Long-term Water Temperature Trends in the Chesapeake Bay

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Background and Motivation

- To assess the effect of climate change on the water quality of the Chesapeake Bay, it is important to isolate the increase in temperature throughout the water column due to long-term climate warming conditions.
- In the past, the WQSTM estimated a slower increase in temperature near the bottom of the Bay than at the surface in response to climate change conditions.

Background and Motivation

- If this process is still in effect, it could have meaningful implications on nutrient goals, as hypoxic volume is sensitive to small changes in water temperature, especially in deep water below the pycnocline.

Background and Motivation

- Thus, we need to investigate the effect water depth has on the long term temperature trends in the Chesapeake Bay.

Literature Review

- We reviewed pertinent literature on the subject and found that climate change scenarios have been run in the Chesapeake Bay by applying a constant change in water temperatures across time and space
- The method, applied in the ChesROM model, is based on the assumption that the Bay is sufficiently shallow that any long-term change in water temperature will be constant throughout the water column.

Literature Review

- The primary evidence for this assumption was a study of long term temperature trends of surface and subsurface observations at different locations in the Chesapeake Bay published in 2004.
- This study reported ‘insignificant’ changes in long term temperature trends based on whether or not the measurements were surface (1 or less meters from surface) or subsurface (15 meters or more from surface)

Literature Review

- 1 meter or less and 15 meters or more were deemed not a complete enough look into the the effect of depth on long term temperature for our climate change applications.
- Thus, we investigated our own observation data in a similar manner to see where our data stand in comparison to literature results.

Consistency Check

Change over 30 years (degrees C) (1984-2015)

		Summer	Summer	Winter	Winter
Region	**Stations**	**Surface**	**Bottom**	**Surface**	**Bottom**
Upper Bay	**CB2.2**	**0.96**	**1.31**	**-0.60**	**-1.00**
Deep trench	**CB3.2, CB4.2C, CB5.2C**	**0.96**	**0.35**	**-0.88**	**0.00**
Rappahannock Shoals	**CB6.1**	**0.95**	**0.84**	**0.92**	**0.58**
North open boundary	**CB7.4N**	**0.37**	**0.55**	**1.60**	**1.93**
Central open boundary	**CB7.4**	**0.75**	**0.0**	**1.08**	**1.29**
South open boundary	**CB8.1E**	**0.86**	**0.95**	**1.73**	**1.64**

Methods

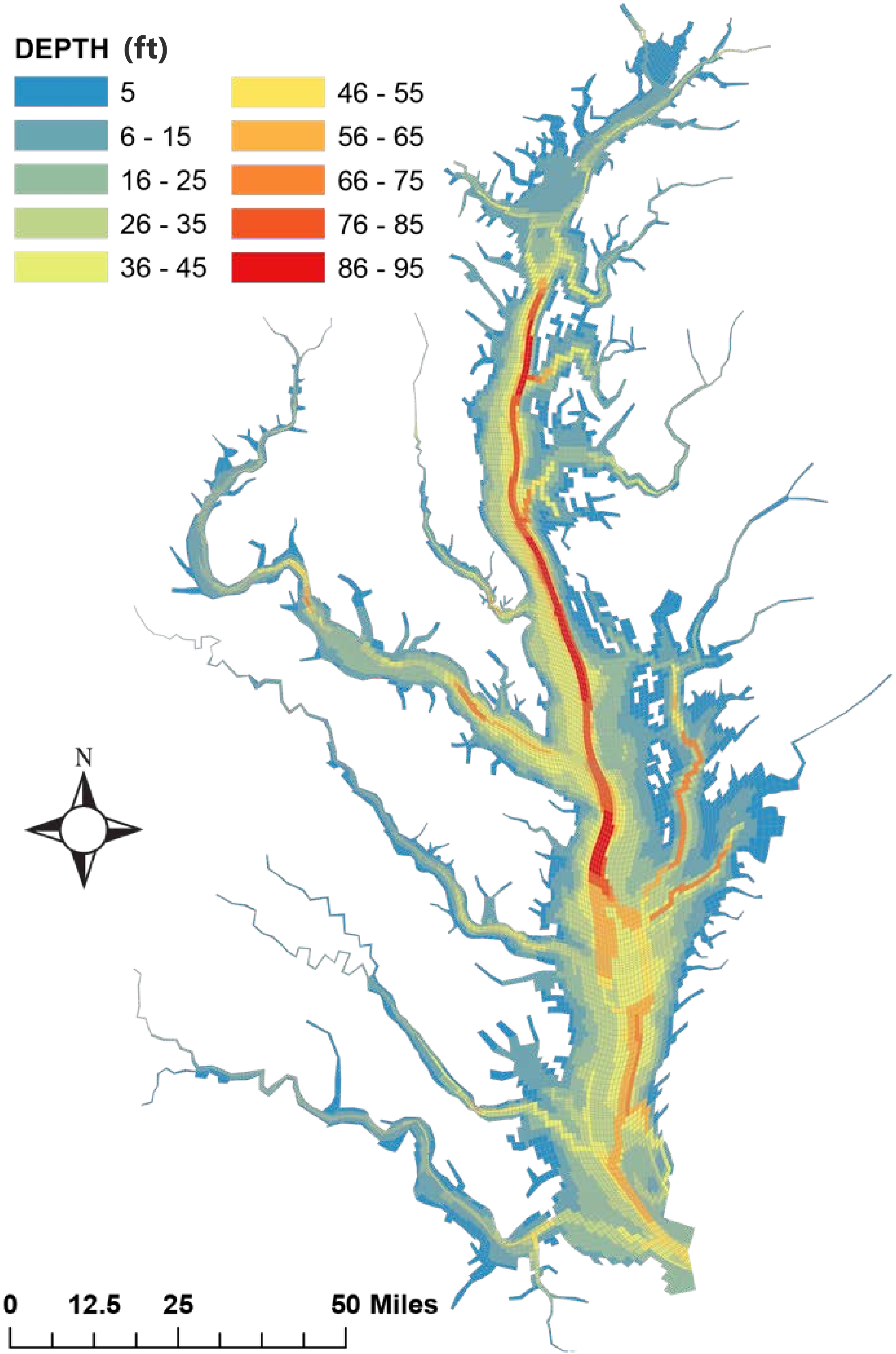
- We approached this investigation from three main points-of-view
  - Further investigation of observed data via subsets and simple linear regression over time
  - Bayesian multiple linear regression on observed data with variable interactions to assess probability of slope values
  - Investigation of WQSTM estimates over a 30 change in climate forcing

