



Celestial Navigation Arctic Research (First phase)

A methodological study of navigation techniques at
the edge of the world

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Prelude

In today's technological era, where the Global Positioning System (GPS) is ubiquitous in our daily lives, from mobile phones to smartwatches, we sometimes forget that the previous step in the timeline of navigation was the sextant. Indeed, GPS is relatively recent when we look back, and even more so when we consider its availability and accessibility to the general public. Since then, the arts and sciences of celestial navigation have unfortunately been reduced to vague memories of a distant and bygone era, but the reality is quite different. While the efficiency and ease of use of GPS make it an unparalleled resource in terms of navigation, an experienced navigator will recognize the value of having a secondary system in case of malfunction or breakdown. Although generally very reliable, electrical incidents, breakages, malfunctions, weather phenomena, and, in more extreme cases, the threat of potential sabotage or jamming operations should not be dismissed. In the current geopolitical context, where many are taking an interest in the Arctic as tensions between certain actors increase day by day, the fragility of GPS is becoming increasingly evident, and solutions must be proposed to navigate effectively in this polar region. Adding to this, the consequences of climate change show no respite and are already having huge impacts on local wildlife and flora. Moreover, the melting ice is revealing new opportunities for navigable trade routes, and it would not be surprising to see an increased presence of tourism and recreational boating in the years to come. This only increases the importance of safe navigation beyond the Arctic Circle. The world has changed a great deal since the Age of Discovery, and our modern technological means continue to impress and improve, enabling us to tackle new challenges and explore further. But some things do not change, and we should know and understand them, as the next technological step may very well be one backward. Regardless of your interest in celestial navigation, one of PilgriNAV's main missions is to raise public awareness and introduce the subject, thus promoting the establishment of a new generation to ensure this discipline does not vanish under the erosion of time. Although our workshop specializes in older, more rudimentary techniques and the construction of instruments preceding the sextant, the principles of navigation often remain the same and can be summarized as understanding the physical mechanisms governing the celestial bodies that illuminate the skies.



Pingualuit Crater (ᐱᓄᓄᓄᓄᓄᓄᓄ), Ungava Peninsula

Lexicon

Azimuth:

An angle on the horizontal plane between an object or direction relative to a reference axis. In this context, azimuth could be translated as a course to follow or observe in order to orient oneself and navigate in relation to true north (magnetic north for compasses).

Altitude-intercept method:

A technique in celestial navigation aimed at determining one's position from an estimated position by comparing the actual elevation measurement of a celestial body with those predicted for the estimated position.

Ephemeris:

Data tables used to accurately predict the position of celestial bodies at each moment of the year. This document, the Nautical Almanac, also includes correction tables to adjust the navigator's altitude in relation to sea level, as well as refraction corrections due to pressure and temperature.

Komatik:

A sled, with or without rigid sides, pulled by a snowmobile or dogs, used to transport equipment over long distances in the tundra.

Margin of Error:

More or less half of the smallest measurement value. For example, measuring the diameter of a Canadian dollar with a 30cm ruler graduated to the millimeter will be written as 26mm +/- 0.5mm.

Noonsight for latitude:

A technique in celestial navigation used to measure the angle of a celestial body with the horizon at its highest point in the sky (when it crosses the same meridian of longitude as the navigator).

Nautical Mile:

A unit of measurement primarily used in maritime and aerial navigation, equivalent to 1852 meters.

Dead Reckoning Navigation:

A type of navigation based on the last known position, the distance traveled, and the course followed. Dead reckoning navigation relies on instruments such as a compass for orientation and, in our case, the snowmobile's odometer to measure the distance traveled.

Celestial Navigation:

A type of navigation that involves determining one's position by observing celestial bodies and measuring the angle between their height in the sky relative to the horizon.

Coastal Navigation:

A type of navigation where one's position is determined in relation to elements on a map and landmarks on the coast by measuring their azimuths and plotting them on a regional map.

Introduction

The objectives of the navigation tests conducted in the Canadian High Arctic during this first phase of the study were aimed at identifying the strengths and weaknesses of preselected instruments and navigation techniques in the most unfavorable conditions possible. The goal was to push both the instruments and the navigator to their limits and assess the subsequent needs for future tests. In other words, to break the ice and test the waters to gain an overview of the project. During these methodological tests, it is important to note that no new navigation techniques were invented from scratch, and only some of them were subject to evaluation. Having had prior experience in northern expeditions, I knew how to properly prepare for operating in these hostile conditions. In fact, I do not recommend that the public undertake such adventures unless they have been properly trained and supported in such an environment beforehand. Survival in the High Arctic is an entirely different dimension from our everyday reality, and we will delve into this subject in the first part of this study. We will also discuss the equipment used in the field and the navigation techniques employed in certain situations rather than others. In winter, with Canadian waters frozen, most movements on the terrain are carried out by vehicle or snowmobile, or, if the distances are shorter, on cross-country skis or (though rarely) on foot. These movements, when traveling from one point to another and not requiring immediate return, necessitate setting up a camp along the way. These bivouacs, while necessary for survival, impose certain restrictions on the navigator. The majority



of the time, it is more important to have shelter than to know one's position, and in an ideal world, the bivouac should also be set up before nightfall. Indeed, the Arctic reality quickly catches up with you, with its very short daylight hours (and none at certain times of the year), and where temperatures drop in tandem with visibility. The terrain itself also presents some particularities to navigation routines. The absolute lack of trees in this desolate region often provides the navigator with a clear horizon, allowing

the use of the Sun (if present) and offering a vast array of stars once night falls. However, it is customary, when possible, to carry out our movements and set up our bivouacs out of the elements, usually on hill slopes or in a riverbed, thus negating the visual advantage the navigator might wish to exploit. We will revisit the impact of the terrain on navigation as well as the challenges encountered in the second part of this document. Based on my previous experiences in Iceland, Nunavik, and Nunavut, a precise selection of instruments was made for the tests, as some instruments are unfortunately not suitable for the environment or did not allow for the execution of the navigation techniques targeted by this research. A collateral effect of this is undoubtedly my regrettable decision regarding the use of the sextant in the Arctic. I immediately think of the famous photo of Amundsen taking a Sun sight with a sextant and what appears to be an artificial horizon during his South Pole expedition. It goes without saying that this instrument surpasses all others in terms of precision and effectiveness. That said, the context I found myself in during my tests did not allow for the transportation of this preferred instrument. But I hope to make the necessary

