Science investigations facilitated by the JPL Tropical Cyclone Information System

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Motivation Improving our understanding and forecasting of hurricane genesis and intensity changes remains a challenge for the operational and research communities. Significant amount of work remains to be done in validating hurricane forecast models, understanding their sensitivities and improving their parameterizations. None of this can be accomplished without a comprehensive set of of multi-platform and multi-sensor observations that are relevant to both the large-scale and the storm-scale processes in the atmosphere and in the ocean.

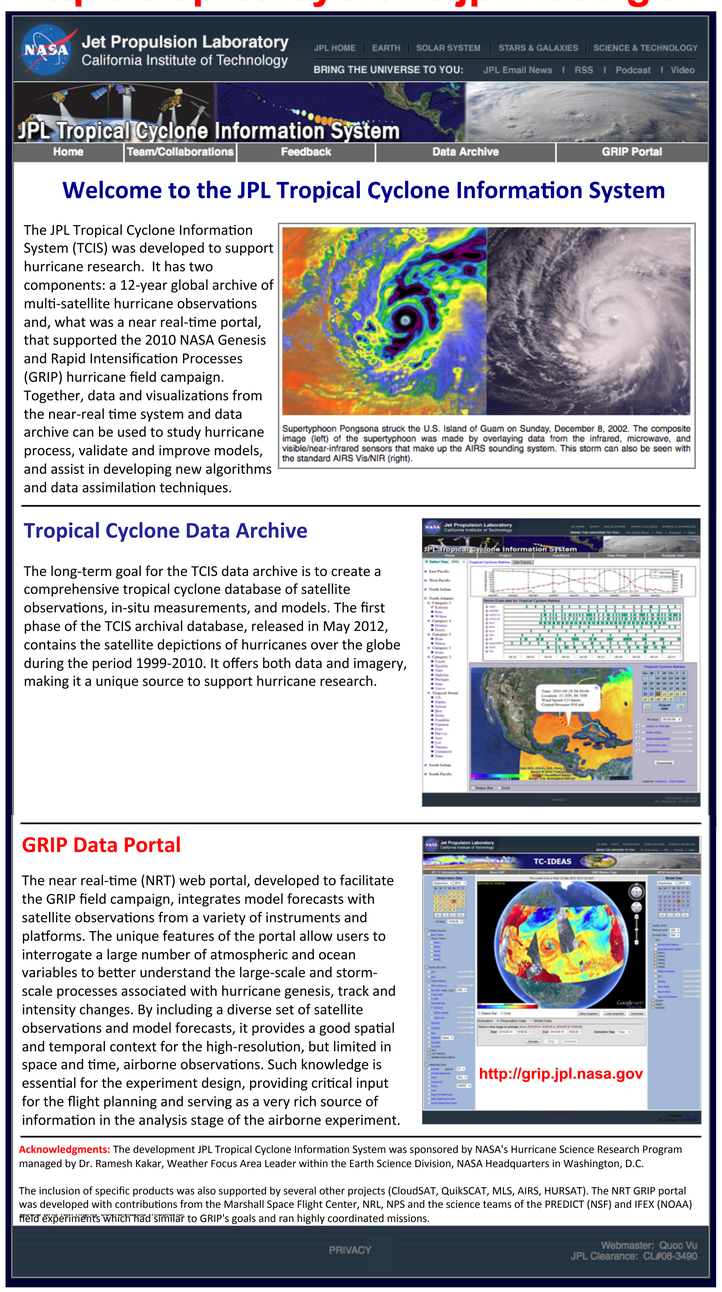
To facilitate hurricane research, we developed the JPL Tropical Cyclone Information System (TCIS). We illustrate here how the information system can be used for hurricane research and applications.

