Noisy Input Generalised Additive Models for Relative Sea Level Change

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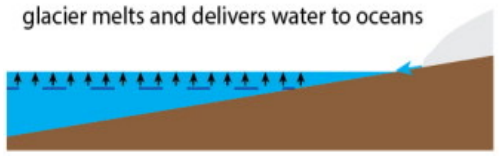
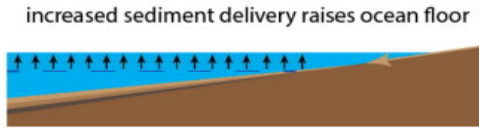
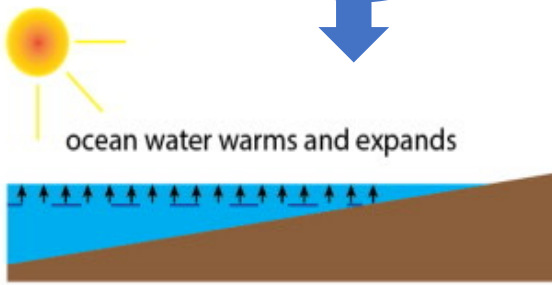
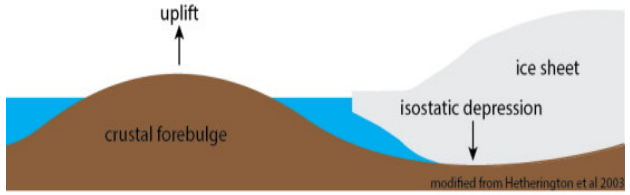
Drivers of RSL change





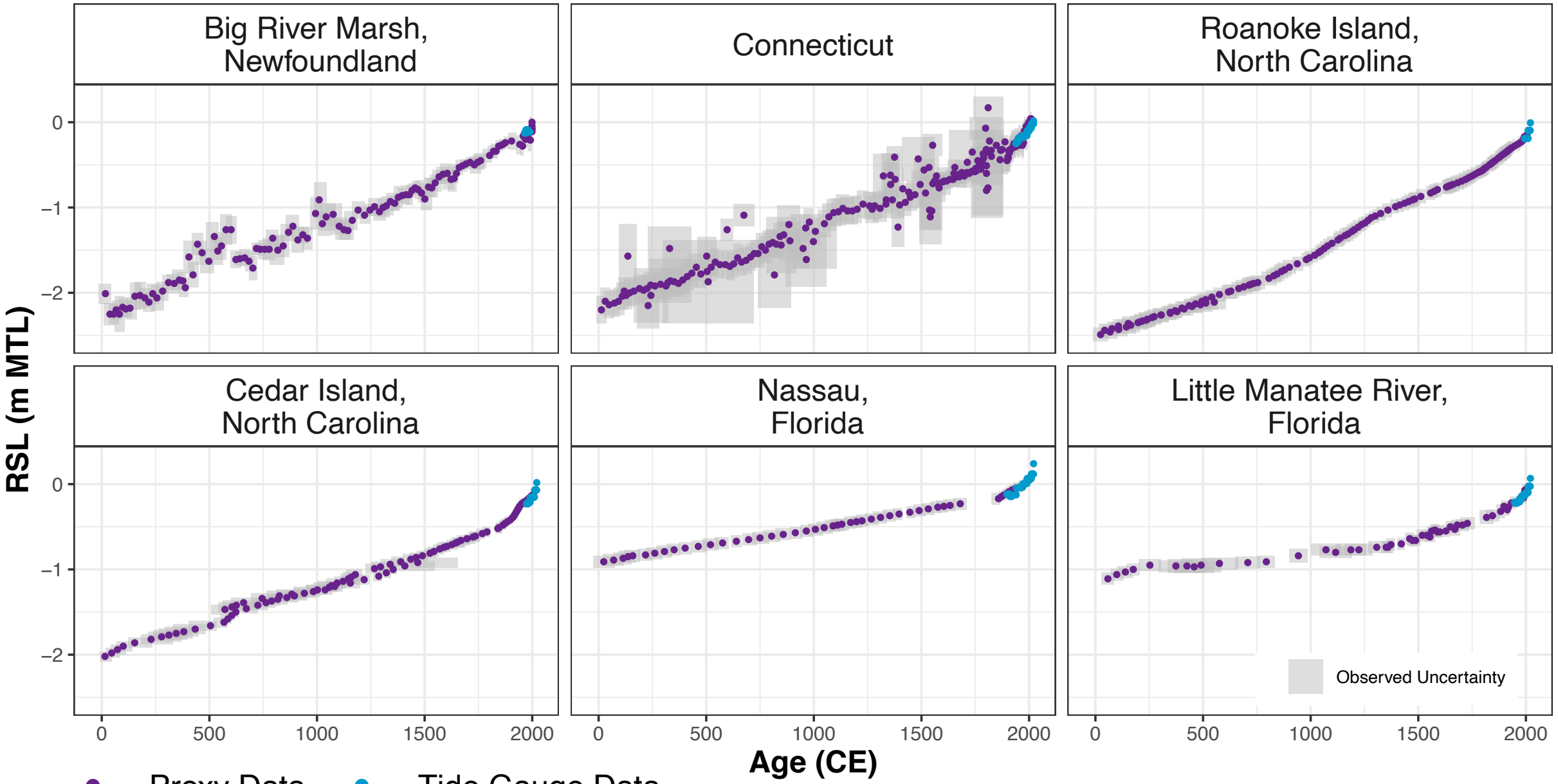
Eustatic Influence + Steric Expansion + Glacial Isostatic Adjustment (GIA) + Local Factors = Relative Sea Level



