Atmospheric pressure and temperature correction models for POLA muon rates

**** Preliminary work ****

Ombretta

Pressure effect

- anticorrelation between rate and pressure
- barometric coefficient depends on cutoff rigidity and zenithal angle
- atmospheric pressure variations effect bigger than temperature effect

	Barometric $\boldsymbol{\beta}$	Temperature α
Neutrons	~ -0.7 %/mbar	O(10^{-2}) %/°K
Muons	~ -0.2 %/mbar	O($10^{-1} – 10^{-2}$) %/°K

- Empirical model $\left(\frac{\Delta I}{I}\right)_P = \beta \cdot \Delta P$

$$\Lambda I\,(t) = ln\left[\frac{I_{\mathrm{OBS}}\,(t)}{I_M}\right] * \ 100 = \beta^{*}\Delta P\,(t)$$

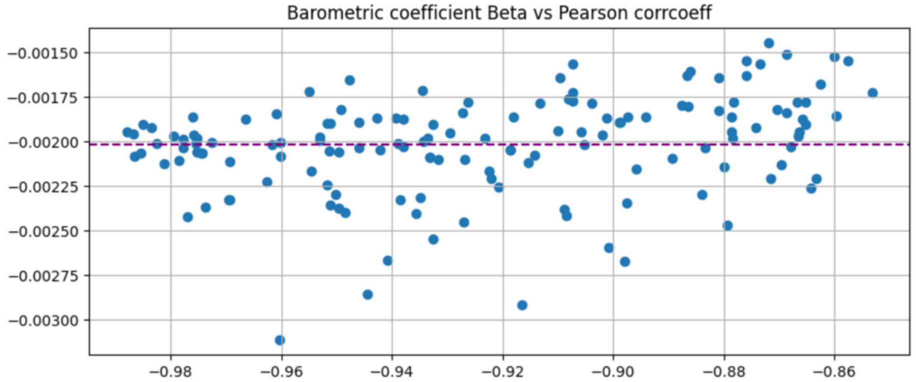
$$\Delta P\,(t) = \ P\,(t) - P_M$$

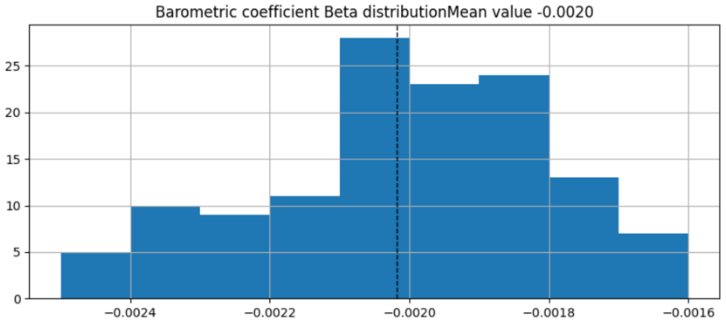
$\boldsymbol{\beta}$ estimated by linear regression between $\Lambda I\,(t)$ and ΔP

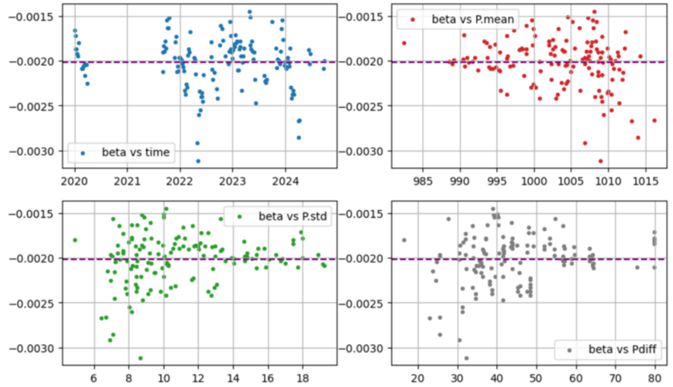
$$I_P = I_0 * e^{0.01*\beta*(P-P_0)}$$

Barometric coefficient POLA-1

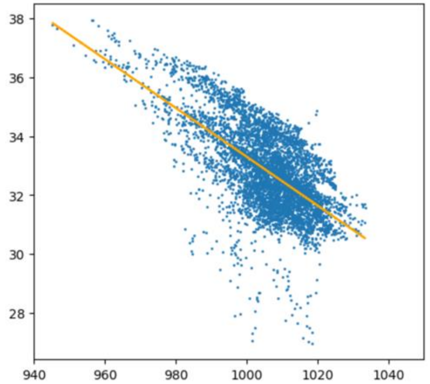
- 1h resampled data, 30 days running window, Pearson>-0.85 -0.00202