Methods – Observed Data

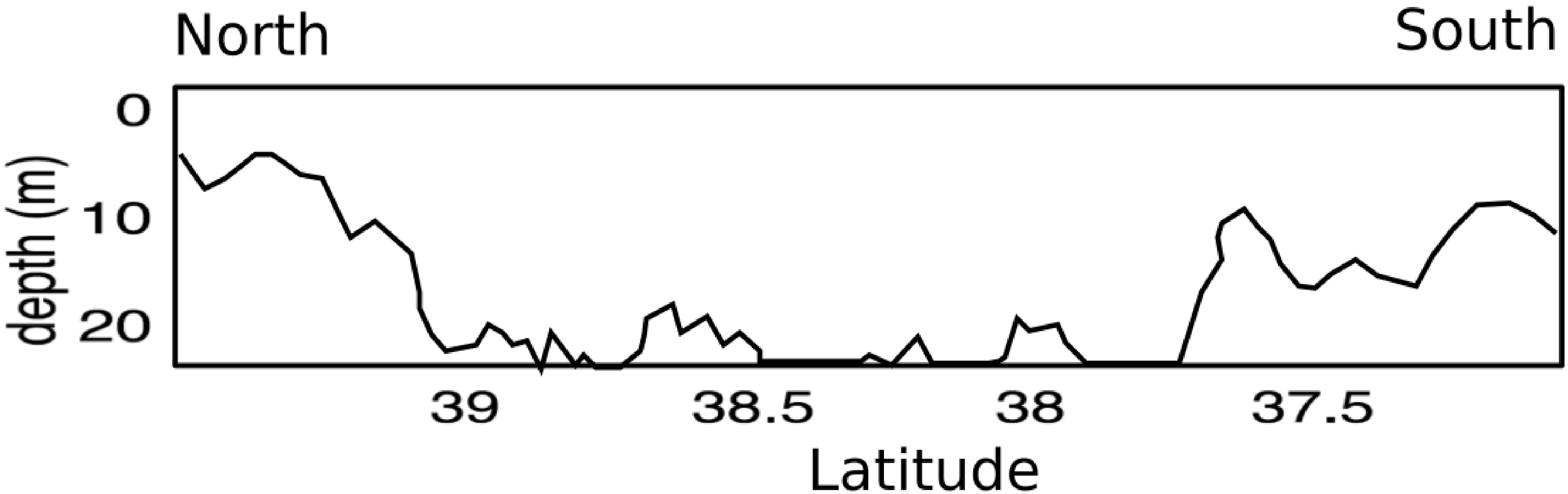
- We studied observations in two major ways:
  - By splitting up the data into meaningful unique subsets and performing individual simple linear regressions
  - By including multiple variables in single data sets, rather than using them to subset the data, and performing Bayes multiple linear regressions to measure the independent and interactive effects of depth

