Delta-X Workshop– 9 May 2024

Numerical Understanding of Marsh Accretion & Resilience-
NUMAR Unit Model

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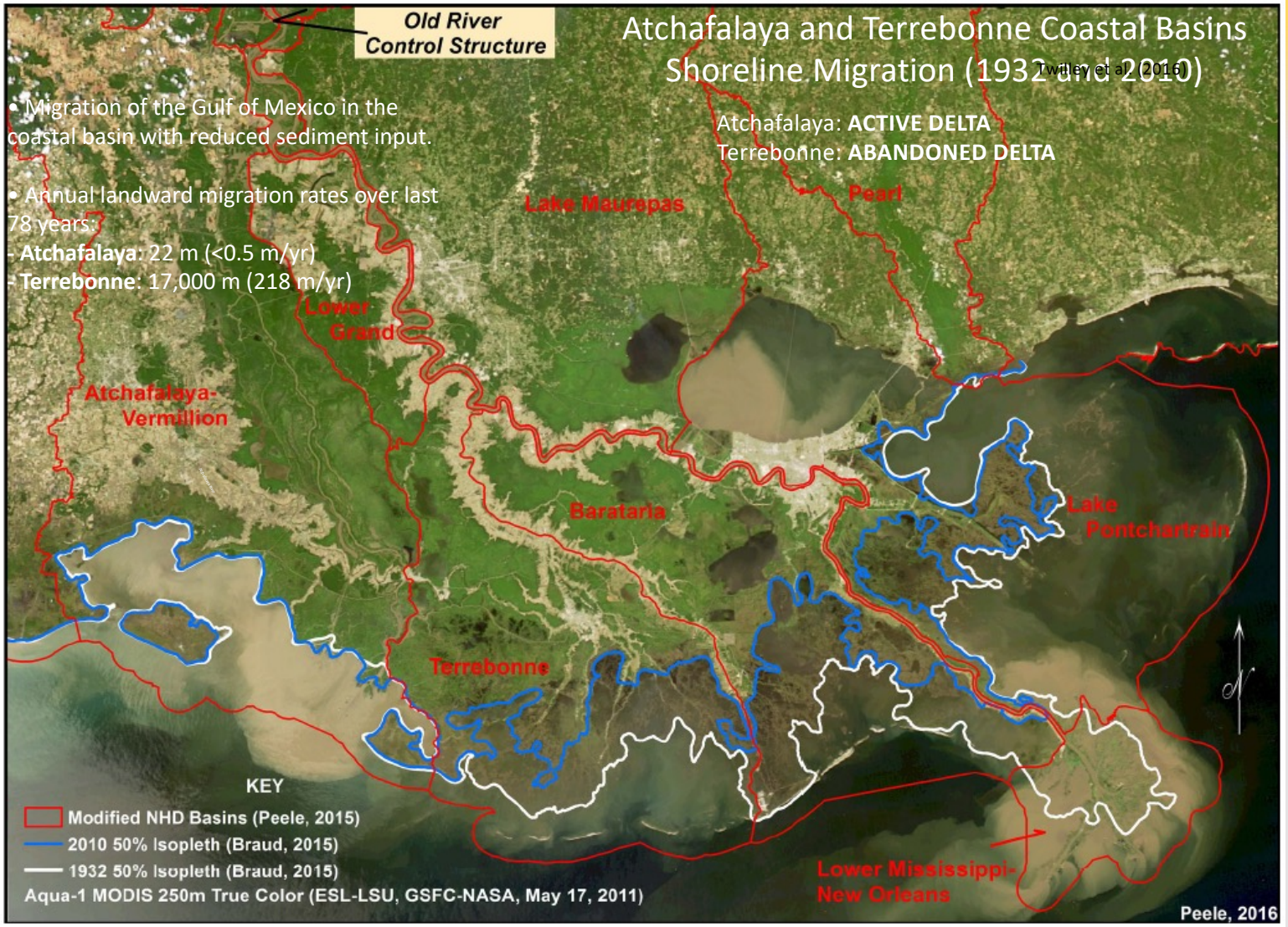
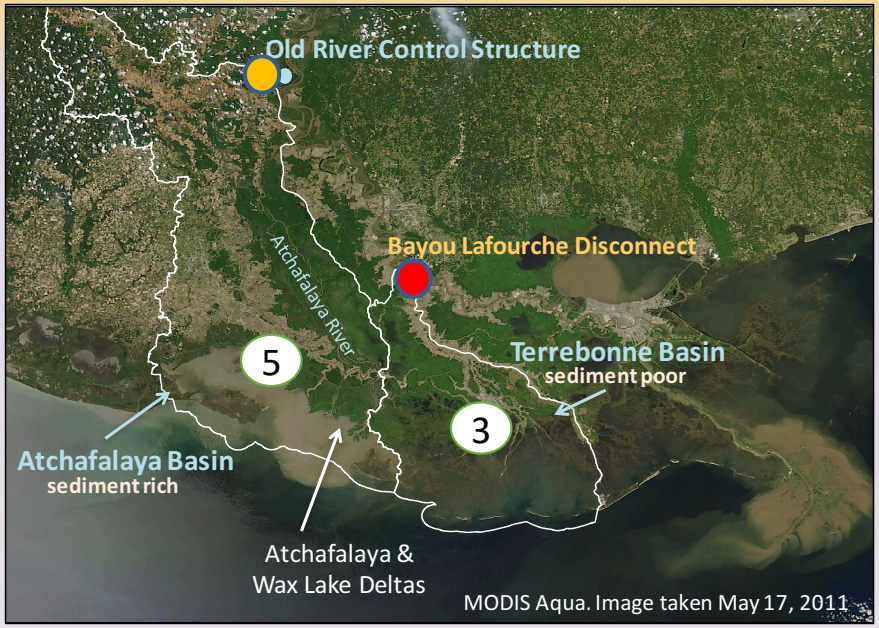
LSU | College of Coast & Environment

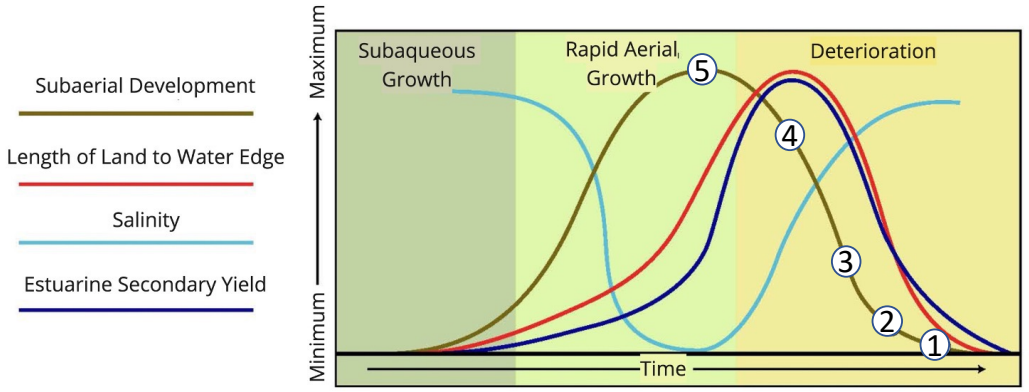

Old River
Control Structure
Atchafalaya and Terrebonne Coastal Basins
Shoreline Migration (1932 and 2010)
Twilley et al. (2016)
• Migration of the Gulf of Mexico in the coastal basin with reduced sediment input.
• Annual landward migration rates over last 78 years:
- Atchafalaya: 22 m (<0.5 m/yr)
- Terrebonne: 17,000 m (218 m/yr)
Atchafalaya: ACTIVE DELTA
Terrebonne: ABANDONED DELTA
Lake Maurepas
Pearl
Lower
Grand
Atchafalaya-
Vermillion
Barataria
Lake
Pontchartrain
Terrebonne
KEY
Modified NHD Basins (Peele, 2015)
2010 50% Isopleth (Braud, 2015)
1932 50% Isopleth (Braud, 2015)
Aqua-1 MODIS 250m True Color (ESL-LSU, GSFC-NASA, May 17, 2011)
Lower Mississippi-
New Orleans
Peele, 2016

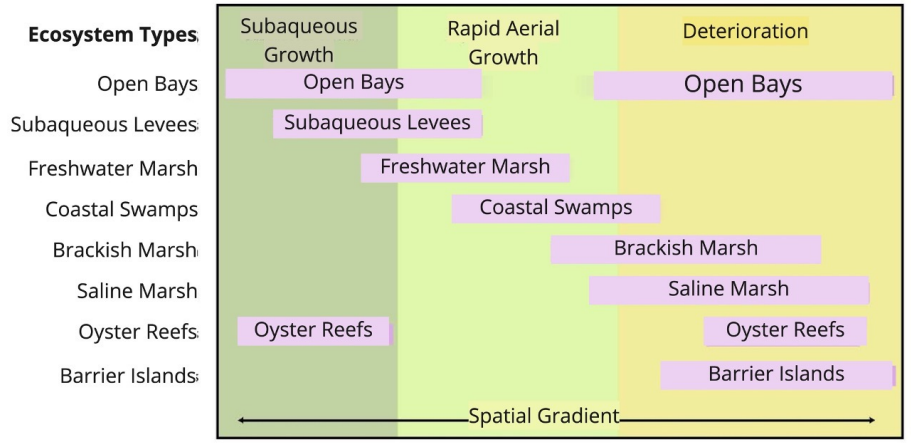
Experimental Questions: Processes of Delta Cycle

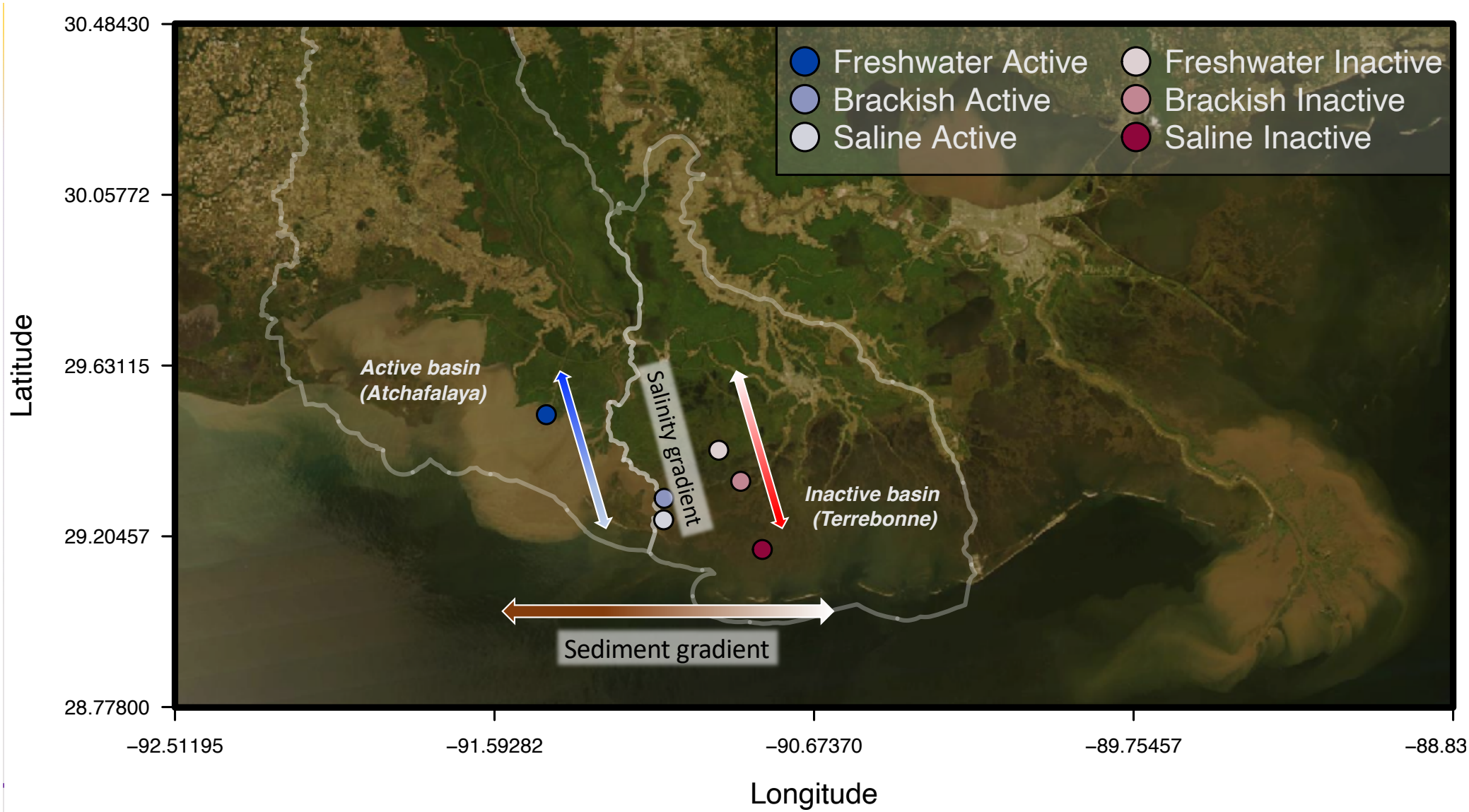


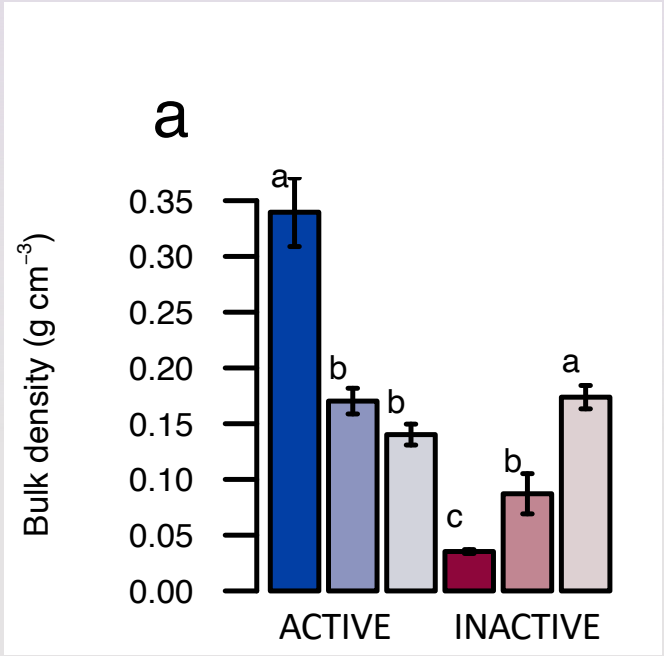
1. The delta cycle has been used to capture self-organization of morphology and ecosystem types associated with river occupations of the landscape.
2. The processes are associated with river-dominated delta landscapes.

