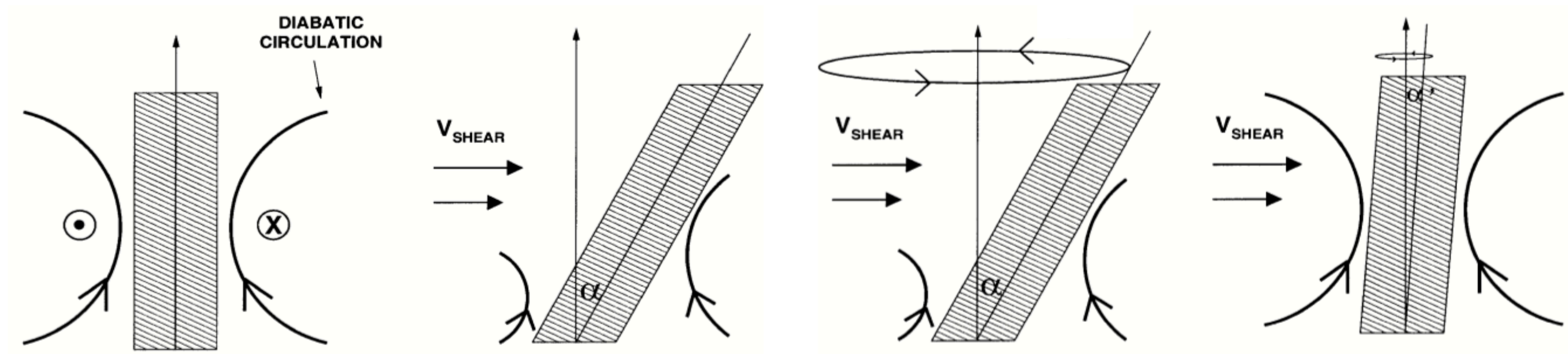
Predictability and dynamics of tropical cyclones: sensitivity to environmental shear, sea-surface temperature and moisture

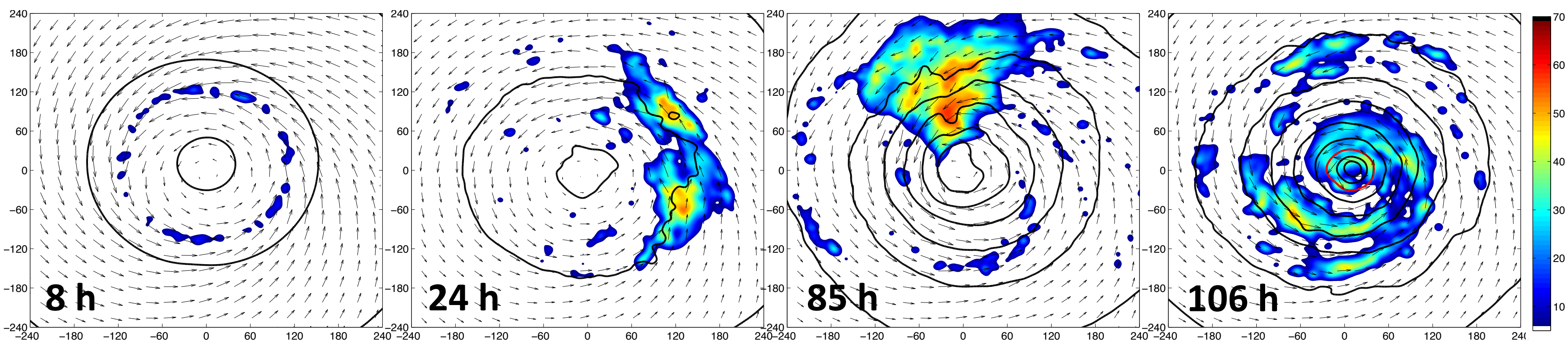
Dandan Tao
Fuqing Zhang
Group meeting 12/11/2013

Behavior of initial straight TC Vortex under Vertical Wind Shear



Straight Vortex Column **Tilt** **Precession** **Alignment**

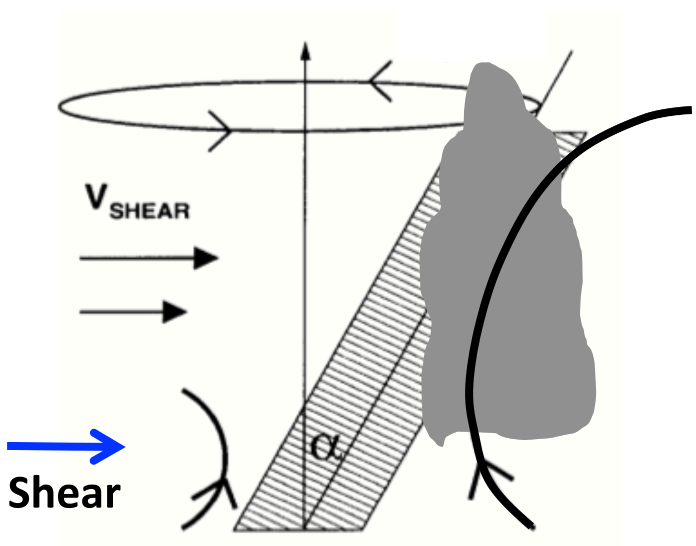
Reasor et al. (2004)

