All-Sky Radiance Assimilation for COAMPS-TC Tropical Cyclone Track and Intensity Prediction

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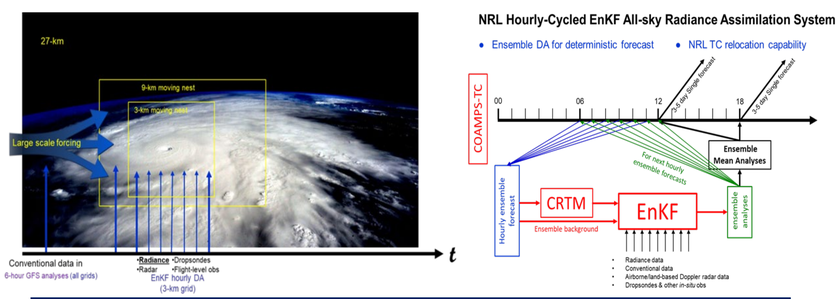
Introduction

New data assimilation capabilities have been developed within the NRL EnKF for COAMPS-TC[1] in collaboration with scientists from Penn State University.

- Advances include assimilation of all-sky geostationary IR radiances, airborne Tail Doppler Radar (TDR) data, dropsondes from hurricane reconnaissance aircraft, and other special *in-situ* observations.
- New capabilities were implemented to make COAMPS-TC model work more effectively with the new EnKF-based DA system.
- The NRL COAMPS-TC/EnKF system was tested with two challenging TC cases (Patricia and Harvey). Our experiments show substantial impacts of all-sky radiance assimilation on both TC intensity and track forecasts with the impacts lasting more than 3 days into the forecasts.

All-sky Radiance DA Setup



NRL COAMPS-TC/EnKF Key Features

- All-sky geostationary IR radiance assimilation (water vapor channel)
- Hourly cycling DA, with initialization at both the synoptic and off synoptic times
- GFS used for initial (cold start) conditions and perturbed boundary conditions
- TC relocation for the 60 (40) ensemble members for EnKF DA

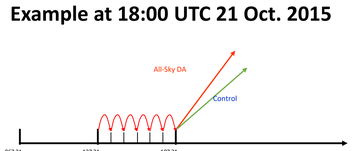
COAMPS-TC/EnKF New Methodology

- COAMPS-TC has been modified to relocate the entire TC structures (within the moving nests) for the ensemble forecasts for used for the EnKF data assimilation.
- Hourly interpolated TC center locations used for the relocation
- This allows the model dynamical balance for each ensemble member to be maintained.

- NRL EnKF includes:
  - 3-km inner (moving) nest
  - All-Sky radiance using CRTM v2.1.3 (with minor modifications by PSU)
  - Airborne Doppler radar wind assimilation (not used for these tests)
  - Hourly GOES-13(16) imager water vapor radiances ~ 6.55 um were assimilated
  - GOES-13(16) water vapor radiances ~ 10.7 um were used for additional verification
  - Covariance localization (radius=300 km) and adaptive error inflation following Minamide (2018)

Experiment Setup Patricia (2015)

Example at 18:00 UTC 21 Oct. 2015

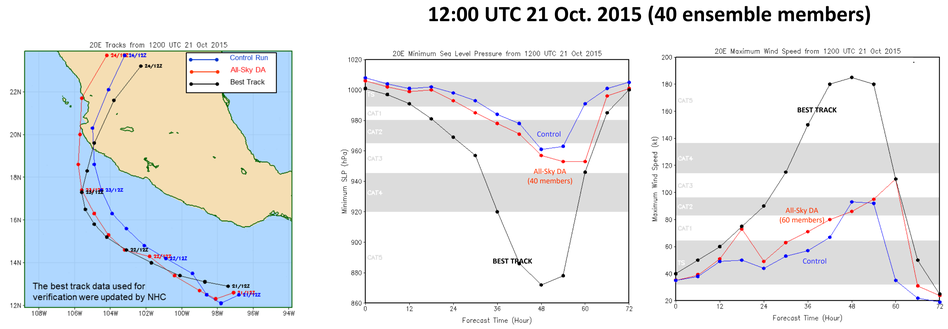


- Control: GFS cold started with TC bogus
- EXP: Initialized with EnKF mean perturbations from hourly-cycled all-sky radiance DA (**60 or 40 members**)
- GOES-13 Imager Channel 3 (6.55 um) for Patricia
- GOES-16 ABI Channel 8 (6.15 um) for Harvey

