Blanford, J.I. (2025) Teaching material. Temperature variations across space and time: making statistics fun with geographic information and spatial analysis.

Title: Temperature variations across space and time: making statistics fun with geographic information and spatial analysis.
Author: Justine I. Blanford
Objectives: To make statistics fun with geographic information and spatial analysis

Cite: *Blanford, J.I. (2025) Teaching material. Temperature variations across space and time: making statistics fun with geographic information and spatial analysis.*
Further information: Blanford, J.I. (2025) Temperature variations across space and time: making statistics fun with geographic information and spatial analysis.

Background: Temperature affects many organisms in the environment. A variety of sensors are being used to collect a variety of information about our environment including temperatures. Sensors can be remote (e.g. satellites) or on the ground (e.g static (e.g. Meteorological Stations or citizens) or mobile (e.g. variety of mobile devices (e.g. citizens or transportation vehicles)). Since sampling can be expensive, we must identify the best place to put sensors to collect our data to ensure we are collecting a representative sample. During this project you will be learning about sampling, data and spatial analysis while learning about temperature. Temperature affects plants - where they grow and how quickly they grow; species behaviour and distribution (e.g. annual hummingbird migration or hibernation of plants and animals). Disease prevalence and distribution and health effects related to heat and rising temperatures. These are but a few examples. The aim of this class project is to make statistics fun with geographic information and spatial analysis while also learning about our environment.

Learning objectives:
- define the role of statistics and spatial analysis in the analysis of (spatial) data,
- able to take a scientific approach to collect, integrate and analyse data, and
- gain a deeper appreciation for temperature in the environment

By the end of this project students will be able to:
- collect data
- transform data from the real-world into digital geographic data
- conduct spatial and statistical analyses
- develop basic data handling skills
- develop basic GIS skills
- develop basic R skills
- apply these skills to analyse spatial data.

Prerequisite: High school maths. Elementary Statistics is a benefit. No prior GIS or R skills are needed.

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Software Requirements:

- GIS Software. The assignment is designed for use with ArcGIS Pro. If your school or university does not have a license available for use you can purchase a 1 year personal use license for $100/year. Prices will vary. The software can be purchased from the link provided.
  Link: **ArcGIS Pro Student/Personal use license**
- Statistics Software. The assignment is designed for use with R/R Studio. R/R Studio is open software that can be obtained from the link provided.
  Link: **R/R Studio Software**
- Spreadsheet. The assignment is designed for use with Microsoft Excel but similar functions are also available in Google Sheets. Microsoft Excel if not available through your university can be purchased for about $100/year. Prices will vary.
  Link: **Blanford_2025_Parton_and_Logan_1981_model.xlsx**

Teachers or Students: Teachers or students without prior GIS skills review the videos on YouTube (Table 1), without prior R/R Studio skills review the videos on YouTube (Table 2), without prior Excel skills review the videos on YouTube (Table 3).

Table 1: Video series to learn GIS and get familiar with ArcGIS

Video	Description	Total Time	Link
Intro to ArcGIS Pro	Learn the essentials about ArcGIS Pro	3:58 6:35 3:52	https://www.youtube.com/watch?v=bmjDQ2mvGII https://www.youtube.com/watch?v=h3EozDlYHrI https://www.youtube.com/watch?v=JNtoAoiMmUU
Overview of GIS	Module 100: Overview	5:20	https://www.youtube.com/watch?v=I7a42ZU3cXw
Intro to Spatial Data 1-5	Module 110: Spatial Data 1-5	2:32 2:40 4:21 6:49 2:29	https://www.youtube.com/watch?v=WeAgkF-HX-s https://www.youtube.com/watch?v=JpNh9a8z5AY https://www.youtube.com/watch?v=lDFdc3QIpns https://www.youtube.com/watch?v=N7P4YltaIEs https://www.youtube.com/watch?v=N7P4YltaIEs
Intro to Visualisation and Cartographic Visualisations	Module 120: Visualisation Part 1	3:11	https://www.youtube.com/watch?v=XCtNMosgaAg
Intro to Spatial Analysis	Module 130: Spatial Analysis	4:34	https://www.youtube.com/watch?v=SlIKjV1bCZY

Other sources for GIS learning can be found at Esri.

