CREST
Coupled Routing and Excess Storage
User Manual
Version 2.0

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1 Introduction

The Coupled Routing and Excess STorage (CREST) distributed hydrological model is a hybrid modeling strategy that was developed by the University of Oklahoma (http://hydro.ou.edu) and NASA SERVIR Project Team (www.servir.net). The CREST model was initially developed to provide real-time regional and global hydrological prediction by simultaneously running over multi-basins with relatively cost-effective computational efficiency (http://eos.ou.edu), however it is also very applicable for small to medium size basins at high-resolutions. CREST simulates the spatiotemporal variation of water and energy fluxes and storages on a regular grid with the grid cell resolution being user-defined, thereby enabling multi-scale applications (Figure 1-1). The scalability of CREST simulations is accomplished through sub-grid scale representation of soil moisture storage capacity (using a variable infiltration curve) and multi-scale runoff generation processes (using multi-linear reservoirs). The representation of the primary water fluxes such as infiltration and routing are physically related to the spatially variable land surface characteristics (i.e., vegetation, soil type, and topography etc.). The runoff generation component and routing scheme are coupled, thus providing realistic interactions between lower atmospheric boundary layers, terrestrial surface, and subsurface water. The above features enable CREST to be applicable at large global, regional, and small catchment scales.

This user manual and the accompanying code provide a single basin example to test the model. The CREST model can be forced by gridded potential evapotranspiration and precipitation datasets (e.g. satellite-based precipitation estimates, interpolated rain gauge observations, weather radar, and quantitative precipitation forecasts from numerical weather prediction models). The flexible simulation modes and embedded automated calibration algorithms make the CREST a powerful yet cost-effective tool for distributed hydrological modeling and implementation at a range of scale from globe, region, basin, to small catchment.
Figure 1-1 Core Components of the CREST model

(a) Vertical profile of a cell including rainfall-runoff generation, evapotranspiration, sub-grid cell routing and feedbacks from routing; (b) variable infiltration curve of a cell; (c) plane view of cells and flow directions; and (d) vertical profile along several cells including sub-grid cell routing, downstream routing, and subsurface runoff redistribution from a cell to its downstream cells.
2 Compilations

CREST v2.0 is written in FORTRAN, and will run under most operating systems. It has been successfully implemented on Pentium & PC based systems (under Microsoft Windows and Linux).

It is not necessary to modify the source code of CREST in order to change settings or switch to other basins. In CREST v1.6, the control file with a default name of “control.txt” and basic grids dictate the necessary settings for running the model. However, CREST v2.0 uses “ProjectName.Project” instead of the “control.txt”. User can use project name as the Project file’s name, this makes the Project file more readable.

2.1 Compiling on Linux

The Linux/Unix operating systems are case sensitive. So when you compile CREST v2.0, you must pay attention to the name and extension of the default file.

2.1.1 Using “ifort” compiler

Compiling CREST is easy with FORTRAN compiler. The source code of CREST model is contained in a single file for ease of use. As such, in order to compile CREST using ifort all you need to do is to type a simple command line "ifort crest_v2_0.for –o crest_v2_0.lx". This will compile the CREST FORTRAN source code file into an executable named "crest_v2_0.lx". The Intel FORTRAN compiler has many other command line arguments to enable additional optimizations and other features. If you want a full list and description of how to use ifort, please consult the Intel FORTRAN compiler user manual.

2.2 Compiling on Windows

2.2.1 Using “Compaq Visual FORTRAN” (CVF) compiler

Compiling CREST is also very easy using CVF on Windows platforms, you can just open the “crest_v2_0.for” by CVF, and then compile it, and finally, “crest_v2_0.exe” will be created. If you want a full list and description of how to use CVF, please consult the Compaq Visual FORTRAN compiler user manual.
3 Framework of CREST v2.0

3.1 Programming Framework of CREST v2.0

Comparing to previous CREST v1.6c, the programming framework of CREST v2.0 was redesigned to better suit for distributed hydrological modeling. As shown in Figure 3-1, CREST v2.0 includes more spatially distributed input data (including a prior parameters) and outputs more variables data.

![Figure 3-1 Programming Framework of CREST v2.0](image)

3.2 Organization of the files and folders

The previous version CREST v1.6c puts all data information into “Control.txt” (Figure 3-2); this will make the control file too big when modelers want to add other parameters or data into the CREST. Additionally, when implementation of the model becomes complex, it will contain too many files under one file folder, causing non-necessary confusion and inconvenience to users or modelers.
In CREST v2.0, control file was divided into “ProjectName.Project”, “Parameters.txt”, “InitialConditions.txt” and “Calibrations.txt”. Each of four files is put in standalone folders, including other related data and files. Thus the “ProjectName.Project” file only contains the model’s input information and its
configuration. This will enables user to build and modify these files easily. Figure 3-3 shows all the folders defined in CREST v2.0 based on their functionality. More detailed information of these folders will be discussed in following sections.

Figure 3-3 Files’ and Folders’ Organization of CREST v2.0
4 Project File

The file “ProjectName.Project” contains the information about Model Area, Run Time Information, Configuration Directory, Run Style, Outputs Information for Specified Pixels and Outlet, Outputs States and Outputs Date, and it also contains file assignments and their formats (One line for each assignment or information).

The “ProjectName” is the name of the project, when run CREST v2.0 on Linux/Unix operating system, the extension of project file should write as “Project”, not “project” or others.

Note:

The statement in the project file can be listed in any order, but the keywords should not be changed. The format of the statement is:

```
Keyword    =    Value
```

The statement appearing on the same line should be space- or tab-separated.

