Searching for Neutron Monitor Sites as Alternatives to Mawson and Cape Schmidt

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Motivation for New Locations

Neutron monitors are ground based devices used to detect cosmic radiation. By utilizing multiple monitors, we can more accurately observe the space weather our planet is experiencing. However, gaps in the network can hinder this understanding. For this reason, we want to supplement less reliable and accessible stations with newer ones that can be more easily integrated into the network. Cape Schmidt in Eastern Russia on the Arctic Sea has recently become completely inactive. The Mawson station, owned by the University of Tasmania but located in Antarctica, could become unreliable due to its inaccessibility. The station is currently taking data but if technical issues were to arise, we could lose data for an indefinite amount of time. Therefore, we want to create reliable backups in the form of new neutron monitors that would see particles coming from equivalent (or as close as possible) directions as these older sites. These new locations would make the Simpson Neutron Monitor Network more robust and foster new collaborations with other organizations and universities.

How the Neutron Monitor Network Functions

The sensitivity of a station is limited by its geomagnetic cutoff rigidity, which is a measure of shielding from Earth's magnetic field, and its asymptotic direction. The cutoff implies that only particles at that energy or higher will be able to reach the monitor. By pooling data together from different stations, we can derive an energy spectrum of the incident particles, important for estimating the magnitude of the space weather effect, such as Ground Level Enhancements (GLE)[2]. A GLE occurs when a significant number of charged solar particles reach the Earth's surface. Although a single monitor may register a heightened count rate under these conditions, that is not sufficient to determine whether a GLE has occurred, since there could be other causes for the increase in counts. As such, multiple stations need to observe an increase in quick succession for the event to be considered a GLE.

How Neutron Monitors Function

Cosmic protons interact with the atmosphere, producing secondary neutrons. Each interacting neutron induces fission in the lead, producing several 1-10 MeV neutrons. The polyethylene sleeve around the tube serves to moderate the fast neutrons down to thermal levels. If they diffuse into the proportional tube, the neutrons can be captured on ^{10}B in the BF_3 gas, yielding a ^{7}Li nucleus and an α particle. The two products recoil in opposite directions and ionize gas molecules. The freed electrons are multiplied by the accelerating electric field. The total collected charge is proportional to the deposited energy of the ^{10}B fragments. The current pulse is amplified before digitization. When the thermal neutron is captured on the ^{10}B, there are two possibilities, corresponding to the energy levels in the boron nucleus. The Q-Values of 2.792 MeV or 2.310 MeV correspond to the ground and first excited states, respectively[1]. 94% of the time, the reaction ends in the excited state. Because some reactions take place in proximity to the detector wall, either the lithium or alpha particle can leave the detector, not depositing its full energy in the gas. This is called the Wall Effect and produces a continuum of energy deposits.

Asymptotic Direction

We use the signals from multiple stations to determine the incident direction of the particles. Due to Earth's magnetic field, particles coming to Earth follow a complicated path down to the ground. The program OTSOpy calculates this trajectory by simulating an anti-particle leaving the station[3]. This is allowed because the Lorenz force, which governs the particle's path, is time-reversible. Once free from the magnetosphere, the particle path is only dependent on the Interplanetary Magnetic Field, which we do not attempt to model. The antiparallel path from that point back to Earth is known as the asymptotic direction[4]. Our maps are created from a collection of these directions, as the particle's trajectory is dependent on its rigidity.

