# 3D Printing the Weather
Guide for Teachers

Overview

The Central England Temperature (CET) data record, the longest instrument record of temperature in the world, is held by the Met Office. This data includes the average monthly temperature each month from January 1659 to December 2018.

This project and the accompanying resources allow you to create 3D models that will represent 10 years of temperature data. These can be consecutive years or consist of any other year grouping. In addition to this the models have been designed to interlink, so students can create a series of models to represent larger timeframes. Once the 3D models have been created and 3D printed, you will have a tactile resource that you can use in multiple ways in your classroom to visualise and study the weather and climate.
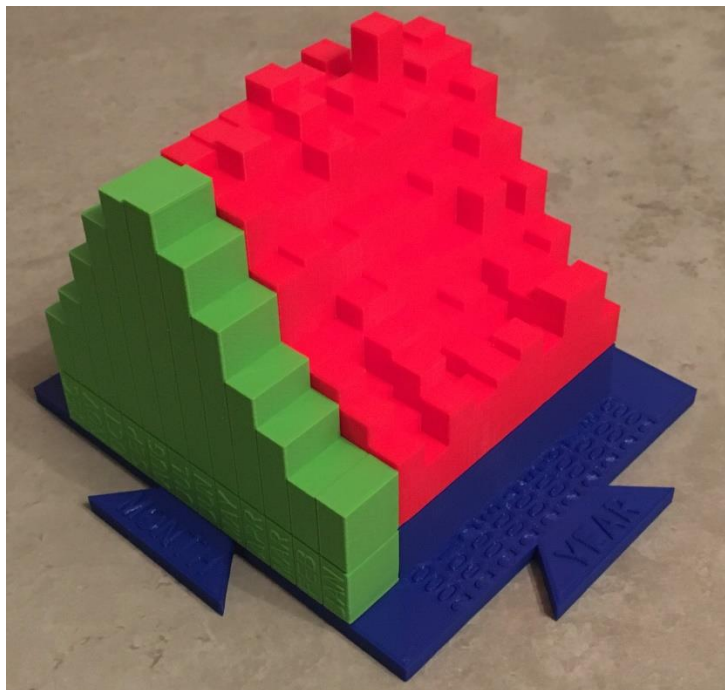
Alongside the 3D modelling resources, the Royal Meteorological Society have created a series of lesson ideas for using the models to study the temperature, climate and climate change.

The project will consist of the following stages:

- Stage 1: Introduction to the project (2 lessons)
- Stage 2: 3D modelling (2 lessons)
- Stage 3: Slicing and 3D printing (1 lesson)
- Stage 4: Studying the weather (as required) – A series of lesson ideas have been provided as part of the project resources. Please ensure that you review these lesson ideas before designing the models as for some activities, data from specific time periods are required for the models.

Project Resources

In addition to this teacher guide, the following resources are available to support this project, these are all available to download at the project resource page at www.createeducation.com/resource/3d-printing-the-weather

- **Central England Temperature Data Set**
  This is a spreadsheet containing the average monthly temperature data from January 1659 to December 2018. The spreadsheet contains three complete sets of figures – the raw data, the data offset by 4° to eliminate negative temperatures and the offset data scaled into mm for 3D modelling purposes.

- **Lesson Activity Ideas**
  A set of different lesson activities that can be used alongside the student models to explore the weather, climate and climate change. These activities are relevant for 11-16 geography and PSHE.

- **Example Model File**
  This STL model file is an example of the models that students will be able to create using the resources. This particular model shows the monthly temperature data from January 2000 to December 2009.

- **Climate Comparison Model File**
  This STL model file shows the current monthly climate (1981-2010 average) which can be printed and used alongside the example model or any 10 year model that the students produce and is useful for comparing the temperatures of different time periods to the current climate to visualise climate change and the difference between weather and climate.

- **Model Base Template File**
  This is a Tinkercad file that can be accessed and copied. It provides a standard base that the students attach their 10 year data models to. The year labels can be easily edited on the template to correspond with the data set that forms the print. The base is designed so that it can link to other bases in order to combine multiple models together (like a jigsaw). The bases will interlink when printed in any scale from 50% to 100%, however if you are scaling the final model down to less than 50% to make smaller prints, they are not likely to fit together.

