Delta-X Workshop -9th May 2024

Numerical Understanding of Marsh Accretion & Resilience – NUMAR

Robert R. Twilley[1], Principal Investigator
Andre Rovai [1,2]
Andy Cassaway [4]
Alexandra Christensen [3]
Ivan A. Vargas-Lopez[1] , Postdoctoral Researcher
Pradipta Biswas[1], Graduate Assistant

[1] Louisiana State University
[2] U.S. Army Engineer Research and Development Center
[3] Jet Propulsion Laboratory, California Institute of Technology
[4] GIS Engineering, LLC

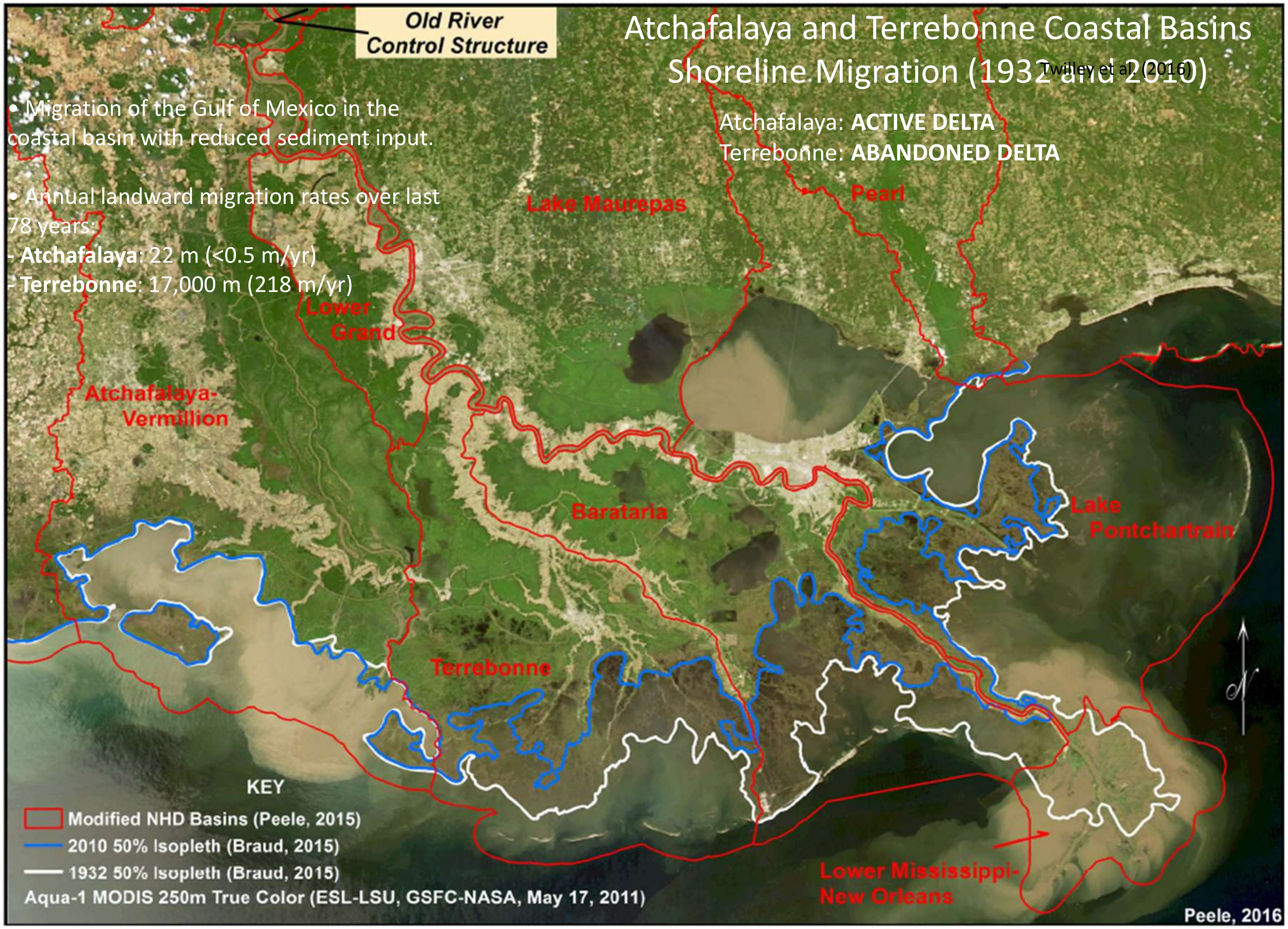
LSU | College of Coast & Environment

Atchafalaya and Terrebonne Coastal Basins Shoreline Migration (1932 and 2010)

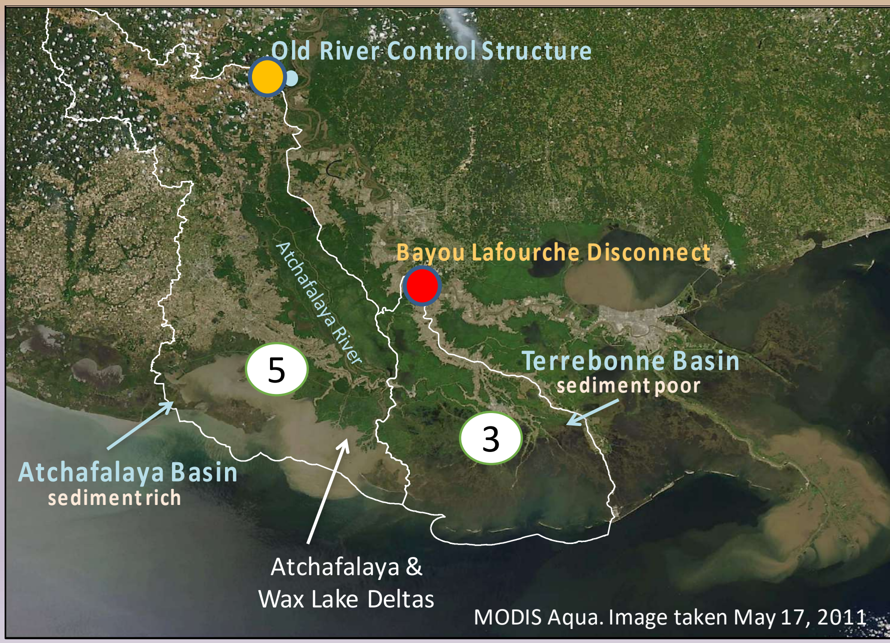
Twilley et al. (2016)

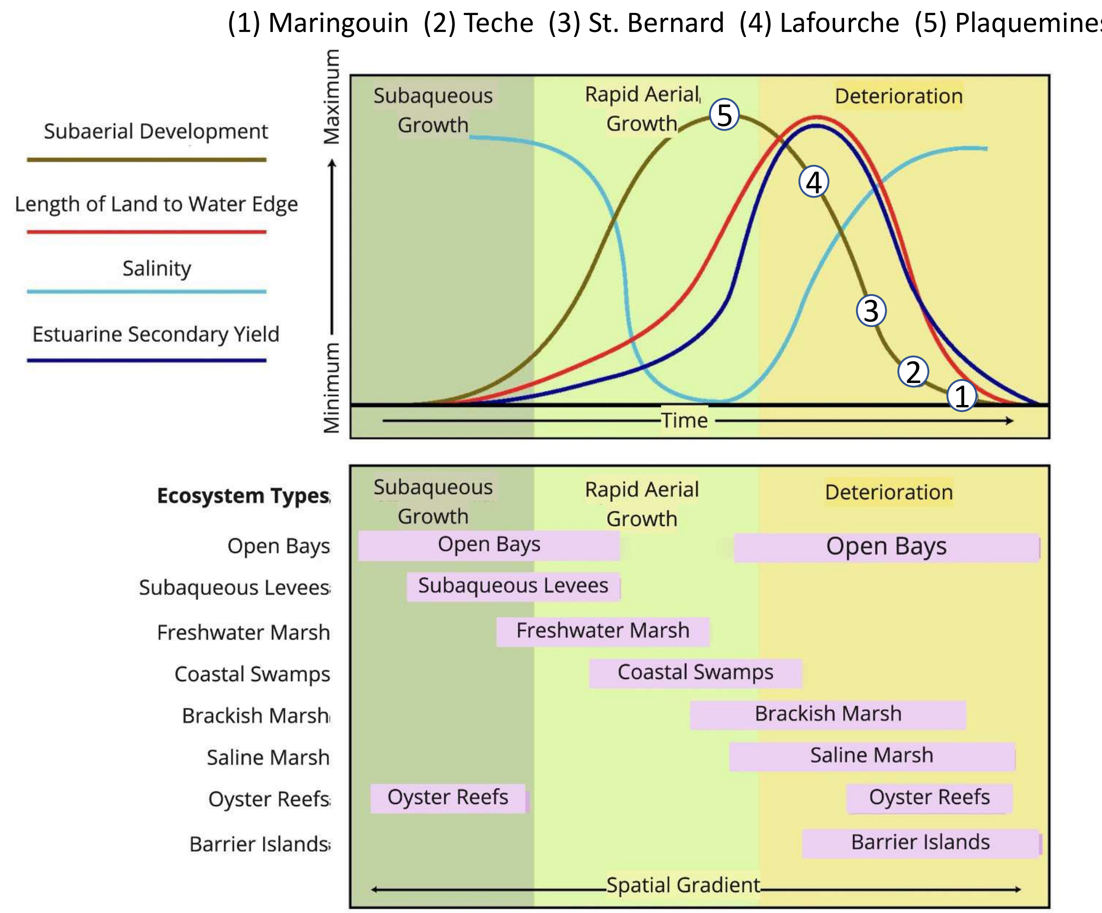
Atchafalaya: **ACTIVE DELTA**
Terrebonne: **ABANDONED DELTA**

- 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)