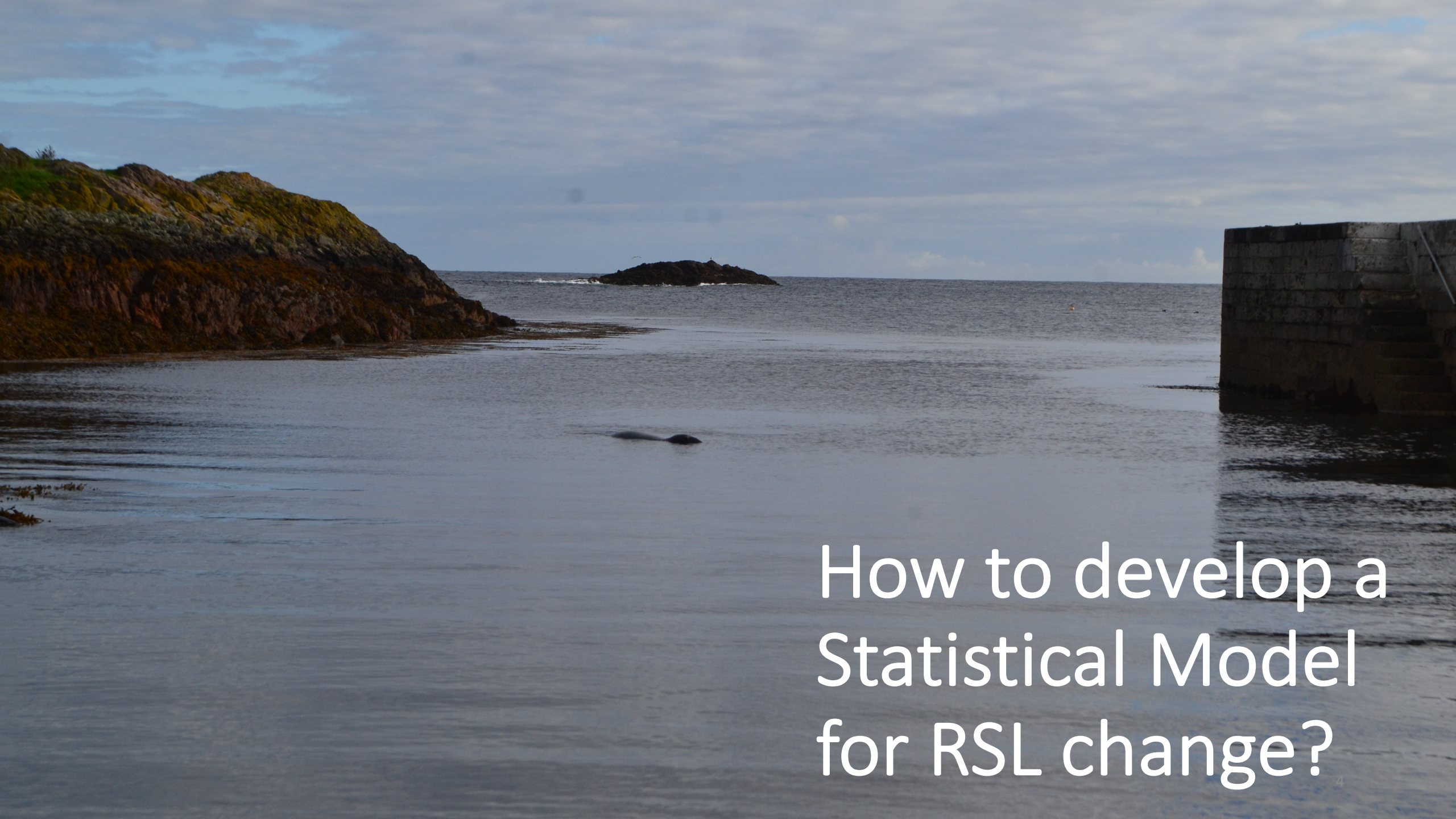


[3]

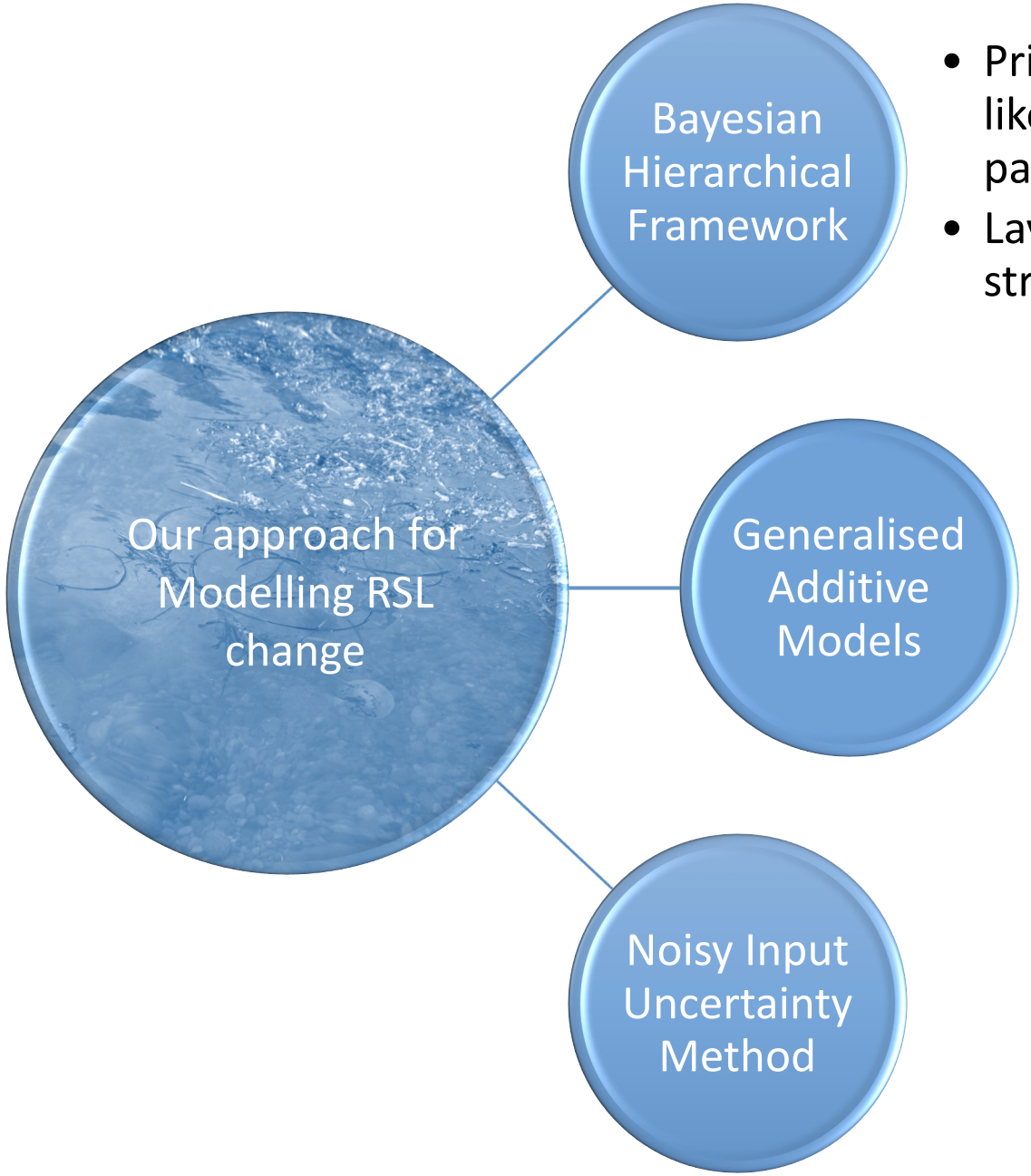
Tide Gauge and Proxy Data for East Coast of North America



