The role of diurnal solenoidal circulation on propagating rainfall episodes near the eastern Tibetan Plateau

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2nd SoWMEX/TiMREX SCIENCE WORKSHOP
CWB, Taipei, *2009/10/20*

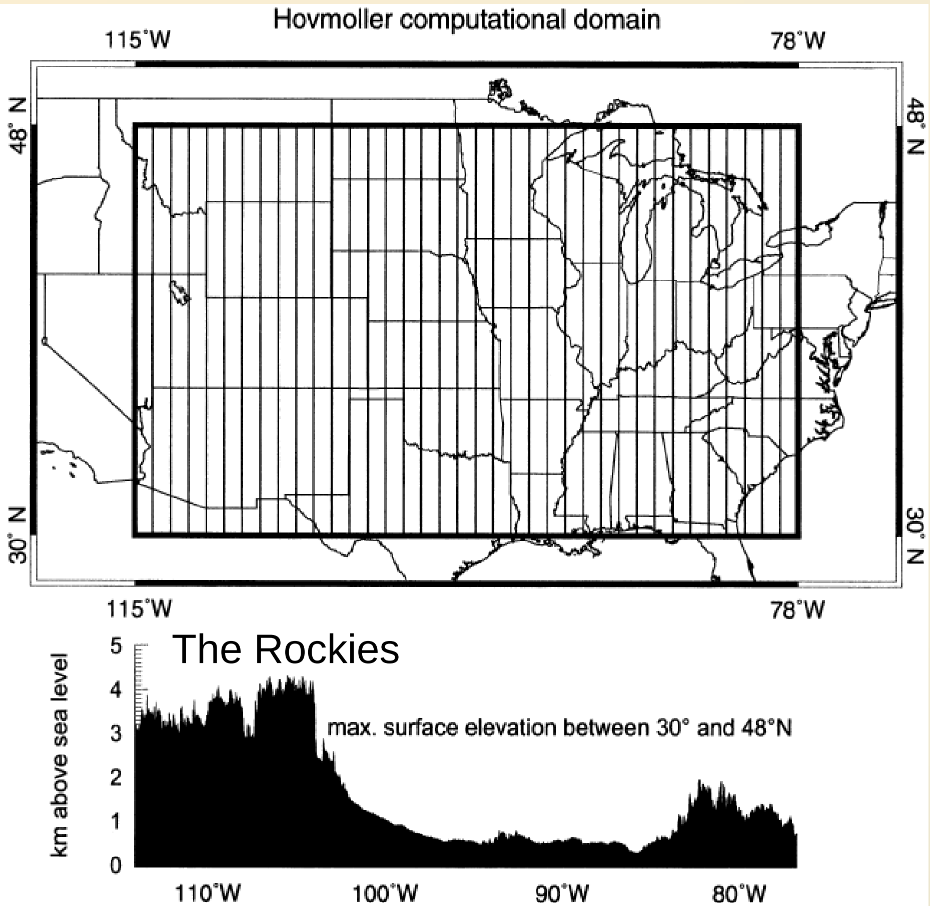
Presentation outline

1. Research background
2. Case description
3. WRF model domain and physics
4. Result of control experiment (CT)
5. Sensitivity tests (NR and RT runs)
6. Summary

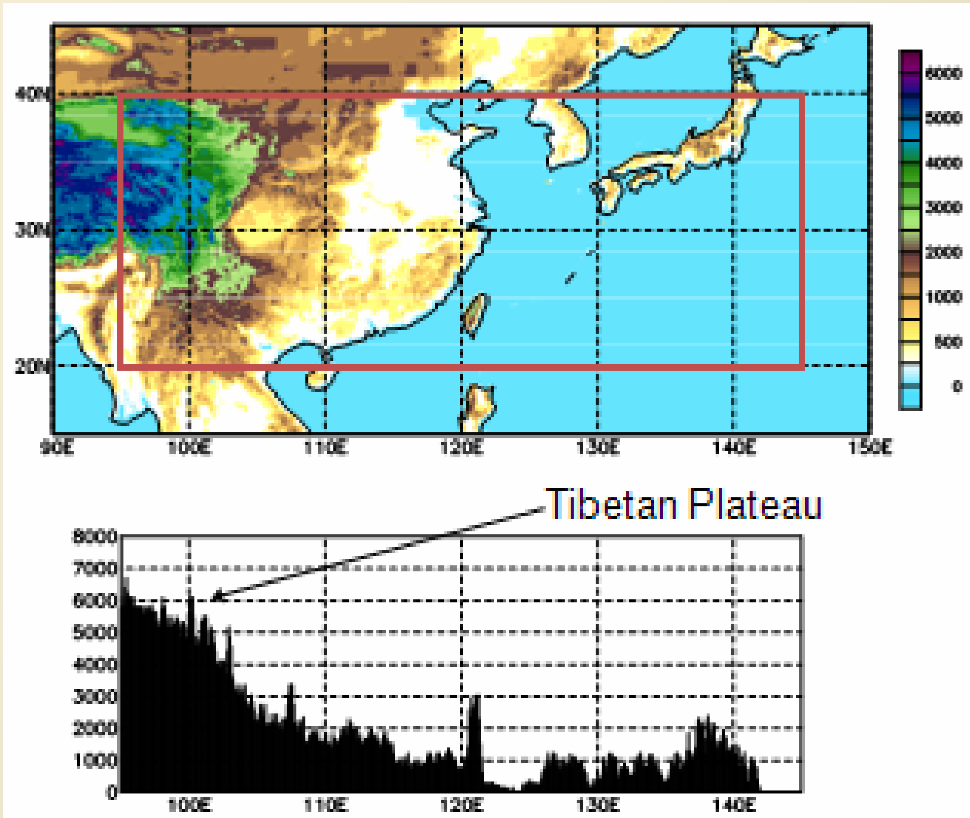
1. Research background

- Present skills for warm-season quantitative precipitation forecasts (QPFs) are low all over the world
- One area where improvements can be made is to the lee of major mountains, such as the Rockies in the North America and the Tibetan Plateau (TP) in the East Asia

Continental US
(*Carbone et al. 2002*)



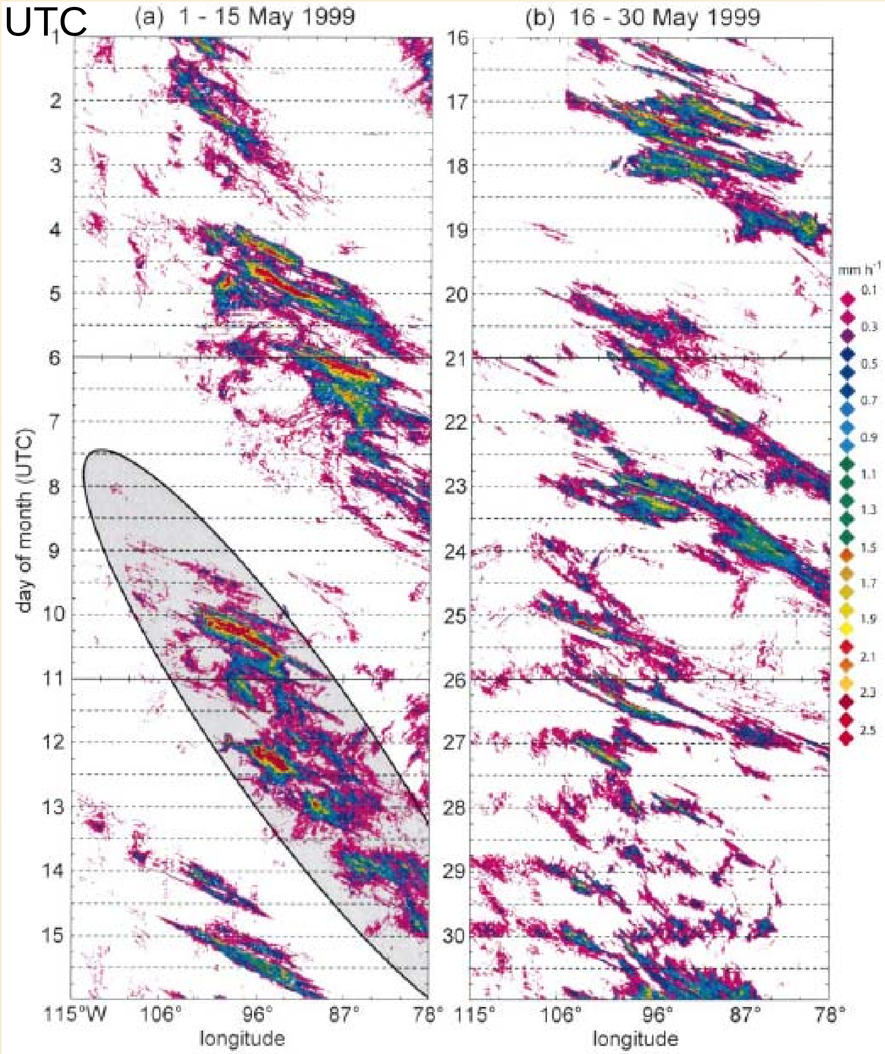
East Asia
(*Wang et al. 2004*)



Example in Hovmöller plots (selected one-month period)

Continental US

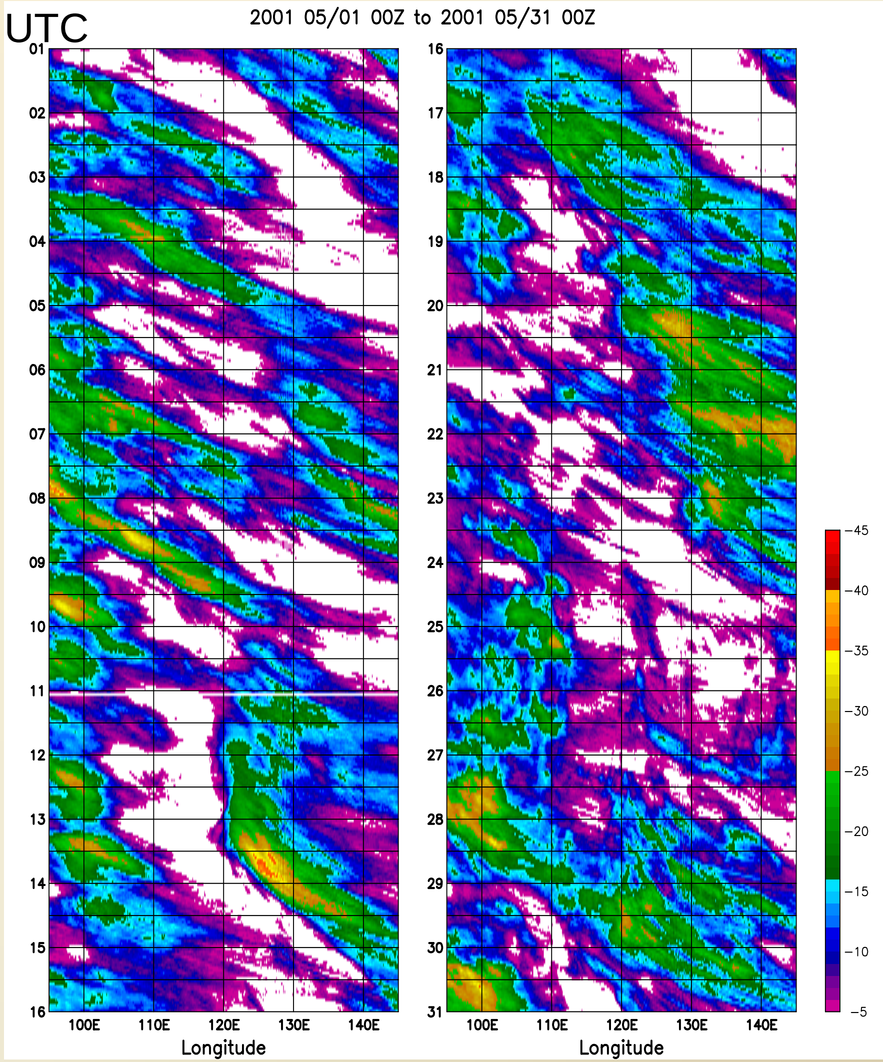
NEXRAD (4 km, 15 min), May 1999



Carbone et al. (2002)

