Marsh Model Notes

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**Goal:** Develop a 1D Marsh eco-geo model for vertical growth that has 2 new additions:

1. incorporates temporal dynamics in two ways:
   1. marsh phenology
   2. time variability of sediment load
2. Incorporates both sed trapping and water blocking in vegetation-deposition feedback

**Intellectual Merit:** This type of eco-geo model w/ seasonality/ time dependence is not done. That is b/c working with Non-autonomous differential equations are annoying (e.g., Goldstein and Moore 2016)

**Hypotheses:**

1. Including temporal dynamics destabilizes the marsh. As a result:
   1. tipping points that occur sooner in time
   2. equilibrium states that take longer time to reach
2. Synchrony of sed and veg is a key controlling parameter in determining the time to equilibrium elevation
3. Temporal dynamics seen in observational records (e.g., Morris et al 2002 paper) are explained by inclusion of temporal dynamics

**Code:** <https://github.com/ebgoldstein/MarshModel>

**Model:** The model is built from 2 coupled ODEs:

1. An EQN representing the change in biomass as a fn of time.
2. An EQN representing the change in marsh platform surface as a fn of time.

*EQN 1:* We walk through the construction of these ODEs. First, we address the change in biomass as a function of time. Morris et al 2002 defined an equation for Above Ground Production as a function of marsh platform depth relative to a datum.

Where: B is the Aboveground Production (g/m^2 yr), D is depth below MHT (m; but note that Morris et al 2002 use cm), and a (g/m^3 yr) b (g/m^4 yr) c (g/m^2 yr) are all dimensional constants. We use converted values from Morris for the parameters, so a = 15500, b = -18550, and c = -1364.

In some ways, I’m not really sure what ‘productivity’ is. So I am going to just make some assumption that this equation effectively parameterized the peak biomass for a given depth. In that way it can function as a carrying capacity in a logistic model:

Where r is the intrinsic growth rate (with dimensions 1/t). This equation defines the growth of biomass toward the carrying capacity defined by the Morris curve. We could add phenology to this eqn, but it’s tricky, so I am choosing to add it in the next eqn.

r, the intrinsic growth rate, is currently unconstrained… I wonder if there is data for this?

*EQN 2:* So now we need an EQN representing the change in marsh platform surface as a fn of time. Morris et al 2002 use:

Where is the marsh surface elevation, q is the ‘rate of sediment loading’, and k is the efficiency of vegetation for trapping. Intuitively, deposition rate (increase with:

1. Increases in D — more water (with sediment) is brought onto the marsh
2. Increases in q — more background sediment in the water column
3. Increases in k — veg better at trapping
4. Increases in B — more veg to trap sediment

We can modify this eqn slightly by introducing MHT (S), and casting the equation above w.r.t. MHT and marsh depth:

Taking the derivative w.r.t time yields:

Subbing in the Morris change in depth EQN from above yields:

Rearranging yields:

Currently using values from Morris et al., (Charleston, SC SLR of 3mm/yr), q = 0.0018, and k = 0.000015.

Taking a step back, I am not sure I love this equation. In my mind one could construct a slightly different and simpler eqn where:

Where the ‘Supply Term’ is the Sed. Concentration, the ‘Delivery Term’ is a linear increasing function of depth, and the ‘Capture Term’ is the parabolic blocking/trapping effect.

But regardless, we can work with the Morris et al 2002 formulation right now, which we need to modify in three ways:

1. Include temporal change in B
2. Include blocking/trapping
3. Include temporal sediment load

*Inclusion of temporal change in B:*

I chose a very simple way to do this. We have the peak annual biomass expected from the logistic eqn w/ Morris et al. 2002 encoded as the carrying capacity. This is what is included as the biomass in the morphological equation. Instead of including the Biomass directly from the Morris equation, we can provide a modified version that is time sensitive:

Where is the temporal biomass, and t is time. The periodic part of the function ( looks like this:

Chart, line chart

Description automatically generated

Bouncing from y = 0 -> 1 -> 0 in each interval of x. In this way it mimics a phenology curve when multiplied by the B from the Logistic model, bouncing from 0 to the max predicted biomass in yearly intervals. A downside is that at x = integer values the function is not differentiable, so I imagine there is some introduced instability in the continuous model.. in the future we may want to get a different/better/smooth function.

*Inclusion of Blocking and Trapping:*

This needs to be a parabolic function. Y values need to go from 0 to 1 to 0 as x goes from no biomass (no trapping) to a prescribed amount of biomass (blocking dominates). This is where I stopped…

0 biomass, 0 efficiency (no trapping) ,

4000 biomass?, 0 efficiency (all blocking).