arrangements in the future to bring it along. I certainly could have used it, as you will see later in your reading. The reasons behind my selection of instruments, avenues for improvement, and future projects will be described in the third and final part of this report. To be frank and honest with you, I still do not consider myself an accomplished astronavigator, and I believe I still have a lot to learn in this field. My enthusiasm for this science drives me to continue learning more each year and testing the knowledge I have acquired, as described in this text. As a great admirer of astronomy and terrestrial navigation, the idea came to me one day to combine the two, and to my great and pleasant surprise, I discovered celestial navigation. The veterans of this discipline among you will surely see solutions to problems encountered or alternatives that should have been considered. In the name of progress and the preservation of this art, I encourage you to share your experience and ideas constructively. While I am fully capable of taking criticism, I would nonetheless prefer that this document serve others and help us improve together (especially after having frozen myself in Santa Claus kingdom). For the sake of transparency and to give credit where it's due, I also want to point out that I was not in charge of navigation for our group on the ground, and that I conducted the tests described below during my free time and when opportunities allowed. The responsibility for navigation fell instead to Mr. Gabriel Goulet, who also managed a subgroup carrying out various related tasks, including terrain reconnaissance. Not being new to this type of journey and with many years of experience in terrestrial navigation, he was able to brilliantly navigate the tundra and lead the entire group from start to finish of the expedition. His comments and challenges encountered will be found in the upcoming parts of this text.



Part 1 – Tools & techniques

Astrolabe

Being a strong advocate for the astrolabe, it was predictable that this instrument would accompany me on this adventure. Furthermore, as mentioned in the introduction, this choice was somewhat forced since I had not brought a sextant with me, and I needed something to measure the elevation of celestial bodies. Indeed, my personal space in my alpine backpack being restricted to Arctic survival gear, I couldn't carry the instrument in its protective case. This constraint, however, was specific to this type of land-based expedition (though one could almost call the ocean land in this region in March). Future arrangements could be made to address this space issue (for example, transporting the case in a snowmobile komatik, if there's space left, or attaching it to the passenger backseat, if there is one). The astrolabes made in the PilgrinaV's workshop are graduated to the nearest degree, allowing for an error margin of $\pm \frac{1}{2}$ arc degree for each observation. Of course, it is possible to estimate a better precision by visually dividing the degree into four equal parts, but even then, we are still far from the performance of a sextant. This would theoretically give us an error margin of 7.5' (for a 15' graduation), equivalent to a 7.5 nautical mile error on the ground (13.89 km) in the best conditions, and I emphasize the word "best". In comparison, professional sextants have a micrometer drum allowing for readings as precise as 0.1' of arc, giving an error margin of ± 92.6 meters. My perspective on the astrolabe was to combine its use with dead reckoning and a thorough study of maps to compensate for its "lack" of precision. If we had had a greater distance to cover without assistance or if the context of the trip had been different (such as on the open sea), I believe it would have been entirely possible to navigate and maintain proper navigation with this level of precision. As you will see in the following image, the area where my results placed my position during noon sights is shown. It's quickly apparent that for the given



context, it would have been desirable to have an instrument with sharper precision since the actual position was in the upper right area (Cornwallis Island) of the zone, and we were making short moves due to a blizzard alert. However, in a maritime situation or when crossing a larger territory, one can see that on a global scale, it's really not that bad (in my opinion). In an emergency situation where one must find shelter quickly at a very precise coordinate or transmit coordinates for a medical evacuation, I don't believe the astrolabe would be up for the challenge, for now. It would

likely be more effective to simply carry out a quick reconnaissance of the surroundings on a snowmobile with a map and compass (we will revisit the compass).

One undeniable advantage of the astrolabe is its compactness and robustness. The one I selected for the tests was my planispheric astrolabe for its hollow design, allowing for the storage of the plates. While the use of the plates is still somewhat unclear to me and will require more study to operate properly, I mostly used them as star maps to see which stars were visible at my latitude. I had also engraved my sidereal compasses on the back to optimize space and thus carry two navigation instruments in one go. We will discuss the use of the sidereal compass later in this section and the challenges associated with space in the second. My instrument was simply wrapped in a dish towel as protection, all packed in a freezer bag inside my alpine backpack. No equipment damage occurred throughout the expedition, despite multiple moves by snowmobile, on foot, and by plane. I wanted to test its robustness given its pine wood construction against the extreme cold of the Arctic winter, and I was pleasantly surprised. Another advantage of the composition of our astrolabes is that they allow for ergonomic use without the risk of cold burns (by touch). This would not have been the case if it had been made entirely of metal. This is a very personal opinion, as I didn't like handling the alidade with gloves and found it uncomfortable and imprecise. I instead chose to support the astrolabe in the air by its ring with a gloved hand and perform the manipulations with a bare hand on the wooden alidade. Using good judgment with this method is strongly advised, as frostbite can occur at alarming speeds, and it is generally customary not to expose any skin to the elements. We all react differently to the cold, and effective training before embarking on your expedition helps you prepare properly and learn a lot about yourself and your equipment.



