Exploitation of Ensemble Prediction System Information in Support of Atlantic Tropical Cyclogenesis Prediction

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NGGPS FFO Meeting
3rd August 2016

Objectives

Utilise ensemble forecasts to provide genesis probabilities on invests and pre-invest disturbances.

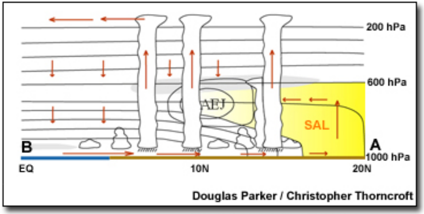
Assess the bias and skill of ensemble systems, to develop bias-corrected system based probabilities.

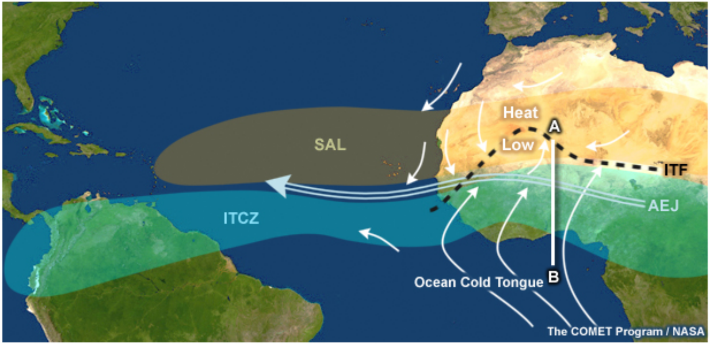
Provide improved real-time ensemble diagnostics available to NHC forecasters for 1-5 day genesis forecasts.

Overview

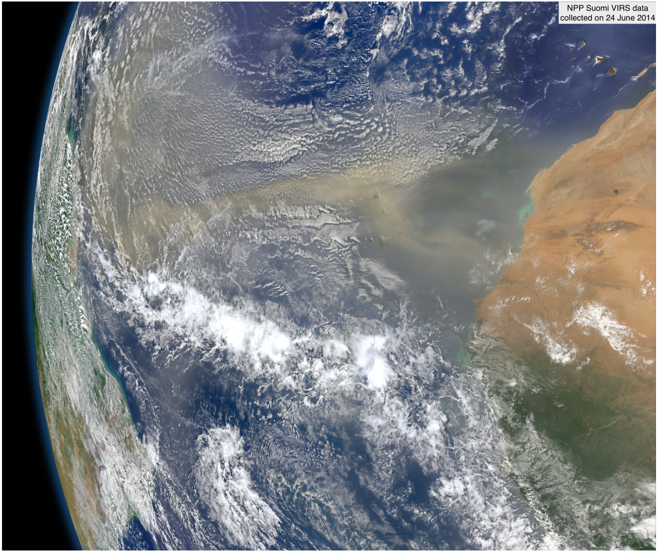
West African Monsoon

Large-scale Features of the West African Monsoon and the Tropical Atlantic

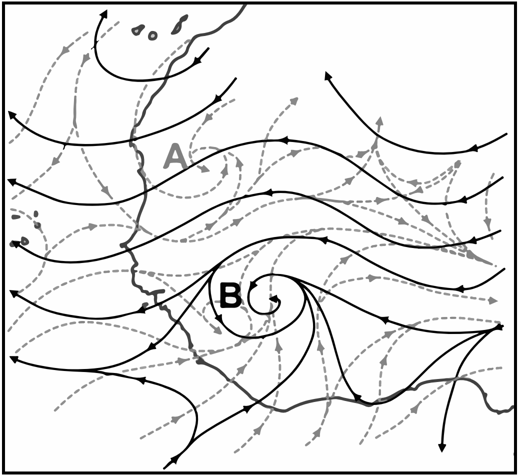




Dry Air over the Eastern Atlantic



AEW Structure



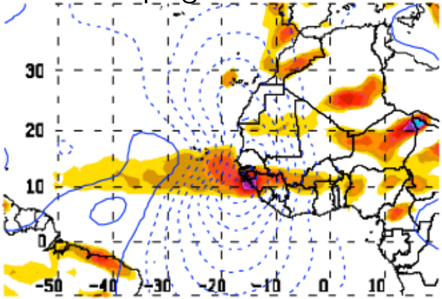
Streamlines at 700 hPa (black solid) and 925 hPa (dashed gray).

A and B denote the northern low-level and southern mid-level circulations, respectively.

