# Land surface Verification Toolkit (LVT)

## *LVT 7.8 Users Guide*

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# Chapter 1. Introduction

This is the Users Guide for Land surface Verification Toolkit (LVT; [kumar_etal_gmd_2012]). This document describes how to download and install the LVT software. It also describes LVT's run-time configuration options (the *lvt.config* file).

This document consists of 9 sections, described as follows:

1. **Introduction**: the section you are currently reading.
2. **Background**: general information about the LVT.
3. **Preliminary Information**: general information, steps, instructions, and definitions used throughout the rest of this document.
4. **Obtaining the Source Code**: the steps needed to download the source code.
5. **Building the Executable**: the steps needed to build the LVT executable.
6. **Running the Executable**: the steps needed to run the LVT executable.
7. **LVT config File**: describes the user-configurable options.
8. **Configuration of metrics**: describes the specification of various metrics in LVT.
9. **Model Output Specifications**: describes the specification of the model output from LIS.

## 1.1. What's New

### 1.1.1. Version 7.8

1. Includes new runmode
   - SNIPpost
2. Supports additional data streams
   - SMAP L2 NRT soil moisture retrieval product

# Chapter 2. Background

Verification and evaluation are essential processes in the development and application of simulation models. The Land surface Verification Toolkit (LVT) is an integrated framework designed specifically for evaluating land surface model (LSM) outputs. The system was originally designed as a post processor to the NASA Land Information System (LIS), which is an integrated framework to conduct multi-model land surface model simulations and data assimilation integrations. LVT also includes the capabilities to convert any land surface-specific dataset to a “LIS output format/style”, thus enabling cross-comparisons of a broad set of land surface datasets (in-situ, remotely sensed, and reanalysis products).

## 2.1. LVT

LVT provides a formal system for LSM output evaluation and verification. The capabilities of LVT also provides a tool to systematically evaluate and benchmark LSM performance and the impact of computational enhancements such as data assimilation. LVT includes a range of both deterministic and probabilistic verification measures, with similarity-based and object-based methods in development.

LVT is designed as an object oriented framework, with a number of points of flexibility known as “plugins”. Specific implementations are added to the framework through the plugin-interfaces. LVT uses the plugin-based architecture to support the processing of different types of observational data sets, ranging from in-situ, satellite and remotely sensed and reanalysis products.

In addition to providing methods for model output verification, LVT also provides capabilities to analyze the outputs from LIS data assimilation (LIS-DA) and the LIS optimization and uncertainty estimation (LIS-OPTUE) subsystems.

## 2.2. Summary of key features

The key capabilities of LVT can be summarized as follows:

- Capability to convert a given dataset to “LIS-style format”
- A text-based, configurable input interface
- Supports a broad range of in-situ, remotely-sensed and reanalysis data products. For e.g.:
  - Surface fluxes - Ameriflux, ARM, CEOP, AMMA
  - Soil moisture - SCAN, SMOSREX, AMSR-E retrievals
  - Snow - COOP, GSOD, SNODAS, SNODEP, CMC, FMI, GlobSnow, SNOTEL
  - LST - ISCCP
  - Radiation - SURFRAD
- A number of deterministic and probabistic verification measures. E.g. RMSE, Bias, Correlations, POD, FAR, etc.
- Supports the computation of land surface model diagnostics and closure checks. E.g.: Energy, water balance checks, seasonal and average diurnal cycles

- Options of time series extraction of individual grid points and area averages
- Options of temporal averaging. E.g. : Comparisons at hourly, daily, monthly scales
- Options for data masking. E.g. Apply an external mask to the comparisons, apply thresholds on the comparisons
- Supports the analysis of outputs from LIS-OPTUE and LIS-DA subsystems. For e.g: Analysis of normalized innovations from LIS-DA

# Chapter 3. Preliminary Information

This section provides some preliminary information to make reading this guide easier.

Commands are written with a fixed-width font. E.g.:

```
% cd /path/to/LVT
```

```
% ls
```

"... compiler flags, then run `gmake`."

| NOTE | The `%` symbol represents the command-line prompt. You do **not** type that when entering any of the commands. |
|---|---|

File names are written in italics. E.g.:

*/path/to/LVT/src*

# Chapter 4. Obtaining the Source Code

This section describes how to obtain the source code needed to build the LVT executable.

Beginning with Land Information System Framework (LISF) public release 7.3, the LVT source code is available as open source under the Apache License, version 2.0. (Please see Apache's web-site for a copy of the license.) LVT is one of the three main components of LISF (LDT, LIS, and LVT).

From LVT public release 7.1rp1 through 7.2, the LVT source code is available as open source under the NASA Open Source Agreement (NOSA). Please see LISF's web-site for a copy of the NOSA.

Due to the history of LVT's development, versions of the LVT source code prior to 7.1rp1 may not be freely distributed. Older source code is available only to U.S. government agencies or entities with a U.S. government grant/contract. LISF's web-site explains how qualified persons may request a copy of older source code.

| | |
|---|---|
| **NOTE** | All users are encouraged to go to LISF's web-site to fill in the Registration Form and join the mailing list. |

## 4.1. Important Note Regarding File Systems

LVT is developed on Linux/Unix platforms. Its build process expects a case sensitive file system. Please make sure that you unpack and/or `git clone` the LISF source code into a directory within a case sensitive file system. In particular, if you are using LVT within a Linux-based virtual machine hosted on a Windows or Macintosh system, do not compile/run LVT from within a shared folder. Move the LISF source code into a directory within the virtual machine.

## 4.2. Release Source Code

The LISF public release 7.8 source code is available both on LISF's web-site under the "Source" menu and on GitHub under the NASA-LIS organization at https://github.com/NASA-LIS/LISF under the "Releases" link.

After downloading the LISF tar-file:

### Step 1

Create a directory to unpack the tar-file into. Let's call it *TOPLEVELDIR*.

### Step 2

Place the tar-file in this directory.

```
% mv LISF_public_release_7.8.0.tar.gz TOPLEVELDIR
```

### Step 3

Go into this directory.

```
% cd TOPLEVELDIR
```

### Step 4

Unzip and untar the tar-file.

```
% tar xzf LISF_public_release_7.8.0.tar.gz
```

## 4.3. master branch

The LVT source code is maintained in a git repository hosted on GitHub. If you wish to work with the latest development code (in the master branch), then you must use the `git` client to obtain the LISF source code. If you need any help regarding `git` or GitHub, please go to https://github.com.

### Step 1

Create a directory to clone the code into. Let's call it *TOPLEVELDIR*.

### Step 2

Go into this directory.

```
% cd TOPLEVELDIR
```

### Step 3

Clone the master branch.

```
% git clone https://github.com/NASA-LIS/LISF
```

## 4.4. Source files

Unpacking or cloning the LISF source code (according to the instructions in Section Obtaining the Source Code) will create a directory named *LISF*. The LVT specific source code is in *LISF/lvt*.

| | |
|---|---|
| **NOTE** | The directory containing the LVT source code, *LISF/lvt*, will be referred to as *$WORKING* throughout the rest of this document. |

## 4.5. Documentation

Processed documentation for each release may be found on LISF's web-site under the "Docs" menu. Starting with LISF public release 7.4, processed documentation may also be found on GitHub under the NASA-LIS organization at https://github.com/NASA-LIS/LISF under the "Releases" link.

Processed documentation for the master branch is available on GitHub under the NASA-LIS organization's GitHub pages at https://nasa-lis.github.io/LISF/.

# Chapter 5. Building the Executable

This section describes how to build the source code and create LVT's executable: named *LVT*.

Please see Section Important Note Regarding File Systems for information regarding using a case sensitve file system for compiling/running LVT.

## 5.1. LISF Dependencies

Please first read the companion document *LISF Installation Guide*. This document describes the required and optional libraries used by LISF. It also describes the supported development environments.

## 5.2. Build Instructions

### Step 1

Perform the steps described in Section Obtaining the Source Code to obtain the source code.

### Step 2

Go to the *$WORKING* directory. This directory contains two scripts for building the LVT executable: *configure* and *compile*.

### Step 3

Set the appropriate LVT environment variables. These are used to control the compilation of LVT and to specify the locations of the required and optional libraries.

| Variable | Description | Usage |
|---|---|---|
| LVT_ARCH | Architecture | required |
| LVT_FC | Fortran 90 | required |
| LVT_CC | C compiler | required |
| LVT_MODESMF | path to ESMF modules files | required |
| LVT_LIBESMF | path to ESMF library files | required |
| LVT_OPENJPEG | path to openJPEG library | required |
| LVT_ECCODES | path to ecCodes library | required |
| LVT_NETCDF | path to NETCDF library | optional |
| LVT_HDF4 | path to HDF4 library | optional (required to use HDFEOS2) |
| LVT_HDF5 | path to HDF5 library | optional |
| LVT_HDFEOS | path to HDFEOS2 library | optional |

| Variable | Description | Usage |
|---|---|---|
| LVT_GDAL | path to GDAL library | optional |
| LVT_FORTRANGIS | path to FortranGIS library | optional (required to use GDAL) |
| LVT_JPEG | path to JPEG library | optional (use system libjpeg by default) |
| LVT_RPC | path to RPC library | optional (use system RPC library by default) |

Set the LVT_ARCH environment variable based on the system you are using. The following commands are written using Bash shell syntax.

*For a Linux system with the Intel Fortran compiler*

```
% export LVT_ARCH=linux_ifc
```

*For a Linux system with the GNU Fortran compiler*

```
% export LVT_ARCH=linux_gfortran
```

*For a Cray system with the Intel Fortran compiler*

```
% export LVT_ARCH=cray_ifc
```

*For a Cray system with the Cray Fortran compiler*

```
% export LVT_ARCH=cray_cray
```

*For an IBM system with the GNU Fortran compiler*

```
% export LVT_ARCH=ibm_gfortran
```

Note that the LVT_CC variable must be set to a C compiler, not a C++ compiler. A C++ compiler may mangle internal names in a manner that is not consistent with the Fortran compiler. This will cause errors during linking.

You may encounter errors either when trying to compile LVT or when trying to run LVT because the compiler or operating system cannot find these libraries. To fix this, you must add these libraries to your $LD_LIBRARY_PATH environment variable. For example, say that you are using ESMF, ecCodes, NetCDF, and HDF5. Then you must execute the following command (written using Bash shell syntax):

```
% export
LD_LIBRARY_PATH=$LVT_HDF5/lib:$LVT_LIBESMF:$LVT_NETCDF/lib:$LVT_ECCODES/lib:$LD_LIBRAR
Y_PATH
```

It is suggested that you set these environment variables in a modulefile [1] to load or in an environment script to source before compiling and/or running LVT.

## Step 4

Run the *configure* script first by typing:

```
% ./configure
```

This script will prompt the user with a series of questions regarding support to compile into LVT.

#### Example

An example execution of the configure script is shown below:

```
% ./configure
-------------------------------------------------------------------------
Setting up configuration for LVT
Optimization level (-3=strict checks with warnings, -2=strict checks, -1=debug,
0,1,2,3, default=2):
Assume little/big_endian data format (1-little, 2-big, default=2):
Use GRIBAPI/ECCODES? (1-gribapi, 2-eccodes, default=2):
Use NETCDF? (1-yes, 0-no, default=1):
NETCDF version (3 or 4, default=4):
NETCDF use shuffle filter? (1-yes, 0-no, default = 1):
NETCDF use deflate filter? (1-yes, 0-no, default = 1):
NETCDF use deflate level? (1 to 9-yes, 0-no, default = 1):
Use HDF4? (1-yes, 0-no, default=1):
Use HDF5? (1-yes, 0-no, default=1):
Use HDFEOS? (1-yes, 0-no, default=1):
Enable AFWA-specific grib configuration settings? (1-yes, 0-no, default=0):
Enable GeoTIFF support? (1-yes, 0-no, default=1):
Use MATLAB support? (1-yes, 0-no, default=0):
-----------------------------------------------------
 configure.lvt file generated successfully
-----------------------------------------------------
Settings are written to configure.lvt in the make directory.
If you wish to change settings, please edit that file.

To compile, run the compile script.
-------------------------------------------------------------------------
```

At each prompt, select the desired value. If you desire the default value, then you may simply press the Enter key.

Most of the configure options are be self-explanatory. Here are a few specific notes:

- for `Assume little/big_endian data format (1-little, 2-big, default=2):`, select the default

value of 2. By default, LVT reads and writes binary data in the big endian format. Only select the value of 1, if you have reformatted all required binary data into the little endian format.

- for `Use GRIBAPI/ECCODES? (1-gribapi, 2-eccodes, default=2):`, select the default value of 2. Technically, GRIB support is not required by LVT; however, most of the commonly used met forcing data are in GRIB, making GRIB support a practical requirement. ecCodes is ECMWF's replacement to their GRIB-API library. GRIB-API is supported only for historical reasons; thus, please use ecCodes.

| | |
|---|---|
| **IMPORTANT** | GRIB-API support is now deprecated. Future releases will support only ecCodes. |

- for `Enable GeoTIFF support? (1-yes, 0-no, default=1):`, GeoTIFF means the GeoTIFF support provided by the GDAL library.

Note that due to an issue involving multiple definitions within the NetCDF 3 and HDF 4 libraries, you cannot compile LVT with support for both NetCDF 3 and HDF 4 together.

Note that if you compiled NetCDF 4 without compression, then when specifying `NETCDF version (3 or 4, default=4):`, select 3. Then you must manually append `-lnetcdff` to the `LDFLAGS` variable in the *make/configure.lvt* file.

### Step 5

Compile the LVT source code by running the *compile* script.

```
% ./compile
```

This script will compile the libraries provided with LVT, the dependency generator and then the LVT source code. The executable *LVT* will be placed in the *$WORKING* directory upon successful completion of the *compile* script.

### Step 6

Finally, copy the *LVT* executable into your running directory, *$RUNNING*. (See Section Running the Executable.)

[1] See the "Creating a Custom Modulefile" document found at https://nasa-lis.github.io/LISF/

# Chapter 6. Running the Executable

This section describes how to run the LVT executable.

First you should create a directory to run LVT in. It is suggested that you run LVT in a directory that is separate from your source code. This running directory shall be referred to as *$RUNNING*. Next, copy the LVT executable into your running directory

```
% cp $WORKING/LVT $RUNNING
```

The single-process version of `LVT` is executed by the following command issued in the *$RUNNING* directory.

```
% ./LVT <configfile>
```

where `<configfile>` represents the file containing the run time configuration options for LVT. Currently LVT only supports a serial mode.

Some systems require that you submit your job into a batch queue. Please consult with your system adminstrator for instructions on how to do this.

Note that before running LVT, you must set your environment to have an unlimited stack size. For the Bash shell, run

```
% ulimit -s unlimited
```

To customize your run, you must specify a LVT runtime configuration file. See Section LVT config File for more information.

# Chapter 7. LVT config File

This section describes the options in the *lvt.config* file.

## 7.1. Overall driver options

`LVT running mode:` specifies the running mode to be used. Acceptable values are:

| Value | Description |
|---|---|
| “Data intercomparison” | standard analysis mode where a particular data is compared against another |
| “Benchmarking” | A benchmarking output is generated based on the input training datasets |
| “DA statistics processing” | data assimilation diagnostics analysis |
| “DA observation processing” | data assimilation observation analysis |
| “OPTUE output processing” | parameter estimation/uncertainty output analysis |
| “RTM output processing” | radiative transfer model output analysis |
| “557 post” | LIS postprocessing mode for 557WW operations |
| “USAFSI post” | special postprocessing mode for USAFSI |
| “SNIP post” | special postprocessing mode for SNIP |
| “LIS postprocessing” | postprocessing mode for quilting LIS distributed binary output |

*Example lvt.config entry*

```
LVT running mode:                       "Data intercomparison"
```

`Map projection of the LVT analysis:` specifies the map projection used in the LVT analysis. Acceptable values are:

| Value | Description |
|---|---|
| latlon | Lat/Lon projection with SW to NE data ordering |
| mercator | Mercator projection with SW to NE data ordering |
| lambert | Lambert conformal projection with SW to NE data ordering |
| gaussian | Gaussian domain |
| polar | Polar stereographic projection with SW to NE data ordering |

| Value | Description |
|---|---|
| UTM | UTM domain |

*Example lvt.config entry*

```
Map projection of the LVT analysis:          "latlon"
```

`LVT output format:` specifies the format of the LVT output. Acceptable values are:

| Value | Description |
|---|---|
| binary | Write output in binary format |
| grib1 | Write output in Grib format (not supported yet) |
| netcdf | Write output in NETCDF format |

See Appendix Description of output files from LVT for more details about the structure of the LVT output files.

