Modification of the distributed modeling structure to account for grid water exchange

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Background

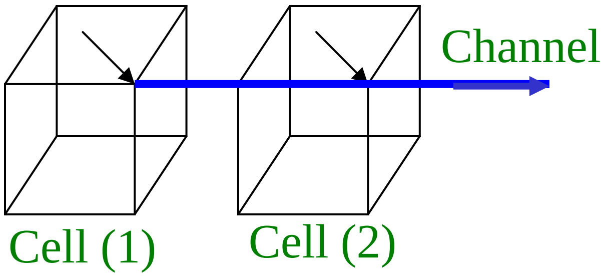
Hydrology Lab – Research Distributed Hydrologic Model (HL-RDHM)

- Defined on a regular rectangular grid cells
- Each grid cell:
  - Water balance component: SAC-SMA
  - Hill-slope and channel routing component: Kinematic Wave (KW)
- From the water balance :
  - Fast response runoff : routed over the conceptual hill-slopes to a conceptual channel in each cell.
  - Slow response runoff : bypass the hill-slope routing, and enter to the channel system directly from the soil.
- Cell-to-cell channel routing is done using a flow direction grid.

Problem statement

In Koren et al (2004), it was mentioned that there is a **deficiency** in the **modeling structure** of the **HL-RDHM** :

There is **no physical connection** between **soil moisture states in adjacent grids**, and **channel** is the only source of **water exchange** between neighboring computational elements.



This is considered a weakness in the current NWS distributed system.

Why weakness? (Literature review)

- NWS distributed modeling system:

no physical connection = **no subsurface** flow btw/ **adjacent grids:** probable **not** to be the case in **reality**.

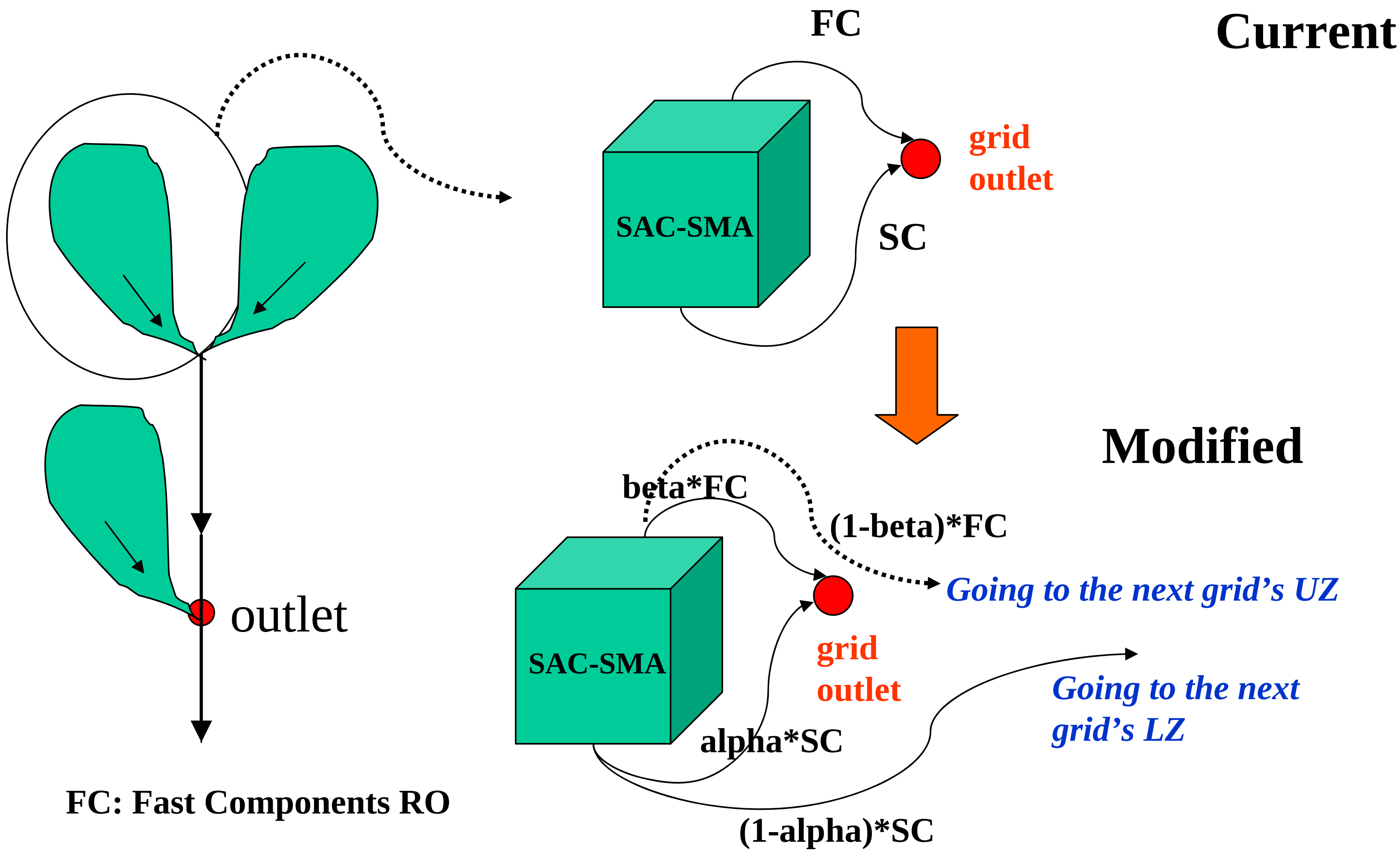
- Move from "**lumped**" to "**distributed**": **reducing size** of the constructing **elements** (comparing to the lumped), **no guarantee** all of the subsurface flow appears in the grid's outlet. => potential for **part** or **all** of the **subsurface** flow to go to the **neighbor** constructing **element.**

