CCI Land Surface Temperature

Re-gridding and Sub-setting User Manual

Ref.: LST-CCI-D3.5.2-3

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Organisation: Consortium CCI LST

Applicable Documents

AD-1	Re-gridding and Sub-setting ATBD v0.1
AD-2	Product User Guide D4.3

1. Background

1.1. Objectives

The Re-gridding and sub-setting tool has been developed in the frame of the LST_cci project, in response to requests expressed by the users during the LST_cci Users Workshop in 2020. Its main objective is to map a LST product onto a new grid in a coarser resolution, while propagating the uncertainties in a trustable way. It is also capable of re-gridding products in the temporal dimension, aggregating results over a given temporal period. The tool is also able to produce a real subset of the product defined by user-provided latitude and longitude, minimum and maximum coordinates.

1.2. Scope

The tool is dedicated to LST_CCI products. It relies on input product name which must conform to the CCI naming convention. A list of currently known CCI LST products is given in table 1.

CCI LST Product Name
ERS-2_ATSR__L2P
ERS-2_ATSR__L3C
ENVISAT_ATSR__L2P
ENVISAT_ATSR__L3C
TERRA_MODIS_L2P
TERRA_MODIS_L3C
AQUA_MODIS_L2P
AQUA_MODIS_L3C
SENTINEL3A_SLSTR_L2P
SENTINEL3A_SLSTR_L3C
MSG_SEVIRI_L3U
SSMI_SSMIS_L2P
SSMI_SSMIS_L3C
MULTISENSOR_IRCDR_L3S
MULTISENSOR_IRMGP_L3S

Table 1: List of currently known LST products from [AD-2]

Sub-setting

The tool allows to select an area of interest and generates the ouput corresponding to this area.

Spatial regridding

The tool is designed to produce an output file with a coarser resolution only. Finer resolutions are forbidden and will cause the tool to abort with an error message. Nevertheless, an output resolution equal to the input resolution is authorized.

As the tool applies a mean function on a floating window over input product, the floating window size must fit the product map: the target resolution must be a multiple of the input file resolution. (for instance, a 0.5 degrees resolution input file can be re-gridded towards a coarser 0.25 degrees resolution, but cannot target a resolution of 0.16 degrees: the re-gridded map would not fit the input one).

Temporal regridding

The tool is designed to produce a unique output file from a temporal series. For example, from daily files to weekly or monthly or yearly file.

Common functions

It is possible to mix the three above functions, e.g. subsetting, spatially and temporally regridding at once.

The tool expects variables to be present in the input file. If not, variables are simply ignored in the output file. A warning message will be displayed to the user informing him of the missing variables.

Errors detected during processing are reported in a log file to help user solving it. By default, the log file is erased, and kept only in case of error detection. User can avoid the log file deletion with the –keep-log option.

1.2.1. Version updates

1.2.1.1. Version 1.1 updates (sub-setting and spatial regridding)

The LST CCI re-gridding tool version 1.1 is a rehearsal of the version 1.0 with implementation of bug fixing and correction unwanted behaviour discovered during the 2022 workshop. The new implementation is related to:

- Removal of the DOI in the re-gridded product
- Implementation of the IR and MW use cases as defined in ATBD 1.2
- Add a verification on sub-coordinates: the sub-coordinates must be inside the input product frame
- Minor updates on error management and error display.

1.2.1.2. Version 1.2 updates (sub-setting and spatial regridding)

Release 1.2 fixes two bugs reported by users. The binary interface remains unchanged.

- Fix chunk sizes: a better estimation of chunk sizes for processing tends to a better exploitation of processor on-chip RAM memory. Global performances are improved.
- Add a check on user target resolution against input file resolution

1.2.1.3. Version 2.0 updates (sub-setting, spatial regridding and temporal regridding)

Release 2.0 mainly focuses on adding temporal aggregation capabilities and better memory management and performance, but offers other new features.

- The spatial regridding is now possible using a different latitude and longitude factors
- Temporal aggregation: Added temporal aggregation capabilities. Users can now use the –time-resolution argument to do temporal aggregation of data over different time periods. The –time-resolution argument supports these inputs nDAILY, nWEEKLY, nMONTHLY, nYEARLY. For example, a user can provide as input 365 days of data from January 1st to December 31st and temporally aggregate this data using the argument –time-resolution 1YEARLY (to generate one YEARLY file). The calculations are done following the ATBD equations. Similarly, a user can request MONTHLY aggregation, with –time-resolution 12MONTHLY, this will produce 12 MONTLHY files for each month.
- The tool will now automatically handle multiple files in a directory and sub-directories by searching for files recursively trough the input folder given. A single path can also be passed. This works in coordination with the "–designation" argument.
- Memory management and performances: The tool will now consider the user's system capabilities with RAM memory and CPU cores available to make the computations as efficiently as possible. The tool should adapt to its environment automatically unless the user specifies memory and CPU cores constraints with the –memory-limit and –threads arguments. The tool has been tested on different kinds of machines with different configurations of amount of RAM and CPU cores.
- Other improvements: Added multiple command line arguments to make the usage of tool easier for the user.
    - –designation (DAY, NIGHT, ASC, DES, ALL) ALL. This argument specifies which kind of files to process if the user has multiple kinds of files in the input directory. By default, it will take all of them, but the tool might exit if it finds incompatible files to work with.
    - –keep-tree (True, False) default False. If set to true, the same directory tree will be used in the output directory. Useful in spatial re-gridding.
    - –skip-existing (True, False) default False. This will skip already processed files if they are found in the output directory.
    - –skip-bad-files (True, False) default True. This will skip possibly corrupted NetCDF files in the input directory. A WARNING message will be displayed to the user if any are found.

1.2.2. Disclaimer

The LST re-gridding and subsetting tool was developed with Python3 on Linux Ubuntu 20.04 and is designed to work on Linux systems. The binary file is provided for Linux and won't run on other OS. Running the tool directly as a python module (from source code) should work on Windows 10/11.

2. Installation

The installation package is a standalone executable for Linux OS accessible to LST_cci members on the project sharepoint.

The version for the users will be made available in the Open Data Portal (tbc).

It is proposed in two versions:

- A zip file containing LST regrid tool script file and all necessary libraries (350MB Zipped - 470 MB unzipped)
- A single binary file embedding all the zipped libraries (350 MB) (requires the download of the landsea_mask folder and the two landmask files: landmask_001.nc and landmask_005.nc)

NB: The single file bundle requires the decompression of embedded libraries, consuming some overhead time before the re-gridding process really starts.

The LST re-gridding tool requires land maps (to identify cloudy pixels) and expects a directory named 'landsea_mask' containing files landmask_001.nc and landmask_005.nc beside the binary file. Those files are provided on the download page. The files are already included in the zip bundle but must be added manually beside the single self-content binary package.

The tool now also requires climatology files, which are used for temporal re-gridding. They are stored along the tool's binary under climatology/IR/

```
ESACCI-LST-L3C-LST_VARIANCE-MODISA-0.05deg_1MONTHLY_DAY_CLIMATOLOGY20251117-00000000-fv4.00.nc
ESACCI-LST-L3C-LST_VARIANCE-MODISA-0.05deg_1MONTHLY_NIGHT_CLIMATOLOGY20251114-00000000-fv4.00.nc
ESACCI-LST-L3C-LST_VARIANCE-MODISA-0.05deg_1YEARLY_DAY_CLIMATOLOGY20251117-00000000-fv4.00.nc
ESACCI-LST-L3C-LST_VARIANCE-MODISA-0.05deg_1YEARLY_NIGHT_CLIMATOLOGY20251114-00000000-fv4.00.nc
```

And climatology/MW/

```
ESACCI-LST-L3C-LST_VARIANCE-AMSRX-0.125deg_1MONTHLY_ASC_CLIMATOLOGY20251117-00000000-fv5.00.nc
ESACCI-LST-L3C-LST_VARIANCE-AMSRX-0.125deg_1MONTHLY_DES_CLIMATOLOGY20251117-00000000-fv5.00.nc
ESACCI-LST-L3C-LST_VARIANCE-AMSRX-0.125deg_1YEARLY_ASC_CLIMATOLOGY20251117-00000000-fv5.00.nc
ESACCI-LST-L3C-LST_VARIANCE-AMSRX-0.125deg_1YEARLY_DES_CLIMATOLOGY20251117-00000000-fv5.00.nc
ESACCI-LST-L3C-LST_VARIANCE-SSMIX-0.125deg_1MONTHLY_ASC_CLIMATOLOGY20251117-00000000-fv5.00.nc
ESACCI-LST-L3C-LST_VARIANCE-SSMIX-0.125deg_1MONTHLY_DES_CLIMATOLOGY20251117-00000000-fv5.00.nc
ESACCI-LST-L3C-LST_VARIANCE-SSMIX-0.125deg_1YEARLY_ASC_CLIMATOLOGY20251117-00000000-fv5.00.nc
ESACCI-LST-L3C-LST_VARIANCE-SSMIX-0.125deg_1YEARLY_DES_CLIMATOLOGY20251117-00000000-fv5.00.nc
```

The "climatology" directory should stay in the same directory as the binary, otherwise the tool will not be able to find them and an error will occur.

2.1. Installation of the single binary file

- Download the lst_cci_regrid binary file
- Export the PATH variable in a terminal:
- *export PATH=$PATH:/path/where/you/put/the/tool*
- Type lst_cci_regrid to run this executable file

Additional information and instructions are written in the provided README.md file.

NB: the export command can be appended to the user '.profile' file to set it automatically in each newly-opened terminal.

NB: Depending on your system setup you may have to change the permissions of your executable file. The following command will enable all users to execute the file:

chmod 755 lst_cci_regrid

2.2. Installation of the zip bundle

- Download the zip file
- Decompress in a dedicated folder:
- *tar xvzf lst_cci_regrid.tgz*
- Run the lst_cci_regrid binary file: it is located at the root directory of the unpacked bundle (NB. It might be necessary to prepend './' to the binary command for the OS to recognize it: use './lst_cci_regrid')

NB: The decompressing process takes some time to achieve the decompression of a huge number of files. Decompressed files will occupy 1.2 GB of disk space.

lst_cci_regrid tool is a binary file based on a Python3 script and can be used with the following command followed with arguments:

```
./lst_cci_regrid <arguments>
```

The '-h' option provides help on parameters:

```
lst_cci_regrid -h
```

```
usage: lst-cci-regrid [-h] [--resolution RESOLUTION] [--time-resolution TIME_RESOLUTION] [--coords
COORDS]
                      [--output-file OUTPUT_FILE] [--threads THREADS] [--memory-limit MEMORY_LIMIT]
                      [--comp-level COMP_LEVEL] [--designation {DAY,NIGHT,ASC,DES,ALL}] [--keep-tree]
                      [--skip-existing] [--keep-temp-files] [--keep-log] [--skip-bad-files]
                      [--log-level {DEBUG,INFO,SUCCESS,WARNING,ERROR,CRITICAL}] [--verbose] [--version]
                      input output_dir

LST CCI Regrid v2.0 - Spatial and/or temporal regridding of LST CCI products

positional arguments:
  input                 Input LST CCI product (.nc file), directory containing products (scanned recursively),
or
                        text file (.txt) with list of products
  output_dir            Output directory for processed files
```

```
options:
 -h, --help          show this help message and exit
 --resolution RESOLUTION
                     Output spatial resolution for regridding (lat lon) in decimal degrees. Use quotes if
                     providing both: --resolution "0.05 0.05". Single value applies to both dimensions. If not
                     provided, only temporal aggregation and/or subsetting are applied.
 --time-resolution TIME_RESOLUTION
                     Output time resolution for temporal aggregation. Format: [n]DAILY, [n]WEEKLY,
[n]MONTHLY,
                     or [n]YEARLY where [n] is optional (default 1). Examples: 1MONTHLY, 5MONTHLY,
8DAILY. If
                     not provided, only spatial regridding and/or subsetting are applied. When both spatial
and
                     temporal are enabled, spatial is applied first.
 --coords COORDS     Rectangular spatial subsetting area: "latmin latmax lonmin lonmax". Latitudes
in [-90,
                     90], longitudes in [-180, 180]. Example: --coords "35 70 -10 40" for Europe
 --output-file OUTPUT_FILE
                     Force specific output filename (only for single file input). If not provided, filename is
                     auto-generated based on operations.
 --threads THREADS   Number of parallel CPU threads to use (default: auto = physical cores). Auto-
detected: 20
                     on this machine.
 --memory-limit MEMORY_LIMIT
                     Maximum RAM memory to use during processing (e.g., 16GB, 32GB). Default: auto-
detect and
                     use 70% of available memory. Format: number followed by unit (GB or GiB).
 --comp-level COMP_LEVEL
                     NetCDF4 compression level: 0 (none) to 9 (max), or 'auto' to match input. Default: auto
 --designation {DAY,NIGHT,ASC,DES,ALL}
                     Filter files by designation (DAY/NIGHT for IR, ASC/DES for MW). Default: ALL (process all
                     files)
 --keep-tree         Preserve input directory structure in output directory when processing recursively.
 --skip-existing     Skip processing if the output file already exists.
 --keep-temp-files   Keep intermediate/temporary files in output directory when doing combined
spatial+temporal
                     operations. Temp files are stored in <output_dir>/.temp/. Default: False (temporary
files
                     are deleted after processing)
 --keep-log          Save a log file in the output directory with timestamped filename. Format:
                     lst_cci_regrid_YYYYMMDD_HHMMSS.log. Default: False
 --skip-bad-files    Skip unreadable/corrupt files instead of aborting. Summary of skipped files will be
                     logged. Default: True
 --log-level {DEBUG,INFO,SUCCESS,WARNING,ERROR,CRITICAL}
                     Set logging level (default: INFO)
 --verbose           Enable verbose debug logging (equivalent to --log-level DEBUG)
 --version           show program's version number and exit
```

```
Examples:
  Temporal aggregation: daily files to monthly
  lst-cci-regrid ./daily_data ./output --time-resolution 1MONTHLY

  Temporal aggregation: daily files to dekadal (10-day)
  lst-cci-regrid ./daily_data ./output --time-resolution 10DAILY

  Spatial regridding: 0.01° to 0.25° resolution
  lst-cci-regrid ./input_data ./output --resolution "0.25 0.25"

  Combined: spatial regrid + temporal aggregation
  lst-cci-regrid ./daily_data ./output --resolution 0.25 --time-resolution 1MONTHLY

  Regional subset (Europe) with temporal aggregation
  lst-cci-regrid ./input_data ./output --coords "35 70 -10 40" --time-resolution 1MONTHLY

  Filter by designation (daytime IR only)
  lst-cci-regrid ./input_data ./output --time-resolution 1MONTHLY --designation DAY

  Control memory and parallelism
  lst-cci-regrid ./input_data ./output --resolution 0.25 --memory-limit 16GB --threads 4

Exit Codes:
  0   - Success
  1   - Processing error
  2   - Argument parsing error
  130 - Keyboard interrupt (Ctrl+C)
  255 - Validation error (invalid parameters, insufficient files, etc.)
```

- input_file: input LST product is a required argument indicating the file to process.
- Output_dir: output directory is a required argument indicating where to store the result product.
- h/help: the help argument is optional and displays a quick help on tool usage
- resolution: the resolution argument is optional and required for re-gridding operations only. If not provided, only a subsetting is realised (the original image is cropped to the sub area dimensions).
- Output-file: the optional output-file argument is used to force the name of the output product to user's demand
- Threads: the optional thread argument is used to speed up the process dividing the computation into as many threads as specified. To be efficient, we advise to set a number of threads between 1 and the number of available cores on the hardware device.
- Comp-level: the optional compression level indicates the compression ratio into the NETCDF file. The compression-level can significantly impact the processing performances.
- Keep-log: the optional keep-log argument keeps the log file intact at the end of reprocessing. By default, the log file is removed if no error occurred.

