Impacts of Diurnal Radiation Cycle on Secondary Eyewall Formation of Hurricane Edouard (2014)

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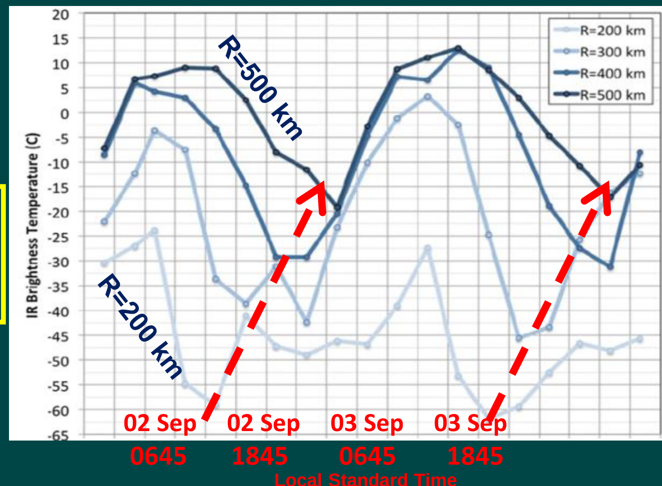
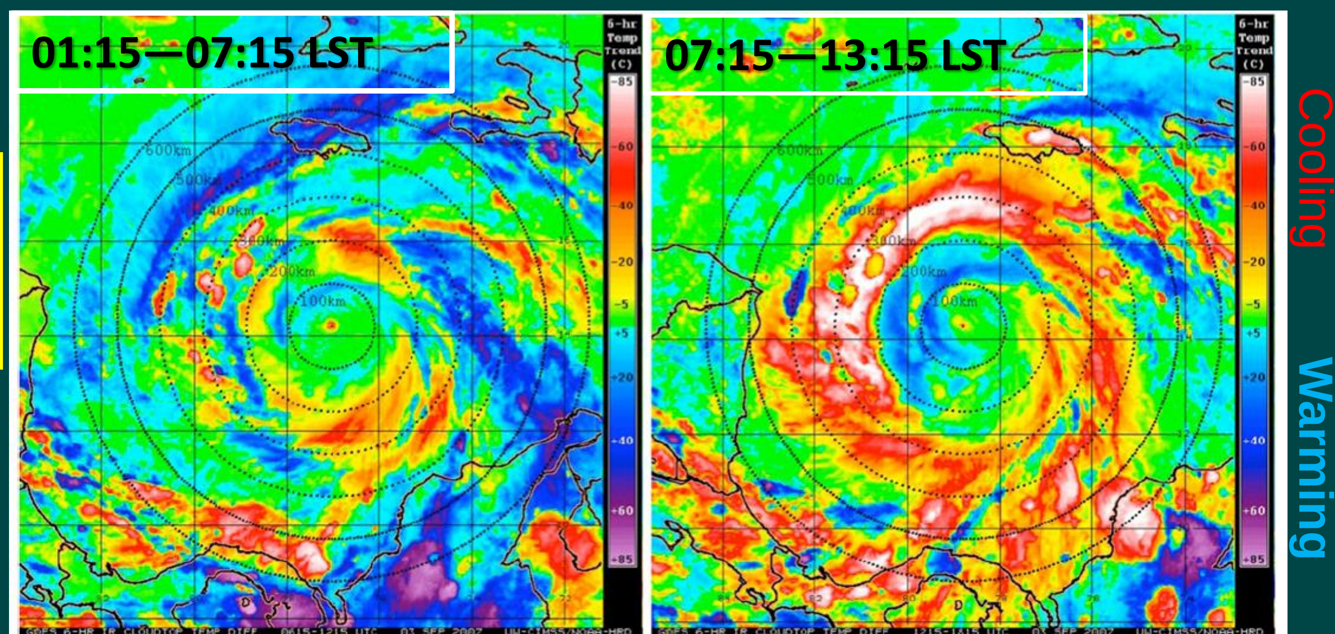
Tropical Cyclone Diurnal Cycle

IR brightness temperature



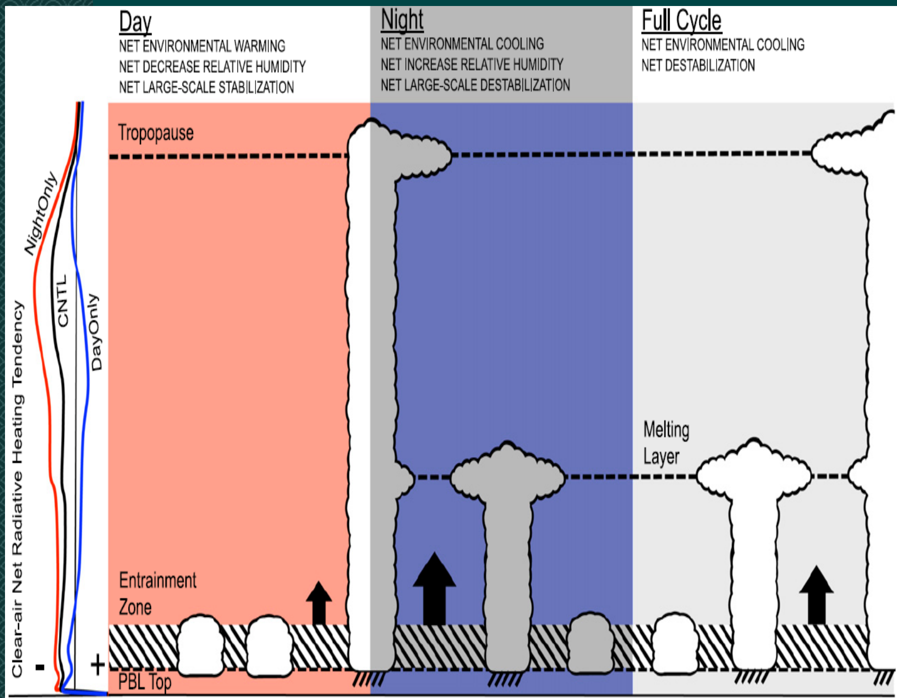
Diurnal pulses begin forming in the inner core near sunset each day, and move outwards overnight, reaching several hundred kilometers away by the following afternoon.

