Simulation of Stormwater Runoff in the C-111 Basin Using the RSM-TVDLF Model

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Abstract

Detailed water levels and surface flow vectors during major runoff events can be simulated only after studying the hydraulics and hydrology within a system with the necessary spatial and temporal detail. This is because the flooding that takes place during large storm events is partly caused by what happens at a smaller scale along small streams and flow paths determined by the microtopographic features of the system. Flow along such paths is often kinematic in the upstream reaches and diffusive in the downstream reaches. It is necessary to understand and simulate these features along with groundwater flow in the south Florida hydrologic system when understanding the overall flow patterns of south Florida.

Total Variation Diminishing Lax Friedrichs (TVDLF) method using linearized implicit numerical method is used in the model currently used to test the C-111 sub-watershed of south Florida to see if the method can simulate the integrated surface and groundwater systems. This numerical approach can solve such kinematic-diffusive flows along uneven local topography that exist in various parts of South Florida. This TVDLF method was implemented through the RSM model, evolved as a model targeted at modernizing the 1980s version of the South Florida Water Management Model (SFWMM). It has been applied to the upper Russian River watershed in California and Metro Colombo watershed in Sri Lanka.

The model results show flow patterns within the C-111 basin as well as the shallow bay that are not commonly available when using commercially available models. The results include water levels and discharges during the Hurricane Irma storm event at a much finer 200 m grid scale. Investigating the storm surge propagation along the C111 canal is also part of the study.

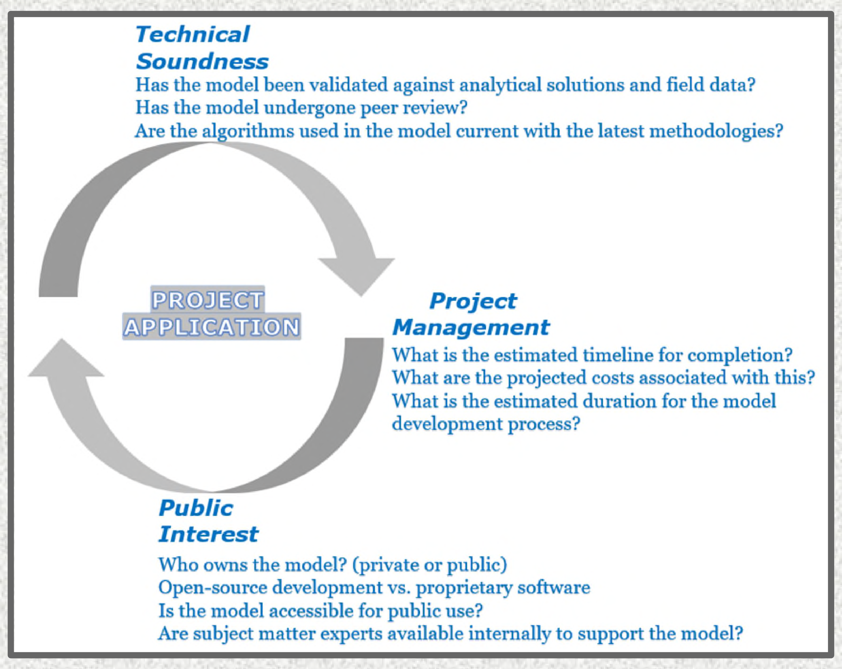
Introduction

The Total Variation Diminishing Lax-Friedrichs (TVDLF) method is a numerical approach that blends shock-capturing (TVD) and smoothing (Lax-Friedrichs) techniques to simulate water flow, particularly under conditions of rapid change, such as overland flooding or runoff on steep terrain. It calculates variations in water depth and velocity over space and time in systems with fast, nonlinear flows that may include kinematic shocks. TVDLF enhances modeling accuracy across a variety of flow regimes—from kinematic flows in steep urban settings to diffusive flows in wetlands—and is especially effective in complex systems where all these surface processes interact with groundwater dynamics simultaneously.

