Underwater sound speed Netcdf calculator

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NETCDF UNDERWATER SOUND VELOCITY CALCULATION TOOL

The paper describes and presents preliminary results of a Netcdf Transformer tool, developed under java environment, for calculating and producing underwater Sound Speed Netcdf files. This study has been conducted using E.U. Copernicus Marine Service Information (CMEMS). By combining distinct Salinity and Temperature Netcdf data output from CMEMS, a compatible with low end machines Netcdf calculator is created, suitable for "at sea" calculations of the underwater sound speed. The calculations performed are based on Mackenzie (1981) 9 term formula for underwater sound speed. Products of the calculator are depicted in results. The soundscape / acoustic environment of the area bounded by 36N to 42N and Prime Meridian to 009E is calculated, with the distinct halo-clinic fronts of the area in mind. As input data, monthly mean hind casted average salinity and temperature data are selected for a period of 12 months. The calculator input data are the salinity and temperature Netcdf data outputs of Mediterranean Sea physical reanalysis component (product MEDSEA_REANALYSIS_PHYS_006_004), as made available by CMEMS. The output is a single Netcdf sound speed data file, plotted using NASA's Panoply software. The use of the calculator, permits the production of Military Oceanography (MILOC) related products, thus allowing the comprehensive and robust identification of the soundscape, therefore directly enhances the Environmental Knowledge and Operational Effectiveness (EKOE) principle for all level commands.

Keywords: Underwater sound speed, acoustic environment, soundscape, Netcdf underwater sound speed analysis tool, Operational Oceanography, MILOC support

INTRODUCTION

One of the fundamental aspects of providing Military Oceanography (MILOC) related products, is the underwater acoustical description of each area of operations. Therefore a tool for the calculation of the underwater sound speed and the production of the relevant thematic maps is needed to support all levels of command. In order to achieve this, a Sound Speed Calculator is created with the aim to produce Netcdf format files containing sound speed values for the selected area. The input files are Netcdf data from CMEMS MFS model MEDSEA_REANALYSIS_PHYS_006_004, as made available by CMEMS online catalogue[1-2] set. The output of the program is a new Netcdf file, containing sound velocity values and has the exact same space-time dimensions as the original source files. A secondary input option for the calculator is the use of a single source Netcdf data, as available from the global reanalysis model of CMEMS [3] (not included in the current paper). The full analysis of the input data used, goes beyond the scope of this paper, but for a more detailed description and analysis, the reader is encouraged to visit references 1 to 3.

METHODOLOGY (CALCULATOR DOCUMENTATION)

The NetcdfSoundVelocityTransfomer.jar is a Java Application which uses the *netcdfAll-4.5* and *javax.swing* java libraries to read, construct and manipulate .nc files through a user friendly desktop graphic interface. This client side application is customizable to utilize .nc files, with salinity and temperature data of the common chronological period with the purpose of creating a new .nc file with same timestamps and sound velocity data derived/transformed from the previous two files.

The input files for the program to process are netCDF (network common data form) files, with array-oriented scientific data, which pertain to unidata' s Common Data Model (CDM) and their exact file type is **NetCDF-3/CDM**. One primary and one secondary implementation of source data are developed.
This paper presents only the primary mode. By designating the input data as 2 distinct .nc files[3] with one file containing salinity data (variable name: *vosaline*) and the second file containing temperature data (variable name: *votemper* or *thetao*)
Alternatively it works with one global analysis .nc file [4] containing both salinity and temperature variables.

The algorithm for calculation of the new variable is based on the Mackenzie formula for underwater sound speed [5]. The use of this formula, allows the calculator to be used on low end machines, usually carried “at sea”, by avoiding complex calculations which are resourceful demanding.

Salinity file description

The following description is an example of a salinity file named: sv04-med-ingv-sal-an-fc-m_1555267048618.nc downloaded from CMEMS online catalogue plotted by Panoply, a cross-platform application which plots geo-referenced and other array datasets like netCDF, HDF (Hierarchical Data Format) and GRIB (General Regularly-distributed Information in Binary form).