6-hr IR Temperature Trend



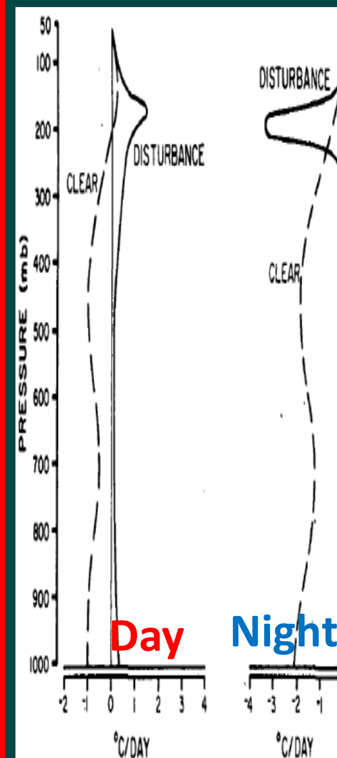
(Dunion et al. 2014) **Hurricane Felix (2007)**

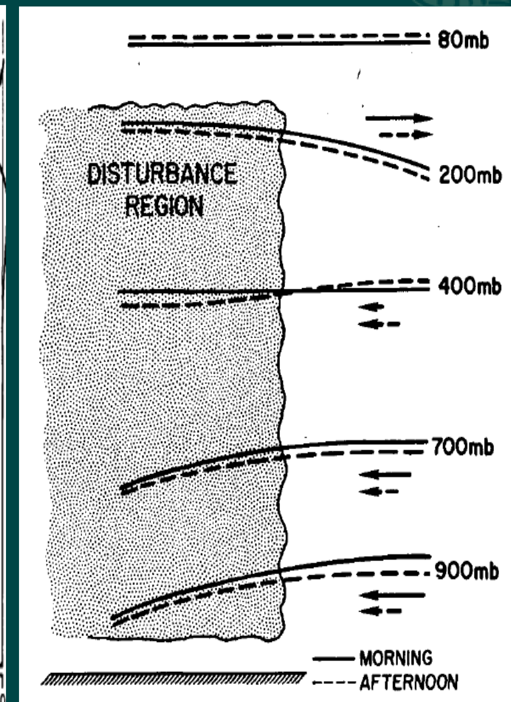
Two mechanisms



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

(Melhauser and Zhang 2014)





Differential radiative heating

(Gray and Jacobson 1977)

Diurnal Radiation Cycle Impact in Different Stages?

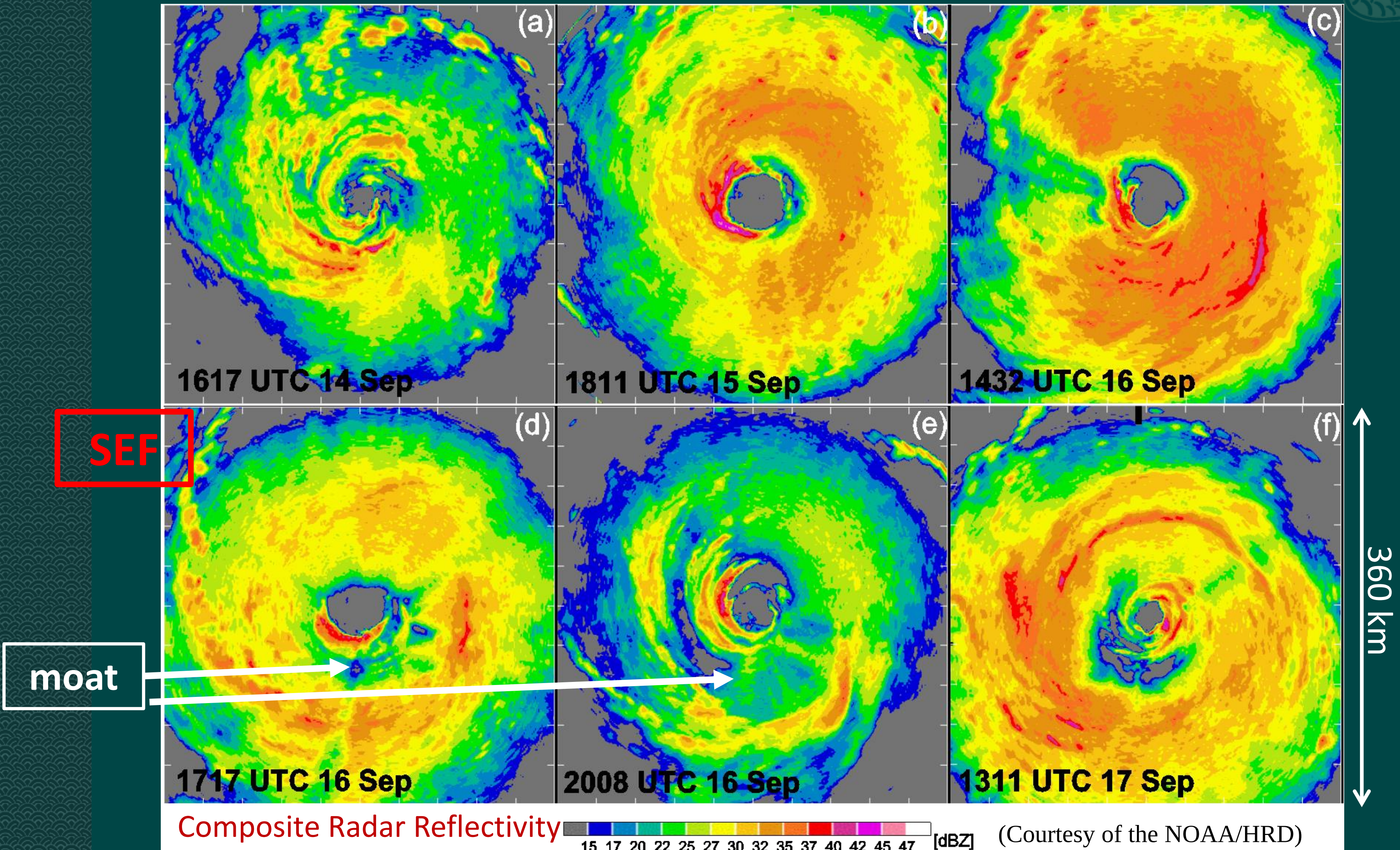
- All the stages: Both convective instability changes and large-scale nighttime cooling play important roles

- RI and mature stages: Differential heating mechanism act together with the other two

(Tang and Zhang, 2016, JAS)

How about its impact on SEF?

