Examining the sensitivity and impact of anthropogenic climate change on North Atlantic major hurricane landfall drought and activity

Emma Levin[1] and Hiroyuki Murakami[2]

Emma.Levin@noaa.gov

[1]Paul D. Schreiber High School, [2]Princeton University / Geophysical Fluid Dynamics Laboratory/NOAA, Princeton, NJ, USA

1. Motivation

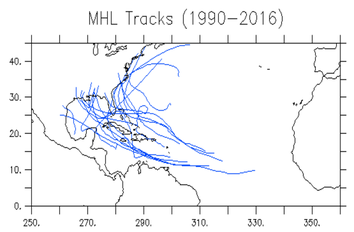
The 2017 hurricane season in the Northern Atlantic Ocean terminated a 12 year major hurricane landfall (MHL) "drought" (Fig. 1a).

Anthropogenic climate change is increasing in prevalence (Fig. 1b) with increasing temperatures in the North Atlantic Ocean.

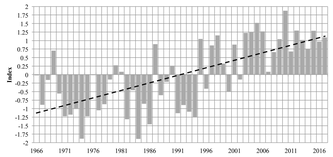
The SST index over the main development region from July-November during the drought years, however, was relatively high (Fig. 1c).

How does anthropogenic forcing influence MHL drought frequency and length?

(a) North Atlantic MHL tracks 1990-2016



(b) Normalized SST Jul-Nov index for 1966-2017



(c)(2006-2017) – (1958-2017) SST anomaly (Jul–Nov)

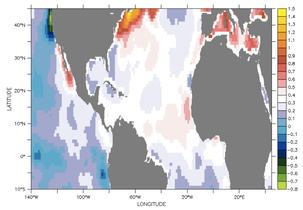


Fig 1. *(a) MHL tracks from 1900 to 2015, (b) mean July-October SST indexes from 1966 to 2017, (c) SST anomaly comparing drought years to all years from 1958 to 2017.*

2. Buffer Creation

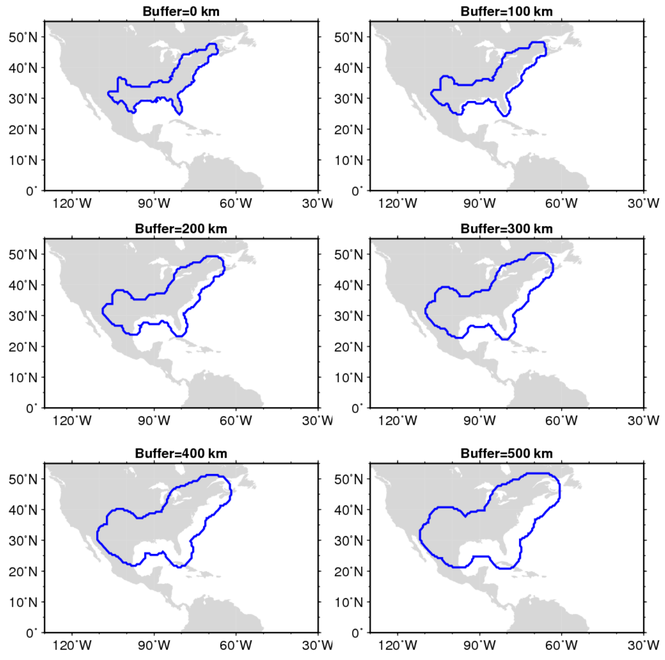
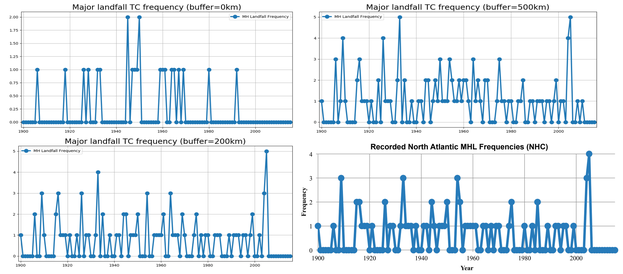


Fig 2. *Illustrated buffers through continental US. Northwestern continental sections of buffers are not influential.*

As documented in Hart (2016), MHL frequency depends on the definition of MHL, which is arbitrary. To analyze MHL sensitivity to the Atlantic Coast of the US, we created 6 different "buffers" extending the coastline: 0 km, 100 km, 200 km, 300 km, 400 km, and 500 km using QGIS. This changed the definition of a landfall, for when the center of a hurricane passed through the buffer, it was considered to have made landfall.

Observational Study

North Atlantic hurricane observations from 1900 to 2015 were run through all 6 buffers to assess which buffer most similarly represents recorded observational data from the NHC:



1. The MHL frequency (and MHL drought) depend on the buffer distance.
2. The 200 km buffer most closely resembles the reference observed data of MHL

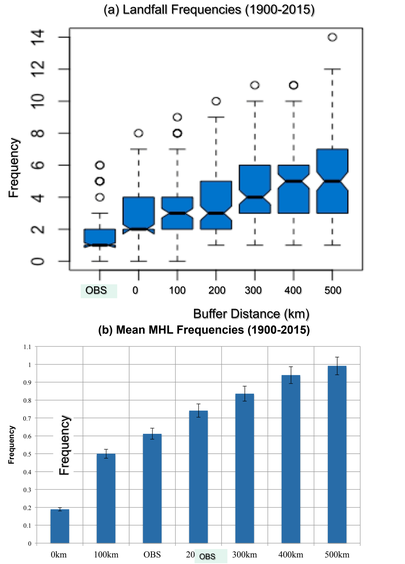


Fig 3. *(a) Landfall frequency boxplot by buffer distance and (b) MHL mean frequencies with 5% error bars by buffer distance.*

We found the correlation coefficients comparing each buffer's estimated MHL frequencies to the recorded data to find how well trends matched.

