Satellite and Aircraft Observations of Upper-Level Outflow in Hurricanes Iselle and Julio (2014)

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Data

- Navy Global Environment Model (NAVGEM) data were provided courtesy of the Naval Research Laboratory, Monterey, CA (NRL) and were obtained from the U. S. Global Data Assimilation Experiment (USGODAE) for July – August 2014.
  - Spatial Resolution: 0.5° lat
  - Temporal Resolution: 6 h
- Tropical Cyclone Track and Intensity data were provided by the National Hurricane Center (NHC) and the Central Pacific Hurricane Center (CPHC).
- Atmospheric Motion Vector (AMV) data were provided by University of Wisconsin-CIMSS; included thousands of wind speed observations of 200-hPa winds within 1 hour of synoptic times from 1-15 August 2014.
- The GPS dropsonde data were provided courtesy of the NOAA/AOML/Hurricane Research Division in Miami, FL (USA) and were obtained from Tropical Atlantic; included 39 observations of 200-hPa winds within 1 hour of synoptic times during four G-IV flights between 5-10 August 2014.

Storm Tracks and Intensities of Hurricanes Iselle and Julio

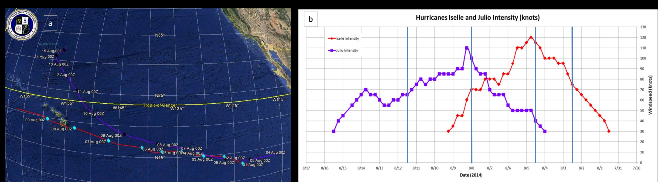

Fig. 1. The NHC and CPHC (a) track (in Google Earth courtesy NRL MRY), and b) intensity (kts) for Hurricanes Iselle (in red) and Julio (in purple) from 31 July - 15 August 2014. Blue vertical lines in (b) denote the four focal points of the analysis .

NAVGEM Outflow in Iselle and Julio

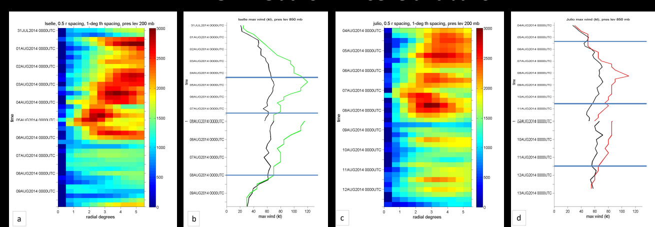

Fig. 2. Evolution of (a,c) the radial variation in total outflow (m s-1) derived from 200-hPa NAVGEM analyses for Hurricanes (a) Iselle and (c) Julio (both shaded, scales at right); and, (b,d) the TC intensity (kts) from the best track (colored (b) green for Iselle and (d) red for Julio) and the 850-hPa NAVGEM wind field (black lines). All plots extend from 0000 UTC 31 July 2014 to 0000 UTC 10 August 2014. Blue horizontal lines mark the four selected analysis times in Fig. 1b.

NAVGEM Outflow Analysis

Location of TC outflow

1. ***Vertical:*** **Maximum outflow consistently near 200 hPa.**
   - Subjective analysis of Hovmollers for each of the 9 vertical levels revealed the outflow magnitude was greatest at 200 hPa over time.
2. ***Horizontal:*** **Radial location of the maximum outflow varied.**
   - Outflow extended radially more than 500 km from the TC center.

Relationship between outflow and TC intensity

3. **The TC intensity increased:**
   - **a. during periods of greater outflow**
     - There were clear shifts in outflow magnitude.
       - Iselle: 90-kt intensification during the first 102 h of greater outflow
       - Julio: 80-kt intensification within 102 h of greater outflow
   - **b. when the maximum outflow was located closer to the storm center**
     - There were radially inward progressions of the outflow maximum.
       - Iselle: Nearly 300 km shift toward TC center over a 102-h period
       - Julio: Nearly 200 km shift toward TC center over a 72-h period

Methodology

- Calculate *u* and *v* components and storm-relative *Ur* for AMV and dropsonde observations.
  - Calculation of *Ur* was based on TC center locations for Iselle and Julio that were visually identified using the center of the NAVGEM 850-hPa circulation.
- Interpolate NAVGEM data (u, v) to the AMV and dropsonde observation locations. Calculate *Ur* at each observation location.
- Calculate Pearson product-moment correlation, bias and mean absolute error between NAVGEM and AMV 200-hPa wind speeds for both large-scale eastern North Pacific environment and a smaller 5-degree box surrounding each storm center for at each analysis time. Repeat this calculation for the TC outflow (Ur).
- Repeat statistical calculations for the NAVGEM and dropsonde 200-hPa wind speeds and TC outflow.

References

Goerss, J. S., and R. A. Jeffries, 1994: Assimilation of synthetic tropical cyclone observations into the Navy Operational Global Atmospheric Prediction System. *Wea. Forecasting*, **9**, 557-76.

