Impacts of Diurnal Radiation Cycle on Secondary Eyewall Formation

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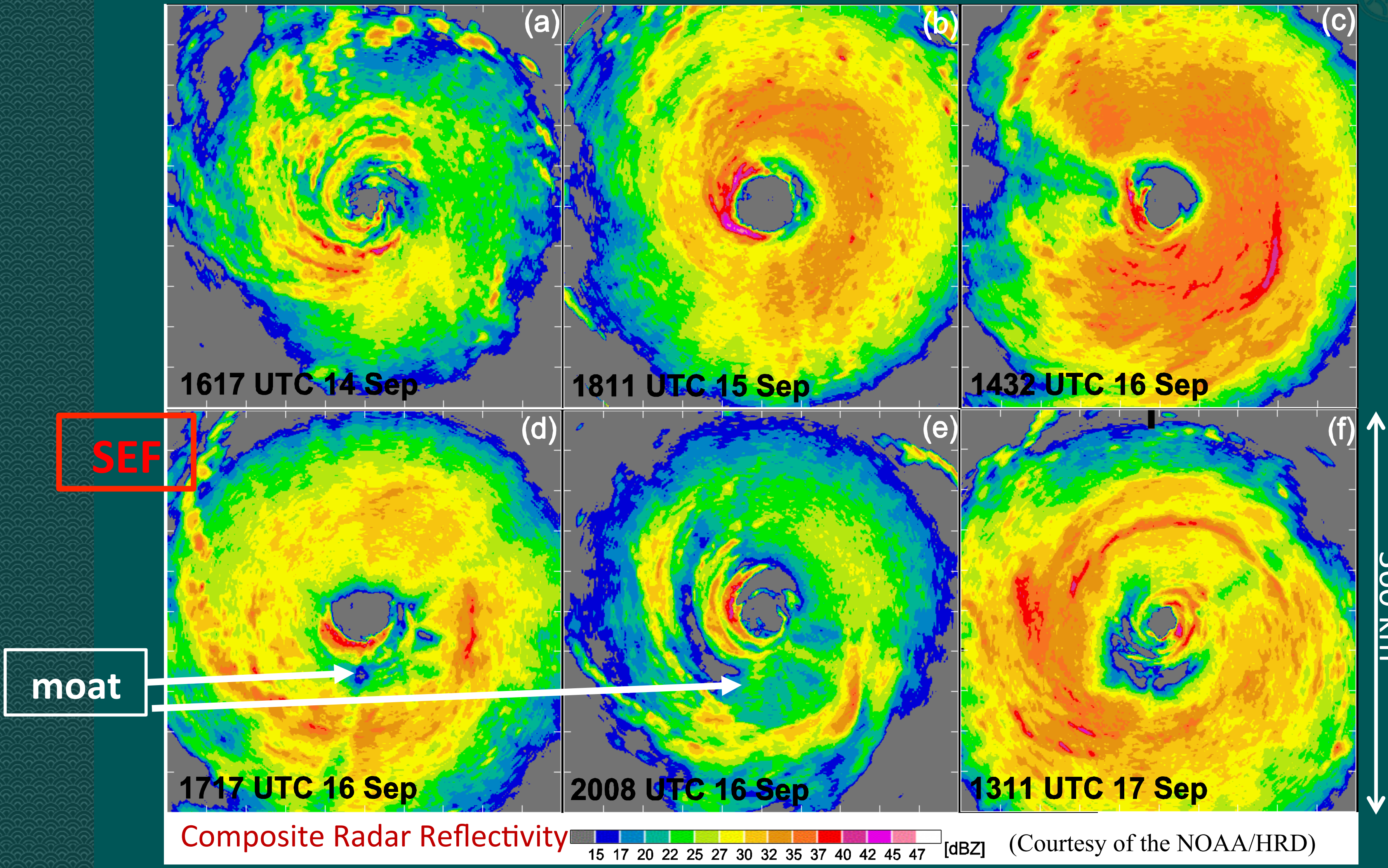
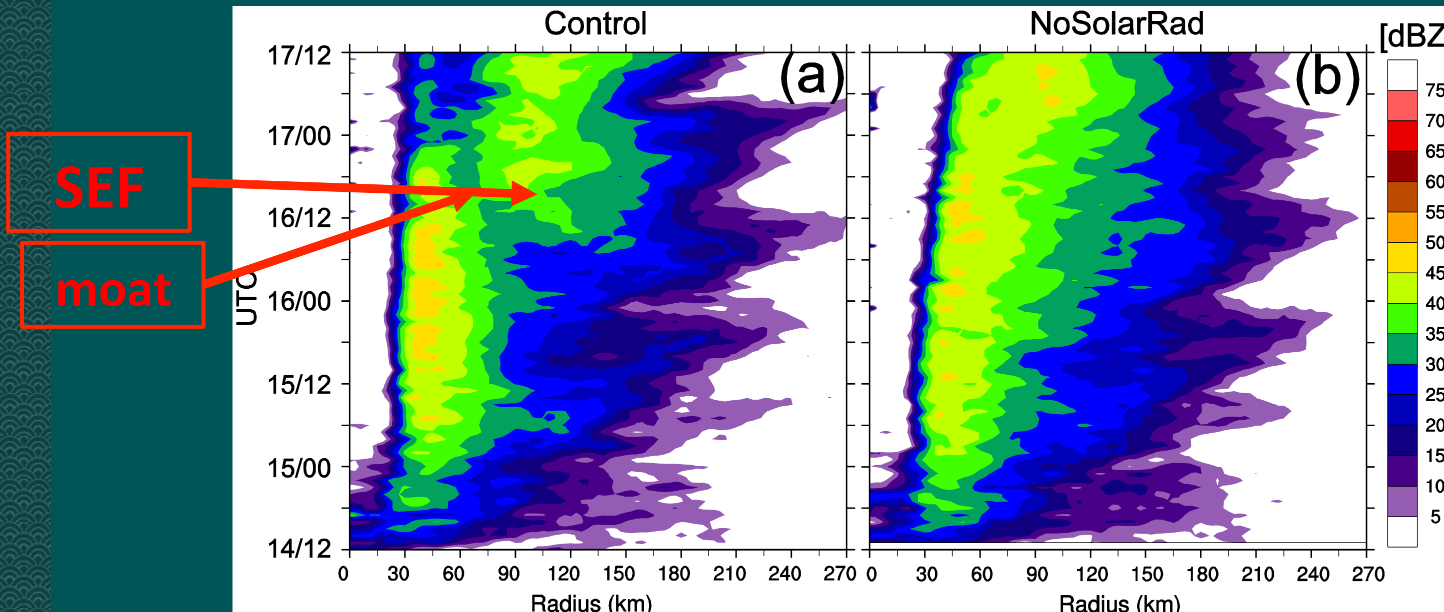
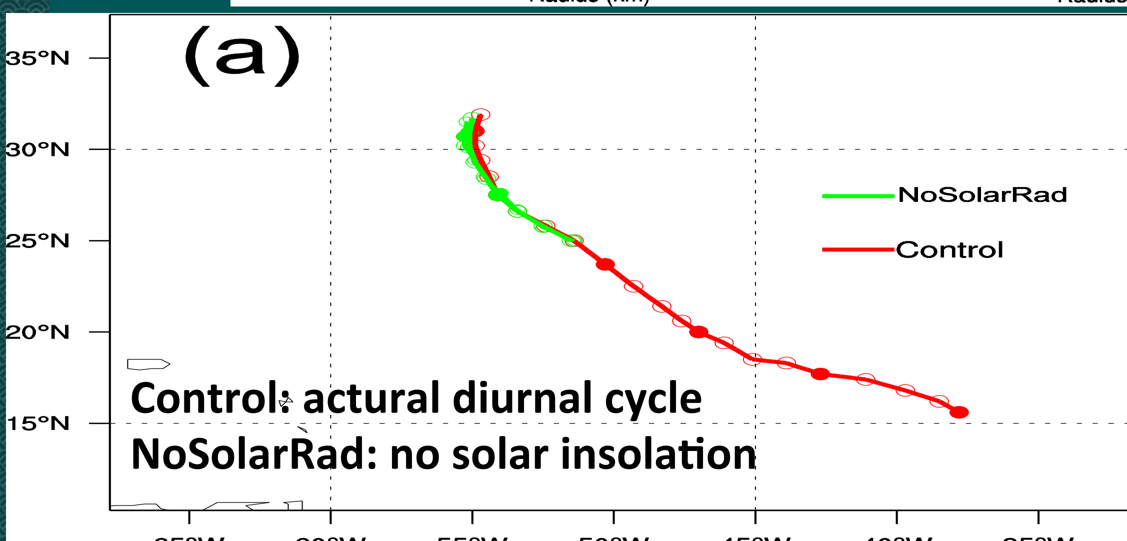
Observation of Concentric Eyewall in Edouard (2014)

