U.S. NAVAL RESEARCH LABORATORY

All-Sky Radiance Assimilation for COAMPS-TC: Impact on Tropical Cyclone Inner Core Structure and Rapid Intensification

Yi Jin, Qingyun Zhao,
Nancy L. Baker, James. D. Doyle
Naval Research Lab, Monterey, CA
David Ryglicki
ACME Atron-O-Matic, LLC, Orlando, FL
Robert G. Nystrom
NCAR, Boulder, CO
Xingchao Chen, Jerry Zhang
Penn State University, PA

DoD Cloud Post-Processing and Verification Workshop, 13-14 Sept 2023, Boulder, CO

NASA Image of Patricia

Introduction

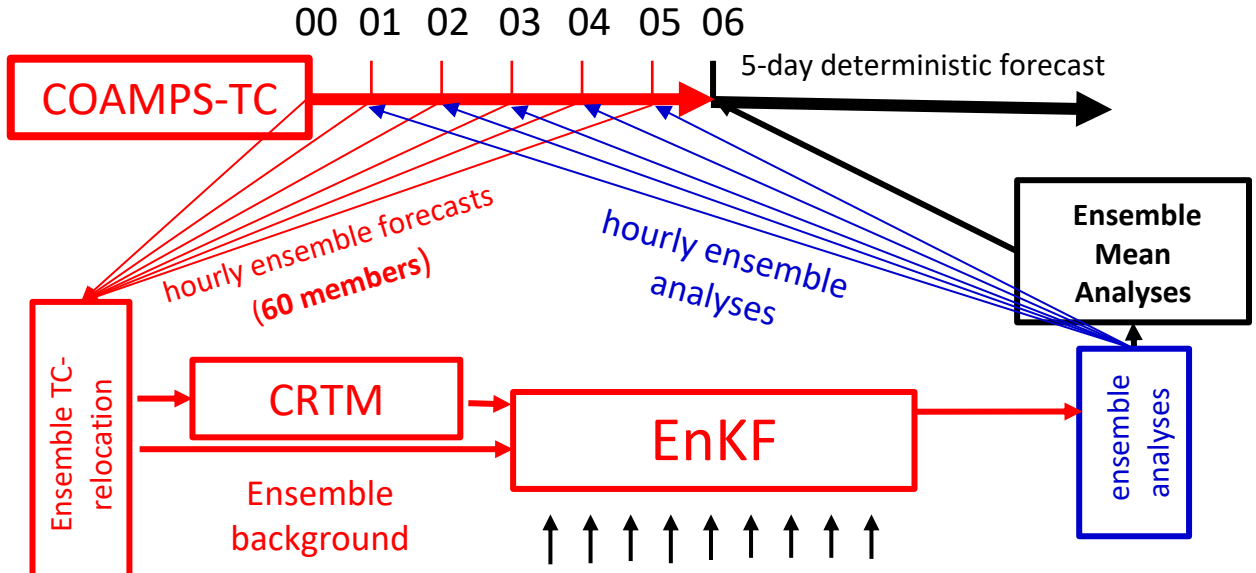
- New data assimilation capabilities have been developed for COAMPS-TC to assimilate all-sky IR radiance from geostationary satellites along with airborne radar data, dropsondes, and other *in-situ* observations to improve tropical cyclone (TC) forecasts.

- The all-sky radiance assimilation technique was originally developed at Penn State University and implemented into NRL EnKF through a collaboration between NRL and PSU.

- New techniques have also been developed at NRL to further improve the system's effectiveness and efficiency for COAMPS-TC.

- The system was tested with TC cases from Atlantic, Pacific, and Indian Oceans with intensity ranging from tropical storm (TS) to strong hurricanes (e.g., Patricia (2015) and Harvey (2017)).