Comment lines must have a pound sign, #, in the first column.

Comment for the statement in the line must be placed after Value and be sure to leave at least one space or tab between the Value and the comments.

Keyword is not case sensitive.

4.1 Model Area

```
# MODEL AREA
NCols     =    197   # Number of columns
NRows     =    167   # Number of rows
XLLCorner =   33.94999
YLLCorner =  -0.1083333
CellSize  =  0.008333334
NoData_value =  -9999.
```

Figure 4-1 Sample Model Area in “ProjectName.Project”

NCols: Number of cell columns;
NRows: Number of cell rows.
XLLCorner : X coordinate of the origin (by lower left corner of the cell).
YLLCorner : Y coordinate of the origin (by lower left corner of the cell).
CellSize: Cell Size.
NoData_Value: The input values to be No Data in the input/output map file.

4.2 Model Run Time Information

<table>
<thead>
<tr>
<th>Line</th>
<th>Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>14</td>
<td>#########################################################################</td>
</tr>
<tr>
<td>15</td>
<td># MODEL Run Time Information</td>
</tr>
<tr>
<td>16</td>
<td>y(year);m(month);d(day);h(hour);u(minute);s(second)</td>
</tr>
<tr>
<td>17</td>
<td>#########################################################################</td>
</tr>
<tr>
<td>18</td>
<td>TimeMark = h</td>
</tr>
<tr>
<td>19</td>
<td>TimeStep = 3</td>
</tr>
<tr>
<td>20</td>
<td>StartDate = 2003010100</td>
</tr>
<tr>
<td>21</td>
<td>LoadState = no</td>
</tr>
<tr>
<td>22</td>
<td>WarmupDate = 2003010100</td>
</tr>
<tr>
<td>23</td>
<td>EndDate = 200301100</td>
</tr>
<tr>
<td>24</td>
<td>SaveState = no</td>
</tr>
<tr>
<td>25</td>
<td>#########################################################################</td>
</tr>
</tbody>
</table>

Figure 4-2 Sample Model Run Time Information in “ProjectName.Project”

TimeMark: The unit of time step. The possible units are “y” (year), “m” (month), “d” (day), “h” (hour), “u” (minute), “s” (second).

TimeStep: Time Step.

StartDate: Start date of the simulation, its format is defined as “yyyyymmddhhmsu”, the length is up to the time step unit, for example, “yyyy” when time step unit is “y”; “yyyyymmddhhmsu” when time step unit is “s”

LoadState: The mark for reading the state file. “yes” means user want to run the model by state files as initial value, “no” means the initial values are read determined by initial condition file.

WarmupDate: Warm up date for the simulation, its format is defined the same as “StartDate”.

EndDate: End date for the simulation, its format is defined the same as “StartDate”.

SaveState: The mark for saving the state file. “yes” means user want to save the state files when finished running the model, “no” means user does not want to save the state files.
4.3 Model Run Style

```plaintext
#!/usr/bin/env python

#='%MODEL Run Style

RunStyle = simu # simu, cali SCEUA, RealTime, repe
```

Figure 4-3 Sample Model Run Style in “ProjectName.Project”

The run style “simu” means simulation; other possible run styles are “cali_SCEUA” (automatic calibration using SCE-UA method), “RealTime” (on line mode), “repe” (return period) and “Forecast_KMDQPF” (Forecast using KMD QPF Data) modes.

4.4 Model Directory

```plaintext
#ForResourceDirectory

BasicFormat = asc
BasicPath = ".\XXW_NZ01a_Project\Basics\"

ParamFormat = asc
ParamPath = ".\XXW_NZ01a_Project\Params\"

StateFormat = asc
StatePath = ".\XXW_NZ01a_Project\States\"

ICsFormat = asc
ICsPath = ".\XXW_NZ01a_Project\ICS\"

RainFormat = asc
RainPath = ".\XXW_NZ01a_Project\Rains\NZ01a.rain."

PETFormat = asc
PETPath = ".\XXW_NZ01a_Project\PETs\NZ01a.pet."

ResultFormat = asc
ResultPath = ".\XXW_NZ01a_Project\Results\"

CalibFormat = asc
CalibPath = ".\XXW_NZ01a_Project\Calibs\"

OBSFormat = asc
OBSPath = ".\XXW_NZ01a_Project\OBS\"
```

Figure 4-4 Sample Model Directory in “ProjectName.Project”
As shown in Figure 3-3, CREST v2.0 divides the input and output data into 9 groups, each groups has a standalone folders, such as “Basics”, “Params”, “States”, “ICS”, “Rains”, “PET”, “Results”, “Calibs” and “OBS” (the name of the folder can be user-specified, but the its keyword is fixed). Each folder contains some files (detailed content will be introduced in the next chapter), the format of the folder means all or most of the files in this folder will use this format. The file possible formats of CREST v2.0 are "ASC", "TXT", "DBIF", "BIFFIT", "TRMMRT", "TRMMV6", "NMQBIN", "ASBIMO" and "BIBIMO".

4.5 OutPix Information

![Sample OutPix Information in “ProjectName.Project”](image)

**NOutPixs**: The number of output pixels

**OutPixColRow**: **OutPixColRow** is specified if the pixel is relative to the basic grids or in latitude and longitude. A value of “yes” means the location of the pixels is a column and row, a value of “no” means the location is longitude and latitude.

