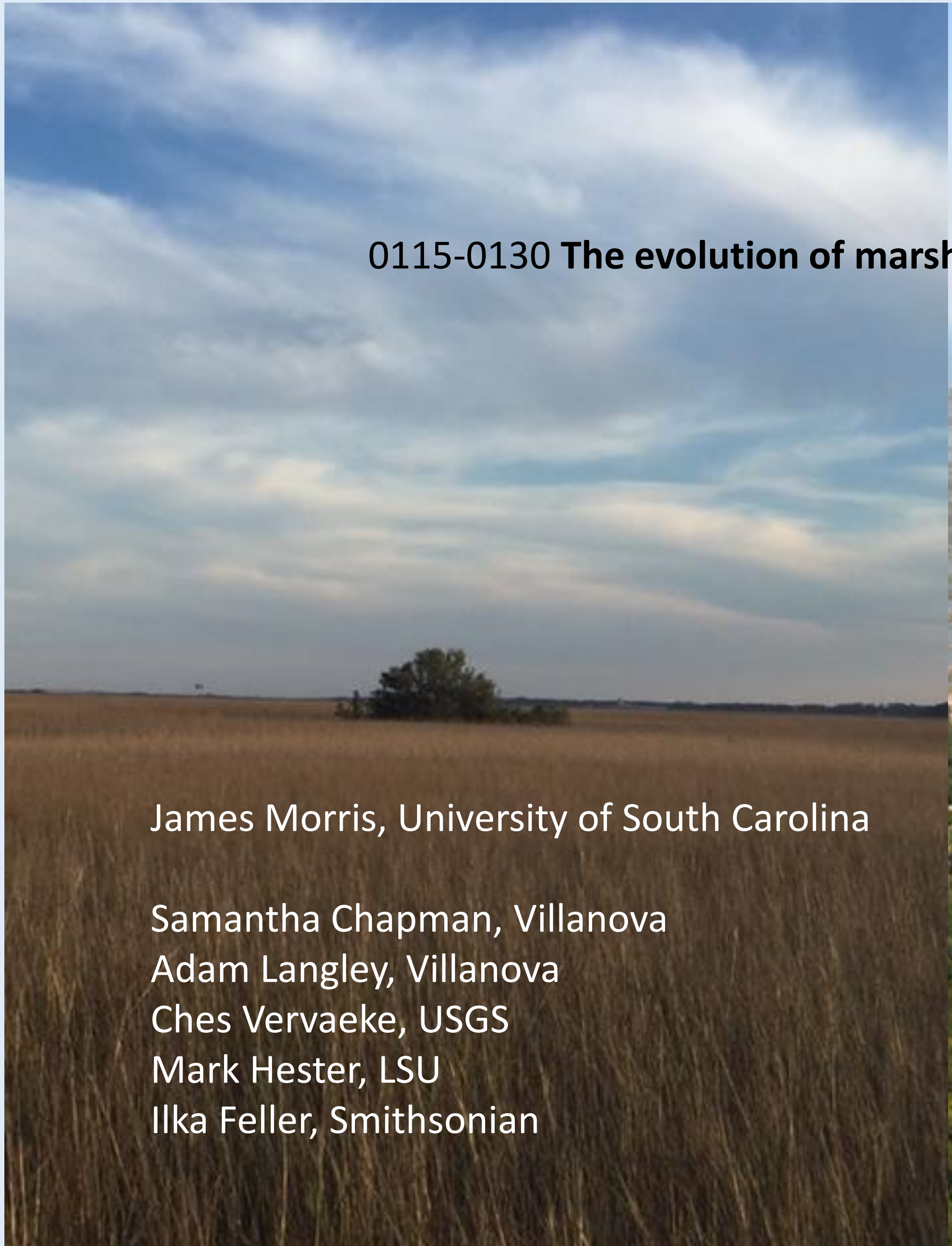
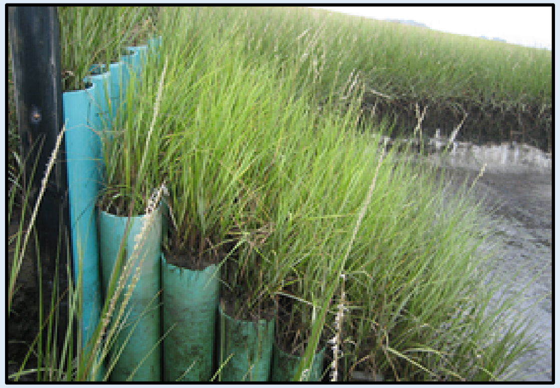


0115-0130 **The evolution of marsh equilibrium theory: from marshes to mangroves**

James Morris, University of South Carolina

Samantha Chapman, Villanova
Adam Langley, Villanova
Ches Vervaeke, USGS
Mark Hester, LSU
Ilka Feller, Smithsonian



Marsh organ – a bioassay designed to measure the plant’s response to relative elevation or hydroperiod.

