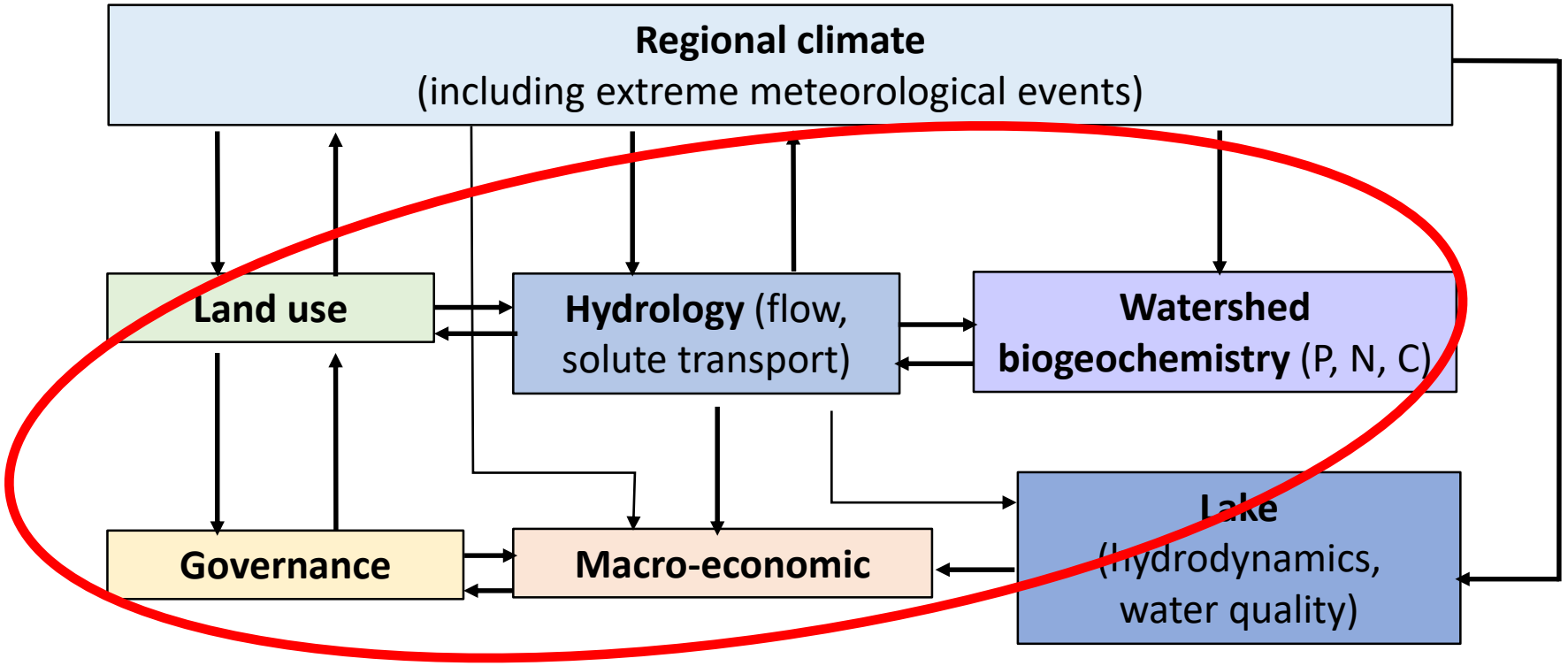
BREE
Basin Resilience to Extreme Events
in the Lake Champlain Basin

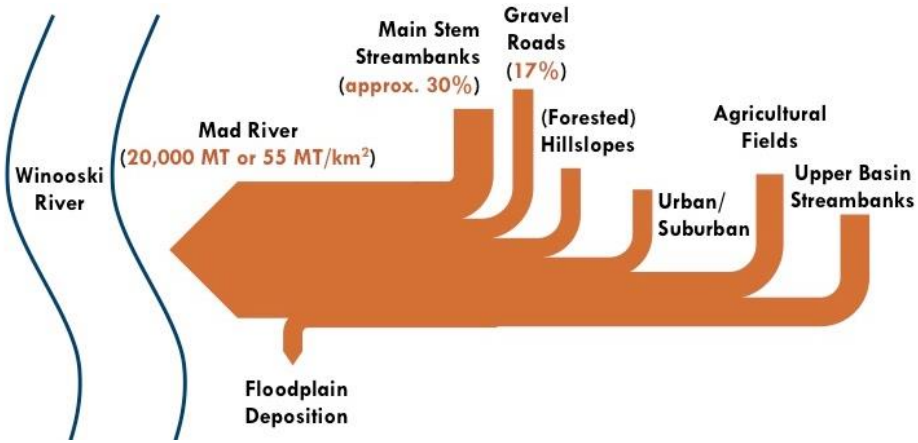
Major Features of the BREE Integrated Assessment Model



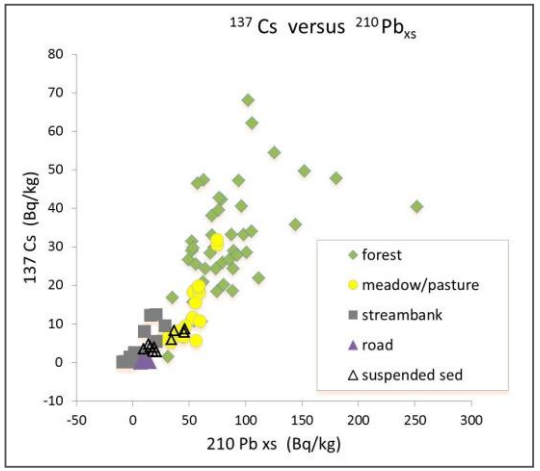
Where do riverine sediments originate?

BREE Basin Resilience to Extreme Events in the Lake Champlain Basin

- Sediment Budget

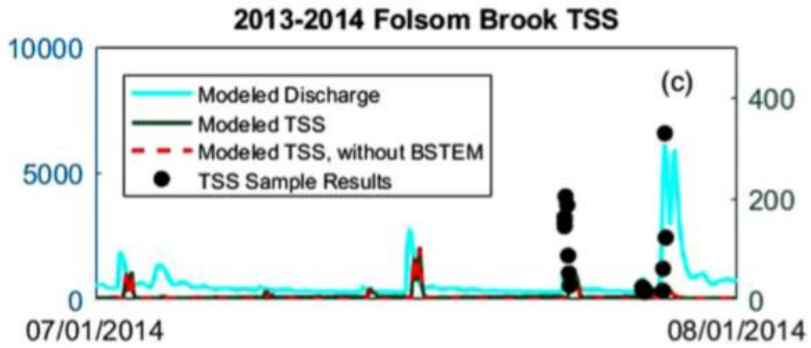


- Sediment Fingerprinting



Kristen Underwood

- Watershed Modeling



Stryker et al. 2017

- Hamshaw, S.D., et al., "Application of unmanned aircraft system for monitoring bank erosion along a river corridor", *Geomatics, Natural Hazards and Risk*, (In Review).
- Underwood, K.L., et al, "Evaluating Spatial Variability in Sediment and Phosphorus Concentration-Discharge Relationships Using Bayesian Inference and Self-Organizing Maps", *Water Resources Research,* (2017).
- Hamshaw, S.D., et al., "Quantifying streambank movement and topography using unmanned aircraft system (UAS) photogrammetry with comparison to terrestrial laser scanning (TLS)", *River Research and Applications,* (2017).

Thrust 3:
Goal 3.1; Obj. 3.1b

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in the Lake Champlain Basin

Another approach to understanding sediment dynamics within watersheds

Scott Hamshaw,

BREE – postdoc

Thrust 3:
Goal 3.1; Obj. 3.1b

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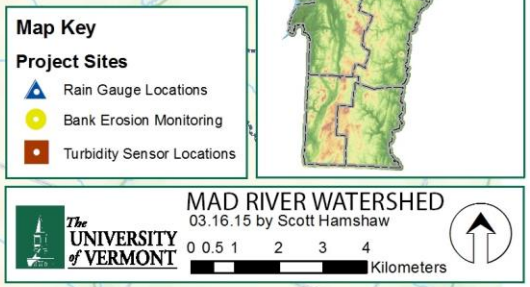
Basin Resilience to Extreme Events
in the Lake Champlain Basin

