Signs of climate variability in double tropopause global distribution from two decades of radio occultation data

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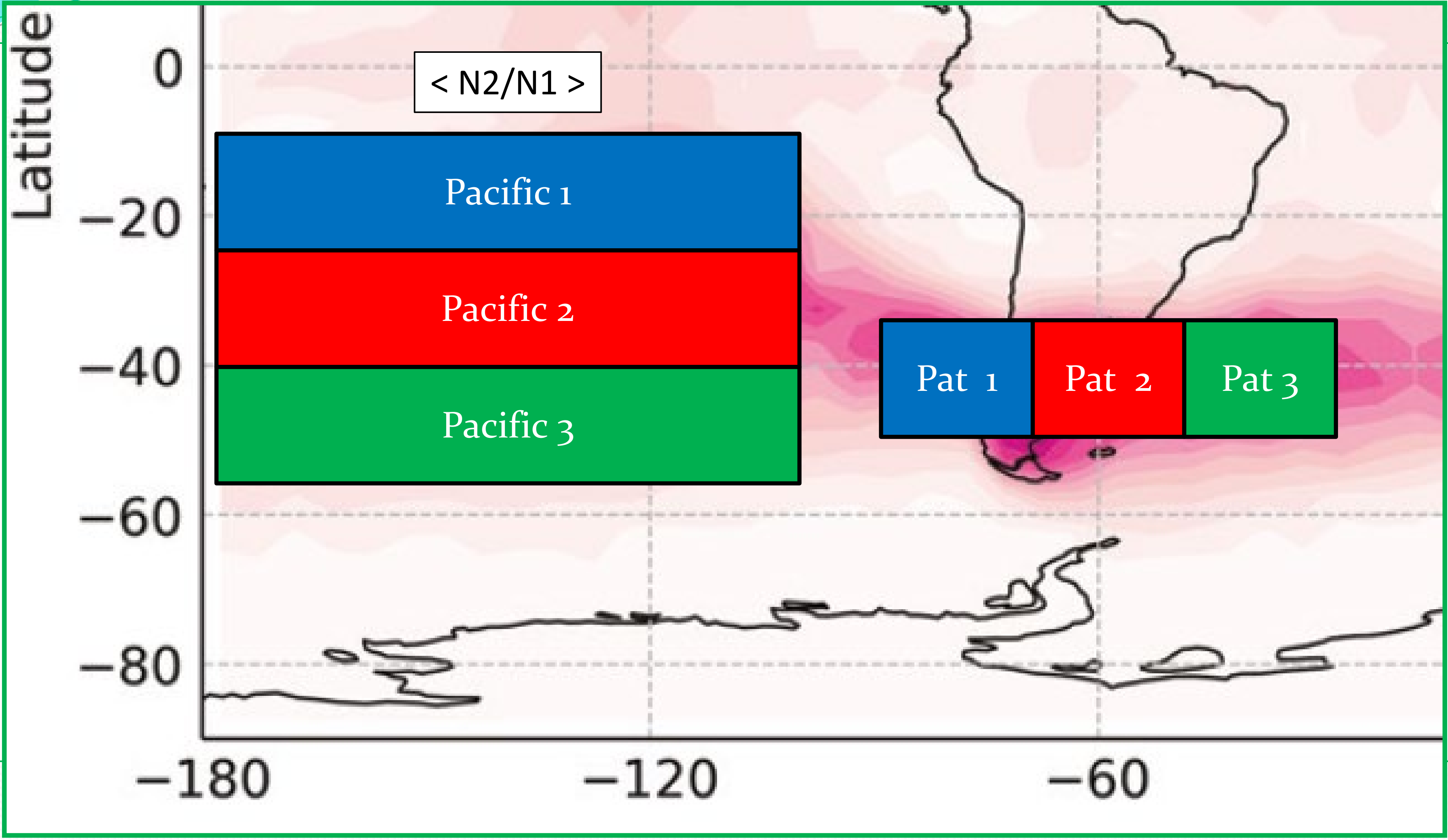
Some previous knowledge