**OutPixNameX**: The name of the Xth Pixels. The value of “X” is up to **NOutPixs** (X = [1~ NOutPixs]).

**OutPixLongX**: The longitude of the Xth Pixels when OutPixColRow is assigned “no”.

**OutPixLatiX**: The latitude of the Xth Pixels when OutPixColRow is assigned “no”.

**OutPixColX**: The Column of the Xth Pixels when OutPixColX is assigned
“yes”.

OutPixRowX: The Row of the Xth Pixels when OutPixColX is assigned “yes”.

4.6 Outlet Information

```
73 ##########################################################
74 #Outlet Information
75 ##########################################################
76 HasOutlet = yes
77 OutletColRow = no
78 OutletName = NZ01a
79 OutletLong = 34.08749
80 OutletLati = 0.1208334
81 ##########################################################
```

Figure 4-6 Sample Outlet Information in “ProjectName.Project”

HasOutlet: Whether have outlet or not, a value of “yes” means research area has an outlet, a value of “no” means have not.

OutletColRow: **OutletColRow** is specified if the outlet is relative to the basic grids or in latitude and longitude. A value of “yes” means the outlet of the pixels is a column and row, a value of “no” means the outlet is longitude and latitude.

OutletName: The name of the outlet Pixels.

OutletLong: The longitude of the Outlet Pixels when **OutletColRow** is assigned “no”.

OutletLati: The latitude of the Outlet Pixels when **OutletColRow** is assigned “no”.

OutletCol: The Column of the Outlet Pixels when **OutletColRow** is assigned “yes”.

OutletRow: The Row of the Outlet Pixels when **OutletColRow** is assigned “yes”.

4.7 Grid Outputs

**Grid Outputs** is the control of 2-D grid-based output, “yes” means output and “no” means do not output. The run time of the model depends on the number of
outputs. A faster CREST model runtime can be achieved by reducing the number of output variables. Output format is controlled by the ResultFormat in section 4.4. All outputs are spatially interpolated to the proper resolution and clipped to either the basic grids or the drainage area automatically.

```plaintext
# Grid Outputs
GOVar_Rain = no
GOVar_PET = no
GOVar_EPOT = no
GOVar_EAct = no
GOVar_W = no
GOVar_SM = no
GOVar_R = no
GOVar_ExcS = no
GOVar_ExcI = no
GOVar_RS = no
GOVar_RI = no
```

Figure 4-7 Sample Grid Outputs in “ProjectName.Project”

- **GOVar_Rain**: The input precipitation; unit is mm/hour.
- **GOVar_PET**: The input PET; unit is mm/hour.
- **GOVar_EPOT**: $\text{GOVar_PET} \times KE$
- **GOVar_EAct**: The depth of simulated actual evapotranspiration; unit is mm/hour.
- **GOVar_W**: The depth of water filling the pore space bucket "$\text{WM}$"
- **GOVar_SM**: Soil Moisture, a percentage of the $\text{WM}$ and equals $\text{GOVar_W}/\text{WM}$
- **GOVar_R**: The simulated discharge of each grid cell; unit is m³/s.
- **GOVar_ExcS**: The depth of surface excess rain; unit is mm/hour.
- **GOVar_ExcI**: The depth of interflow excess rain; unit is mm/hour.
- **GOVar_RS**: The depth of overland flow; unit is mm/hour.
- **GOVar_RI**: The depth of interflow flow; unit is mm/hour.
4.8 Date Outputs

Figure 4-8 Sample Output Dates in “ProjectName.Project”

Date Outputs is to be specified some dates what user is interested in.

NumOfOutputDates: The Number of Output Date
OutputDate_X: The Xth Date to output, The value of “X” is up to NumOfOutputDates (X = [1~ NumOfOutputDates]).

4.9 Number of Lakes

Figure 4-9 Sample Number Lake in “ProjectName.Project”

NumOfLakes is to be specified the number of Lakes in this research region.

NumOfLakes: The Number of Lakes
5 Inputs & Outputs

CREST v2.0 can read all the Grid file formats (such as "ASBIMO", "BIBIMO", "ASC", "TXT", "DBIF","BIFFIT", "TRMMRT", "TRMMV6" and "NMQBIN") and can clip the file automatically when this file is not equal to the extent defined in “ProjectName.Project”, so user does not need to extract the research area by themselves as long as your prepared input files have broader space domain.

5.1 Basics Folder

This folder contains the basic file for the model, such as DEM file, FDR file (Flow Direction), FAC file (Flow Accumulation) and so on.

5.1.1 DEM File

Required:
Always

Name:
DEM.*

Format:
All Formats

Purpose:
Contains a digital elevation model of the basin area, with heights in meters

Notes:
The coordinate system of CREST v2.0 can use both Geographic Coordinate System and Projected Coordinate System (PCS)

5.1.2 FDR File

Required:
Always
**Name:**

FDR.*

**Format:**

All Formats

**Purpose:**

Contain a flow direction from each cell to its steepest downslope neighbor of the basin area.

**Notes:**

The coordinate system of FDR File should be same as DEM File.

In the former version of CREST, direction coding only use the rule like Figure 5-1 (a) generated by “CNT”, however, most popular software (like ArcGIS) use the rule like Figure 5-1 (b), so CREST v2.0 uses both of the two rules.

![Figure 5-1 Flow Direction Coding](image)

5.1.3 FAC File

**Required:**

Always

**Name:**

FAC.*
**Format:**

All Formats

**Purpose:**

Contains accumulation flow to each cell of the basin area.

**Notes:**

The coordinate system of FAC File should be same as DEM File.

---

### 5.1.4 Mask File

**Required:**

Optional

If omitted

If `HasOutlet` == "yes", then CREST v2.0 will generate the mask file based on Outlet location.

