

Land surface Verification Toolkit

LVT 7.1 Users' Guide

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Revision 1.2

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1 Introduction

This is the User's Guide for Land surface Verification Toolkit (LVT;[\[1\]](#)). This document describes how to download and install LVT codes and instructions on building an executable.

This document consists of several 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

1.1 What's New

1.1.1 Version 7.1

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

1.1.2 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

1.1.3 Version 1.2

1. Updates related to OptUE processing

1.1.4 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.

1.1.5 Version 1.0

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

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 probabilistic 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

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.”
```

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

```
/path/to/LVT/src
```

You need to create a working directory on your system to install LVT. Let's call this directory */path/to/LVT/*. Throughout the rest of this document, this directory shall be referred to as *\$WORKING*. You should create a directory to run LVT in. This directory can be created anywhere on your system, but, in this document, we shall refer to this running directory as *\$WORKING/run*.

4 Obtaining the Source Code

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

4.1 Downloading the Source Code

To obtain the source code needed for LVT, you can follow the download links from the LVT web page <http://lis.gsfc.nasa.gov/LVT/>.

Go to the working directory and uncompress the source code.

5 Building the Executable

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

5.1 Development Tools

This code has been compiled and run on Linux PC (Intel/AMD based) systems, IBM AIX systems, and SGI Altix systems. These instructions expect that you are using such a system. In particular you need:

- Linux
 - Compilers
 - * either Intel Fortran Compiler version 13 (13.1.3.192 or higher) or version 14, both with corresponding Intel C Compiler
 - * or Absoft's Pro Fortran Software Development Kit, version 10.0 with GNU's C and C++ compilers, gcc and g++, version 3.3.3
 - * or Lahey/Fujitsu's Fortran 95 Compiler, release L6.00c with GNU's C and C++ compilers, gcc and g++, version 3.3.3
 - GNU's make, gmake, version 3.77
- IBM
 - XL Fortran version 10.1.0.6
 - GNU's make, gmake, version 3.77
- SGI Altix
 - Intel Fortran Compiler version 12
 - GNU's make, gmake, version 3.77

5.2 Required Software Libraries

In order to build the LVT executable, the following libraries must be installed on your system:

- Earth System Modeling Framework (ESMF) version 5.2.0rp3 (or higher). (<http://www.earthsystemmodeling.org/download/releases.shtml>)

Please read the ESMF User's Guide for details on installing ESMF with MPI support and without MPI support ("mpiuni").

Note that starting with ESMF version 5, the ESMF development team is trying to maintain backwards compatibility with its subsequent releases. The LIS development team, however, has neither compiled nor tested against versions of ESMF newer than 5.2.0rp3.

5.3 Optional Software Libraries

The following libraries are not required to compile LVT. They are used to extend the functionality of LVT.

- GRIB-API version 1.12.3 (or higher).
(<https://software.ecmwf.int/wiki/display/GRIB/Home>)
GRIB-API is developed by ECMWF and supports both grib1 and grib2 formats.
Note that GRIB-API requires the JasPer library (<http://www.ece.uvic.ca/~frodo/jasper/>).
- NetCDF either version 3.6.3 or version 4.3.0 (or higher).
(<http://www.unidata.ucar.edu/software/netcdf/>)

Please read the on-line documentation for details on installing NetCDF.

Additional notes for NetCDF 4:

- You must also choose whether to compile with compression enabled. Compiling with compression enabled requires HDF 5 and zlib libraries. To enable compression, add `--enable-netcdf-4` to the `configure` options. To disable compression, add `--disable-netcdf-4` to the `configure` options.

An example of installing NetCDF 4 without compression:

```
% ./configure --prefix=$HOME/local/netcdf-4.3.0 --disable-netcdf-4
% gmake
% gmake install
```

An example of installing NetCDF 4 with compression:

```
% CPPFLAGS=-I$HOME/local/hdf5/1.8.11/include \
> LDFLAGS=-L$HOME/local/hdf5/1.8.11/lib \
> ./configure --prefix=$HOME/local/netcdf/4.3.0 --enable-netcdf-4
% gmake
% gmake install
```


- You must also download the *netcdf-fortran-4.2.tar.gz* file. First install the NetCDF C library, then install the NetCDF Fortran library. Again, please read the on-line documentation for more details.

An example of installing the NetCDF 4 Fortran library:

```
% LD_LIBRARY_PATH=$HOME/local/netcdf/4.3.0/lib:$LD_LIBRARY_PATH \
> CPPFLAGS=-I$HOME/local/netcdf/4.3.0/include \
> LDFLAGS=-L$HOME/local/netcdf/4.3.0/lib \
> ./configure --prefix=$HOME/local/netcdf/4.3.0
% gmake
% gmake install
```

- HDF

You may choose either HDF version 4, HDF version 5, or both.

HDF is used to support a number of remote sensing datasets.

If you wish to use MODIS snow cover area observations or NASA AMSR-E soil moisture observations, then you need HDF 4 support.

If you wish to use ANSA snow cover fraction observations, then you need HDF 5 support.

If you wish to use PMW snow observations, then you need both HDF 4 and HDF 5 support.

- HDF 4

If you choose to have HDF version 4 support, please download the HDF source for version 4.2r4 (or later) from (<http://www.hdfgroup.org/products/hdf4>) and compile the source to generate the HDF library. Make sure that you configure the build process to include the Fortran interfaces by adding the `--enable-fortran` option to the `configure` command. Note that HDF4 contains its own embedded version of NetCDF. You must disable this support by adding the `--disable-netcdf` option to the `configure` command.

Note that when compiling LVT with HDF 4 support, you must also download and compile HDF-EOS2 (<http://hdfeos.org/>).

- HDF 5

If you choose to have HDF version 5 support, please download the HDF source for version 1.8.11 (or later) from (<http://www.hdfgroup.org/HDF5/>) and compile the source to generate the HDF library. Make sure that you configure the build process to include the Fortran interfaces by adding the `--enable-fortran` option to the `configure` command.

To install these libraries, follow the instructions provided at the various URL listed above. Please note that though GRIB-API and NETCDF are optional, they are highly recommended as the functionality of LVT will be hugely reduced without these two libraries.

5.4 Build Instructions

1. Perform the steps described in Section 4 to obtain the source code.
2. Goto the `$WORKING/src/` directory. This directory contains two scripts for building the LVT executable: `configure` and `compile`.
3. Set the `LVT_ARCH` environment variable based on the system you are using. The following commands are written using Bash shell syntax.
 - For an AIX system
`% export LVT_ARCH=AIX`
 - For a Linux system with the Intel Fortran compiler
`% export LVT_ARCH=linux_ifc`
 - For a Linux system with the Absoft Fortran compiler
`% export LVT_ARCH=linux_absoft`
 - For a Linux system with the Lahey Fortran compiler
`% export LVT_ARCH=linux_lf95`

It is suggested that you place this command in your `.profile` (or equivalent) startup file.

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, requiring the user to specify the locations of the required and optional libraries via several LVT specific environment variables. The following environment variables are used by LVT.

Variable	Description
<code>LVT_SRC</code>	Location of the LVT source tree (<code>\$WORKING/src/</code>)
<code>LVT_ARCH</code>	LVT architecture (See below)
<code>LVT_FC</code>	Fortran compiler to be used (<code>mpif90</code> , if mpi is installed)
<code>LVT_CC</code>	C compiler to be used (<code>mpicc</code> , if mpi is installed)
<code>LVT_GRIBAPI</code>	path to grib api library
<code>LVT_NETCDF</code>	path to NETCDF library
<code>LVT_HDF4</code>	path to HDF4 library
<code>LVT_HDF5</code>	path to HDF5 library
<code>LVT_HDFEOS</code>	path to HDFEOS library
<code>LVT_MODESMF</code>	path to ESMF header files
<code>LVT_LIBESMF</code>	path to ESMF library files

Note that the `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.

It is suggested that you add these definitions to your *.profile* (or equivalent) startup file.

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, GRIB-API, 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_GRIBAPI/lib:$LD_LIBRARY_PATH
```

It is also suggested that you add this command to your *.profile* (or equivalent) startup file.

