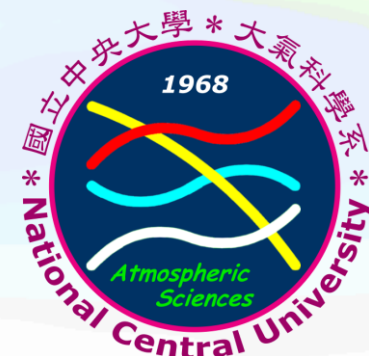


Effect of Low-level Jets on the Movement of the Mei-yu Front and Heavy Rainfall

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¹*National Central University, Taiwan*

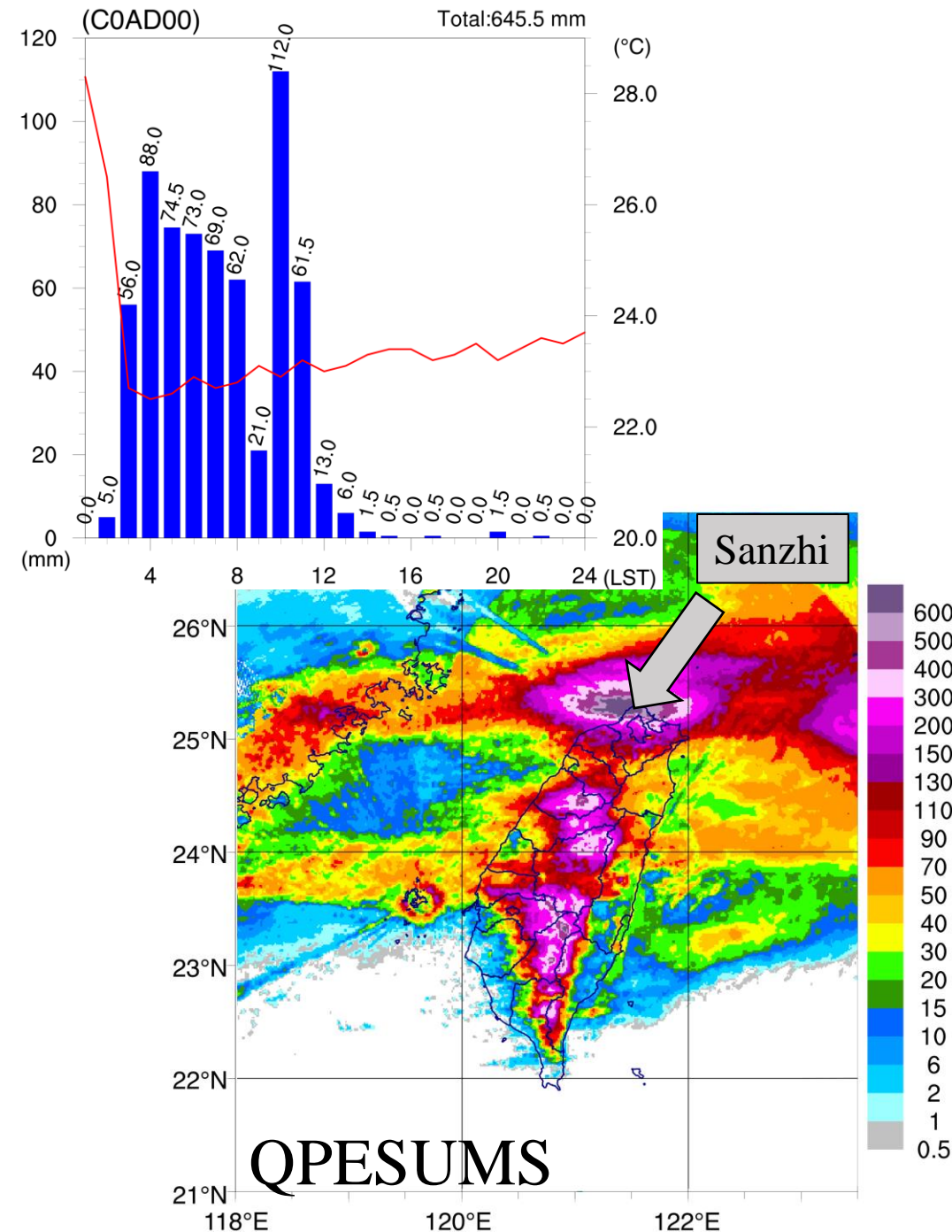
²*University of Hawaii at Manoa, United States*



Case overview

2 June 2017 heavy rainfall event

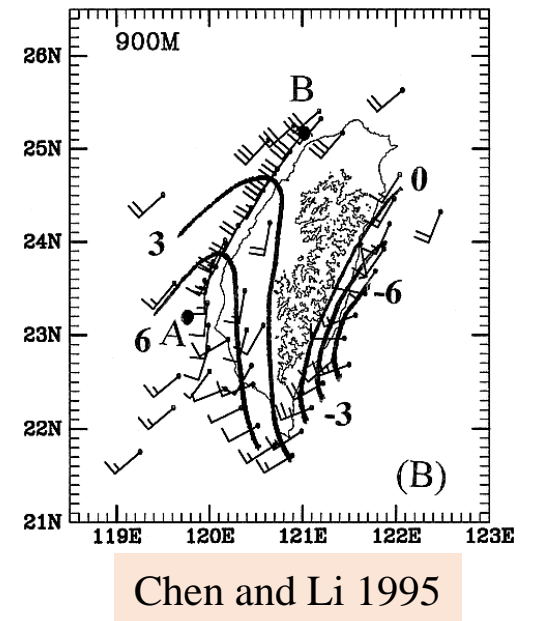
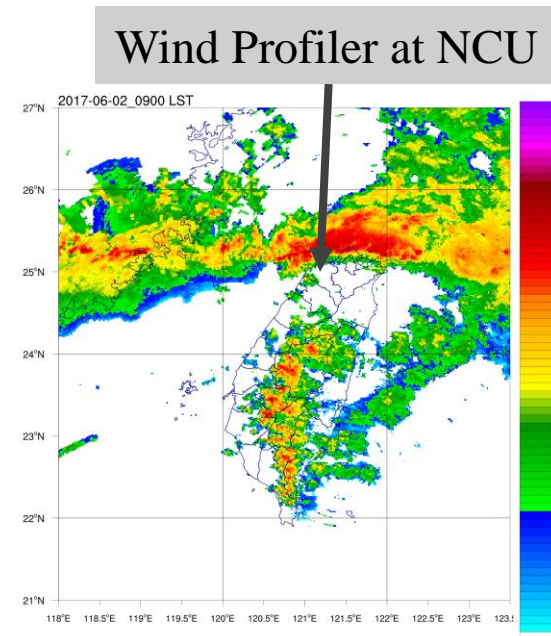
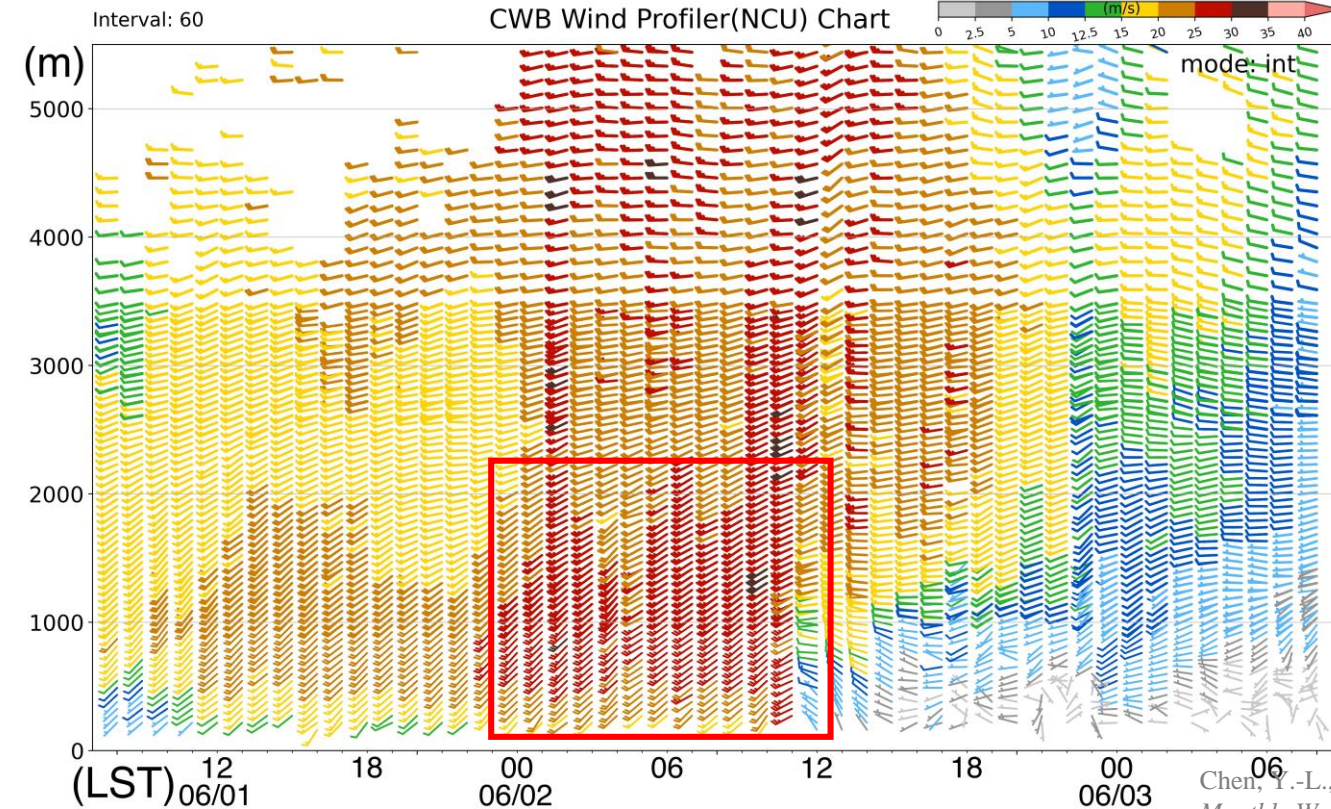
- A Mei-Yu frontal system affected northern Taiwan on 2 June 2017.
- The front remained quasi-stationary, producing extreme rainfall.
- More than 600 mm of rainfall was accumulated within 10 hours (total: 645.5 mm).
- Observations indicate the presence of a barrier jet during the event.



