



# Using In-situ pCO<sub>2</sub> Observations to Evaluate Trends in Ocean Carbon Sink: A North Atlantic Case Study

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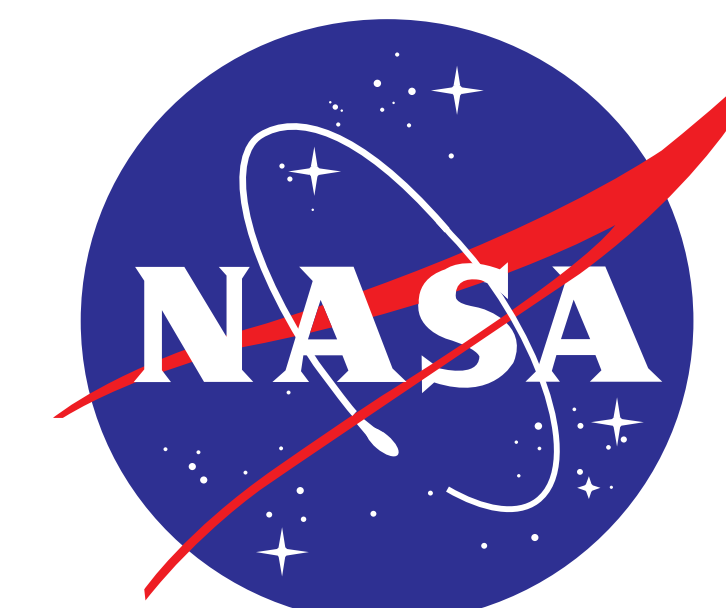


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## I. OVERVIEW/GOAL

The world's oceans are an important sink for atmospheric CO<sub>2</sub>, which is rising primarily due to anthropogenic fossil fuel burning and deforestation.

The North Atlantic region is a particularly strong CO<sub>2</sub> sink due to its vertical circulation and biological productivity (Takahashi et al. 2002). However, both spatial and temporal variability persist in its uptake patterns. This variability, along with limited available pCO<sub>2</sub> data, limits our ability to predict interannual and decadal changes in ocean carbon uptake (Gruber et al. 2002).

Schuster et al (2009) suggests a decreasing sink in the subpolar gyre and an increasing sink in the subtropical gyre. We strive to confirm these trends using recently released pCO<sub>2</sub> database of Takahashi et al. (2009).

**GOAL: (1) Evaluate pCO<sub>2</sub> trends in the North Atlantic with 0.9 million points now available through Takahashi's 2010 dataset and (2) Include robust error estimates.**

## III. BIOMES

Limited data availability makes analyzing pCO<sub>2</sub> trends in uniform size grid boxes difficult. Large portions of the basin contain insufficient data to conduct viable analysis of trends.

We subdivide the North Atlantic Ocean into biomes based on climatological observations of chlorophyll-a, SST climatology, and mixed layer depth. Using guidelines proposed in Sarmiento et al (2004), we formed 5 biomes:

- Marginal sea ice biome (ICE)
- Subpolar biome (SPO)
- Seasonally stratified subtropical biome (SSS)
- Permanently stratified subtropical biome (PSS) and
- Low-latitude upwelling biome (LLU).

We use no model output in biome selection. Further subdividing each biome into east/west and north/south regions confirms consistency over the entire biome.