5. An example execution of the configure script is shown below:

```
$ ./configure
-----
Setting up configuration for LVT version 1.0...
Optimization level (-2=strict checks, -1=g, 0,1,2,3, default=2):
Assume little/big_endian data format (1-little, 2-big, 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 = 9):
Use HDF4? (1=yes, 0=no, default=1):
Use HDF5? (1=yes, 0=no, default=1):
Use HDFEOS? (1=yes, 0=no, default=1):
-----
  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.
-----
```

6. 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/src/` directory upon successful completion of the *compile* script.

7. Finally, copy the *LVT* executable into your running directory, `$WORKING/run`.

5.5 Generating documentation

LVT code uses the ProTex documenting system [2]. The documentation in L^AT_EX format can be produced by using the `doc.csh` in the `$WORKING/src/utills` directory. This command produces documentation, generating a number of L^AT_EX files. These files can be easily converted to pdf or html formats using utilites such as `pdflatex` or `latex2html`.

6 Running the Executable

This section describes how to run the LVT executable.

The single-process version of LVT is executed by the following command issued in the *\$WORKING/run/* directory.

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

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

To customize your run, you must specify a LVT runtime configuration file. See Section 7 for more information.

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
“Observation processing”	observation processing (to convert to a “LIS format”)
“LIS output processing”	standard analysis mode where analysis is conducted on the LIS output
“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

LVT running mode:	"LIS output processing"
-------------------	-------------------------

Map projection of the LIS run: specifies the map projection used in the LIS simulation. 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
UTM	UTM domain

Map projection of the LIS run:	"latlon"
--------------------------------	----------

LIS nest index: specifies the nest index of the LIS output being compared using LVT

LIS nest index:	1
-----------------	---

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

Number of surface model types:	1
--------------------------------	---

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

Surface model types:	"LSM"
----------------------	-------

LIS output source: specifies the specific subsystem within LIS that generated the output being analyzed Acceptable values are:

Value	Description
LSM	LSM output
Routing	Routing output
RTM	RTM output

LIS output source:	"LSM"
--------------------	-------

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

Value	Description
binary	LIS output in binary format
grib1	LIS output in Grib format
netcdf	LIS output in NETCDF format

LIS output format:	"netcdf"
--------------------	----------

LIS output naming style: specifies the style of the model output names and their directory organization 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 naming style:	"5 level hierarchy"
--------------------------	---------------------

LIS output methodology: specifies the output methodology used in the LIS simulation. 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 methodology:	"2d gridspace"
-------------------------	----------------

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 B for more details about the structure of the LVT output files.

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 tile space"	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

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

Map projection of parameter data: specifies the map projection of the parameter datasets. Note that the grid description options for the parameters will be different for different map projections

Acceptable values are:

Value	Description
latlon	Equidistant cylindrical (lat/lon)
mercator	Mercator projection
lambert	Lambert conformal projection
gaussian	Gaussian
polar	Polar Stereographic
UTM	UTM projection

Map projection of parameter data:	"latlon"
-----------------------------------	----------

Number of observation sources: specifies the number of observation sources

Number of observation sources:	1
--------------------------------	---

Observation source: specifies the observational data to be used for comparing LIS model output

Acceptable values are:

Value	Description
“none”	template
“LIS LSM”	output from another LIS run
“LIS DAOBS”	processed observations from a LIS DA run
“ISCCP tskin”	ISCCCP skin temperature observations
“SCAN”	SCAN 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”	NASA (NSIDC) retrieval of AMSR-E soil moisture
“AMSR-E LPRM”	LPRM (VU) retrieval 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”	WMO snow depth station observations
“MOD10A1”	MOD10A1 fractional snow cover data from MODIS
“ANSA snowdepth”	ANSA snow depth retrievals
“ANSA SWE”	ANSA SWE retrievals
“CPC precipitation”	CPC unified precipitation product
“USGS streamflow”	USGS streamflow observations
“Naturalized streamflow”	Naturalized streamflow estimates
“FLUXNET”	Gridded FLUXNET data from MPI
“MOD16A2”	MOD16A2 ET products from MODIS
“UW ET”	University of Washington ET products from MODIS
“ALEXI”	ALEXI model ET estimates from USDA
“USDA ARS soil moisture”	soil moisture measurements from USDA ARS watersheds
“GHCN”	Global Historical Climatology Network data
“NLDAS2”	North American Land Data Assimilation System Phase-2 data
“GRACE”	processed GRACE data used in a LIS-DA instance

Observation source:	"SURFRAD"
---------------------	-----------

7.2 Runtime options

LIS version: specifies the version of LIS that generated the output. Defaults to 7.

Acceptable values are:

Value	Description
6	LIS version 6
7	LIS version 7

LIS version: 7

Land surface model: specifies the land surface model used that generated the output.

Note — Only needed when using LVT on LIS 6 output.

Acceptable values are:

Value	Description
“CLSM”	Catchment land surface model
“CLM”	CLM 2.0
“CLSMF25”	Catchment Fortuna 2.5
“HYSSIB”	HySSiB
“MOS”	Mosaic
“NOAH271”	Noah 2.7.1
“NOAH32”	Noah 3.2
“NOAH33”	Noah 3.3
“SiB2”	SiB2
“TEMPLATE”	template (no model)
“VIC411”	VIC 4.1.1
“WRSI”	GeoWRSI 2.0

Land surface model:

Experiment code: LIS-6 experiment code number.

Note — Only needed when using LVT on LIS 6 output.

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

Start mode:	"coldstart"
-------------	-------------

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

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

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

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

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

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

LIS output temporal convention: specifies the temporal style of LIS outputs Acceptable values are:

Value	Description
regular	outputs at regular time intervals
dekad	outputs at irregular, dekad intervals

LIS output temporal convention:	"regular"
---------------------------------	-----------

LIS output timestep: specifies the frequency of model outputs used in the LIS simulation

LIS output timestep:	"1da"
----------------------	-------

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

Undefined value:	-9999
------------------	-------

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

LVT diagnostic file:	lvtlog
----------------------	--------

LIS output directory: specifies the name of the top-level LIS output directory. Acceptable values are any 40 character string. For simplicity, throughout the rest of this document, this top-level output directory shall be referred to by its default name, *\$WORKING/LIS/OUTPUT*.

LIS output directory:	./CTRL/OUTPUT
-----------------------	---------------

Number of ensembles per tile: specifies the number of ensembles of tiles used in the LIS simulation. The value should be greater than or equal to 1.

Number of ensembles per tile:	1
-------------------------------	---

This section specifies the 2-d layout of the processors in a parallel processing environment. The user can specify the number of processors along the east-west dimension and north-south dimension using **Number of processors along x:** and **Number of processors along y:**, respectively. Note that the layout of processors should match the total number of processors used. For example, if 8 processors are used, the layout can be specified as 1x8, 2x4, 4x2, or 8x1.

NOTE:Currently parallel processing is not supported within LVT. So these options are ignored.

Number of processors along x:	2
Number of processors along y:	2

7.3 Domain specification

LVT expects three sets of domain specification. (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 7.1 lists the projections that LIS supports.