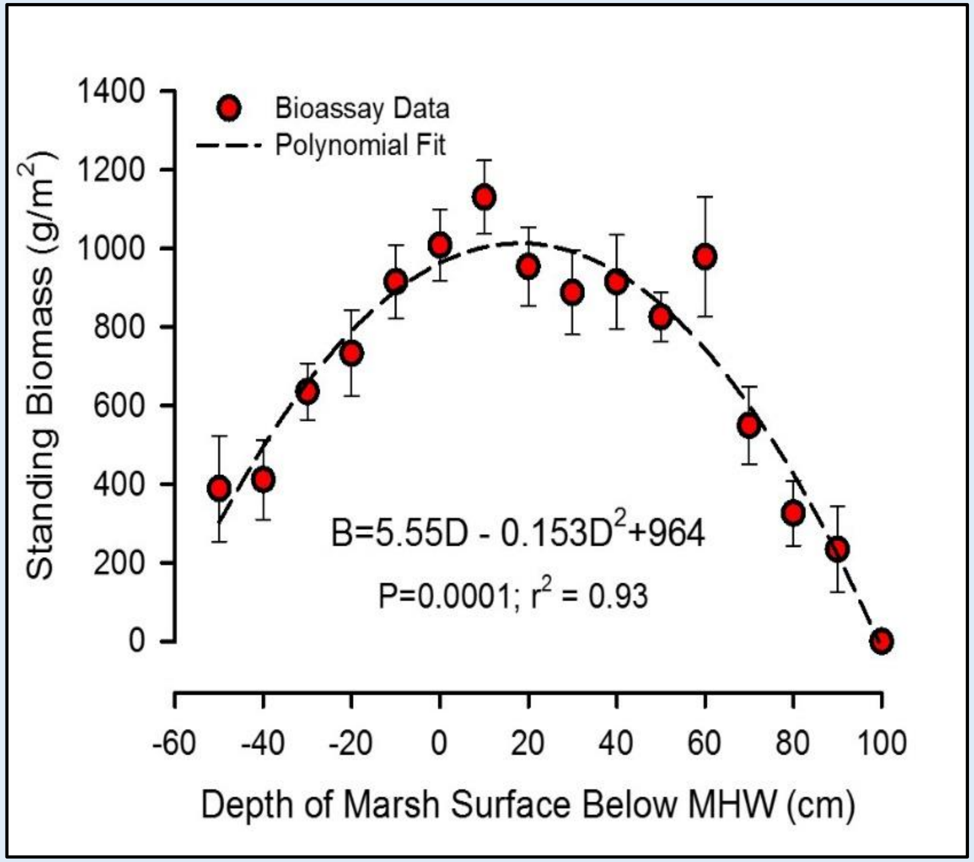
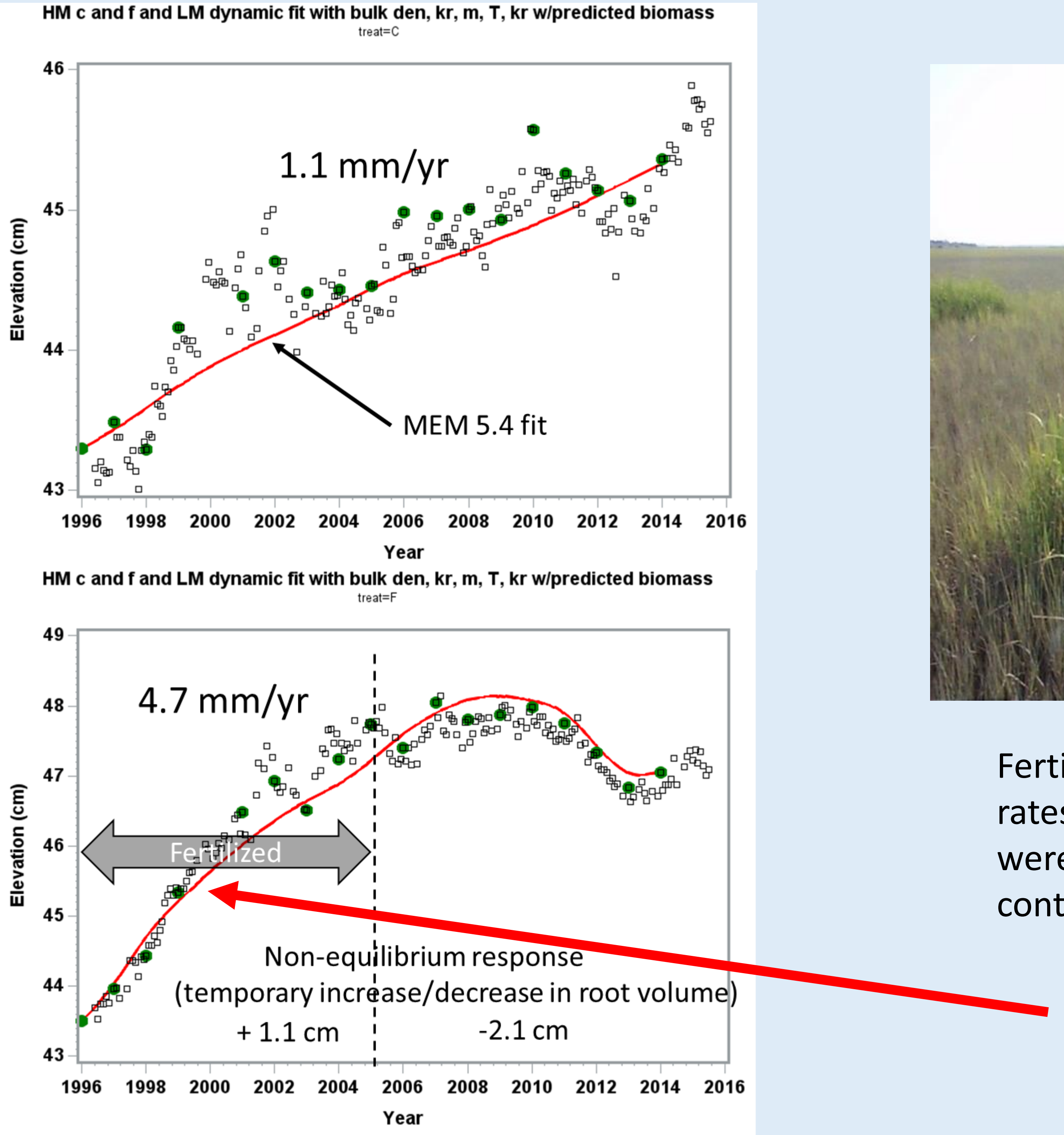


