CLIMATOLOGY AND PREDICTABILITY OF MID-ATLANTIC TROPICAL CYCLONE LANDFALLS IN HIGH-ATMOSPHERIC-RESOLUTION SEASONAL PREDICTION SYSTEM

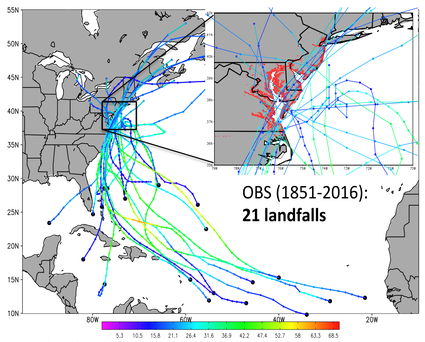
Julia V Manganello, Ben Cash & Erik Swenson

George Mason University and Center for Ocean-Land-Atmosphere Studies (COLA) , Fairfax, VA

Introduction

Motivation

- TC landfalls over the Mid-Atlantic are very rare (Fig. 1). When these events do occur, the resulting consequences could be devastating. A recent example is Hurricane Sandy (2012).
- We have utilized *Minerva* hindcasts as "extensions" of the observational record to compile statistics of these rare events.
- Are Mid-Atlantic TC landfalls predictable in *Minerva*? Does predictability depend on model resolution?



Only **6 landfalls** during 1980-2016

Fig. 1. TC landfalls over the Mid-Atlantic (the coastline is shown in red in the inset).

MINERVA PROJECT Modeling System

System	Atmosphere model cycle	Atm. resolution	Atm. vertical levels	Ocean model	Ocean resolution	Ocean vertical levels
Minerva	IFS cy 38r1	**T319** (64km) **T639** (32km) **T1279** (16km)	91 levels, top=1 Pa	NEMO v3.0/3.1	1 deg., ~ 0.3 deg. Lat.	42 levels

Subset of Hindcasts

Resolution	Start Dates	Ensembles	Length	Period of Integration
T319 (64km)	May 1	51	7 months	1980-2012
T639 (32km)	May 1	15	7 months	1980-2013
T1279 (16km)	May 1	15	7 months	1980-2013

Basic statistics of Mid-Atlantic TC landfalls in OBS and *Minerva*[1]

	IBTrACS v03r07		T1279 *(510 seas.)*	T639 *(510 seas.)*	T319	
	1851-2016 *(166 seas.)*	1900-2016 *(117 seas.)*			15 ens. *(495 seas.)*	51 ens. *(1,683 seas.)*
Average rate	0.13	0.11	0.10	0.09	0.09	0.09
Average Return Period	8	9	10	11	11	11
Probability of Landfall[2]	12%	11%	9%	9%	9%	9%
Probability of landfall in the next 10 seasons	74%	69%	64%	61%	63%	61%

[1] All results are for the MJJASON season.
[2] Probability of a landfall of one or more TCs based on the Poisson distribution. Differences between the model and observational values are statistically insignificant.

Climatology of Mid-Atlantic tropical cyclones landfalls

Genesis Density

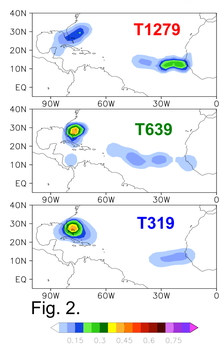


Fig. 2.

Lifetime Max. Intensity (10m speed)

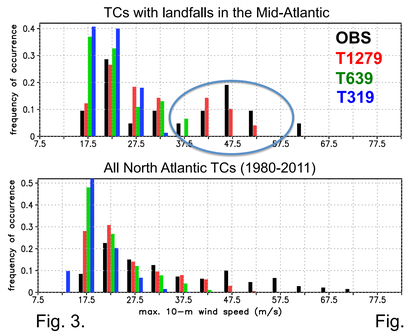


Fig. 3.

Seasonal Cycle

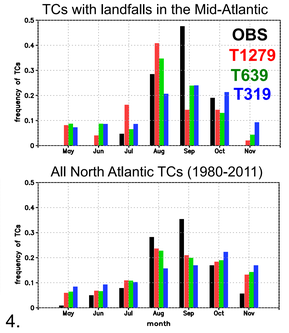


Fig. 4.

Composite atmospheric anomalies during Mid-Atlantic TC landfalls, T1279

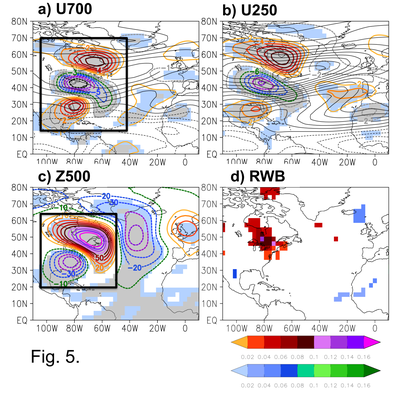


Fig. 5.

How frequent are the dipole (Z500) and tripole (U700) patterns during the landfalls?