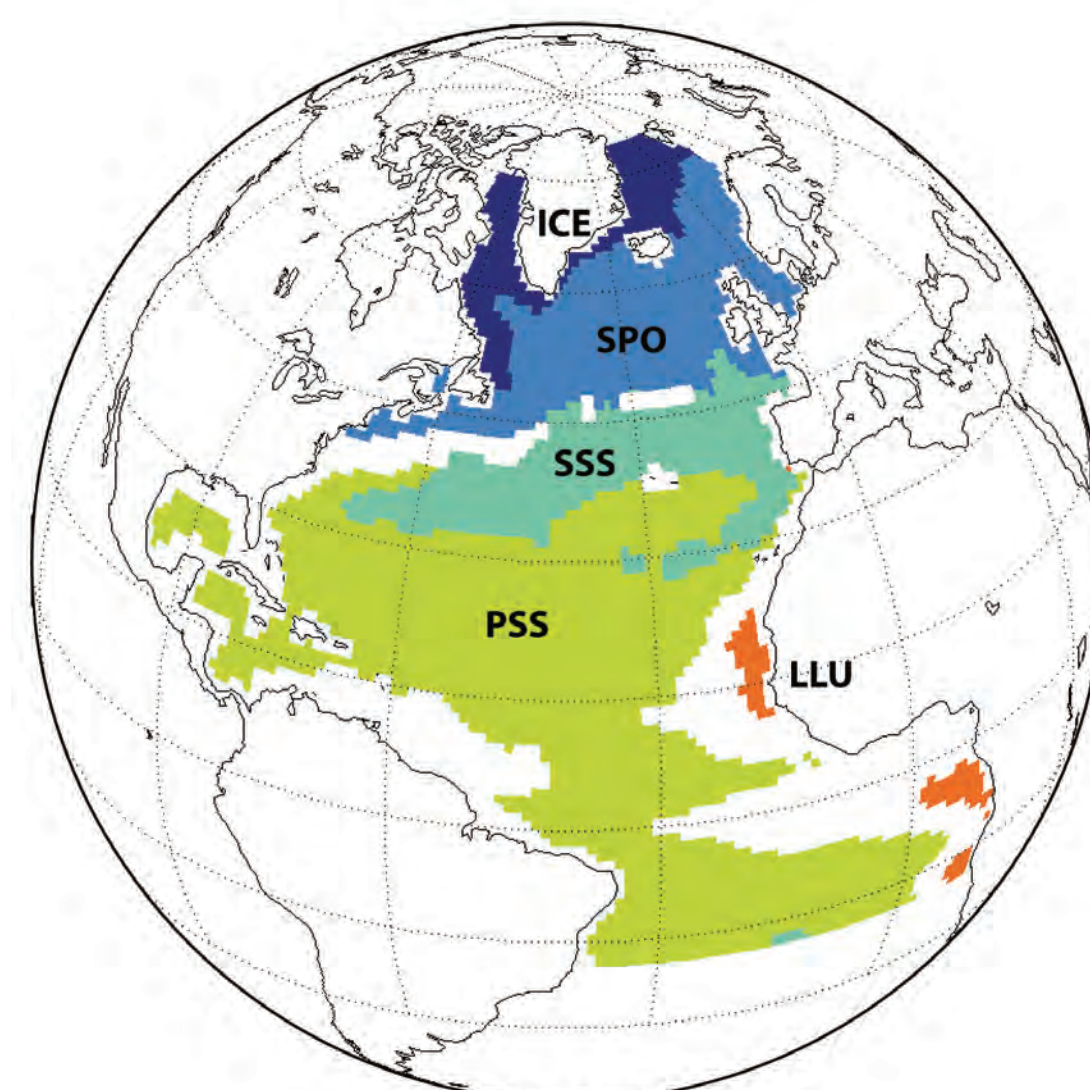


Figure 2: North Atlantic Biomes

## V. FINDINGS

Regardless analysis method, the data indicate, with 95% confidence, that oceanic pCO<sub>2</sub> trends are not significantly different from the observed atmospheric increase rate of 1.8 μatm/year.

Harmonic fit analysis results in slightly smaller error bars on linear trend as compared to a simple linear fit to monthly mean values.

More observations are needed during all seasons of the year in order to minimize the confidence intervals and detect a significant trend.