*Example lvt.config entry*

```
LVT output format:                      "netcdf"
```

`LVT output methodology:` specifies the output methodology used in LVT. The LVT output is written as a 1-D array containing only land points or as a 2-D array containing both land and water points. 1-d tile space includes the subgrid tiles and ensembles. 1-d grid space includes a vectorized, land-only grid-averaged set of values. Acceptable values are:

| Value | Description |
|---|---|
| “1d tilespace” | LVT output in a 1-D tile domain |
| “2d gridspace” | LVT output in a 2-D grid domain |
| “1d gridspace” | LVT output in a 1-D grid domain |
| “2d ensemble gridspace” | LIS ensemble output in a 2-D grid domain |

*Example lvt.config entry*

```
LVT output methodology:                 "2d gridspace"
```

`Analysis data sources:` specifies the two sources of data to be used in an LVT comparison. The user must always choose two sources specified in adjacent columns. The second column entry will be taken as the reference data and the first column will be used as the data being evaluated (against the reference data). If the comparison LIS output against a non-LIS data, it is recommended to specify the first source as “LIS output” and then the other data as the second data source. Acceptable values for each column are:

| Value | Description |
|---|---|
| “none” | template |
| “LIS output” | output from another LIS run |
| “LIS DAOBS” | processed observations from a LIS DA run |
| “ISCCP LST” | ISCCP skin temperature observations |
| “MODIS LST” | MODIS (Terra/Aqua) land surface temperature observations |
| “SCAN” | SCAN soil moisture station observations |
| “NASMD” | North American Soil Moisture Database soil moisture station observations |
| “ISMN” | ISMN soil moisture station observations |
| “SURFRAD” | SURFRAD observations |
| “SNOTEL” | SNOTEL snow water equivalent observations |
| “LSWG Tb” | Tb brightness temperature observations at the LSWG sites |
| “FMI SWE” | Finnish Meteorological Institute (FMI) snow course data |
| “CMC” | Canadian Meteorological Center (CMC) snow depth analysis |
| “SNODAS” | NOHRSC SNow Data Assimilation (SNODAS) product |
| “AMSR-E NASA soil moisture” | NASA (NSIDC) retrival of AMSR-E soil moisture |
| “AMSR-E LPRM soil moisture” | LPRM (VU) retrival of AMSR-E soil moisture |
| “AMMA” | AMMA station observations |
| “Ameriflux” | Ameriflux station observations |
| “ARM” | ARM station observations |
| “SMOSREX” | SMOSREX station observations |
| “AGRMET” | AGRMET land surface analysis |
| “Globsnow” | GlobSnow SWE analysis |
| “SNODEP metobs” | WMO snow depth station observations |
| “MOD10A1” | MOD10A1 fractional snow cover data from MODIS |
| “MOD10A1V6” | MOD10A1.006 Normalized Difference from MODIS |
| “ANSA snowdepth” | ANSA snow depth retrievals |
| “ANSA SWE” | ANSA SWE retrievals |

| Value | Description |
|---|---|
| “CPC precipitation” | CPC unified precipitation product |
| “GPM IMERG” | IMERG precipitation data product |
| “GPM IMERG Monthly” | IMERG-Monthly precipitation product |
| “USGS streamflow” | USGS streamflow observations |
| “Naturalized streamflow” | Naturalized streamflow estimates |
| “FLUXNET MTE” | Gridded FLUXNET MTE data from MPI |
| “MOD16A2” | MOD16A2 ET products from MODIS |
| “UW ET” | University of Washington ET products from MODIS |
| “ALEXI” | Atmosphere Land Exchange Inverse (ALEXI) model ET estimates from USDA |
| “USDA ARS soil moisture” | soil moisture measurements from USDA ARS watersheds |
| “GHCN” | Global Historical Climatology Network data |
| “ALEXI ESI” | Atmosphere Land Exchange Inverse (ALEXI) model Evaporative Stress Index (ESI) estimates |
| “NLDAS2” | North American Land Data Assimilation System Phase-2 data |
| “GRACE” | processed GRACE data used in a LIS-DA instance |
| “PBO H2O” | plate boundary observatory data |
| “USGS ground water well data” | USGS ground water well data |
| “SMOS L2 soil moisture” | SMOS level 2 soil moisture |
| “SMOS L1 TB” | SMOS level 1 brightness temperature |
| “GCOMW AMSR2 L3 soil moisture” | GCOMW AMSR2 level 3 soil moisture |
| “SMOPS soil moisture” | Soil Moisture Operational Product System data |
| “ESA CCI soil moisture” | ESA CCI soil moisture |
| “GIMMS NDVI” | GIMMS NDVI data |
| “GIMMS AVHRR NDVI” | GIMMS AVHRR NDVI data |
| “GIMMS MODIS NDVI” | GIMMS MODIS NDVI data |
| “GLASS albedo” | GLASS MODIS and AVHRR albedo data |
| “GLDAS2” | NASA Global Land Data Assimilation System version 2 data |
| “MERRA2” | MERRA version 2 data |
| “ERA interim land” | ERA Interim Land data |

| Value | Description |
|---|---|
| “ERA5” | ERA5 data (currently only precipitation and near surface air temperature variables are supported) |
| “SSEB” | USGS SSEB operational ET and ET anomaly data |
| “GRDC” | Global Runoff Data Center data |
| “GLERL hydro data” | Great Lakes hydrology data |
| “GL6 JULES data” | GL6 JULES data |
| “GLEAM” | GLEAM data |
| “FLUXNET2015 dataset” | Measurements from FLUXNET2015 dataset |
| “USCRN soil moisture” | USCRN soil moisture data |
| “SMAP soil moisture” | SMAP soil moisture data |
| “SMAP vegetation water content” | SMAP vegetation water content |
| “SMAP vegetation optical depth” | SMAP vegetation optical depth |
| “LPRM vegetation optical depth” | LPRM vegetation optical depth |
| “WG SWRC” | Walnut Gulch Southwest Watershed Research Center data |
| “UA SNOW” | University of Arizona SWE/Snow depth data |
| “SMAP L3 Tb” | SMAP L3 brightness temperature |
| “OzFlux” | OzFlux ground measurements |
| “JASMIN soil moisture” | JASMIN soil moisture analysis |
| “FluxSAT GPP” | FluxSat GPP data |
| “THySM” | Thermal Hydraulic disaggregation of Soil Moisture |
| “MCD15A2H LAI” | MODIS MCD15A2H LAI data |
| “GRUN runoff” | GRUN runoff data |
| “COAMPSout” | COAMPS forcing data |
| “OPL E SMAP soil moisture retrieval” | Operational enhanced SMAP soil moisture retrieval data |
| “SMAP L2 NRT soil moisture” | SMAP L2 NRT soil moisture data |

*Example lvt.config entry*

```
Analysis data sources:     "LIS output"  "SURFRAD"
```

`Experiment code:` LIS-6 experiment code number.

| NOTE | Only needed when using LVT on LIS 6 output. |
|---|---|

*Example lvt.config entry*

```
Experiment code:                    111
```

`Start mode:` specifies if the LVT analysis is to be restarted from a previous (unfinished) analysis. Note that if "restart" option is selected, then the starting time (below) must be changed appropriately. Acceptable values are:

| Value | Description |
|---|---|
| coldstart | Fresh analysis |
| restart | Restart from a previous analysis |

*Example lvt.config entry*

```
Start mode:                         "coldstart"
```

`LVT output restart files:` a flag to specify if LVT restart files should be written out. The default is to turn off writing these restart files. To enable writing of LVT restart files, change this option to "1".

*Example lvt.config entry*

```
LVT output restart files:           0
```

`LVT restart output interval:` specifies the frequency at which the restart files must be written during a LVT analysis. The time interval is specified with a number followed by a 2 character suffix that indicates the units. For example, a restart interval of 1 hour can be specified as "1hr", "60mn", or "3600ss". Acceptable values for the 2 character suffix are:

| Value | Description |
|---|---|
| ss | second |
| mn | minute |
| hr | hour |
| da | day |
| mo | month |
| yr | year |

*Example lvt.config entry*

```
LVT restart output interval:        "1mo"
```

`LVT restart filename:` specifies the name of the LVT restart file

*Example lvt.config entry*

```
LVT restart filename:                   "none"
```

The start time of the evaluation period is specified in the following format:

| Variable | Value | Description |
|---|---|---|
| `Starting year:` | integer 2001 – present | specifying starting year |
| `Starting month:` | integer 1 – 12 | specifying starting month |
| `Starting day:` | integer 1 – 31 | specifying starting day |
| `Starting hour:` | integer 0 – 23 | specifying starting hour |
| `Starting minute:` | integer 0 – 59 | specifying starting minute |
| `Starting second:` | integer 0 – 59 | specifying starting second |

*Example lvt.config entry*

```
Starting year:                       2007
Starting month:                        11
Starting day:                           1
Starting hour:                          0
Starting minute:                        0
Starting second:                        0
```

The end time of the evaluation period is specified in the following format:

| Variable | Value | Description |
|---|---|---|
| `Ending year:` | integer 2001 – present | specifying ending year |
| `Ending month:` | integer 1 – 12 | specifying ending month |
| `Ending day:` | integer 1 – 31 | specifying ending day |
| `Ending hour:` | integer 0 – 23 | specifying ending hour |
| `Ending minute:` | integer 0 – 59 | specifying ending minute |
| `Ending second:` | integer 0 – 59 | specifying ending second |

*Example lvt.config entry*

```
Ending year:                         2008
Ending month:                          5
Ending day:                           31
Ending hour:                           0
Ending minute:                         0
Ending second:                         0
```

`LVT clock timestep:` specifies the timestep to be used in the LVT analysis. It is recommended to use

a timestep consistent with the output frequency of the first data stream.

*Example lvt.config entry*

```
LVT clock timestep:                    "1da"
```

`Undefined value:` specifies the undefined value. The default is set to -9999.

*Example lvt.config entry*

```
Undefined value:                        -9999
```

`LVT diagnostic file:` specifies the name of run time diagnostic file. Acceptable values are any 40 character string.

*Example lvt.config entry*

```
LVT diagnostic file:                    lvtlog
```

## 7.2. Domain specification

LVT expects two sets of domain specifications. (1) the domain over which the LVT analysis needs to be carried out; (2) the domain in which LIS simulation was carried out (LIS run domain). Section Overall driver options lists the projections that LIS supports.

### 7.2.1. LVT run domain

This section describes how to specify the run domain over which LVT will perform its analysis. See the LDT Users' Guide for more details about setting these values.

*Example lvt.config entry*

```
Run domain lower left lat:            30.125
Run domain lower left lon:          -124.875
Run domain upper right lat:           50.125
Run domain upper right lon:          -69.875
Run domain resolution (dx):            0.25
Run domain resolution (dy):            0.25
```

`Input domain and mask data file:` specifies the name of the parameter input file to be used for the definition of domain and parameters in LVT. This file should be in NetCDF format and must include details about the map projection (as global attributes) and must include a landmask field. LVT uses the landmask specified in this file to derive the landmask for the LVT run domain. The extents of the run domain should be inclusive of the landmask specified in this file (but it doesn't have to match exactly).

*Example lvt.config entry*

```
Input domain and mask data file:                ./lis_input.d01.nc
```

`LVT datastream attributes table::` specifies the variables being analyzed and their attributes. The list of variables are to be specified in a table form with each line representing the variable specification from datastream 1 and datastream 2. In the example below, latent heat flux variable from datastream 1 is compared against the sensible heat flux from datastream 2. In addition, the root zone soil moisture from datastream 1 is compared against the root zone soil moisture from datastream 2. Each variable specification consists of 7 columns representing the short name, starting index of the level of the variable (0 indicates that variable is not selected), ending index of the level of the variable, units, direction type, time-averaging option (0 = instantaneous, 1 = time-averaged) and total number of vertical levels.

| | |
|---|---|
| **NOTE** | This line must end with two colons after the word table (e.g., "table::"), and the final line of the table is a line with only two colons (e.g., "::"). The table information is contained on the lines in-between these beginning and end lines. For example, if the soil moisture variable has 4 levels and the user choses levels 2 to 3, then they can be entered as (for a datastream. |

SoilMoist 2 3 m3/m3 - 1 4

*Example lvt.config entry*

```
LVT datastream attributes table::
Qle         1 1 W/m2   DN   1   1 Qh        1 1 W/m2    DN    1  1
RootMoist   1 1 m3/m3   -   1   1 RootMoist 1 1 m3/m3   -     1  1
::
```

`LVT surface soil layer thickness:` specifies the thickness (in m) of the surface soil layer to be considered in the LVT analysis.

*Example lvt.config entry*

```
LVT surface soil layer thickness:       0.1
```

`LVT root zone soil layer thickness:` specifies the thickness (in m) of the root zone soil layer to be considered in the LVT analysis.

*Example lvt.config entry*

```
LVT root zone soil layer thickness:     1.0
```

## 7.3. Analysis options specification

This section of the config file specifies the type of analysis to be conducted during the verification/evaluation. Note that some options are only available in certain running modes.

`Apply external mask:` Specifies whether to apply an external mask in limiting the analysis to a selected set of data points. Note that undefined value is considered to be the value used for omitting grid points. All values other than "undefined values" (e.g. -9999.0) are considered as valid. Acceptable values are:

| Value | Description |
|---|---|
| 0 | Do not apply external mask (default) |
| 1 | Apply external, temporally varying mask |
| 2 | Apply fixed mask |
| 3 | Apply temporal monthly mask |

*Example lvt.config entry*

```
Apply external mask:                    0
```

`Temporal (monthly) mask flags:` specifies the temporal (monthly) mask flags (specified as 0/1 for each calendar month). This option is only read when the `Apply external mask:` option is set to 3.

*Example lvt.config entry*

```
Temporal (monthly) mask flags: 0 0 0 0 0 1 1 1 0 0 0 0
```

`External mask directory:` Specifies the name of the data mask file/directory. If the mask varies temporally, then this option specifies the top-level directory containing data mask. Note that the mask files are expected to be in binary, sequential access format.

*Example lvt.config entry*

```
External mask directory:                "none"
```

`Compute ensemble metrics:` specifies whether to compute ensemble-based metrics or not. If this option is turned on, then all the traditional (non-ensemble) metrics will be turned off. Acceptable values are:

| Value | Description |
|---|---|
| 0 | Do not compute (default) |
| 1 | compute ensemble metrics |

*Example lvt.config entry*

```
Compute ensemble metrics:               0
```

`Compute information theory metrics:` specifies whether to compute information theory-based metrics or not. If this option is turned on, then the ensemble and traditional metrics will be turned off. Acceptable values are:

| Value | Description |
|---|---|
| 0 | Do not compute (default) |
| 1 | compute information theory metrics |

*Example lvt.config entry*

```
Compute information theory metrics:     0
```

`Metrics attributes file:` specifies the attributes of the metrics that are used in the LVT analysis. Section Configuration of metrics describes the format of the metrics attributes file.

*Example lvt.config entry*

```
Metrics attributes file:                ./METRICS.TBL
```

`Observation count threshold:` Specifies the number of observations to be used as the minimum threshold for computing statistics. Grid points with observation count less than this value will be ignored. Acceptable values are 0 or higher

*Example lvt.config entry*

```
Observation count threshold:            50
```

`Metrics computation frequency:` Specifies the temporal averaging interval of the LIS output and observation data.

**NOTE**

The ending time and the `Metrics computation frequency:` must be consistent. For example, for a `Metrics computation frequency:` of 1da, you must have an ending time of:

```
Ending hour: 0
Ending minute: 0
Ending second: 0
```

*Example lvt.config entry*

```
Metrics computation frequency:            "1da"
```

`Temporal lag in metrics computations:` Specifies the temporal lag in metric computations. The values can be positive or negative (e.g. “+1da” or “-1da”)

*Example lvt.config entry*

```
Temporal lag in metrics computations:    0
```

`Spatial averaging mode:` Specifies the spatial averaging mode to be used. Acceptable values are:

| Value | Description |
|---|---|
| pixel-by-pixel | each pixel is treated separately (default) |
| region-based | stats are computed for on a region by region basis |

*Example lvt.config entry*

```
Spatial averaging mode:     "pixel-by-pixel"
```

`Regional mask file for spatial averaging:` Specifies the name of the regional mask file to be used for determining the (sub) regions, if region-based spatial averaging mode is selected.

This file must be in big-endian, sequential access format and must correspond exactly to the LVT run domain.

*Example lvt.config entry*

```
Regional mask file for spatial averaging: none
```

`Metrics output directory:` Specifies the top-level directory where the output from the analysis is to be written.

*Example lvt.config entry*

```
Metrics output directory:                ./STATS
```

`Metrics output frequency:` Specifies the frequency (in seconds) of the analysis output.

**NOTE** The `Metrics output frequency:` is simply a setting for specifying the frequency of LVT outputs. If the `Metrics output frequency:` is different from (greater than) the time averaging interval, no additional averaging will be performed between the time averaging intervals.

*Example lvt.config entry*

```
Metrics output frequency:                "1da"
```

`Apply temporal smoothing to obs:` specifies whether to temporal smoothing to the observations. If enabled,the code will compute an average value across the specified time window, instead of only using the value that corresponds to the current time. Acceptable values are:

| Value | Description |
|---|---|
| 0 | do not apply temporal smoothing to obs (default) |
| 1 | apply temporal smoothing to obs |

*Example lvt.config entry*

```
Apply temporal smoothing to obs: 0
```

`Obs temporal smoothing window half length:` specifies the observation temporal smoothing window half length. The smoothing window is then defined as (current time +/- half length).

*Example lvt.config entry*

```
Obs temporal smoothing window half length: "2da"
```

`Obs temporal smoothing window interval:` specifies the observation temporal smoothing window interval. This will be used as the increment length across the smoothing window. For e.g., if the window half length is specified as 2 days the smoothing window will be of 5 days. If the smoothing window interval is 1 day, then number of points in the smoothing window will be 5 (-2 da, -1da, current day, +1da, +2da).

*Example lvt.config entry*

```
Obs temporal smoothing window interval: "1da"
```

`Time series location file:` specifies the name of the file which lists the locations and regions in the domain where ASCII time series data are to be derived.

The locations can be specified in five different formats: (1) using the lat/lon values; (2) using the column/row indices; (3) using the tile indices; (4) specifying lat/lon values to draw a polygon around a region; and (5) using a categorical from which to define subregions.

Note that LVT has been updated so the format of the time series locations file uses a minimum fraction of the domain before the temporal calculations will occur. Previously, the time series locations file used a minimum number of observations. A value for this “min frac” of 0.1 (for example) implies that at least 10 percent of the total number of points in the domain location must be available for the temporal calculations to occur.

A sample file with location style 1 is shown below:

```
#Number of locations
2
#Location style (1-lat/lon, 2-col/row, 3-tile, 4-polygon, 5-map)
1
#Name (then, next line), SW-lat, SW-lon, NE-lat, NE-lon, min frac
WEST_US
40.0 -130.0 50.0 -110.0 0.0
HIGH_PLAINS_US
43.0 -110.0 49.0 -100.0 0.0
```

If the location style is 2, the user specifies the column and row indices for the bounding boxes, instead of the corner lat/lon values. A sample file with location style 2 is shown below:

```
#Number of locations
2
#Location style (1-lat/lon, 2-col/row, 3-tile, 4-polygon, 5-map)
2
#Name (then, next line), SW-col, SW-row, NE-col, NE-row, min frac
WEST_US
 1 1 20 30 0.0
EAST_US
21 1 40 30 0.0
```

If the location style is 3, the user specifies the tile indices for specifying the bounds (starting tile index and ending tile index). A sample file with location style 3 is shown below:

```
#Number of locations
2
#Location style (1-lat/lon, 2-col/row, 3-tile, 4-polygon, 5-map)
3
#Name (then, next line), Start index, End index, min frac
WEST_US
 1 20 0.0
EAST_US
21 40 0.0
```

If the location style is 4, the user explicitly specifies the lat/lons of each grid point to be used to specify a region in the shape of a polygon. Users should be careful with this location style option, as they cannot specify a minimum fraction of the domain that must have valid observations. A sample file with location style 4 is shown below:

```
#Number of locations
2
#Location style (1-lat/lon, 2-col/row, 3-tile, 4-polygon, 5-map)
4
#Number of points followed by lat/lon of each point
REGION1
3
34.4 -103.2
33.4 -100.2
32.1  -99.3
REGION2
2
40.2 -103.3
42.2 -104.2
```

If the location style is 5, the user explicitly specifies a categorical map from which to define subregions. In the map, the categories must be in numerically increasing order from 1. The map must be a binary direct-access file, with point (1,1) in the southwest corner of the domain. A sample file with location style 5 is shown below:

```
#Number of stations
3
#Location style (1-lat/lon, 2-col/row, 3-tile, 4-polygon, 5-map)
5
#Name (then, next line), min frac
NEWENGLAND
0.0
MIDATLANTIC
0.0
SOUTHATLANTIC
0.0
#categorical map
../huc02_conus_0.125dg.1gd4r
```

Please see the sample TS_LOCATIONS.TXT file for an example in location format (1).

