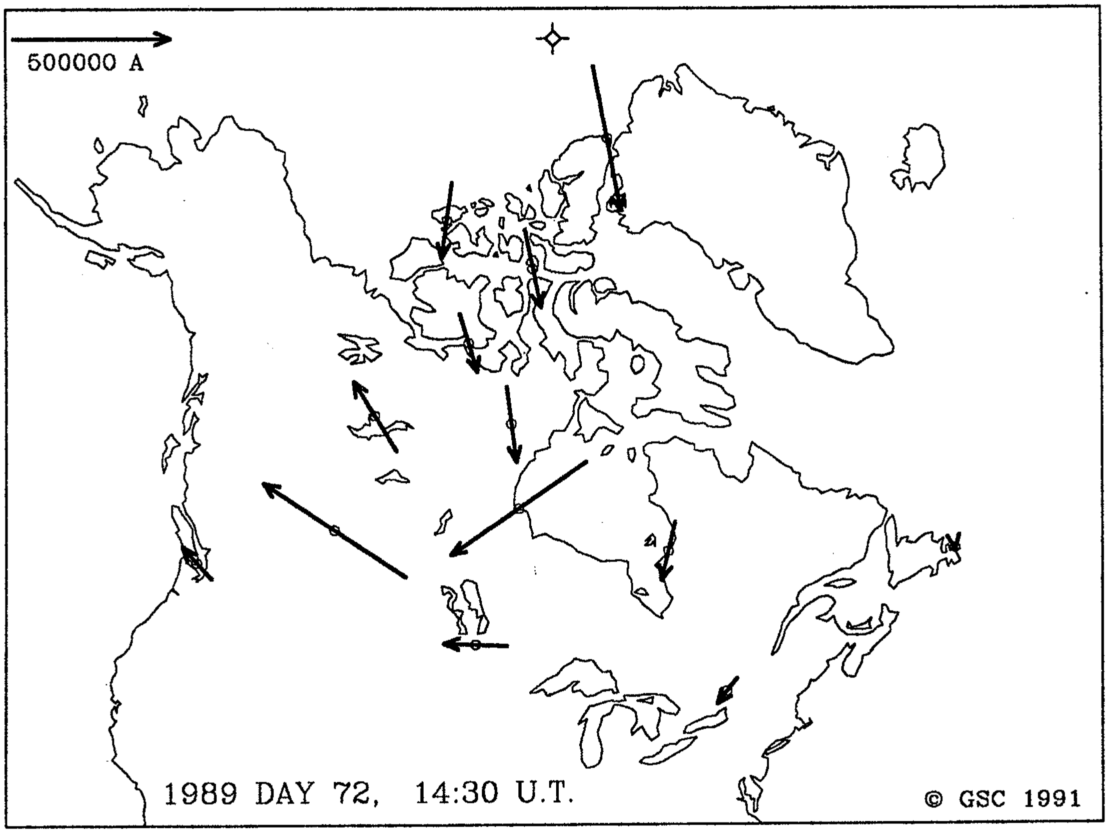
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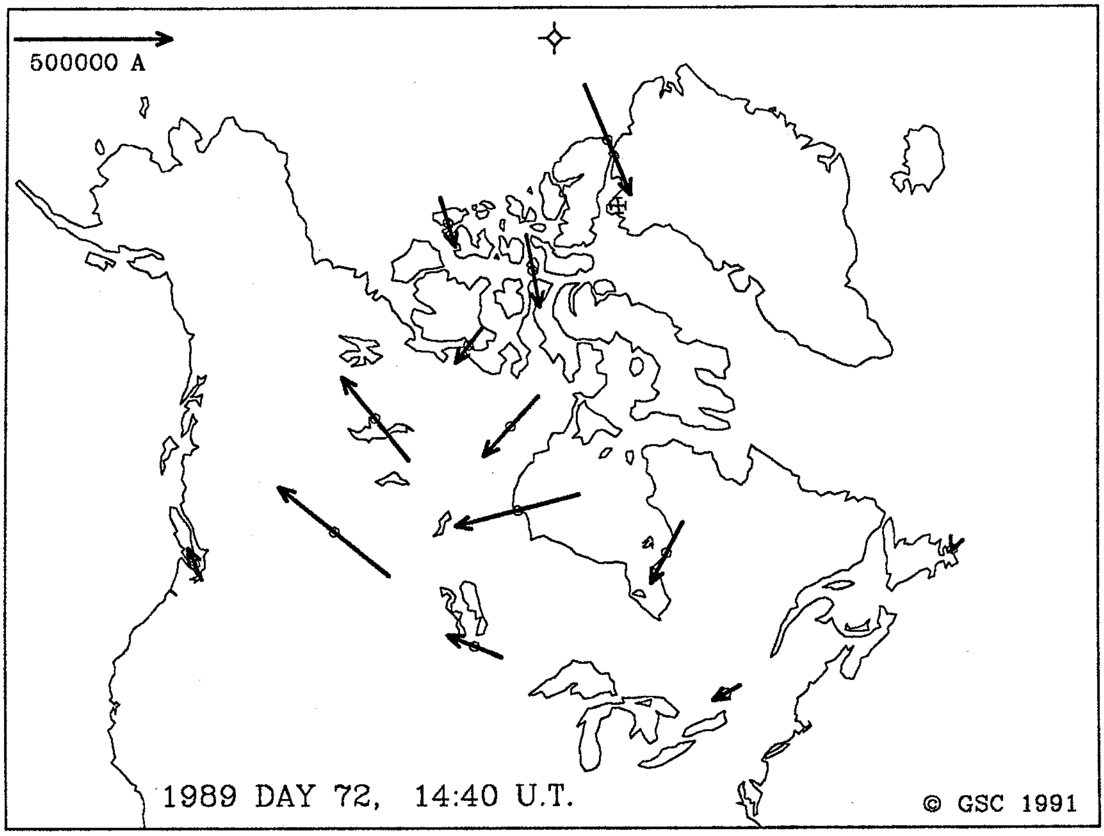
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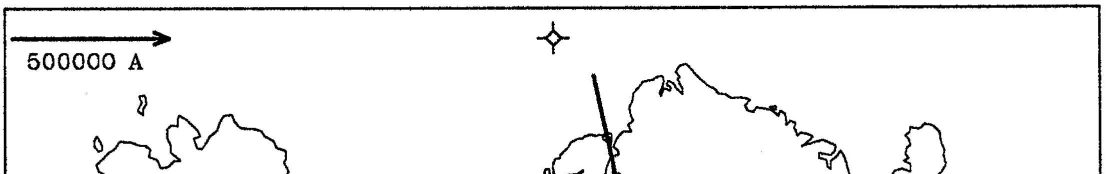
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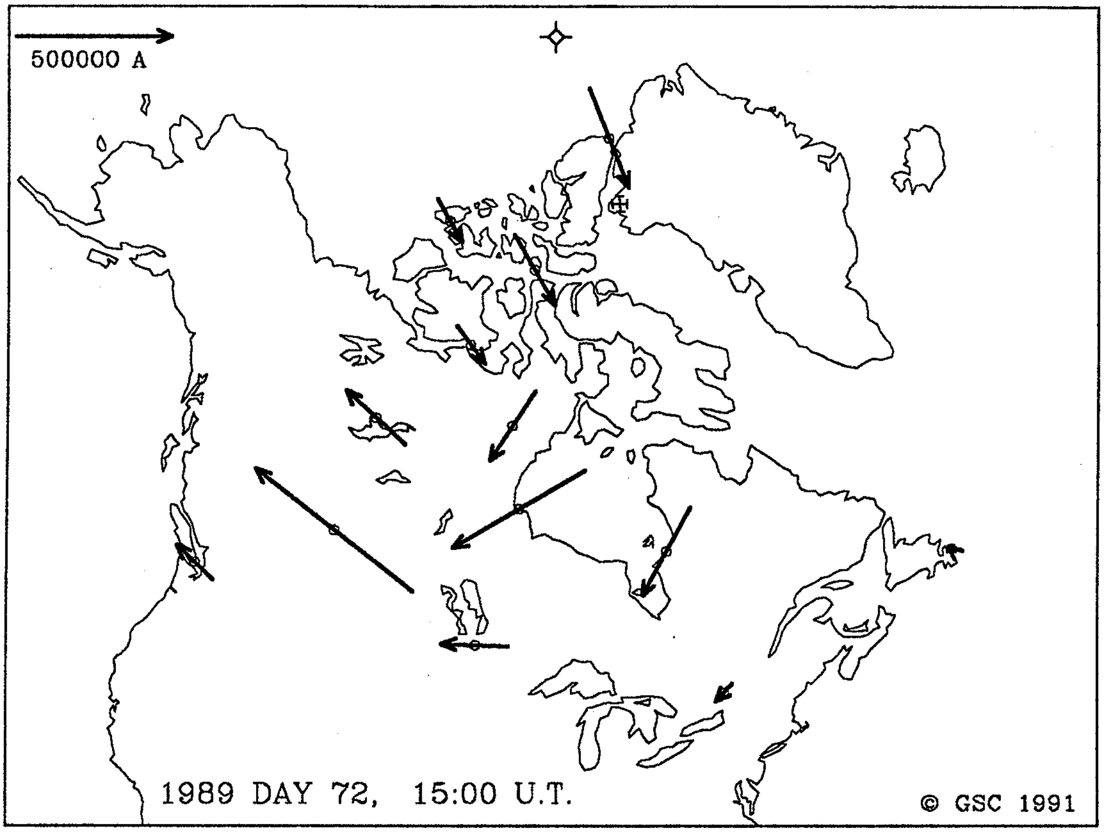
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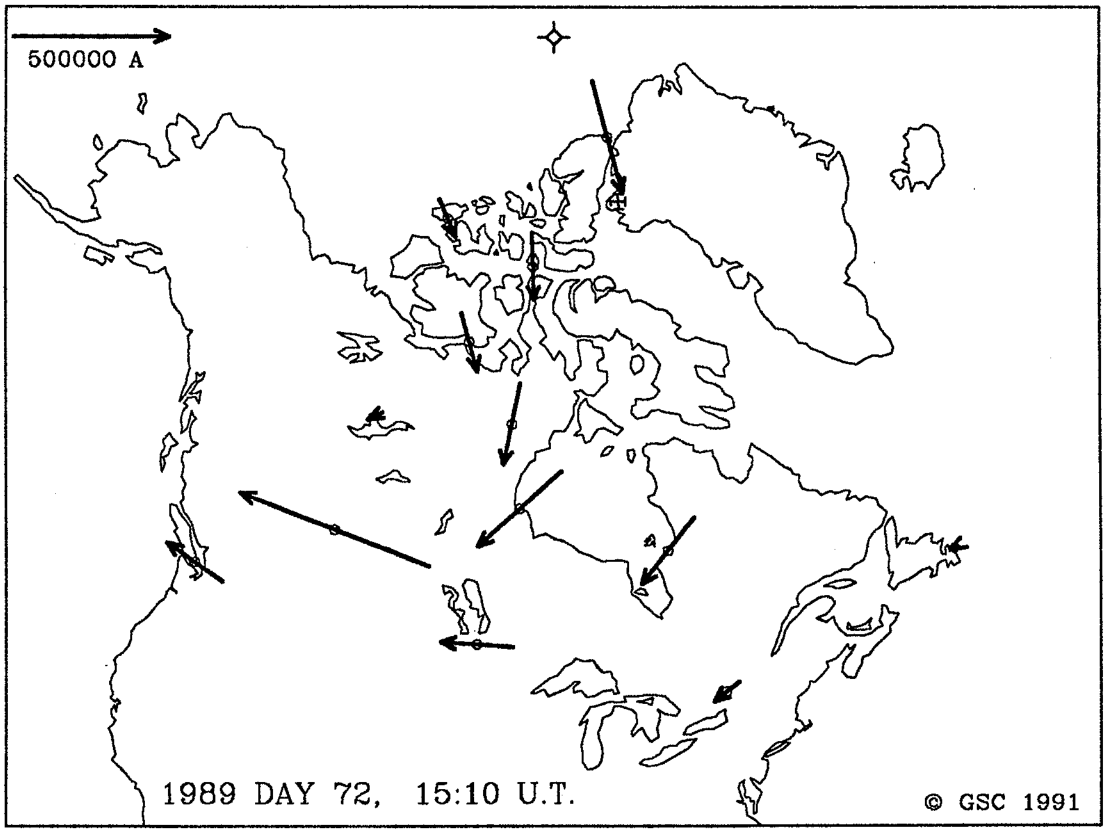
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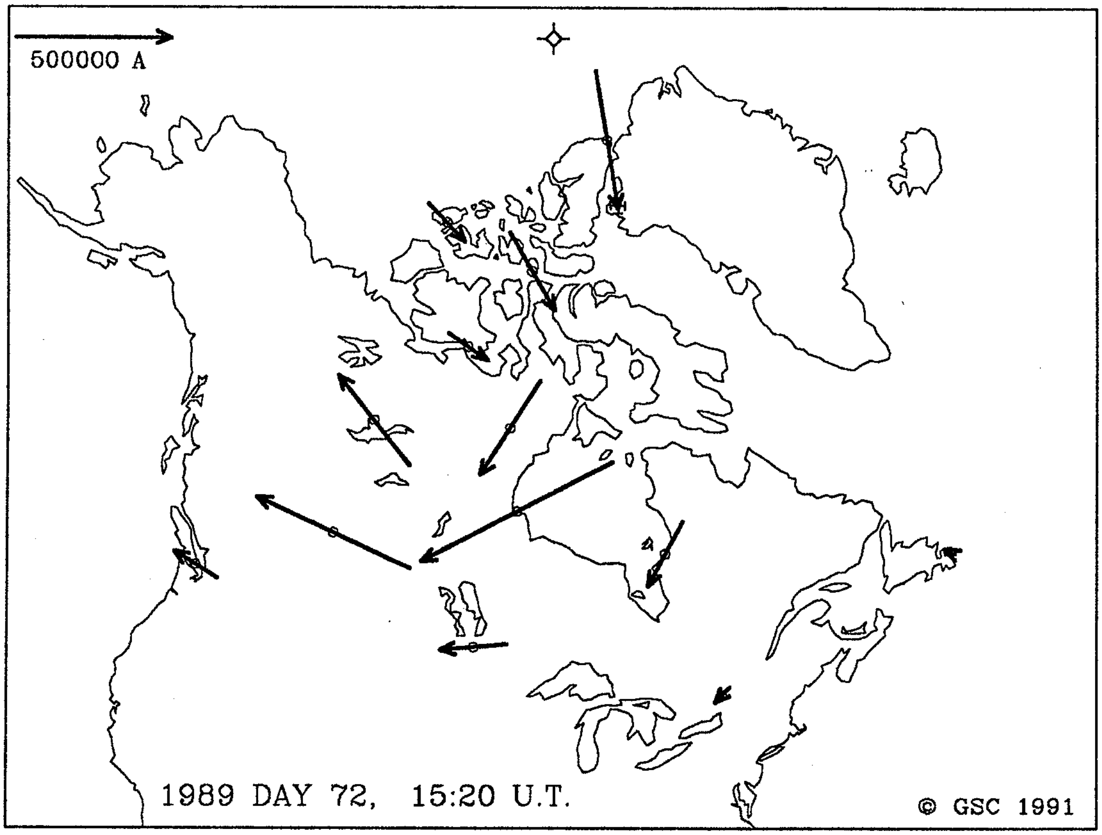
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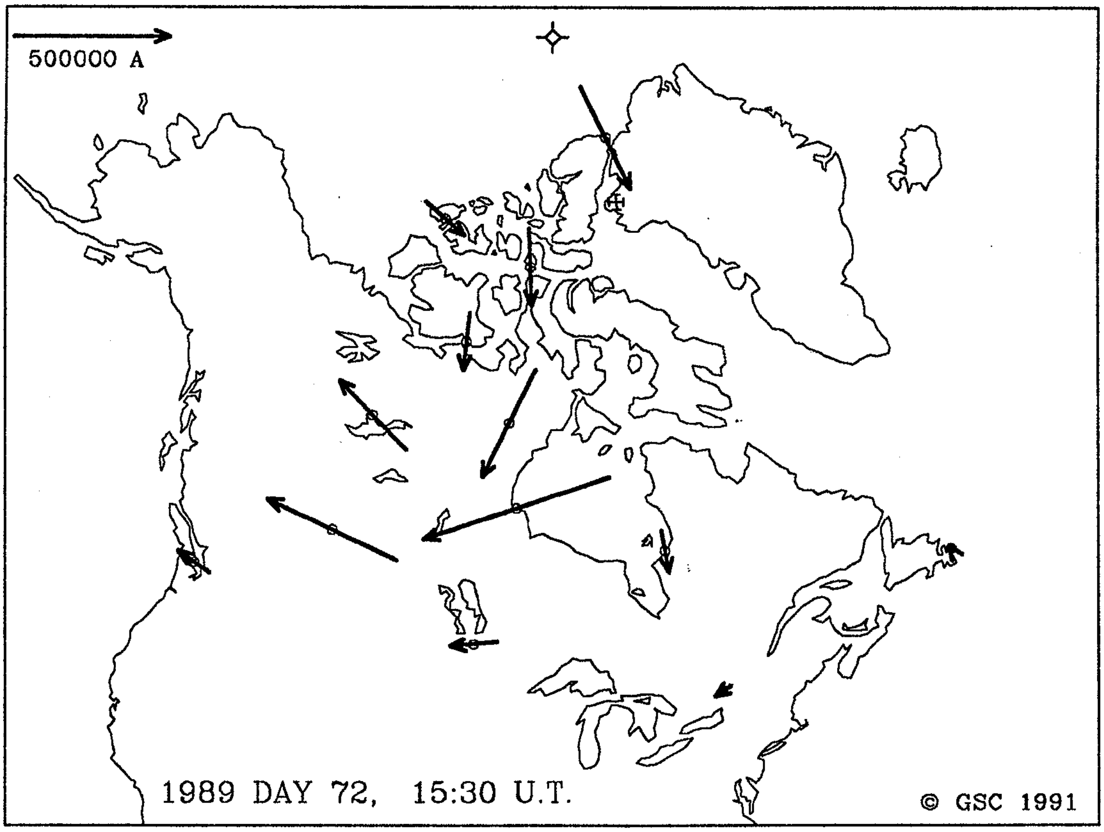
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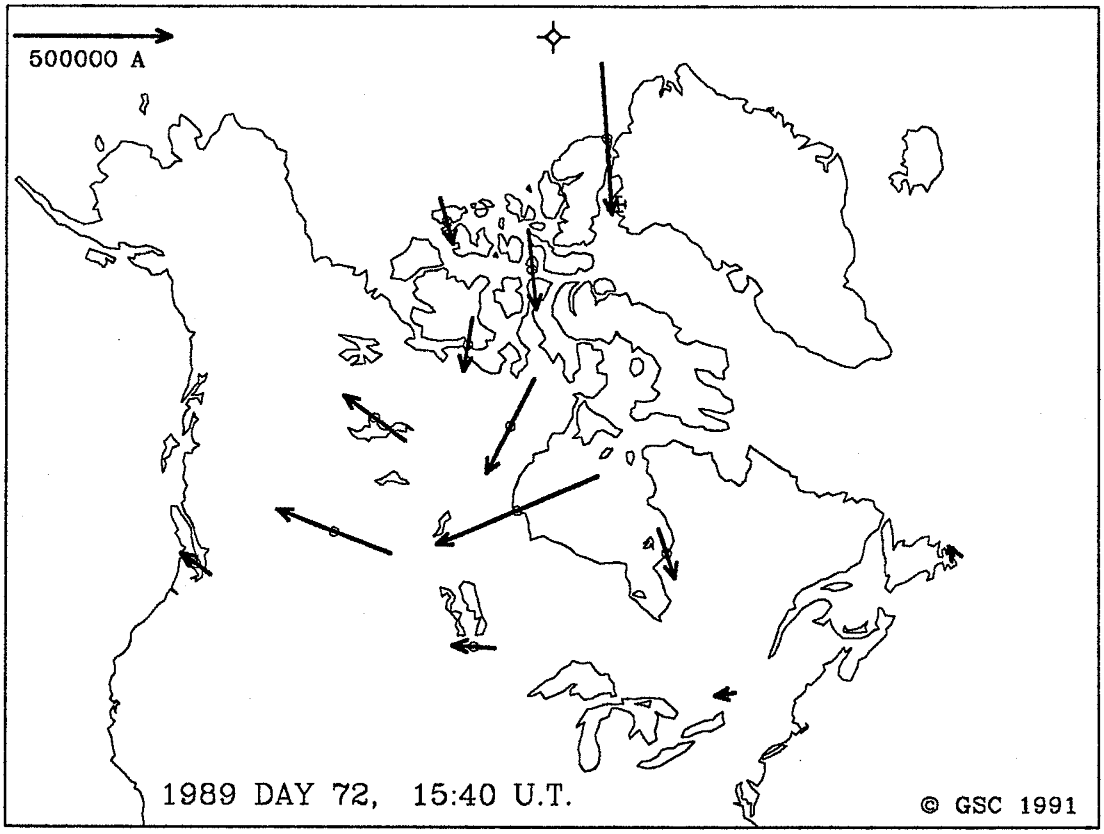
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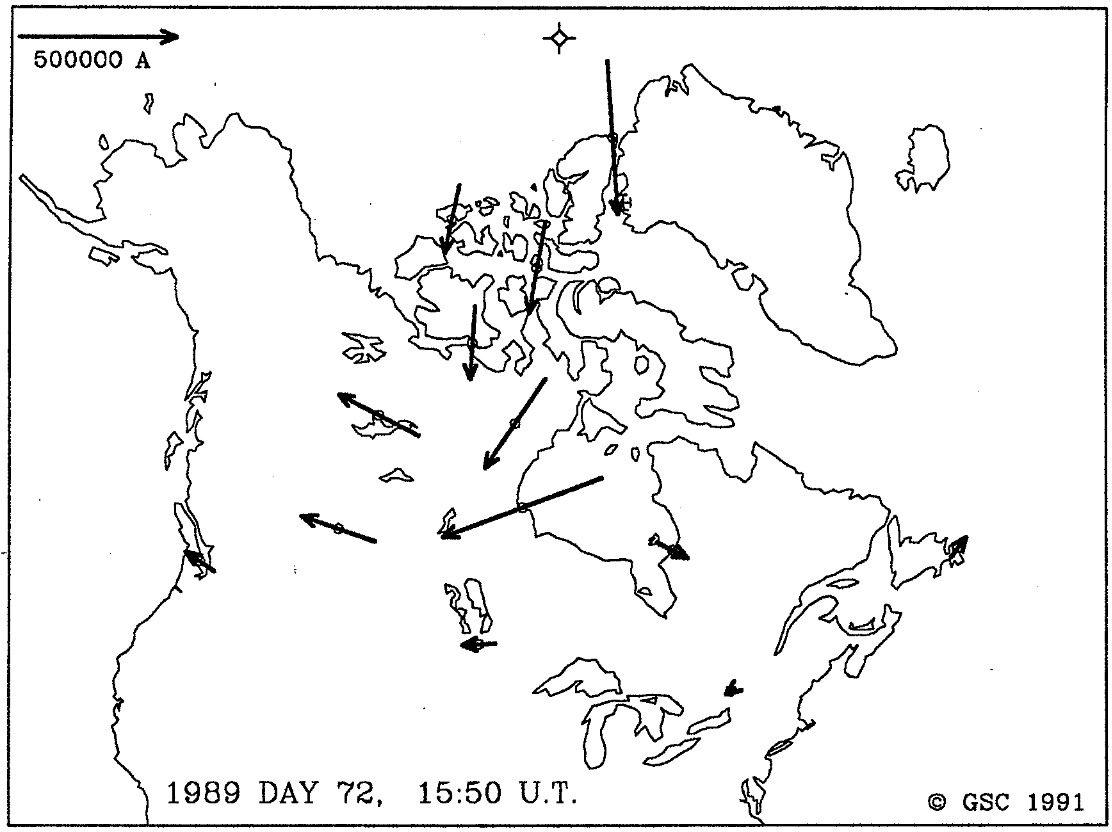
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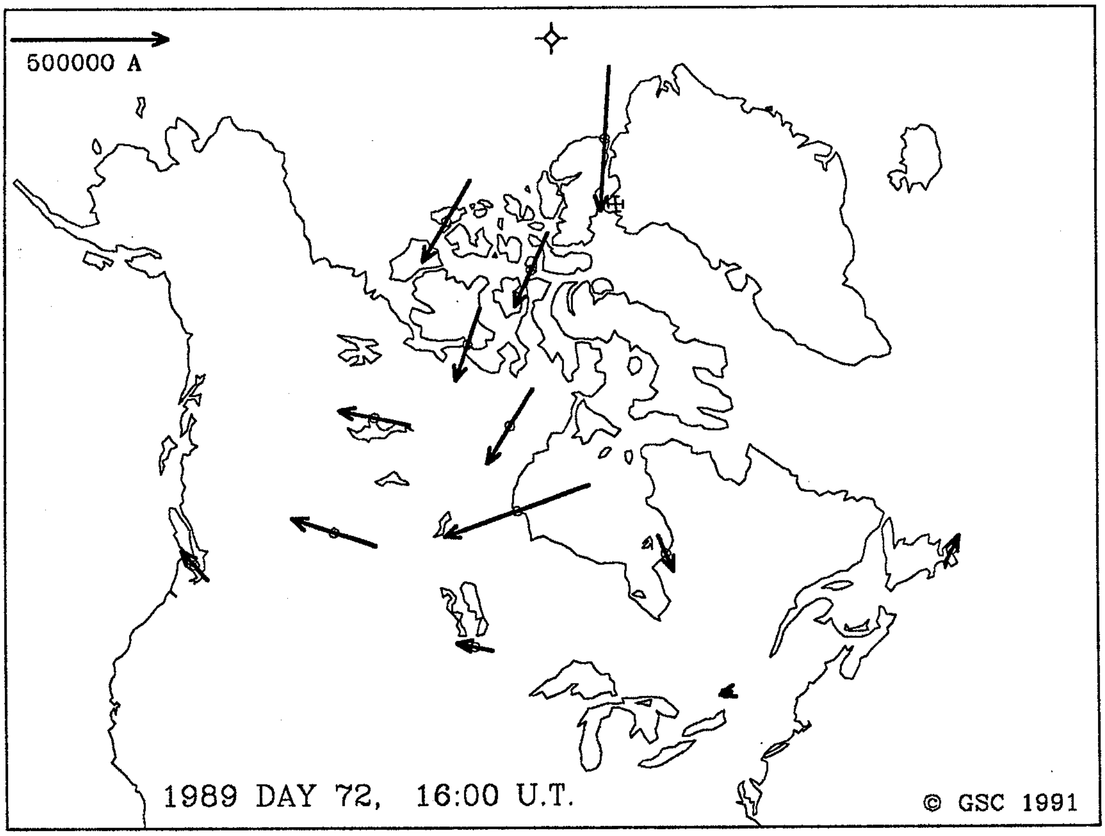
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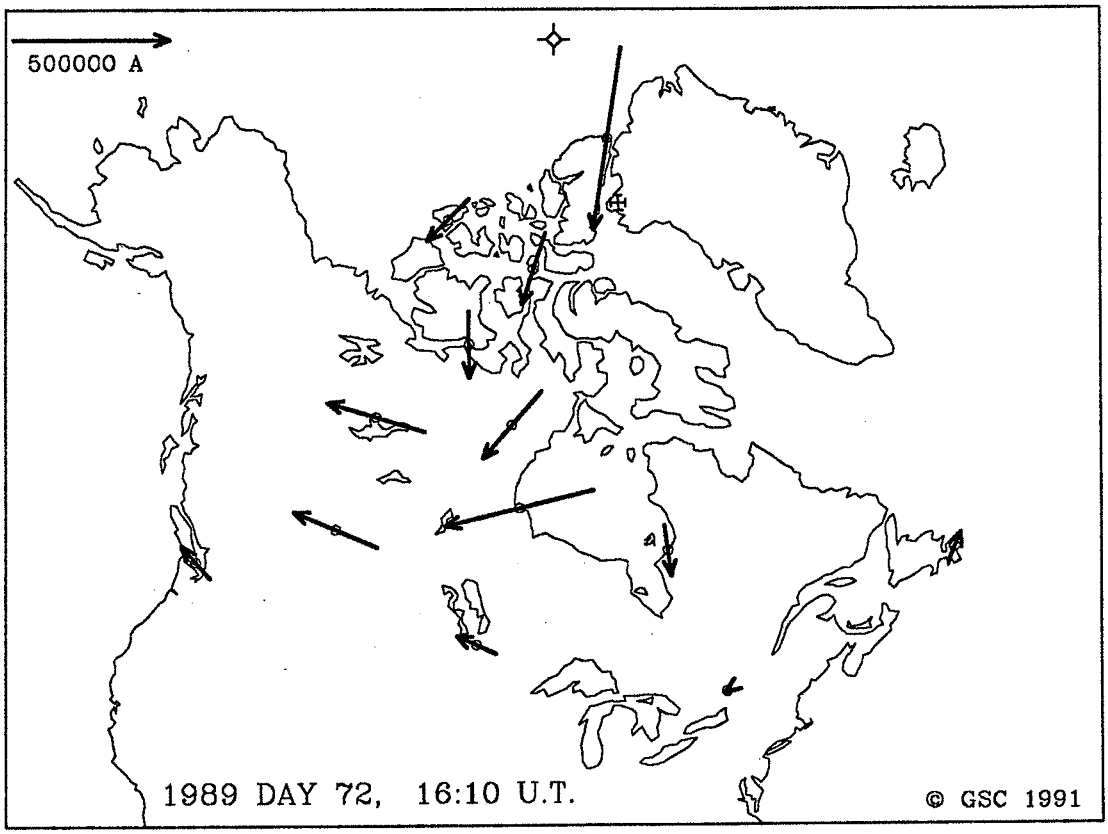
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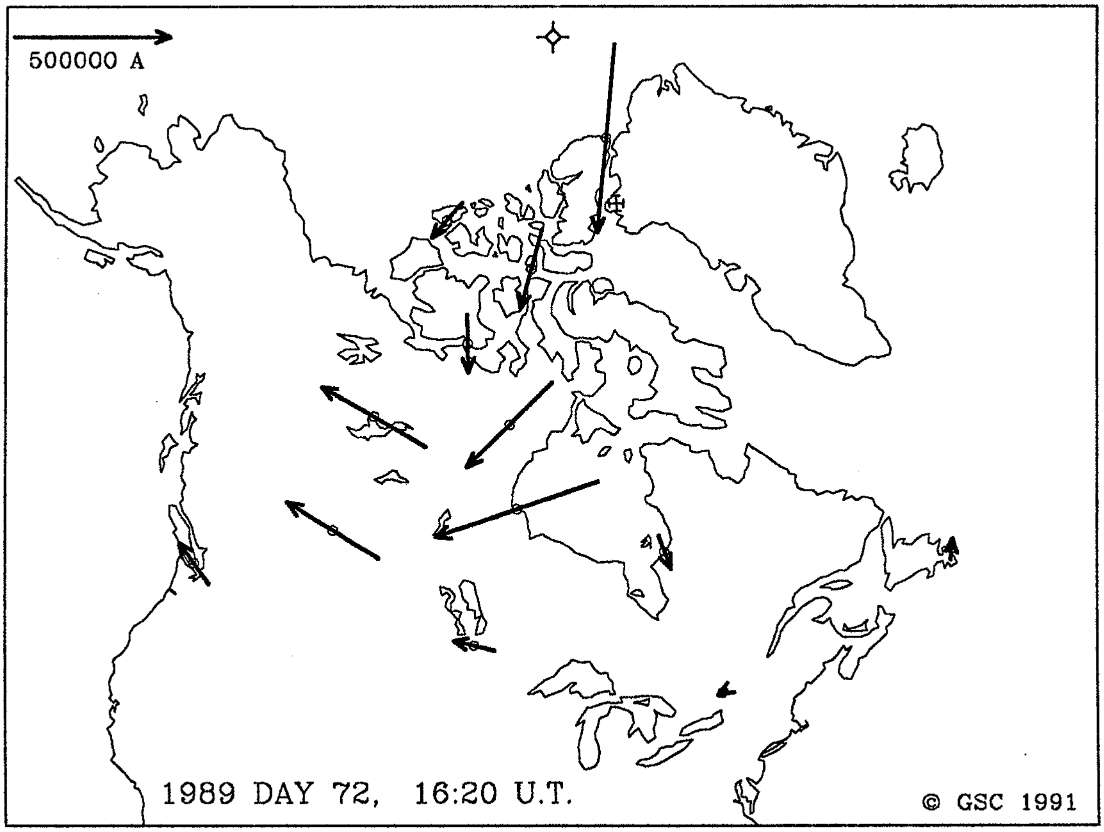
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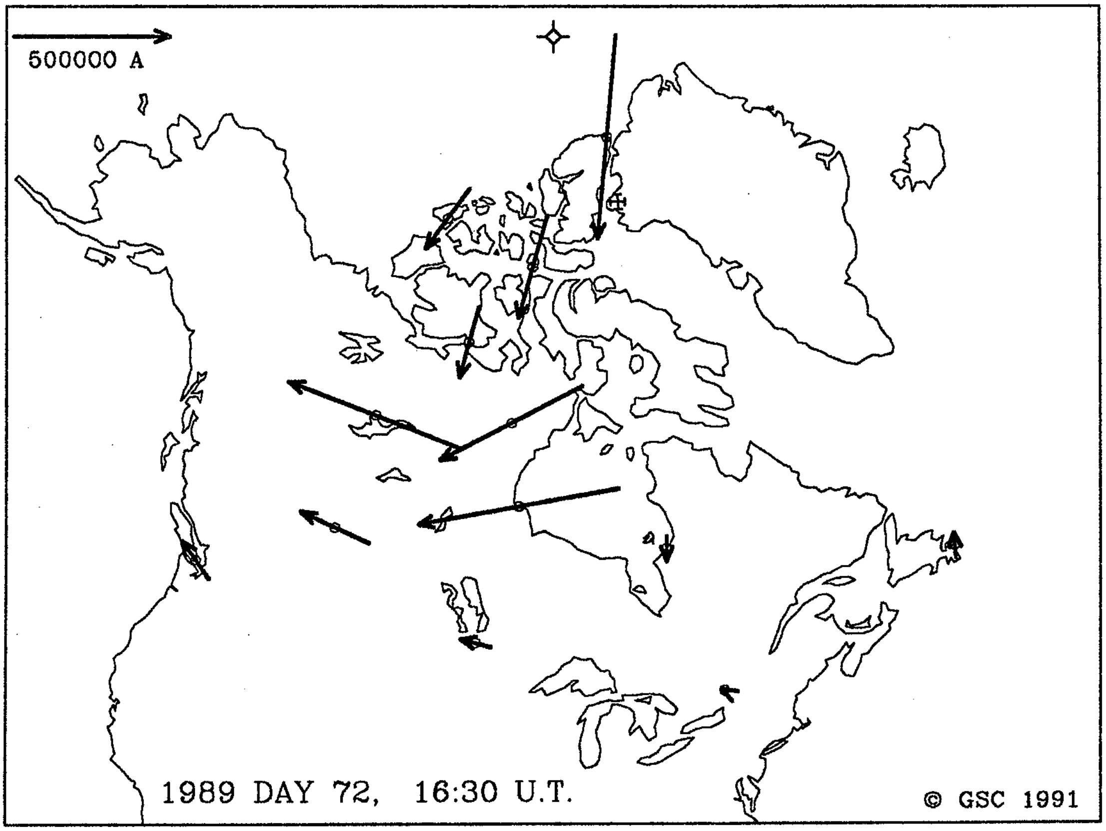
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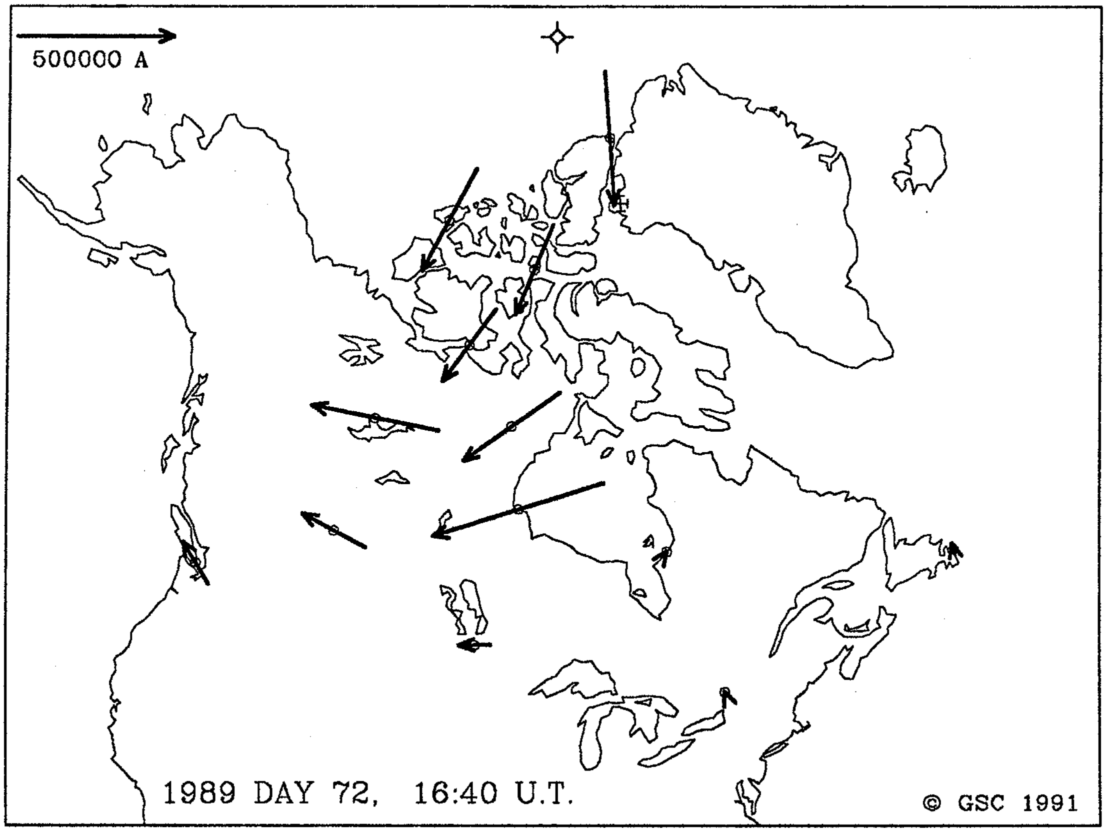
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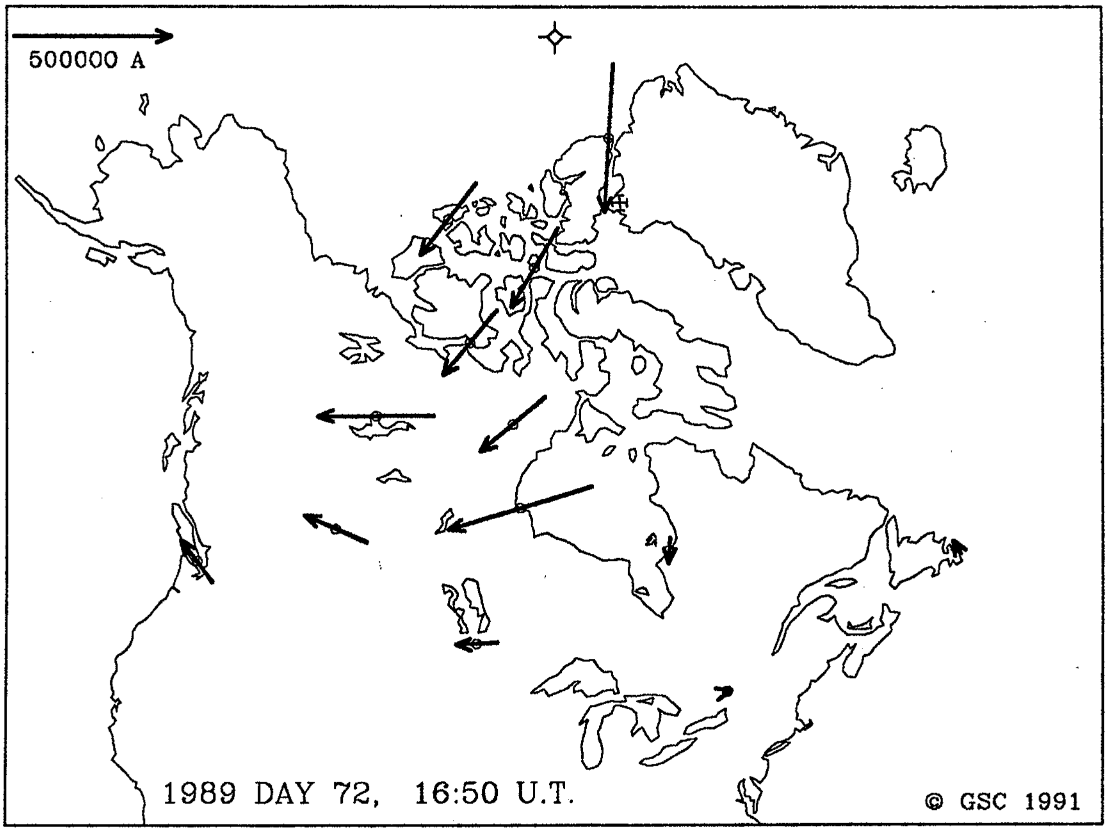
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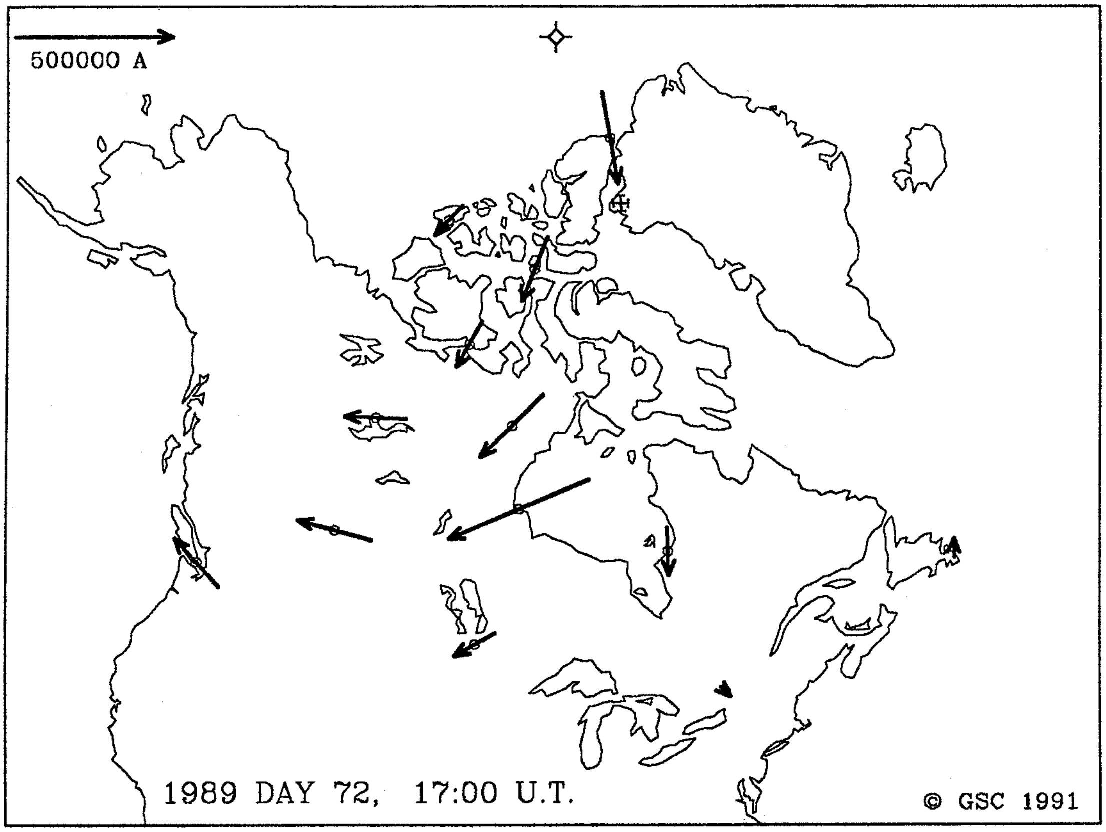
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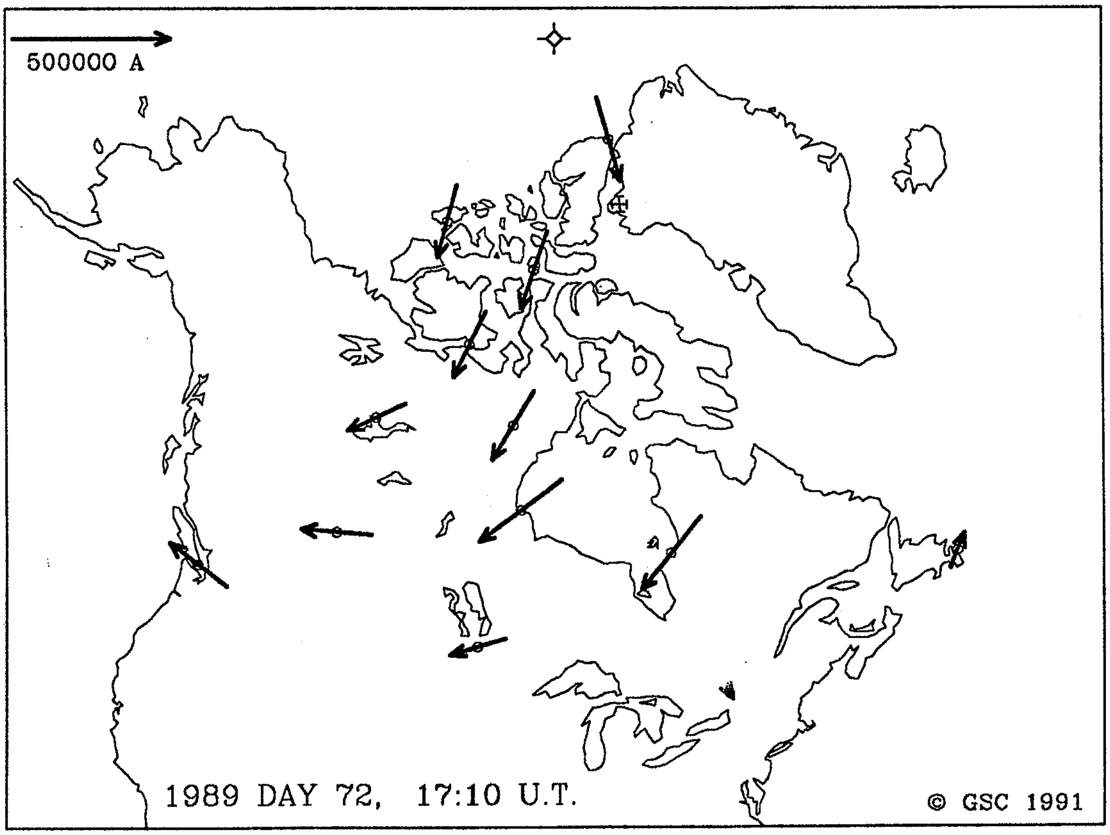
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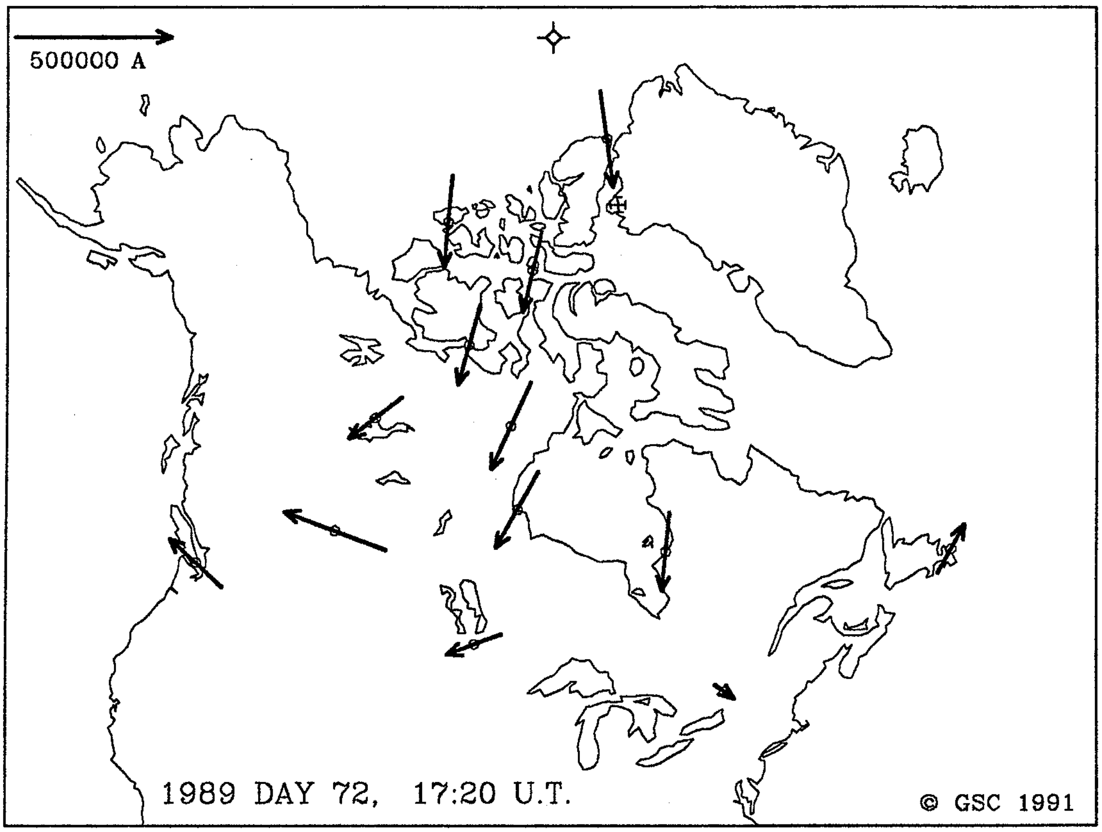
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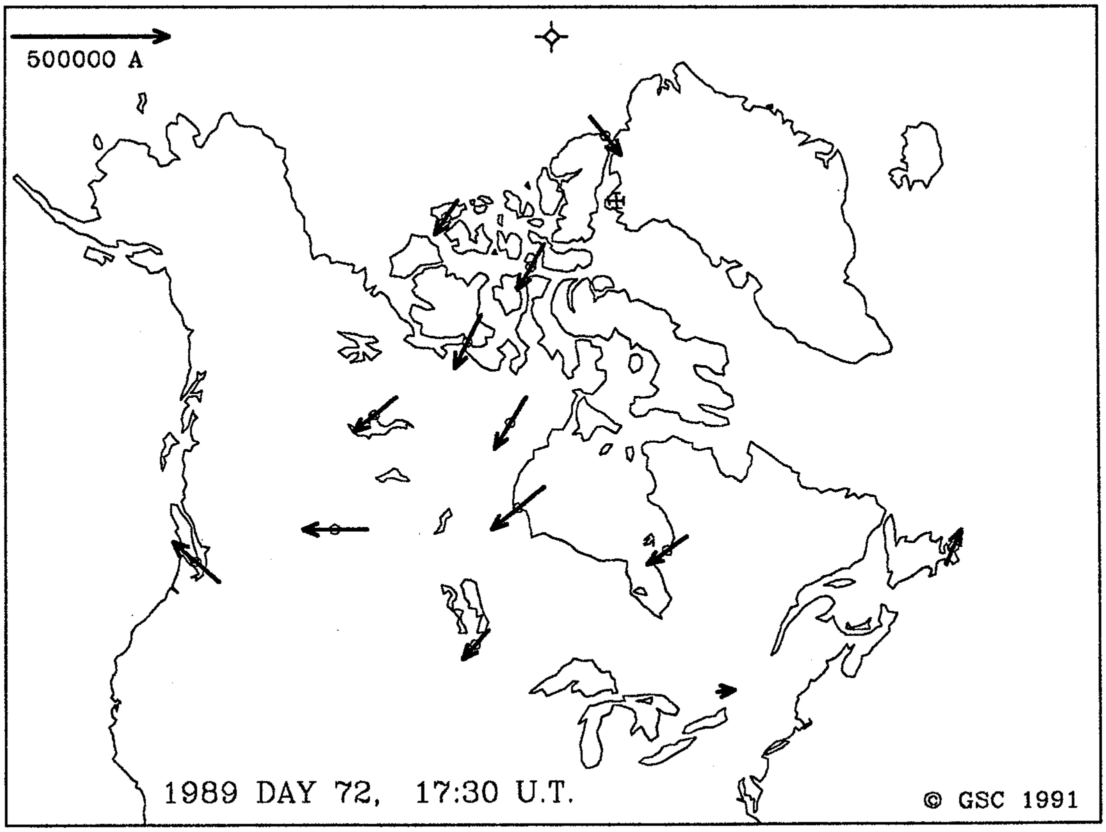
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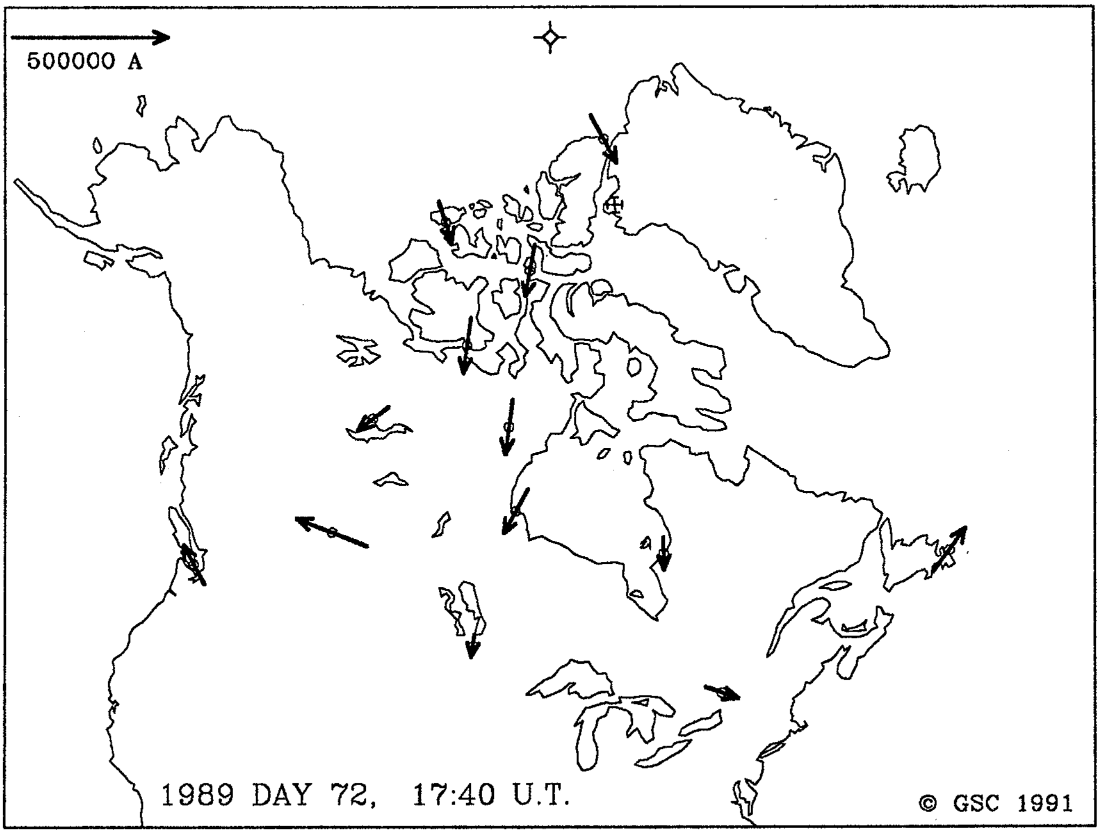
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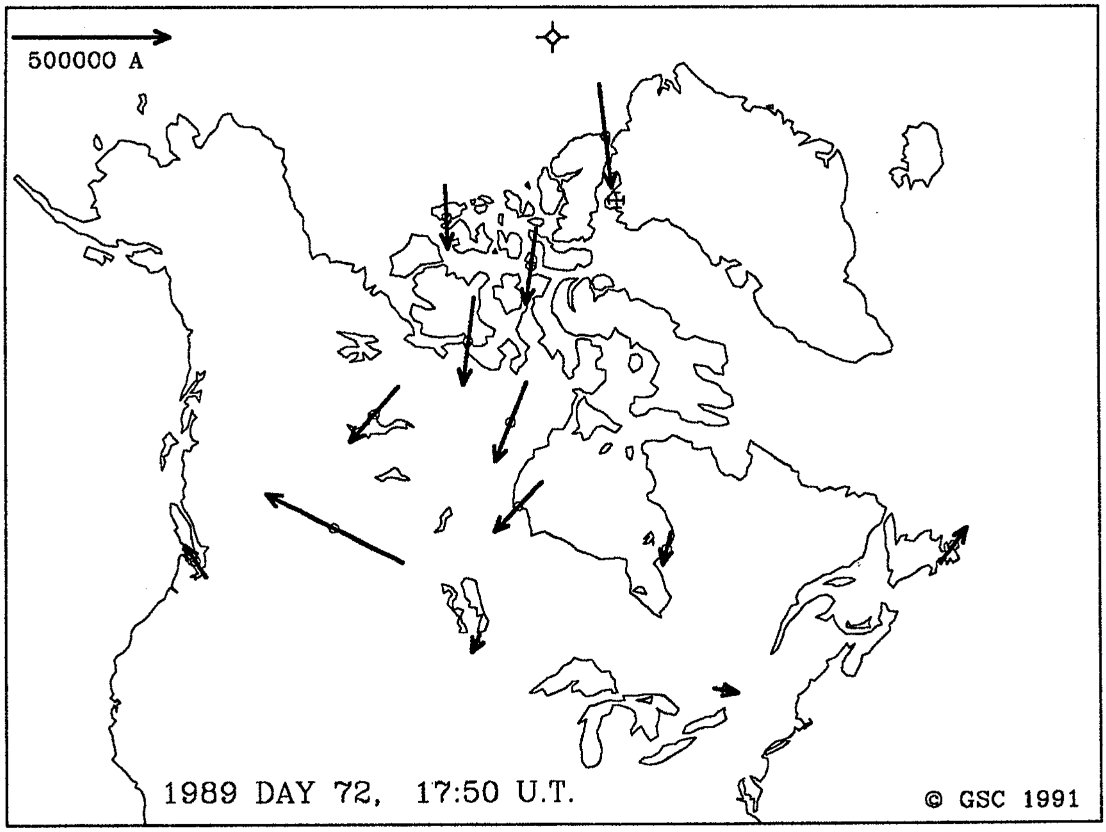
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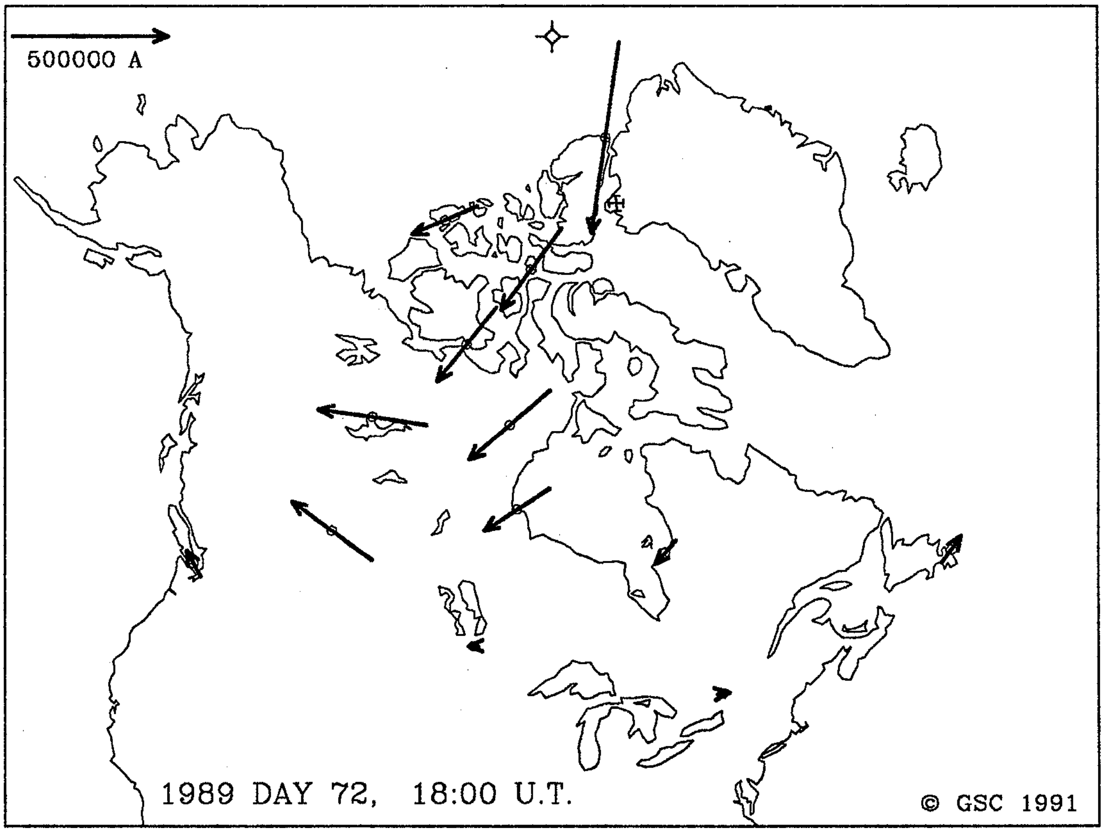
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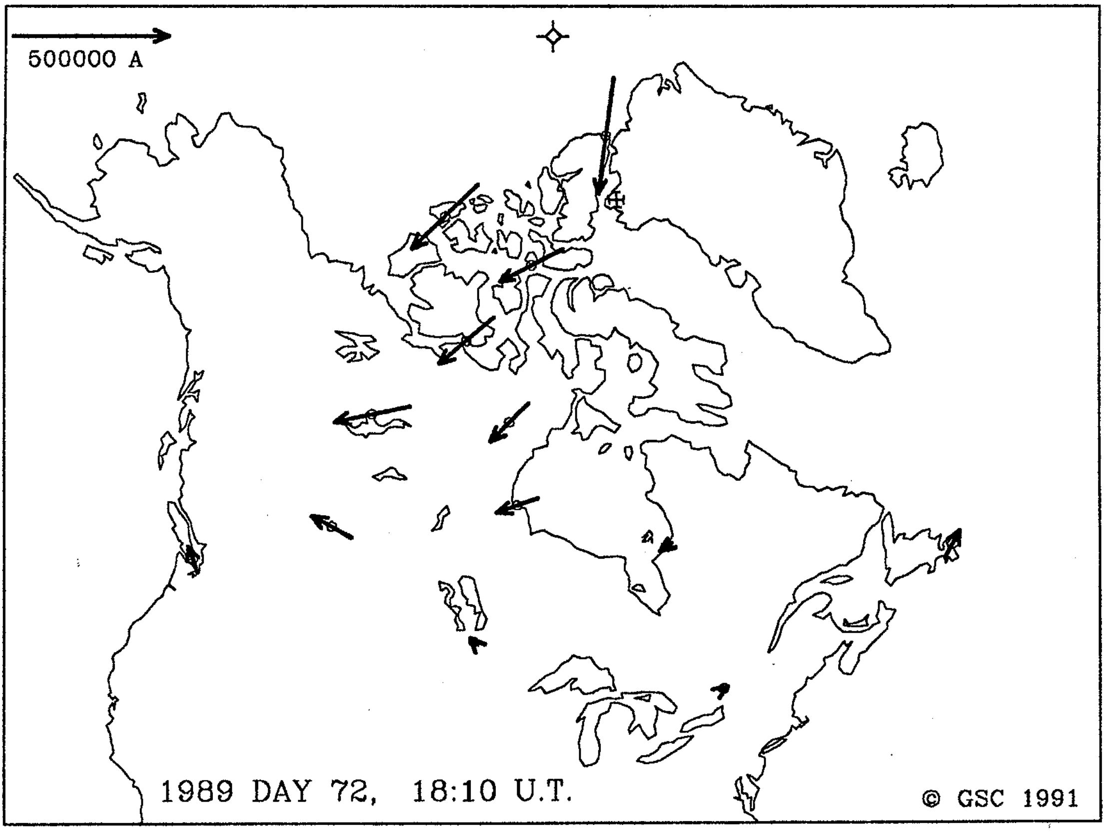
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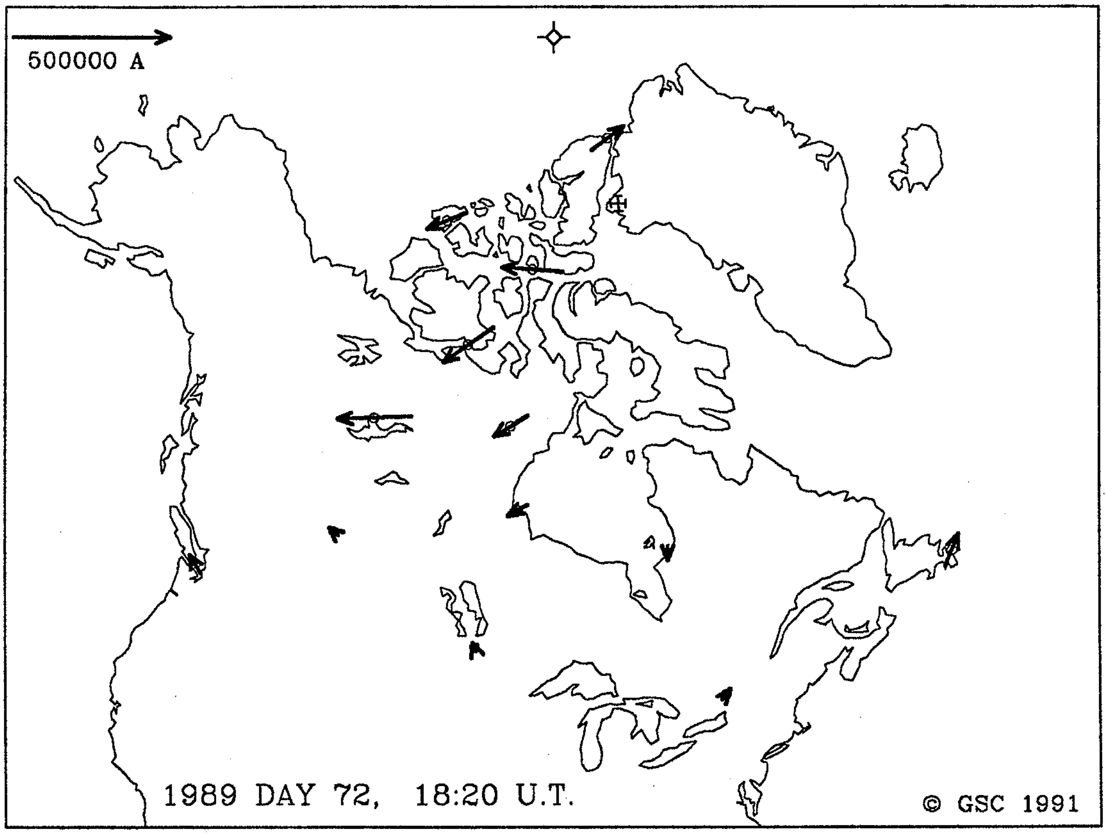
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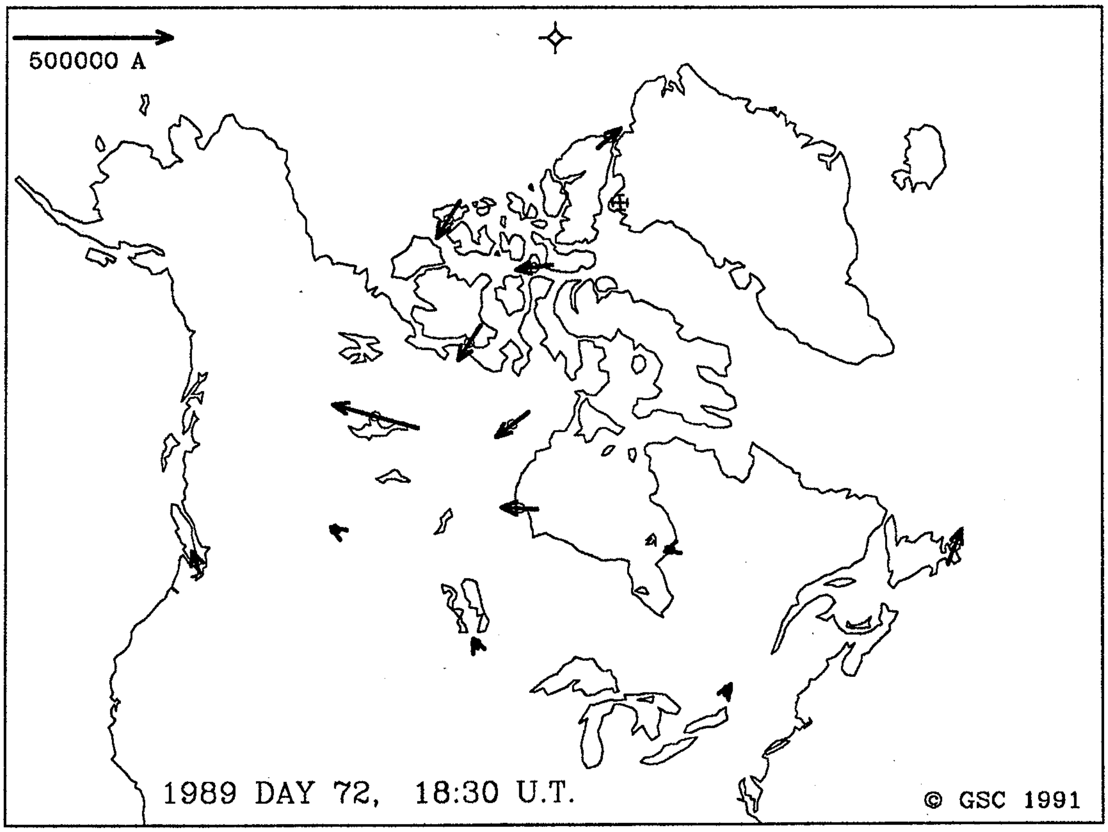
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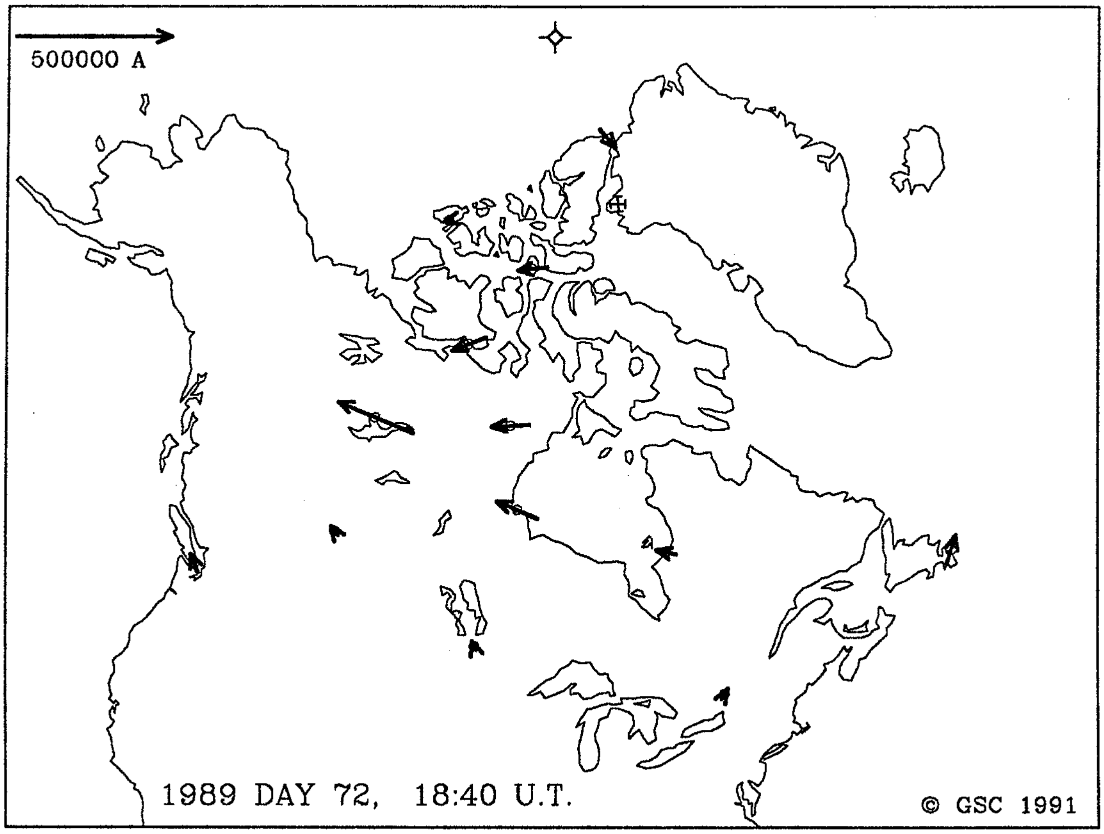
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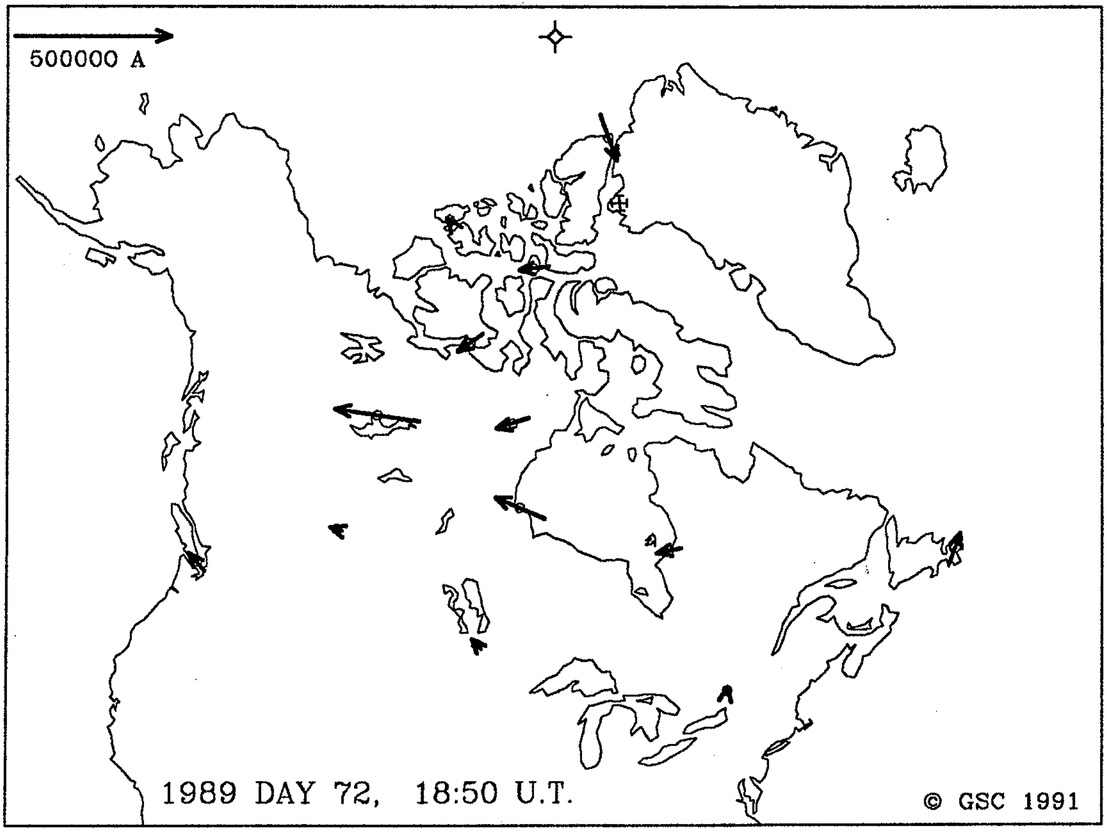
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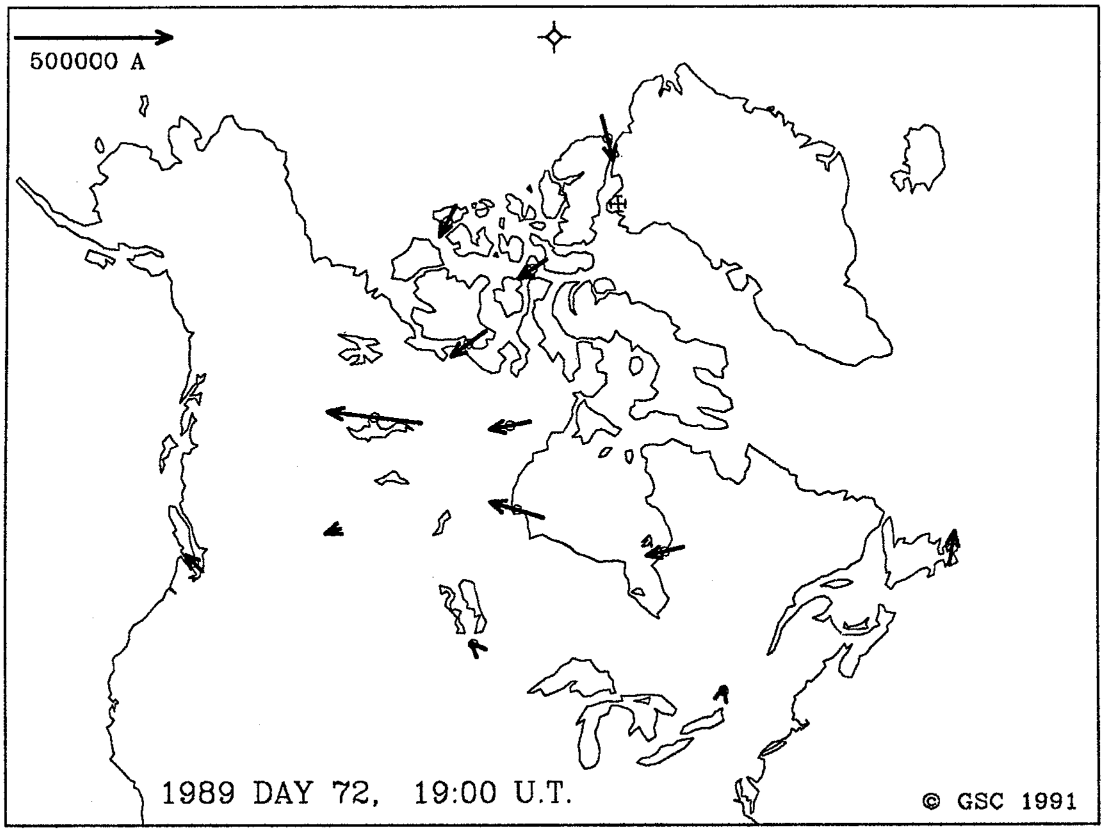
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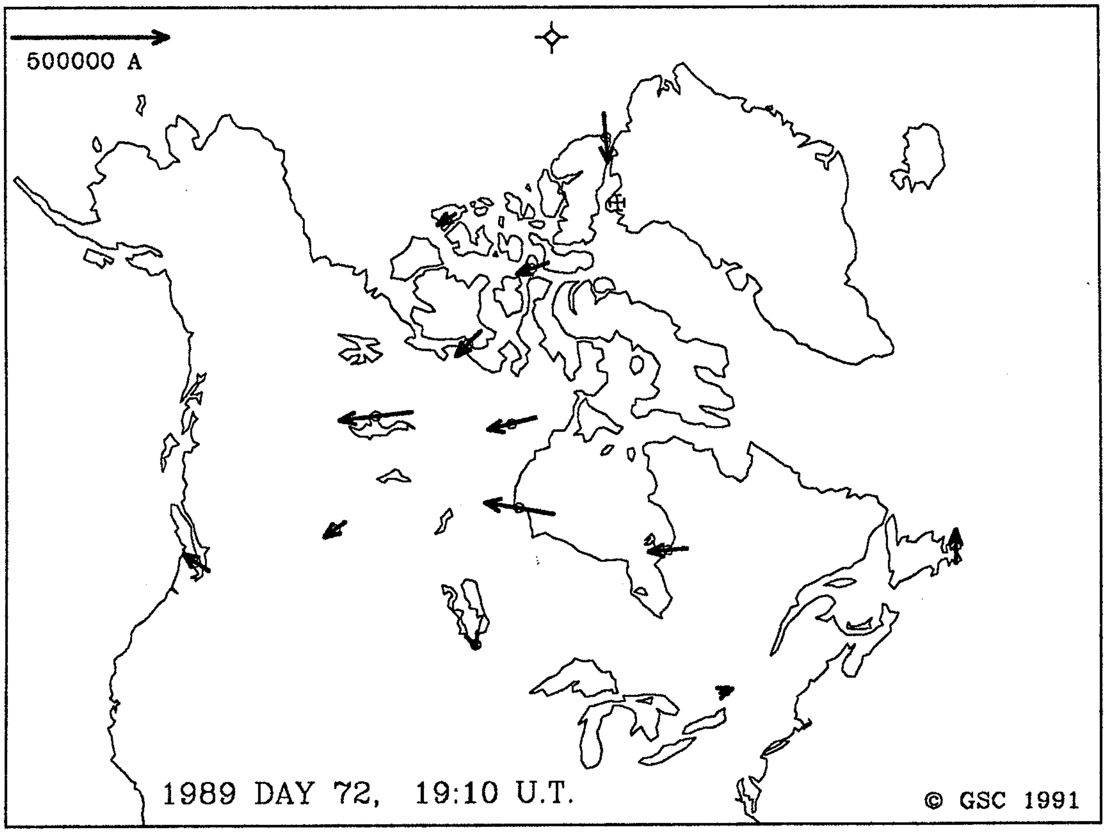
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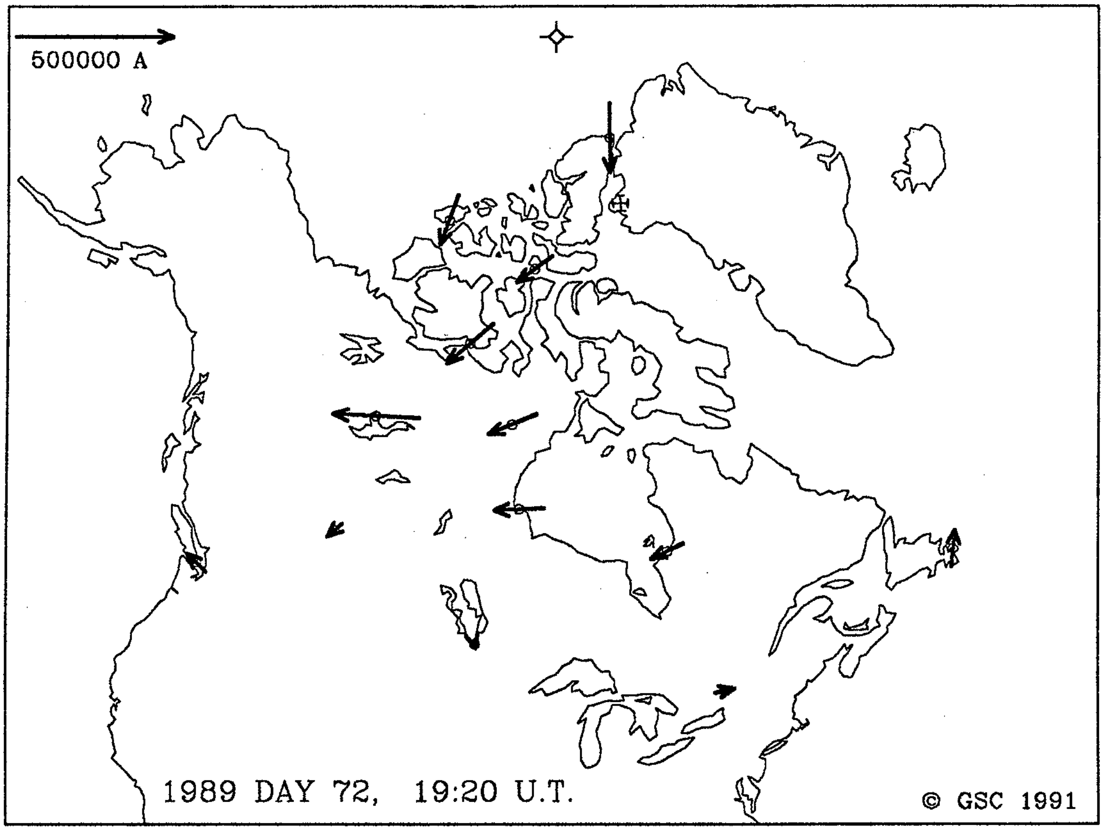
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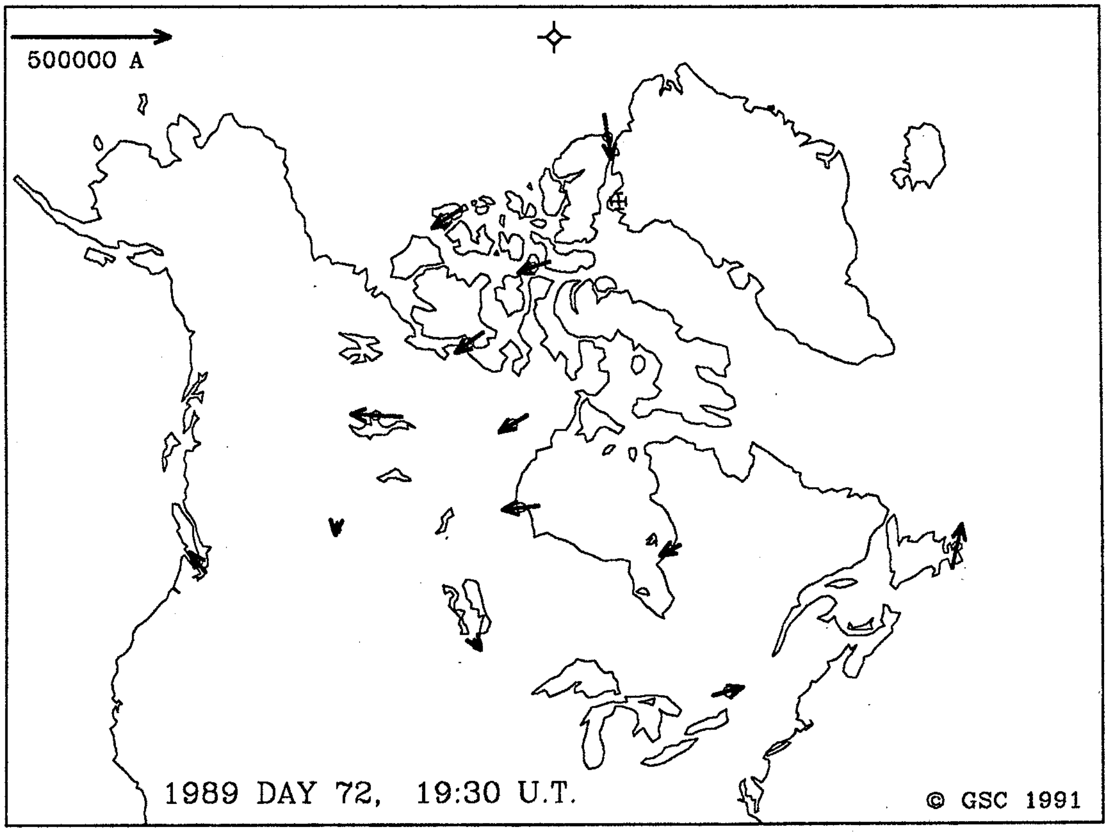
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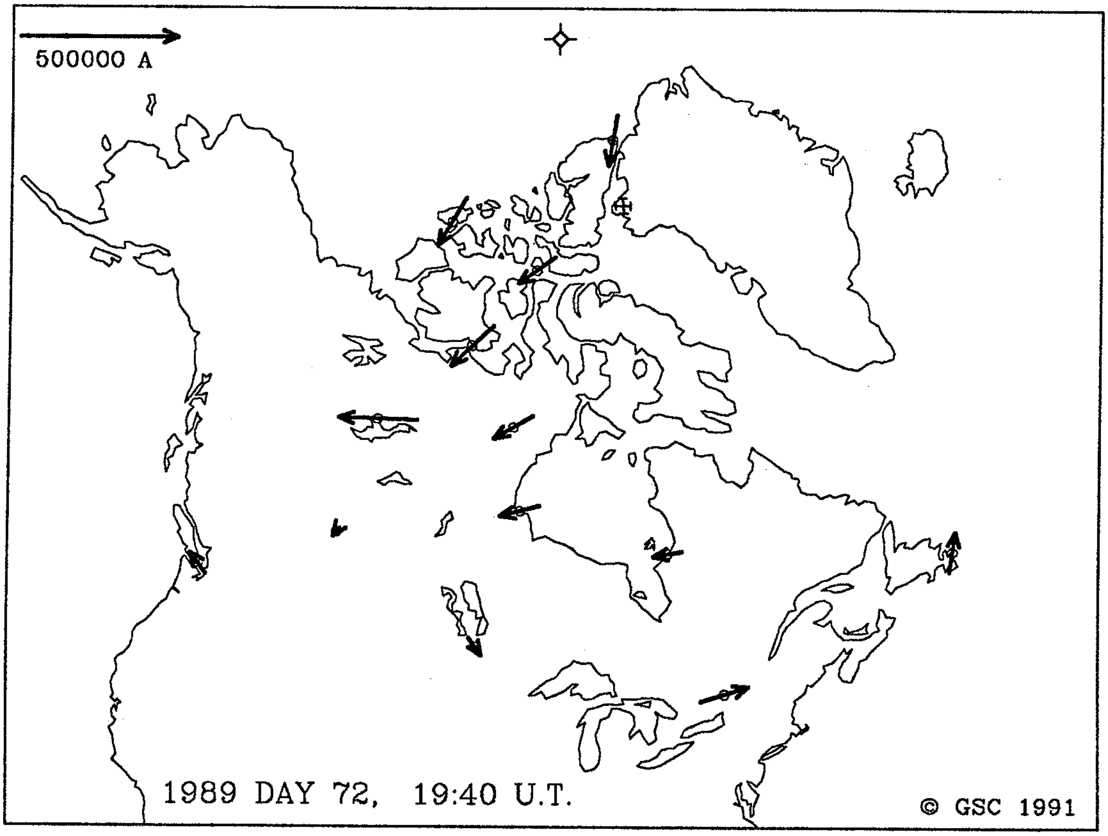
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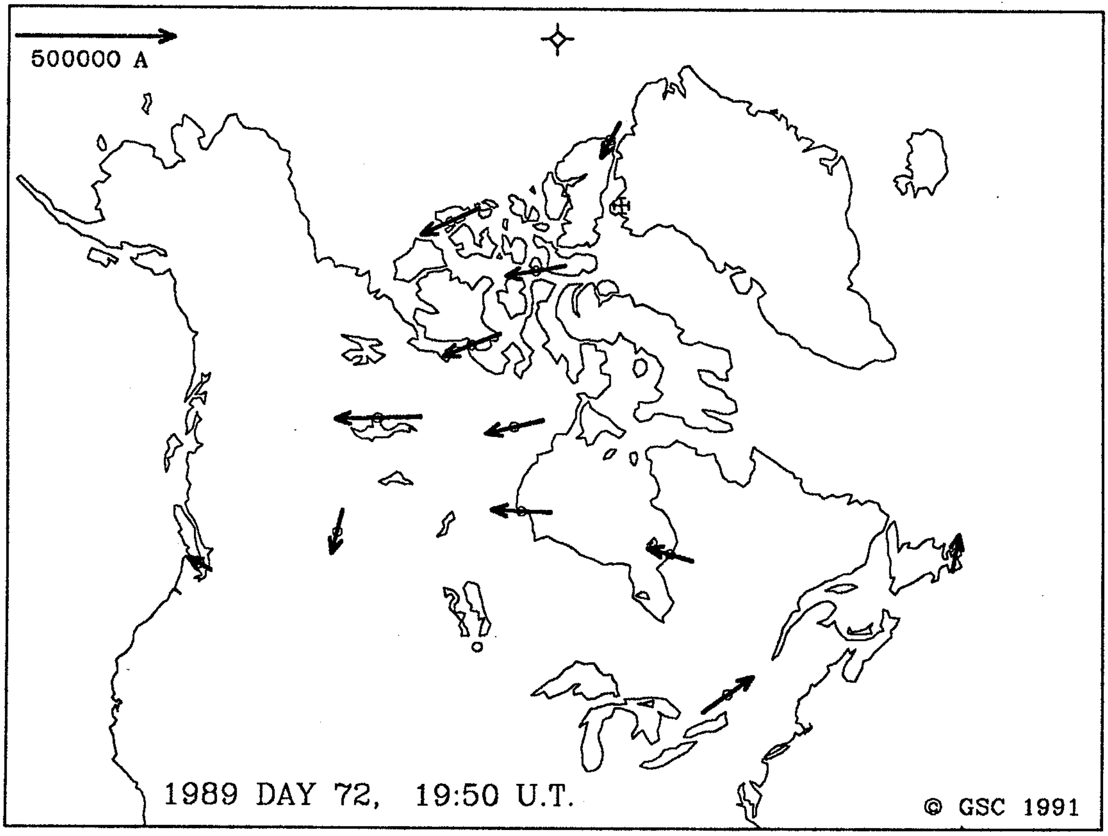
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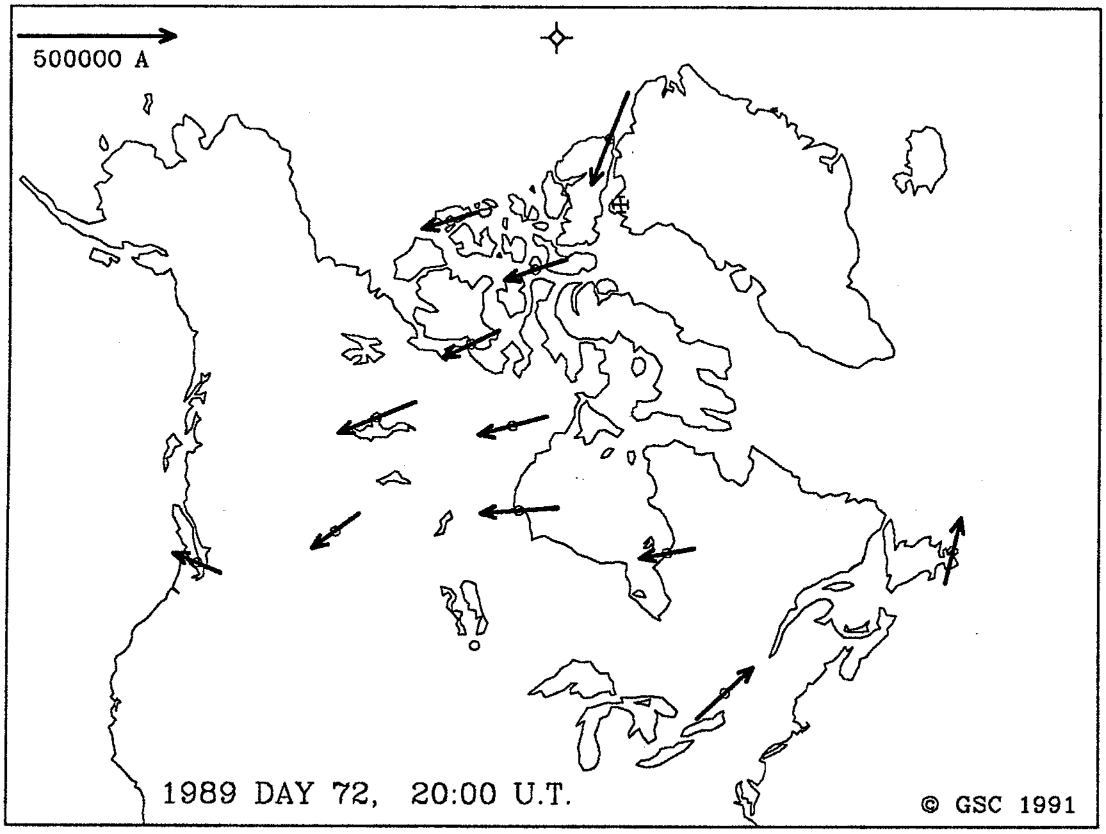
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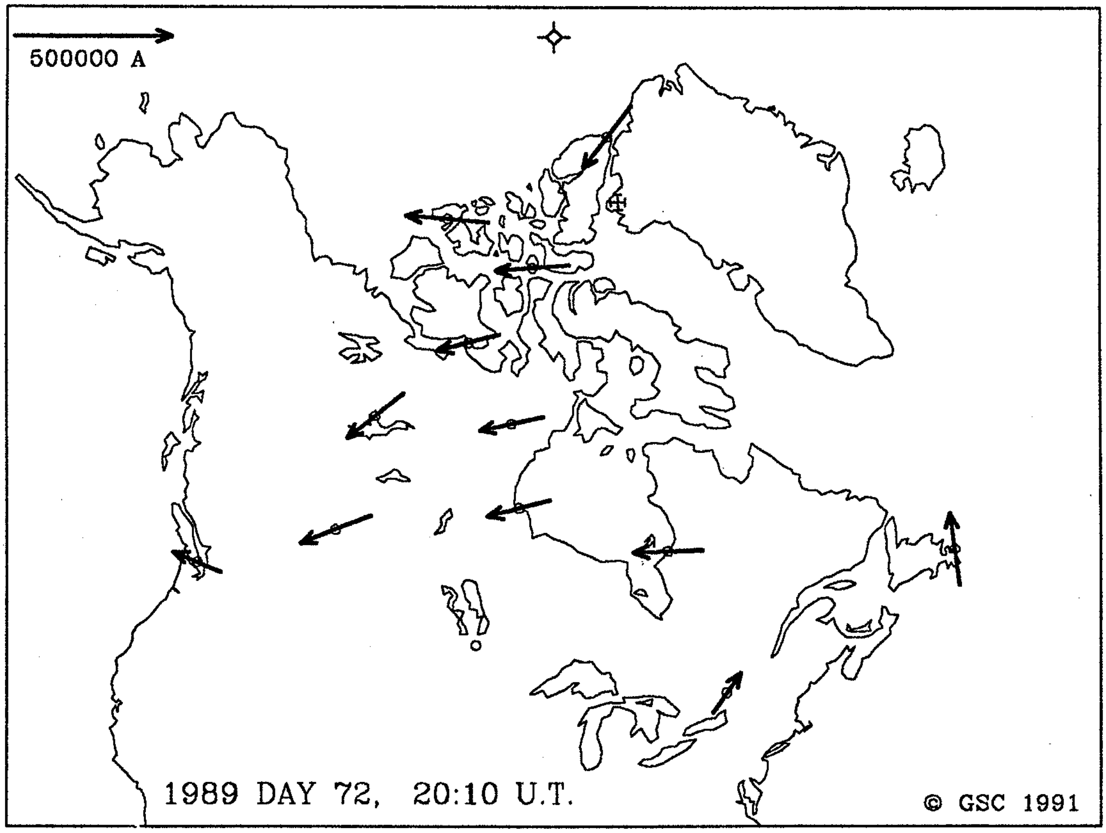
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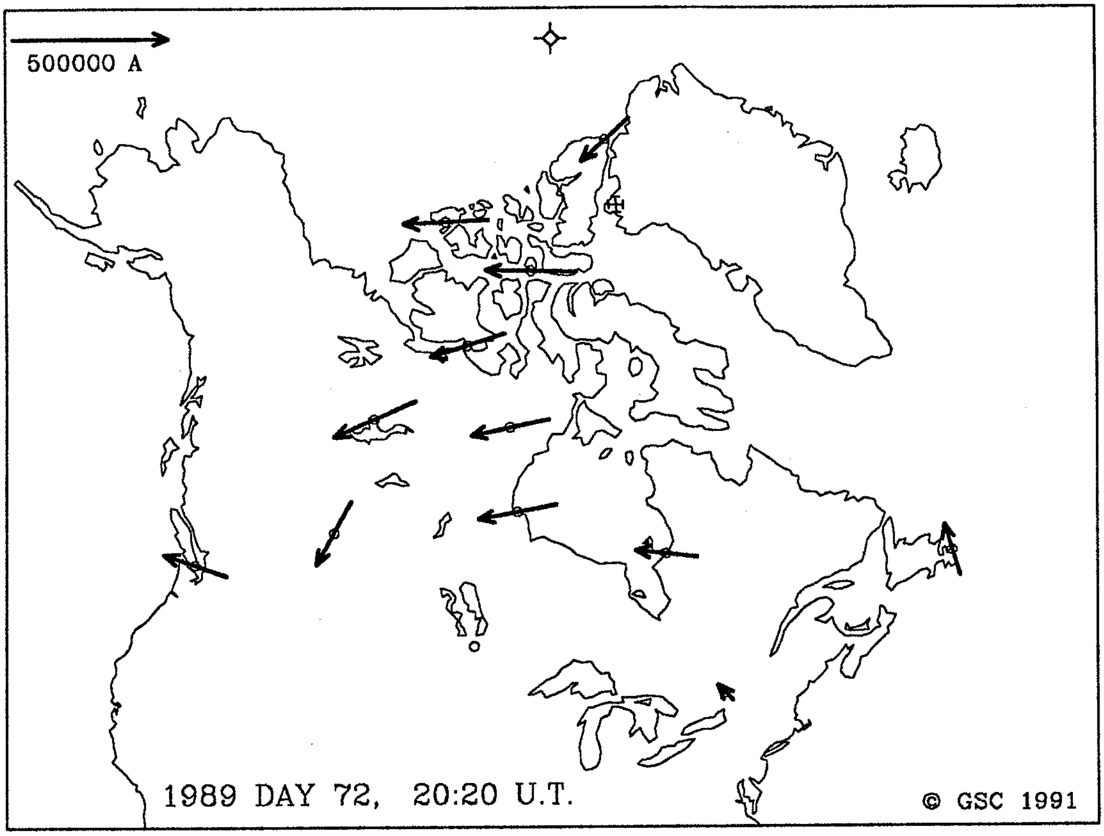
