Impacts of Coastal Terrain on Warm-Sector Heavy-Rain-Producing MCSs in Southern China

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OUTLINE

INTRODUCTION

WARM-SECTOR HEAVY RAINFALL

Warm-Sector Heavy Rainfall (Huang 1986; Luo et al. 2013; Wang et al. 2014; Wu and Luo 2016; Li et al. 2021)

- occurring within a weakly forced synoptic environment under the influence of monsoonal airflows
- located near the southern coast of China
- characterized by poor predictability
- closely related to the coastal terrain (~500 m)

- When the low-level oceanic flow impinges on the mountainous terrain near the coast, prominent orographic effects on the rainfall intensity and life cycle of related heavy-rain-producing MCSs occur. (Chu and Lin 2000; Miglietta and Rotunno 2009, 2010; Tu et al. 2019)
- The coastal terrain altered the marine boundary layer jet and greatly influenced the occurrence and intensity of convection; while the local coastal concave mountain geometry was found to be able to increase coastal convergence and block the upstream moisture tongue thus fostering convection initiation (CI) and subsequent growth of initial convection. (Du et al. 2020)
- Coastal small mountains may change the location of the high frequency of CI through generating substantial local variations in the lifting and moisture pooling. (Bai et al. 2021)

INTRODUCTION

OBJECTIVES

- What is the quantitative change in heavy rainfall accumulations when the coastal terrain is modified?
- How does the coastal terrain generally modify the CI, upscale convective growth, convective evolution mode and maintenance of the heavy-rain-producing MCSs?
- What essential dynamic and thermodynamic environmental fields are modified by the coastal terrain?

DATA AND METHODS

PRECIPITATION AND ANALYSIS DATA

Precipitation Data

The rainfall observations were obtained from the merged and gridded precipitation dataset over China based on the Climate Prediction Center morphing technique (CMORPH) rainfall data and more than 30000 automatic rain gauges over China.

Analysis Data

The NCAR-archived National Centers for Environmental Prediction Final Analysis (FNL) dataset was used for composite analyses of the synoptic environments and the initial and boundary conditions for the quasi-idealized WRF simulations.

Warm-Sector Heavy Rainfall Cases

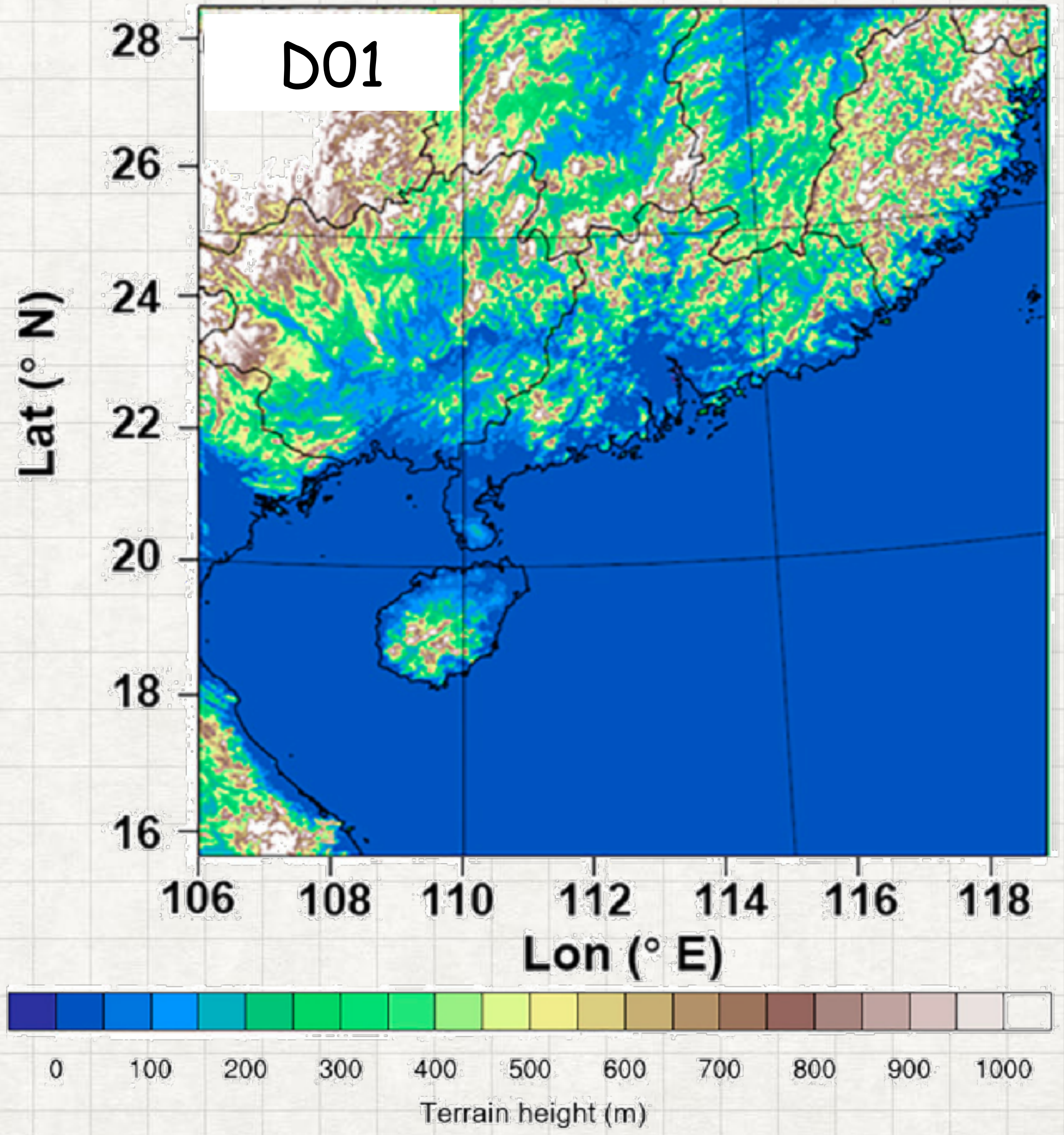
Three typical warm-sector heavy rainfall events over the southern coast in China from 2013 to 2015 with similar CI timing, organization mode and duration were selected in the present study.

	Date	Initial time (LST)	Dissipation time (LST)	Duration (h)
Case 1	26 May 2013	0400	1700	13
Case 2	9 May 2014	0300	1700	14
Case 3	17 May 2015	0400	1600	12

DATA AND METHODS

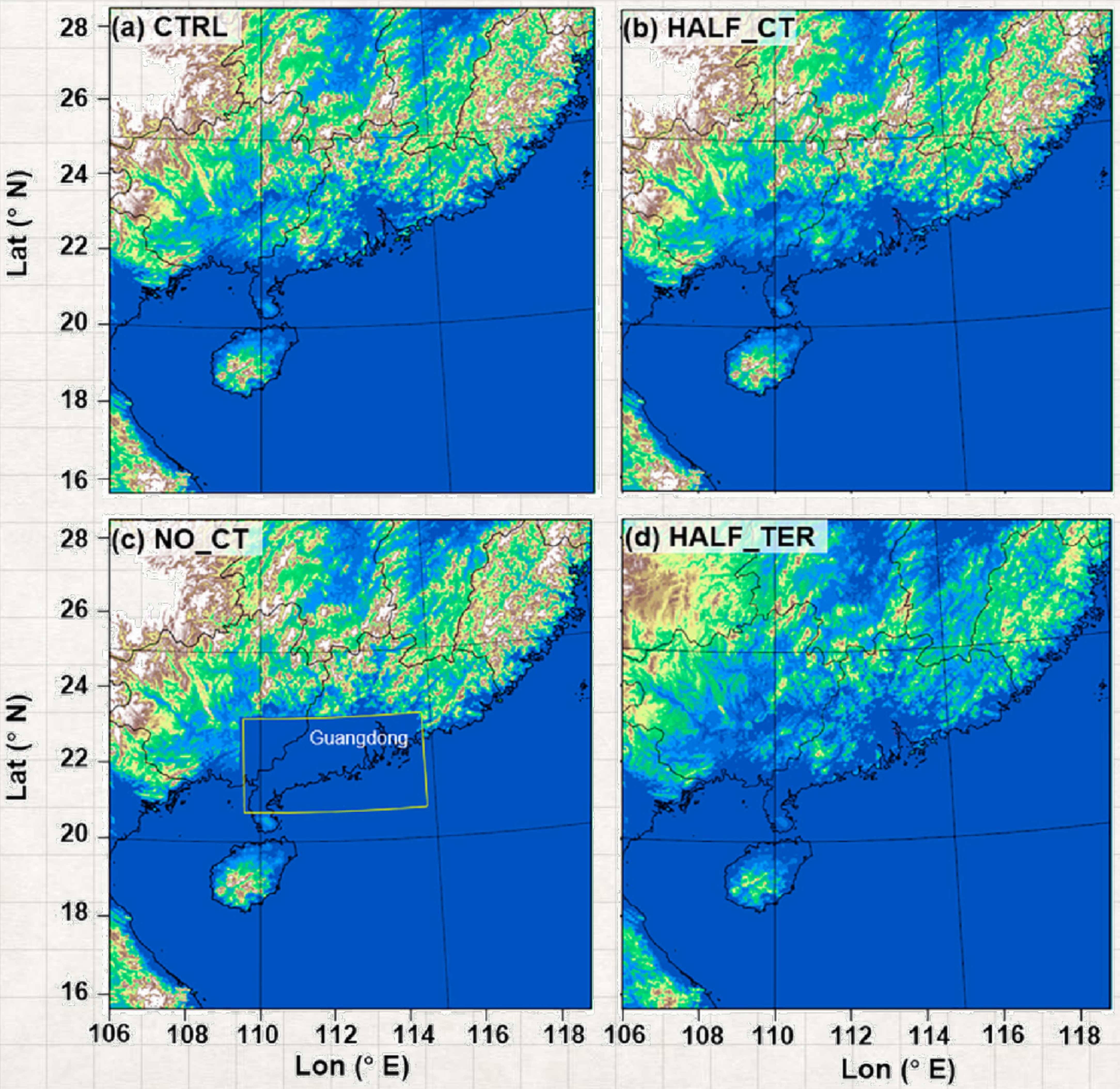
QUASI-IDEALIZED SIMULATIONS AND MODEL CONFIGURATIONS

WRF Version	3.9.1.1
Vertical Layers	51
Spin-up Time	6 hrs
Domain	D01 (2 km)
IC and BC	
IC	1200 UTC Day 1
BC	Every 6 hrs after
Physics Setting	
MP Physics	WSM5
LWR	RRTM
SWR	Dudhia
PBL	YSU



