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Principles of Planetary Climate - Assignment 1 Question 2

30th January 2023

Dataset analysis - El Nino and La Nina

El Nino and La Nina are terms used to describe the two different modes of interaction between (primarily) the Pacific Ocean and the atmosphere, with the El Nino state occurring every two to seven years. El Nino years are characterised by weakened trade winds and heavy rainfall over the central and eastern Pacific (off the west coast of South America). La Nina is the exact opposite- trade winds are strengthened and more warm water is pushed toward Asia, allowing the upwelling of cool, nutrient rich water off the South American coast. However, these changes are not localised, and trigger a cascade of other climate anomalies across the globe.

DATA

Datasets used: CERES satellite measurements of (1° x 1° resolution, from March 2010 to March 2021, all months):

1. Top of atmosphere outgoing longwave radiation
2. Top of atmosphere outgoing shortwave radiation
3. Top of atmosphere incoming shortwave radiation
4. Surface incoming shortwave radiation
5. Surface incoming longwave radiation
6. Surface outgoing longwave radiation
7. Cloud cover area
8. Effective cloud temperature

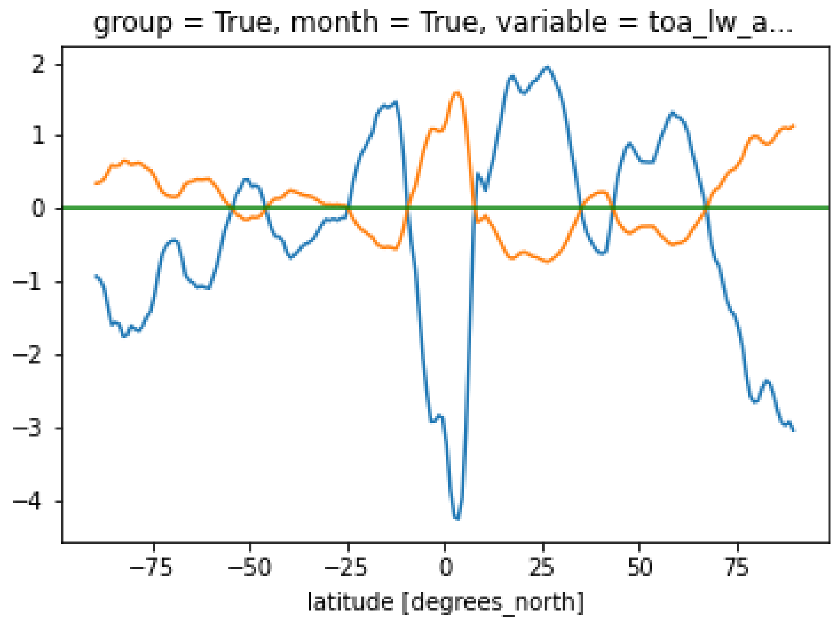

Figure 1: Deviation of outgoing longwave radiation at the top of the atmosphere from climatology for the month of December (averaged over year and longitude) for El Nino (blue) and La Nina (orange) years.

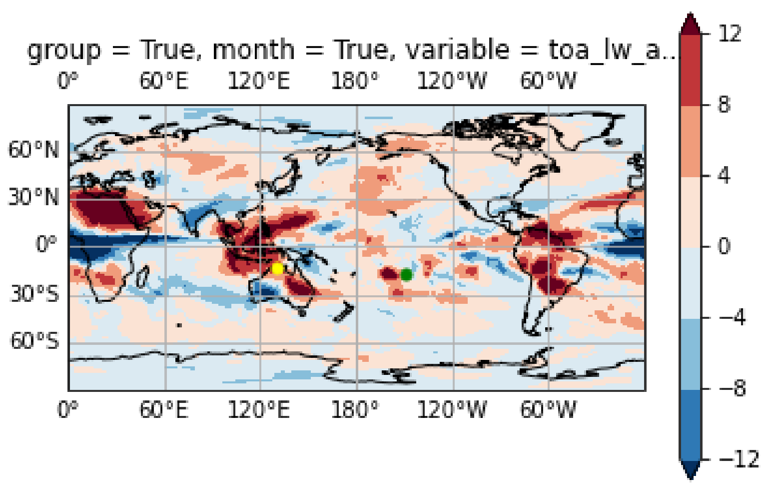

Figure 2: Deviation of outgoing longwave radiation at the top of the atmosphere from climatology during El Nino Decembers (averaged over year). The yellow dot indicates Darwin, and the green Tahiti.

