Impacts of the Diurnal Radiation Cycle on the Formation, Intensity and Structure of Hurricane Edouard (2014)

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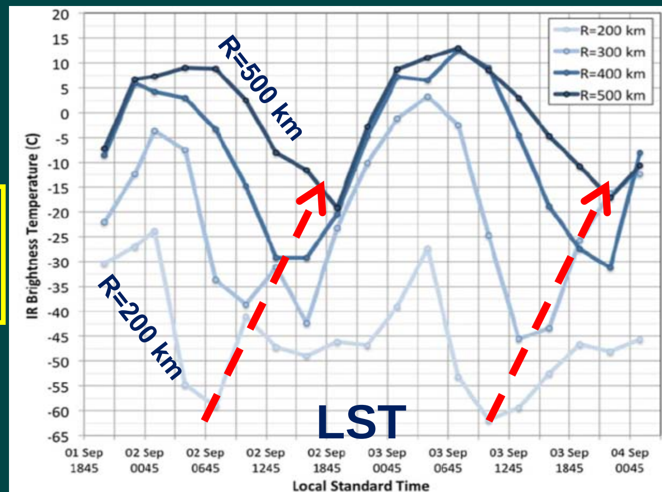
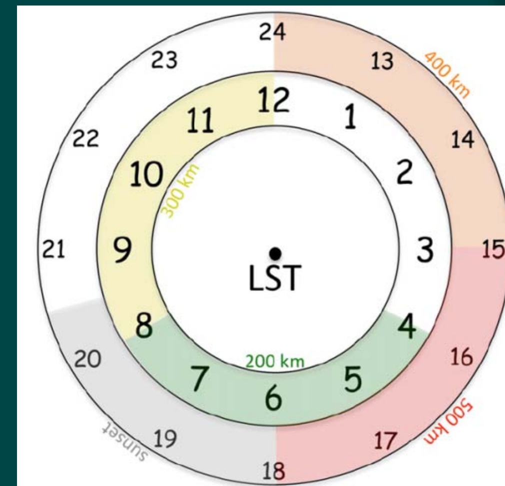
17- 22 April, 2016, San Juan, PR

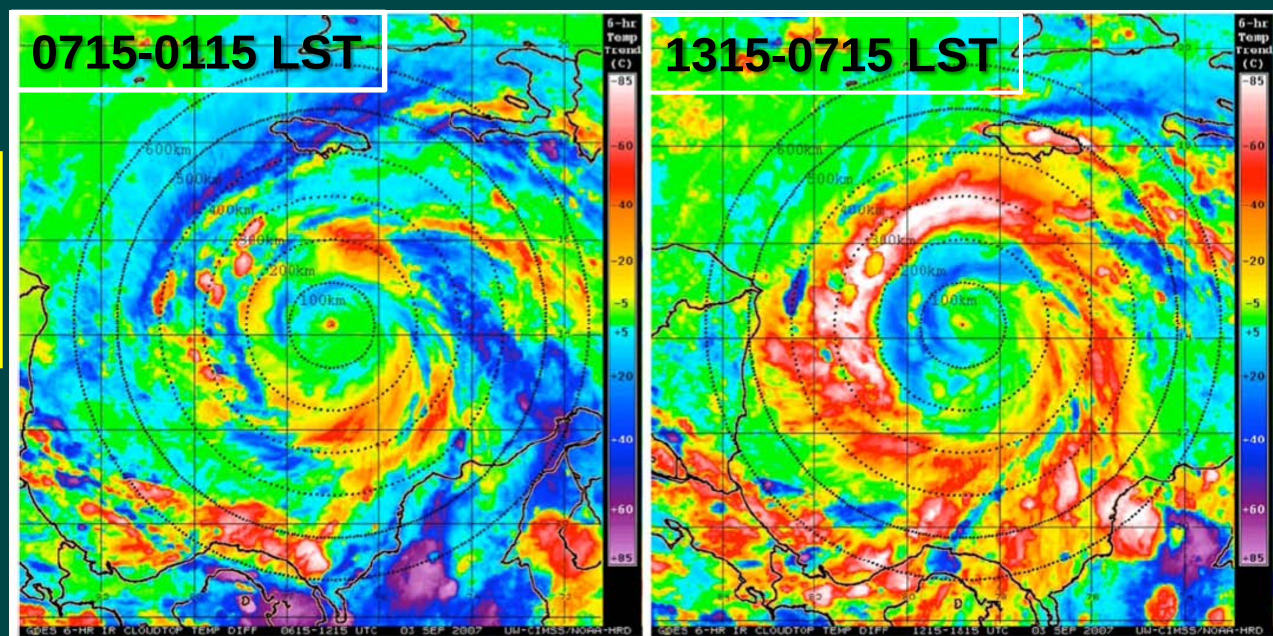
Tropical Cyclone Diurnal Cycle

IR brightness temperature



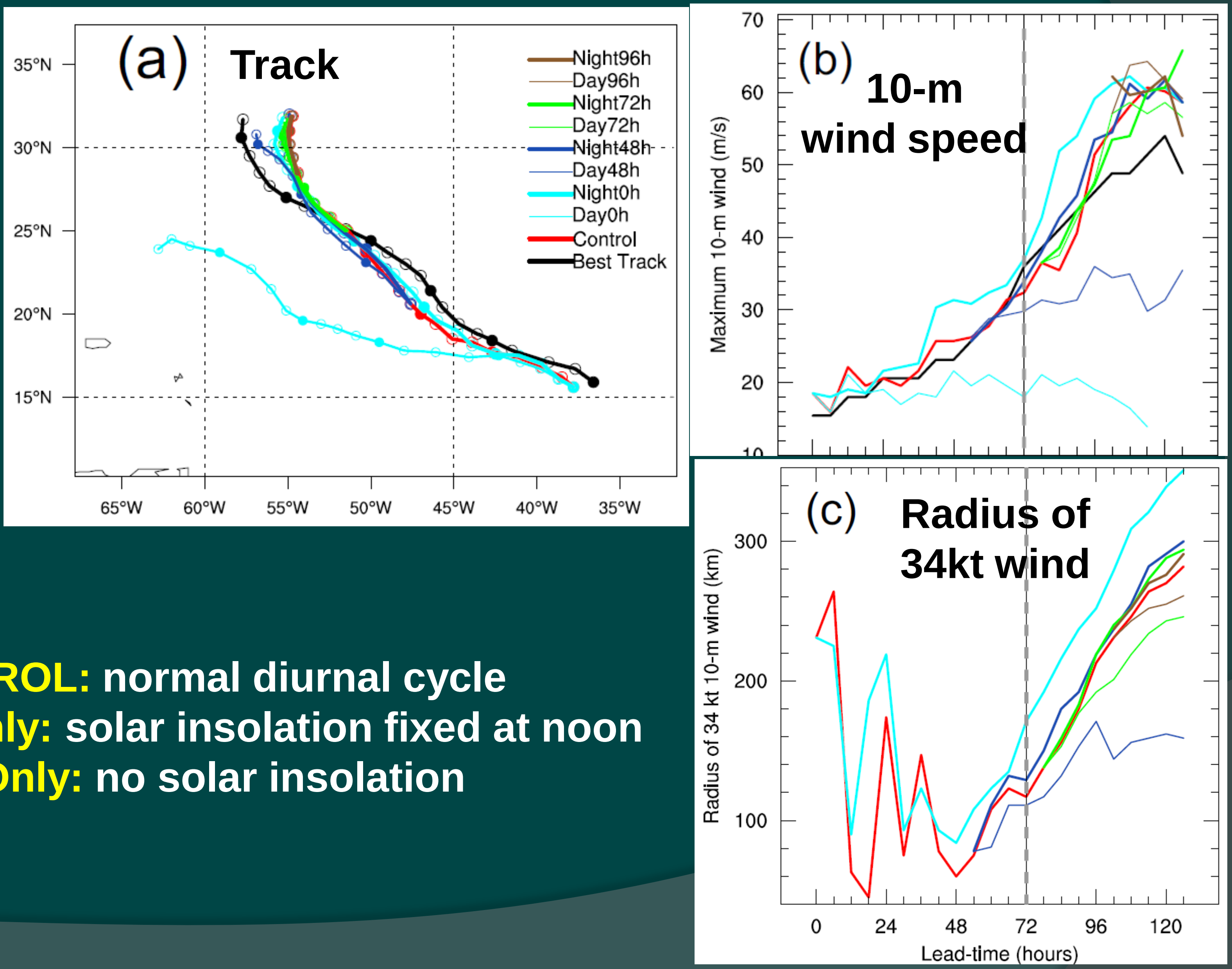


6-hr differencing images



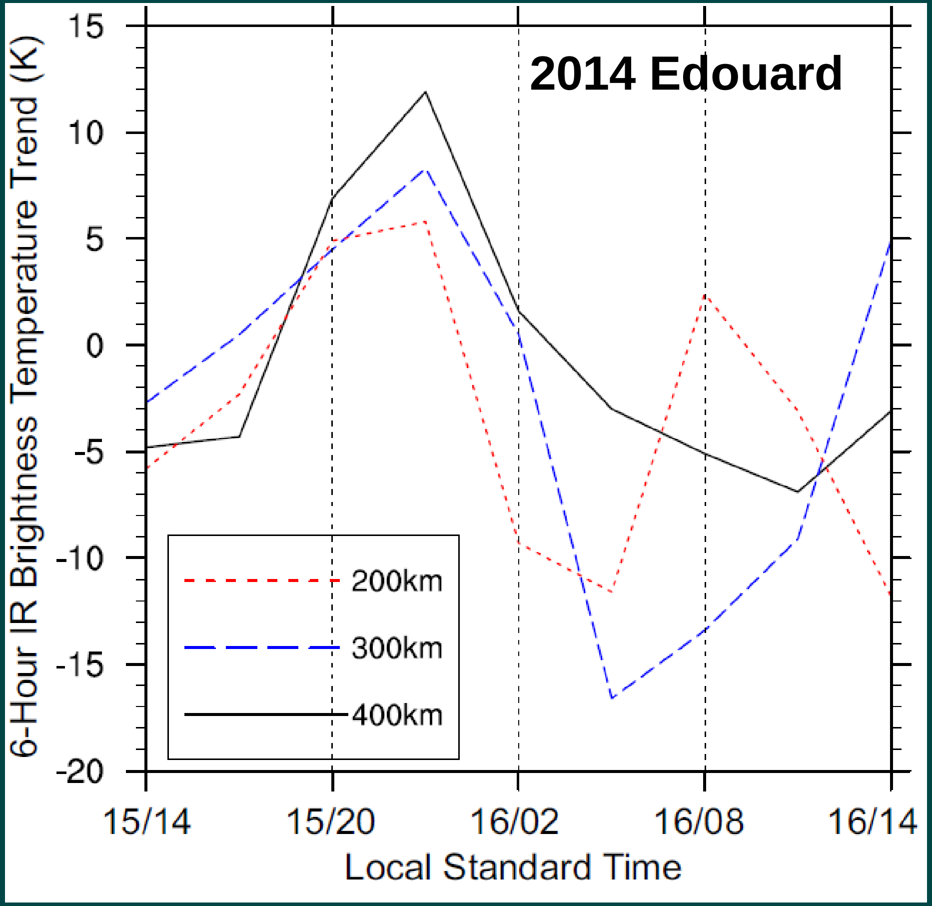
(Dunion et al. 2014) **Hurricane Felix (2007)**