If `HasOutlet` == "no", then CREST v2.0 will generate the mask file based on NoData_Value in DEM file.

**Name:**

Mask.*

**Format:**

All Formats

**Purpose:**

Contains a mask of the basin, indicating which cells in the other terrain are inside the basin.

**Notes:**

The coordinate system of Mask File should be same as DEM File.

---

### 5.1.5 GridArea File

**Required:**

Optional
If omitted, CREST v2.0 will generate the GridArea file based on the coordinate system.

**Name:**

GridArea.*

**Format:**

All Formats

**Purpose:**

Contain the area of each cell in the basin

**Notes:**

The coordinate system of GridArea File should be same as DEM File.

### 5.1.6 AreaFact File

**Required:**

Optional

If omitted, CREST v2.0 will assign AreaFact.file a uniform value (1.00).

**Name:**

AreaFact.*

**Format:**

All Formats

**Purpose:**

Contains the area of each cell in the basin

**Notes:**

The coordinate system of AreaFact File should be same as DEM File.

### 5.1.7 Stream File

**Required:**

Optional, however if Stream file is omitted, Stream.def must be required.

If omitted, CREST v2.0 will read the threshold to determinate the stream from Stream.def.
**Name:**
Stream.*

**Format:**
All Formats

**Purpose:**
Contain the information to show whether each cell is the stream.

**Notes:**
The coordinate system of Stream File should be same as DEM File.

### 5.1.8 Stream.def File

**Required:**
Optional, however if Stream.def is omitted, Stream file must be required.
Only use when Stream file omitted.

**Name:**
Stream.def

**Format:**
ASCII, only contain one value

**Purpose:**
Contain the threshold for determining the stream.

**Notes:**
Stream.def is used to compatible with the former version of CREST, instead of Th parameter in the former version of CREST.

### 5.1.9 Slope File

**Required:**
Optional
If Slope omitted
If Slope.def exists, CREST v2.0 will calculate the Slope like the former version.
If Slope.def does not exist, CREST v2.0 will calculate the Slope automatically.

**Name:**
Slope.*

**Format:**
All Formats

**Purpose:**
Identify the rate of maximum change in DEM file from each cell.

**Notes:**
The coordinate system of Slope File should be same as DEM File.

### 5.1.10 Slope.def File

**Required:**
Optional

Only use when Slope file omitted, CREST v2.0 will read this file. If Slope.def is omitted yet, CREST v2.0 will calculate the Slope automatically.

**Name:**
Slope.def

**Format:**
ASCII, only contain one value

**Purpose:**
Contain the threshold for determining the stream.

**Notes:**
Slope.def is used to compatible with the former version of CREST, instead of GM parameter in the former version of CREST.

### 5.1.11 Lake Mask File

**Required:**
Optional

If NumOfLakes==0 then
omitted
Name:
LakeMask.*

Format:
All Formats

Purpose:
Contains a mask of lakes in this region, indicating which cells is the lake

Notes:
The coordinate system of LakeMask File should be same as DEM File.

5.2 Params Folder

This folder contains all the configuration and values of parameters for the model. There are total 18 parameters, classified into four types in this new version (see Table 5-1).

CREST v2.0 puts the initial condition into ICS folder (will introduce later), TH and GM are optional control parameters, and AreaFact can be calculated by ArcGIS or other software, or by CREST v2.0 automatically. So, there are 12 essential parameters in CREST v2.0. The look up tables, the range and the default value of part/all of these parameters are listed in Appendices Table 10-1, Table 10-2 and Table 10-3.
### Table 5-1 Classification in CREST v2.0 vs v1.6c

<table>
<thead>
<tr>
<th>Module</th>
<th>Symbol (v2.0)</th>
<th>Symbol (v1.6c)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Initial condition</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Initial</td>
<td>W0</td>
<td>iWU</td>
<td>Initial Value of Soil Moisture</td>
</tr>
<tr>
<td>condition</td>
<td>SS0</td>
<td>iSO</td>
<td>Initial value of Overland Reservoir</td>
</tr>
<tr>
<td></td>
<td>SI0</td>
<td>iSI</td>
<td>Initial value of Interflow reservoir</td>
</tr>
<tr>
<td><strong>Physical</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ksat</td>
<td>pFc</td>
<td></td>
<td>the Soil saturate hydraulic conductivity</td>
</tr>
<tr>
<td>RainFact</td>
<td>Rain</td>
<td></td>
<td>the multiplier on the precipitation field</td>
</tr>
<tr>
<td>WM</td>
<td>pWm</td>
<td></td>
<td>The Mean Water Capacity</td>
</tr>
<tr>
<td>B</td>
<td>B</td>
<td></td>
<td>the exponent of the variable infiltration curve</td>
</tr>
<tr>
<td>IM</td>
<td>pIM/100</td>
<td></td>
<td>Impervious area ratio</td>
</tr>
<tr>
<td>KE</td>
<td>pKE</td>
<td></td>
<td>The factor to convert the PET to local actual</td>
</tr>
<tr>
<td>coeM</td>
<td>coeM</td>
<td></td>
<td>overland runoff velocity coefficient</td>
</tr>
<tr>
<td><strong>Conceptual</strong></td>
<td>expM</td>
<td>expM</td>
<td>overland flow speed exponent</td>
</tr>
<tr>
<td>Parameters</td>
<td>coeR</td>
<td>River</td>
<td>multiplier used to convert overland flow speed</td>
</tr>
<tr>
<td></td>
<td>coeS</td>
<td>Under</td>
<td>multiplier used to convert overland flow speed</td>
</tr>
<tr>
<td></td>
<td>KS</td>
<td>LeakO</td>
<td>Overland reservoir Discharge Parameter</td>
</tr>
<tr>
<td></td>
<td>KI</td>
<td>LeakI</td>
<td>Interflow Reservoir Discharge Parameter</td>
</tr>
<tr>
<td><strong>Adjustment</strong></td>
<td>(Omitted)/TH</td>
<td>TH</td>
<td>Threshold to determine which cells are river cells</td>
</tr>
<tr>
<td>Parameters</td>
<td>(Omitted)/GM</td>
<td>GM</td>
<td>downstream cell is higher than the upstream</td>
</tr>
<tr>
<td></td>
<td>AreaFact</td>
<td>AreaC</td>
<td>multiplier that modifies the area of grid cells</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### 5.2.1 Parameters.txt File

