CWEM 9.01

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Introduction

Before you do anything else, make a backup copy of the model. If you should inadvertently delete or move anything of value, you will be glad you had a backup.

The Coastal Wetland Equilibrium Model, CWEM 9, is the latest version of MEM. There are several important enhancements, notably the ability to grow intertidal trees like mangroves, hence the name change. On the IO_Page under Biological Inputs there are two columns, one labelled ‘young’ and the other ‘mature’. This is where you put in the vertical dimensions, peak aboveground biomass, root-shoot ratios, and turnover rates of young and mature canopies. You must enter parameters for young and old, but they could be the same, i.e. picking lower growth limits as an example, the lower limits for young and old might be -25 and -25. This is also where you would enter metrics for a community that had been disturbed with loss of vegetation. For instance, a thin layer placement application that devastates a marsh. It grows back to a mature size in the ‘Time to maturity’. Sorry this feature is currently disabled, but you can simulate a disturbance (episodic sediment addition) without loss of vegetation. This could be due to tidal surge, flood, or wind tide.

Another new feature is the front end. MEM and CWEM have embedded cohort models. These cohorts have to be populated at time zero. This was done originally by assuming the marsh has been in equilibrium with sea level, which results in the model filling the cohorts depending on user inputs (vegetation growth range, biomass suspended sediments, etc.). This is still the default unless you choose to input Loss On Ignition (LOI) data. CWEM 9 allows the user to input LOI data, and the model interpolates these data to populate the cohorts. There are several hardwired examples of this in the model on the LOI profile sheet. Do not change any of the yellow highlighted areas on the LOI sheet. The model copies these data into cols A and B and then interpolates using cohort dimensions determined by the initial accretion rate.

The IO page is where you will do most model interactions. That is where all the input parameters go. There is nothing you can't change. Try some permutations of parameters, elevation range, RS ratio, etc. To reload parameters from a hardwired site, say after trying permutations, you must first key on a different hardwired site, then key on the original site to restore the parameters. Try running different hardwired sites and note the differences in results. Disclaimer: I have not run all permutations and it is possible you could crash the model with either legitimate or illegitimate parameter values. This will not harm the model, but keep a backup copy in any case.

There is an interesting Cohort_Hist page. This captures various metrics of the behavior of the original surface cohort through time. On this page you will find a plot of the cohort volume over time and depth. You can see how it grows in size with age and depth. In some simulations it grows and then shrinks. Cohorts swell and shrink as they are buried, as root biomass is added, and as decomposition removes organic matter.

This model is distributed freely, and is not to be used for commercial purposes or distributed to third parties.

Sincerely, James Morris

Inputs on the IO_Page

Option Check Boxes	
Use a generic biomass profile to simulate a *Spartina alterniflora* marsh	Checking this results in a vertical growth profile that is symmetrical and with a lower limit at 10 cm below MSL and upper limit of 30 cm above MHW
Disturbance w/o loss of vegetation	Check this to episodically add sediment to the surface at a depth (cm) and interval (yrs) specified by the Episodic Disturbance parameters. This option can simulate thin layer placement (TLP), sediment delivery via tidal surge or flood, wind tide, or river diversion.
Disturbance w/loss of vegetation	This is currently disabled. When enabled, this is meant to simulate instances of TLP where the vegetation is substantially reduced. If you select this option, you must set the peak aboveground biomass of a young canopy to an appropriate value (less than that of a mature canopy), and you must set a time to maturity, which in this case is actually a recovery time. If you fail to do this, the model uses a default time to maturity of 5 yr and a young biomass equal to 10% of that of mature biomass.
Grow the Canopy	Check this if simulating the growth of trees: juvenile and mature trees have different growth profiles specified under Biological Inputs.
Linear root distribution	Check this if you want the root distribution to be linear with depth, otherwise the distribution will be exponential. Look at the 'rootdist' tab to see the difference.
Leaf Drop	Checking this results in surface litter incorporation into soil, dictated by leaf to total canopy weight ratio and leaf turnover rate (below)
Populate cohorts with LOI	If you have empirical LOI soil data, check this box and enter that data on the LOIprofile sheet. IMPORTANT: Then enter an initial accretion rate in the Physical Inputs panel. WARNING: And you must enter an initial accretion rate that is evenly divisible into 10. For example, you should put in an accretion rate of 0.5, 1, 2.5, or 5 mm/y; not 3. The model will use this accretion rate and the LOI profile to populate the cohorts at time zero. The precise value is not important for the forecasts of vertical accretion going forward. A default of 2.5 mm/yr is used if you do not specify.