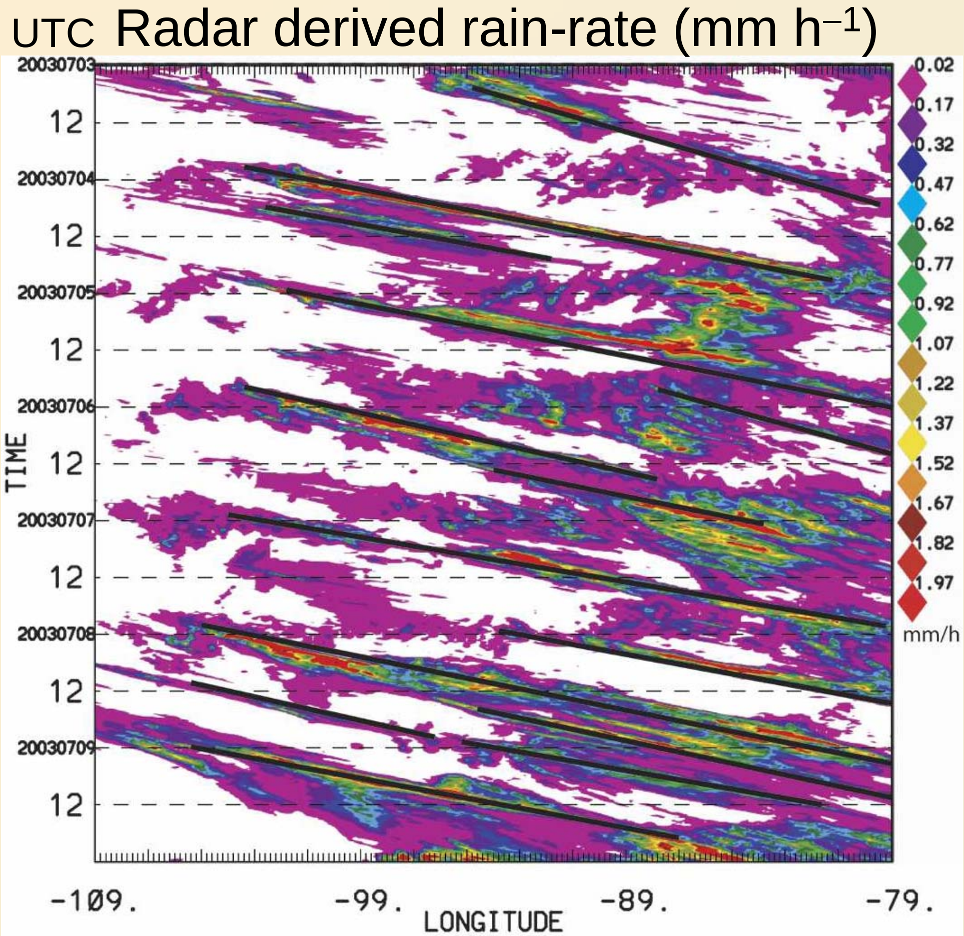
East Asia

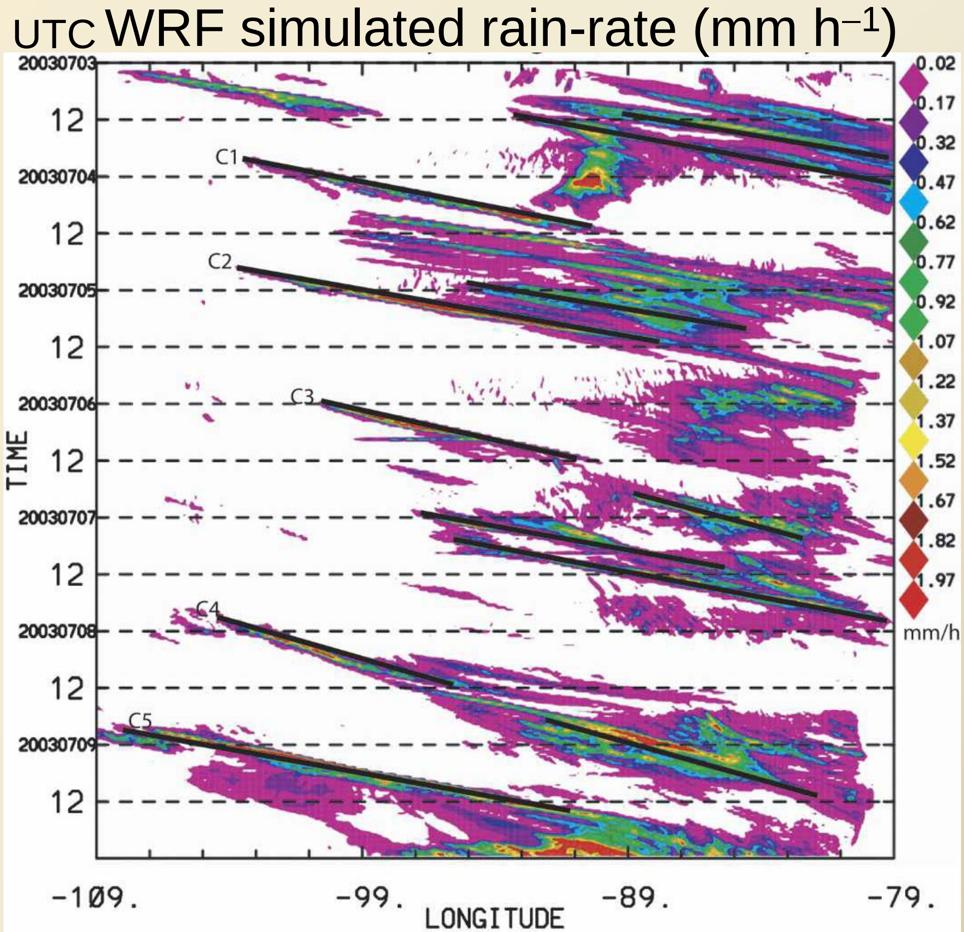
GMS T_B (5 km, 1 h), May 2001



Wang et al. (2004)

Radar observation vs 4-km WRF simulation in the US





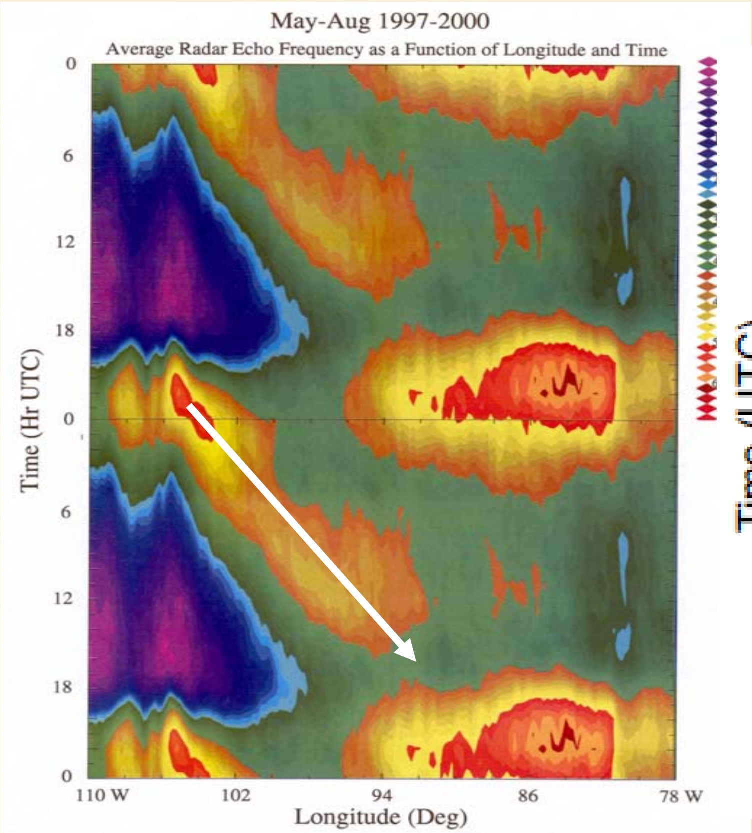
Trier et al. (2006)

- In Hovmöller (longitude-time) space, precipitation/cloud episodes exhibit coherent behavior of downstream propagation
  - Zonal speed at 10-25 m s^{-1} with westerly steering flow aloft
  - Some with long duration (>24 h) and zonal span (>1000 km), suggesting intrinsic predictability
  - Often consist of multiple organized MCSs

Diurnal cycle tied to elevated terrain

Continental US

Radar echo frequency

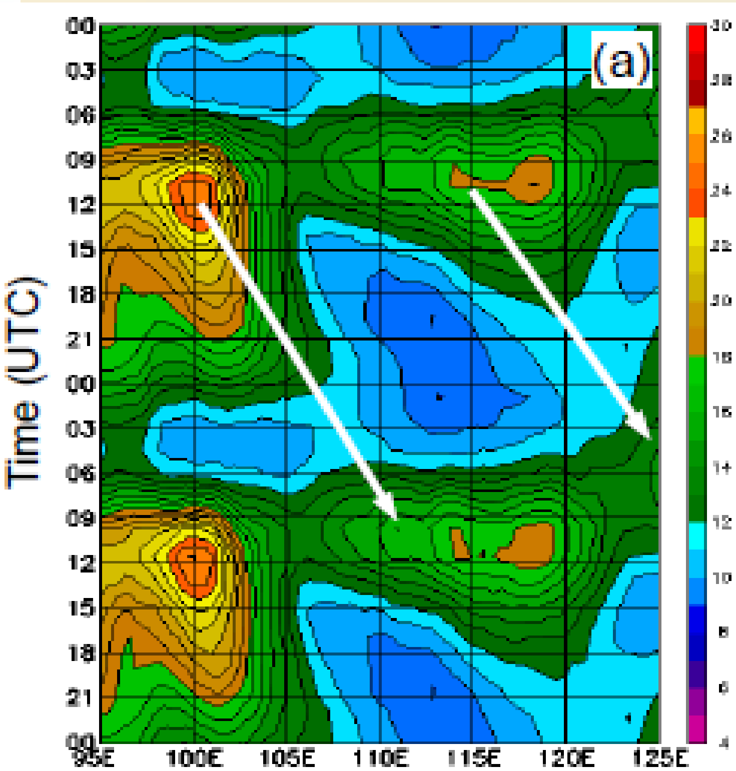


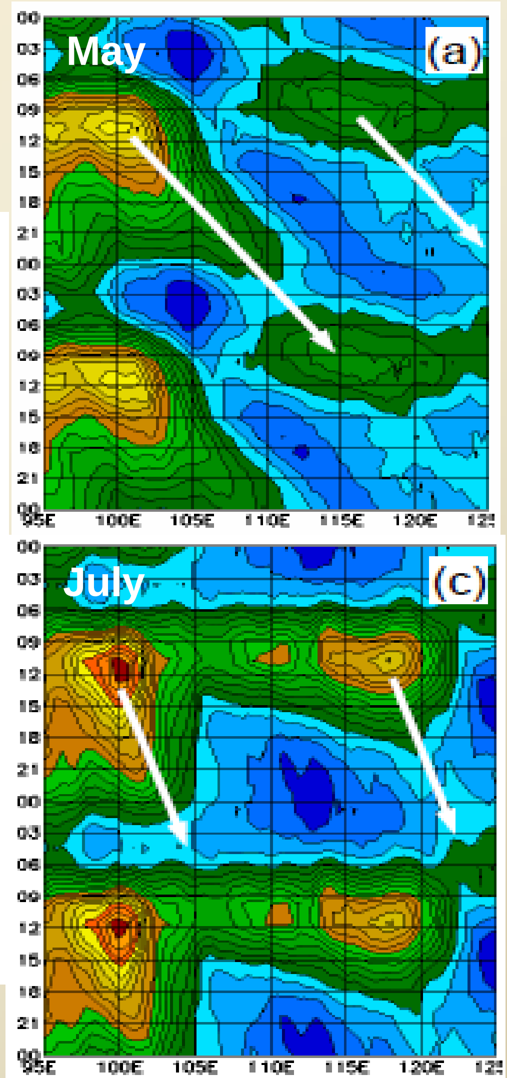
Carbone et al. (2002)

East Asia

Cold cloud (<–32ºC) frequency

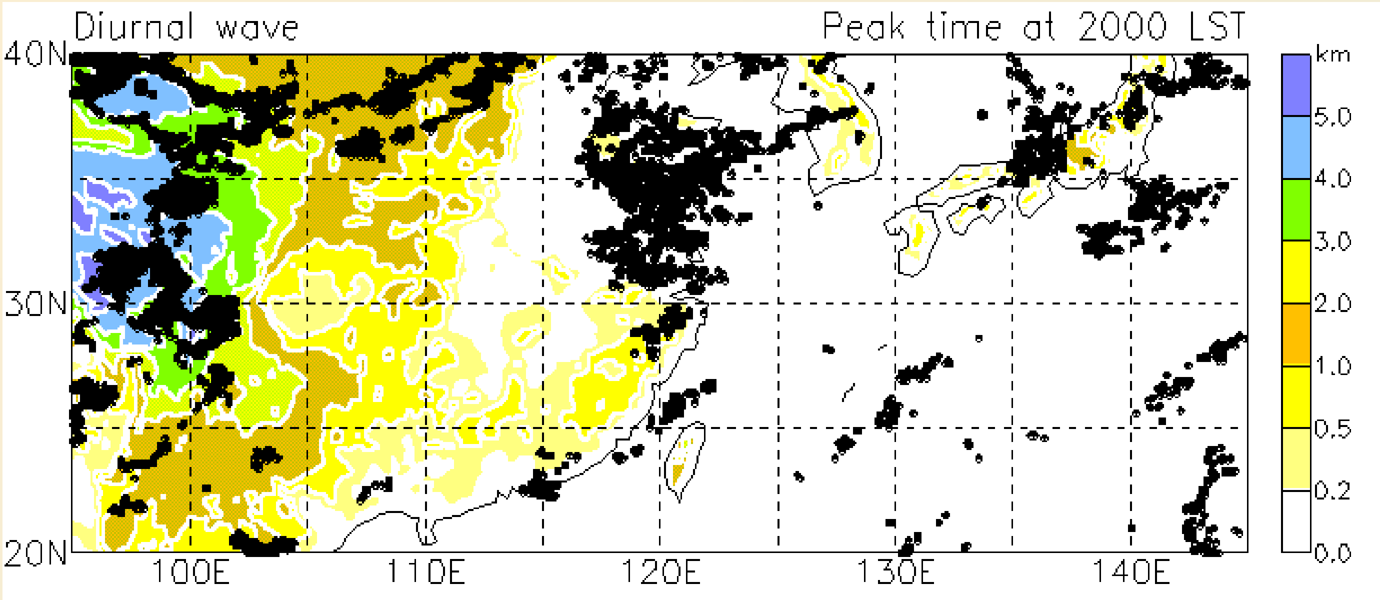
25º-40ºN, May-Aug 1997-2003





Wang (2007)