- **Video Tutorials**
  A set of video tutorials that guide the students, step-by-step, through the process of creating a 3D model design from a 10 year set of temperature data. These include preparing the model base, 3D modelling the data set, combining the data model with the base template and slicing the model in Cura.

Project Requirements

3D Printing is a three-stage process – you start by creating a 3D model, then this is "sliced" into layers for 3D printing by a software program and finally the file is 3D printed. To run this project in full, in addition to the project resources supplied, you will need access to the following:

- **Tinkercad 3D modelling software**
  To develop their temperature models, students will be using Tinkercad 3D modelling software. This is free online software accessible to all at www.tinkercad.com

The software requires each user to have a user account. Using the Tinkercad classrooms functionality, you can register for your own teacher account, then set up a class within your account containing individual students accounts. Then you will be able to access and moderate all the students' work.

You can learn how to set up and use Tinkercad Classrooms, create a class and student accounts and generate a class join code at https://blog.tinkercad.com/2019/08/05/introducing-tinkercad-classroom

Student Tinkercad accounts should be set-up and a class join code should be generated prior to starting the project.

- **Slicing software**

  Before a 3D model file can be 3D printed, there is an intermediate process called "Slicing". This uses specific slicing software that slices the model into layers that are recognised by a 3D printer. The software also allows you to resize models, configure the print settings, check the file and save the file as a 3D printable file type.
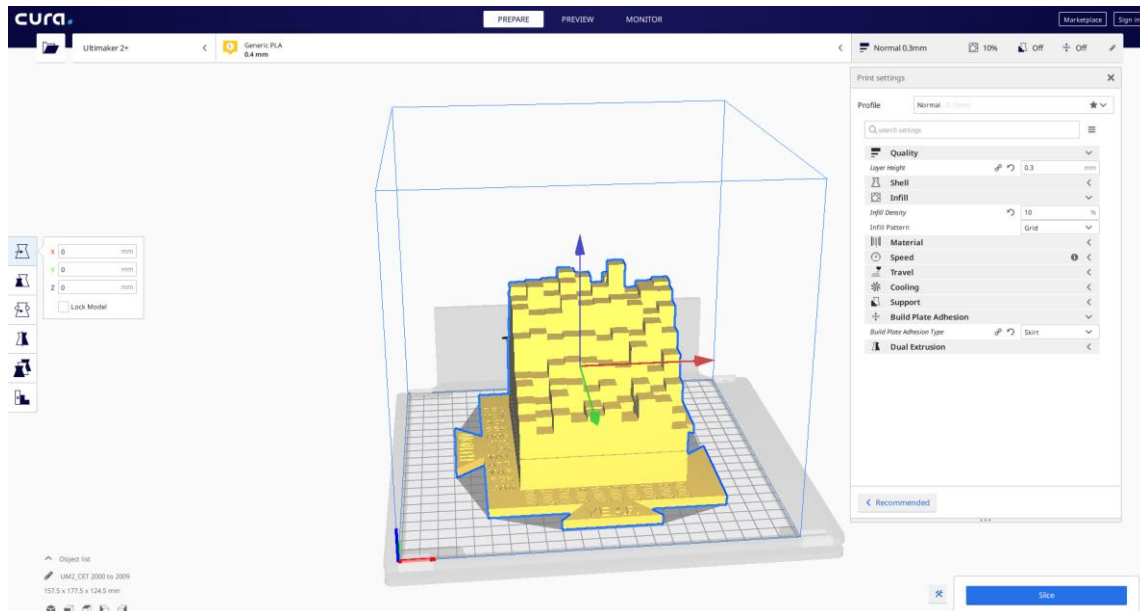
  The software used for this depends upon which 3D printer you will be using. The instructions in this guide are for using the Cura Slicing Software*, this software is open-source, FREE to download and suitable for using alongside any Ultimaker 3D printer (Ultimaker 3D printers are supplied with the 3D printer loan scheme) and many other 3D printer brands.

