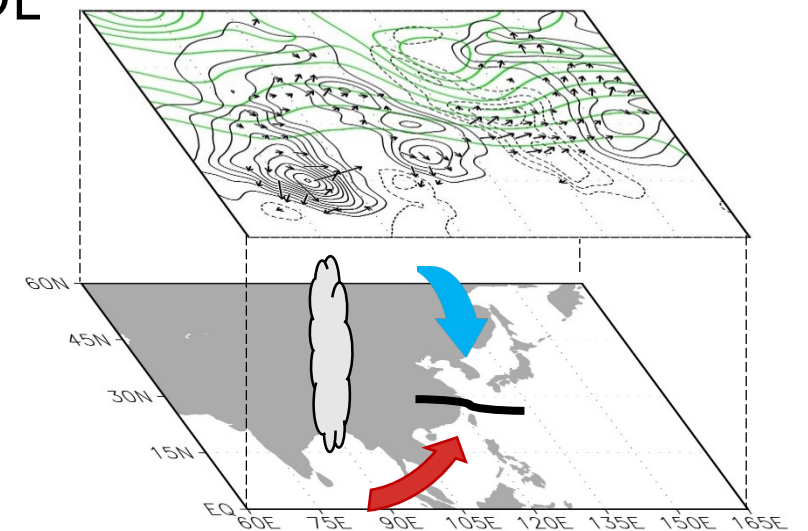
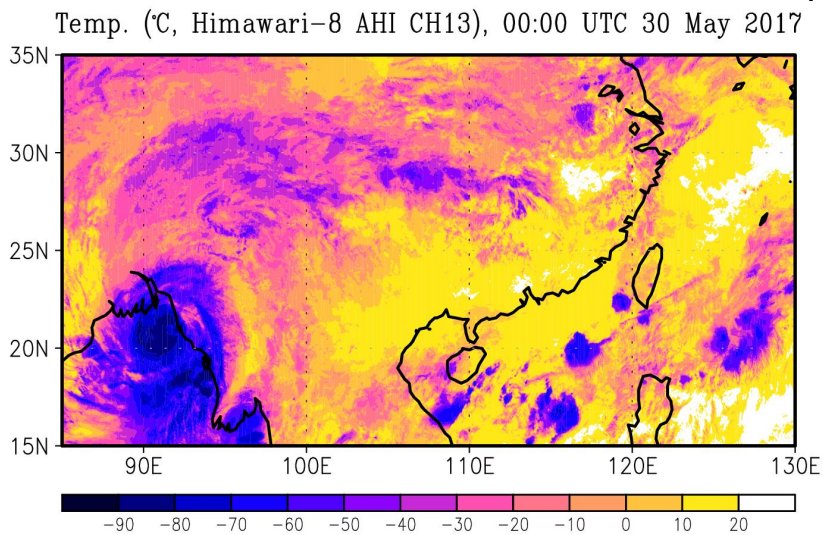


Remote Triggering Effect of a Tropical Cyclone in the Bay of Bengal on a Heavy Rainfall Event in Subtropical East Asia

Sho Arakane¹, Huang-Hsiung Hsu¹, Chia-Ying Tu¹, Hsin-Chien Liang¹,
Zheng-Yu Yan¹, and Shian-Jiann Lin²

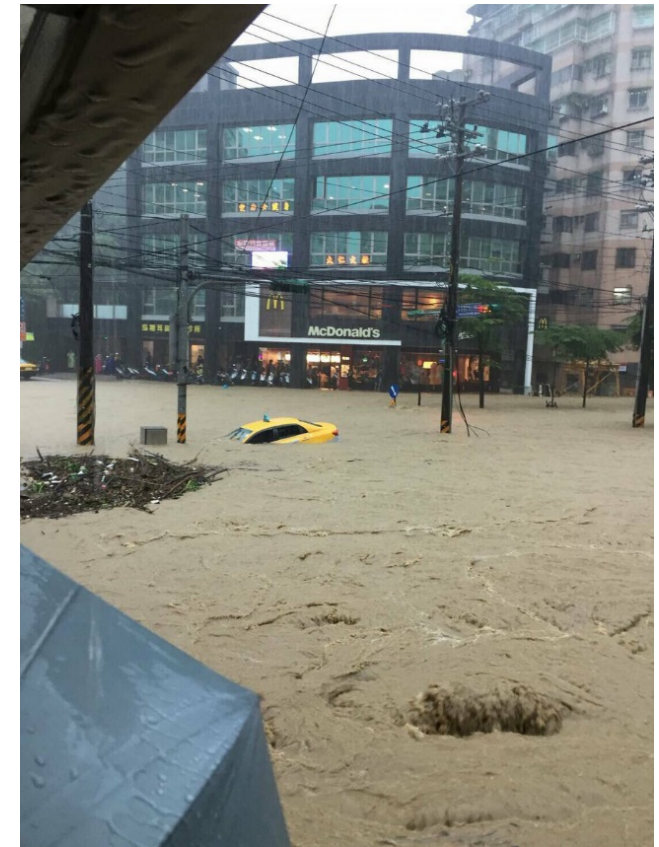
¹RCEC, Academia Sinica, ²GFDL



Introduction

- Torrential frontal rainfall occurred over northern Taiwan on June 1, 2017
- Amount of precipitation: 600mm/12hr in northern Taiwan
- The heavy rainfall induced severe floods and mudslides

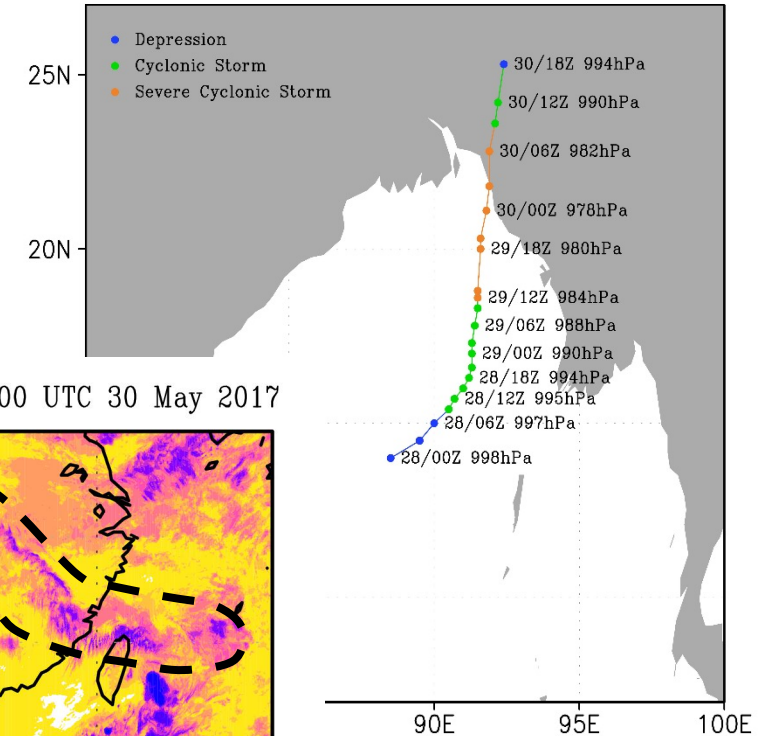
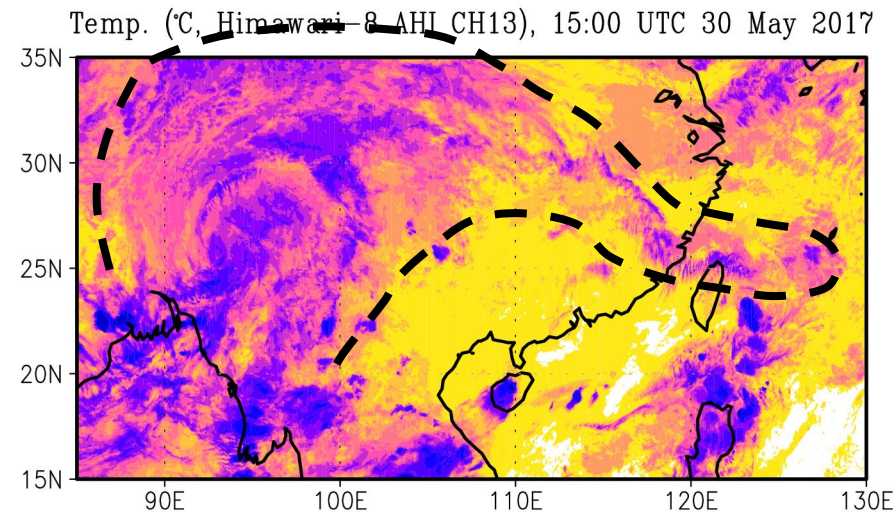
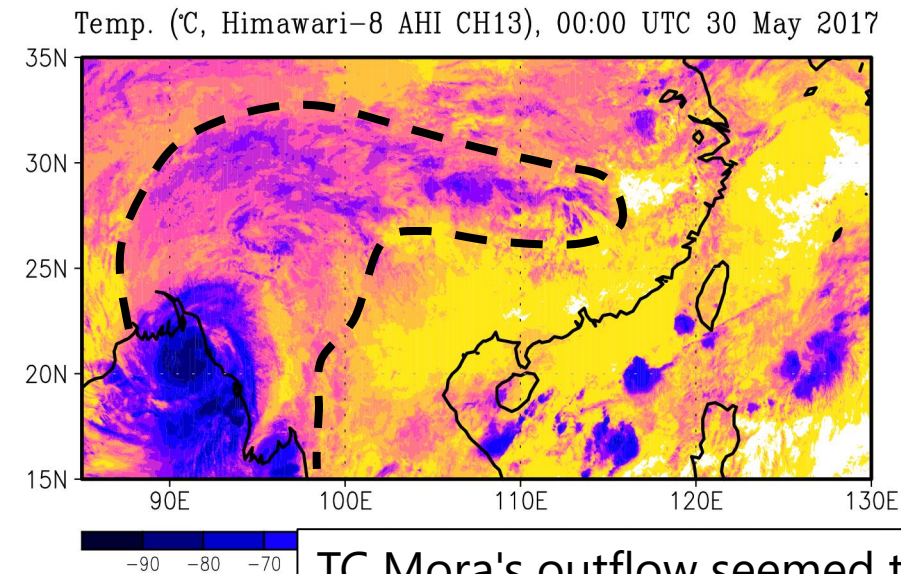
→ three people were killed and two people were missing



Source: twitter.com (@SaiShouYuu)

Introduction

- Prior to the rainfall, Tropical Cyclone (TC) Mora formed over the Bay of Bengal (28/00Z-30/18Z May)



TC Mora's outflow seemed to influence a weather system near Taiwan
→ **Did TC Mora affect the heavy rainfall?**