Physical Inputs	
Sea Level Forecast (cm/100 yr)	The expected change in mean sea level or mean water level in the number of years specified in run time.
Run Time (years)	How many years into the future is this simulation? 100 years is the maximum.
Sea Level at Start (cm NAVD)	This is the time zero sea level in cm relative to NAVD 88. Time zero can be present or past time (for a hindcast)
Starting sea-level rise (cm/yr)	This is the current or time zero rate of sea-level rise. The model uses it to calculate the coefficients in the polynomial formula used to forecast the acceleration in rate of sea-level rise. You can simulate a linear rate of SLR by inputting a sea-level forecast of 100 times the linear rate. For example, to simulate a constant rate of 0.4 cm/yr, you enter a starting rate of 0.4 and centenary sea level of 40 cm.
Mean Tidal Amplitude (cm)	This is average amplitude of MHW: amp=MHW-MSL (NAVD)
Marsh Elevation at t0 (cm rel to MSL)	This is starting elevation of the marsh surface relative to MSL. Example: If MSL is -10 cm NAVD, and marsh elevation is 10 cm NAVD, then marsh elevation relative to MSL is 20 cm.
Suspended Min Sed Conc (mg/L)	This is SSC in the water that floods over the marsh surface. For marshes use the SSC in the nearest creek, preferably towards the end of a flood tide. This is one variable that determines what I refer to as sediment loading = volume in a 1 cm^2 column over the marsh surface (=average depth in cm) x concentration (mg/cm^3) x number of inundations per year. The model converts mg/L (your input unit) to mg/cm^3.
Suspended Org. Conc (mg/L)	Ditto the above, but this is for particulate organics. This is where you could simulate allochthonous inputs or inputs due to edge erosion (cannibalization). These inputs are assumed to be refractory, i.e., they do not degrade. Do not include concentrations of algae here. I assume alga are composed of labile organic matter and do not contribute volume to the soil.
Initial Accretion Rate (mm/yr)	If you are using LOI data to populate the cohorts at time zero, the value you put here is used to size the cohorts. Otherwise, this box will be populated with an accretion rate computed by the model at the start of the simulation. In this case, the accretion rate is an output, and is a function of the inorganic and organic inputs that you specify, based on a number of the physical and biological input parameters.

Biological Inputs	
Lower growth limits (cm rel to MSL)- initial and final or young and mature	The lower and upper growth limits define the breadth of the growth curves of young and mature canopies. A marsh recently buried in a thin layer of sediment might have a narrow distribution, for example, while the mature marsh could have a wider range of tolerance. If you are not simulating canopy growth, the model defaults to the mature growth limit.
Upper growth limits (cm rel to MSL)- initial and final	These inputs define the upper limits of the vertical range of young and mature marshes. If you are not simulating canopy growth, the model uses the mature limit.
Optimum elevation (cm rel to MSL)	This is the optimum elevation for growth, first for 1st year vegetation and for the mature marsh. Again, the mature optimum is used when not simulating canopy growth.
Initial and final root depth (cm rel to marsh surface)	These are maximum root depths for the recently buried and mature marshes. For an exponential distribution this is the depth above which 95% of root and rhizome biomass is concentrated. For a linear distribution, this is the maximum depth of root biomass (zero intercept).
Peak aboveground biomass (g/m2)	These inputs define the average, seasonal peak standing biomass of young and mature vegetation. If not simulating canopy growth, only the mature biomass is used, but do not leave blank any of the inputs in the young column.
Leaf:total canopy weight (g/g)	If simulating litter-fall and addition to soil, this ratio gives the ratio of leaf weight to total canopy weight.
Leaf turnover rate (1/y)	If simulating litter-fall, this is the turnover rate of leaves. The annual input is the canopy biomass x leaf:canopy weight ratio x turnover rate
BGBio to Shoot Ratio (g/g)	The ratio of belowground biomass to canopy biomass, e.g. a 2:1 ratio would be entered as a 2. For a marsh the belowground biomass is the sum of roots and rhizomes. You can specify initial and final weight ratios (young vs old)
BG turnover rate (1/yr)	This is the turnover rate of belowground biomass, enter it as a fraction, e.g. 1 per year. You can specify initial and final (young vs mature) turnover rates.
Time to maturity (years)	This is the number of years required for the marsh to regenerate to maximum biomass following a TLP application. The default should be 1 if you are not simulating canopy growth.
OM decay rate (1/yr)	The decay rate of the labile fraction of organic matter. Enter it as a fraction, e.g. 0.4 per year
LOI of above-marsh site	This is used only for sites at time zero that are above MHW and above the growth zone. This is the loss upon ignition of dry soil (LOI) as a percent of dry weight. The model has to start with a stack of cohorts populated with