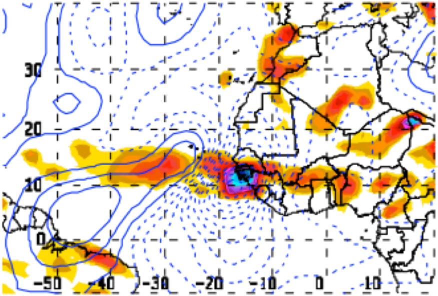
Adapted by (Janiga 2012) from Fig. 4a in (Carlson 1969)

AEW & Tropical Cyclones

Non-Developing



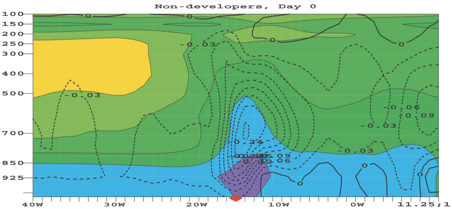
Developing



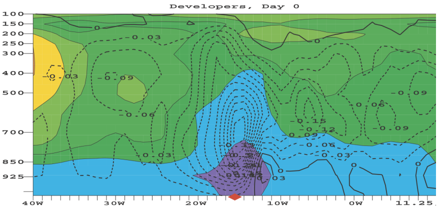
Developing waves had stronger vorticity when leaving Africa (Hopsch et. al. 2010)

AEW & Tropical Cyclones

Non-Developing



Developing



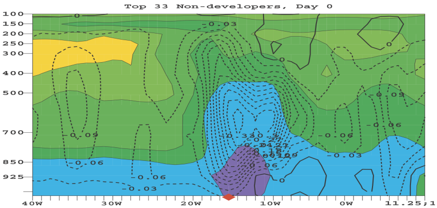
Increased moisture & ascent in trough over coastal region

Increased moisture at mid-levels

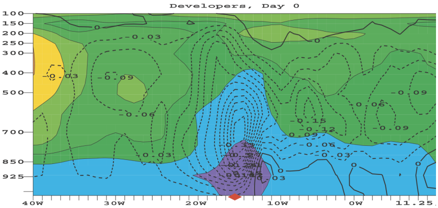
Longitude Height Cross section along 11.25°N. (Hopsch et. al. 2010)

AEW & Tropical Cyclones

Strong Non-Developing



Developing



Differences between waves with strong 850 hPa Rel. Vort. very similar to developing

Longitude Height Cross section along 11.25°N. (Hopsch et. al. 2010)

AEW & Tropical Cyclones

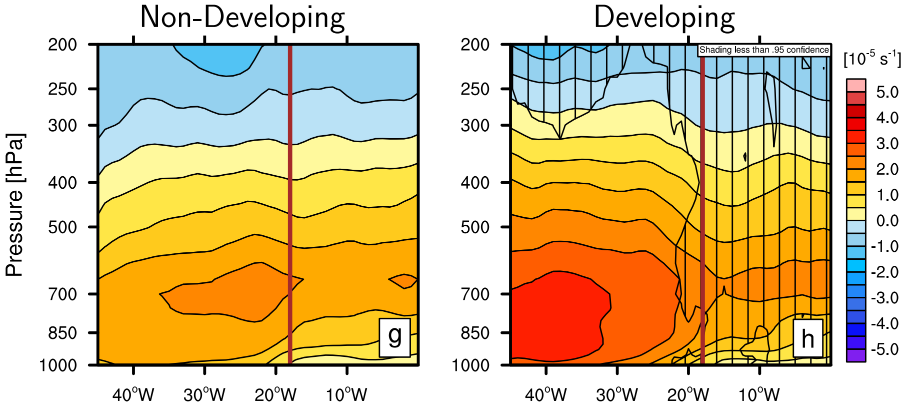
Deep convective bursts over West African coastline feedback on trough increasing vorticity for developing waves (Ross & Krishnamurti 2009,2012)

Widespread deep convection over coast more important than small intense convection (Leppert et al 2013)

Horizontal flux of moist enthalpy important for sustained MCSs moving off the coast (Arnault & Roux 2009,2010)

TPW, precipitation, SST, 1000-600 hPa vertical shear among best predictors for developing / non-developing systems over Atlantic (Peng et al 2012)

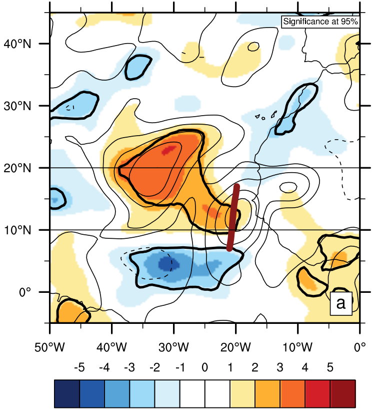
Vertical Profile Evolution



Relative Vorticity

Vertical evolution of trough centred variables averaged over 500 km radius. Mean favourable non-developing waves (a,c,e,g; n=51) and mean favourable developing Waves (b,d,f,h; n=51). Hatched region denotes area not significantly different to non-developing composite at 95% (Brammer & Thorncroft 2015)