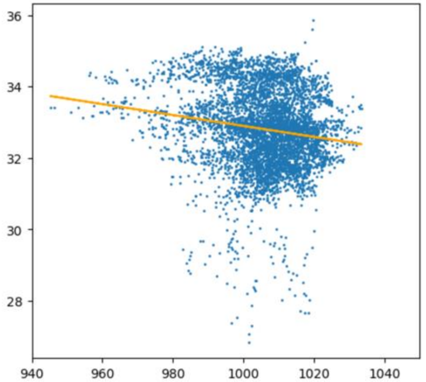




Pearson before = -0.576

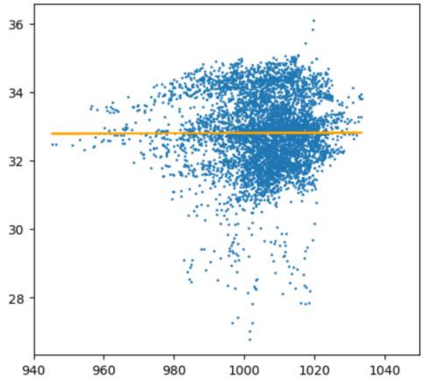


Pearson with Beta_avg = -0.132



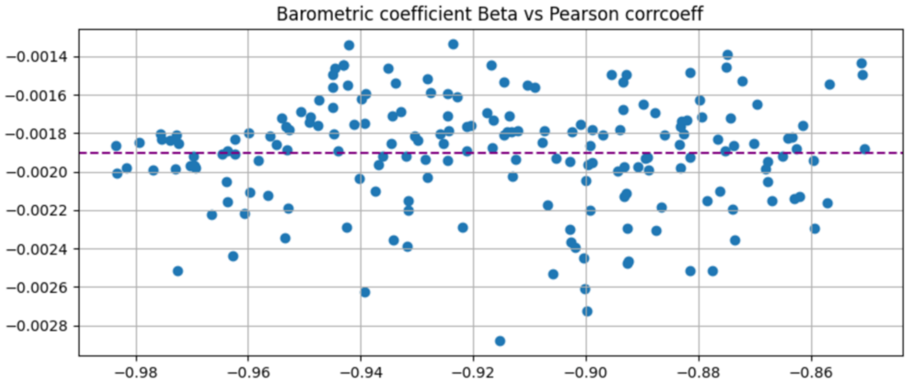
Beta computed over 5 years = -0.002492

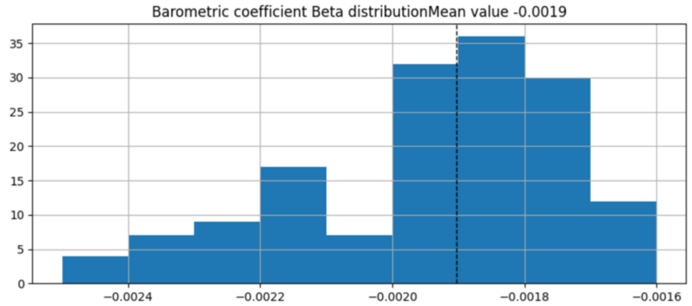
Pearson = -0.00001

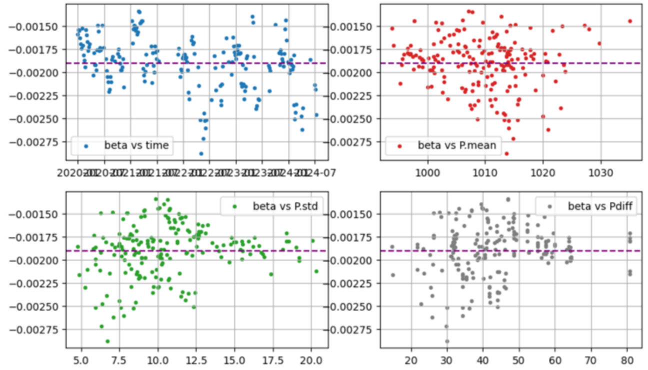


Barometric coefficient POLA-3

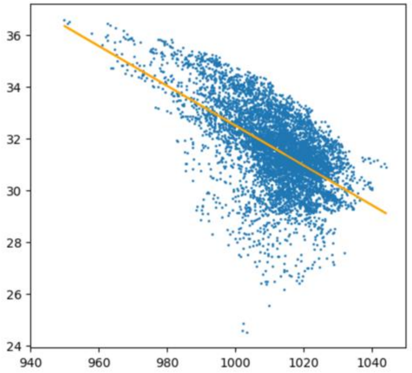
- 1h resampled data, 30 days running window, Pearson>-0.85 -0.00190