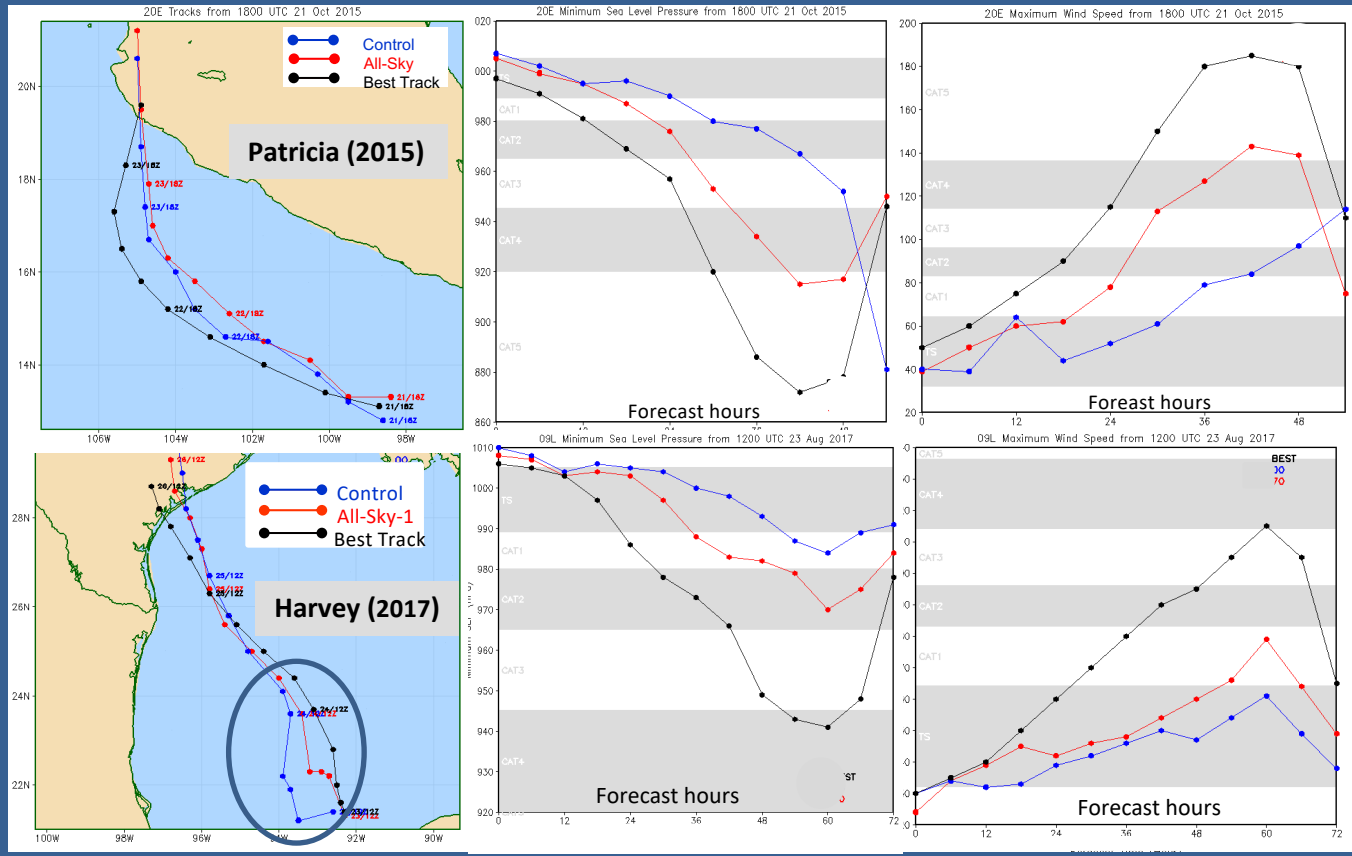
NRL Hourly-Cycled EnKF All-sky Radiance Assimilation System



- Hourly-cycled EnKF all-sky radiance assimilations are performed over a 6-h data assimilation period.
- A 5-day deterministic forecast initialized with the ensemble mean analyses is launched at the end of the 6-h data assimilation period.
- For comparison, a 5-day deterministic control forecast initialized with GFS analyses with TC vortex initialization is also launched at the same time.
- COAMPS-TC domains: 27km, 9km, 3km for nest1,2,3, respectively, with nests 2&3 following TC center. All-sky radiance assimilation is performed for nest 3.

COAMPS-TC Forecasts with and without Radiance Assimilation

- All-sky assimilation improves model performance for intensity forecasts, including the peak intensity and intensification rate, especially for Hurricane Patricia (2015).
- The track forecast for Hurricane Harvey (2017) is improved, especially during the first 24 h.