Methods – Observed Data

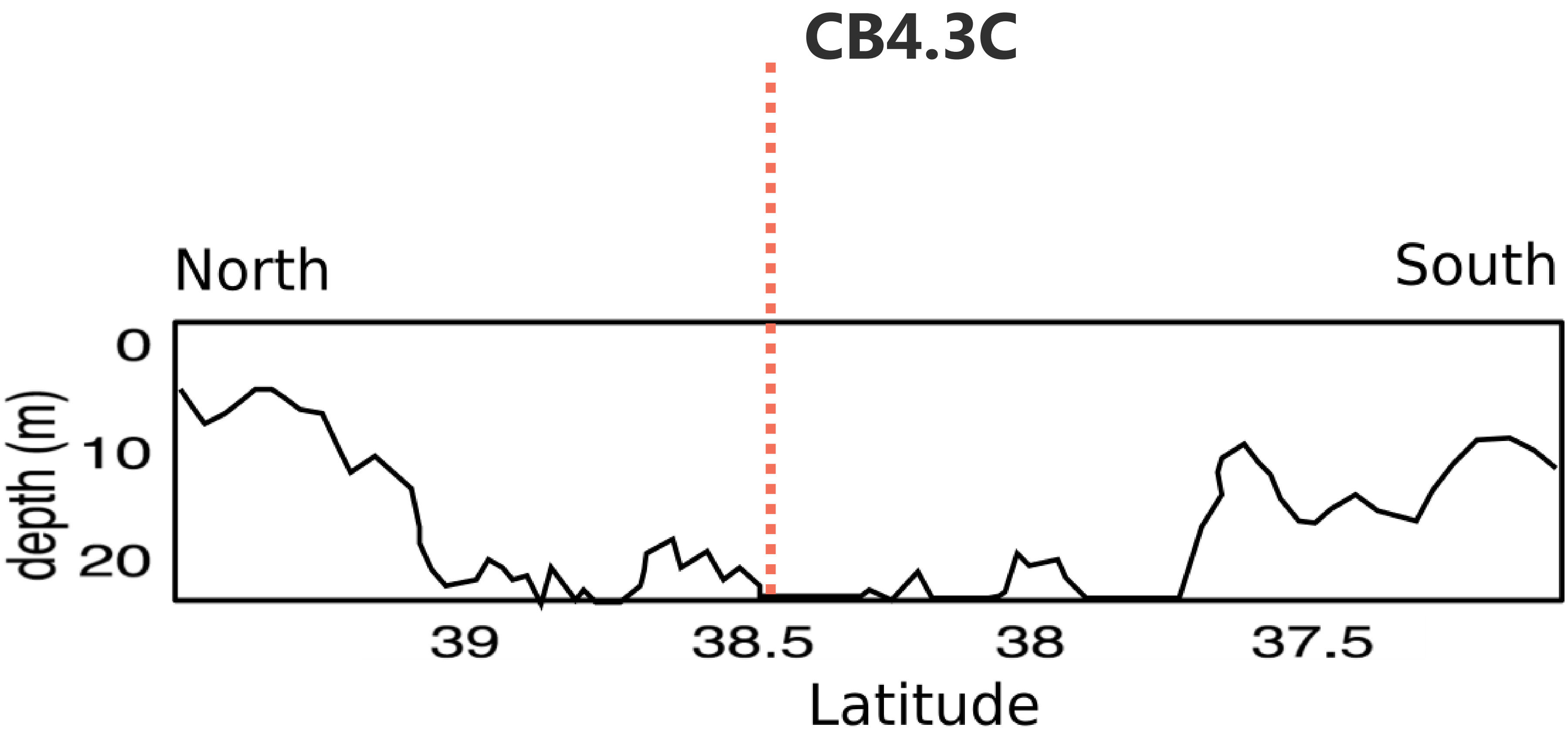
- In both cases using observed data, the analysis is performed by unique station


DEPTH (ft)
5
6 - 15
16 - 25
26 - 35
36 - 45
46 - 55
56 - 65
66 - 75
76 - 85
86 - 95
N
0 12.5 25 50 Miles

Methods – Observed Data



Methods – Observed Data



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Methods – Data Subsets

By splitting up the data into meaningful unique subsets and performing individual simple linear regressions, we could investigate the long-term slope from many “points-of-view”

- Advantages → simple and quick
- Disadvantages → variable quality, hard to check all assumptions

Methods – Bayes Regression

By including multiple variables in single data sets, rather than using them to subset the data, and performing Bayes multiple linear regressions to measure the independent and interactive effects of depth

- Advantages → Convenient equations to estimate slope and isolate effects, probabilistic interpretation
- Disadvantages → requires priors, takes longer to build and quality control model