*Example lvt.config entry*

```
Time series location file:              ./TS_LOCATIONS.TXT
```

`Variable-based stratification:` Specifies if the errors are to be stratified using one of the model output variables. The errors will be stratified into two levels (1) where the values of the stratification variable falls above the specified threshold and (2) where the values of the stratification variable falls below the specified threshold. Acceptable values are:

| Value | Description |
|---|---|
| 0 | Do not stratify (default) |
| 1 | Stratify errors |

*Example lvt.config entry*

```
Variable-based stratification:          0
```

`Stratification variable:` Specifies the name of the variable to be used in the stratification

*Example lvt.config entry*

```
Stratification variable:                SWdown_f
```

`Stratification threshold:` Specifies the minimum value to be used as the stratification threshold.

*Example lvt.config entry*

```
Stratification threshold:               1.0
```

`Confidence interval (%):` Specifies the confidence interval threshold (in percentage) of the

computed statistics. The default value is 0.95.

*Example lvt.config entry*

```
Confidence interval (%):                95
```

`External data-based stratification:` Specifies if the errors are to be stratified based on an external (static) dataset (e.g. landcover, elevation,etc.) The associated attributes file specifies the stratification details. Acceptable values are:

| Value | Description |
|---|---|
| 0 | Do not stratify (default) |
| 1 | Stratify errors |

*Example lvt.config entry*

```
External data-based stratification:     0
```

`Stratification attributes file:` Specifies the name of the file which lists the details of the stratification. The format of the time series location file is as follows:

```
   #Number of stratification data sources
   3
   #Stratification data files
   srtm_elev1km.1gd4r
   srtm_slope1km.1gd4r
   srtm_aspect1km.1gd4r
   #stratifcation variable name
   ELEV
   SLOPE
   ASPECT
   #Max (row 1) min (row2) values for each category
   7000 1.0 6
   500  0.0 0
   #number of bins
   12 12 12
```

*Example lvt.config entry*

```
Stratification attributes file:         ./strat_attribs.txt
```

`Seasonal cycle interval type:` Specifies the interval type for average seasonal cycle computations (when enabled in the METRICS.TBL file) Acceptable values are:

| Value | Description |
|---|---|
| monthly | monthly seasonal cycles (default) |

| Value | Description |
|---|---|
| 3 monthly | 3-monthly seasonal cycles (DJF,MAM,JJA,SON) |
| 3 monthly WY | 3-monthly seasonal cycles based on water/calendar year (JFM,MAJ,JAS,OND) |
| 6 monthly | 6-monthly seasonal cycles |
| yearly | yearly seasonal cycles |

*Example lvt.config entry*

```
Seasonal cycle interval type:          "monthly"
```

`Seasonal cycle minimum count threshold:` Specifies minimum number of points to be used in computing the average seasonal cycle computations. The default value is 0.

*Example lvt.config entry*

```
Seasonal cycle minimum count threshold:          10
```

`Average diurnal cycle minimum count threshold:` Specifies minimum number of points to be used in computing the average diurnal cycle computations. The default value is 0.

*Example lvt.config entry*

```
Average diurnal cycle minimum count threshold:    10
```

`Averaging window for computing mean values in anomaly calculations:` Specifies the time window to use for computing mean values to be used in anomaly calculations. This option only applies to the Anomaly metrics (Anomaly, Anomaly R, Anomaly RMSE). Acceptable values are:

| Value | Description |
|---|---|
| monthly | use monthly means |
| yearly | use annual means |

*Example lvt.config entry*

```
Averaging window for computing mean values in anomaly calculations: monthly
```

`Compute only the climatology for percentiles:` If set to 1, then LVT will only calculate the climatology when calculating percentiles. After the percentiles have been calculated, then LVT can be run in restart mode using these climatology files without having to calculate the climatology every time. If set to any value other than 1, LVT will first calculate percentiles climatology, and then calculate the percentiles.

*Example lvt.config entry*

```
Compute only the climatology for percentiles:     0
```

`Scale model data prior to computing percentiles:` specifies whether to scale model data prior to computing percentiles. The standard normal deviate based scaling is employed. Acceptable values are:

| Value | Description |
|---|---|
| 0 | do not scale |
| 1 | scale |

`Percentile scaling mean (input data) filename:` specifies the name of the file containing the input data mean.

`Percentile scaling standard deviation (input data) filename:` specifies the name of the file containing the input data standard deviation.

`Percentile scaling mean (scaled data) filename:` specifies the name of the file containing the scaled data mean.

`Percentile scaling standard deviation (scaled data) filename:` specifies the name of the file containing the scaled data standard deviation

`Percentile scaling start time for scaling:` specifies the time to start scaling.

`Percentile scaling end time for scaling:` specifies the time to end scaling.

*Example lvt.config entry*

```
Scale model data prior to computing percentiles: 0
Percentile scaling mean (input data) filename:
Percentile scaling standard deviation (input data) filename:
Percentile scaling mean (scaled data) filename:
Percentile scaling standard deviation (scaled data) filename:
Percentile scaling start time for scaling:
Percentile scaling end time for scaling:
```

`Compute only the climatology for SGWI:` If set to 1, then LVT will only calculate the climatology for SGWI.

*Example lvt.config entry*

```
Compute only the climatology for SGWI:     0
```

`Compute only the climatology for SPI:` If set to 1, then LVT will only calculate the climatology for SPI.

*Example lvt.config entry*

```
Compute only the climatology for SPI:     0
```

`Compute only the climatology for SRI:` If set to 1, then LVT will only calculate the climatology for SRI.

*Example lvt.config entry*

```
Compute only the climatology for SRI:     0
```

`SPI timescale of computation:` Set to 1,3,6,...for SPI (or SRI, SSWI) agregations.

`Compute only the climatology for SSWI:` If set to 1, then LVT will only calculate the climatology for SSWI.

*Example lvt.config entry*

```
Compute only the climatology for SSWI:     0
```

`Starting month if a shifted year definition is used in temporal averaging:` The starting month (integer from 1 to 12) if doing a yearly average or outputting the stats in yearly intervals. Setting this value to 10, for example, represents the start of a hydrologic water year. The default value is 1.

*Example lvt.config entry*

```
Starting month if a shifted year definition is used in temporal averaging: 10
```

`Time specification option for MinTime metric:` The “MinTime” metric computes the time at which the minimum value occcurs within the stats writing time window. This particular option specifies the nature of the time value saved. Acceptable values are:

| **Value** | **Description** |
|---|---|
| doy | day of year |
| mo | month |
| da | day |
| hr | hour |
| mn | minute |
| ss | second |

If doy is chosen, for example, then the day of the year at which the minimum value occurs will be saved.

*Example lvt.config entry*

```
Time specification option for Mintime metric: doy
```

`Time specification option for MaxTime metric:` The “Maxtime” metric computes the time at which the maximum value occcurs within the stats writing time window. This particular option specifies the nature of the time value saved. Acceptable values are:

| Value | Description |
|---|---|
| doy | day of year |
| mo | month |
| da | day |
| hr | hour |
| mn | minute |
| ss | second |

If doy is chosen, for example, then the day of the year at which the maximum value occurs will be saved.

*Example lvt.config entry*

```
Time specification option for MaxTime metric: doy
```

`Calculate reference ET without energy balance:` allows for the reference evapotranspiration to be calculated without using surface energy flux variables that are generated by the land-surface model. The calculation follows the methodology in Hobbins, M. et al. 2016.

| Value | Description |
|---|---|
| 0 | use default Reference ET calculation |
| 1 | use Reference ET without LSM output |

This option is only valid for Template LSM runs.

*Example lvt.config entry*

```
Calculate reference ET without energy balance: 1
```

# 7.4. Data stream sources

This section of the config file specifies the details of the sources of data streams.

## 7.4.1. LIS output

`LIS output analysis data class:` specifies the type of land surface data that is being analyzed.

Acceptable values are:

| Value | Description |
|---|---|
| LSM | LSM variables |
| Routing | Routing variables |
| RTM | Radiative transfer model variables |
| Irrigation | Irrigation model output |

`LIS output number of surface model types:` specifies the number of surface model types used in the LIS simulation

`LIS output surface model types:` specifies the surface model types used in the LIS simulation, in consecutive columns. Acceptable values are:

| Value | Description |
|---|---|
| LSM | land surface model types |
| Lake | Lake model types |

`LIS output model name:` specifies the name of the model used that generated the output. Acceptable values are:

| Value | Description |
|---|---|
| “CLSM” | Catchment land surface model |
| “CLM” | CLM 2.0 |
| “CLSM F2.5” | Catchment Fortuna 2.5 |
| “HYSSIB” | HySSiB |
| “MOS” | Mosaic |
| “Noah.2.7.1” | Noah 2.7.1 |
| “Noah.3.2” | Noah 3.2 |
| “Noah.3.3” | Noah 3.3 |
| “SiB2” | SiB2 |
| “TEMPLATE” | template (no model) |
| “VIC411” | VIC 4.1.1 |
| “WRSI” | GeoWRSI 2.0 |

`LIS output domain and parameter file:` specifies the name of the parameter input file used in the LIS simulation This file is generated by the Land Data Toolkit (LDT).

`LIS output directory:` specifies the LIS output directory

`LIS output naming style:` specifies the style of the LIS output. Acceptable values are:

| Value | Description |
|---|---|
| “5 level hierarchy” | 5 levels of hierarchy |
| “3 level hierarchy” | 3 levels of hierarchy |
| “2 level hierarchy” | 2 levels of hierarchy |
| “WMO convention” | WMO convention for weather codes (written by LIS) |
| “WMO convention (AFW OPS)” | WMO convention for weather codes (for AFW production use) |

`LIS output methodology:` specifies the output methodology used for generating the output. The LIS output is written as a 1-D array containing only land points or as a 2-D array containing both land and water points. 1-d tile space includes the subgrid tiles and ensembles. 1-d grid space includes a vectorized, land-only grid-averaged set of values. Acceptable values are:

| Value | Description |
|---|---|
| “1d tilespace” | LIS output in a 1-D tile domain |
| “2d gridspace” | LIS output in a 2-D grid domain |
| “1d gridspace” | LIS output in a 1-D grid domain |

`LIS output format:` specifies the format of the LIS output. Acceptable values are:

| Value | Description |
|---|---|
| binary | Write output in binary format |
| distributed binary | Write output in distributed binary format where each processor writes outputs for the respective local domain |
| grib1 | Write output in Grib format (not supported yet) |
| netcdf | Write output in NETCDF format |

`LIS output interval:` specifies the frequency at which the LIS output was written. The time interval is specified with a number followed by a 2 character suffix that indicates the units. For example, an output interval of 1 hour can be specified as “1hr”, “60mn”, or “3600ss”. Acceptable values for the 2 character suffix are:

| Value | Description |
|---|---|
| ss | second |
| mn | minute |
| hr | hour |
| da | day |
| mo | month |
| yr | year |

`LIS output attributes file:` specifies the model output attribute file used for generating the LIS output

`LIS output maximum number of surface type tiles per grid:` defines the maximum surface type tiles per grid (this can be as many as the total number of vegetation/landcover types) used in the LIS simulation.

`lIS output minimum cutoff percentage (surface type tiles):` defines the smallest percentage (among the surface type distributions within a grid cell) for which to create a tile, used in the LIS simulation. The percentage value is expressed as a fraction.

`LIS output maximum number of soil texture tiles per grid:` defines the maximum soil texture type tiles per grid (this can be as many as the total number of soil texture types) used in the LIS simulation.

`LIS output minimum cutoff percentage (soil texture tiles):` defines the smallest percentage (among the soil texture distributions within a grid cell) for which to create a tile, used in the LIS simulation. The percentage value is expressed as a fraction.

`LIS output maximum number of soil fraction tiles per grid:` defines the maximum soil fraction tiles per grid used in the LIS simulation.

`LIS output minimum cutoff percentage (soil fraction tiles):` defines the smallest percentage (among the soil fraction distributions within a grid cell) for which to create a tile, used in the LIS simulation. The percentage value is expressed as a fraction.

`LIS output maximum number of elevation bands per grid:` defines the maximum elevation bands per grid used in the LIS simulation.

`LIS output minimum cutoff percentage (elevation bands):` defines the smallest percentage (among the elevation distributions within a grid cell) for which to create a tile, used in the LIS simulation. The percentage value is expressed as a fraction.

`LIS output maximum number of slope bands per grid:` defines the maximum slope bands per grid used in the LIS simulation.

`LIS output minimum cutoff percentage (slope bands):` defines the smallest percentage (among the slope distributions within a grid cell) for which to create a tile, used in the LIS simulation. The percentage value is expressed as a fraction.

`LIS output maximum number of aspect bands per grid:` defines the maximum aspect bands per grid used in the LIS simulation.

`LIS output minimum cutoff percentage (aspect bands):` defines the smallest percentage (among the aspect distributions within a grid cell) for which to create a tile, used in the LIS simulation. The percentage value is expressed as a fraction.

`LIS output nest index:` specifies the nest index of the domain.

`LIS output elevation data source:` specifies the name of the topographical elevation data source used in the LIS run (This information is used to replicate the domain creation that was done in the

LIS run).

`LIS output slope data source:` specifies the name of the topographical slope data source used in the LIS run (This information is used to replicate the domain creation that was done in the LIS run).

`LIS output aspect data source:` specifies the name of the topographical aspect data source used in the LIS run (This information is used to replicate the domain creation that was done in the LIS run).

`LIS output soil texture data source:` specifies the name of the soil texture data source used in the LIS run (This information is used to replicate the domain creation that was done in the LIS run).

`LIS output soil fraction data source:` specifies the name of the soil fraction data source used in the LIS run (This information is used to replicate the domain creation that was done in the LIS run).

`LIS output number of soil moisture layers:` specifies the number of soil moisture layers used in the LIS output.

`LIS output number of soil temperature layers:` specifies the number of soil temperature layers used in the LIS output.

`LIS output soil moisture layer thickness:` specifies the thicknesses of soil moisture layers in the LIS output.

`LIS output soil temperature layer thickness:` specifies the thicknesses of soil temperature layers in the LIS output.

*Example lvt.config entry*

```
LIS output analysis data class:                       "LSM"
LIS output number of surface model types:            1
LIS output surface model types:                      "LSM"
LIS output model name:                               "Noah.3.3"
LIS output domain and parameter file:                "lis_input.d01.nc"
LIS output directory:                               ./CLSM/OUTPUT
LIS output naming style:            "3 level hierarchy"
LIS output methodology:            "2d gridspace"
LIS output format:                  "netcdf"
LIS output interval:                "1da"
LIS output attributes file:    ../Data/Noah33_CONUS/NOAH33_OUTPUT_LIST.TBL
LIS output maximum number of surface type tiles per grid:     1
LIS output minimum cutoff percentage (surface type tiles):    0.10
LIS output maximum number of soil texture tiles per grid:     1
LIS output minimum cutoff percentage (soil texture tiles):    0.10
LIS output maximum number of soil fraction tiles per grid:    1
LIS output minimum cutoff percentage (soil fraction tiles):   0.10
LIS output maximum number of elevation bands per grid:        1
LIS output minimum cutoff percentage (elevation bands):       0.10
LIS output maximum number of slope bands per grid:            1
LIS output minimum cutoff percentage (slope bands):           0.10
LIS output maximum number of aspect bands per grid:           1
LIS output minimum cutoff percentage (aspect bands):          0.10
LIS output number of ensembles per tile:  1
LIS output nest index:     1
LIS output elevation data source: none
LIS output slope data source:     none
LIS output aspect data source:     none
LIS output soil texture data source: none
LIS output soil fraction data source: none
LIS output number of soil moisture layers:  4
LIS output number of soil temperature layers:  4
LIS output soil moisture layer thickness: 0.1 0.3 0.6 1.0
LIS output soil temperature layer thickness:  0.1 0.3 0.6 1.0
```

### 7.4.2. AGRMET data

`AGRMET data directory:` specifies the location of the AGRMET data.

`AGRMET data security class name:` specifies the security level classification of the data (U for unclassified)

`AGRMET data distribution class name:` specifies the distribution classification of AGRMET data

`AGRMET data category name:` specifies category name for AGRMET data.

`AGRMET data area of data:` specifies geographical extent of AGRMET data

*Example lvt.config entry*

```
AGRMET data directory:                  ./AGRMET_data
AGRMET data security class name:      U
AGRMET data distribution class name:  C
AGRMET data category name:            ANLYS
AGRMET data area of data:             GLOBAL
```

### 7.4.3. ALEXI data

`ALEXI data directory:` specifies the location of the ALEXI ET data.

`ALEXI data domain extent:` specifies the domain extent of the ALEXI data. Acceptable values are "CONUS" and "GLOBAL".

`ALEXI data resolution (in km):` specifies the resolution of the ALEXI ET data in km. Acceptable values are 4 or 10 (for "CONUS") or 5 (for "GLOBAL").

*Example lvt.config entry*

```
ALEXI data directory:                   ./ALEXI
ALEXI data resolution (in km):  4
```

### 7.4.4. Ameriflux station observations

`Ameriflux observation directory:` specifies the location of the Ameriflux datasets. Under this directory, the Ameriflux data is expected to be organized by the station names and then under each station name directory, the Level3 Ameriflux files are expected to be staged.