- Coords: the optional coords argument is used to specify a sub-area. The sub-area is a rectangle aligned with latitude and longitude axis. The argument is a string composed of the 4 values separated with a space, ‘ ‘, and indicates the rectangle borders, ordered like this:
    1. latitude min
    2. latitude max
    3. longitude min
    4. longitude max

  Example:

  lst_cci_regrid <input file> <output_dir> --coords "-20 10 -100 100"

2.3. Output product naming

If not specified with the --output-file argument, the output file name is copied from the input file name with resolution field updated with the target resolution.

In other terms, in case of sub-setting without re-gridding, the resolution is kept: the output file name is the same as the input file name. The only way to differentiate input and output product is with the –output-dir argument provided in input.

NB: inside the NETCDF output product, global attributes are updated to reflect the use of the LST re-gridding tool.

3. Tool data handling

3.1. Re-gridding and sub-setting

The LST re-gridding tool offers two main functions which are re-gridding (spatial and temporal) and sub-setting.

The spatial re-gridding operation lowers a product resolution according to provided parameters, with specific mean functions applied to LST variables. The re-gridding operation obtains a coarser resolution (it cannot output a resolution finer than the original).

The temporal re-gridding operation lowers the temporal dimension (e.g., from daily to monthly) according to provided parameters, with specific mean functions applied to LST variables. The re-gridding operation gives a unique file from a temporal series.

The sub-setting operation is a crop step which consists in reducing tool operations to a selected sub-map defined with longitude-latitude extremum coordinates of the rectangular map under consideration. Focusing on a sub-map instead of the whole product results in a significant computation time saving.

The re-gridding (spatial and temporal) and sub-setting operations can be used either together or separately: the mean functions are applied on the LST variables inside the sub-setting window if --coords is provided, or the whole product if --coords is not specified. By default, if no –resolution or –time-resolution option is provided, only the sub-setting step is performed, and the input resolution is kept.

3.2. Working steps

The tool handles a pre-defined set of variables (see AD-1) in the LST_CCI input product through a mean function before copying the result in the output product.

The output file name is computed based on the input file name and the LST_CCI file naming convention: the file resolution and creation date are replaced in the input file name.

During processing, the variable currently being processed and the mean function used are displayed.

After all variables are forwarded to the output product, the total uncertainty is computed from the actual result.

If minimum / maximum latitude and longitude coordinates are provided, the processing will be applied on this sub-map only and the output product will appear as zoomed in.

All variable attributes are preserved.

Global attributes are either copied or updated.

Input variables not identified in the predefined set are ignored.

By default, the lst_unc_loc_atm and lst_unc_loc_sfc variables mean functions is an arithmetic mean. If the output resolution is greater than 0.05 deg, then the variables mean function is nanmean_uncorrelated_loc as specified in column 2 'Propagation from 0.05˚' of the following table (extracted fromATB [AD-1]).

Category	Variable		Propagation to 0.05° Daily Files	Propagation to 0.05° Monthly Files	Propagation from 0.05° (any temporal period)	(0.05° or less) Propagation within 1-month	(0.05° or less) Propagation >1-month
Coordinates	time		Direct copy	Direct copy	Direct copy	Direct copy	Direct copy
	dtime		Eq. 1	Eq. 1	Eq. 1	Eq. 1	Eq. 1
	lat		Remapping	Remapping	Remapping	Remapping	Remapping
	lon		Remapping	Remapping	Remapping	Remapping	Remapping
	Channel		Direct copy	Direct copy	Direct copy	Direct copy	Direct copy
Geophysical variables	Lst		Eq. 1	Eq. 1	Eq. 1	Eq. 1	Eq. 1
	Lcc		Non-propagation	Non-propagation	Non-propagation	Non-propagation	Non-propagation
	lst_time_correction		Eq. 1	Eq. 1	Eq. 1	Eq. 1	Eq. 1
Uncertainty information – total uncertainty	lst_uncertainty	IR	Eq. 9	Eq. 9	Eq. 9	Eq. 9	Eq. 9
		MW	Eq. 2	Eq. 2	Eq. 2	Eq. 2	Eq. 2
Uncertainty information – individual components	lst_unc_ran		Eq. 4	Eq. 4	Eq. 4	Eq. 4	Eq. 4
	lst_unc_loc_atm		Eq. 6	Eq. 7	Eq. 7	Eq. 7	Eq. 7
	lst_unc_loc_sfc	UOL	Eq. 6	Eq. 6	Eq. 7	Eq. 6	Eq. 7
		GSW, SMW, NNEA	Eq. 6	Eq. 6	Eq. 7	Eq. 6	Eq. 7
	lst_unc_loc_cor		Eq. 6	Eq. 6	Eq. 6	Eq. 6	Eq. 6
	lst_unc_time_correction	IR	Eq. 5	Eq. 5	Eq. 5	Eq. 5	Eq. 5
		MW	Eq. 2	Eq. 2	Eq. 2	Eq. 2	Eq. 2

	lst_unc_sys	Eq. 5	Eq. 5	Eq. 5	Eq. 5	Eq. 5
Retrieval information	Satze	Eq. 1	Eq. 1	Eq. 1	Eq. 1	Eq. 1
	Sataz	Eq. 1	Eq. 1	Eq. 1	Eq. 1	Eq. 1
	Solze	Eq. 1	Eq. 1	Eq. 1	Eq. 1	Eq. 1
	solaz	Eq. 1	Eq. 1	Eq. 1	Eq. 1	Eq. 1
	n	Arithmetic sum	Arithmetic sum	Arithmetic sum	Arithmetic sum	Arithmetic sum
Quality information	qual_flag	Non-propagation	Non-propagation	Non-propagation	Non-propagation	Non-propagation

Many of the CCI LST products from IR sensors are provided at a spatial resolution of 0.01°. If the input file resolution is less than 0.05°, while the resolution argument is greater than 0.05 then the re-gridding is processed in two steps: to an intermediate 0.05° resolution first, then to the target resolution. The same two-step method also applies in temporal re-gridding but with a MONTHLY threshold. For example a DAILY to YEARLY re-gridding will be processed as two-steps : DAILY to MONTHLY and then MONTHLY to YEARLY as each step requires potentially different equations to be applied.

While processing, warnings and errors can occur. Both cases give rise to an informational message on the display console. The tool tries to recover from warnings but ends in error if fails. Errors provide a message and abort processing.

During the process, a log file is created as indicated in the standard output. If no error is detected, the log file is deleted. Otherwise, the log file is preserved and informs on errors (Log file can be preserved with the –keep-log option as argument).

4. Examples with spatial re-gridding

4.1. Subsetting of a product:

```
lst_cci_regrid TDS/ESACCI-LST-L3C-LST-MODISA-0.05deg_1MONTHLY_DAY-20060701000000-fv3.00.nc output_05 --coords "0 90 0 180"
```

```
(base) [hillel@sci1 tmp]$ lst_cci_regrid_v1.00  ~/lst_regrid_tool/TDS/ESACCI-LST-L3C-LST-MODISA-0.05deg_1MONTHLY_DAY-20060701000000-fv3.00.nc output_05 --coords "0 90 0 180"
charset_normalizer/assets/__init__.py:17: UserWarning: Charset-Normalizer require '/tmp/_MEIdyvtpq/charset_normalizer/assets/frequencies.json' to be existent for language/coherence detection. Detection WILL be weaker.
2022-09-26 10:55:54,657 -  INFO  - log file: /tmp/_MEIdyvtpq/lst_cci_regrid_ESACCI-LST-L3C-LST-MODISA-0.05deg_1MONTHLY_DAY-20060701000000-fv3.00.nc_to_None.log
2022-09-26 10:55:54,692 -  INFO  - output_05 directory not found, creating it.
2022-09-26 10:55:54,716 -  INFO  - spatial resolution used is geospatial_lat_resolution
2022-09-26 10:55:54,717 -  INFO  - Use 8 parallel CPU threads
2022-09-26 10:55:54,718 -  INFO  - Output file: output_05/ESACCI-LST-L3C-LST-MODISA-0.05deg_1MONTHLY_DAY-20060701000000-fv3.00.nc
2022-09-26 10:55:54,718 -  INFO  - Input file resolution: 0.05
2022-09-26 10:55:54,718 -  INFO  - Output file resolution: 0.05
2022-09-26 10:55:54,718 -  INFO  - Sub grid coordinates: [0 90 0 180]
2022-09-26 10:55:54,718 -  INFO  - ----------------------------------------
2022-09-26 10:55:56,023 -  INFO  - COPY 'dtime' variable
2022-09-26 10:55:56,024 -  INFO  - COPY 'satze' variable
2022-09-26 10:55:56,026 -  INFO  - COPY 'sataz' variable
2022-09-26 10:55:56,028 -  INFO  - COPY 'solze' variable
2022-09-26 10:55:56,030 -  INFO  - COPY 'solaz' variable
2022-09-26 10:55:56,032 -  INFO  - COPY 'lst' variable
2022-09-26 10:55:56,034 -  INFO  - COPY 'lst_uncertainty' variable
2022-09-26 10:55:56,036 -  INFO  - COPY 'lst_unc_ran' variable
2022-09-26 10:55:56,039 -  INFO  - COPY 'lst_unc_loc_atm' variable
2022-09-26 10:55:56,041 -  INFO  - COPY 'lst_unc_loc_sfc' variable
2022-09-26 10:55:56,043 -  INFO  - COPY 'lst_unc_sys' variable
2022-09-26 10:55:56,046 -  INFO  - COPY coordinates 'channel'
2022-09-26 10:55:56,061 -  INFO  - ==================================
2022-09-26 10:55:56,061 -  INFO  - Writing output file
2022-09-26 10:56:04,850 -  INFO  - File output_05/ESACCI-LST-L3C-LST-MODISA-0.05deg_1MONTHLY_DAY-20060701000000-fv3.00.nc written
2022-09-26 10:56:04,895 -  INFO  - Regridding successfully ended.
2022-09-26 10:56:04,896 -  INFO  - Regridding duration: 0:00:10.241470
2022-09-26 10:56:04,896 -  INFO  - ==================================
```

