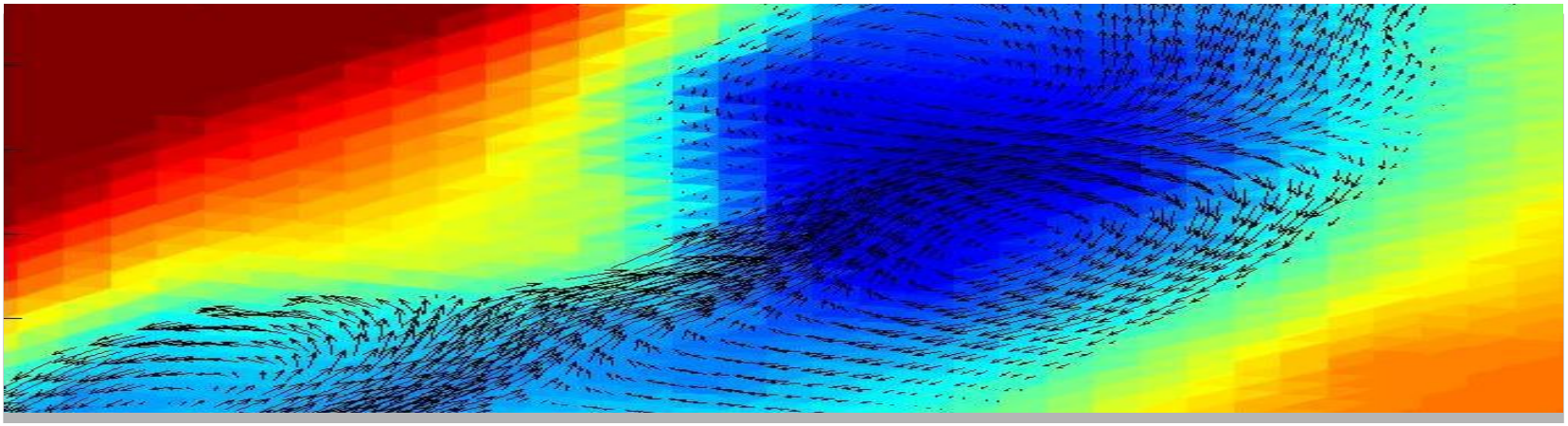

CHaMP Site CFD Modeling:

Modeled results and Validation Data Comparisons

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CHaMP Site CFD Modeling:

Modeled results and Validation Data Comparisons

- Objectives
- Brief Background on CFD Modeling
  - Steps in Modeling
- Model Validation and Optimization
  - Sources of Potential Errors
  - Model vs. Validation Comparisons
  - Optimizing Model Parameters
- Results: Modeled vs. Measured Depths and Velocities
  - For current best model optimization (11/27/2013)
- Next Steps

CHaMP Site CFD Modeling: Objectives

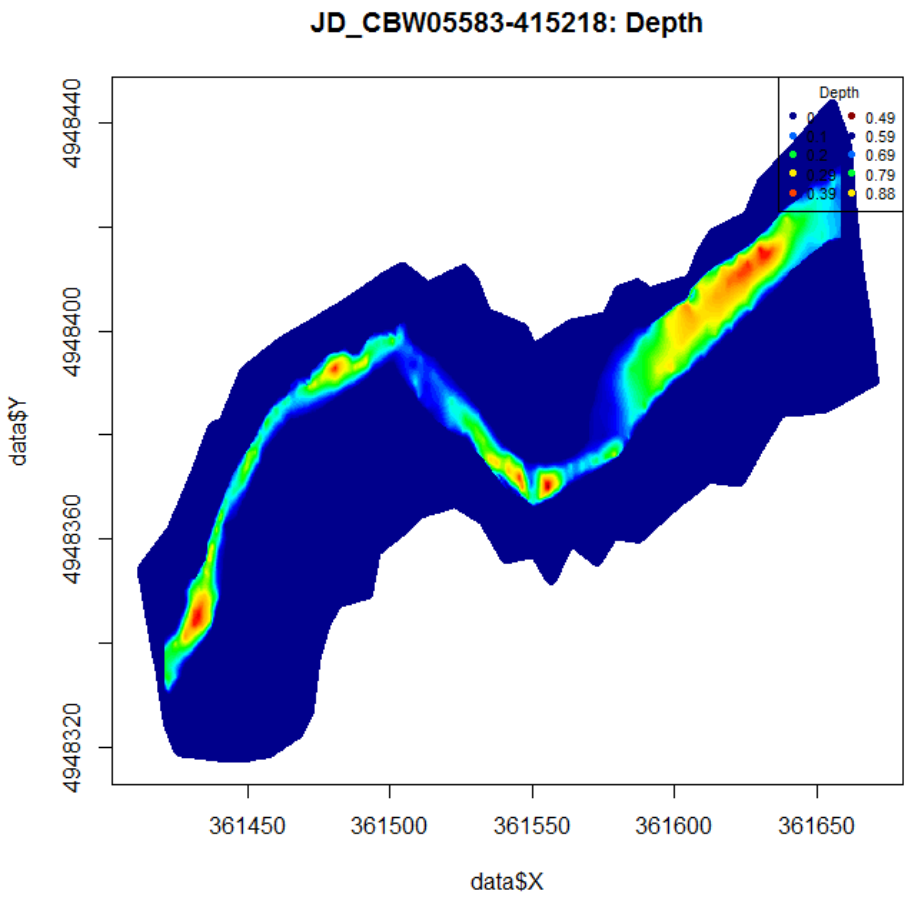
- Enable accurate hydraulic (CFD) modeling of large number of CHaMP sites over range of flow rates
  - Results sufficiently accurate, and reported on spatial scale suitable for, inputs to mechanistic fish-habitat models (HSI, NREI, shear-zone modeling, etc.)
  - Enable modeling of High volume of CHaMP sites (all CHaMP sites?)
    - Automation or near-automation of modeling

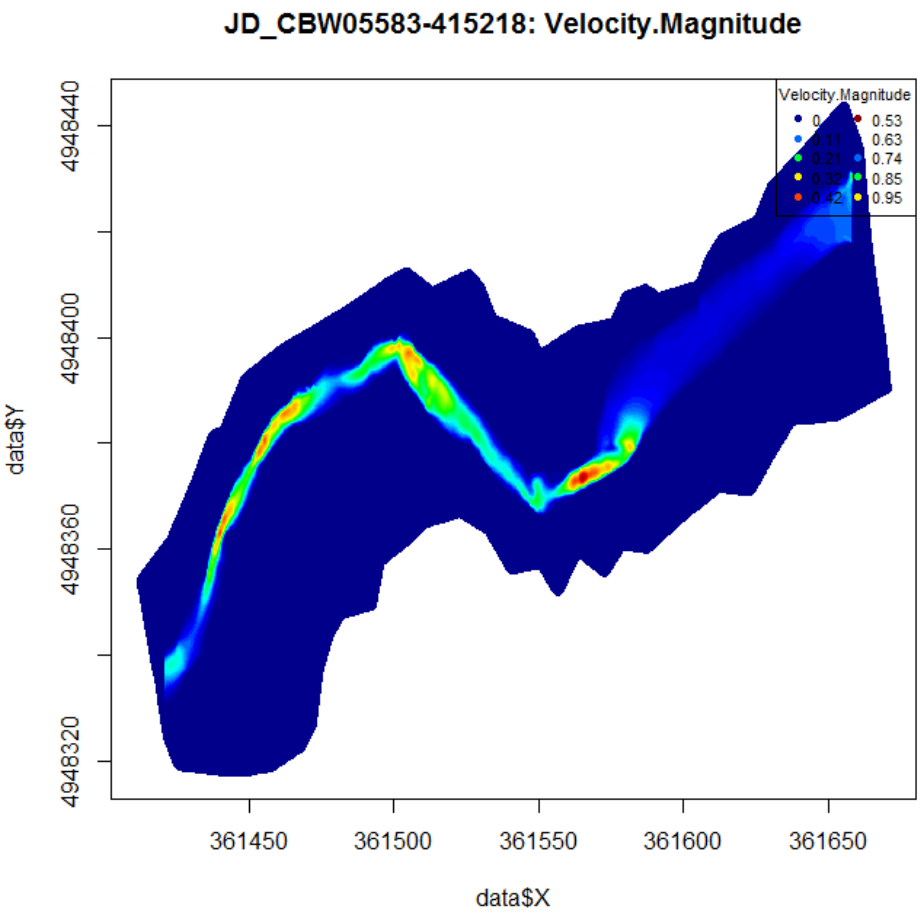
CHaMP CFD Modeling Steps

- **Receive Input Data (CHaMP)**
  - DEM, WSE-DEM, Thalweg; Particle Size Distribution (D84), Discharge
- **Convert Raw Data into Delft-3D Input Files (R-Code)**
  - 8-10 Input files per sites
- **Run the Delft-3D Code (0.5 – 10 computational hours per site)**
  - Low flow rates require longer simulation times
- **Convert Output Files into text files (Matlab macro)**
- **Map Delft-3D results back onto DEM Grid (R-code)**
- **Create Curvilinear Grid and Map Delft-3D results onto Curvilinear Grid**
  - For NREI Inputs Only (R-Code)
- **Check Results for Convergence and Stability (R-code)**
- **Compare Results to validation data (R-Code) when available (R-Code)**
- **Ship Results!**

Example Results:

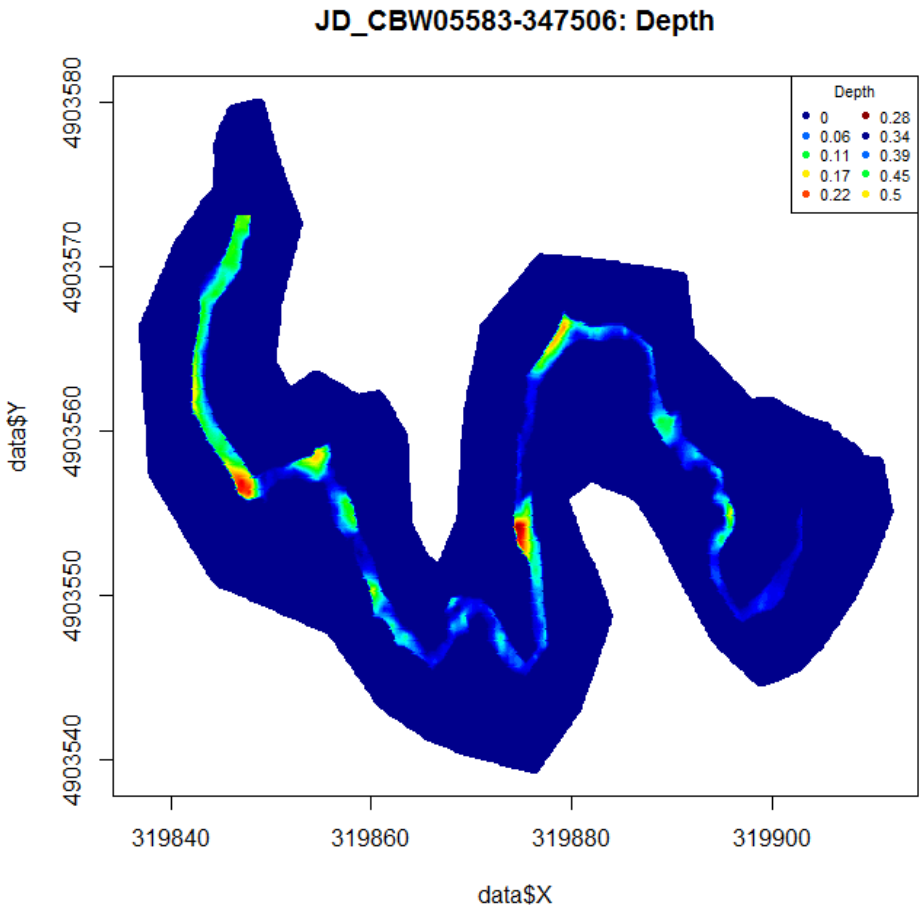
Depth and Velocity Magnitude

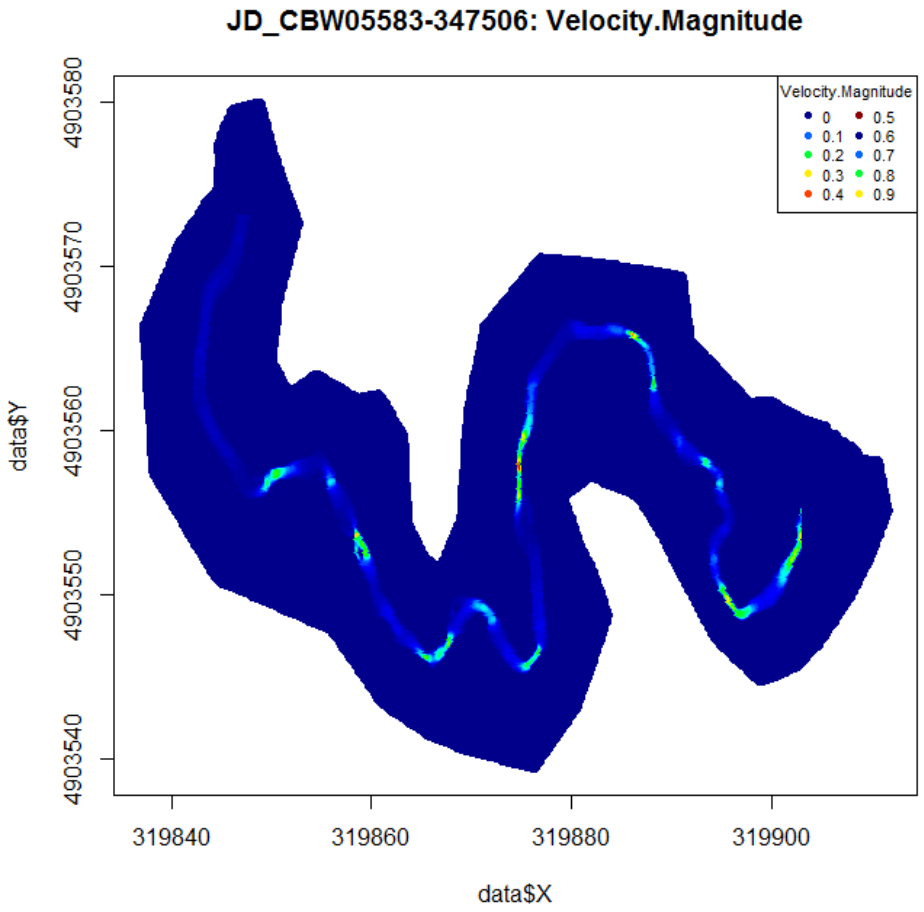




Example Results:

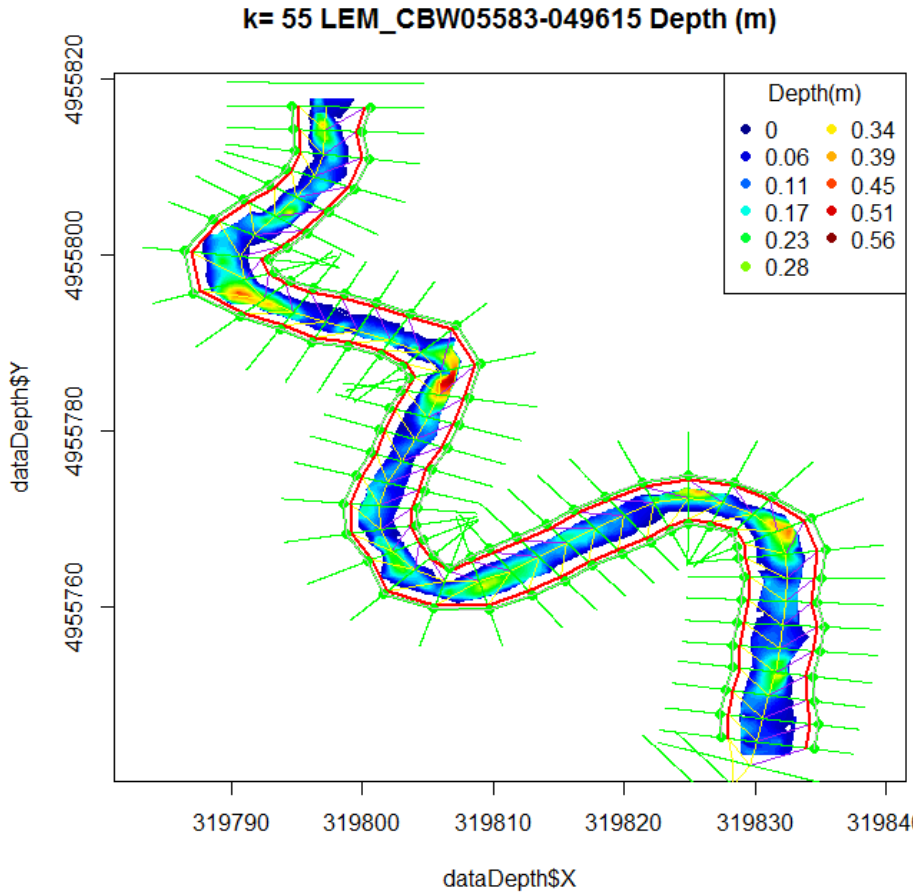
Depth and Velocity Magnitude

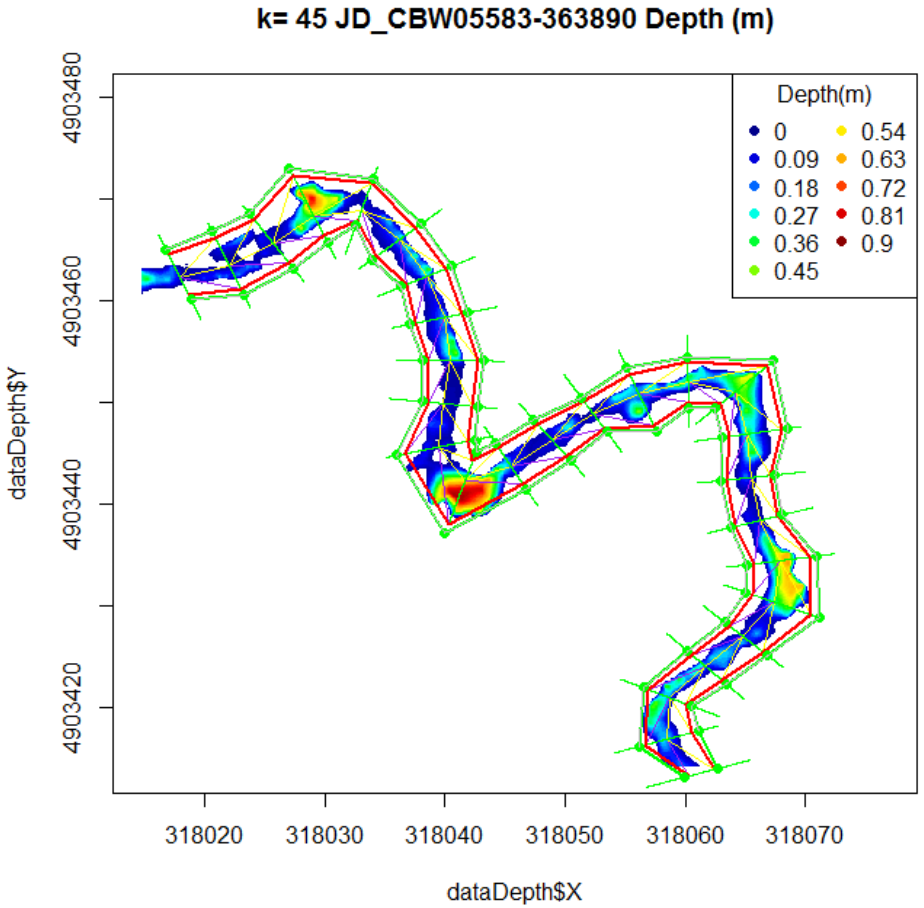




Translating Results to Curvilinear Grids (for NREI)

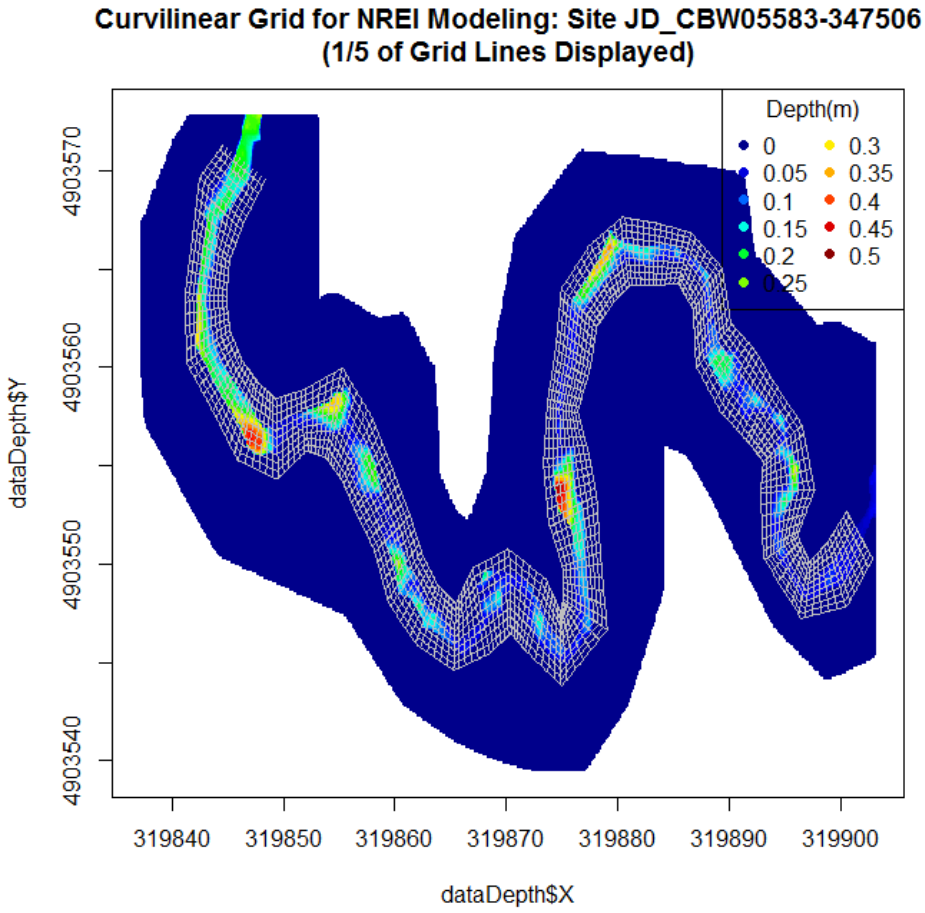
Challenge: Build algorithm that takes CFD solution, create an orthogonal grid that follows just outside wetted edge, with reasonable cell geometry, that doesn't fold back on itself.