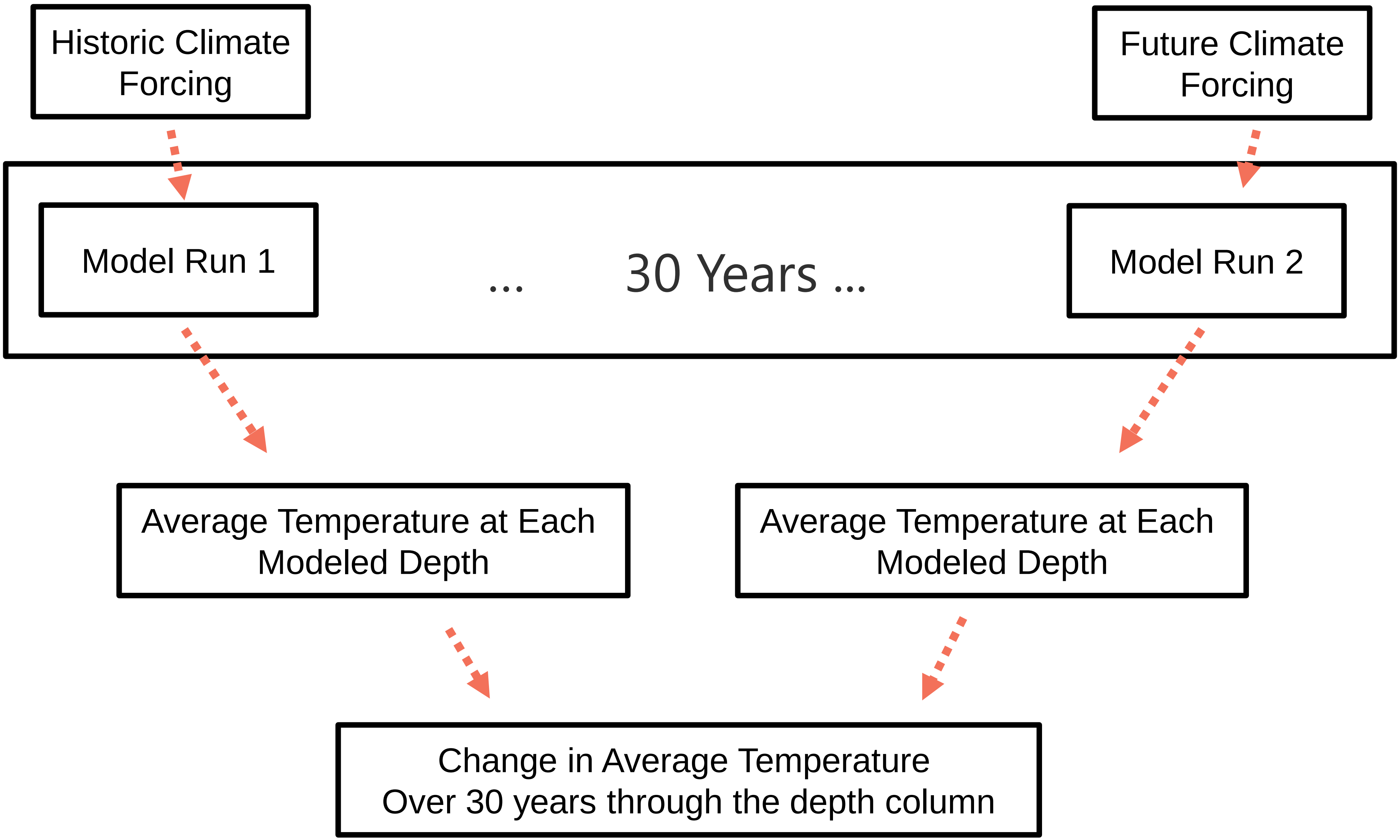
Methods – Model Estimates

- Additionally, we investigated our WQSTM estimates to quantify the long term temperature trends in the Bay across the depth column.
- Differences in water temperature in model estimates are due to climate forcing data (i.e., hotter air temp and changing conditions at the open boundary cause the Bay water column temperature to increase).

Methods – Model Estimates

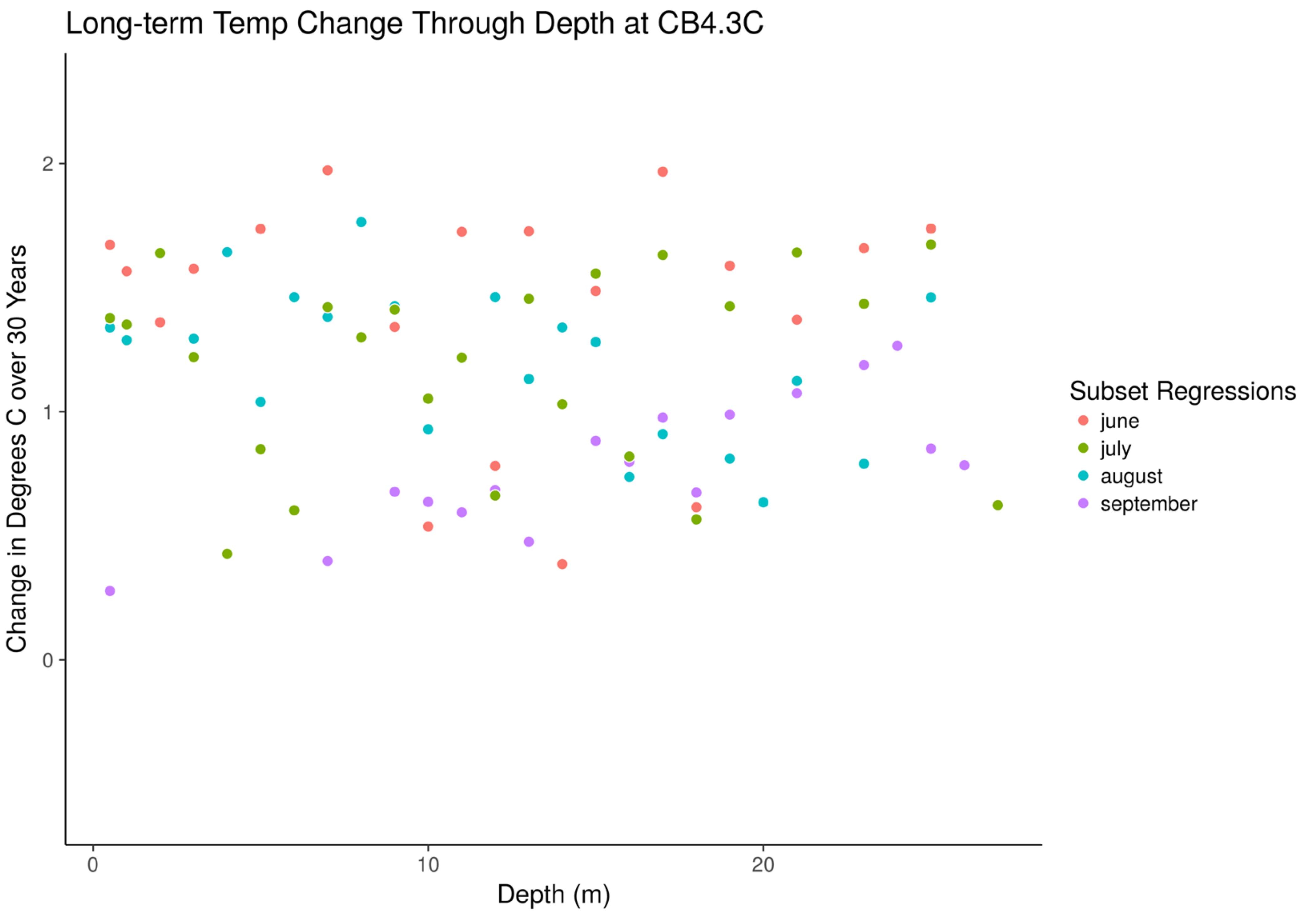
- Two ten year WQSTM runs were performed to investigate the modeled temperature trend.
- These runs were 30 years apart, and the temperature change was calculated by comparing differences in the average water temperatures between the runs