Barometric coefficient Beta vs Pearson corrcoeff

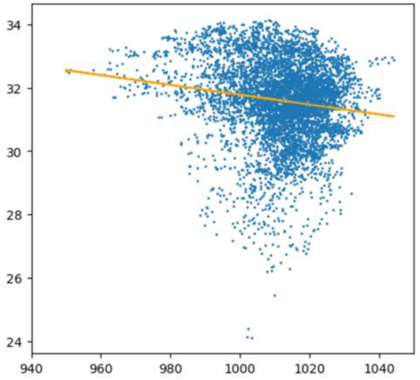

Barometric coefficient Beta distributionMean value -0.0019



Pearson before = -0.526

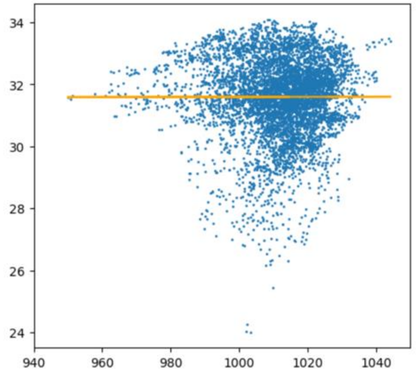


Pearson with Beta_avg = -0.125



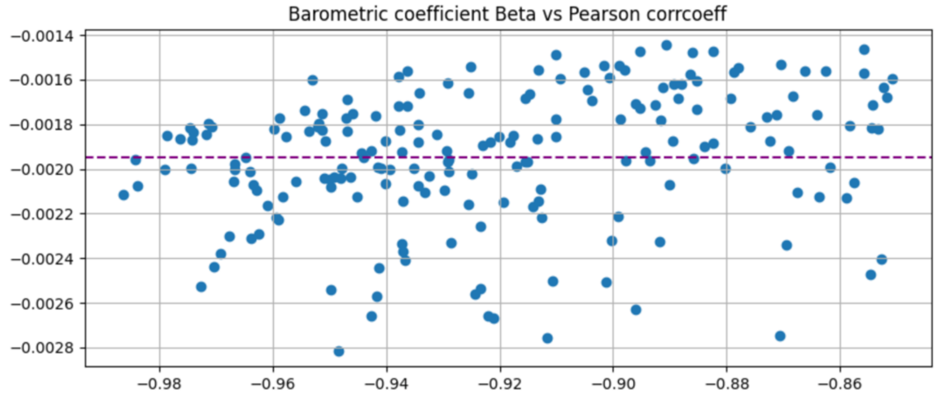
Beta computed over 5 years = -0.002394

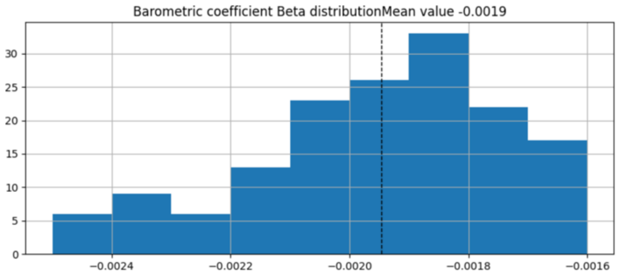
Pearson = -0.00001

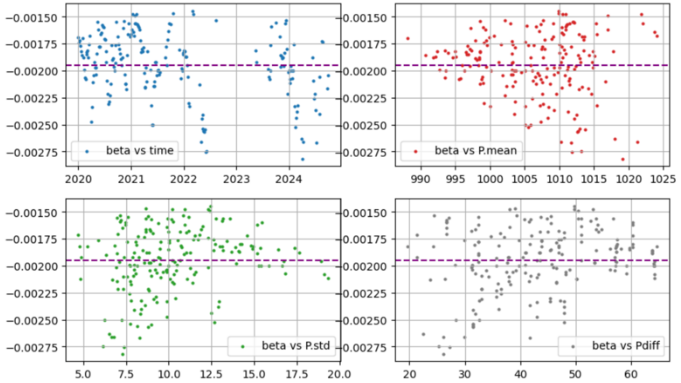


Barometric coefficient POLA-4

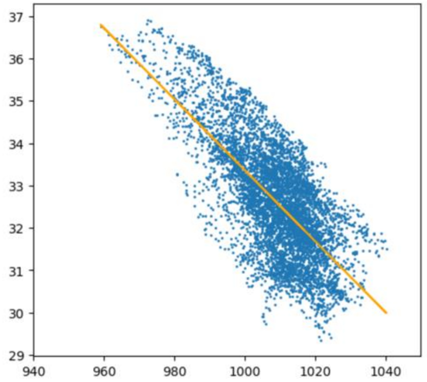
- 1h resampled data, 30 days running window, Pearson>-0.85 -0.00195



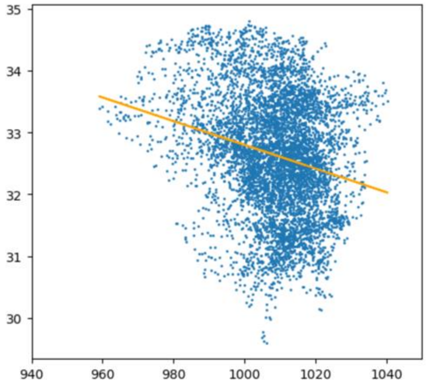




Pearson before = -0.623

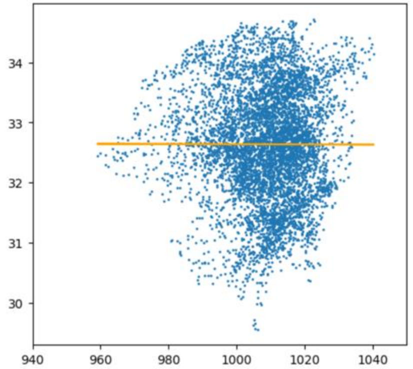


Pearson with Beta_avg = -0.179



Beta computed over 5 years = -0.002526

Pearson = -0.00002



Temperature effects on rates

In scientific literature, two opposite effects:

1. negative effect: increasing temperature (ex. winter to summer) causes expansion of the atmosphere, so more muons decay because their propagation path is longer, and we observe a decrease of muon intensity at ground level
2. positive effect: temperature influence on muon production from the decay of charged pions

Models

$$\left(\frac{\Delta I}{I}\right)_T = K_G \Delta T(h_G) + C_H \Delta H(h_M) + K_M \Delta T(h_M)$$

