THE INFLUENCE OF SOLAR RADIATION AND ATMOSPHERIC CIRCULATIONS ON TEMPERATURE ANOMALIES IN WARSAW

Filip Kaczorowski

Thesis advisor: prof. dr hab. Krzysztof Markowicz,
Institute of Geophysics, University of Warsaw

UNIVERSITY
OF WARSAW

Climate and its changes in recent decades

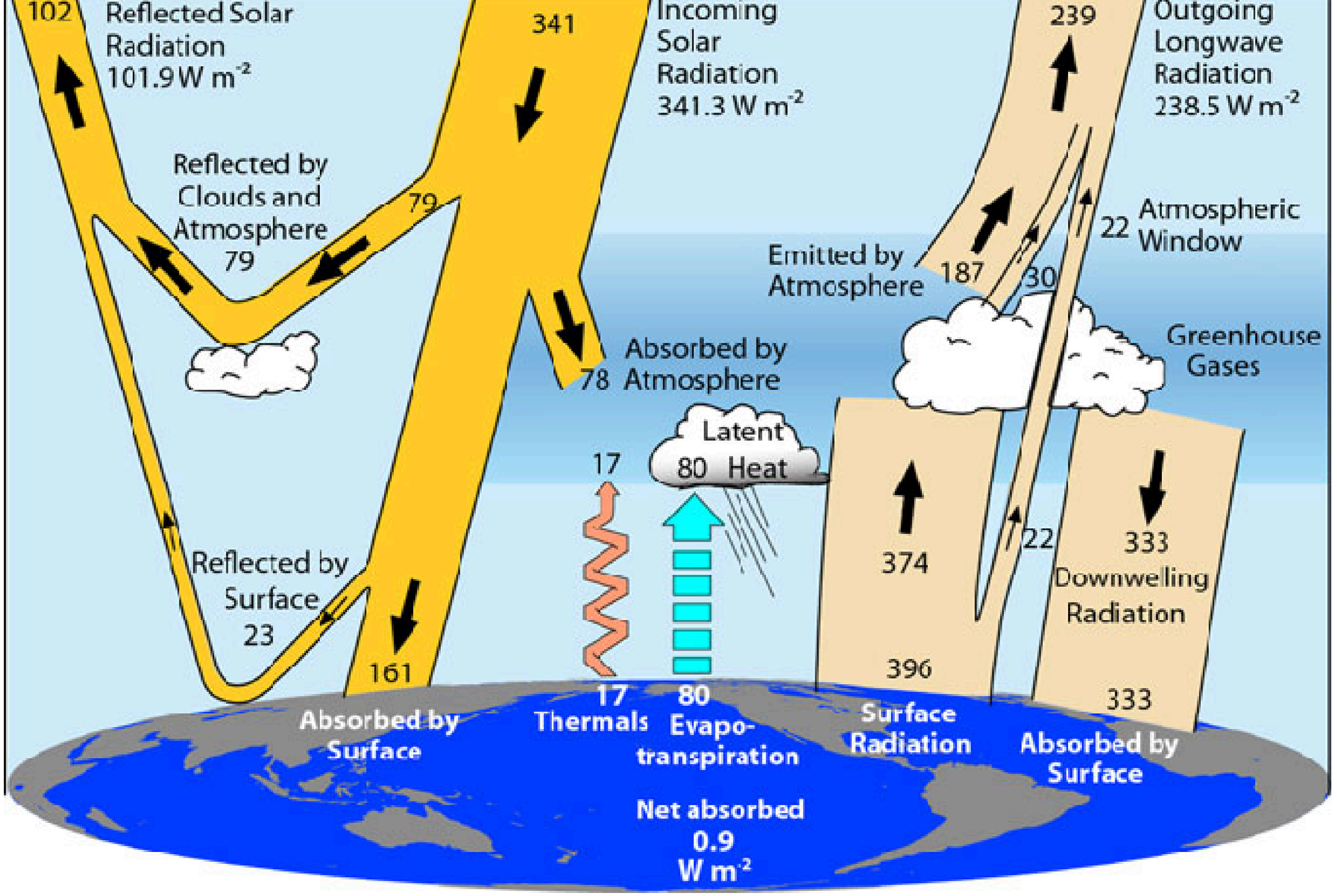
- Climate (geographic def.)- The characteristic pattern of atmospheric conditions for a given area, determined based on a minimum of 30 years of observations (atmospheric state statistics)
- The increase in the Earth's average temperature from 2011 to 2020 compared to 1850-1900 reached 1.0-1.1 degrees Celsius (1.59 degrees Celsius on land).
- Since 1970, the global surface temperature has been rising faster than in any other 50-year period in at least the last 2000 years.

Earth's energy budget

The Earth's energy balance is determined by the flux of solar radiation incident on and reflected by the atmosphere, as well as the longwave radiation emitted by the Earth's surface and the atmosphere. In conditions of ideal radiative equilibrium, the energy equation between our planet and the Sun would satisfy the following equality:

$$\pi R^2 F_o = \pi R^2 A F_o + 4\pi R^2 \sigma T^4$$

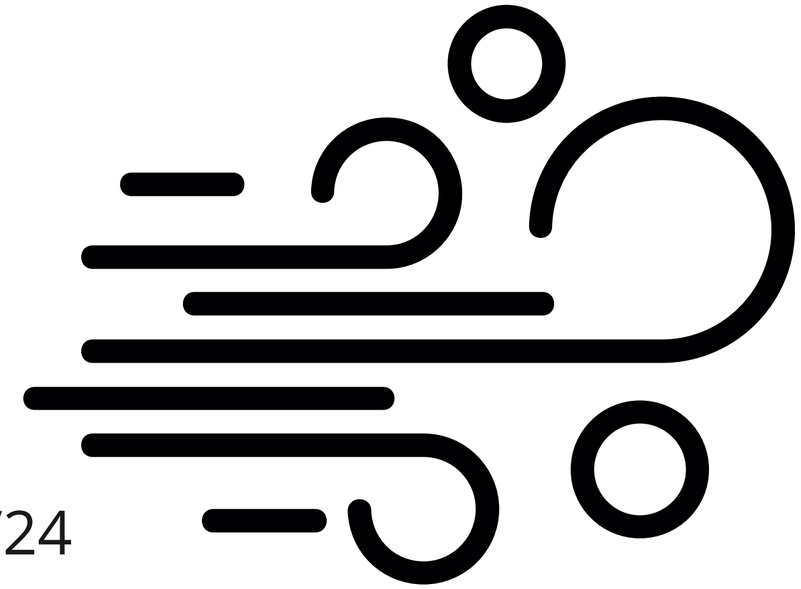
In the case of our planet, this equality is not satisfied due to the greenhouse effect, which results from the presence of greenhouse gases (such as water vapor, CO2 in the atmosphere, methane). Consequently, the Earth's energy balance is continuously increasing by about 0.9 W/m²

