The Impact of Intra-Seasonal Oscillations on the Stationary Rainband over Taiwan in the Mei-yu season

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Introduction

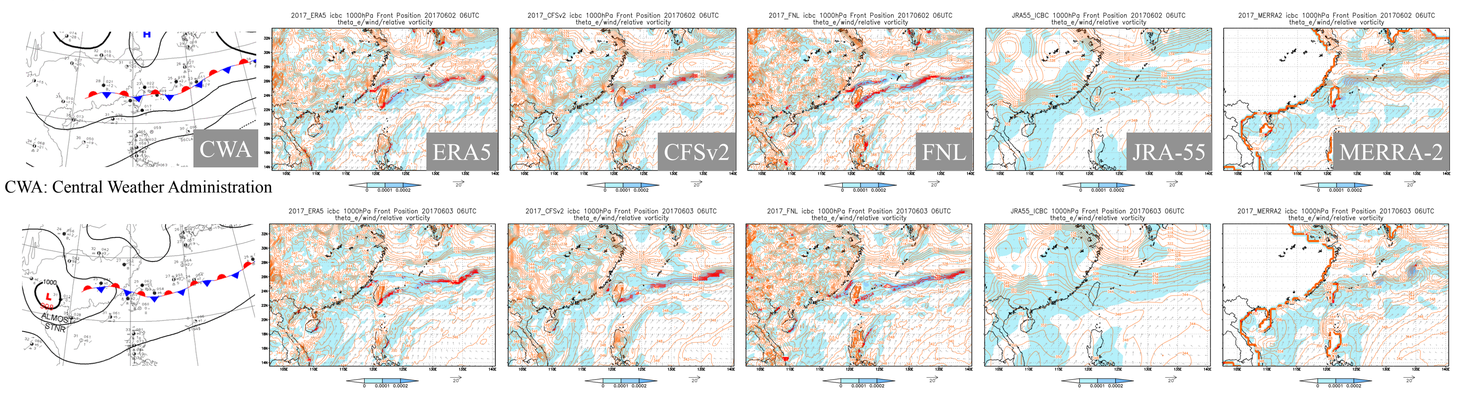
The Mei-yu season brings persistent rainbands to Taiwan, impacting regional hydrology and disaster management. Ding et al. (2020) highlighted the role of quasi-biweekly (QBW) and 30–60-day (MJO) oscillations in Mei-yu variability, but the influence of intra-seasonal oscillations (ISO) across different time scales remains unclear. This study examines how ISO affects the Mei-yu front's movement, moisture transport, and convection organization through numerical simulations and observational analysis.

Methods

	Initial / Boundary Condition	CE – SE
2017 case Control Experiment (CE)	ERA5	
2017 case Sensitivity Experiment (SE)	ERA5 – ISO-S -> **NISO-S** (10-30-days)	Impact of ISO-S
2007 case Control Experiment (CE)	ERA5	
2007 case Sensitivity Experiment (SE)	ERA5 – ISO-L -> **NISO-L** (30~90-days)	Impact of ISO-L

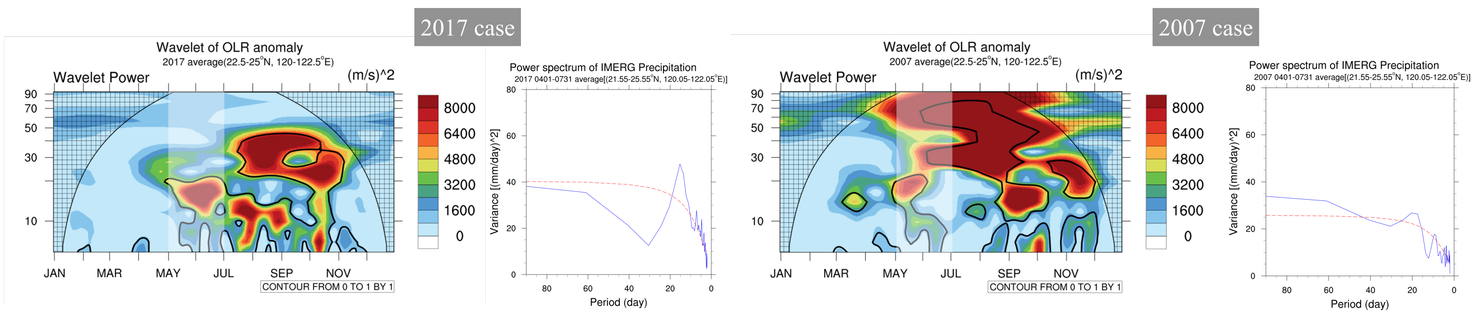
- Model: Cloud-Resolving Storm Simulator (CReSS)
- Filter: Butterworth Bandpass Filter