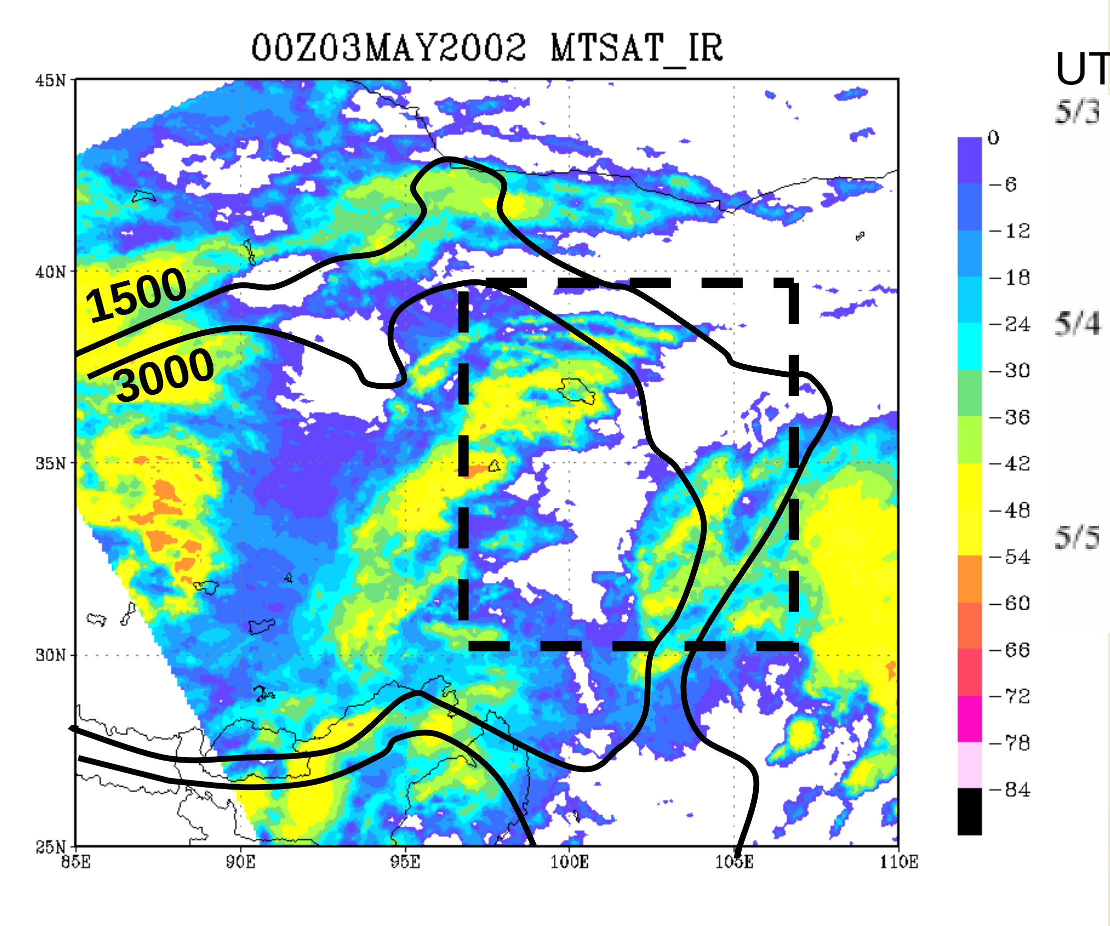
➢ Peaking time (LST) of highest cold cloud frequency in a day



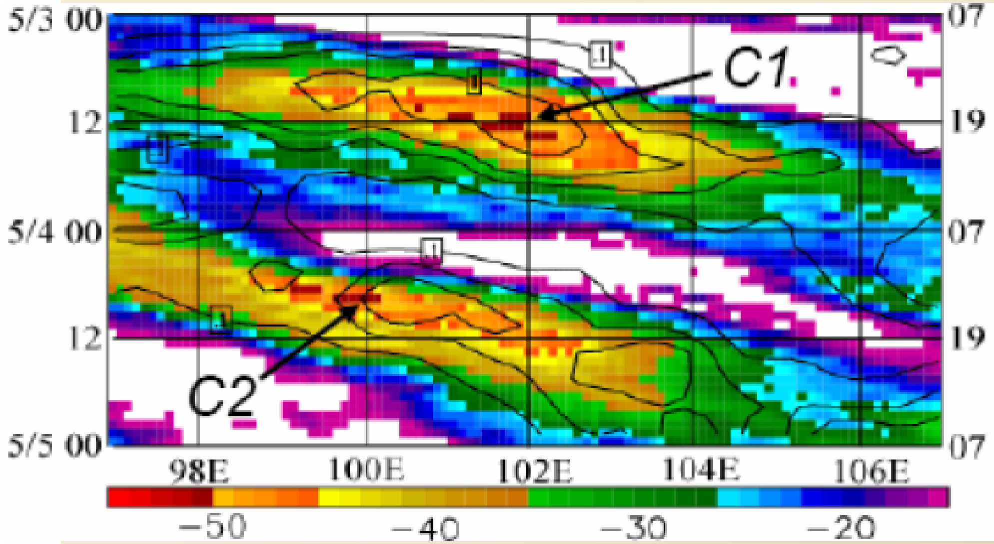
➢ Episodes have close ties to elevated terrain:
- Develop over the eastern slope in afternoon, then propagate eastward (downstream) overnight, sometime into the next day

2. Case description

- Case period: 3-5 May 2002

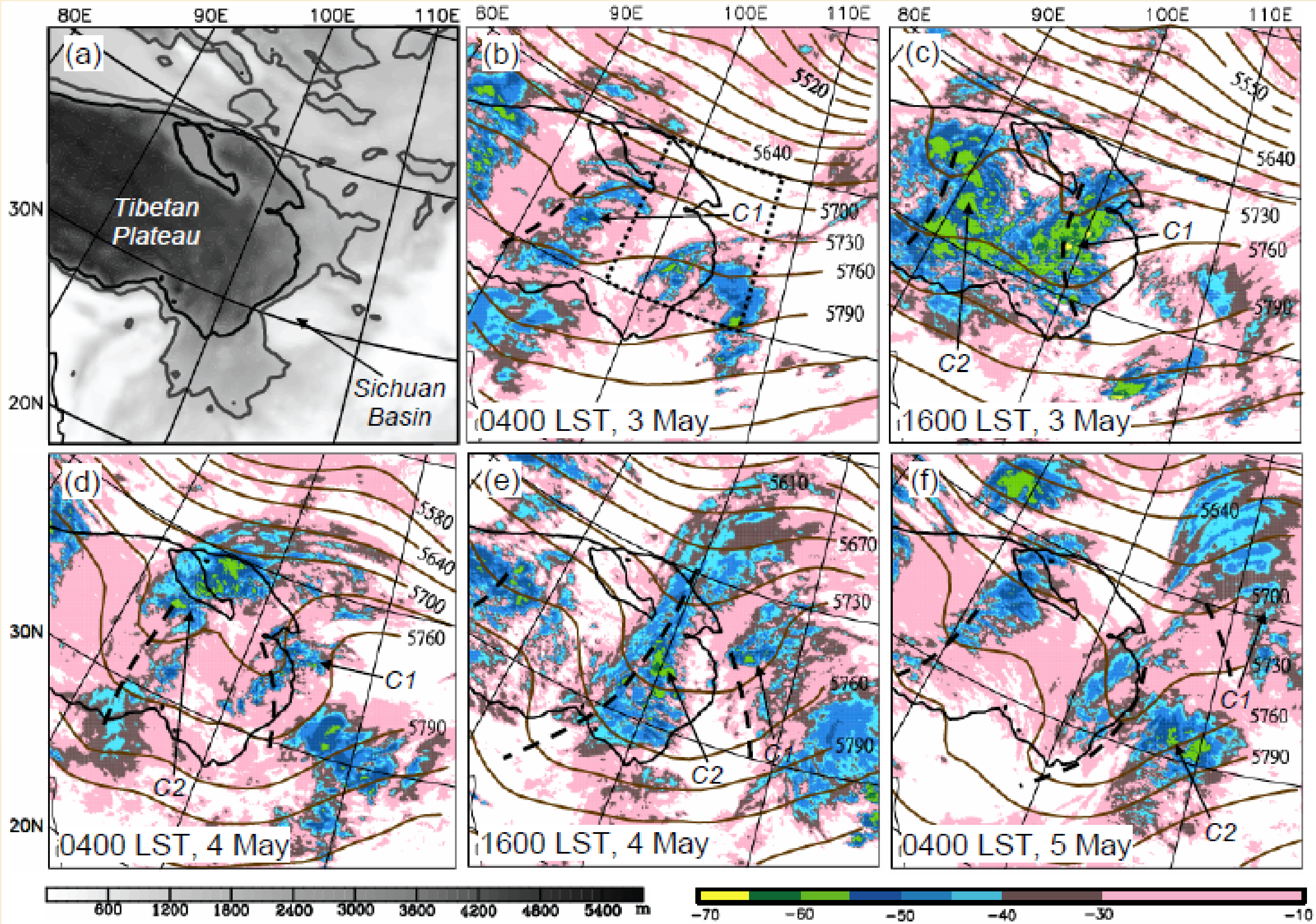


Mean GMS-5 IR T_B (°C) and TRMM 3B42 0.25° rain-rate (mm h^{-1}), 30°-40°N



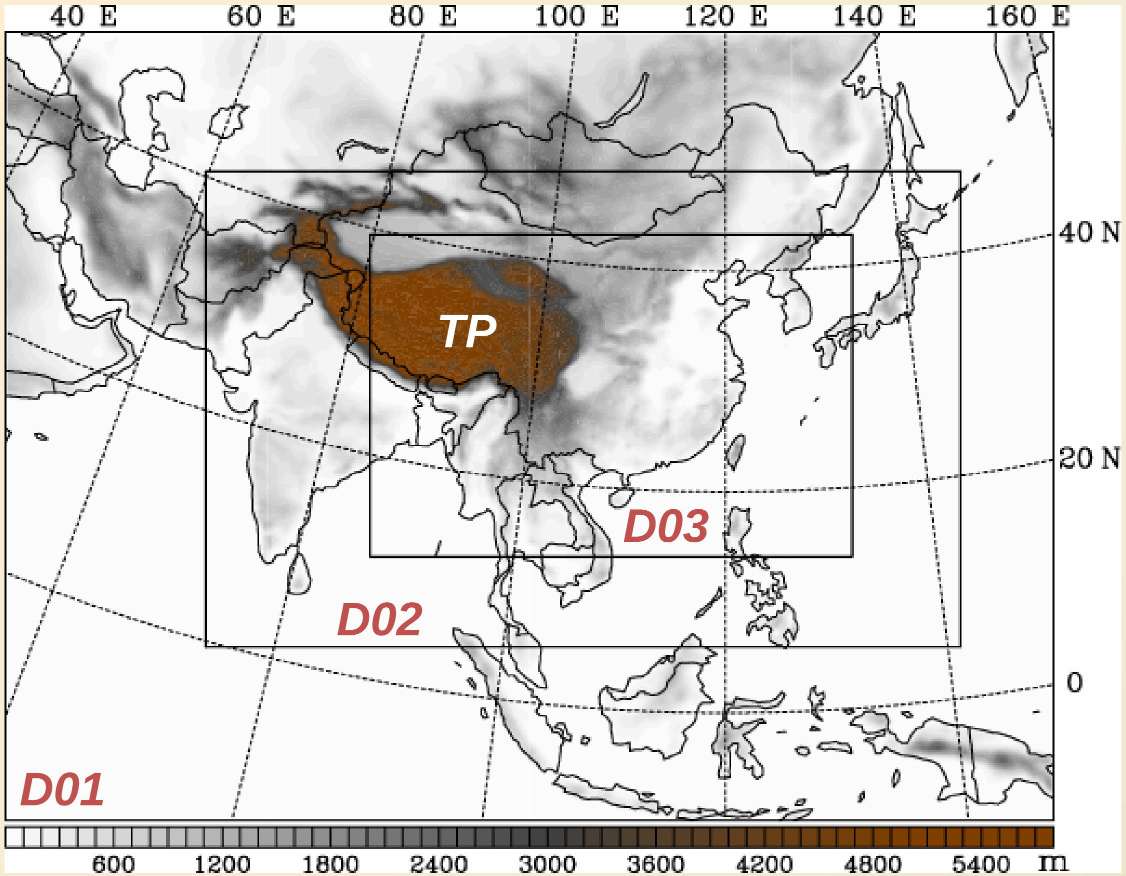
- Two rainfall episodes (C1 & C2) occurred in consecutive days with close ties to the terrain
- Zonal speed about 12.2 m s^{-1}

- Topography, clouds every 12 h and 500-hPa *z* (3-h earlier)



3. WRF model domain and physics

- Triply-nested domain: 45/15/5 km (241x181, 526x331, 991x661)

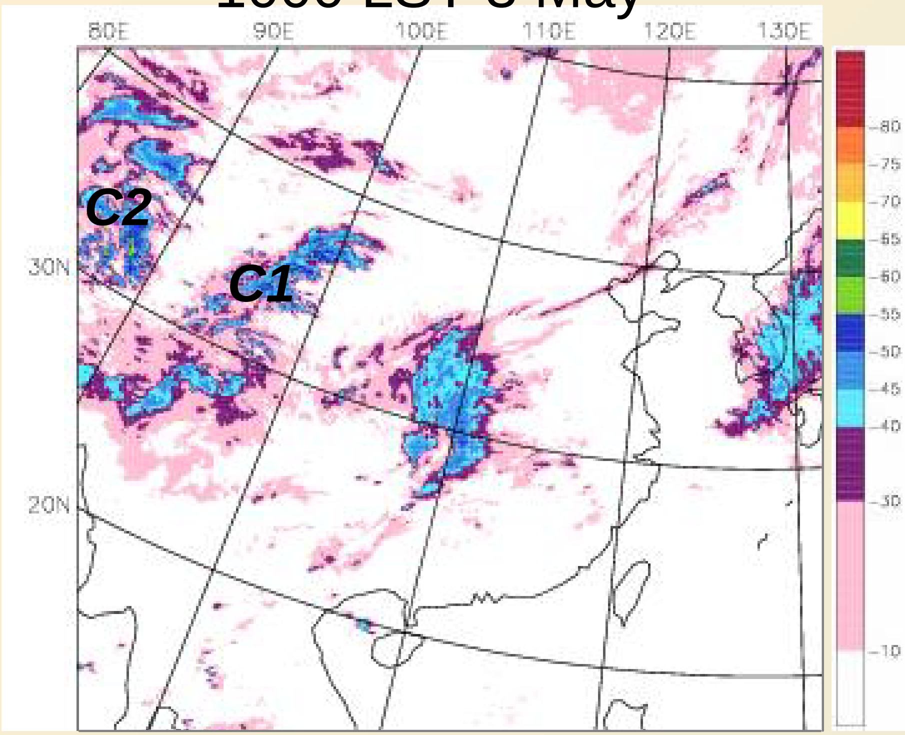


- 31 sigma (σ) levels
- Two-way feedbacks
- Purdue-Lin 6-class cloud microphysics
- Grell Cumulus PS
- YSU turbulence scheme
- Dudhia surface radiation
- IC/BC: 6-h ECMWF 1.125º lat/lon analysis
- Initial time: 1200 UTC, 2 May 2002
- Integration length: 72 h