The Regional Simulation Model (RSM), utilizing the TVDLF approach, was applied to the C-111 basin during the period of Hurricane Irma (Sept 9– Sept 12, 2017). A comparison was made between RSM-TVDLF, Miami-Dade Regional Simulation Model (MDRSM) and historical data.

Our objective is to highlight the advantages of applying the RSM-TVDLF scheme in South Florida.

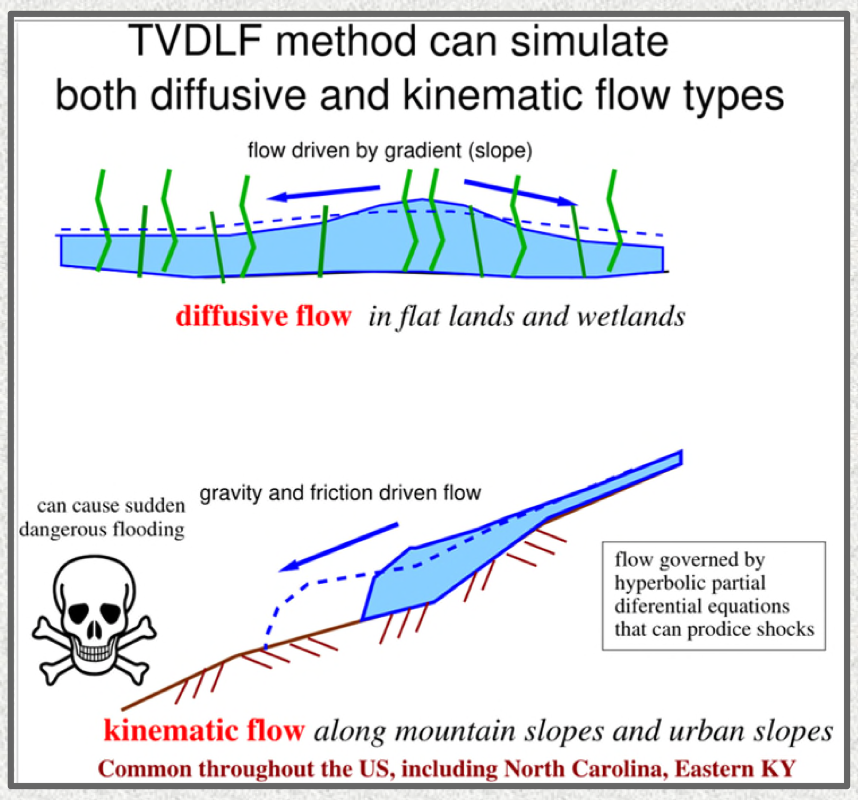
Selection of Model

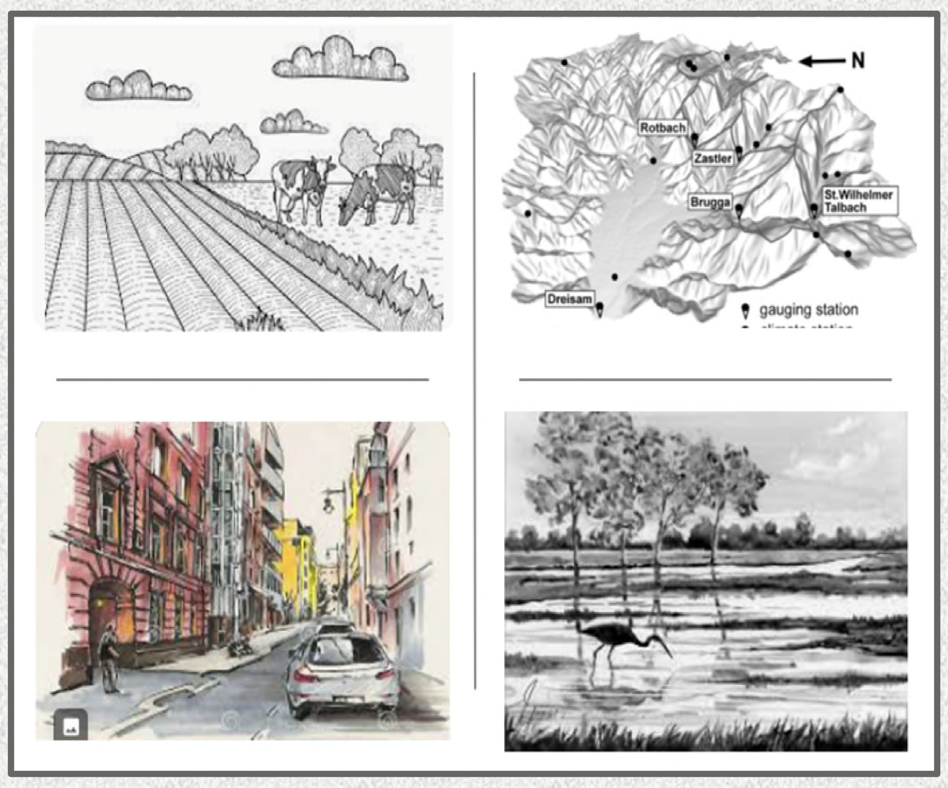


- **Fast moving shallow flows through Urban areas**
- **Fast surface runoff through Hillside slopes**
- **Slow moving flows through wetlands**
- **Discharges through farmlands**

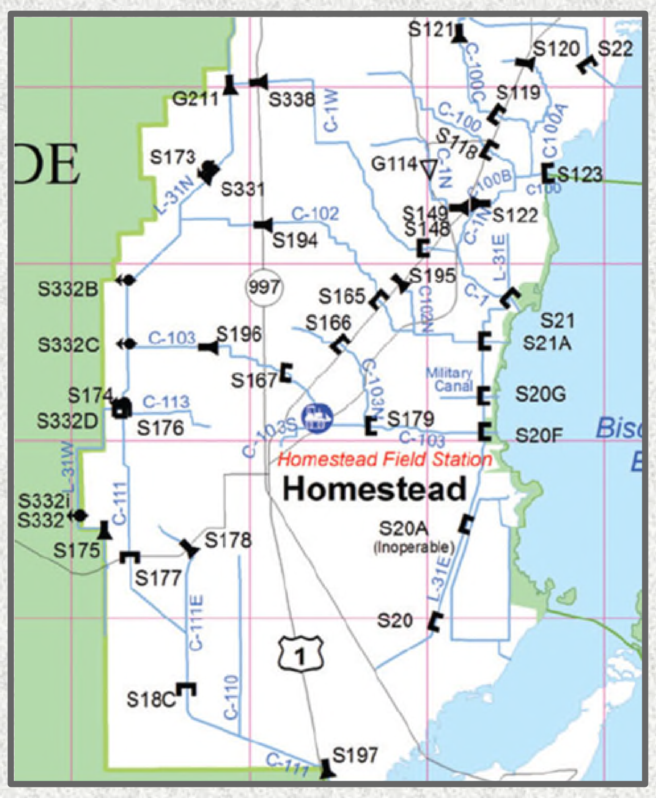
Models that use explicit methods without TVD