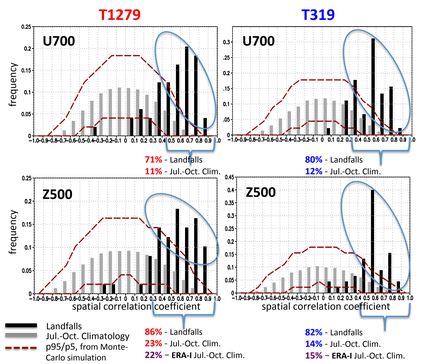
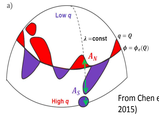


Fig. 6.

Local finite-amplitude wave activity (LWA) as a diagnostic of Z500 evolution

LWA has been Introduced by Huang and Nakamura (JAS, 2016)



q – a quasi-conservative dynamic quantity;
Q – a given value of q;
$\phi_e(Q)$ – equivalent latitude after an area-conserving adjustment of the Q contour to a zonally symmetric state;
$A_s(\lambda, \phi_e)$ – **southern LWA**, or cyclonic wave activity to the south of the latitude ϕ_e;
$A_n(\lambda, \phi_e)$ – **northern LWA**, or anticyclonic wave activity to the north of the latitude ϕ_e;

LWA has been shown to be an effective diagnostic of weather extremes at the regional scales, and capture the local wave amplification associated with the blocking episode during Hurricane Sandy (2012).

Persistence of LWA anomalies leading to Mid-Atlantic TC landfalls

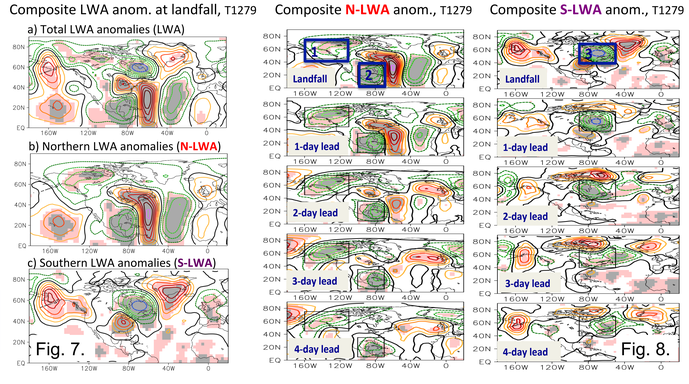


Fig. 7. Fig. 8.

Persistence of SST anomalies leading to Mid-Atlantic TC landfalls

Composite detrended sea surface temperature (SST) anomalies (stat. sign.), **T1279**

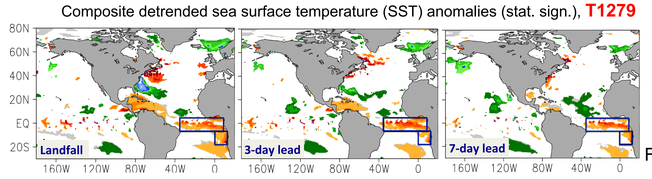


Fig. 9.

(no significant SST anomalies for the **T319** model)

Statistical modeling of Mid-Atlantic TC landfalls

LWA Index (LWAI) = -1.0*(N-LWA$_1$ + N-LWA$_2$ + S-LWA$_3$),

$_1$ – N-LWA anomalies averaged over Region 1 (see Fig. 8), etc.

SSTA Index (SSTI): SSTAs averaged over the equatorial Atlantic (see Fig. 9.)

LWAI (SSTI) at **1-day lead** is LWAI (SSTI) averaged over 1 to 3 days prior to landfall,
LWAI (SSTI) at **2-day lead** is LWAI (SSTI) averaged over 2 to 4 days prior to landfall.

TC locations **2 days** prior to landfalls

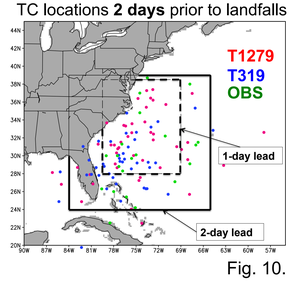


Fig. 10.

All other TC positions (July-October) within outlined limits are used in the model as "No Landfall", or "Zero" events.

- ✧ A case of **rare events**, **unbalanced** data set.
- ✧ We use **binary quantile regression**, which utilizes skewed links (higher quantiles) that could offer a better fit to unbalanced data.

Area under the ROC curve (AUC)*

	Landfall ~ **LWAI**	Landfall ~ **SSTI**	Landfall ~ **LWAI + SSTI**
1-day lead			
T1279	0.66	0.61	0.68
T319	0.59	-	-
2-day lead			
T1279	0.63	0.60	0.63
T319	0.58	-	-

* K-fold cross-validation is used on the model.

Summary & Conclusions

- *Minerva* hindcasts exhibit skill in reproducing climatological characteristics of Mid-Atlantic TC landfalls particularly at the highest T1279 resolution (16-km grid spacing).
- There are large-amplitude quasi-stationary features in the LWA and SST anomaly distributions that persist up to a week leading to these landfalling events.
- A statistical model utilizing indices based on the LWA and SST anomalies as predictors is developed. It shows skill in predicting Mid-Atlantic TC landfalls one day (and possibly two days) in advance only when applied to T1279 data.
- Using the LWA Index as a metric may have potential for assessing statistics of Mid-Atlantic TC landfalls in longer timescale predictions including climate change projections.