120.081 Climate and Environmental Remote Sensing (VU, 2019S) – Exercise 1: Climate trends and variability

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1 Introduction

In situ observation and long-term satellite datasets provide the possibility to analyse changes in the climate system on various time scales. The aim of exercise 1 in the Climate and Environmental Remote Sensing course is to analyse long-term trends and annual variability in global temperature, sea level, and climate oscillation time series (Figure 1). Specifically, the exercise promotes the development of abilities to analyse trends in time series data and to discuss obtained results.

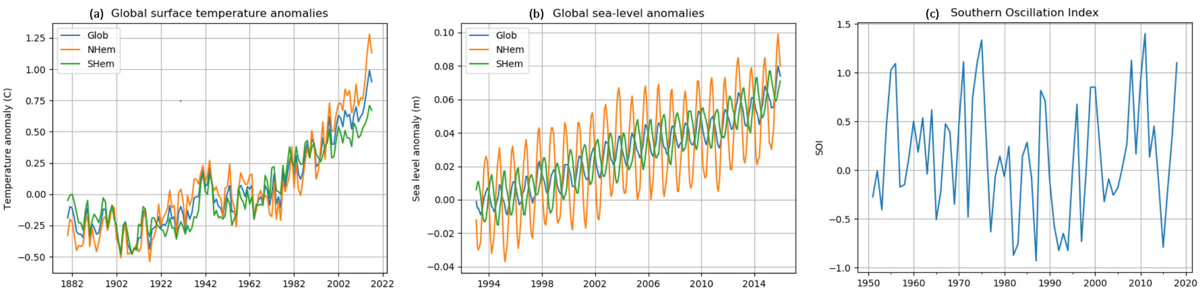

Figure 1: Time series of (a) global temperature anomalies (deviations to the 1951-1980 means, NASA GISS dataset), (b) global sea level anomalies (ESA SL_cci V2.0 dataset), and (c) the southern oscillation index.

2 Data and methods

2.1 Datasets

Three datasets are provided for this exercise:

- Global surface temperature anomalies from the National Aeronautics and Space Administration (NASA) Goddard Institute for Space Studies (GISS) dataset (GISSTEMP, Figure 1 a) (GISSTEMP Team, 2018; Hansen et al., 2010). The GISSTEMP dataset combines temperature measurements from meteorological stations with ship, buoy, and satellite-based measurements of sea surface temperature (SST) into a global homogenized dataset from 1880 onwards (Hansen et al., 2010). Temperature anomalies are expressed as deviations to the 1951-1980 mean temperature.
- Global sea-level anomalies from the European Space Agency (ESA) Climate Change Initiative (CCI) dataset (SL_cci version 2.0, Figure 1 b) (Cazenave and Sea Level CCI Team, 2016; Legeais et al., 2018). The SL_cci dataset combines measurements from different altimetry satellite missions into a homogenous long-term dataset of sea level anomalies (relative to mean sea level).
- The Southern Oscillation Index (SOI, Figure 1 c) is a measure for the difference in sea level pressure between Tahiti and Darwin, Australia (NOAA National Centers for Environmental Information, 2018). SOI is one metric to quantify the occurrence of El Niño and La Niña episodes.

The GISSTEMP and SL_cci datasets are provided as spatially-averaged time series for several latitudinal bands or regions (Table 1).

Table 1: Definition of latitudinal bands and regions in the GISSTEMP and SL_cci datasets.

