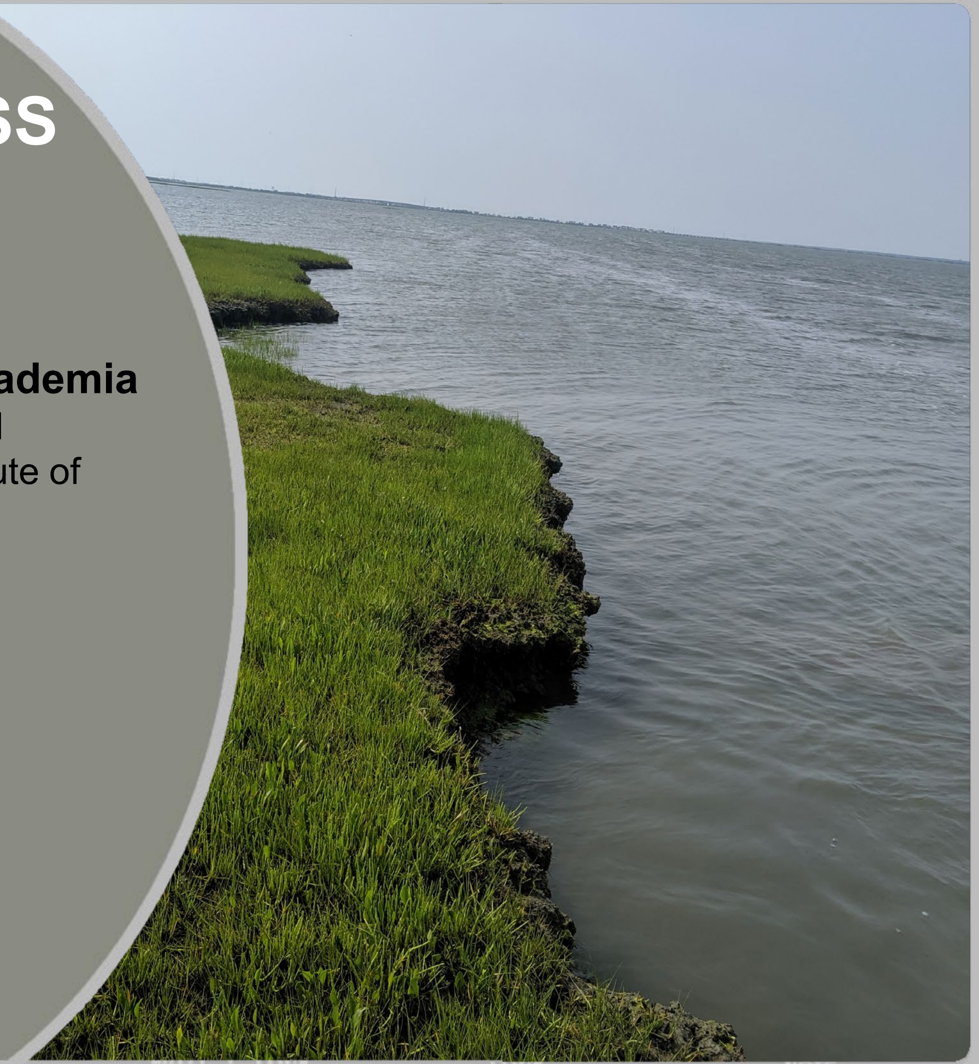
THE MARSH TRANSECT MODEL: A RAPID SCREENING TOOL TO ASSESS LONG-TERM MARSH ELEVATION CHANGE AND EROSION

Doug Krafft, Rachel Bain, Richard Styles, Candice Piercy, Joe Gailani

Collaborators in Academia
Matt Kirwan and Kendall Valentine (Virginia Institute of Marine Science)



COASTAL INLETS RESEARCH PROGRAM

FY22 TECHNICAL DISCUSSION

US Army Corps of Engineers

CHL COASTAL & HYDRAULICS LABORATORY

ERDC ENGINEER RESEARCH & DEVELOPMENT CENTER

Goals & Intended Uses

- The MTM modifies models from Kirwan et al. (2016) & Valentine et al. (in prep) to simulate marsh edge erosion, elevation change, & migration under wave impact & sea level rise
- Semi-empirical decadal scale predictions of coastal marsh extent can help determine:
  - Viability for coastal marsh persistence
  - Structures required to maintain coastal marsh
  - The capacity of the marsh to reduce erosion & storm surge in the future
  - Maintenance needs to achieve required coastal marsh geometry

Talk Layout

- Model Framework
- Simulated Process
- User Interface & Example Simulations

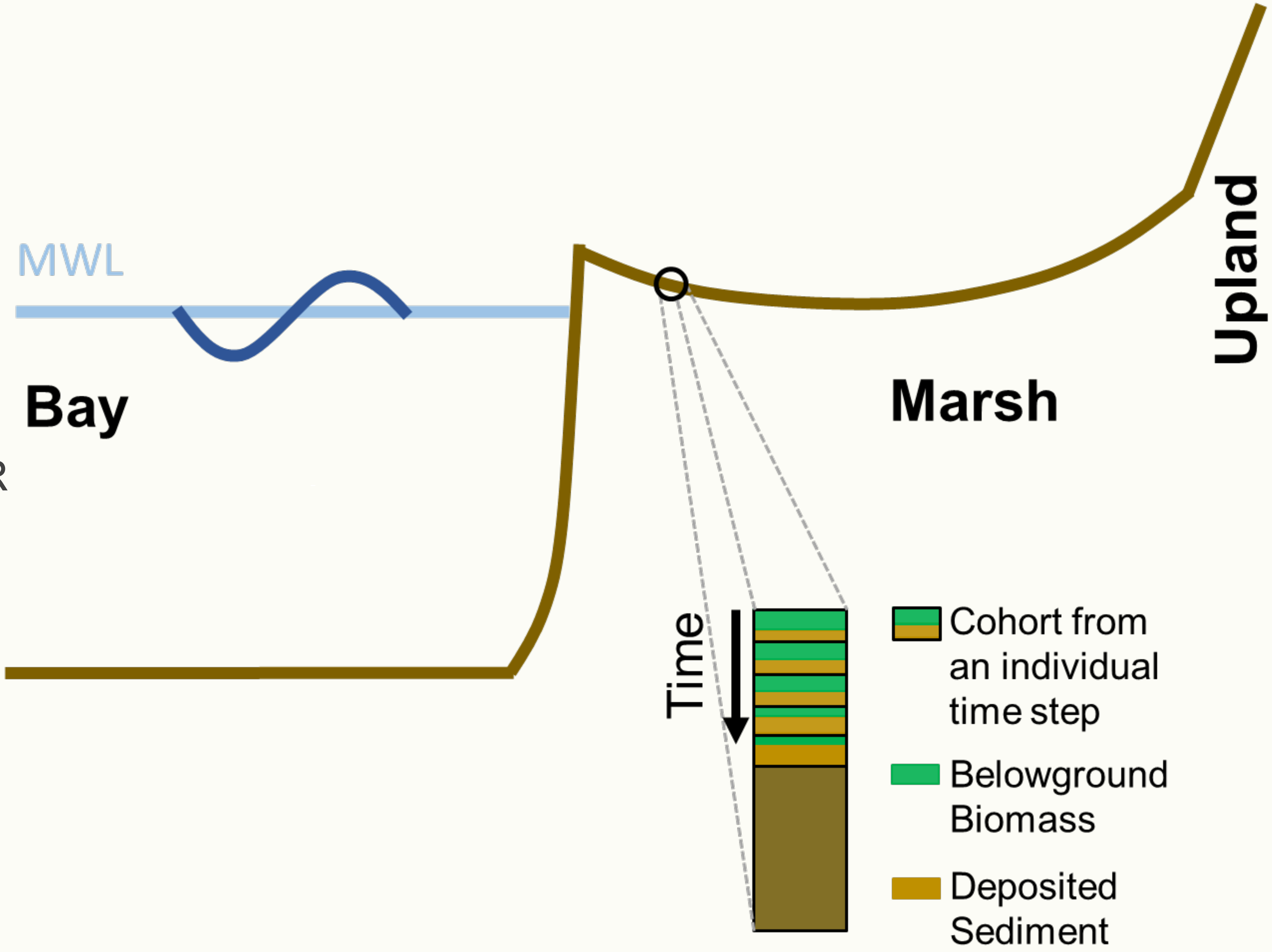
Model Framework

Domain: 1D elevation transect

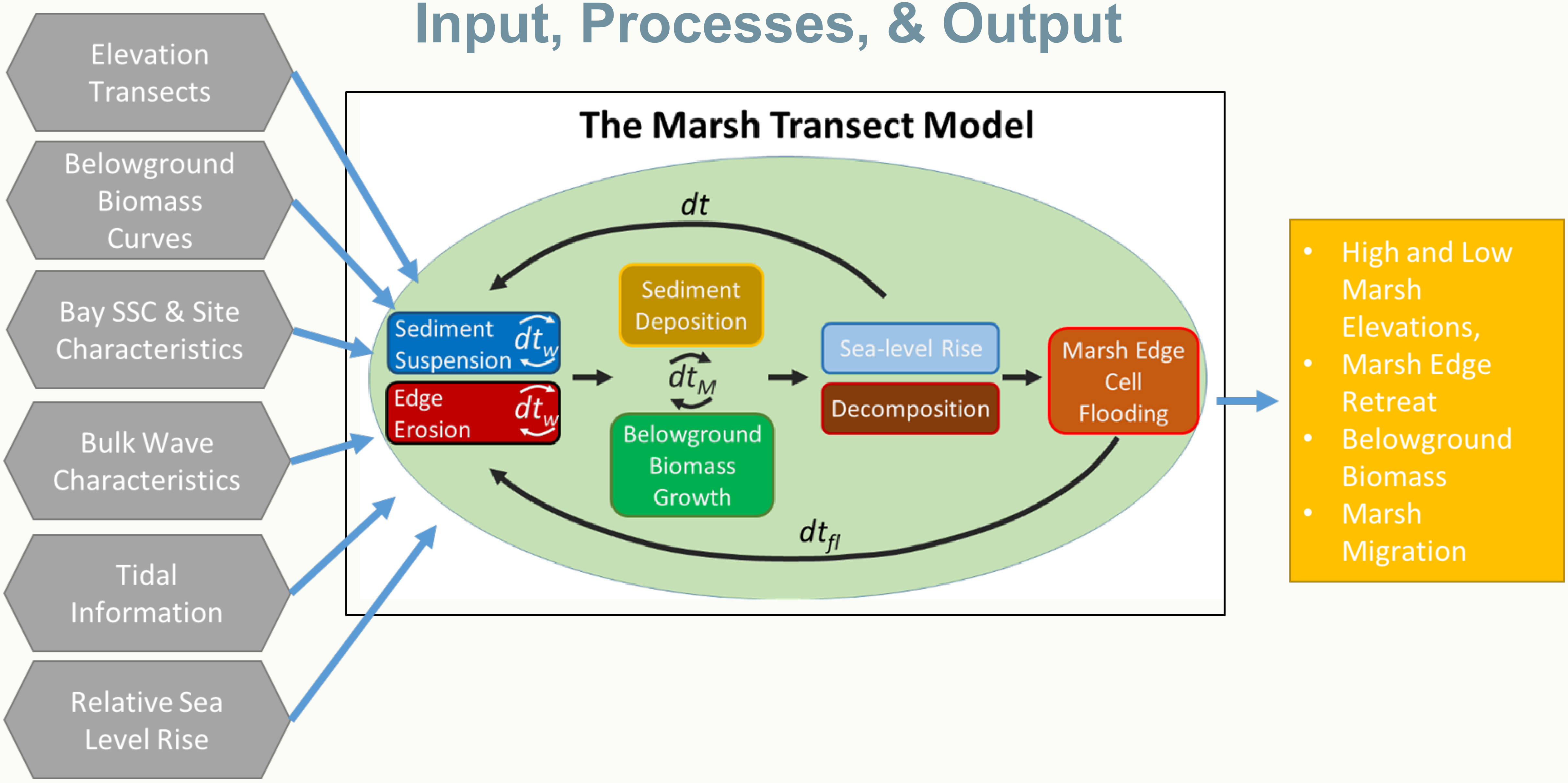
- Bay – set to uniform depth
- Marsh – changes size & elevation
- Upland – static area past simulated plant communities – allows migration with RSLR