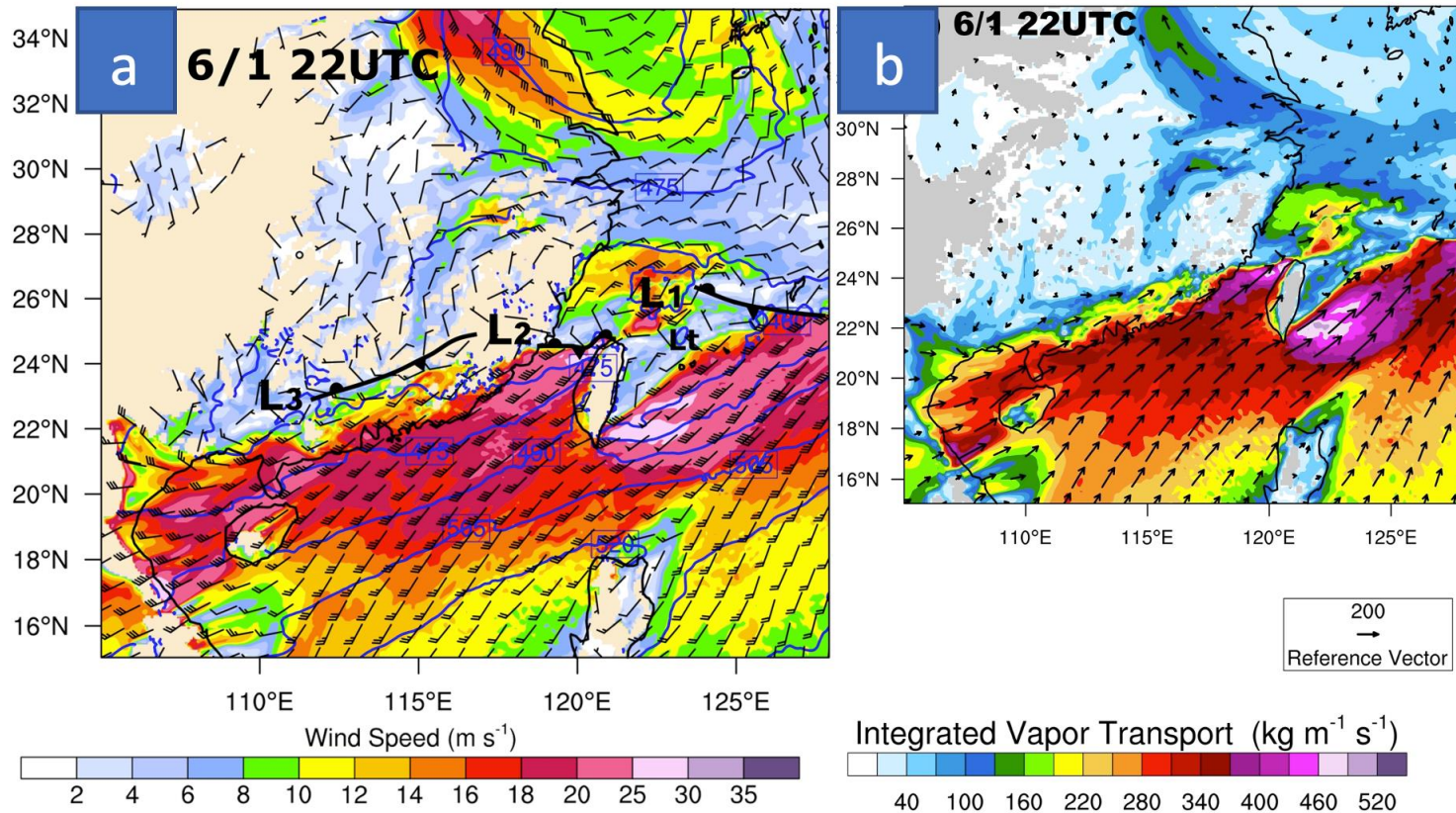
Barrier jet

How does the barrier jet influence frontal movement and rainfall distribution?

- Southwesterly flow interacts with Taiwan's topography (southern CMR).
- Wind speeds enhance to 25 m/s over northwestern Taiwan as the Mei-Yu front approaches.
- A persistent barrier jet is present before and during the heavy rainfall.
- The barrier jet occurs concurrently with the stationary front and heavy rainfall.

