Exercises: Sea surface temperature anomaly

YSC2210 - DAVis with R

Michael T. Gastner

Introduction

Sea surface temperature is defined as the temperature of the top millimetre of the ocean's surface. A sea surface temperature anomaly is a temporary deviation from the long-term average temperature for a particular location. The National Aeronautics and Space Administration (NASA) calculates the average temperatures on a longitude-latitude grid from data collected by the NOAA Pathfinder satellites from 1985 to 1997. Some sea surface temperature anomalies are simply transient phenomena. Other anomalies occur periodically (e.g. El Niño events), and some persist over longer periods (e.g. as a signal of climate change).

Sea surface temperature anomalies have practical consequences. For example, warmer or colder water temperatures may be beneficial for some species in a marine ecosystem, but detrimental to other species, with immediate effects for fisheries. Other environmental consequences of sea surface temperature anomalies include coral bleaching and harmful algal blooms.

Objectives

We map observational data for the same month in two different years. We learn how to handle raster data, project them to new coordinate reference systems and visualise them with the **tmap** package. Figure 1 is an illustration of the type of image we would like to create.

Data

Go to the NASA Earth Observations website:

https://neo.sci.gsfc.nasa.gov/view.php?datasetId=AMSRE_SSTAn_M

Choose the year 2002 from the dropdown menu. Then click on 'November 2002'. From the 'Downloads' panel on the right-hand side of the website, choose 'GeoTIFF (floating point)' as file type. For code development, download the lowest resolution available (1.0 degrees, see figure 2). The downloaded file is called `AMSRE_SSTAn_M_2002-11-01_rgb_360x180.FLOAT.TIFF`. Afterwards repeat the same steps to download data for November 2007.

If you are ambitious, you can try higher resolution versions for a 'production run' at the end, but bear in mind that the calculations will be significantly slower.

Tasks

(1) We would like to centre the map at ±180° longitude so that we can get an uninterrupted view of the Pacific Ocean, which is the most interesting water body for the study of sea surface temperature anomalies. I suggest using the function `pacificCentric()` from the **envirem** package. This function only accepts `raster` objects (i.e. the native data structure of the **raster** package) as input; thus, we must import the GeoTIFFs with the `raster()` function from the **raster** package. After applying

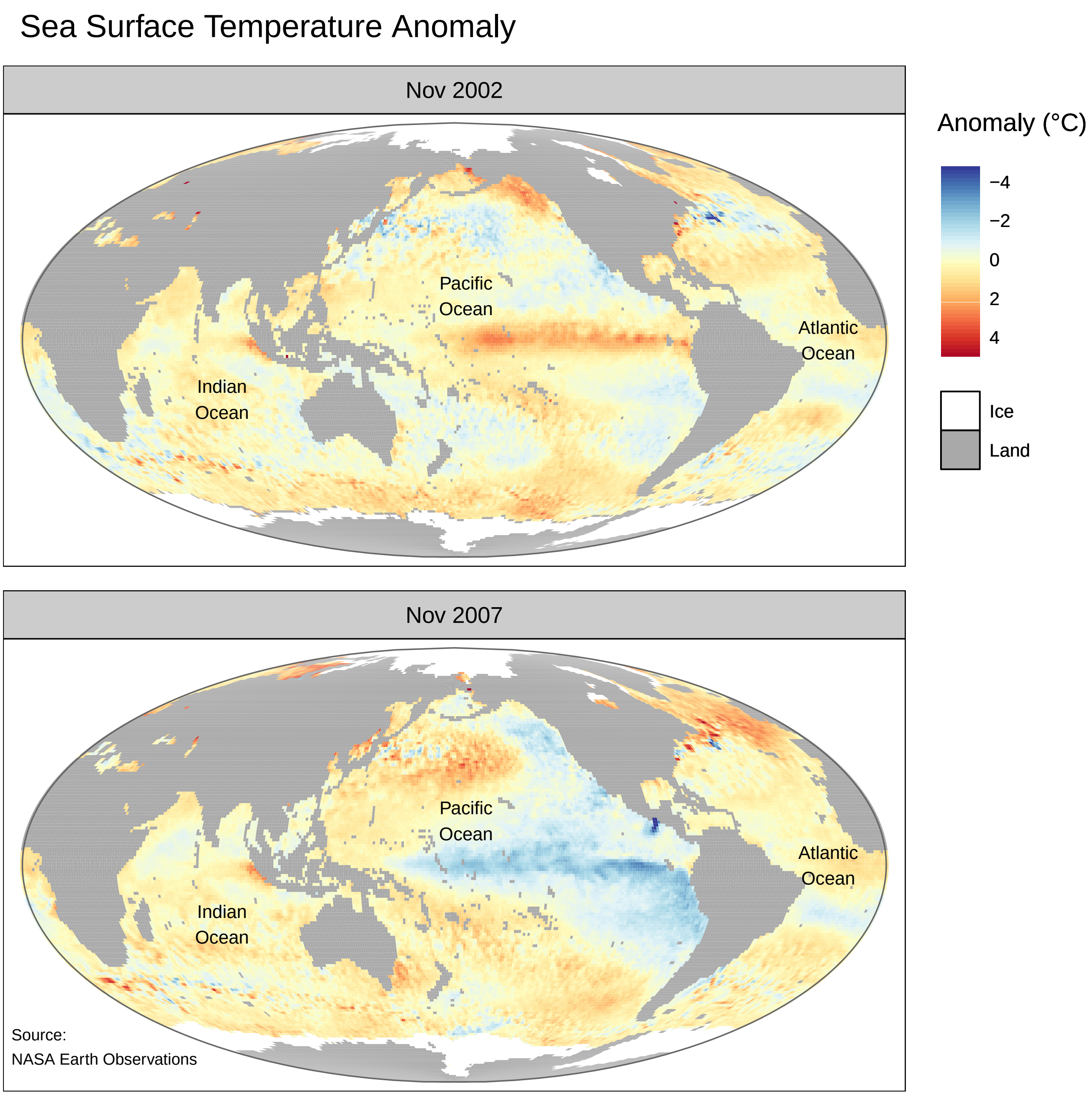

Figure 1: Sea surface temperature anomalies.