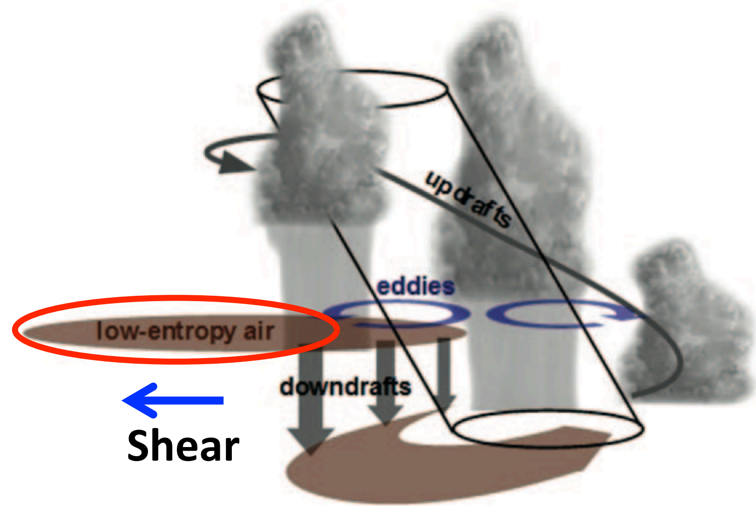


Zhang and Tao (2013)

Vertical Wind Shear Effect on TC

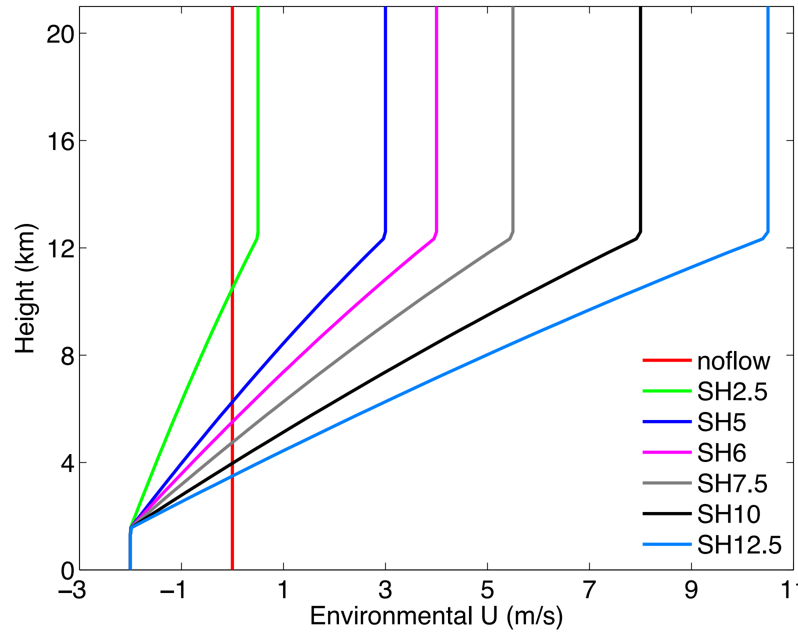
- effect of vertical shear on spatial distribution/organization/intensity of cumulus convection and related impact of system-scale convergence of absolute angular momentum
- dry air ventilation effect, which is about the midlevel dry air been flushed down to the boundary layer by the downdraft and then taken into the updraft by the radial inflow





Tang and Emanuel 2012

Experimental Design



- **WRF version 3.1**
- **18km, 6km, 2km; 4320km, 1440km, 720km**
- **41 vertical levels**
- **Physics: YSU, WSM6**
- **Vmax = 15 m/s**
- **Rmax = 135 km**
- **Random moisture perturbation: ± 0.5 g/kg under 950hPa**
- **20 members in each set:**

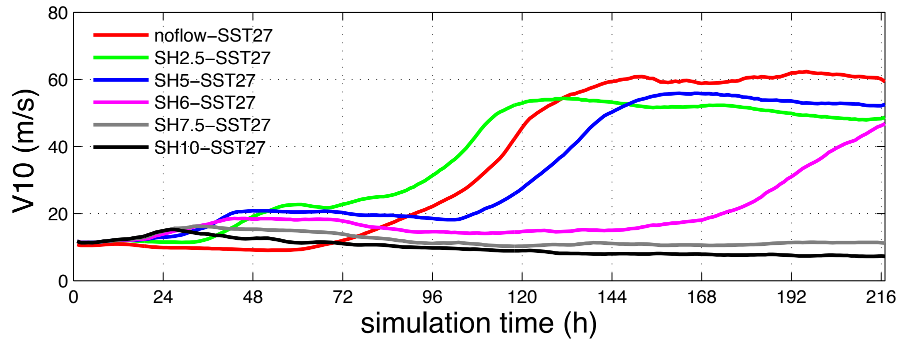
  shear condition: noflow, SH2.5, SH5, SH6, SH7.5, SH10, SH12.5