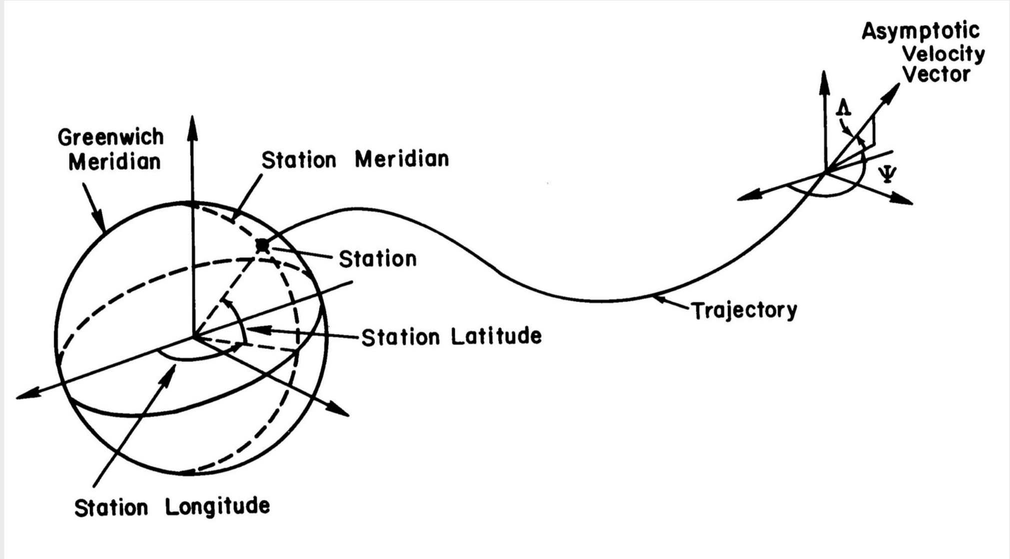


Figure 1: The trajectory of the anti-particle and its asymptotic direction[5]

Location Logistics for Potential Sites

Name	Population	Possible Collaborating Institution	Access	R (GV)*	Subjective Ranking
Reykjavík	135,714	• Iceland Academy of the Arts • Reykjavík University • University of Iceland	• Ring Road/Route 1 • Keflavík International Airport • Reykjavík Airport • Eimskip (shipping service)	• 0.50	1
Húsavík	2,485	• Húsavík Academic Center (HAC) • STEM Húsavík	• Eimskip (shipping service)	• 0.45	4
Reyðarfjörður	1,368	• Reykjavík University	• Eimskip (shipping service)	• 0.54	5
Sauðárkrókur	2,614	• Fjölbrautaskóli Norðurlands vestra (FNV)	• Sauðárkrókur Airport (Now defunct) • Eimskip (shipping service)	• 0.46	3
Akureyri	20,050	• University of Akureyri	• Ring Road/Route 1 • Akureyri Airport • Eimskip (shipping service)	• 0.44	2

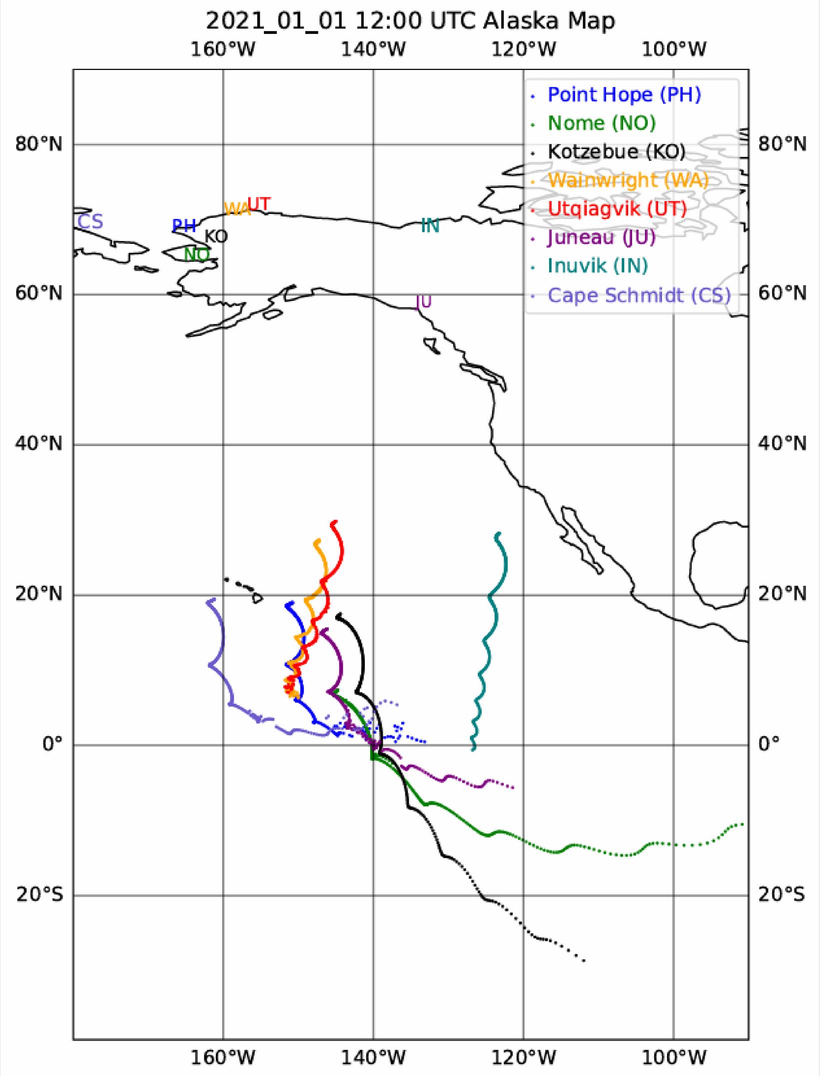
Name	Population	Possible Collaborating Institution	Access	R (GV)*	Subjective Ranking
Point Hope	830	• Tikigaq School up to grade 12 and adult basic education classes	• Air Bering • Alaska Airlines • Barge Service during summer	• 0.27	4
Nome	3,699	• Northwest Campus of the University of Alaska – Fairbanks	• Barge Service during summer • Arctic Deep Draft Port • Alaska Airlines	• 0.64	3
Kotzebue	3,102	• Chukchi Campus of the University of Alaska - Fairbanks	• Barge Service during summer • Alaska Airlines.	• 0.35	2
Wainwright	628	• Alak School up to grade 12 and adult basic education and vocational education	• Transportation to Wainwright is available by scheduled and chartered air service from Utqiagvik	• 0.04	5
Utqiagvik	4,927	• Ilisagvik College • NOAA	• Alaska Airlines • Barge Service during summer • Air Cargo	• 0.03	1
Juneau	31,609	• University of Alaska Southeast	• Local public transportation (bus) • Alaska Airlines	• 0.74	6