DATA AND METHODS

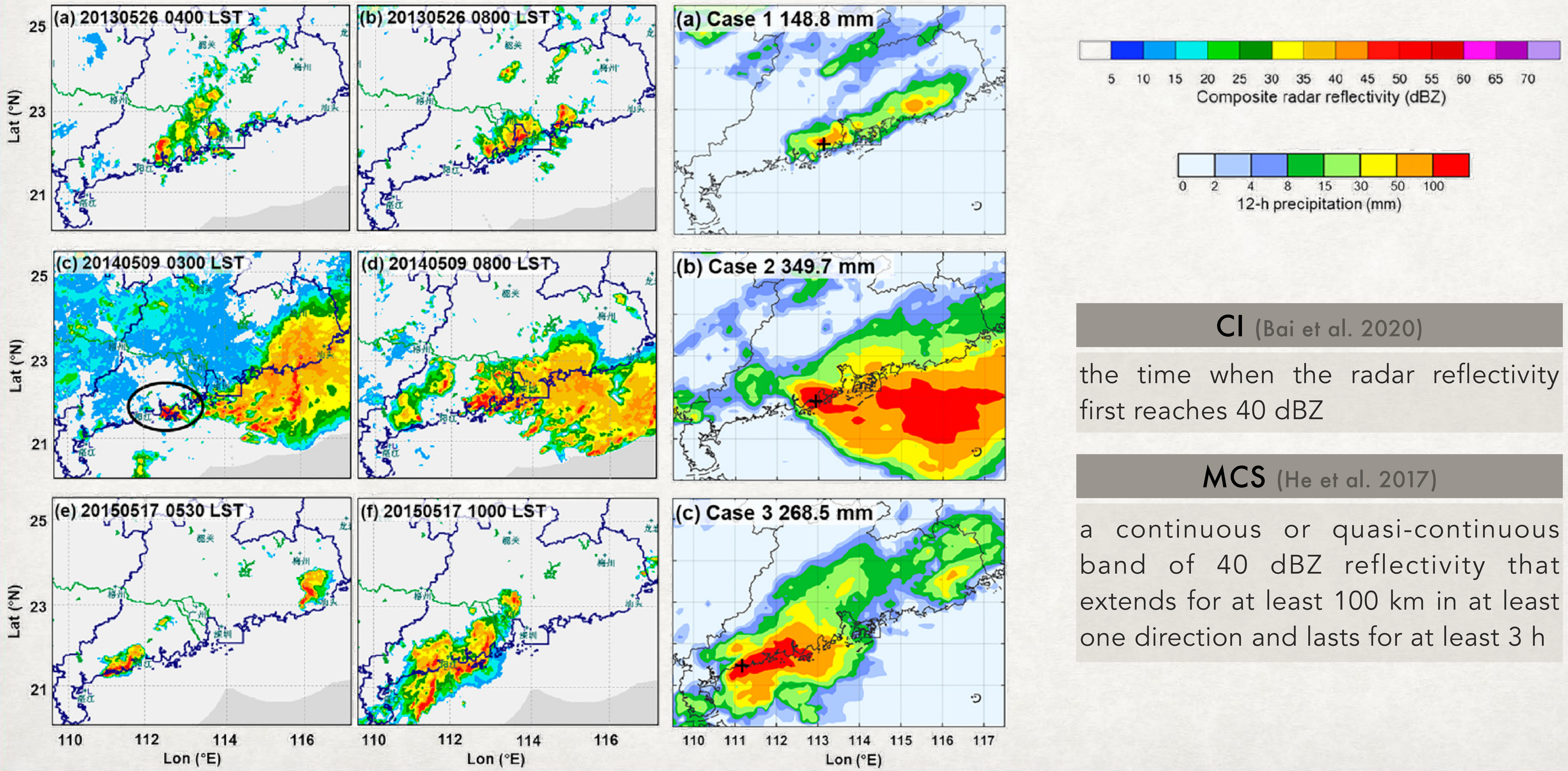
TERRAIN-MODIFICATION SENSITIVITY EXPERIMENT DESIGN



Expt name	Description
CTRL	Control run of quasi-idealized simulation
HALF_CT	Reduce 50% of the coastal terrain (yellow box in Fig. 1c)
NO_CT	Remove coastal terrain
HALF_TER	Reduce 50% of the terrain over whole domain
NO_TER	Remove terrain over whole domain

CASES OVERVIEW AND COMPARISON BETWEEN CTRL AND OBSERVATIONS

CASE OVERVIEW



CI (Bai et al. 2020)

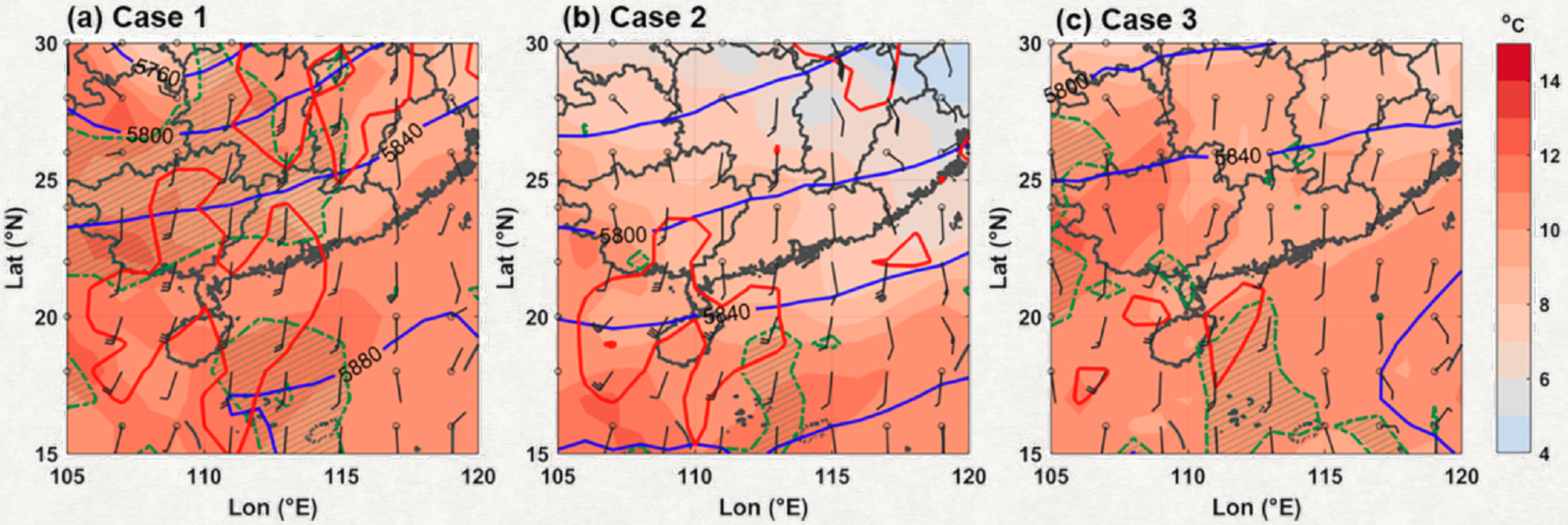
the time when the radar reflectivity first reaches 40 dBZ

MCS (He et al. 2017)

a continuous or quasi-continuous band of 40 dBZ reflectivity that extends for at least 100 km in at least one direction and lasts for at least 3 h