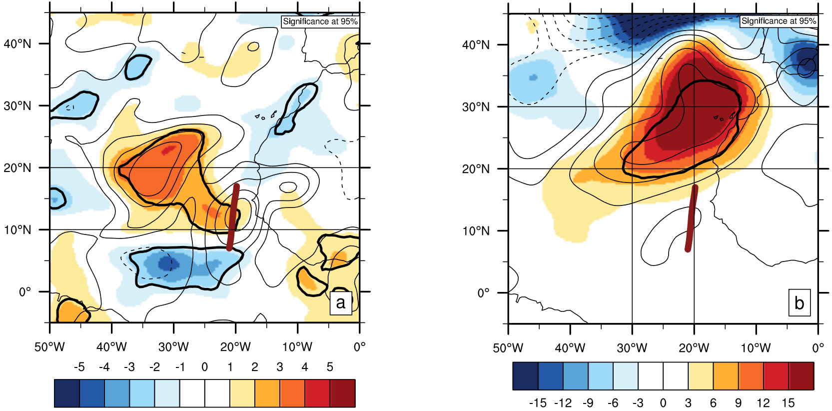
Day 0 Composite Differences



(a) TPW [mm]

Favourable developing waves - favourable non-developing waves (shading). Contours = composite dev waves. Shading and contour intervals are equivalent. Thick black contour statistically significant area $\geq$ 95%. (Brammer & Thorncroft 2015)

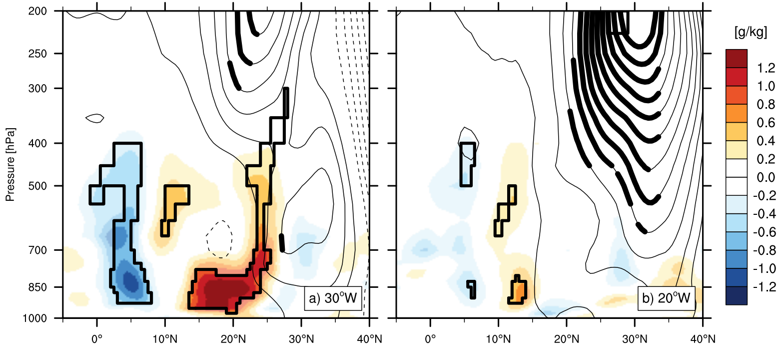
Day 0 Composite Differences



(a) TPW [mm] (b) 300 hPa Geopotential height [gpm].

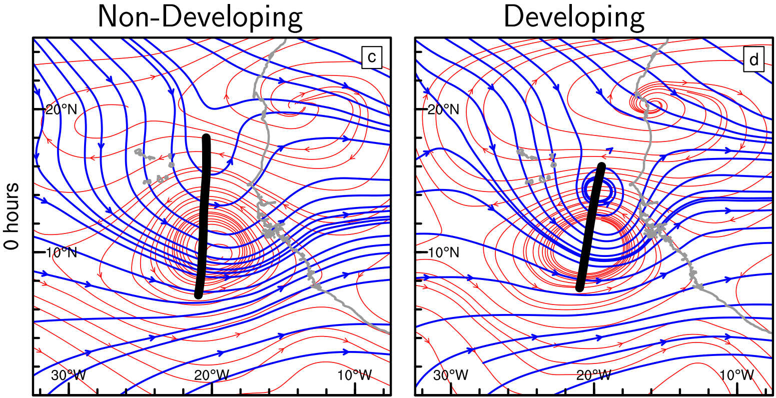
Favourable developing waves - favourable non-developing waves (shading). Contours = composite dev waves. Shading and contour intervals are equivalent. Thick black contour statistically significant area ≥ 95%. (Brammer & Thorncroft 2015)

Day 0 Composite Lat-Height Differences.



Latitude - height cross section showing favourable developing waves - favourable non-developing waves along 30°W (a) and 20°W (b) of specific humidity [g/kg] (shading) and Geopotential height every 2.5m (contours). Bold contours and shading (outlined) denote areas of statistical significance. (Brammer & Thorncroft 2015)

Trough Relative Flow 20°W



Composite wave relative streamlines at 2 levels for day -3 (a,b), day 0 (c,d) and day +3 (e,f) and favourable non-developing and developing waves (left, right respectively). Streamlines represent 700 hPa (Red), 850 hPa (Blue) wave relative flow. Thick black contour shows the 700 hPa trough line. (Brammer & Thorncroft 2015)

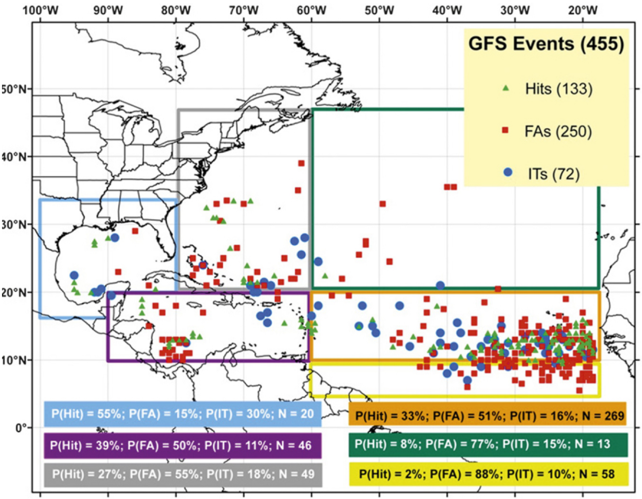
AEW & Tropical Cyclones

Convective activity around deep & moist vortex over coastal region.