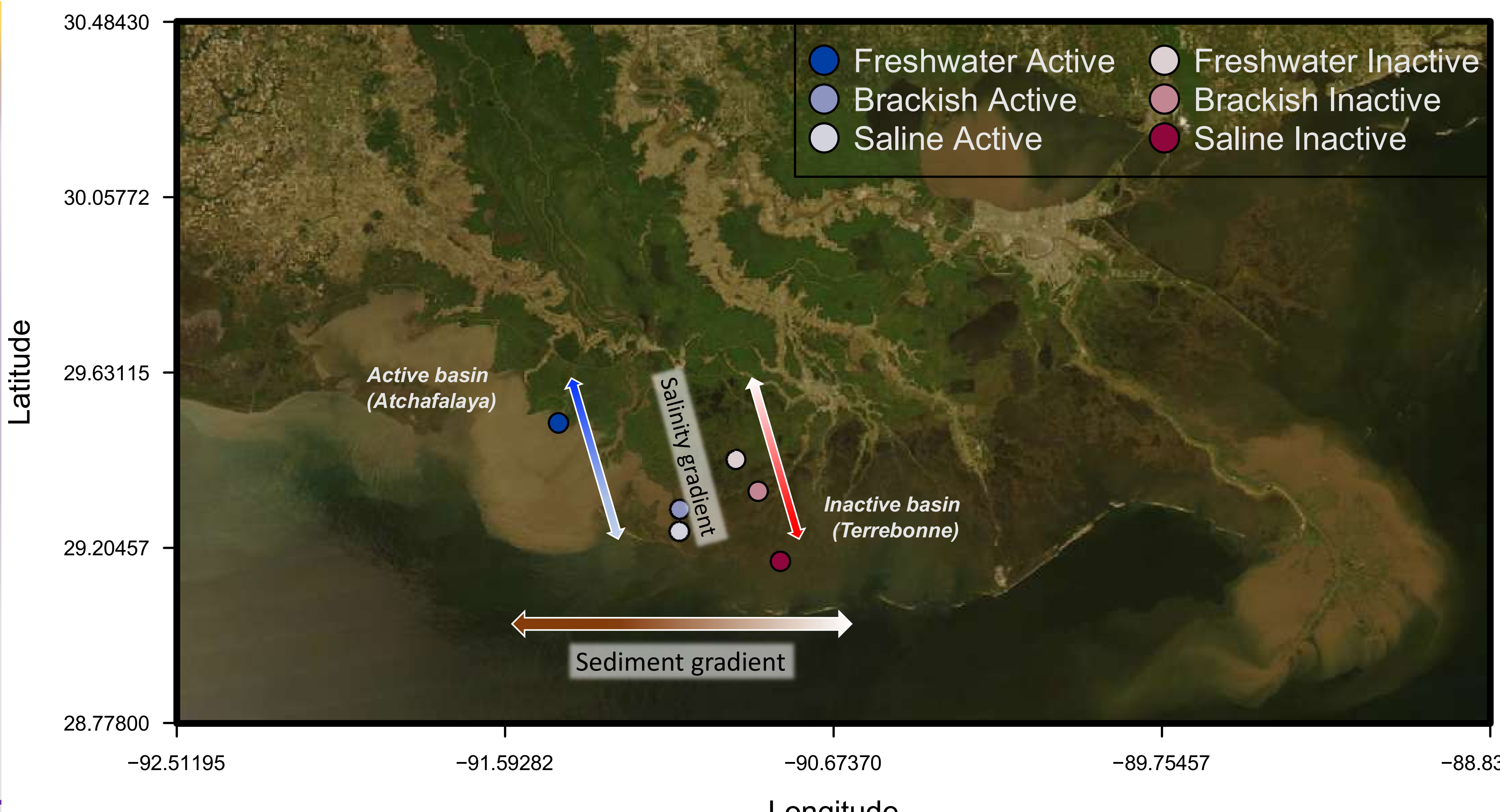


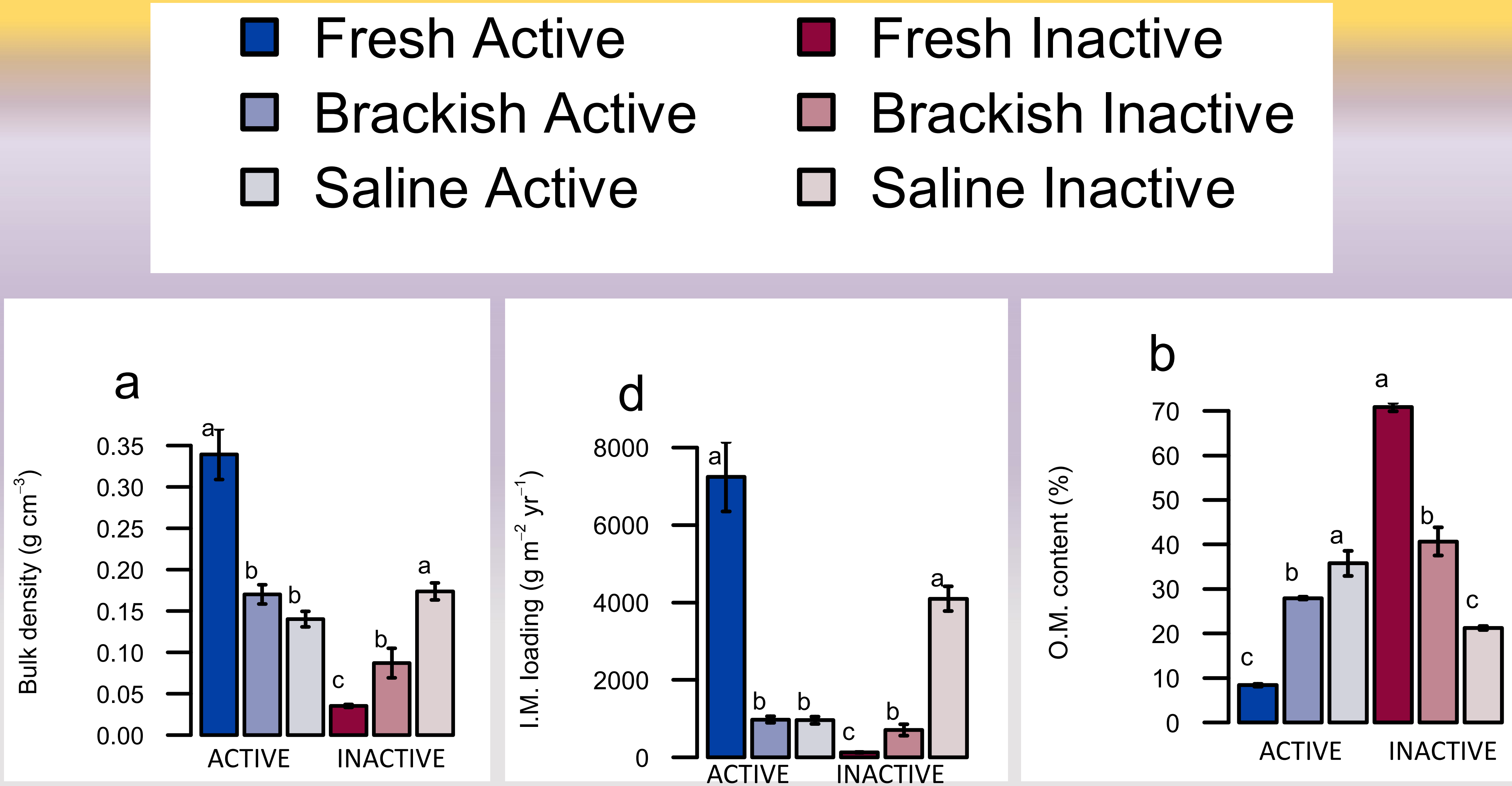
Experimental Questions: Processes of Delta Cycle





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.

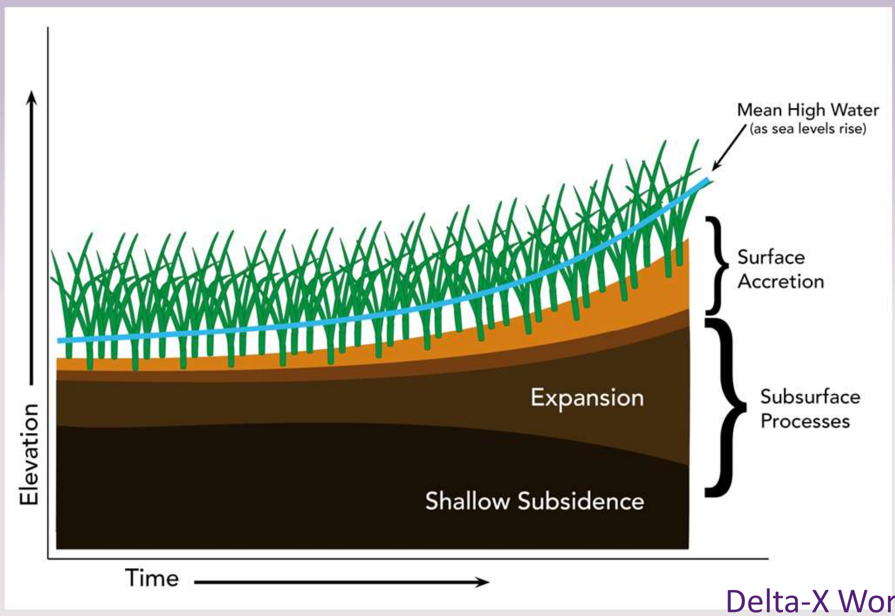

30.48430
30.05772
29.63115
29.20457
28.77800
Latitude
−92.51195
−91.59282
−90.67370
−89.75457
−88.83
Longitude
Freshwater Active
Brackish Active
Saline Active
Freshwater Inactive
Brackish Inactive
Saline Inactive
Active basin
(Atchafalaya)
Salinity gradient
Inactive basin
(Terrebonne)
Sediment gradient

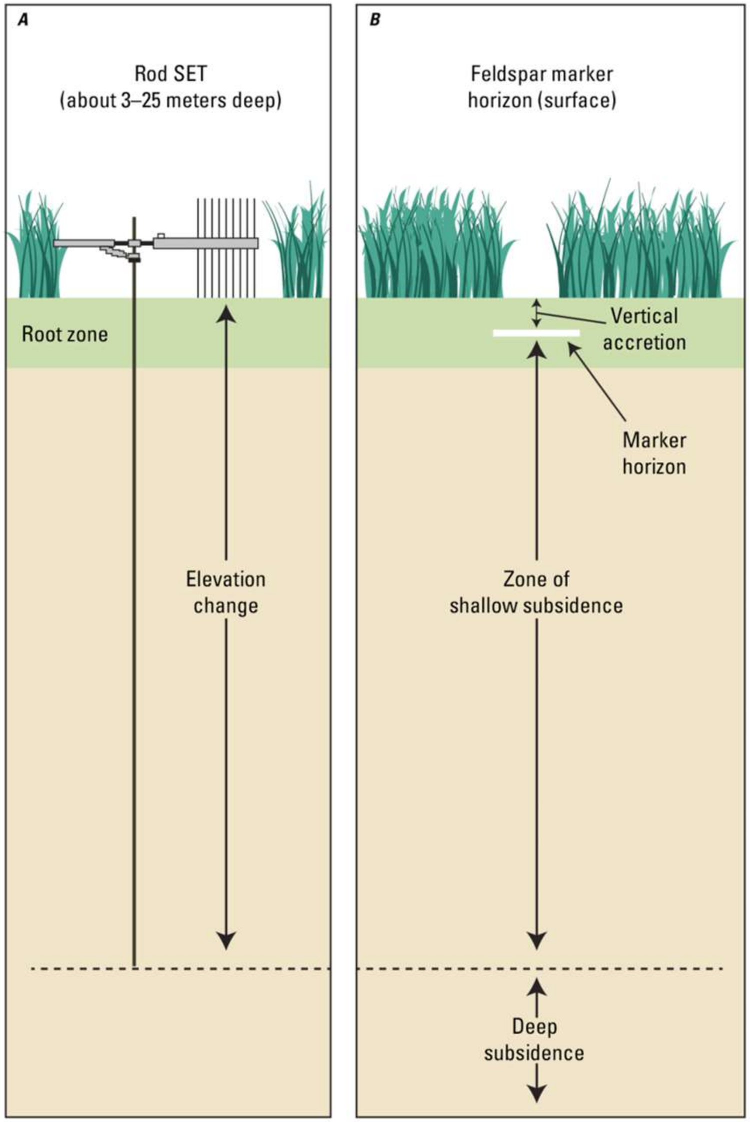


Fresh Active
Brackish Active
Saline Active
Fresh Inactive
Brackish Inactive
Saline Inactive
a
Bulk density (g cm^{-3})
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
ACTIVE
INACTIVE
d
I.M. loading (g m^{-2} yr^{-1})
8000
6000
4000
2000
0
ACTIVE
INACTIVE
b
O.M. content (%)
70
60
50
40
30
20
10
0
ACTIVE
INACTIVE

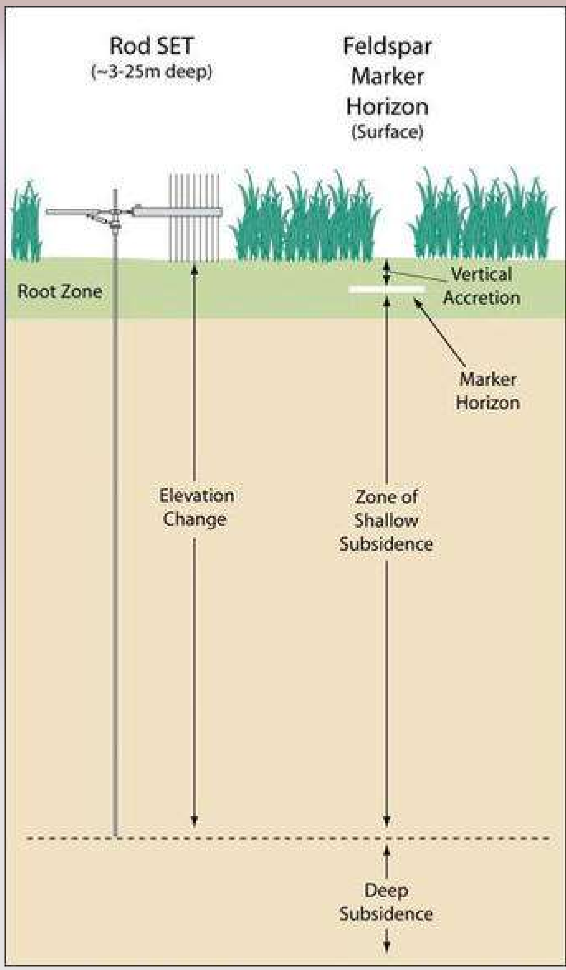
Clarifying the Dynamics of Sediment Surface Elevation (Platform Elevation)

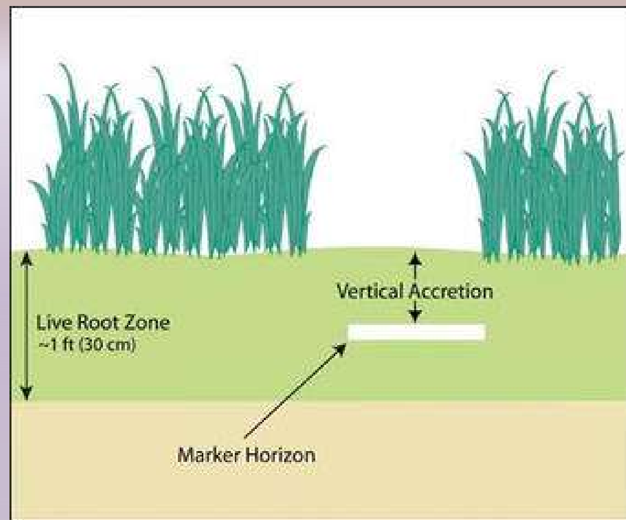
1. Sediment Surface Elevation is the Platform Elevation relative to a datum
2. The dynamics of platform elevation are combination of surface deposition and subsurface process of shallow subsidence and expansion (water volume filling pore spaces)
3. Methods to separate out these processes – Sediment Elevation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





Feldspar Marker Horizons – Surface Deposition





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

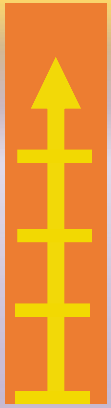
Feldspar Marker Horizon to measure sediment deposition

Surface Accretion Rates (SAR)

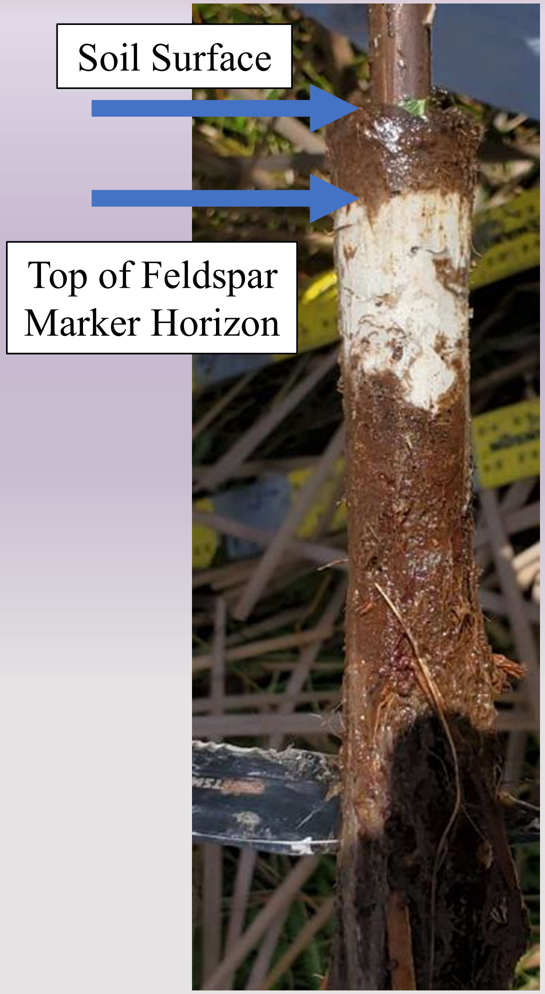
- Deposition of inorganic + organic sediment on marsh surface;
- Contribution to soil development – elevation;
- Cryocore measures of marsh surface elevation above a soil marker – feldspar;