Methods – Model Estimates



Results – Data Subsets

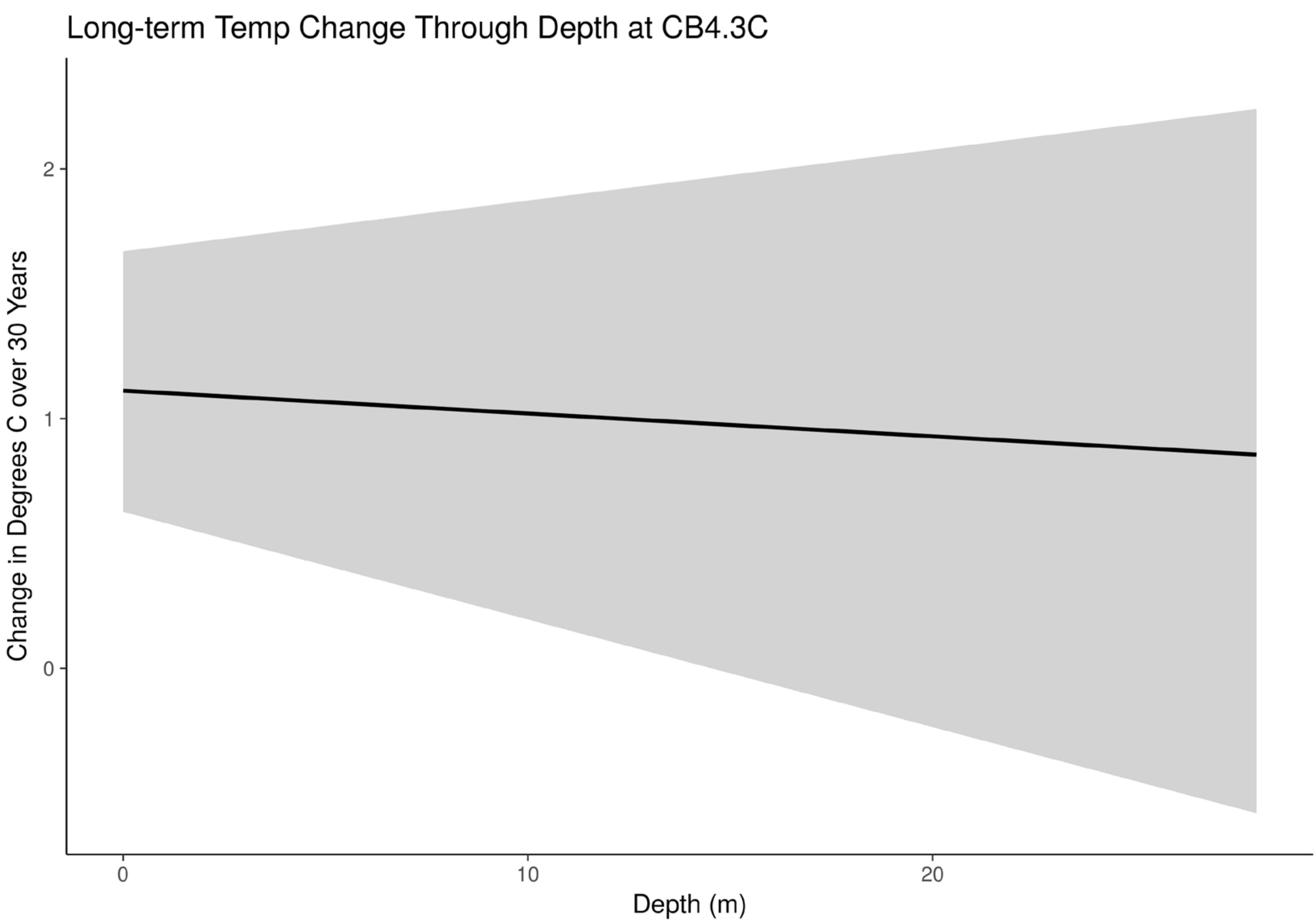
- Looking at simple linear trends from pertinent data subsets is useful to quantity the effect depth has on temperature in various locations in time and space.