	soil, and this is where you specify the composition. The vertical profile in this scenario is assumed to be constant.
Minimum Mineral Input (mg cm^{-2} yr^{-1})	For marsh surfaces higher than MHW there is no flooding. A minimum mineral input simulates what is added to the surface from storms, spring tides, etc. It should have a non-zero value to prevent a division by zero. Its value is empirically determined based on the LOI value of surface sediment.
Model Coefficients	
Max Capture Efficiency (q)	For North Inlet the best fit to accretion data is obtained with q=2.8 That is the default. This parameter determines how much of the sediment loading settles out. The sediment load is scaled by the fraction of time the surface is submerged. The product of that fraction and q cannot exceed 1, i.e. the maximum sediment that can settle is no greater than the sediment load.
Refrac Fraction (kr) (g/g)	This is the fraction of organic production that is stable. Statistical fits and numerous simulations suggest that this value is equal to the lignin concentration of the tissues. In Spartina this value is about 0.1
DT (years)	This is the time step. It should only be 1.0 or a fraction of 1, evenly divisible into 1 (e.g. 0.5, 0.1 etc). Large biomass, like a mature mangrove, can produce sizable numerical error and instability. Reducing the time step reduces numerical error. The model uses an Euler integration.
Carbon Conversion	The concentration of carbon in dry organic matter (gC/g dry wt). This is not as straight forward as you may think. I would use the C content of peat.

Episodic Disturbance - THIS IS CURRENTLY DISABLED	
1st occurrence	How many years from time zero do you want to start the first disturbance?
Repeat interval	How many years between each application?
Add elevation (cm)	How many cm of sediment will be added? Note: this is the consolidated volume, not the fresh volume.

Inputs on the LOI profile Sheet

Use of LOI data to populate the cohorts is optional, but if you have the data you have the option. You activate this option by checking the Populate cohorts with LOI checkbox on the IO_Page and entering an initial accretion rate under Physical Inputs. CWEM uses the initial accretion rate to size the cohorts.

CWEM 9 allows the user to input empirical LOI data into columns A and B on the LOIprofile sheet. The model interpolates these data to populate the cohorts at time zero. There are several hardwired examples of this in the model on the LOI profile sheet. Do not change any of the yellow highlighted areas on the LOI sheet. When you click on one of the hardwired sites on the IO_Page, for those that have the option to Populate the cohorts with LOI checked, the model will copy those yellow highlighted data into cols A and B. It then interpolates over the top 100 cm or less using cohort dimensions that are pulled from the Initial Accretion Rate input, under Physical Inputs. If you simulate something other than a hardwired site a different site and want to use your own empirical LOI profile, you should be enter the sediment depths and LOI directly in cols A and B on the LOIprofile sheet. Check the Populate cohorts with LOI box, and enter an Initial Accretion Rate. Do not forget to do this. Also, enter an initial accretion rate that is evenly divisible into 10, like 5, 2.5, 1, or 0.5 mm/y.

