Impacts of Large scale Flow Field on Diurnal Variation of mesoscale Circulation and Precipitation During Mei-Yu Season

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Outline

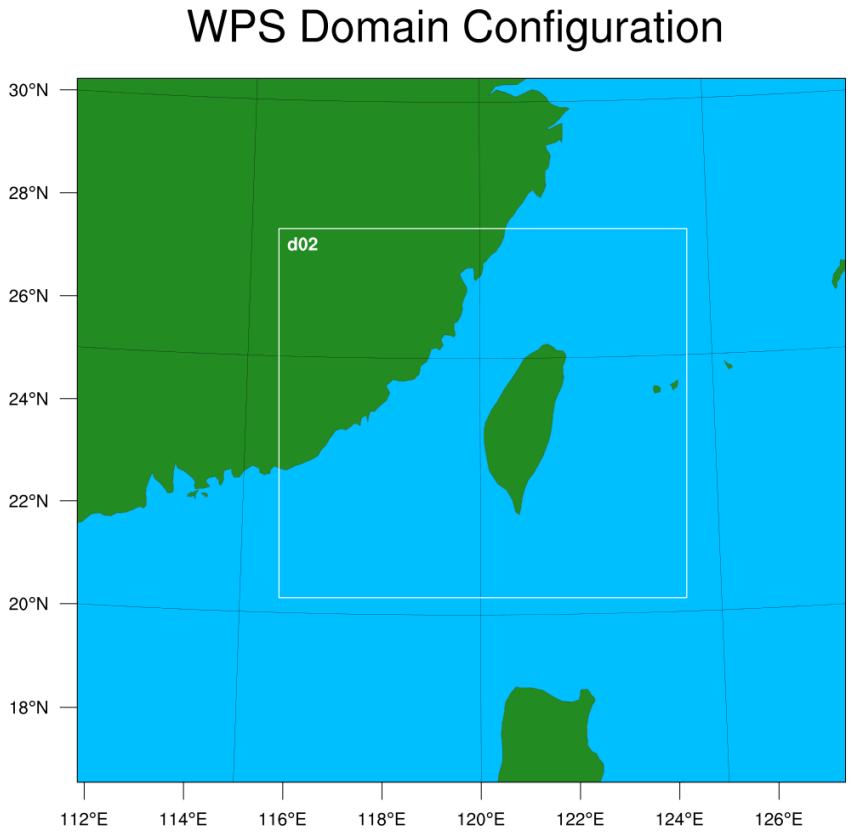
- Introduction
- Data and Methodology
- Scientific Objectives
- Mean Flows and Local Circulation Change as the Season Progresses
- Topographic Effects and barrier jets
- Diurnal Variation of Wind and Precipitation
- Conclusion

Scientific Issues

- Many previous studies about rainfall during Mei-Yu season are case studies. Few are climatological analysis. Moreover, they studied the whole Mei-Yu season rather than a shorter time period of Mei-Yu season.

- During Mei-Yu season, large-scale circulation exhibits significant seasonal changes as the season progresses. Therefore, this study divides the Mei-Yu season into **Early Mei-Yu Season (5/15-5/31), Mid-Mei-Yu Season (6/1-6/15), Late Mei-Yu Season (6/16-6/30)** in order to discuss the interaction between fronts, the large-scale flow and land-sea breeze circulation throughout the Mei-Yu season.

Data and Methodology



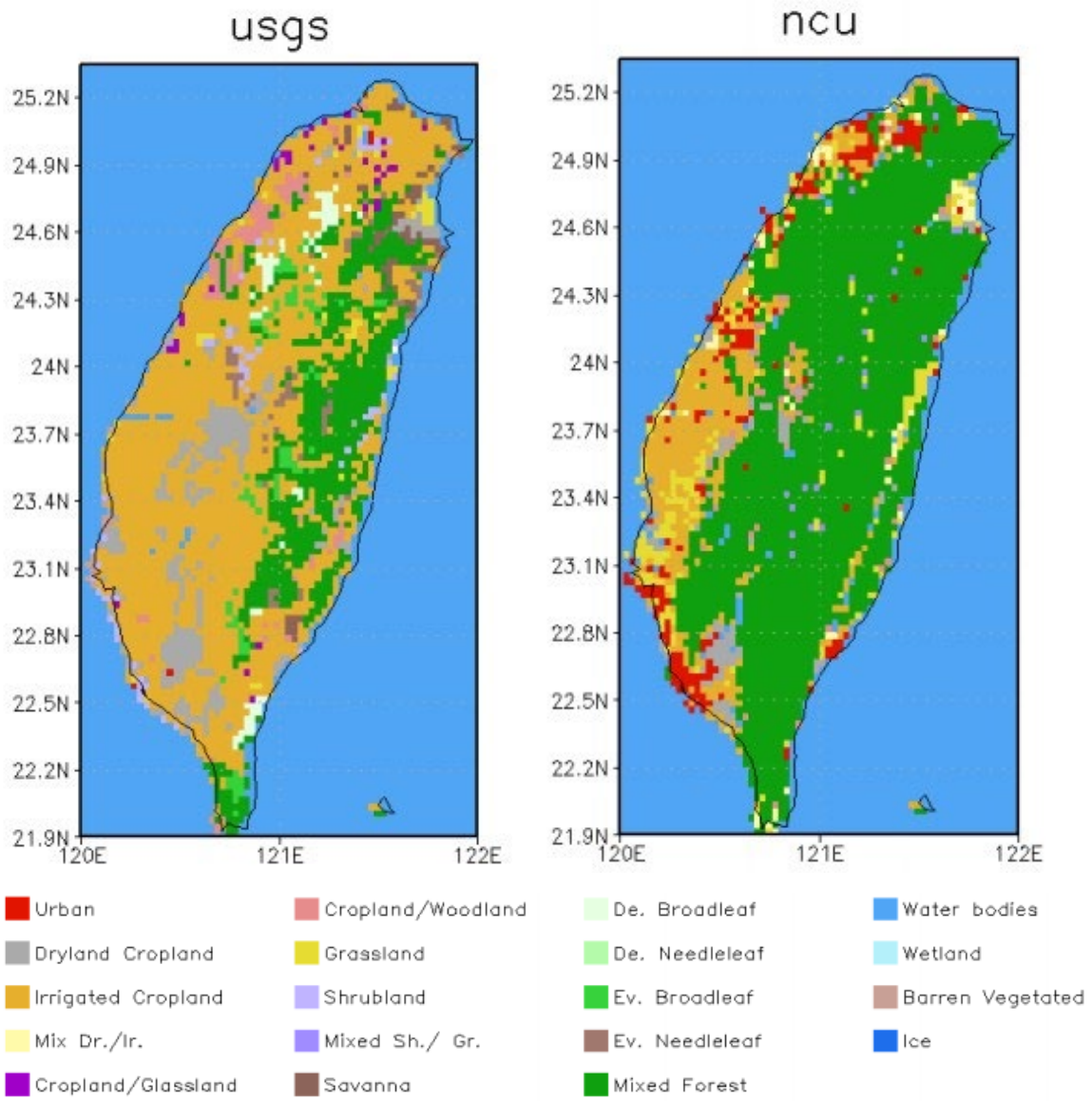
WRF version: WRF 3.5.1

Domain1	**9KM**
Domain2	**3KM**
Data	**CFSR**
Time	**2008~2012**
Date	**5/15~6/30**
Spin up	**12hr**
Data used	**12-36h model output**

Weather Research and Forecasting Model (WRF) Setup

&physics		
mp_physics	Goddard GCE scheme (also uses gsfcgce_hail, gsfcgce_2ice)	
ra_lw_physics	rrtm scheme	
ra_sw_physics	Goddard short wave	
Radt	10 (minutes between radiation physics calls)	
sf_sfclay_physics	MM5 Monin-Obukhov scheme	
sf_surface_physics	Unified Noah land-surface model	
bl_pbl_physics	YSU scheme	
isfflx	heat and moisture fluxes from the surface	
cu_physics	**Domain 1**---Kain-Fritsch (new Eta) scheme	**Domain 2**---no cumulus
topo_wind	turn on topographic surface wind correction from Mass (YSU PBL only)	
landuse	Cheng et.al（2013)	

Landuse data in the model run (NCU)



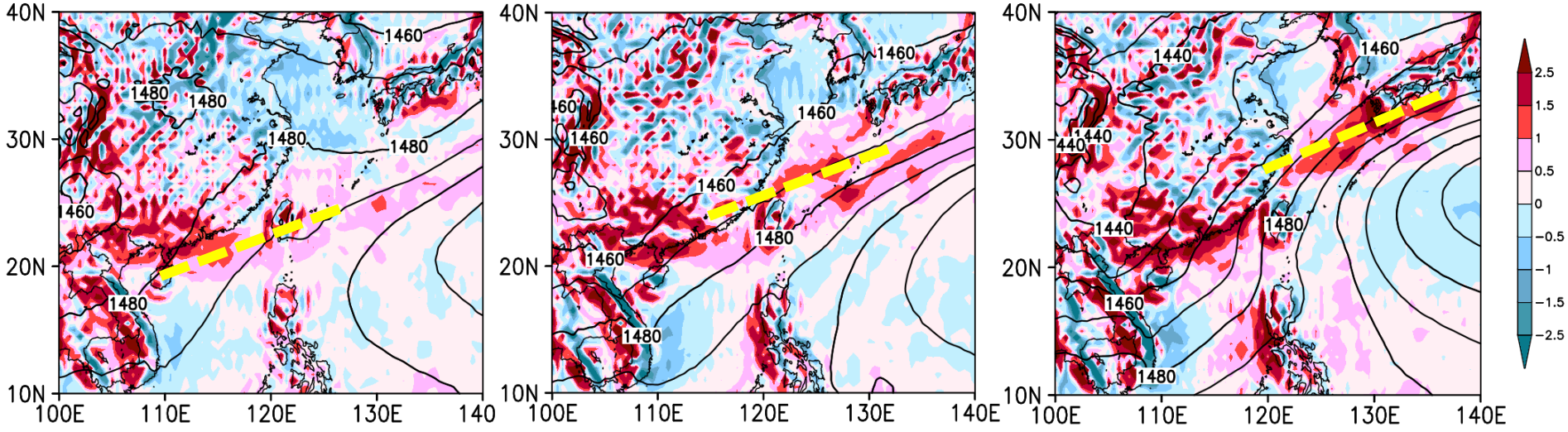
(Cheng et.al 2013)

Model output analysis

- 2008~2012 5/15-5/31 *Early Mei-Yu Season*
- 2008~2012 6/01-6/15 *Mid-Mei-Yu Season*
- 2008~2012 6/16-6/30 *Late Mei-Yu Season*

850hPa CFSR averaged vertical motion (cm/s) and geopotential height (gpm): Convection associated with Mei-Yu frontal system moves northward as the season progresses

5/15-5/31 6/1-6/15 6/16-6/30



Part I:
Mean Flows and Local Circulation Change as the Season Progresses

10-m winds (1bar=2m/s) & 2-m temperature (°C)

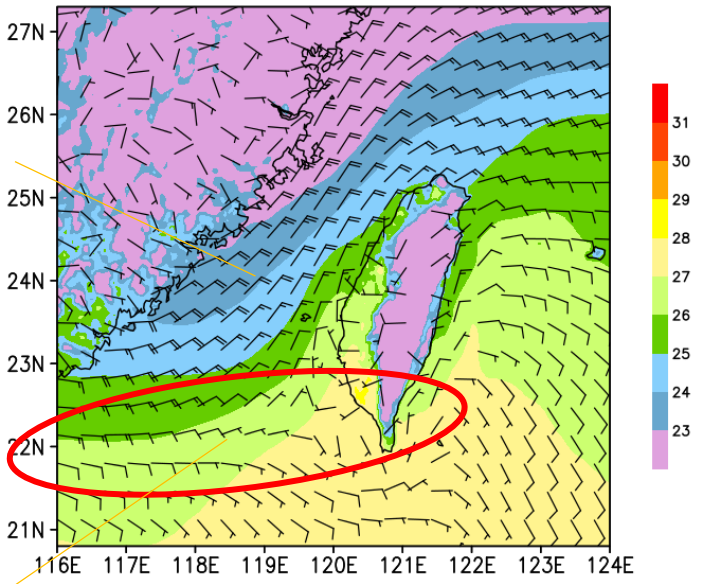
In the afternoon, cold, dry post-frontal NE flow is deflected by Taiwan terrain and leaves a warm, moist atmosphere in the leesside over southwestern Taiwan