  SST condition: 27°C and 29°C

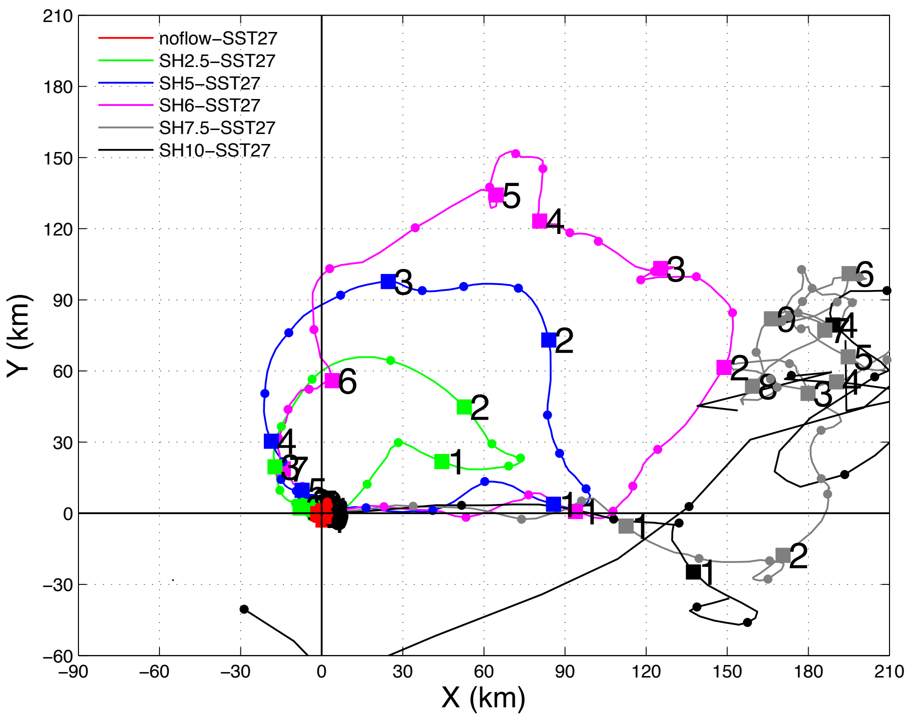
- **Dry Air sensitivity Dry50: > 300 km qvapor is reduced to 50% of its original value; linearly decrease from 200 km to 300 km**
- **The mean states are studied.**