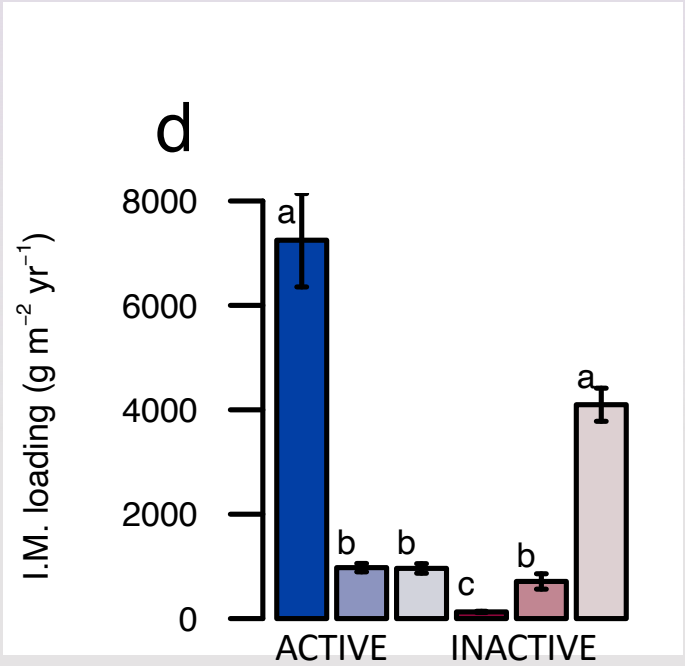
(1) Maringouin (2) Teche (3) St. Bernard (4) Lafourche (5) Plaquemines

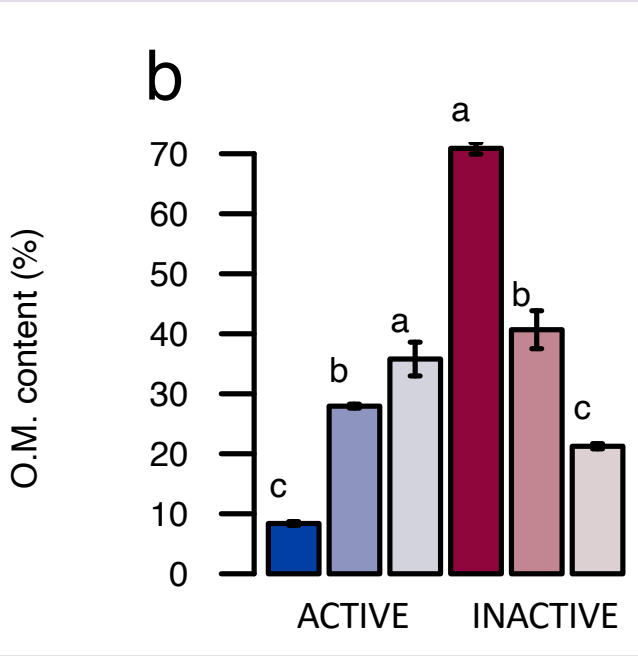





Freshwater Active
Brackish Active
Saline Active
Freshwater Inactive
Brackish Inactive
Saline Inactive
Active basin
(Atchafalaya)
Salinity gradient
Inactive basin
(Terrebonne)
Sediment gradient
30.48430
30.05772
29.63115
29.20457
28.77800
Latitude
−92.51195
−91.59282
−90.67370
−89.75457
−88.83
Longitude



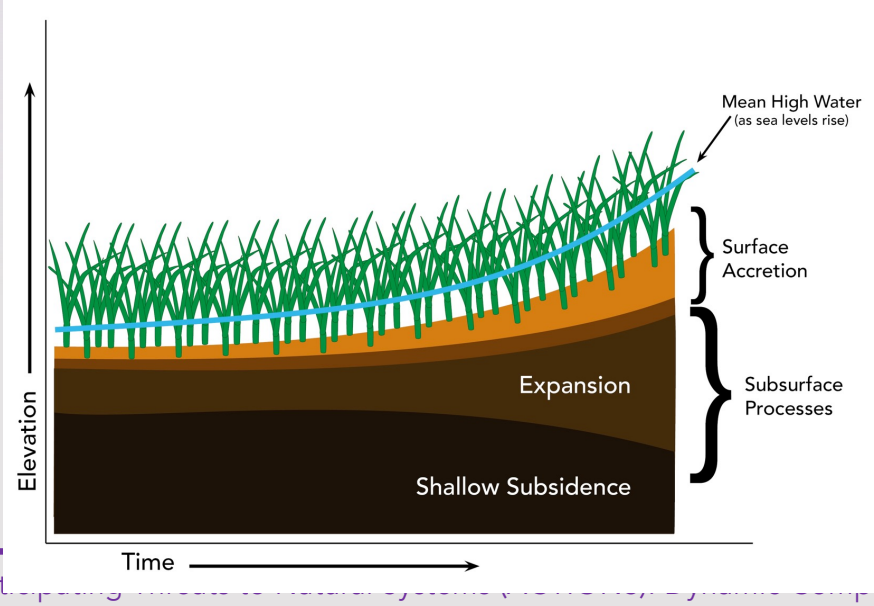


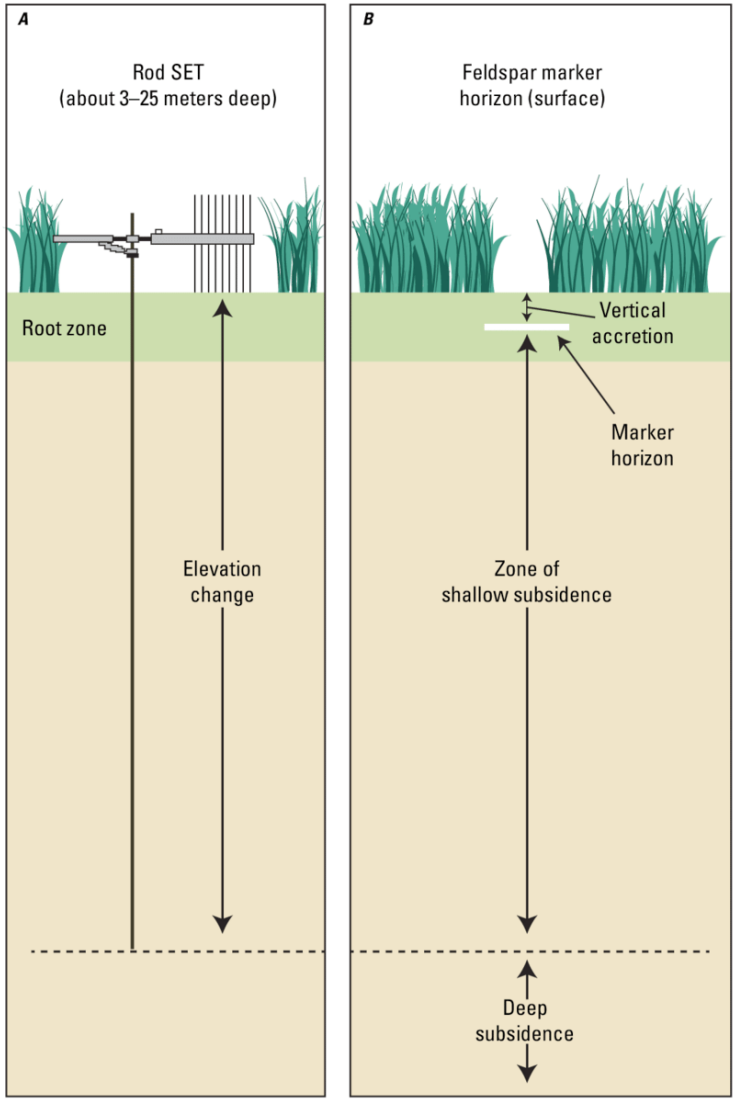


Fresh Active
Brackish Active
Saline Active
Fresh Inactive
Brackish Inactive
Saline Inactive

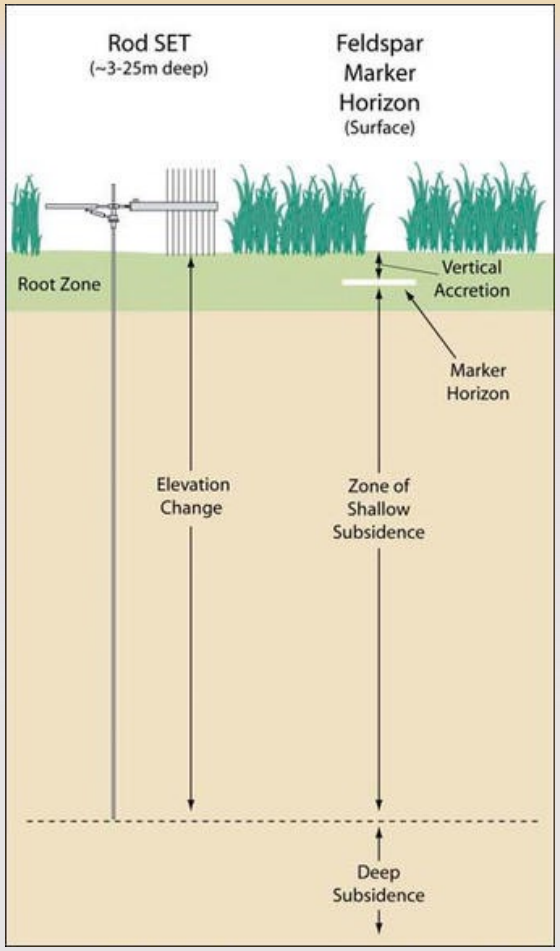
Clarifying the Dynamics of Sediment Surface Elevation (Platform Elevation)

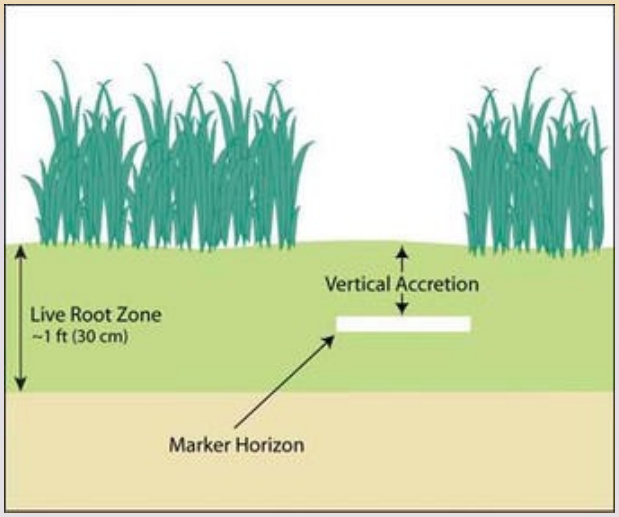
1. Sediment Surface Elevation is the Platform Elevation relative to a datum
2. The dynamics of platform elevation are combination of surface deposition and subsurface process of shallow subsidence and expansion (water volume filling pore spaces)
3. Methods to separate out these processes – Sediment Elevation Tables (SET)





Feldspar Marker Horizons – Surface Deposition



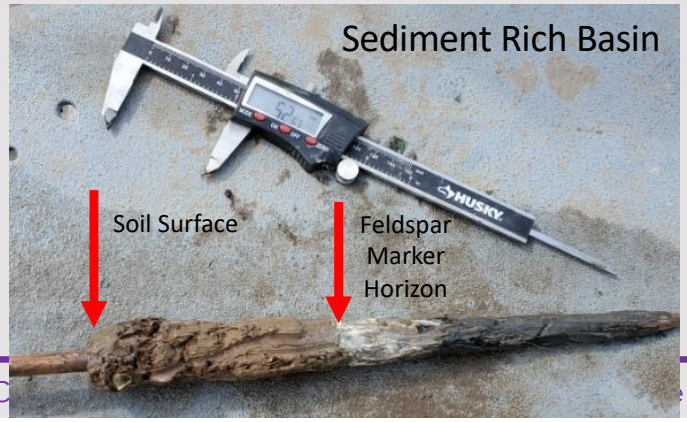


USGS SET webpage:
http://www.pwrc.usgs.gov/set/

Feldspar Marker Horizon to measure sediment deposition

Surface Accretion Rates (SAR)

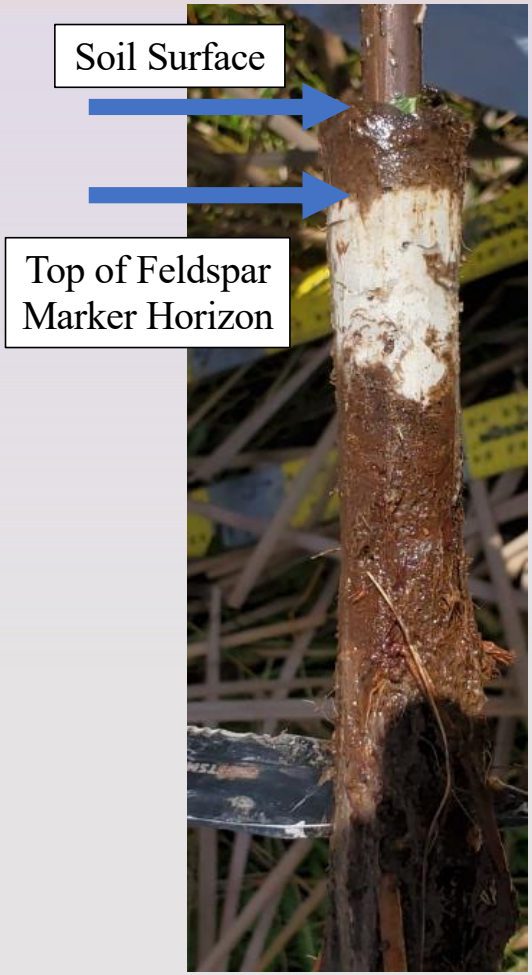
- Deposition of inorganic + organic sediment on marsh surface;
- Contribution to soil development – elevation;
- Cryocore measures of marsh surface elevation above a soil marker – feldspar;