Early Season
5/15-5/31

Cold, dry post-frontal northeasterlies

Leading edge of the Mei-Yu surface front

mean



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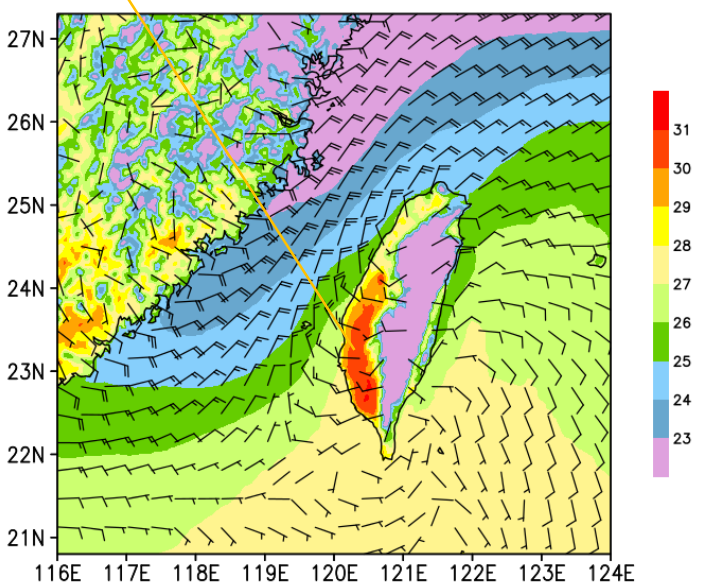
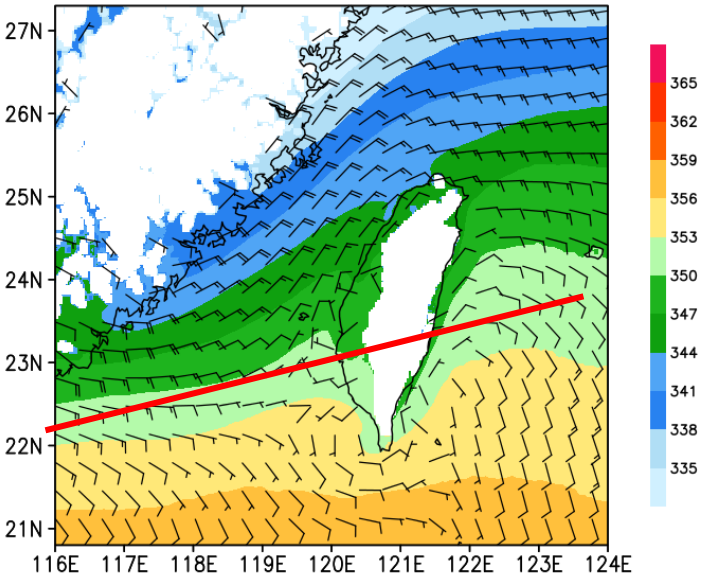


975hPa-mean thetae & winds



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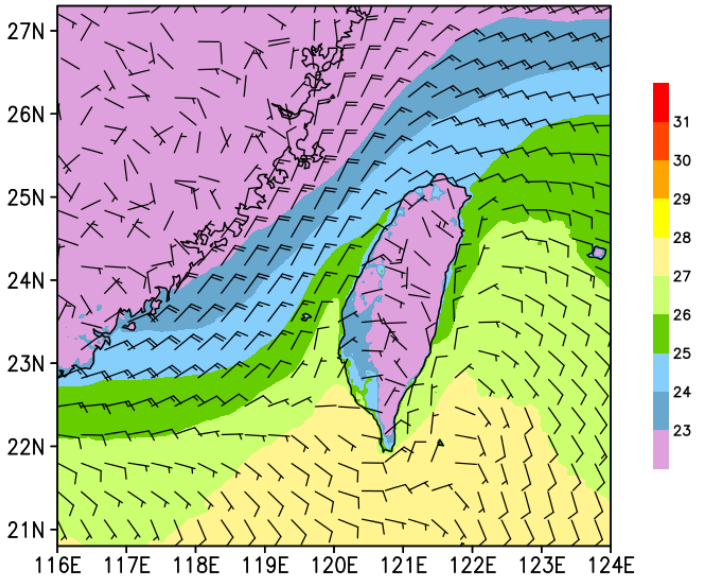

10-m winds deviation from the daily means (1bar=2m/s)

Early Season
5/15-5/31

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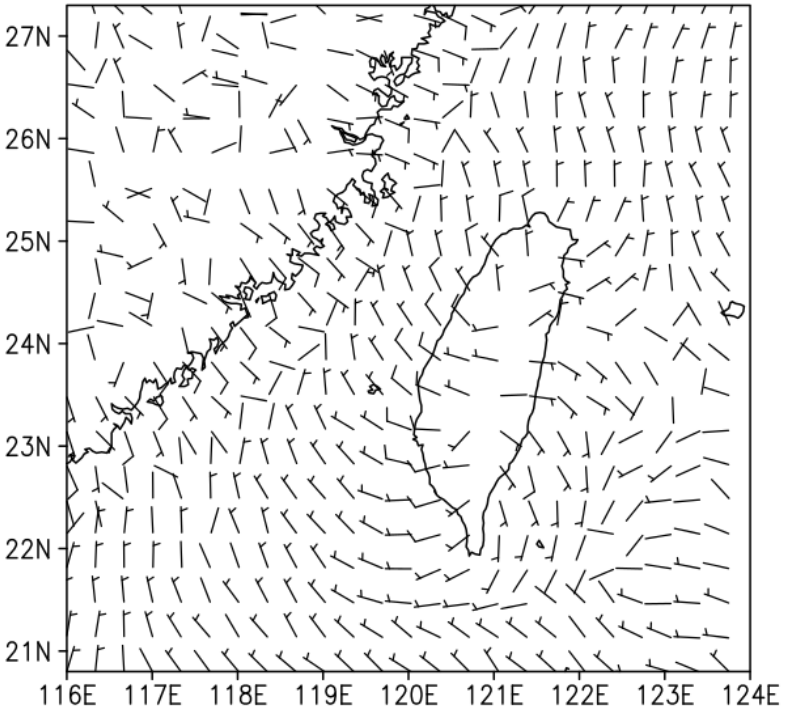

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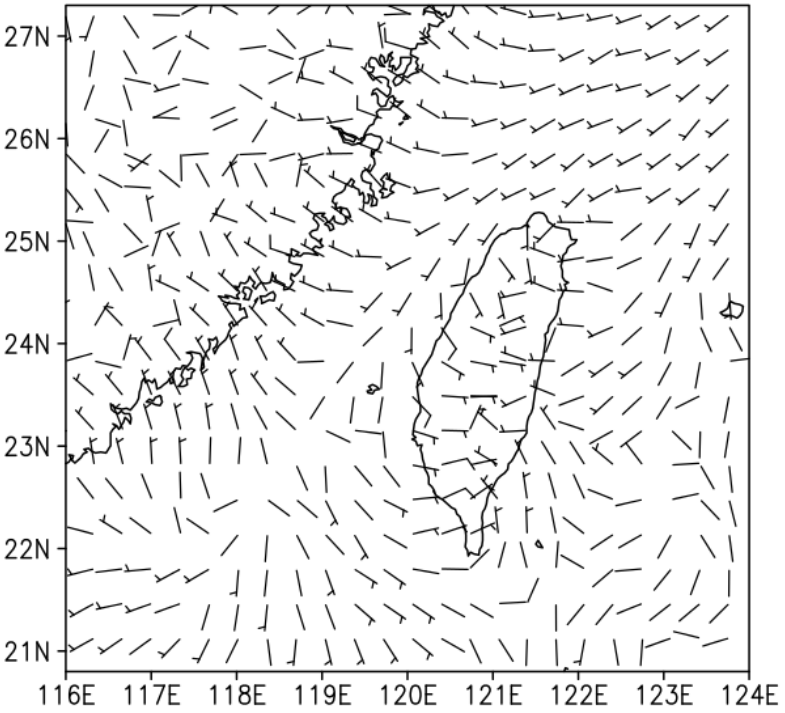


Daytime sea breezes and nighttime land breezes along both the southeastern China coast and coastal region over Taiwan.

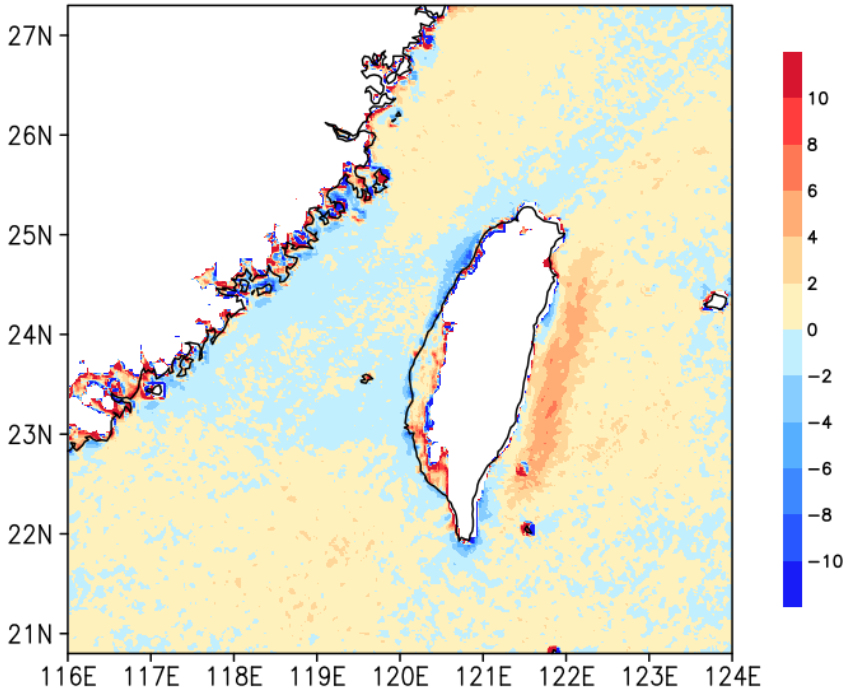
Daytime divergence and nighttime convergence within the Taiwan Strait.

1000hPa convergence (10^{-4} s^{-1})

Early Season
5/15-5/31

Diurnal variation:
Daytime divergence and nighttime convergence within the Taiwan Strait.

mean



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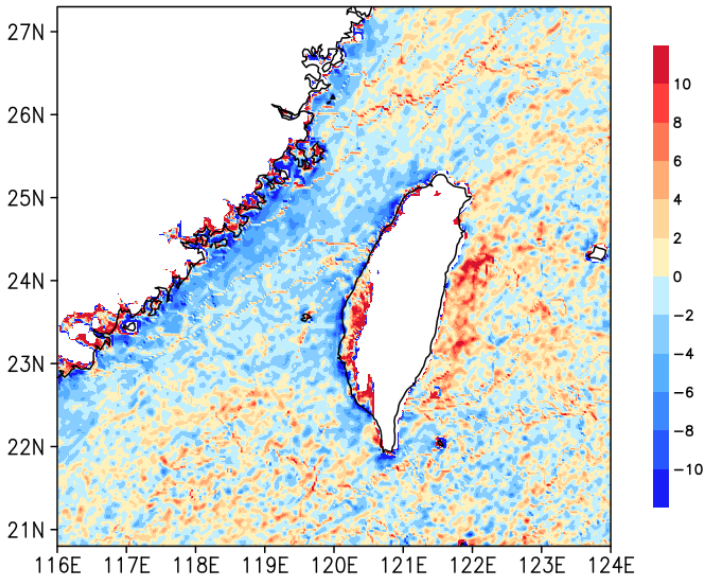