Mean state of the ensemble sets
under different shear magnitude with SST=27°

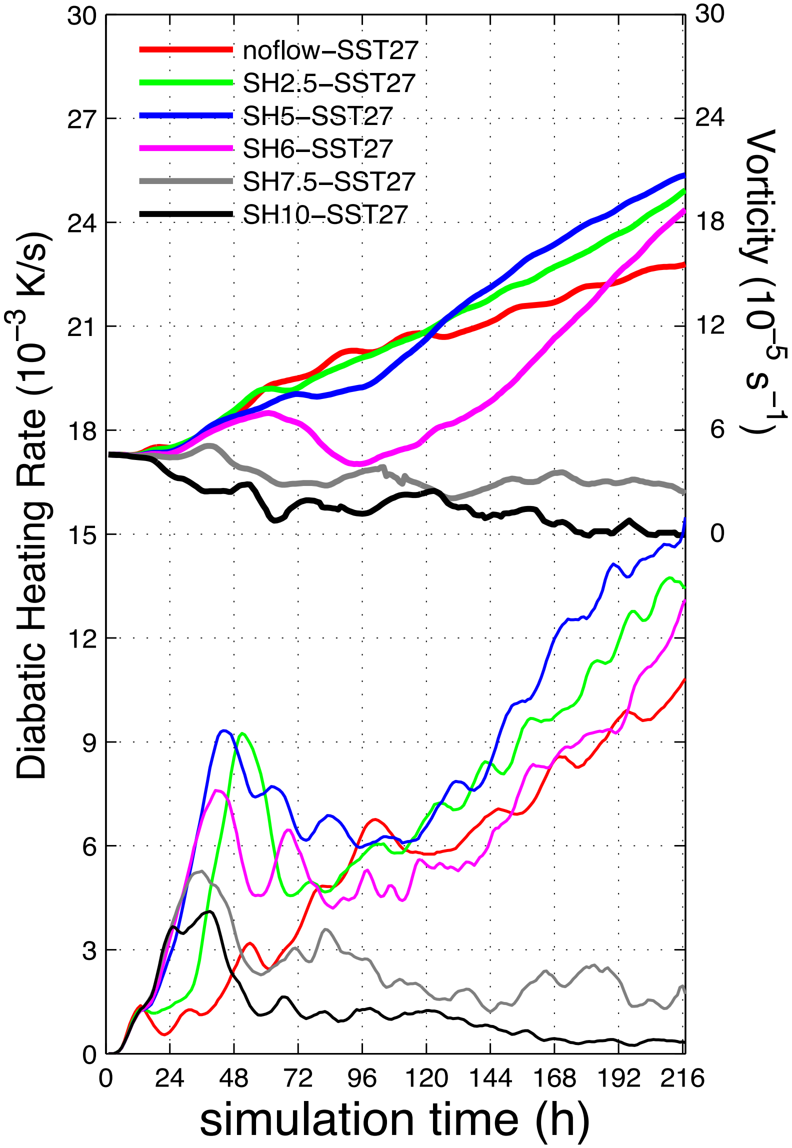
Maximum 10-m Wind Evolution



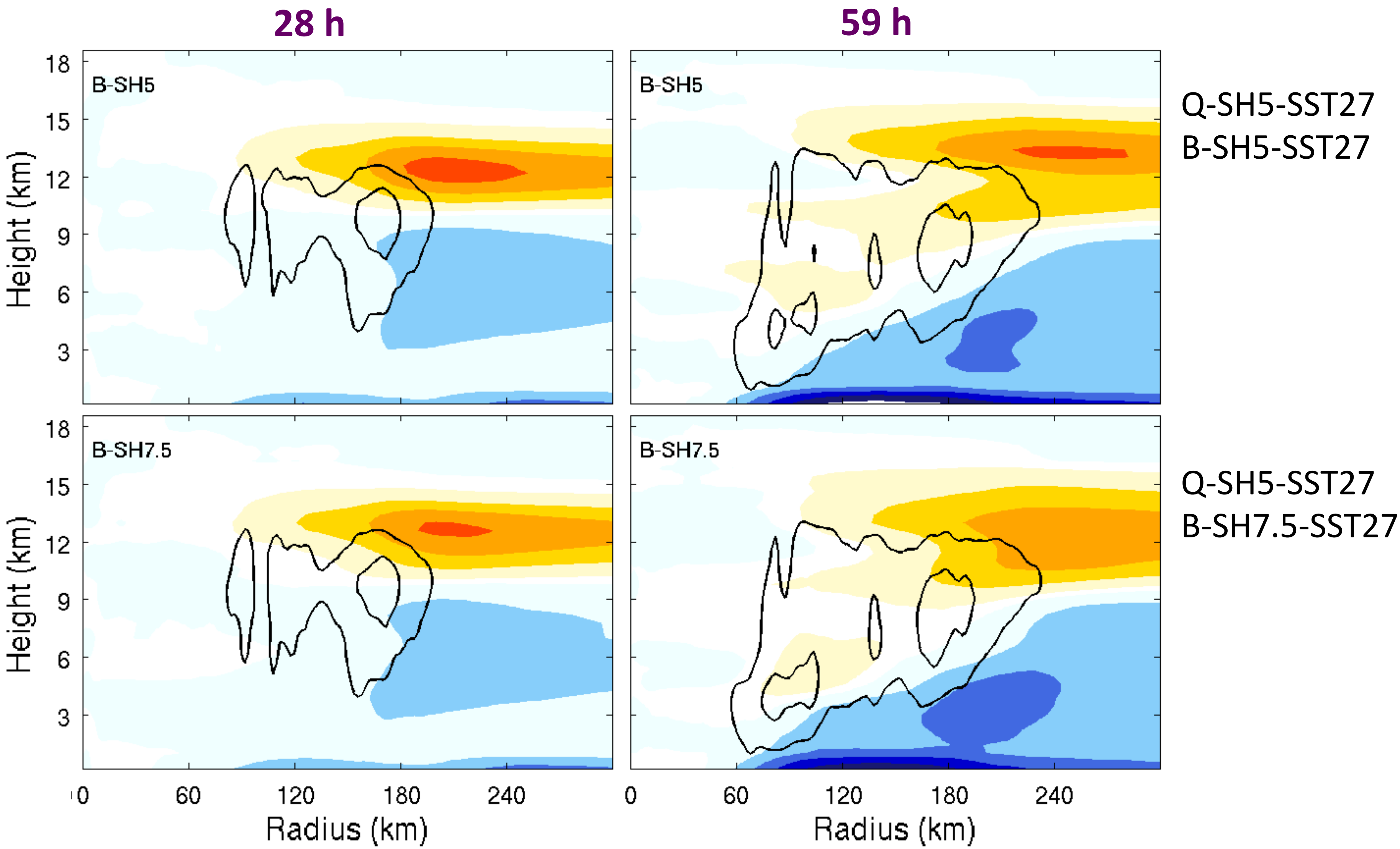
Tilt Vector Evolution



Vorticity and Heating Evolution



Secondary Circulation (Sawyer-Eliassen output)



Secondary circulation is mainly dominated by the heat forcing.

