Impacts of Diurnal Radiation Cycle on Secondary Eyewall Formation
Observation of Concentric Eyewall in Edouard (2014)

Composite Radar Reflectivity (Courtesy of the NOAA/HRD)
Experimental design

Column maximum radar reflectivity

Control: actual diurnal cycle
NoSolarRad: no solar insolation

SEF moat

10-m wind speed

Sep 14 1200 UTC
SEF and ERC in simulation

Stronger primary eyewall

Weaker primary eyewall

Control

NoSolarRad

Clear moat and SEF

Stronger inner rainbands

No SEF

surface rain rate
• Stronger inner rainbands in NoSolarRad $\Rightarrow$ more convergence outside of primary eyewall
• Heating outside the RMW in the midtroposphere $\Rightarrow$ increasing (reducing) low-level tangential wind outside (near and inside) the RMW $\Rightarrow$ outward expansion of the RMW
The evolution of vertical velocity shows several key features:

- 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)

- 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

Unit: $10^{-5}$K/s for (a), (b), (c), and $10^{-3}$K/s for (d)
Radiative effects on moat formation

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

(60 km < R < 75 km)
Evolution of outer rainbands (front-like zone)

- Front-like zone is accompanied by distinct positive horizontal vorticity in the tangential direction
  \[ \eta = \frac{\partial u}{\partial z} - \frac{\partial w}{\partial r}. \]

- Necessary lifting is helpful to the convection in the upward branch of direct thermal circulation with positive \( \eta \)

Horizontal vorticity \( \eta \) (shaded) and equivalent potential temperature (\( \theta_e \), 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)

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

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

\[ \left[ -\frac{\vec{v}}{r} \left( \frac{\partial \vec{v}}{\partial r} \right) \right]^{-0.5} \]

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

greater PV in stratiform region
Balanced aspects of SEF: Early stage

The absence of diabatic heating forcing and resulted smaller $\nu$ in the moat region in CNTL is more important for moat formation in the early stage of SEF

$$\frac{\partial \tilde{\nu}}{\partial t} = -\tilde{u}(f + \zeta) - \tilde{w} \frac{\partial \tilde{\nu}}{\partial z}$$
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
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 with different intensities and sizes
- The impacts of the diurnal radiation cycle to the timing and radial location of SEF
- ......

TC
Thanks for attention!

Reference:

