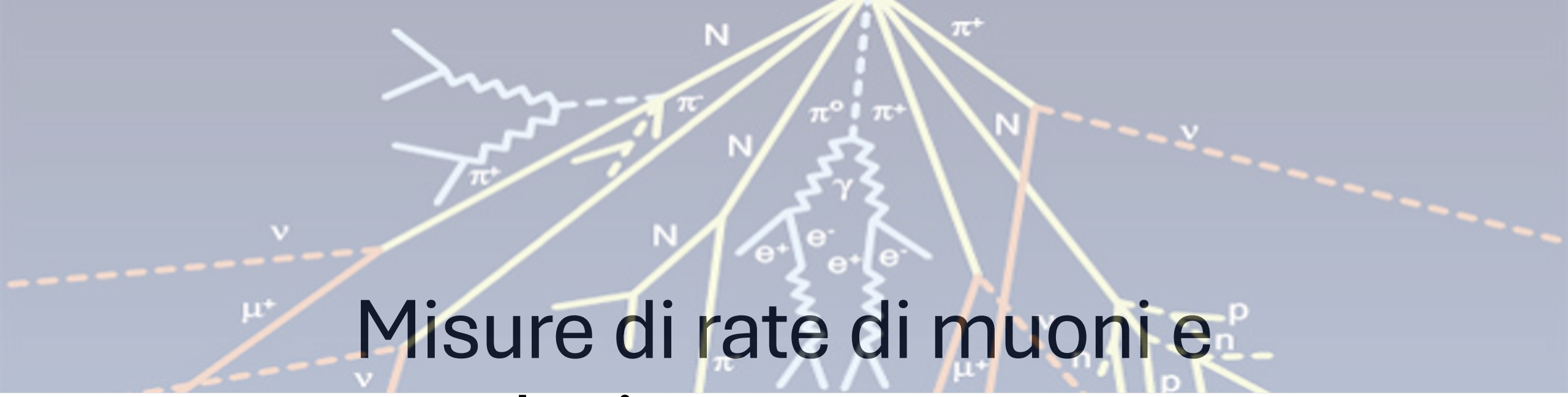


Misure di rate di muoni e correlazione con struttura dell'atmosfera a diverse latitudini

Rosario e Ombretta

Collaborazione EEE, Roma 1/7/2026

Effetto della temperatura atmosferica sul rate di muoni

- l'effetto principale della temperatura atmosferica è la variazione della densità dell'aria, che influisce sulla combinazione dei due principali meccanismi di produzione dei muoni:
  - decadimento di pioni
  - re-interazione e successive cascate
- un aumento di temperatura provoca espansione dell'atmosfera:
  - i muoni vengono prodotti ad altitudini maggiori, aumenta il libero cammino medio, aumenta la probabilità di decadimento, e il rate a terra diminuisce (in particolare per muoni a bassa energia)
    CORRELAZIONE NEGATIVA fra temperature e rate

    rivelatori in superficie medie latitudini
  - in condizioni di bassa densità atmosferica, più muoni ad alta energia riescono ad arrivare a terra senza interagire o decadere
    CORRELAZIONE POSITIVA fra temperature e rate

    rivelatori sotterranei

Discrete Correlation Method (DCM)

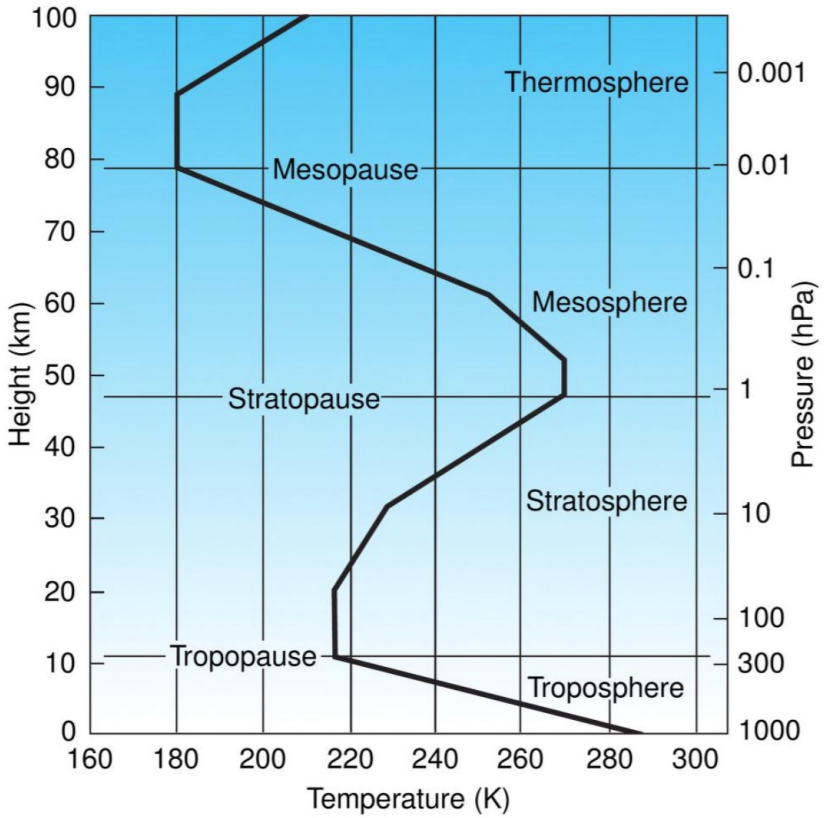
“Atmospheric effects on cosmic-ray muon rate at high latitude (78.9°N)”
Eur. Phys. J. Plus (2026) 141:691
https://doi.org/10.1140/epjp/s13360-026-07843-x

DCM, Discrete Correlation Method, proposto da noi

- si propone di calcolare localmente la dipendenza del rate dalla temperatura atmosferica
- anziché usare:
  - un singolo valore (temperatura a 16.5 km, temperatura o altitudine all’isobara 100 hPa)
  - o una curva di peso *empirica* per integrare su tutta l’atmosfera,
- utilizziamo direttamente la curva di correlazione rate/temperatura calcolata ai diversi livelli di pressione

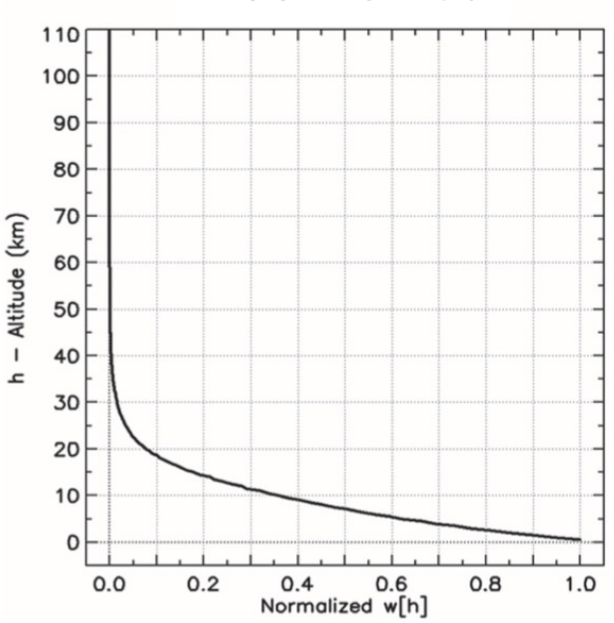
Metodi integrali per stimare l'effetto temperatura

$$\Delta I_T = \int_0^{x_{\mathrm{GRD}}} \alpha_{\mathrm{THR}}[x] * \Delta T[x] * dx$$

