Interactive comment on "Mg/Ca, Sr/Ca and stable isotope from planktonic foraminifera *T. sacculifer*: testing a multi-proxy approach for inferring paleo-temperature and paleo-salinity" *by* Delphine Dissard et al.

William Gray

william.gray@lsce.ipsl.frReceived and published: 24 June 2020

nice idea to try and leverage some information from Sr to try and improve the paleo- SST/SSS estimation. I have several comments (mainly on the statistical aspects).

while this seems like a great new dataset, you mention it was a 'meridional' transect in the Atlantic (line 98) - this screams covariance of temperature and salinity to me. co- variance of predictor variables is going to seriously impact your ability to determine the correct coefficients (especially with a relatively small dataset), however I see no mention/discussion of T/S covariance in the dataset. I really think this potential covariance between T and S needs to be looked at and discussed in relation to your regressions.

Answer:
The covariance of temperature and salinity is indeed inevitable when considering planktonic foraminifera along a meridional transect. Nevertheless, we disagree with the fact that this covariance is going to '*seriously impact our correlation coefficients*'.

In our data set, the impact of salinity remains negligible in comparison to the impact of temperature on Mg incorporation. This is described line 243-248*: "Regression for the relationship between salinity and Mg/Ca ratios does not show any clear correlation (R^2=0.09, p-value=0.32). This is in good agreement with previous culture experiments studies which only report a minor sensitivity of Mg/Ca to salinity in planktonic foraminifera (e.g. Dueñas-Bohórquez et al., 2009; Hönisch et al., 2013; Kisakürek et al., 2008; Nürnberg et al., 1996).*

Following this statement, we nevertheless recalculated regressions of Mg/Ca-T°C incorporating salinity (line 252):

$$\ln(Mg/Ca[mmol/mol]) = (-5.02\pm2)+(0.09\pm0.009)*T+(0.11\pm0.05)*S,$$

$$R^2=0.91 \text{ pvalue} = 5e\text{-}06$$

And then we compared it with your regression: Gray and Evans (2019), as this was the only other regression we could find in the literature allowing to assess the sensitivity of foraminiferal Mg/Ca of *T. sacculifer* to temperature and salinity combined.
Finally, and as described line 265-268: "*We can conclude, that if the equation of Gray and Evans (2019), is in perfect agreement with our equation with regards to the temperature parameter, this is not the case for salinity, which shows a strong difference between the two equations, most probably explained by the weak correlation of Mg/Ca to salinity in our data."*

This strengthen our idea, that in our data set, the impact of salinity is not significantly impacting our correlation coefficients.

I do not think your regression approach is valid. there is no problem with the regressions of Mg and Sr against T (or T and S) individually (except the covariances mentioned above), but then you invert the regression, such that you are regressing SST against Mg and Sr. I do not think this is a valid approach with least squares regression, as the residuals are calculated along the y vector. you also mention that there is an improvement in fit compared to the single regressions above (line 234), however these regressions results are not comparable in this way as i) the equations are inverted (and the residuals are thus not calculated in the same way), and ii) you have changed the degrees of freedom it would be better to regress the Mg and Sr data individually against T and S, then solve the resulting equations simultaneously - you could then test if there is an improvement in the observed versus predicted T/S using Mg only and (Mg+Sr).

Answer:
We confirm that our regression approach as well as our results are valid. Nevertheless, we understand, reading this comment, that the given information were not detailed enough, hence the confusion. Therefore, for clarity, relevant information has been added to the manuscript line 224-244:

"The relationship between both Mg/Ca and Sr/Ca ratios and measured temperatures were calculated using least square differences. Both show a good correlation with surface water temperature (Fig. 2, Tab. 3). The Mg/Ca ratio increases exponentially by 8.3%/°C (best fit) (Mg/Ca and Sr/Ca ratios given in mmol/mol):

$Mg/Ca=(0.42\pm0.13)\exp((0.083\pm0.001)*T)$, $R^2=0.86$ pvalue=2,9e-06 (equation 1)

whereas Sr/Ca ratio increases linearly by 0.6%/°C (Fig. 2a and b), best fit:

$Sr/Ca=(0.009\pm0.002)*T+(1.24\pm0.05)$, $R^2=0.67$ pvalue=5.e-04 (equation 2)

Concerning the temperature reconstruction, by inversing the approach, univariate regressions yields to:

$T= (12.3\pm1.5)+((10.5\pm1.2)*\log(Mg/Ca)$, $R^2=0.86$ pvalue=2,9e-06 (equation 1')

