









US-based Simpson neutron monitor network

”Back to the future“

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Abstract

The status and condition of the various neutron monitors operated by the US reached its nadir in the mid 2000s. Now with significant investments by the National Science Foundation, the existing network will be repaired, upgraded and selectively modernized. Furthermore, a key site on the summit of Haleakala will be outfitted once again with a monitor, supported by a Space Weather Center in Honolulu. We report on the start of this work, plans for the near future with funds from the NSF and longer-term plans to take the network to a new operational and scientific level. We also report on a complementary deployment of a new portable monitor on the summit of Haleakala on Maui – a joint effort between Thai and US institutions.

1. Introduction

The years 1957–1958 were named the International Geophysical Year. Global scientific collaboration attacked a variety of puzzling phenomena, one of which was to understand cosmic-ray variability that showed dependence on location and time. The clearest way to address this phenomenon and others was to conduct a contemporaneous global study. Being prior to the space age, cosmic rays could only be studied from the ground, typically with neutron monitors. To this end, the world was well equipped for

Tab. 1: List of NM stations within the Simpson Network that were at risk.

	Station	pre-Simpson	Now
U New Hampshire	Mount Washington	Threatened	secure
	Climax	Lost	Replaced by Leadville
	Haleakala	Lost	to be redeployed
U Delaware	Inuvik	Threatened	secure
	Fort Smith	Threatened	secure
	Peawanuck	Threatened	secure
	Nain	Threatened	secure
	McMurdo	Lost	moved to Jang Bogo
	South Pole	Threatened	secure (UWRF)
	Goosebay	decommissioned	moved to Daejeon

the task with dozens of neutron monitors at a variety of locations and latitudes, covering many longitude ranges. This global system did what was intended, i.e., making key measurements that greatly expanded our understanding of cosmic rays. However, for several reasons, this global network atrophied over the years. Many scientists saw their investment in neutron monitors wither. The problem became acute in the US in the 2000s. In the mid 2010s, the National Science Foundation recognized the problem, noting that neutron monitor data usage was widespread, while US-based stations were being de-commissioned, abandoned or given away. This concern along with new and increased national interest in space weather culminated with the funding of the Simpson Neutron Monitor Network in 2021. Its intent is the securing and revitalizing the remaining US stations, investigating new deployments and training new scientists, all the while conducting science. We report here on the status of the Simpson network. Table 1 is a list of US-based stations that were de-commissioned, abandoned, lost or threatened, circa 2020. Many are now in the new Simpson Network.

2. The network

The network is the responsibility of three collaborating US institutions: the University of New Hampshire, the University of Delaware and the University of Wisconsin-River Falls. Also listed in the Table 1 is the current status of those stations with many now secure from funding cuts. The legacy station at Climax has been functionally replaced by a new station at Leadville CO, 20 km to the south and 300 m lower in altitude. The McMurdo station is now in the hands of South Korea (now Jang Bogo), still operating, but no longer part of the US network.

The tasks the collaboration has defined for itself follow. For operating stations, these objectives for the network include:

- Secure, repair, maintain existing NM stations, including structures, power and data connections.
- Increase reliability where necessary.

- Improve the capabilities of stations with improved electronics.
- Improve spectroscopic sensitivity.
- Cross calibrate with spacecraft instruments (PAMELA, AMS-02).

Periodic maintenance was long overdue at many stations. That backlog of attention is now being addressed with many stations now restored to their earlier operating condition. Some of the electronics, in particular the front-end discriminators and amplifiers, date back decades and they rely on parts that are no longer available. These electronic boards have now been mostly replaced with front-end electronics of more modern designs. In addition, the capability of detecting and measuring multiple coincident signals is being implemented in several stations. This capability effectively constitutes a new data channel with a different yield function that can be used for an independent spectral measurement. Finally, with spacecraft instruments that cover the same energy range as neutron monitors, we can actually confirm the response of the monitors.