`Ameriflux data level:` specifies the level of Ameriflux data (Note that only level 3 data is currently supported)

`Ameriflux station list file:` specifies the file that lists the location of the Ameriflux stations. The format of the station list is as follows:

```
#nstns
76
#stnname; location name; lat; lon; SWC1 depth; SWC2 depth; TS1 depth; TS2 depth
ARM_SGP_Burn; USARb; 35.5497; -98.0402; 10; 30; 5; 15
ARM_SGP_Control; USARc; 35.5465; -98.0401; 10; 30; 5; 15
ARM_SGP_Main; USARM; 36.6058; -97.4888; 5; 25; 5; 15
Atqasuk; USAtq; 70.4696; -157.4089; -1; -1; 0; 5
Audubon_Grasslands; USAud; 31.5907; -110.5092; 10; 20; 2; 4
Austin_Cary; USSP1; 29.7381; -82.2188; -1; -1; 0; 5
Barrow; USBrw; 71.3225; -156.6259; -1; -1; 0; 5
Bartlett_Experimental_Forest; USBar; 44.0645; -71.2881; 10; -1; 5; -1
Blodgett_Forest; USBlo; 38.8953; -120.6328; 10; 20; 5; 10
Bondville; USBo1; 40.0062; -88.2904; 5; 20; 2; 4
```

*Example lvt.config entry*

```
Ameriflux observation directory:        ./AmeriFlux
Ameriflux data level:                   Level3
Ameriflux station list file:           ./AmeriFlux/Ameriflux_stns.txt
```

### 7.4.5. ANSA snow depth data

`ANSA snow depth observation directory:` specifies the location of the ANSA snow depth observation data (Note that this plugin handles the raw observations that go into the generation of the AFWA ANSA snow depth product)

*Example lvt.config entry*

```
ANSA snow depth observation directory:  ./SNODEP
ANSA snow depth lower left lat:      -89.875
ANSA snow depth lower left lon:     -179.875
ANSA snow depth upper right lat:      89.875
ANSA snow depth upper right on:      179.875
ANSA snow depth resolution (dx):       0.25
ANSA snow depth resolution (dy):       0.25
```

### 7.4.6. ANSA SWE data

`ANSA SWE observation directory:` specifies the location of the ANSA snow water equivalent observation data (Note that this plugin handles the raw observations that go into the generation of the AFWA ANSA snow swe product)

*Example lvt.config entry*

```
ANSA SWE observation directory:  ./ANSA_SWE
ANSA SWE lower left lat:      -89.875
ANSA SWE lower left lon:     -179.875
ANSA SWE upper right lat:      89.875
ANSA SWE upper right on:      179.875
ANSA SWE resolution (dx):       0.25
ANSA SWE resolution (dy):       0.25
```

### 7.4.7. ARM station observations

`ARM observation directory:` specifies the location of the ARM datasets

`ARM site identifier name:` specifies the text identifier (e.g. sgp, twp, nsa, etc.)

`ARM station list file:` specifies the file that lists the location of the ARM stations. The format of the station list is as follows:

```
#nstns
22
#stnname; lat; lon
E1; 38.202; -99.316
E2; 38.306; -97.301
E3; 38.201; -95.597
E4; 37.953; -98.329
E5; 38.114; -97.513
E6; 37.842; -97.020
E7; 37.383; -96.180
E8; 37.333; -99.309
E9; 37.133; -97.266
```

`ARM use BAEBBR data:` specifies if to use the BAEBBR data or not

`ARM use EBBR data:` specifies if to use the EBBR data or not

`ARM use ECOR flux data:` specifies if to use the ECOR data or not

`ARM use SWATS data:` specifies if to use the SWATS data or not

`ARM use SMOS data:` specifies if to use the SMOS data or not

*Example lvt.config entry*

```
ARM observation directory:              ./ARM_SGP
ARM site identifier name:               sgp
ARM station list file:                  ./ARM_SGP/sgp_stns.txt
ARM use BAEBBR data:                    1
ARM use EBBR data:                      1
ARM use ECOR flux data:                 1
ARM use SWATS data:                     1
ARM use SMOS data:                      1
```

### 7.4.8. USDA ARS soil moisture observations

`ARS soil moisture observation directory:` specifies the location of the ARS soil moisture observation data

`ARS soil moisture station list file:` specifies the file that lists the location of the ARS stations. The format of the file is as follows: ARS station name, station lat, station lon

```
#nstns
4
#stns
wg 31.73 -110.05
lr 31.50 -83.550
lw 34.95 -97.983
rc 43.07 -116.75
```

*Example lvt.config entry*

```
ARS soil moisture observation directory: ./ARS_Watersheds
ARS soil moisture station list file:     ./ARS_Watersheds/stnlist.dat
```

### 7.4.9. SNODAS snow analysis data

`SNODAS observation directory:` specifies the location of the SNODAS data

*Example lvt.config entry*

```
SNODAS observation directory:           ./SNODAS
```

### 7.4.10. CPC precipitation data

`CPC PCP observation directory:` specifies the location of the CPC unified precipitation data

`CPC PCP domain type (CONUS or GLOBAL):` specifies the version of the CPC unified precipitation data

`CPC PCP use real time data:` specifies whether to use the real time version of the CPC unified

precipitation data

*Example lvt.config entry*

```
CPC PCP observation directory:            ../CPC_CONUS
CPC PCP domain type (CONUS or GLOBAL):    CONUS
CPC PCP use real time data:               0
```

### 7.4.11. GPM IMERG precipitation data

`IMERG data directory:` specifies the location of the GPM IMERG precipitation product

`IMERG version:` specifies the version of the GPM IMERG precipitation product. Most current version is V06B.

`IMERG product:` specifies the GPM IMERG precipitation product. Current options are: early, late, or final.

*Example lvt.config entry*

```
IMERG data directory:            ../IMERG
IMERG version:                   V06B
IMERG product:                   final
```

### 7.4.12. GPM IMERG Monthly precipitation data

`IMERG monthly data directory:` specifies the location of the GPM IMERG Monthly precipitation product

`IMERG monthly version:` specifies the version of the GPM IMERG Monthly precipitation product. Most current version is V07A.

`IMERG monthly product:` specifies the GPM IMERG Monthly precipitation product. Current option is: final. (early and late will be added later)

*Example lvt.config entry*

```
IMERG monthly data directory:            input/IMERGF_V07A_Monthly
IMERG monthly version:                   V07A
IMERG monthly product:                   final
```

### 7.4.13. ESA CCI soil moisture data

`ESA CCI soil moisture data directory:` specifies the location of the ESA CCI soil moisture data

`ESA CCI soil moisture data version:` specifies the version of the ESA CCI data (1 or 2)

*Example lvt.config entry*

```
ESA CCI soil moisture data directory: ../ECV_sm_v2.0/
ESA CCI soil moisture data version:    2
```

### 7.4.14. Gridded FLUXNET MTE data

`FLUXNET data directory:` specifies the location of the gridded FLUXNET MTE data

*Example lvt.config entry*

```
FLUXNETmte data directory:           ./FLUXNET
```

### 7.4.15. Global Change Observation Mission - Water (GCOMW)

`GCOMW AMSR2 L3 soil moisture observation directory:` specifies the location of the GCOMW AMSR2 L3 soil moisture observations.

*Example lvt.config entry*

```
GCOMW AMSR2 L3 soil moisture observation directory:
```

### 7.4.16. Global Historic Climatology Network (GHCN) data

`GHCN observation directory:` specifies the location of the GHCN data

`GHCN station file:` specifies the file that lists the GHCN stations in the following format (station id, latitude, longitude, elevation)

```
 USC00020170   33.63920      -109.3278       2792.000
 USC00020678   35.23000      -111.8214       2179.900
 USC00020750   36.67780      -110.5411       2220.800
 USC00021001   36.21470      -112.0620       2438.400
 USC00023009   35.16110      -111.7311       2171.700
 USC00023828   34.74330      -111.4139       2279.900
 USC00025412   34.11420      -109.8589       2237.200
 
```

*Example lvt.config entry*

```
GHCN observation directory:             ./GHCN
GHCN station file:                      ./GHCN/ghcnd-qc-stations.txt
```

### 7.4.17. GlobSnow data

`GlobSnow data directory:` specifies the location of the GlobSnow data.

*Example lvt.config entry*

```
GlobSnow data directory:                ./GlobSnow
```

### 7.4.18. ISMN soil moisture observations

`ISMN observation directory:` specifies the location of the ISMN (International Soil Moisture Network) soil moisture observation data

*Example lvt.config entry*

```
ISMN observation directory:             ./ISMN
```

### 7.4.19. LPRM AMSR-E soil moisture retrievals

`LPRM AMSR-E soil moisture observation directory:` specifies the location of the LPRM AMSR-E soil moisture retrievals.

`LPRM AMSR-E data version:` specifies the version of LPRM soil moisture data to be used. Acceptable values are:

| Value | Description |
|---|---|
| GES-DISC | NASA GES-DISC version |
| V5 | version 5 data (from VU) |

`LPRM AMSR-E data channel:` specifies the frequency channel of the soil moisture retrieval. (This option is only needed for the GES-DISC data version.) Acceptable values are:

| Value | Description |
|---|---|
| X-band | X-band retrieval |
| C-band | C-band retrieval |

`LPRM AMSR-E use raw data:` specifies whether to use the LPRM AMSR-E raw data. (This option is only used for V5 data.) Acceptable values are:

| Value | Description |
|---|---|
| 0 | Do not use |
| 1 | Use |

*Example lvt.config entry*

```
LPRM AMSR-E soil moisture observation directory: ./LPRM-AMSRE
LPRM AMSR-E soil moisture data version:  GES-DISC
LPRM AMSR-E soil moisture data channel: X-band
LPRM AMSR-E use raw data:                       0
```

### 7.4.20. MOD16A2 data

`MOD16A2 data directory:` specifies the location of the MOD16A2 - MODIS based ET data.

*Example lvt.config entry*

```
MOD16A2 data directory:                ./MOD16
```

### 7.4.21. MODIS LST

`MODIS LST data directory:` specifies the location of the MODIS LST data.

*Example lvt.config entry*

```
MODIS LST data directory:
```

### 7.4.22. North American Soil Moisture Database (NASMD)

`NASMD observation directory:` specifies the location of the NASMD observation directory.

`NASMD coord file:` specifies the name of the NASMD coordinates file.

`NASMD number of stations:` specifies the number of NASMD stations.

*Example lvt.config entry*

```
NASMD observation directory:   ../TAMU_NASMD
NASMD coord file:              ../TAMU_NASMD/nasmd_stations.txt
NASMD number of stations:      1289
```

### 7.4.23. Naturalized monthly streamflow data

`Naturalized streamflow observation directory:` specifies the location of the naturalized monthly streamflow observation data

`Naturalized streamflow station list file:` lists the locations of the streamflow stations in the following format (total number of stations followed by each usgs station id, latitude, longitude,data coverage begin year, data coverage end year).

```
#nstns
23
#name, lat, lon
ala 31.55  -87.51 1950 1993
apa 29.95  -85.02 1950 1993
del 39.69  -75.69 1948 1987
ftp 48.04 -106.36 1950 2009
gar 47.39 -101.39 1950 2009
gre 40.91 -109.42 1905 2006
```

*Example lvt.config entry*

```
Naturalized streamflow observation directory: ./Naturalized_StreamFlow
Naturalized streamflow station list file:
./Naturalized_StreamFlow/Naturalized_stnlist.txt
```

### 7.4.24. NLDAS2

`NLDAS2 data directory:` specifies the location of the NLDAS-2 data directory.

`NLDAS2 hourly or monthly:` specifies if the NLDAS-2 files to be read in are hourly or are monthly-averaged.

`NLDAS2 land surface model:` specifies the NLDAS-2 forcing or land-surface model dataset. Acceptable values are:

| Value | Description |
|---|---|
| FORCINGA | NLDAS-2 primary forcing |
| FORCINGB | NLDAS-2 secondary forcing |
| NOAH | NLDAS-2 Noah LSM |
| MOS | NLDAS-2 Mosaic LSM |
| VIC | NLDAS-2 VIC LSM |
| SAC | NLDAS-2 SAC LSM (hourly only) |
| SACSM | NLDAS-2 SAC LSM soil moisture variables (hourly only) |
| NOAHST | NLDAS-2 Noah LSM streamflow variables (hourly only) |
| MOSST | NLDAS-2 Mosaic LSM streamflow variables (hourly only) |
| VICST | NLDAS-2 VIC LSM streamflow variables (hourly only) |

| Value | Description |
|---|---|
| SACST | NLDAS-2 SAC LSM streamflow variables (hourly only) |

`NLDAS2 analysis data class:` specifies the type of NLDAS-2 data that is being analyzed. Acceptable values are:

| Value | Description |
|---|---|
| LSM | LSM variables |
| Routing | Routing variables |

`NLDAS2 soil moisture volumetric:` specifies if LVT should convert the NLDAS-2 soil moisture values in amounts (kg m-2) to volumetric (m3 m-3), when `LVT running mode:` is set to "Observation processing". If `NLDAS2 soil moisture volumetric:` is set to ".true.", then the values will be converted.

`NLDAS2 VIC soil depth1 file:` specifies the name of the VIC soil depth 1 binary file.

`NLDAS2 VIC soil depth2 file:` specifies the name of the VIC soil depth 2 binary file.

`NLDAS2 VIC soil depth3 file:` specifies the name of the VIC soil depth 3 binary file.

*Example lvt.config entry*

```
NLDAS2 data directory:              ./NLDAS2.VIC
NLDAS2 hourly or monthly:           hourly
NLDAS2 land surface model:          VIC
NLDAS2 analysis data class:         LSM
NLDAS2 soil moisture volumetric:    .true.
NLDAS2 VIC soil depth1 file:        ./vic_depth1.1gd4r
NLDAS2 VIC soil depth2 file:        ./vic_depth2.1gd4r
NLDAS2 VIC soil depth3 file:        ./vic_depth3.1gd4r
```

### 7.4.25. Soil Moisture Operational Processing System (SMOPS)

`SMOPS soil moisture observation directory:` specifies the location of the SMOPS soil moisture observation directory.

`SMOPS soil moisture use ASCAT data:` specifies whether to use the ASCAT data. Acceptable values are:

| Value | Description |
|---|---|
| 0 | do not use |
| 1 | use |

`SMOPS soil moisture use WindSat data:` specifies whether to use the WindSat data. Acceptable values are:

| Value | Description |
|---|---|
| 0 | do not use |
| 1 | use |

`SMOPS soil moisture use SMOS data:` specifies whether to use the SMOS data. Acceptable values are:

| Value | Description |
|---|---|
| 0 | do not use |
| 1 | use |

*Example lvt.config entry*

```
SMOPS soil moisture observation directory: ./SMOPS
SMOPS soil moisture use ASCAT data:        1
SMOPS soil moisture use WindSat data:      0
SMOPS soil moisture use SMOS data:         0
```

### 7.4.26. SMOS L1 TB

`SMOS L1 TB observation directory:` specifies the location of the SMOS L1 TB observation directory.

*Example lvt.config entry*

```
SMOS L1 TB observation directory:
```

### 7.4.27. SMOS L2 soil moisture

`SMOS L2 soil moisture observation directory:` specifies the location of the SMOS L2 soil moisture observation directory.

*Example lvt.config entry*

```
SMOS L2 soil moisture observation directory:
```

### 7.4.28. SNODEP metobs snow depth data

`SNODEP metobs directory:` specifies the location of the SNODEP observation data (Note that this plugin handles the raw observations that go into the generation of the AFWA SNODEP product)

*Example lvt.config entry*

```
SNODEP metobs directory:           ./SNODEP
```

### 7.4.29. SNOTEL SWE observations

`SNOTEL observation directory:` specifies the location of the SNOTEL SWE observation data

`SNOTEL coord file:` specifies the file that lists the location of the SNOTEL stations. The format of the station list is as follows:

```
AZ        BAKER BUTTE                    11R06S          308    34.450  -111.400
AZ        BAKER BUTTE SMT                11R07S         1140    34.450  -111.367
AZ        BALDY                          09S01S          310    33.967  -109.500
AZ        BEAVER HEAD                    09S06S          902    33.683  -109.200
```

*Example lvt.config entry*

```
SNOTEL observation directory:          ./SNOTEL
SNOTEL coord file:                     ./SNOTEL/SNOTEL_CONUS_list.txt
```

### 7.4.30. SURFRAD observations (radiation, wind speed, pressure)

`SURFRAD observation directory:` specifies the location of the SURFRAD radiation data

*Example lvt.config entry*

```
SURFRAD observation directory:         ./SURFRAD
```

### 7.4.31. SCAN soil moisture observations

`SCAN observation directory:` specifies the location of the SCAN soil moisture observation data (Note that the plugin handles the “reprocessed” SCAN data from NASA GMAO.

`SCAN number of stations:` specifies the number of SCAN stations used in the analysis

`SCAN coord file:` specifies the file that lists the location of the SCAN stations. The format of the metadata file is as follows: station id, station lat, station lon, elevation, SCAN state

```
2058  34.43   -87     633 AL
2030  34.85   -91.88      250 AR
2091  34.28   -91.35      197 AR
2026  31.73   -110.05     4500    AZ
2013  33.88   -83.43      770 GA
2027  31.5    -83.55      350 GA
```

*Example lvt.config entry*

```
SCAN observation directory:             ./SCAN
SCAN number of stations:                37
SCAN coord file:                        ./SCAN_coord.txt
```

### 7.4.32. USGS ground water

`USGS ground water (well data) observation directory:` specifies the location of the USGS ground water (well data) observation directory.

`USGS ground water (well data) coord file:` specifies the name of the USGS ground water (well data) coordinates file.

*Example lvt.config entry*

```
USGS ground water (well data) observation directory: ./USGS_GW_welldata
USGS ground water (well data) coord file:            ./USGS_GW_welldata/Well_mdata.txt
```

### 7.4.33. USGS daily streamflow data

`USGS streamflow observation directory:` specifies the location of the USGS daily streamflow observation data

`USGS streamflow station list file:` lists the locations of the streamflow stations in the following format (total number of stations followed by each usgs station id, latitude, longitude).

```
#nstns
961
#name, lat, lon
01010000   46.70060      -69.71560
01010500   47.11310      -69.08810
01011000   47.06970      -69.07940
01013500   47.23750      -68.58280
01022500   44.60810      -67.93530
01030500   45.50110      -68.30580
01031500   45.17500      -69.31470
01038000   44.22280      -69.59390
01047000   44.86920      -69.95500
01052500   44.87750      -71.05750
01054200   44.39060      -70.97970
```

*Example lvt.config entry*

```
USGS streamflow observation directory:  ./USGS_StreamFlow
USGS streamflow station list file:      ./USGS_StreamFlow/USGS_stnlist_nldas.txt
```

### 7.4.34. University of Washington ET data

`UW ET data directory:` specifies the location of the UWET ET data.

