“Experimental Data Processing”

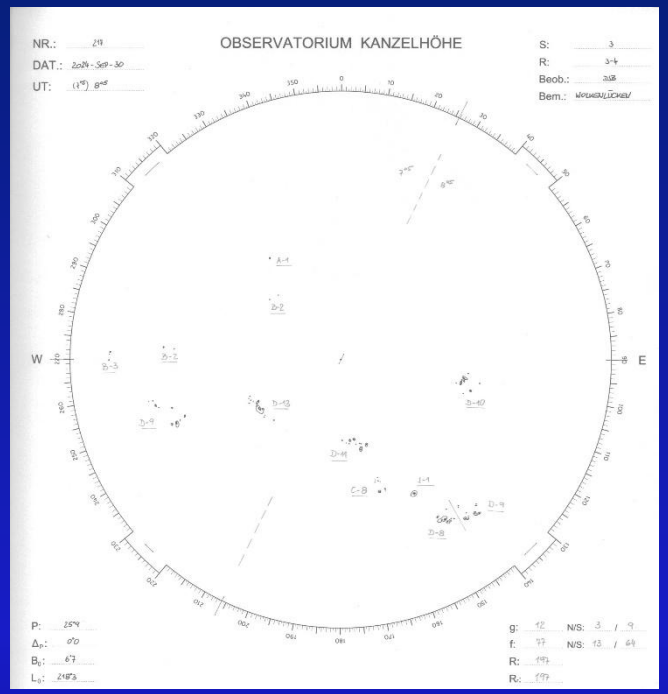
Assignment 1
Reconstructing the past:
Estimating solar radio flux F10.7 from sunspot records.

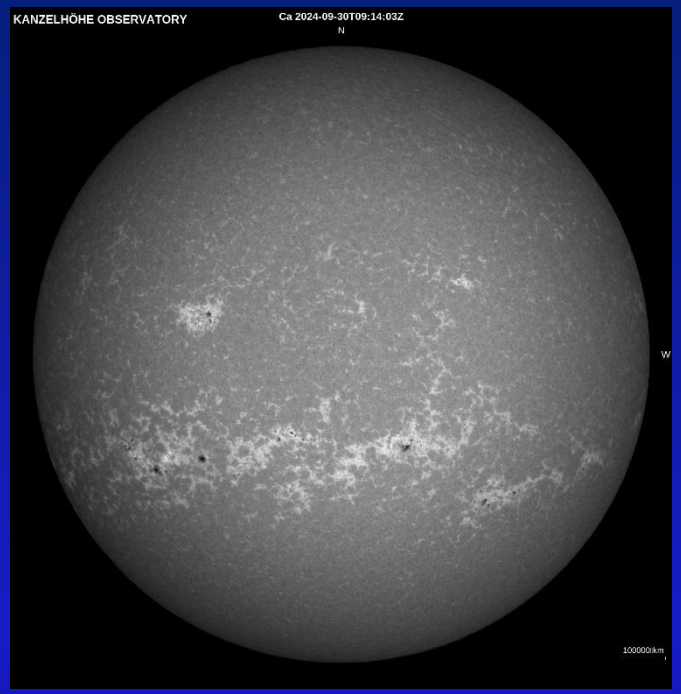
Tatiana Podladchikova
Term 1B, October 2025
t.podladchikova@skol.tech

