Literature Review

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Abstract

The effects of *El Niño* are now known to be significant both locally and globally. In the pacific effects are strongest with important humanitarian results owing to flooding and changing fishing grounds. Research has found effects due to *ENSO* in regions as remote as China and Africa. It is the purpose of this report to motivate our research into climatological effects of *ENSO* on Europe and Africa, providing a review of important results in contemporary literature.

1 Introduction

Early twentieth century observations of atmosphere pressures showed a peculiar relationship between those measurements in the western tropical Pacific and those in the southeastern tropical Pacific (Holton and Dmowska, 1989). Namely, that they were out of phase — when one measure was positive, the other was negative. This was termed the *Southern Oscillation*. Later studies would show that there were accompanying variations in rainfall, sea surface temperatures, and wind patterns. The combination of these effects would come to be known collectively as the *El Niño Southern Oscillation*, with the warm phase named *El Niño* and the cold phase *La Niña*.

2 Cloud coverage

Cloud coverage calculations are an important part of climate science owing in no small part to their effects on human life. Clouds bring precipitation, and precipitation brings flourishing vegetation. Alternatively, extensive rainfall can cause catastrophic floods, while a prolonged dearth of clouds can cause drought such as those currently seen in Cape Town, South Africa, where useful water is soon expected to be completely depleted. One way or the other, cloud cover plays a significant role in human life, and thus is deserving of careful observation and examination.

Cloud coverage analyses were initially constructed using land-based observation stations. With the advent of continuous satellite data, alternative methods analysis were invented. The most common of these is thresholding — described in detail in this section.

The remainder of this section discusses a number of papers that automated cloud-coverage calculations using one of the above mentioned methods. The relevance of these papers is discussed in the context of our proposed work.

Derrien et al. (1993) employs thresholding, as do many of the researched papers. The thresholds are determined from monthly sea surface temperature measurements, and the thresholds themselves are temperatures. Most approaches where thresholding is used treat the threshold as a temperature, rather than a simple pixel value. Our preliminary work has solely treated with raw pixel values of typically a greyscale image. It will require extra research to first determine the reason for this choice of threshold unit, and second how to accurately (if at all) calculate temperatures from our data.

The method employed by the above first thresholds in an infrared channel that finds low temperature pixels corresponding to medium to high clouds. A second threshold is then applied to detect cirrus clouds characterized by larger temperature differences than for ground. The paper further describes application of the method to many scenarios not just limited to daytime observations but allowing for nighttime observations.

The ISSCP was a research effort to determine statistical variances in radiances and the significance of variations in number of cloudy regions (Rossow and Garder, 1993). This research was motivated by the desire to understand the importance of the optical properties and type of cloud on their radiative effects. Such determination could not be made with contemporary data, which was typically ground-based observation. Instead satellite data was analysed allowing for better measurements of the above.

To do this, they developed a multi-step thresholding algorithm. The paper notes that thresholding is an effective and simple method of determining cloud coverage, and that comparison of thresholding algorithms (including statistical methods) shows variation mostly in highly time-dependent areas (for example in ice-covered land). An important note from this paper is that due to the great diversity of Earth conditions there is no one-fits-all algorithm, and so any algorithm must be context-aware. As our preliminary work involves using global cloud data, we must be cautious when drawing locally relevant conclusions. The paper notes there are four significant contributors to *spatial variation*: cloudiness, cloud property, surface property, and atmospheric property; cloudiness being the largest factor.

The step determining pixel condition (cloudy, clear) is as follows. First, the pixel is first tested for *spatial contrast* by comparing its temperature with some threshold. This is motivated by noting that clouds will tend to be cooler than land. Second, the pixel is tested for *temporal contrast* where pixel temperature today is compared to the pixel temperature for yesterday. Depending on this difference, the pixel may be cloudy, clear, or undecided. Finally, the conditions from both steps are combined logically to produce a condition of cloudy, clear, mixed, or indeterminate.