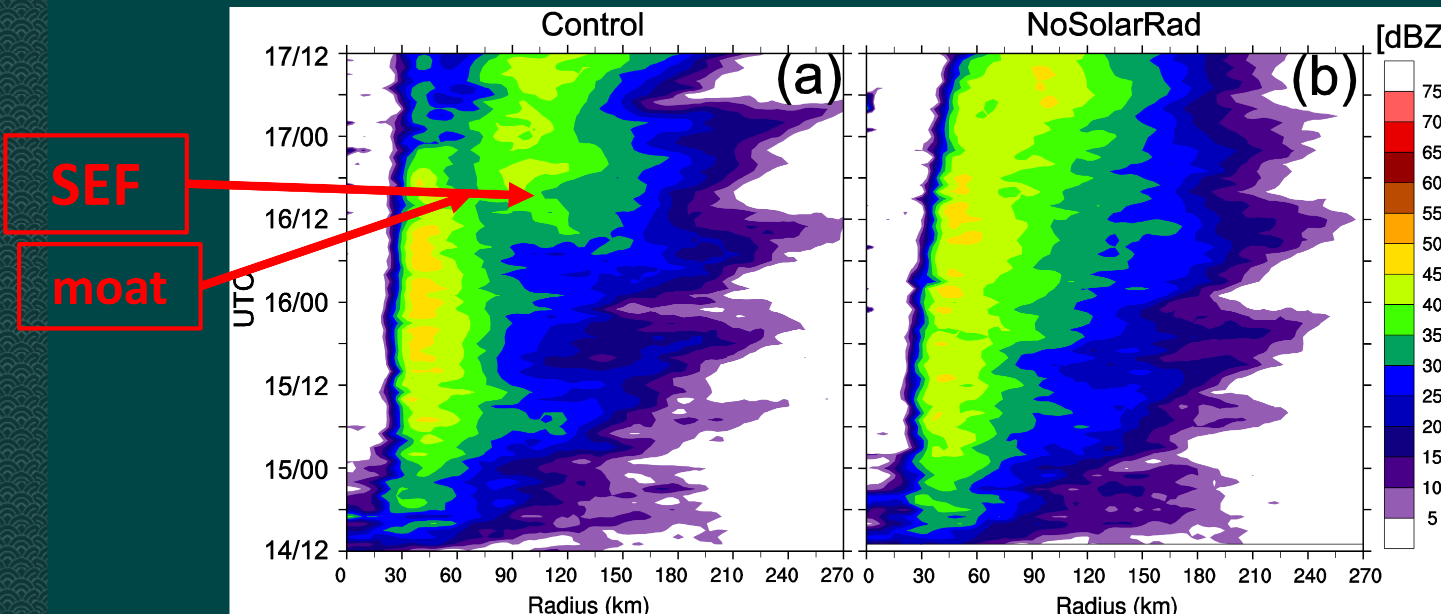
Observation of Concentric Eyewall in Edouard (2014)

