DATA ANALYSIS OF SHIP-BORNE NEUTRON MONITOR DURING ANTARCTIC VOYAGES: 2018 AND BEYOND

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On behalf of Thailand research group

Astronomy and Astrophysics from Antarctica

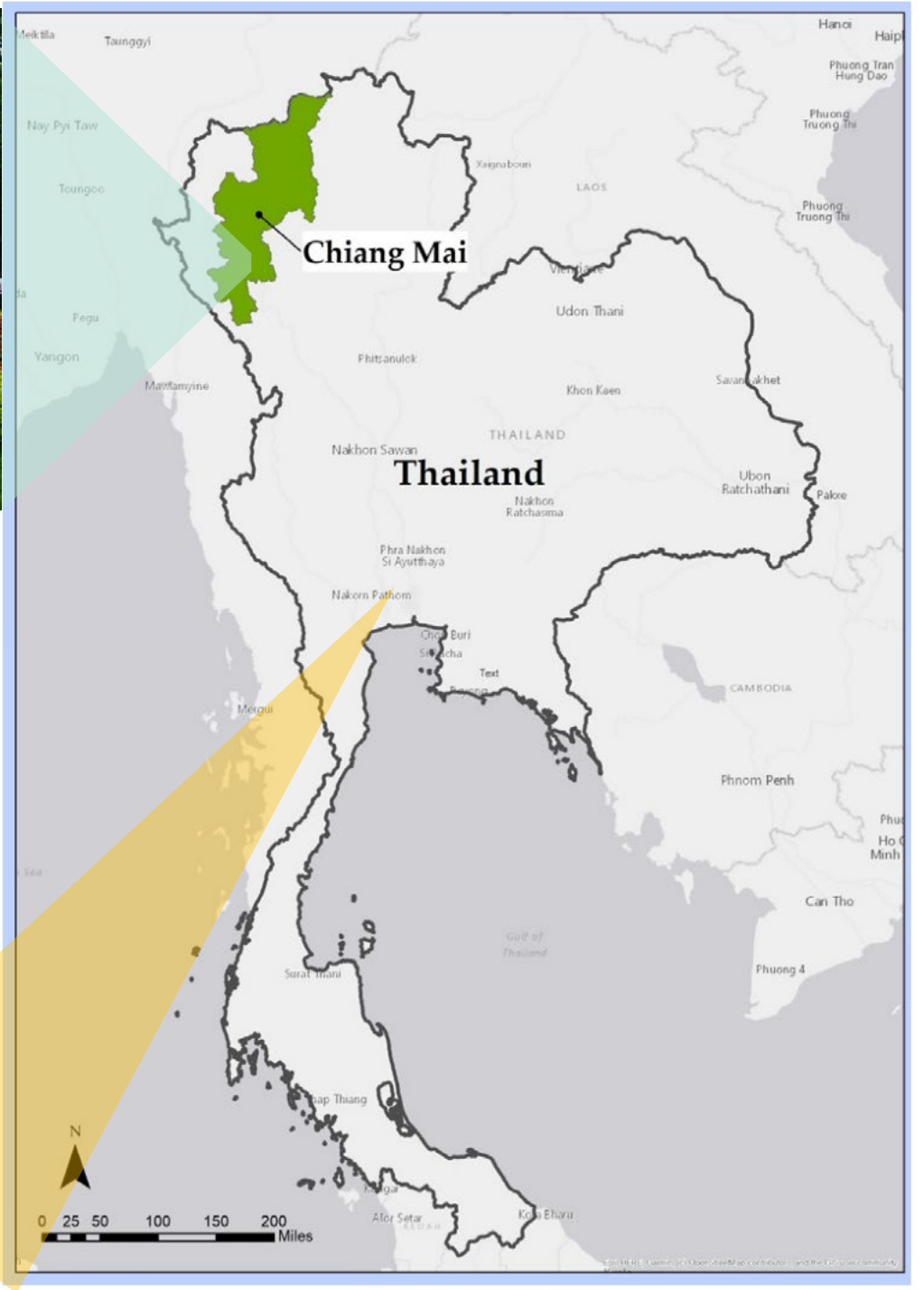
September 19-21, 2023

Svalbard, Norway


SCAR AAA Meetings
• AAA2011 Sydney, Australia
• AAA2013 Certosa di Pontignano, Italy
• AAA2015 Hawaii, USA
• AAA2017 Chiang Mai, Thailand
• AAA2019 Aosta Valley, Italy
• AAA2021 Remote, hosted by WIPAC at UW-Madison, USA
• AAA2023 Svalbard, Norway
• AAA2025 ???
Jim Madsen SCAR AAA 2023

ALLOW ME TO INTRODUCE ABOUT MYSELF

Sep 18, 2023



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OUTLINE

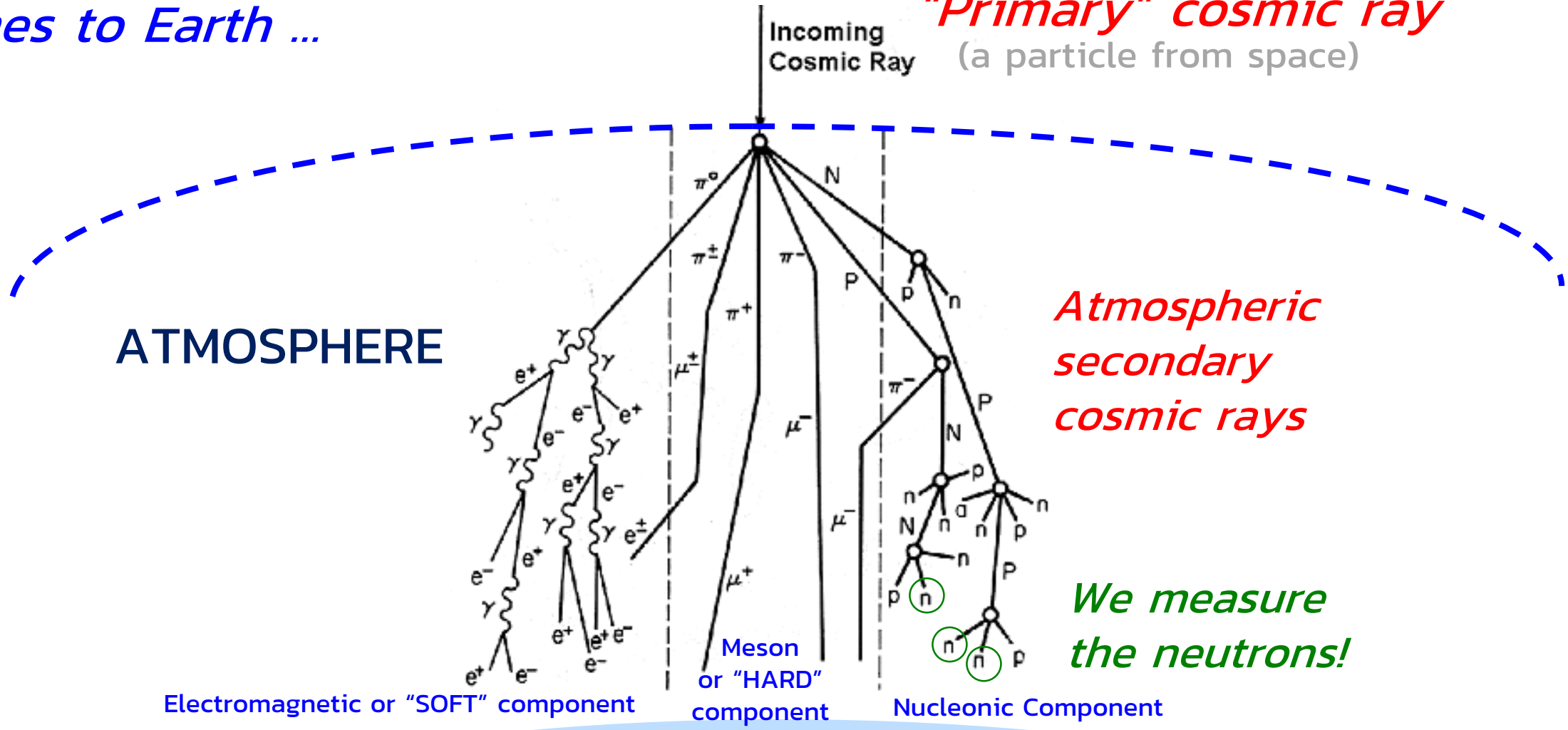
- Introduction: Cosmic Rays
- Instrumentation
  - Standard Neutron Monitor (NM64)
  - Semi-Leaded Neutron Monitor “Changvan”
  - Solar Modulation
  - Cosmic Ray Spectrum
- Latitude Survey Project
  - Count Rates & Differential Response Functions
  - Voyages
  - Dorman Functions
  - Spectral Crossovers
- New Collaborations
- Conclusions