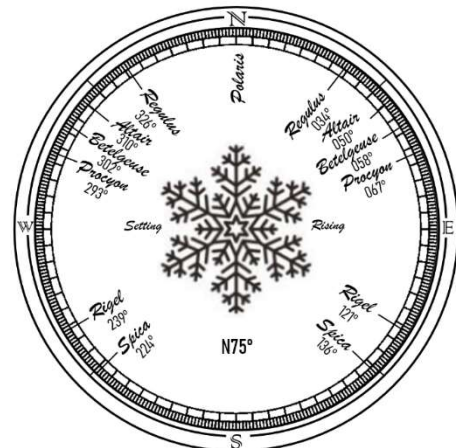
In terms of positioning by the stars, meridian crossing observations (noon sights) were used to validate our bivouac coordinate. During this trip, with almost all movements occurring in daytime, and given the lack of practice while on the move, it was the most viable option to conduct the tests, considering a day time shorter than home of one hour and 58 minutes and the very low maximum elevation of 11° for the Sun at this time of year (compared to the solstice with 38.8° according to timeanddate.com). At least in March, there's Sun in the Arctic. But it's important to remember that in the heart of winter, darkness reigns for several days in a row (polar night), and the period of time surrounding this darkness only allow the Sun to rise above the horizon just long enough to see it dip back down. The use of this technique is therefore restricted to certain months of the year, making it difficult, if not impossible, the rest of the time. A currently theoretical case that could be tested in the future is the ability of the navigator (on the back seat) to take sights using the astrolabe during snowmobile travel and thus perform an altitude-intercept method or a noon sight while on the move. Most movements take place on a relatively flat terrain, allowing the passenger to navigate while the driver continues on their way. Of course, there is a problem with this reckless method: wind resistance! The only conceivable solution in my opinion would be to create a very thin mariner's astrolabe, stripped down of its non-essential surfaces to significantly reduce its surface area, and add weight to the bottom part to limit swaying. Despite this tailor-made adaptation to this

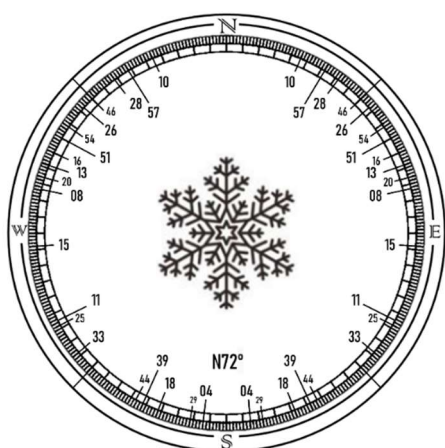
specific problem, I doubt it would be an application worth adopting, let alone a precision solution. But trying it could be fun at the very least, and maybe we'll have a pleasant surprise, who knows? Having been designated as a snowmobile driver during the preparatory training for the expedition and during the trip itself, I wasn't able to carry out this kind of test. Nevertheless, I keep the idea in the back of my mind for a future snowmobile ride. One strength of the astrolabe is that it does not require a visible horizon, allowing for position circles using stars at any time of night. With patience and warm clothing, it is also possible to perform meridian crossing sight just like with the Sun at noon. This technique, however, is not very popular with a sextant since often the horizon won't be visible after twilight unless the moon comes into play to light it.

This brings me to question the rivalry between the astrolabe and the sextant, each bringing their own set of advantages and disadvantages. On one hand, you have flexibility of use, compactness, and robustness, but lower precision. On the other hand, you are restricted to the horizon, or an artificial horizon, but have incredible precision, only surpassed by GPS. My opinion might seem polarizing, but I see no other option than to bring both instruments in the future (ideally). Because even by designing a larger astrolabe, the graduation scale could not match the quality of the sextant, even if it were made in an exaggerated size, and the very short daylight hours (in winter) disadvantage the sextant in favor of the astrolabe. Admit it, they complement each other rather well, don't they?

Sidereal compasses

The sidereal compass is an instrument that I particularly appreciate for its quick and on-the-go usage. Indeed, this tool serves a function quite different from those instruments used for angular measurements of celestial bodies, as it instead provides the azimuth of stars at their rising and setting point on the horizon, allowing for adjustments, corrections, and course changes before or even during travel. Reflecting back on my previous northern adventures, I saw the use of sidereal compasses as an interesting choice for nocturnal travel, and I remain convinced of it to this day. Unfortunately, we did not travel at night during this expedition, so I was unable to verify this theory. It's a test I'll leave for a future trip, because having navigated at night using the Orion constellation near Kangiqsujuaq in 2018, I know that the navigation techniques specific to the sidereal compass work and are very satisfying to use. In fact, such memories are what ultimately led me to celestial navigation over time. However, it's important to remember that the further one progresses toward the edge of the globe, the less effective the instrument's range becomes, as fewer navigational stars (of the 57 selected) cross the horizon during the night. Most of them are either below the horizon or constantly above it. One particularity of the sidereal compass is its restriction to a fixed latitude, much like the plates of a planispheric astrolabe, for example. This means that preparatory work must be done before the adventure even begins, as the azimuths for the same star will differ depending on the latitude. Not being an expert in this area, I used the United States Naval Observatory (USNO) website to find the necessary information for building compasses. This process is relatively lengthy and inefficient due to the repetition involved in searching for one star at a time. For reference, the sidereal compass I made for Resolute Bay only had six stars on it, and only four for Eureka. But in order to obtain this information, I had to check all the stars in the USNO catalog, unless it was obvious that a star didn't meet the search criteria due to its declination being too far south.





While designing my compasses for the expedition, and knowing that this type of problem usually draws the attention of the astronomy community, I threw a bottle into the sea by posting in the Facebook group of the Fédération des Astronomes Amateurs du Québec (FAAQ) in hopes that a kind soul would help me out. Sure enough, a kind gentleman, Pierre Paquette, responded to the call. He created a website allowing simultaneous searches for all navigational stars in one go for a given coordinate, displaying all the relevant star information, their azimuths, as well as a sky representation based on the entered coordinates. In a word: WOW! Another admirable feature of his site is that it shows all the navigational stars, while the USNO only

lists twenty-two. Needless to say, this greatly expands the range of effectiveness for the sidereal compass. You can access the site here: <https://ecliptiq.ca/pilgrinav.php>.

Historically, several civilizations and cultures have used the principles of this instrument, which has proven its worth through the ages. However, a certain trend emerges regarding the starting and ending points. Generally, guides or monuments were erected on site based on certain stars, leading to a neighboring city or port from a fixed point. But what intrigues me is whether, in the past, there were complete routes, with multiple waypoints, crossing various latitudes. What is certain is that with today's knowledge, it is indeed possible to trace such a route. And with the aforementioned website, it is now much easier and more enjoyable to prepare your navigation plan. Perhaps, and let's hope, this study will help make these compasses popular again and replace compasses in polar regions where magnetic declination changes too drastically for effective use.