Figure 6. End-of-season aboveground standing biomass from marsh organs operating at North Inlet. Biomass is plotted against depth below mean high water (MHW). Mean sea level is about 70 cm below MWH.



Fertilized plots (high biomass) had rates of sediment accretion that were significantly greater than controls.

Sediment accretion is proportional to depth : $dY_2/dt \propto D$

Sediment accretion is proportional to biomass: $dY_2/dt \propto (q+kB)$ Where B=biomass, q & k are consts.

Combining these yields: $dY_2/dt = D(q+kB)$ for $D>0$ (1)

Biomass is a function of D: $B=aD+bD^2+c$ (2)
where a, b and c are constants.

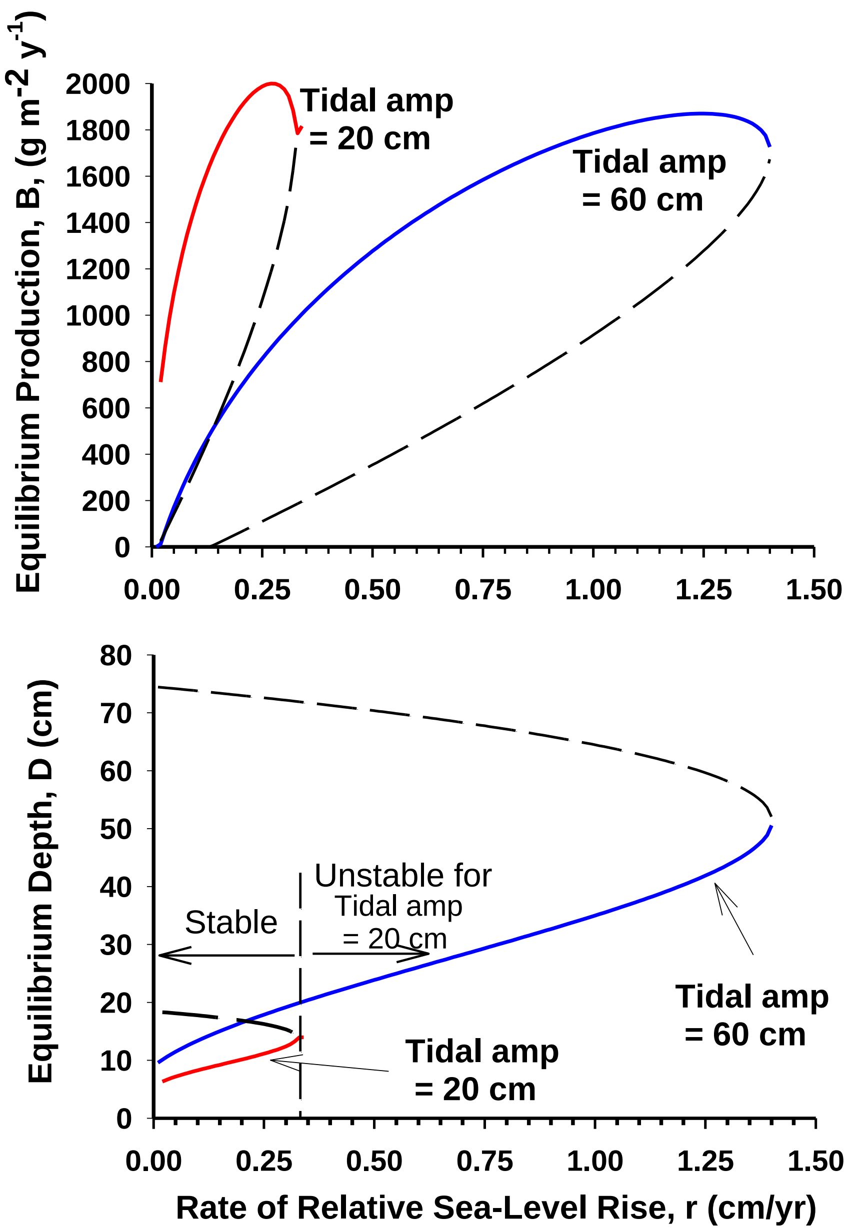
If the marsh surface is in equilibrium with sea level change, then:

$$dY_2/dt = dY_1/dt = r \qquad (3)$$

Substitute from Eqs 1 & 2 :

$$kbD^3 + kaD^2 + (q + kc)D - r = 0 \qquad (4)$$

Equation 4 has two real roots over a limited range of r (rate of change of sea level), depending on values of a, b, c, q and k.