  You can download Cura from https://ultimaker.com/software/ultimaker-cura

  *Please note
  Some 3D printer manufacturers have their own slicing software, so please check that this is the case before using Cura to slice your model. If using another manufacturer's software, you will need to consult their documentation for instructions on using the software.

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- **Access to a 3D printer**
  It is likely that you will already have a 3D printer in school, these are commonly found in the Design Technology Department but sometimes also in the Computing or Science Departments. If you do not have access to a 3D printer, you can borrow one free of charge for 4 weeks with The CREATE Education Project 3D Printer Loan Scheme. You can learn more and apply for a loan at
  https://www.createeducation.com/loan-scheme

  Please note that the scheme is popular and works on a first come first served basis, so if you are planning to run this project, please apply well in advance and we can inform you of availability.

- **Exemplar and Climate Comparison 3D Models**
  Prior to starting the project with students, we advise that you 3D print the exemplar model file and the climate comparison model file. These models will provide a context for the project, the models can be used as a learning aid to study the recent temperature data and can also be used to introduce the 3D modelling aspect of the project to students, so that they can visualise how the data can be used to create a 3Dmodel.

  The exemplar 3D model files will need to be downloaded from the project resource page at www.createeducation.com/resource/3d-printing-the-weather

  These files can then be sliced, if you are using Cura slicing software, by following the slicing video tutorial. Both of the files have been designed to print at full size or scaled down to any size between 50% and 100%. However, if scaling the models, both models need to be scaled to the same percentage.

  When comparing the data model to the climate, the climate model sits on the base with the month labels on show, covering the month labels on the base, as in the image below.
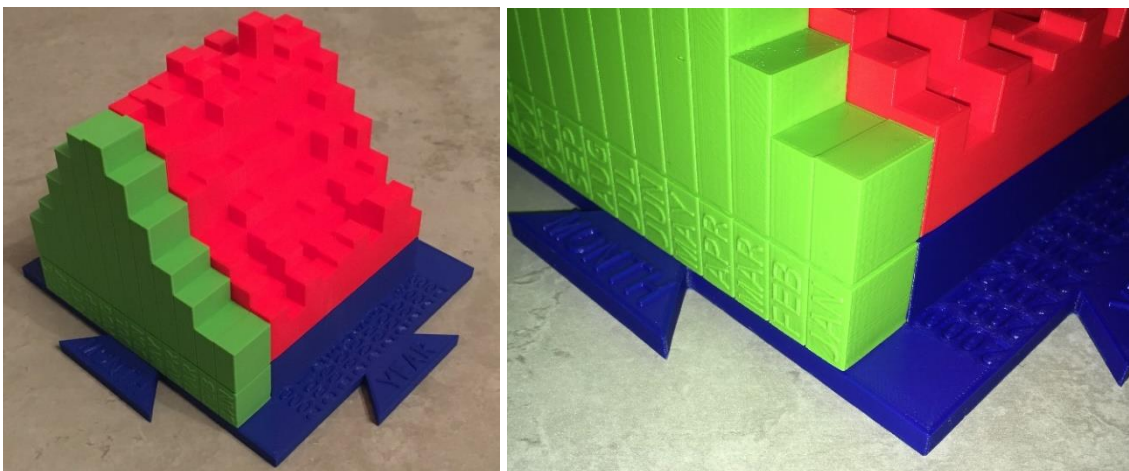
  Finally, the models can be 3D printed. To do this, if you are new to 3D printing, please follow the manufacturer's instructions for the 3D printer you have access to.

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Stage 1: Introducing the project

Typically, the project should be introduced over 2 lessons. The first lesson should provide an introduction to the Central England Temperature (CET) data record using the Data Set spreadsheet. You may like to ask the students to discuss why having such a long data record is useful, as well as maybe considering the potential problems with instrumental records that are so old.

Students can look at the data set, then focus on the Year 2000-2009 data and then see how this data has been converted to a 3D model (using the exemplar 3D printed model). This will help them to visualise what they can produce.

At this stage, the students can also be put into groups for producing the 3D models, students can work alone, in pairs or in groups of 3 to produce the models. This would be dependent upon the class size, the ability of the students and the computing facilities you have available to run the project. Each group should be allocated a specific 10 year set of data that they will produce a 3D model of. The accompanying Lesson Plan document provides suggested data sets to model and study.