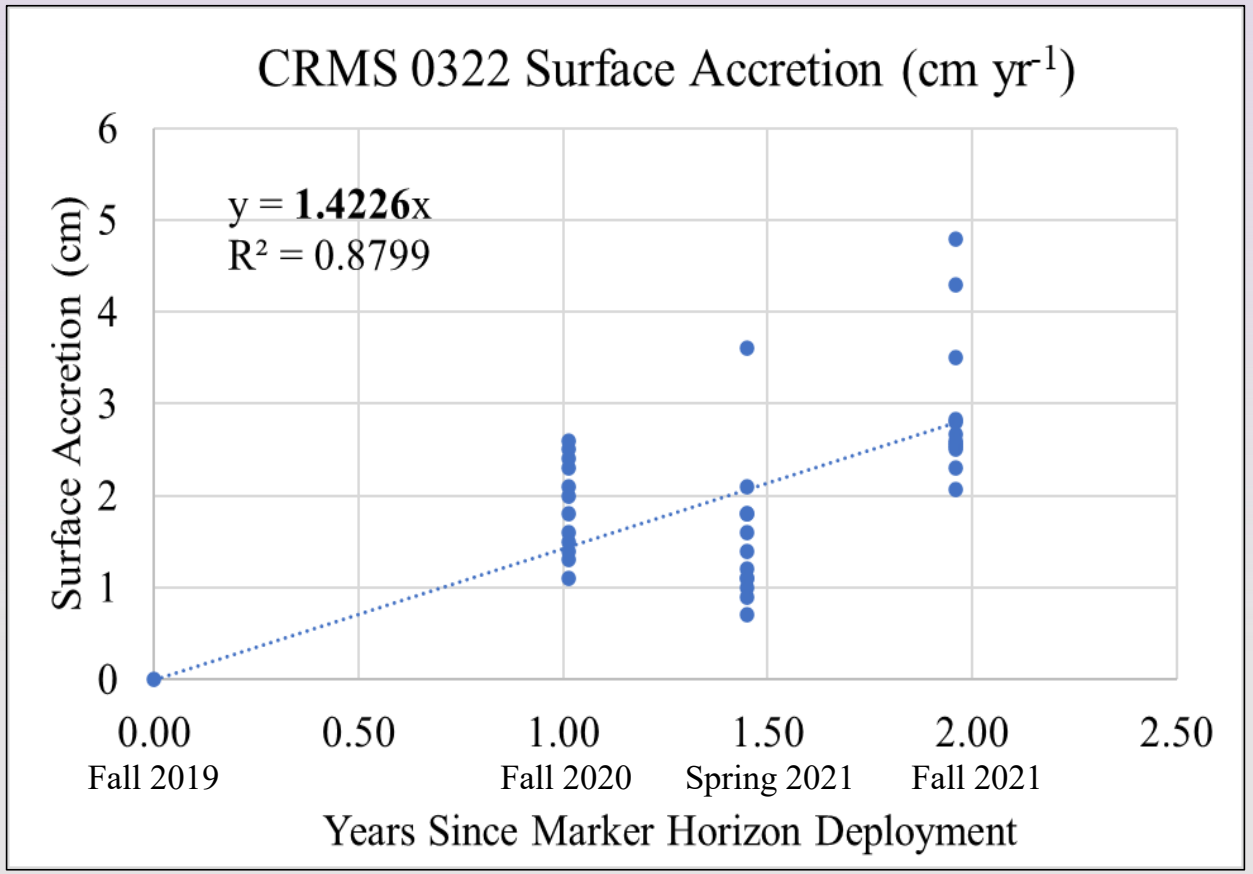


Feldspar Marker Horizons – Surface Accretion

- Spring 2022 – Measure 2.5yr
- Fall 2021 – Measure 2yr
- Spring 2021 – Measure 1.5yr
- Fall 2020 – Measure 1yr
- Fall 2019 – Marker Deployment

Feldspar Marker Horizons – Surface Accretion

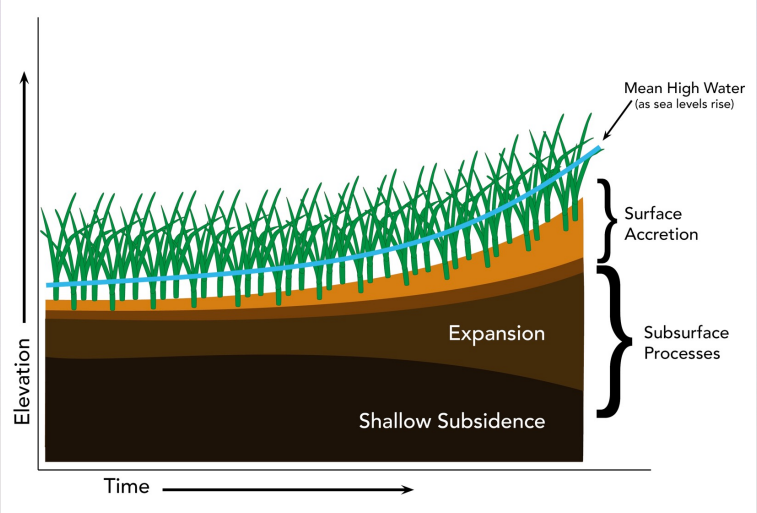


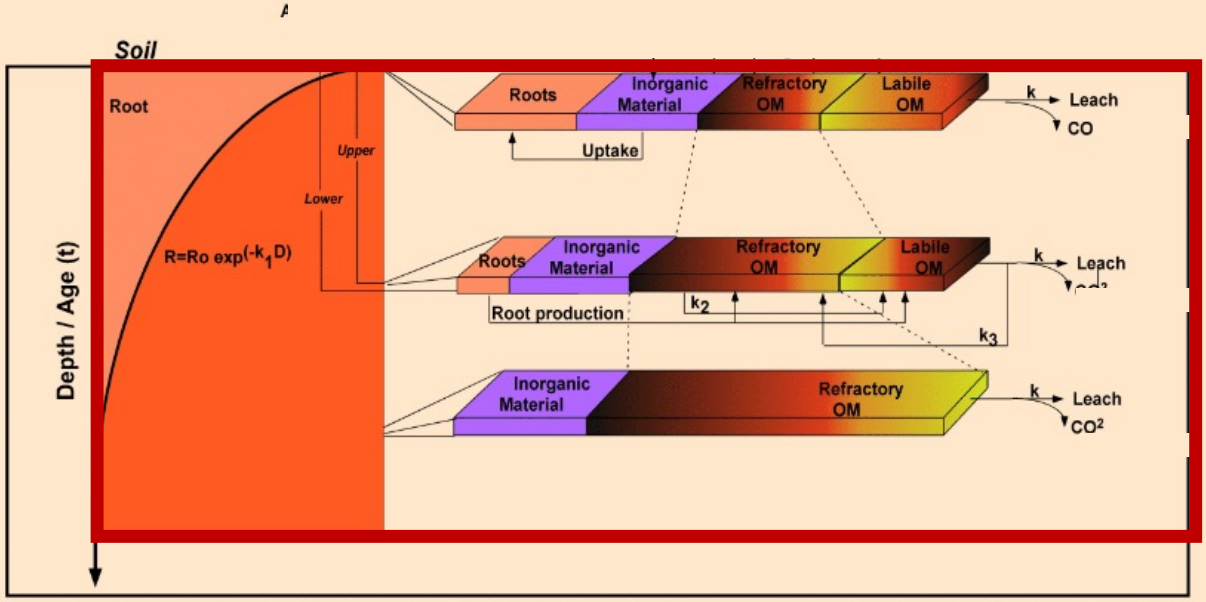


Numerical Understanding of Marsh Accretion & Resilience (NUMAR – soil formation & accretion, carbon sequestration)

Important Parameters

1. Soil Accretion (formation) = cohort of surface & belowground processes (cm/yr) over 100 yr time frame;





Numerical Understanding of Marsh Accretion & Resilience (NUMAR – soil formation & accretion, carbon sequestration)

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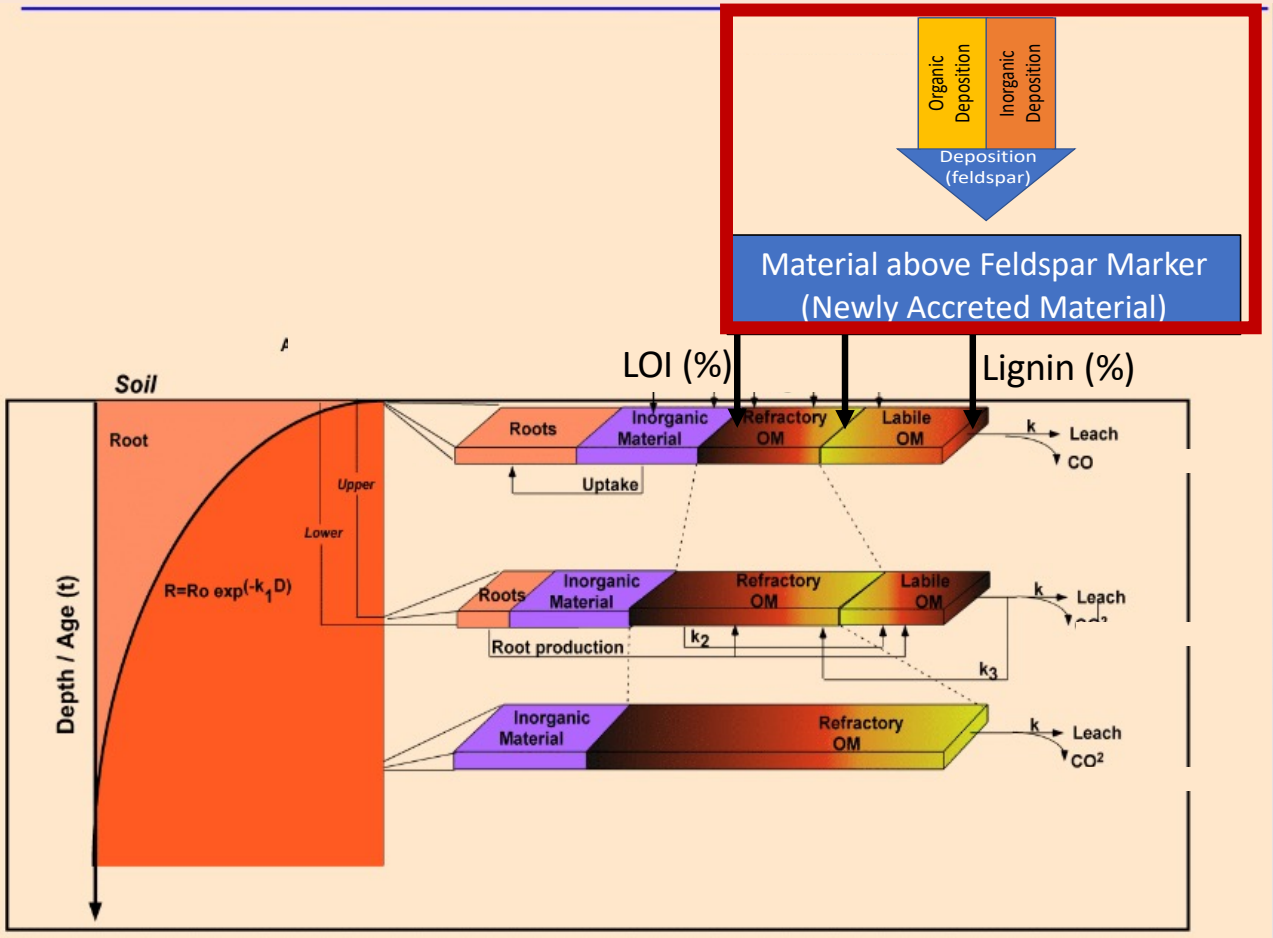
2. Surface Deposition: organic and inorganic deposition (feldspar) (cm/yr) over 1-3 yr time frame;



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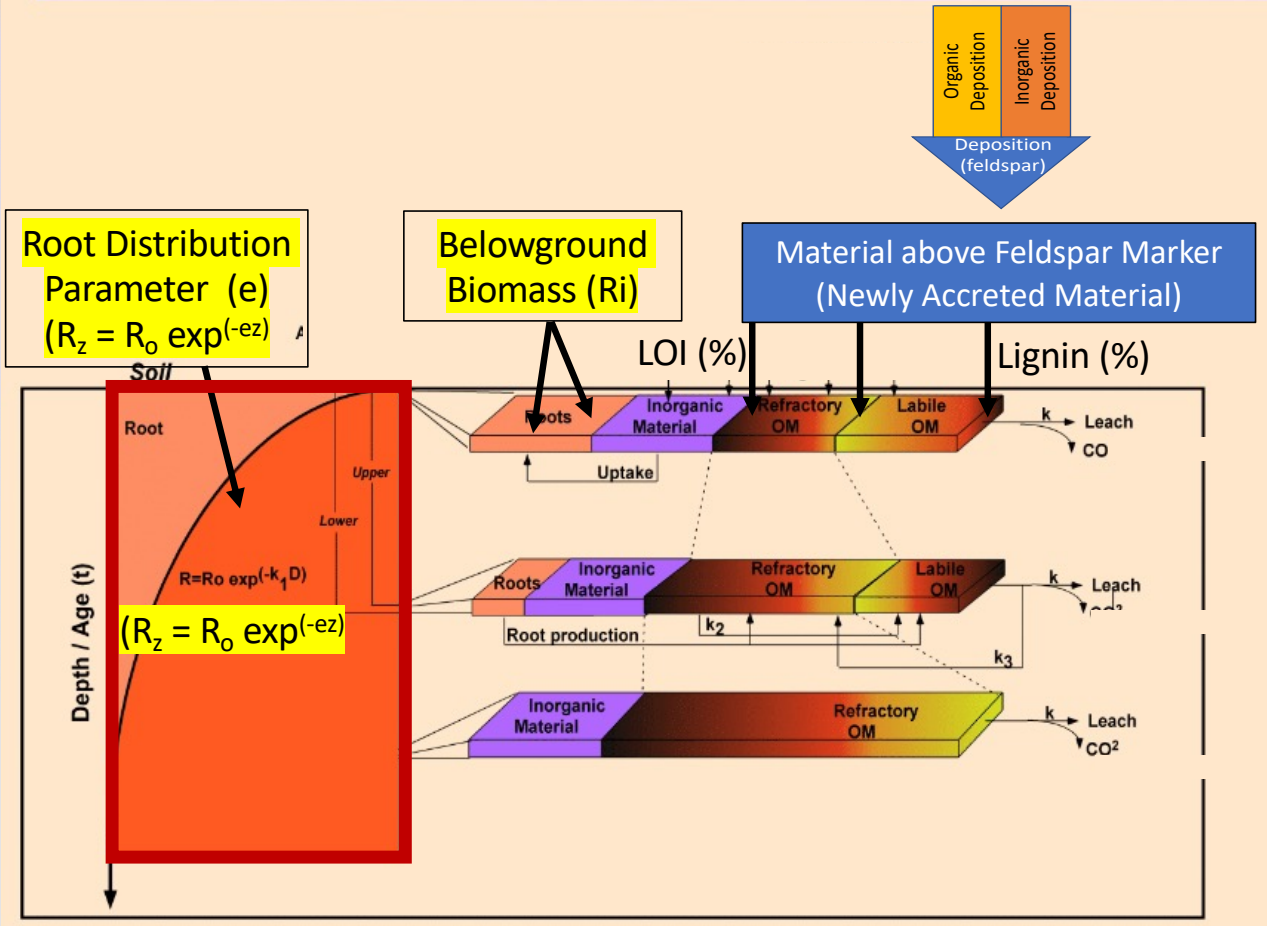