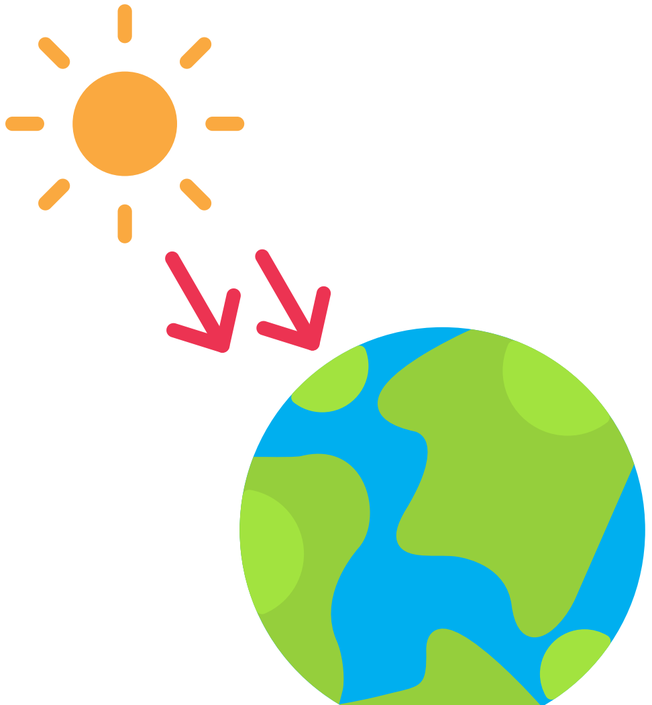

102
Reflected Solar Radiation 101.9 W m-2
341
Incoming Solar Radiation 341.3 W m-2
239
Outgoing Longwave Radiation 238.5 W m-2
Reflected by Clouds and Atmosphere 79
79
22 Atmospheric Window
Emitted by Atmosphere
187
30
Absorbed by 78 Atmosphere
Greenhouse Gases
Latent 80 Heat
17
374
22
333 Downwelling Radiation
Reflected by Surface 23
161
396
333
17 Thermals
80 Evapo-transpiration
Absorbed by Surface
Surface Radiation
Absorbed by Surface
Net absorbed 0.9 W m-2

[1]

Energy balance varies with latitude, primarily due to the distribution of radiation across the Earth's surface.

Atmospheric circulations are among the factors responsible for the distribution of thermal energy across our planet.



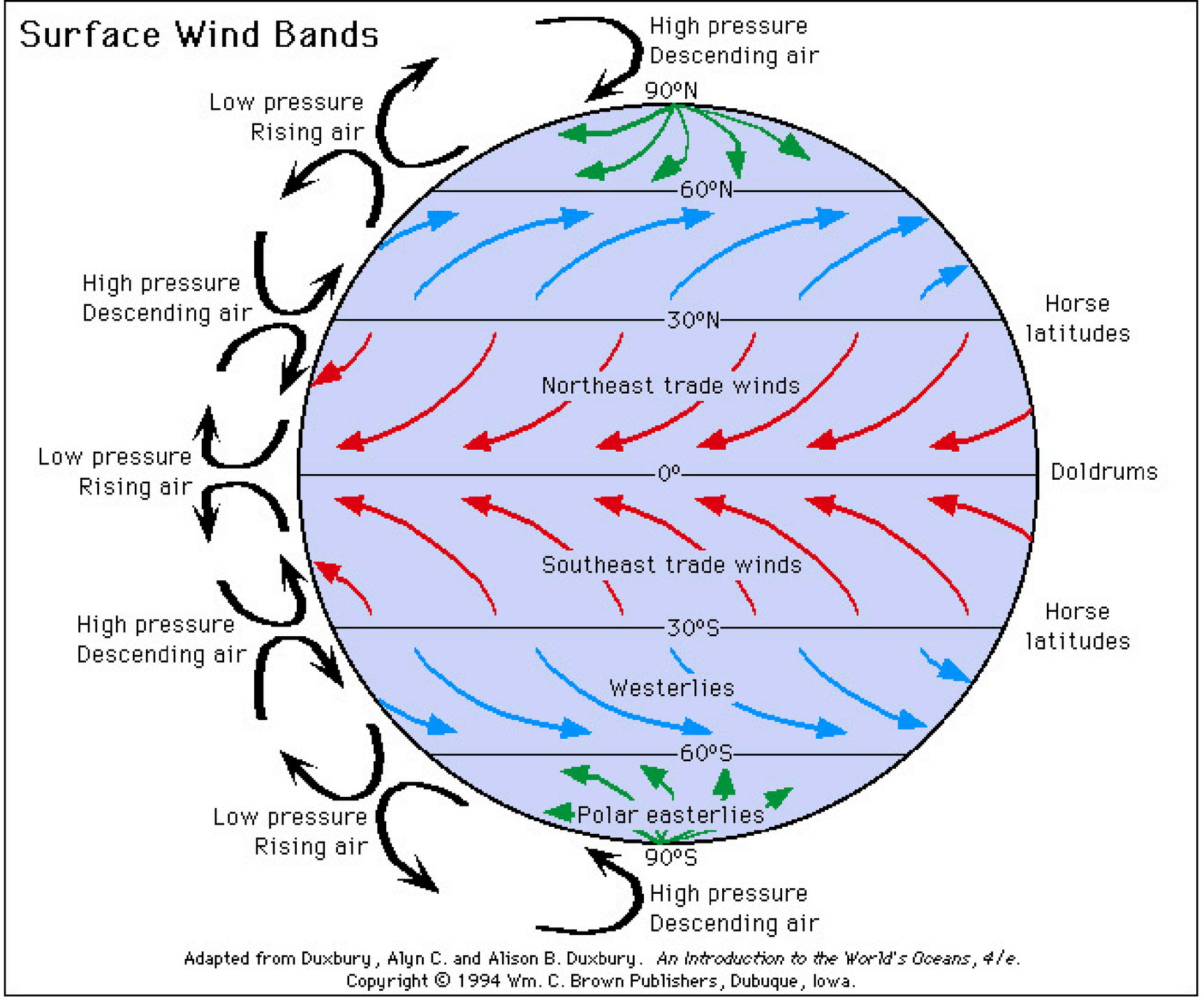


Atmospheric circulations

- The system of air currents over the surface of the Earth
- The cause of air circulation in the troposphere is the differences in heating of the Earth's surface, which depend on the Earth's illumination zones. These differences in surface heating result in differences in air heating.
- Convective currents cause the formation of high and low pressure systems. The pressure differences are the reason for the formation of wind.

Types of Circulation and Heat Distribution

- Hadley cells occur between the equator and 30° latitude both north and south. Warm air rises at the equator, moves toward higher latitudes, and then descends around the tropics, creating high-pressure zones
- Ferrel cells are located between 30° and 60° latitude in both the Northern and Southern Hemispheres.
- They cover areas from 60° latitude to the poles. Cold air descends at the poles and moves toward lower latitudes, where it rises around 60° latitude.


Surface Wind Bands
High pressure
Descending air
90°N
Low pressure
Rising air
60°N
High pressure
Descending air
30°N
Horse
latitudes
Northeast trade winds
Low pressure
Rising air
0°
Doldrums
Southeast trade winds
High pressure
Descending air
30°S
Horse
latitudes
Westerlies
60°S
Low pressure
Rising air
Polar easterlies
90°S
High pressure
Descending air
Adapted from Duxbury, Alyn C. and Alison B. Duxbury. An Introduction to the World's Oceans, 4/e.
Copyright © 1994 Wm. C. Brown Publishers, Dubuque, Iowa.

[2]

Since Poland is located near the boundary between the Ferrel and polar cells, it experiences significant weather variability. Sometimes, for example, the boundary of the polar cell shifts southward. When this happens, Poland is under the strong influence of Arctic air, which results in icy winters or cool summers.