Students without R skills: Students without prior R Studio skills review the videos on YouTube @Justineblanford2030. These provide a quick introduction to R Studio (Table 2).

Table 2: Videos to learn R/R Studio

Video	Description	Total Time	Link
Intro to R Studio	Learn the essentials about R	5:38	https://youtu.be/qL_38YRXJIE

Students without Excel skills: Students without prior Excel skills review the video on YouTube @justineblanford2030 to get a quick introduction to essentials for Excel (Table 3).

Table 3: Videos to learn Excel

Video	Description	Total Time	Link
Intro to Excel	Learn the essentials about Excel	2:27	https://youtu.be/Rogy-w0U_aQ

Data needs:
All data needed for this project, except for the data collected during the project, is available in the public domain (Table 4).

Table 4: Summary of data used and collected during this project.

Data	Description	Source and URL
Daily Minimum and Maximum temperature	Daily minimum and maximum temperature Meteorological Stations data around the world.	World Meteorological Organisation (WMO): https://www.ncei.noaa.gov/maps/daily/
Land Surface temperature	Land surface temperatures	https://neo.gsfc.nasa.gov/
Administrative Boundaries	Administrative boundary information for countries around the world. The level of administrative boundaries varies for each country but can range from Admin Level 0 (country boundary) to Admin level 3.	GADM https://gadm.org/
Various basic information	Volunteered Geographic Information. A variety of information about a place can be obtained from OSM. Data includes Transportation (roads and other transportation networks), Land use, Points of Interest, Buildings, waterways, and more	OSM via Geofabrik: http://download.geofabrik.de/
Elevation	Elevation	Copernicus https://spacedata.copernicus.eu/collections/copernicus-digital-elevation-model
Land use	Global land use	ESA https://worldcover2020.esa.int/
Temperature data (hourly)	Hourly data from past projects	https://github.com/jb2018/geo_temperature

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Background

Temperature affects many organisms in the environment. Sensors are being placed throughout our environment to collect temperature information. Since sampling can be expensive, we must identify the best place to place a sensor to collect our data to ensure we are collecting a representative sample. During this project you will be placing temperature loggers in the environment and collect data for about 1 month. After a month you will analyze the data and create a continuous temperature surface for the study area. To accomplish this you will work through a set of questions. At the end of the project you will provide a final written report of your findings that will include maps, statistical analysis and a summary of the framework you used. The project has been broken down into several five parts (1-5) (Table 5).

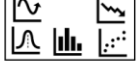
Each part contains a series of question that you will need to answer based on the analysis of the data. As you write up and answer these sections, you will be creating the final report for this project. Ensure that each section is written in a comprehensive manner. Each section will be completed as data becomes available.

During the project you will also be applying what you learn in class. You will be using a variety of statistical and spatial analysis methods as detailed below.

- Descriptive statistics will be used to understand what data has been collected, summarize data, and assess error.
- Spatial analysis will be used to visualise the data across spac, create continuous surfaces, evaluate sampling distribution and to make comparisons.
- Modeling methods to explore model fitting and predictions.

GIS, Statistics and Data Science are important for analysing these data. During this course you will learn about the different spatial analysis and statistical methods that can be used to analyse real-world data such as temperature. The topics covered are summarized in Figure 1.

Figure 1. Overview of GIS, statistical and spatial analysis methods components covered during the course.