7.3.1 LVT run domain

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

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

7.3.2 LIS run domain

This section describes how to specify the domain over which LIS was run to generate output. See Appendix C for more details about setting these values.

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

LIS parameter data file: specifies the name of the parameter input file used in the LIS run. This file will be generated by the Land Data Toolkit (LDT).

LIS parameter data file:	./lis_input.d01.nc
--------------------------	--------------------

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).

Soil texture data source:	"STATSGO"
---------------------------	-----------

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).

Soil fraction data source:	"none"
----------------------------	--------

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

Soil color data source:	"none"
-------------------------	--------

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).

Elevation data source:	"none"
------------------------	--------

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).

Slope data source:	"none"
--------------------	--------

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).

Aspect data source:	"none"
---------------------	--------

The following options are used for subgrid tiling based on vegetation, soils or topography.

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.

Maximum number of surface type tiles per grid:	1
--	---

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.

Minimum cutoff percentage (surface type tiles):	0.10
---	------

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.

Maximum number of soil texture tiles per grid:	1
--	---

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.

Minimum cutoff percentage (soil texture tiles):	0.10
---	------

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

Maximum number of soil fraction tiles per grid:	1
---	---

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.

Minimum cutoff percentage (soil fraction tiles):	0.10
--	------

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

Maximum number of elevation bands per grid:	1
---	---

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.

Minimum cutoff percentage (elevation bands):	0.10
--	------

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

Maximum number of slope bands per grid:	1
---	---

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.

Minimum cutoff percentage (slope bands):	0.10
--	------

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

Maximum number of aspect bands per grid:	1
--	---

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.

Minimum cutoff percentage (aspect bands):	0.10
---	------

LIS output attributes file: specifies the output attributes file. This file can be specified by using the model output attributes used to for customizing the LIS model output. An extra column needs to be added in this file to specify which variables among the LIS output are to be included in the evaluation/verification.

LIS output attributes file:	./MODEL_OUTPUT_LIST_LVT.TBL
-----------------------------	-----------------------------

LIS surface soil layer thickness: specifies the thickness (in m) of the surface soil layer

LIS surface soil layer thickness:	0.1
-----------------------------------	-----

LIS root zone soil layer thickness: specifies the thickness (in m) of the root zone soil layer

LIS root zone soil layer thickness:	1.0
-------------------------------------	-----

LIS soil moisture layer thickness: specifies the thicknesses (in m) of the soil moisture layers in the LIS simulation

LIS soil moisture layer thickness:	0.1 0.3 0.6 1.0
------------------------------------	-----------------

LIS soil temperature layer thickness: specifies the thicknesses (in m) of the soil temperature layers in the LIS simulation

LIS soil temperature layer thickness:	0.1 0.3 0.6 1.0
---------------------------------------	-----------------

7.4 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
1	Apply external, temporally varying mask
2	Apply fixed mask

<code>Apply external mask:</code>	<code>0</code>
-----------------------------------	----------------

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.

<code>External mask directory:</code>	<code>"none"</code>
---------------------------------------	---------------------

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
1	compute ensemble metrics

<code>Compute ensemble metrics:</code>	<code>0</code>
--	----------------

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
1	compute information theory metrics

<code>Compute information theory metrics:</code>	<code>0</code>
--	----------------

Metrics attributes file: specifies the attributes of the metrics that are used in the LVT analysis. Section 8 describes the format of the metrics attributes file.

<code>Metrics attributes file:</code>	<code>./METRICS.TBL</code>
---------------------------------------	----------------------------

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

<code>Observation count threshold:</code>	<code>50</code>
---	-----------------

Temporal averaging interval: Specifies the temporal averaging interval of the LIS output and observation data.

Note that the ending time and the **Temporal averaging interval:** must be consistent. For example, for a **Temporal averaging interval:** of 1da, you must have an ending time of:

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

<code>Temporal averaging interval:</code>	<code>"1da"</code>
---	--------------------

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

```
Temporal lag in metric computations: 1da
```

Spatial averaging mode: Specifies the spatial averaging mode to be used.

Acceptable values are:

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

```
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.

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

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

```
Stats output directory: ./STATS
```

Stats output interval: Specifies the frequency (in seconds) of the analysis output.

Note that the stats output interval is simply a setting for specifying the frequency of LVT outputs. If the stats output interval is different from (greater than) the time averaging interval, no additional averaging will be performed between the time averaging intervals.

```
Stats output interval: "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	apply temporal smoothing to obs
1	do not apply temporal smoothing to obs

```
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).

```
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).

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

Temporal (monthly) mask flags: specifies the temporal (monthly) mask flags.

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

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 three different formats: (1) using the lat/lon values (2) using the column/row indices and (3) using the tile indices. A sample file is shown below:

```

#Number of locations
2
#Location style (1-lat/lon, 2-col/row, 3-tile)
1
#Location name, (next line) SW-lat, SW-lon, NE-lat, NE-lon,
min number of grid points
WEST_US
40 -130 50 -110 5
HIGH_PLAINS_US
43 -110 49 -100 2
.....
.....

```

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
1
#Location style (1-lat/lon, 2-col/row, 3-tile)
2
#Location name, (next line) SW-col, SW-row, NE-col, NE-row,
min number of grid points
WEST_US
1 1 20 30 5
EAST_US
1 1 10 10 5
.....
.....

```

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
1
#Location style (1-lat/lon, 2-col/row, 3-tile)
3
#Location name, (next line) Start index, Ending index,
min number of grid points

```



```
WEST_US
1 20 5
EAST_US
1 10 5
.....
.....
```

If the location style is 4, the user explicitly specifies the lat/lons of each grid point to be used to specify a region. A sample file with location style 4 is shown below:

```
#Number of locations
2
#Location style
3
#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. A sample file with location style 5 is shown below:

```
#Number of stations
3
#style
5
#names
NEWENGLAND
1
MIDATLANTIC
1
SOUTHATLANTIC
```

```
1
#categorical map
../huc02_conus_0.125dg.1gd4r
```

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

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
1	Stratify errors

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

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

Stratification variable:	SWdown_f
--------------------------	----------

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

Stratification threshold:	1.0
---------------------------	-----

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

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
1	Stratify errors

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
#stratification variable name
ELEV
SLOPE
ASPECT
#Max min values
7000 1.0 6
500 0.0 0
#number of bins
12 12 12
```

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
3 monthly	3-monthly seasonal cycles (DJF,MAM,JJA,SON)
6 monthly	6-monthly seasonal cycles
yearly	yearly seasonal cycles

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.

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.

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

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.

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.

```
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.

```
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.

```
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.

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

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

```
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.

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

7.5 OptUE processing options

This section of the config file specifies the details of the optimization and uncertainty estimation processing options, and the specialized options to analyze outputs from the Optimization/Uncertainty 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.

```
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.

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

OptUE algorithm used: specifies the index of the optimization/uncertainty estimation algorithm used

Acceptable values are:

Value	Description
1	Levenberg- Marquardt
2	Genetic Algorithm
3	SCE-UA
4	MCSIM
5	MCMC
6	DEMC

OptUE algorithm used:	2
-----------------------	---

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

OptUE decision space attributes file:	./GARun/noah_sm_decspace.txt
---------------------------------------	------------------------------

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

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)

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

```

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

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

OptUE total number of parameters:	2
-----------------------------------	---

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

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.

<code>Compute Innovation Distribution:</code>	1
<code>Compute analysis gain:</code>	0
<code>Number of state variables in the DA update:</code>	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 variable. If multiple observation types are present in the DA output, then column number 2 should be appropriately modified.

7.8 Observation sources

This section of the config file specifies the details of the observational sources.