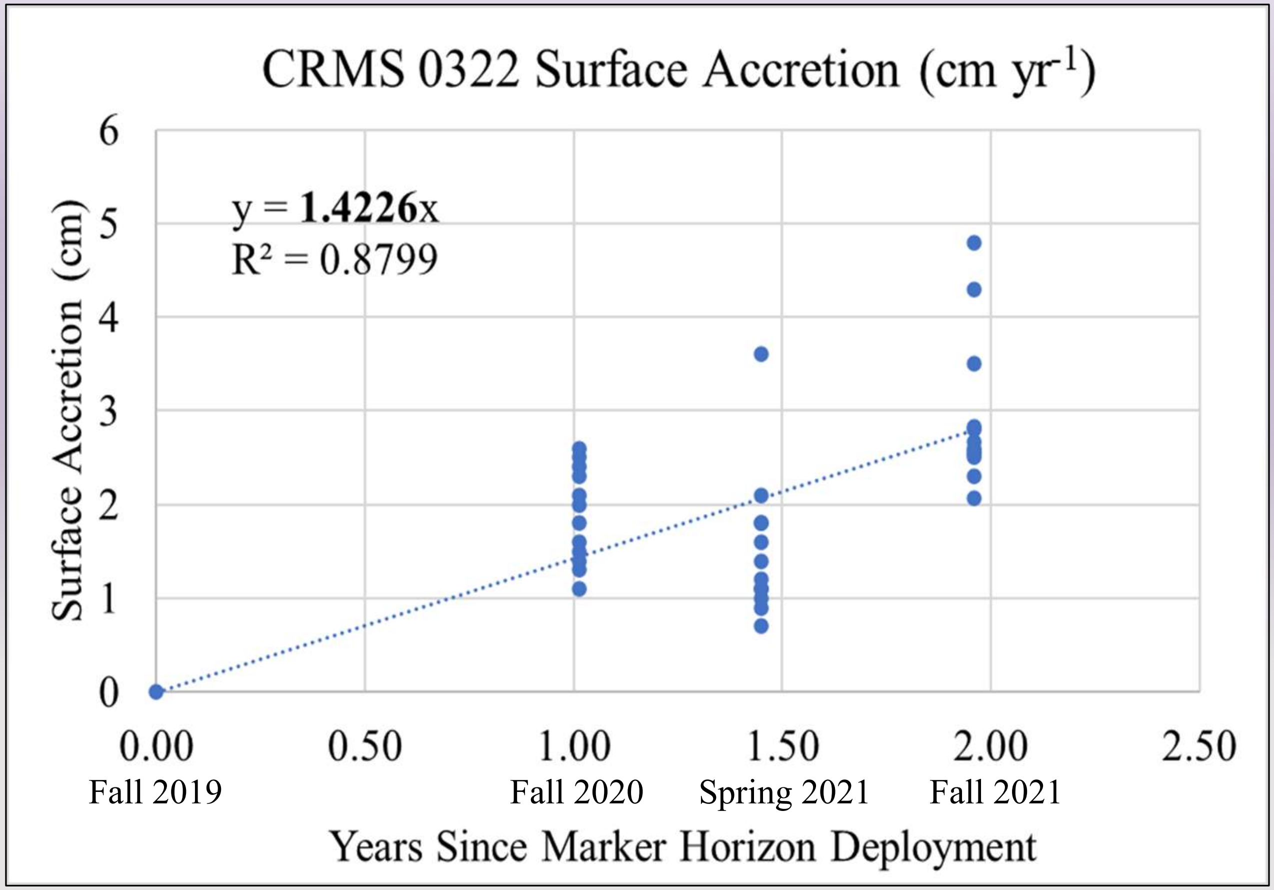
Feldspar Marker Horizons – Surface Accretion

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



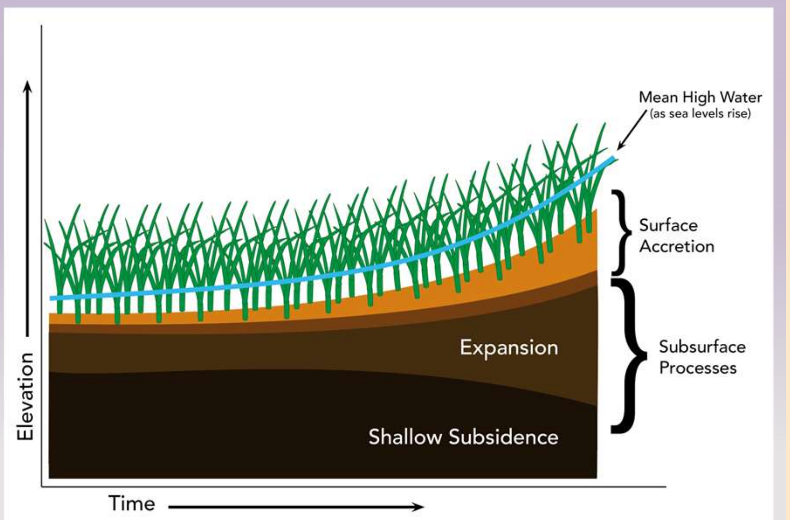
Feldspar Marker Horizons – Surface Accretion



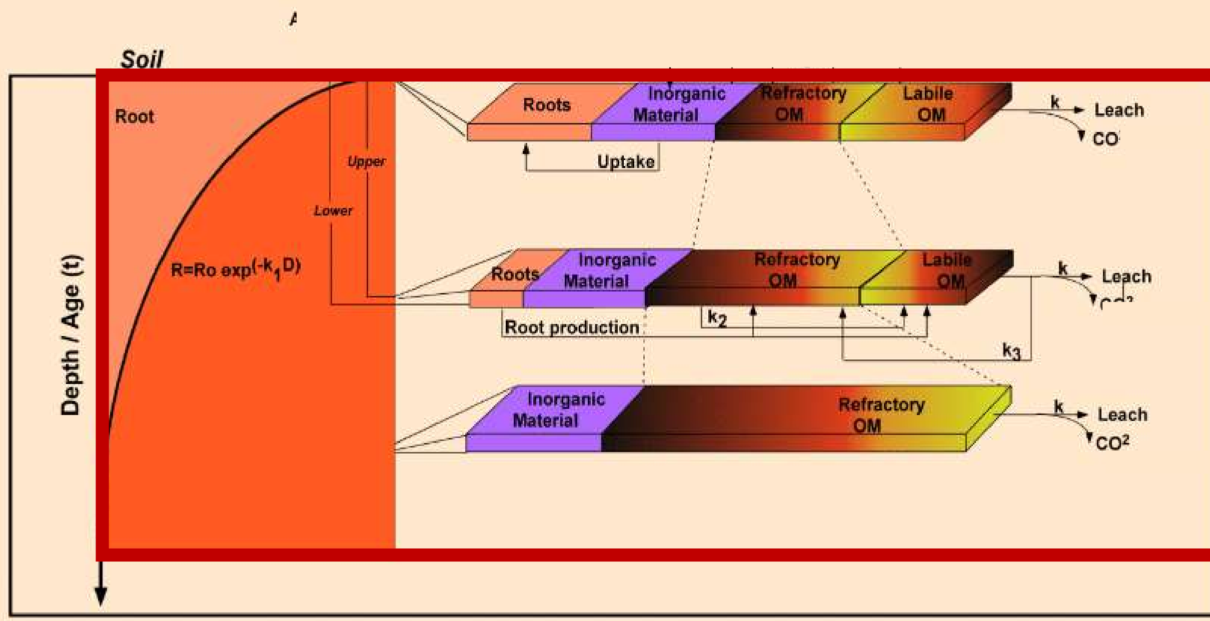


Important Parameters

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



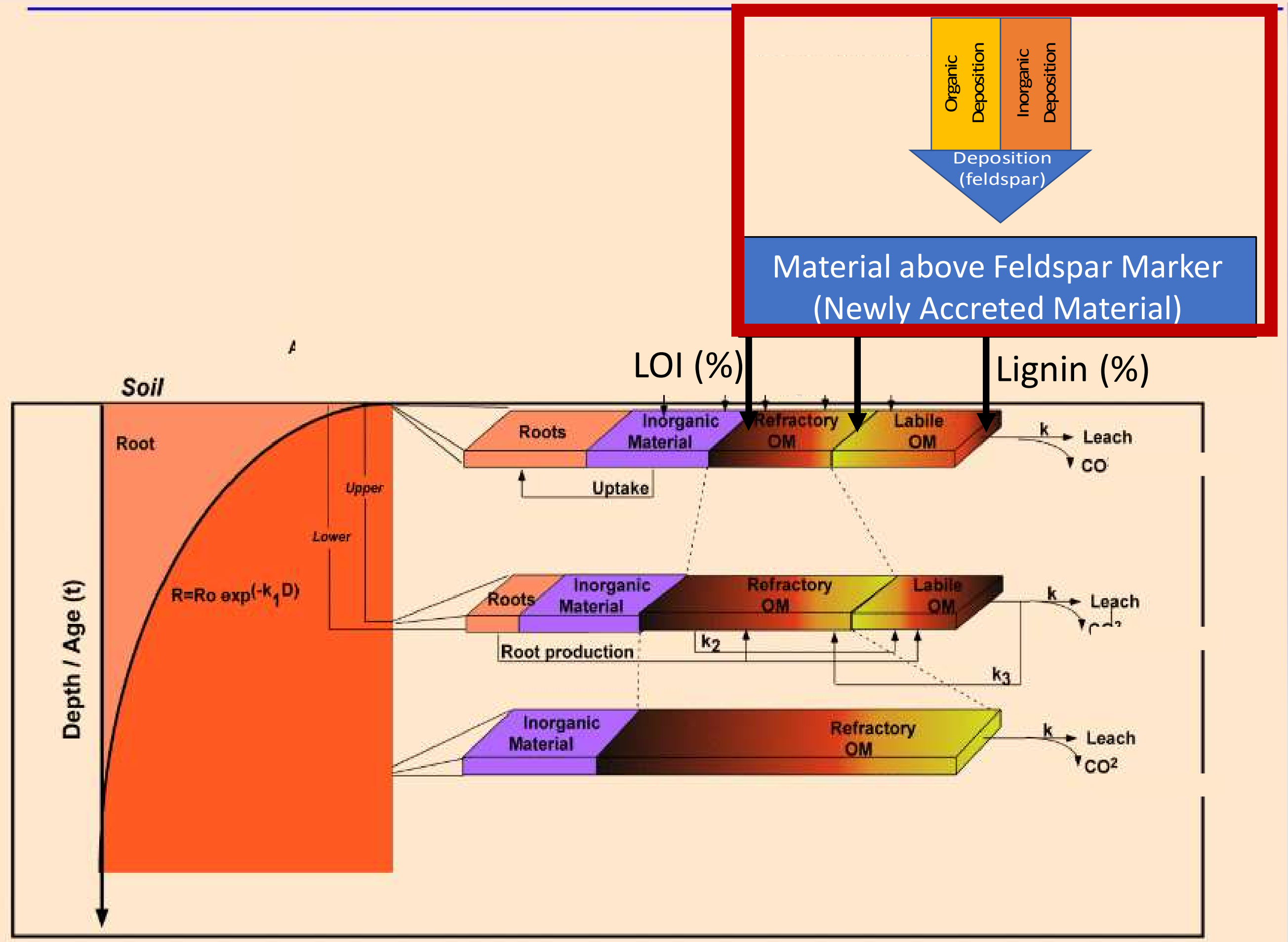
Numerical Understanding of Marsh Accretion & Resilience (NUMAR – soil formation & accretion, carbon sequestration)



Important Parameters

1. Soil Accretion (formation) = cohort of surface & belowground processes;
2. Surface Deposition: organic and inorganic deposition (feldspar) (cm/yr) over 1-3 yr time frame;