Warren et al. (2007) looked at cloud cover and cloud type variation in the period 1971–1976. A large inter-annual change was found for Australia, with a small but statistically significant change found for Africa. This result suggests motivation for our work focusing on the effect of *ENSO* – which is known to strongly affect Australia – upon Africa. These results were arrived at by analysing land observations of cloud cover and cloud type for approximately 5400 stations, covering much of the globe. Monthly and yearly averages of the data were produced in order to diminish small-scale variation. A similar approach ought to be employed in our analysis. Preliminary analysis of our data shows occasional large day-to-day variation – as is to be expected from cloud behaviour.

3 Vegetation

A motivating factor of our research is to quantify any correlation between *ENSO* events and factors affecting human life. Particularly, we are concerned with vegetation response to *ENSO*. If our investigation into cloud coverage shows a measurable *ENSO* correlation, then we can reasonably expect to see a vegetation cover response: vegetation is coupled to cloud cover (Zhang et al., 2005).

Anyamba et al. (2002) studied the vegetation response in East and Southern regions of Africa, which found a significant anomaly in measurements of the normalized difference vegetation index (NDVI). The study found that the regions studied – namely East and Southern Africa – showed a complementary response to the warm and cold phases of *ENSO*; if NDVI for East Africa was showing positive, then Southern Africa was showing negative, and vice versa. Interestingly the study makes reference to a paper (Linthicum et al., 1999), stating that increased cloud cover stemming from *ENSO* lead to significant impacts on human life.

The NDVI was calculated using surface reflectance data in near-infrared and red bands:

$$\mathrm{NDVI} = \frac{\rho_{\mathrm{nir}} - \rho_{\mathrm{r}}}{\rho_{\mathrm{nir}} + \rho_{\mathrm{r}}}.$$

The chlorophyll in vegetation absorbs strongly in the visible part (ρ_{r}) and reflects the near-infrared part (ρ_{nir}). Hence, healthy vegetation is expected to have a smaller contribution to ρ_{r} giving a larger overall NDVI.

An earlier paper (Anyamba and Eastman, 1996) describes a method for calculating NDVI from a time-series analysis, employing principal component analysis (PCA). Importantly, the paper makes note of the growing research and consensus that *ENSO* has far-reaching effects, further motivating our work. The paper lists a number of droughts, floods, and forest fires – varying greatly in global position – that were linked to *ENSO* causes. In this research PCA is employed to find trends in NDVI data, and it is noted that four trends were found corresponding to four components of the PCA: the first two of which being the regular NDVI and seasonal variations respectively. The study concludes by stating that NDVI is a useful measure for this area of research.

4 Conclusion

This literature review has presented relevant contemporary research into two main subjects:

1. *Cloud coverage* is the process of analysing satellite data and identifying whether a pixel is cloudy or clear. This is often – and most simply – performed using thresholding: a pixel is cloudy (clear) if its temperature is below (above) some reference threshold value. The calculation of that threshold is the important choice. The threshold can be chosen by calculating the temperature that “splits” the bimodal histogram of temperatures as in the Otsu method (Vala and Baxi, 2013). Alternatively, the threshold could be calculated as the pixels average value over some period of time; this of course assumes that the pixel will more often than not be clear.

Generally, cloud coverage is determined using thresholding in multiple bands, as in Rossow and Garder (1993).

2. *NDVI* is the measure of difference between reflected and absorbed solar radiation in two bands by vegetation. Healthy vegetation absorbs strongly in the visible band and reflects near-infrared.

   NDVI has been used extensively to investigate the links between *ENSO* events and the African climate. For example Anyamba et al. (2002) found a significant effect from both warm and cold phases of *ENSO* on African NDVI.

   Alternative methods have been employed to the same end, for example Anyamba and Eastman (1996) used principal component analysis to find trends in NDVI in response to *ENSO*.

This literature review has been presented in the context of motivating research into the statistical connections between *ENSO* events and African (and European) climate anomalies. This connection has been noted in many recent papers, for example in de Oliveira et al. (2018), Fan et al. (2017), and Anyamba et al. (2002). Thus we believe our interest is well-placed and motivated. We can build upon recent research using well understood methods of analysis, and produce useful results.