*Example lvt.config entry*

```
UW ET data directory:                    ./UW_ET_MODIS-SRB_Monthly
```

### 7.4.35. GIMMS AVHRR NDVI data

`GIMMS AVHRR NDVI data directory:` specifies the location of the GIMMS NDVI data.

*Example lvt.config entry*

```
GIMMS AVHRR NDVI data directory:                    ./GIMMS-3g/
```

### 7.4.36. GIMMS MODIS NDVI data

`GIMMS MODIS NDVI data directory:` specifies the location of the GIMMS MODIS NDVI data.

*Example lvt.config entry*

```
GIMMS MODIS NDVI data directory:                    ./GIMMS_MODIS_NDVI
```

### 7.4.37. GLASS MODIS/AVHRR albedo data

`GLASS ALBEDO data directory:` specifies the location of the GLASS albedo data.

`GLASS ALBEDO data source:` specifies the name of the GLASS albedo data. Acceptable GLASS albedo names are MODIS or AVHRR.

*Example lvt.config entry*

```
GLASS ALBEDO data directory:                  ./GLASS/Albedo/AVHRR/V4/HDF
GLASS ALBEDO data source:                      AVHRR
```

### 7.4.38. GLDAS version 2 data

`GLDAS2 data directory:` specifies the location of the GLDAS2 data.

`GLDAS2 data model name:` specifies the name of the land surface model used in the GLDAS2 data.

*Example lvt.config entry*

```
GLDAS2 data directory:                   ./GLDAS2/
GLDAS2 data model name:                  NOAH
```

### 7.4.39. MERRA version 2 data

`MERRA2 data directory:` specifies the location of the MERRA2 data.

*Example lvt.config entry*

```
MERRA2 data directory:                    ./MERRA2/
```

### 7.4.40. ERA Interim Land data

`ERA interim land data directory:` specifies the location of the ERA Interim Land data.

*Example lvt.config entry*

```
ERA interim land data directory:                    ./ERA_Interim_Land/
```

### 7.4.41. ERA5 data

`ERA5 data directory:` specifies the location of the ERA5 data.

`ERA5 forcing tile to grid mapping file:` specifies the location of the ERA5 forcing tile to grid mapping file.

*Example lvt.config entry*

```
ERA5 data directory:                          ./ERA5/
ERA5 forcing tile to grid mapping file:     ./ERA5/mapping.nc
```

### 7.4.42. SSEB operational data

`SSEBop data directory:` specifies the location of the SSEB data.

`SSEBop process anomaly data:` specifies whether to process the ET anomaly data or the raw ET data.

*Example lvt.config entry*

```
SSEBop data directory:                    ./SSEB/ETA/
SSEBop process anomaly data:              1
```

### 7.4.43. GRDC data

`GRDC data directory:` specifies the location of the GRDC data.

`GRDC station list file:` specifies the file that contains the listing of the GRDC stations

`GRDC frequency of data:` specifies the frequency of the GRDC data (monthly/daily)

`GRDC file version:` specifies the version of the GRDC data (1 or 2)

*Example lvt.config entry*

```
GRDC data directory:    ../GRDC_data
GRDC station list file: ../GRDC_data/GRDC_stations.txt
GRDC frequency of data:  monthly
GRDC file version:       1
```

### 7.4.44. GRUN data

`GRUN data directory:` specifies the location of the GRUN data.

*Example lvt.config entry*

```
GRUN data directory:    ../GRDC_data
```

### 7.4.45. LIS DAOBS output as the observation

`LIS DAOBS output directory:` specifies the LIS DAOBS output directory

*Example lvt.config entry*

```
LIS DAOBS output directory:             ./DAOBS
```

`LIS DAOBS use scaled obs:` specifies whether to use scaled obs. Acceptable values are:

| Value | Description |
|---|---|
| 0 | Do not use scaled obs |
| 1 | Use scaled obs |

*Example lvt.config entry*

```
LIS DAOBS use scaled obs: 0
```

### 7.4.46. ISCCP land surface temperature observations

`ISCCP Tskin data directory:` specifies the location of the ISCCP land surface temperature data

*Example lvt.config entry*

```
ISCCP Tskin data directory:             ./ISCCP
```

### 7.4.47. LSWG Tb observations

`LSWG Tb observation filename:` specifies the name of the LSWG filename containing Brightness Temperature (Tb) observations

`LSWG Tb satellite name:` specifies the name of satellite — same as what's used in CRTM

`LSWG Tb data format:` 0 for AMSR-E, 1-for AMSU

`LSWG Tb metadata file:` specifies the file that lists the metadata for LSWG Tb observations. The format of the metadata file is as follows:

```
#nstns, undef, starting time, ending time, timestep (mins)
1 -1 2006 07 01 10 00 2007 06 30 17 00 3600
#LIS channel  data index in  file
1   1
2   2
3   3
4   4
5   5
6   6
7   7
8   8
9   9
10  10
11  11
12  12
13  13
14  14
15  15
```

`LSWG Tb include cloud masking:` specifies if data is to be ignored in the presence of clouds (0-do not ignore, 1-ignore)

`LSWG Tb cloud mask file:` specifies the name of the cloud mask file

`LSWG Tb cloud mask column:` specifies what?

`LSWG Tb cloud mask threshold(%):` specifies the threshold below which clouds can be ignored (used only if cloud masking is enabled).

*Example lvt.config entry*

```
LSWG Tb observation filename:           ./_LSWG/C3VP.txt
LSWG Tb satellite name:                 "N18_"
LSWG Tb data format:                    1
LSWG Tb metadata file:                  ./C3VP_mdata
LSWG Tb include cloud masking:          1
LSWG Tb cloud mask file:                ./cloud_mask.txt
LSWG Tb cloud mask column:              ??
LSWG Tb cloud mask threshold(%):        75
```

### 7.4.48. FMI SWE observations

`FMISWE observation directory:` specifies the location of the FMI snow course data

*Example lvt.config entry*

```
FMISWE observation directory:           ./FMI_SWE
```

### 7.4.49. CMC daily snow depth observations

`CMC snow depth observation directory:` specifies the location of the CMC snow depth observation data

*Example lvt.config entry*

```
CMC snow depth observation directory:   ./CMC_data
```

### 7.4.50. NASA AMSR-E soil moisture retrievals

`NASA AMSR-E soil moisture observation directory:` specifies the location of the standard (NASA) AMSR-E soil moisture retrievals

*Example lvt.config entry*

```
NASA AMSR-E soil moisture observation directory: ./NASA_AMSRE
```

### 7.4.51. AMMA station observations

`AMMA observation directory:` specifies the location of the AMMA in-situ observations.

`AMMA static txt file list:` specifies the file with the station file names in text format (.txt)

A sample static txt file list is shown below:

```
12
20100614033213 2535.csv
20100614033734 2536.csv
20100614034708 2537.csv
20100614034859 2538.csv
20100614035138 2539.csv
20100614035858 2540.csv
20100614040053 2541.csv
20100614040220 2542.csv
20100614064030 2543.csv
20100614064144 2544.csv
20100614064242 2545.csv
20100614064337 2546.csv
```

`AMMA static netcdf file list:` specifies the file with the station file names in netcdf format

A sample static txt file list is shown below:

```
10
ceh-aws_agoufou_20050414.nc
ceh-aws_bamba_20050426.nc
ceh-aws_banizoumbou_20051115.nc
ceh-aws_belifoungou_20051111.nc
ceh-aws_bira_20051113.nc
ceh-aws_hedgerit_20050415.nc
ceh-aws_kelema_20050416.nc
ceh-aws_nalohou_20051111.nc
ceh-aws_pobe_20050220.nc
ceh-aws_wankama_20051117.nc
```

`AMMA soil moisture layer weights:` normalized weights to be applied for root zone computations of soil moisture

`AMMA soil temperature layer weights:` normalized weights to be applied for root zone computations of soil temperature

*Example lvt.config entry*

```
AMMA observation directory:             ./AMMA
AMMA static txt file list:              amma_static_txtfiles.txt
AMMA static netcdf file list:           amma_static_ncfiles.txt
AMMA soil moisture layer weights:       0.1875 0.1875 0.625 0.0 0.0
AMMA soil temperature layer weights:    0.1875 0.1875 0.625 0.0 0.0
```

### 7.4.52. SMOSREX in-situ soil moisture observations

`SMOSREX observation filename:` specifies the name of the SMOSREX observation filename. Currently this plugin only handles a single observation location.

*Example lvt.config entry*

```
SMOSREX observation filename:           ./SMOSREX/Toulouse_SMOSREX.dat
```

### 7.4.53. MOD10A1 snow cover data

`MOD10A1 observation directory:` specifies the location of the 1km resolution MOD10A1 fractional snow cover data

*Example lvt.config entry*

```
MOD10A1 observation directory:          ./MOD10A1
```

### 7.4.54. MOD10A1V6 snow cover data

`MOD10A1V6 observation directory:` specifies the location of the 1km resolution MOD10A1V6 fractional snow cover data

*Example lvt.config entry*

```
MOD10A1V6 observation directory:          ./MOD10A1V6
```

### 7.4.55. GRACE (processed from LDT) data

`GRACE data directory:` specifies the location of the GRACE data (note that this plugin handles the "processed" GRACE data, where the GRACE TWS anomalies have been added to the LIS model TWS).

`GRACE configuration:` specifies the GRACE configuration. Acceptable values are:

| Value | Description |
|---|---|
| default | GRACE |
| follow-on | GRACE follow-on |
| GRACE-2 | GRACE 2 |

*Example lvt.config entry*

```
GRACE data directory:  ./GRACE
GRACE configuration:   default
```

### 7.4.56. CEOP

`CEOP data directory:` specifies the location of the CEOP data.

`CEOP station list file:` specifies the location of the CEOP station list file.

`CEOP read surface meteorology data:` specifies whether to read the CEOP surface meteorology data. Acceptable values are:

| Value | Description |
|---|---|
| 0 | do not read |
| 1 | read |

`CEOP read flux data:` specifies whether to read the CEOP flux data. Acceptable values are:

| Value | Description |
|---|---|
| 0 | do not read |
| 1 | read |

`CEOP read soil moisture and temperature data:` specifies whether to read the CEOP soil moisture

and temperature data. Acceptable values are:

| Value | Description |
|---|---|
| 0 | do not read |
| 1 | read |

*Example lvt.config entry*

```
CEOP data directory:                          ./CEOP
CEOP station list file:
CEOP read surface meteorology data:           1
CEOP read flux data:                          1
CEOP read soil moisture and temperature data: 1
```

### 7.4.57. COOP

`COOP data directory:` specifies the location of the COOP data.

`COOP coord file:` specifies the name of the COOP coordinates file.

`COOP metadata file:` specifies the name of the COOP metadate file.

*Example lvt.config entry*

```
COOP data directory:
COOP coord file:
COOP metadata file:
```

### 7.4.58. Great Lakes Environmental Research Lab (GLERL)

`GLERL hydro data directory:` specifies the location of the GLERL hydro data.

`GLERL hydro lake locations file:` specifies the name of the GLERL hydro lake locations file.

*Example lvt.config entry*

```
GLERL hydro data directory:
GLERL hydro lake locations file:
```

### 7.4.59. GSOD

`GSOD observation directory:` specifies the location of the GSOD observation data.

`GSOD coord file:` specifies the name of the GSOD coordinates file.

`GSOD metadata file:` specifies the name of the GSOD metadate file.

*Example lvt.config entry*

```
GSOD observation directory:
GSOD coord file:
GSOD metadata file:
```

### 7.4.60. Plate Boundary Observatory H2O (PBOH2O)

`PBOH2O observation directory:` specifies the location of the PBOH2O observation directory.

`PBOH2O station list file:` specifies the name of the PBOH2O station list file.

*Example lvt.config entry*

```
PBOH2O observation directory:
PBOH2O station list file:
```

### 7.4.61. WG PBMR

`WG PBMR observation directory:` specifies the location of the WG PBMR observation directory.

`WG PBMR site index:` specifies the location of the WG PBMR site index.

*Example lvt.config entry*

```
WG PBMR observation directory:
WG PBMR site index:
```

### 7.4.62. GLEAM

`GLEAM data directory:` specifies the location of the GLEAM data directory.

`GLEAM data version:` specifies the version of the GLEAM data. Acceptable values are:

| Value | Description |
|---|---|
| 3.2a | version 3.2a |
| 3.2b | version 3.2b |
| 3.1a | version 3.1a |
| 3.1b | version 3.1b |
| 3.1c | version 3.1c |
| 3.0a | version 3.0a |
| 3.0b | version 3.0b |
| 3.0c | version 3.0c |

*Example lvt.config entry*

```
GLEAM data directory:          ./GLEAM/
GLEAM data version:            "3.2a"
```

### 7.4.63. FLUXNET2015

`FLUXNET2015 observation directory:` specifies the location of the FLUXNET2015 data

`FLUXNET2015 station list file:` specifies the list of stations in the FLUXNET2015 data.

*Example lvt.config entry*

```
FLUXNET2015 observation directory: ./FLUXNET2015_STN/
FLUXNET2015 station list file:     ./FLUXNET2015_STN/STN_list.dat
```

### 7.4.64. USCRN soil moisture

`USCRN soil moisture observation directory:` specifies the location of the USCRN soil moisture data

`USCRN soil moisture station file:` specifies the list of stations in the USCRN data.

*Example lvt.config entry*

```
USCRN soil moisture observation directory:   ./USCRN
USCRN soil moisture station file:            ./USCRN/USCRN_stations.txt
```

### 7.4.65. SMAP soil moisture

`SMAP soil moisture observation directory:` specifies the location of the SMAP soil moisture observation directory.

`SMAP soil moisture data designation:` specifies the designation of the SMAP data. Acceptable values are:

| Value | Description |
|---|---|
| SPL3SMP | SMAP L3 Radiometer Global Daily 36 km EASE-Grid Soil Moisture |
| SPL3SMP_E | SMAP Enhanced L3 Radiometer Global Daily 9 km EASE-Grid Soil Moisture |
| SPL2SMP | SMAP L2 Radiometer Global Daily 36 km EASE-Grid Soil Moisture |
| SPL2SMP_E | SMAP Enhanced L2 Radiometer Global Daily 9 km EASE-Grid Soil Moisture |

*Example lvt.config entry*

```
SMAP soil moisture observation directory: ../SPL3SMP.005
SMAP soil moisture data designation:      SPL3SMP
```

### 7.4.66. SMAP L2 NRT soil moisture

`SMAP L2 NRT soil moisture observation directory:` specifies the location of the SMAP soil moisture observation directory.

| Value | Description |
|---|---|

*Example lvt.config entry*

```
SMAP L2 NRT soil moisture observation directory: ./SMAP_L2_SM_NRL
```

### 7.4.67. SMAP vegetation optical depth

`SMAP vegetation optical depth observation directory:` specifies the location of the SMAP vegetation optical depth (VOD) observation directory.

`SMAP vegetation optical depth data designation:` specifies the designation of the SMAP data. Acceptable values are:

| **Value** | **Description** |
|---|---|
| SPL3SMP | SMAP L3 Radiometer Global Daily 36 km EASE-Grid VOD |
| SPL3SMP_E | SMAP Enhanced L3 Radiometer Global Daily 9 km EASE-Grid VOD |

*Example lvt.config entry*

```
SMAP vegetation optical depth observation directory: ../SPL3SMP.005
SMAP vegetation optical depth data designation:      SPL3SMP
```

### 7.4.68. LPRM vegetation optical depth

`LPRM vegetation optical depth observation directory:` specifies the location of the LPRM vegetation optical depth (VOD) observation directory.

`LPRM vegetation optical depth data designation:` specifies the designation of the LPRM data. Acceptable values are:

| **Value** | **Description** |
|---|---|
| X-band | X-band retrievals of VOD |

| Value | Description |
|---|---|
| C-band | C-band retrievals of VOD |

*Example lvt.config entry*

```
LPRM vegetation optical depth observation directory: ../LPRM_VOD
LPRM vegetation optical depth data designation:      X-band
```

### 7.4.69. SMAP-E-OPL soil moisture retrieval

`SMAP_E_OPL soil moisture data directory:` specifies the location of the Operational enhanced SMAP soil moisture retrieval data directory.

*Example lvt.config entry*

```
SMAP_E_OPL soil moisture data directory: ./SM_retrieval
```

### 7.4.70. WG SWRC

`WG SWRC observation directory:` specifies the location of the WG SWRC observation directory.

`WG SWRC station list file:` specifies the name of the WG SWRC station list file.

*Example lvt.config entry*

```
WG SWRC observation directory:
WG SWRC station list file:
```

### 7.4.71. UA SNOW observations

`UA SNOW observation directory:` specifies the location of the University of Arizona SWE data.

*Example lvt.config entry*

```
UA SNOW observation directory:             ./UA_SNOW
```

### 7.4.72. OzFlux soil moisture

`OzFlux observation directory:` specifies the location of the OzFlux data directory.

`OzFlux station list file:` specifies the location of the OzFlux stations.

A sample file is shown below:

```
#Nstns
9
#names
CapeTribulation; -16.103219; 145.446922
CumberlandPlainMelaleuca; -33.613996; 150.726418
Longreach ; -23.5232657644973; 144.310415719645
Riggs; -36.656; 145.576
Robson; -17.11746943; 145.6301375
Tumbarumba; -35.6566; 148.1516
Whroo; -36.6732; 145.0294
WombatStateForest; -37.4222; 144.0944
Yanco; -34.9878; 146.2908
```

*Example lvt.config entry*

```
OzFlux observation directory: ../OzFlux
OzFlux station list file:     ../OzFlux/stnlist.dat
```

### 7.4.73. JASMIN soil moisture

`JASMIN soil moisture data directory:` specifies the location of the JASMIN soil moisture data directory.

*Example lvt.config entry*

```
JASMIN soil moisture data directory: ../JASMIN
```

### 7.4.74. FluxSat GPP

`FluxSat data directory:` specifies the location of the FluxSat GPP data directory.

*Example lvt.config entry*

```
FluxSat data directory: ./FluxSat
```

### 7.4.75. THySM soil moisture

`THySM data directory:` specifies the location of the THySM data directory.

*Example lvt.config entry*

```
THySM data directory: ../THySM
```

### 7.4.76. MCD15A2H LAI

`MCD15A2H data directory:` specifies the location of the MCD15A2H data directory.

*Example lvt.config entry*

```
MCD15A2H data directory: ./MCD15A2H.006/2019
```

### 7.4.77. COAMPS forcing data

`COAMPS output forcing directory:` specifies the location of the COAMPS output forcing data directory.