The paper

A part of my navigation equipment is what I affectionately call "the paper". As the name suggests, these are documents that help make sense of the readings taken with instruments. An excerpt from the Sun tables and the first point of Aries ☐ (now in the Pisces constellation due to the precession of the equinoxes) extending slightly beyond the dates of the expedition in case of delays due to the weather, formulas for calculating the Sun's declination, a list of navigational stars and their information, a conical map of the Arctic Circle, and a plotting sheet (laminated for multiple uses). Why not simply bring the entire Nautical Almanac? To save space and weight, quite simply. An excess of zeal for some and an obvious choice for others. Indeed, if you've done a lot of outdoor activities or even survival exercises, you know that every extra gram adds to the already uncomfortable weight of the gear. It's not uncommon to have to remove excess packaging from food or equipment to keep only the essentials, and the same applies to the Almanac. This reality becomes more pronounced as the distances from the base camp increase, requiring more fuel, food, and water. This trip was only one week long, and even then, the work of extracting and condensing everything onto a few pages took some time. So, doing the same procedure for longer trips would be even more demanding and would span on multiple pages. In such cases, I would honestly be tempted to simply bring the full book, even if this means sacrificing something less important to save up space.

Maps

Concretely, on the ground, navigation by dead reckoning using a regional map prevailed over celestial navigation, as the terrain allowed for it without too much difficulty, to my great surprise. Analyzing the terrain and its relief helped us navigate with ease for the movements we had to make. I had previously had the chance to briefly visit Cornwallis Island in 2019, near Resolute Bay, before heading to Devon Island further east, and I did not think that such navigation in the region could be feasible given the lack of visual landmarks I was accustomed to. To some extent, I saw a parallel with coastal navigation, where one uses landmarks and prominent terrain features. But all too often in the Arctic, there are no visible points of reference available to locate oneself. In these situations, I believe that turning to celestial navigation would be the wise choice, once again, if the context and weather conditions allow. I remind you here that the central effort of this research was to simulate the absence of GPS. It goes without saying that in other situations, one should not deprive themselves of such a resource if it is available, unless they are taking on a personal challenge safely.

Mr. Goulet (in charge of our navigation) also adds that he mainly looked at the distance of his traces and the terrain's relief in relation to the contour lines and high points, as these are perceptible over vast distances. He reiterates that, when possible, one should also pay attention to prominent or man-made features on the map (although in general, these are rare in the Arctic). This glaring lack of landmarks makes everything difficult, and the aspect of distance estimation very laborious. This requires monitoring the snowmobile odometer to track progress on the ground. One invaluable resource he mentions, when the opportunity arises, is to consult with local terrain experts, such as the local Inuit or Rangers, to obtain tips or relevant information before heading out to navigate on our own. This navigation method demands a sharp observation of one's environment, as one must be very attentive to anything that might be useful in the terrain. At one point, when there were no visible landmarks and the terrain was flat on the horizon, Mr. Goulet spotted cabins that appeared to be for fishing, as well as a small boat beside one of them, just before the terrain descended toward what seemed to be the sea. He was then able to position himself on the map based on his trajectory and this crucial information. From a safety perspective, Mr. Goulet finally adds that he tried to plan his routes to pass through the lower parts of valleys in order to reduce bumps and obstacles, thus avoiding the risk of an expedition member falling or getting injured on rough and dangerous terrain. He emphasizes that in this region, one is so far from anything and isolated from the rest of the world that even the slightest accident could quickly turn into a very serious situation.



Part 2 – Challenges & Solutions

workspace and ergonomics

Not having the luxury of a personal vehicle or any dedicated storage space for the navigator's equipment in the context of this dismantled expedition (if we do not take into account the snowmobiles and the rare vehicle trips to and from the airport), the navigation equipment used had to be compact, sturdy, or at least protected, ideally kept safe from water and/or condensation, easily accessible, and transportable with ease. This material challenge goes well beyond the parameters of the navigator and affects every member of the expedition, to varying degrees. Our personal belongings, food, spare clothing, water, all these elements and more had to meet the criteria mentioned above to avoid getting bogged down in our bags out in the cold. In the komatiks pulled by the snowmobiles were the collective equipment such as the tent, our tools, heating and cooking equipment, petroleum products (diesel, gasoline, naphta, oil, etc.), waste, food, water (in the form of ice blocks), and finally our personal bags. Not immune to mistakes, and fully aware of the equipment storage plan, I initially left my instruments in my bag (in our komatik, under a tarp secured with tight ropes or cargo straps), with no access to them until we set up a bivouac site. Without any effort, I thus broke my rule about accessibility. At least the phrase, "but where is my astrolabe when I need it?" led to some reflection and prompted change.

Choosing the planispheric astrolabe as the primary instrument was a wise decision in terms of space management, as I was able to attach my sidereal compasses in place of the plates (on the back). The quest for optimizing space was successful after a few minutes of mental Tetris, and the result was very satisfying. After that, I only had to add a flat-head screwdriver attachment to my Arctic collar, and I could now switch from plates to compasses as needed.

From experience in the North and the Arctic, it is customary to bring a book to kill time during waits and to occupy oneself during guard shifts (safety and filling of heating elements). The dilemma with this tradition is that a book takes up unnecessary space for survival. Since Nautical Almanacs or even PUB NO.229 aren't the best bedtime reading, I chose to extract only what I needed for the expedition to minimize the impact on available space. This way, I was able to bring *Celestial Navigation* by David Burch as my personal reading to stay in the navigation mindset. We discussed earlier in the first part the reality of very limited space, and I find that this choice is a nice compromise to allow a bit of luxury while remaining efficient with the navigator's tools. However, it is worth noting that an expedition lasting several weeks or covering very long distances would likely not allow for this compromise, and the navigator would need to bring more documentation or make sacrifices elsewhere in their luggage.