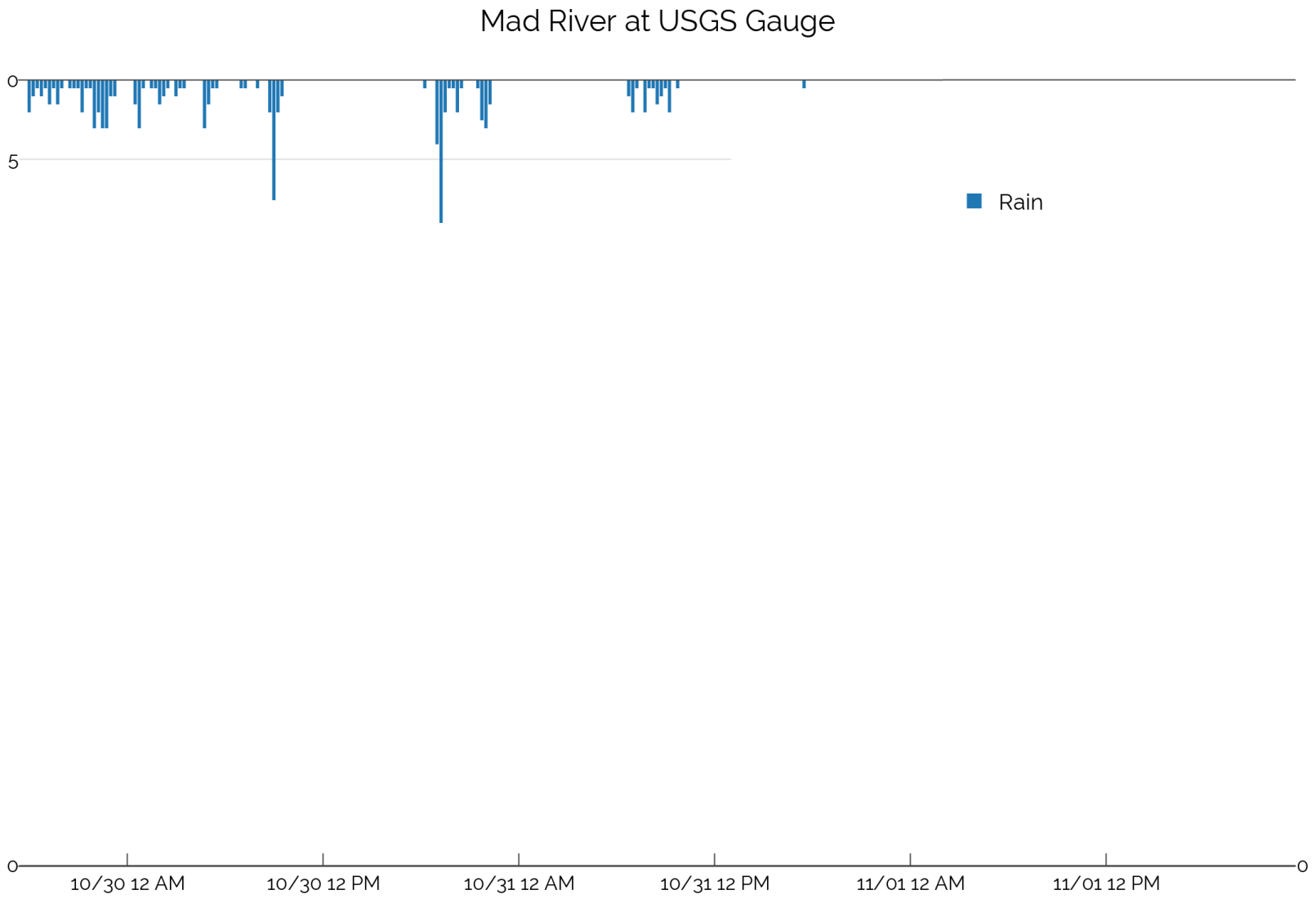
What if monitoring only the watershed outlet allowed us to infer sediment dynamics within the watershed?

Turbidity monitoring



Thrust 3:
Goal 3.1; Obj. 3.1b

A close look at hydrological events



Thrust 3: Goal 3.1; Obj. 3.1b

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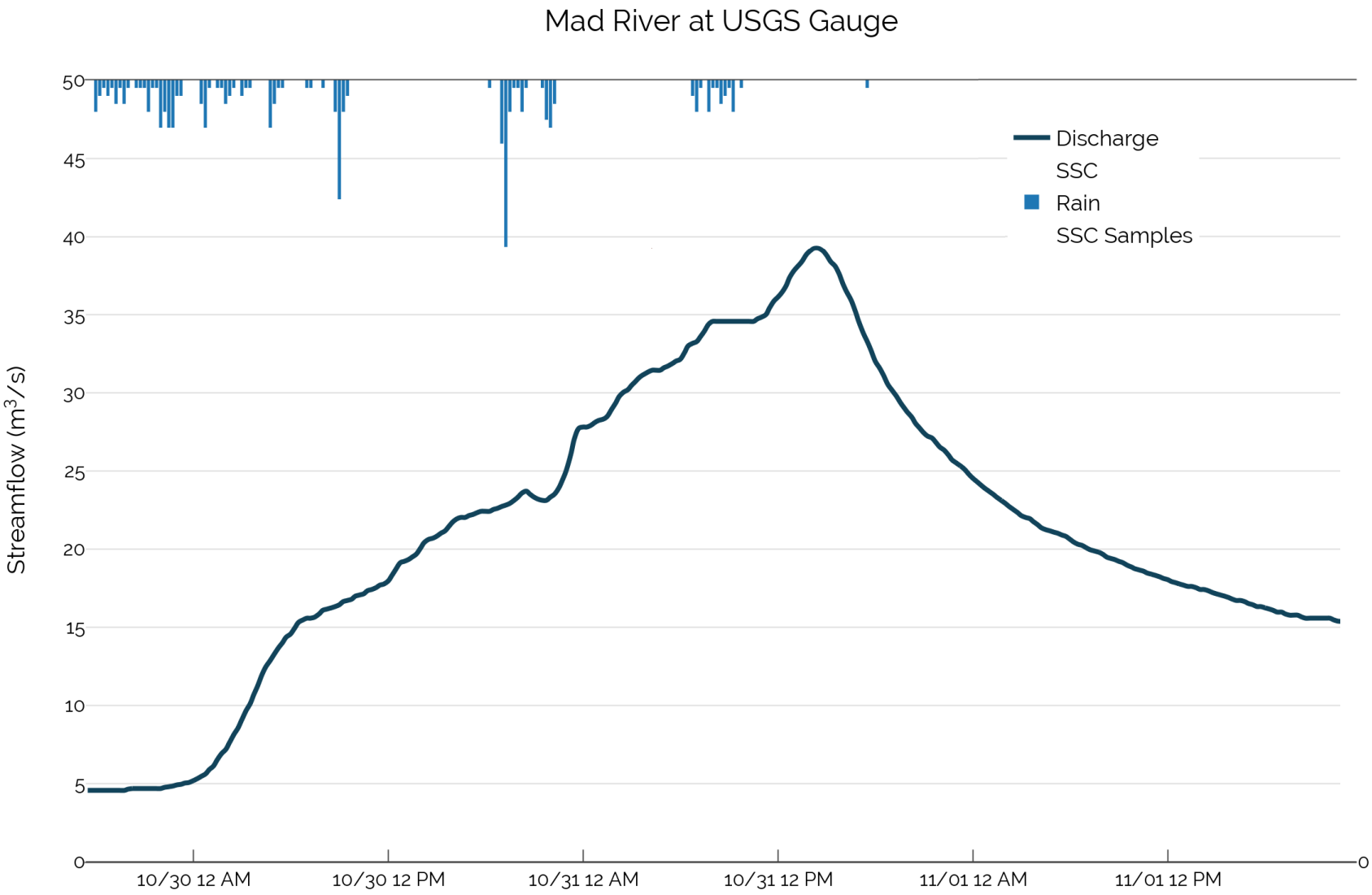

Thrust 3: Goal 3.1; Obj. 3.1b

A close look at hydrological events

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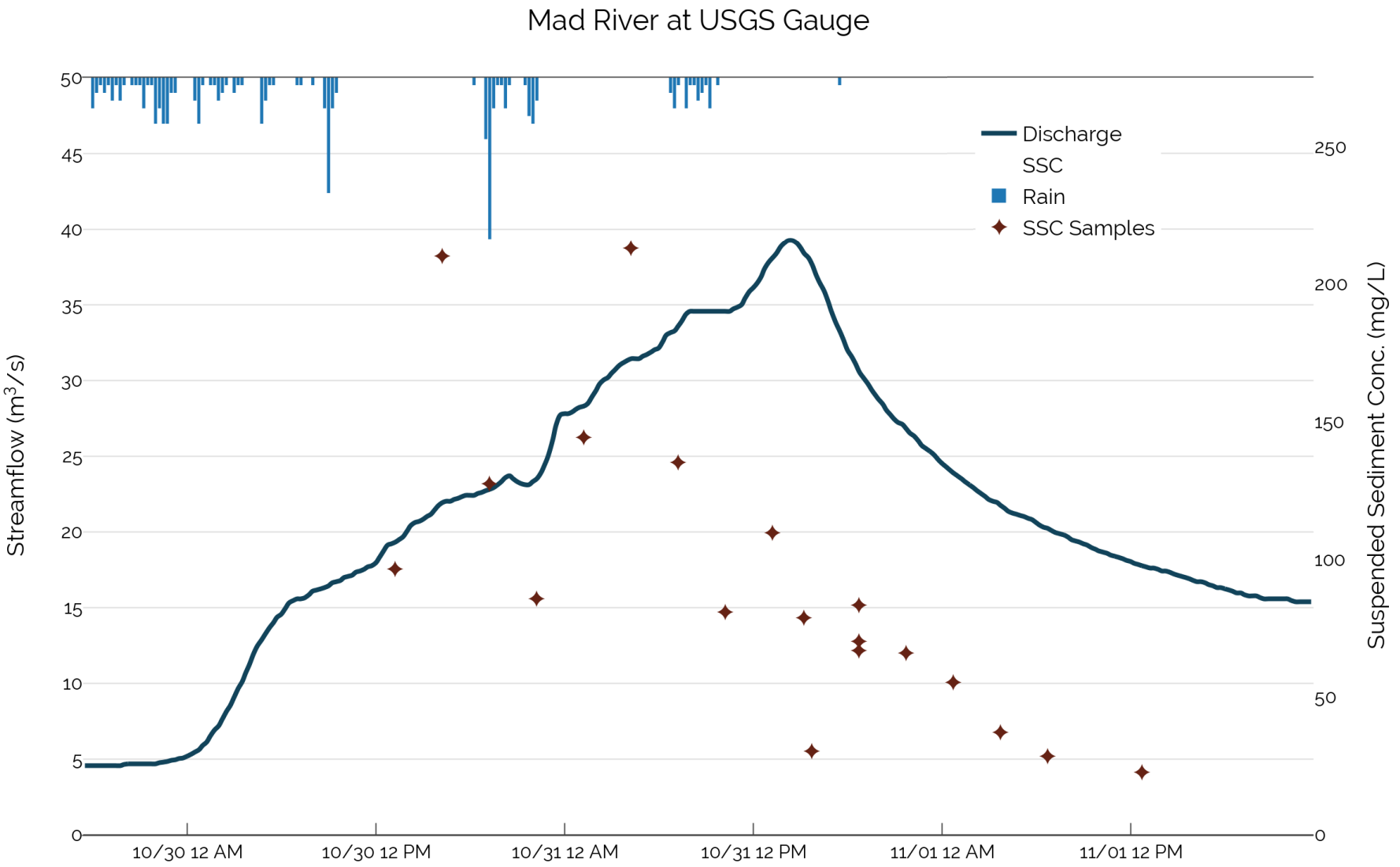