Simulated Characteristics:

- Elevation
- Deposited sediment
- Belowground biomass
- Marsh edge position



Input, Processes, & Output



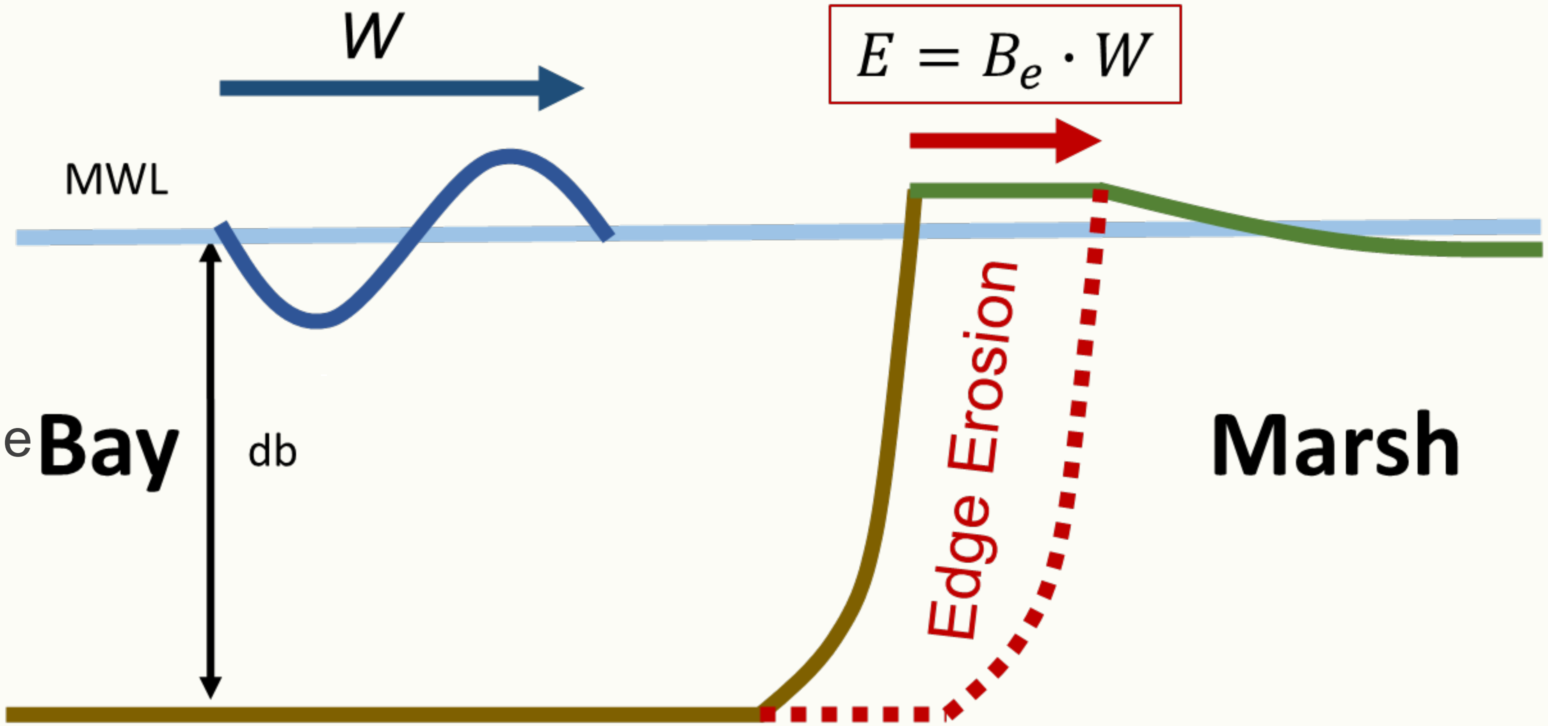
Marsh Edge Erosion

Erosive forcing input options

- Wind speed and fetch
- Wave height and period
- Wave energy flux

Edge Erosion Equation

- Erosion is related to wave energy flux
- Users are also able to input unique equations



Sediment Suspension Concentrations

Sediment Suspension

- Sediment is suspended in the bay & deposited in the marsh
- Shear stress (τ), density (ρ), critical shear stress (τ_{cr}), & a parameter (λ) suspend sediment

SSC

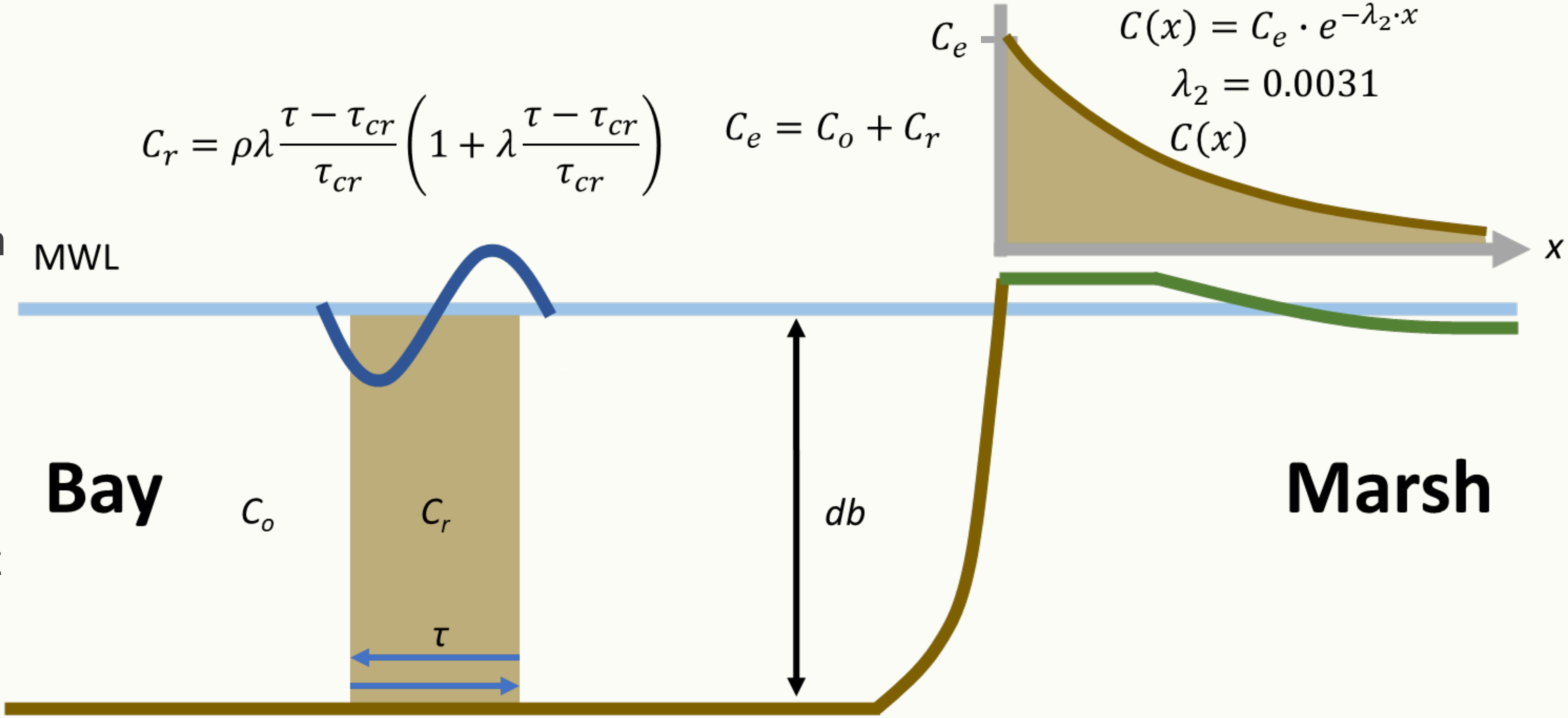
- SSC decays exponentially with distance into the marsh

$$C_r = \rho\lambda\frac{\tau - \tau_{cr}}{\tau_{cr}}\left(1 + \lambda\frac{\tau - \tau_{cr}}{\tau_{cr}}\right)$$