Experimental design

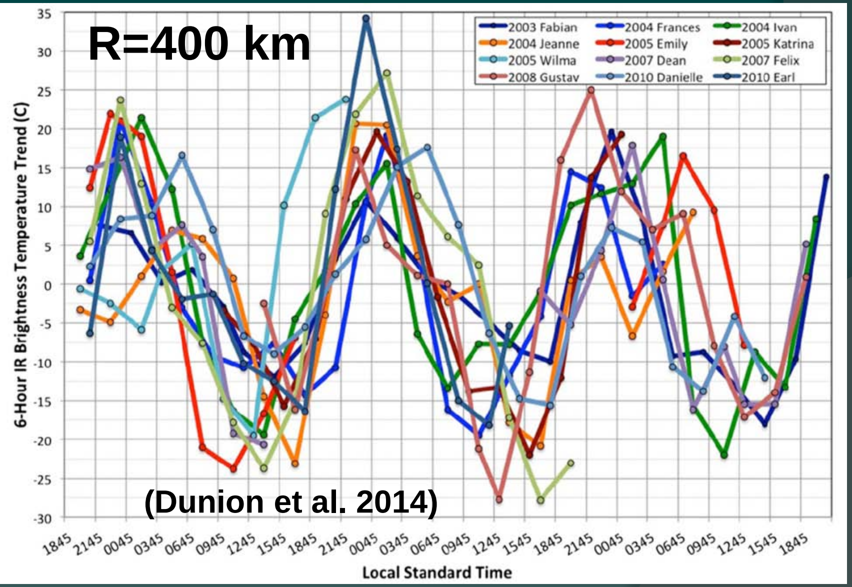


CONTROL: normal diurnal cycle
DayOnly: solar insolation fixed at noon
NightOnly: no solar insolation

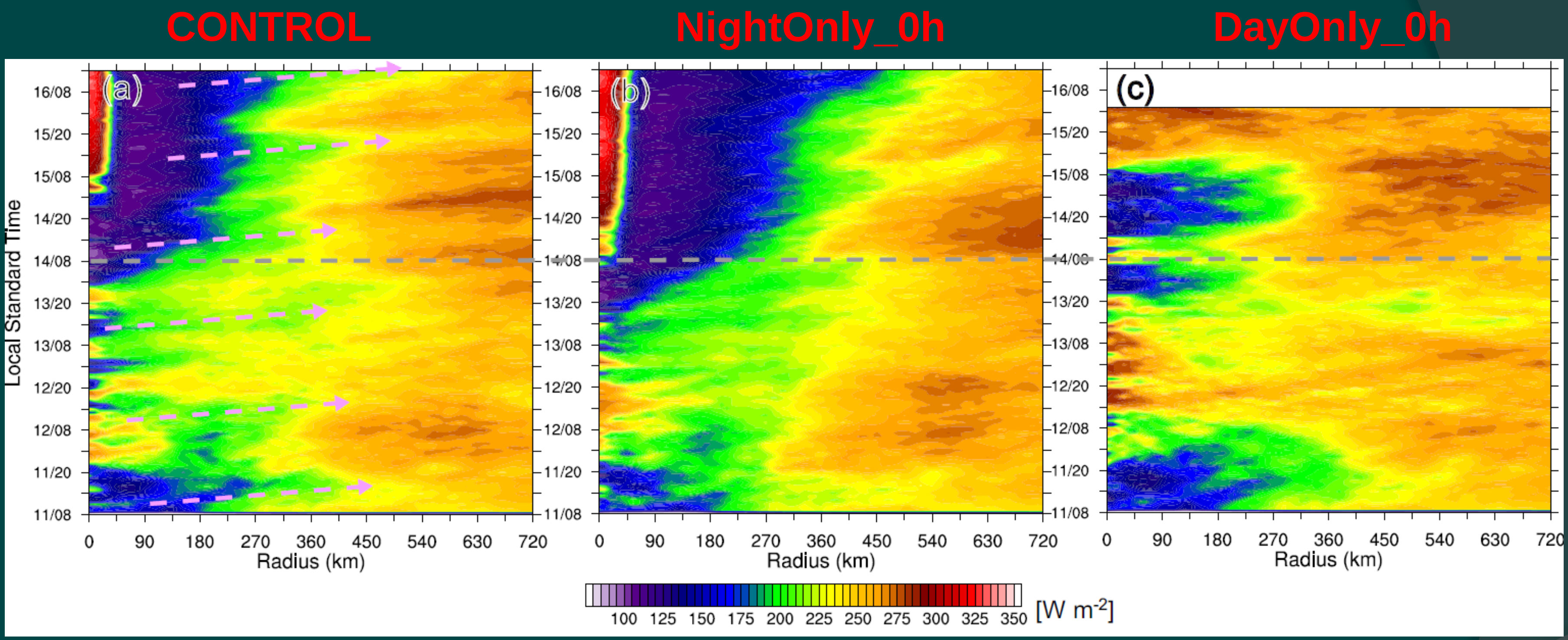
Simulated diurnal cycle of Hurricane Edouard



Diurnal pulses move outwards, reaching several hundred kilometers away by the following afternoon

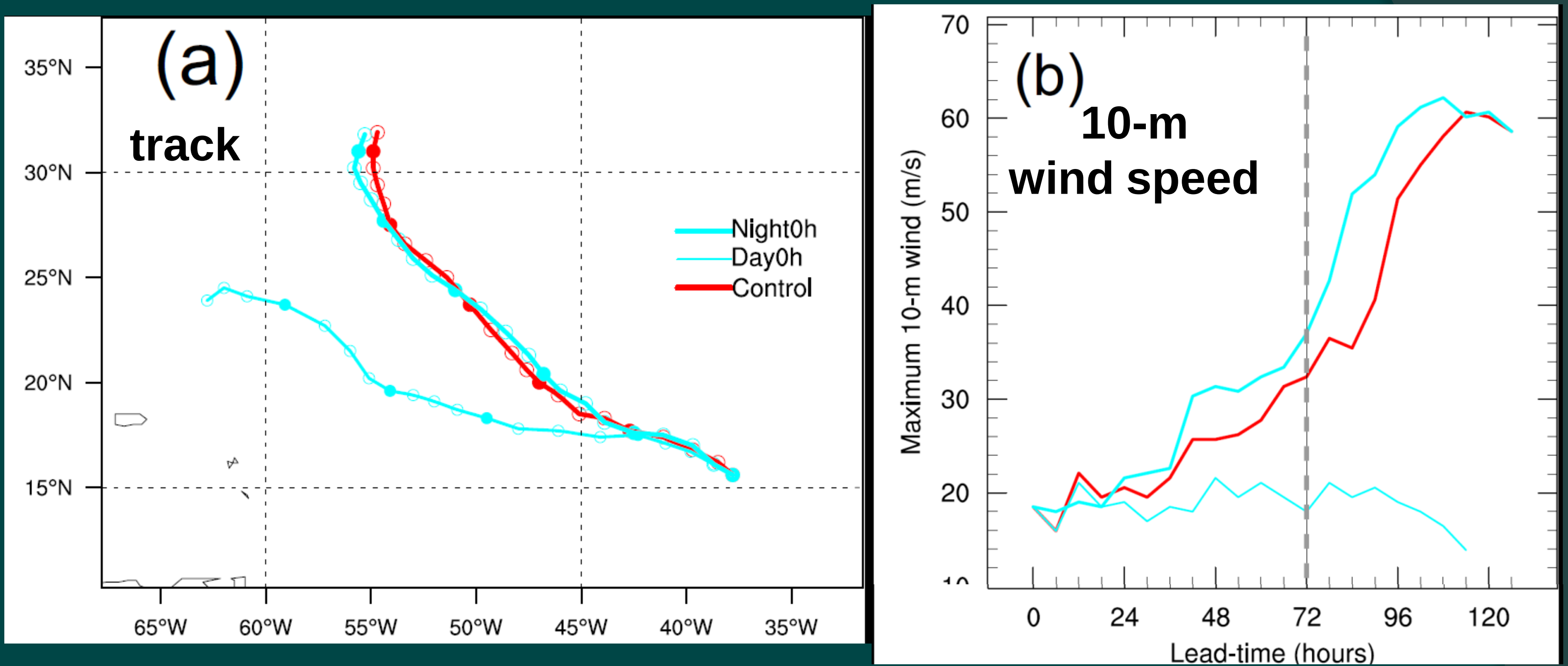


Diurnal Variation of OLR (Outgoing Longwave Radiation)



✓Apparent outwards propagation of diurnal pulses in CNTL
✓No diurnal cycle in NightOnly or DayOnly experiments