The values of interest in this file are *so* variable which is the salinity float type value, possible names to parse are either *vosaline* or *so*, both acceptable by the application.

Datasets | Catalogs | Bookmarks

Name	Long Name	Type
sv04-med-ingv-sal-an-fc-m_155...	sv04-med-ingv-sal-an-fc-m_155526704...	Local File
depth	depth	1D
lat	latitude	1D
lon	longitude	1D
so	salinity	Geo2D
time	time	1D

Figure 1. . Caption of variable description for sv04-med-ingv-sal-an-fc-m_1555267048618.nc salinity file from Panoply

Temperature file description

The following description is an example of a temperature file named: sv04-med-ingv-tem-an-fc-m_1555266829350.nc .

The critical variable for this file is the *thetao* variable which is the temperature float type value, possible names to parse are either *votemper* or *thetao*, both acceptable by the application.

Datasets | Catalogs | Bookmarks

Name	Long Name	Type
sv04-med-ingv-tem-an-fc-m_1...	sv04-med-ingv-tem-an-fc-m_1555266...	Local File
bottomT	Sea floor potential temperature	Geo2D
depth	depth	1D
lat	latitude	1D
lon	longitude	1D
thetao	temperature	Geo2D
time	time	1D

Figure 2. Caption of variable description for sv04-med-ingv-tem-an-fc-m_1555266829350.nc temperature file from Panoply

Variable definition

- **FillValue**: The _FillValue attribute specifies the fill value used to pre-fill disk space allocated to the variable. The fill value is returned when reading values that were never written. If _FillValue is defined then it should be scalar and of the same type as the variable. If the variable is packed using scale_factor and add_offset attributes (see below), the _FillValue attribute should have the data type of the packed data. This application accepts 1.0E20f as fill value so this value is shown as NaN(empty) in Panoply.

- **missing_value:** This attribute is not treated in any special way by the library or conforming generic applications, but is often useful documentation and may be used by specific applications. The missing_value attribute can be a scalar or vector containing values indicating missing data. These values should all be outside the valid range so that generic applications will treat them as missing.

- **units:** A character string that specifies the units used for the variable's data.

- **coordinates:** The value of the coordinates attribute is a blank separated list of names of auxiliary coordinate variables and (optionally) coordinate variables. There is no restriction on the order in which the variable names appear in the coordinates attribute string.

- **standard_name:** The physical description of a variable

- **long_name:** A long descriptive name. This could be used for labeling plots, for example. If a variable has no long_name attribute assigned, the variable name should be used as a default.

- **ChunkSizes:** Array with the 4 numbers/sizes of chunks for each dimension of the variable

DATA INPUT

As a case study, the monthly mean hindcasted averaged data of salinity and temperature for the area bounded by 36N to 42N and Prime Meridian to 009E was selected. The input Netcdf files are downloaded from CMEMS interactive catalogue for the period from Jan 1992 to Dec 1992. Depth range selected is from the surface down to 313m (partial use of the available z levels of the model). The area chosen represents an area with distinct halo clinic variations, as the surface water masses originating from the Atlantic Ocean, after entering the Mediterranean Sea through the Gibraltar strait, meet with the saltier waters masses of the Mediterranean Sea. As an indicative representation of the input data 2 thematic maps are created using NASA's Netcdf data viewer software Panoply [6].