Region (= column names in data files)	Description	Longitude boundaries	Latitude boundaries
Glob	global	180°W – 180°E	90°S – 90°N
NHem	Northern hemisphere	180°W – 180°E	Equator – 90°N
SHem	Southern hemisphere	180°W – 180°E	90°S – Equator
b24N.90N	Northern extratropics	180°W – 180°E	24°N – 90°N
b24S.24N	Tropics	180°W – 180°E	24°S – 24°N
b90S.24S	Southern extratropics	180°W – 180°E	90°S – 24°S
b64N.90N	Arctic	180°W – 180°E	64°N – 90°N
b44N.64N	Northern temperate zone	180°W – 180°E	44°N – 64°N
b24N.44N	Northern subtropics	180°W – 180°E	24°N – 44°N
bEQU.24N	Northern tropics	180°W – 180°E	Equator – 24°N
b24S.EQU	Southern tropics	180°W – 180°E	24°S – Equator
b44S.24S	Southern subtropics	180°W – 180°E	44°S – 24°S
b64S.44S	Southern temperate zone	180°W – 180°E	64°S – 44°S
b90S.64S	Antarctic	180°W – 180°E	90°S – 64°S
Nino34 (only in SL_cci)	Nino 3.4 region (Trenberth, 1997)	170°W – 120°W	5°S – 5°N

2.2 Groups and Data access

- **TUWEL is used to organize the exercises (https://tuwel.tuwien.ac.at/course/view.php?id=18244).**
- Build **groups of three persons** and write yourself into the sheet of paper circulating in class.
- Download the data and example scripts from **TUWEL (climers_exercise01.zip,** Table 2). The package also contains some supplementary material.

2.3 Software

We recommend doing the exercise in Python. You are free to use other software but we provide support only for Python. Information on how to install and use miniconda for this exercise on Windows and Linux systems is provided in the Appendix (below). We provide the example script **exercise01.py** and the environment file **climers_env.yml** that you can use to get started with your own analysis. Please contact Leander Mösinger in case of Python-related questions.

Table 2: Contents of the unzipped file.

Dataset	Directory or file
GISSTEMP	data\GISSTEMP dataset NASA-GISSTEMP\nasa_giss_dTs+dSST_ZonAnn.csv
SL_cci	data\ESACCI-SEALEVEL-L4-MSLA-MERGED-1993-2015-fv02\ESACCI-SEALEVEL-L4-MSLA-MERGED-1993-2015-fv02_Zonal.csv
SOI	data\NOAA-NCDC-SOI\noaa_ncdc_soi_data.csv
Example script	exercise01.py
Conda setup	climers_env.yml

2.3 Tasks

2.3.1 Task A: Trends in surface temperature and sea level

Analyse long-term trends in the GISSTEMP and SL_cci datasets for the globe, the northern and southern hemisphere, and for different latitudinal bands (as defined in Table 1). Compute the trends based on ordinary least squares regression (i.e. linear regression) and the Theil-Sen slope estimator (Sen, 1968; Theil, 1992). The example Python script shows how to apply these methods. Investigate how you can assess the significance of trends from the two methods.
Visualize, compare, and discuss the computed trends in surface temperature and sea level anomalies, (a) for the globe, (b) for different latitudinal zones, and (c) from the two trend methods.

2.3.2 Task B: Robustness of trends: a global warming "pause"?

In the 2000s there was a discussion in the general public about a "pause" or "slowdown" of global warming, also known as the "global warming hiatus" (Trenberth and Fasullo, 2013). This public discussion affected later also the scientific community (Karl et al., 2015; Lewandowsky et al., 2015). Global mean temperature data has been used to show a global warming "pause" for the period 1998-2012 (or 1998-2014).
Investigate the GISSTEMP dataset for a global warming "pause". Specifically, compute trends for different periods each with a length of 15 years during the 1990s, 2000s, and 2010s. Visualize your results. Discuss the results with respect to the above-mentioned literature.

2.3.3 Task C: El Nino and climate variability

El Nino/Southern Oscillation (ENSO) is a variation in atmospheric and oceanic circulation in the Eastern Pacific region that affects climate, ecosystems, and societies across many regions of the world (Trenberth, 1997).
Analyse based on statistical approaches such as correlations or regressions how ENSO affects regional and global temperature and sea level anomalies. Take into account long-term trends in temperature and sea level.