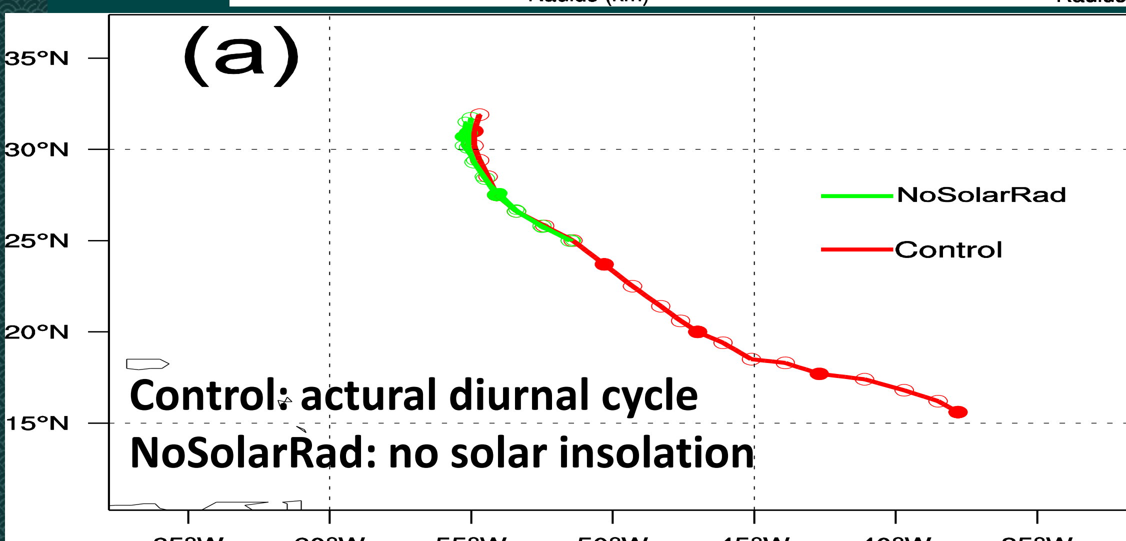


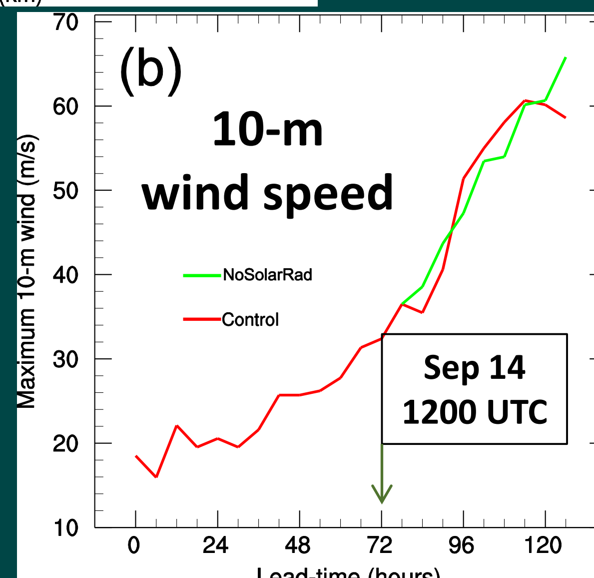
(Courtesy of the NOAA/HRD)