Agenda

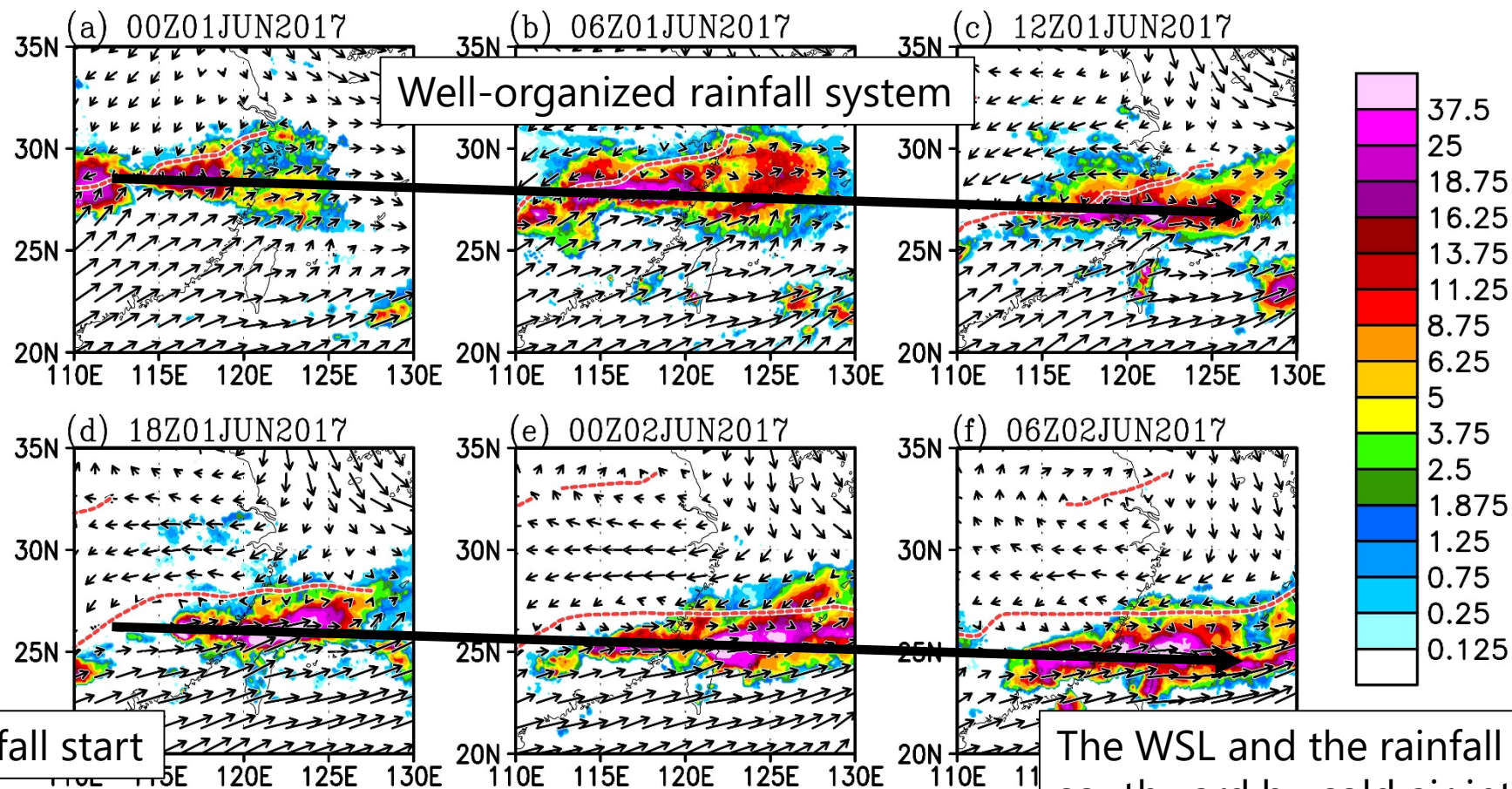
1. Introduction
2. Overview (satellite data, JRA-55 with 1.25° res.)
3. Numerical experiment
 1. Model setting
 2. Validation with observation and JRA-55
 3. Comparison with the sensitivity experiment
4. Conclusion with schematic diagram

Overview (rainfall)

Red-colored line: wind shift line (WSL)

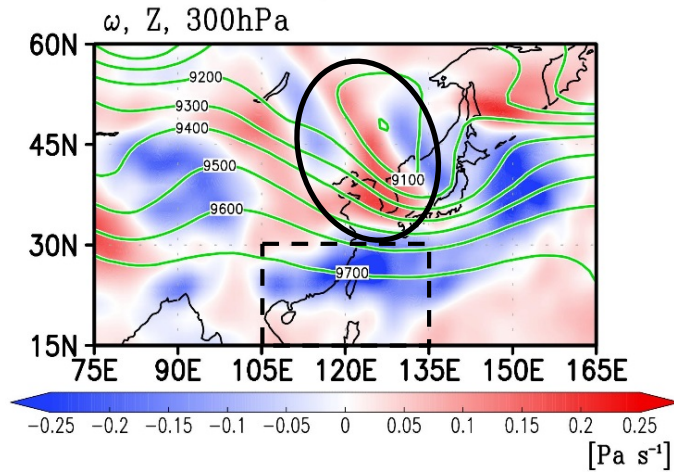
→ Leading edge of airmass

3-hour Precip. [GSMaP, mm (3h)⁻¹], 850hPa Wind [JRA55, m s⁻¹]

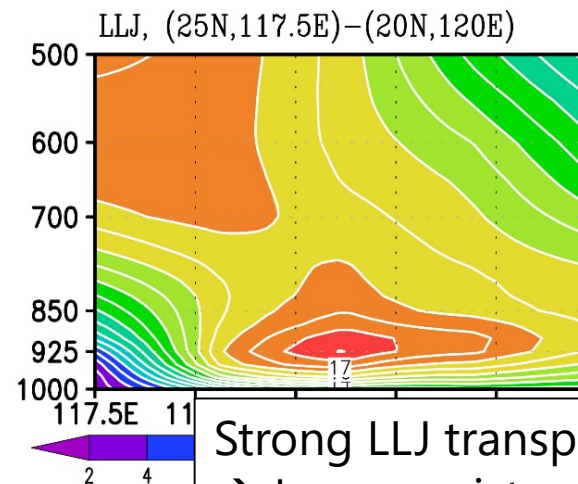
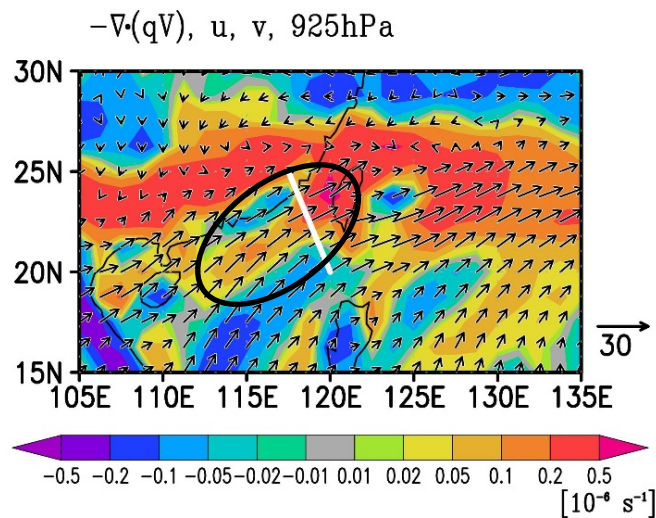


Overview (upper and low-level fields)

18Z01JUN2017 (JRA55)



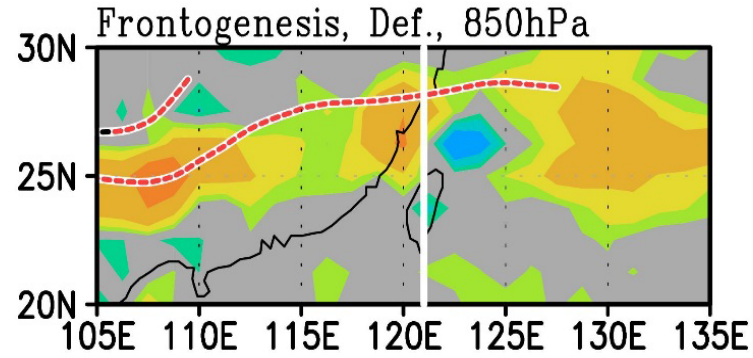
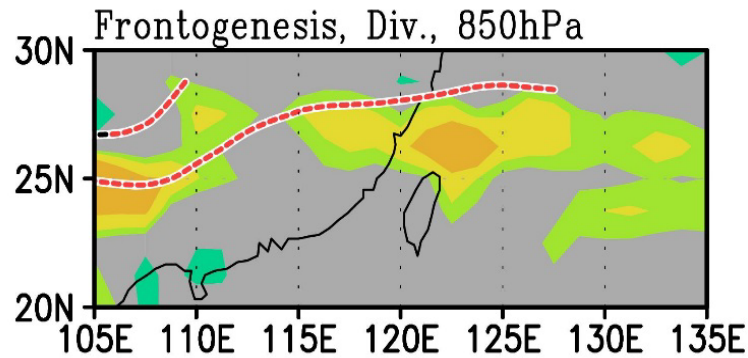
Upper-level trough
→ **Subsiding northerly**



Strong LLJ transported warm/moist air
→ Large moisture convergence around Taiwan

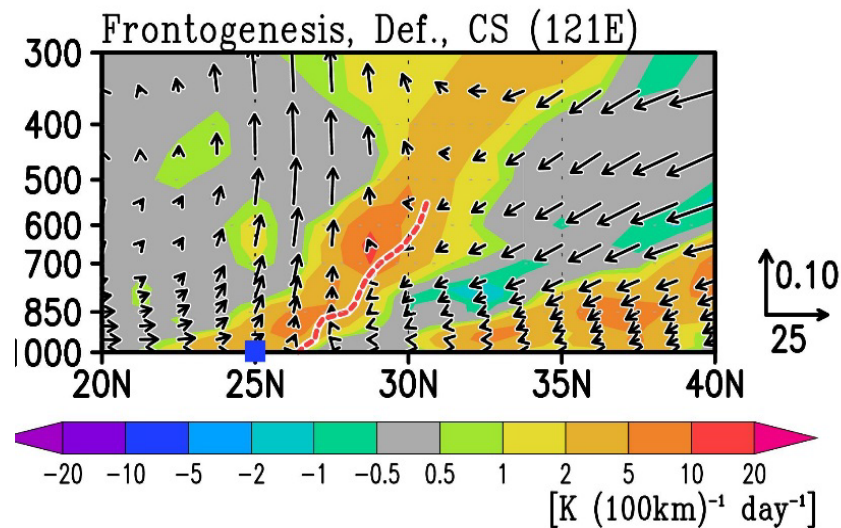
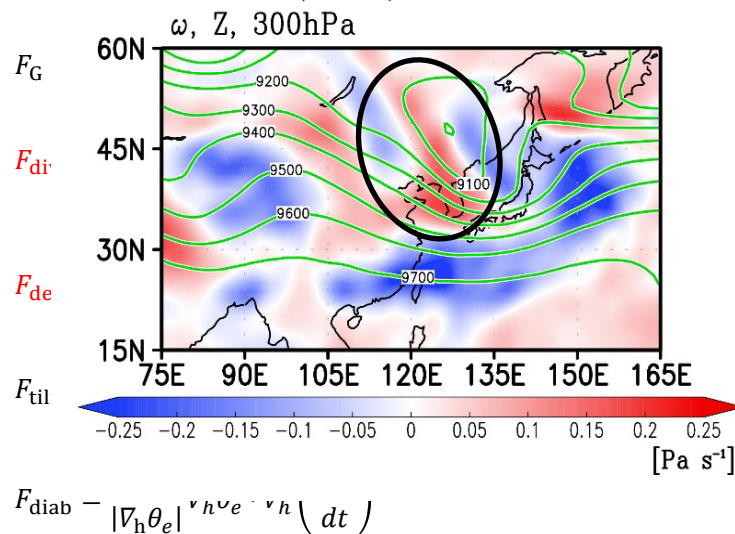
Overview (frontogenesis)

18Z01JUN2017 (JRA55)