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



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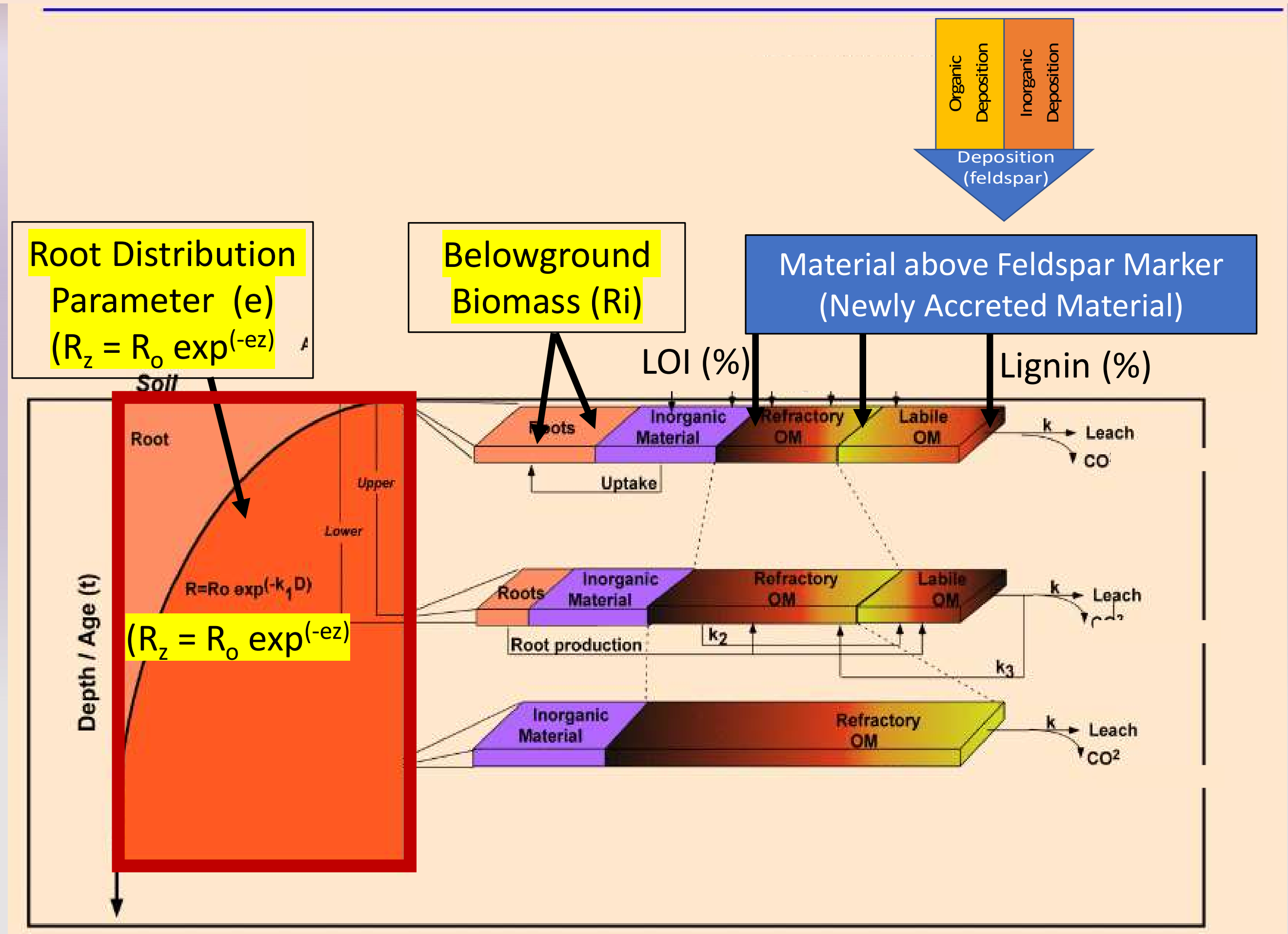

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2. <u>Surface Accretion</u>: organic and inorganic deposition (feldspar);
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4. Belowground biomass distribution is function of ‘e’;

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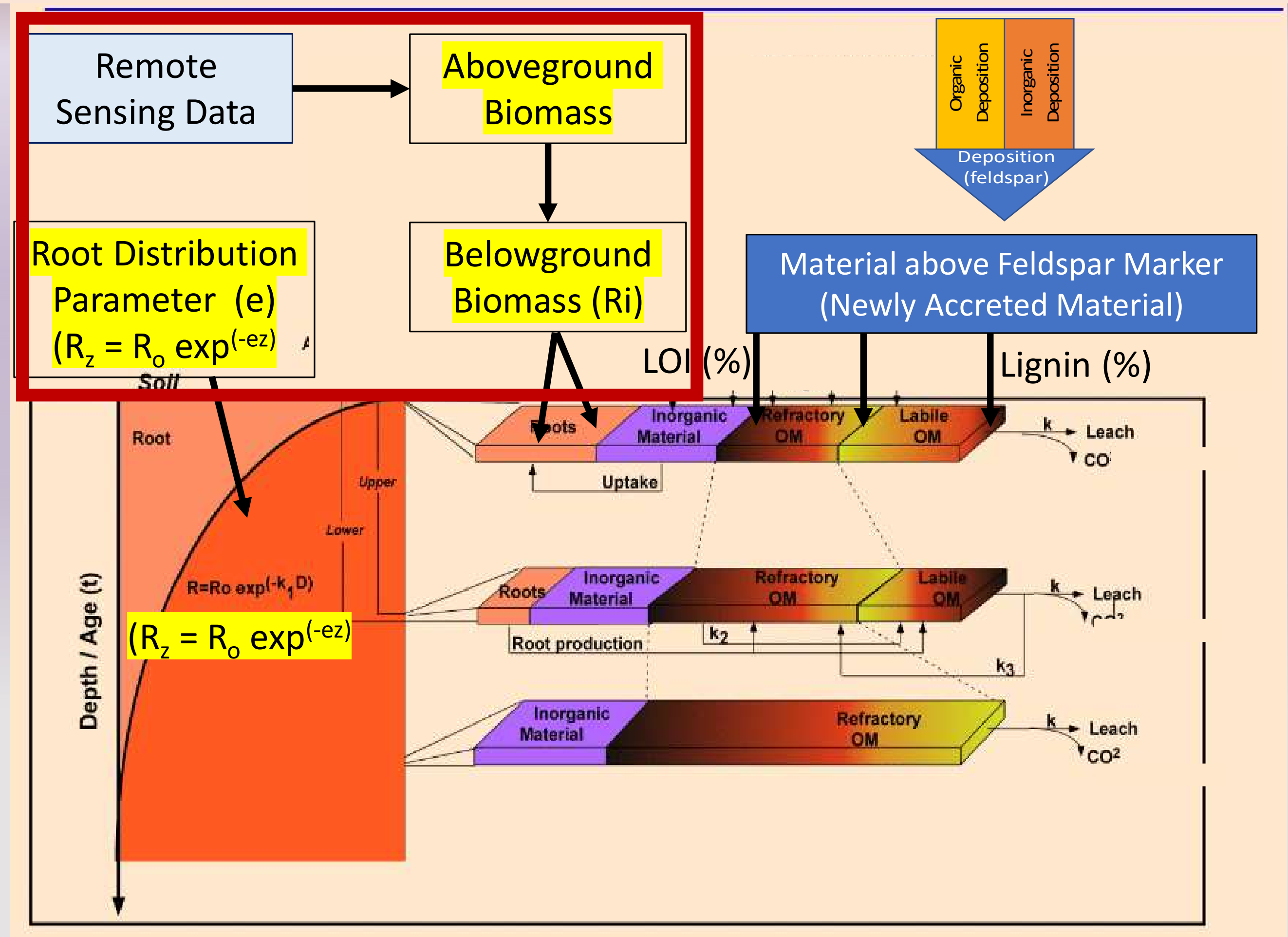

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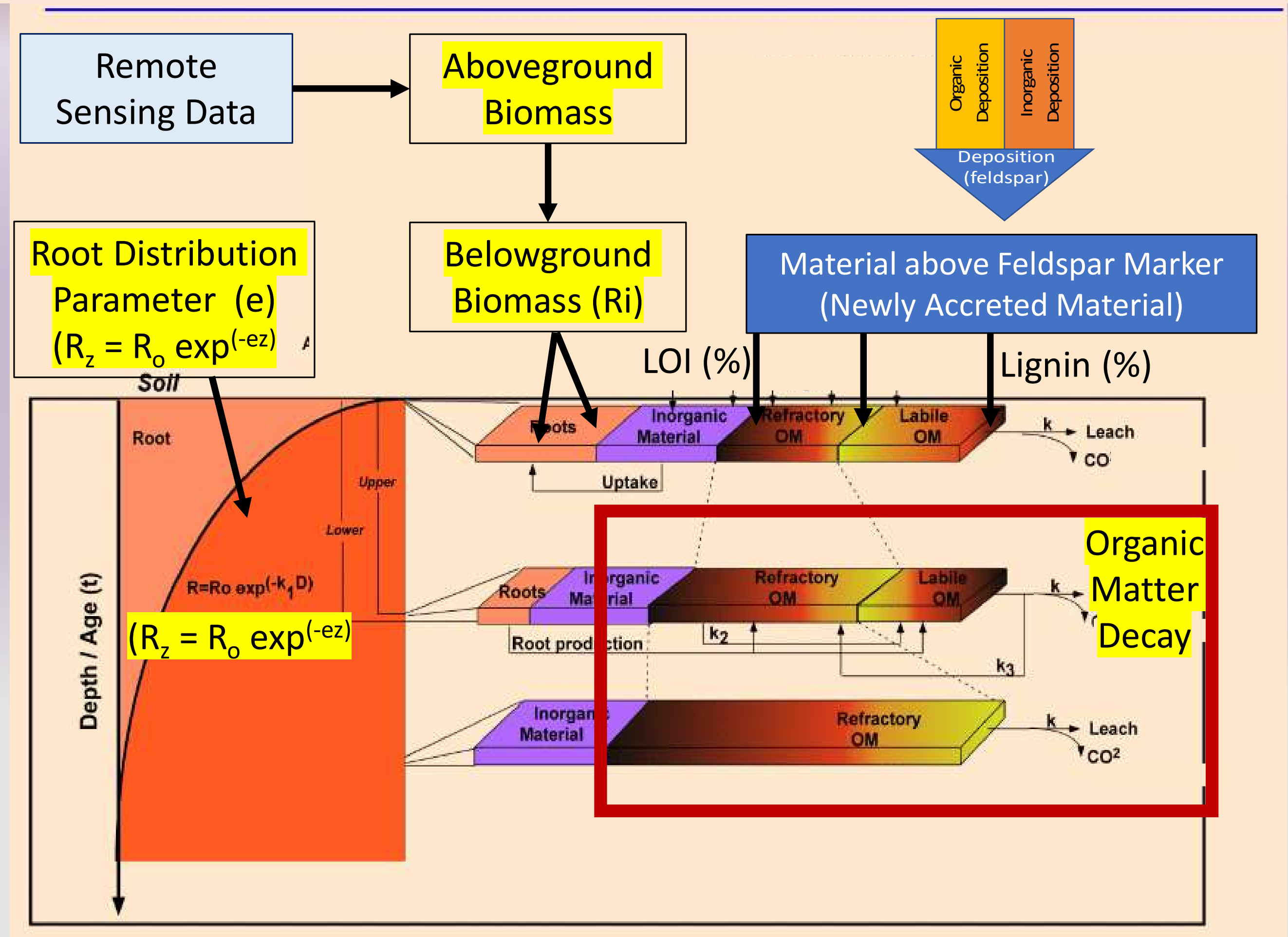
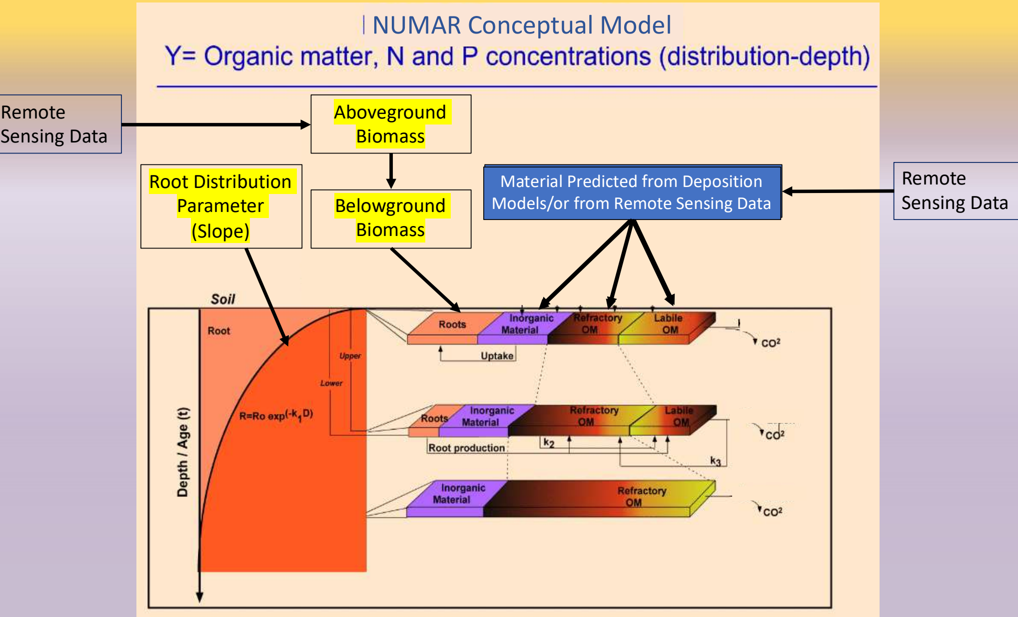
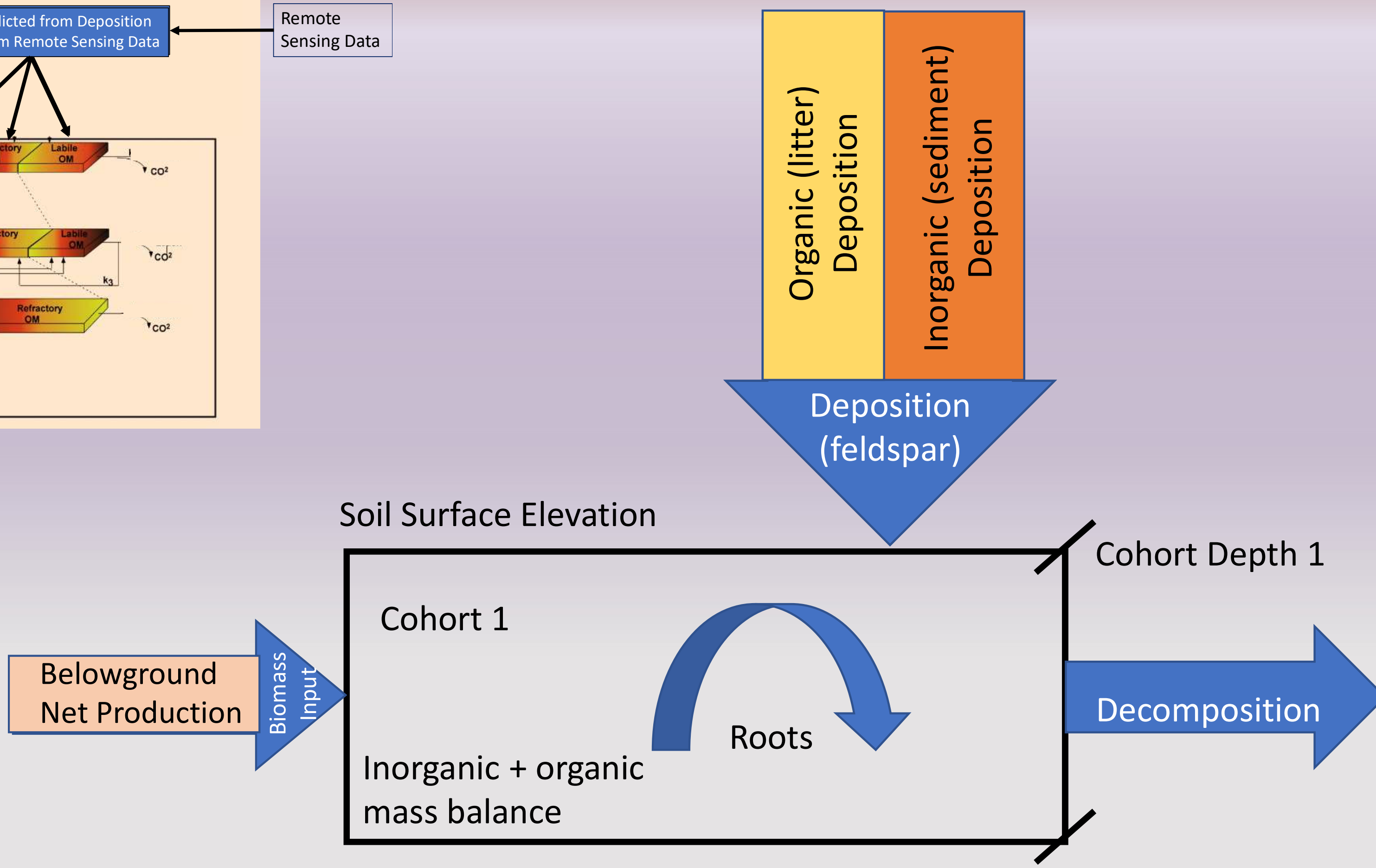
4. Belowground biomass distribution is function of ‘e’;
5. <u>Also need organic matter (OM) decay rate (labile vs refractory) – builds necromass;</u>
6. <u>Simulations are 60-100 yr time periods at 1 yr time steps</u>