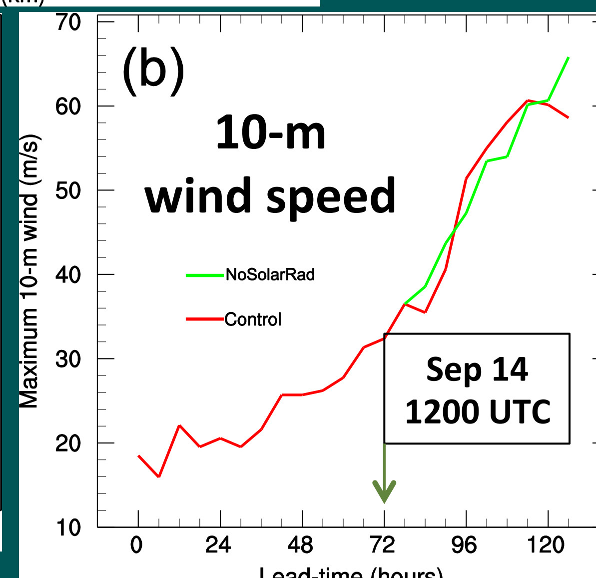


Experimental design

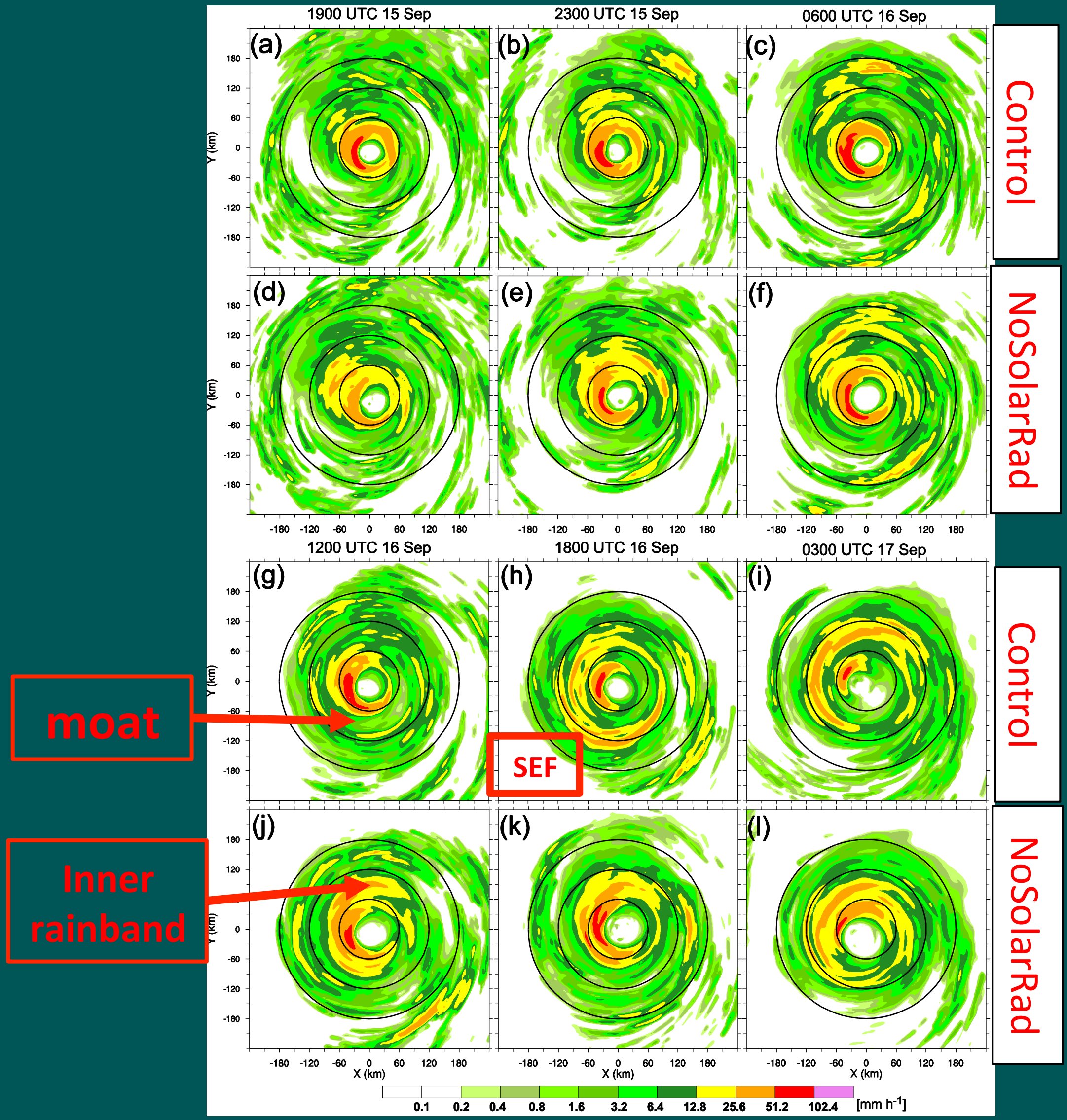
Column maximum radar reflectivity







SEF and ERC in simulation



Stronger primary eyewall

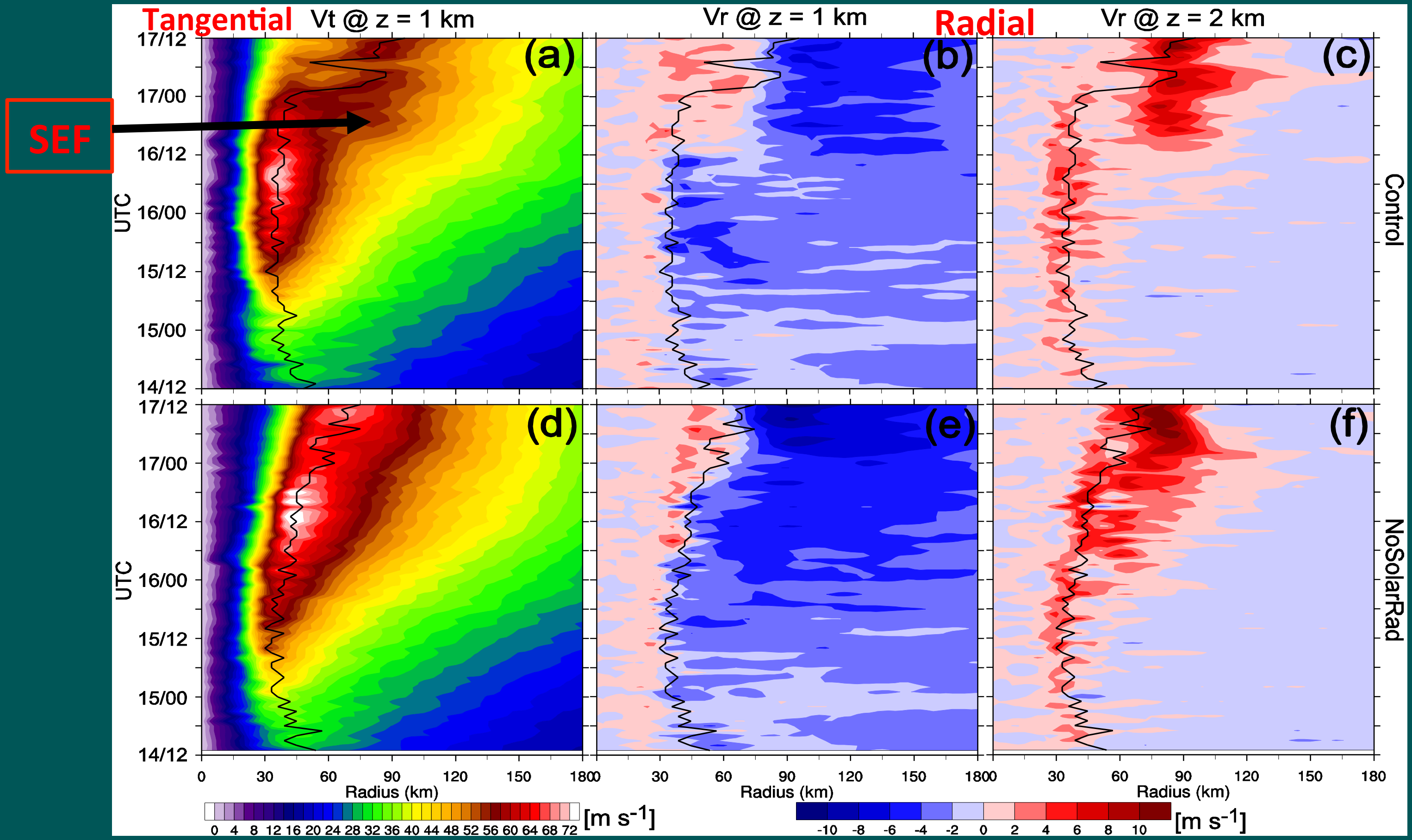