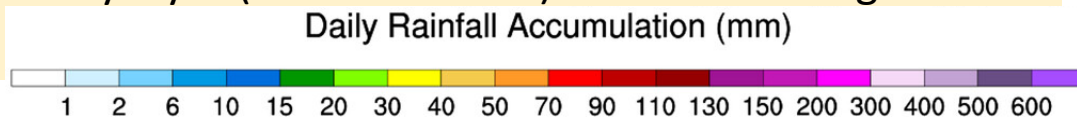
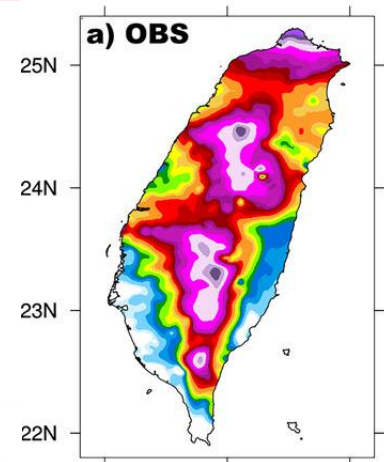


Three kinds of LLJs coexist for this Case.

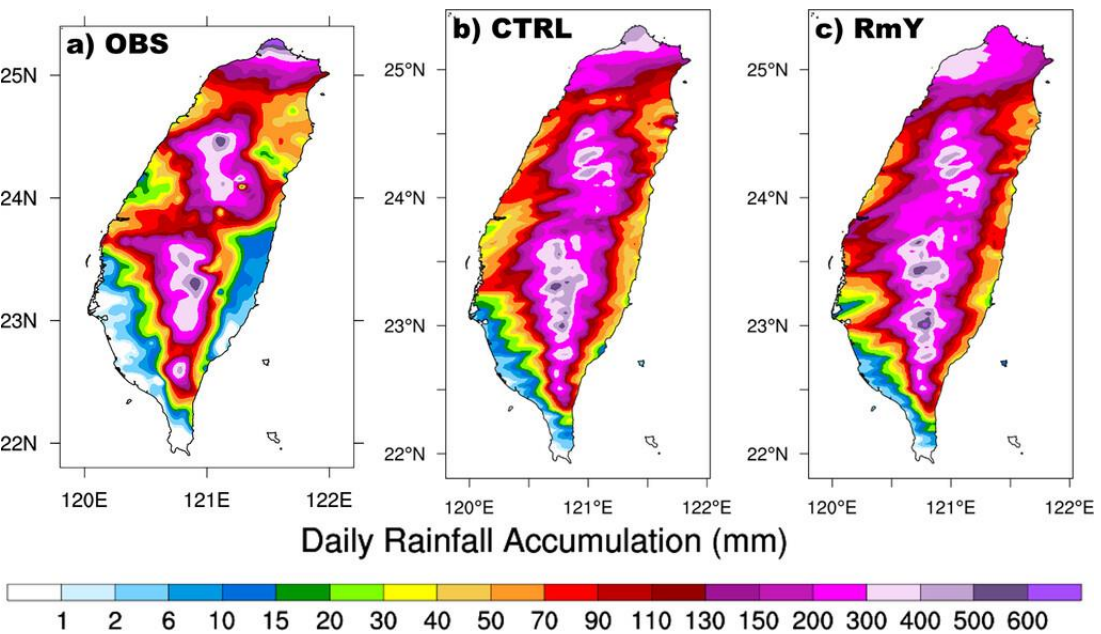


- From the early morning of 2 June 2017 (LT), the southwesterly barrier jet with maximum winds in the 900-950-hPa layer brings in abundant moisture and converges with the northwesterly flow in the southwestern flank of the mei-yu frontal cyclone (L_1).
- Therefore, torrential rain (> 600 mm) occurs over the northern side of the Yang-Ming Mountains.

(a) Simulated **950-hPa winds** (m s^{-1} ; one full barb represents 5 m s^{-1}), and geopotential height (gpm; contours) from the 9-km gridded domain (domain 2) at **2200 UTC 1 Jun (0600 LST 2 Jun) 2017**. The light yellow shading represents an area with no data where the station pressure is below 950 hPa; L_1 , L_2 , and L_3 represent mei-yu frontal cyclones; and L_t represents a lee vortex. (b) Same as (a) but for simulated **integrated vapor transport (IVT; $\text{kg m}^{-1} \text{s}^{-1}$)** in the boundary layer (below 900 hPa) from the 9-km gridded domain (domain 2).

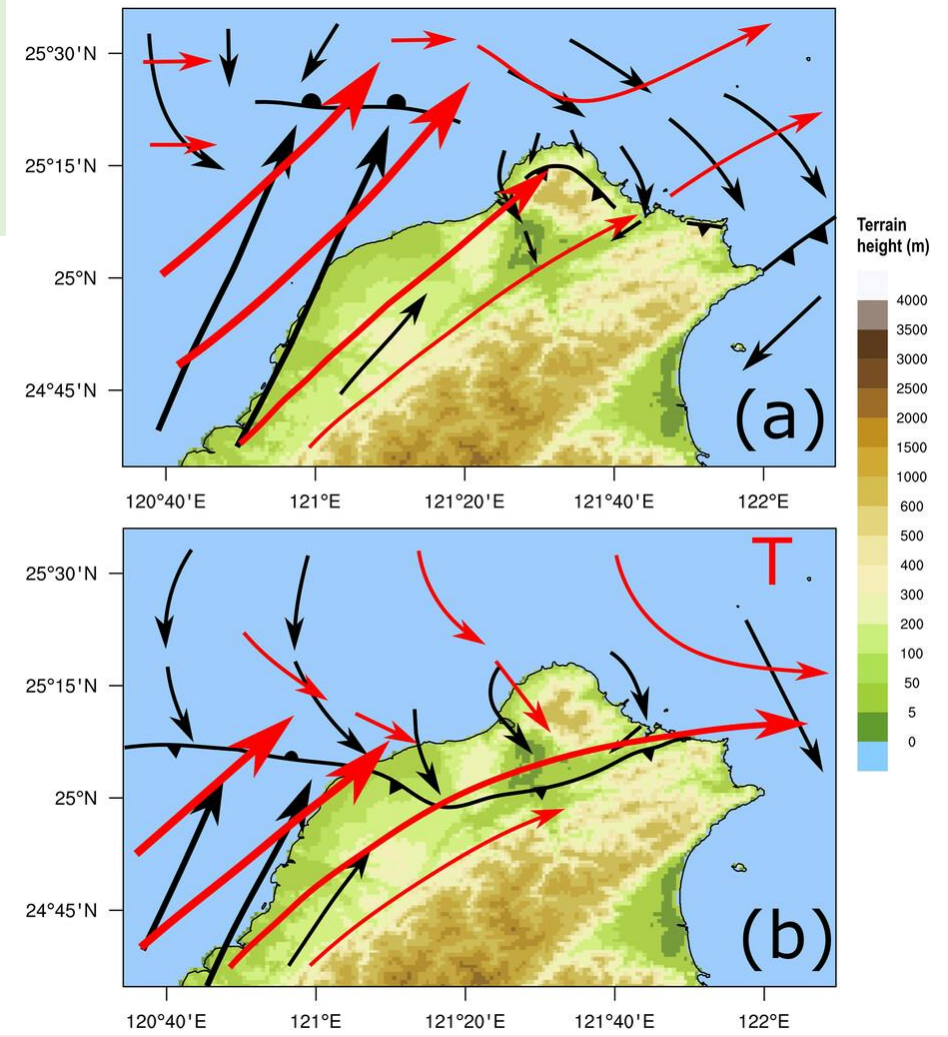


(2) There is no daily rainfall maximum over the northern tip of Taiwan in the **RmY run**. Instead, a rainfall maximum is simulated over northwestern Taiwan where the BJ converges with the postfrontal northwesterly flow.