7.8.1 LIS LSM output as the observation

`LIS LSM output map projection:` specifies the map projection used in generating the LIS output.

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

`LIS LSM output directory:` specifies the LIS output directory

`LIS LSM output naming style:` specifies the style of the LIS output (options are described in 7.1).

LIS LSM output format: specifies the format of the LIS output (options are described in 7.1).

The domain used in the LIS LSM output is described next, which is based on the map projection (please see 7.3 for more options). A lat/lon domain example is shown below:

LIS LSM output attributes file: specifies the model output attribute file used for generating the output
LIS LSM output methodology: specifies the output methodology used for generating the output
LIS LSM output soil moisture layer thickness: specifies the thicknesses of soil moisture layers in the LIS LSM output

LIS LSM output map projection:	"latlon"
LIS LSM output nest index:	1
LIS LSM output directory:	./CLSM/OUTPUT
LIS LSM output naming style:	"3 level hierarchy"
LIS LSM output methodology:	"2d gridspace"
LIS LSM output format:	"netcdf"
LIS LSM output domain lower left lat:	30.5
LIS LSM output domain lower left lon:	-124.5
LIS LSM output domain upper right lat:	50.5
LIS LSM output domain upper right lon:	-75.5
LIS LSM output domain resolution (dx):	1.0
LIS LSM output domain resolution (dy):	1.0
LIS LSM output attributes file:	./CLSM_OUTPUT_LIST.TBL
LIS LSM output soil moisture layer thickness:	0.02 1.0 1.0

7.8.2 LIS DAOBS output as the observation

LIS DAOBS output directory: specifies the LIS DAOBS output directory

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

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

7.8.3 ISCCP land surface temperature observations

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

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

7.8.4 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: SCAN state, station id, station lat, station lon, elevation

```
AL 2058 34.43 -87 6 633
AR 2030 34.85 -91.88 6 250
AR 2091 34.28 -91.35 6 197
AZ 2026 31.73 -110.05 7 4500
GA 2013 33.88 -83.43 5 770
GA 2027 31.5 -83.55 5 350
....
....
```

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

7.8.5 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
```

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

7.8.6 ISMN soil moisture observations

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

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

7.8.7 SURFRAD observations (radiation, wind speed, pressure)

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

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

7.8.8 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
.....
.....
```

SNOTEL metadata file: specifies the file that lists the metadata for the SNOTEL stations. The format of the metadata file is as follows:

```
#nstns, undef, starting time, ending time data, timestep
712 -9999.0 2007 01 01 01 00 2008 12 31 00 00 86400
```

<pre>SNOTEL observation directory: ./SNOTEL SNOTEL coord file: ./SNOTEL/SNOTEL_CONUS_list.txt SNOTEL metadata file: ./SNOTEL/SNOTEL_mdata</pre>

7.8.9 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:
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`: ?? LSWG Tb `cloud mask threshold(%)`: specifies the threshold below which clouds can be ignored (used only if cloud masking is enabled).

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

7.8.10 FMI SWE observations

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

FMISWE <code>observation directory</code> :	<code>./FMI_SWE</code>
---	------------------------

7.8.11 CMC daily snow depth observations

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

CMC snow depth metadata file: specifies the file that lists the metadata for the CMC snow depth data. The format of the metadata file is as follows:

```
#undef, starting time, ending time data, timestep  
-9999.0 2007 11 01 00 00 2008 12 30 00 00 86400
```

CMC snow depth observation directory:	./CMC_data
CMC snow depth metadata file:	./CMC_data/CMC_SNWD_mdata

7.8.12 SNODAS snow analysis data

SNODAS observation directory: specifies the location of the SNODAS data

SNODAS metadata file: specifies the file that lists the metadata for the SNODAS. The format of the metadata file is as follows:

```
#undef, starting time, ending time data, timestep  
-9999.0 2007 11 01 00 00 2008 12 30 00 00 86400
```

SNODAS observation directory:	./SNODAS
SNODAS metadata file:	./SNODAS/SNODAS_mdata

7.8.13 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

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

7.8.14 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 use raw data: specifies whether to use the LPRM AMSR-E raw data. Acceptable values are:

Value	Description
0	Do not use
1	Use

LPRM AMSR-E soil moisture observation directory: ./LPRM-AMSRE

7.8.15 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
201006140332132535.csv
201006140337342536.csv
201006140347082537.csv
201006140348592538.csv
201006140351382539.csv
201006140358582540.csv
201006140400532541.csv
201006140402202542.csv
201006140640302543.csv
201006140641442544.csv
201006140642422545.csv
201006140643372546.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_belifougou_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

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

7.8.16 Ameriflux station observations

Ameriflux observation directory: specifies the location of the Ameriflux datasets.
 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
.....
.....

```

Ameriflux observation directory:	./AmeriFlux
Ameriflux station list file:	./AmeriFlux/Ameriflux_stns.txt

7.8.17 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:

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

```

#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 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

7.8.18 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.

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

7.8.19 AGRMET data

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

AGRMET data directory:	./AGRMET_data
------------------------	---------------

7.8.20 GlobSnow data

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

GlobSnow data directory:	./GlobSnow
--------------------------	------------

7.8.21 SNODEP snow depth data

SNODEP observation 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)

SNODEP observation directory:	./SNODEP
-------------------------------	----------

7.8.22 MOD10A1 snow cover data

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

MOD10A1 observation directory:	./MOD10A1
--------------------------------	-----------

7.8.23 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)

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

7.8.24 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)

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

7.8.25 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
.....
.....
```

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

7.8.26 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
.....
.....

```

Naturalized streamflow observation directory: <code>./Naturalized_StreamFlow</code> Naturalized streamflow station list file: <code>./Naturalized_StreamFlow/Naturalized_stnlist.</code>

7.8.27 Gridded FLUXNET data

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

FLUXNET data directory:	<code>./FLUXNET</code>
-------------------------	------------------------

7.8.28 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 observation directory:	<code>./CPC-UNI</code>
CPC PCP domain type (CONUS or GLOBAL):	<code>CONUS</code>

7.8.29 MOD16A2 data

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

MOD16A2 data directory:	<code>./MOD16</code>
-------------------------	----------------------

7.8.30 ALEXI data

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

ALEXI data resolution (in km): specifies the resolution of the ALEXI ET data in km. Acceptable values are 4 or 10.

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

7.8.31 University of Washington ET data

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

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

7.8.32 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
.....
.....
```

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

7.8.33 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
GRACE	GRACE
GRACEFO	GRACE follow-on
GRACE-2	GRACE 2

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

7.8.34 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

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

7.8.35 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 metadata file.

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

7.8.36 Global Change Observation Mission – Water (GCOMW)

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

GCOMW AMSR2 L3 soil moisture observation directory:

7.8.37 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.

GLERL hydro data directory:
GLERL hydro lake locations file:

7.8.38 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 metadata file.

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

7.8.39 MODIS LST

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

```
MODIS LST directory:
```

7.8.40 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.