- **HEC-RAS 2D**
- **FLO-2D**
- **TELEMAC-2D**
- **MIKE 21 FM (by DHI)**

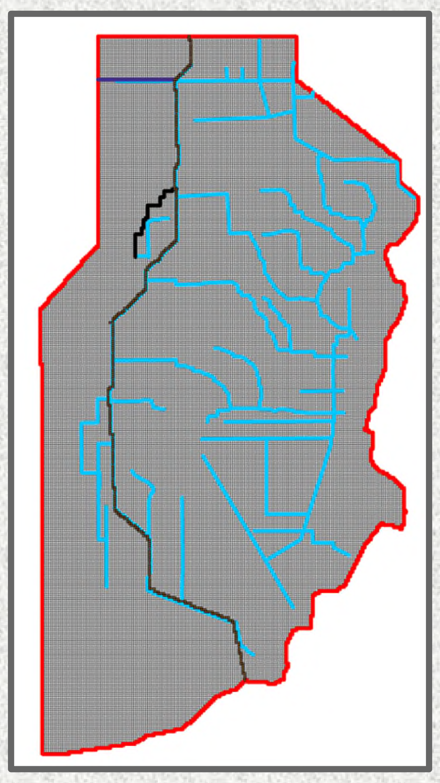




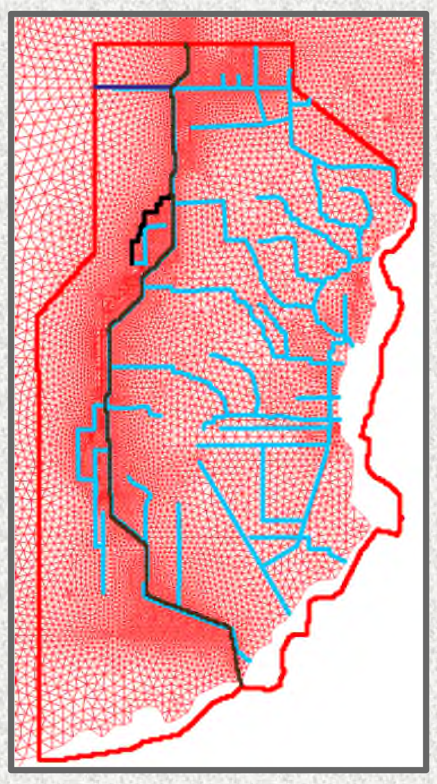
Modeling



LOCATION MAP



RSMGL-TVDLF MESH



MDRSM MESH

Historical Data

- Historical stage/flow data from DBHYDRO

DBHYDRO is the South Florida Water Management District's corporate environmental database that stores hydrologic, meteorologic, hydrogeologic and water quality data.