Data Capture, Create  **Data Engineering** Transform, clean, enrich data 	**Data Collection** Sampling & Spatial Sampling Point, line, area Systematic, Random, Stratified Stratified-systematic, Stratified-random Data Acquisition Finding data	**Data Reporting and Management** Data Fields and Attributes Projections – Map coordinate systems Managing spatial information Data structuring and organisation	**Data Engineering** Data fusion and integration Data wrangling Data conversion Data Grouping/Aggregation Working with data from various sources.
Visualisation and exploration 	**Data visualisation** line graphs, bar graphs, histograms/ frequency graphs, divided bar graphs, pie graphs, flow diagrams, radial graphs and wind rose graphs, scatter graphs, triangular graphs Boxplots, violin plots	**Cartographic visualisations** Cartographic representation, symbology, Key design principles - legibility, visual contrast, figure-ground organization, hierarchical organization, and balance.	**Data Exploration** Interact with data Explore attributes Explore data ranges, data errors, data uncertainties, outliers, missing information Data summaries
Data Analysis Statistical Analysis of the data  **Spatial Analysis**  **Domain Area** 	**Basic statistical methods** mean, median, mode, ranges, variance, standard deviation, confidence intervals; standard error of the mean Data distributions, outliers **Statistical inference & hypothesis** t-test Chi-square Correlation Regression (linear, multi-linear)	**Spatial Analysis** **Measurement** – distance between stations **Topological analysis –** adjacency, proximity, within, neighbour **Surface analysis** – Interpolation of temperature to create continuous temperature surface; compare and contrast temperatures **Spatial Statistical analysis** – Point Pattern Analysis of Samples, Kernel Density Estimates, Nearest Neighbour Analysis	**Trends in the data** **Comparisons between data** **Models: prediction, forecasting** Working with models Parton & Logan, 1981 Model for hourly temperature predictions

Overview of the Project.

Table 5: Overview of the project with a breakdown of the tasks associated with each of the five parts.

Part	Data	Description	Tasks
1.0	**Data Collection**	Data sampling, collection and logger placement	
1.1		Data sampling and collection	• Discuss design data collection: discuss where to place the loggers • Discuss sampling: Explore sampling regimes and determine what sampling regime will you use? • Where to place the loggers, what temporal interval to collect the temperature loggers (e.g. 5s to hourly or daily) and for how long (1 week, 2 weeks… 4 weeks). • Capture where loggers were placed.
2.0	**Data Management**	Data collection, documentation and management of logger data	
2.1		Data management, open science and reporting	Data Management, Sharing and Reporting. • Record the data in a central spreadsheet. • Describe how you recorded the location of the logger. • Describe why you placed the loggers where you did.
2.2			• Retrieve the loggers and document issues, errors or challenges. • Clean and organise the data. Quality check the data • Data Sharing • Examine data and deal with missing data, data errors, integrate data from each of the loggers.
2.3		Map the location of the loggers	• GIS – Create a map of the loggers and label the loggers. Examine the spatial distribution of the loggers.
3.0	**Data analysis I**	Data preparation, exploration and analysis	
3.1			• Prepare data for analysis. • Create data summaries and aggregate data (hourly, daily and monthly)
3.2		Statistical Analysis of the temperature data for the locations your group collected	• Statistical Analysis – conduct various descriptive analysis (minimum, maximum, range, mean, variability) on the data your group collected. • Assess the temperature trends during the data collection period. Did temperatures change during the study period? • Discuss what you found (only discuss the loggers you collected).
3.3		Analyse the temperature data using all of the data	• Data handling – combine all of the temperature data collected by all of the groups.
3.4		Spatial Analysis of the temperature data using all of the data spatially	GIS – create a continuous temperature surface using an interpolation method. • What was the minimum/maximum temperature? • Assess where the coldest and hottest locations were. How different were the temperatures between the hottest and coldest locations? • What factors may have influenced these differences, if any? Did you take additional data into