Getting Started with Tinkercad 3D Modelling Software

At the beginning of the project, if students have no prior experience of using Tinkercad, a dedicated lesson should be spent introducing it to the students. This will allow them to learn how to navigate the software interface and use some of the controls, prior to starting to create their 3D model.

Students will first need to login to their student account, for this they will need to know their Username (nickname) and the Class Join Code – this will be generated when you set up a class in Tinkercad prior to starting the project.
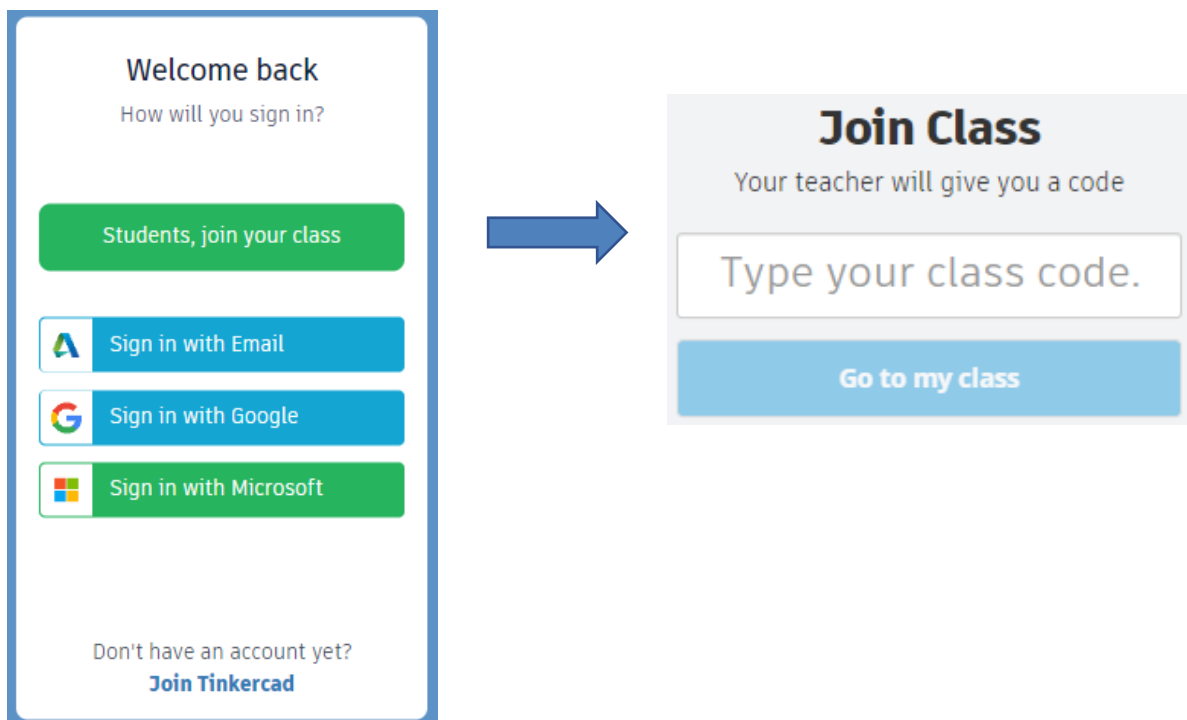
Tinkercad has some very useful self-paced tutorials that guide students step-by-step through this. To access these resources, after logging in to Tinkercad, click on the "Learn" button to the right of the top navigation bar.
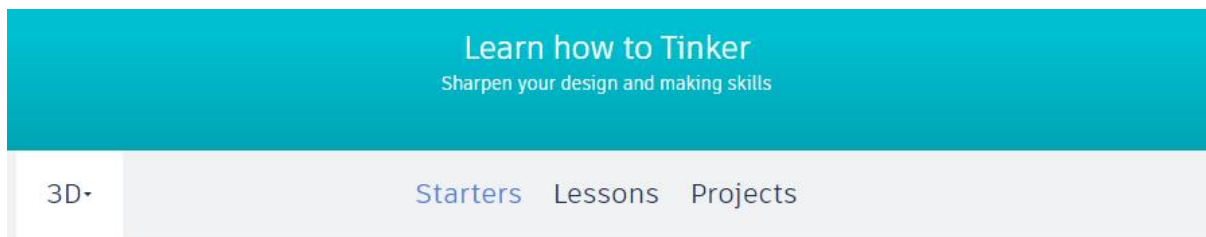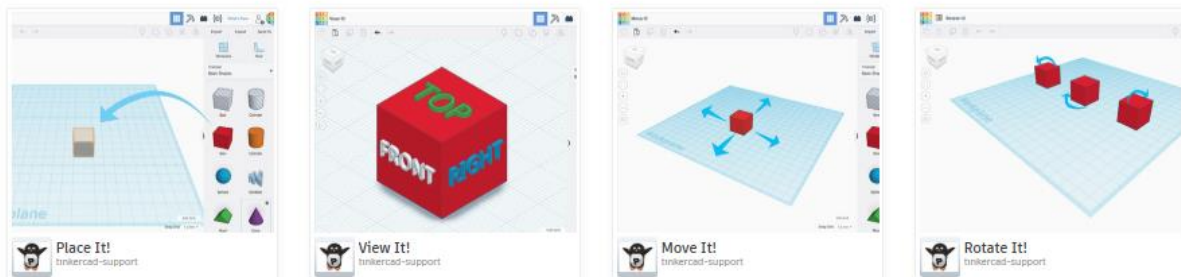
We suggest that students start by working through the "Starters" tutorials. There are seven of these in total and it is likely to take around 30 minutes to complete them all. Students can start these by clicking on the "Place It!" starter, when they have completed this they can automatically move onto the other starters to complete each one in turn.