**Required:**

*Always*

**Name:**

Parameters.txt

**Format:**

ASCII

**Purpose:**
Contain the configuration for all parameters in CREST v2.0

Notes:

The statement in the “Parameters.txt” file can be listed in any order, but the keywords should not be changed. The format of the statement is:

Keyword = Value

Such as:

SymbolType = Uniform/Distributed

If SymbolType = Uniform then
    Symbol = Value
Else
    Symbol.* file must be provided in the same folder.
End if

The statement appearing on the same line should be space- or tab-separated.
Comment lines must have a pound sign, #, in the first column.
Comment for the statement in the line must be placed after Value and be sure to leave at least one space or tab between the Value and the Comments.
Keyword is not case sensitive.

5.2.2 “Symbol.*” File

Required:

Optional

Only needed when this parameter’s style is Distributed.

Name:

ParameterName.*
“ParameterName” possibly likes “Rain”

**Format:**

ASCII

**Purpose:**

Contain the configuration for all parameters in CREST v2.0

**Notes:**

The file coordinate system of Slope File should be same as DEM File.

### 5.3 State Folder

This folder contains the state files, such as “State_StartDate_SS0.*”, “State_StartDate_SI0.*” and “State_StartDate_W0.*” when `LoadState = “yes”`. When `SaveState = “yes”`, then “State_EndDate_SS0.*”, “State_EndDate_SI0.*” and “State_EndDate_W0.*” will be created after running the model.

### 5.4 ICS Folder

This folder contains all the configuration and values of initial conditions for the mode.

#### 5.4.1 InitialConditions.txt File

**Required:**

Always

**Name:**

InitialConditions.txt

**Format:**

ASCII

**Purpose:**

Contain the configuration for initial conditions in CREST v2.0

**Notes:**
The statement in the “InitialConditions.txt” file can be listed in any order, but the keywords should not be changed. The format of the statement is:

Keyword = Value

Such as:

SymbolType = Uniform/Distributed
If SymbolType = Uniform then
    Symbol = Value
Else
    Symbol.* file must be provided in the same folder.
End if

The Symbol includes “SS0”, “SI0” and “W0” (see Table 5-1).
The statement appearing on the same line should be space- or tab-separated.
Comment lines must have a pound sign, #, in the first column.
Comment for the statement in the line must be placed after Value and be sure to leave at least one space or tab between the Value and the Comments.
Keyword is not case sensitive.

5.4.2 “Sysmbol.*” File

Required:
Optional
Only needed when this parameter’s style is Distributed.

Name:

ParameterName.*

“ParameterName” possibly likes “Rain”

Format:

ASCII
**Purpose:**

Contain the configuration for all parameters in CREST v2.0

**Notes:**

The file coordinate system of Slope File should be same as DEM File.

### 5.5 OBS Folder

This folder contains all the observed runoff data for the model calibration or verification. The file's name is name as “OutPixNameX_Obs.csv” and/or “OutletName_Obs.csv” (“.csv” is the comma delimited file). “OutPixNameX” and “OutletName” are the same as the project file.

### 5.6 Calibs Folder

This folder contains all the configuration and values of calibration for the model.

#### 5.6.1 Calibrations.txt File

**Required:**

Always

**Name:**

Calibrations.txt

**Format:**

ASCII

**Purpose:**

Contain the configuration for calibrations in CREST v2.0

**Notes:**

The statement in the “Calibrations.txt” file can be listed in any order, but the keywords should not be changed. The format of the statement is:

```
Keyword = Value
```
The statement appearing on the same line should be space- or tab-separated.
Comment lines must have a pound sign, #, in the first column.
Comment for the statement in the line must be placed after **Value** and be sure to leave at least one space or tab between the **Value** and the **Comments**.
Keyword is not case sensitive.

```
1 # CREST Calibrations File (Version more than 2.0)
2 #################################################################################
3 iseed  =  -3
4 maxn  =  2000
5 kstop =  10
6 pctnc =  0.0001
7 ngs  =  2
8 NCalibStations =  1
9 IsColRow = no    # yes: use Col & Row; No: Lat & Lati
10 [Station 1 Begin]
11 Name_1 = NZ01a
12 Long_1 =  34.08749
13 Lat_1  =  0.1208334
14 #RainFact_1 = 0.9  0.95  1.2
15 #Ksat_1  = 0.9  0.95  1.2
16 #WM_1   = 0.9  0.95  1.2
17 #B_1    = 0.9  0.95  1.2
18 #LM_1   = 0.9  0.95  1.2
19 #KE_1   = 0.9  0.95  1.2
20 #cmeM_1 = 0.9  0.95  1.2
21 #expM_1 = 0.9  0.95  1.2
22 #corR_1 = 0.9  0.95  1.2
23 #cosM_1 = 0.9  0.95  1.2
24 #RS_1   = 0.9  0.95  1.2 # Min Value Max
25 #R1    = 0.9  0.95  1.2
26 [Station 1 End]
```