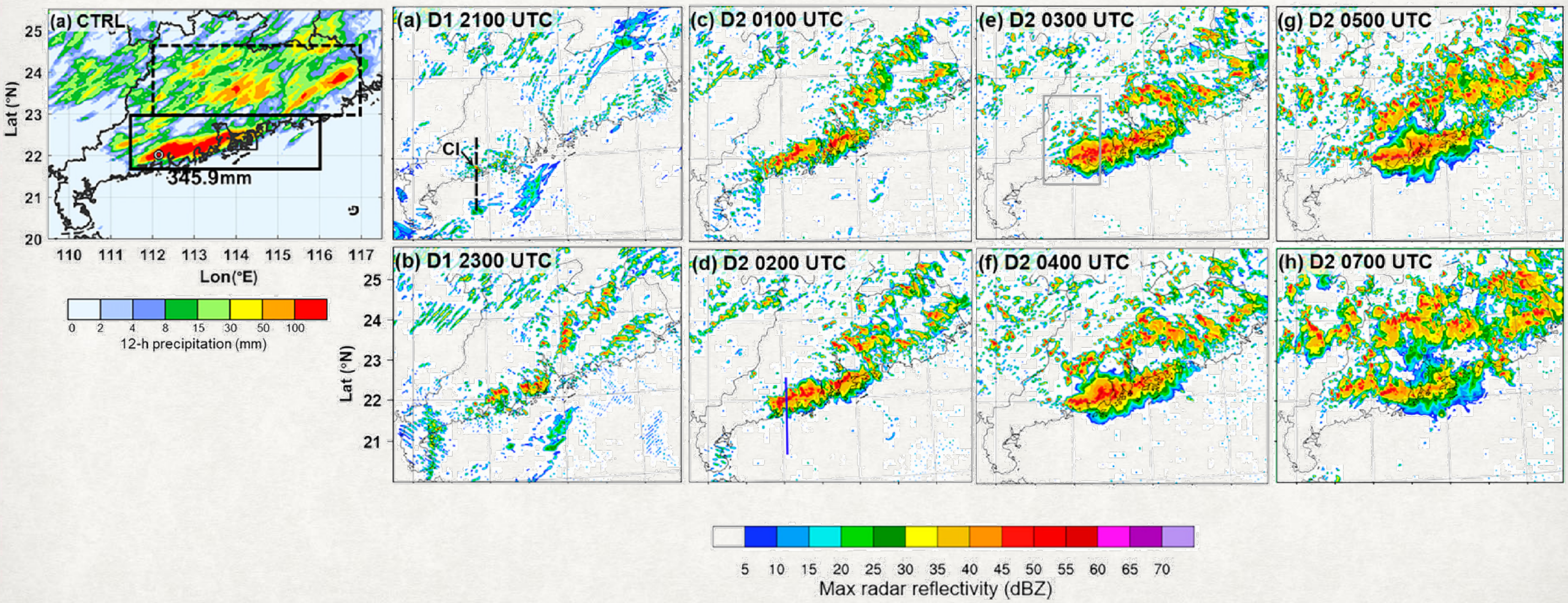
CASES OVERVIEW AND COMPARISON BETWEEN CTRL AND OBSERVATIONS

CASE OVERVIEW

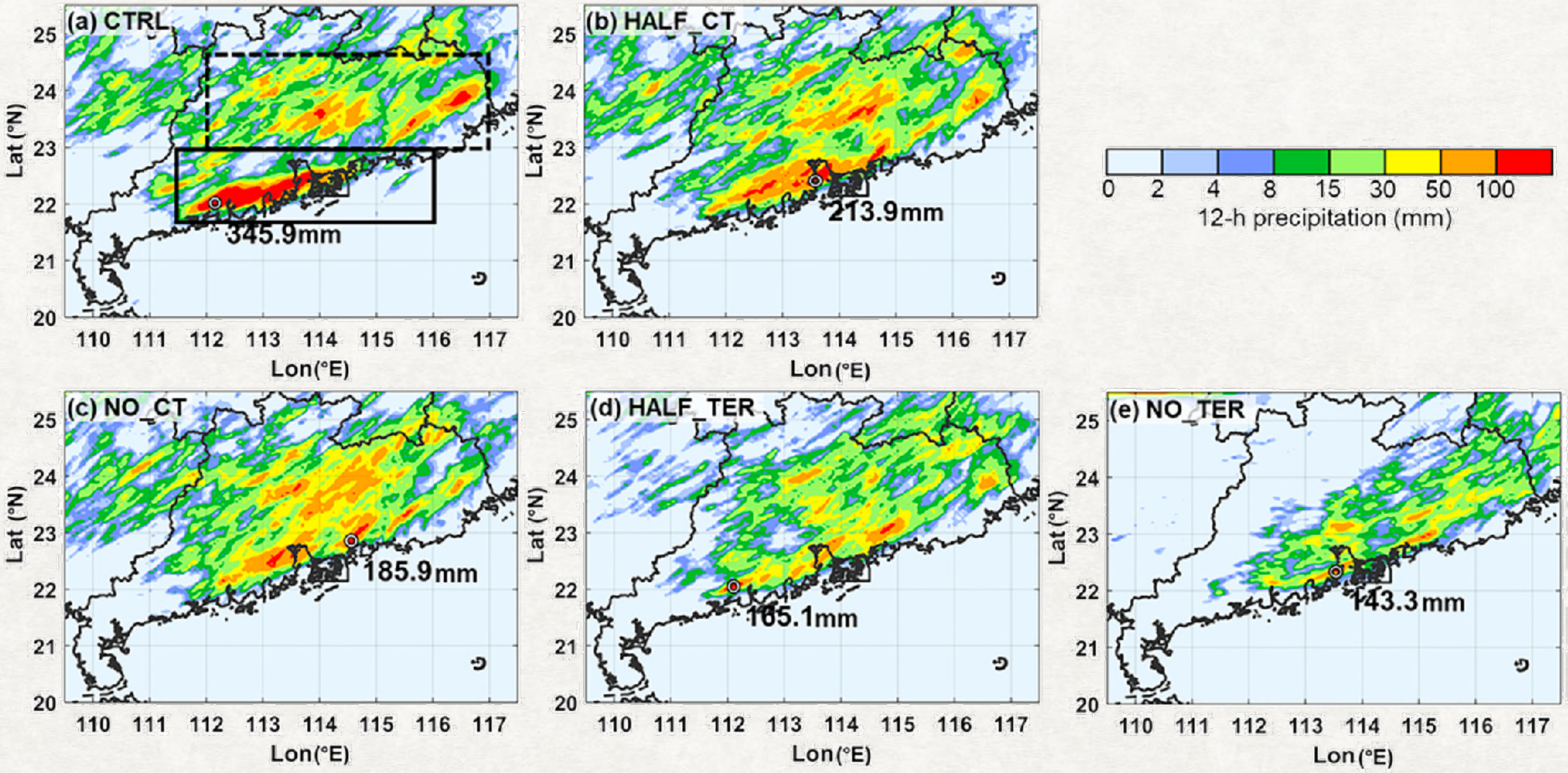


CASES OVERVIEW AND COMPARISON BETWEEN CTRL AND OBSERVATIONS

CONTROL RUN (CTRL)