If time allows, students could also progress onto the "Name that Keychain" project to practice their skills prior to working on their weather model. This is accessed by clicking on the "Projects" tab, then the "See all projects" button.

Stage 2: 3D modelling

In this stage of the project, groups of students will use Tinkercad to create their own 3D models to represent a specific year set of temperature data. This should take approximately 2 lessons.10

To produce the 3D model students will need to start with the standard base template model, this can be accessed at https://www.tinkercad.com/things/fY0WYmphOFH

Students should sign into their Tinkercad account first, then paste the link into the browser to access the model.

Finally, students should then click on the "Copy and Tinker" button, this will open a copy of the template and save it to their Tinkercad account.

Once the students have an open base model, they can then follow the step-by-step video tutorials to create their own 10 year data set model like the one shown here.

If you are new to 3D modelling, we suggest you follow these tutorials and produce your own model first, so that you are aware of the process and are more able to support the students through this process.
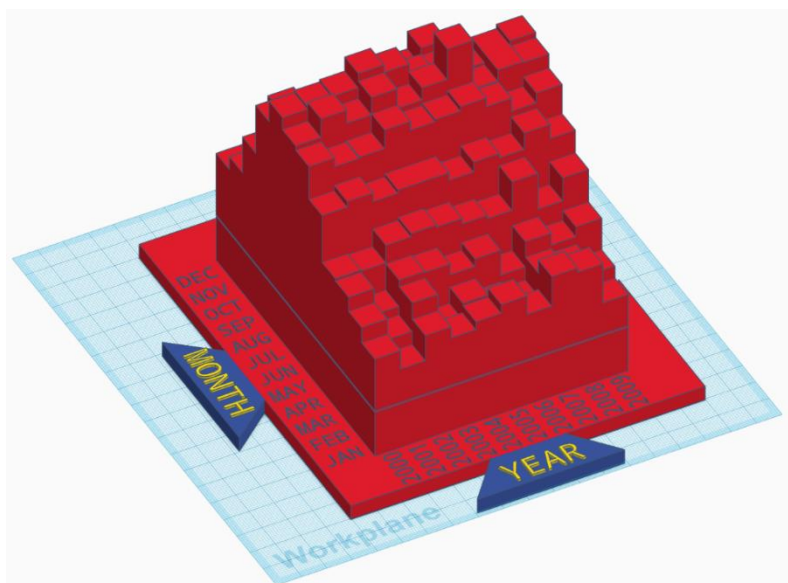
Stage 3: Slicing and 3D printing

Once the students have finished creating their models, the next stage is to prepare them for 3D printing in a process called slicing.