```
NASMD observation directory:  
NASMD coord file:  
NASMD number of stations:
```

7.8.41 NLDAS2

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

NLDAS2 land surface model: specifies the NLDAS-2 land-surface model.

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.

NLDAS2 data directory:	./NLDAS2.VIC
NLDAS2 land surface model:	VIC
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

7.8.42 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.

PBOH2O observation directory:
PBOH2O station list file:

7.8.43 Real Time Soil Moisture Operational Processing System (RT SMOPS)

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

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

Value	Description
0	do not use
1	use

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

Value	Description
0	do not use
1	use

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

Value	Description
0	do not use
1	use

RT SMOPS soil moisture observation directory: RT SMOPS soil moisture use ASCAT data: RT SMOPS soil moisture use WindSat data: RT SMOPS soil moisture use SMOS data:
--

7.8.44 SMOS L1 TB

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

SMOS L1 TB observation directory:

7.8.45 SMOS L2 soil moisture

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

SMOS L2 soil moisture observation directory:
--

7.8.46 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.

USGS ground water (well data) observation directory: USGS ground water (well data) coord file:

7.8.47 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.

WG PBMR observation directory: WG PBMR site index:

7.8.48 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.

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

7.9 Observation processing

This runmode is used to convert a given observational data into a “LIS style”. Once the data is converted, intercomparisons with any observation-plugin in LVT can be made.

No specialized options are necessary, except that the 'LIS Output directory:' correspondes to the directory where the converted data will be written.

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 no write
1	write

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

Acceptable values are:

Value	Description
0	Do no write
1	write

Threshold: The threshold value to be used in computing the metric. Note that this is used only for the categorical metrics.

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 no generate
1	generate

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 no generate
1	generate

#name	total	in-time	writeTS	extractTS	threshold	SC	ADC	short_name
Mean:			1	1	0	1	-9999.0	0 0 #Mean
Min:			0	0	0	0	-9999.0	0 0 #Minimum
Max:			0	0	0	0	-9999.0	0 0 #Maximum
Sum:			0	0	0	0	-9999.0	0 0 #Sum
Anomaly:			0	0	0	0	-9999.0	0 0 #Anomaly
Standard deviation:			0	0	0	0	-9999.0	0 0 #Std
RMSE:			0	0	0	0	-9999.0	0 0 #RMSE
Bias:			0	0	0	0	-9999.0	0 0 #Bias

ubRMSE:	0	0	0	0	-9999.0	0	0	#ubRMSE
Mean absolute error:	0	0	0	0	-9999.0	0	0	#MAE
Anomaly RMSE:	0	0	0	0	-9999.0	0	0	#ARMSE
Anomaly correlation:	0	0	0	0	-9999.0	0	0	#ARMSE
Raw correlation:	0	0	0	0	-9999.0	0	0	#RCORR
Probability of detection (PODy):	0	0	0	0	0.1	0	0	#PODy
Probability of detection (PODn):	0	0	0	0	0.1	0	0	#PODn
False alarm ratio (FAR):	0	0	0	0	0.1	0	0	#FAR
Probability of false detection (POFD):	0	0	0	0	0.1	0	0	#POFD
Critical success index (CSI):	0	0	0	0	0.1	0	0	#CSI
Accuracy measure (ACC):	0	0	0	0	0.1	0	0	#ACC
Frequency bias (FBIAS):	0	0	0	0	0.1	0	0	#FBIAS
Equitable threat score (ETS):	0	0	0	0	0.1	0	0	#ETS
Area metric:	0	0	0	0	-9999.0	0	0	#Area
Nash sutcliffe efficiency:	0	0	0	0	-9999.0	0	0	#NSE
Ensemble mean:	1	1	0	1	-9999.0	0	0	#ensmean
Ensemble standard deviation:	1	1	0	1	-9999.0	0	0	#ensstd
Ensemble likelihood:	1	1	0	1	-9999.0	0	0	#ensll
Ensemble cross correlation:	1	1	0	1	-9999.0	0	0	#ensxcorr
Ensemble skill:	0	0	0	0	-9999.0	0	0	#ensskill
Ensemble mean error:	0	0	0	0	-9999.0	0	0	#ensmerror
Ensemble mean bias:	0	0	0	0	-9999.0	0	0	#ensmbias
Ensemble spread:	0	0	0	0	-9999.0	0	0	#ensspread
Metric entropy:	0	0	0	0	-9999.0	0	0	#mentropy
Information gain:	0	0	0	0	-9999.0	0	0	#igain
Fluctuation complexity:	0	0	0	0	-9999.0	0	0	#fcomplexity
Effective complexity:	0	0	0	0	-9999.0	0	0	#ecomplexity
Wavelet stat:	0	0	0	0	-9999.0	0	0	#waveletstat
Hausdorff norm:	0	0	0	0	-9999.0	0	0	#Hnorm
Standard precipitation index:	0	0	0	0	-9999.0	0	0	#SPI
Standard runoff index:	0	0	0	0	-9999.0	0	0	#SRI
Standardized soil water index:	0	0	0	0	-9999.0	0	0	#SSWI
Standardized ground water index:	0	0	0	0	-9999.0	0	0	#SGWI
Percentile:	0	0	0	0	-9999.0	0	0	#Percentile
River flow variate:	0	0	0	0	-9999.0	0	0	#RFV

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
<i>n</i>	Enable the variable for analysis and include additional (<i>n</i>) 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)

#Cold season processes
Snowcover:   0 -     -   0 0 0 1 238 100   0 # Snow cover (-)
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
#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

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`, `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
```

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 : Q_{le} , Q_h
- Metrics : *MEAN* and *RMSE*
- LSM : *Noah 3.2*
- location (from *TS_LOCATIONS.TXT*) : *E20*
- Experiment name : *RUN*

B.0.1 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_Q1e          1
VARIABLE: OBS_COUNT_Q1e    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.0.2 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: Q1e
-----
      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_Q1e
-----
      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.0.3 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 de-

viation, 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_qlc rmse_qlc_STD rmse_qlc_min rmse_qlc_max
rmse_qlc_ensSTD rmse_qlc_CI
2007 05 02 02 00 rmse_qlc rmse_qlc_STD rmse_qlc_min rmse_qlc_max
rmse_qlc_ensSTD rmse_qlc_CI
.....
.....
```

B.0.4 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 extension of '.gs4r' will be used instead of '.nc'.

B.0.5 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 NETCDF output file extension of '.gs4r' will be used instead of '.nc'.

C Cylindrical Lat/Lon Domain Example

This section describes how to compute the values for the run domain and LIS run domain sections on a cylindrical lat/lon projection.

First, we shall generate the values for the LIS run domain. This is the domain over which LIS was run, which can be found in the *lis.config* file corresponding to the run.

Next, we shall generate the values for the LVT Run domain.

If you wish to analyze the whole domain defined by the LIS run domain then you simply copy the values defined in the LIS run domain section in the run domain section. This gives:

Now say, you ran LIS over a 1/4 deg global domain, but you wish to analyze only over the region given by $(-97.6, 27.9)$, $(-92.9, 31.9)$. Since the LVT Run domain is a sub-set of the LIS run domain, it is also a Latitude/Longitude domain at 1/4 deg. resolution. Thus,

```
Run domain resolution dx: 0.25
Run domain resolution dy: 0.25
```

Now, since the LVT Run domain must fit onto the LIS run domain, the desired running region must be expanded from $(-97.6, 27.9)$, $(-92.9, 31.9)$ to $(-97.75, 27.75)$, $(-92.75, 32.0)$. The south-west grid-cell for the running domain is the box $(-97.75, 27.75)$, $(-97.5, 28.0)$. Its center is $(-97.625, 27.875)$; giving

```
Run domain lower left lat: 27.875
Run domain lower left lon: -97.625
```

The north-east grid-cell for the running domain is the box $(-93, 31.75)$, $(-92.75, 32.0)$. Its center is $(-92.875, 31.875)$; giving