Anomaly

- Deviation from the average (mean)
- The concept of anomaly is often used in climatology to analyze variability in weather conditions

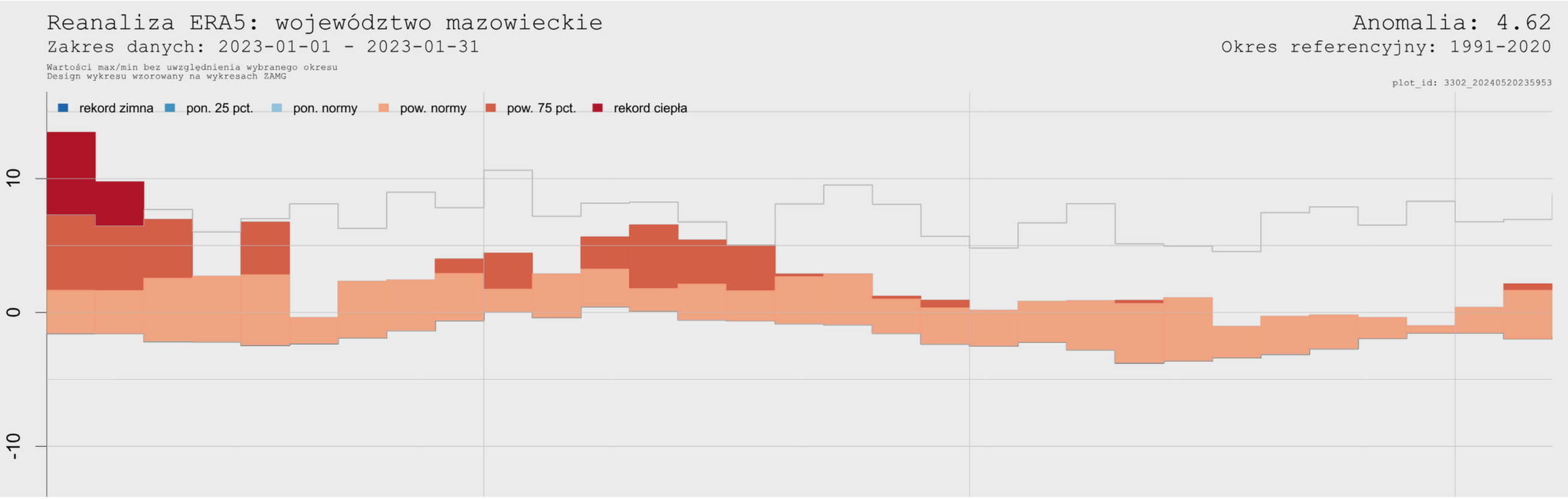
Do anomalies indicate climate change?

No, only when an anomaly persists over a sufficiently long period of time (about 30 years) can it indicate climate change

What causes air temperature anomalies?

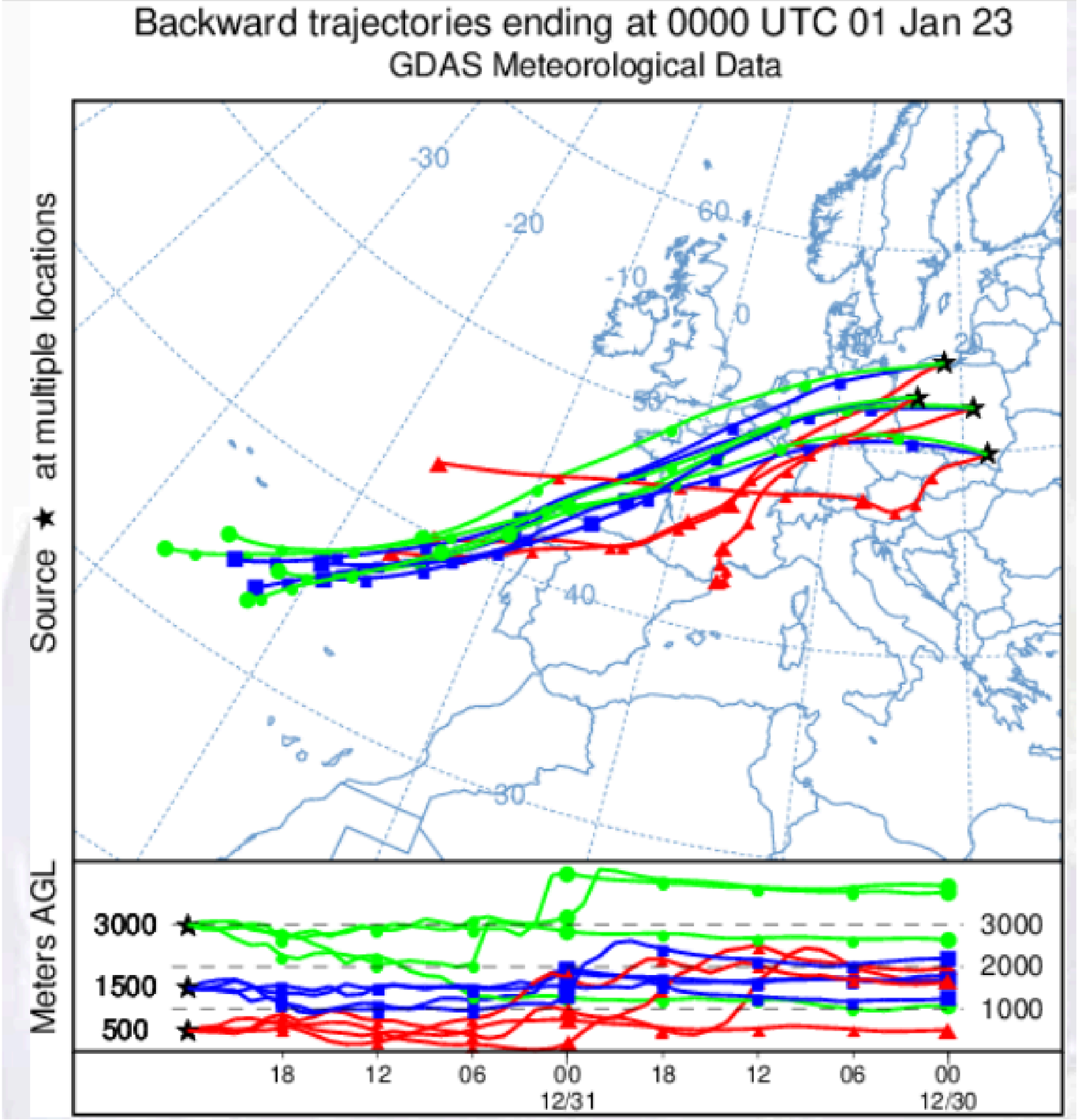
Changes in the energy budget (including solar radiation)