Experimental design

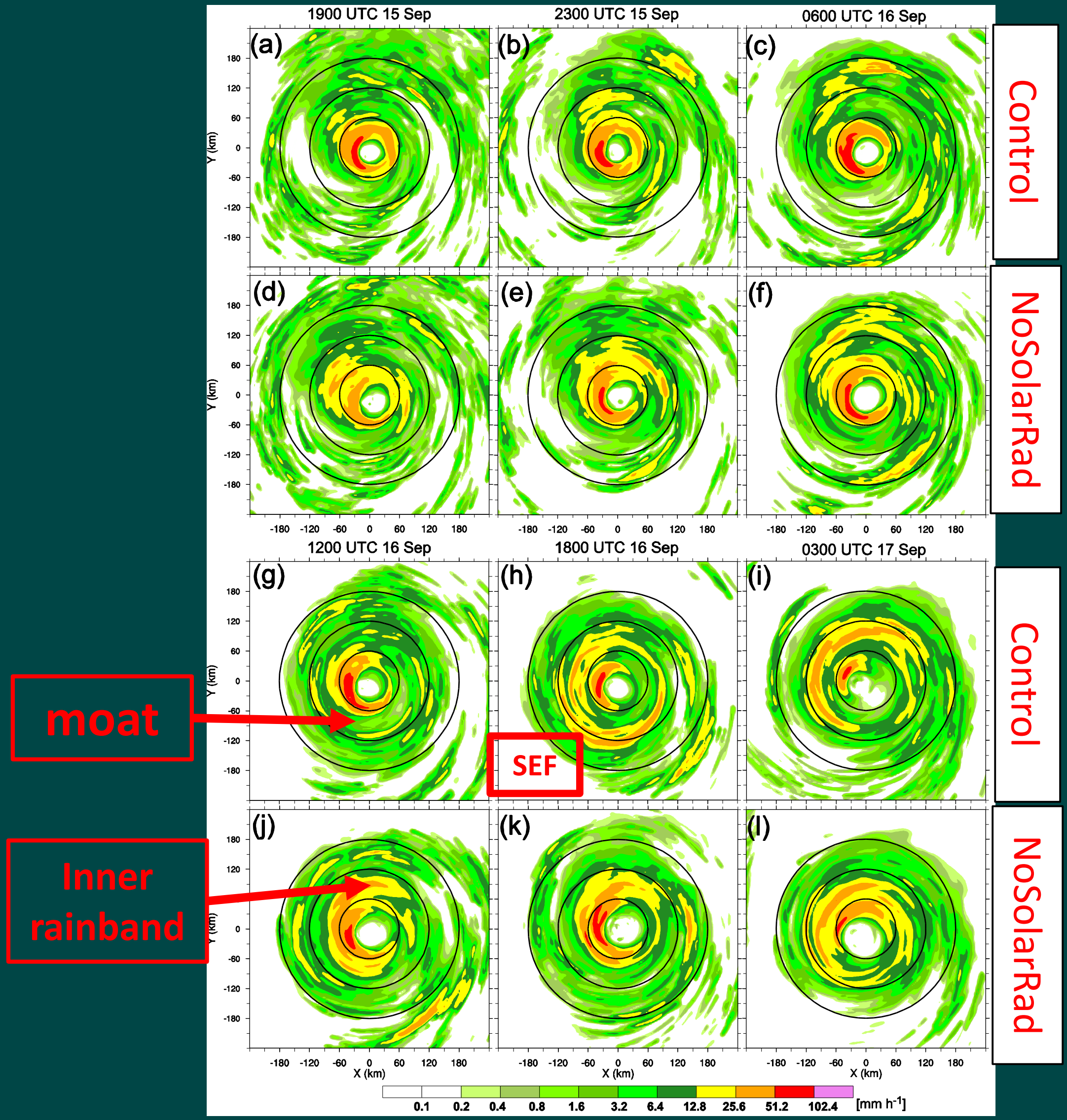
Column maximum radar reflectivity







SEF and ERC in simulation



Stronger primary eyewall

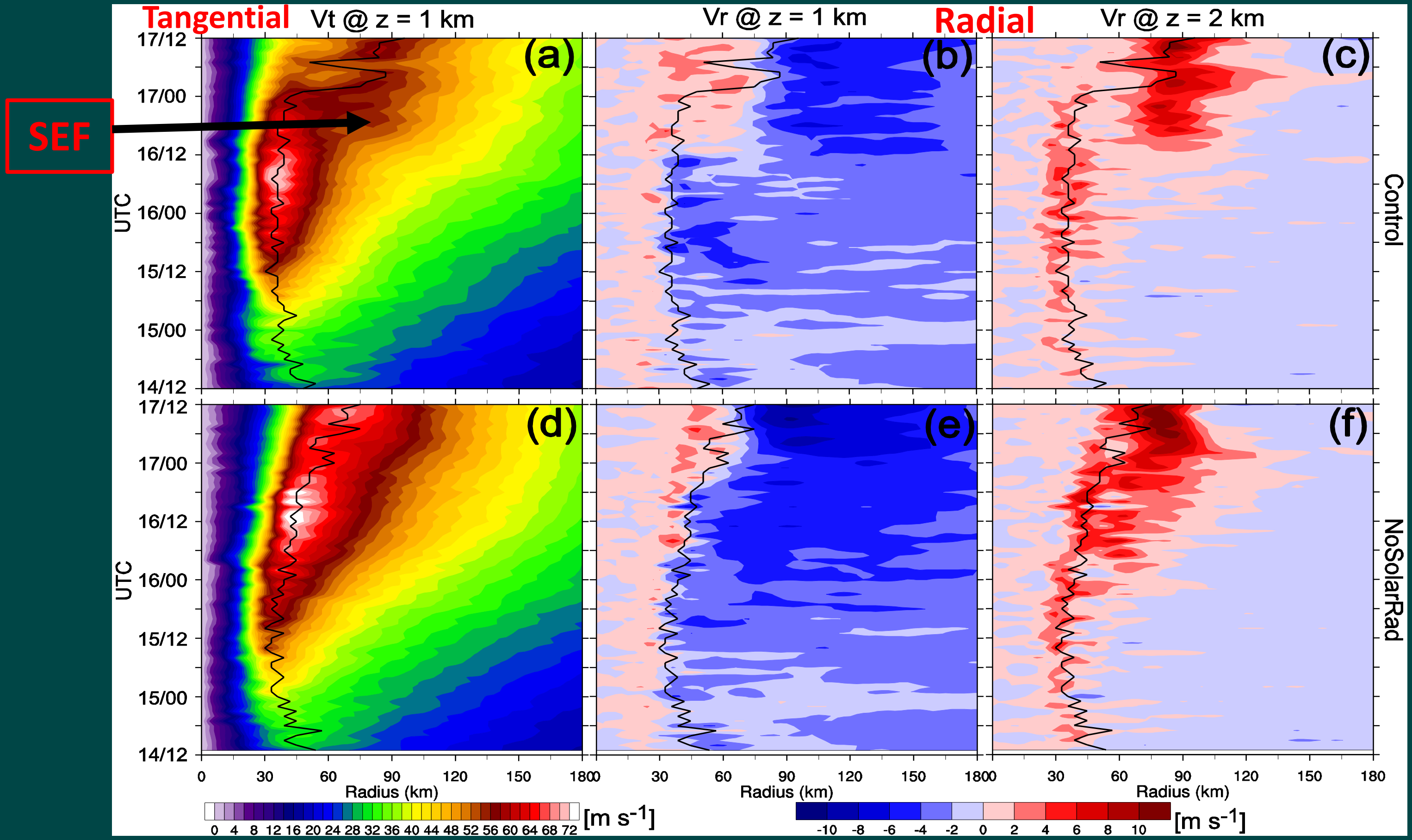
Weaker primary eyewall

Clear moat and SEF

Stronger inner rainbands
No SEF

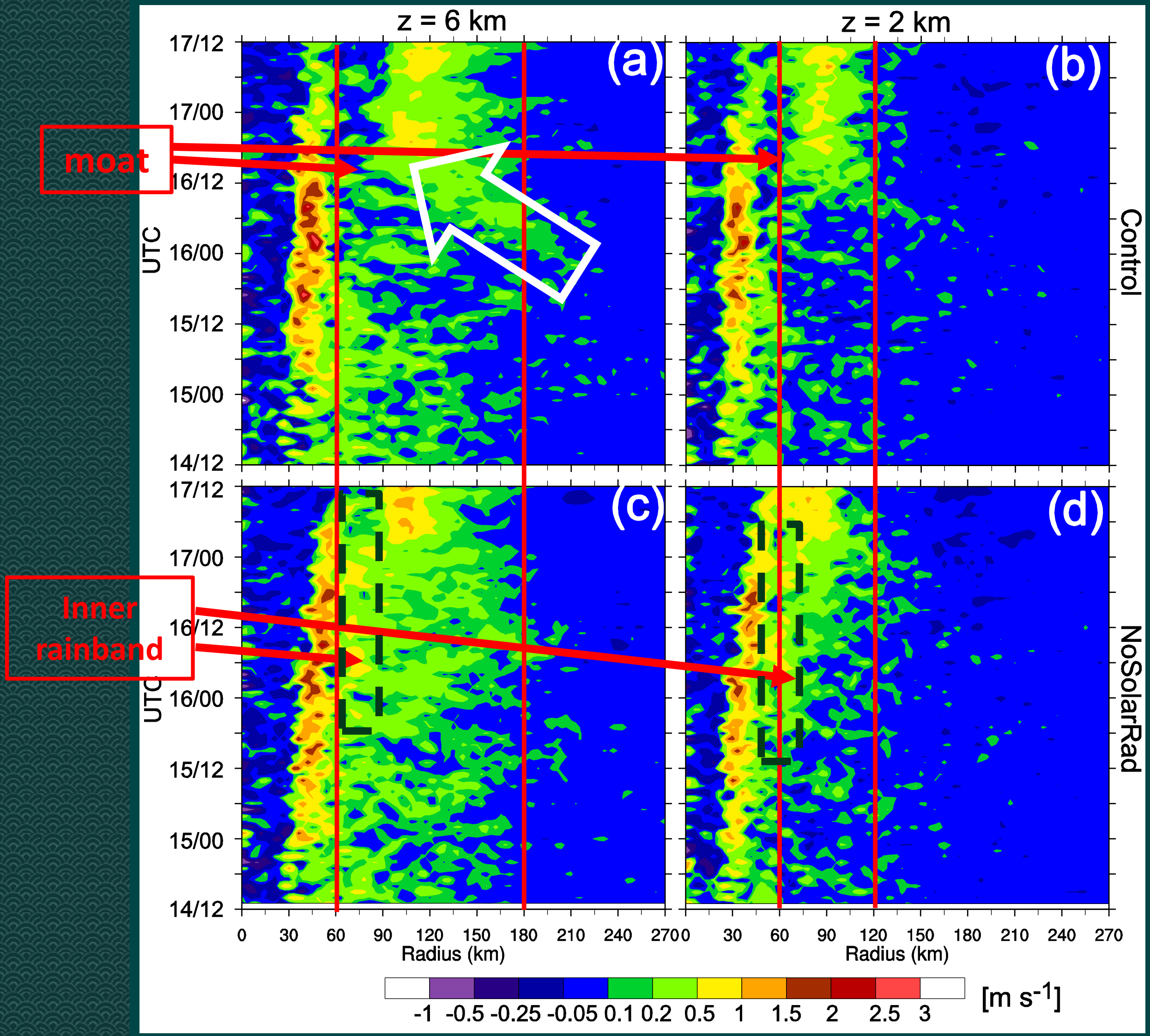
surface rain rate

Evolution of BL wind



- Stronger inner rainbands in NoSolarRad → more convergence outside of primary eyewall