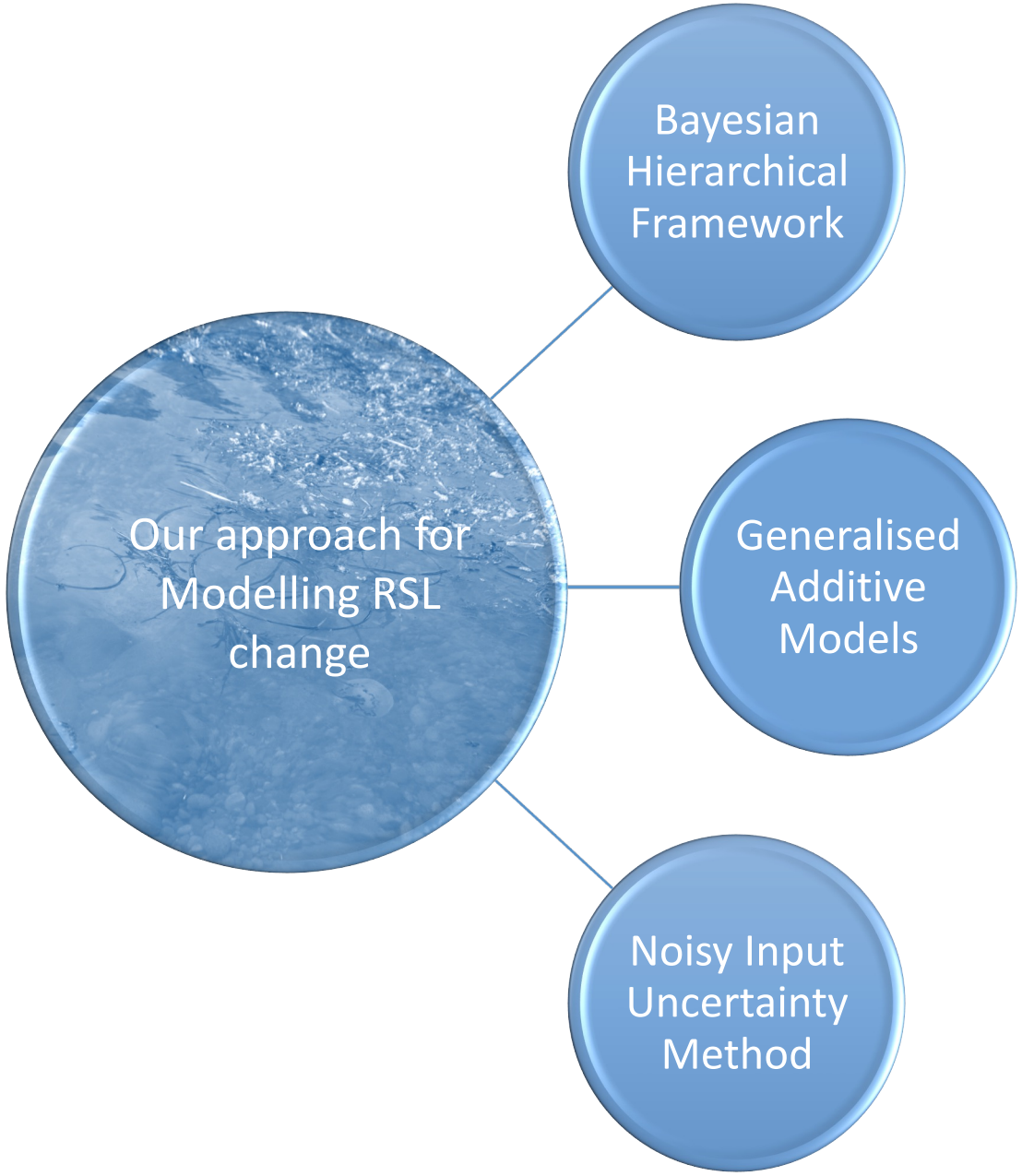
[2]



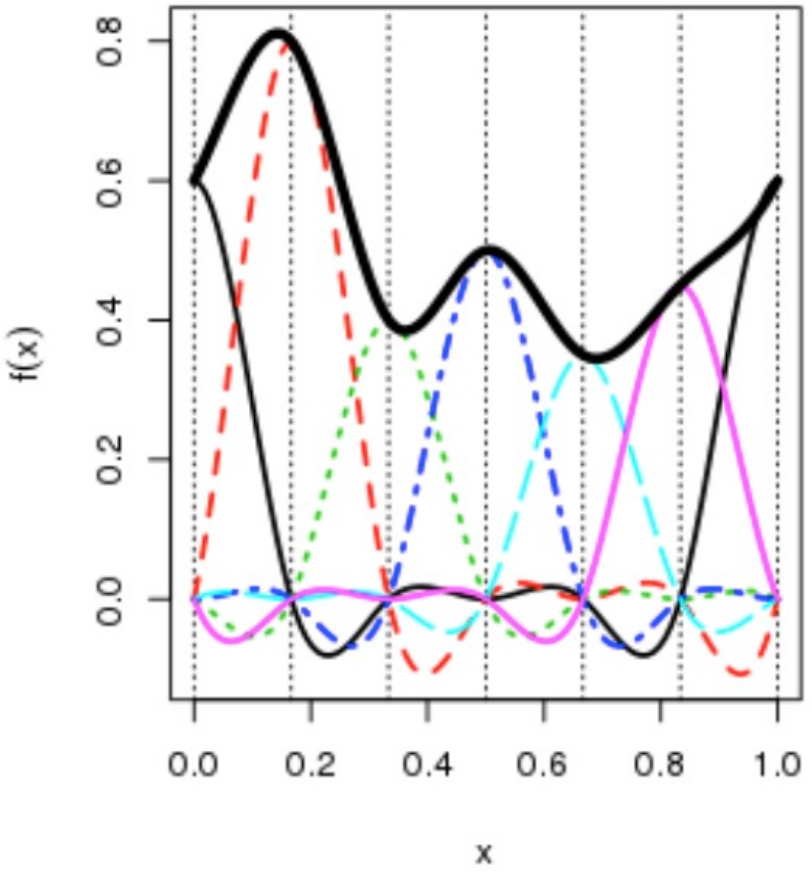
How to develop a Statistical Model for RSL change?



