EFFECTS OF AIR-SEA COUPLING ON TROPICAL CYCLONE STRUCTURE : A NEW PERSPECTIVE FROM TRACER AND TRAJECTORY ANALYSIS IN COUPLED MODEL.

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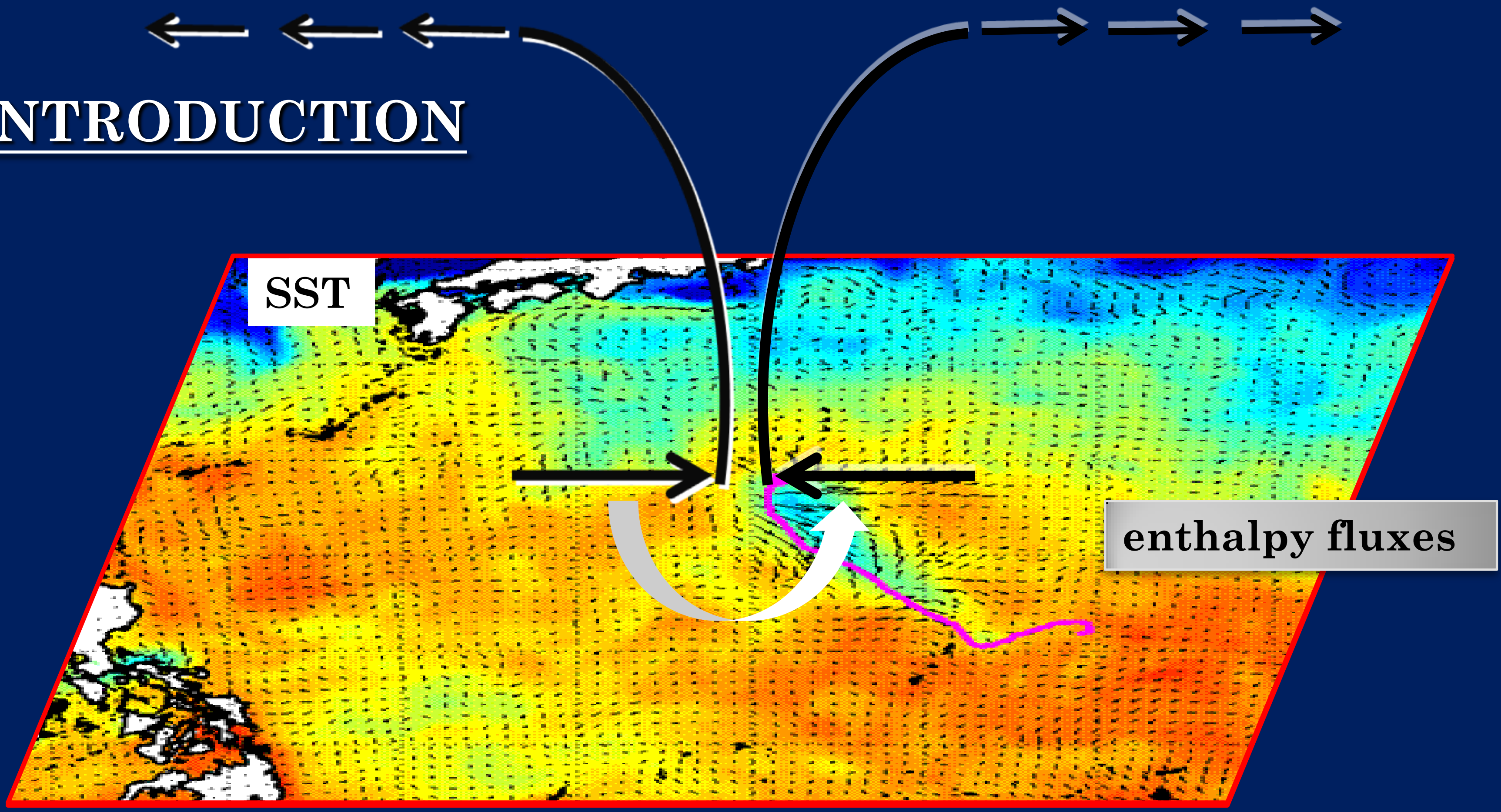
INTRODUCTION



- Emanuel (1986); Rotuno and Emanuel (1987) – air-sea, energetically
- Price (1981) – negative feedback & inhomogeneous SST cooling
- Wright et al. (2001) – inhomogeneous TC-induced surface waves
- Chen et al. (2007; 2010a, b) – significant impacts of atmosphere-wave-ocean coupling on TC intensity

SCIENTIFIC QUESTION

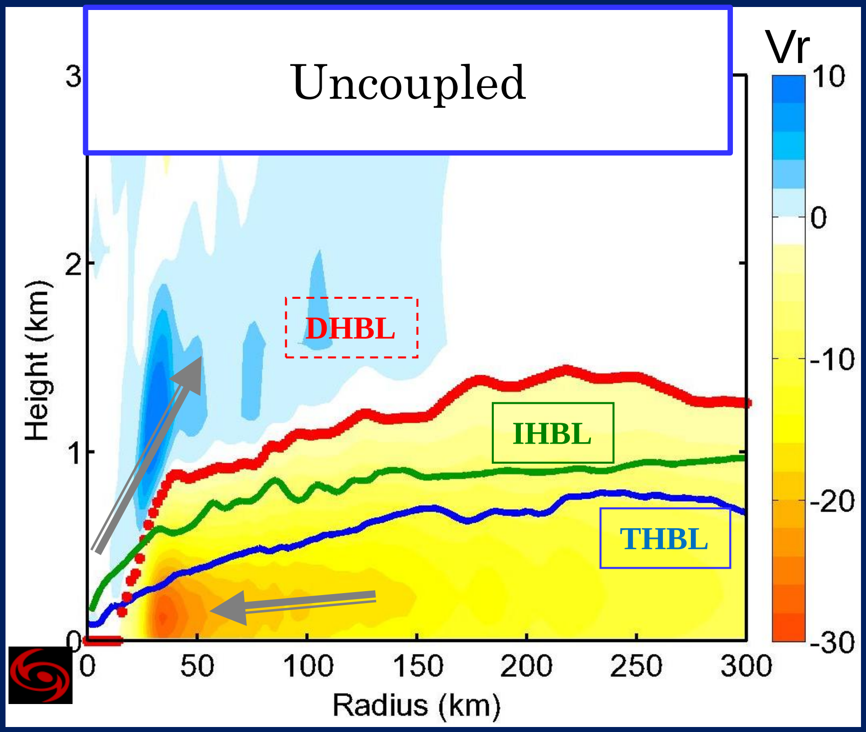
- What are the **physical mechanisms** through which the **air-sea coupling processes affect TC structure** and, therefore, storm intensity.