Long-term Temp Change Through Depth at CB4.3C
Change in Degrees C over 30 Years
Depth (m)
0
1
2
0
10
20
Subset Regressions
june
july
august
september

Results – Bayes Interactions

- Using more data and a more complex modeling process assuming interactions between features, the probability of the slope values can be plotted as a surface.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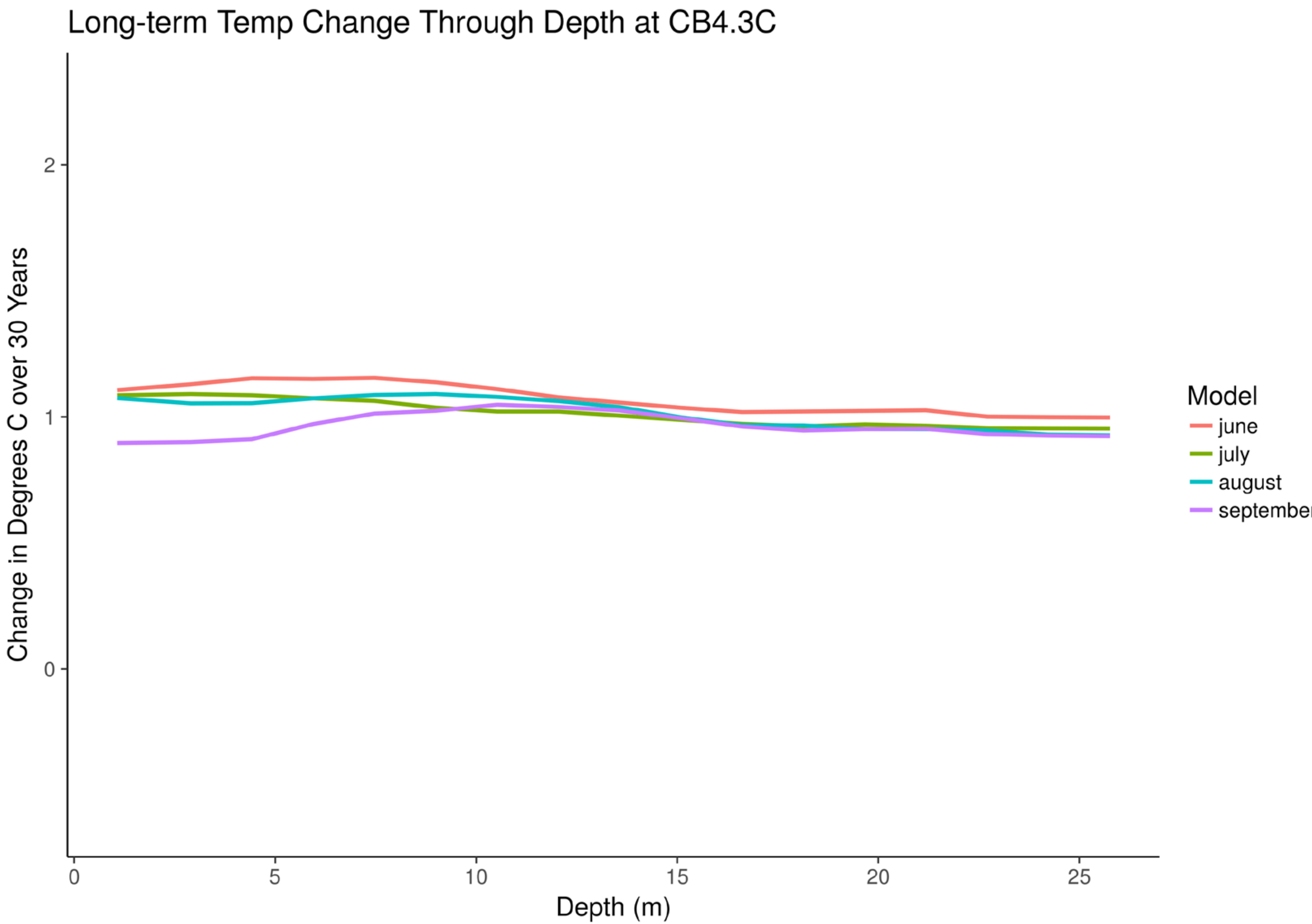
Result – Model Estiamtes