3 Expected results and examination procedure

- Summarize the results of your group in a **report**. The report should be written in the style of a scientific publication (research article). Table 3 lists the requirements for the report. It is especially important that you *describe the contribution of each group member* to the report.
- Present a preliminary version of the report in an **examination meeting** with Prof. Dr. Dorigo and Dr. Forkel **in week 18 (29. April – 3. May)**. We will setup a *calendar in TUWEL* to schedule meetings for each group. Optionally, you can present the exercise in a PowerPoint presentation. During the examination meeting, every group member will get **additional questions** that are related to the exercises and to the contents of the lecture. As a preparation, you can read the corresponding chapters in Bonan (2015).
- **Upload the final version of your report** (.pdf) at TUWEL as a group at the latest until **9. Mai 2019.**
- Every group member will receive a **mark** for (a) the specific contribution to the report (60%), and (b) for the quality of responses to questions during the examination meeting (40%).

Table 3: Requirements for the report of exercise 1.

Item	Description
Template	Please use this description of the exercise as template for your report. The template is largely based on the template of the Copernicus journals from the European Geosciences Union. If you prefer to use Latex, please download the Copernicus Publications LaTeX package from https://www.biogeosciences.net/for_authors/manuscript_preparation.html
Chapters	Include the following chapters in your report: 1. Introduction 2. Data and methods 3. Results and Discussions (can be also split in 3. Results and 4. Discussions) 4. Conclusions References Appendix (optional). The appendix can contain data tables, short descriptions of own developed code or functions (if no standard packages were used), or other material. Please do not include additional figures in the appendix.
Length	The report should have **at least 1000 but no more than 3000 words** (chapters 1 – 4, i.e. word limits are without title, author names/email, references, and appendix).
Figures and tables	Present the results as **figures and tables** in your report. Please follow as much as possible these recommendations for the design of your figures: https://www.biogeosciences.net/for_authors/manuscript_preparation.html
References	We do not expect that you do an extensive literature research for this exercise. However, please include citations and references for the used data and methods. Additionally, please include references if you refer to any publications in your report. Use the citation style of EGU Copernicus publications: https://www.biogeosciences.net/for_authors/manuscript_preparation.html If you are using Zotero for reference management, you can get the reference style template from: https://www.zotero.org/styles/biogeosciences
Author contributions	Add at the end of your report a section that describes the contribution of all group members. Example: X analysed the data for task A and B. Y analysed the data for task C. Z mainly wrote the report with inputs from X and Y. It is your own responsibility to fairly distribute the work within your group.

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Appendix A: Installing and using miniconda on Windows

We recommend using miniconda to manage your python environments. In the following, we provide some information about how to install miniconda for Windows.

- Website about miniconda for windows: https://conda.io/docs/user-guide/install/windows.html
- Getting started
  - https://docs.anaconda.com/anaconda/user-guide/getting-started
  - http://astroconda.readthedocs.io/en/latest/getting_started.html
- Download miniconda from https://conda.io/miniconda.html
- Install conda: double click *.exe and follow instructions
- Setup environment:
  - conda create -n climers_env python=3 pandas numpy matplotlib statsmodels scipy

Appendix B: Installing and using miniconda on Linux

Run all commands in bash (e.g terminal):

- Download the miniconda installer to your current directory
  - wget https://repo.continuum.io/miniconda/Miniconda3-latest-Linux-x86_64.sh
- Install miniconda
  - bash Miniconda3-latest-Linux-x86_64.sh
  - When asked whether to add the miniconda install location to $PATH in ~/.bashrc, type "yes" (warning: default is "no").
  - Refresh .bashrc in terminal which will activate the changes made to .bashrc
  - source .bashrc
- Test if conda works:
  - conda -V
  - Should print out your conda version

- If it does not work (e.g “unknown command conda), likely miniconda is not in $PATH. Check your ~/.bashrc whether the path is correct (open it with any texteditor, e.g. nano or gedit)
- Update conda and pip to newest version:
    - conda update conda pip
- EITHER: Create environment with name climers_env from scratch
    - conda create -n climers_env python=3 pandas numpy matplotlib statsmodels scipy
- OR: Create environment with name climers_env from the supplemented .yml file
    - conda env create -f climers_env.yml