$$C_e = C_o + C_r$$

$$C(x) = C_e \cdot e^{-\lambda_2 \cdot x}$$

$$\lambda_2 = 0.0031$$

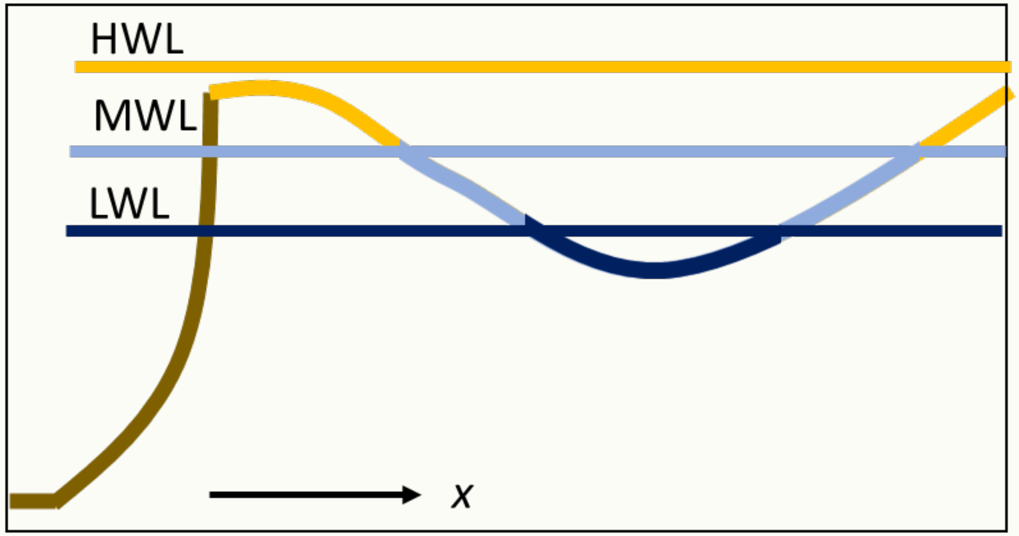


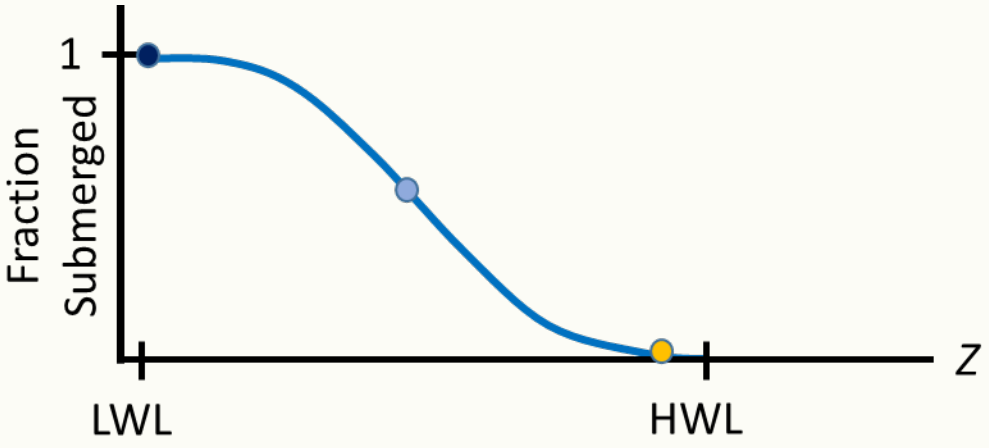
Sediment Deposition

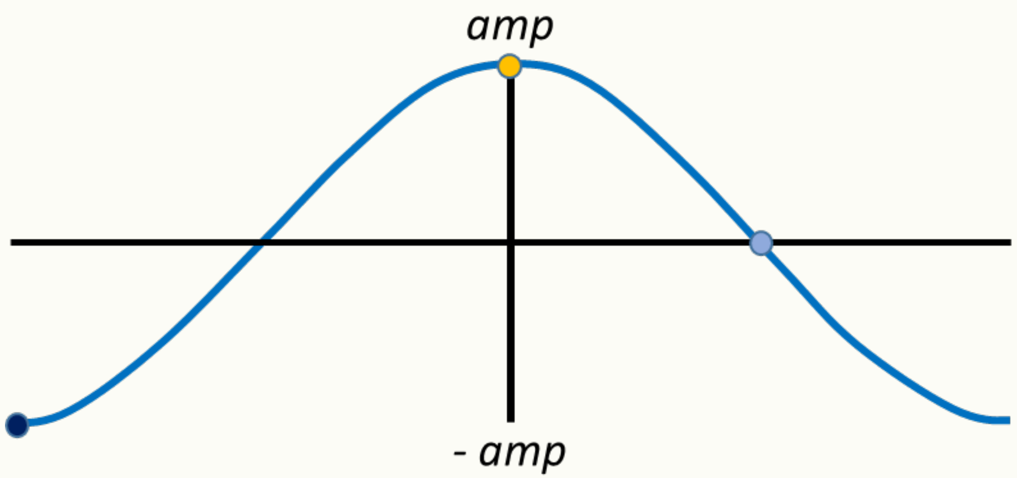
During each tidal phase, submerged grid cells accrete at a rate of,

$$susp\_dep(x,i) = C(x) \cdot ws \cdot dt \cdot dx$$

- $susp\_dep(x,i)$: Deposited sediment in each cell over timestep *i*
- $C(x)$: SSC in each submerged cell
- ws: Fall velocity
- $dt \cdot dx$: Cell size & time step



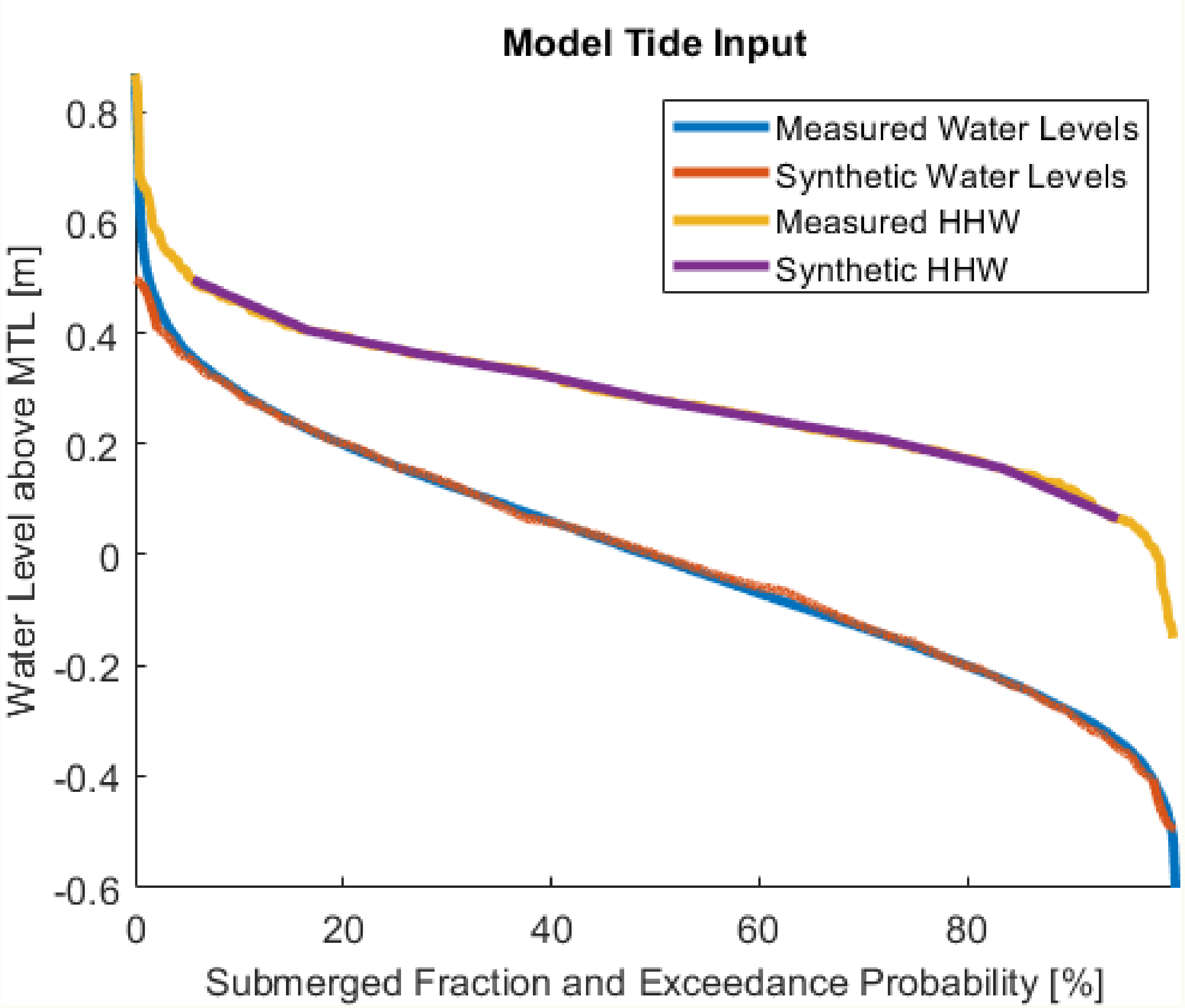




Sediment Deposition and Additional Tidal Datums

Depositing Sediment Using More Accurate Inundation

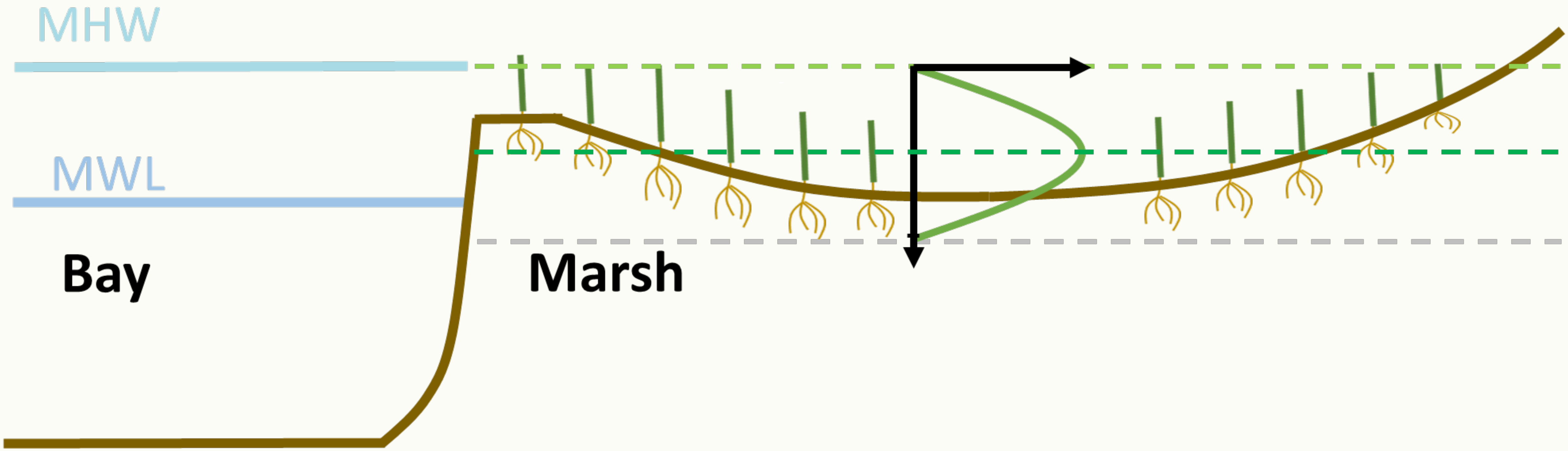
- The model accepts an arbitrary number of amplitudes for different high water datums
- These tidal amplitudes are applied by linking consecutive model runs within the distributable for each amplitude within each time-step
- Realistic inundation probabilities can be achieved
- This determines the locations at which sediment is able to deposit



Belowground Biomass Growth

Growth Rate as a Function of Elevation

- Users can supply unique equations, describing belowground biomass as a function of depth below MHW
- Defaults to a parabolic function of depth below MHW for each cell



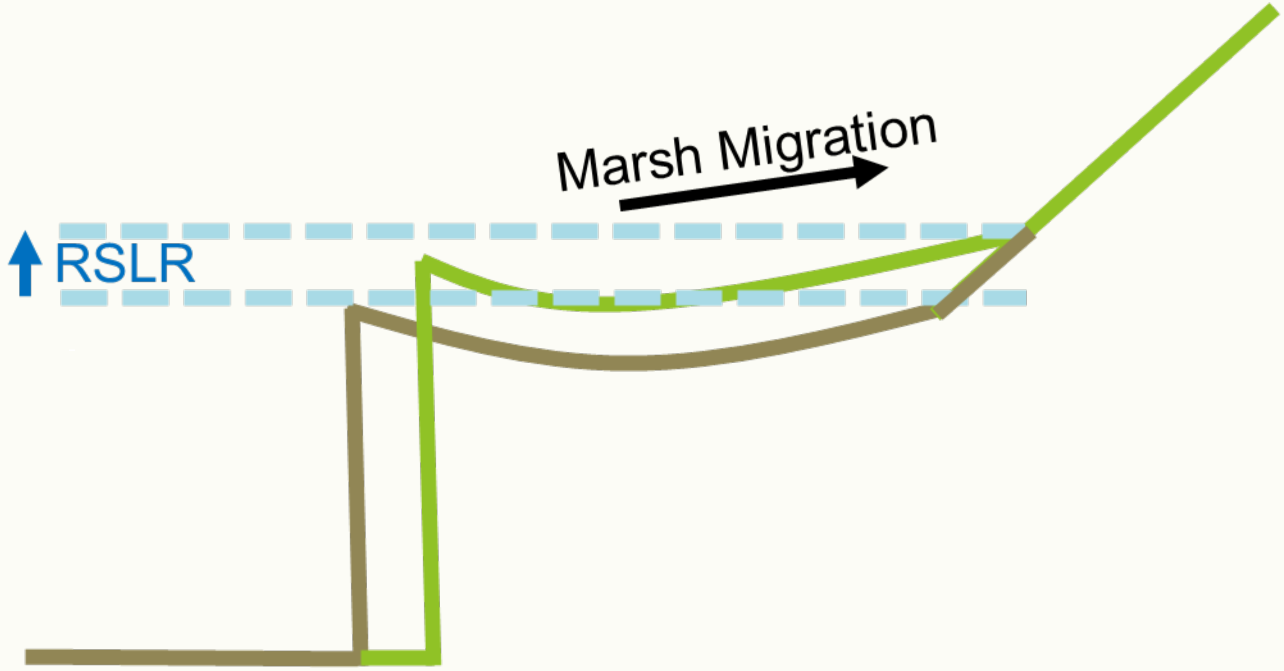
Multiple Plant Communities & Marsh Migration