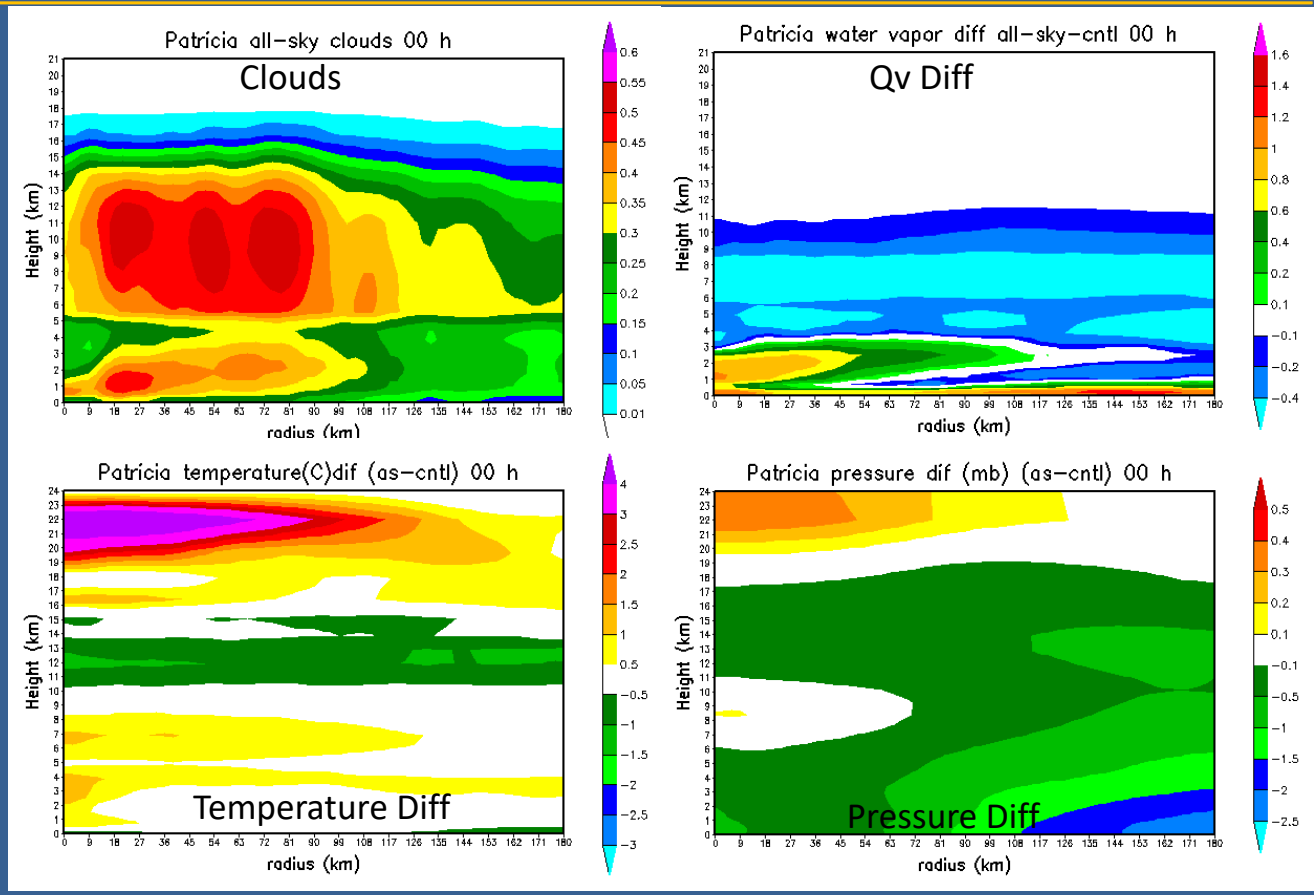


Impact on Patricia's Initial Structure: Inner Core

(Initialized at 1800 UTC 21 Oct. 2015)

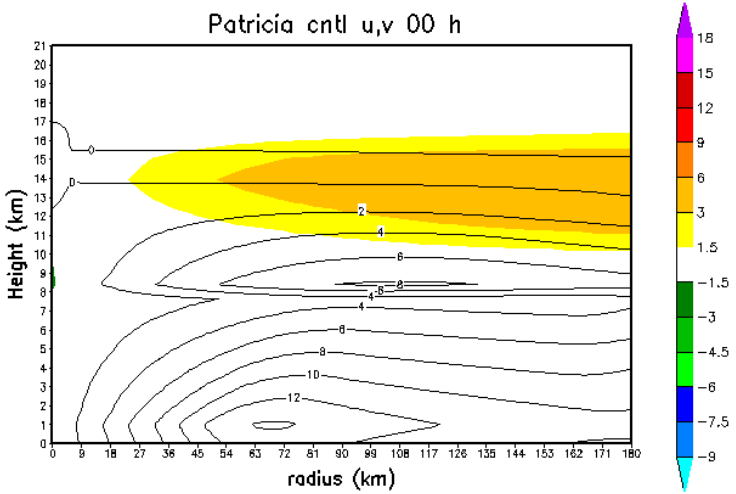
- The 4 prognostic variables directly impacted by all-sky assimilation: clouds, moisture, temperature, and pressure.
- The all-sky assimilation change the inner-core: adding clouds in a deep layer, moistening lower levels, warming the center, and, reducing the pressure in the troposphere.