RESPONSES OF HEAVY RAINFALL AND MCS TO TERRAIN CHANGES



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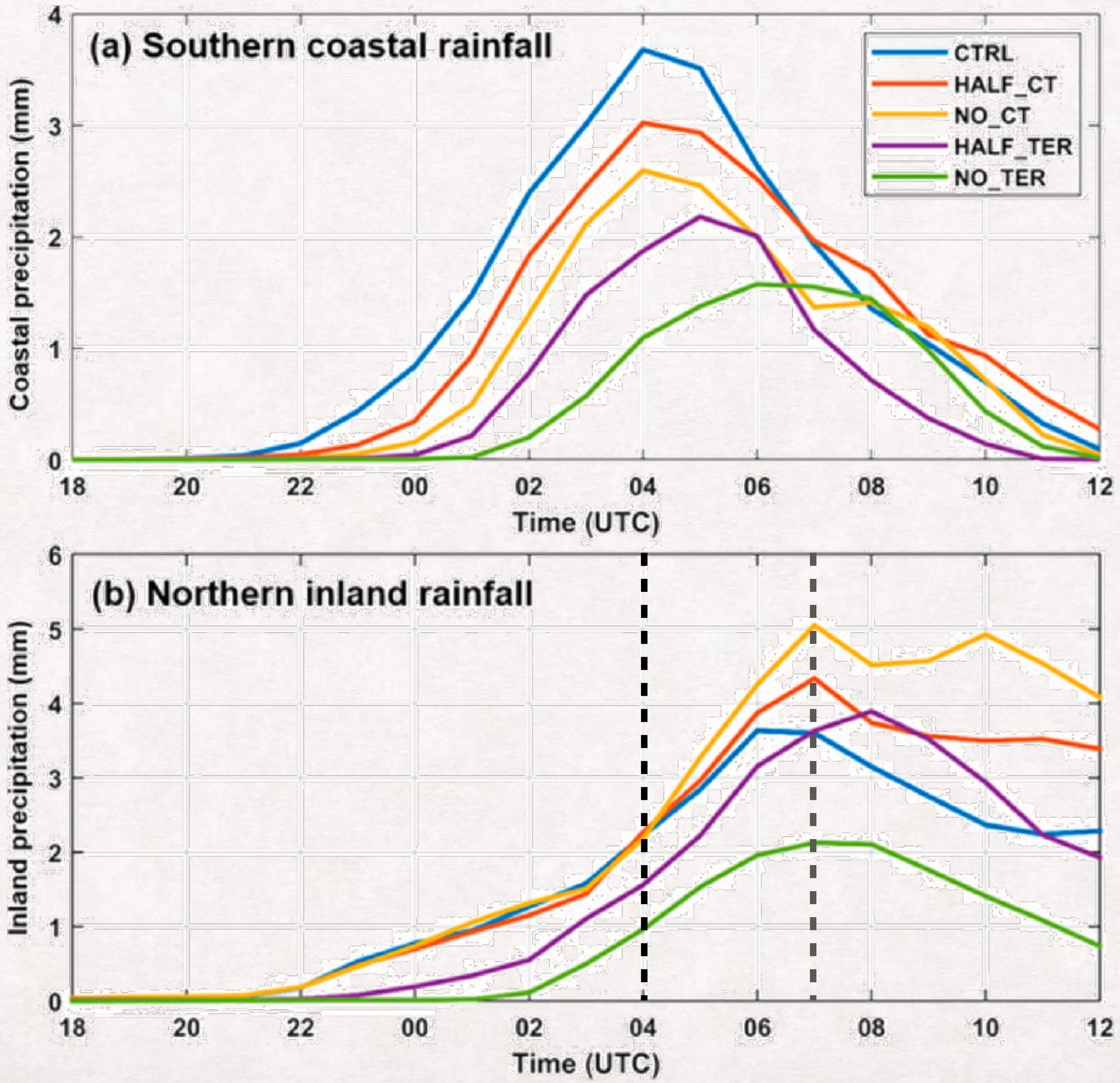
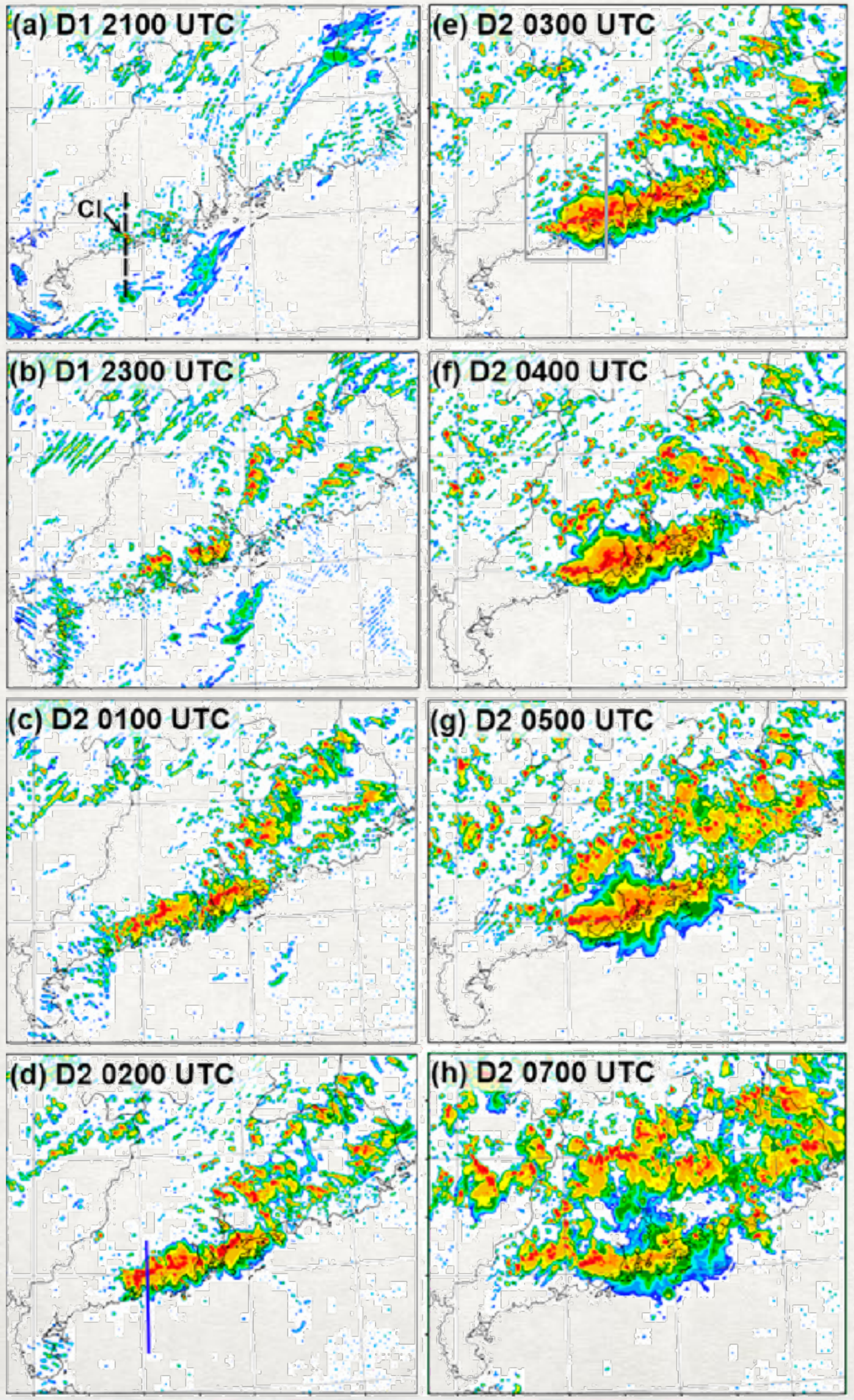
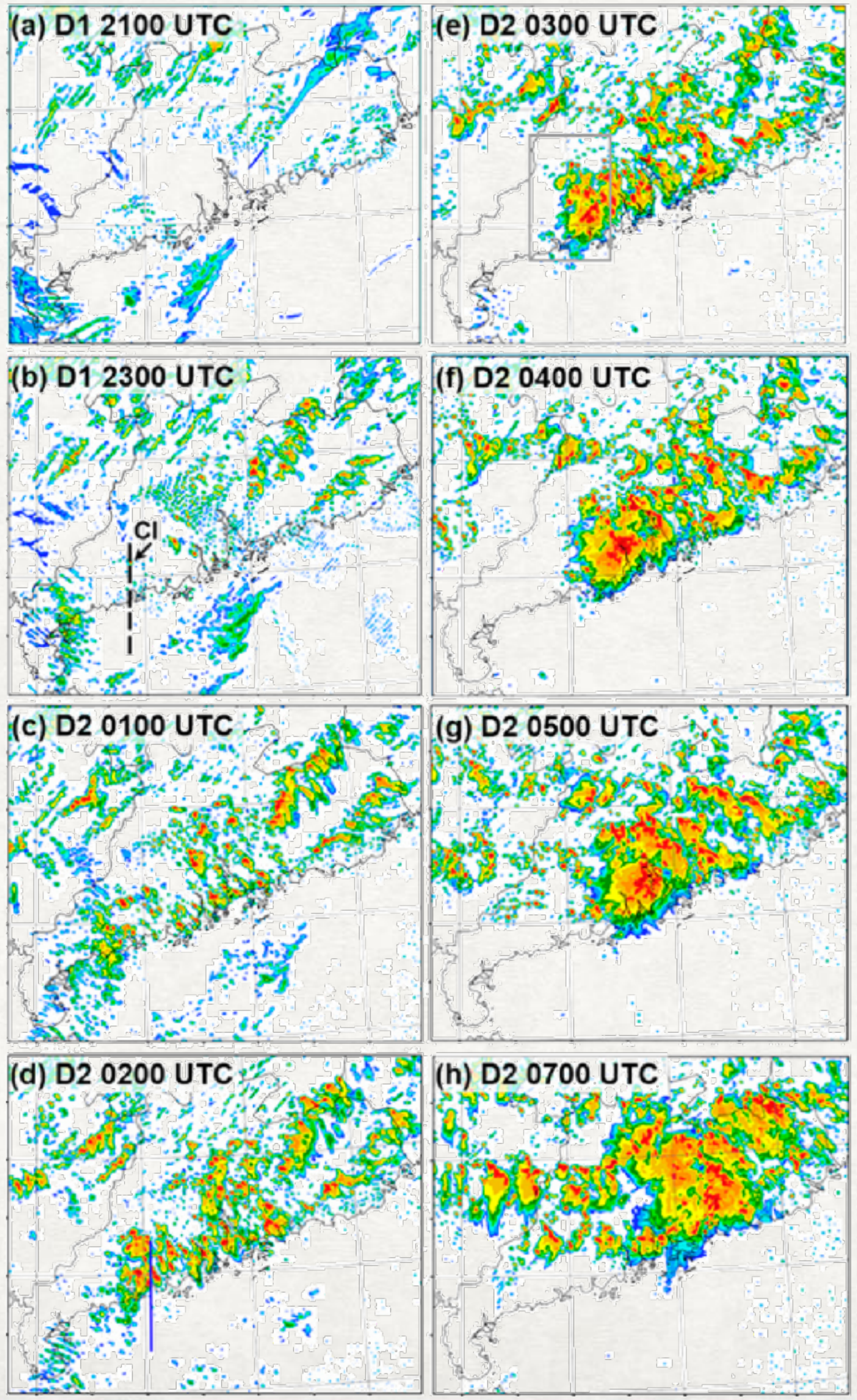
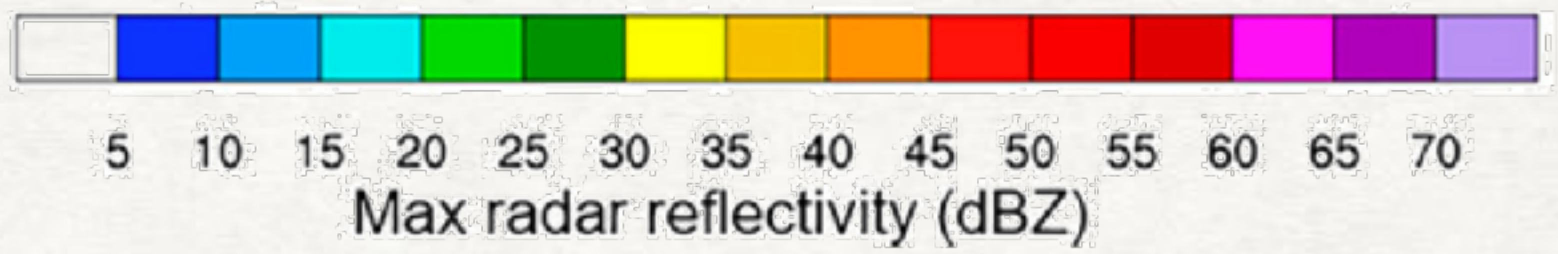