Thrust 3: Goal 3.1; Obj. 3.1b

A close look at hydrological events

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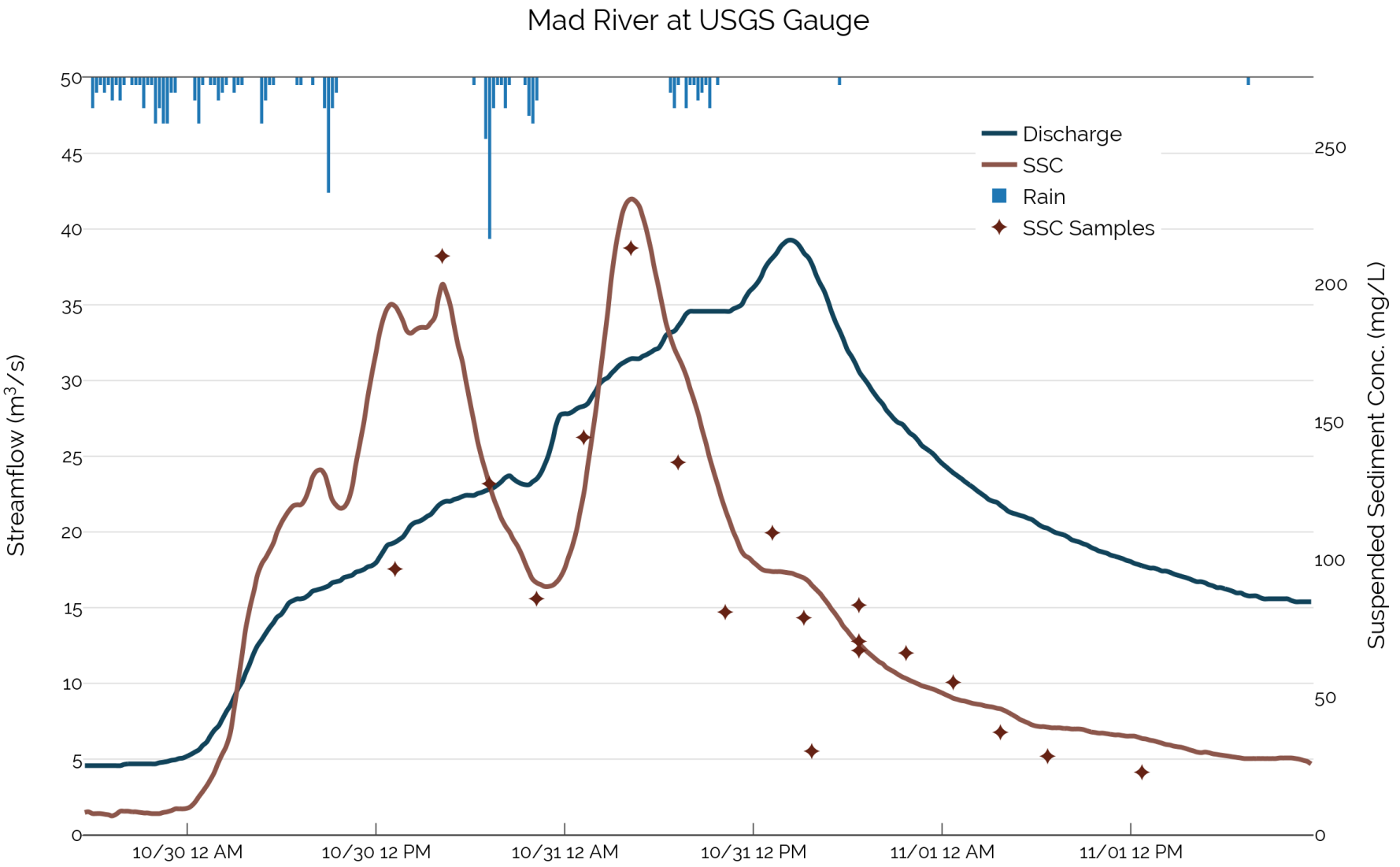


Thrust 3: Goal 3.1; Obj. 3.1b

Smart Hydrological event analysis

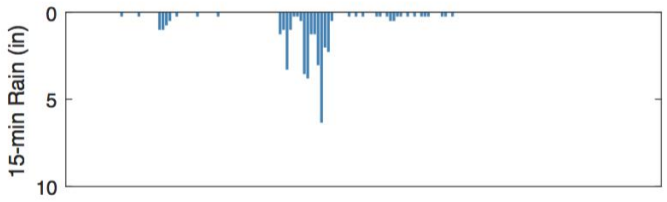
BREE
Basin Resilience to Extreme Events
in the Lake Champlain Basin

Storm Metrics

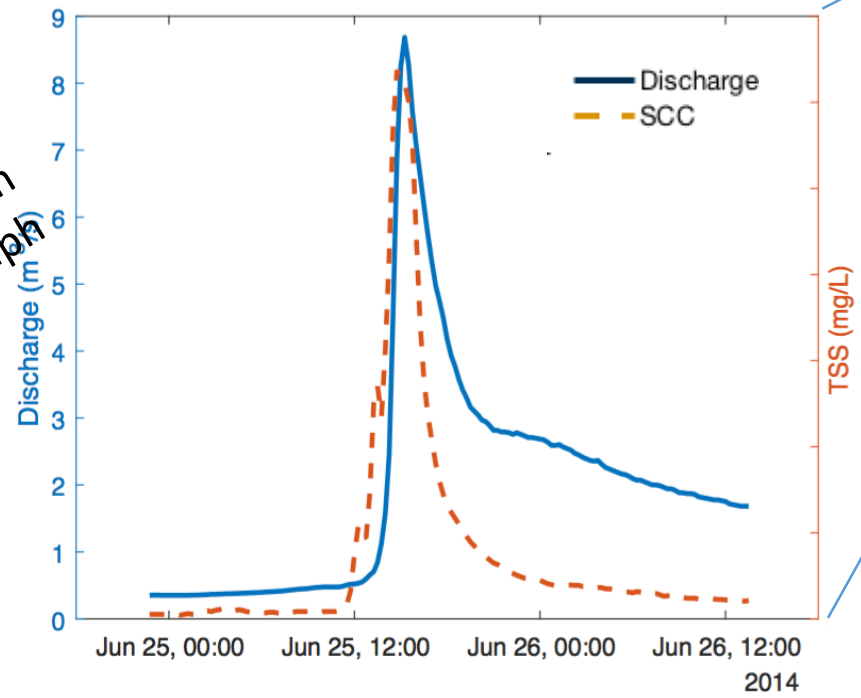
SHP 36

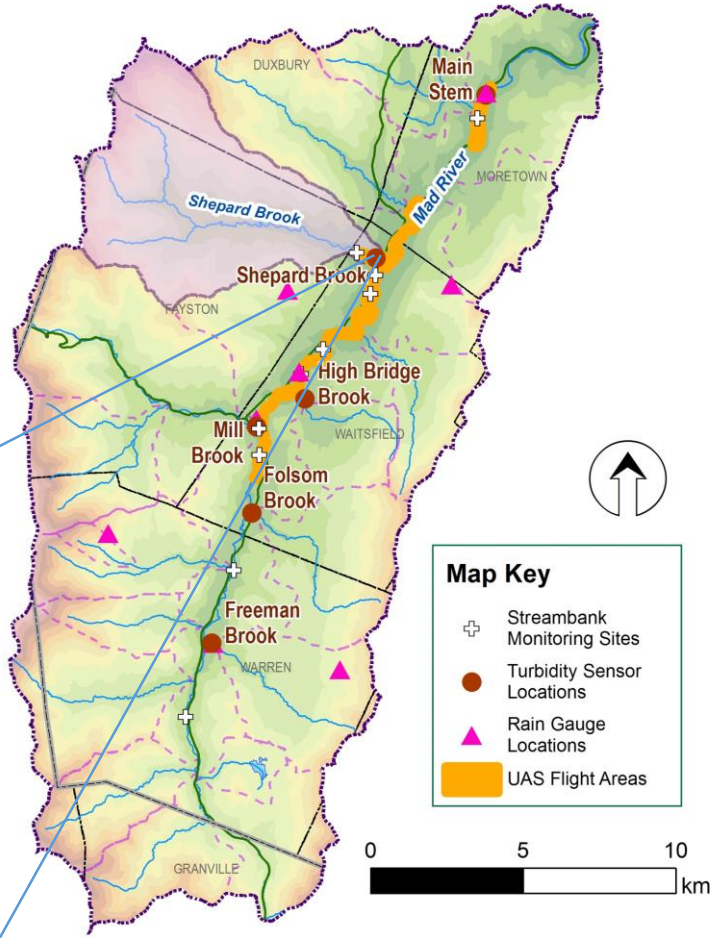
Storm Number: **2.14062422**
Storm Date: **24-Jun-2014 22:45:00**
Rainfall Station: **Fayston Weather (JFR)**
Total Rainfall (mm): **41.40**
Time Since Last Event (hr): **157.75**
Rainfall-Runoff Ratio: **7.35 %**
Turbidity Based Load (kg): **22815**
Flood Intensity: **0.505**
Antecedent Soil Moisture (%): **29.71 %**
Antecedent 7-Day Rainfall (mm): **37.85**

Hyetograph



Hydrograph & Sedigraph





Thrust 3:
Goal 3.1; Obj. 3.1b

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Smart Hydrological event analysis

