Formation Mechanisms of Southwesterly Flows and the Relationship with Rainfall during Mei-Yu Seasons

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ABSTRACT

This study explores the relationship between precipitation during southern Taiwan's Mei-Yu season (May 15 to June 15) from 1997 to 2022 and southwestly flow (SWs) along with the associated weather systems. The findings indicate that SW generation is primarily influenced by the southwest vortex, followed by the low-pressure trough, and finally the subtropical high. Weather systems result from the complex interaction of various factors that lead to rainfall. During subtropical high events, water vapor predominantly affects rainfall intensity. For southwest vortex events, the pivotal factor is the location of the vortex center, while in low-pressure trough events, the distance between the low-pressure center and Taiwan holds great significance. Additionally, in cases of SWs accompanied by subtropical highs, rainfall intensity correlates with the humidity on Taiwan's southwestern side. Conversely, the location of low-pressure systems directly impacts precipitation intensity. Recognizing these key factors aids in monitoring changes during SW events, which is crucial for disaster prevention.

INTRODUTION

Many previous studies have demonstrated research results in the related topics, most of them were based on single case study. A complete examination of all possible formation mechanisms of southwesterly events (SW) is lacking. Furthermore, precipitation characteristics and intensities are very different among different individual SW because precipitation is dominantly influenced by its associated weather systems. The purposes of this study are therefore aiming on not only finding the SW formation mechanisms, but also examining the relationship between the precipitation characteristics and the weather systems that cause the SW events.

- The classification of SW formation mechanisms according to the weather systems.
- The examination of relationship between different formation mechanisms and precipitation in Taiwan.
- What are the reasons behind the precipitation differences caused by SWs generated by different types of weather systems?

DATA AND METHODOLOGY

DATA SOURCES

1. European Centre for Medium-Range Weather Forecasts' (ECMWF) ERA 5 reanalysis data.
2. Central Weather Bureau's (CWB) Rainfall Intensity (RS) data.
3. Japan Meteorological Agency's (JMA) weather charts.

DATA SELECTION

5632 events

selection criteria1 (Chiu and Chien,2023)

565 SWs events

selection criteria 2
- Moisture flux > mean value $147.9 \times 10^{-3}\ m/s$
- Duration ≤ 36 hours

63 events used in this study

Subtropical High | **Southwest Vortex** | **Low-Pressure Trough**

DATA PROCESSING

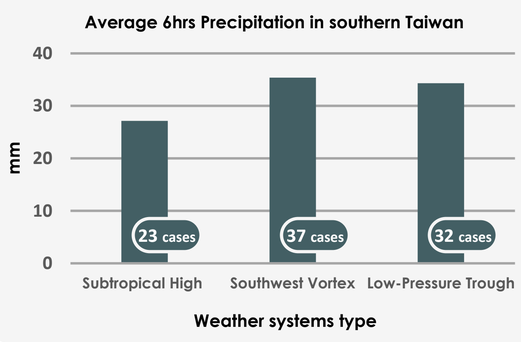
1. Labeling the atmospheric states every 6 hours as events, we observed 128 events during a Mei-Yu season, and a total of 5632 events were analyzed.

2. Subtropical High
   South-westerly (SW) events are determined by calculating the difference between two contour lines to locate the position of the 1500 contour line at 850 hPa (Chiu and Chien, 2023) .
   - When passing through 20°N, it should be west of 125°E.
   - When passing through120 °E, it should be north of 13 °N.

3. Southwest Vortex
   - The 850 hPa weather map
   - An eastward movement of low-pressure within the range of 20-30 °N/100-120 °E.

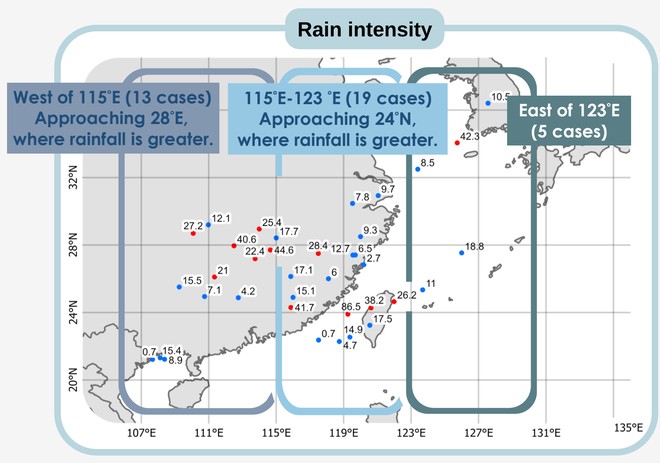
4. Low-Pressure Trough
   - The 700 hPa weather map
   - The northwest Taiwan (30°N/117.5°E) geopotential height falls below the third quartile (= 3086.23) accompanied by low pressure within the range of 30-45 °N and 110- 140 °E.