Figure 1: console execution

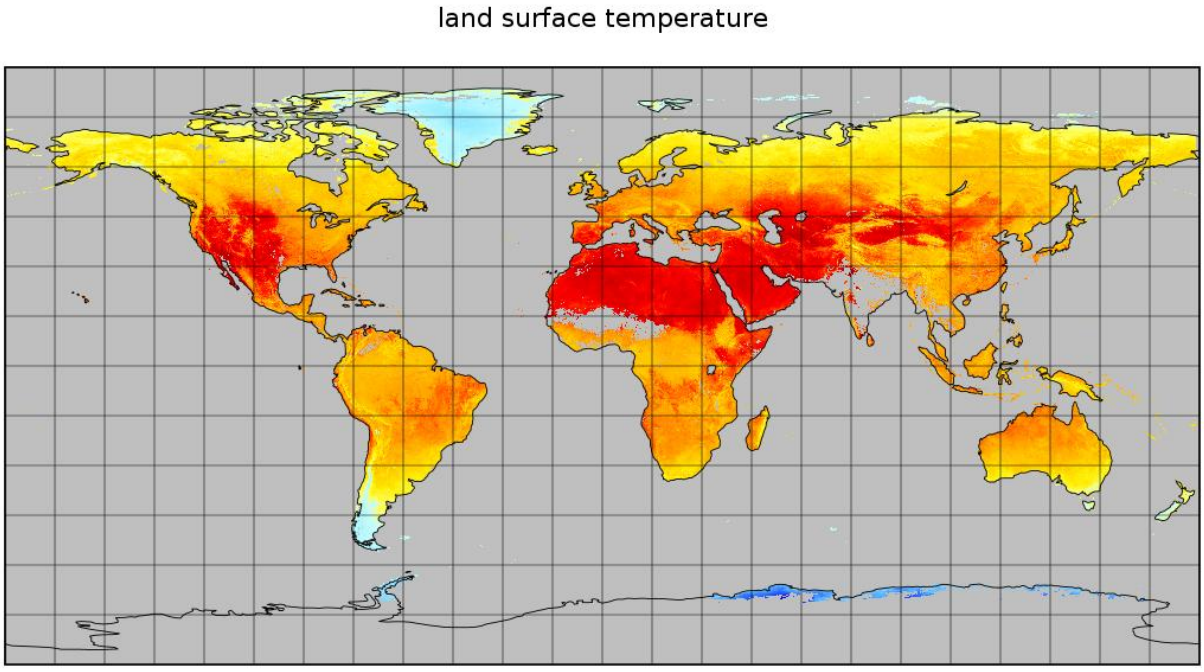


Figure 2: Original temperature

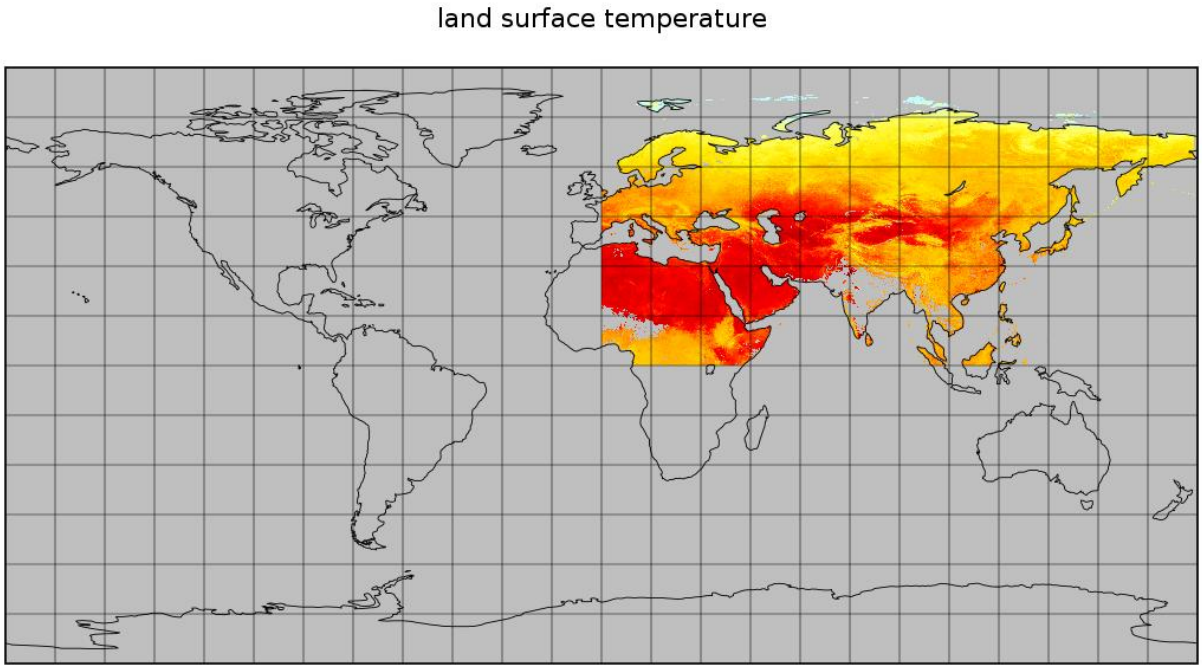


Figure 3: Sub-setted temperature

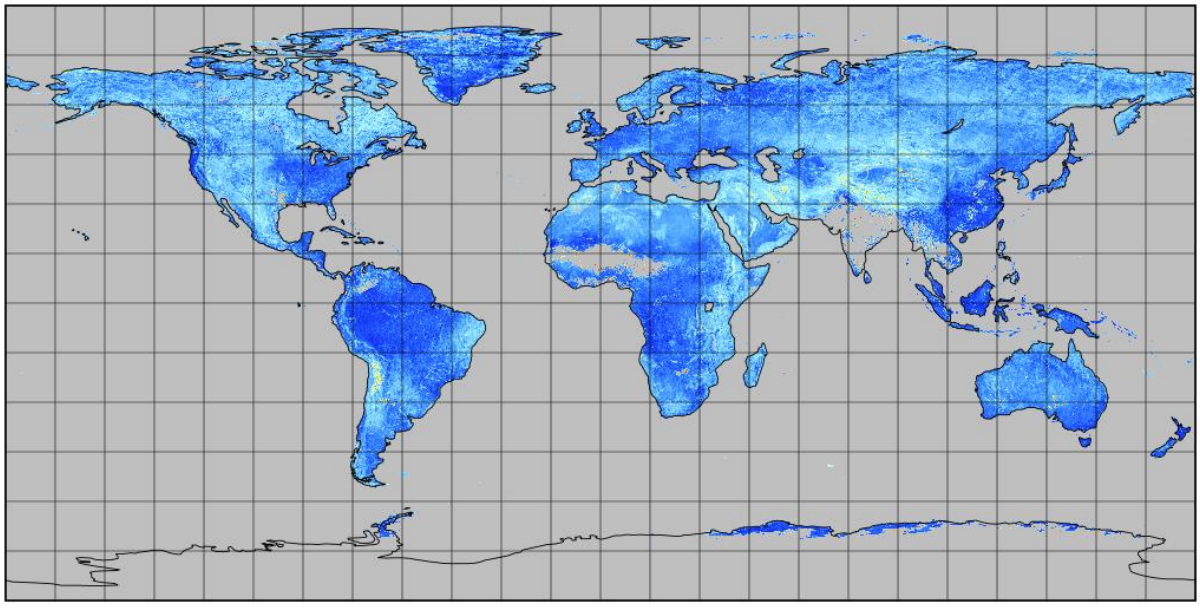


Figure 4: Original LST uncertainties

land surface temperature total uncertainty

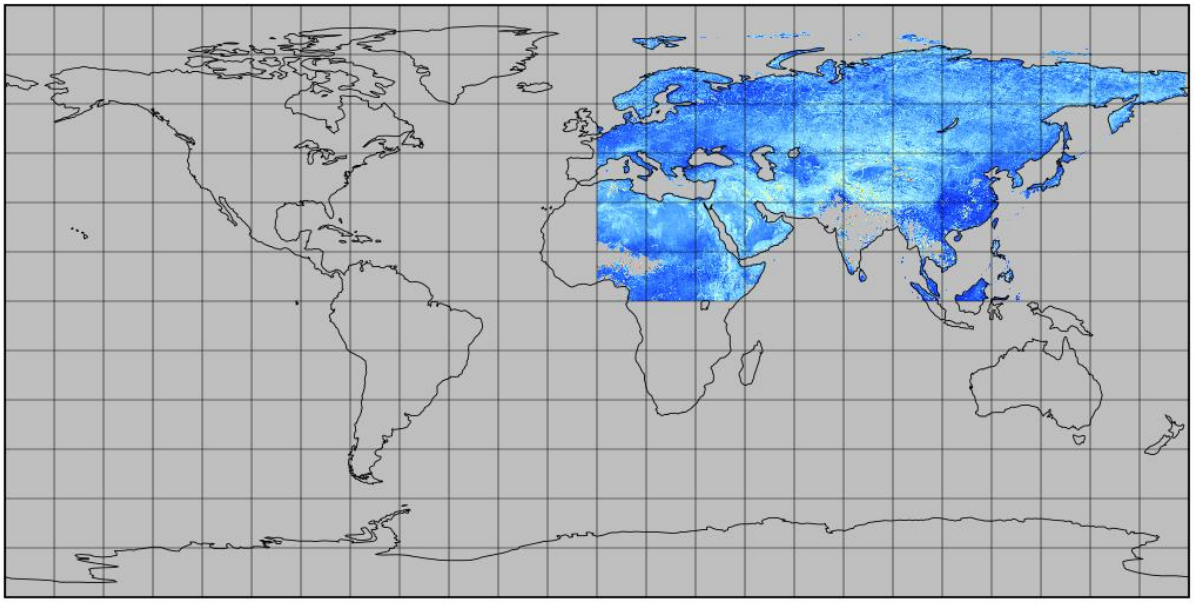


Figure 5: subset of LST uncertainties

4.2. Running the regrid tool on a whole file, lowering the resolution from 0.05 degree to 0.25 degree:

```
lst_cci_regrid TDS/ESACCI-LST-L3C-LST-MODISA-0.05deg_1MONTHLY_DAY-20060701000000-fv3.00.nc output_025 --resolution 0.25
```

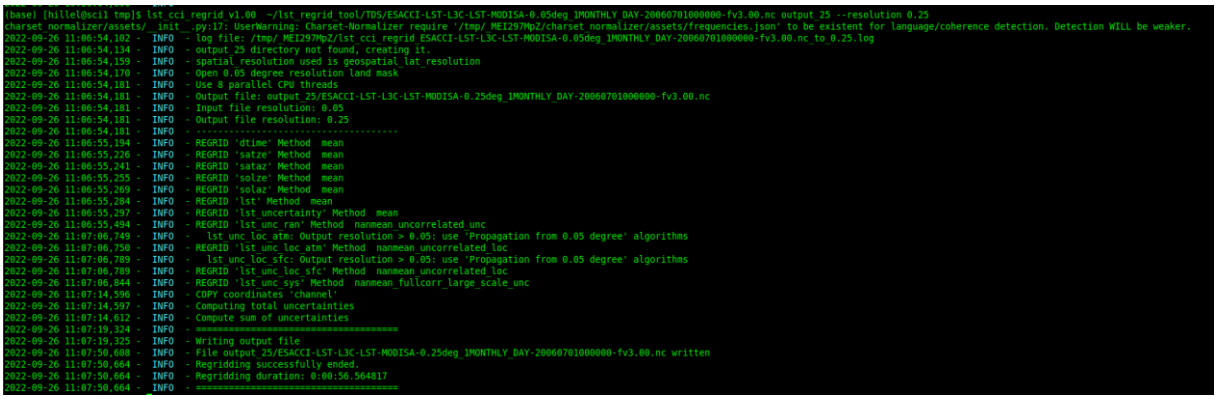


Figure 6: Example of console execution on a whole file

Display example result:

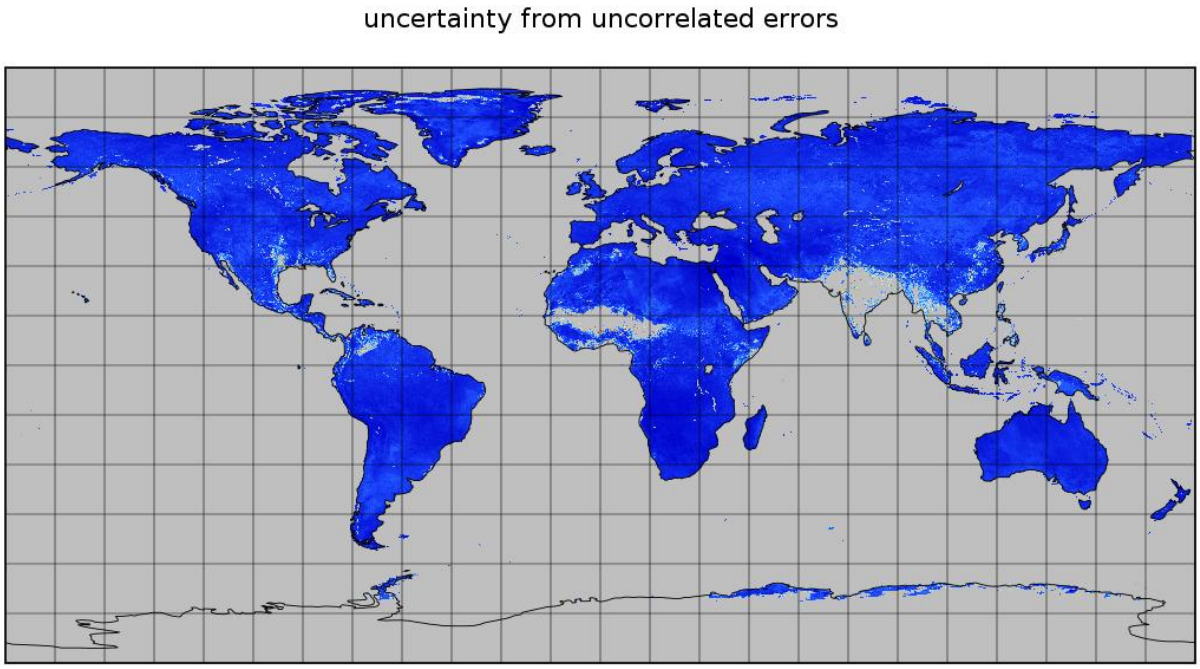


Figure 7: original lst_unc_ran variable

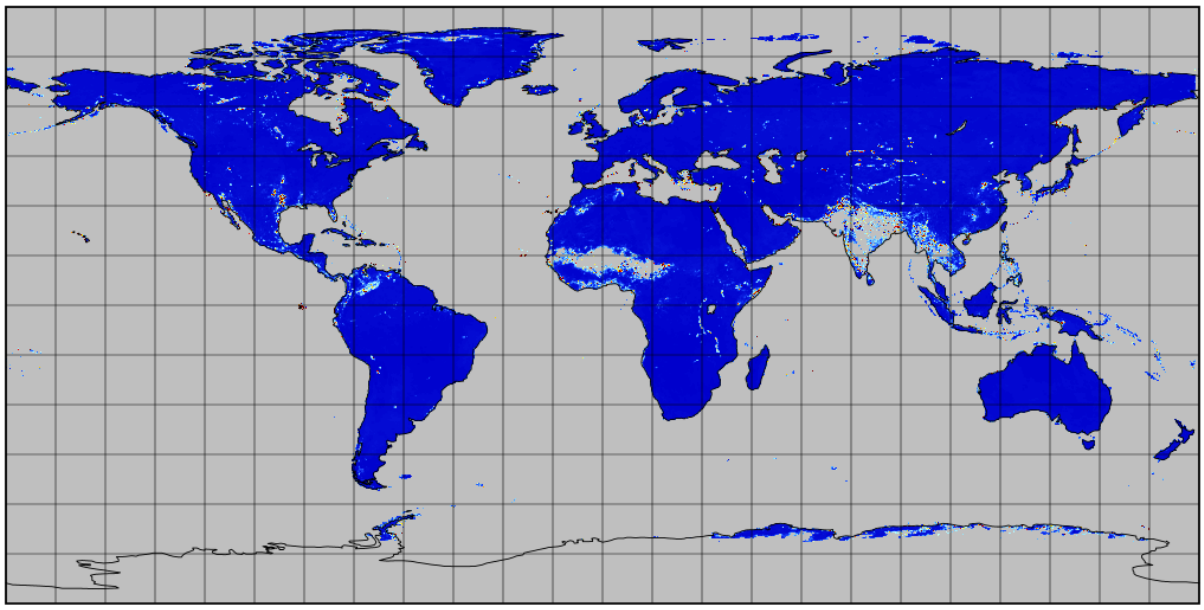


Figure 8: Re-gridded lst_unc_ran variable

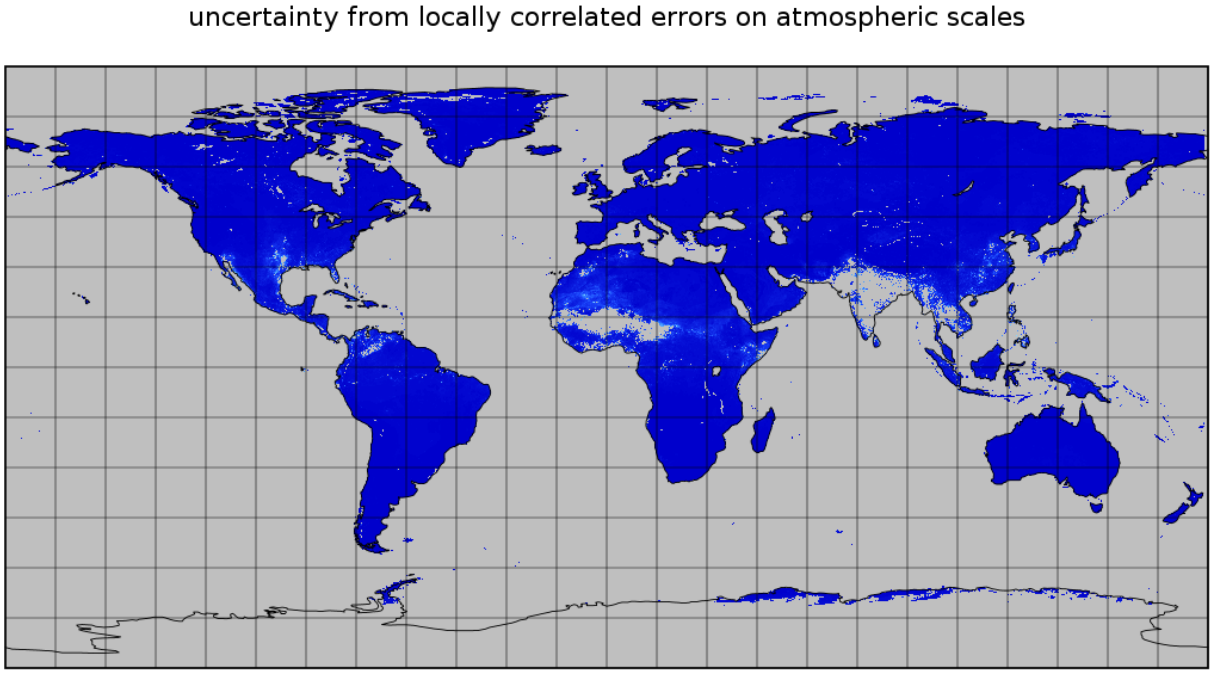


Figure 9: original file lst_unc_loc_atm variable

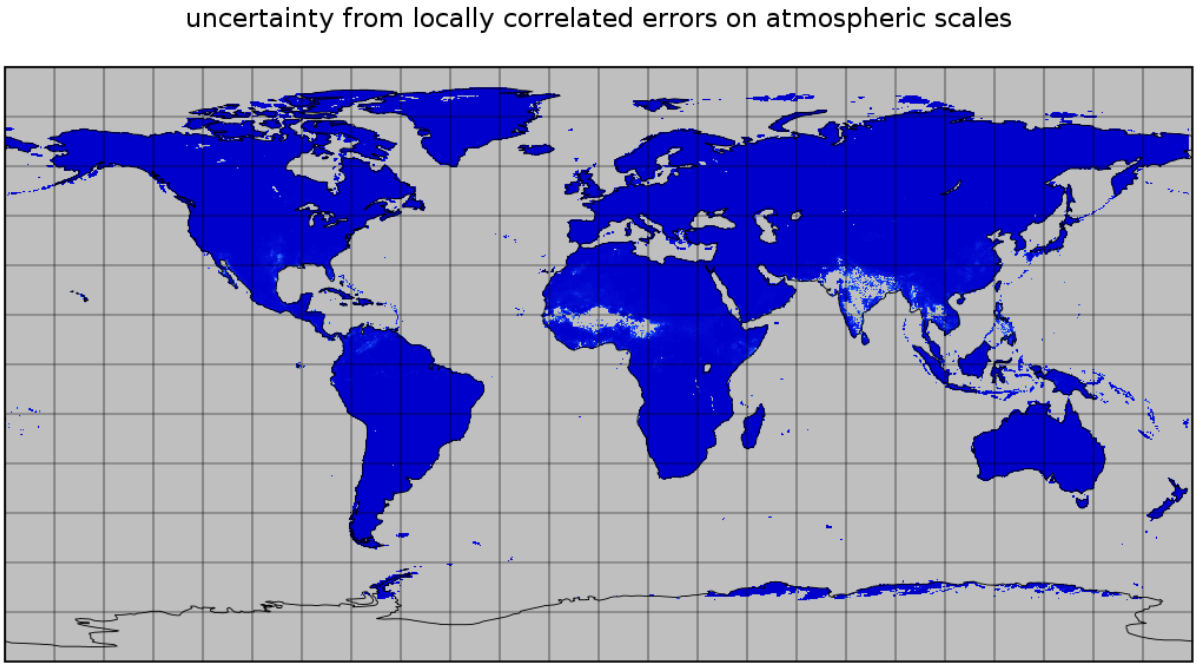


Figure 10: re-gridded lst_unc_loc_atm variable

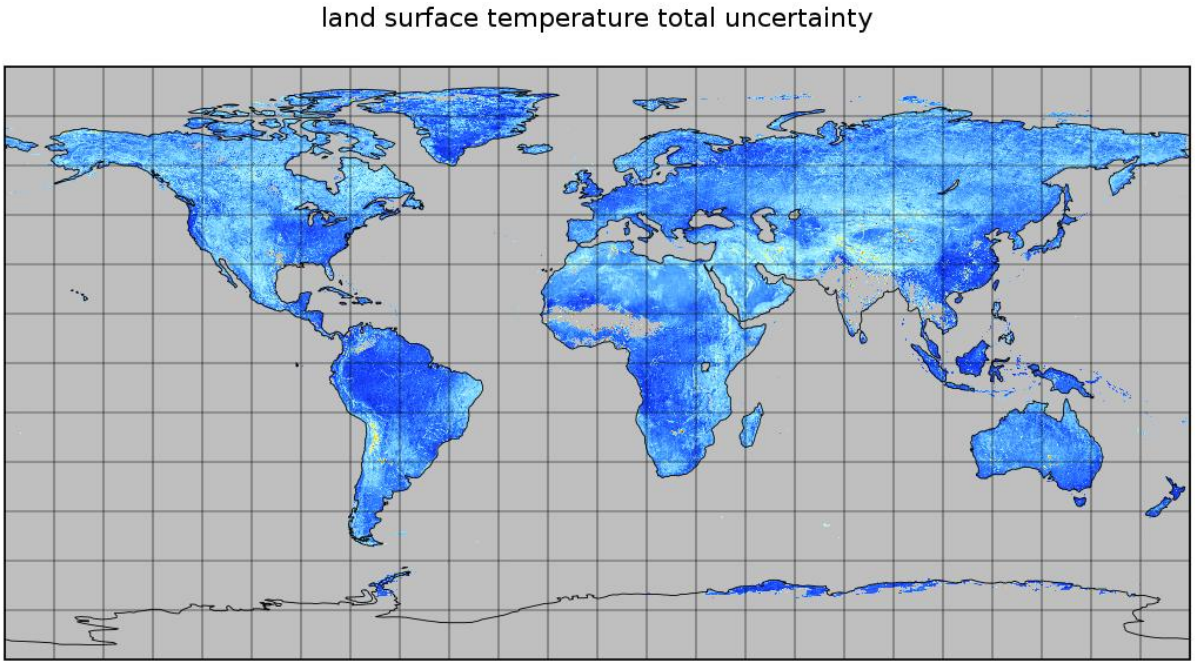


Figure 11: original file total uncertainties

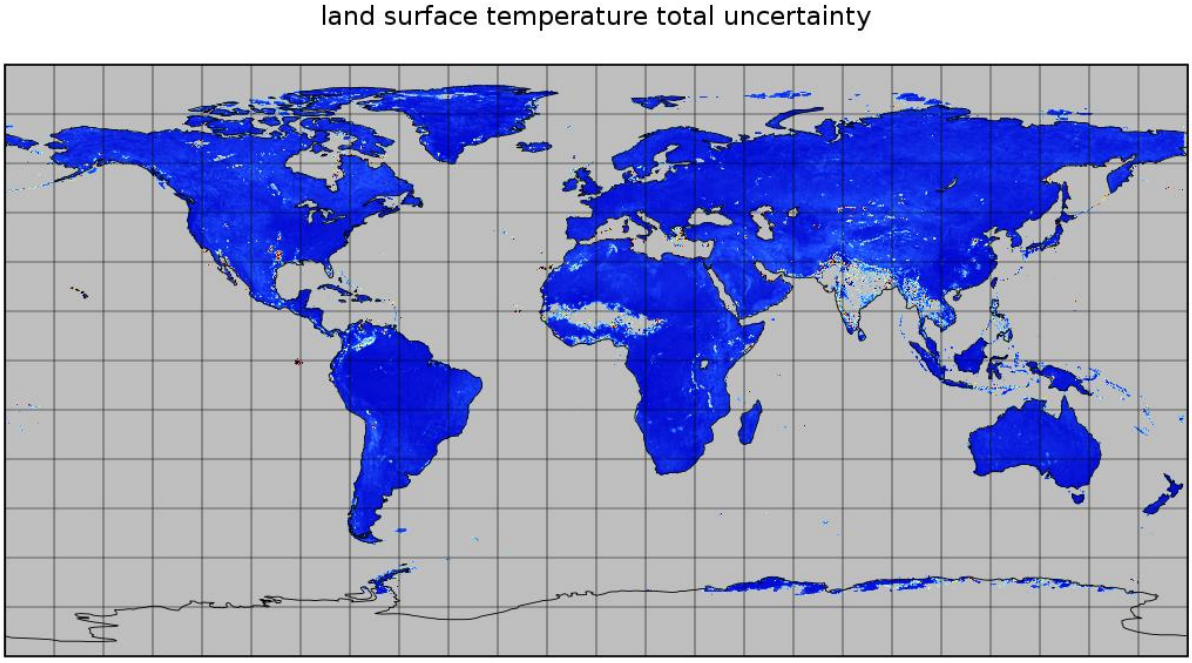


Figure 12: Re-gridded file total uncertainties

4.3. Running the regrid tool on a sub-area, lowering the resolution from 0.05 degree to 0.25 degree:

```
lst_cci_regrid TDS/ESACCI-LST-L3C-LST-MODISA-0.05deg_1MONTHLY_DAY-20060701000000-fv3.00.nc output_25 --coords "0 90 0 180" --resolution 0.25
```

```
(base) [hillel@sci1 tmp]$ lst_cci_regrid_v1.00  ~/lst_regrid_tool/TDS/ESACCI-LST-L3C-LST-MODISA-0.05deg_1MONTHLY_DAY-20060701000000-fv3.00.nc output_25 --coords "0 90 0 180" --resolution 0.25
charset_normalizer/assets/__init__.py:17: UserWarning: Charset-Normalizer require '/tmp/.MEIchytBN/charset_normalizer/assets/frequencies.json' to be existent for language/coherence detection. Detection WILL be weaker.
2022-09-26 11:10:39,182 -  INFO  - log file: /tmp/.MEIchytBN/lst_cci_regrid_ESACCI-LST-L3C-LST-MODISA-0.05deg_1MONTHLY_DAY-20060701000000-fv3.00.nc_to_0.25.log
2022-09-26 11:10:39,244 -  INFO  - spatial resolution used is geospatial_lat_resolution
2022-09-26 11:10:39,251 -  INFO  - Open 0.05 degree resolution land mask
2022-09-26 11:10:39,261 -  INFO  - use a sub selection of land map
2022-09-26 11:10:39,264 -  INFO  - Use 8 parallel CPU threads
2022-09-26 11:10:39,264 -  WARNING  - Output file output_25/ESACCI-LST-L3C-LST-MODISA-0.25deg_1MONTHLY_DAY-20060701000000-fv3.00.nc exists and will be replaced.
2022-09-26 11:10:39,265 -  INFO  - Input file resolution: 0.05
2022-09-26 11:10:39,266 -  INFO  - Output file resolution: 0.25
2022-09-26 11:10:39,266 -  INFO  - Sub grid coordinates: [0 90 0 180]
2022-09-26 11:10:39,266 -  INFO  - ------------------------------------
2022-09-26 11:10:40,321 -  INFO  - REGRID 'dtime' Method  mean
2022-09-26 11:10:40,343 -  INFO  - REGRID 'satze' Method  mean
2022-09-26 11:10:40,351 -  INFO  - REGRID 'sataz' Method  mean
2022-09-26 11:10:40,358 -  INFO  - REGRID 'solze' Method  mean
2022-09-26 11:10:40,366 -  INFO  - REGRID 'solaz' Method  mean
2022-09-26 11:10:40,374 -  INFO  - REGRID 'lst' Method  mean
2022-09-26 11:10:40,382 -  INFO  - REGRID 'lst_uncertainty' Method  mean
2022-09-26 11:10:40,451 -  INFO  - REGRID 'lst_unc_ran' Method  nanmean_uncorrelated_unc
2022-09-26 11:10:43,451 -  INFO  -   lst_unc_loc_atm: Output resolution > 0.05: use 'Propagation from 0.05 degree' algorithms
2022-09-26 11:10:43,451 -  INFO  - REGRID 'lst_unc_loc_atm' Method  nanmean_uncorrelated_loc
2022-09-26 11:10:43,473 -  INFO  -   lst_unc_loc_sfc: Output resolution > 0.05: use 'Propagation from 0.05 degree' algorithms
2022-09-26 11:10:43,473 -  INFO  - REGRID 'lst_unc_loc_sfc' Method  nanmean_uncorrelated_loc
2022-09-26 11:10:43,517 -  INFO  - REGRID 'lst_unc_sys' Method  nanmean_fullcorr_large_scale_unc
2022-09-26 11:10:45,599 -  INFO  - COPY coordinates 'channel'
2022-09-26 11:10:45,601 -  INFO  - Computing total uncertainties
2022-09-26 11:10:45,610 -  INFO  - Compute sum of uncertainties
2022-09-26 11:10:46,943 -  INFO  - ====================================
2022-09-26 11:10:46,943 -  INFO  - Writing output file
2022-09-26 11:10:55,169 -  INFO  - File output_25/ESACCI-LST-L3C-LST-MODISA-0.25deg_1MONTHLY_DAY-20060701000000-fv3.00.nc written
2022-09-26 11:10:55,215 -  INFO  - Regridding successfully ended.
2022-09-26 11:10:55,216 -  INFO  - Regridding duration: 0:00:16.036366
2022-09-26 11:10:55,216 -  INFO  - ====================================
```