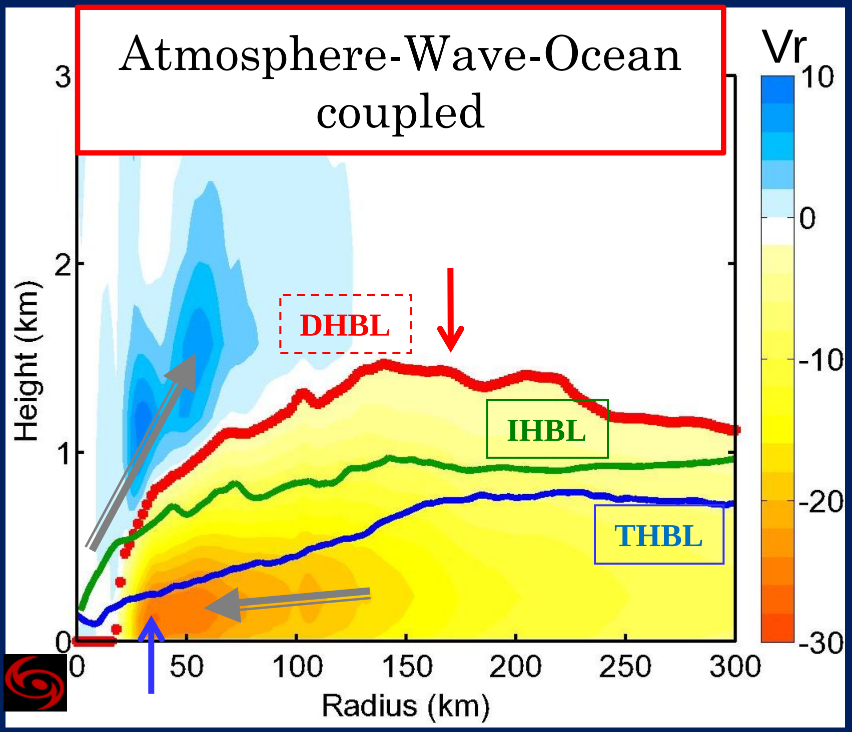
To better understand the variation of hurricane boundary layer (HBL) structure due to the air-sea coupling (Lee and Chen 2010)

SPECIFIC OBJECTIVE:

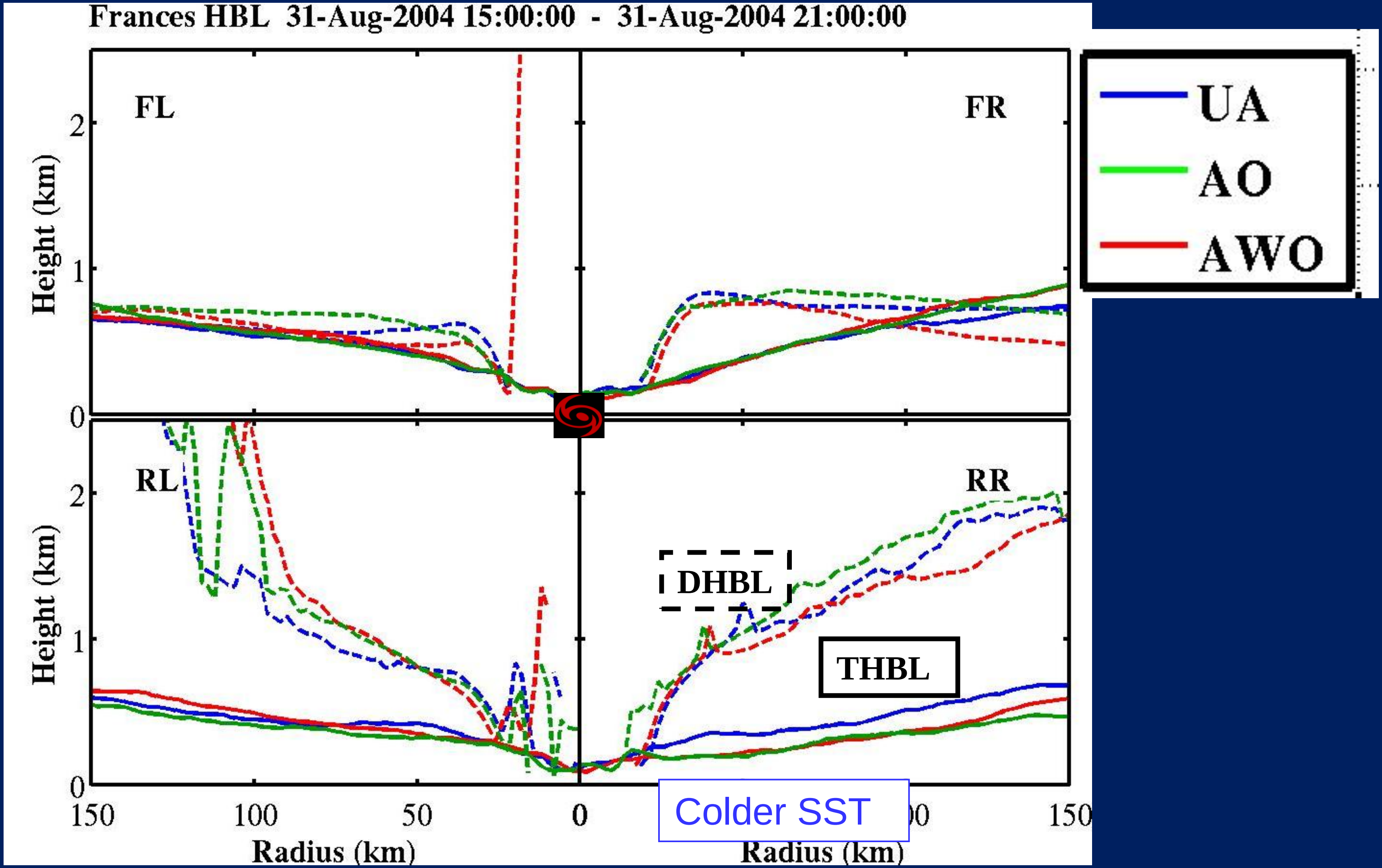
- To examine the property of inflow in HBL, especially over cold wake, and its impact on storm structure

Lee and Chen (2010): the variation of hurricane boundary layer (HBL) due to the air-sea coupling





- Complex boundary layer in hurricanes with different definitions: DHBL (inflow layer) , IHBL, THBL (mixed layer)
- Full atmosphere-wave-ocean coupling increases DHBL and lowers THBL