Multiple Plant Communities

- The model is able to accommodate multiple plant communities

Marsh Migration where Available

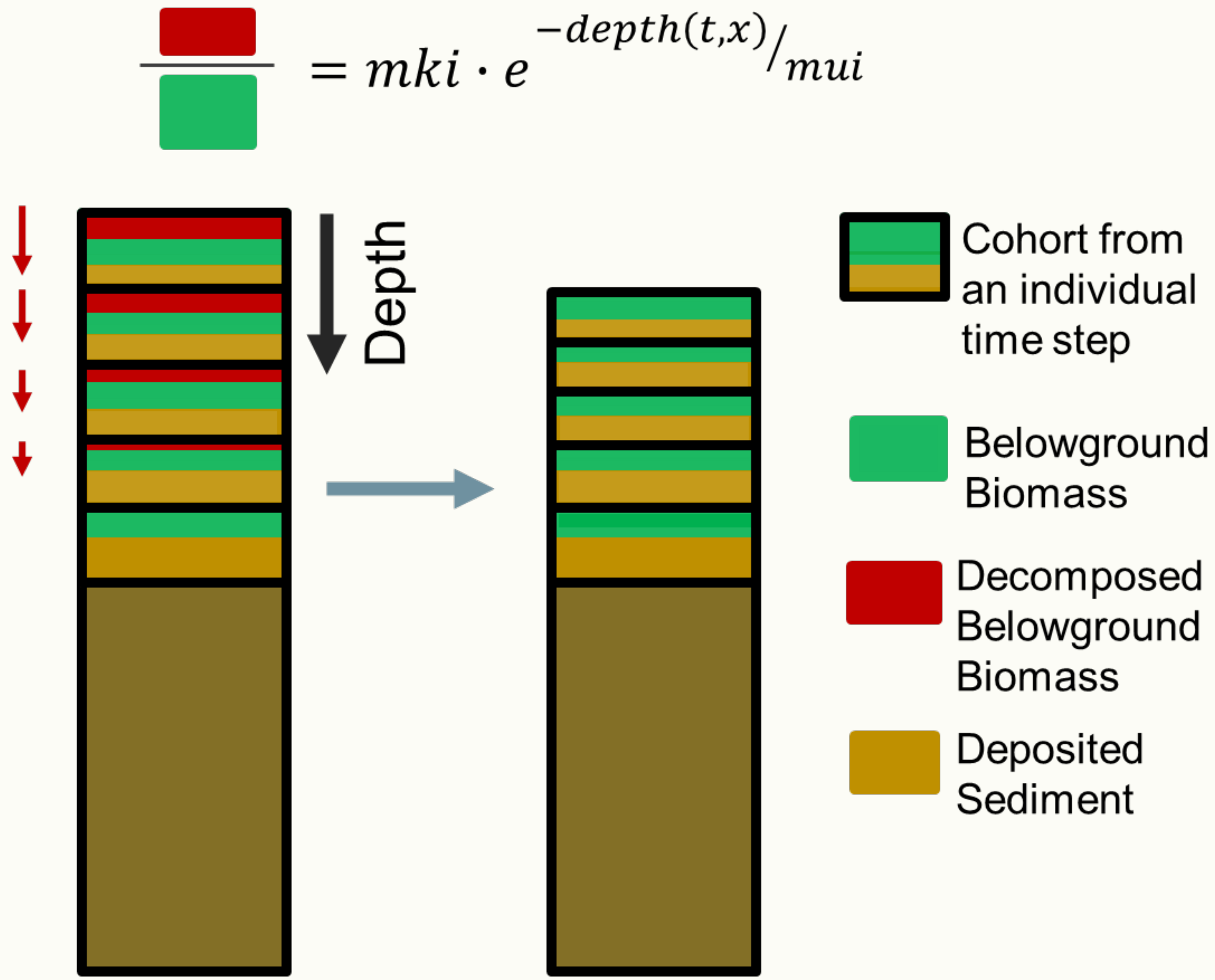
- As relative sea level rises, plants can begin to grow in areas previously outside of their growth range
- This can result in migration into an available upland area, or habitat transition between specified plant communities



Decomposition

Removing Belowground Biomass:

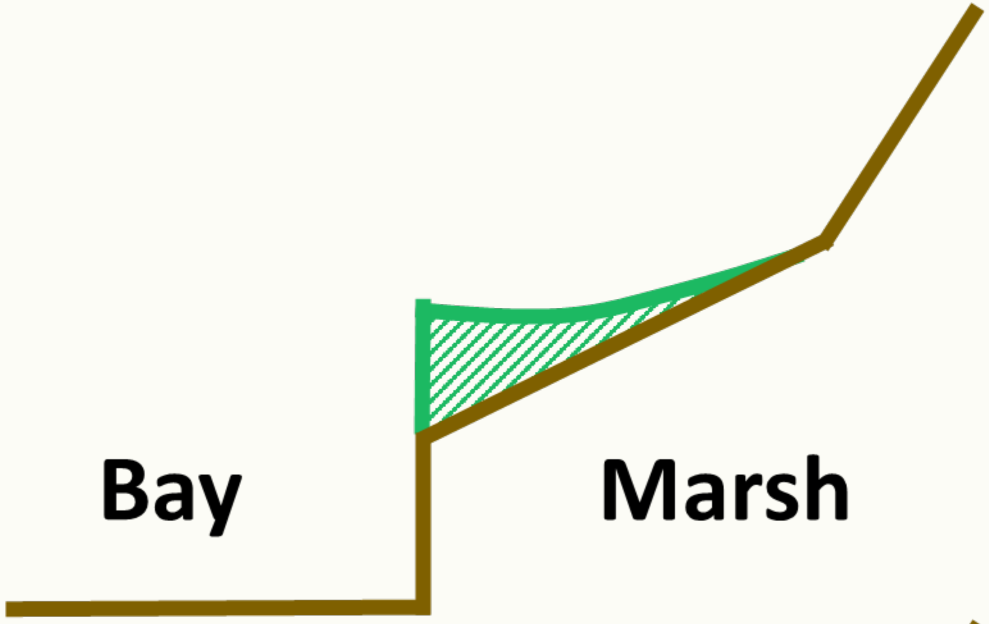
- Belowground biomass decomposes as a function of depth beneath the marsh surface and remaining belowground biomass
- Elevation and belowground biomass are reduced for each cohort



Initial Conditions

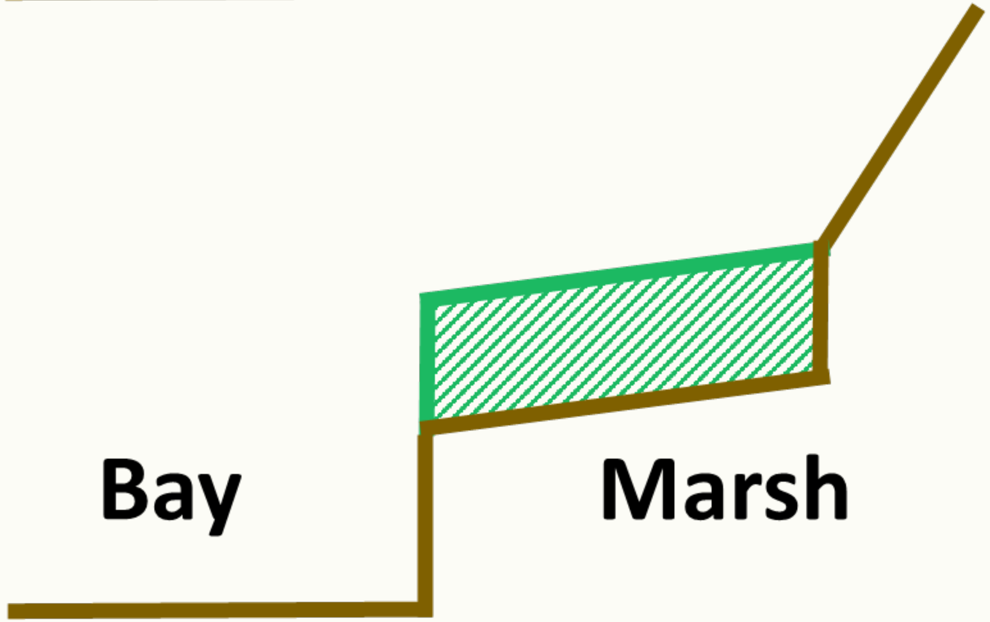
Unknown Elevations

- A spin-up procedure can generate starting elevations and distributions of organic material
- A long simulation slowly floods a shallow slope through the marsh

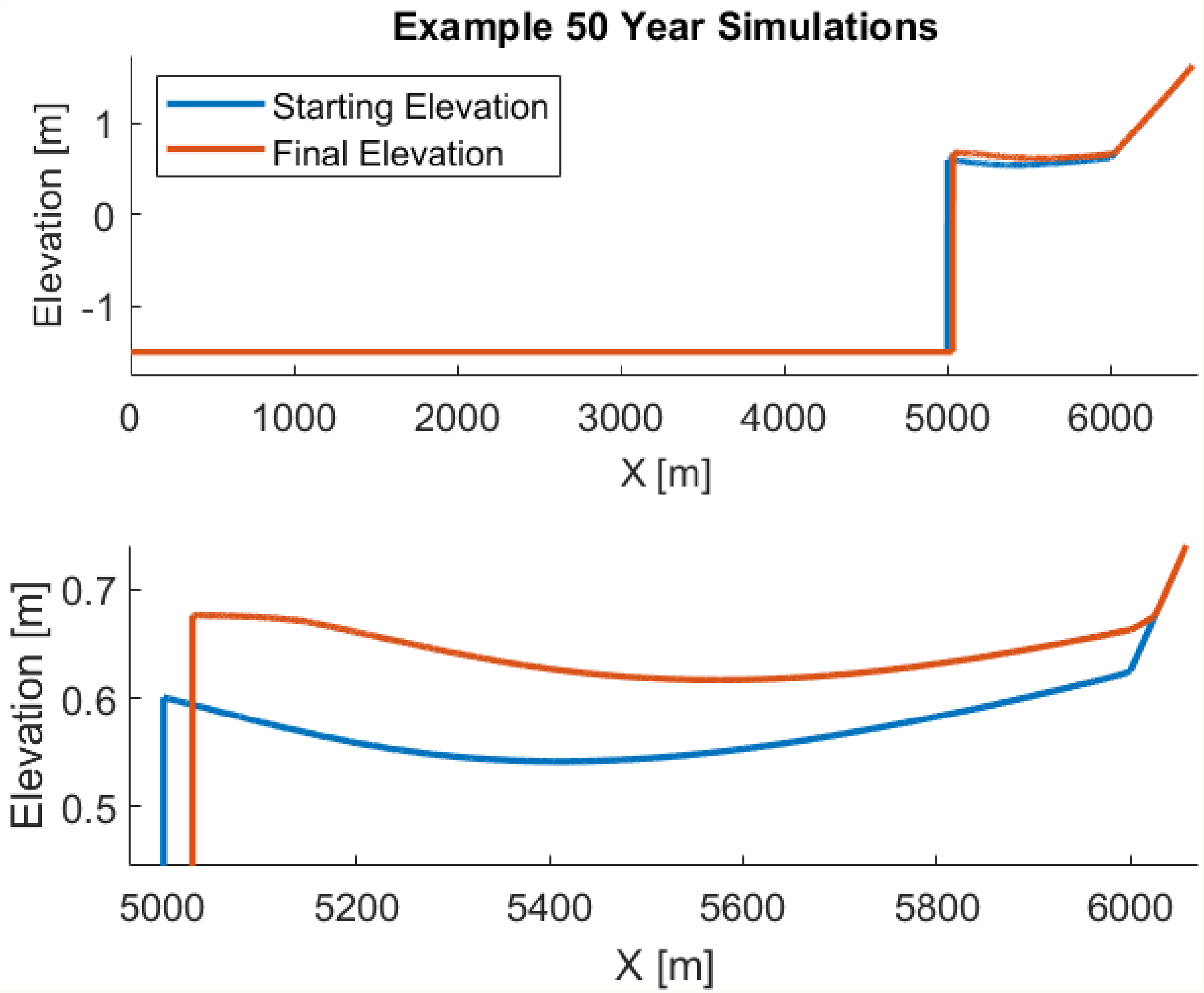


Known Elevations

- Users can also directly specify starting elevations
- Distributions of organic material are supplied as a single fraction