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




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
CO2
Uptake
Root production
k2
k3


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

Belowground Biomass & Necromass

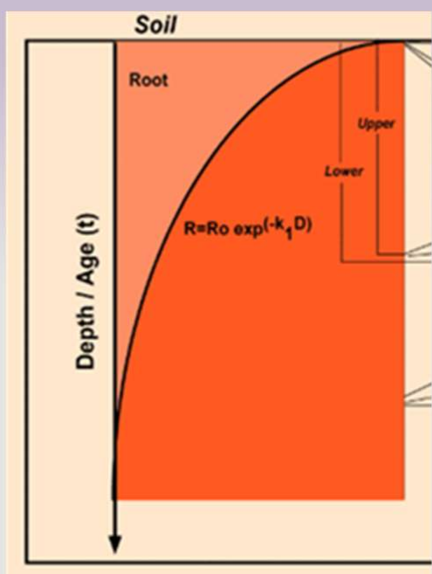
$R(t)$ = root mass at time t

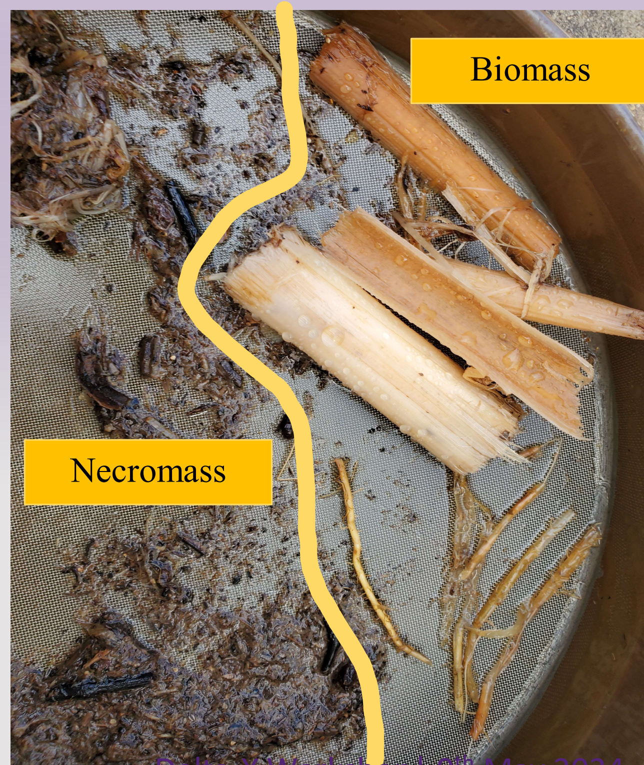
R_0 = root mass at surface (g cm^{-2})

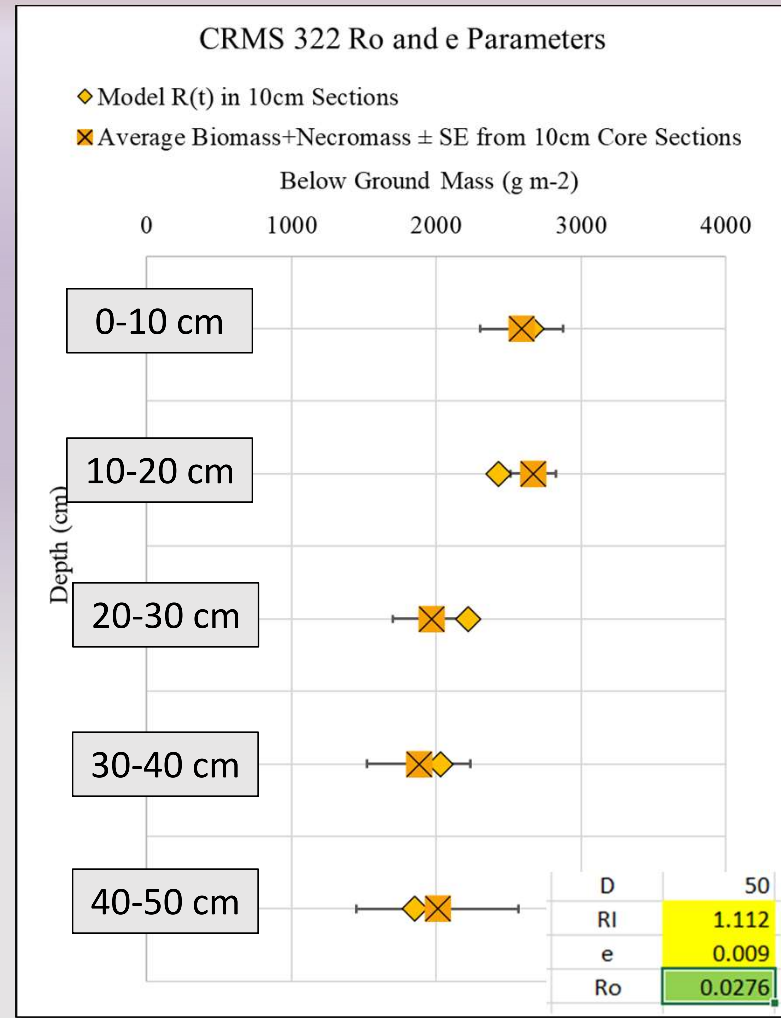
e = root attenuation (cm^{-1})

D = depth (cm)

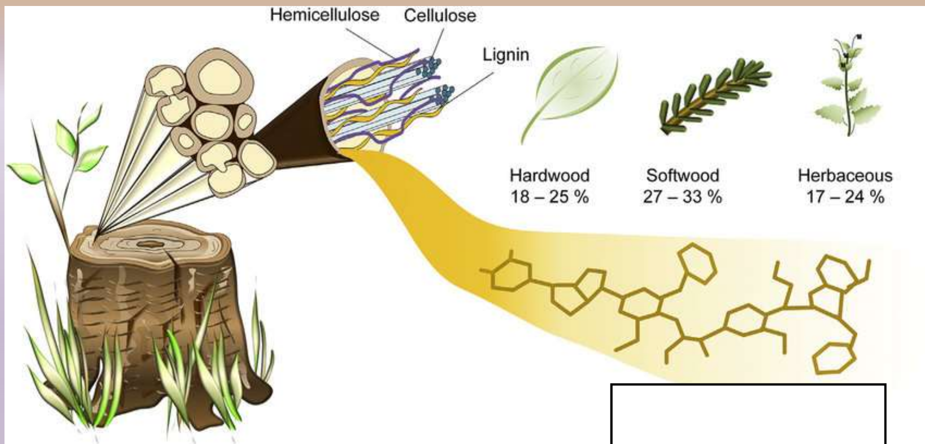
$$R(t) = R_0 * \exp^{(-e*D)}$$







Feldspar Plugs – Newly Accreted Material



(Becker and Wittmann 2019)

Feldspar Plug Sample

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

Inorganic Mineral Sediment

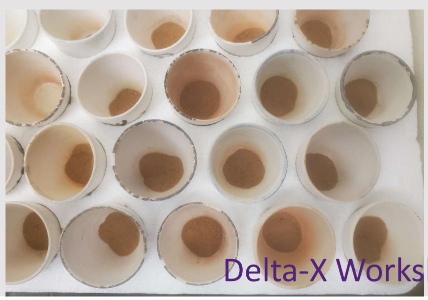
Si

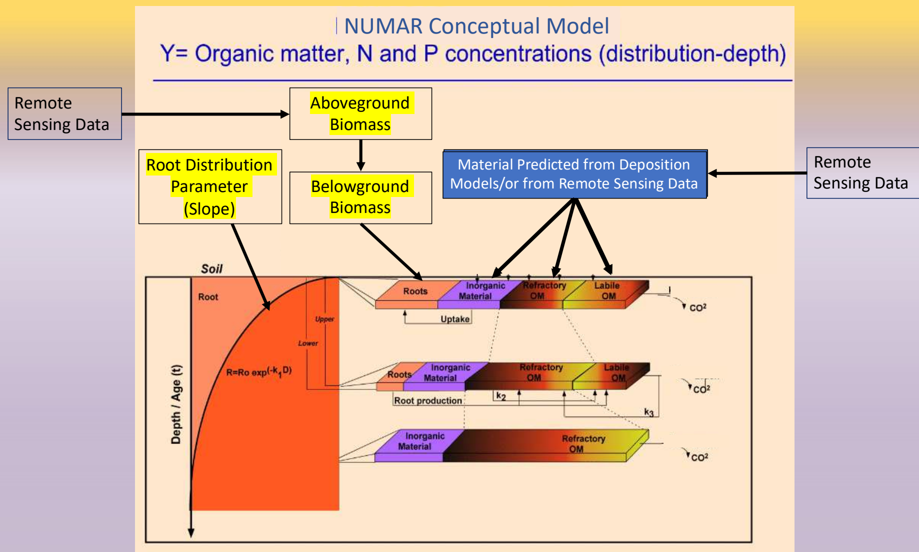
LOI * Lignin Fraction
(LSU Forage Lab)

Refractory Organic Matter

(1- cellulose fraction –lignin fraction –inorganic fraction)