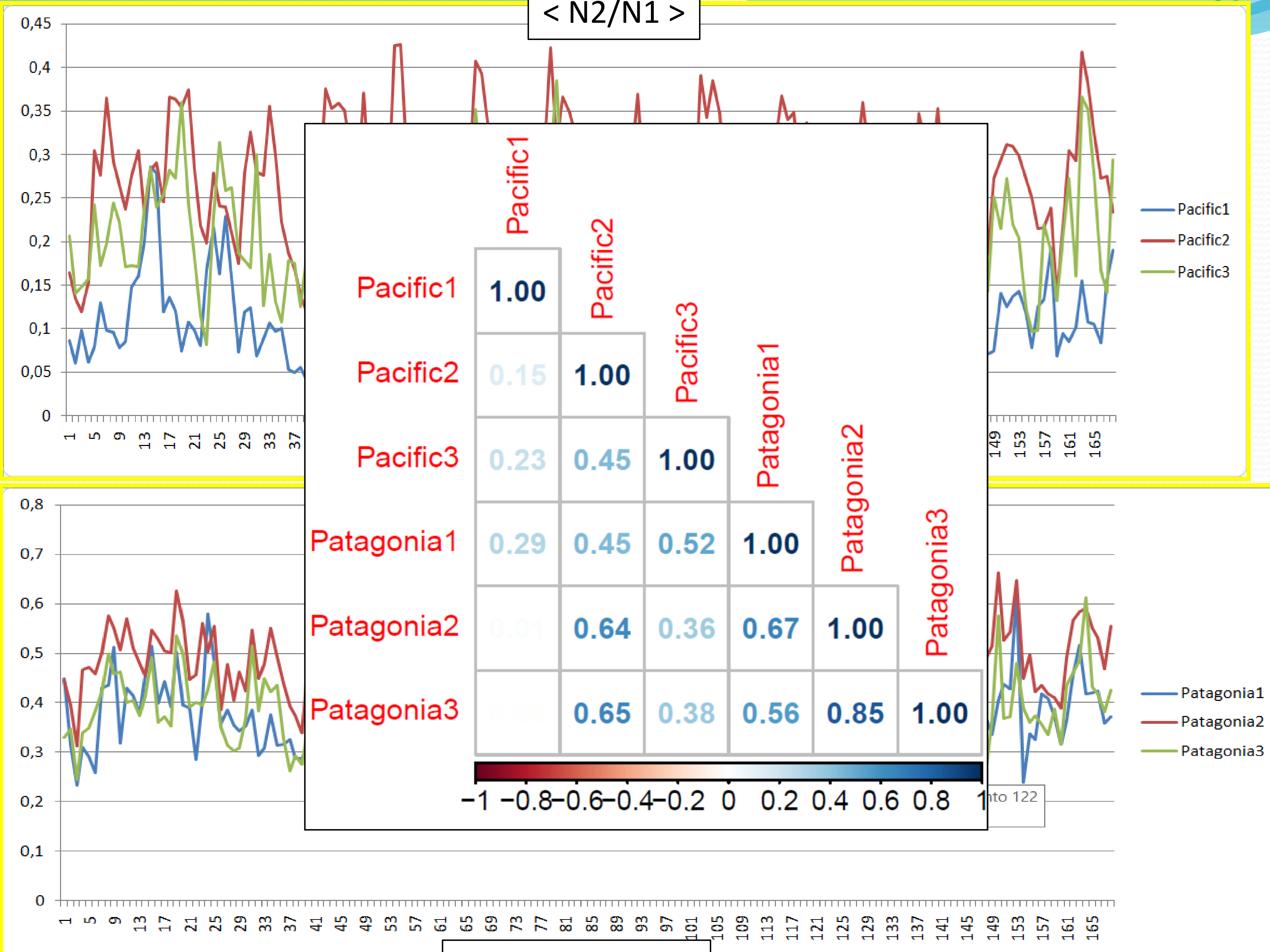
- vertical folding of the tropopause, occurrence of DTs
- midlatitudes (Peevey et al., 2014; Wang & Polvani, 2011, Homeyer et al., 2010; Castanheira et al., 2012; Liu & Barnes, 2018; Pan et al., 2009; Randel et al., 2007)
- storm track regions, subtropical jet stream (Bischoff et al., 2007; Schmidt et al., 2006; Seidel & Randel, 2006)
- mountain gravity waves (Schmidt et al., 2006) and
- cyclogenesis (Añel et al., 2008)
- Brewer-Dobson circulation (Castanheira et al., 2012)
- cloud-top inversion layers (Biondi et al., 2012)
- radiosonde measurements
- RO data (e.g. Randel et al., 2007; Schmidt et al., 2006; Xu et al., 2014) including the relationship to ENSO events (Wilhelmsen et al JGR 2020)



DTs percentage = (N2/N1) x 100

(from Wilhelmsen et al, 2020)

