Talking points for GOES-R Hurricane Intensity Estimate baseline product

1. GOES-R Hurricane Intensity Estimate baseline product
2. Learning Objectives:
   (1) To provide a brief background of the Hurricane Intensity Estimate algorithm.
   (2) To understand the strengths and limitations, including measurement range and accuracy.
   (3) To use an example to become familiar with the text product format.

3. Product Overview:
   The Hurricane Intensity Estimate algorithm is a GOES-R baseline product. In this algorithm, estimates of tropical cyclone intensity are generated in real-time using infrared window channel satellite imagery. This can be used by forecasters to help assess current intensity trends throughout the life of the storm, which is particularly important when direct aircraft reconnaissance measurements are unavailable. The official product is an estimate of the maximum sustained wind speed. Comparing this estimate to tropical cyclone models can identify which model is best capturing current conditions.

   GOES-R channel 13 imagery with a central wavelength of 10.35 µm is used, with full disk coverage both day and night. The measurement range of the Dvorak hurricane intensity scale is 1 to 9, corresponding to wind speeds of roughly 25 to 200 kt. Measurement accuracy and precision are just under 10 and 16 kt.

4. The Algorithm:
   The HIE algorithm is derived from the Advanced Dvorak Technique that is currently in use operationally. It is based on the relationship of convective cloud patterns and cloud-top temperatures to current tropical cyclone intensity. As cloud regions become more organized with stronger convection releasing greater amounts of latent heat, there is a reduction in storm central pressure and increased wind speeds. Using this relationship, observed patterns are identified and assigned a Tropical (T) number, with higher T-number corresponding to greater intensity values. The T-number is converted into a current intensity (CI) number, from which the maximum wind speed and minimum sea level pressure are determined using a set of statistical relationships. The recent trend of strengthening or weakening is also taken into account, and may lead to an adjustment of the final intensity value.

5. Scene Type:
   The algorithm determines the intensity of a tropical cyclone by matching observed brightness temperature convective cloud patterns in the current processed ABI band 13 image to a set of pre-defined tropical cyclone structures. From this correlation, the center and scene type of the tropical cyclone are determined. The imagery in the top row show examples of cloud region scene types with distinctive patterns. This includes Central Dense Overcast, Embedded Center, Curved Band, and Irregular Central Dense Overcast. The bottom row shows eye region scene types, including Clear Eye, Pinhole Eye, and Large Eye with a radius greater than 38 kilometers.

6. Storm Center Determination:
   The storm center location algorithm is an automated process, using the official tropical cyclone short-term track forecast as a first guess. Spiral centering analysis (top right) is used to improve the guess. This is done by fitting a 5-degree log spiral to grid points within a search radius around the

first guess position. Brightness temperature gradients are calculated to determine the position and rotation where the minimum exists.

The best fit is further refined by using the ring fitting analysis (bottom left). This uses the spiral analysis position as the first guess and fits a series of rings with different diameters to search for the ring that fits the maximum brightness temperature gradients, in order to determine the final position of the storm center.

7. PMW Eye Score:

   During cloudy overcast periods, IR imagery can lead to difficulty in determining the center of the storm. In this situation, the formation of an eye will often be obscured by high-level cirrus clouds. The use of passive microwave data to help in the center fixing of the TC in overcast conditions is a feature that will be included in a future upgrade of the HIE algorithm but will not be available in the initial product. When implemented, the algorithm will support receiving additional passive microwave eye score data, using the brightness temperature difference between the eyewall and the warmest eye pixel. A graphical interface will be available for visual inspection of the suggested storm center position.

8. Regression Equations:

   The Hurricane Intensity Estimate algorithm implements linear regression equations to relate cloud and eye parameters to TC intensity. Two separate equations are used: eye scene types and cloud scene types. Parameters used in the regression equations include temperature and symmetry of the cloud region, difference between cloud region and eye temperatures, and cloud region diameter. To illustrate how these are measured, a schematic representation of the four parameters is shown. The regression equations yield intensity estimates in terms of T-number values which can be converted to a maximum wind speed.