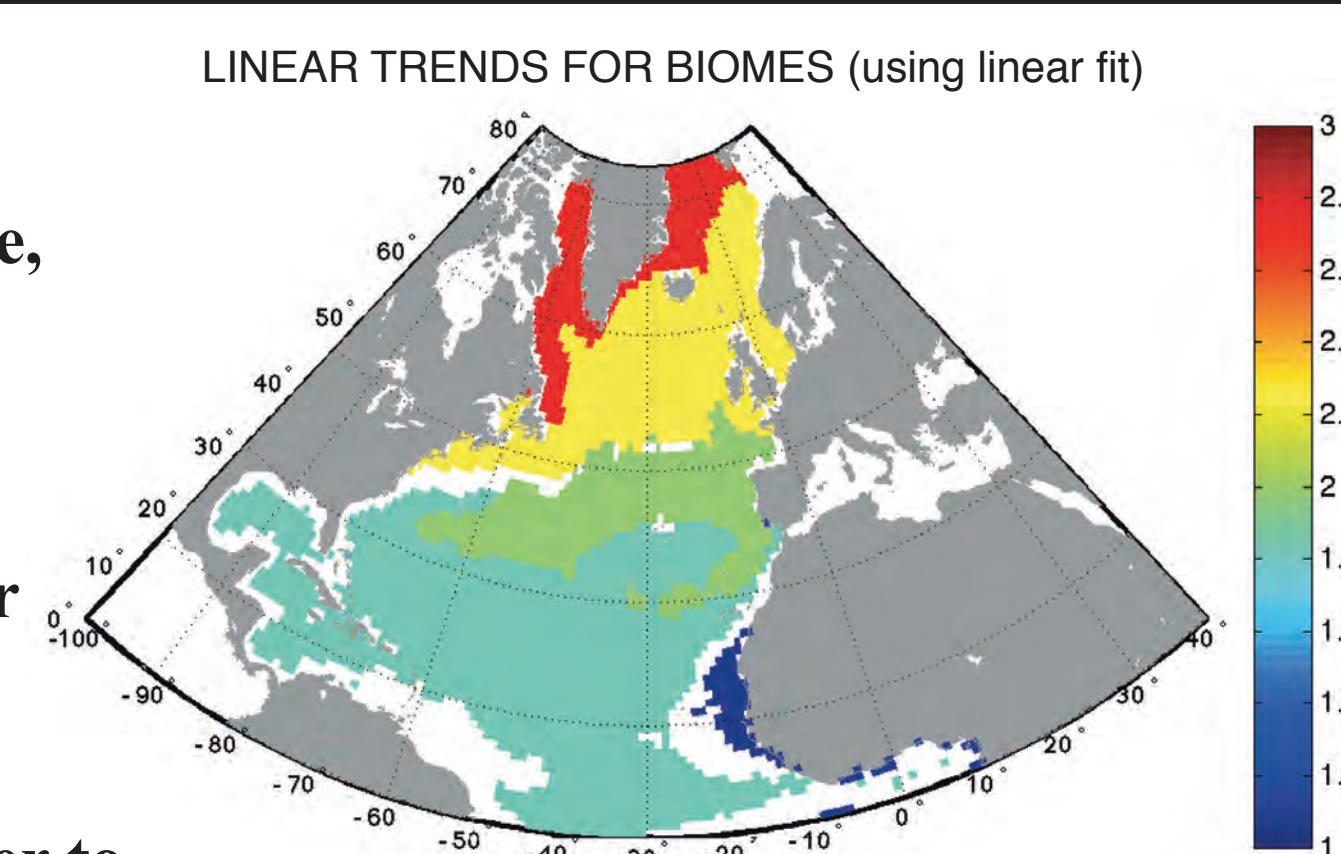


Figure 7: Map of North Atlantic showing annual increase of pCO<sub>2</sub> (μatm/year). See Figure 6 for error bars.

## VI. FUTURE WORK

Continue work to determine best choice for N.

Evaluate robustness of trend estimated by model analysis with sampling.

## REFERENCES

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## II. TAKAHASHI DATASET

Nearly 1 million VOS observations are available for the North Atlantic, spanning the years 1980 through 2009.

Takahashi's dataset (updated Jan 2010) is available at the Carbon Dioxide Information and Analysis Center and can be downloaded through the LDEO database online at <http://cdiac.ornl.gov/oceans/doc.html>