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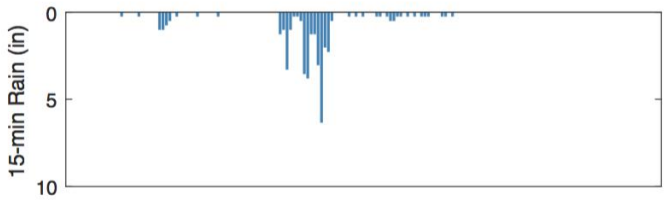
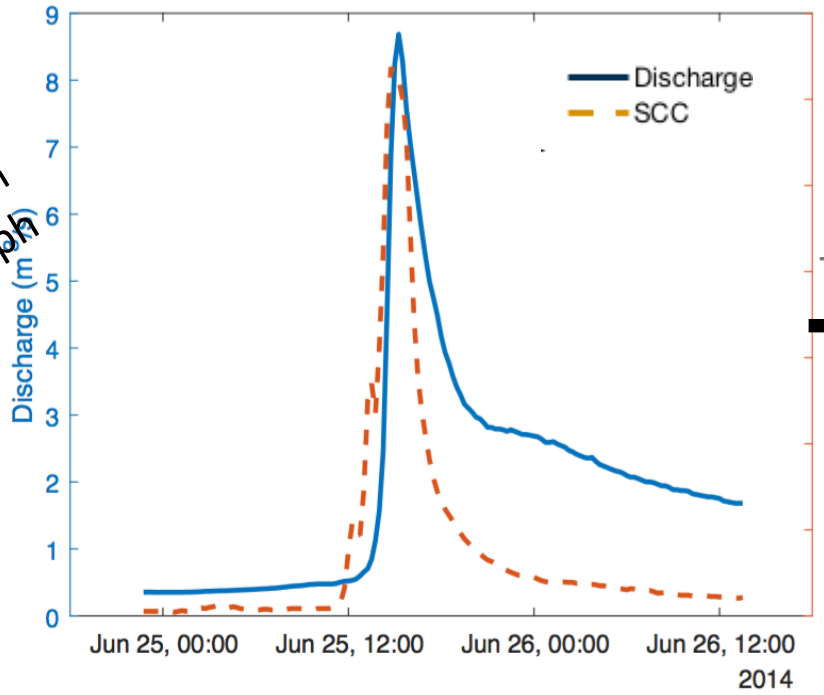
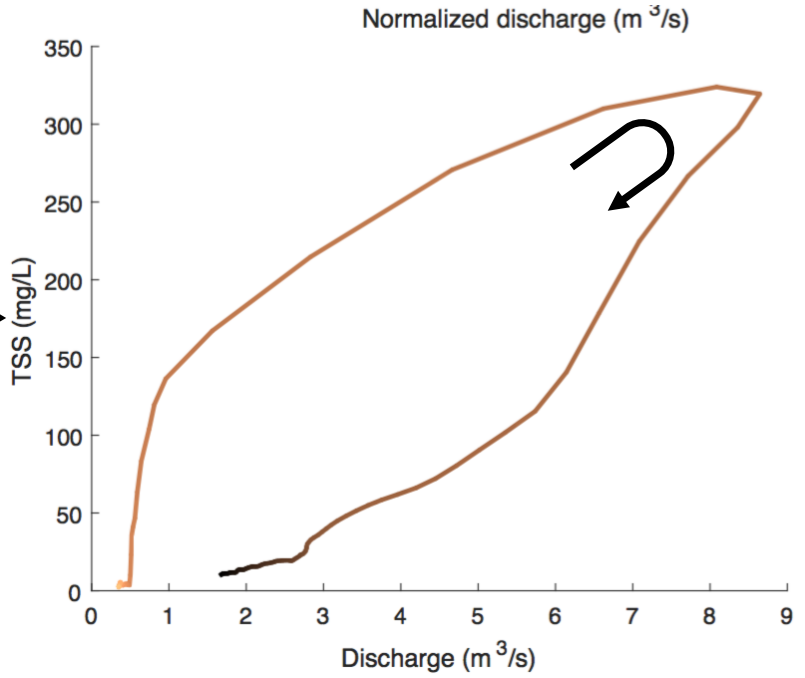


Hydrograph & Sedigraph

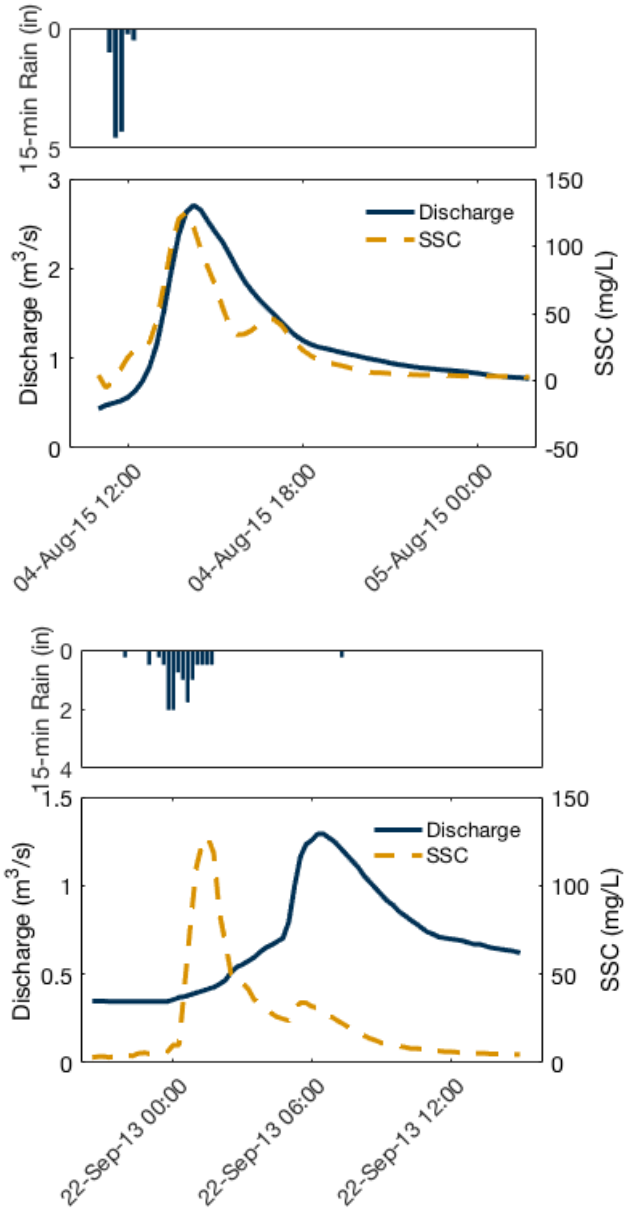


TSS

Clockwise
SSC-Discharge Plot



Hysteresis patterns help to infer watershed processes

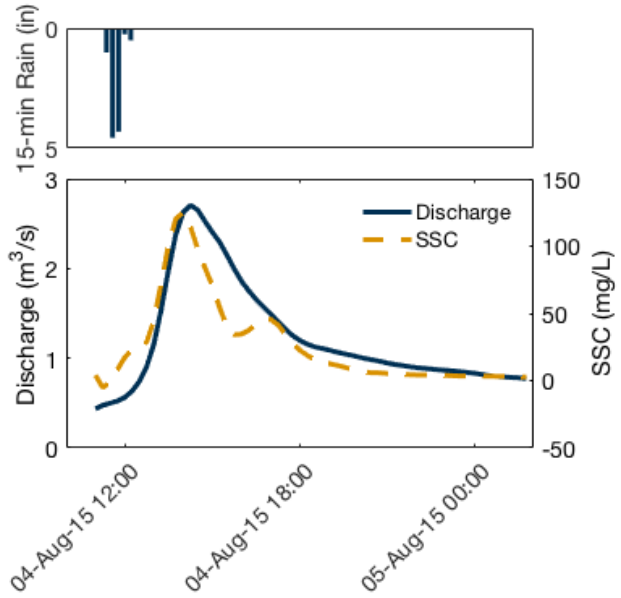


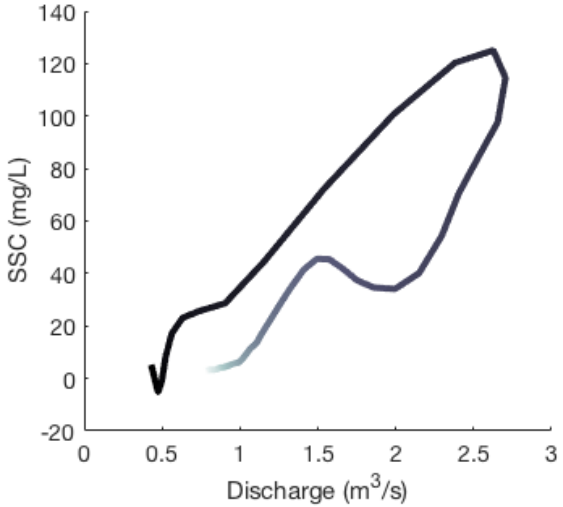
- Shepard Brook
  - Aug 4, 2015
  - Sep 22, 2013

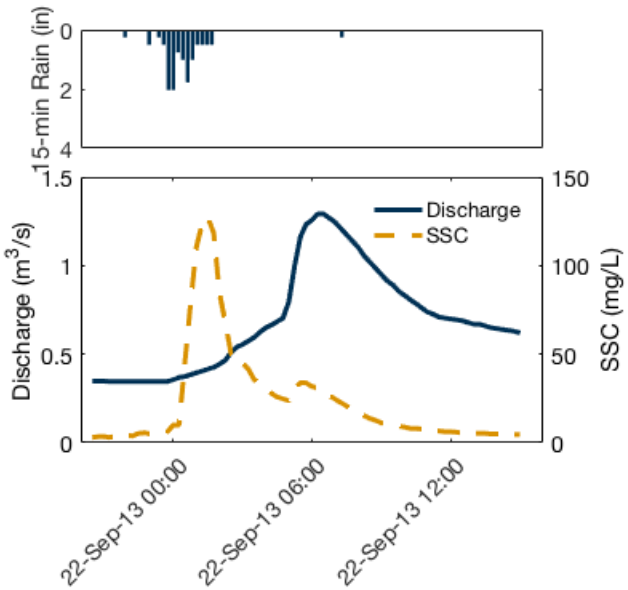
Milestone 3.f: (iv) – Develop self-organizing map to cluster/visualize flow vs turbidity data (hysteresis patterns)

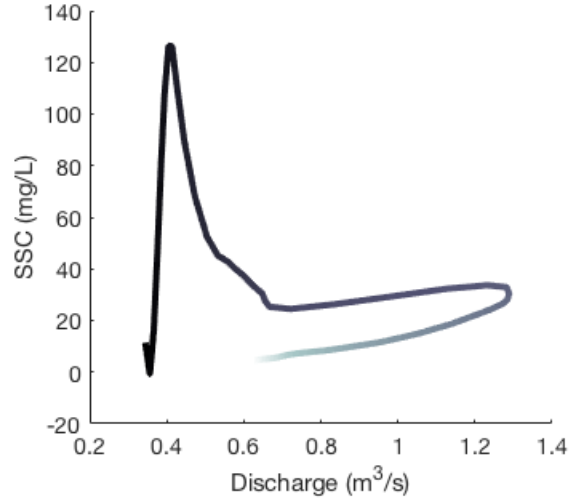
Thrust 3:
Goal 3.1; Obj. 3.1b

Hysteresis patterns help to infer watershed processes









Milestone 3.f: (iv) – Develop self-organizing map to cluster/visualize flow vs turbidity data (hysteresis patterns)