Intensification of low-level vorticity (typically over 2 days) acts to protect from environment at low-levels.

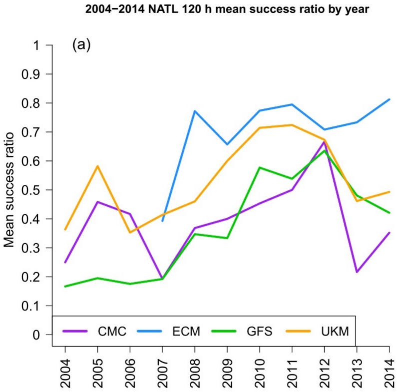
Feedbacks through this environmental flow process during forecasts could lead to over/under intensification.

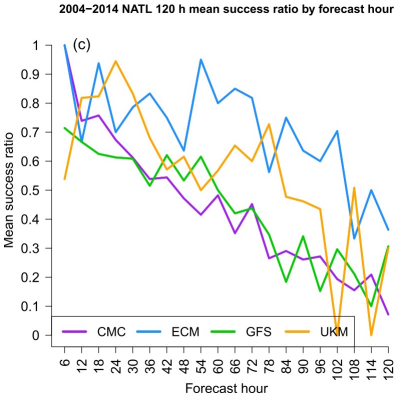
Forecast Genesis Predictability



(Halperin et. al. 2013)

Forecast Genesis Predictability





(Halperin et. al. 2016)

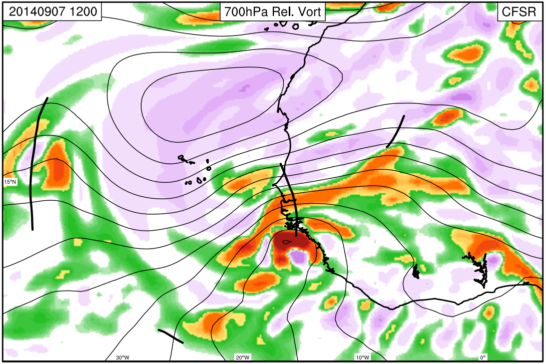
Data & Methodology

Tracking AEWs in analysis and forecasts.

Develop a pre & post genesis tracking to provide increased forecast guidance prior to genesis.

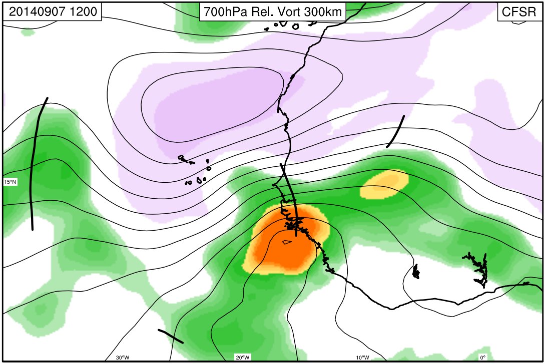
Need to track synoptic and mesoscale features without temporal filtering.

AEW tracking



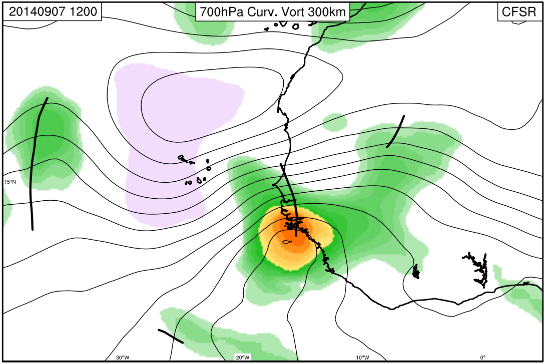
Raw Vorticity at 0.5° grid scale. Can be "noisy" with multiple maxima over West Africa. Grid scale dependent.

AEW tracking



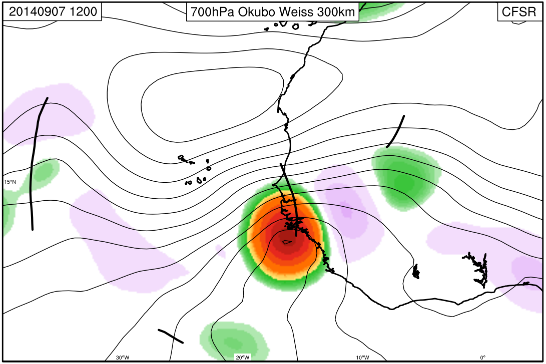
Smooth grid through a 300km averaging script. Dynamically consistent and grid scale independent (ish)

AEW tracking



Curvature Vorticity is a useful variable for identify curvature rather than shear. Berry et al. 2007

AEW tracking



Okubo Weiss - separates shear and strain from vorticity. Noisy without smoothing.

Cyclonic and anticylonic $\geq$ 0

Data & Methodology

Similar to GFDL, track combination of positions.