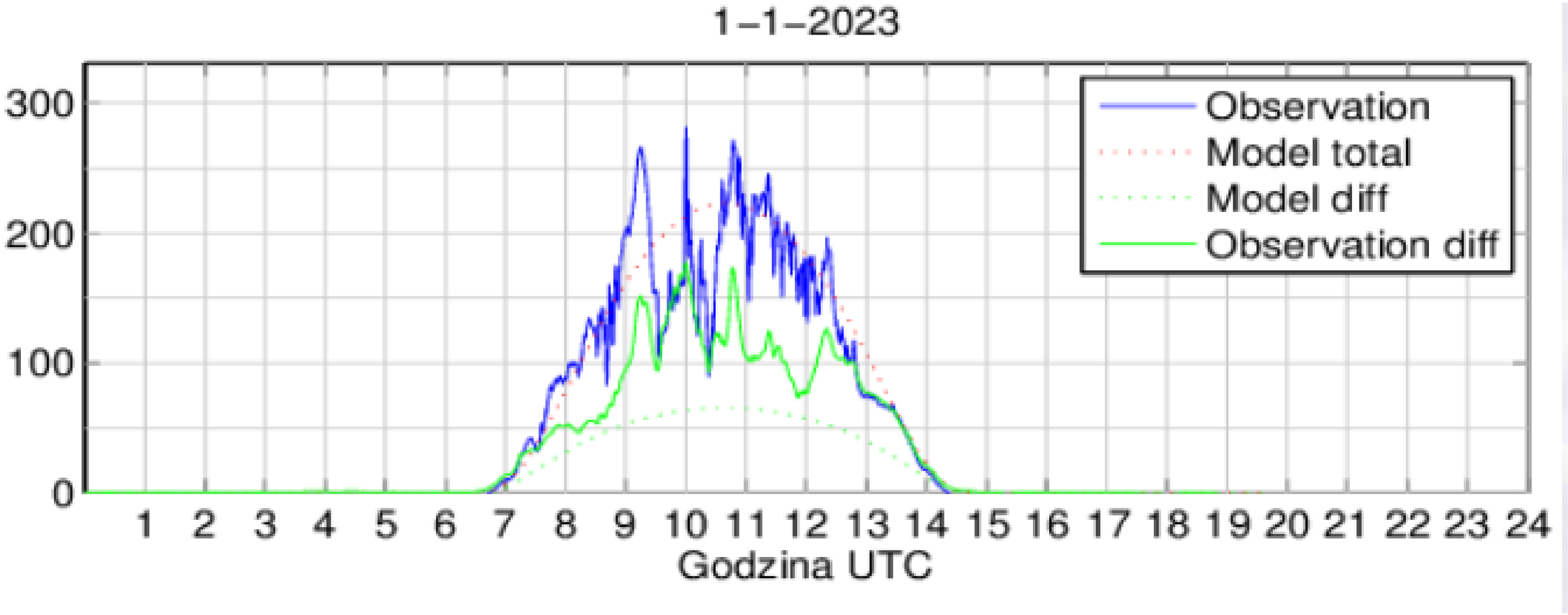
Changes in atmospheric circulation



On January 1, 2023, one of the more notable anomalies in recent years occurred; it was the warmest January 1st since at least 1940. This day is often referred to as a 'one-day summer

Back trajectory of air in Warsaw on January 1, 2023





The average solar radiation intensity on that day was 40.2 W/m², which is about twice the average temperature for January 1st over the past 15 years

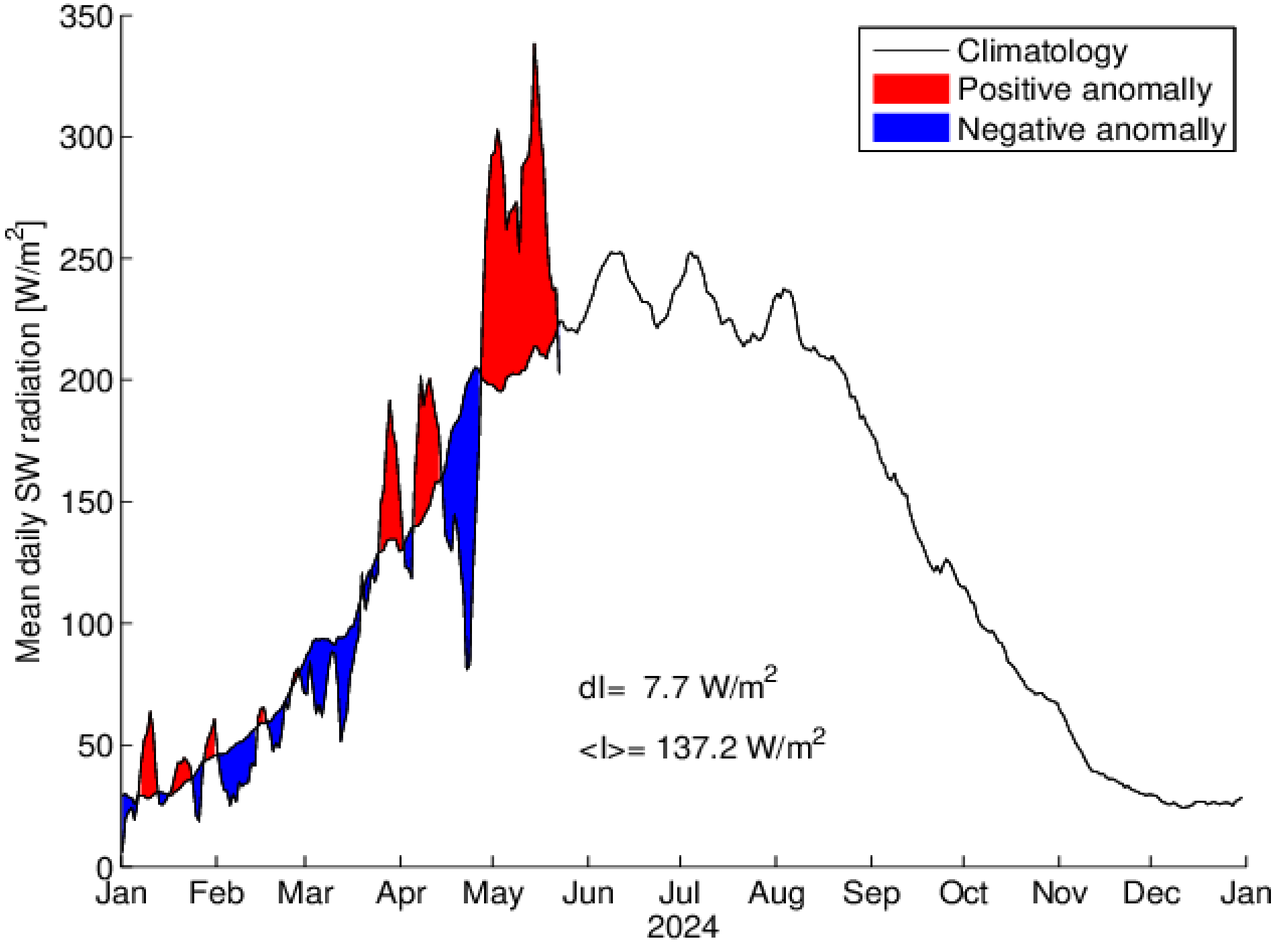
Radiative Transfer Laboratory

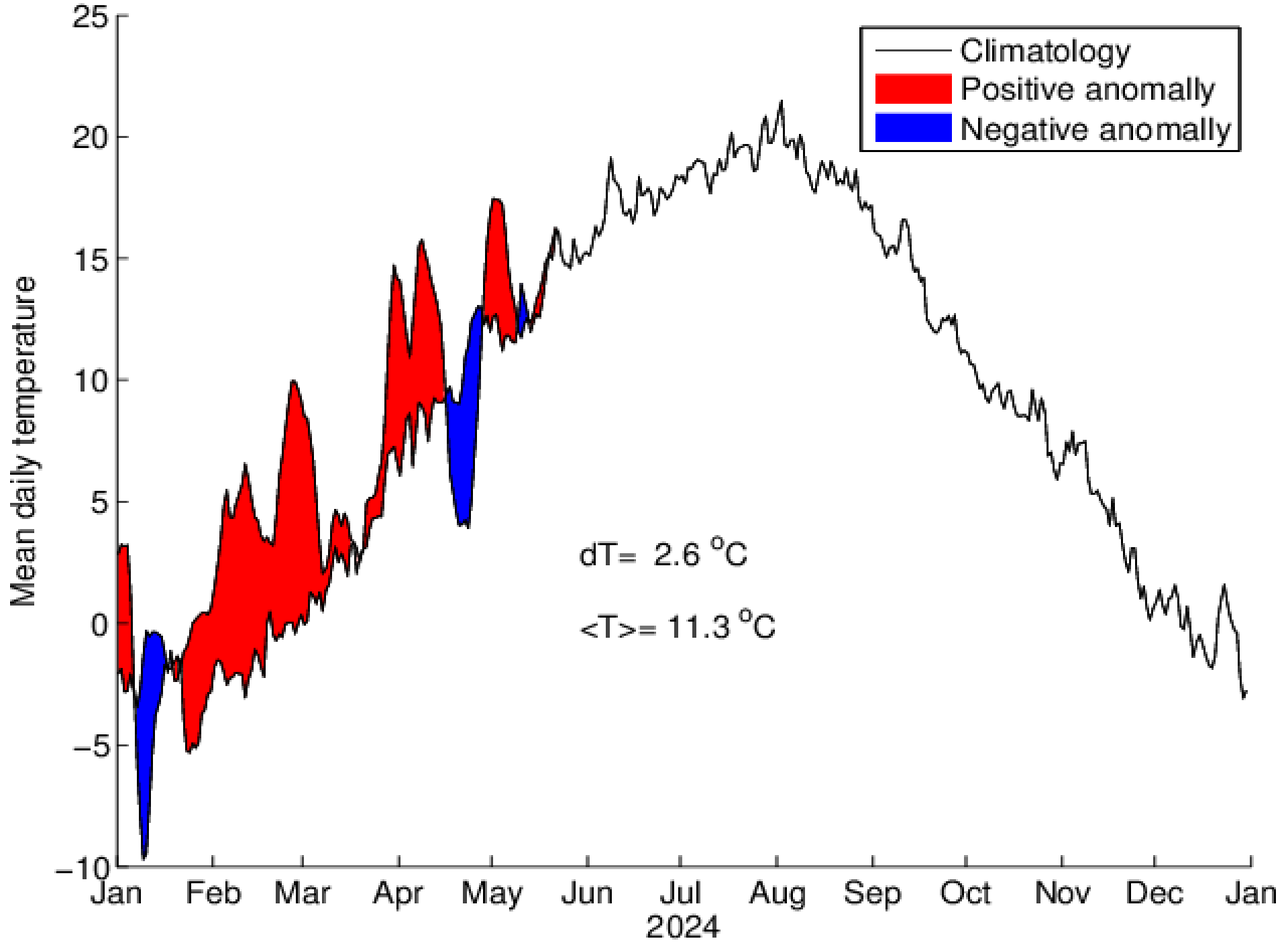
Experimental setup

Used measurement equipment:

- Weather station
- Radiation sensors
- Pyrgeometer

https://www.igf.fuw.edu.pl/pl/laboratories/laboratorium-transferu-radiacyjnego/





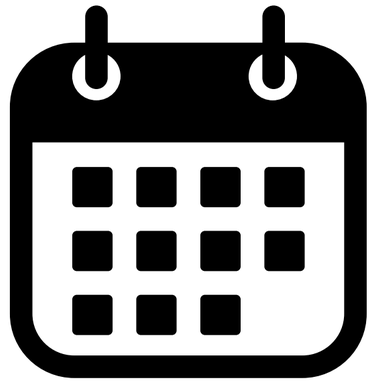
Graphs showing the intensity of solar radiation flux and temperatures, highlighting anomalies.

Data

The data I worked with include the exact date, the average temperature for that day, the average solar radiation intensity per unit area for that day, and the longitude and latitude of the air mass location 4 days prior to its arrival in Warsaw.