- Beven and Wood 1983, Tiefan et al. 2005: **subsurface** flow plays an **important** role in hydrological processes which **may be** an important component to form the **peak flows** especially in **forested** basins.

- Beven and Kirkby, 1979: **Believed** that in a hydrologic model, the **outflow function** is **less sensitive** to the form of the **faster responding** store comparing to the slower response.

Non-linear effect of the subsurface flow should be modeled more carefully in NWS distributed model.

Objective: Modification of the structure to account for water exchange between Neighboring grids (in the connectivity order).



FC: Fast Components RO

SC: Slow Components RO

0<=alpha<=1, 0<=beta<=1

Concepts to be considered in modification:

literature : **Temporal** variations of **soil moisture** in **different parts** of a basin are controlled by **different mechanism**:

- Chirico et al (2003) : "**Vertical** processes of **infiltration** and **evapotranspiration** likely to be **main controls** in temporal variation of **soil moisture** in **top soil** of hill-slopes".

- Beven and Wood (1983): believed **saturated** areas are more probable to be at the **bottom** of hill-slopes or areas with soils of **low hydraulic conductivity** or **low slopes**.

- Most of **down-slope lateral** flow of **saturated or unsaturated** soil water is in the form of **subsurface flow**, but it may **locally** exceed soil storage capacity and **return** to flow **over surface** with much higher velocity (Beven and Kirkby 1979, Elsenbeer and Vertessy 2000).

Modification should be done in such a way that having **different mechanism** for **water exchange** over the basin becomes possible.

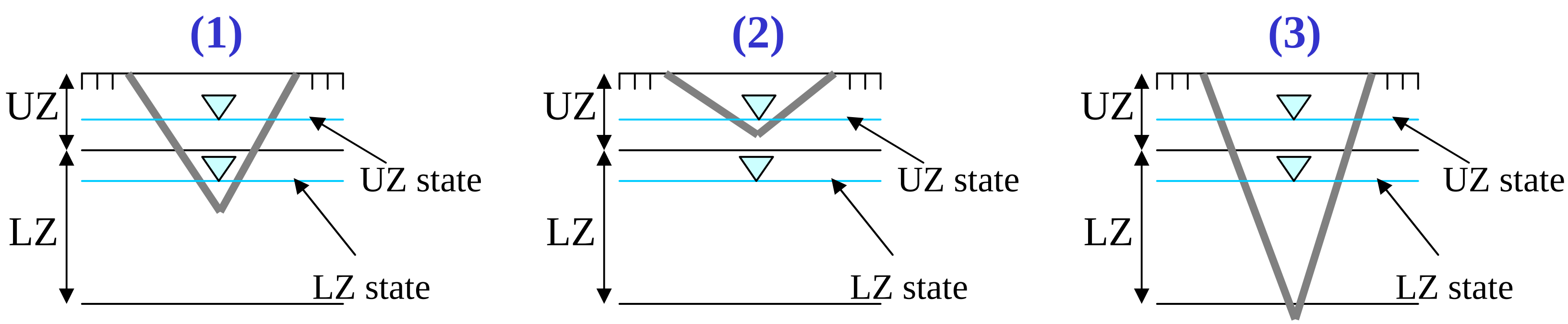
One way is to take the **advantage** of **topographic** condition and **channel** network **properties** in the modeling modification.

Estimation of alpha and beta:

- Relationship btw/ **SAC model** & **soil property** (existing in SAC-HT) helps to **convert** the **UZ** and **LZ soil moisture** into soil moisture contents at a number of **physically based soil layers.**

- **alpha** and **beta** will be estimated based on **overlapping** of the **channel bed elev.** and respective physical **layer elevation**.