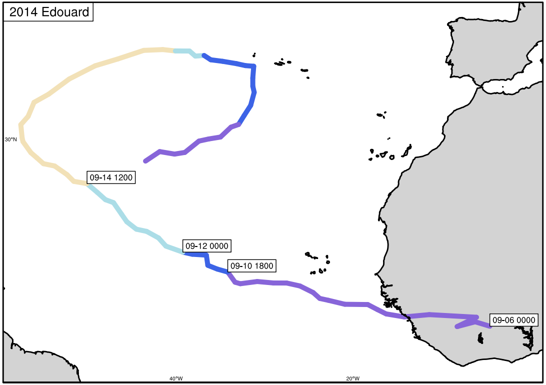
At least 3/6 of vorticity variables at 700 & 850 hPa.

Use lower-troposphere steering flow and track extrapolation for next location guess.

Tracks must last 48 hrs and travel at least 10°.

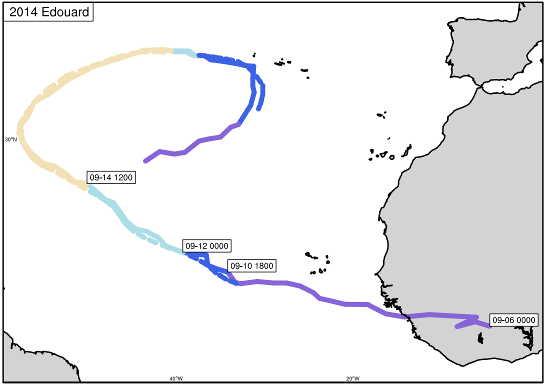
Match reanalysis tracks to HURDAT locations, keep reanalysis locations though.

Example tracking



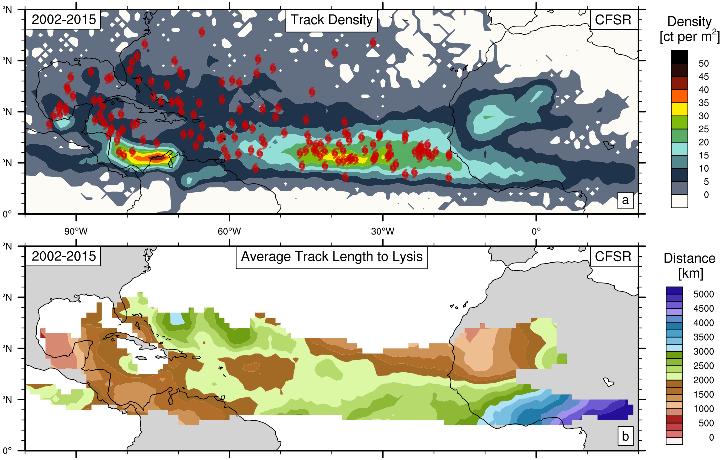
2014 Edouard track

Example tracking

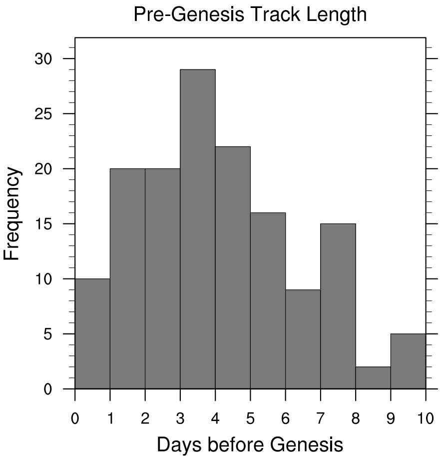


2014 Edouard track with HURDAT track dashed

Reanalysis tracking



Pre-genesis tracking



Pre-genesis tracker provides approximately 1-5 days lead time before genesis occurs.

Tracking coherent disturbances prior to genesis will allow for ensembles to be processed, with respect to the same disturbance, more easily.

GEFS tracking

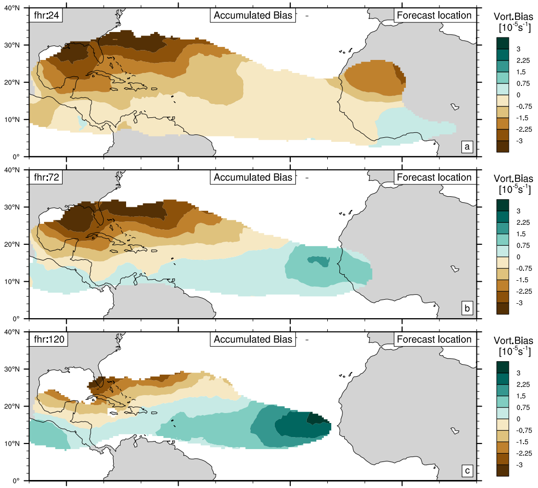
Track each disturbance that exists in CFSR out to 120 hr in GEFS reforecast.

10 ensembles plus control with 6 hr forecast intervals. Initialised every 00z.

