This is the code for the paper Impact of Non-Smooth Observation Operators on Variational and Sequential Data Assimilation for a Limited-Area Shallow Water
Equations Model. J. L. Steward, I.M.Navon,M. Zupanski and N. Karmitsa. Quart. Jour. Roy. Met Soc. , Volume 138, Issue 663, 323--339, January 2012, Part B (2012).
There are the following executables available:

Utility programs:

swe-getEnsemble.exe
swe-getInit.exe

Data assimilation programs:

swe-3dvar.exe
swe-4dvar.exe
swe-enkf.exe
swe-letkf.exe
swe-mlef.exe

These programs are driven by the namelist.swm file.  The contents of this file are:

```
&SIZEDATA
 N = 21
 M = 21
 K_START = 1
 K_END = 1
 K_MAX = 80/
&ICDATA
 LENGTH = 6000000.,
 DEPTH = 4400000.,
 H0 = 2000.,
 H1 = -220.,
 H2 = 133./
&PERTURBATION
 NoMembers=96,
 DX=300.,
 DY=220.,
 CorrH=7000.,
 CovInflation=1.0,
 UBackgroundStddev=20.,
 VBackgroundStddev=20.,
 PhiBackgroundStddev=200./
&OBS_ERRORS
 UObsStddev=1.,
 VObsStddev=1.,
 PhiObsStddev=12./
&TEST_CASES
 ObsOpNum=1,
 OptimizerNum=1,
```

```
 ObsOpSmoothing=0,
 ObsOpSmoothingKU=1.,
 ObsOpSmoothingKV=20.,
 ObsOpSmoothingKPhi=0.01,
 CovLocalizationLength=7000.,
 Delta=1d-4/
```

The SIZEDATA section is for the size of the domain; K is the number of timesteps to evolve the shallow water equations model forward in time.

ICDATA are for parameters related to the Shallow Water Equations initial conditions, which as explained in the paper are derived from Grammelvelt.

The PERTURBATION section describes how to perturb the ensemble for the ensemble-based methods (letkf, enkf, and mlef). This aspect of the data assimilation is highly idealized and could use an update.

The OBS_ERRORS observation errors are the size of the errors to add to the non-smooth observation operators, which again are described in the paper.

Finally, the TEST_CASES section is for the test cases to run. ObsOpNum can be from 1 to 4, where 1 is the smooth (identity) operator, and options 2-4 are for the operators 1-3 listed in the QJRMS paper. The optimizerNum is used to specify the optimization algorithm. 1 is L-BFGS, 2 is LMBM, 3 is DESCON, and 4 is CG-Descent. ObsOpSmoothing attempts to smooth the discontinuity in the fashion of ECWMF e.g. Janiskova, while the other parameters control the length of smoothing. CovLocalizationLength is the localization length used in covariance localization, and finally Delta is the parameter used to control the size of the worst discontinuity, ObsOpNum=4 (test case 3 in the paper).

When running a particular test case, one should:

0) Run make to build the code. The Makefile should be self-explanatory.
1) Change the namelist.swm for the desired options
2) Run swm-getInit.exe to create the necessary initial conditions and observations with the requested observation operator.
3) Run swm-getEnsemble.exe to create the initial ensemble.
4) Run the desired test case, e.g. swm-mlef.exe. This will output the optimization history for each assimilation cycle, with the exception of swe-4dvar.exe, which only has a single cycle over all the observations.
5) Various output files will be created such as the RMSE and Cost history. These should be fairly self-explanatory as well.

Please contact steward@jpl.nasa.gov if you have additional questions.