Initial straight vortex

Vertical Wind Shear →

↓

Vortex tilting: larger shear, lager tilt

↓ **Downtilt convection**

Convection Location and Strength

↓

Secondary Circulation Strength

↓ **Convergence of angular momentum**

The vortex mean circulation strength

Strength of the vortex

↓

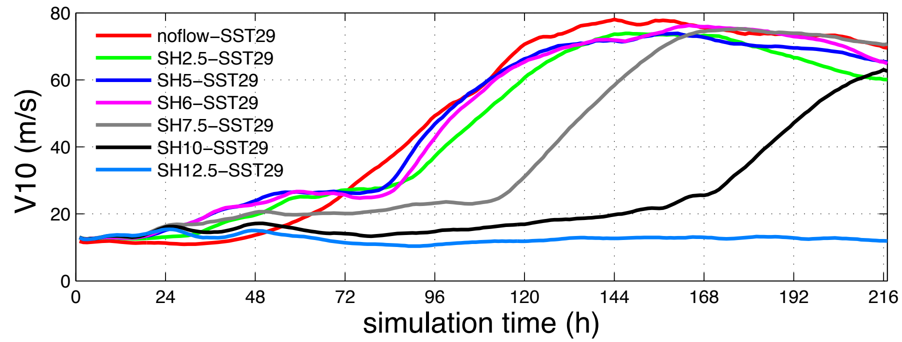
Precession and alignment

↓

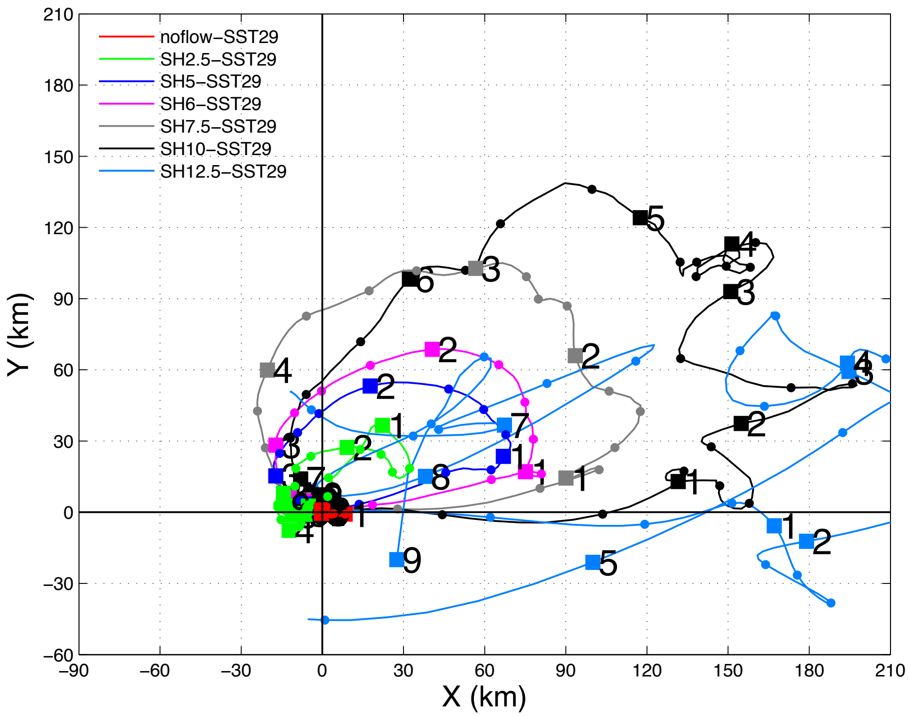
Onset of Rapid Intensification

Mean state of the ensemble sets (SST sensitivity)
under different shear magnitude with SST=29°