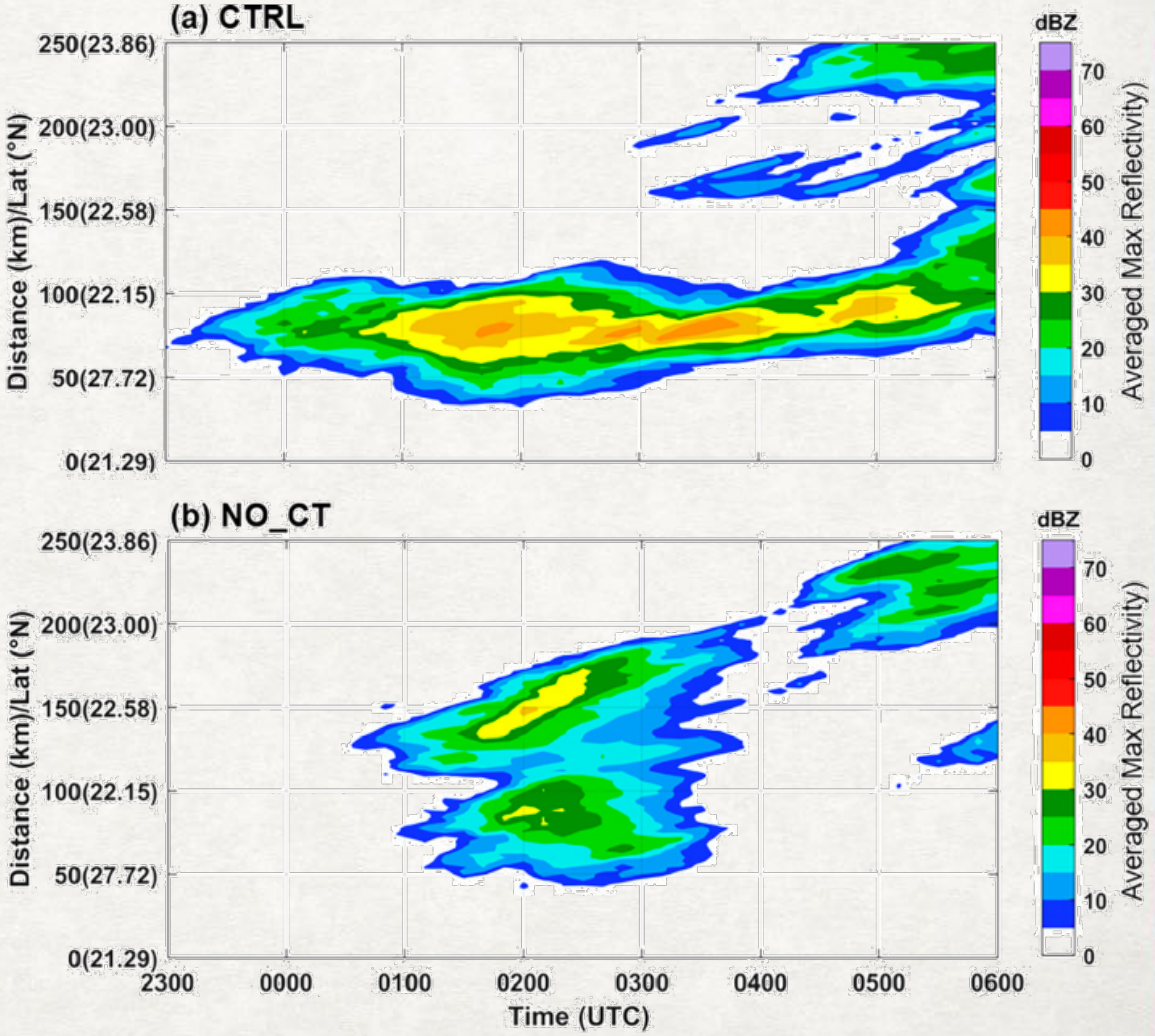
RESPONSES OF HEAVY RAINFALL AND MCS TO TERRAIN CHANGES

CTRL AND NO_CT









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