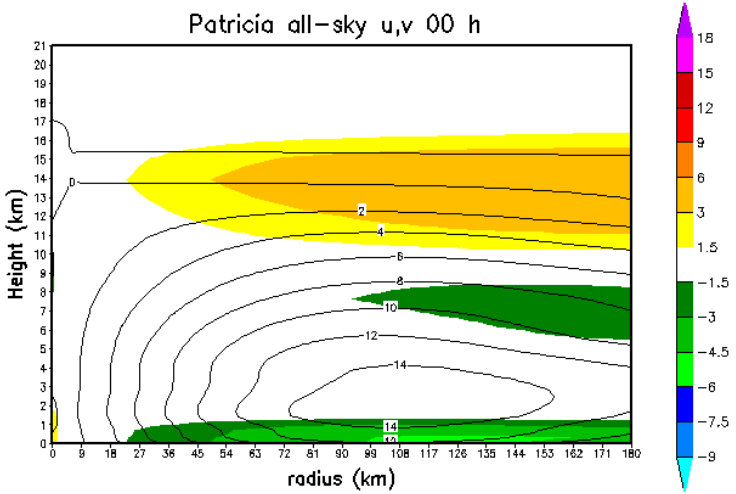
Diff=(all-sky)-control



Impact on Patricia's Secondary Circulation: 0 – 12 h

(Initialized at 1800 UTC 21 Oct. 2015)

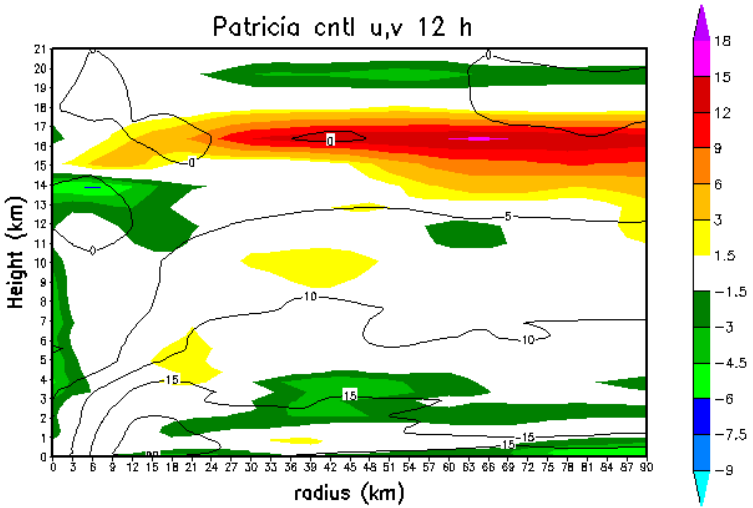


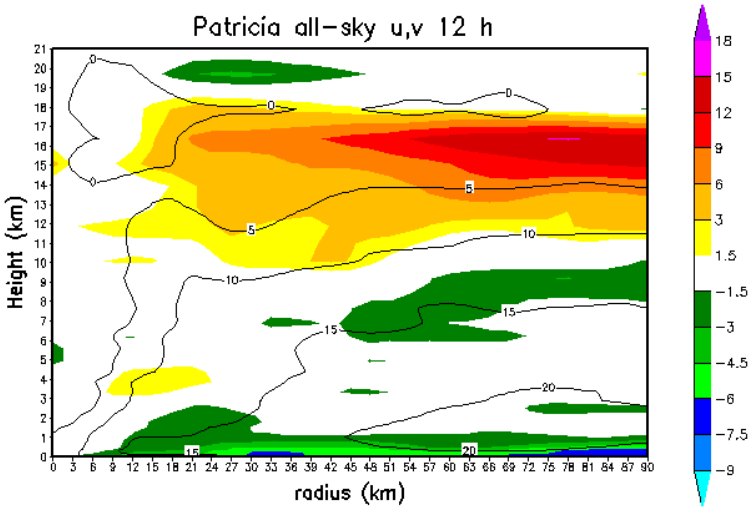


- The EnKF radiance assimilation modify the initial winds and results in a clear signature of secondary circulation in the inner core.
- The secondary circulation in the all-sky run continues to enhance during the first 12 h, at a much faster pace than the control.

Impact on Patricia's Secondary Circulation: 12 – 48 h

(Initialized at 1800 UTC 21 Oct. 2015)