Impact of solar radiation cycle on Edouard's formation

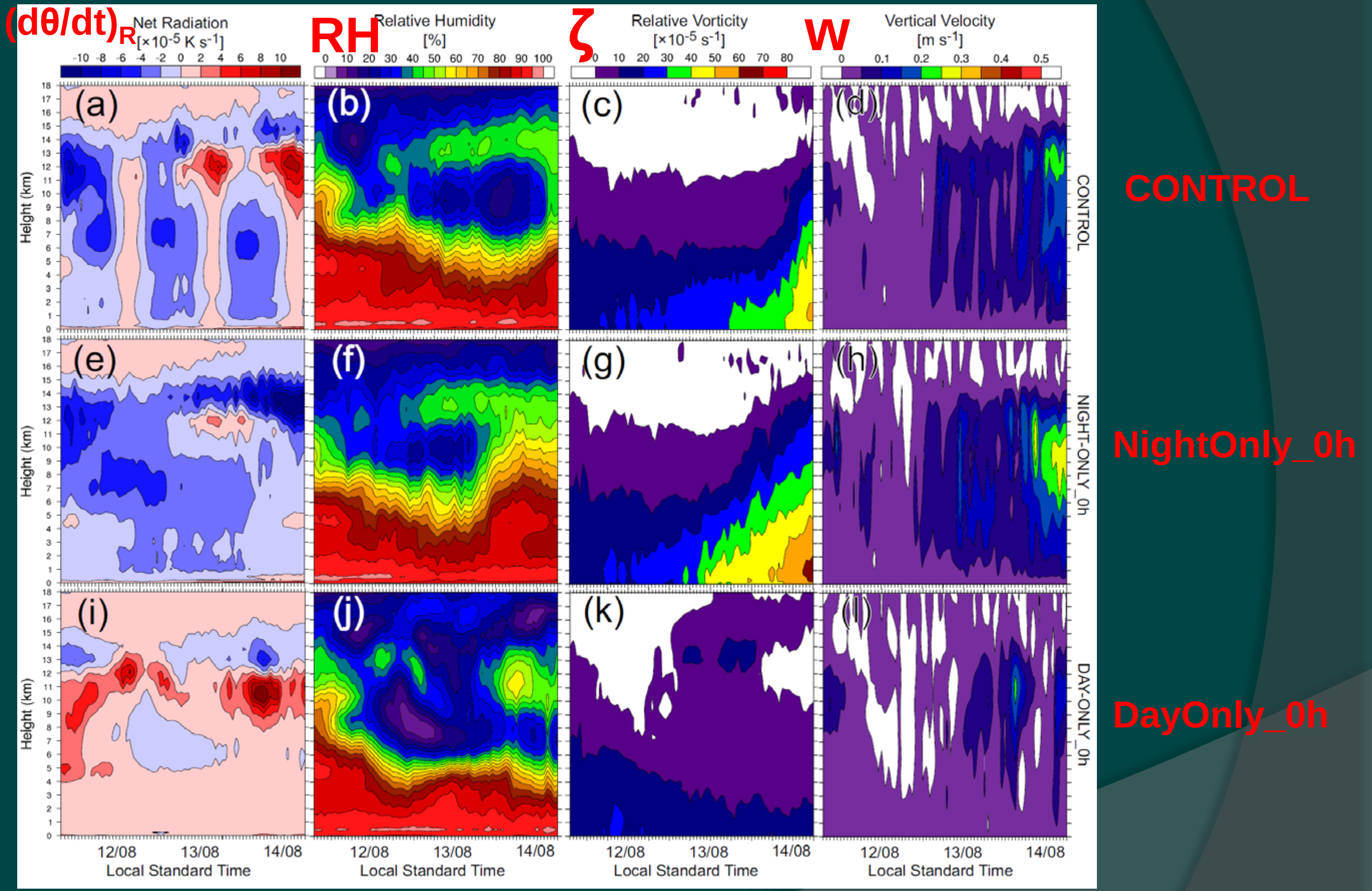


✓DayOnly0h didn't develop, tropical low drifted far leftward of observed track

✓CONTROL and NightOnly0h both develop

✓Net nighttime radiative cooling crucial for the storm's formation

Net nighttime radiative cooling role to the storm's formation

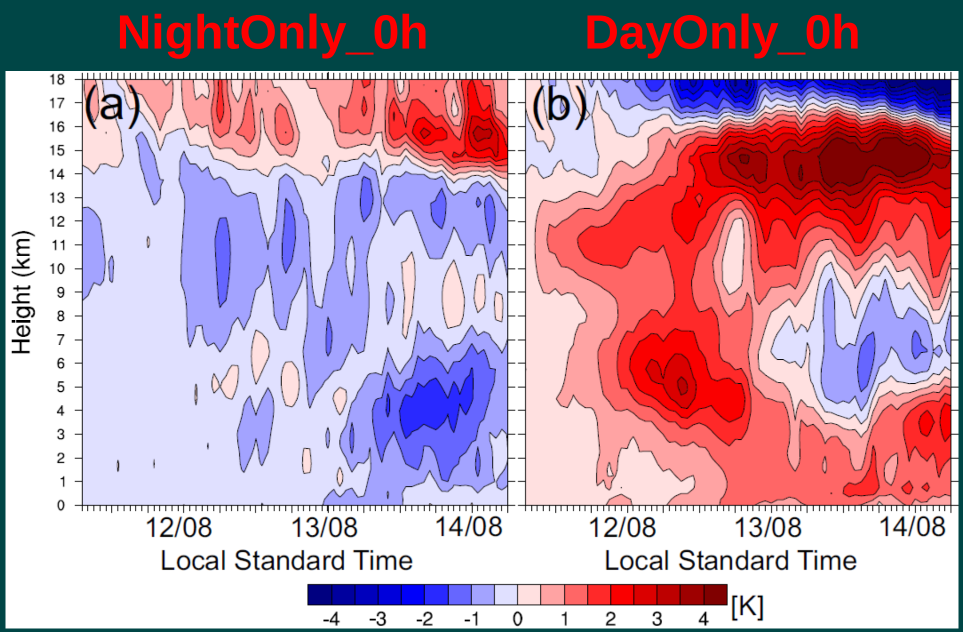


Net nighttime radiation cooling leads to lower T and higher RH

→ Enhancement of moist convection in nighttime

→ Enhancement of the low-level vorticity and upper-level updraft in NightOnly

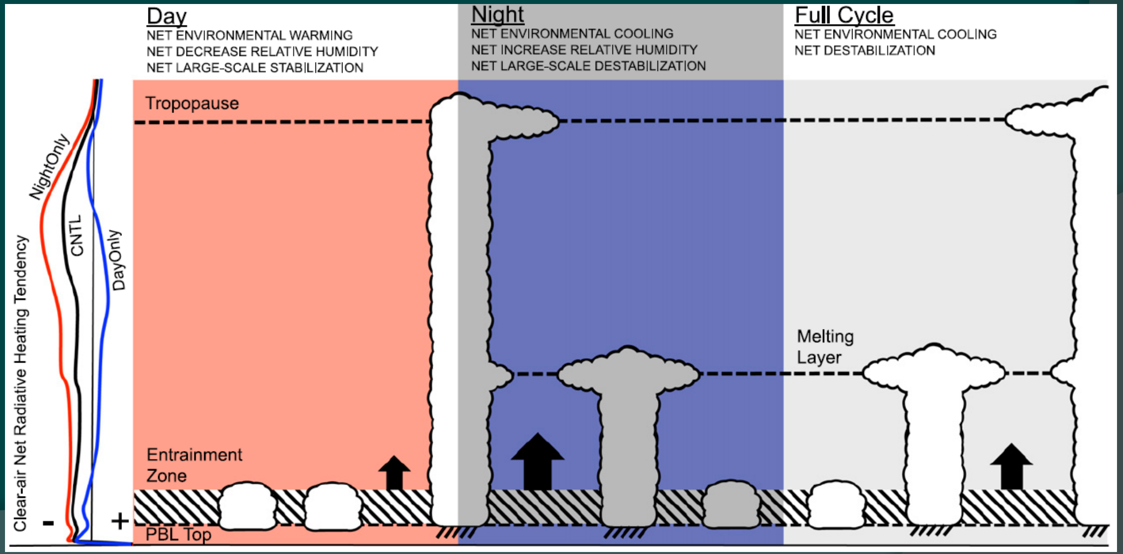
Net nighttime radiative cooling role to the storm's formation



Temperature difference with CNTL

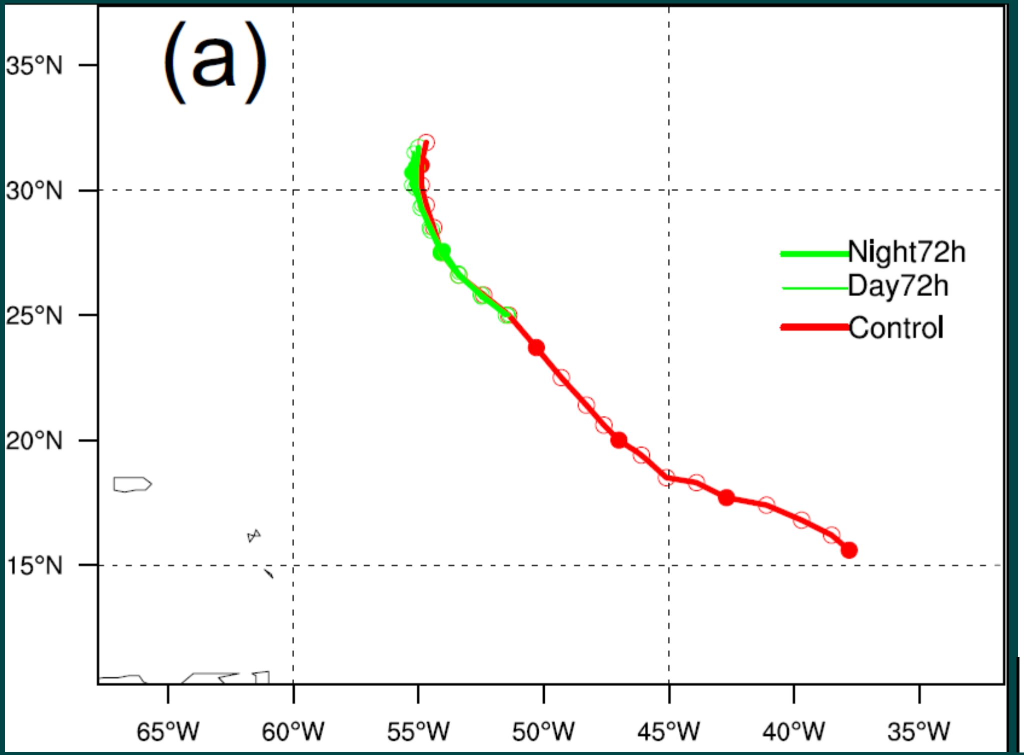
- **Lower/higher temperature in the low to middle levels for the NightOny/DayOnly.**