- Heating outside the RMW in the midtroposphere → increasing (reducing) low-level tangential wind outside (near and inside) the RMW → outward expansion of the RMW

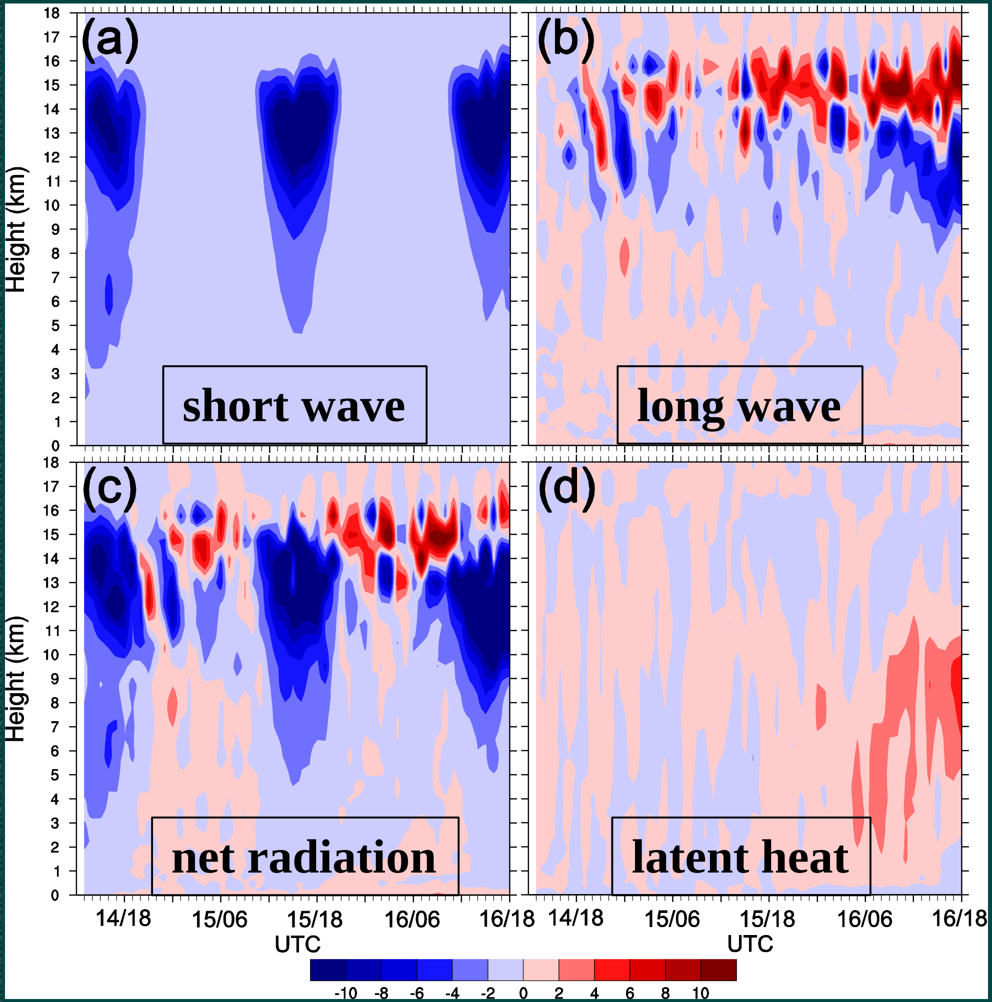
Evolution of vertical velocity



- The outer-core (outside the radius of 150 km) upward motion at mid-level in CNTL became more organized, and began to move inward
- Clear moat formation and SEF
- The latent heating released from more convective activities in the inner rainbands outside of primary eyewall in NoSolarRad