And

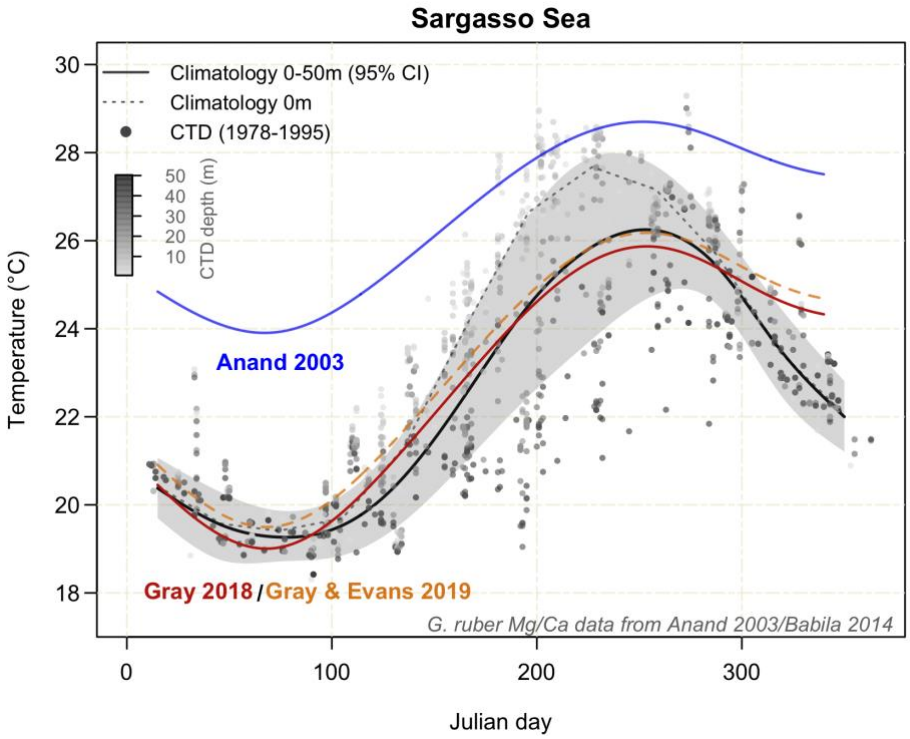
$T= + (-84.1\pm22.9)+((71.7\pm15)*Sr/Ca$, $R^2=0.67$ pvalue=5e-04 (equation 2')

Combining Mg and Sr data for a non-linear multivariate regression allows improvement of the correlation with temperature, best fit:

$T=-(27\pm15)+(8\pm1)*\ln(Mg/Ca)+(28\pm11)*Sr/Ca$, pvalue Mg/Ca: 2.10^-4 (equation 3)

R^2=0.92 pvalue= 2.e-04 “

Finally in several places (i.e. line 290) and figure 3 you refer to the calibration of Anand et al 2003. although this is still a widely applied calibration, in our 2018 paper (Gray et al., 2018, EPSL) we show that the calibrations of Anand et al are inaccurate due to seasonal changes in the d18O of sea water at that site. the equations of Anand et al do not fit the data from Anand if climatological (or measured in situ) temperature is used instead (see attached figure). I mention this as something to be cautious of when discussing this work.



Answer:

We take note of this comment. The *T. sacculifer* equation from Anand et al., (2003), remains, however, the sole, *T. sacculifer* only, Mg/Ca-T°C equation based on sediment trap samples, found in the literature. Moreover, as you mentioned in your comment, this is still a widely applied calibration. We therefore believe discussing the *T. sacculifer* equation of Anand et al., (2003) in section 4.3. of our discussion, remains of high interest. Nevertheless, for accuracy the various hypothesis listed from line 429-431 to explain the discrepancy between our equation et the one from Anand et al., (2003) now read: "In contrast, the equation of Anand et al., (2003) based on sediment trap samples, is appreciably different (Fig. 3b). This may be due to: (1) difference in cleaning and analytical procedures, (2) addition of GAM calcite at greater depth and (3) uncertainty in estimated temperature, indeed, as mentioned in Gray et al., (2019): “Note the calibration line of Dekens et al. (2002) and Anand et al. (2003) does not fit the data of Anand et al. (2003) when climatological temperature, rather than the $\delta^{18}O_{calcite}$–$\delta^{18}O_{water}$ temperature, is used. As shown by Gray et al., 2019, we show the calibrations of Anand et al (2003) are inaccurate due to seasonal changes in the d18O of sea water at that site. "

We thank William Gray for this valuable comment.