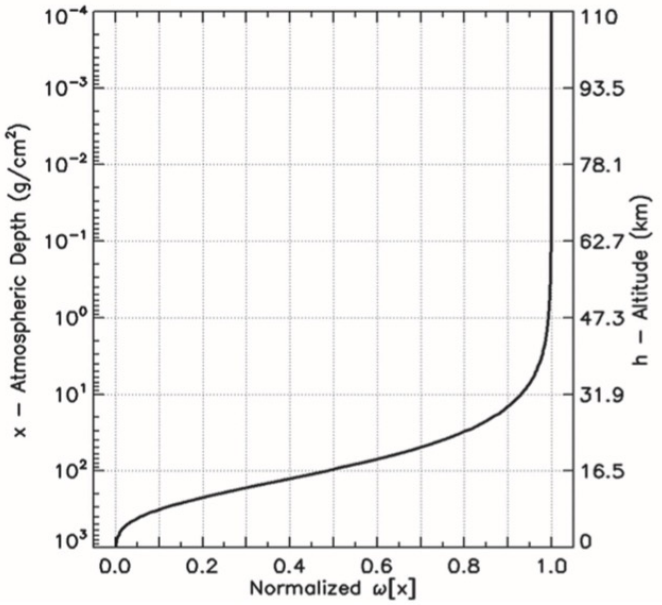


funzioni peso α

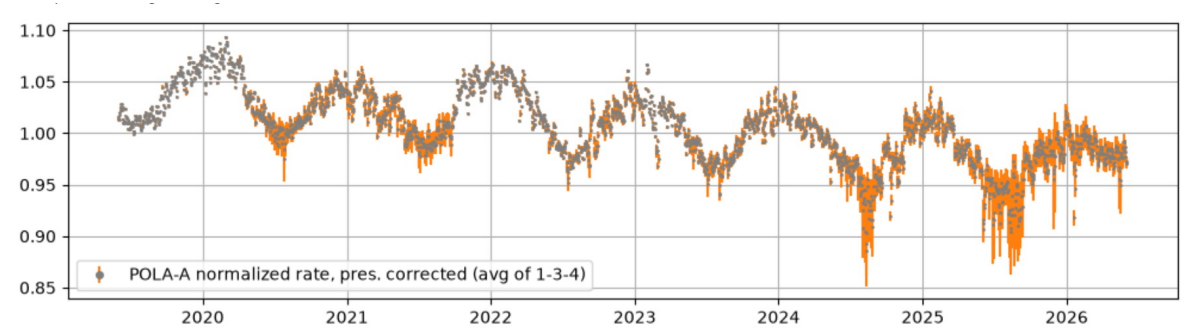
MSS method

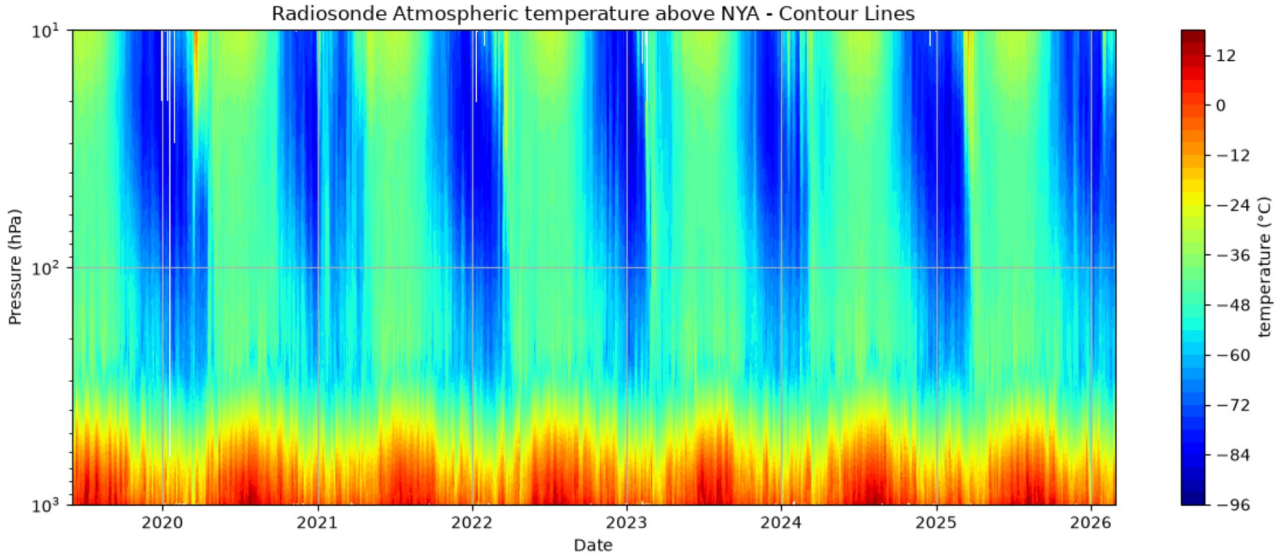


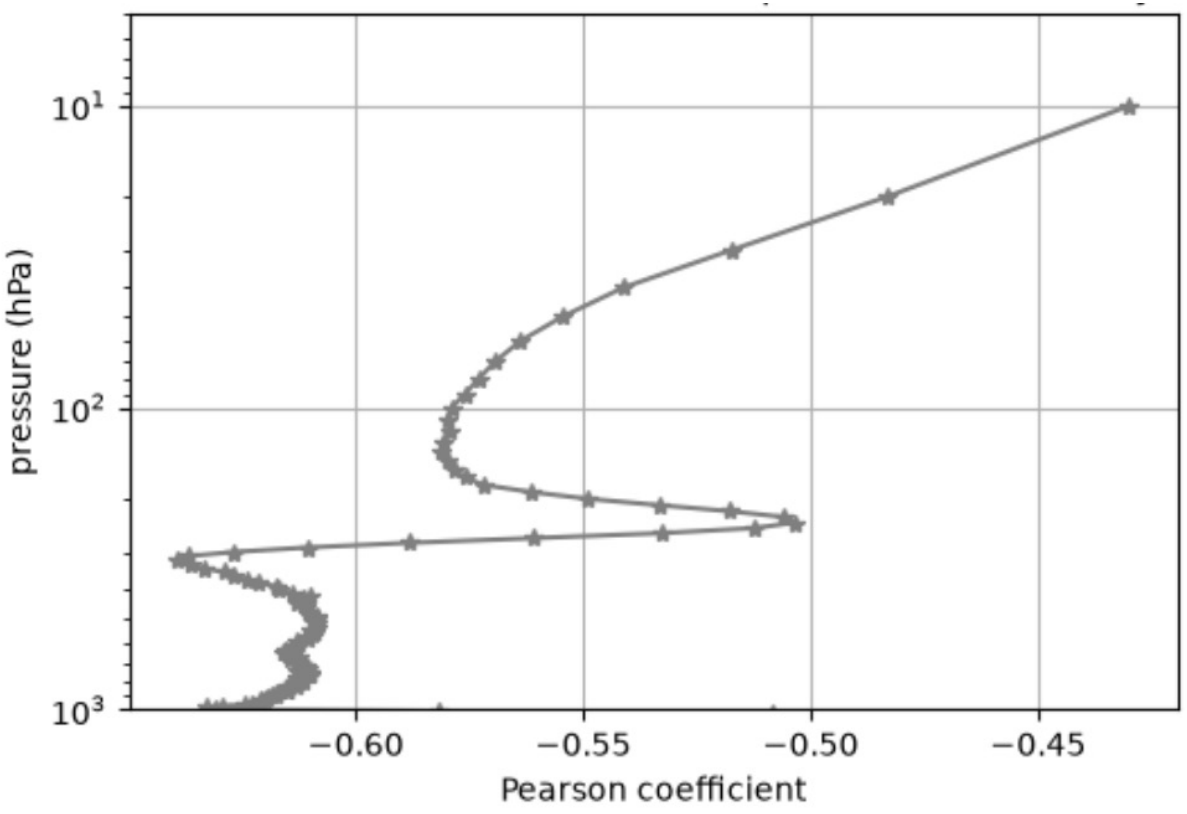
EFF method



Curva di correlazione DCM per POLA-A a NyA



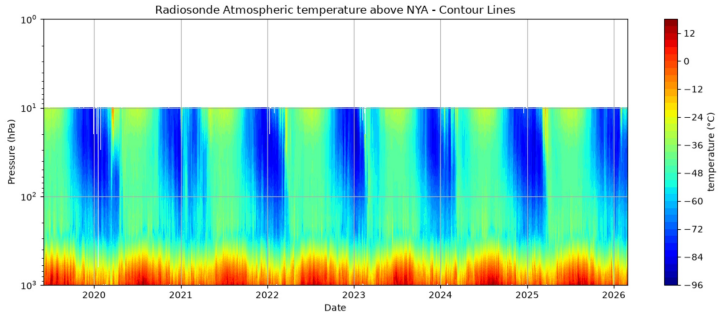




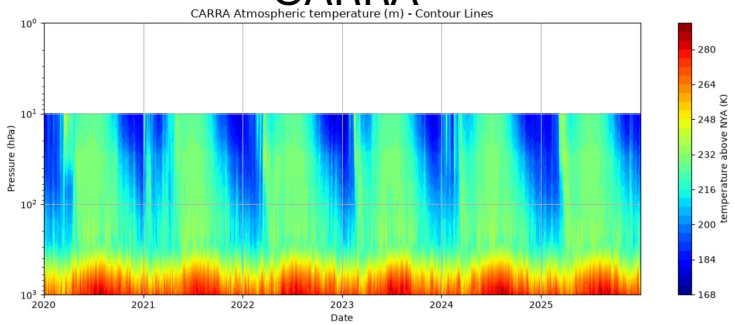
Stabilità della curva di correlazione

Abbiamo verificato che l'andamento fosse lo stesso anche se calcolato per periodi diversi e con dataset di temperature differenti

