The El Niño/La Niña Connection
Literature Review

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This project involves using satellite weather forecasting images from EUMETSAT to investigate the relationship between El Niño (La Niña) events and weather patterns across the world. As part of this project we will look for a connection between El Niño events and vegetation coverage across Africa. We will also try to determine what impact, if any, an El Niño event will have on weather patterns in Europe and the North Atlantic. This project is heavily computational and will require the careful manipulation of large amounts of data to extract useful science.

Due to the complexity of characterising weather patterns, the meaning of the term 'El Niño' has changed over time and there are conflicting definitions. The term originated from Peruvian fishermen who would use it to describe an annual warm ocean current running along the coast of Peru. Later, the name was applied to the large warmings that occur every few years in that region. The El Niño effect consists of both an oceanic and atmospheric component, the latter called the Southern Oscillation. Hence the term for the phenomenon of the ocean and atmosphere coupling together to produce the anomalous weather patterns is the El Niño-Southern Oscillation (ENSO). El Niño (La Niña) is then used to describe the warm (cool) portion of the ENSO. El Niño (La Niña) events are indicated by atypically high (low) sea surface temperatures (SSTs) in the central and eastern tropical Pacific [1]. In our work we will use the definition given by [2] which is that an El Niño event can be said to occur if five month running means of SSTs exceed 0.4°C for six months or more.

One of the key tasks in processing this data is to be able to differentiate between cloud and land. For certain tasks we will need to make sure that we are observing only land and for others we will actually be quantifying the amount of cloud, so being able to distinguish the two is essential. Thresholding is usually used to distinguish between cloud and land [3], as cloud has a higher reflectance than most places on Earth. However simple thresholding methods (i.e. global thresholding) are not appropriate because of the differences in reflectance over the planet, for example the oceans have a lower reflectance than the desert. More advanced methods will have to be used to produce an accurate cloud free image (CFI). Once a CFI has been produced we can use it to observe various effects of El Niño such as vegetation and cloud coverage.

In order to charcterise the effect of ENSO on vegetation we first need some method of quantifying the vegetation coverage. This comes in the form of the normalised difference vegetation index

$$\mathrm{NDVI} = \frac{(\rho_{\mathrm{nir}} - \rho_{\mathrm{r}})}{(\rho_{\mathrm{nir}} + \rho_{\mathrm{r}})} \tag{1}$$

where ρ_{nir} and ρ_{r} are the surface reflectances in the near infrared (NIR) and red bands respectively

[4]. NDVI is a useful measure since plant matter typically has high absorption in the red, due to the presence of chlorophyll, and large reflectance in the NIR which distinguishes it from other surface matter. During the 1997/1998 El Niño event, NDVIs of more than 80% greener than normal were observed over East Africa, while over Southern Africa NDVIs over 80% redder than normal were recorded, corresponding to drought conditions [5]. In the 1999/2000 La Niña the reverse patterns occured, with drought conditions over East Africa and greener than normal conditions over Southern Africa. A study of NDVI data spanning 30 years showed that,in East and Southern Africa, NDVI reliably traces other effects of the ENSO effect, such as rainfall, while there is little evidence of a corresponding effect over Central and Western regions [6].

An El Niño event affects not only vegetation but also cloud coverage. To understand the correlation between an El Niño event and cloud coverage the multivariate ENSO index (MEI) is used. The MEI is a measure that uses more than one observation (i.e. it does not rely solely on SSTs) and takes seasonal variations into account [7]. It has been shown [8] that there is a strong positive correlation between El Niño events and the MEI over the tropical North Atlantic during the months April to June. This, in combination with induced changes in evaporation, lead to a net flux of heat into the oceans, raising SSTs. It is thought that these changes are induced through atmospheric circulations [8, 9], hence providing a mechanism for the teleconnection of the Pacific El Niño event to other places around the world, including the North Atlantic.

The Atlantic meridonial current (AMOC) is repsonsible for carrying warm water northwards with cooler water travelling southwards. An integral part of the Earth's climate system, the AMOC has been weakening in recent history [10] and, using SST values, it may be possible to observe the cooling trend with EUMETSAT data. Climate models incorporating a shutting down of the AMOC have also noticed an effect on ENSO, with some reporting an increase in ENSO amplitude [11] and others report no change in amplitude, but a decrease in ENSO period [12]. It is unlikely that we will be able to observe any of the reported effects on ENSO due to the short timespan of data available, but it may be worth investigating.

While the effect of ENSO in the Pacific is fairly well understood, this is not the case with the effect of ENSO over Europe. In comparison to elsewhere on the globe, the effects of ENSO on Europe are small and may also be subject to interseasonal variability and modulation [13]. However the signal is there and manifests itself most consistently in the winer where it resembles the negative (positive) mode of the North Atlantic Oscillation (NAO) for El Niño (La Niña). The NAO is an atmospheric oscillation with a positive and negative phase, where the positive phase results in larger pressure gradiants over the North Atlantic and the negative phase in reduced pressure gradients [14]. The observed NAO pattern can be accounted for by including stratospheric circulation changes in the teleconnection models [15], although other mechanisms indicate that the NAO-like patterns may not be stationary and only valid for certain decades [9]. The European ENSO signal is indirect in the sense that there are underlying, intermediate circulation changes [13], as with the case for the effects on cloud coverage.

Speaking of the effects of ENSO in terms of NDVI, SSTs and other measures makes it easy for the impetus behind this research to appear purely academic – this is not the case. Given that a large proportion of population of sub-Saharan Africa rely on agriculture to meet their food supply needs, any variation in climate will have a dramatic effect on harvests, and hence on local food supply [16]. Coupling this effect with the widespread social and economic problems facing parts of the continent makes the region incredibly sensitive to climate variability, which all too often can lead to disaster [6]. In 2016 the UN Office for the Coordination of Humanitarian Affairs (UNOCHA) published a report on the response to El Niño in East and Southern Africa [17]; by their estimates over 19.5 million people and 10.5 million children were affected in East Africa alone. As a result of El Niño parts of East Africa received below average rainfall leading to poor harvests and all of the associated problems such as unemployment and food shortages. Similarly, parts of Southern Africa experienced the worst drought for 35 years leading to huge food insecurity. As one of the worst hit countries, Kenya alone now has over 1.2 million people in food security crisis. For this reason it is imperative that we improve our understanding of and ability to predict this effect in order that we may better prepare and coordinate responses to prevent humanitarian disasters.

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