Weaker primary eyewall

Clear moat and SEF

Stronger inner rainbands
No SEF

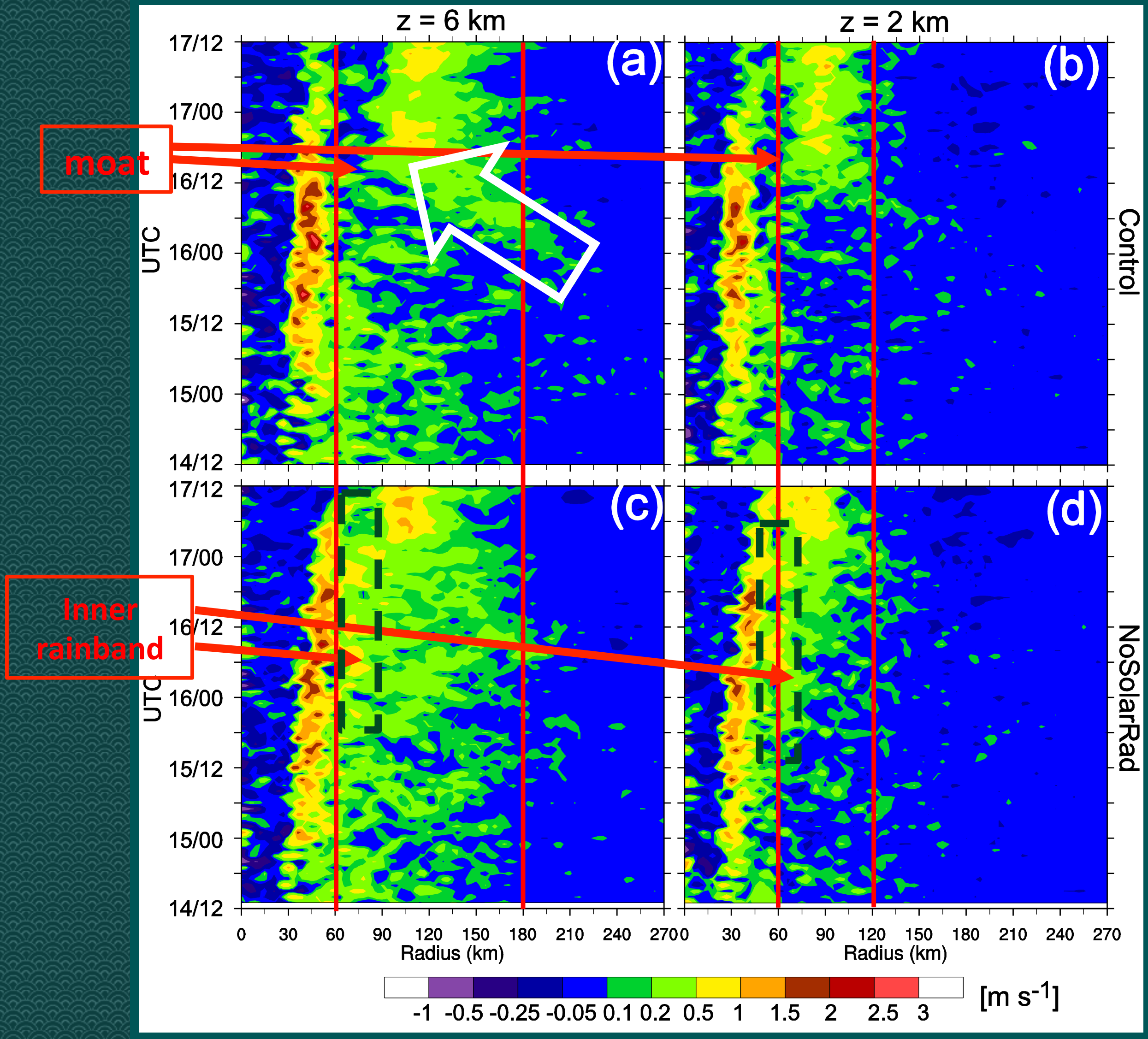
surface rain rate

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

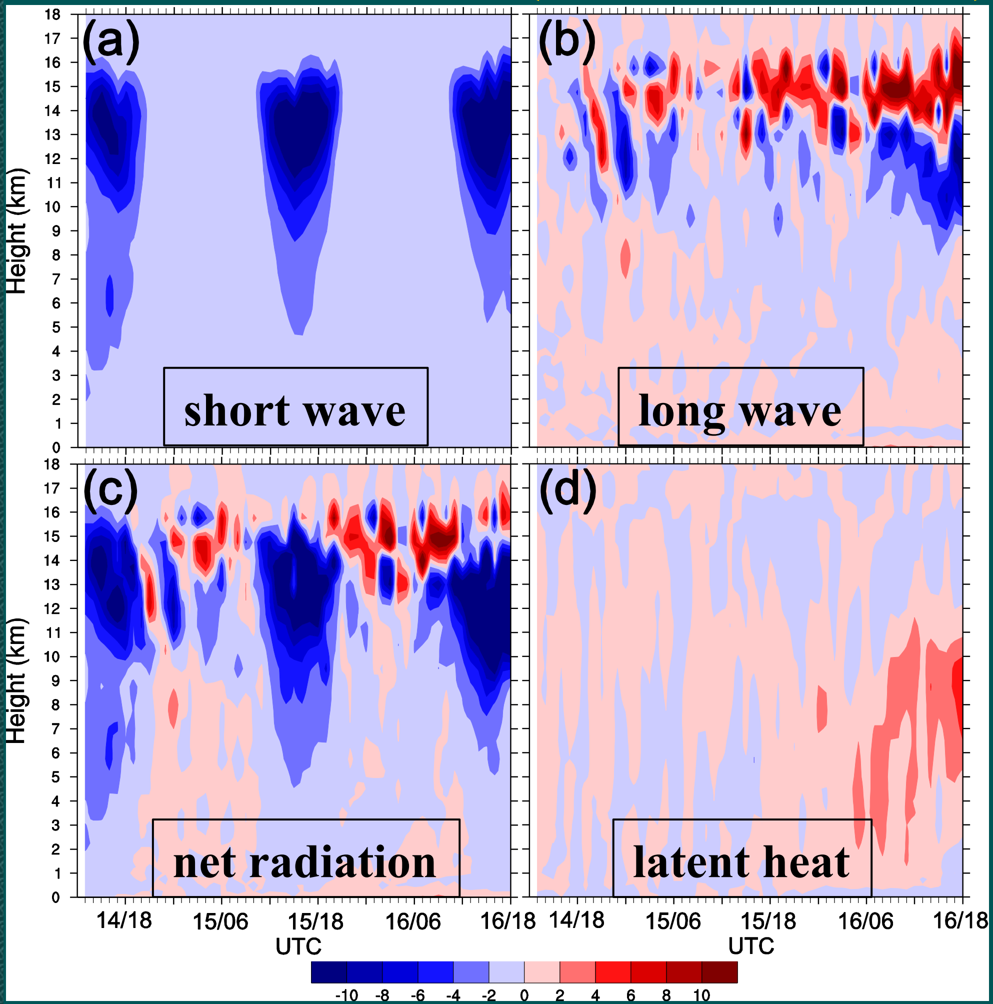
Evolution of vertical velocity