Objective of the TCIS

To develop a one-stop place that provides fusion of multiparameter observations (satellite, airborne and in-situ) and model output, relevant to both the large-scale and the storm-scale hurricane processes in the atmosphere and in the ocean with the purpose to:

- help understand the physical processes that determine hurricane genesis, intensity, track and impact on large-scale environment
- help improve hurricane forecast accuracy by facilitating validation and improvement of hurricane models through comparison with observations and development of new data assimilation techniques
- enable studies aimed at developing new algorithms, sensor systems and missions.

http://tropicalcyclone.jpl.nasa.gov



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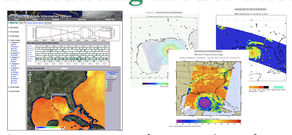
The inclusion of specific products was also supported by several other projects (CloudSAT, QuikSCAT, MLS, AIRS, HURSAT). The NRT GRIP portal was developed with contributions from the Marshall Space Flight Center, NRL, NPS and the science teams of the PREDICT (NSF) and IFEX (NOAA) field experiments which had similar to GRIP's goals and ran highly coordinated missions.

TCIS Data Archive: MODEL EVALUATION

Hristova-Veleva, S. M., Y. Chao, A. Chau, Z. Haddad, B. Knosp, B. Lambrigtsen, P. Li, J. Martin, W. L. Poulsen, E. Rodriguez, B. Stiles, S. Tanelli, J. Turk, D. Vane, Q. Vu 2010: "Impact of microphysical assumptions on the intensity and the structure of simulated hurricanes: Can satellite observations help determine the optimal set of microphysical assumptions?, AMS, 29th Conference on Hurricanes and Tropical Meteorology, May 2010, Tucson, AZ

Hristova-Veleva, S. M., J. Steward, T. Vukicevic, Z. Haddad, S. Aberson, S. Gopalakrishnan, T. Quirino, F. J. Turk, P. P. Li, B. Knosp, B. Lambrigtsen, S. Durden, S. Tanelli, 2012: "The Experimental HWRF-HEDAS system: Using satellite observations to evaluate the model and to assess the impact of data assimilation", AMS, 30th Conference on Hurricanes and Tropical Meteorology, April 2012, Ponte Vedra Beach, FL

Evaluating model microphysics



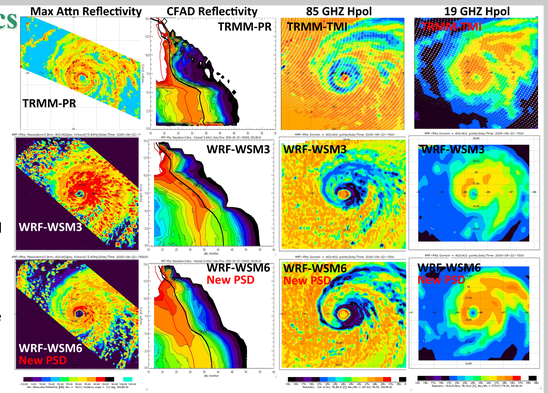


Figure 1. Comparison of two members of an ensemble of high-resolution WRF simulations of Hurricane Rita (2005), each member reflecting different microphysical assumptions. We used the geophysical model fields as input to instrument simulators to produce microwave brightness temperatures and radar reflectivity at the TRMM (TMI and PR) frequencies and polarizations and compared to the observed (radar reflectivity (2D and CFADs in the first two columns) and brightness temperatures – last two columns). Such comparisons highlight those parameterizations that yield a more realistic forecast. This will help the forecasting in two ways: i) providing guidance as to the optimal set of physical parameterizations; ii) improving the data assimilation outcome by designing model forecasts whose radiometric signatures are close to the observed, thus increasing the relative importance of the observations during the assimilation.