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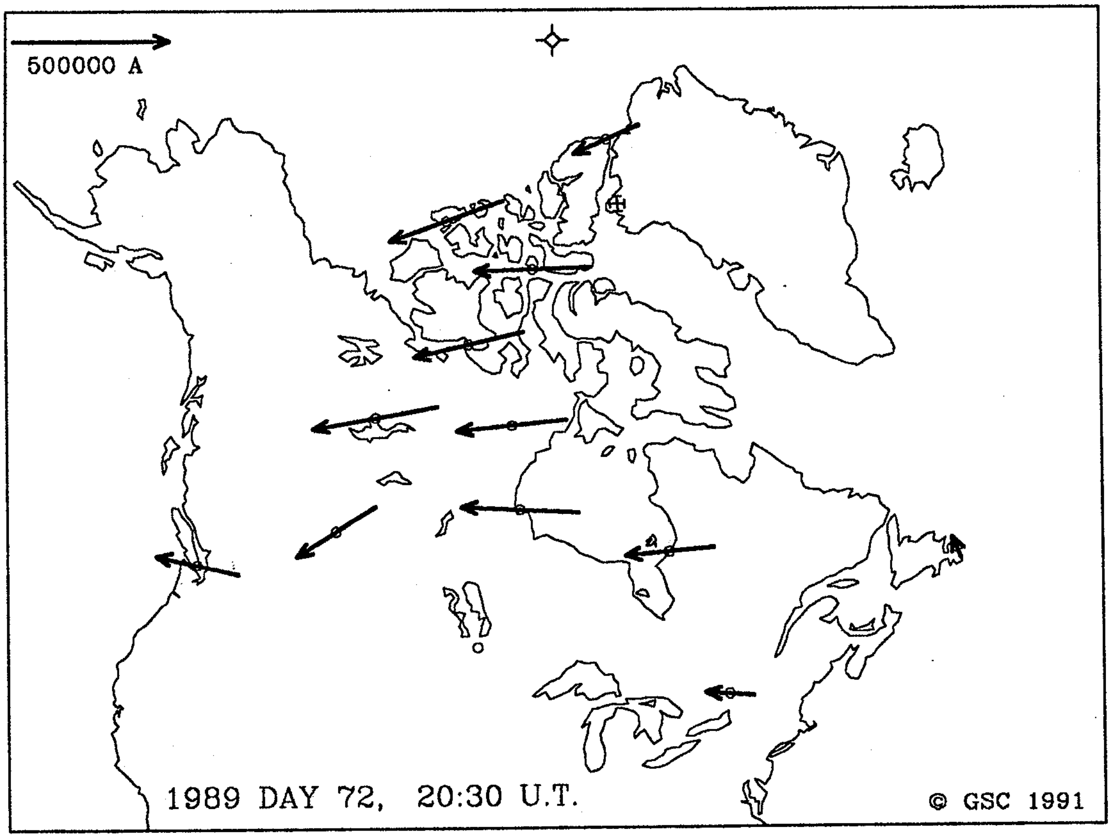
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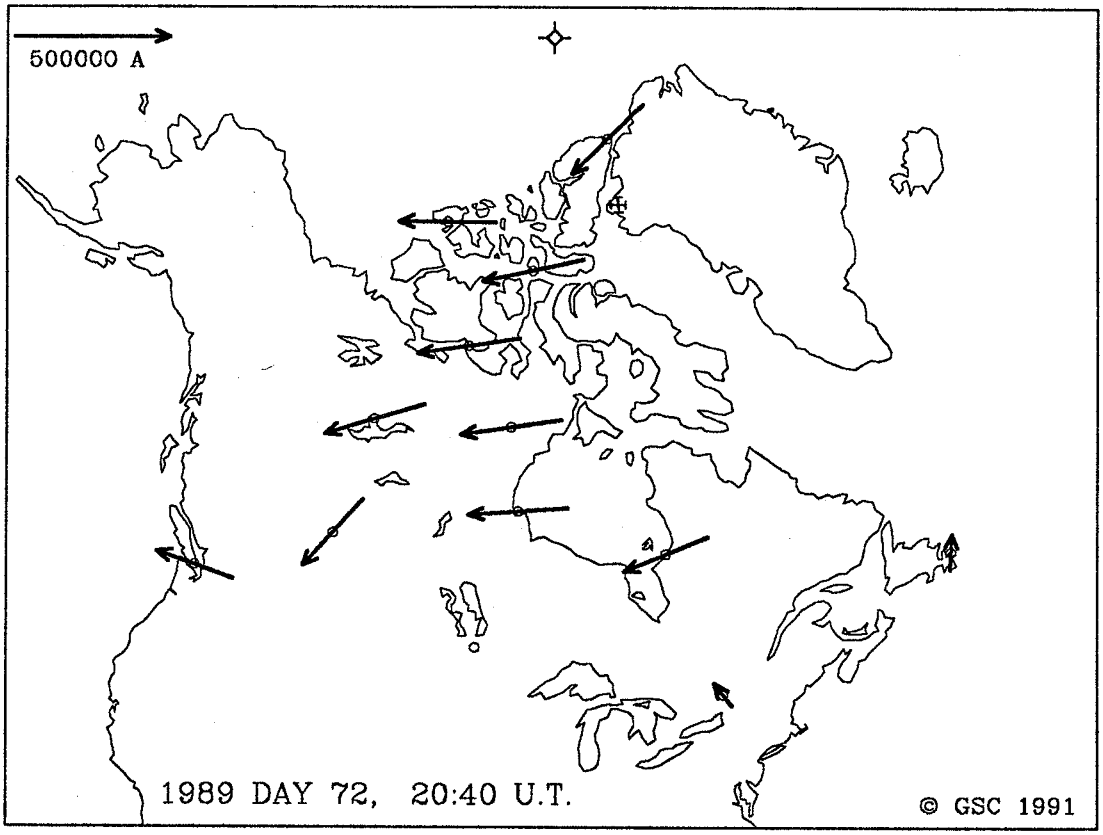
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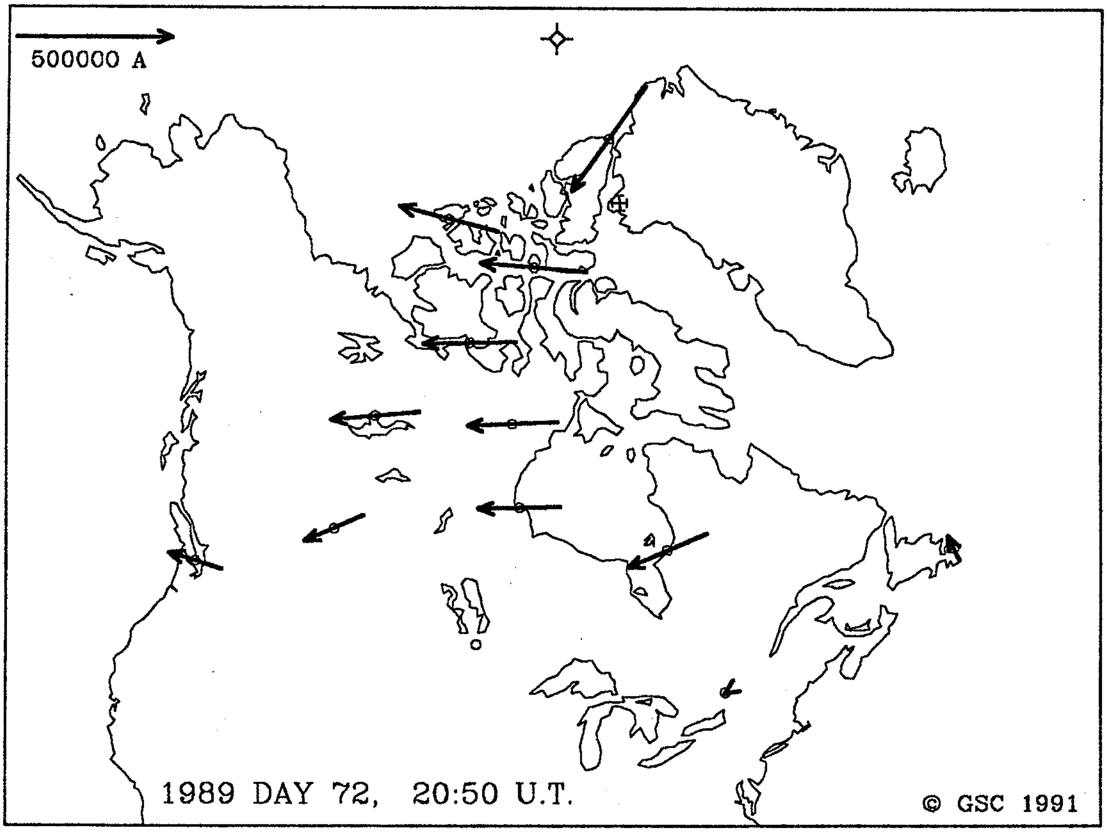
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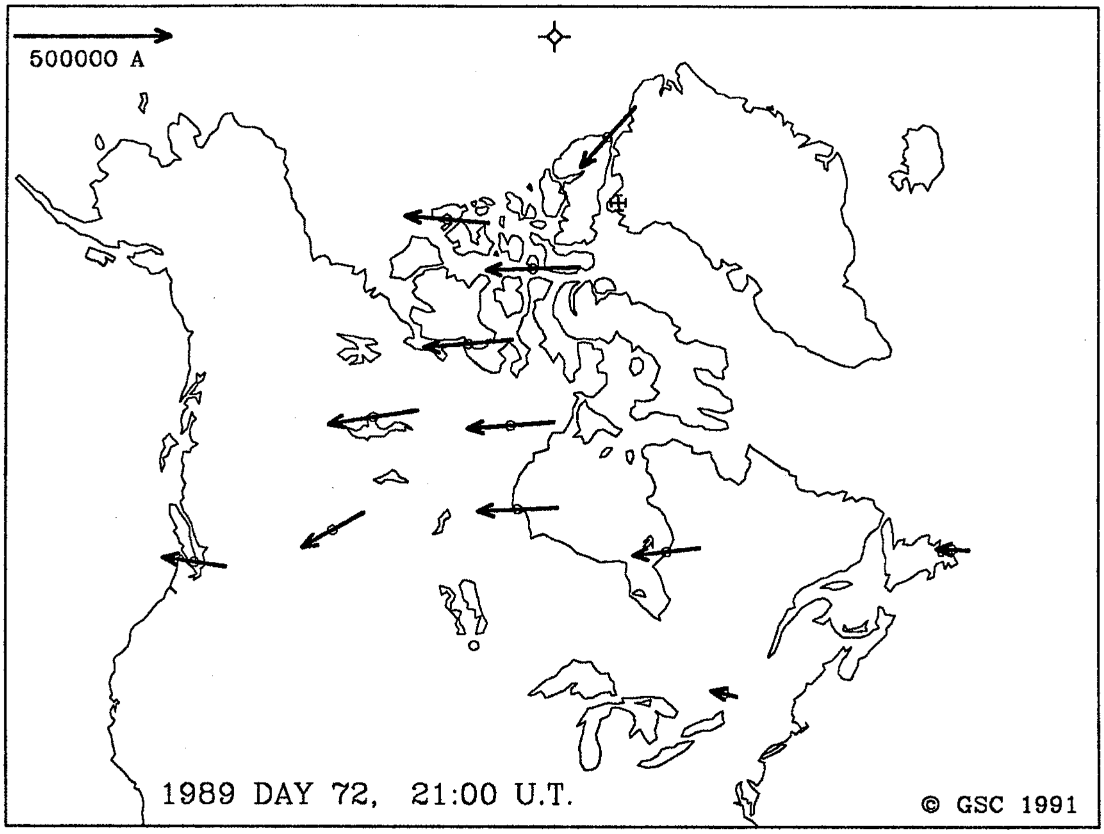
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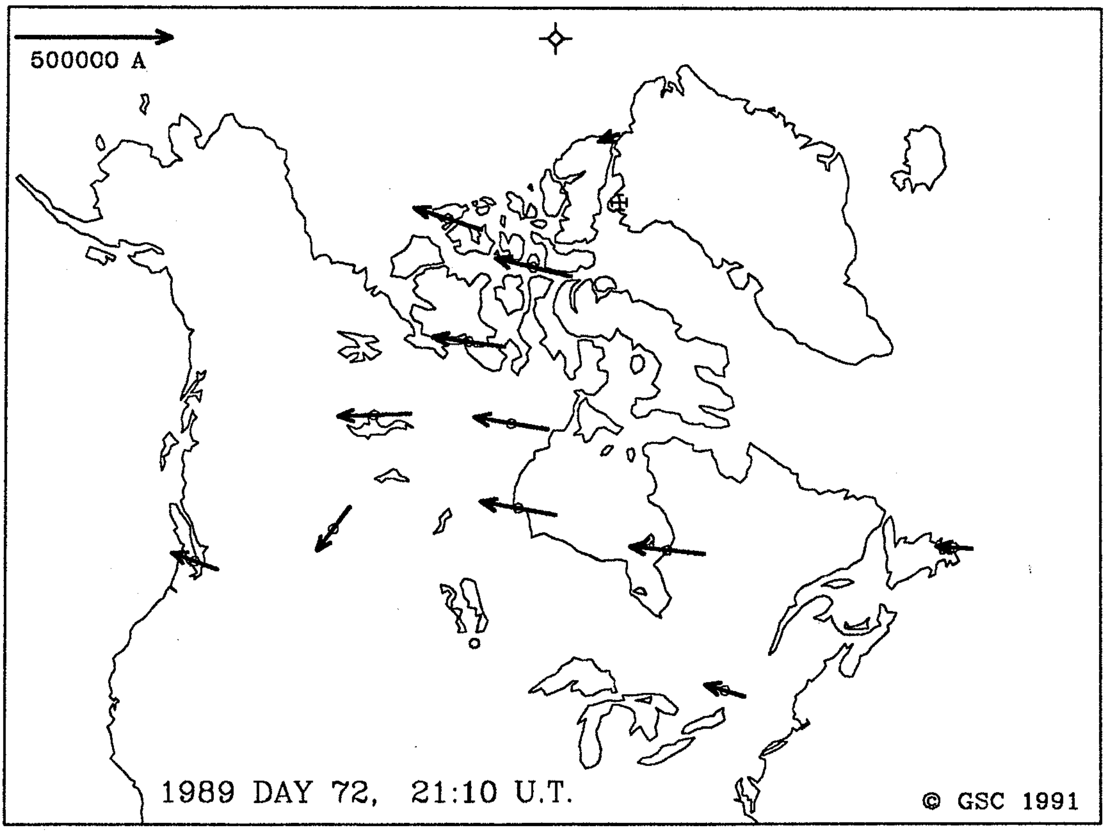
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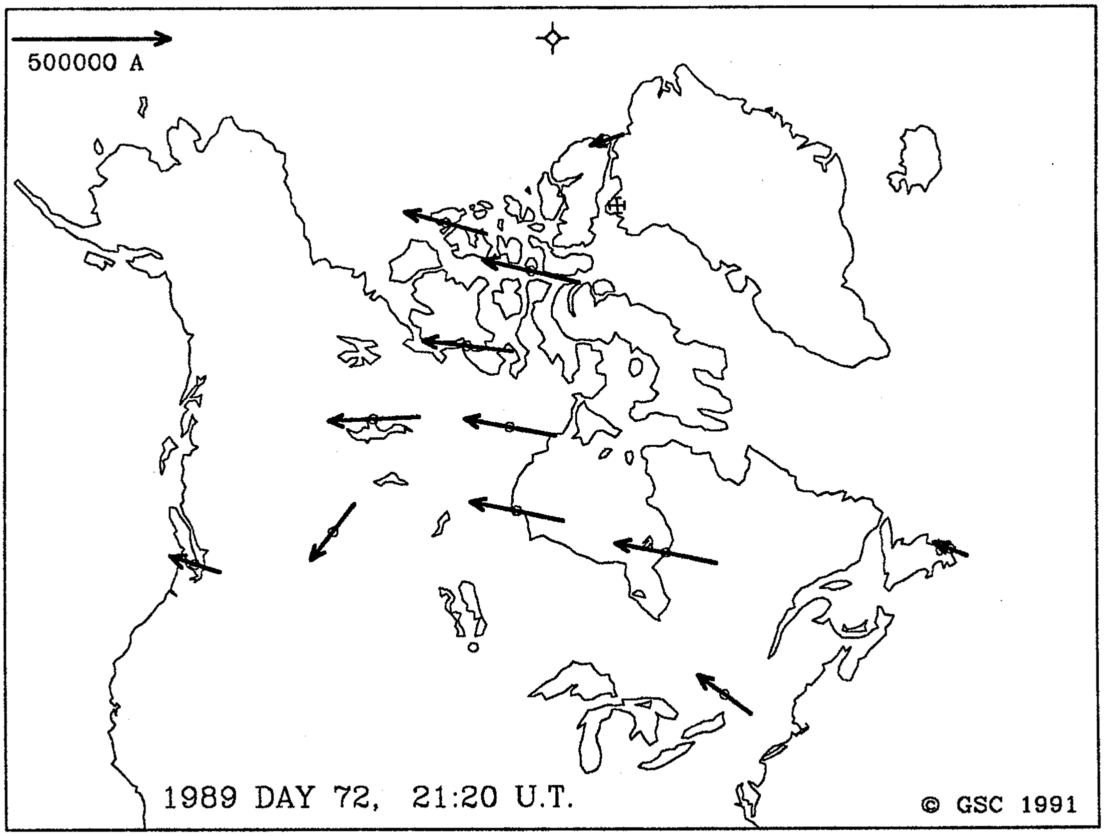
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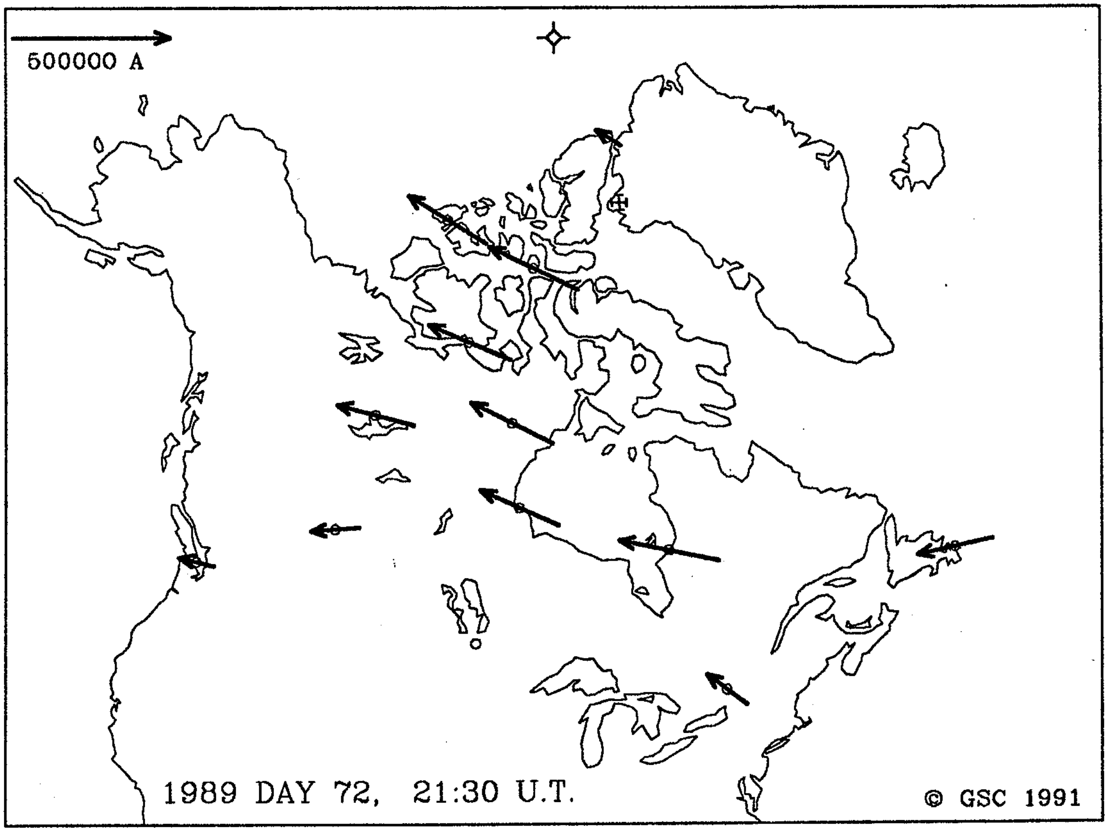
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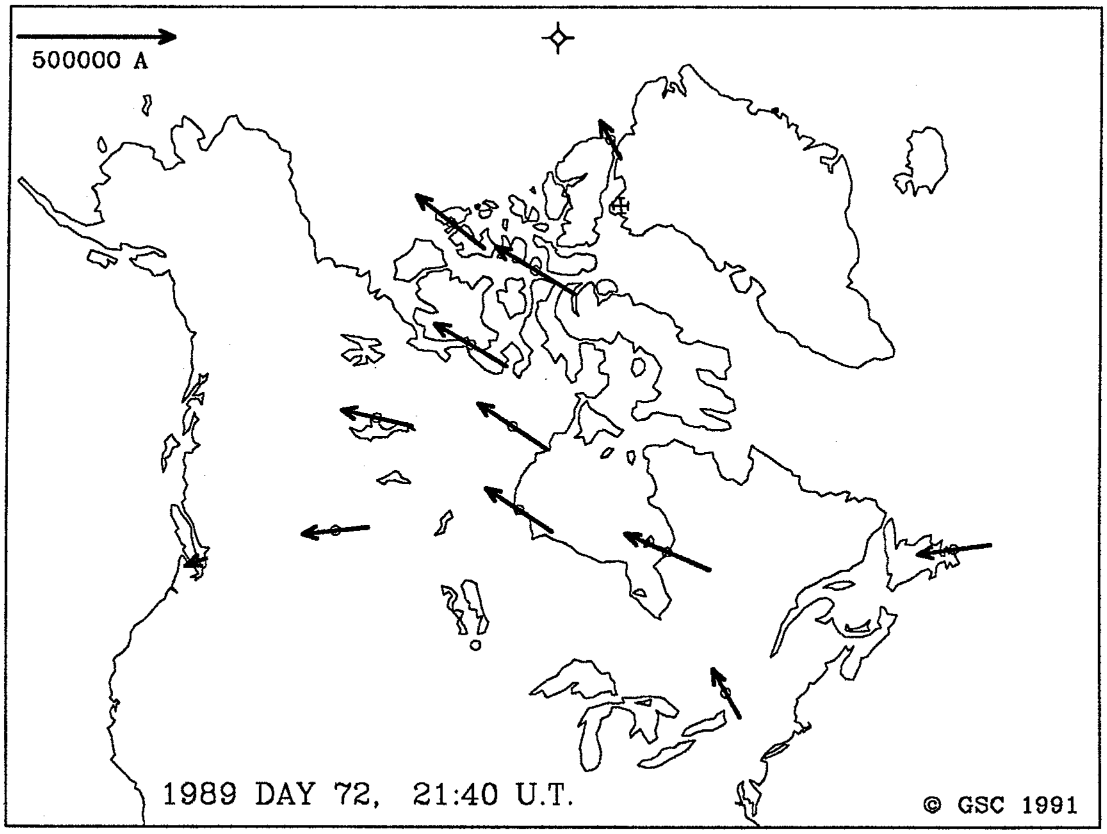
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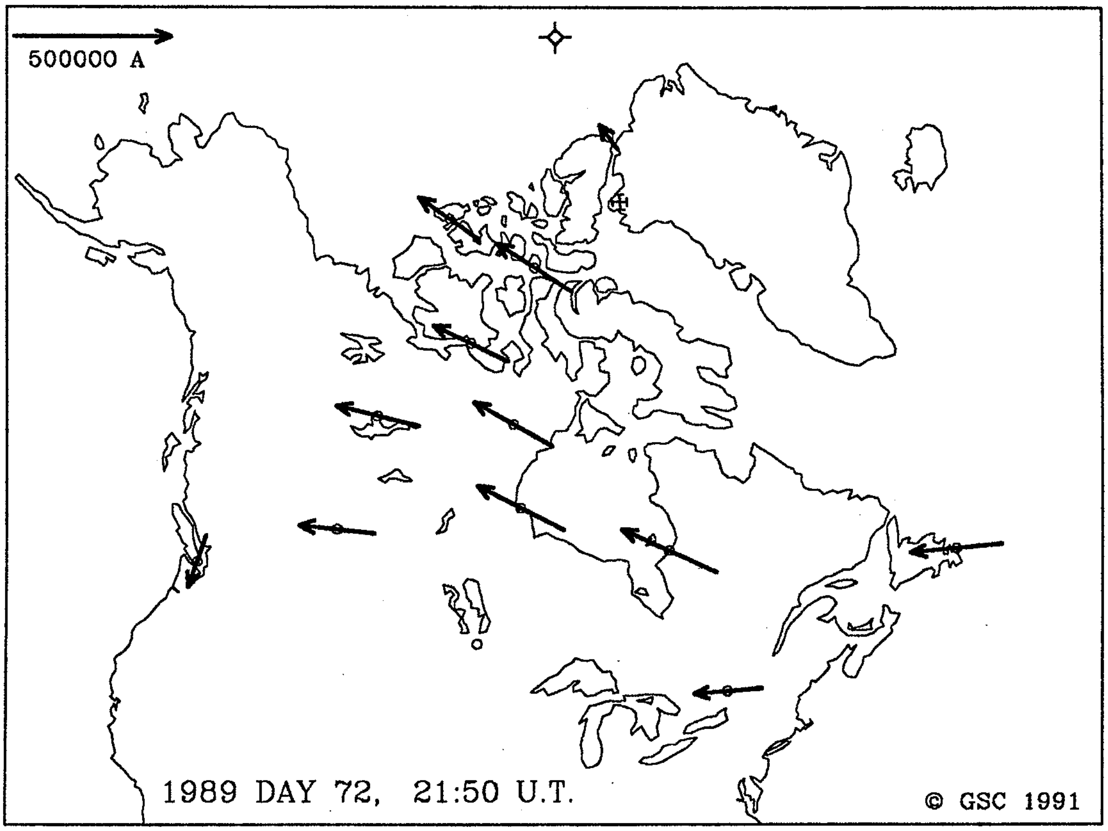
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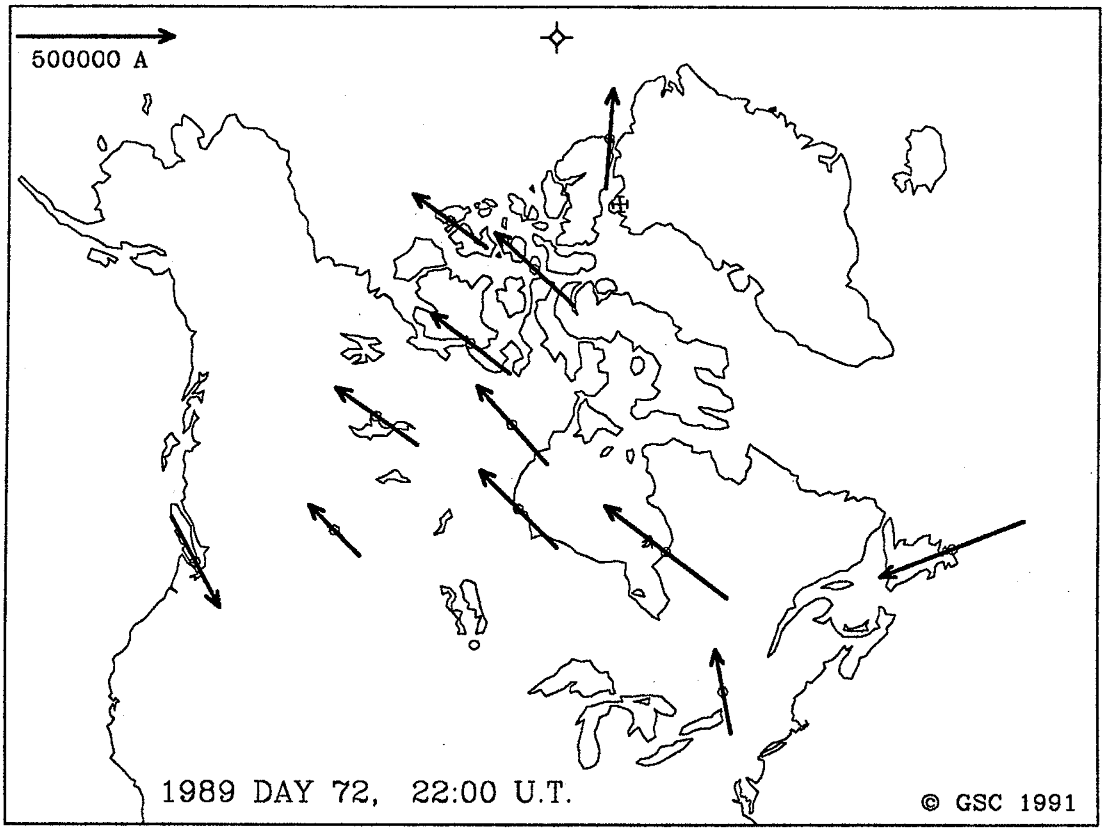
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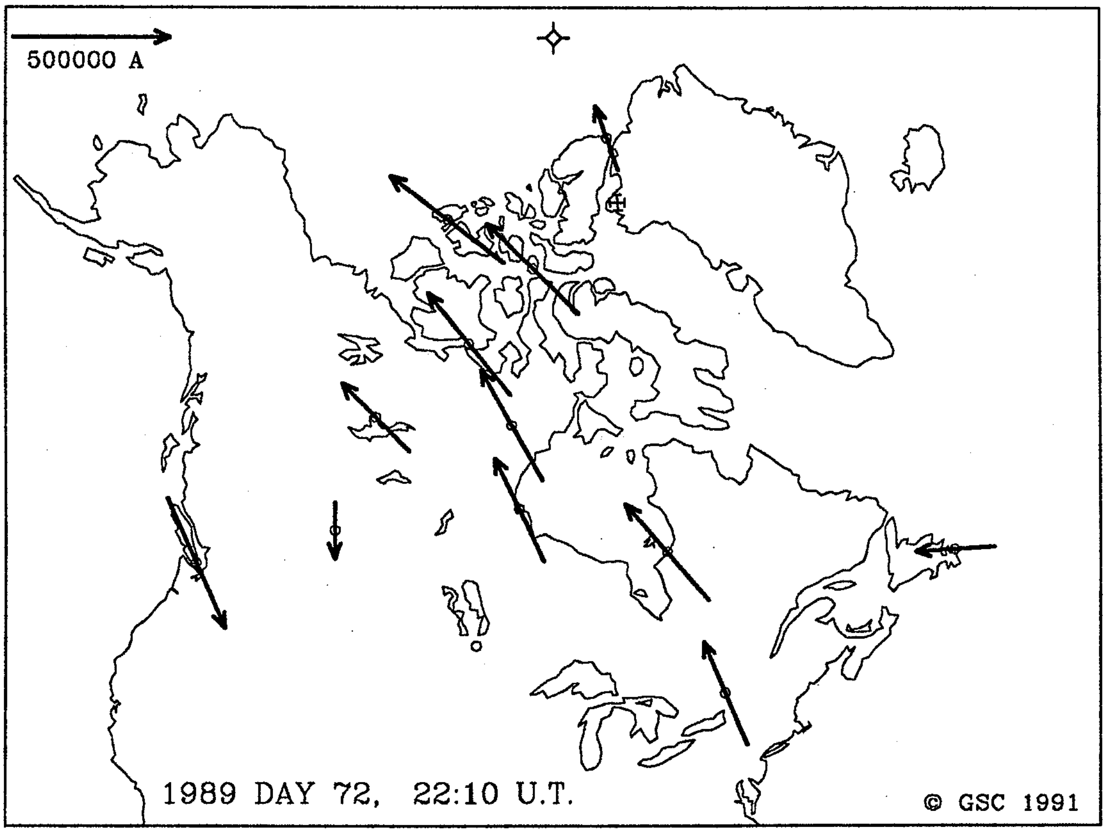
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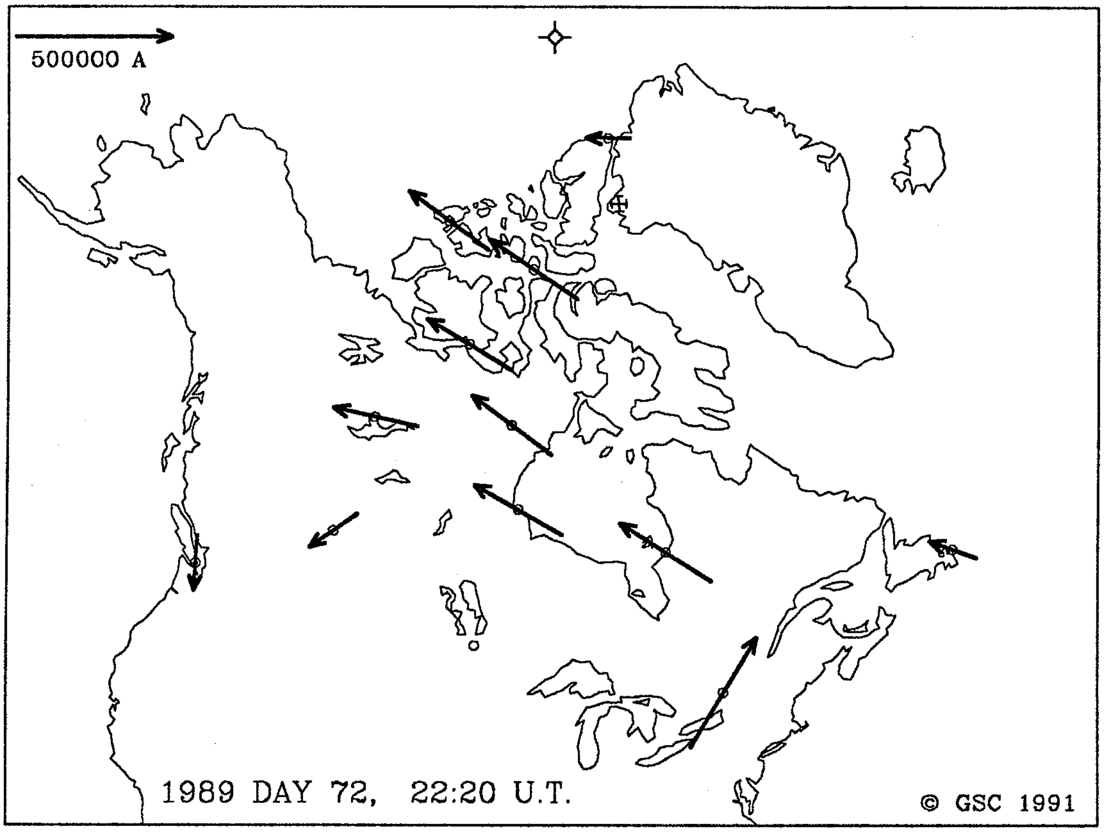
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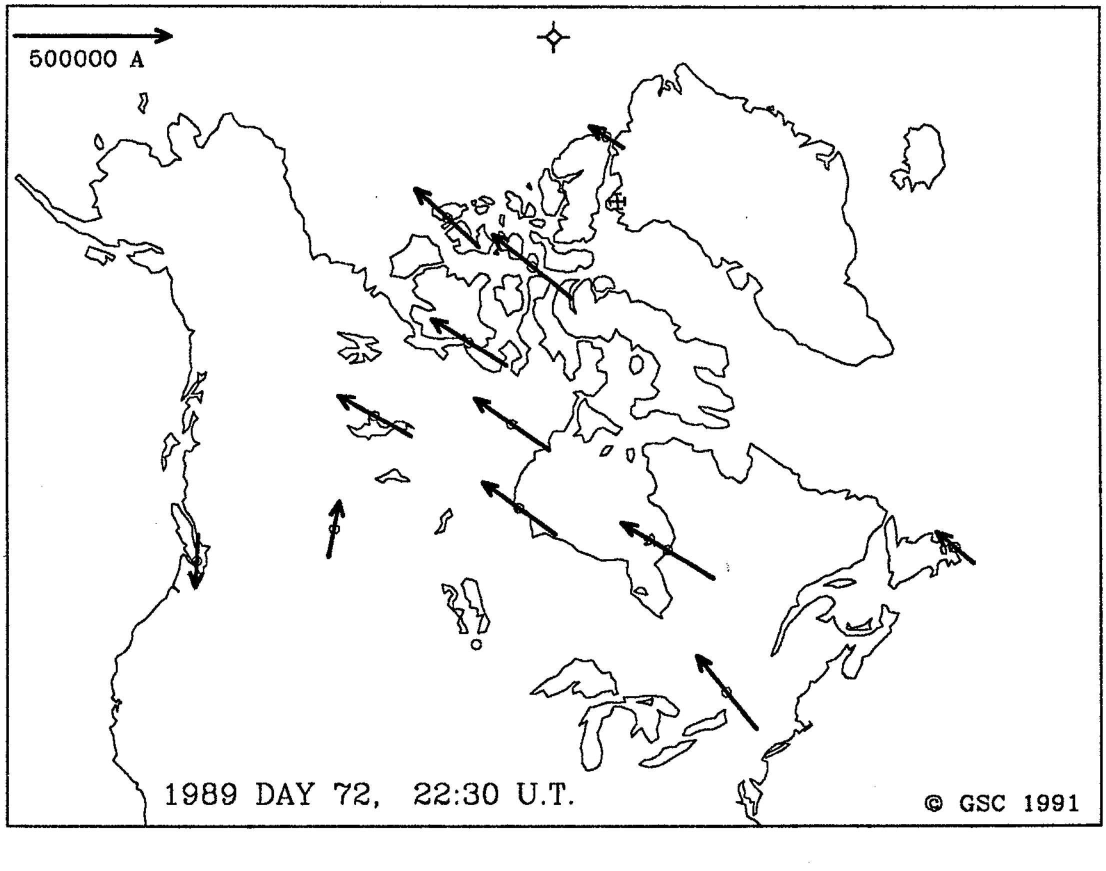
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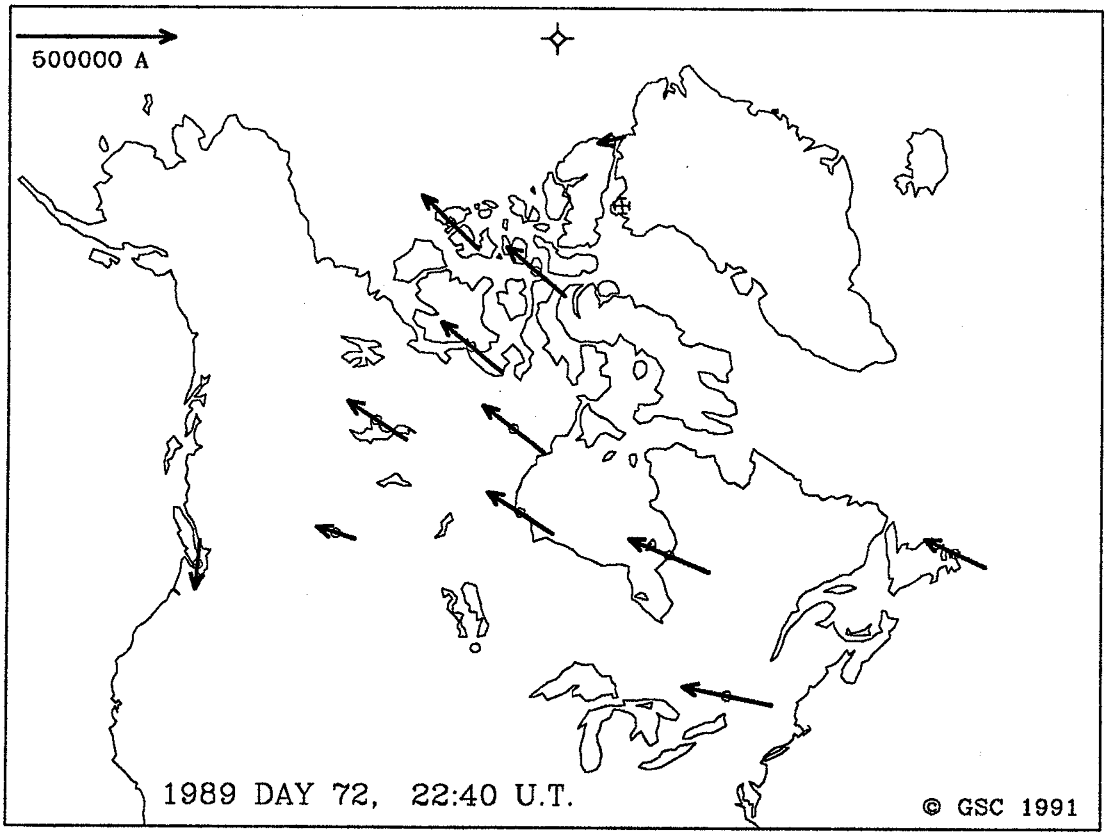
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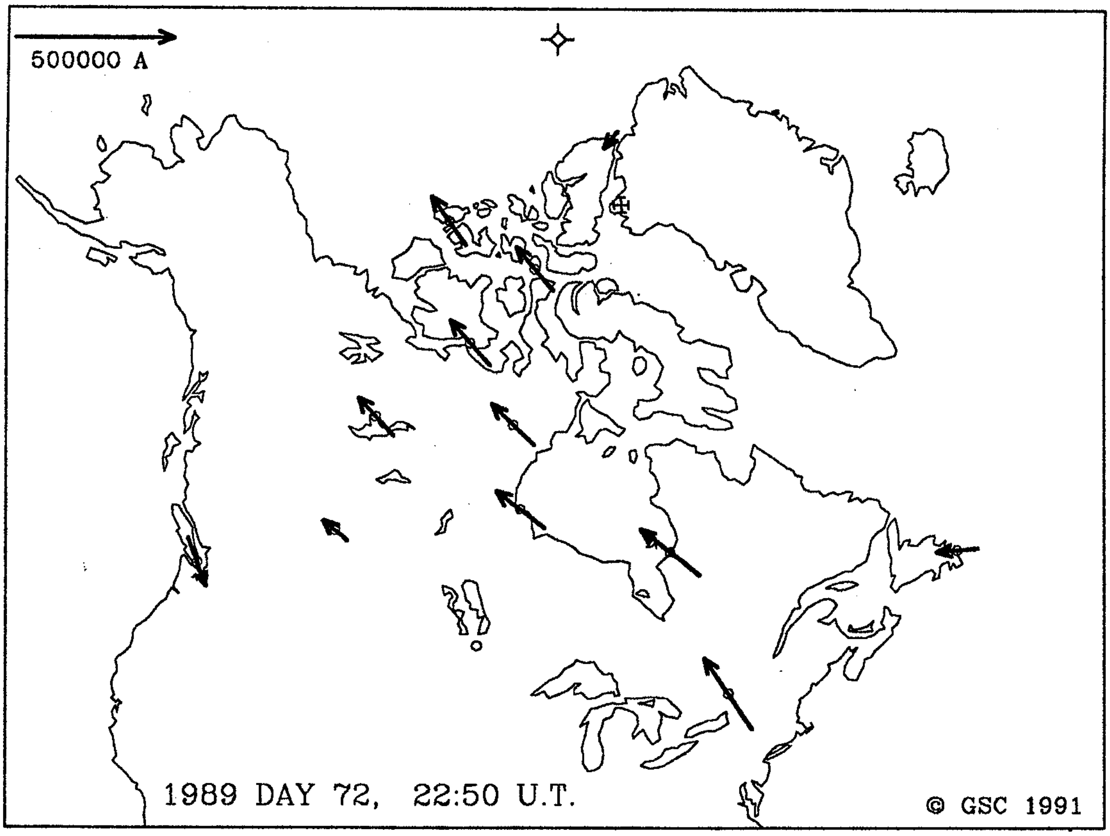
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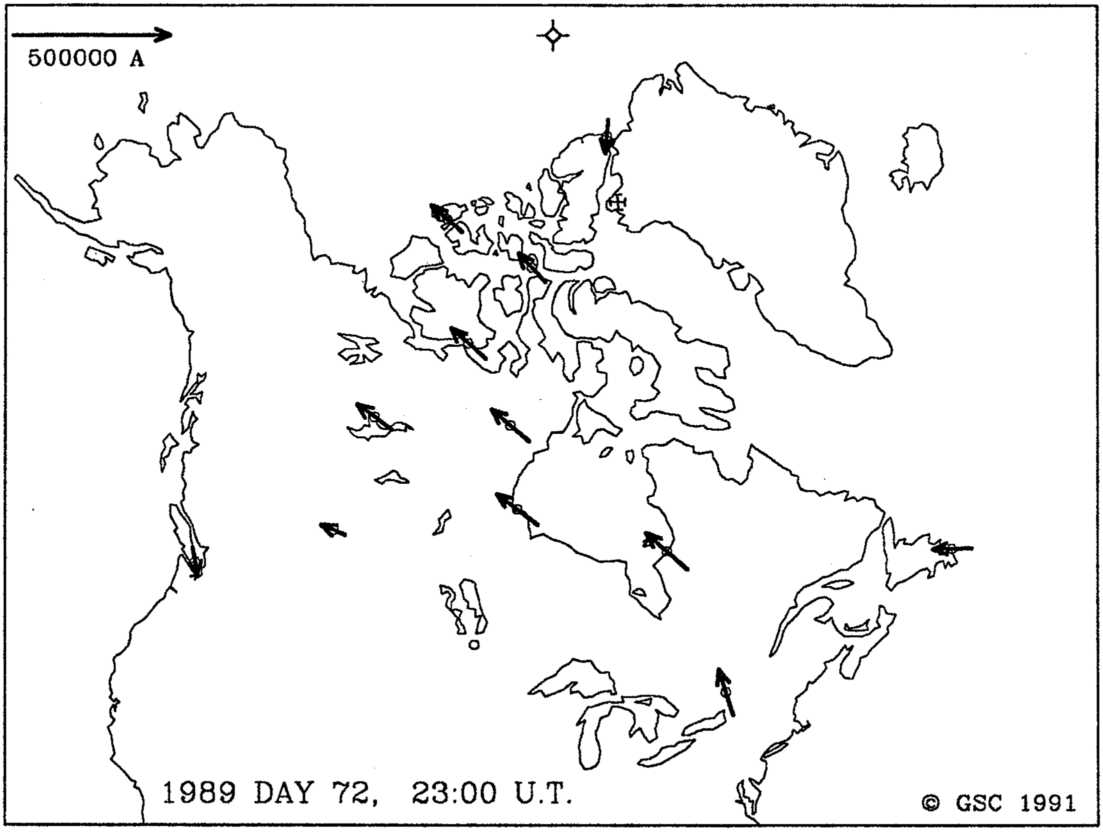
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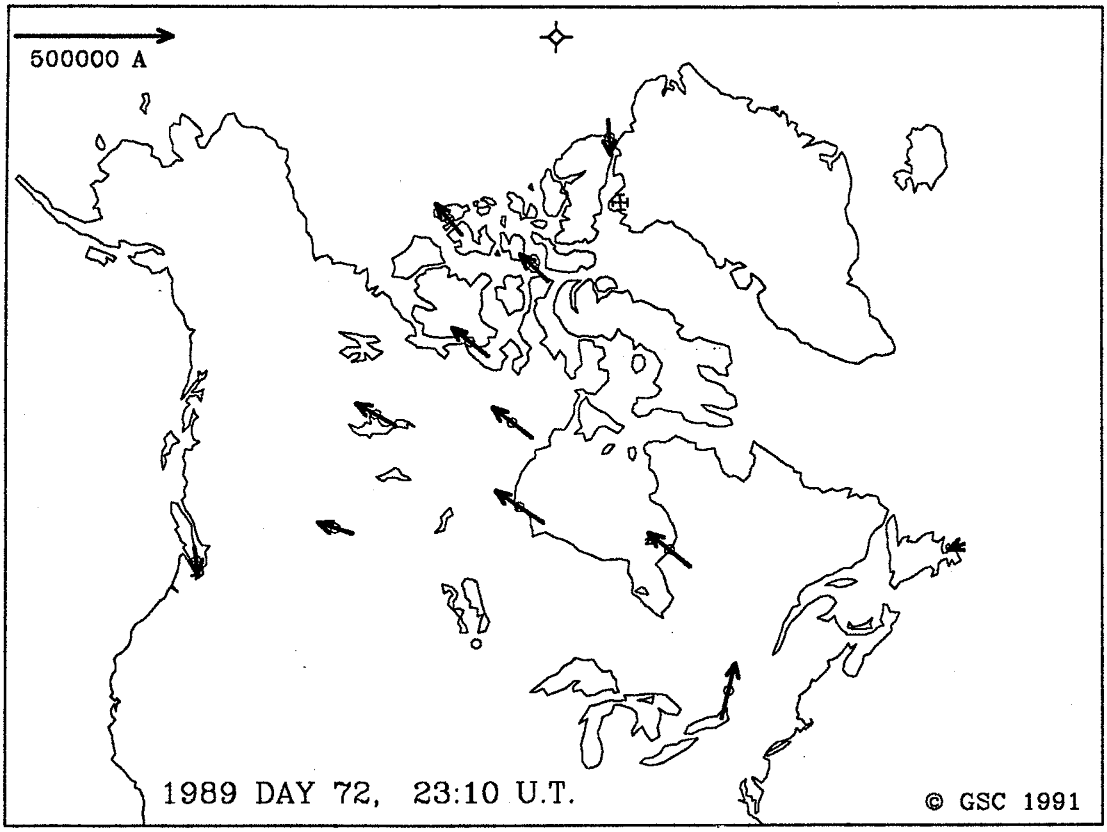
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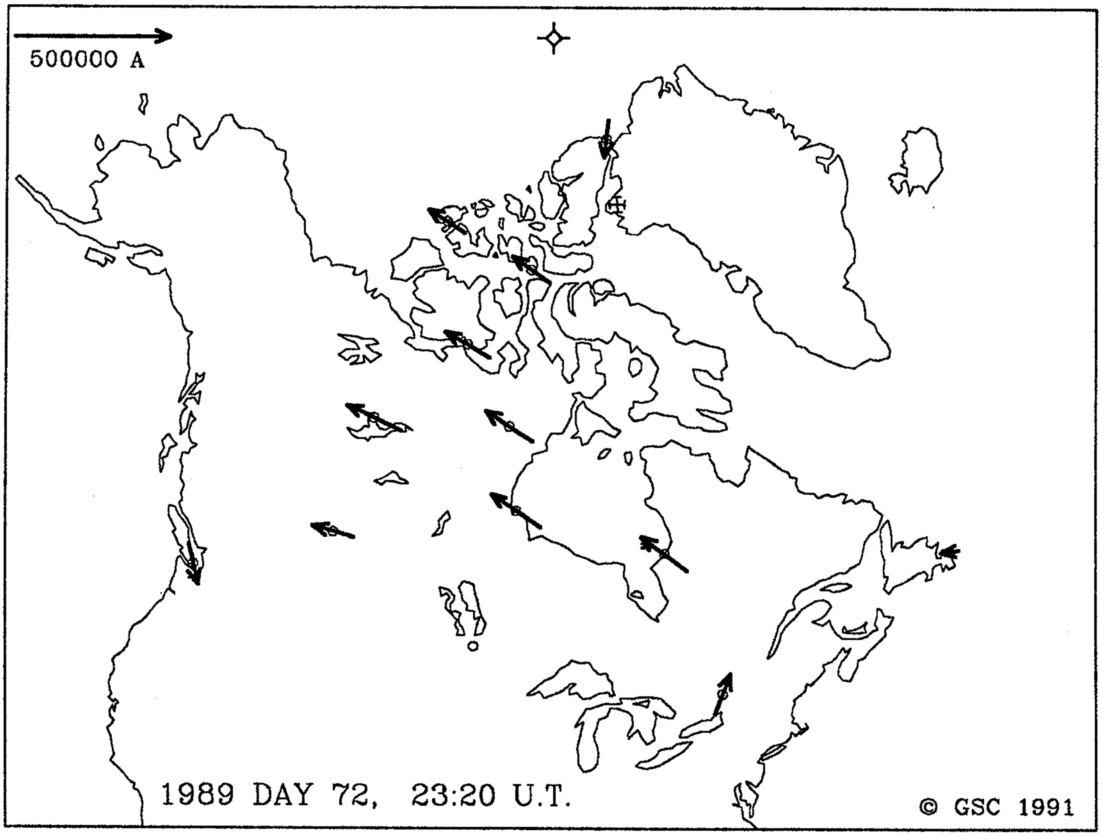
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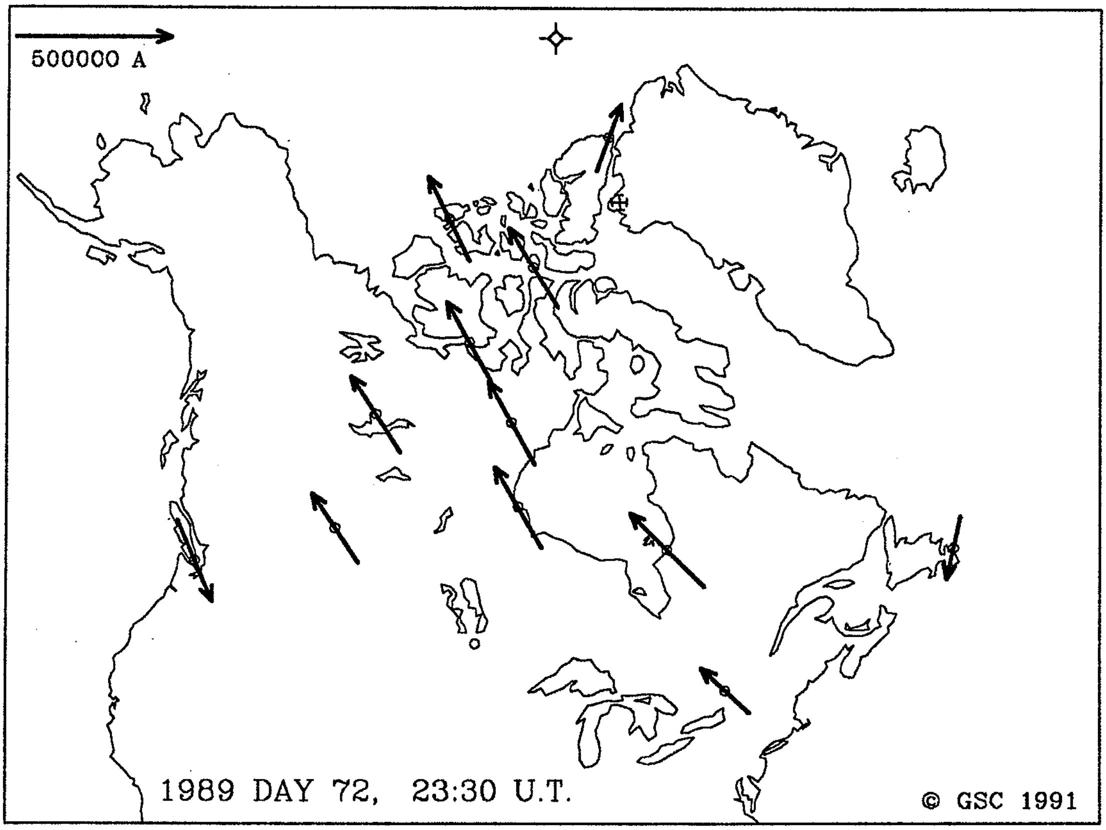
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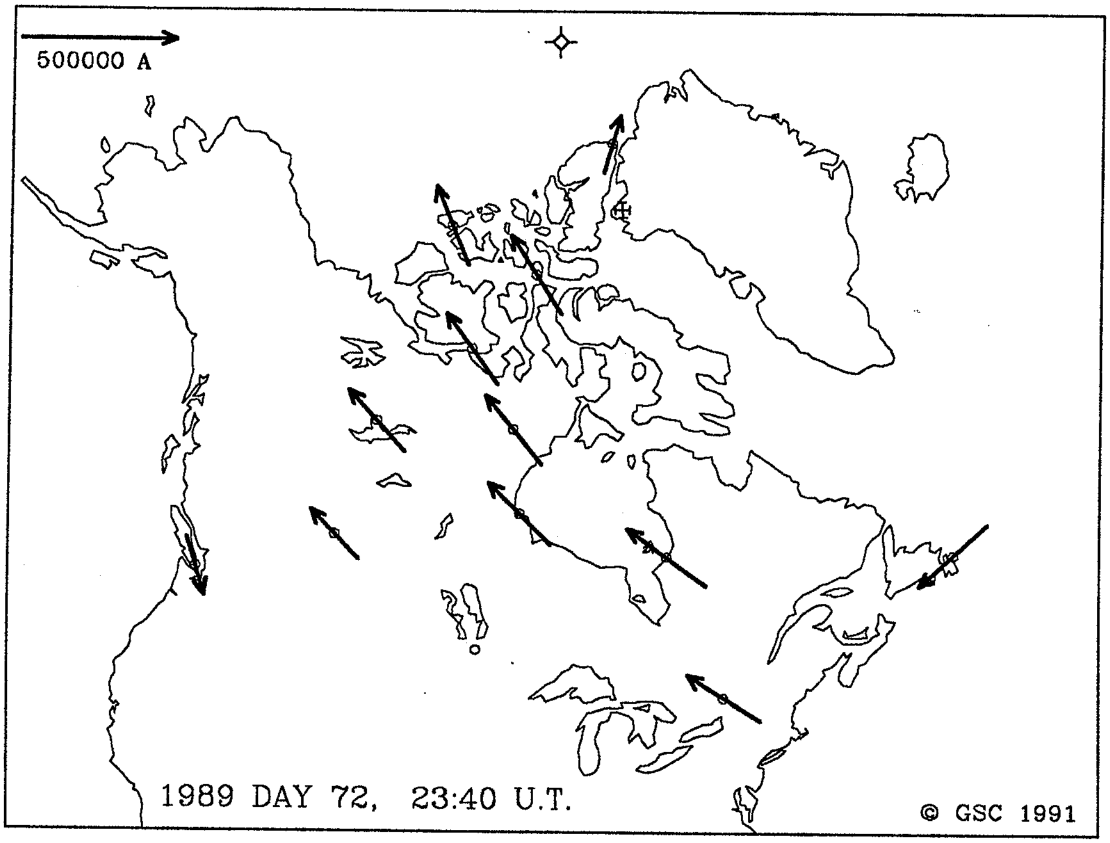
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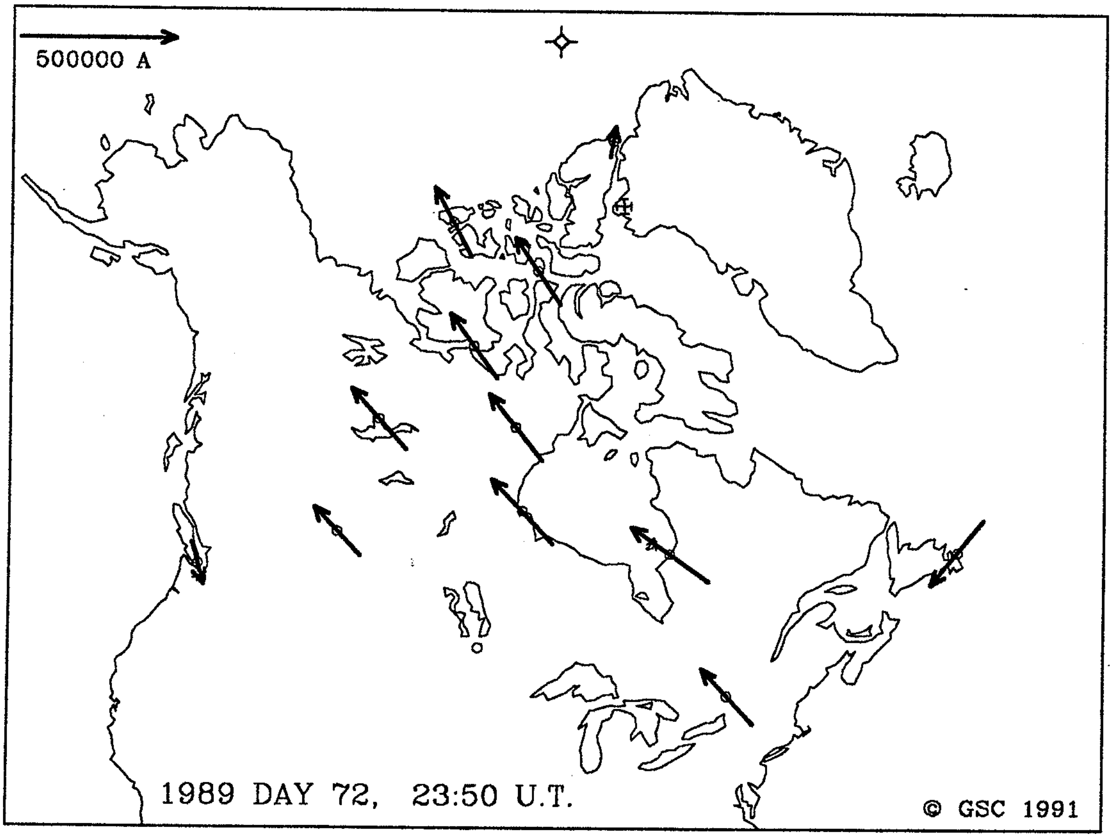
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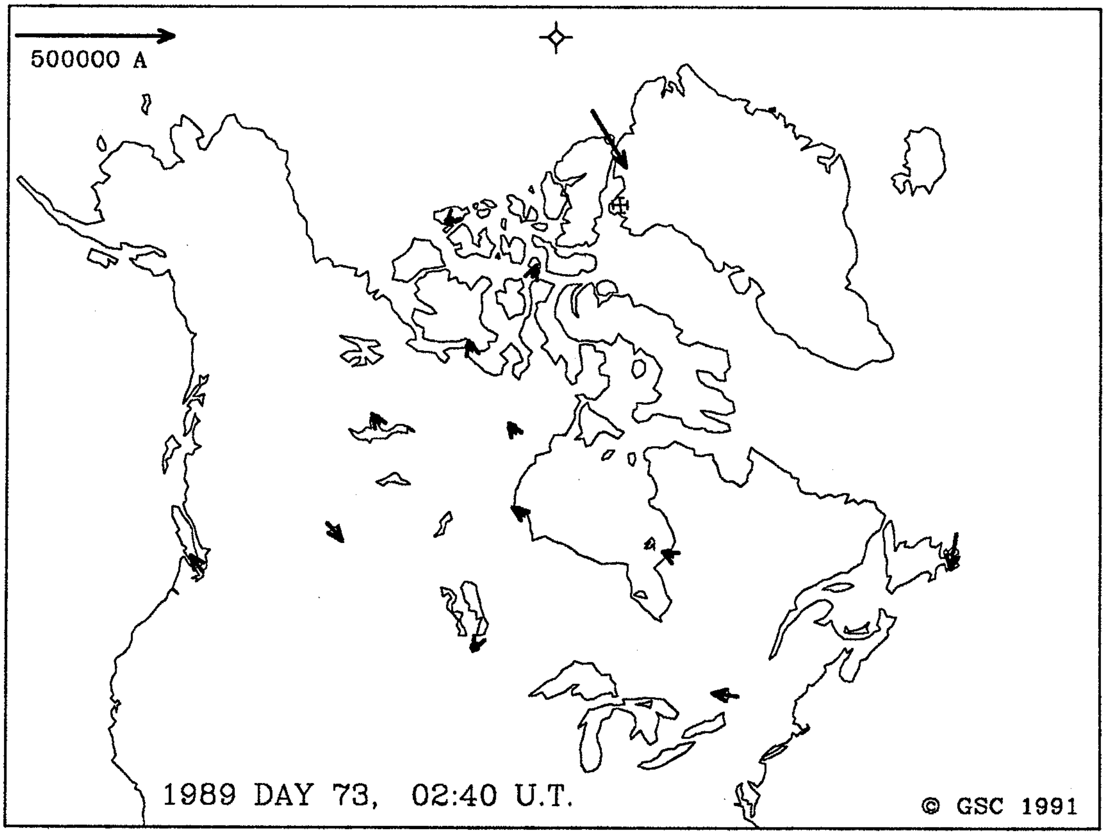
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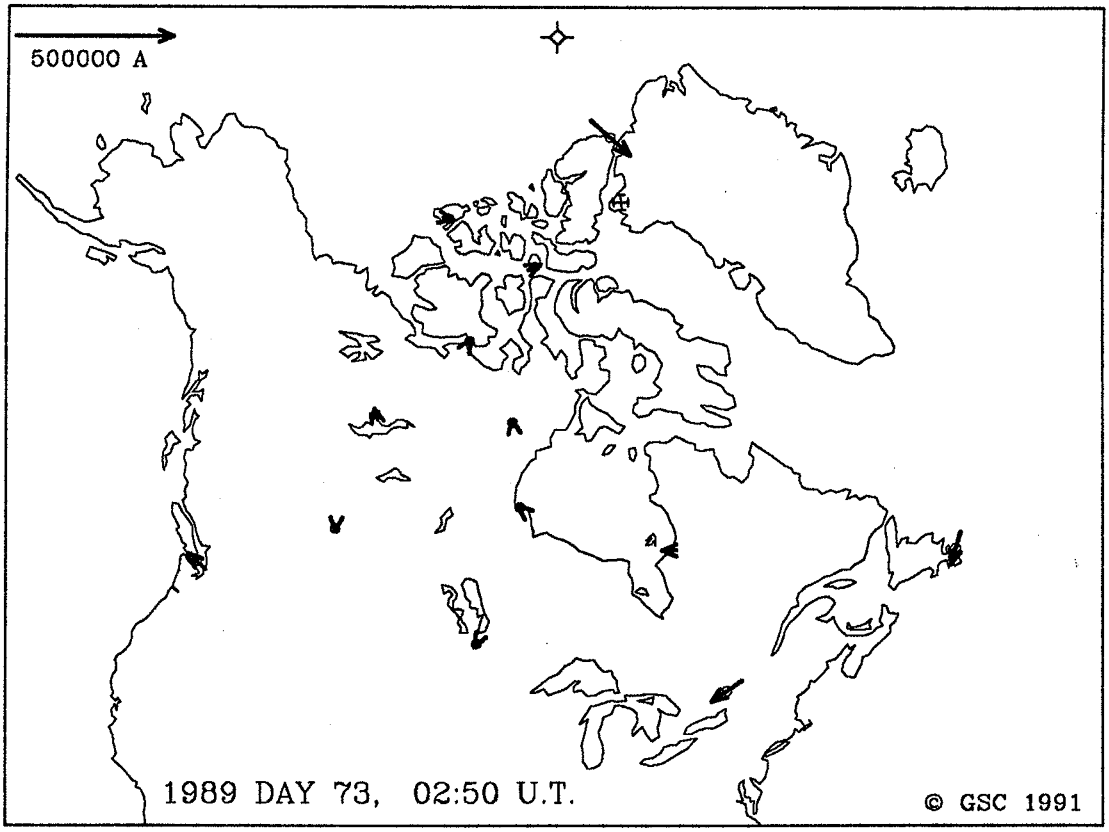
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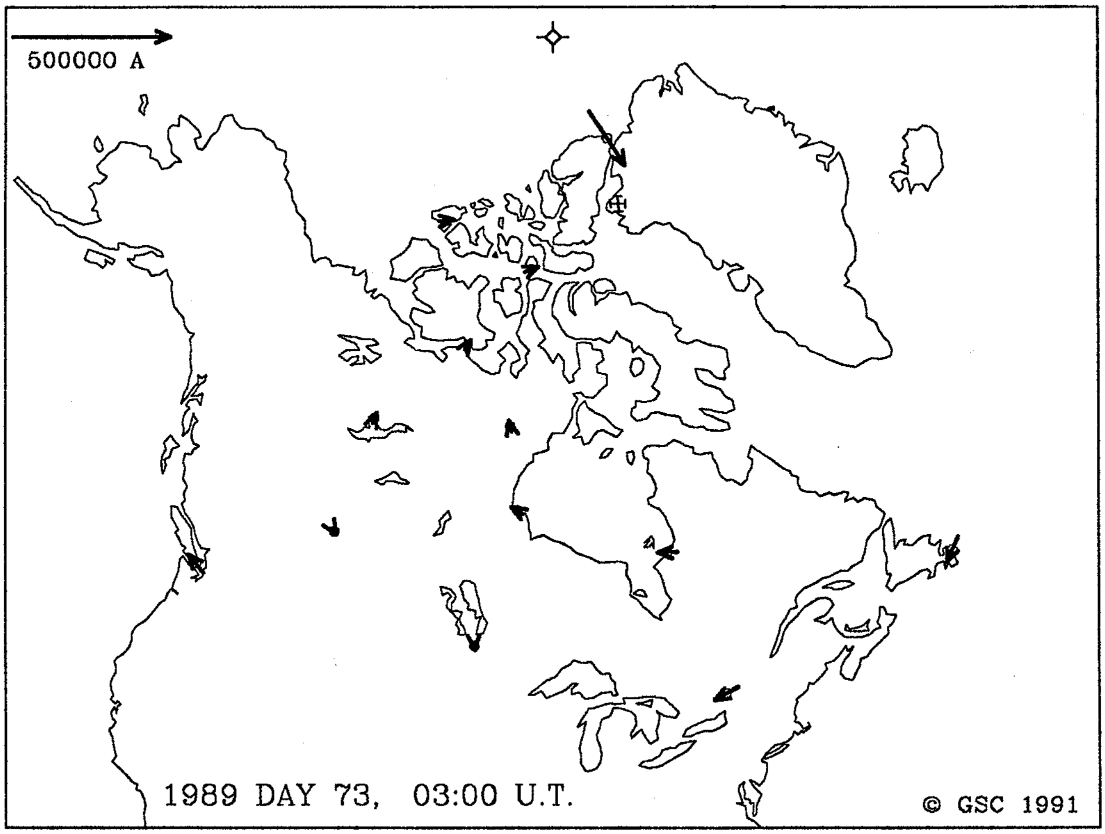
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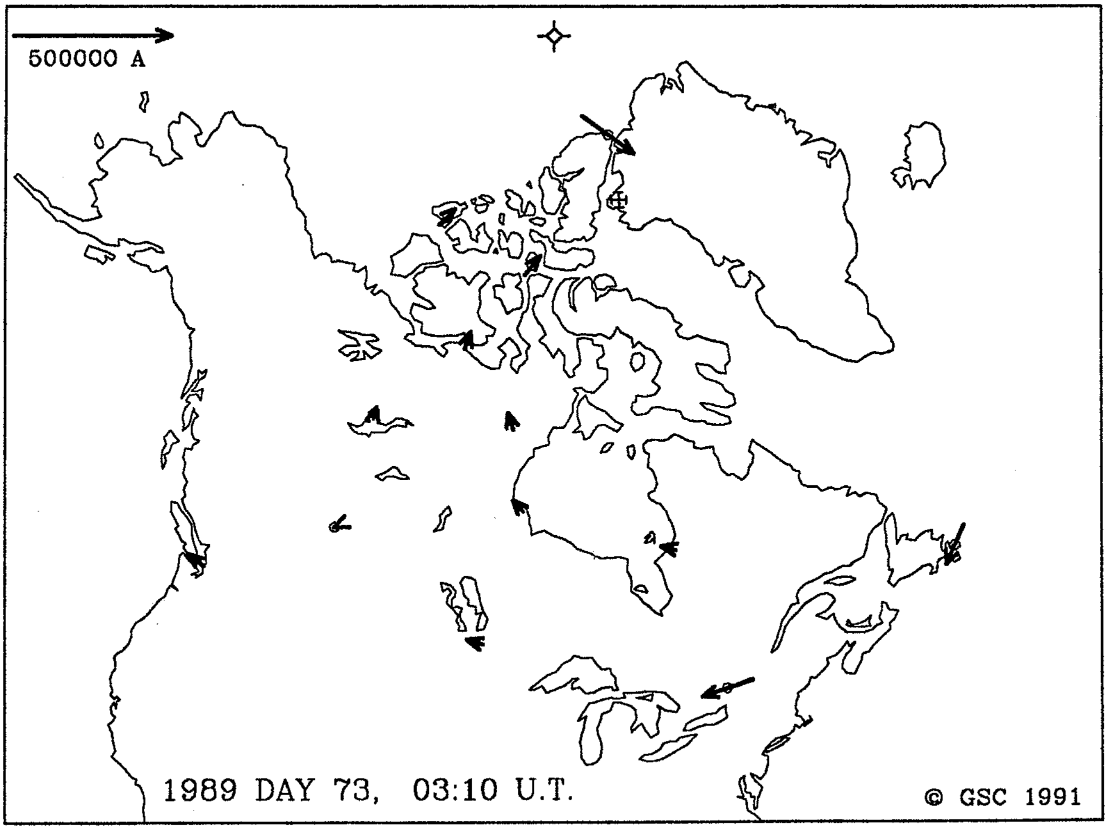
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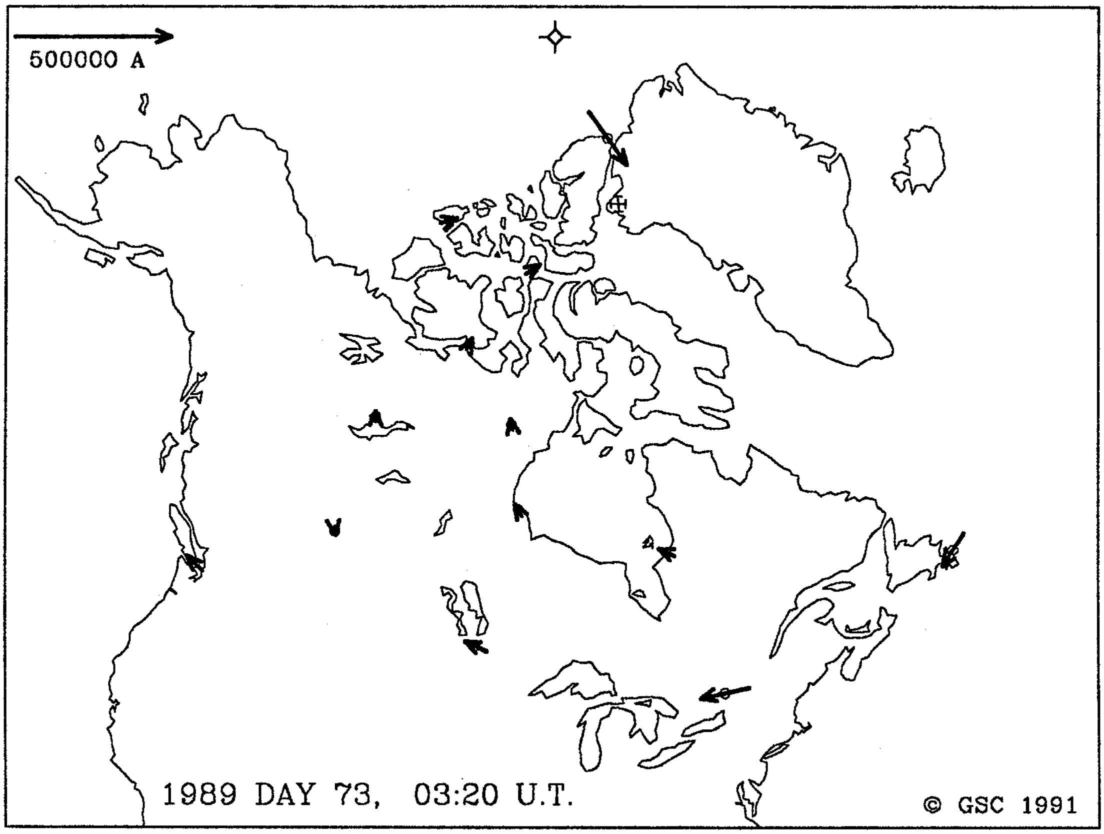
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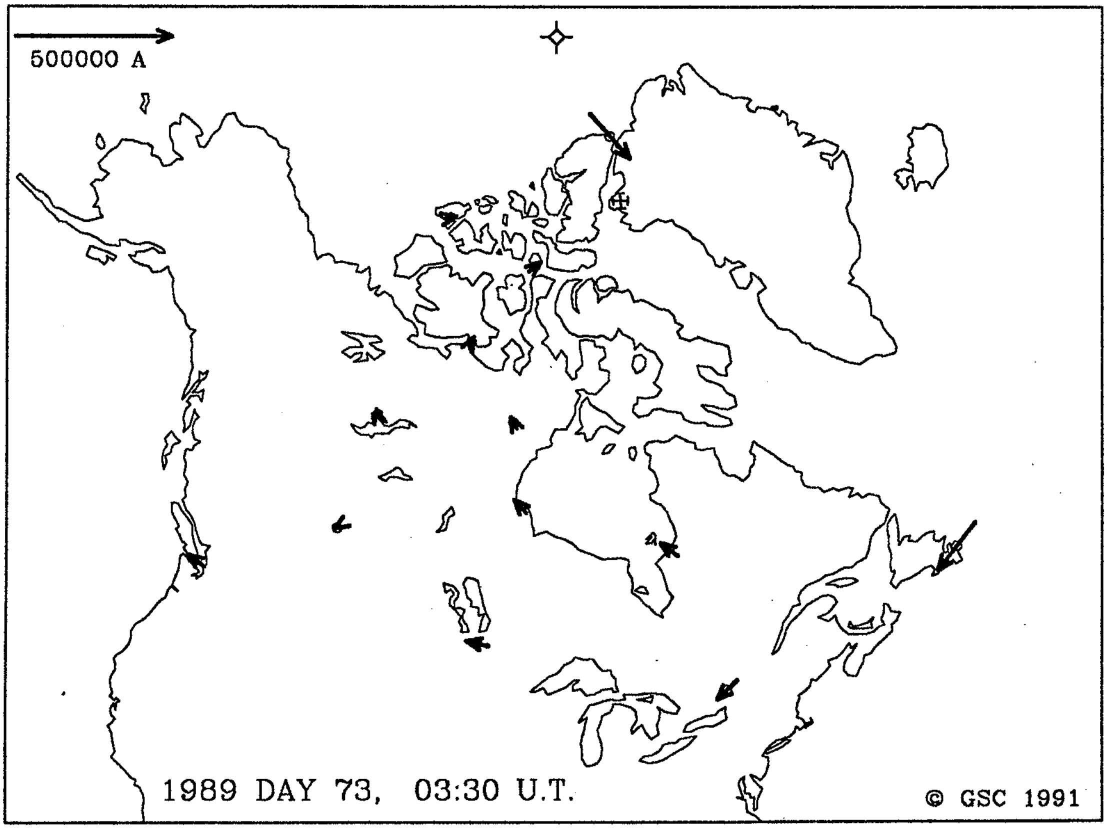
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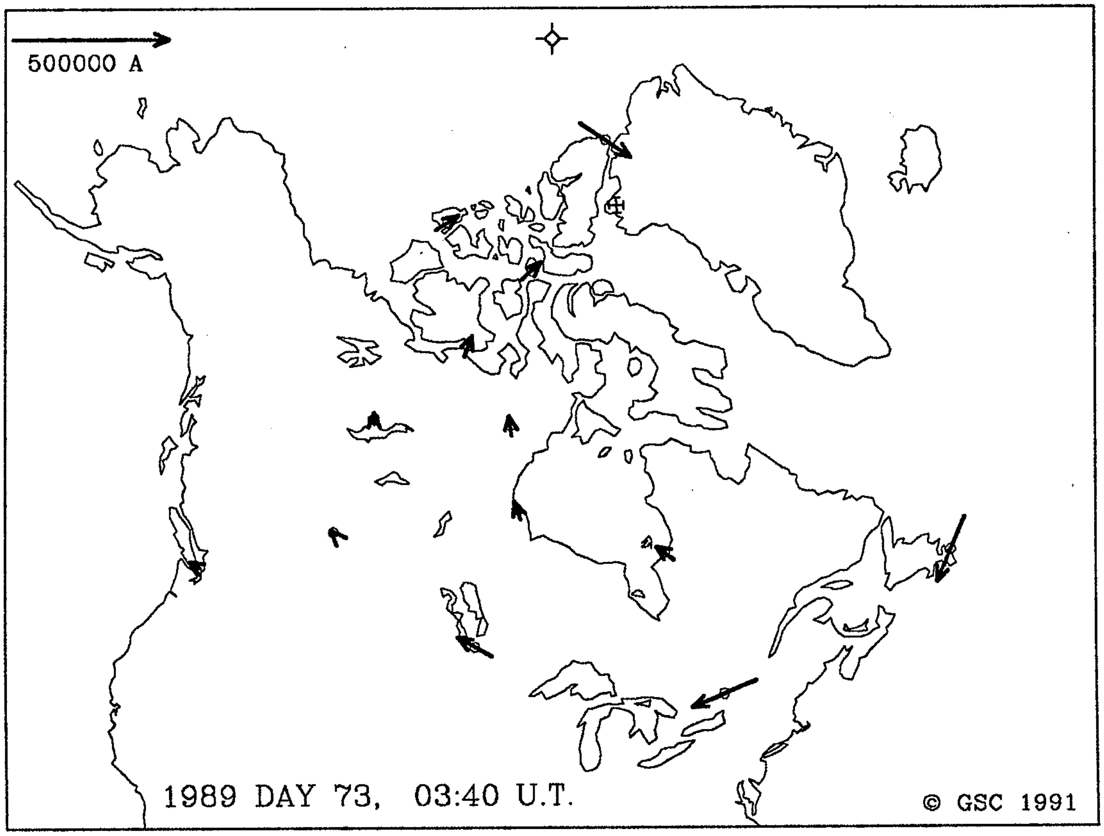
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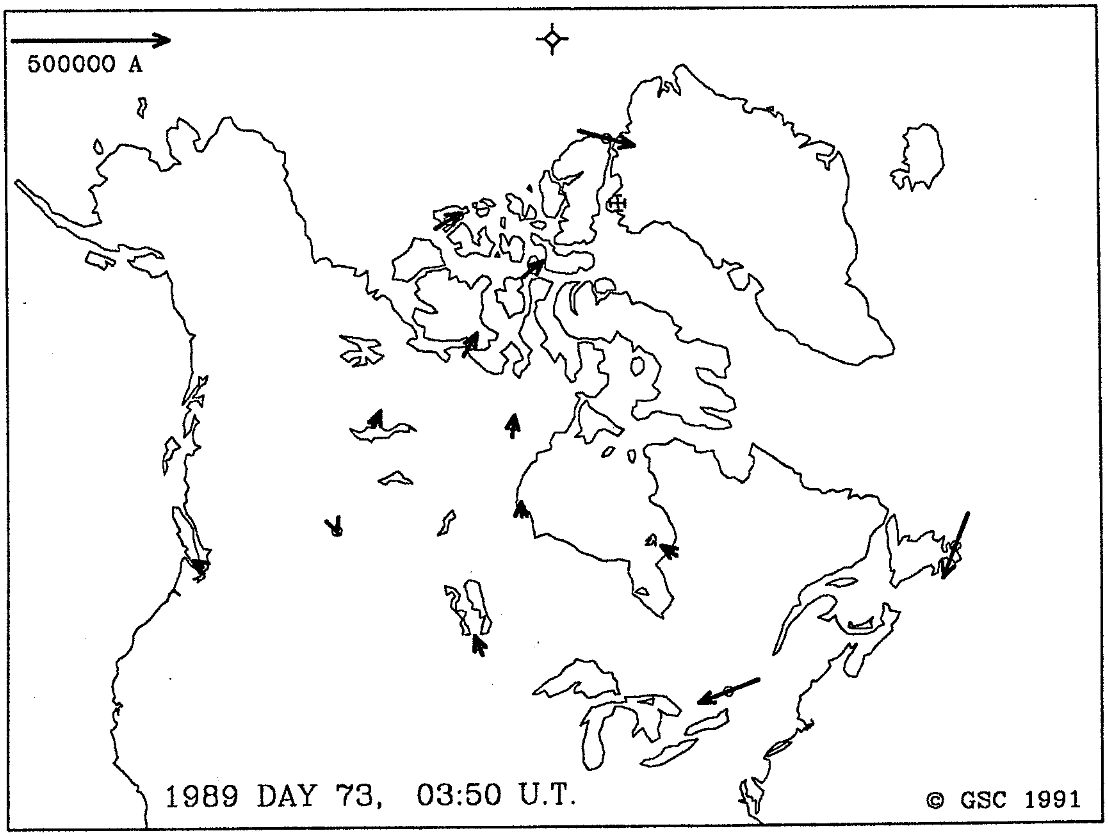
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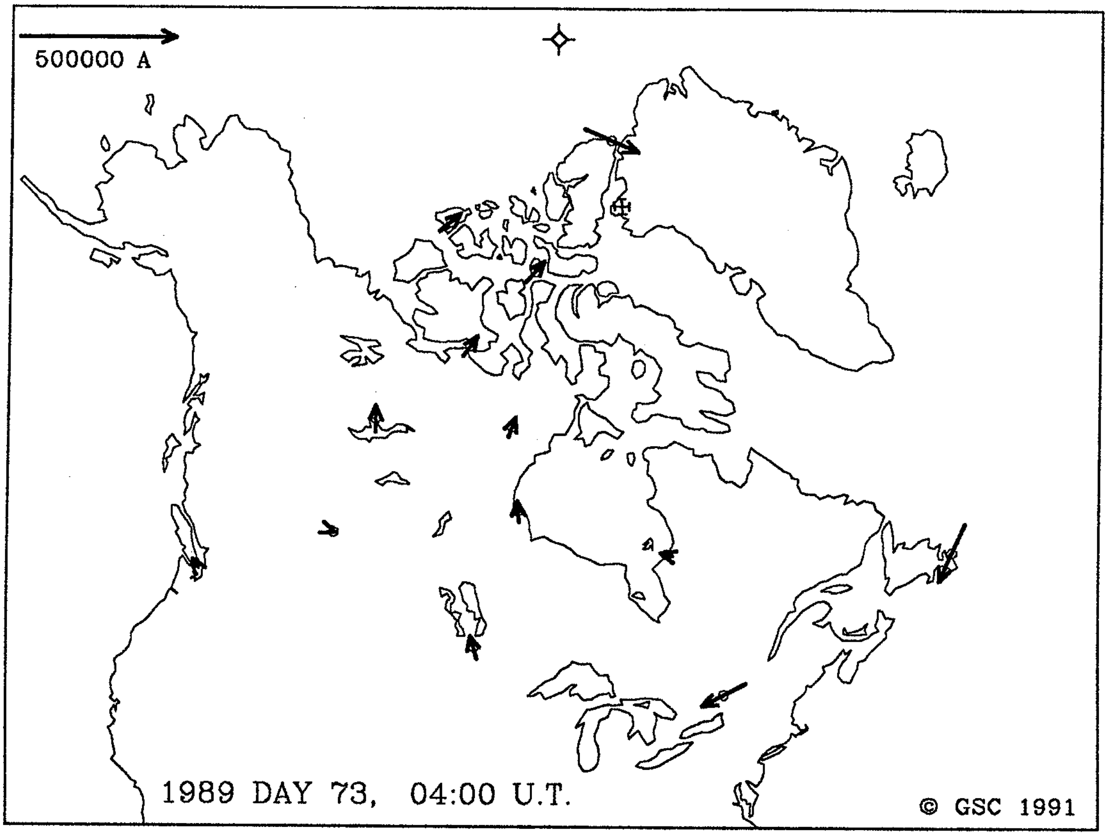
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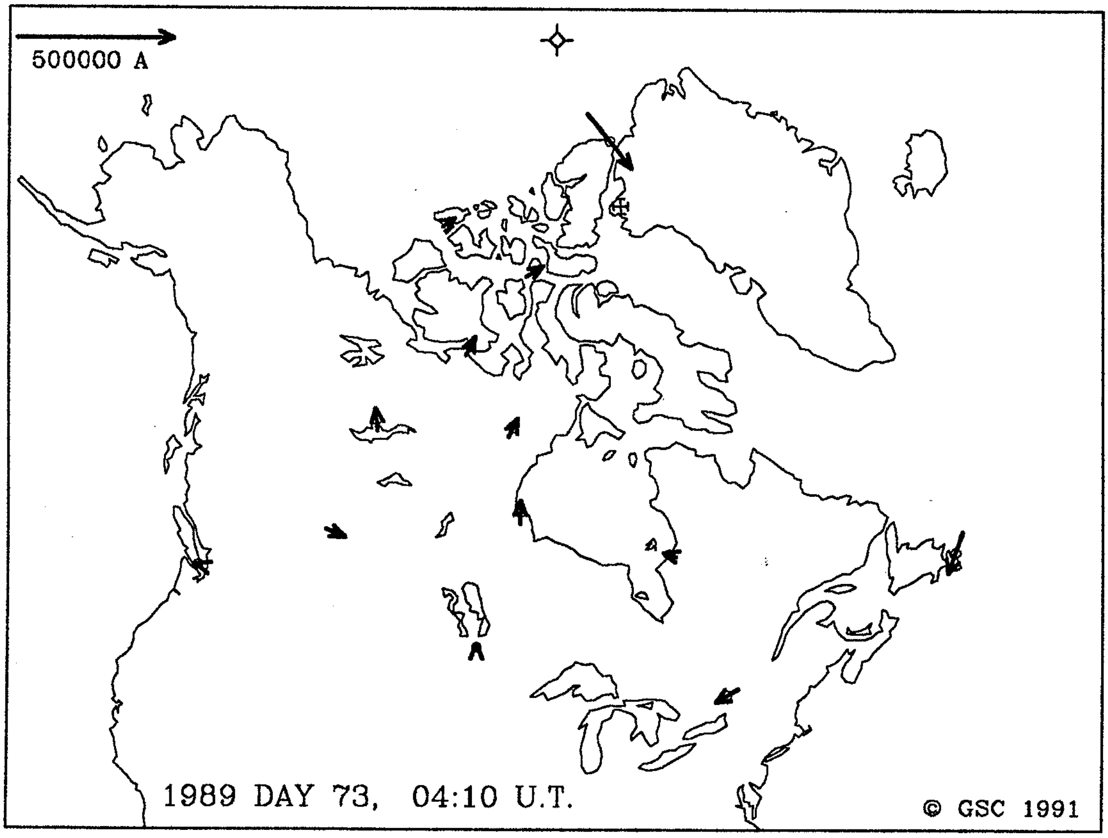
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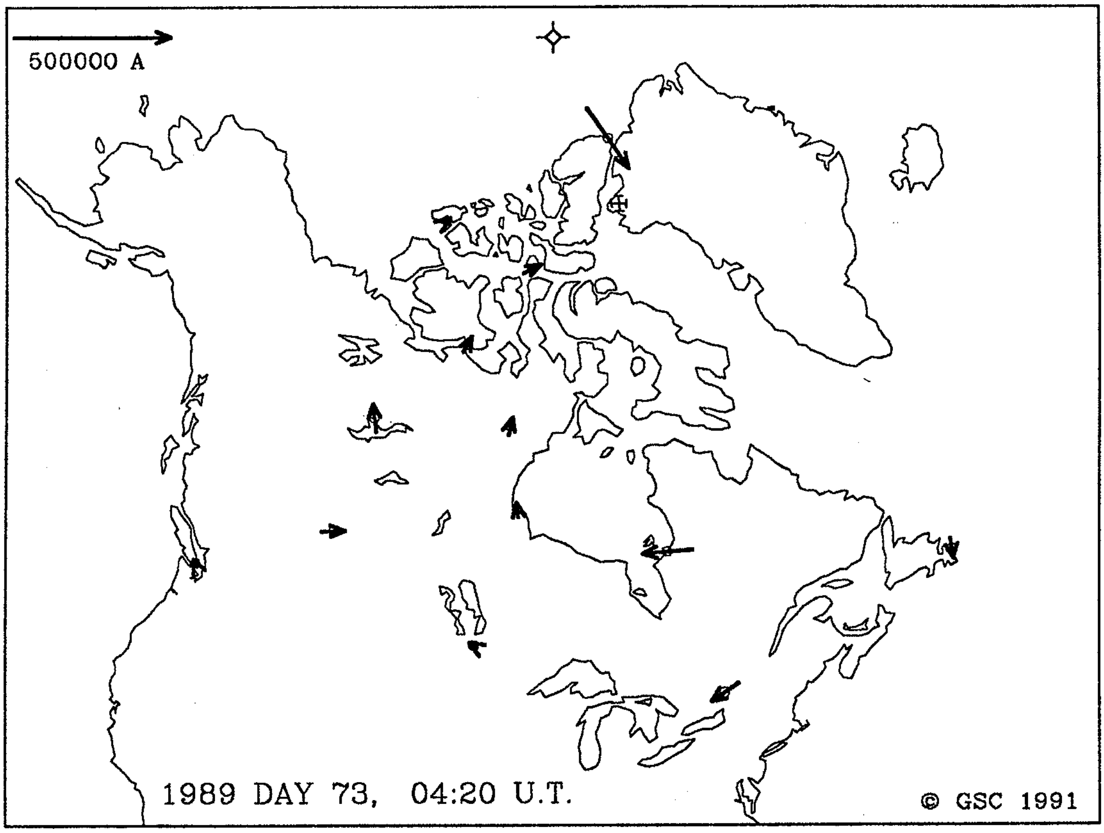

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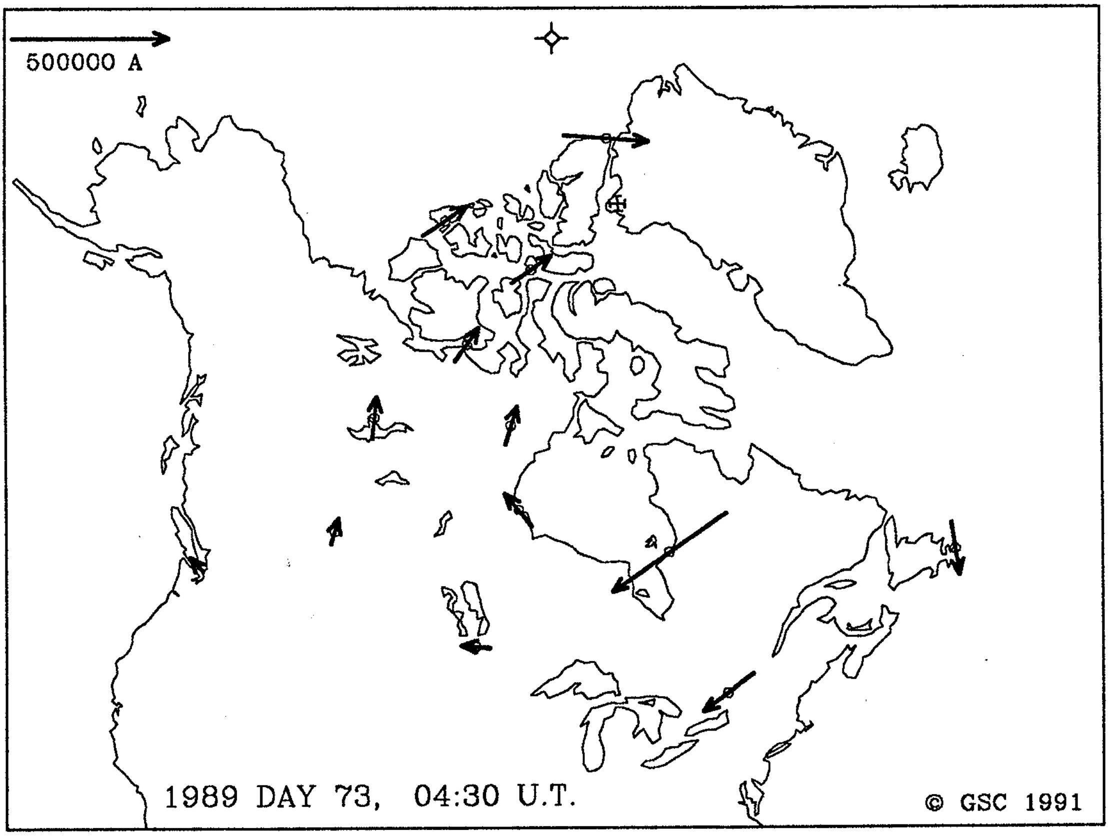

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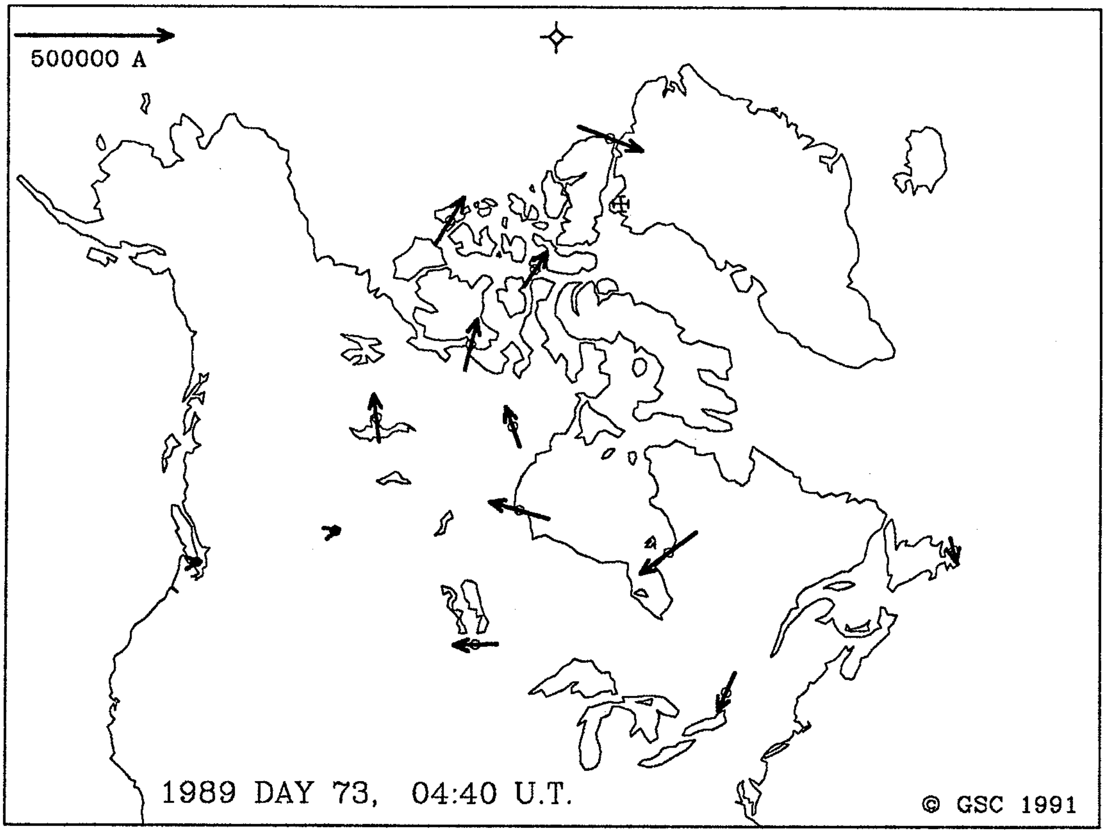
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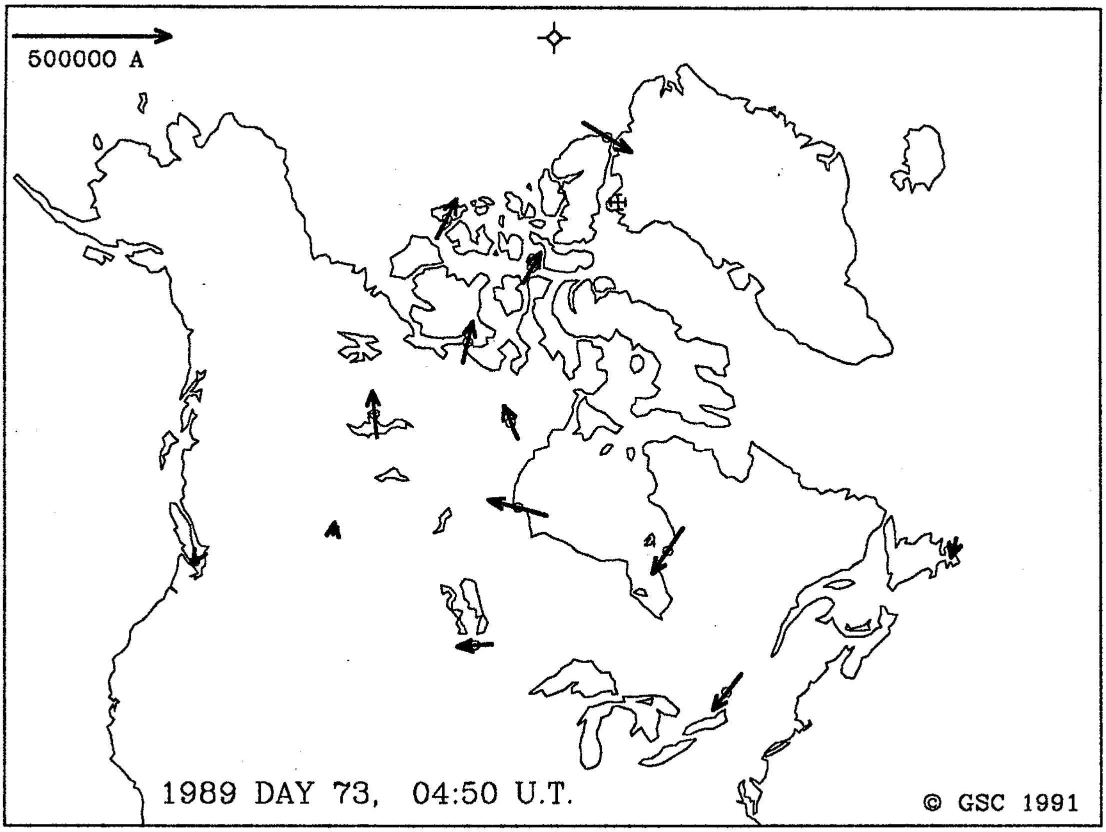