Labile Organic Matter





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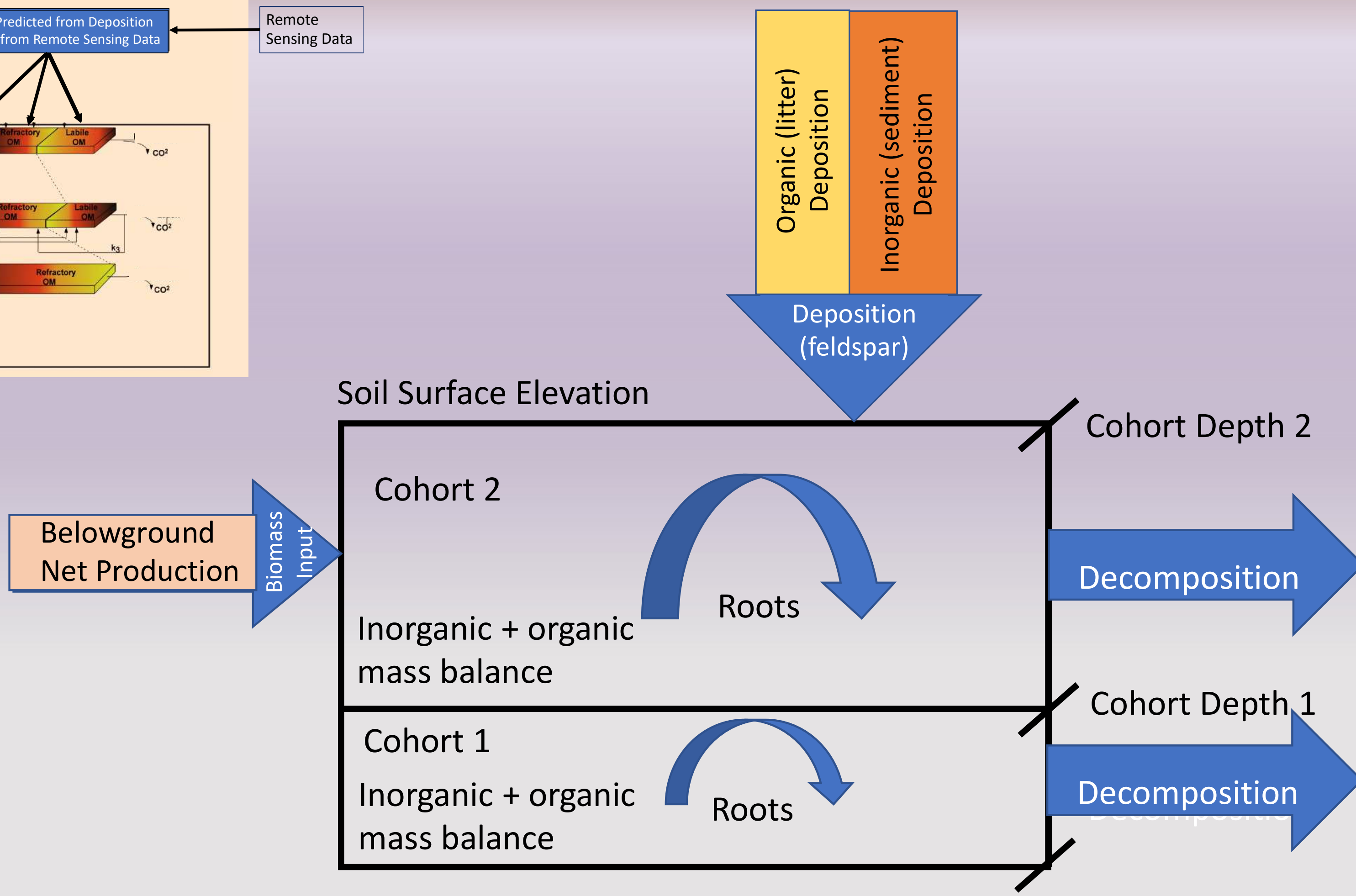
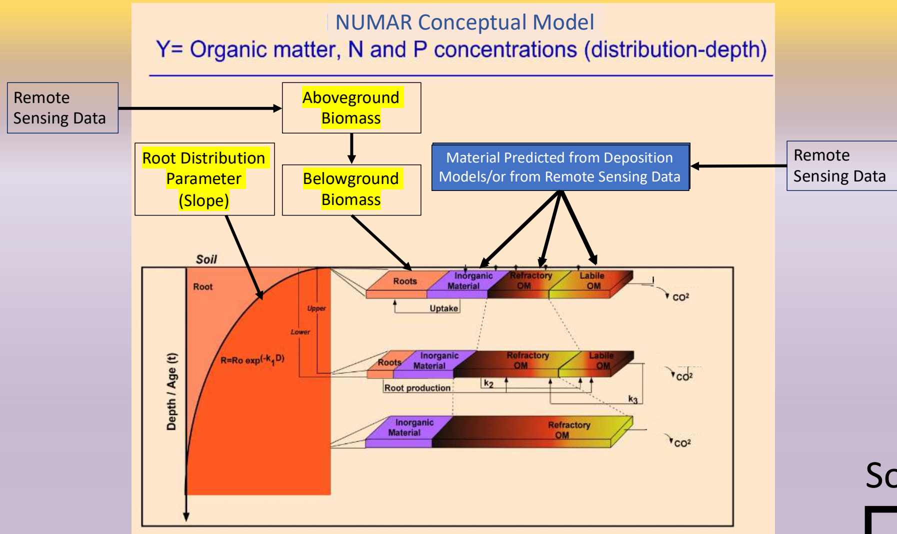
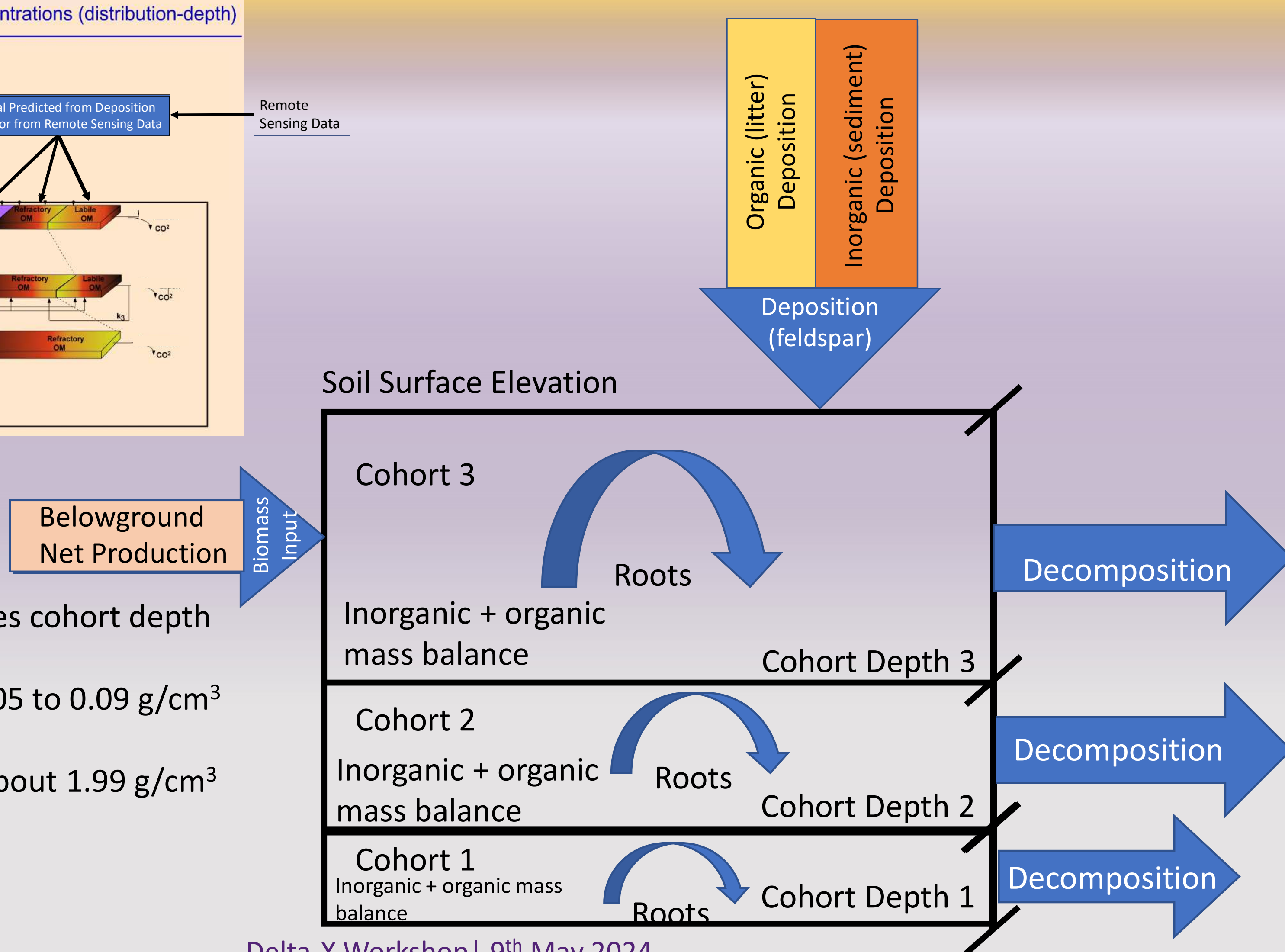
Aboveground Biomass
Root Distribution Parameter (Slope)
Belowground Biomass
Material Predicted from Deposition Models/or from Remote Sensing Data
Remote Sensing Data
Soil
Root
Depth / Age (t)
Roots
Inorganic Material
Refractory OM
Labile OM
Uptake
Root production



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

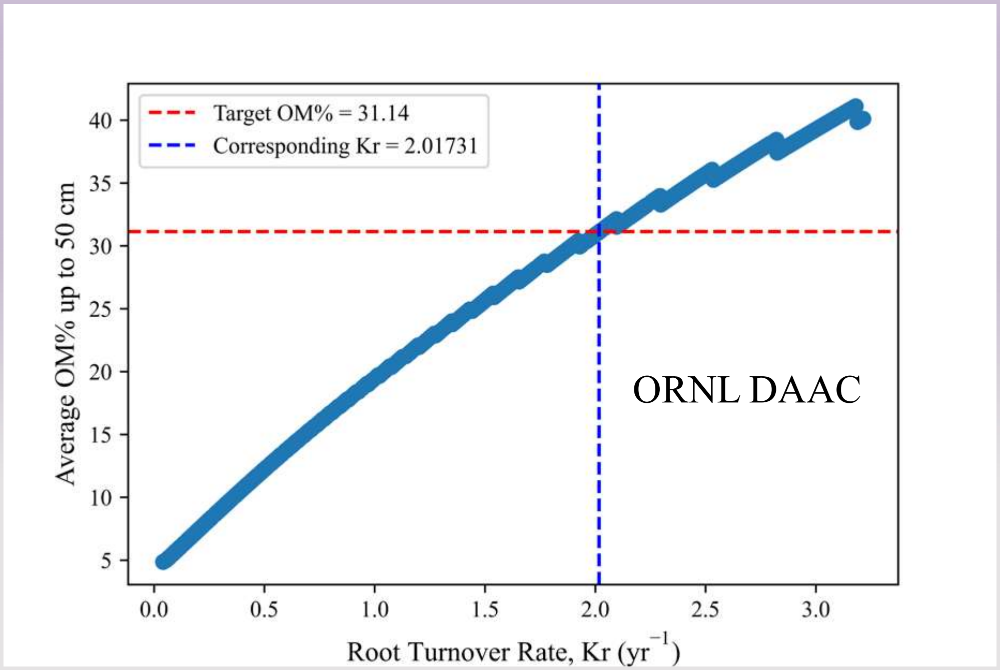
Organic matter (bo): values 0.05 to 0.09 g/cm^3

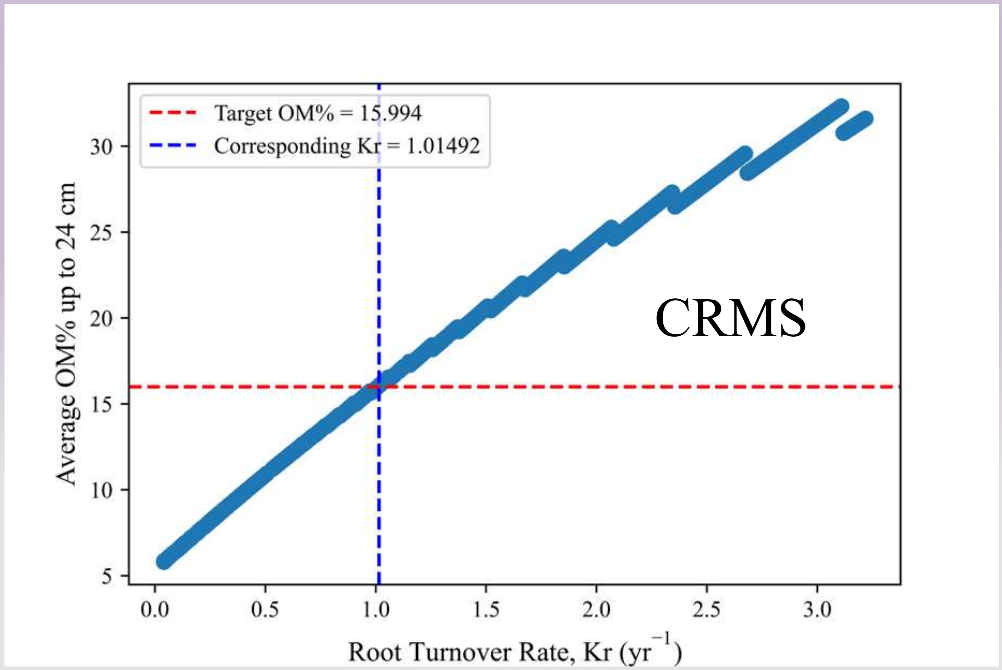
Inorganic matter (bi): values about 1.99 g/cm^3