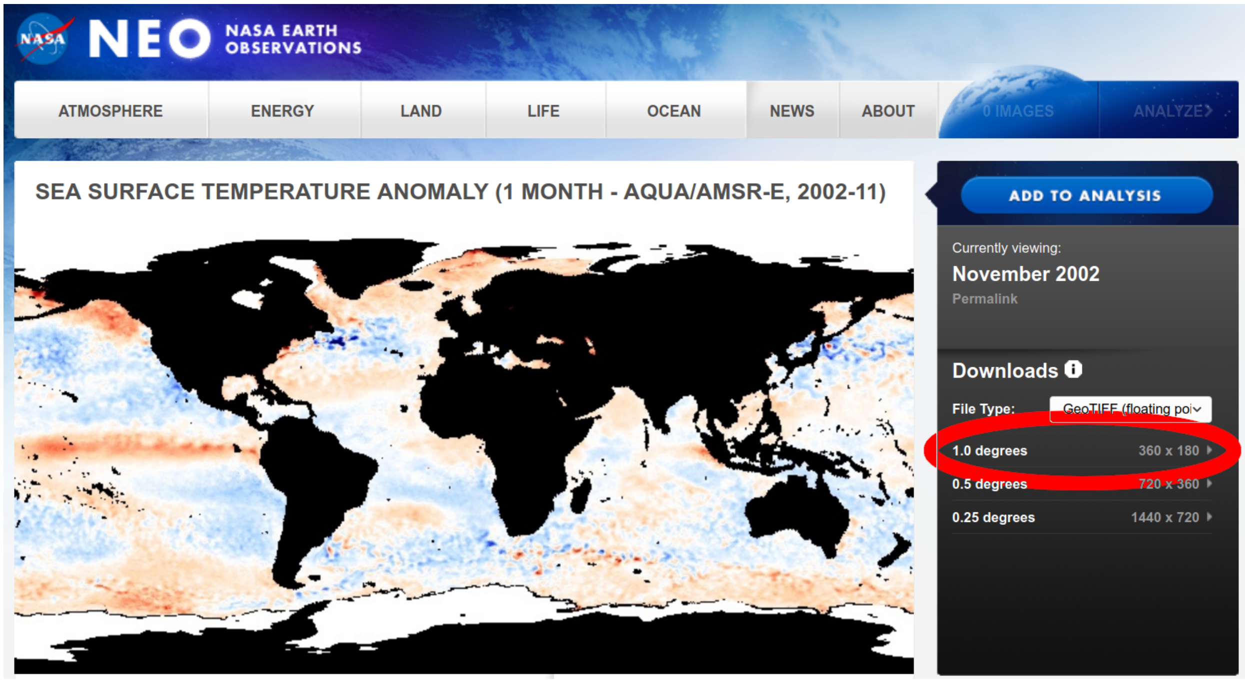

Figure 2: Screenshot of NASA Earth Observations web site

`pacificCentric()` to both downloaded GeoTIFFs (i.e. for November 2002 and November 2007), we can transform the `raster` objects into `stars` objects with `st_as_stars()`. Combine the data into a single `stars` object called `sstan` (for *s*ea *s*urface *t*emperature *an*omaly) so that longitude and latitude are the dimensions, and the observational data at these coordinates appear as two layers (i.e. one layer for the year 2002, another layer for 2007). Make a quick-and-dirty plot to check whether the map is indeed centred on the Pacific Ocean.

(2) Print `sstan` to the console and inspect `sstan` with `str()`. Describe the structure of `sstan` in your own words.

(3) What is the map projection of `sstan`?

(4) Change the map projection of `sstan` with the proj string `"+proj=moll +lon_0=180"`. Afterwards, the coordinates are projected with a Mollweide projection centred at ±180° longitude so that we still get an uninterrupted view of the Pacific Ocean. Make a quick-and-dirty plot to confirm that the map is indeed projected using the Mollweide projection and centred on the Pacific Ocean.

(5) NASA uses floating-point numbers to classify longitude-latitude cells and, if the position is in an ocean, quantifies the observed temperature. If the reported value

- is < 99998, the value in the GeoTIFF is the sea surface temperature anomaly in °C.
- equals 99998, the position is covered by sea ice.
- equals 99999, the position is on land.

Use **dplyr**-style syntax to put the information about the sea surface temperature and the type of surface (ice, land not covered by ice and ocean not covered by ice) in separate layers of `sstan`.

(6) Prepare a map with the **tmap** package. It should contain two facets: one facet for 2002 and another facet for 2007. Here are a few properties the final figure should have.

- Add meaningful titles to the plot and the facets.
- Add labels for the world's oceans.
- Choose an appropriate ColorBrewer palette for temperature.

- Use the same temperature legend for both facets.
- Assign the colours `"white"` and `"darkgrey"` to ice and land respectively. For a nice legend, implement the suggestion at this Stack Overflow page: https://tinyurl.com/y59zakfb.
- Show an oval frame around the earth's boundary in both facets.
- Add credits to the data source.
- Make a sensible choice for the figure dimensions. Labels should be clearly legible without appearing disproportionately large.

Feel free to make more adjustments if you think they improve the quality of the plot.

(7) Briefly explain to a reader what the figure reveals about sea surface temperature anomalies.