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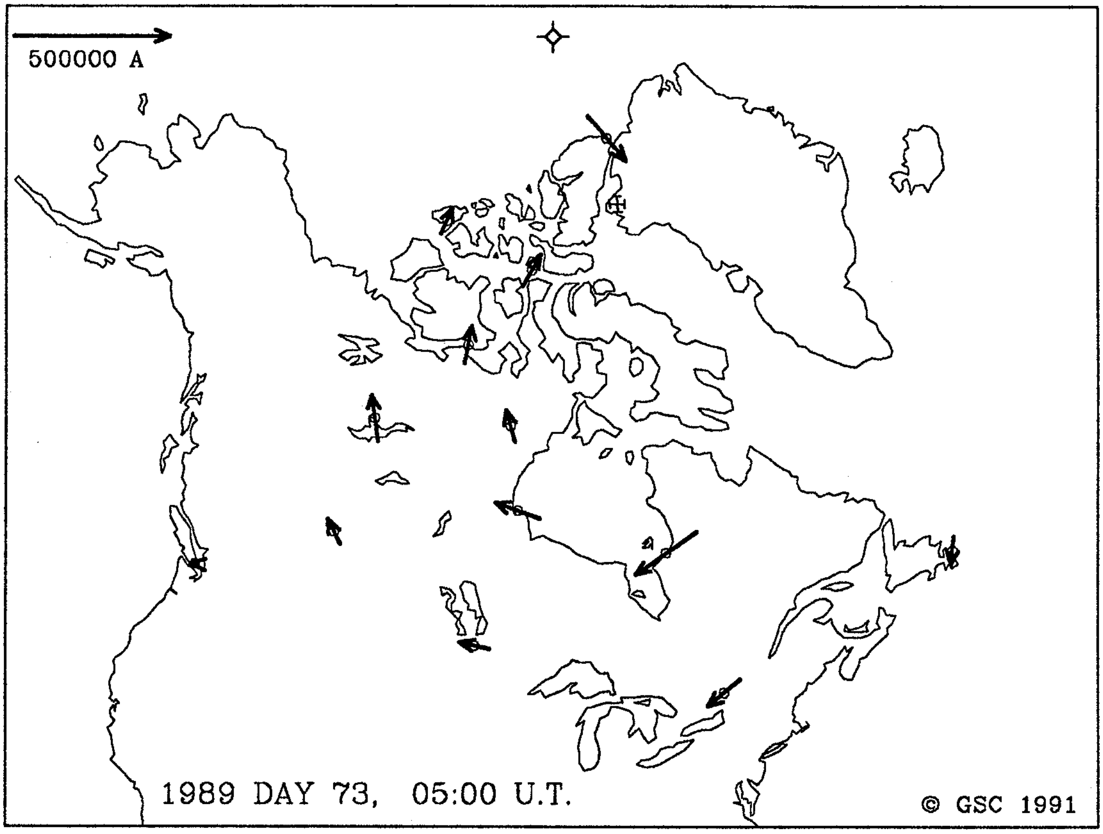
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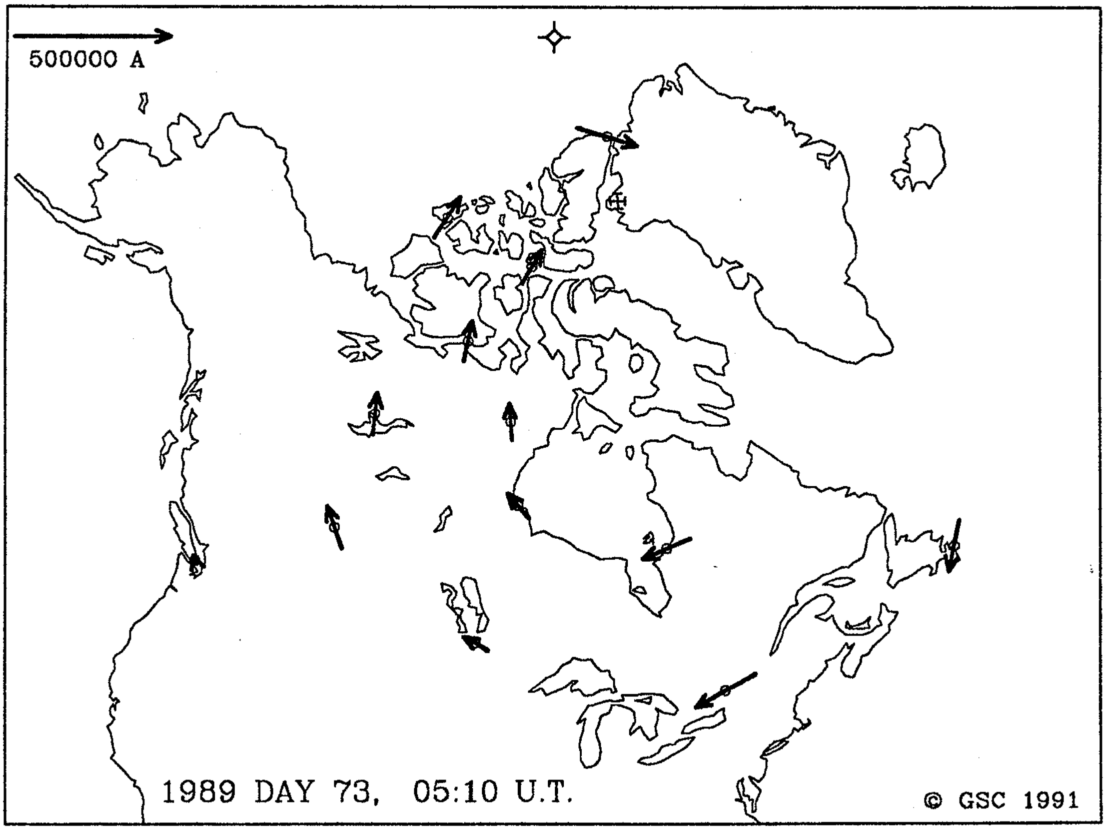
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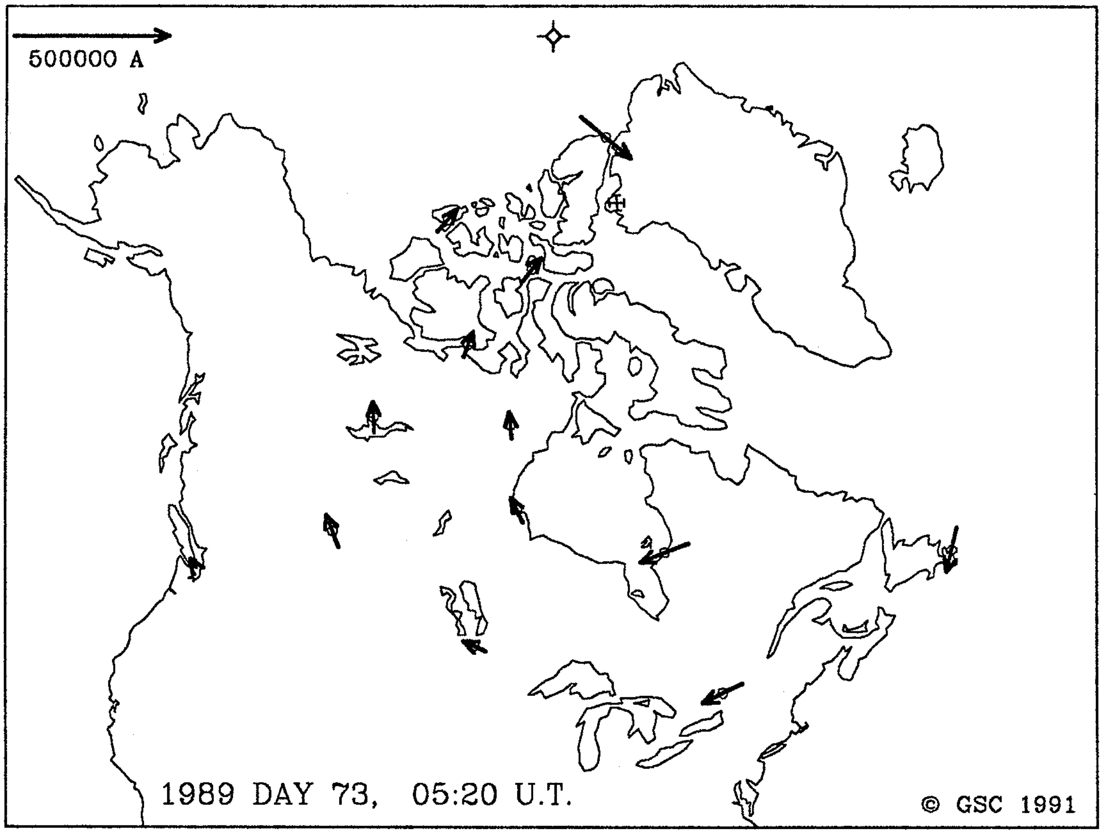
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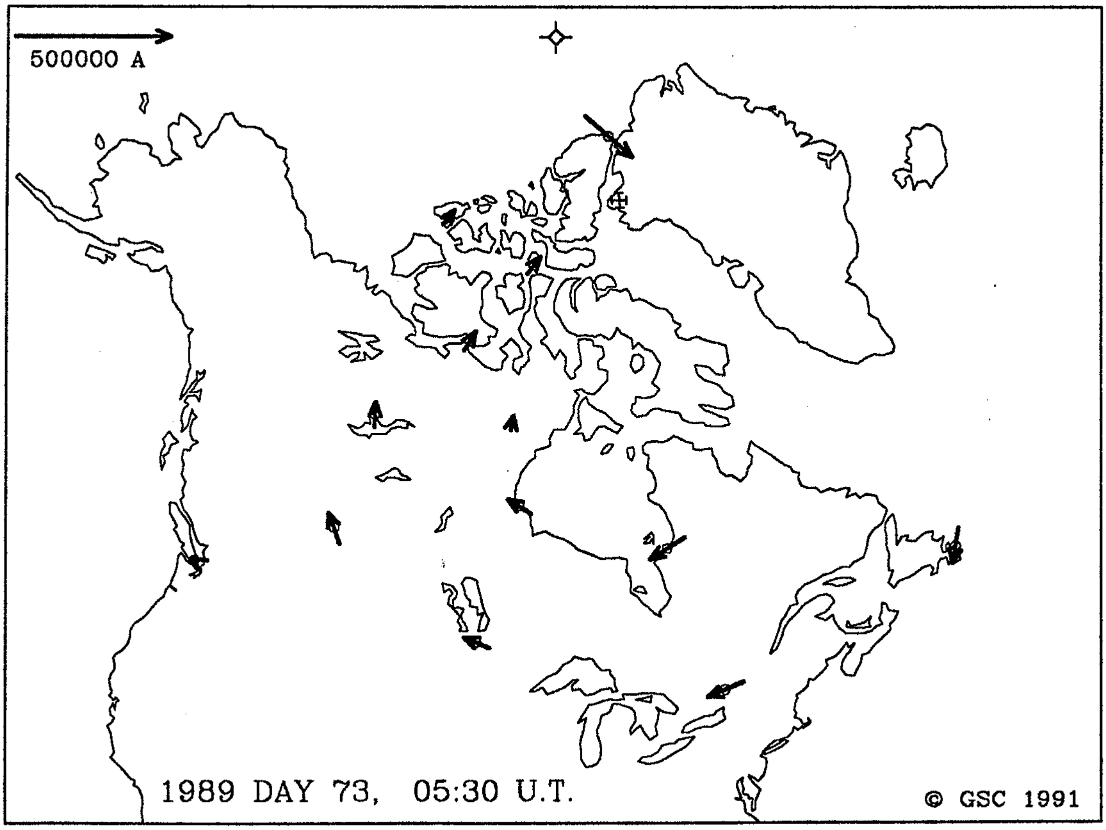
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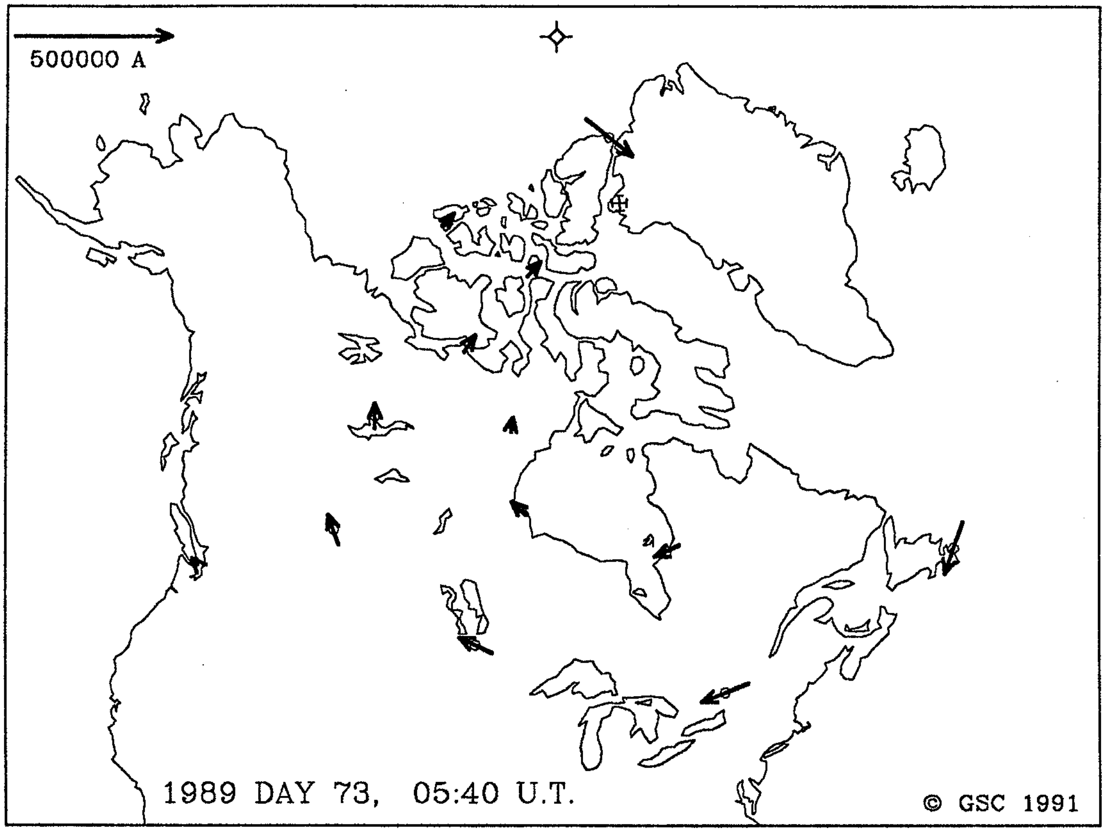
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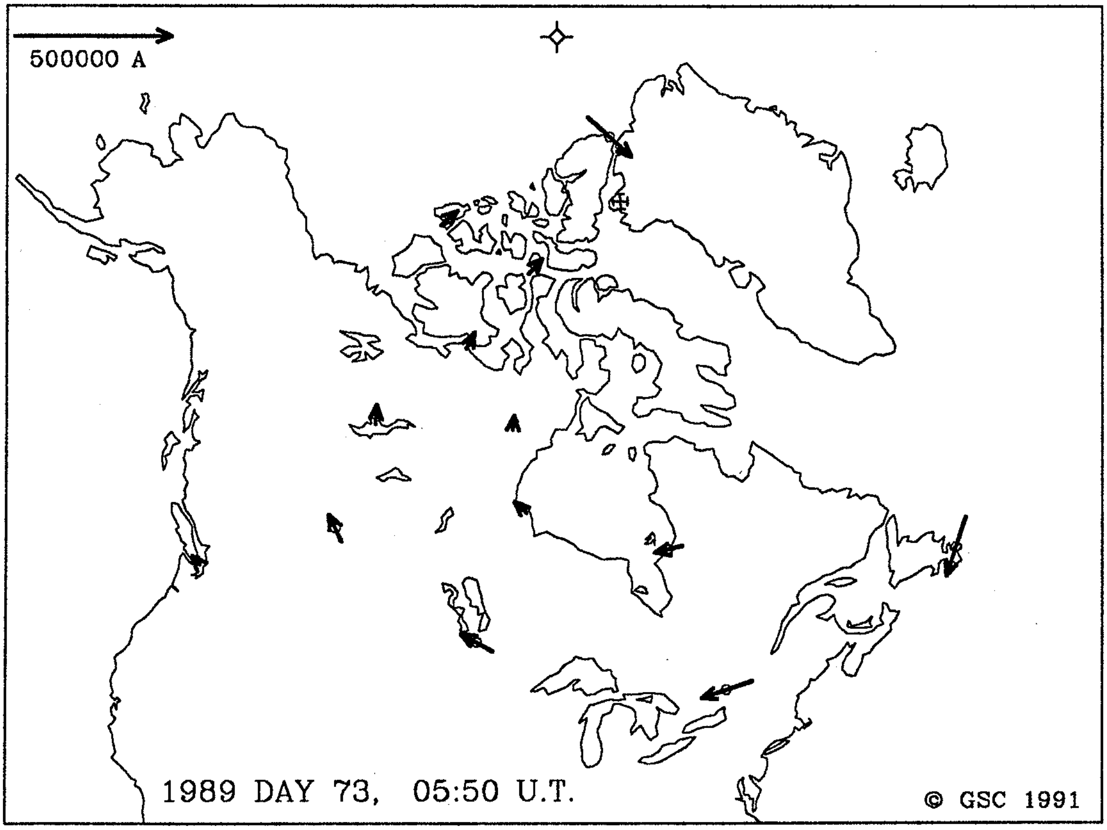
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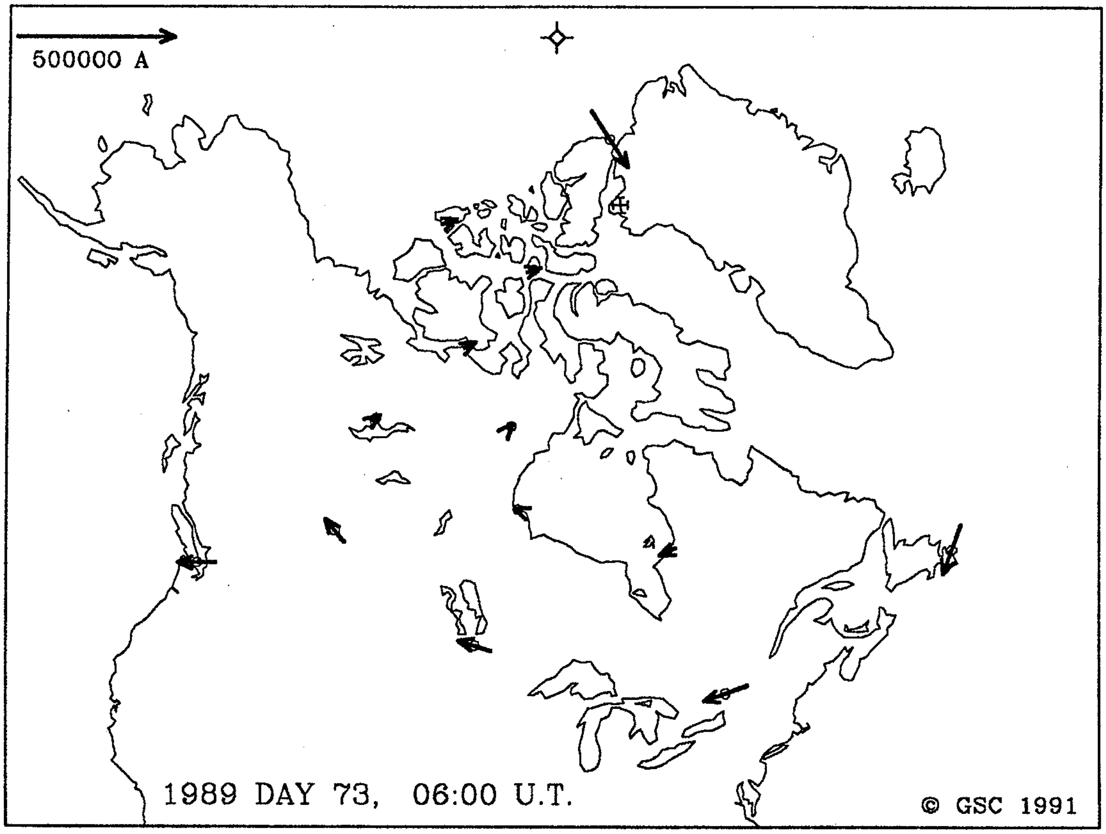
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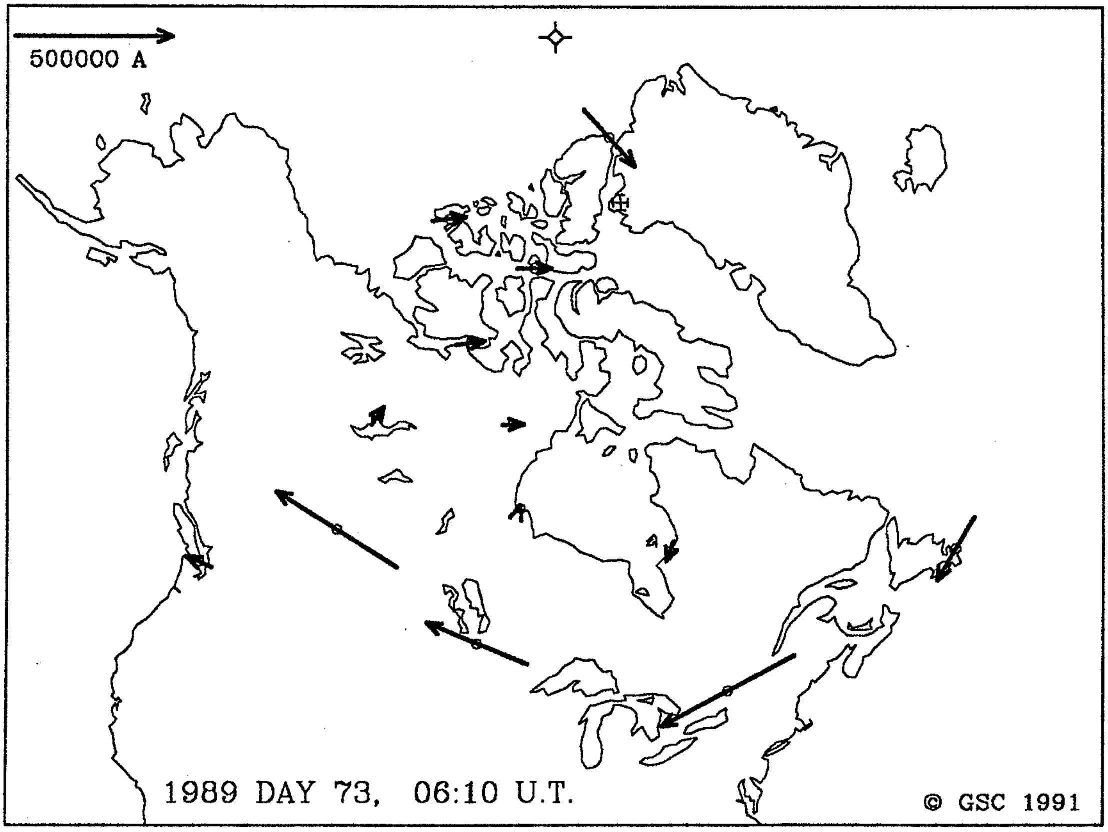
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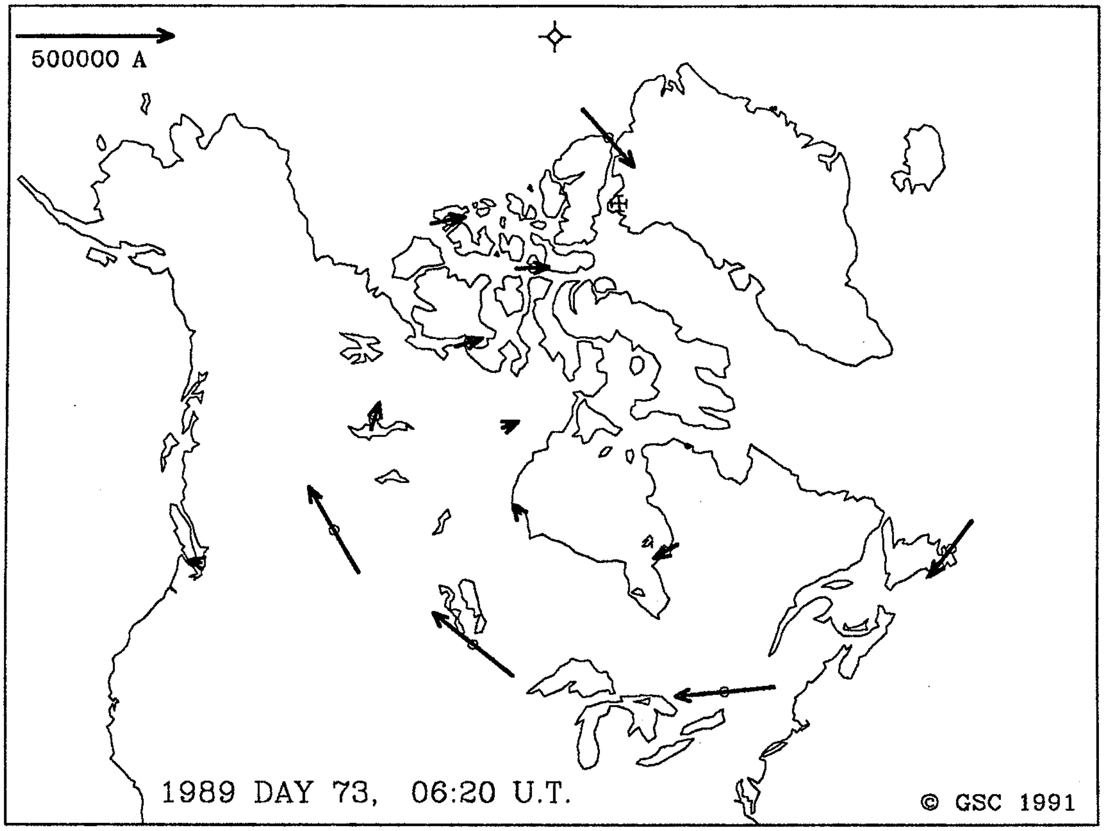
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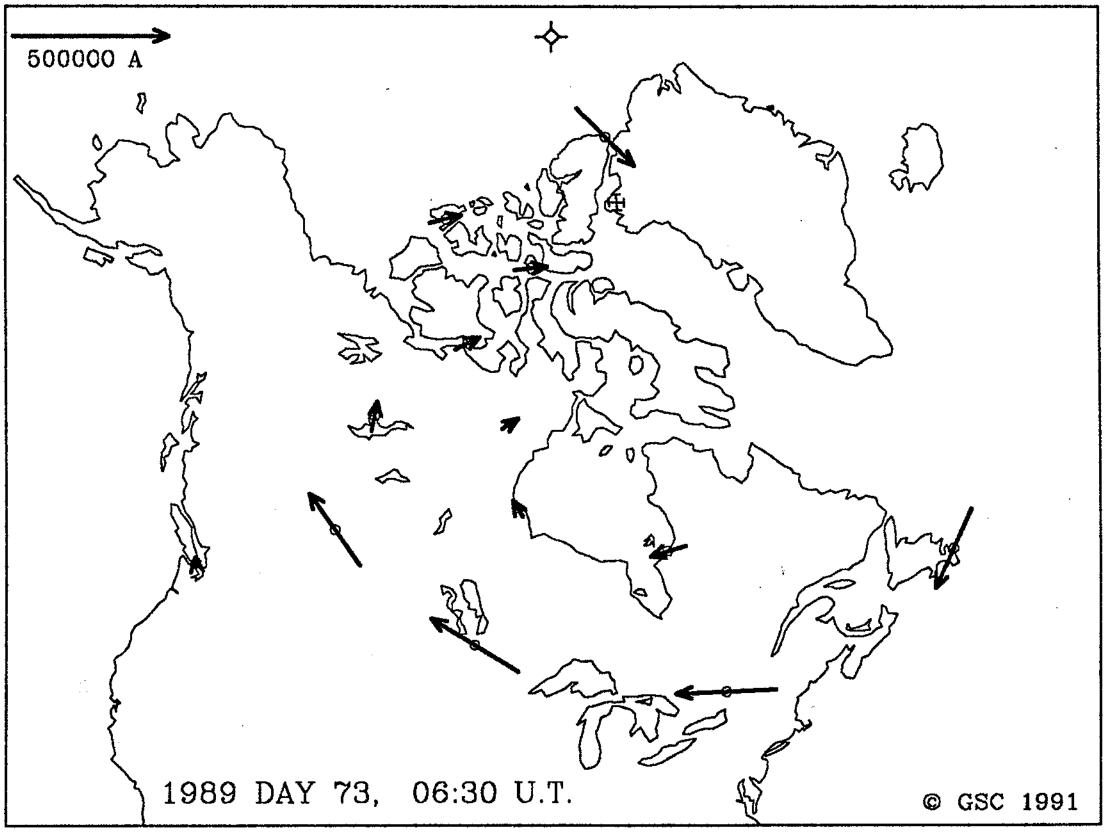
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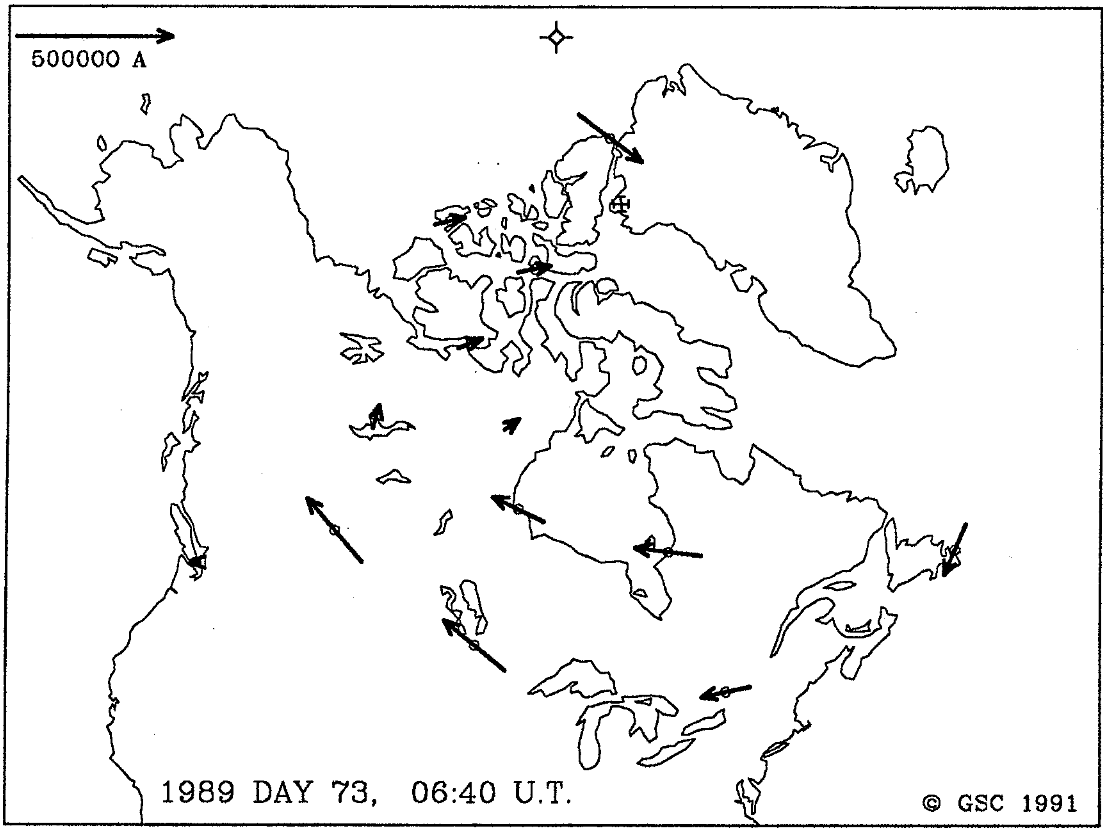
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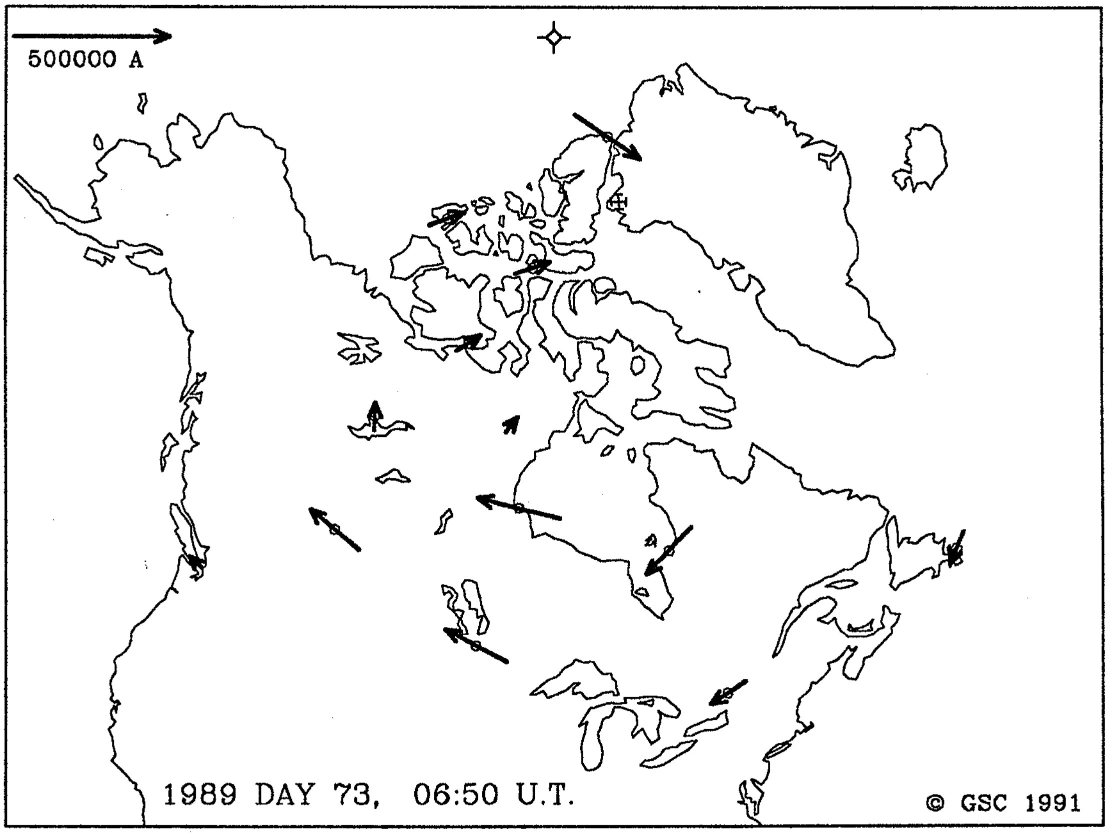
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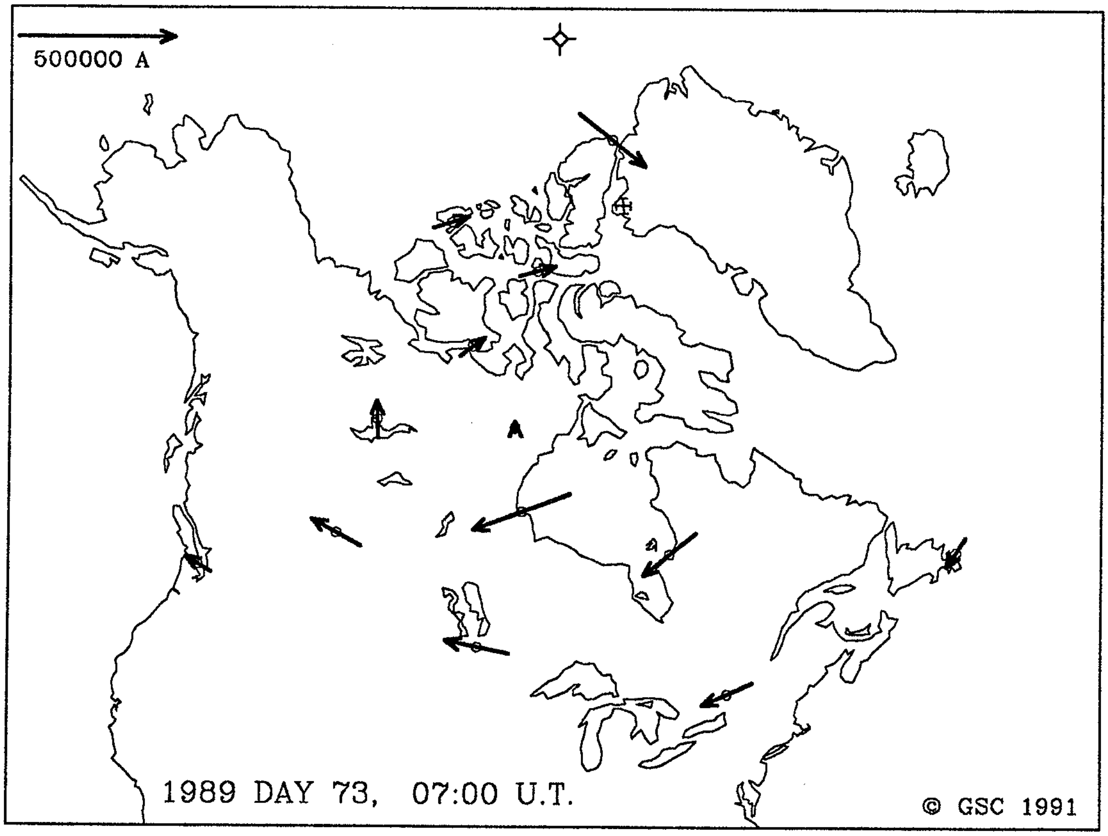
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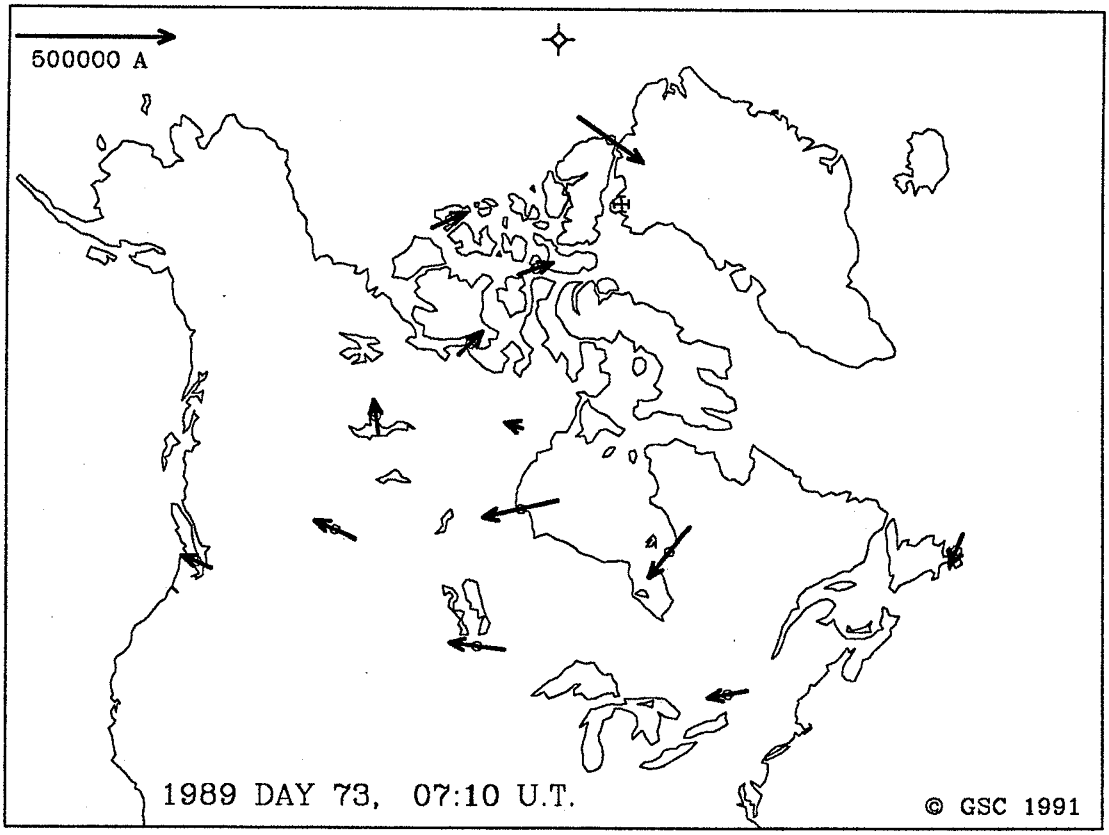
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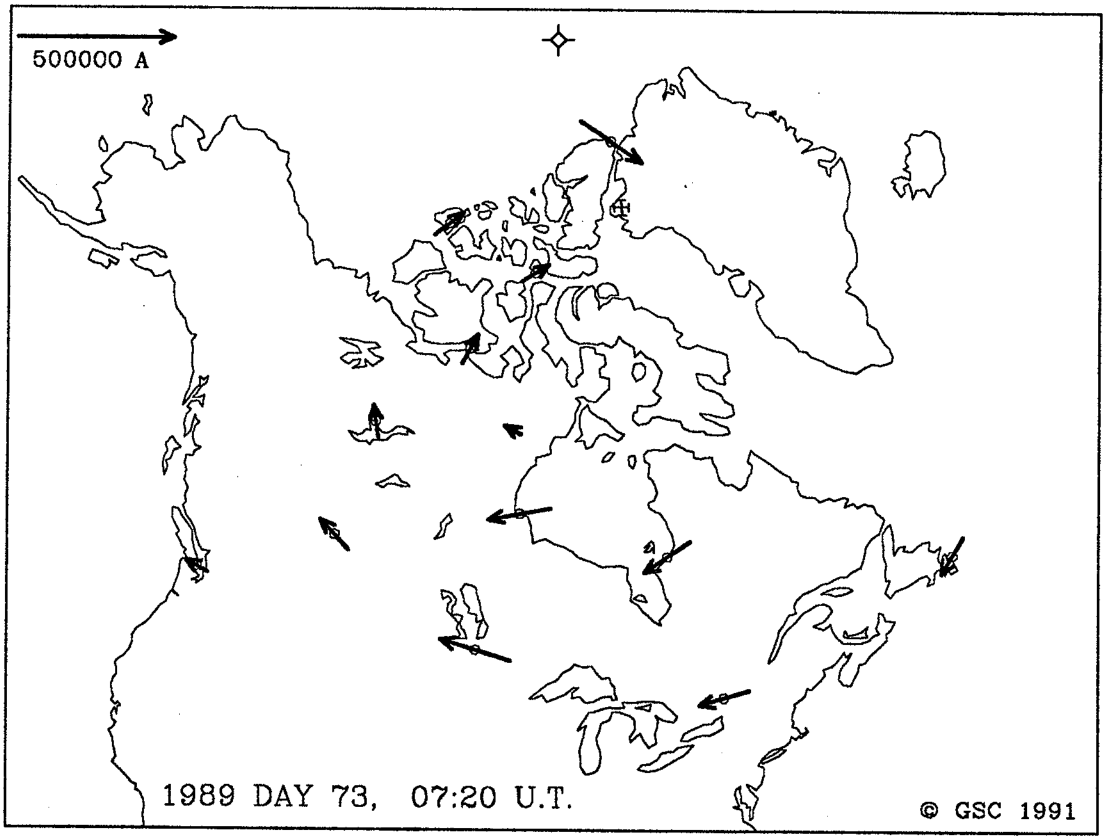
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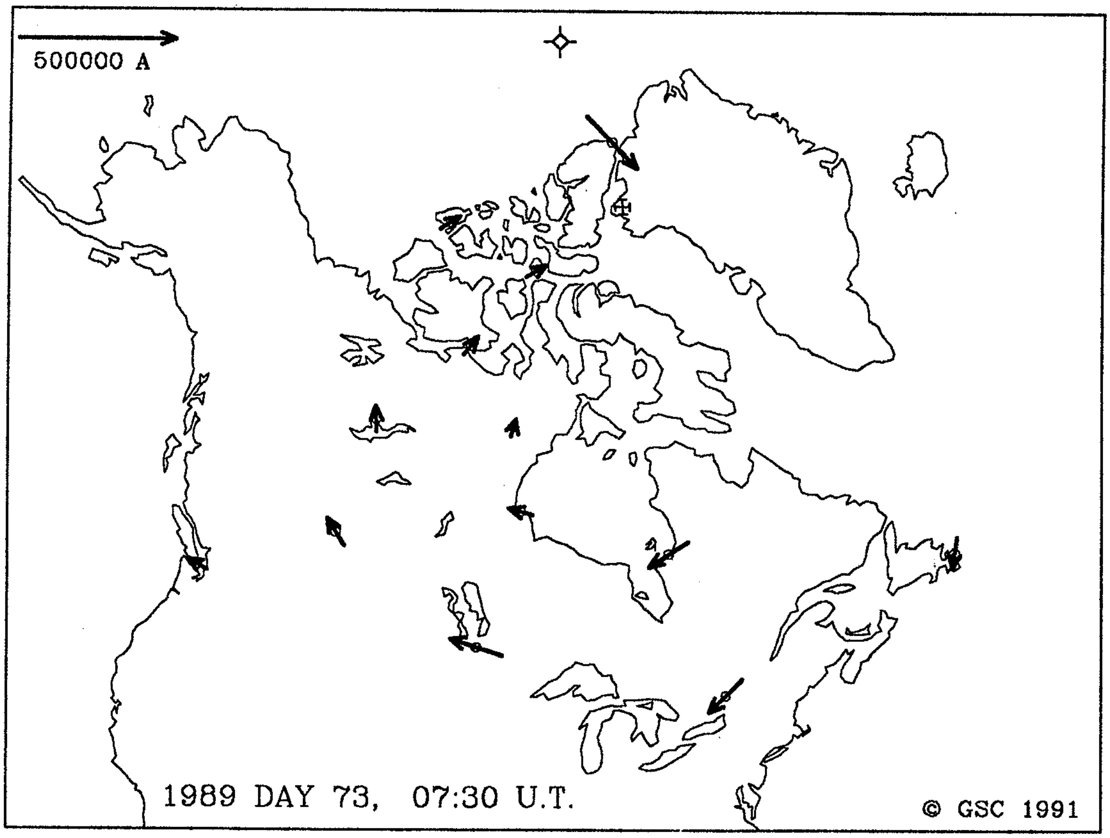
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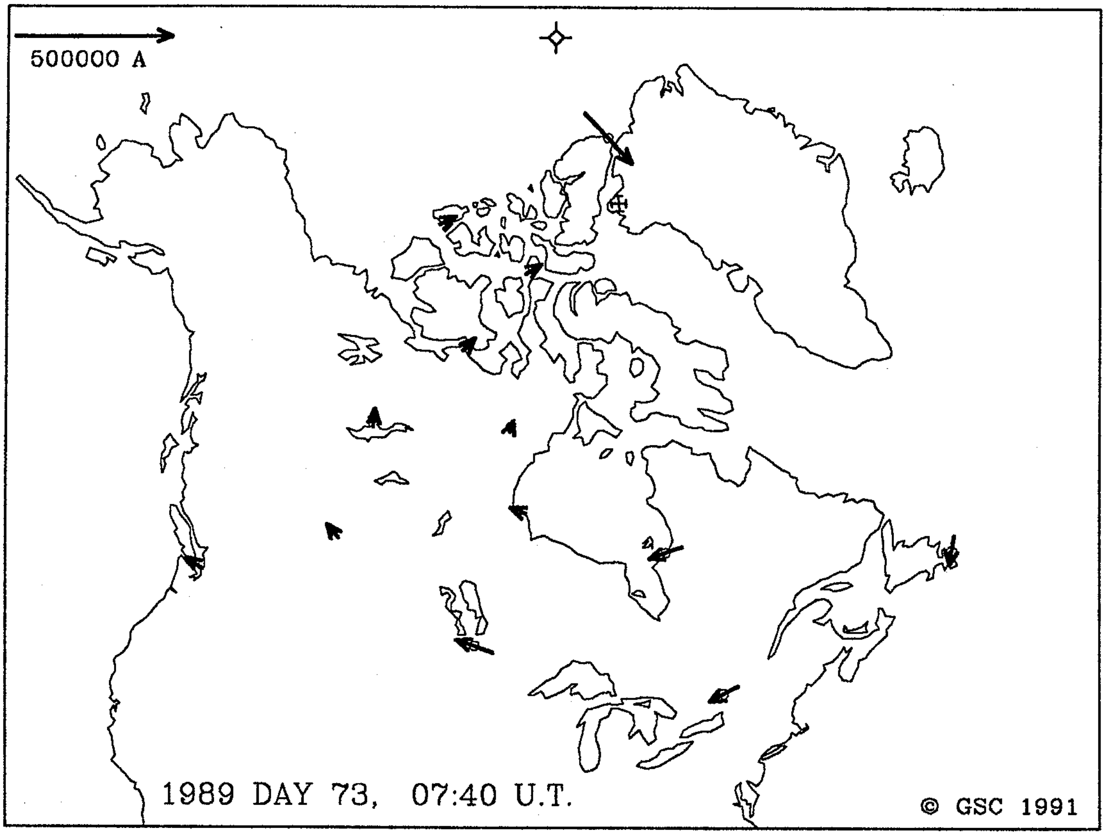
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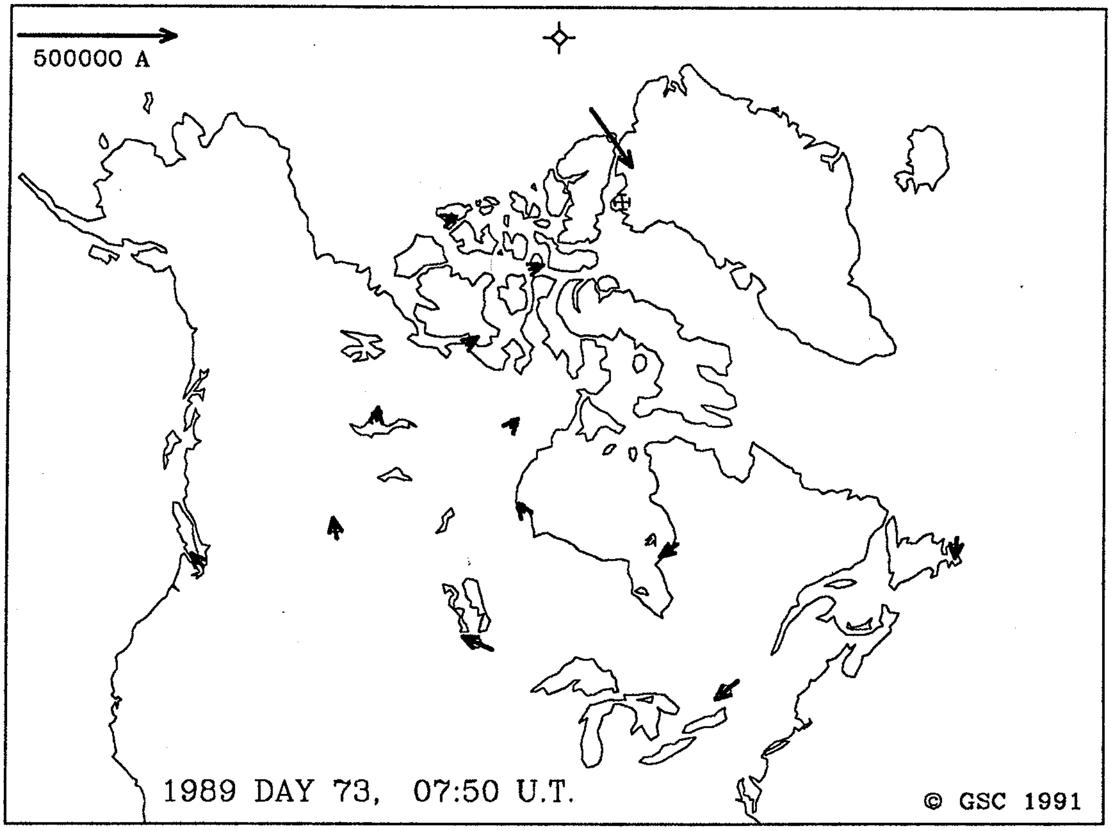
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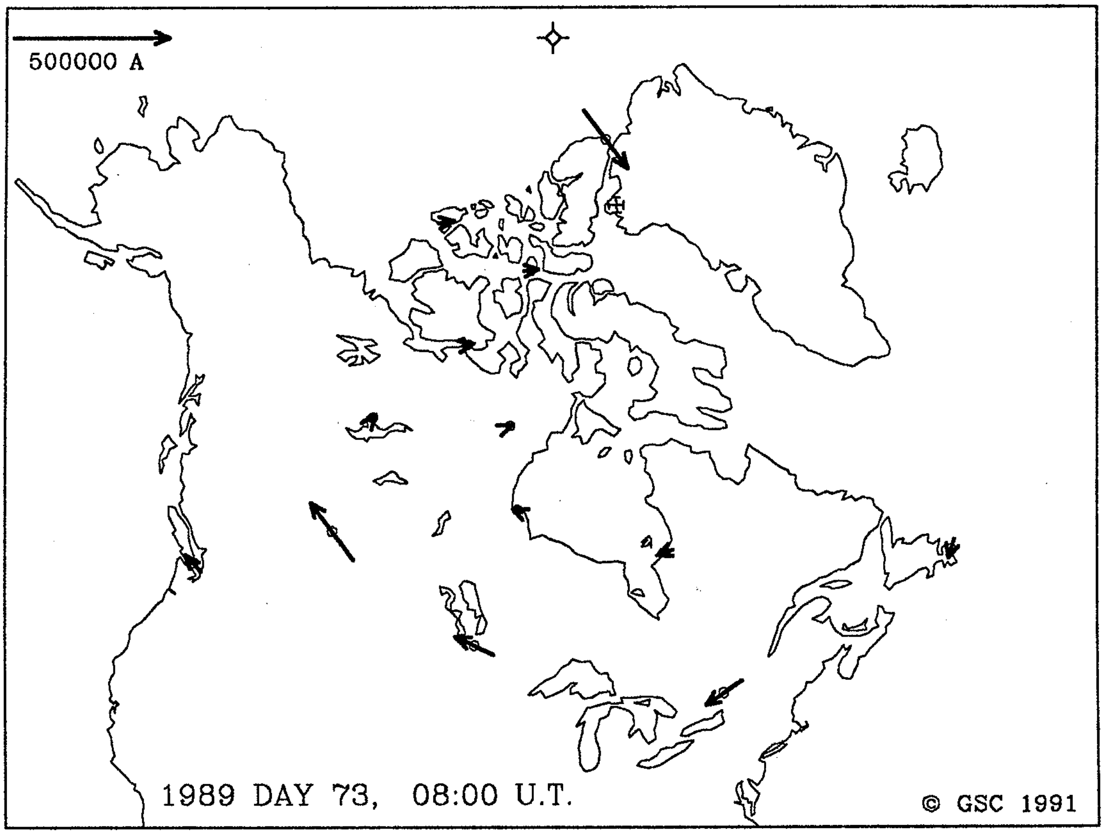
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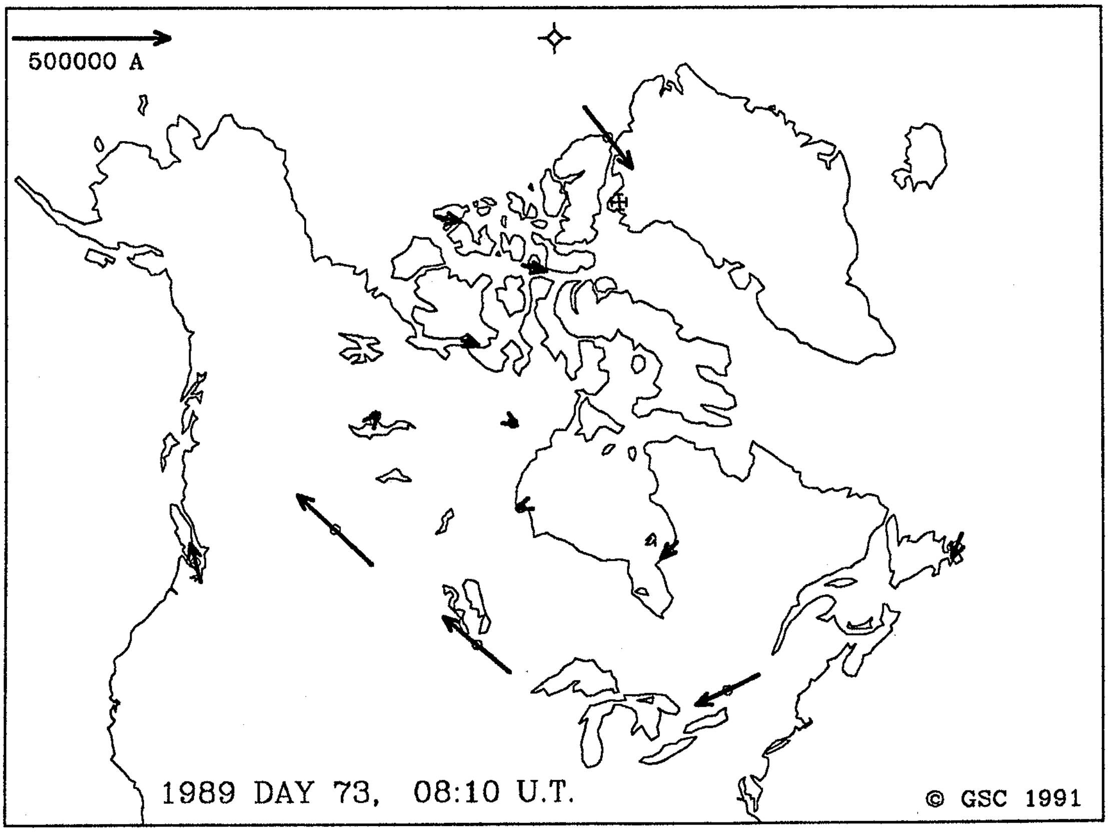
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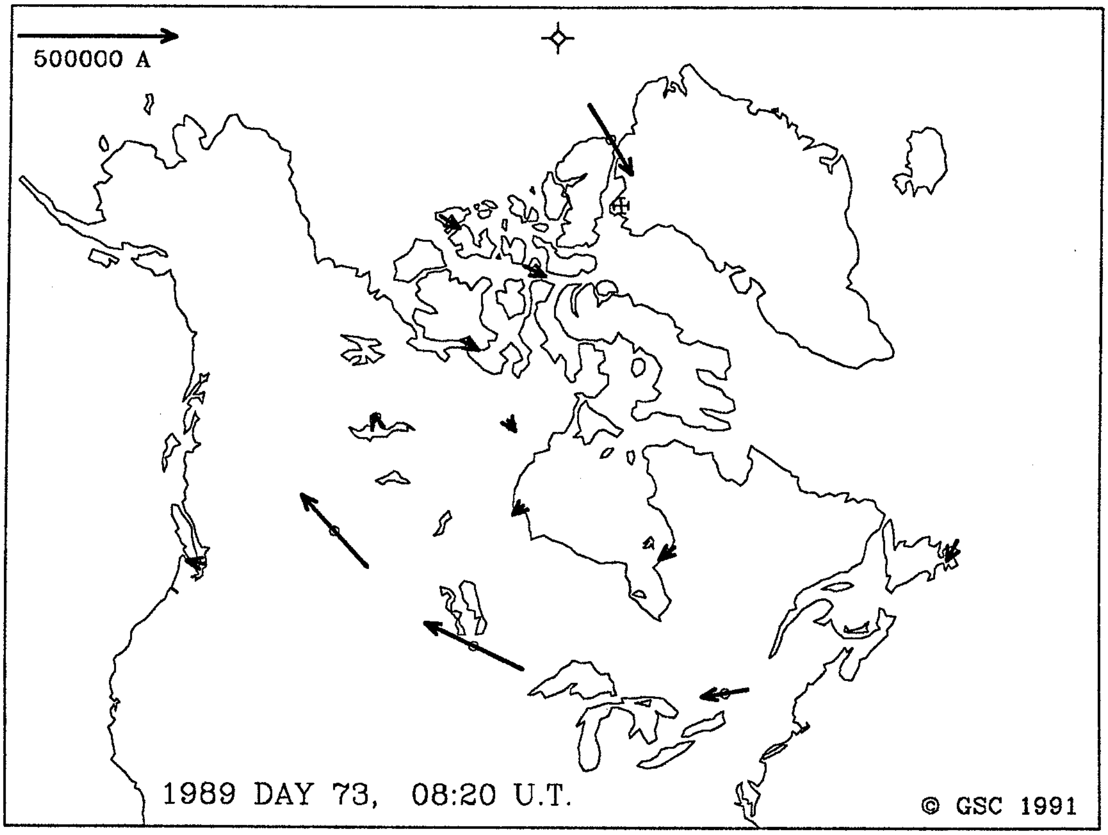
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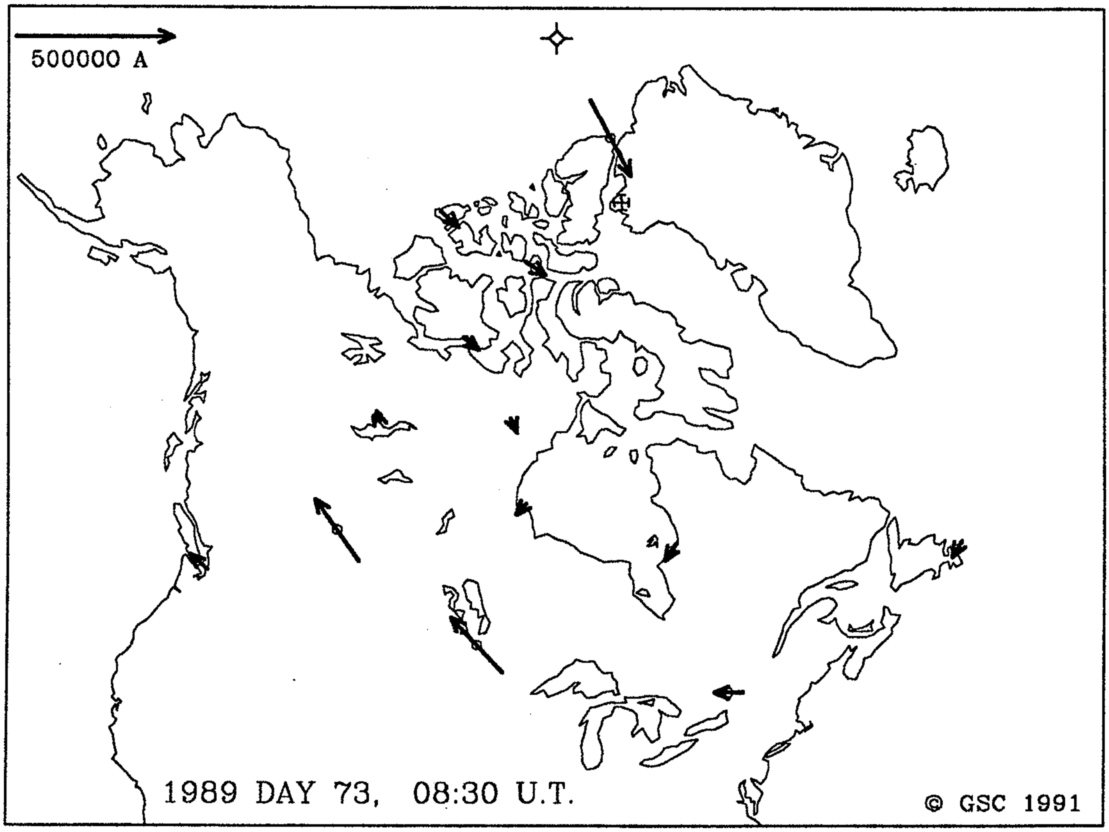
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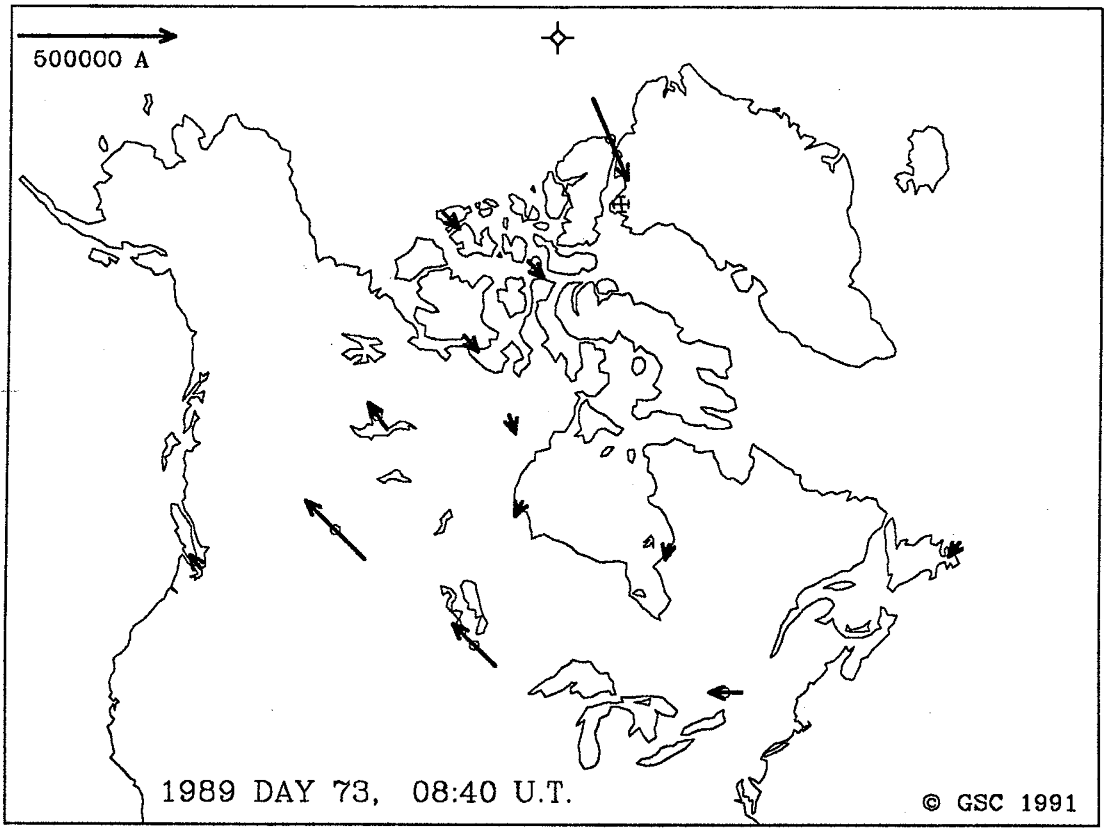

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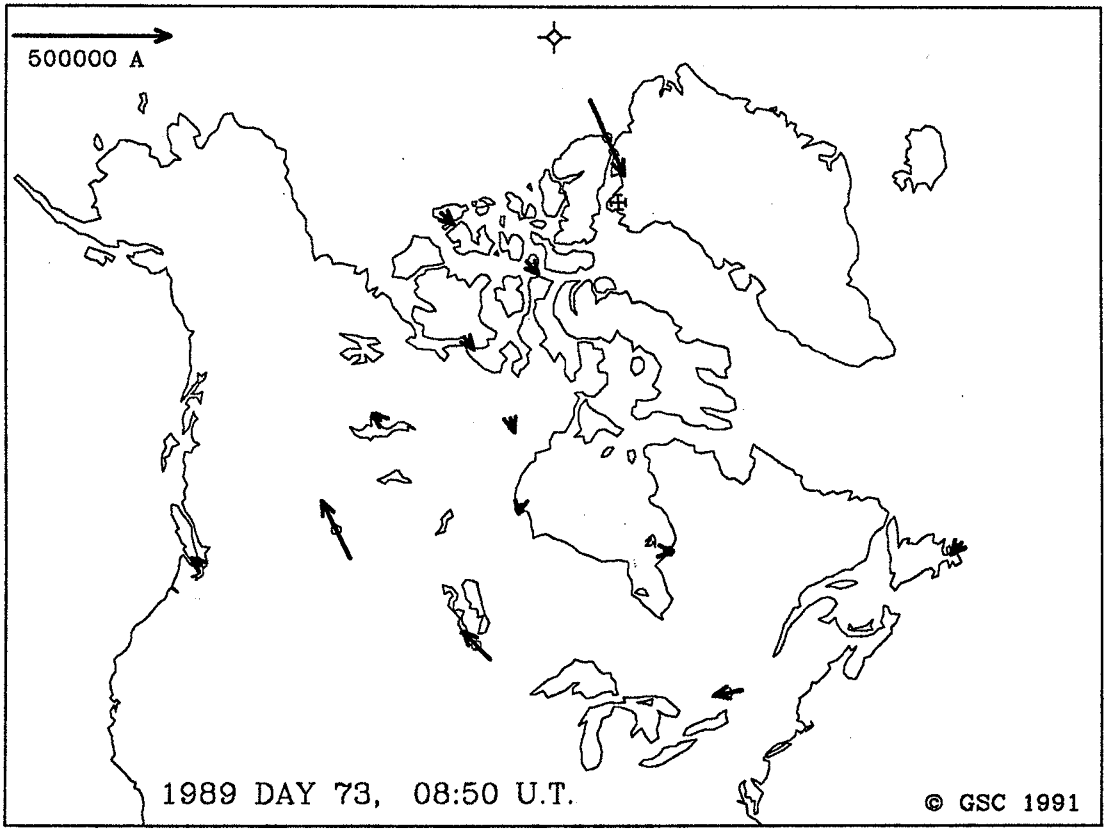

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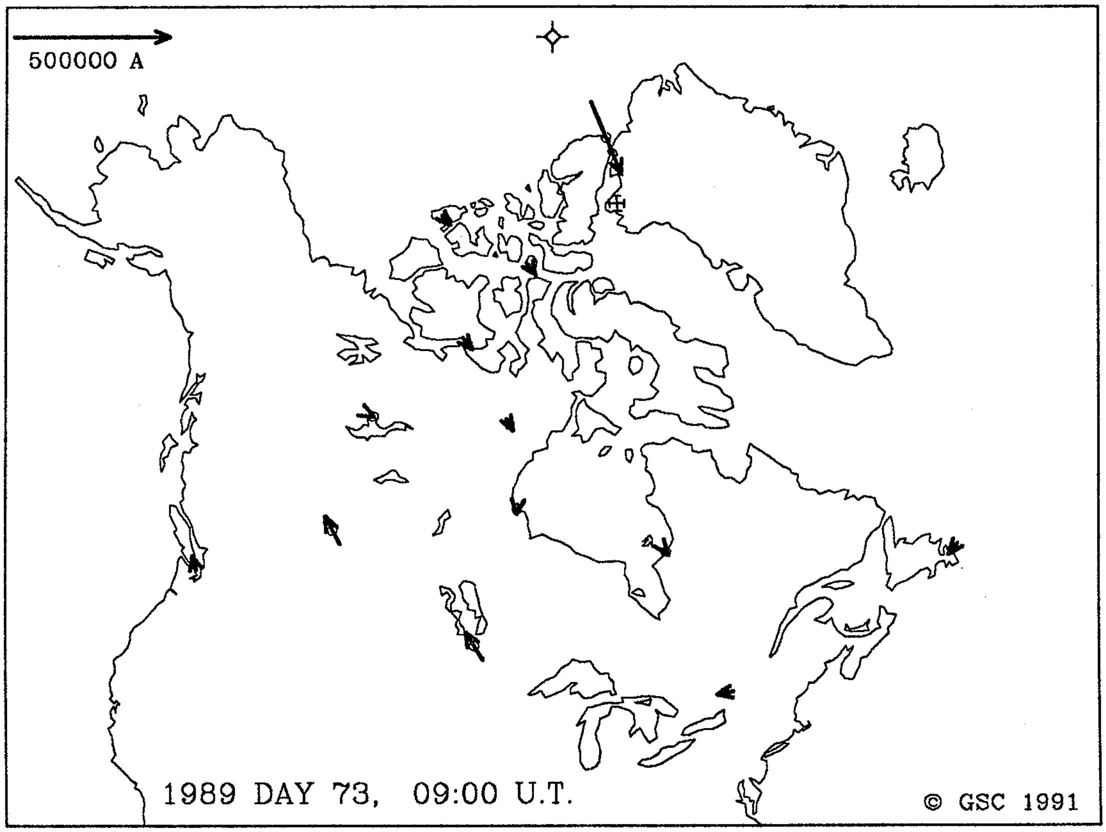
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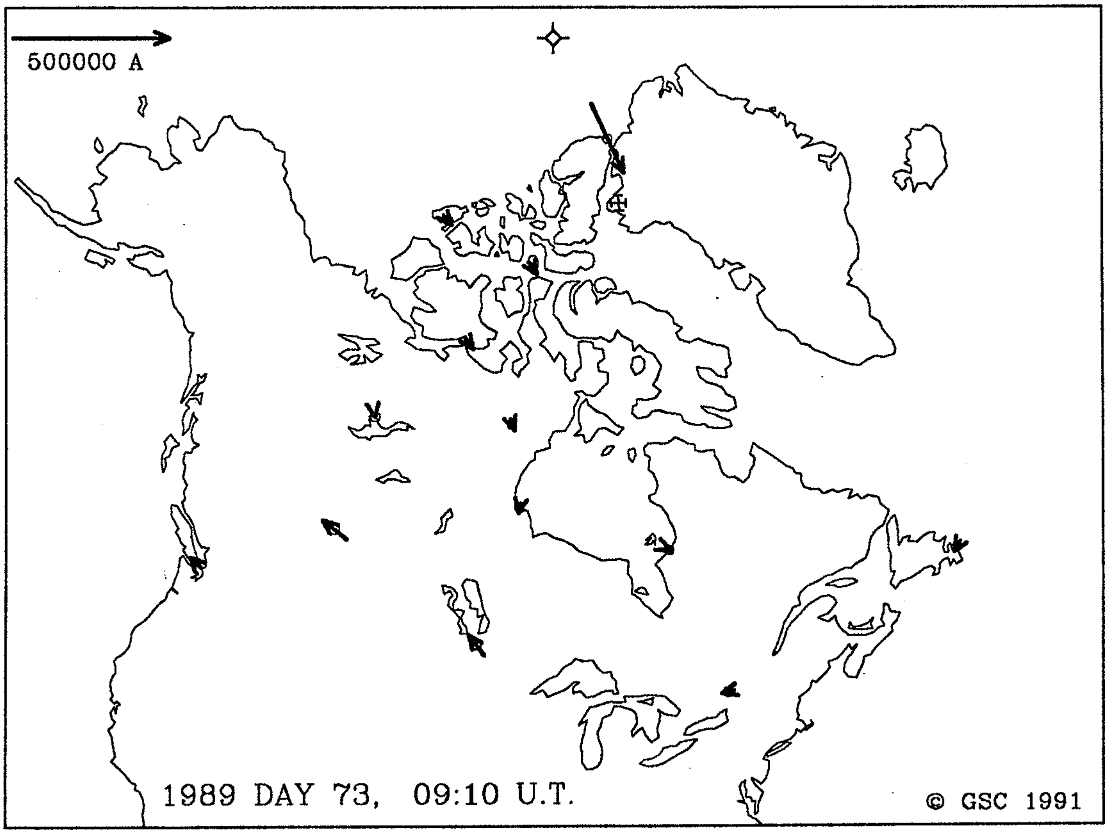
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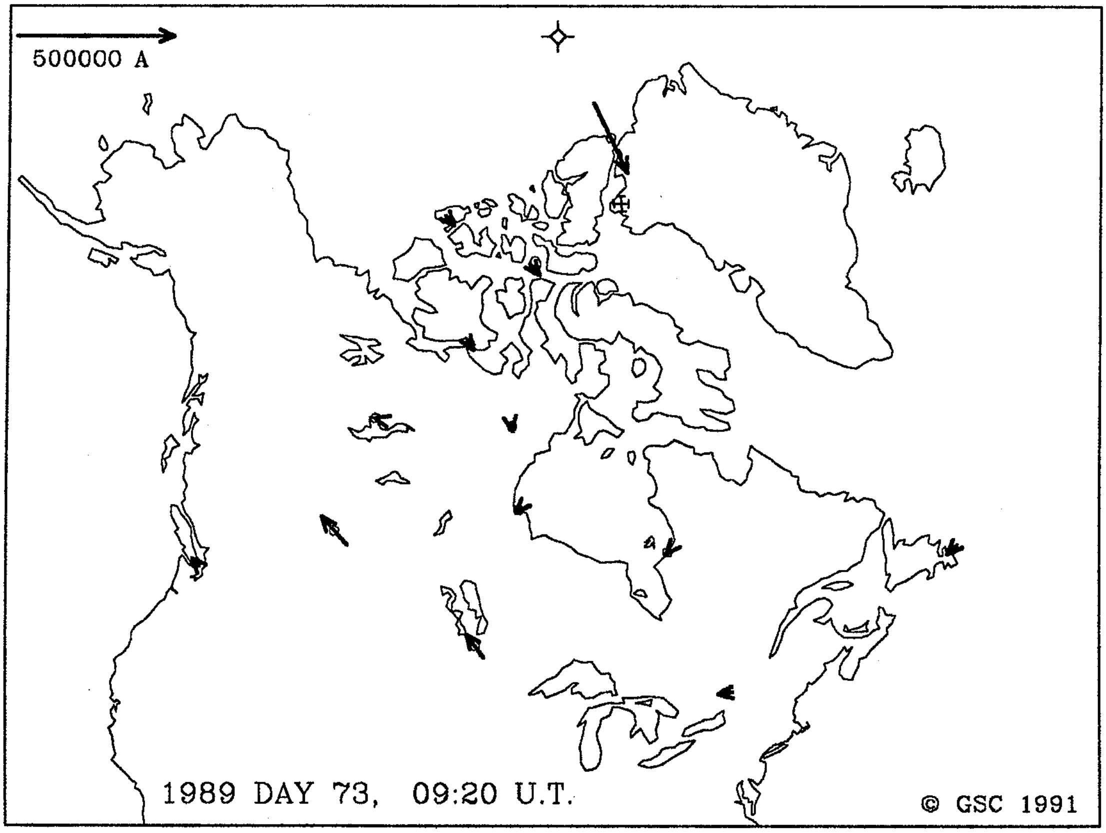
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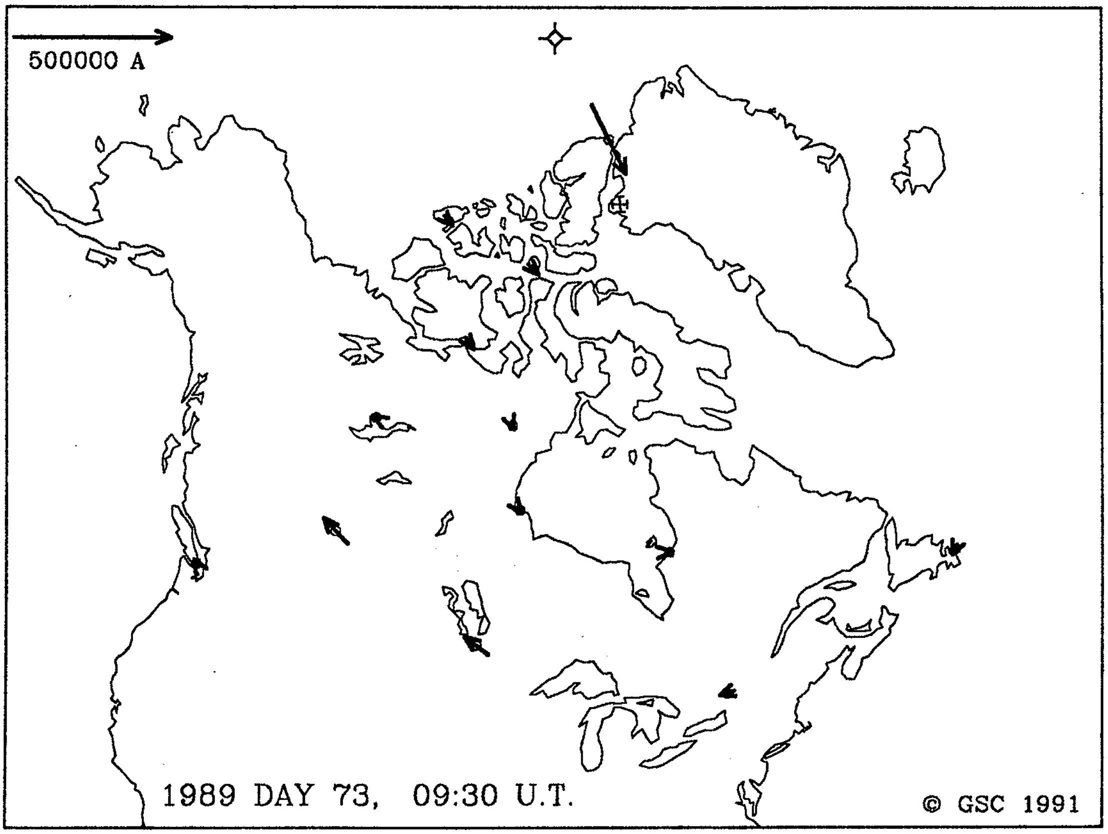
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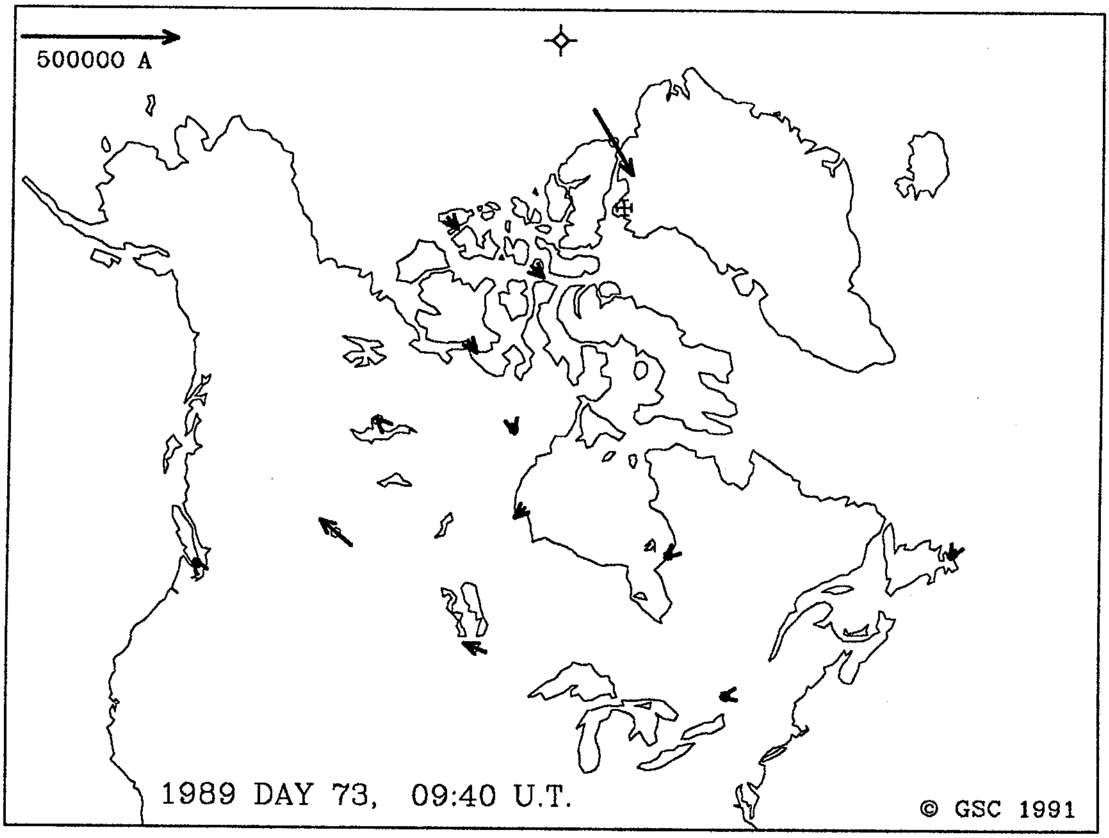
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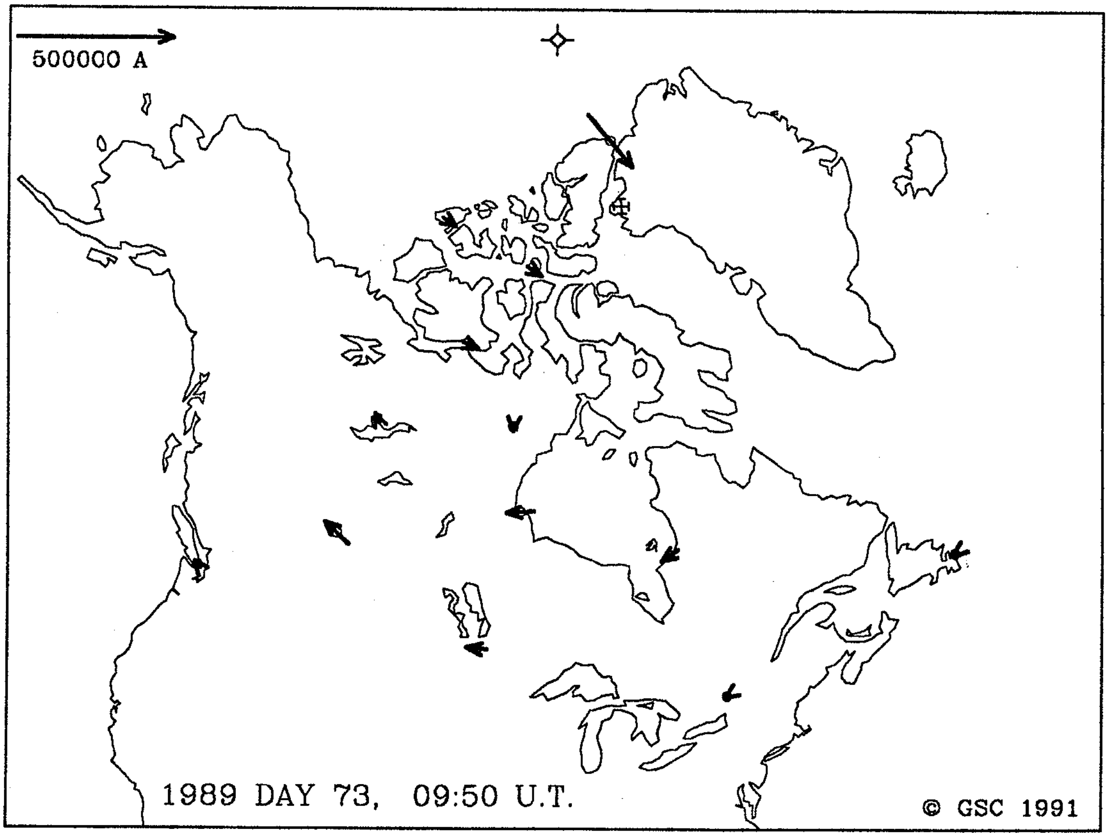
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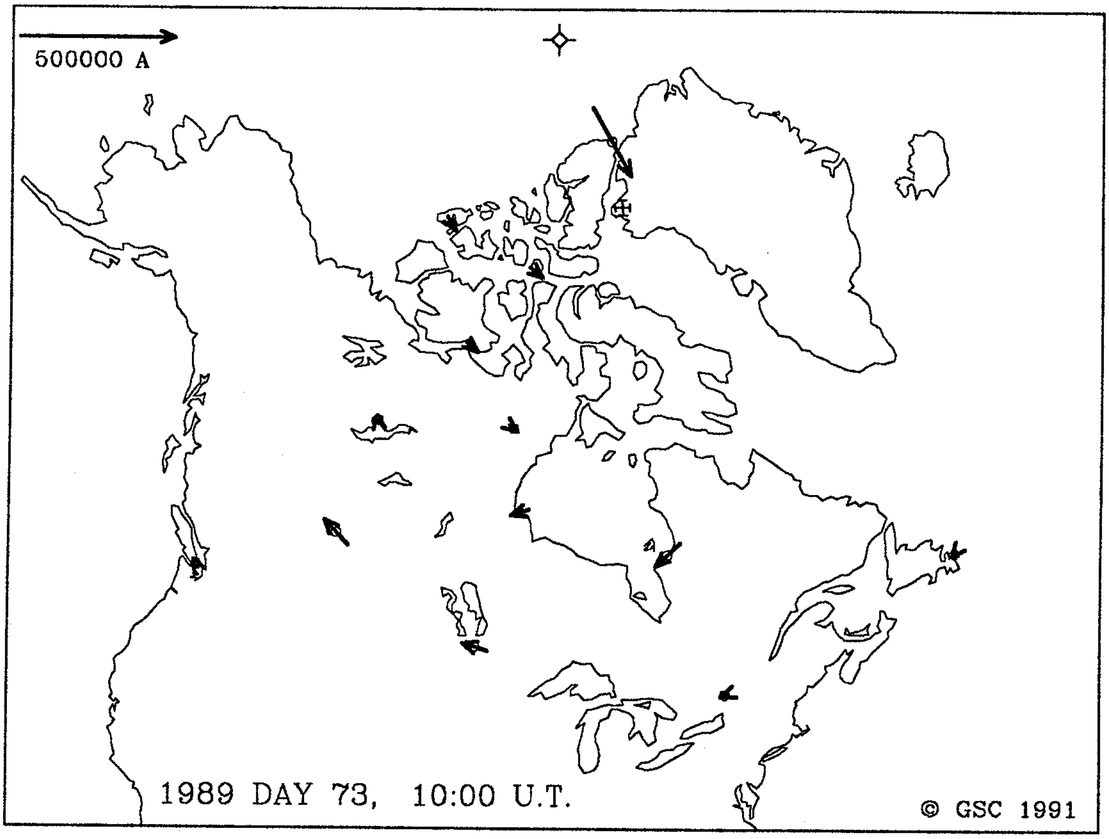
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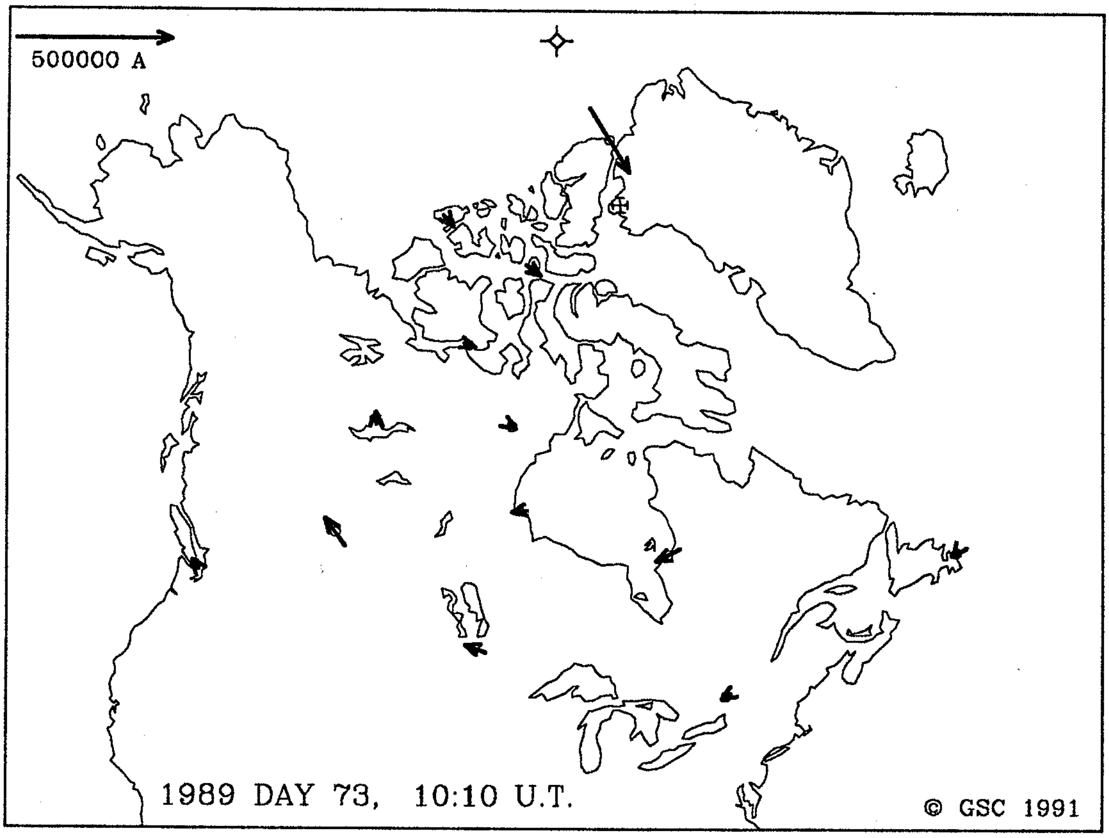
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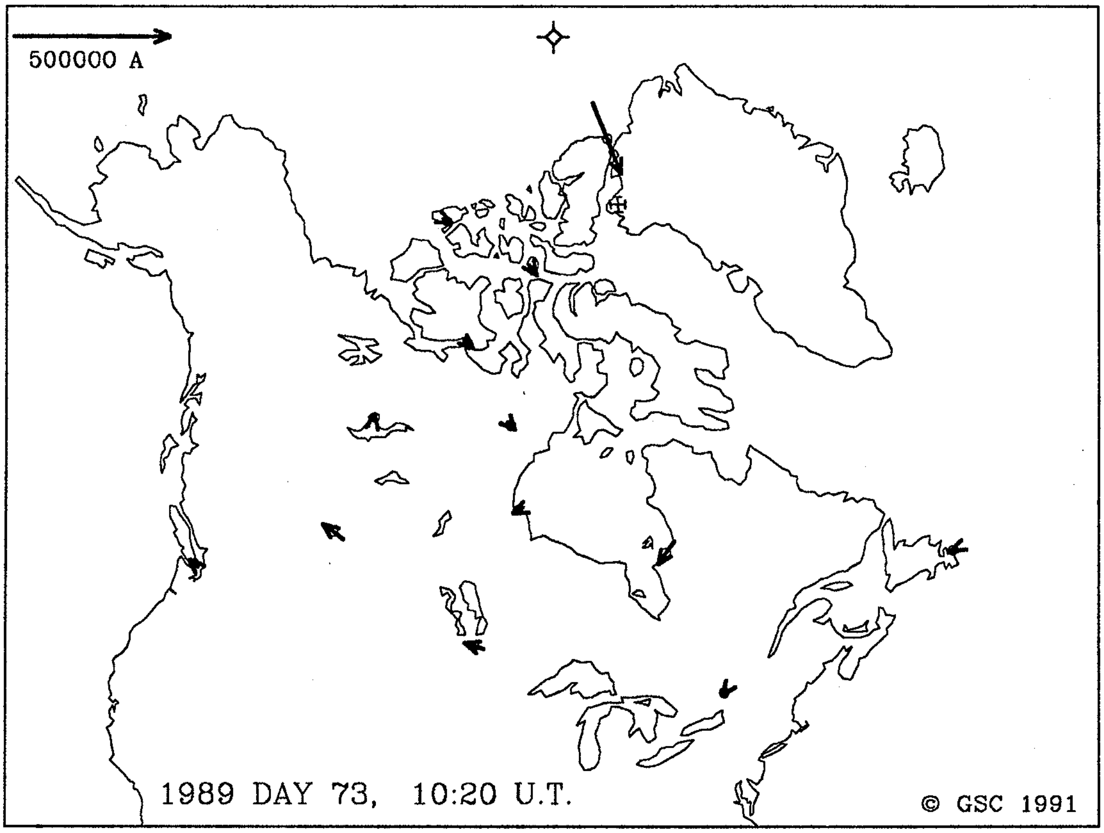
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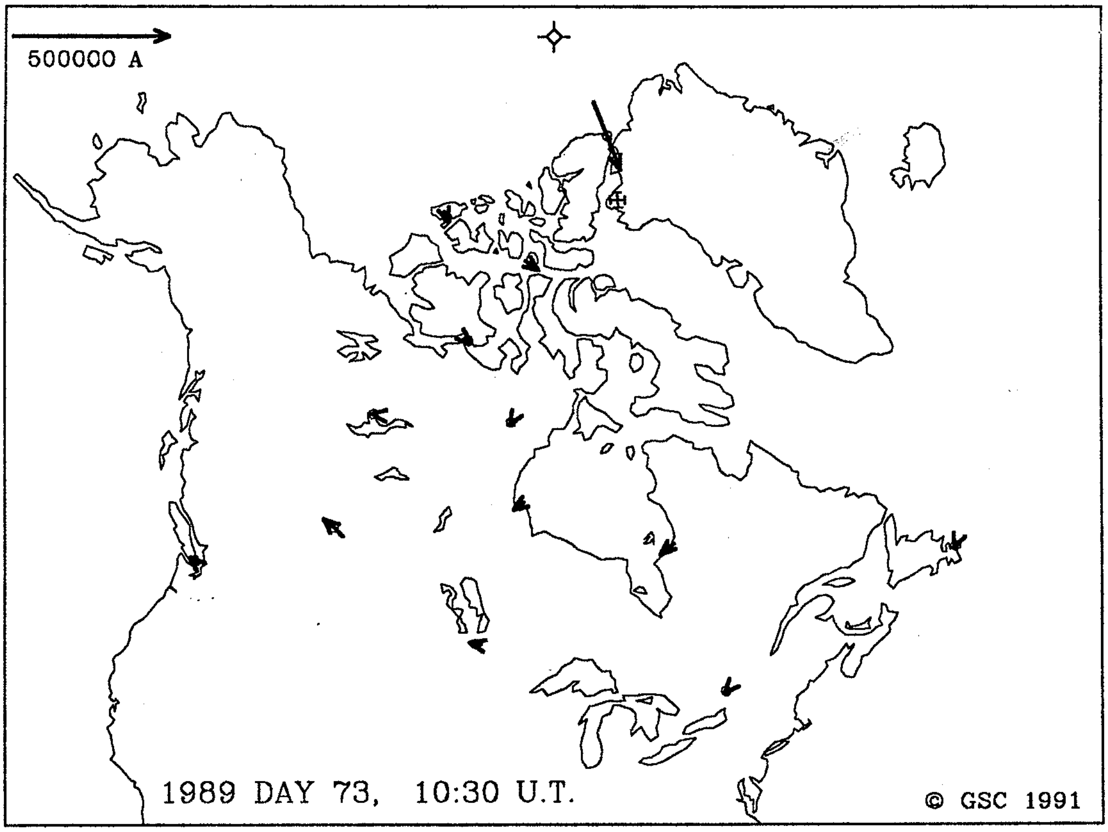
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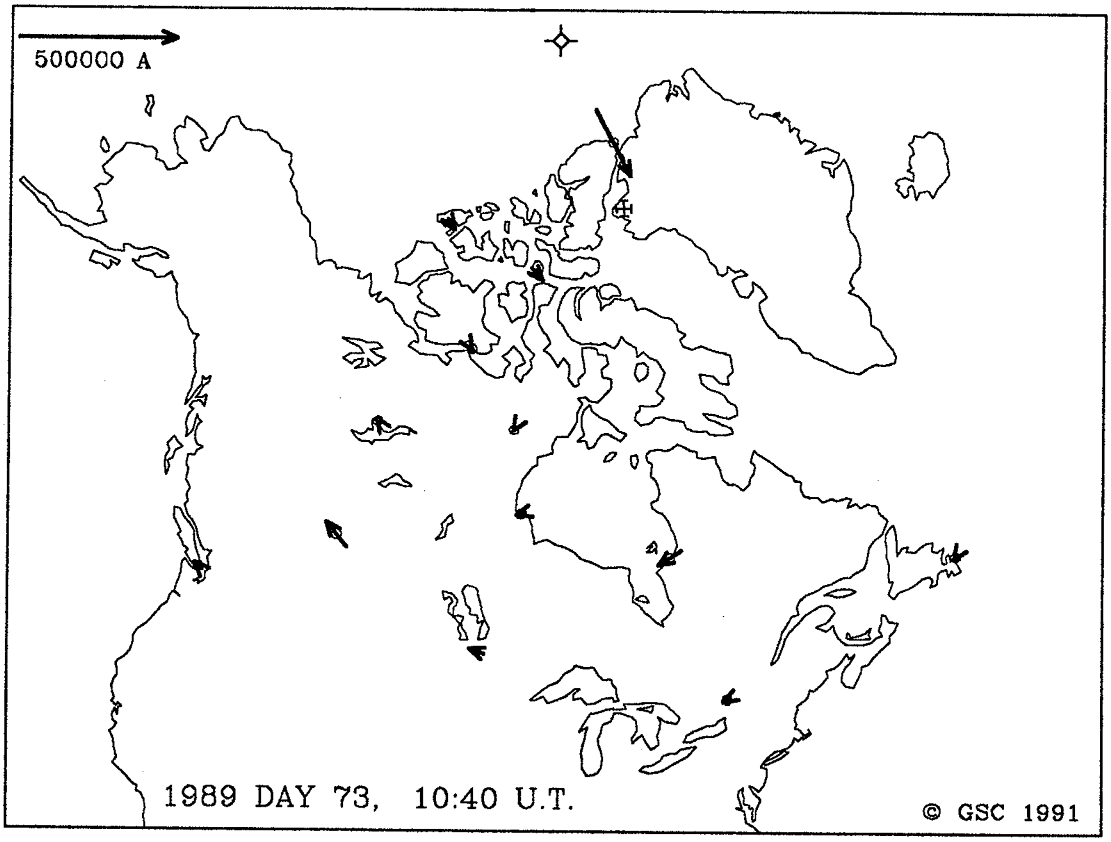