The front was enhanced by the divergence and deformation terms along the WSL

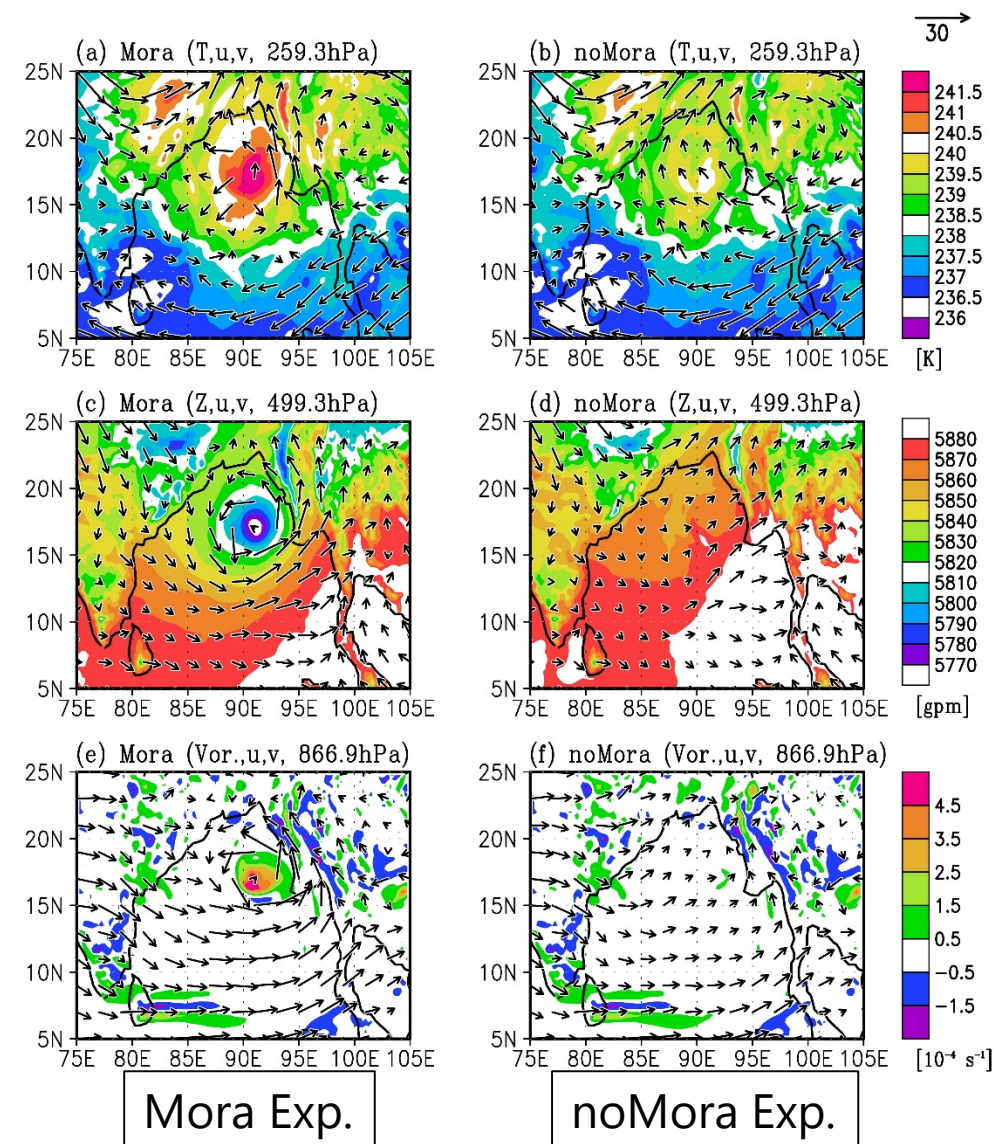
18Z01JUN2017 (JRA55)



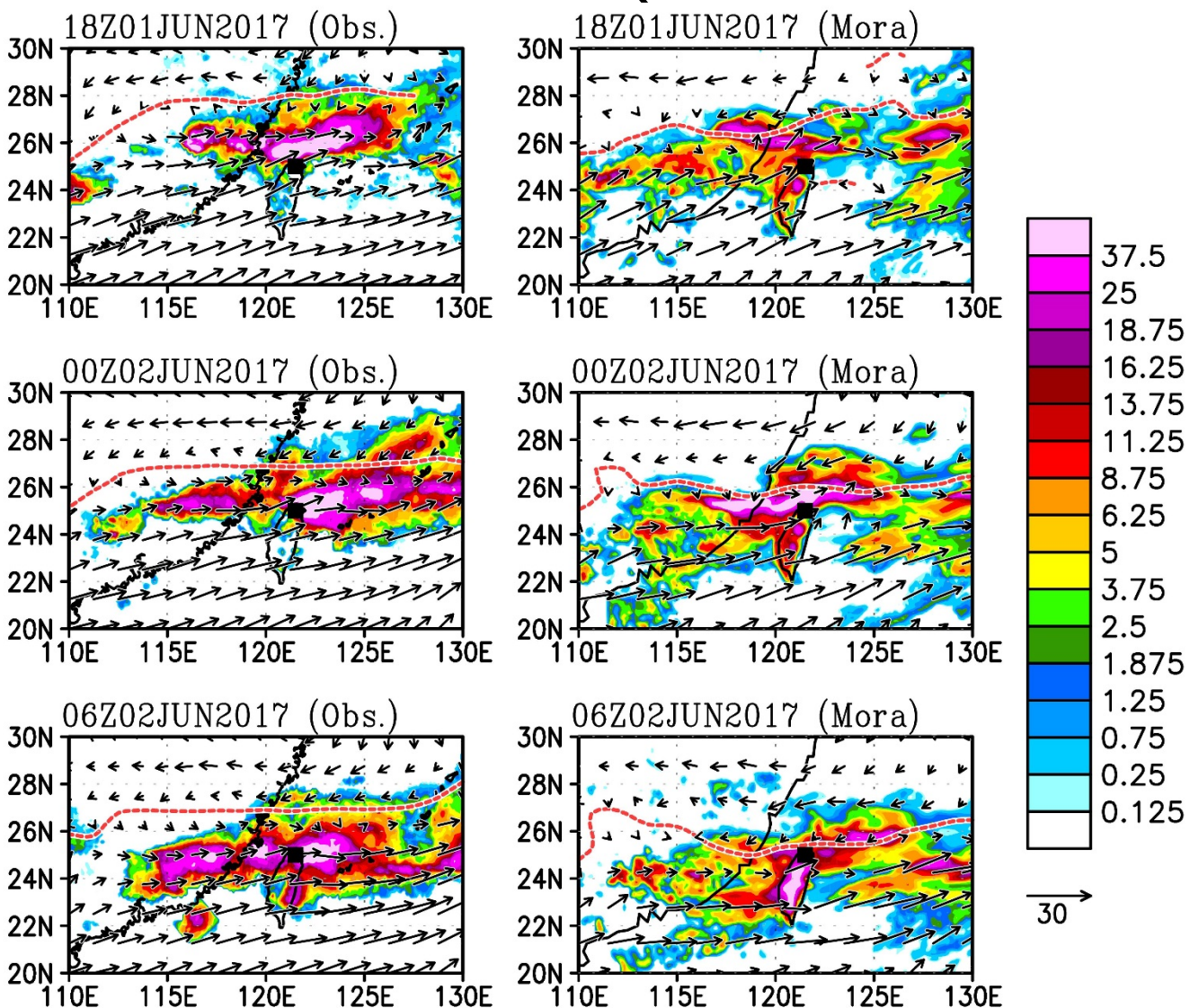
The subsiding northerly originated from the upper-level trough intruded into Taiwan region
 → The confluence of the LLJ and the subsiding northerly created the front near Taiwan

Numerical simulation (Setting)

- Model: **NCEP FV3 GFS**
- Horizontal resolution: **C768 (approx. 12.5 km)**
- Vertical resolution: **64 levels (~0.3 hPa)**
- Cumulus parameterization: **simplified Arakawa–Schubert**
- Microphysics: **single-moment 6-class scheme**
- Initial time: **0000 UTC on May 29 (88h before the rainfall)**
- Control and sensitivity (no TC) exps.



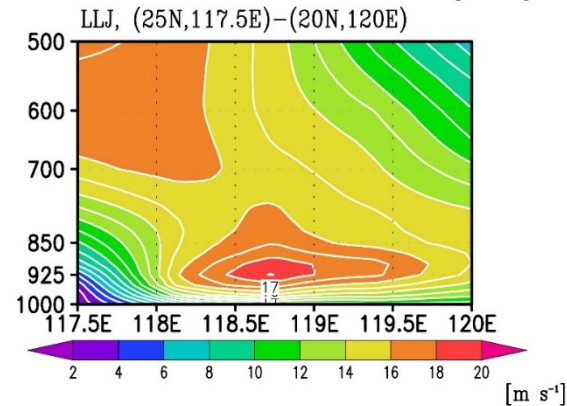
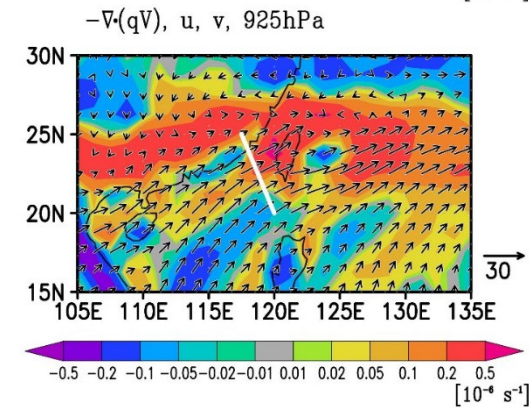
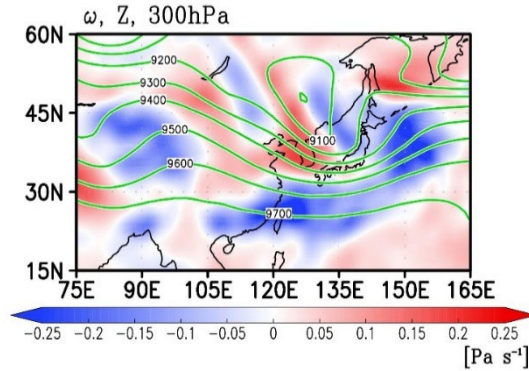
Result (Obs. v Mora exp.)



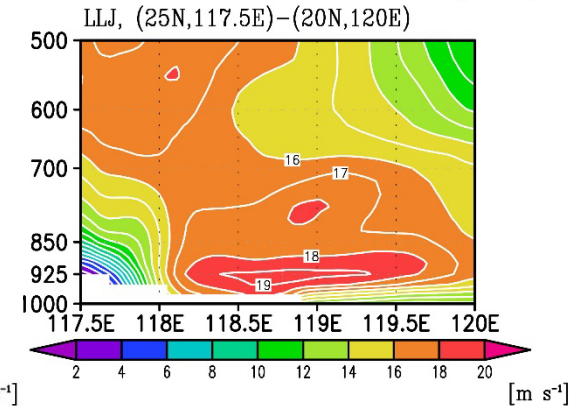
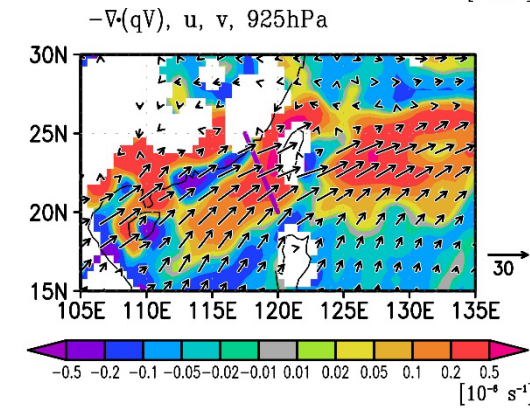
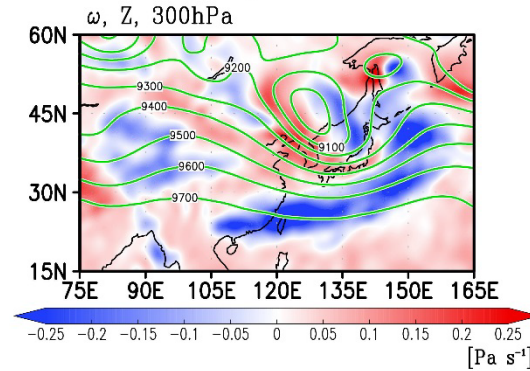
- ✓ Well-organized frontal rainfall system
- ✓ Southward movements of the WSL and rainfall system

Result (Obs. v Mora exp.)