- 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

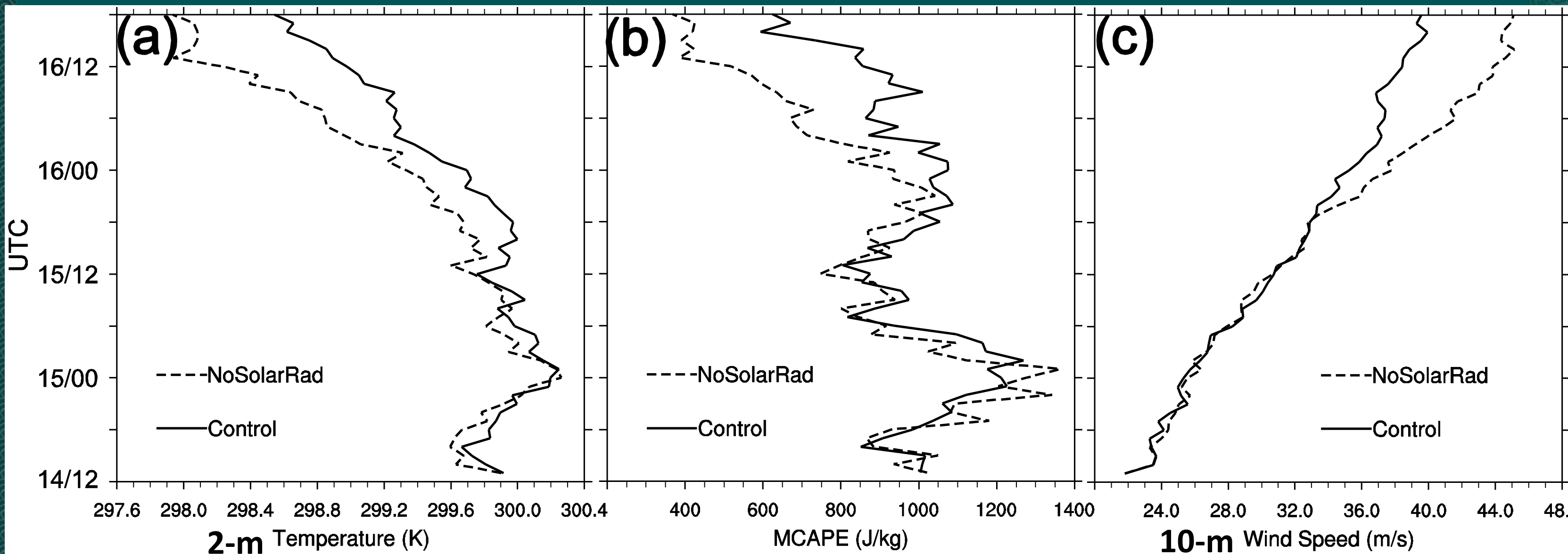
NoSolarRad – CNTL (60 km < R < 75 km)

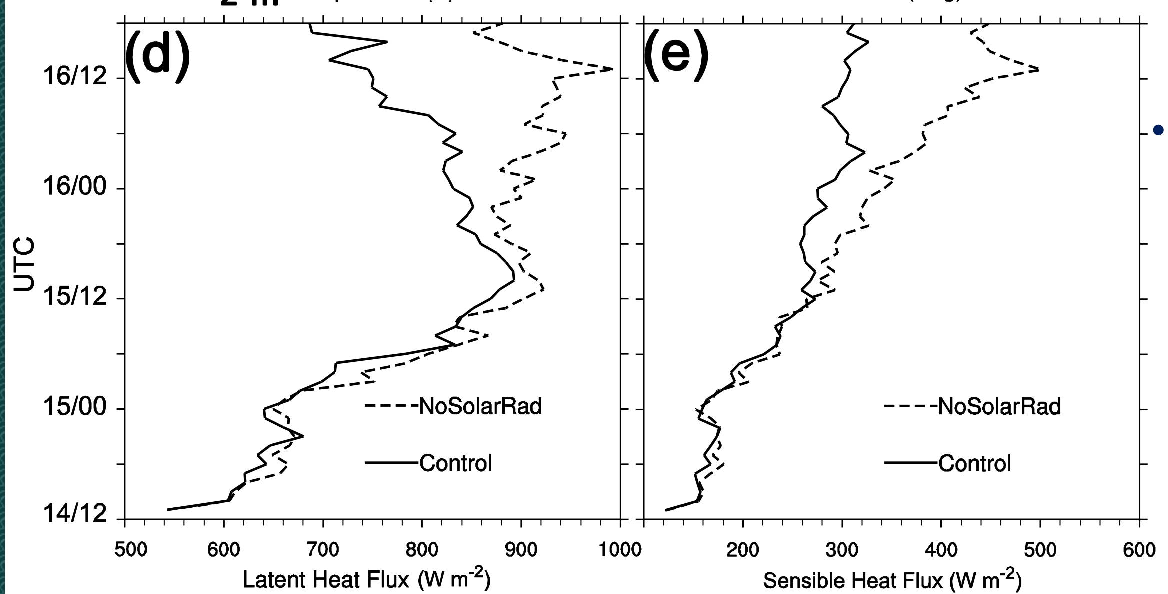


Unit: 10^{-5} K/s for (a), (b), (c), and 10^{-3} K/s for (d)