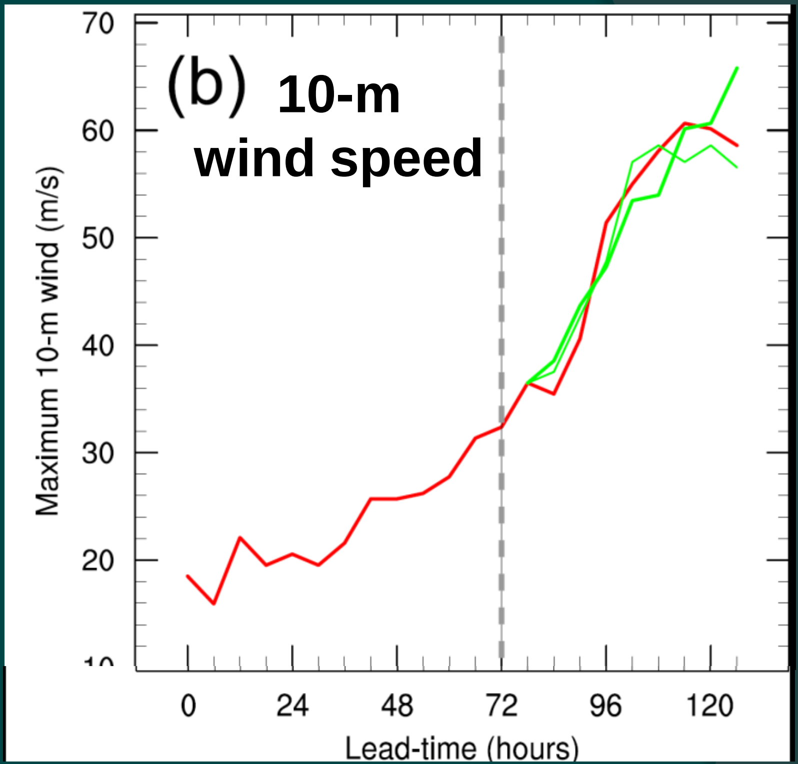
Nighttime radiative cooling → destabilize the local and large-scale environment → deep moist convection → increase the genesis potential



(Melhauser and Zhang 2014)

Impact of diurnal radiation on the mature hurricane

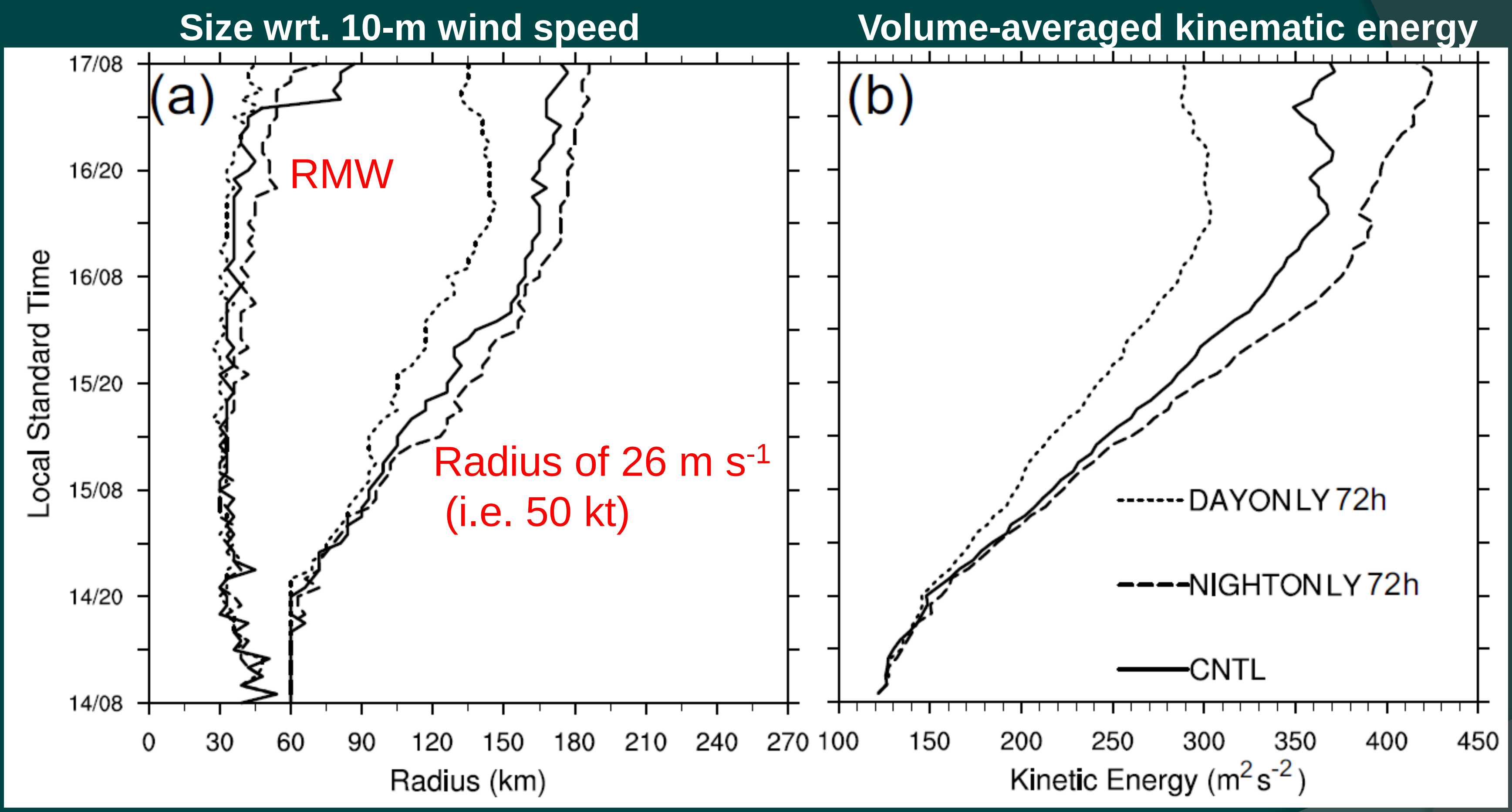




✓After RI, little impact on track, maximum wind speed and SLP

✓However, considerable change in structure and outer rainband (next slides)

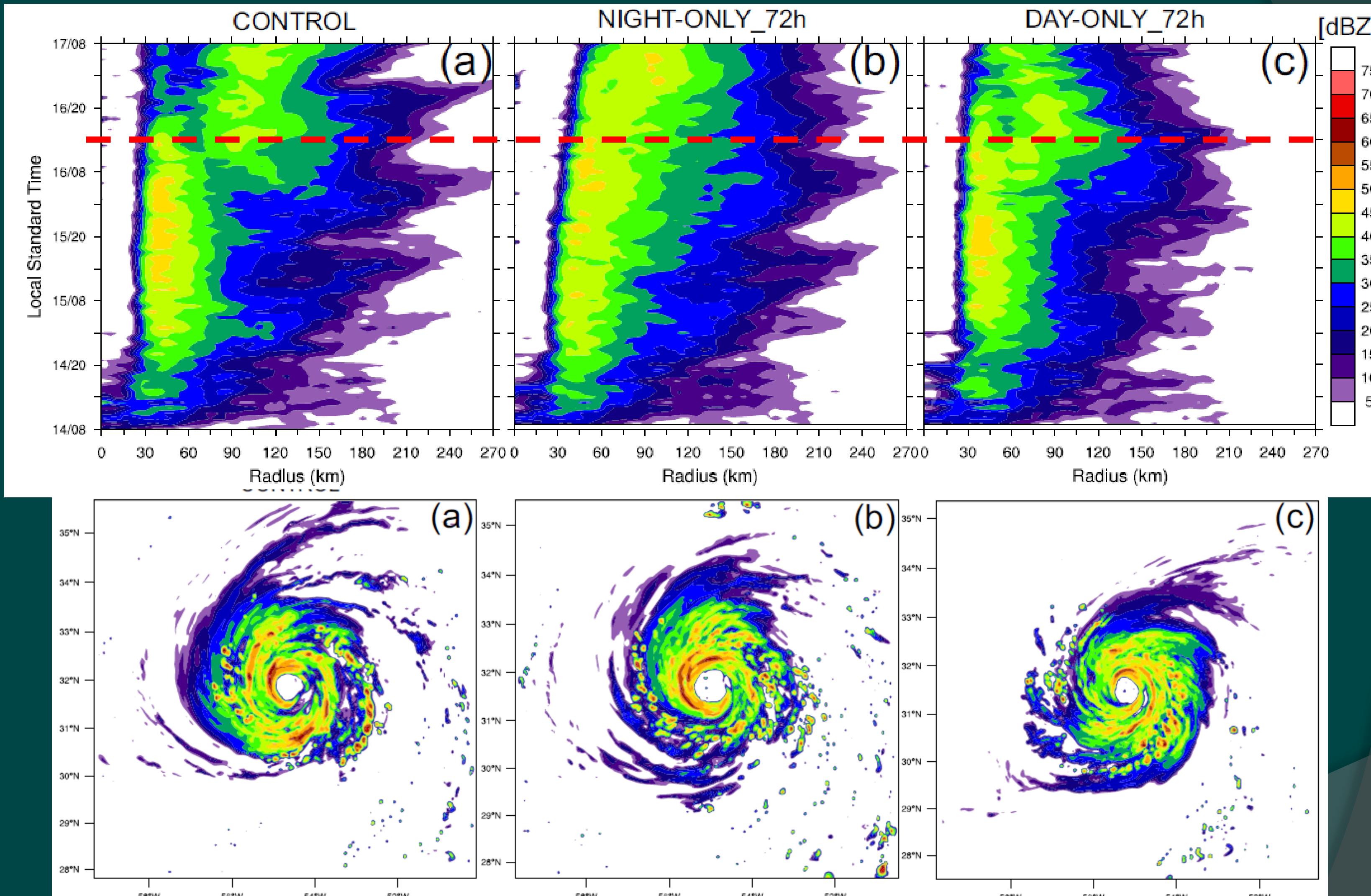
Different size and strength of mature hurricane