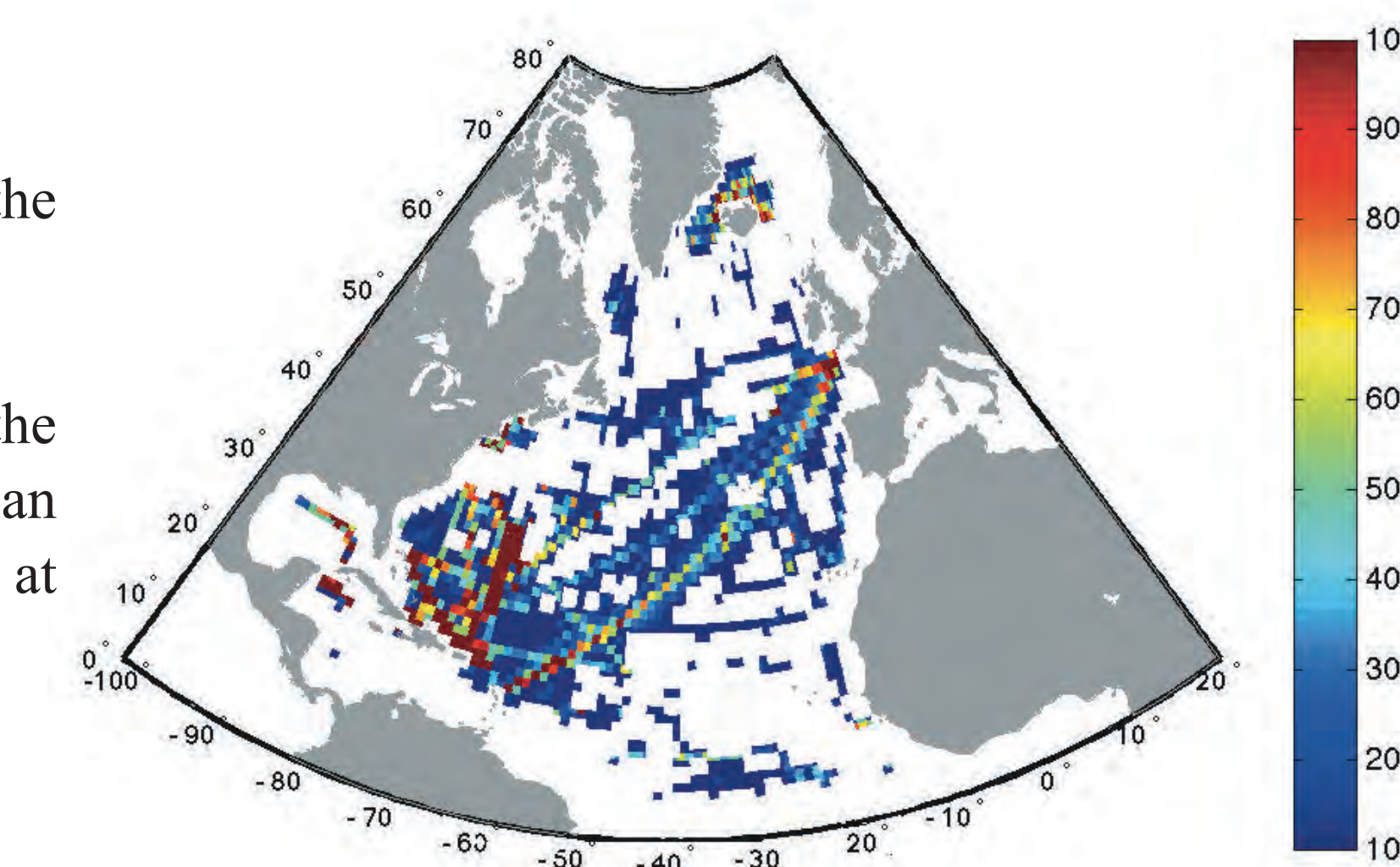


Figure 1: North Atlantic observation concentration using 2010 database

## IV. STATISTICAL ANALYSIS

Determining trends and errorbars requires:

- (1) Selection of timespan
- (2) Harmonic fit
- (3) Determination of N (degrees of freedom)
- (4) Comparison to linear fit

### (1) TIMESPAN

Changing the time span significantly changes trend estimates. Both trend estimates and error bars consistently overlap in each biome (Figure 3).

**We find that using all available values for a region is the best choice, despite skewed temporal spread (Figure 4).**

### (2) HARMONICS

We evaluate various analysis methods including two and three harmonics fit to all the data as well as fit to only monthly mean data. **No significant improvement was gained when using all data or when including a 3rd harmonic.**

### (3) DEGREES OF FREEDOM

Assuming all observations are independent results in negligible error bars due to large N values (>100,000). We feel this is unreasonable since observations are correlated due to:

- spatial proximity
- seasonal cycle
- large-scale climate forcings

McKinley et al. (2010) show with a model, that near Greenland, pCO<sub>2</sub> observations within 10° are highly correlated (R > 0.8) and cannot be considered independent. N equal to the number of months containing data is more appropriate.