			consideration when examining differences in temperature?
4.0	**Data Analysis II**	Comparing temperatures with other data sources and predicted modeled values	
		Meteorological Station	• How different/similar were the temperatures you collected when compared with those from the nearest Met Station? • Where was the closest Met Station (calculate distance). • When you compared the differences in temperature from the loggers and the met station what was the overall difference?
4.2		Comparing temperatures with other data sources – Remotely sensed data	• How different/similar were the temperatures you collected with the land surface temperatures?
4.3		Exploring models to predict temperature	• Discuss models. Why create a model for predicting temperature? • Predict hourly temperatures using the Parton & Logan (1981) Model. Describe what this model does and how it works. • Predict temperatures. Using the spreadsheet provided, predict hourly temperatures using minimum and maximum temperatures. Were you able to find a good fit for the temperature data? What were the final model parameters that you settled on? What limitations are there with using this model? • Calculate the RMSE between the observed and predicted data.
5.0	**Reflection**	Discussion and conclusion	
5.1		Reflect on the analysis, process and what you would differently	Discussion and conclusions highlighting limitations, challenges and future work. • If you had to do this again is there anything you would change? How might you place sensors in the environment in you had to do this again? What were the limitations of this study? • What problems, if any did you encounter? • What did you like most about this exercise? • What did you like least or most challenging about this exercise?

Part 1 – Data planning, sampling and collection

1. **Geography and temperature.** Review a map of the study area. Discuss the geography of the study area. What features may be present and how, if at all, do these features affect temperature? Where to place the temperature loggers in the environment?
2. **Distribution and placement of temperature loggers.** Examine Figure 2. Following on from the discussions what sampling method is appropriate? What factors are you considering in your placement? How many loggers would you like to place?

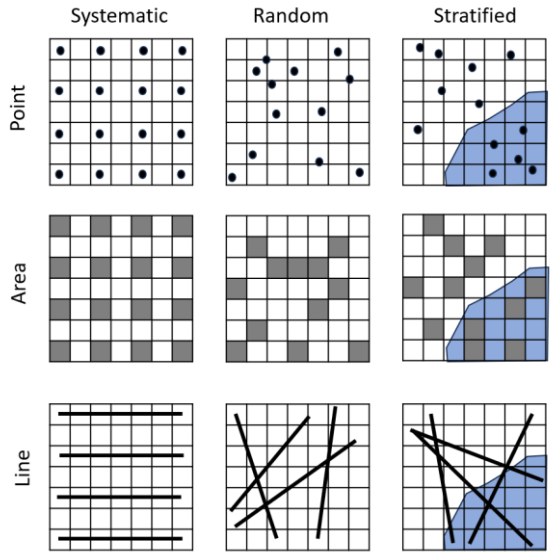


Figure 2: Vary of sampling strategies that can be considered based on points, areas or lines. Image created by Blanford (2024).

Part 2 – Data Management

Finalise the discussion of the placement of the loggers. Place the loggers in the field and write up what you did and capture information about the sensor and the environment in which it was placed.

1. Describe what sampling regime you used and why?
2. Describe how you captured the latitude and longitude for the location of the loggers.
3. Create a map of the spatial distribution of the loggers in the study area.
4. Label the loggers on the map for your group.

Once you have placed the loggers in the field capture the location (latitude and longitude) of where the logger was placed. Include some additional descriptive information about the logger as captured in Table 6. An excel sheet has been created and a link will be provided for you to add the data for your group.

Table 6. Overview of the spreadsheet with the columns where you will be capturing the information.

Group	Logger id	Description of location (or insert picture)	Sun / shade	Height above ground	elevation	Lat	Long	No days	Dates	Interval (mins)
										30
										30

Once each group has completed Table 6, create a map capturing the distribution of the loggers in the study area. Describe what you did to transform and map the data and include any challenges you faced and how you resolved these. Once everyone has created this map we will discuss the spatial distribution of the loggers in class.

Data Retrieval and Preparation

After a month, collect the loggers from the field. Download, organise and prepare the data for analysis. In this part you will organise the data and prepare it for analysis.

1. Retrieve loggers.
2. Download the data and check the data values.
3. Organise the data for statistical and spatial analysis (Part 3)
4. Describe what you did to prepare the data for analysis. Include any challenges you faced. Report any errors in the data.