18Z01JUN2017 (JRA55)



18Z01JUN2017 (Mora)

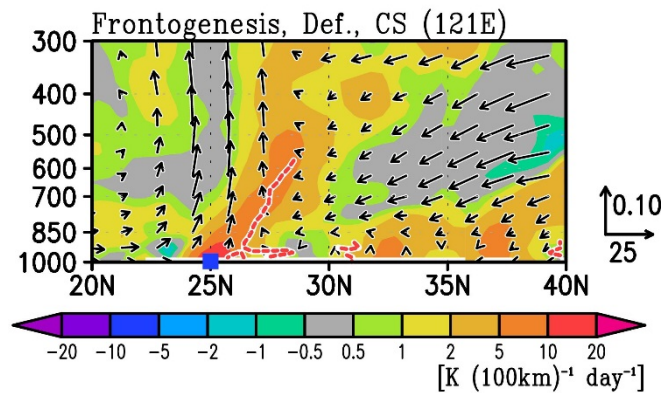
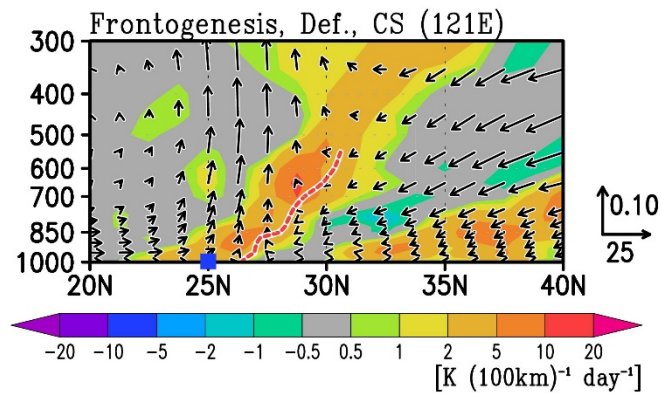
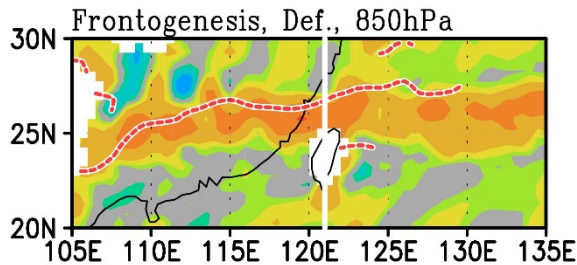
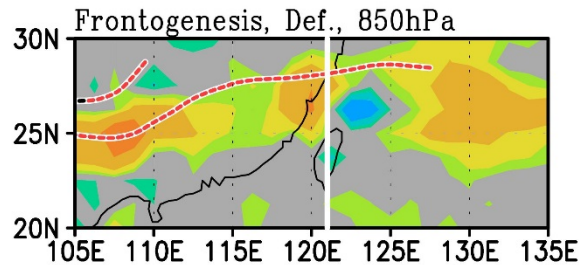
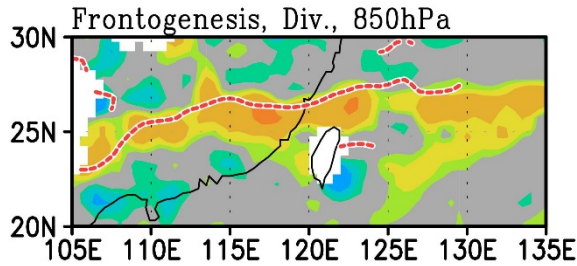
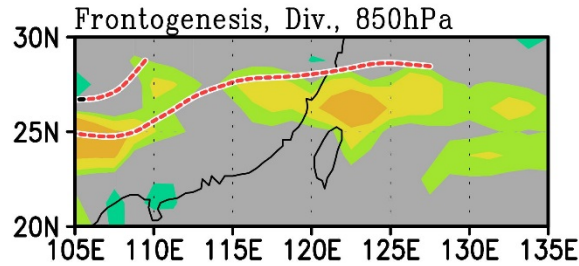


- ✓ The subsiding northerly originated from the upper-level trough
- ✓ The strong southwesterly LLJ
- ✓ The large moisture convergence around Taiwan

Result (Obs. v Mora exp.)

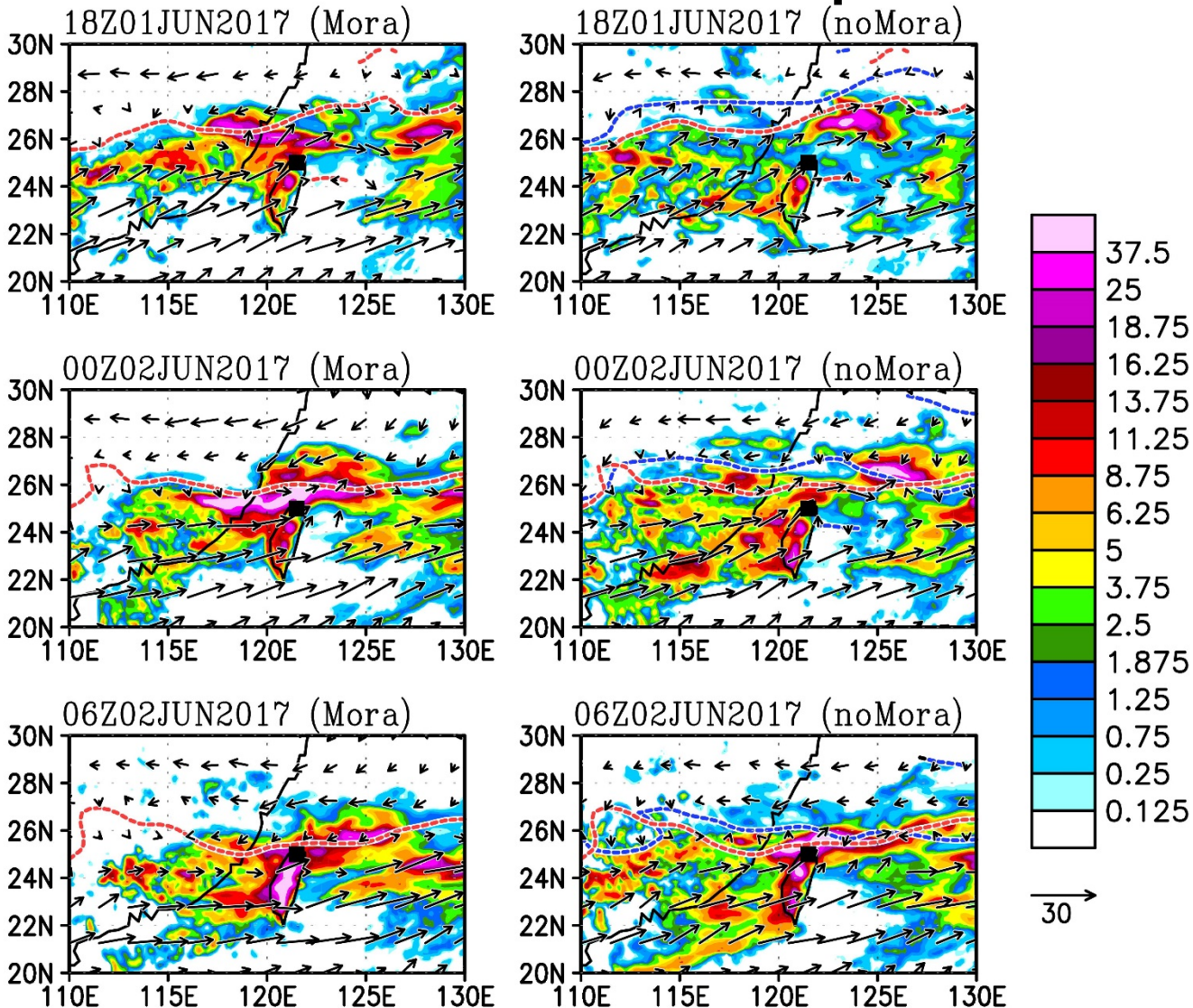
18Z01JUN2017 (JRA55)

18Z01JUN2017 (Mora)



- ✓ The front is enhanced by the divergence and deformation effects along the WSL
- ✓ Intrusion of the subsiding northerly
- ✓ Vertically tilted structure of deformation effect for frontogenesis

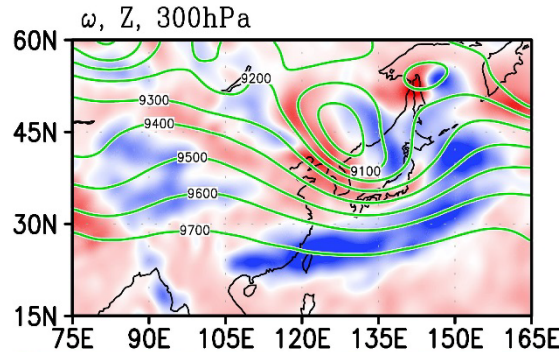
Result (Mora exp. v noMora exp.)



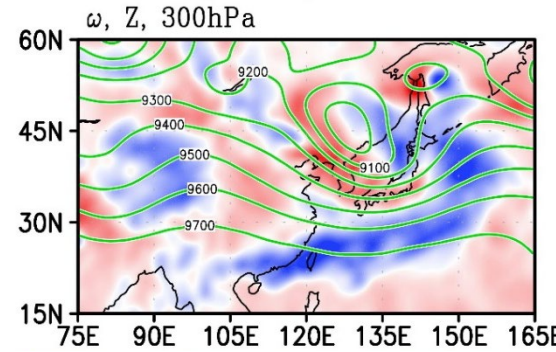
- If TC Mora exists,
 - ✓ The rainfall system is well-organized
 - ✓ The WSL is farther South
- If TC Mora doesn't exist,
 - ✓ The rainfall system is less-organized
 - ✓ The WSL is farther North

Result (Mora exp. v noMora exp.)

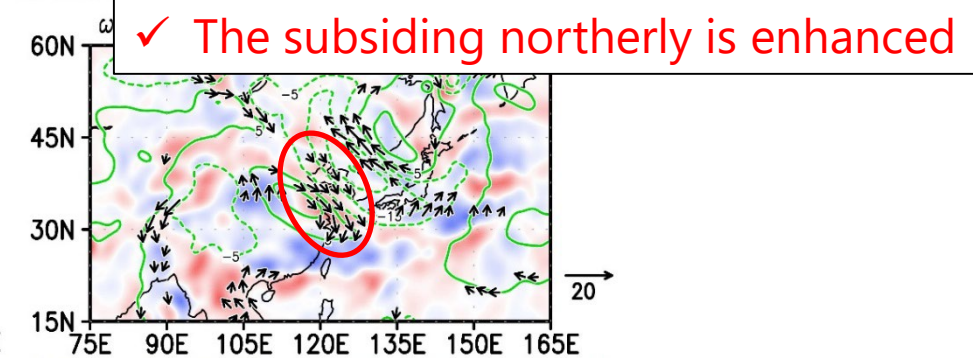
18Z01JUN2017 (Mora)



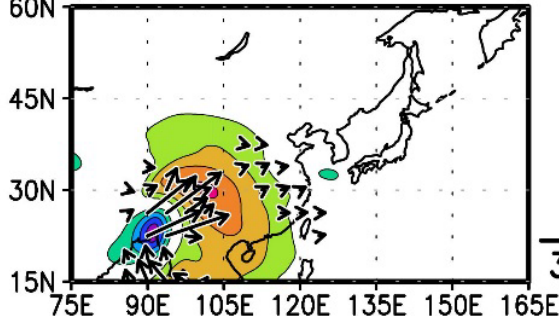
18Z01JUN2017 (noMora)



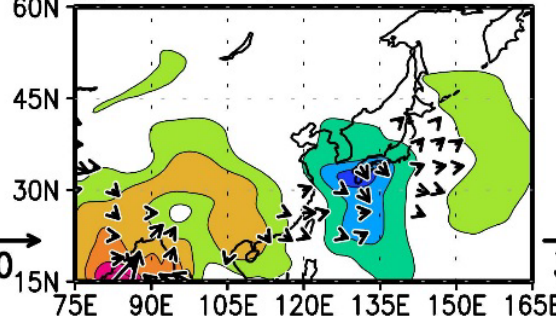
18Z01JUN2017 (Diff.)