Thrust 3:
Goal 3.1; Obj. 3.1b

Methods of hysteresis analysis

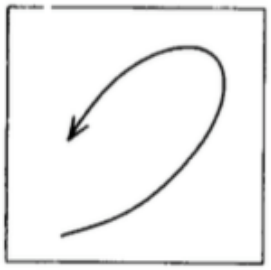
- Visual Patterns

Class I - Linear

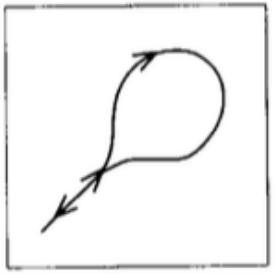
Class II - Clockwise

Garnett Williams, USGS, 1989

Class III - Counterclockwise



Class IV – Linear then Clockwise



Class V – Figure-Eight

Lloyd *et al*. 2015

Thrust 3:
Goal 3.1; Obj. 3.1b

Hysteresis patterns help to infer watershed processes

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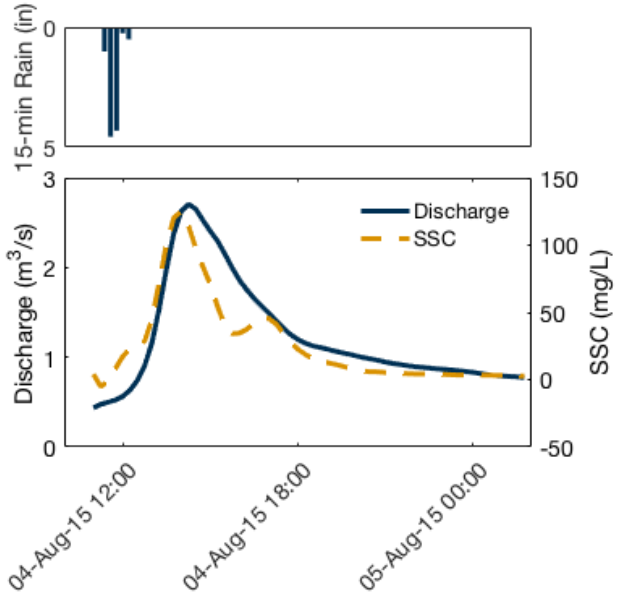
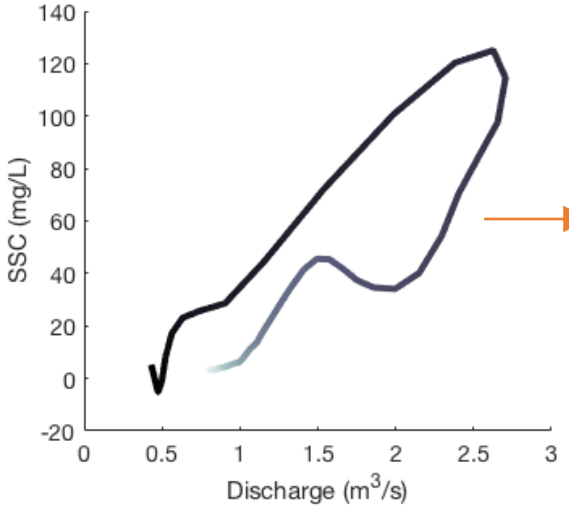
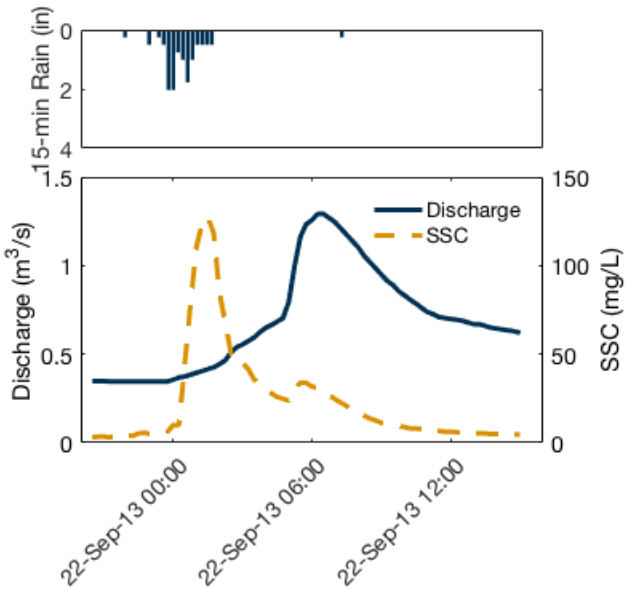
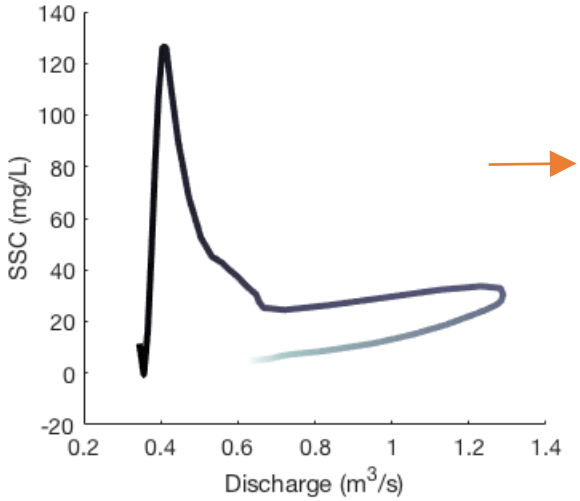




Streamflow activated
(source perhaps more distant)





Rainfall activated
(sources perhaps more local)

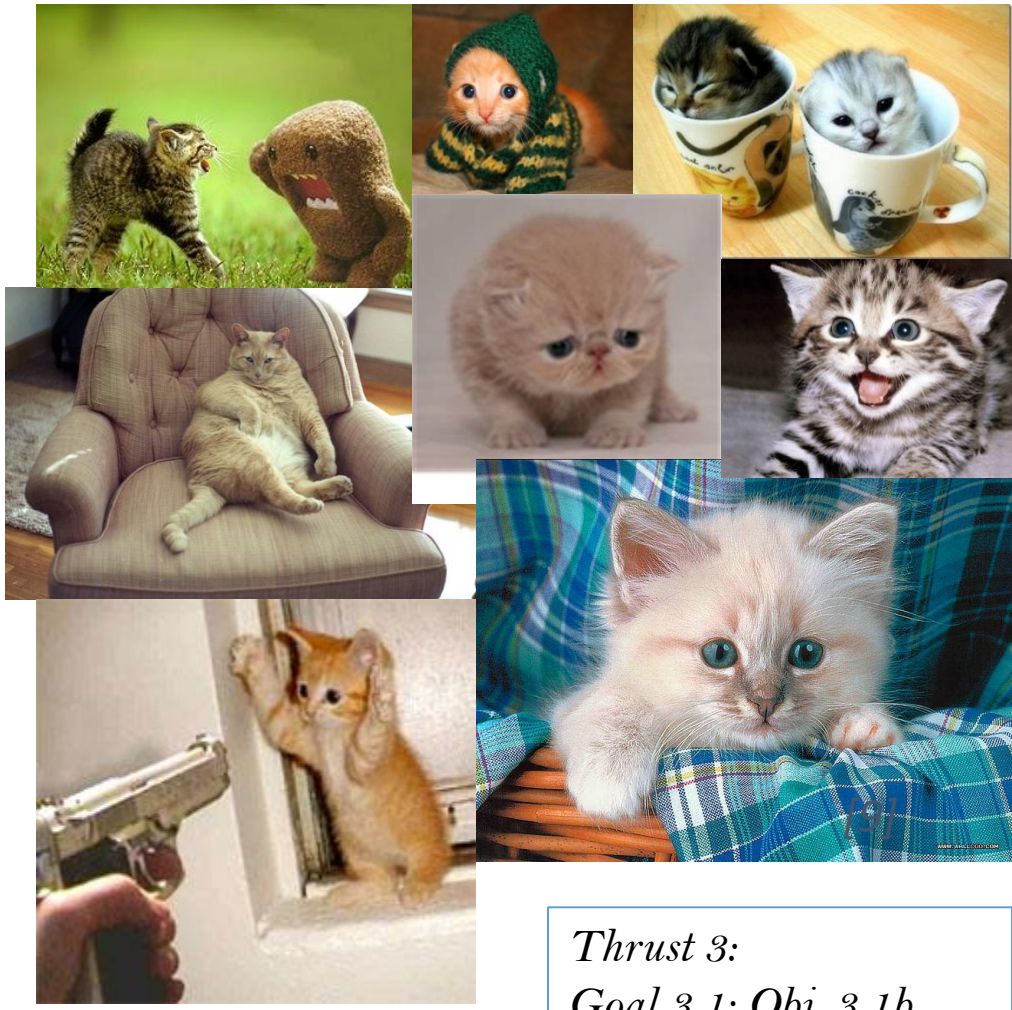
Milestone 3.f: (iv) – Develop self-organizing map to cluster/visualize flow vs turbidity data (hysteresis patterns)

Thrust 3:
Goal 3.1; Obj. 3.1b

Deep Learning Neural Nets (DLNNs)

BREE
Basin Resilience to Extreme Events
in the Lake Champlain Basin

- Very successful in image processing:
  - Similarities to **visual cortex of brain**
- Google (DLNNs) cats