Hogan, T.F., M. Liu, J.A. Ridout, M.S. Peng, T.R. Whitcomb, B.C. Ruston, C.A. Reynolds, S.D. Eckerman, J.R. Moskaitis, N.L. Baker, J.P. McCormack, K.C. Viner, J.G McLay, M.K. Flatau, L. Xu, C. Chen, and S.W. Chang, 2014: The Navy Global Environment Model. *Oceanography* 27(3): 116-125.

Introduction

In the fall of 2014, the United States Naval Academy TROPIC team studied the evolution of the upper-level outflow from Hurricanes Iselle and Julio in the Navy Global Environmental Model (NAVGEM, Hogan et al. (2014)) analyses. For these two westward tracking systems in the eastern North Pacific, outflow was concentrated at the 200-hPa level in the model and was influenced by large-scale synoptic features surrounding the storms. Relationships between outflow and intensity were also noted. Here, the NAVGEM model analyses are compared to observational data to develop confidence in the accuracy of the NAVGEM 200-hPa winds, and thereby also the results of the outflow study. Both satellite and aircraft observational data were evaluated in the large-scale environment of the eastern North Pacific as well as in a smaller region surrounding each TC.

Fig. 9. Geostationary infrared imagery of Hurricanes Iselle (at 1200 UTC 04 August 2014 outlined in red) and Julio (at 0000 UTC 08 August 2014 outlined in purple), courtesy of NRL; and a Tropical Cyclone Condition of Readiness (TCCOR) alert at Naval Station Pearl Harbor, Hawaii.

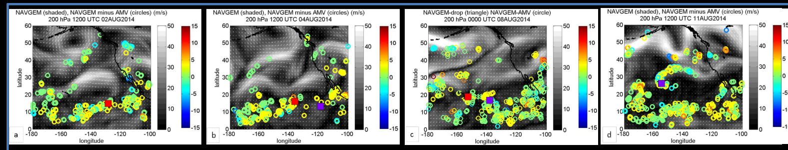

Fig. 3. The NAVGEM operational analysis 200-hPa wind speed (m s-1, shaded gray) and direction (white arrows) overlaid with NAVGEM minus AMV (circles) and NAVGEM minus dropsonde (triangles) wind speed differences (m s-1, colored by magnitude, color bar at right) and with the center of Hurricanes Iselle (red box) and Julio (purple box) for the four times marked by vertical blue lines in Figure 1b.

AMV and Dropsonde Observations

1. ***Locations:*** The AMV observations (circles in Fig. 3) were distributed throughout the eastern North Pacific, while the dropsondes (triangles in Fig. 3) were located closer to the TCs.
2. ***Differences between the model and observed wind speeds*** appeared to be random, and did not appear to be associated with:
   a. Large-scale environmental features (e.g., the subtropical ridge), or
   b. geographic features (e.g., the Hawaiian islands)

Wind Speed

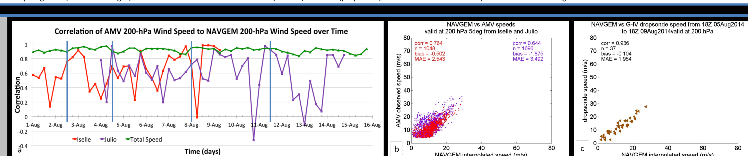

Fig. 4. (a) Correlations over time between AMV and NAVGEM 200-hPa wind speeds at the AMV observation locations in the eastern Pacific (green) and within 5° latitude and longitude of Iselle (red) and Julio (purple); (b) The AMV (observed) vs. NAVGEM (model) wind speeds for locations described in (a); (c) Dropsonde (observed) vs. NAVGEM (model) 200-hPa wind speeds for all NOAA G-IV dropsonde locations.

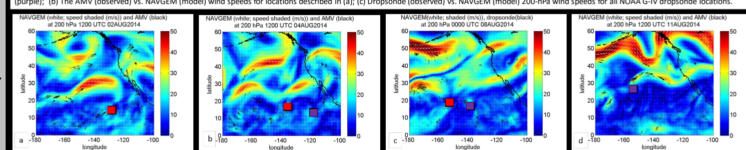

Fig. 5. The NAVGEM operational analysis 200-hPa wind speed (m s-1, shaded) and direction (white arrows) overlaid with AMV (black) and dropsonde (brown) wind vectors and with the centers of Hurricanes Iselle (red box) and Julio (purple box) for the four times marked by vertical blue lines in Figure 1b.

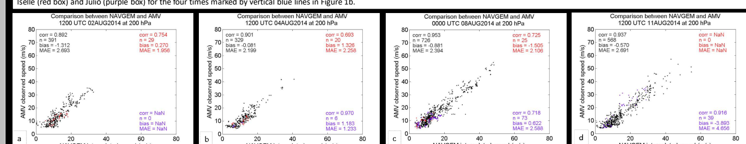

Fig. 6. Comparison between the AMV (observed) and NAVGEM (model) 200-hPa wind speeds (m s-1) at the AMV observation locations in the eastern Pacific (black) and within 5° of Iselle (red) and Julio (purple) for the four times marked by vertical blue lines in Figure 1b.