- **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

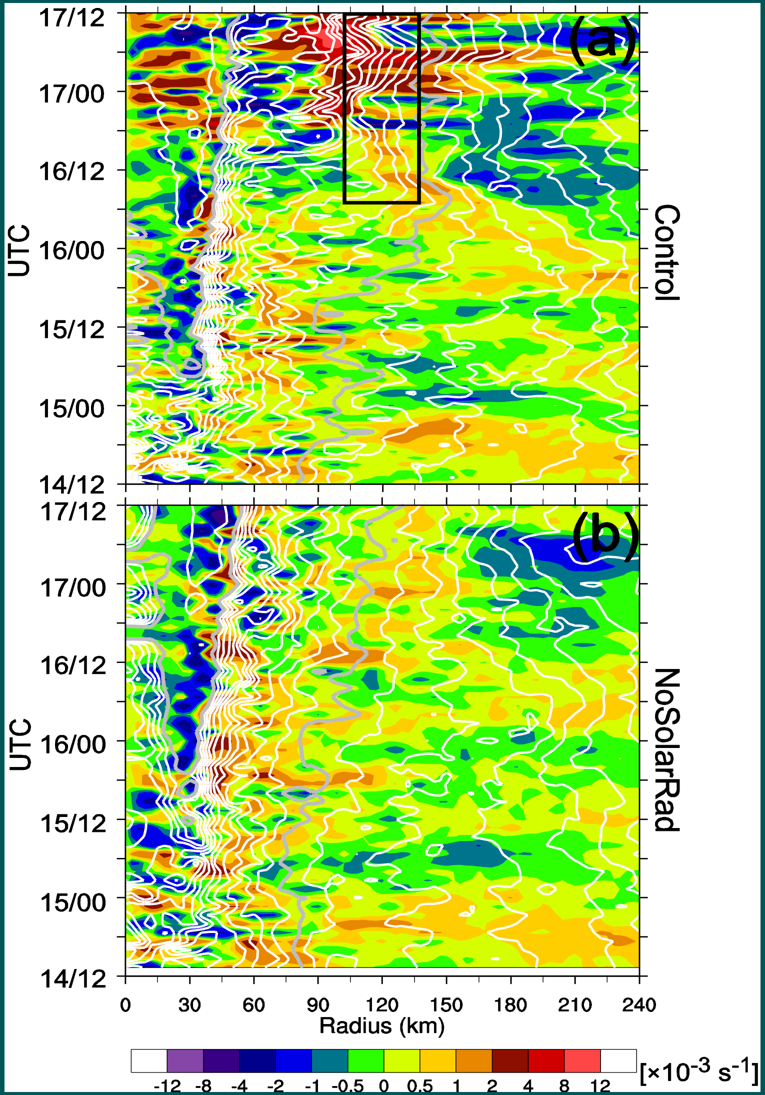




(60 km < R < 75 km)

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

Evolution of outer rainbands (front-like zone)



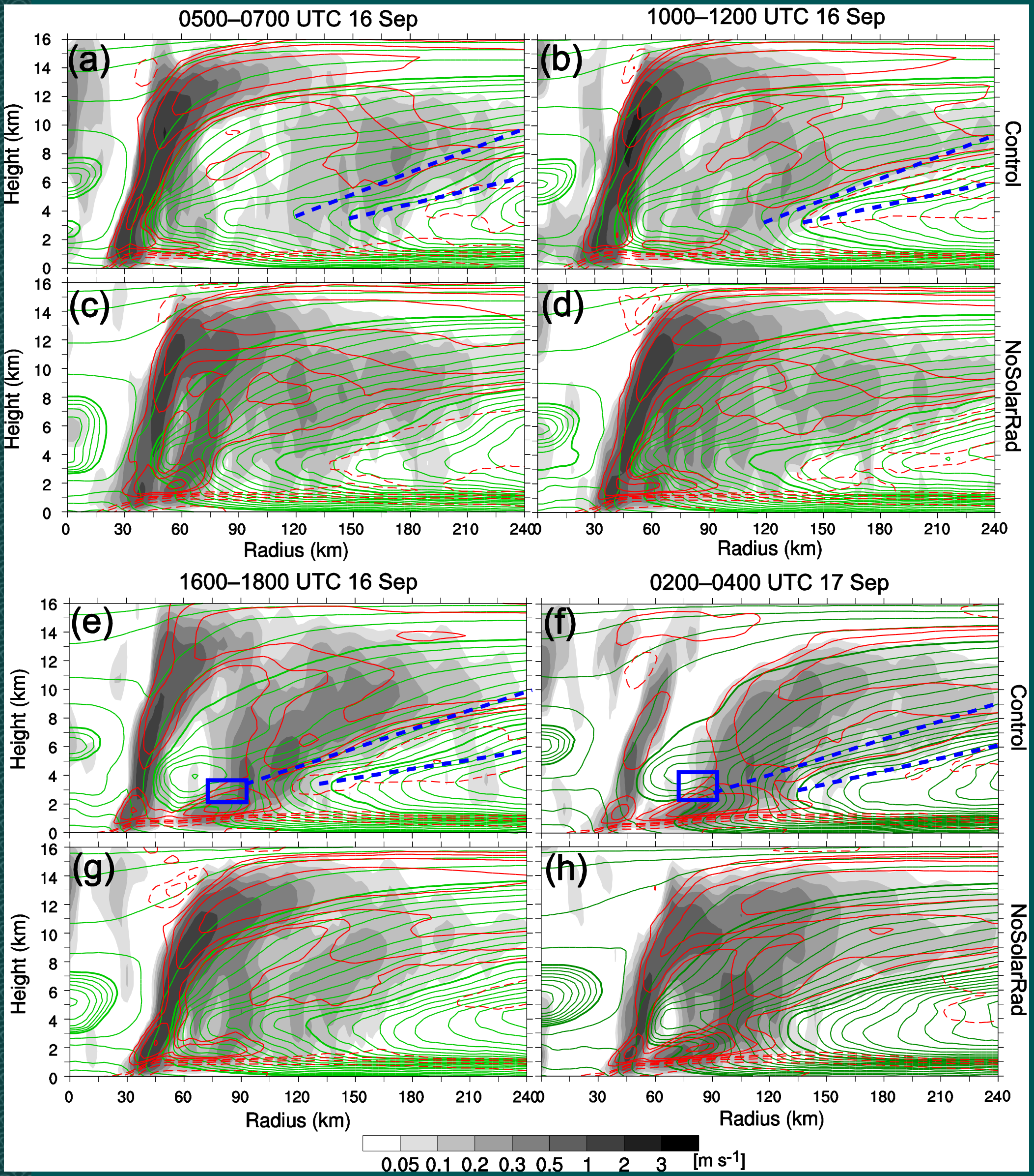
- **Front-like zone is accompanied by distinct positive horizontal vorticity in the tangential direction**

$\eta = \partial u/\partial z - \partial w/\partial r$.

- **Necessary lifting is helpful to the convection in the upward branch of direct thermal circulation with positive η**

Horizontal vorticity η (shaded) and equivalent potential temperature (θ_e, white contours) at the height of 3.5 km

Evolution of outer rainbands (front-like zone)



