120.081 Climate and Environmental Remote Sensing (VU, 2019S) – Exercise 2: Drought in the Danube River basin

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1 Introduction

The Danube River – the second largest river in Europe – flows over 2780 km from the springs in the Black Forest Mountains in Germany until it reaches the Black See in Romania (ICPDR, 2015). The Danube region has experienced several drought episodes in the last decades (Ceglar et al., 2018; Spinoni et al., 2017; Stahl et al., 2016). The drought ICPDR (2015) report concludes that an increase in extreme weather events is expected throughout the Danube catchment; especially an increased frequency and intensity of dry spells and heat waves. Satellite-derived products allow to monitor drought impacts across countries independently on their in-situ infrastructure in near-real time. The aim of this exercise is to evaluate different satellite-derived precipitation datasets for the Danube river catchment, to analyse drought events by computing drought indices from satellite-derived precipitation and evapotranspiration data, and to compare these drought indices with different satellite datasets on surface soil moisture, evapotranspiration, terrestrial water storage, and estimates of the discharge of the Danube river.

2 Data and methods

2.1 Datasets

Different EO datasets and river discharge data are provided. All datasets have monthly resolution, EO datasets have a spatial resolution of 0.25°.

- *Precipitation:*
    - E-OBS is a gridded dataset for precipitation based on interpolated observations from meteorological stations (Cornes et al., 2018).
    - CMORPH (Climate prediction center MORPHing method) uses passive microwave observations and geostationary infrared imagery to estimate precipitation (Joyce et al., 2004).
    - PERSIANN is a Precipitation Estimation from Remotely Sensed Information using Artificial Neural Networks and uses geostationary infrared imagery (Hsu et al., 1997).
    - TRMM TMPA (Tropical Rainfall Measuring Mission Multi-satellite Precipitation Analysis) combines gauge-corrected precipitation estimates from multiple satellite sensors (Huffman et al., 2007).
- *Evapotranspiration (ET):* GLEAM (Global Land Evaporation Amsterdam Model, version 3a) is satellite-data driven model to estimate evaporation, interception and transpiration (Martens et al., 2017). The model uses net radiation, air temperature, precipitation, vegetation optical depth, soil moisture and snow water

equivalent as input. In the exercise, we use p*otential evapotranspiration* (PET) and *actual evapotranspiration* (AET) fom GLEAM.

- *Surface soil moisture (SSM):* The ESA CCI surface soil moisture data set (version 04.5) harmonizes retrievals of SSM from different active and passive microwave satellite sensors into a joint long-term dataset (Dorigo et al., 2017). Provided are the monthly averaged anomalies
- *Terrestrial water storage (TWS):* Retrievals of TWS are taken from the GRACE dataset version RL05 (Swenson, 2012; Landerer et al., 2012; Swenson et al., 2006)
- *River discharge:* River discharge data were obtained from the Global Runoff Data Centre (GRDC). Data are from the two stations closest to the river delta. Provided are the monthly averaged anomalies

2.2 Groups, data access, and software

- **TUWEL is used to organize the exercises (https://tuwel.tuwien.ac.at/course/view.php?id=18244).**
- The exercise should be done in the same groups as in exercise 1.
- Download the data and example scripts from **TUWEL (climers_exercise02.zip,** Table 2). The package also contains some supplementary material.

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 **exercise02.py** and the environment file **climers_env_ex02.yml** that you can use to get started with your own analysis. Please contact Leander Mösinger in case of Python-related questions.

Table 1: Contents of the unzipped file.

Dataset	File
Task description [pdf]	climers-vu_exercise02.pdf
Task description [word]	climers-vu_exercise02.docx
Example script	climers_exercise02.py
Conda setup	climers_env_ex02.yml
Danube catchment mask	data/mask.nc
EOBS; precipitation	data/EOBS_monthly_0d25.nc
CMORPH; precipitation	data/CMORPH_monthly_0d25.nc
TRMM TMPA; precipitation	data/TRMM_TMPA_monthly_0d25.nc
PERSIANN; precipitation	data/PERSIANN_monthly_0d25.nc
ESA_CCI; soil moisture anomalies	data/ESA_CCI_SM_monthly_anomalies_0d25.nc
GRACE; TWS anomalies	data/GRACE_CSR_monthly_0d25.nc
GRDC; discharge station 6742900	data/6742800_Q_Month.txt
GRDC; discharge station 6742900	data/6742900_Q_Month.txt