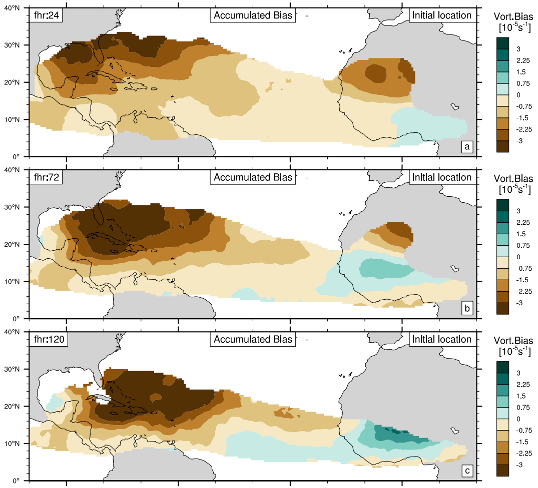
For this talk, verify against CFSR location and intensities. Genesis metrics are in development, and multi-model verification is being considered.

Approx. 1500 disturbances, 13 years, 120 hrs, 11 ensemble members.

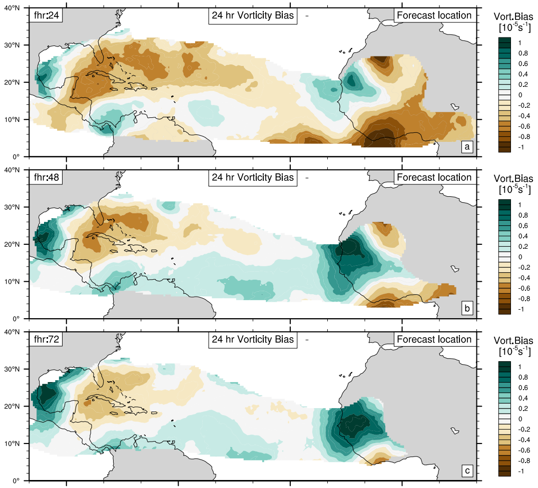
GEFS Disturbance Vorticity Bias



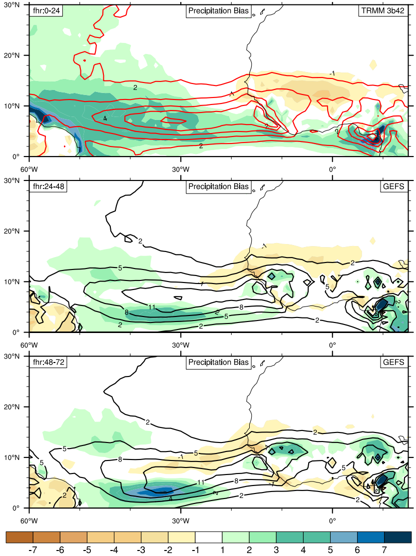
GEFS Disturbance Vorticity Bias



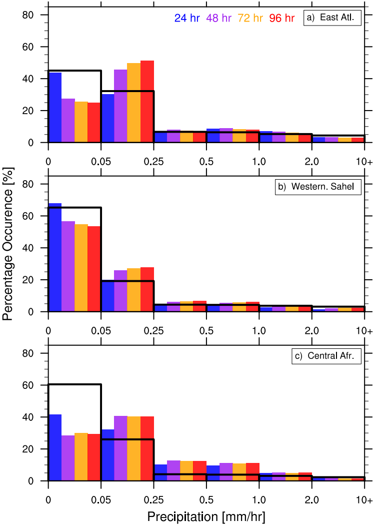
GEFS Disturbance Vorticity Bias

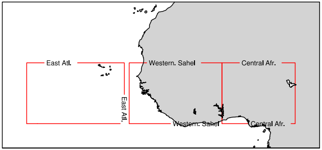


GEFS Precipitation Bias

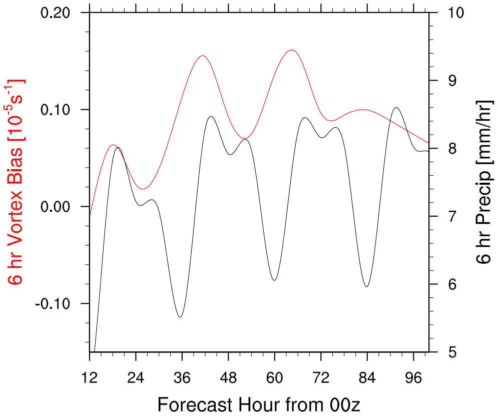


GEFS Precipitation Bias

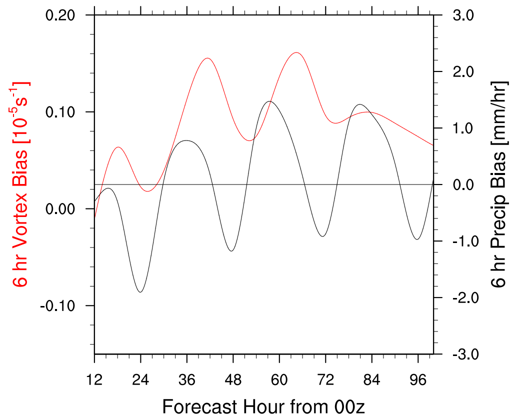




GEFS Diurnal Influence



GEFS Diurnal Influence



Bias Results

Over intensification of AEWs leaving the west African coast

Over intensification of vortices in the deep tropics over the Atlantic.