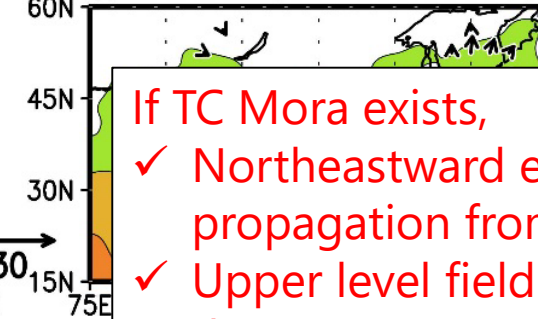
(d) Ψ_{300} , WAF (Diff., 12Z30MAY2017)



(e) Ψ_{300} , WAF (Diff., 12Z31MAY2017)



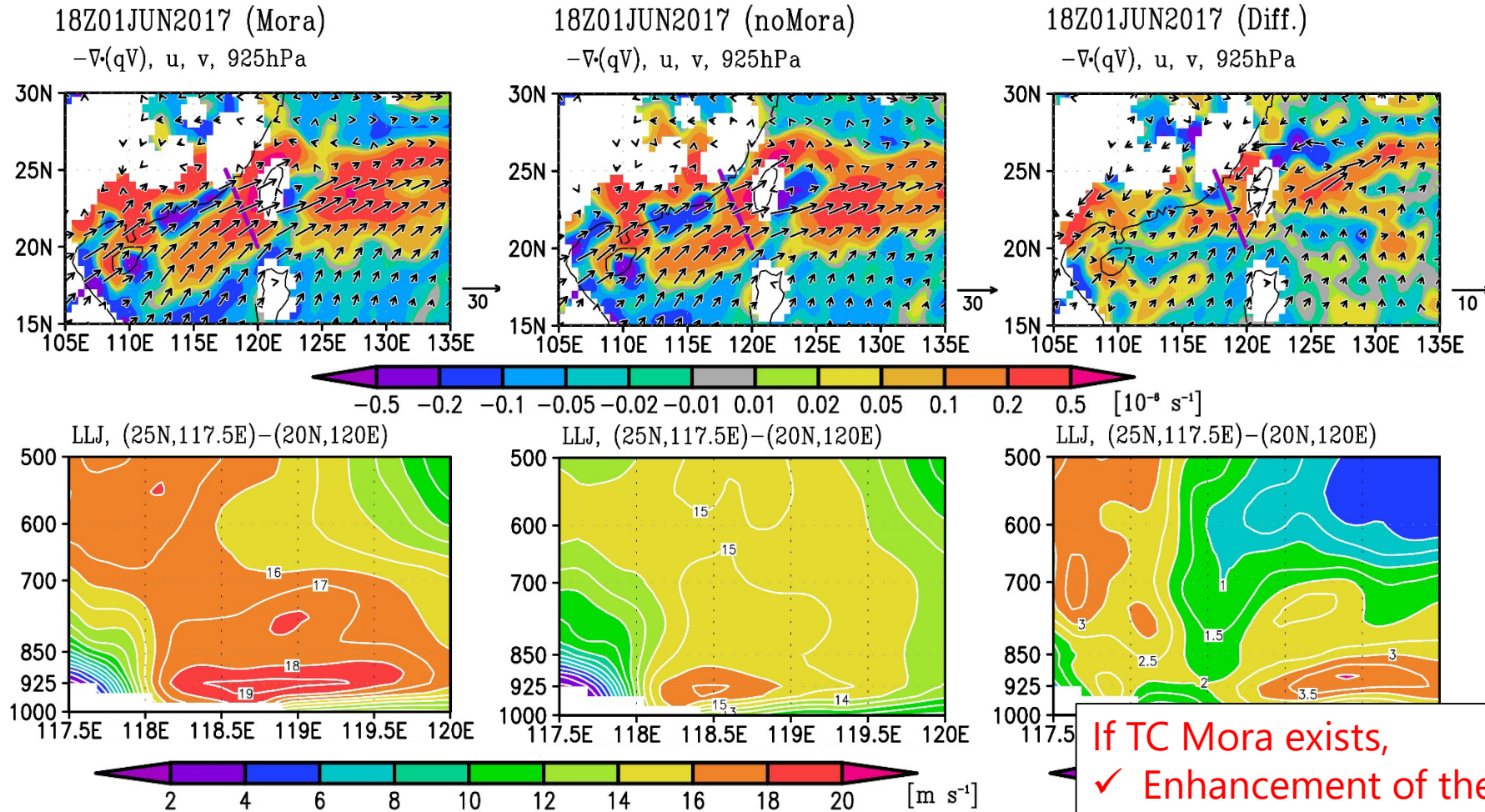
(f) Ψ_{300} , WAF (Diff., 12Z01JUN2017)



- If TC Mora exists,
- ✓ Northeastward energy propagation from the BoB
 - ✓ Upper level field is modulated by the energy propagation
 - ✓ The subsiding northerly is enhanced

Time series of streamfunction difference and WAF difference

Result (Mora exp. v noMora exp.)



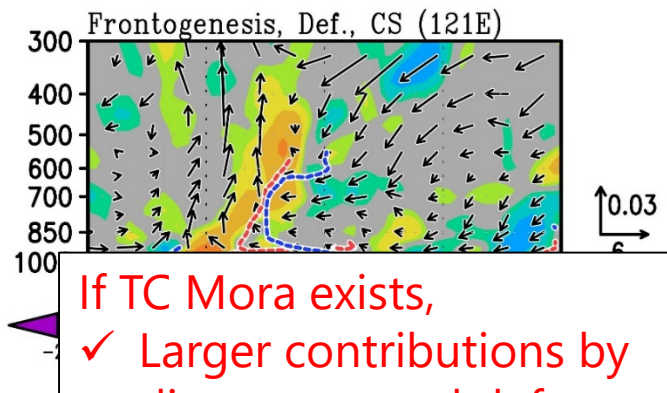
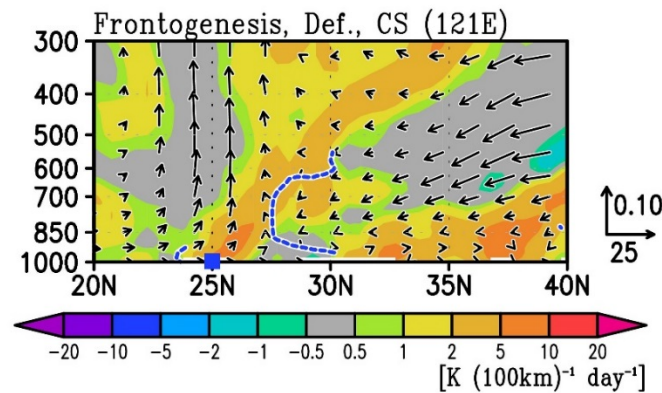
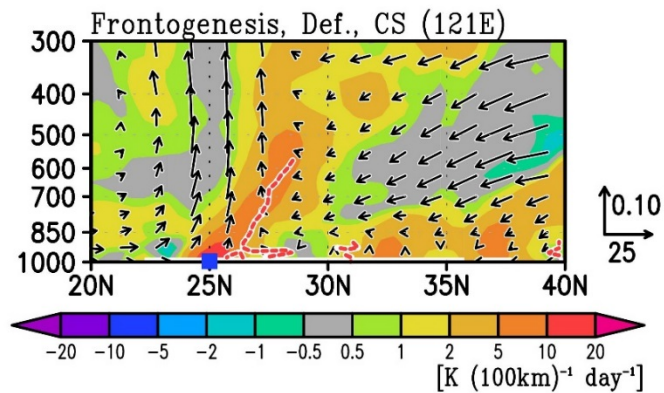
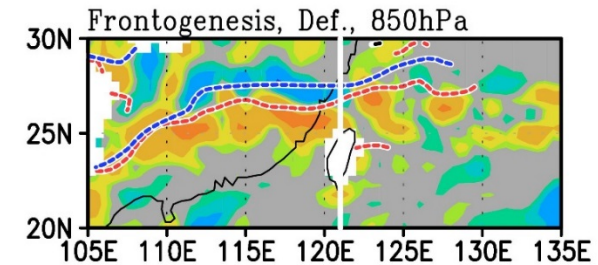
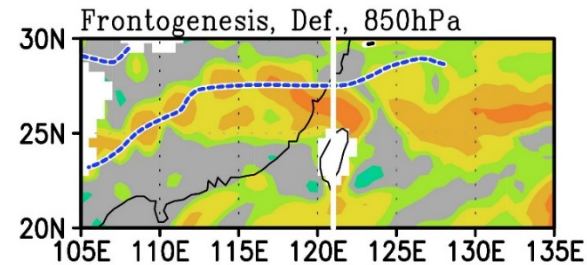
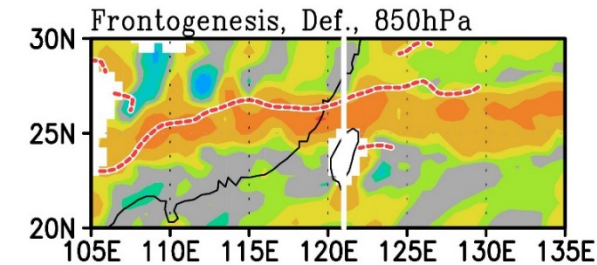
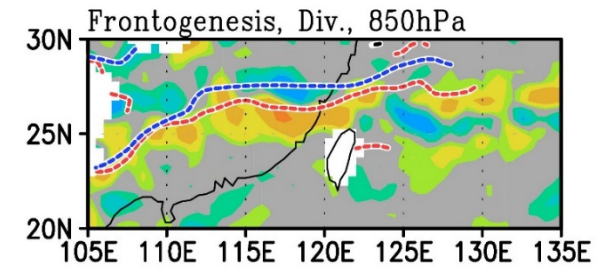
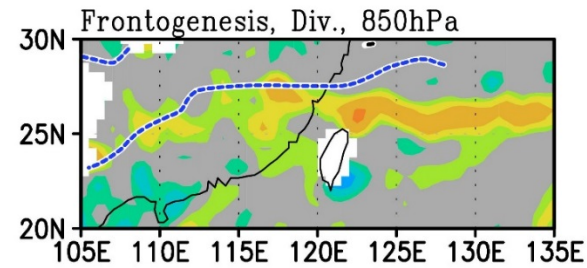
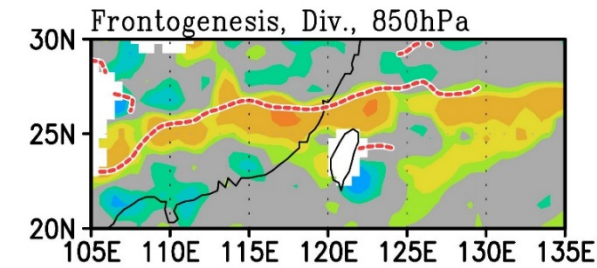
If TC Mora exists,
 ✓ Enhancement of the LLJ
 ✓ Enhancement of moisture convergence around Taiwan

Result (Mora exp. v noMora exp.)

18Z01JUN2017 (Mora)

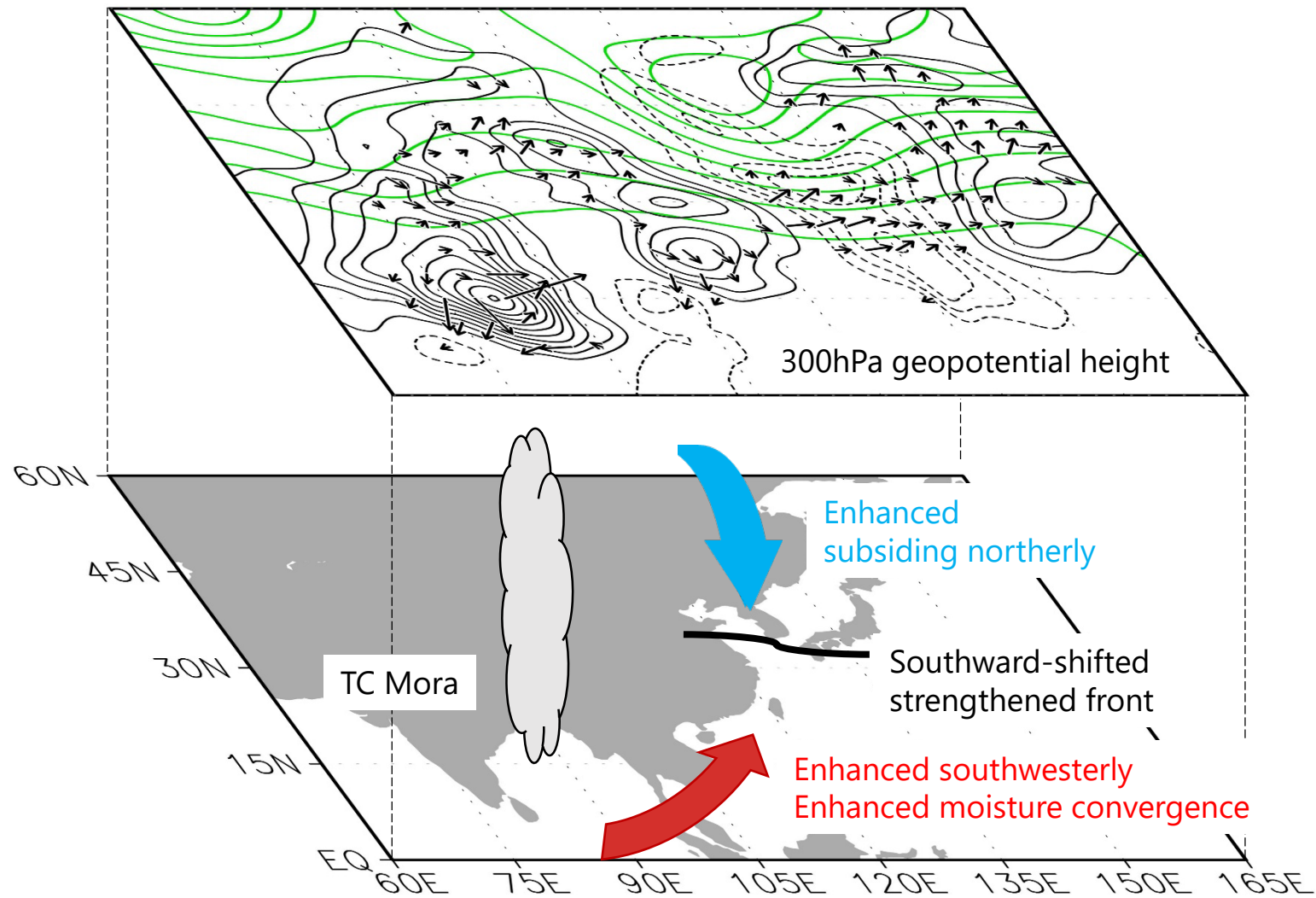
18Z01JUN2017 (noMora)