There is an equilibrium depth (bottom figure) that is a function of the rate of sea-level rise.

Depth affects primary production.

There is an optimum rate of sea-level rise for primary production.

The dynamic range of response increases with increasing tidal amplitude.

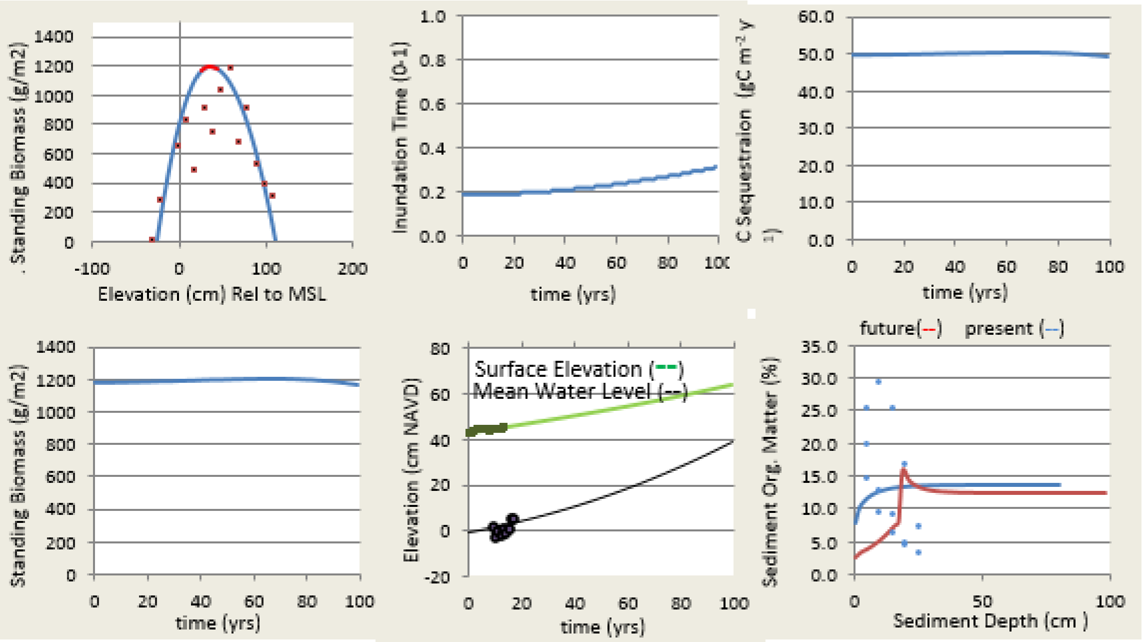
MEM 8.7 User Interface

- Use a generic biom profile
- Simulate storms
- Grow the Canopy
- Linear root dist
- Leaf Drop

TextBox 6

Run Simulation

North Inlet, SC   MEM v8.7



Physical Inputs

Sea Level Forecast	40	cm/time
Run Time	100	years
Sea Level at Start	-1	cm (NAVD)
20th Cent Sea Level Rate	0.2	cm/yr
Mean Tidal Amplitude	70	cm
Marsh Elevation @ t0	44	cm (MSL)
Suspended Min. Sed. Conc.	20	mg/l
Suspended Org. Conc.	0	mg/l
Initial Accretion Rate	1.87	mm/yr

Biological Inputs

	Initial	Final	
Lower Growth Limits	-25	-25	cm rel MSL
Upper Growth Lilmits	110	110	cm rel MSL
Optimum Elevation	35	35	cm rel MSL
Maximum Root Depth	25	25	cm rel surf
Peak Biomass	1200	1200	g/m^2
Leaf:Tot Canopy Wt Ratio			g/g
Leaf Turnover Rate			1/year
Below Grnd Bio to Shoot Ratio	2.0		g/g
Below Ground Turnover Rate	0.50		1/year
Time to Maturity	0	years	
OM decay rate	0.6	g/g	
LOI of above-marsh site	20	% of dry wt	
Minimum Mineral Input	0.01	mg cm^{-2} yr^{-1}	

Model Coeffiients

Max Capture Eff (q)	2.80	
Refrac. Fraction (kr)	0.10	g/g
DT	1.00	years

Hard Wired Sites

- Plum Island, MA
- North Inlet, SC
- Apalachicola, FL
- Grand Bay, MS
- Coon Isl, SFB
- MR generic delta
- young mangrove
- Sac delta tule

Metrics computed at the end of the simulation

0.26 cm yr^{-1}, avg vert accretion in 4th quarter
52 g C m^{-2} yr^{-1}, refractory C sequestration in the last quarter
5709 g C m^{-2}, total C in belowground biomass in top 25 cm

Metrics computed at the mid point simulation

0.21 cm yr-1, avg vert accretion in the second quarter
52 g C m^{-2} yr^{-1}, refractory C seqestration in second quarter
6655 g C m^{-2}, total C in belowground biomass in top 25 cm