9. Algorithm Strengths:

   A key strength of the HIE product is that the algorithm is automated, and operates at the full temporal resolution of available imagery. Tropical cyclone forecast files are easily obtained from a variety of sources and file formats for the first guess position. Intensity estimates are determined throughout the lifecycle of the tropical cyclone, with higher accuracy observed for stronger storm intensity ranges. The algorithm is completely objective, eliminating subjectivity due to differences in chosen scene type, parameter measurements, and TC center locations as originally determined by forecasters.

10. Algorithm Limitations:

    Limitations include a weak-bias when evaluating Central Dense Overcast and Embedded Center scene types. In this situation, use of the Passive Microwave information would help but not eliminate the issue. In determining the storm center, the automated centering routine works best above a threshold storm intensity of 65 kt. Below this threshold, the default is based on the interpolation of the official forecast. This can lead to intensity estimation errors during periods of large changes in storm direction or speed. Due to the nature of the empirical relationships, the algorithm cannot be used for tropical waves, subtropical storms, or during extratropical transition. Furthermore, the HIE product is only generated if the tropical cyclone is positioned over ocean.

11. Validation:

Validation is done through comparison to "ground truth" data sets, including direct aircraft reconnaissance measurements and "best track" storm information from an official tropical cyclone forecast center. The Advanced Dvorak Technique has proven to be as accurate as subjectively-obtained intensity estimates. During Hurricane Patricia (2015), the algorithm was able to correctly analyze the record-setting maximum winds just before landfall on the coast of Mexico.

12. HIE Text Product:

The GOES-R ground system implementation of the Hurricane Intensity Estimate algorithm is fully automated. Activation occurs when the ground system receives an official Tropical Cyclone Forecast file, and executes if both the product's refresh rate criteria is satisfied and if ABI full disk observations are available. The tropical cyclone continues to be monitored throughout its lifespan. The text data product is not currently available in AWIPS. Access through the CIMSS website includes a History File Listing for archived data, as well as a Current Intensity Bulletin available in real-time during tropical cyclone activity. Separate product files are generated for each TC.

13. Example:

Example of the early history file listings for Hurricane Joaquin in September of 2015. The official product is an estimate of the maximum sustained surface wind in units of knots. Additional information related to intensity are provided in the readout, including minimum sea level pressure in units of mb, the unit-less current intensity number, as well as the temperatures and scene types used in determining intensity at each time. Line plots are generated to compare adjusted T-number and CI-number throughout the life of the storm.

14. Improvements with GOES-R:

Satellite imagery from the GOES-R ABI will provide full disk coverage at 2 km horizontal resolution for active tropical cyclones every 30 minutes. This allows for detection and better characterization of smaller-scale features. The higher spatial and temporal resolution will lead to improved forecast accuracy and extended forecast lead times. In the future, the algorithm is moving toward regional TC tendencies and characteristics, and many adjustments will be basin-specific.

15. Himawari Proxy Data:

Himawari data has been used as a proxy for GOES-R ABI data to quantify these improvements. Two tests were conducted during the 2015 West Pacific season. The increased spatial resolution with Himawari data showed a slight tendency for higher estimates, while increased temporal resolution yielded slightly quicker response times in emerging eye situations. These results indicate that switching from current GOES to GOES-R as input data will improve algorithm performance. Further testing with Himawari data will continue in the 2016 season.

16. Summary:

The Hurricane Intensity Estimate algorithm is the next generation version of the objective Advanced Dvorak Technique for Goes-R. It utilizes Channel 13 10.35 µm infrared window channel imagery to produce real-time estimates of tropical cyclone intensity. The algorithm is fully-automated and based on the relationship of convective cloud patterns and cloud-top temperatures to current tropical cyclone intensity. The higher temporal and spatial resolution available with GOES-R ABI imagery will improve forecast accuracy.