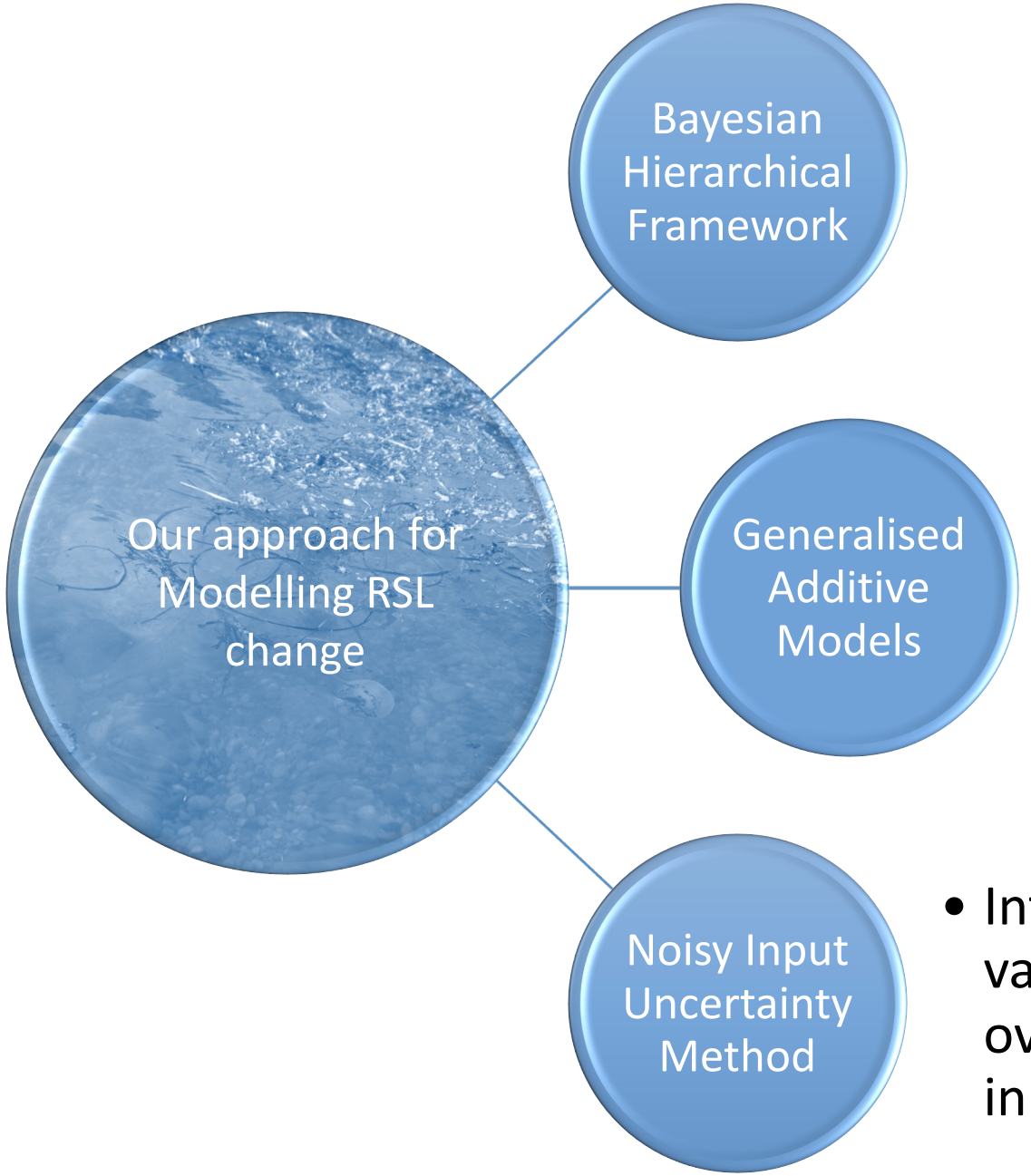
- Prior information & likelihood to estimate parameters
- Layers to borrow strength [3]



- Sum of splines[4]

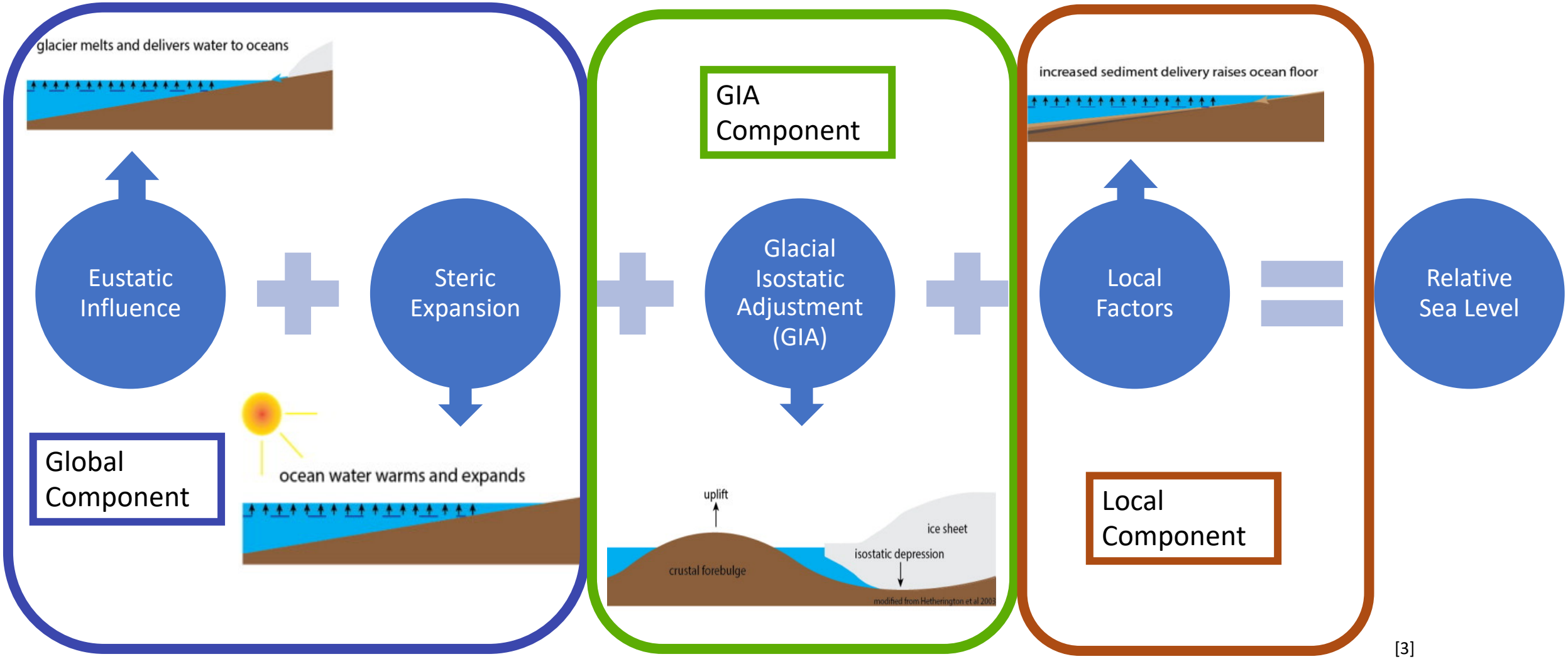


[5]



- Inflate output variance to overcome noisy inputs [5]

Drivers of RSL change



[3]

$g(t)$

$r(z_k)t$

$l(\boldsymbol{x}, t)$

glacier melts and delivers water to oceans

Eustatic Influence

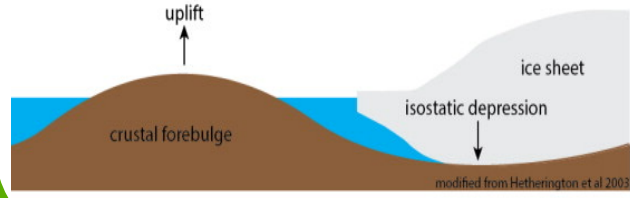
Steric Expansion

ocean water warms and expands

Global Component

GIA Component

Glacial Isostatic Adjustment (GIA)



increased sediment delivery raises ocean floor

Local Factors

Local Component

Relative Sea Level

[3]

New Bayesian Hierarchical GAM Approach to RSL Modelling

The **process level**, $f_\theta(\boldsymbol{x}, t)$, uses a RSL field which is formed by summing separate components[6] given by:

$$f_\theta(\boldsymbol{x}, t) = y_0(z_{\boldsymbol{x}}) + g(t) + r(z_{\boldsymbol{x}})t + l(\boldsymbol{x}, t)$$

y offset
Random effect used to capture spatial variability between sites.