< N2/N1 >



	Pacific1	Pacific2	Pacific3	Patagonia1	Patagonia2	Patagonia3
Pacific1	1.00					
Pacific2	0.15	1.00				
Pacific3	0.23	0.45	1.00			
Patagonia1	0.29	0.45	0.52	1.00		
Patagonia2	0.01	0.64	0.36	0.67	1.00	
Patagonia3	0.00	0.65	0.38	0.56	0.85	1.00

month number

A preliminary work:

As an approximation to relate a meteorological signal using different indices,
Llamedo et al., 2016
(after Randel & Wu, 2015 and other relevant contributions)

ENSO, PW, q and T

$$F(t) = A_0 + A_1 t + A_2 sin(\omega t) + A_3 cos(\omega t) + A_4 sin(2\omega t) + A_5 sin(2\omega t) + A_6 sin(3\omega t) + A_7 cos(3\omega t) + B_1 \mathrm{QBO1}(t) + B_2 \mathrm{QBO2}(t) + B_3 \mathrm{SF}(t)$$

Multiple linear regression

Climate indices from :
psl.noaa.gov/data/climateindices/list

A multiple regression model is written as

$$
\begin{aligned}
y_i &= \beta_0 + \sum_{j=1}^{d} x_{ij}\beta_j + \epsilon_i \\
&= \beta_0 + \beta_1 x_{1i} + \beta_2 x_{2i} + \ldots + \beta_d x_{di} + \epsilon_i, \quad i = 1, 2, \ldots n
\end{aligned}
$$

The β coefficients are obtained by minimizing the residual sum of squares, thus obtaining:

$$\hat{\beta} = (\mathbf{X}^T\mathbf{X})^{-1}\mathbf{X}^T\mathbf{y}$$

Given new data X_{new}, the least squares prediction is:

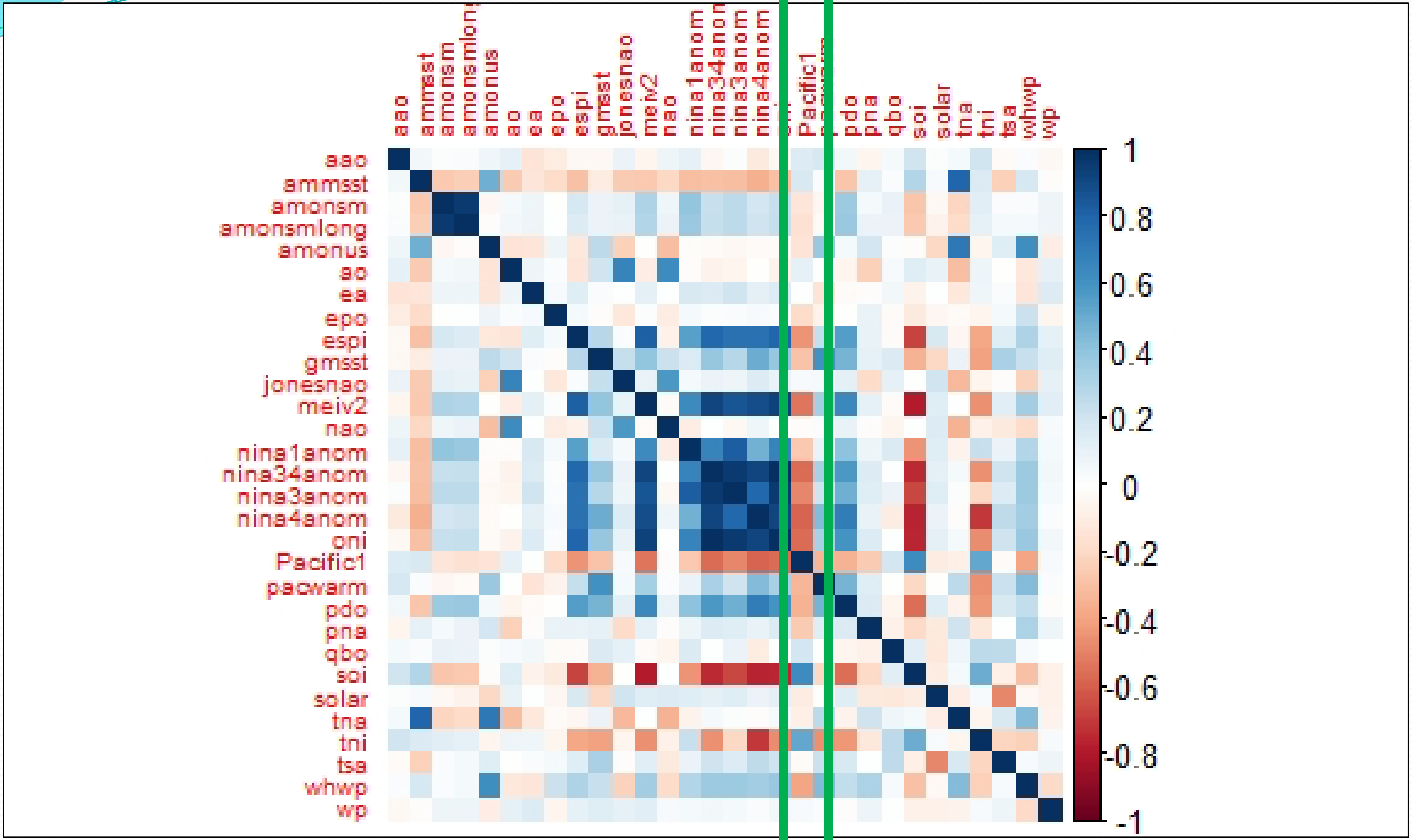
$$\hat{y} = \mathbf{X}_{new}\hat{\beta} = \mathbf{X}_{new}(\mathbf{X}^T\mathbf{X})^{-1}\mathbf{X}^T\mathbf{y}$$