*Example lvt.config entry*

```
COAMPS output forcing directory: ../COAMPS/EU/COAMPS_forcing
```

`COAMPS nest id:` specifies the nest id.

COAMPS forcing usually provides forcing for 2 nests. The first nest is 15km resolution and the second nest is a smaller sub-domain with a resolution of 5km.

*Example lvt.config entry*

```
COAMPS nest id: 1
```

## 7.5. OptUE processing options

This section of the config file specifies the details of the optimization and uncertainty estimation processing options, and the specicialized options to analyze outputs from the Optimization/Uncertainy Estimation algorithms.

`LIS OptUE restart file:` the name of the file that specifies the parameter distributions LVT expects this information to be provided through the uncertainty estimation algorithm restart file. Note that this option needs to be specified only if ensemble cross correlation metric is enabled.

*Example lvt.config entry*

```
LIS OptUE restart file:                MCSIM.001.MCSIMrst
```

`LIS OptUE number of model parameters:` specifies the number of model parameters in the uncertainty estimation algorithm restart file. Note that this option needs to be specified only if ensemble cross correlation metric is enabled.

*Example lvt.config entry*

```
LIS OptUE number of model parameters:   4
```

`OptUE output data directory:` specifies the location of the root directory containing OptUE outputs.

*Example lvt.config entry*

```
OptUE output data directory:  '../OUTPUT'
```

`OptUE algorithm used:` specifies the index of the optimization/uncertainty estimation algorithm used. Acceptable values are:

| Value | Description |
|---|---|
| “Genetic algorithm” | Genetic Algorithm |
| “Monte carlo sampling” | Monte carlo sampling |
| “Random walk markov chain monte carlo” | Random walk markov chain monte carlo |
| “Differential evolution monte carlo” | Differential evolution monte carlo |

*Example lvt.config entry*

```
OptUE algorithm used:                  2
```

`OptUE decision space attributes file:` lists the decision space attributes file used in the LIS optimization/uncertainty estimation integration.

*Example lvt.config entry*

```
OptUE decision space attributes file:   ./GArun/noah_sm_decspace.txt
```

`OptUE number of iterations:` Number of generations used in the optimization/uncertainty estimation algorithm.

*Example lvt.config entry*

```
OptUE number of iterations:            20
```

`OptUE compute time series:` specifies if a time series of OptUE run output data is to be generated (0-no, 1-yes)

*Example lvt.config entry*

```
OptUE compute time series:             1
```

`OptUE time series location file:` specifies the file which lists the locations in the domain where the time series data are to be extracted. The format of the time series location file is as follows:

```
#Number of locations
1
#Location style (1-lat/lon, 2-col/row, 3-tile)
2
#mask filename
none
#site name
Site1
244  236
```

*Example lvt.config entry*

```
OptUE time series location file:        ./STN_LOCATIONS.DAT
```

`OptUE total number of parameters:` specifies the total number of parameters.

*Example lvt.config entry*

```
OptUE total number of parameters:              2
```

`OptUE total number of selected parameters:` specifies the total number of selected parameters.

*Example lvt.config entry*

```
OptUE total number of selected parameters:             1
```

# 7.6. DA diagnostics analysis

This section of the config file specifies the specialized options to analyze the data assimilation diagnostics. These options are employed for runmode="DA statistics processing"

`Compute innovation distribution:` Specifies if innovation distribution analysis (computing mean and variance) is to be computed. Acceptable values are:

| Value | Description |
|---|---|
| 0 | Do not compute |
| 1 | Compute |

`Compute analysis gain:` specifies if analysis gain is to be computed. Acceptable values are:

| Value | Description |
|---|---|
| 0 | Do not compute |
| 1 | Compute |

`Number of state variables in the DA update:` specifies the number of state variables in the DA

update.

*Example lvt.config entry*

```
Compute Innovation Distribution:            1
Compute analysis gain:                      0
Number of state variables in the DA update: 4
```

## 7.7. DA observation analysis

This runmode is used to conduct analysis of observations used in the DA assimilation instance. LIS DA subsystem generates processed (interpolated, QC'd) estimates of input observations. This runmode enables analysis of such data.

No specialized options are necessary, except specifying the "LIS output attributes file:" option to correspond to the DA output. For example, if the DA instance generates estimates of a single variable (say SWE) then specify the LIS output attributes file such that (only) SWE is present in the (LIS) output file. In other words, column number 2 should indicate 1 for SWE variable and 0 for every other varialble. If multiple observation types are present in the DA output, then column number 2 should be appropriately modified.

## 7.8. 557 post

This runmode is used to postprocess LIS data and generate netCDF or GRIB2 output files for use by 557WW. Specific capabilities include:

- Calculate ensemble means and standard deviations (spreads).
- Optionally apply a Gaussian filter to the ensemble products (recommended).
- Postprocess over 3 or 24 hour periods.
- Interpolate US Navy GOFS (HYCOM) sea ice and sea surface temperature data to the LIS grid.
- Output in GRIB2 or netCDF.

Due to memory constraints, only a few (typically one) LIS variable can be processed by a single invocation of LVT in this mode. However, this provides an opportunity to divide a set of LIS variables into a number of independent jobs that can be run in parallel, thus reducing the overall runtime. For GRIB2 output, the files can then be combined using the standard Unix `cat` command. For netCDF, it is necessary to use the NCO tool `ncks` to merge the postprocessed fields together into a single file.

These capabilities are activated by setting LVT running mode to "557 post"

When using this runmode:

- The LVT output format must be set to either "netcdf" or "grib2".
- The LVT output methodology should be "2d ensemble gridspace".
- The first analysis data source must be "LIS output".

- The process HYCOM data setting should only be turned on for a single LVT invocation — otherwise, multiple copies of the HYCOM data may be appended afterwards into a single GRIB2 or netCDF file.
- It is recommended that the LIS output data be in "1d tilespace" to reduce the time required to read and map the data to LVT's internal structures.
- It is recommended that each LVT invocation have it's own specified metrics output directory, to prevent file overwrites from different LVT invocations running in parallel.

It is recommended that scripts be used to customize *lvt.config* files for each LVT invocation, and then run LVT in individual batch modes. Example scripts are provided in lvt/util/afwa/templates, along with customized MODEL_OUTPUT_LIST.TBL files for use by 557WW. Sample scripts to automate merging of GRIB2 or netCDF output files are given in lvt/utils/afwa.

`Process HYCOM data:` Specifies if HYCOM (US Navy GOFS) data are processed in addition to LIS data. Acceptable values are:

| Value | Description |
|---|---|
| 0 | Do not process |
| 1 | Process |

*Example lvt.config entry*

```
Process HYCOM data: 1
```

`HYCOM data directory:` Specifies directory path to HYCOM (US Navy GOFS) data

*Example lvt.config entry*

```
HYCOM data directory: HYCOM
```

`Apply noise reduction filter:` Specifies whether to smooth the postprocessed fields before writing to file. Acceptable values are:

| Value | Description |
|---|---|
| 0 | Do not smooth |
| 1 | Smooth |

*Example lvt.config entry*

```
Apply noise reduction filter: 1
```

`Smoothing filter type:` Specifies which smoothing filter to use, provided smoothing is activated. Acceptable values are:

| Value | Description |
|---|---|
| “box filter” | Box linear filter (or box blur) |
| “gaussian filter” | Gaussian filter (recommended) |

*Example lvt.config entry*

```
Smoothing filter type:       "gaussian filter"
```

## 7.9. USAFSI post

This runmode is used to postprocess USAFSI (snow and ice) analyses, which are originally produced in netCDF format. LVT will optionally convert the fields to GRIB2 format and output on the LDT grid (no interpolations). In addition, three options are provided for GRIB1 output: (1) interpolate to 0.25 deg lat/lon domain; (2) interpolate to Air Force Northern Hemisphere 16th mesh polar stereographic grid; and (3) interpolate to Air Force Southern Hemisphere 16th mesh polar stereographic grid. These GRIB1 products are intended as look-alike replacements for the legacy Air Force SNODEP product. These options are activated for runmode=“USAFSI post”

When run in this mode, LVT will interpret the starting year, month, etc as the valid date/time to process, and will ignore the ending date and time information. (In other words, only a single date and time will be processed.)

LVT will also use the diagnostic file and undefined value entries.

Other entries that are required but not actually used in this runmode include the map projection, analysis sources, output format, output GRIB settings, the output methodology, start mode, clock timestep, metrics computation and output frequencies, option to apply temporal smoothing to obs, option to apply external mask, option for stratifying by external data and/or variable, and an observation count threshold. These other entries are required by the LVT config initialization routine, which is called by the LVT driver for all runmodes.

`USAFSI output GRIB2 native grid:` Specifies if USAFSI should be output in GRIB2 (no interpolation). Acceptable values are:

| Value | Description |
|---|---|
| .true. | Output in GRIB2 |
| .false. | Do not output in GRIB2 |

*Example lvt.config entry*

```
USAFSI output GRIB2 native grid: .true.
```

`USAFSI output GRIB1 global 0.25deg lat/lon:` Specifies if USAFSI should be interpolated to 0.25 deg lat/lon grid and output in GRIB1. Acceptable values are:

| Value | Description |
|---|---|
| .true. | Interpolate and output in GRIB1 |
| .false. | Do not interpolate or output |

*Example lvt.config entry*

```
USAFSI output GRIB1 global 0.25deg lat/lon: .true.
```

`USAFSI output GRIB1 NH 16th mesh polar stereographic:` Specifies if USAFSI should be interpolated to Northern Hemispheric 16th mesh polar stereographic grid and output in GRIB1. Acceptable values are:

| Value | Description |
|---|---|
| .true. | Interpolate and output in GRIB1 |
| .false. | Do not interpolate or output |

*Example lvt.config entry*

```
USAFSI output GRIB1 NH 16th mesh polar stereographic: .true.
```

`USAFSI output GRIB1 SH 16th mesh polar stereographic:` Specifies if USAFSI should be interpolated to Southern Hemispheric 16th mesh polar stereographic grid and output in GRIB1. Acceptable values are:

| Value | Description |
|---|---|
| .true. | Interpolate and output in GRIB1 |
| .false. | Do not interpolate or output |

*Example lvt.config entry*

```
USAFSI output GRIB1 SH 16th mesh polar stereographic: .true.
```

`USAFSI input netcdf directory:` Specifies path of directory containing USAFSI netcdf files to process.

*Example lvt.config entry*

```
USAFSI input netcdf directory: ./USAFSI
```

`USAFSI output grib directory:` Specifies path of directory to write GRIB2 and/or GRIB1 files.

*Example lvt.config entry*

```
USAFSI output grib directory: ./grib
```

# 7.10. SNIP post

This runmode is used to postprocess SNIP (snow and ice) analyses, which are originally produced in netCDF format. LVT will optionally convert the fields to GRIB2 format and output on the LDT grid (no interpolations). In addition, three options are provided for GRIB1 output: (1) interpolate to 0.25 deg lat/lon domain; (2) interpolate to Air Force Northern Hemisphere 16th mesh polar stereographic grid; and (3) interpolate to Air Force Southern Hemisphere 16th mesh polar stereographic grid. These GRIB1 products are intended as look-alike replacements for the legacy Air Force SNODEP product. These options are activated for runmode="SNIP post".

When run in this mode, LVT will interpret the starting year, month, etc as the valid date/time to process, and will ignore the ending date and time information. (In other words, only a single date and time will be processed.)

LVT will also use the diagnostic file and undefined value entries.

Other entries that are required but not actually used in this runmode include the map projection, analysis sources, output format, output GRIB settings, the output methodology, start mode, clock timestep, metrics computation and output frequencies, option to apply temporal smoothing to obs, option to apply external mask, option for stratifying by external data and/or variable, and an observation count threshold. These other entries are required by the LVT config initialization routine, which is called by the LVT driver for all runmodes.

`SNIP output GRIB2 native grid:` Specifies if SNIP should be output in GRIB2 (no interpolation). Acceptable values are:

| Value | Description |
|---|---|
| .true. | Output in GRIB2 |
| .false. | Do not output in GRIB2 |

*Example lvt.config entry*

```
SNIP output GRIB2 native grid: .true.
```

`SNIP output GRIB1 global 0.25deg lat/lon:` Specifies if SNIP should be interpolated to 0.25 deg lat/lon grid and output in GRIB1. Acceptable values are:

| Value | Description |
|---|---|
| .true. | Interpolate and output in GRIB1 |
| .false. | Do not interpolate or output |

*Example lvt.config entry*

```
SNIP output GRIB1 global 0.25deg lat/lon: .true.
```

`SNIP output GRIB1 NH 16th mesh polar stereographic:` Specifies if SNIP should be interpolated to

Northern Hemispheric 16th mesh polar stereographic grid and output in GRIB1. Acceptable values are:

| Value | Description |
|---|---|
| .true. | Interpolate and output in GRIB1 |
| .false. | Do not interpolate or output |

*Example lvt.config entry*

```
SNIP output GRIB1 NH 16th mesh polar stereographic: .true.
```

`SNIP output GRIB1 SH 16th mesh polar stereographic:` Specifies if SNIP should be interpolated to Southern Hemispheric 16th mesh polar stereographic grid and output in GRIB1. Acceptable values are:

| Value | Description |
|---|---|
| .true. | Interpolate and output in GRIB1 |
| .false. | Do not interpolate or output |

*Example lvt.config entry*

```
SNIP output GRIB1 SH 16th mesh polar stereographic: .true.
```

`SNIP input netcdf directory:` Specifies path of directory containing SNIP netcdf files to process.

*Example lvt.config entry*

```
SNIP input netcdf directory: ./SNIP
```

`SNIP output grib directory:` Specifies path of directory to write GRIB2 and/or GRIB1 files.

*Example lvt.config entry*

```
SNIP output grib directory: ./grib
```

## 7.11. LIS postprocessing

This runmode is used to quilt together distributed binary output generated by LIS into a single NetCDF file for each timestep.

`Number of processors used in the LIS output generation:` the number of processors used to generate the distributed binary output.

*Example lvt.config entry*

```
Number of processors used in the LIS output generation: 16
```

`Number of fields in the LIS output:` the number of variable fields contained in the LIS output.

*Example lvt.config entry*

```
Number of fields in the LIS output: 11
```

`Number of vertical levels in the LIS output:` the number of vertical levels contained in the LIS output.

*Example lvt.config entry*

```
Number of vertical levels in the LIS output: 4
```

`LIS output number of soil moisture layers:` specifies the number of soil moisture layers used in the LIS output. This is optional and defaults to 0.

`LIS output soil moisture layer thickness:` specifies the number of soil moisture layers used in the LIS output. These values will be written to the NetCDF as global attributes and should match those used in the LIS configuration file to define the LSM soil moisture layer thicknesses. If the number of soil moisture layers is omitted or set to 0, this entry is not read and soil moisture layer thicknesses are not written to the NetCDF global attributes.

*Example lvt.config entry*

```
LIS output number of soil moisture layers:  4
LIS output soil moisture layer thickness: 0.1 0.3 0.6 1.0
```

`LIS output number of soil temperature layers:` specifies the thicknesses of soil moisture layers in the LIS output. This is optional and defaults to 0.

`LIS output soil temperature layer thickness:` specifies the thicknesses of soil temperature layers in the LIS output. These values will be written to the NetCDF as global attributes and should match those used in the LIS configuration file to define the LSM soil temperature layer thicknesses. If the number of soil temperature layers is omitted or set to 0, this entry is not read and soil temperature layer thicknesses are not written to the NetCDF global attributes.

*Example lvt.config entry*

```
LIS output number of soil temperature layers:  4
LIS output soil temperature layer thickness:  0.1 0.3 0.6 1.0
```

# Chapter 8. Configuration of metrics

This section defines the specification of various metrics in LVT. This file is specified in a space delimited column format. Each row consists of the following entries:

`Name`: Name of the metric

`Use option`: determines whether to use this metric. When enabled, the metric will be computed through the duration of the evaluation and a final file will be written out. Acceptable values are:

| Value | Description |
|---|---|
| 0 | do not use the metric |
| 1 | use the metric |

`Time option`: specifies whether to compute the metric in time, at the specified stats output intervals. Acceptable values are:

| Value | Description |
|---|---|
| 0 | do not compute the metric |
| 1 | compute the metric |

`Temporal output`: determines whether to write (gridded) metric files at the specified stats output intervals. The “Time option” must also be enabled when this option is enabled. Acceptable values are:

| Value | Description |
|---|---|
| 0 | do not write gridded files |
| 1 | write gridded time files |

`Extract time series`: determines whether to extract (ASCII) time series files for the metric, at each sub-domain specified in the time series location file. Acceptable values are:

| Value | Description |
|---|---|
| 0 | do not write ASCII files |
| 1 | write ASCII time files |

`Threshold`: specifies the threshold values to be used in computing the metric. Note that this is used only for the categorical metrics. Two values must be specified. The first value is the minimum threshold and the second values is the maximum threshold.