- 3 different possible cases :



0<Alpha<1
Beta=1

Alpha=0
0<Beta<1

Alpha=1
Beta=1

Note: alpha and beta represent the ratios of water going to the grid's channel.

Starting with distributed model of UCIrvine:

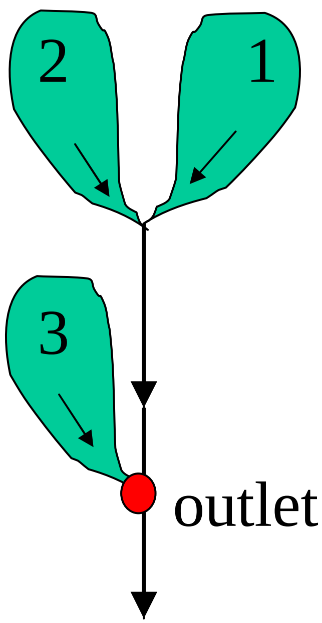
Similar to the HL-RDHM:

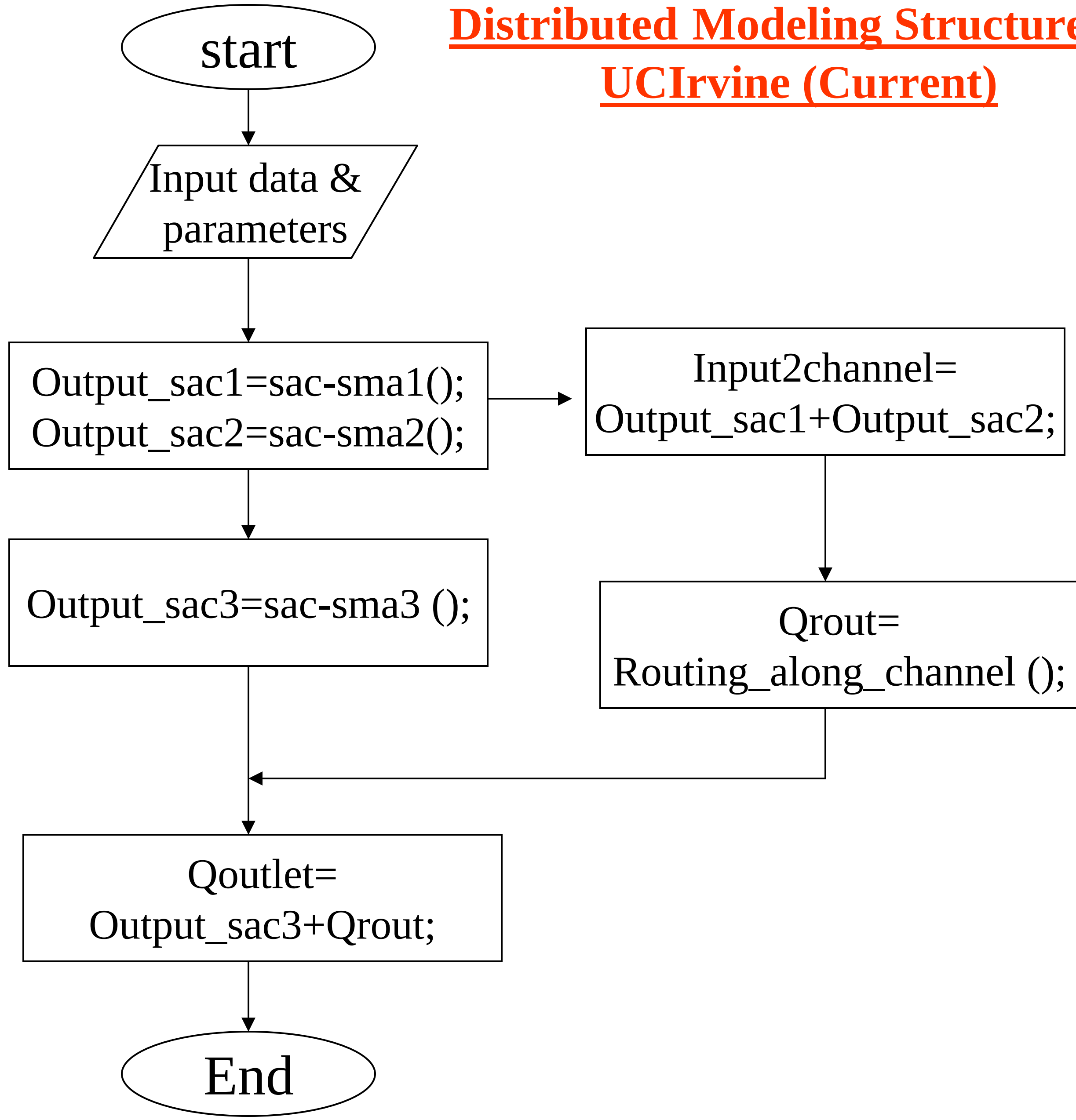
- SAC-SMA: Water balance component
- Unit Hydrograph: Hill-slope routing
- Kinematic wave: Channel routing

