9D.5 DEVELOPMENT AND APPLICATION OF A TROPICAL CYCLONE ENVIRONMENTAL WIND CLIMATOLOGY

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1. INTRODUCTION

A recent modeling study by Finocchio et al. (2016) illustrated how the height and depth of environmental vertical wind shear resulted in a wide range of tropical cyclone (TC) intensities and structures. Their primary goal was to identify sensitivities and they were not constrained to testing realistic environmental flows in doing so. Here we attempt to interpret their idealized simulations in the context of real TC environments. To this end, we compute the mean wind profiles around a large sample of Northern Hemisphere TCs in order to construct a TC environmental wind climatology. The climatology allows us to gain a distributional sense for the types of vertically sheared flows that real TCs experience.

2. DEVELOPING THE CLIMATOLOGY

We use the IBTrACS best track archive (Knapp et al. 2010) to determine locations and intensities of a large sample of TCs in the Northern Hemisphere. We only consider the 00Z and 12Z IBTrACS records between 1979 and 2014 during the active months of May–October. Furthermore, we reject cases that are closer than 500 km to land, poleward of 25°N, or weaker than 34 kt. There are 7496 valid TC cases that satisfy these criteria: 2971 in the Western North Pacific (WP), 3510 in the Eastern North Pacific (EP), and 1015 in the North Atlantic (AL).

We use the JRA-55 reanalysis for defining the environmental flow around each valid case due to its superior representation of the location and intensity of TCs (Murakami 2014, Kobayashi et al 2015). Circulations associated with the vortex can project on to the environmental wind shear, so we remove the vortex at all levels using the method of Kurihara et al. (1993). Briefly, this method optimally interpolates the winds inward from the edge of a cylindrical region centered on the best track position, providing an approximation of the environmental flow as if the TC were absent. From the resulting "non-hurricane" wind field, we compute the mean zonal winds at

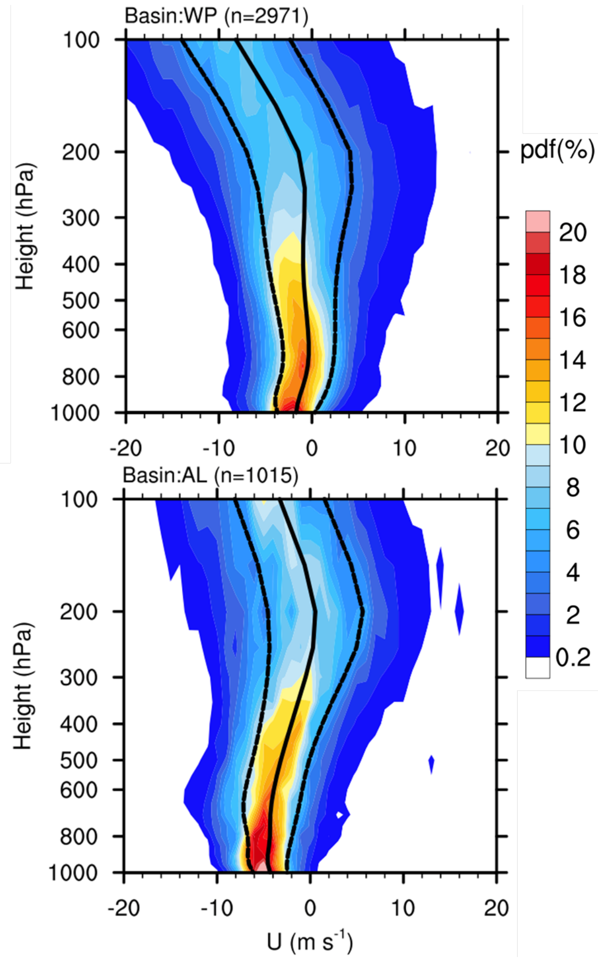

Figure 1: CFADs of zonal wind profiles in TC environments in the WP (top) and AL (bottom). The central black line in each panel is the mean zonal wind profile, bounded by the ± 1-σ profiles.

each level within an annulus between 300 and 1000 km from the best track position in order to obtain an environmental zonal wind profile corresponding to each case.