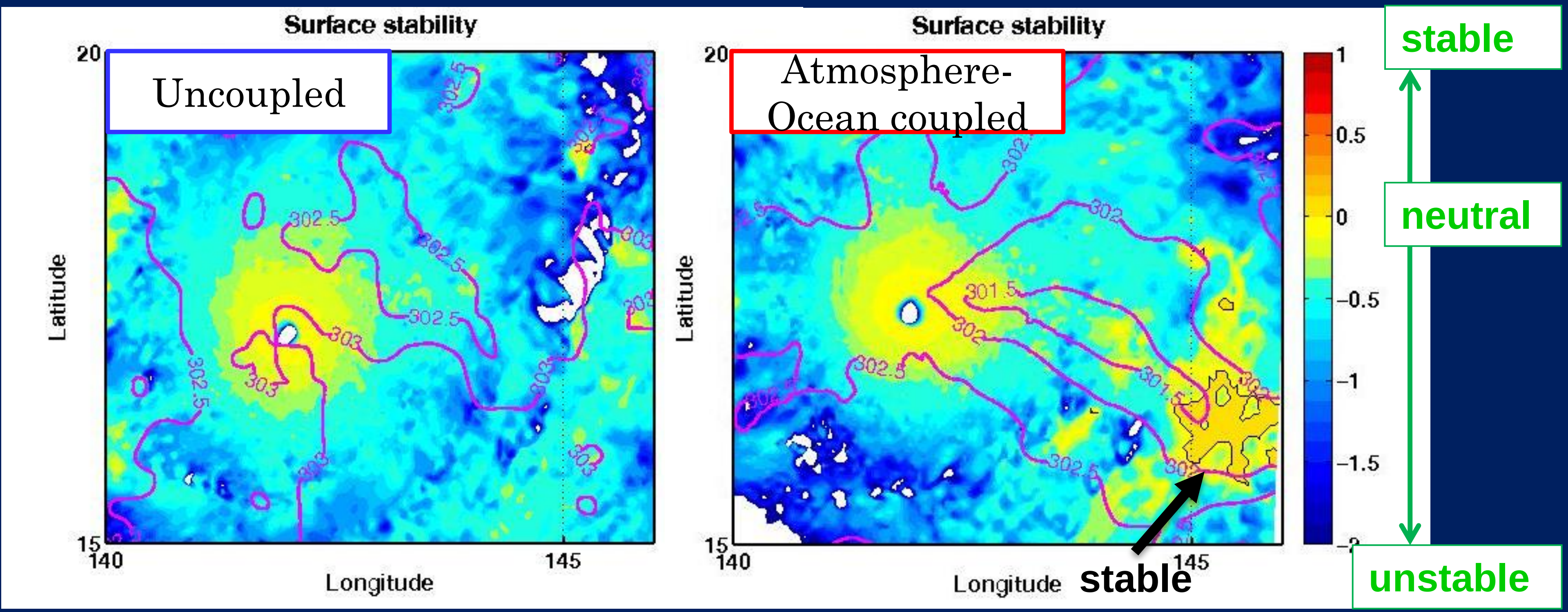
- Coupling-induced/enhanced asymmetry: shallower THBL in the quadrant where the cooling is strongest

→ More stable HBL?

BL STABILITY INDEX:

$$\zeta = \frac{z}{L} = \frac{-kzg\overline{(w'\theta_v')}_s}{\overline{\theta_v} u_*^{\,3}}$$

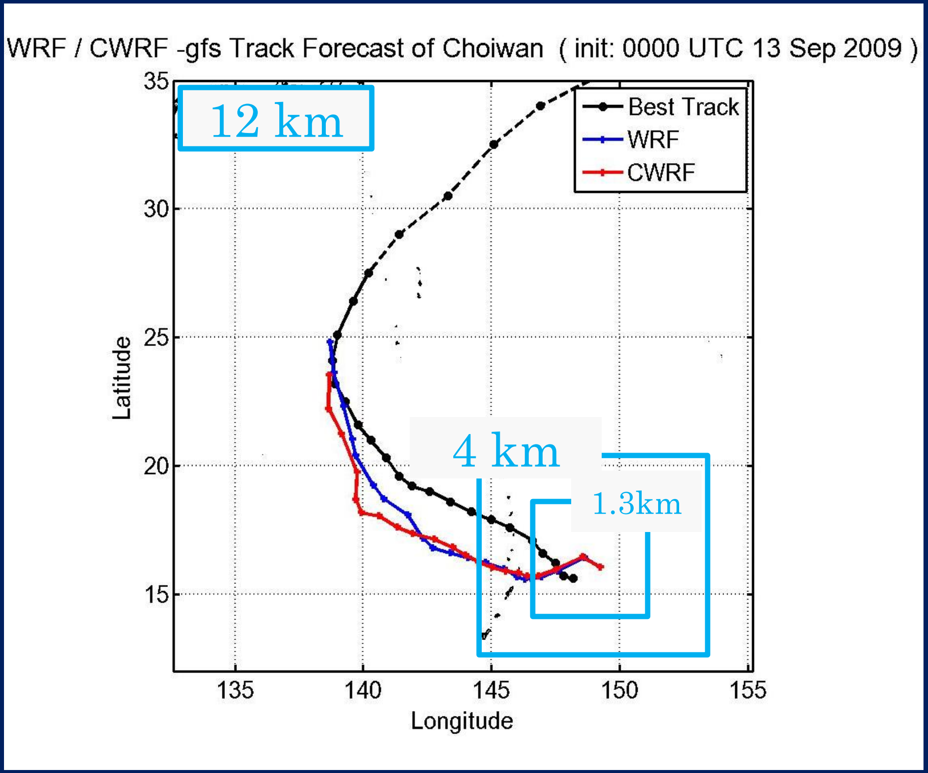
L : Obukhov length
Z : well mixed layer



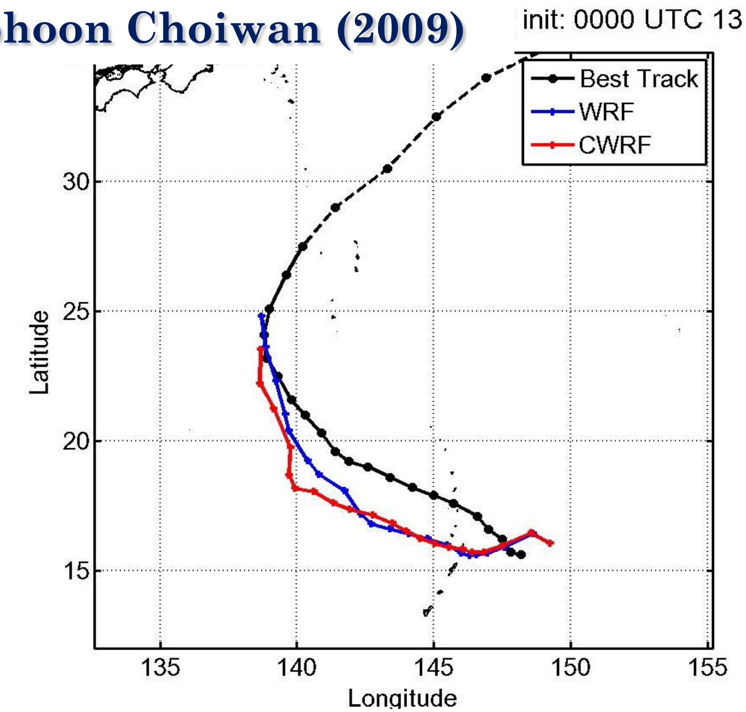
- Cold wake in coupled model → **More stable HBL!**