Skoltech

SUNSPOT NUMBER OBSERVATIONS

30 September 2024





$$R = k(n + 10g)$$

n – number of observed sunspots

g – number of observed sunspot groups

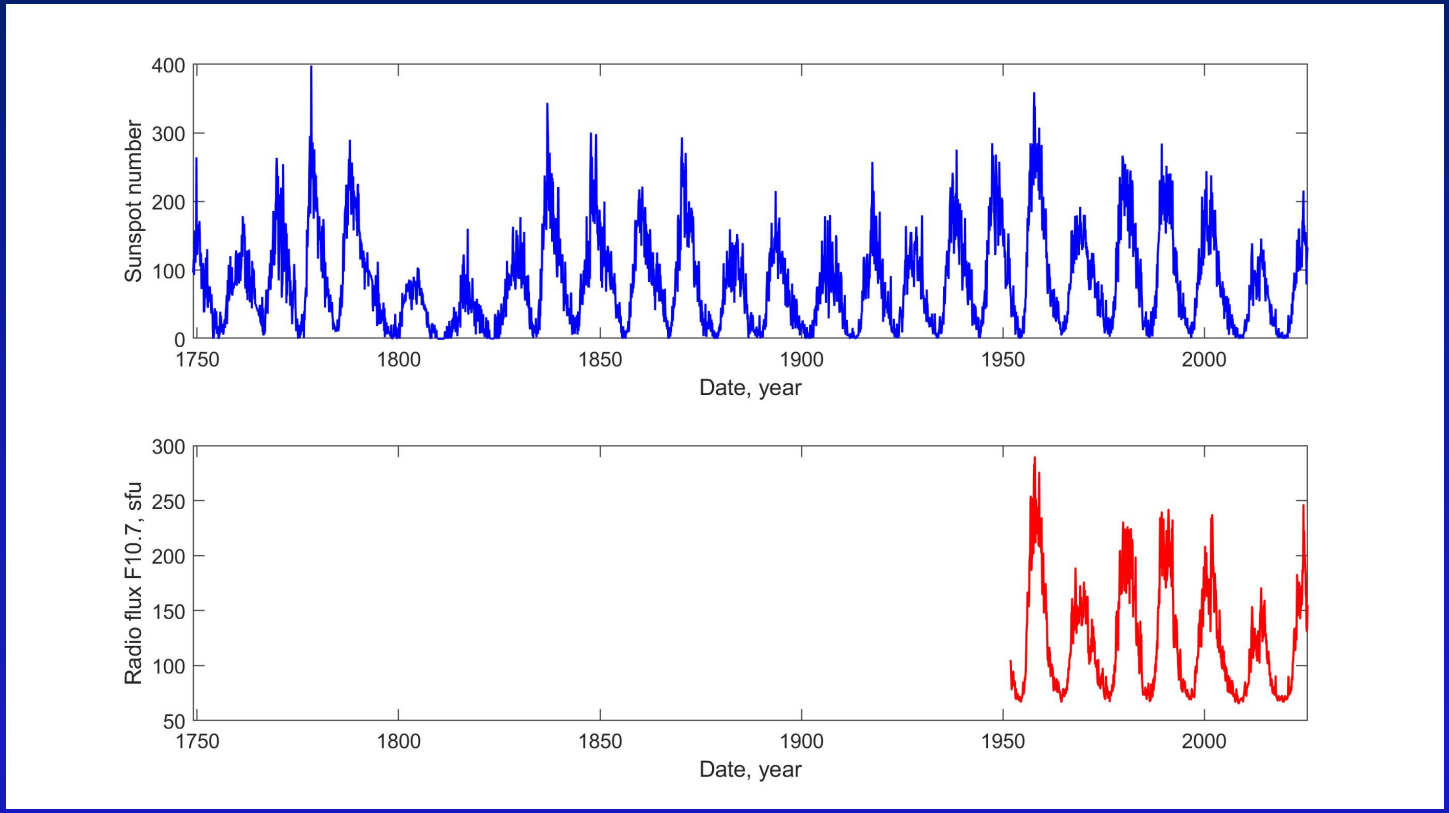
k – coefficient of a telescope

Around 80 cooperating stations around the globe observe sunspot numbers daily

Main indicators of solar activity

Sunspot number

From ground-based observatories



Solar radio flux at 10.7 cm (in sfu)