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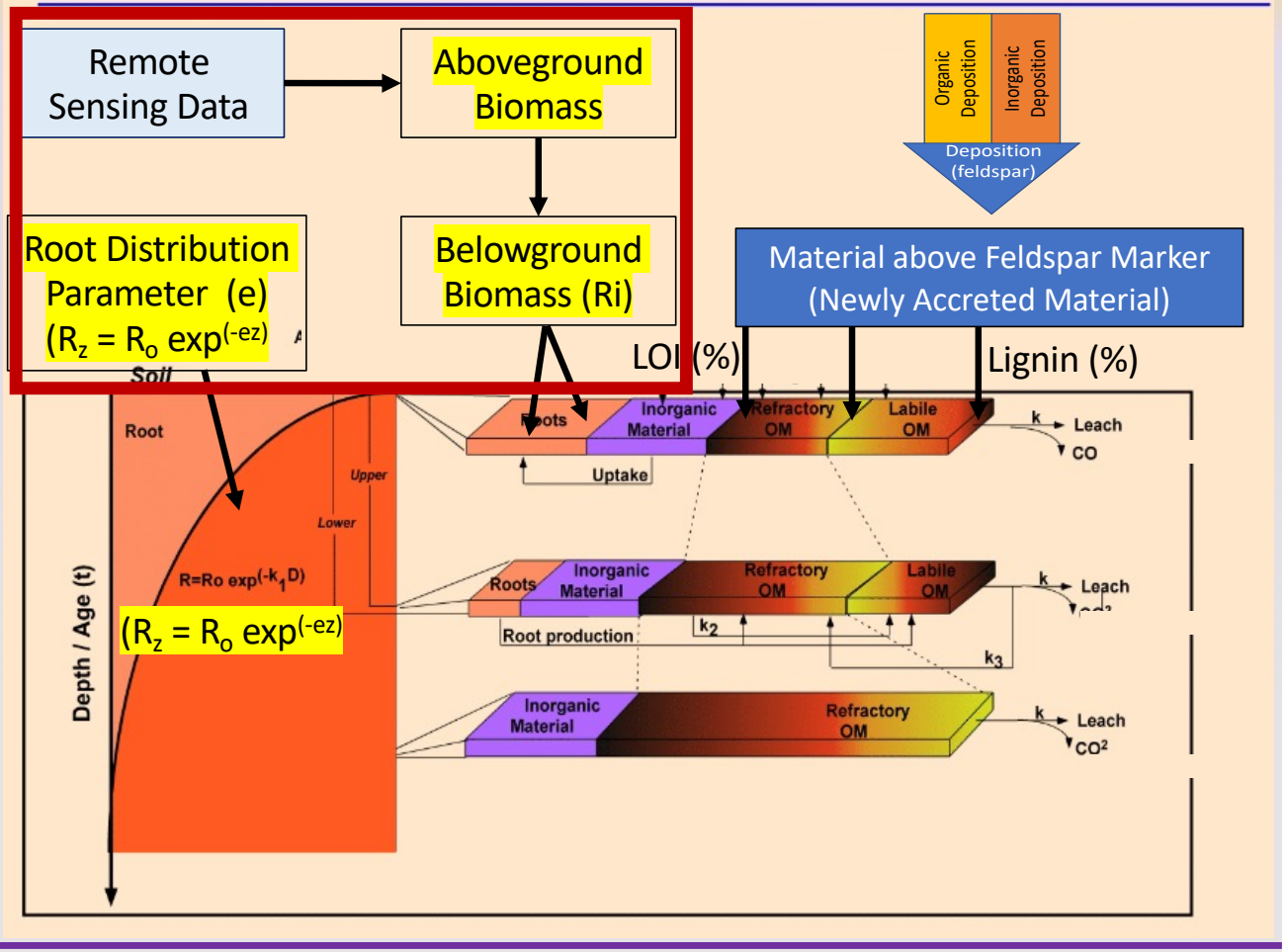
3. Belowground Production: root biomass & necromass; can be estimated from aboveground biomass; (remote sensing);
4. Belowground biomass distribution is function of ‘e’;

Numerical Understanding of Marsh Accretion & Resilience (NUMAR – soil formation & accretion, carbon sequestration)



Numerical Understanding of Marsh Accretion & Resilience (NUMAR – soil formation & accretion, carbon sequestration)

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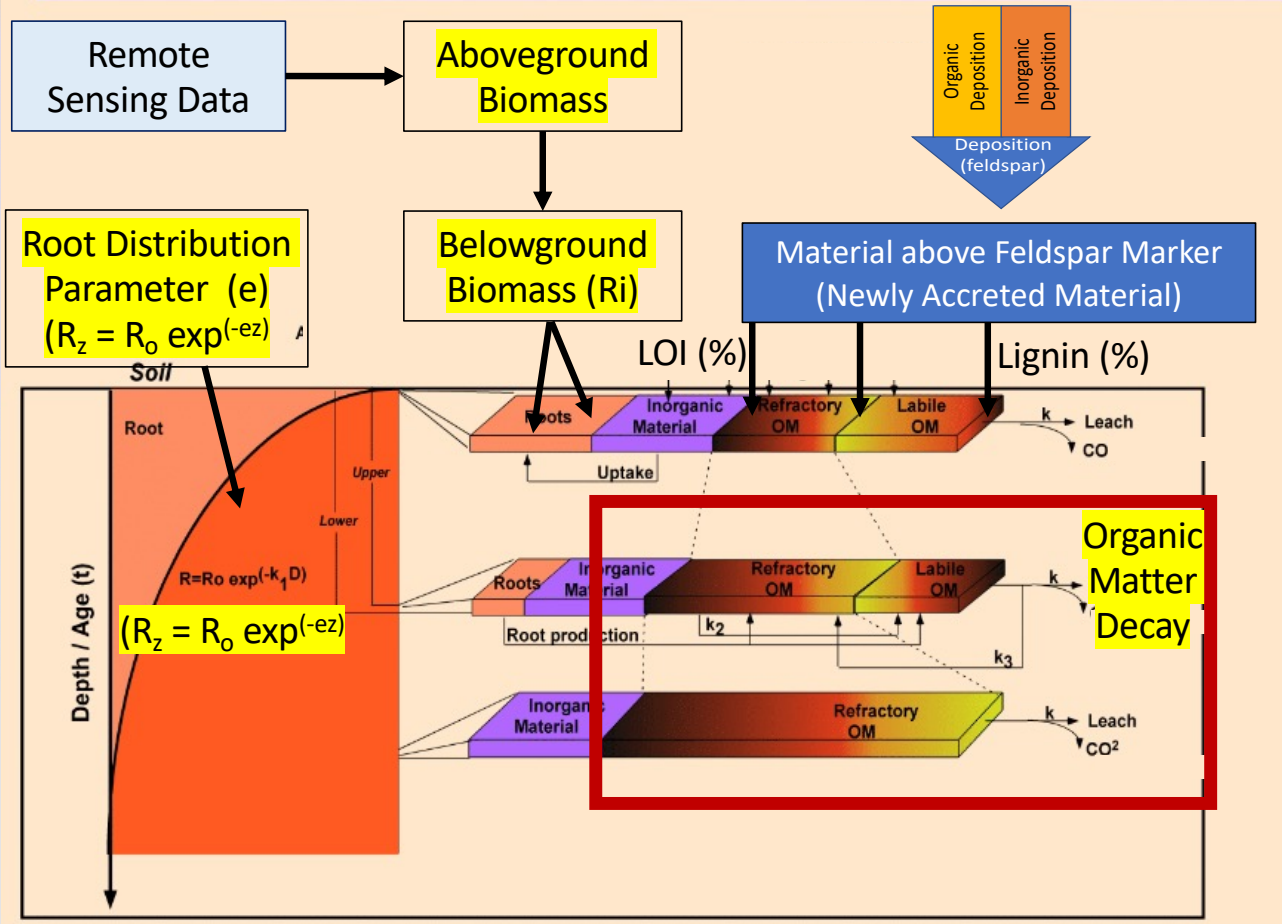
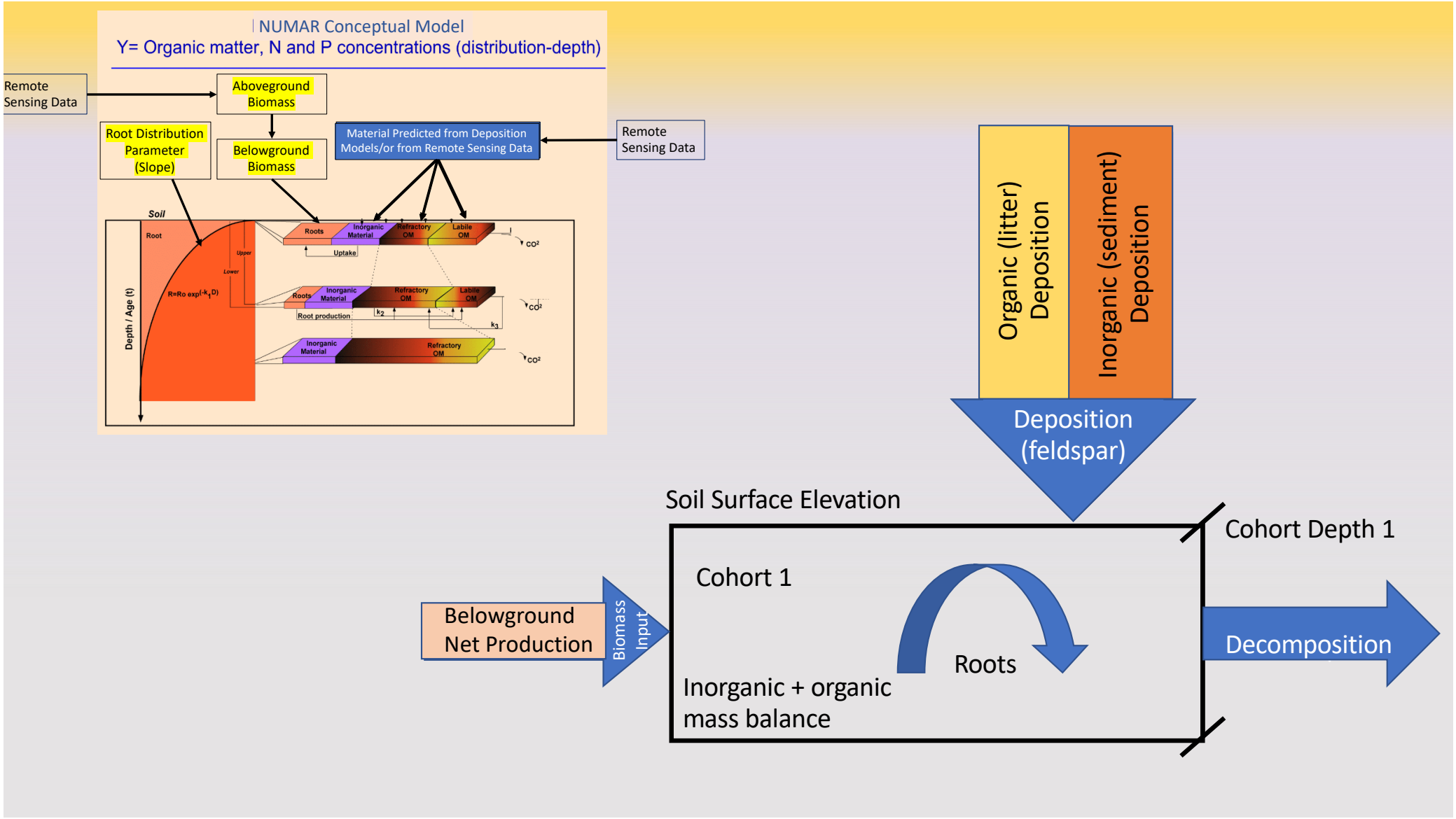
1. Soil Accretion (formation) = cohort of surface & belowground processes;
2. Surface Accretion: organic and inorganic deposition (feldspar);
3. Belowground Production: root biomass & necromass; can be estimated from aboveground biomass; (remote sensing);
4. Belowground biomass distribution is function of 'e';
5. Also need organic matter (OM) decay rate (labile vs refractory) – builds necromass;
6. Simulations are 60-100 yr time periods at 1 yr time steps