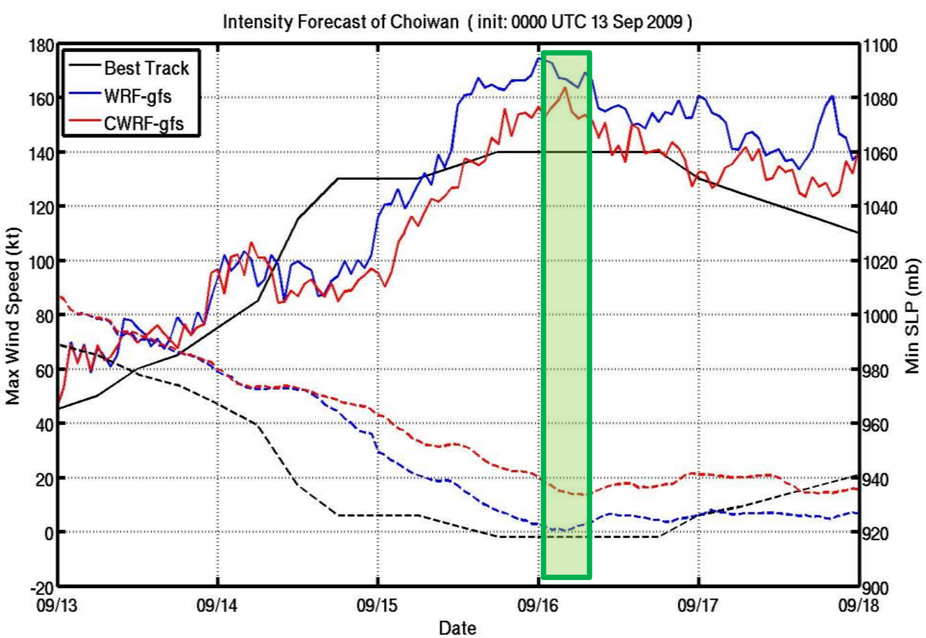
COUPLED WRF-3DPWP (CWRF)

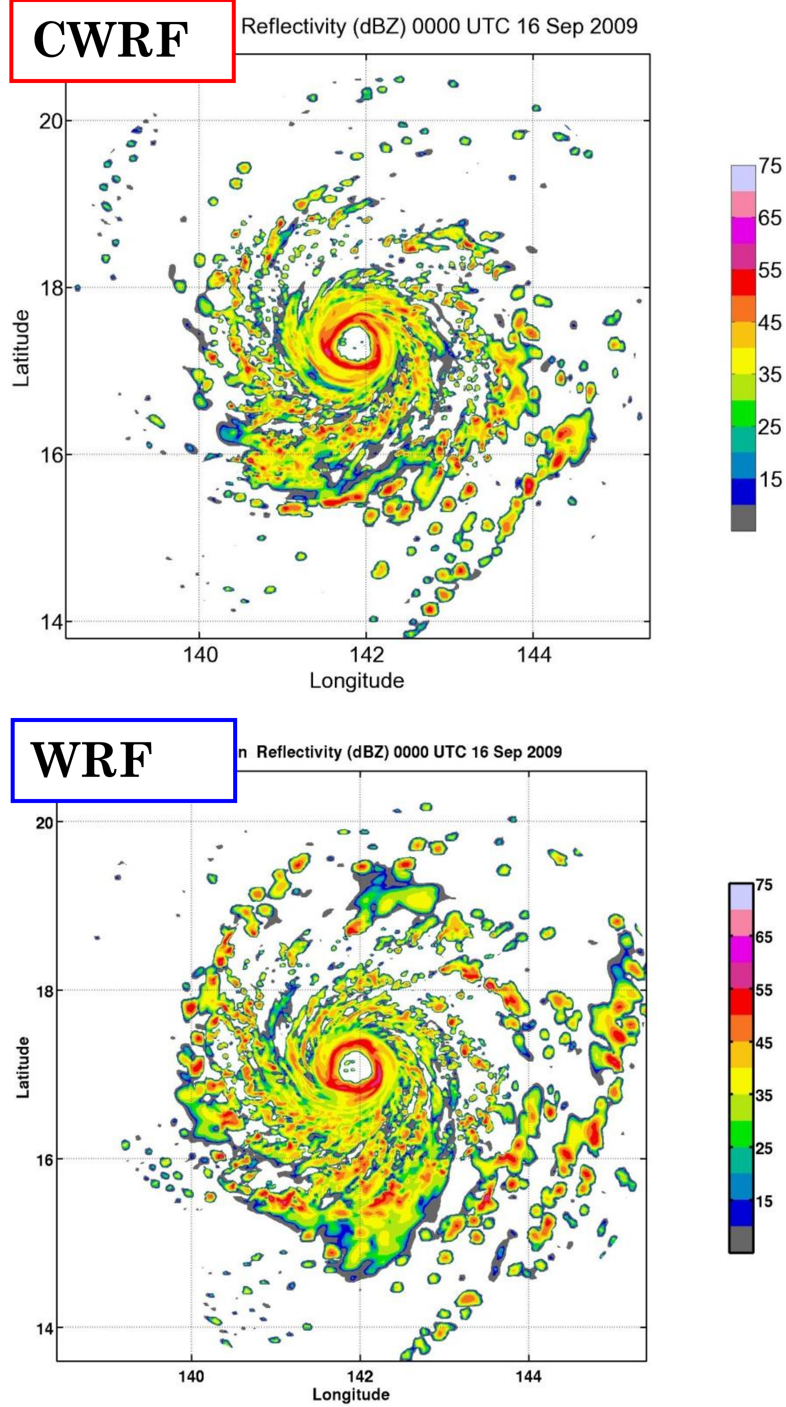
- **WRF V3.1.1**
  - 12, 4, 1.3-km moving nests
  - 36 vertical levels with 9-10 levels within lowest 1km
  - WSM5
  - YSU PBL scheme
  - Donelan (2004) wind-wave surface roughness
  - Garratt (1992) exchange coefficients for T and q
- **3DPWP**
  - 3-D upper ocean circulation model (~0-400 m depth)
- (UM wave model)
  - To be added to CWRF by Curcic/Chen/Donelan.