3. APPLYING THE CLIMATOLOGY

Zonal wind speed contour frequency by altitude diagrams (CFADs, Figure 1) illuminate basin-dependent features of the TC environmental flow. In AL TC environments, the mean zonal wind profile has 5 m s^{-1} of westerly deep-layer (200–850-hPa)

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vertical shear, while the mean profile in the WP has minimal deep-layer shear. Despite the mean profiles in all basins having weak zonal flow in the upper levels, the mean profile in the AL has stronger easterly flow at 850 hPa (-4.4 m s^{-1}) than both the WP (-0.9 m s^{-1}) and EP (-2.0 m s^{-1}, not shown). In both depicted basins, the distributions are broadest at 200 hPa. The spreading of the distributions with height suggests that variability in deep-layer shear results primarily from variability in upper tropospheric winds.

The zonal wind climatology allows us to compute distributions of the derived shear height and depth parameters that Finocchio et al. (2016) examined. Computing these two parameters requires us to first compute the local shear magnitude ($\Delta u/\Delta p$) in each 50-hPa layer between 850 and 200 hPa. The height (hPa) of the layer containing the maximum local shear magnitude is assigned as the shear height, and the depth (hPa) of the deepest continuous layer over which the local shear magnitude exceeds half of its mean value between 200 and 850 hPa is assigned as the shear depth. Figure 2 depicts the distributions of shear height (top) and depth (middle), as well as the distribution of deep-layer vertical shear (bottom). The most frequent shear height is in the upper troposphere. Shear depth exhibits more of a normal distribution with a peak around 250 hPa. There is remarkable consistency in the distributions of shear height and depth among the basins. In contrast, the deep-layer shear distribution in the AL differs from that of the other basins due to its peak at larger westerly shear magnitudes. All deep-layer shear distributions are quite broad, indicating significant variability in this parameter.

We also compute a joint distribution for combinations of shear heights from 200–850 hPa and shear depths from 100–650 hPa. Finocchio et al. (2016) built a TC intensity response surface using smaller ranges of shear height and depth. Superimposing the portion of the joint distribution that coincides with their response surface allows us to evaluate the likelihood of each parameter combination on the response surface. Given that the response surface was constructed from idealized simulations with 10 m s^{-1} deep-layer shear and warm SST, we use the 624 cases from all three basins with deep-layer westerly shear between 8 and 12 m s^{-1} and SST $\geq$ 26 C to compute the joint distribution. Figure 3 depicts the joint distribution atop a snapshot of the response surface at 96 hours.

The most likely TC environmental wind profiles examined in Finocchio et al. (2016) have shallow