NUMAR Conceptual Model
Y= Organic matter, N and P concentrations (distribution-depth)
Remote Sensing Data
Aboveground Biomass
Root Distribution Parameter (Slope)
Belowground Biomass
Material Predicted from Deposition Models/or from Remote Sensing Data
Remote Sensing Data
Soil
Root
Upper
Lower
R=Ro exp(-k1D)
Depth / Age (t)
Roots
Inorganic Material
Refractory OM
Labile OM
Uptake
CO2
Root production
k2
k3
Organic (litter) Deposition
Inorganic (sediment) Deposition
Deposition (feldspar)
Soil Surface Elevation
Cohort 1
Cohort Depth 1
Belowground Net Production
Biomass Input
Roots
Inorganic + organic mass balance
Decomposition

Belowground Biomass & Necromass

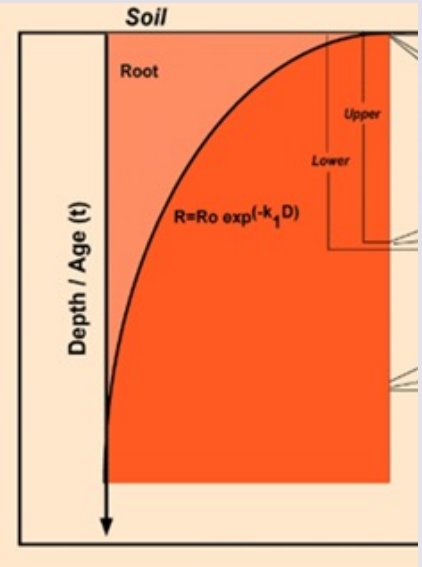
R(t) = root mass at time t

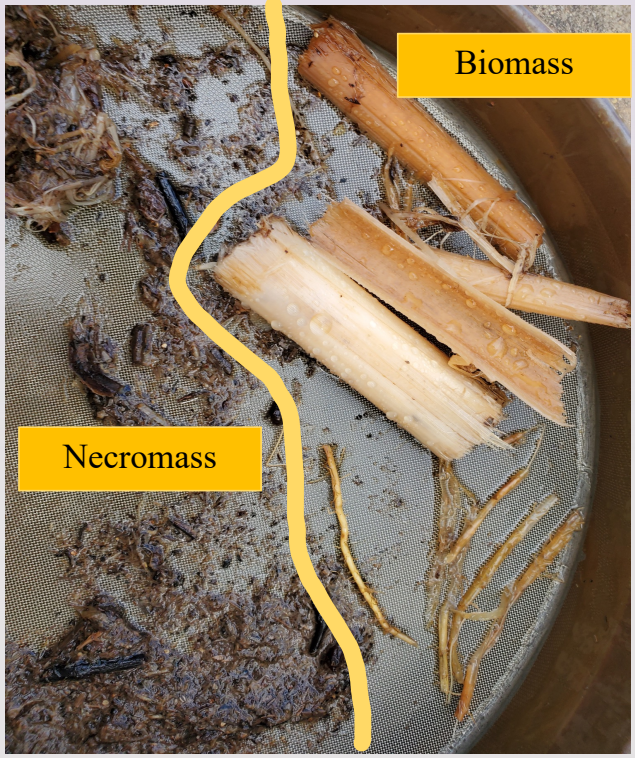
R_0 = root mass at surface (g cm^{-2})

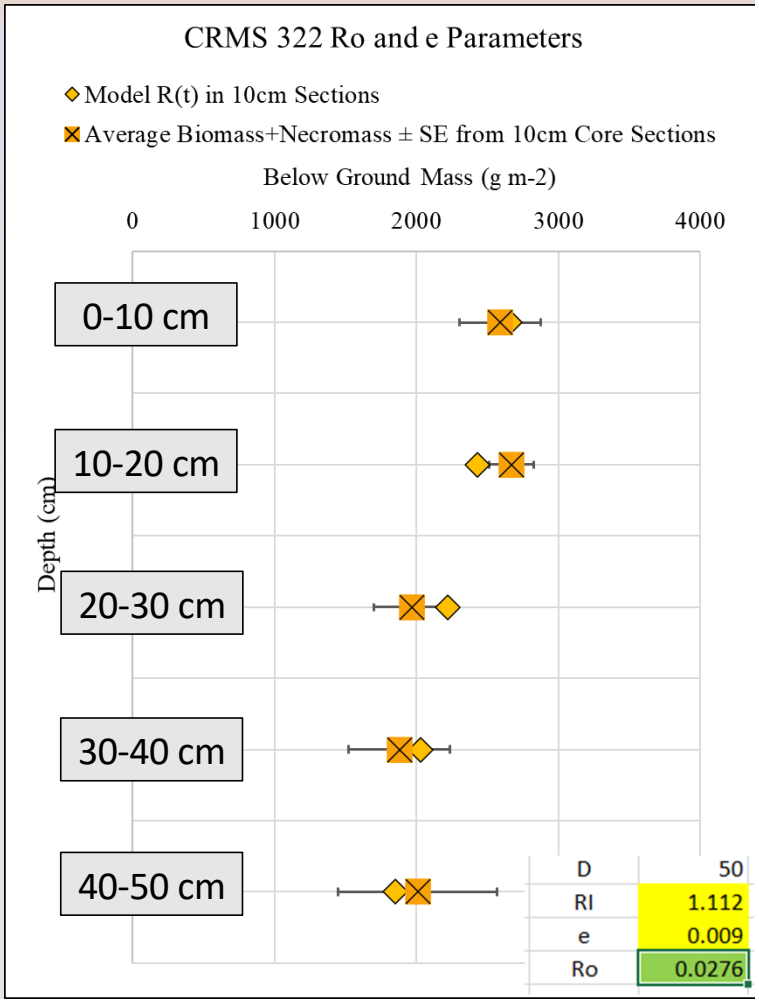
e = root attenuation (cm^{-1})

D = depth (cm)

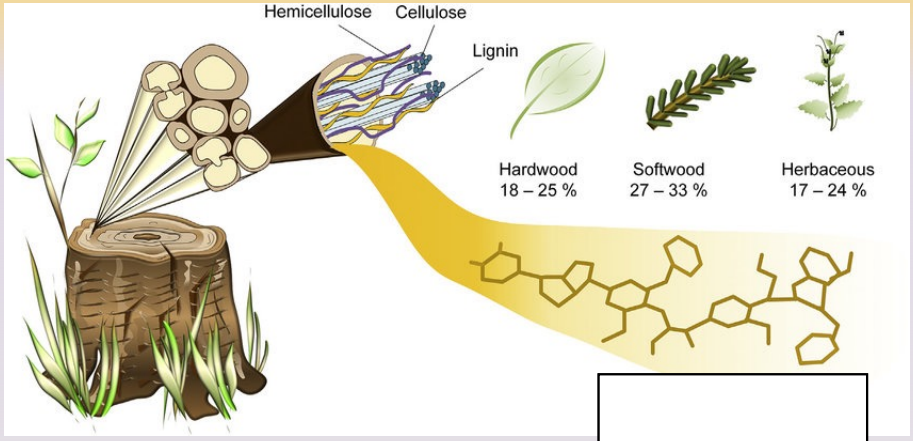
$$R(t) = R_0 * exp^{(-e*D)}$$



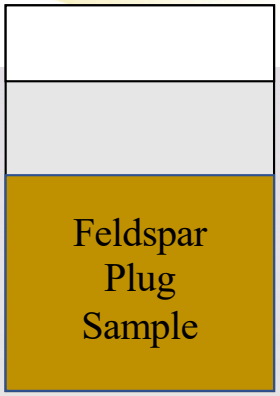


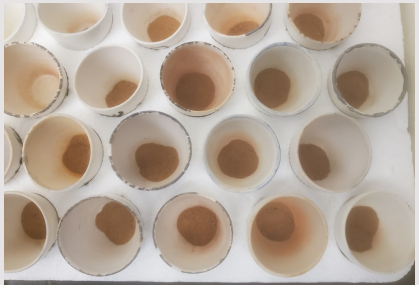


Feldspar Plugs – Newly Accreted Material



(Becker and Wittmann 2019)





1-Organic Matter Fraction
(1 - Loss on Ignition (LOI))

Inorganic Mineral Sediment

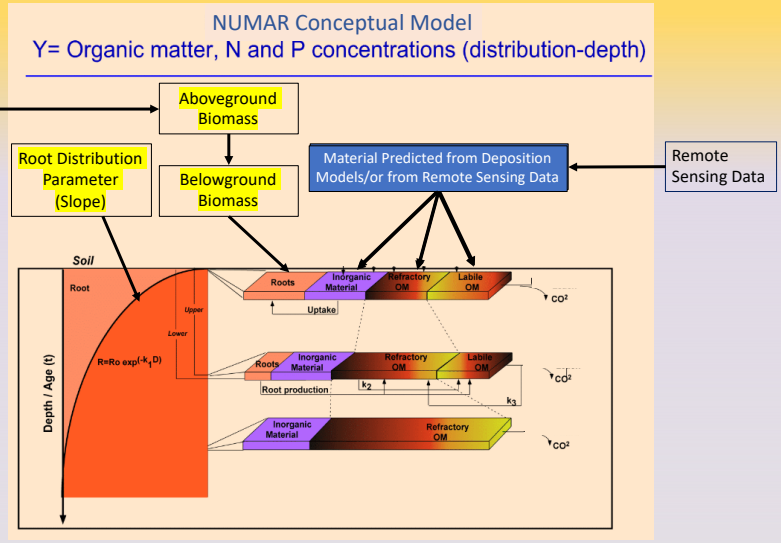
Si

LOI * Lignin Fraction
(LSU Forage Lab)

Refractory Organic Matter

LOI – (LOI * Lignin Fraction)
(LOI – Lignin)

Labile Organic Matter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Aboveground Biomass
Root Distribution Parameter (Slope)
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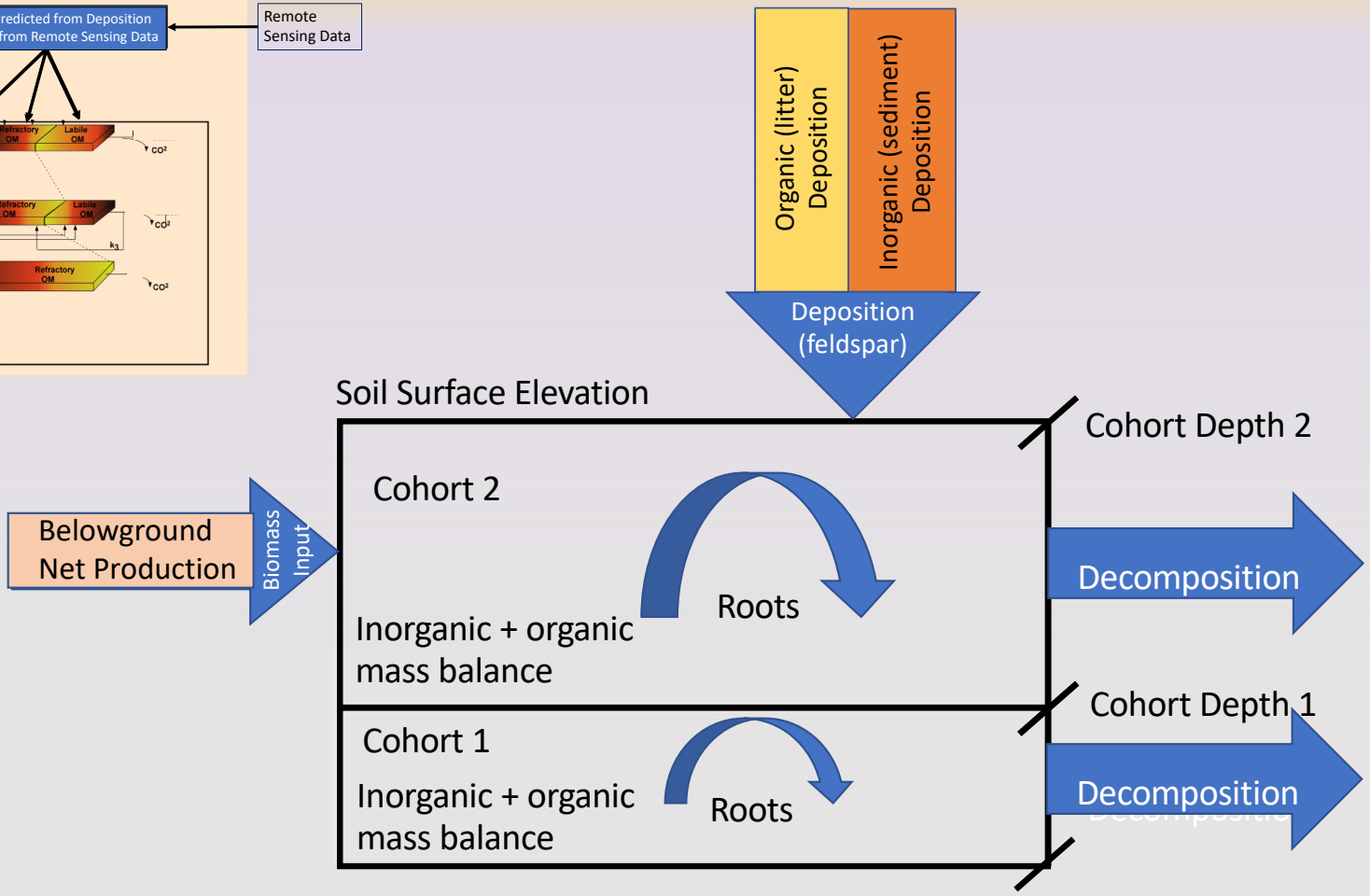
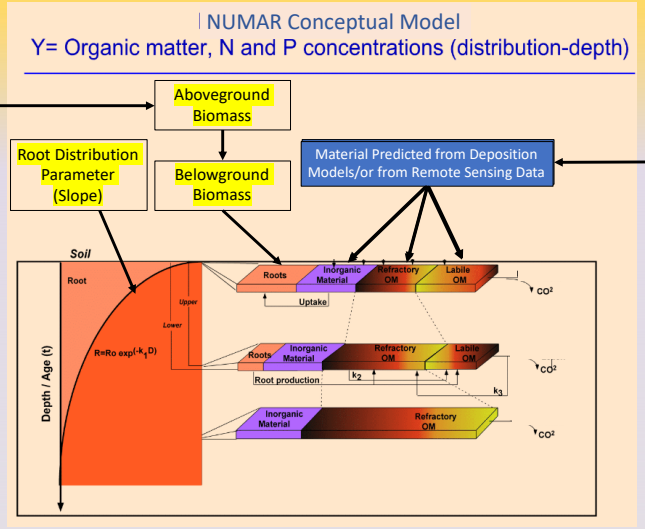
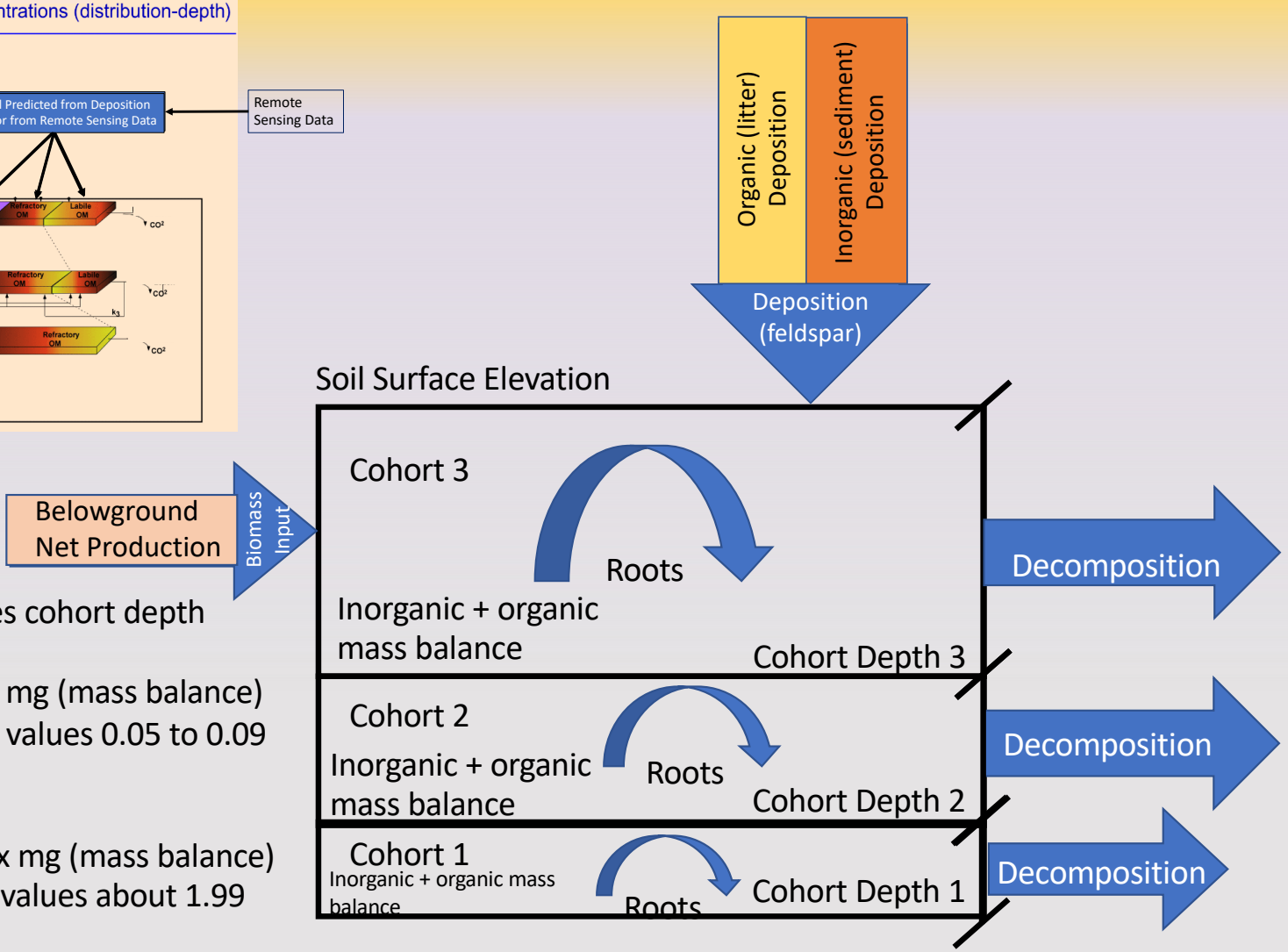
Material Predicted from Deposition Models/or from Remote Sensing Data
Remote Sensing Data
Soil
Root
Upper
Lower
Depth / Age (t)
Roots
Inorganic Material
Refractory OM
Labile OM
Uptake
Root production
CO2