at 10-m level within radius of 270 km

Different structure and outer rainband of mature hurricane

radar reflectivity



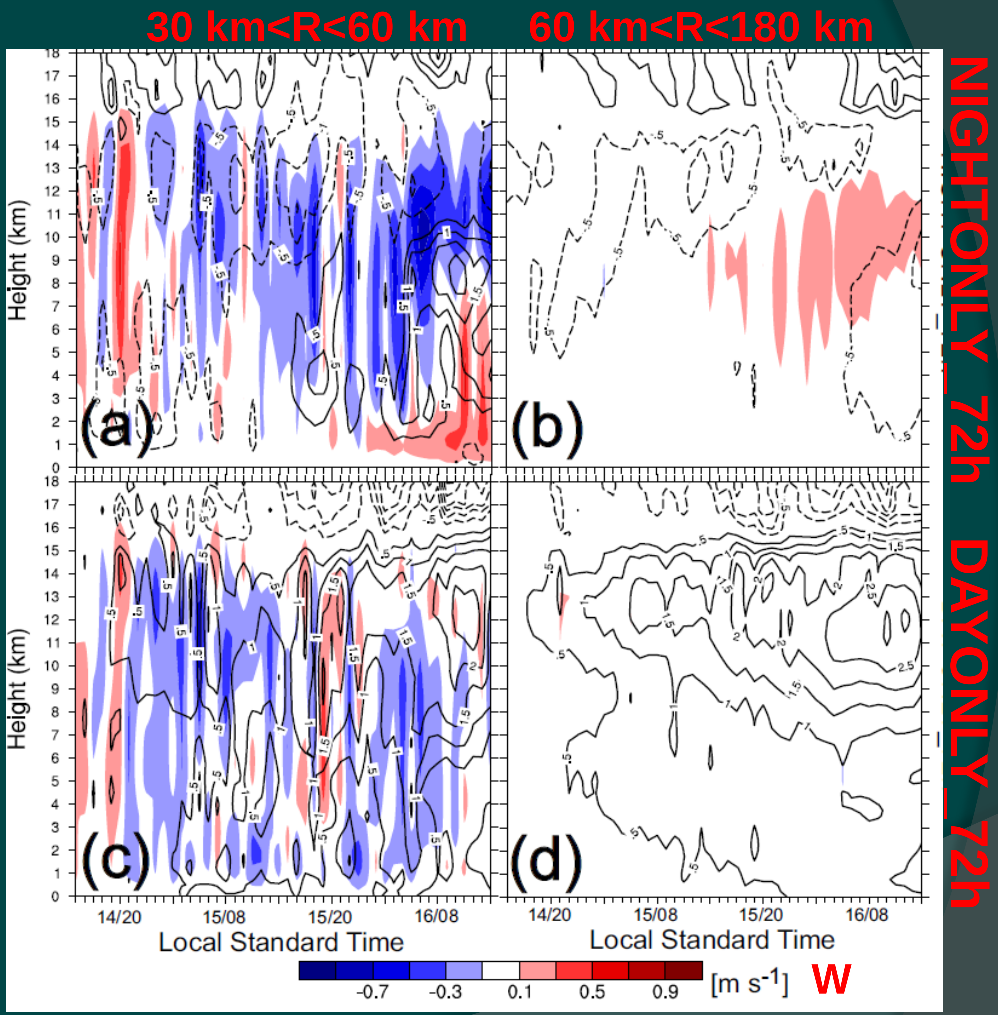
✓Control run: Secondary eyewall formation as observed

✓NightOnly: Stronger strength and bigger size, bigger eye, no SEF

✓DayOnly: Narrower moat

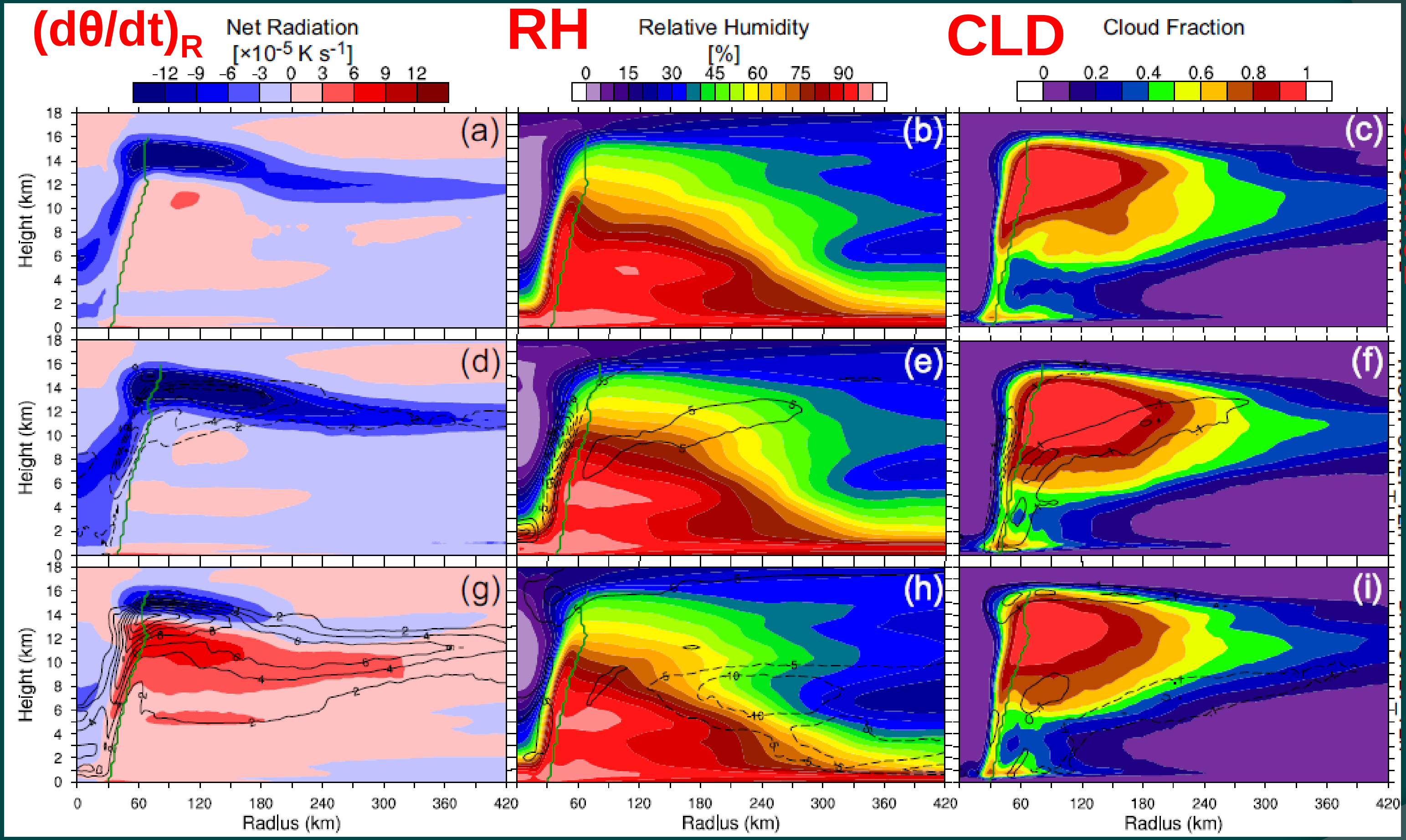
Net nighttime radiative cooling role to mature hurricane

- ✓ Temperature increasing at troposphere in DayOnly
- ✓ Destabilization of outer core, more deep moist convection in the NightOnly
- ✓ The decreasing vertical velocity in (a) is due to the eyewall expanding



Vertical profiles differences of vertical velocity (shading) and temperature (contour)

Different structure induced by radiation



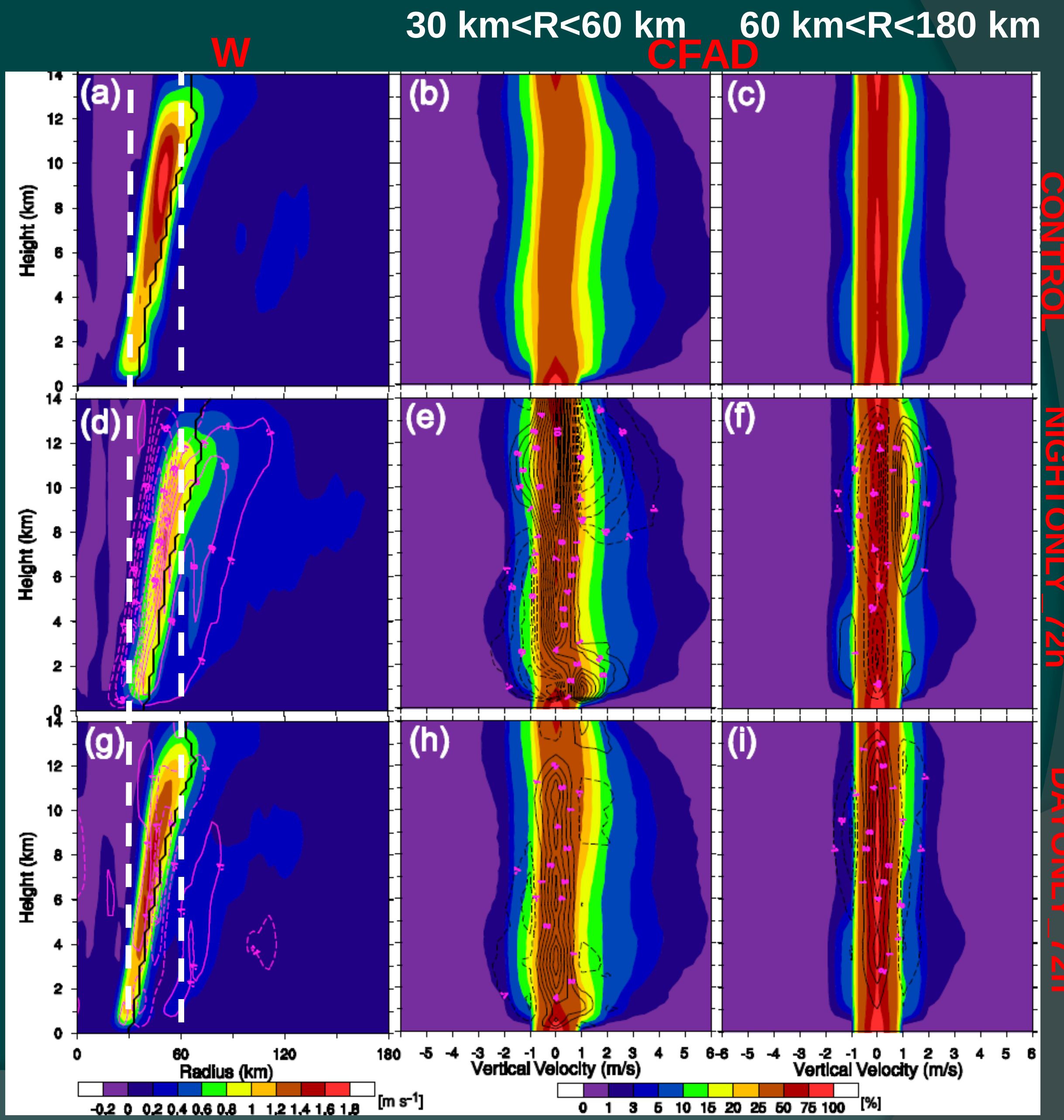
NightOnly :