50 g C m^{-2} yr^{-1}, refractory C sequestration over all simulation time

6 sec Run Time

2992

North Inlet salt marsh

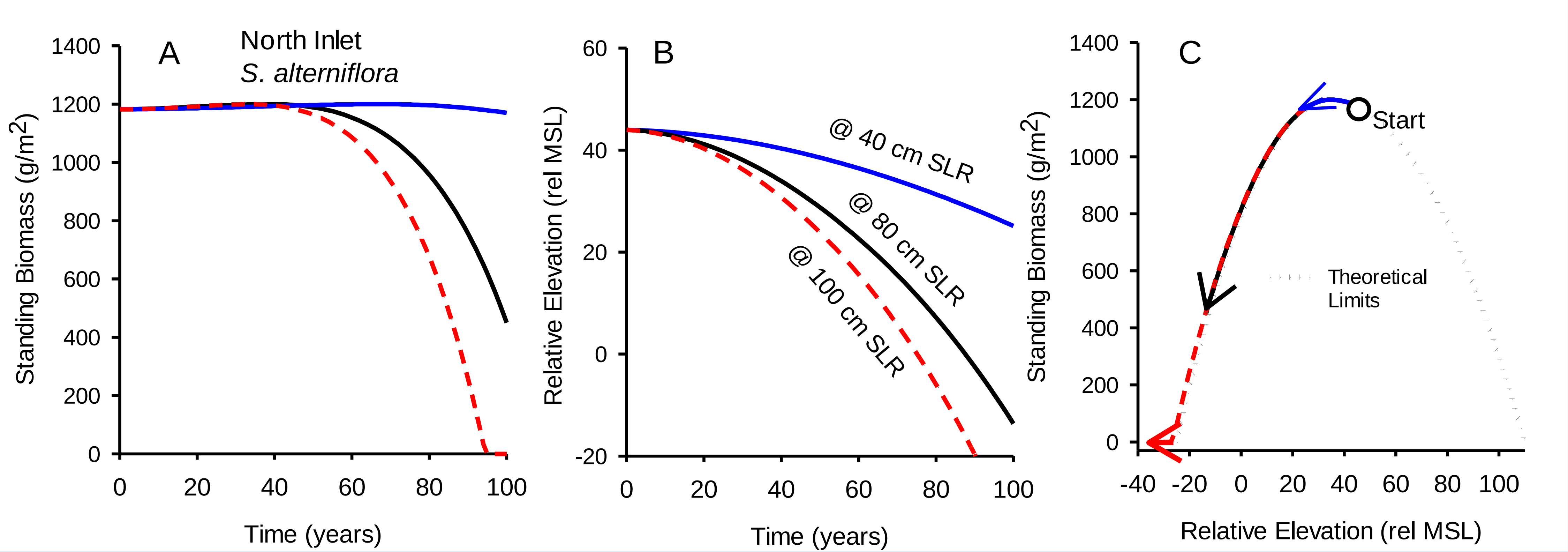


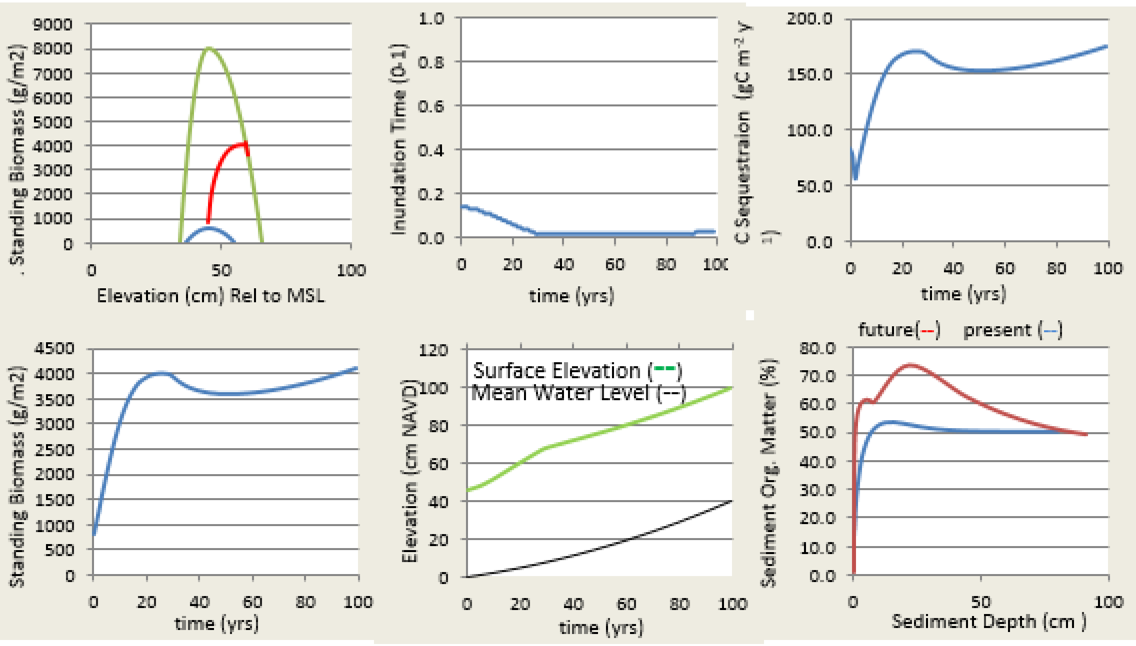
Figure 2. A) Simulated standing biomass of North Inlet *S. alterniflora* over time at three scenarios of sea level rising to 40, 80, and 100 cm in the next century; B) the corresponding marsh elevations relative to MSL and C) the simulated standing biomass in A plotted against the relative elevation in B, and the theoretical vertical growth distribution.