Organic (litter) Deposition
Inorganic (sediment) Deposition
Deposition (feldspar)
Soil Surface Elevation
Cohort Depth 2
Cohort 2
Belowground Net Production
Biomass Input
Roots
Inorganic + organic mass balance
Decomposition
Cohort Depth 1
Cohort 1
Inorganic + organic mass balance
Roots
Decomposition





Self-packing density determines cohort depth

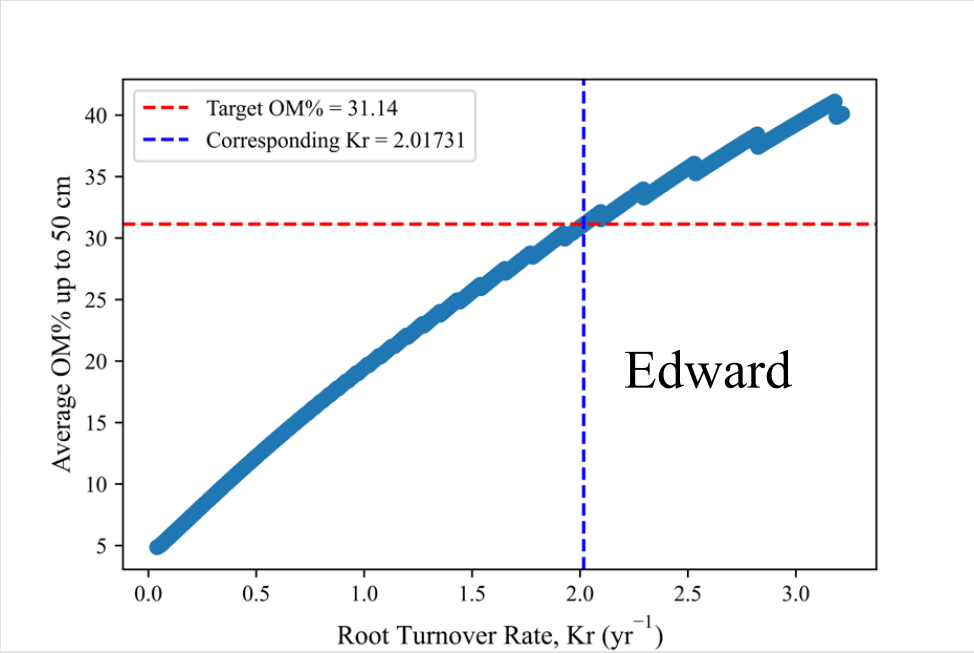
Organic matter (bo): mg/cm^3 x mg (mass balance) = cm3 at cm^2 area = cm depth; values 0.05 to 0.09 mg/cm^3

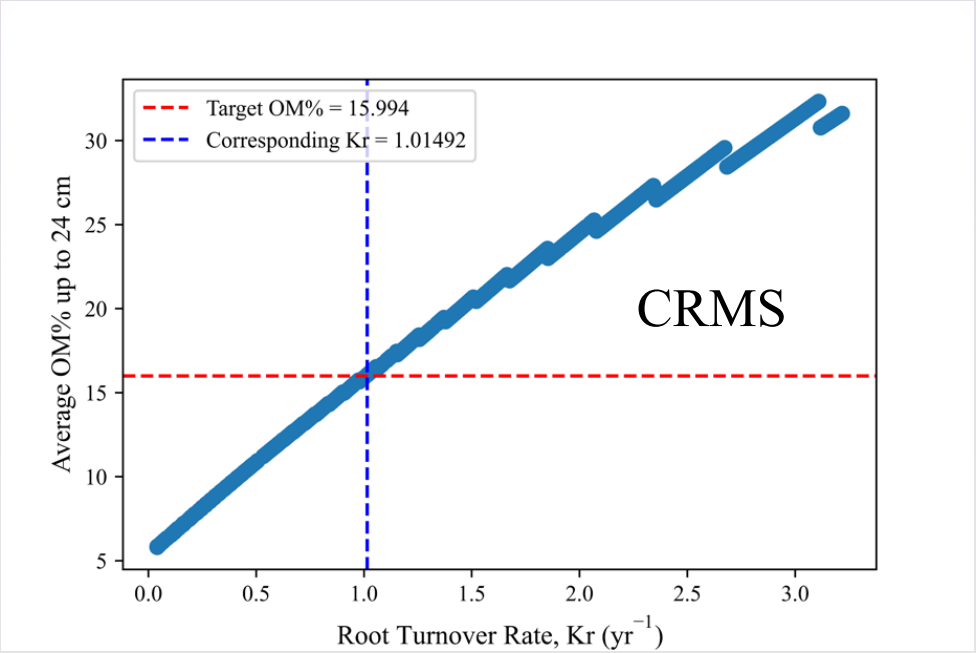
Inorganic matter (bi): mg/cm^3 x mg (mass balance) = cm^3 at cm^2 area = cm depth; values about 1.99 mg/cm^3

Difference in Self Packing Density of OM ($b_o, g.cm^{-3}$)

	Best-fit bo		Best-fit bi	
	CRMS	Delta-X	CRMS	Delta-X
Active Basin				
0479 (Fresh)	0.066	0.087	1.992	2.002
0399 (Brackish)	0.056	0.055	1.999	1.997
0322 (Saline)	0.058	0.085	1.999	2.000
Inactive Basin				
0294 (Fresh)	0.054	0.036	2.000	2.000
0396 (Brackish)	0.053	0.050	1.998	2.000
0421 (Saline)	0.076	0.055	2.000	1.998

Terrebonne Saline Intertidal (CRMS 0421)





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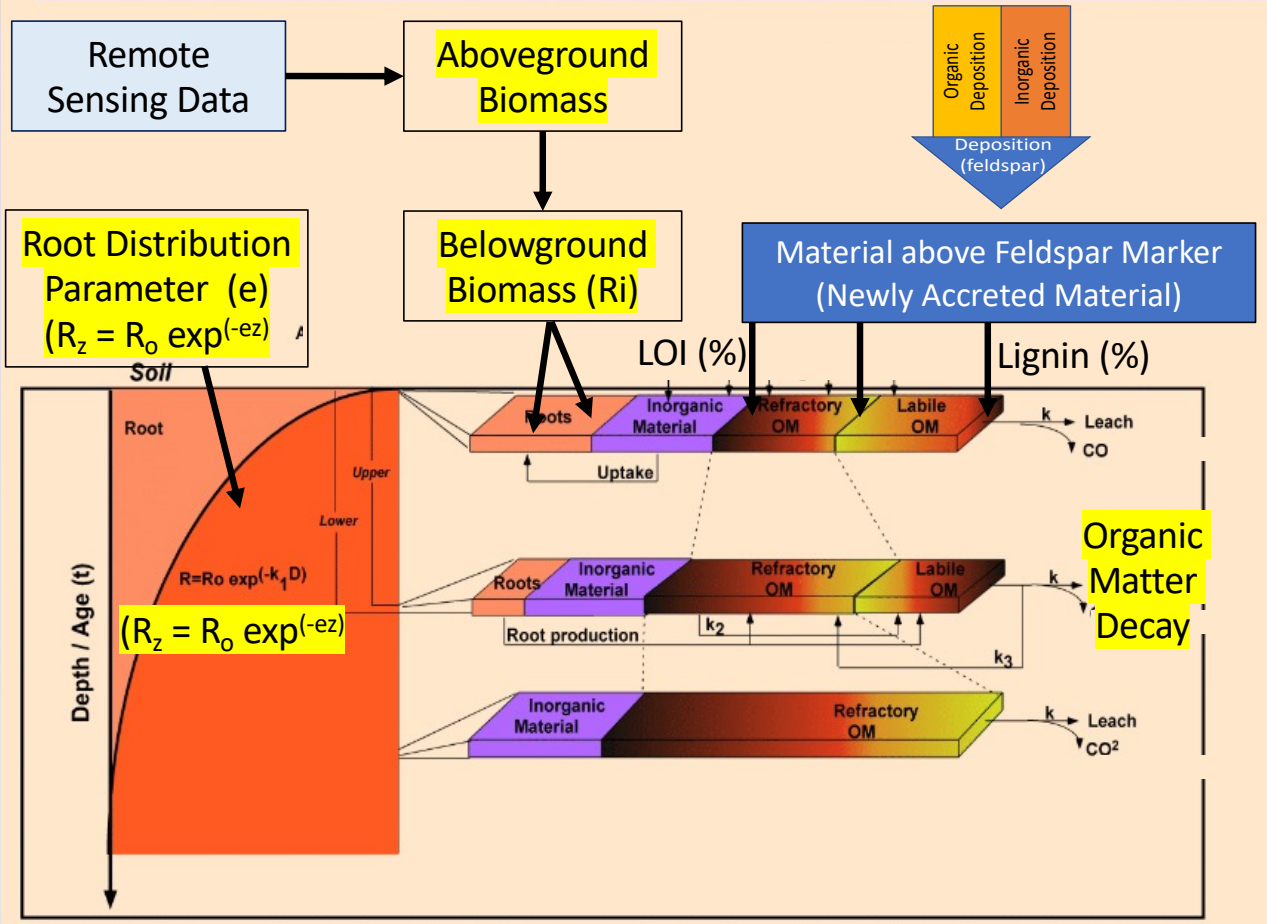
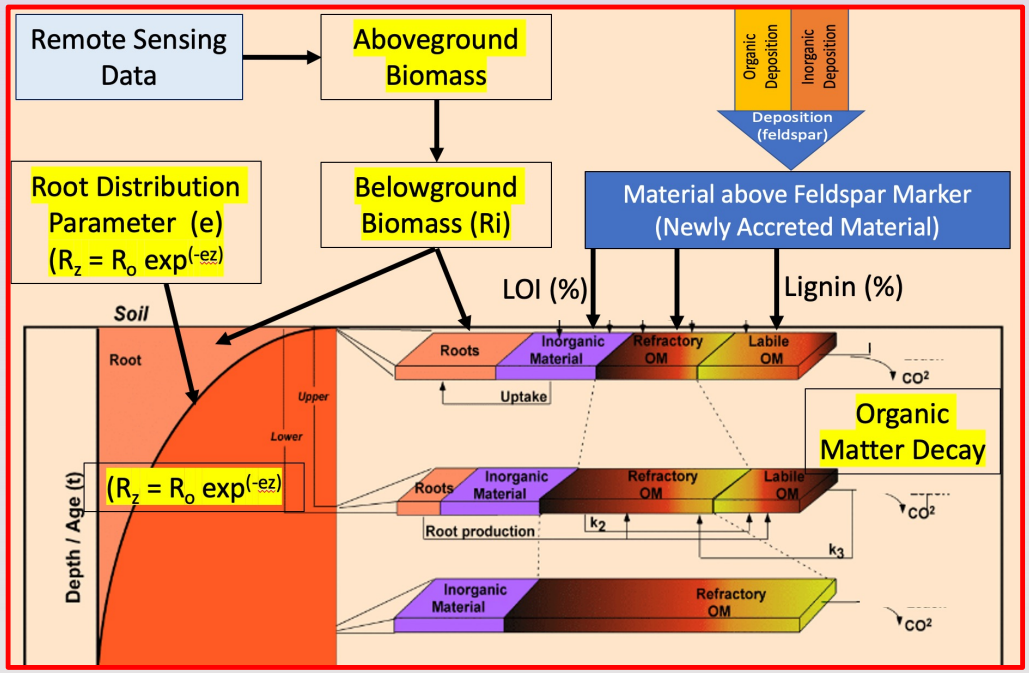
6. Also need organic matter (OM) decay rate (labile vs refractory);