```
Run domain upper right lat: 31.875
Run domain upper right lon: -92.875
```

This completely defines the LVT Run domain.

Note, the LIS project has defined 5 km resolution to be 0.05 deg. and 1 km resolution to be 0.01 deg. If you wish to run at 5 km or 1 km resolution, redo the above example to compute the appropriate grid-cell values.

See Figure 1 for an illustration of adjusting the running grid. See Figures 2 and 3 for an illustration of the south-west and north-east grid-cells.

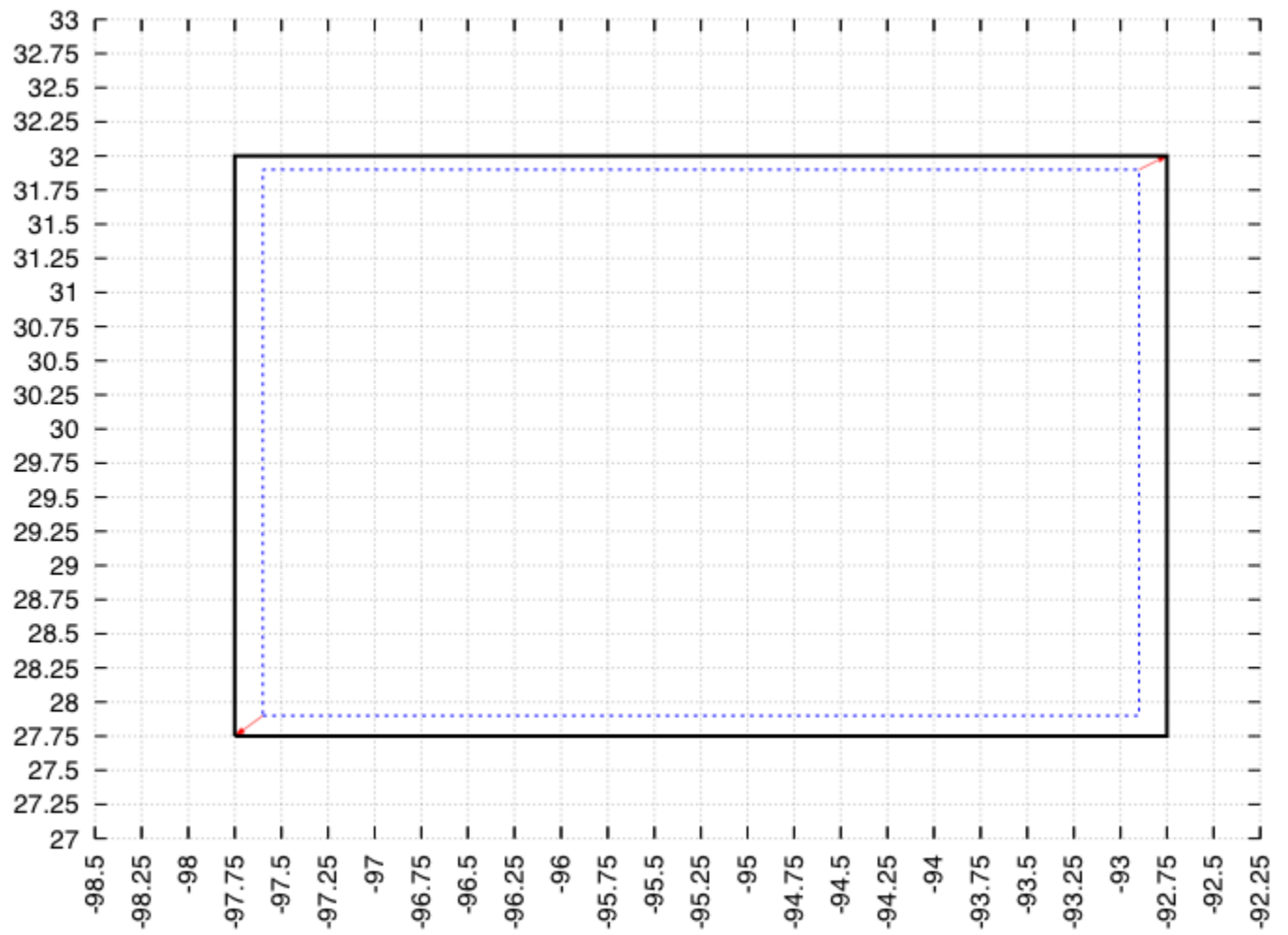


Figure 1: Illustration showing how to fit the desired running grid onto the actual grid

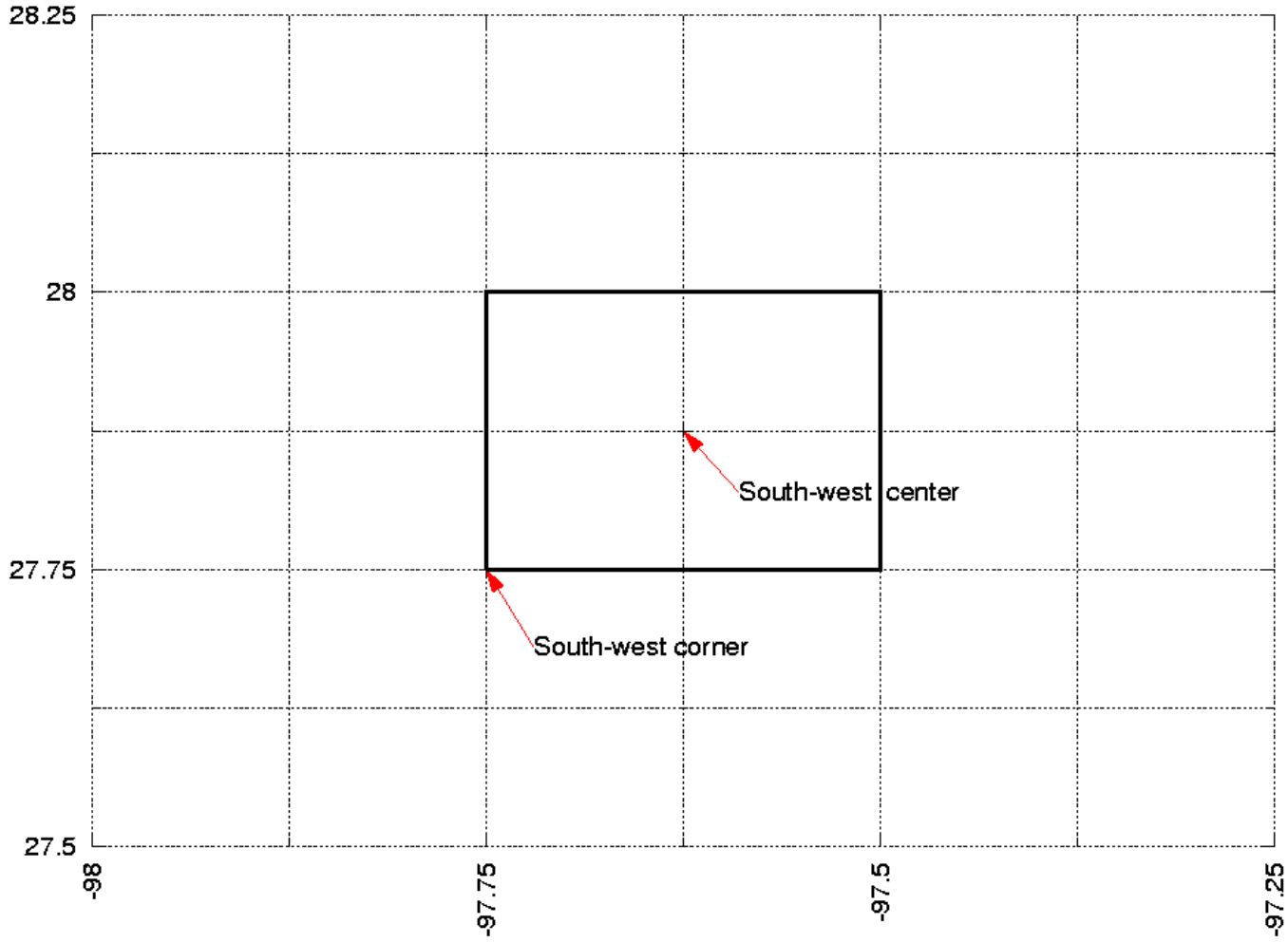


Figure 2: Illustration showing the south-west grid-cell corresponding to the example in Section C