Figure 13: Example of console execution on a sub-area

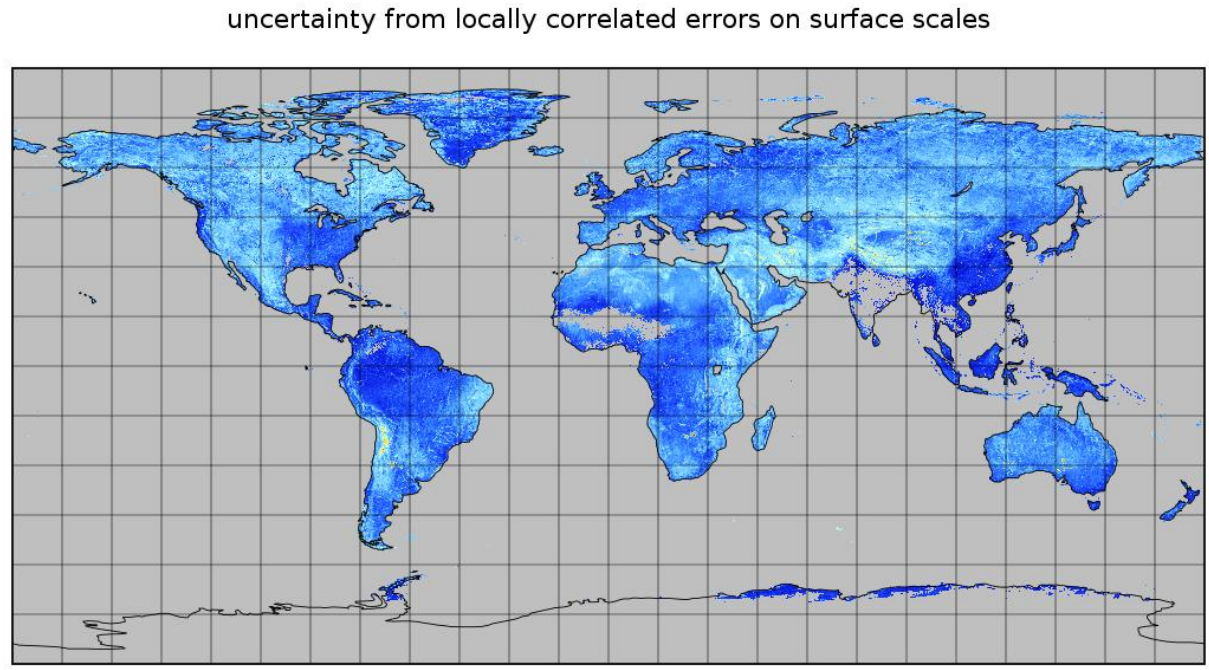


Figure 14: Original lst_unc_loc_sfc values

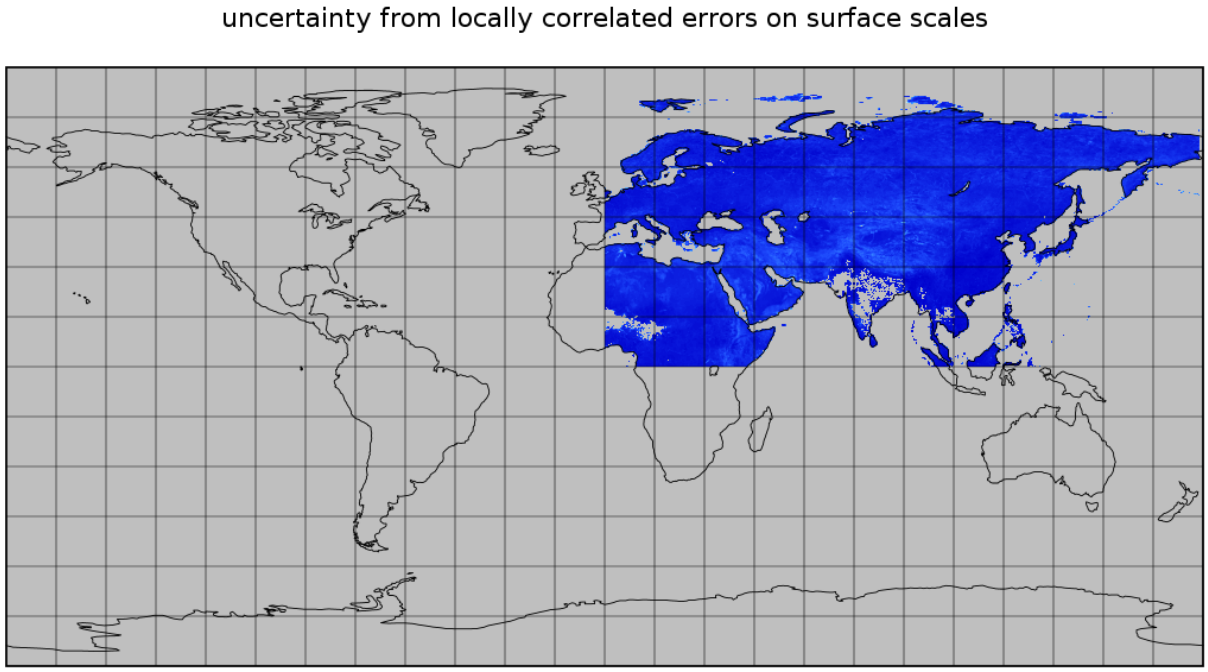


Figure 15: Re-gridded lst_unc_loc_sfc values

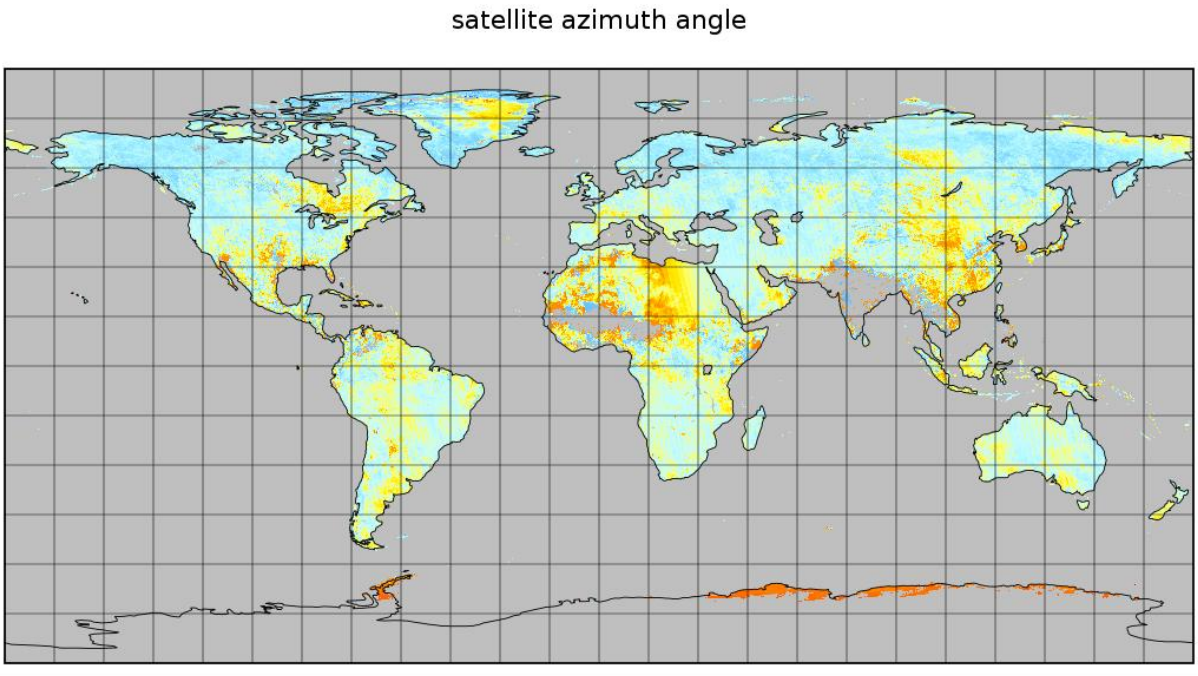


Figure 16: Original SATAZ values

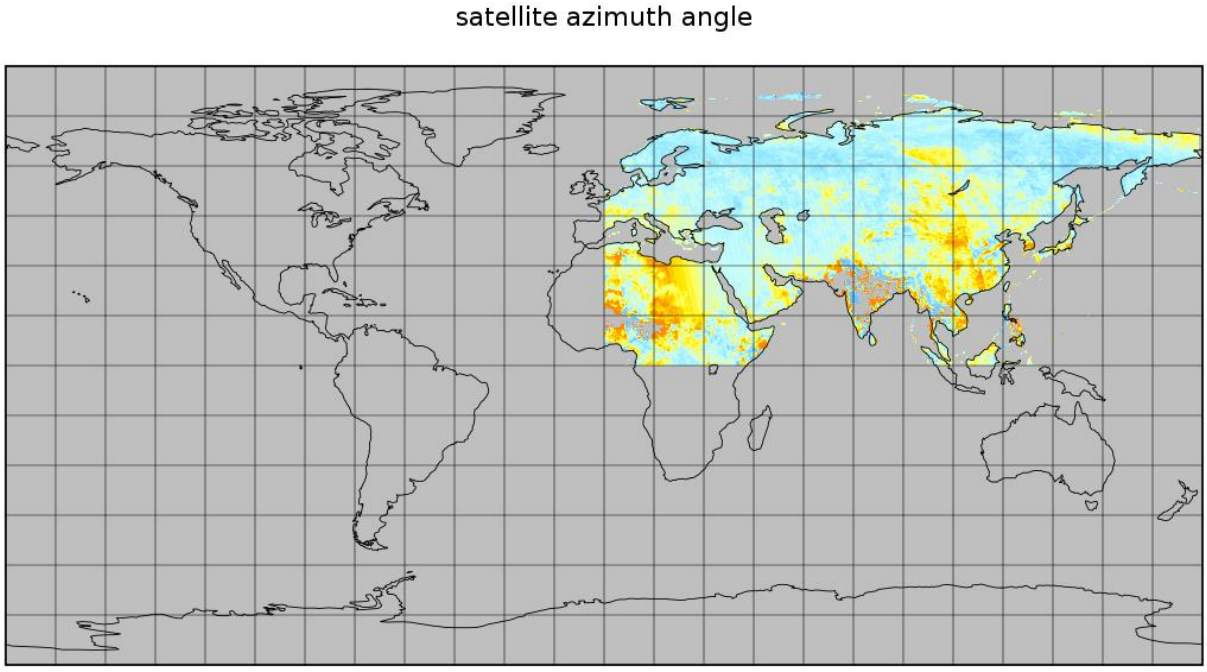


Figure 17: Re-gridded SATAZ values

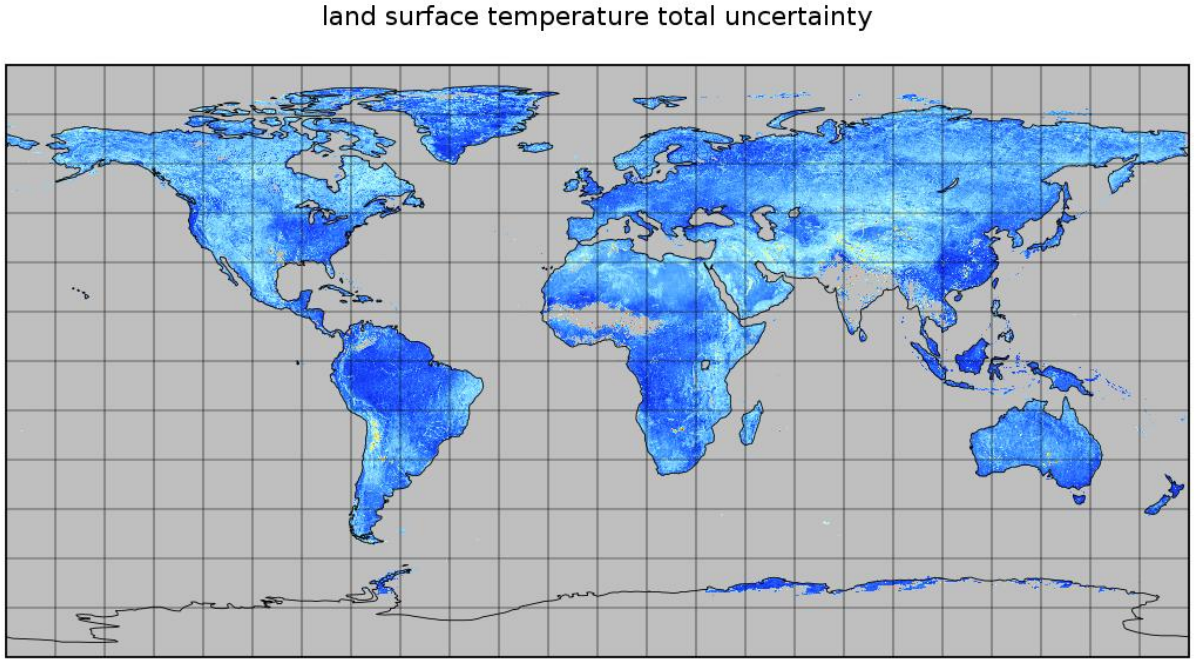


Figure 18: Original LST uncertainty

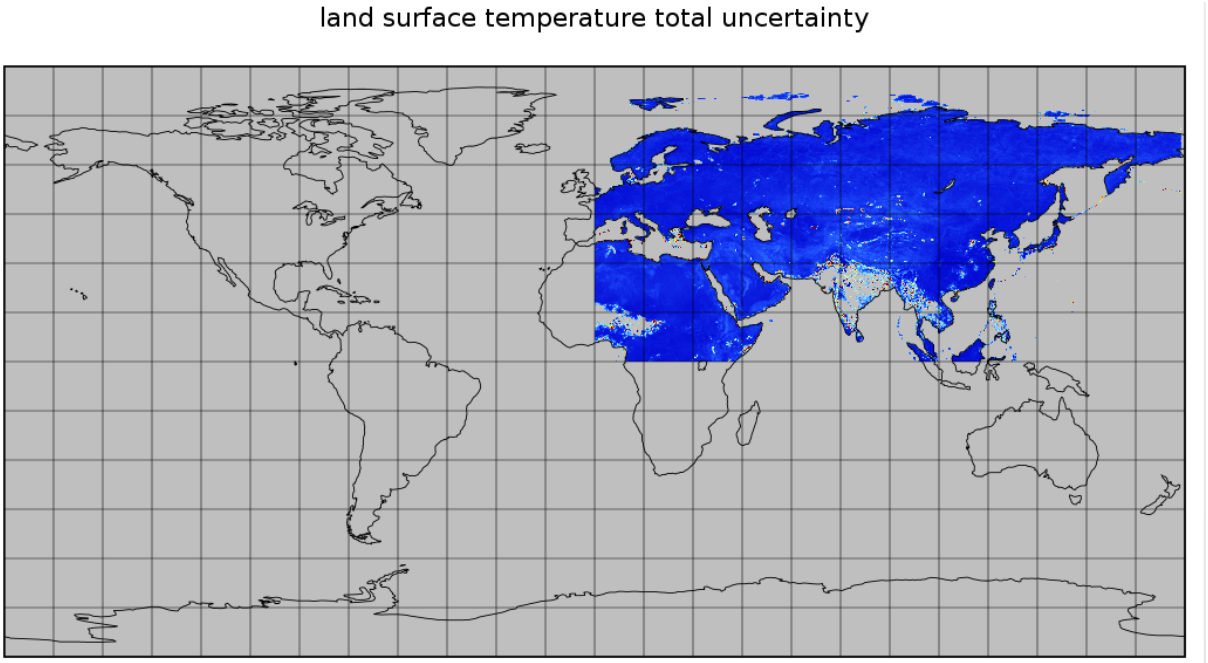


Figure 19: Re-gridded LST uncertainty

4.4. Running the regrid tool using '2 steps' algorithm and threads:

```
lst_cci_regrid TDS/ESACCI-LST-L3C-LST-MODISA-0.01deg_1MONTHLY_DAY-20060701000000-fv3.00.nc output_05 --coords "0 90 0 180" --resolution 0.5 --threads 3
```