Radiative effects on moat formation and SEF

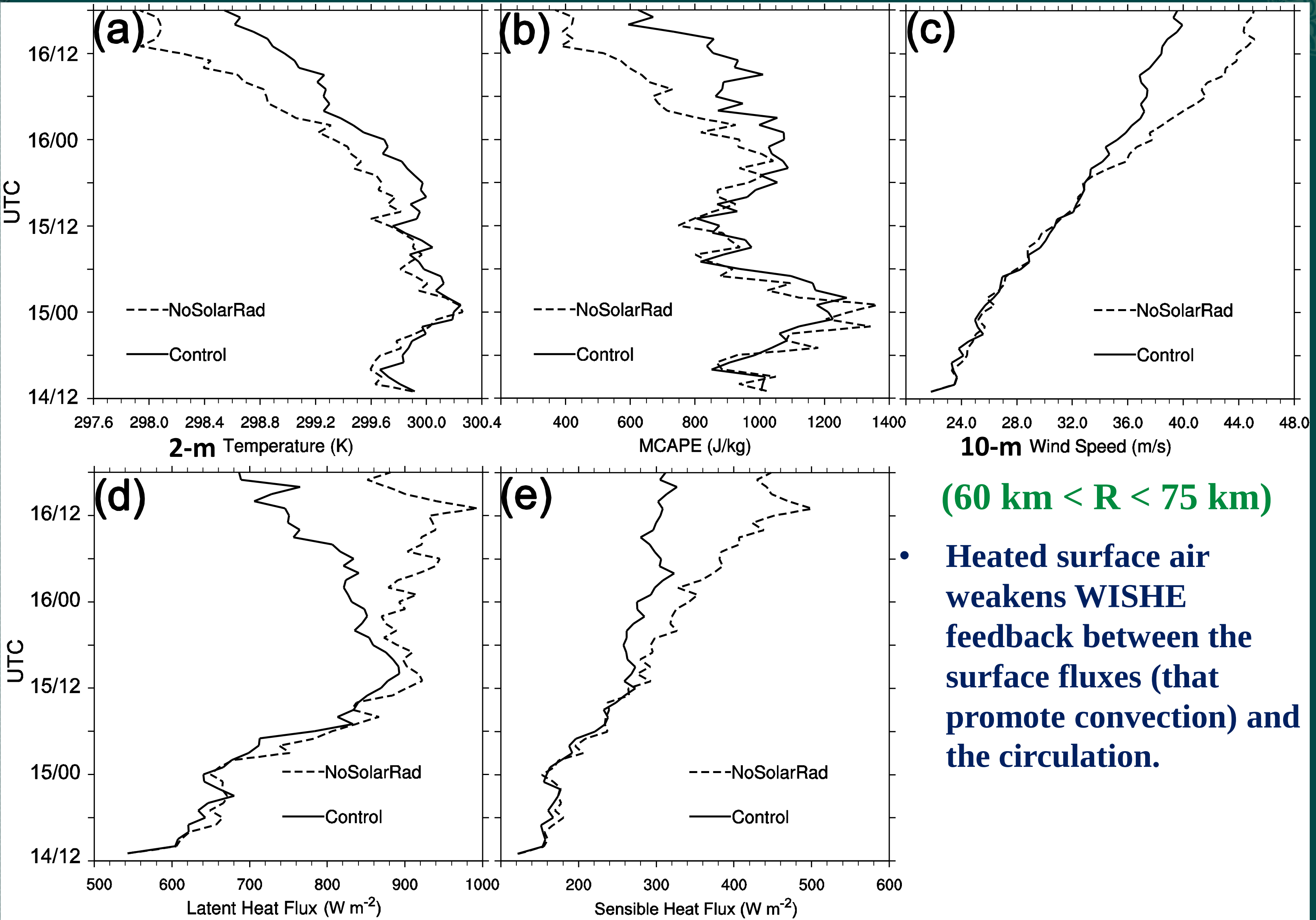
NoSolarRad – CNTL (60 km < R < 75 km)



Unit: 10^{-5}K/s for (a), (b), (c), and 10^{-3}K/s for (d)

- The net radiative heating in CNTL is much stronger due to the solar insolation at daytime.
- Less conducive for deep moist convection in CNTL
- Less diabatic heating due to suppressed convection in CNTL
- Difference: 0.5–1 K/day at the top of the boundary layer

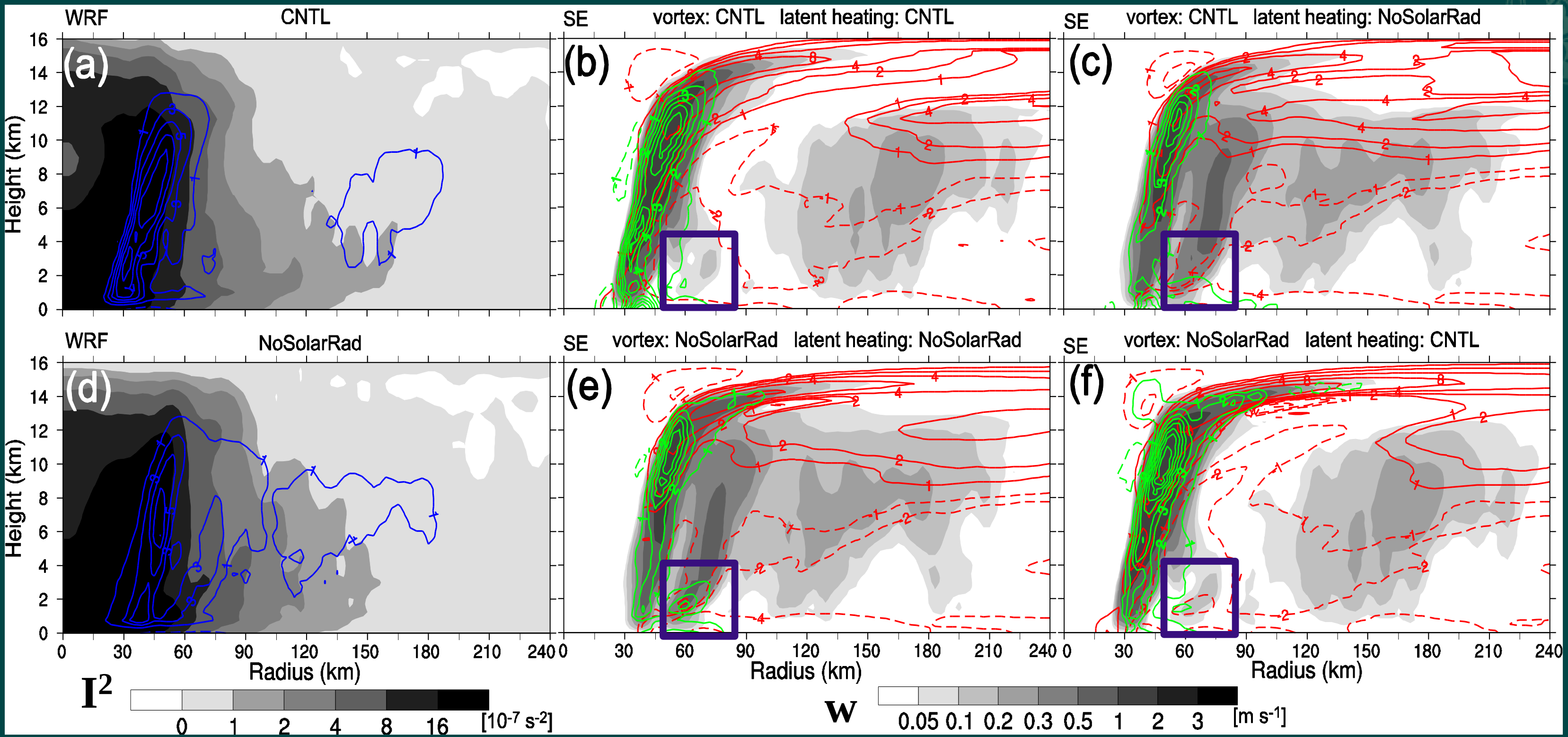
Radiative effects on moat formation



(60 km < R < 75 km)