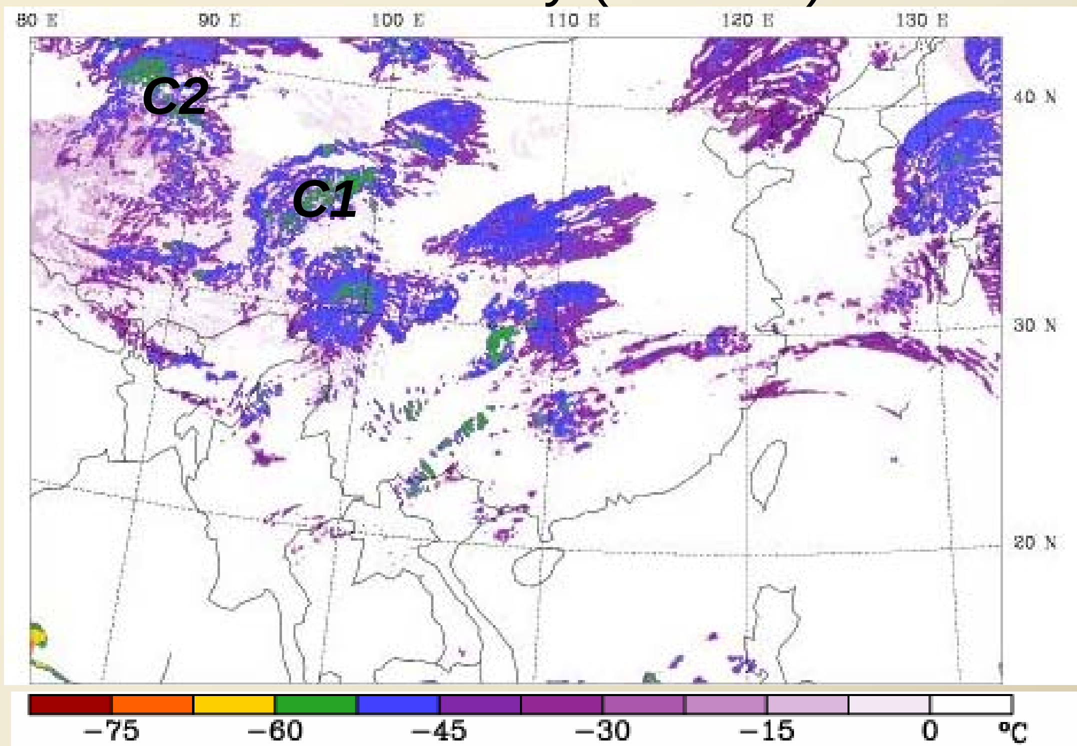
4. Result of control experiment (CT)

- Comparison between GMS T_B and model cloud-top temp (°C)

1000 LST 3 May



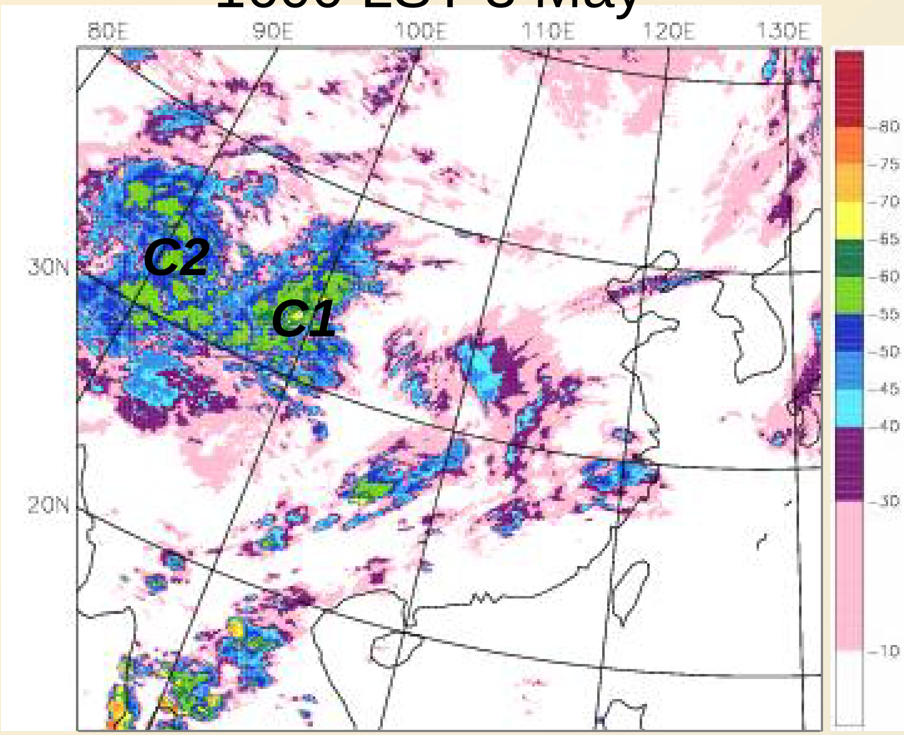
1000 LST 3 May (*t* = 15 h)



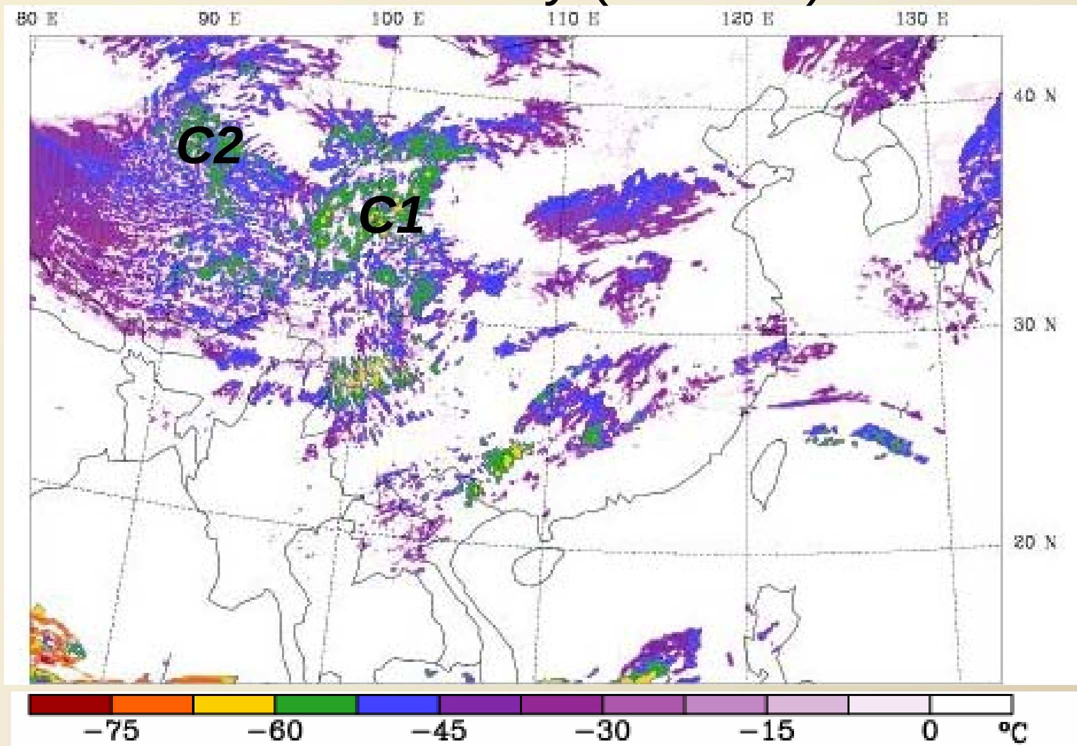
4. Result of control experiment (CT)

- Comparison between GMS T_B and model cloud-top temp (°C)

1600 LST 3 May



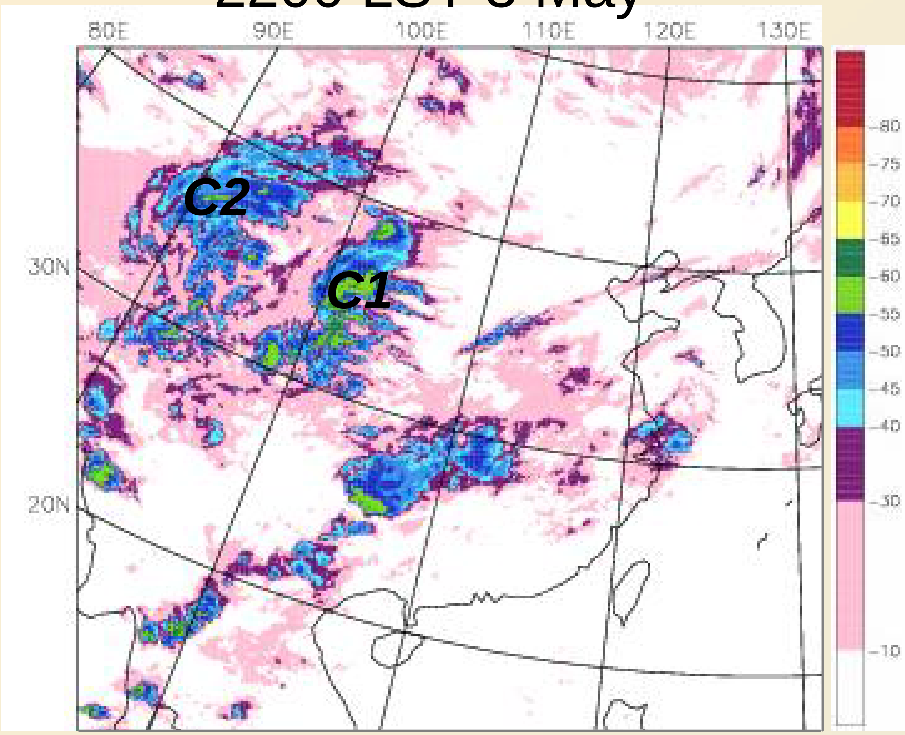
1600 LST 3 May (*t* = 21 h)



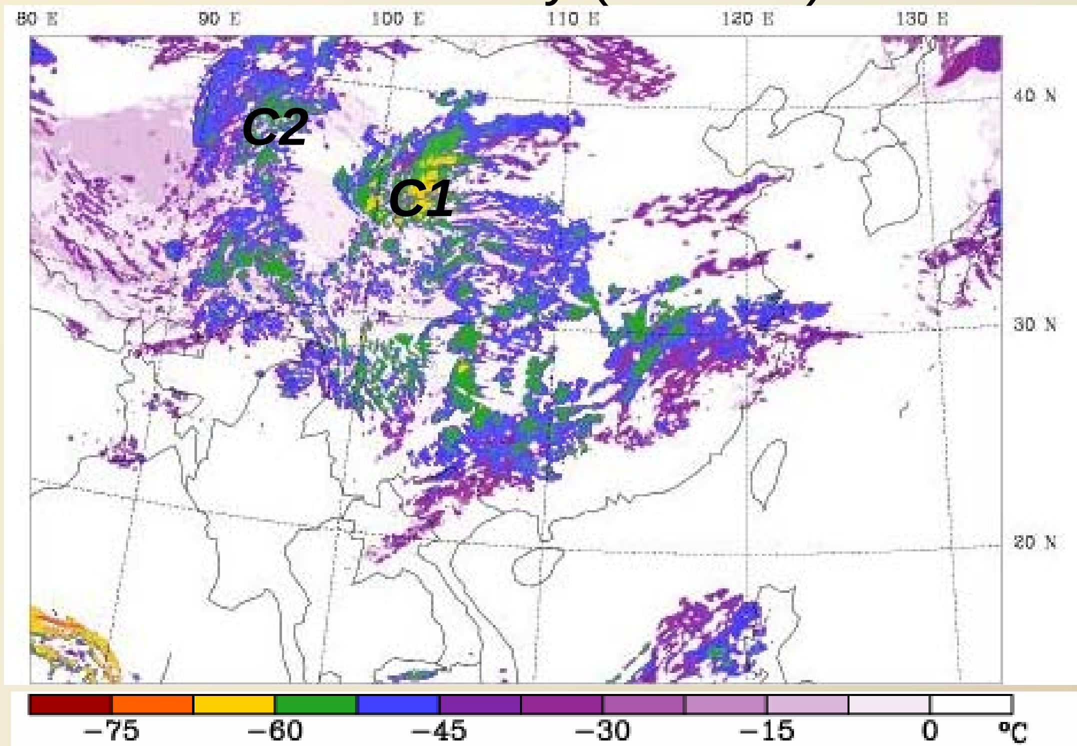
4. Result of control experiment (CT)

- Comparison between GMS T_B and model cloud-top temp (°C)