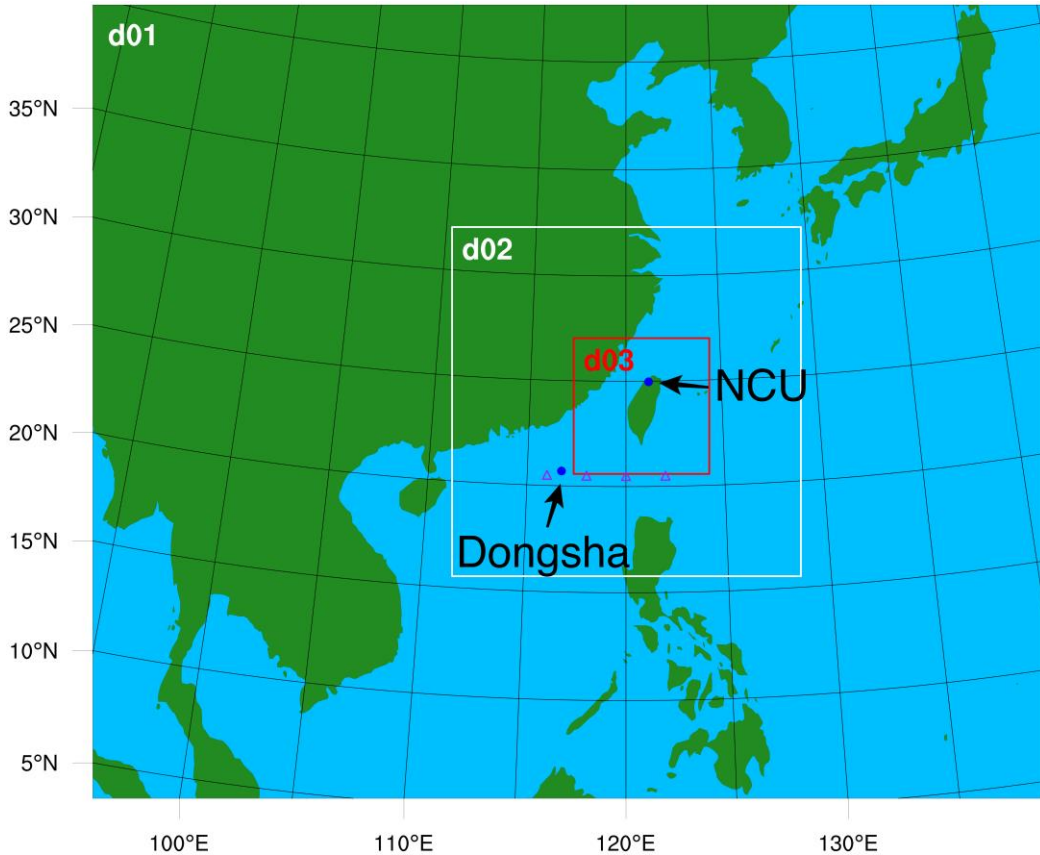
(Tu et al. 2022)

(a) Daily (0000–2400 LST) rainfall accumulation (mm; color shaded) for 2 Jun 2017 from rain gauge observations. The simulated daily rainfall accumulation (mm; color shaded) for 2 Jun 2017 (LST) from the 3-km gridded domain (domain 3): (b) the CTRL run and (c) the RmY run.



- **(1) A schematic diagram** shows the surface (black solid arrows) and 900-hPa (red solid arrows) flow patterns with the barrier jet (thick red solid arrows). **(a) The shallow (<1 km) mei-yu front cannot move over the Yang-Ming Mountains (with peaks ~ 1120 m) when it first arrives. It is anchored over the northern side of the Yang-Ming Mountains for almost 8 h during the morning of 2 Jun 2017 (0200–1000 LST 2 Jun).** At the 900-hPa level, the southwesterly BJ converges with the northwesterly flow in the southwestern flank of the mei-yu frontal cyclone around the northern tip of Taiwan. **(b) Around noontime, the mei-yu front finally moves southward over the Yang-Ming Mountains into the Taipei basin and converges with the southwesterly BJ over the Taipei basin.**

Model & experiments



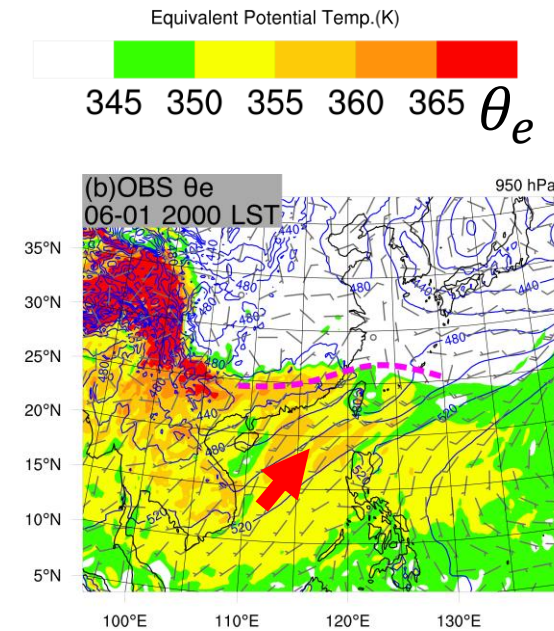
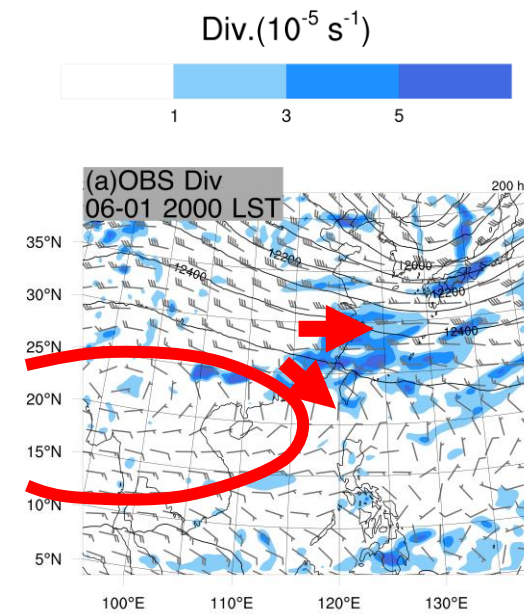
Sensitivity experiments are designed to modify the barrier jet intensity.

Experiment	Terrain	Description
CTRL	Full terrain	Control run
NS	Southern terrain removed	weakened barrier jet
ENH	Full terrain	Enhanced barrier jet (nudging)

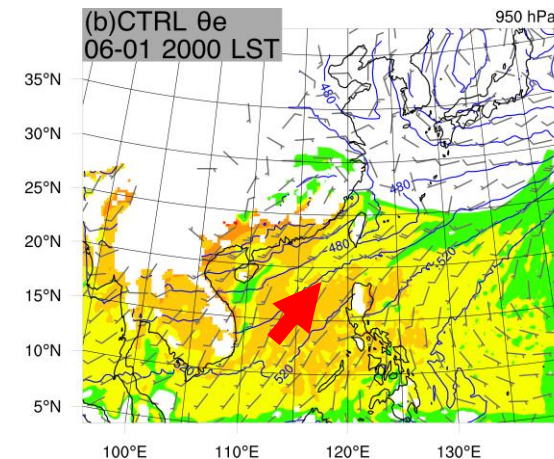
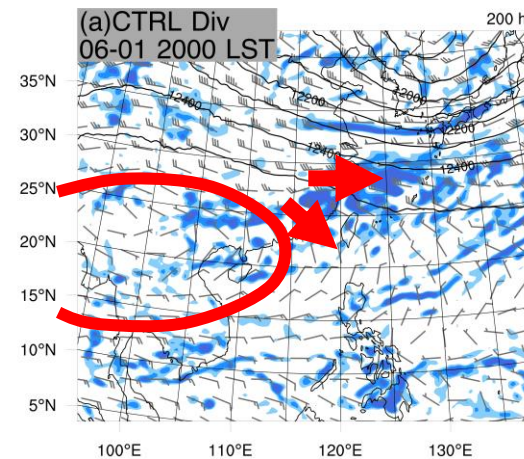
Version	WRF 3.9.1.1		
Grid Size	D01(27km)	D02(9km)	D03(3km)
Initial condition	NCEP-FNL 0.25°×0.25°		
Period	48hr (from 2017/6/1 0800 LST)		