MHL frequencies	0 km	100 km	200 km	300 km	400 km	500 km
Correlation to recorded NHC MHL frequencies (r)	0.3289	0.8018	0.8649	0.8625	0.8385	0.8425

All buffers ≥ 100 km illustrate a strong correlation to recorded observation (r > 0.8), and the 200 km buffer is most closely correlated to recorded observation.

3. GFDL HiFLOR Model Use

To examine the potential influence of anthropogenic forcing on MHL frequency, we analyzed two control experiments of 1860-Control and 1990-Control using HiFLOR. We predicted that because the drought years occurred during relatively warm years, an increase in anthropogenic forcing will increase the frequency of long droughts.

Control Experiments

Observation

North Atlantic recorded data (NOAA and NHC), 1900-2015

1990 Control

Climate conditions beginning at a 1990 level taking anthropogenic forcing into account, 300-year simulations

1860 Control

Climate conditions beginning at a 1860 level without anthropogenic forcing taken into account, 1200-year simulations

Model Use

GFDL HiFLOR (High- Resolution Forecast-oriented Low Ocean Resolution)

Atmosphere: 25 km, L32

Ocean: 100 km L50

We computed length of years during which no MHL occurred and how often these different drought lengths occurred. For each group using all 6 buffers focusing most closely on the 200 km buffer because of its similarity to observational data.

Because each group has a different simulation length, data was collected in 116-year moving means for 1990 and 1860 control, and error bars (max, min) were added to plots.

0 km buffer underestimates OBS data and predicts ≥ 26 year drought frequencies are similar in both groups.

500 km buffer overestimates OBS data and predicts ≥ 6 year drought frequencies are greater for 1860 control.

200 km buffer overestimates OBS data and predicts ≥ 11 year drought frequencies are greater for 1860 control.

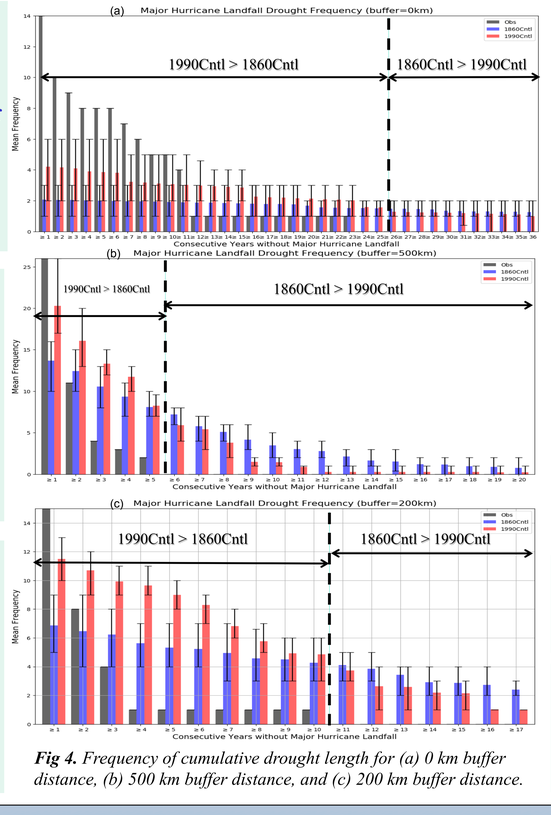
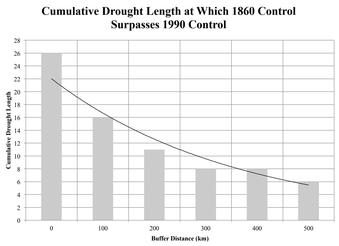


Fig 4. *Frequency of cumulative drought length for (a) 0 km buffer distance, (b) 500 km buffer distance, and (c) 200 km buffer distance.*

We plotted the cumulative drought frequency at which the 1860 control passes the 1990 control and found the exponential regression curve.



As buffer distance increases, the cumulative drought length at which the 1860 control passes the 1990 control decreases exponentially.

The model underestimates MHL events, over predicting MHL drought.

Anthropogenic forcing is not associated with increased frequencies of long MHL droughts.

4. Summary

6 "buffers" are created that analyze the sensitivity of landfalling hurricanes and MHL to the US coastline. 1900-2015 hurricanes were run through these buffers and compared to recorded data.

(a) No buffer distance closely estimates landfall hurricanes. They all overestimated.

(b) The 200 km buffer most closely estimates MHL to referenced observational data.

(c) MHL frequency and drought depend on the buffers.

All 6 "buffers" are run through the HiFLOR model (with an 1860 control dismissing anthropogenic forcing and a 1990 control taking anthropogenic forcing into account) to determine how anthropogenic forcing influences the frequency of long MHL droughts.

(a) All buffers indicate that 1860 control either passes or illustrates similar trends to 1990 control with regards to frequency of long droughts.

(b) The high-resolution model underestimates MHL frequencies.

(c) Anthropogenic forcing is not associated with longer MHL droughts.