`Compute average seasonal cycle`: determines whether to generate the average seasonal cycle of the metric (for each domain specified in the time series location file). Acceptable values are:

| Value | Description |
|---|---|
| 0 | do not generate |
| 1 | generate seasonal cycle |

`Compute average diurnal cycle`: determines whether to generate the average diurnal cycle of the metric (for each domain specified in the time series location file). Acceptable values are:

| Value | Description |
|---|---|
| 0 | do not generate |
| 1 | generate diurnal cycle |

```
#name                                 Use  Time  WriteTS  ExtractTS
Threshold(min/max)  ASC  ADC  short_name
Mean:                                 1    1       1         1       -9999.0  -9999.0
1    0  #MEAN
Anomaly:                              0    0       0         0       -9999.0  -9999.0
0    0  #Anomaly
Min:                                  0    0       0         0       -9999.0  -9999.0
0    0  #MIN
Max:                                  0    0       0         0       -9999.0  -9999.0
0    0  #MAX
MinTime:                              0    0       0         0       -9999.0  -9999.0
0    0  #MINTIME
MaxTime:                              0    0       0         0       -9999.0  -9999.0
0    0  #MAXTIME
Sum:                                  0    0       0         0       -9999.0  -9999.0
0    0  #SUM
Standard deviation:                   0    0       0         0       -9999.0  -9999.0
0    0  #STDEV
Variance:                             0    0       0         0       -9999.0  -9999.0
0    0  #VARIANCE
Bias:                                 0    0       0         0       -9999.0  -9999.0
0    0  #BIAS
RMSE:                                 0    0       0         0       -9999.0  -9999.0
0    0  #RMSE
ubRMSE:                               0    0       0         0       -9999.0  -9999.0
0    0  #ubRMSE
Anomaly RMSE:                         0    0       0         0       -9999.0  -9999.0
0    0  #ARMSE
Mean absolute error:                  0    0       0         0       -9999.0  -9999.0
0    0  #MAE
Anomaly correlation:                  0    0       0         0       -9999.0  -9999.0
0    0  #ACORR
Raw correlation:                      0    0       0         0       -9999.0  -9999.0
0    0  #RCORR
Rank correlation:                     0    0       0         0       -9999.0  -9999.0
0    0  #RNKCORR
Anomaly rank correlation:             0    0       0         0       -9999.0  -9999.0
```

```
0    0  #ARNKCORR
Probability of detection (PODy):       0    0       0         0           0.1      0.3
0    0  #PODY
Probability of detection (PODn):       0    0       0         0           0.1      0.3
0    0  #PODN
False alarm ratio (FAR):               0    0       0         0           0.1      0.3
0    0  #FAR
Detection failure ratio (DFR):         0    0       0         0           0.1      0.3
0    0  #DFR
Probability of false detection (POFD): 0    0       0         0           0.1      0.3
0    0  #POFD
Critical success index (CSI):          0    0       0         0           0.1      0.3
0    0  #CSI
Accuracy measure (ACC):                0    0       0         0           0.1      0.3
0    0  #ACC
Frequency bias (FBIAS):                0    0       0         0           0.1      0.3
0    0  #FBIAS
Equitable threat score (ETS):          0    0       0         0           0.1      0.3
0    0  #ETS
Event frequency (EF):                  0    0       0         0           0.1      0.3
0    0  #EF
Forecast frequency (FF):               0    0       0         0           0.1      0.3
0    0  #FF
Heidke skill score (HSS):              0    0       0         0           0.1      0.3
0    0  #HSS
Peirce skill score (PSS):              0    0       0         0           0.1      0.3
0    0  #PSS
Clayton skill score (CSS):             0    0       0         0           0.1      0.3
0    0  #CSS
Area metric:                           0    0       0         0       -9999.0  -9999.0
0    0  #AREA
Nash sutcliffe efficiency:             0    0       0         0       -9999.0  -9999.0
0    0  #NSE
Metric entropy:                        0    0       0         0       -9999.0  -9999.0
0    0  #Mentropy
Information gain:                      0    0       0         0       -9999.0  -9999.0
0    0  #Igain
Fluctuation complexity:                0    0       0         0       -9999.0  -9999.0
0    0  #Fcomplexity
Effective complexity:                  0    0       0         0       -9999.0  -9999.0
0    0  #Ecomplexity
Wavelet stat:                          0    0       0         0       -9999.0  -9999.0
0    0  #Waveletstat
Hausdorff norm:                        0    0       0         0       -9999.0  -9999.0
0    0  #Hnorm
Standard precipitation index:          0    0       0         0       -9999.0  -9999.0
0    0  #SPI
Standard runoff index:                 0    0       0         0       -9999.0  -9999.0
0    0  #SRI
Standard dS index:                     0    0       0         0       -9999.0  -9999.0
0    0  #SdSI
```

```
Standardized soil water index:          0    0       0         0       -9999.0  -9999.0
0    0  #SSWI
Standardized ground water index:        0    0       0         0       -9999.0  -9999.0
0    0  #SGWI
Percentile:                             0    0       0         0       -9999.0  -9999.0
0    0  #Percentile
River flow variate:                     0    0       0         0       -9999.0  -9999.0
0    0  #RFV
Tendency:                               0    0       0         0       -9999.0  -9999.0
0    0  #TENDENCY
Tendency correlation:                   0    0       0         0       -9999.0  -9999.0
0    0  #TENDENCYCORR
Z score:                                0    0       0         0       -9999.0  -9999.0
0    0  #ZSCORE
Trend:                                  0    0       0         0       -9999.0  -9999.0
0    0  #TREND
Triple collocation:                     0    0       0         0       -9999.0  -9999.0
0    0  #TC
Reliability:                            0    0       0         0       -9999.0  -9999.0
0    0  #REL
Resilience:                             0    0       0         0       -9999.0  -9999.0
0    0  #RES
Vulnerability:                          0    0       0         0       -9999.0  -9999.0
0    0  #VUL
Information entropy:                    0    0       0         0       -9999.0  -9999.0
0    0  #IE
Conditional entropy:                    0    0       0         0       -9999.0  -9999.0
0    0  #CE
Joint entropy:                          0    0       0         0       -9999.0  -9999.0
0    0  #JE
Relative entropy:                       0    0       0         0       -9999.0  -9999.0
0    0  #RE
Mutual information:                     0    0       0         0       -9999.0  -9999.0
0    0  #MI
```

# Chapter 9. Model Output Specifications

This section defines the specification of the model output from LIS. This file is specified in a space delimited column format. Each row consists of the following entries:

`Short Name` ALMA compliant short name of the variable.

`Use option` determines whether to write the variable. Acceptable values are:

| Value | Description |
|---|---|
| 0 | do not write the variable |
| 1 | write the variable |

`Units` the desired unit of the output variable.

`Sign Convention` direction in which the variable is considered to have positive values. Note that the land models in LIS employ the "traditional approach" where all variables are considered positive in their dominant direction. i.e. precipitation and radiation are positive towards the surface (downward), evaporation, sensible heat and runoff are positive away from the surface. Acceptable values are:

| Value | | Description |
|---|---|---|
| - | | No sign |
| UP | DN | Up or Down (Used for fluxes, Precip) |
| IN | OUT | In or Out of the grid cell (Used for runoff, baseflow) |
| INC | DEC | Increase or Decrease (Used for change in storager terms) |
| S2L | L2S | Solid to Liquid and Liquid to Solid (for phase change terms) |
| S2V | V2S | Solid to Vapor and Vapor to Solid (for phase change terms) |
| E | N | Eastward and Northward (used for Wind components) |

`Time Average option` determines how temporally process the variable. Acceptable values are:

| Value | Description |
|---|---|
| 0 | Instantaneous output |
| 1 | Time averaged output |
| 2 | Instantaneous and Time averaged output |
| 3 | Accumulated output |

`Min/Max option` determines whether to record minimum and maximum values for the variable. For a given grid-cell, the minimum and maximum values correspond to the minimum and maximum found for all subgrid tiles and ensembles contained in the grid-cell during that output interval. Acceptable values are:

| Value | Description |
|---|---|
| 0 | Do not compute minimum and maximum values |
| 1 | Do compute minimum and maximum values |

`Standard Deviation option` determines whether to record the standard deviation of the values for the variable. For a given grid-cell, the standard deviation is a measure of the spread of the subgrid tiles and ensembles contained within the grid-cell from the grid-cell's mean. Acceptable values are:

| Value | Description |
|---|---|
| 0 | Do not compute standard deviation |
| 1 | Do compute standard deviation |

`Number of vertical levels` The number of vertical levels corresponding to the variable.

`grib ID` The grib ID to be used for the variable if output is written in grib1 format.

`grib scale factor` The grib scale factor to be used for the variable if output is written in grib1 format.

`Use in LVT option` determines whether to include the variable in the LVT analysis. Acceptable values are:

| Value | Description |
|---|---|
| 0 | Do not include the variable |
| 1 | Do include the variable |
| *n* | Enable the variable for analysis and include additional (*n*) layers |

Note that this is a full list of output variables. Not all models support all these variables. You must check the source code to verify that the model you want to run supports the variables that you want to write.

```
#short_name select? units signconv timeavg? min/max? std? vert.levels grib_id
grib_scalefactor LVT? longname

#Energy balance components
Swnet:         0  W/m2    DN   1 0 0 1 111 10     0 # Net shortwave radiation (W/m2)
Lwnet:         0  W/m2    DN   1 0 0 1 112 10     0 # Net longwave radiation (W/m2)
Qle:           1  W/m2    UP   1 0 0 1 121 10     1 # Latent heat flux (W/m2)
Qh:            1  W/m2    UP   1 0 0 1 122 10     1 # Sensible heat flux (W/m2)
Qg:            1  W/m2    DN   1 0 0 1 155 10     1 # Ground heat flux (W/m2)
```

```
Qf:           0  W/m2    S2L  1 0 0 1 229 10     0 # Energy of fusion (W/m2)
Qv:           0  W/m2    S2V  1 0 0 1 198 10     0 # Energy of sublimation (W/m2)
Qa:           0  W/m2    DN   1 0 0 1 136 10     0 # Advective energy (W/m2)
Qtau:         0  N/m2    DN   1 0 0 1 172 10     0 # Momentum flux (N/m2)
DelSurfHeat:  0  J/m2    INC  1 0 0 1 137 10     0 # Change in surface heat storage
(J/m2)
DelColdCont:  0  J/m2    INC  1 0 0 1 138 10     0 # Change in snow cold content
(J/m2)
BR:           0  -       -    1 0 1 1 256 10     0 # Bowen ratio
EF:           0  -       -    1 0 1 1 256 10     0 # Evaporative fraction

#Water balance components
Snowf:        0  kg/m2s  DN   1 0 0 1 161 10000  0 # Snowfall rate (kg/m2s)
Rainf:        0  kg/m2s  DN   1 0 0 1 162 10000  0 # Rainfall rate (kg/m2s)
RainfConv:    0  kg/m2s  DN   1 0 0 1  63 10000  0 # Convective rainfall rate (kg/m2s)
TotalPrecip:  1  kg/m2s  DN   1 0 0 1  61 10000  0 # Total precipitation rate (kg/m2s)
Evap:         0  kg/m2s  UP   1 0 0 1  57 10000  0 # Total evapotranspiration (kg/m2s)
Qs:           0  kg/m2s  OUT  1 0 0 1 235 10000  0 # Surface runoff (kg/m2s)
Qrec:         0  kg/m2s  IN   1 0 0 1 163 10000  0 # Recharge (kg/m2s)
Qsb:          0  kg/m2s  OUT  1 0 0 1 234 10000  0 # Subsurface runoff (kg/m2s)
Qsm:          0  kg/m2s  S2L  1 0 0 1  99 10000  0 # Snowmelt (kg/m2s)
Qfz:          0  kg/m2s  L2S  1 0 0 1 130 10000  0 # Refreezing of water in the
snowpack (kg/m2s)
Qst:          0  kg/m2s  -    1 0 0 1 131 10000  0 # Snow throughfall (kg/m2s)
DelSoilMoist: 0  kg/m2   INC  1 0 0 1 132 10000  0 # Change in soil moisture (kg/m2)
DelSWE:       0  kg/m2   INC  1 0 0 1 133 1000   0 # Change in snow water equivalent
(kg/m2)
DelSurfStor:  0  kg/m2   INC  1 0 0 1 134 1000   0 # Change in surface water storage
(kg/m2)
DelIntercept: 0  kg/m2   INC  1 0 0 1 135 1000   0 # Change in interception storage
(kg/m2)
RHMin:        0  -       -    1 0 0 1  52 10     0 # Minimum 2-meter relative humidity
(-)
Ch:           0  -       -    1 0 0 1 208 10     0 # Surface exchange coefficient for
heat
Cm:           0  -       -    1 0 0 1 252 10     0 # Surface exchange coefficient for
momentum
MixRatio:     0  kg/kg   -    1 0 0 1  53 10     0 # Mixing ratio

#Surface state variables
SnowT:        0  K       -    1 0 0 1 165 10     0 # Snow surface temperature (K)
VegT:         0  K       -    1 0 0 1 146 10     0 # Vegetation canopy temperature (K)
BareSoilT:    0  K       -    1 0 0 1 147 10     0 # Temperature of bare soil (K)
AvgSurfT:     0  K       -    1 0 0 1 148 10     0 # Average surface temperature (K)
RadT:         0  K       -    1 0 0 1 149 10     0 # Surface radiative temperature (K)
Albedo:       0  -       -    0 0 0 1  84 100    0 # Surface albedo (-)
SWE:          0  kg/m2   -    0 0 0 1  65 1000   0 # Snow Water Equivalent (kg/m2)
SWEVeg:       0  kg/m2   -    1 0 0 1 139 1000   0 # SWE intercepted by vegetation
(kg/m2)
SurfStor:     0  kg/m2   -    1 0 0 1 150 1000   0 # Surface water storage (kg/m2)
```

```
#Subsurface state variables
SoilMoist:    1  kg/m2   -    0 0 0 4  86 1000   0 # Average layer soil moisture
(kg/m2)
SoilTemp:     1  K       -    0 0 0 4  85 1000   0 # Average layer soil temperature
(K)
SmLiqFrac:    0  -       -    0 0 0 4 160 100    0 # Average layer fraction of liquid
moisture (-)
SmFrozFrac:   0  -       -    0 0 0 4 140 100    0 # Average layer fraction of frozen
moisture (-)
SoilWet:      0  -       -    0 0 0 1 144 100    0 # Total soil wetness (-)
RelSMC:       0  m3/m3   -    0 0 0 4 141 1000   0 # Relative soil moisture
RootTemp:     0  K       -    0 0 0 1 142 1000   0 # Rootzone temperature (K)

#Evaporation components
PotEvap:      0  kg/m2s  UP   1 0 0 1 145 1      0 # Potential evapotranspiration
(kg/m2s)
ECanop:       0  kg/m2s  UP   1 0 0 1 200 1      0 # Interception evaporation (kg/m2s)
TVeg:         0  kg/m2s  UP   1 0 0 1 210 1      0 # Vegetation transpiration (kg/m2s)
ESoil:        0  kg/m2s  UP   1 0 0 1 199 1      0 # Bare soil evaporation (kg/m2s)
EWater:       0  kg/m2s  UP   1 0 0 1 197 1      0 # Open water evaporation (kg/m2s)
RootMoist:    0  kg/m2   -    0 0 0 1 171 1      0 # Root zone soil moisture (kg/m2)
CanopInt:     0  kg/m2   -    0 0 0 1 223 1000   0 # Total canopy water storage
(kg/m2)
EvapSnow:     0  kg/m2s  -    1 0 0 1 173 1000   0 # Snow evaporation (kg/m2s)
SubSnow:      0  kg/m2s  -    1 0 0 1 198 1000   0 # Snow sublimation (kg/m2s)
SubSurf:      0  kg/m2s  -    1 0 0 1 143 1000   0 # Sublimation of the snow free area
(kg/m2s)
ACond:        0  m/s     -    1 0 0 1 179 100000 0 # Aerodynamic conductance
CCond:        0  m/s     -    1 0 0 1 181 100000 0 # Canopy conductance

#Other hydrologic variables
WaterTableD:  0  m       -    0 0 0 1 174 1      0 # Water table depth (m)
TWS:          0  mm      -    0 0 0 1 175 1      0 # Terrestrial water storage (mm)
GWS:          0  mm      -    1 0 0 1 176 1      0 # Ground Water Storage (mm)
WT:           0  mm      -    1 0 0 1 177 1      0 # Noah-MP WT variable (mm)

#Cold season processes
Snowcover:    0  -       -    0 0 0 1 238 100    0 # Snow covered fraction (-)
SAlbedo:      0  -       -    0 0 0 1 184 1000   0 # Albedo of the snow-covered area
(-)
SnowTProf:    0  K       -    0 0 0 1 239 1000   0 # Temperature of the snow pack (K)
SnowDepth:    0  m       -    0 0 0 1  66 1000   0 # Snow depth (m)
SLiqFrac:     0  -       -    0 0 0 1 185 1000   0 # Fraction of SWE in the liquid
phase

#Variables to compared against remote sensed data
LWup:         0  W/m2    UP   1 0 0 1 212 1      0 # Longwave radiation up from the
surface (W/m2)

#Carbon variables
GPP:          0  kg/m2s2 DN   1 0 0 1 256 1      0 # Gross Primary Production
```

```
NPP:          0  kg/m2s2 DN   1 0 0 1 256 1      0 # Net Primary Production
NEE:          0  kg/m2s2 UP   1 0 0 1 256 1      0 # Net Ecosystem Exchange
AutoResp:     0  kg/m2s2 UP   1 0 0 1 256 1      0 # Autotrophic respiration
HeteroResp:   0  kg/m2s2 UP   1 0 0 1 256 1      0 # Heterotrophic respiration
LeafResp:     0  kg/m2s2 UP   1 0 0 1 256 1      0 # Leaf respiration
TotSoilCarb:  0  kg/m2   -    1 0 0 1 256 1      0 # Total soil carbon
TotLivBiom:   0  kg/m2   -    1 0 0 1 256 1      0 # Total living biomass

#Forcings
Wind_f:       1  m/s     -    1 0 0 1  32 10     0 # Near surface wind (m/s)
Rainf_f:      0  kg/m2s  DN   1 0 0 1 162 1000   0 # Average rainfall rate
Snowf_f:      0  kg/m2s  DN   1 0 0 1 161 1000   0 # Average snowfall rate
Tair_f:       1  K       -    1 0 0 1  11 10     0 # Near surface air temperature
Qair_f:       1  kg/kg   -    1 0 0 1  51 1000   0 # Near surface specific humidity
Psurf_f:      1  Pa      -    1 0 0 1   1 10     0 # Surface pressure
SWdown_f:     1  W/m2    DN   1 0 0 1 204 10     0 # Surface incident shortwave
radiation
LWdown_f:     1  W/m2    DN   1 0 0 1 205 10     0 # Surface incident longwave
radiation
PARDR_f:      0  W/m2    DN   1 0 0 1 256 10     0 # Surface incident PAR direct
PARDF_f:      0  W/m2    DN   1 0 0 1 256 10     0 # Surface incident PAR diffuse

#Additional forcings
DirectSW_f:   0  W/m2    -    1 0 0 1 166 10     0 # Surface direct incident shortwave
radiation
DiffuseSW_f:  0  W/m2    -    1 0 0 1 167 10     0 # Surface diffuse incident
shortwave radiation
NWind_f:      0  m/s     N    1 0 0 1  34 10     0 # Northward wind
EWind_f:      0  m/s     E    1 0 0 1  33 10     0 # Eastward wind
FHeight_f:    0  m       -    1 0 0 1 256 10     0 # Height of forcing variables
CH_f:         0  -       -    1 0 0 1 208 10     0 # Surface exchange coefficient for
heat
CM_f:         0  -       -    1 0 0 1 252 10     0 # Surface exchange coefficient for
momentum
Emiss_f:      0  -       -    1 0 0 1 256 10     0 # Surface emissivity
MixRatio_f:   0  kg/kg   -    1 0 0 1  53 10     0 # Surface mixing ratio
CosZenith_f:  0  -       -    1 0 0 1 256 10     0 # Cosine of zenith angle
Albedo_f:     0  -       -    1 0 0 1  84 10     0 # Surface albedo

#Parameters
Landmask:     0  -       -    0 0 0 1  81 1      0 # Land mask (0 - Water, 1 - Land)
Landcover:    0  -       -    0 0 0 1 225 1      0 # Land cover
Soiltype:     0  -       -    0 0 0 1 224 1      0 # Soil type
SandFrac:     0  -       -    0 0 0 1 256 1      0 # Sand fraction
ClayFrac:     0  -       -    0 0 0 1 256 1      0 # Clay fraction
SiltFrac:     0  -       -    0 0 0 1 256 1      0 # Silt fraction
Porosity:     0  -       -    0 0 0 1 240 1      0 # Porosity
Soilcolor:    0  -       -    0 0 0 1 256 1      0 # Soil color
Elevation:    0  m       -    0 0 0 1 196 10     0 # Elevation
Slope:        0  -       -    0 0 0 1 222 10     0 # Slope
LAI:          0  -       -    0 0 0 1 182 100    0 # LAI
```

```
SAI:          0  -       -    0 0 0 1 256 100    0 # SAI
Snfralbedo:   0  -       -    0 0 0 1 184 100    0 # Snow fraction albedo
Mxsnalbedo:   0  -       -    0 0 0 1 159 100    0 # Maximum snow albedo
Greenness:    0  -       -    0 0 0 1  87 100    0 # Greenness
Roughness:    0  m       -    1 0 0 1  83 10     0 # Roughness
Tempbot:      0  -       -    0 0 0 1 256 10     0 # Bottom soil temperature

#Routing
Streamflow:   0  m3/s    -    0 0 0 1 256 10     0 # Streamflow

#Noah-MP
LeafMass:           0  g/m2    -    1 0 0 1 148 10      # leaf mass
RootMass:           0  g/m2    -    1 0 0 1 148 10      # stem mass
StemMass:           0  g/m2    -    1 0 0 1 148 10      # wood mass
WoodMass:           0  g/m2    -    1 0 0 1 148 10      # mass of wood including woody
roots [g/m2]
DeepSoilCarbon:     0  g/m2    -    1 0 0 1 148 10      # stable carbon in deep soil
[g/m2]
ShallowSoilCarbon:  0  g/m2    -    1 0 0 1 148 10      # short-lived carbon in
shallow soil [g/m2]

#LVT combination variables
EBAL:         0  -       -    1 0 0 1 256 10     0 # Energy balance
WBAL:         0  -       -    1 0 0 1 256 10     0 # Water balance
EVAPBAL:      0  -       -    1 0 0 1 256 10     0 # Evaporation balance
SWE/P:        0  -       -    1 0 0 1 256 10     0 # SWE over precipitation
ET/P:         0  -       -    1 0 0 1 256 10     0 # Evapotranspiration over
precipitation
Qs/P:         0  -       -    1 0 0 1 256 10     0 # Surface runoff over precipitation
Qsb/P:        0  -       -    1 0 0 1 256 10     0 # Subsurface runoff over
precipitation
```