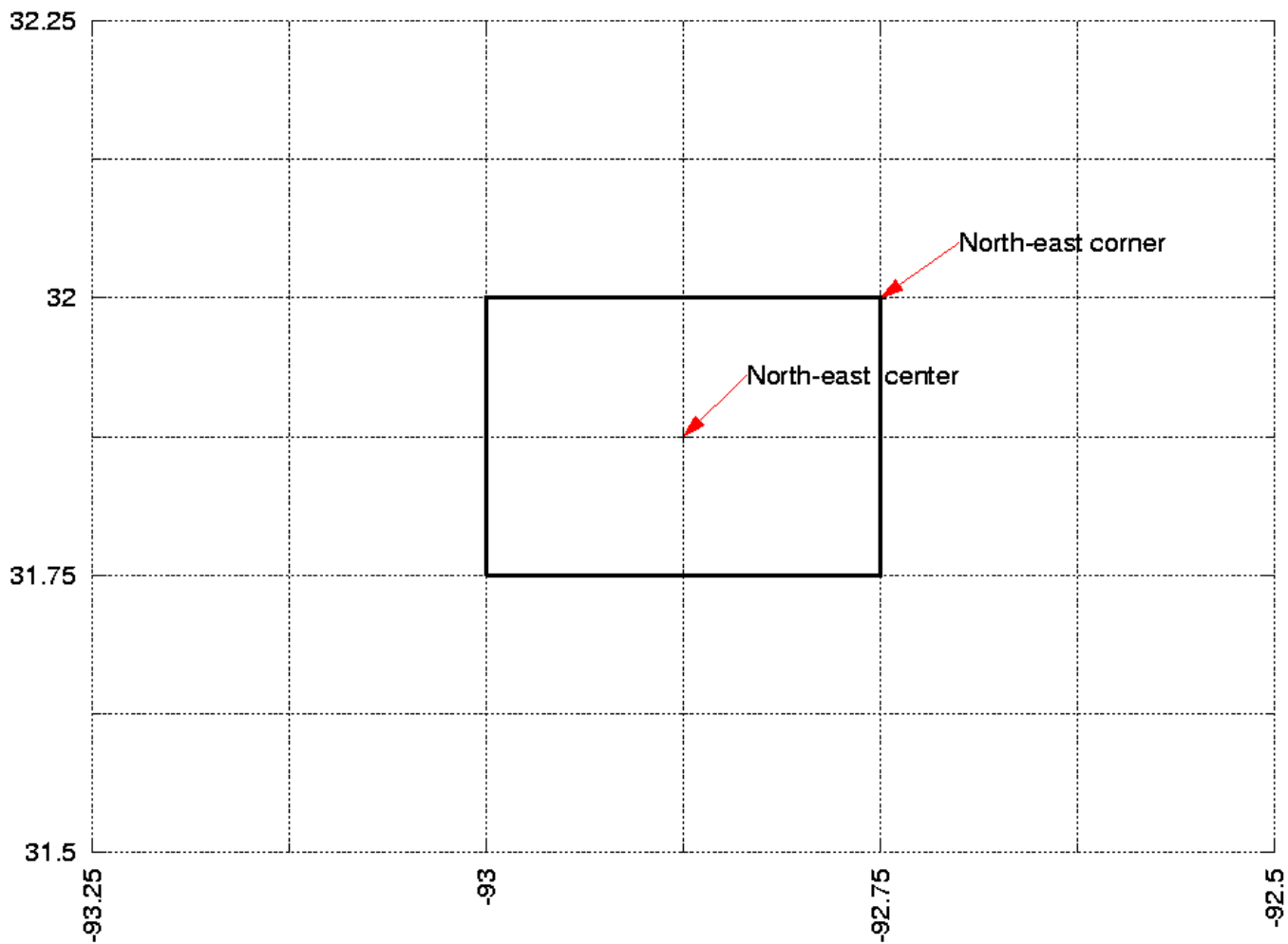


Figure 3: Illustration showing the north-east grid-cell corresponding to the example in Section C

D Polar Stereographic Domain Example

This section describes how to compute the values for the run domain and param domain sections on a polar stereographic projection.

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E Gaussian Domain Example

This section describes how to compute the values for the run domain and param domain sections on a Gaussian projection.

First, we shall generate the values for the parameter data domain. LIS' Gaussian parameter data is defined from -180 to 180 degrees longitude and from -90 to 90 degrees latitude. Note that the first longitude point is at 0 .

The parameter domain must be specified as follows:

```
param domain first grid point lat:      -89.27665
param domain first grid point lon:       0.0
param domain last grid point lat:       89.27665
param domain last grid point lon:       -0.9375
param domain resolution dlon:           0.9375
param domain number of lat circles:     95
```

Next, we shall generate the values for the running domain.

If you wish to run over the whole domain defined by the parameter data domain then you simply set the values defined in the parameter domain section in the run domain section. This gives:

```
run domain first grid point lat:      -89.27665
run domain first grid point lon:       0.0
run domain last grid point lat:       89.27665
run domain last grid point lon:       -0.9375
run domain resolution dlon:           0.9375
run domain number of lat circles:     95
```

If you wish to run over a sub-domain, then you must choose longitude and latitude values that correspond to the T126 Gaussian projection. Tables of acceptable longitude and latitude values are found below.

Now say you wish to run only over the region given by $(-97.6, 27.9)$, $(-92.9, 31.9)$. Since the running domain must fit on the T126 Gaussian grid, the running domain must be expanded to $(-98.4375, 27.87391)$, $(-91.875, 32.59830)$. Thus the running domain specification is:

```
run domain first grid point lat:       27.87391
run domain first grid point lon:      -98.4375
```

run domain last grid point lat:	32.59830
run domain last grid point lon:	-91.875
run domain resolution dlon:	0.9375
run domain number of lat circles:	95

Table 1: Acceptable longitude values

0.000000	0.937500	1.875000	2.812500	3.750000
4.687500	5.625000	6.562500	7.500000	8.437500
9.375000	10.312500	11.250000	12.187500	13.125000
14.062500	15.000000	15.937500	16.875000	17.812500
18.750000	19.687500	20.625000	21.562500	22.500000
23.437500	24.375000	25.312500	26.250000	27.187500
28.125000	29.062500	30.000000	30.937500	31.875000
32.812500	33.750000	34.687500	35.625000	36.562500
37.500000	38.437500	39.375000	40.312500	41.250000
42.187500	43.125000	44.062500	45.000000	45.937500
46.875000	47.812500	48.750000	49.687500	50.625000
51.562500	52.500000	53.437500	54.375000	55.312500
56.250000	57.187500	58.125000	59.062500	60.000000
60.937500	61.875000	62.812500	63.750000	64.687500
65.625000	66.562500	67.500000	68.437500	69.375000
70.312500	71.250000	72.187500	73.125000	74.062500
75.000000	75.937500	76.875000	77.812500	78.750000
79.687500	80.625000	81.562500	82.500000	83.437500
84.375000	85.312500	86.250000	87.187500	88.125000
89.062500	90.000000	90.937500	91.875000	92.812500
93.750000	94.687500	95.625000	96.562500	97.500000
98.437500	99.375000	100.312500	101.250000	102.187500
103.125000	104.062500	105.000000	105.937500	106.875000
107.812500	108.750000	109.687500	110.625000	111.562500
112.500000	113.437500	114.375000	115.312500	116.250000
117.187500	118.125000	119.062500	120.000000	120.937500
121.875000	122.812500	123.750000	124.687500	125.625000
126.562500	127.500000	128.437500	129.375000	130.312500
131.250000	132.187500	133.125000	134.062500	135.000000
135.937500	136.875000	137.812500	138.750000	139.687500
140.625000	141.562500	142.500000	143.437500	144.375000
145.312500	146.250000	147.187500	148.125000	149.062500
150.000000	150.937500	151.875000	152.812500	153.750000
154.687500	155.625000	156.562500	157.500000	158.437500
159.375000	160.312500	161.250000	162.187500	163.125000
164.062500	165.000000	165.937500	166.875000	167.812500
168.750000	169.687500	170.625000	171.562500	172.500000
173.437500	174.375000	175.312500	176.250000	177.187500
178.125000	179.062500	180.000000	-179.062500	-178.125000

-177.187500	-176.250000	-175.312500	-174.375000	-173.437500
-172.500000	-171.562500	-170.625000	-169.687500	-168.750000
-167.812500	-166.875000	-165.937500	-165.000000	-164.062500
-163.125000	-162.187500	-161.250000	-160.312500	-159.375000
-158.437500	-157.500000	-156.562500	-155.625000	-154.687500
-153.750000	-152.812500	-151.875000	-150.937500	-150.000000
-149.062500	-148.125000	-147.187500	-146.250000	-145.312500
-144.375000	-143.437500	-142.500000	-141.562500	-140.625000
-139.687500	-138.750000	-137.812500	-136.875000	-135.937500
-135.000000	-134.062500	-133.125000	-132.187500	-131.250000
-130.312500	-129.375000	-128.437500	-127.500000	-126.562500
-125.625000	-124.687500	-123.750000	-122.812500	-121.875000
-120.937500	-120.000000	-119.062500	-118.125000	-117.187500
-116.250000	-115.312500	-114.375000	-113.437500	-112.500000
-111.562500	-110.625000	-109.687500	-108.750000	-107.812500
-106.875000	-105.937500	-105.000000	-104.062500	-103.125000
-102.187500	-101.250000	-100.312500	-99.375000	-98.437500
-97.500000	-96.562500	-95.625000	-94.687500	-93.750000
-92.812500	-91.875000	-90.937500	-90.000000	-89.062500
-88.125000	-87.187500	-86.250000	-85.312500	-84.375000
-83.437500	-82.500000	-81.562500	-80.625000	-79.687500
-78.750000	-77.812500	-76.875000	-75.937500	-75.000000
-74.062500	-73.125000	-72.187500	-71.250000	-70.312500
-69.375000	-68.437500	-67.500000	-66.562500	-65.625000
-64.687500	-63.750000	-62.812500	-61.875000	-60.937500
-60.000000	-59.062500	-58.125000	-57.187500	-56.250000
-55.312500	-54.375000	-53.437500	-52.500000	-51.562500
-50.625000	-49.687500	-48.750000	-47.812500	-46.875000
-45.937500	-45.000000	-44.062500	-43.125000	-42.187500
-41.250000	-40.312500	-39.375000	-38.437500	-37.500000
-36.562500	-35.625000	-34.687500	-33.750000	-32.812500
-31.875000	-30.937500	-30.000000	-29.062500	-28.125000
-27.187500	-26.250000	-25.312500	-24.375000	-23.437500
-22.500000	-21.562500	-20.625000	-19.687500	-18.750000
-17.812500	-16.875000	-15.937500	-15.000000	-14.062500
-13.125000	-12.187500	-11.250000	-10.312500	-9.375000
-8.437500	-7.500000	-6.562500	-5.625000	-4.687500
-3.750000	-2.812500	-1.875000	-0.937500	

Table 2: Acceptable latitude values

-89.27665	-88.33975	-87.39729	-86.45353	-85.50930
-84.56487	-83.62028	-82.67562	-81.73093	-80.78618
-79.84142	-78.89662	-77.95183	-77.00701	-76.06219
-75.11736	-74.17252	-73.22769	-72.28285	-71.33799
-70.39314	-69.44830	-68.50343	-67.55857	-66.61371
-65.66885	-64.72399	-63.77912	-62.83426	-61.88939
-60.94452	-59.99965	-59.05478	-58.10991	-57.16505
-56.22018	-55.27531	-54.33043	-53.38556	-52.44069
-51.49581	-50.55094	-49.60606	-48.66119	-47.71632
-46.77144	-45.82657	-44.88169	-43.93681	-42.99194
-42.04707	-41.10219	-40.15731	-39.21244	-38.26756
-37.32268	-36.37781	-35.43293	-34.48805	-33.54317
-32.59830	-31.65342	-30.70854	-29.76366	-28.81879
-27.87391	-26.92903	-25.98415	-25.03928	-24.09440
-23.14952	-22.20464	-21.25977	-20.31489	-19.37001
-18.42513	-17.48025	-16.53537	-15.59050	-14.64562
-13.70074	-12.75586	-11.81098	-10.86610	-9.921225
-8.976346	-8.031467	-7.086589	-6.141711	-5.196832
-4.251954	-3.307075	-2.362196	-1.417318	-0.4724393
0.4724393	1.417318	2.362196	3.307075	4.251954
5.196832	6.141711	7.086589	8.031467	8.976346
9.921225	10.86610	11.81098	12.75586	13.70074
14.64562	15.59050	16.53537	17.48025	18.42513
19.37001	20.31489	21.25977	22.20464	23.14952
24.09440	25.03928	25.98415	26.92903	27.87391
28.81879	29.76366	30.70854	31.65342	32.59830
33.54317	34.48805	35.43293	36.37781	37.32268
38.26756	39.21244	40.15731	41.10219	42.04707
42.99194	43.93681	44.88169	45.82657	46.77144
47.71632	48.66119	49.60606	50.55094	51.49581
52.44069	53.38556	54.33043	55.27531	56.22018
57.16505	58.10991	59.05478	59.99965	60.94452
61.88939	62.83426	63.77912	64.72399	65.66885
66.61371	67.55857	68.50343	69.44830	70.39314
71.33799	72.28285	73.22769	74.17252	75.11736
76.06219	77.00701	77.95183	78.89662	79.84142
80.78618	81.73093	82.67562	83.62028	84.56487
85.50930	86.45353	87.39729	88.33975	89.27665

F Lambert Conformal Domain Example

This section describes how to compute the values for the run domain and param domain sections on a Lambert conformal projection.

Note that this projection is often used for a coupled run with the Weather Research and Forecasting (WRF) model. As such, Lambert domains are first generated when configuring WRF via WRF's preprocessing system (WPS). The domain information is then copied into LIS' *lis.config* file.

Please see WRF's User's Guide found at <http://www.mmm.ucar.edu/wrf/users/pubdoc.html> for more information.

G Mercator Domain Example

This section describes how to compute the values for the run domain and param domain sections on a Mercator projection.

Note that this projection is often used for a coupled run with the Weather Research and Forecasting (WRF) model. As such, Mercator domains are first generated when configuring WRF via WRF's preprocessing system (WPS). The domain information is then copied into LIS' *lis.config* file.

Please see WRF's User's Guide found at <http://www.mmm.ucar.edu/wrf/users/pubdoc.html> for more information.

H UTM Domain Example

This section describes how to compute the values for the run domain and param domain sections on a UTM projection.

STUB!

References

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- [2] W. Sawyer and A. da Silva. Protex: A sample fortran 90 source code documentation system. Technical report, NASA GMAO, 1997. DAO Office Note 97-11.