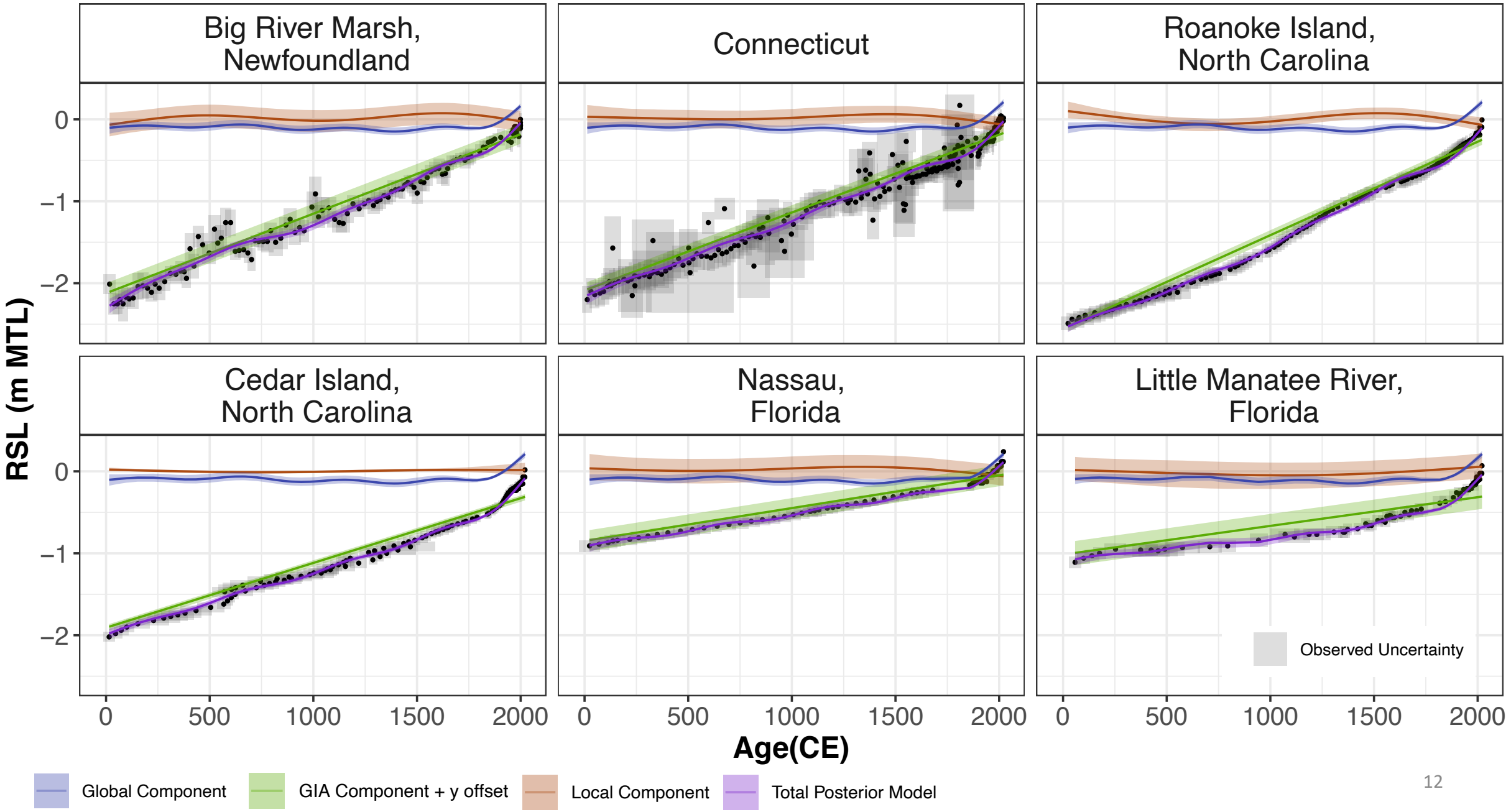
Global Component
Common across all sites represented with spline in time.

GIA Component
Random effect where $z_{\boldsymbol{x}}$ represents the different sites.

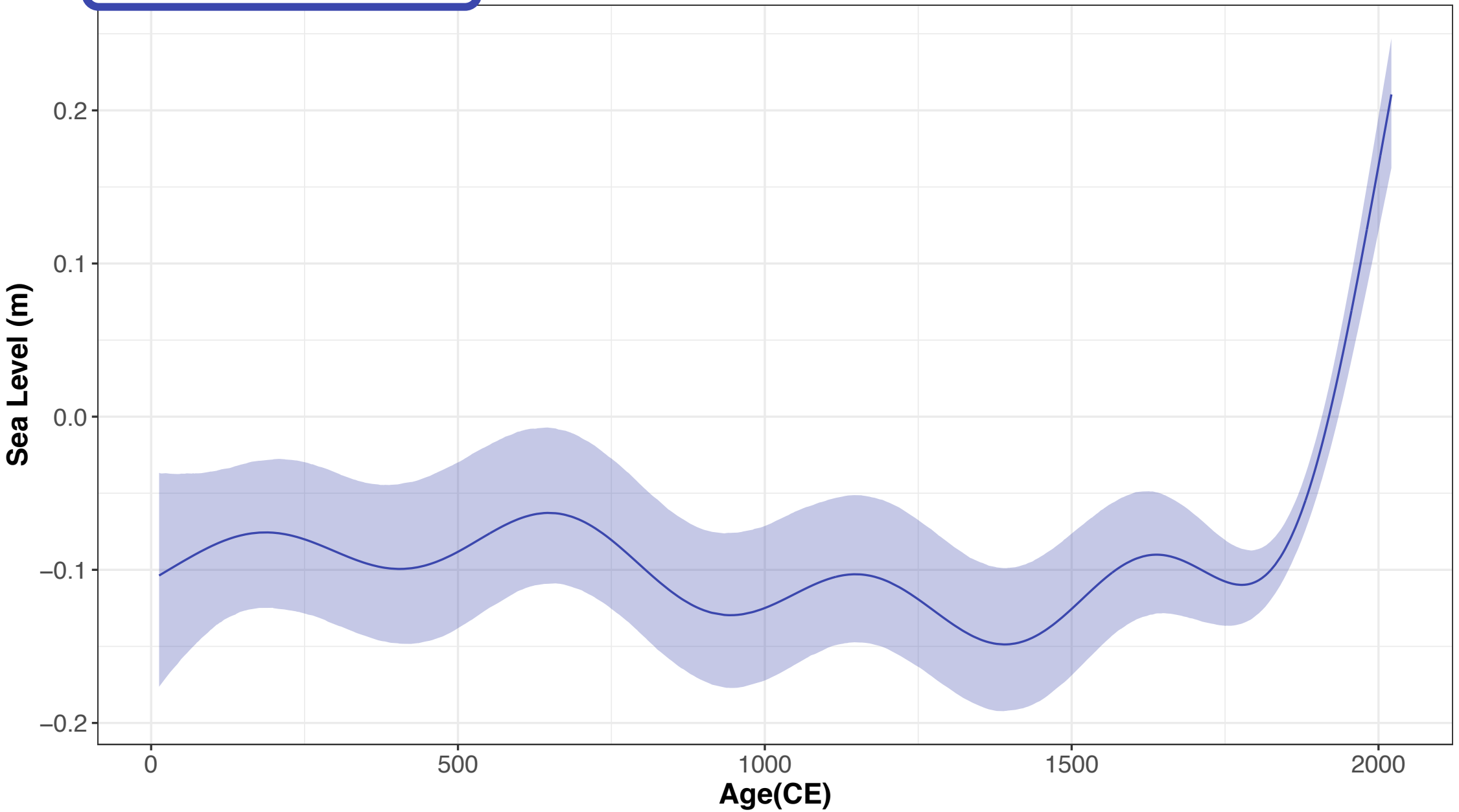
Local Component
Regionally varying, temporal nonlinear field represented with spline in space time