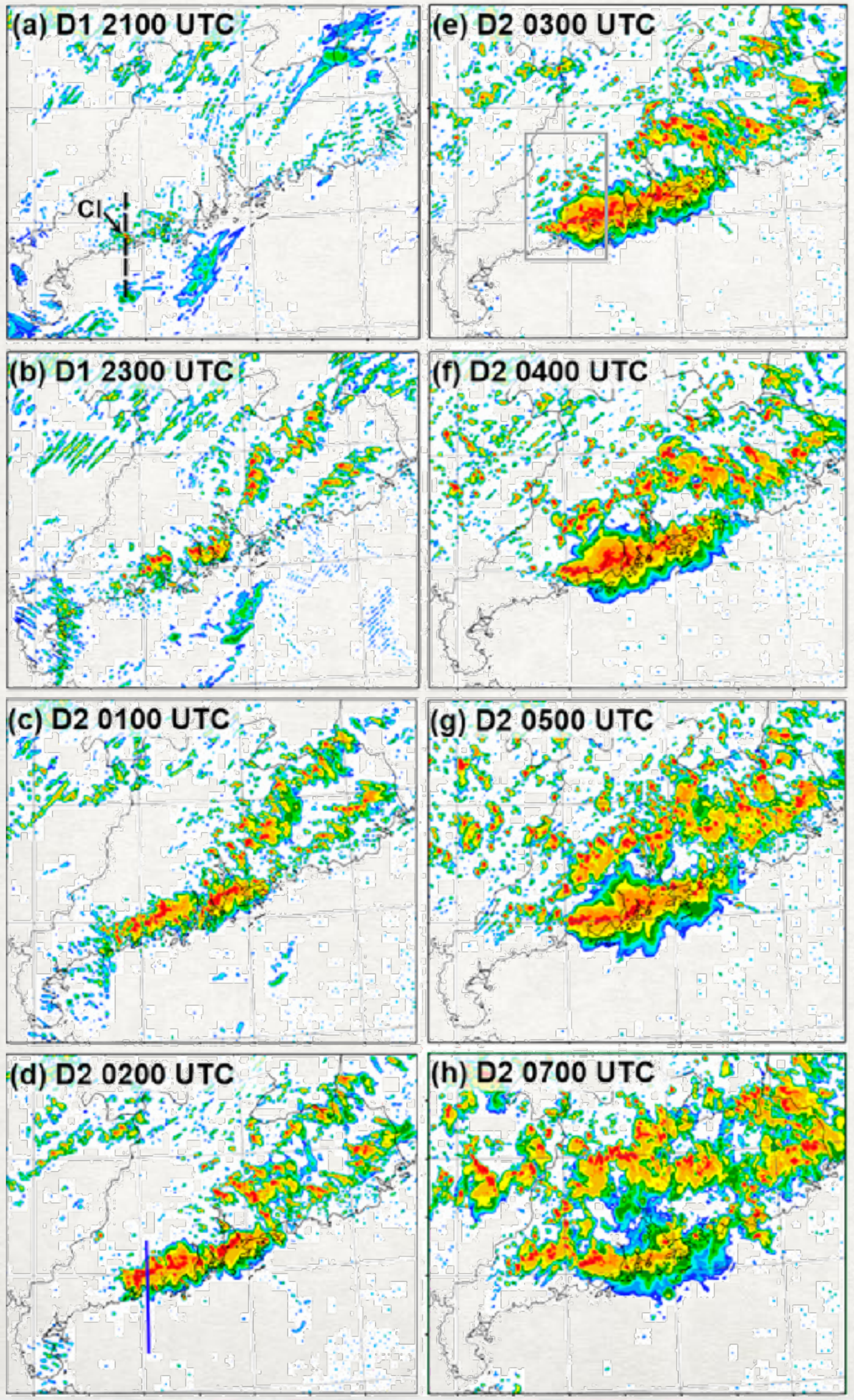
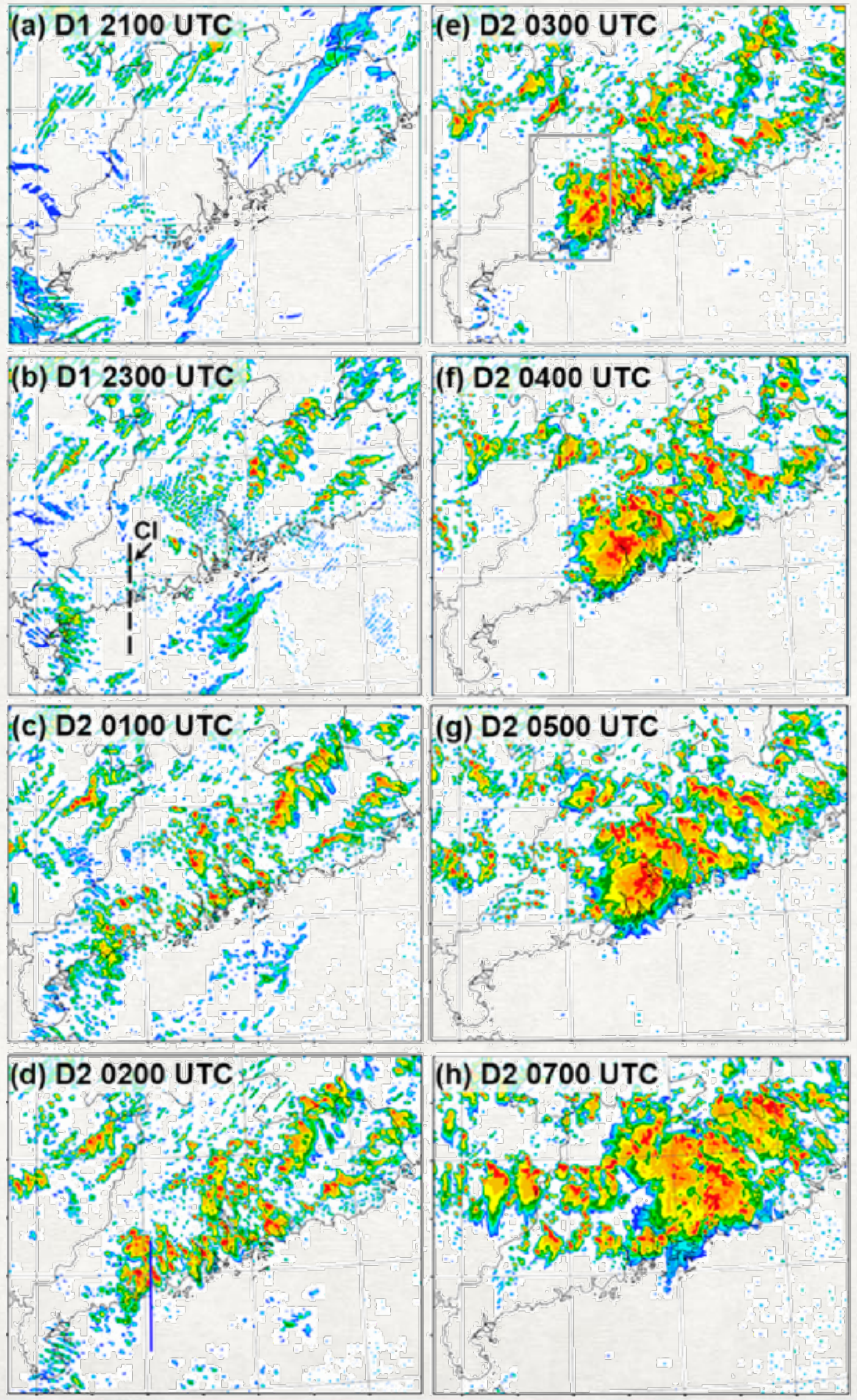
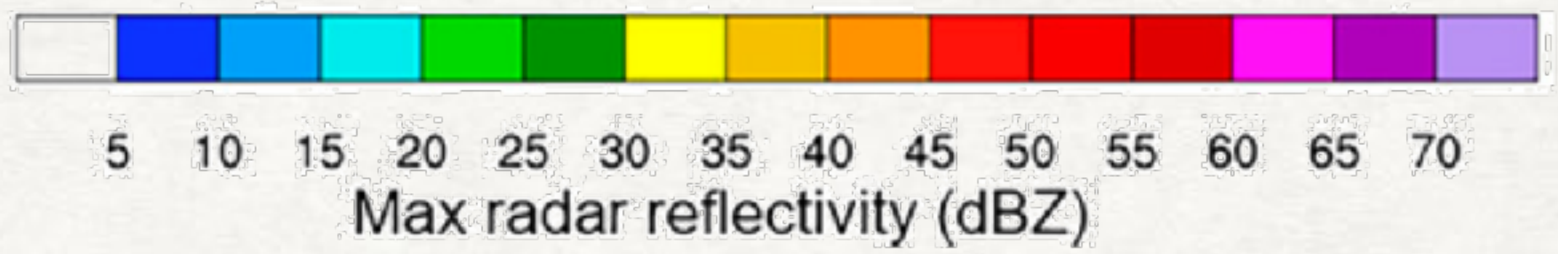
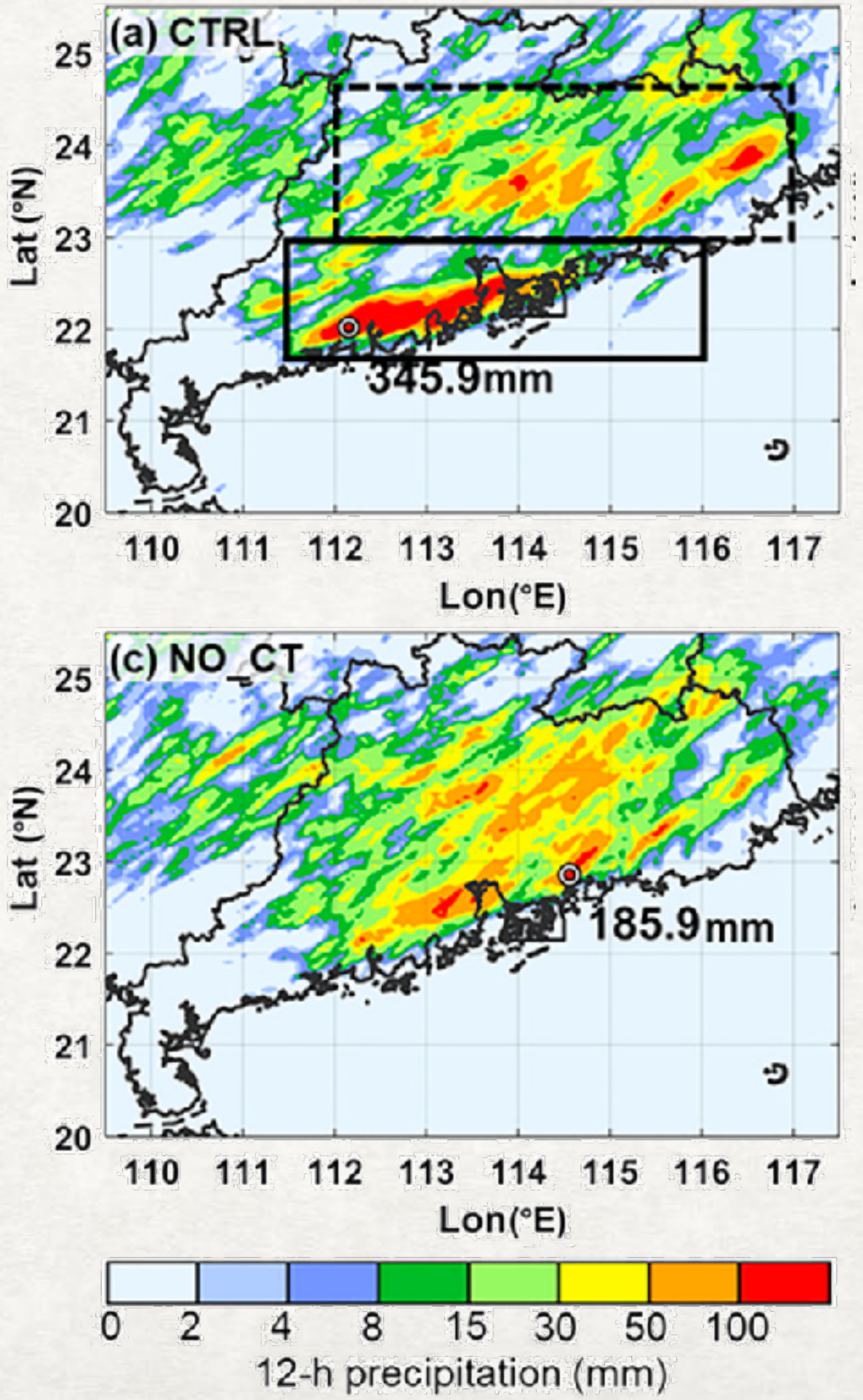
CTRL AND NO_CT