$$\left(\frac{\Delta I}{I}\right)_T = \int_0^p \alpha(x) \Delta T(x) dx$$

h_M = altitude of maximum production of secondary particles

$\Delta T(h_G)$ temperature variation at ground level

$\Delta H(h_M)$ height variation at the altitude of maximum production of secondary particles

$\Delta T(h_M)$ temperature variation at the altitude of maximum production of secondary particles

de Mendonça (2013)

de Mendonça comparing 4 methods:

1. only temperature variations measured at ground level (h_G)
2. only temperature variations measured at the altitude where there is the maximum in secondary cosmic rays production ($h_M \sim 16.5\ km$)
3. both h_G and h_M factors
4. approximated integral method

$$\left(\frac{\Delta I}{I}\right)_T = \int_0^p \alpha(x)\Delta T(x)dx$$

de Mendonça (2016) comparing more methods

- Atmospheric expansion method $\Delta I_T = \alpha_{\mathrm{ATE}} * \Delta H\,[p],\ p = 100\,\mathrm{hPa}$
- Ground method $\Delta I_T = \alpha_{\mathrm{GRD}} * \Delta T\,[h_{\mathrm{GRD}}]$
- MMP method $\Delta I_T = \alpha_{\mathrm{MMP}} * \Delta T\,[h_{\mathrm{MMP}}]$
- combination of the 3 $\Delta I_T = \sigma_{\mathrm{ATE}} * \Delta H\,[p] + \sigma_{\mathrm{MMP}} * \Delta T\,[h_{\mathrm{MMP}}]$