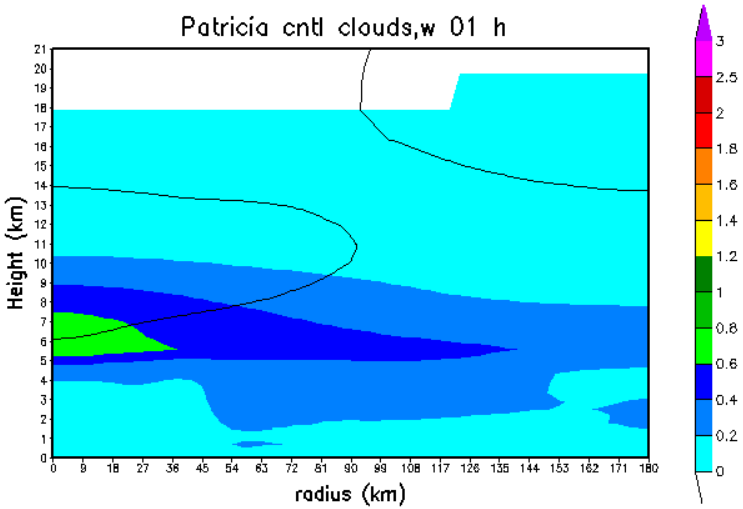


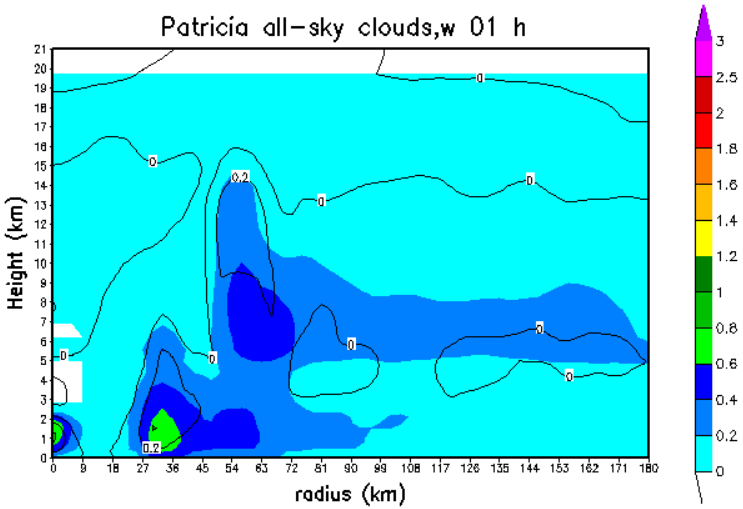


- The secondary circulation in the all-sky simulation is stronger and better organized than that in the control simulation during Patricia's RI.

Impact on Patricia's Convection Organization

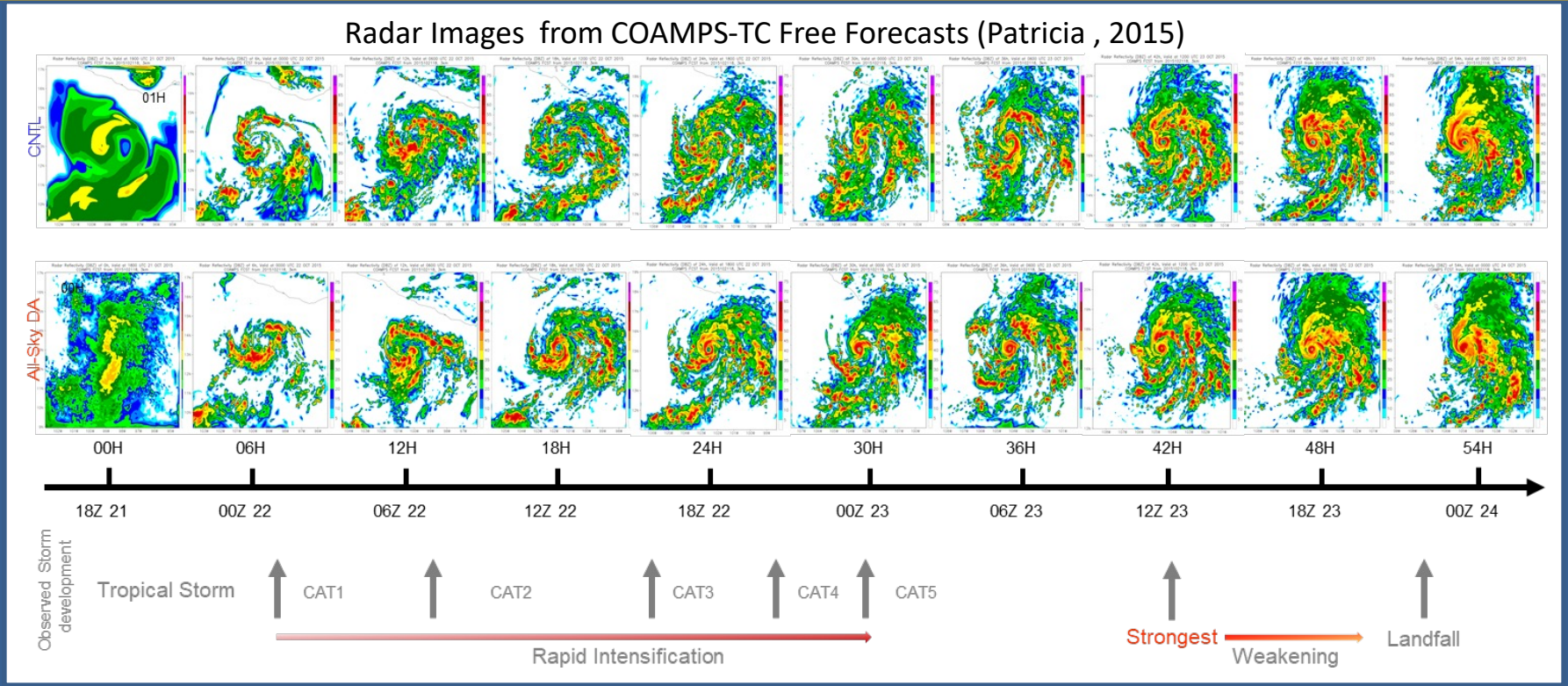
(Initialized at 1800 UTC 21 Oct. 2015)