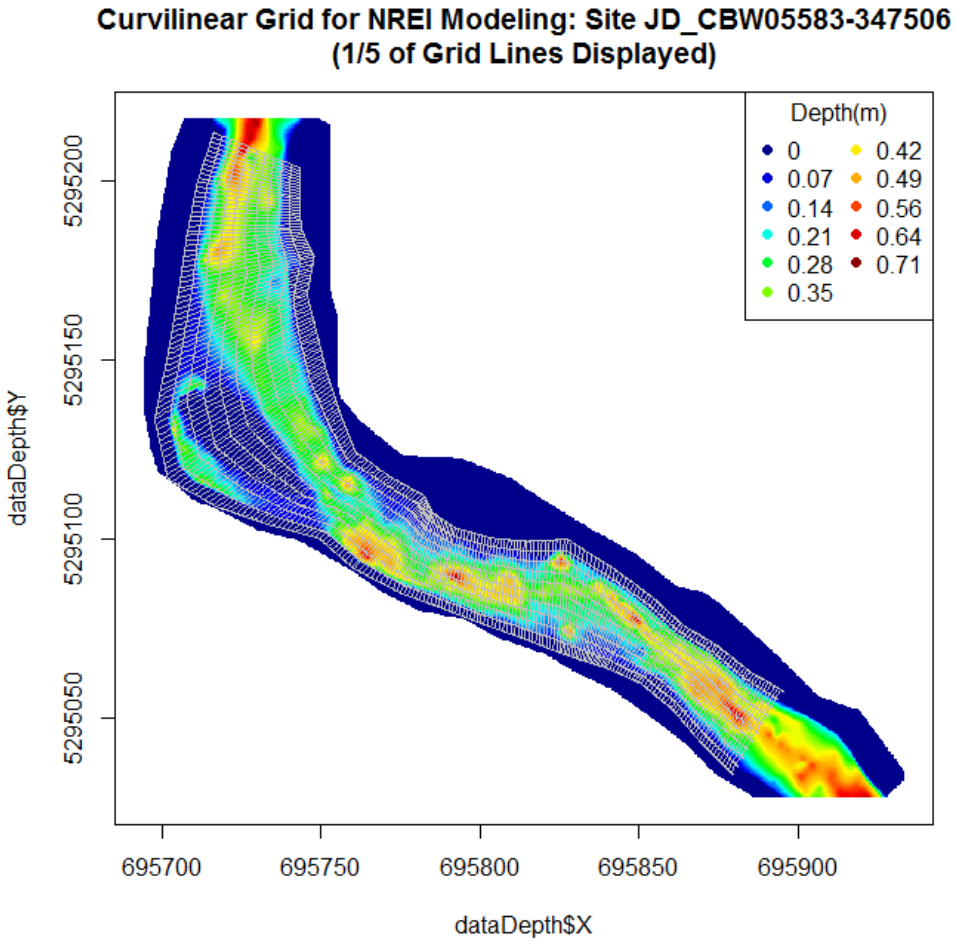




Translating Results to Curvilinear Grids

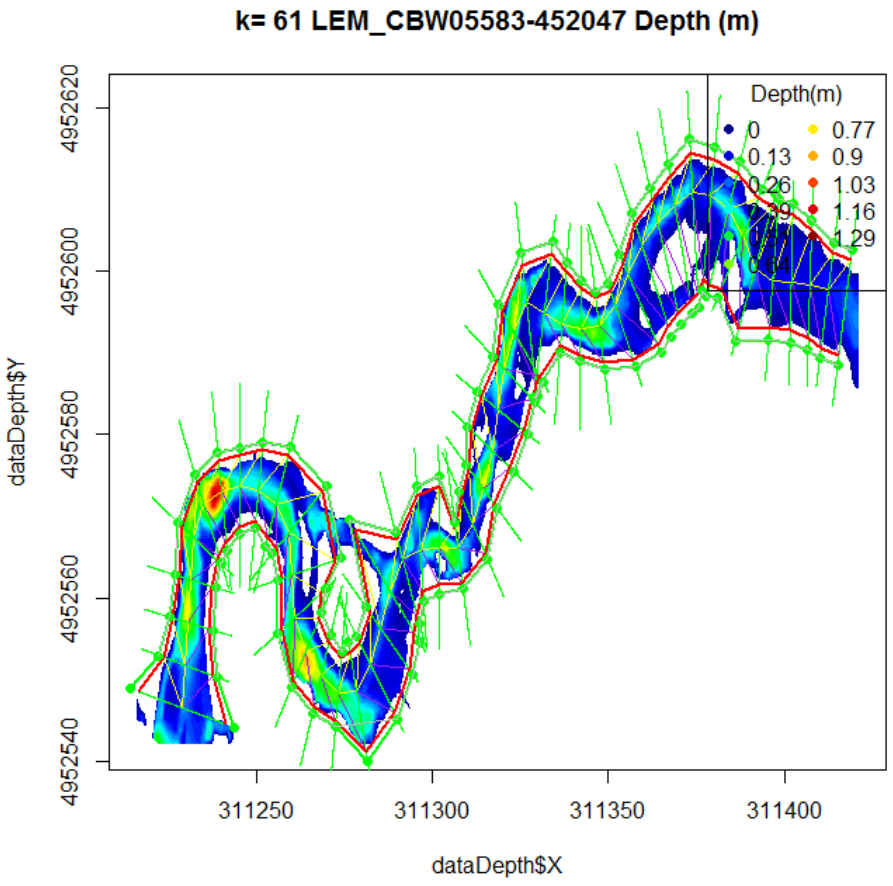
(For NREI Inputs)

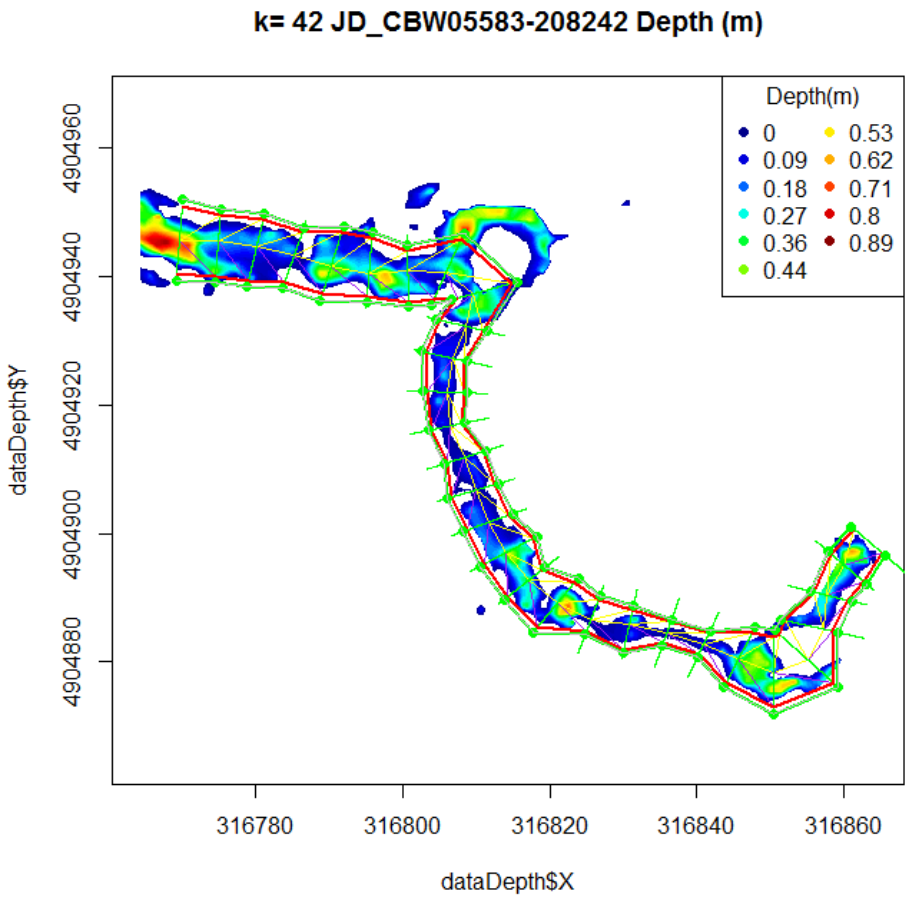




Translating Results to Curvilinear Grids

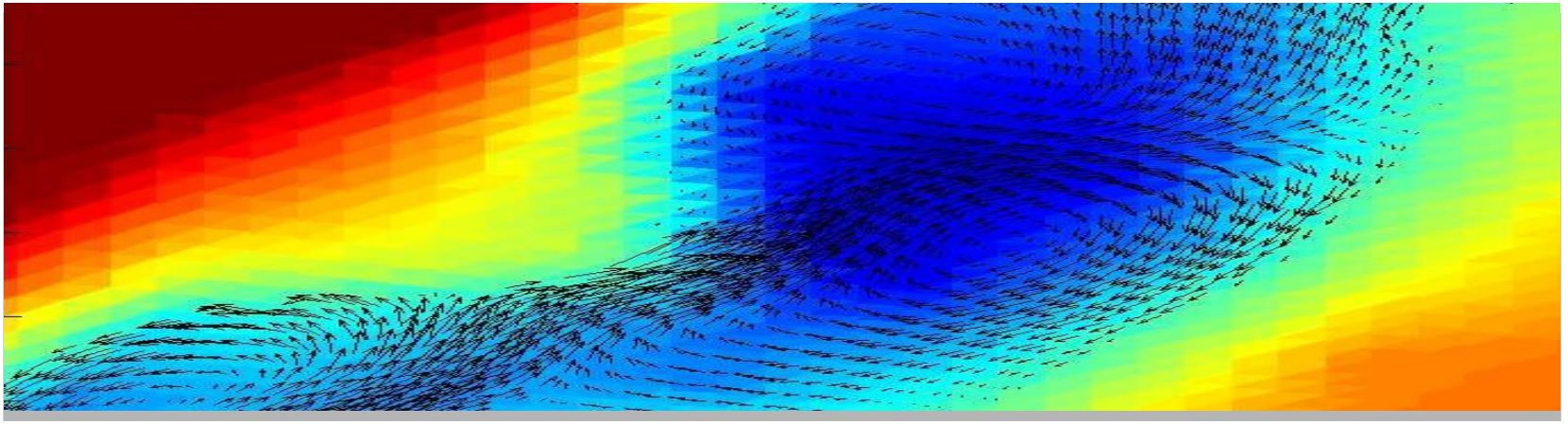
Curvilinear Grid “Problem Children” sites, requiring manual manipulation to generate successful grid





10-20% of sites require manual manipulation to generate valid curvilinear grids

- 3 Input values created to manipulate algorithm to suit stream geometry
- A few sites have “issues” that may or may not be problematic for NREI



CHaMP Site CFD Modeling Results

MODEL VALIDATION AND OPTIMIZATION

CHaMP Site CFD Modeling: Potential Error Sources

- Sources of Error*:
  - Error in Discharge Estimates
  - **Error and Lack of Detail in Bathymetry data (DEM)**
    - **Important Geometry (pebbles, rocks) exists on a finer scale than DEM can map.**
      - **DEM data tends to smooth out localized variability**
    - **Features affecting flow may not be represented in DEM data**
      - **Bushes, woody debris, etc.**
    - **Porous or hidden features may be represented as solid features in DEM data**
      - Beaver Dams, Bank Undercuts
    - **Local variation in Surface roughness not currently used in model**
  - Boundary Conditions Imperfect
    - Distribution of discharge along inlet to modeled stream section
    - Water Surface elevation along outlet to modeled stream section
  - Numerical Simulation Imperfect
    - Grid Spacing or time step too effects
    - Turbulent and/or localized 3D flows not modeled accurately
      - Localized Eddies difficult to model accurately
    - Surface roughness inputs not optimal

* Items in **BOLD** are what I believe are our current limiters for accuracy

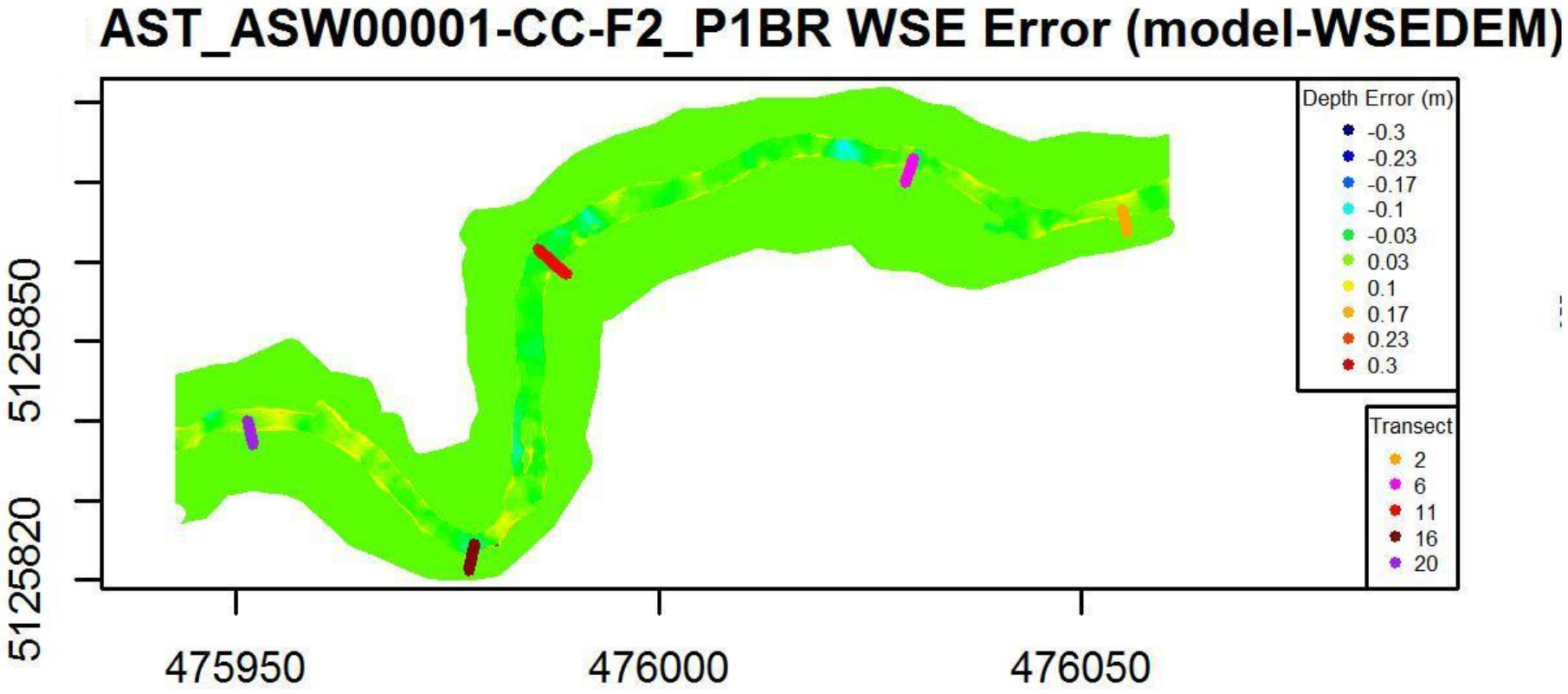
CFD Model Output and Available Validation Data