Typhoon Choiwan (2009)







Two ways to track the property of air mass:

- **Trajectory:** an undiluted air parcel advected by the motion of fluid

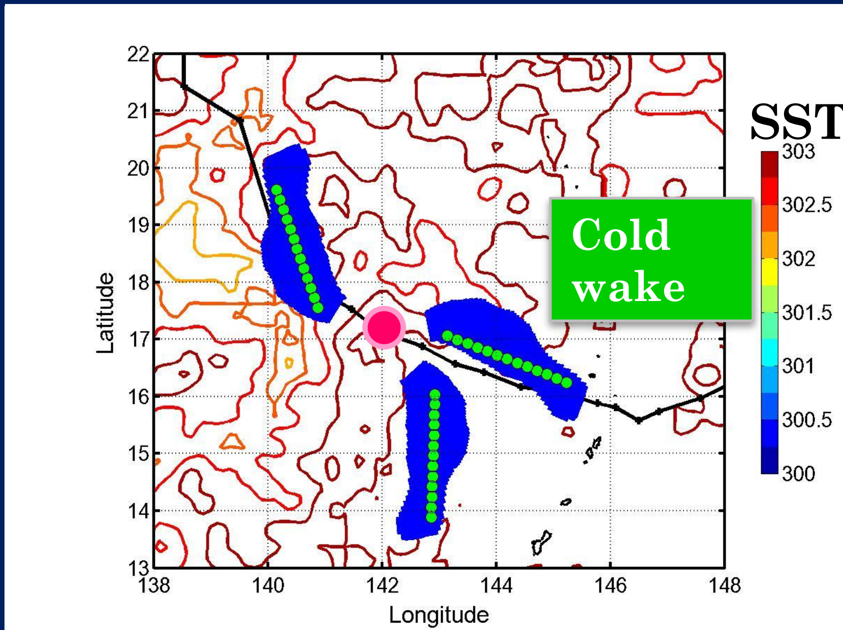
$$x_{i,t+1} = \delta x_i + x_{i,t}$$

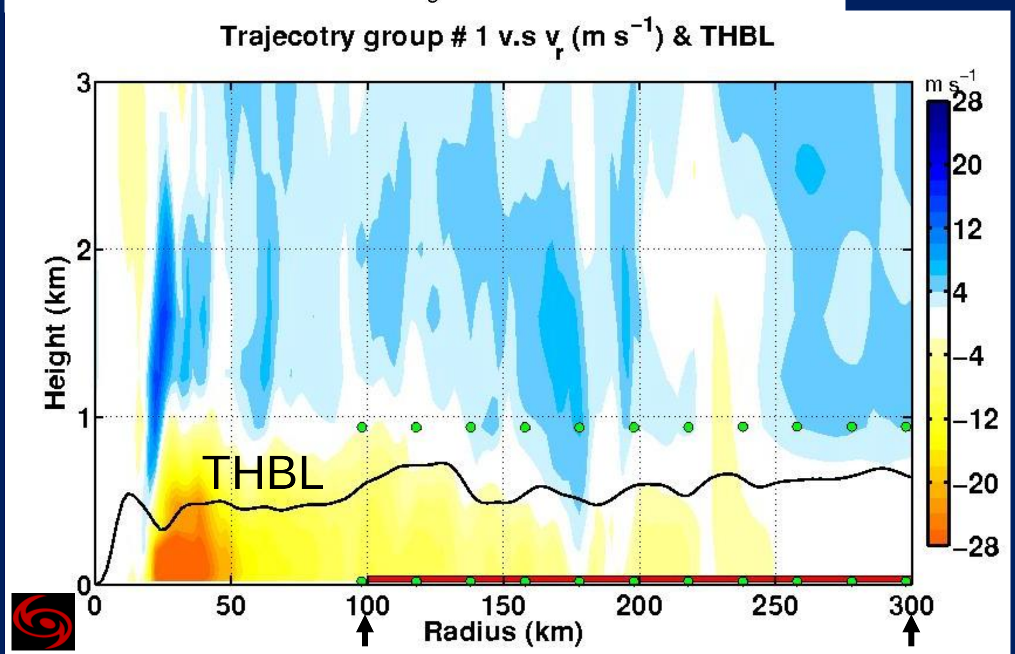
$$\delta x_i = \mathrm{U}_i \times \delta t$$

- **Tracer:** air parcel that subjected to advection, mixing, and diffusion

$$\frac{\partial \mathrm{C}}{\partial t} + \mathrm{U}_j \frac{\partial \mathrm{C}}{\partial x_j} = v_c \frac{\partial^2 \mathrm{C}}{\partial^2 x_j{}^2} + \mathrm{S}$$

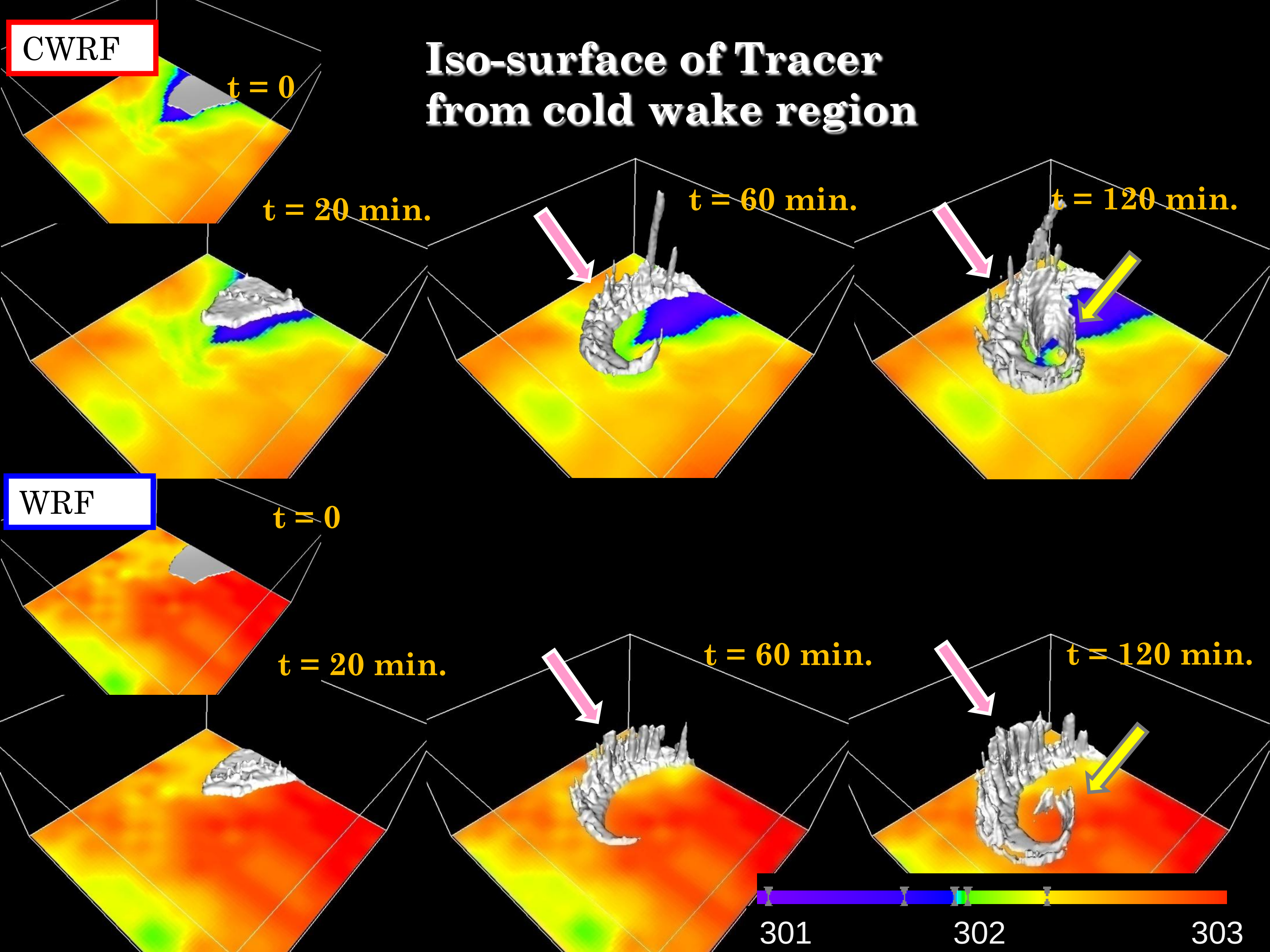
Initial locations of tracer and trajectories