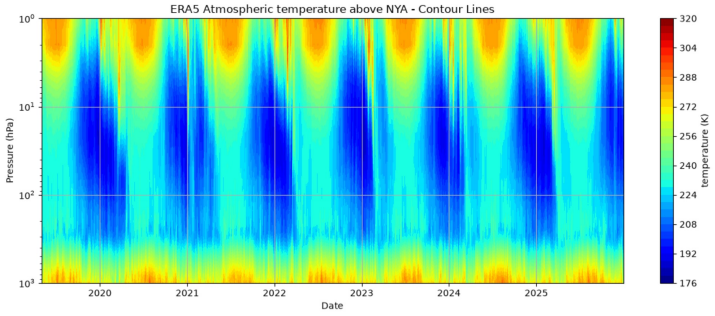
radiosonde

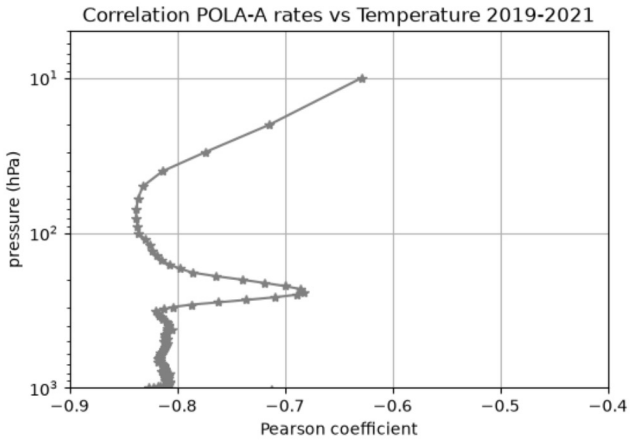


CARRA

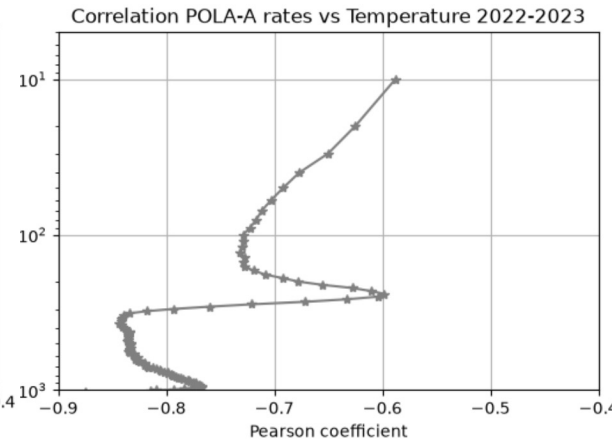


ERA5

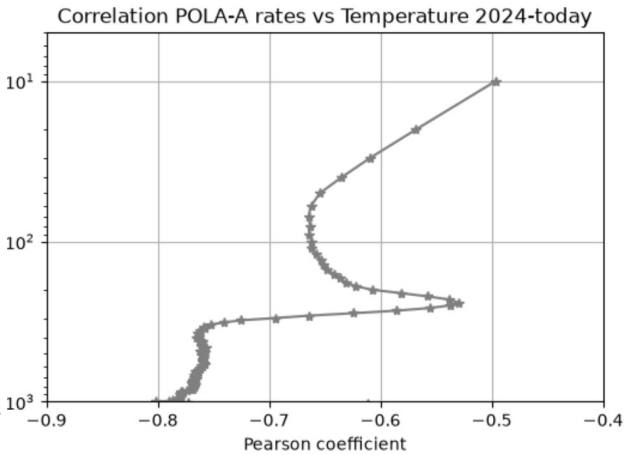




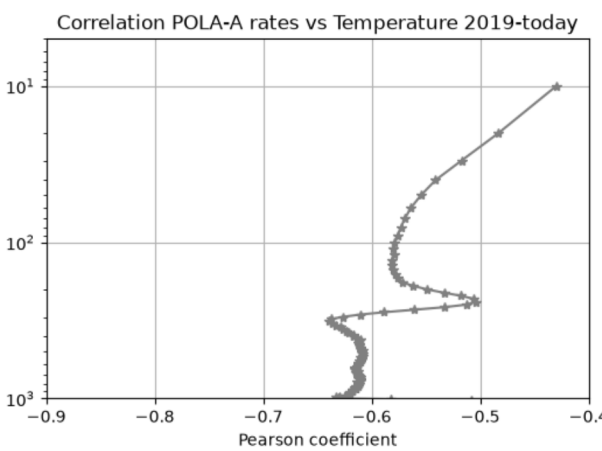
2019july-2020-2021



2022-2023

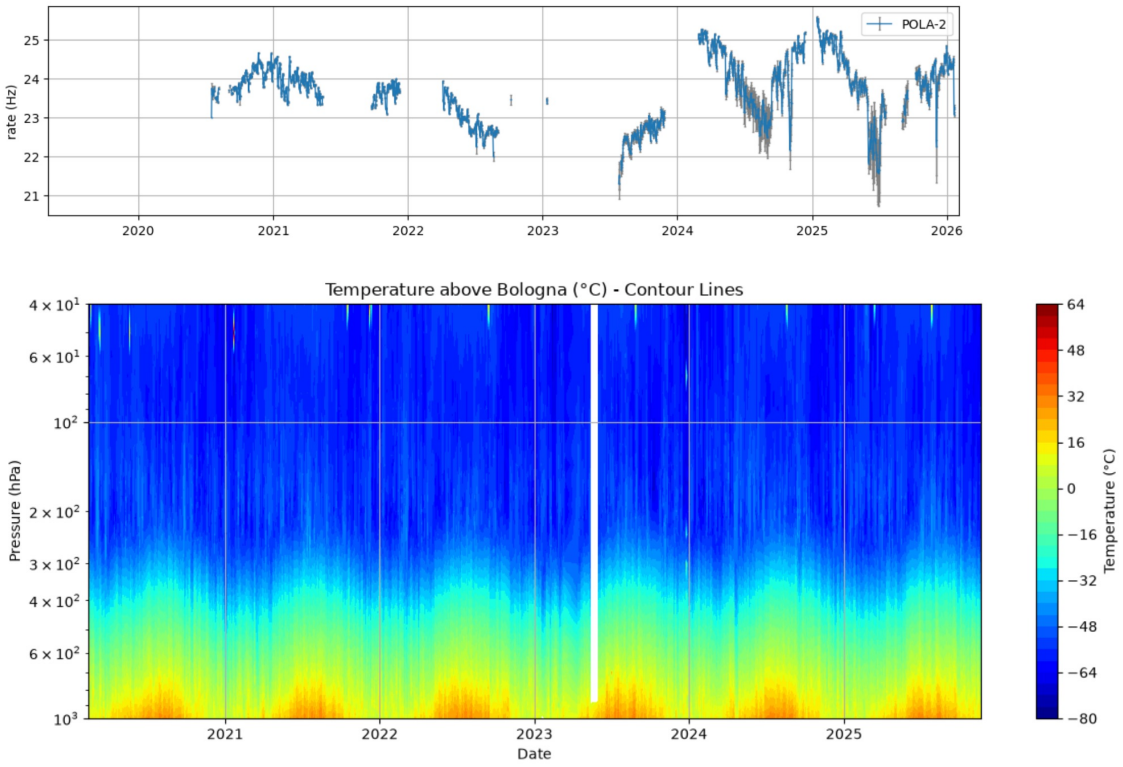


2024-2025-2026june

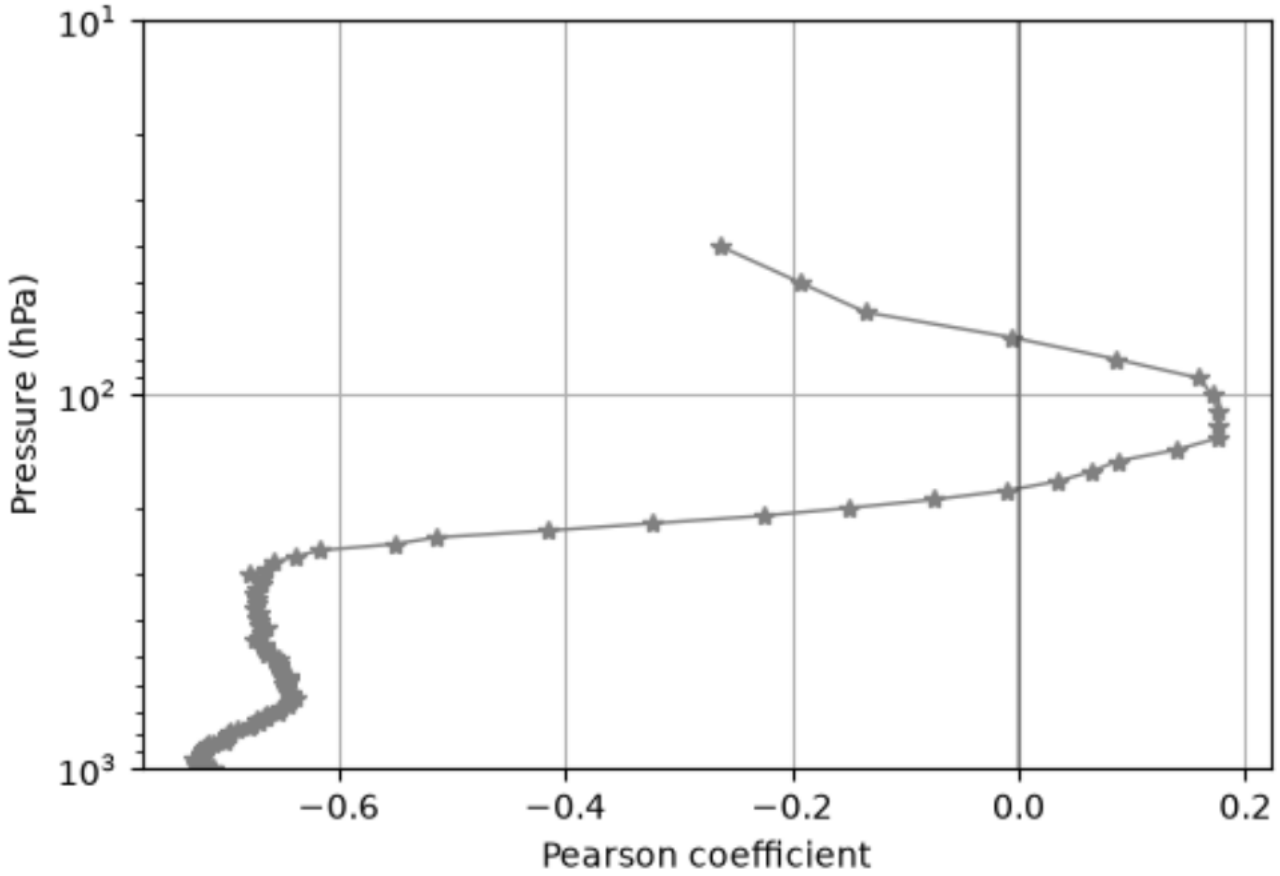


2019july-2026june

DCM per POLA-2 a Bologna
44.5°N, Rc=6.7 GV

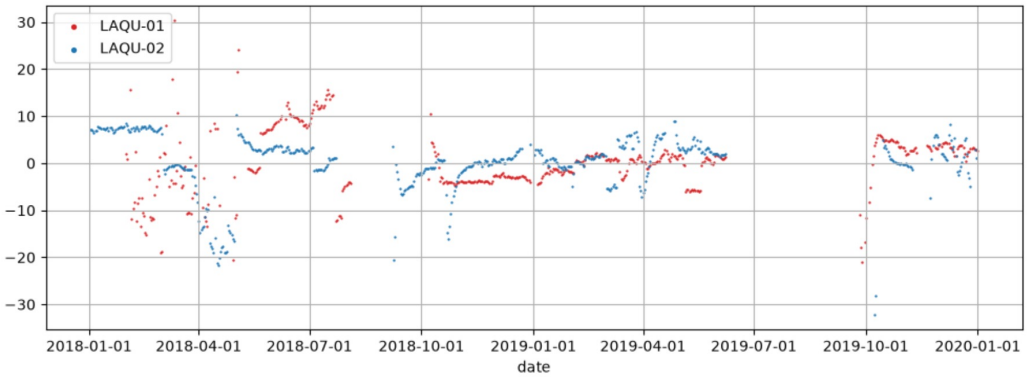