Example Output



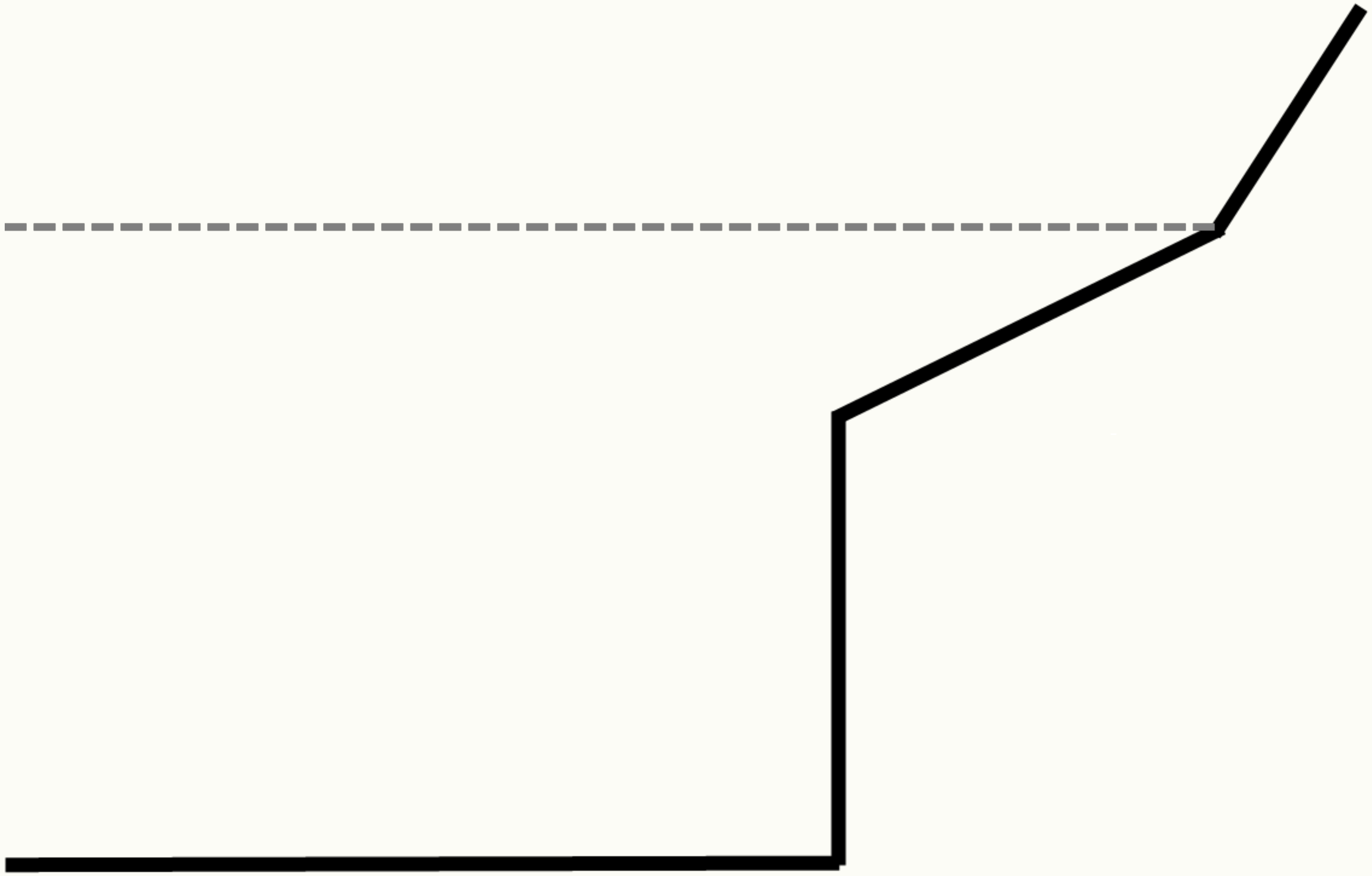
Running the model

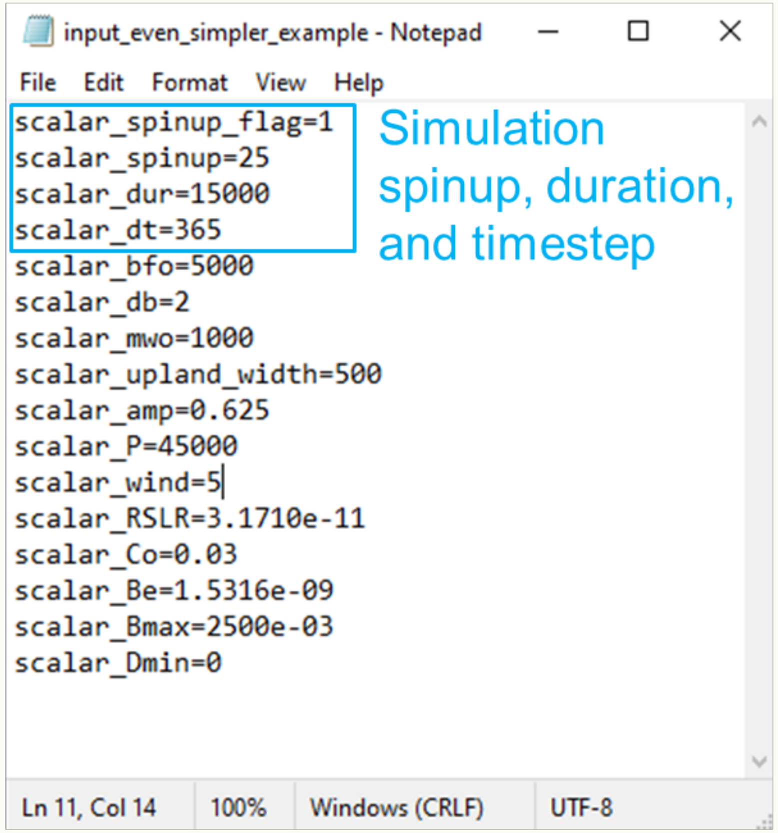
Marsh Transect Model was originally coded in MATLAB, but we recently converted it into an executable to facilitate implementation.

- **No MATLAB license required!**
- **No coding ability required!**
- **If you have a text editor on your computer, you can run this model!**

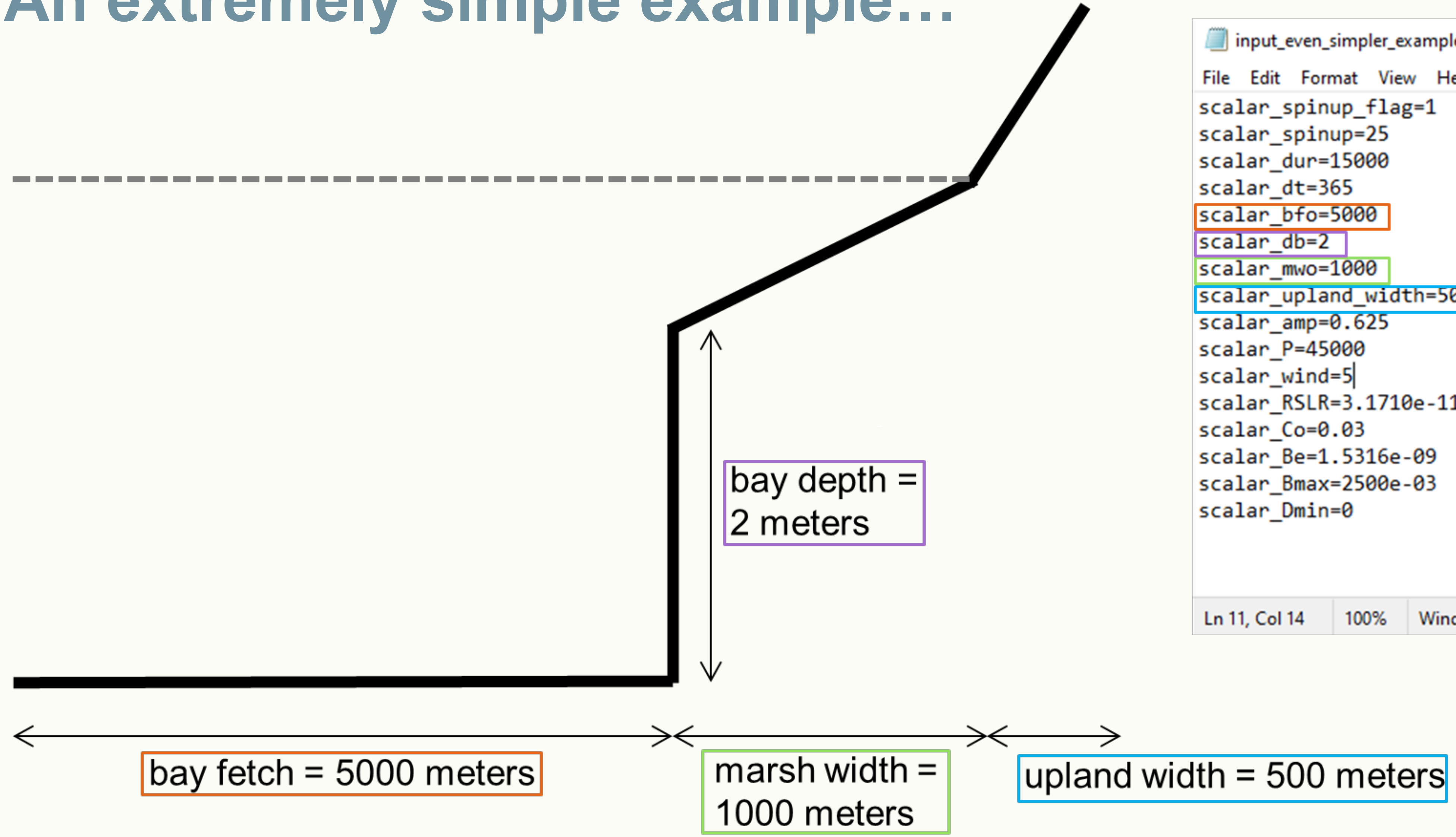
The following slides contain two *very* non-exhaustive examples of how to run this program.