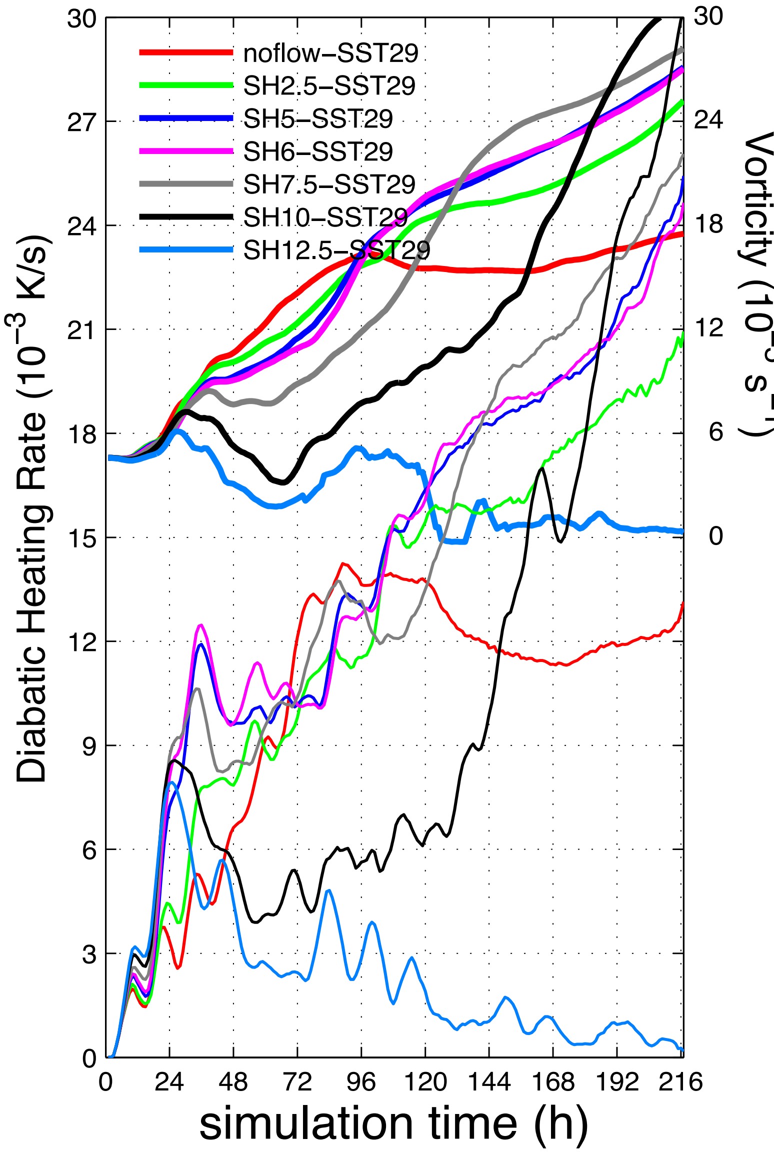
Maximum 10-m Wind Evolution



Tilt Vector Evolution



Vorticity and Heating Evolution



Initial straight vortex

Vertical Wind Shear →

↓

Vortex tilting: larger shear, lager tilt

↓ Downtilt convection

Convection Location and Strength

↓

Secondary Circulation Strength

↖ Higher SST influence
Much more diabatic heating release

↓ Convergence of angular momentum