The data come from the period 2008-2023, totaling exactly 5844 days.
Unfortunately, some of the data contained errors, or measurements were not taken for certain days.

Ultimately, the analysis of temperature anomalies included data from 5777 days, which accounts for approximately 99% of all days.



Statistical analysis of temperature anomalies

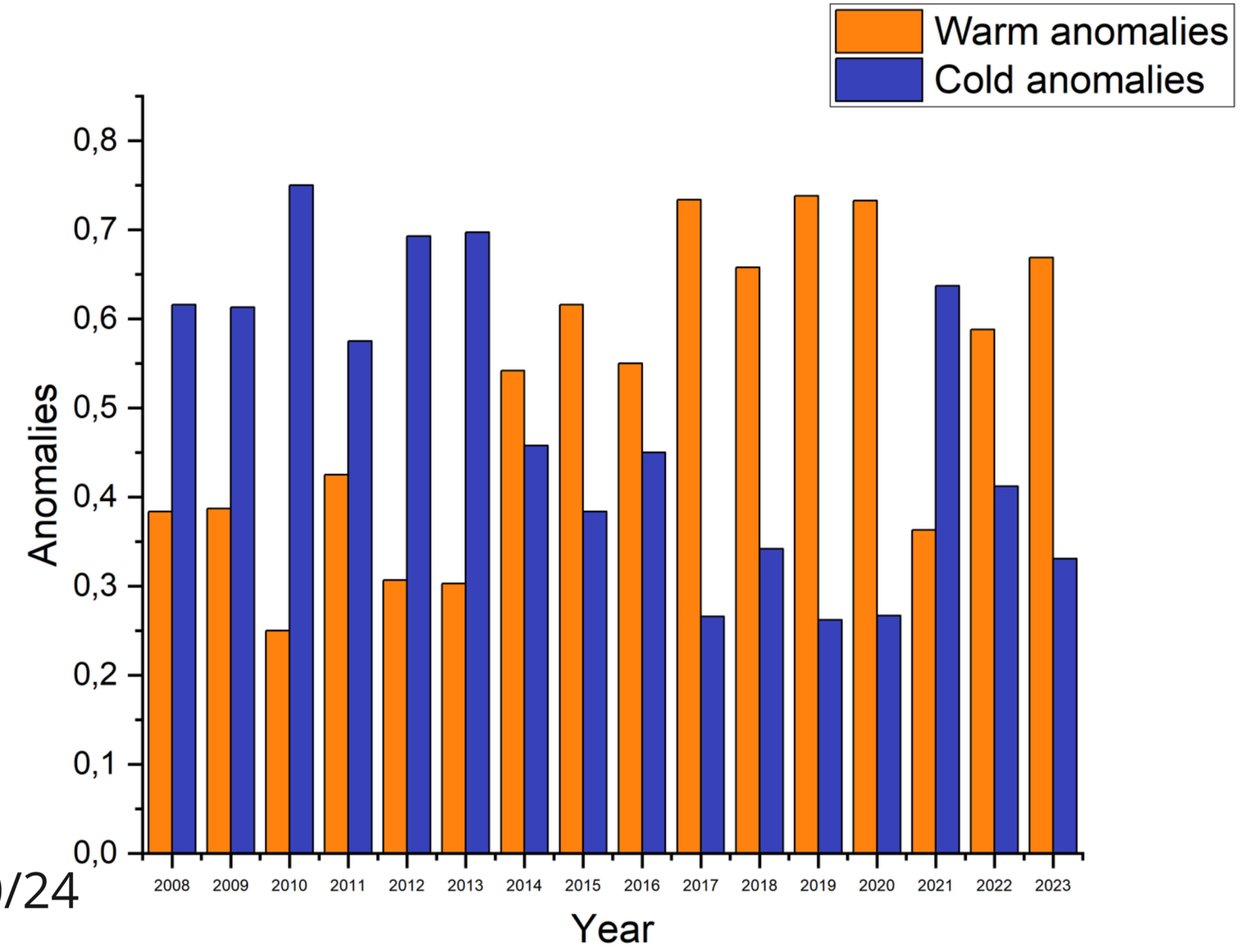
For the analysis of temperature anomalies, average temperatures and standard deviations were calculated for each day of the year. This approach was employed to provide a comprehensive understanding of temperature variations and to accurately identify anomalies.