18Z01JUN2017 (Diff.)



If TC Mora exists,
✓ Larger contributions by
divergence and deformation for
the frontal development

Schematic Diagram

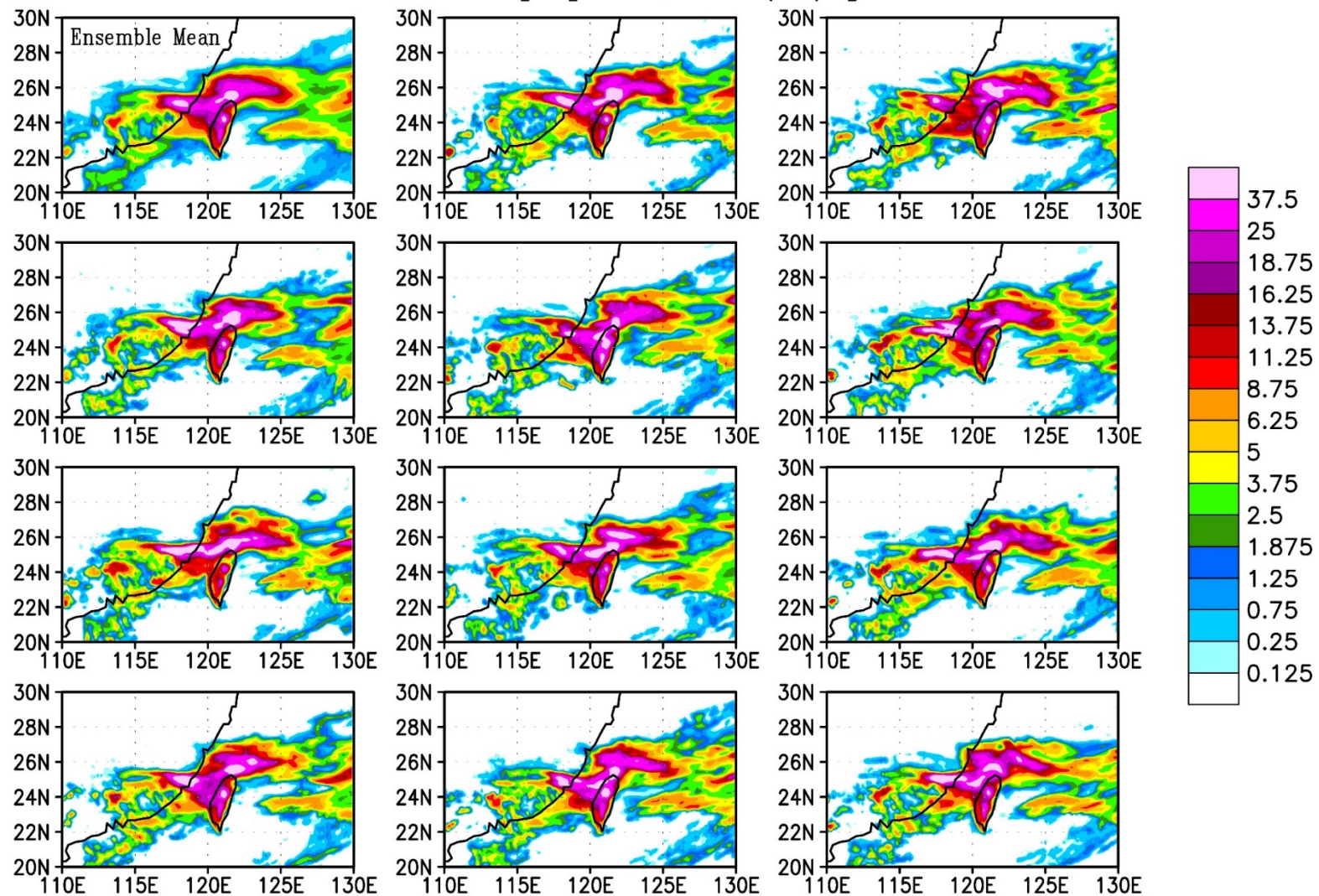


Conclusion

- ✓ **TC Mora remotely and extensively affected circulation over East Asia**
- ✓ **The effect on circulation enhanced the subsiding northerly to the north of Taiwan and the southwesterly over the South China Sea to the southwest of Taiwan**
- ✓ **The strong northerly moved cooler air mass farther southward in the north of Taiwan and promoted the enhancement of low-level convergence**
- ✓ **The strengthened and widened low-level jet over the South China Sea transported moisture-laden air toward Taiwan and enhanced low-level moisture convergence near Taiwan**
- ✓ **The stronger confluent zone induced by the strengthening of the warm moist southerly and cool dry northerly resulted in a strong baroclinic zone (front), which shifted further southward toward northern Taiwan through the deformation and divergence processes**
- ✓ **The enhanced low-level moisture convergence and frontal system generated heavy rainfall over northern Taiwan.**

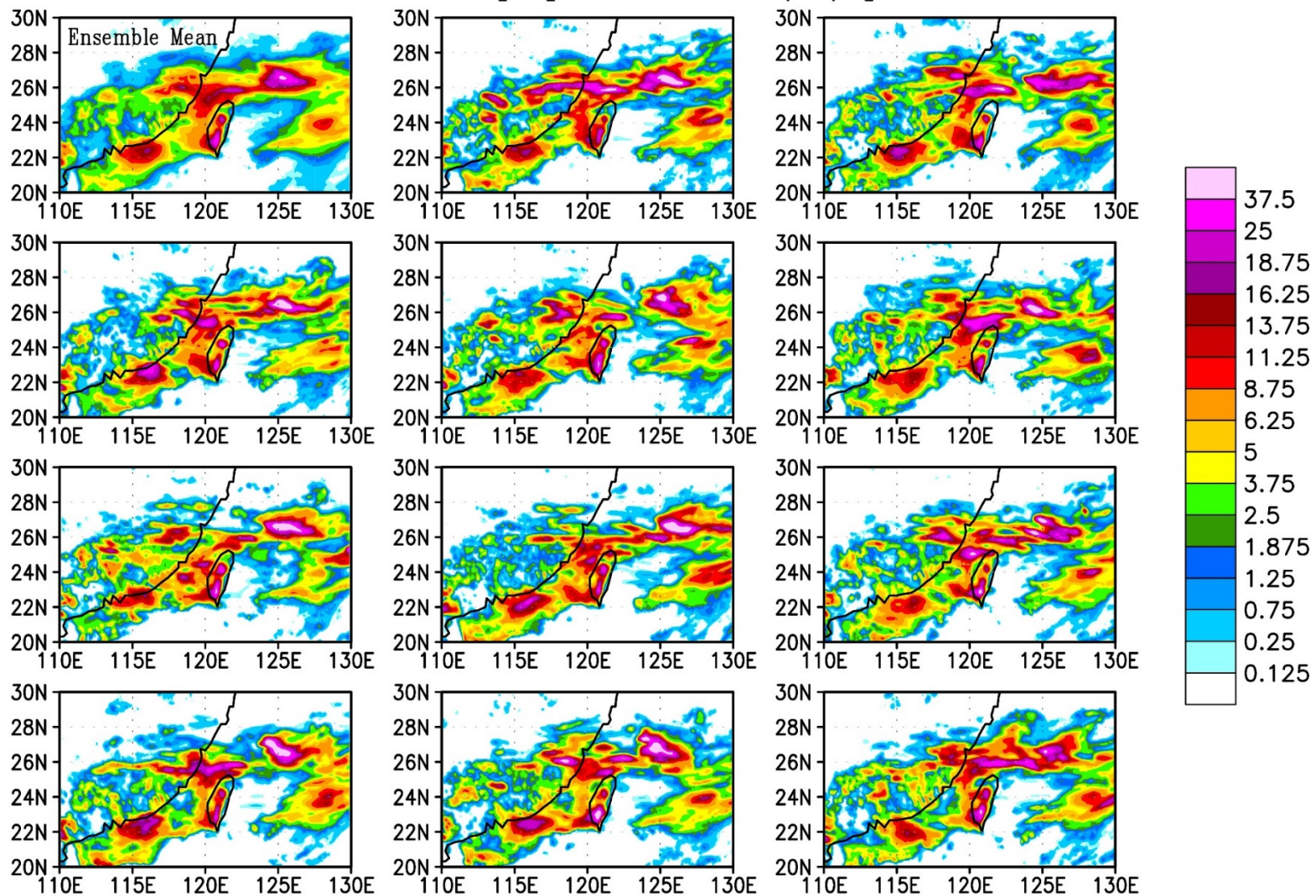
Ensemble simulation

3-hour Precip. [Mora, mm (3h)⁻¹]