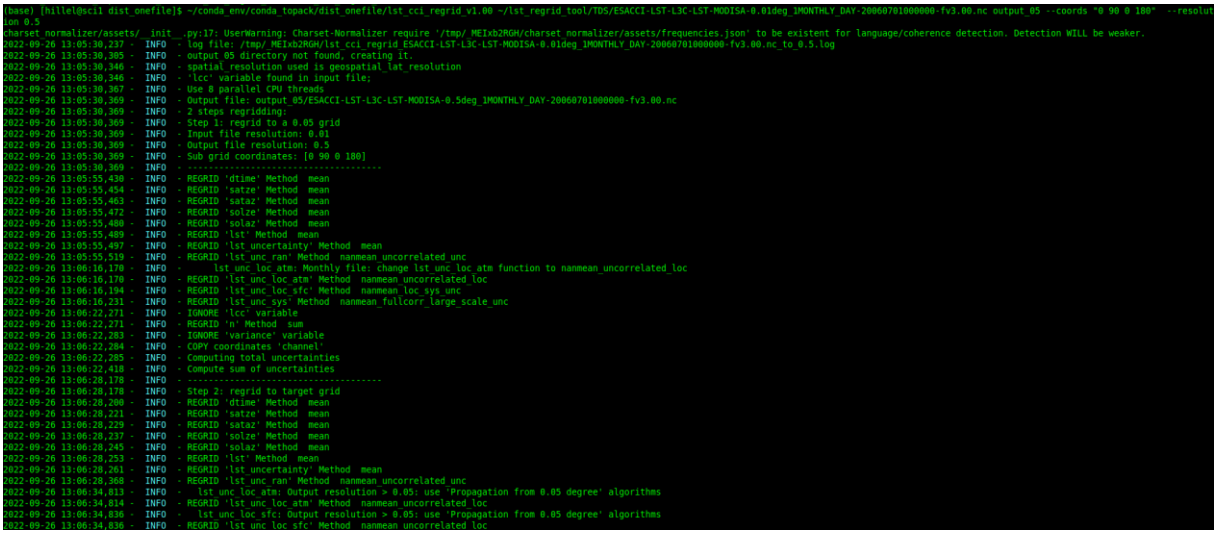


Figure 20:Example of console execution using 2 steps algorithm

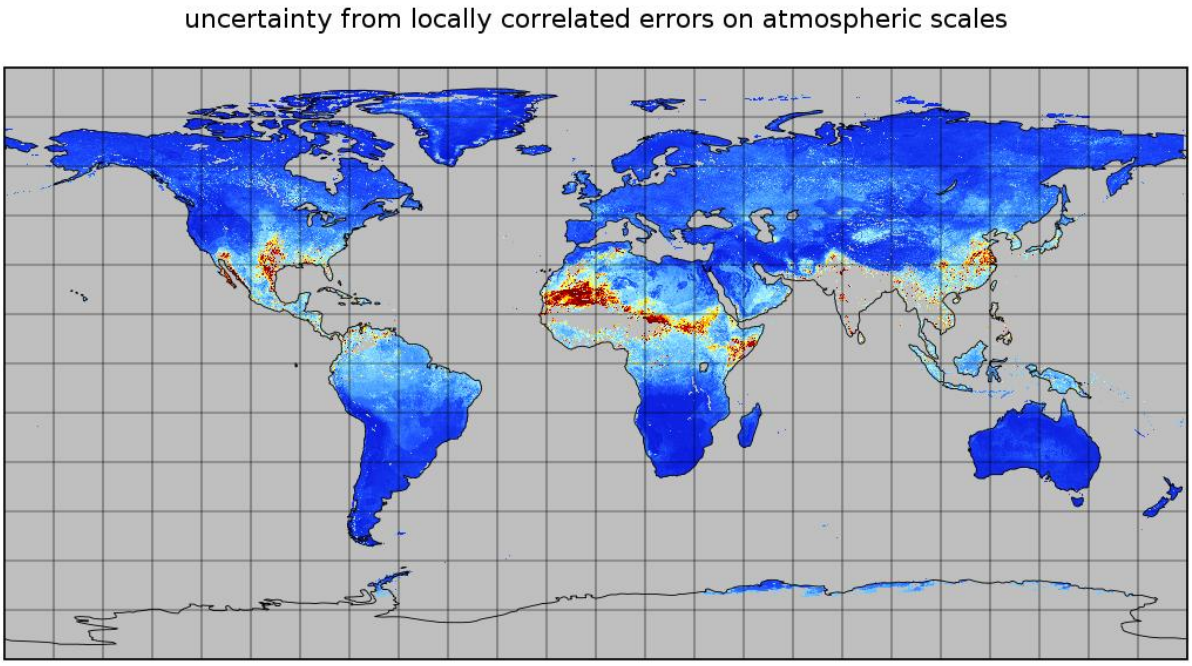


Figure 21: original file lst_unc_loc_atm variable

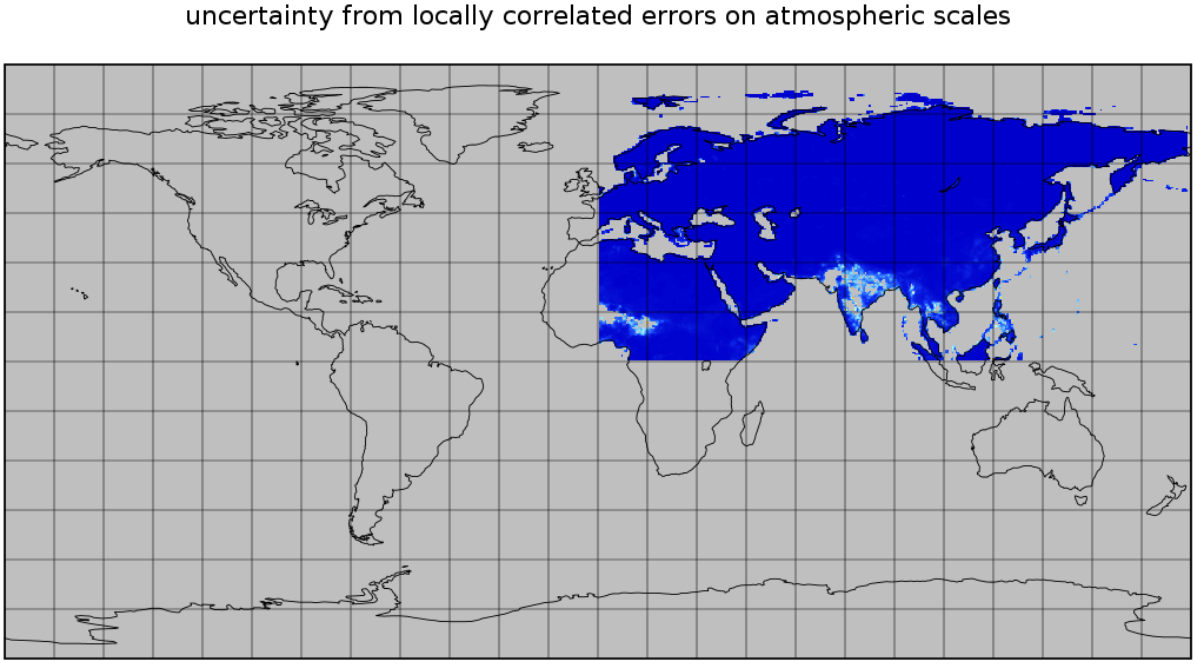


Figure 22: re-gridded lst_unc_loc_atm variable

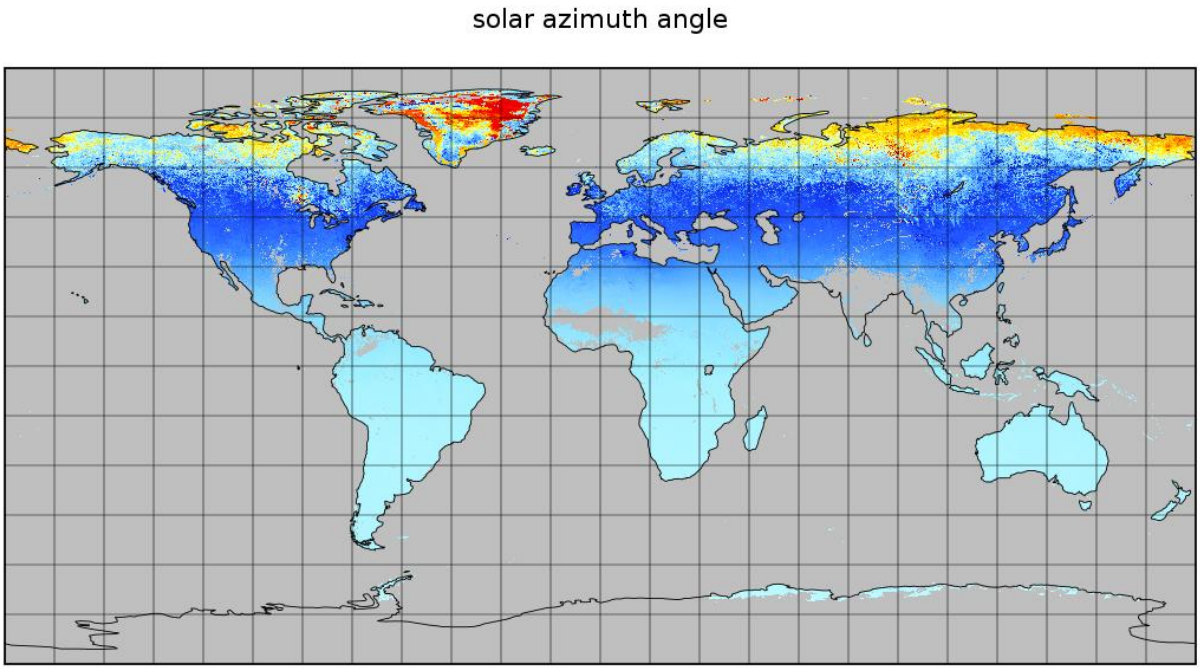


Figure 23: original solaz variable

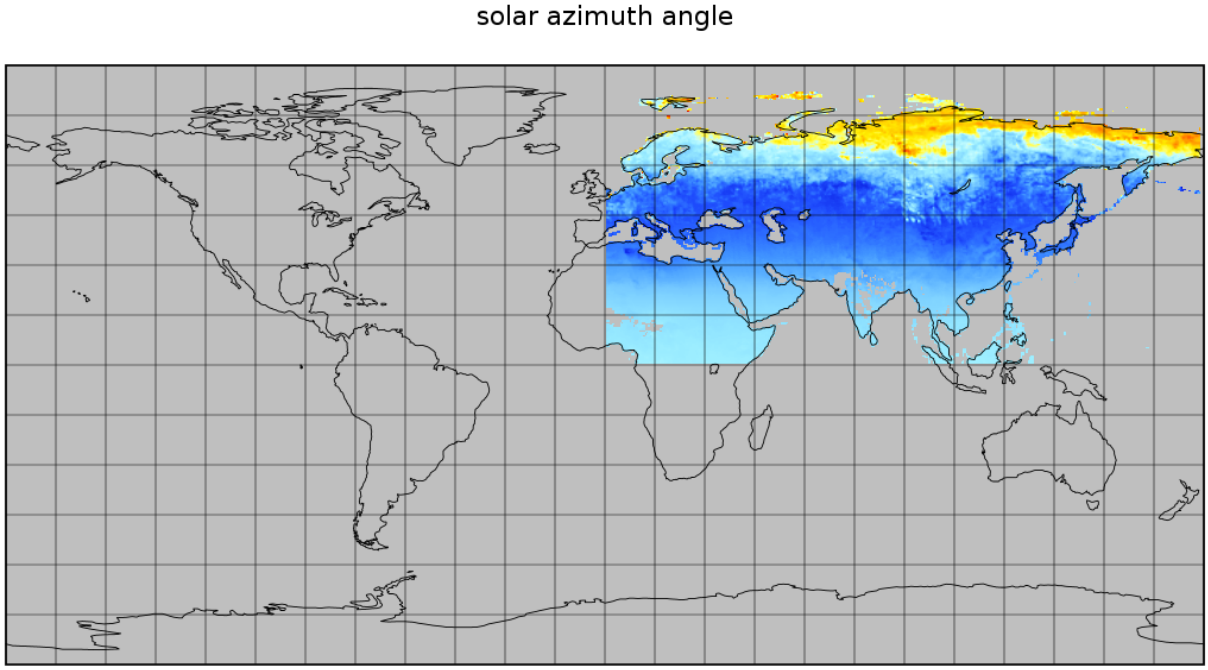


Figure 24: re-gridded solaz variable

4.5. Error cases

Some error handling examples:

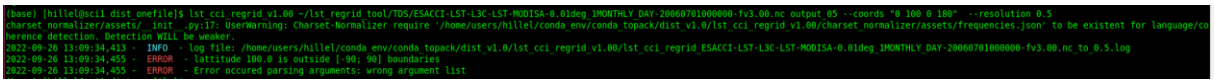


Figure 25: lat / lon out of bound

Figure 26: lat/lon wrongly ordered

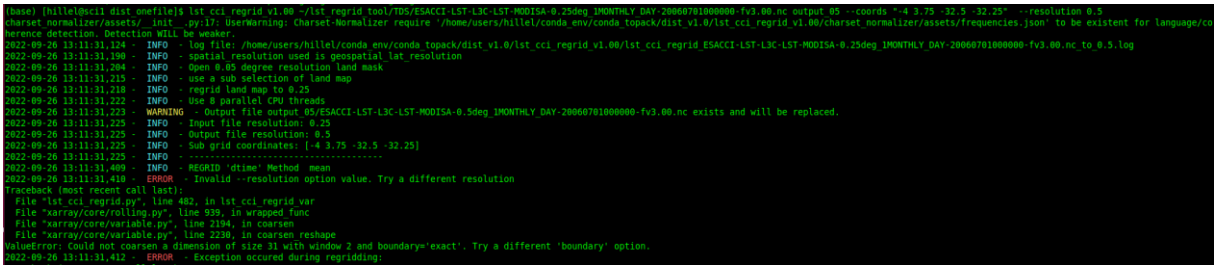


Figure 27: wrong resolution

NB: resolution value is not fully checked before the re-gridding starts. Resolution errors are raised at execution time.