- integral (theoretical) method $\Delta I_T = \int_0^{x_{\mathrm{GRD}}} \alpha_{\mathrm{THR}}\,[x] * \Delta T\,[x] * dx$
- approximation $\Delta I_T = \alpha_{\mathrm{MSS}} * \Delta T_{\mathrm{MSS}}$ $T_{\mathrm{MSS}} = \sum_{i=0}^{n} w\,[h_i] * T\,[h_i],\ w\,[h_i] = \frac{x\,[h_i] - x\,[h_{i+1}]}{x\,[h_0]}$
    - definition of ‘effective temperature’ $T_{\mathrm{EFF}-M} = \frac{\int_0^{x_{\mathrm{GRD}}} \omega_M\,[x] * T\,[x]\,dx}{\int_0^{x_{\mathrm{GRD}}} \omega_M\,[x]\,dx},\ \omega_M\,[x] = x * (e^{-\frac{x}{\lambda_\pi}} - e^{-\frac{x}{\lambda_n}})$

Temperature profile from NASA + balloons

- The temperature height profiles observed between 14 and 111 km are provided by the SABER (Sounding of the Atmosphere Using Broadband Emission Radiometry) instrument on NASA’s Thermosphere, Ionosphere, Mesosphere, Energetics and Dynamics mission
- No SABER temperature data measurements are available below 14 km.

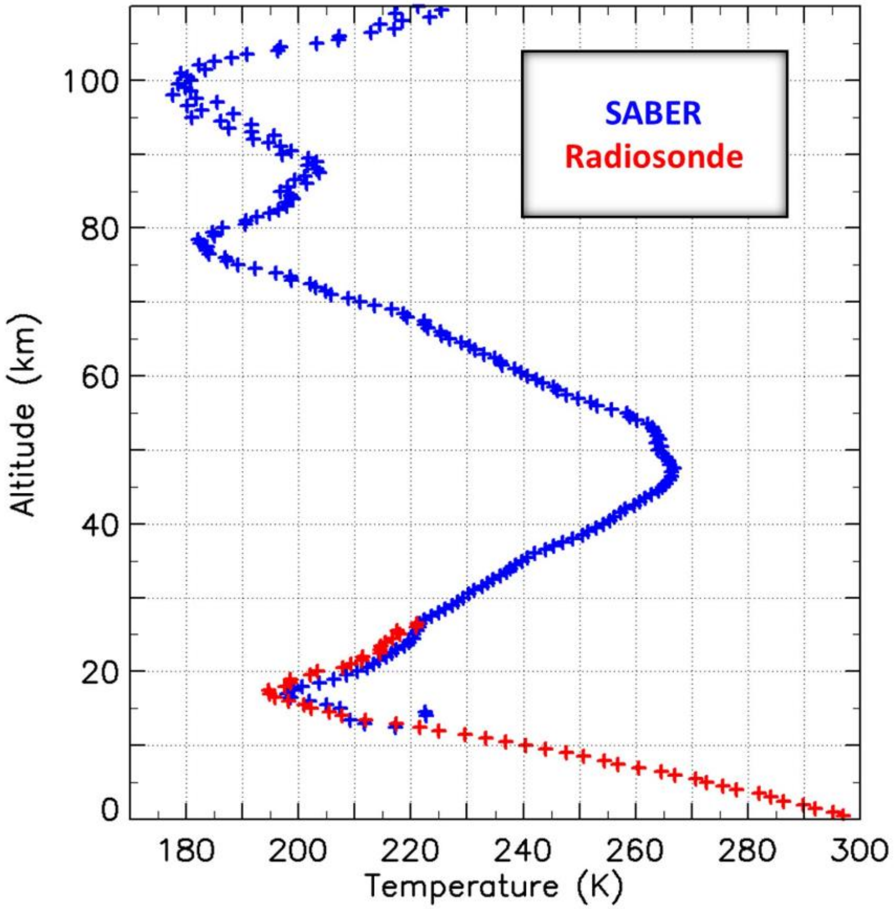
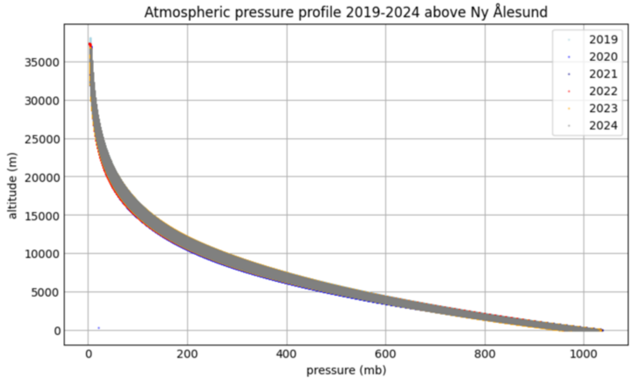
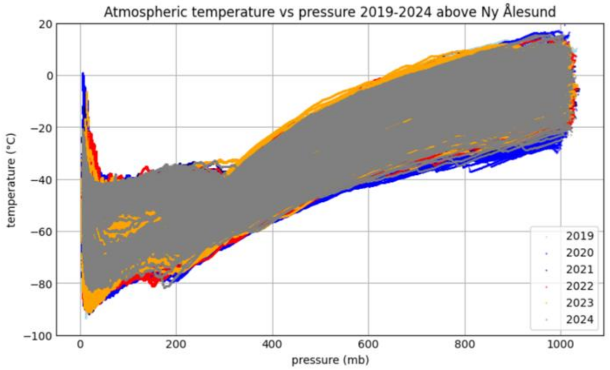