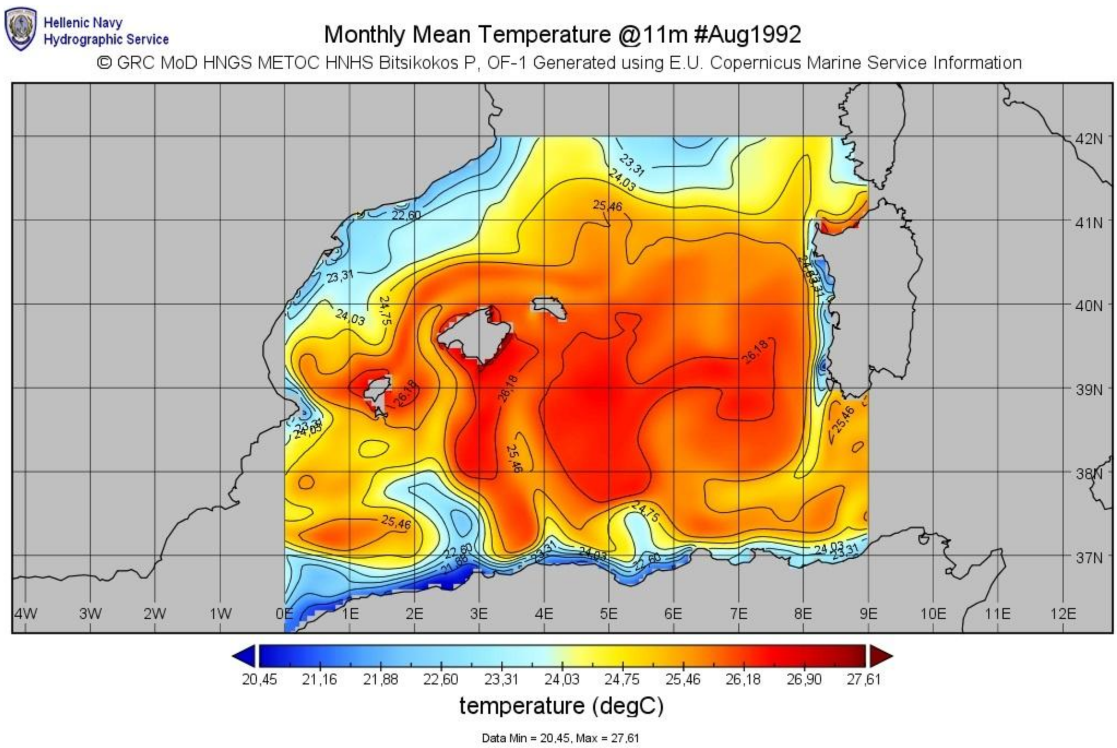

Figure 3. Input Netcdf file plotted. It presents the monthly average Sea Temperature at a depth of 11m for Aug 1992.

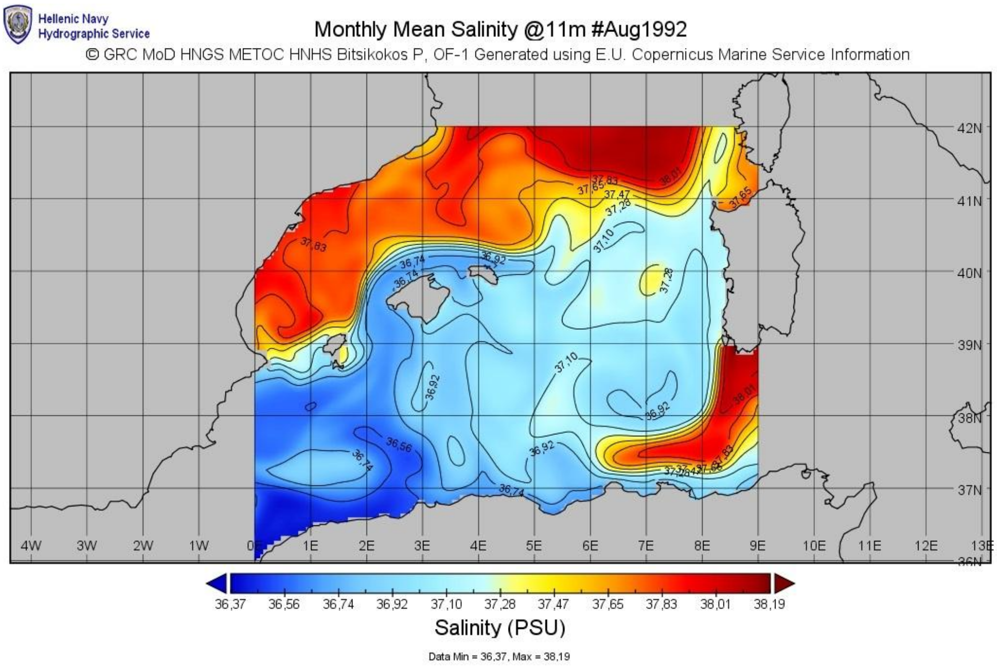

Figure 4. Input Netcdf file plotted. It presents the monthly average Salinity at a depth of 11m for Aug 1992.