References

James R Holton and Renata Dmowska. *El Niño, La Niña, and the southern oscillation*, volume 46. Academic press, 1989.

M. Derrien, B. Farki, L. Harang, H. LeGlau, A. Noyalet, D. Pochic, and A. Sairouni. Automatic cloud detection applied to NOAA-11 /AVHRR imagery. *Remote Sensing of Environment*, 46 (3):246–267, 1993. ISSN 0034-4257. doi: https://doi.org/10.1016/0034-4257(93)90046-Z. URL `http://www.sciencedirect.com/science/article/pii/003442579390046Z`.

William B. Rossow and Leonid C. Garder. Cloud Detection Using Satellite Measurements of Infrared and Visible Radiances for ISCCP. *Journal of Climate*, 6 (12):2341–2369, 1993. doi: 10.1175/1520-0442(1993)006¡2341:CDUSMO¿2.0.CO;2. URL `https://doi.org/10.1175/1520-0442(1993)006<2341:CDUSMO>2.0.CO;2`.

Stephen G. Warren, Ryan M. Eastman, and Carole J. Hahn. A Survey of Changes in Cloud Cover and Cloud Types over Land from Surface Observations, 197196. *Journal of Climate*, 20(4):717–738, 2007. doi: 10.1175/JCLI4031.1. URL `https://doi.org/10.1175/JCLI4031.1`.

Xiaoyang Zhang, Mark A. Friedl, Crystal B. Schaaf, Alan H. Strahler, and Zhong Liu. Monitoring the response of vegetation phenology to precipitation in Africa by coupling MODIS and TRMM instruments. *Journal of Geophysical Research: Atmospheres*, 110(D12), 2005. ISSN 2156-2202. doi: 10.1029/2004JD005263. URL `http://dx.doi.org/10.1029/2004JD005263`. D12103.

Assaf Anyamba, Compton J. Tucker, and Robert Mahoney. From El Niño to La Niña: Vegetation Response Patterns over East and Southern Africa during the 19972000 Period. *Journal of Climate*, 15(21):3096–3103, 2002. doi: 10.1175/1520-0442(2002)015¡3096:FENOTL¿2.0.CO;2. URL https://doi.org/10.1175/1520-0442(2002)015<3096:FENOTL>2.0.CO;2.

Kenneth J. Linthicum, Assaf Anyamba, Compton J. Tucker, Patrick W. Kelley, Monica F. Myers, and Clarence J. Peters. Climate and Satellite Indicators to Forecast Rift Valley Fever Epidemics in Kenya. *Science*, 285(5426):397–400, 1999. ISSN 0036-8075. doi: 10.1126/science.285.5426.397. URL http://science.sciencemag.org/content/285/5426/397.

A. Anyamba and J. R. Eastman. Interannual variability of NDVI over Africa and its relation to El Nio/Southern Oscillation. *International Journal of Remote Sensing*, 17(13):2533–2548, 1996. doi: 10.1080/01431169608949091. URL https://doi.org/10.1080/01431169608949091.

Miss Hetal J Vala and Astha Baxi. A review on otsu image segmentation algorithm. *International Journal of Advanced Research in Computer Engineering & Technology (IJARCET)*, 2(2), 2013.

Cristiano Prestrelo de Oliveira, Luis Aímola, Tércio Ambrizzi, and Ana Carolina Vasques Freitas. The Influence of the Regional Hadley and Walker Circulations on Precipitation Patterns over Africa in El Niño, La Niña, and Neutral Years. *Pure and Applied Geophysics*, February 2018. ISSN 1420-9136. doi: 10.1007/s00024-018-1782-4. URL https://doi.org/10.1007/s00024-018-1782-4.

Jingfang Fan, Jun Meng, Yosef Ashkenazy, Shlomo Havlin, and Hans Joachim Schellnhuber. Network analysis reveals strongly localized impacts of El Niño. *Proceedings of the National Academy of Sciences*, 114(29):7543–7548, 2017. ISSN 0027-8424. doi: 10.1073/pnas.1701214114. URL http://www.pnas.org/content/114/29/7543.