While these tasks are being undertaken, science data still flow from the array of monitors. This enables the researchers to continue to conduct studies, such as those listed here:

- Continue studies of ground level enhancements, solar neutron events, Forbush decreases and heliospheric modulation.
- Examine means to predict onset and severity of geomagnetic storms.
- Collaborate with domestic and international ground-based observatories, such as Ice Top and muon telescopes.
- Study possible new station sites and augmenting existing ones to optimize coverage in rigidity and longitude.
- Provide greater input to space weather problem through collaborations with US agencies.

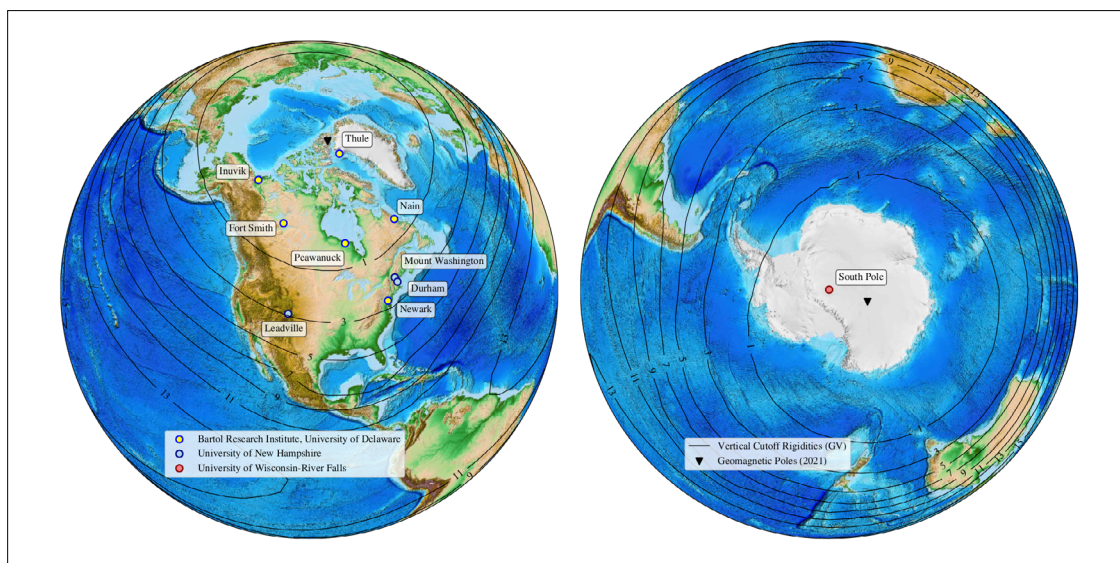
Some of the more important uses for neutron monitors have become commonplace in recent years. We note that low-latitude stations can be particularly important for detecting and measuring direct high-energy solar-flare neutrons for more than a few hours per day and more than a few weeks around the solstices. The redeployment of the Maui instrument, as discussed more below, enables these measurements and provides a high-rigidity measure of solar modulation. Also, using neutron monitors in conjunction with other ground-based detectors greatly increases the utility of the monitors, as well as the complementary detectors. Two examples of this have been to use Climax with the Milagro ground-based TeV gamma-ray detector and the use of Ice Top with the South Pole detectors. Because these are fundamentally different instruments with significantly different yield functions, they can provide single point spectral measurements that have been historically difficult or impossible, in particular, for ground level enhancements (GLE) in their highly anisotropic phase.

Because the gyroradius of neutron monitor protons is so large, they can sense changes in the interplanetary medium at great distances. Consequently, neutron monitors coupled with higher energy instruments, such as muon telescopes, can detect the presence of an approaching, otherwise invisible, CME shock. This could enable advanced warning of geomagnetic storms or Forbush decreases.

The current status of the monitors in the network is given in [Table 2](#) and their locations are illustrated in [Figure 1](#).

Tab. 2: List of stations in the Simpson network and their attributes. Cutoff calculations, courtesy of Don Smart, February 2023.