Model Validation

- **Upper-level divergence is well reproduced in CTRL:**
At 200 hPa, diffluent upper-level flow over Taiwan is induced by the South Asian High and the midlatitude westerlies.
- **High θ_e air in the lower troposphere is captured in CTRL:**
At 950 hPa, southwesterly flow of 15–20 $m s^{-1}$ prevails over the South China Sea, accompanied by high θ_e (>350K).
- **The simulated synoptic environment agrees well with observations.**



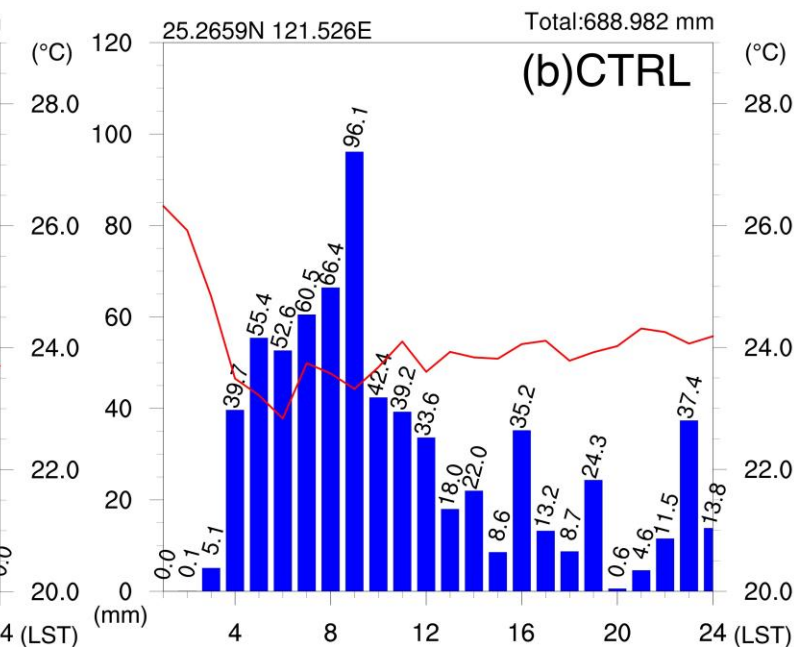
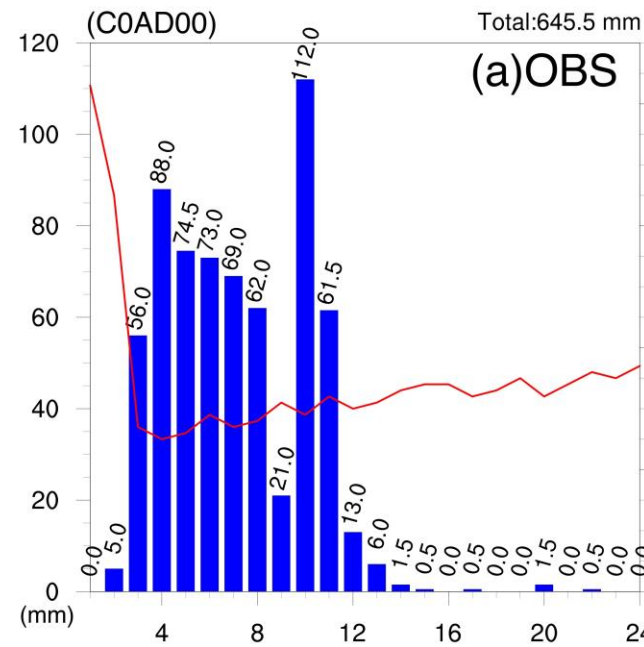
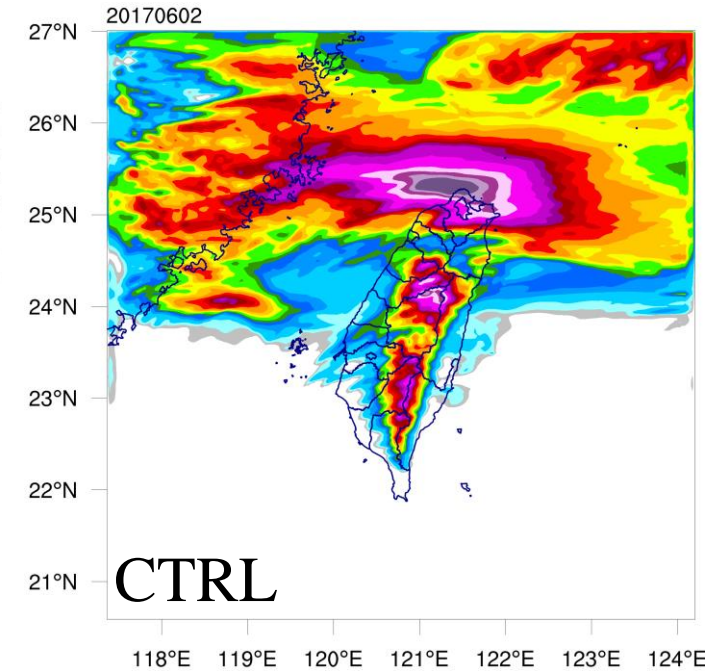
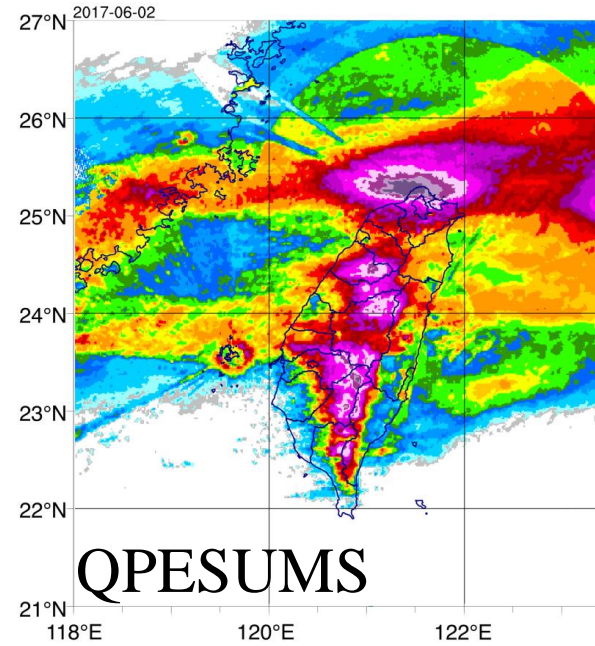
NCEP-FNL analysis