Exposing the need for precipitation data assimilation

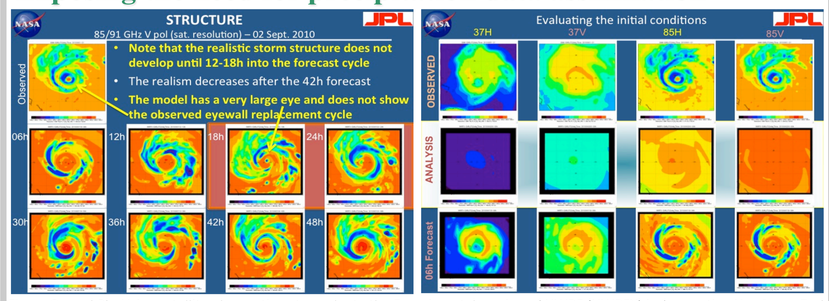


Figure 2a and 2b. Using satellite observations to evaluate the Experimental version of HWRF (HWRFX) in forecasting **Hurricane Earl** Found that It takes 12 to 18h (even 24h) for the model to develop realistic structures! By that time the forecasted storm position has likely drifted from the observed and the modeled storm is developing in conditions different from that of the observed! The long spin-up time might be the result of sub-optimal initial conditions which do not contain the observed precipitation structures!

TCIS Data Archive: Climatology – Environmental Humidity and TC Intensity and Change

Longtao Wu[1,2], Hui Su[1], Robert G. Fovell[3], Bin Wang[4], Janice T. Shen[1], Brian H. Kahn[1], Svetla M. Hristova-Veleva[1], Bjorn H. Lambrigtsen[1], Eric J. Fetzer[1], Jonathan H. Jiang[1], 2012: "Relationship of Environmental Relative Humidity with Tropical Cyclone Intensity and Intensification Rate over North Atlantic", *to be submitted*

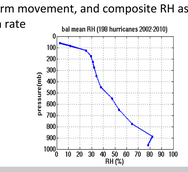
DATA

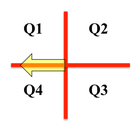
198 North Atlantic Ocean TCs from 09/2002 to 11/2010 based on NHC Best Track Data
- 74 Cat 1-5 hurricanes (37%)
- 36 Cat 3-5 hurricanes (18%)
- 10 Cat 5 hurricanes (5%)

AIRS Level 2 Relative Humidity (filtered by *pgood*)

Approach

To sort RH by the radial distance to the storm center, separated by four quadrants relative to storm movement, and composite RH as a function of storm intensity and intensification rate





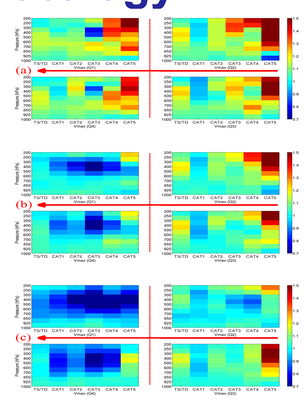


Figure 3. Normalized RH as a function of maximum TC intensity at three radial distances: (a) near environment; (b) medium environment; and (c) far environment. The normalization is with respect to the mean RH profile averaged for all 198 TC cases over the North Atlantic from 2002 to 2010 (see supplementary Figure 1). The four panels in each figure represent the four quadrants numbered from the front-right side of the TC (Q1) clockwise around to the front-left quadrant (Q4). The red arrows indicate the preferential translation direction of TCs in the North Atlantic.

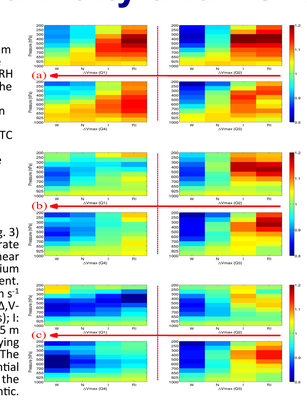


Figure 4. Normalized RH (as in Fig. 3) as a function of TC intensification rate at three radial distances: (a) near environment; (b) medium environment; and (c) far environment. W: weakening (Δ,V-max.< -1.25 m s^{-1} per 6 hrs); N: neutral (-1.25 < Δ,V-max.< 1.75 m s^{-1} per 6 hrs); I: Intensifying (1.75 < Δ,V-max.< 4.75 m s^{-1} per 6 hrs); RI: rapidly intensifying (Δ,V-max.> 4.75 m s^{-1} per 6 hrs). The red arrows indicate the preferential translation direction of TCs in the North Atlantic.