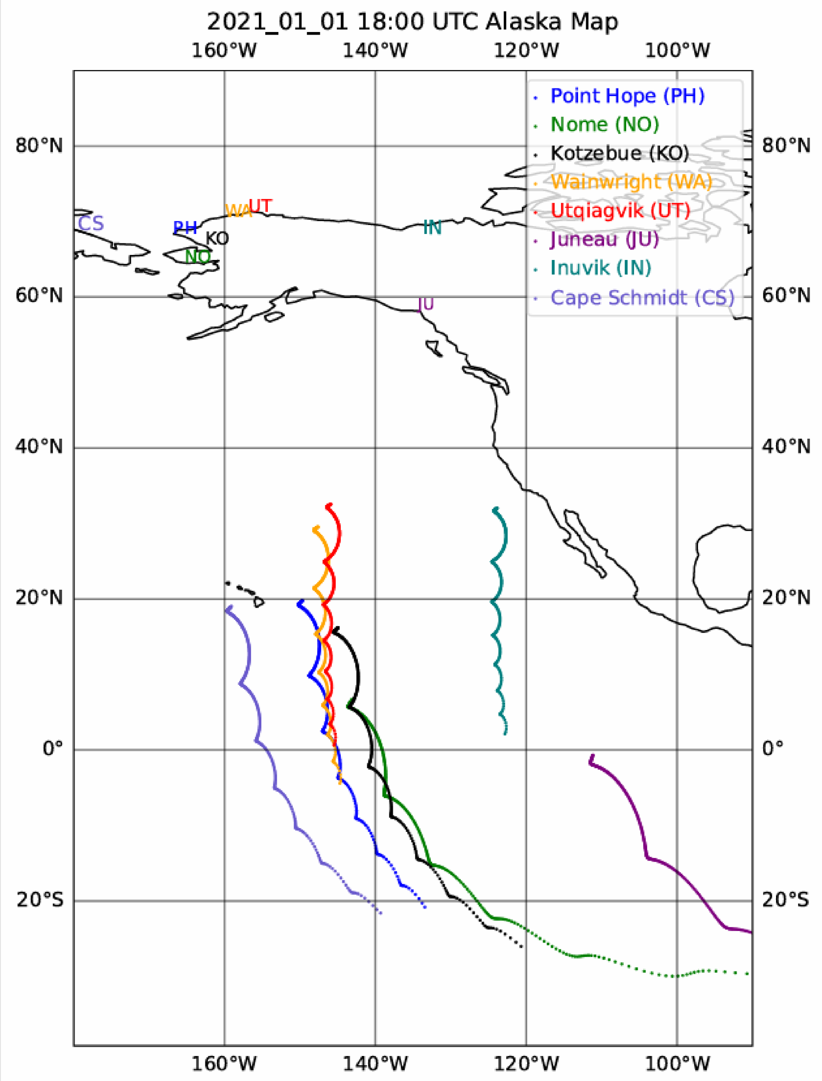
*Note: These are geomagnetic cutoffs, calculated by OTSOpy. All these stations are approximately at sea level so they are affected by the 1 GV atmospheric cutoff[7].