Ensemble simulation

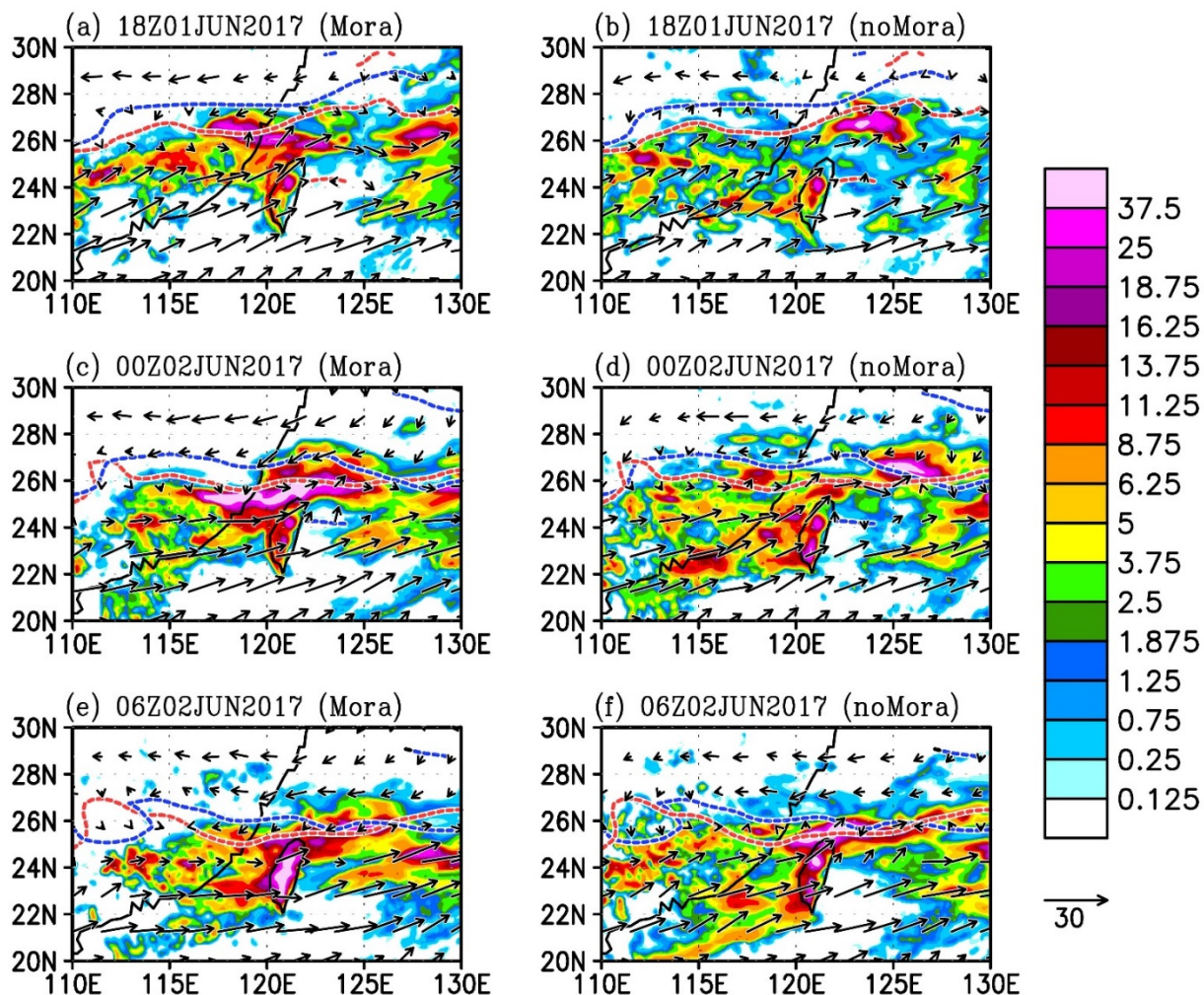
3-hour Precip. [noMora, mm (3h)⁻¹]



Ensemble simulation

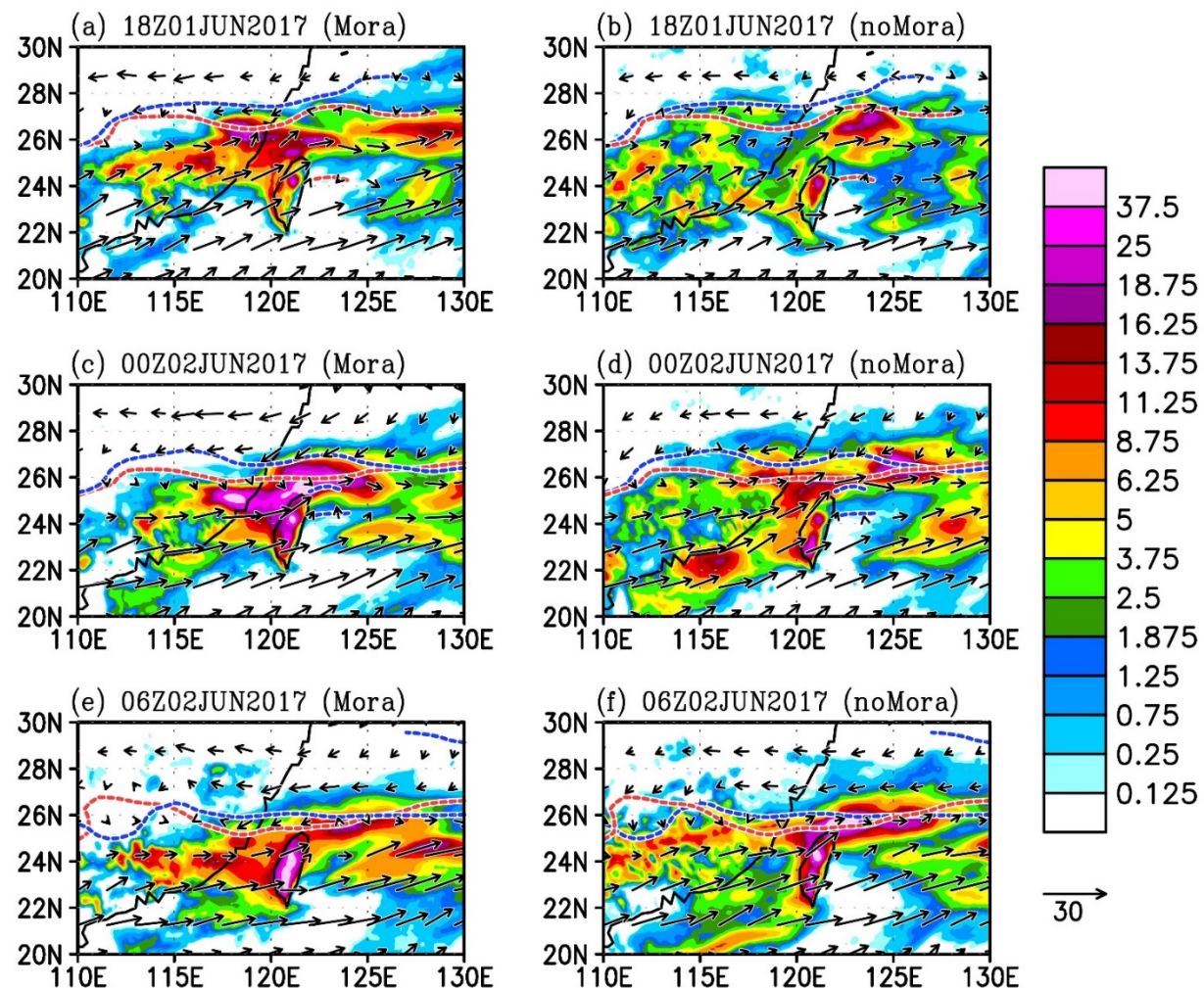
One member

FV3, 3-hour Precip. [mm (3h)^{-1}], 850hPa Wind [m s^{-1}]



Ensemble mean

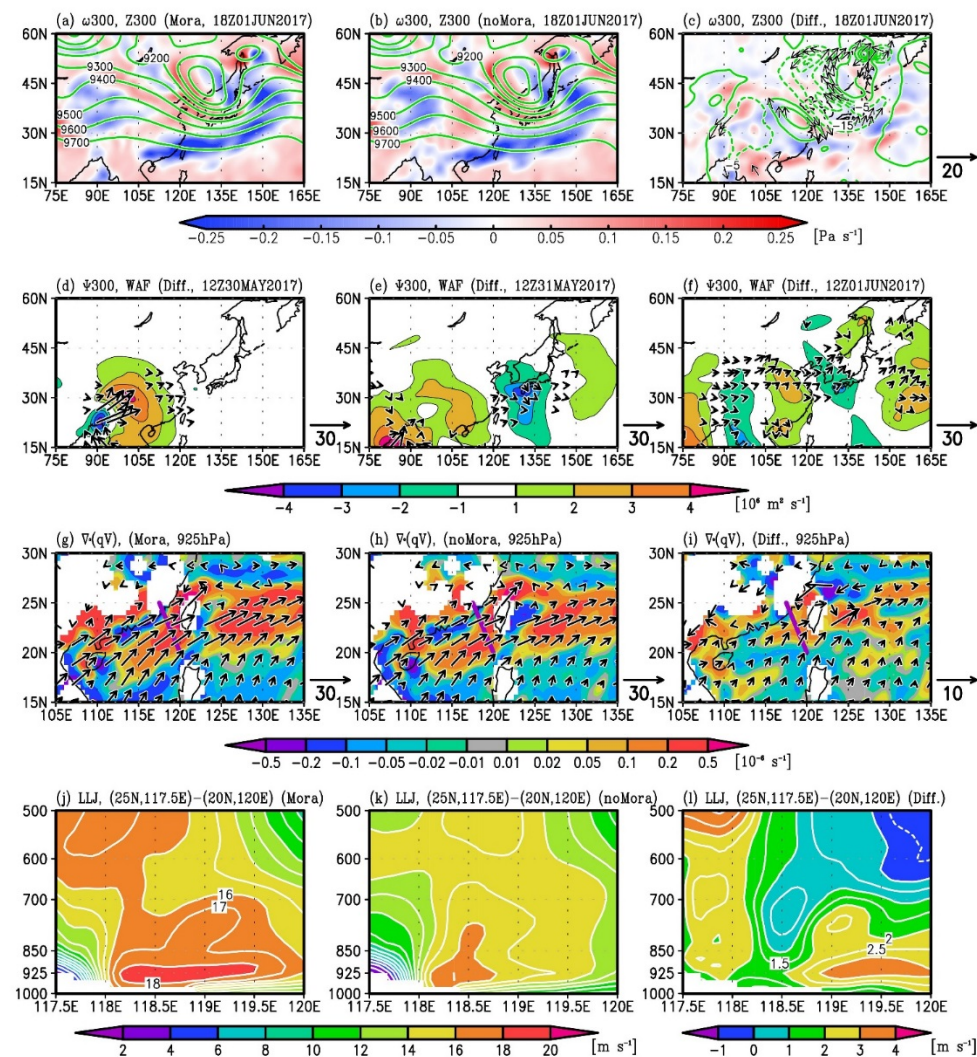
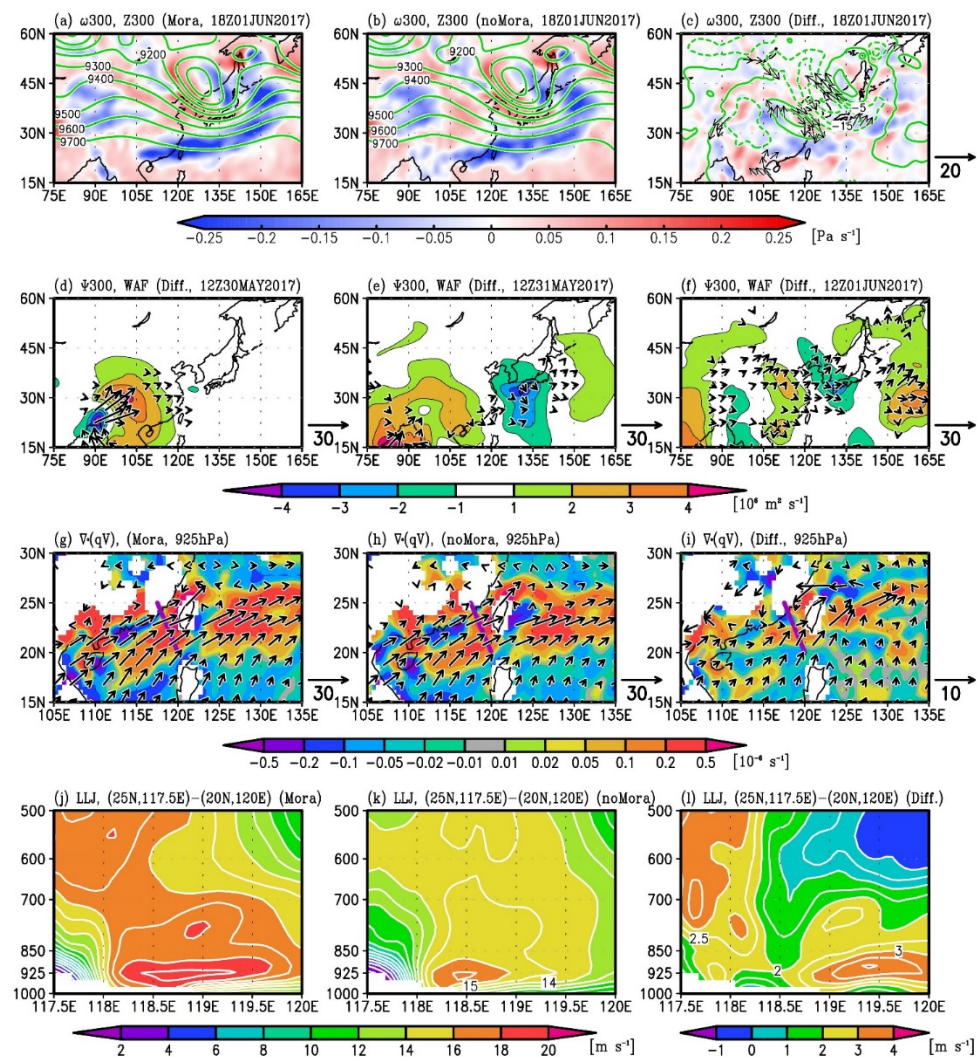
FV3, 3-hour Precip. [mm (3h)^{-1}], 850hPa Wind [m s^{-1}]