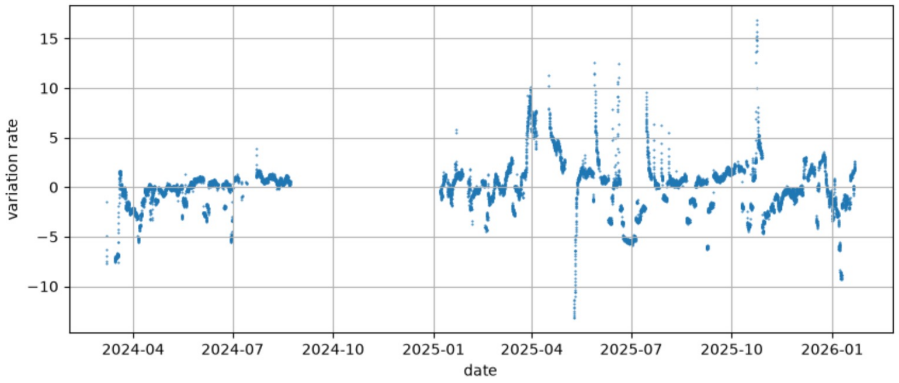
dati di temperatura da radiosonde (CNR)

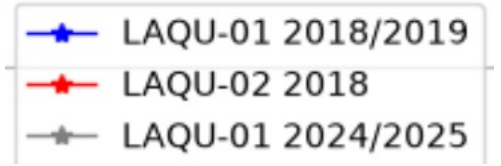


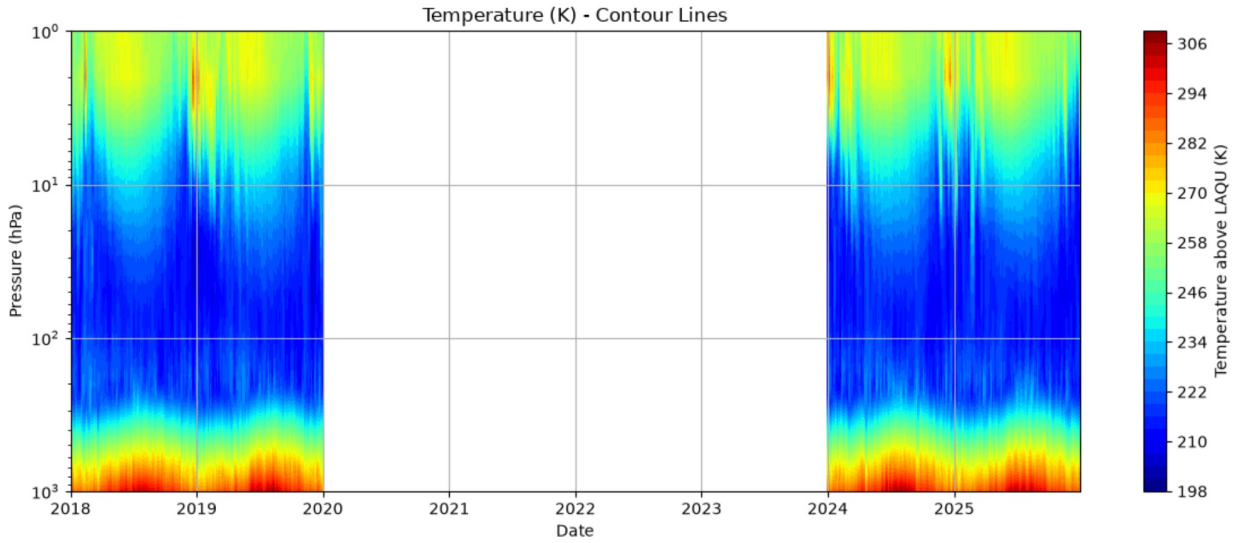
IDEA per una nuova analisi: verificare se la differenza fra contributo positivo e negativo, così come l'altezza caratteristica in cui i due contributi cambiano di peso, dipendono dalla latitudine (o dal cutoff geomagnetico)

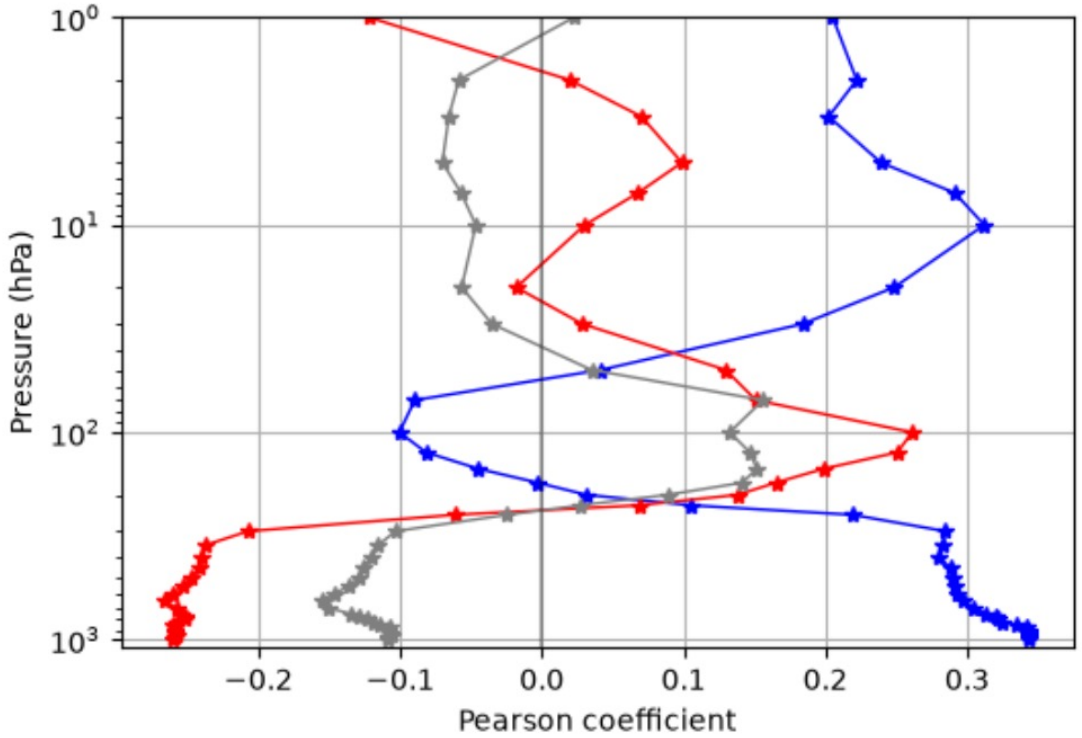
DCM per L'Aquila (42.4°N, Rc=6.3 GV)