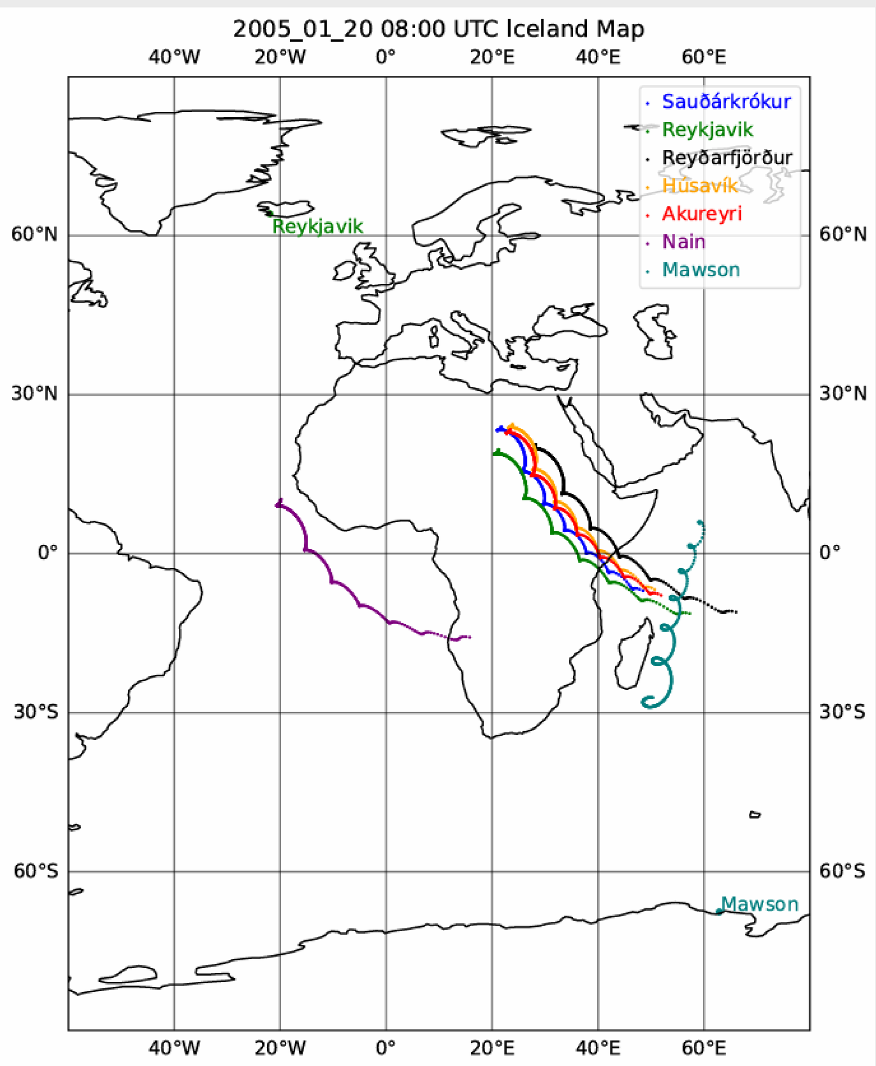
Space Weather Safety

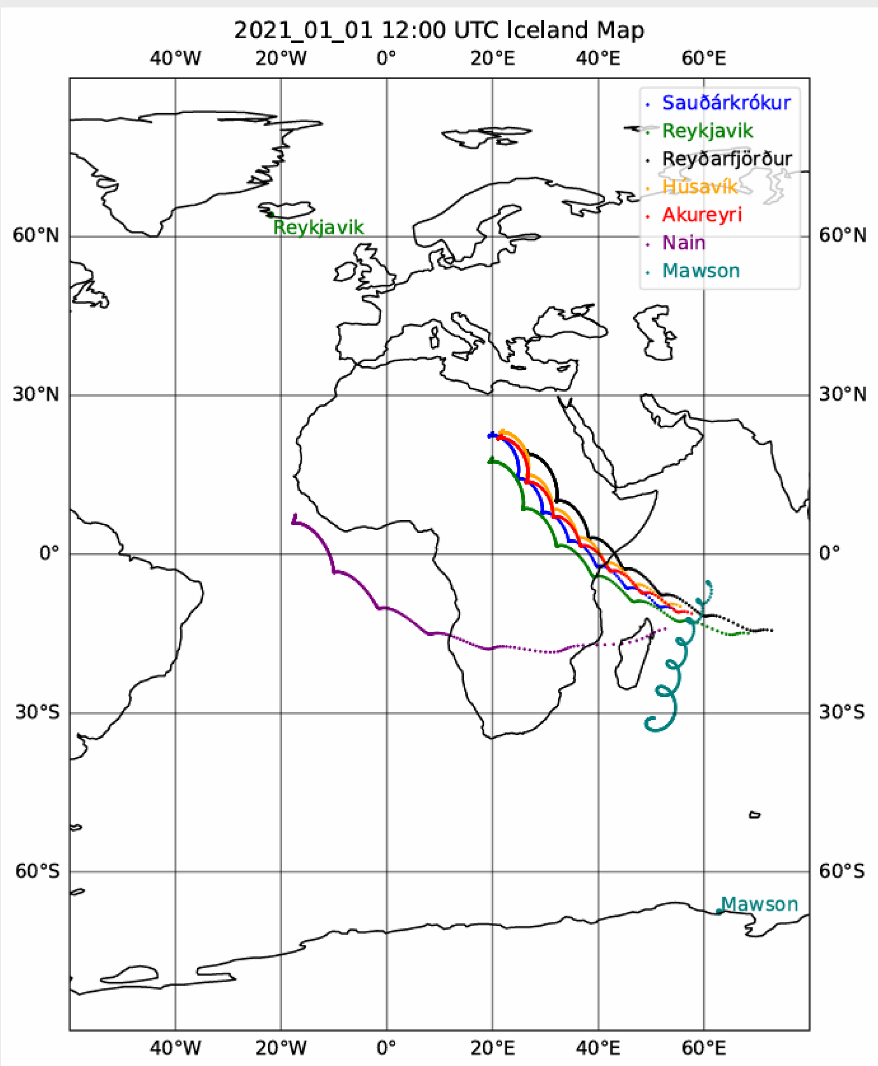
There are astronauts and numerous national assets in space, all of which can be adversely affected by incoming radiation. The information a single monitor provides can be scientifically rich but not practically actionable. It is unlikely a lone detector would even see the particles that interact with the instruments in space or their crews. When an ionizing particle interacts with equipment, this can cause chip errors, which can be potentially catastrophic but also fixable with a system reboot. Radiation safety for humans, however, is much more complicated. The probability of developing health issues rises as exposure increases so it is critical for flight crews to accurately understand how much radiation is present in their working conditions.[6]

Asymptotic Direction Maps









Figures 2-5: Maps showing the asymptotic directions for particles arriving at each potential new monitor with rigidities from 1-5 GV (The point closest to the instrument location has the highest rigidity). The pair of Alaskan maps compare two local times (six hours apart) on a quiet day while the pair of Icelandic maps compare that same quiet day to GLE 69. In addition to the candidate sites and sites to be replaced, some currently operational monitors were added for comparison. We included Nain in the Icelandic map and Inuvik in the Alaskan map.

Next Steps

Until now, all the asymptotic direction maps have been produced under the assumption that all particles reaching the station are incident mostly from the local zenith. Of course, this is an idealized case, because higher rigidity particles can also arrive at the monitor from other directions[8]. OTSOpy accounts for this, so in our future work we will expand the viewing direction for each station to gain a more robust idea of each new site's suitability for replacing the defunct stations. Finally, the choice for a new site is a complex process, depending on a variety of factors, and the final decision will be made by others.

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