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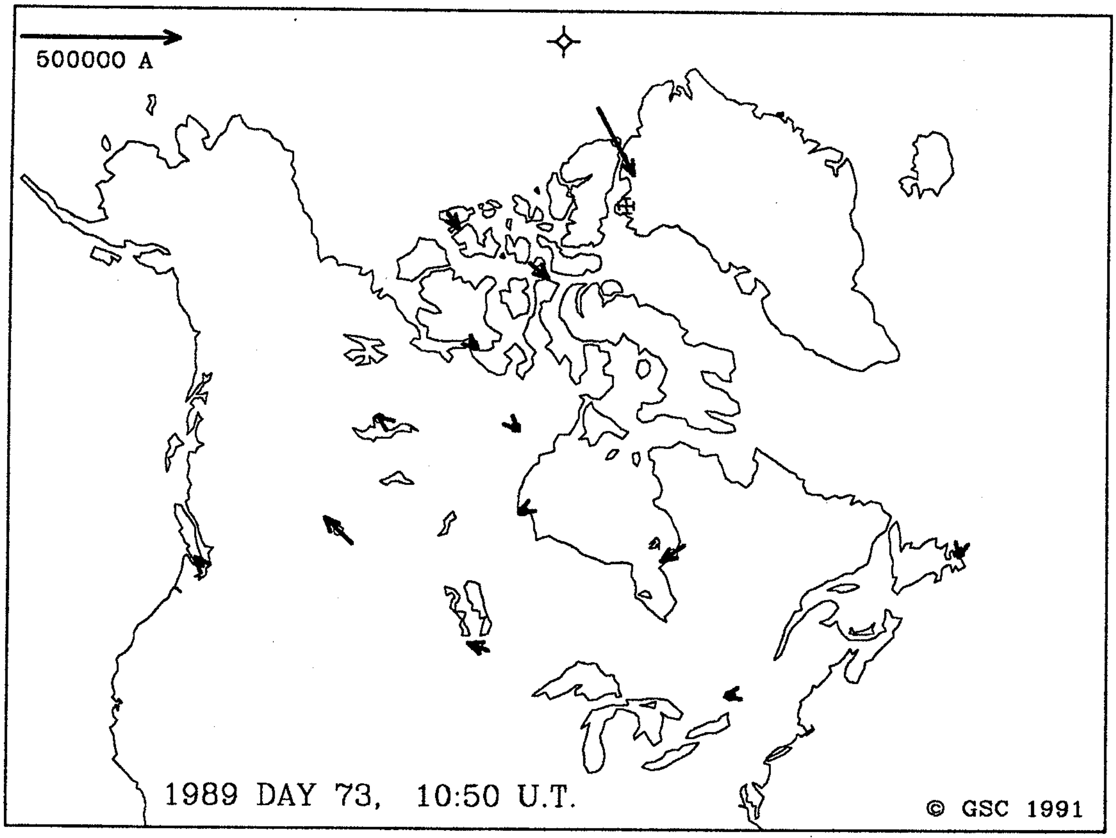
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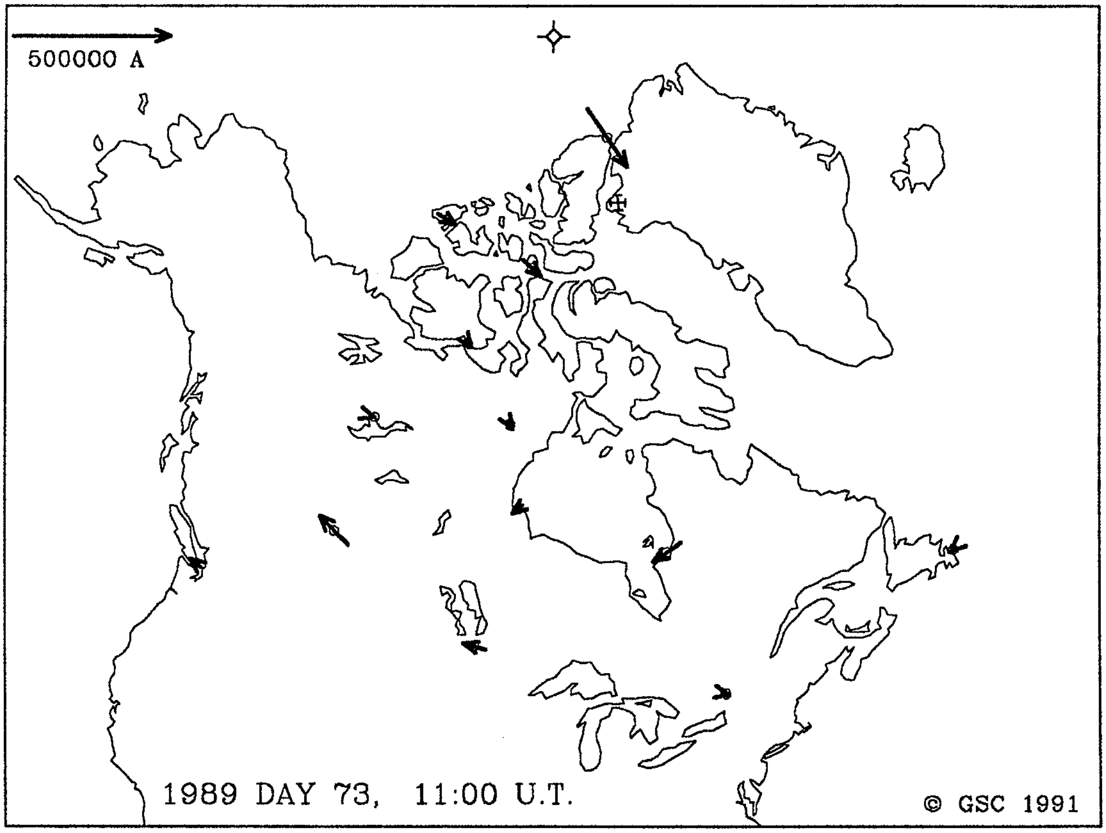
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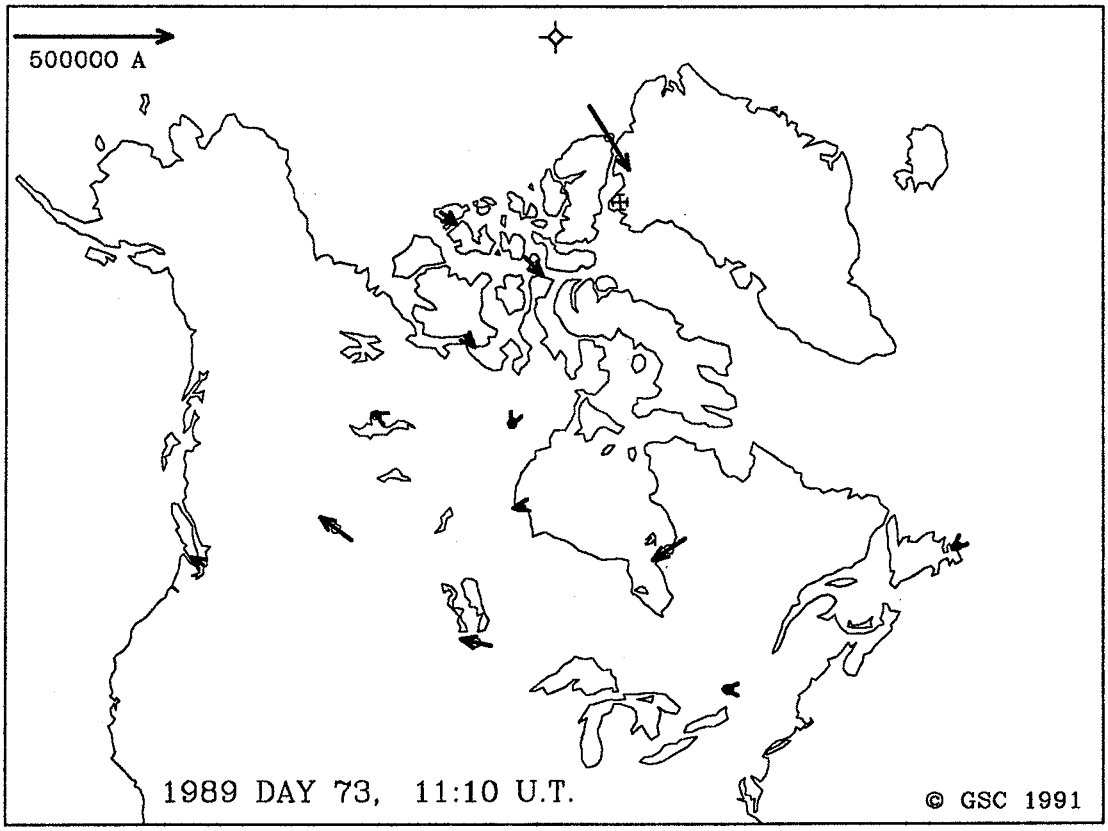
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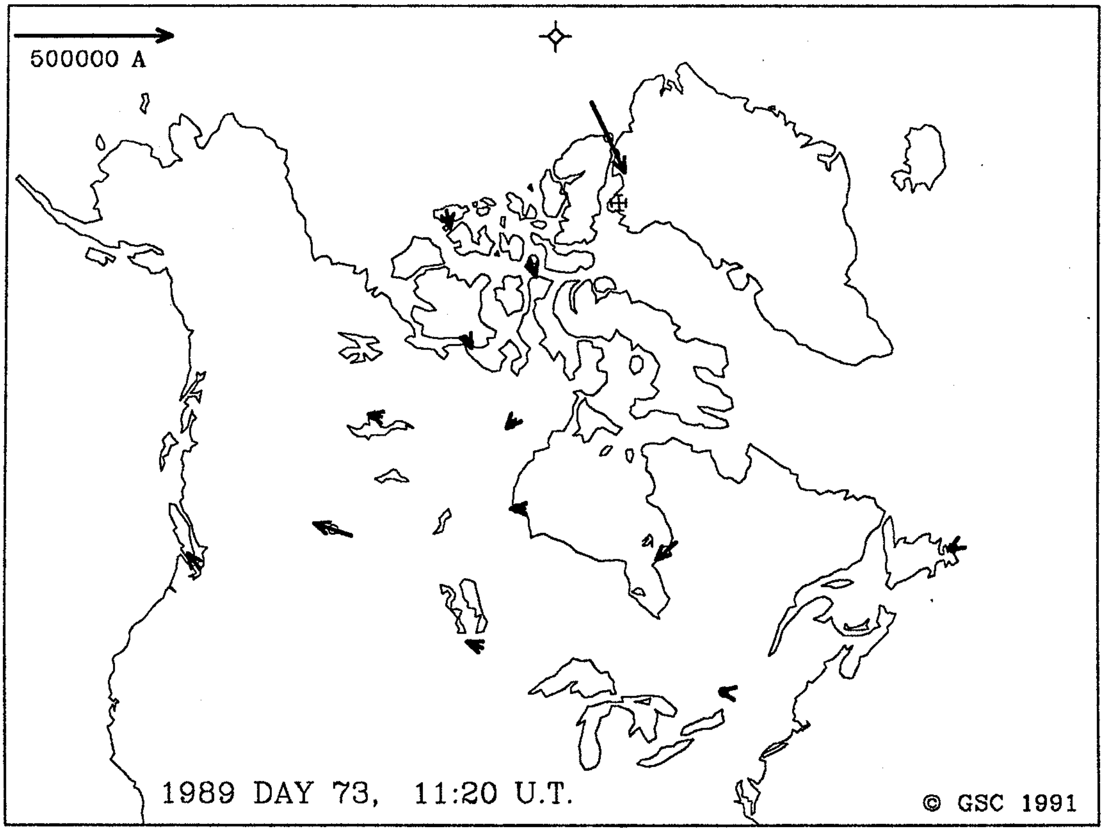
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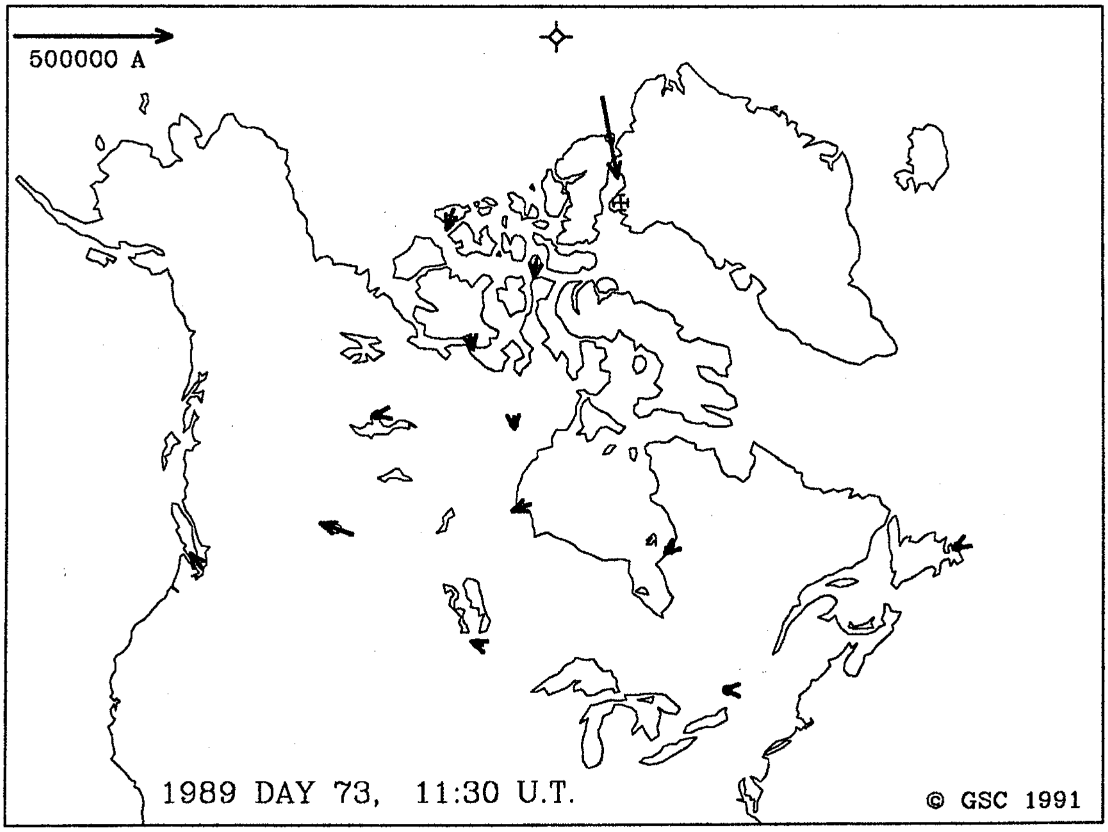
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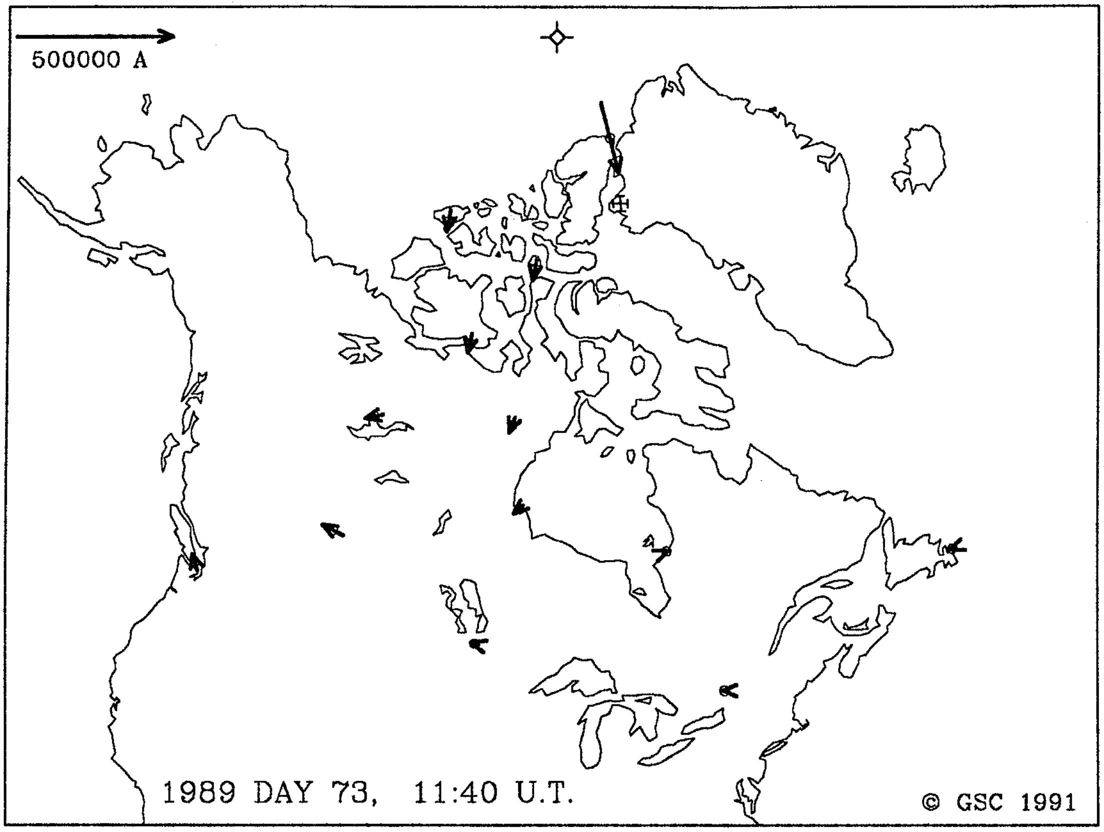
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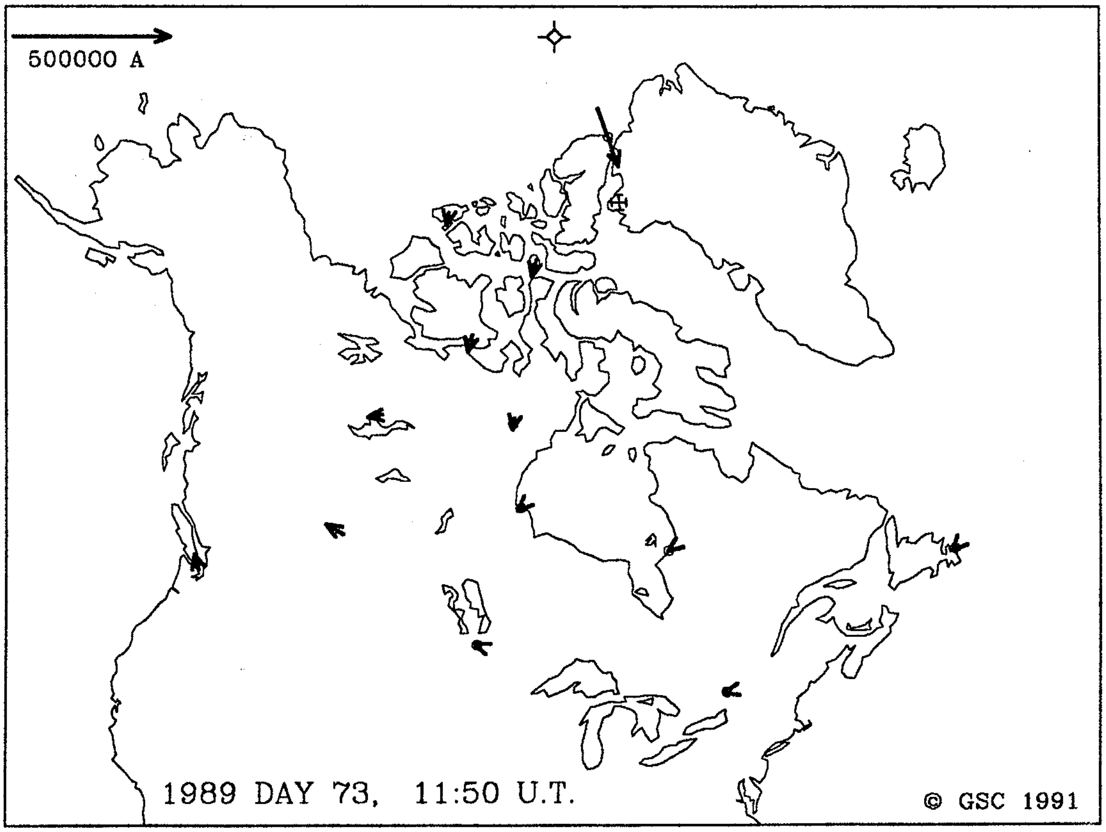
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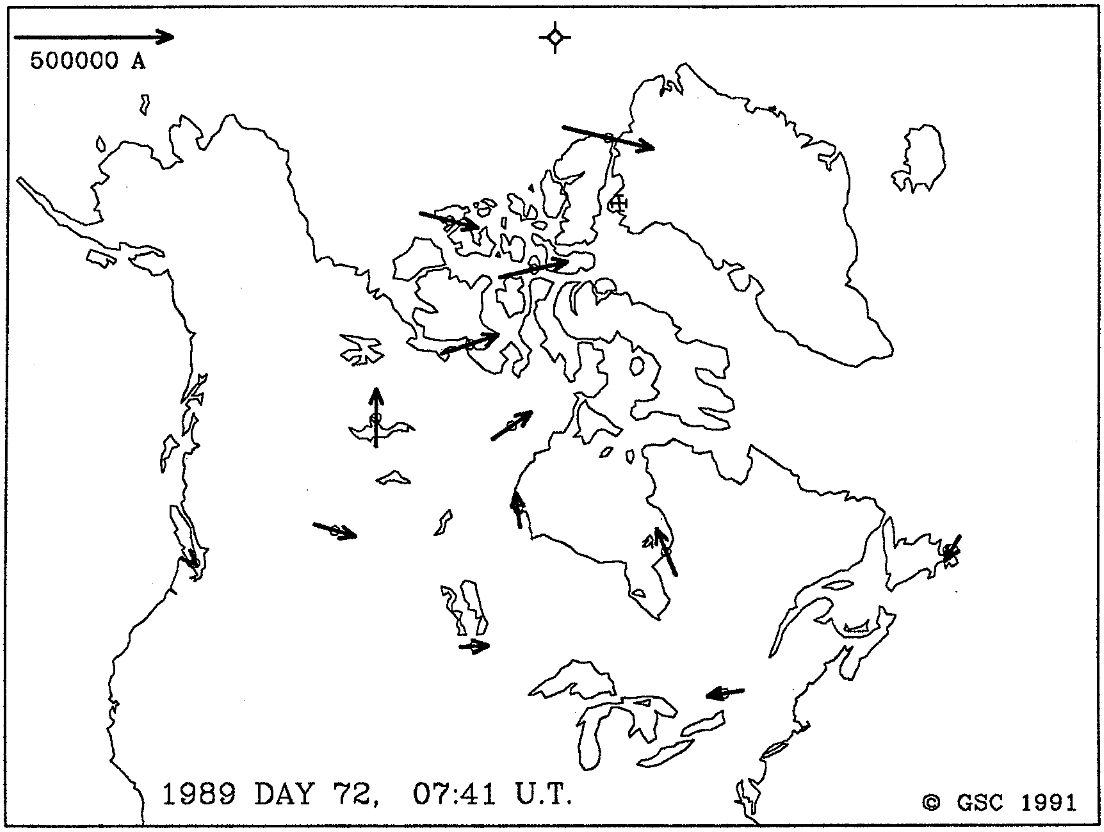
Equivalent Currents at 1 minute intervals

07:41 UT March 13 (Day 72) 1989
to
08:12 UT March 13 (Day 72) 1989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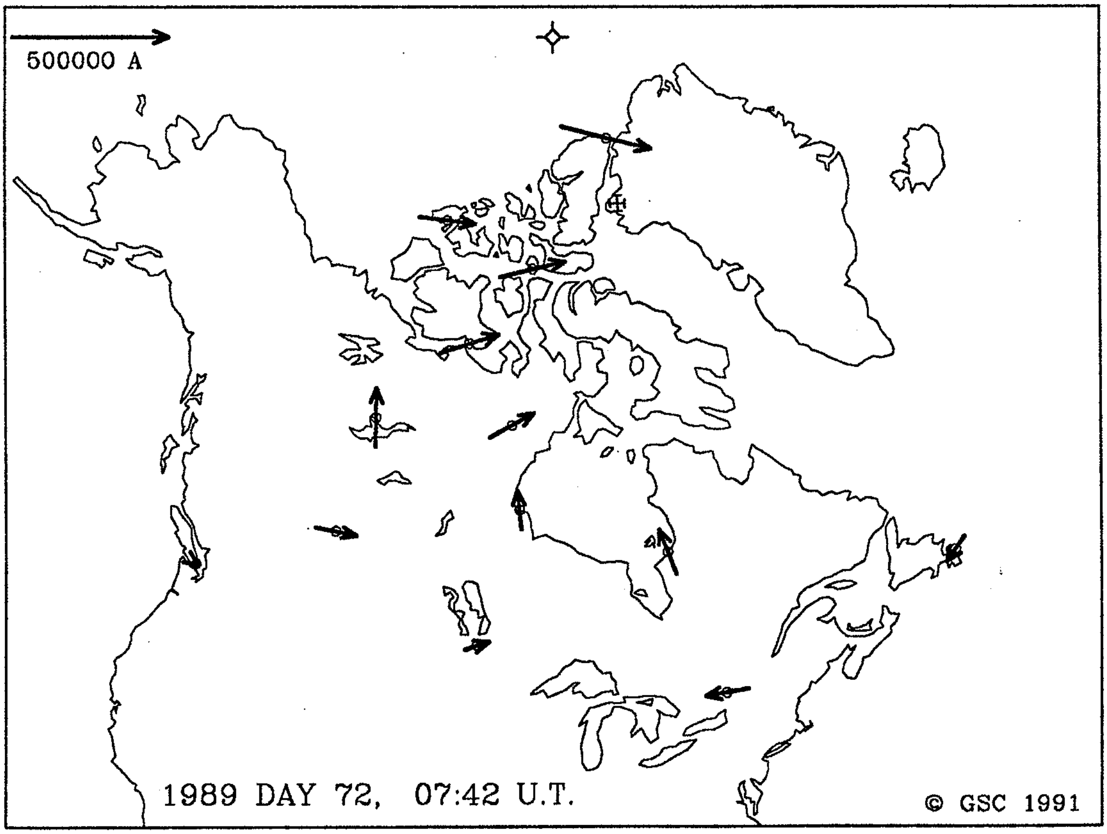
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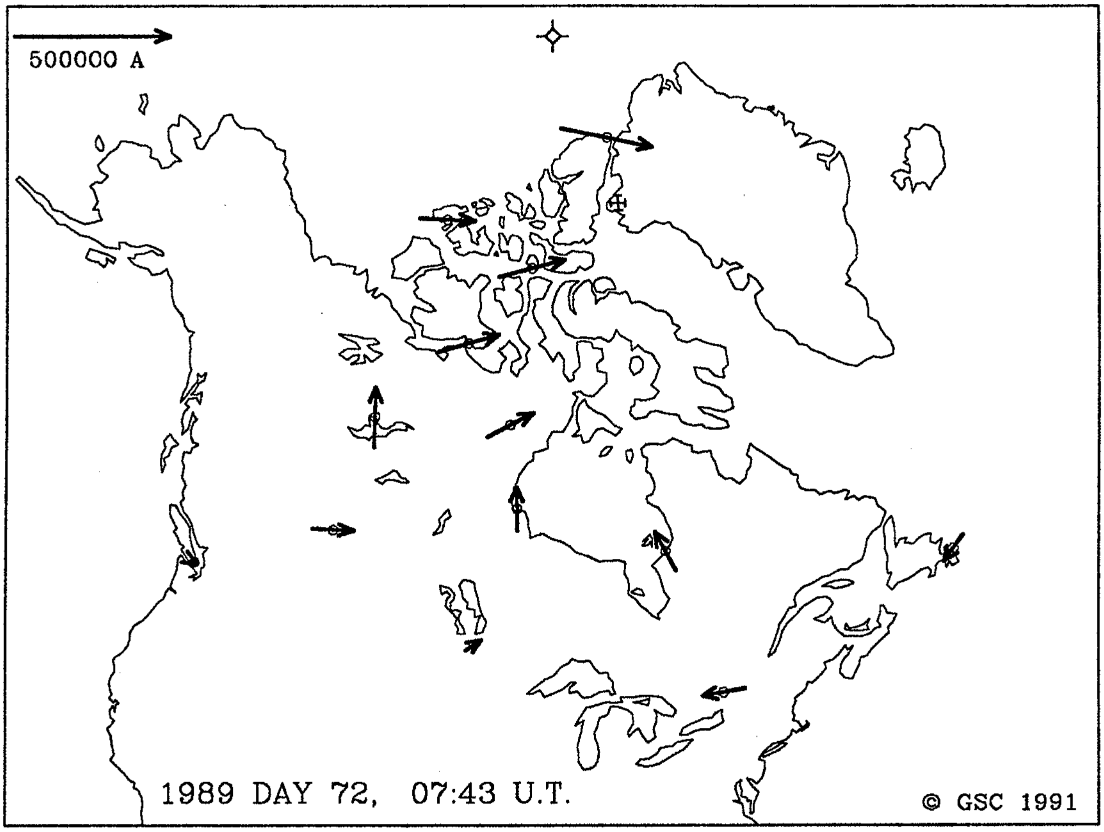
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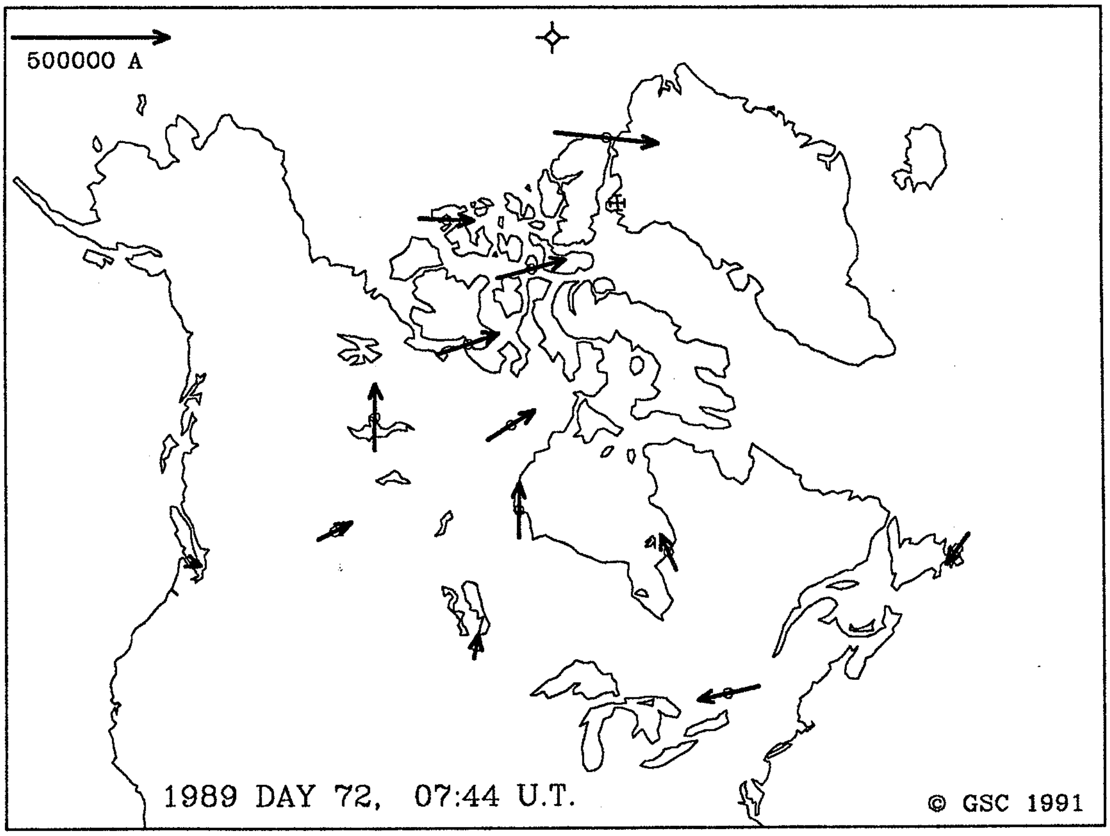
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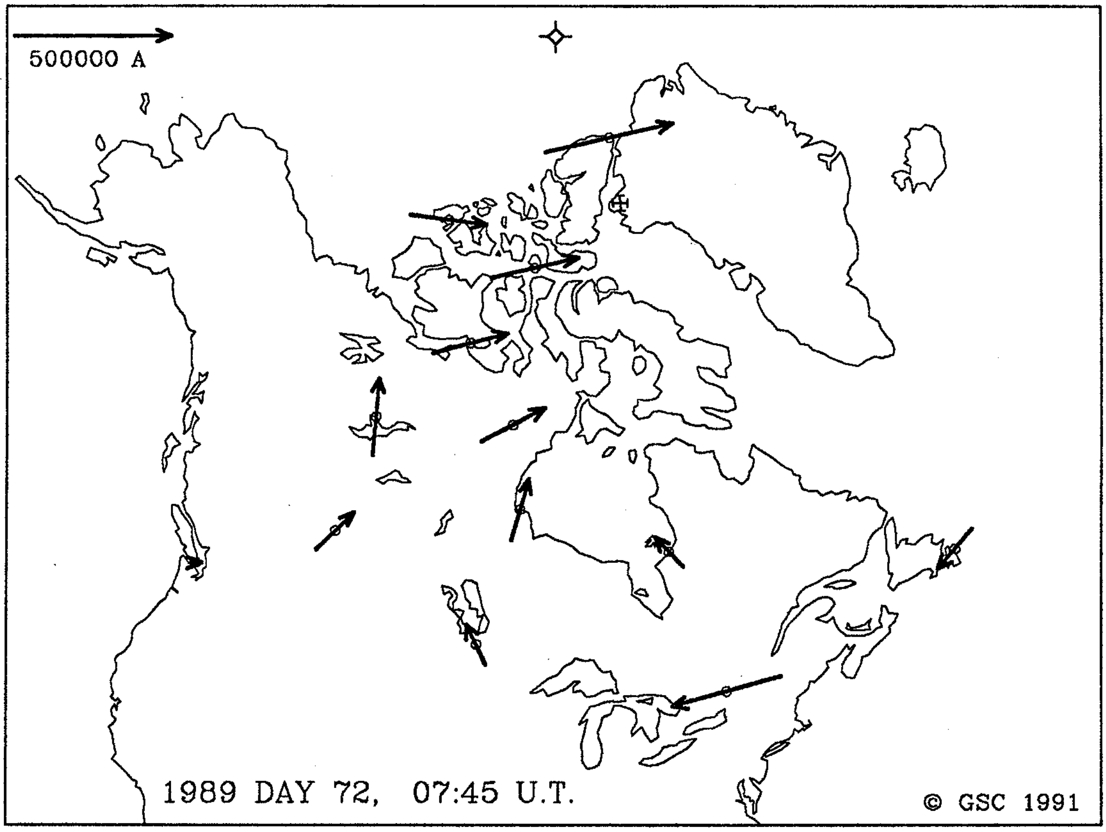
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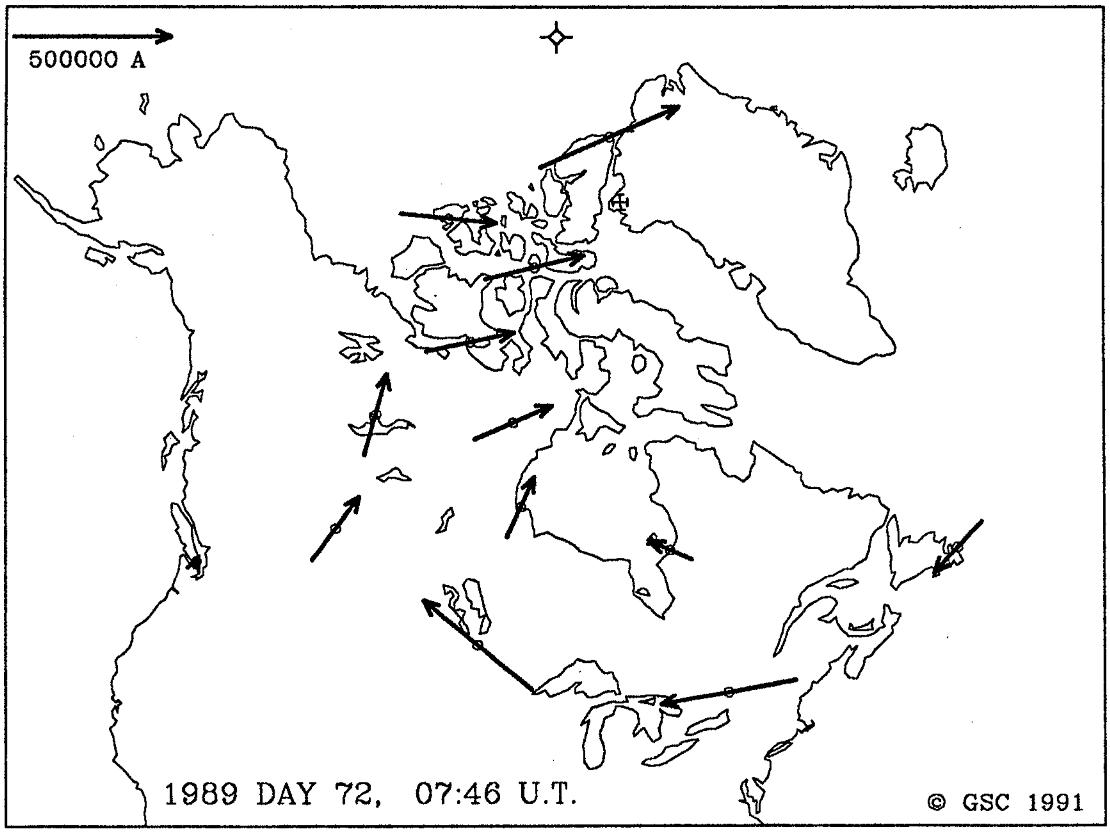
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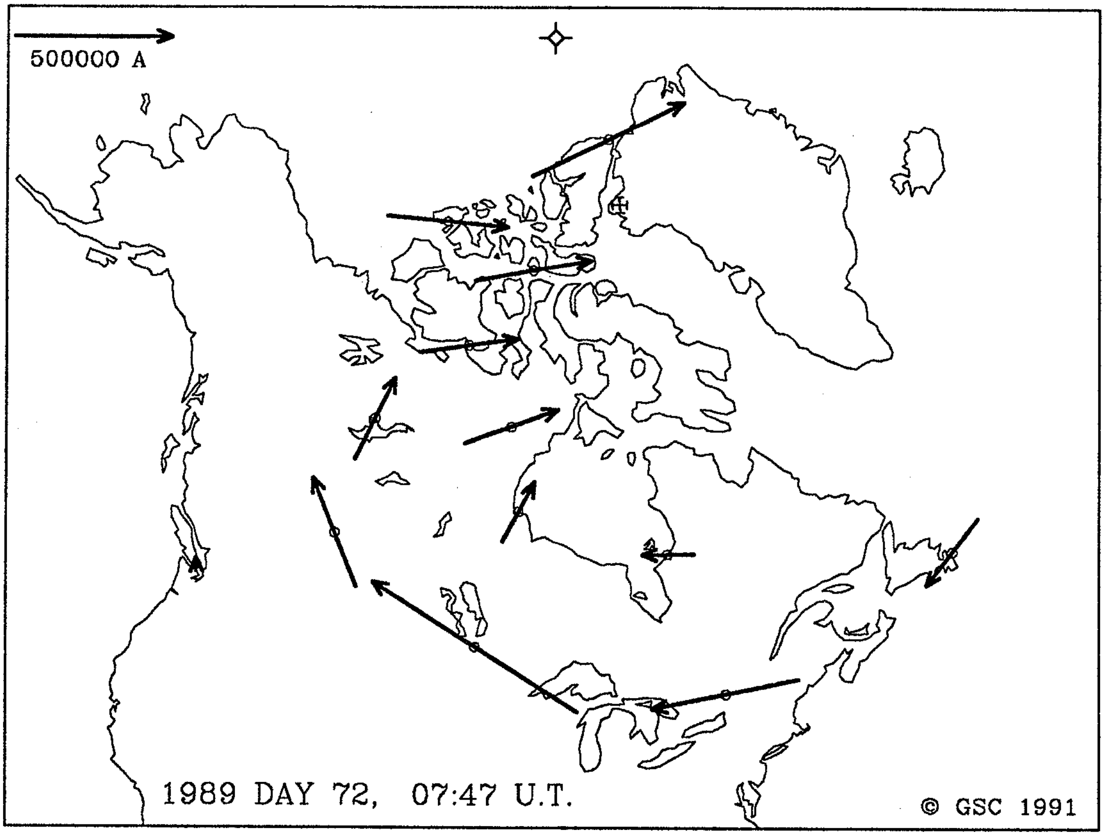
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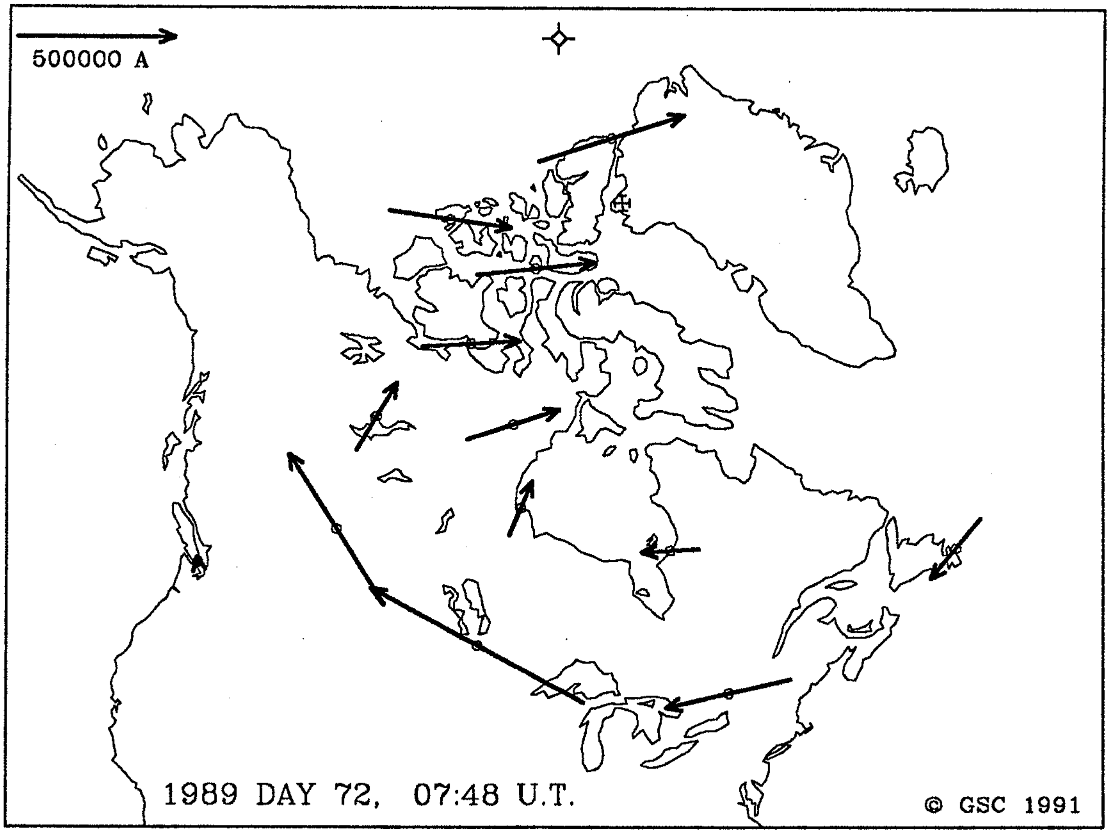
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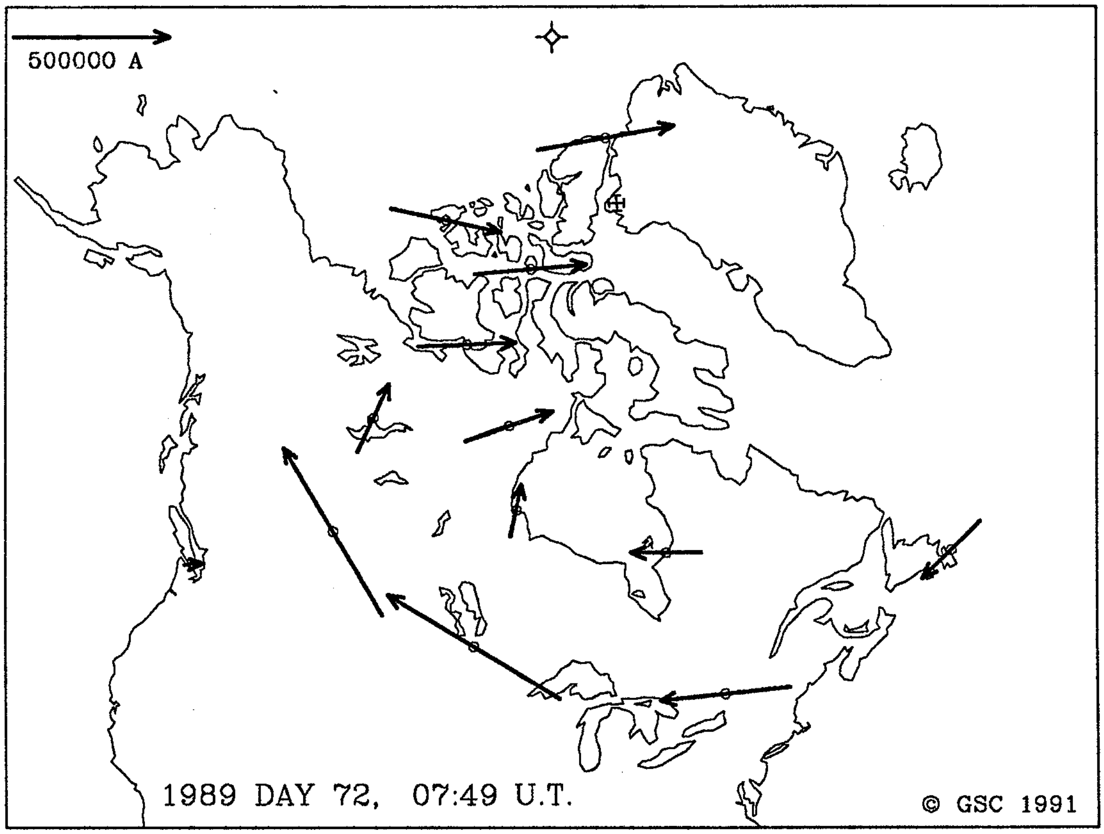
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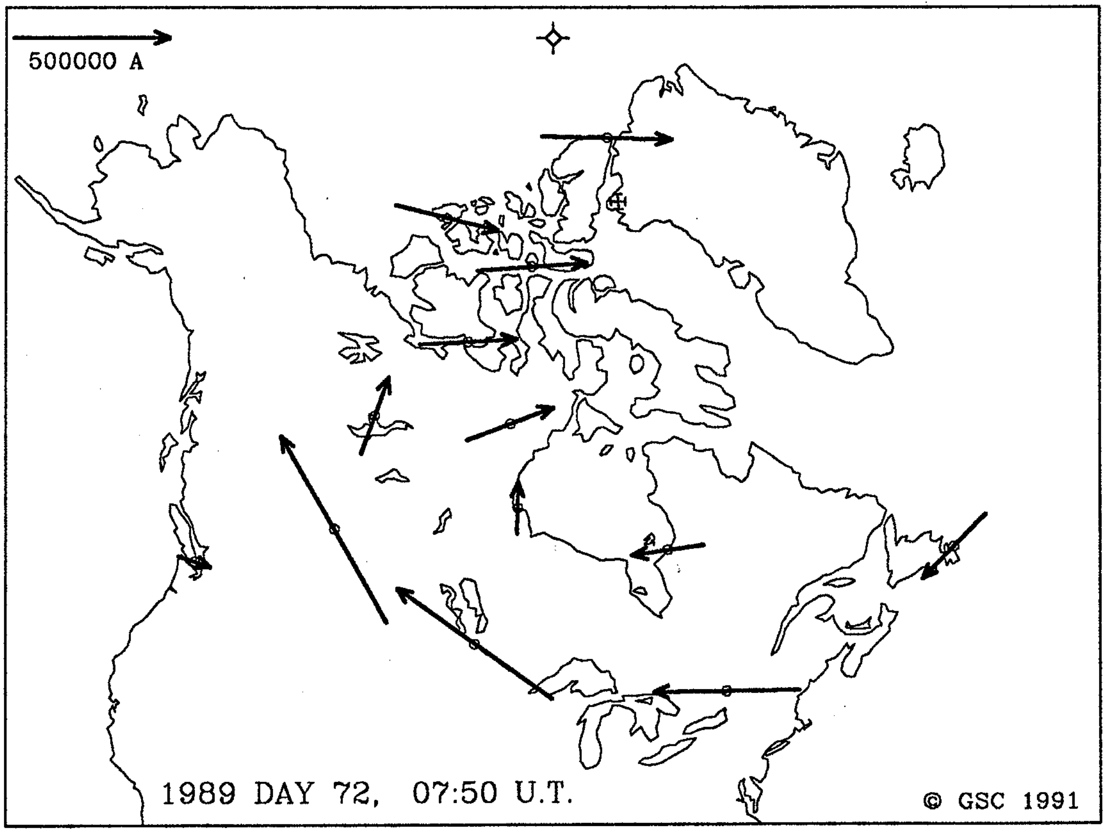
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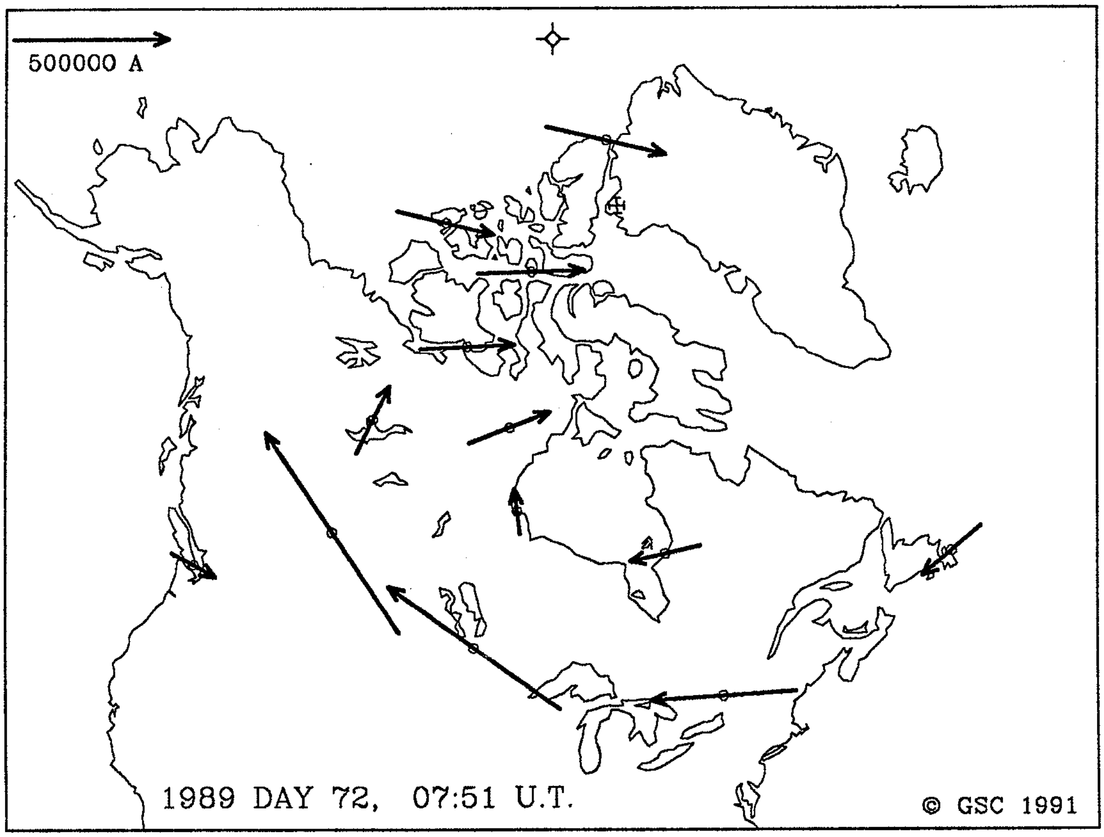
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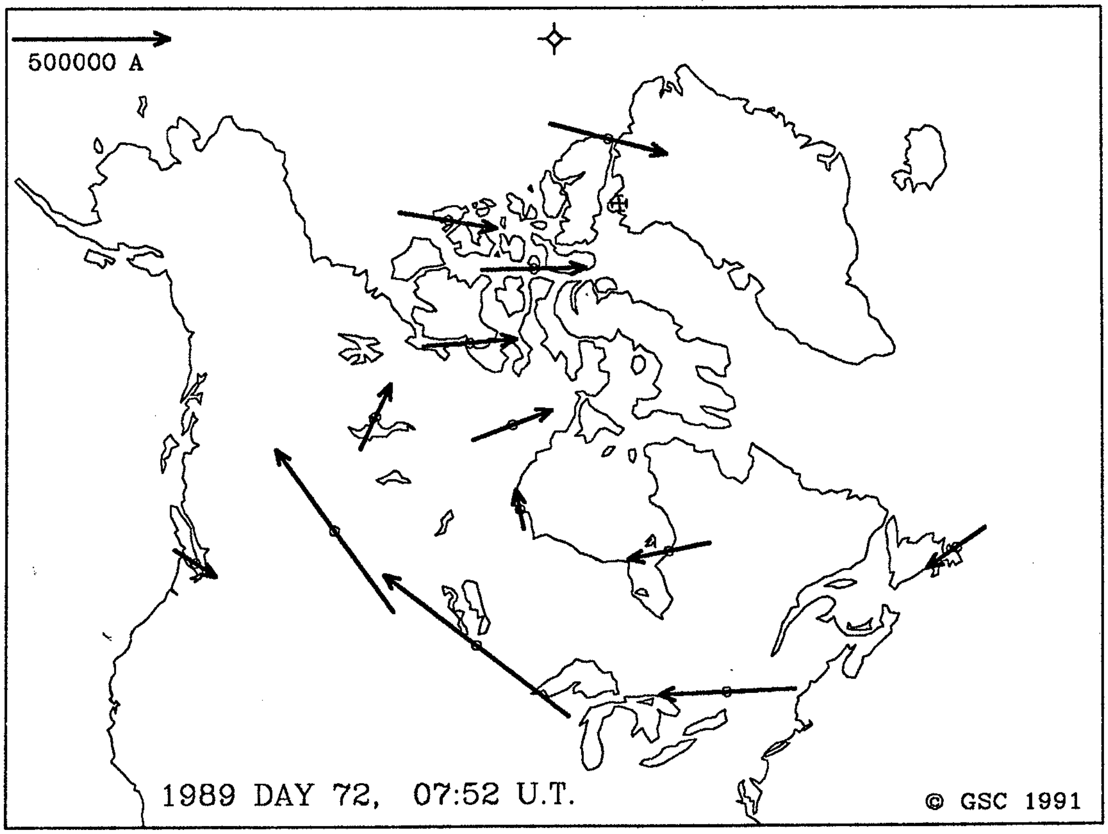
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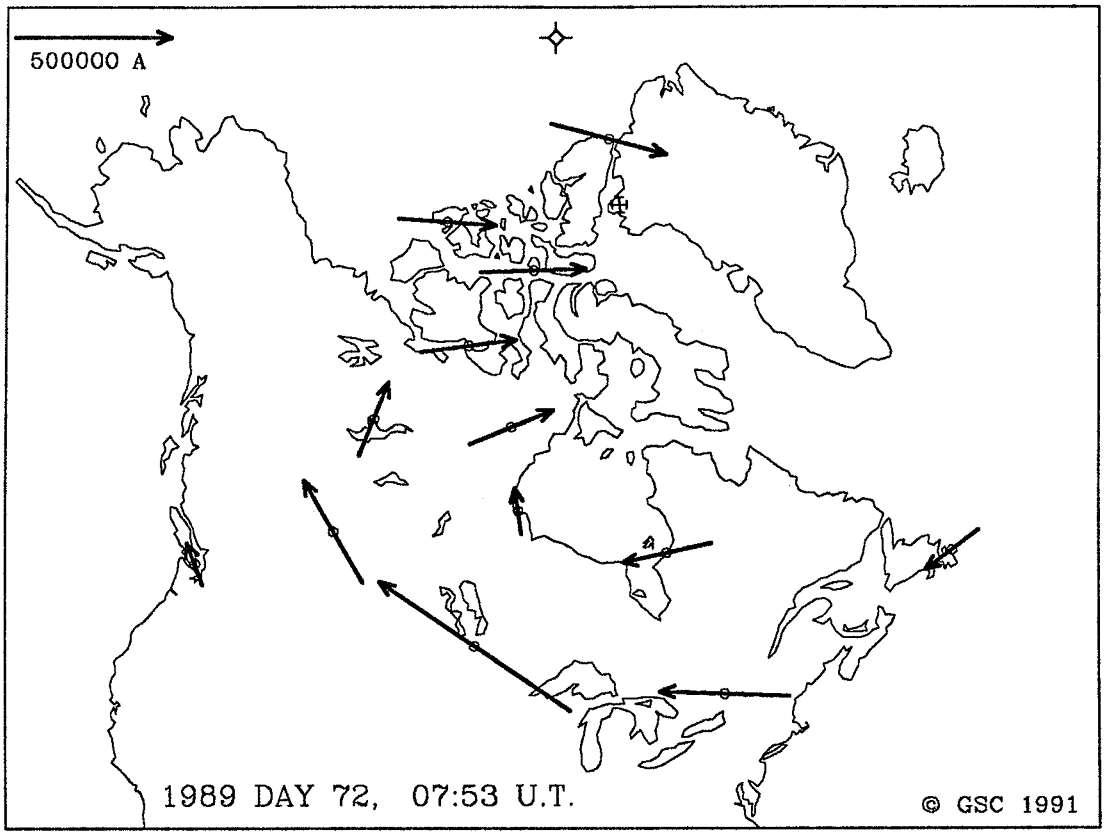
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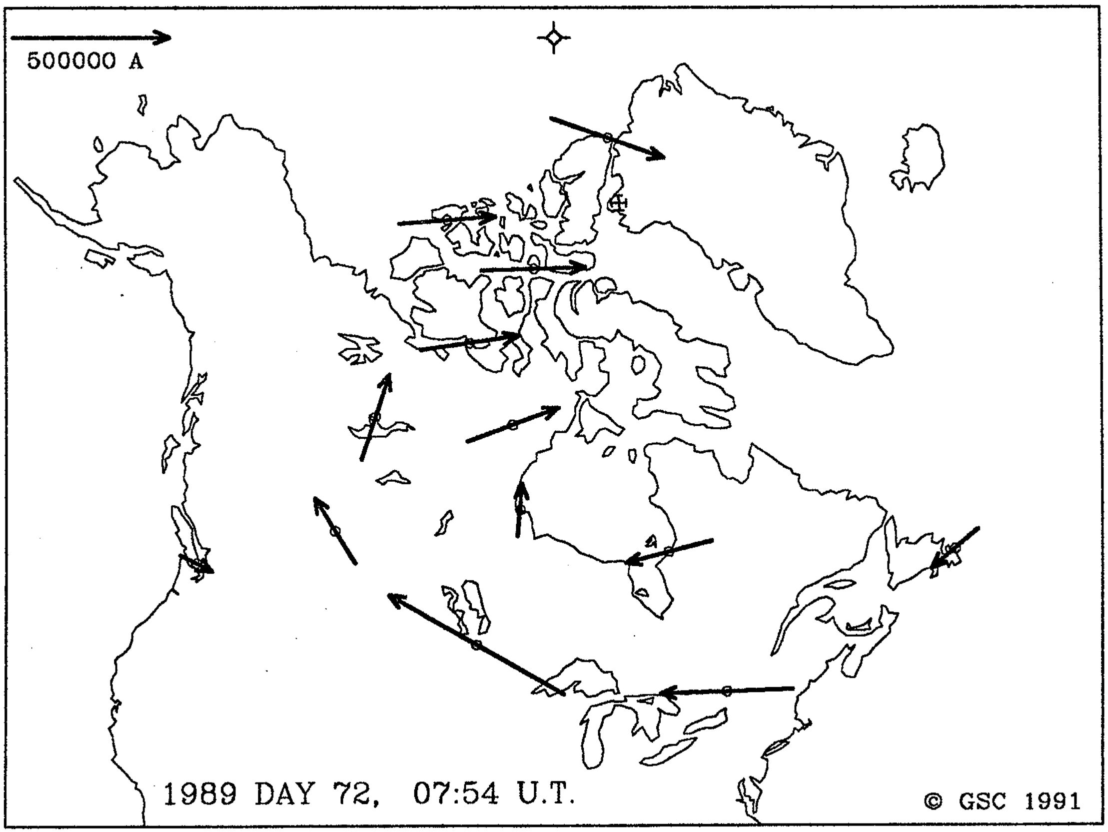
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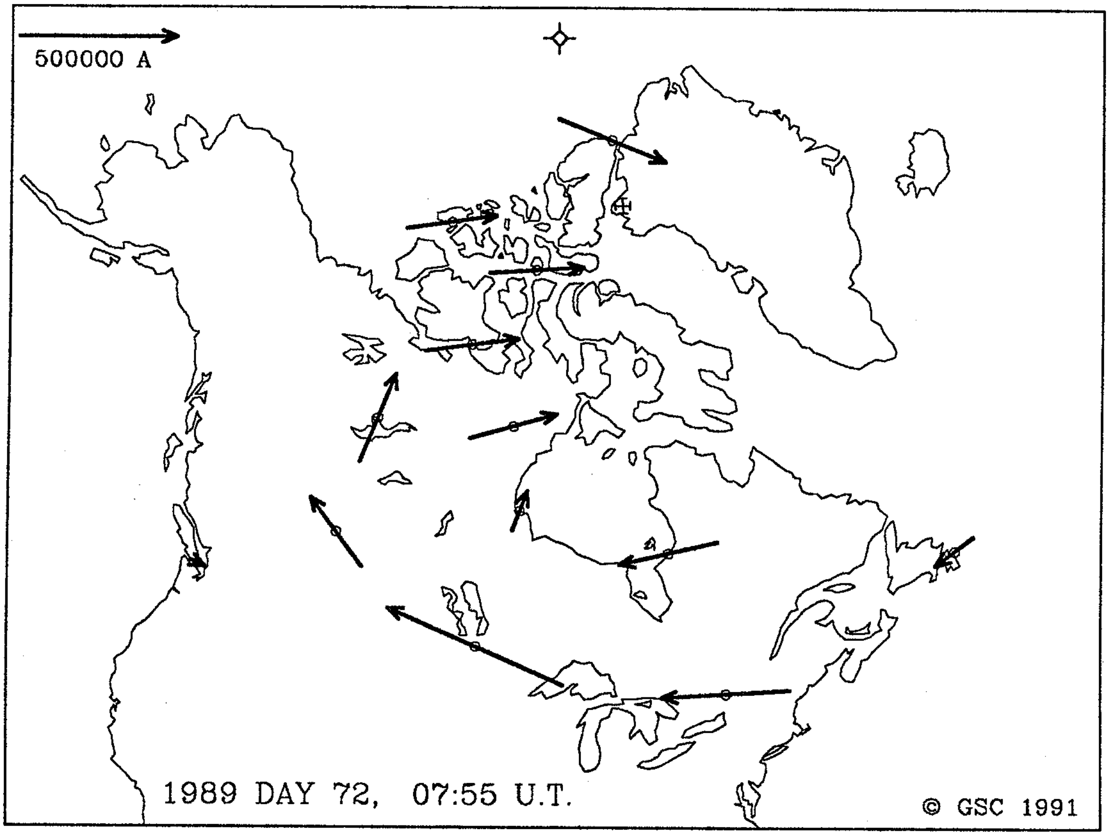
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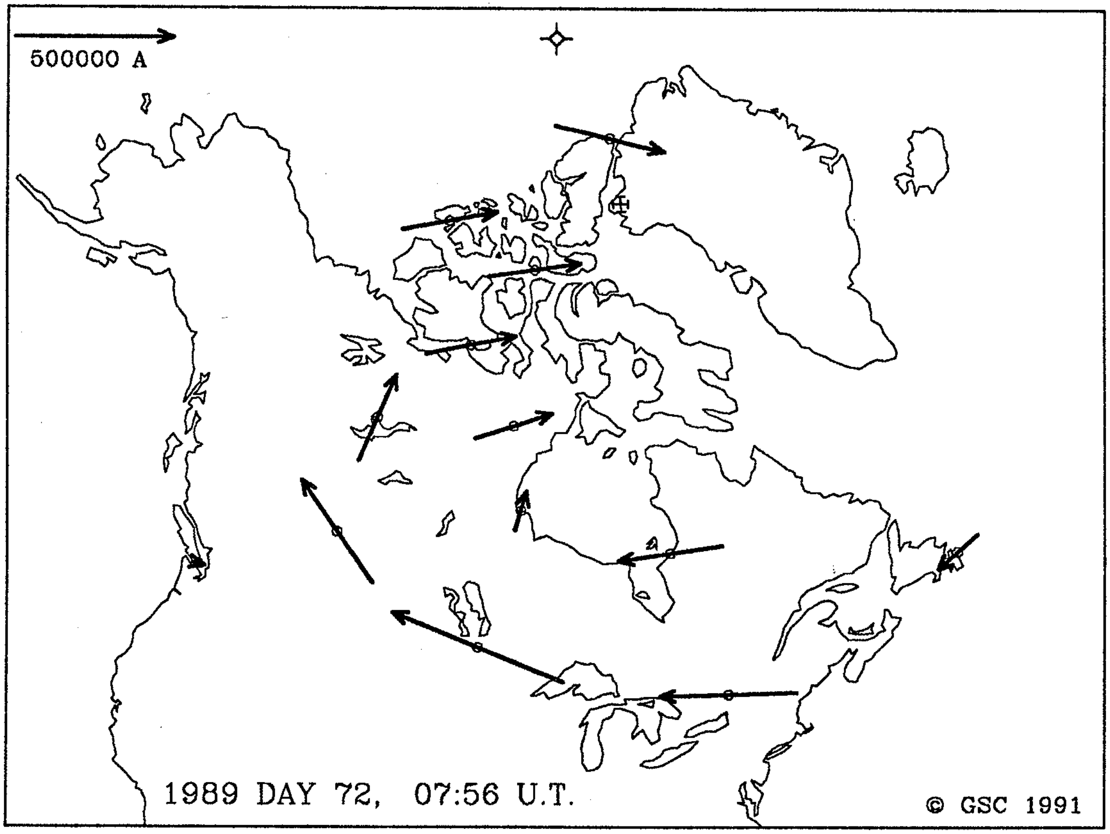
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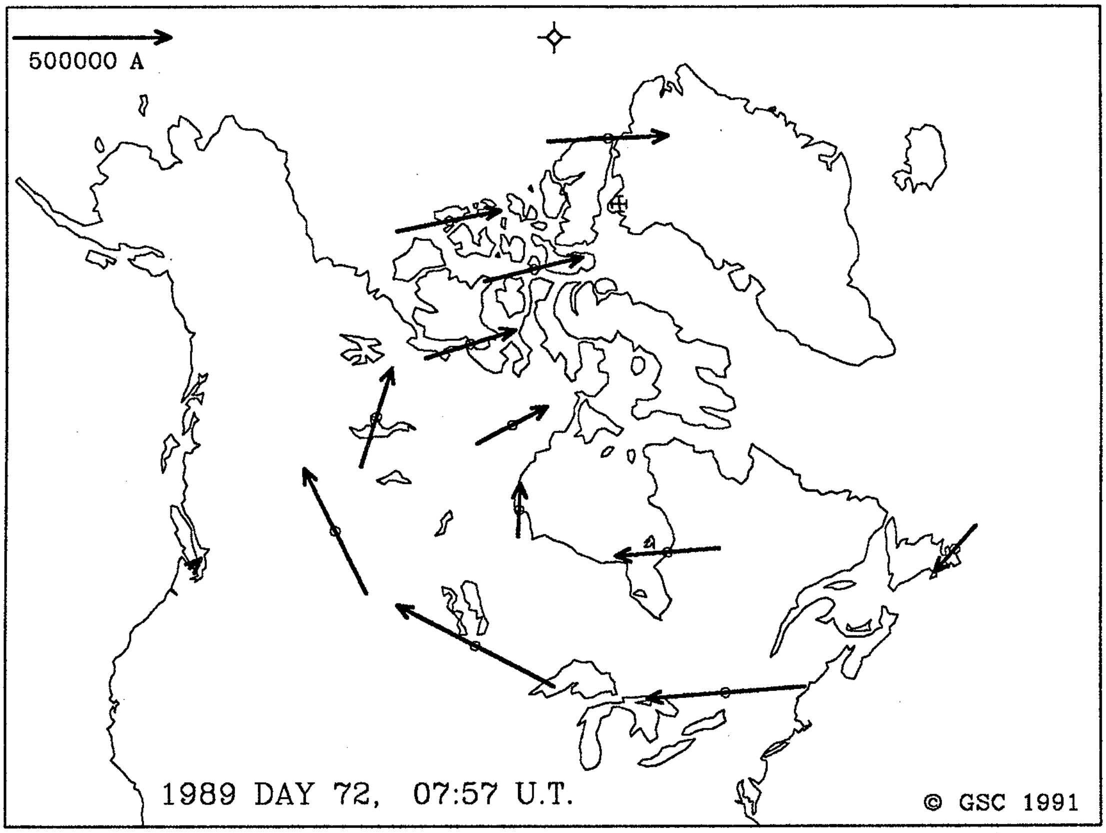
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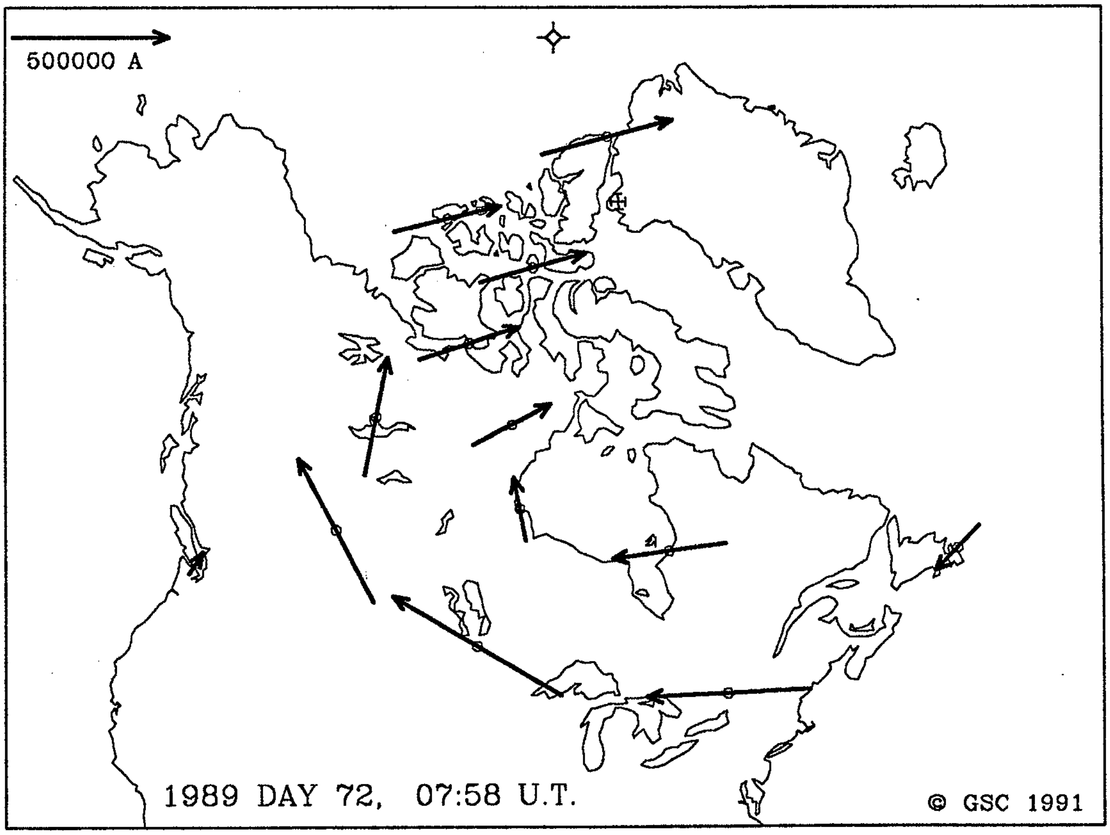
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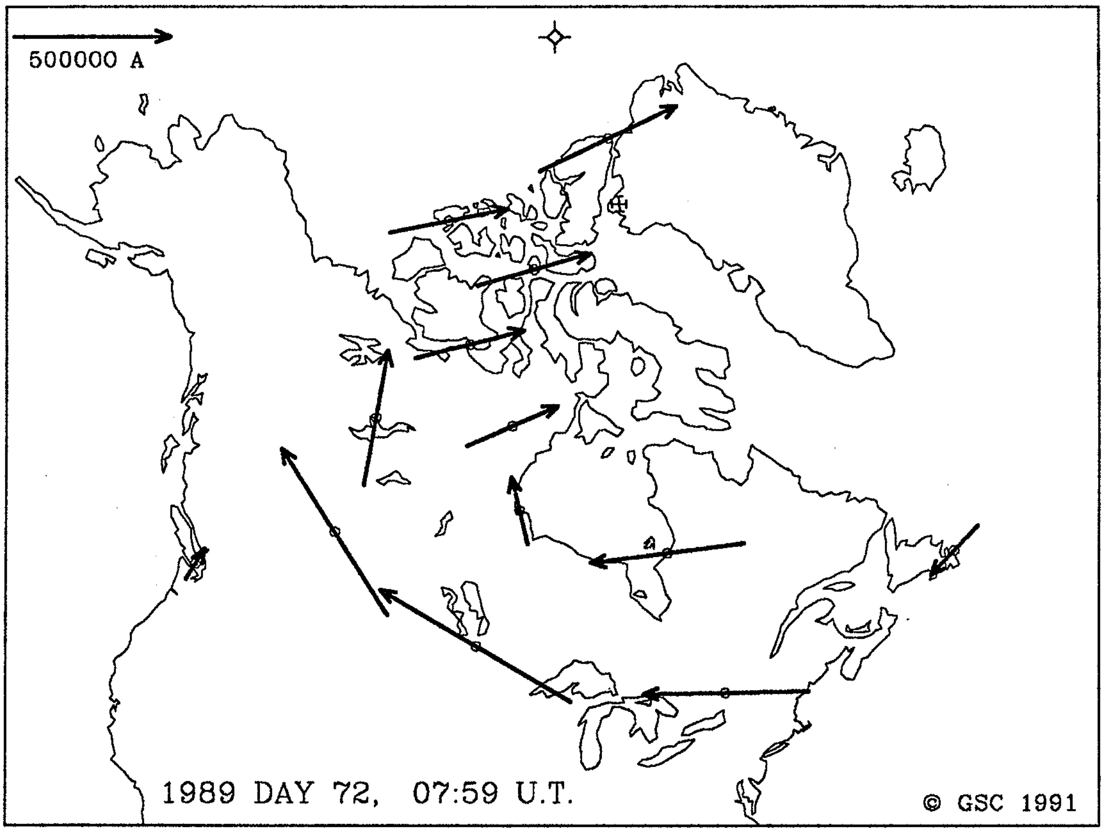
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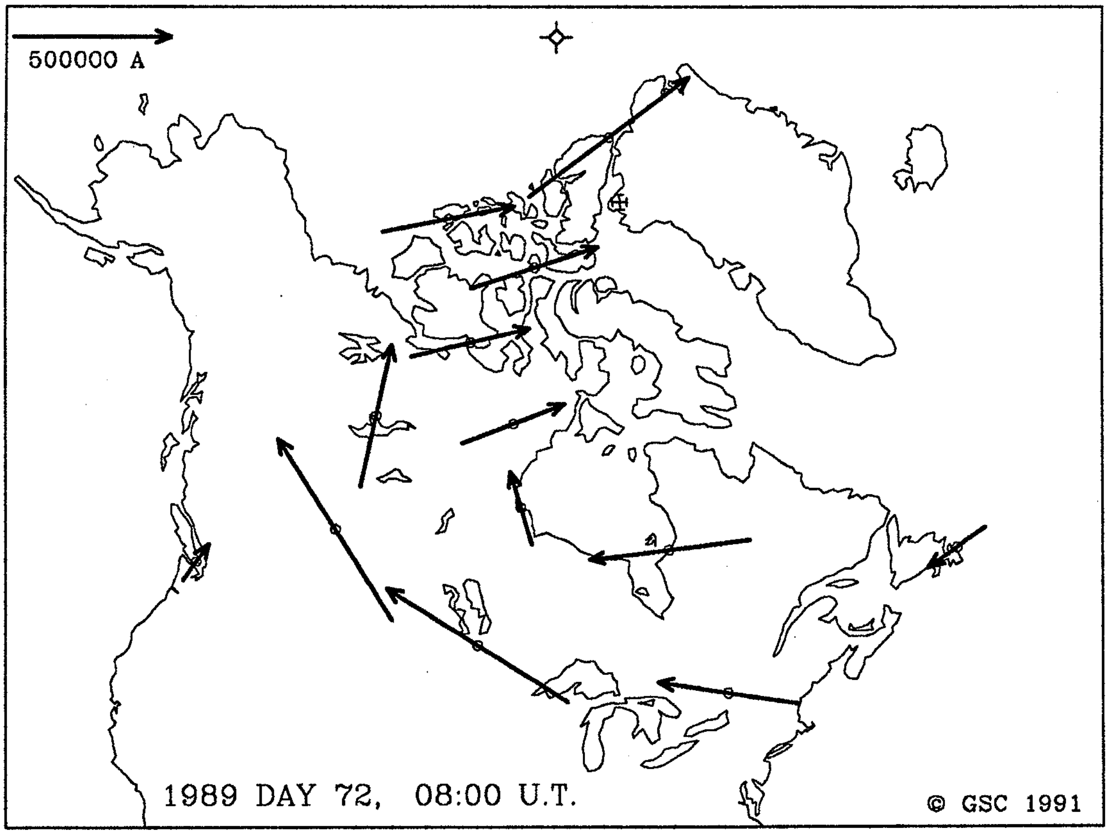
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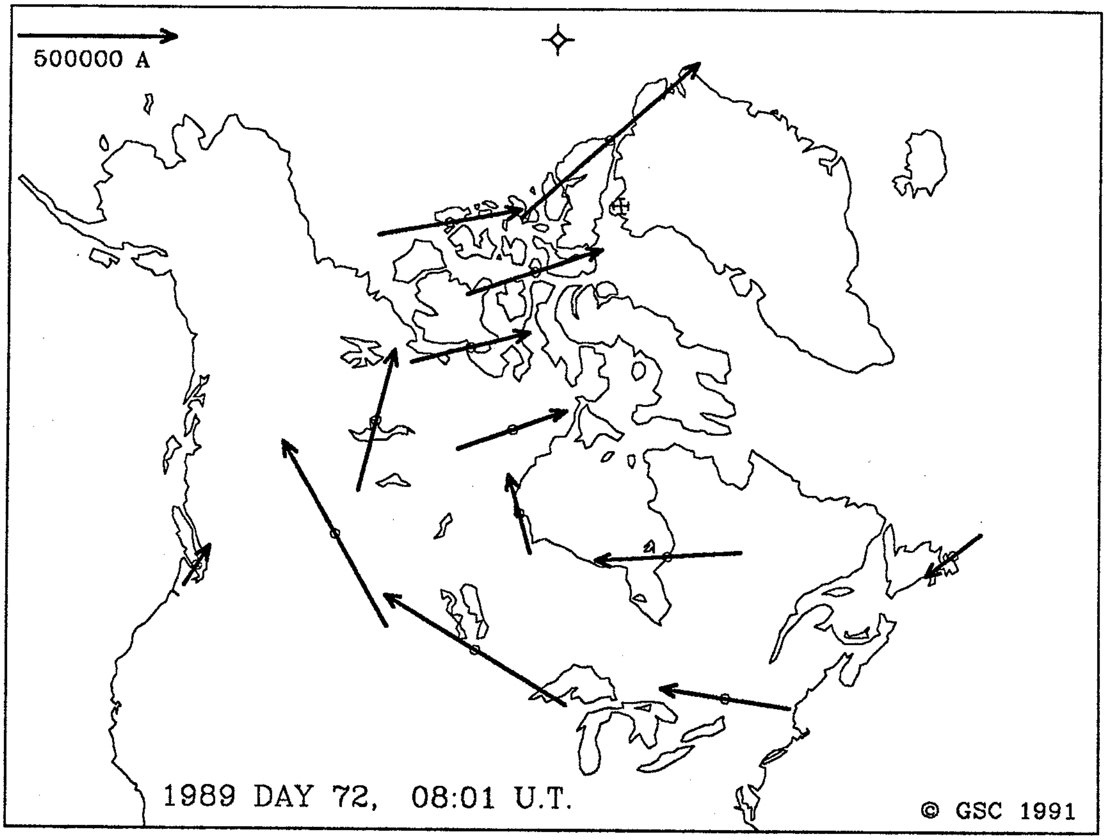
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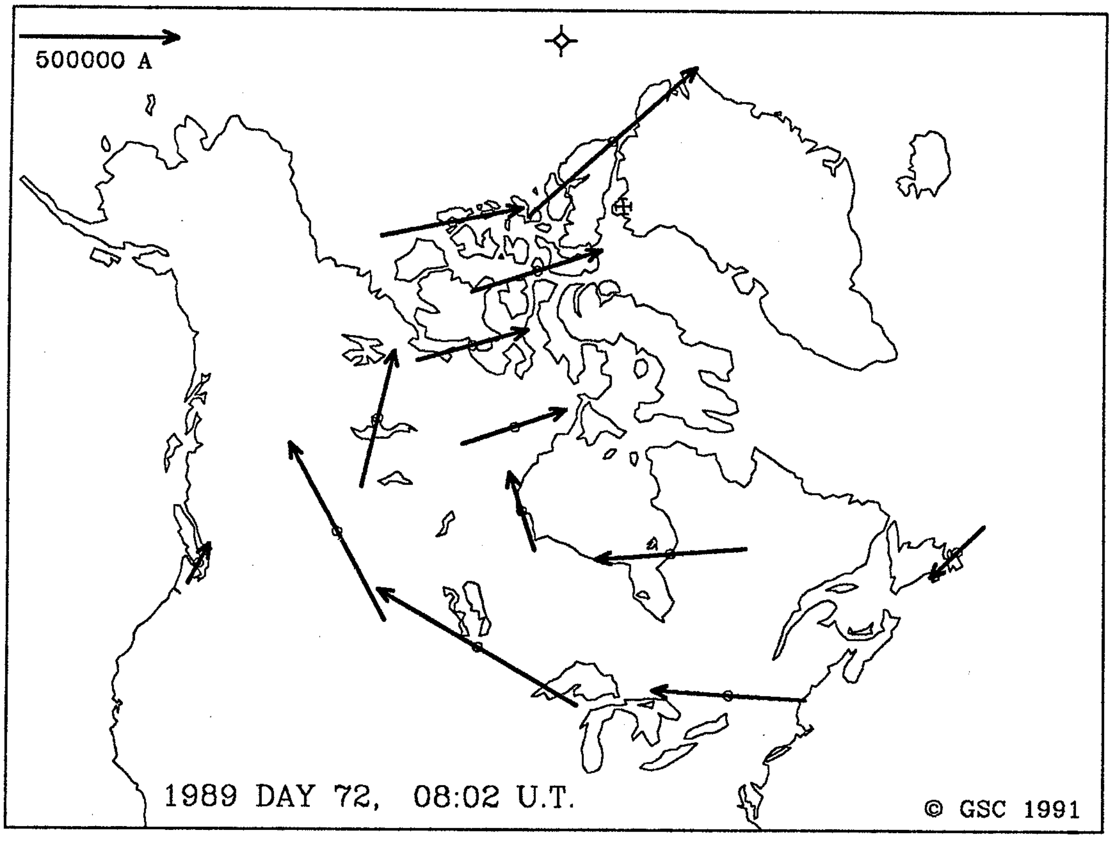
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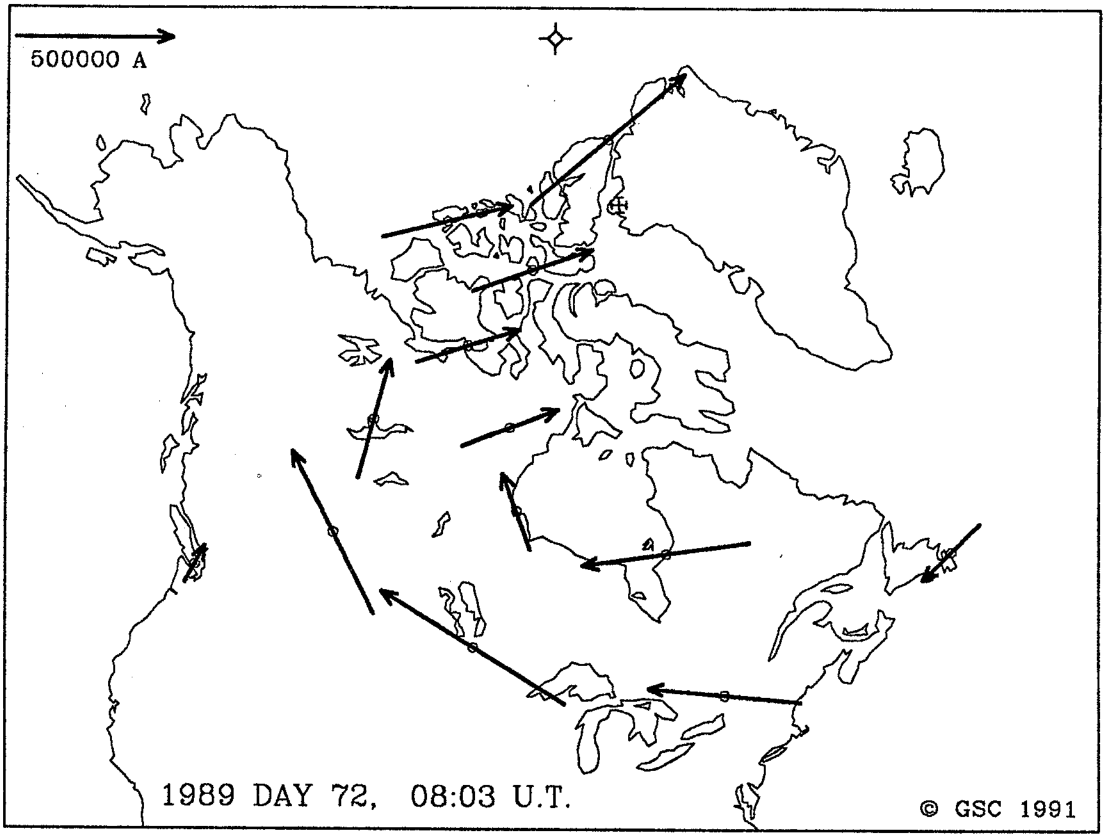
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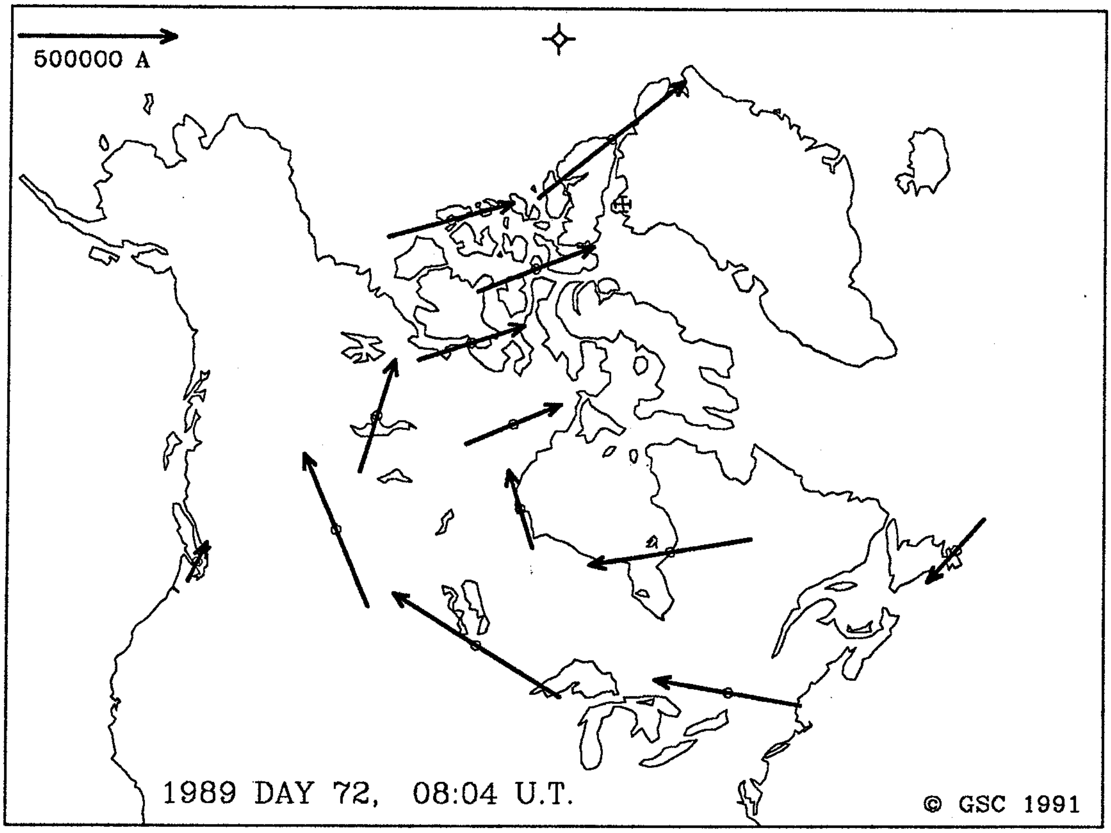
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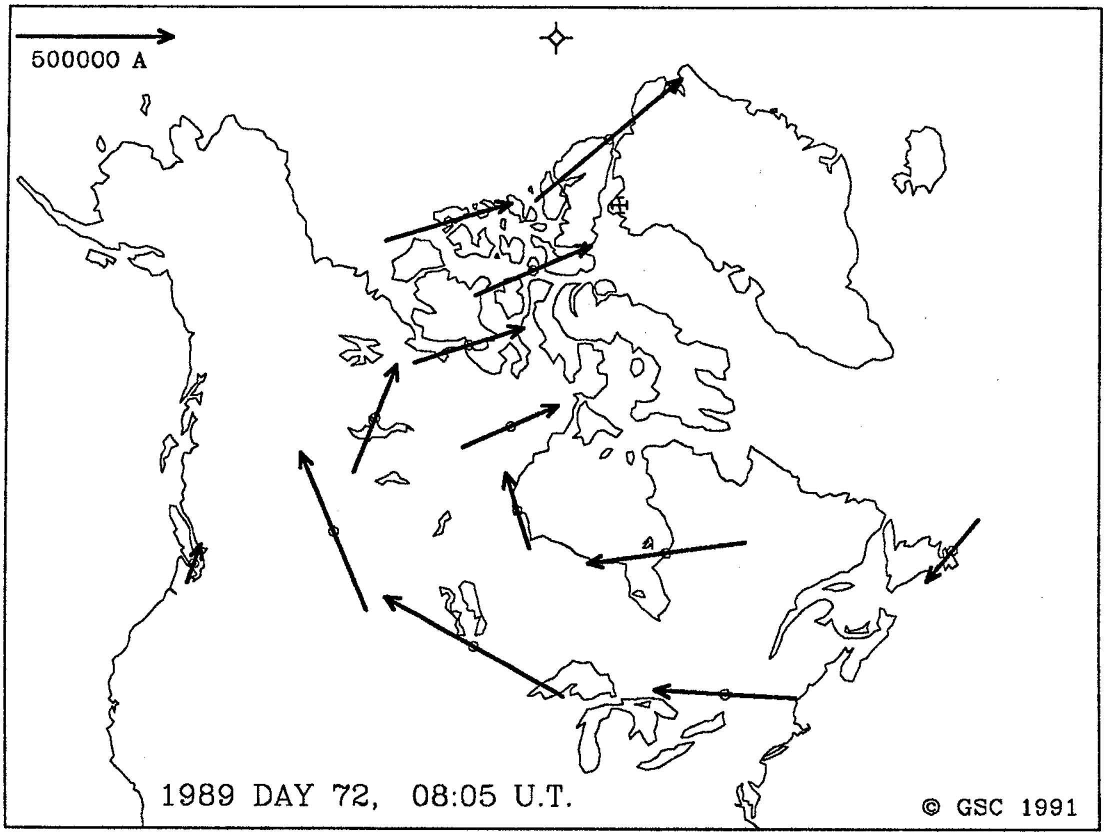
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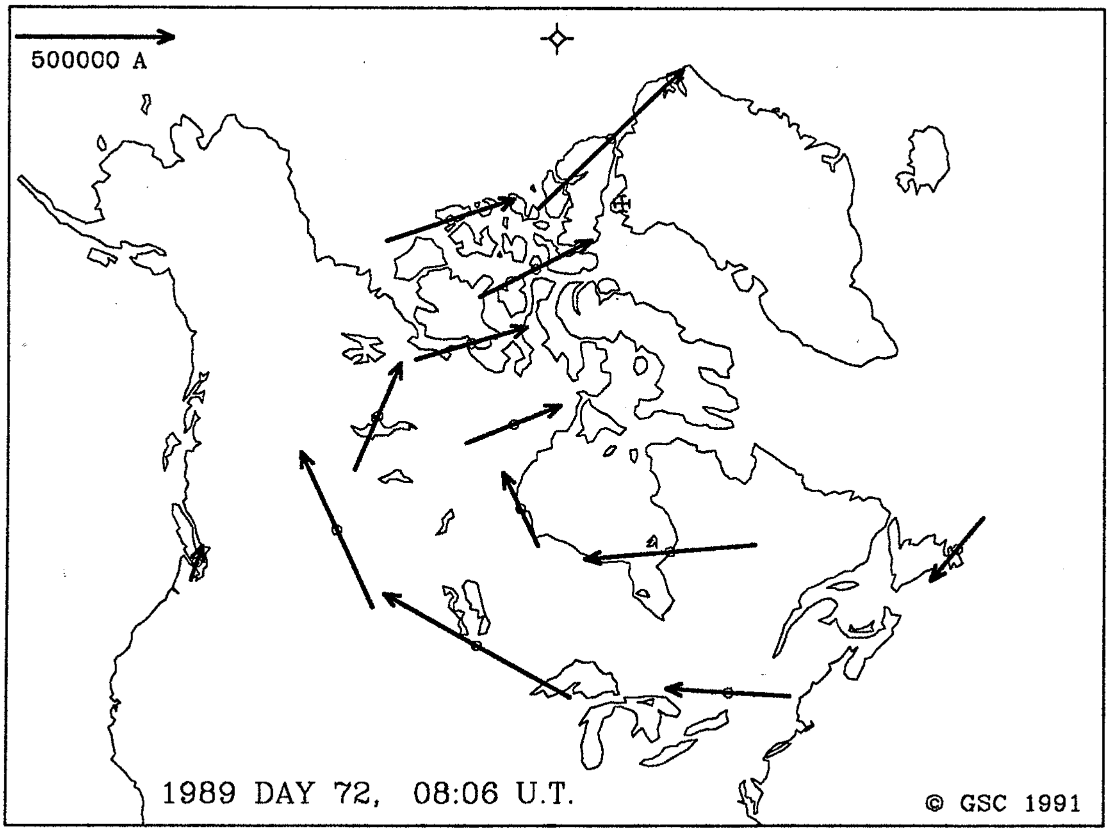
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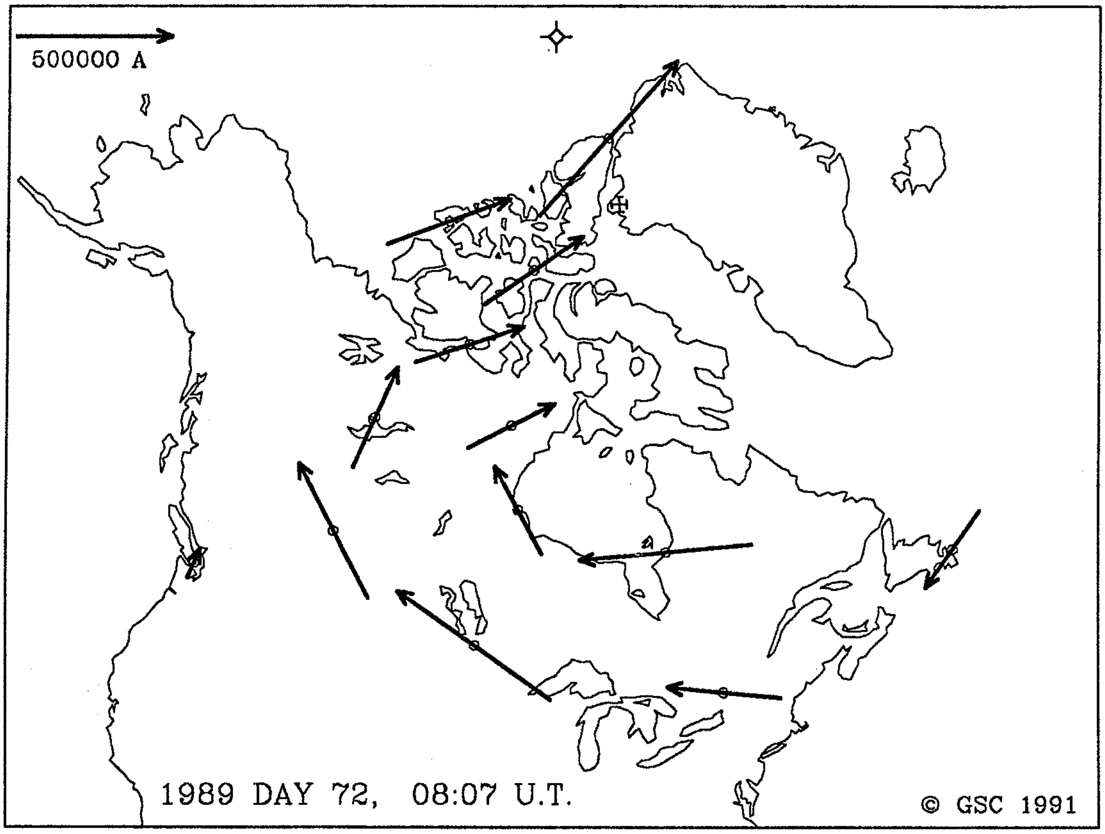