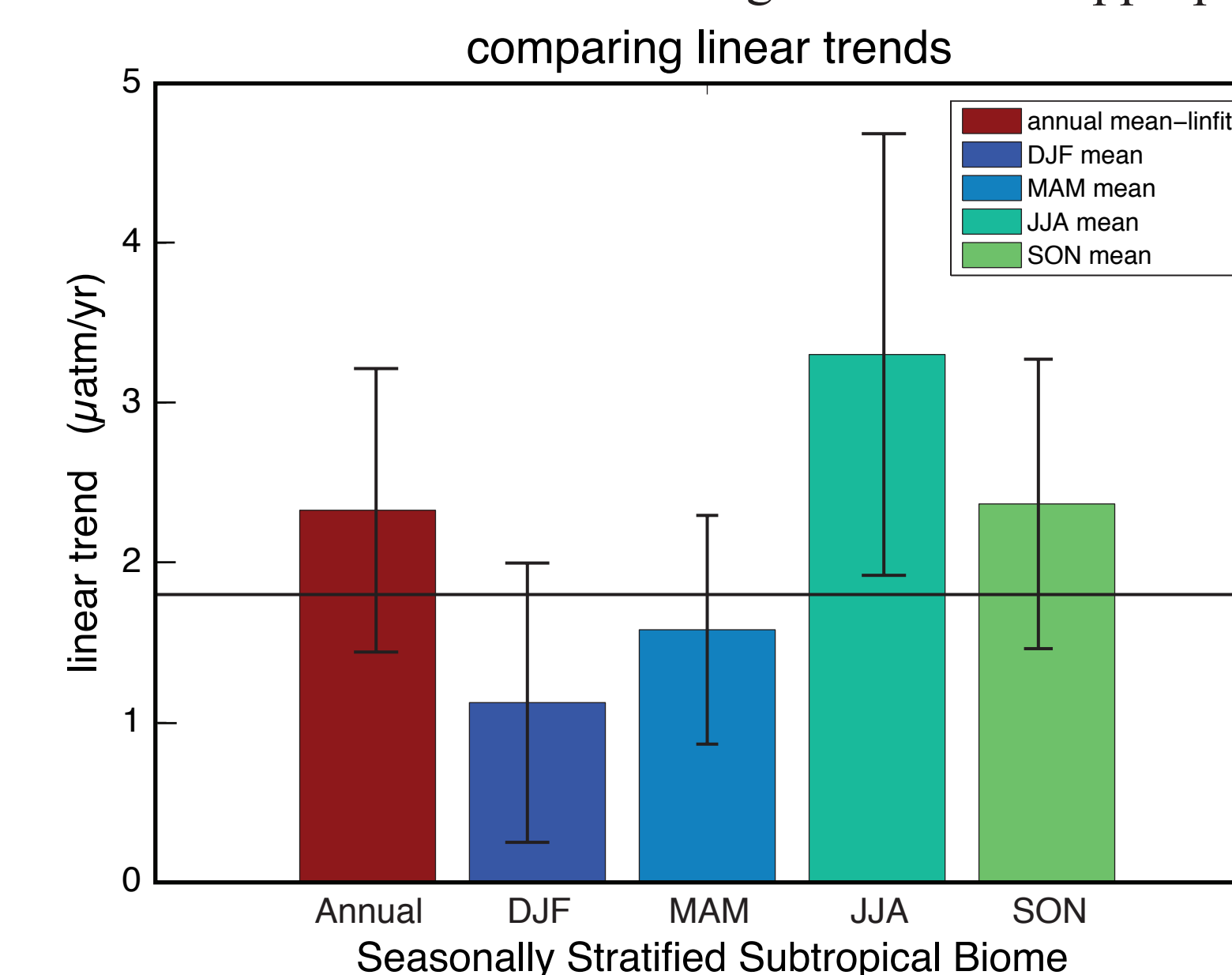


Figure 5: Comparison of seasonal trends using a simple linear trend fit to mean annual values for the seasonally stratified subtropical biome