5. Examples with temporal re-gridding

In this section the user can use the TDS distributed with the tool to follow the same examples.

The TDS provided with the tool contains 7 DAILY DAY files. These files are a subset over Europe.

Under TDS_FOR_RELEASE\EUROPE_WEEK\001\ the files are provided at a 0.01deg resolution.

Under TDS_FOR_RELEASE\EUROPE_WEEK\005x01\ the files are provided at a lat0.05_long0.1deg resolution.

Under TDS_FOR_RELEASE\EUROPE_WEEKLY the user can find the WEEKLY temporal re-gridding of the files cited above.

To re-create the WEEKLY files using the TDS :

```
lst-cci-regrid TDS_FOR_RELEASE/EUROPE_WEEK/001/ TDS_FOR_RELEASE/EUROPE_WEEKLY/ --time-resolution 1WEEKLY
```

And

```
lst-cci-regrid TDS_FOR_RELEASE/EUROPE_WEEK/005x01/ TDS_FOR_RELEASE/EUROPE_WEEKLY/ --time-resolution 1WEEKLY
```

5.1. Running a temporal aggregation

Command to use :

```
lst-cci-regrid TDS_FOR_RELEASE/EUROPE_WEEK/001/ TDS_FOR_RELEASE/EUROPE_WEEKLY/ --time-resolution WEEKLY
```

This command will produce a WEEKLY re-gridding of the input files.

The processed output file will have the following name :

ESACCI-LST-L3C-LST-SLSTRA-0.01deg_1WEEKLY_DAY-20171009000000-fv3.00.nc

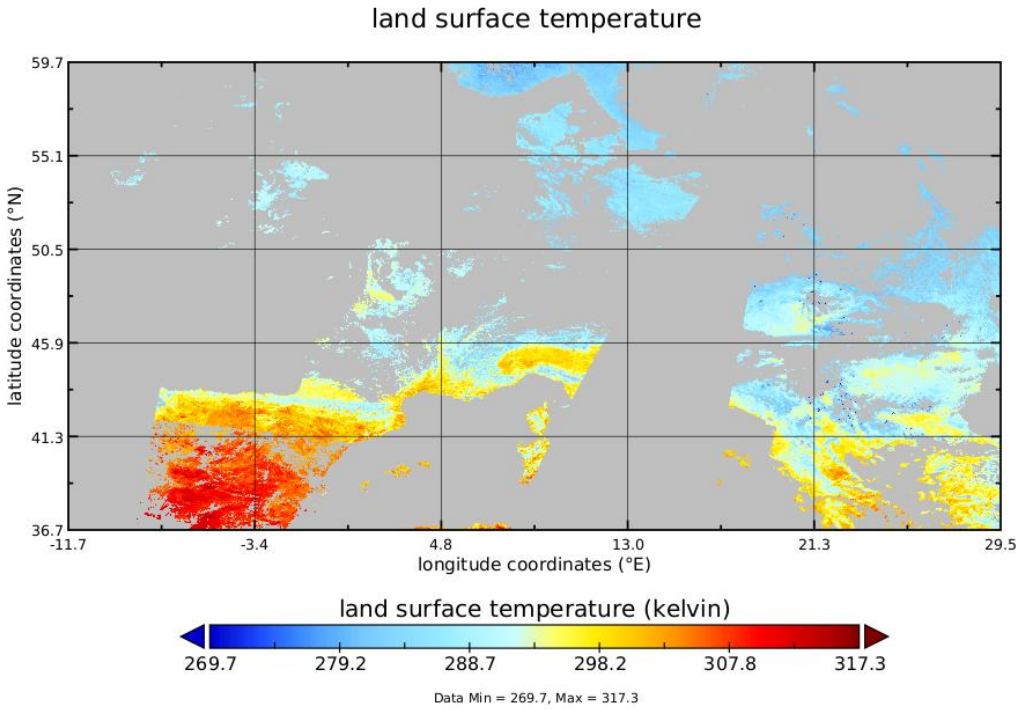


Figure 28: example lst in TDS input file

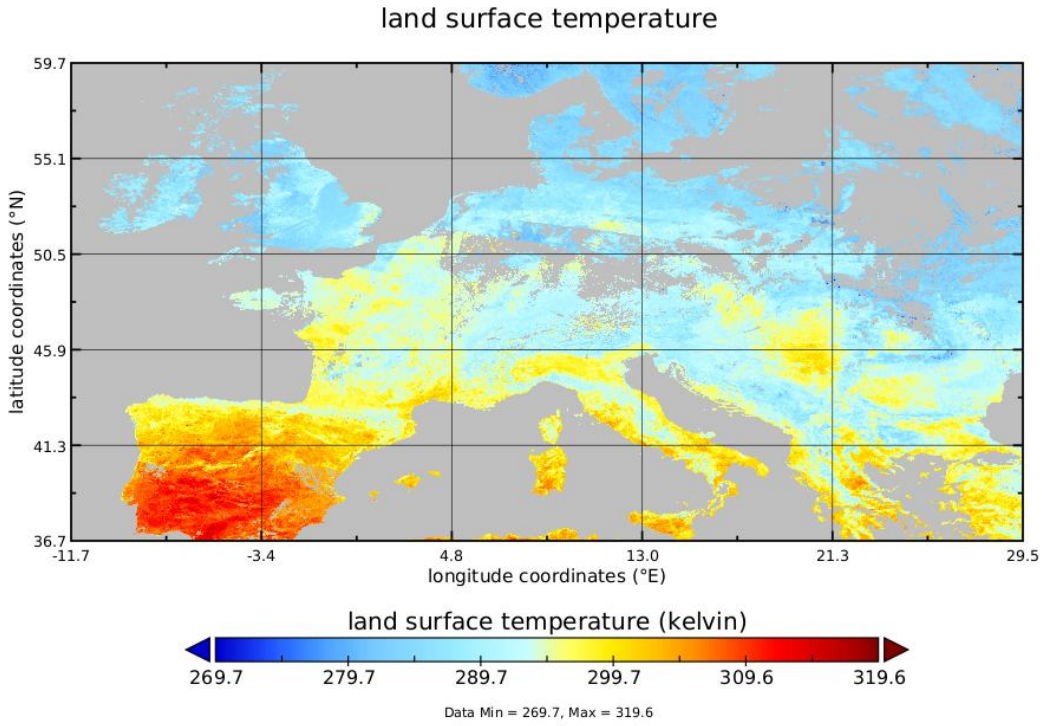


Figure 29: lst in the output TDS WEEKLY file

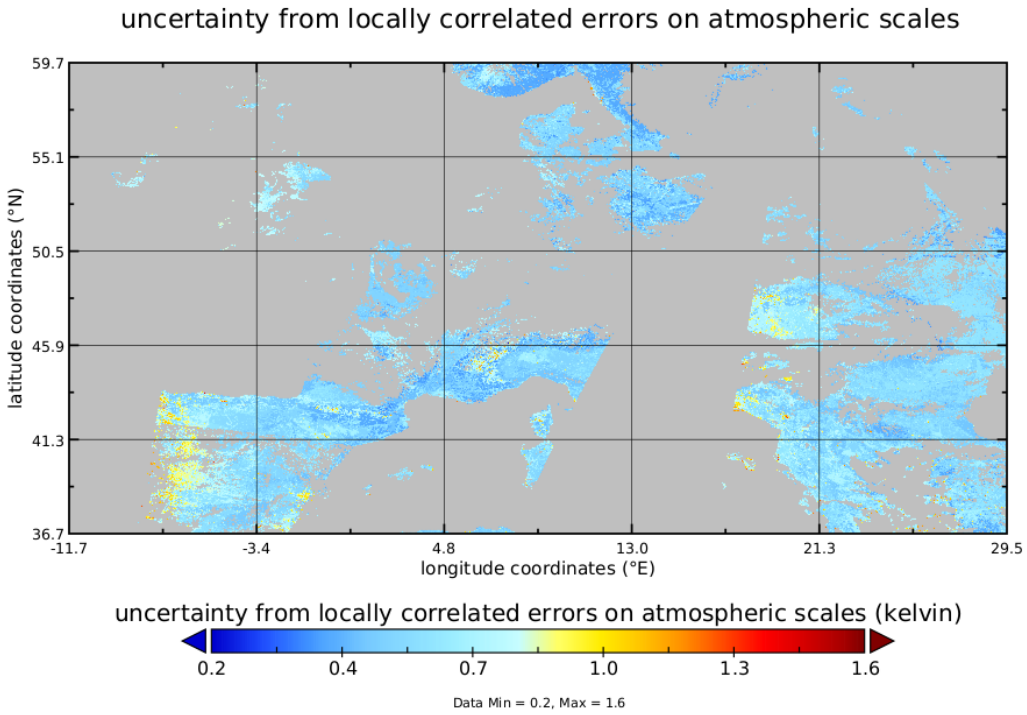


Figure 30: example lst_unc_loc_atm in input file

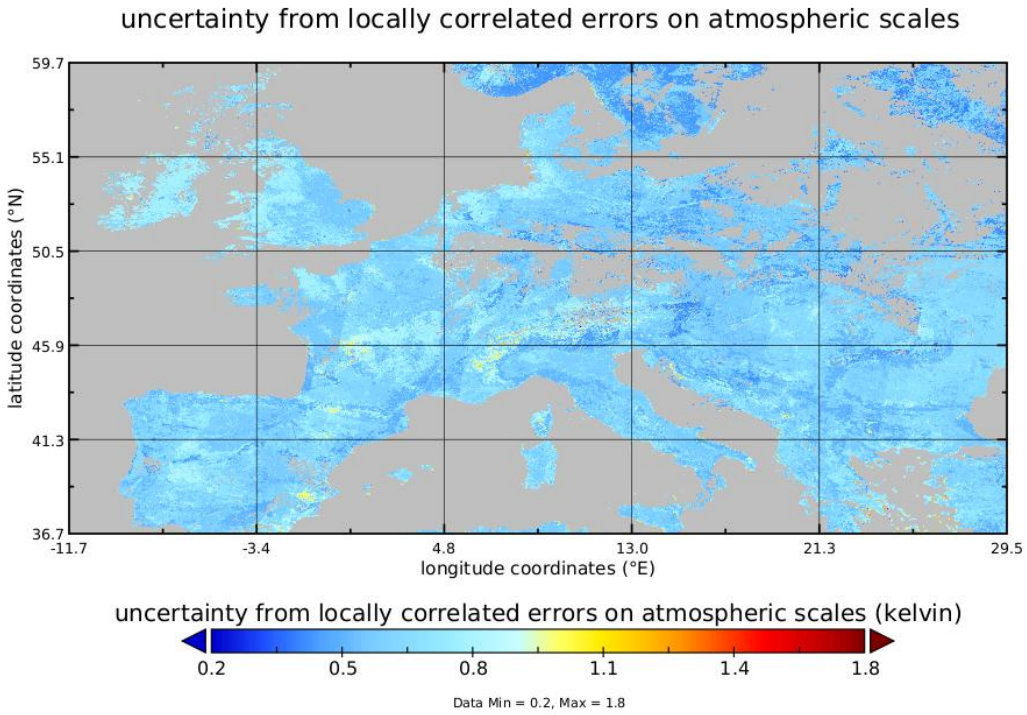


Figure 31: lst_unc_loc_atm in the output WEEKLY file

5.2. Running a temporal re-gridding with different latitude and longitude resolutions

Command to use :

```
lst-cci-regrid /TDS_FOR_RELEASE/EUROPE_WEEK/001/ /TDS_FOR_RELEASE/EUROPE_WEEKLY/ --time-
resolution WEEKLY --resolution "0.05 0.1"
```