Figure 5-2 Sample of “Calibrations.txt” file

1. SCE-UA Parameters
   - **iseed**: Initial random seed;
   - **maxn**: Max no. of trials allowed before optimization is terminated
   - **kstop**: Number of shuffling loops in which the criterion value must change by the given percentage before optimization is terminated
pcento: Percentage by which the criterion value must change in given number of shuffling loops
ngs: Number of complexes in the initial population

2. Configuration for calibration
   NCalibStations: Number of Calibrated Stations
   IsColRow: Specified if the location of calibrated station is relative to the basic grids or in latitude and longitude. A value of “yes” means the outlet of the pixels is a column and row, a value of “no” means the outlet is longitude and latitude.

3. Configuration for Each Station
   Name_X: The name of the Xth station
   Value_X: The region value of the Xth station
   Long_X: The longitude of the Xth station when IsColRow is assigned “no”.
   Lati_X: The latitude of the Xth station when IsColRow is assigned “no”.
   Col_X: The Column of the Outlet Pixels when IsColRow is assigned “yes”.
   Row_X: The Row of the Outlet Pixels when IsColRow is assigned “yes”.
   Label_X: The minimum, initial value and maximum of the Xth Label parameter for calibration. The label name can see Table 5-1. The format of this statement is:
   Label_X = Min Value Max
   X is the number of station to calibration.
   Only required when user want to calibrate this parameter.

5.6.2 CalibMask.* File

Required:
   Allways

Name:
CalibMask.*

**Format:**
All Formats

**Purpose:**
Contain the order number for calibration, when have more than ONE calibrated station. The number depends on the regional number of each station.

**Notes:**
The coordinate system of CalibMask File should be same as DEM File.

**5.7 Rains Folder**

This folder contains the precipitation data, the format of file in the folder depending on the **RainFormat** specified in the “ProjectName.Project” file. The CREST v2.0 can clip the region defined in the “ProjectName.Project” file automatically.

**5.8 PETs Folder**

This folder contains the potential evaporation data, the format of file in the folder depending on the **PETFormat** specified in the “ProjectName.Project” file; and the CREST v2.0 can clip the region defined in the “ProjectName.Project” file automatically.

**5.9 Results Folder**

This folder contains the output files, the format of file in the folder depending on the **ResultFormat** specified in the “ProjectName.Project” file.
6 Run Styles

Different run styles have different combinations of outputs; the following section will introduce the outputs for each style.

6.1 Simulation

6.1.1 Running in Simulation Mode

To run the model in simulation mode the run style in the project file must be set to "simu". Precipitation data and PET data are also needed for the simulation period. By default CREST reads the “ProjectName.Project” located in the current working directory. However, as of CREST v2.0 it is possible to specify the project file name as a command line option to the CREST executable.

6.1.2 Simulation Mode Standard Outputs

![Figure 6-1 Output results in screen for Simulation mode](image)
The 1 line is the comment for requiring user to enter the name of the project file. The 2 line is the user-typed line for the name and path of the project file. The 3 line is the separation line. The 4~6 line is the information of the CREST v2.0. The 7 line is the separation line. The 8 line is the start date and time for running the model. The 9 line is the separation line. The 10~21 line is the reading and writing data. The 22 line is the separation line. The 23 line is the information for running style to the current running model. The 24~32 line is the reading and writing data. The 33 line is the separation line. The 34~37 line is the output results. The 38 line is the separation line. The 39 line is the end date and time for running the model. The 40 line is the elapsed run time for running the model.

6.1.3 Simulation Mode File Outputs

Besides output the results to the screen, CREST v2.0 also outputs the results to a log file in the same folder as project file, named as “ProjectName_YYYY.MM.DD-HH.UU.SS_CREST.log”, for example: “NZoia_2011.02.07-00.33.05_CREST.log”. The time in this file’s name depending on the date and time the model is running. The log file will help the user record all the things the user wants to see, even on the Linux operating system.

There are many files to output when the model is running in the simulation mode:

- **Mask.**: When the mask file is omitted in the basics folder.
- **Slope.**: When the slope file is omitted in the basics folder.
- **Outlet_OutletName_Mask.**: The mask file for the specified outlet.
- **Outlet_OutletName_Results.csv**: The results for the outlet location (Table 6-1). (Regional Mean Value based on the **Outlet_OutletName_Mask.**)
6.2 Automatic Calibration using SCE-UA

6.2.1 Running in Automatic Calibration Mode using SCE-UA

To run the model in automatic calibration mode using SCE-UA, the run style in the project file must be set to "cali_SCEUA". Precipitation data, PET data and observed discharge are all needed for the calibration period. A special feature such as Reinitializing or Resuming Calibration has been included in CREST v2.0.

6.2.2 Automatic Calibration Mode Standard Output using SCE-UA
Figure 6-2 Output results in screen for cali_SCEUA mode
6.2.3 Automatic Calibration Mode File Output using SCE-UA

Besides output the results to the screen, CREST v2.0 also outputs the results to a log file in the same folder as project file, named as “ProjectName_YYYY.MM.DD-HH.MM.SS_CREST.log”, for example: “NZoia_2011.02.07-00.33.05_CREST.log”. The time in this file’s name depending on the date and time the model ran. The log file will help the user record all the things the user wants to see, even on the Linux operating system.