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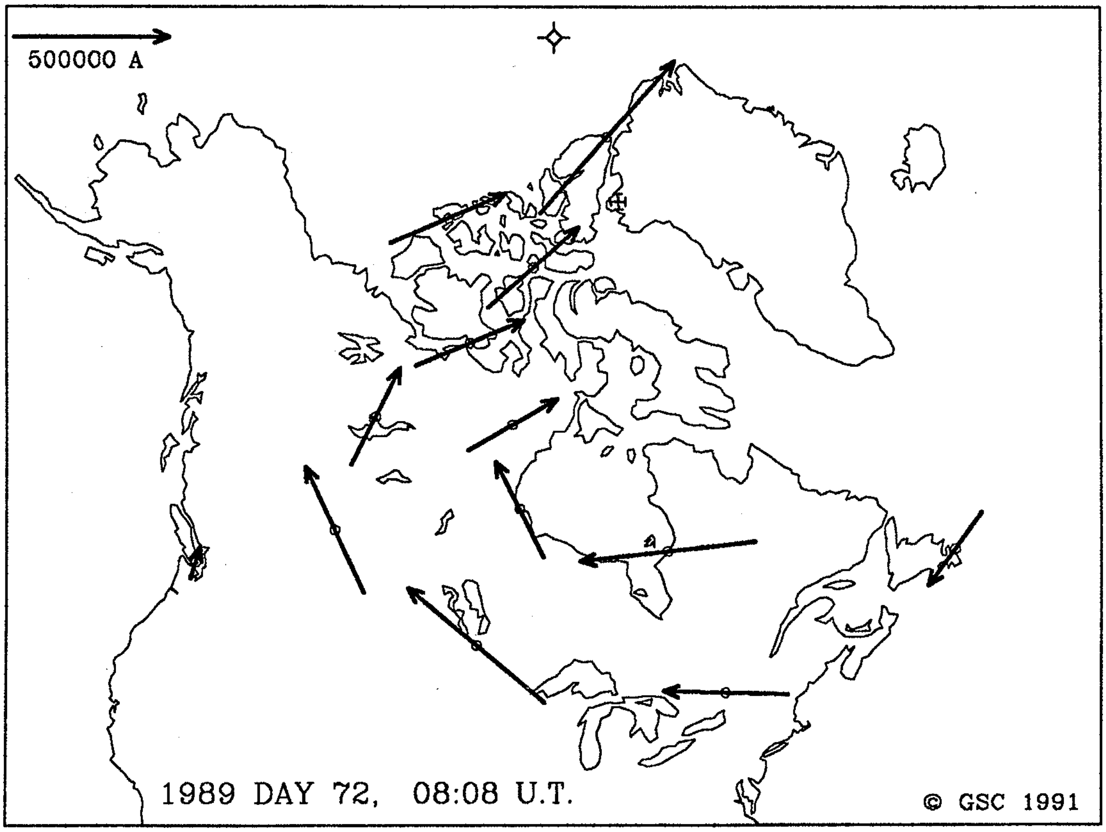
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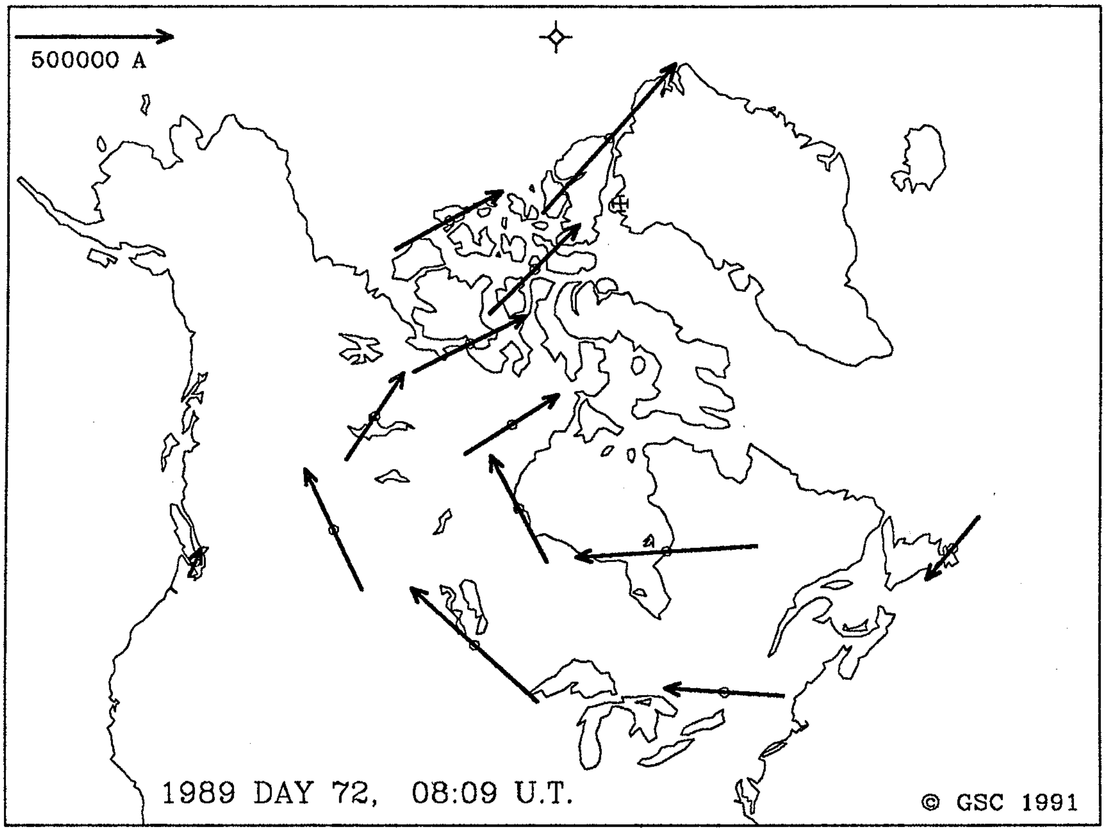
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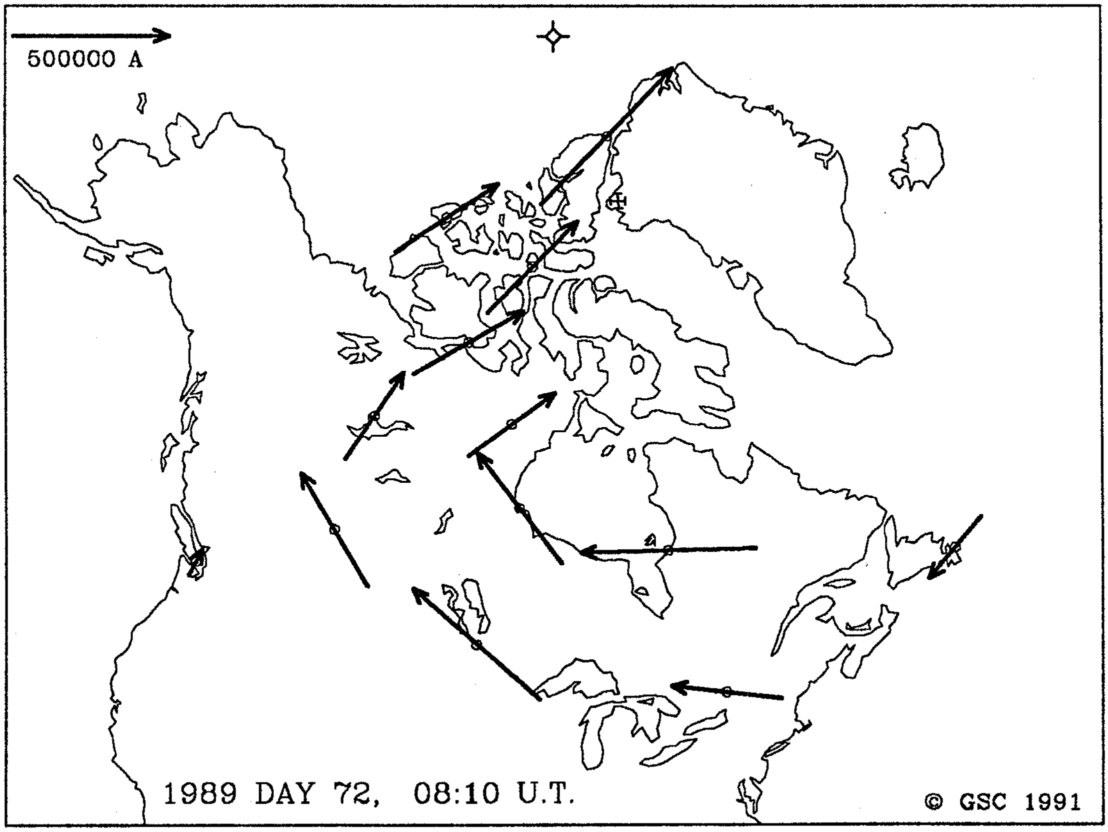
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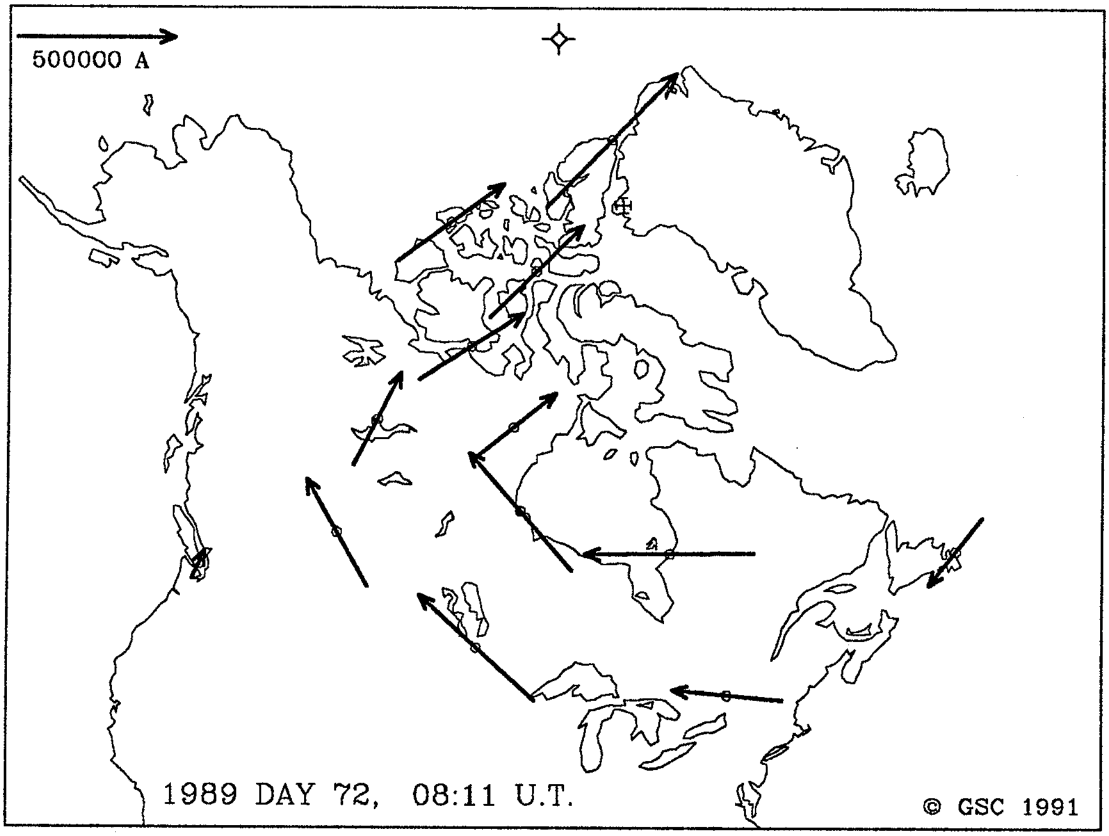
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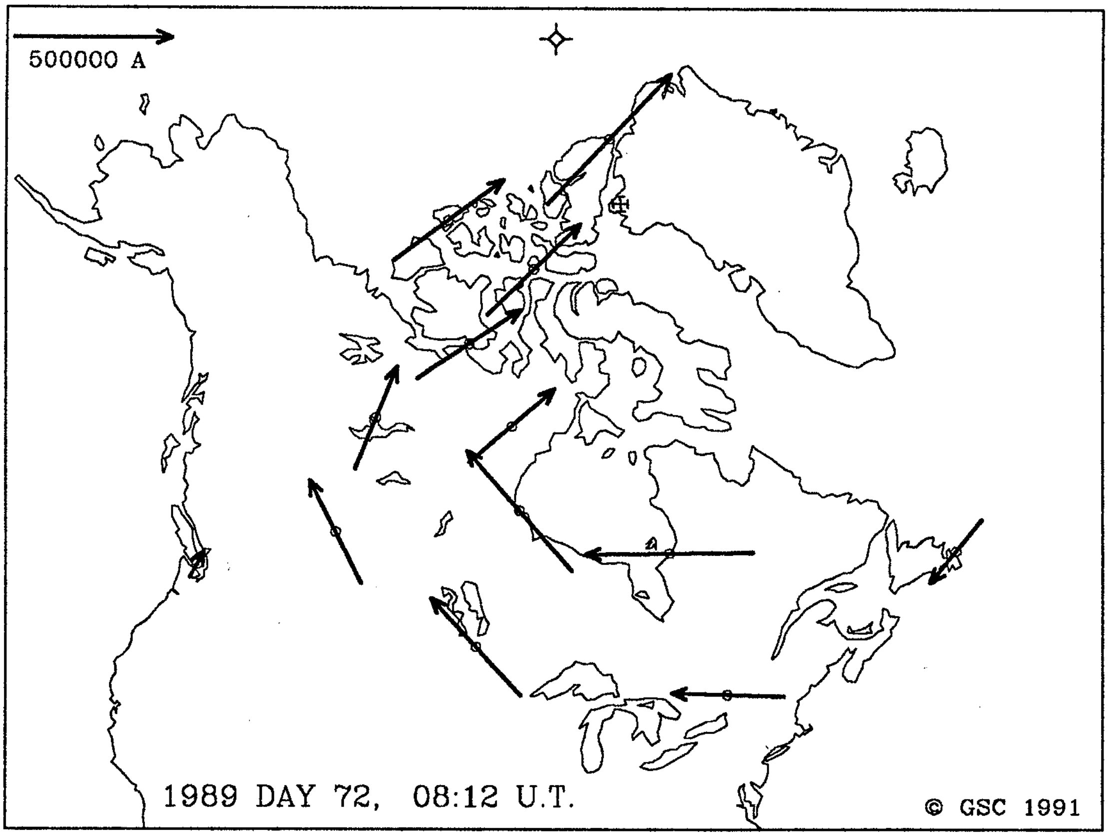
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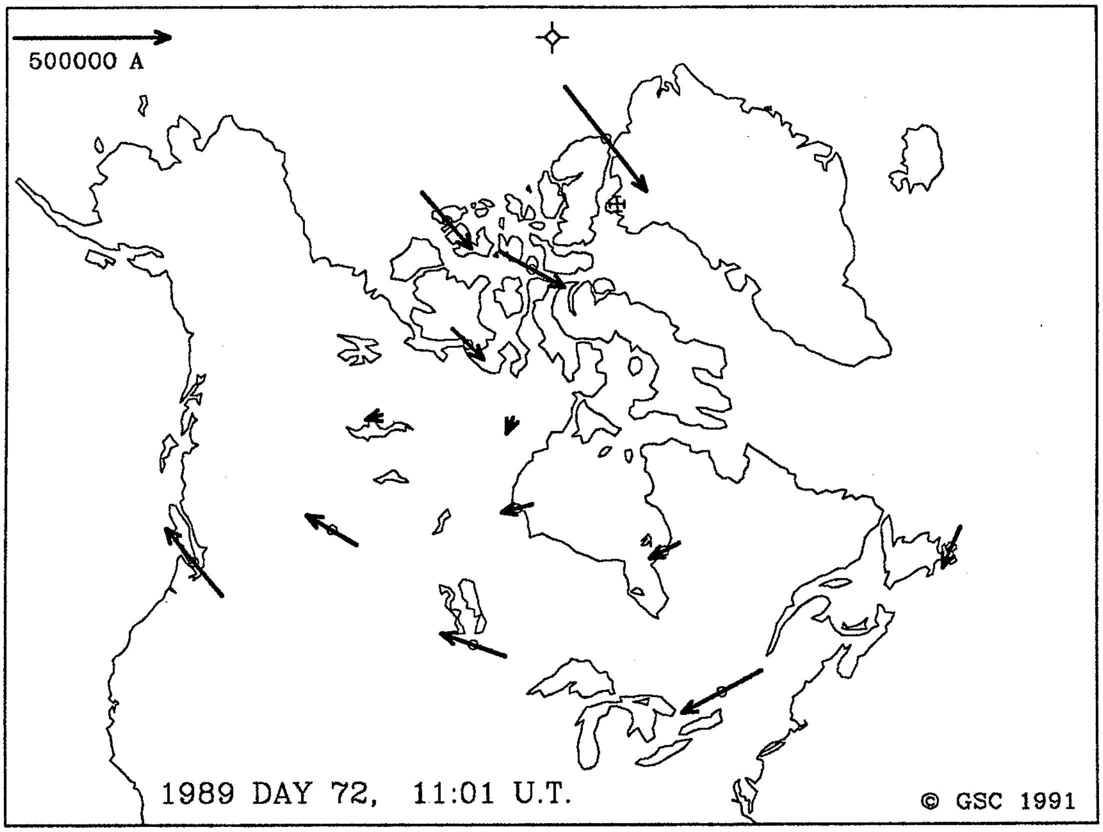
Equivalent Currents at 1 minute intervals

11:01 UT March 13 (Day 72) 1989
to
12:00 UT March 13 (Day 72) 1989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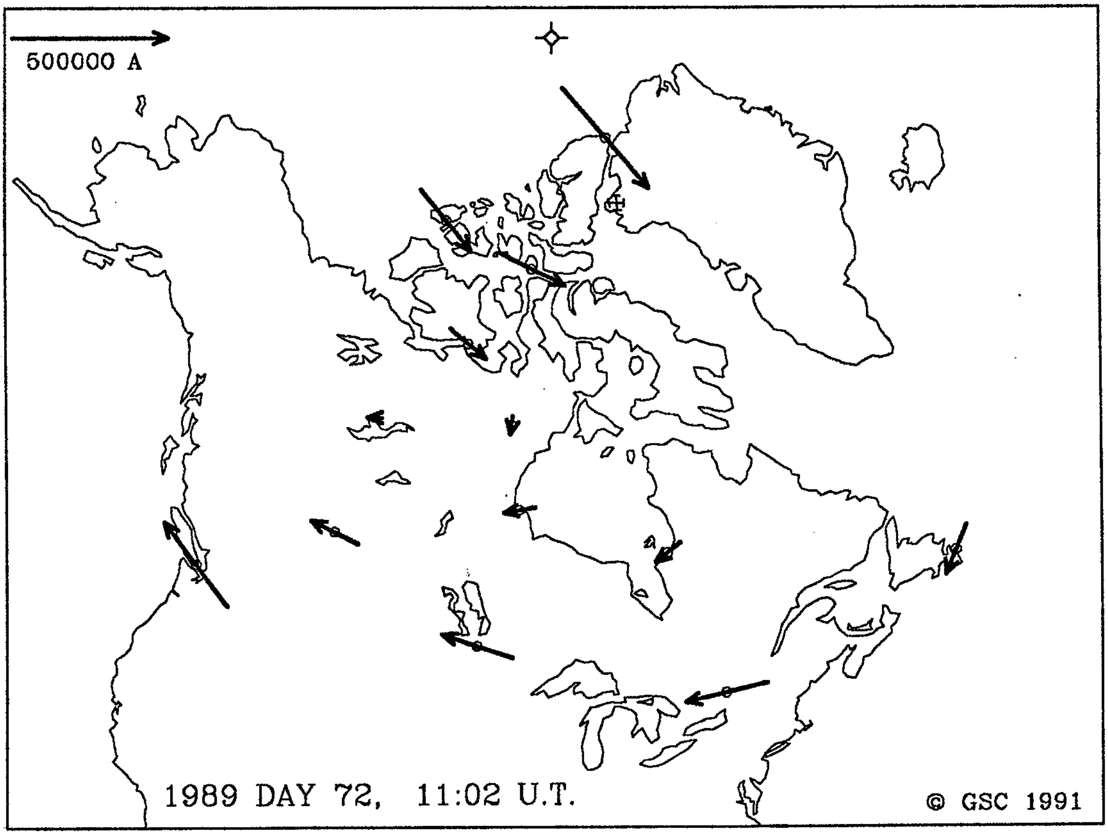
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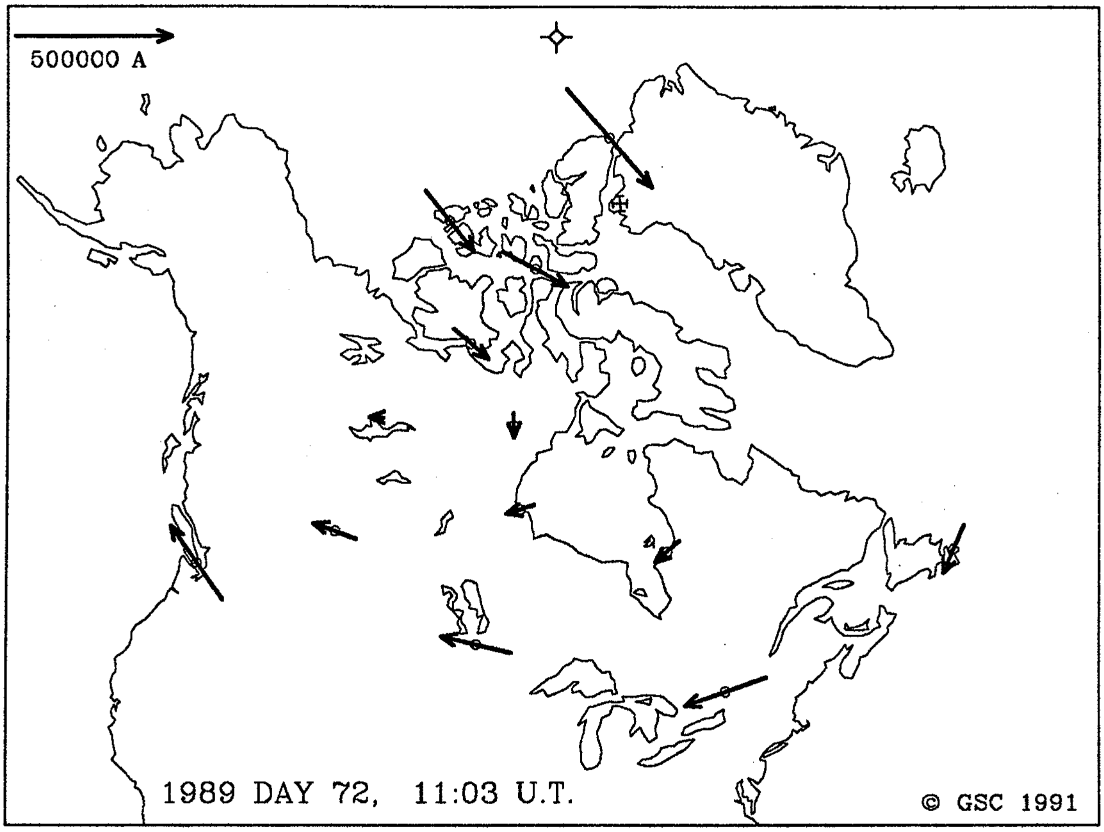
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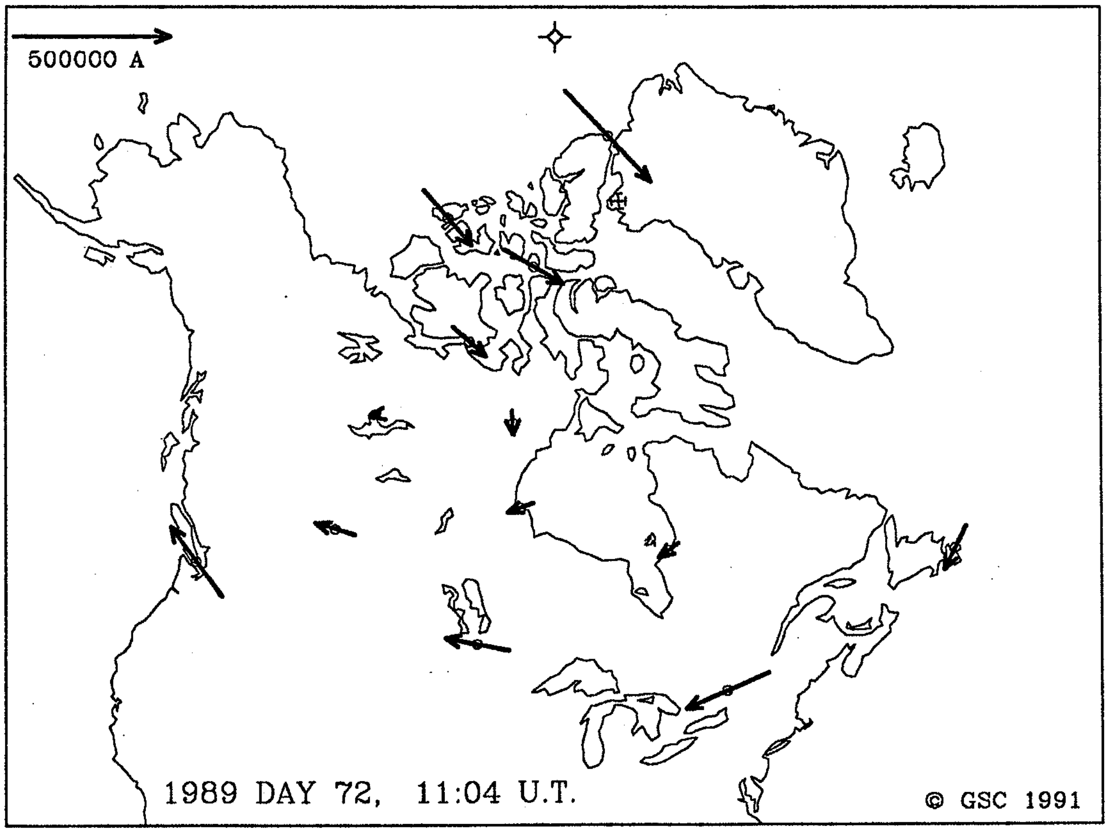
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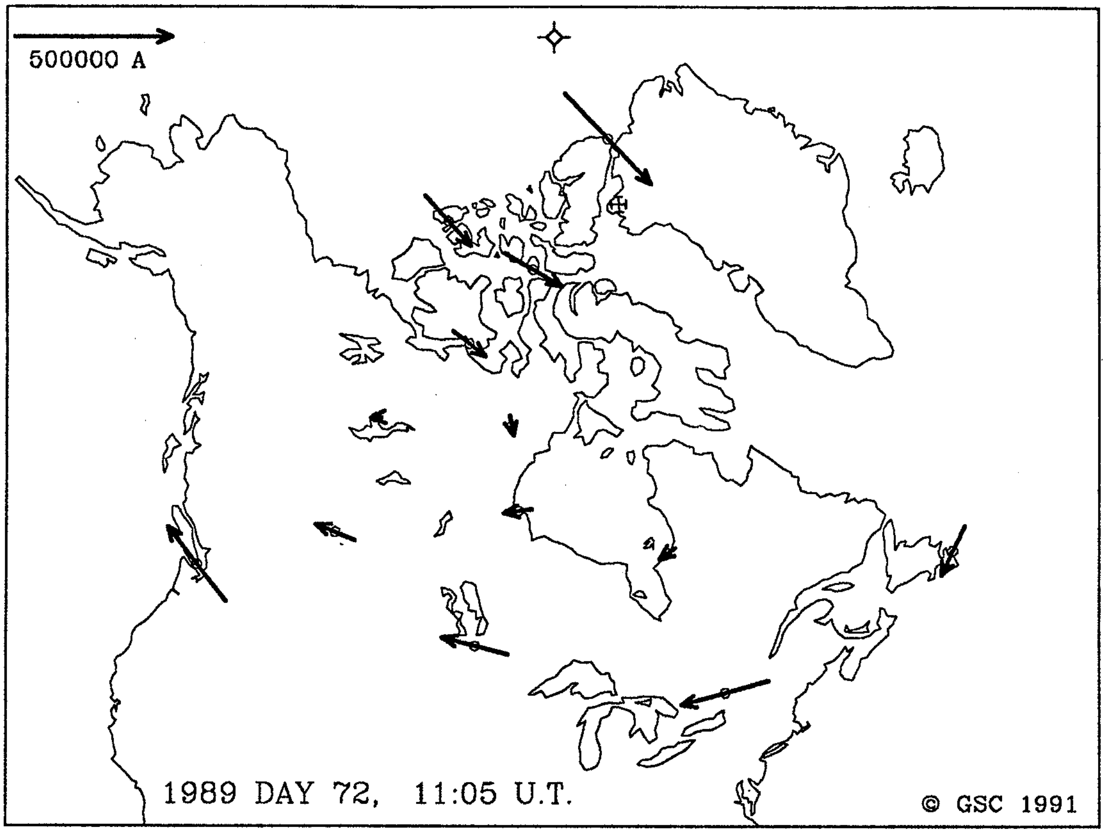

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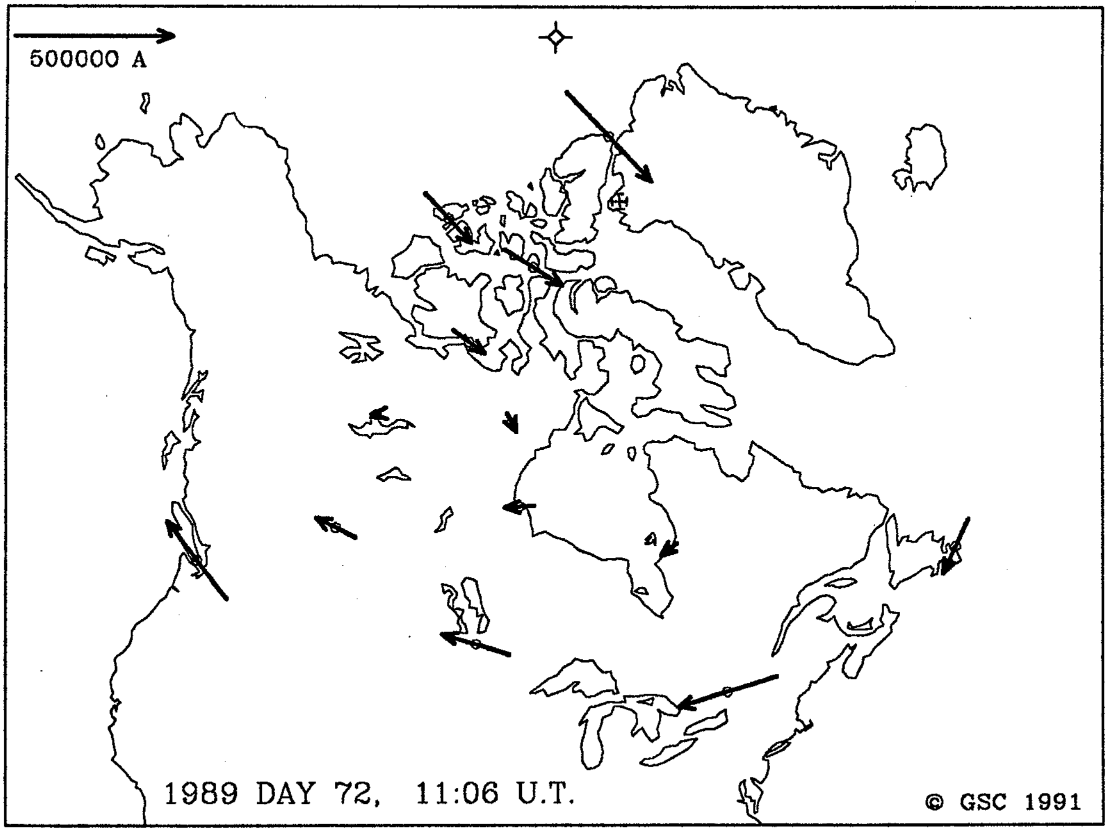

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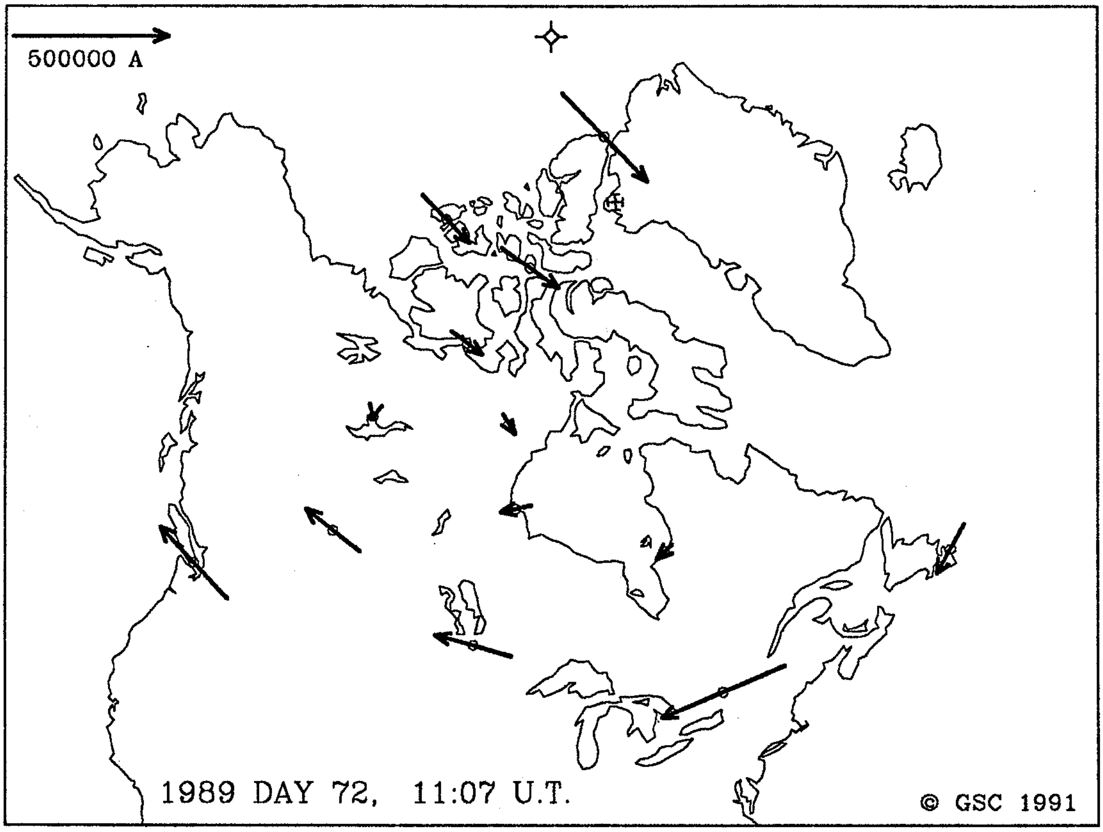
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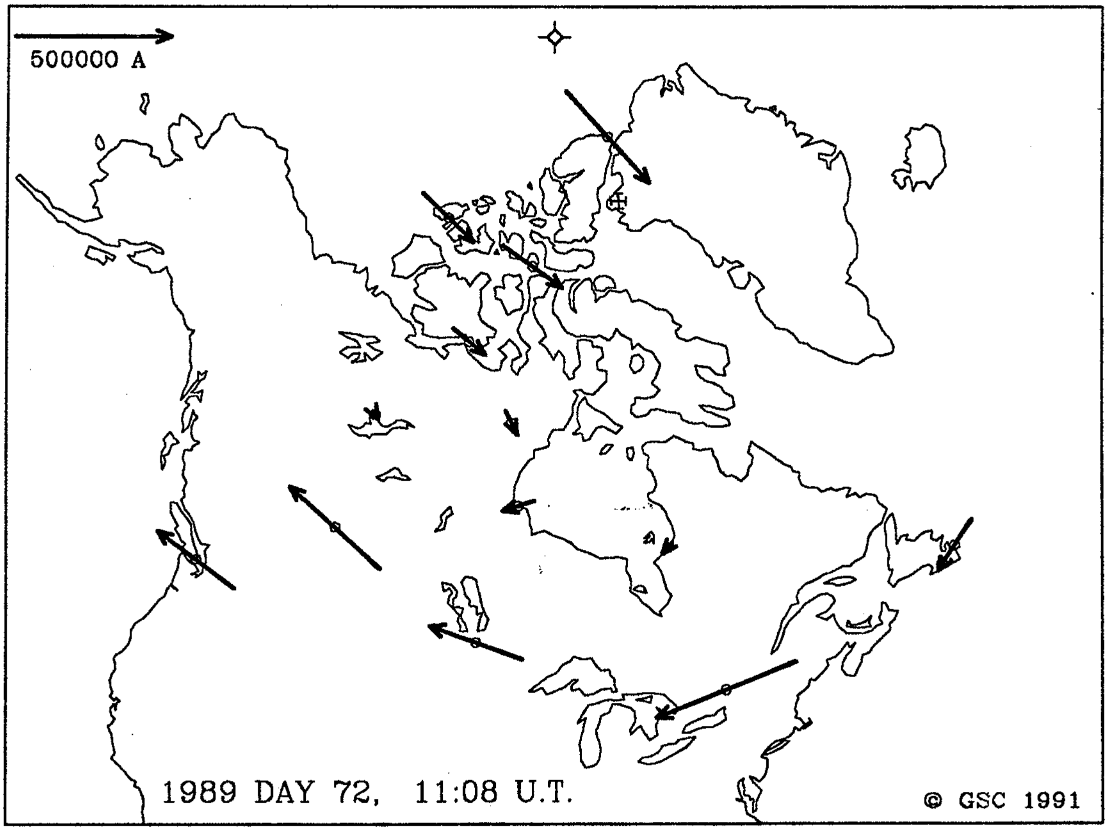
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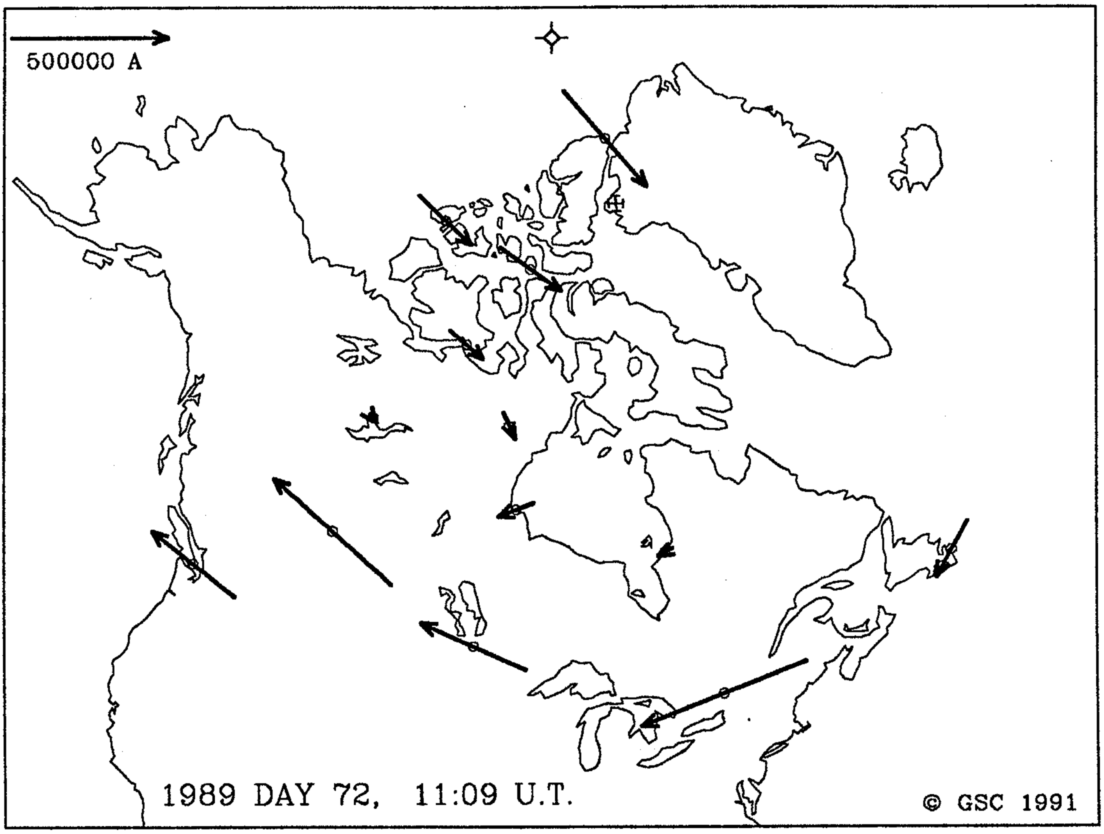
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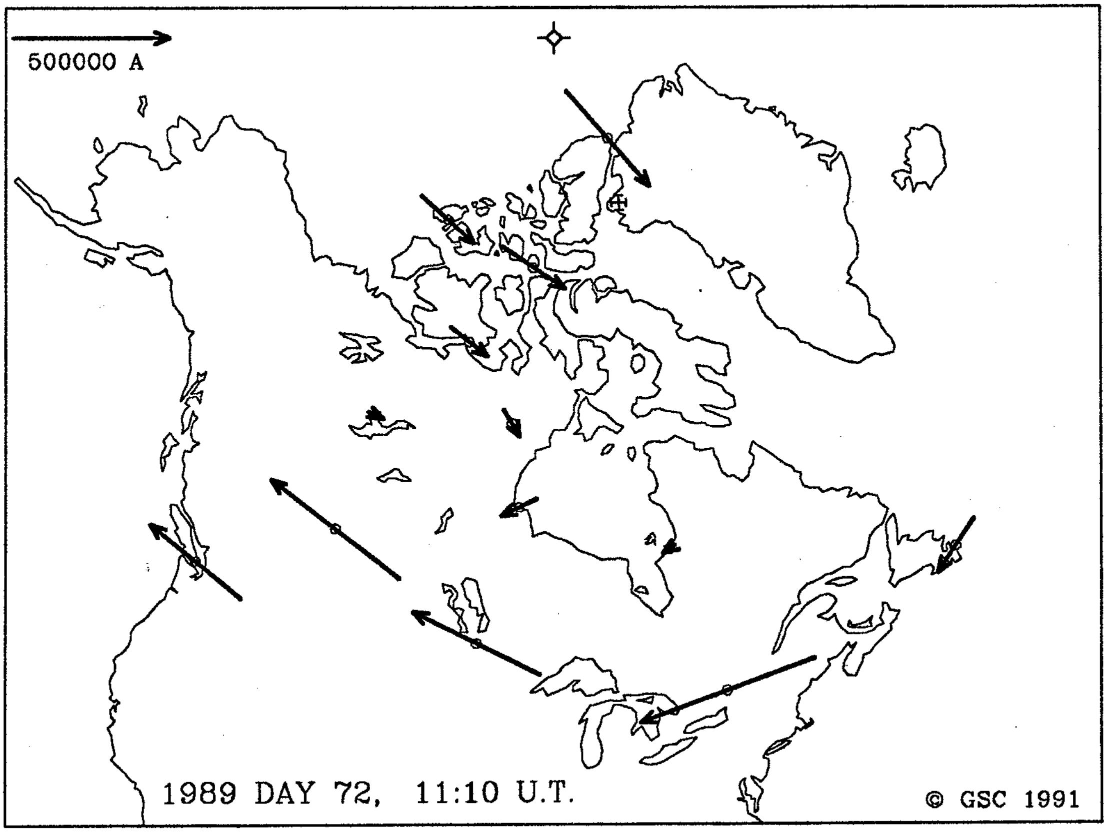
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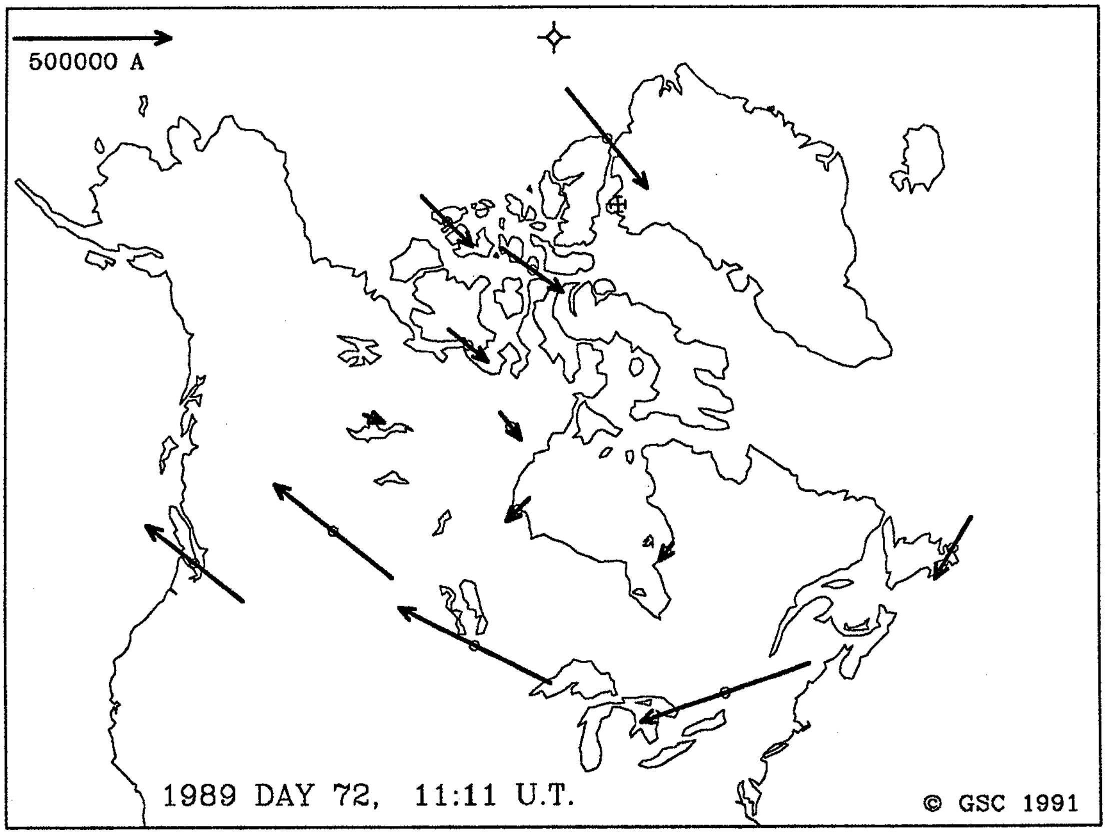
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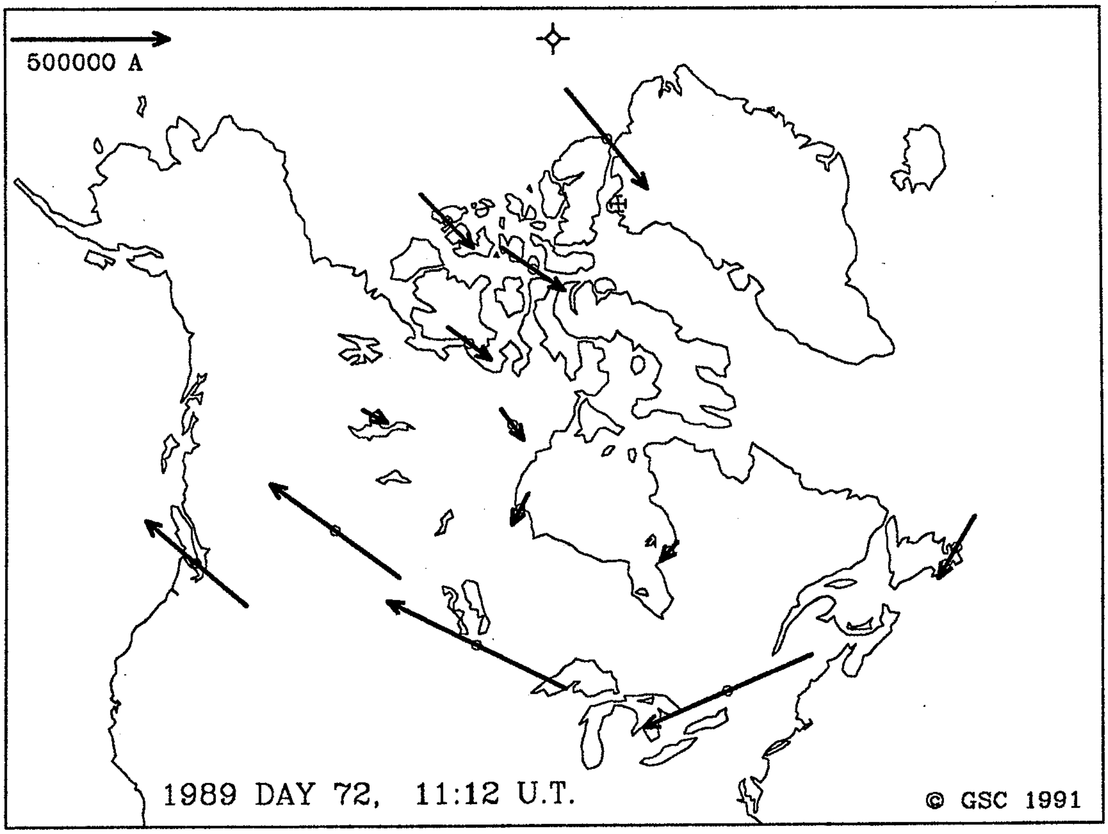
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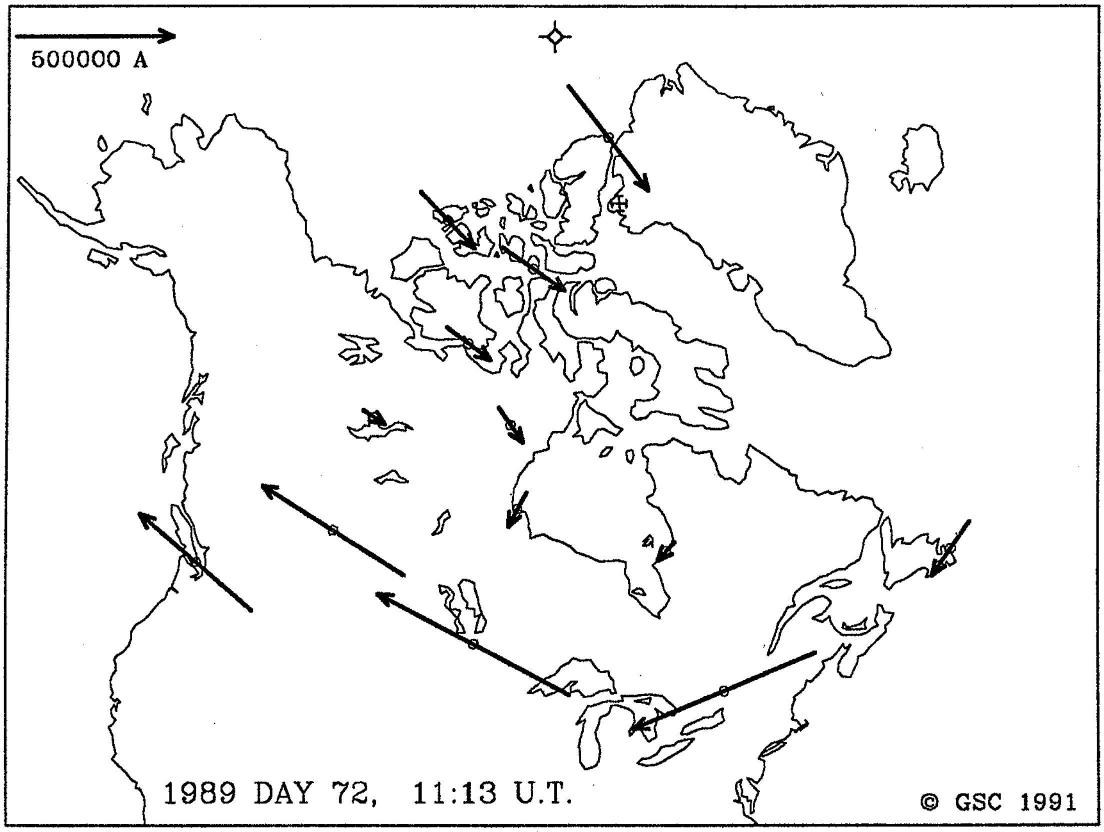
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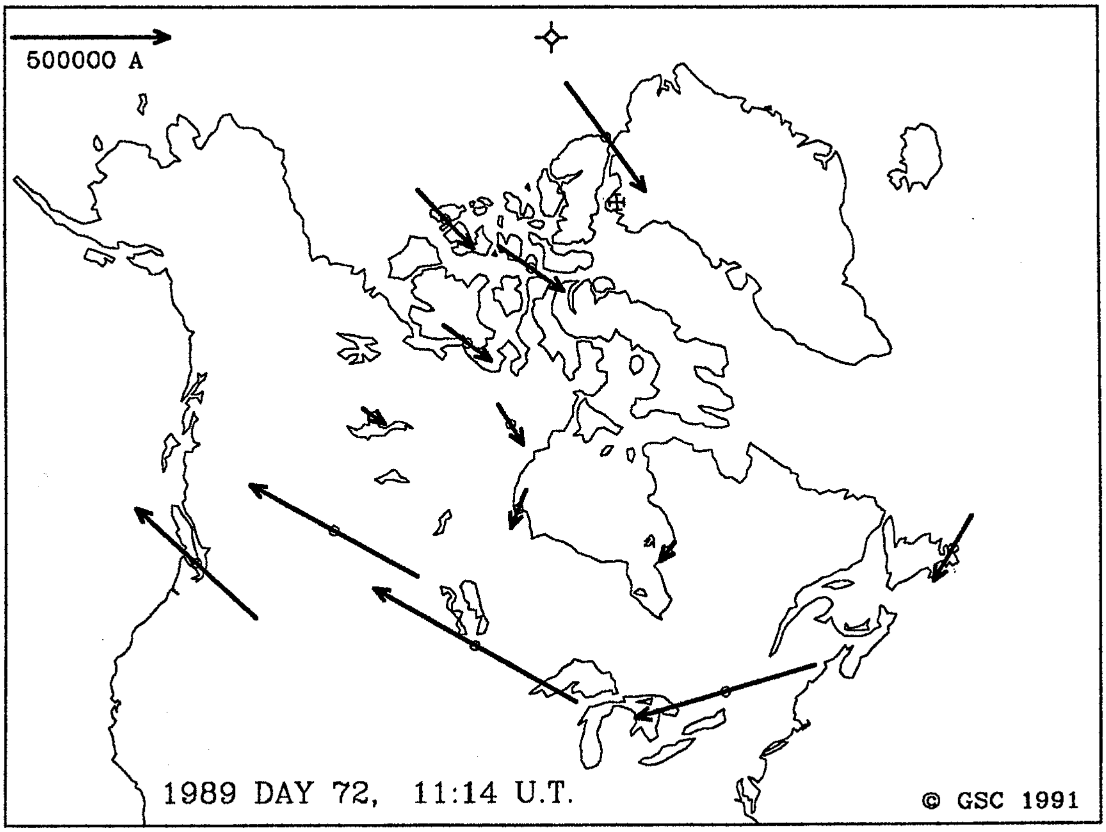
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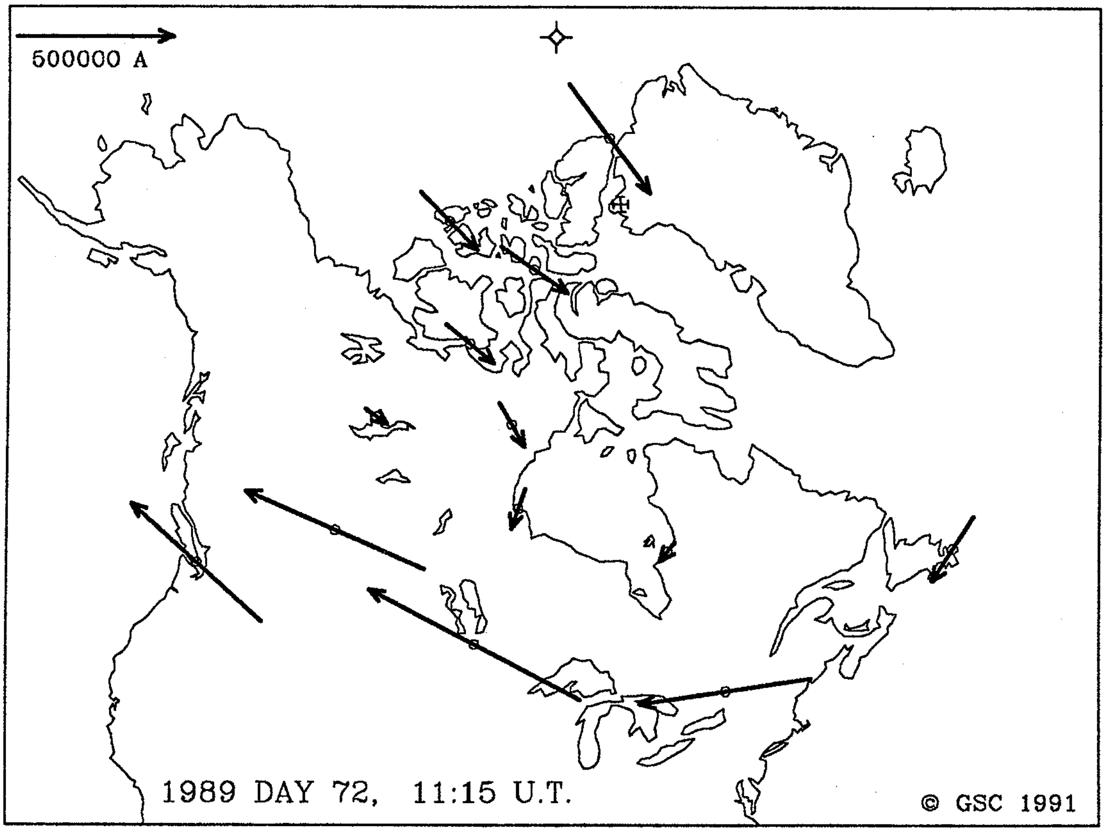
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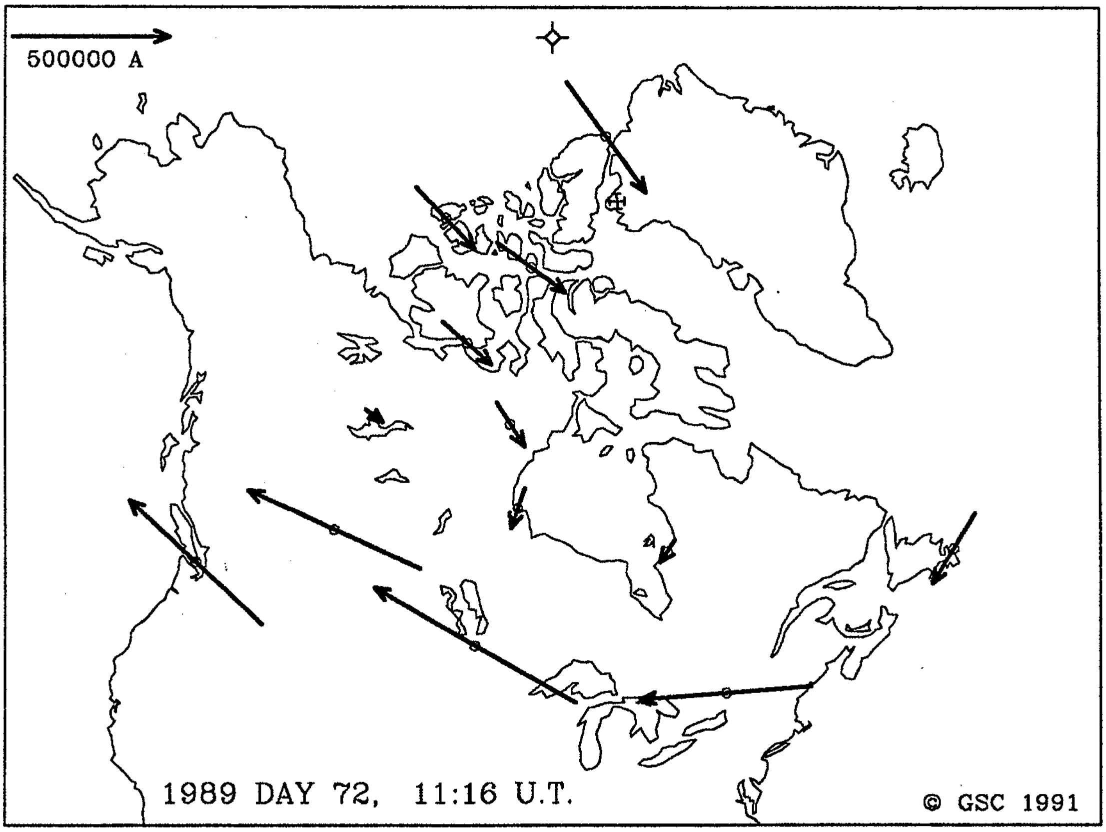
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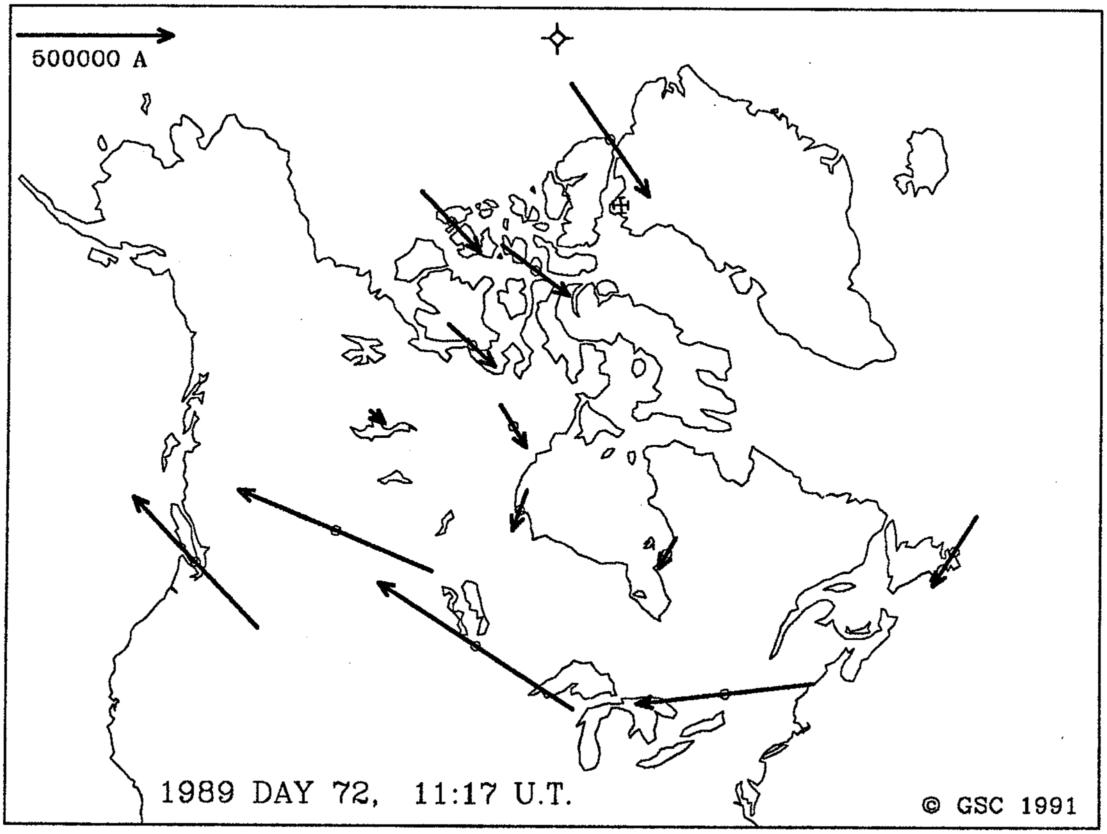
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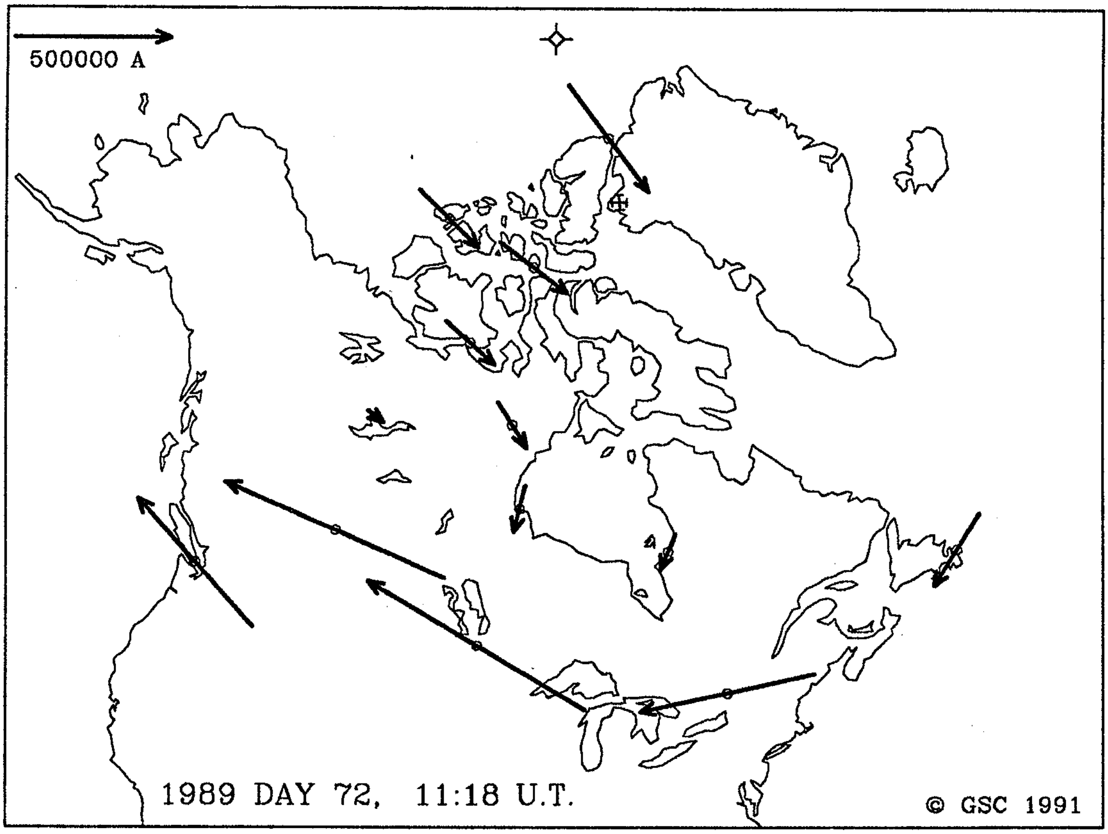
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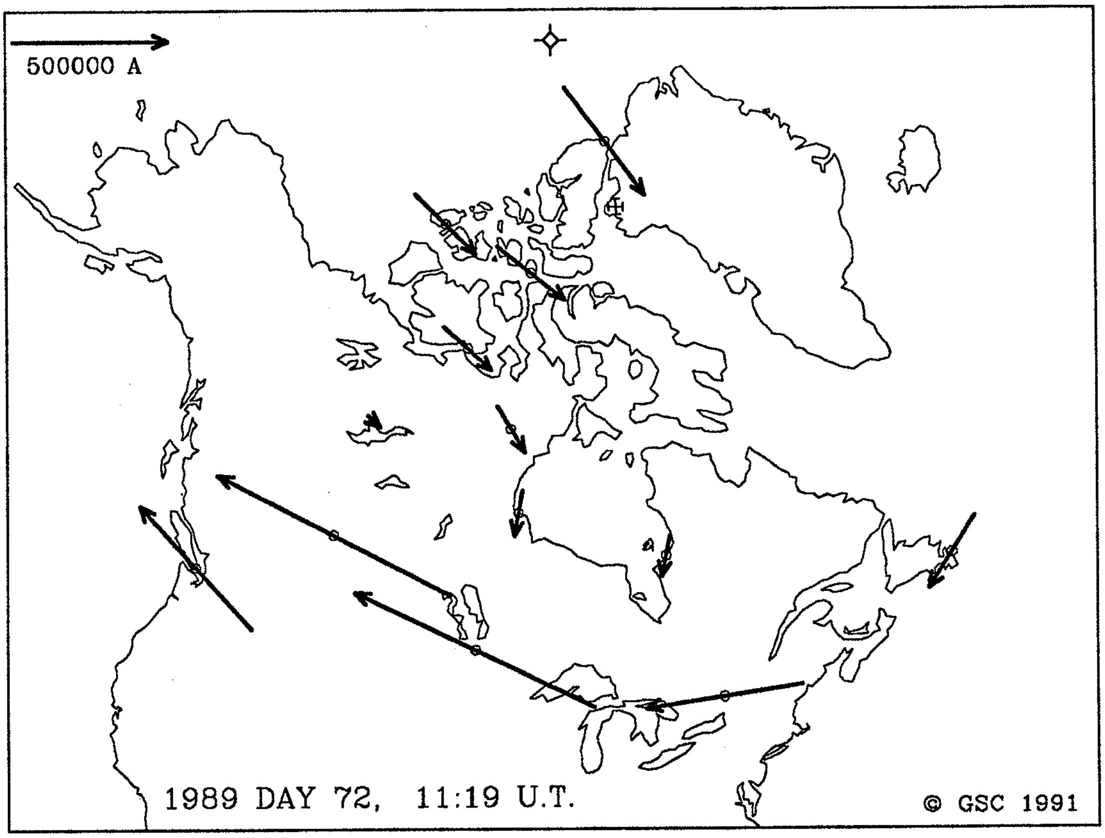
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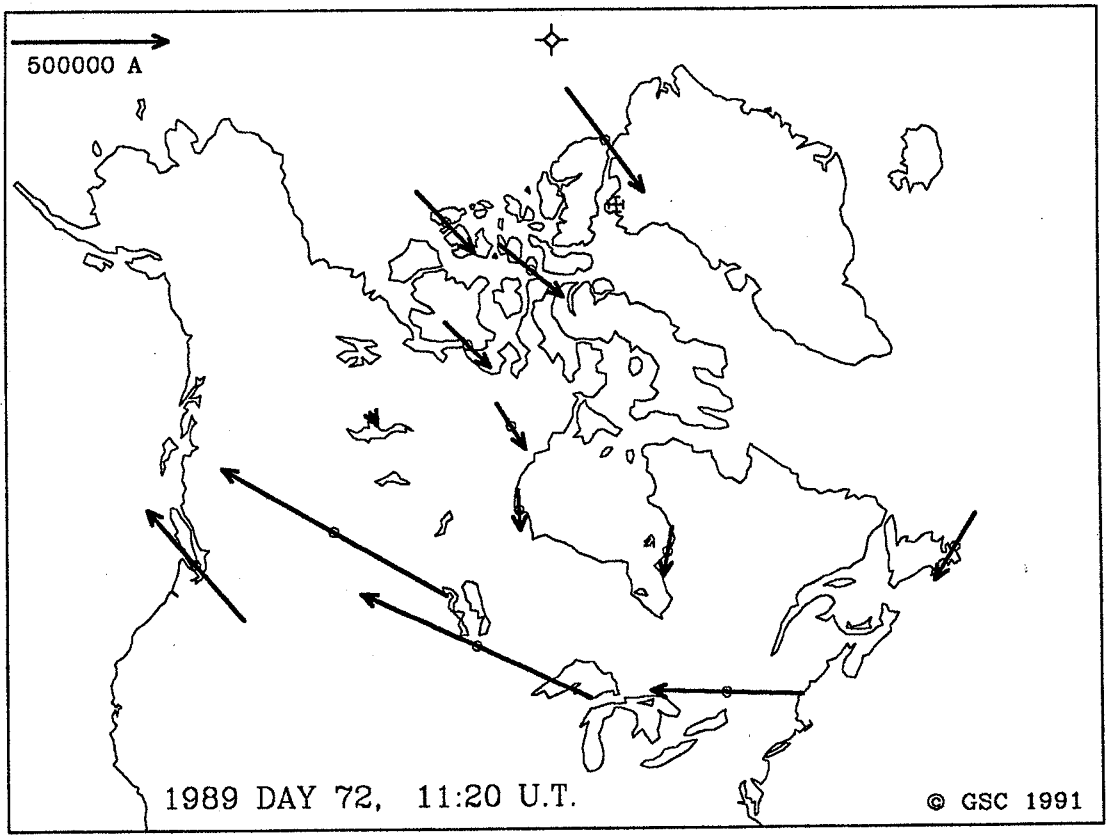
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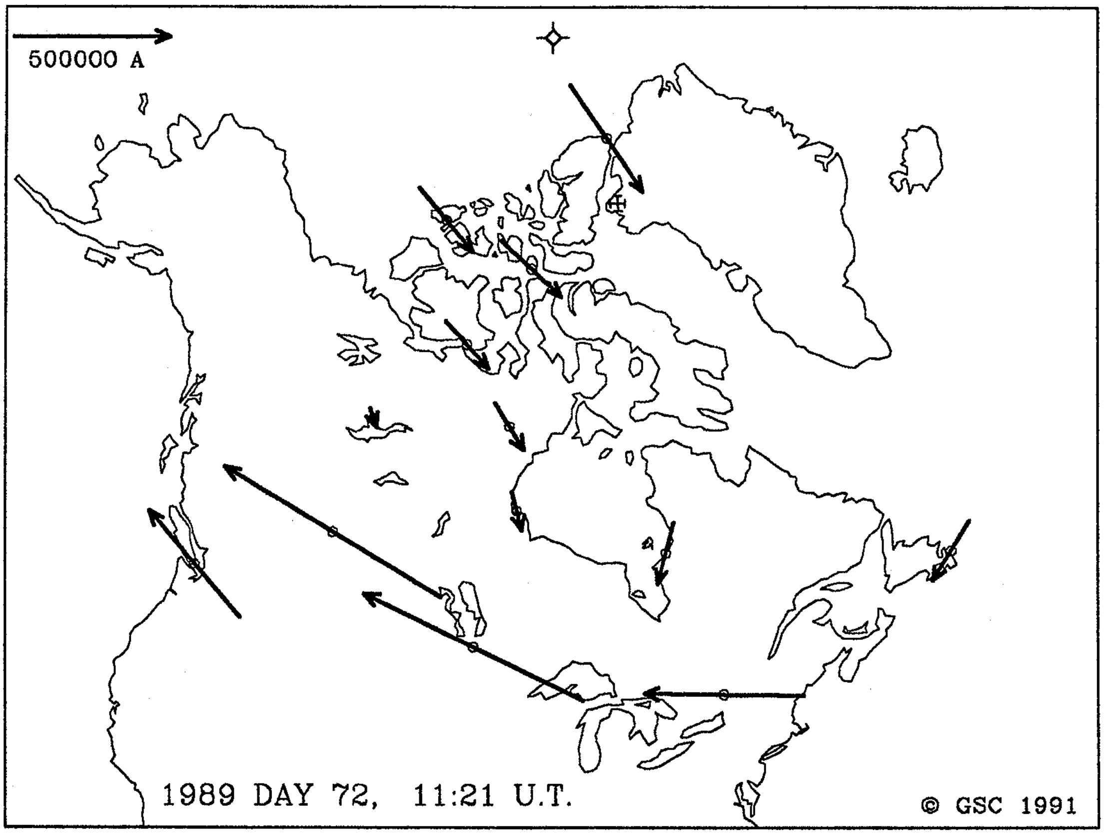
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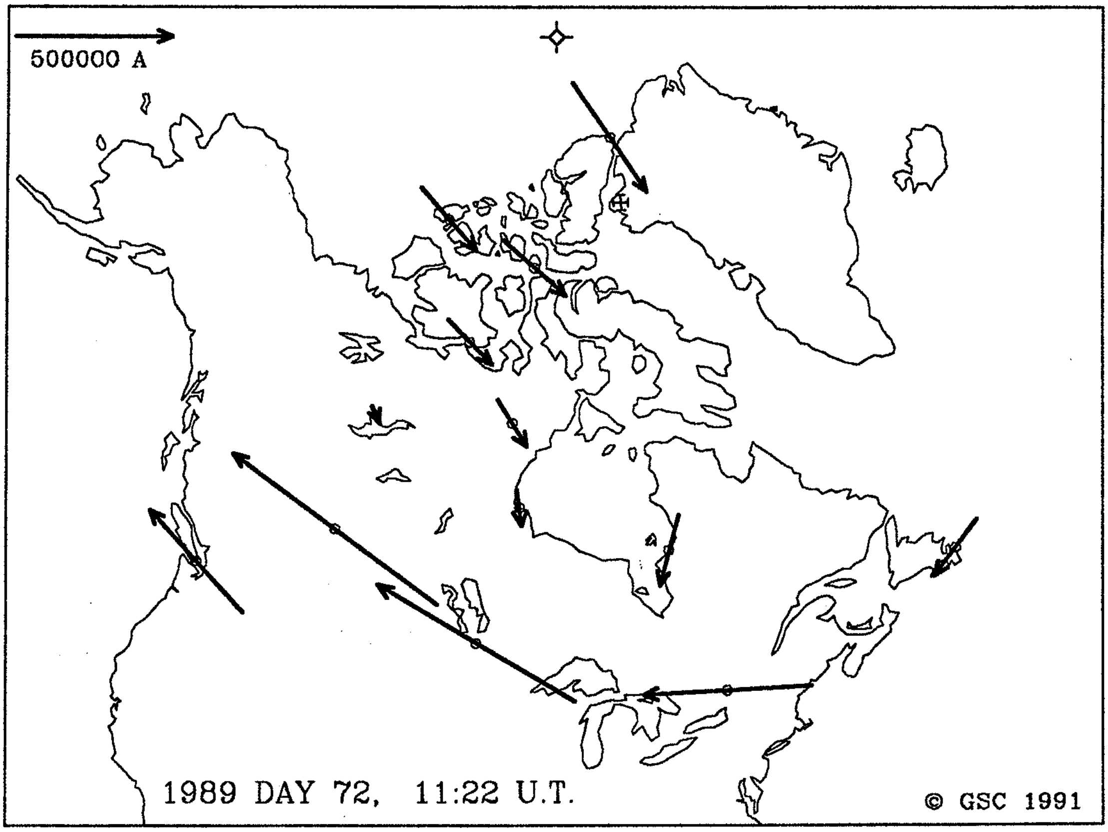
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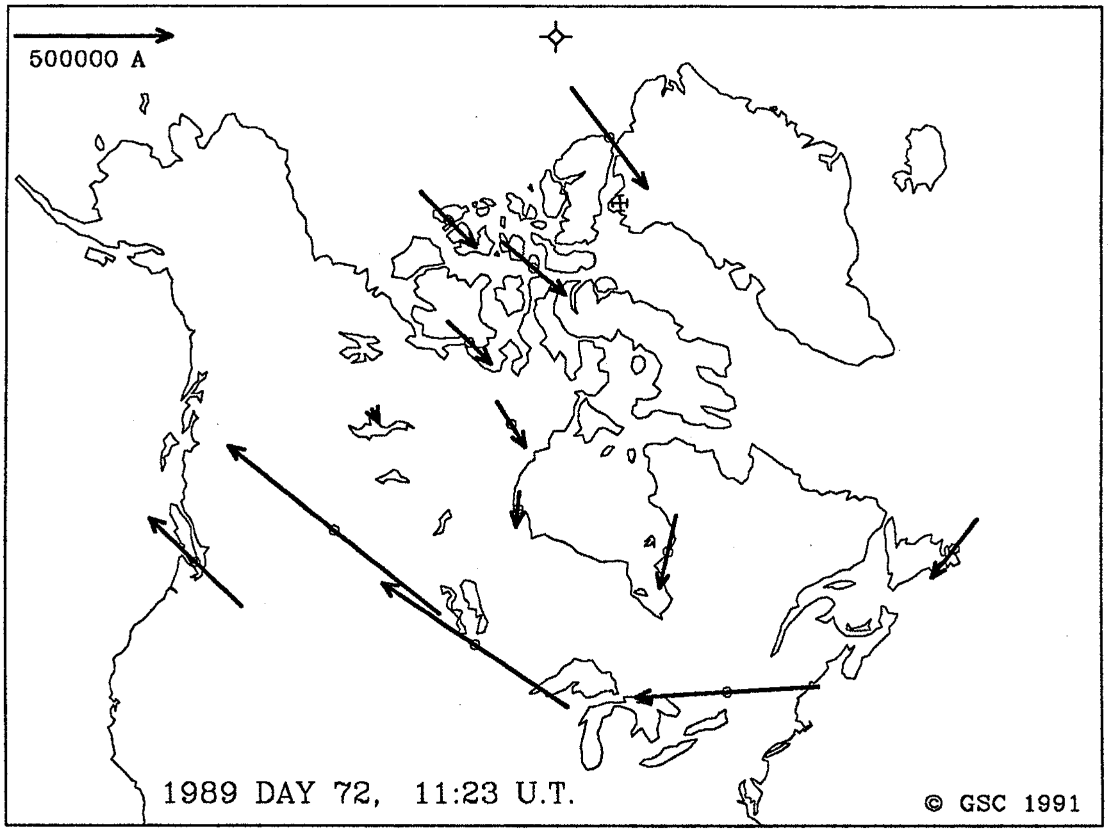
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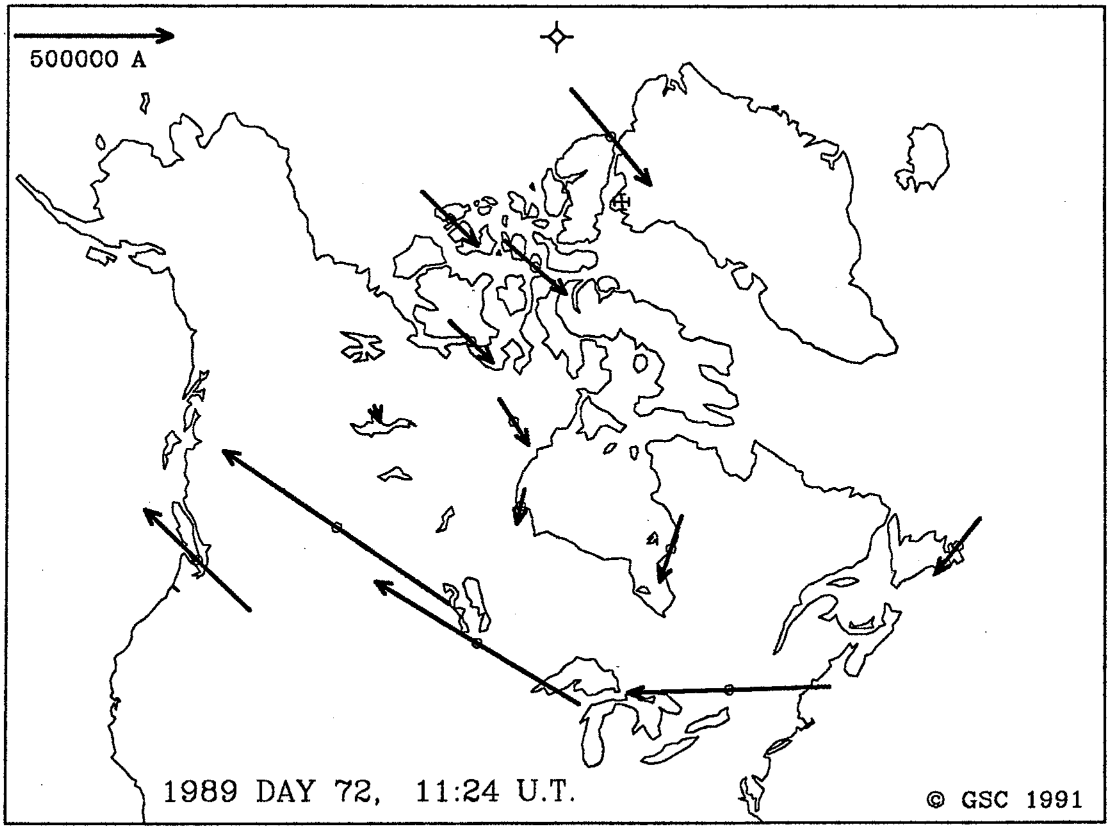
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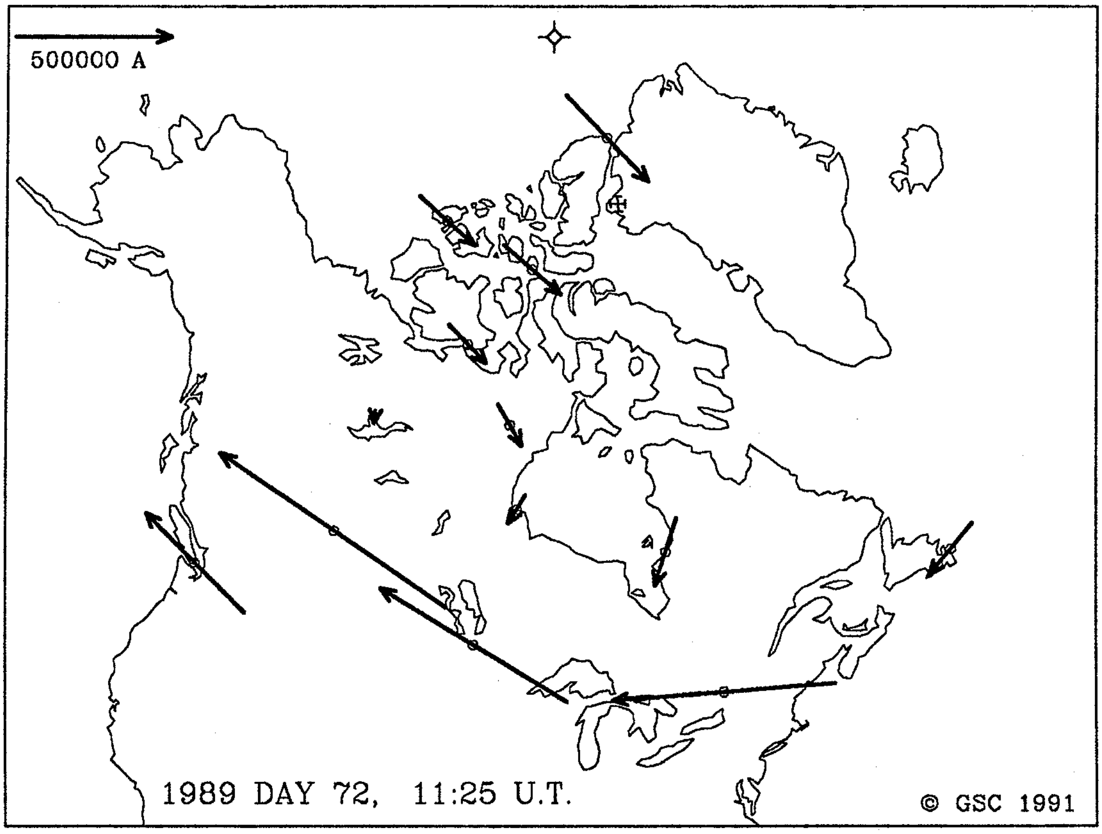
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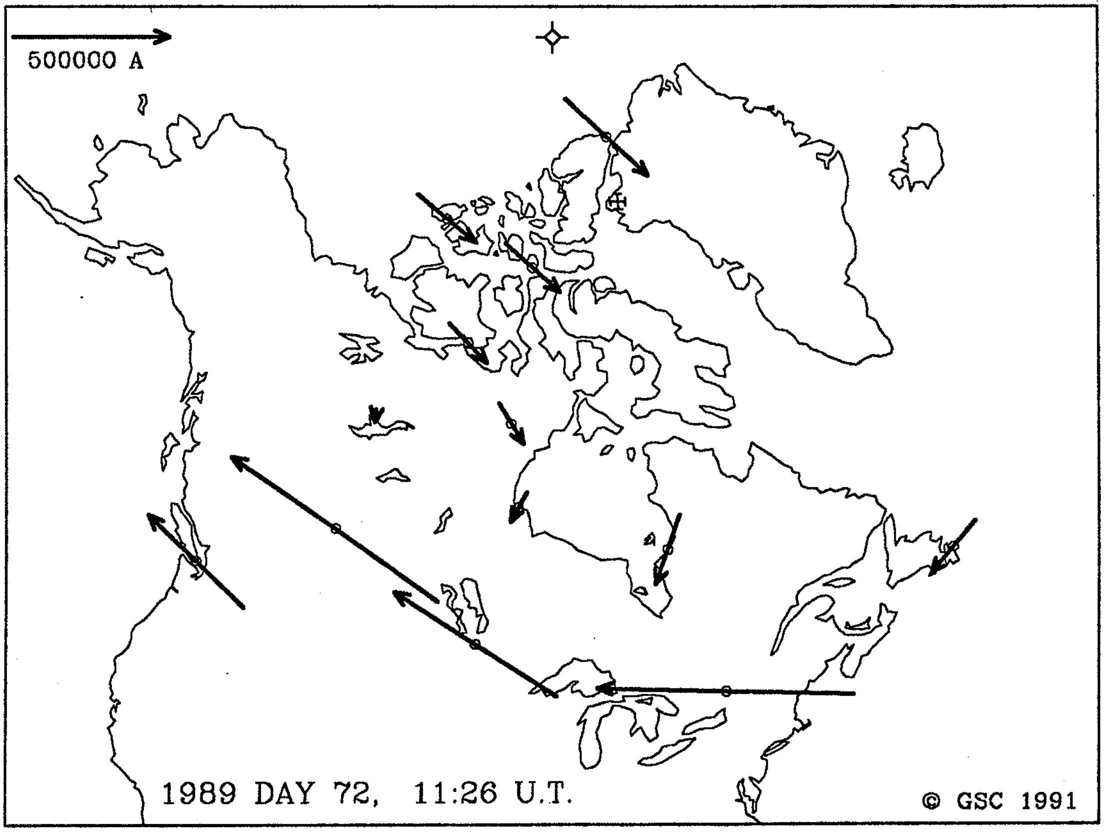
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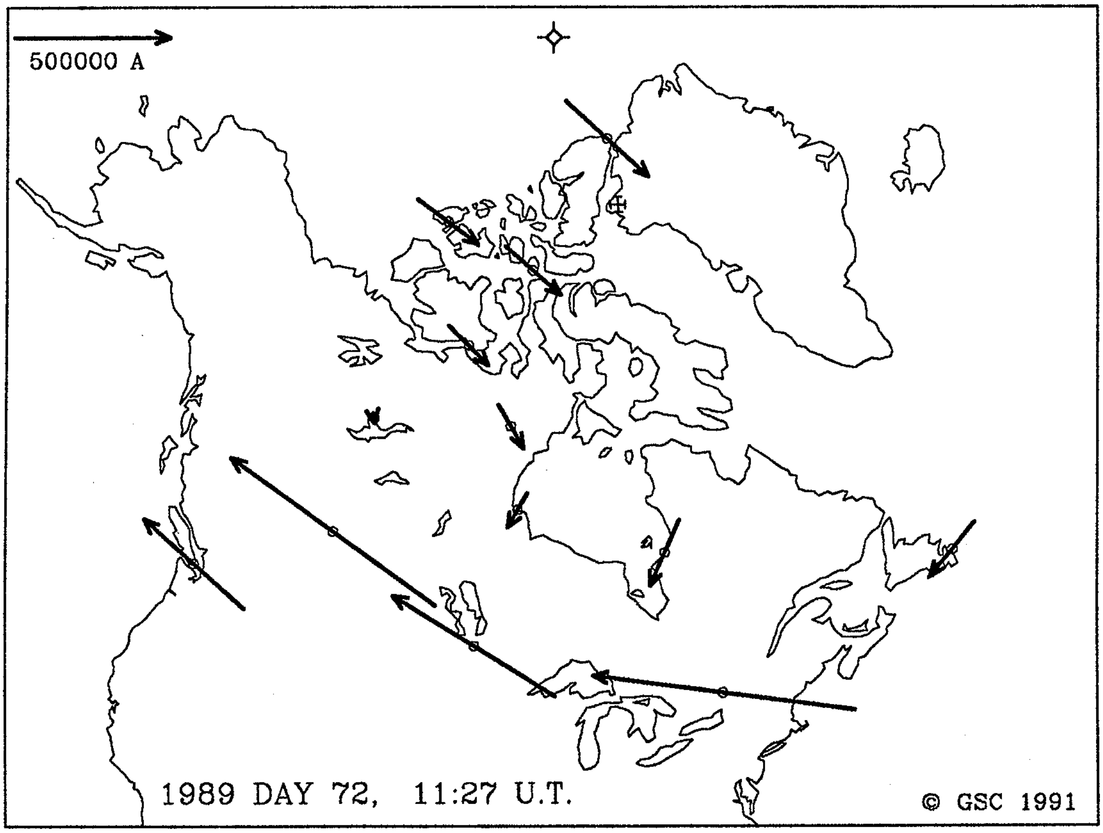
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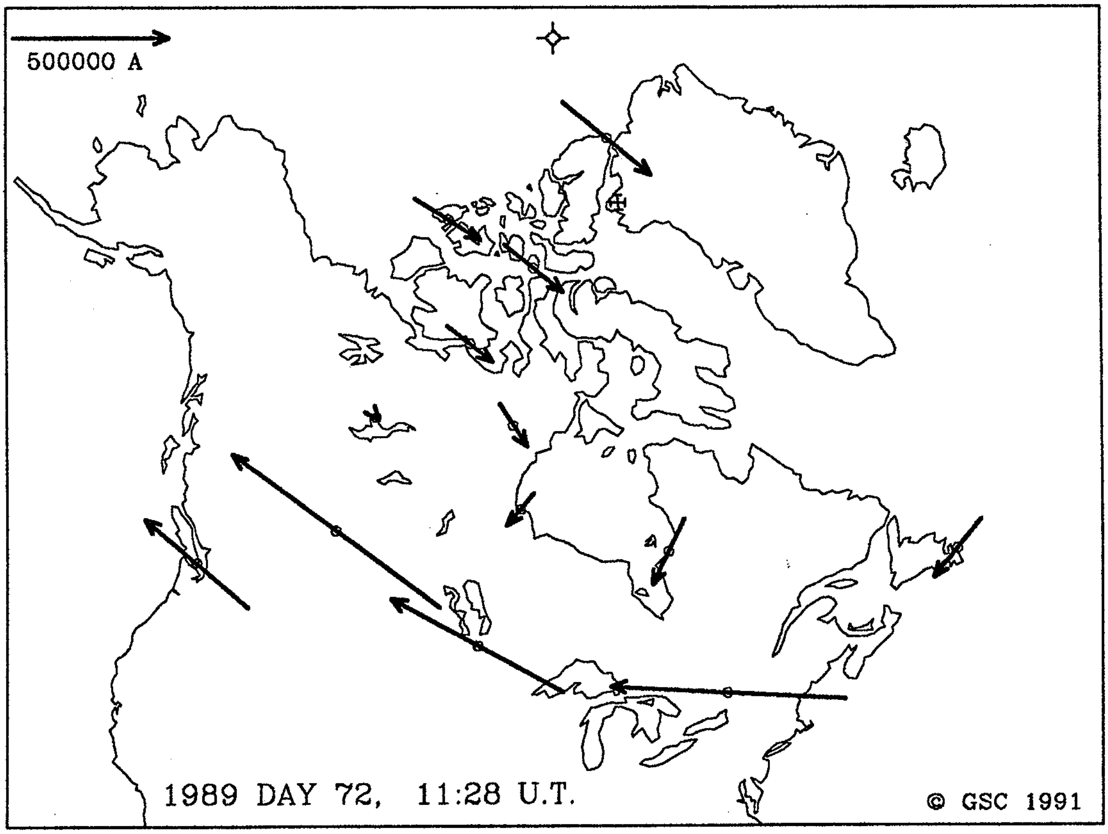
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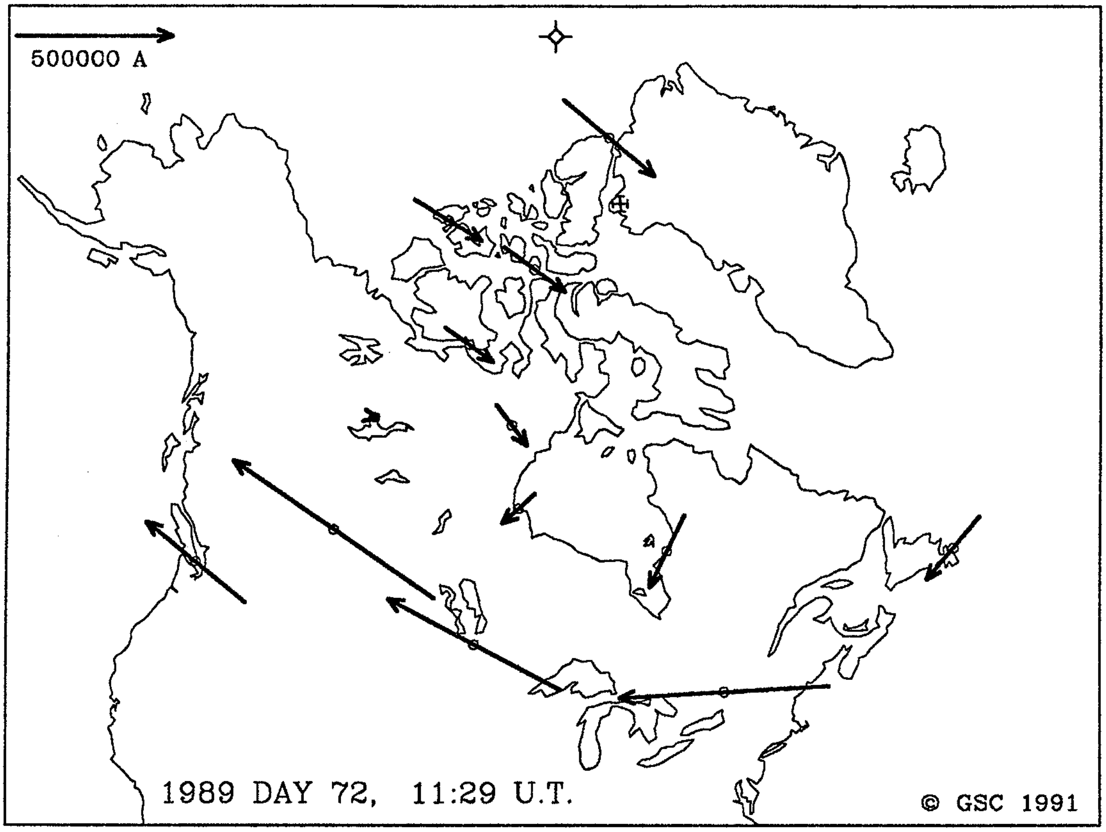