Results

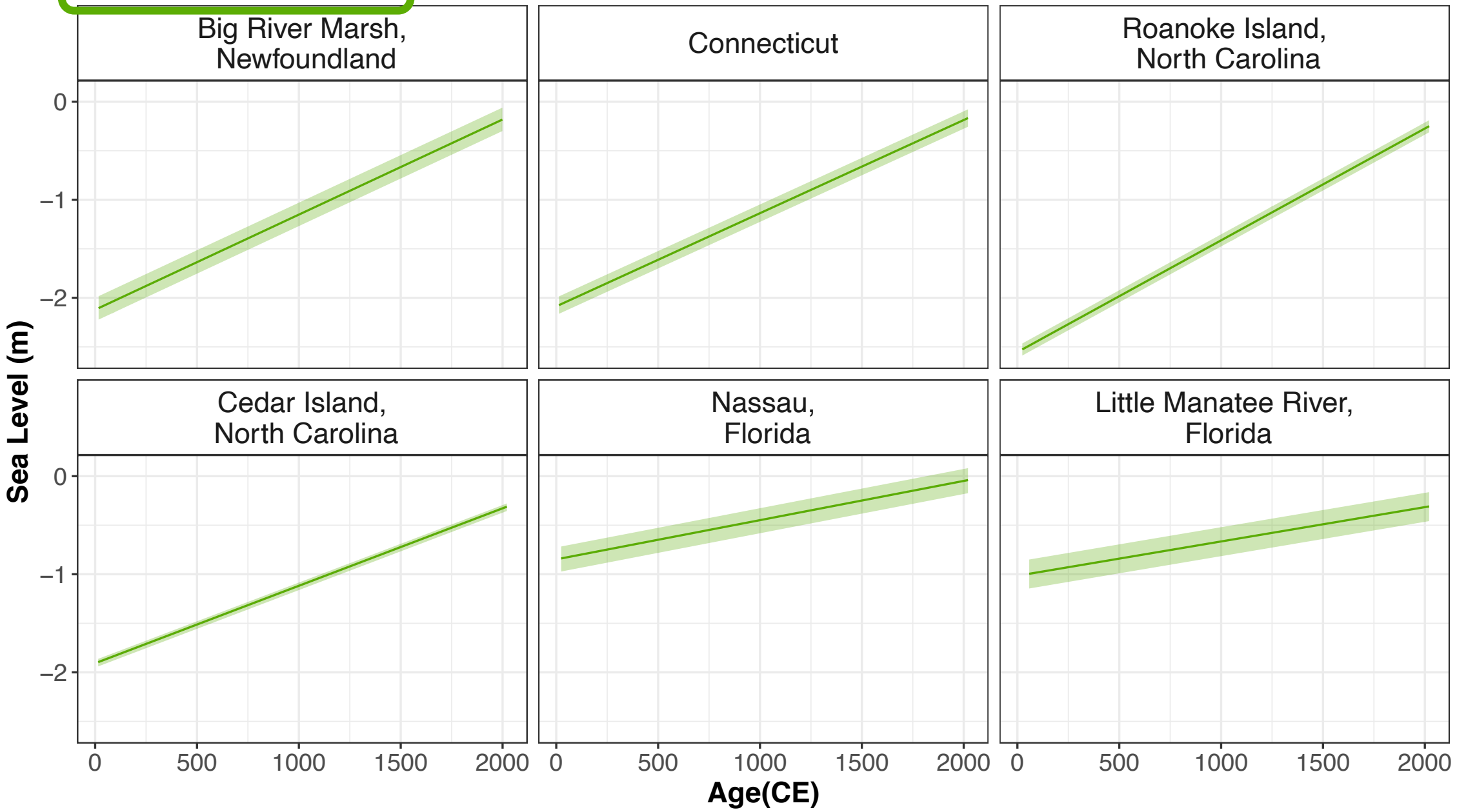
NIGAM – All components of RSL field for East coast of North America



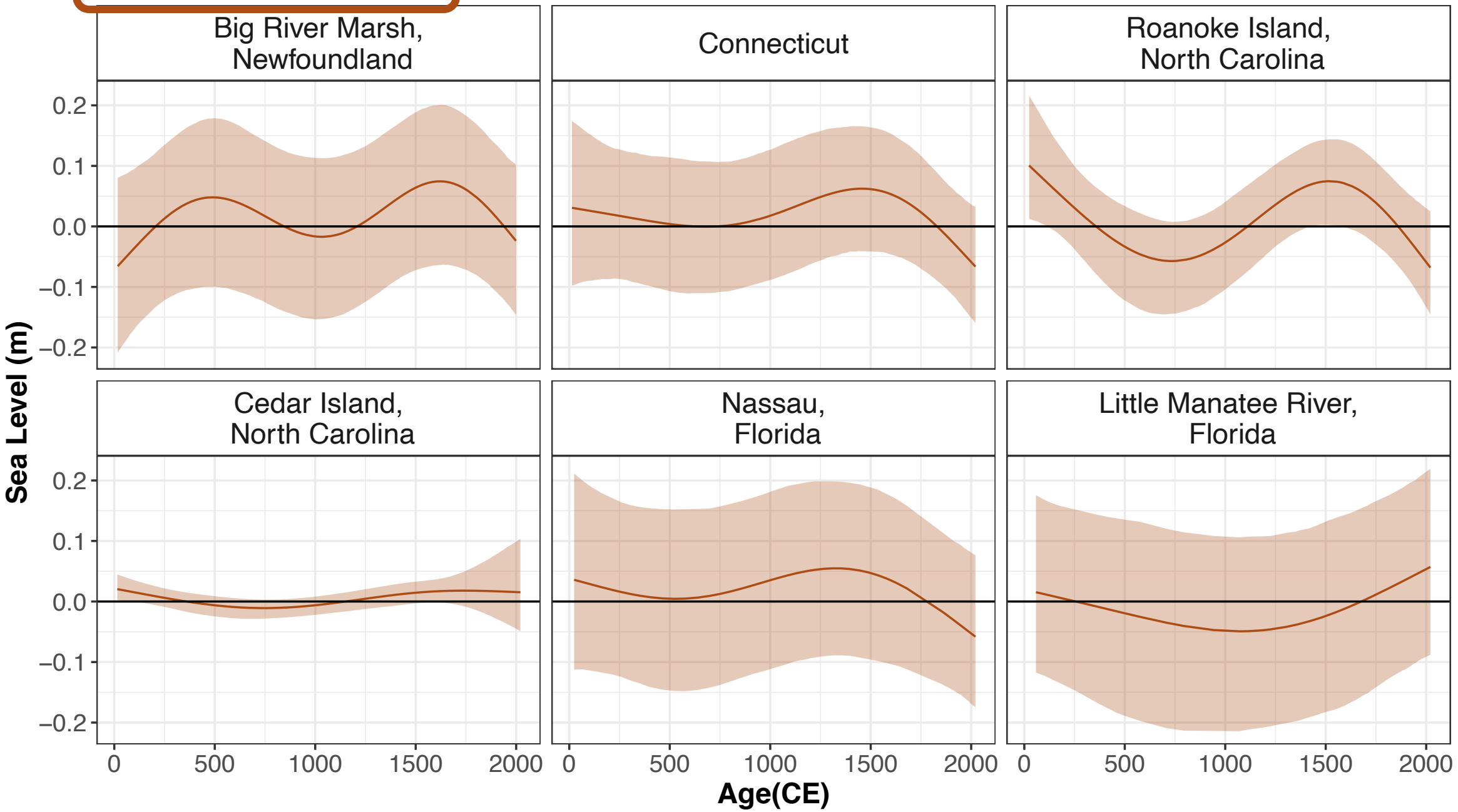
Global Component for East Coast of North America