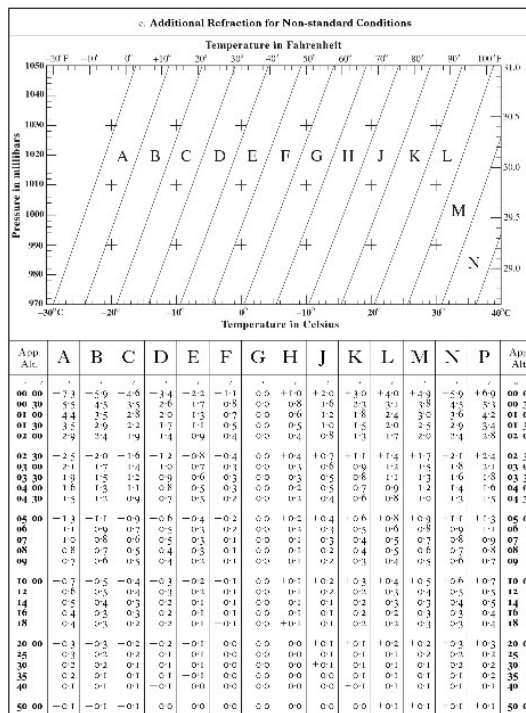
By ergonomics, I mean the workspace to take angular measurements and perform the associated calculations. On the move and in the field, I already knew the drill, but to help you visualize it, try imagining your navigation routine in the available space of a snowmobile seat. It was probably the largest space I had during the trip. Now you can imagine the rest. Once stopped, however, there is no shortage of places to use the instruments in the tundra. But with temperatures this low in winter (and I consider myself quite resilient to the cold), one can only stay still for a few minutes. During the solar meridian passage, I took nearly fifteen minutes to follow its altitude to determine the highest point, before quickly jotting down my results on my hand with a half-frozen pen before heading back into my team's tent. At this time of day, which fairly coincides with dinner, there is space available in the tent for calculations if needed. But in the evening or at night, when sleeping bags are out and our wet clothes are hung on a rope or net to dry, we end up crowded together, and the workspace is reduced to our thighs. Unfortunately, I don't see any possible improvement to

address this, as this routine somewhat fosters our own survival. Using an app or a ready-to-fill memory aid would make the task faster, thus shortening the discomfort. This was also my first real experience with celestial navigation in the Arctic, and I hope that, over time and with practice, I will become more comfortable and efficient in performing those tasks that falls to the navigator.

The cold

I'll spare you all the challenges related to the cold weather, as the list could prove to be endless. I'd rather focus on the navigation tests rather than the impact of the cold on the person, but to give a very brief summary: yes, the navigator gets cold too! Joking aside, I remain open to questions on the subject to help you better prepare if you ever feel like visiting the white desert. We already discussed, in the previous section, the wooden composition of my instruments and the concerns I had about this during my preparations. Apart from the insufficient space to bring my sextant, I had some hesitations about bringing my trusty Davis Mark 15, which I bought early on in my celestial navigation career. You've probably noticed, but this model of sextant is made of plastic, and despite its shockproof description, I feared the Arctic conditions would have been too much for it if I had brought it. Having already seen jerrycans crack and even break during transport due to extreme cold, and for budgetary reasons among others, I decided that it would be better to risk a wooden astrolabe, which I can remake, rather than my sextant. That being said, I've also seen metal cans shatter in the cold as if they were made of cheap papier-mâché, so I suppose the key to durability lies in the density and/or flexibility of the material. This is why I will need to bring a solid, sturdy metal sextant if I want to conduct tests with that instrument up there.

One factor of precision that I'm less accustomed to is the impact of the cold on refraction. I only thought about it after my return, and so I didn't conduct any tests on the subject. But it would be interesting to address it next time in order to quantify this factor, and I wanted to at least mention it in this text. In the ephemerides, we can see that the table is valid from -30°C to 40°C , which seems to be sufficient for all situations a navigator might encounter, but that's not true. It's not uncommon for the temperature to drop well below -30°C in the Canadian Arctic, and my future intention would be to find a way to extend the range of this correction. As mentioned in the first section, the "rough" precision of my astrolabe compared to the sextant probably doesn't warrant such a meticulous and surgical correction, but since we're at it, I might as well conduct some tests on this during a future trip.



Visibility & weather phenomena

It's not uncommon in the Arctic to hear about a blizzard risk or whiteout, and I consider myself lucky to have never been caught in such a storm, only a few attempts from the wind to scare me. The fine, volatile layer of snow on the frozen ground is quickly lifted up by the wind, and even a light breeze can temporarily create this phenomenon when the terrain is flat enough. No navigation is possible during a blizzard, and I would even say that movement, of any kind, should be prohibited, with the main effort being to seek shelter and set up a bivouac site while waiting for the storm to subside.

Sometimes, after the Sun sets, visibility can be quite poor, almost like a hazy veil. Either I had never really noticed it, or it had never happened to me before, but it was the case during this expedition. I'm not sure I understand the phenomenon, but I'll definitely pay more attention to it in the future. This "distant fog" only lasted for a certain amount of time (at most a few hours) and was soon replaced by beautiful starry skies. From a perspective where you would want to use a sextant at twilight, this haze would make the task impossible, and later at night, the horizon might be difficult to distinguish in the darkness. This is another reason why I like the astrolabe, as you can use it whenever you want, with or without a visible horizon. Unless, of course, the visibility is completely null.

At these latitudes, the northern lights are breathtaking. It's not uncommon for people to step out of their tents, despite the freezing cold, to admire this celestial magnetic dance. Sometimes they're shy, and sometimes they are very colorful; they can also sometimes steal the show from the sky and make it hard to see the stars (or at least make them difficult to discern). During this trip, we only had one aurora borealis, so no major problems on that front. In any case, there's not much to be done about it, other than enjoying the show and waiting for the sky to clear up.