The vortex mean circulation strength
Strength of the vortex

↓

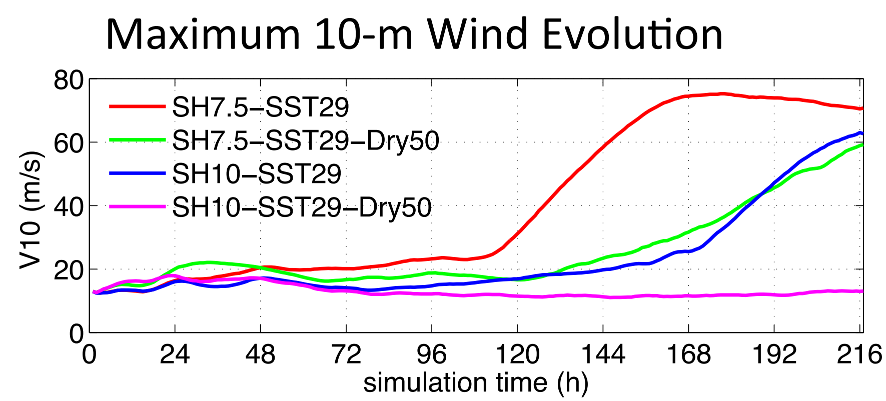
Precession and alignment

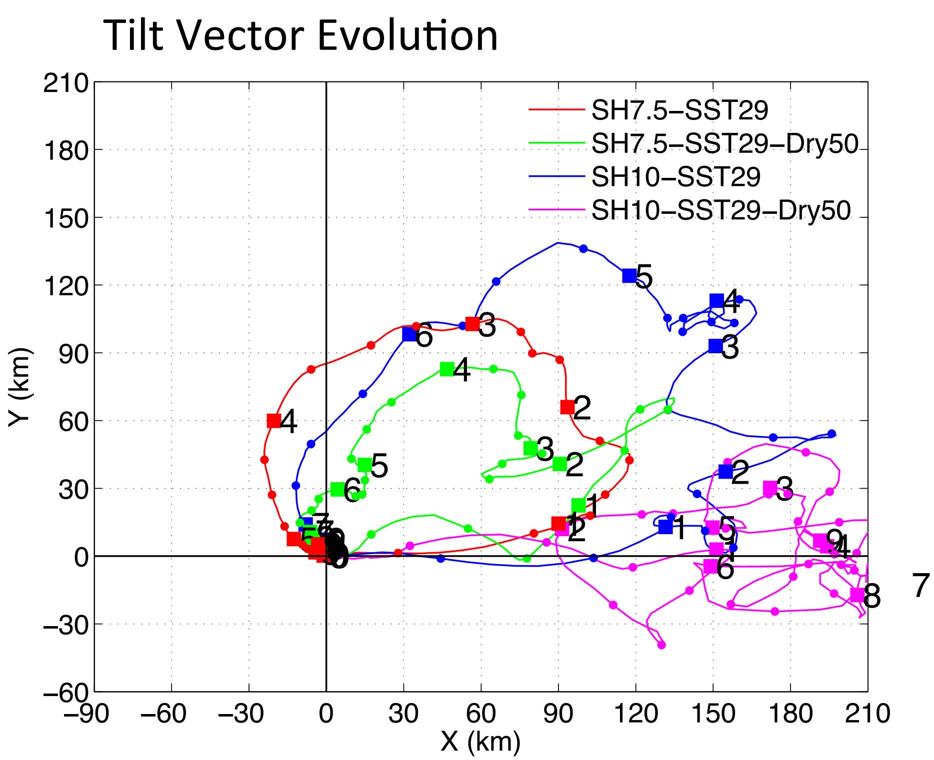
↓

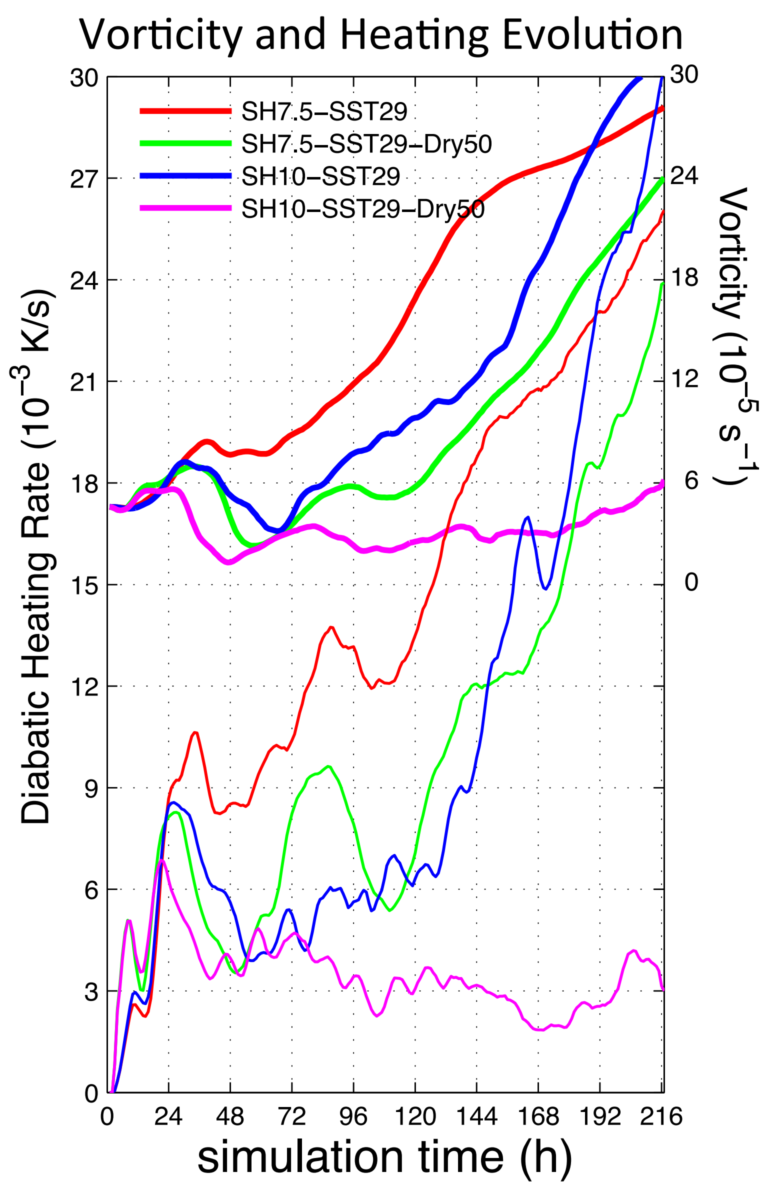
Onset of Rapid Intensification

Mean state of the ensemble sets with and without dry air

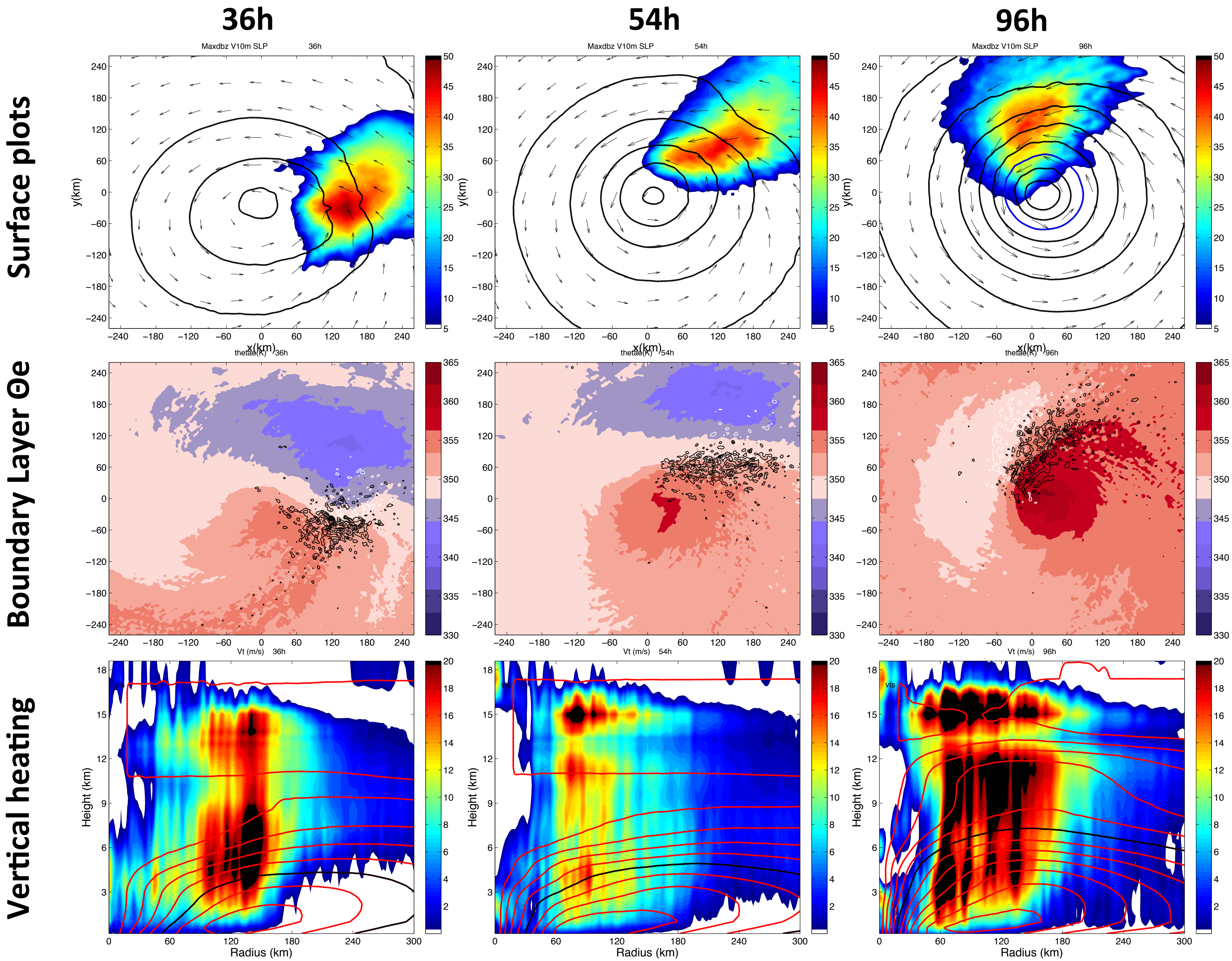
under shear 7.5m/s and 10m/s with SST=29°