- Modeled estimates are not missing any values, and make smooth lines across depth for each month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Change in Degrees C over 30 Years
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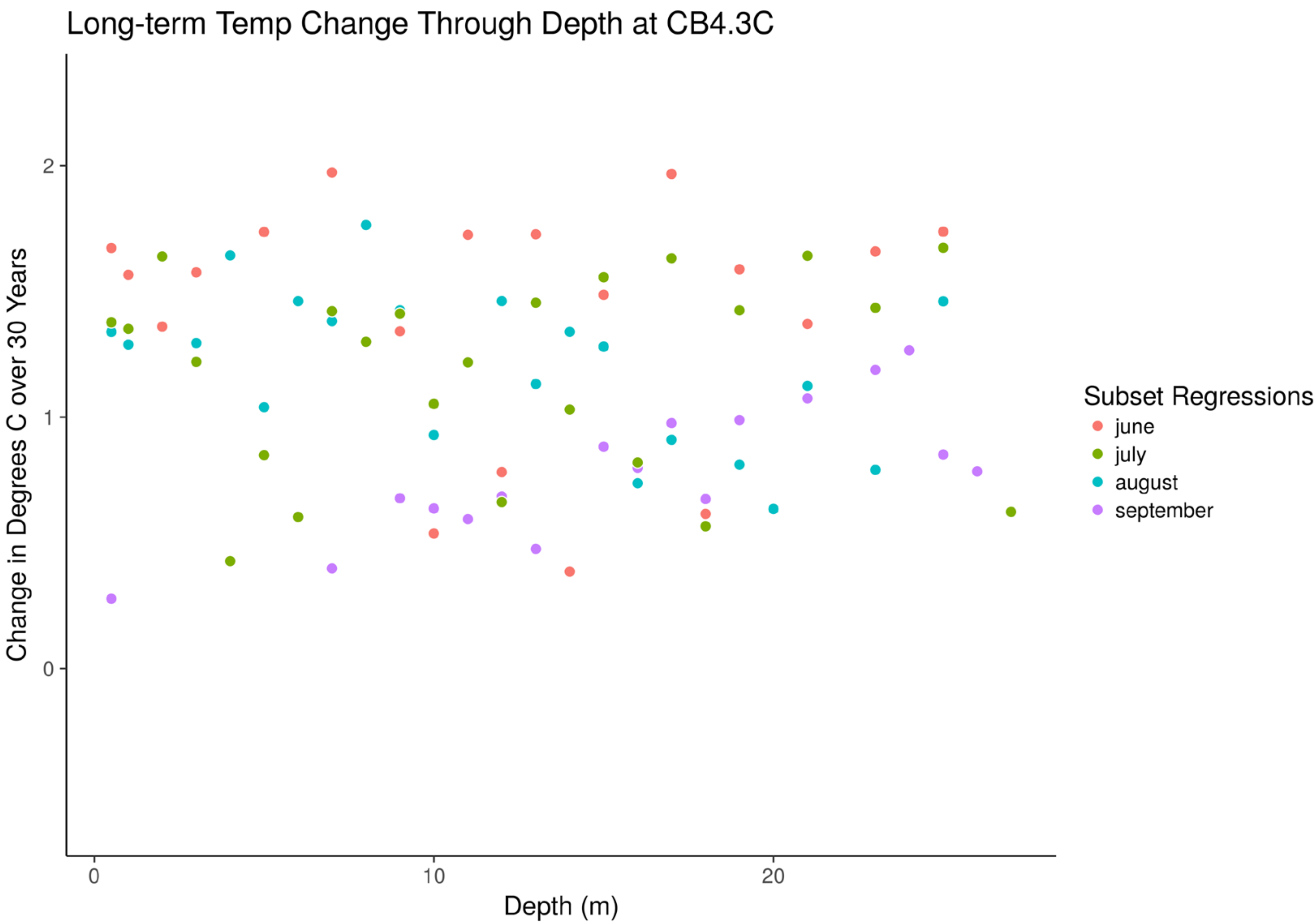
1
0
0
5
10
15
20
25
Depth (m)
Model
june
july
august
september

Discussion

- The methods suggest depth has some effect that changes when viewed from different portions of the year, but it seems to be small
- Additionally, the WQSTM estimated effect depth has on our long-term temperature trend is within reason compared to our statistical analysis of observed data.