### HARMONIC VS. LINEAR FIT

Using a harmonic fit to the data does not give a significantly improved result as compared to a simple linear fit assigned to the monthly mean values. Figure 6 shows the comparison along with 95% confidence error bars. **All 5 biomes are in agreement- neither method results in a trend significantly different from the atmospheric trend (1.8 μatm/year).**

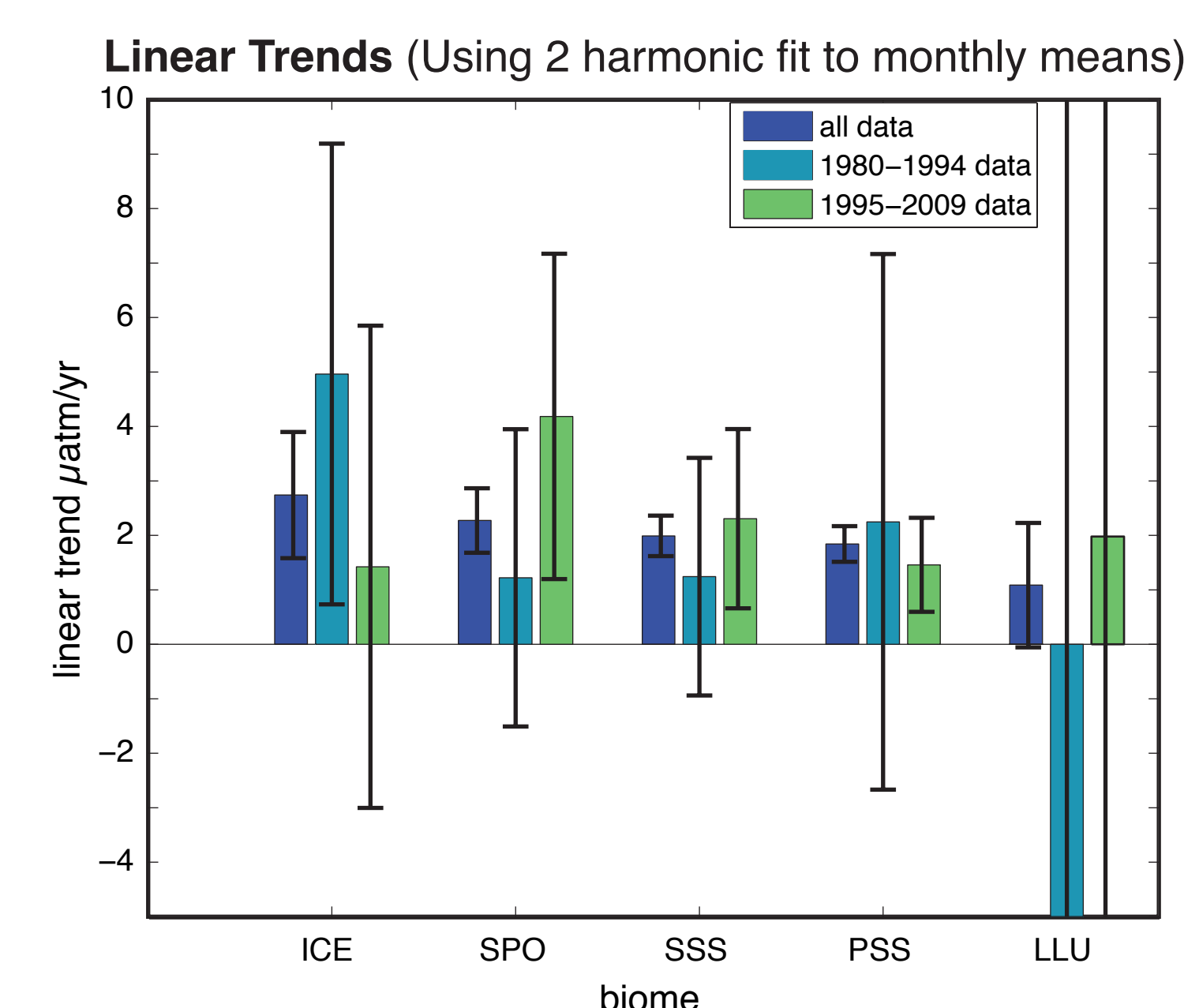


Figure 3: Linear trend comparison for two harmonics fit to temporal subsets of data for each biome. Error bar size is determined by N values (N = 83 for all data vs. N = 47 for pre95 and N=36 for post95)