I remember that at one point, I noticed that the moon was unusually absent from the sky, both day and night. I first thought it must have been related to the new moon (the phase when the moon is between the Earth and the Sun). After doing some research upon my return, it turns out that it was simply below the horizon during that whole period. Therefore, a navigator who wants to use the moon for navigation or to determine the time would be quite inconvenienced, but such is life in polar regions. It also made the night particularly dark and could affect maritime navigation that uses the horizon as a reference. Fortunately, this isn't the case all year round, but just like the presence of the Sun, it remains a challenge to consider in the Arctic. (source: timeanddate.com)

Moonrise, Moonset, and Phase Calendar for Resolute Bay, mars 2024

< février

mars

avril >

Month: mars

Year: 2024

Go

2024	Moonrise/Moonset			Meridian Passing		
mar	Moonrise	Moonset	Moonrise	Time	Distance (km)	Illumination
1	-	Down all day	-	04 h 30 (-4.7°)	397 287	71.6%
2	-	Down all day	-	05 h 18 (-8.9°)	392 712	62.0%
3	-	Down all day	-	06 h 10 (-12.1°)	387 274	51.5%
4	-	Down all day	-	07 h 07 (-13.9°)	381 194	40.6%
5	-	Down all day	-	08 h 07 (-13.9°)	374 834	29.8%
6	-	Down all day	-	09 h 08 (-12.0°)	368 688	19.6%
7	-	Down all day	-	10 h 08 (-8.2°)	363 334	10.8%
8	-	Down all day	-	11 h 06 (-1.8°)	359 345	4.3%
9	09 h 03 ↘ (138°)	15 h 39 ↗ (232°)	-	12 h 01 (4.2°)	357 191	0.7%
Note: hours shift because clocks change forward 1 hour. (See the note below this table for details)						
10	08 h 52 ↘ (108°)	19 h 46 ← (265°)	-	13 h 53 (11.4°)	357 139	0.3%

A silent enemy in the Far North is snow blindness, also called Photokeratitis. It is an inflammation of the cornea that occurs after prolonged exposure to UV rays without proper eye protection. It's a bit like getting a sunburn, but on the eyes, and it greatly affects vision. Indeed, the vast snowfields stretching beyond the horizon drastically increase the effects of albedo, which can reflect up to 80% of UV rays. Although the reflection of light on the snow has little impact on navigation, the navigator's eyes, on the other hand, must be in good condition to navigate.

In summary, if the weather doesn't align with our plans, we must either wait for it to pass or navigate by dead reckoning while keeping a good logbook, waiting for the opportunity to fix our position by other means later on. In our modern culture of immediacy, where everything is available on demand, this might seem inefficient and even frustrating. But it's important to reiterate that without GPS, this would be our everyday reality. Hence the importance of studying the issue and having secondary systems so that we are never without means of navigation.

On the road

We briefly discussed this challenge earlier, and clearly, using navigation instruments remains a challenge during movement. No matter the context in which a navigator finds themselves, each method of locomotion seems to affect the navigator's precision, and each environment brings its own unique twist. Ideally, one would stop for a moment and remain stationary to take the readings, but reality often proves otherwise. I'm especially thinking about my astrolabe as I write these lines, as the sidereal compass is specifically designed to be used while moving, making this instrument a well-appreciated complementary tool. Although at sea the sextant is the most efficient, in the context described here, it must be used when stationary and in combination with an artificial horizon. This feature essentially makes the sextant impossible to use while moving (on a land-based nav context). I think it might be possible for the passenger to take lunars sights with the sextant while the snowmobile driver focuses on operating the vehicle. But, to be honest, I don't know enough about this navigation technique to confirm or deny its feasibility. Moreover, from what I know, it would be used to determine the time. As mentioned earlier, the Moon wasn't even visible during the dates of the expedition, so this technique couldn't have been tested, even if we had wished to.

Regarding the plotting sheets, I strongly doubt that a navigator, even if seated on the back of a snowmobile, would have the dexterity to complete the task effectively. These turbulent conditions, combined with the polar cold, once again require stopping in order to perform the calculations and tracings correctly. However, as we'll see in the next section, it's possible to take note of elevation and time values while in motion and then do the navigation at a stop, considering the time elapsed and the distance traveled between readings and when making the tracings. A lot of meticulous work in a small, exposed workspace... just talking about it makes the task seem ridiculous, and needless to say, much practice would be needed before becoming comfortable with this method. Normally, the navigator is seated at the navigation table or in the wheelhouse to perform all of this, and even this "comfort" requires practice, time, and space.

In relation to movement comes the speed of travel and the pace at which tasks are completed. In the North, the rule of thumb is to take one's time to avoid sweating. During this expedition, and this is my personal opinion, I found the pace relatively high. But it might just be me needing to get back into the rhythm, as my last experience of this kind was in 2020, in Rankin Inlet. One must also keep in mind that when exposed to wind and cold, you can't stop for too long. I'll need to find the right balance between taking the time to use my navigation tools properly and not delaying the group, which is eager to reach a bivouac site. As for speed, let's just say that a snowmobile moves

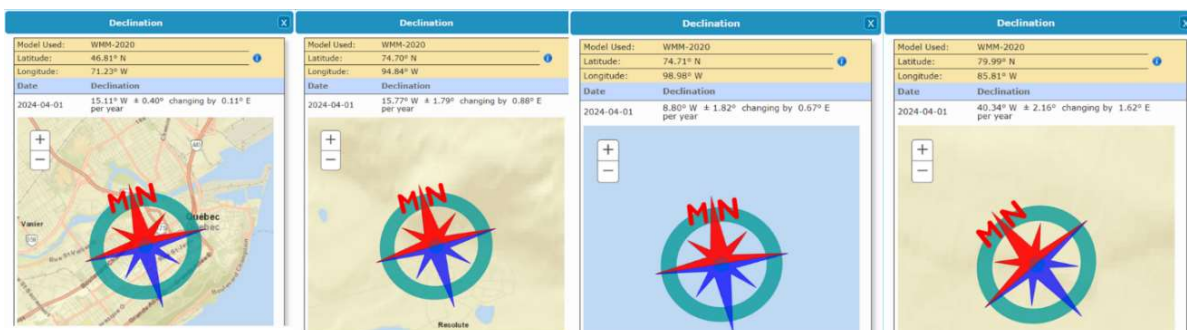
a lot faster than a sailboat, so every delay in calculations can represent significant distances traveled. The combination of these two factors led me to make position fixes only when stationary, at times when I knew we wouldn't be leaving quickly. During this expedition, for movements, Mr. Goulet handled navigation based solely on his interpretation of the terrain and the analysis of his map. While the combination of these two navigation techniques proved effective for our needs, I fully intend to remedy this situation in the future with some improvements.

