LIS Data Assimilation (DA) Experiment

Step-6

In this presentation ...

- Overview of the LIS SMAP soil moisture (SM) data assimilation (DA) experiment.
- LIS-Soil Moisture DA setup and files;
- Viewing the LIS config DA options.
- Running the SMAP SM DA configuration.

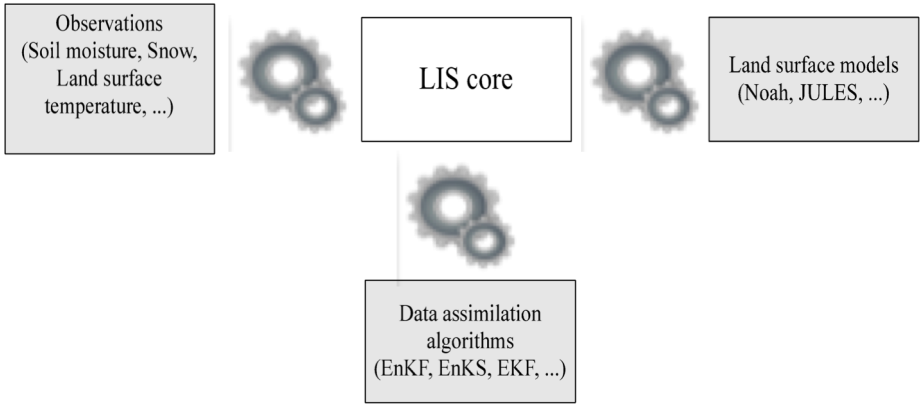
Data Assimilation Subsystem in LIS

Primarily used for state estimation - Corrects model states based on observations.

Advanced algorithms such as the Ensemble Kalman Filter (EnKF), Ensemble Kalman Smoother (EnKS) (originally developed based on the the NASA GMAO infrastructure).

Supports the interoperable use of multiple land surface models, multiple algorithms, and multiple observational data sources.

Support for concurrent data assimilation, forward models, radiance assimilation, observation operators employing advanced data fusion methods (deep learning).



Kumar, S.V., R.H. Reichle, C.D. Peters-Lidard, R.D. Koster, X. Zhan, W.T. Crow, J.B. Eylander, P.R. Houser (2008), A Land Surface Data Assimilation Framework using the Land Information System: Description and Applications, *Adv. Wat. Res.*, 31, 1419-1432.

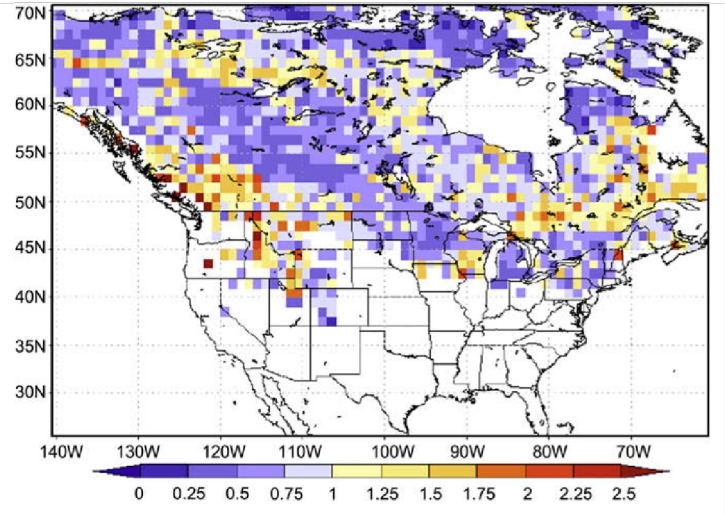
DA Diagnostics

DA subsystem outputs a number of diagnostics:

-- DA innovations, normalized innovations, ensemble spread

-- Processed/bias-corrected/QC'd observational data

Also, the Land Verification Tookit (LVT) handles the automated processing of these outputs.