If you want students to learn and fully understand the process of slicing, you can add an additional lesson "Introduction to Slicing and Cura" to the project, the lesson resources are available to download at www.createeducation.com/resource/slicing-cura-lesson

However, this is not essential to run the project. If you are using the Cura slicing software, students can simply follow the steps in the Cura slicing video tutorial for this project. If you are using different slicing software, you will need to either demonstrate this stage to the students or slice their models yourself.

Before slicing their model, students will first need to export it from Tinkercad as an ".STL" file. This file can then be opened in the slicing software.
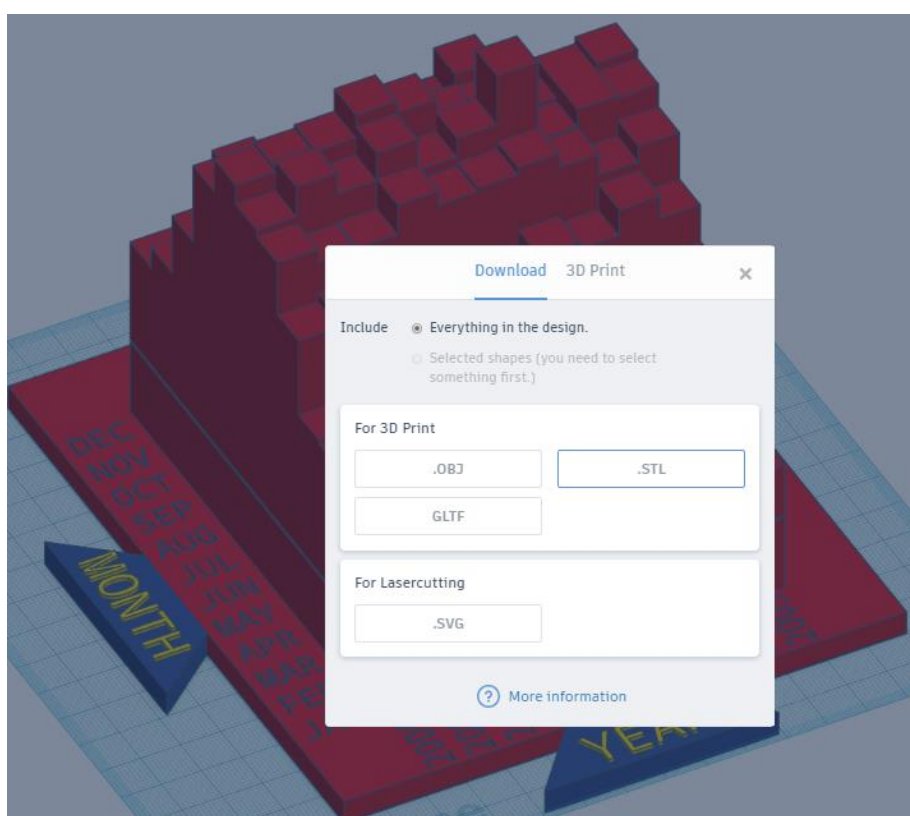
Slicing settings

3D models can take a long time to 3D print and the time taken (and material usage) depends upon a number of factors including the size of the model, the nozzle diameter, the layer height (and therefore the number of layers to print), the wall thickness and the infill (how hollow or solid the object is). It is always a compromise between print speed and final quality of the print. Therefore, you need to choose which print settings are best suited for you, depending upon how much time (and materials) you have for printing the models.

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Scale

The model base template has been designed to fit together when the model is printed at any scale between 50% and 100%. 100% scale produces a full-size model but takes a lot longer to print (also dependent upon other print settings) so you may need to scale the model the model down.