INTRODUCTION: COSMIC RAYS

- Energetic particles or γ-rays from space
- Discovered by Hess in 1912 (Nobel Prize in 1936)
- Ordinary matter accelerated to high energies
  - p, ^{4}He, ^{12}C, ^{16}O, heavy nuclei and γ, e^{+}, e^{-}, μ, ν, …
- Key sources of CRs for Earth's radiation environment:
  - From solar storms (solar energetic particles)
  - From supernova explosions inside the Milky-Way Galaxy (Galactic cosmic rays)
  - From intense events/objects GRB, AGN outside the Galaxy (Extra Galactic cosmic rays)
- Key cause of biological mutation

When an energetic cosmic ray comes to Earth …

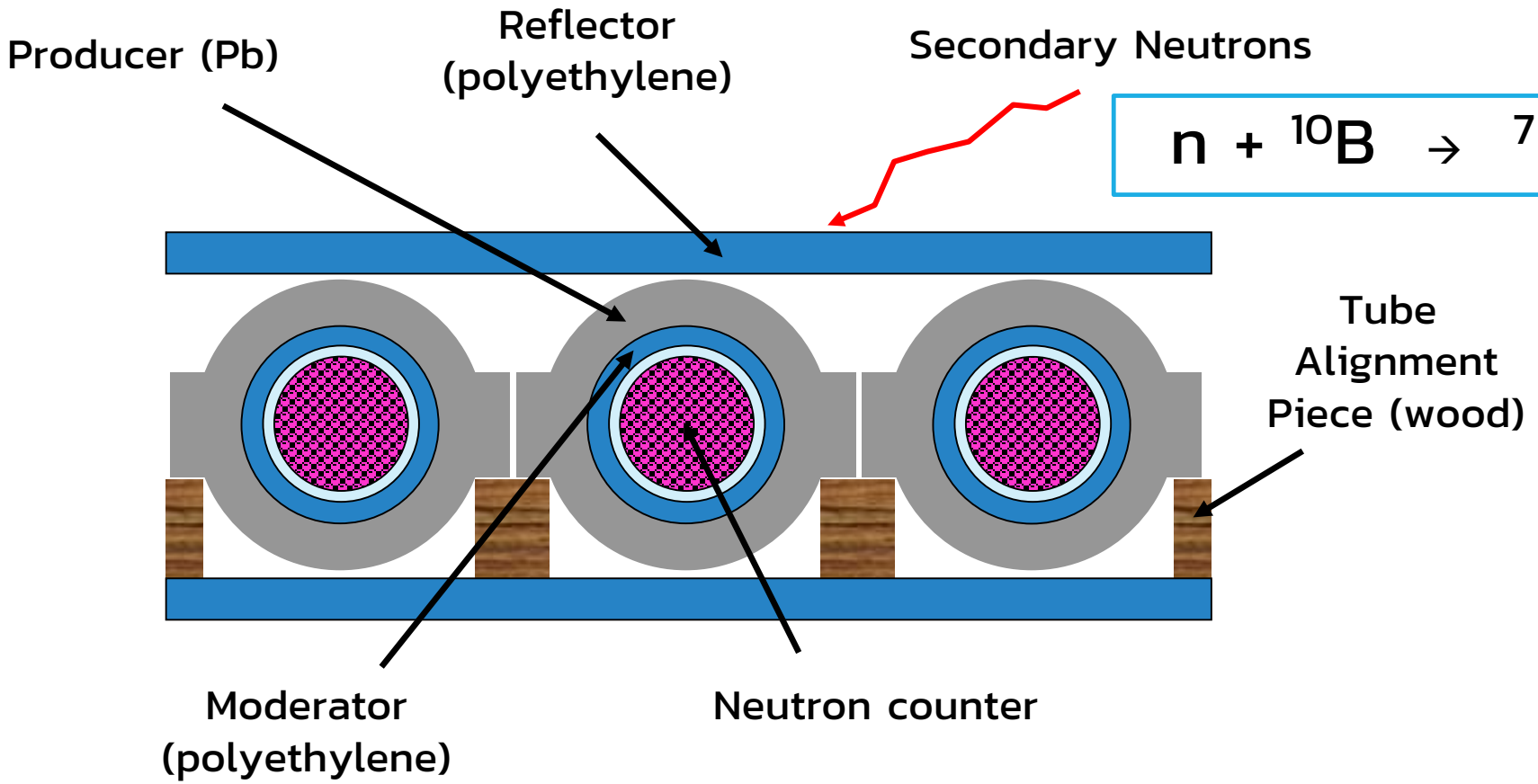
"Primary" cosmic ray
(a particle from space)