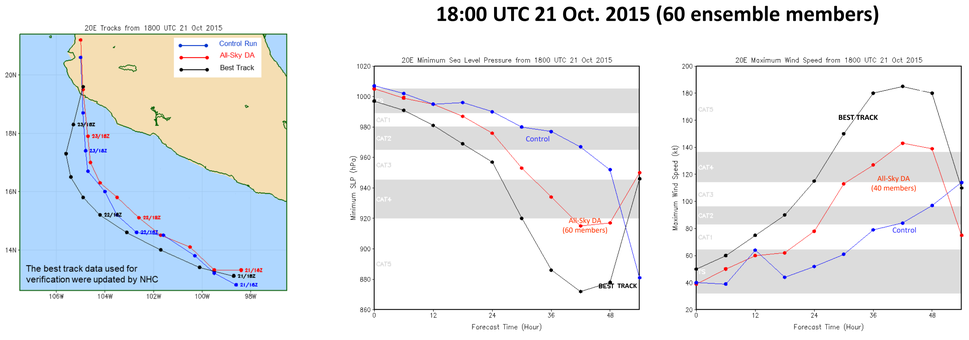
- Reduced the Intensity errors by up to 58% with much improved trend of TC development
- 3-km grid spacing is widely used for real-time TC forecast

Patricia (2015)

12:00 UTC 21 Oct. 2015 (40 ensemble members)



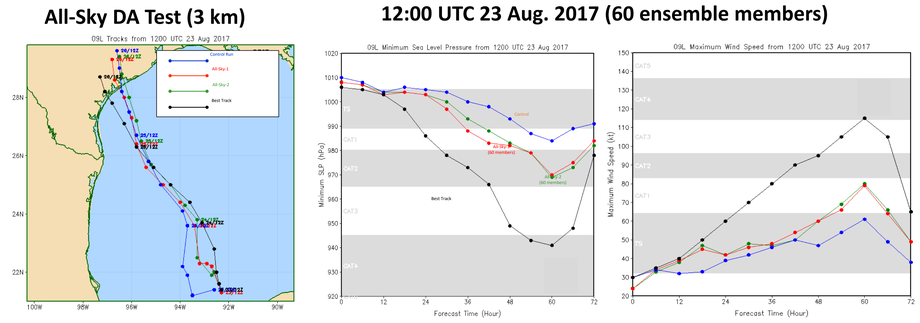
18:00 UTC 21 Oct. 2015 (60 ensemble members)



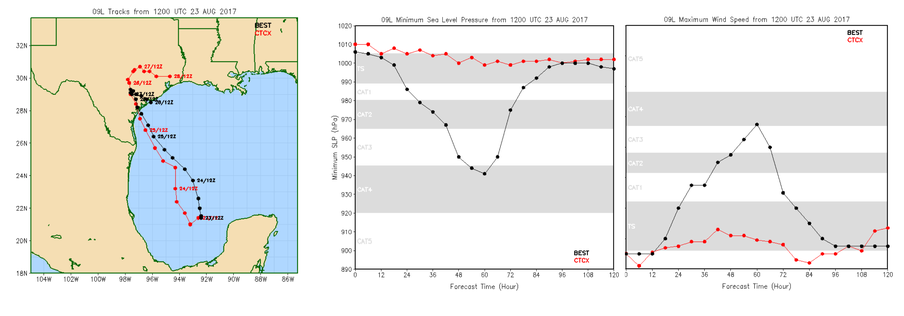
Harvey (2017)

All-Sky DA Test (3 km)

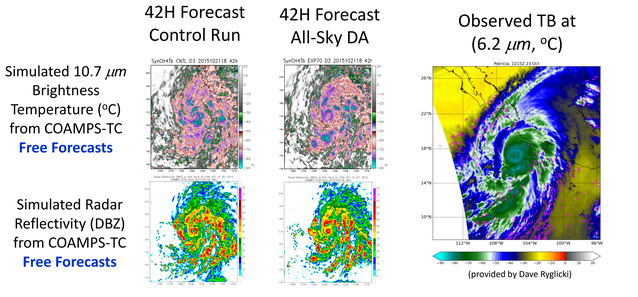
Real-Time Run (4 km)