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(pred_i - obs_i)^2}{n}}$$

Root Mean Squared Error

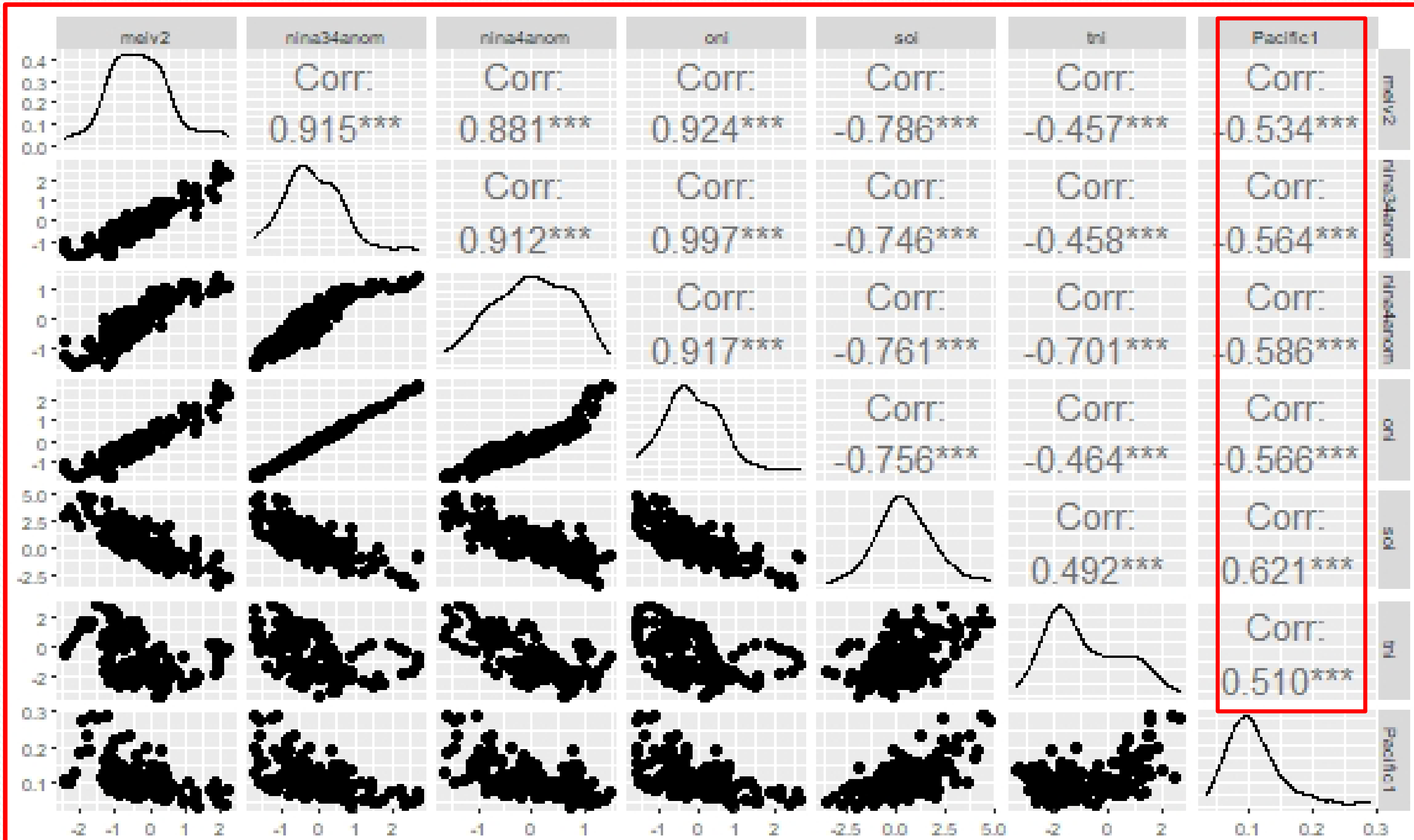
e.g.: Pacific 1 subregion

Climate indices from : psl.noaa.gov/data/climateindices/list



Correlations with $R^2 > 0.5$ is found between the response variable and predictors: "meiv2" , "nina34anom", "nina4anom", "oni" ,"soi", "tni"

Considering only these latter “best” predictors
(**"meiv2" , "nina34anom", "nina4anom“, "oni" ,"soi", "tni’’) for “Pacific1”**:



Three regression models to predict DTs from different sets of arbitrary predictors were compared:

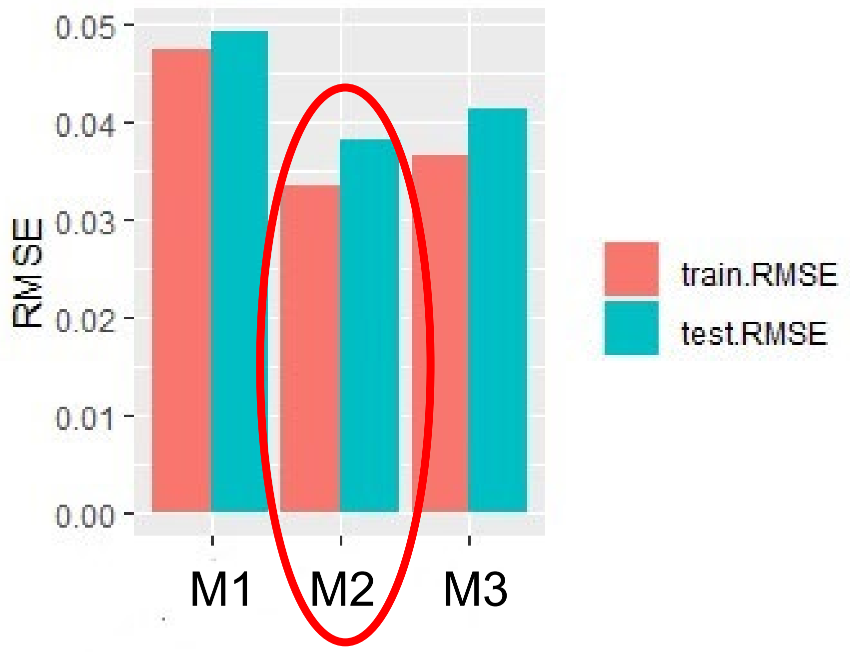
M1) "baseline" (only β_0)
M2) $\beta_0 + \beta_1 soi + \beta_2\, whwp + \beta_3\, tni + \beta_4\, oni$
M3) "linear" ($\beta_0 + \beta_1 soi$)

- As an example, for **M2**:
- Residuals:

Min	1Q	Median	3Q	Max
-0.0677	-0.0234	-0.0030	0.0171	0.1009

- Coefficients:

	Estimate	Std. Error	t value
(Intercept)	0.118982	0.004959	23.993
soi	0.011925	0.003033	3.931
whwp	-0.004230	0.001483	-2.852
oni	-0.005017	0.005591	-0.897
tni	0.007947	0.002397	3.316



model	train RMSE	test RMSE
M1	0.04759141	0.04926829
→ M2	0.03345134	0.03828805
M3	0.03656820	0.04127345

Summary

- 5 sub-regions (Pacific 2-3 and Patagonia 1-2-3) show a correlation between their respective monthly averaged TDs
- DTs in *Pacific 1* (to the north of the subtropical jet) exhibit a different behavior
- However, it correlates better with the global indices than the other 5 subregions do
- Progressive addition of global indices to the model improves its performance, reducing the RMSE of training and testing.

Current work

- A possible correlation between the observed distribution of DTs (from RO) and inertio gravity waves, usually radiated by geostrophic adjustment near to the subtropical jet (predictor proposed: cross-current Rossby number) is being analyzed.
- A principal component study is being performed on the available 20-year DTs dataset and 5x5 lat/lon deg pixels in the southern hemisphere.

- *Thank you for your attention*
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