✓**Prominent cooling along the cloud top; higher RH and Cloud Fraction outside;**

DayOnly:

✓**Warming within the cloud; lower RH and Cloud Fraction in outer region of low level**

Radiation's role on convection



NightOnly :

✓Stronger updraft outside of RMW

✓Bigger slope of primary eyewall

✓Convection increasing outside of eyewall

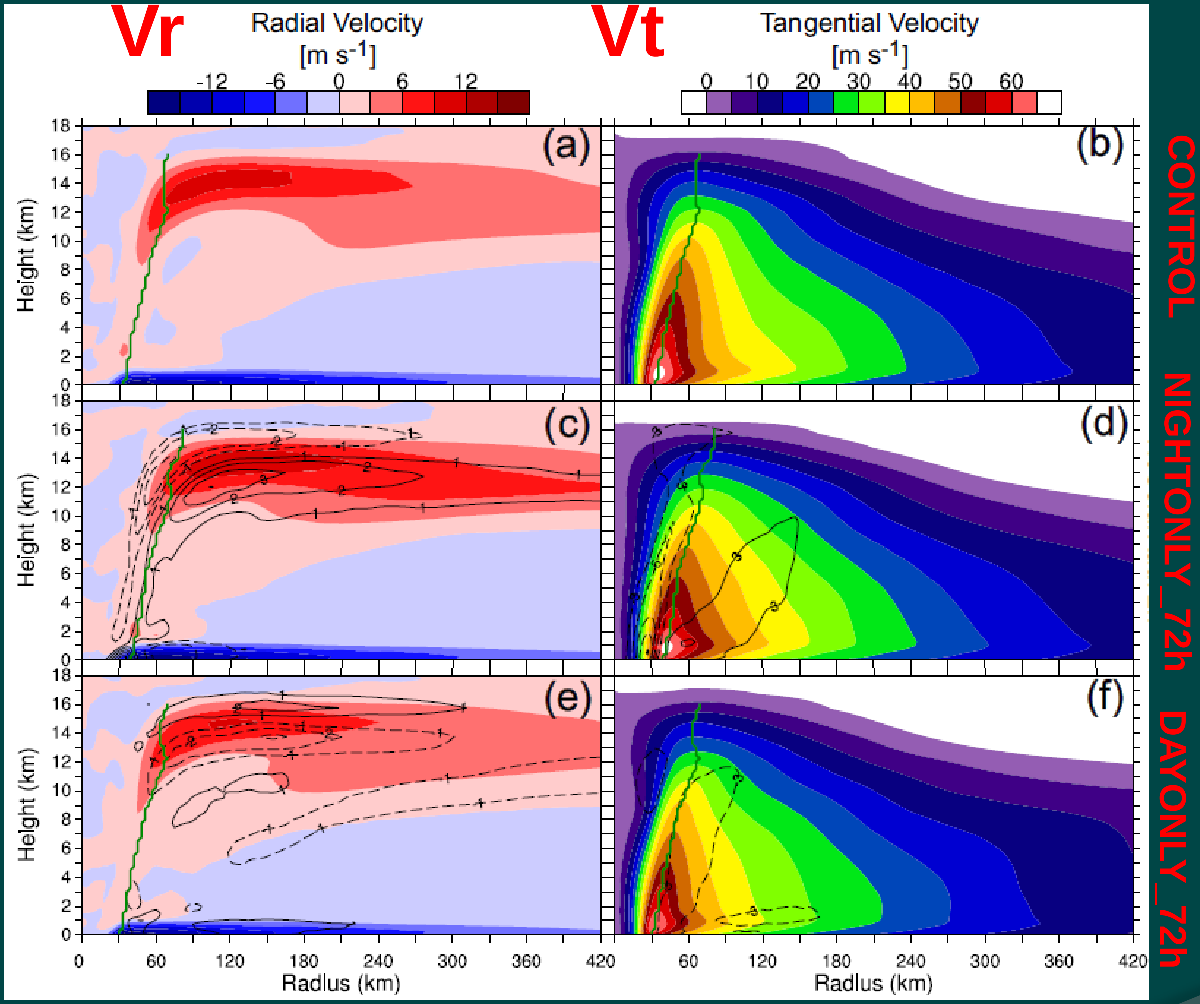
DayOnly:

✓Weaker updraft at both sides of RMW

✓More upright primary eyewall

✓Convection decreasing outside of eyewall

Different structure induced by radiation



NightOnly :

✓Stronger upper/low level radial outflow/inflow, and tangential wind outside of eyewalll;

✓Outward slope of primary eyewall increase

DayOnly:

✓Weeker updraft, upper/low level radial outflow/inflow, and tangential wind besides eyewalll

✓More upright primary eyewall

Concluding Remarks

- Formation stage: nighttime radiative cooling → humidification and destabilization → promote deep moist convection → storm genesis
  - The storm track may be altered by changing the initial vortex strength
- Mature stage: nighttime radiative cooling → increase convective activities outside of eyewall → stronger/broader rainbands and larger storm size caused by hydrostatic adjustment
  - Little impact on maximum surface wind speed
  - Potential role of the radiative impact to concentric eyewall formation
- All the stages: Both convective instability changes and large-scale nighttime cooling play important roles
- RI and mature stages: Differential heating mechanism may act together with the other two

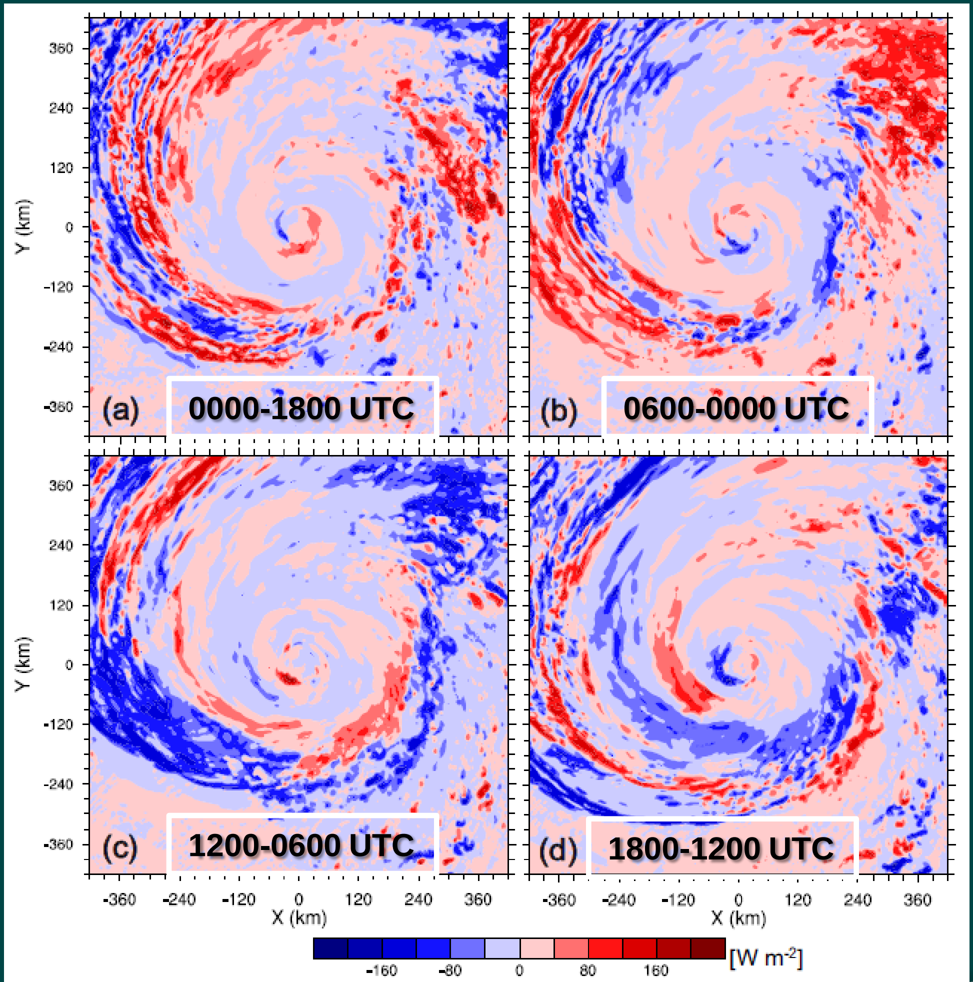
Citation:

Tang, X., and F. Zhang, 2016: Impacts of the Diurnal Radiation Cycle on the Formation, Intensity and Structure of Hurricane Edouard (2014), *J. Atmos. Sci.*, doi:10.1175/JAS-D-15-0283.1, in press.