Example settings and print times

The following table shows an example of the print times (and material usage) at different scales for a model, Using an Ultimaker 2+ with a recommended 0.4mm printer nozzle and 10% infill setting. Please bear in mind this will vary from model to model as the data is different and it will also vary dependent upon what model 3D printer you are using.

| Scale	Best Quality Longest print time 0.1mm Layer Height	Good quality Medium print time 0.15mm Layer Height	Lowest quality Quickest print time 0.3mm Layer Height
100%	🕐 1 day 16 hours 16 minutes ▥ 209g · 26.42m	🕐 1 day 2 hours 8 minutes ▥ 205g · 25.95m	🕐 13 hours 50 minutes ▥ 209g · 26.42m
75%	🕐 20 hours 1 minute ▥ 99g · 12.56m	🕐 12 hours 59 minutes ▥ 97g · 12.31m	🕐 6 hours 53 minutes ▥ 99g · 12.55m
50%	🕐 7 hours 52 minutes ▥ 36g · 4.57m	🕐 5 hours 4 minutes ▥ 35g · 4.46m	🕐 2 hours 43 minutes ▥ 36g · 4.58m

It is important that all student groups slice their model using the same settings so that the models are comparable in size and quality and fit together well. Decide which settings you are going to use and run a test print first to make sure you are happy with the print quality, then share these slicing settings with the students so that they can all slice their models using the same settings. You should also ensure that you slice the climate model file using the same scale and slicing settings as the student models so that it can be used alongside the student models for comparing each ten-year data set with the current climate.

3D printing the models

Once the model file has been sliced, the 3D print file (usually .GCODE) just needs saving and then the file is ready for 3D printing.

You can 3D print in any colour filament, however printing in white will allow you to colour or mark the models.

The 3D printed models can be used as stand-alone models, or multiple models can be connected together at the base to create larger models covering longer periods of time. When connecting together multiple models, we recommend arranging them side by side in a single row so that the years increase from left to right. There will be space in between each ten-year data set to place the climate model (from the Climate Model Comparison File) for comparison purposes as shown in the image below. If you are printing lots of the climate models and space is an issue, you can arrange them in multiple rows, perhaps one row per 100 years.
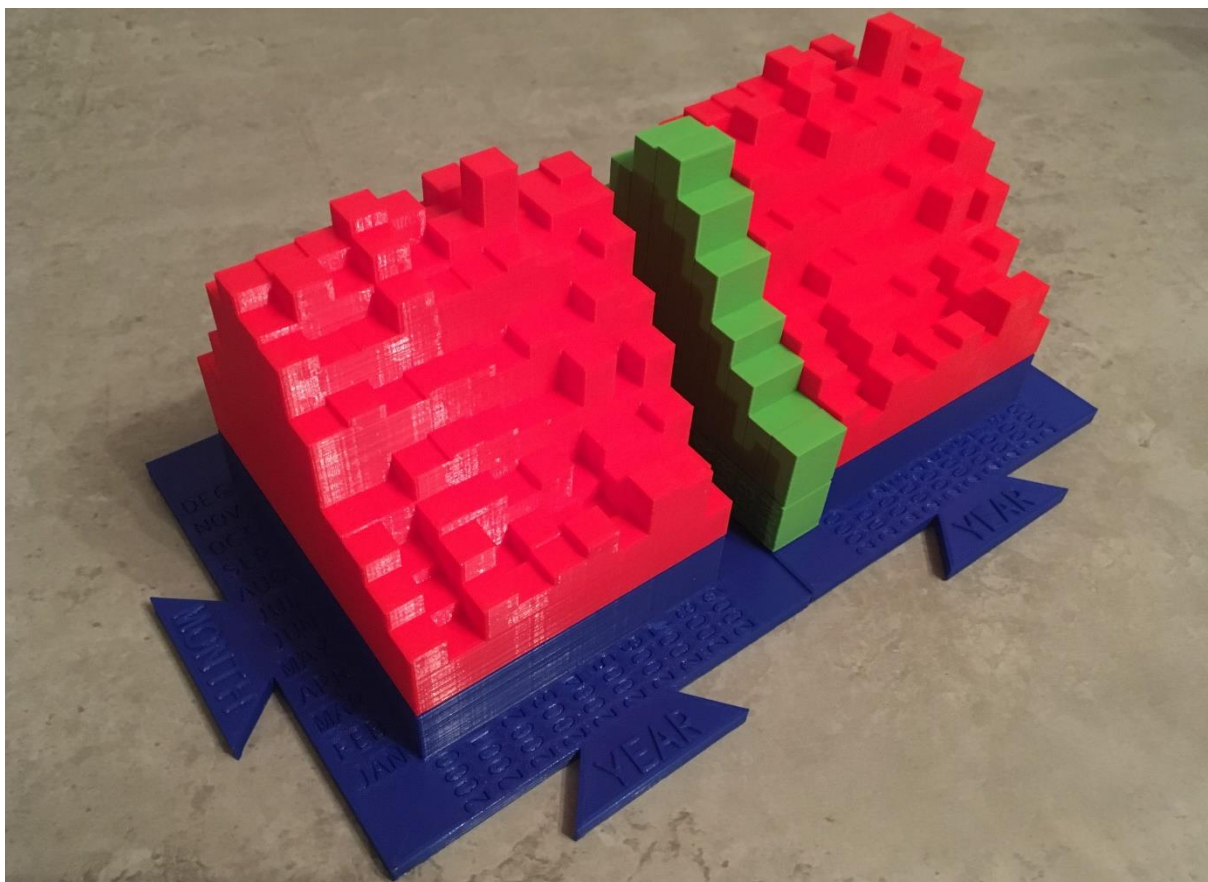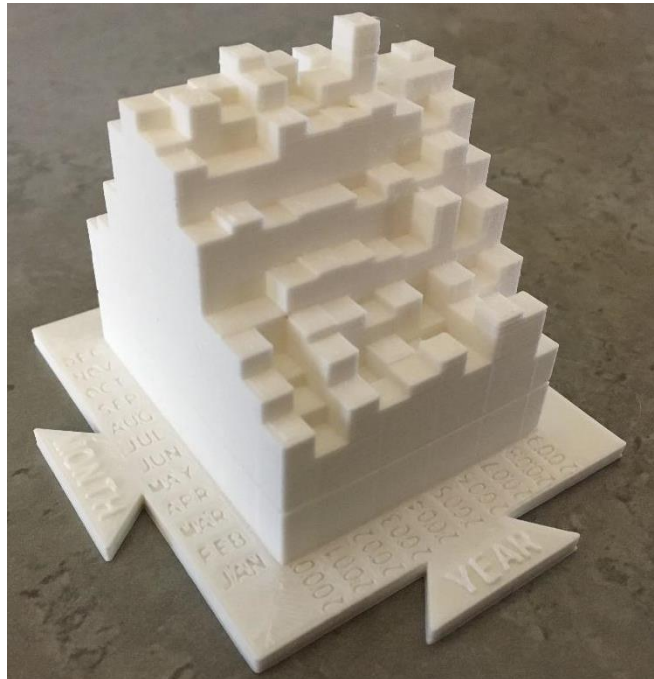
3D printing dual colour models