Weak bias however over the Western Atlantic and north Caribbean.

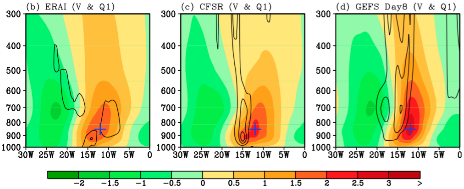
Wet bias over the ocean; after 24 hrs bias is focused south of the ITCZ.

Sahel has a slight wet bias, and excessive moderate rain rates over Central Africa.

Diurnal bias in precipitation aligned with peaks in vorticity bias.

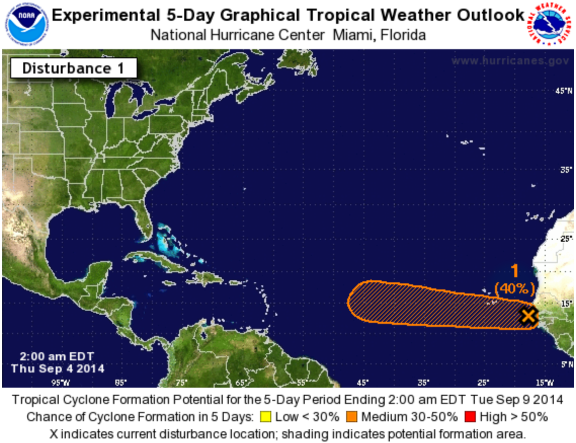
Bias Results

Similar precipitation and AEW findings to Li et al. 2016.



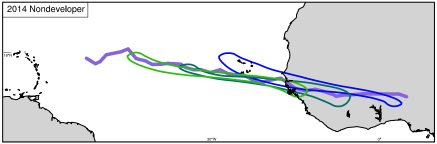
Precipitation rate bias not as strong as shown over the Indian Monsoon region e.g. Bombardi et al. 2015.
Research is ongoing for AEW centric precipitation verification.

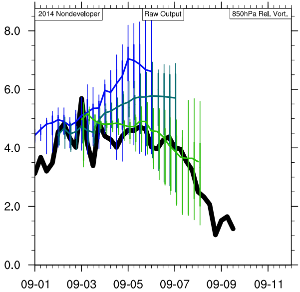
2014 AL90


Experimental 5-Day Graphical Tropical Weather Outlook
National Hurricane Center Miami, Florida
Disturbance 1
www.hurricanes.gov
1
(40%)
2:00 am EDT
Thu Sep 4 2014
Tropical Cyclone Formation Potential for the 5-Day Period Ending 2:00 am EDT Tue Sep 9 2014
Chance of Cyclone Formation in 5 Days: Low < 30% Medium 30-50% High > 50%
X indicates current disturbance location; shading indicates potential formation area.

2014 AL90

GEFS Forecast Cones & Intensity Distribution





2014 AL90

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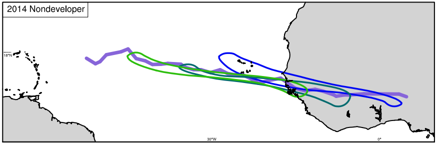

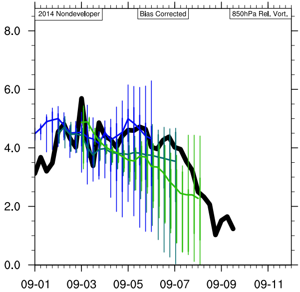

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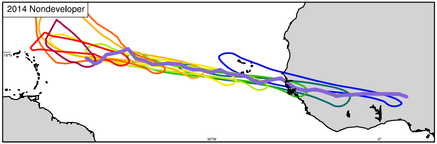
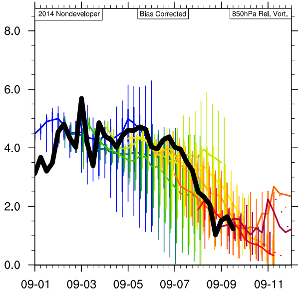


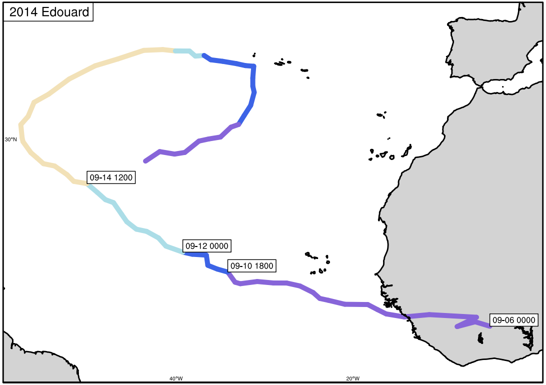


AL90 Results

Vortex bias correction, reduces over intensification of system over Guinea Highlands.