Calculating the average temperature for each specific day allows for the establishment of a baseline against which deviations can be measured. By doing so, we can account for seasonal variations and ensure that the identified anomalies are not simply due to expected seasonal changes but represent significant deviations from the norm.

Frequency of anomalies

	Number of anomalies	Frequency (%)	WARM ANOMALIES			COLD ANOMALIES		
			WEAK	MEDIUM	STRONG	WEAK	MEDIUM	STRONG
SPRING	491	33,6%	30,1%	13,9%	5,1%	30,1%	14,7%	6,1%
SUMMER	501	35,1%	30,1%	13,2%	6,2%	32,9%	15%	2,6%
AUTUMN	486	33,4%	29,8%	16,9%	6,6%	27,6%	14%	5%
WINTER	430	30%	34,9%	9,5%	1%	22,8%	14,4%	17%

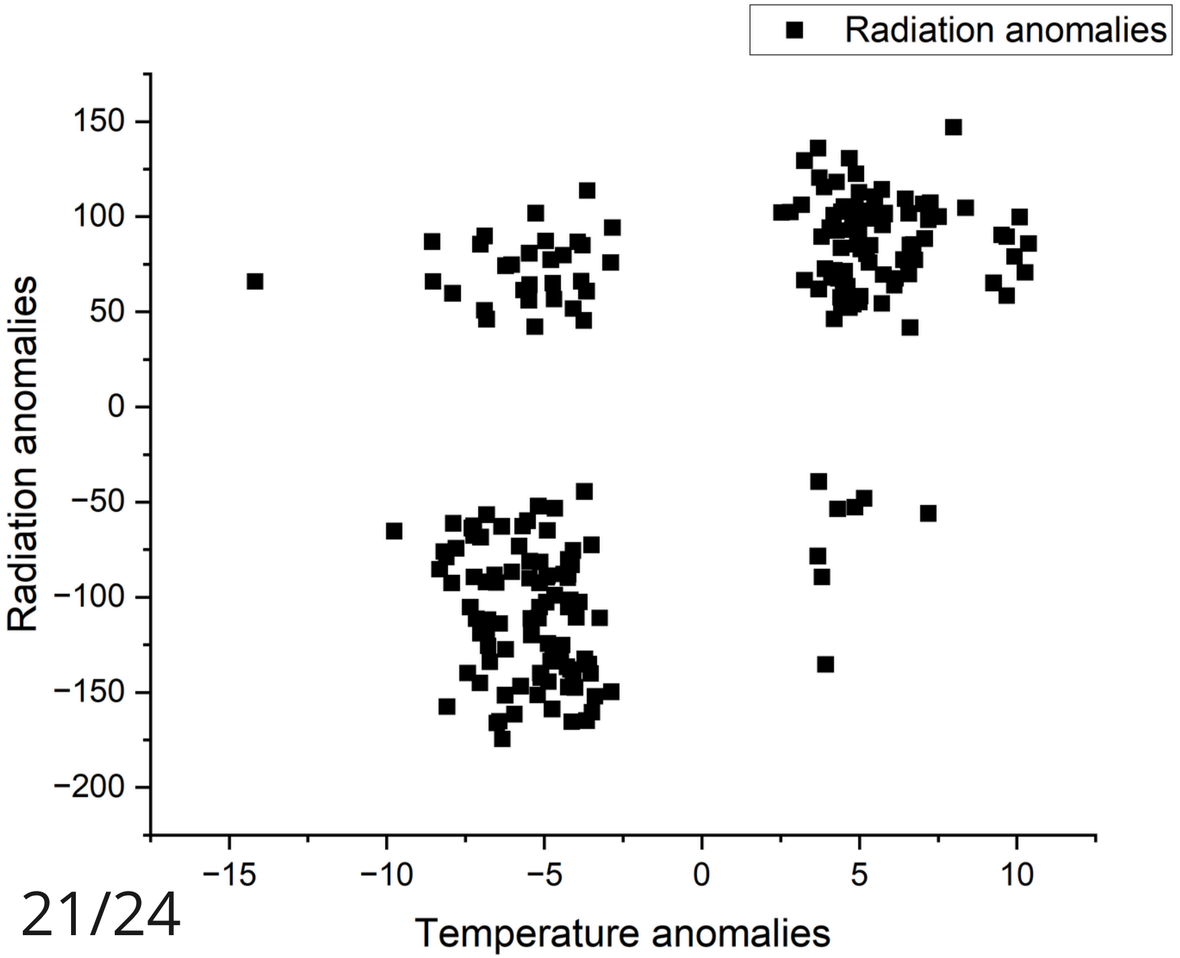
Types of anomalies over the years



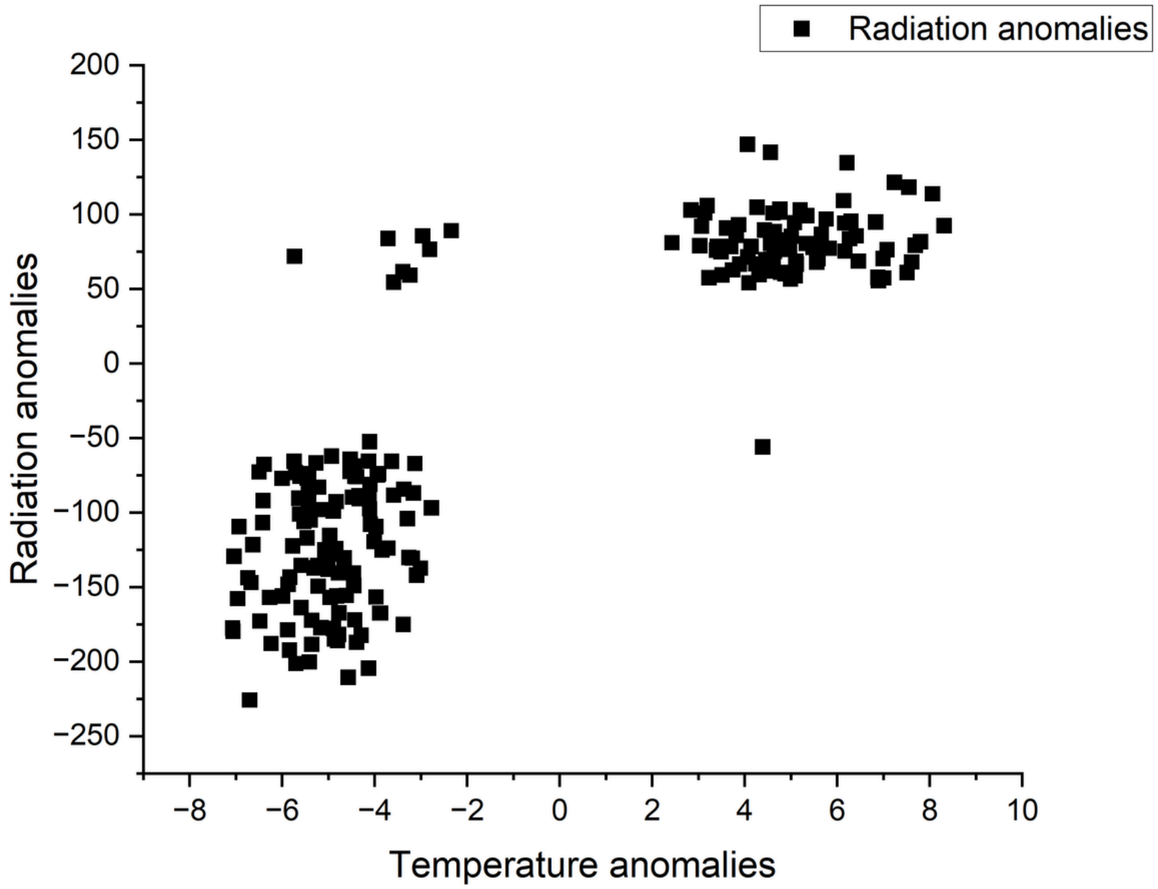
- General number of anomalies varies between 100-150 each year
- The number of warm anomalies (in opposite of cold anomalies) has been increasing in recent years
- The increased number of cold anomalies in 2021 was likely a result of the influence of the La Niña anomaly on weather conditions in Poland.