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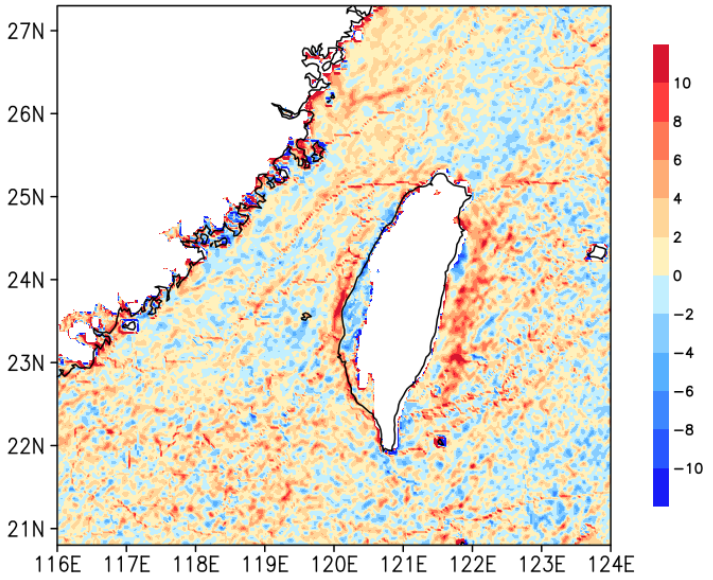


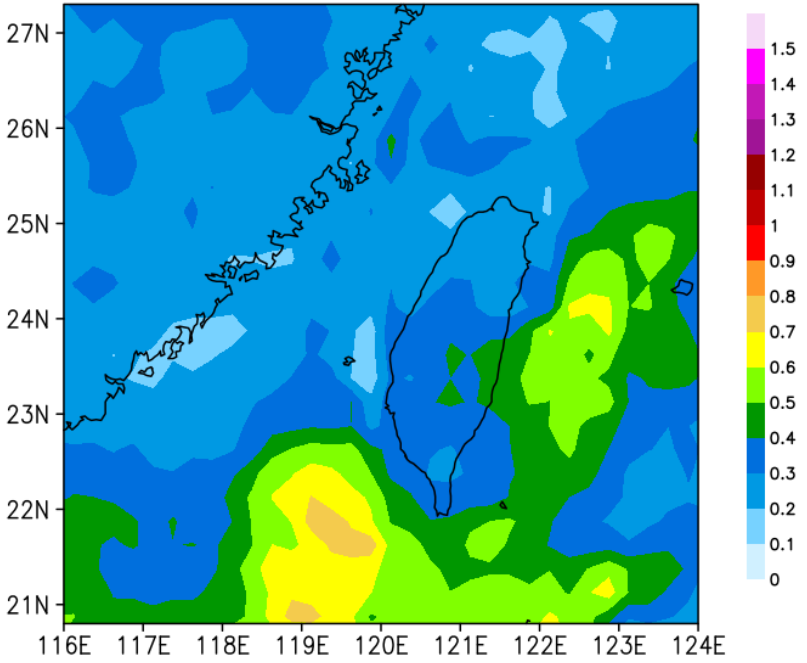
Mean:

1. Convection line off the eastern coast of Taiwan due to blocking of NE flow there.
2. Low-level convergence is off the southwestern Taiwan due to the presence of fronts.

TRMM rainfall distribution (mm/hr)

Early Season
5/15-5/31

mean



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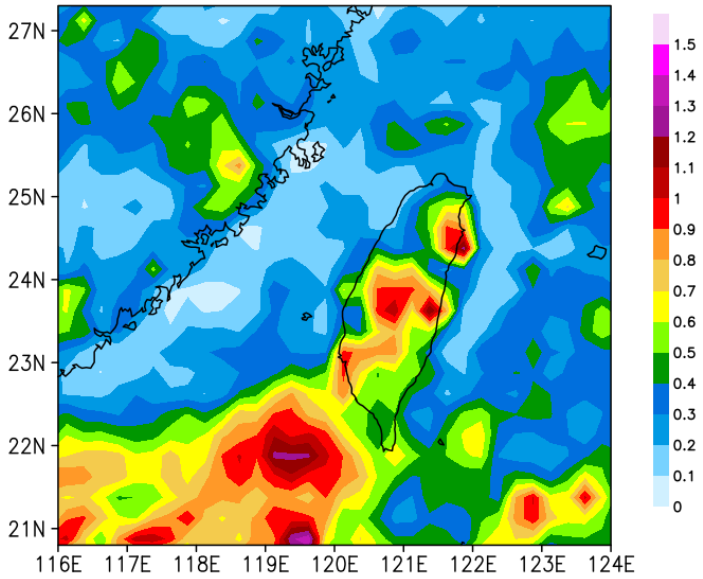

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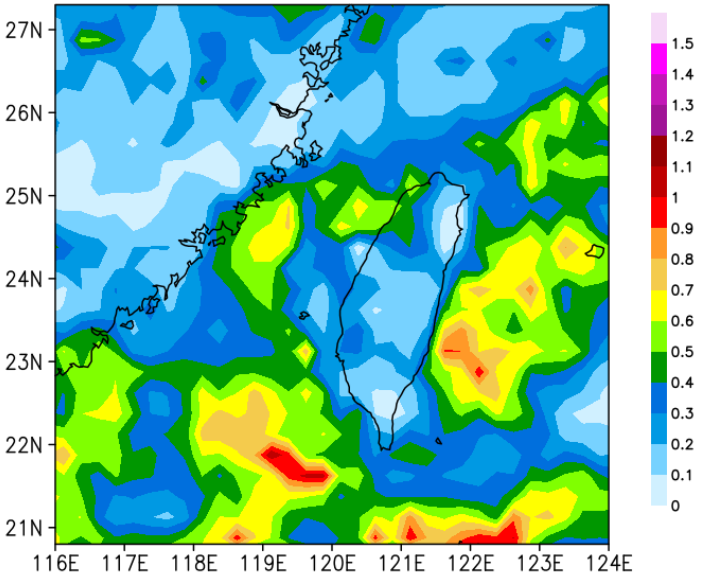


- Mean:

Rainfall occurs off eastern coast c
Taiwan and southwestern Taiwan.

- Diurnal variation:

Signification nighttime rainfall within the Taiwan Strait is due to low-level convergence there.

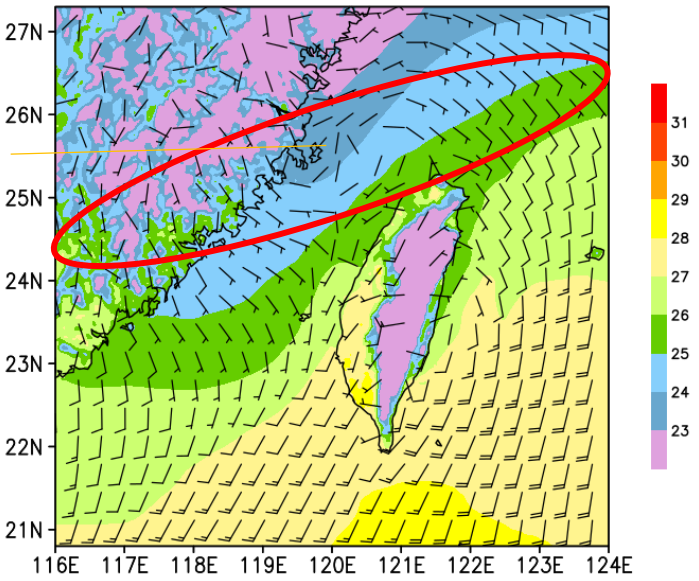
10-m winds (1bar=2m/s) & 2-m temperature (℃)

The SW flow intensifies. In the afternoon, surface heating on the southwestern Taiwan enhanced. Sea breeze-upslope flow strengthens under SW flow regime.

Mid-Season
6/1-6/15

Mei-Yu surface front moves northward as compared with Early Mei-Yu season to NW of Taiwan

mean



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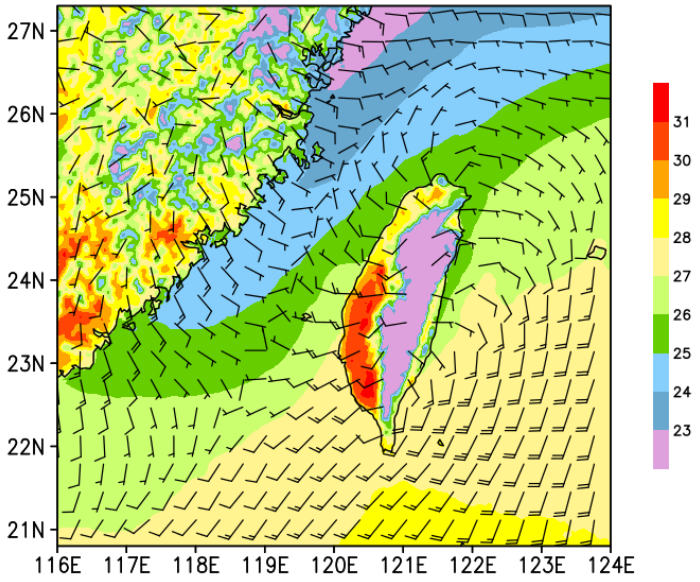
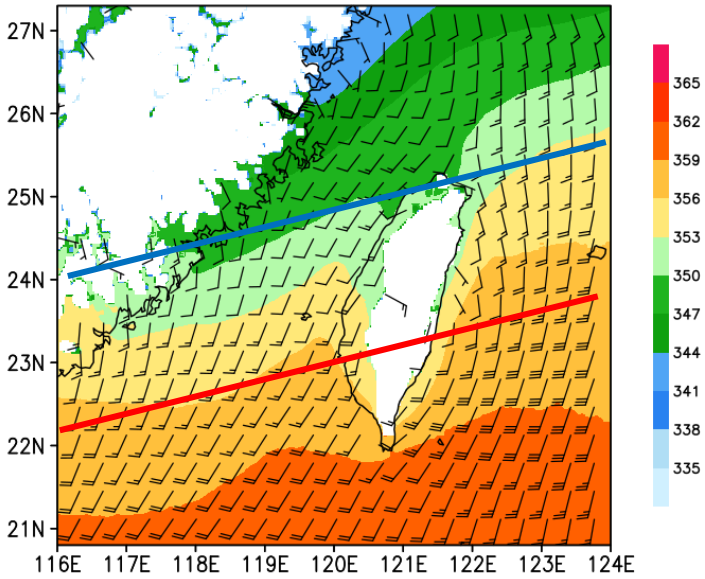


975hPa-mean thetae & winds



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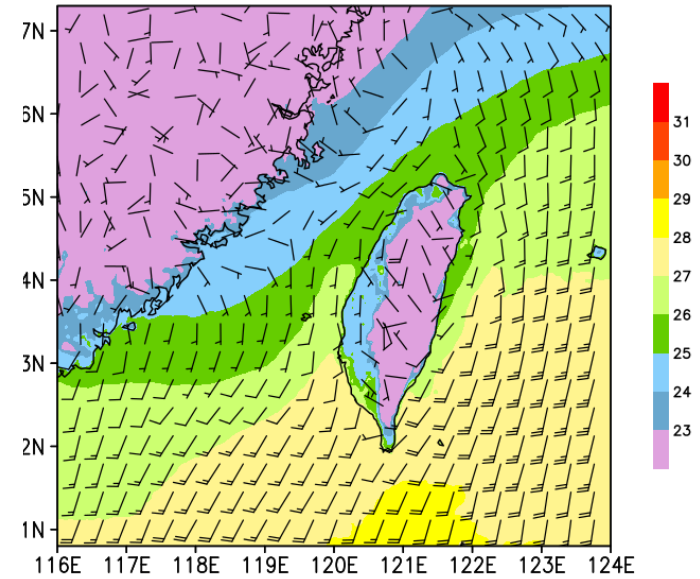

10-m winds deviation from the daily means (1bar=2m/s)

