The El Niño/Southern Oscillation (ENSO) contributes to inter-annual variability of lightning production more than any other atmospheric oscillation. This study further investigated how ENSO phase affects lightning production in the tropics and subtropics using the Tropical Rainfall Measuring Mission (TRMM) Lightning Imaging Sensor (LIS). Lightning data were averaged into mean annual warm, cold, and neutral ‘years’ for analysis of the different phases and compared to model reanalysis data. An examination of the regional sensitivities and preliminary analysis of the three locations was conducted using model reanalysis data to determine the leading convective mechanisms in these areas and how they might respond to the ENSO phases.

**Abstract**

The El Niño/Southern Oscillation (ENSO) contributes to inter-annual variability of lightning production more than any other atmospheric oscillation. This study further investigated how ENSO phase affects lightning production in the tropics and subtropics using the Tropical Rainfall Measuring Mission (TRMM) Lightning Imaging Sensor (LIS). Lightning data were averaged into mean annual warm, cold, and neutral ‘years’ for analysis of the different phases and compared to model reanalysis data. An examination of the regional sensitivities and preliminary analysis of the three locations was conducted using model reanalysis data to determine the leading convective mechanisms in these areas and how they might respond to the ENSO phases.

**Data and Methods**

- **Oceanic Niño Index (ONI)** as outlined in Table 1 [Huang et al., 2017]
- **ENSO years kept ENSO max in one year (e.g. ENSO 2000 ran from 4/1/00 to 3/31/01)
- **Lightning Data**
  - TRMM LIS Low Resolution Time Series (LRTS) [Cecil et al., 2014]
  - 2.5° x 2.5° spatial resolution
- **Model Data**
  - NCEP/NCAR 40 Year Reanalysis Project (NCNC) [Kalnay et al., 1996]
  - 2.5° x 2.5° daily averages

**Results**

- **Regional Sensitivities**
  - Warm Phase Positive Magnitude Anomalies (Figure 2)
  - Cold Phase Positive Magnitude Anomalies
  - Neutral Phase Positive Magnitude Anomalies
  - The two global lightning maxima of Lake Maracaibo and the Democratic Republic of the Congo, central South America, Eastern Australia, Himalayas, Northern Arabian Peninsula
  - Percentage anomalies are dominated by the oceans and deserts, where flash rates rarely exceed 0.25flk/m³−1 and therefore can be dominated by singular events

- **Central Africa**
  - Overall lower conv. precip. rate, but more lightning during warm phase
  - Maximum conv. and later during warm phase
  - Consistent shift, but some cold years have greater maxima
  - Little change in wind pattern
  - **Southern Africa**
  - Higher conv. precip. rate, more lightning during cold phase
  - Enhanced northerly flow compared to mean phase, significantly more than warm phase (not pictured)
  - Very consistent pattern
  - **Cuba/Florida Peninsula**
  - Annual variability hard to tie to ENSO phase, with positive and negative anomalies from all three phases (Fig 4)
  - More stable during warm phase, less during cold phase

- **Initial Conclusions**
  - **Regional Sensitivities**
    - Most areas consistent with previous literature
    - Potentially new regions include the three African regions of Central Africa, Southeastern Africa, and Djibouti/Red Sea
    - Most ‘neutrally sensitive’ regions’ lightning from topography, differential heating, and land/sea contrast which are generally unaffected by ENSO
    - Some regions have a single response to ENSO phase (e.g. Central African warm phase), others are dipoles (e.g. Argentina, Southeastern Africa)
  - **Central Africa- Warm Phase**
    - Maybe tied to ITCZ pattern shift with ENSO
    - Enhances and extends (in space and time) the peak lightning activity
    - Better aligns with max in annual moisture and land/sea contrast
  - **Central Africa- Cold Phase**
    - Indian Ocean High (IOH) may shift with ENSO during austral summer
    - With weaker (stronger) easterlies during warm (cold) phase
    - May move ITCZ north during warm phase and south during cold phase
    - Southeast ITCZ produces more lightning in Madagascar and Mozambique
  - **Evidence: northward extension of lightning, decrease in CP rate, stronger southerly winds in austral summer
  - **Southern Africa- Cold Phase**
    - Indian Ocean High (IOH) may shift with ENSO during austral summer
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    - May move ITCZ north during warm phase and south during cold phase
    - Southeast ITCZ produces more lightning in Madagascar and Mozambique
  - **Evidence: northward extension of lightning, decrease in CP rate, stronger southerly winds in austral summer
  - **Cuba/Florida Peninsula- Null Case**
    - Localized processes drive lightning and appear indifferent to ENSO phase
    - Potential ‘net zero’ effect between cold and warm phases

- **Further Investigations**
  - Central Africa
    - Overall lower conv. precip. rate, but more lightning during warm phase
    - Maximum conv. and later during warm phase
  - Consistent shift, but some cold years have greater maxima
  - Little change in wind pattern
  - **Southern Africa**
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    - Annual variability hard to tie to ENSO phase, with positive and negative anomalies from all three phases (Fig 4)
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**Table 1: ONI values for each three phases years.**

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**Acknowledgments**

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