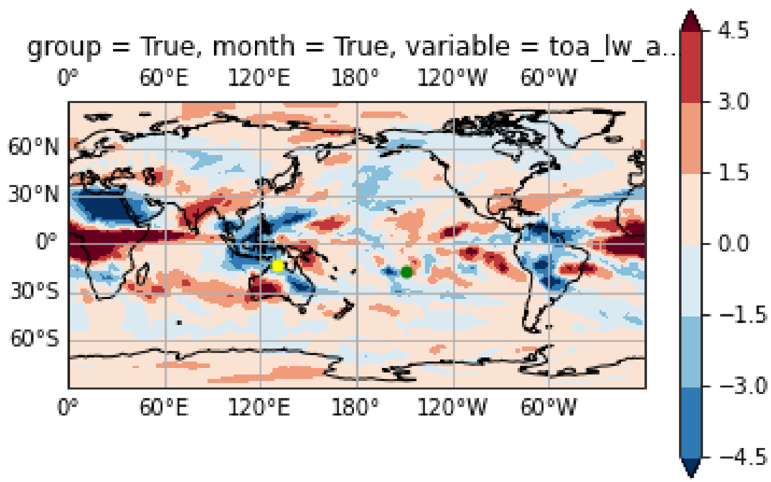

Figure 3: Deviation of outgoing longwave radiation at the top of the atmosphere from climatology during La Nina Decembers (averaged over year). The yellow dot indicates Darwin, and the green Tahiti.

xarray.DataArray

array(0.92107326)

Figure 4: Deviations of TOA-OLR (blue) and effective cloud temperature (orange) from climatology during El Nino Decembers (averaged over year and longitude), and the Pearson correlation coefficient of the two deviations

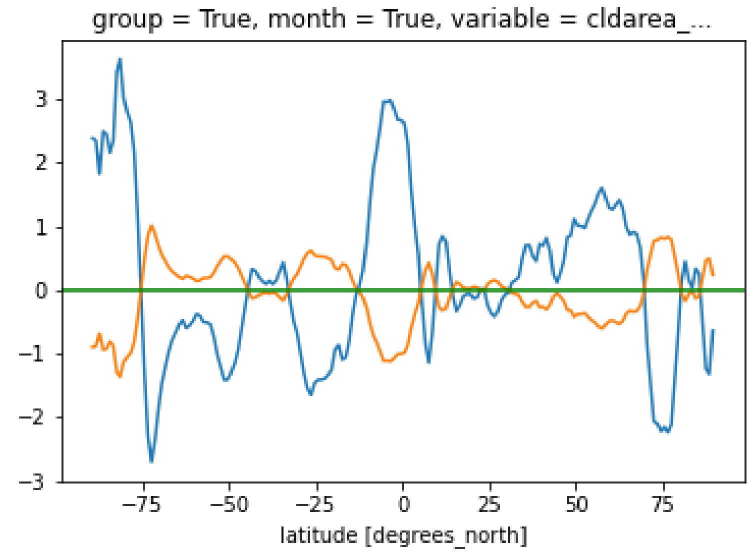

Figure 5: Deviation of cloud area from december climatology (averaged over year and longitude) during El Nino (blue) and La Nina (orange) decembers

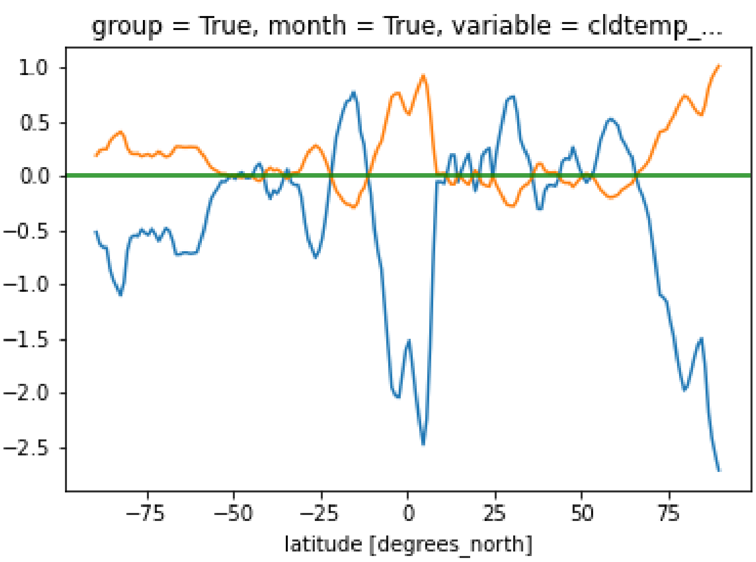

Figure 6: Deviation of effective cloud temperature from december climatology (averaged over year and longitude) during El Nino (blue) and La Nina (orange) decembers