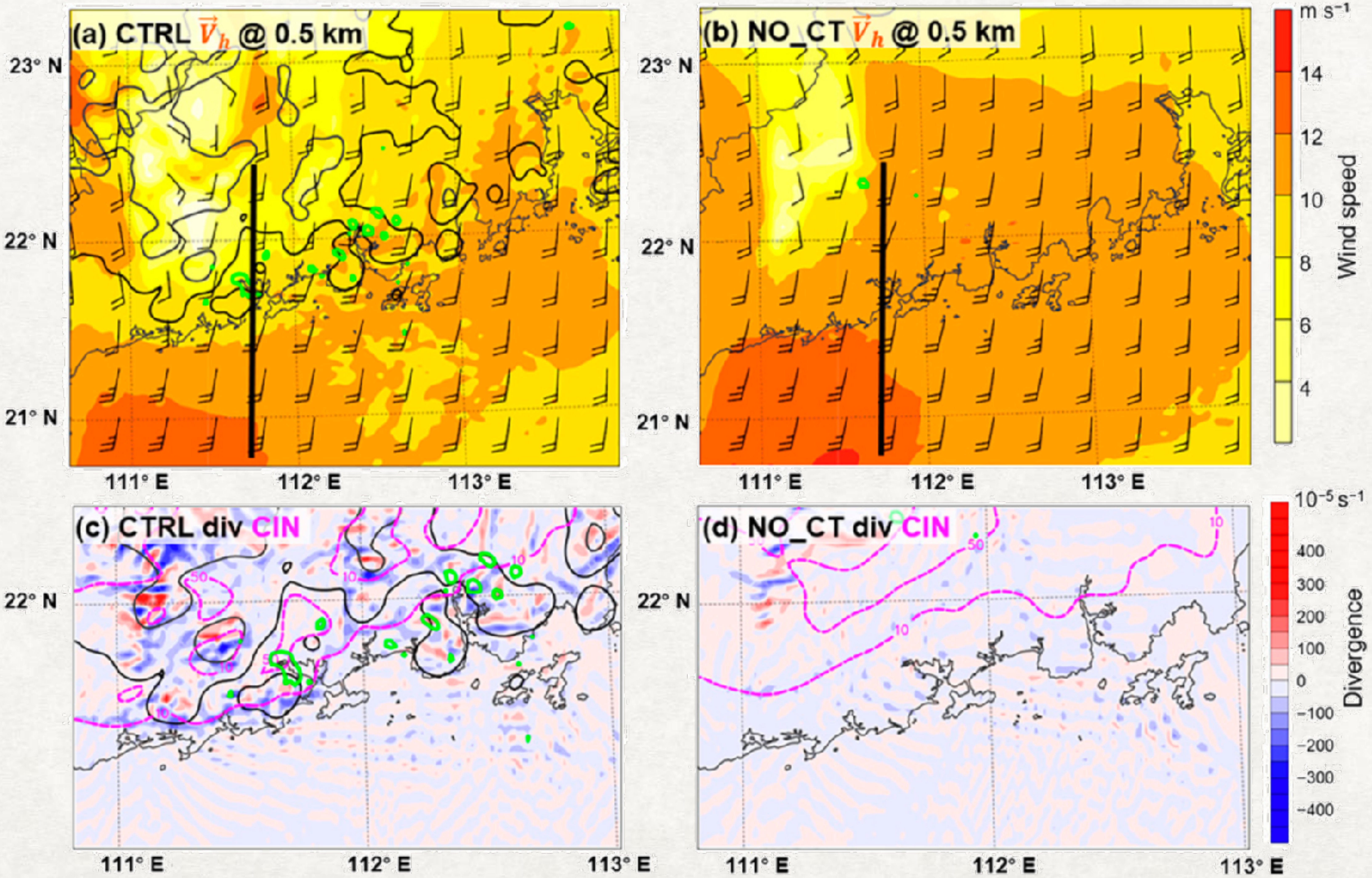






COASTAL TERRAIN INFLUENCE ON THE INITIATION AND ORGANIZATION OF THE MCS

CONVECTION INITIATION



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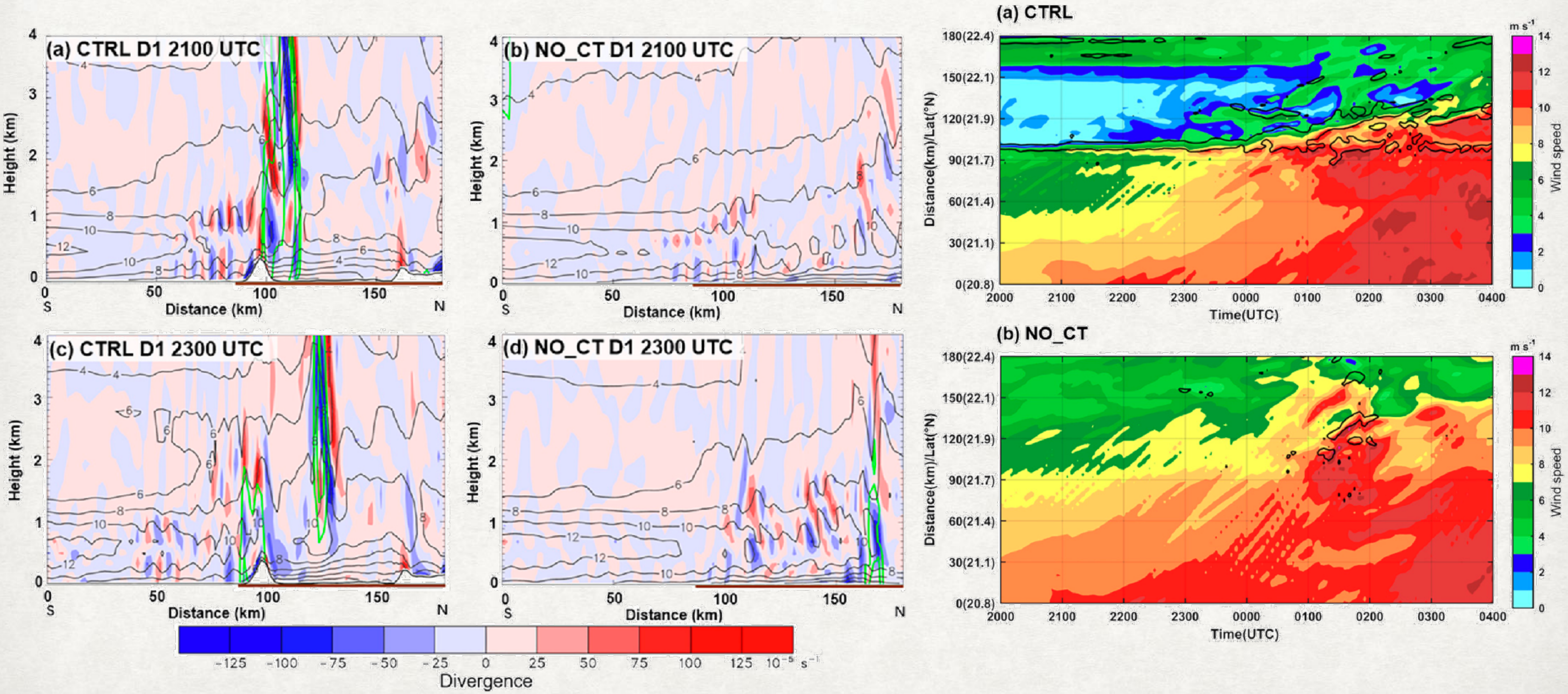
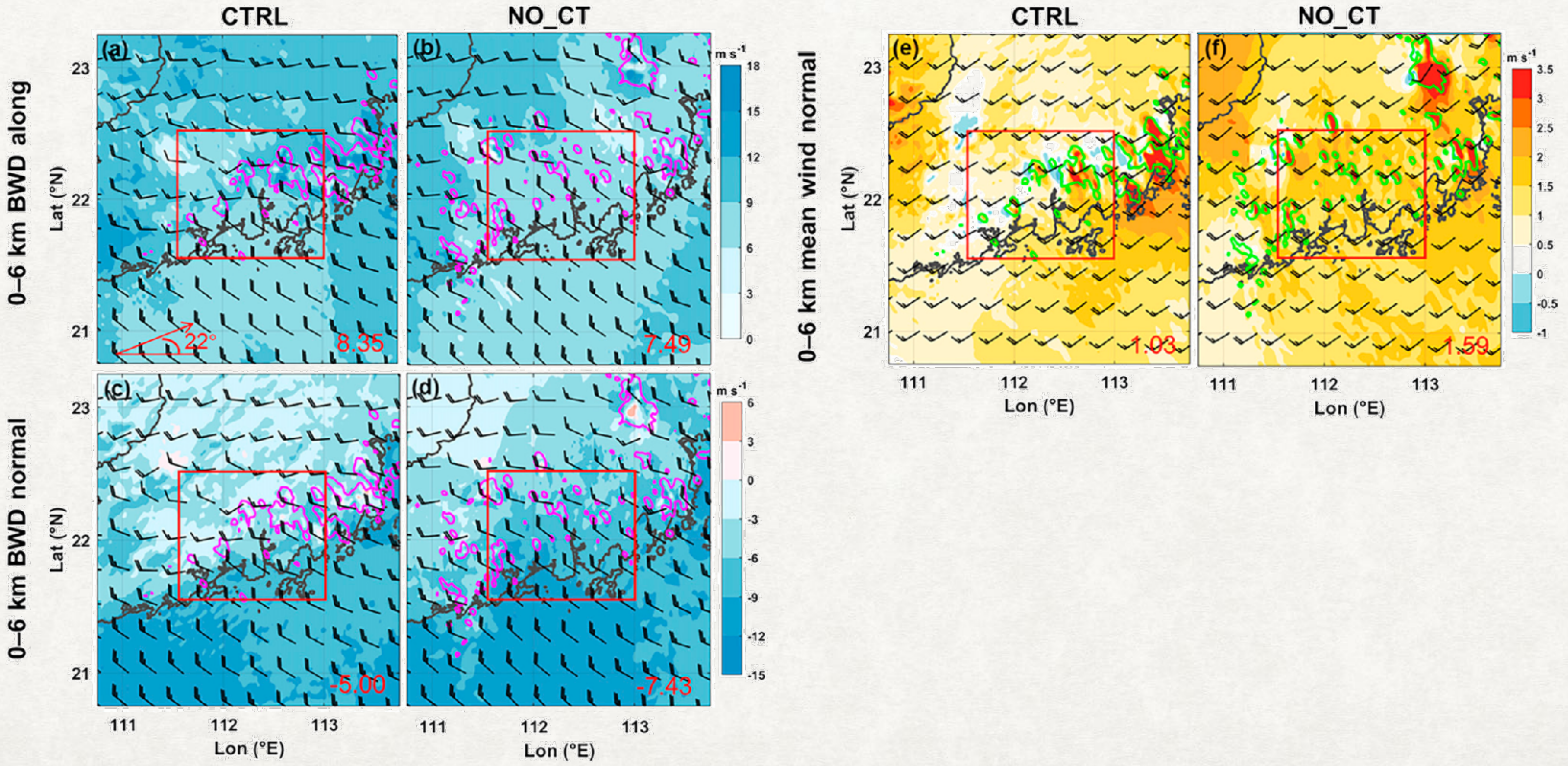


COASTAL TERRAIN INFLUENCE ON THE INITIATION AND ORGANIZATION OF THE MCS

MCS ORGANIZATION



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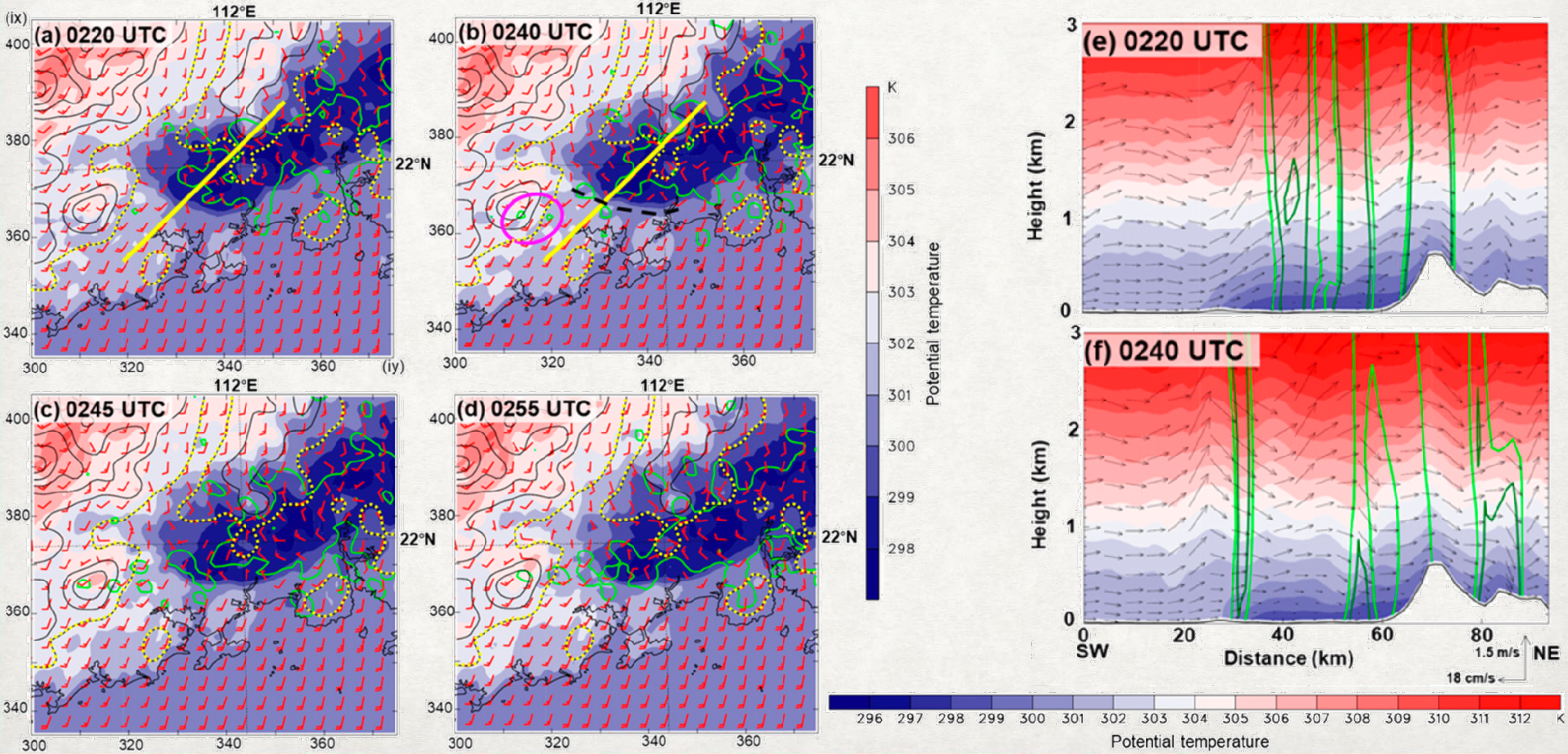
MCS ORGANIZATION