Mid-Season
6/1-6/15

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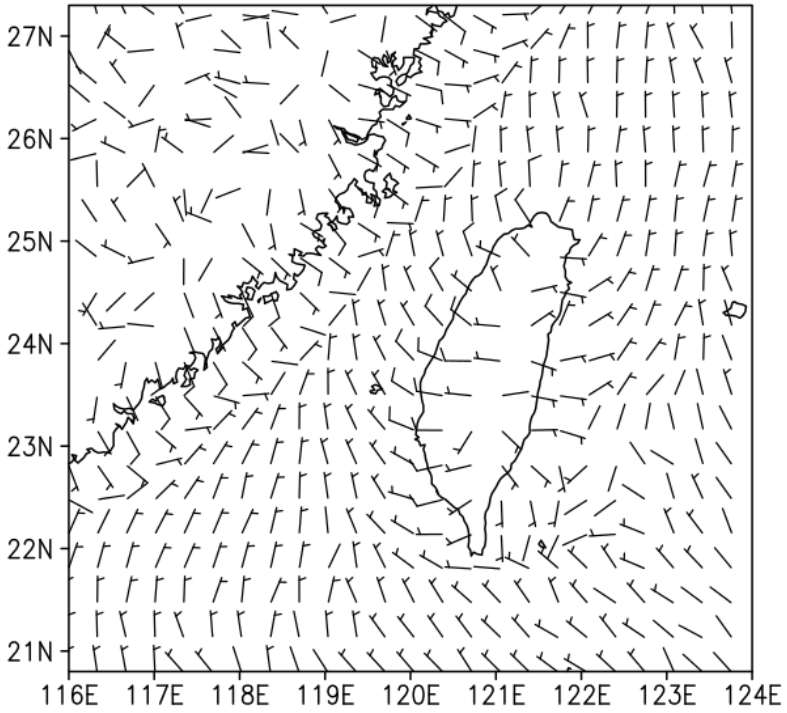

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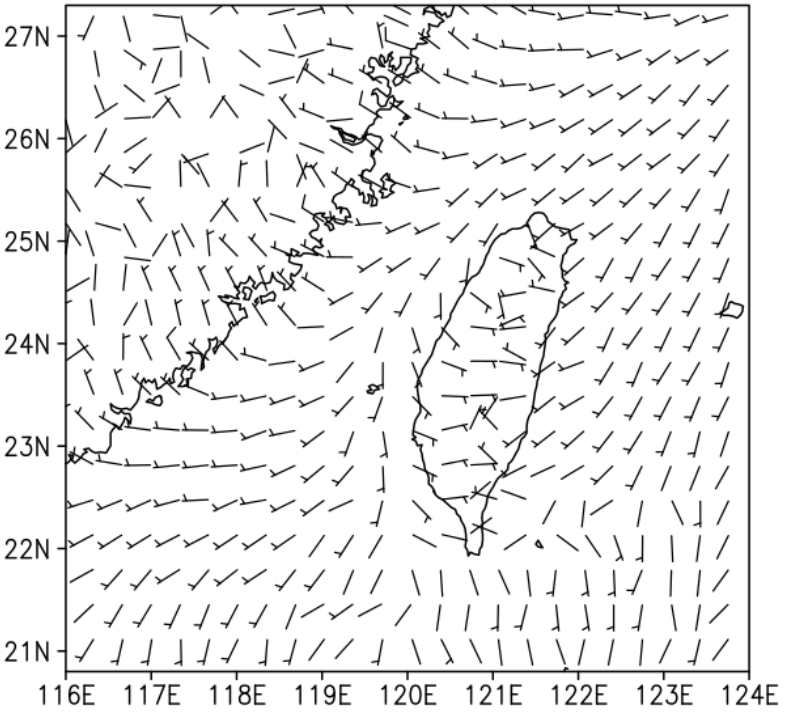


Same as the Early Season:

Daytime sea breeze and nighttime land breeze along both the southeastern China coast and coastal region over Taiwan.

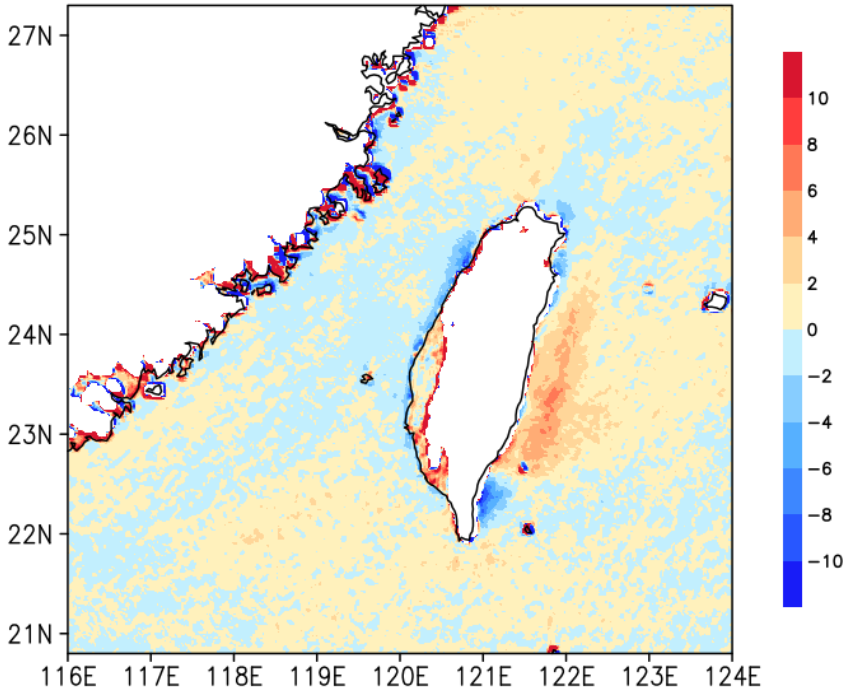
Daytime divergence and nighttime convergence within the Taiwan Strait.

1000hPa convergence (10^{-4} s^{-1})

Mid-Season
6/1-6/15

Diurnal variation:
Daytime divergence and nighttime convergence within the Taiwan Strait.

mean



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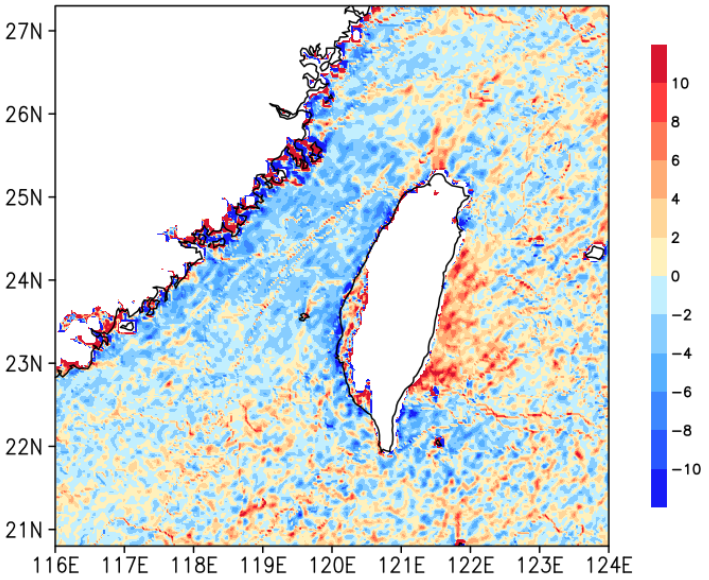

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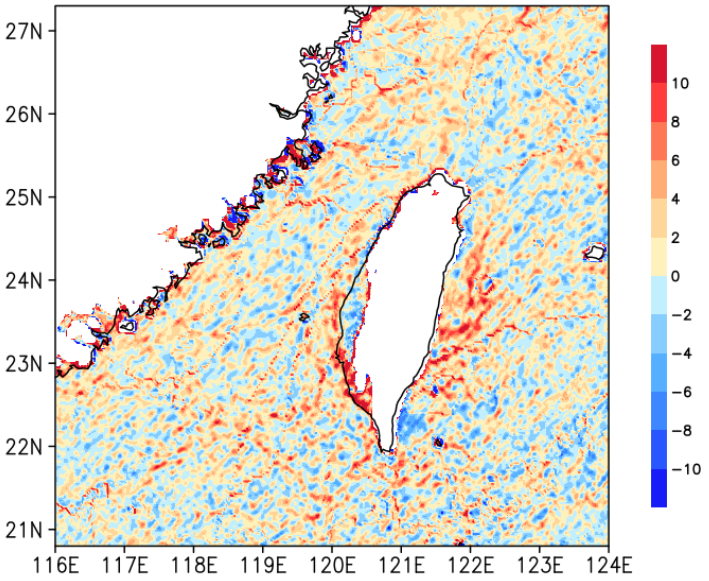
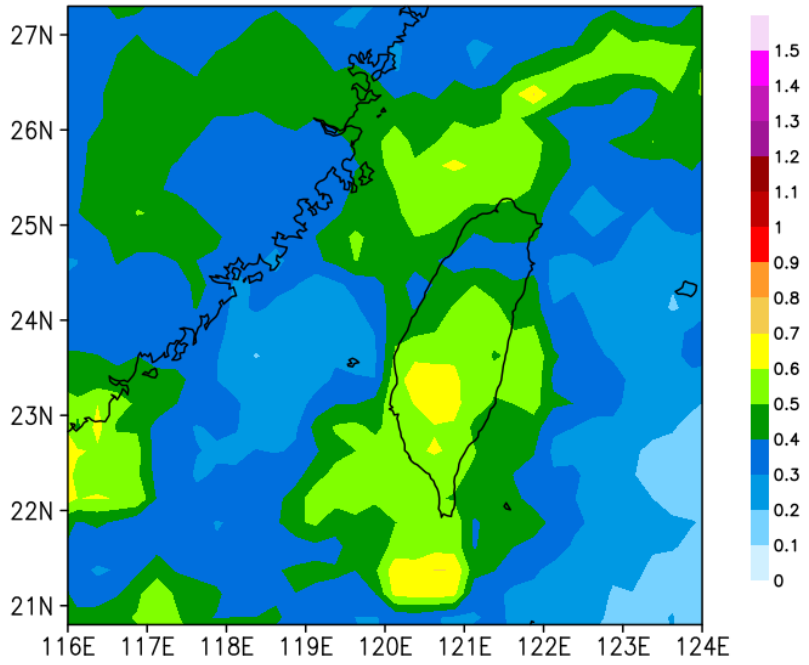


Mean:
1. Convection zone off the eastern coast of Taiwan (Will be discussed in Part II later).
2. Low-level convergence is off the southwestern Taiwan.

TRMM rainfall distribution (mm/hr)

Mid-Season
6/1-6/15

mean



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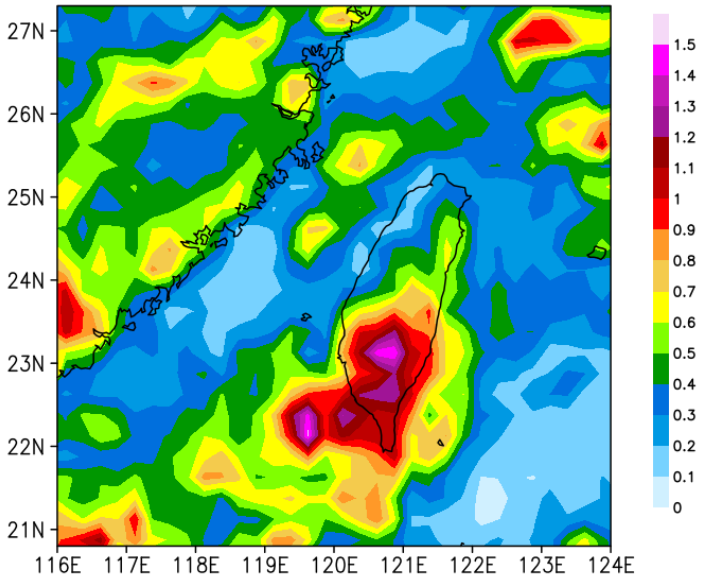

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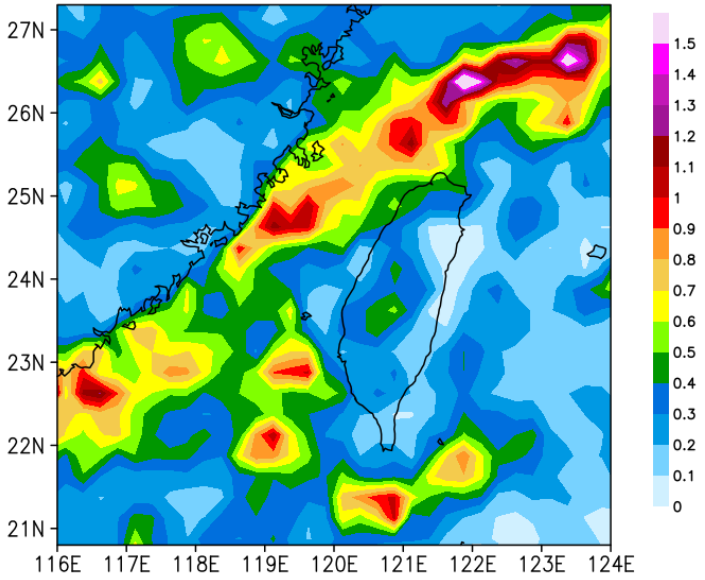


- Mean:

Rainfall off northwestern Taiwan is associated Mei-Yu front and southwestern Taiwan.