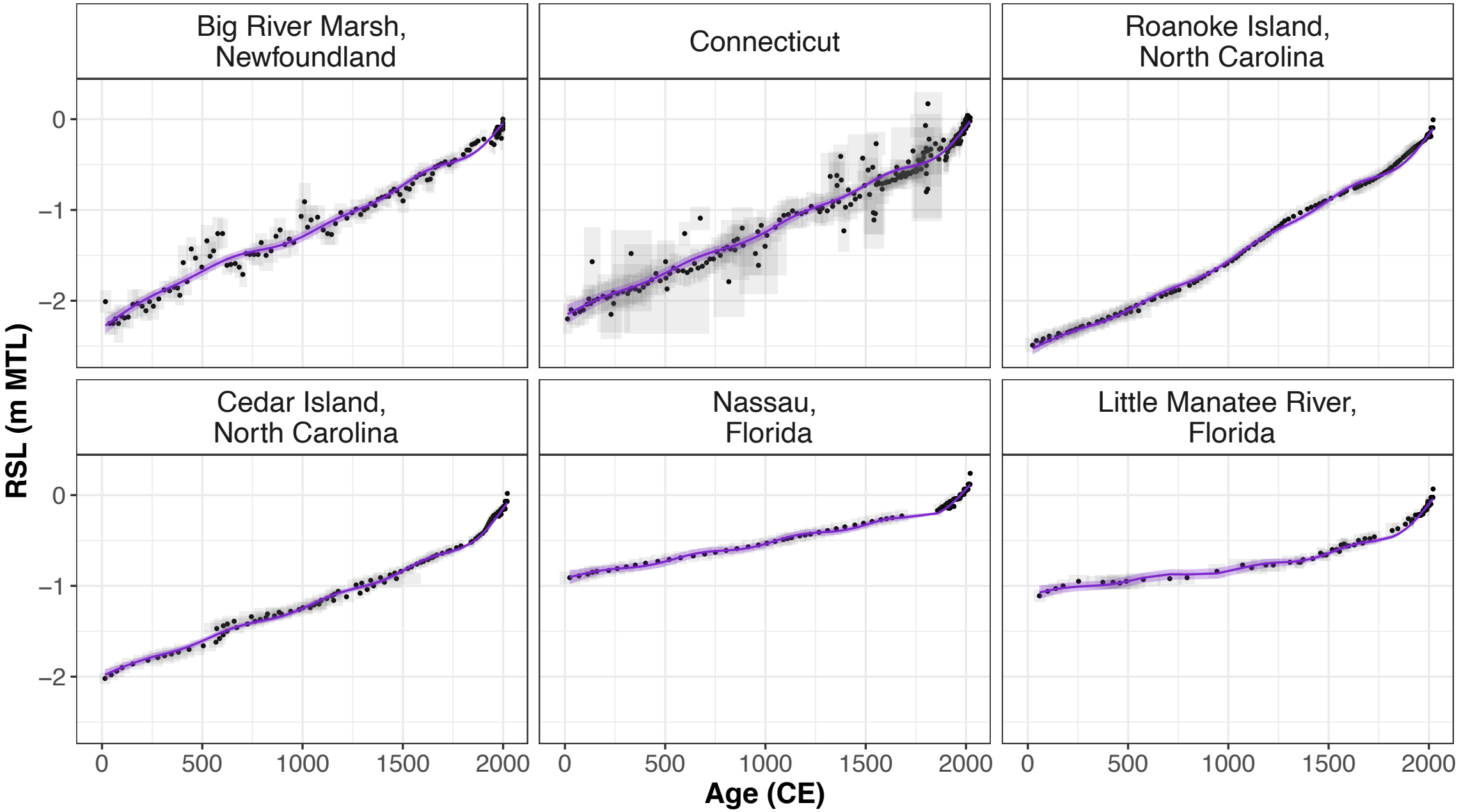
GIA Component + y offset for East Coast of North America