2.3 Tasks

2.3.1 Task A: Evaluation of satellite-derived precipitation data sets

Evaluate the satellite-derived precipitation datasets CMORPH, PERSIANN, and TRMM TMPA against the E-OBS dataset for the Danube river basin. Therefore, compute the bias and correlation between each satellite dataset and E-OBS for each 0.25° x 0.25° grid cell within the Danube river basin (use the provided mask). In addition, evaluate the monthly total precipitation in the basin, i.e. aggregate each dataset for each month over the entire basin and compare the different satellite datasets against E-OBS.
What are the differences between the precipitation datasets with respect to E-OBS? In which areas do the products agree better/worse with E-OBS and why? Which precipitation dataset agrees best with E-OBS?

2.3.2 Task B: Computation and analysis of drought indices

The Standardized Precipitation Index (SPI) (McKee et al., 1993) and the Standardized Precipitation Evapotranspiration Index (SPEI) (Vicente-Serrano et al., 2009) are commonly used metrics to quantify droughts. Implement the calculation of SPI and SPEI as functions in Python. Use precipitation from TRMM TMPA and potential evapotranspiration from GLEAM to compute SPI and SPEI integrated for the entire river basin. Note that you need first to compute monthly total precipitation and total PET for the entire basin as in task A. Compute SPI and SPEI aggregated for 3, 12, and 48 months. Plot time series of precipitation, PET, AET, SPI and SPEI for the different aggregation times and compare the results.
Which years had the largest drought and wetness conditions? Make a short news and literature search to verify the detected drought/wetness years with locally observed hydrological impacts.

2.3.3 Task C: Comparison of drought indices with other hydrological variables

Analyse how the temporal variability in drought conditions (as quantified using SPI and SPEI) is reflected in surface soil moisture, terrestrial water storage and river discharge. Therefore, aggregate TWS and SSM for the entire basin and compute monthly anomalies of river discharge. Compute correlations between SPI and SPEI at 3, 12, and 48 months with SSM anomalies, TWS and discharge anomalies and present the results as a table.
Which variables show high and weak correlations with SPI and SPEI? Discuss how environmental processes could influence the strength of the correlations.

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 1 lists the requirements for the report. It is especially important that you *describe the contribution of each group member* to the report (Table 1).
- Present a preliminary version of the report in an **examination meeting** with the lecturers **(27.-28. May)**. Scheduling of the meetings will be done though TUWEL. Optionally, you can present the exercise in a PowerPoint presentation. During the examination meeting, every group member will get **additional questions** related to the contents of the lecture and the corresponding chapters and review questions in the extra literature provided.
- **Upload the final version of your report** (.pdf) at TUWEL as a group at the latest until **6. June 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 2: Requirements for the report of exercise 2.

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.

References

Ceglar, A., Croitoru, A.-E., Cuxart, J., Djurdjevic, V., Güttler, I., Ivančan-Picek, B., Jug, D., Lakatos, M. and Weidinger, T.: PannEx: The Pannonian Basin Experiment, Clim. Serv., doi:10.1016/j.cliser.2018.05.002, 2018.

Cornes, R. C., van der Schrier, G., van den Besselaar, E. J. M. and Jones, P. D.: An Ensemble Version of the E-OBS Temperature and Precipitation Data Sets, J. Geophys. Res. Atmospheres, 123(17), 9391–9409, doi:10.1029/2017JD028200, 2018.

Dorigo, W., Wagner, W., Albergel, C., Albrecht, F., Balsamo, G., Brocca, L., Chung, D., Ertl, M., Forkel, M., Gruber, A., Haas, E., Hamer, P. D., Hirschi, M., Ikonen, J., de Jeu, R., Kidd, R., Lahoz, W., Liu, Y. Y., Miralles, D., Mistelbauer, T., Nicolai-Shaw, N., Parinussa, R., Pratola, C., Reimer, C., van der Schalie, R., Seneviratne, S. I., Smolander, T. and Lecomte, P.: ESA CCI Soil Moisture for improved Earth system understanding: State-of-the art and future directions, Remote Sens. Environ., 203, 185–215, doi:10.1016/j.rse.2017.07.001, 2017.