Thanks for attention

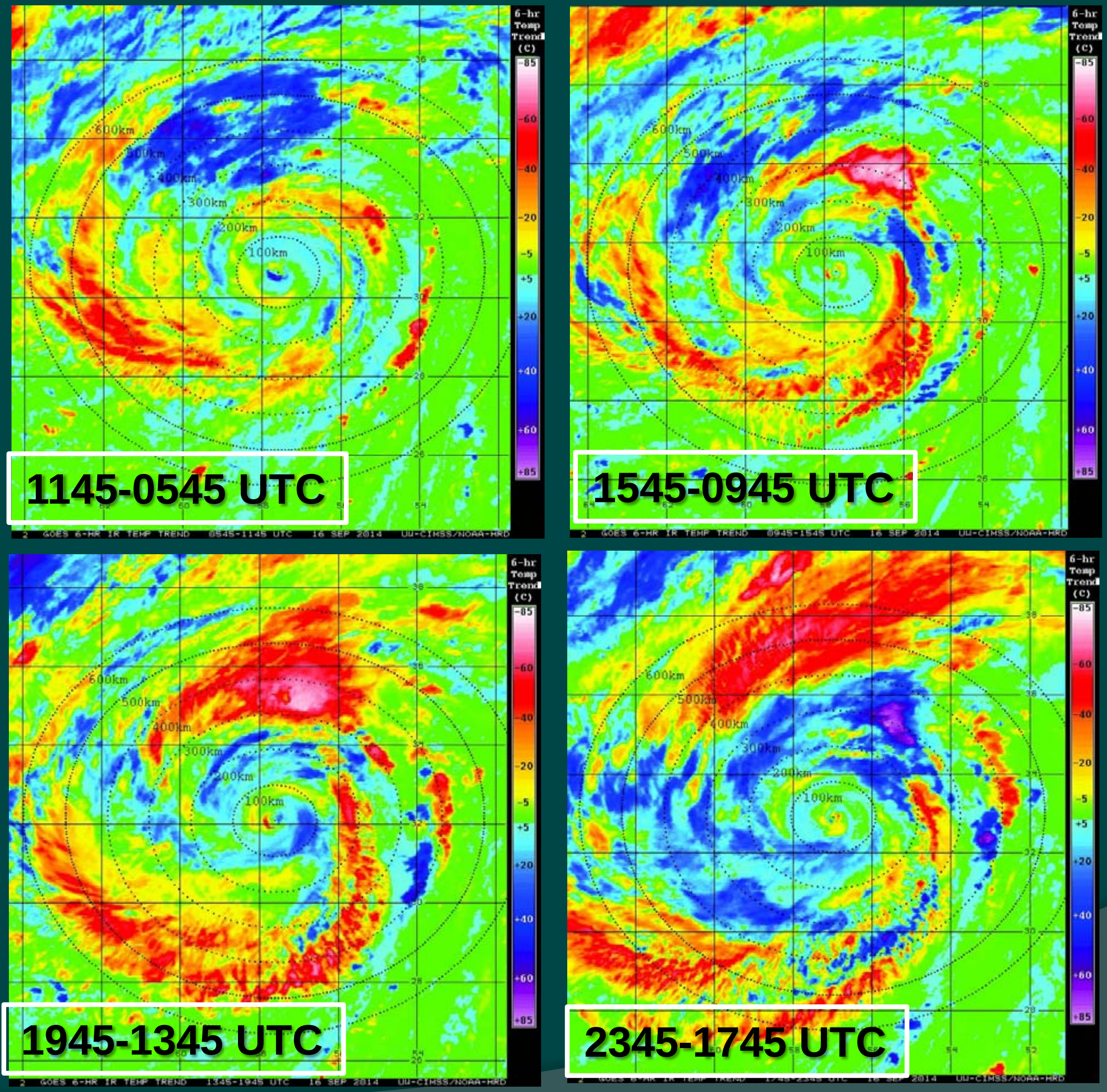
Simulated diurnal cycle of Hurricane Edouard: Sept 16

6-h OLR differencing images for control run



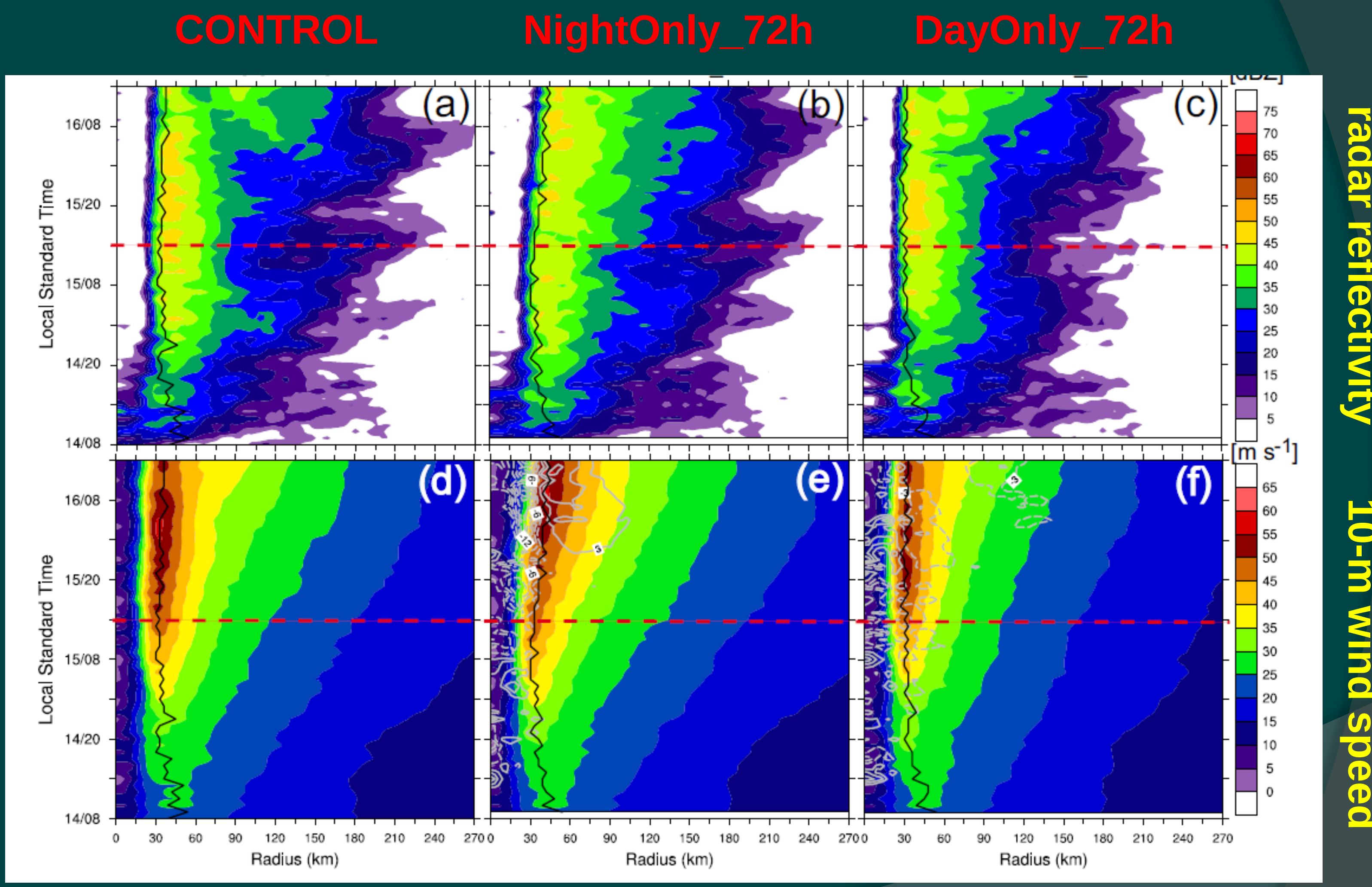
✓Simulated diurnal cycle in mature stage, which is simliar with observation