Data & Cases Select



CWA: Central Weather Administration

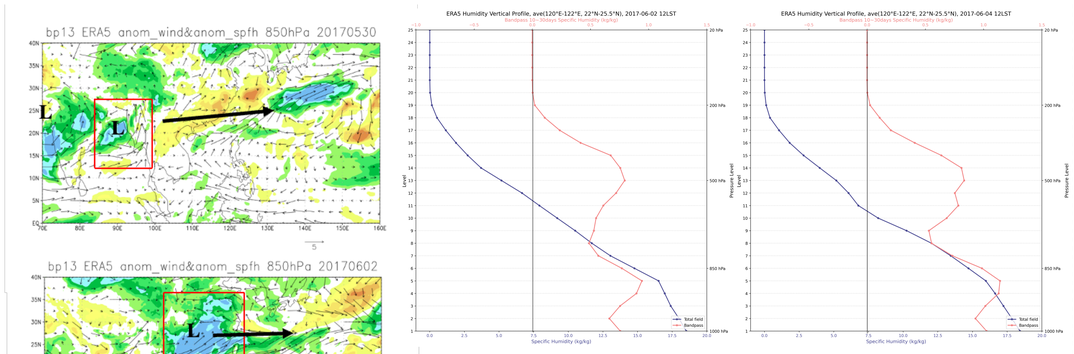
- The front is defined where the equivalent potential temperature gradient > 0.01 and relative vorticity > 0.0001.
- ERA5 accurately captures the front's slow movement and ensures stable frontal evolution and structure.



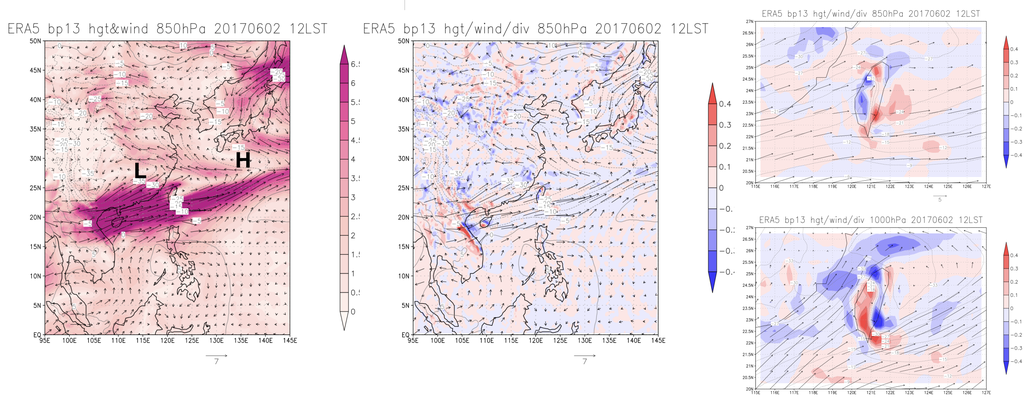
- In 2017, short-period oscillations dominated, while long-period oscillations were more prominent in 2007.
- This study defines ISO-S (10–30–days) and ISO-L (30–90–days).

Result

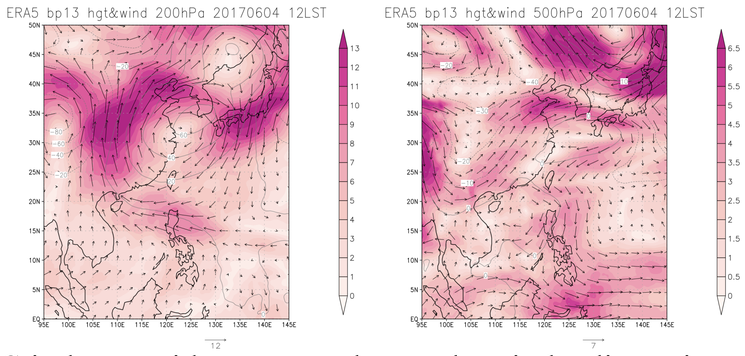
Structural Characteristics of ISO-S



- A westward cyclone enhanced southwesterly winds and moisture transport, increasing humidity at all levels.



- Cyclone-anticyclone interaction induced strong wind shear and a slow-moving convergence zone (SCZ) near northern Taiwan.
- Leeward terrain in eastern Taiwan caused significant low-level divergence (850 hPa, red).