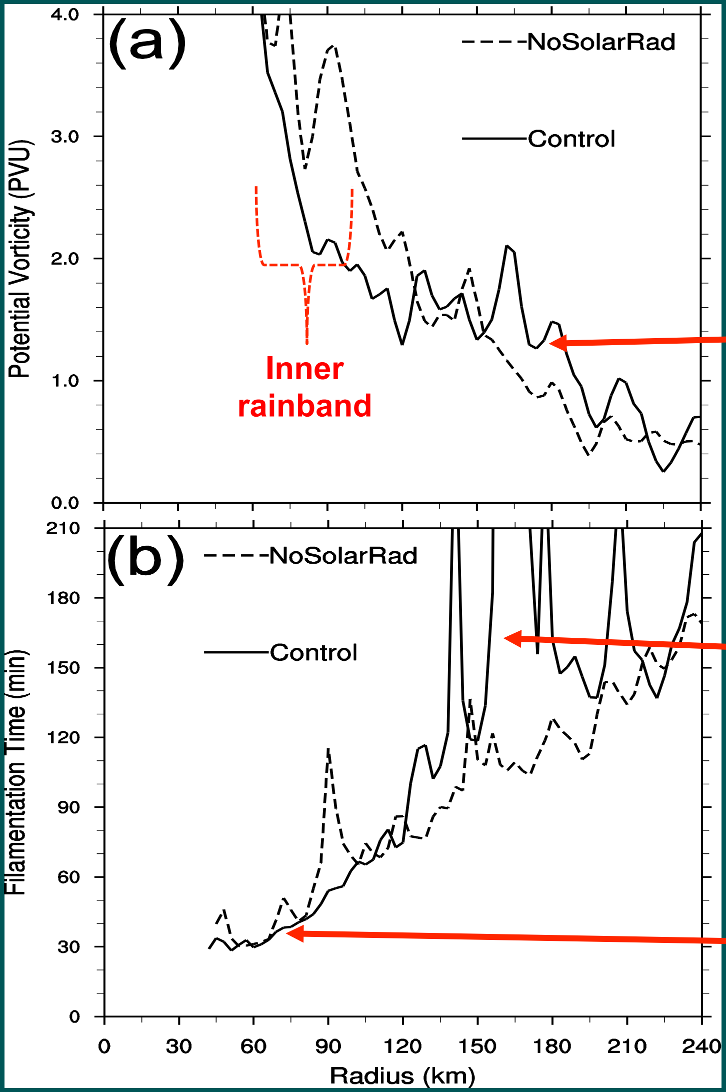
CNTL:

- **A positive feedback between front-like zone and active convection contributes to the outer rainbands enhancement and inward movement.**
- **A typical SEF with a clear moat**

NoSolarRad:

- **Inner rainbands developed and maintained in radius of about 60–90 km**

Evolution of outer rainbands (front-like zone)



greater PV in stratiform region

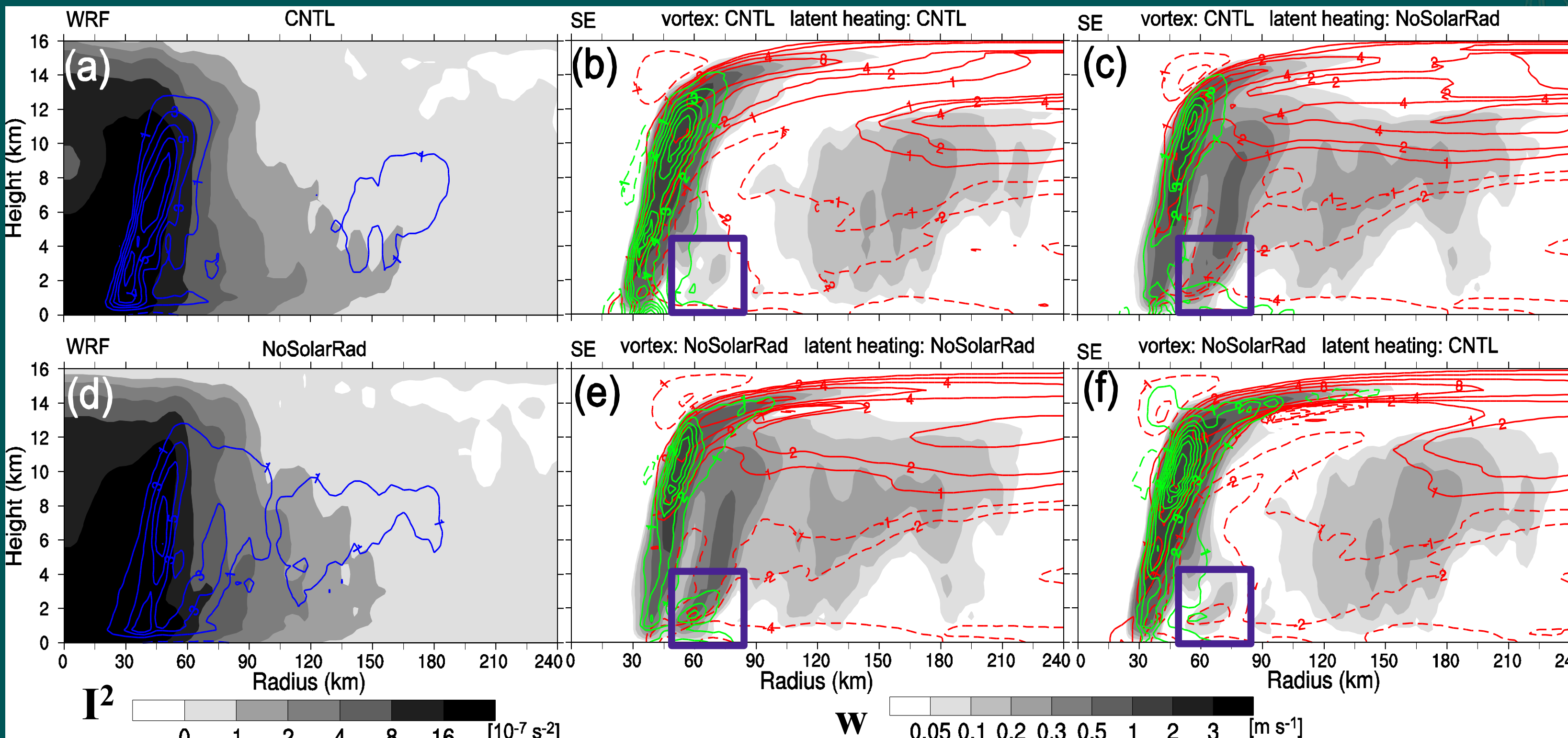
A more convection-friendly region because of the relatively weak straining process

$$[-(\bar{v}/r)(\partial\bar{v}/\partial r)]^{-0.5}$$

Rapid filamentation zone formation to suppress convection and eventually resulted in moat formation

At the height of 5 km,
averaged from 0500 to 0700 UTC 16 Sep (12 hours before SEF)