$1\ \text{sfu} = 10^{-22}\ \text{W m}^{-2}\ \text{Hz}^{-1}$

Ottawa and Pentincton Observatory, Canada

$$R = k(n + 10g)$$

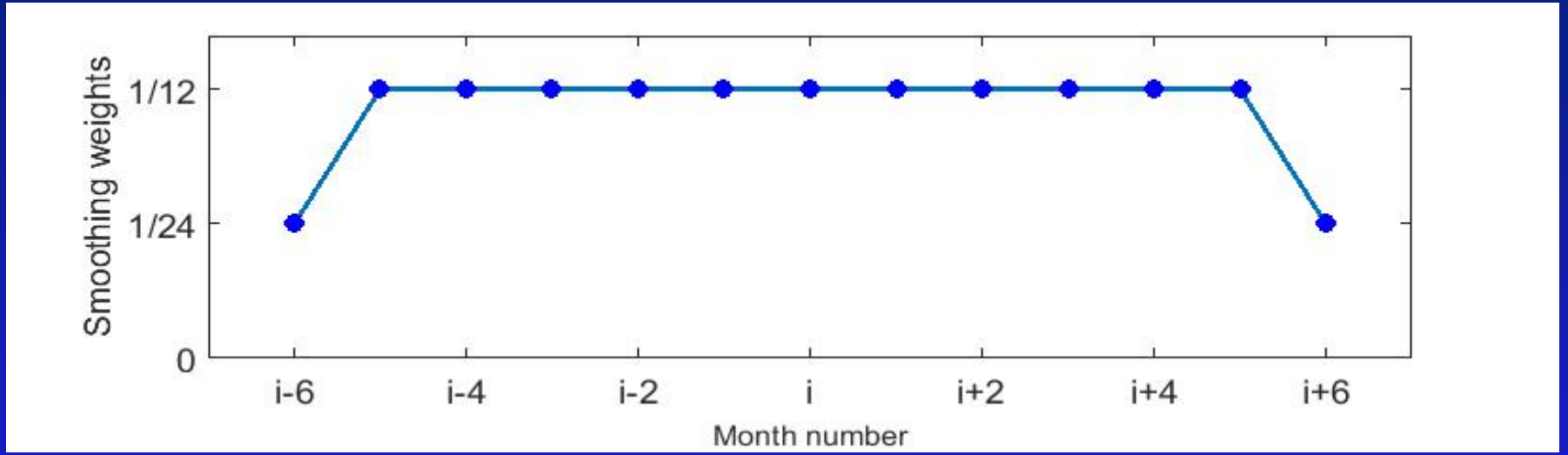
n – number of observed sunspots

g – number of observed sunspot groups

k – coefficient of a telescope

A measurement of radio emission at a wavelength of 10.7 cm (2800 MHz) from all sources present on the solar disk

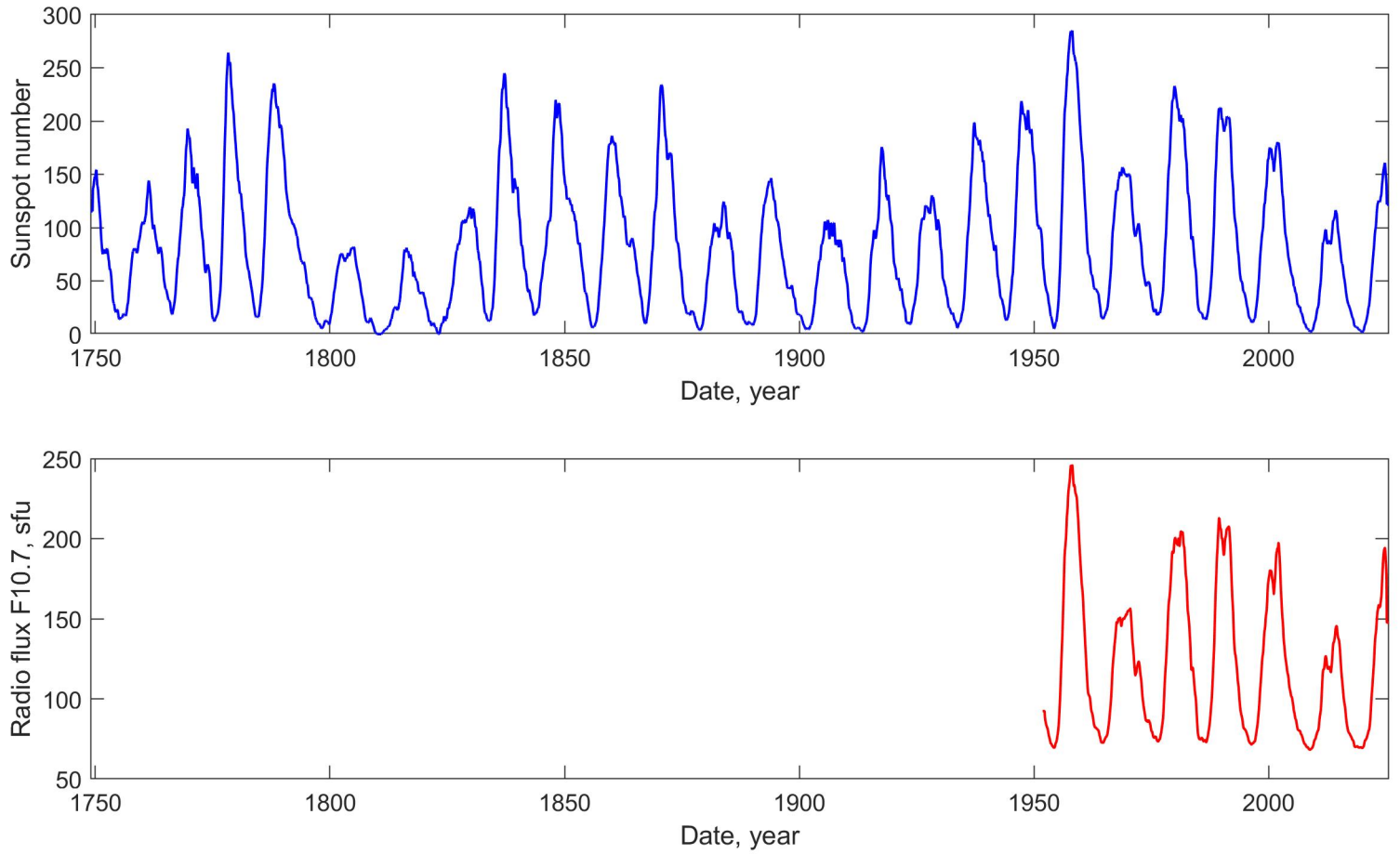
13-month sequent monthly mean sunspot numbers



13-month running mean $\overline{R}$

$$\frac{1}{24}R_{i-6}+\frac{1}{12}(R_{i-5}+R_{i-4}+\ldots+R_{i-1}+R_i+R_{i+1}+\ldots+R_{i+5})+\frac{1}{24}R_{i+6}$$

Smoothing: 13-month running mean



Multi-dimensional linear regression

$$F_i = \beta_0 + \beta_1 R_i + \beta_2 R_i^2 + \beta_3 R_i^3 + \varepsilon_i$$

$$i = 1, \ldots N$$

F_i
Dependent variable
Regressand

β_j
Coefficients of regression

R_i
Independent variable
Regressor

ε_i
Unbiased uncorrelated Gaussian noise with constant variance

Coefficients β_j are determined by LSM

$$\sum_{i=1}^{N} \varepsilon_i^2 \rightarrow min$$

Multi-dimensional linear regression

$$F = \begin{vmatrix} f_1 \\ f_2 \\ \dots \\ f_N \end{vmatrix}$$

Vector of dependent variables

$$\beta = \begin{vmatrix} \beta_0 \\ \beta_1 \\ \beta_2 \\ \beta_3 \end{vmatrix}$$

Vector of coefficients

$$R = \begin{vmatrix} 1 & r_1 & r_{1^2} & r_1^3 \\ 1 & r_2 & r_2^2 & r_3^3 \\ \dots & \dots & \dots & \dots \\ 1 & r_N & r_N^2 & r_N^3 \end{vmatrix}$$

Matrix of independent variables

$$\varepsilon = \begin{vmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \dots \\ \varepsilon_N \end{vmatrix}$$

Vector of random errors

Linear regression in matrix form

$$F = R \cdot \beta + \varepsilon$$

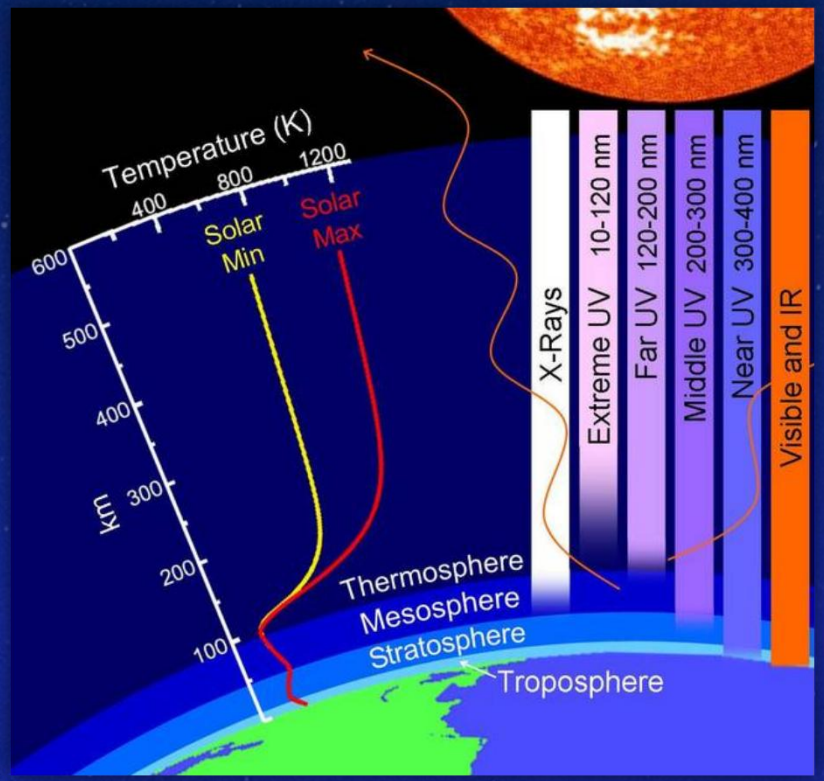
$$\hat{\beta} = (R^T R)^{-1} R^T F$$

Linear Regression Analysis,
G.A.F. Seber and J. Lee, Wiley, N.Y., 2003

Estimation error of solar radio flux F10.7

Covariance matrix of estimation error

$$\sigma^2 = \frac{1}{N-1}\sum_{i=1}^{N}\left(f_i - \hat{f}_i\right)^2$$



Properties of Earth's atmosphere, NASA

Solar EUV irradiance

↓

Variability in the thermosphere **density** and **temperature**

↓

Atmospheric **drag** change

↓

Decay and following **re-entry**

→ Estimated via **atmosphere models**

↘

Require **F10.7 and F30** as a proxy for **solar input**

Specification of satellite orbits | Re-entry services | Collision avoidance | Modeling of space debris evolution