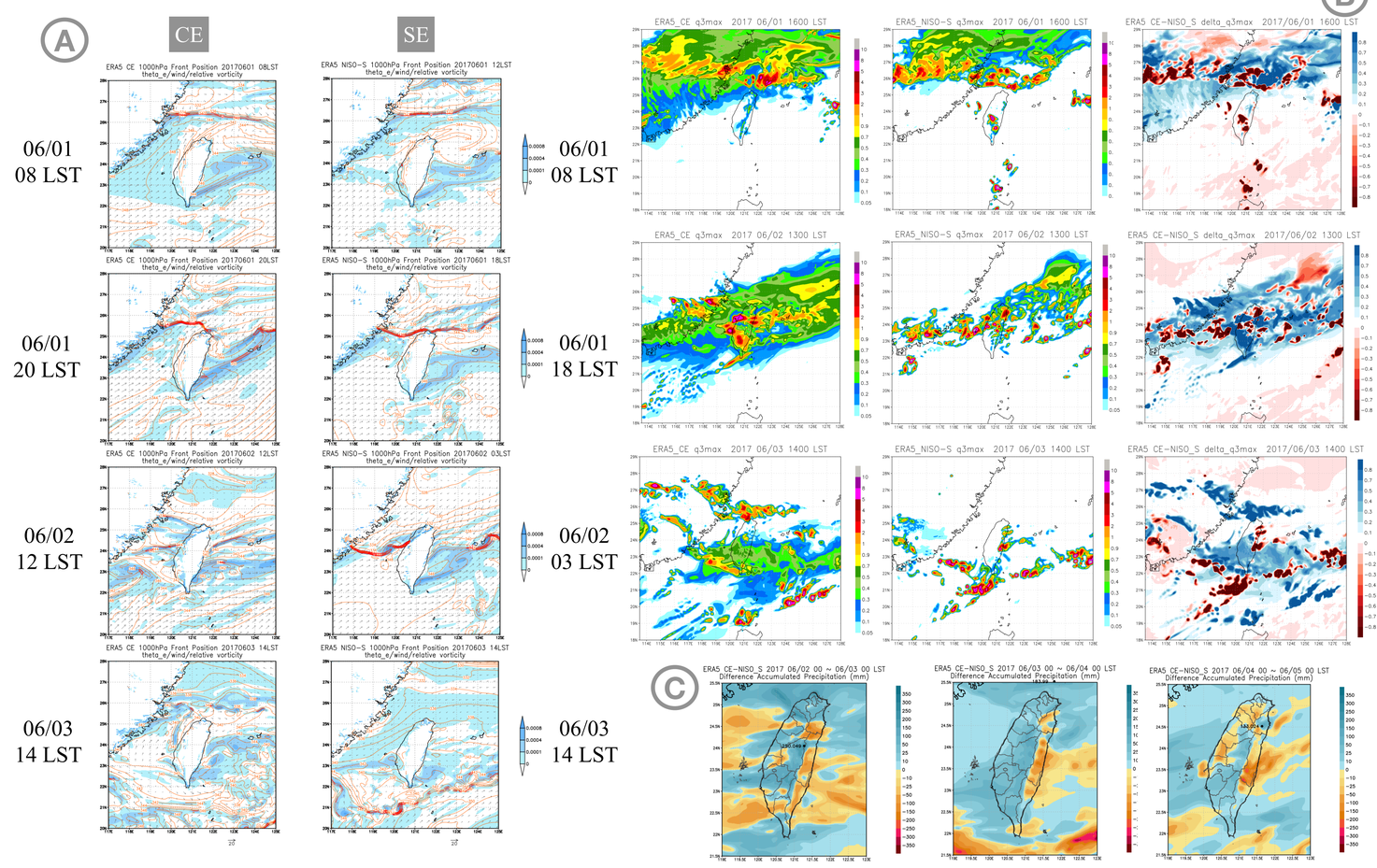


- ISO-S induces mid-upper northeasterly winds, disrupting the front's southwesterly flow and weakening vertical wind shear.

Impact of ISO-S on Meiyu Front

- Enhances western Taiwan rainfall, possibly reducing it in the east.
- Low-pressure cyclone stalls the front over northern Taiwan.
- SCZ strengthens frontal signals and northern rainfall (June 3–4).
- Weakens the front, loosens structure, and reduces convection.

Simulation results (CE, SE) – 2017 case



ISO-S Influence on Front Position (Shown in A)

- ISO-S Slow the front's southward shift, prolonging its stay over northern Taiwan and offshore.
- Weakens the front's structure, making it more diffuse and less identifiable.
- Contributed to frontal signals over northern Taiwan from the afternoon of June 3 to June 4.

ISO-S Influence on Convective Rainbands and Precipitation (Shown in B and C)

- Weakens frontal convection while enhancing surrounding convection, expanding the rainfall area.
- Increases rainfall in western Taiwan. Reduces rainfall in eastern Taiwan.