Variance of normalized Innovations

SMAP soil moisture data assimilation test case

Input directories required for performing this DA run step:

DA_ensrst – example of generating an ensemble restart file

DA_proc_LSM – example of generating model CDF

DA_proc_SMAP – example of generating observation (SMAP) CDF

DA_INPUT – contains model, obs, and forcing perturbation files

RS_DATA – contains sample of the SMAP soil moisture observations

INPUT – contains the NLDAS2 forcing and Noah model files

* In the interest of reducing file sizes, the open loop outputs and SMAP data are limited to several months

Download necessary files to run this step …

1) Download the "*Step 6*" tarred-gzipped file from the LIS testcases webpage ("*testcase6_lis_da.tgz*").

2) Unpack the above testcase files in your working directory, `$WORKING_DIR`,

3) Once unpacked, you will see the following directories and files:

- `DA_INPUT` ➔ Contains the perturbation files used in the assimilation run;
- `lis.config_noah36_smapda` ➔ The lis.config file for this testcase
- `target_SMAPDA_OUTPUT` ➔ The "target" DA run directory output generated by LIS
- `target_log/lislog_smapda.0000` ➔ The "target" LIS log file;
- `target_da.xdf, test_da.xdf` ➔ GrADS description files to look at the output.

Noah 3.6 SMAP DA: LIS Config File

Choose "restart" and use ensemble restart file generated by LDT in Step 3.

Change the # of ensemble members to 12. We have already generated an ensemble of restart file with 12 ensemble members.

Set the DA options

Choose the scaling strategy

```
Start mode:                    restart
Noah.3.6 restart file:
./DA_ensrst/LIS_EnRST_NOAH36_201801010000.d01.nc
```

```
Number of ensembles per tile:          12
```

```
Number of data assimilation instances:          1

Data assimilation algorithm:                "EnKF"
Data assimilation set:                      "SMAP(NASA) soil moisture"
Number of state variables:                        4
Data assimilation use a trained forward model:    0
Data assimilation trained forward model output file: none
Data assimilation exclude analysis increments:    0
Data assimilation output interval for diagnostics:  "1da"
Data assimilation number of observation types:    1
Data assimilation output ensemble spread:         1
Data assimilation output processed observations:  1
Data assimilation output innovations:             1
```

```
Data assimilation scaling strategy:             "CDF matching"
Data assimilation observation domain file:  ./lis_input.nldas.noah36.d01.nc

Bias estimation algorithm:              "none"
Bias estimation attributes file:        "none"
Bias estimation restart output frequency:
Bias estimation start mode:
Bias estimation restart file:
```

LIS Perturbations and SMAP DA Options

Set up the perturbation options

Forcing perturbation

State perturbation

Observation perturbation

Observation data entry

SMAP soil moisture product

```
Perturbations start mode:                "coldstart"
Perturbations restart output interval:    "1mo"
Perturbations restart filename:          "none"
Apply perturbation bias correction:       0
```

```
Forcing perturbation algorithm:          "GMAO scheme"
Forcing perturbation frequency:           "1hr"
Forcing attributes file:                 ./DA_INPUT/forcing_attribs.txt
Forcing perturbation attributes file:    ./DA_INPUT/forcing_pert_attribs.txt

State perturbation algorithm:            "GMAO scheme"
State perturbation frequency:             "6hr"
State attributes file:                   ./DA_INPUT/noah_sm_attribs.txt
State perturbation attributes file:      ./DA_INPUT/noah_sm_pertattribs.txt

Observation perturbation algorithm:      "GMAO scheme"
Observation perturbation frequency:       "6hr"
Observation attributes file:              ./DA_INPUT/smap_attribs.txt
Observation perturbation attributes file: ./DA_INPUT/smap_pertattribs.txt
```

```
SMAP(NASA) soil moisture data designation:       SPL3SMP
SMAP(NASA) soil moisture data directory:     ./RS_DATA/SMAP/SPL3SMP.005
SMAP(NASA) soil moisture use scaled standard deviation model:  0
SMAP(NASA) soil moisture apply SMAP QC flags:                  1
SMAP(NASA) model CDF file:           ./DA_proc_LSM/cdf_noah36.nc
SMAP(NASA) observation CDF file:  ./DA_proc_SMAP/cdf_smapobs.nc
SMAP(NASA) soil moisture number of bins in the CDF:          100
SMAP(NASA) soil moisture use scaled standard deviation model:   0
```