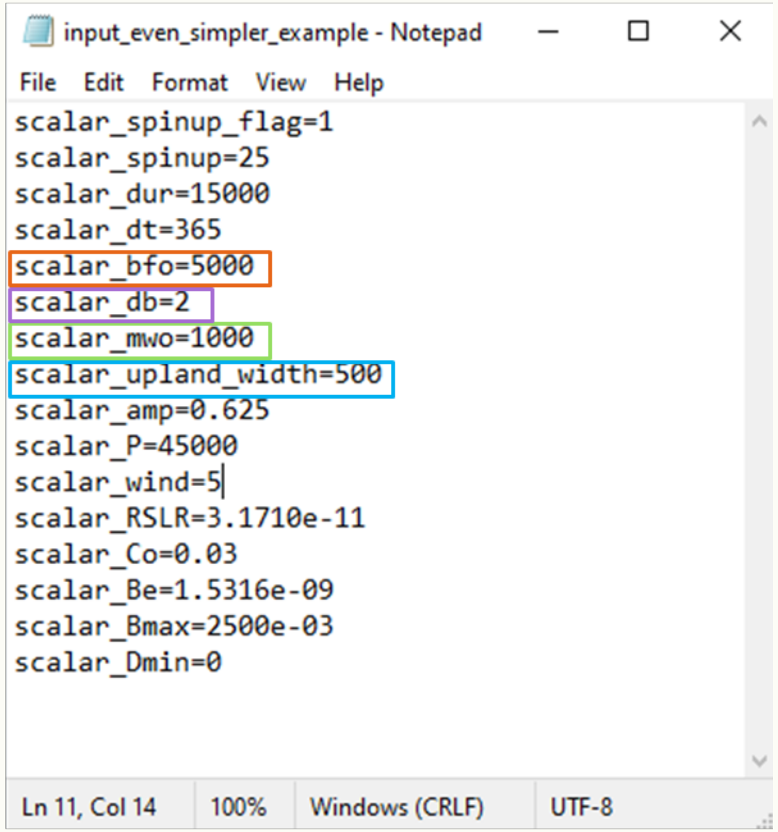
An extremely simple example…





An extremely simple example…





input_even_simpler_example - Notepad

File Edit Format View Help

```
scalar_spinup_flag=1
scalar_spinup=25
scalar_dur=15000
scalar_dt=365
scalar_bfo=5000
scalar_db=2
scalar_mwo=1000
scalar_upland_width=500
scalar_amp=0.625
scalar_P=45000
scalar_wind=5
scalar_RSLR=3.1710e-11
scalar_Co=0.03
scalar_Be=1.5316e-09
scalar_Bmax=2500e-03
scalar_Dmin=0
```

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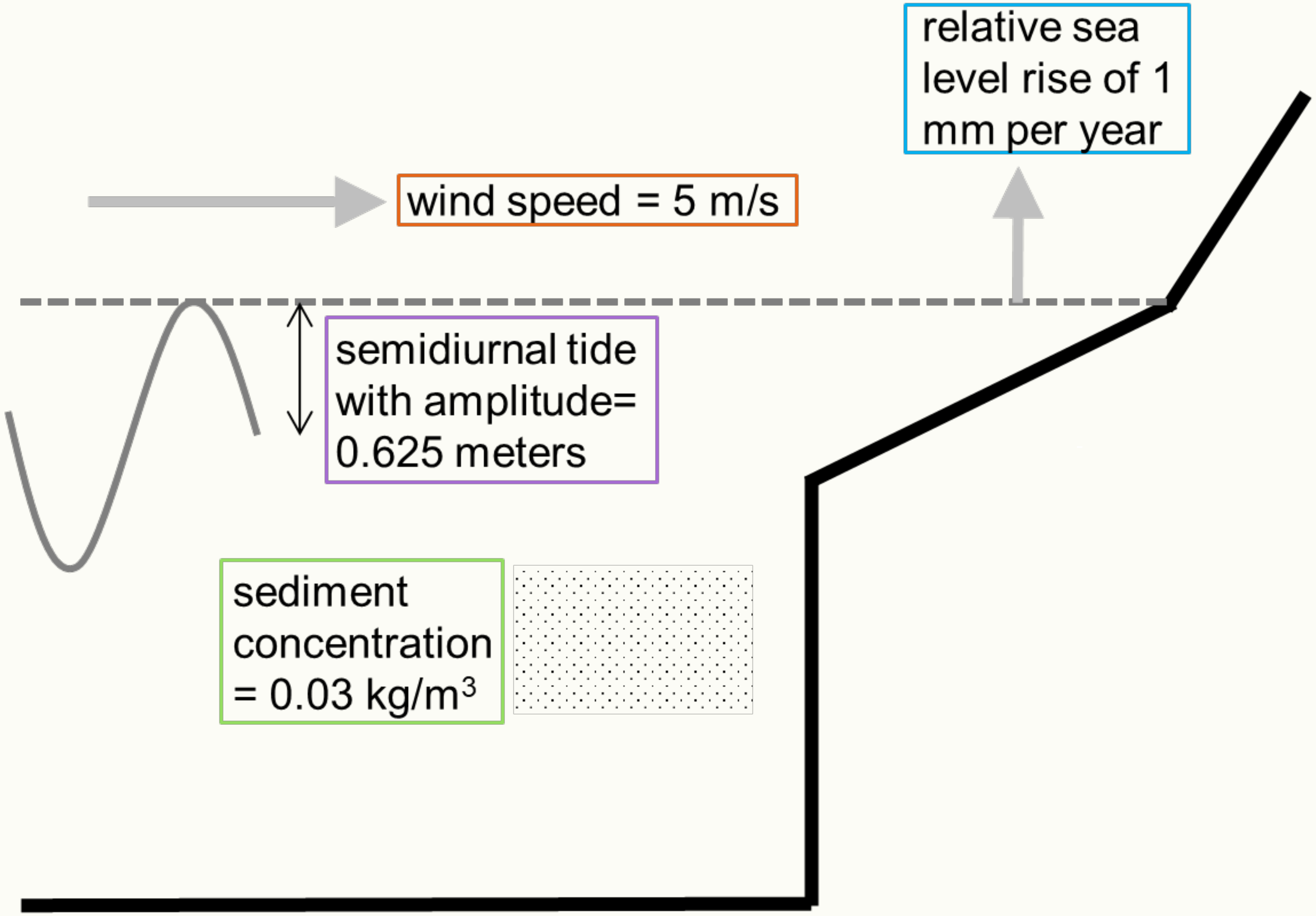
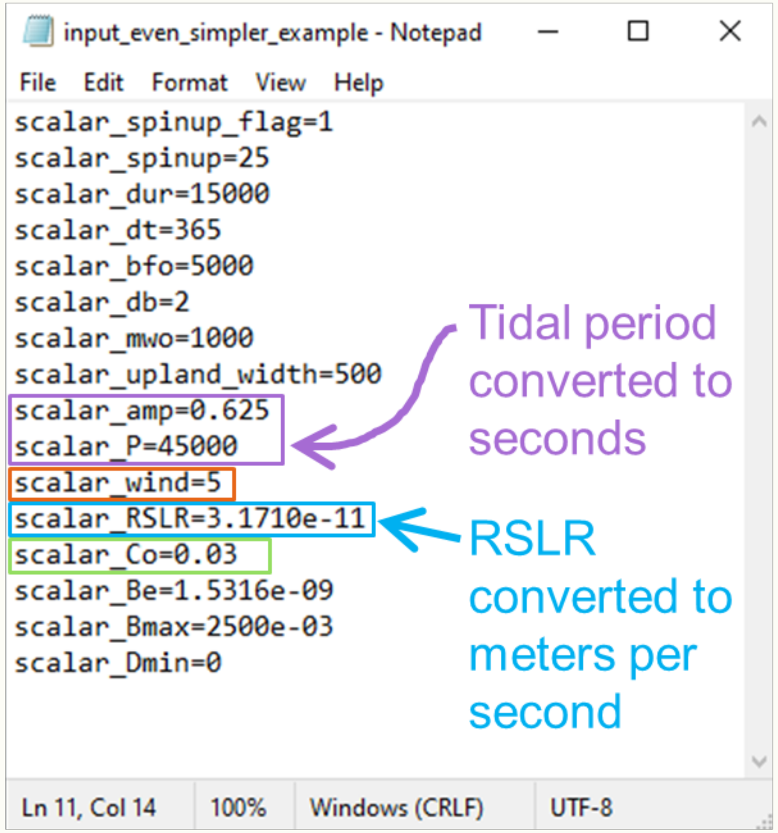

relative sea level rise of 1 mm per year
wind speed = 5 m/s
semidiurnal tide with amplitude= 0.625 meters
sediment concentration = 0.03 kg/m3