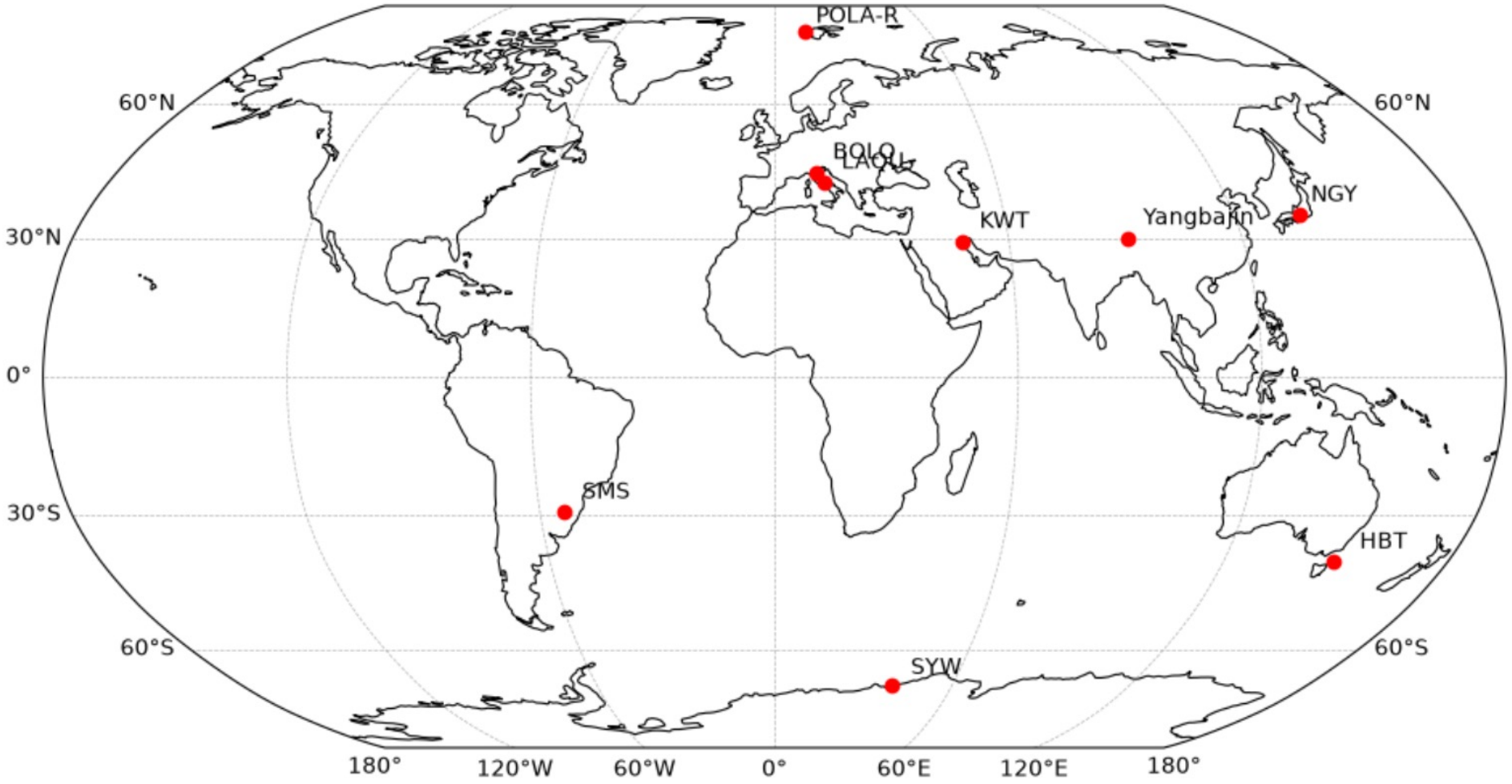




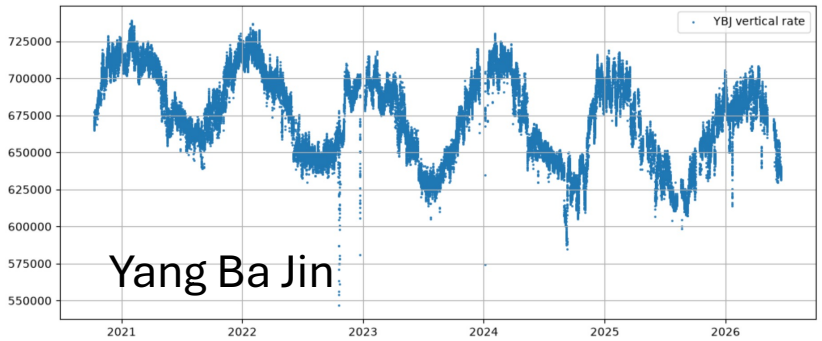


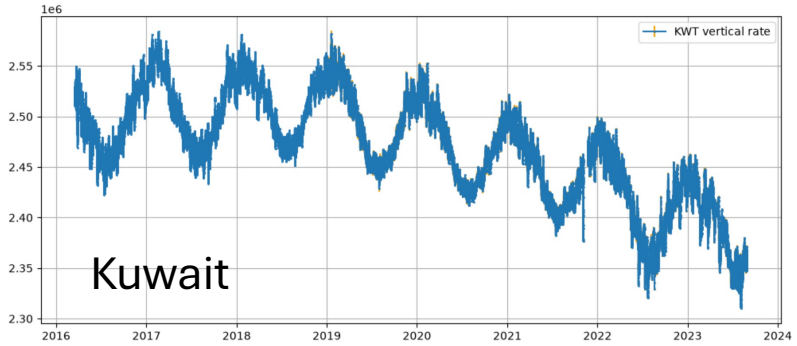
dati di temperatura ERA5 Copernicus

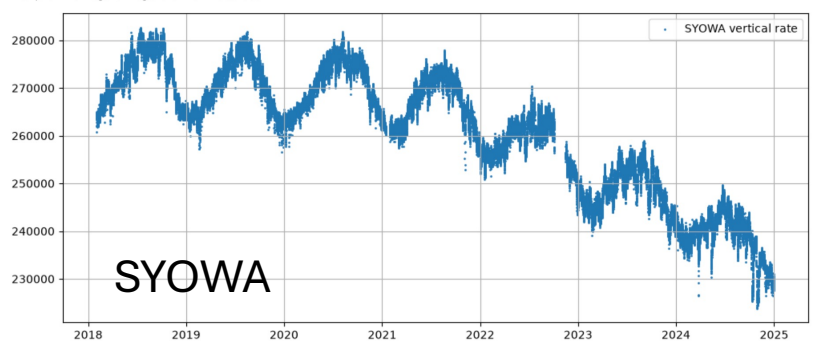
Rivelatori di muoni con dati disponibili