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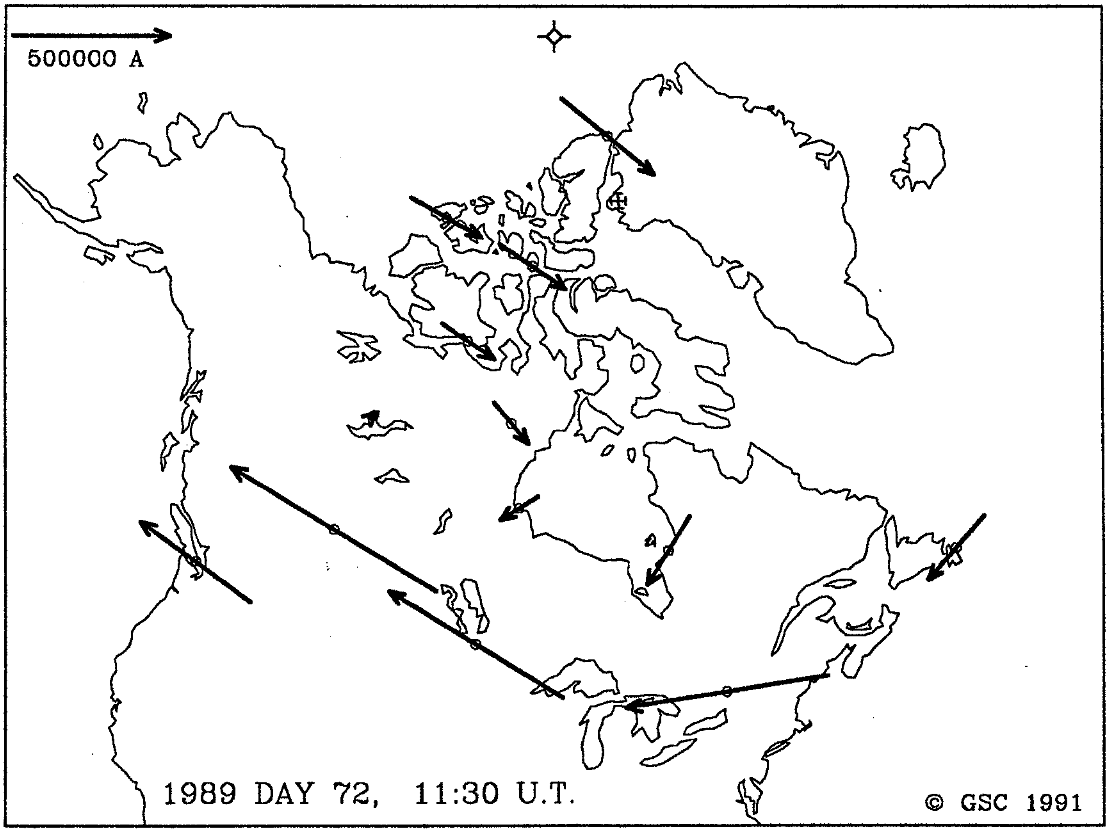
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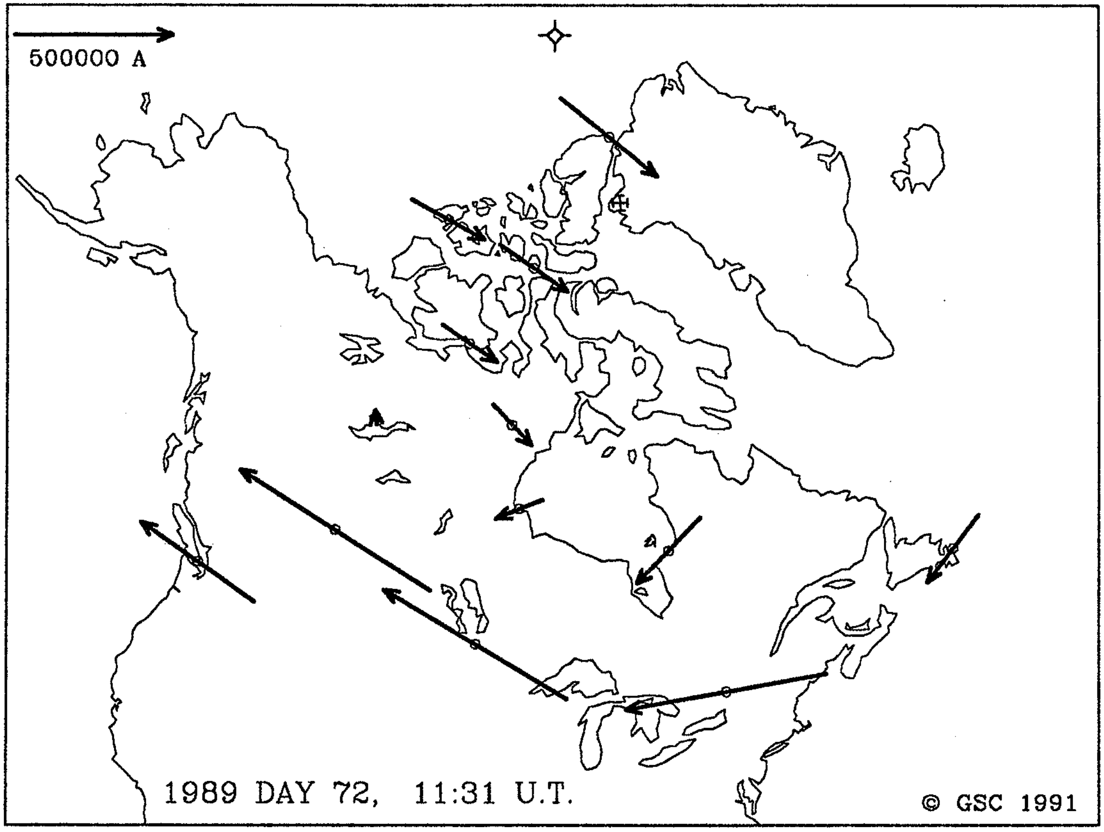
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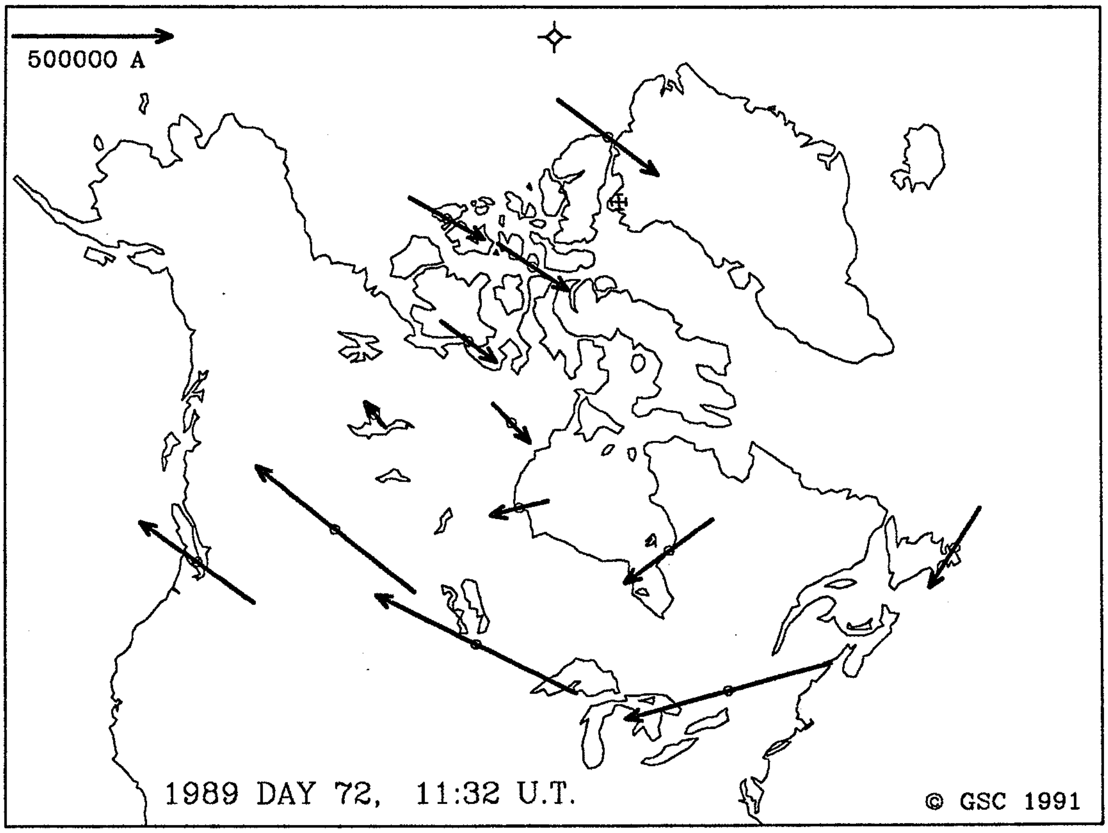
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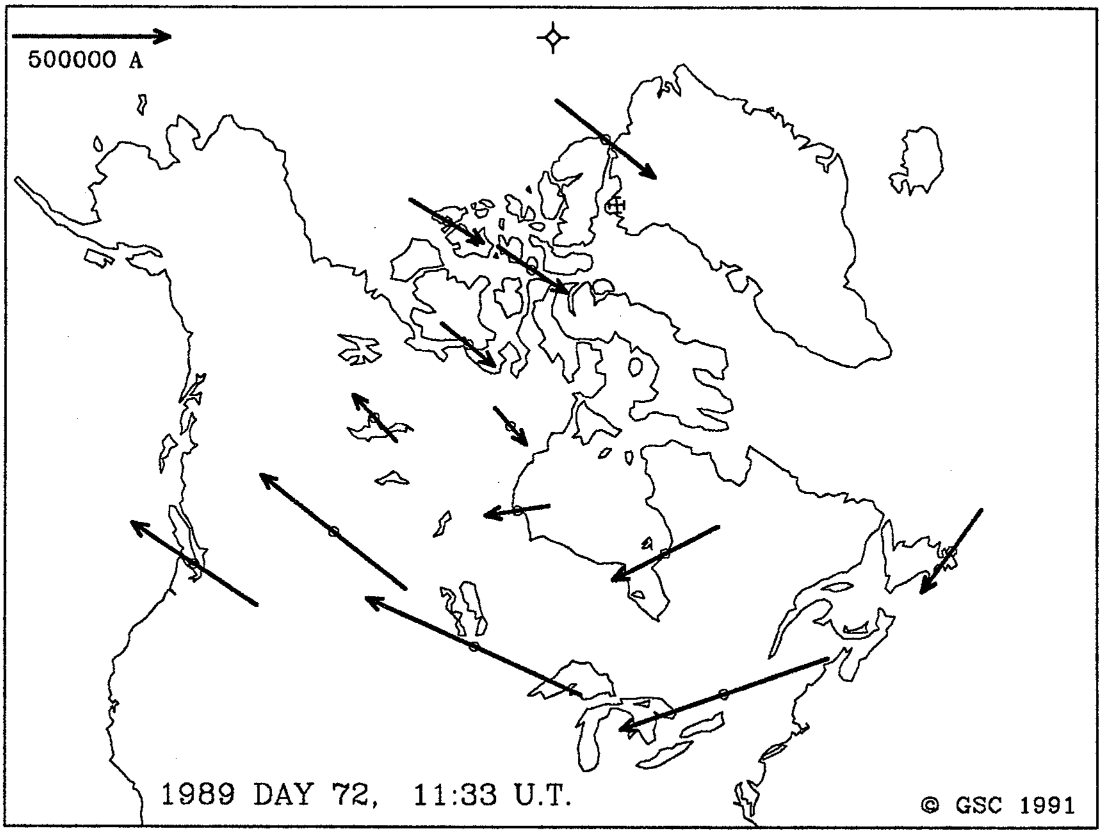
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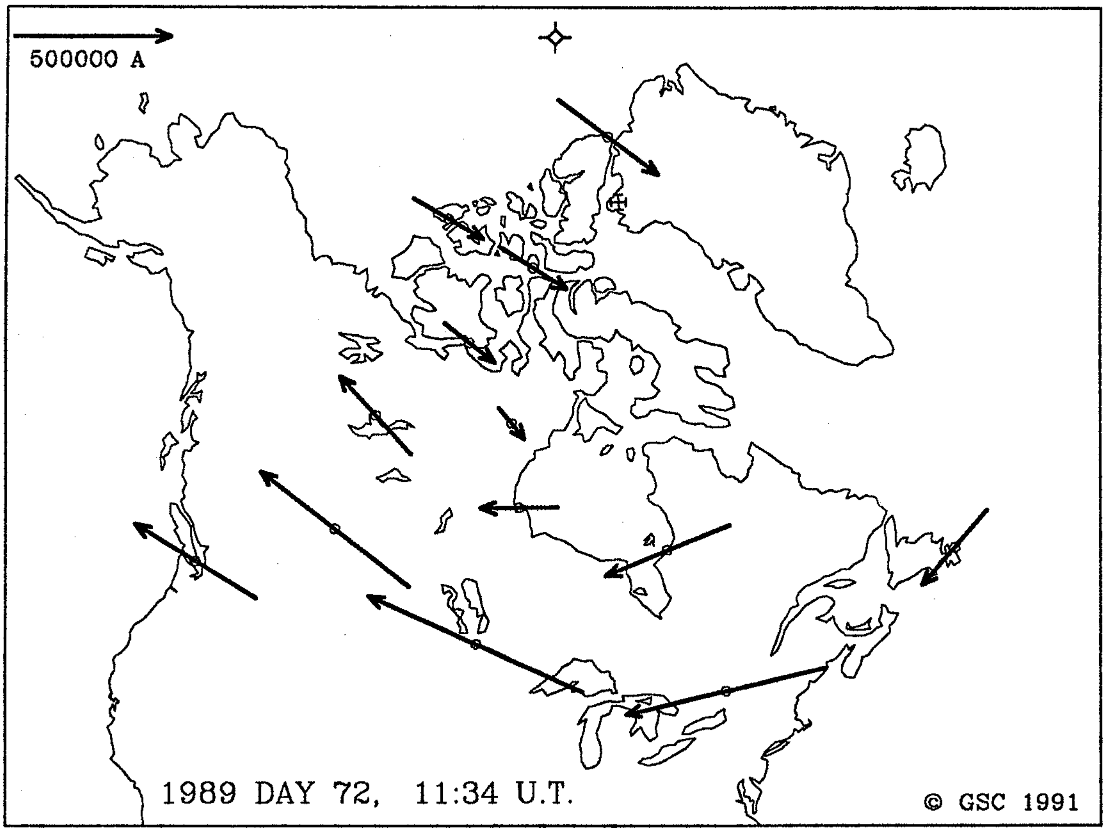
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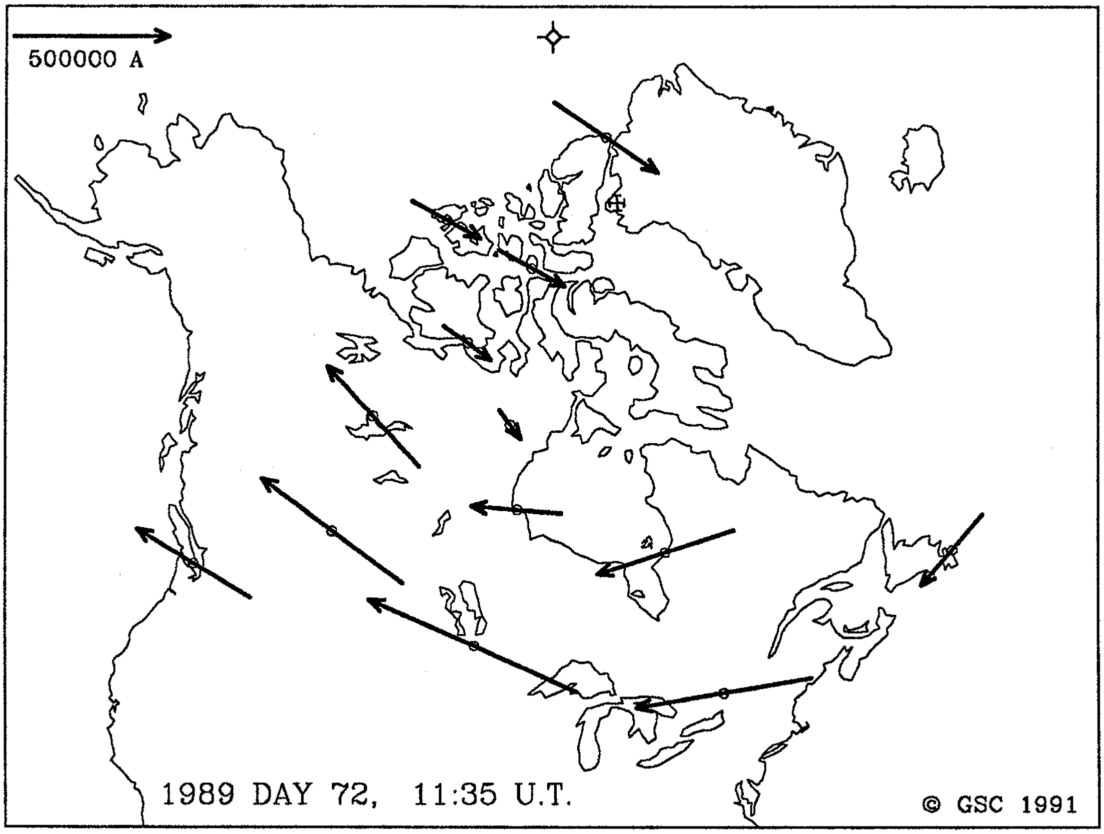
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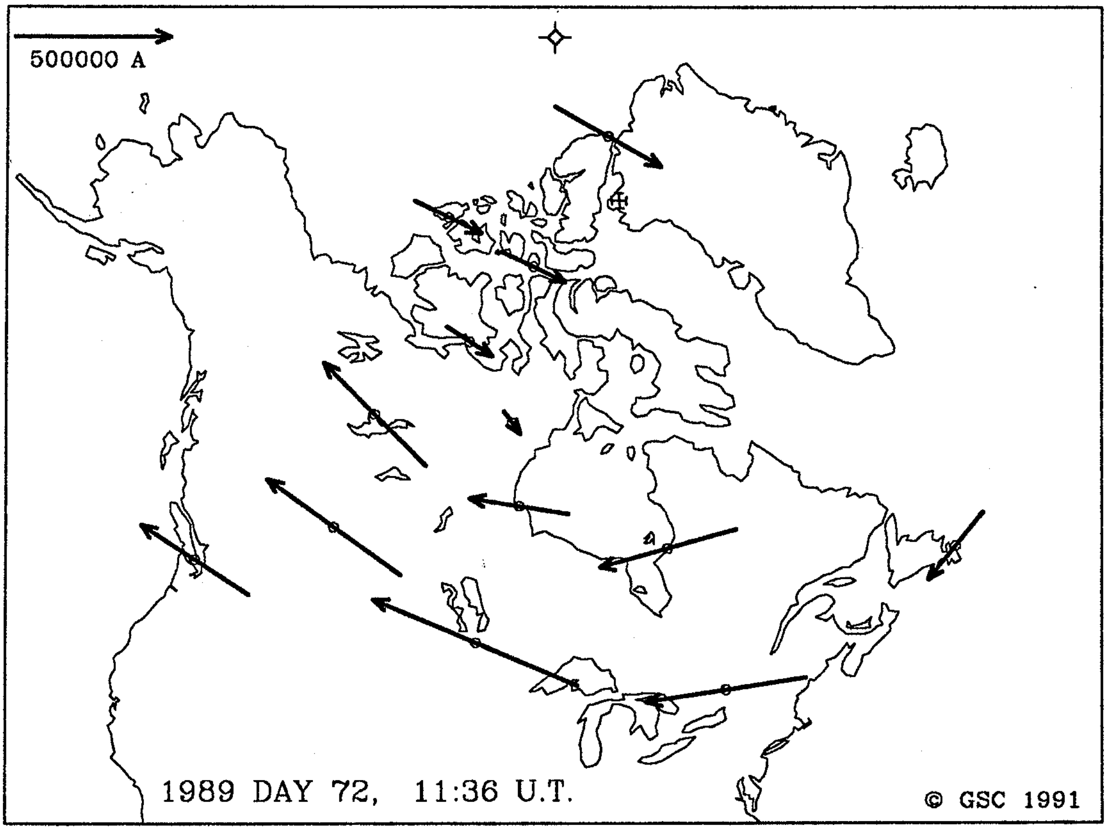
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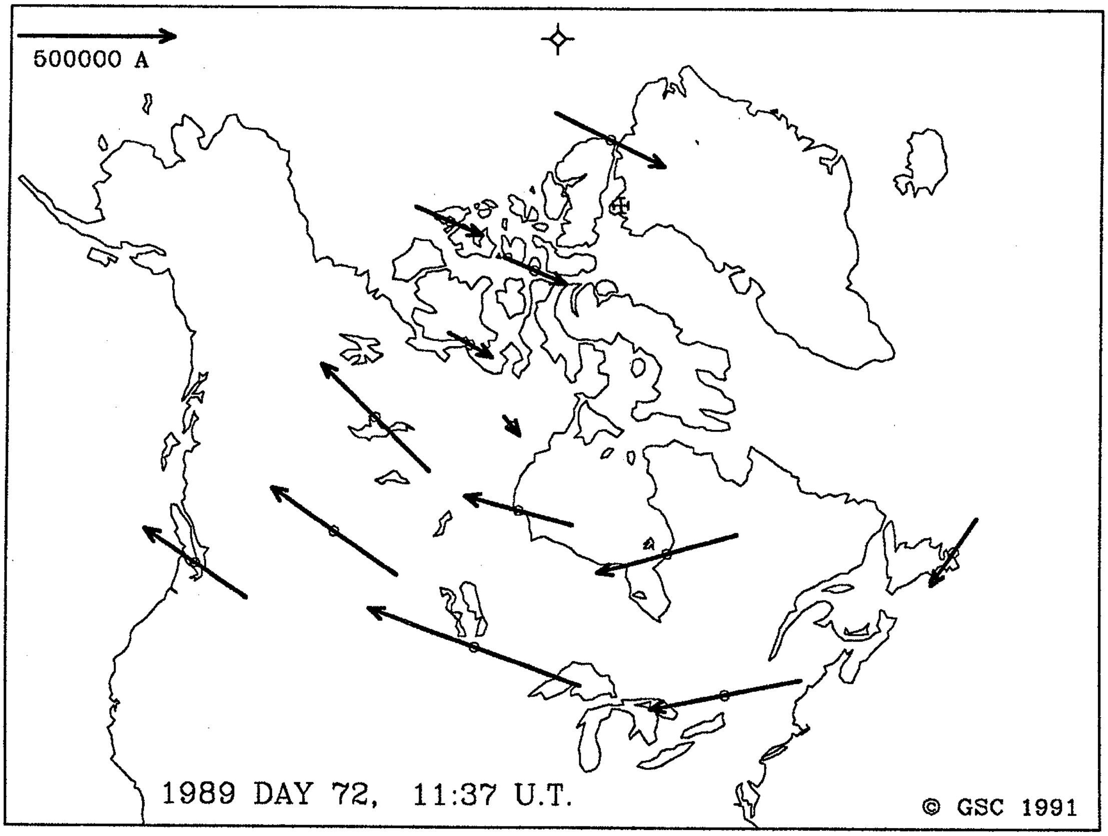
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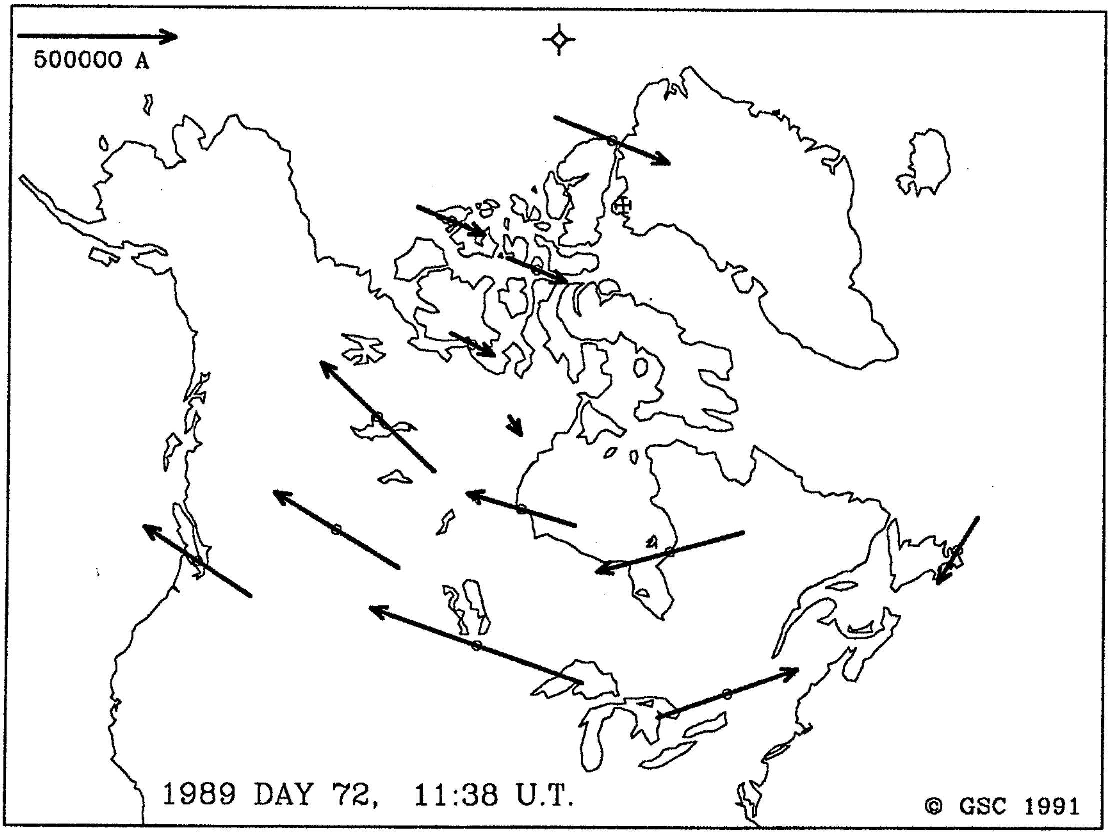
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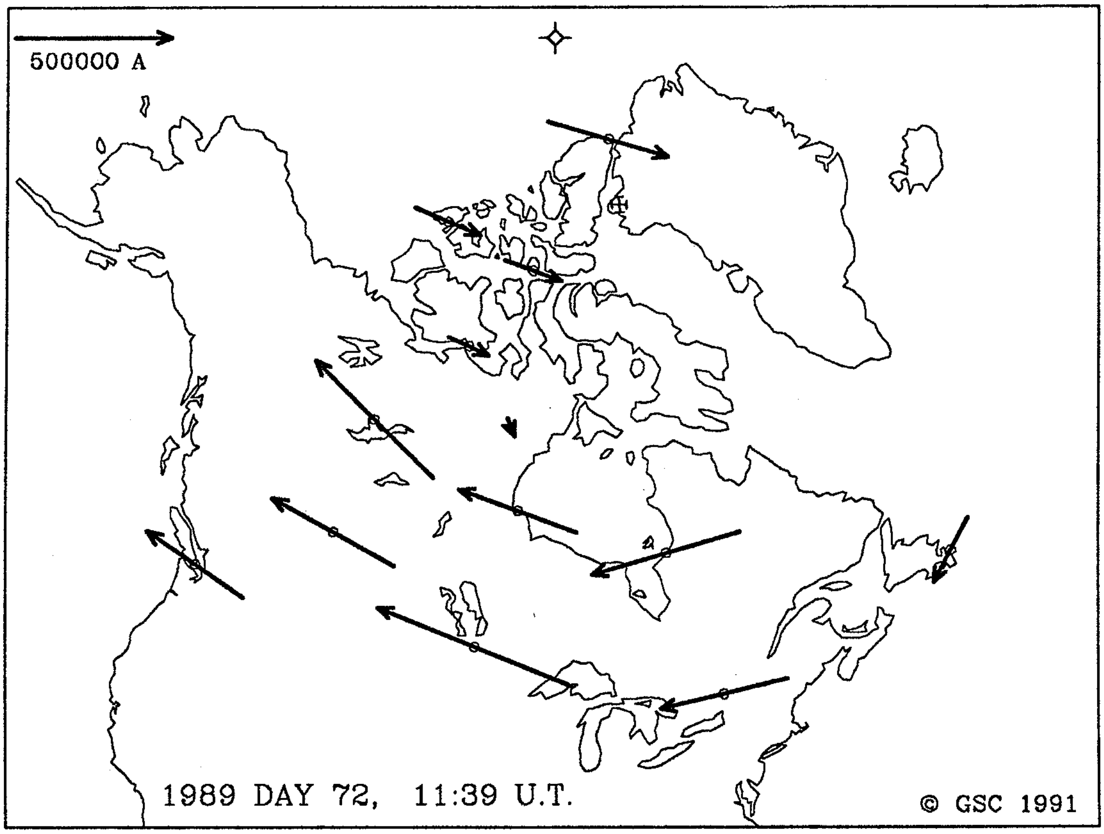
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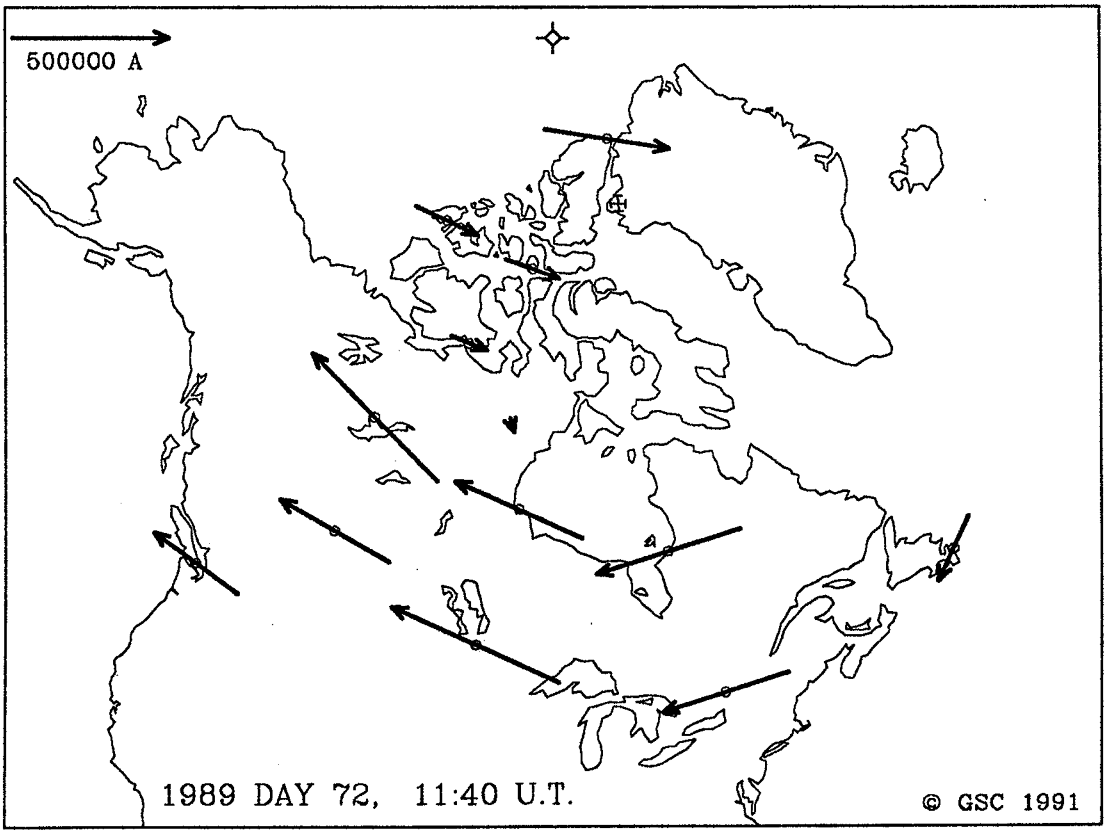
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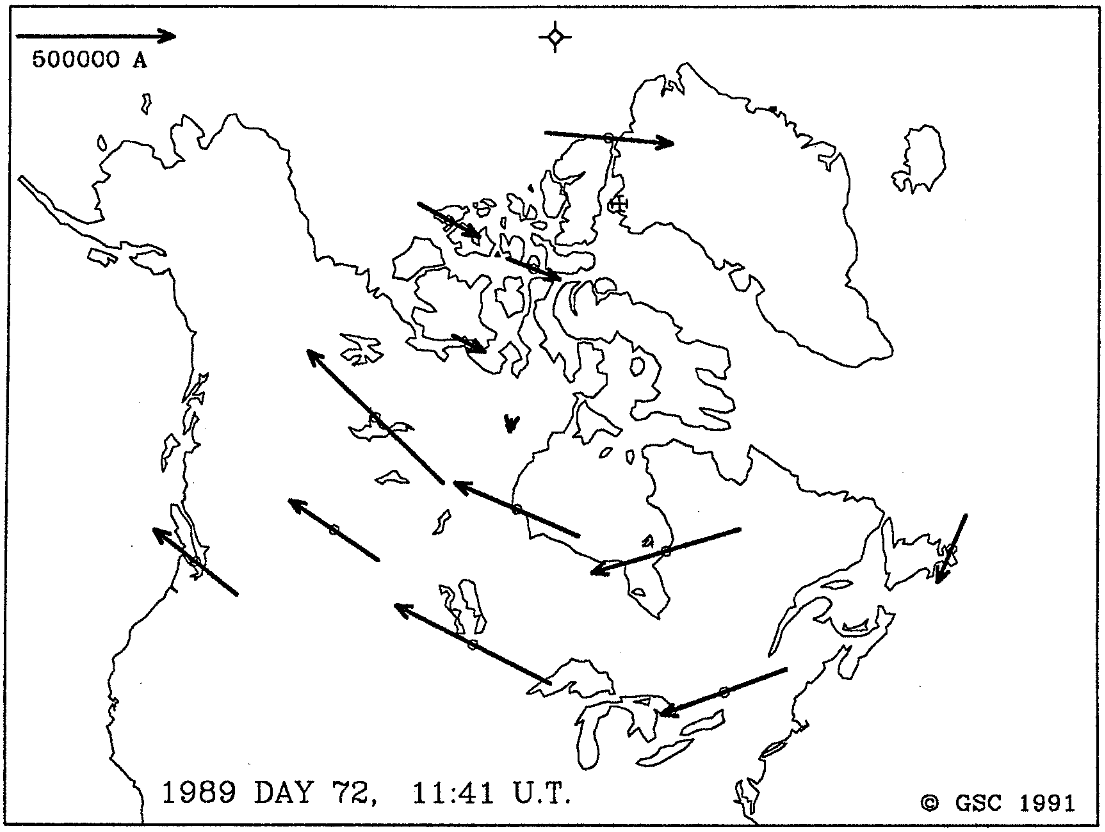
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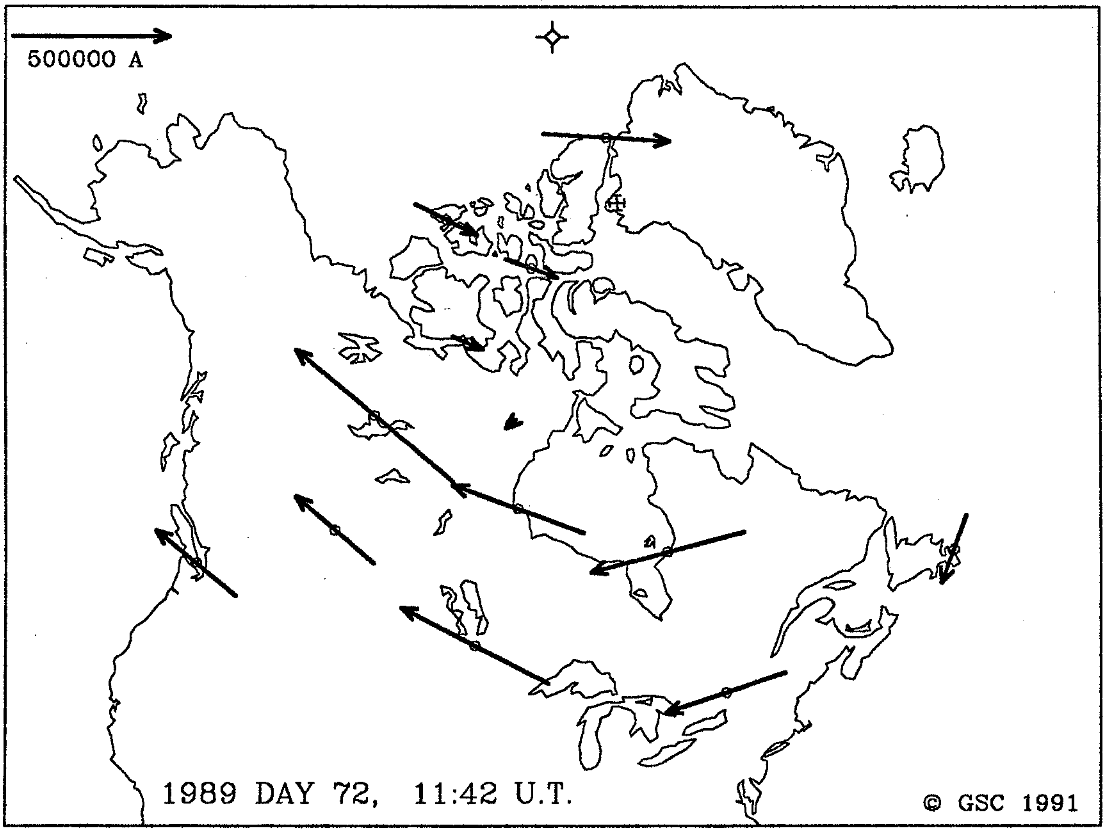
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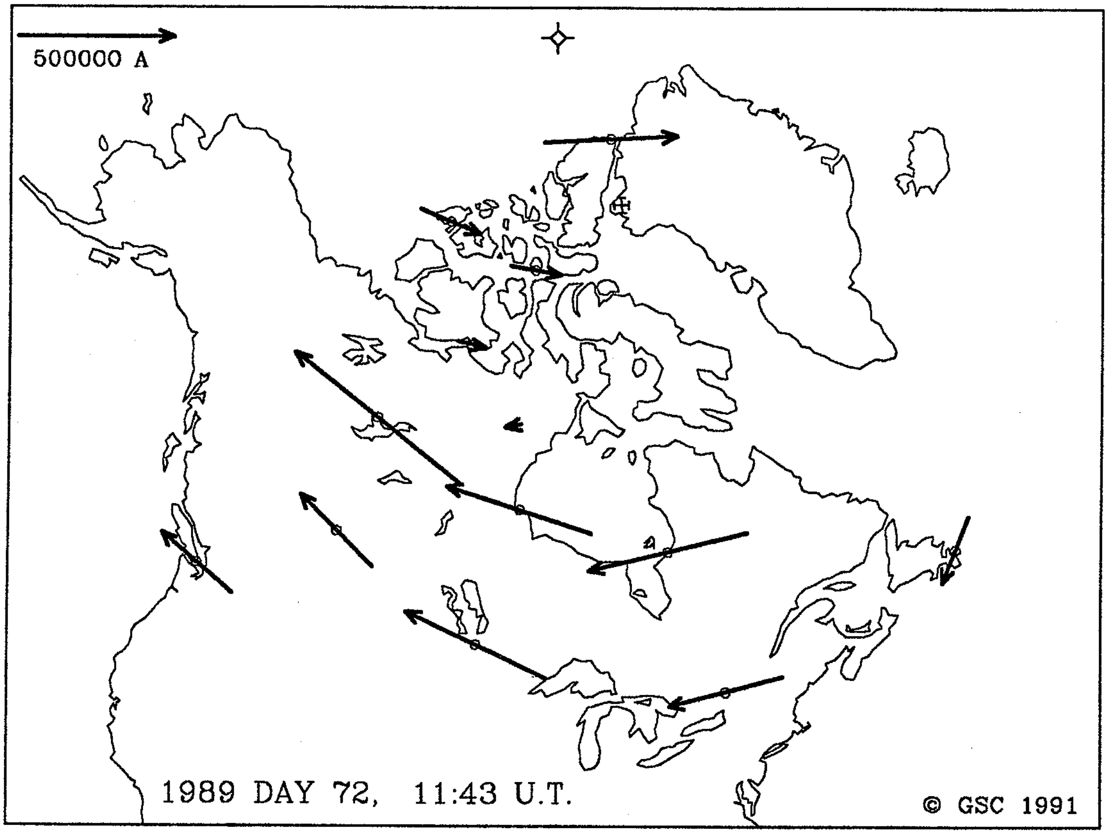
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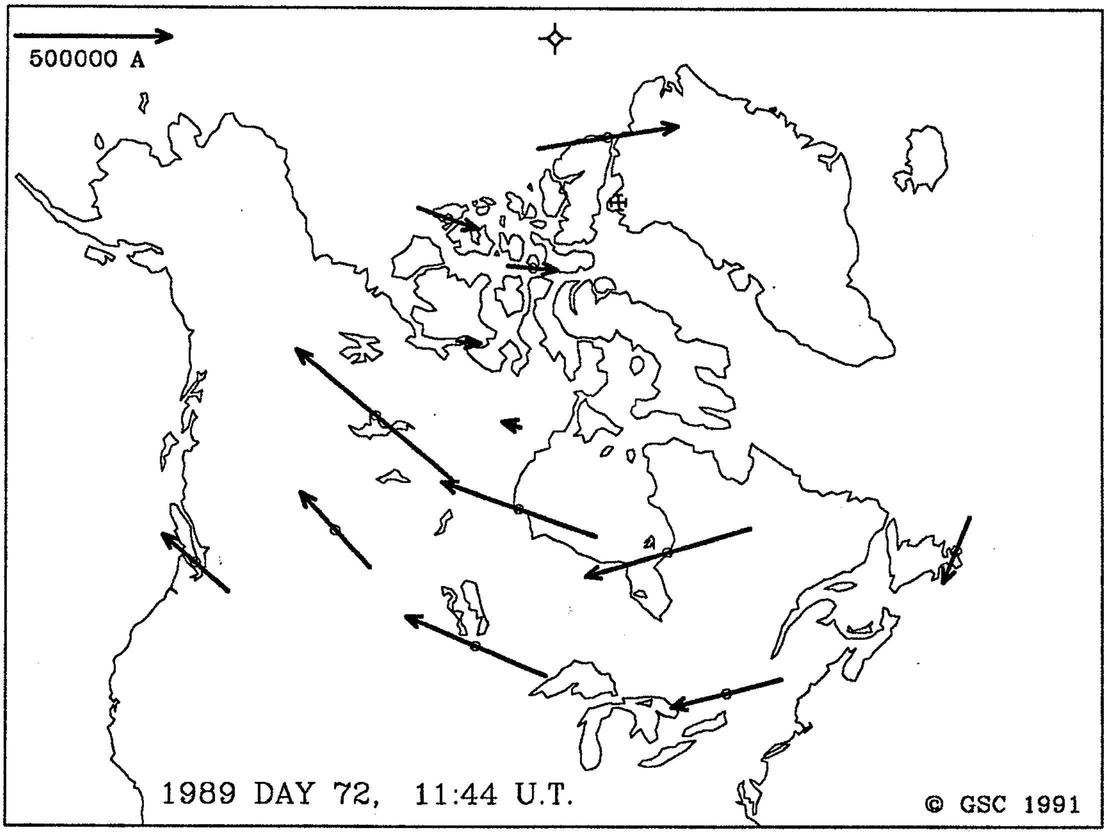
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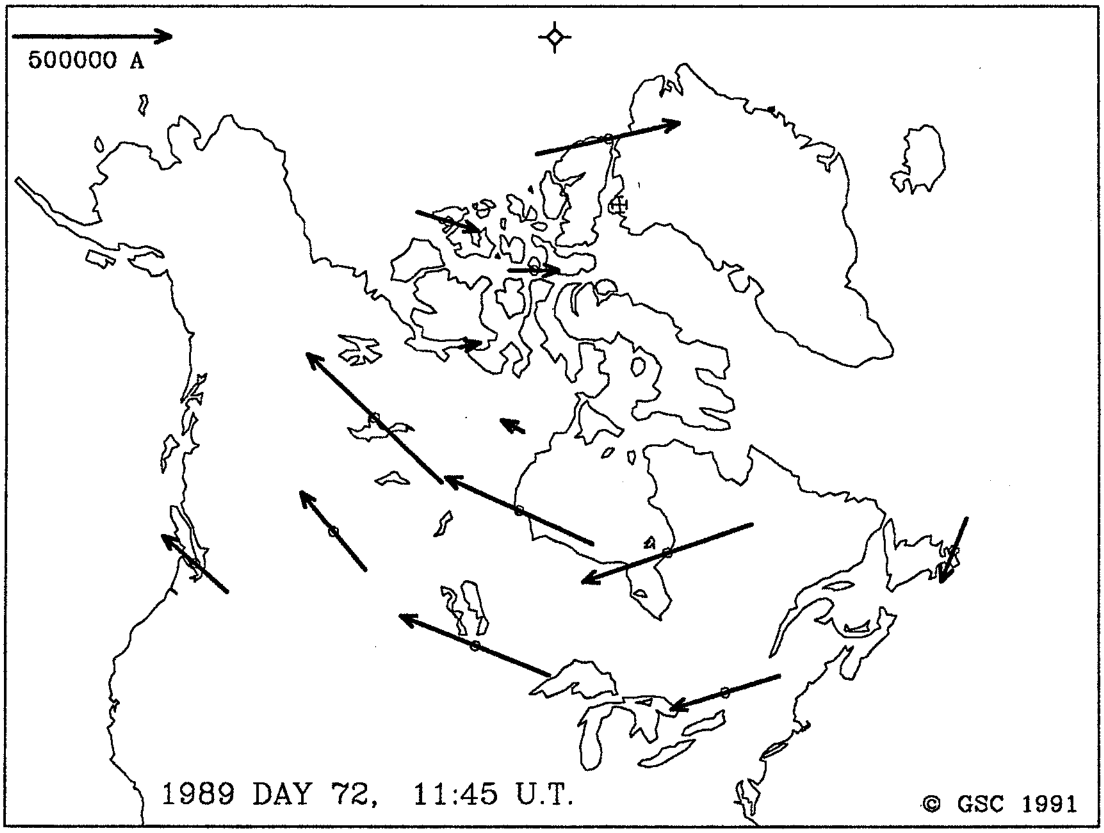
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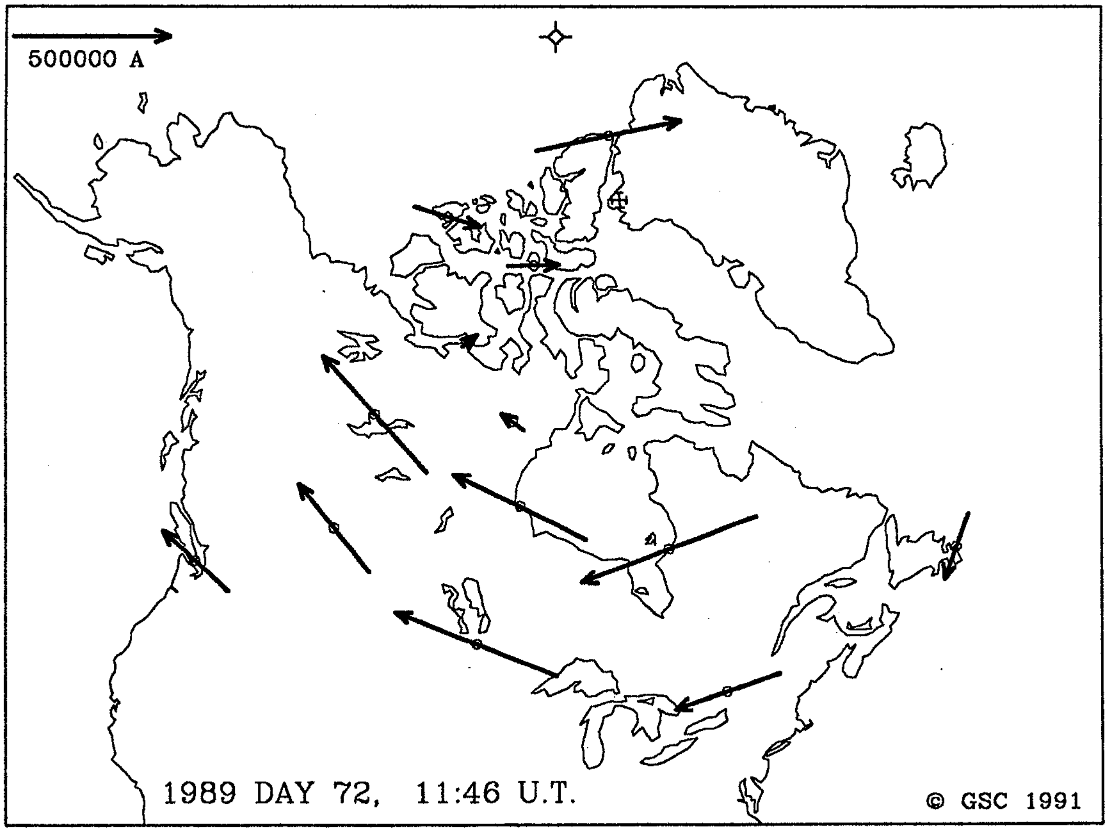
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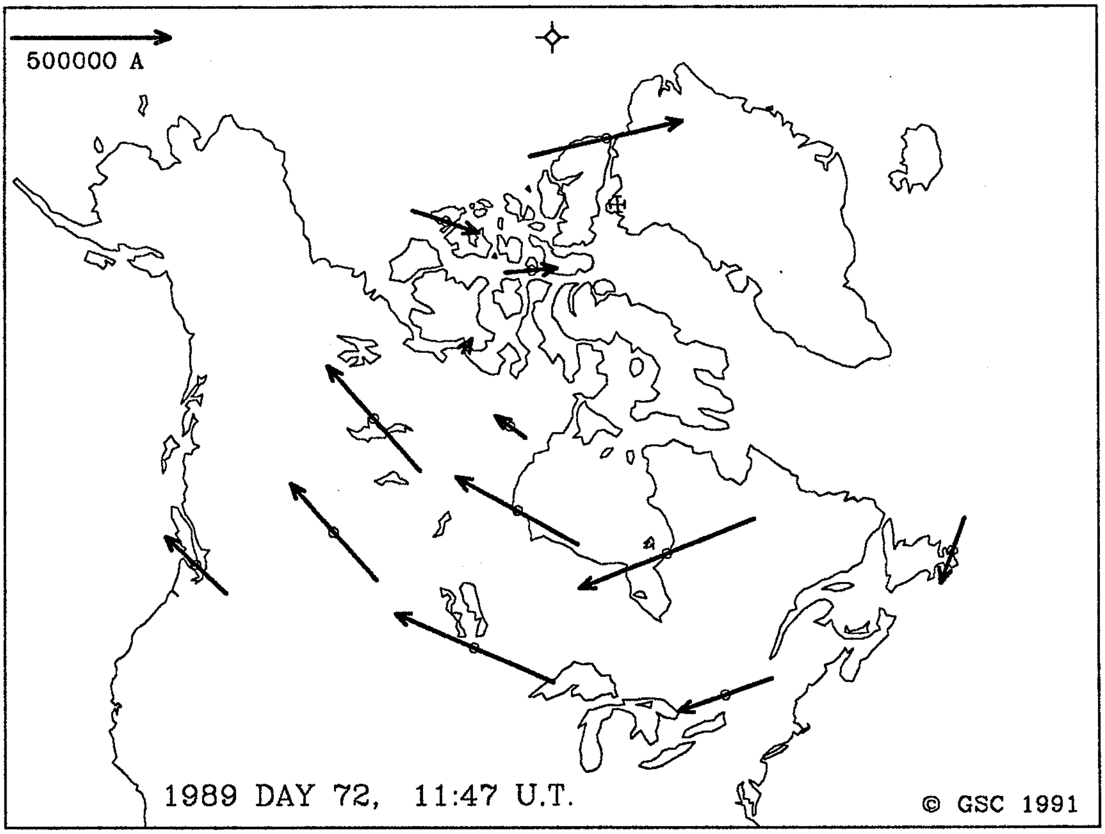
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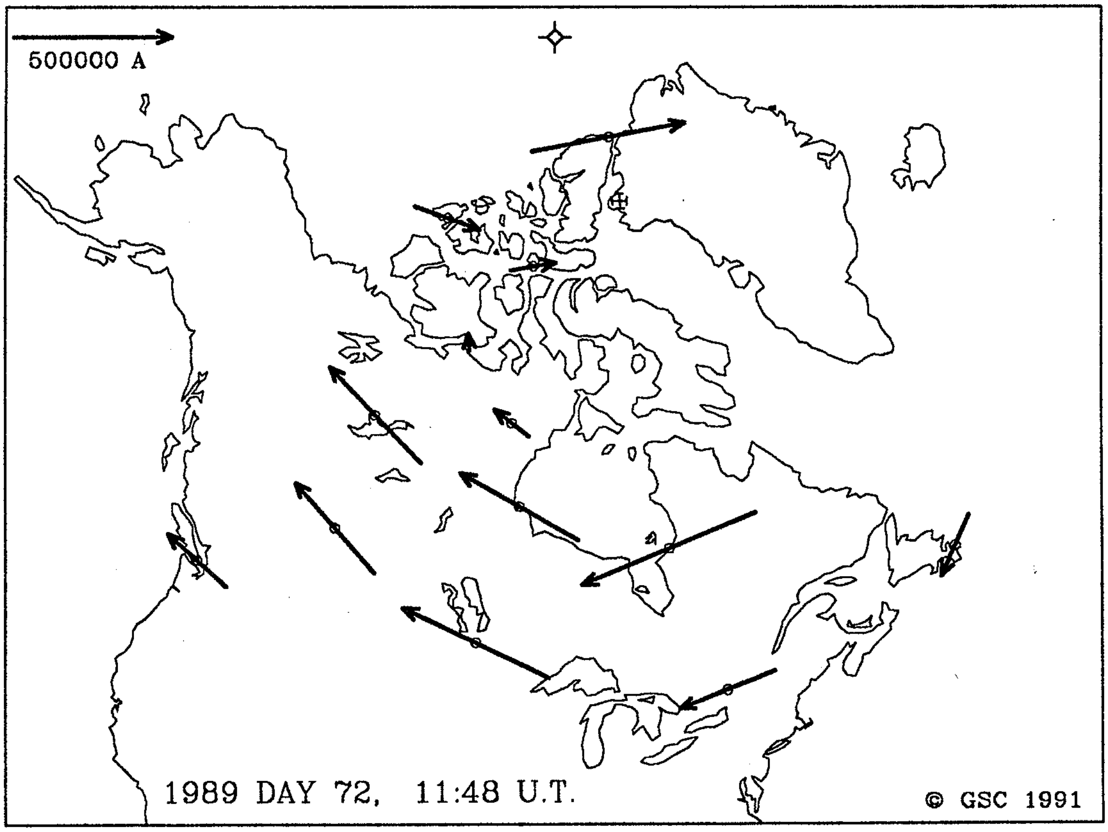
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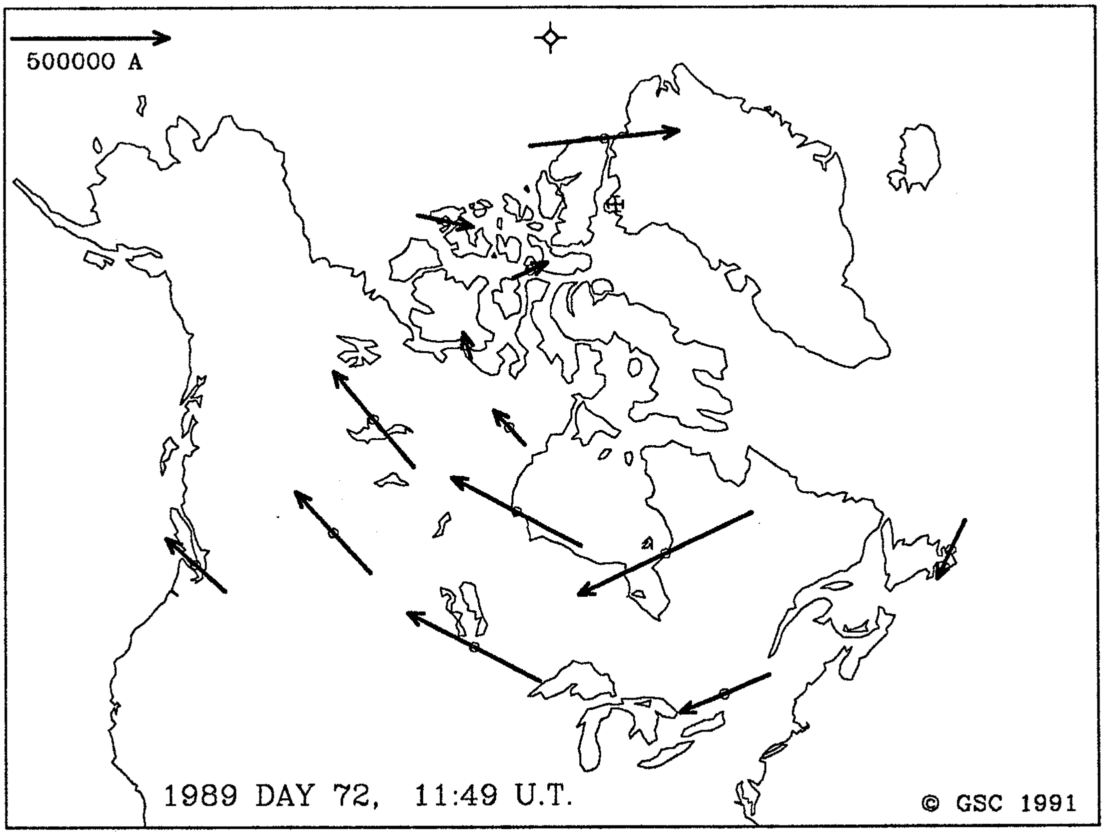
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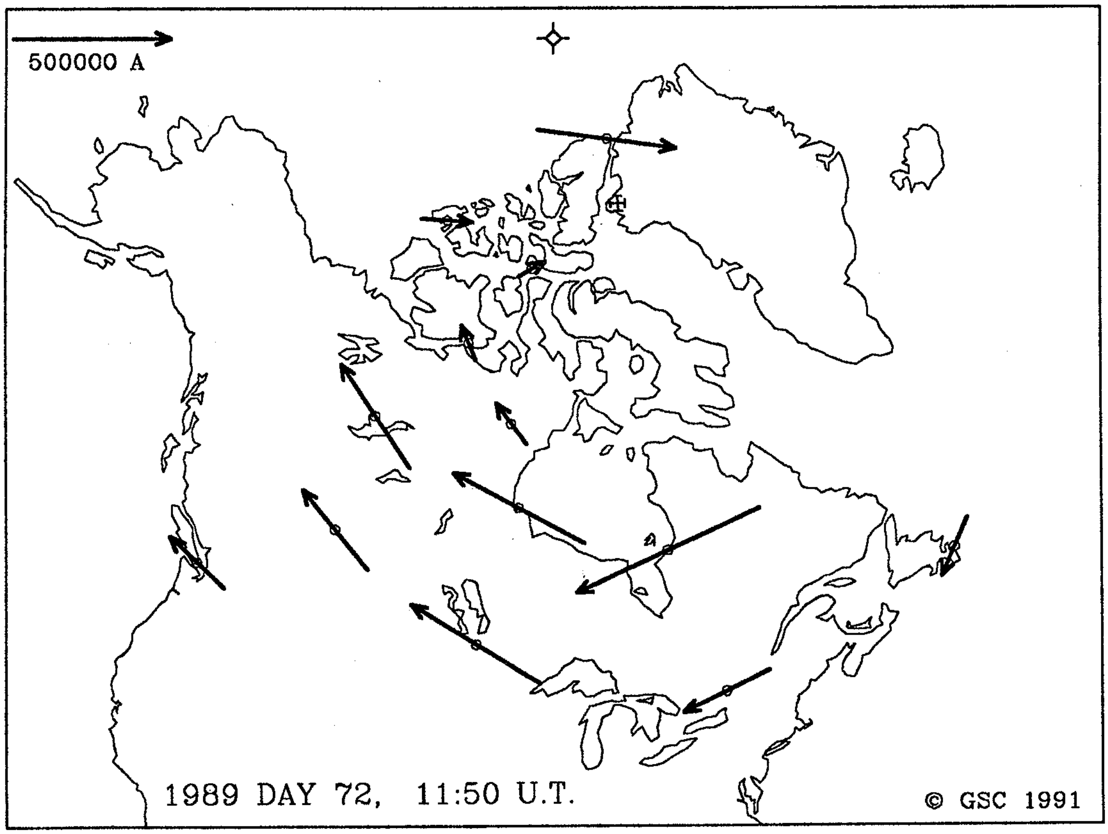
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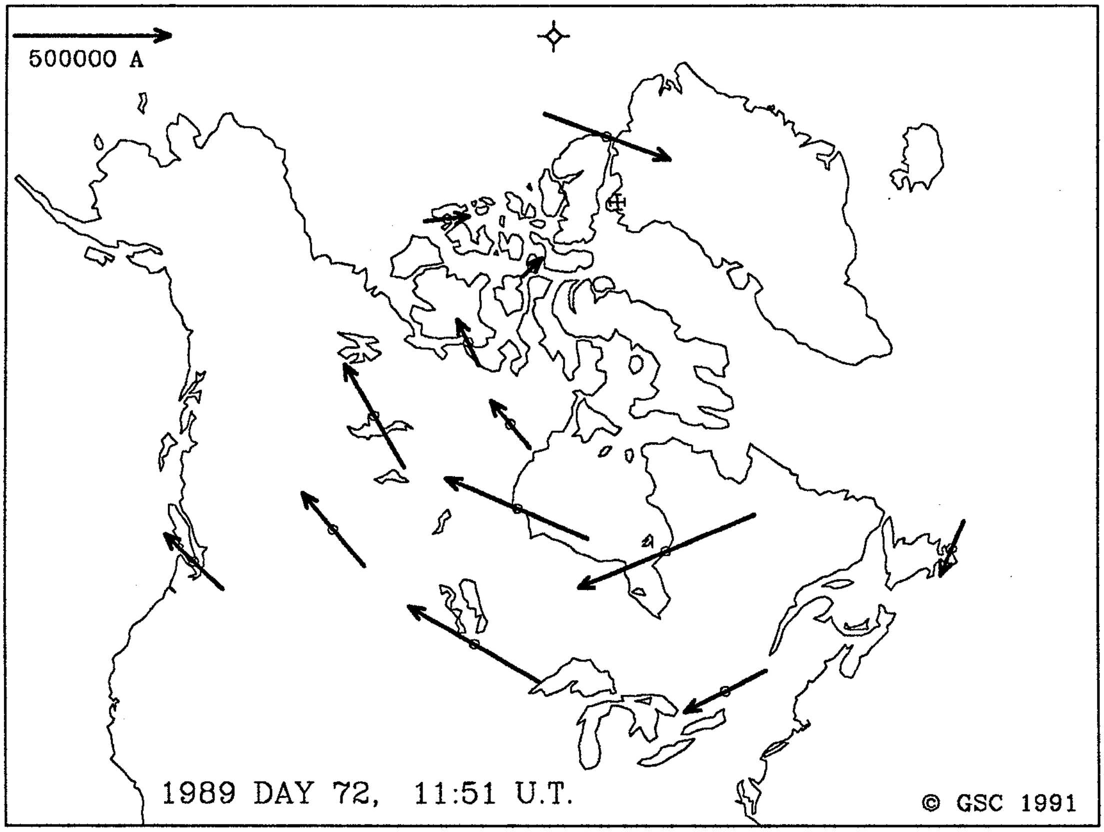
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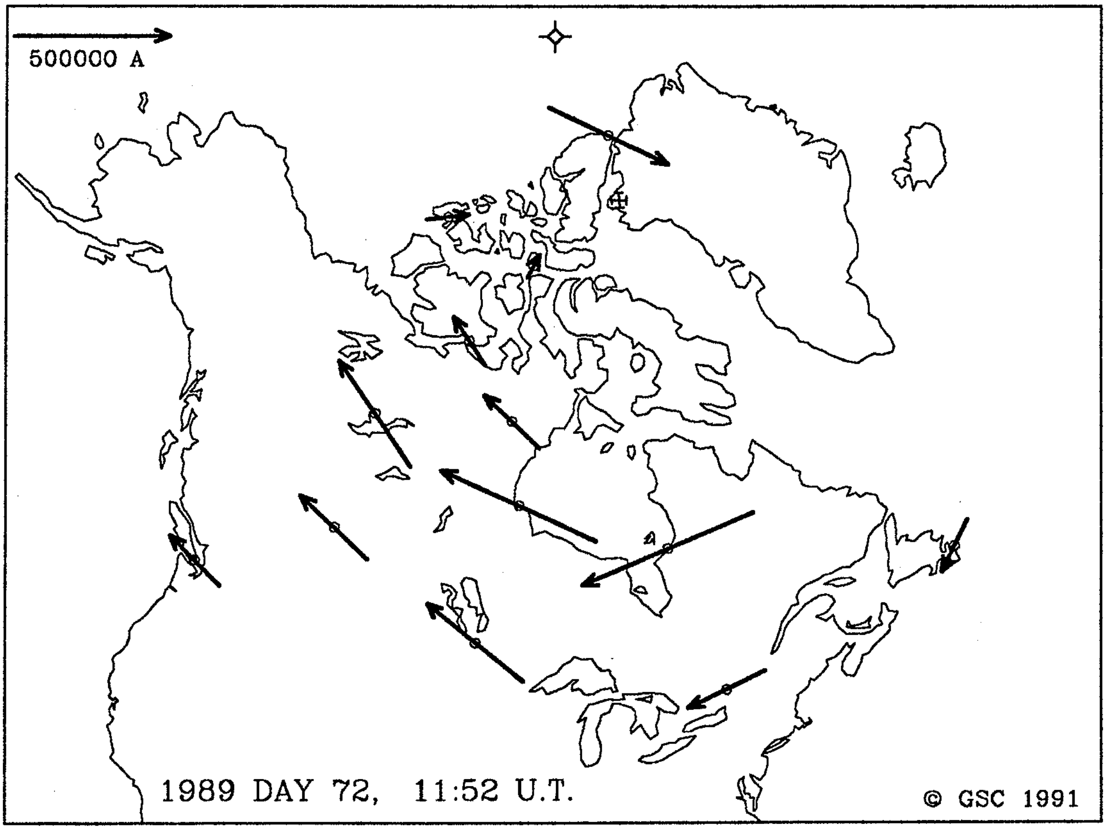
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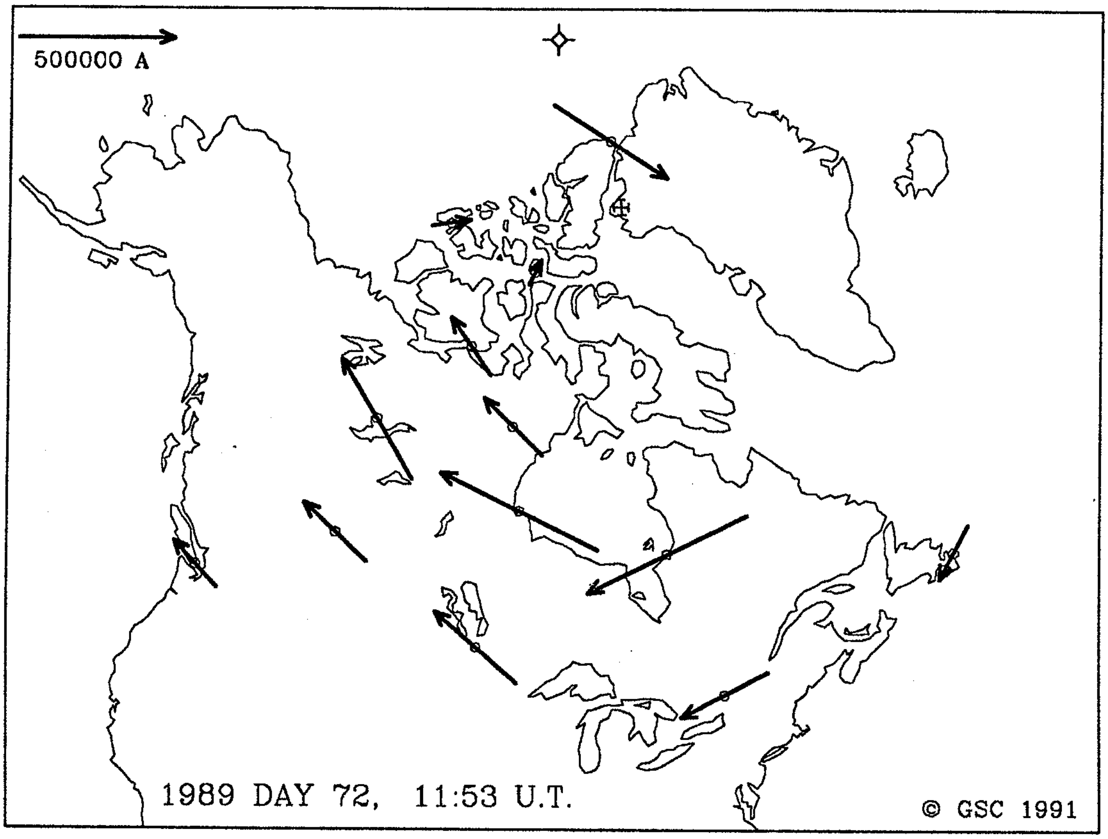
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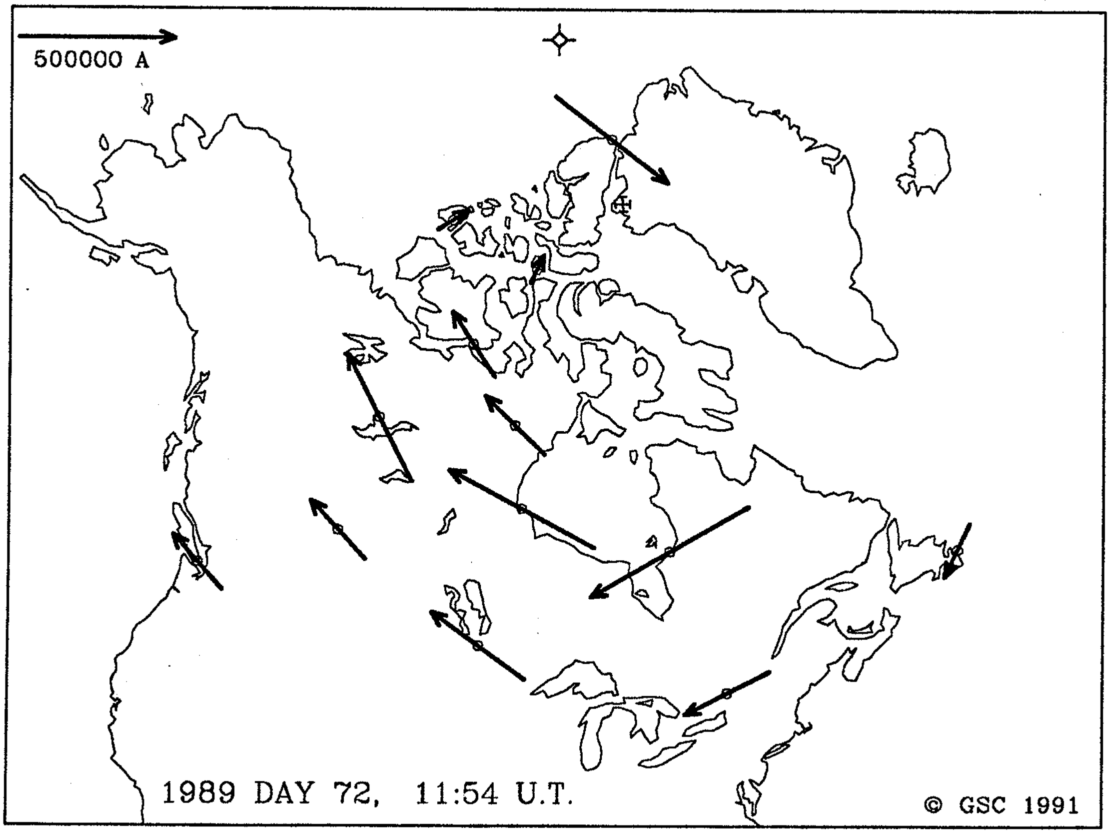
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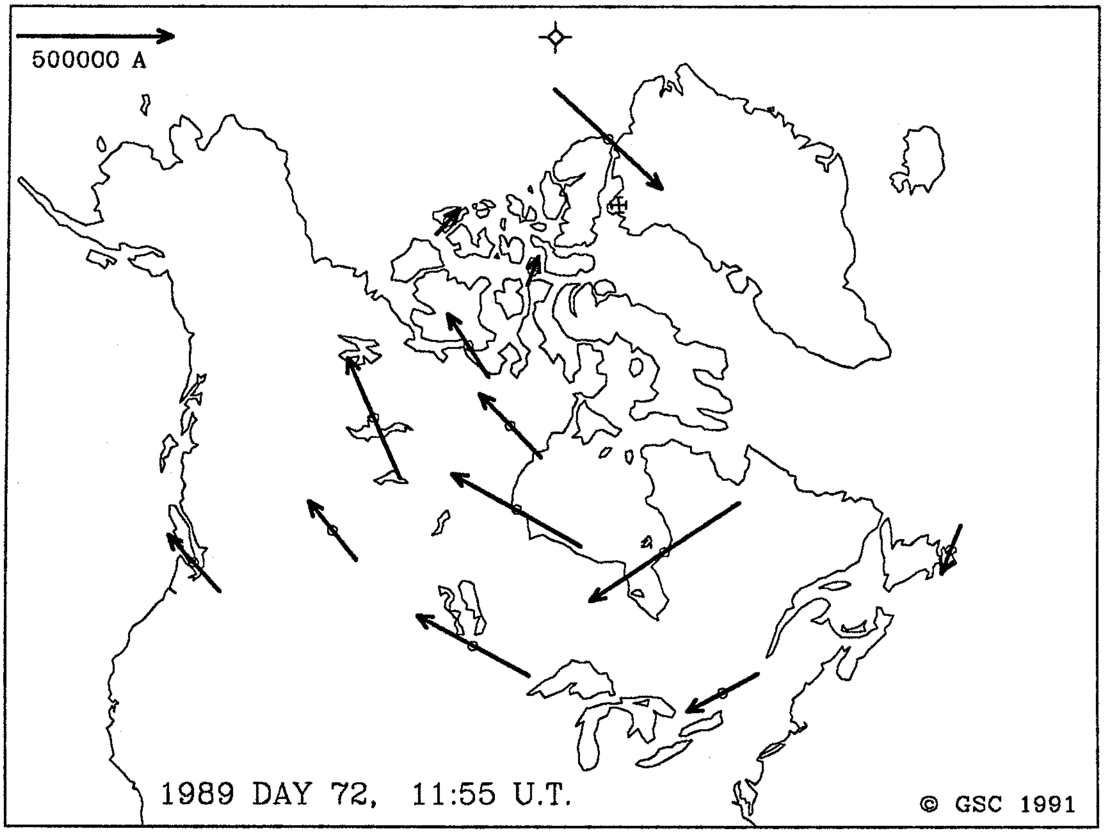
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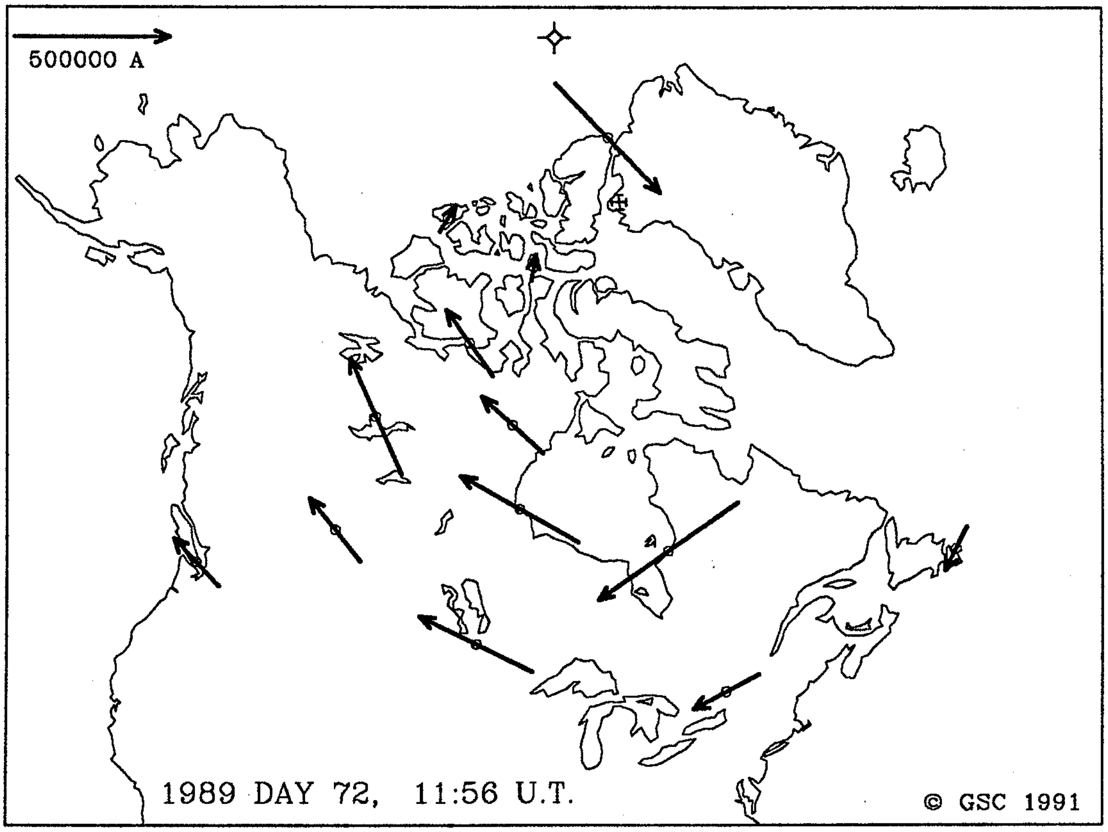
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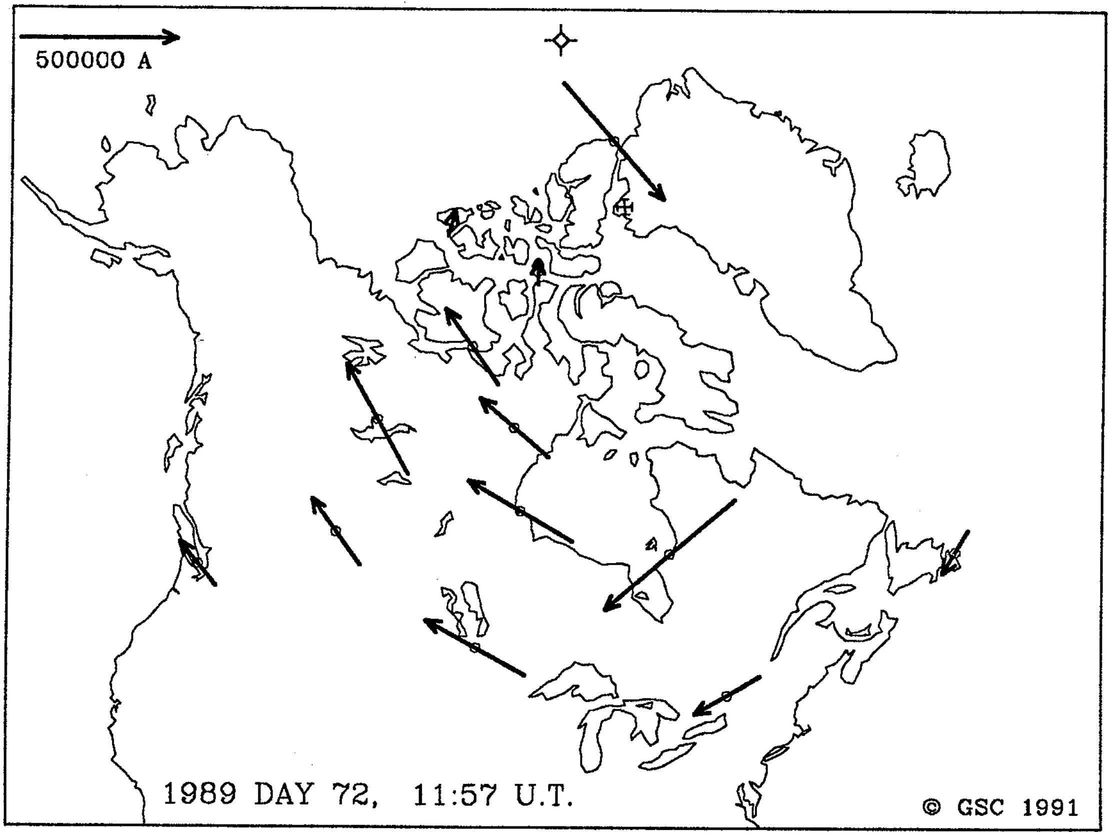
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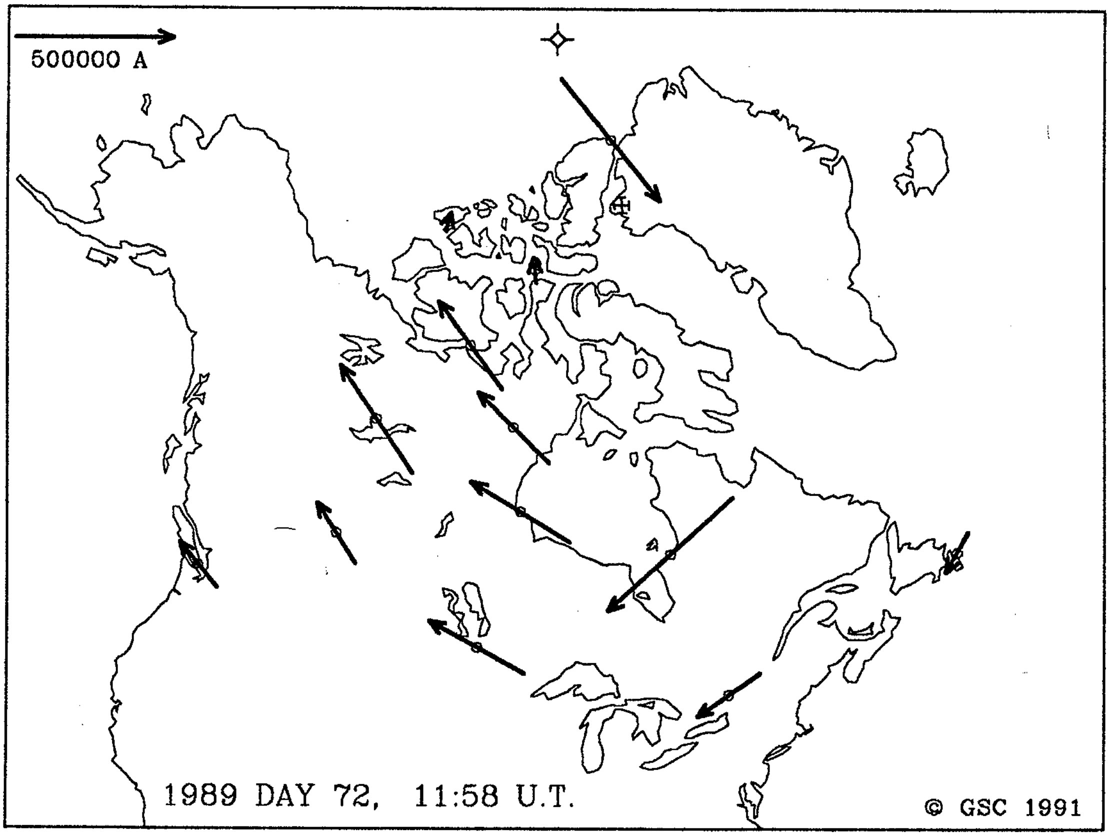
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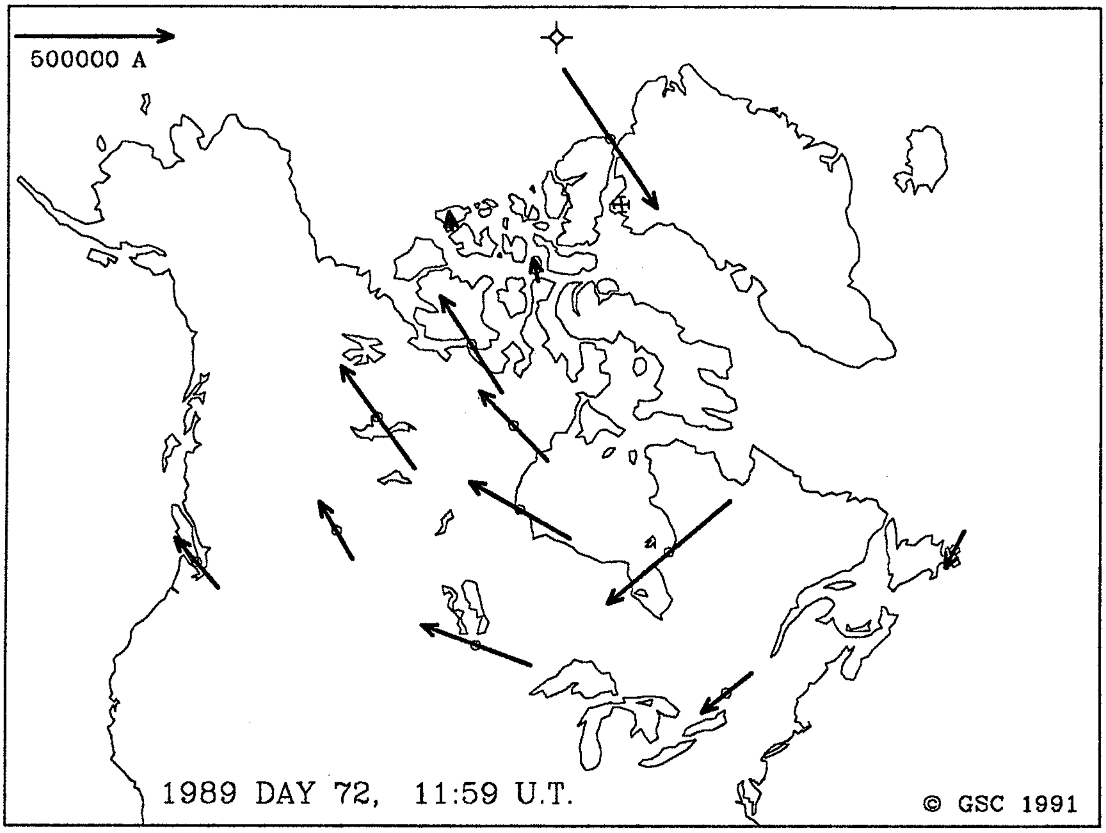
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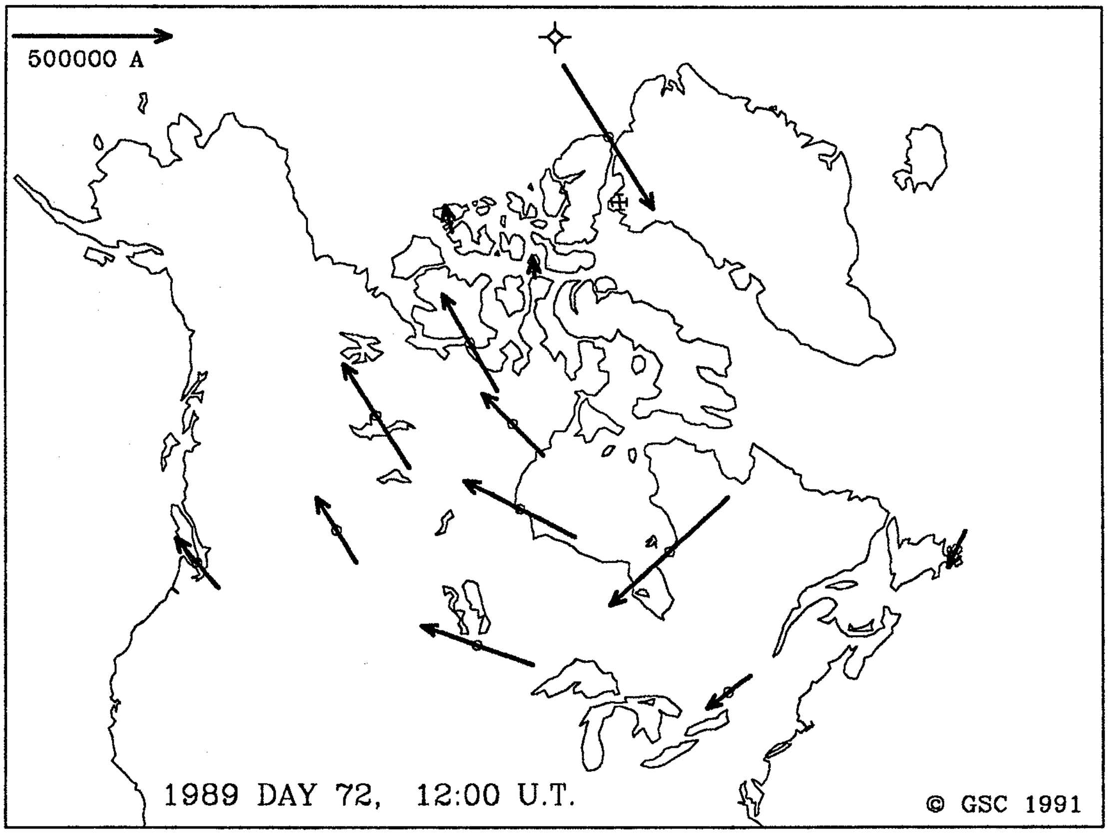
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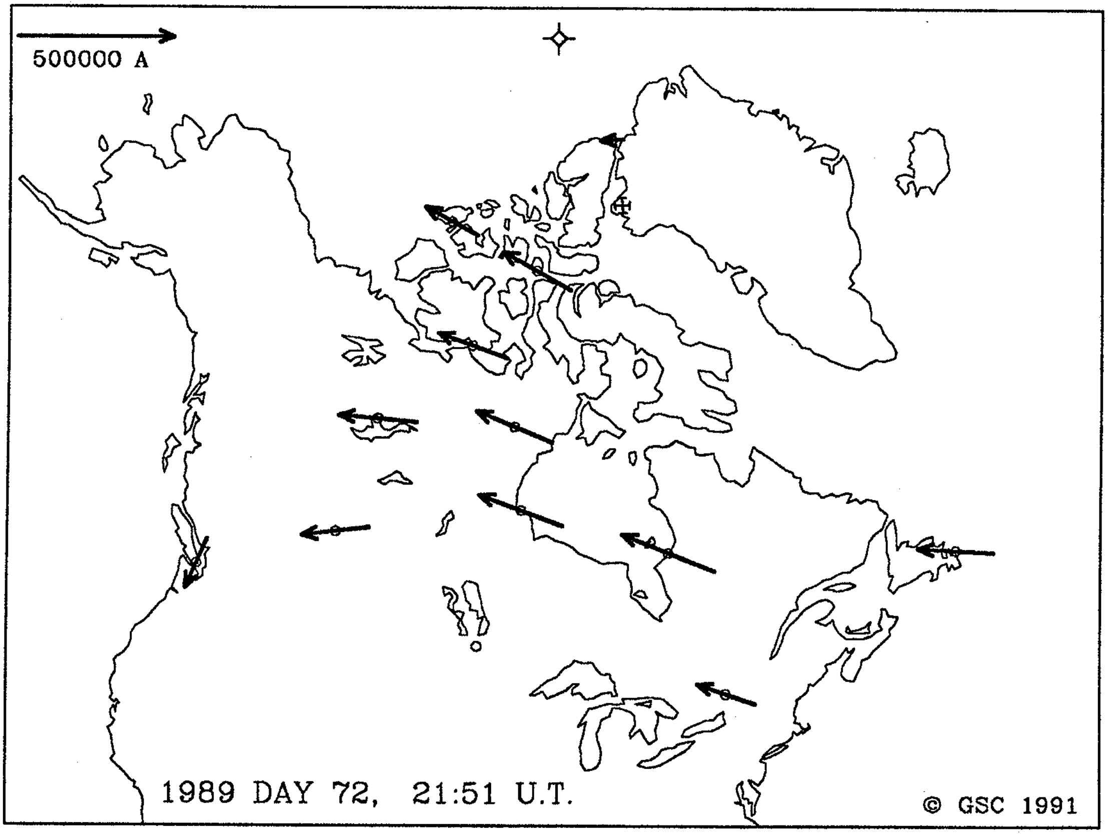
Equivalent Currents at 1 minute intervals

21:51 UT March 13 (Day 72) 1989
to
22:30 UT March 13 (Day 72) 1989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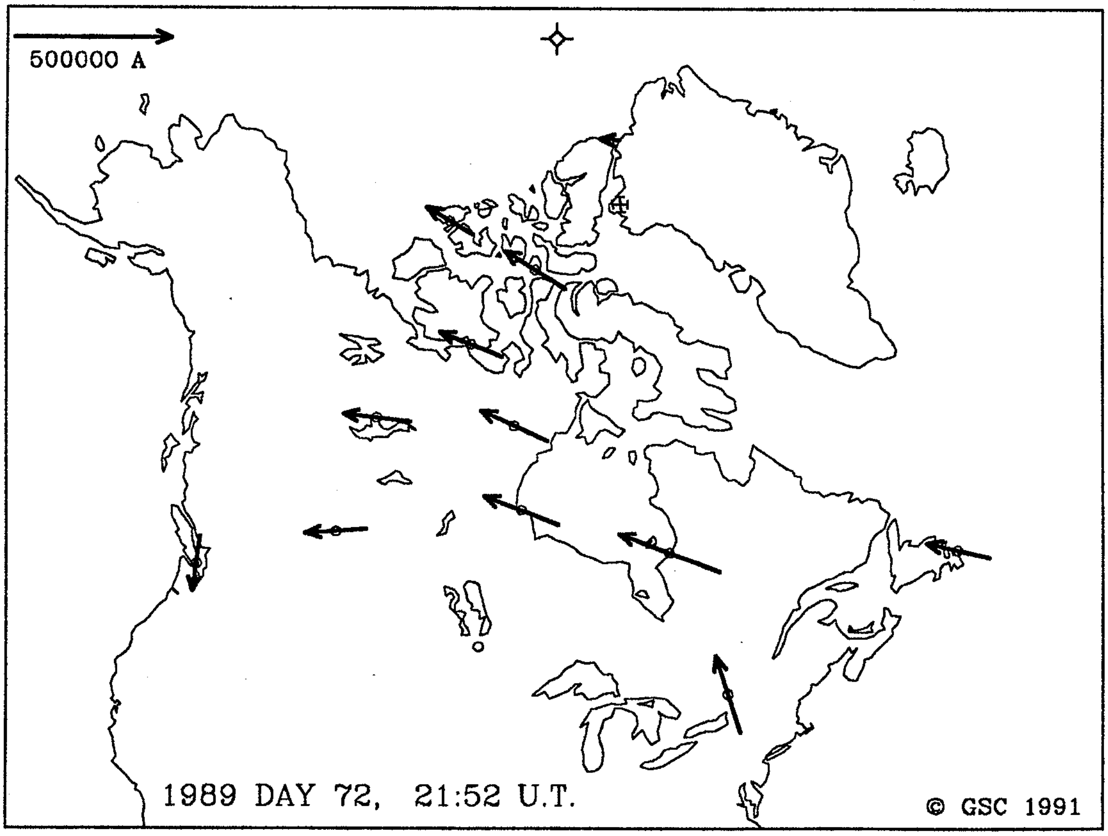
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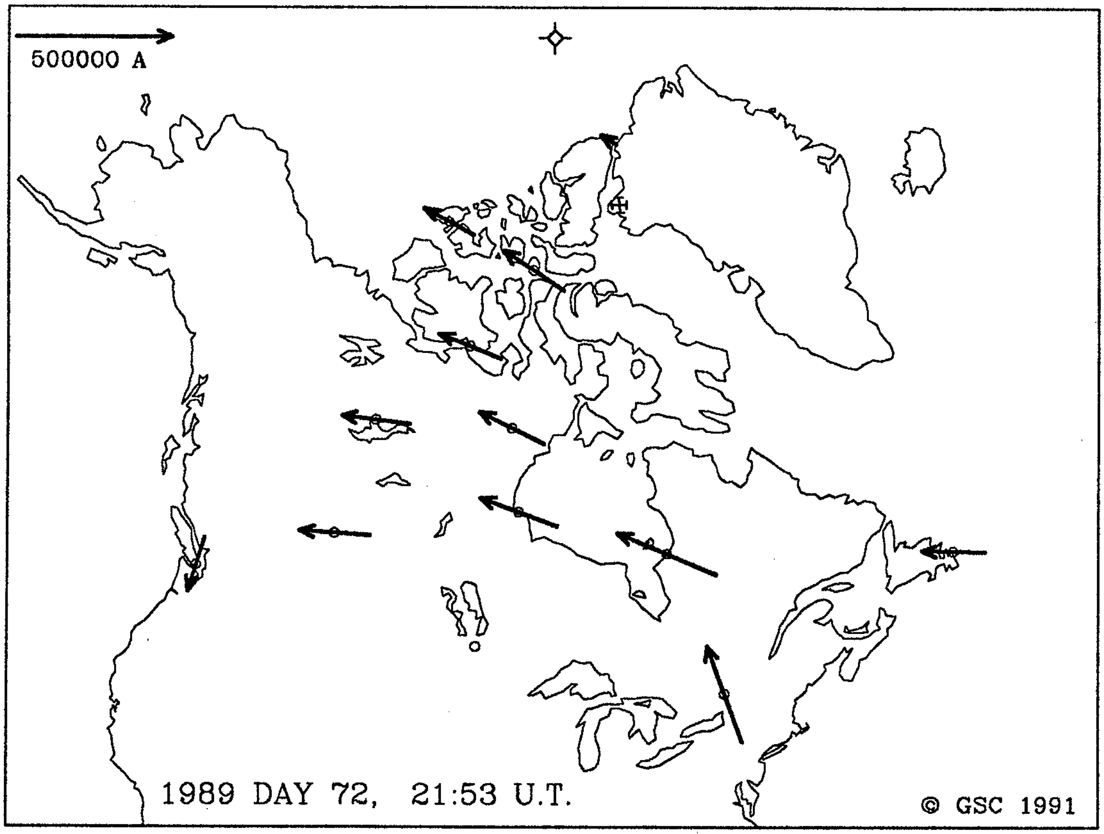