Atmospheric secondary cosmic rays

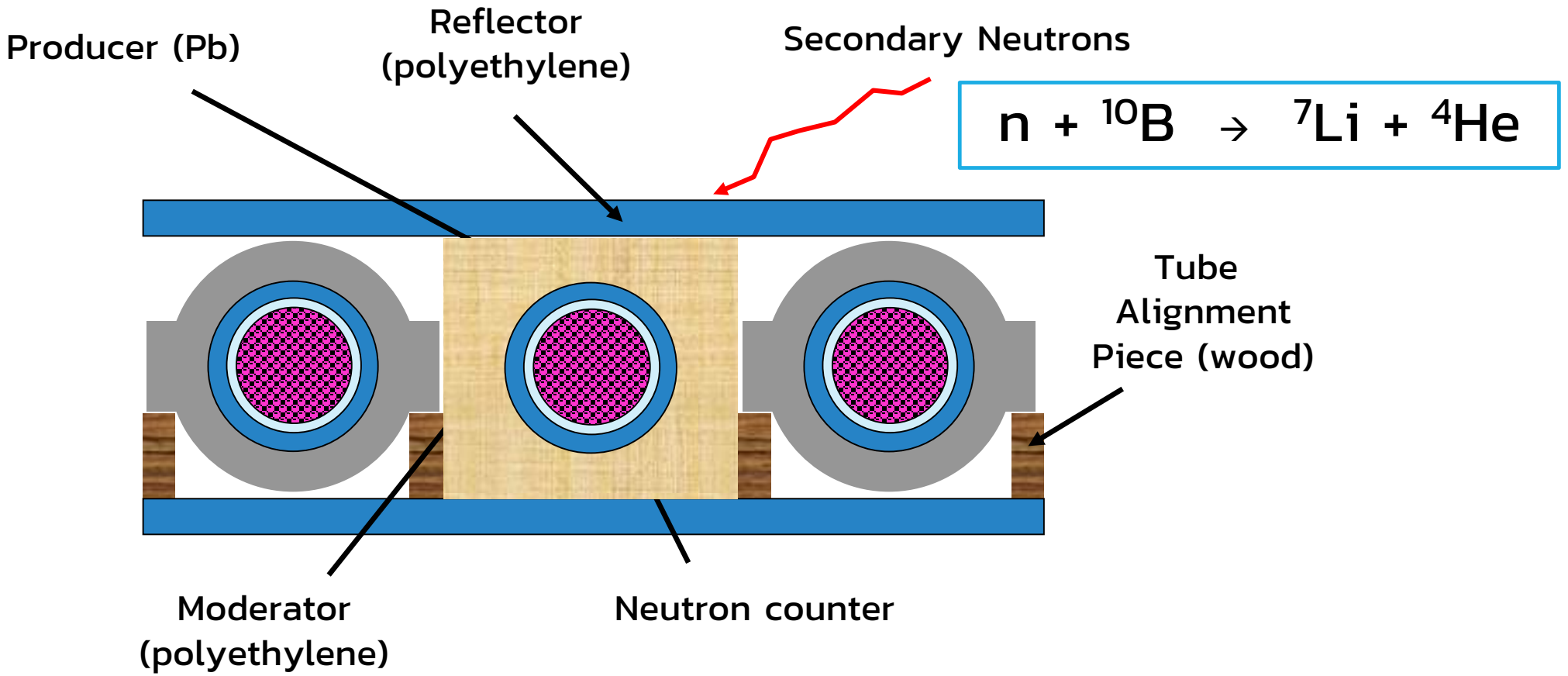
We measure the neutrons!

INSTRUMENTATION: STANDARD NEUTRON MONITOR (NM64)

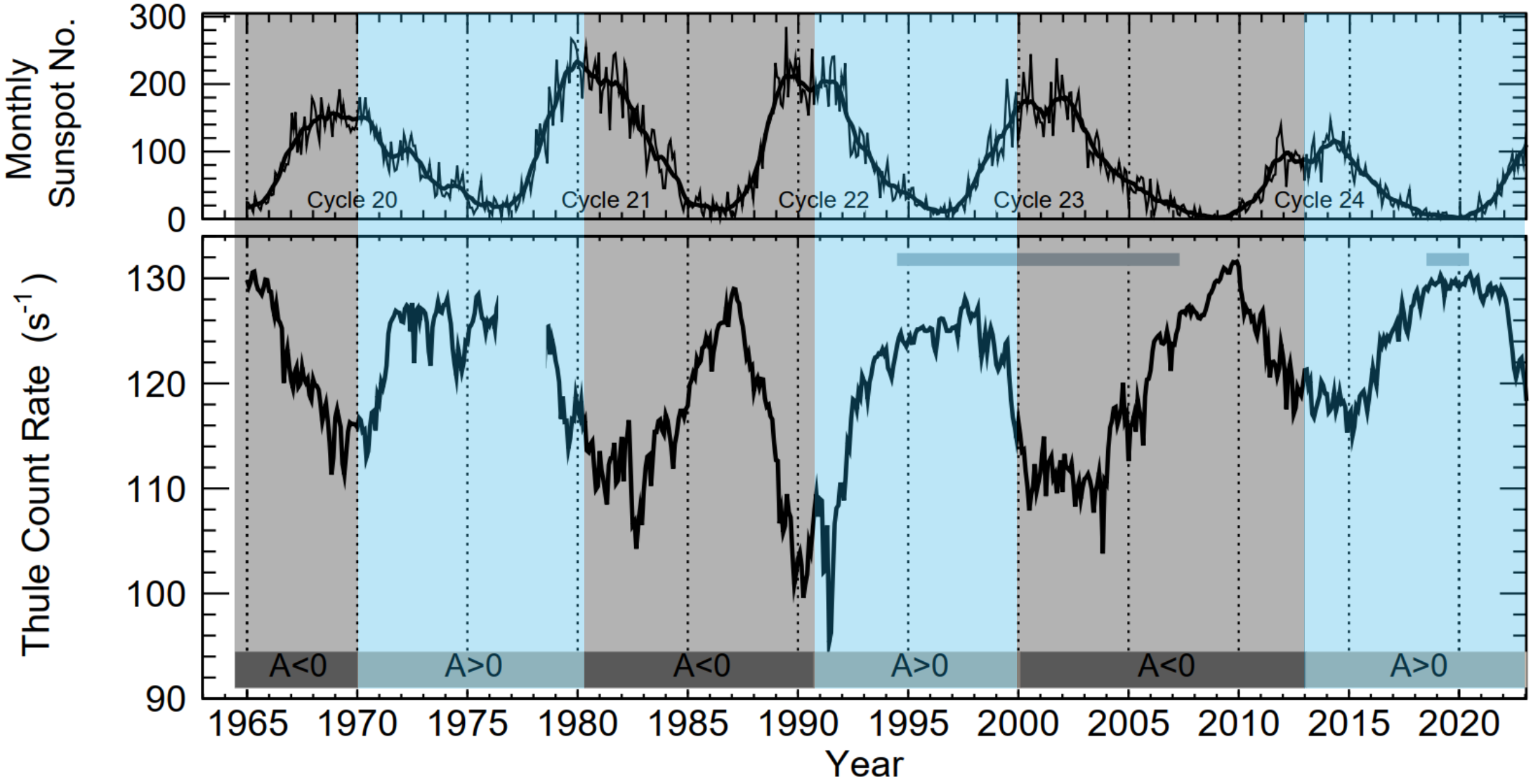


Sketch of the standard neutron monitor (NM64)