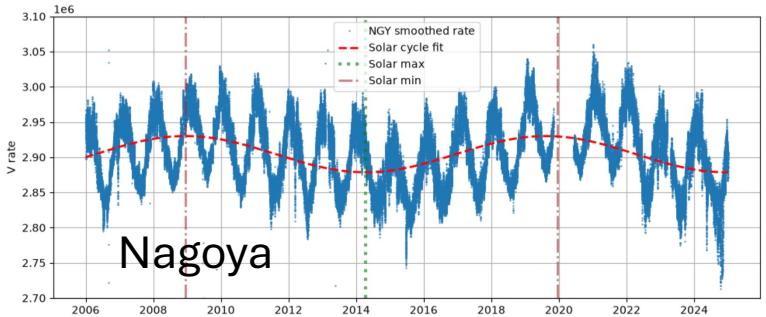


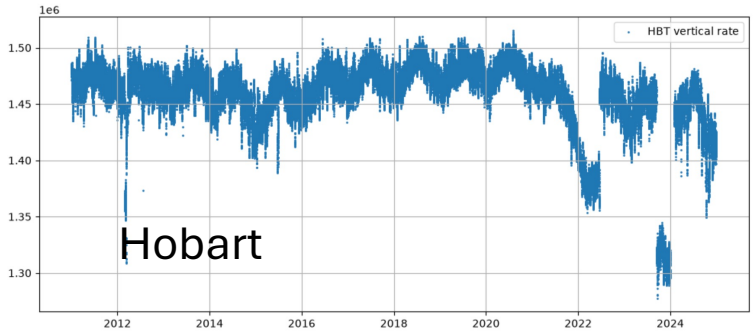
Rivelatori con serie di dati lunghe



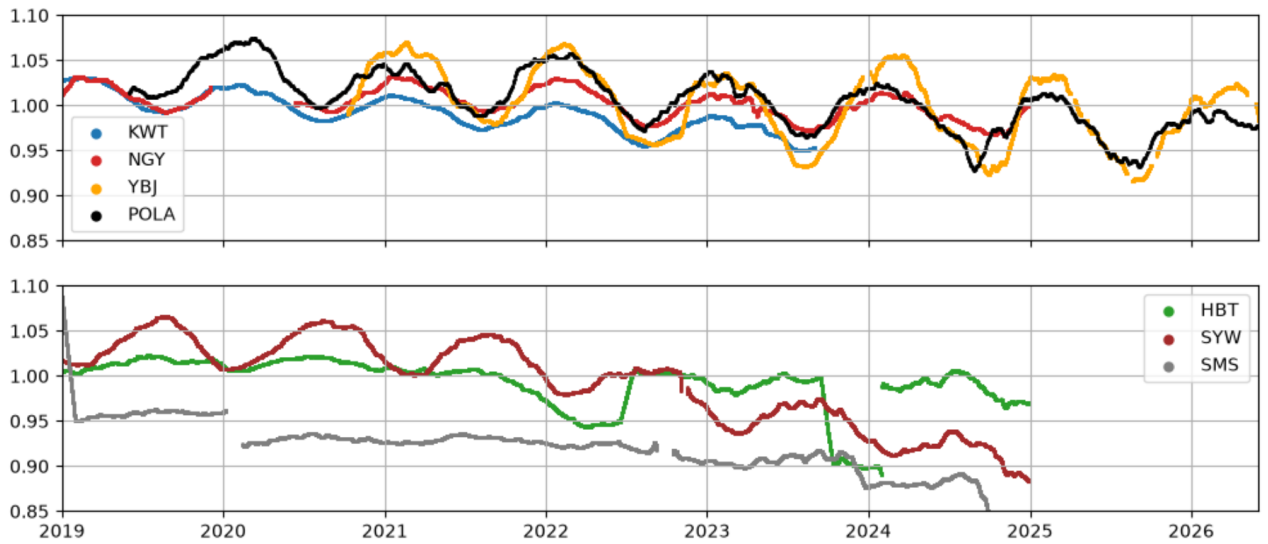






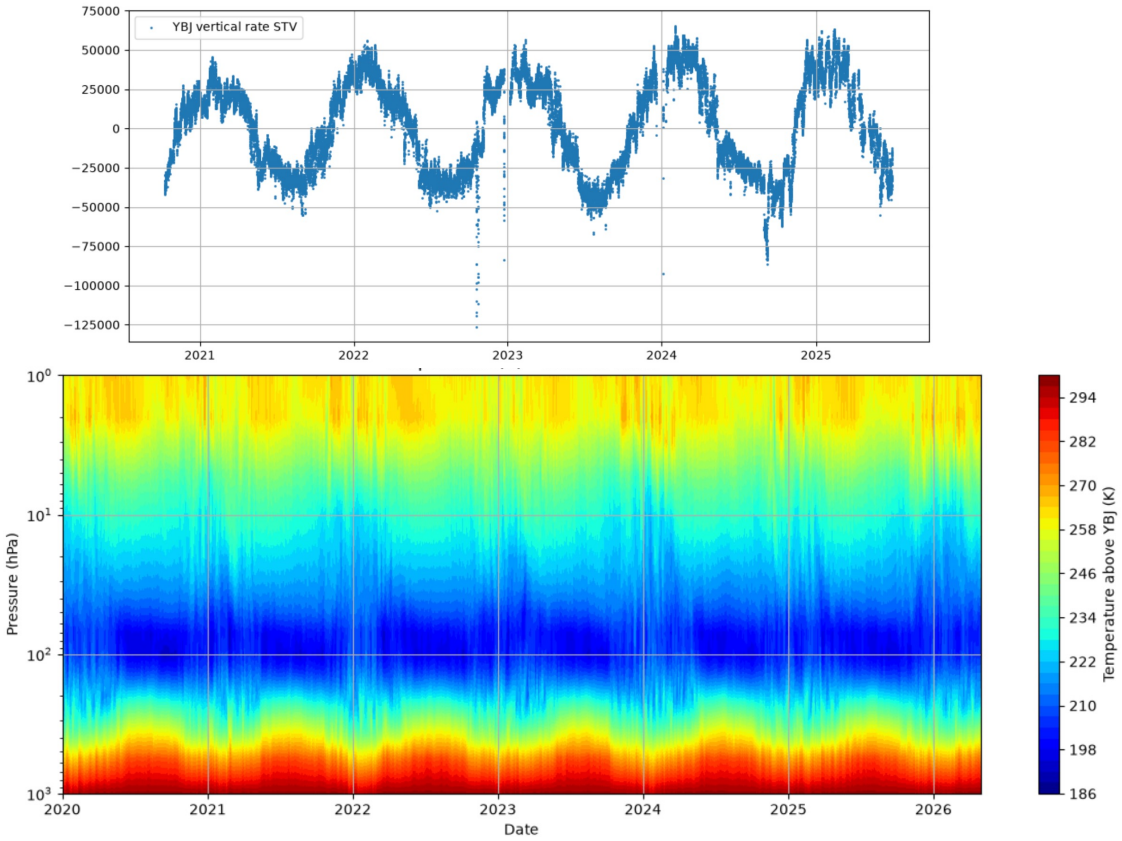


emisfero NORD

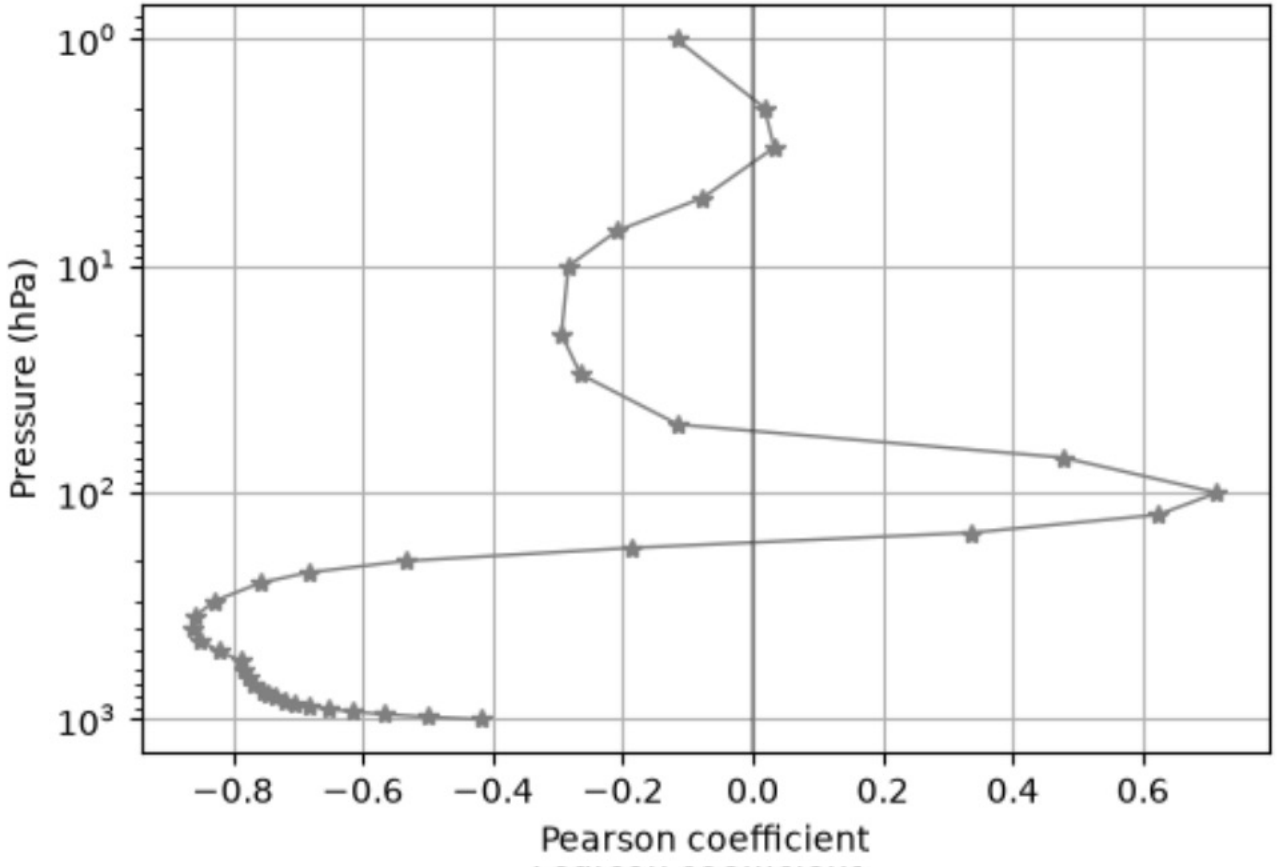


emisfero SUD

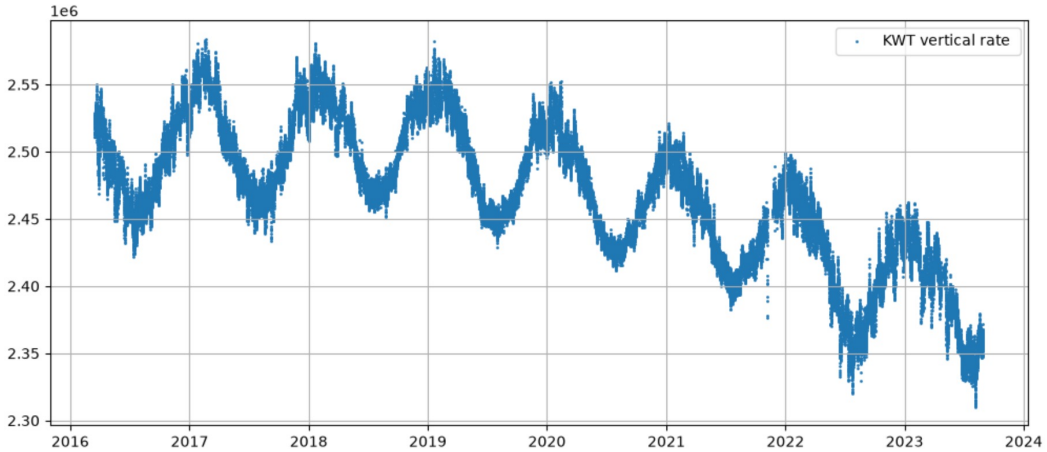
DCM per Yang Ba Jin
30.1°N, 4300 m.s.l, Rc=14 GV