- CFD Model Output Generate for each Site includes:
  - Velocity (m/s)
    - X and Y Component Vectors
  - Depth (m) and Water Surface Elevation (m)
  - Bed Shear Stress (N/m^2)
  - Vorticity (1/s)

- Field Data useful for validation includes
  - Depth
    - At all DEM points
    - Along Validation Transects
  - Velocity
    - Along Validation Transects

Difference (m) between Modeled Depth Results - DEM Depth

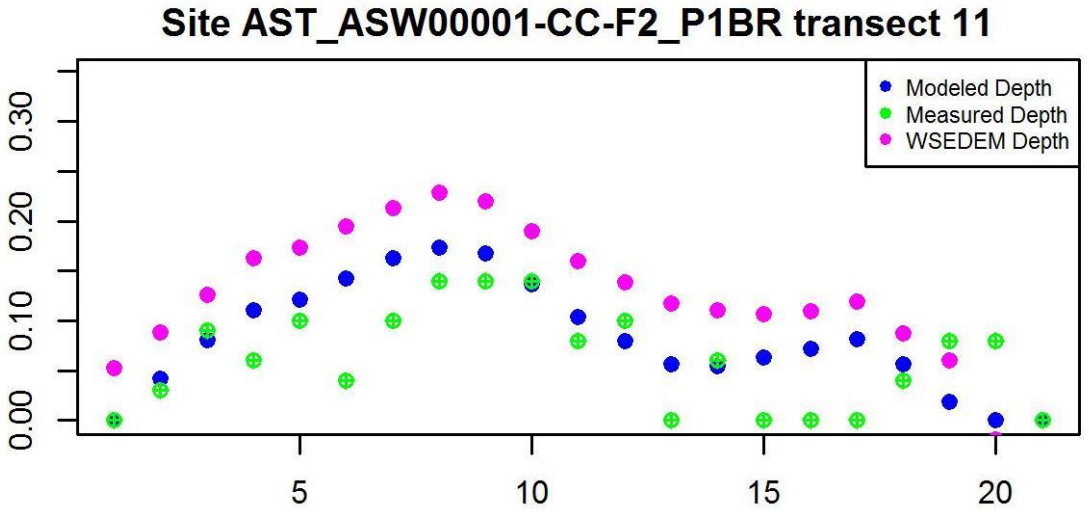
- A “perfect” match would be solid green
- Yellow through red indicates modeled depth greater than DEM
- Cyan through dark blue indicates modeled depth less than DEM Depth



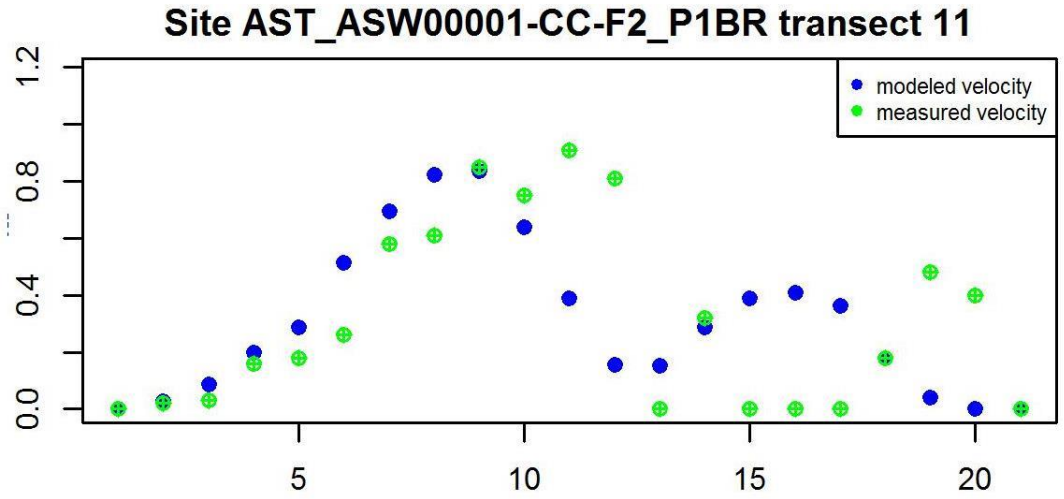
Comparison Plots Between Modeled and Validation Data for Depth and Velocity

Plots Created for Each Validation Transect at Each Site

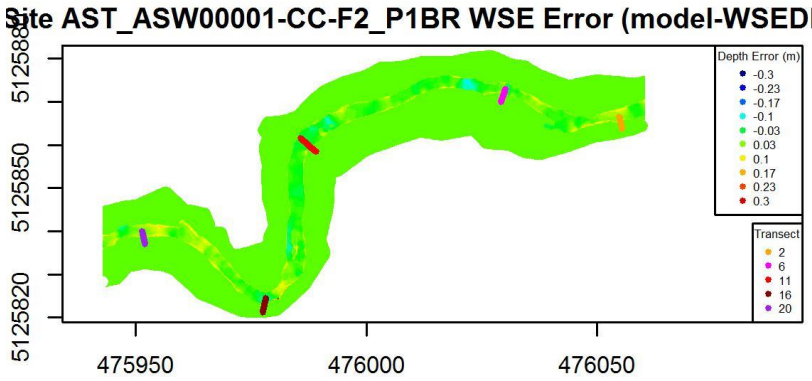
Depth (m)

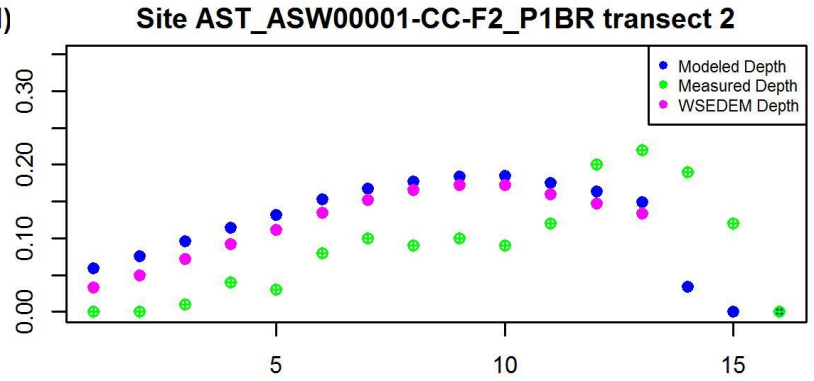


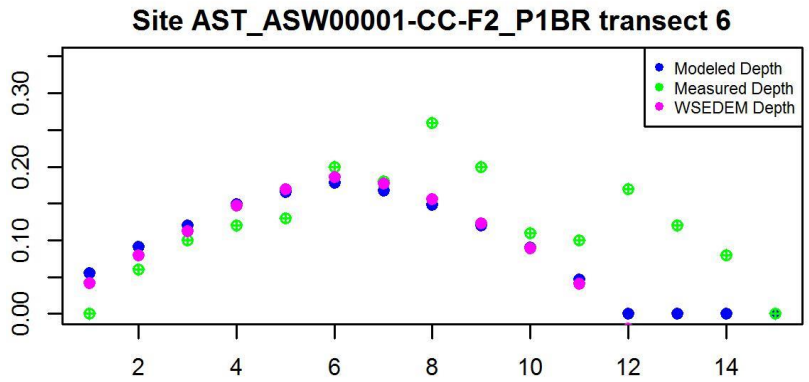
Depth Averaged Velocity (m/s)

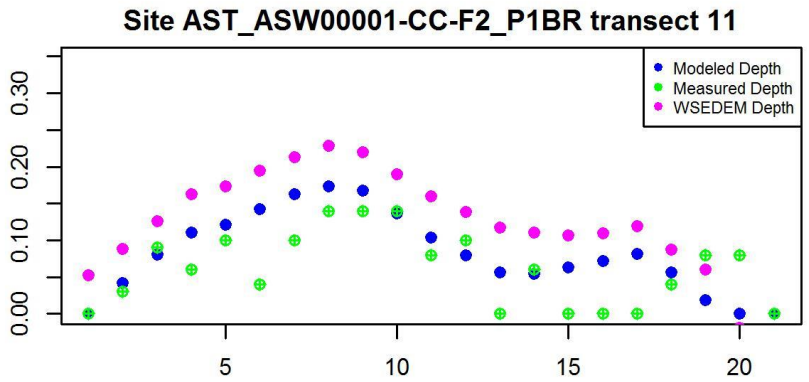


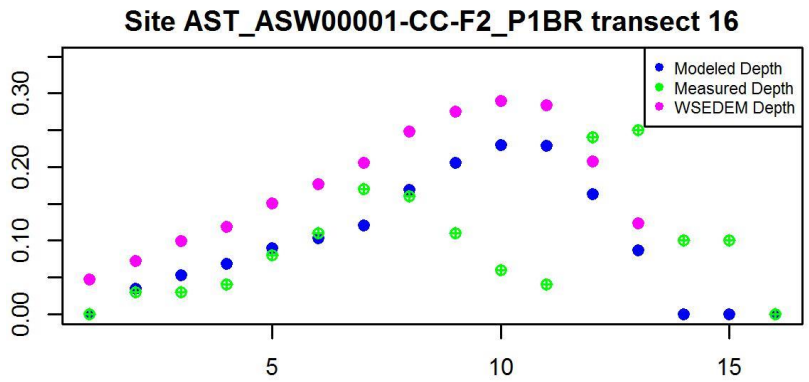
Validation Plots Created for Each Site: Depth