Model vs. Observed Wind Speeds

1. NAVGEM 200-hPa wind speeds vs. AMV 200-hPa wind speeds
   - A. ***Correlations were high in the eastern North Pacific***: In the eastern North Pacific, correlations between every available AMV and NAVGEM 200-hPa wind speed were > 0.8 at every time step (green line in Fig. 6a).
   - B. ***Within 5° of the TC centers, correlation consistency varied:*** Close to the TC centers, correlations were lower at individual time steps (red and purple lines in Fig. 6a), but remained relatively high for each full TC lifecycle: 0.76 for Iselle (red in Fig. 6b), and 0.64 for Julio (purple in Fig. 6b).
   - C. ***At the four selected analysis times***, Iselle and Julio moved westward beneath the subtropical ridge (Fig. 5). Correlations at these times (Fig. 6) ranged between 0.69 and 0.97, and corresponded to values at each vertical blue line in Fig. 4a.
2. NAVGEM 200-hPa wind speeds vs. G-IV dropsonde 200-hPa wind speeds
   - A. ***The G-IV dropsonde observations were much fewer in number*** (Fig. 6c) , and were therefore not evaluated at each time step.
   - B. ***Together, the 37 200-hPa dropsonde observations*** within 1 hour of the NAVGEM analysis times ***were highly correlated to the NAVGEM wind speeds***.
3. Assimilation of Real and Synthetic Observations
   - A. ***High correlations were likely due to assimilation*** of both the satellite AMV and G-IV dropsonde data into the NAVGEM model.
   - B. ***Lower correlations near the TC centers*** are hypothesized to result ***numerically*** from fewer observations comprising the correlation and ***physically*** from the assimilation of synthetic observations (Goerss and Jeffries, 1994) in the NAVGEM model.

Outflow

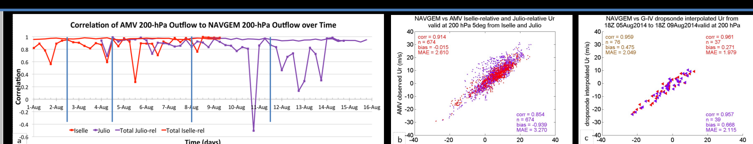

Fig. 7. As in Figure 4, except for 200-hPa outflow (*Ur*) wind speeds and in (a) the total observations (green line in Figure 4a) are broken down into Iselle-relative (solid red) and Julio-relative (solid purple).

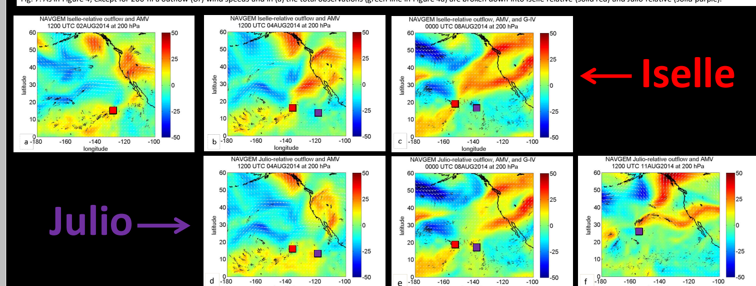

Fig. 8. The NAVGEM operational analysis 200-hPa (a-c) Iselle-relative and (d-f) Julio relative outflow (*Ur*) wind speeds (m s-1, shaded) and direction (white arrows) overlaid with AMV (black) and dropsonde (brown) wind vectors and with the centers of Hurricanes Iselle (red box) and Julio (purple box) for the four times marked by vertical blue lines in Figure 1b (one time per column) .

Model vs. Observed TC Outflow

1. Outflow Correlations were Higher than Wind Speed Correlations
   - A. ***All NAVGEM-AMV outflow (Ur) correlations were higher and more consistent*** at each analysis time than in the respective wind speed correlations (Figs. 7a and 4a). The inherent inclusion of the wind direction in the Ur vector may contribute to this increase.
   - A. ***Within 5° of the TC centers,*** the NAVGEM-AMV outflow ***(Ur) correlations were .15 (Iselle) and 0.21 (Julio) higher*** than the respective wind speed correlations across each TC lifecycle (Figs. 7b and 4b).
   - B. ***The NAVGEM-dropsonde correlations increased slightly*** (Figs. 4c and 7c).
   - C. ***At the four selected analysis times***, outflow channels were evident near the TC center (warm colors, Fig. 8). Correlations at these times corresponded to values at each vertical blue line in Fig. 7a, and exceeded 0.8 in each case.
2. Results increased confidence in the accuracy of the NAVGEM 200-hPa winds, and thereby also in the results of the outflow study
   - A. ***High correlations between the NAVGEM and observations*** for each TC life cycle gives confidence to the relationships between outflow and intensity developed in the fall 2014 study.

Acknowledgements

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