2200 LST 3 May



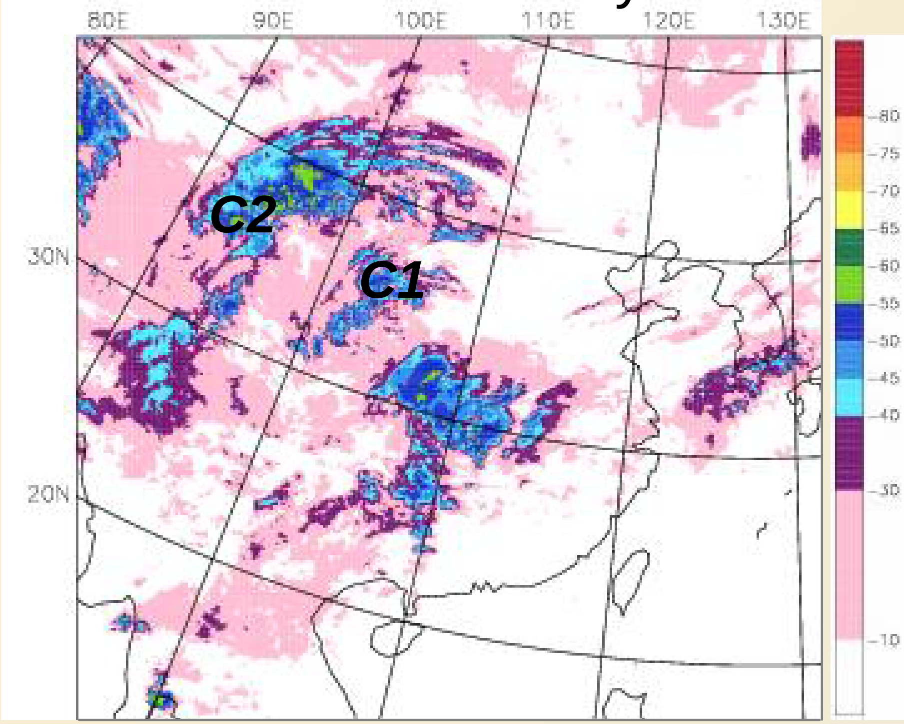
2200 LST 3 May (t = 27 h)



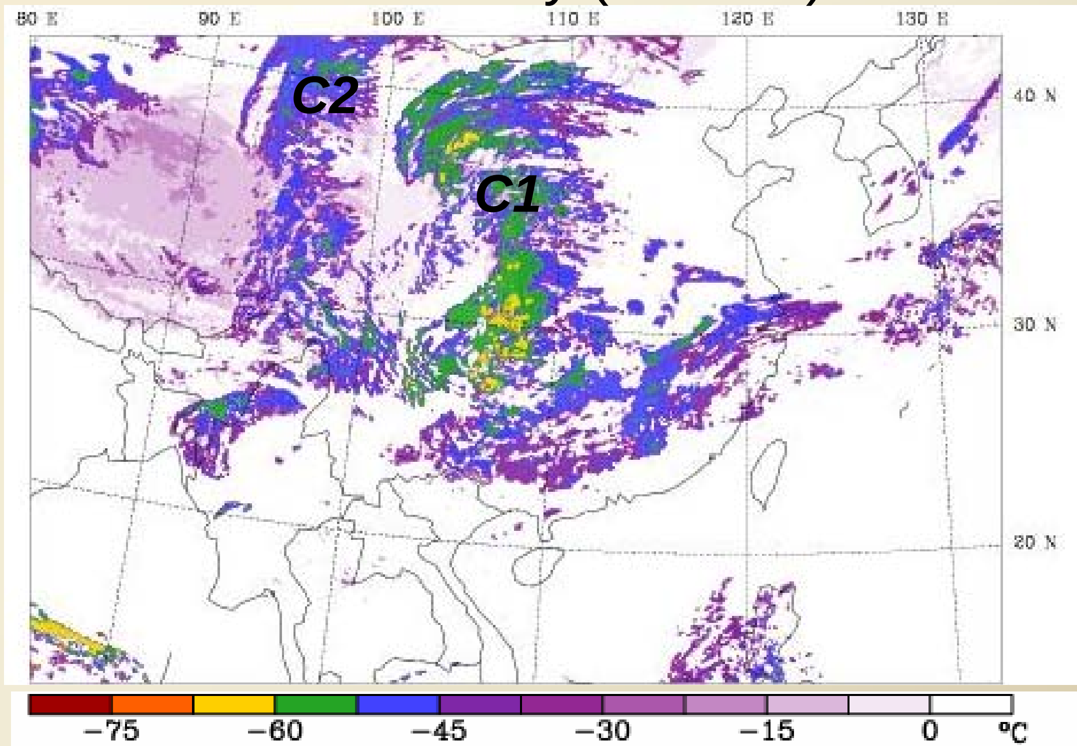
4. Result of control experiment (CT)

- Comparison between GMS T_B and model cloud-top temp (°C)

0400 LST 4 May



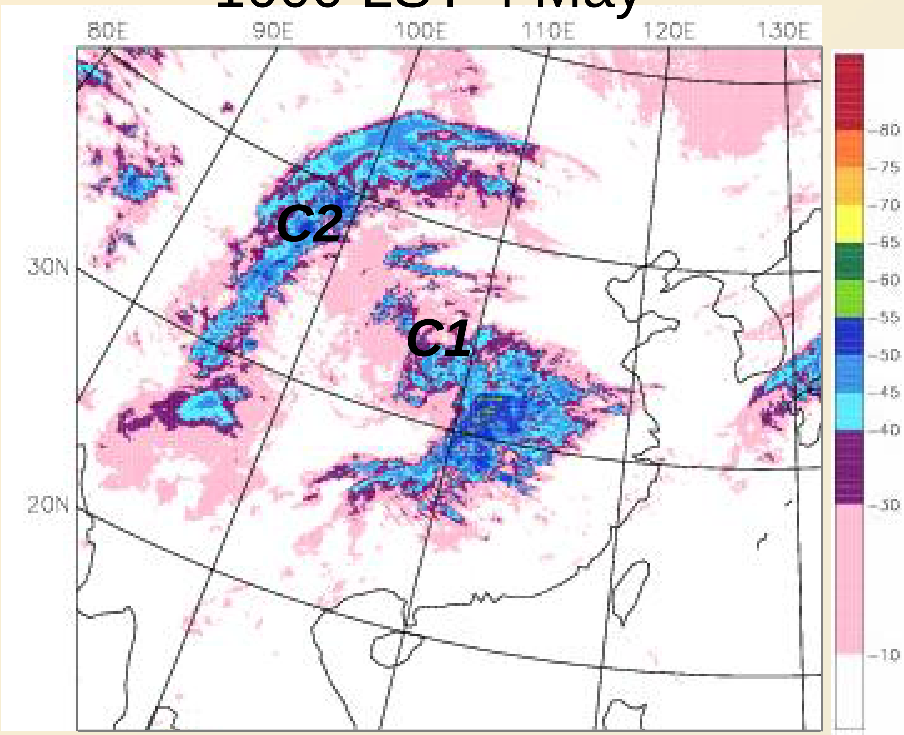
0400 LST 4 May (*t* = 33 h)



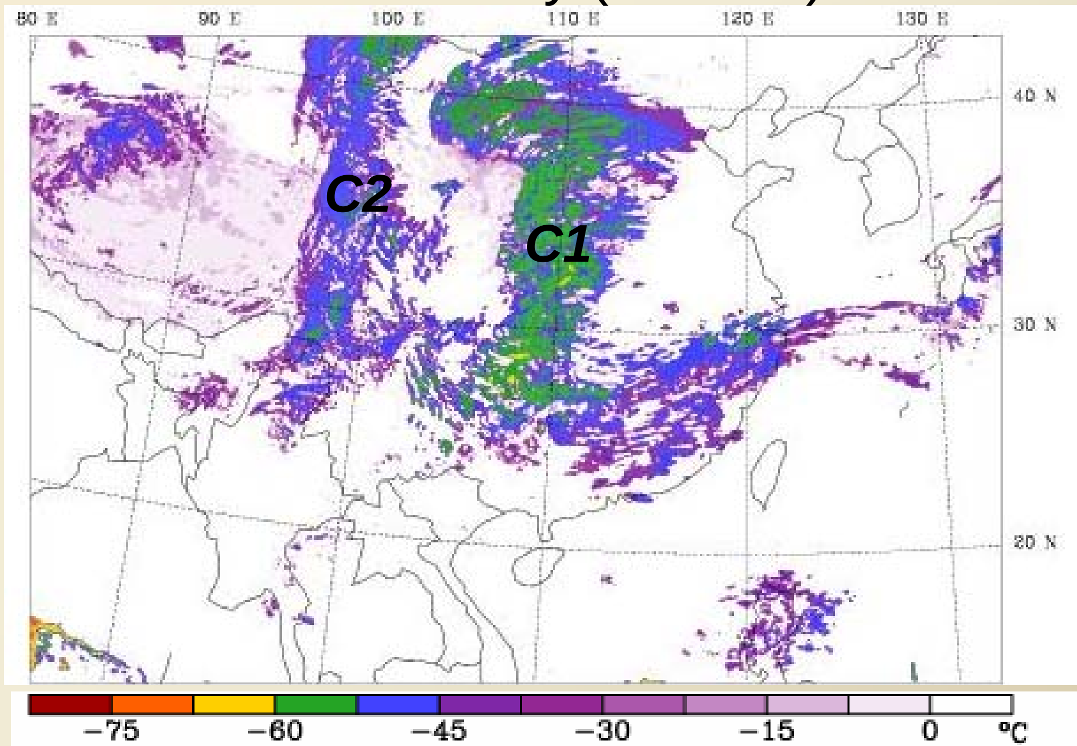
4. Result of control experiment (CT)

- Comparison between GMS T_B and model cloud-top temp (°C)

1000 LST 4 May



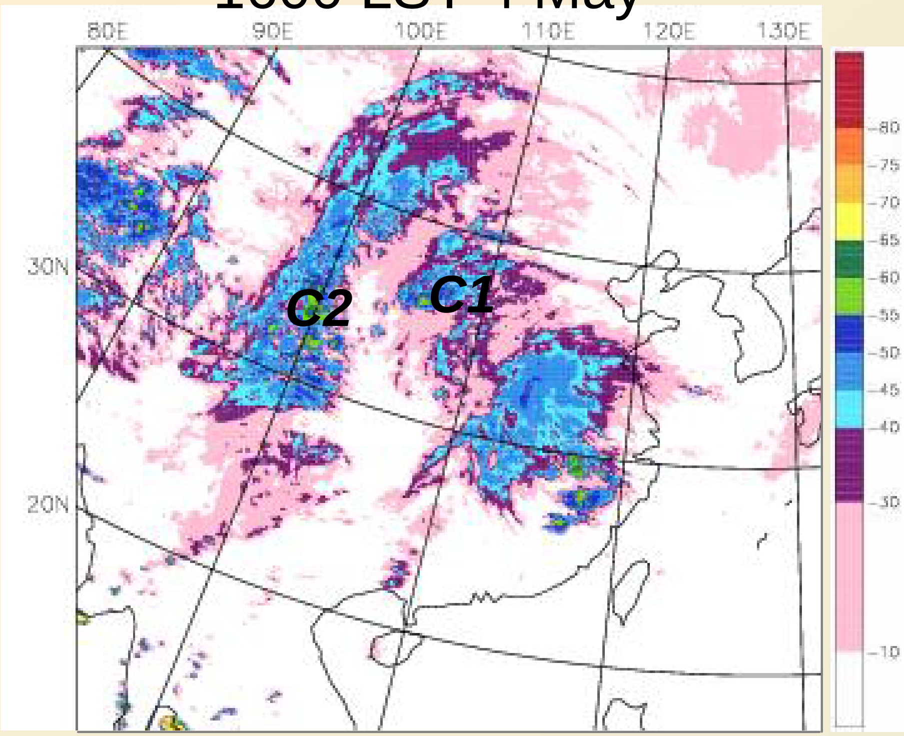
1000 LST 4 May (*t* = 39 h)



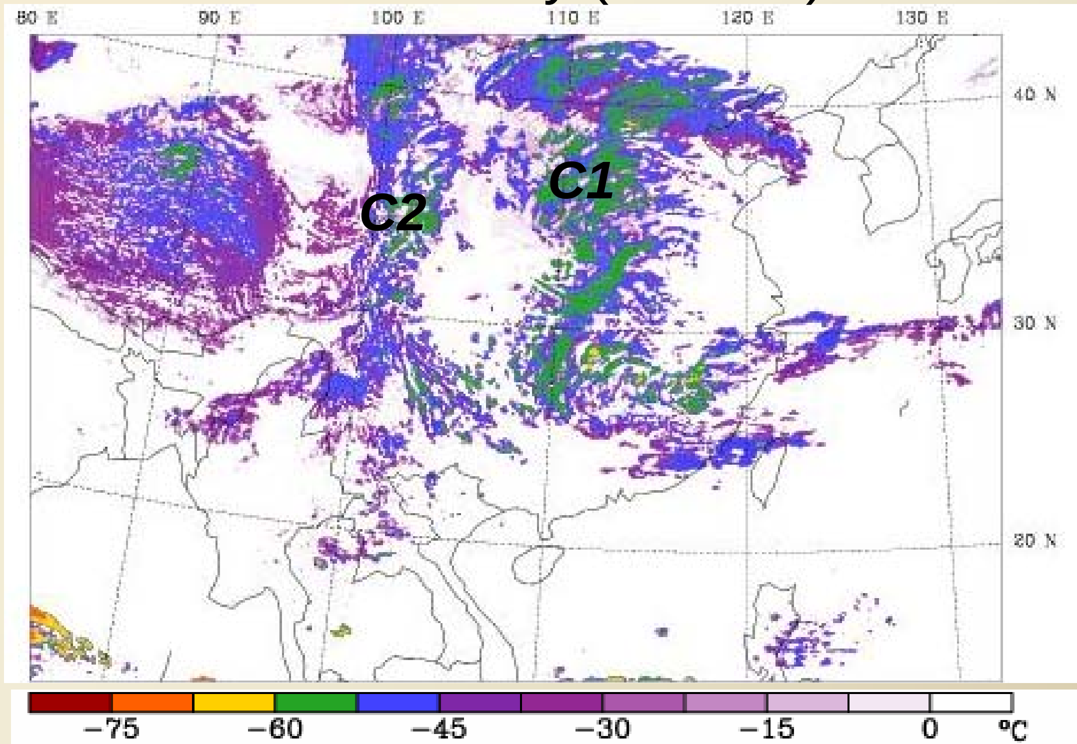
4. Result of control experiment (CT)