Simplified:

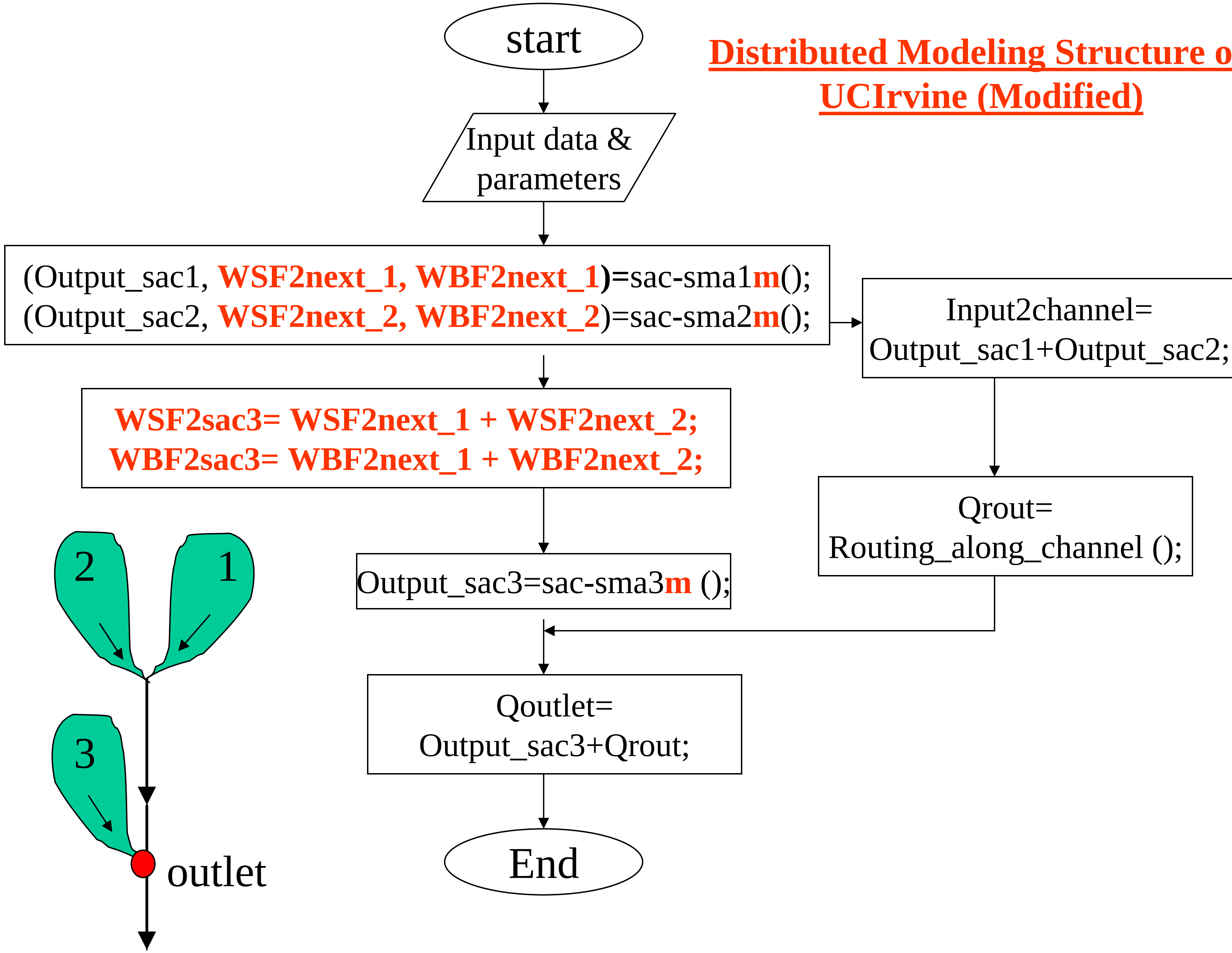
- Sub-basins as constructing elements instead of grids

Distributed Modeling Structure of UCIrvine (Current)





Distributed Modeling Structure of UCIrvine (Modified)



Modifications to sac-sma (sac-sma m)

