利用三維風場反演、系集數值模擬和群集分析方法 解析台灣北部極端降雨事件

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CWA 38th, Sep. 03-05, 天氣分析研討會, 台北



I. Introduction and Motivation

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- Ensemble simulations
- Radar Retrieval: WISSDOM

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- WISSDOM and clustering
- Pre-frontal rainfall period
- Heavy rainfall period

IV. Summary



INTRODUCTIONS ~~~~

- From May to July, namely the **seasonal transition**, a frequent weather system which always brings extreme rainfall and significant damage over southern China and Taiwan, called the **Mei-Yu front**.
- LLJ/barrier jet (BJ, 1km) is a positive factor to enhance heavy rainfall. (e.g. Chen and Yu 1988; Kuo and Chen 1990; Li et al., 1997; Li and Chen 1998; Chen 2005; Chen 2018; Ke et al. 2019; Tu et al. 2022).
- Tu et al. (2020) notes the presence of the southwesterly marine boundary layer jet **(MBLJ)** before the arrival of the mei-yu jet/front system from June 1 to 4, 2017.







• Ke et al. (2019) investigate the heavy rainfall in detail during 11-12 June, 2012 through Wind Synthesis System using Doppler Measurements (WISSDOM) (Liou et al., 2014, 2016) system.



⁽Ke et al., 2019)

- The atmospheric dynamic reveals highly **nonlinear**.
- **Ensemble** simulations is an important tool to examine the performance of the model.
- Du et al., 2018 analyzed ensemble simulations to find the deterministic factor of DLLJ for causing heavy rainfall.
- Lin et al. (2020) clustered ensemble simulations of Typhoon Fanapi in 2010 through the accumulated rainfall pattern and landfall position of them.
- Chen et al. (2021) cluster by using the **K-means** algorithm for cluster analysis the QPF of the **36** ensemble members can be divided into four sub-ensemble groups.

- Mei-Yu front extreme rainfall Event
 - June 01-02 2017
 - over 550mm in 8 hours

Mesoscale Convective System

Mei-Yu front







Squall Line





METHOD: MODEL & ENSEMBLE

	Model settings
Model	WRF 4.2.1 (Ensemble)
Initial condition	NCEP FNL (0.25°x 0.25°) Operational Global Analysis data
Initial time	2017/06/01 00UTC
resolution	27km/9km/3km/1km, 52 levels, top-10 hPa
MP scheme	GCE
Ensemble perturb	WRF 3DVAR randomcv CV3
Ensemble number	128 members in total



- 90 - 70 - 50

- 40 - 30 - 20

- 15 - 10 - 6

- 2 - 1









Results

- WISSDOM and clustering
 Pre-frontal rainfall period
- Heavy rainfall period





$\overset{\textbf{Result of K-means}}{\overset{\overset{\overset{}}{\overset{}}}{\overset{\overset{}}{\overset{}}}}$

Silhouette score

(Peter Rousseeuw, 1987)

- Silhouette Coefficient = (b(i) a(i)) / max(a(i), b(i))

 a(i): the mean intra-cluster distance
 b(i): the mean nearest-cluster distance
- The best value is 1, the worst value is -1

Highest Score: 0.4067 (best=1)



longitude







RESULT OF PRE-FRONTAL RAINFALL PERIOD

Z at 6/1 15UTC

- duster1
- duster2
- duster3
- ---- duster4 ---- duster5

Low center A at 6/1 12UTC A at 6/1 18UTC



850hPa geopotential height - at 15UTC

- Short wave trough speed:
 - cluster1 > cluster2 > cluster3
 > cluster5 > cluster4



RESULT OF HEAVY RAINFALL PERIOD

Cluster 2



Near topography

- Low pattern encounter northern terrain
- Strong BJ to the front directly
- 925-hPa Low center at around 26.5N

Far away from topography

- Wide-spread BJ to east-edge of Low
- 925-hPa Low center at north of 27.0N



SCHEMATIC DIAGRAMS $\sim \sim \sim \sim$



Ensemble forecasts

-useful and important tool to examine the

multi-factors cause heavy rainfall

Machine learning of Clustering

-spatial k -means clustering were used for

categorizing the rainfall characteristics

-clustering 5 groups by k-means approach

Radar Retrieval: WISSDOM

-a reference as the reality

-the barrier jet and the frontal system

Other groups





Radar retrieval

FUTURE WORKS

Plans:

- Examine different meteorological variables (ex: wind, temperature, water vapor...)
- Ensemble sensitivity analysis
- Applying to 2022 TAHOPE different cases





250

200

150

100

ò





SPATIALLY K-MEANS CLUSTERING



K-means (get 5 group centers)

Mean_SCC = 0.688, silhouette = 0.149

2D K-means (one times) clustering by SCC score

Mean_SCC = 0.736, silhouette = 0.168

1-D K-means clustering



0 1 2 6 10 15 20 30 40 50 70 90 110130150200300

2-D K-means clustering (one times)



2-D K-means clustering (iteration)

2D K-means (iteration) Clustering by SCC score until the members in clusters not changing

Mean_SCC = 0.742, silhouette = 0.176





RESULT OF PRE-FRONTAL RAINFALL PERIOD



from 0200 UTC 1 June to 0000 UTC 2 June (dots, interval is 2 hours)

The performance of cluster-averaged wind (MBLJ, Tu et al.,2019)

- V-wind increase and then decrease when the low moving eastward
- Different initial wind condition at SW domain:



cluster **1**, **2**, **3**

27

Stronger V-wind

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