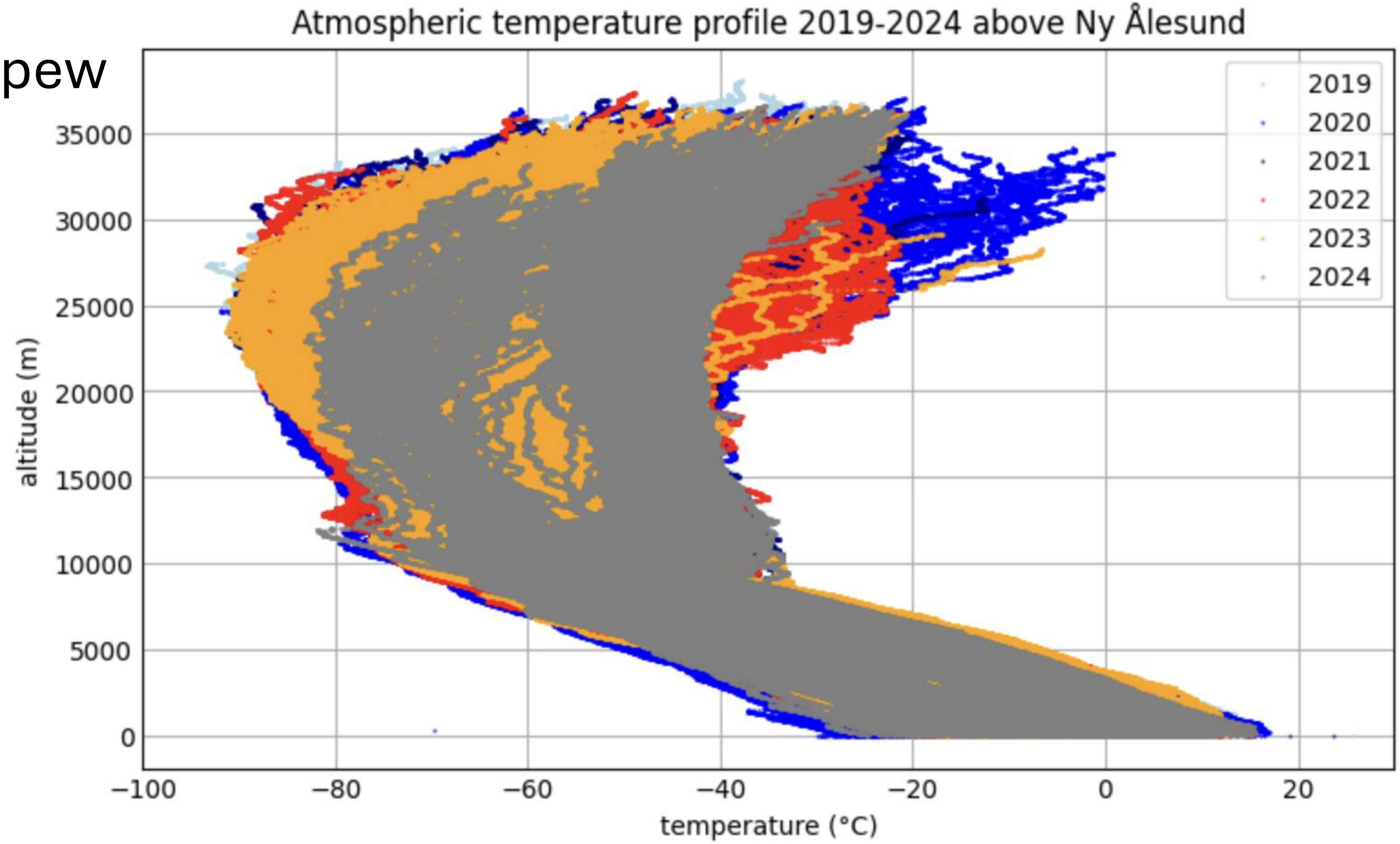
Figure 2. Atmospheric temperature profile composite using SABER (blue) and radiosonde (red) data observed above the SMS detector region on 2009/11/06.