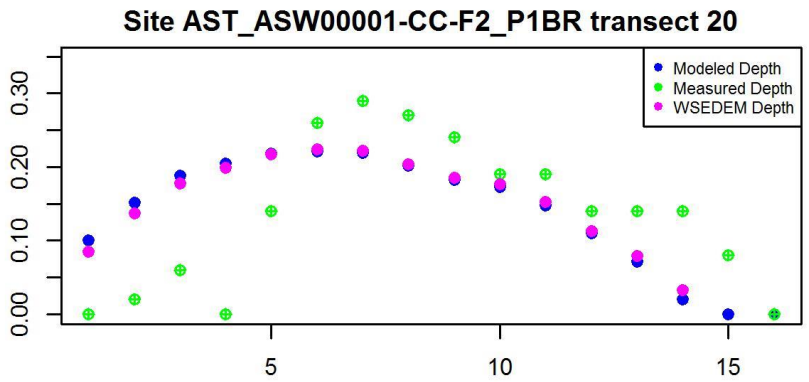




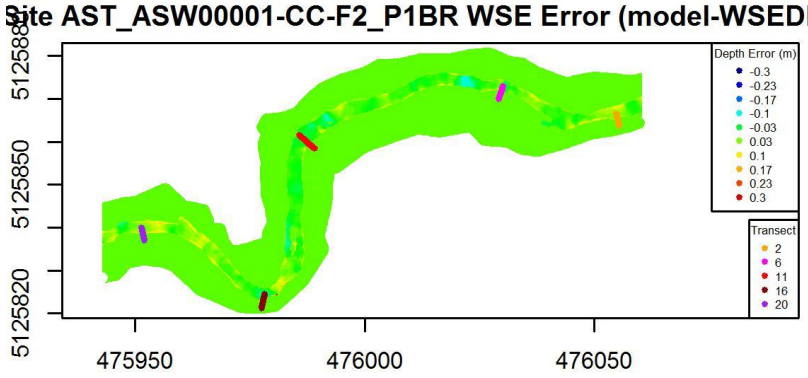


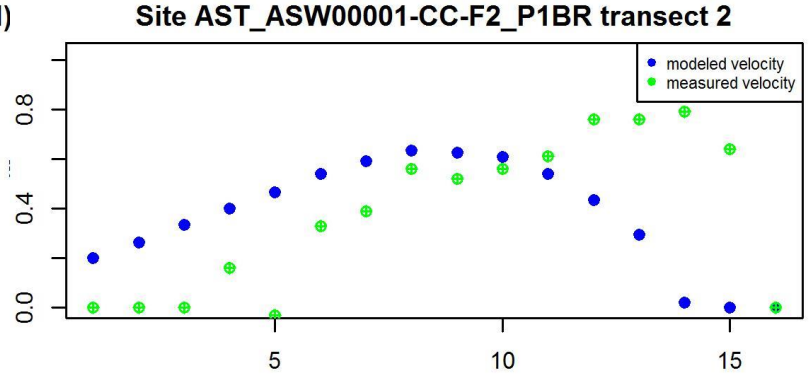


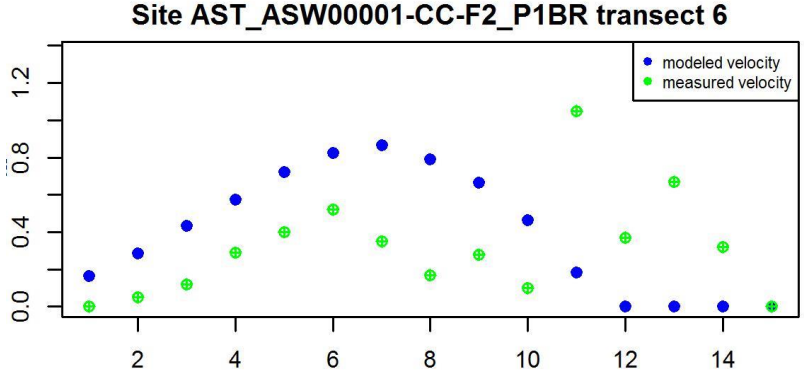


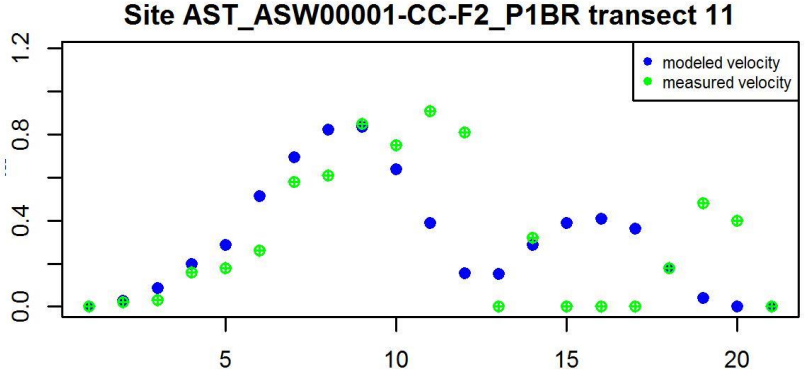


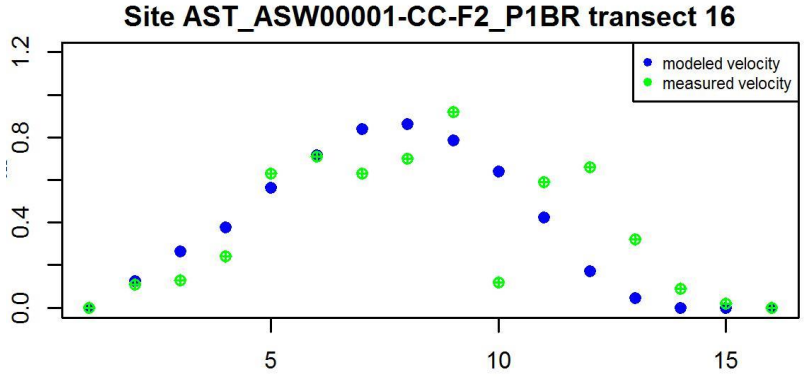
Validation Plots Created for Each Site: Depth

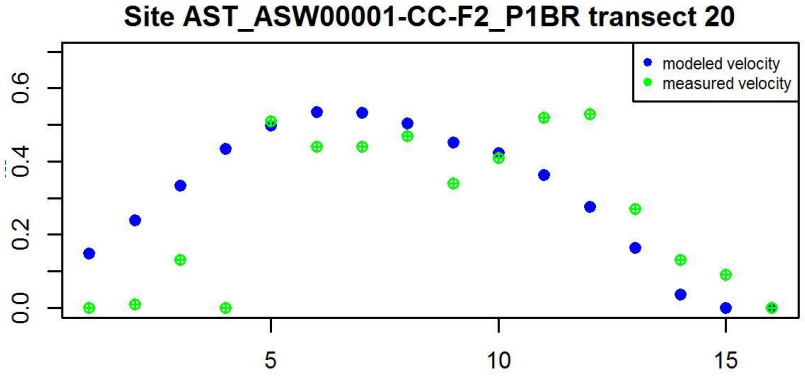






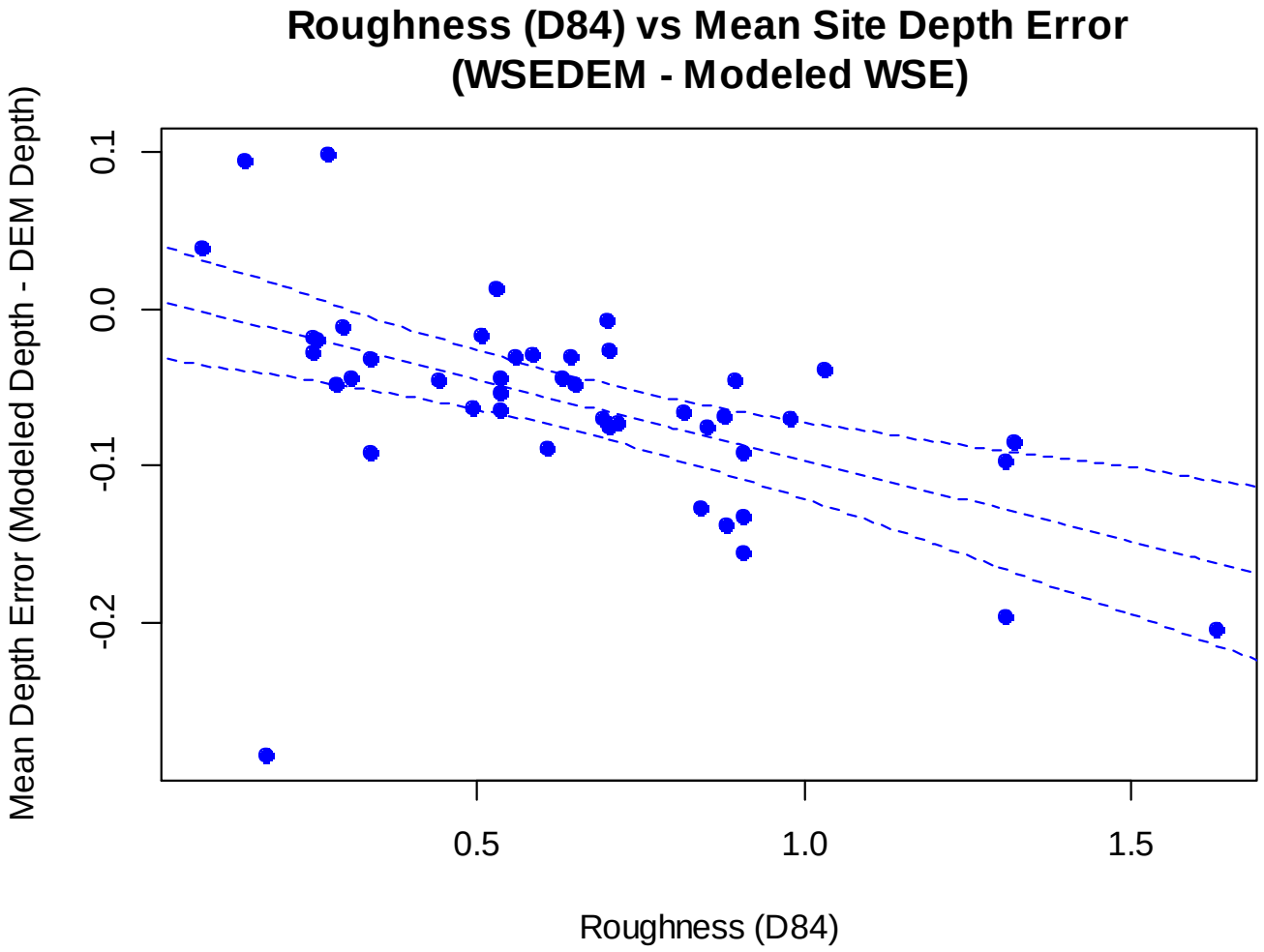






Model Optimization

Initial Results (using D84 as roughness) showed relationship between increasing roughness, and increasing under-prediction of depth



Model Optimization

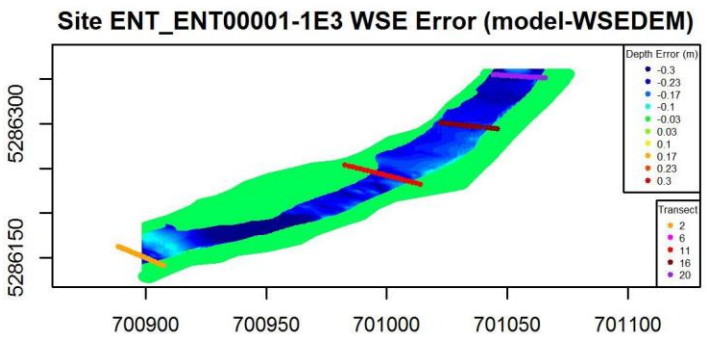
- Two “Fudge Factors” are available with which to fine-tune model.
  - Horizontal Eddy Viscosity
    - Generally appears that the “best” HEV is the smallest value that can be used, while still achieving a stable numerical solution.
  - Surface Roughness (White-Colebrook Coefficient)
    - Metrics of surface roughness (D16, D50, D84) are available.
    - Goal is to use a consistent, optimized function of one or more metrics to define White-Colebrook coefficient for each sites
      - A scalar on D84 is currently used
      - Chezy and Manning surface roughness models also available
    - A range of scalar values to convert D84 to a WC coefficient were used, and scalar the minimized bias over depth and velocity results, over all sites, was selected