- Diurnal variation:

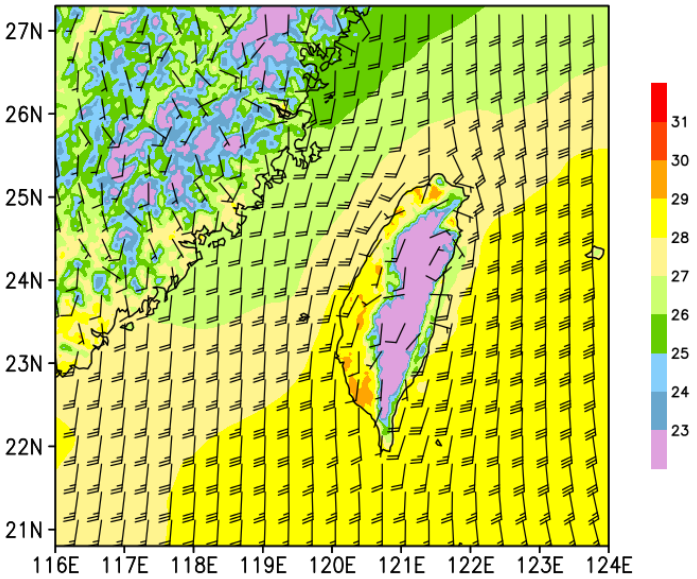
Signification nighttime rainfall within the Taiwan Strait is due to low-level convergence there.

10-m winds (1bar=2m/s) & 2-m temperature (℃)

The southerly flow intensifies. In the afternoon, surface heating on the southwestern and northwestern Taiwan further enhanced.

Late Season
6/16-6/30

mean



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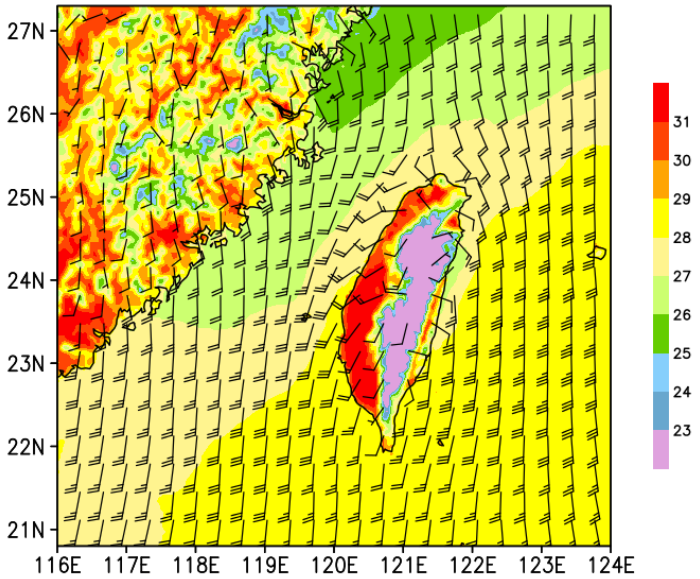
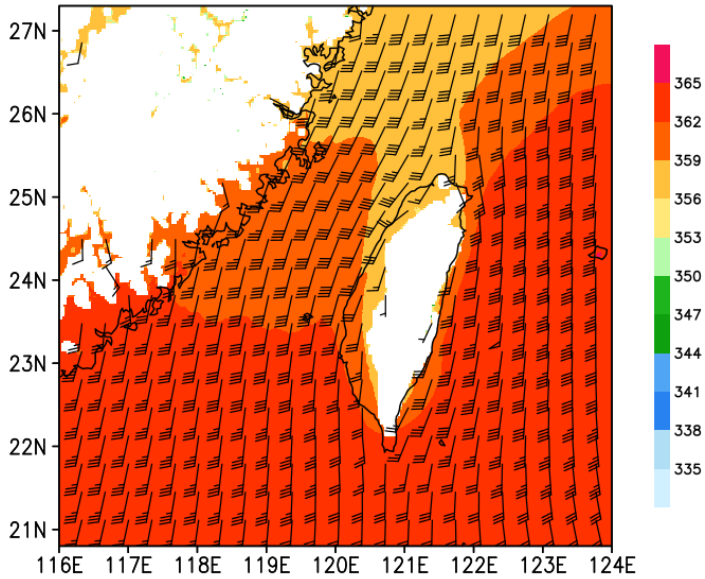


975hPa-mean thetae & winds



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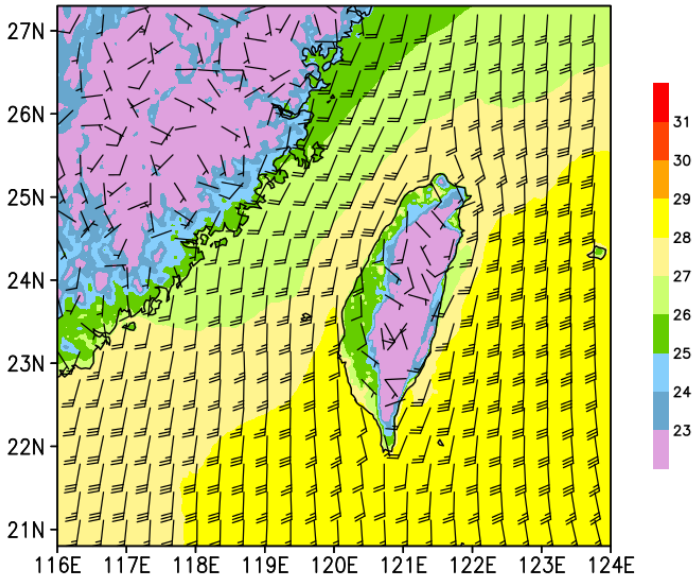

10-m winds deviation from the daily means (1bar=2m/s)

Late Season
6/16-6/30

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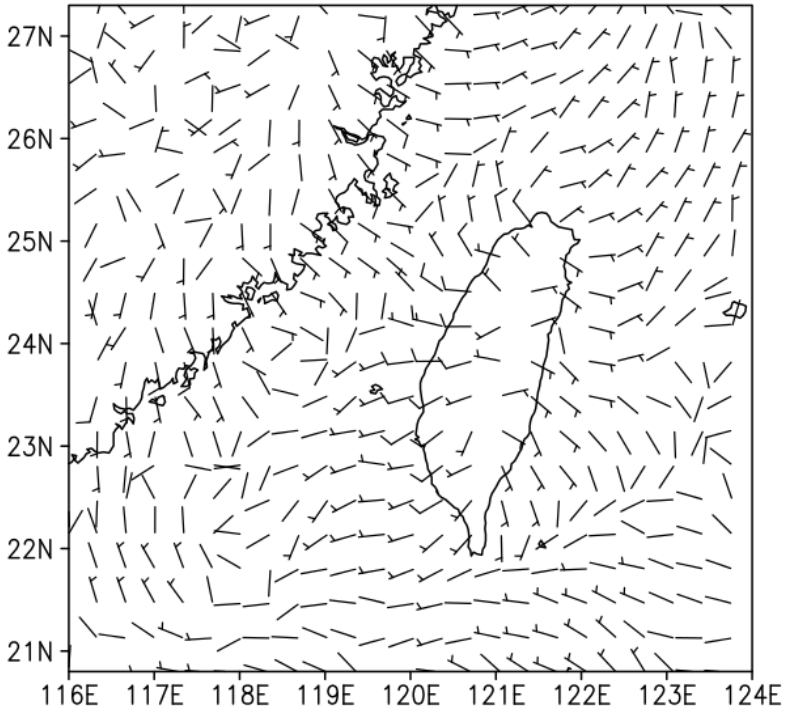

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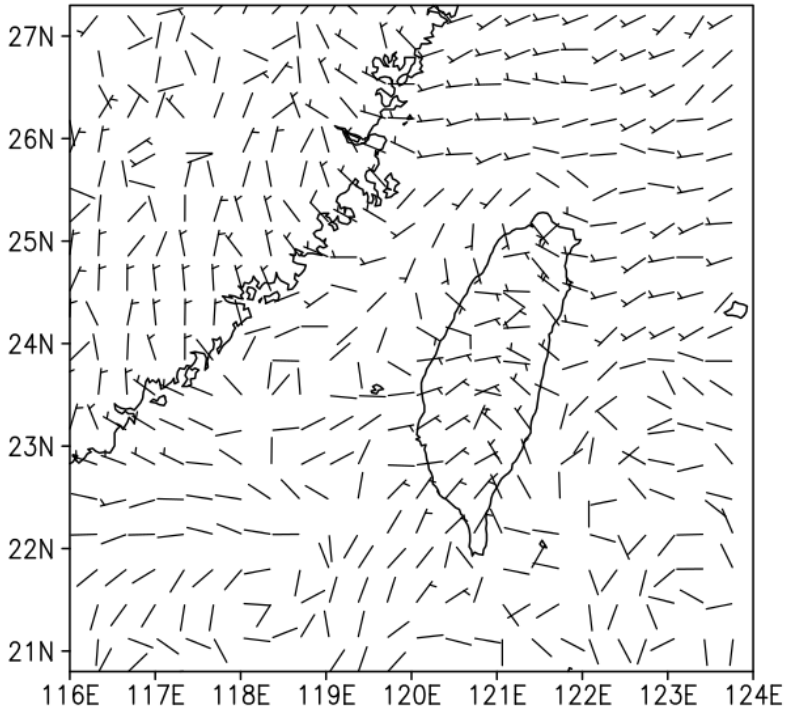


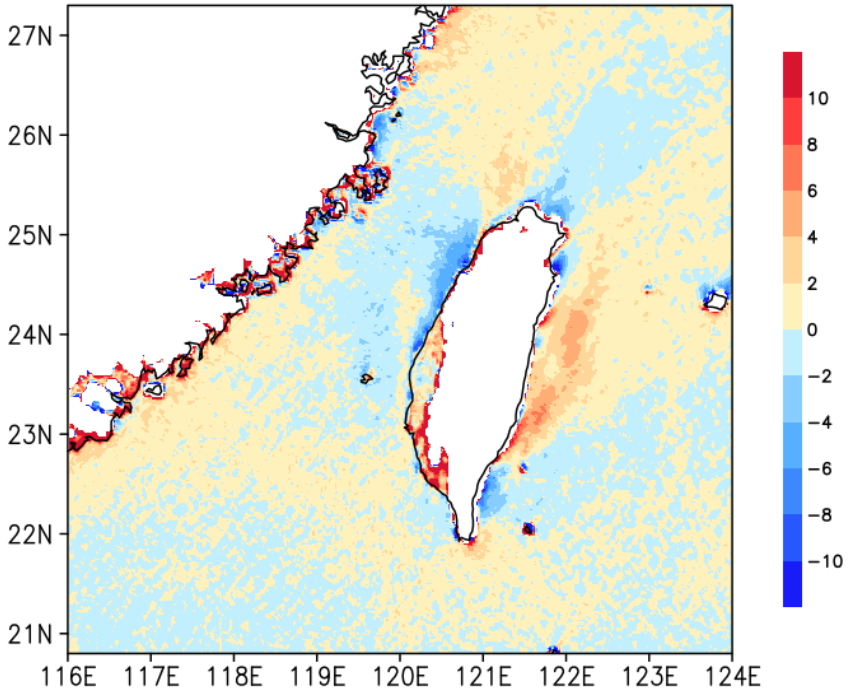
During the Late Mei-Yu season, **due to strengthened prevailing flow**, the nighttime convergence within the Taiwan Strait is less signification than the Early and Mid-season.