INSTRUMENTATION: CHANGVAN SEMI-LEADED DETECTOR

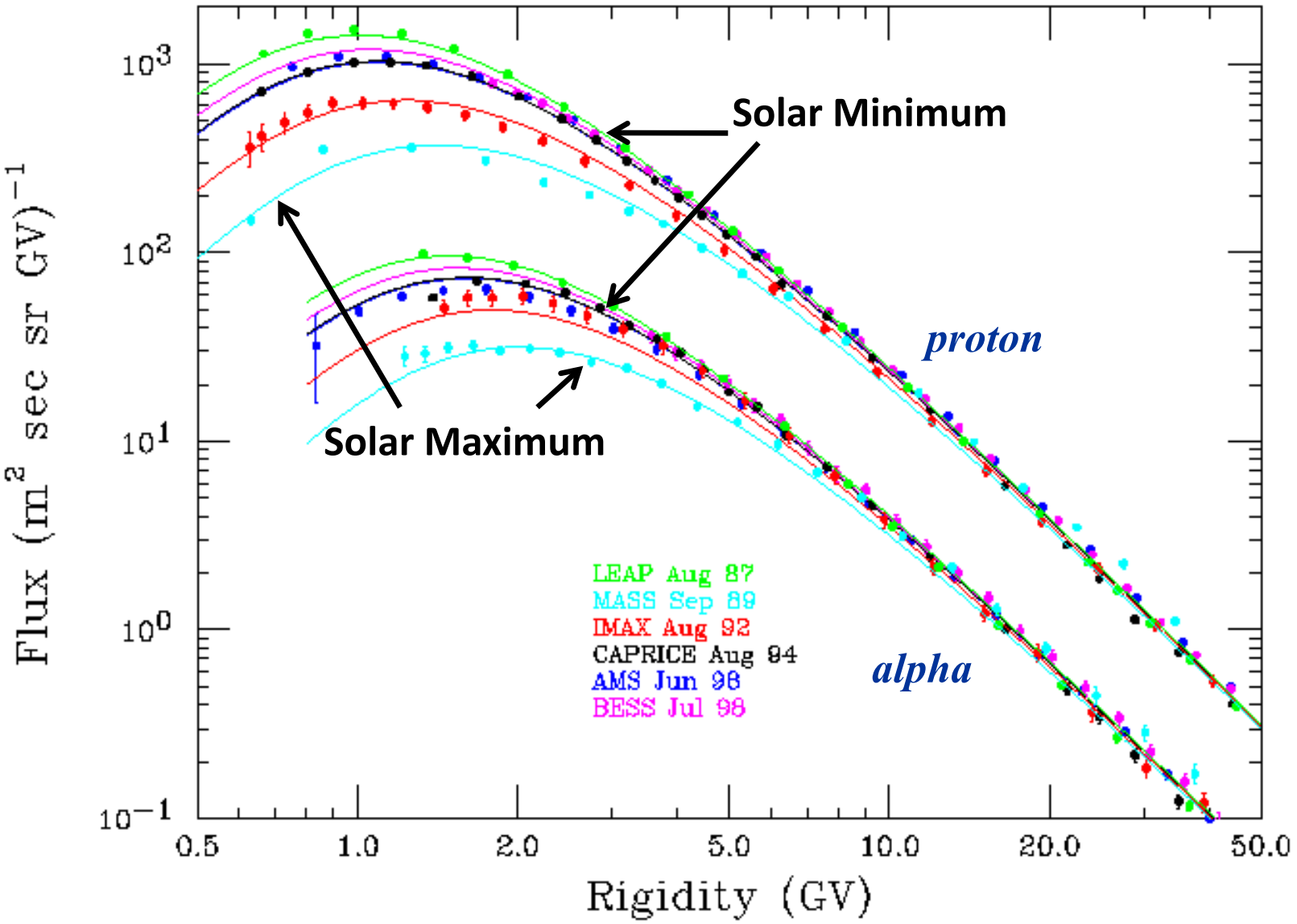


Sketch of the semi-leaded neutron monitor Changvan



Solar Modulation

Image Credit: Poopakun et al. (2023)



Cosmic ray spectrum

Current Collaborations:

South Korea (KOPRI):

- Survey year 2023-2024
- Survey year 2024-2025
- Survey year 2025-2026

There is a possibility of changes occurring.

University of Hawaii: Haleakala summit

Chinese Icebreaker Xue Long

survey years:

- 2018-2019
- 2019-2020

GCR spectrum — Yield function

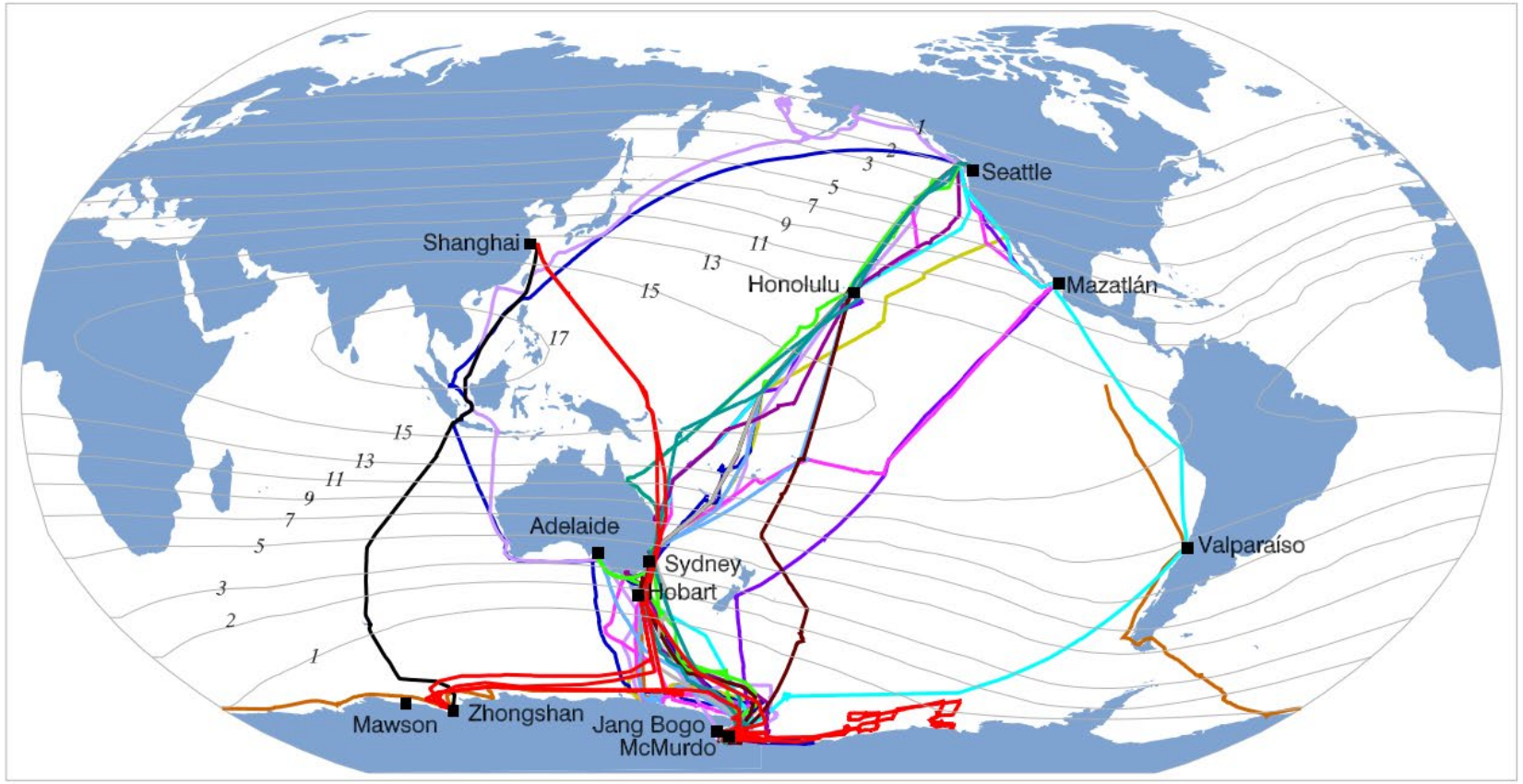
Count Rate

$$N(P_c, h, t) = \int_{P_c}^{P_L} J_i(P, t) Y_i(P, h) dP$$

Differential Response function

$$DRF(P) = -\left[\frac{dN}{dP}\right]_p = \sum_i J_i(P, t) Y_i(P, h)$$

LATITUDE SURVEY: VOYAGES IN 2018 & 2019 SURVEY YEARS

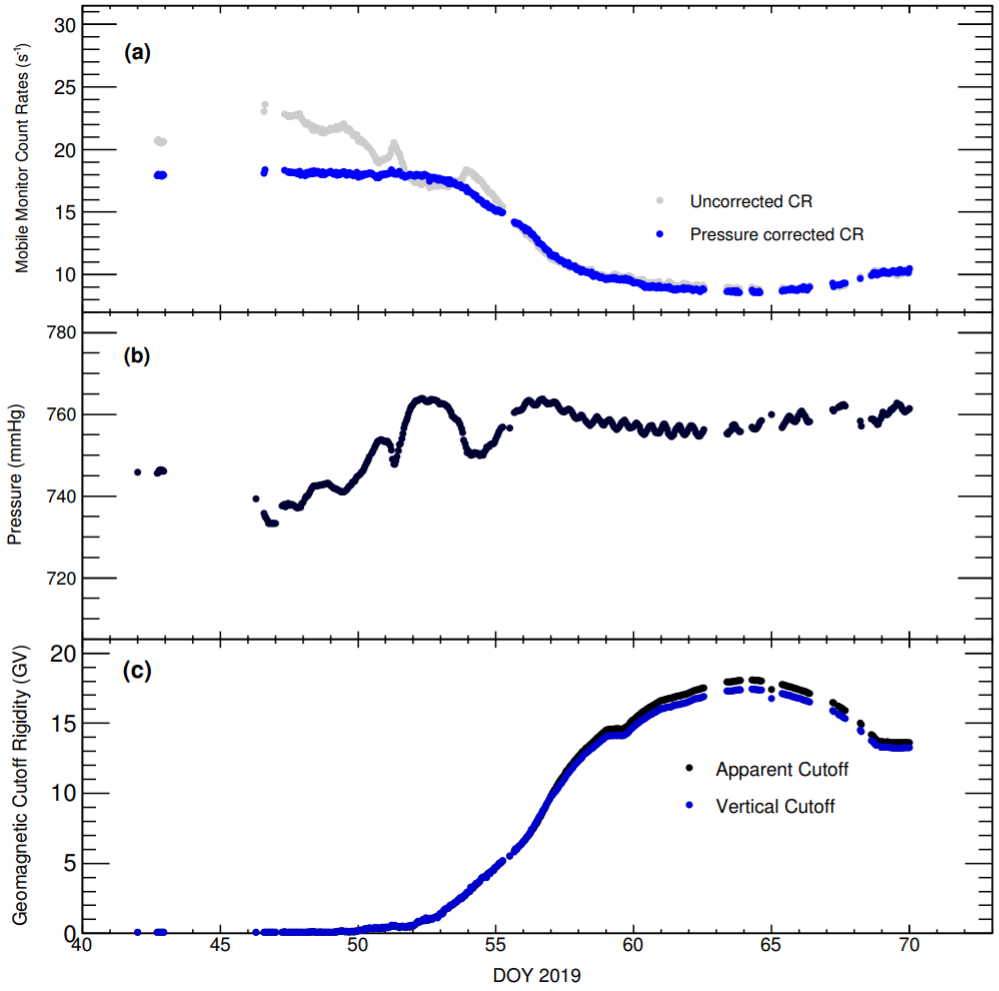


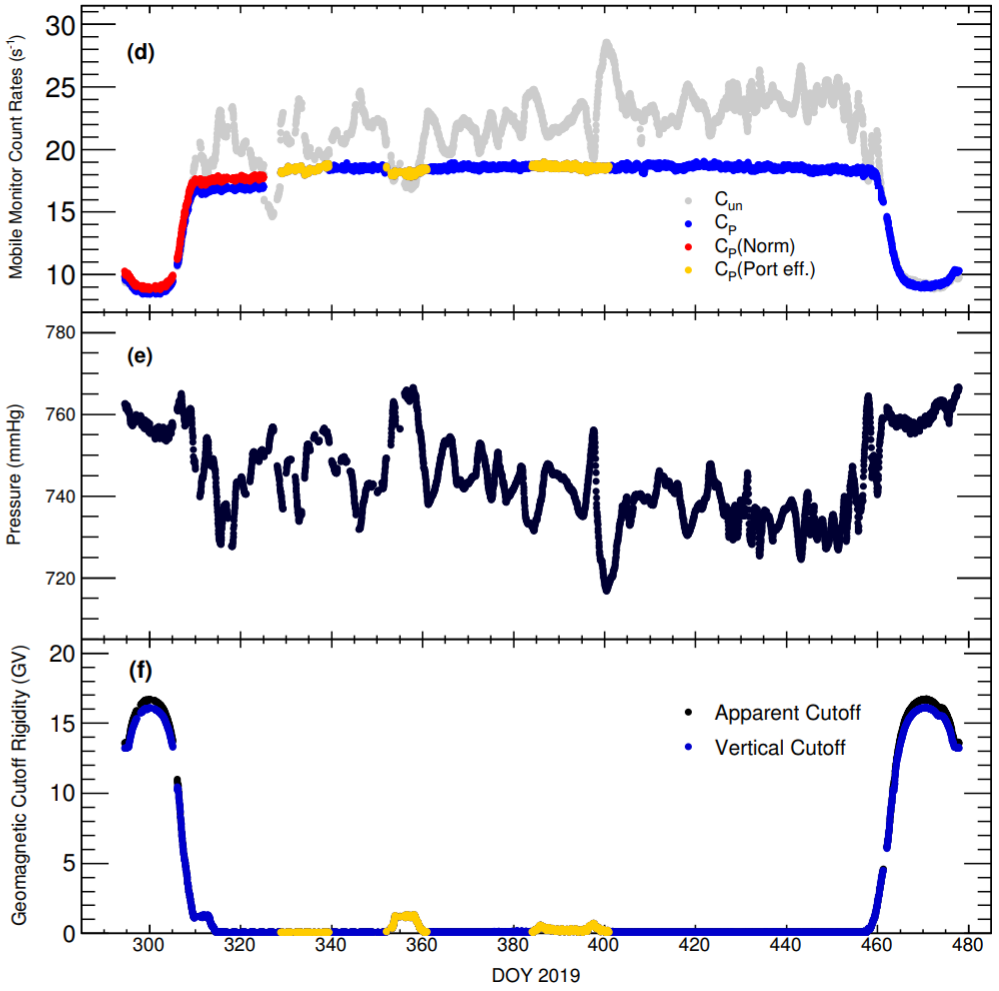
The tracks of the ship-borne neutron monitor latitude surveys are overlaid onto a contour map of the vertical cutoff rigidity (GV) calculated for February 11, 2019 at 12:00 UT.