Optimization of WC Roughness Coefficient

Depth: Modeled vs. DEM, by Roughness Coefficient

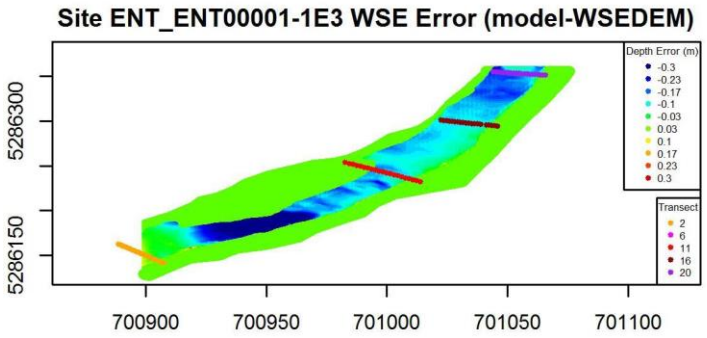
White-Colebrook Roughness Coefficient

1 x D84

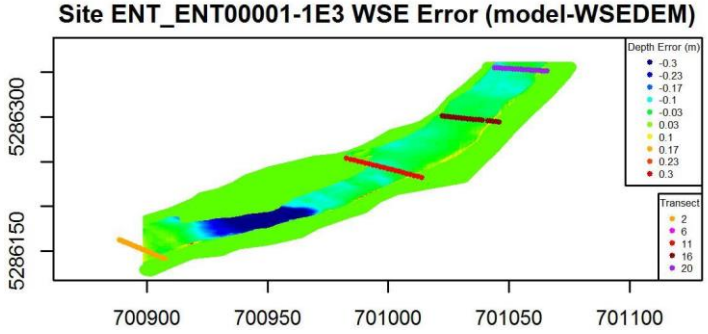


White-Colebrook Roughness Coefficient

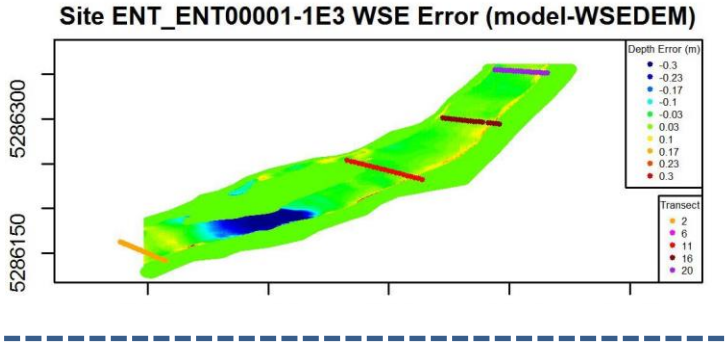
2 x D84



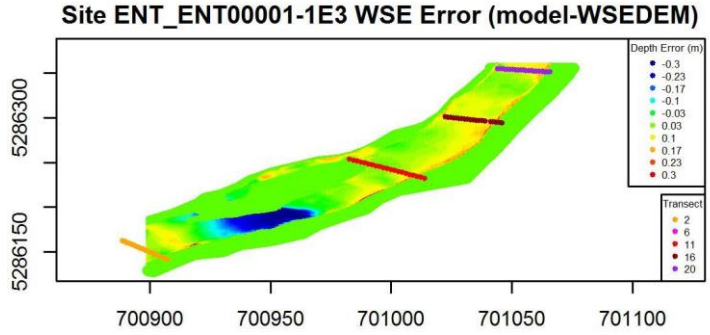
4 x D84



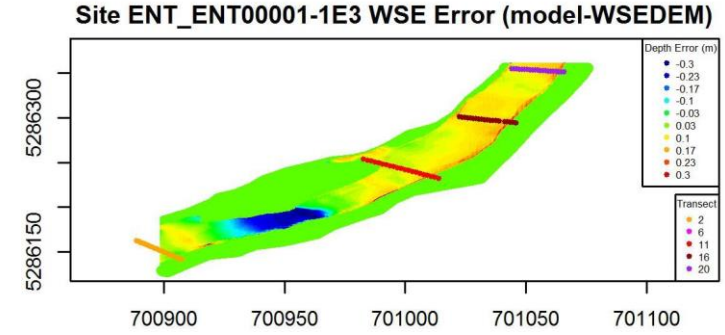
6 x D84



8 x D84

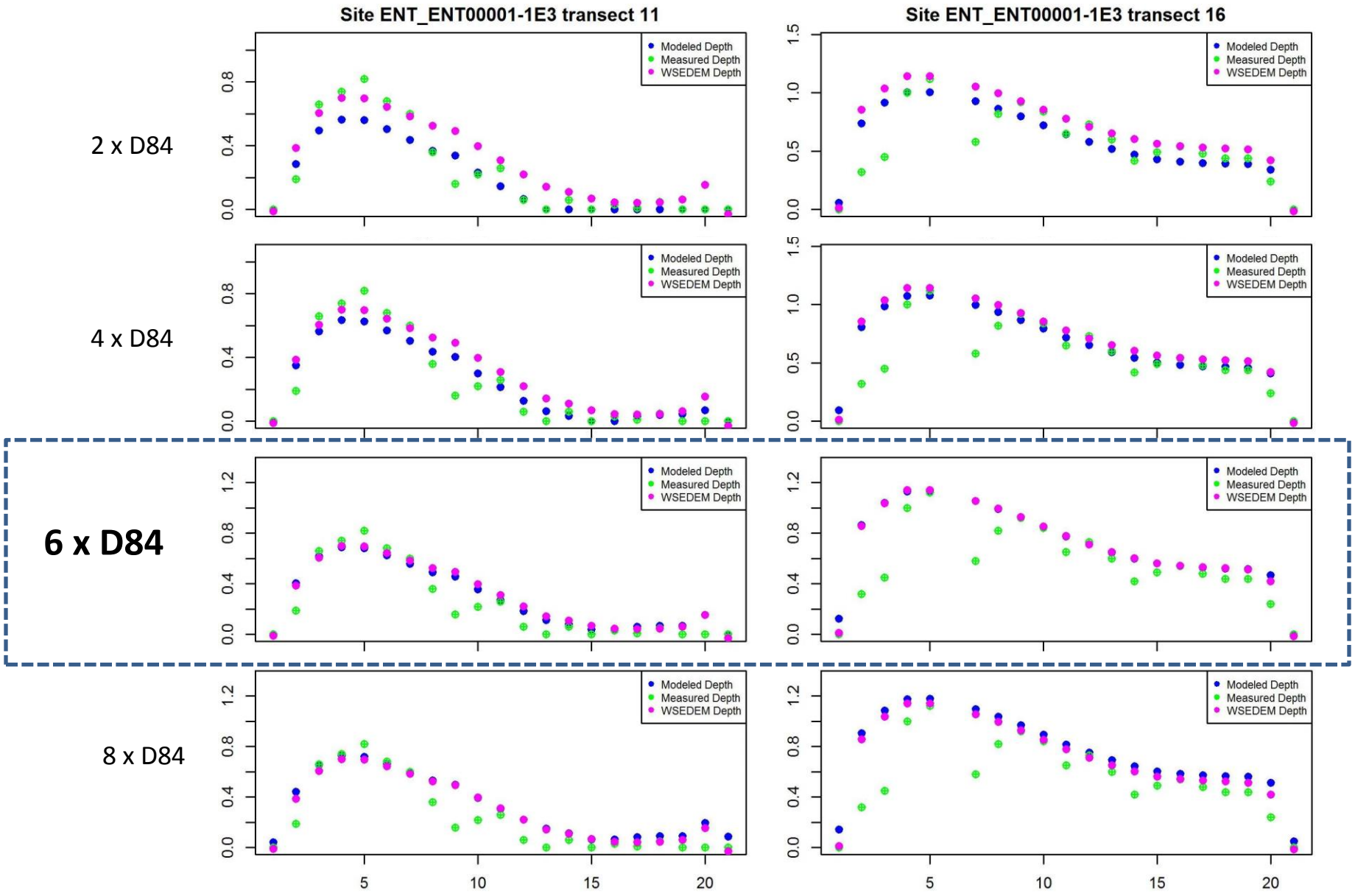


10 x D84



Optimization of Roughness Coefficient

Depth: Modeled vs. Measured by Roughness Coefficient



Velocity: Modeled vs. Measured by Roughness Coefficient

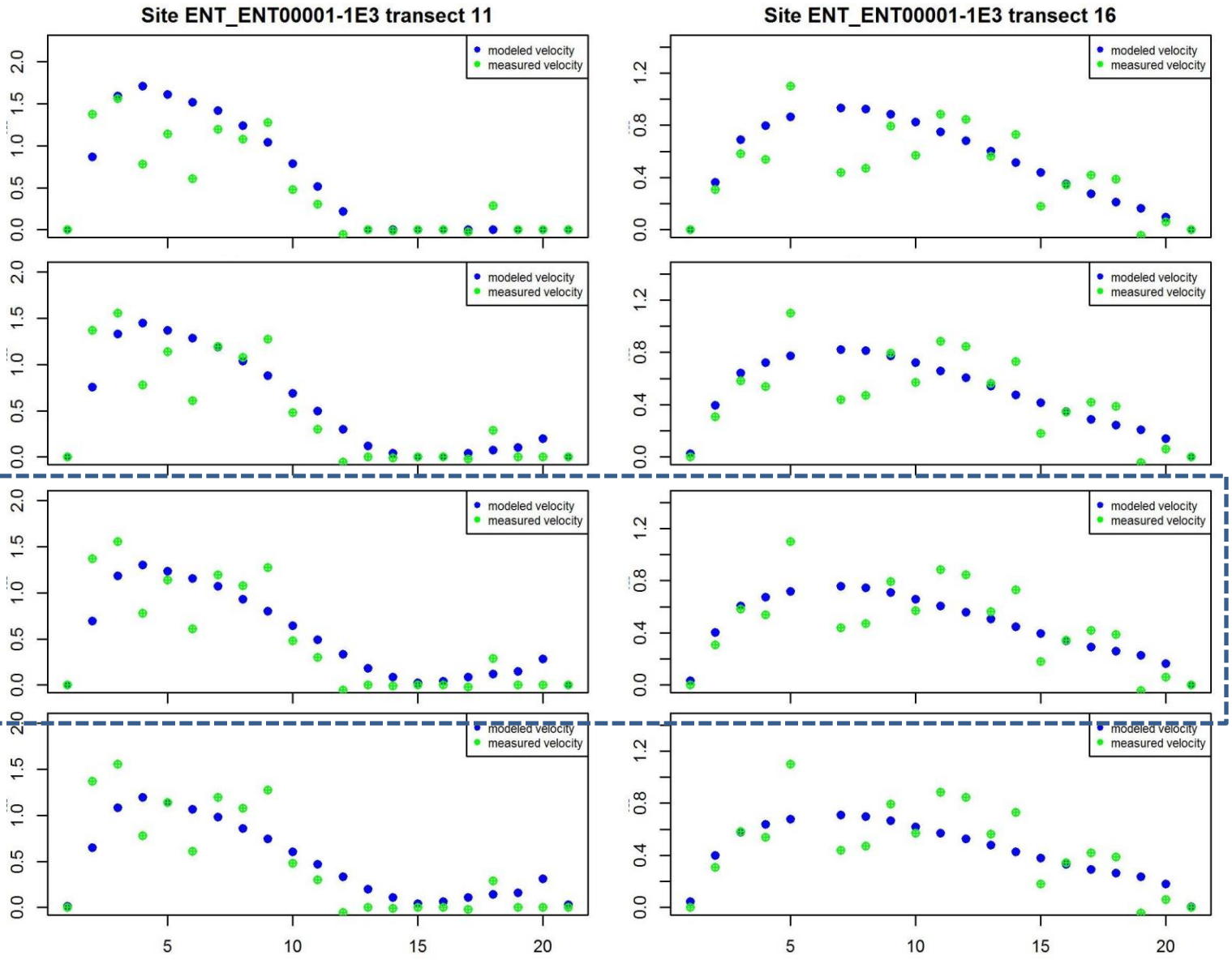