CTRL results

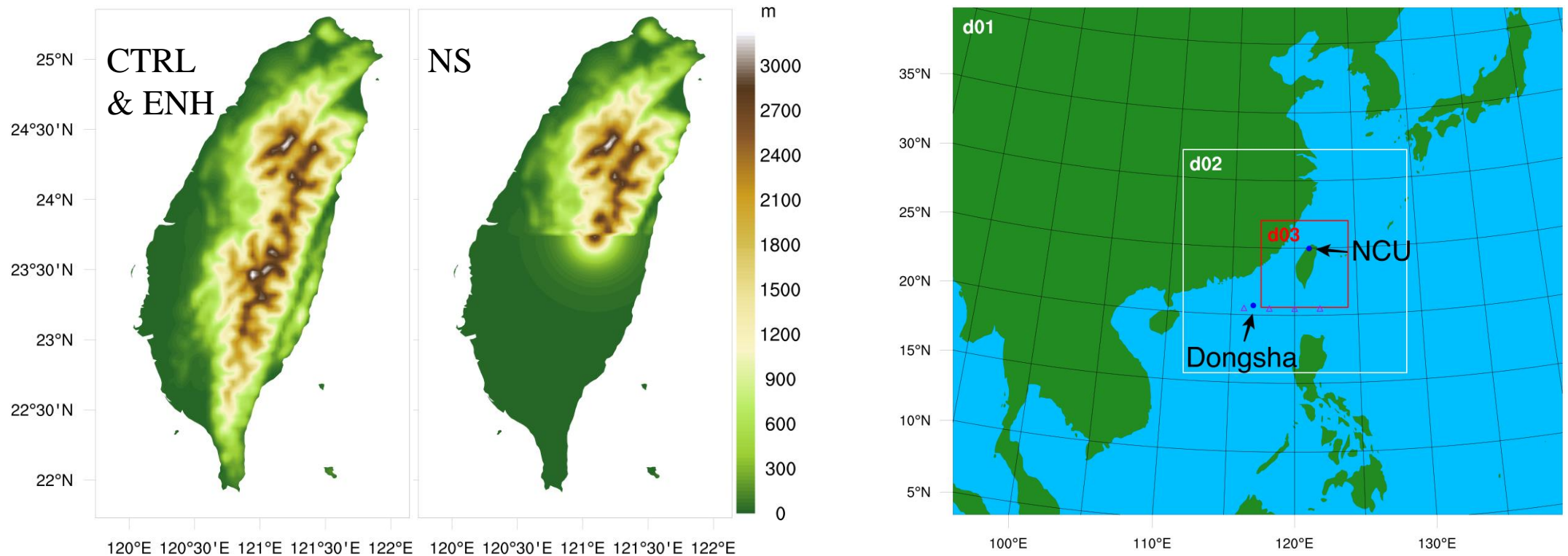
Rainfall validation

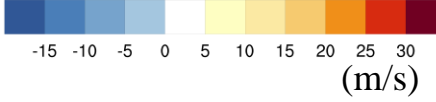
- The location of maximum rainfall is well reproduced.
- The magnitude of accumulated rainfall is reasonably captured.
- The timing and duration of rainfall are well represented.
- Overall, the key characteristics of the rainfall event are captured.



Experimental design for modifying the barrier jet

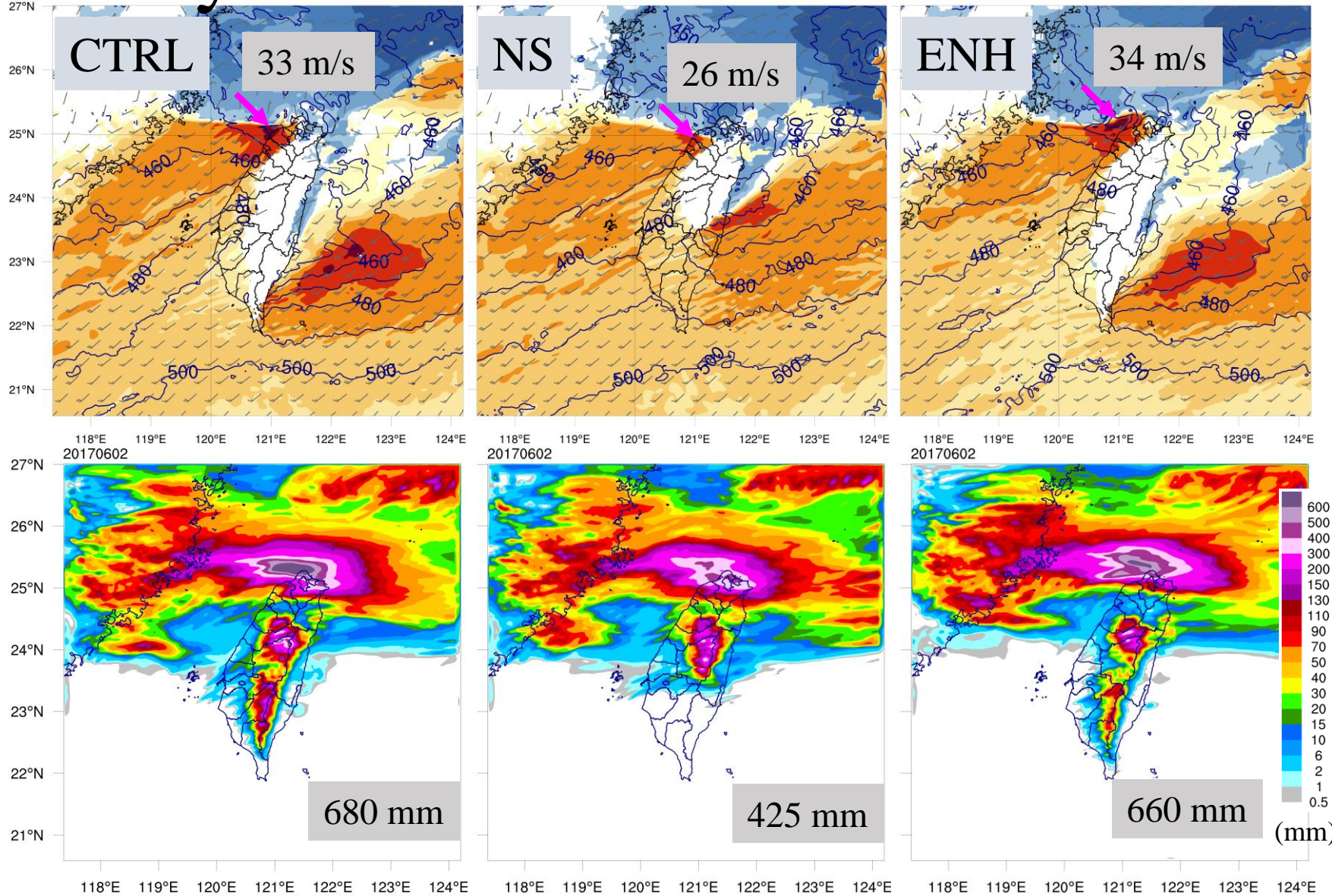
- Southern Taiwan terrain is modified to control the barrier jet.
- Northern terrain is preserved to maintain the interaction with the front.
- Observation nudging is applied to enhance the barrier jet (ENH experiment).
- These experiments allow us to isolate the impact of barrier jet intensity.