Image Credit: Poopakun et al., 2023

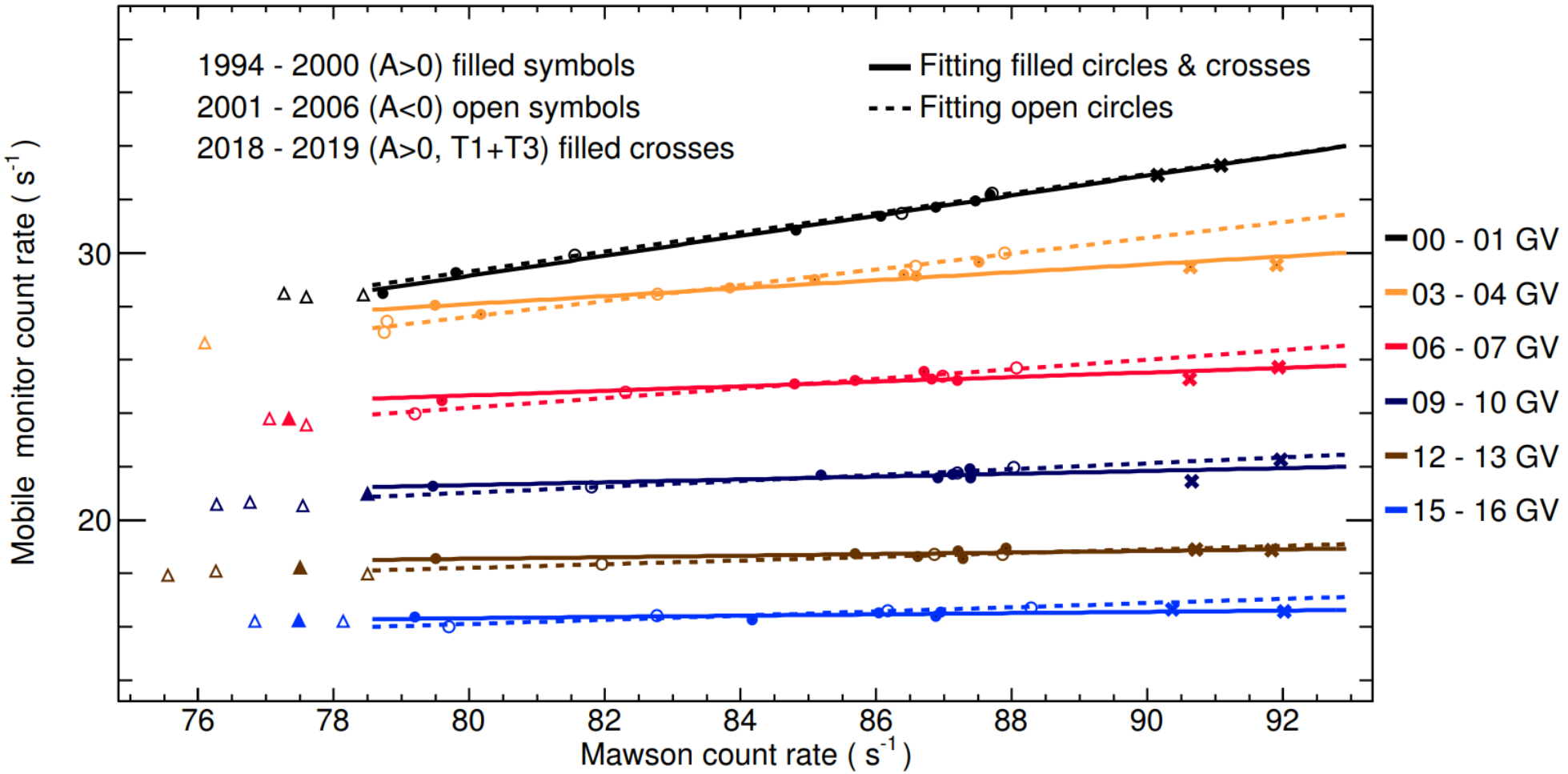
2018 Survey Year

2019 Survey Year





Comparative Overview of Changvan Data for the Survey Years: (LEFT) 2018 and (RIGHT) 2019. Categories: (a) Count Rate, (b) Pressure, and (c) Geomagnetic Cutoff Rigidity (GV). Image Credit: Poopakun EA 2023



Regression of the mobile neutron monitor count rate in different apparent cutoff rigidity bins against the count rate of the Mawson neutron monitor station in Antarctica. Credit Poopakun et al. 2023

DORMAN FUNCTION

$$N(P_c) = N_0\left(1 - e^{-\alpha P_c^{-\kappa}}\right),$$

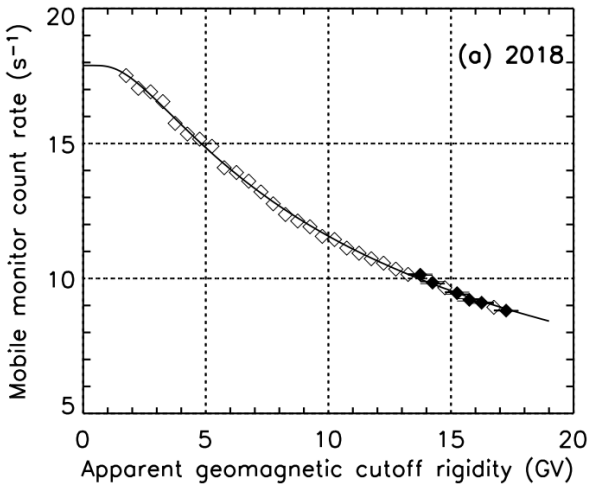
$$N(P_c) = \int_{P_c}^{\infty} DRF(P)dP,$$

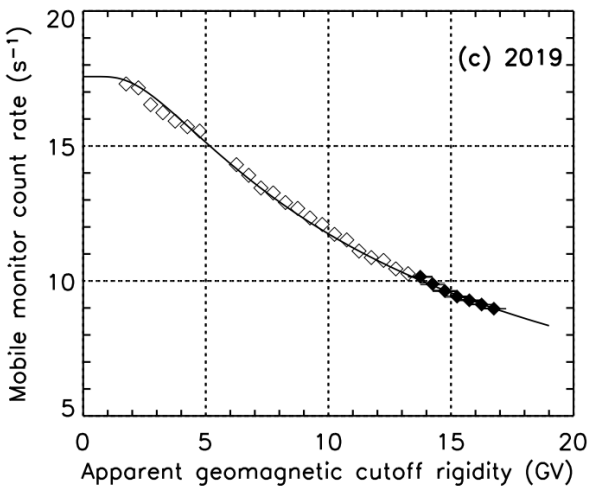
$$DRF(P) = N_0 \alpha P^{-\kappa-1} \kappa e^{-\alpha P^{-\kappa}}.$$

$$DRF(P) = -\left[\frac{dN}{dP_c}\right]_p = \sum_i J_i(P,t)Y_i(P,h)$$

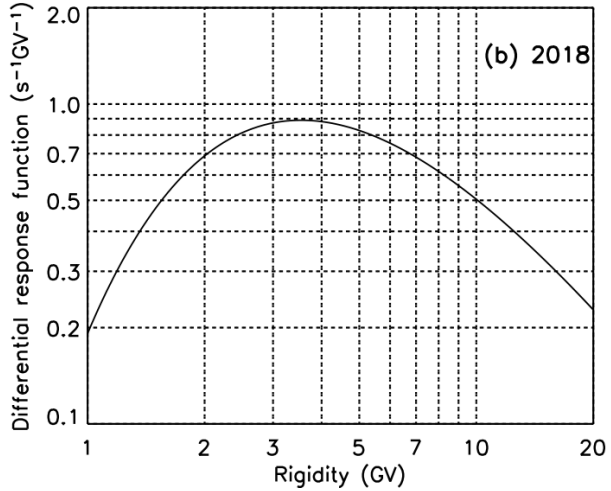
Response functions for survey years 2018 and 2019.
(a) and (c) show the data and the Dorman function fits, determining the integral response functions.
(b) and (d) are the differential response functions calculated analytically from the Dorman functions.
A filled symbol indicates the availability of data for multiple voyage segments.