- **Heated surface air weakens WISHE feedback between the surface fluxes (that promote convection) and the circulation.**

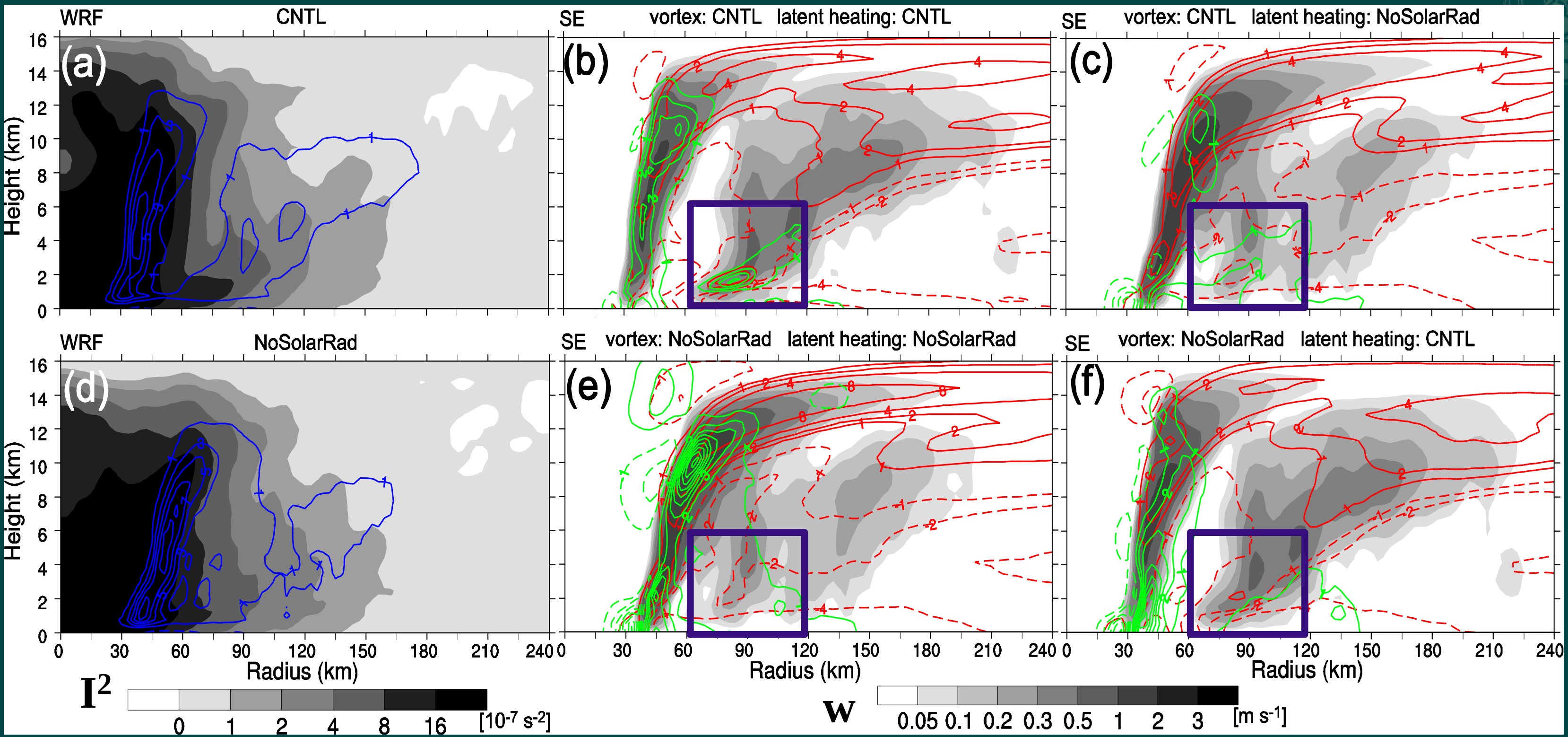
SEF: Early stage



$$\frac{\partial \bar{v}}{\partial t} = -\bar{u}(f + \bar{\zeta}) - \bar{w}\frac{\partial \bar{v}}{\partial z}$$

- **The absence of diabatic heating forcing and resulted smaller $\dot{v}$ in the moat region in CNTL is more important for moat formation in the early stage of SEF**

SEF: Late stage



- **The enhanced inertial stability is more efficient in the low-level (above BL) wind intensification than enhancing latent heating near the incipient outer eyewall in the later stage of SEF**

Conclusion

- Moat region is highly sensitive to the solar shortwave radiative heating mostly in the mid- to upper-level at daytime, which leads to a net stabilization effect and suppresses convective development.
- The heated surface air weakens WISHE feedback between the surface fluxes (that promote convection) and convective heating (that feeds to the secondary circulation and then the tangential wind).
- NoSolarRad: without solar radiation, active inner rainband, suppressed primary eyewall, no moat, no SEF
- The radiation-induced absence of latent heating is more important on moat formation in the early stage of SEF.

Thanks for attention !

References:

- 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.,* 73, 2871-2892.
- Tang, X. et al, 2017: Impacts of Diurnal Radiation Cycle on Secondary Eyewall Formation, *J. Atmos. Sci.,* 74, 3079-3098.