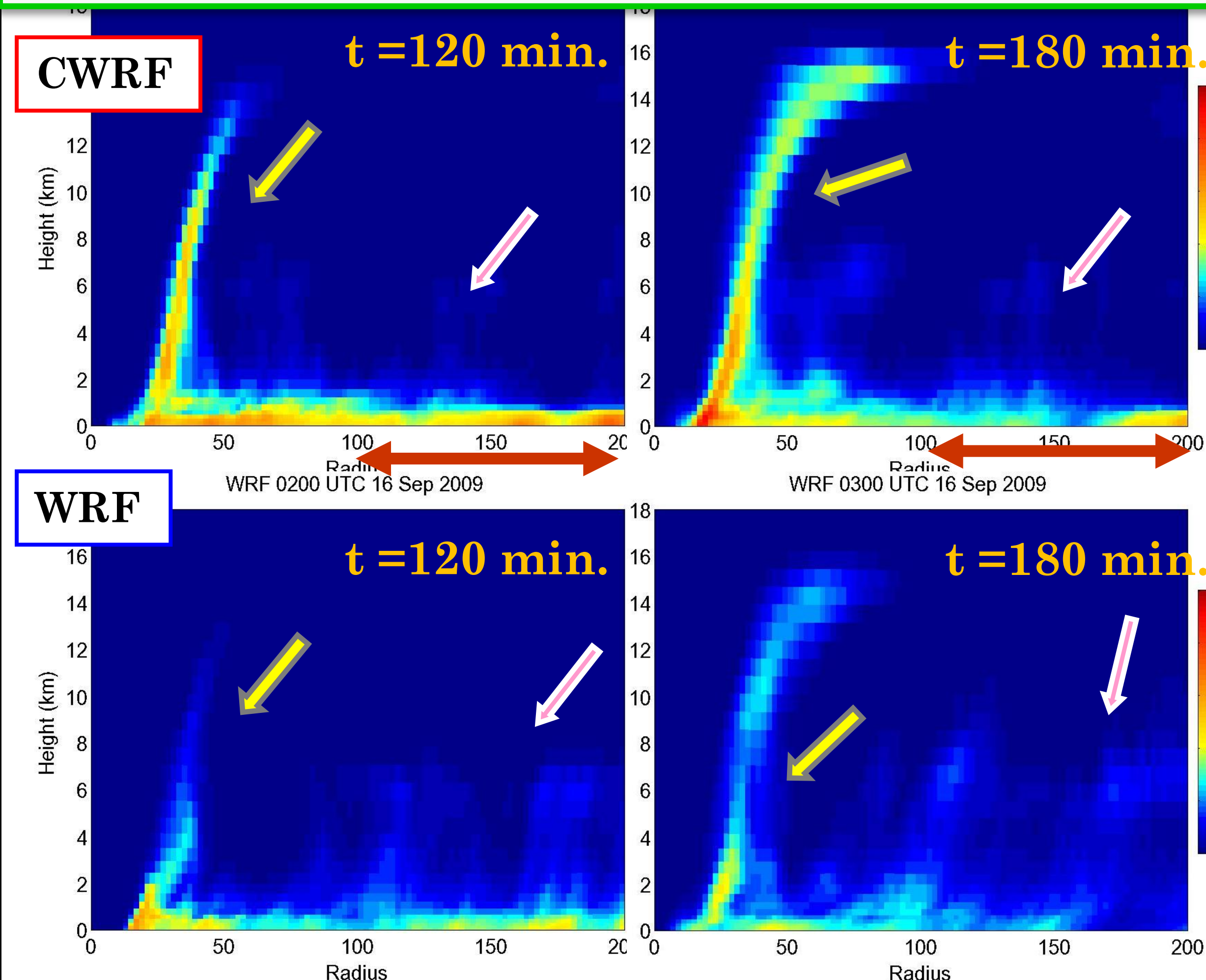
- **CWRF**
  1. cold wake region
  2. upstream of cold wake
  3. ahead of the storm track
  - vertical extent:
    - Tracer - near-sfc (1st two levels) and
    - Trajectory - boundary layer (1st & 9th levels)
  - ~100 – 300 km away from the storm center
- **WRF**
  - same storm-relative locations as in CWRF

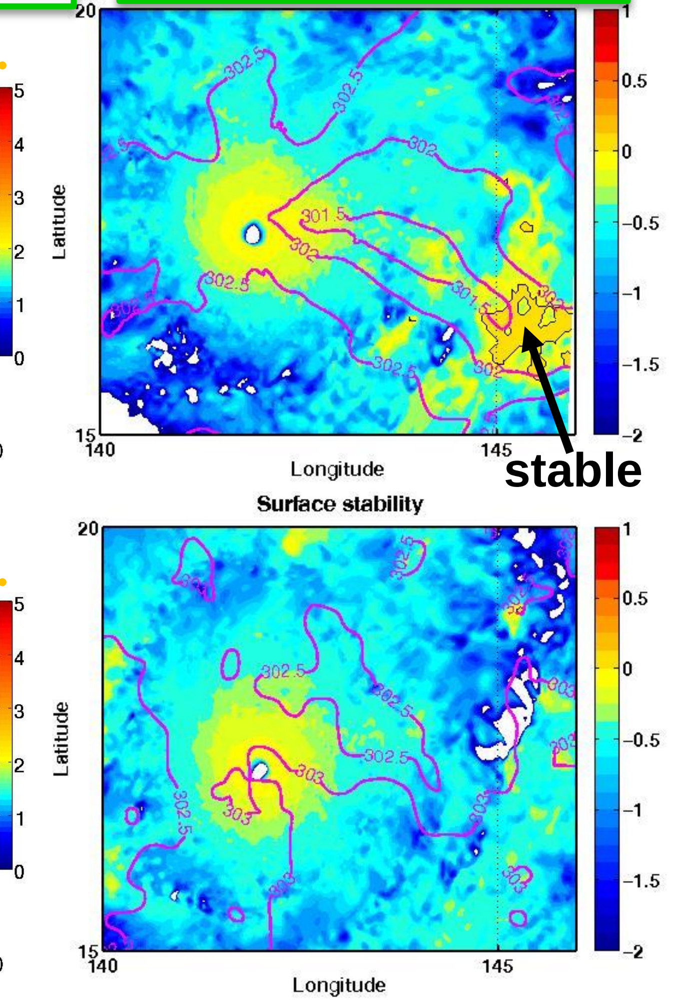
Iso-surface of Tracer from cold wake region