Observed diurnal cycle of Hurricane Edouard: Sept 16

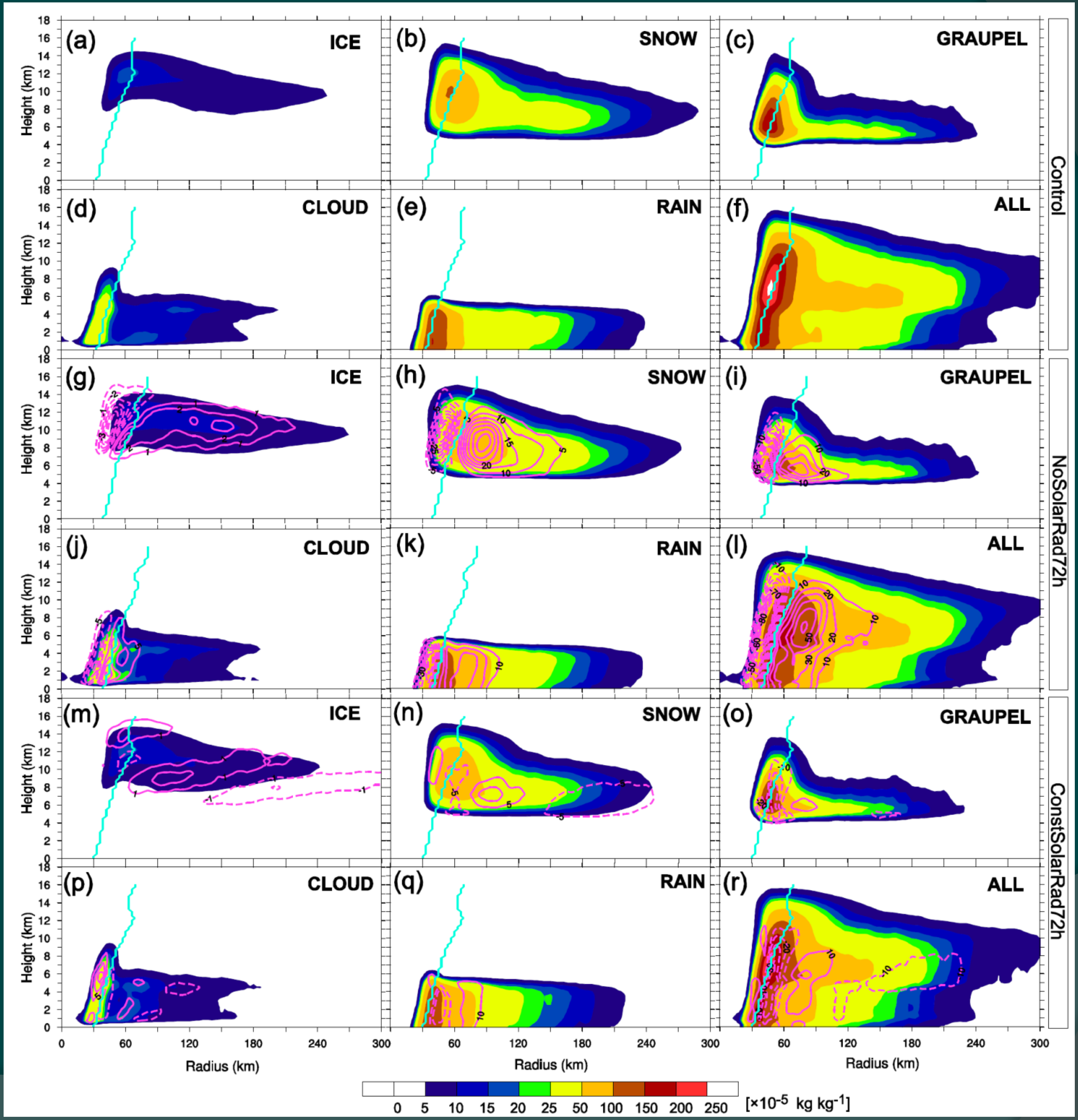


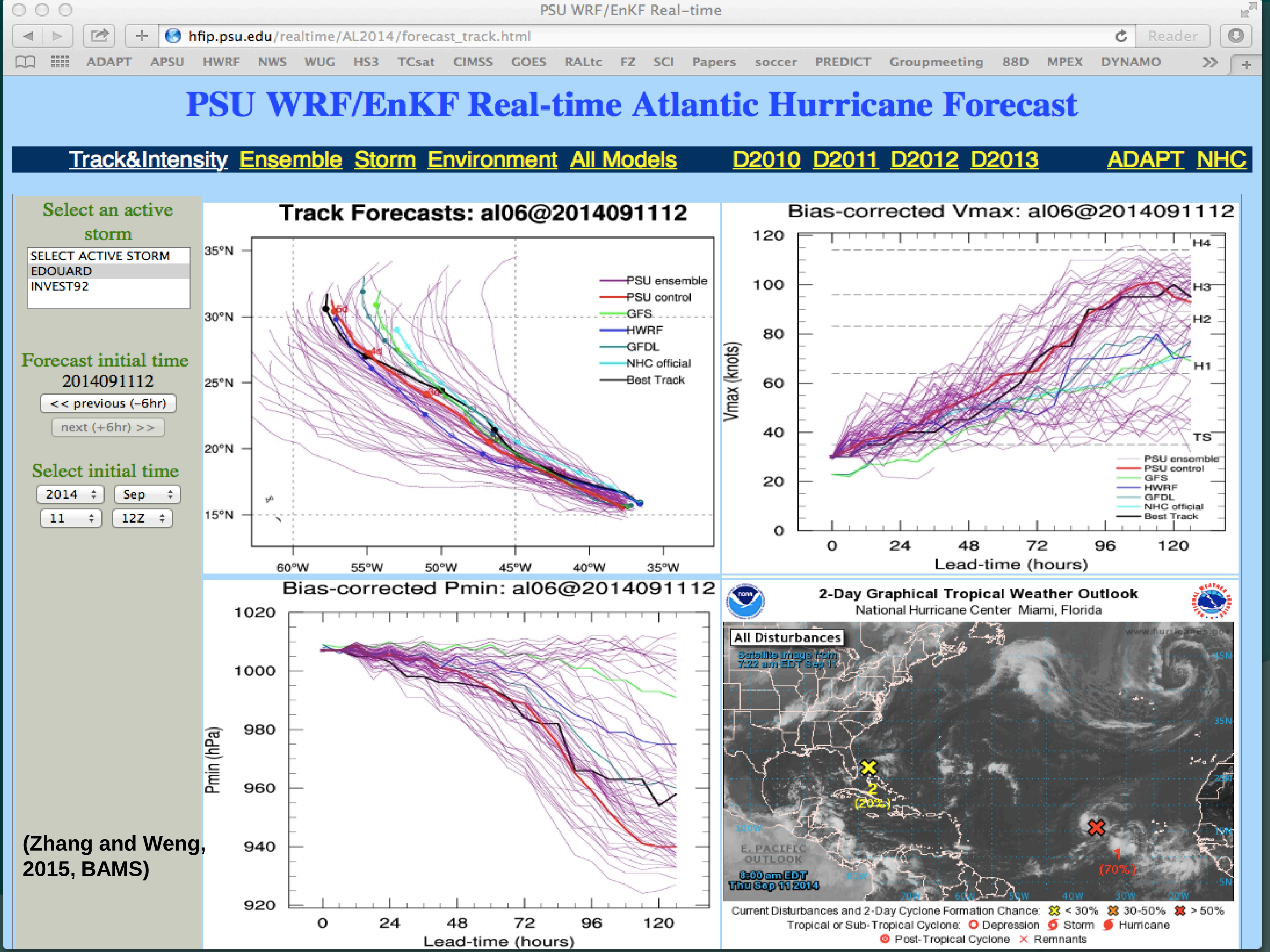
(Courtesy of Jason Dunion)

Different structure and outer rainband of mature hurricane



✓Control run undergoes secondary eyewall formation as observed
✓Stronger strength and bigger size for NightOnly

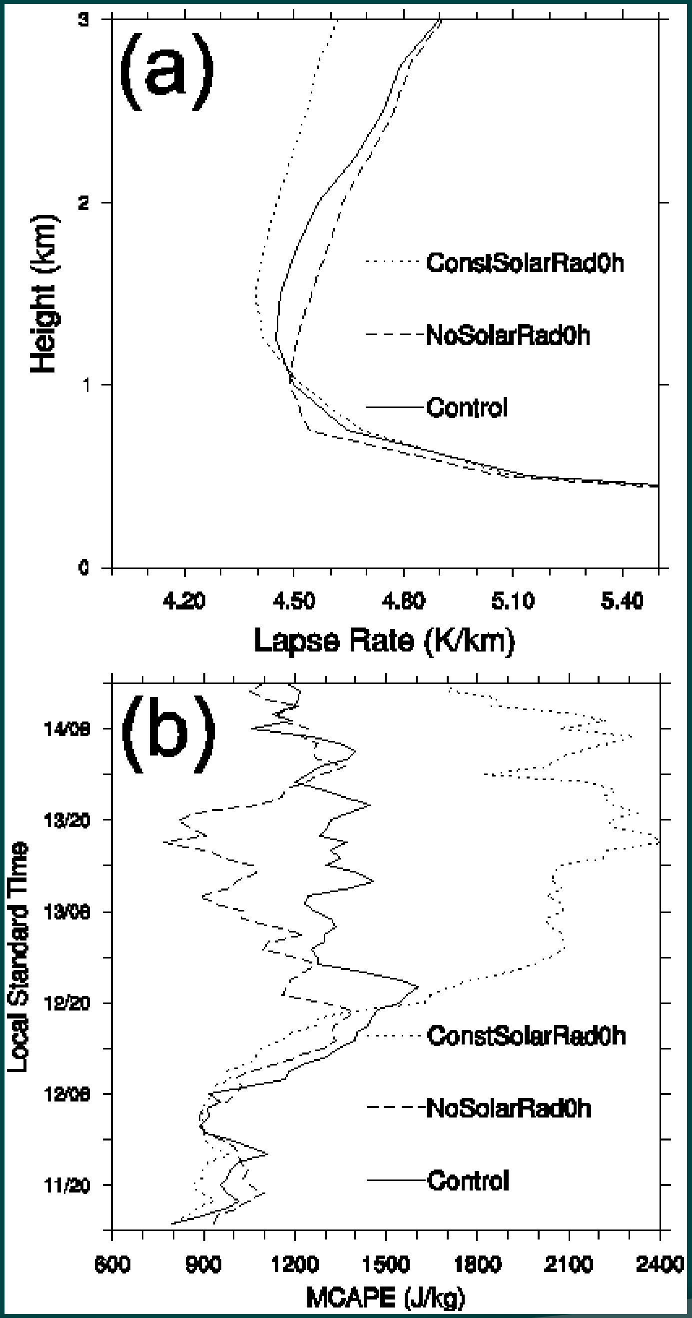

(a) ICE
(b) SNOW
(c) GRAUPEL
(d) CLOUD
(e) RAIN
(f) ALL
(g) ICE
(h) SNOW
(i) GRAUPEL
(j) CLOUD
(k) RAIN
(l) ALL
(m) ICE
(n) SNOW
(o) GRAUPEL
(p) CLOUD
(q) RAIN
(r) ALL
Control
NoSolarRad72h
ConstSolarRad72h
Height (km)
Radius (km)
0 5 10 15 20 25 50 100 150 200 250
[×10-5 kg kg-1]



(Zhang and Weng, 2015, BAMS)

Name	Start time	Integration hours	Radiation	
			Solar shortwave	Longwave
Control	1200 UTC 11 Sept.	168	Normal diurnal cycle	Normal
NoSolarRad0h	1200 UTC 11 Sept.	126	Off	Normal
ConstSolarRad0h	1200 UTC 11 Sept.	126	Fixed at local noon	Normal
NoSolarRad48h	1200 UTC 13 Sept.	78	Off	Normal
ConstSolarRad48h	1200 UTC 13 Sept.	78	Fixed at local noon	Normal
NoSolarRad72h	1200 UTC 14 Sept.	96	Off	Normal
ConstSolarRad72h	1200 UTC 14 Sept.	96	Fixed at local noon	Normal
NoSolarRad96h	1200 UTC 15 Sept.	30	Off	Normal
ConstSolarRad96h	1200 UTC 15 Sept.	30	Fixed at local noon	Normal

$$KE = \frac{1}{2}\int_{z_1}^{z_2}\int_{0}^{2\pi}\int_{0}^{R}\rho(u^2+v^2+w^2)\,r\,dr\,d\theta\,dz$$



(a) Average vertical profiles of the local-environment lapse rate, temporally averaged during 1900 UTC (1500 LST) 11 to 1800 UTC (1400 LST) 13 September, and (b) Evolution of average most unstable convective available potential energy (MCAPE) for a parcel (defined as a 500-m-vertical layer average with the highest equivalent potential temperature below 3000 m AGL) within 180 km of the vortex center for control run and two sensitivity experiments.