input_even_simpler_example - Notepad
File Edit Format View Help
scalar_spinup_flag=1
scalar_spinup=25
scalar_dur=15000
scalar_dt=365
scalar_bfo=5000
scalar_db=2
scalar_mwo=1000
scalar_upland_width=500
scalar_amp=0.625
scalar_P=45000
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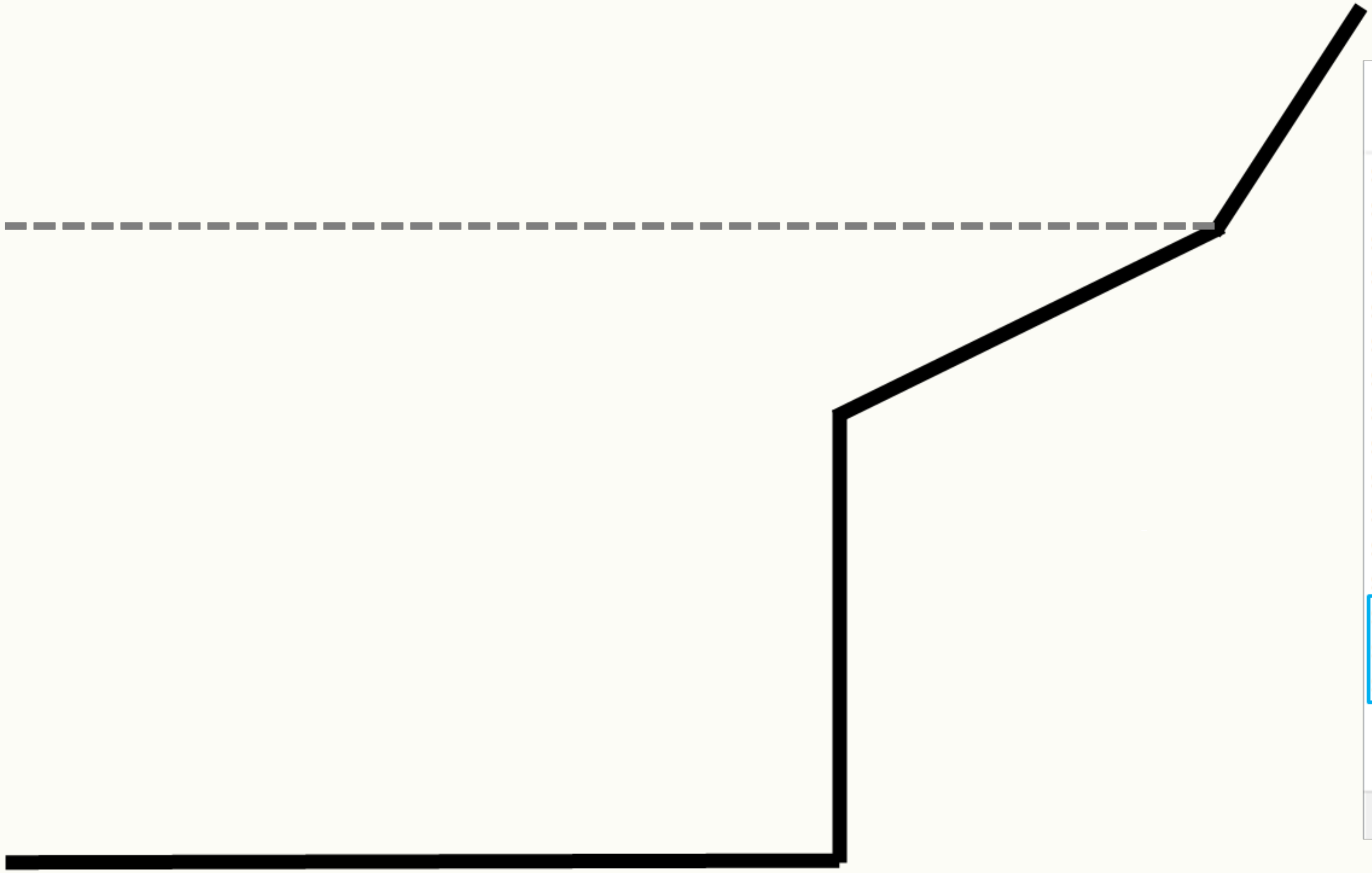
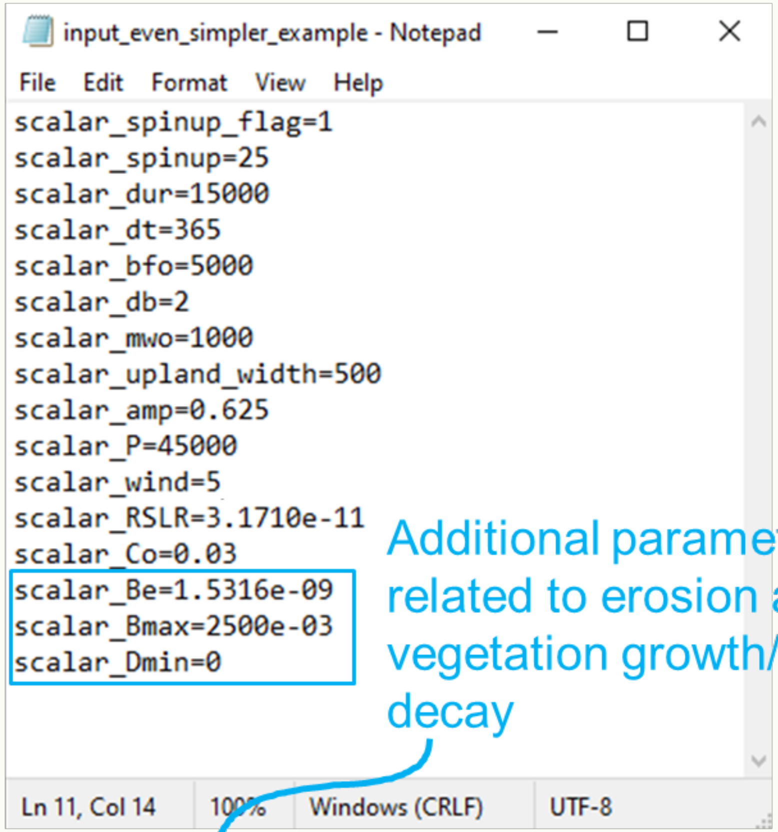
scalar_Co=0.03
scalar_Be=1.5316e-09
scalar_Bmax=2500e-03
scalar_Dmin=0
Ln 11, Col 14
100%
Windows (CRLF)
UTF-8
Tidal period converted to seconds
RSLR converted to meters per second



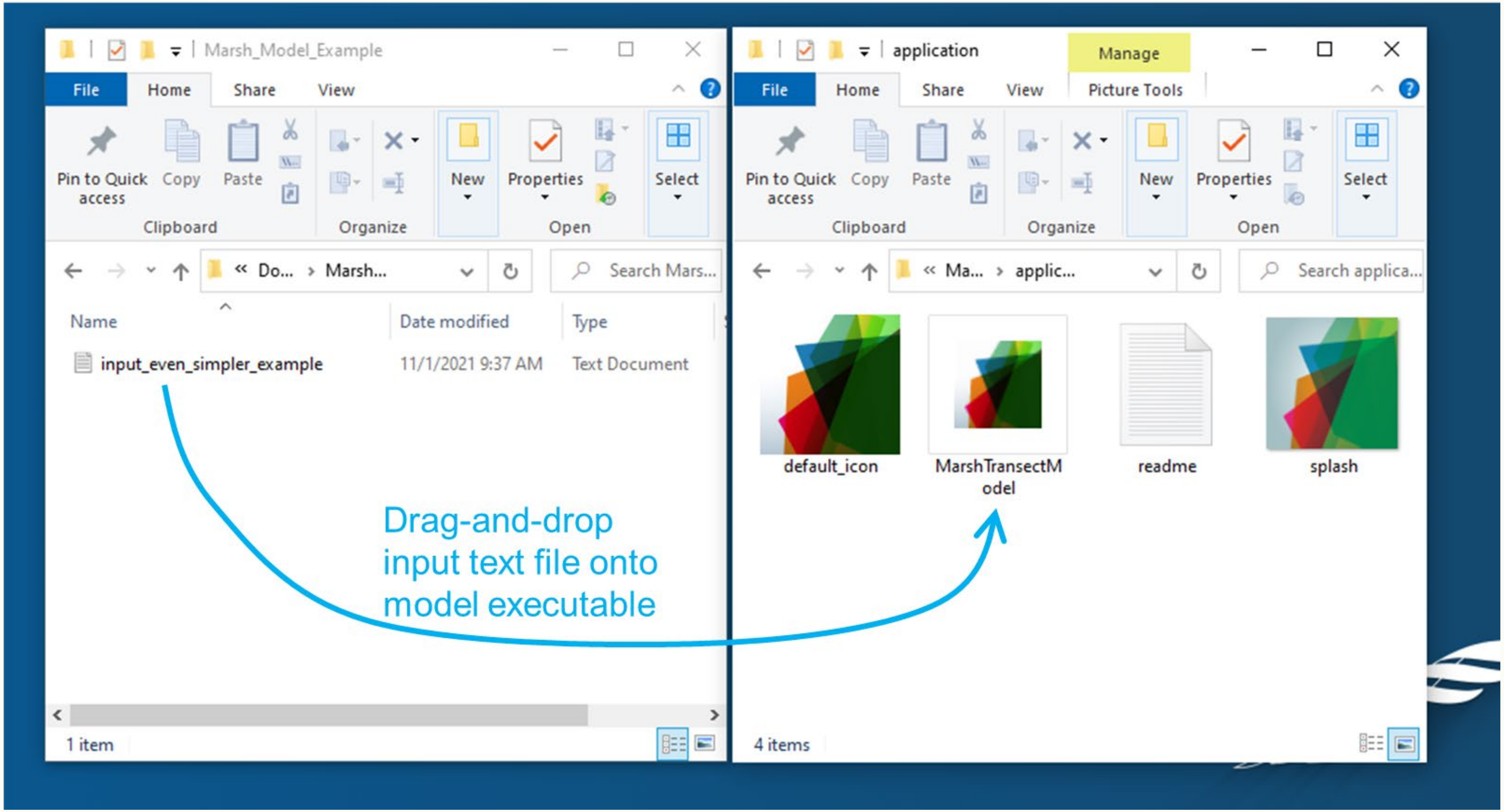



```
scalar_spinup_flag=1
scalar_spinup=25
scalar_dur=15000
scalar_dt=365
scalar_bfo=5000
scalar_db=2
scalar_mwo=1000
scalar_upland_width=500
scalar_amp=0.625
scalar_P=45000
scalar_wind=5
scalar_RSLR=3.1710e-11
scalar_Co=0.03
scalar_Be=1.5316e-09
scalar_Bmax=2500e-03
scalar_Dmin=0
```

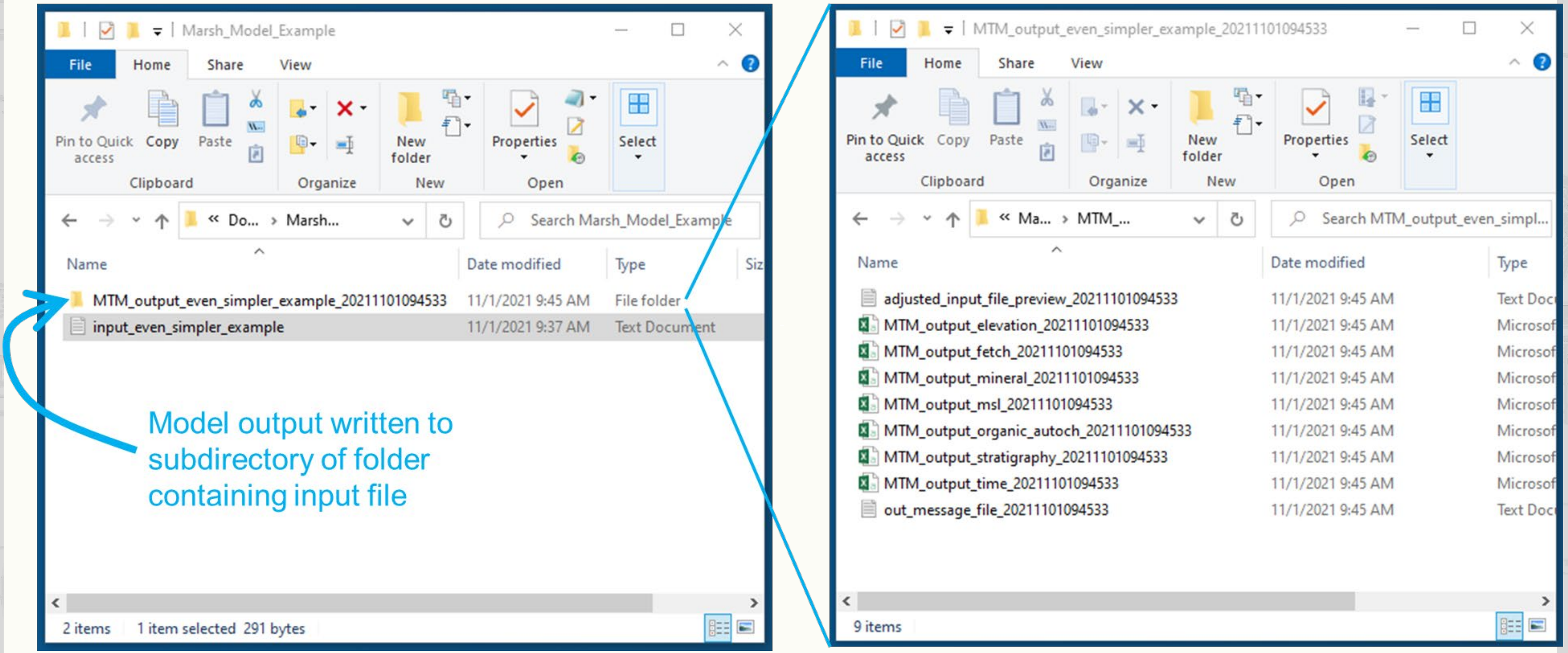
Additional parameters related to erosion and vegetation growth/ decay

(Not an exhaustive list! See instruction manual for full range of possibilities!)