➢ Comparison between GMS T_B and model cloud-top temp (°C)

1600 LST 4 May



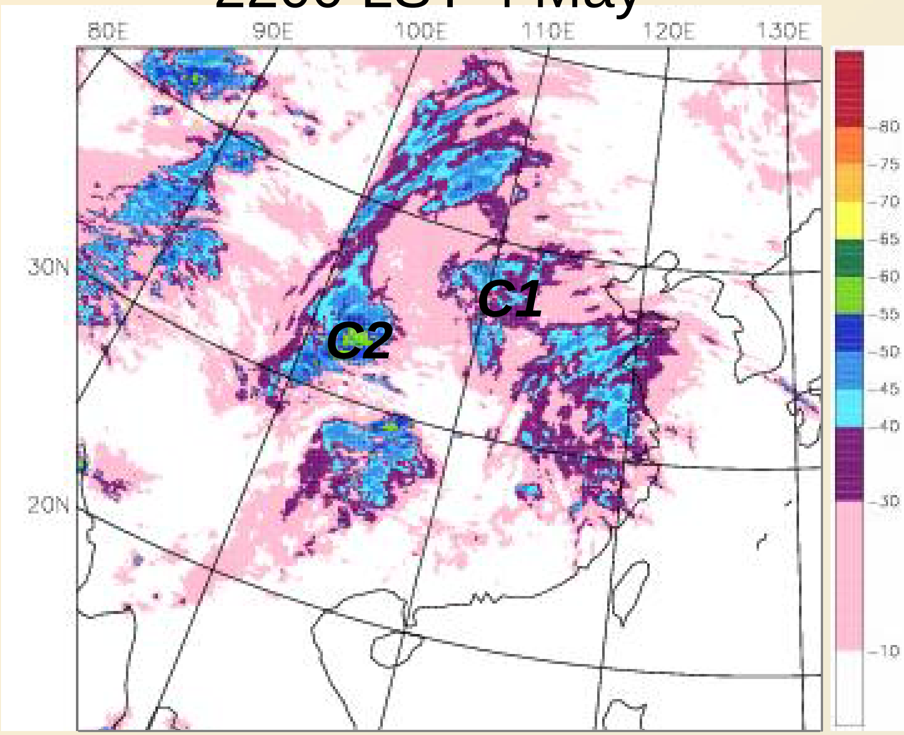
1600 LST 4 May (*t* = 45 h)



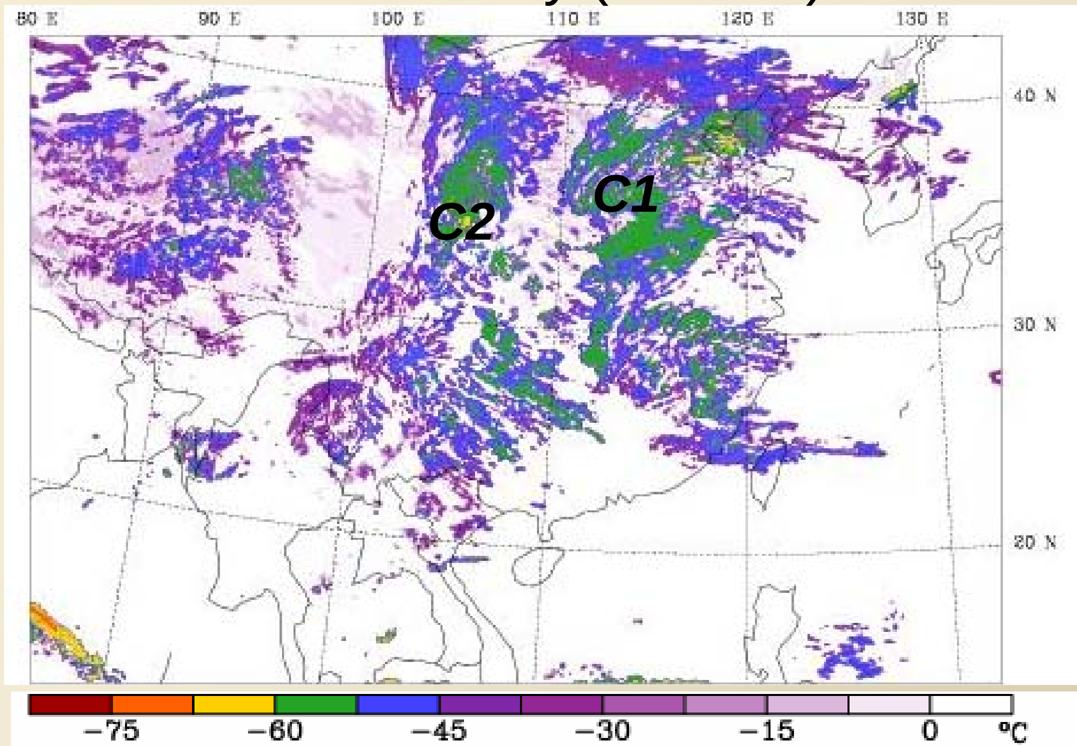
4. Result of control experiment (CT)

- Comparison between GMS T_B and model cloud-top temp (°C)

2200 LST 4 May



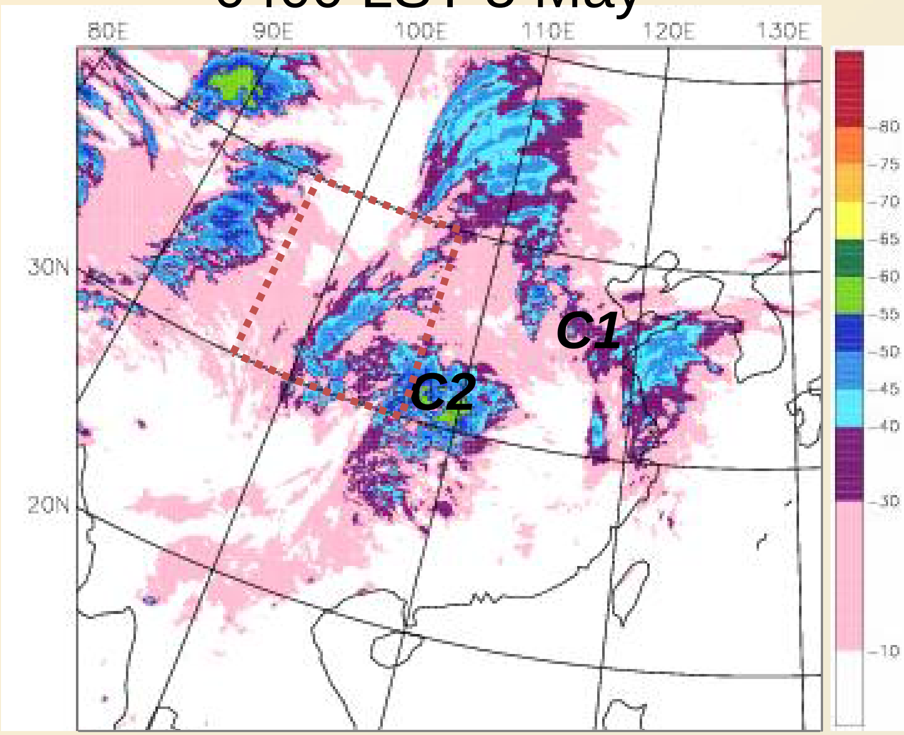
2200 LST 4 May (*t* = 51 h)



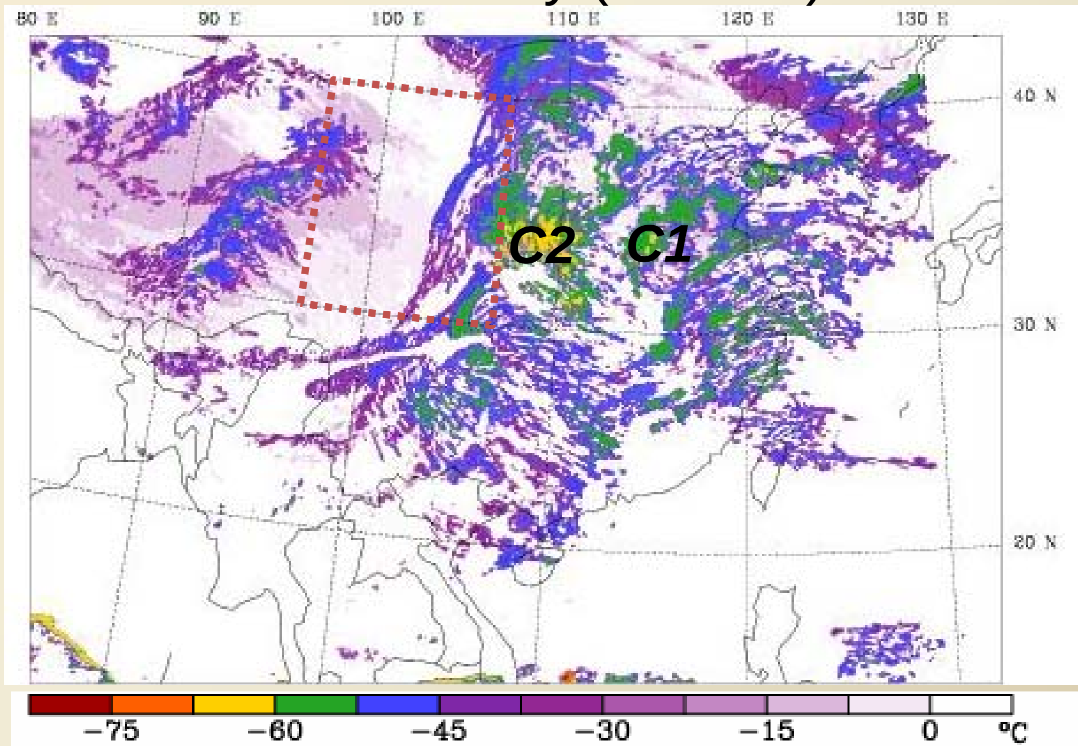
4. Result of control experiment (CT)

- Comparison between GMS T_B and model cloud-top temp (°C)

0400 LST 5 May



0400 LST 5 May (*t* = 57 h)

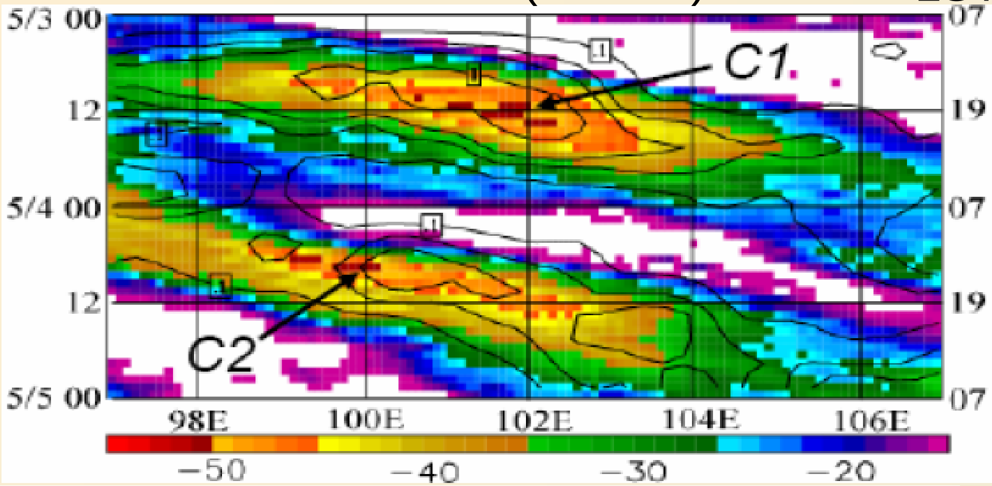


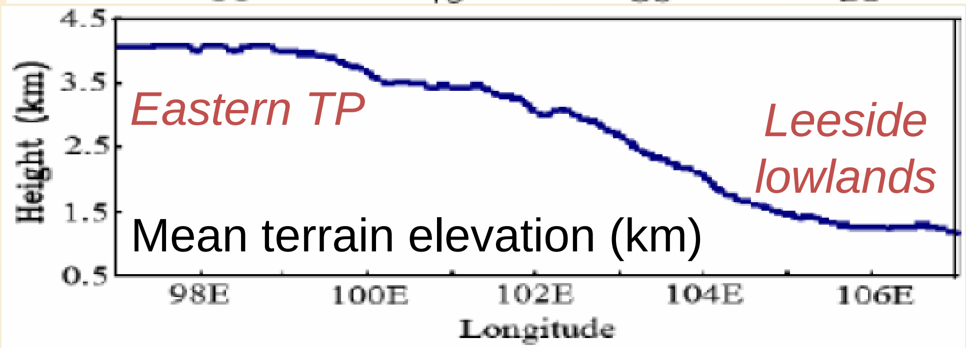
➢ Comparison between Hovmöller diagrams (30°-40°N)

Mean T_B (°C) and TRMM rain-rate (mm h^{-1})