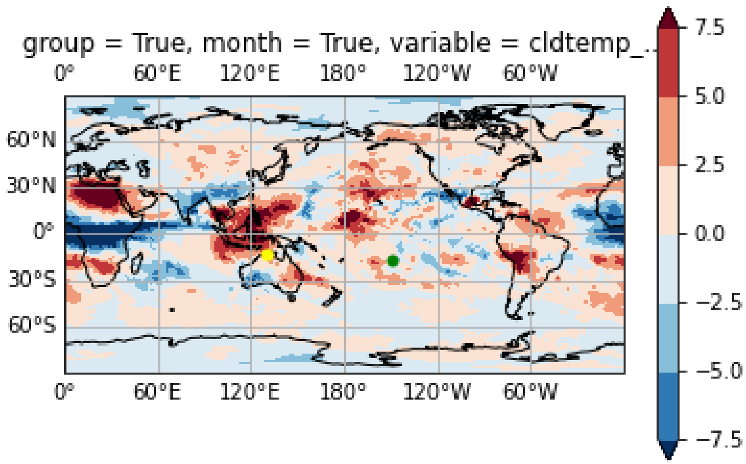

Figure 7: Deviation of effective cloud temperature from december climatology (averaged over year) during El Nino decembers

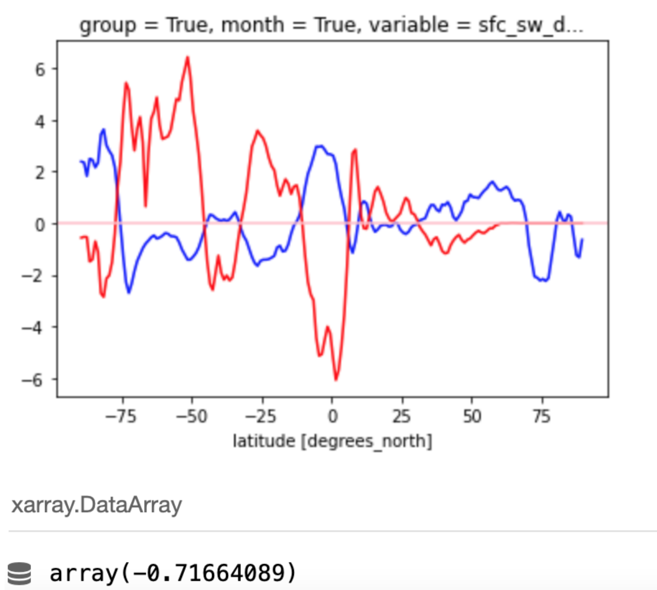

Figure 8: Deviations of cloud area (blue) and incoming surface shortwave radiation (red) from december climatology (averaged over year and longitude) during El Nino decembers, pearson's correlation coefficient for the two deviations

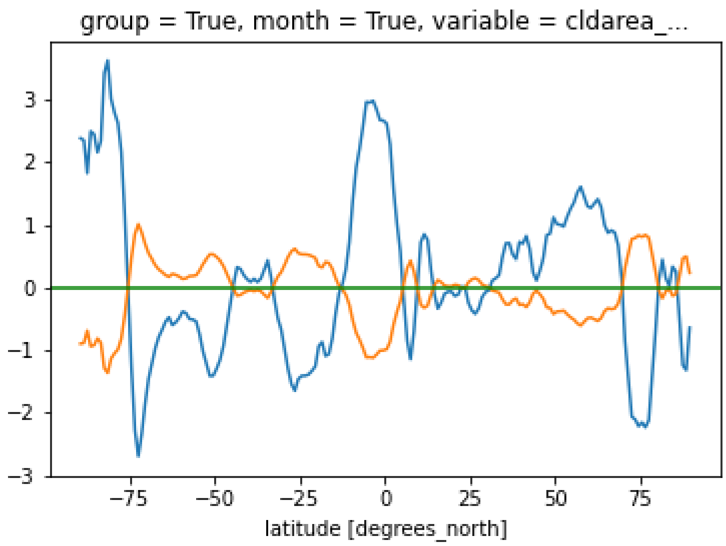

Figure 9: Deviation of cloud cover area from december climatology (averaged over year and longitude) during El Nino (blue) and La Nina (orange) decembers

Variable:	*cld_area*	*cld_teff*	*surf_olr*
toa_olr	*-0.19 (+ve over equator)*	*0.92*	*0.34*
surf_isr	*-0.71*	*0.31*	*-0.25*
surf_olr	*-*	*0.34 (-ve over the equator)*	*-*