Ensemble simulation

One member

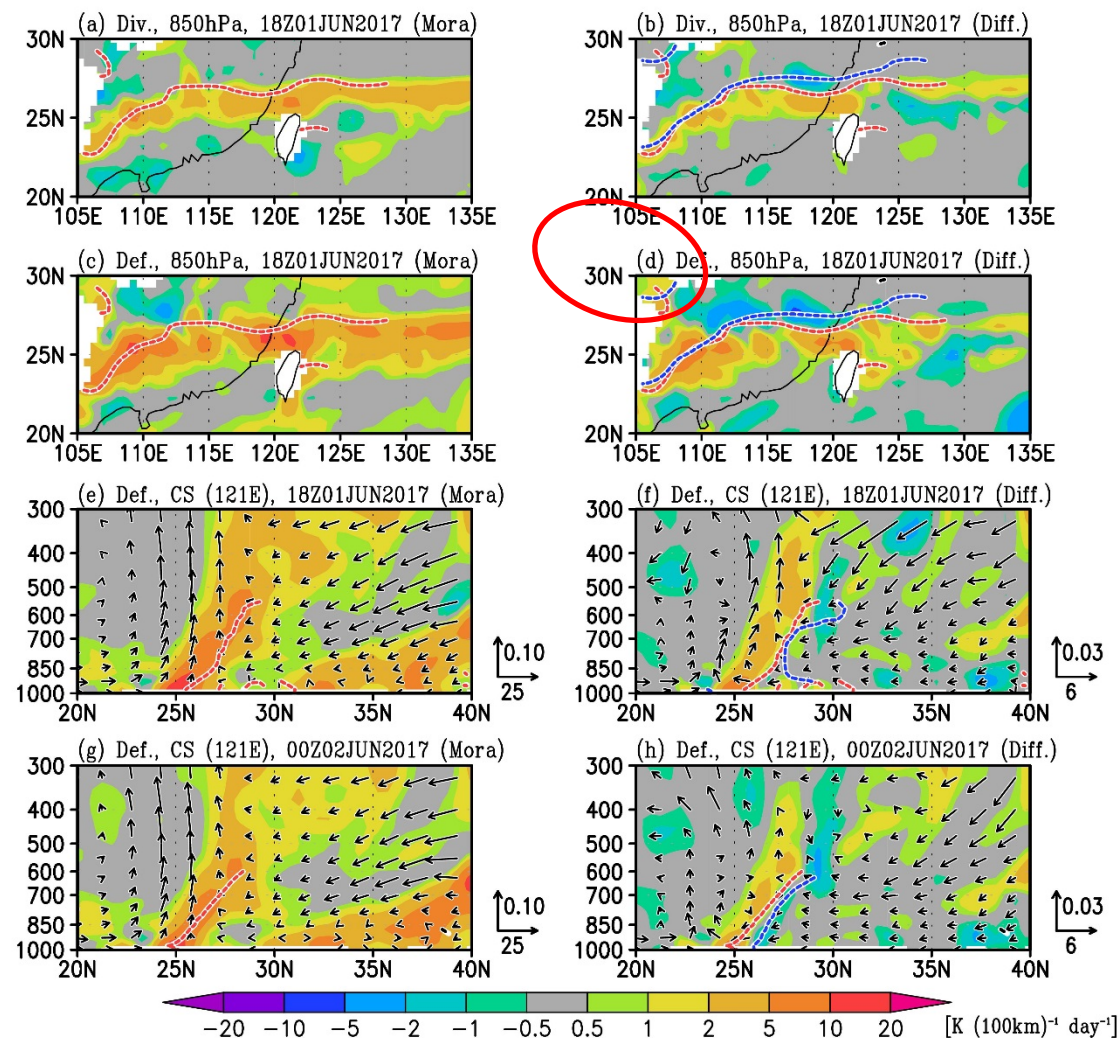
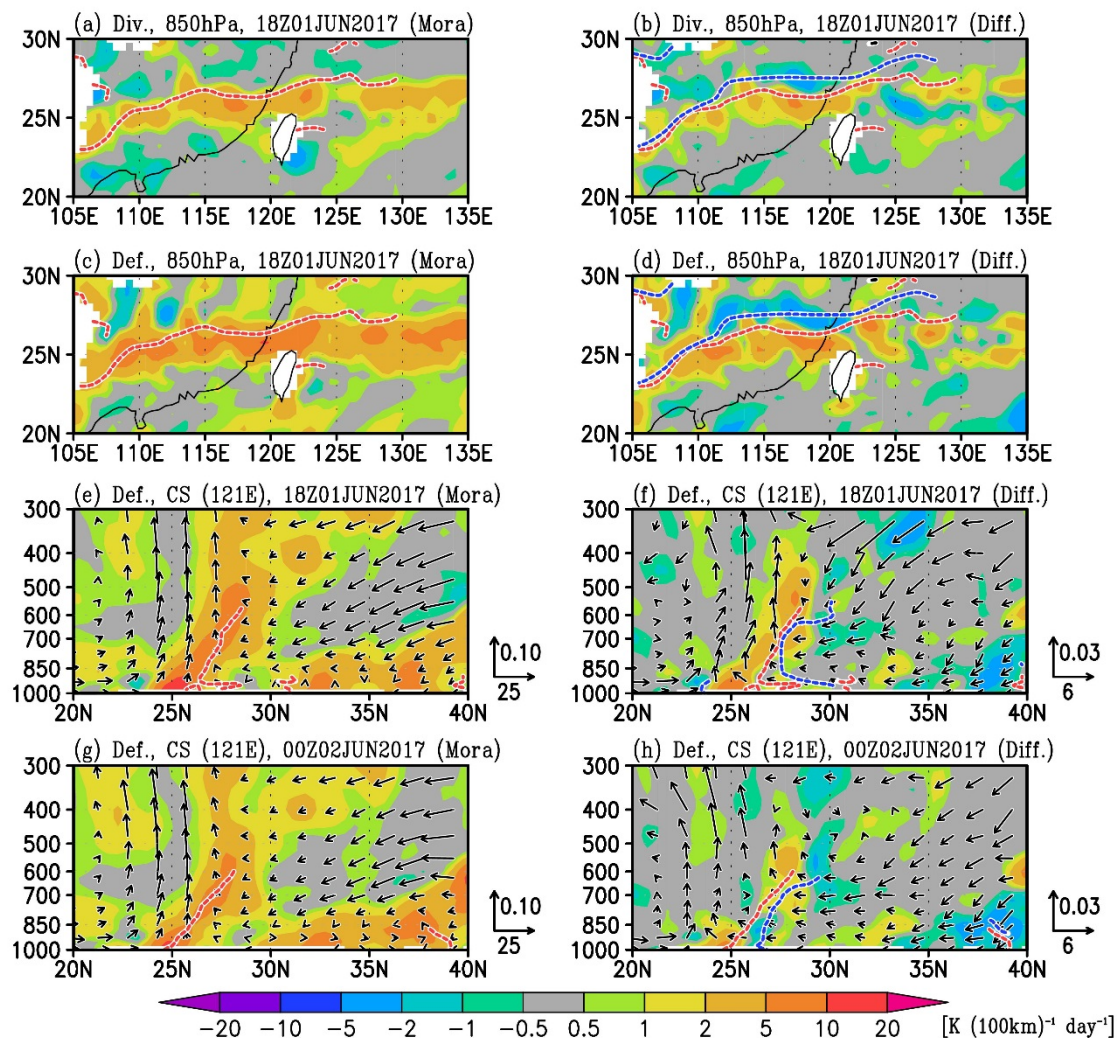
Ensemble mean



Ensemble simulation

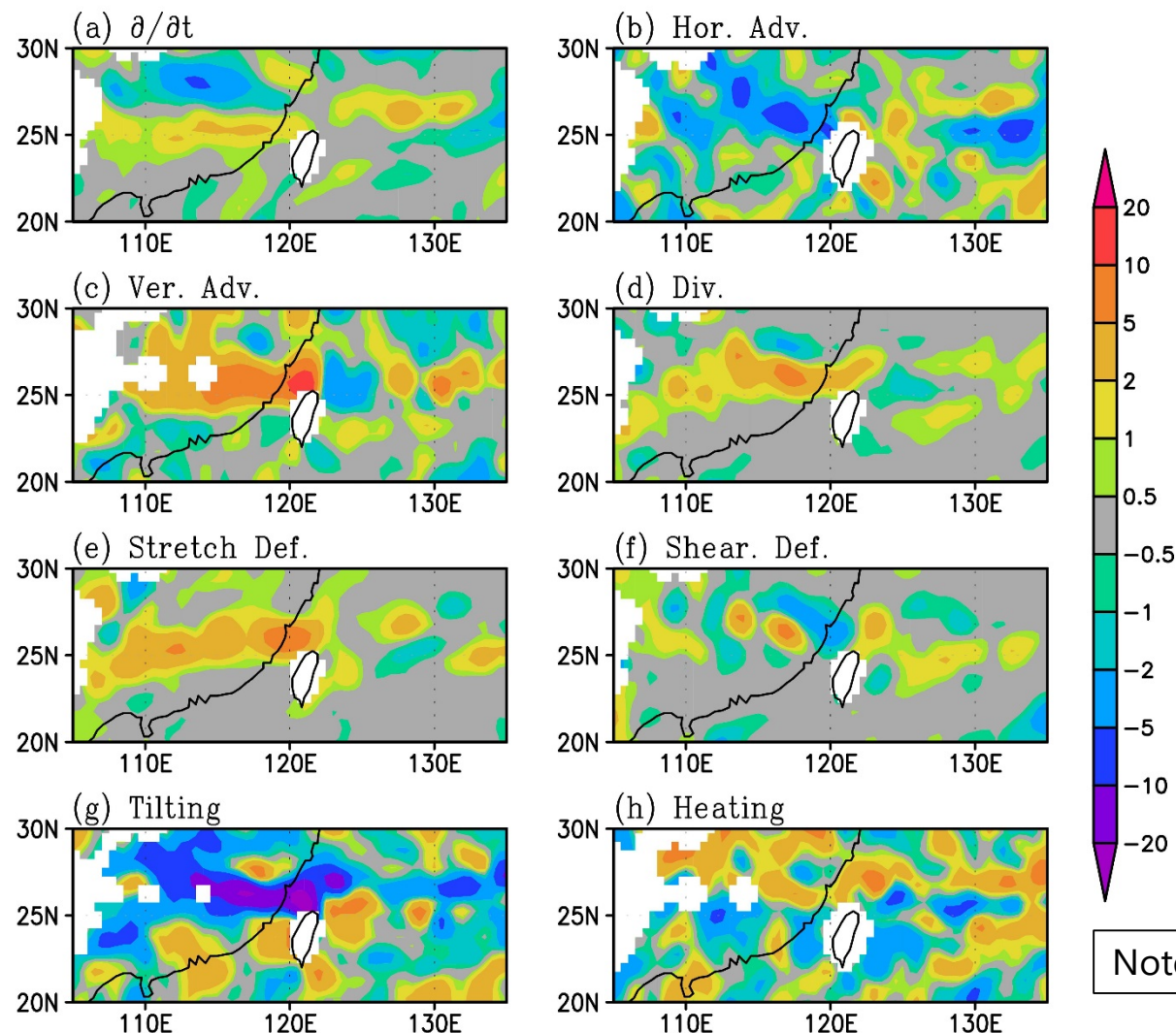
One member

Ensemble mean



Frontal budget (Mora – noMora)

Front. budget [θ_* , K/day/(100km)], 850hPa, 12Z01JUN2017



Frontal budget (Mora – noMora)

Front. budget [θ , K/day/(100km)], 850hPa, 18Z01JUN2017