Adding water from previous grid's SF to forcing of next grid

sac-ma **m**

If tag_basin=2: Pxv= Precip+ **WSF2sac3;**
If tag_basin=1 : no change

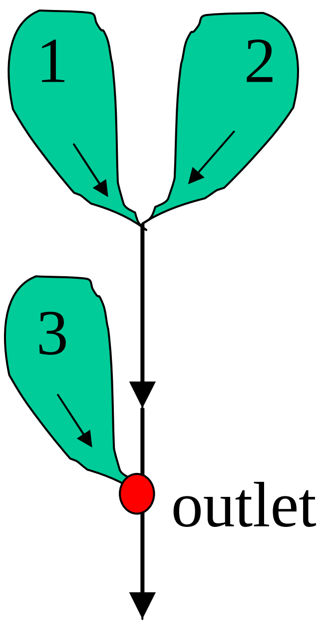
Adding water from previous grid's BF to percolation of next grid

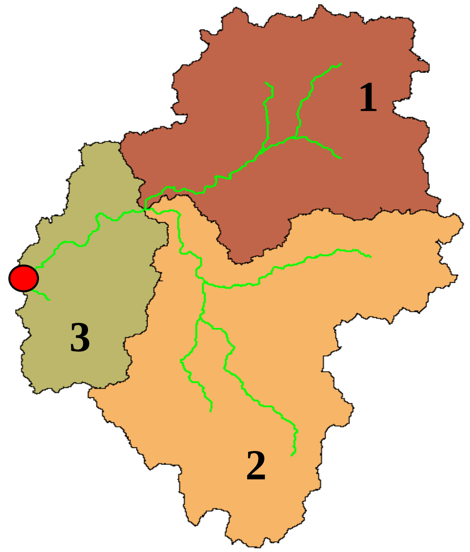
Fland1**m**()