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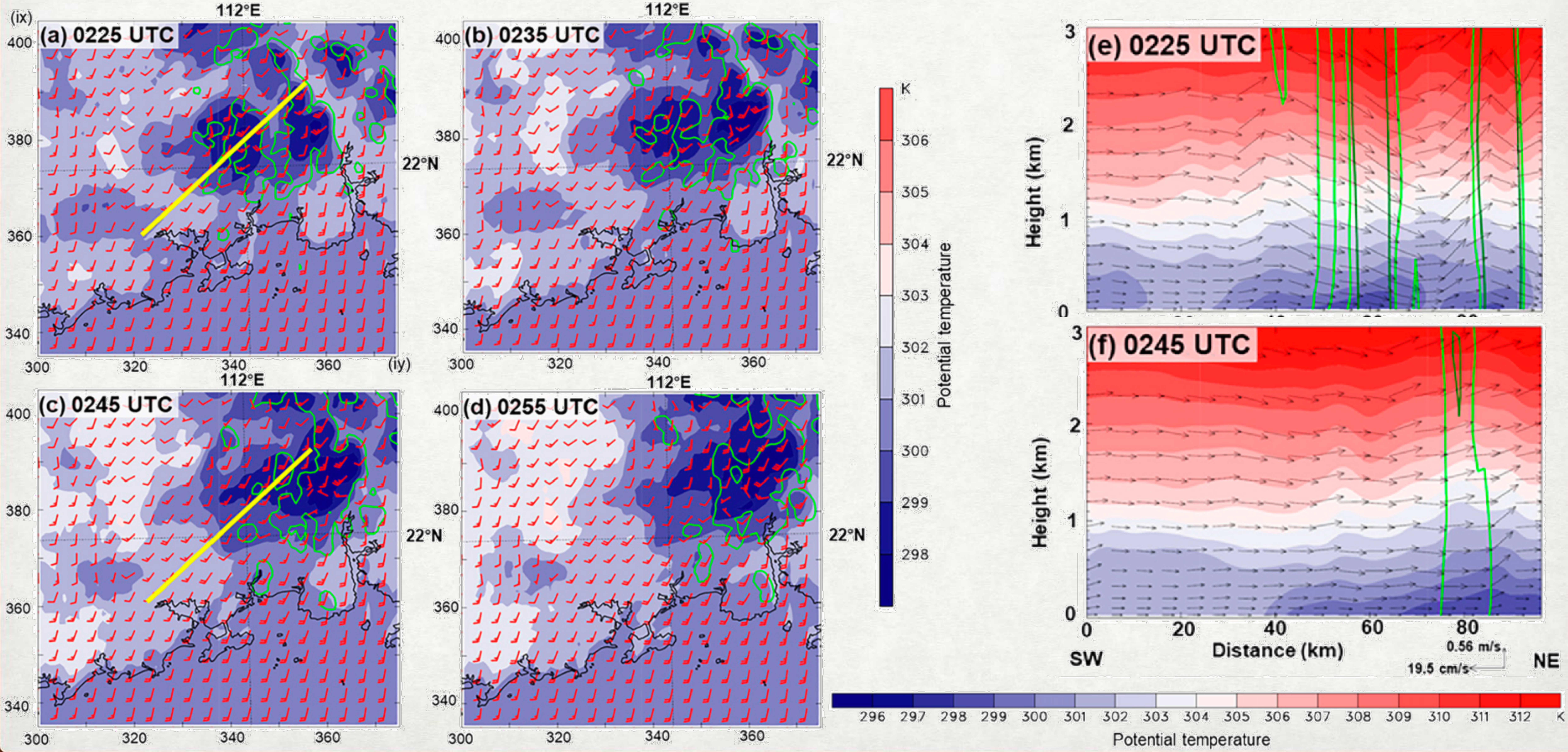
MCS ORGANIZATION



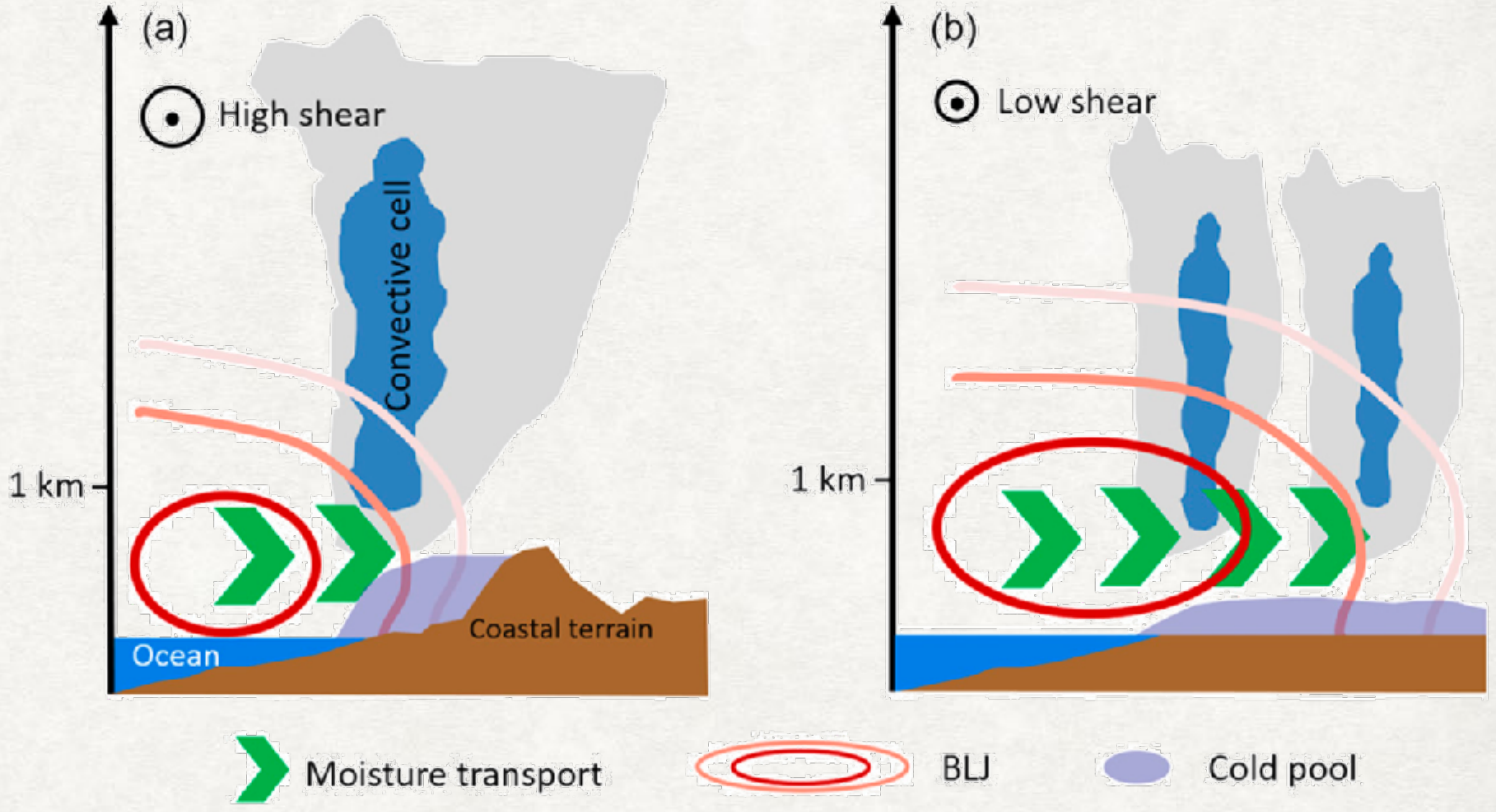
SUMMARY

CI:

1. There is a weaker BLJ with a stronger horizontal wind speed gradient and convergence near the coast in CTRL compared with NO_CT.
2. The convection initiates ~2h earlier as the BLJ impinges on the coastal terrain in the early morning.

Dynamic and Thermodynamic Environments:

1. The weaker near-surface winds due to the friction of the coastal terrain result in a smaller 0–6-km vertical wind shear component perpendicular to the coast and a larger component parallel to the coast.
2. The environmental 0–6-km mean wind is also weakened by the coastal terrain.
3. The coastal terrain traps the cold pool which favors the persistent generation of new cells on the western side of the MCS.



Thanks for listening!