Azimuthal sum of tracer from cold wake region

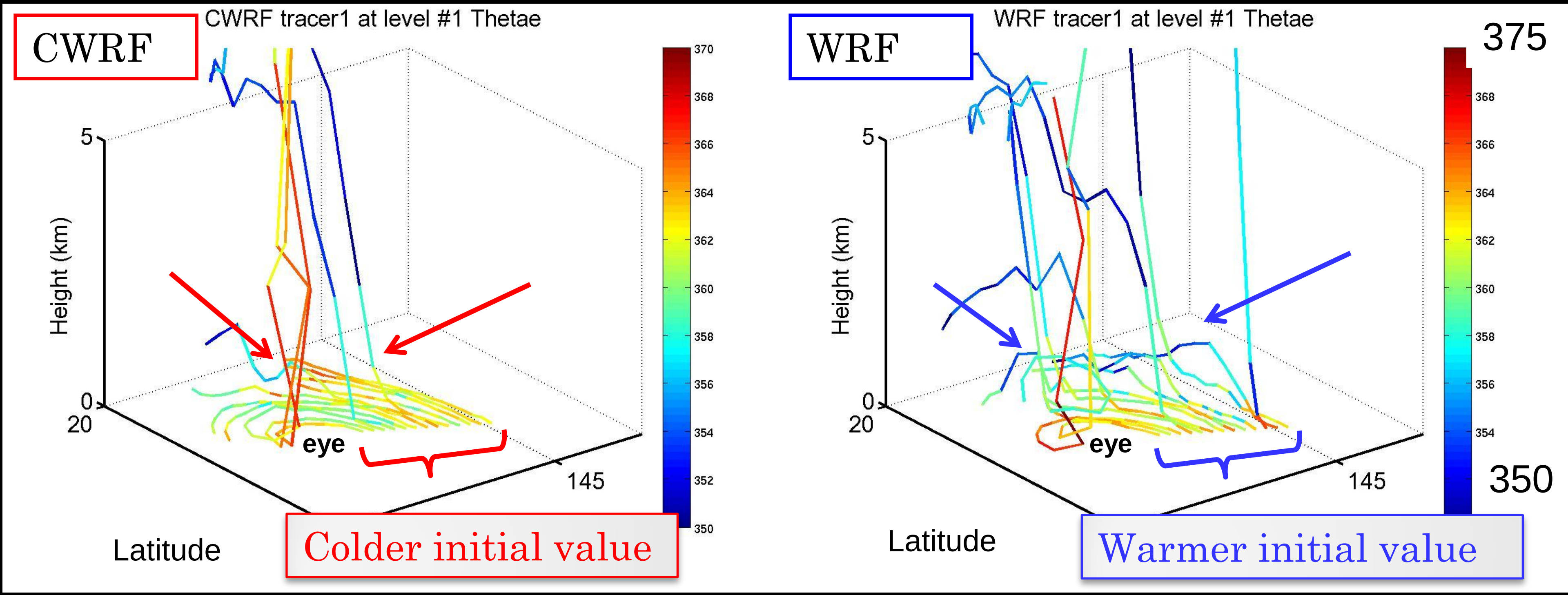
HBL stability





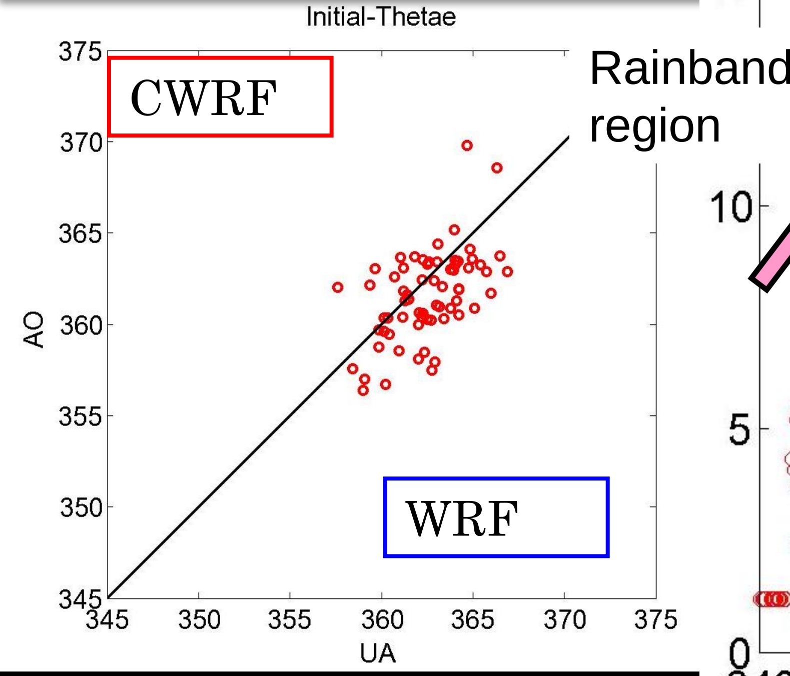
Same initial position with the same tracer concentration