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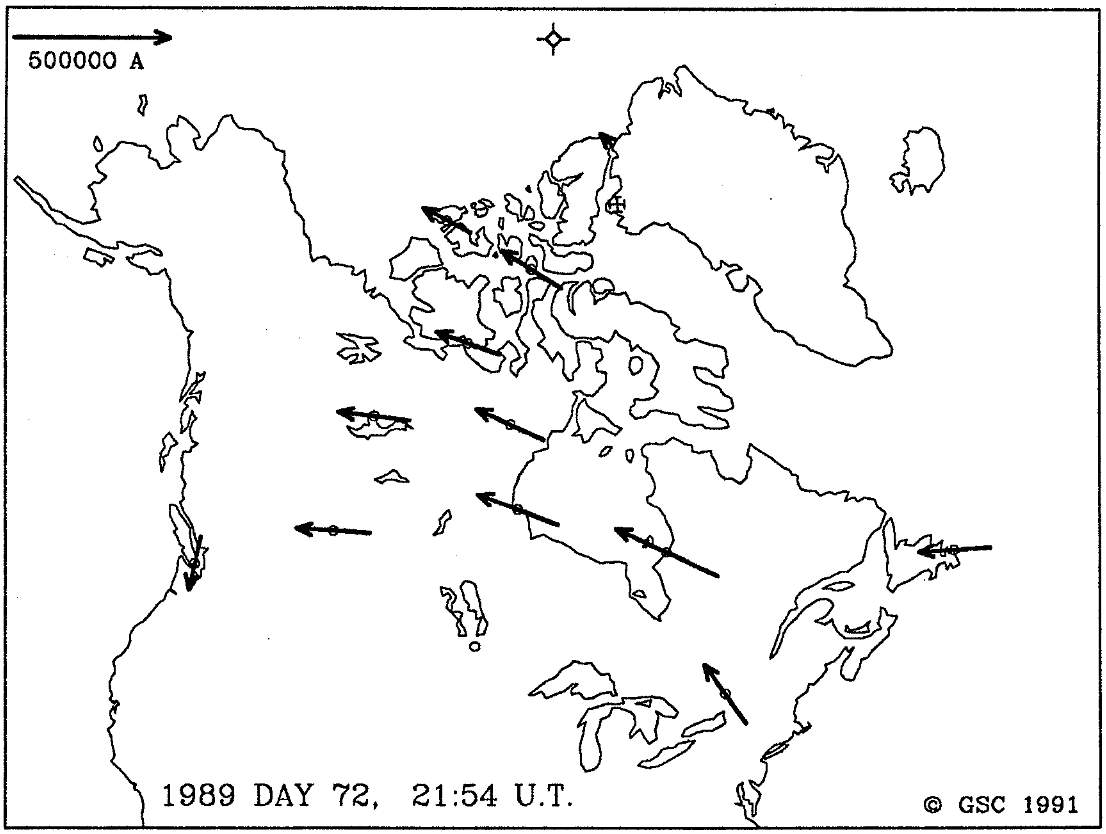
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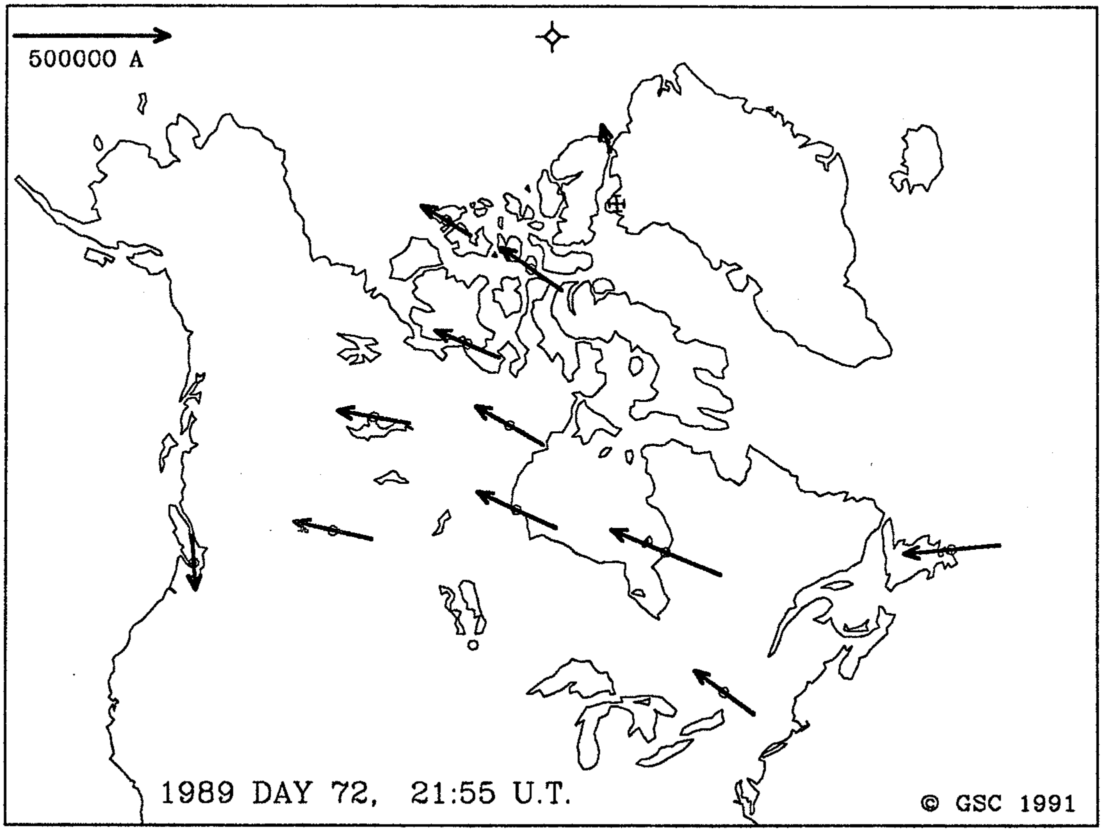
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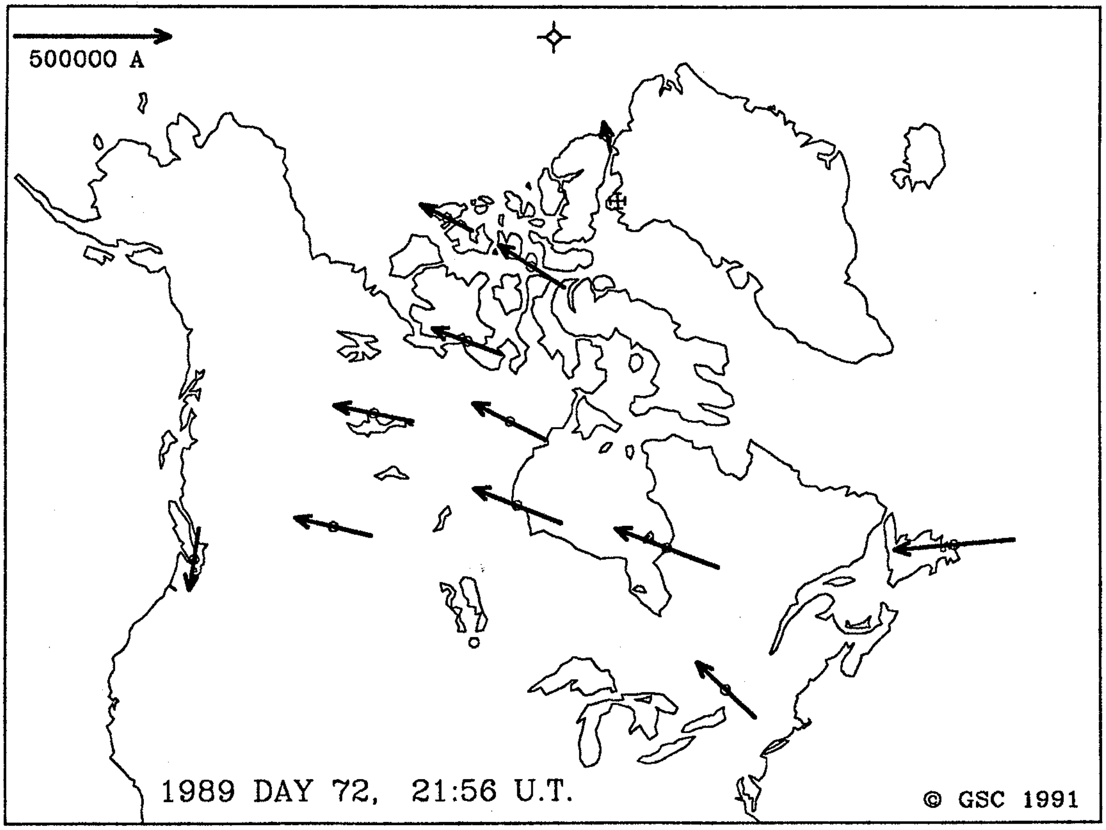
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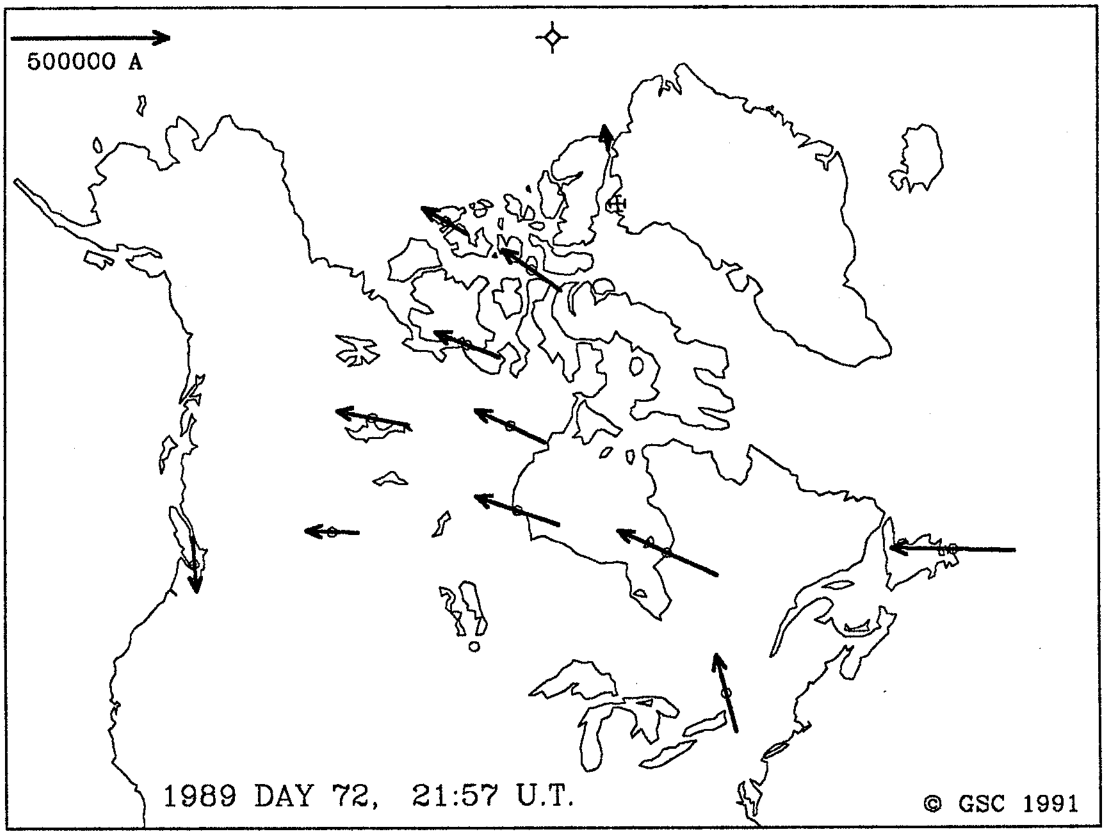
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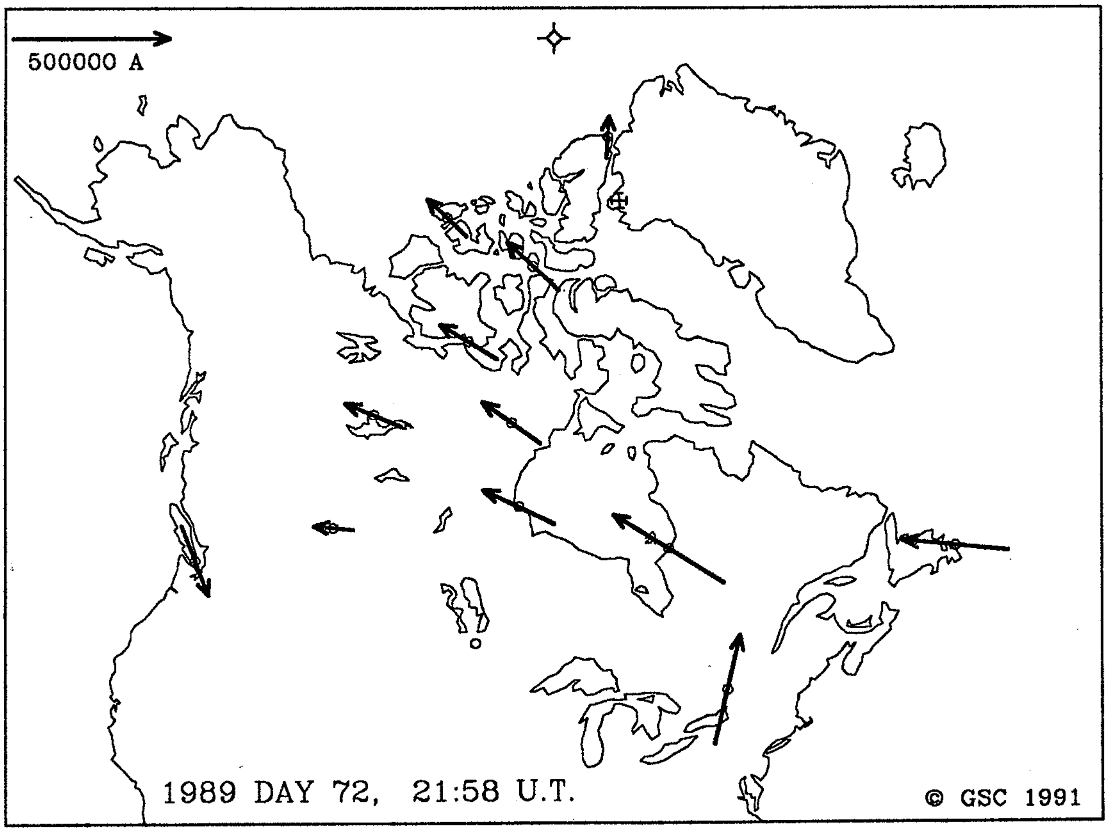
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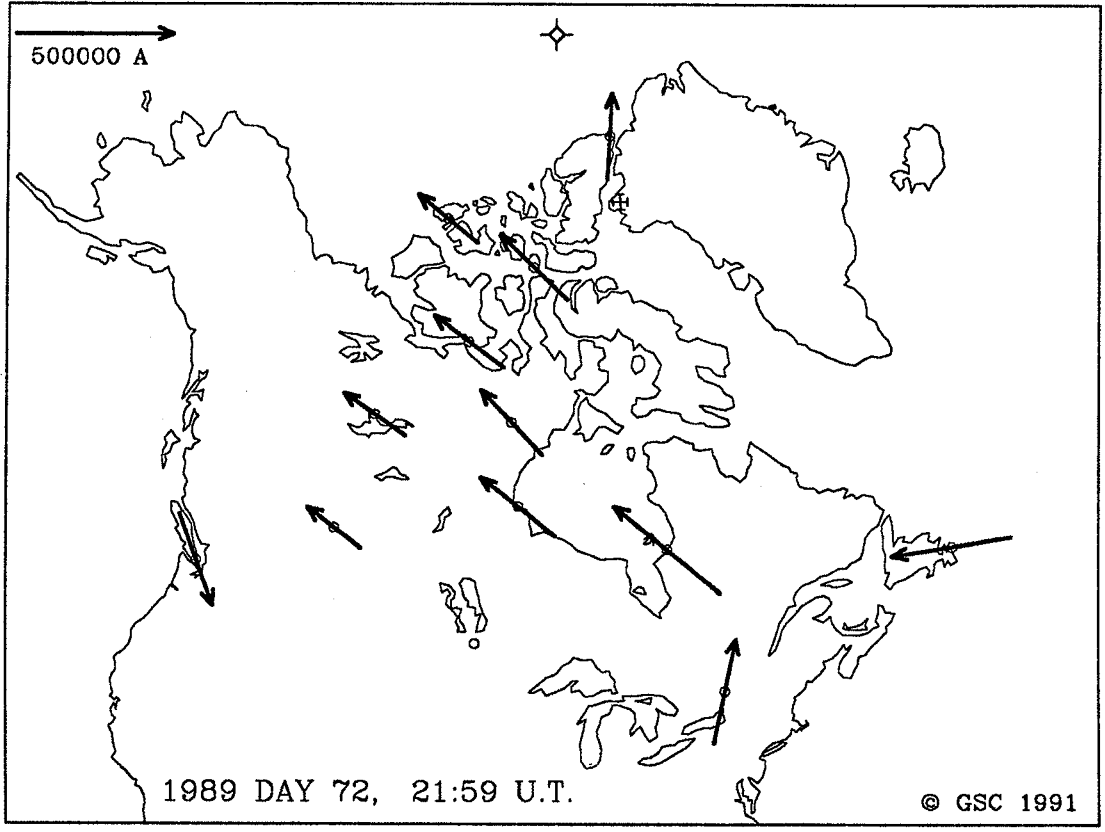
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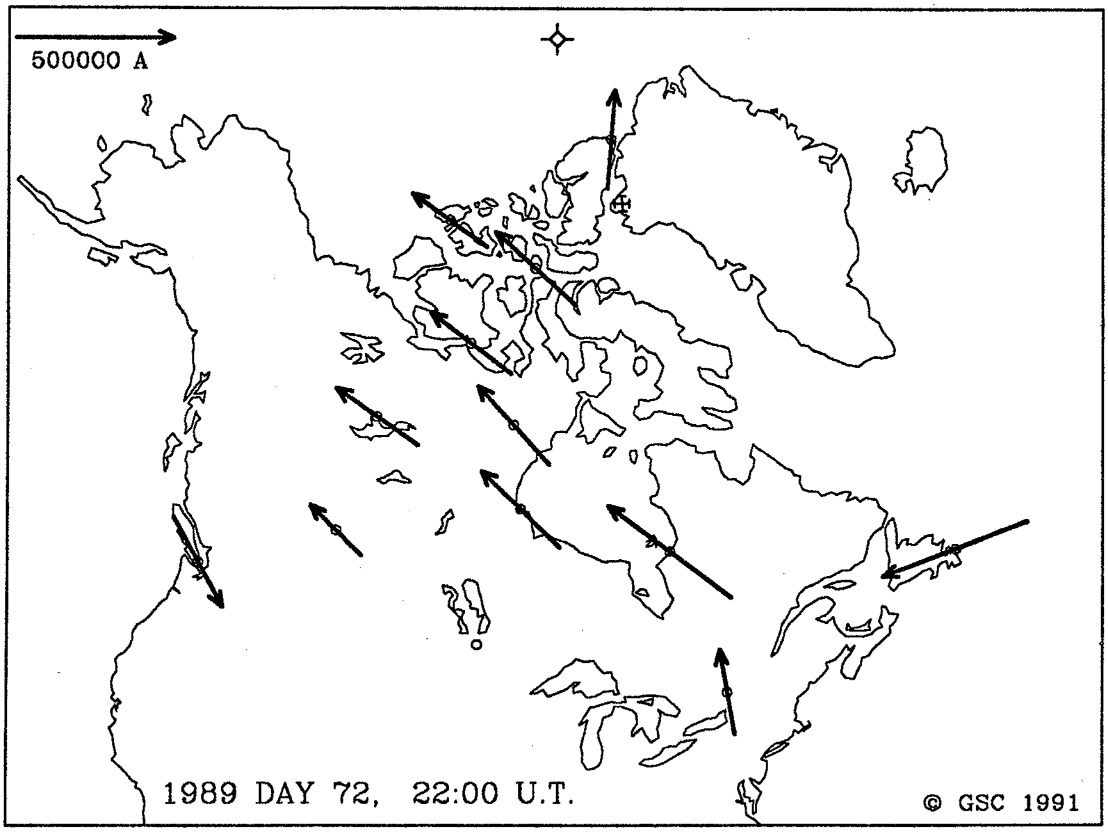
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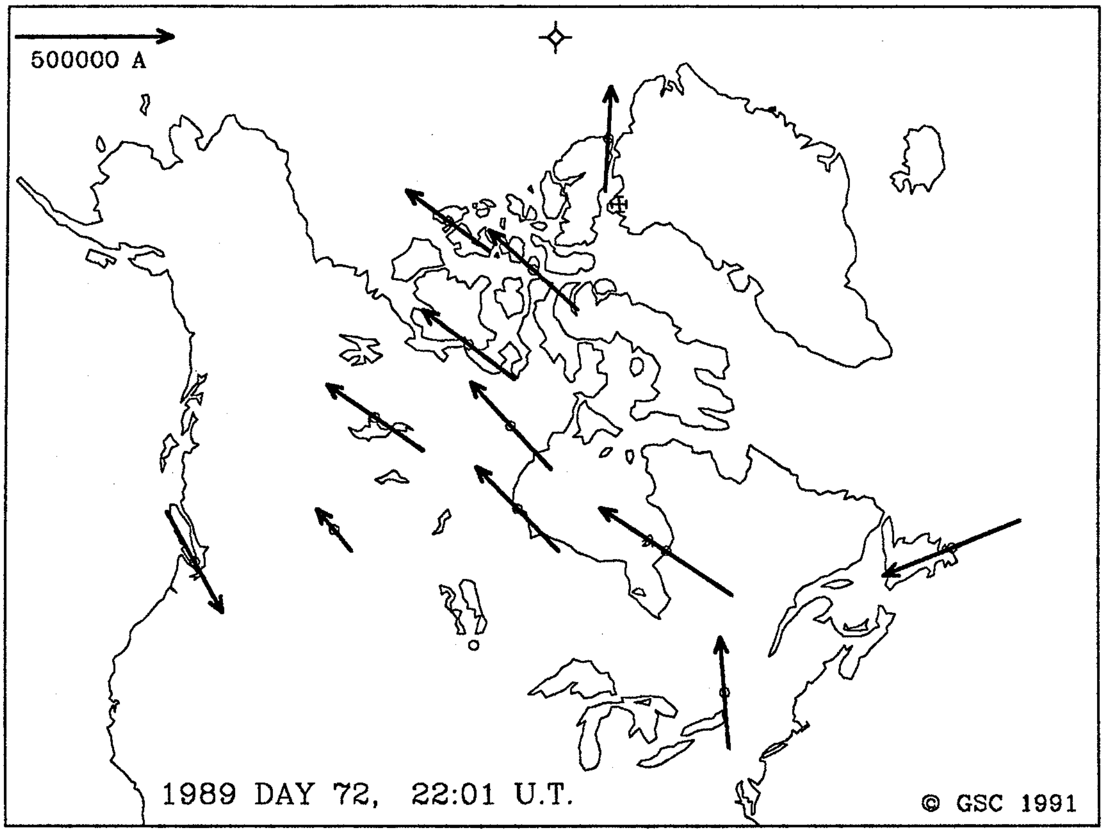
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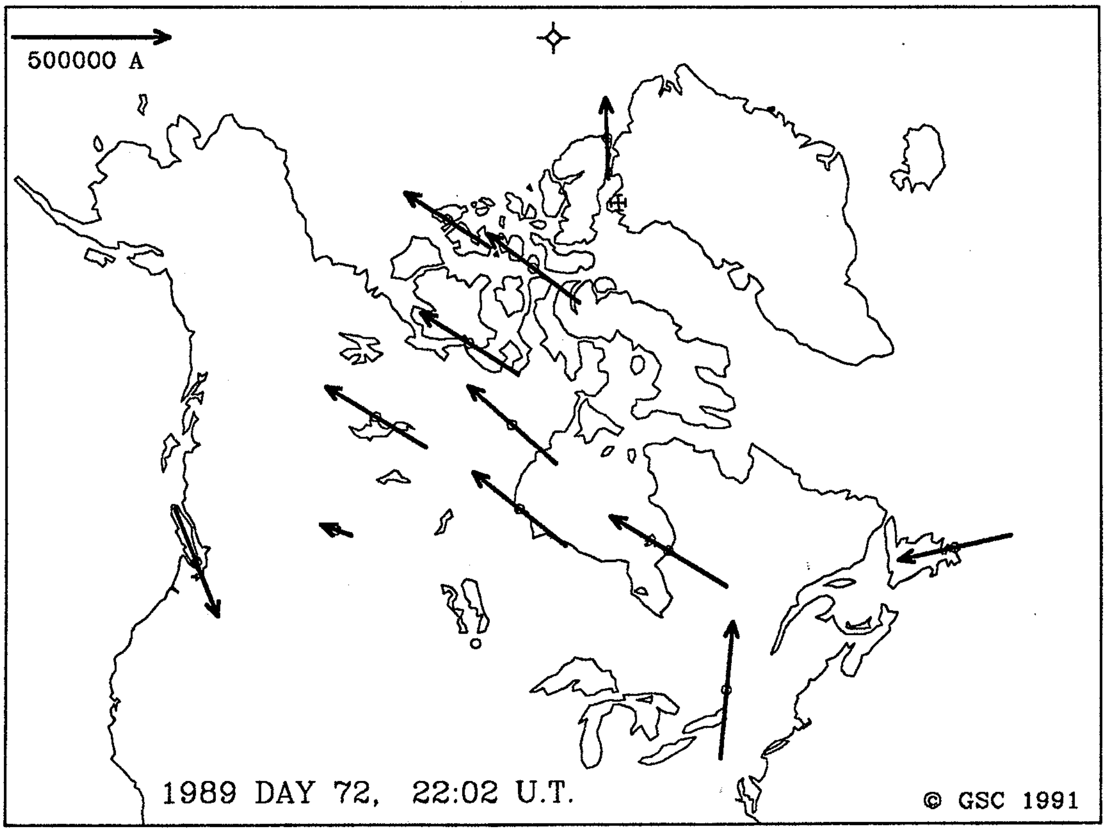
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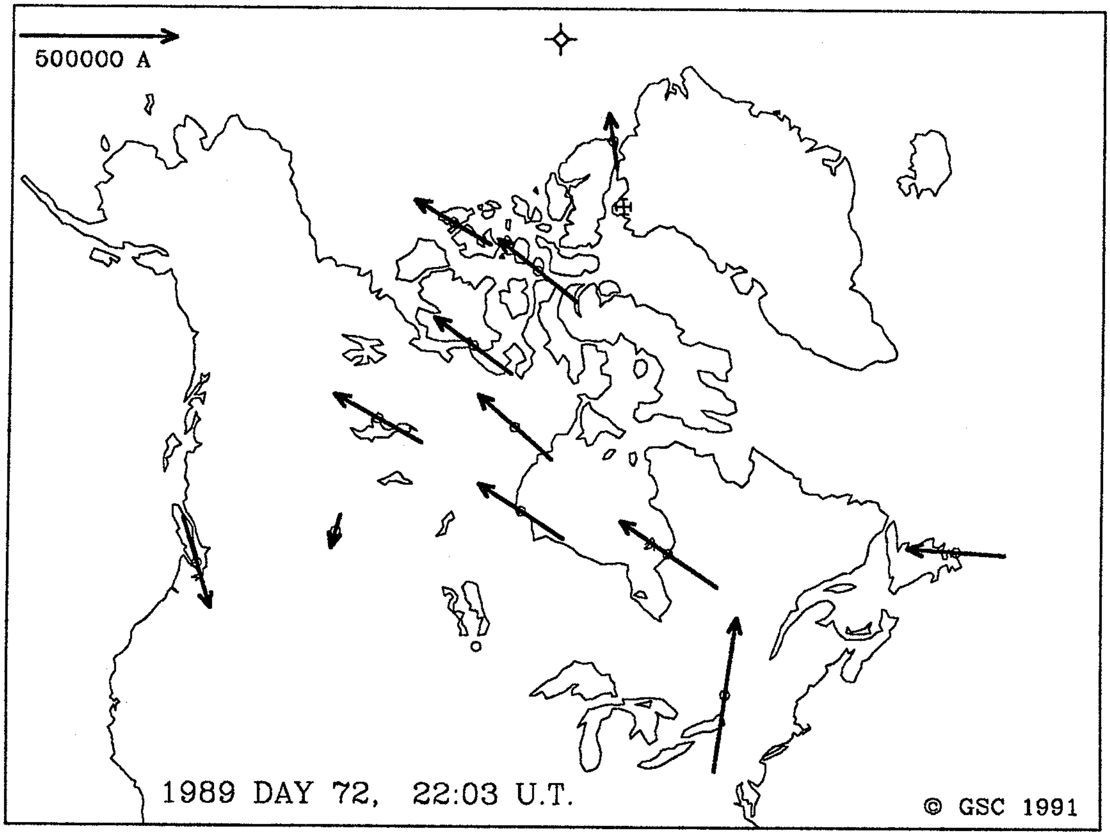
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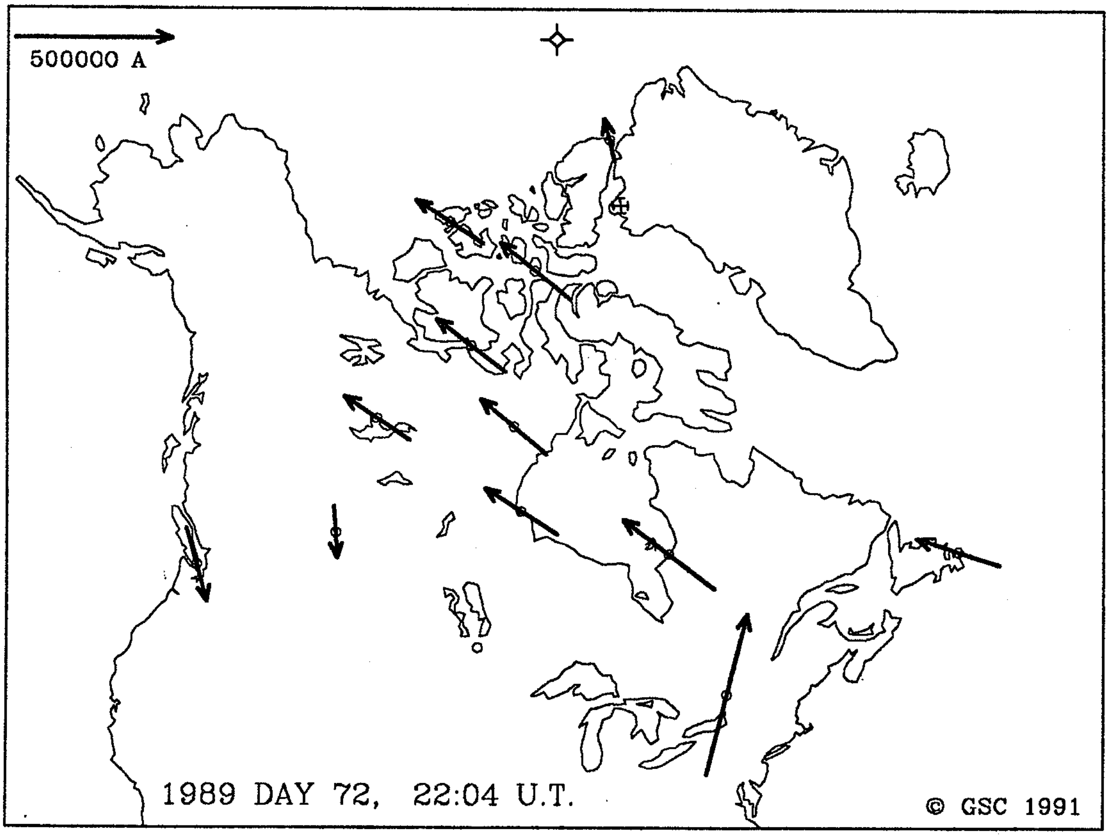
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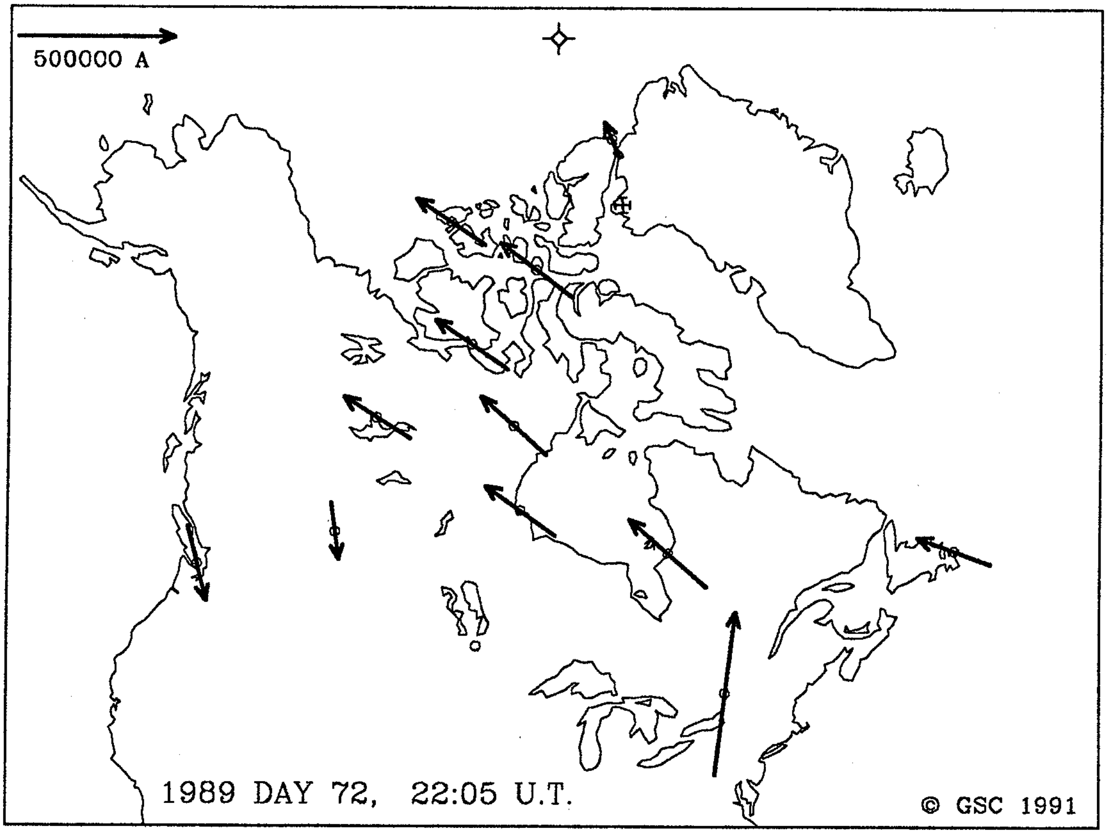
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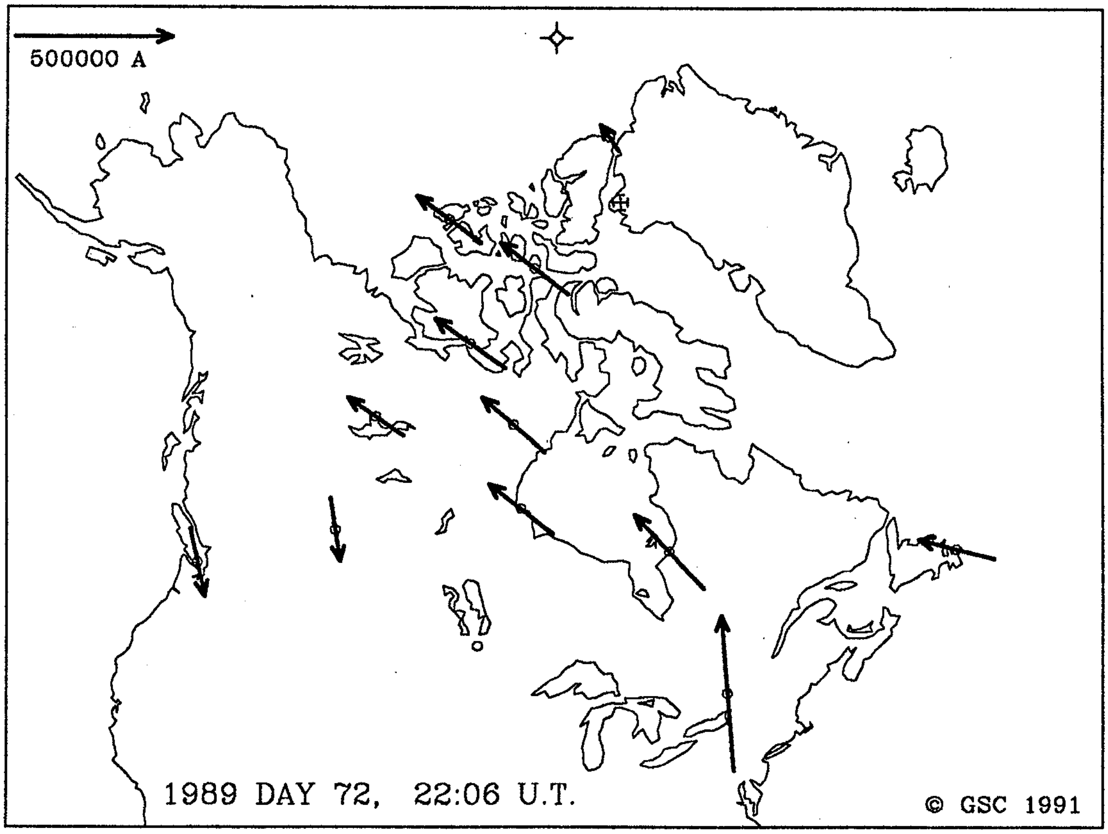
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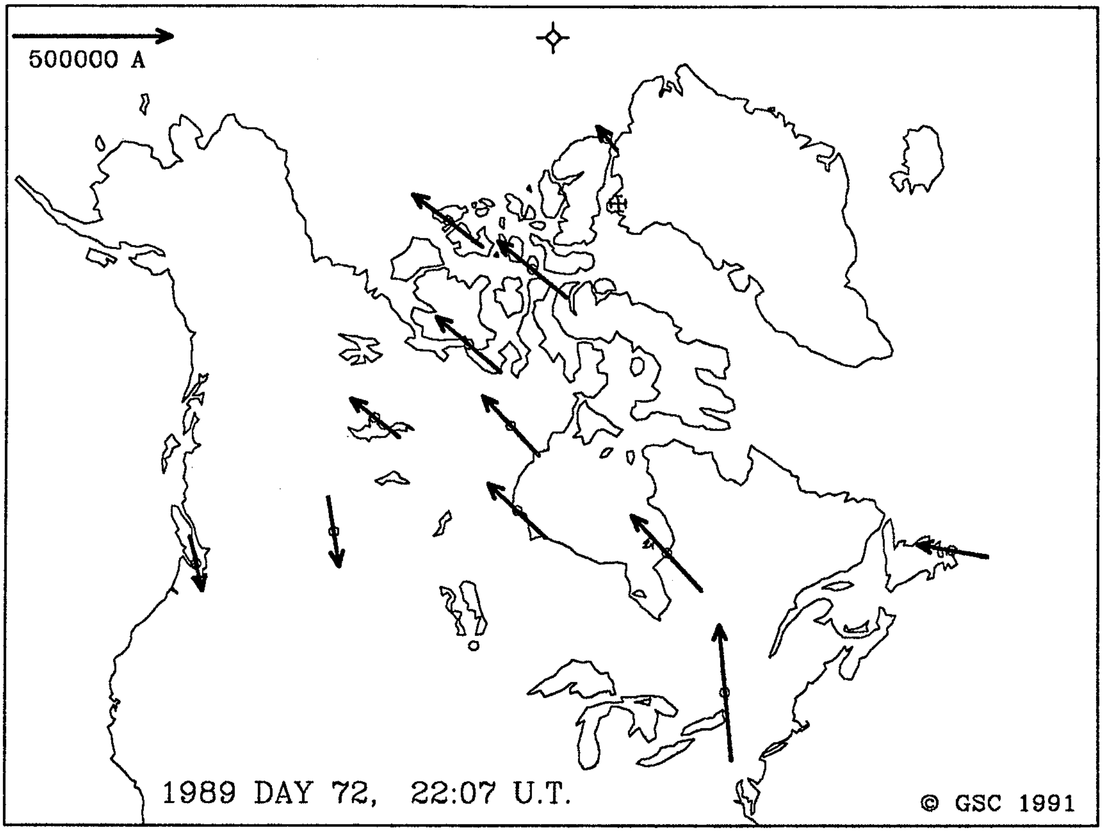
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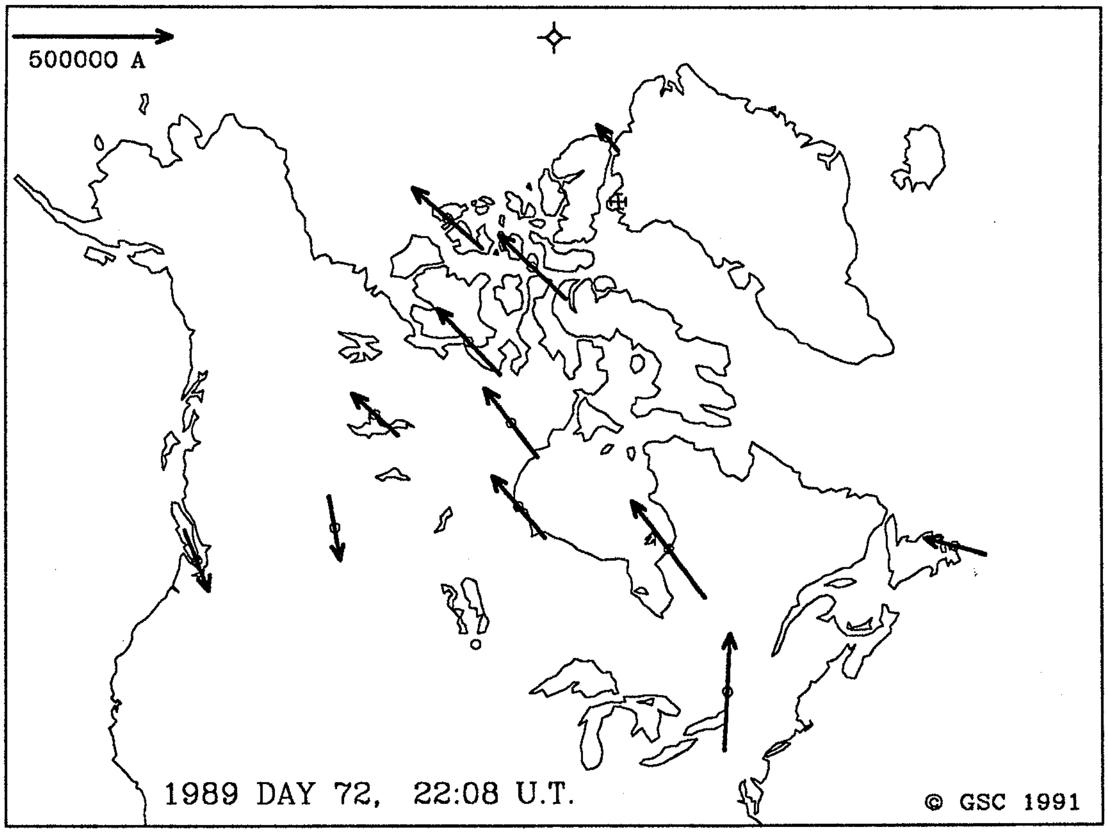
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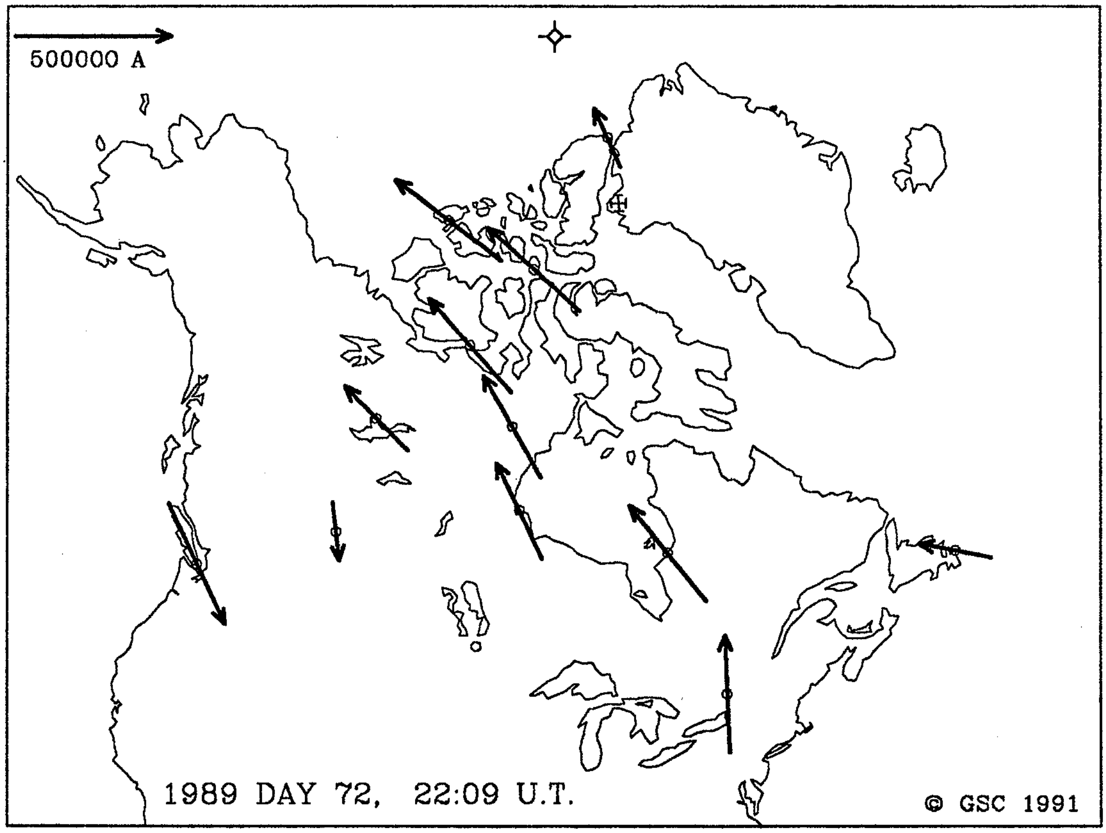
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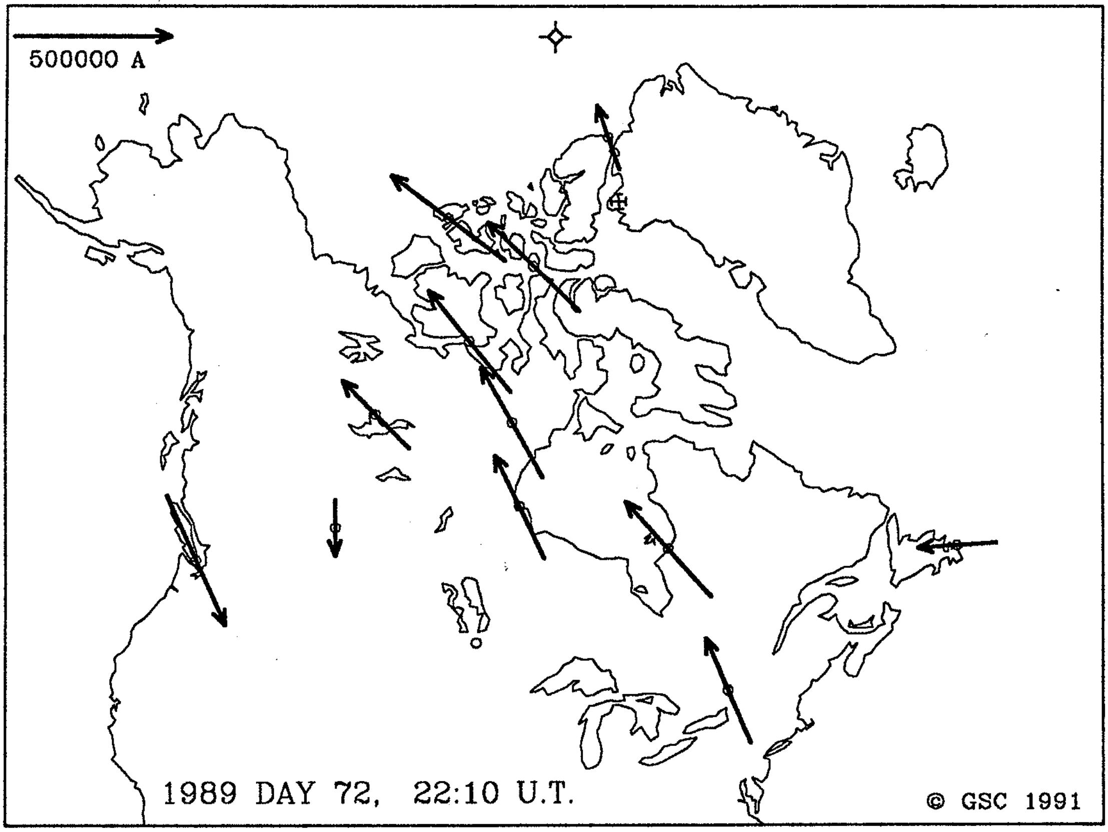
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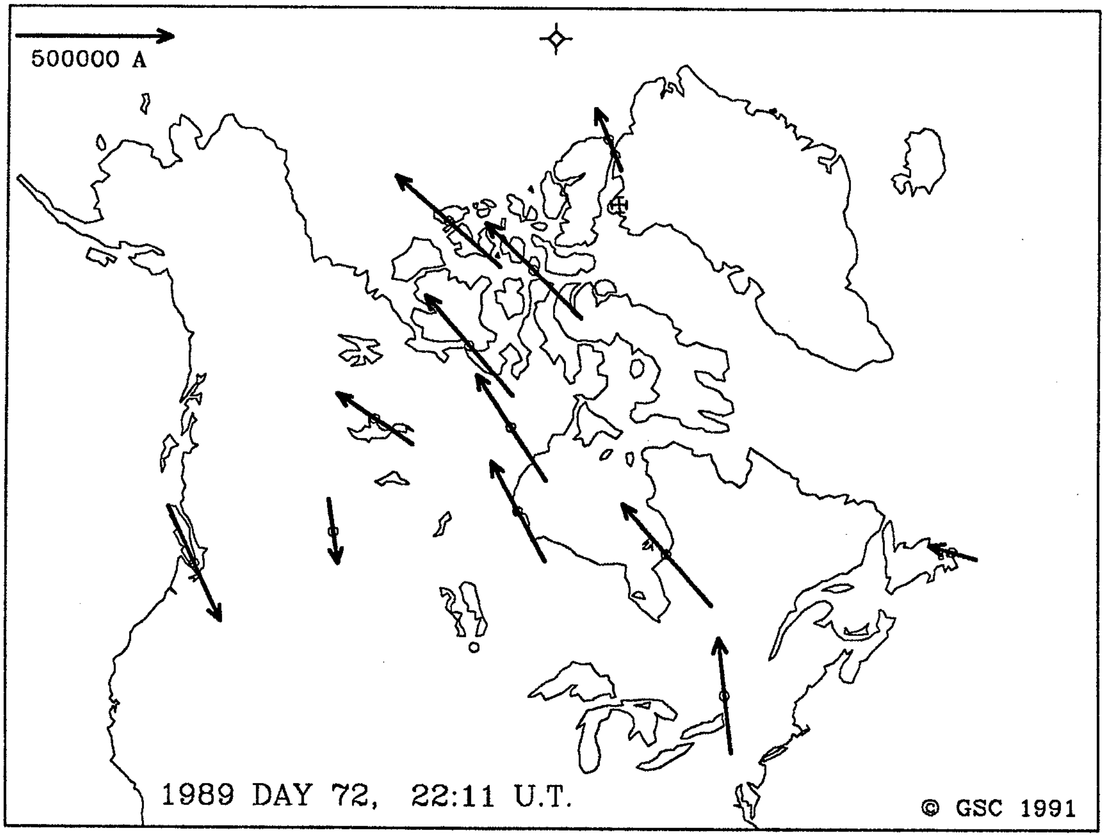
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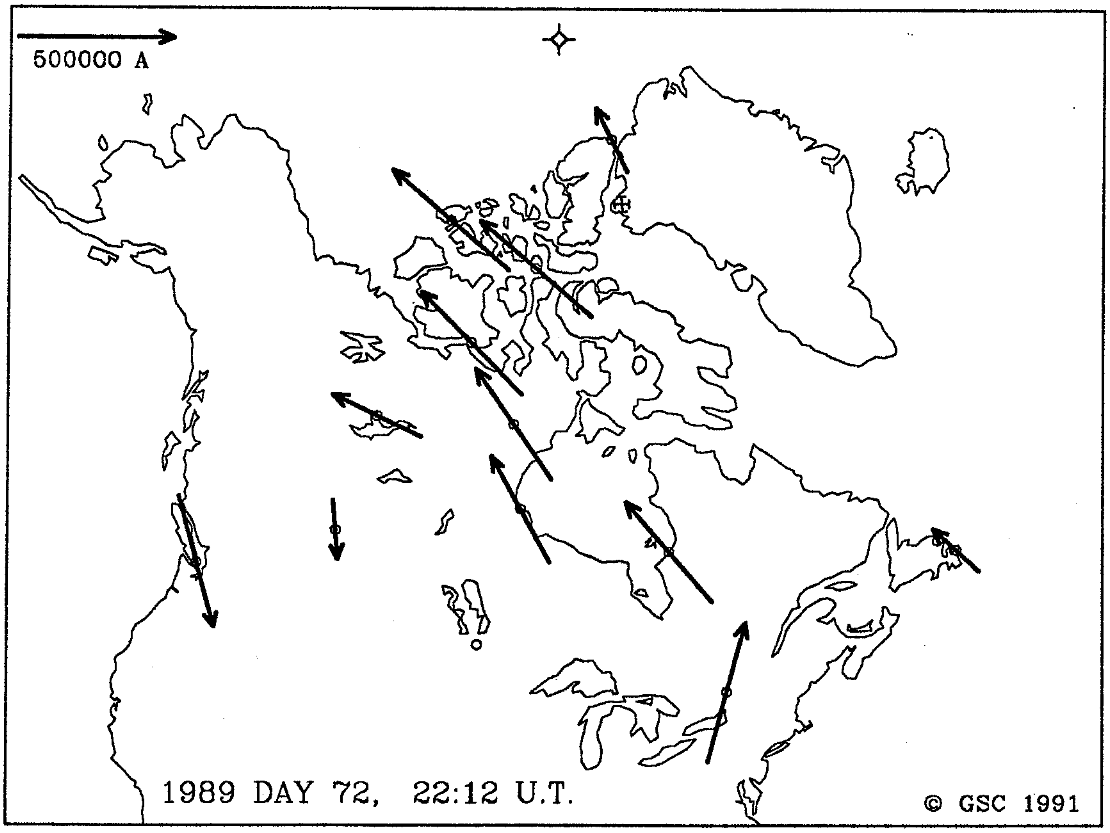
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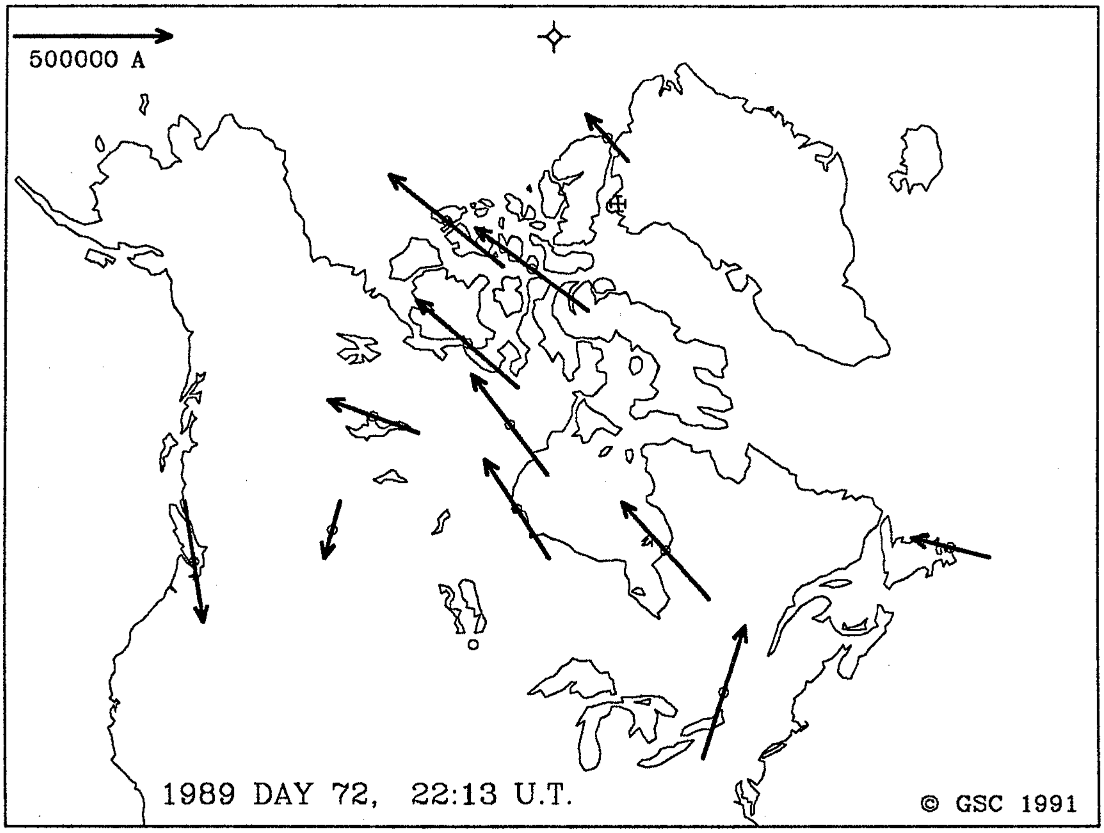
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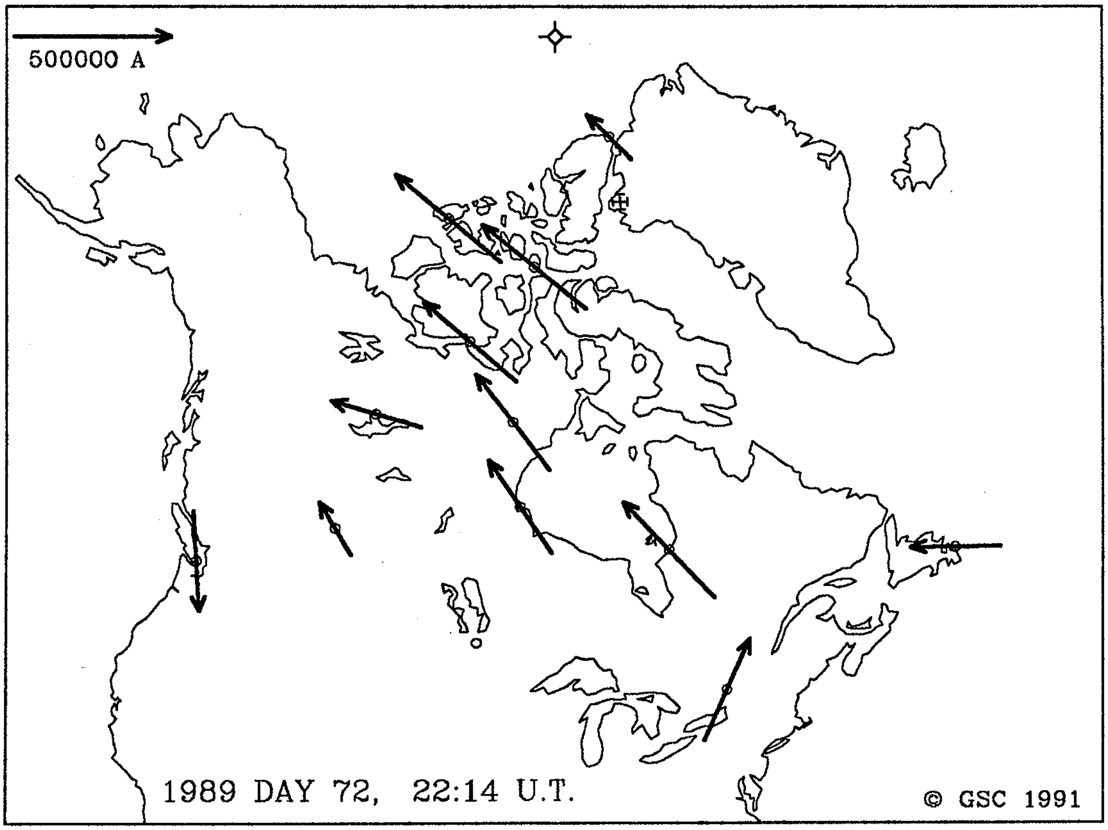
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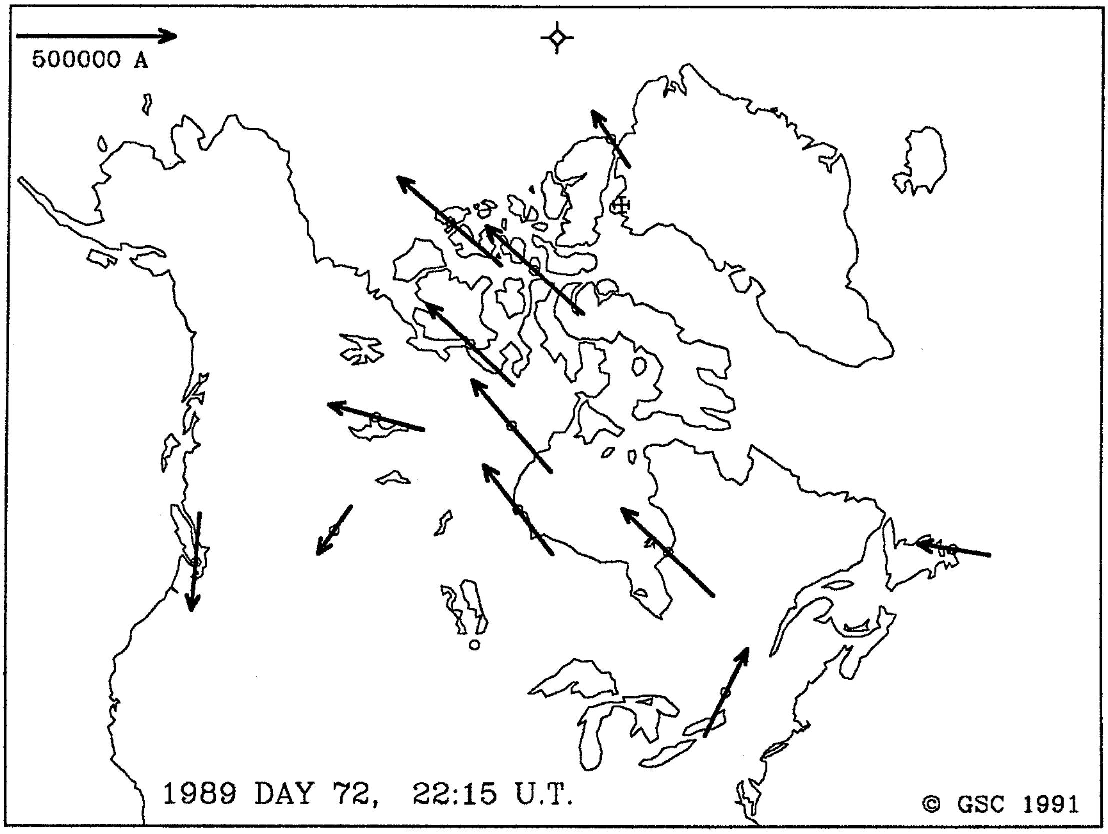
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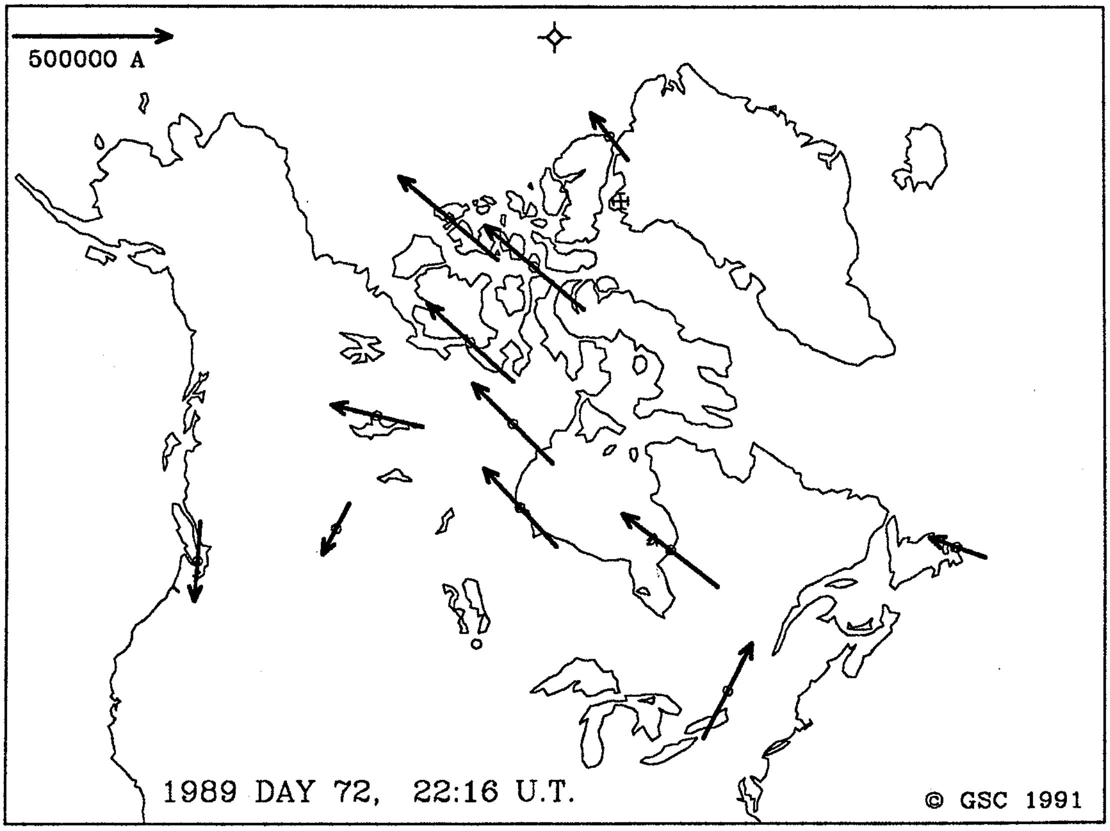
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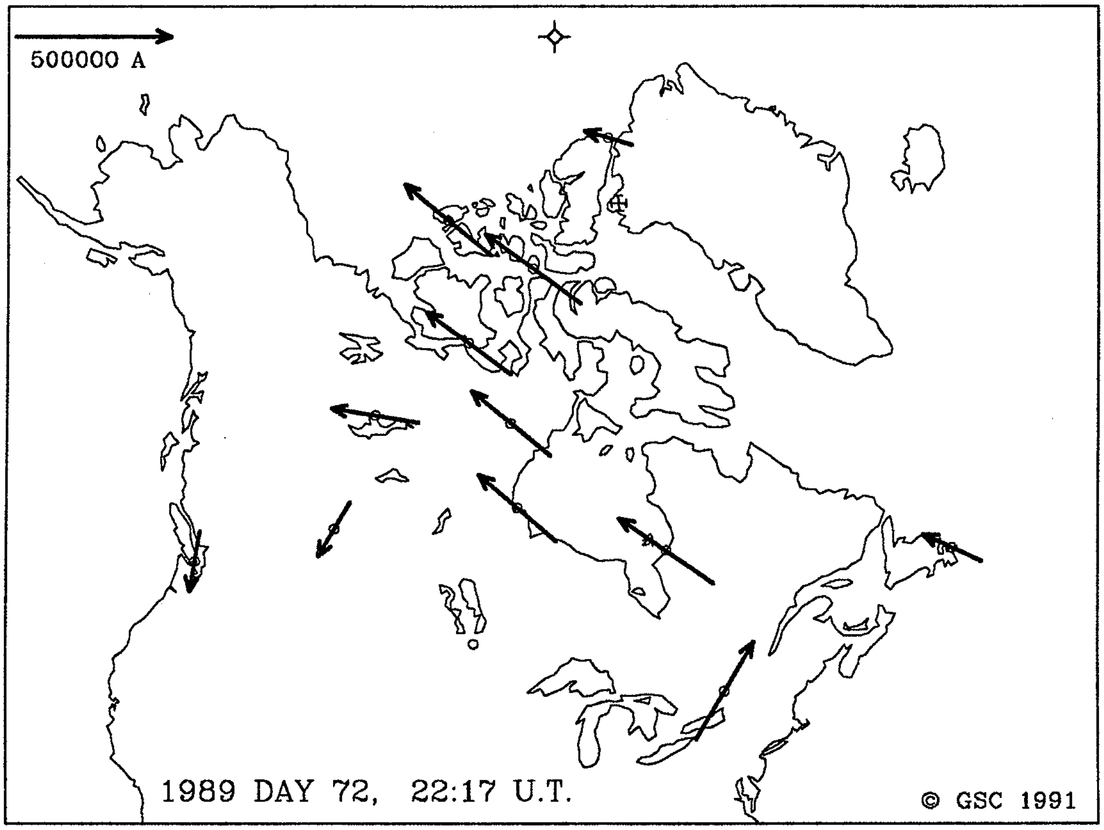
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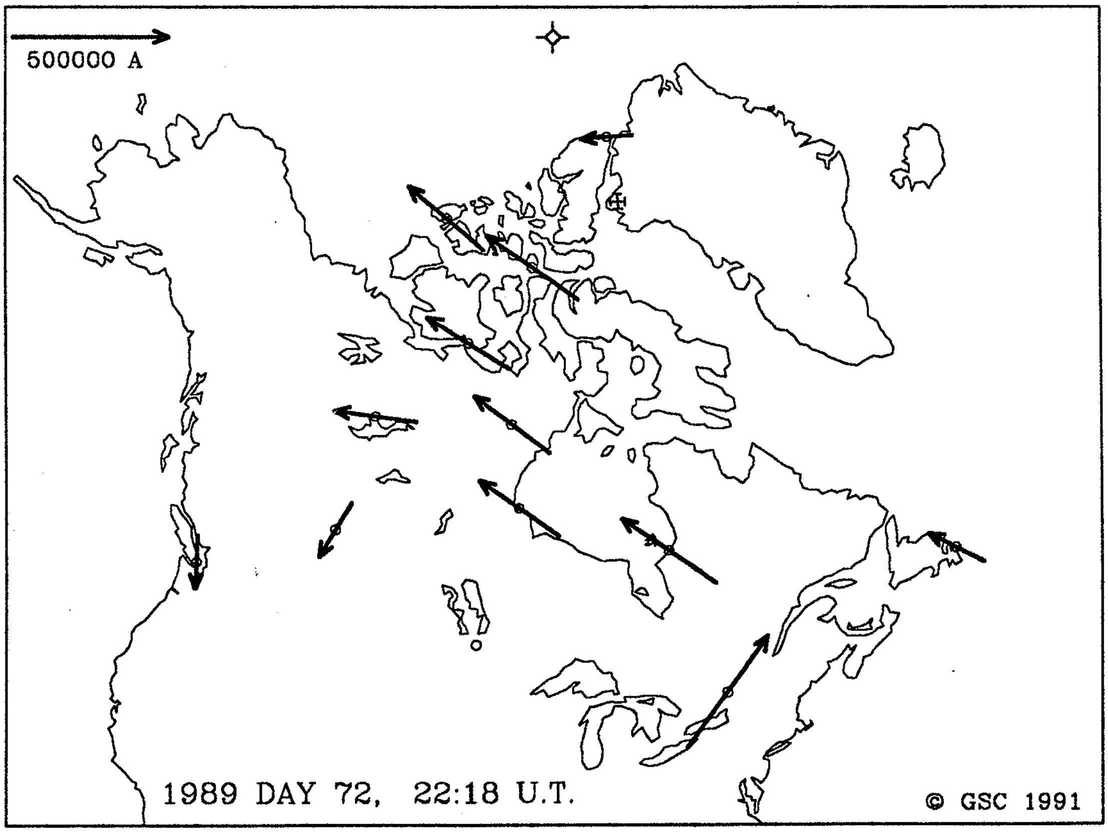
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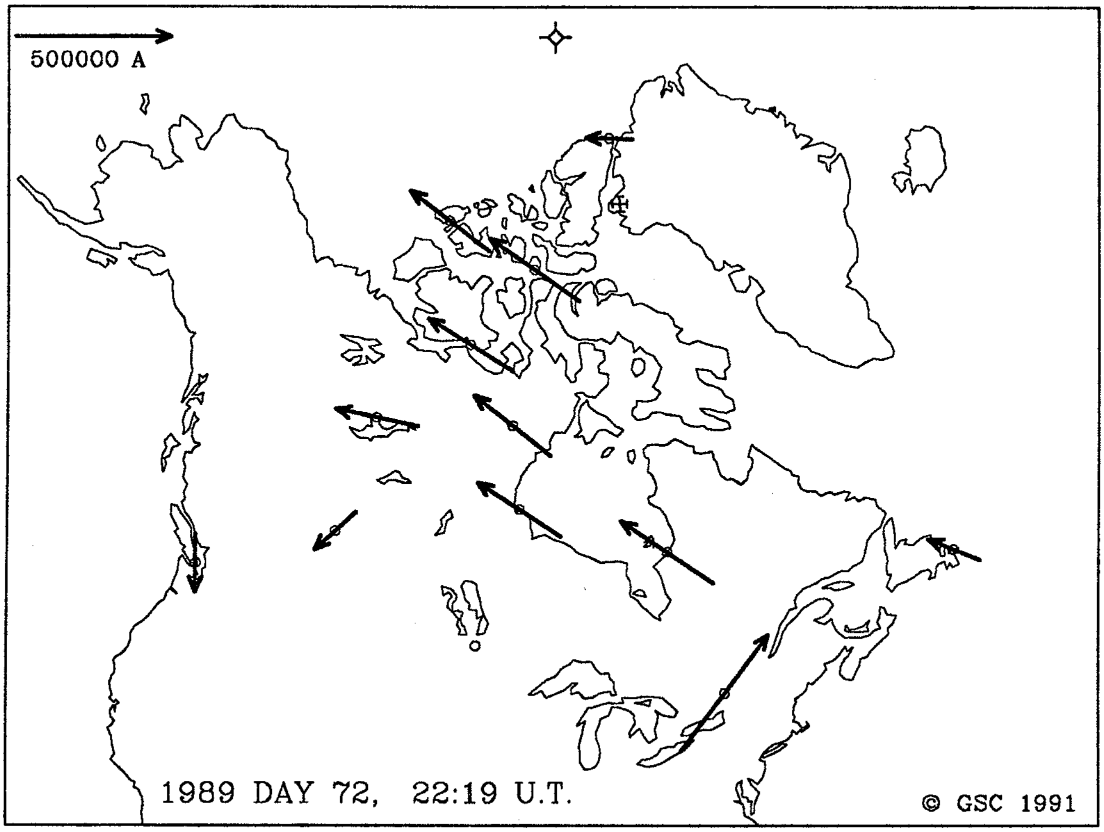
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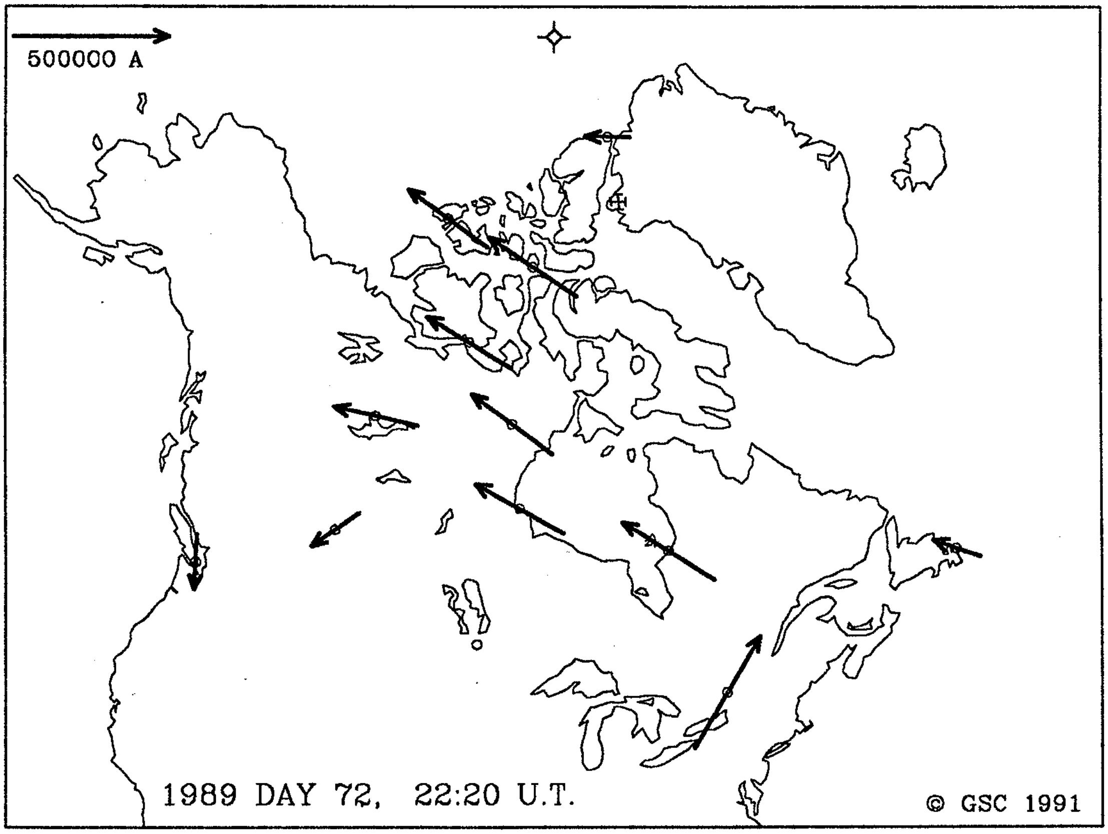
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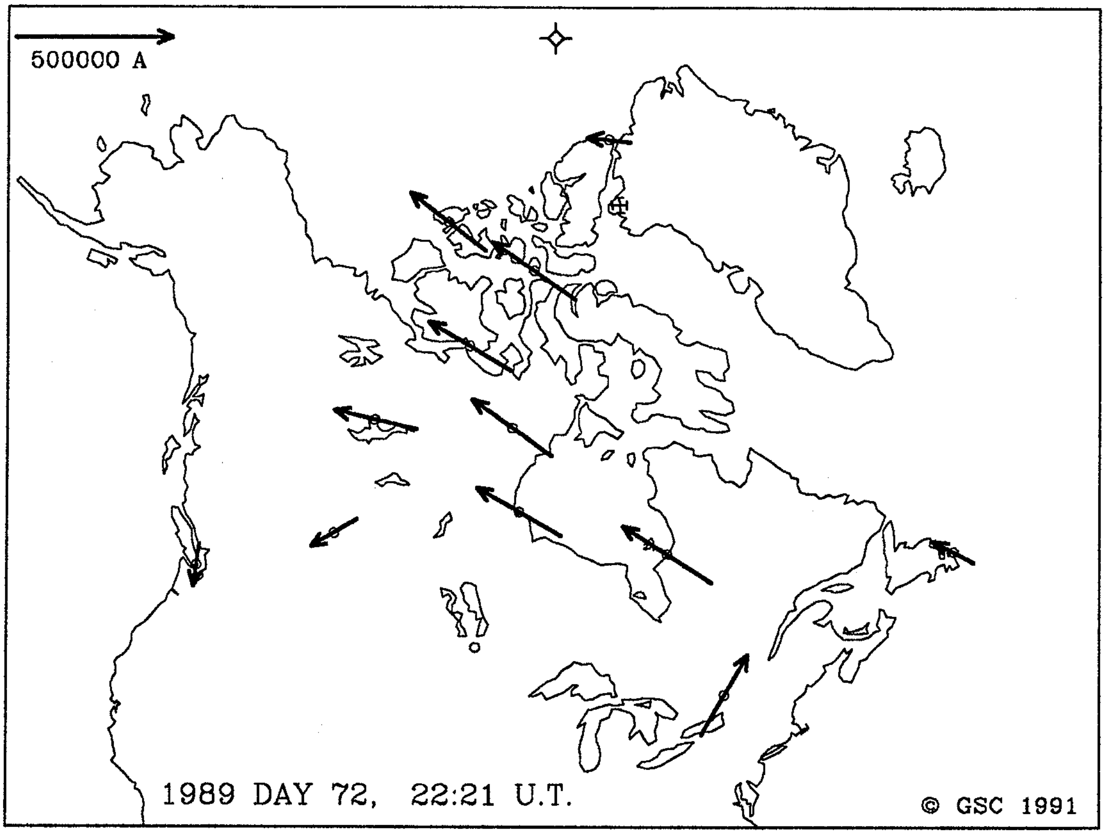
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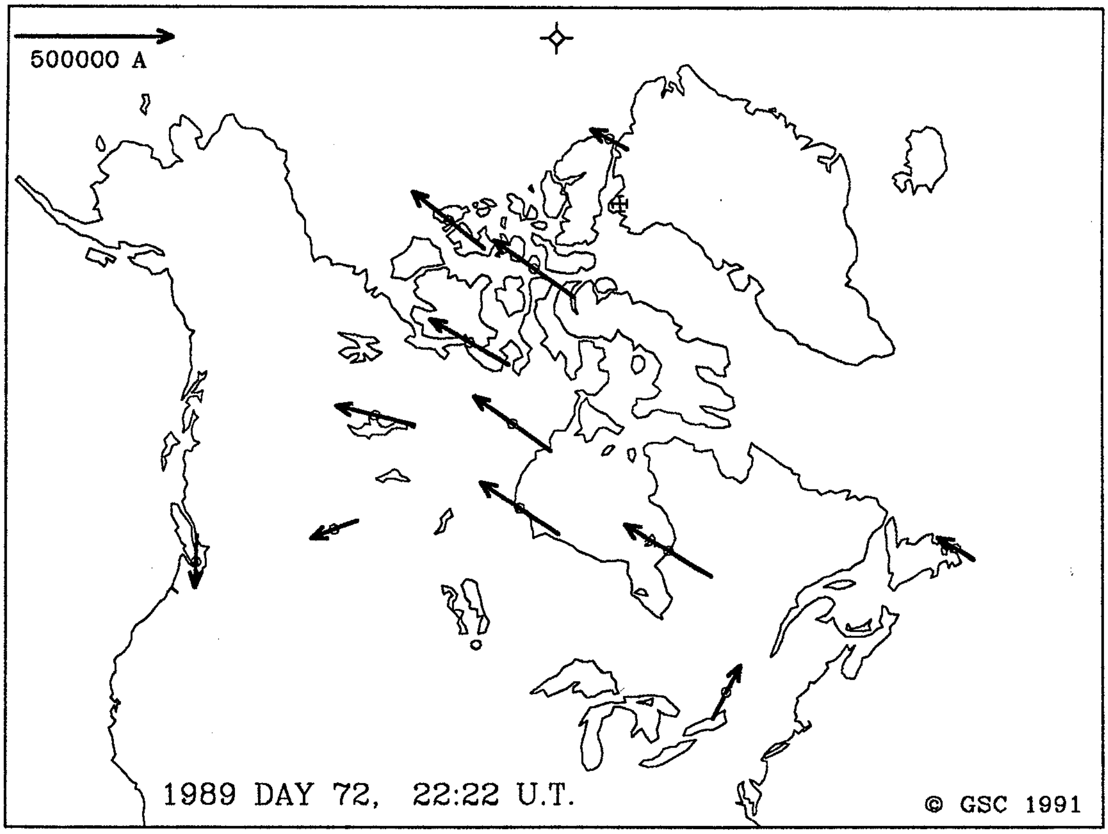
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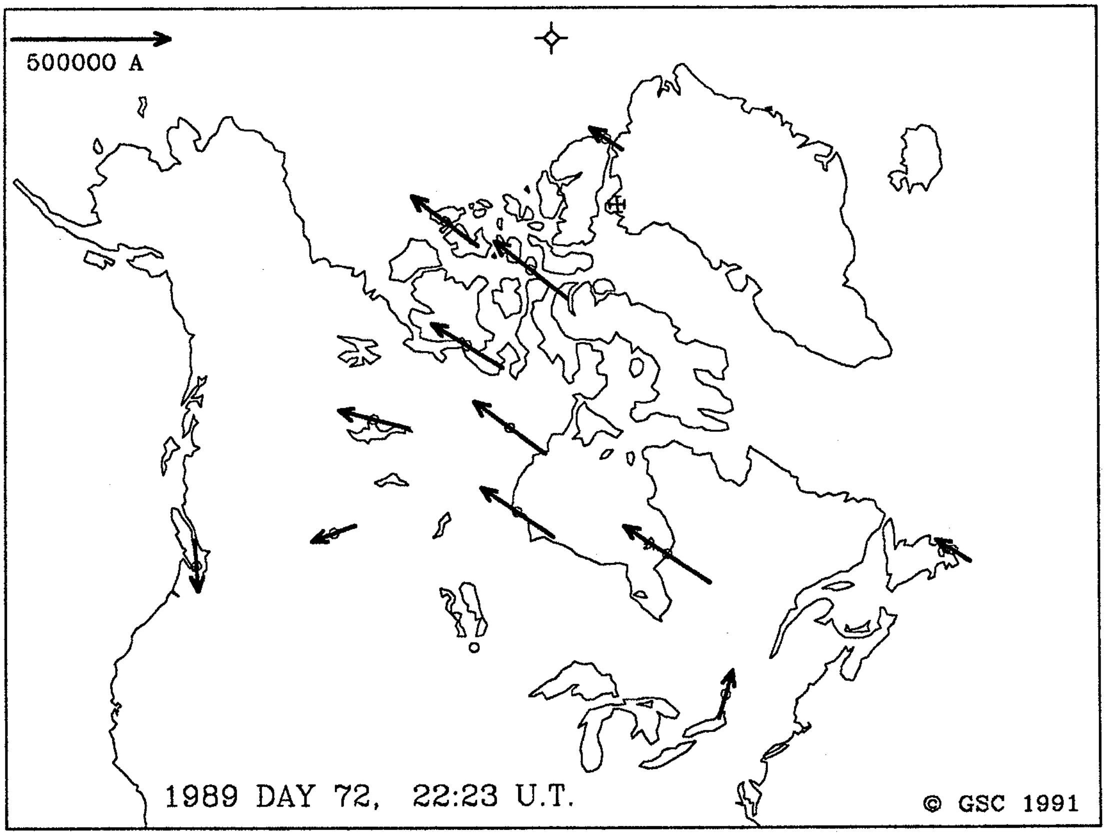
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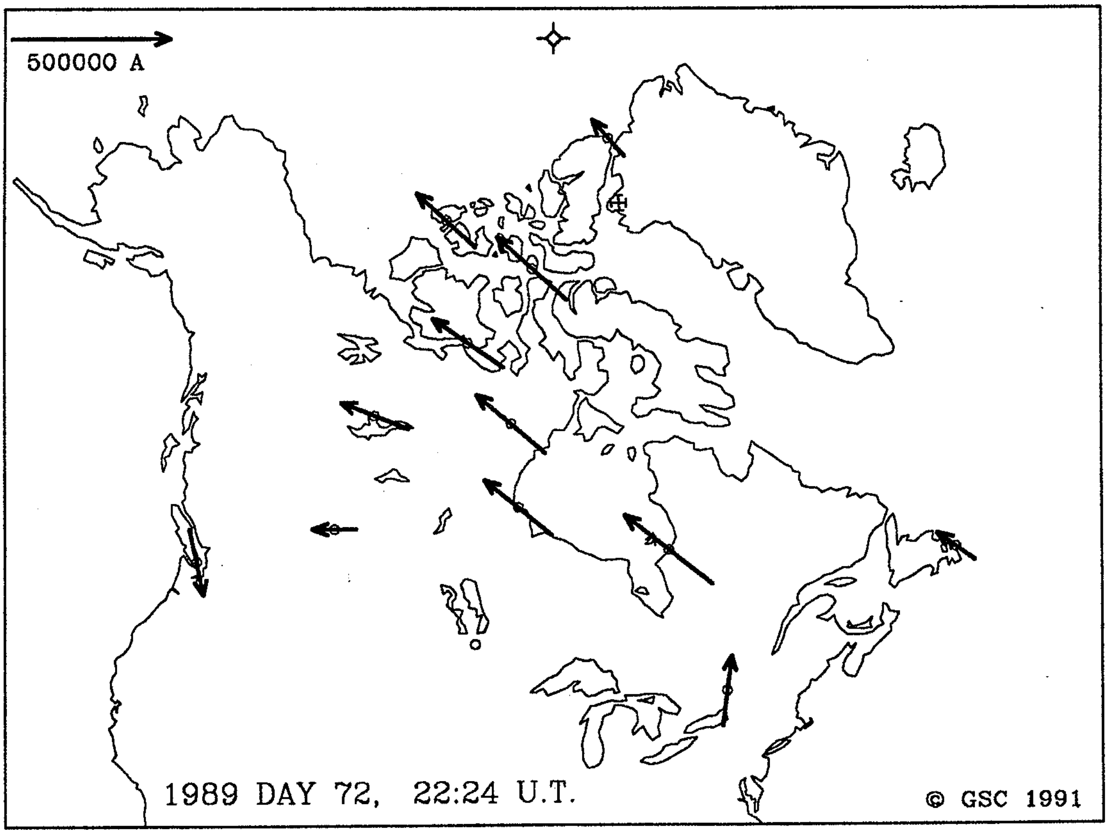
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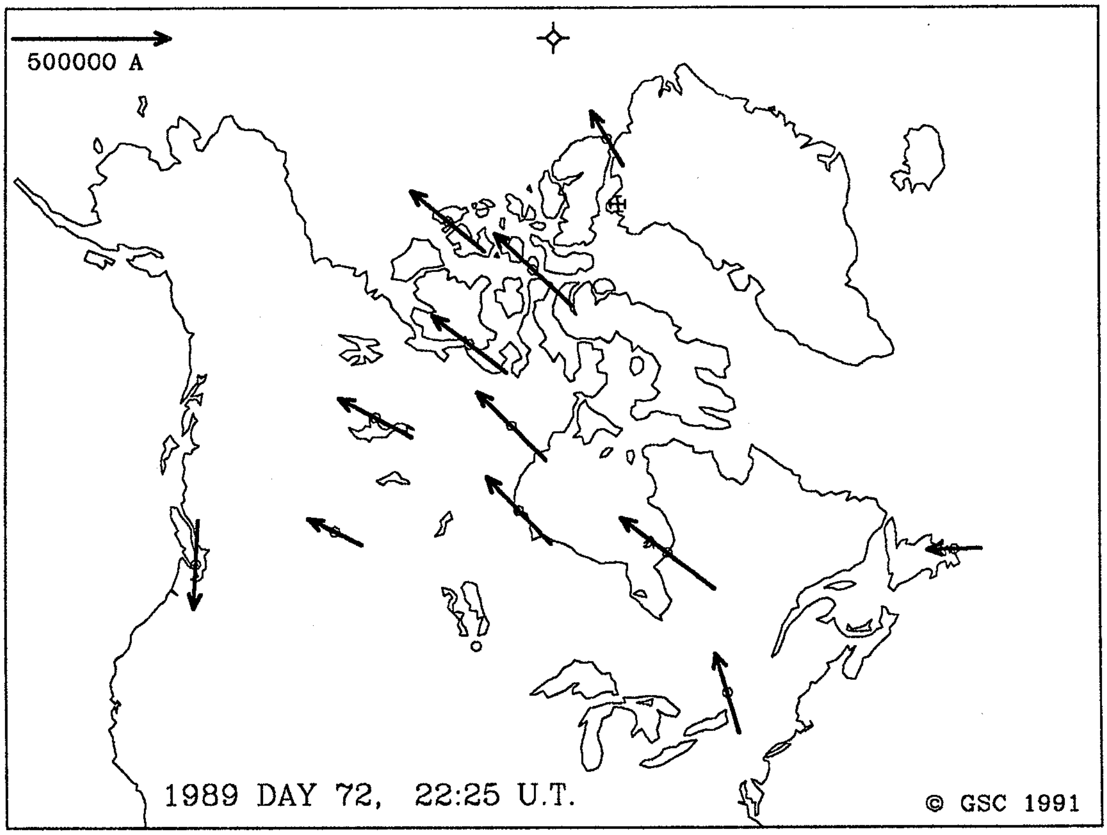
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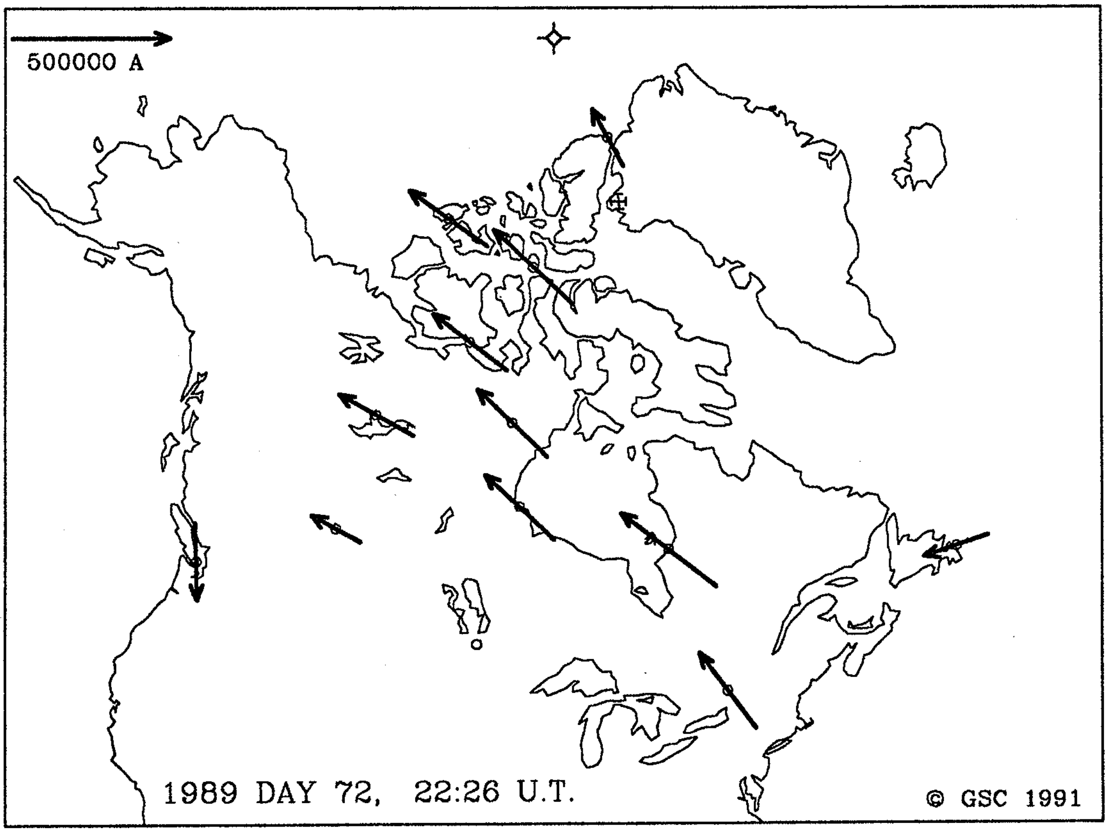
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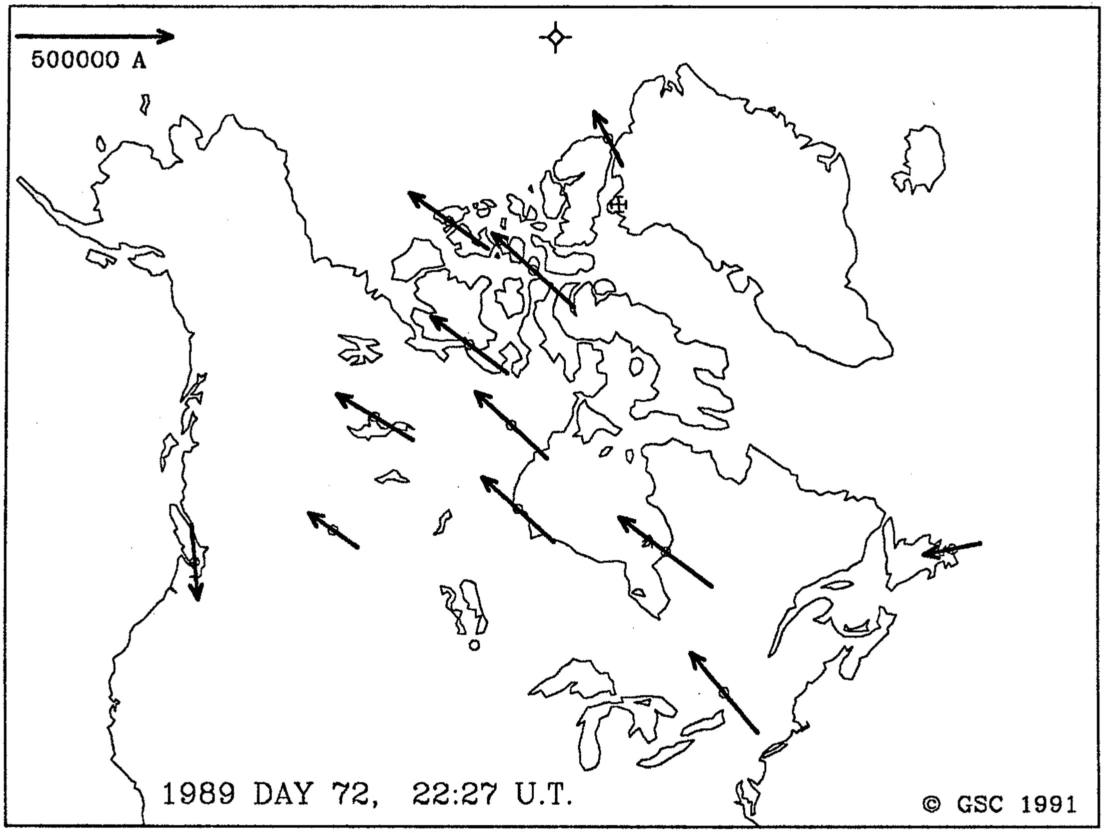
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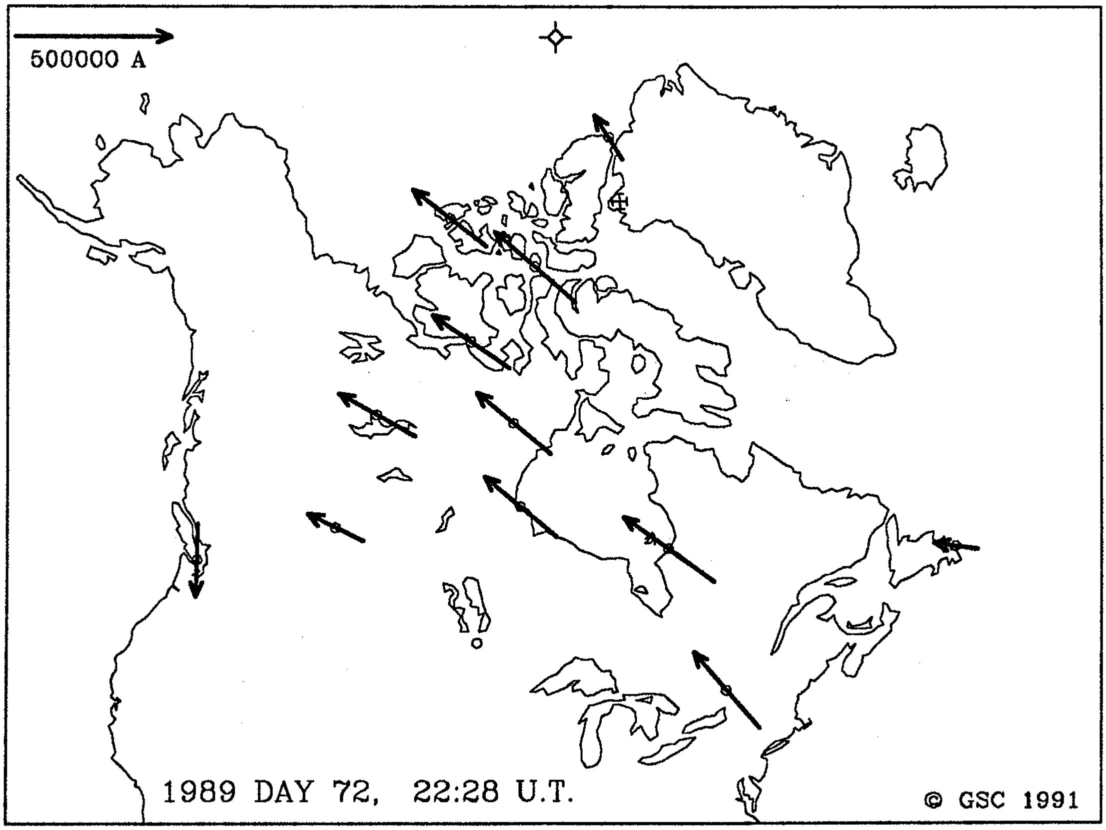
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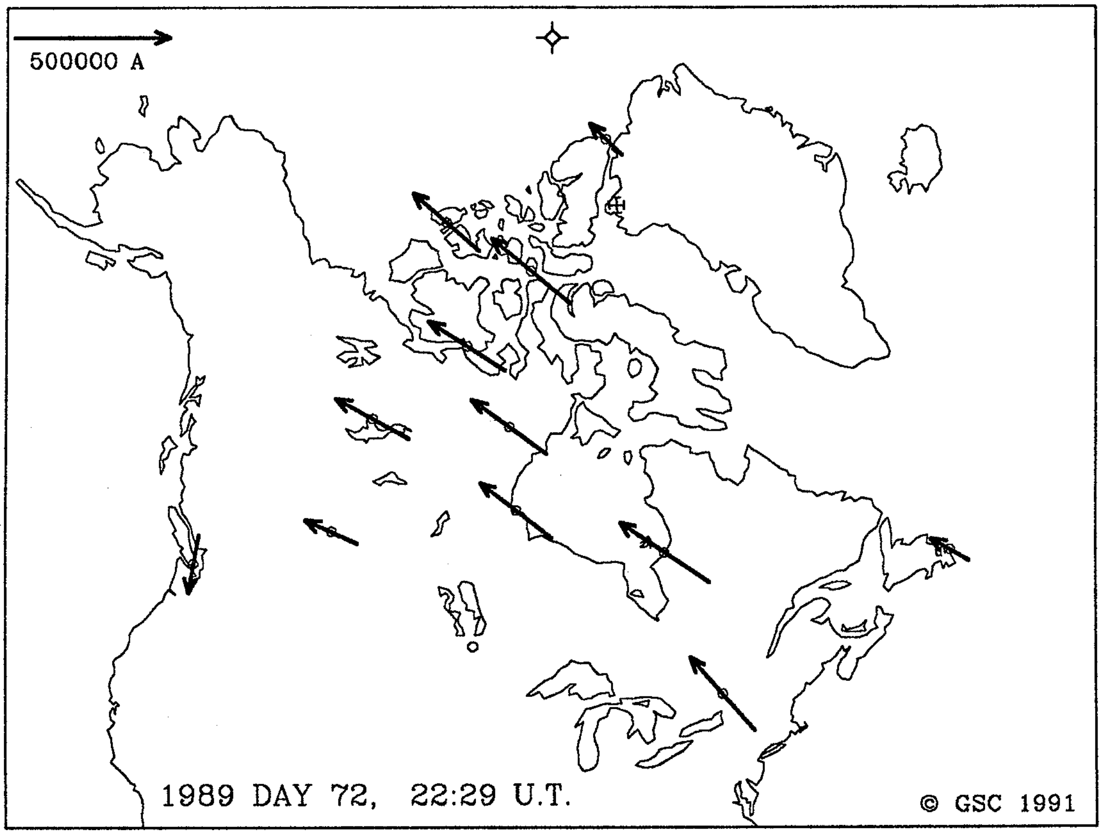