Thrust 3:
Goal 3.1; Obj. 3.1b

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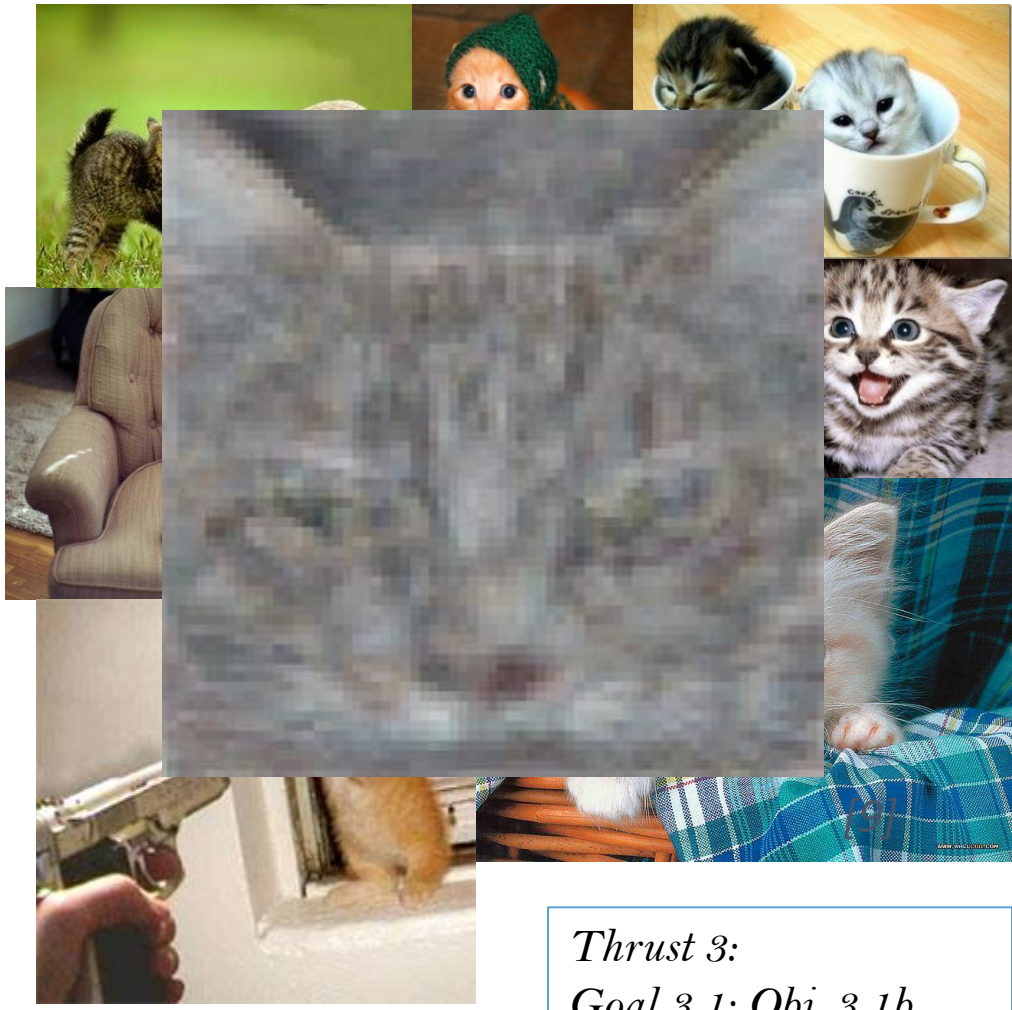
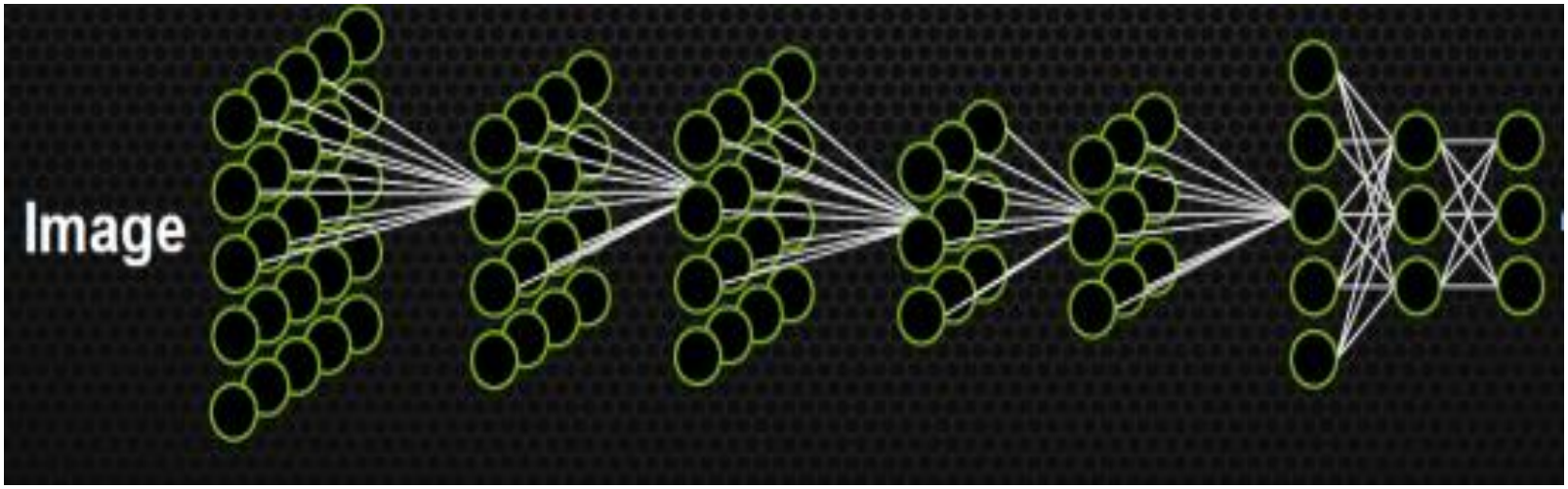


Thrust 3:
Goal 3.1; Obj. 3.1b

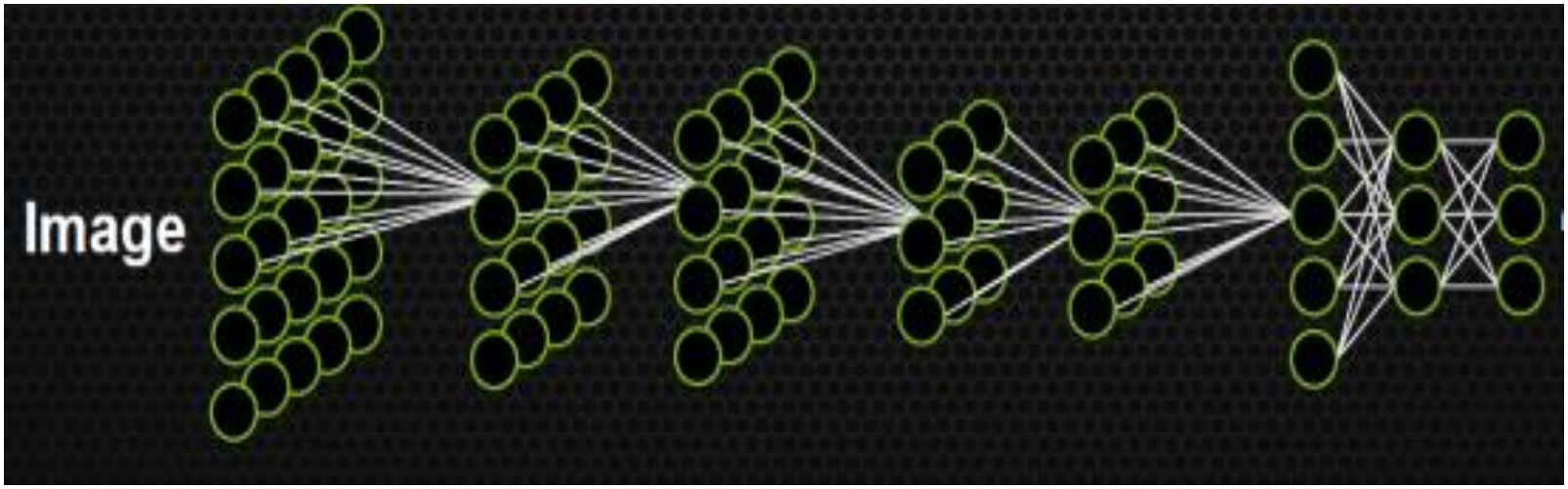
Deep Learning Neural Nets (DLNNs)

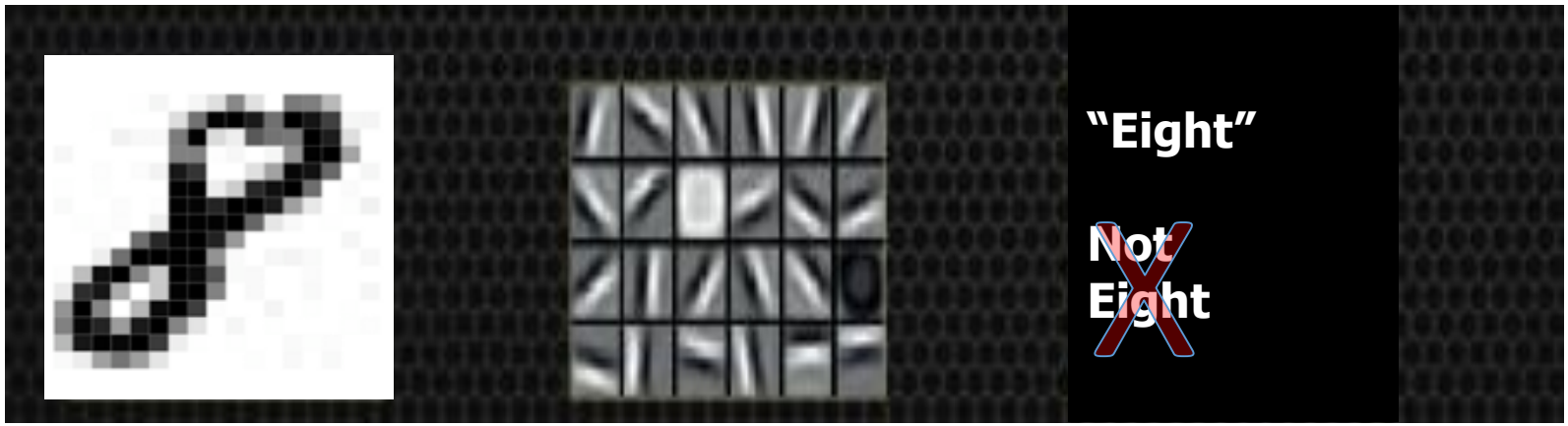


Handwritten character recognition

Thrust 3:
Goal 3.1; Obj. 3.1b

Deep Learning Neural Nets (DLNNs)