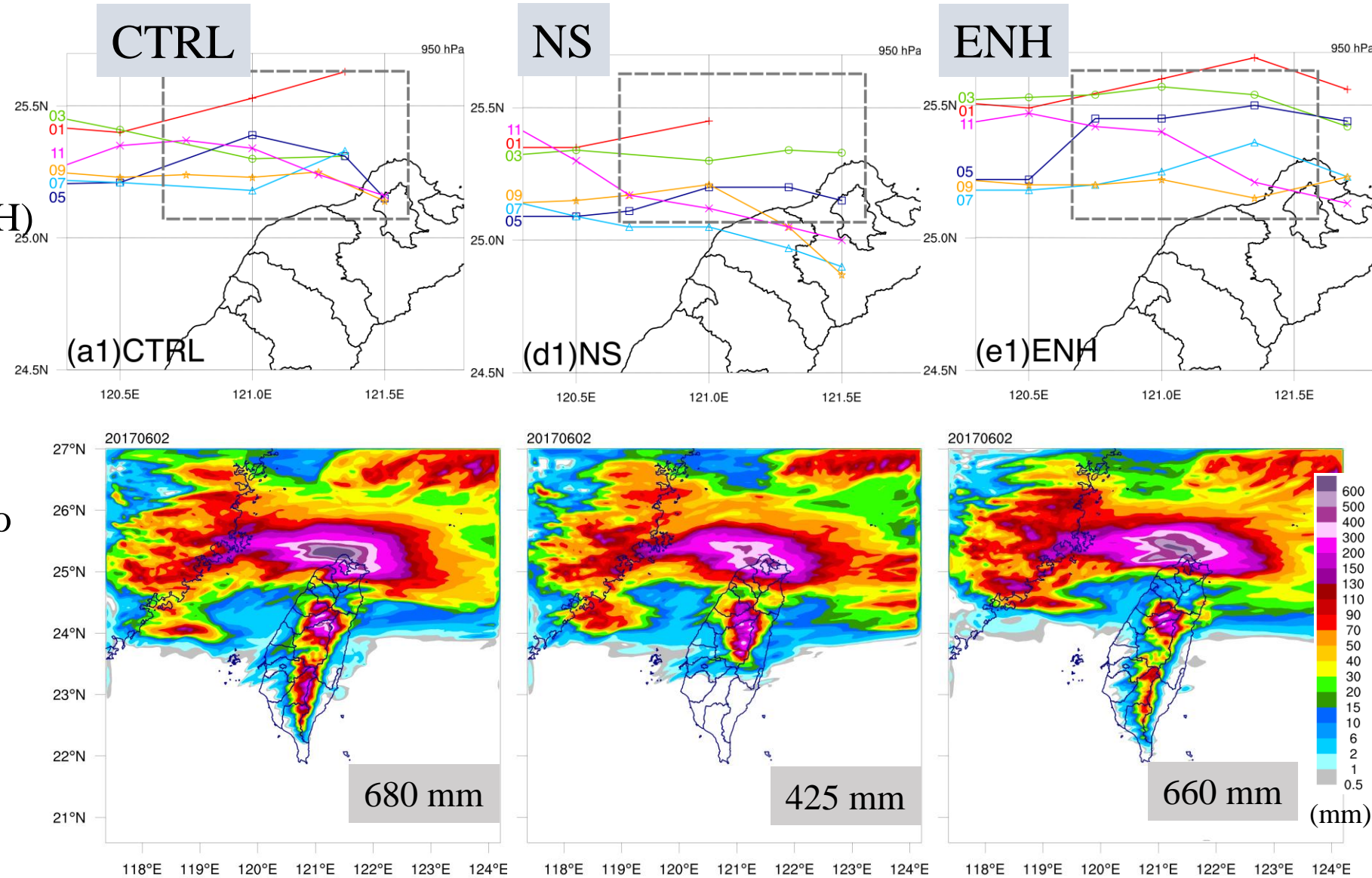
Barrier jet intensity and rainfall distribution

- Barrier jet intensity varies across experiments (ENH > CTRL > NS).
- Rainfall distribution responds to changes in jet strength.
- Stronger jets produce more concentrated rainfall in northern Taiwan, while weaker jets lead to more dispersed rainfall.



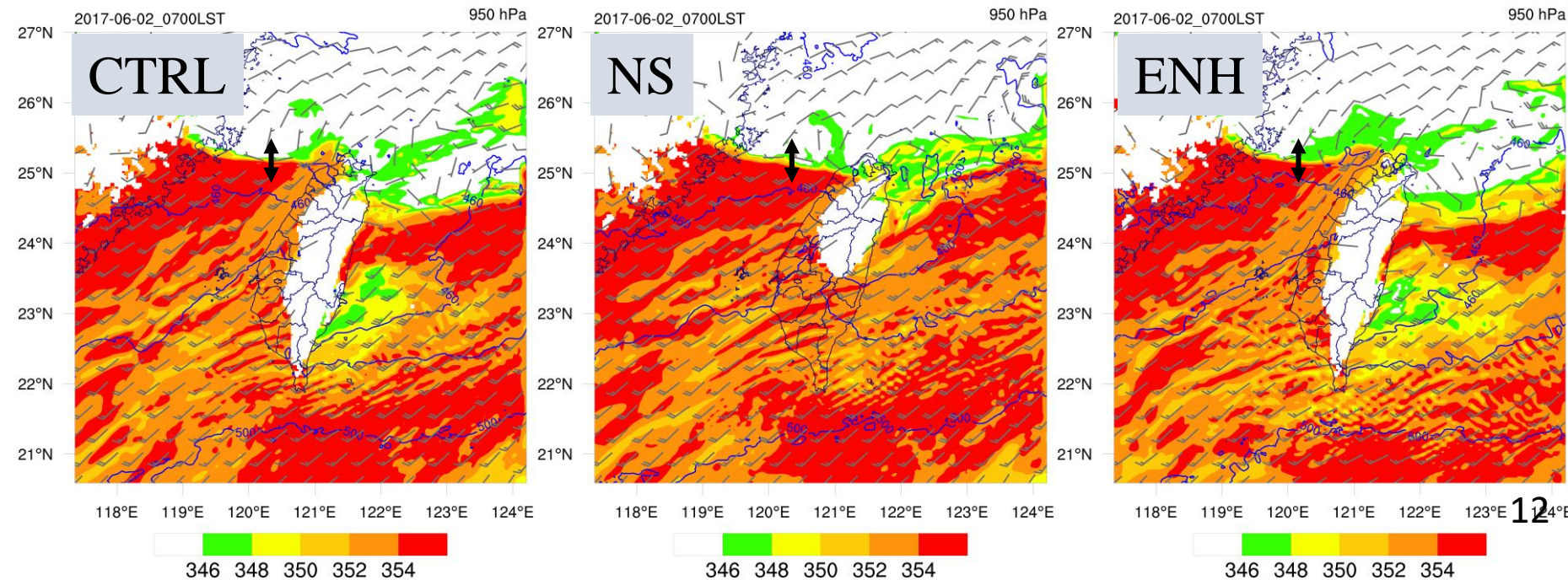
Rainfall distribution and frontal behavior

- Frontal movement is slower with stronger barrier jets (ENH) and faster with weaker jets (NS).
- Stronger jets prolong the frontal residence time over northern Taiwan.
- Longer residence time leads to longer rainfall duration and higher accumulation.