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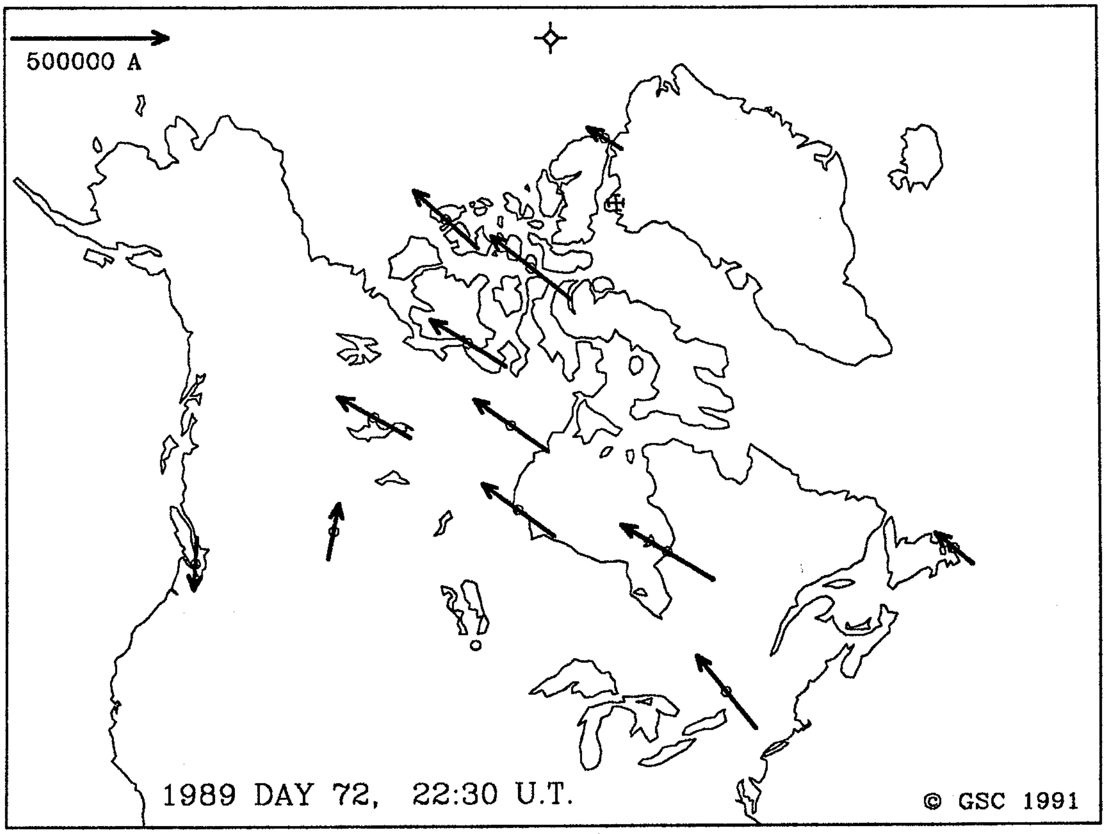
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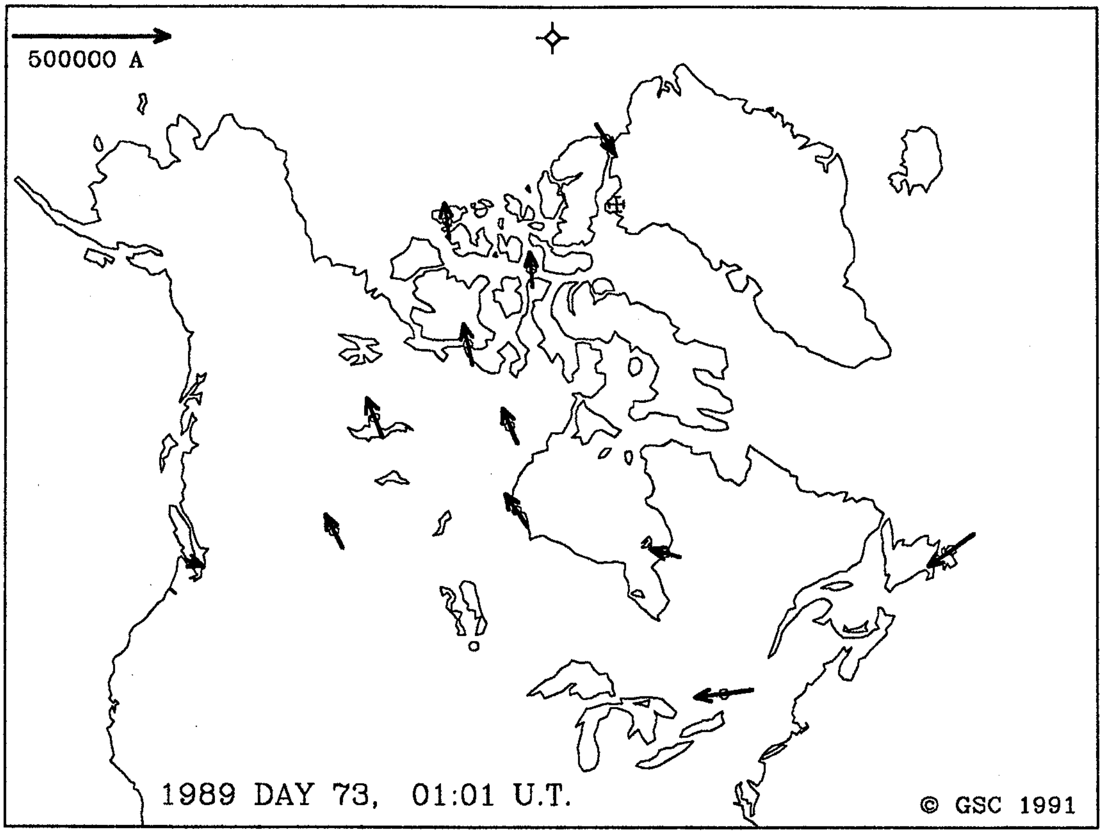
Equivalent Currents at 1 minute intervals

01:01 UT March 14 (Day 73) 1989
to
01:32 UT March 14 (Day 73) 1989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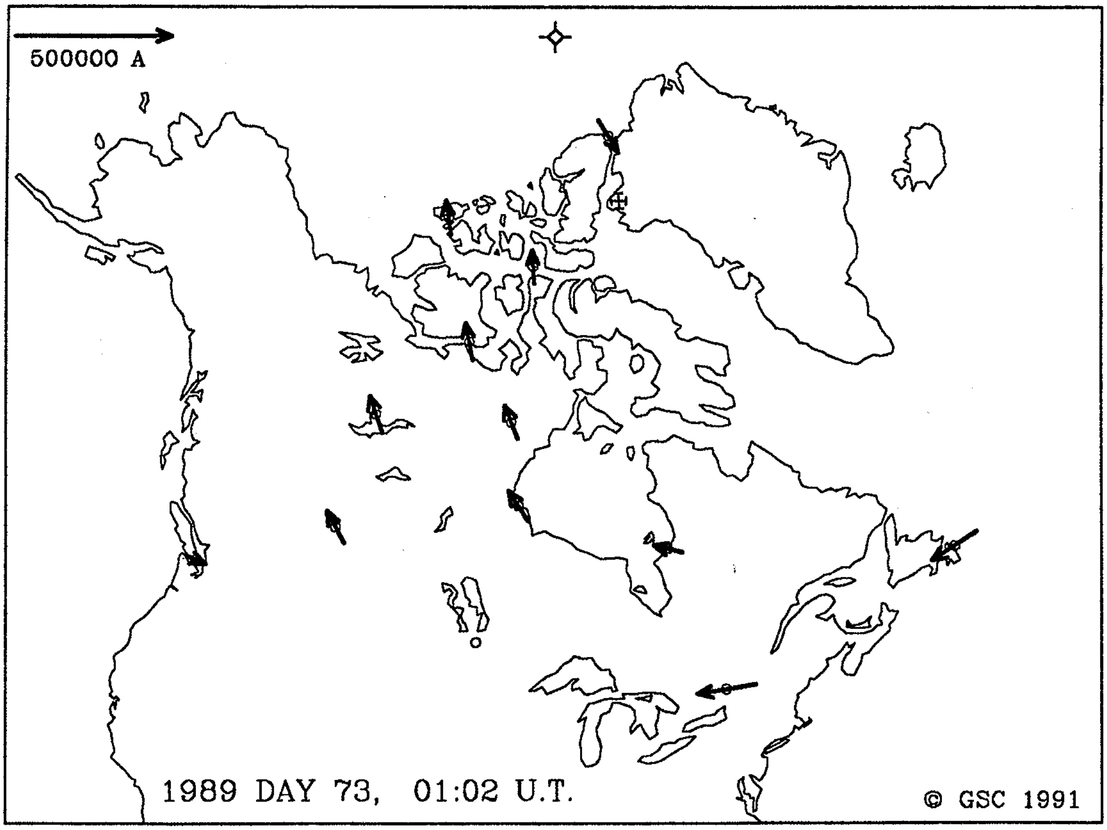
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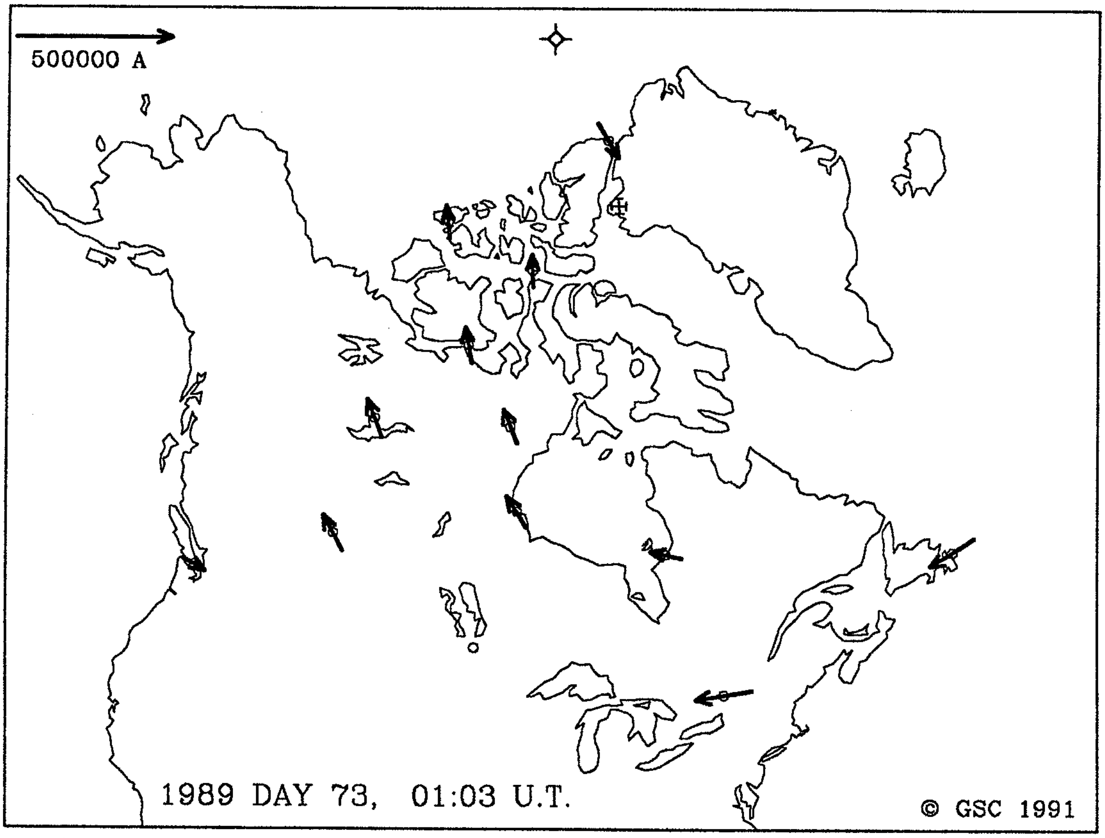
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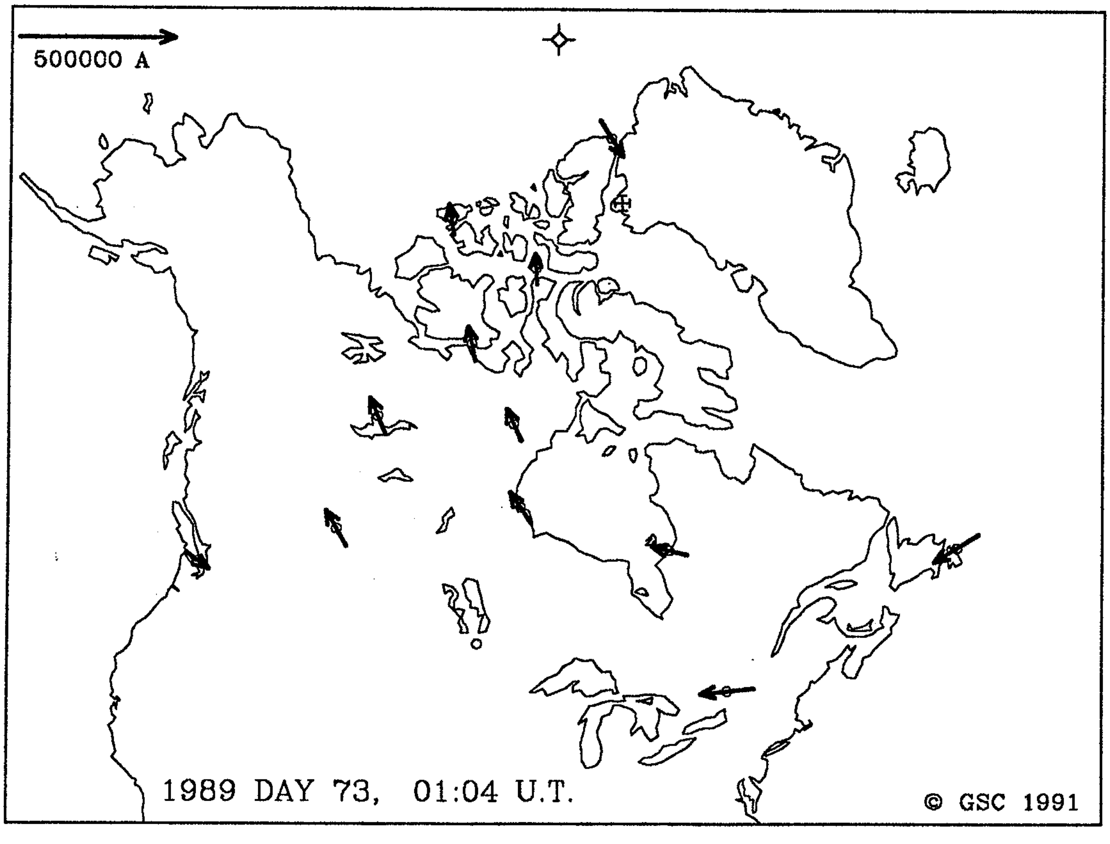
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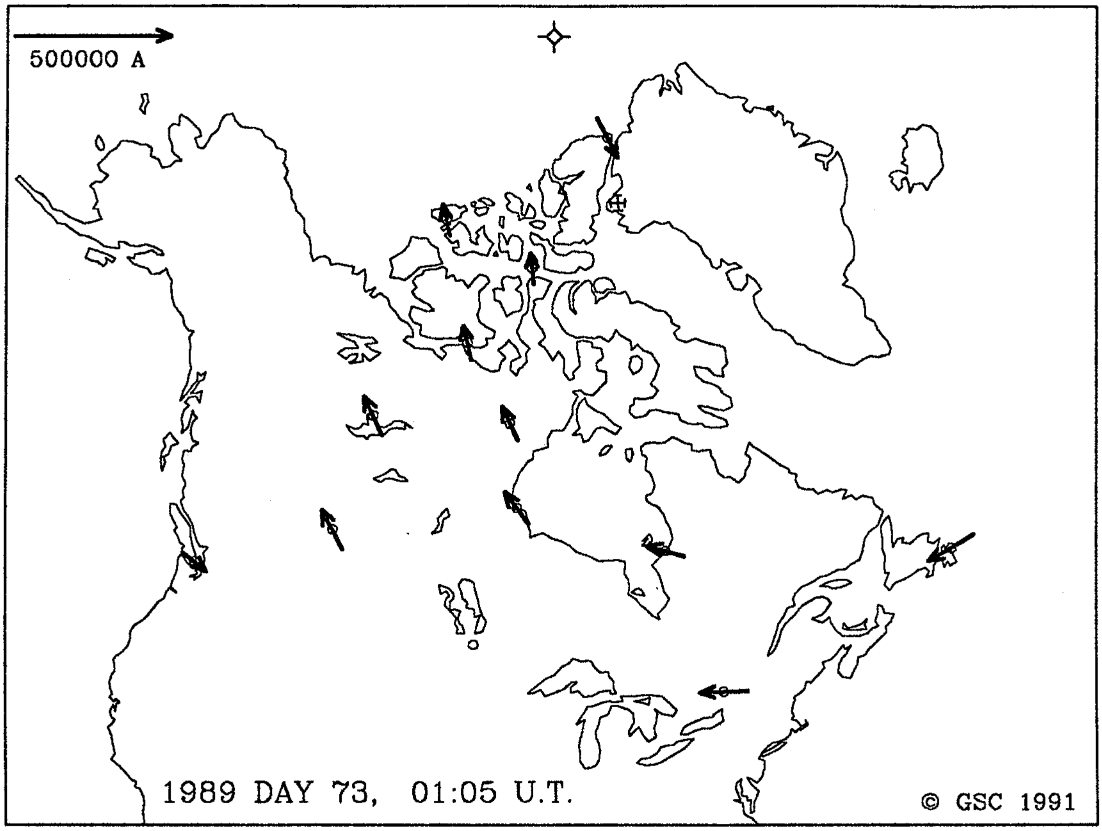
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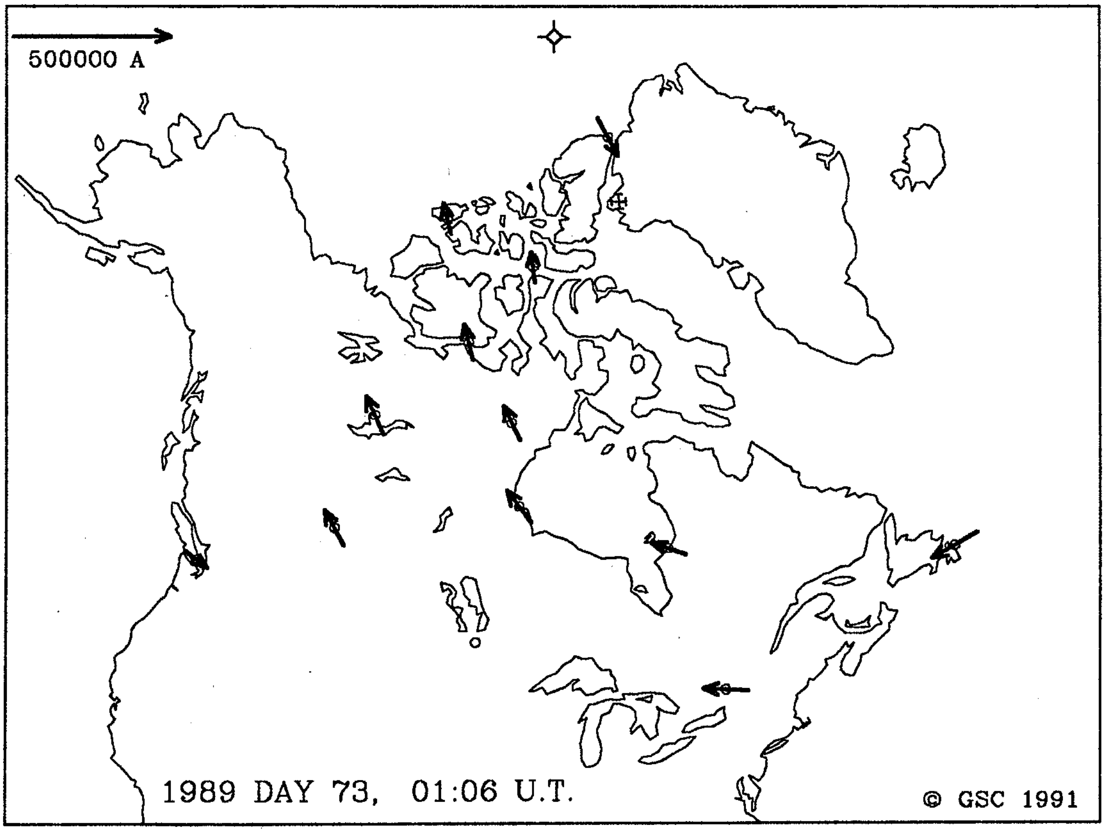
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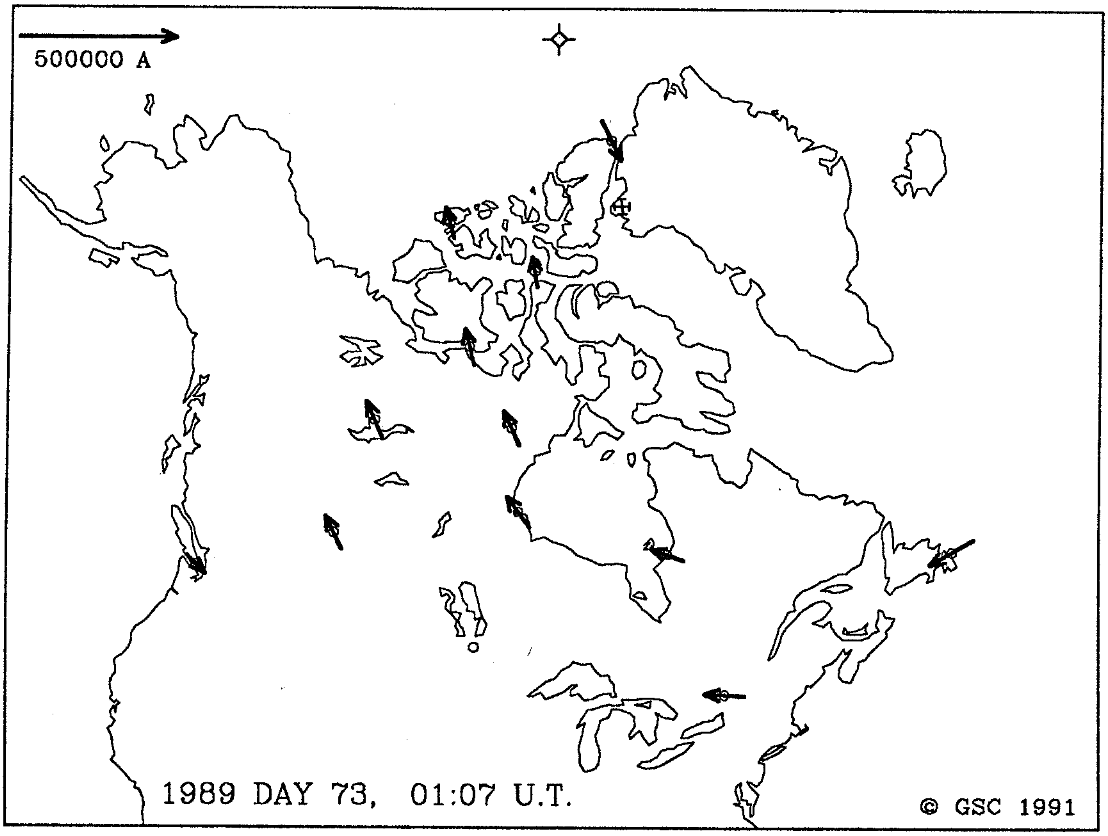
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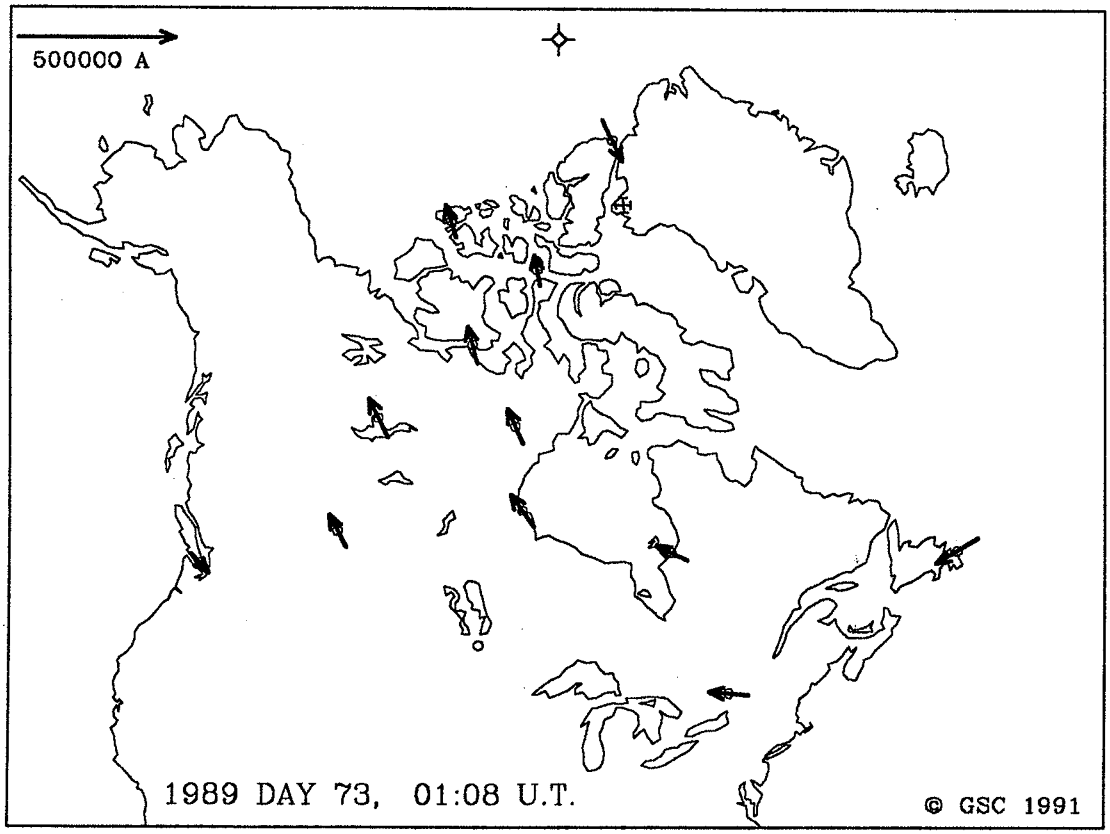
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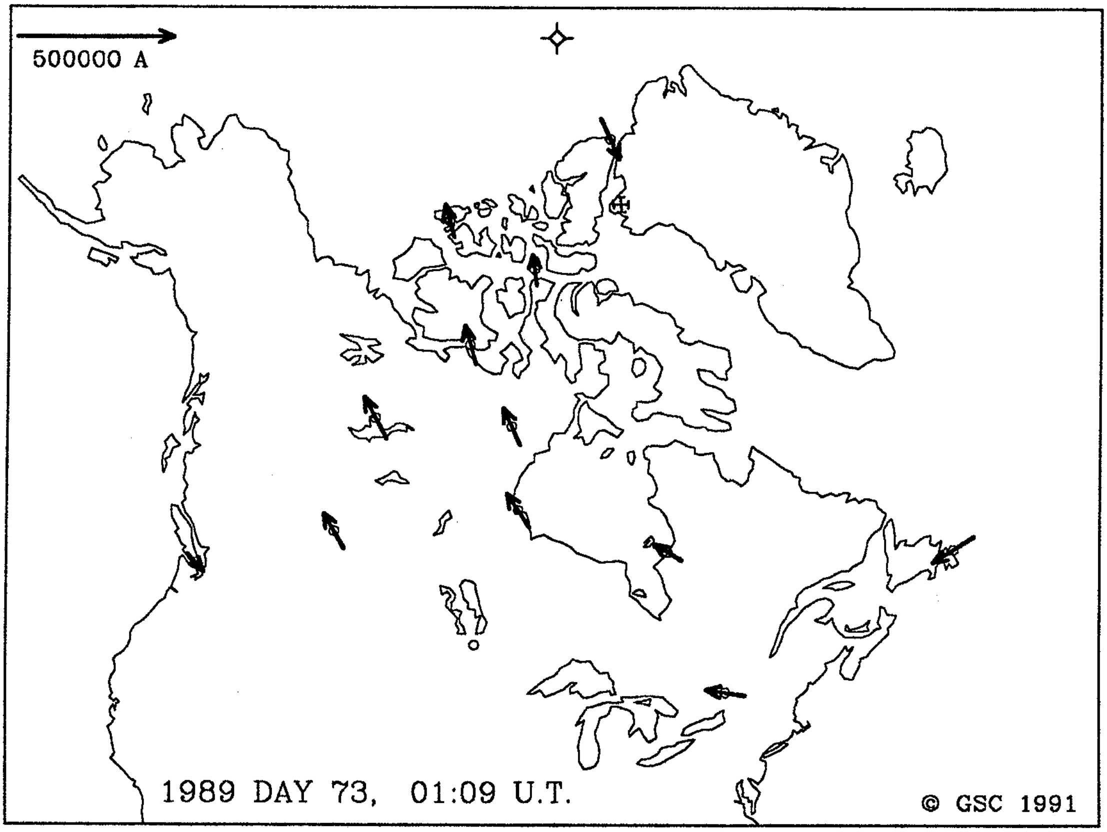

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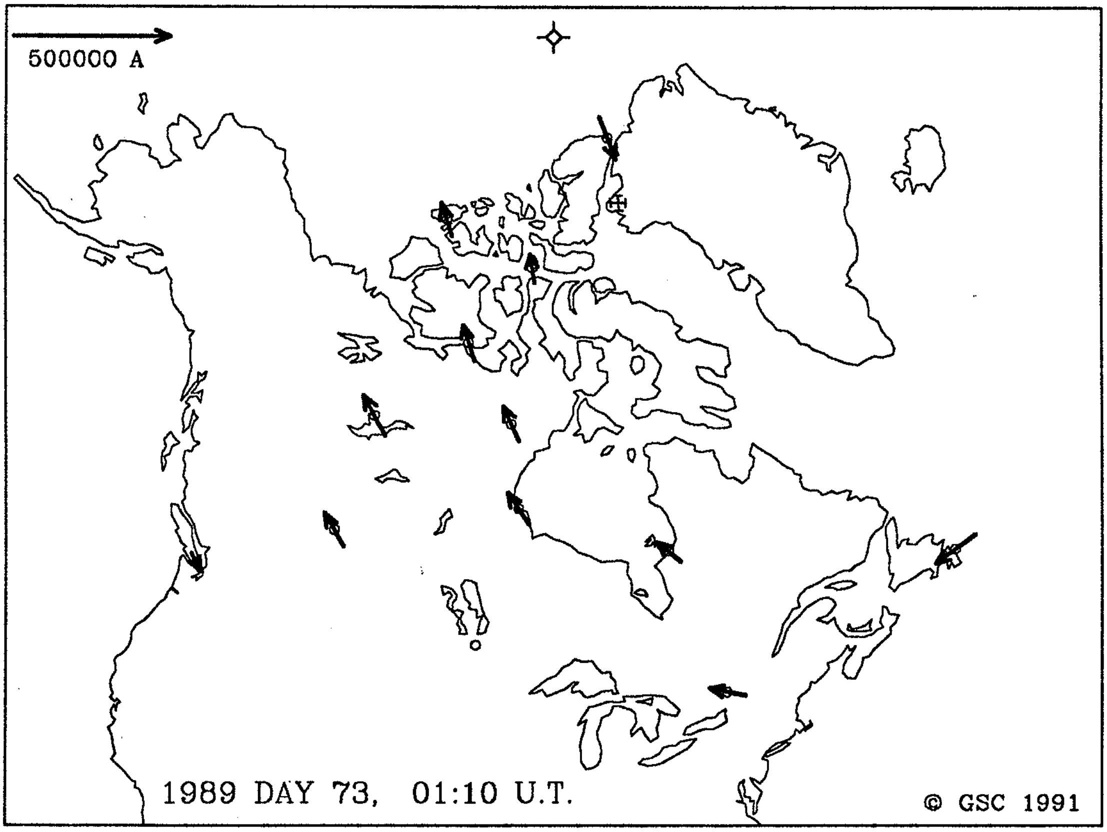

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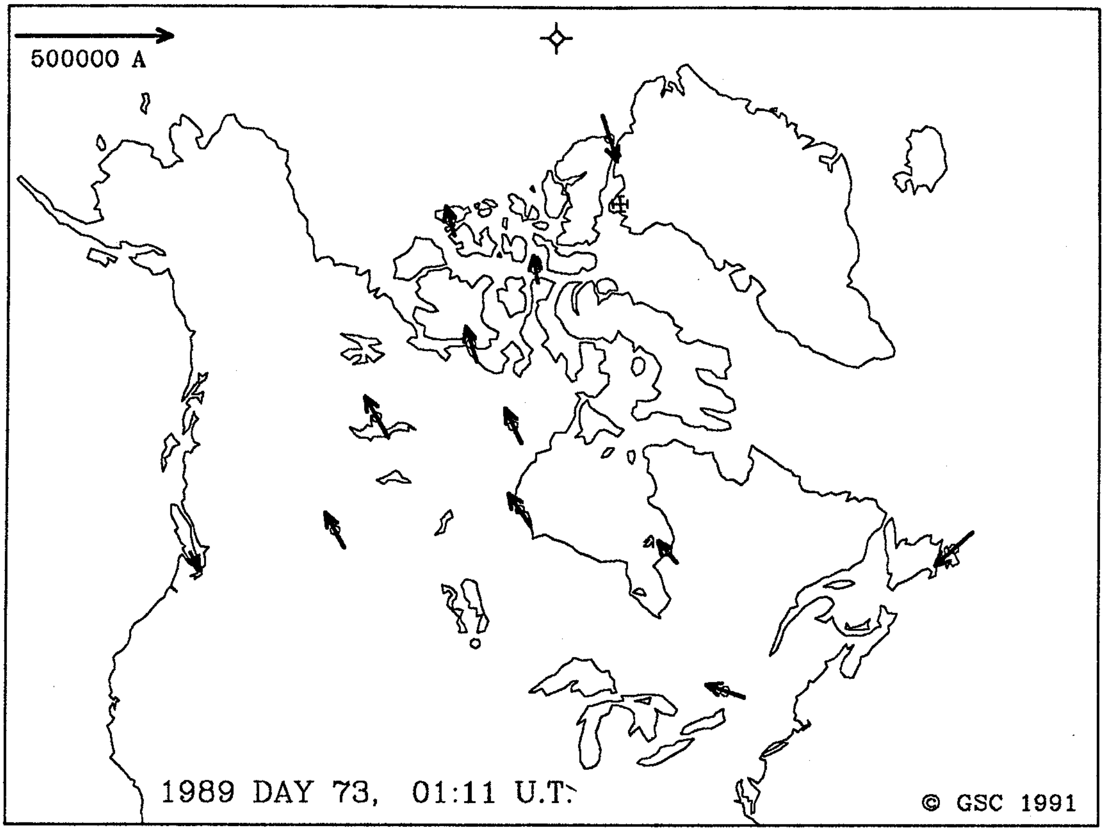
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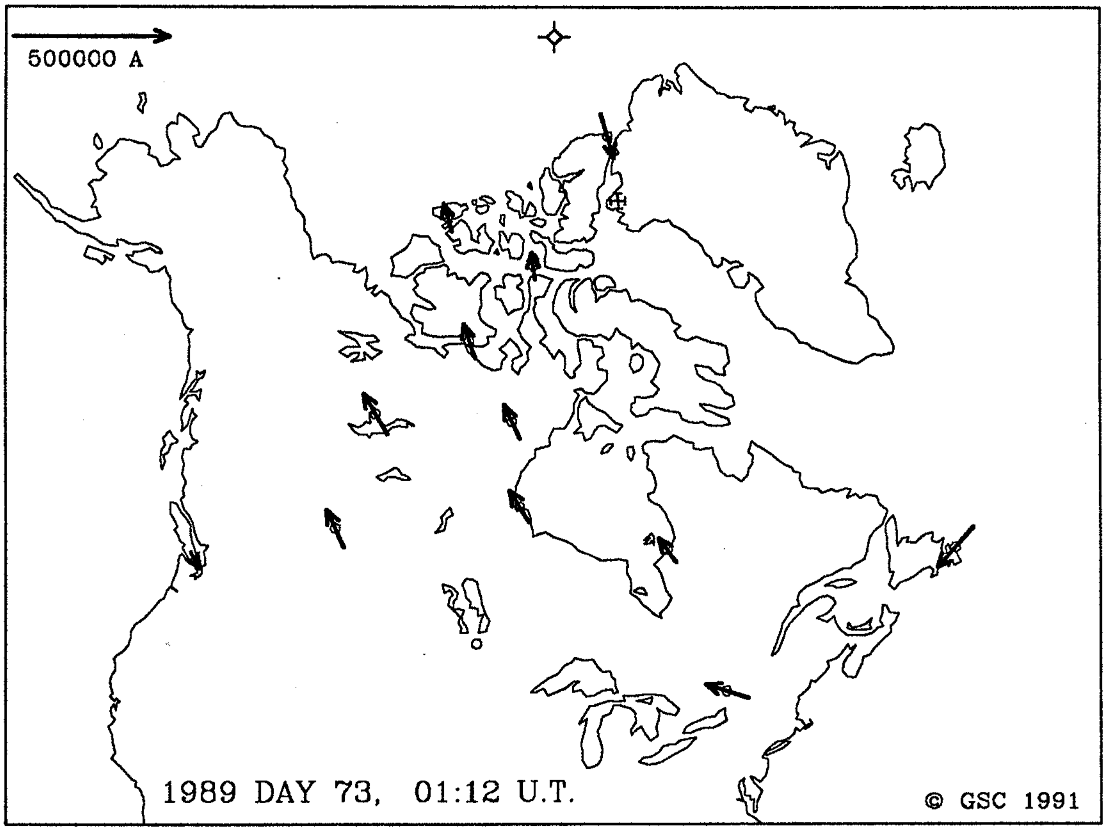
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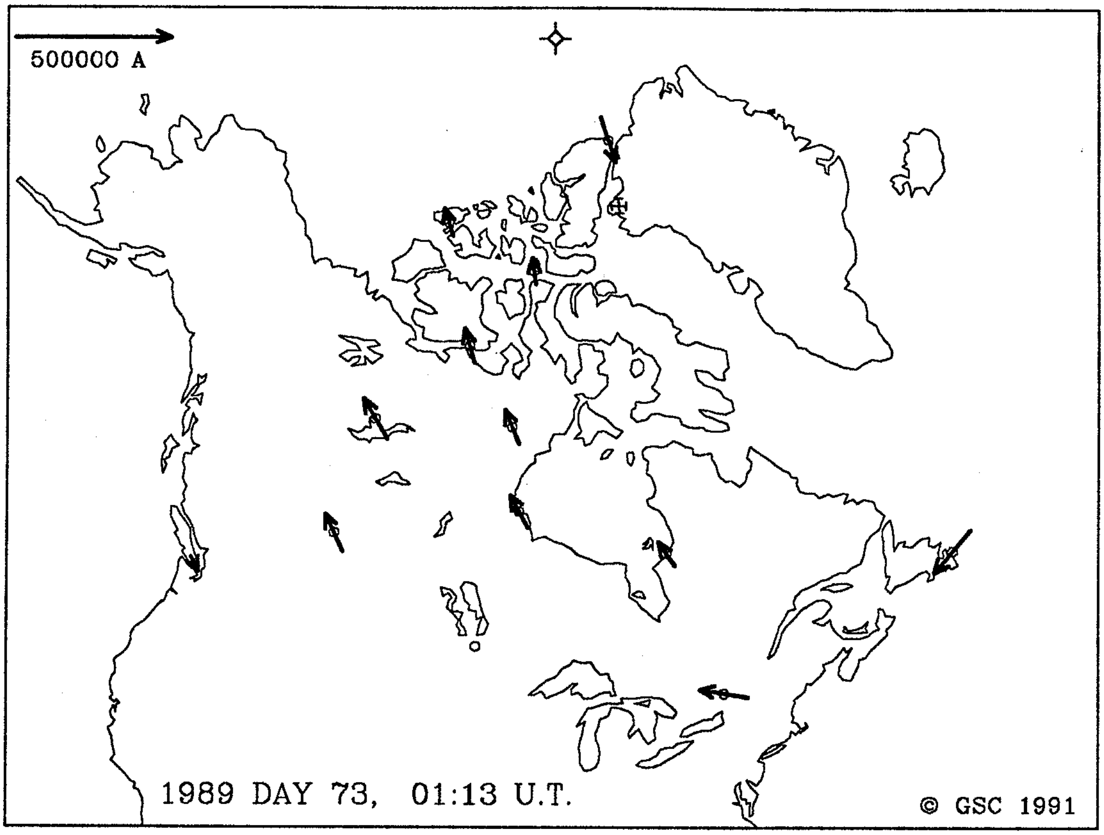
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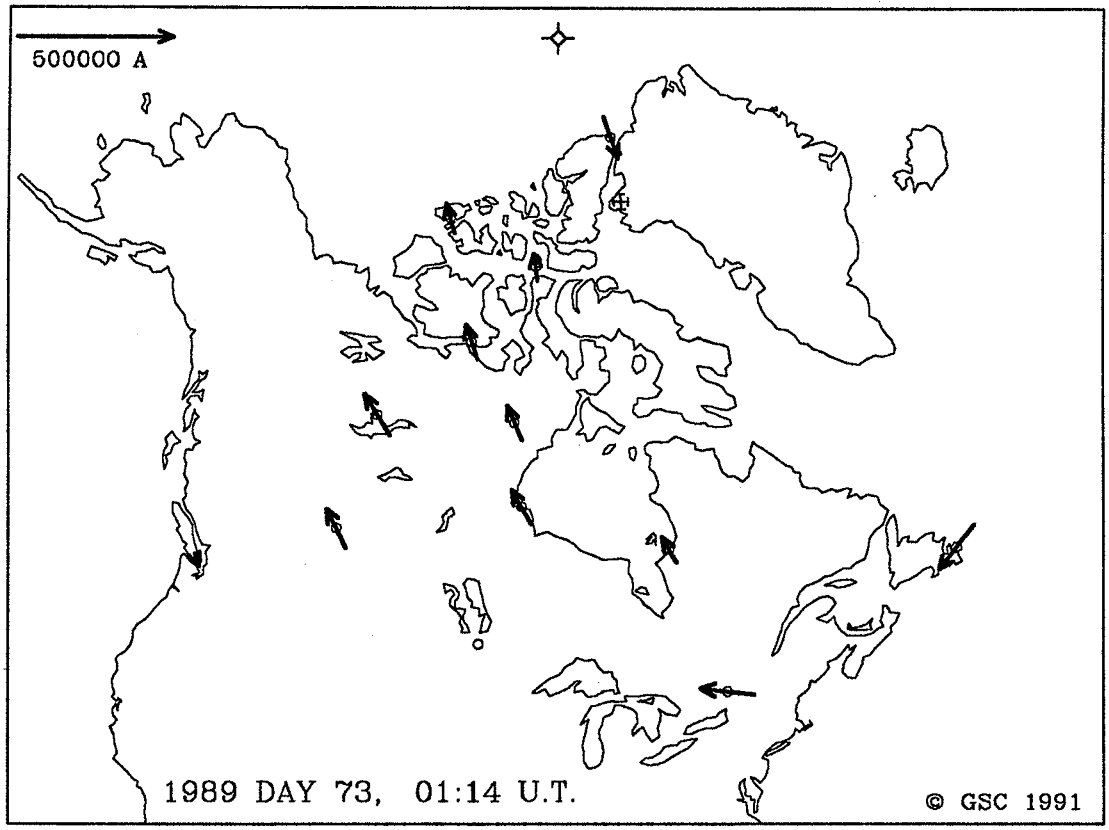
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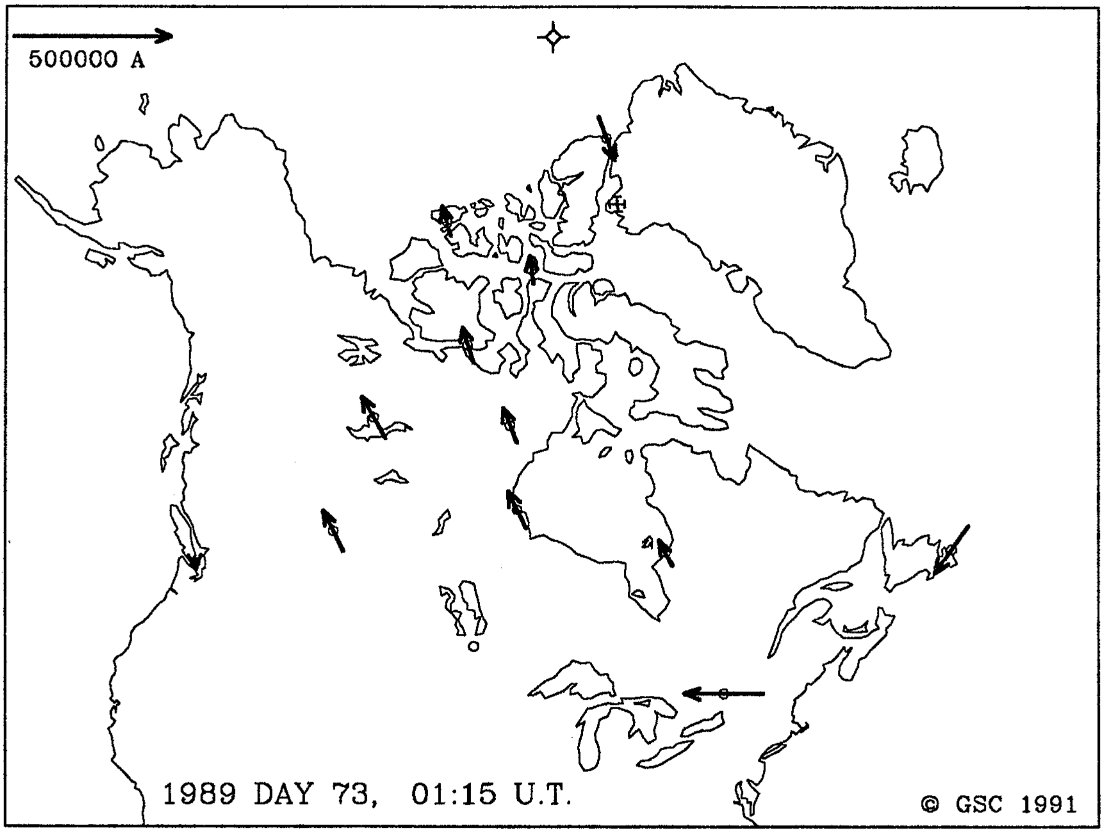
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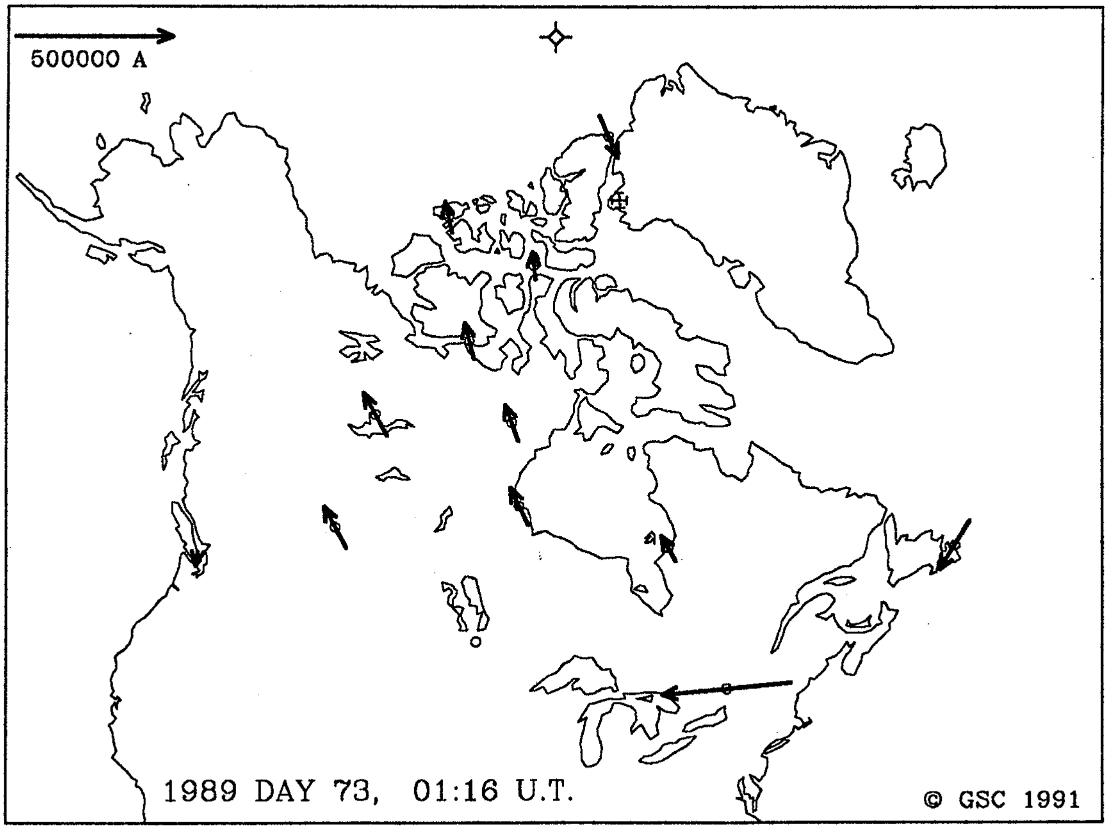
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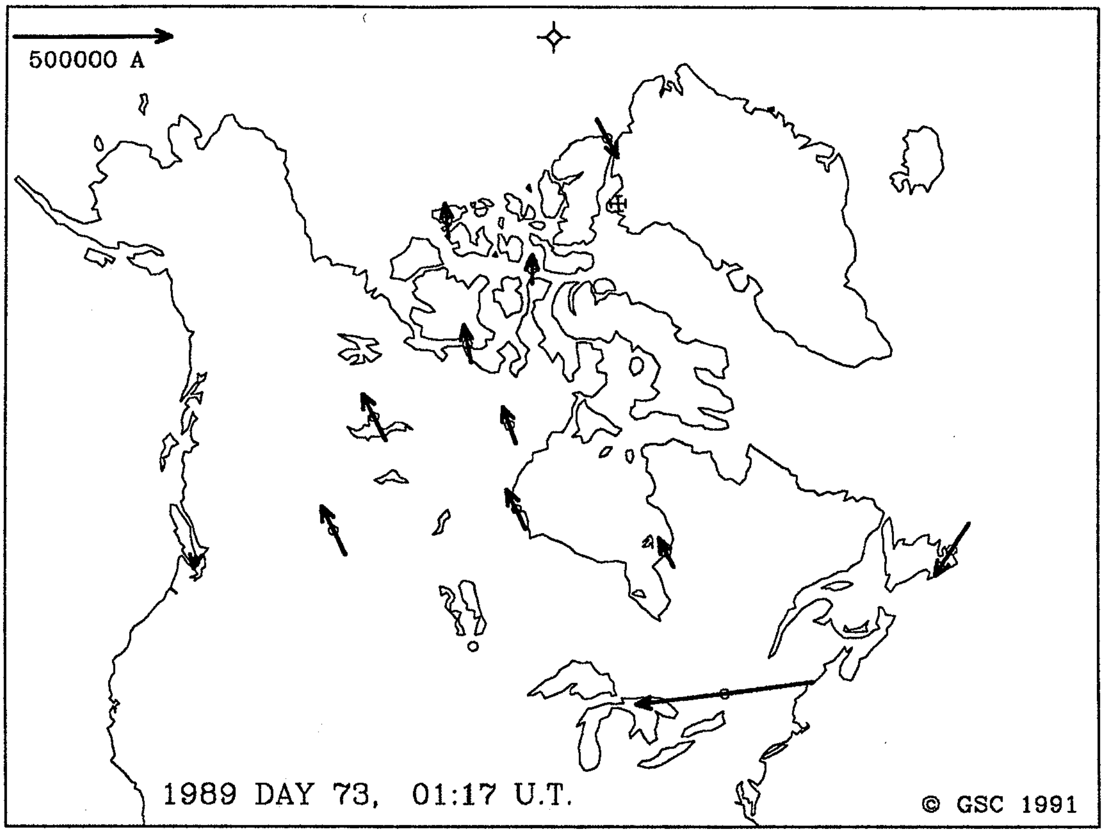
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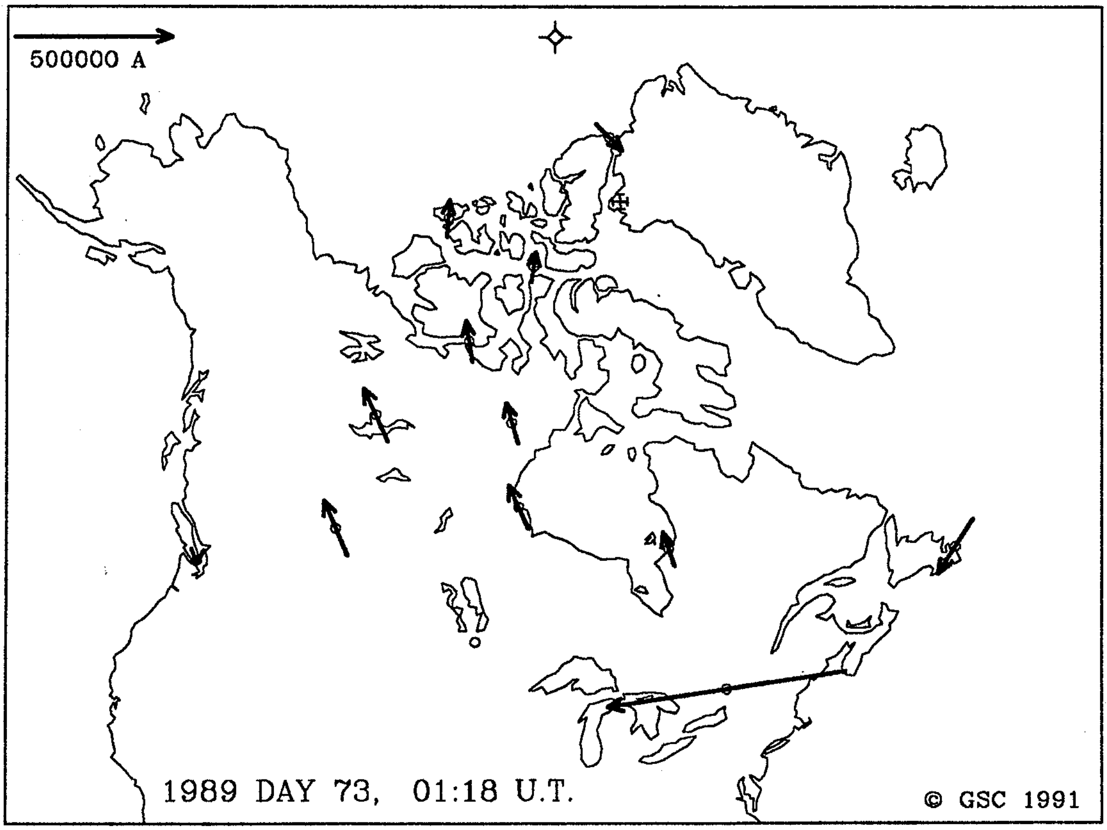
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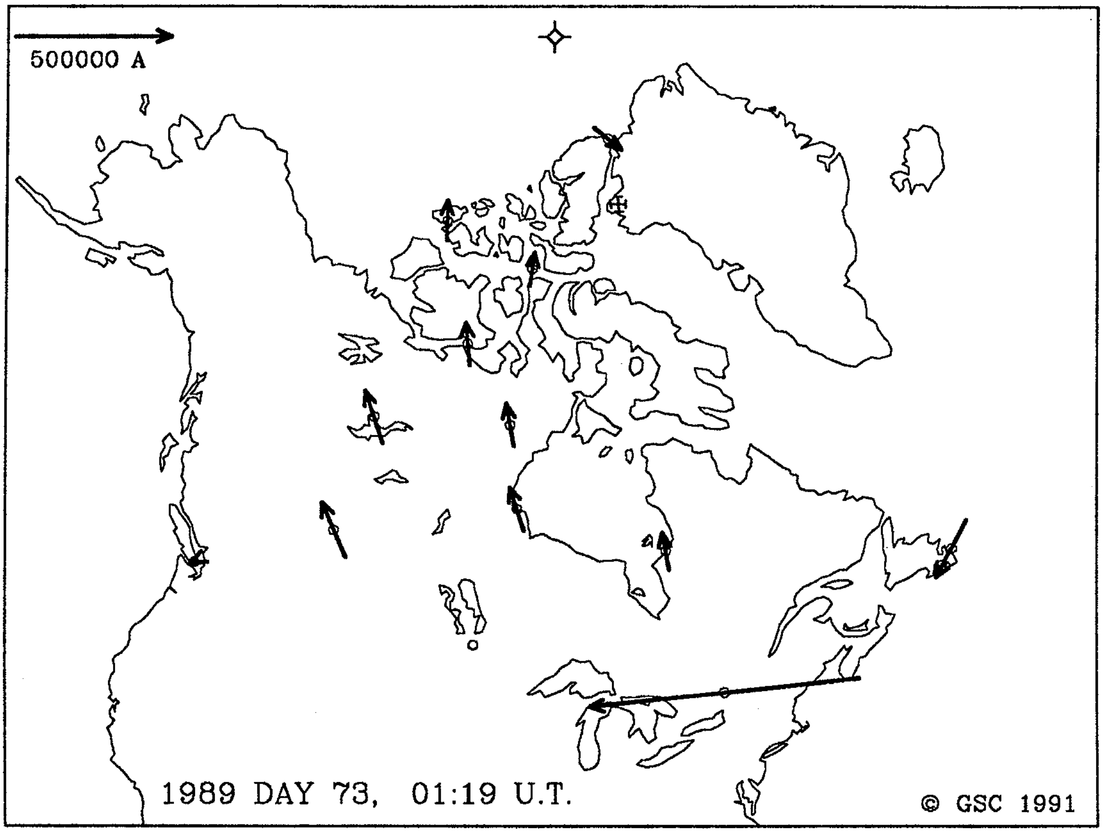
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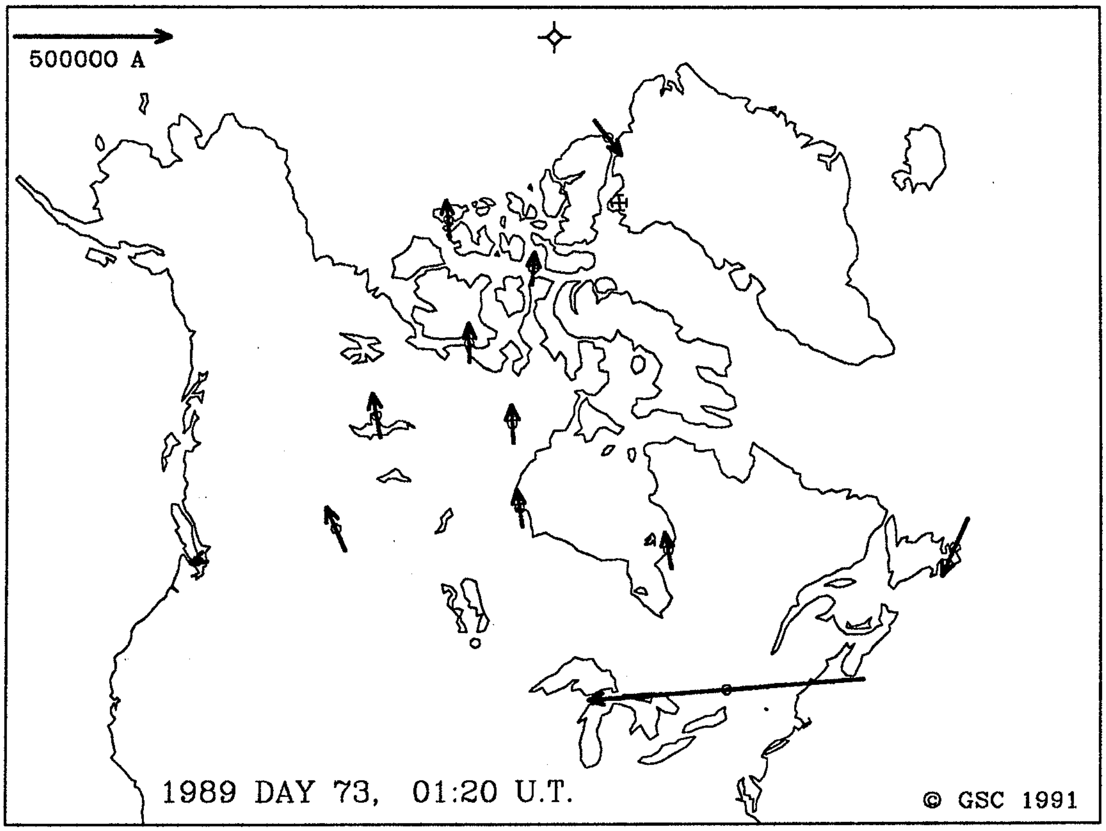
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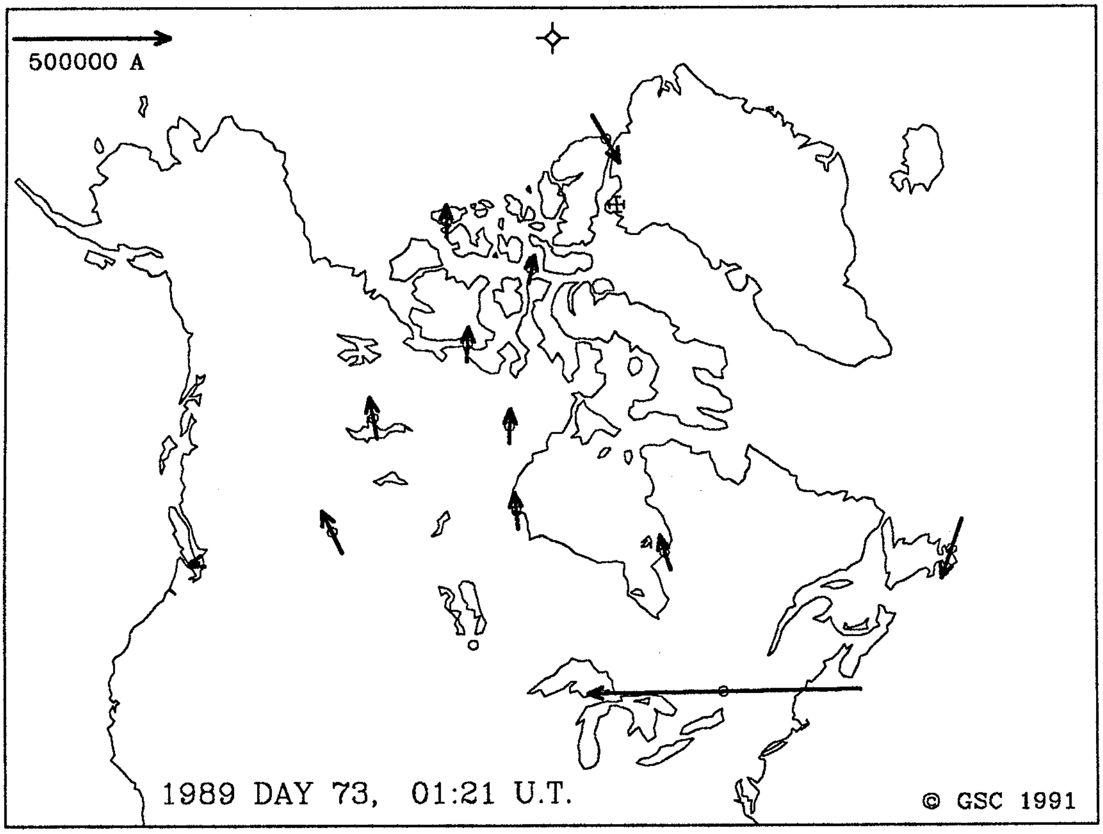
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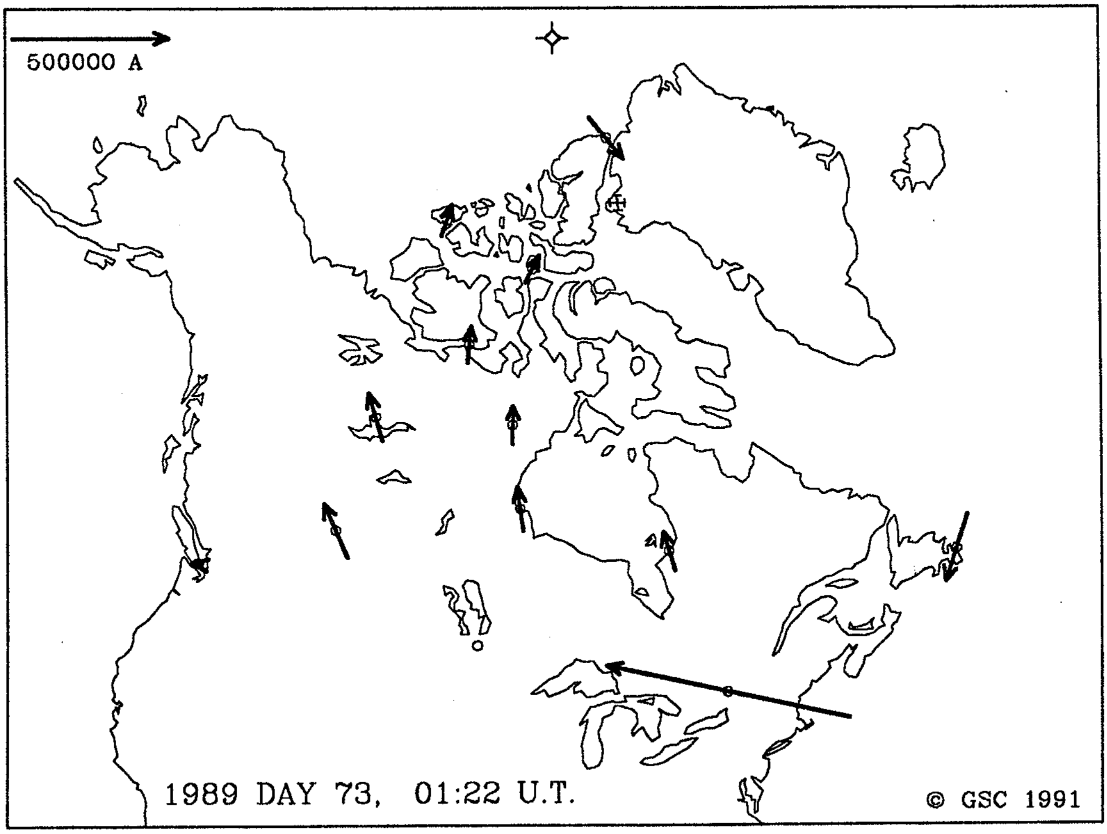
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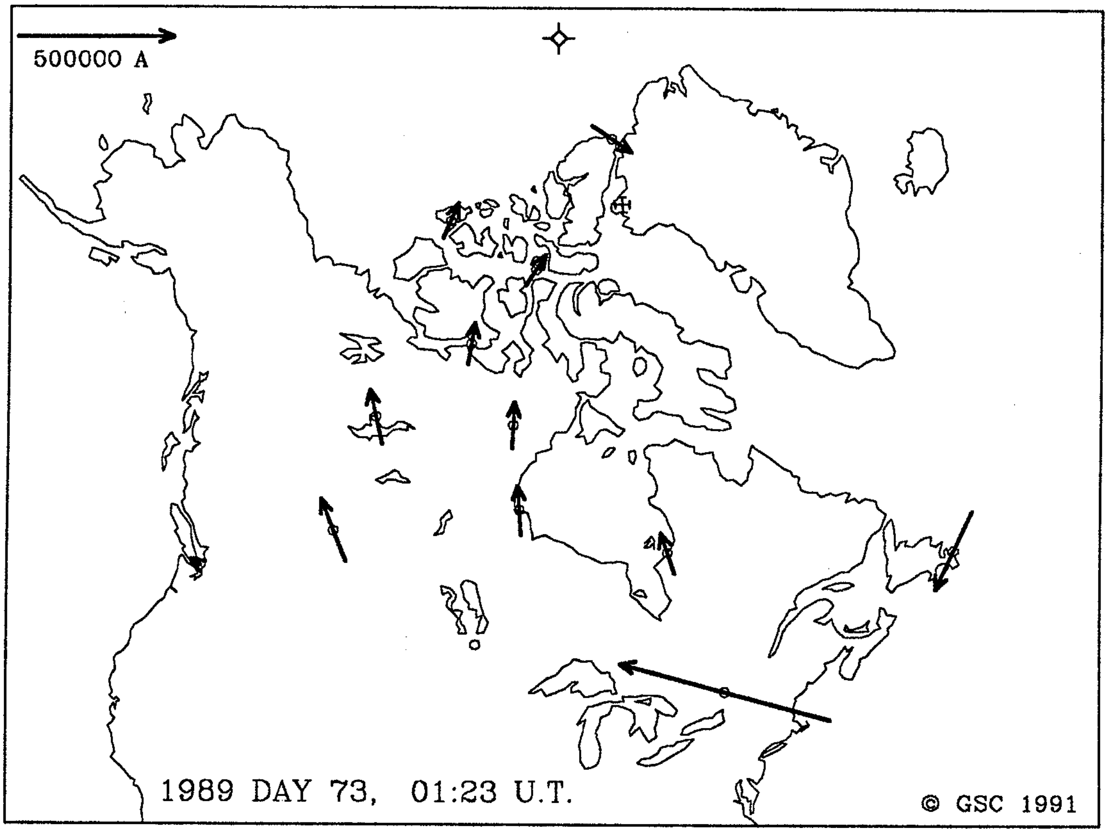
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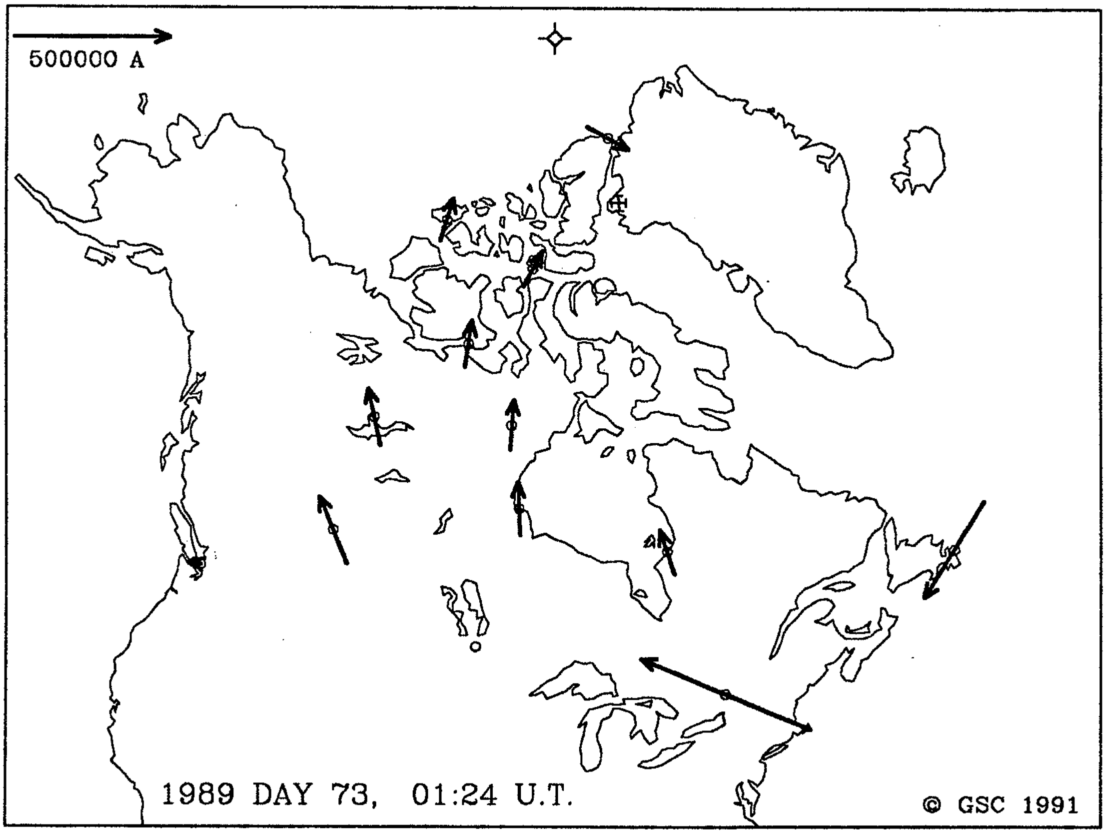
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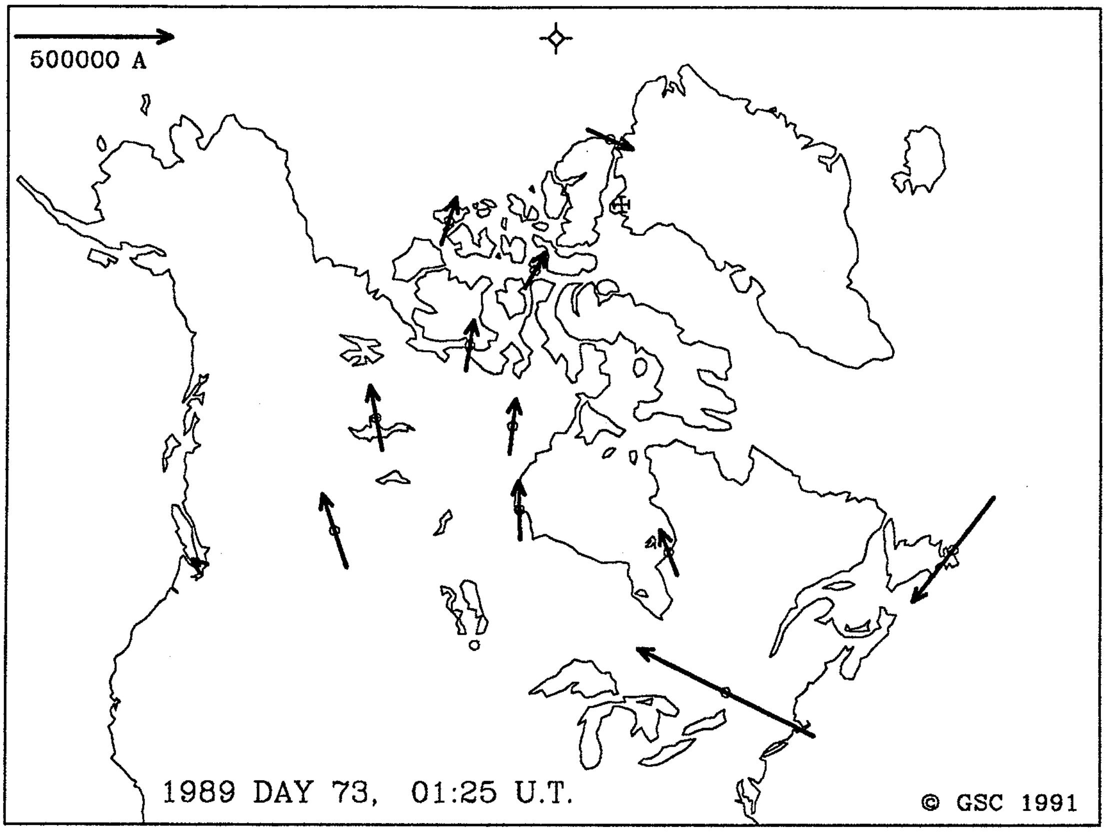
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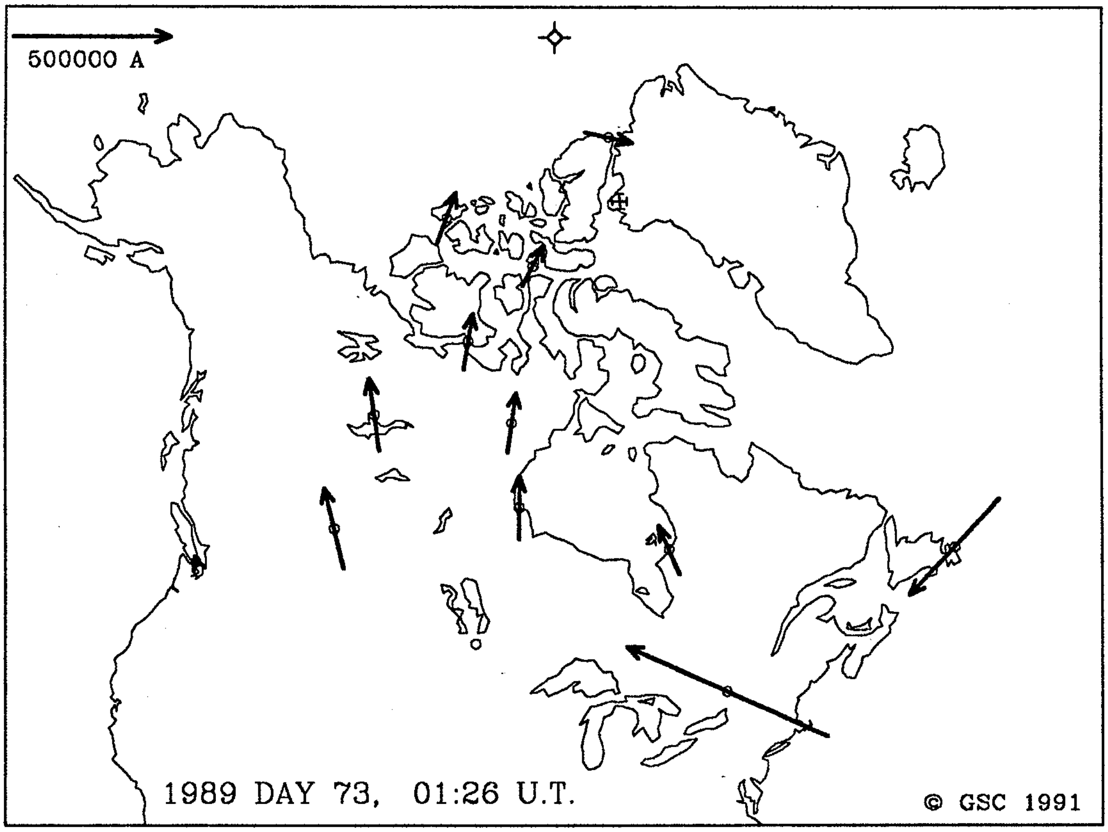
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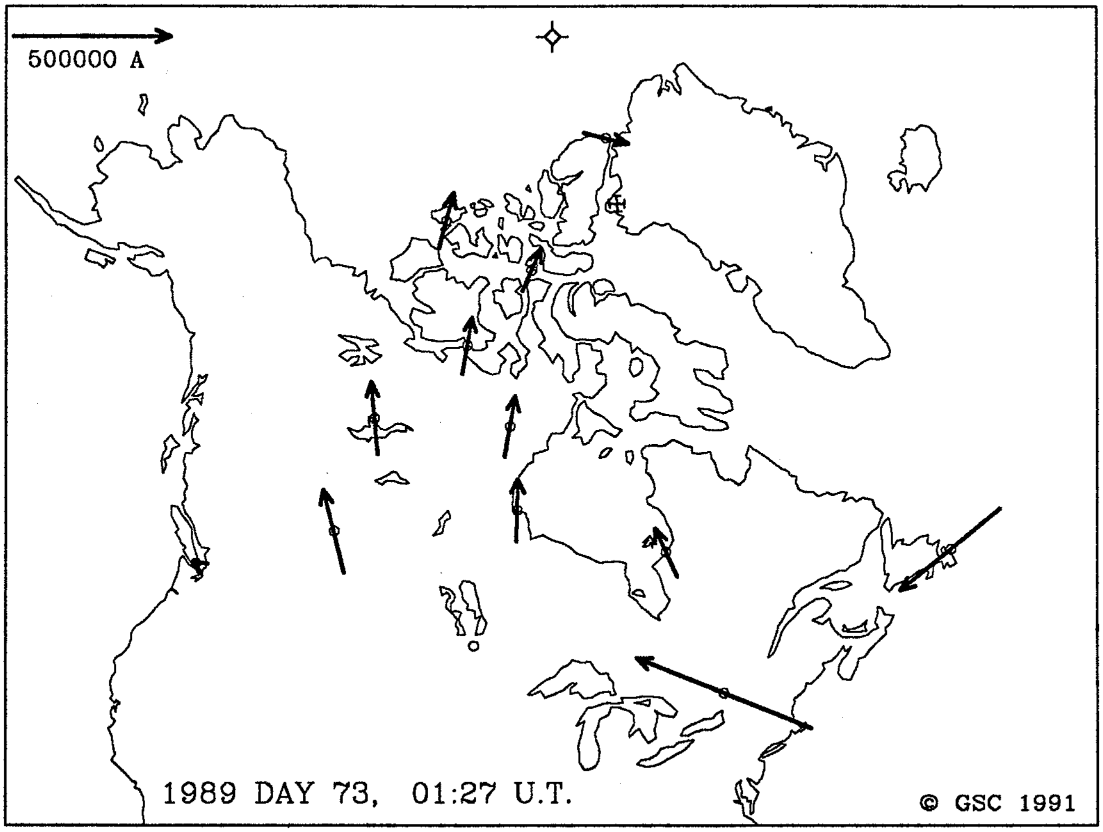
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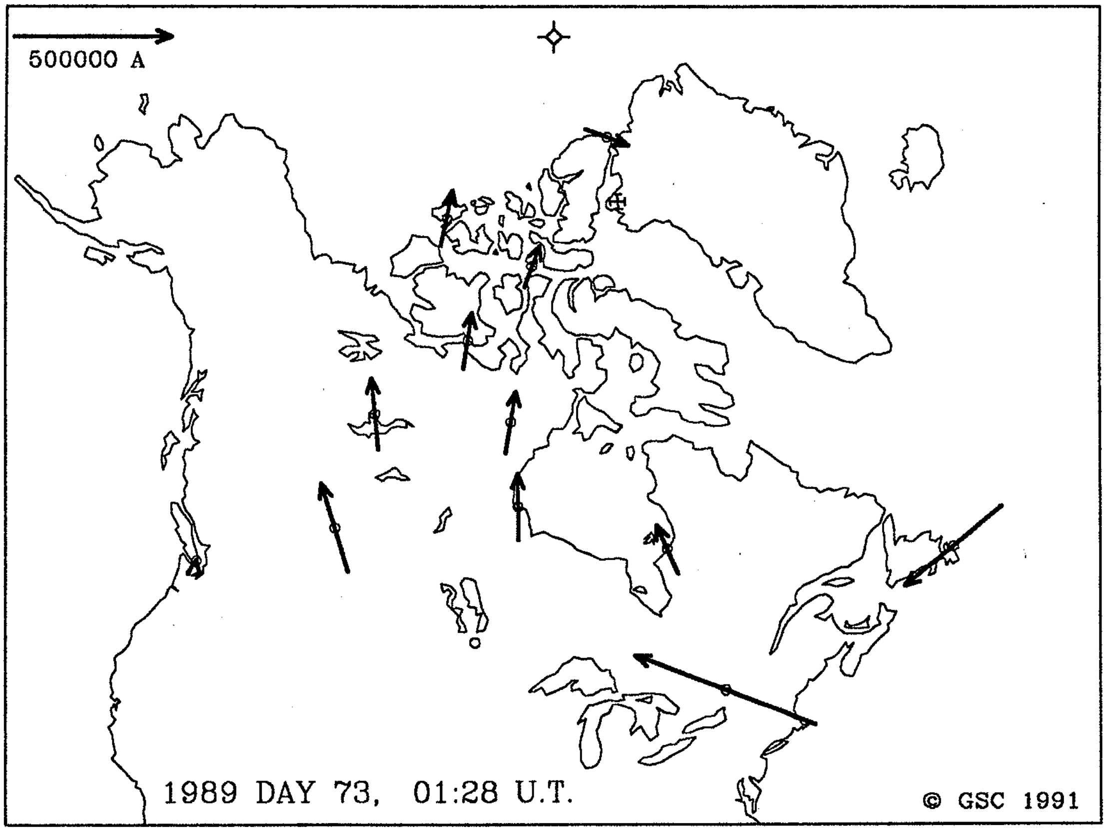
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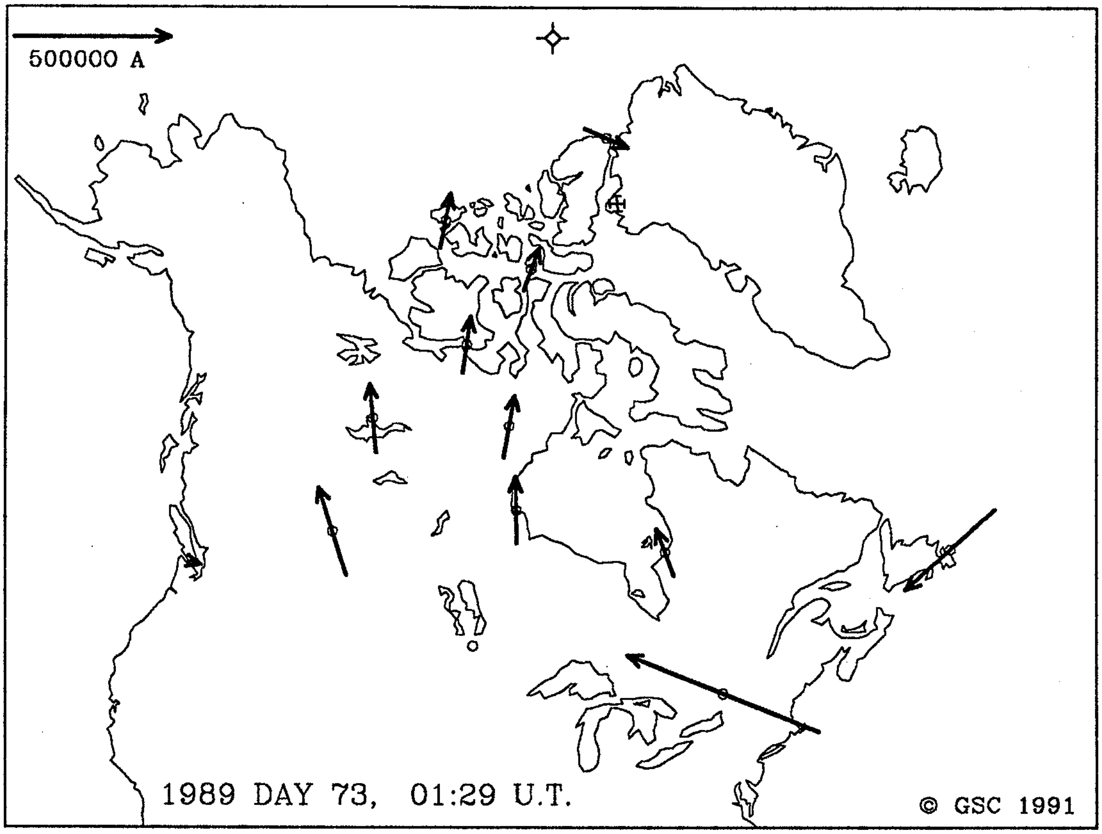
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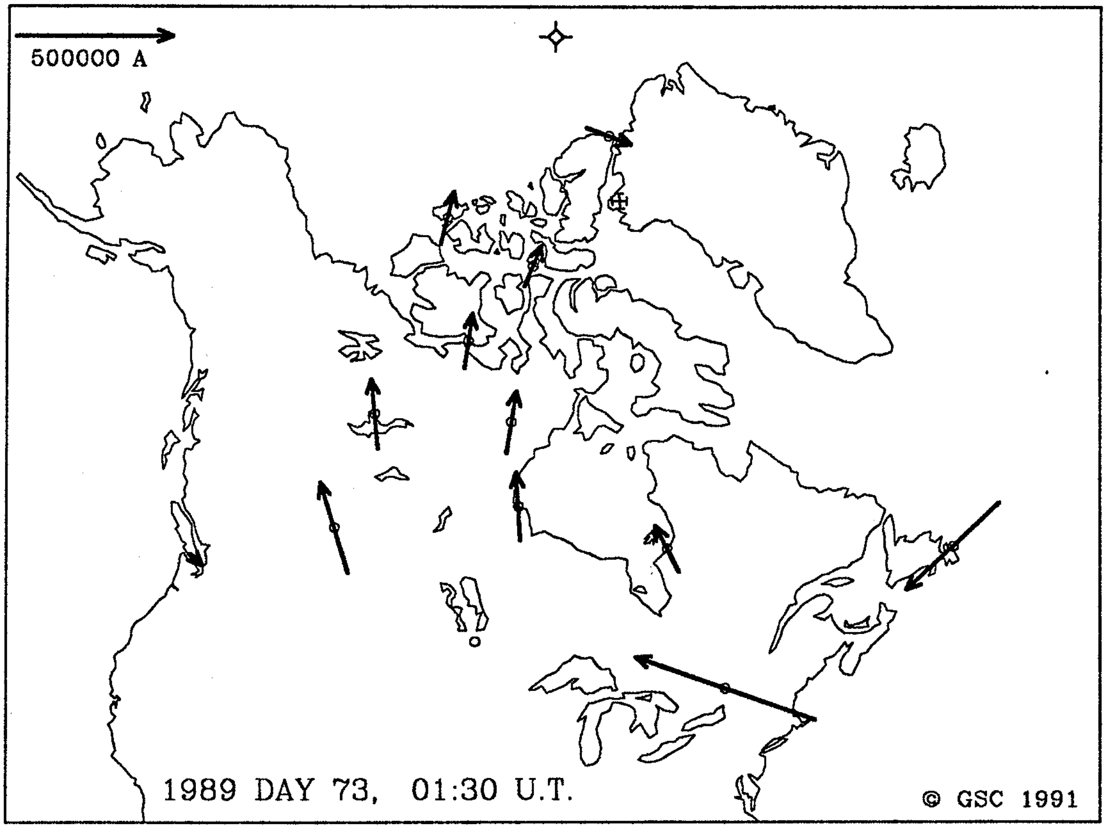
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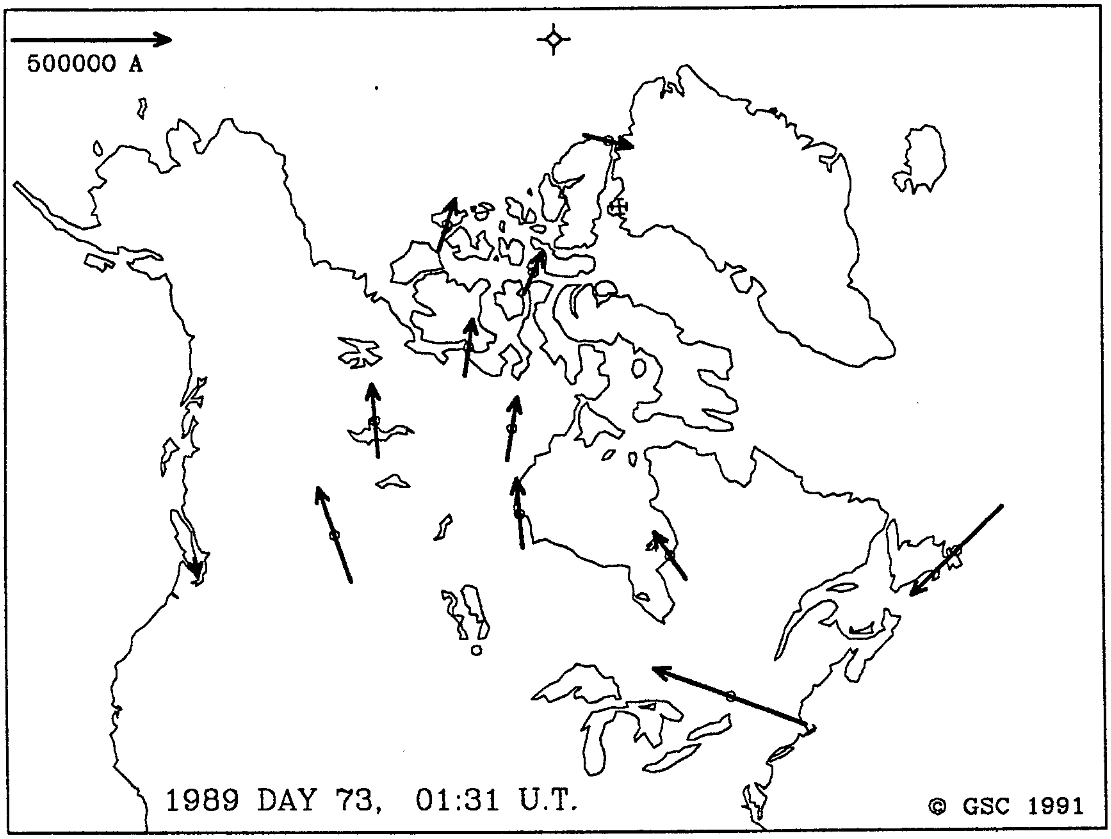
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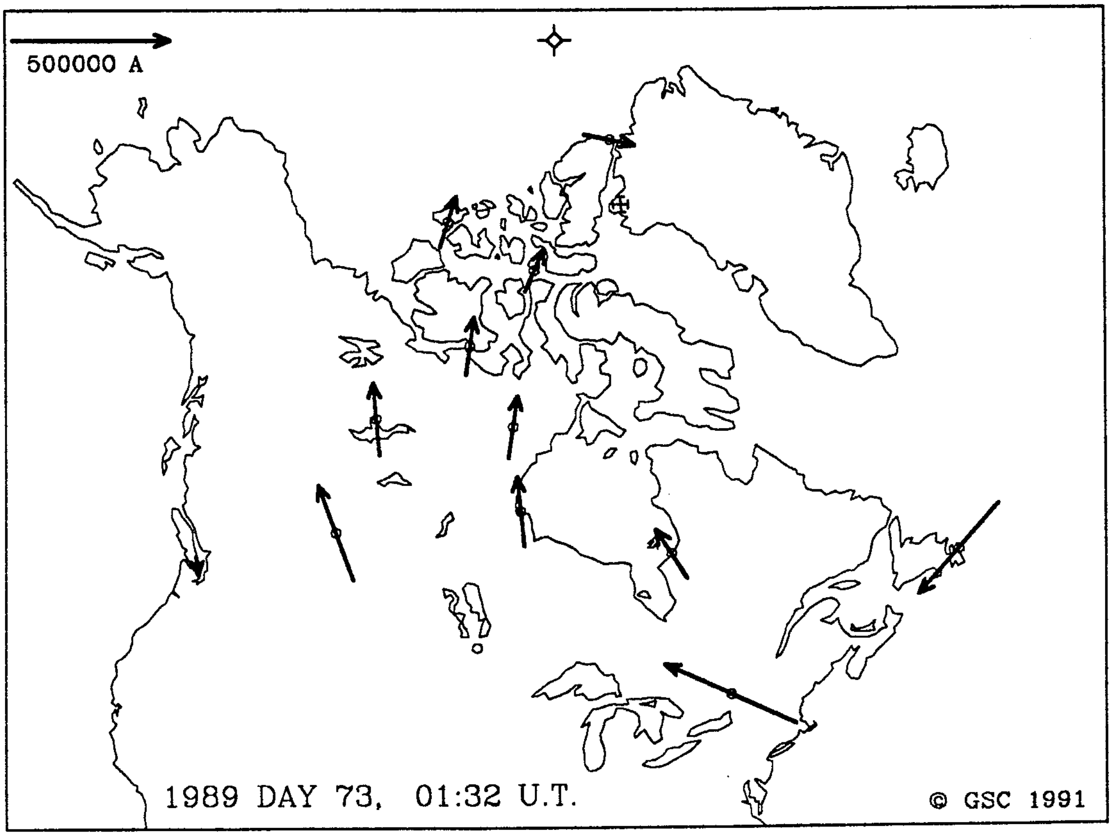
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