- ☐ Use a generic biom profile
- ☐ Simulate storms
- ☑ Grow the Canopy
- ☐ Linear root dist
- ☐ Leaf Drop

Run Simulation

Northern FL Mangroves

MEM v8.7



Physical Inputs

Sea Level Forecast	40	cm/time
Run Time	100	years
Sea Level at Start	0	cm (NAVD)
20th Cent Sea Level Rate	0.2	cm/yr
Mean Tidal Amplitude	63	cm
Marsh Elevation @ t0	45	cm (MSL)
Suspended Min. Sed. Conc.	11.1	mg/l
Suspended Org. Conc.	0	mg/l
Initial Accretion Rate	3.15	mm/yr

Biological Inputs

	Initial	Final	
Lower Growth Limits	36	34	cm rel MSL
Upper Growth Lilmits	55	66	cm rel MSL
Optimum Elevation	45	45	cm rel MSL
Maximum Root Depth	30	85	cm rel surf
Peak Biomass	500	8000	g/m²
Leaf:Tot Canopy Wt Ratio			g/g
Leaf Turnover Rate			1/year
Below Grnd Bio to Shoot Ratio	1.4	1.7	g/g
Below Ground Turnover Rate	0.67	0.22	1/year
Time to Maturity	30	years	
OM decay rate	0.071	g/g	
LOI of above-marsh site	30	% of dry wt	
Minimum Mineral Input	0.1	mg cm^{-2} yr^{-1}	

Model Coeffiients

Max Capture Eff (q)	2.80	
Refrac. Fraction (kr)	0.33	g/g
DT	0.10	years

Hard Wired Sites

- ○ Plum Island, MA
- ○ North Inlet, SC
- ○ Apalachicola, FL
- ○ Grand Bay, MS
- ○ Coon Isl, SFB
- ○ MR generic delta
- ◉ young mangrove
- ○ Sac delta tule