	Station	Altitude (m)	2020 Cutoff (GV)*	Gas	Type	Features
U New Hampshire	Mt. Washington	1900	1.88	$^{10}\text{BF}_3$	12 IGY	
	Durham	20	2.21	$^{10}\text{BF}_3$	18 NM64	
	Leadville	3030	2.96	$^{10}\text{BF}_3$	3 NM64	
U Delaware	Newark	50	2.63	$^{10}\text{BF}_3$	6 NM64	
				^3He	3 LND-NM64	
	Thule	16	~0	^3He	9 LND-NM64	
				$^{10}\text{BF}_3$	9 NM64	
	Nain	46	0.60	^3He	18 LND-NM64	
	Ft. Smith	206	0.32	^3He	18 LND-NM64	
	Inuvik	21	0.10	$^{10}\text{BF}_3$	18 NM64	
	Peawanuck	53	0.51	^3He	8 LND-NM64	
U Wisconsin-River Falls	South Pole	2820	0.06	^3He	3 LND-NM64	
	South Pole (Polar Bare)			^3He	12 LND	no Pb
	*Don Smart (priv. comm.)					

**Fig. 1:** Locations of neutron monitors in the Simpson Network. Iso-cutoff contours are approximate.

Various types of monitors are listed in Table 2. The standard NM-64 design is based on the Chalk River BP-28 BF₃ tubes. Recently, however, tubes provided by LND replace the Chalk River tubes, but still retain the BF₃ gas with no significant change in dimensions or operating voltage. The oldest design employs IGY tubes built into an assembly of Pb and paraffin. Only the Mount Washington station in the Simpson network is of that design. When ³He was not prohibitively expensive and available, several NM-64 configurations were filled with helium. The only operating site in the network without lead is the Polar Bare station. As with others, it uses polyethylene as the moderator and as the outer reflector, but the Pb converter is absent.

3. Future additions

3.1 The Haleakala neutron monitor (HLEA)

The 18NM-64 monitor on the summit of Haleakala since 1991 was de-commissioned in 2007 because of lack of funds. Under a different NSF grant (see Consolandi et al., this volume: <https://doi.org/10.38072/2748-3150/p42>), a new monitor is in the early stages of construction on the summit (3000 m a.s.l.). It will be either a 3- or 6NM-64 configuration, depending on construction costs. Upon completion, this will restore measurements in the mid-Pacific at a low latitude (21°N), several time zones removed from the nearest other low-latitude station. This places it at an ideal location for detecting and measuring direct solar-flare neutrons, because the Sun will be at a high elevation during the summer months and a workable elevation for much of the year. Placed in proximity to the Daniel K Inouye Solar Telescope (DKIST) observatory of the National Solar Observatory, contemporaneous optical imaging will be available, provided there is acceptable seeing. DKIST is the ideal neighbor with its capability of polarimetry, magnetographs and fast tracking of active regions, allowing researchers to link the detected neutrons with coronal and flare activity.

3.2 US-Thai collaboration

Chang Mai University has led latitude ocean-based surveys. A sea container designed for such a survey, complete with a 3NM-64 instrument, minus the BF₃ tubes, now resides in Honolulu, with no immediate plans for a sea-based survey. Thimon, as it is called, will be placed on the summit of Haleakala then outfitted with BP-28 tubes from the original Maui station. When outfitted with tubes and supporting electronics, it will be a fully functional 3NM-64 instrument that will work in tandem with the new US station (6NM-64). Together they will have half the effective area of the original Maui station, still large enough to address the objectives listed above, but with consequently poorer count statistics and small event sensitivity. The station on Haleakala will be expandable and modular, housed in sea containers, each with three or six tubes. Utilizing the remainder of the original BP-28 tubes will require additional sea containers with the appropriate configuration of BP-28 tubes, Pb and polyethylene.

4. Discussion and conclusions

The Simpson Neutron Monitor Network by 2024 should resemble that of 2020, but secure for decades to come. Data archiving and availability will exist for all stations. Temporal resolution will be 10s for all stations, along with multichannel count rates for spectral sensitivity in several stations. Locations and

features of prospective monitors will be studied in the event of the availability of future funding. The Haleakala station will begin operating as tubes come online. Plans to refurbish and re-deploy the Climax legacy station will be studied for possible future work.

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