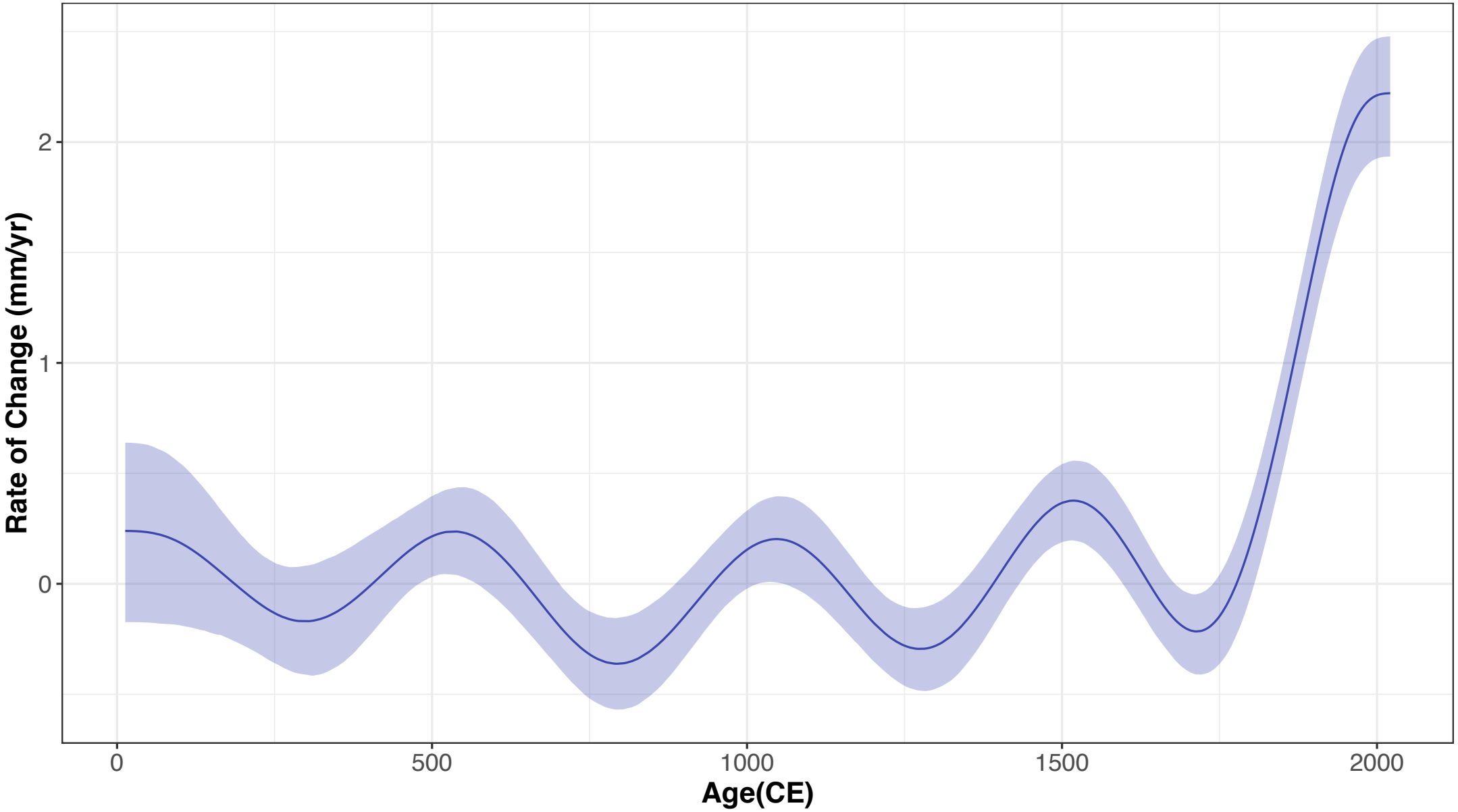
Local Component for East Coast of North America



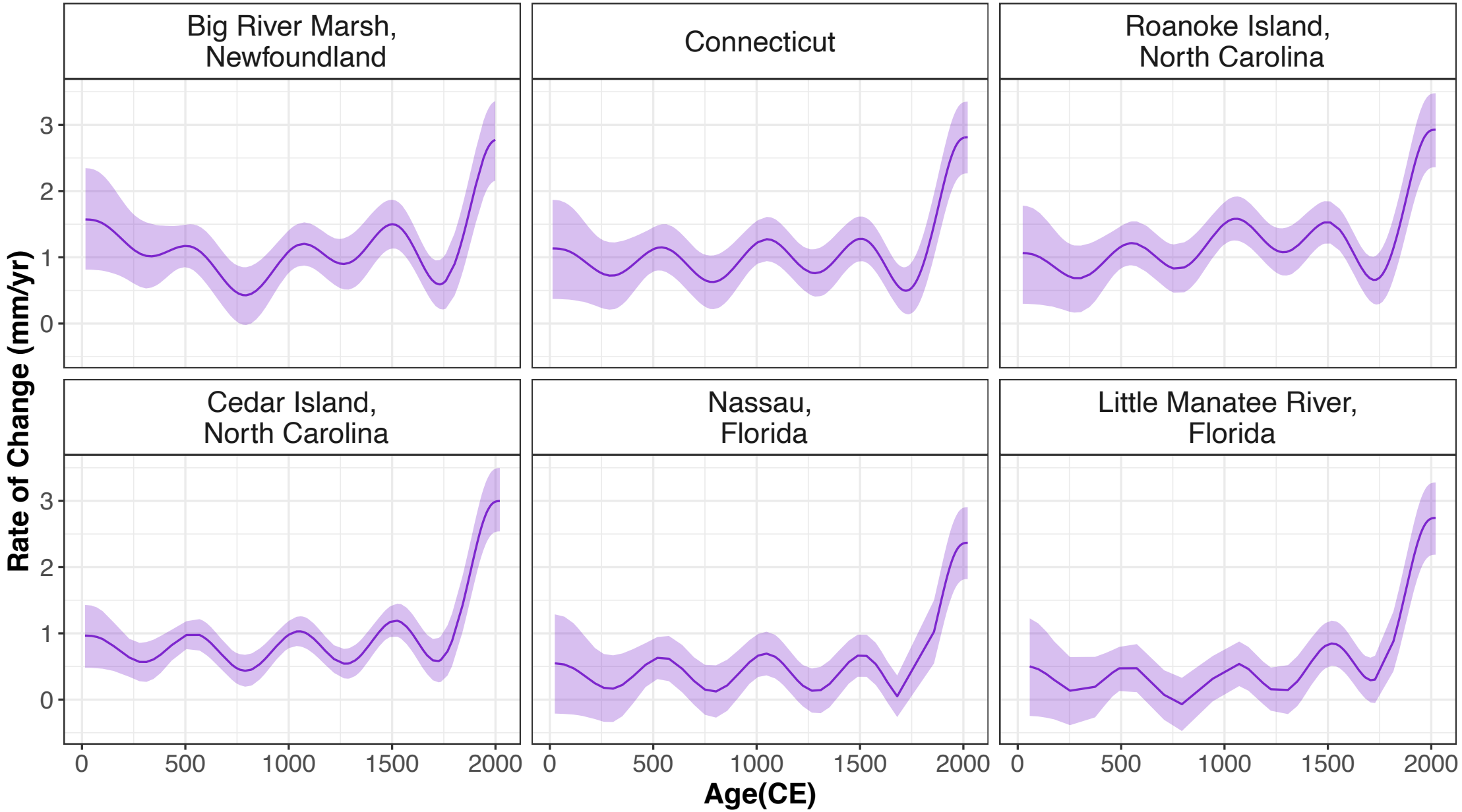
NI GAM – Total Model Fit for East Coast of North America



Rate of Change for Global Component



Rate of Change for NIGAM for East Coast of North America



Summary

1. **GAMs** allow for flexible modelling of RSL change and allow for **different components** of RSL change to be examined using **different splines**
2. GAM **reduces the computational complexity** compared with previous studies using Gaussian Processes.
3. Current sea level along North America's east coast is the **highest** it has been in at least the last **20 centuries**.

References

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[2] Data: Walker et al. (2021), Kemp et al. (2018), Kemp et al. (2013), Cahill et al. (2016), Kemp et al. (2014), Kemp et al. (2017), Khan et al (2015), Khan et al(2014)
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[5] Simpson,G. (2014), *"Modelling seasonal data with GAMs".* https://www.r-bloggers.com/2014/05/modelling-seasonal-data-with-gams/
[6] McHutchon, A., Rasmussen, C. E. (2011) "Gaussian Process Training with Input Noise", Advances in Neural Information Processing Systems
[7] Kopp, R. E., Kemp, A. C., Bittermann, K., Horton, B. P., Donnelly, J. P., Gehrels, W. R., Hay, C. C., Mitrovica, J. X., Morrow, E. D, Rahmstorf, S. (2016) "Temperature-driven global sea-level variability in the Common Era", PNAS, vol. 113, no. 38

Thank you for your attention

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