Thrust 3:
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Smart Hydrological event analysis

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SHP 36

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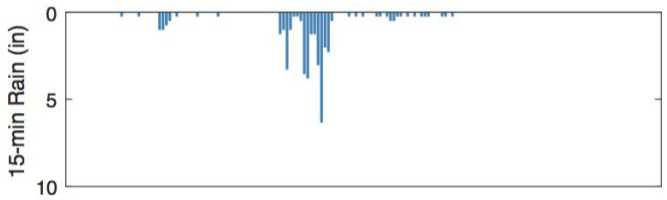
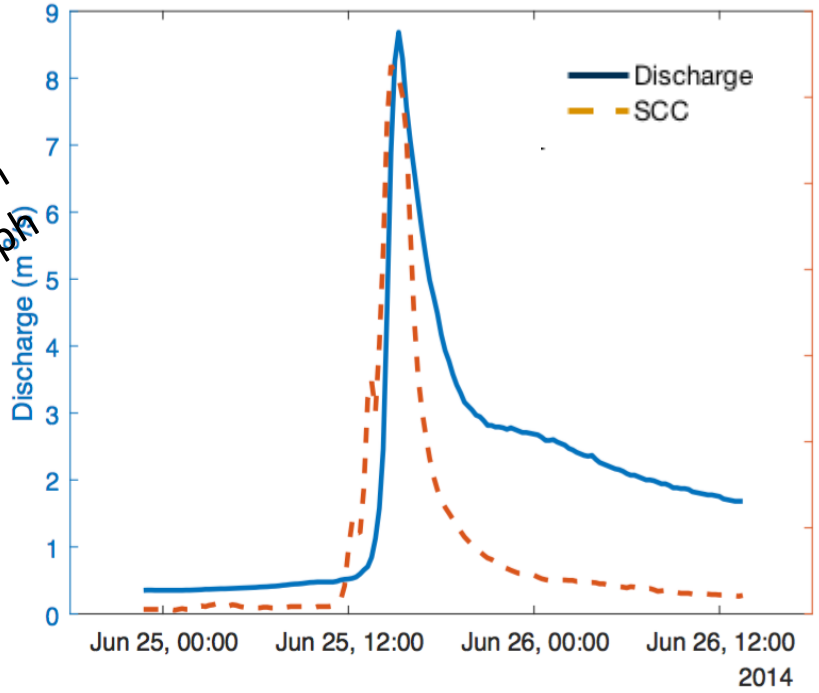
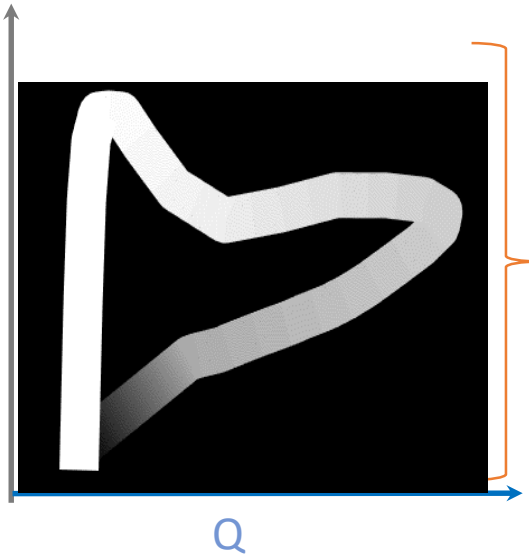
Hyetograph