If tag_basin=2:
percolation=percolation + preBF_inc ;
If tag_basin=1 : no change

If the sub-basin is a headwater basin : tag_basin=1
Otherwise: tag_basin=2

Synthetic case study



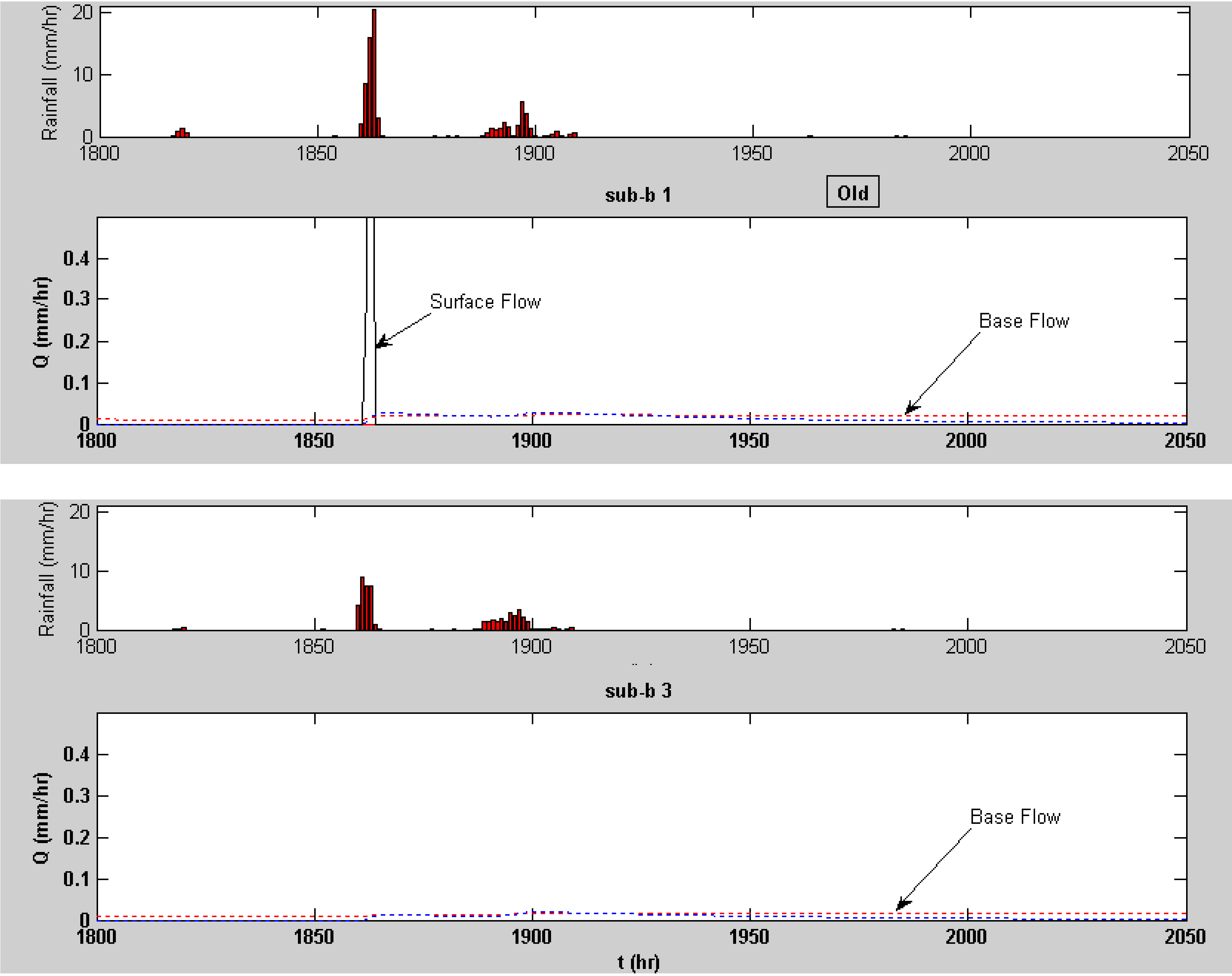


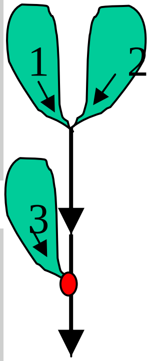
Illinois River basin at
Siloam spring, AR

Precipitation: 1/10/1995 - 31/12/1995 (3 month hrly precip-the rest: zero precipitation)
Running period: 1/10/1995 – 31/12/1997

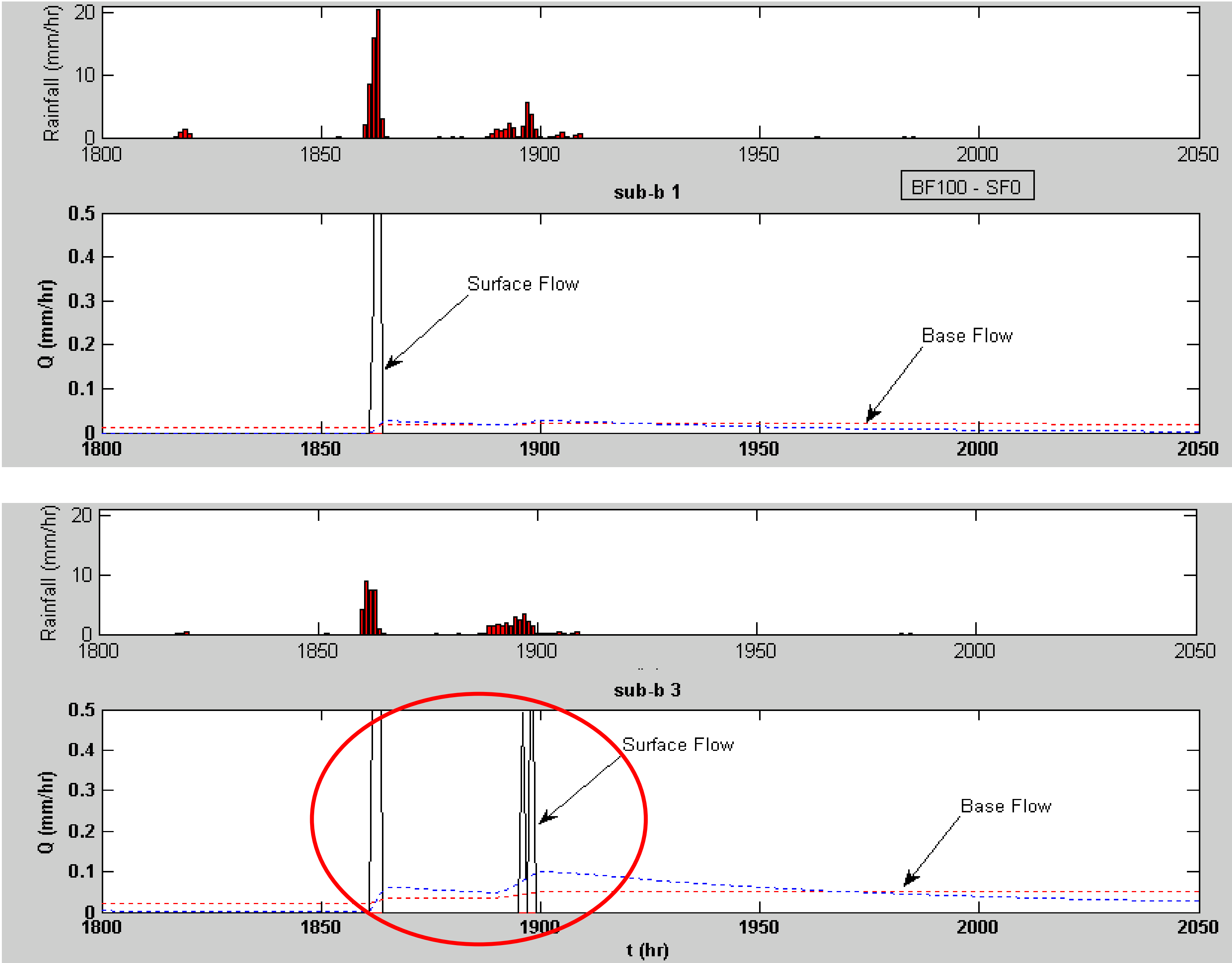
Note: The old and modified models were run using same parameter set and no calibration.