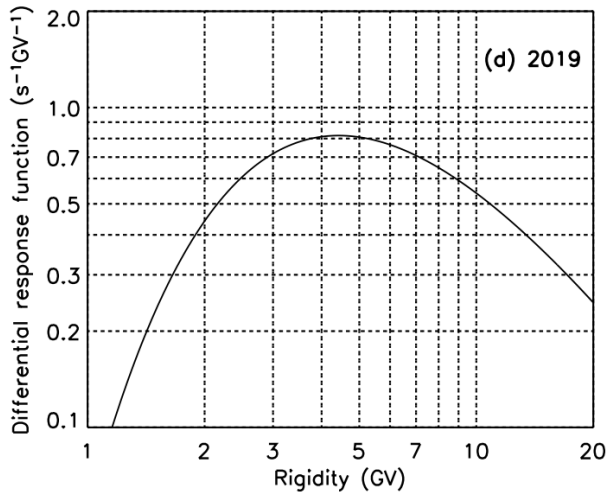
Integral Response Function

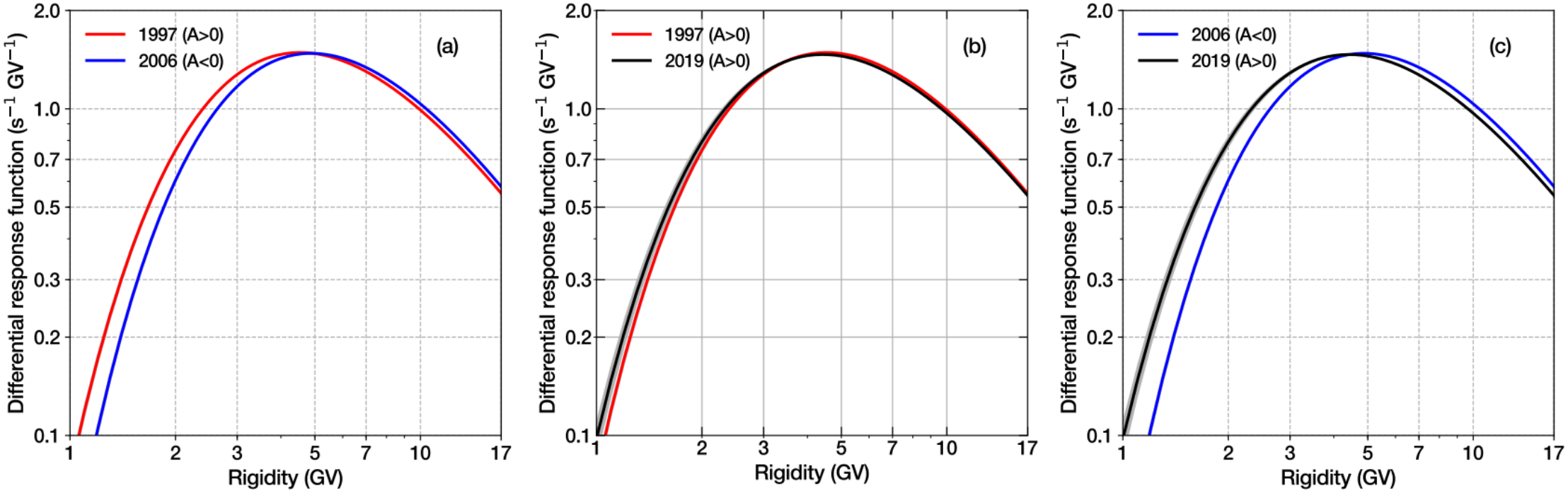




Differential Response Function





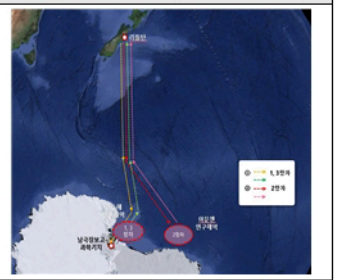


- *The crossover is clearly visible when the solar magnetic polarities are opposite.*
- *There is no evidence of the crossover when observing the same positive magnetic polarity.*

This work has just been submitted to the Astrophysical Journal on Sep 1. We received very positive feedback and hope will be accepted by October, 2023.