Stress

There's often talk about the stress people in leadership positions can feel. They don't want to disappoint those under their charge and aspire to high performance. The same goes for the navigator, who nevertheless has a crucial responsibility. The slightest mistake could cost dearly! Whether we're talking about material goods or time, but especially in the harsh conditions of the Arctic, we must consider human lives as a precious and fragile resource to protect as well. Mr. Goulet states that no one wants to get lost, especially when all the members of the expedition are following and placing their trust in the navigator, particularly in the Arctic. The ultimate challenge, he adds, is to remain confident and clear-headed during navigation, remembering the elements of the map and what one is supposed to see along the way, all while performing navigation checks as often as possible to confirm the route and estimate the remaining distance to the destination.

Magnetic Declination and Deviation

Contrary to popular belief, a compass doesn't spin uncontrollably in the North. But there are still some factors to watch out for. Those familiar with compasses know well the sneaky enemy that is magnetic declination and how to live with it. With a handheld compass, it's easier to forget about it by mistake compared to the compass on a boat, because you can adjust the declination directly on it and then stop thinking about it. This false peace of mind often leads to easily avoidable mistakes among off-trail outdoor enthusiasts, myself included. On the National Oceanic and Atmospheric Administration (NOAA) website, I checked the declination for the areas we were to explore. Surprisingly, the magnetic declination in the Resolute Bay area (15.77°W) wasn't far off from what I knew in Québec (15.11°W), and I thought there might have been an error in the parameters. It wasn't until I looked at the relationship between these two locations, the magnetic pole, and true North that it all made sense. However, while we commonly say the expedition took place in Resolute Bay, to identify it quickly on a map, we were actually farther to the northwest. This is the impact of declination at high latitudes in action, because the actual value was closer to 8.8°W. In contrast, Eureka's magnetic declination was 40.34°W. As you can see, the angle changes drastically depending on your location, especially when you're near the pole. From the outset, it's always important to keep in mind the effects of declination on your compass, but forgetting it in the Far North is almost like not bringing the instrument at all. That's why many land navigators in this region prefer to rely on the surrounding landscape with a map rather than use the compass. It would require several adjustments along the way or a massive amount of preparation before setting off on an adventure. Below are screenshots from the NOAA showing declinations from left to right for downtown Québec, Resolute Bay, the Resolute Bay airport, and the Eureka airport.



Less known than declination is its cousin, deviation. Better known in maritime contexts due to its omnipresence, it has little to no impact on someone on land in a national park trail. To summarize quickly, deviation is the magnetic interference caused by materials and tools surrounding the instrument that affect its use. A striking example would be taking a handheld compass reading on the beach and then boarding a sailboat, placing your instrument near the helm right next to your VHF radio, motor, autopilot, etc., and taking a second reading. Your result is probably as different as day and night. A snowmobile, being less imposing than a boat, will of course have less deviation, maybe even imperceptible, but not nonexistent. Also, if you're navigating by compass and you have a radio under your coat, batteries in your pockets, or other things likely to affect your compass, it would be wise to make a deviation chart, taking care to always place your equipment in the same spot as during your tests. If, like me, you're wearing a thermal tops sewn with chest pockets to protect your cell phone and battery charger from the cold, take a moment to consider your old friend, deviation.

Part 3 – Improvements & Future Projects

Equipment & Movement

It goes without saying that a solution must be found for navigation while moving in the Arctic. In the first part, I mentioned that someone sitting in the back seat of a snowmobile could take a Sun sight using a modified astrolabe for that purpose. While it may seem unusual, I believe there's something to explore here, but unfortunately, a single observation is not very useful. The ephemeris tables should also be easily accessible to the navigator and kept attached to avoid misplacing them. Then come the calculations. My hypothesis is that a small-sized, touch-screen drawing tablet, attached to the navigator's arm, could allow them to perform calculations while in motion, providing a certain ergonomic comfort. Whether the pencil and screen of the tablet would still work in the cold is a test to be conducted later. For the time value, a watch should be easily accessible, though more exposed to the cold. This compromise will require the navigator to ensure that the batteries are fully charged so that it doesn't turn off along the way. I learned while writing these lines that it's common for modern watches to use lithium batteries. This is good news since such batteries have a high energy density, allowing for longer continuous use in cold temperatures. That said, it wouldn't hurt to have a spare battery or make sure the watch is rechargeable if necessary. I see this method being used for solar meridian crossing observations. However, it would be interesting to integrate the performance of the altitude-intercept technique, which requires a bit more calculation, time, and sometimes additional documents. My humble opinion is that stops will still be necessary at some point. The alternative would be to consider the opposite: take the observations during a stop and do the calculations while in motion. In this case, why not simply take a longer stop to do everything and reduce the risk of error? Or even do it in two stops, tracking

progress on the terrain by estimate between the two breaks? Note that for the meridian, we don't have the luxury of choosing when to stop; the observation must be made at the exact moment.

As for the plotting sheets, I don't think any material or practical improvement could solve the associated issues with them, primarily the nature of the workspace. However, using an electronic application could allow the input of all parameters and values into a table, with automatic resolution displayed on the screen. It would be important to keep in mind all the specifics of electronic equipment exposed to the cold. Such an app should be able to function without GPS or internet connection for the same reasons that prompted this study. Some might argue that using this kind of app is an insult to the discipline. While I don't fully agree, I do understand the point. It's true that relying on this technological luxury is risky given the potential for electronic problems or equipment failure. But these technologies could allow altitude-intercept lines to be drawn while in motion without requiring a stop. The pros and cons are stacking up, as you can see, and tests will need to be done to learn more! Several apps of this type already exist, and I plan to test a few before the next trip to see how they perform. Of course, your advice and recommendations will always be welcome.

The use of the sidereal compass during nighttime travel is definitely a project I'm particularly interested in. In combination with a map of the area mounted on the snowmobile's windshield, this method is, in my opinion, one of the best alternatives to the classic compass for maintaining or finding a heading at night. We agree that a compass would do the job normally, provided you account for the difficulties associated with its use mentioned in the second part. It would even be possible for the driver to use the sidereal compass if it were removable and mounted on a plate attached to the fuel cap, which offers a relatively flat, unused, and accessible space for the driver. But with this option, I already anticipate potential equipment failure due to the cold. In the worst case, attaching the compass with a small rope to the driver's neck or the snowmobile's handlebars provides a somewhat unglamorous and ergonomic option, but functional nonetheless. To be continued!