There are many files to output when the model is running in the “cali_SCEUA” mode:

- **Mask.**: When the mask file is omitted in the basics folder.
- **Slope.**: When the slope file is omitted in the basics folder.
- **Outlet_OutletName_Mask.**: The mask file for the specified outlet.
- **Outlet_OutletName_Results.csv**: The results for the outlet location (Table 6-1).
(Regional Mean Value based on the
Outlet_OutletName_Mask.*)

Outlet_OutletName_Results_Statistics.csv: The statistics for outlet location.

OutPix_OutPixName_X_Mask.*: The mask file for the specified output pixel.

OutPix_OutPixName_X_Results.csv: The results for the output pixel location.

(Regional Mean Value based on the
Outlet_OutPixName_X_Mask.*)

OutPix_OutPixName_X_Results_Statistics.csv: The statistics for outlet location.

SCEUAOut_YYYY.MM.DD-HH.UU.SS.dat: The results for SCE-UA method

Label.*: The calibrated parameters file. Labels shows in Table 5-1.

6.3 Simulation in real time mode

6.3.1 Running in Real Time Mode

To run the model in real time mode, the run style in the project file must be set to "RealTime". Precipitation data and PET data are needed for the real time period.

6.3.2 Real Time Mode Standard Output

It is the same as Simulation mode, however, the end date and time depending on the latest available precipitation and PET data or images.

6.3.3 Real Time Mode File Output

It is the same as Simulation, however, the end date and time is up to the available precipitation and PET.

6.4 Return Period mode

6.4.1 Running in “repe” Mode

To run the model in “repe” (Return Period) mode, the run style in the project file must be set to "repe". It needs run the model in “simu” mode with GOVar_R="yes" in advance, and then run the model in “repe” mode.
Figure 6-3 Output results in screen for Return Period mode

The 1 line is the comment for requiring user to enter the name of the project file.
The 2 line is the user-typed line for the name and path of the project file.
The 3 line is the separation line.
The 4~6 line is the information of the CREST v2.0.
The 7 line is the separation line.
The 8 line is the start date and time for running the model.
The 9 line is the separation line.
The 10~19 line is the reading and writing data.
6.4.3 Return Period Mode File Output

Besides output the results to the screen, CREST v2.0 also outputs the results to a log file in the same folder as project file, named as “ProjectName_YYYY.MM/DD-MM.SS_CREST.log”, for example: “NZoia_2011.02.07-00.33.05_CREST.log”. The time in this file’s name depending on the date and time the model ran. The log file will help the user record all the things the user wants to see, even on the Linux operating system.

There is only one types of file to output when the model is running in the “repe” mode:

- **Level.X.**: X is the level number, recording the return period values.

6.5 Forecast_KMDQPF mode

6.5.1 Running in “Forecast_KMDQPF” Mode

To run the model in forecast KMDQPF mode, the run style in the project file must be set to "Forecast_KMDQPF". Precipitation data and PET data are also needed for the Forecast KMDQPF period mode.

6.5.2 Forecast KMDQPF Mode Standard Output

The same as the standard output of real time running mode, except of the
information for running style to the current running model.

6.5.3 Forecast KMDQPF Mode File Output

Besides output the results to the screen, CREST v2.0 also outputs the results to a log file in the same folder as project file, named as “ProjectName_YYYY.MM.DD-HH.MM.SS_CREST.log”, for example: “NZoia_2011.02.07-00.33.05_CREST.log”. The time in this file’s name depending on the date and time the model ran. The log file will help the user record all the things the user wants to see, even on the Linux operating system.
7 Implementation of the CREST model for other basins

The CREST model automatically runs over the region defined by the project file. Therefore, if you are operating with global basic grids it is possible to easily and quickly model a basin in the world by just simply defining the outlet of a new basin. In the event that the basic grids you are using do not cover the region which you want to model or if you want to model a region with a finer resolution then it is necessary to derive new project file. The steps to do this are described below.

Fully implementing the CREST model on any basin can be achieved in a three step process:

1. A project file for the new modeling region needs to be created.
   a. Copy an existing project file (even one of the provided example project files) and modify the paths to point to the location of the new paths of the folders.
   b. Determine the latitudes and longitudes of a rectangle around the region which you wish to model. These do not have to be precise by any means and can be pulled from Google Earth or Google Maps for an approximate region around the basin you wish to model. However, **the basin you wish the model on must be entirely contained in the bounding rectangle you specified.**
   c. In order for CREST to work with the DEM, FDR and FAC files produced by the CNT Tool or other software, they must be named DEM.*, FDR.* and FAC.*.

2. The model can now be run for your new basin in any desired modes. To get realistic results it is necessary to generate *a prior* parameters from available land surface datasets or later calibrate the model using a gauged station within your defined new basin. The automatic calibration built into the CREST model is the easiest way to calibrate the model.
8 Contact us

Development and maintenance of the current official version of the OU-NASA CREST model is conducted at the University of Oklahoma, Hydrometeorology and Remote Sensing Laboratory (http://hydro.ou.edu) and Atmospheric Radar Research Center (ARRC) located in the National Weather Center (http://nwc.ou.edu). For information about the current release of the CREST model or to get the source code for beta versions of releases under development, please send e-mail to Dr. Yang Hong (yanghong@ou.edu) and/or Dr. Xianwu Xue (xuexianwu@ou.edu).