Metrics computed at the end of the simulation

0.55 cm yr^{-1}, avg vert accretion in 4th quarter

174 g C m^{-2} yr^{-1}, refractory C sequestration in the last quarter

9069 g C m^{-2}, total C in belowground biomass in top 25 cm

Metrics computed at the mid point simulation

0.49 cm yr-1, avg vert accretion in the second quarter

166 g C m^{-2} yr^{-1}, refractory C seqestration in second quarter

8841 g C m^{-2}, total C in belowground biomass in top 25 cm

154.3 g C m^{-2} yr^{-1}, refractory C sequestration over all simulation time

31 sec Run Time

2992

Northeast Florida pioneer *Avicennia*

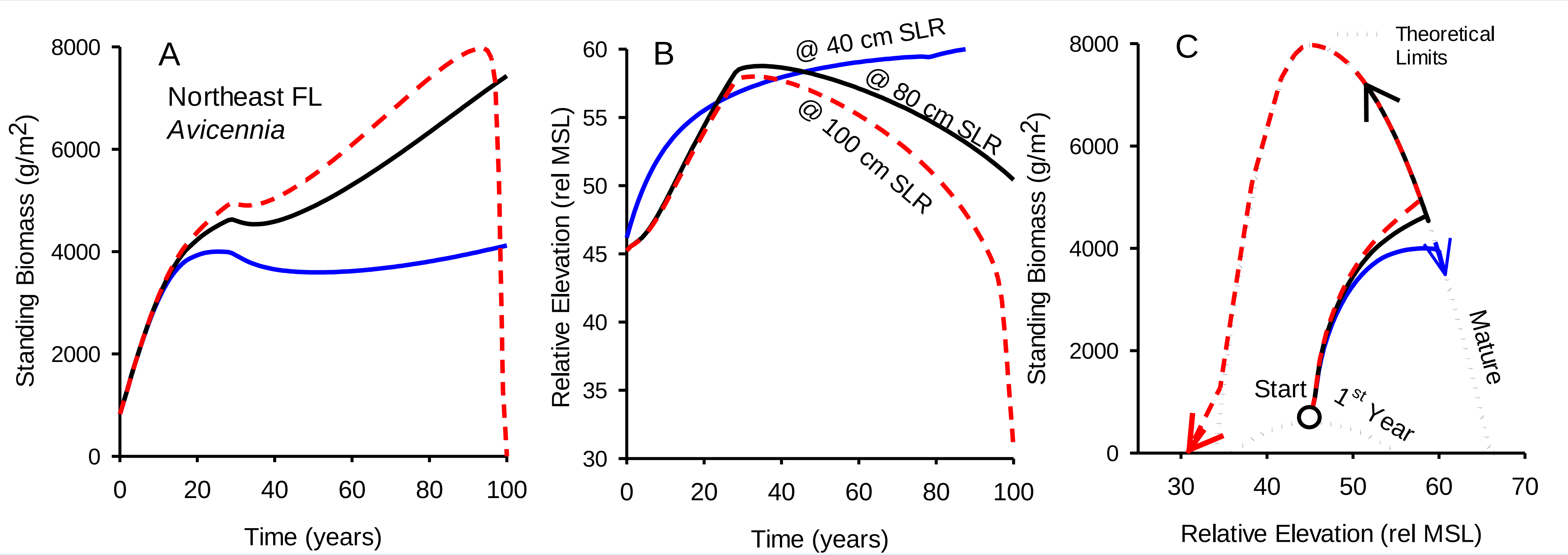


Figure 3. A) Simulated standing biomass of *A. germinans* in Northeast Florida over time at three scenarios of sea level rising to 40, 80, and 100 cm in the next century; B) the corresponding wetland elevations relative to MSL and C) the simulated standing biomass in A plotted against the relative elevation in B, and the theoretical vertical growth distributions of 1st year mangroves and mature mangroves.

Northeast Florida mature *Avicennia*

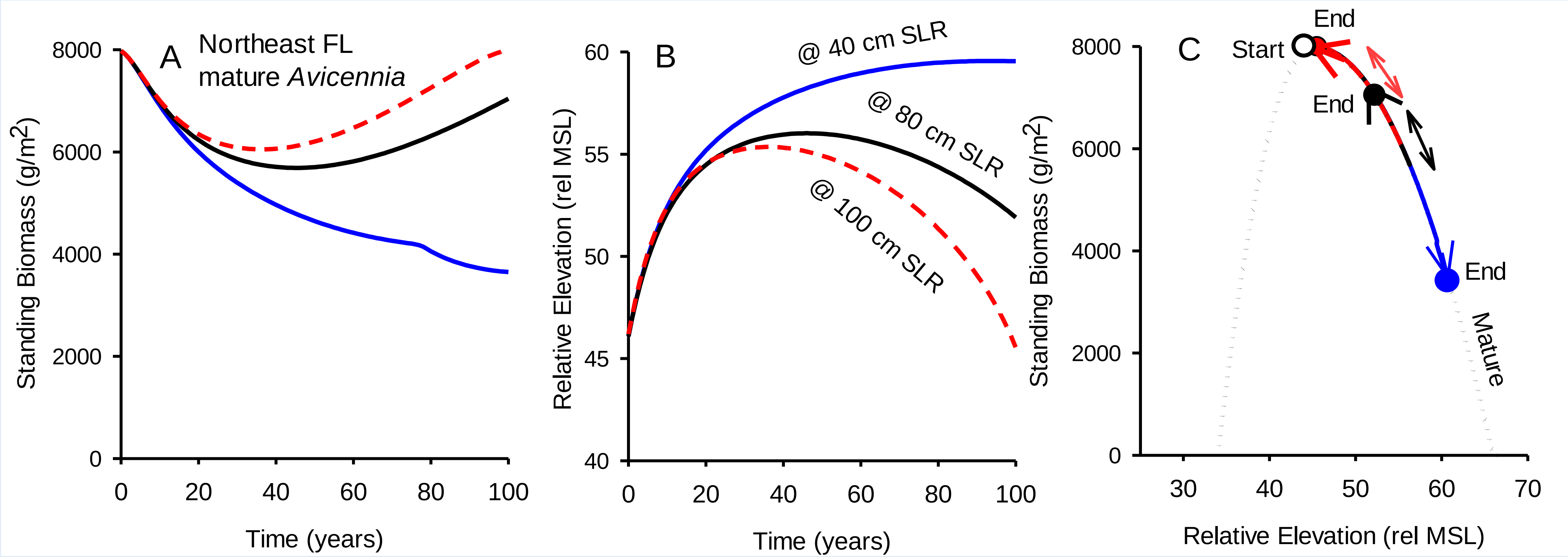
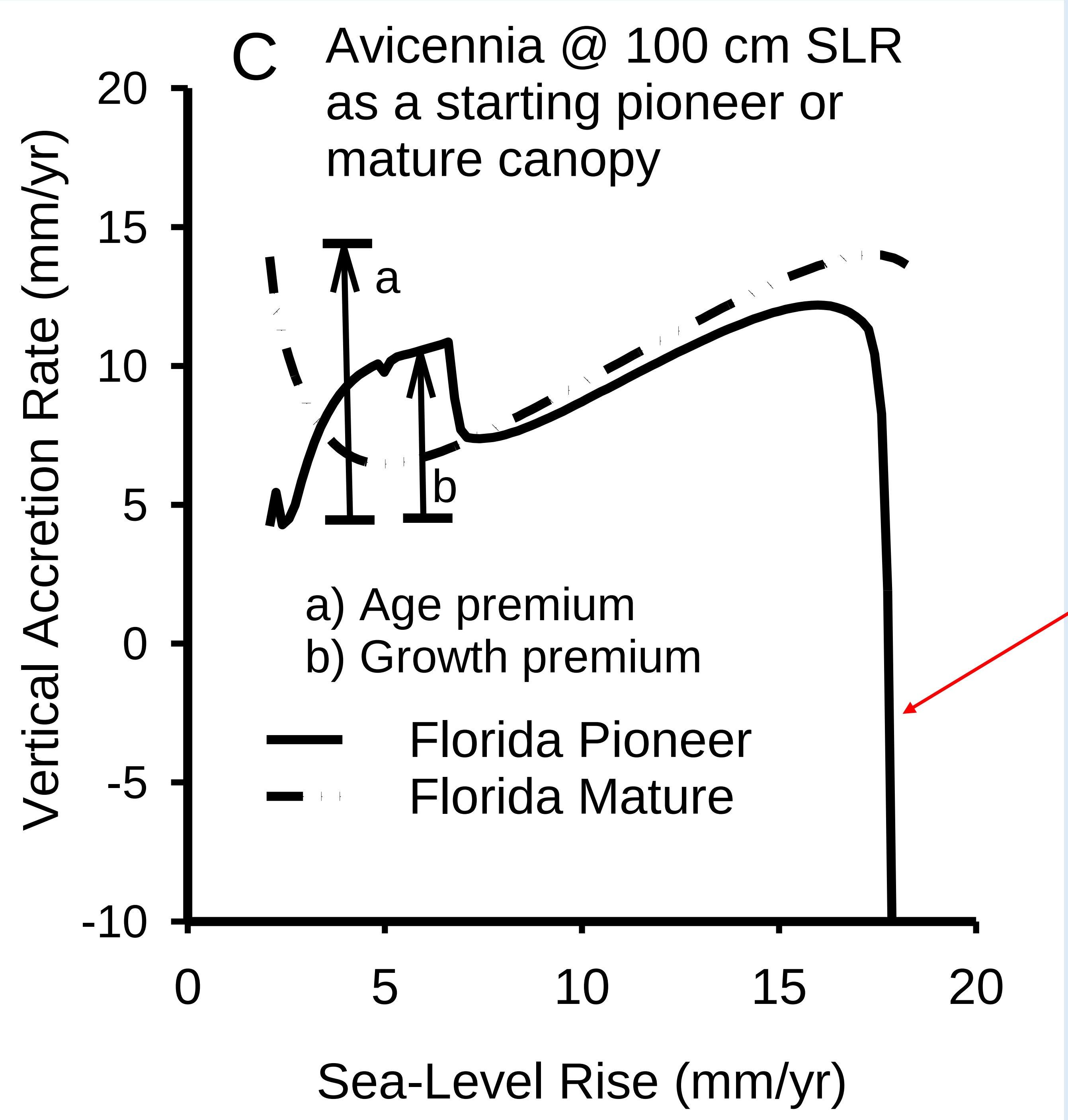