Hydrograph & Sedigraph



TSS

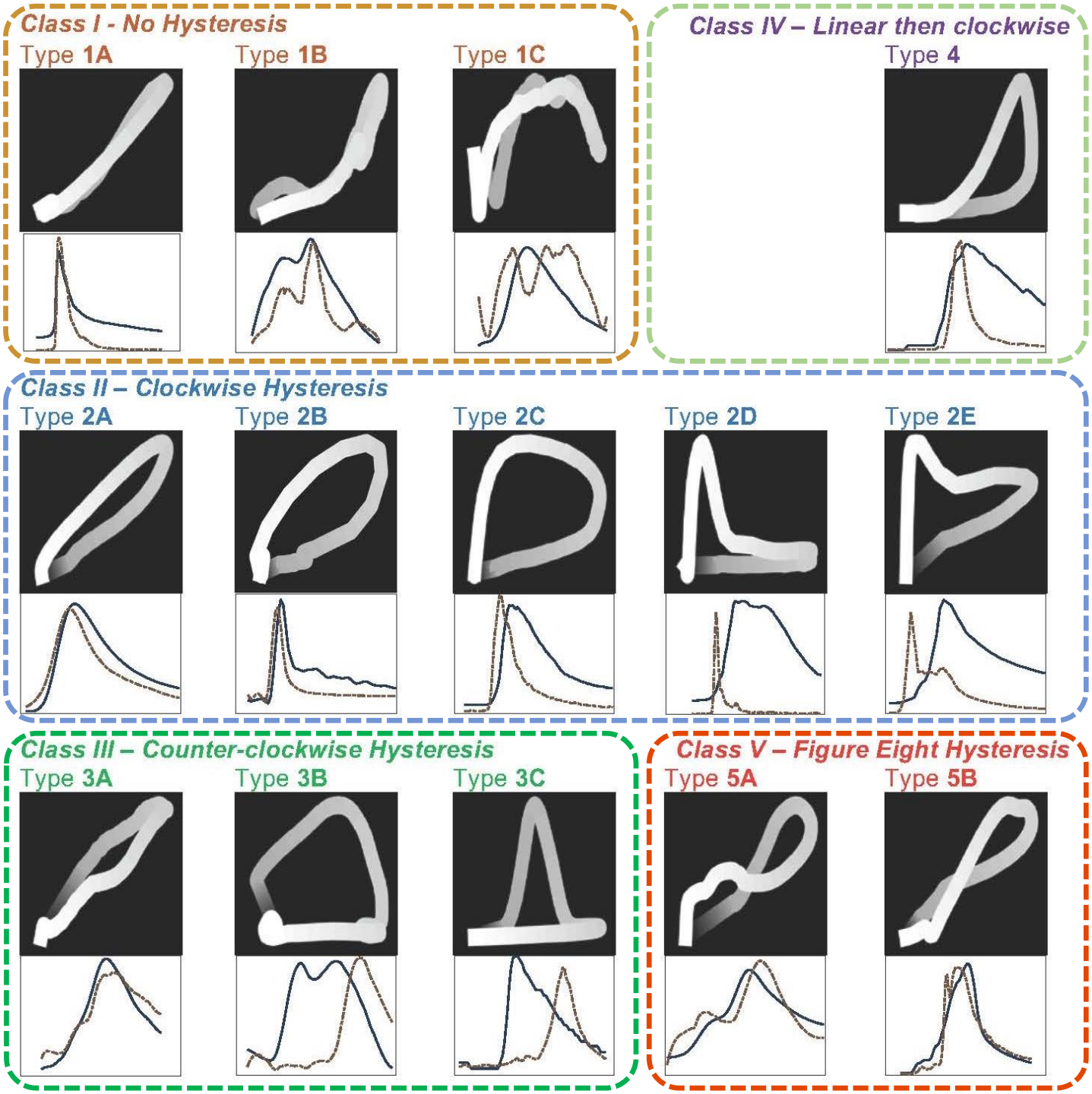


SSC-Discharge Plot

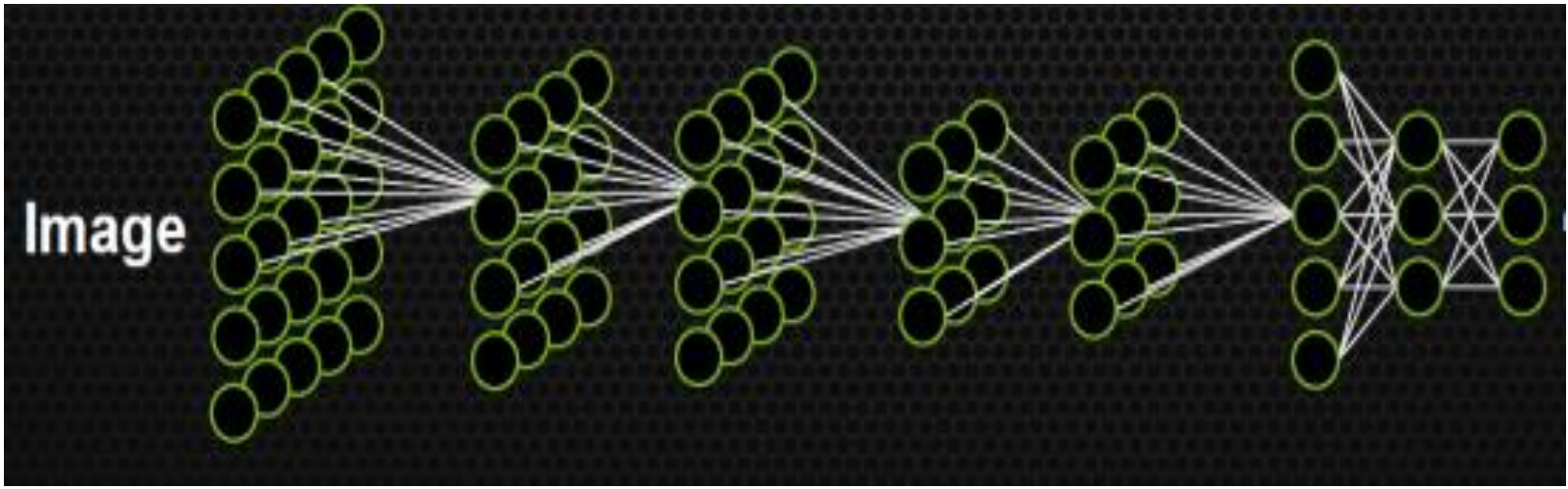
Thrust 3: Goal 3.1; Obj. 3.1b

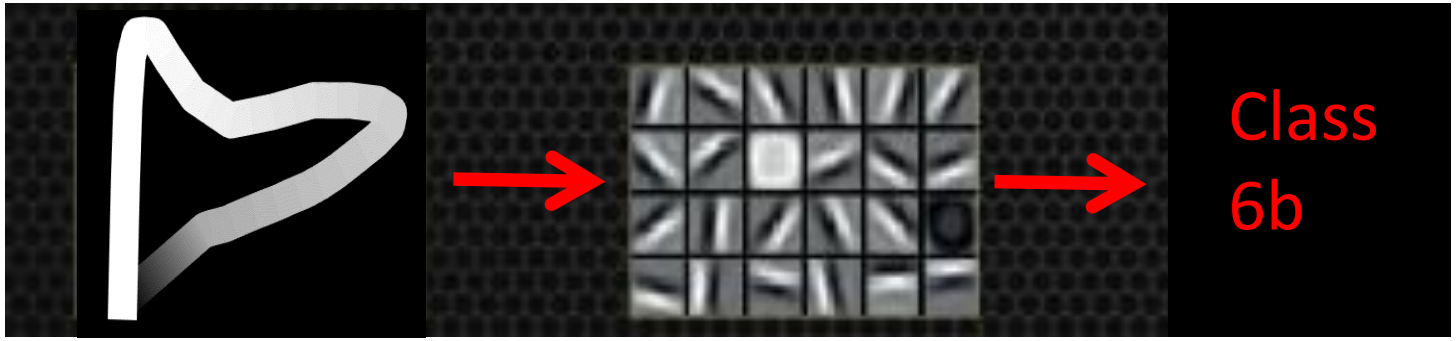
Patterns

- 14 Types recognized in data from Mad River watershed
- 5% unable to be classified
- How to automatically classify?



Deep Learning Neural Nets (DLNNs)





Milestone 3.g: (i) – Identify DBNN framework for use. Using NVIDIA machine, compare clustering results from SOM to DBNN to ensure algorithm validity.

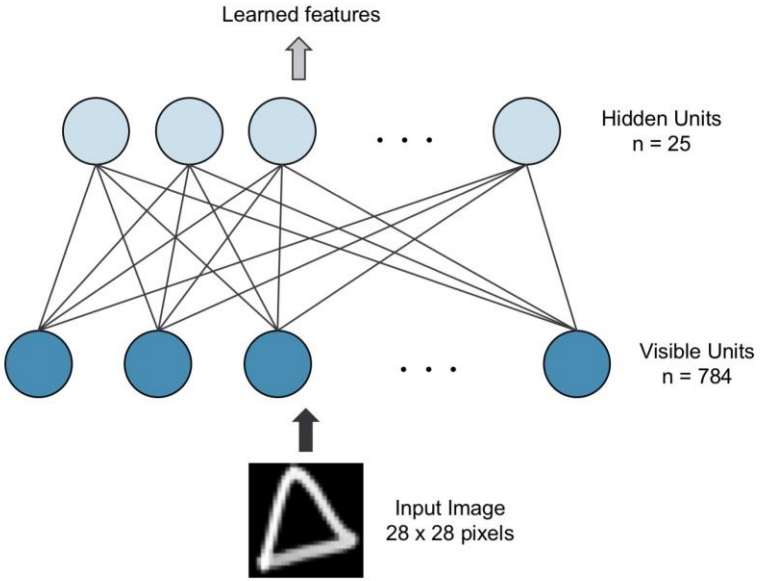
Thrust 3:
Goal 3.1; Obj. 3.1b

Automated Classification using a DLNNs

Restricted Boltzmann Machine (RBM)

- Training: 210 events
- Testing: 306 events

Restricted Boltzmann Machine (RBM)

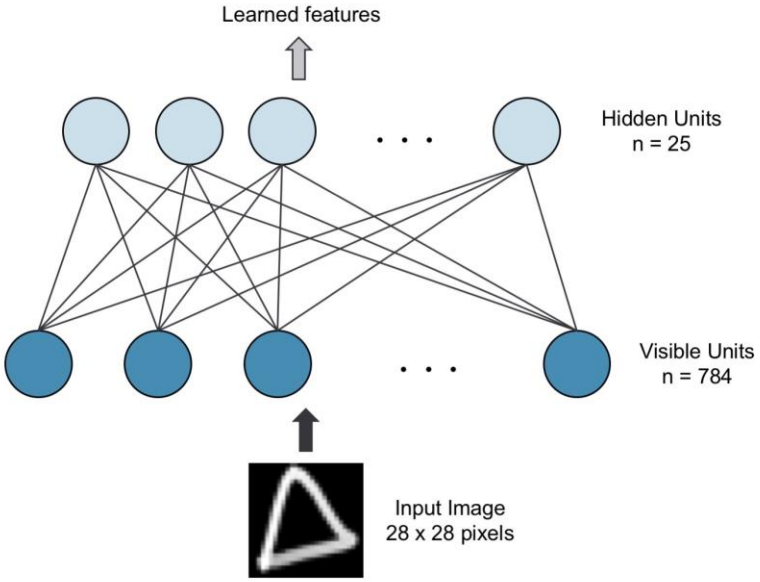


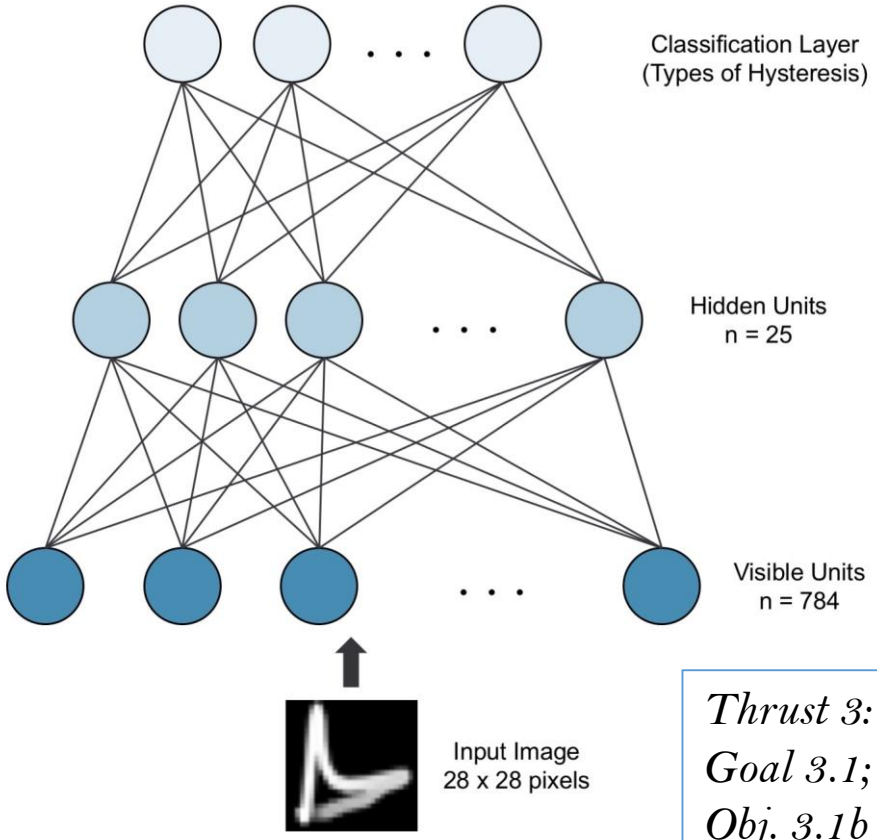
Thrust 3:
Goal 3.1; Obj. 3.1b

Automated Classification using a DLNNs

Restricted Boltzmann Machine (RBM)with Classifier Layer

Restricted Boltzmann Machine (RBM)

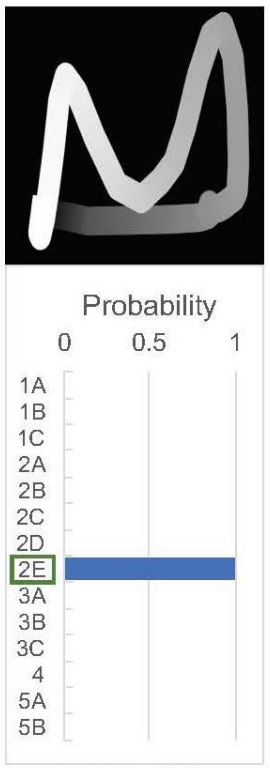


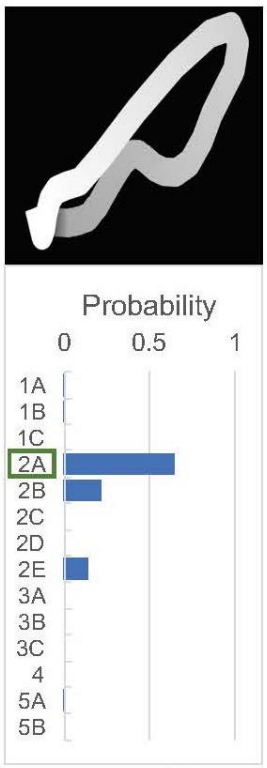


Thrust 3: Goal 3.1; Obj. 3.1b

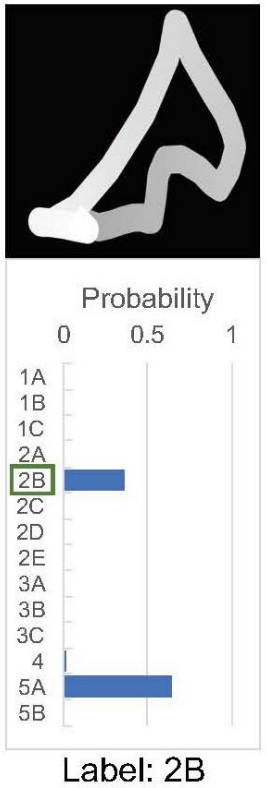
Classification of hysteresis types

Data set	Number of Model Runs	Number of Events (N)	Average Accuracy: Correct & Similar Types
Training	25	210	97%
Testing	25	361	71%





Correctly Classified



Misclassified

Thrust 3: Goal 3.1; Obj. 3.1b