Hsu, K., Gao, X., Sorooshian, S. and Gupta, H. V.: Precipitation Estimation from Remotely Sensed Information Using Artificial Neural Networks, J. Appl. Meteorol., 36(9), 1176–1190, doi:10.1175/1520-0450(1997)036<1176:PEFRSI>2.0.CO;2, 1997.

Huffman, G. J., Bolvin, D. T., Nelkin, E. J., Wolff, D. B., Adler, R. F., Gu, G., Hong, Y., Bowman, K. P. and Stocker, E. F.: The TRMM Multisatellite Precipitation Analysis (TMPA): Quasi-Global, Multiyear, Combined-Sensor Precipitation Estimates at Fine Scales, J. Hydrometeorol., 8(1), 38–55, doi:10.1175/JHM560.1, 2007.

ICPDR: The Danube River Basin District Management Plan. Part A - Basin-wide overview., [online] Available from: http://www.icpdr.org/main/sites/default/files/nodes/documents/drbmp-update2015.pdf, 2015.

Joyce, R. J., Janowiak, J. E., Arkin, P. A. and Xie, P.: CMORPH: A Method that Produces Global Precipitation Estimates from Passive Microwave and Infrared Data at High Spatial and Temporal Resolution, J. Hydrometeorol., 5(3), 487–503, doi:10.1175/1525-7541(2004)005<0487:CAMTPG>2.0.CO;2, 2004.

Landerer F.W. and S. C. Swenson, Accuracy of scaled GRACE terrestrial water storage estimates. Water Resources Research, Vol 48, W04531, 11 PP, doi:10.1029/2011WR011453, 2012.

Martens, B., Miralles, D. G., Lievens, H., van der Schalie, R., de Jeu, R. A. M., Fernández-Prieto, D., Beck, H. E., Dorigo, W. A. and Verhoest, N. E. C.: GLEAM v3: satellite-based land evaporation and root-zone soil moisture, Geosci Model Dev, 10(5), 1903–1925, doi:10.5194/gmd-10-1903-2017, 2017.

McKee, T. B., Doesken, N. J. and Kleist, J.: The Relationship of Drought Frequency and Duration to Time Scales, in Proceedings of the Eighth Conference on Applied Climatology, pp. 179–184, American Meteorological Society, Anaheim, California, The United States., 1993.

Spinoni, J., Naumann, G. and Vogt, J. V.: Pan-European seasonal trends and recent changes of drought frequency and severity, Glob. Planet. Change, 148, 113–130, doi:10.1016/j.gloplacha.2016.11.013, 2017.

Stahl, K., Kohn, I., Blauhut, V., Urquijo, J., De Stefano, L., Acácio, V., Dias, S., Stagge, J. H., Tallaksen, L. M., Kampragou, E., Van Loon, A. F., Barker, L. J., Melsen, L. A., Bifulco, C., Musolino, D., de Carli, A., Massarutto, A., Assimacopoulos, D. and Van Lanen, H. A. J.: Impacts of European drought events: insights from an international database of text-based reports, Nat Hazards Earth Syst Sci, 16(3), 801–819, doi:10.5194/nhess-16-801-2016, 2016.

S.C. Swenson. 2012. GRACE monthly land water mass grids NETCDF RELEASE 5.0. Ver. 5.0. PO.DAAC, CA, USA. Dataset accessed at http://dx.doi.org/10.5067/TELND-NC005.

Swenson, S. C. and J. Wahr, Post-processing removal of correlated errors in GRACE data, Geophys. Res. Lett., 33, L08402, doi:10.1029/2005GL025285, 2006.

Vicente-Serrano, S. M., Beguería, S. and López-Moreno, J. I.: A Multiscalar Drought Index Sensitive to Global Warming: The Standardized Precipitation Evapotranspiration Index, J. Clim., 23(7), 1696–1718, doi:10.1175/2009JCLI2909.1, 2009.

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
- 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