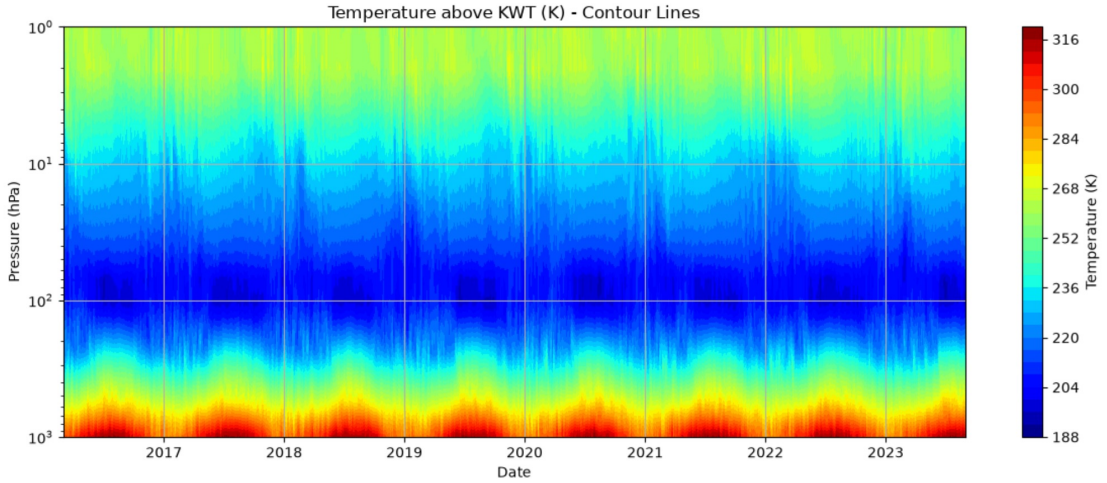


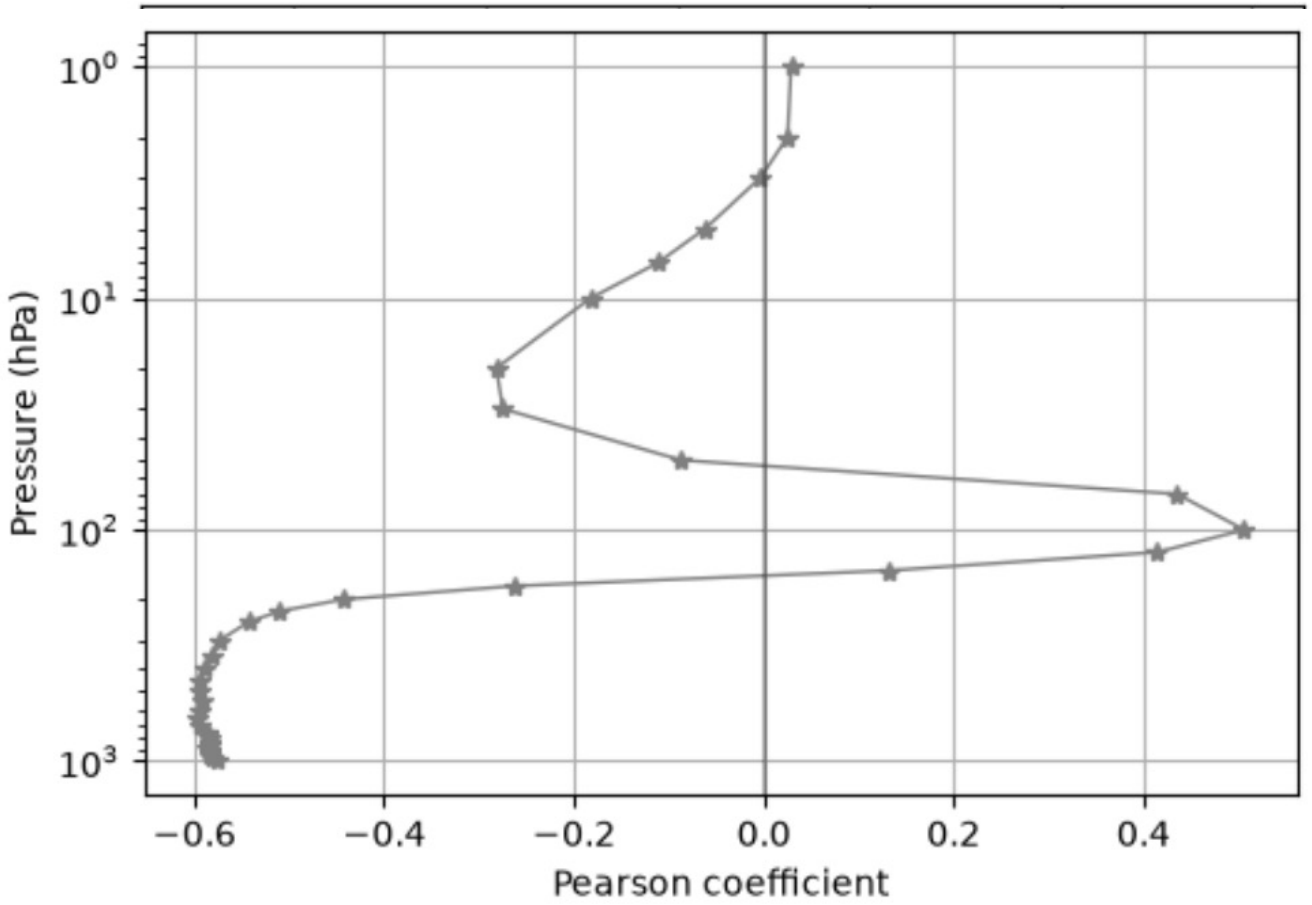
dati di temperatura ERA5 Copernicus



DCM per Kuwait
29.4°N, 19 m.s.l, Rc=13.8 GV

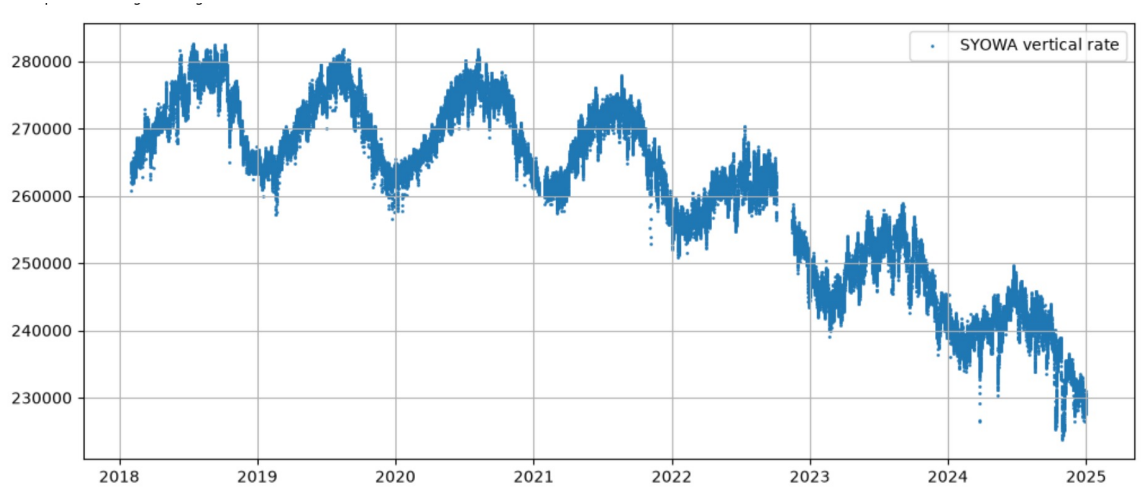


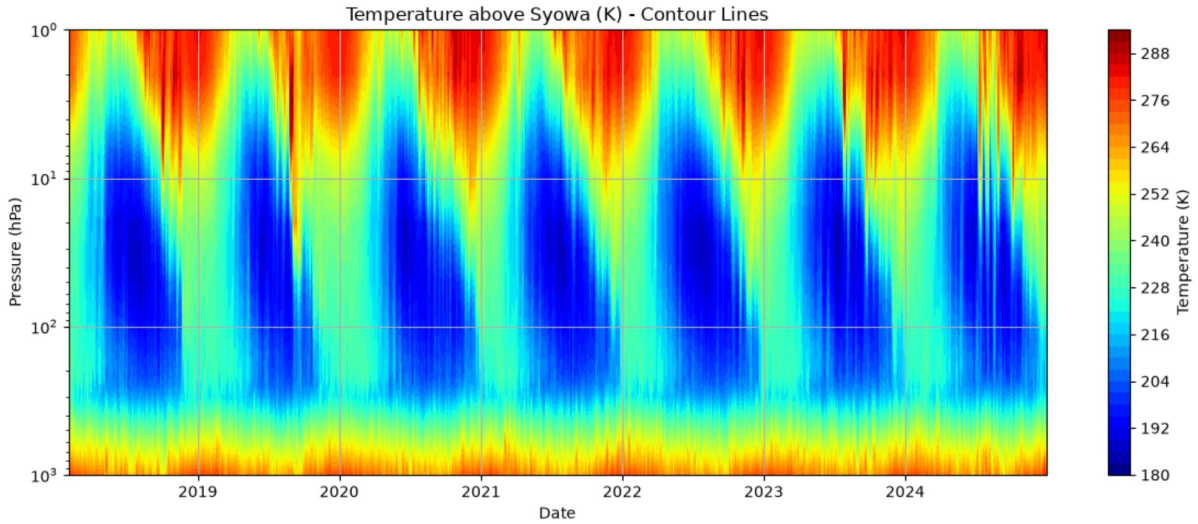


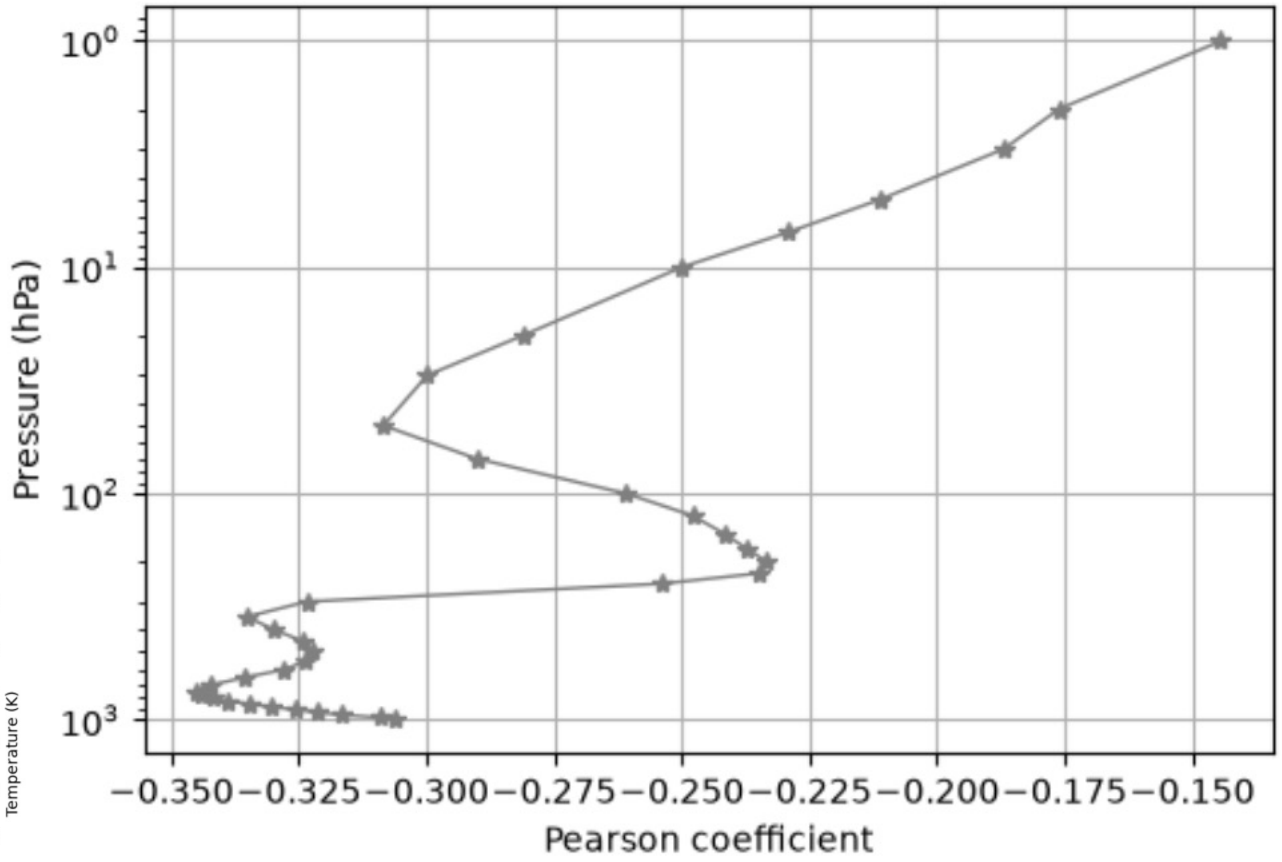


dati di temperatura ERA5 Copernicus

DCM per Syowa
69.0°S, 25 m.s.l, Rc=0.4 GV







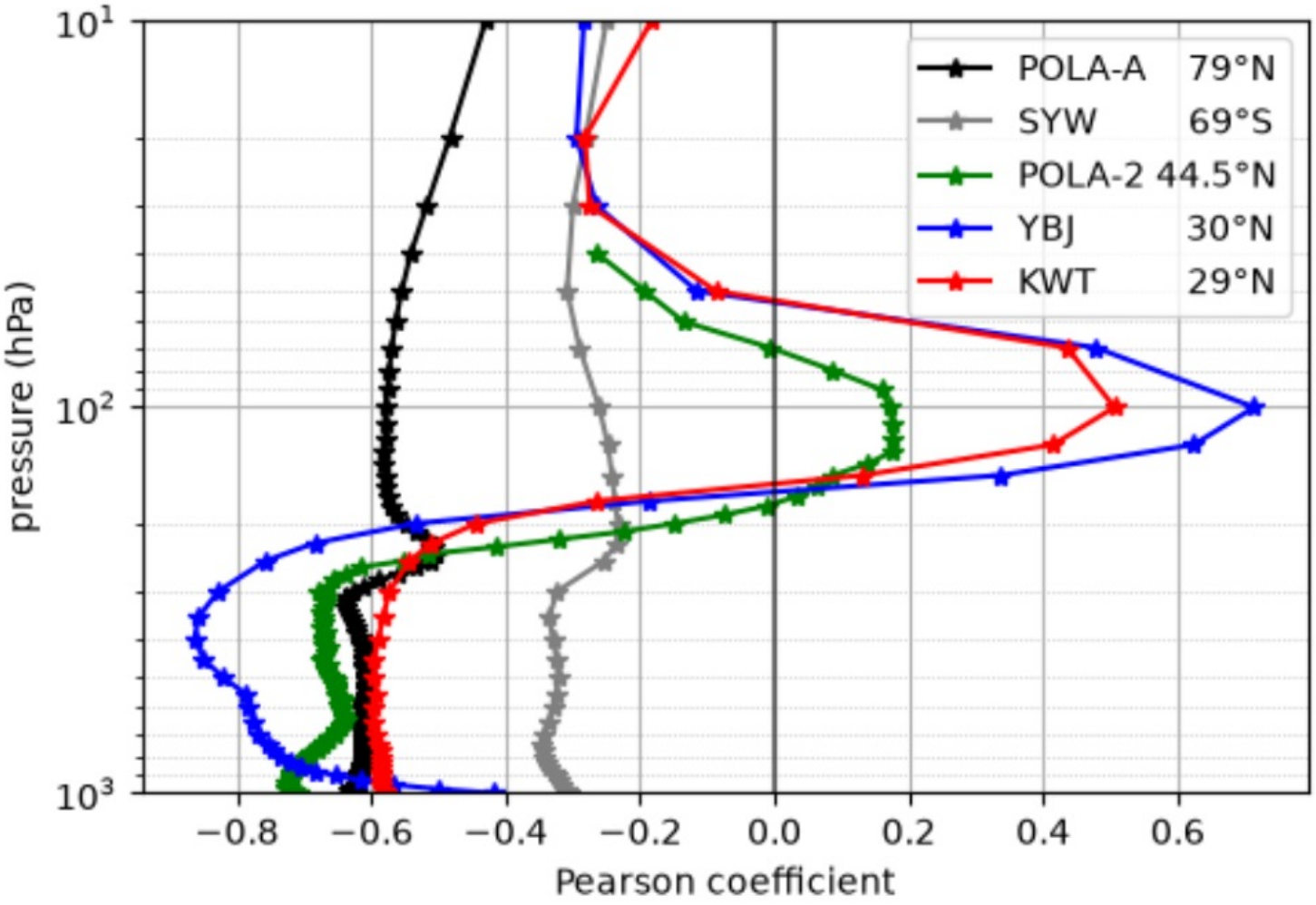
Plot riassuntivo

Rivelatori alle **medie latitudini**:

- mostrano un massimo positivo a 100 hPa (~16.5 km)
- e contributi negativi fino a 200 hPa (~13 km).

Rivelatori a **latitudini polari**:

- sono presenti solo contributi negativi
- un massimo a ~200 hPa (~8 km)
- un minimo a ~300 hPa (~10 km).



Conclusioni

In questa analisi preliminare **non** abbiamo ancora esaminato le **energie** e abbiamo utilizzato **solo rate verticali**.

Pensiamo che la curva di correlazione rate/temperatura mostri la combinazione fra muoni prodotti per decadimento e per reinterazione.

Vorremmo studiare la correlazione rate/temperatura a diverse latitudini, per verificare se l'equilibrio fra i due meccanismi dipende dalla **latitudine** (o cutoff geomagnetico).

Vorremmo trovare serie ragionevolmente continue (>1.5 anni, anche con gaps) per **telescopi EEE**.

Questioni aperte per la Collaborazione

- I referenti locali possono segnalarci telescopi EEE con serie di qualità e lunghezza ragionevole?
- Siamo interessati a portare avanti un'analisi su dati di altri, in particolare YBJ, GMDN?
- Se ci fosse richiesto, qual è la politica dei dati di EEE, sono pubblici (come quelli di GMDN)?

- Altri suggerimenti o indicazioni?