https://my.sfwmd.gov/dbhydroplsql/show_dbkey_info.main_menu

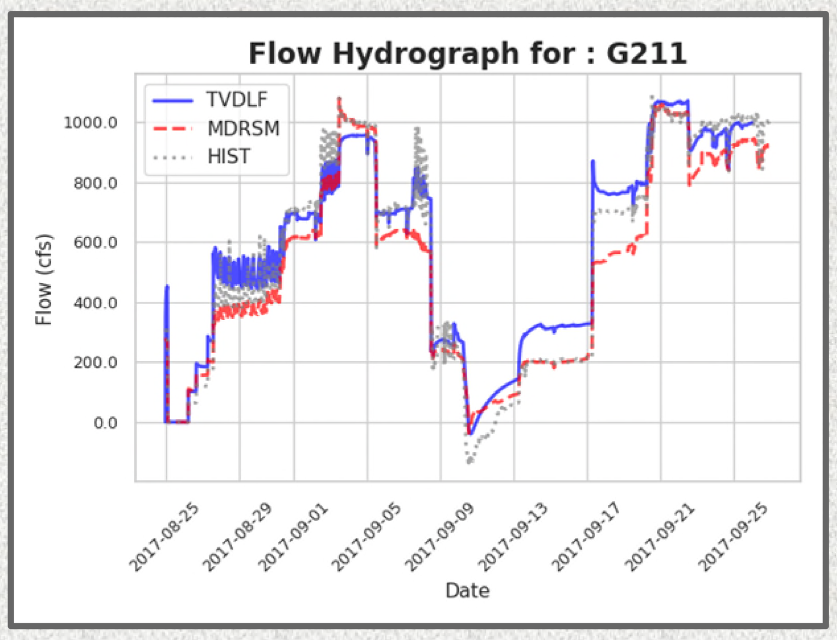
C111-TVDLF

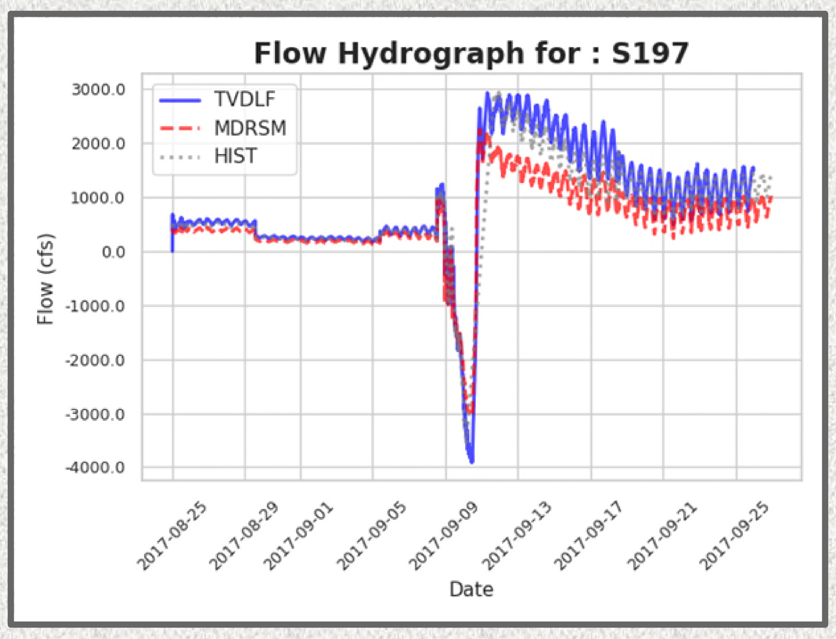
- square mesh
- Time-step=15-min
- Number of cells = 47,934
- cell size = 10 acres
- Simulation period = 25aug2017-25sep2017
- Fully-coupled:
  - 1-D canal flow,
  - 2-D overland and groundwater flow
- Object oriented design
- High resolution implicit solver (TVDLF)
- Not calibrated
- Historical stage/gate data imposed (shown in yellow)
- Boundary stage data imposed from MDRSM

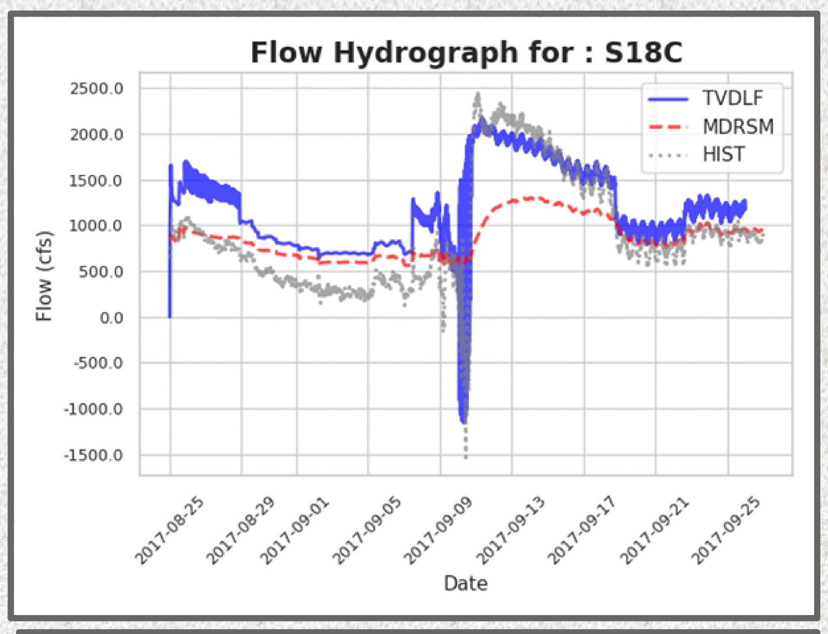
MDRSM

- Variable-sized triangular mesh
- Time-step=15-min
- Number of cells = 28,990
- Average cell size = 54 acres
- Simulation period = 25aug2017-25sep2017
- Fully-coupled:
  - 1-D canal flow,
  - 2-D overland and groundwater flow
- Object oriented design
- Fully calibrated