How to make it "go":



Model output:



Model output:

x-coordinate

time

-2	-2	0.60669	0.60653	0.60637	0.60622	0.60607	0.60593	0.60581	0.60562	0.60544	0.60524	0.6
-2	-2	-2	-2	0.60469	0.60452	0.60435	0.60418	0.60407	0.60386	0.60365	0.60343	0.6
-2	-2	-2	-2	-2	0.60389	0.60371	0.60352	0.60338	0.60315	0.60293	0.60269	0.6
-2	-2	-2	-2	-2	-2	0.60374	0.60358	0.60342	0.60318	0.60295	0.6027	0.6
-2	-2	-2	-2	-2	-2	-2	0.60407	0.60389	0.60364	0.6034	0.60315	0.6
-2	-2	-2	-2	-2	-2	-2	-2	0.60461	0.60436	0.60412	0.6039	0.6
-2	-2	-2	-2	-2	-2	-2	-2	-2	0.6053	0.60509	0.60486	0.6
-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	0.60616	0.60593	0.6
-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	0.60706	0.6
-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	0.6
-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	
-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	

Recall input bay depth of 2 meters

A slightly more complex example…

Almost identical to the previous example with the following exceptions:

1. The initial elevation profile is input explicitly.
2. There are multiple vegetation populations.

input_even_si...

```
scalar_spinup_flag=1
scalar_spinup=25
scalar_dur=15000
scalar_dt=365
scalar_bfo=5000
scalar_db=2
scalar_mwo=1000
scalar_upland_width=500
scalar_amp=0.625
scalar_P=45000
scalar_wind=5
scalar_RSLR=3.1710e-11
scalar_Co=0.03
scalar_Be=1.5316e-09
scalar_Bmax=2500e-03
scalar_Dmin=0
```

Old input file

input_intermediate_example_3 - Notepad

```
scalar_spinup_flag=0
scalar_spinup=5
scalar_dur=15000
scalar_dt=365
scalar_bfo=5000
scalar_db=2
vector_xz=C:\Users\RDCHLRLB\Documents\Marsh_Model_Example\xz_transect.csv
scalar_amp=0.625
scalar_P=45000
scalar_wind=5
scalar_RSLR=3.1710e-11
scalar_Co=0.03
scalar_Be=1.5316e-09
vector_Bmax=[2.5 2.5]
vector_Dmin=[-0.18 -0.48]
vector_Dmax=[0.42 -0.18]
function_biofun1=@(z) 4*(-4.4804e+05*z.^5+2.6947e+05*z.^4-1.1732e+03*z.^3-1.8056e+04*z.^2+824.2899*z+571.4103)/1000
function_biofun2=@(d) (-6*(0.22*100-d*100-25).^2+375.7*(0.22*100-d*100-25)-3315.8)/1000
```

New input file

A slightly more complex example…

Almost identical to the previous example with the following exceptions:

1. **The initial elevation profile is input explicitly.**
2. There are multiple vegetation populations.

input_even_si...

File Edit Format View Help

```
scalar_spinup_flag=1
scalar_spinup=25
scalar_dur=15000
scalar_dt=365
scalar_bfo=5000
scalar_db=2
scalar_mwo=1000
scalar_upland_width=500
scalar_amp=0.625
scalar_P=45000
scalar_wind=5
scalar_RSLR=3.1710e-11
scalar_Co=0.03
scalar_Be=1.5316e-09
scalar_Bmax=2500e-03
scalar_Dmin=0
```

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input_intermediate_example_3 - Notepad

File Edit Format View Help

```
scalar_spinup_flag=0
scalar_spinup=5
scalar_dur=15000
scalar_dt=365
scalar_bfo=5000
scalar_db=2
vector_xz=C:\Users\RDCHLRLB\Documents\Marsh_Model_Example\xz_transect.csv
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function_biofun2=@(d) (-6*(0.22*100-d*100-25).^2+375.7*(0.22*100-d*100-25)-3315.8)/1000
```

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Known initial elevation profile → No need for model spinup

Initial marsh profile (not including bay) is now stored in CSV file.

A slightly more complex example…

Almost identical to the previous example with the following exceptions:

1. The initial elevation profile is input explicitly.
2. **There are multiple vegetation populations.**

input_even_si...

File Edit Format View Help

```
scalar_spinup_flag=1
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scalar_db=2
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scalar_RSLR=3.1710e-11
scalar_Co=0.03
scalar_Be=1.5316e-09
scalar_Bmax=2500e-03
scalar_Dmin=0
```

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input_intermediate_example_3 - Notepad

File Edit Format View Help

```
scalar_spinup_flag=0
scalar_spinup=5
scalar_dur=15000
scalar_dt=365
scalar_bfo=5000
scalar_db=2
vector_xz=C:\Users\RDCHLRLB\Documents\Marsh_Model_Example\xz_transect.csv
scalar_amp=0.625
scalar_P=45000
scalar_wind=5
scalar_RSLR=3.1710e-11
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function_biofun2=@(d) (-6*(0.22*100-d*100-25).^2+375.7*(0.22*100-d*100-25)-3315.8)/1000
```

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A slightly more complex example…

Almost identical to the previous example with the following exceptions:

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input_even_si...

File Edit Format View Help

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scalar_spinup_flag=1
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scalar_dt=365
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scalar_db=2
scalar_mwo=1000
scalar_upland_width=500
scalar_amp=0.625
scalar_P=45000
scalar_wind=5
scalar_RSLR=3.1710e-11
scalar_Co=0.03
scalar_Be=1.5316e-09
scalar_Bmax=2500e-03
scalar_Dmin=0
```

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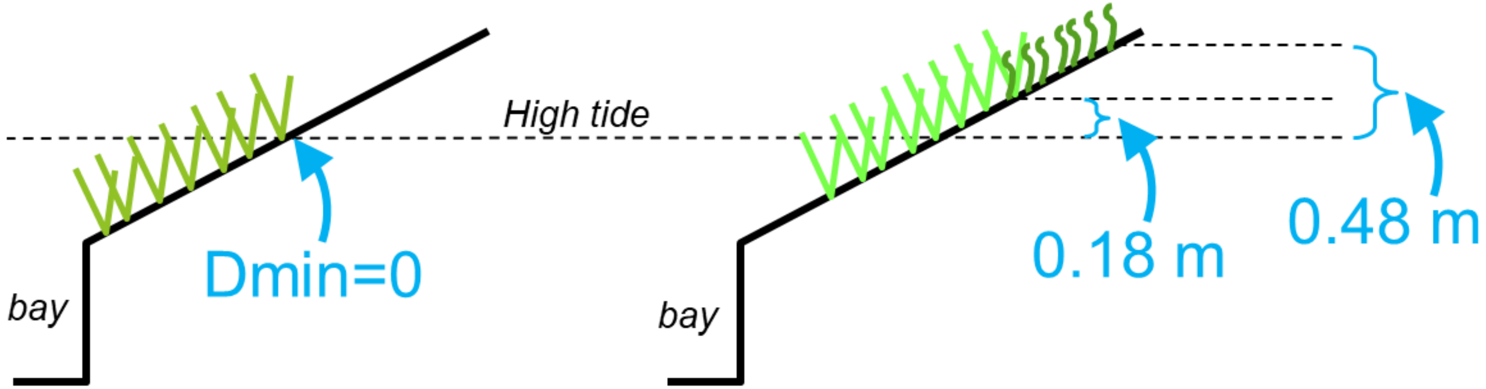
input_intermediate_example_3 -

File Edit Format View Help

```
scalar_spinup_flag=0
scalar_spinup=5
scalar_dur=15000
scalar_dt=365
scalar_bfo=5000
scalar_db=2
vector_xz=C:\Users\RDCHLF
scalar_amp=0.625
scalar_P=45000
scalar_wind=5
scalar_RSLR=3.1710e-11
scalar_Co=0.03
scalar_Be=1.5316e-09
vector_Bmax=[2.5 2.5]
vector_Dmin=[-0.18 -0.48]
vector_Dmax=[0.42 -0.18]
function_biofun1=@(z) 4*(
function_biofun2=@(d) (-(
```

Parameter Dmin is the minimum inundation depth for vegetation growth (relative to high water).



First example:
Dmin=0 indicates that vegetation will growth will begin at an elevation of 0 meters relative to high tide.

Second example:
The first vegetation population will grow up to 18 cm above high tide (*i.e.*, an inundation depth of Dmin= -0.18 meters). The second vegetation population will grow up to 48 cm above high tide.

A slightly more complex example…

Almost identical to the previous example with the following exceptions:

1. The initial elevation profile is input explicitly.
2. **There are multiple vegetation populations.**

input_even_si...

File Edit Format View Help

```
scalar_spinup_flag=1
scalar_spinup=25
scalar_dur=15000
scalar_dt=365
scalar_bfo=5000
scalar_db=2
scalar_mwo=1000
scalar_upland_width=500
scalar_amp=0.625
scalar_P=45000
scalar_wind=5
scalar_RSLR=3.1710e-11
scalar_Co=0.03
scalar_Be=1.5316e-09
scalar_Bmax=2500e-03
scalar_Dmin=0
```

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input_intermediate_example_3 - Notepad

File Edit Format View Help

```
scalar_spinup_flag=0
scalar_spinup=5
scalar_dur=15000
scalar_dt=365
scalar_bfo=5000
scalar_db=2
vector_xz=C:\Users\RDCHLRLB\Documents\Marsh_Model_Example\xz_transect.csv
scalar_amp=0.625
scalar_P=45000
scalar_wind=5
scalar_RSLR=3.1710e-11
scalar_Co=0.03
scalar_Be=1.5316e-09
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vector_Dmin=[-0.18 -0.48]
vector_Dmax=[0.42 -0.18]
function_biofun1=@(z) 4*(-4.4804e+05*z.^5+2.6947e+05*z.^4-1.1732e+03*z.^3-1.8056e+04*z.^2+824.2899*z+571.4103)/1000
function_biofun2=@(d) (-6*(0.22*100-d*100-25).^2+375.7*(0.22*100-d*100-25)-3315.8)/1000
```

Vegetation growth rate now specified as a function of depth.

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Conclusions

- The Marsh Transect Model rapidly simulates decadal scale marsh edge erosion, elevation change, and migration in response to wave action and sea level rise
- Flexible input requirements allow a wide range of parameters to help match site-specific observations
- A new executable allows users to access the model without any licensing requirements or coding experience
- Predictions from the Marsh Transect Model may help determine:
  - Viability for coastal marsh persistence
  - Structures required to maintain coastal marsh
  - The capacity of the marsh to reduce erosion & storm surge in the future
  - Maintenance needs to achieve required coastal marsh geometry

Learning More & Accessing the Model

- The model and supporting documents will soon be hosted on the CIRP website: https://cirp.usace.army.mil/products/marshtransect.php
- Supporting documentation
  - A Tech Note describing the MTM is in review (draft accessible)
  - A Users Guide describes how to run the model and provides details on input and output
  - Kirwan et al. (2016) & Valentine et al. (in prep) describe the models that the Marsh Transect Model builds off of

Follow-up

- Thanks for attending today's talk!
- Please contact Doug Krafft (Douglas.R.Krafft@usace.army.mil), Rachel Bain (Rachel.L.Bain@erdc.dren.mil), or Richard Styles (Richard.Styles@usace.army.mil) with additional follow-up comments or questions