New Journeys (Araon Icebreaker): Departure date: December 26, 2023

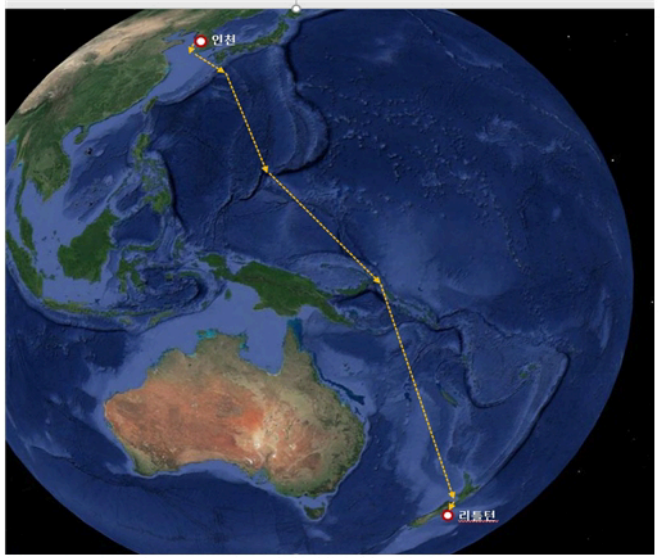
□ 아라온호 남극 항적도

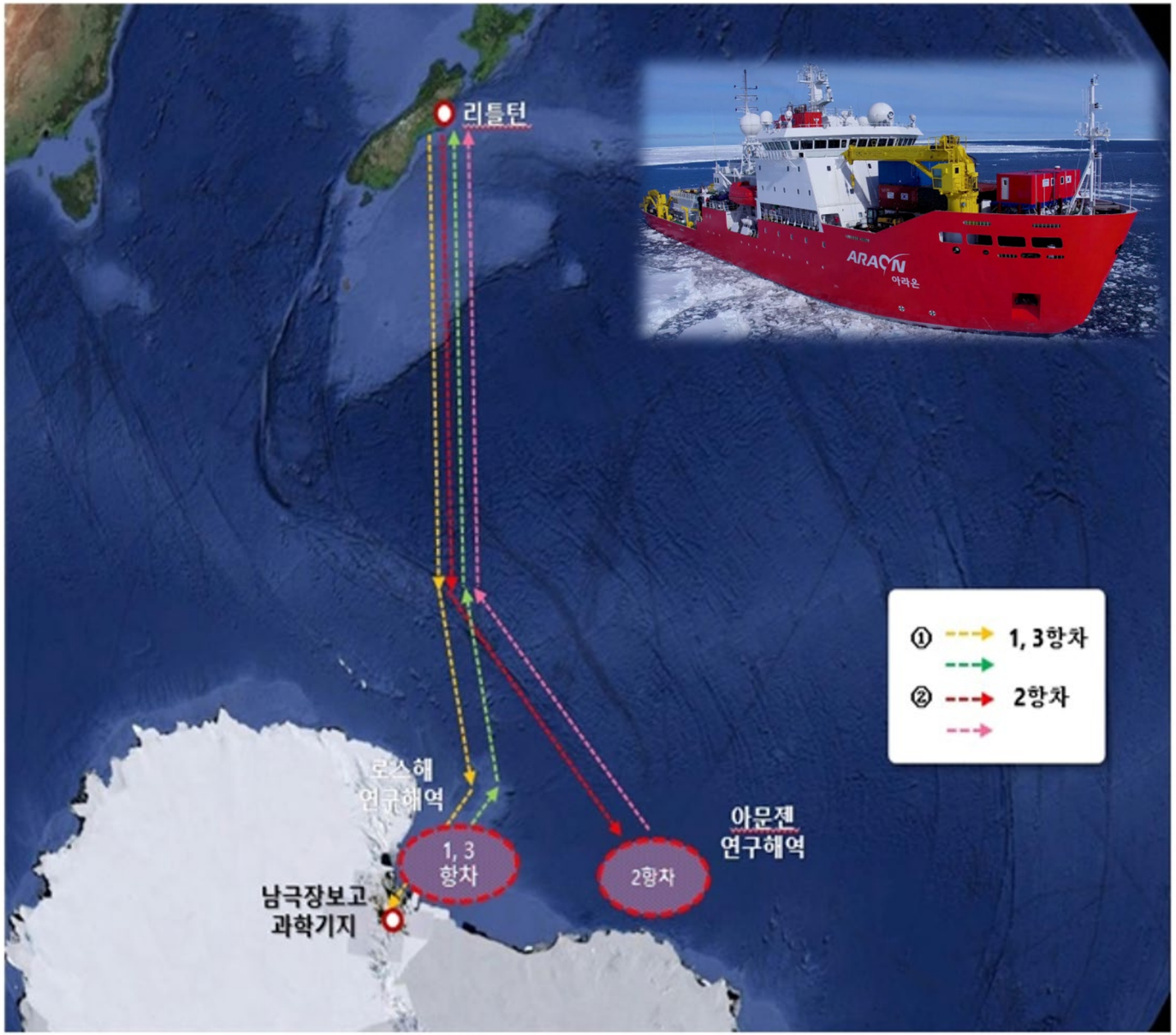
구분	항차별 이동경로	
아라온호 (남극)		
	이동항로	1,2,3 항차

① 아라온호(남극항해)

- 공동활용 가능기간 : '23.10.31~'24.4.22

구분 \ 항차		이동	1항차	2항차	3항차	이동
운항 일수	(전체)	20일	34일	45일	38일	20일
	단독 활용	0	1일	2일	2일	0





Thimon

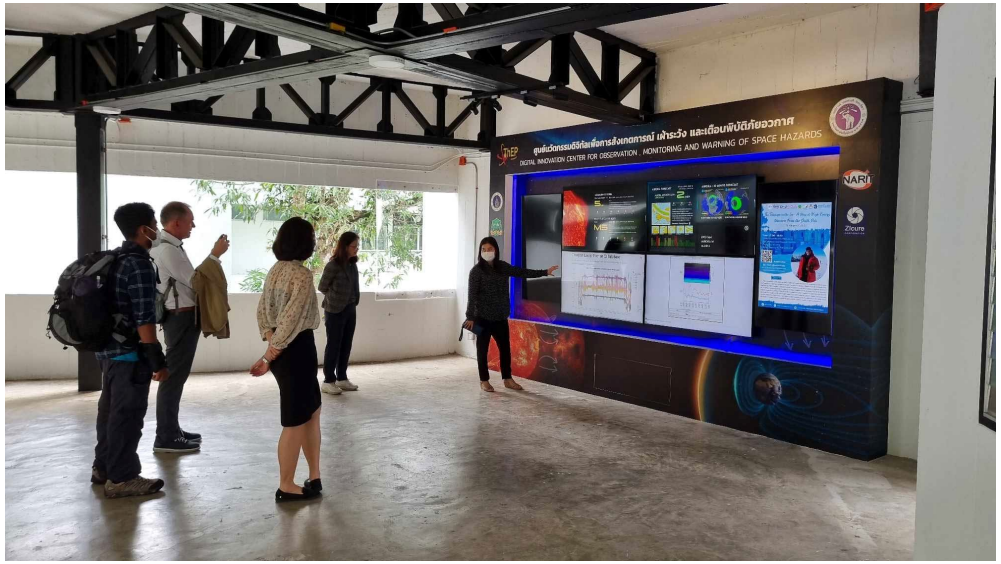
Exterior

Interior

Thimon, currently situated at the University of Hawaii on O'ahu, will be transported to Maui and installed at the summit of Haleakala.

Veronica shared insights at ICRC 2023 in Nagoya, Japan.

- *The original proportional BP-28 counter tubes ($^{10}BF_3$) that were part of the previous HLEA will be used for the new HLEA and for Thimon.*
- *The nesting period for the Nene (Hawaiian goose) occurs from July to November, leading to the scheduling of site preparation work in November 2023.*



- *The Thimon electronics were prepared by University of Delaware, equipped for analyzing Leader Fraction (LF).*

- *At Chiang Mai University, a Space Weather Monitoring War Room has been established. Its purpose is to display real-time data from ground-based, space-based, and underground cosmic ray detectors worldwide. We also have an all-sky camera to study the total electron content and plasma bubbles.*

CONCLUSIONS

- *The Changvan and Thimon neutron monitors represent portable neutron monitors.*
- *Pressure correction is required for neutron monitors globally.*
- *Short-term modulation correction is also important for neutron monitors*
- *Utilizing these mobile monitors, we have the capability to derive a differential response function, enabling the study of changes within the spectrum.*
- *Nuntiyakul et al. (2014) noted that magnetic helicity can produce charge sign dependence in the opposite direction and suggested that the relative magnitude of the two effects might be energy dependent, resulting in the crossover. In our recent work with Changvan, we concluded that drifts dominated at lower rigidity and helicity at higher rigidity.*
- *Our (new) collaboration for portable neutron monitors:*
  - ***Changvan**: with South Korea (KOPRI, KASI, and Chonnam National University)*
  - ***Thimon**: with University of Hawaii, USA (revising MoU)*
- *The upcoming Antarctic expedition for Changvan is scheduled for December 26, 2023.*

Kob Kun Ka / Thank you

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