VALIDATIONS

The client side application of the Netcdf Sound Velocity Transformer, before constructing the output data sv file, performs several necessary validations of the two input files which are described above:

- Depth variable must have same size in both salinity and temperature file.
- Latitude variable must have same size in both salinity and temperature file.
- Longitude variable must have same size in both salinity and temperature file.
- Time variable must have same size in both salinity and temperature file.
- Both files must have different name and path.
- Acceptable variable name for salinity variable must be either vosaline or so.
- Acceptable variable name for temperature variable must be votemper or thetao.
- Name of the output file and absolut path must be unique (different the input files).

Moreover, important to mention is that the application can handle cases where *scale_factor* and *add_offset* attributes exist in the data set variables of salinity and temperature. In these cases these values are transformed with the formula.

Final value = Value * scale_factor + add_offset

Where the attributes "*scale_factor*" and "*add_offset*" should both be of the type intended for the unpacked data (float values).

RESULTS

The output file is a new .nc file containing a new float value variable which is defined as sv and units are meters/second using the Mackenzie's formula.

```
netcdf file:/C:/Users/bitsikokos/Desktop/NCfiles/ResultFile.nc {
  dimensions:
    time = 36;
    depth = 74;
    lat = 145;
    lon = 169;
  variables:
    float sv(time=36, depth=74, lat=145, lon=169);
      :long_name = "sound velocity";
      :units = "m/s";
      :missing_value = 1.0000000200408773E20; // double
    float lat(lat=145);
      :units = "degrees_north";
      :axis = "Y";
    float lon(lon=169);
      :units = "degrees_east";
      :axis = "X";
    float time(time=36);
      :units = "seconds since 1970-01-01 00:00:00";
      :axis = "T";
    float depth(depth=74);
      :long_name = "depth";
      :units = "m";
      :axis = "Z";
  // global attributes:
  :title = "Example Data";
```

Figure 5. Output Netcdf file description.

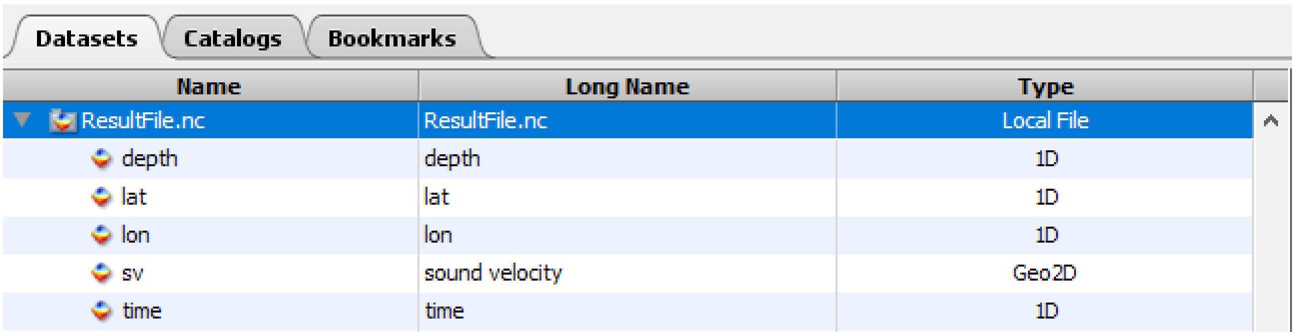

Figure 6. Caption of variable description for Result.nc sound velocity file from Panoply

The thematic maps in jpeg format show the areas where the combination of temperature and salinity values, produce mid and large scale acoustic fronts at various depths. The calculator combines all temperature and salinity values, correlating them both spatially and timely with the Mackenzie sound speed equation and produces the new Netcdf file which contains the sound velocity results per each point. The plotted final product is shown below.