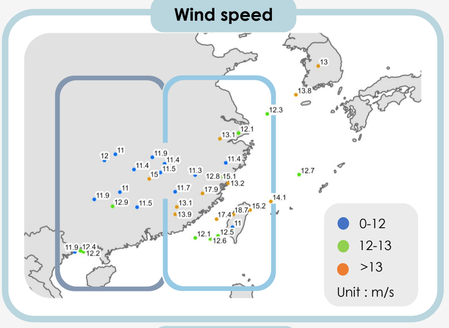
Result

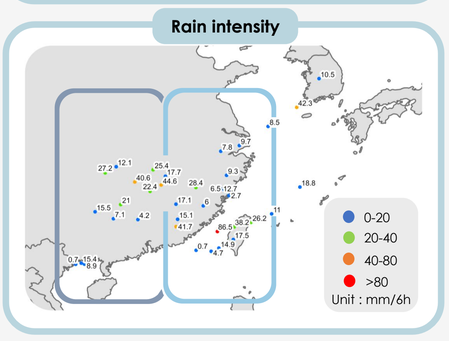


The average rainfall for the Southwest Vortex event, with a total of 37 cases, was greater than that of the Low-Pressure Trough event, which had 32 cases, and also greater than the Subtropical High event, which had 23 cases.

1. Southwest Vortex :







	Total Taiwan Rainfall	Southern Taiwan Rainfall	Water Vapor Flux	Wind Speed	Specific Humidity
West of 115°E The distance from 28°N/112.5°E	**-0.49**	**-0.62**	**-0.16**	**0.05**	**-0.52**
115°E-123°E The distance from 24°N/120°E	**-0.32**	**-0.36**	**-0.68**	**-0.49**	**-0.44**

SWV events west of 115°E exhibit a relatively low correlation between water vapor flux and precipitation

The southern side of the southwest vortex tends to gather more moisture, which is why the wind speed doesn't increase significantly as the vortex approaches Taiwan. The slightly northern position of the southwest vortex center contributes to an overall increase in moisture near Taiwan. Therefore, when the center is around 28°N, rainfall in Taiwan becomes more intense. When the center moves from passing over Taiwan to the eastern side of Taiwan, the correlation between its position and precipitation will transition from high correlation to low correlation.

2. Low-Pressure Trough :

Since the trough's position to the far north of Taiwan does not significantly impact rainfall in the region, we have selected cases within a 15-degree range of latitude and longitude, resulting in a total of 13 cases.

The closer a low-pressure system is to Taiwan, the stronger its intensity [Correlation Coefficient(CC) =-0.65] . This results in higher wind speeds [CC=-0.6], leading to an increased moisture flux [CC=-0.54] and subsequently more rainfall [CC=-0.34].

3. Subtropical High :

The northward extension of a subtropical high or the southward shift of a northern trough results in an increased pressure gradient, leading to the strengthening of southwestern winds and higher wind speeds [CC=+0.35]. However, there is a relatively reduced amount of moisture [CC=-0.46], consequently resulting in decreased precipitation[CC=+0.56].

Conclusion

In the southwesterly flow, the dominant weather systems are in the following order: Southwest Vortex, Low-Pressure Trough, Subtropical High. Additionally, both the Southwest Vortex and the Low-Pressure Trough contribute to heavy rainfall during the Southwest Vortex event, while the Subtropical High results in comparatively lighter rainfall. In the scenario of the subtropical high during SWs, precipitation intensity is influenced by the humidity originating from the southwestern side of Taiwan. Conversely, in the context of a low-pressure system, precipitation intensity is directly impacted by the location of the low-pressure system.

Reference

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