1000hPa convergence (10^{-4} s^{-1})

Late Season
6/16-6/30

Diurnal variation:
Daytime divergence and nighttime convergence within the Taiwan Strait.

mean



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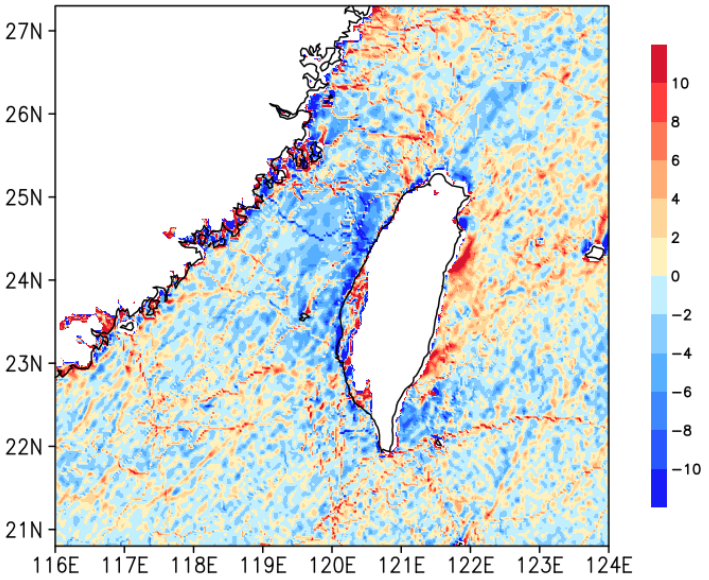

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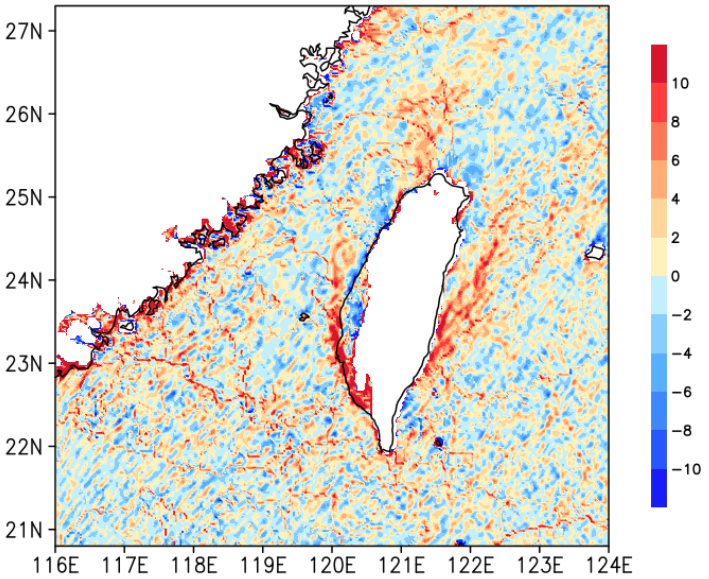
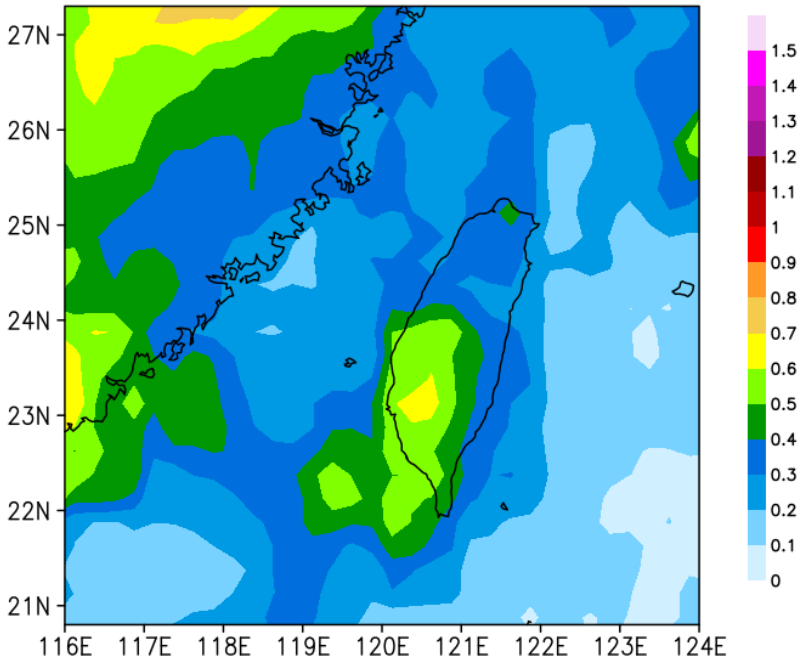


Mean:
Low-level convergence is off the southwestern Taiwan and eastern Taiwan.

TRMM rainfall distribution (mm/hr)

Late Season
6/16-6/30

mean



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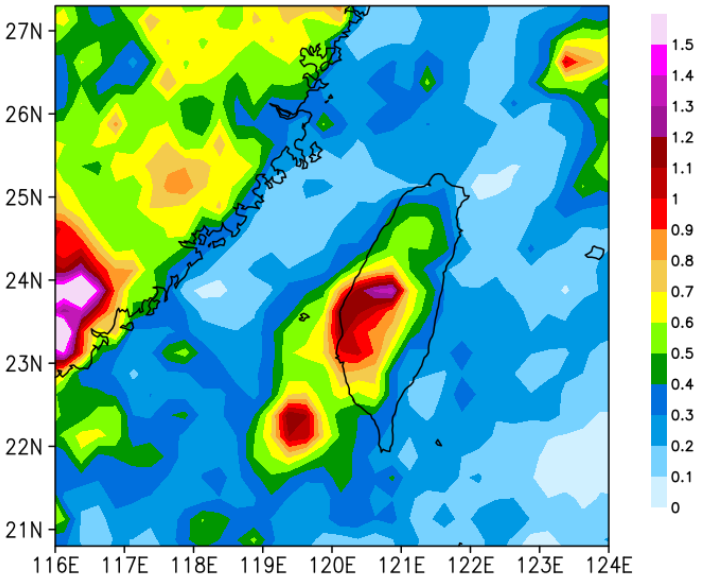

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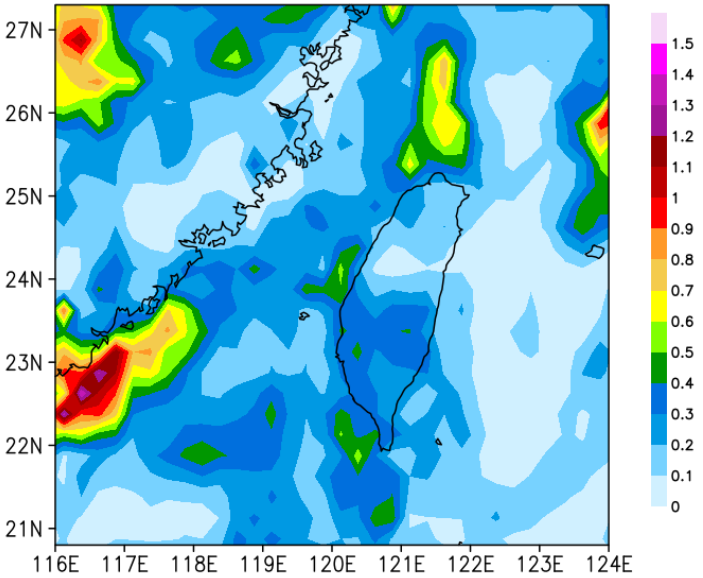


- Mean:

Rainfall occurs off southwestern Taiwan under convective unstable atmosphere and low-level convergence.

- Diurnal variation:

More nighttime rainfall occurs within the Taiwan Strait due to low-level convergence there.

Conclusion (I)

- **The impact range of land-sea breezes along the coast of southeastern China and western Taiwan is limited only over the Taiwan Strait.**

- **Nighttime is more favorable for precipitation within the Taiwan Strait than daytime. During the Late Mei-Yu season, due to strengthened prevailing flow, the nighttime convergence within the Taiwan Strait is less signification than the Early and Mid-season.**

- **During the Early Mei-Yu season, the frontal zone lies off the southwestern Taiwan coast and brings in lots of rainfall. During Mid-Mei-Yu season and Late Mei-Yu season, due to the change of the large-scale circulation, warmer and moister air is brought to the region with convective instability resulting in abundant rainfall.**

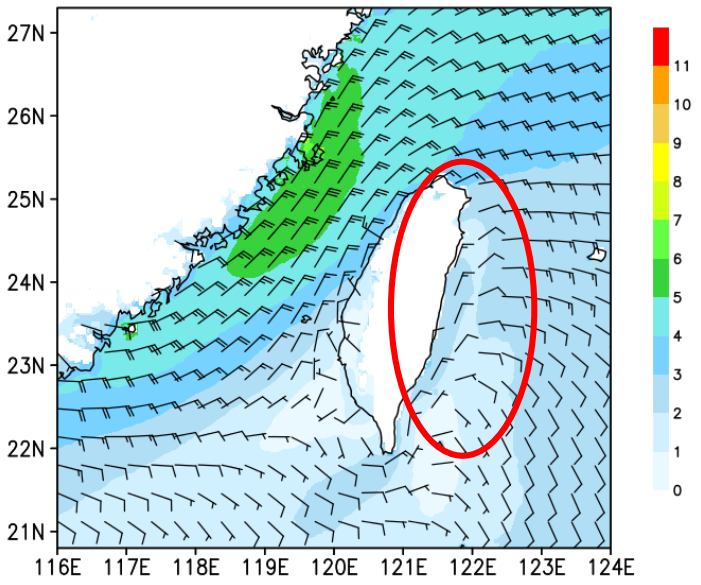
Part II:
Topographic effects and barrier jets over northwestern Taiwan and offshore regions

1000hPa-winds (1bar=2 m/s) and wind speed (m/s)

Flow within the Taiwan Strait is modified by the land-sea breezes

Early Season
5/15-5/31

mean



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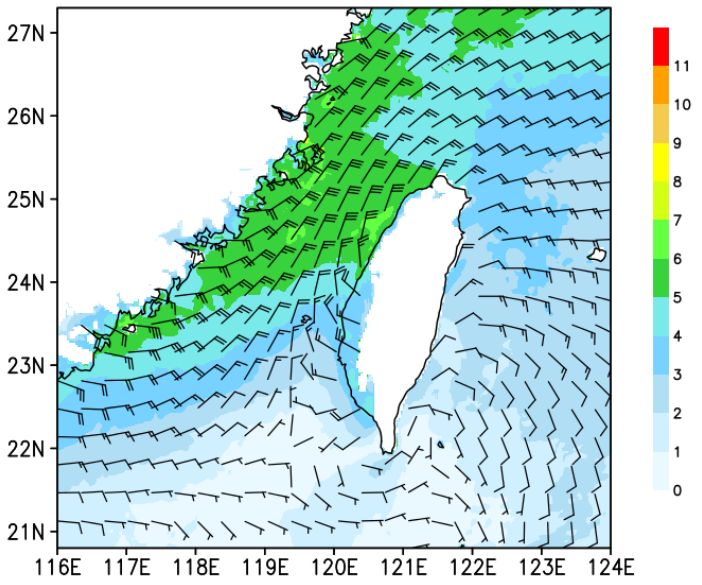
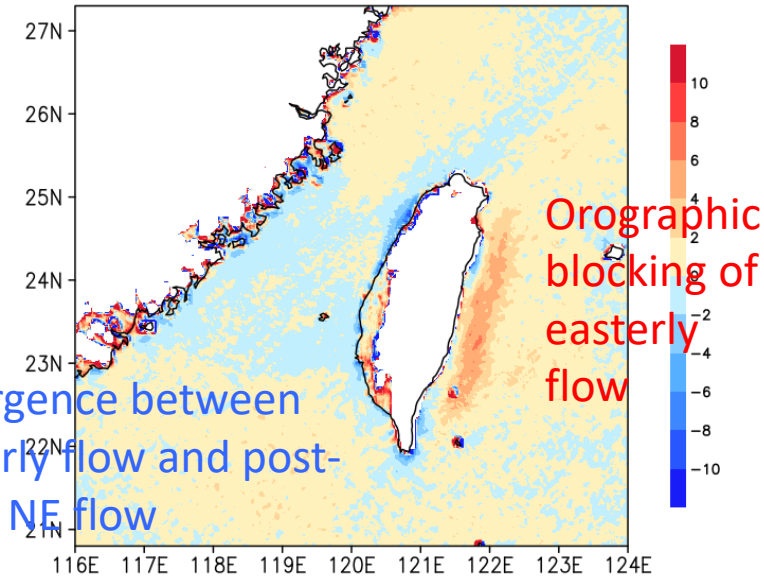