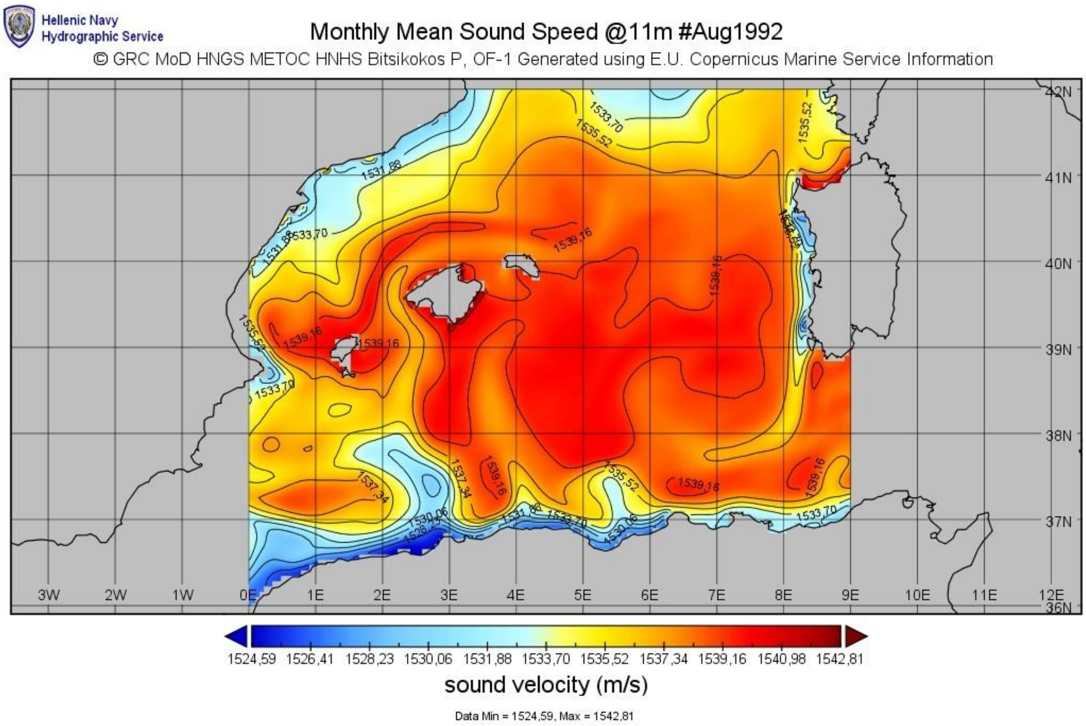

Figure 7. Output Netcdf file plotted. It presents the monthly average Sound Speed at a depth of 11m for Aug 1992.

As depicted at fig.7, the production of a Sound Speed thematic map, validates the effect of temperature gradients to the sound speed. Additionally the effects of salinity spatial distribution are also accounted for, allowing for a more robust soundscape / acoustic environment analysis of the area of interest (AOI).

CONCLUSIONS

The current project is utilized as a calculation tool for marine researchers and specialists, thus for future reference, message queue mechanisms could be used in order to process larger files and support a larger software ecosystem.

The **NetcdfSoundVelocityTransformer.jar** can also be used as a support java reference library for other netcdf file processing java projects. For further information/queries and details please contact the authors.

As graphically presented above, a robust analysis for the soundscape of an AOI can be produced by creating sound velocity thematic maps. The use of these maps by all levels of command, allows the commander to have a detailed description of the subsurface acoustic environment. Therefore, the thorough knowledge of the environment, procures the Environmental Knowledge and Operational Effectiveness (EKOE) principle, thus allowing the optimal use of the assets involved.

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