White-Colebrook Roughness Coefficient

2 x D84

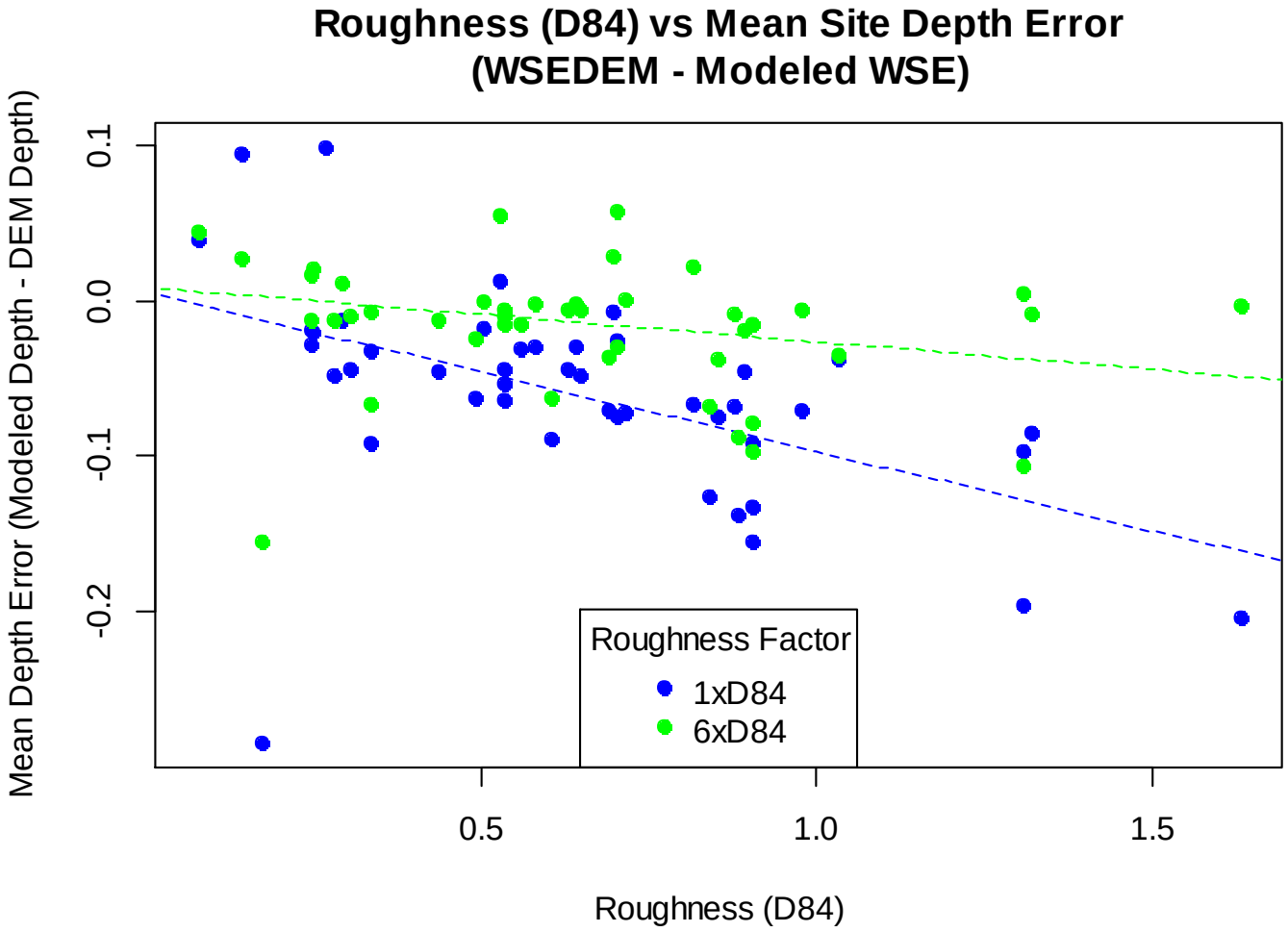
4 x D84

6 x D84

8 x D84



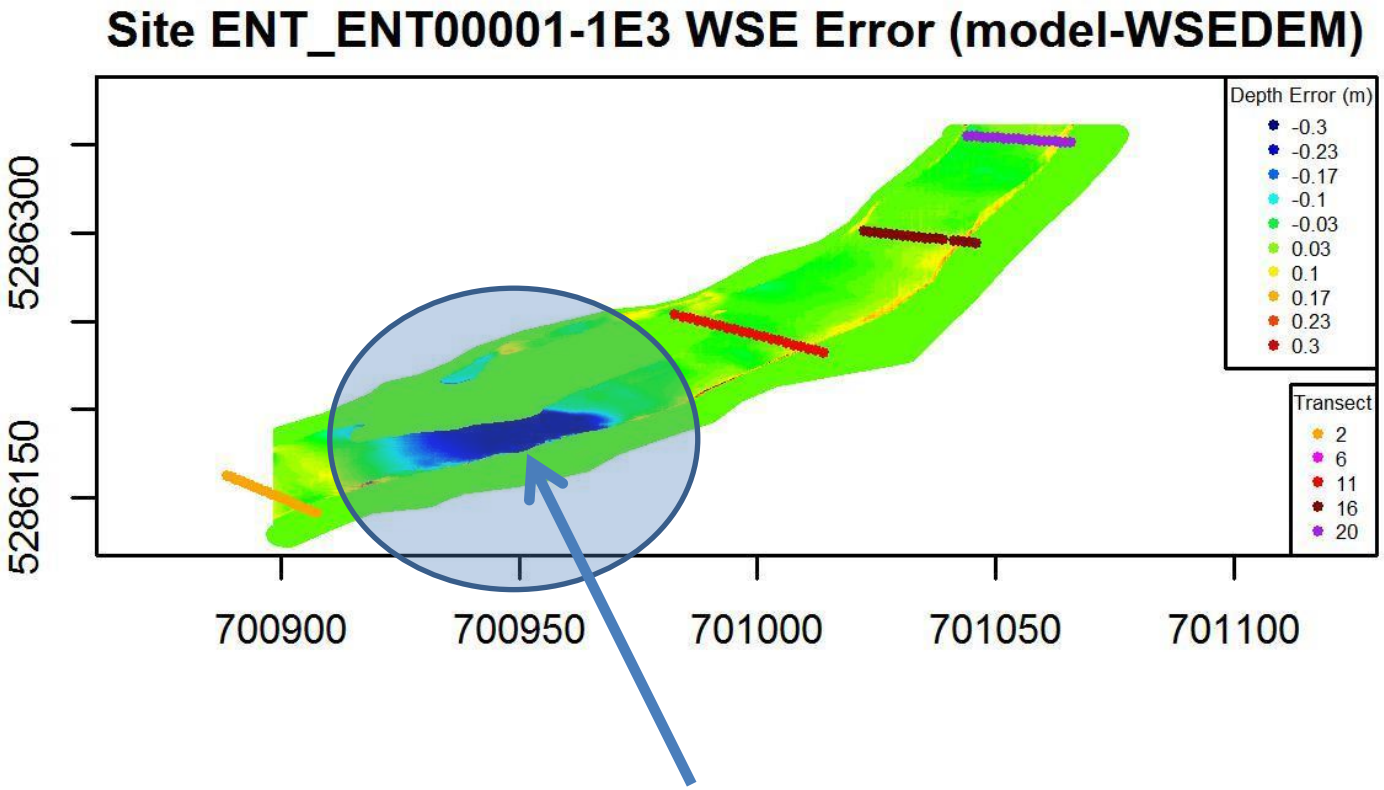
Model Optimization



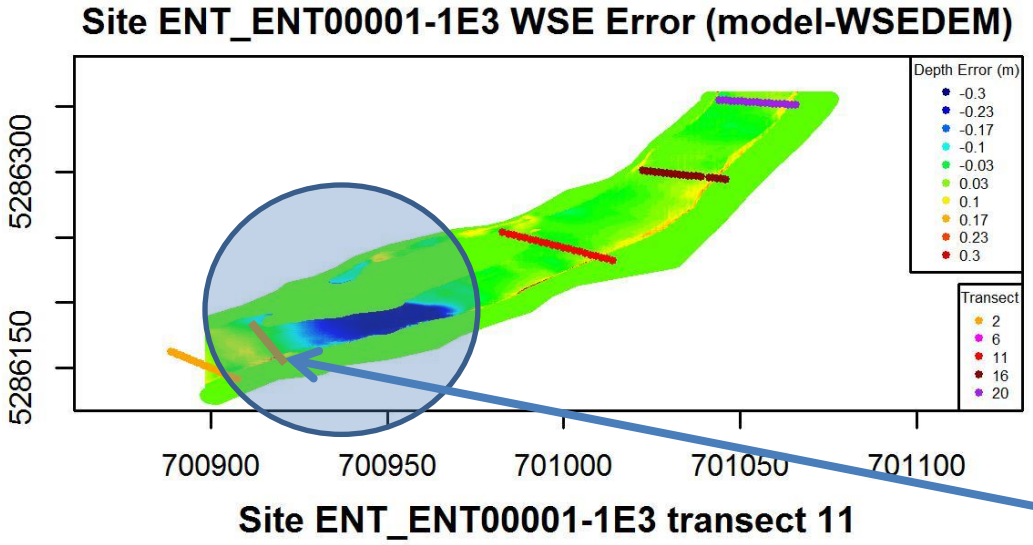
Optimization Results:

White-Colebrook Roughness Coefficient = 6x D84

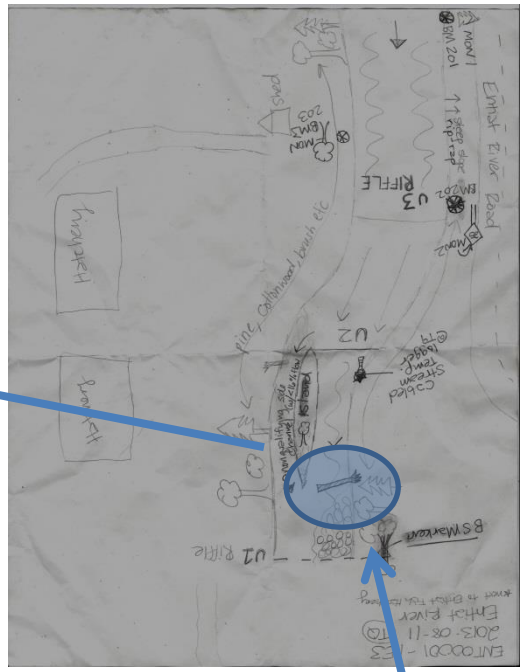
Horizontal Eddy Viscosity = .01



What about that localized error?



Site Map



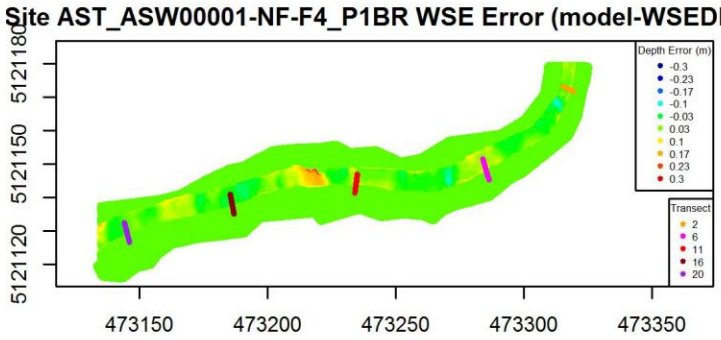
Likely Source of Error:

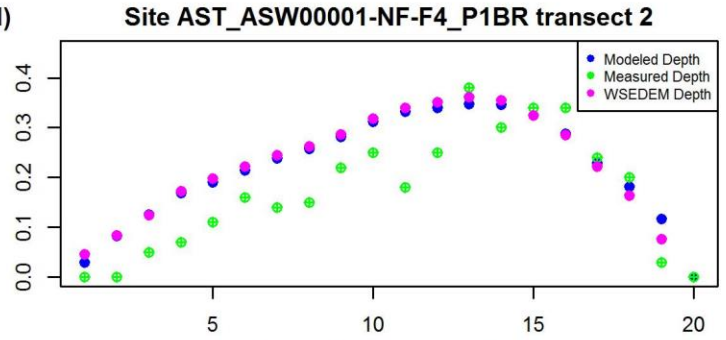
- Fallen Tree in River
- Not reflected in DEM
- **Unable to Model**

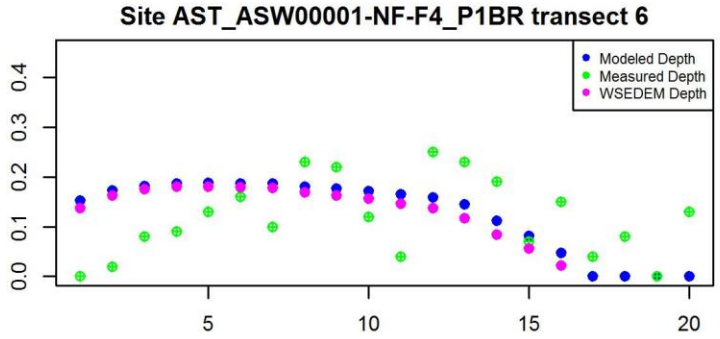
Site ASW00001-NF-F4-P1BR: Modeled vs. Measured Depths