1000hPa convergence (10^{-4} s^{-1})



Orographic blocking of easterly flow

Convergence between southerly flow and post-frontal NE flow

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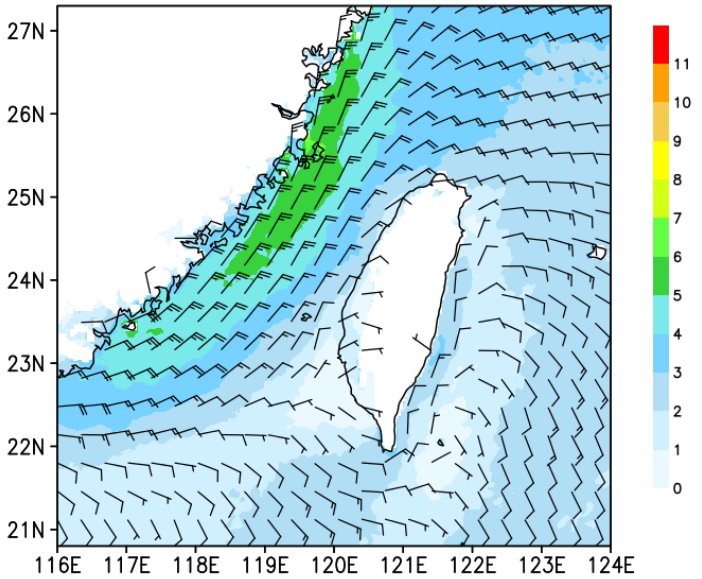
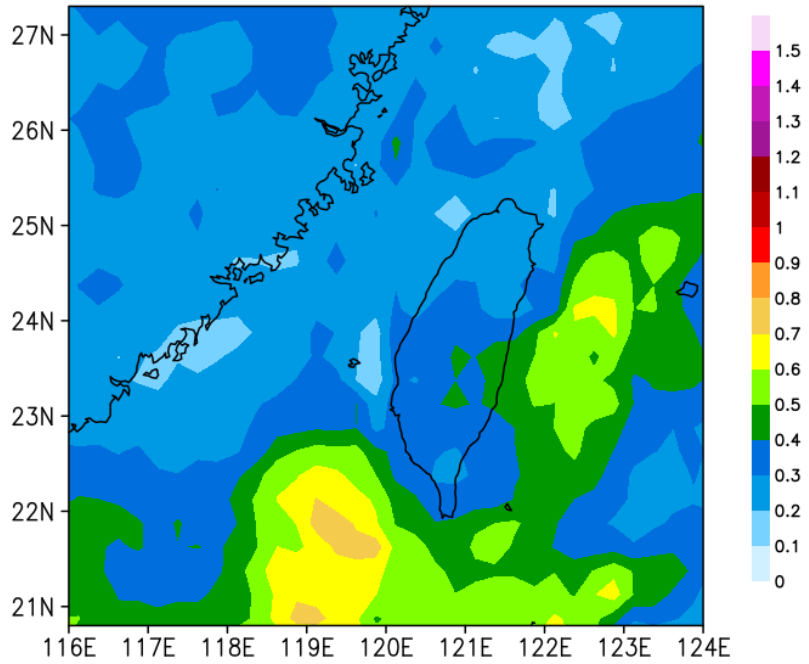


TRMM rainfall distribution (mm/hr)

Early Season
5/15-5/31

mean



- Mean:

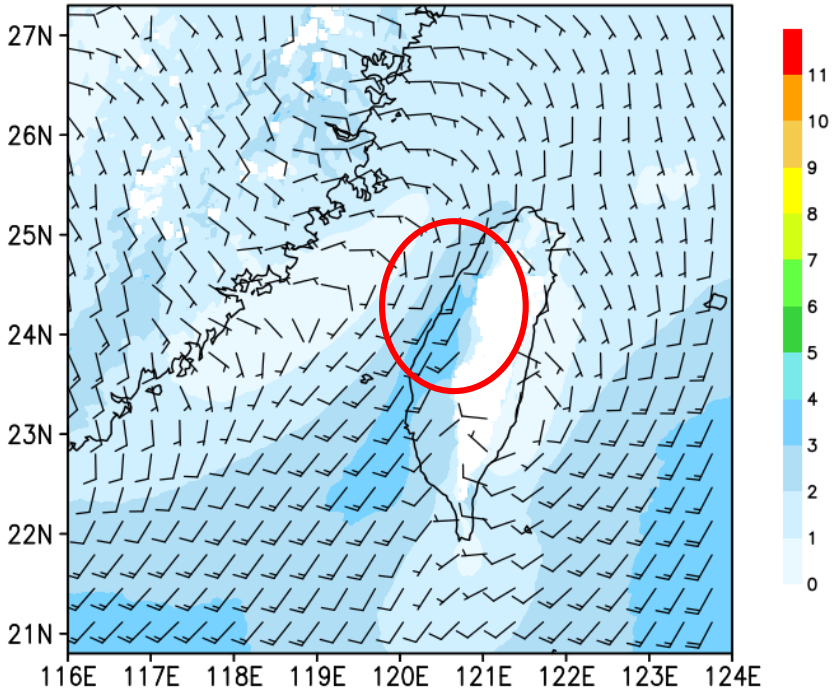
Rainfall off eastern coast of Taiwan is due to orographic blocking of NE flow and low-level convergence there.

900hPa-winds (1bar=2 m/s) and wind speed (m/s)

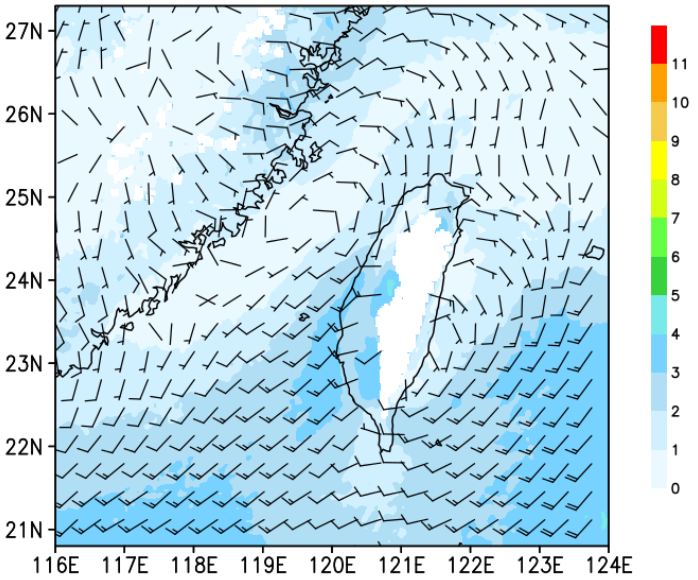
Early Season
5/15-5/31

1. The cold, dry NE flow is shallow (<1km) within the Taiwan Strait.
Above 900hPa level, the upstream flow is southwesterly flow.

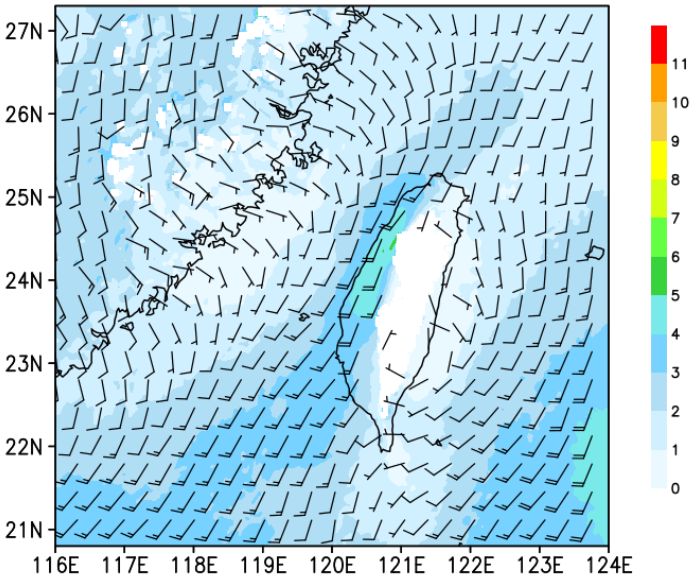
mean



06UTC(14LT)



21UTC(05LT)

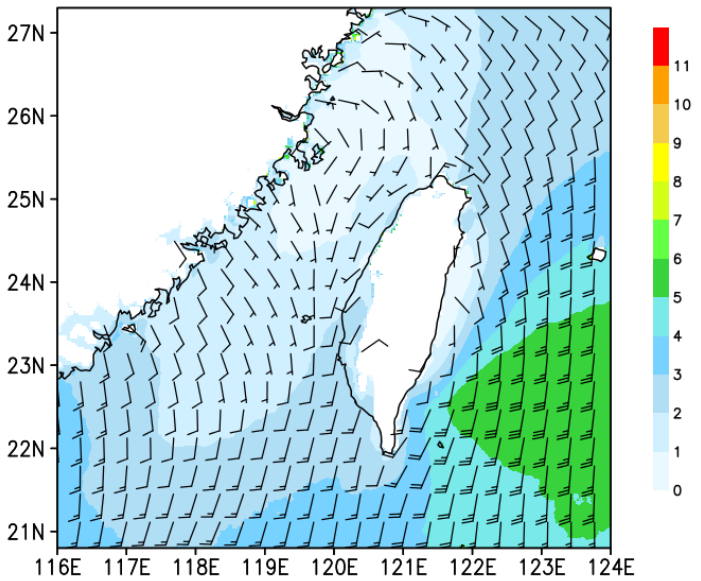


2. Nighttime orographic blocking of SW flow over southwestern Taiwan is more significant.

1000hPa-winds (1bar=2 m/s) and wind speed (m/s)

Mid-Season
6/1-6/15

mean



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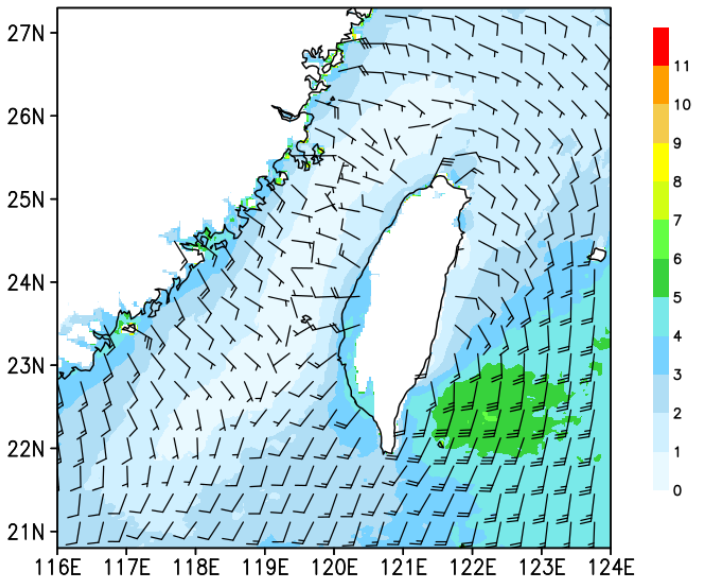
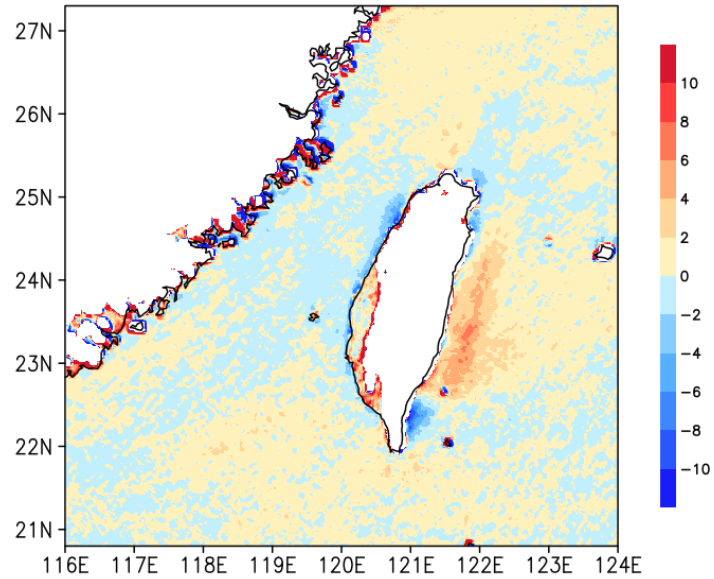
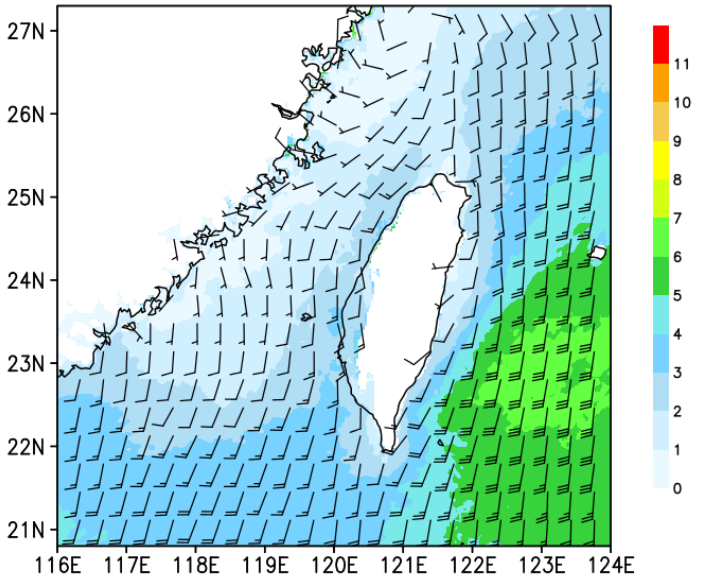