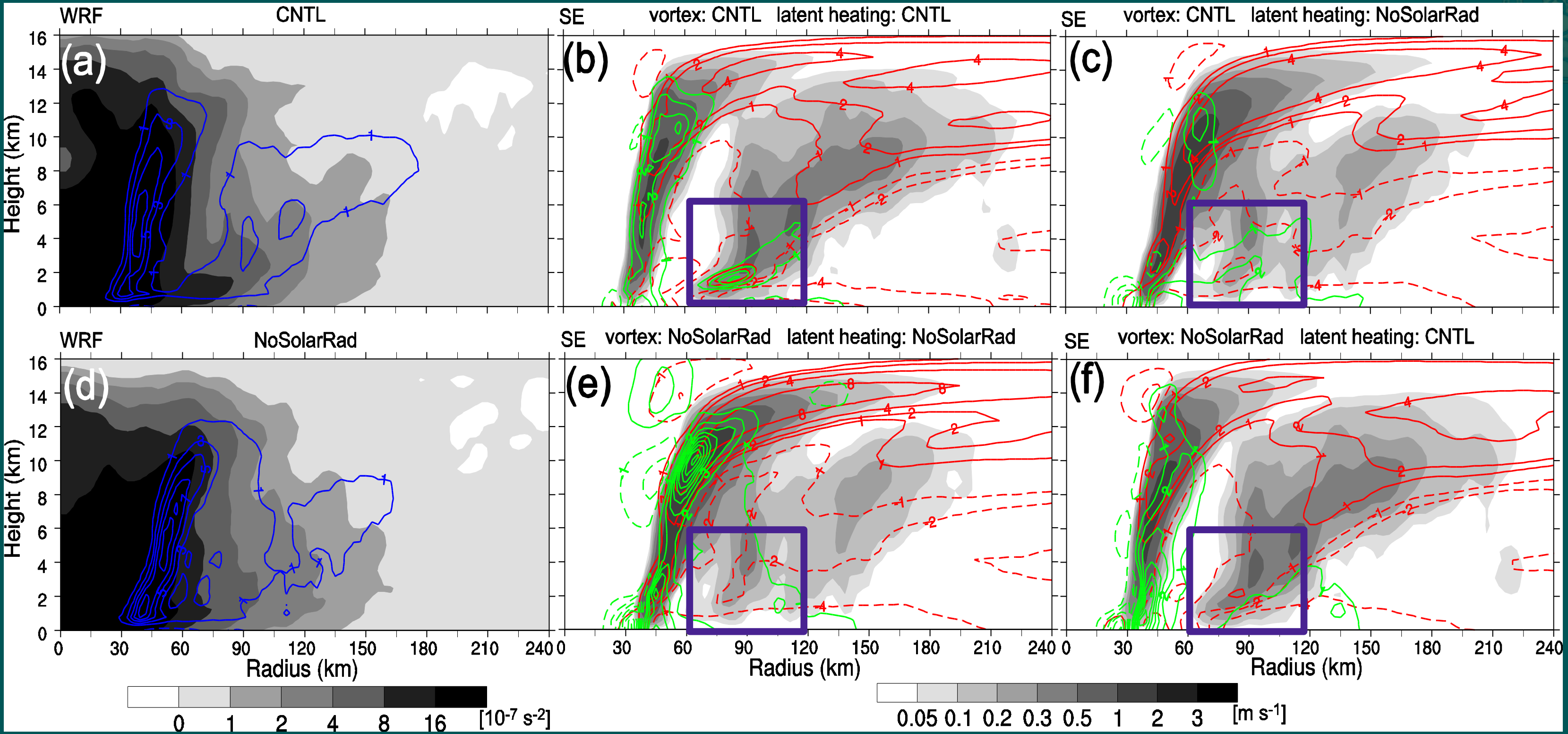
Balanced aspects of SEF: Early stage



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

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

Balanced aspects of 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.