θ_e along the trajectories from cold wake region

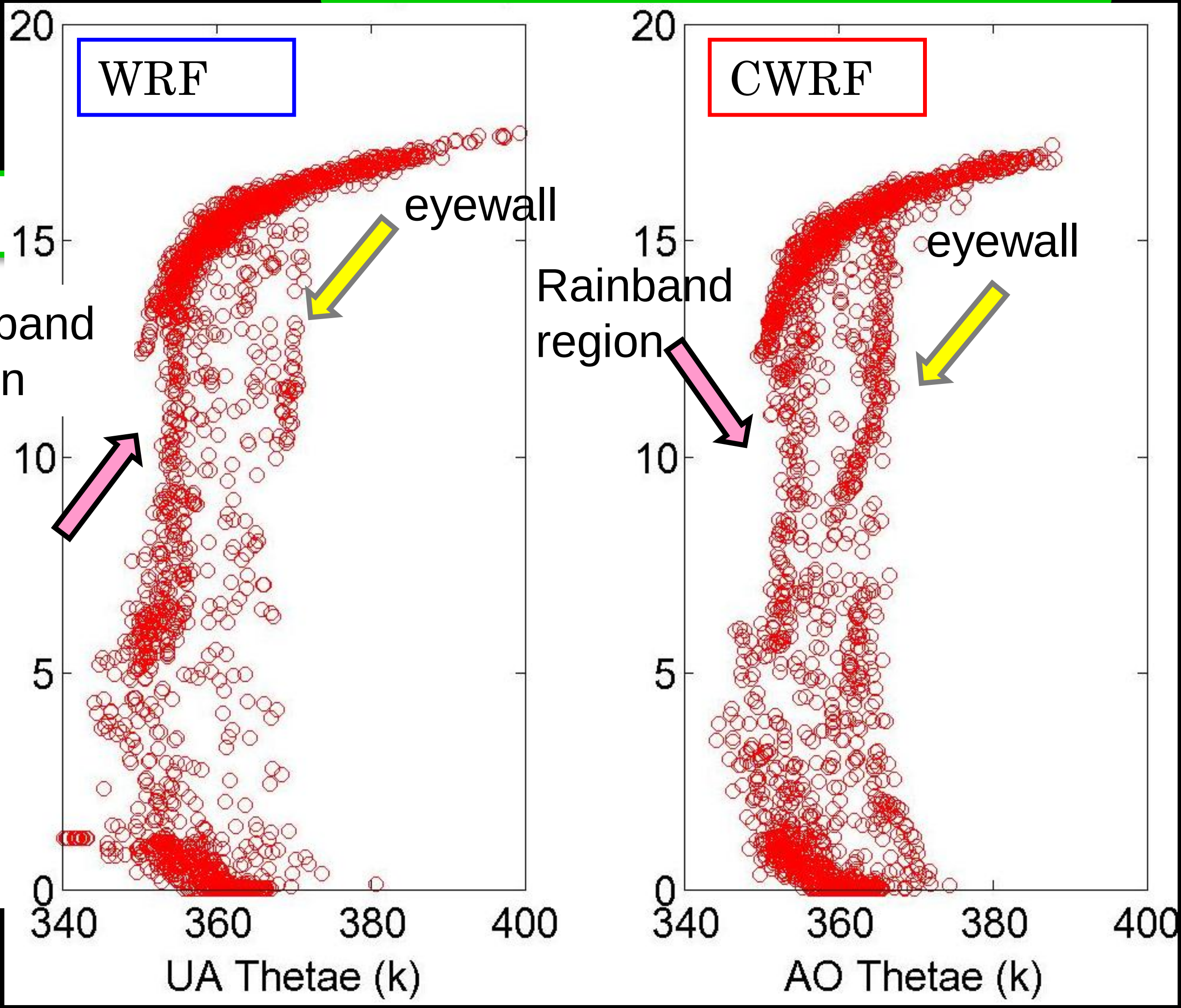


- 13 trajectories in WRF and CWRF respectively
- Trajectories in CWRF tend to stay in HBL longer than those in WRF
- More high energy air-parcels enter eyewall in CWRF

Initial distribution of θ_e



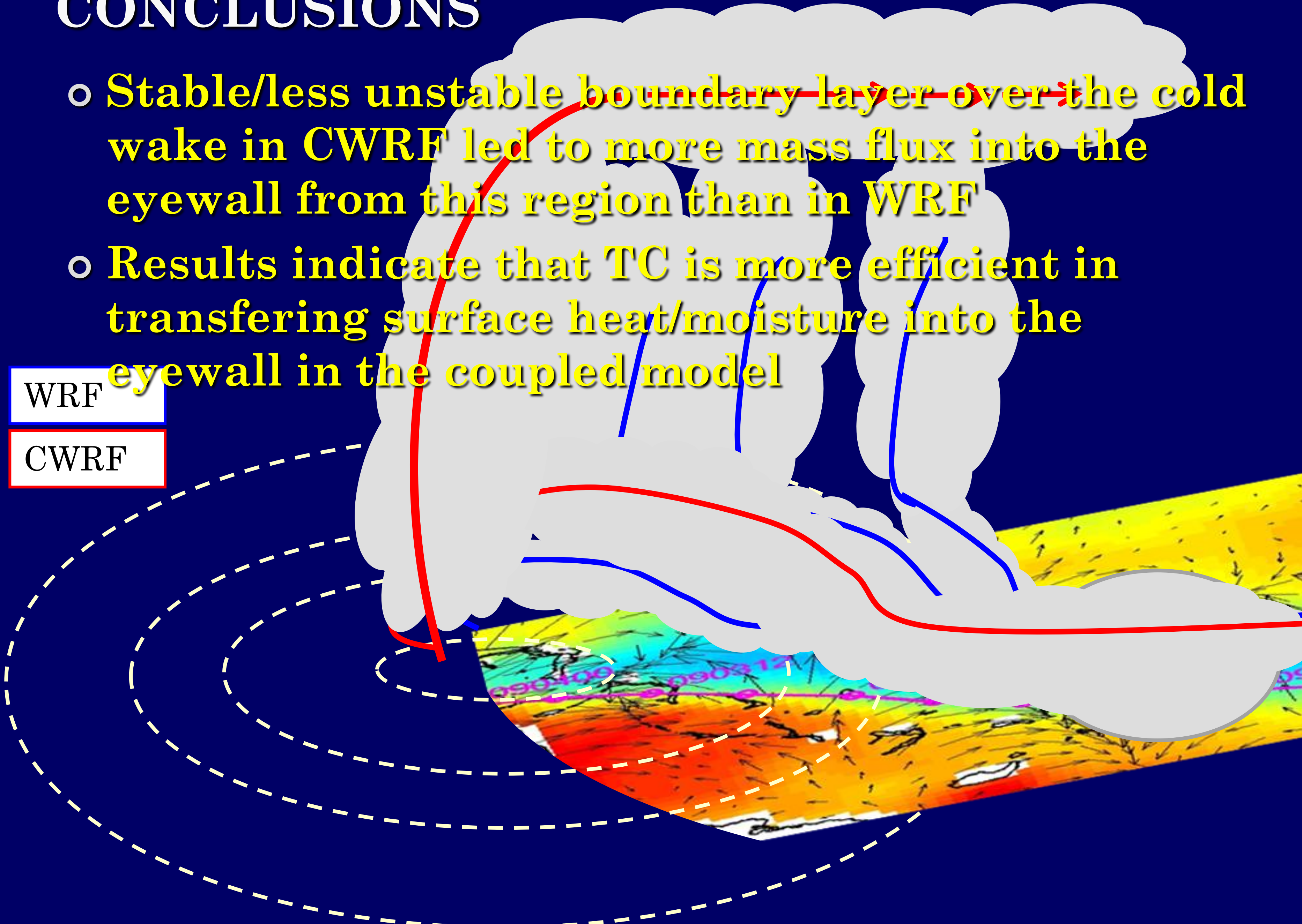
θ_e along all trajectories



	rainband	eyewall
CWRF	54	43
WRF	65	34

CONCLUSIONS

- Stable/less unstable boundary layer over the cold wake in CWRF led to more mass flux into the eyewall from this region than in WRF
- Results indicate that TC is more efficient in transfering surface heat/moisture into the eyewall in the coupled model



FUTURE WORK:

- To test generality of the current results in other cases over the Atlantic and Western Pacific.

- To better quantify the impacts on TC structure in terms of wind and rain in the eyewall and rainbands, temperature in the eye, etc.

- Examine impact of the surface waves on TC structure using the fully coupled model with the addition of the UM Wave Model (soon to be implemented in CWRF).

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