1000hPa convergence (10^{-4} s^{-1})



21UTC(05LT)

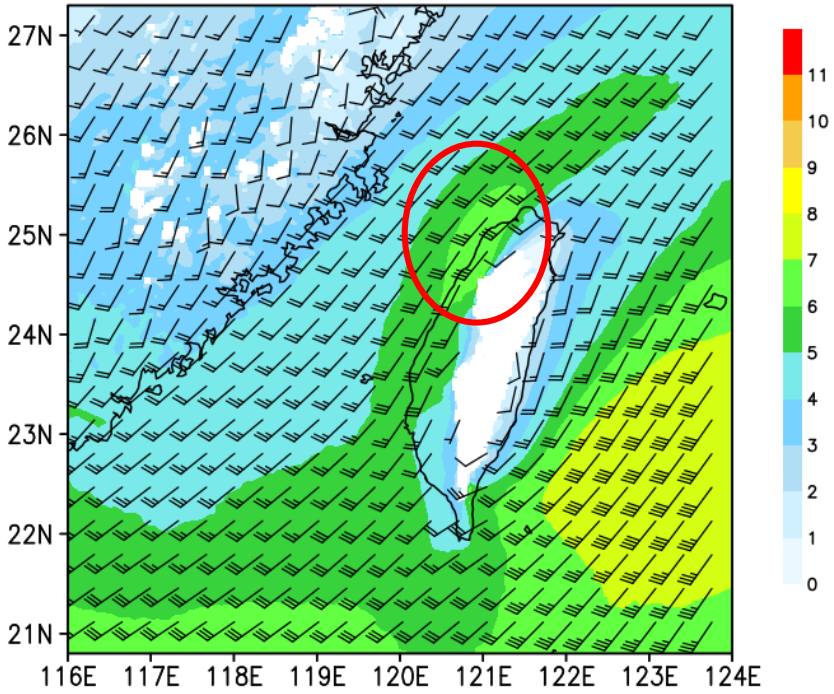


900hPa-winds (1bar=2m/s) and wind speed (m/s)

Mid-Season
6/1-6/15

1. The southwesterly flow is enhanced resulting a significant orographic blocking over southwestern Taiwan and the barrier jet over northeastern Taiwan and surrounding ocean.

mean



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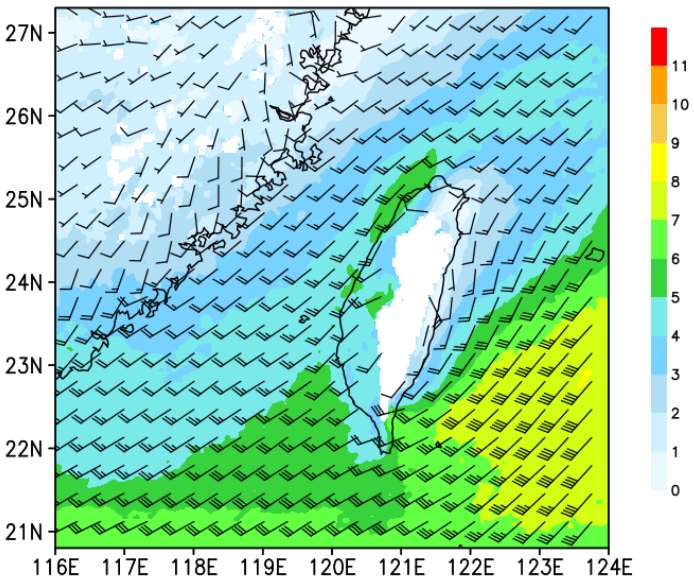

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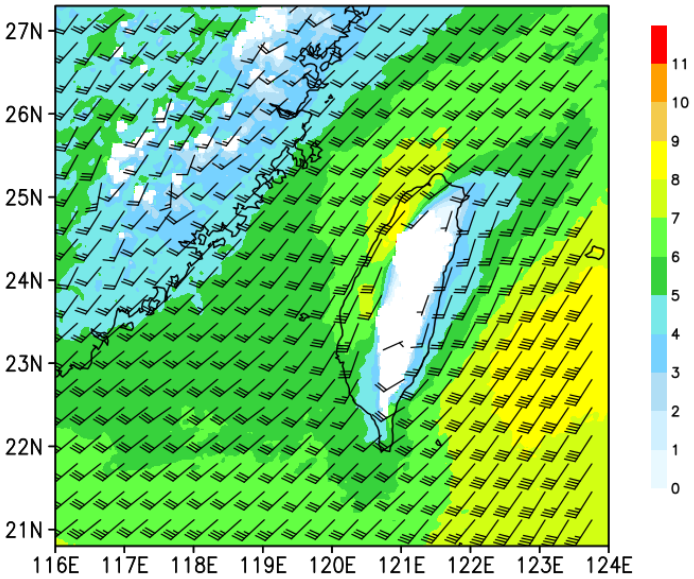
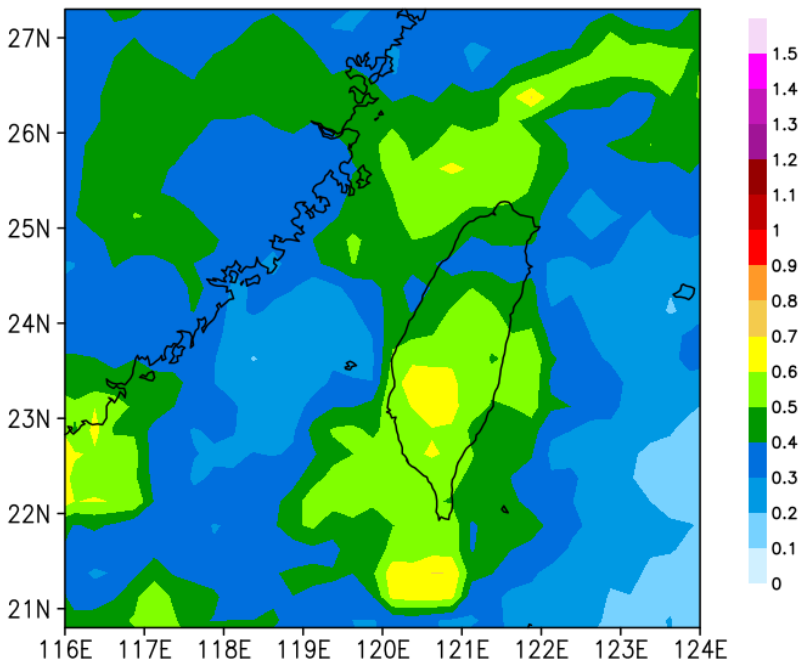


2. The barrier jets over and off northwestern Taiwan is more significant during nighttime/early morning than daytime.

TRMM rainfall distribution (mm/hr)

Mid-Season
6/1-6/15

mean



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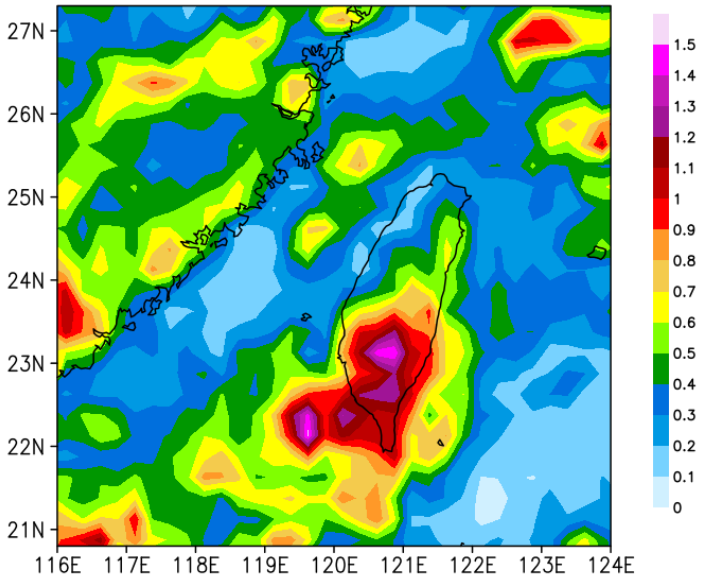

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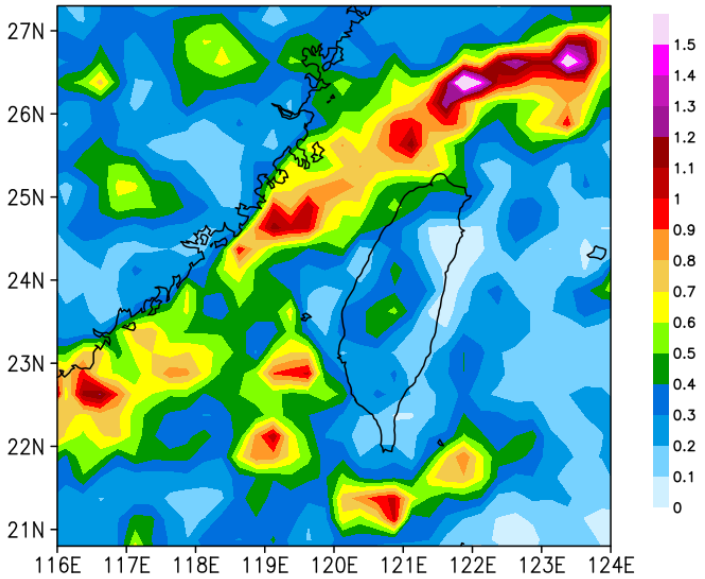

- Mean:

1. Rainfall off eastern coast of Taiwan reduces because it is drier and warmer in the leeside of SW flow during Mid-Mei-Yu season.
2. Rainfall off northwestern Taiwan increases related to interaction among large-scale flow, fronts and barrier jets.

Conclusion (II)

- **Orographic blocking over southwestern Taiwan under southwesterly flow is most significant in the early morning when the land surface is coolest due to nighttime radiative cooling. As a result, the barrier jets over northwestern Taiwan and the surrounding ocean is more significant during nighttime/early morning than daytime.**

- **At 1000hPa level, easterly/southeasterly prevails over eastern Taiwan. Thus, the orographic blocking occurs over eastern Taiwan. Due to the impacts of land breezes during nighttime and early morning, the convergence zone east of Taiwan is evident at that time.**

- **At 900hPa level, the strong southwesterly flow is blocked over southwestern Taiwan which leads to the occurrence of barrier jets off northwestern Taiwan during Mid-Mei-Yu season. More frequent rainfall off northwestern Taiwan is related to the interaction along the large-scale flow, fronts and barrier jets.**

Thanks for your listening