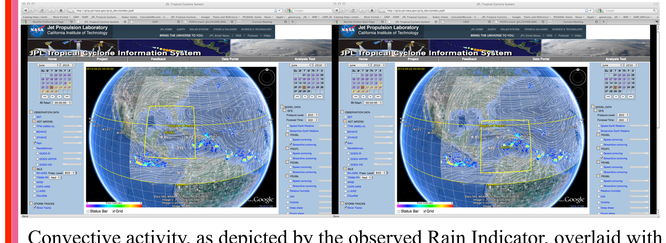
The principal findings from this investigation are:

- Environmental Relative Humidity (ERH) in the free troposphere decreases with time as the TC evolves while ERH in the boundary layer is generally constant.
- Higher intensity TCs have higher ERH.
- TC intensification rate is positively correlated with ERH above the boundary layer. Rapidly intensifying TCs are associated with higher ERH than weakening and neutral storms. However, the difference between rapidly intensifying and intensifying cases are not always statistically significant.
- The azimuthal asymmetry of ERH becomes evident at radial distances > 400 km. The rear-left quadrant tends to have the highest ERH and the front-right quadrant appears to have the lowest ERH in the far environment.
- In the front-right quadrant (Q1), a sharp decrease in upper tropospheric (above 400hPa) RH from the near to the far environment appears during rapid intensification. This radial RH gradient is weaker in TCs with lower intensification rates. For weakening TCs, Q1 has slightly more upper tropospheric ERH in the far environment.

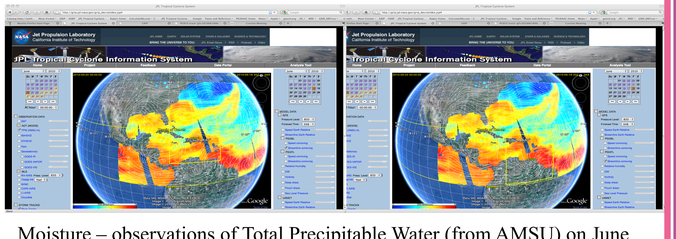
The AIRS-centric investigation provides new insights regarding the environment moisture within which TCs grow, decay, and propagate. The relationship of ERH with TC intensity and more so intensification rate, especially its azimuthal and radial variations may lead to improvements in TC intensity forecasts from statistical models.

GRIP portal: Bringing together satellite observations, large-scale models and airborne data

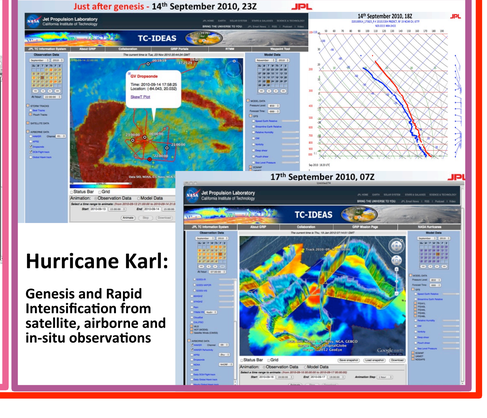
Developers versus Non-Developers;



Convective activity, as depicted by the observed Rain Indicator, overlaid with GFS analysis of co-moving flow on June 22nd (left-PGI06, right - PGI07) – by the 22nd PGI06 shows no signs of development while PGI07 has convection near the center. PGI07 became hurricane ALEX.



Moisture – observations of Total Precipitable Water (from AMSU) on June 20th (00Z), overlaid with co-moving flow for each of the pouches from the GFS 48h forecast stating on June 18th at 00Z. PGI06 has dry air north of the center while PGI07 is in moister environment.



Hurricane Karl:

Genesis and Rapid Intensification from satellite, airborne and in-situ observations