- The all-sky simulation has better organized convection earlier into the simulation than the control.

Composite Radar Reflectivity of Patricia



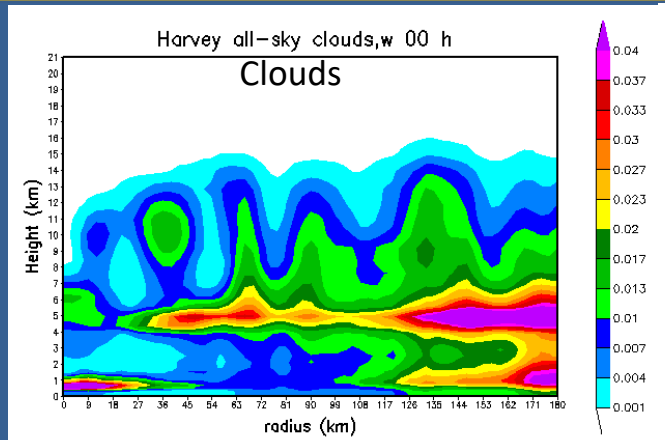
- The all-sky radiance assimilation helped the inner core convection organize.
- Tighter inner core and smaller eye were simulated by the all-sky run and compares better with the obs.

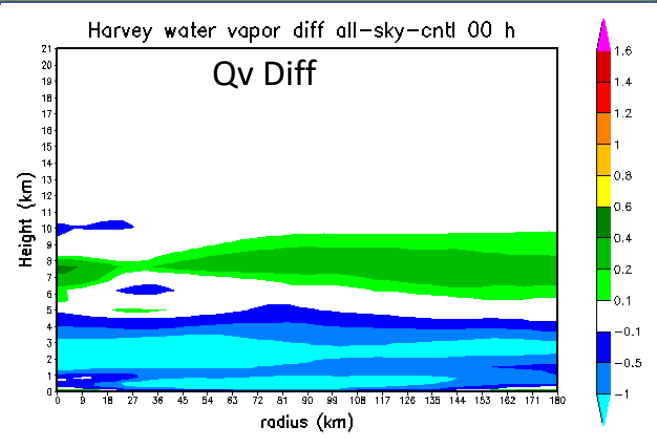
Impact on Harvey's Initial Structure: Inner Core

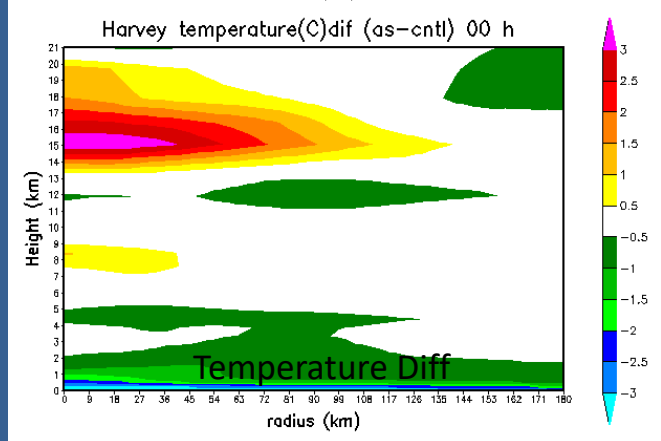
(Initialized at 1200 UTC 23 Aug. 2017)