Grazie, Rosario e Ombretta

Materiale extra

GMDN, data policy

Conditions of use for the data

You are welcome to use Global Muon Detector Network data of Shinshu University under the following conditions:

1 Cite our data as "GMDN collaboration, Global Muon Detector Network (GMDN) data, http://hdl.handle.net/10091/0002001448"
when you publish or report on your research using our data.

2 You may share these data with colleagues, provided you inform them of these conditions.
This is most simply accomplished by including the header information that came with the file when you share the data.

3 While these data are accurate to our knowledge, we reserve the right to correct errors without notifying possible recipients of these data.

4 We would appreciate if you could send a copy of any paper or presentation material referring our data when you publish it.
The destination address and e-mail address can be found above.

DATA FILE CONTENTS

All times are UT at the start of the hour interval.
Count rates are in units of counts per hour.
Pressure is in units of hPa.
Count rates are corrected for atmospheric pressure effect but NOT corrected for atmospheric temperature effect.
A -999999 in any data field denotes a data gap.

Note: Data for each station may have level gaps.

Le ultime pubblicazioni

- **Measurement of the cosmic-ray rate over the period 2019–2025 at very high latitude (78.9°N)**
  Eur. Phys. J. C **86**, 289 (2026).
  https://doi.org/10.1140/epjc/s10052-026-15502-9
- **Atmospheric effects on cosmic-ray muon rate at high latitude (78.9°N)**
  Eur. Phys. J. Plus **141**, 691 (2026)
  https://doi.org/10.1140/epjp/s13360-026-07843-x