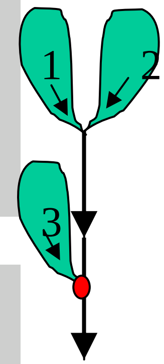
Old structure : Runoff Response Components (RRC) (mm/hr)



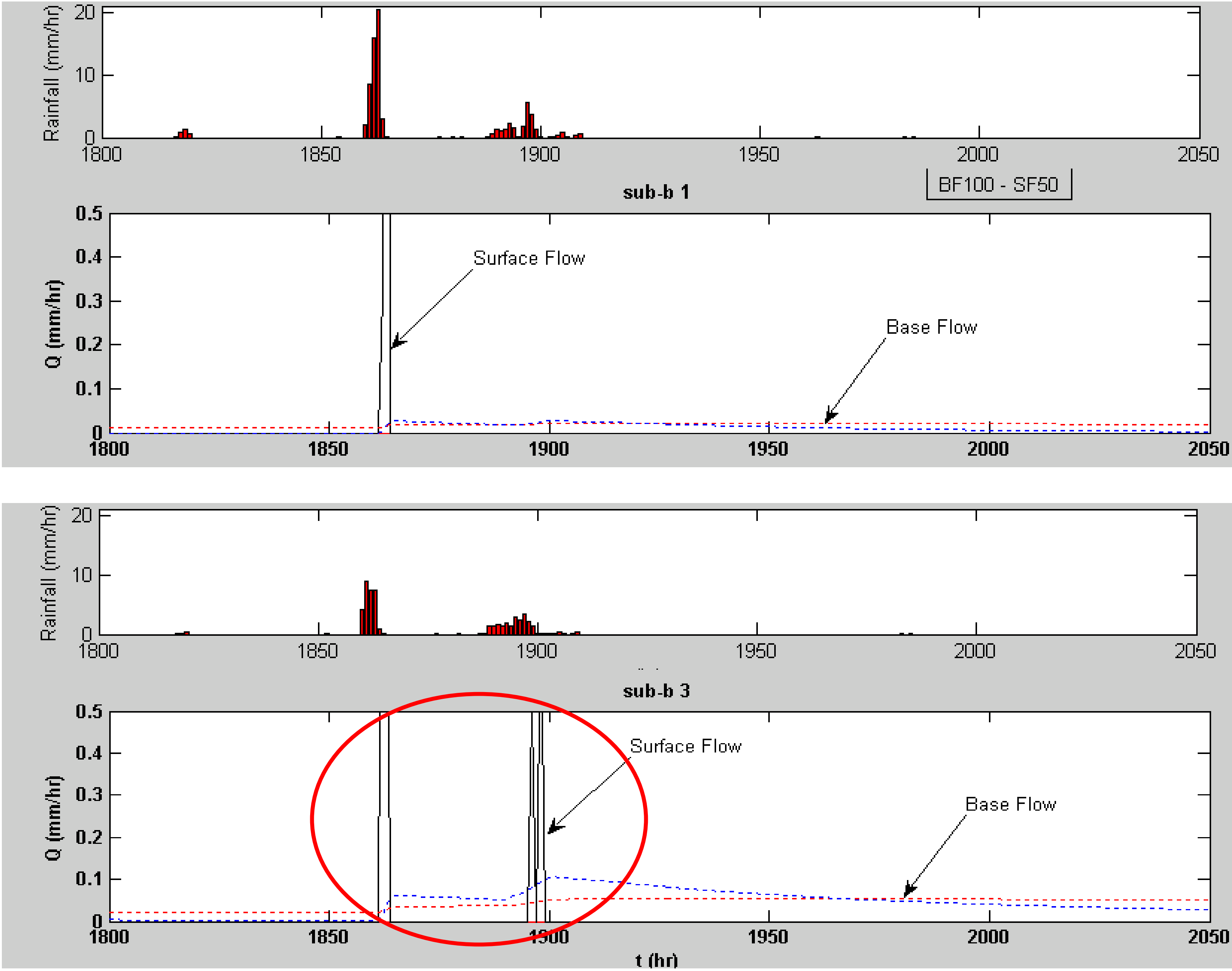


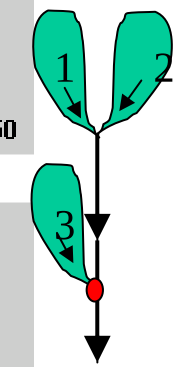
Modified structure : RRC (mm/hr) Passing 100% BF & 0% SF to next grid