Table 1: Pearson correlation coefficients between atmospheric variables

OBSERVATIONS AND INFERENCES

Observations (with hypotheses as to how these correlate to El Nino, not explored further for time constraints)

1. *Highly significant positive correlation (0.92) between deviations in outgoing longwave radiation at the top of the atmosphere and effective cloud temperature, and highly significant negative correlation (-0.71) between deviations in incoming surface shortwave and cloud area. The deviations in these variables when plotted together follow nearly the same latitudinal oscillation pattern.*
    a. *The first correlation has again got to do with the fact that El Nino conditions favour the formation of convective towers of cloud, which radiate at a far lower temperature due to elevation of their top surfaces, thereby greatly reducing the outgoing longwave radiation from that patch.*
    b. *The second correlation might not necessarily be a feature of El Nino particularly- the reflective properties of clouds. This is absolute conjecture with no evidence again but this negative feedback from the reflection of the clouds might help cool the anomalously warm sea surface down, and help transition from El Nino to La Nina. Since Walker circulation is like a positive feedback loop, it probably wouldn't even need very large changes to trigger a reversal in SST anomalies.*
    c. *The third observation again indicates that the correlated variables are very significant in determining deviations in each other*
2. *Deviations follow some sort of oscillation across latitudes- alternating bands of latitudes have deviations with opposite signs (observed for all variables) : implies large-scale meridional energy transfer, else all these deviations would not be so synchronous and significant across all latitudes):*

a. *As a consequence of sea surface temperatures increasing during the El Nino mode, more evaporation and convection take place over the central and eastern Pacific, releasing huge amounts of latent heat into the upper atmosphere- this creates a steeper energy gradient between the equator and poles, resulting in an intensification of the Hadley circulation. Heat distribution through these cells produces definite cloud patterns (with more convergence and high cloudiness near the equator and subpolar-midlatitude regions, and divergence in the subtropics). More storms are also pushed along the polar front in the northern hemisphere.*

b. *This can be observed in the cloud area latitudinal deviation plot (figure 5), for example, where cloudiness dips over the subtropics, and increases steeply in the polar and subpolar regions. Cloudiness, and the presence of large convective clouds with cooler radiating surfaces (as they are higher in the atmosphere) due to convergence from the Hadley cell plays an important role in regulating outgoing longwave radiation, as we can see from the outgoing longwave radiation and effective cloud temperature deviation plot (figure 4): outgoing longwave radiations dips almost linearly as cloud temperature drops (such as the steep decrease at the equator) and picks up significantly over the subtropics (where there is less cloudiness and fewer convective towers)*

3. *Deviations corresponding to El Nino and La Nina are perfectly out of phase for all latitudes (observed for the time and longitudinally averaged plots of december deviations*

of ALL variables except incoming shortwave radiation at the top of the atmosphere- henceforth 'all variables' does not include surface incoming shortwave radiation):

   a. *This checks out with theory, El Nino and La Nina are complementary modes with global effects, so deviations should be out of phase at all latitudes*
   b. *However, the agreement is almost too good to be true- because I have taken the La Nina dataset to be perfectly complementary to the El Nino one, rather than selecting individual La Nina years (I read in a book -El Nino and the Southern Oscillation by S. Philander- that there really isn't such a thing as a neutral state for the tropical Pacific, it's either El Nino or La Nina with no inbetween- this may not be entirely accurate but serves its purpose for this assignment)*

4. *Deviations are far more significant at the equator for all variables*
   a. *This can be understood from the fact that evaporated moisture from the warm sea surface leads to the formation of significant convective tower cloud cover right over the equatorial pacific- energy not dissipated by transport, so these clouds and the associated heavy rainfall can cause far more significant change.*
5. *Deviations for the same variable are usually larger in magnitude during the El Nino mode*
   a. *Refer to observation 1: Since the La Nina dataset contains nearly all of the years in the total dataset, its deviations from the climatology are expected to be much smaller.*

6. *Area-weighted average of deviations in total outgoing longwave radiation in the tropical-subtropical band (30 S to 30 N) was extremely low: (-0.0011) implying efficient redistribution of energy within the tropical band during El Nino mode.*
    a. *Would be interesting to see how this distribution works to produce almost no significant deviation in this band, presently I have no explanation for it.*

CONCLUSION

Datasets corroborated my limited knowledge of ENSO.

Works Cited

How ENSO leads to a cascade of global impacts- NOAA