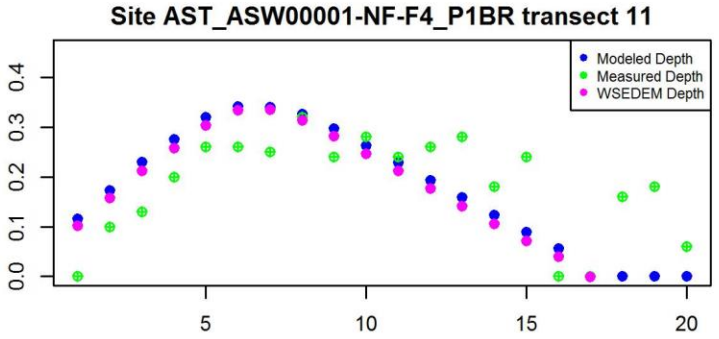
Generally good agreement between modeled and DEM depths

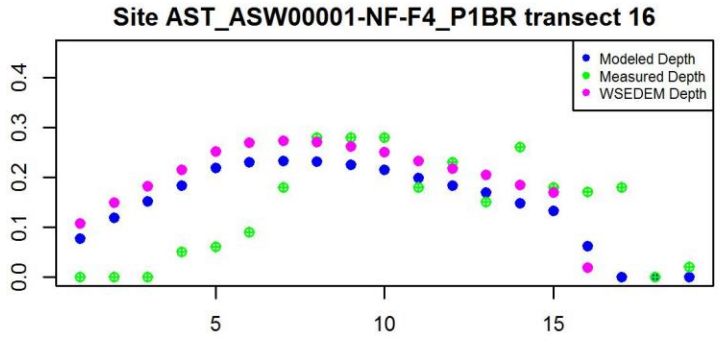
Localized Over-Prediction of Water Depth

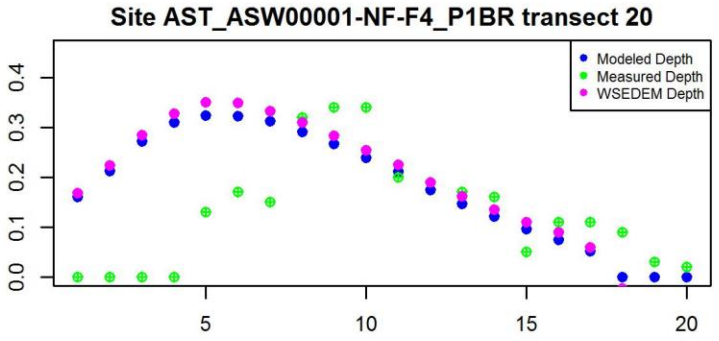


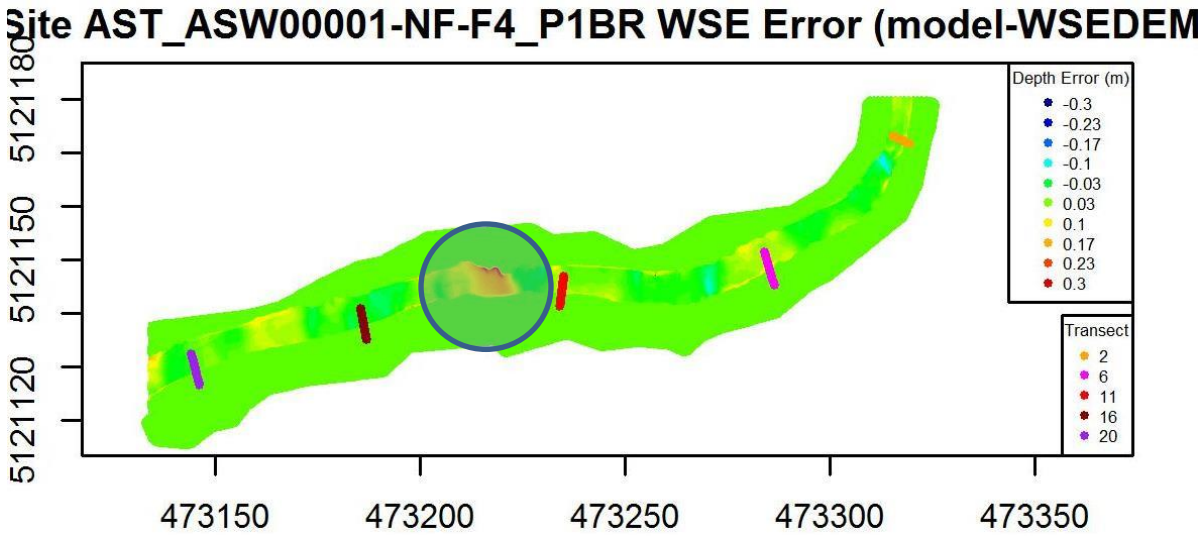






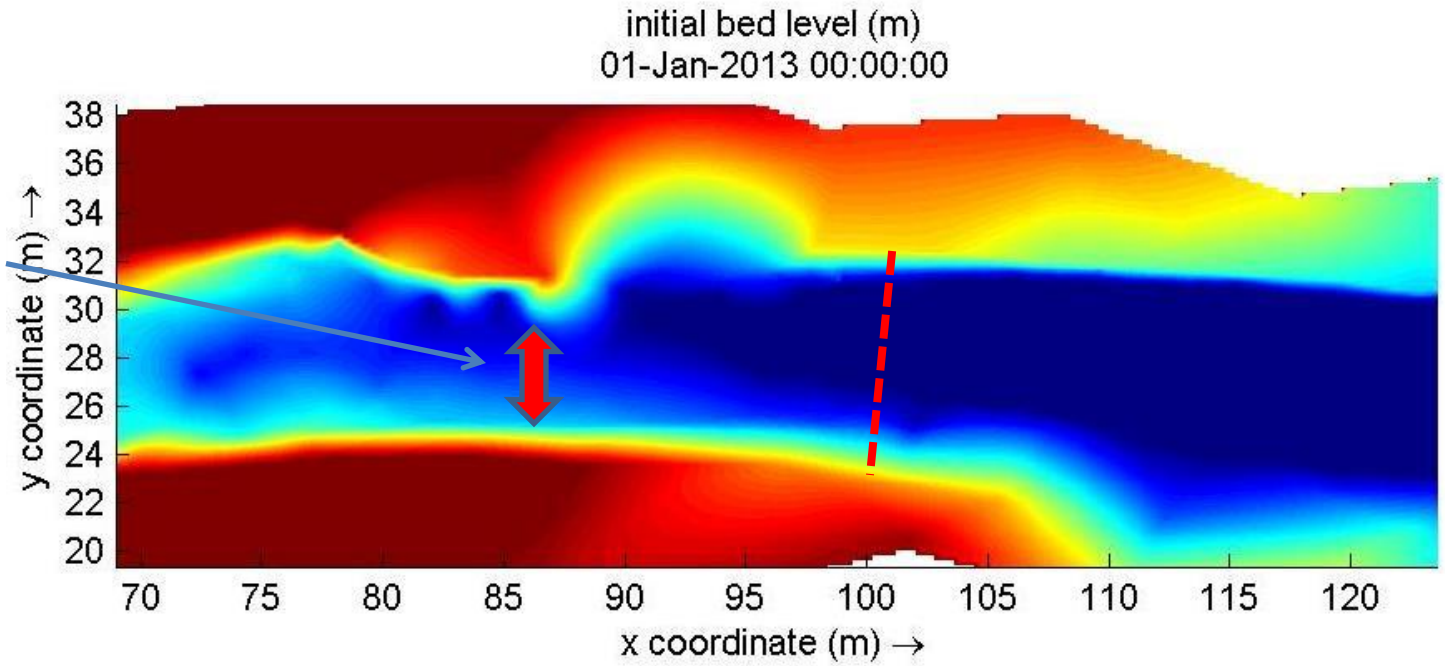


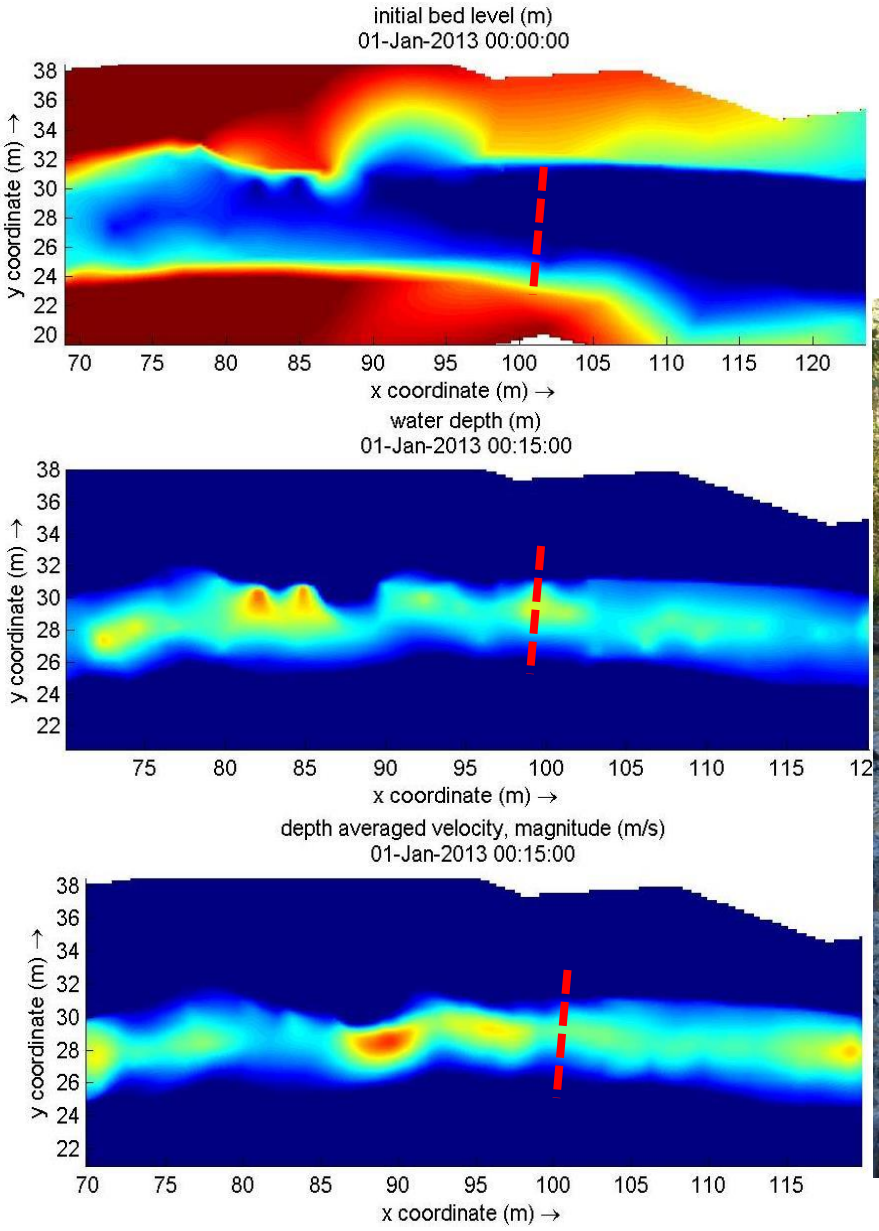




Note localized area where model as over-predicted depth

DEM suggest channel narrows, resulting in deeper, faster modeled flow





Site ASW00001-NF-F4-P1BR

View Upstream from Transect 11:

Note Undercut on Bank (or possibly large boulder further upstream), possibly not reflected accurately in DEM model and leading to localized over-prediction of depth (and velocity)

CHaMP Site CFD Modeling Results

ADDITIONAL VALIDATION PLOTS

CHaMP Site CFD Modeling: Next Steps

- Input spatially explicit surface roughness
  - D84 by channel unit
- Simulate selected sites at range of flow rates
  - Determine sensitivity to induced exit boundary condition errors
- Explore sensitivity to 2½D vs. 3D solutions
- Continue push toward automation