Discussion

- Lets go back through the results and overlay them in order of process complexity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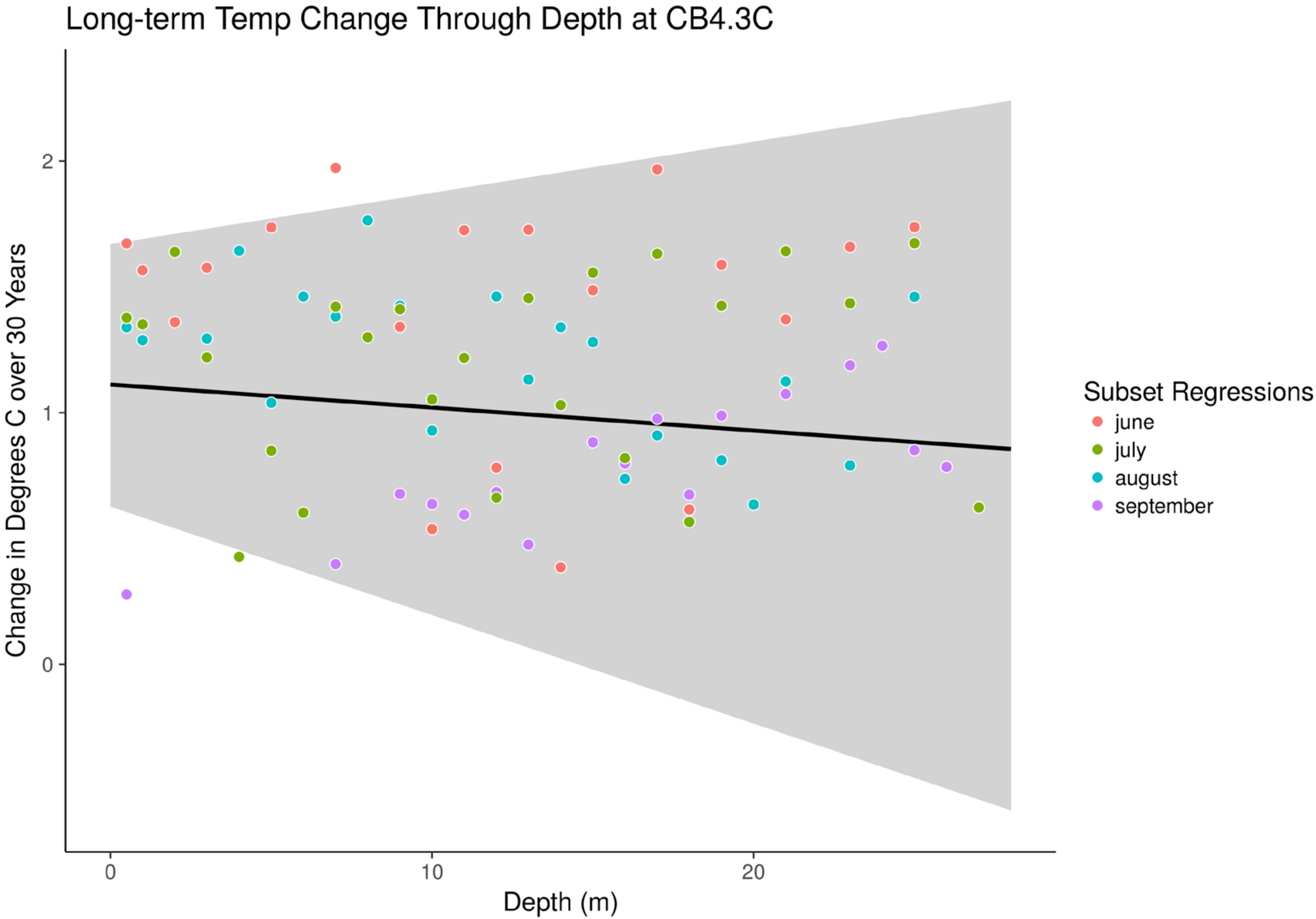
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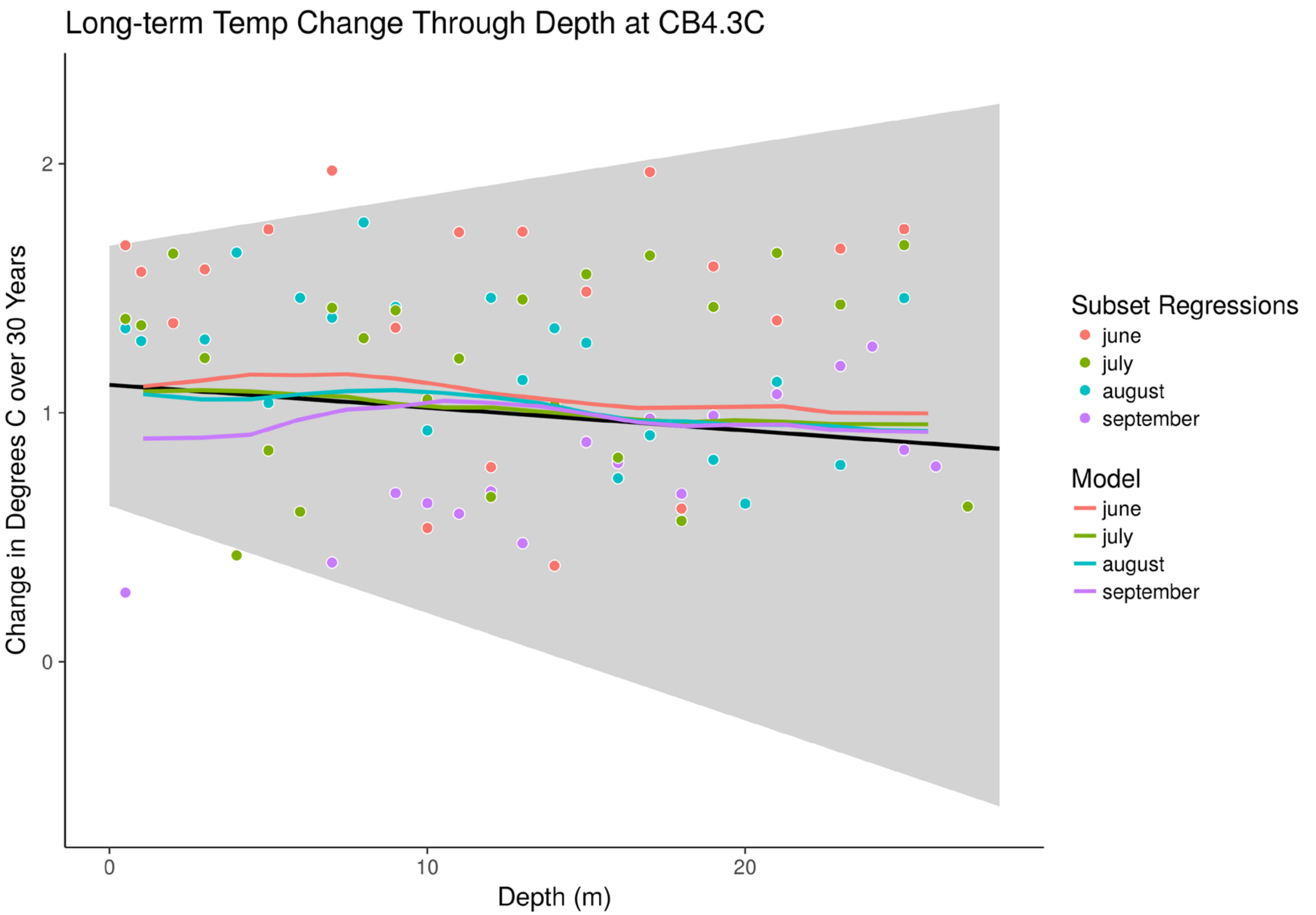

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Summary

- So far, we have a lot of agreement between our different statistical models for observed data, and our modeling process

Next Steps

- Perform statistics on more stations
- Model the 2050 scenario