CWEM 9.0 Outputs

Graphical Outputs on the IO_Page	
Standing Biomass vs Elevation	This is the user-defined growth curve for vertical biomass profile. When simulating TLP there are two curves. The green curve is the biomass profile of the mature marsh, the blue curve is the profile of the post-TLP marsh. The red line is a trace of the actual biomass vs elevation during the simulation. Note that elevation here is relative to MSL.
Inundation Time (0-1)	The fraction of time the surface is inundated with water.
C-sequestration (g C m^{-2} yr^{-1})	This is the annual rate of carbon sequestration over time.
Standing Biomass (g/m^2) vs time (years)	This is peak standing crop (dry weight) during the simulation
MSL and marsh elevation (cm NAVD)	These are the graphs of simulated mean sea level and marsh elevation, both in units of cm NAVD
Sediment Org Matter (%)	This is the depth profile of simulated LOI at the start of the simulation (blue) and end of the simulation (red).
Numerical Outputs on the IO_Page	
Metrics Computed at the mid-point of the simulation	
Avg. vertical accretion (cm/yr)	This is the vertical accretion rate in the 2^{nd} quarter, i.e. in the case of a 100-yr simulation, this would be years 26-50.
Refractory carbon sequestration (g C m^{-2} yr^{-1})	This is the annual carbon sequestration averaged over the preceding 25 years at the mid-point of the simulation.
Total carbon (gC m-2) in belowground biomass.	This is the carbon in the top 25 cm of sediment, calculated at the mid-point of the simulation.
Metrics Computed at the end of the simulation	
Avg. vertical accretion (cm/yr)	This is the vertical accretion rate in the 4th quarter. In the case of a 100-yr simulation, this would be years 76-100.
Refractory carbon sequestration (g C m^{-2} yr^{-1})	This is the annual carbon sequestration in the 4th quarter. Note that 25 or less years of time can represent a small piece of the top of the sediment column.
Total carbon (g C m^{-2}) in belowground biomass.	This is the carbon in the top 25 cm of sediment, basically in the root zone. Dividing this by 25 will give you the annual rate.
Refractory carbon sequestration (g C m^{-2} yr^{-1}) over all time	This is the annual carbon sequestration averaged over the entire time of the simulation.

Outputs on the Computations Page	
Year	Simulation year starting with 1
	blank
dzdt	The annual change in marsh elevation (mm/yr) at the elapsed times. Immediately below this column are the point-in-time dzdt from years 25,

	50, 75, and 100. And below this are the average accretion rates computed of 25, 50, 75, and 100 years.
Standing Biomass	The standing biomass (g/m2) in the current year
Fractional Inundation Time	The fraction of time the site is inundated between 0 (never) to 1 (always)
Suspended organic Input	The annual deposition of suspended organic matter (mm cm^{-1} yr^{-1})
Depth relative to MHW	Depth of marsh surface relative to mean high water (cm). Immediately below this column is the change in relative marsh surface depth since time zero.
Cquest	Annual rate of carbon sequestration (g C m^{-2} y^{-1}), computed from root mortality. This is concentrated within the root zone.
totBGB	Total live and necrotic belowground biomass (dry kg/m^2) over all cohorts including the time zero cohorts
MSL (NAVD)	Mean sea level (cm NAVD). Immediately below this is the total change in sea level (cm) since time zero
SLR	The annual rate of sea-level rise (mm/y) at the elapsed time computed from the first derivative (a + 2bt) of the sea level curve ($at+bt^2+c$). Immediately below this column are the annual SLR rates from years 25, 50, 75, and 100.
Marsh E NAVD	Marsh elevation (cm NAVD) at the elapsed time. Immediately below this column is the change in marsh elevation (cm) since time zero.
Marsh E rel MSL	Marsh elevation relative to MSL (cm)
pedonD	The total pedon depth or vertical dimension (cm) summed over all cohorts, including its time zero dimension. Immediately below this is the change in pedon depth (cm) since time zero.
Inorg	The annual deposition of inorganic matter (mm yr^{-1})
Tot Live BG BIO	Total live dry weight biomass belowground (dry kg/m2)
Org Vol Fraction	The volume fraction of organic matter (living and dead) computed over all cohorts including time zero
top level root vol	Root volume in the top cohort at the elapsed time (mm/cm^2). Used for trouble shooting.
Root Mort	The annual point-in-time mortality of roots (kg dry wt m^{-2} yr^{-1}).
Sum Org Vol	The total volume of organic matter in the pedon (cm^3 per cm^2) including time zero cohorts. Immediately below this column is the total change in organic volume (cm^3 per cm^2) since time zero, and below this column are point-in-time organic volumes from years 25, 50, 75, and 100.
Sum Mineral	The total volume of mineral matter in the pedon (cm^3 per cm^2) including time zero cohorts. Immediately below this column is the total change in mineral volume (cm^3 per cm^2) since time zero, and below this column are point-in-time mineral volumes from years 25, 50, 75, and 100.
Cum Change Org Vol	The cumulative change in volume of organic matter from time zero to current time (mm/cm^2). Immediately below this column are cumulative changes in organic volumes from years 25, 50, 75, and 100.