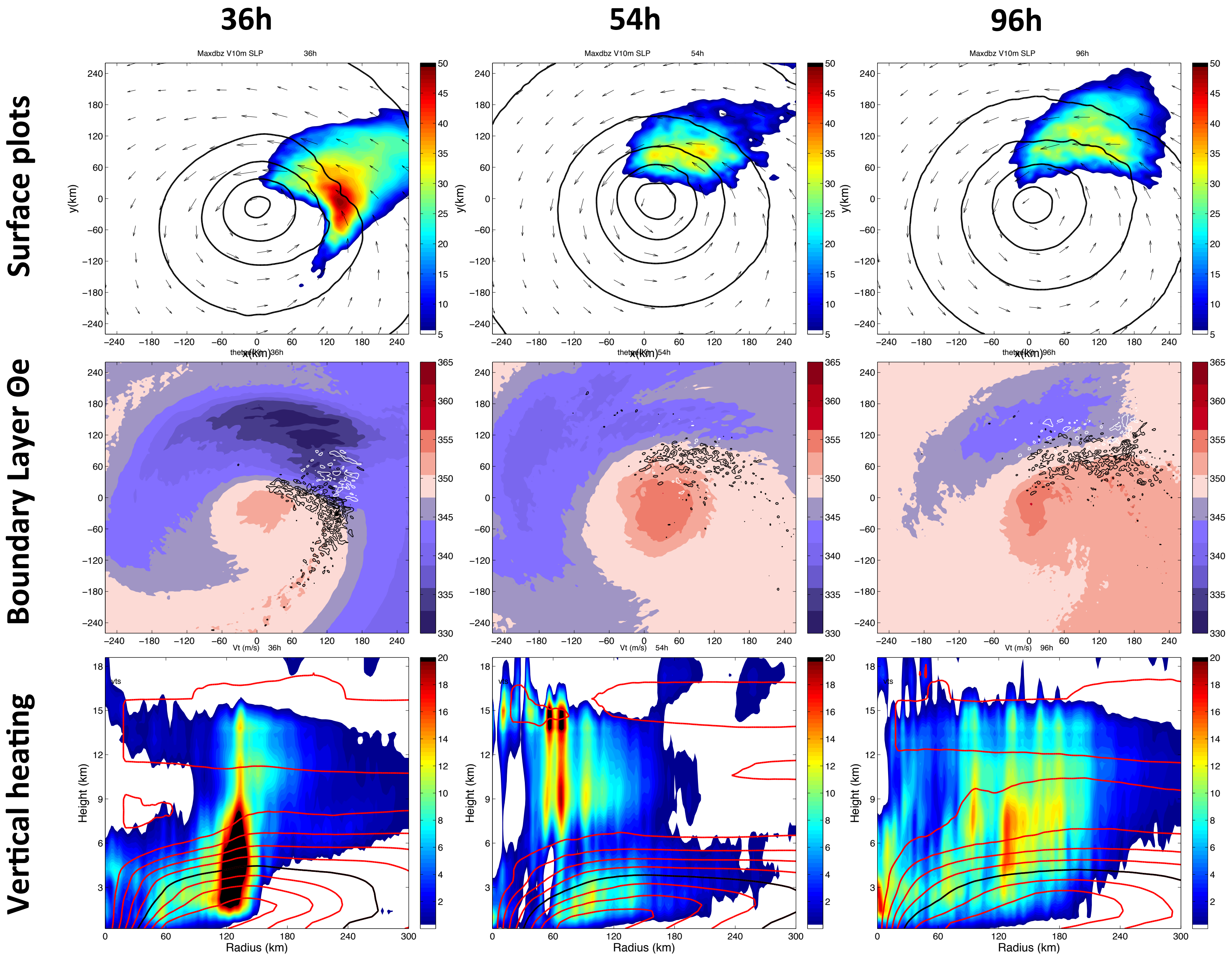




SH7.5_SST29_Moist



SH7.5_SST29_Dry50



Initial straight vortex

Vertical Wind Shear →

↓

Vortex tilting: larger shear, lager tilt

↓ **Downtilt convection**

Convection Location and Strength

← **Environmental Dry Air**
Low Θe air from midlevel

↓

Secondary Circulation Strength

↓ **Convergence of angular momentum**

The vortex mean circulation strength
Strength of the vortex

↓

Precession and alignment

↓

Onset of Rapid Intensification

- The convection cannot develop in the far field with dry air.
- The ventilated midlevel dry air weakens the convection and then weakens the secondary circulation

Concluding Remarks

- The environmental vertical wind shear can significantly affect the timing of tropical cyclone formation.
- The influence takes place through organizing spatial distribution and intensity of the convection and then changing the positive feedback between diabatic heating and TC vortex strength.
- The smaller the shear, the stronger and closer the convection, the stronger secondary circulation leading to the stronger vortex mean circulation and then the precession speed is faster.
- The higher SST condition enhances diabatic release and thus strengthens the mean vortex circulation, which later shortens the precession time.
- The environmental dry air dilutes the boundary layer inflow air moisture, which leads to less diabatic heating release and weaker vortex strength and finally longer precession time.