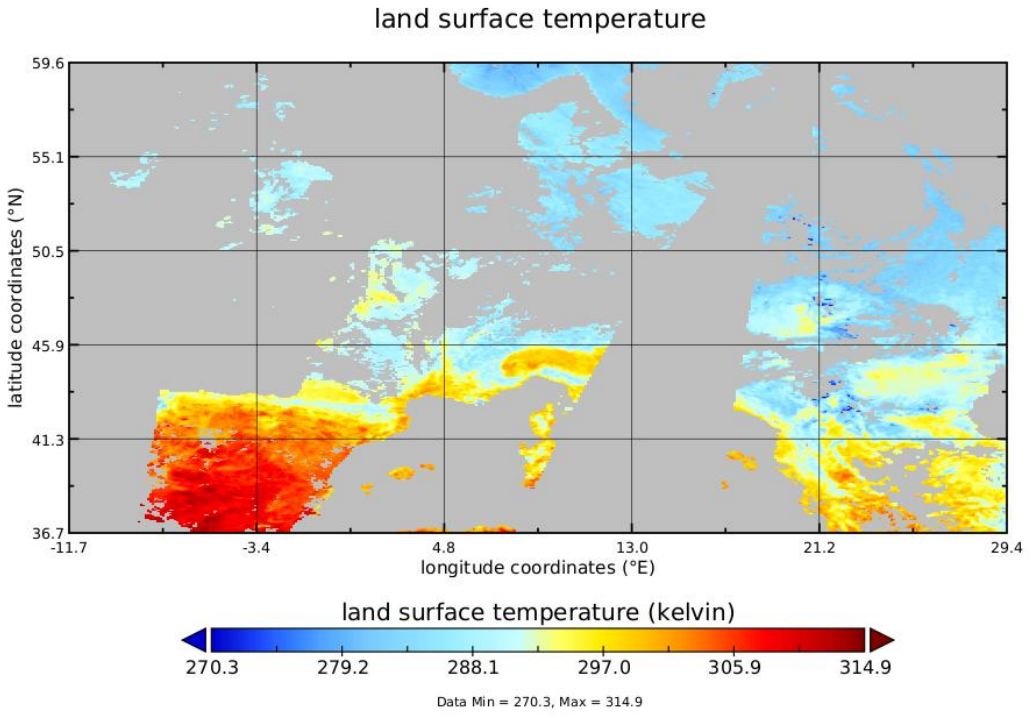


Figure 32: lst in example 0.05x0.1 input file

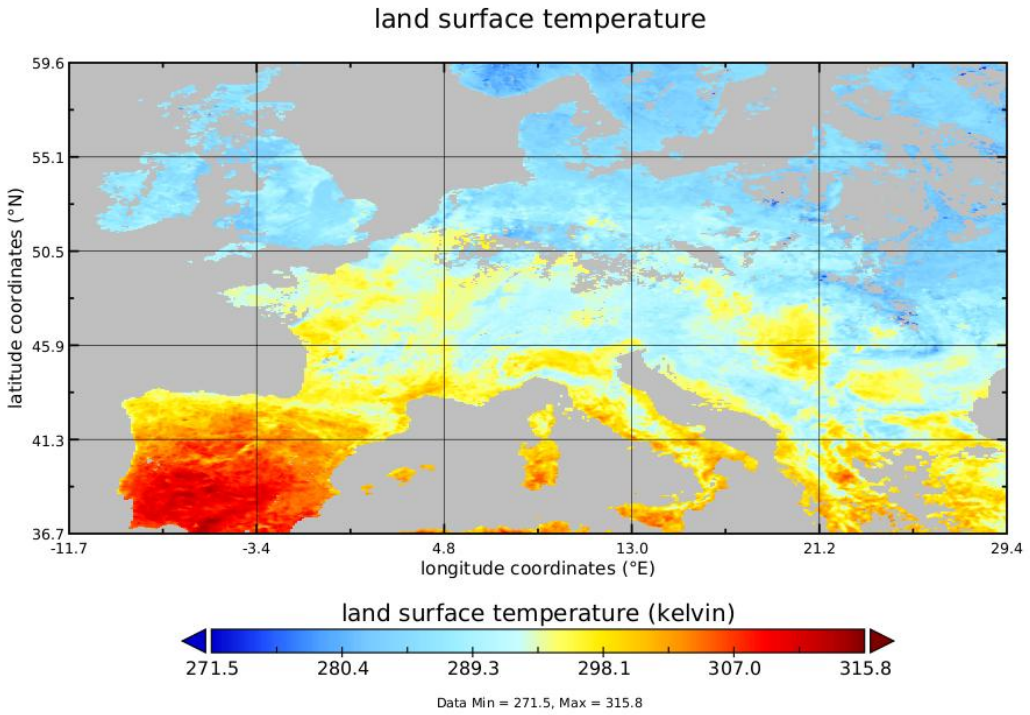


Figure 33: lst in example WEEKLY output file at 0.05x0.1

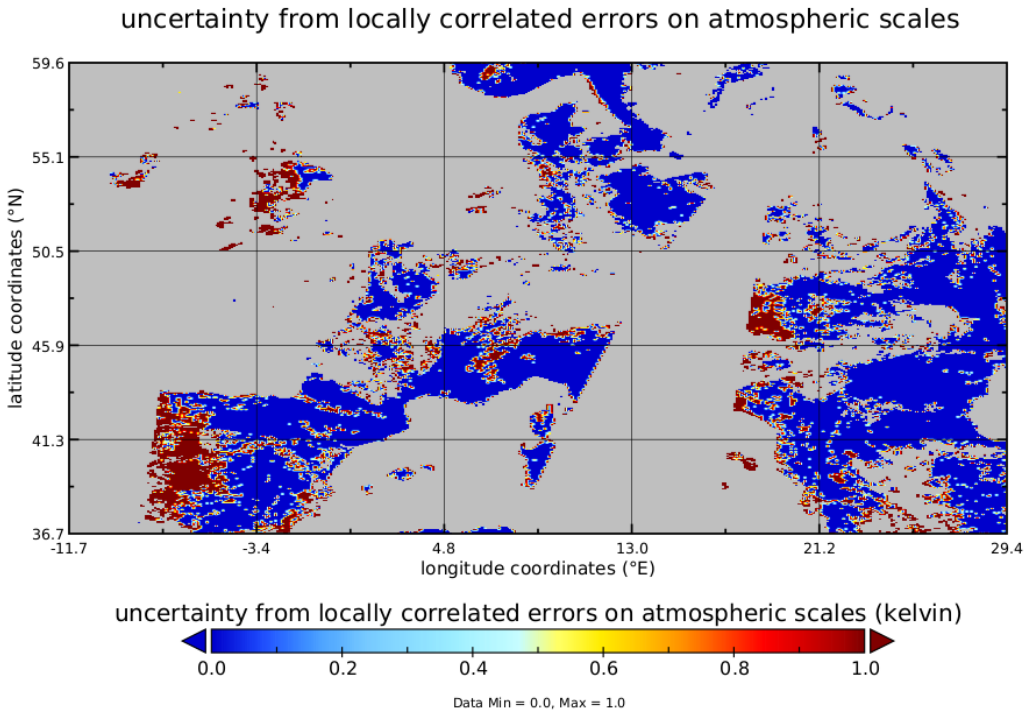


Figure 34: lst_unc_loc_atm in example 0.05x0.1 input file

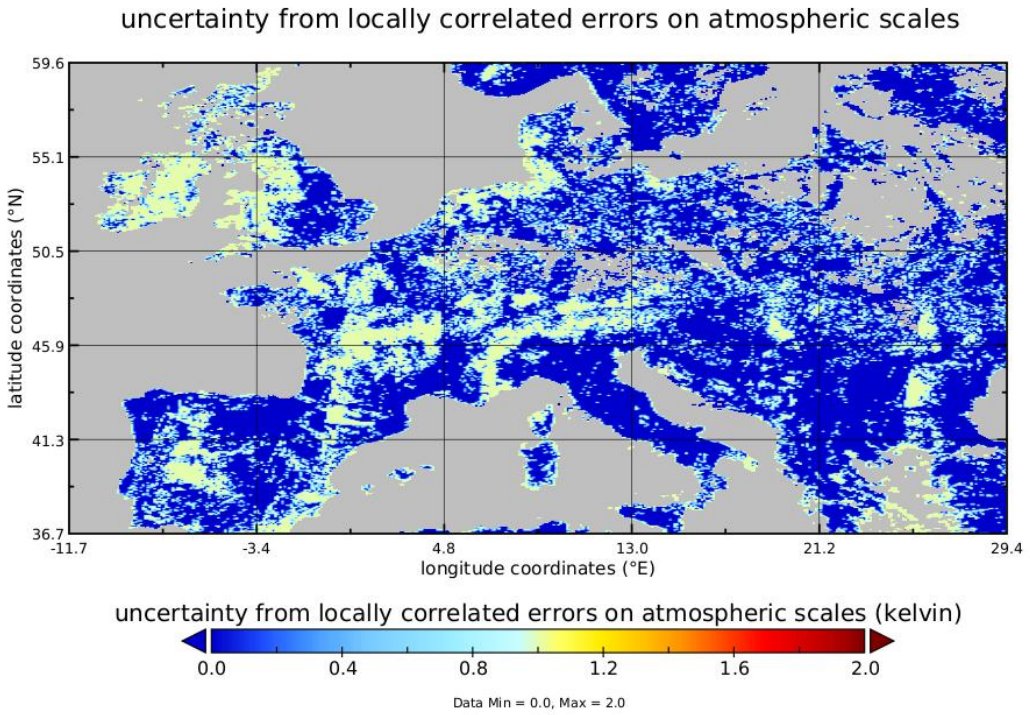


Figure 35: lst_unc_loc_atm in example 0.05x0.1 WEEKLY file

5.3. Error cases

Trying to re-grid to a finer temporal resolution MONTHLY to WEEKLY :

```
2026-01-20 10:30:34 - INFO     :
**********************************************************************
2026-01-20 10:30:34 - INFO     : LST CCI Re-gridding and Subsetting Tool
2026-01-20 10:30:34 - INFO     : Version: 2.0.0
2026-01-20 10:30:34 - INFO     :
**********************************************************************
2026-01-20 10:30:34 - INFO     : Auto-detected thread count: 20 physical cores
2026-01-20 10:30:34 - INFO     : Available system memory: 51.63 GB
2026-01-20 10:30:34 - INFO     : Using 100% of available memory: 51.63 GB (of 51.63 GB total)
2026-01-20 10:30:34 - INFO     : LST CCI Regrid v2.0 - Pipeline Start
2026-01-20 10:30:34 - INFO     : Using 20 threads, 51.63 GB memory limit
2026-01-20 10:30:34 - INFO     : Scanning directory: /mnt/d/GEN_TDS/005_monthly
2026-01-20 10:30:34 - INFO     : Found 12 NetCDF files
2026-01-20 10:30:34 - INFO     : Filtering files by designation: DAY
2026-01-20 10:30:34 - INFO     : After filtering: 12 files match designation DAY
2026-01-20 10:30:34 - INFO     : Processing 12 input files
2026-01-20 10:30:34 - INFO     : Running temporal aggregation
2026-01-20 10:30:34 - ERROR    : Cannot upscale temporal resolution: MONTHLY → WEEKLY. Temporal
aggregation can only produce coarser or equal resolution.
2026-01-20 10:30:34 - ERROR    : Validation error: Temporal aggregation validation failed with 1
error(s)
```

6. Performances

6.1. Performance tests regarding spatial re-gridding

The re-gridding tool is a python script supporting multi-threading.

Performances depend on host capabilities, the input file size, the claimed resolution, and the sub-map size.

Tests done on: Intel(R) Core(TM) i7-4770S CPU @ 3.10GHz with 28 GB of RAM

latmin=0 latmax=50 lonmin=0 lonmax=50 Threads=1

Compression Level	0,01° to 0,01° Duration (s)	0,01° to 0,01° Size (MB)	0,01° to 0,05° Duration (s)	0,01° to 0,05° Size (MB)
1	26,44	273	21,73	13
4	30,07	263	21,06	12
9	188,04	256	26,32	12
RAM (MB)	800		550	

latmin=0 latmax=50 lonmin=0 lonmax=50 Thread=2

Compression Level	0,01° to 0,01° Duration (s)	0,01° to 0,01° Size (MB)	0,01° to 0,05° Duration (s)	0,01° to 0,05° Size (MB)
1	20,91	273	13,24	13
4	27,05	263	13,72	12
9	184,83	256	18,48	12
RAM (MB)	820		590	

latmin=-90 latmax=90 lonmin=-180 lonmax=180 Threads=1

Compression Level	0,01° to 0,01° Duration (m)	0,01° to 0,01° Size (MB)	0,01° to 0,05° Duration (m)	0,01° to 0,05° Size (MB)
1	6,72	2279	7,95	102
4	7,53	2164	7,88	97
9	26,7	2111	8,67	95
RAM (GB)	15		6,7	

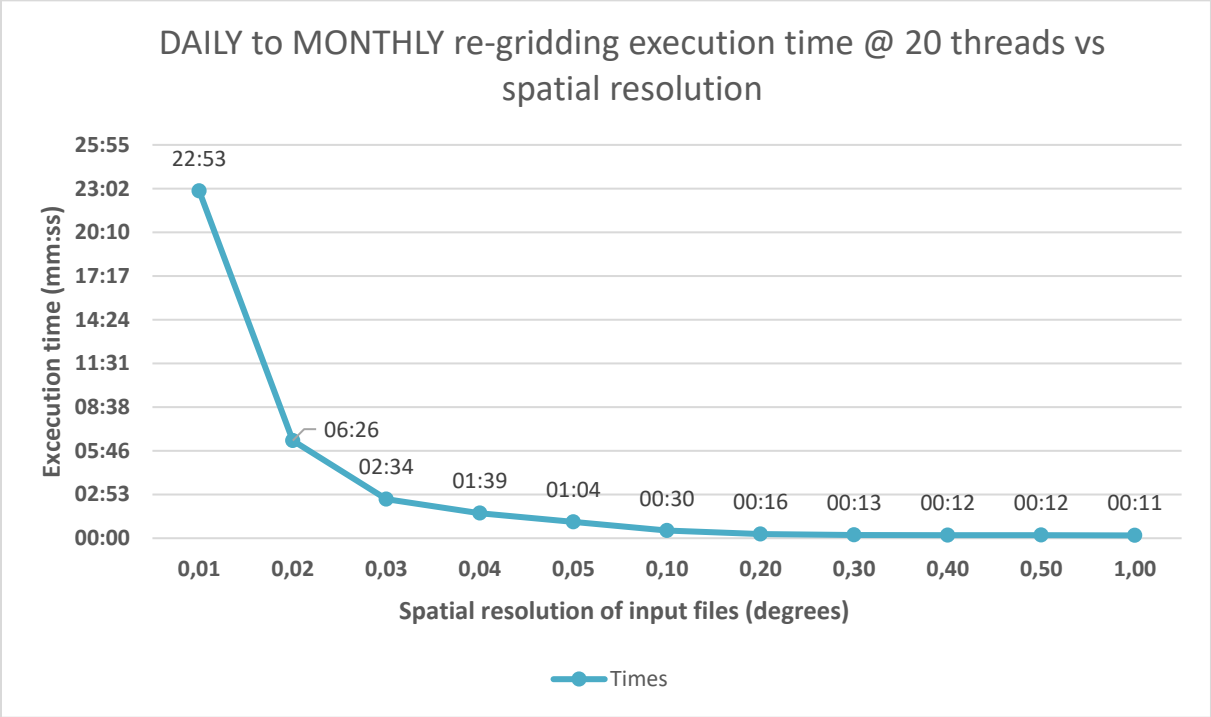
6.2. Performance tests regarding temporal re-gridding

This benchmark was done with 64GB of RAM and an Intel(R) Core(TM) Ultra 7 265 @ 4.5GHz with 20 cores.

Input files for this benchmark is a full map of the earth at varying resolution (spatially re-gridded with the tool)

Note: this benchmark was done with simple temporal re-gridding with the –time-resolution 1MONTHLY option. The input files had been spatially re-gridded beforehand.

Resolution (degrees)	Execution time (s)	Execution time (mm:ss)
0,01	1372,72	22:53
0,02	386,01	06:26
0,03	154,09	02:34
0,04	98,93	01:39
0,05	64,45	01:04
0,10	30,34	00:30
0,20	16,38	00:16
0,30	12,84	00:13
0,40	11,91	00:12
0,50	12,10	00:12
1,00	11,04	00:11



End of document