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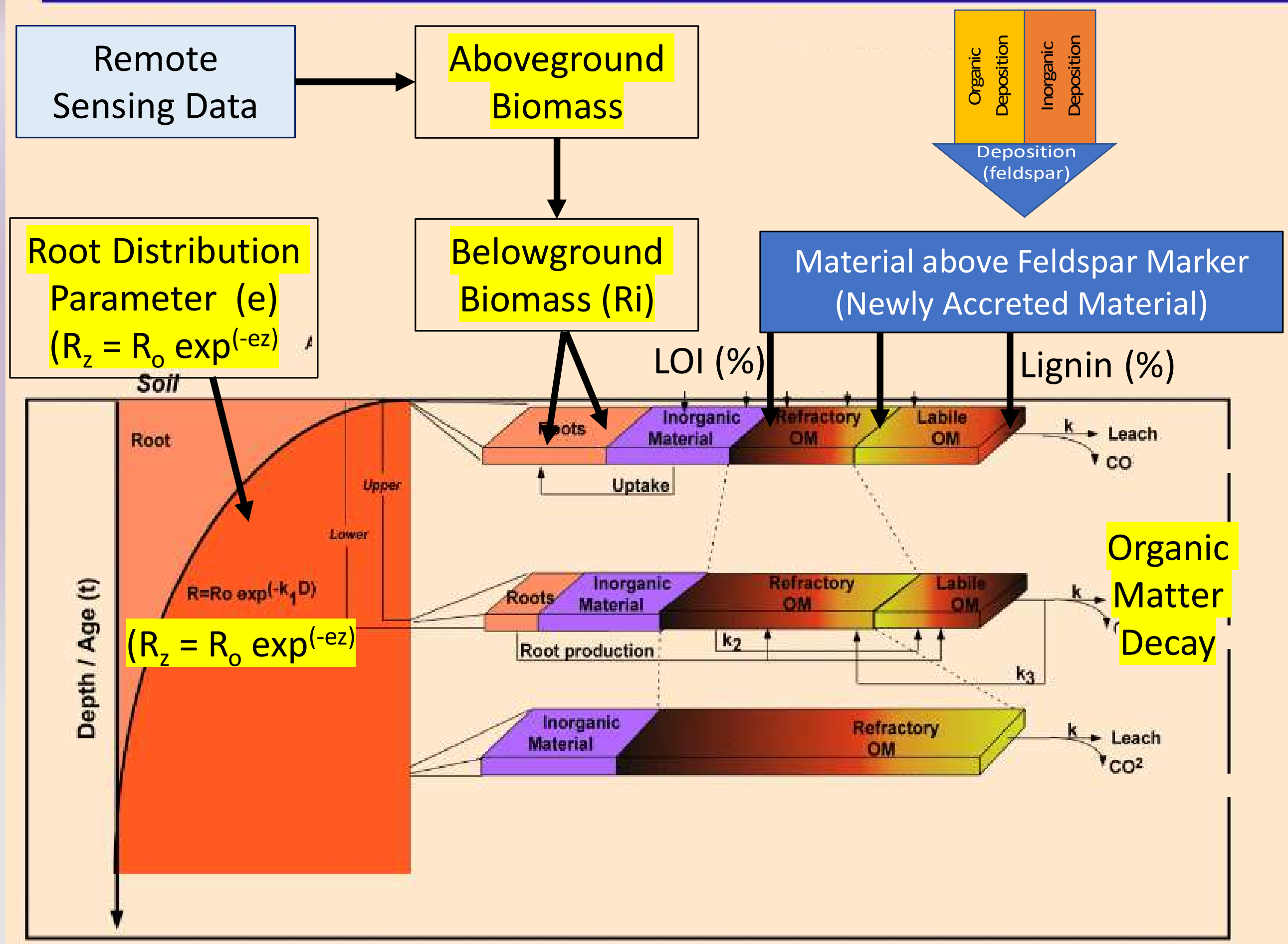
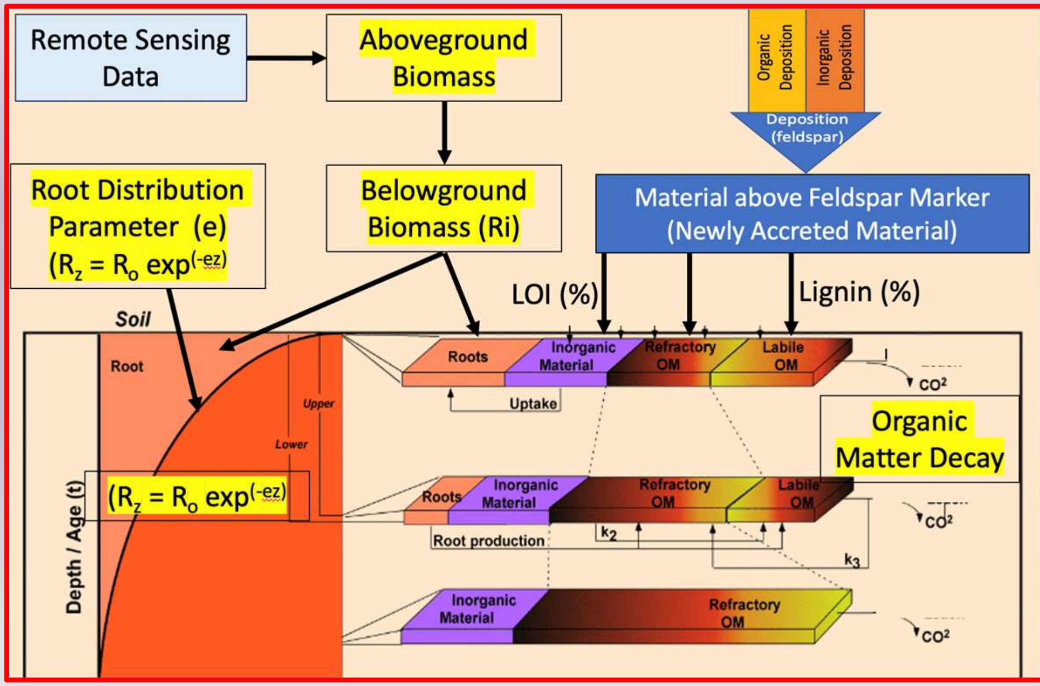
6. Also need organic matter (OM) decay rate (labile vs refractory);

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



Updates on performance of NUMAR

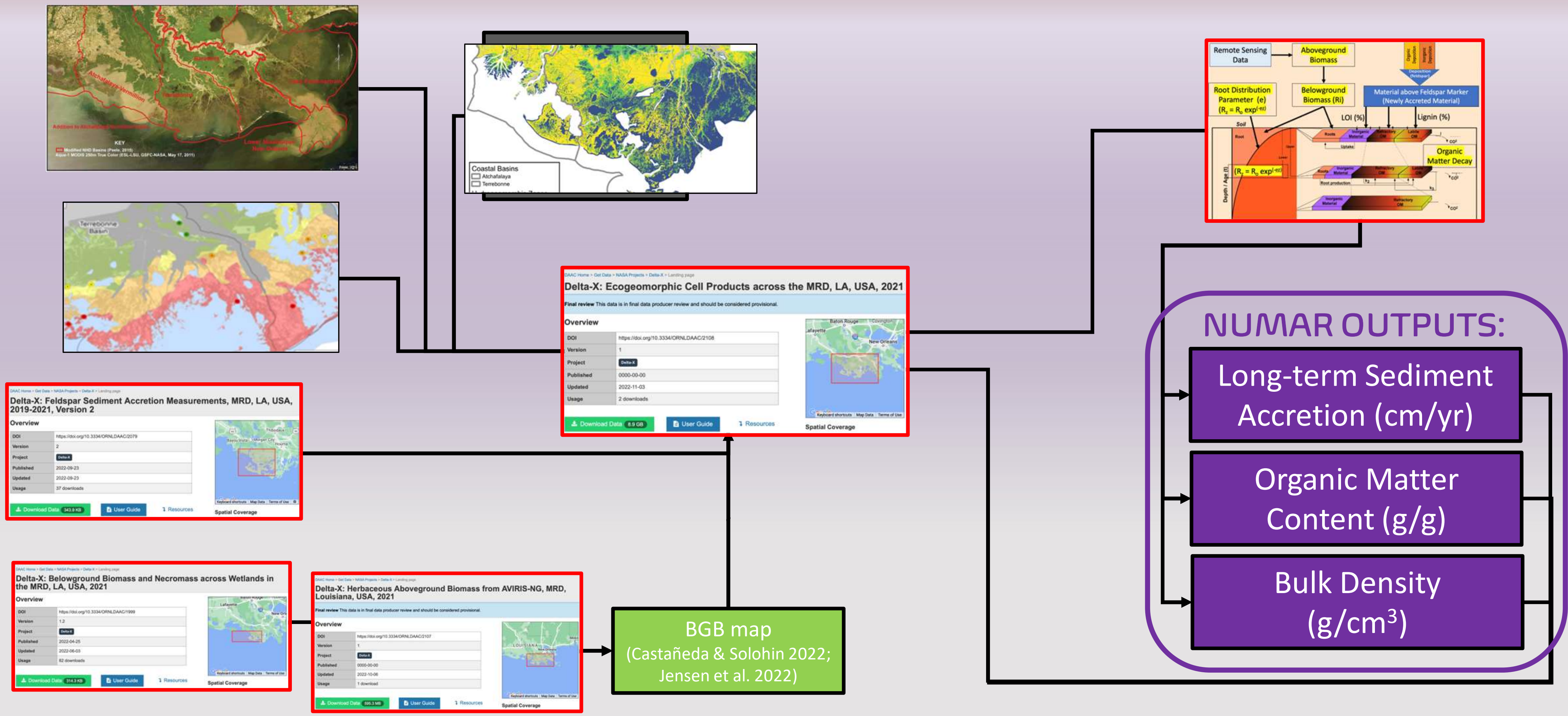


NUMAR OUTPUTS:

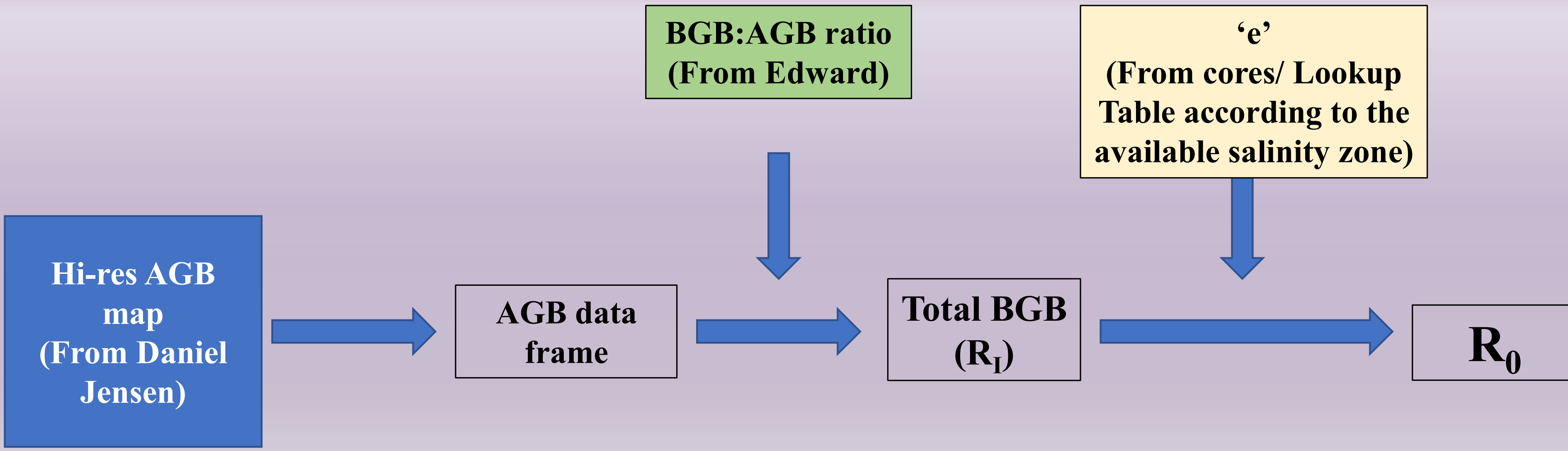
NUMAR Model (Biswas et al., 2023)

- Long-term Sediment Accretion (cm/yr)
- Organic Matter Density (g/cm3)
- Carbon Sequestration gC m^{-2} yr^{-1}

Workflow to scale NUMAR across LA coastalscape



Workflow contd…



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

Workflow contd…

Field measurements & Lab Analyses → **Andy's Lookup table** → **Populate Ecogeomorphic cells (Marc's) With oms, si, ROM, LOM**

- Organic matter deposition rate (oms)
- Inorganic matter deposition rate (si)
- Inorganic fraction of deposited material (c1)
- Lignin fraction of deposited material (c0)
- Cellulose fraction of the deposited material (c4)

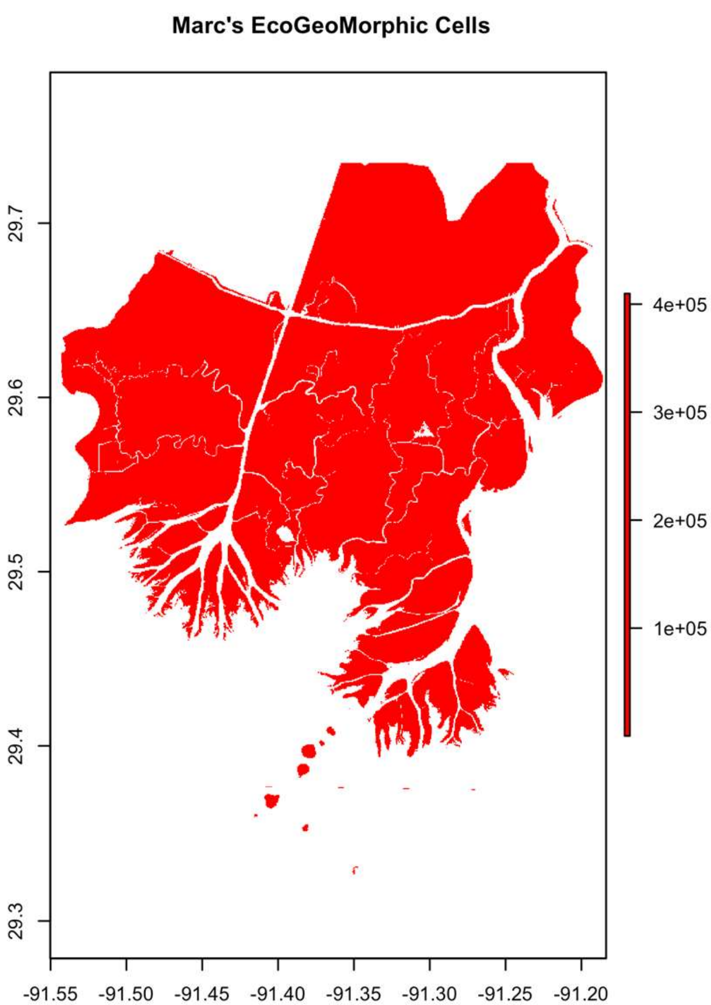
Within NUMAR python code:

$$\boldsymbol{ROM_{cell}(0) = (oms + si) * c_4}$$

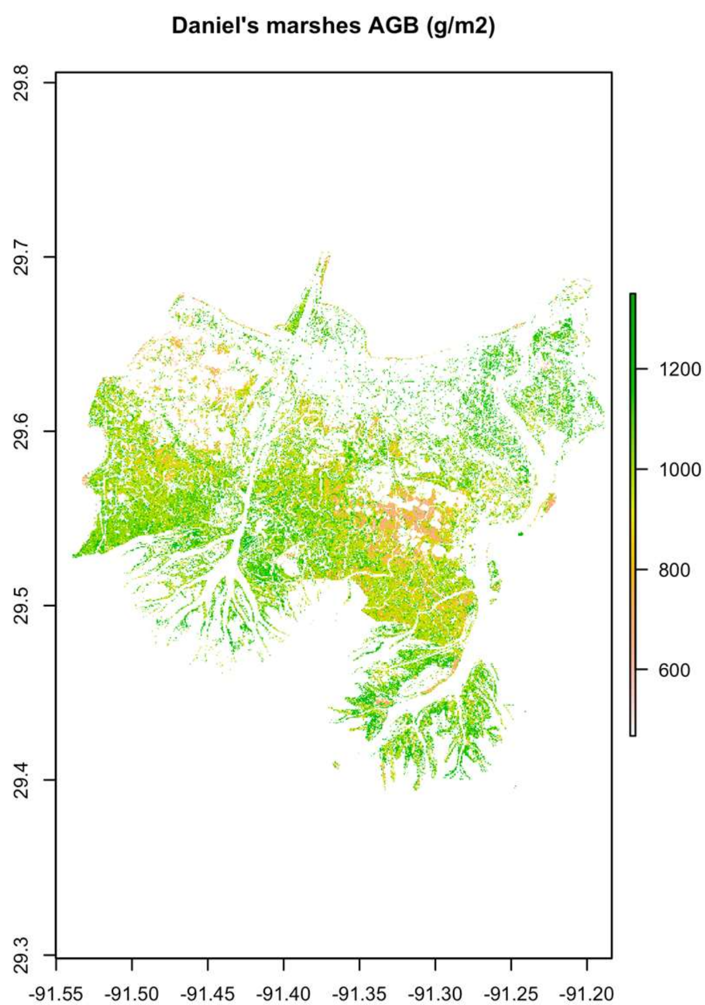
$$\boldsymbol{ROM_{lig}(0) = (oms + si) * c_0}$$