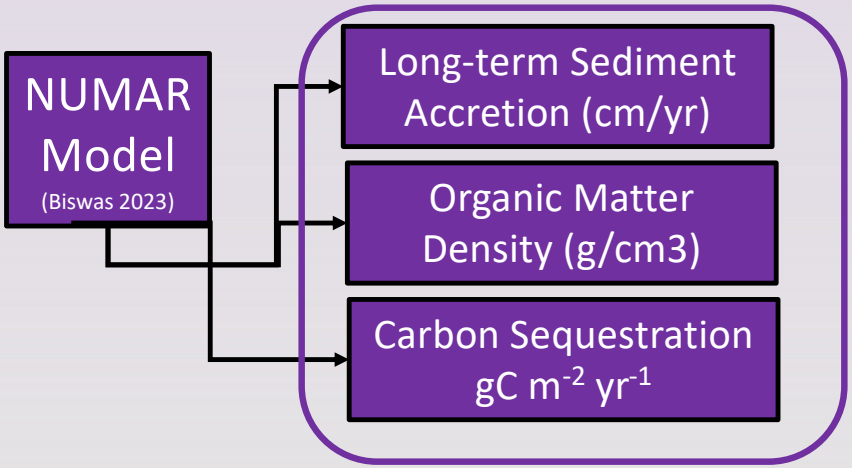
NUMAR Conceptual Model
(calculate bulk density, OM concentration, accretion)



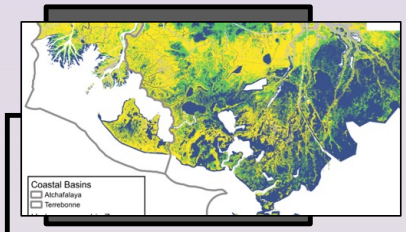
Updates on performance of NUMAR

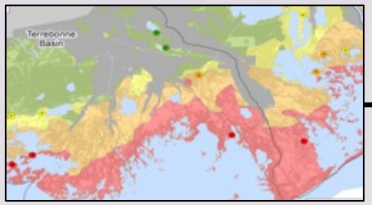


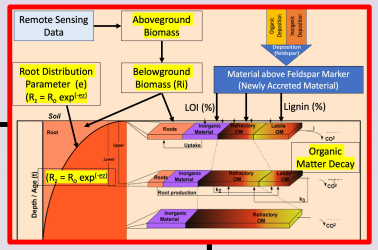
NUMAR OUTPUTS:

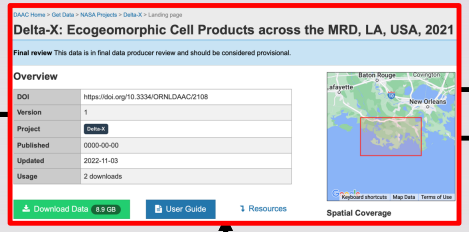


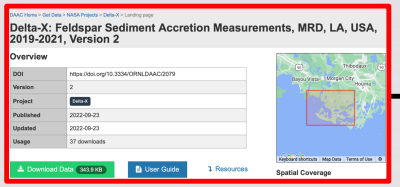
Workflow to scale NUMAR across LA coastalscape

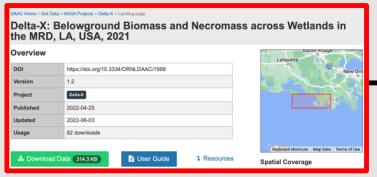


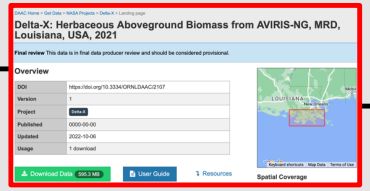








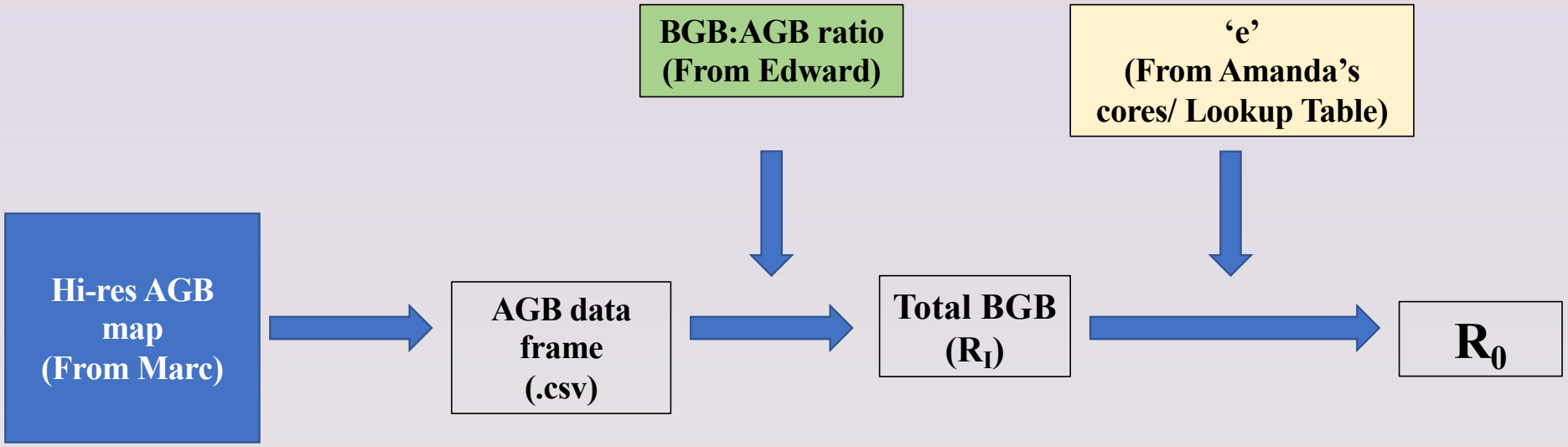




BGB map
(Castañeda & Solohin 2022; Jensen et al. 2022)

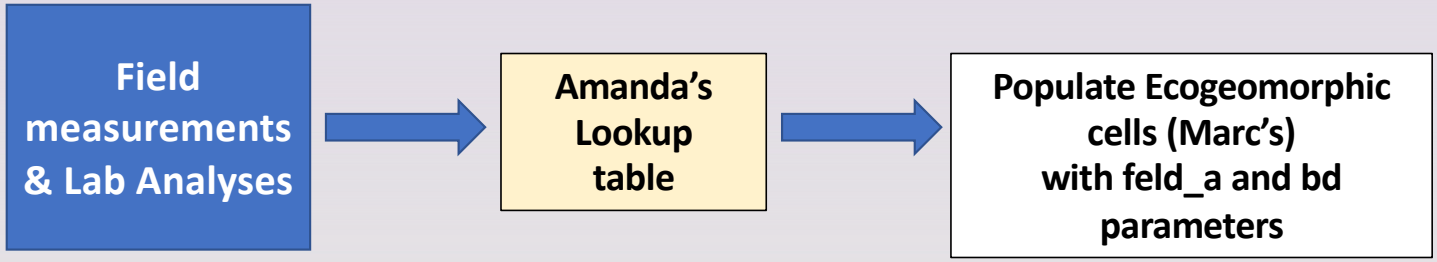
NUMAR OUTPUTS:

- Long-term Sediment Accretion (cm/yr)
- Organic Matter Content (g/g)
- Bulk Density (g/cm^3)



$$R_0 = R_I \left[\frac{-e}{exp^{(-eD)} - 1} \right]$$

Using Feldspar Accretion Rates



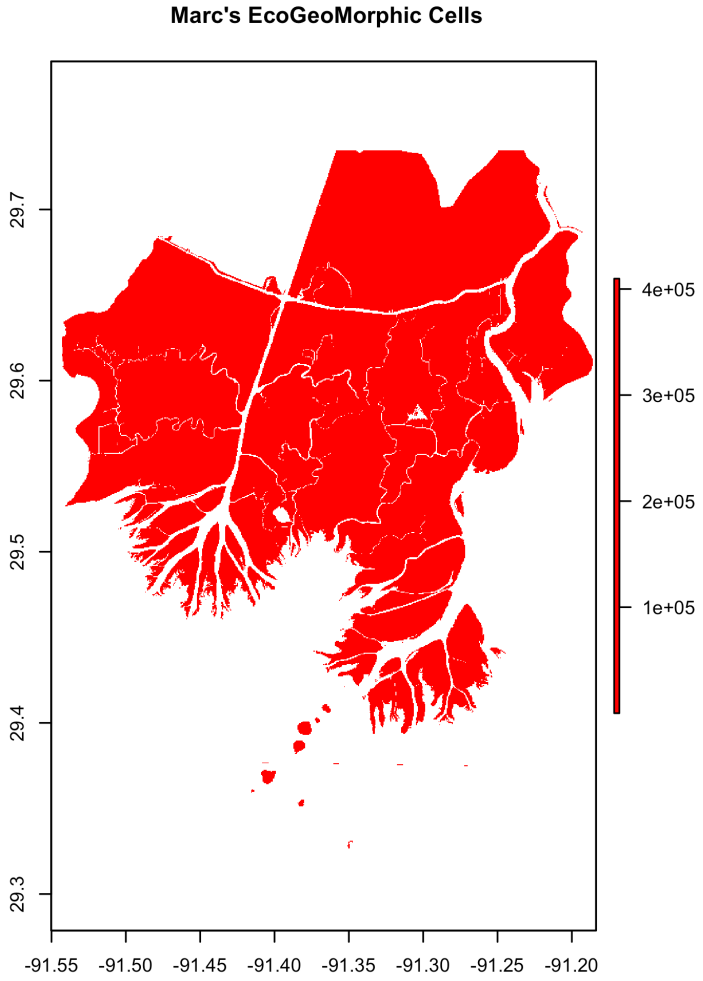
- Feldspar surface accretion rates (feld_a)
- Bulk density of feldspar plug samples (bd)
- Inorganic fraction of sediment (c1)
- Lignin fraction of sediment (c0)

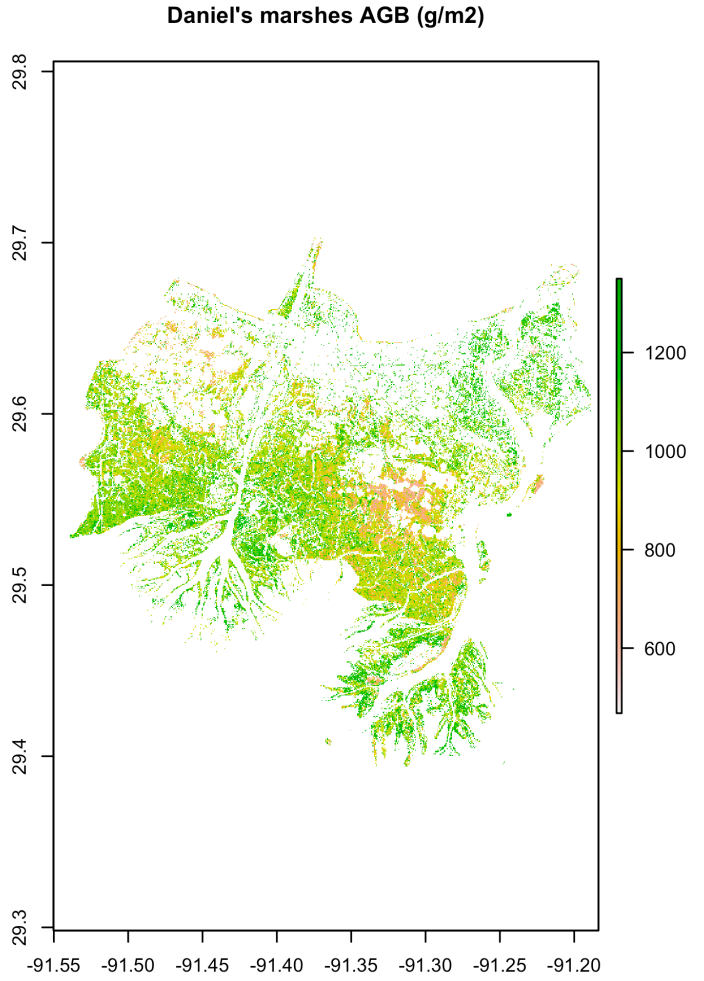
Within NUMAR python code:

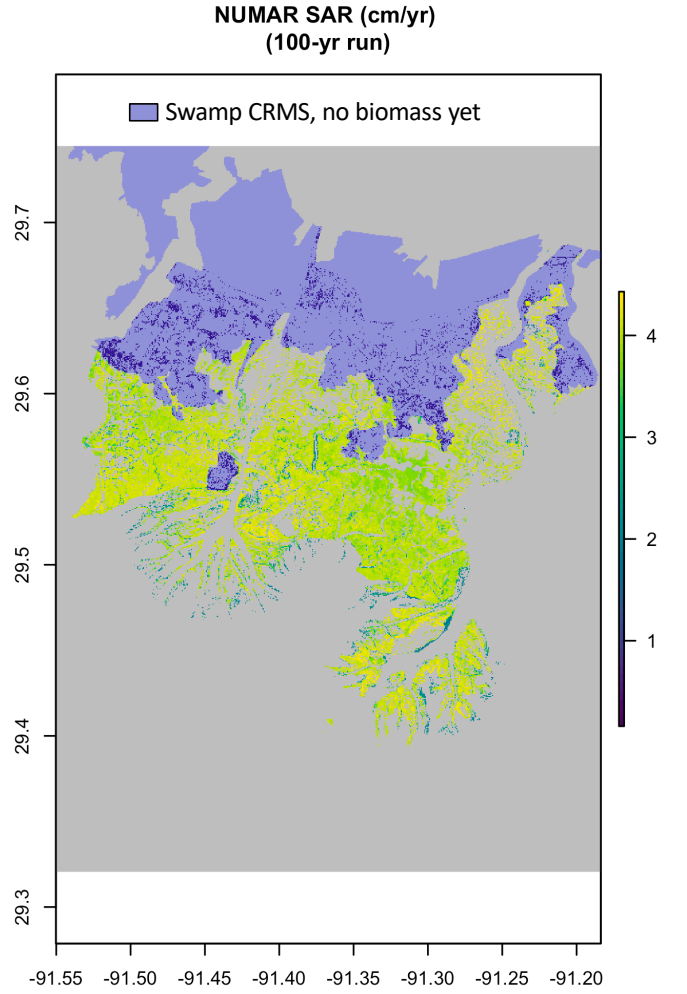
$$Si = feld\_a * bd * c_1$$

$$ROM(0) = feld\_a * bd * c_0$$

$$LOM(0) = feld\_a * bd * ((1 - c_1) - c_0)$$


Marc's EcoGeoMorphic Cells
29.7
29.6
29.5
29.4
29.3
-91.55 -91.50 -91.45 -91.40 -91.35 -91.30 -91.25 -91.20
4e+05
3e+05
2e+05
1e+05


Daniel's marshes AGB (g/m2)
29.8
29.7
29.6
29.5
29.4
29.3
-91.55 -91.50 -91.45 -91.40 -91.35 -91.30 -91.25 -91.20
1200
1000
800
600


NUMAR SAR (cm/yr)
(100-yr run)
Swamp CRMS, no biomass yet
29.7
29.6
29.5
29.4
29.3
-91.55 -91.50 -91.45 -91.40 -91.35 -91.30 -91.25 -91.20
4
3
2
1

Feldspar Landscape Run – CSV Inputs for NUMAR

ECOGEO-MORPHIC CELL

Accretion (cm/yr)
Bulk density (g/cm3)
Lignin Fraction
Inorganic Fraction
Root Biomass at surface
Depth dist. roots
Root turnover rate
LOM Decomp. Rates (T=1)
LOM Decomp. Rates (T>1)
ROM Decomp. Rates
Lignin biomass
Inorganic biomass
% microbial reps. decomp
Cellulose Concentration
BD organic (to generate elevation)
BD inorganic (to generate elevation)
Simulation time

SiteName	lon	lat	feld_a	bd	c0	c1	r0	e	kr	ka	kb	kc	fc0	fc1	f2	fc2	bo	bi	ts
1232																			
1233																			
1234																			
1235																			
1236																			
1237																			
1238																			
1239																			
1240																			
1241																			
1242																			
1243																			
1244																			
1245																			

Andy

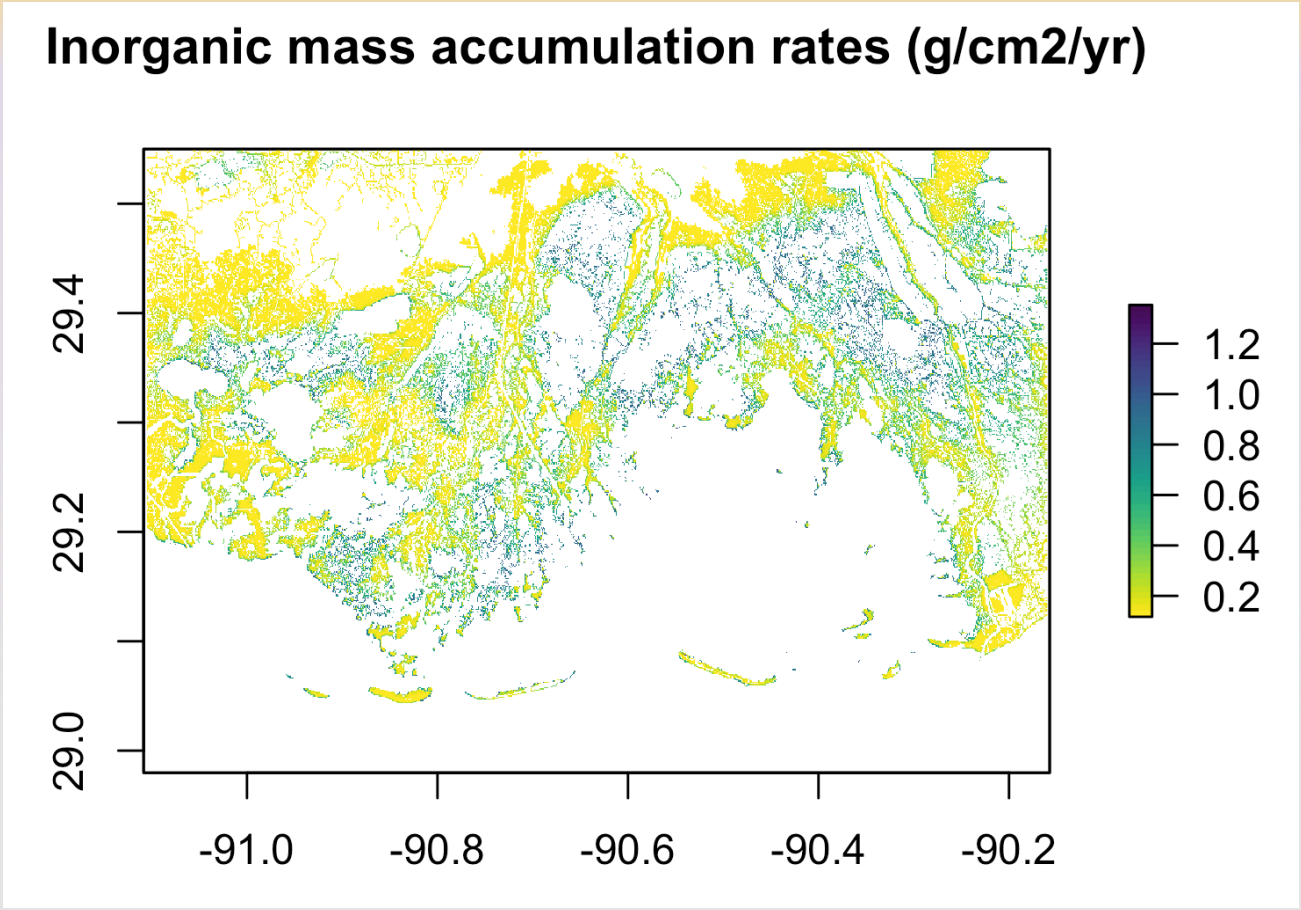
Edward R:S ratio

Andy

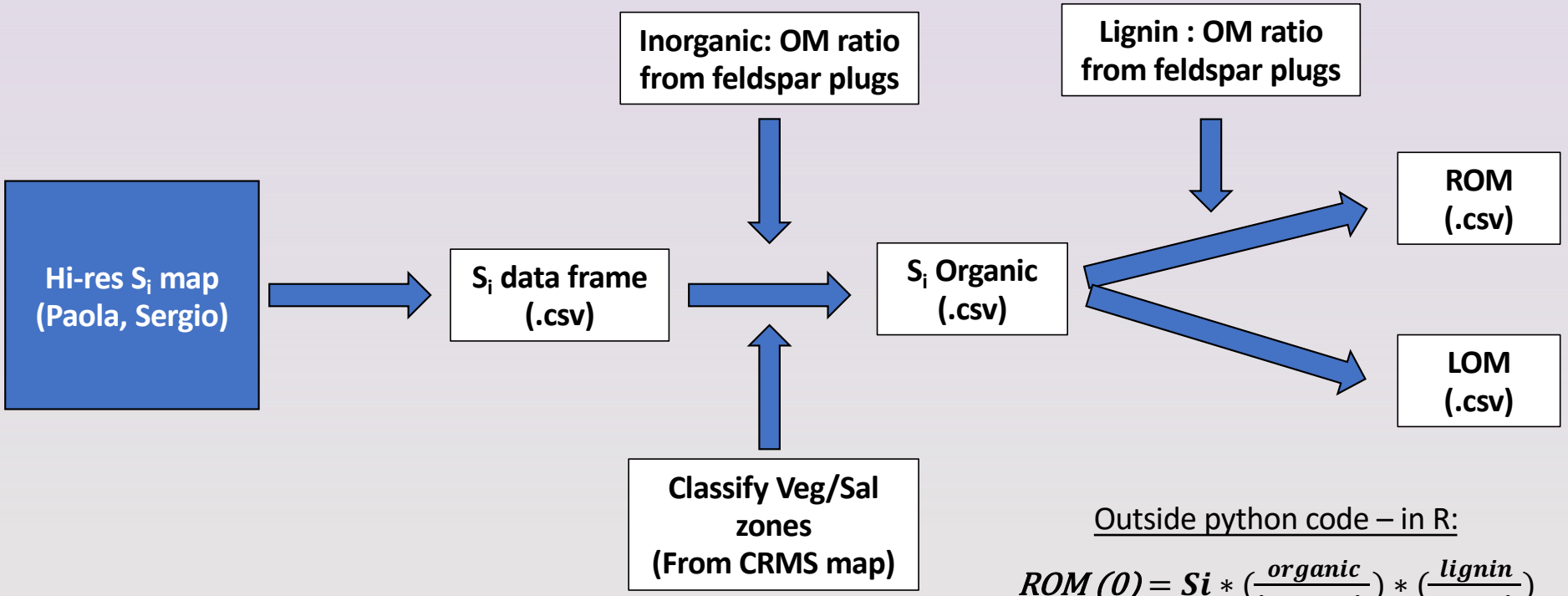
New NUMAR Calculations

Original NUMAN parameters

New NUMAR Calculations


Inorganic mass accumulation rates (g/cm2/yr)
29.4
29.2
29.0
-91.0
-90.8
-90.6
-90.4
-90.2
1.2
1.0
0.8
0.6
0.4
0.2

Using Si Map



Outside python code – in R:

$$ROM\,(0) = Si * \left(\frac{organic}{inorganic}\right) * \left(\frac{lignin}{organic}\right)$$

$$LOM\,(0) = Si * \left(\frac{organic}{inorganic}\right) * \left(1 - \frac{lignin}{organic}\right)$$

Si Landscape Run – CSV Inputs for NUMAR

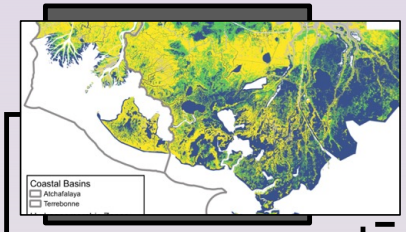
SiteName	lon	lat	si	LOM	ROM	c0	c1	r0	e	kr	ka	kb	kc	fc0	fc1	f2	f3	bo	bi	ts
1232																				
1233																				
1234																				
1235																				
1236																				
1237																				
1238																				
1239																				
1240																				
1241																				
1242																				
1243																				
1244																				
1245																				

Sergio

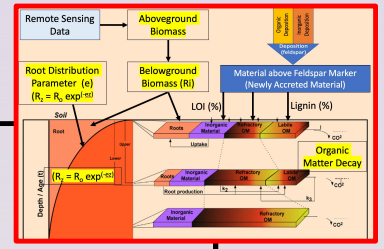
Amanda

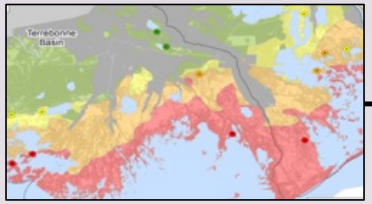
Edward/Marc Ro Equation

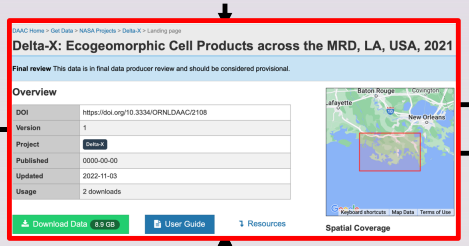
Workflow to scale NUMAR across LA coastalscape

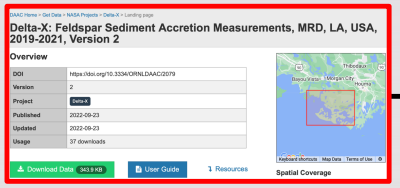


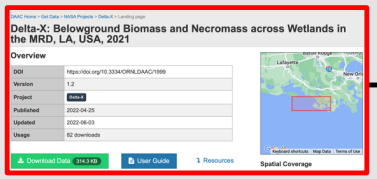
Inorganic Sediment Loading Map (Luca & Fagherazzi)

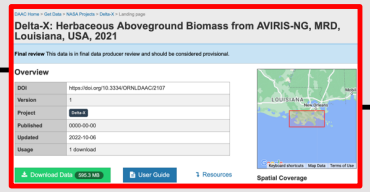












BGB map (Castañeda & Solohin 2022; Jensen et al. 2022)

NUMAR OUTP

Long-term Sediment Accretion (cm/yr)

Organic Matter Content (g/g)

Bulk Density (g/cm^3)

2024 Delta-X NUMAR Modeling

THANK YOU!

Robert R. Twilley, Principal Investigator

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