Part 3 – Data analysis I

In this part you will analyse the data using statistical and spatial analysis methods.

1. Conduct descriptive statistical analysis of the data (Q1-Q2)
2. Conduct spatial analysis of the data (Q3.-Q4)

Statistical analysis of the temperature data for your group.

- **Q1. Descriptive statistical analysis of temperature**. For each station you collected data for, calculate the average temperature recorded, examine the minimum and maximum temperature and the range in temperatures. Create a graph to show the temperatures and range of temperatures collected. How much did the temperature change, did you notice any trends in the data?
- **Q2. Variability.** How much variability occurred during the time the data was collected for your sites?

Spatial analysis of the temperature data using all of the data.

- **Q3.Temperature surface for the study area.** Create a continuous temperature surface of the mean temperature using all of the data loggers collected by the class? Where was the coldest/hottest location? Describe factors that might influence these differences?
- **Q4. Descriptive statistical analysis of temperatures.** What was the minimum/maximum and mean temperatures? What was the range in temperatures? How different were the temperatures between the hottest and coldest location?

Part 4 – Data Analysis II - Comparison of local temperature data with other nearby locations, other data sources and modeled predictions

For this part you will compare the temperature data you collected with the loggers with the temperature data collected from different sources.

1. Describe what you did to prepare the data to conduct the comparative analysis. Include any challenges you faced.
2. Conduct comparison analysis – logger and Meteorlogical Station temperature data (Q5)
3. Conduct comparison analysis – logger and Land Surface temperature data (Q6)
4. Explore temperature modeling and predict hourly temperature using the Parton & Logan (1981) model (Q7)

Q5. Comparison of logger and Meteorological Station temperature data. Compare the temperatures collected using the loggers and the closest Met Station. Describe what you did to compare the logger data with the Met Station data.

- How different/similar were the temperatures you collected when compared with those from the nearest Met Station?
- Where was the closest Met Station (calculate distance).
- What was the overall temperature difference between the loggers and Met Station? (data will be provided and obtained from (https://www.ncei.noaa.gov/maps/daily/)

Q6. Comparison of logger and Land Surface Temperature (LST) data. Compare the temperatures collected using the loggers with the LST. Describe what you did to compare the logger data with the LST.

- How different/similar were the temperatures you collected with the LST?

Q7. Predicting hourly temperatures (optional). Collecting and sampling data from a variety of locations is costly therefore being able to predict temperatures can be useful. Parton & Logan (1981) developed a model that can be used to predict temperatures. During this exercise you will use this model to predict temperatures and compare how similar the predictions are to the logger data.

- Read the paper (link provided below) to learn about the model.
- Discuss how it works.
- Use the Parton & Logan (1981) model to predict hourly temperatures for 30 hours. An excel spreadsheet will be provided. **LINK** - https://github.com/jb2018/geo_temperature
  The paper can be accessed **LINK -** https://doi.org/10.1016/0002-1571(81)90105-9.
- Were you able to find a good fit for the temperature data?
- What were the final model parameters that you settled on?
- Calculate the error between the observed and predicted data.
- What limitations are there with using this model?

Reference

Parton, W. J., and J. A. Logan. 1981. "A model for diurnal variation in soil and air temperature." *Agricultural Meteorology* 23:205-216. doi: https://doi.org/10.1016/0002-1571(81)90105-9.

Part 5 – Reflection

In this section discuss your findings and conclusions and reflect on the process, highlight limitations and challenges you encountered. Lastly reflect on the project itself and what you liked or found challenging.

Q8. Discussion and conclusion. Capture what you found out about temperatures in your study area.
Q9. If you had to do this again is there anything you would change? How might you place sensors in the environment in you had to do this again?
Q10. What challenges or issues did you encounter during the data collection and analysis, if any?
Q11. Were there any limitations associated with this study?
Q12. What did you like most about the project?
Q13. What did you like least / challenging about the project?