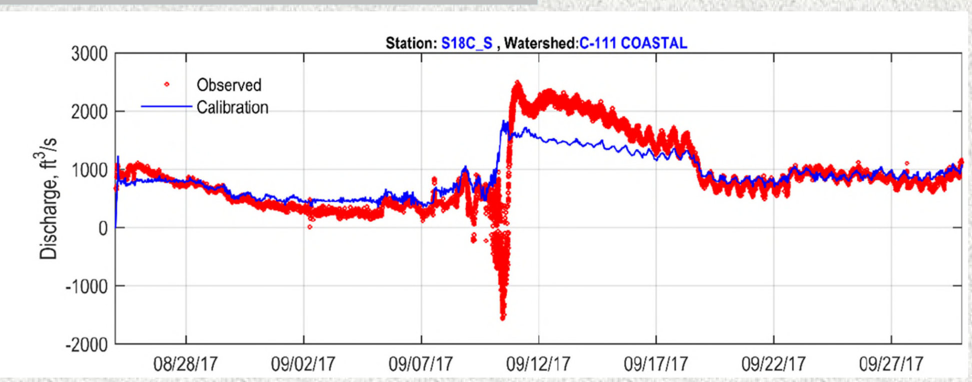
Results

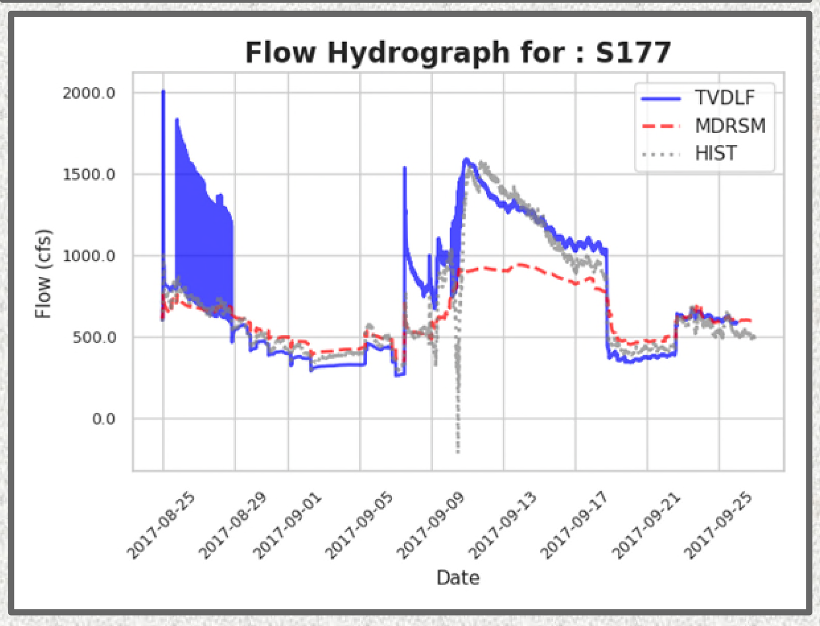




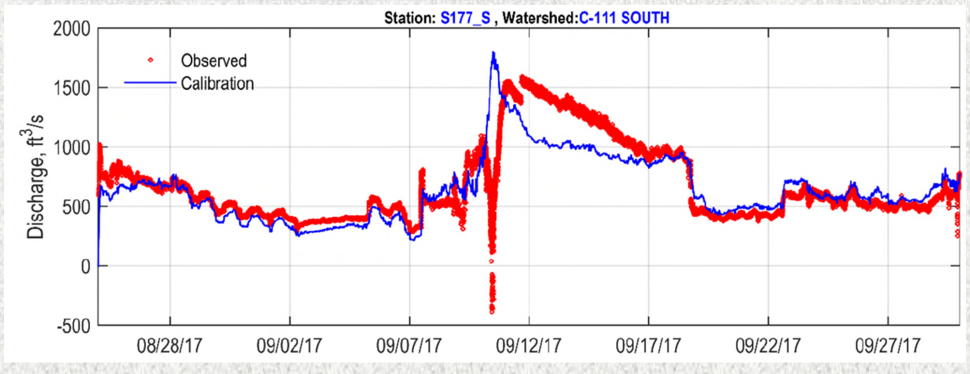


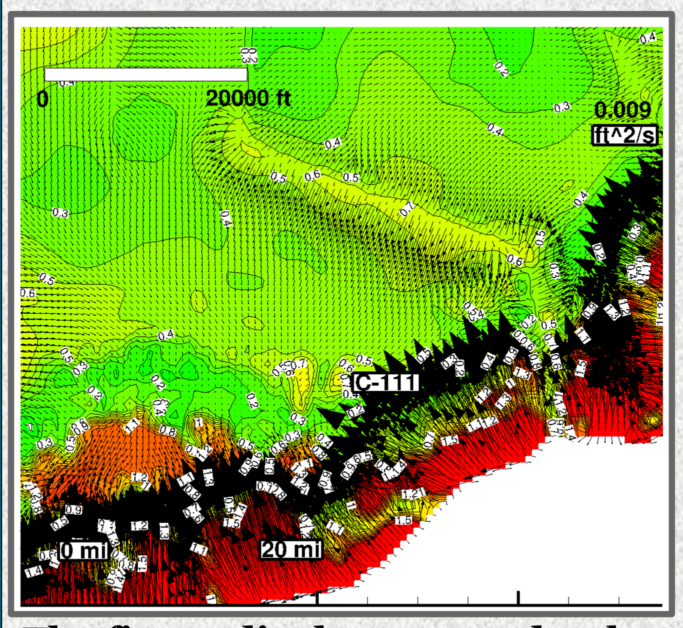
C-111 LOS Study MIKE SHE & MIKE 1D



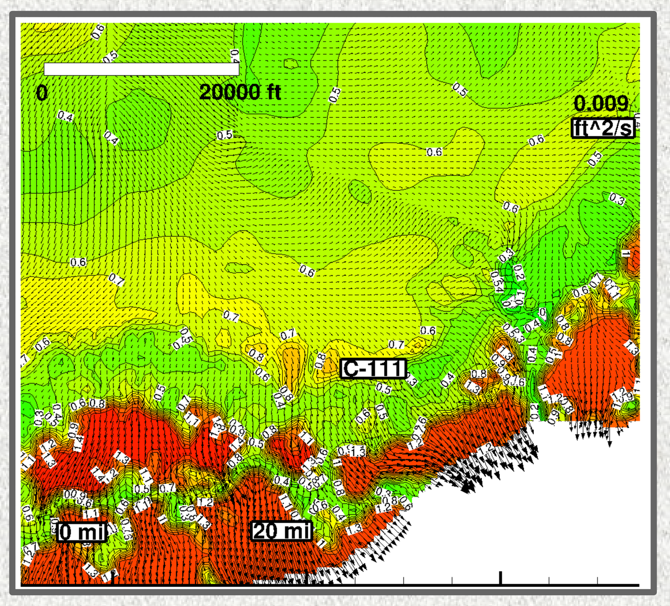


C-111 LOS Study MIKE SHE & MIKE 1D





The figure displays water depths, contour lines, and both surface and subsurface flow vectors near the C-111 canal, where water is seen spilling onto an adjacent strip of land just as Irma reaches the shore. It highlights that the surge wave propagates much more rapidly through the canal compared to the shallow ocean. Additionally, the figure shows that the discharge vectors along the shoreline are significantly larger in magnitude than those associated with the canal spillover.



The figure shows ponding depth contours during the ebb cycle after hurricane Irma. It shows that the discharge vectors at the shore are much smaller when compared to the discharge vectors during the surge.

The figure also shows that surface and subsurface water fills back into the C-111 canal.

Conclusions

Although the calibration of the RSM-TVDLF model is incomplete, its application to the C-111 basin demonstrates that the TVDLF method can effectively simulate both diffusive and kinematic flow in complex hydrological systems characterized by variable topographies and land use types. The results indicate that the model is capable of simulating both tidal conditions and the effects of Hurricane Irma, even though it currently simulates inertia-free flow.

The model highlights how ocean surges affect shallow bay areas and impact the C-111 canal, resulting in the transmission of these effects along the canal at an accelerated rate.

Lal, Wasantha, A. M., Van Zee, J Randy and Graulau-Santiago, Jaime A. (2025) "TVDLF method to simulate two-dimensional flow through large hydrologic systems with wetlands and hillslopes. J. of Hydraulic Engrg. 151(3)