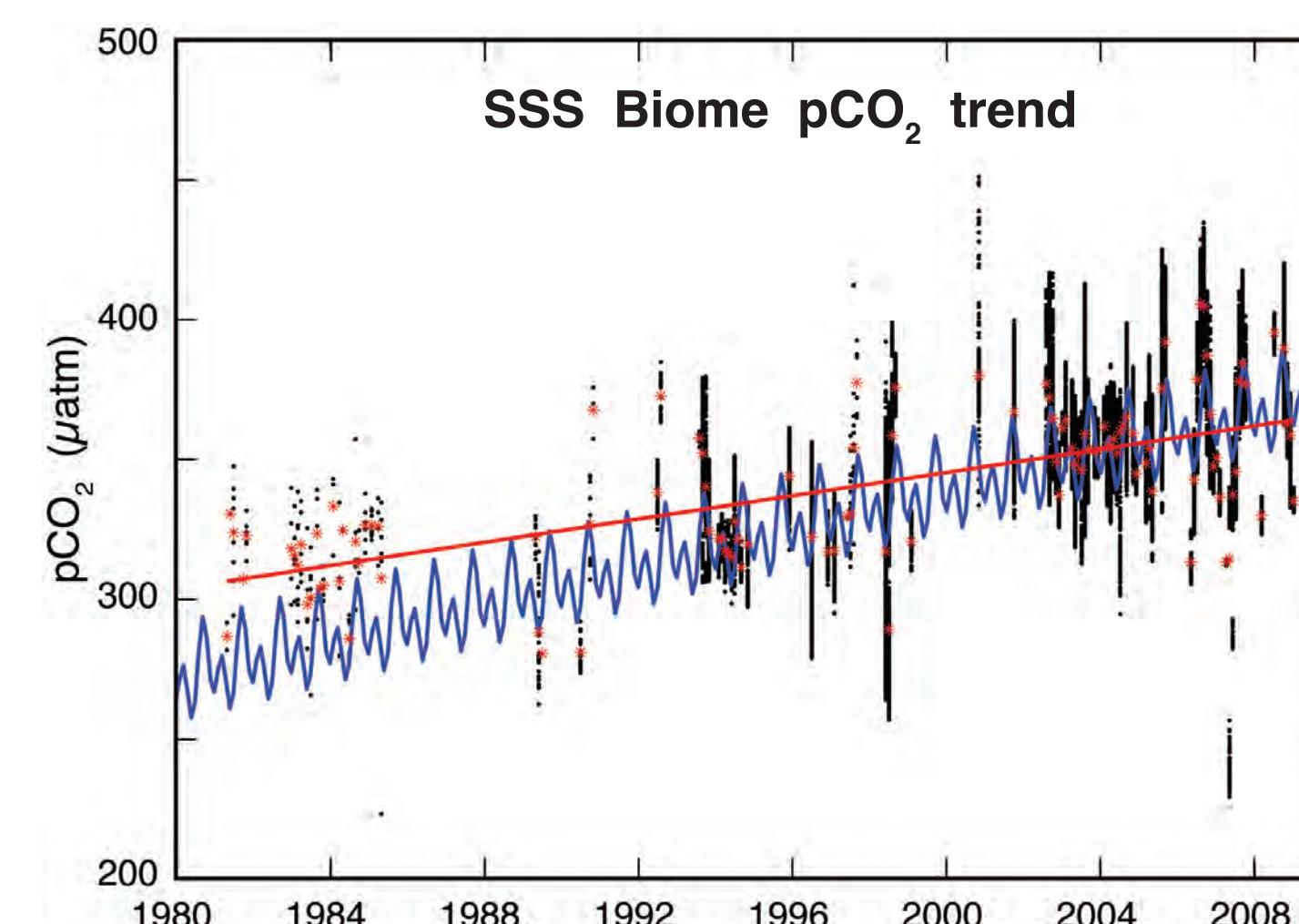


Figure 4: Time series plot for the SSS biome. Comparison between all observations (black), monthly mean values (red), 2 harmonic fit to all observations (blue curve), and linear trend fit to monthly mean values (red line).