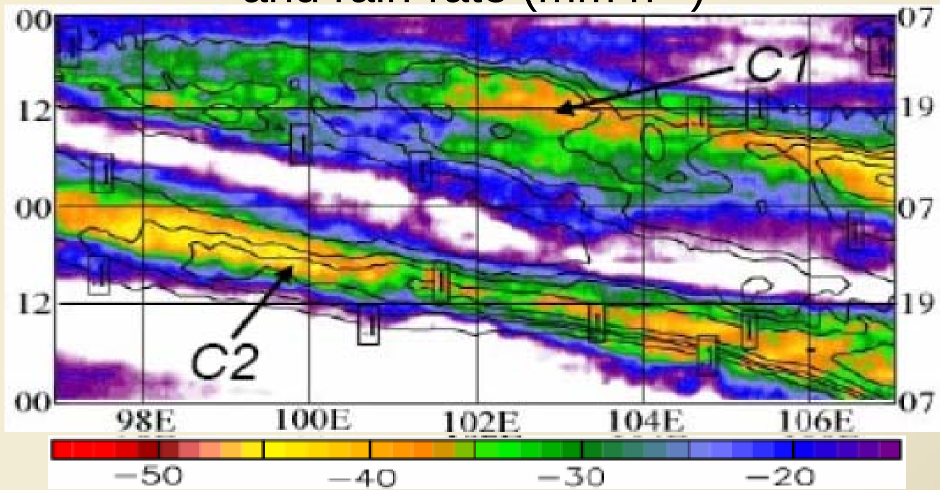
UTC

LST





Model cloud-top temp (°C) and rain-rate (mm h^{-1})

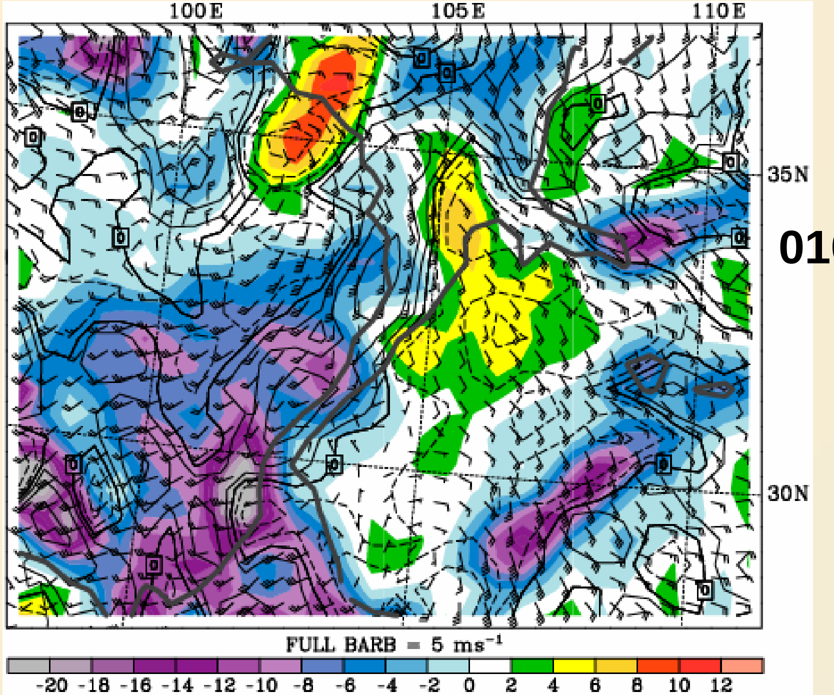


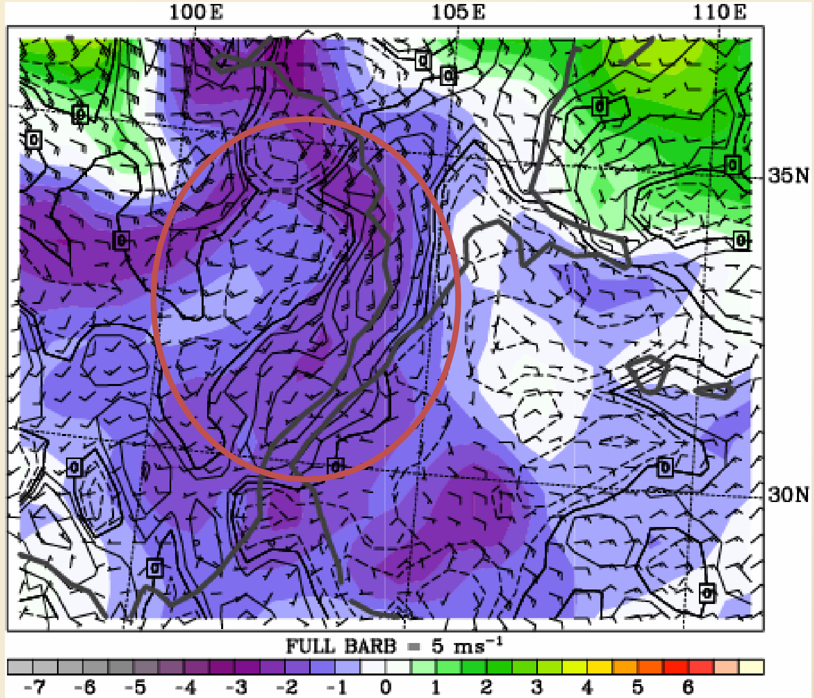
- Phase and zonal propagation speed reproduced reasonably well by WRF model

➢ Associated with diurnal heating/cooling over eastern TP (ETP)

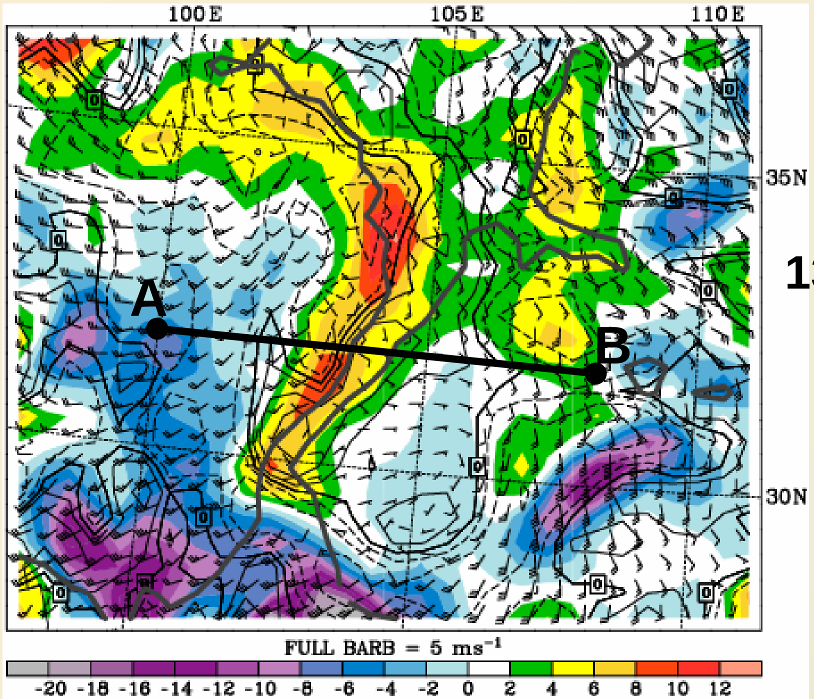
u/*v*, *w*, and conv/div at $\sigma = 0.94$

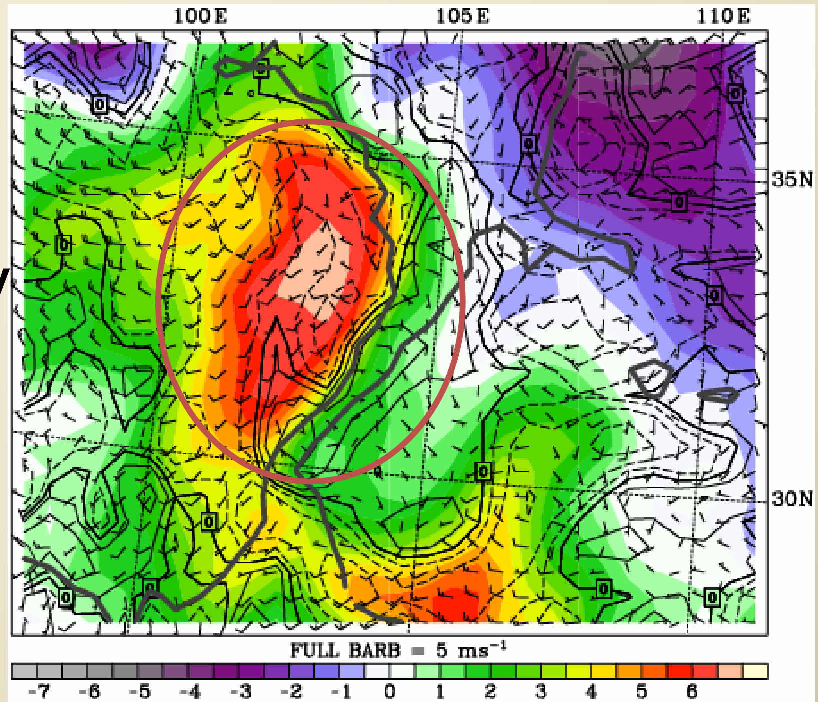
u/*v* and θ anomalies at $\sigma = 0.94$