$$\boldsymbol{LOM(0) = oms - ROM_{lig}(0) - ROM_{cell}(0)}$$

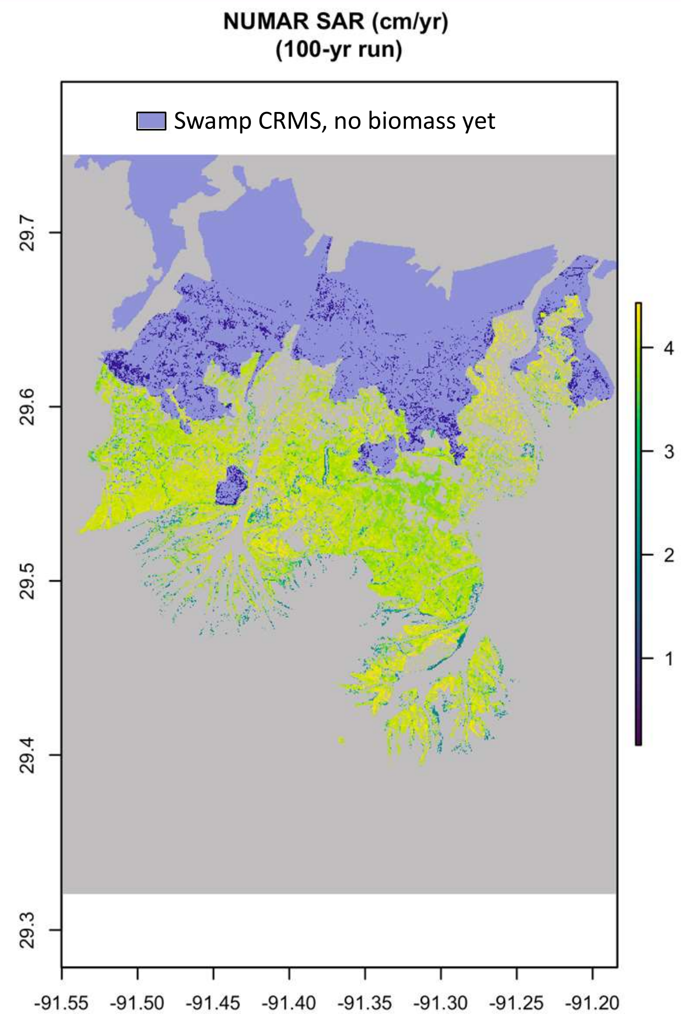
Initial Run



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



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



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

Feldspar Landscape Run – CSV Inputs for NUMAR

ECOGEO-MORPHIC CELL

Organic loading rate
Inorganic loading rate
Self packing density of OM (g/cm3)
Self packing density of IM (g/cm3)
Lignin Fraction
Inorganic Fraction
Cellulose fraction in deposited feldspar
Cellulose Fraction in the root
Depth dist. roots
Lignin fraction in roots
LOM Decomp. Rates
Cellulose Decomposition rate
Lignin Decomp. Rates
Root turnover rate
Root Bio @ surfac

Site	lat	long	oms	si	b0	bi	c0	c1	c2	c4	e	fc1	kb	kc	kl	kr	r0
1																	
2																	
3																	
4																	
5																	
6																	
7																	
8																	
9																	
10																	
....																	
78000																	

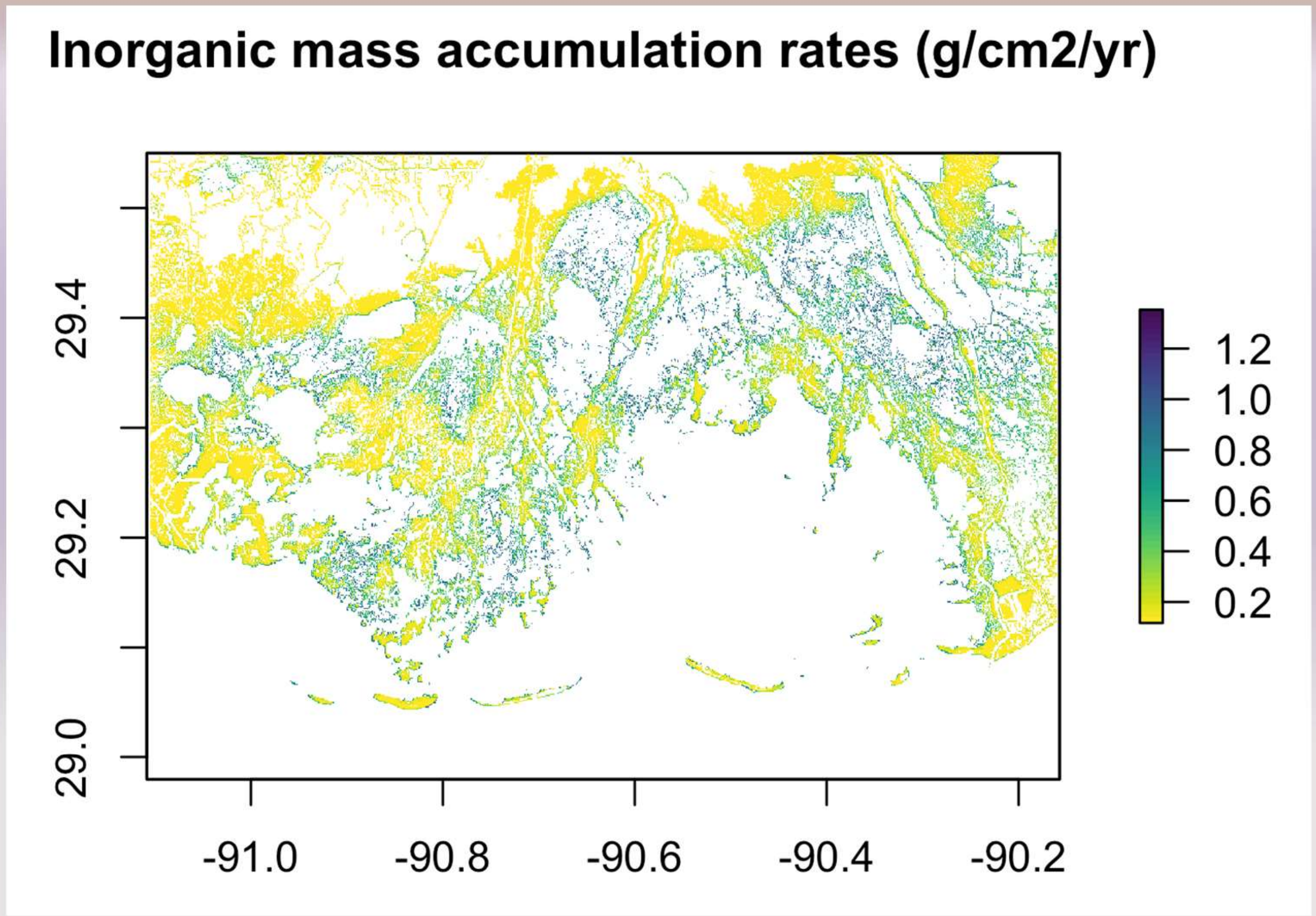
from BU si map

Ratio oms:si Andy and si from BU si map

Lookup table according to salinity zone

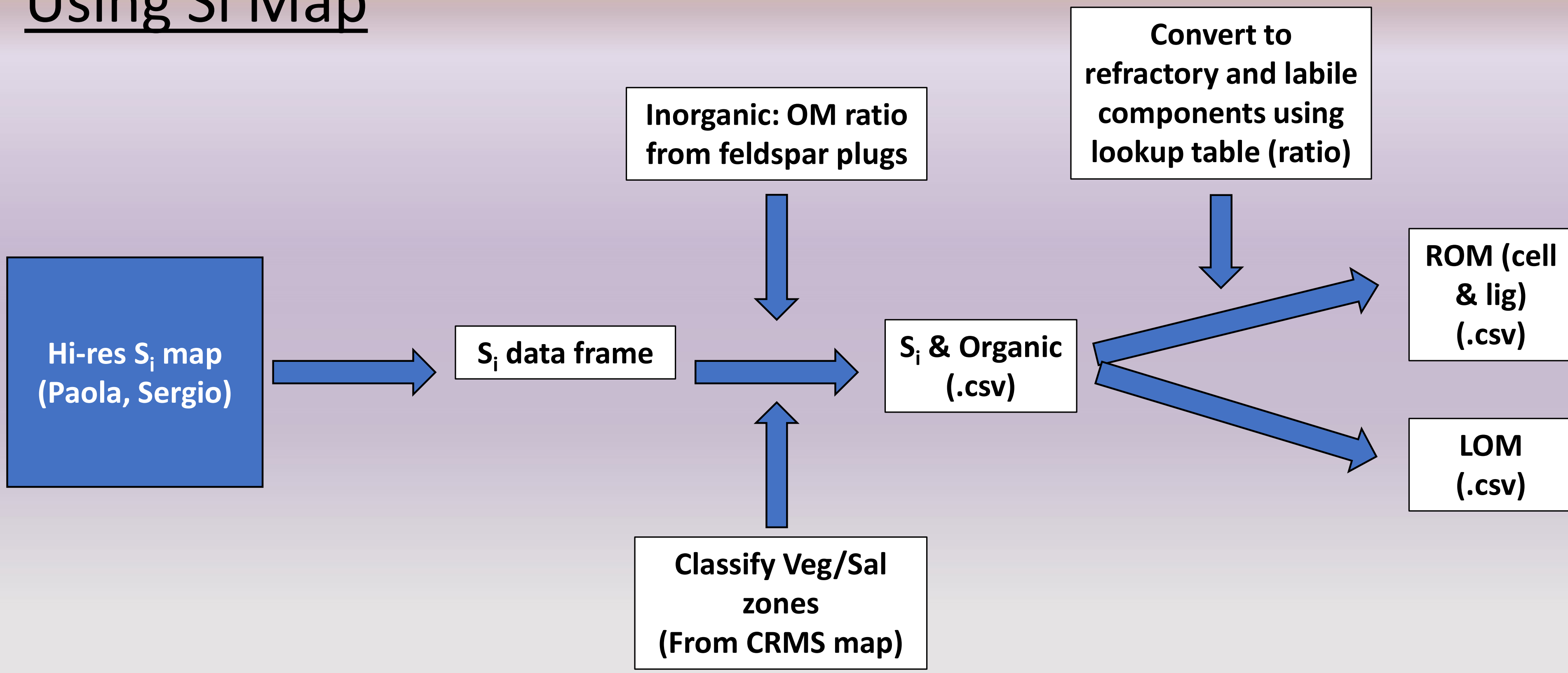
Estimated using field observation

Biomass map



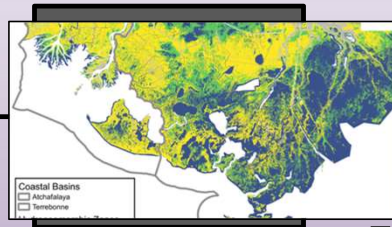
Inorganic mass accumulation rates (g/cm2/yr)
29.0
29.2
29.4
-91.0
-90.8
-90.6
-90.4
-90.2
1.2
1.0
0.8
0.6
0.4
0.2

Using Si Map

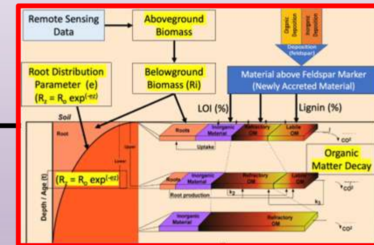


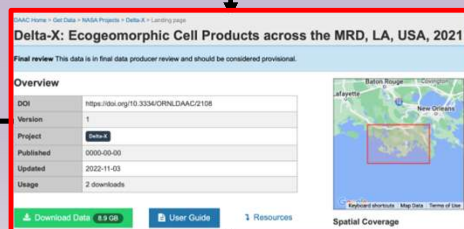
Hi-res S_i map (Paola, Sergio)
S_i data frame
Inorganic: OM ratio from feldspar plugs
Classify Veg/Sal zones (From CRMS map)
S_i & Organic (.csv)
Convert to refractory and labile components using lookup table (ratio)
ROM (cell & lig) (.csv)
LOM (.csv)

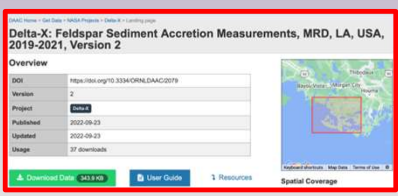
Workflow to scale NUMAR across LA coastalscape

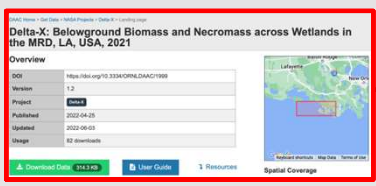


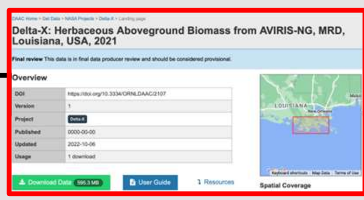
Inorganic Sediment Loading Map
(Luca & Fagherazzi)











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)

2024 Delta-X NUMAR Modeling

THANK YOU!

Robert R. Twilley, Principal Investigator

rtwilley@lsu.edu

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