Analysis intensity falls within inter-quartile range of multiple forecasts after correction.

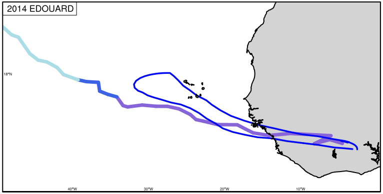
2014 Pre-Eduoard

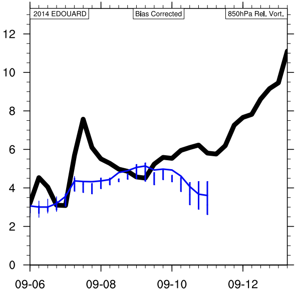


2014 Edouard track

2014 Pre-Eduoard

GEFS Forecast Cones & Intensity Distribution





2014 Pre-Eduoard

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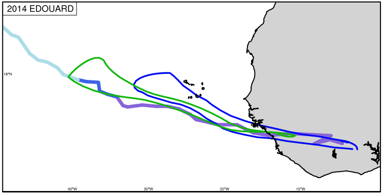
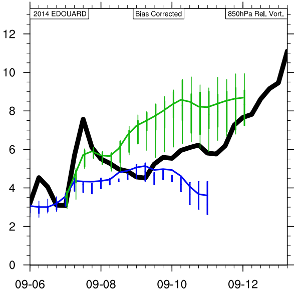
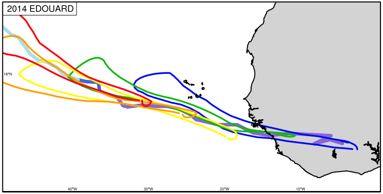
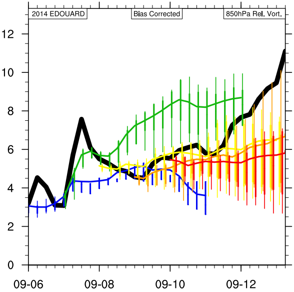




2014 Pre-Eduoard

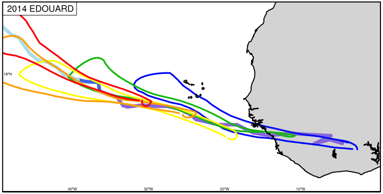
GEFS Forecast Cones & Intensity Distribution

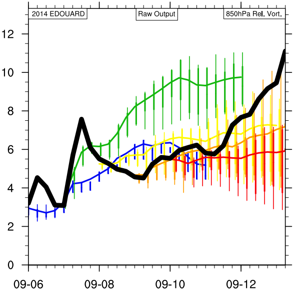




2014 Pre-Eduoard

GEFS Forecast Cones & Intensity Distribution





Edouard Results

Bias correction does not impact forecasts significantly, over intensification occurs after trough has left the coast.

Possible diurnal timing and location increasing error in forecast.

Preliminary analysis shows that the spatial distribution of precipitation, is confined around trough center unrealistically.

Project so far

Developed pre + post genesis tracking algorithm, largely based on Marchok tracker with vorticity variables for weak disturbances.

Tracked 1500+ vortices across the Atlantic over 14 year dataset. Calculated bias statistics based on vortex forecasts.

Strong over intensification of AEWs over West Africa and as they leave the coast.

Forecasts typically too weak once over the western Atlantic.

Currently training genesis thresholds to determine objective genesis skill scores.

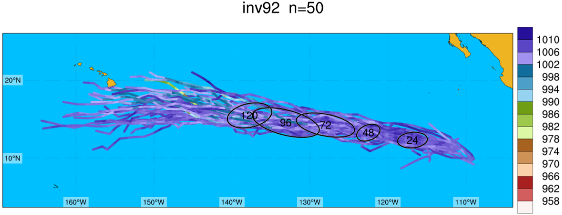
Current Work

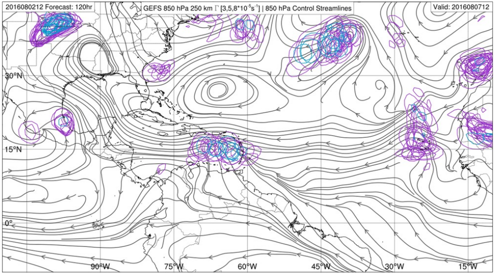
Diagnosing differences between developing and non-developing genesis cases within ensemble spread and between initializations hours.

Meeting with NHC forecasters (next week) to focus efforts on useful real-time genesis products for use in their forecasts.

Working with the NOAA SHOUT field campaign, providing GEFS and ECEF forecasts. Developing ensemble based genesis products for real-time use.

Current Work





Future Work

Identify and analyze cases of “good” and “bad” forecasts, to determine significant differences.

Test whether incorporation of GFS and GEFS forecasts into a statistical Tropical Cyclogenesis forecast model provide valuable information. (i.e. the TCGI product)

Establish a website for real-time tracking and bias correction for the pre-genesis disturbances in the GEFS.

Thanks for listening.

contact: abrammer@albany.edu