Cum Change Min Vol	The cumulative change in volume of mineral matter from time zero to current time (mm/cm^2). Immediately below this column are cumulative changes in mineral volumes from years 25, 50, 75, and 100.
Cum Delta (cm) Marsh Elevation	The cumulative change in marsh elevation since time zero (cm). Immediately below this column are the volume % mineral composition computed over all cohorts including time zero.

Numerical Output Page	
Time Series Outputs	
year	Simulation year starting with 1
MSL (cm NAVD)	Mean sea level by year
Marsh Elevtion (cm NAVD)	Marsh elevation by year (cm NAVD)
Standing Biomass (g/m^2)	Aboveground biomass by year (g/m2)
Cohort Characteristics In the Final Year	
dzdd	Vertical cohort dimension (cm) starting from the top
Sediment Depth (cm)	Cumulative depth of sediment (cm) from the surface to the bottom on each cohort
Live BG Biomass (g/m^2)	Live biomass in each cohort (g dry wt/m^2)
Labile OM (g/m2)	Labile organic matter in each cohort (g/m^2)
Refractory OM (g/m^2)	Refractory (stable) organic matter in each cohort (g/m^2)
Tot BG Biomass (g/m^2)	Total organic biomass in each cohort (g/m^2)
LOI (%)	Percent loss upon ignition (dry weight basis)
Inorganic Sed. (mg/cm^2)	Inorganic sediment in each cohort
Bulk Density (g/cm^3)	Cohort dry bulk density
Live Root (mg/cm^3)	Density of live roots in each cohort (mg/cm3) (root weight/cohort volume)
Decay Rate (g dry wt m^{-2} yr^{-1})	Annual decay rate (loss of dry, organic weight) within each cohort
Initial and Final Sediment Profiles in 2 cm Slices‡	
Sediment Depth (cm)	These will be approximately 2 cm each, except in the case of the final profile in a TLP application. The idea here is to simulate what you would see in a sediment core. The model integrates over cohorts, and summarizes the contents when the dimension of the stack equals or exceeds 2 cm each. In the case of a TLP application, the model skips over cohorts from one depth to the next and simply summarizes the cohort at each depth interval.
Live BG Biomass (g/m^2)	The live biomass in each 2 cm slice, except for the final profile of a TLP application. See Sediment Depth above.

Tot BG Biomass (g/m^2)	Total organic biomass (live and dead) in each 2 cm slice, except for the final profile of a TLP application. See Sediment Depth above.
Inorganic Sed. (dag/m^2)	The weight of inorganic sediment (decagrams/m2) in each 2 cm slice, except for the final profile of a TLP application. See Sediment Depth above.
SOM (%)	This is LOI in each 2 cm slice, except for the final profile of a TLP application. See Sediment Depth above.
Bulk Density (g/cm^3)	Bulk density in each 2 cm slice, except for the final profile of a TLP application. See Sediment Depth above.
Biomass and SOM graphs	These are here for diagnostic reasons. They will look a bit noisy because the 2 cm slices are not exactly uniform. The model has to integrate over cohorts that do not add up precisely to 2 cm.

‡ There are 2 stacks, each of 100 cm depth or more. The first stack of slices is the initial condition. Below it, the second stack is from the final year of the simulation.