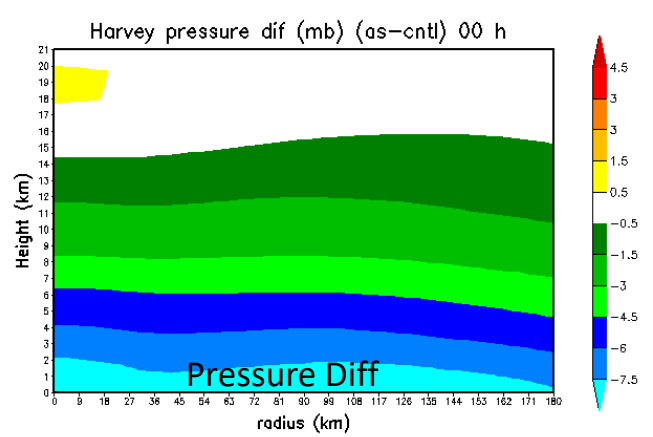
- Similar to the impact on Patricia, all-sky assimilation produces clouds at 0 h for Harvey, and reduces the pressure in a deep layer.
- Different impact: the moisture is reduced in the low levels (lowest 4 km), and temperature is lower near the surface.
- A warm core near the tropopause is formed in the all-sky run, similar to the case of Patricia.

Diff=(all-sky)-control



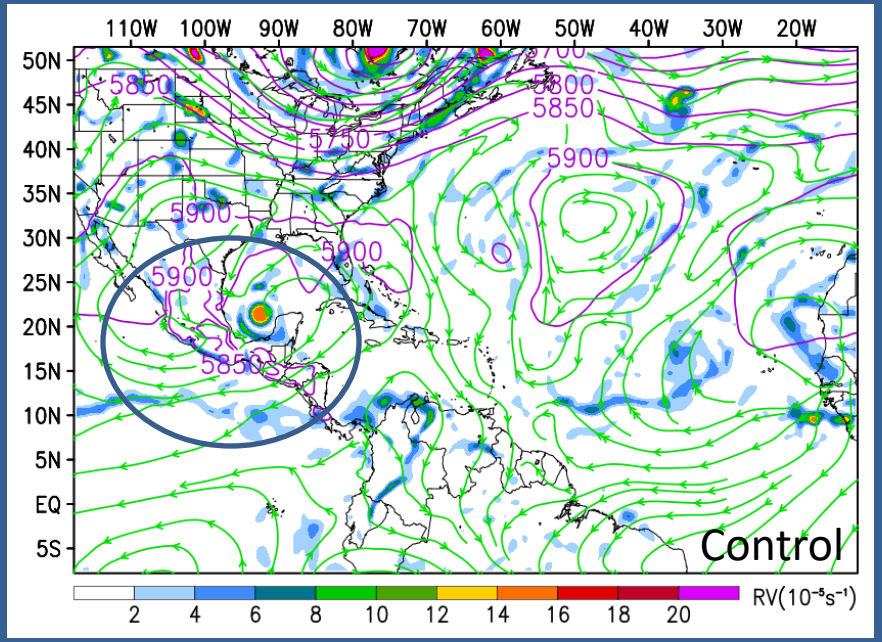


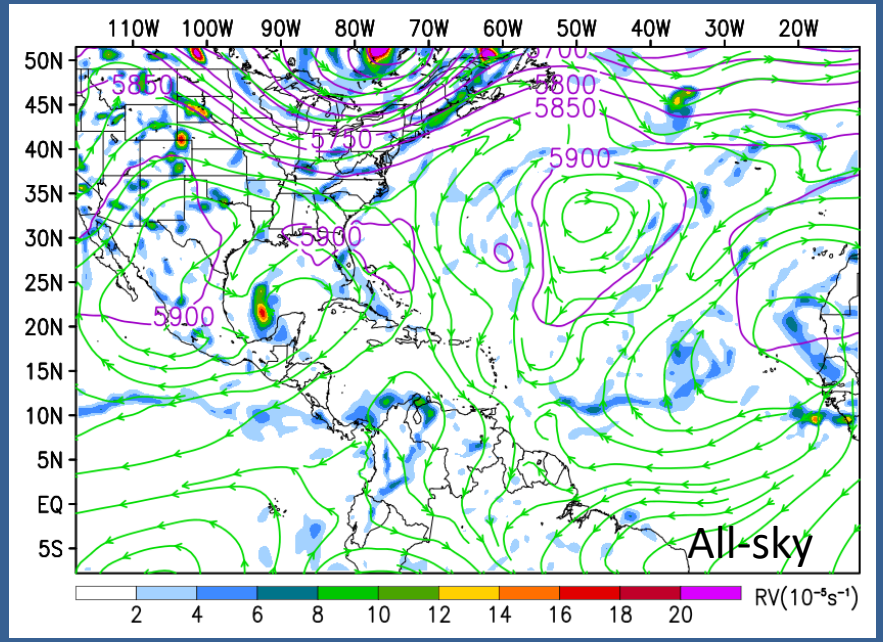




Impact on Harvey's Initial Environment

(Initialized at 1200 UTC 23 Aug. 2017)