In order to eliminate negative values (which could not be represented on the model) the data set has been offset by 4°. The model design contains a marker line around it to visually represent 0°. If printing the model in a single colour, you could highlight this with a fine marker pen, however visually this would look even better if you printed your model in dual colour as shown in the image above. The ability to do this depends on the 3D printer you have.

If you have a dual extrusion printer the model could be split along this marker and combined/set up in the slicing software for a dual extrusion print.

If you only have a single extrusion 3D printer, you will only be able to print in one colour at a time, however many printers have the ability to pause a print so that you can change the filament colour part way through a print, then resume the print. This can often be done manually directly through the printer controls or you may have the option to specify the layer or height that the print pauses at in the slicing software.

Please refer to your manufacturer's instructions on how to configure the slicing and printing to allow for printing in dual colours.

Stage 4: Studying the weather (Several lessons, as required)

Once the models have been designed, they can be used in a series of lessons by using the Central England Temperature data in a practical way to study the weather, climate and climate change.

There are many ways that you can use the models, but the Lesson Activity Ideas resource that accompanies this project provides a series of practical activities that could take part over several lessons including:

- The difference between climate and weather
- The current climate of the UK
- The Changing Climate of the UK
- Looking at Past Extreme Weather Events and Researching their Impacts on People in the UK

Please ensure that you review these lesson ideas before designing the models as for some activities, data from specific time periods are required for the models.

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