0100 LST, 4 May
(nighttime)

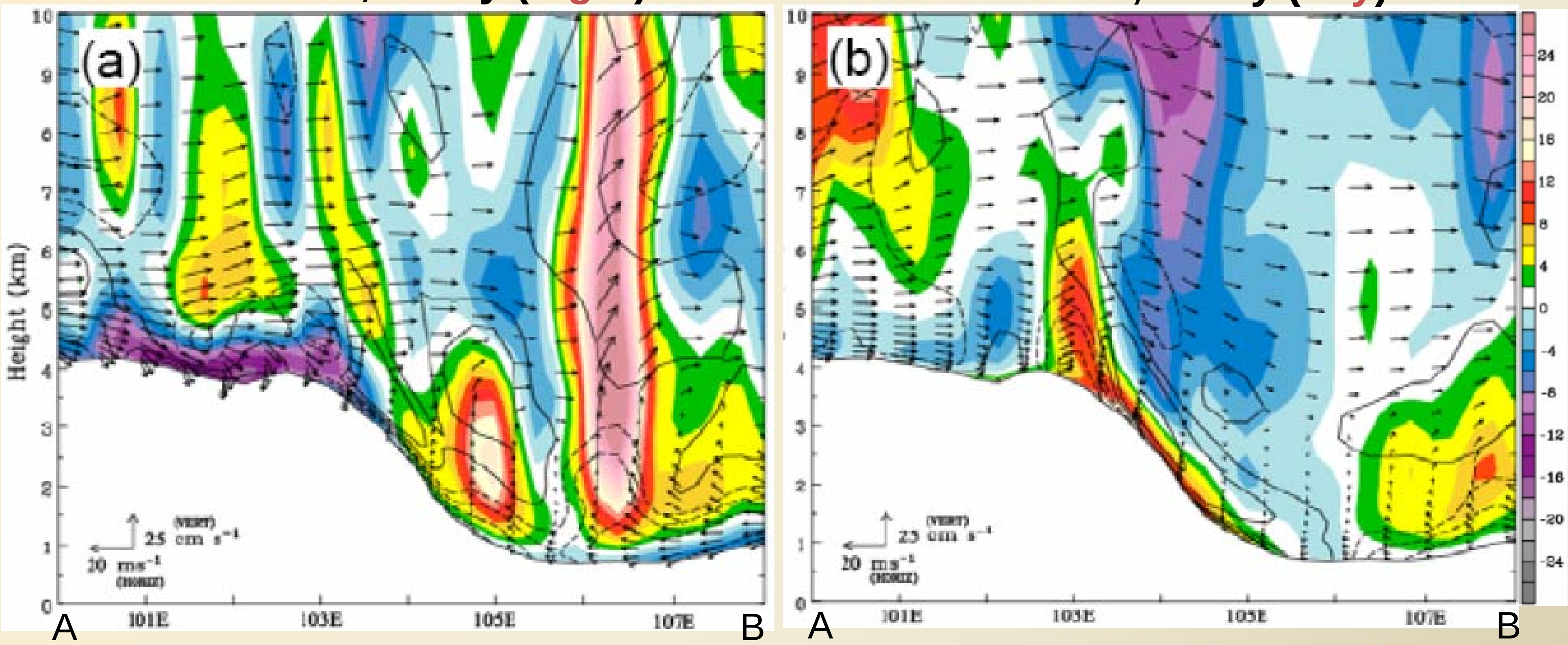




1300 LST, 4 May
(daytime)

- Cross-section along 32°N over 100°-108°E

0100 LST, 4 May (night) **1300 LST, 4 May (day)**

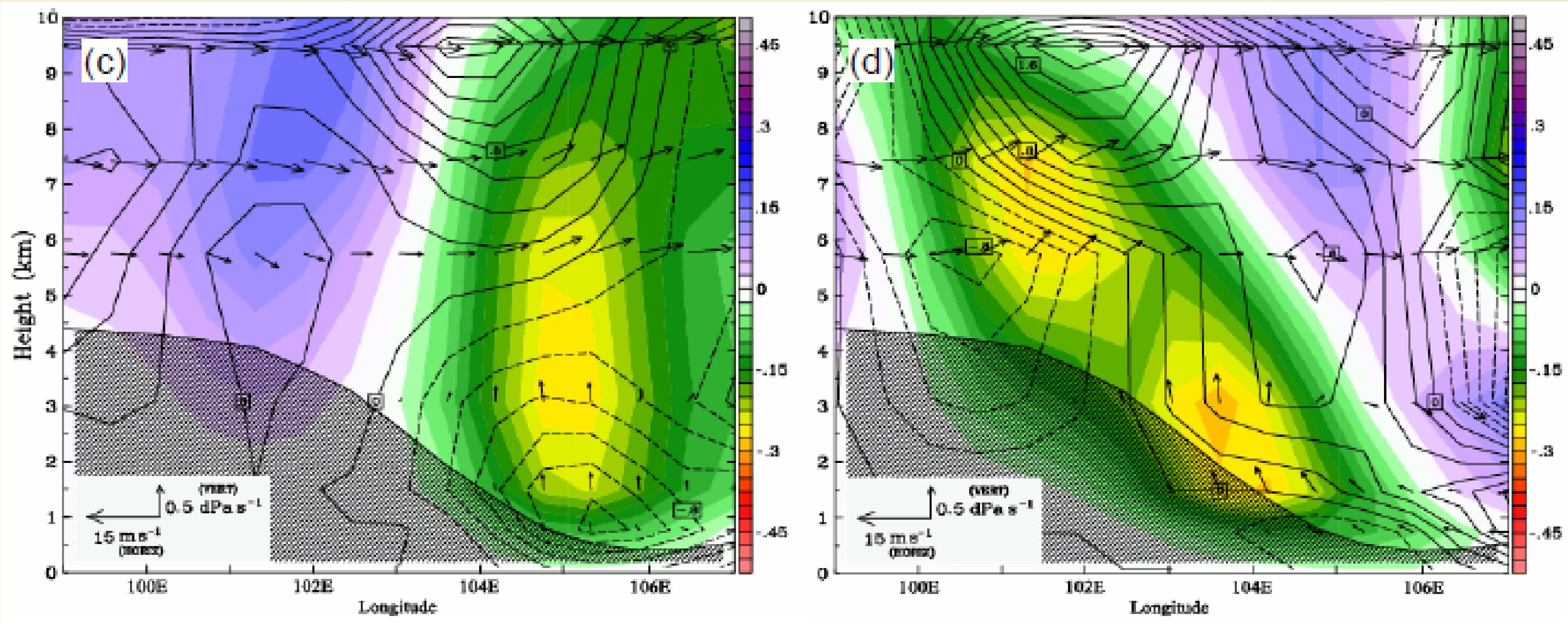


- Rising motion over leeside at night, but over ETP during the day

- Similar but weaker pattern also seen in ECMWF analyses

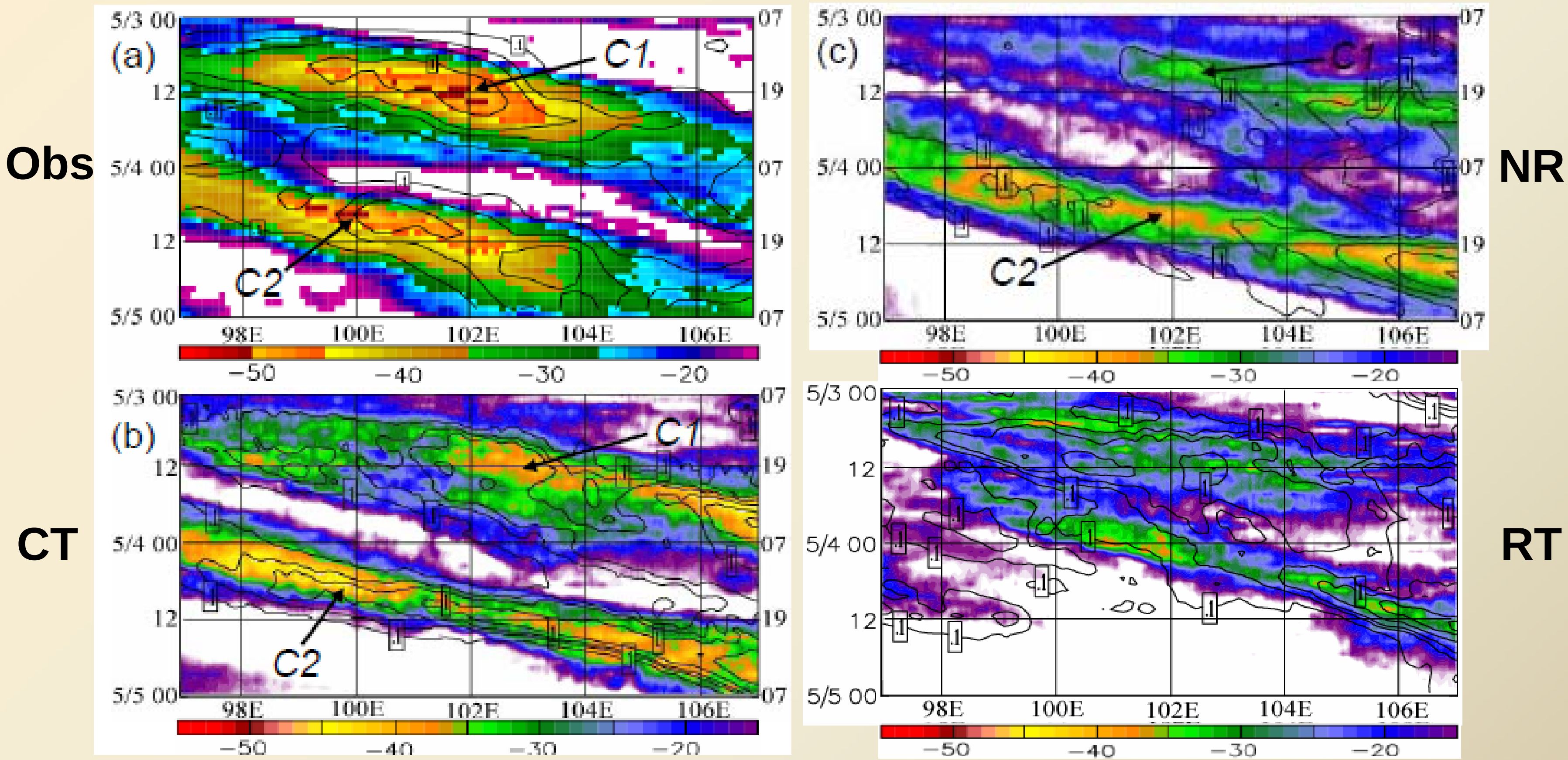
0100 LST, 4 May (night) **1300 LST, 4 May (day)**

Wind vector on plane (m s^{-1}), ω (dPa s^{-1}), and div (10^{-5} s^{-1}) along 31°N



5. Sensitivity tests (NR and RT runs)

- No-radiation (NR) run: Radiation (S & L) turned off
- Reduced-terrain (RT) run: Terrain height >2 km reduced by half



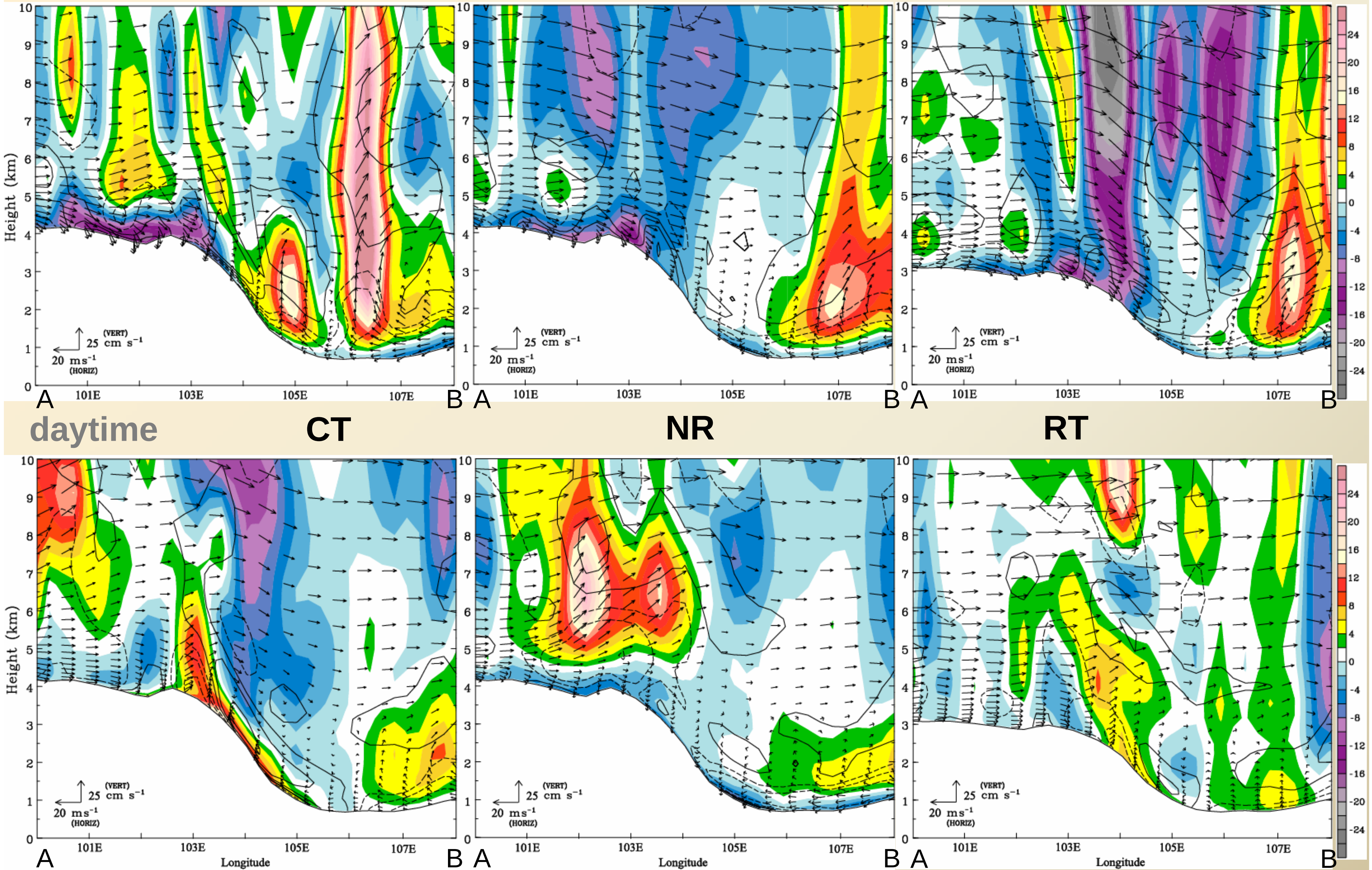
Ex: 5 km → 3.5 km

2+(5-2)*0.5

➢ Comparison among vertical cross-sections along 32°N (line AB)

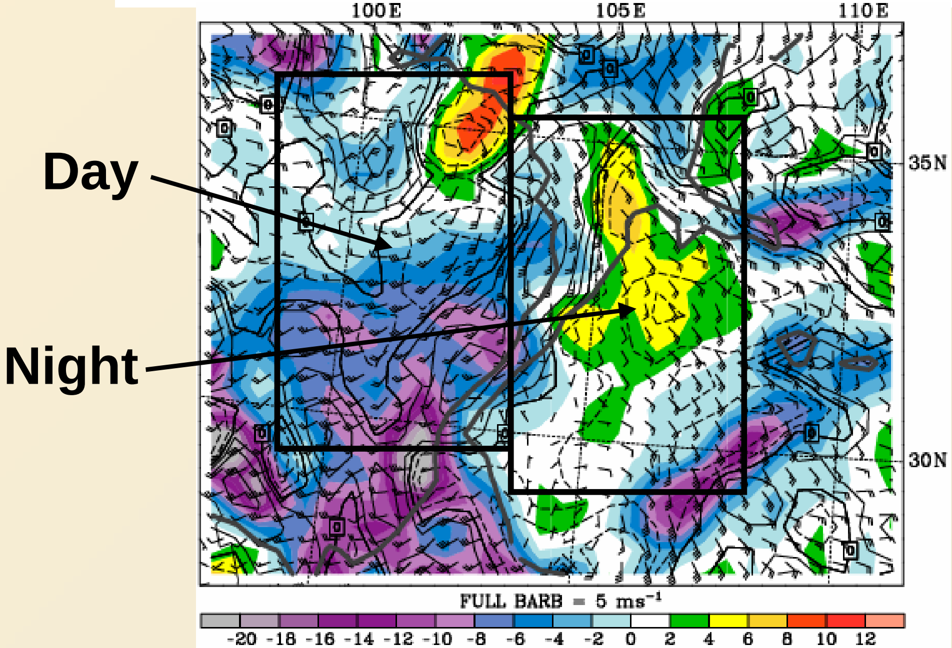
nighttime

daytime



- Mean strength of solenoids and rainfall over a larger area

Experiment		CT	NR	RT
Area LL (nighttime)	w (cm s^{-1})	4.24	2.47	2.26
	rainfall (mm)	8.46	3.78	3.49
Area EP (daytime)	w (cm s^{-1})	2.83	2.21	1.12
	rainfall (mm)	1.72	1.10	0.68



Accumulated rain and w (cm s^{-1}) at $\sigma = 0.77$

Night: 2200-0400 LST, 3-4 May
at Leeside Lowland (LL)
Day: 1000-1600 LST, 4 May
at eastern plateau (EP)

- Strength of solenoids and associated rainfall are reduced in both NR and RT runs compared to the CT run

- Diurnal solenoids contributed to episodes and their propagation

6. Summary

- Two propagating rain episodes with close ties to the diurnal cycle of TP over a two-day period (3-5 May 2002) are studied through WRF model simulation and sensitivity tests
- Propagation of rainfall episodes, at about 12.2 m s^{-1}, were in-phase with the upward branch of the solenoidal circulation
- The eastern TP not only acts as a heat source for convection, but the diurnal solenoidal circulation near its eastern edge also contributes to the longevity and further propagation of episodes
  - Low-level convergence/ascent over eastern TP with upslope winds by day, but over the leeside lowlands with down-slope winds by night

--- The End ---

Thank you for your attention!