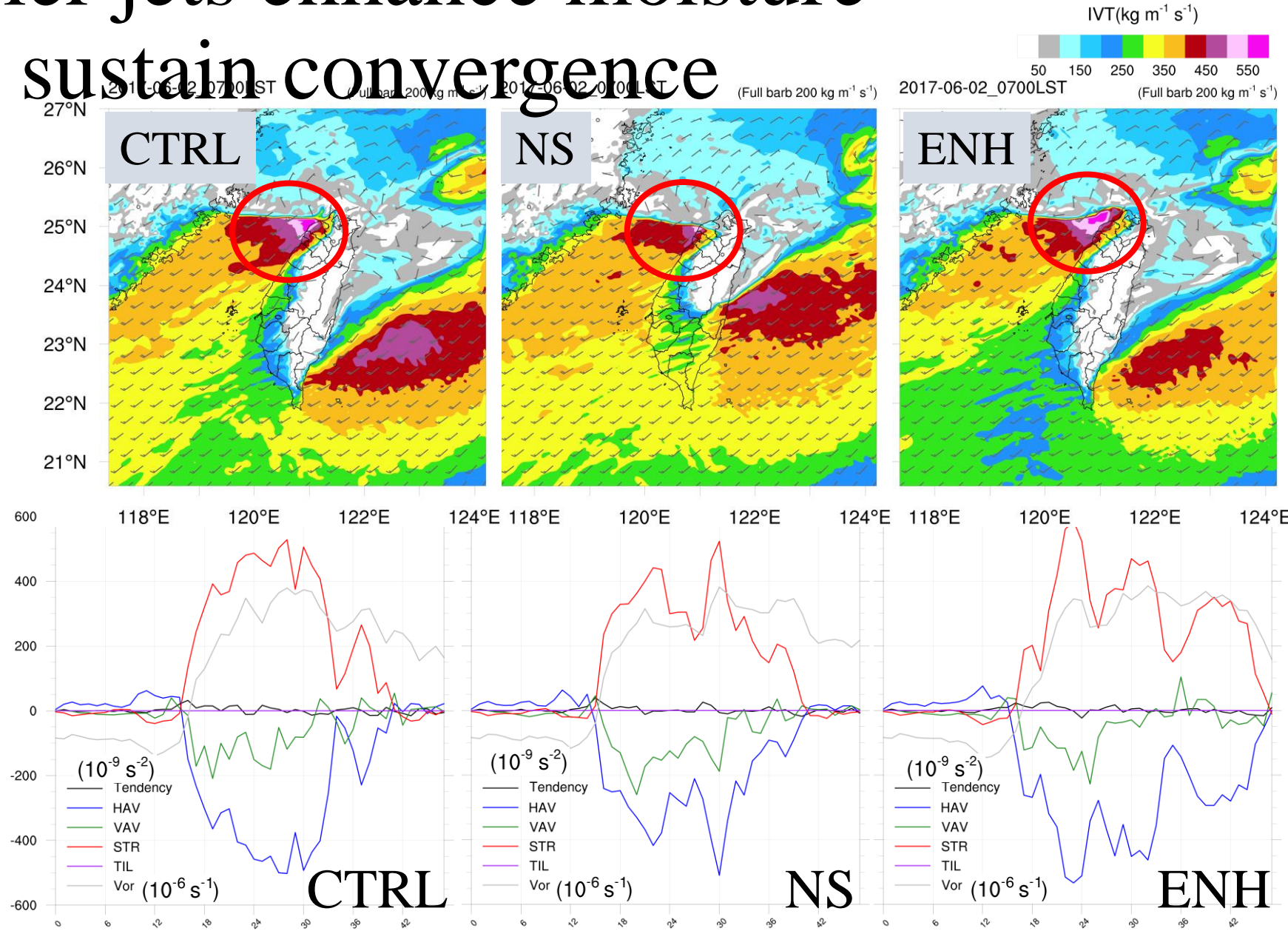
θ_e Distribution

- Frontal θ_e differences are evaluated within ± 25 km of the frontal position.
- All experiments show a similar θ_e gradient (~ 10 K over 50 km).
- This indicates comparable frontal strength across experiments.
- Therefore, rainfall differences are primarily attributed to variations in barrier jet intensity.



Stronger barrier jets enhance moisture transport and sustain convergence

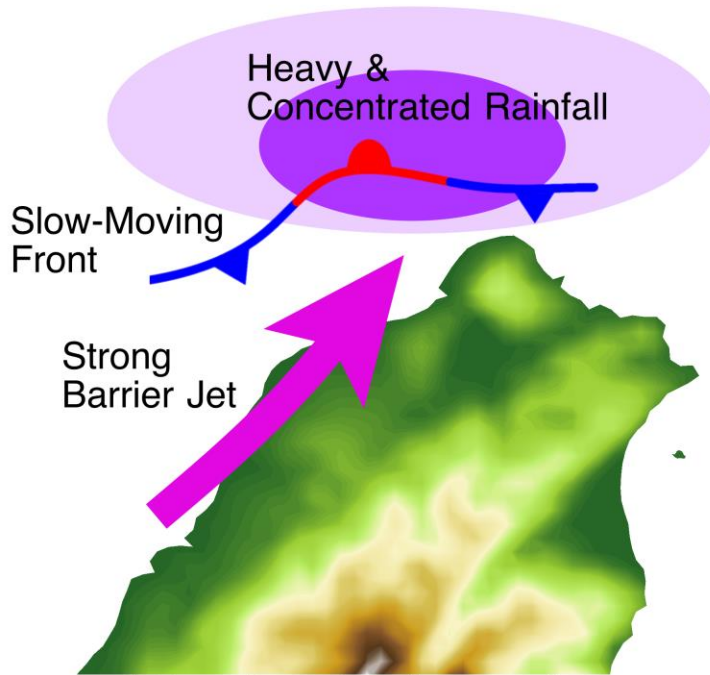
- Stronger barrier jets enhance moisture transport (IVT), reflecting stronger **horizontal advection**.
- They sustain low-level convergence near the front (**stretching effect**).
- The balance between advection and convergence maintains a quasi-steady, slow-moving front (**tendency**).
- This leads to longer-lasting convection and increased rainfall accumulation.



Conceptual model

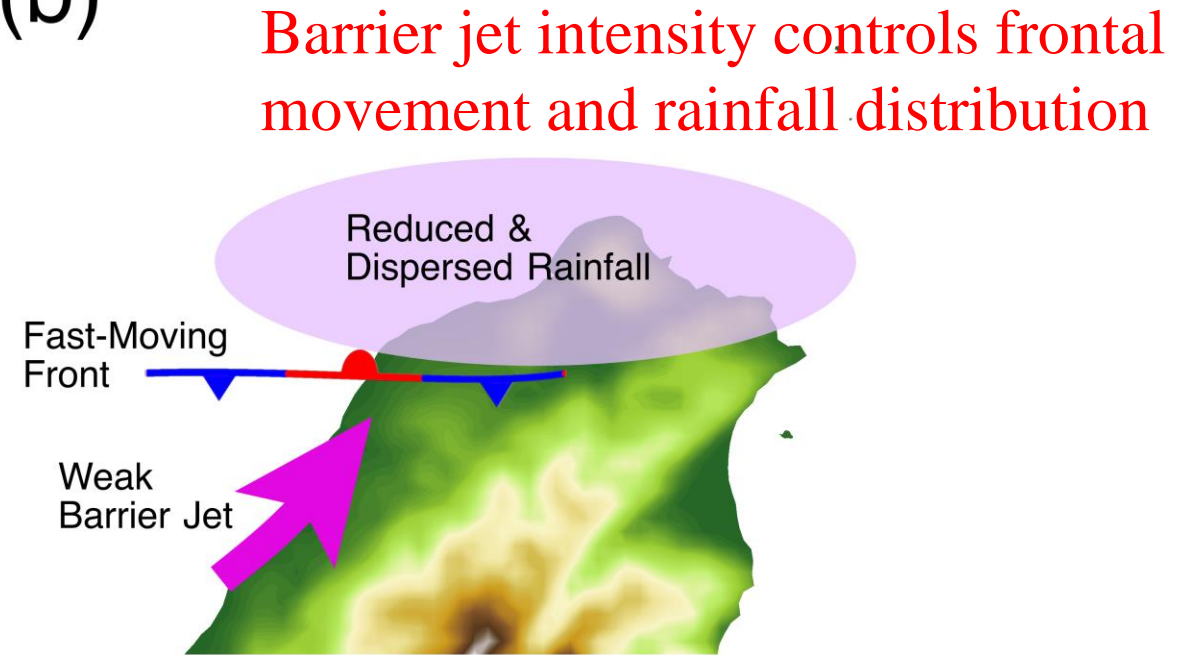
Barrier jet control on frontal movement and rainfall

(a)



- Strong barrier jet
- slow-moving front
- prolonged & concentrated rainfall

(b)



- Weak barrier jet
- fast-moving front
- reduced & dispersed rainfall