Temperature profile above Ny Ålesund

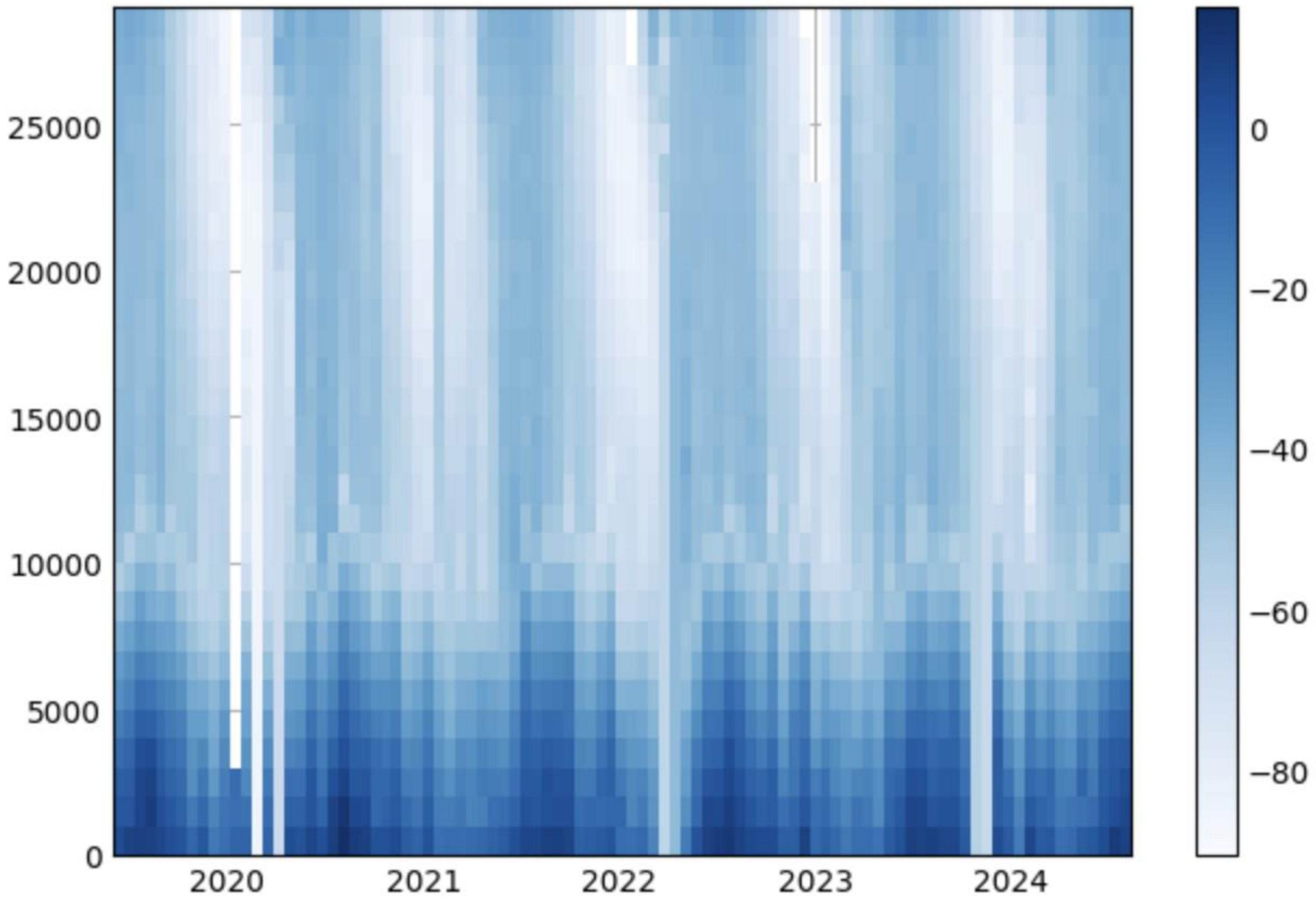
- Radiosonde Awipew





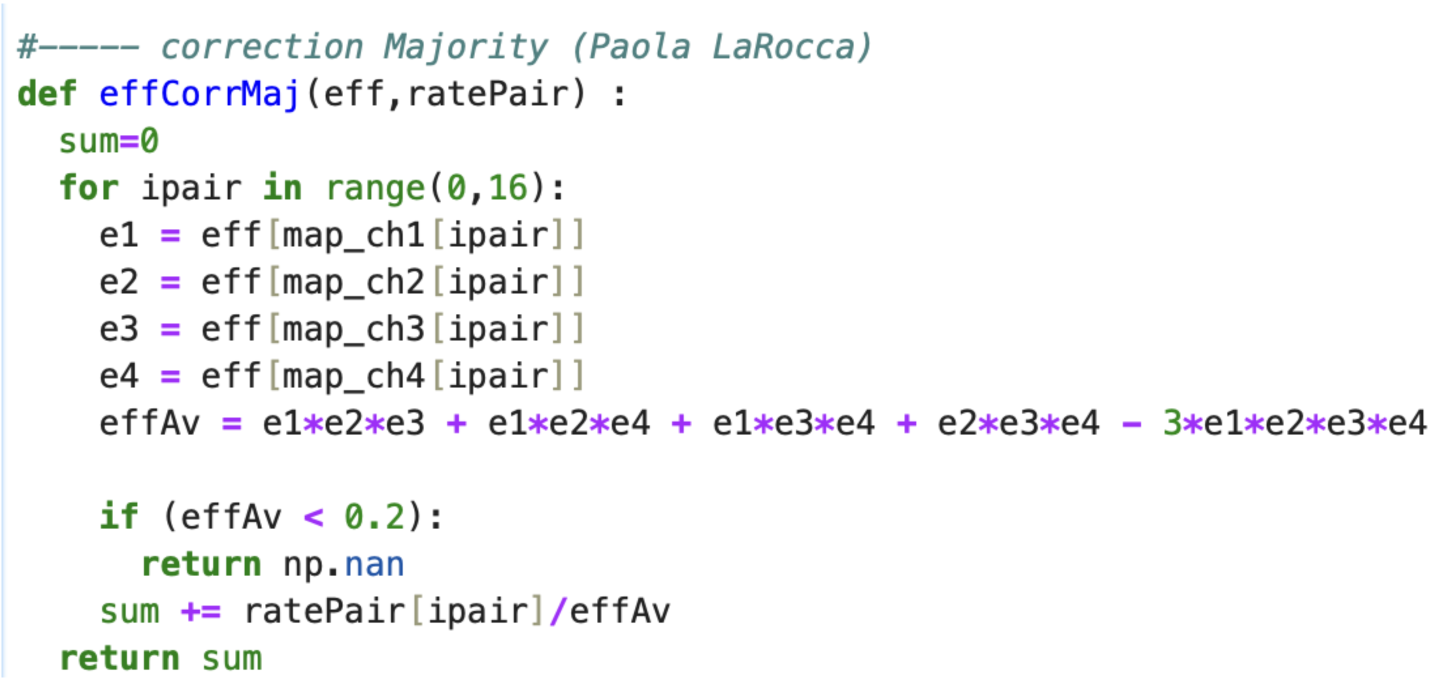


Temperature profile map (approximation)



Note

All POLA rates are first corrected for pseudoefficiency



```
#----- correction Majority (Paola LaRocca)
def effCorrMaj(eff,ratePair) :
  sum=0
  for ipair in range(0,16):
    e1 = eff[map_ch1[ipair]]
    e2 = eff[map_ch2[ipair]]
    e3 = eff[map_ch3[ipair]]
    e4 = eff[map_ch4[ipair]]
    effAv = e1*e2*e3 + e1*e2*e4 + e1*e3*e4 + e2*e3*e4 - 3*e1*e2*e3*e4

    if (effAv < 0.2):
      return np.nan
    sum += ratePair[ipair]/effAv
  return sum
```