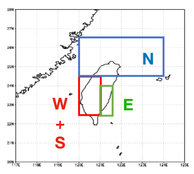
Water budget (Trenberth and Guillemot, 1995)

$$P + \underbrace{\frac{\partial}{\partial t}(W_v + W_h)}_{\text{TDC}} = \underbrace{-\int_0^\infty \nabla\cdot(\rho_v \mathbf{V})dz}_{\text{CVF}} \underbrace{-\int_0^\infty \nabla\cdot(\rho_h \mathbf{V})dz}_{\text{CHF}} + E + R$$

$$\underbrace{-\int_0^\infty \nabla\cdot(\rho_v \mathbf{V})dz}_{\text{CVF}} = \underbrace{-\int_0^\infty \rho_v(\nabla\cdot\mathbf{V})dz}_{\text{CONV}} \underbrace{-\int_0^\infty (\mathbf{V}\cdot\nabla)\rho_v dz}_{\text{ADV}}$$

$$\mathrm{PW}_{5.5} = -\int_0^{5.5km} \rho_v dz \qquad \mathrm{IHC}_{5.5} = -\int_0^{5.5km} (\mathbf{V}\cdot\nabla)dz$$

- P : precipitation
- TDC : tendency of total water content
- CVF : convergence of vapour flux
- CHF : convergence of hydrometeor flux
- E : evaporation
- R : residual



120°-124°E, 24.5°-26.5°N 6/3 00 LST ~ 6/5 00 LST		P	TDC	CVF					CHF	E	R	R/P(%)
				TOTAL	CONV			ADV				
					TOTAL	PW5.5	IHC5.5					
N	CE	1.007	0.103	0.971	1.076	56.263	1.494	-0.104	-0.002	0.048	0.093	9.199
	NISO-S	0.091	0.117	0.132	-0.031	48.645	-0.107	0.163	-0.001	0.07	0.007	8.085
	CE – NISO-S	0.916	-0.014	0.839	1.107	7.618	1.601	-0.267	-0.001	-0.022	0.086	
	CE – NISO-S / CE (%)	91%	-14%	86%	103%	14%	107%	-257%	-50%	-46%	92%	

120°-121°E, 22.5°-24.5°N 6/2 00 LST ~ 6/4 00 LST		P	TDC	CVF					CHF	E	R	R/P(%)
				TOTAL	CONV			ADV				
					TOTAL	PW5.5	IHC5.5					
W + S	CE	3.175	0.027	3.686	3.352	51.515	7.699	0.335	-0.48	0.081	-0.085	-2.663
	NISO-S	1.773	-0.02	2.025	0.709	50.64	-0.578	1.316	-0.439	0.064	0.102	5.774
	CE – NISO-S	1.402	0.047	1.661	2.643	0.875	8.277	-0.981	-0.041	0.017	-0.187	
	CE – NISO-S / CE (%)	44%	174%	45%	79%	2%	108%	-293%	-9%	21%	-220%	

121°-121.5°E, 22.5-24°N 6/2 00 LST ~ 6/5 00 LST		P	TDC	CVF					CHF	E	R	R/P(%)
				TOTAL	CONV			ADV				
					TOTAL	PW5.5	IHC5.5					
E	CE	1.491	0.062	-0.221	2.639	43.13	9.287	-2.86	0.873	0.08	0.82	55.001
	NISO-S	2.284	0.072	1.842	-1.053	44.143	-3.126	2.895	0.132	0.066	0.316	13.817
	CE – NISO-S	-0.793	-0.01	-2.063	3.692	-1.013	12.413	-5.755	0.741	0.014	0.504	
	CE – NISO-S / CE (%)	-53%	-16%	-933%	140%	-2%	134%	-201%	85%	18%	53%	

- P is mainly driven by CVF. ISO-S enhances CONV, but the negative contribution of ADV partially offsets it. In eastern Taiwan, ADV exceeds CONV, reducing P.

Conclusion & Future Work

- ISO-S slows front movement, weakens vertical wind shear, enhances southwesterly flow, and drives late-stage rainfall, greatly increasing rainfall, especially in western and northern Taiwan.
- Future work will explore how ISO-L influenced the Meiyu front in the 2007 case.

Reference

- Ding, Y., et al., 2020: Multiscale variability of Meiyu and its prediction: A new review. J. Geophys. Res., 125.
- Trenberth, K. E., and C. J. Guillemot, 1995: Evaluation of the Global Atmospheric Moisture Budget as Seen from Analyses. *J. Climate*, **8**, 2255–2272.

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