9 Selected CREST model Related References


## 10 Appendix A Look-up Tables

### Table 10-1 Look-up Table for UMD Vegetation Types

<table>
<thead>
<tr>
<th>Value</th>
<th>UMD Vegetation Category</th>
<th>Rooting Depth (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Water</td>
<td>0.001</td>
</tr>
<tr>
<td>1</td>
<td>Evergreen Needleleaf Forest</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>Evergreen Broadleaf Forest</td>
<td>1.25</td>
</tr>
<tr>
<td>3</td>
<td>Deciduous Needleleaf Forest</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>Deciduous Broadleaf Forest</td>
<td>1.25</td>
</tr>
<tr>
<td>5</td>
<td>Mixed Forest</td>
<td>1.125</td>
</tr>
<tr>
<td>6</td>
<td>Woodland</td>
<td>0.997</td>
</tr>
<tr>
<td>7</td>
<td>Wooded Grassland</td>
<td>0.872</td>
</tr>
<tr>
<td>8</td>
<td>Closed Shrubland</td>
<td>0.651</td>
</tr>
<tr>
<td>9</td>
<td>Open Shrubland</td>
<td>0.578</td>
</tr>
<tr>
<td>10</td>
<td>Grassland</td>
<td>0.75</td>
</tr>
<tr>
<td>11</td>
<td>Cropland</td>
<td>0.75</td>
</tr>
<tr>
<td>12</td>
<td>Bare Ground</td>
<td>0.55</td>
</tr>
<tr>
<td>13</td>
<td>Urban and Built</td>
<td>0.797</td>
</tr>
</tbody>
</table>
### Table 10-2 Look-up Table for HWSD Soil Texture

<table>
<thead>
<tr>
<th>Code</th>
<th>Texture</th>
<th>Abbr.</th>
<th>$\theta_f$ (m$^3$/m$^3$)</th>
<th>$\theta_{pw}$ (m$^3$/m$^3$)</th>
<th>$K_{sat}$ (cm/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>No_Soil</td>
<td>NS</td>
<td>0</td>
<td>0</td>
<td>0.00001</td>
</tr>
<tr>
<td>1</td>
<td>Clay(heavy)</td>
<td>CH</td>
<td>0.36</td>
<td>0.21</td>
<td>0.03</td>
</tr>
<tr>
<td>2</td>
<td>Silty Clay</td>
<td>SIC</td>
<td>0.36</td>
<td>0.21</td>
<td>0.05</td>
</tr>
<tr>
<td>3</td>
<td>Clay</td>
<td>C</td>
<td>0.36</td>
<td>0.21</td>
<td>0.075</td>
</tr>
<tr>
<td>4</td>
<td>Silty Clay Loam</td>
<td>SICL</td>
<td>0.34</td>
<td>0.19</td>
<td>0.1</td>
</tr>
<tr>
<td>5</td>
<td>Clay Loam</td>
<td>CL</td>
<td>0.34</td>
<td>0.21</td>
<td>0.1</td>
</tr>
<tr>
<td>6</td>
<td>Silt</td>
<td>SI</td>
<td>0.32</td>
<td>0.165</td>
<td>0.495</td>
</tr>
<tr>
<td>7</td>
<td>Silt Loam</td>
<td>SIL</td>
<td>0.3</td>
<td>0.15</td>
<td>0.65</td>
</tr>
<tr>
<td>8</td>
<td>Sandy Clay</td>
<td>SC</td>
<td>0.31</td>
<td>0.23</td>
<td>0.15</td>
</tr>
<tr>
<td>9</td>
<td>Loam</td>
<td>L</td>
<td>0.26</td>
<td>0.12</td>
<td>0.34</td>
</tr>
<tr>
<td>10</td>
<td>Sandy Clay Loam</td>
<td>SCL</td>
<td>0.33</td>
<td>0.175</td>
<td>0.15</td>
</tr>
<tr>
<td>11</td>
<td>Sandy Loam</td>
<td>SL</td>
<td>0.23</td>
<td>0.1</td>
<td>1.09</td>
</tr>
<tr>
<td>12</td>
<td>Loamy Sand</td>
<td>LS</td>
<td>0.14</td>
<td>0.06</td>
<td>2.99</td>
</tr>
<tr>
<td>13</td>
<td>Sand</td>
<td>S</td>
<td>0.12</td>
<td>0.04</td>
<td>11.78</td>
</tr>
</tbody>
</table>

### Table 10-3 Range and Default value of Each Parameter

<table>
<thead>
<tr>
<th>Params</th>
<th>Min</th>
<th>Default</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>RainFact (l)</td>
<td>0.5</td>
<td>1</td>
<td>1.2</td>
</tr>
<tr>
<td>Ksat (mm/d)</td>
<td>0</td>
<td>500</td>
<td>1000</td>
</tr>
<tr>
<td>WM(mm)</td>
<td>80</td>
<td>120</td>
<td>200</td>
</tr>
<tr>
<td>B (l)</td>
<td>0.05</td>
<td>0.25</td>
<td>1.5</td>
</tr>
<tr>
<td>IM (l)</td>
<td>0</td>
<td>0.05</td>
<td>0.2</td>
</tr>
<tr>
<td>KE (l)</td>
<td>0.1</td>
<td>0.95</td>
<td>1.5</td>
</tr>
<tr>
<td>coeM</td>
<td>1</td>
<td>90</td>
<td>150</td>
</tr>
<tr>
<td>expM (l)</td>
<td>0.1</td>
<td>0.5</td>
<td>2</td>
</tr>
<tr>
<td>coeR (l)</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>coeS (l)</td>
<td>0.001</td>
<td>0.3</td>
<td>1</td>
</tr>
<tr>
<td>KS (l)</td>
<td>0</td>
<td>0.6</td>
<td>1</td>
</tr>
<tr>
<td>KI (l)</td>
<td>0</td>
<td>0.25</td>
<td>1</td>
</tr>
</tbody>
</table>