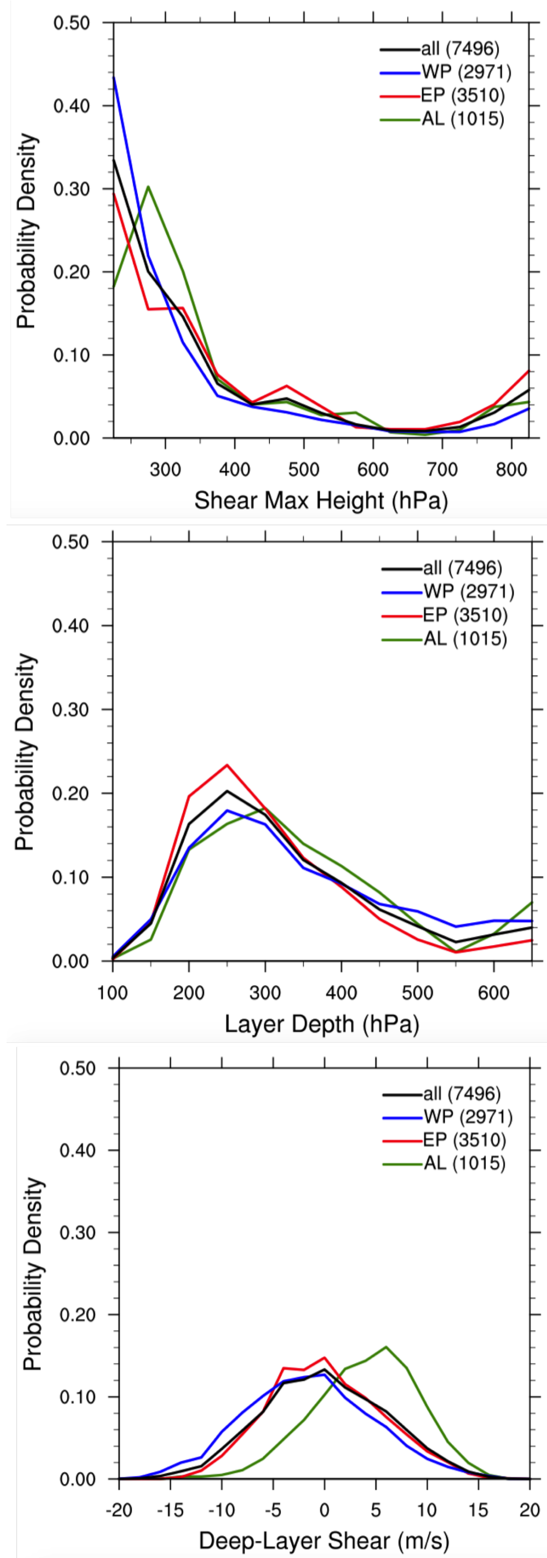

Figure 2: Distributions of shear height (top), shear depth (middle), and deep-layer 200-850-hPa shear in each basin. The number of cases used to build each distribution appears in parentheses in the legend.

upper-level wind shear, but even the largest probability density on the response surface is $< 4\%$. Higher probability densities are confined to a small parameter range that is outside of the ranges depicted in Figure 3, and distant from the sharpest intensity gradients on the response surface. On the other hand, deep-layer vertical wind shear exhibits more variability in nature and frequently achieves magnitudes capable of producing a significant TC intensity response, which may explain why the deep-layer shear is such a skillful predictor of TC intensity change. Environmental wind observations resolving the deep-layer vertical wind shear are, therefore, more important for TC intensity prediction than wind observations resolving the height and depth of vertical shear. Nevertheless, observing finer structural aspects of vertical wind shear is likely to be beneficial in less-predictable situations where the deep-layer shear is less skillful at predicting TC intensity changes.

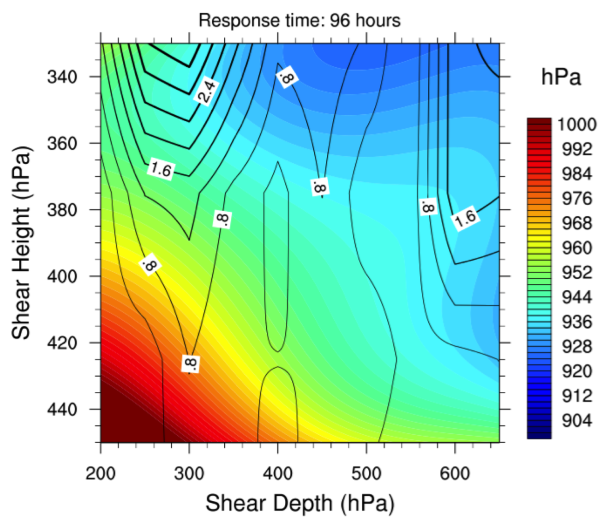

Figure 3: TC intensities at 96 hours diagnosed from idealized simulations (shading, hPa) and joint shear height-depth distribution for all three basins (black contours, %)

References

Finocchio, P. M., Majumdar, S. J., Nolan, D. S., & Iskandarani, M., 2016: Idealized Tropical Cyclones Responses to the Height and Depth of Environmental Vertical Wind Shear. *Mon Wea Rev*, *In Revision*.

Knapp, K.R., Kruk, M.C., Levinson, D.H., Diamond, H.J., and Neumann, C.J., 2010: The International Best Track Archives for Climate Stewardship (IBTrACS). *Bull Amer Met Soc*, 91, 363-376.

Kobayashi, S. and Coauthors, 2015: The JRA-55 Reanalysis: General Specifications and Basic Characteristics. *J Met Soc Japan*, 93, 5-48.

Kurihara, Y., Bender, M. A. & Ross, R.J., 1993: An initialization scheme of hurricane models by vortex specification. *Mon Wea Rev*, 121, 2030-2045.

Murakami, H., 2014: Tropical cyclones in reanalysis data sets. *Geophys Res Lett*, GL059519, 2133-2141.