Figure 4. A) Simulated standing biomass of mature *A. germinans* in Northeast Florida over time at three scenarios of sea level rising to 40, 80, and 100 cm in the next century; B) the corresponding wetland elevations relative to MSL and C) the simulated standing biomass in A plotted against the relative elevation in B, with the theoretical vertical growth distributions of mature mangroves.



Mature canopies enjoy an age premium, pioneers enjoy a growth premium. The relative advantage depends on the starting elevation.

When mangroves fail they fail spectacularly.

Table 1. Vertical accretion rates and carbon sequestration rates averaged over the 2nd and 4th quarters of the simulation, total carbon (live and dead) inventory in the top 25 cm (or top 50 cohorts if < 25cm) at the end of the 2nd and 4th quarters, and carbon sequestration integrated over the entire 100-yr simulation at different sea-level rise scenarios (40, 80, and 100 cm in 100 yr) for different habitats: *S. alterniflora* in North Inlet, SC, young and mature *A. germinans* in NE Florida, and hypothetical *A. germinans* in North Inlet.

	North Inlet *S. alterniflora*			NE Florida pioneer *A. germinans*			NE Florida mature *A. germinans*
	@ 40 cm	@ 80 cm	@ 100 cm	@ 40 cm	@ 80 cm	@ 100 cm	@ 100 cm
Second Quarter Summary							
avg vertical accretion (cm/yr)	0.21	0.24	0.25	0.49	0.75	0.87	0.84
C sequestration (g C m^{-2} yr^{-1})	52	52	52	166	206	224	335
Surface inventory (C g/m^2)	6655	6411	6322	8841	8778	8861	8929
Fourth Quarter Summary							
avg vertical accretion (cm/yr)	0.26	0.28	0.26	0.55	1.11	0.82	1.41
C sequestration (g C m^{-2} yr^{-1})	52	34	16	174	300	360	415
Surface inventory (C g/m^2)	5709	3802	2854	9069	8884	8805	8848
Integrated over the century							
C sequestration (g C m^{-2} yr^{-1})	50	45	39.6	154.3	215.3	244.4	358.3

Preliminary Conclusions

1. Tidal mangroves consistently have higher rates of vertical accretion and greater rates of carbon sequestration than salt marshes. The ES value of mangroves is greater!
2. Mature mangroves are more resilient than young mangroves. They have a significant head-start that endows them with greater vertical accretion rates. To successfully transgress, growth of young mangroves will need to outpace SLR.
3. The limiting factor for mangrove northward migration is seed transport. We could proactively accelerate migration, which would offer greater protection of our coasts from rising sea level, greater carbon sequestration, and greater protection from coastal storms.
4. However, when mangroves drown they do so with significant loss of elevation due to the large volume of labile organic matter and roots in their soils. Mangrove coasts will change episodically, salt marshes will transgress gradually.