Temperature and radiation anomalies over the seasons

Spring

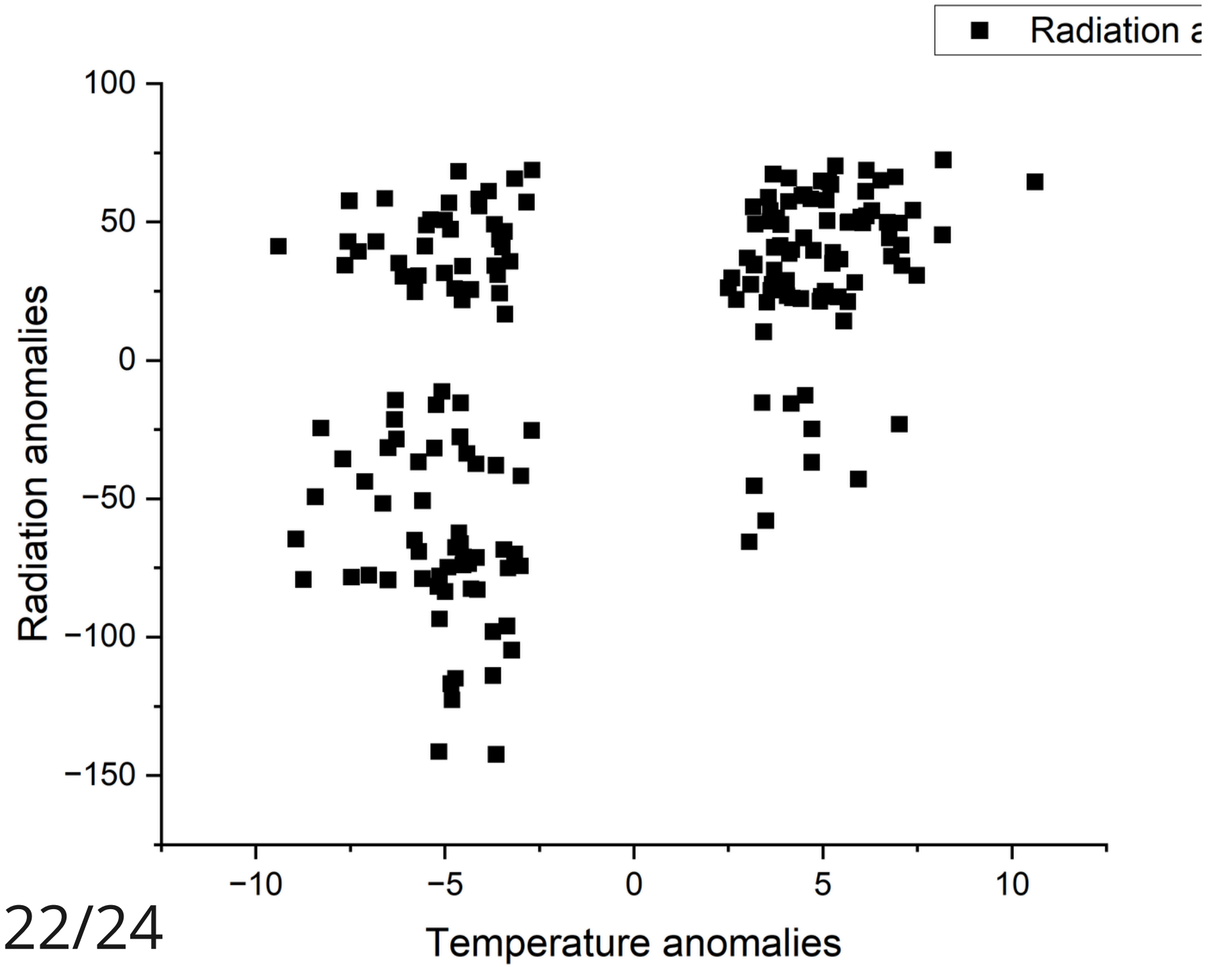


Summer

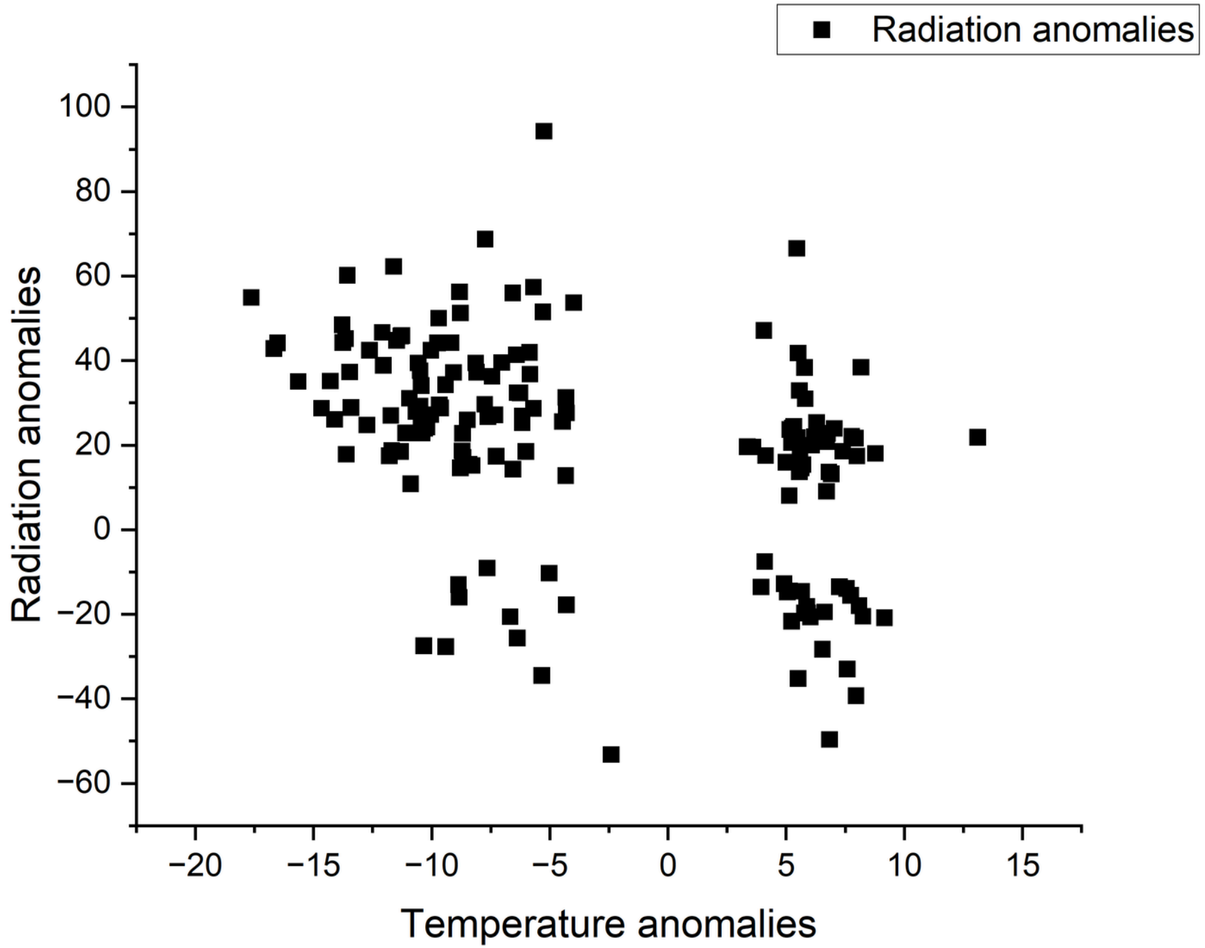


Temperature and radiation anomalies over the seasons

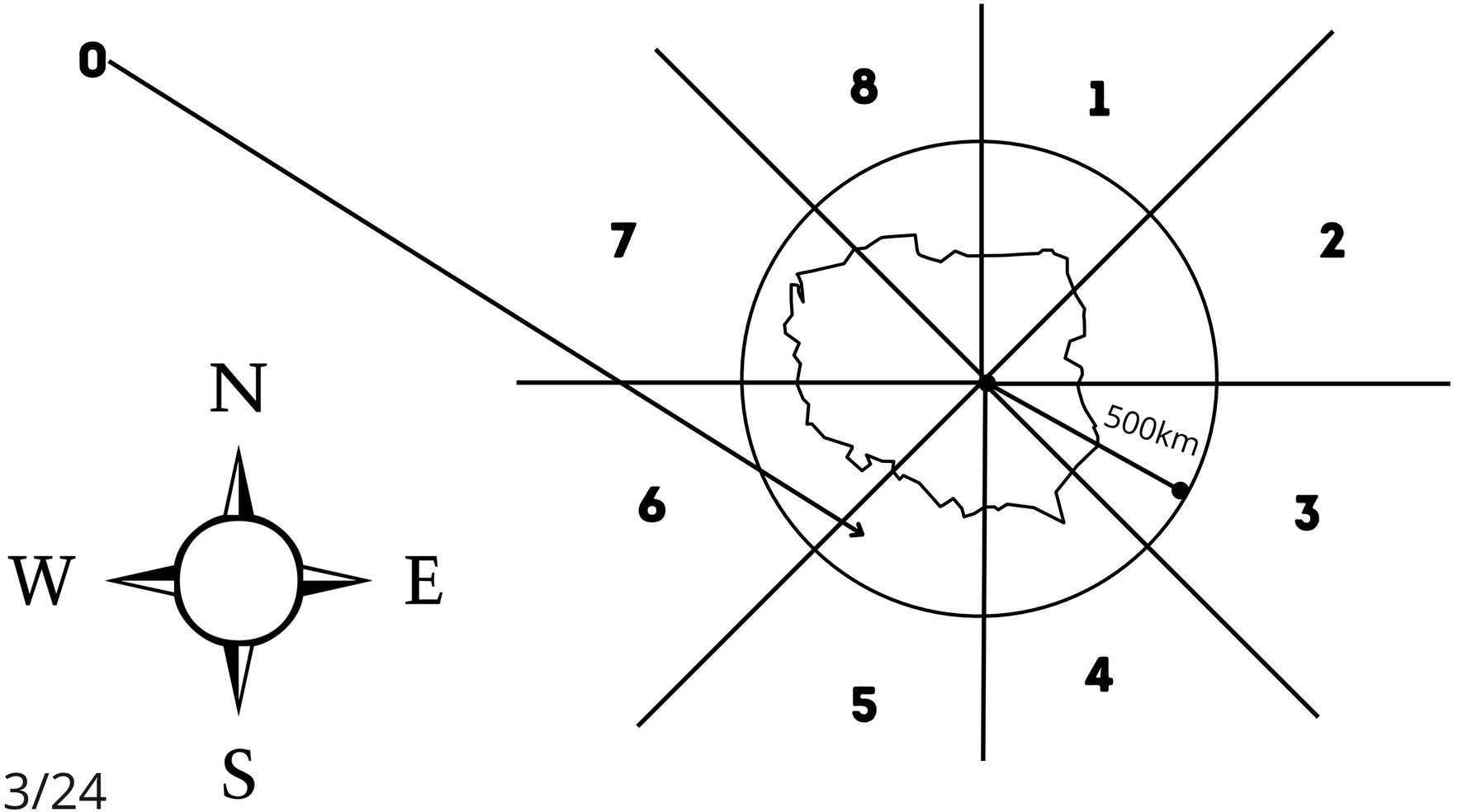
Autumn



Winter



The influcence of athmospheric circulations on temperature anomalies



Estimations

- Due to the relatively low solar radiation intensity and shorter days during the winter season and parts of autumn/spring, atmospheric circulations have a greater influence on temperature anomalies during these seasons.

- The occurrence of temperature anomalies in summer, due to higher solar radiation intensity and longer days, is strongly dependent on the level of solar radiation.

THE WORK AND DATA ANALYSIS ARE NOT YET COMPLETED, AND THE GOAL IS TO FIND A MORE PRECISE RELATIONSHIP BETWEEN THE PRESENTED PHENOMENA.

Thank you for attention!

[1]https://www.researchgate.net/publication/257564838_Tracking_Earth's_Energy_From_El_Nio_to_Global_Warming

[2]https://history.aip.org/climate/xGenCirc.htm