### (4) LINEAR FIT TO ANNUAL OR SEASONAL MEANS

By analyzing each season independently we omit the need for harmonics. Figure 5 shows an example of the calculated linear trends for each season in the seasonally stratified subtropical biome. While there are differences between each season's trend and the annual mean fit, 95% confidence interval error bars overlap. This is true for all biomes.

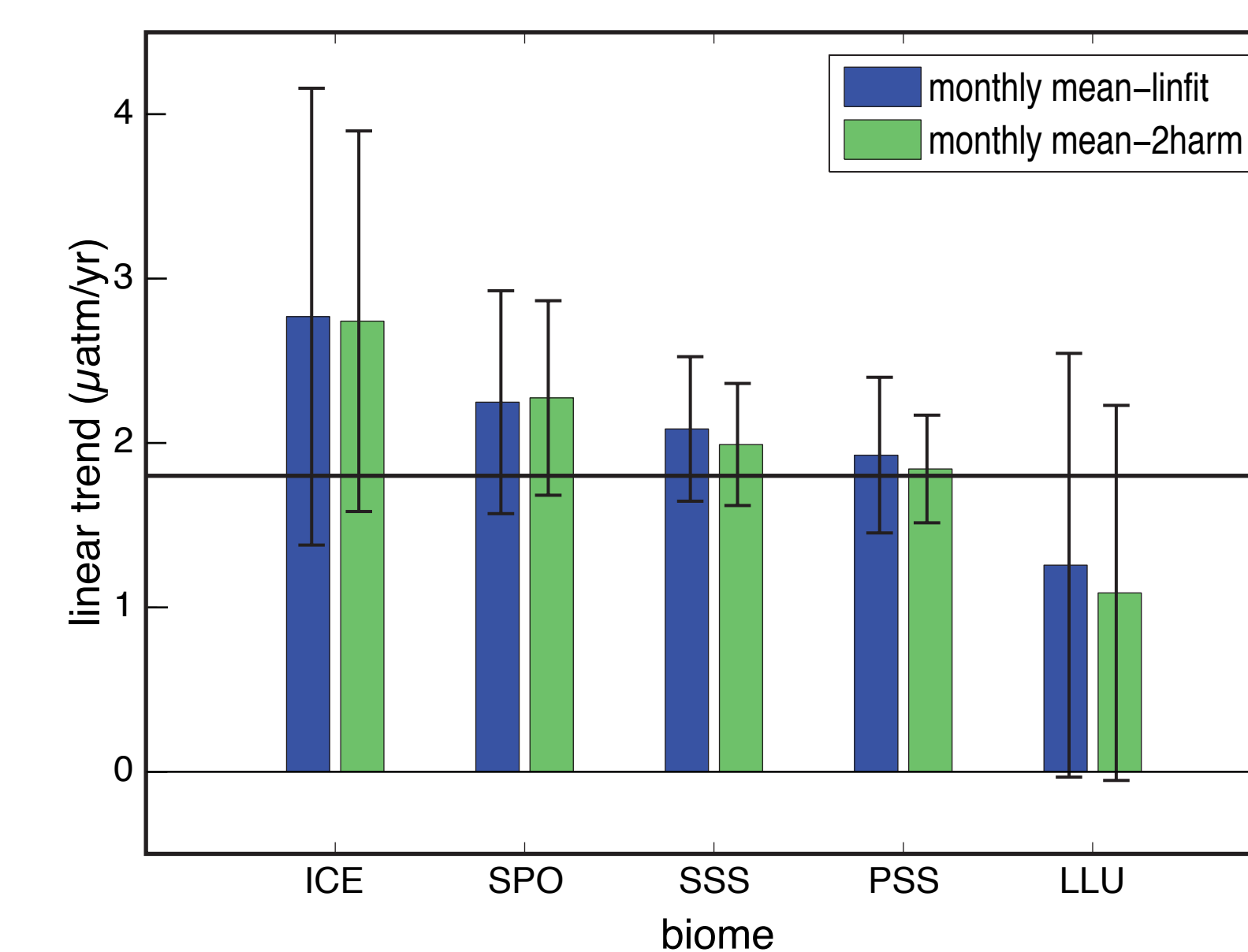


Figure 6: Linear trend comparison between a linear fit and 2 harmonics.