Specifying Forcing Perturbations

```
Apply perturbation bias correction:          0

Forcing perturbation algorithm:              "GMAO scheme"
Forcing perturbation frequency:              "1hr"
Forcing attributes file:                     ./DA_INPUT/forcing_attribs.txt
Forcing perturbation attributes file:        ./DA_INPUT/forcing_pert_attribs.txt
```

forcing_pert_attribs.txt
specifies the perturbation settings

```
#ptype   std    std_max   zeromean  tcorr  xcorr ycorr ccorr
Incident Shortwave Radiation Level 001
1       0.20     2.5   1                    86400  0     0     1.0  -0.3 -0.5  0.3
Incident Longwave Radiation Level 001
0       30.0     2.5   1                    86400  0     0     -0.3   1.0  0.5  0.6
Rainfall Rate Level 001
1       0.50     2.5   1                    86400  0     0     -0.5   0.5  1.0  -0.1
Near Surface Air Temperature Level 001
0       0.5      2.5    1            86400  0     0     0.3   0.6  -0.1  1.0
```

forcing_attribs.txt
specifies the variables and their ranges

```
#varmin  varmax
Incident Shortwave Radiation Level 001
0.                    1300.
Incident Longwave Radiation Level 001
-50.     800.
Rainfall Rate Level 001
0.0      0.001
Near Surface Air Temperature Level 001
220.0   330.0
```

Perturbation type: additive (0) or multiplicative (1)

Std: standard deviation of perturbations

Std_max: maximum allowed normalized perturbation (relative to $N(0,1)$)

Zero mean: enforce zero mean across the ensemble

Tcorr: temporal correlation scale (in seconds) used in the AR(1) model

Xcorr, Y-corr: Spatial correlation scale (deg)

Ccorr: cross correlations between variables

State perturbations

```
State perturbation algorithm:          "GMAO scheme"
State perturbation frequency:           "6hr"
State attributes file:                 ./DA_INPUT/noah_sm_attribs.txt
State perturbation attributes file:    ./DA_INPUT/noah_sm_pertattribs.txt
```

noah_sm_attribs.txt
specifies the variables and their ranges

```
#nfields
4
#name  varmin  varmax
Soil Moisture Layer 1
  0.01                0.55
Soil Moisture Layer 2
  0.01                0.55
Soil Moisture Layer 3
  0.01                0.55
Soil Moisture Layer 4
  0.01                0.55
```

noah_sm_pertattribs.txt
specifies the perturbation settings

```
#perttype  std    std_max   zeromean  tcorr  xcorr ycorr ccorr
Soil Moisture Layer 1
  0  0.02     0.1          1       10800   0    0    1.0 0.0 0.0 0.0
Soil Moisture Layer 2
  0  0.00     0.1          1       10800   0    0    0.0 1.0 0.0 0.0
Soil Moisture Layer 3
  0  0.00     0.1          1       10800   0    0    0.0 0.0 1.0 0.0
Soil Moisture Layer 4
  0  0.00     0.1          1       10800   0    0    0.0 0.0 0.0 1.0
```

Observation perturbations

```
Observation perturbation algorithm:        "GMAO scheme"
Observation perturbation frequency:        "6hr"
Observation attributes file:                ./DA_INPUT/smap_attribs.txt
Observation perturbation attributes file:   ./DA_INPUT/smap_pertattribs.txt
```

smap_attribs.txt
specifies the variables and their ranges

```
#nfields
1
#name  varmin  varmax
SMAP soil moisture
  0.01 1.0
```

smap_pertattribs.txt
specifies the perturbation settings

```
#perttype std  std_max  zeromean  tcorr  xcorr ycorr ccorr
SMAP soil moisture
  0   0.04     2.5      1  43200   0    0    1.0
```

Running the LIS SMAP DA Experiment

- Run the ***LIS*** executable with the Noah 3.6 - SMAP DA config file:

  LIS -f lis.config_noah36_smapda

- We will run this experiment with 1 processor, though you could set it up to run in parallel. With 1 processor, it could take about 30 minutes to run.
- Was the run successful?
  - **Yes** ⇒ *Great job!*
  - **No** ⇒ *look at the error message and lislog file*
- When the run is complete, you can view the output and compare with the OL case (from Step 2), with GraDS, Matlab, etc.
- In Step 7, we will use LVT to process the output of the OL and DA runs.