Implementing Dataset Enhancements on the THREDDS Data Server

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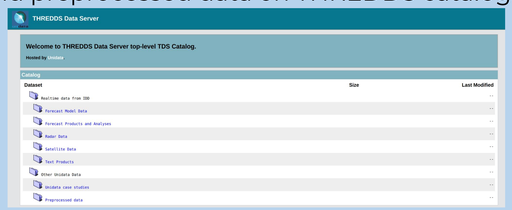
SUMMARY

- Unidata has ongoing efforts to provide new datasets and open source workflows for machine learning.
- This project aims to perform dataset preprocessing before user access targeting machine learning applications.
- As part of the preprocessing step, two common types of rescaled data are provided: standardized and normalized.
- Enable original + rescaled datasets of interest on THREDDS-test server.

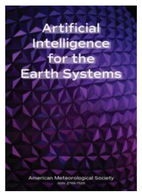
Find preprocessed data on THREDDS catalog:



1. Background

THREDDS Data Server (**TDS**)[1] is an open access web server that provides catalog, metadata and data access for real-time and archived datasets of environmental data sources at a number of distributed server sites, using a variety of remote data access protocols.

2. Motivation



There is an extensive use of machine learning (ML) models in earth sciences research.

- Artificial Intelligence for the Earth Systems (AIES)[2] is a AMS journal launched in 2022.

Data preprocessing in ML generally involves cleaning, rescaling and splitting the data.

- The goal of rescaling is to transform features to be on a similar range and improve the performance and training stability of the model.

Two common types of rescaling are Standardization and Normalization.

- In 7 AIES issues, 13 papers used Standardizer or Normalizer to preprocess their dataset, including forecast (GFS), satellite (GOES), and radar (NEXRAD) data.

Goal: Add dataset preprocessing on TDS targeting ML applications.

3. Preprocessing Data

Based on Python's Scikit-learn [3] machine learning library that has an extensive list of scaling types, we implement StandardScaler and MinMaxScaler.

Standardizer

$$s = \frac{z - \mu}{\sigma}$$

- z Data point
- μ Mean value in the variable
- σ Standard deviation value in the variable
- s Standardized data point

Random variable s with μ 0 and σ 1.

Normalizer

$$n = \frac{z - z_{\min}}{z_{\max} - z_{\min}}$$

- z Data point
- n Normalized data point

Values range between 0 and 1.

4. Code

External library implementations (Apache Commons Mathematics Library [4]):

- Computes summary statistics for very large data streams (values are not stored in memory).

Integrating with netcdf-java codebase:

- Create constants / attributes in the Common Data Model class.
- Include Standardizer / Normalizer in the set of data enhancements.
- Apply enhancements to the data if "standardizer", "normalizer" is a variable attribute and data is floating point type.

Using it in the TDS:

- Preprocess the THREDDS catalog.xml using the NetCDF Markup Language (NcML) [5].
- NcML creates a virtual dataset without changing the original data.

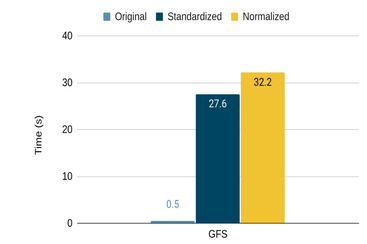
5. Testing

Automated tests to evaluate if behaviour is as expected.

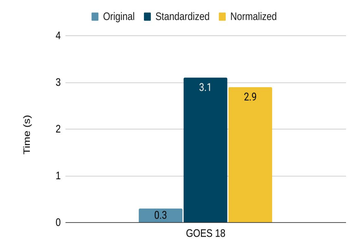
- Calculate mean, standard deviation and standardized values.
- Calculate minimum, maximum and normalized values.
- Standardizer and Normalizer act on floating points data types.
- Return the same input for data that contain integer data type and / or equal values.

Performance test using Apache HTTP server benchmarking tool[6]

GFS 0.25 Degree - Forecast Model Data +80 variables

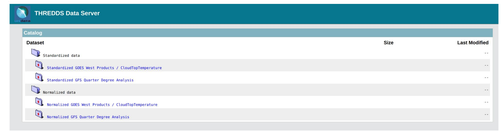


GOES 18 Product - Full Conus 1 variable

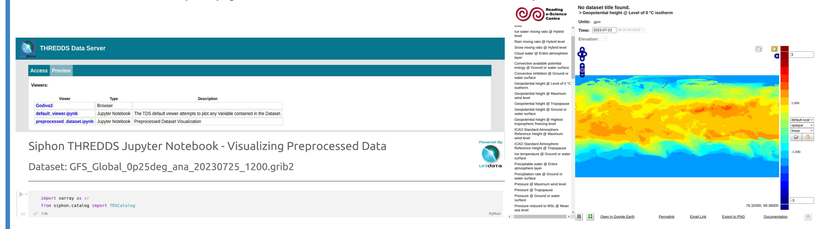


6. Results

Choose a preprocessed dataset:



Visualization (Jupyter notebook and Godiva3):



7. Next Steps

- Improvements on performance (caching for example).
- Provide more datasets relevant to the users.

References:

[1] https://www.unidata.ucar.edu/software/tds/
[2] https://www.ametsoc.org/index.cfm/ams/publications/journals/artificial-intelligence-for-the-earth-systems/
[3] https://scikit-learn.org/
[4] https://commons.apache.org/proper/commons-math/
[5] https://docs.unidata.ucar.edu/netcdf-java/current/userguide/ncml_overview.html
[6] https://httpd.apache.org/docs/2.4/programs/ab.html