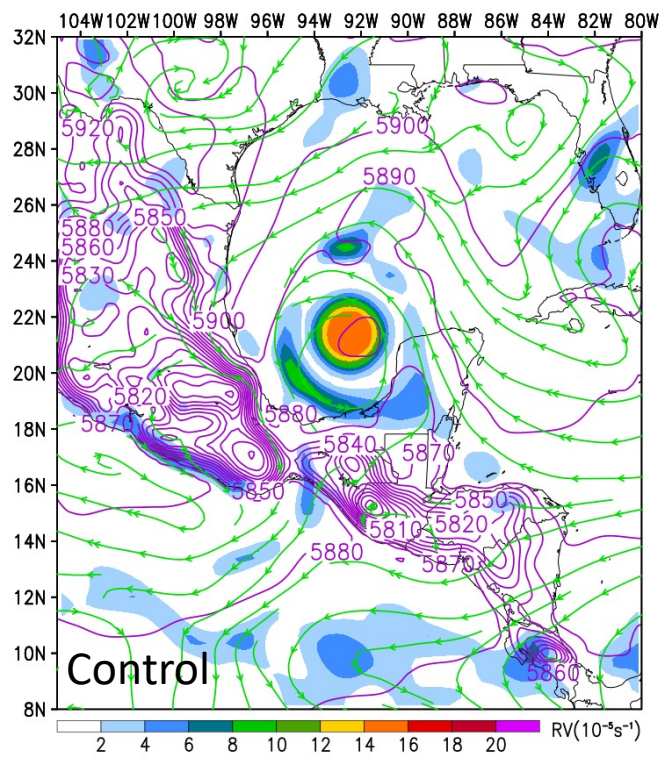


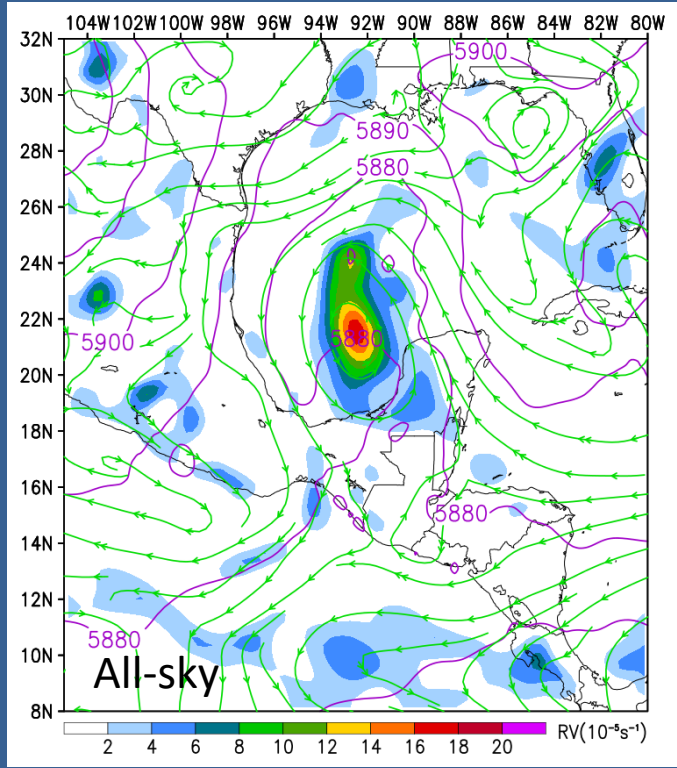
Shading: 850-hPa relative vorticity; 500-hPa geopotential heights (m), 200-hPa streamlines

- The control run generate low centers at 500 hPa over Mexico at the initial time, which was associated with the sudden westward detour of the forecast storm track.
- The all-sky run does not have this problem.

Impact on Harvey's Initial Environment – zoomed in

(Initialized at 1200 UTC 23 Aug. 2017)





- The low centers at 500 hPa in the control run becomes more obvious when zoomed in.
- This low centers quickly dissipated within the first several hours.
- The control run has a symmetric structure in the storm center, whereas the all-sky run has a elongated center.

Summary

- An all-sky radiance assimilation system, developed for the COAMPS-TC, has demonstrated capability to improve Hurricanes Patricia (2015) and Harvey (2017) forecasts by assimilating IR water vapor channel radiance data in both clear-sky and cloudy regions.

- Preliminary analysis for the Patricia case indicated that the all-sky radiance assimilation changed the initial clouds, moisture, temperature and pressure fields in TC inner core. Moreover, the all-sky assimilation helped establish the secondary circulation, which helped better organize the convection into a tight eyewall. The impact on initial TC structures was carried over the subsequent storm development.

- The all-sky radiance assimilation also impact the forecast of Hurricane Harvey, although the detailed impact differs from that in the Patricia case. The all-sky assimilation did not generate spurious low centers over Mexico and hence improves the first day track forecast.