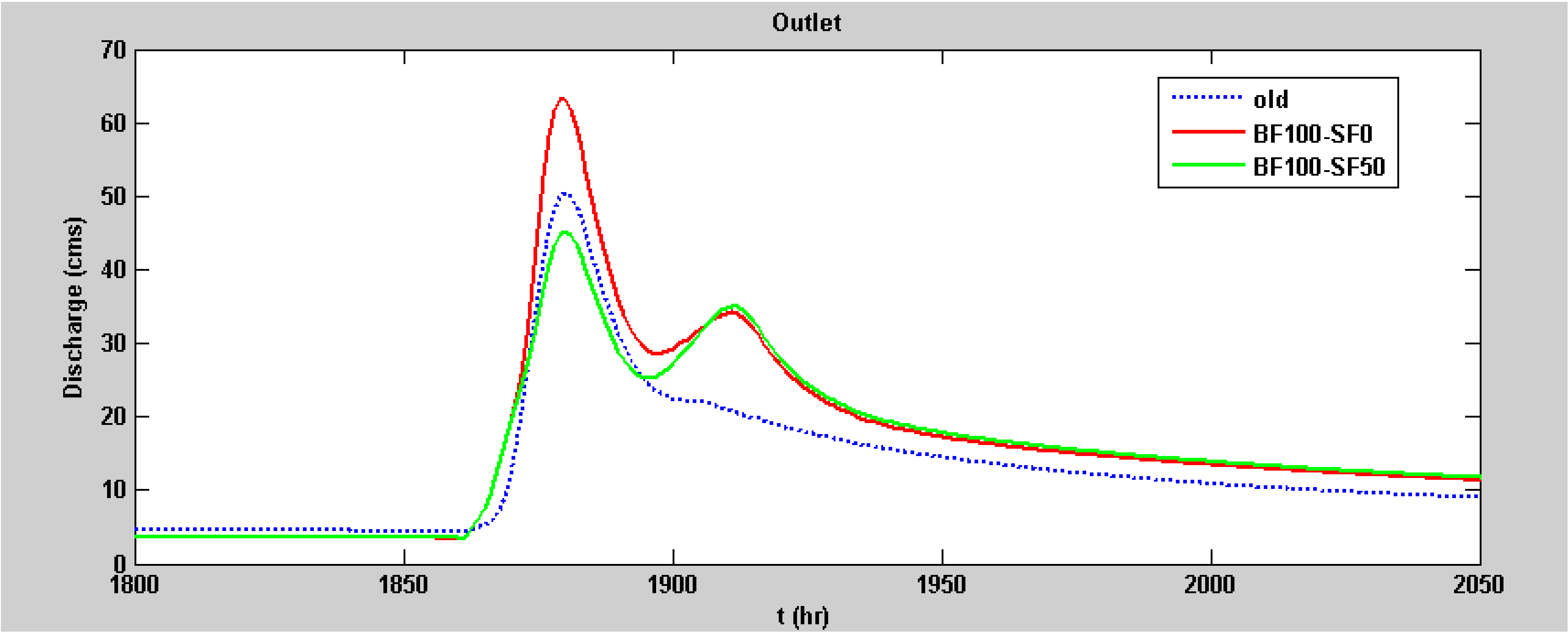


Modified structure : RRC (mm/hr)   Passing 100% BF & 50% SF to next grid





Old & modified structure : Simulated discharge at the outlet (cms)



Observations :

- When we add 100% of BF from 2 previous grids to the next grid, the LZ deficit of the 3rd grid is satisfied. So, less percolation happens from its uzfwc storage. Therefore, the interflow from the uzfwc of the 3rd grid and subsequently the Q peak at the outlet will increase.

- When we add 100% of BF from 2 previous grids to the next grid LZ and 50% of SF to the next grid UZ, not much change happens in terms of RO in the 3rd grid comparing to BF100-SF0 case; but, the routed flow from 2 previous grids decreases a lot to go to the next grids UZ. Therefore, the 3rd grid's storages dampen the magnitude of peak flow.

Next steps:

- Generating channel bed elevations
- Estimation of alpha and beta in the model
- Setting the semi-distributed model with more sub-basins
- Calibrating the SAC-SMA parameters in modified structure
- Applying the approach in grid-based distributed model
- Verification