Another idea that came to me upon my return is the use of a Bris-type sextant. I'm not very familiar with this type of instrument yet, but the concept interests me. With a slight modification, it could be attached to the ski goggles and take observations (of the Sun) effortlessly at set times (altitudes) throughout the day. All that would remain is to note the time and do the calculations. I've already tried to make one myself, but let's just say that glass is very different to work with than the wood we use in our workshop. I'd like to give it another shot (forewarned is forearmed, right?) or buy one if I can't make it work. However, just like the traditional sextant, the Bris requires a visible horizon. This somewhat limits its use in a terrestrial context but doesn't make it impossible either. However, I'm also questioning the level of precision that could be achieved with such an instrument and I'm not convinced that its ease of use compensates enough. It will have to be added to the list of things to test.

Buddy System

Navigating on your own on a day-to-day basis provides a completely different atmosphere compared to my experience in the High Arctic. By now, you've gathered from reading this that managing equipment, operations performed by the navigator, calculations, and so on requires excellent organization in such an environment. Also, if time is tight and you need to fix your position quickly to validate the location of a camp while dealing with freezing temperatures, a bit of help certainly won't hurt. From the outset, it's always good to do these tasks in pairs, and there were times when I thought an extra pair of hands would have made the job much easier and more

enjoyable, even just to take down values and the time. For the next expedition, I plan to remedy this (with my teammate's consent, of course). Celestial navigation always attracts a few curious individuals, and I'm sure that with a little mentorship, a volunteer will step forward. Navigating in pairs also reduces the risk of calculation errors by providing a second set of eyes on the results. Finally, I've often talked about space management throughout this text, and once again, I'll point out that equipment could be distributed between the two people.

Heading to Greenland – Phase 2 Begins

If all goes well and we secure funding and/or sponsors, I plan to continue this study on the West Coast of Greenland by the end of 2025. As you may already know, PilgriNAV is not full of money and really not of the cash driven kind, as nearly all our revenue is reinvested into purchasing tools for the workshop to keep our instrument prices affordable, materials to manufacture them, events we participate in voluntarily, and large-scale projects like this one. Depending on the context of this next expedition, some improvements will be tested, while others will have to wait. It's clear that adding equipment for snowmobilers belongs to a completely different reality than using it on a sailboat, cross-country skis, or dog sleds, for example. In this case, the expedition will take place primarily at sea (if not entirely), bringing a new dimension to this northern adventure. I already anticipate having more space to perform my calculations and plotting. But life on board will still be a community experience in confined space, and I'm well aware of that. This expedition will mark the start of Phase 2 tests, aimed at testing certain improvements, experimenting with other types of instruments, and validating the lessons learned from Phase 1. As you read these lines, we are already designing a new type of astrolabe focused on greater precision and adaptability to the context in which it is used up North.

Following in Amundsen's Footsteps

The North is all well and good, but what about the South? A challenge awaiting me in the next few years is finally a good trip to the South. You might be surprised, but I've never set foot in the Southern Hemisphere, and I plan to remedy that by going to Antarctica. What? Not the South you were thinking? I think the biggest navigation challenge will be orienting myself in the sky, which will be completely different from what I'm used to in the Northern Hemisphere. But they say it's worth it because the sky there is magnificent. Not seeing Polaris in the sky will likely be disorienting at first. I'm not yet sure of the format this project will take, nor what is realistic or possible to do there nowadays. Most trips to Antarctica are tourist cruises, sometimes allowing passengers to disembark on the White Continent, but without venturing far into the territory. Planting a PilgriNAV flag at the South Pole would be quite a humorous sight, especially if we could see the faces of future expeditions members! But more seriously, such a goal requires incredible logistics and preparation to achieve success. In the meantime, other adventures, tests, solutions, and challenges will take place, slowly preparing me for this unusual endeavor. This expedition is not yet scheduled but is planned to be a continuation of Phase 2, with the same objectives, but testing a new series of tests and improvements.

Conclusion

To me, it's clear that much more will follow, and the project will grow in scope in the years to come. Before I left, I thought my research would only focus on using my astrolabe and finding a way to adapt (as a CelNav navigator) to the harsh Arctic conditions. Instead, I come out of this experience with a multitude of ideas to test in future icy odysseys, and I'm already excited about

the idea of embarking on another adventure. I've particularly found it interesting to consider the disparity of contexts the navigator can find themselves in and to think of ways to react to them. Moving between land based and celestial navigation in this Arctic environment to achieve my objectives, I found that the challenge was real, and I plan to face it again with the suggestions provided. One personal difficulty I encountered was my lack of fluidity as a navigator, and for me, the solution is nothing other than practice and even more practice to develop procedures adapted to these extreme conditions. Although my focus is currently on modernizing ancient instruments and adapting them to a polar context, I'm not closing the door on new technologies in the field. The aim of the study is to develop and improve secondary solutions to GPS, and it wouldn't be justified (in my opinion) to sit on the principles of yesteryear in the current era when an abundance of technological resources is at our fingertips.

Acknowledgments

I would like to take a few lines of this text to thank everyone who supported me during this first phase of the project. As you read this article, you may not immediately grasp the extent of all the work behind it, the extended deadlines, the administration, and all the hours spent in front of a screen and in the workshop to reach this result, in addition to the fieldwork. Your moral support, curiosity, and interest are heartwarming and motivate me to keep pushing forward, delivering topics, content, and innovations with PilgrinAV. Thanks to Gabriel for his comments and advice on Arctic navigation, to Pierre for improving the processes with sidereal compasses, and to Francine for text corrections in French!

As you can see, while PilgrinAV is not sponsored right now, this is not the work of just one person, which is why I like to refer to this study as a citizen research project. If you want to get involved, support the cause, or have some ideas to bring solutions to the problems mentioned in this text, please feel free to contact us via social media or by email at pilgrinav@hotmail.com, and we'll be more than happy to discuss with you.

- AVANCE AU LARGE -

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