12:00 UTC 23 Aug. 2017 (60 ensemble members)

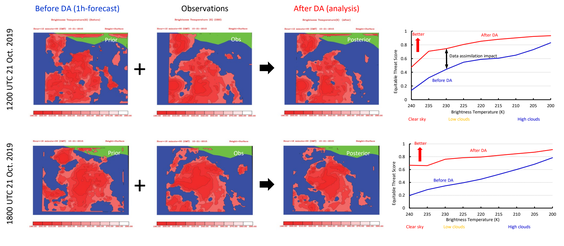


Observation-based Verification for Patricia (2015)



Tighter inner core and smaller hurricane eye

Brightness Temperature (K) from IR water vapor channel (6.2 μm)

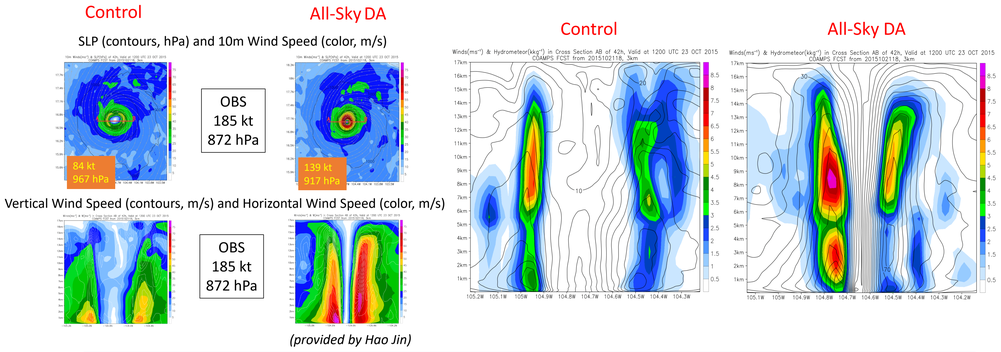


- All-Sky radiance assimilation is effective
- Improves TB for both clear sky and cloudy areas

Model-based Comparisons for Patricia (2015)

Horizontal and Vertical Cross-Sections at Strongest Stage (42hr)

Winds and Hydrometeor Mixing Ratio in Cross-Section AB at Strongest Stage (42h)



(provided by Hao Jin)

- EnKF leads to stronger winds, lower sea-level pressure, and a tighter inner core structure.
- The EnKF cross-variances also enhance the microphysics structure.

Summary and Next Steps

For the two challenging TC storms (Patricia and Harvey), the new EnKF DA capabilities work well with COAMPS-TC. In particular, the geostationary IR radiance assimilation and the CRTM-based forward operator perform very well in both **clear and cloudy sky regions**.

The system (based on the testing so far) demonstrates the potential for improved TC **intensity, structure, and track forecasts** that last for days with improved initial storm conditions, indicating the potential benefits of a well-designed DA system to COAMPS-TC.

We plan to further develop the system by:

- Connecting the NRL observation stream to the EnKF system.
- Adapt/develop algorithms for generating perturbed initial and boundary conditions from real-time GFS (or GEFS) for COAMPS-TC
- Optimizing the system for improved effectiveness and computational efficiency
- Completing more extensive testing with storms from 2020 hurricane season (offline) to further evaluate the system performance
- Exploring the potential to develop all-sky microwave radiance assimilation with collaborations within DA community

References

Minamide, M., and F. Zhang, 2017: Adaptive Observation Error Inflation for Assimilating All-Sky Satellite Radiance. *MWR*, **145**, 1063-1081.

Zhang, F., M. Minamide, and E. E. Clothiaux, 2016: Potential impacts of assimilating all-sky infrared satellite radiances from GOES-R on convective-permitting analysis and prediction of tropical cyclones. *Geophys. Res. Lett.*, **43**, 2954-2963.

[1]COAMPS-TC is the Coupled Ocean/Atmosphere Mesoscale Prediction System for Tropical Cyclones (COAMPS-TC)