# Appendix A: How to verify a “non-LIS” dataset?

This section provides a description of how to convert a non-LIS data to a “LIS-style” so that verification and evaluation can be conducted using LVT.

First, an observation plugin for the dataset of interest must be developed within LVT. This plugin will handle the reading, processing and any spatial interpolation of the data and will connect the processed variables to the LVT core using the `LVT_logSingleVar` interface.

In the *lvt.config* file, specify the runmode to be “Observation processing”.

```
LIS Running mode: "Observation processing"
```

Though not used, the files *METRICS.TBL* and *TS_LOCATIONS.TXT* must be provided as a placeholder. The sample files provided along with the source code (under *src/configs*) can be used.

Finally, specify the *MODEL_OUTPUT_LIST_LVT.TBL* file such that the selection option for all the variables that should appear in the reprocessed files is enabled (Note that this is the second column in the file *MODEL_OUTPUT_LIST_LVT.TBL*. The last column which specifies “Use in LVT” option is ignored in this running mode.

The processed files in the “LIS-style” will be generated in the location specified by the following option:

```
Stats output directory: ./OUTPUT
```

# Appendix B: Description of output files from LVT

This section provides a description of various output files generated during an LVT analysis.

For the purposes of illustration, consider the following parameters for an LVT analysis

- Variables : *Qle, Qh*
- Metrics : *MEAN* and *RMSE*
- LSM : *Noah 3.2*
- location (from *TS_LOCATIONS.TXT*) : *E20*
- Experiment name : *RUN*

## B.1. METADATA files

If the LVT output format is specified as binary, then a number of METADATA files will be output. The METADATA files contain the spatial domain, grid and map projection specifications and the list of variables and the order in which they appear. For the above example, a file named *MEAN_NOAH32_E20RUN_METADATA.dat* will be created with entries such as the following:

```
DIMENSIONS
east-west          499
north-south          499

Missing value   -9999.000

GRID INFORMATION
MAP_PROJECTION: LAMBERT CONFORMAL
SOUTH_WEST_CORNER_LAT   34.42922
SOUTH_WEST_CORNER_LON  -100.6136
TRUELAT1   36.70000
TRUELAT2   36.70000
STANDARD_LON  -97.90000
DX   1.000000
DY   1.000000
VARIABLE: Qle           1
VARIABLE: COUNT_Qle           1
VARIABLE: OBS_Qle           1
VARIABLE: OBS_COUNT_Qle           1
VARIABLE: Qh           1
.....
.....
```

This file can be used to determine the order of variables written to the gridded output files.

For NETCDF output, the header of each file contains similar information.

## B.2. Stats summary file

The LVT analysis will write out a summary file, for each computed metric with the following name: *MEAN_SUMMARY_STATS.dat*. This file can be used to not only determine the domain averaged statistics, but also the order in which variables are written to files. For the above example the file *MEAN_SUMMARY_STATS.dat* will contain entries such as the following (The columns 1 to 4 represent the location name, average value for that location, confidence interval, number of points contributing to the average):

```
------------------------------------------------------------
VAR: Qle
------------------------------------------------------------
    ALL:      0.710E+02 +/-      0.492E+01            22
      E1:     0.767E+02 +/-       -                    1
      E2:     0.826E+02 +/-       -                    1
      E3:     0.421E+02 +/-       -                    1
      E4:     0.659E+02 +/-       -                    1
.....
.....


------------------------------------------------------------
VAR: OBS_Qle
------------------------------------------------------------
    ALL:      0.906E+02 +/-      0.834E+02            11
      E1:    -0.100E+05 +/-       -                    0
      E2:     0.670E+02 +/-       -                    1
      E3:    -0.100E+05 +/-       -                    0
      E4:     0.496E+02 +/-       -                    1
.....
.....


------------------------------------------------------------
VAR: Qh
------------------------------------------------------------
    ALL:      0.151E+02 +/-      0.564E+01            22
      E1:     0.329E+02 +/-       -                    1
      E2:    -0.678E+01 +/-       -                    1
      E3:     0.164E+02 +/-       -                    1
      E4:     0.207E+02 +/-       -                    1
.....
.....
```

## B.3. ASCII Time Series files

If the extract time series option is enabled for a particular metric in METRICS.TBL, then a corresponding time series file will be generated (similar files will be generated for each location in

the *TS_LOCATIONS.TXT* file).

The time series files with the following names will be generated: *MEAN_E4.dat*, *RMSE_E4.dat*

The *MEAN_E4.dat* file will have entries such as the following:

```
2007 05 02 01 00  qle qle_STD qle_min qle_max qle_ensSTD qle_CI obs_qle obs_qle_STD
obs_qle_min obs_qle_max obs_qle_ensSTD obs_qle_CI qh qh_STD qh_min qh_max qh_ensSTD
qh_CI obs_qh obs_qh_STD obs_qh_min obs_qh_max obs_qh_ensSTD obs_qh_CI

2007 05 02 02 00  qle qle_STD qle_min qle_max qle_ensSTD qle_CI obs_qle obs_qle_STD
obs_qle_min obs_qle_max obs_qle_ensSTD obs_qle_CI qh qh_STD qh_min qh_max qh_ensSTD
qh_CI obs_qh obs_qh_STD obs_qh_min obs_qh_max obs_qh_ensSTD obs_qh_CI
.....
.....
```

The columns represent Time (columns 1-5: year, month, day, hour, minute), mean value, spatial standard deviation, minimum, maximum, ensemble standard deviation, confidence interval of Qle from model (columns 6-11), and mean value, spatial standard deviation, minimum, maximum, ensemble standard deviation, confidence interval of Qle from observations (columns 12-17), and mean value, spatial standard deviation, minimum, maximum, ensemble standard deviation, confidence interval of Qh from model (columns 18-23), and mean value, spatial standard deviation, minimum, maximum, ensemble standard deviation, confidence interval of Qh from observations (columns 24-29).

If more variables are included in the analysis, then additional columns will be included for each variable (6 columns per variable).

For metrics such as RMSE (e.g. *RMSE_E4.dat*, the file entries will be as follows (note that there are no columns for observation values):

```
2007 05 02 01 00 rmse_qle rmse_qle_STD rmse_qle_min rmse_qle_max
rmse_qle_ensSTD rmse_qle_CI
2007 05 02 02 00 rmse_qle rmse_qle_STD rmse_qle_min rmse_qle_max
rmse_qle_ensSTD rmse_qle_CI
.....
.....
```

# B.4. Domain time Series files (Binary/NETCDF)

LVT will output a gridded/tiled output file for each chosen metric, at each stats output interval, if the “write time series” option is enabled (in METRICS.TBL) for that metric. For the above example, files such as the following will be generated.

*MEAN_TS.200705020000.d01.nc*
*MEAN_TS.200705030000.d01.nc*
*MEAN_TS.200705040000.d01.nc*

*RMSE_TS.200705020000.d01.nc*
*RMSE_TS.200705030000.d01.nc*
*RMSE_TS.200705040000.d01.nc*

where the timestamp indicates the end time of each analysis interval. For binary output file extention of ".gs4r" will be used instead of ".nc".

## B.5. Final domain files (Binary/NETCDF)

LVT will output a gridded/tiled output file for each chosen metric. For the above example, two final files will be generated with filenames of *MEAN_FINAL.200705100000.d01.nc* and *RMSE_FINAL.200705100000.d01.nc*, where the timestamp indicates the end time of the LVT analysis. For binary output file extention of ".gs4r" will be used instead of ".nc".

# Appendix C: What's New (continued)

| NOTE | There were no public releases for versions 7.6 or 7.7. |
|---|---|

## C.1. Version 7.5

1. Supports additional data streams
    - COAMPS forcing data (COAMPSout)
    - GRUN runoff data (GRUNrunoff)
    - GPM IMERG Monthly precipitation data (IMERG_monthly)
    - Operational enhanced SMAP soil moisture retrieval data (SMAP_E_OPL)

## C.2. Version 7.4

1. Includes new runmodes
    - LISpost
2. Supports additional data streams
    - FluxSat GPP
    - MCD15A2H
    - Thermal hydraulic disaggregation of soil moisture (THySM)
    - UA SMAP

## C.3. Version 7.3

1. Includes new runmodes
    - 557post runmode
    - USAFSIpost runmode
2. Includes additional metrics
    - Anomaly Rank Correlation metric
    - Clayton Skill Score (CSS) metric
    - Conditional Entropy metric
    - Detection Failure Ratio (DFR) metric
    - Event Frequency (EF) metric
    - Forecast Frequency (FF) metric
    - Heidke Skill Score (HSS) metric
    - Information Entropy metric
    - Joint Entropy metric

- K-means metric
- Mutual Information metric
- Peirce Skill Score (PSS) metric
- Reliability metric
- Resiliance metric
- Relative Entropy metric
- Standard Precipitation Index (SPI) metric
- Triple collocation metric
- Tian False Alarm Bias (TFB) metric
- Tian Hit Bias (THB) metric
- Tian Miss Bias (TMB) metric
- Trends metric
- Vulnerability metric

3. Supports additional data streams
   - TRMM 3B42V7 data stream
   - Atmospheric Land Exchange Inverse (ALEXI) model Evaporative Stress Index (ESI) data stream
   - APHRODITE (Asian Precipitaton - Highly-Resolved Observational Data Integration Towards Evaluation) daily gridded precipitation data stream
   - NASA Airborne Snow Observatory (ASO) snow water equivalent (SWE) data stream
   - CHIRPSv2 data stream
   - ECMWF forcing data stream
   - ERA5 data stream
   - FLUXCOM data stream
   - FLUXNET2015_NC data stream
   - GDAS forcing data stream
   - GLASS albedo data stream
   - GLASS LAI data stream
   - High Asia Reanalysis (HAR) precipitation data stream
   - Indian Meteorological Department (IMD) unified gauge-based analysis of daily precipitation data stream
   - IMERG data stream
   - JULES2Ddata data stream
   - Land Parameter Retrieval Model (LPRM) vegetation optical depth data stream
   - MERRA2 asm data stream

- MOD10A1V6 fractional snow cover data stream
- MODIS SPoRT LAI data stream
- MODSCAG fractional snow cover data stream
- OCO-2 Solar Induced Fluorescence (SIF) data stream
- OzFlux data stream
- Soil Moisture Active Passive (SMAP) L3 Tb data stream
- Soil Moisture Active Passive (SMAP) vegetation optical depth data stream
- Soil Moisture Active Passive (SMAP) vegetation water content data stream
- University of Arizona (UA) SWE/Snow Depth data stream
- UCLA SWE reanalysis data stream
- jasmin data stream

## C.4. Version 7.2

1. Supports new data streams
   - datastreams/CMORPH
   - datastreams/Daymet
   - datastreams/FLUXNETmte
   - datastreams/GCOMW_AMSR2L3snd
   - datastreams/GIMMS_MODIS_NDVI
   - datastreams/GLDAS1
   - datastreams/GOES_LST
   - datastreams/GOME2_SIF
   - datastreams/JULESdata
   - datastreams/LIS6out
   - datastreams/LISDAdiag
   - datastreams/LVTpercentile
   - datastreams/MERRA-Land
   - datastreams/SCANGMAO
   - datastreams/simGRACE
   - datastreams/SMAPsm
   - datastreams/SMAPTB
   - datastreams/SMOS_CATDS_L3sm
   - datastreams/SMOS_NESDIS
   - datastreams/SNODEP

- datastreams/USCRNsm
- datastreams/USDM
- datastreams/USGS_streamflow_gridded

## C.5. Version 7.1

1. Supports Global Change Observation Mission - Water (GCOMW) observations
2. Supports Advanced Scatterometer (ASCAT) data
3. Supports Soil Moisture and Ocean Salinit (SMOS) observations
4. Supports Soil Moisture and Ocean Salinit (SMOS) L1 Tb observations
5. Supports MODIS LST data
6. Supports Great Lakes Hydro data
7. Supports time lagged computations

## C.6. Version 7.0

Note that LVT has been renumbered to version 7.0.

1. Supports NLDAS-2 SAC datasets, including the post-processed SAC soil moisture on Noah levels
2. Supports the capability to compute metrics on a basin/region scale rather than on a pixel-by-pixel basis.
3. Supports the capability to process USGS ground water well data
4. Supports the capability to process Plate Boundary Observatory data (snow depth and soil moisture)
5. Supports the North American Soil Moisture Database (NASMD) data
6. Supports the ALEXI data
7. Supports the metric to compute percentiles for each ensemble member separately
8. Supports GRACE observations (these are the “processed” GRACE observations generated by LDT)
9. Supports the UW ET data
10. Supports the options for restart for SRI, SPI, SSWI and percentile calculations
11. Supports metric called SGWI - standardized ground water index — which is similar to SSWI, but for TWS variable
12. Support for a number of ratio variables are added:
    - SWE/P (snow water equivalent over precip)
    - ET/P (evapotranspiration over precip)
    - Qs/P (surface runoff over precip)
    - Qsb/P (subsurface runoff over precip)
13. Supports the river flow variate metric

14. Supports metrics for computing min, max and sum
15. Support to read LIS DA processed observations

## C.7. Version 1.2

1. Updates related to OptUE processing

## C.8. Version 1.1

1. Added the plugin for processing processed LIS DA observations
2. Removed the FEWSNET SOS processing metric
3. Added plugins for NLDAS2, Natural streamflow
4. Updated to provide backwards support for LIS 6.1.

## C.9. Version 1.0

1. This is the initial version developed for evaluating output from LIS version 6.0 or higher.

# Appendix D: Revision history

| Revision | Summary of Changes | Date |
|---|---|---|
| 5.0 | LISF Public 7.8.0 release | May 5, 2026 |
| 4.1 | LISF 557WW 7.6.1 release | Nov 21, 2025 |
| 4.0 | LISF 557WW 7.6.0 release | Nov 12, 2024 |
| 3.0 | LISF Public 7.5.0 release | Jan 10, 2024 |
| 2.4 | LISF 557WW 7.5.9 release | Jul 05, 2023 |
| 2.3 | LISF 557WW 7.5.8 release | Jun 30, 2023 |
| 2.2 | LISF 557WW 7.5.4 release | May 5, 2023 |
| 2.1 | LISF 557WW 7.5.0 release | Nov 30, 2022 |
| 2.0 | LISF Public 7.4.0 release | Jun 22, 2022 |
| 1.9 | LISF Public 7.3.2 release | Dec 06, 2021 |
| 1.8 | LISF Public 7.3.1 release | Mar 31, 2021 |
| 1.7 | LISF 557WW 7.4.0 release | Mar 4, 2021 |
| 1.6 | LISF Public 7.3.0 release | Dec 21, 2020 |
| 1.5 | LVT 557WW 7.3.0 release | Aug 24, 2020 |
| 1.4 | LVT 557WW 7.3 release candidate 4 | Aug 28, 2019 |
| 1.3 | LVT 7.2 public release | May 6, 2015 |
| 1.2 | Update lvt.config documentation | May 12, 2015 |
| 1.1 | LVT 7.1 AFWA rp2 | May 11, 2015 |
| 1.0 | LVT 7.1 public release | April 24, 2015 |

# References


- [kumar_etal_gmd_2012] S.V. Kumar, C.D. Peters-Lidard, J.A. Santanello, K. Harrison, Y. Liu, and M. Shaw. Land surface Verification Toolkit (LVT) - a generalized framework for land surface model evaluation. *Geosci. Model Dev.*, pages 869–886, 2012.