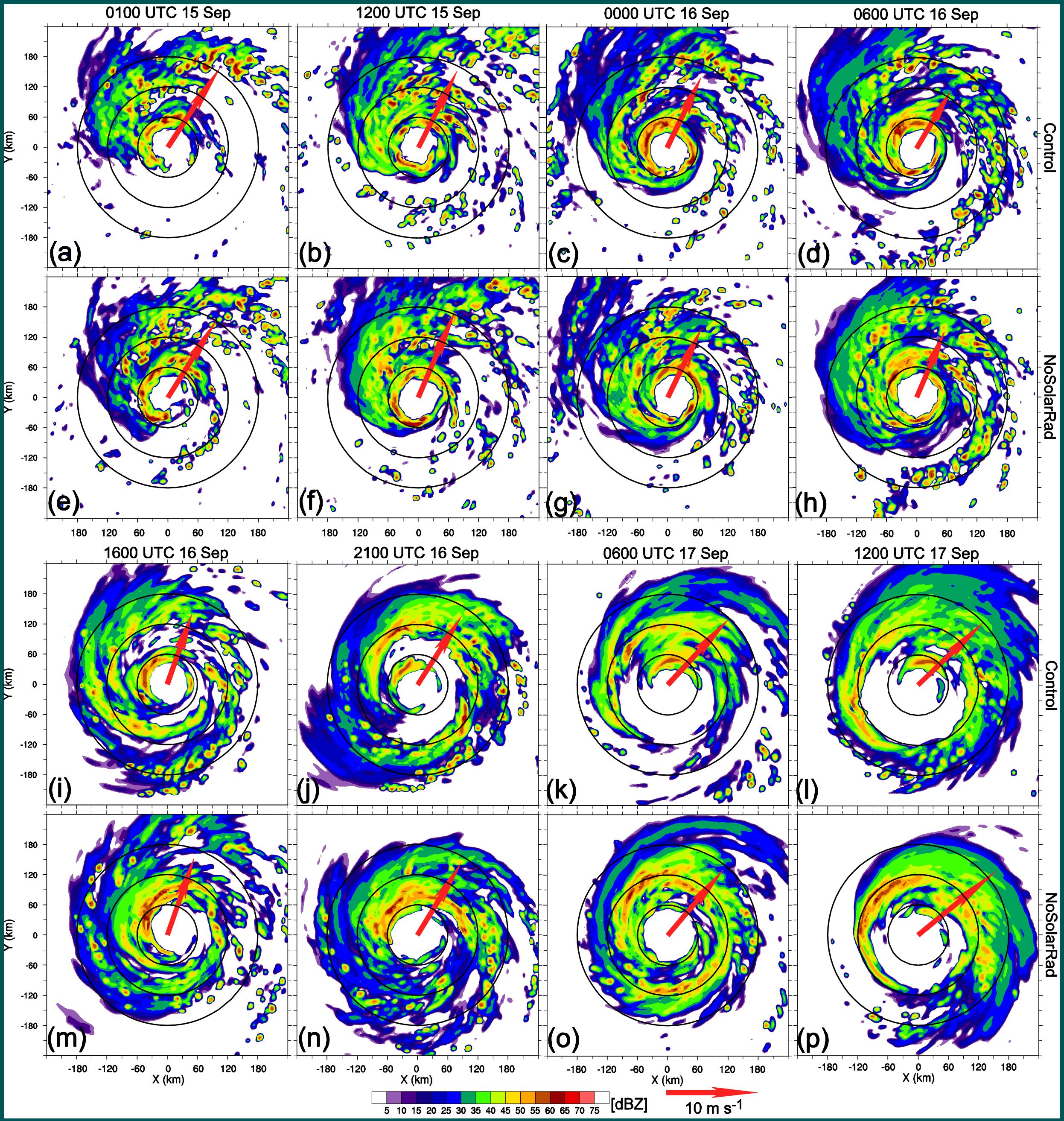
Future work

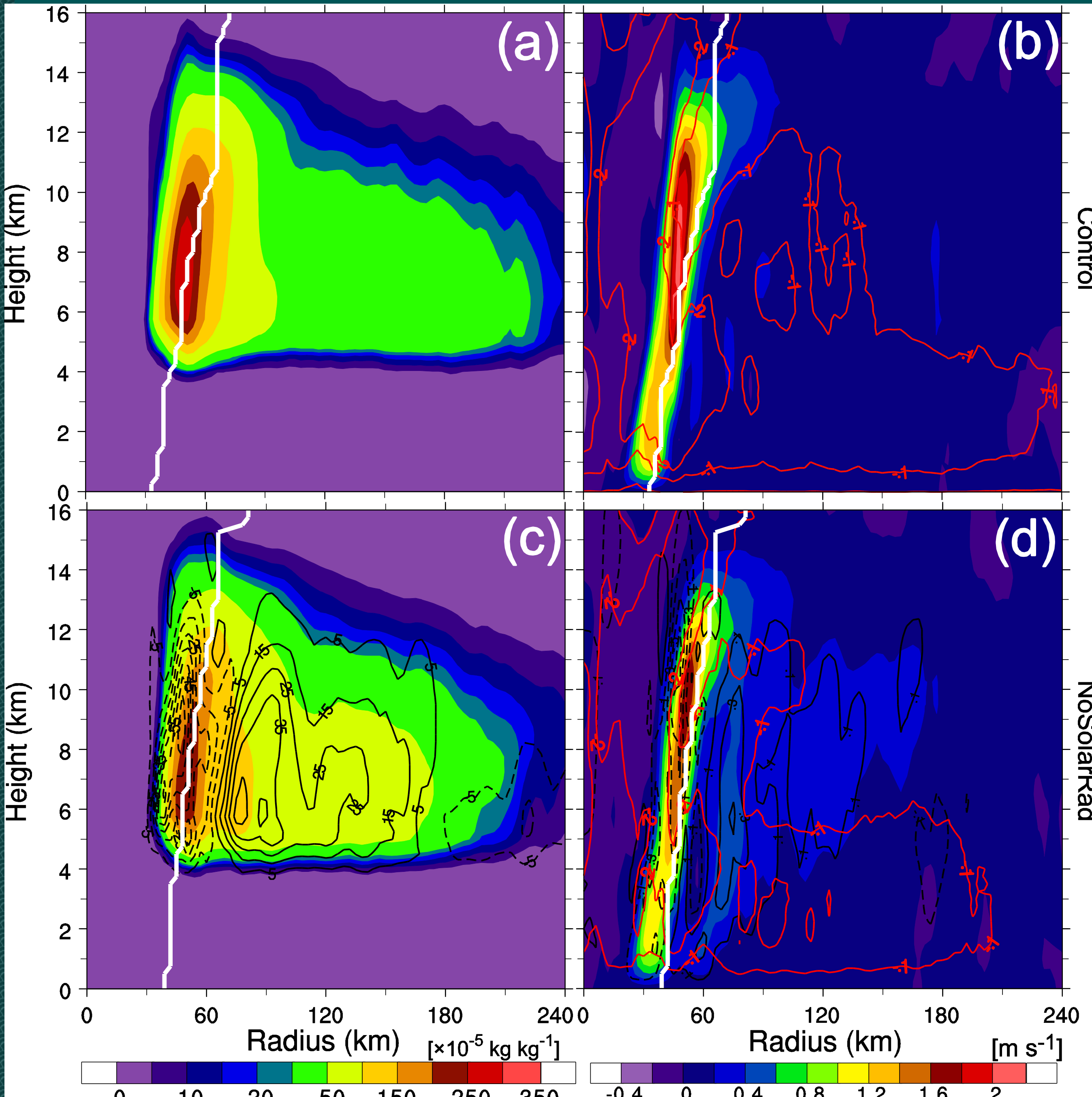
- Response of nonlinear boundary layer dynamics to radiation and impact on SEF
- Asymmetric aspect of impact of radiation on SEF
- The robustness of the sensitivity of SEF to diurnal solar insolation cycles← TC with different intensities and sizes
- The impacts of the diurnal radiation cycle to the timing and radial location of SEF
- ……

Thanks for attention !

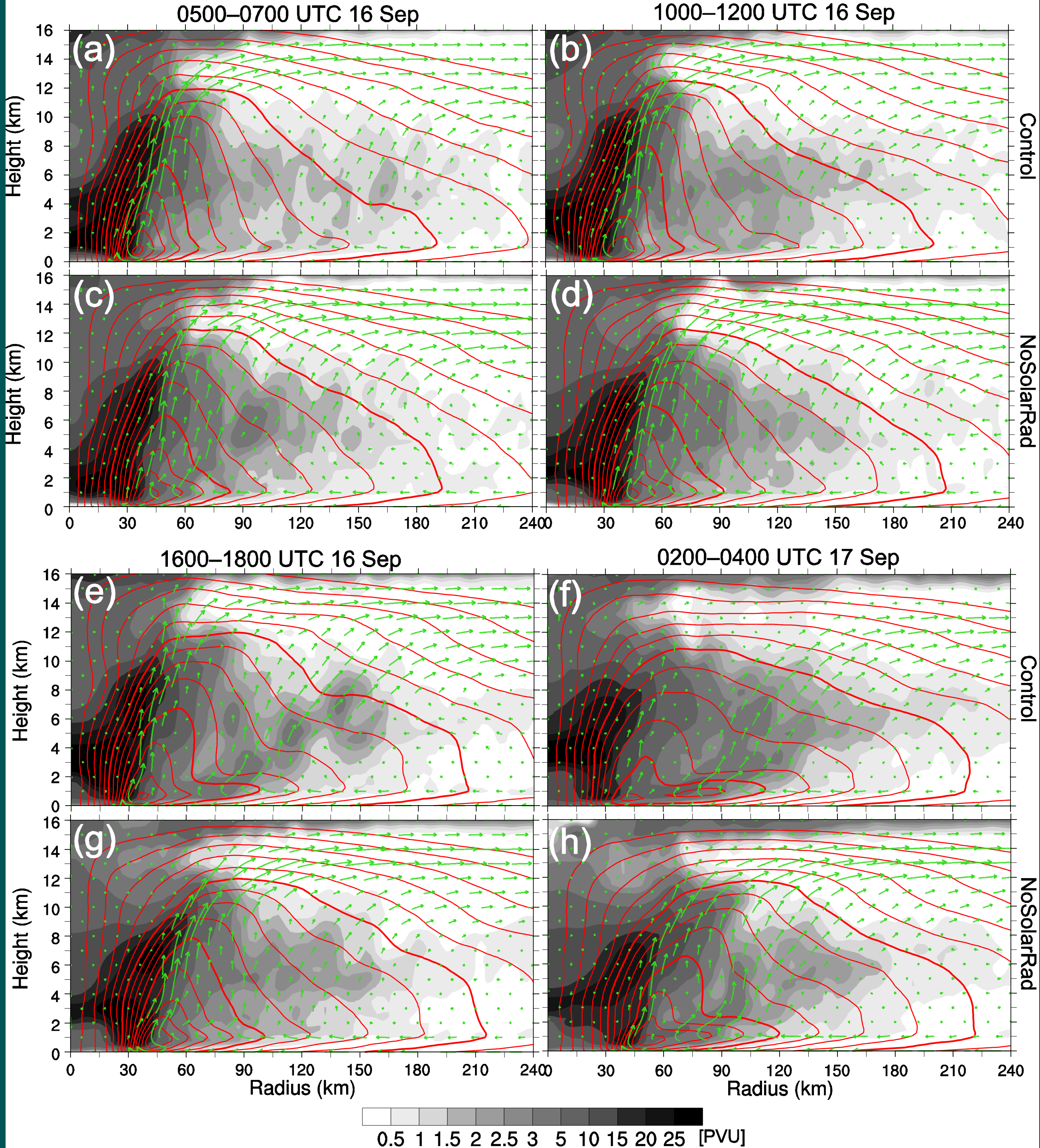
Reference:

- **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: Impact of the Diurnal Radiation Cycle on Secondary Eyewall Formation, *J. Atmos. Sci.,* in press.**


0100 UTC 15 Sep
1200 UTC 15 Sep
0000 UTC 16 Sep
0600 UTC 16 Sep
1600 UTC 16 Sep
2100 UTC 16 Sep
0600 UTC 17 Sep
1200 UTC 17 Sep
Control
NoSolarRad
Y (km)
X (km)
(a)
(b)
(c)
(d)
(e)
(f)
(g)
(h)
(i)
(j)
(k)
(l)
(m)
(n)
(o)
(p)
5 10 15 20 25 30 35 40 45 50 55 60 65 70 75
[dBZ]
10 m s-1



(a)
(b)
(c)
(d)
Height (km)
Radius (km)
Control
NoSolarRad
[×10^-5 kg kg^-1]
[m s^-1]
0 10 20 50 150 250 350
-0.4 0 0.4 0.8 1.2 1.6 2
0 60 120 180 240
0 2 4 6 8 10 12 14 16



0500–0700 UTC 16 Sep
1000–1200 UTC 16 Sep
1600–1800 UTC 16 Sep
0200–0400 UTC 17 Sep
(a)
(b)
(c)
(d)
(e)
(f)
(g)
(h)
Control
NoSolarRad
Control
NoSolarRad
Height (km)
Radius (km)
0.5 1 1.5 2 2.5 3 5 10 15 20 25 [PVU]