A study of cumulus parameterization schemes using land use and roughness length in tropical cyclone convection simulations.

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Introduction

- The Weather Research and Forecasting (WRF) model has several cumulus parameterization scheme (CPS) options that help the user improve and control the WRF model under different regimes.
- First goal of this study is to understand how the available CPSs perform in a WRF model simulation of a tropical cyclone (TC)
- Provide a brief overview of past research – only what is necessary to understand the poster.
- Typhoon Fanapi (2010), which brought very heavy rainfall (1131 mm) to the south plain of Taiwan, was selected for this thesis as a study case.
- Clouds and their associated physical processes strongly influencing the couplings between the atmosphere and oceans (or ground) through modifications of radiation and planetary boundary layer (PBL) processes.
- Since, this study also want to investigate the affect of 2 PBL index in Tropical Cyclone convection.

Model setting study case and methods

WRF configuration

Domain:10km, 3km

Time:

00Z 2010,Sep 17 – 00Z 2010, Sep 21

Data:

NCEP High Resolution Global Forecast System (0.5°GFS),

Terrain: Modis

Physic option:

Microphysics: WRF Single-Moment 5-class scheme

Longwave Radiation: RRTM scheme

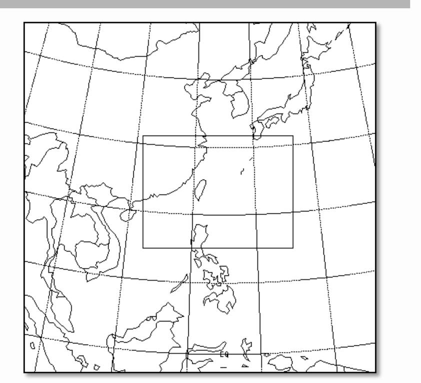
Shortwave Radiation: Dudhia scheme

Surface Layer: MM5 similarity

Land Surface: Noah Land Surface Model

Planetary Boundary layer: Yonsei University scheme

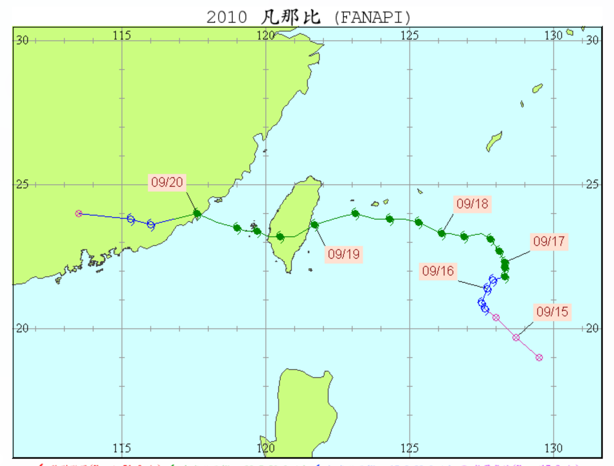
Cumulus Parameterization: Kain-Fritsch scheme, Betts-Miller-Janjic scheme, Grell-Devenyi ensemble scheme, Grell three-dimension ensemble



Two domain with horizontal solution of 10 and 3 km

Typhoon Fanapi (2010)

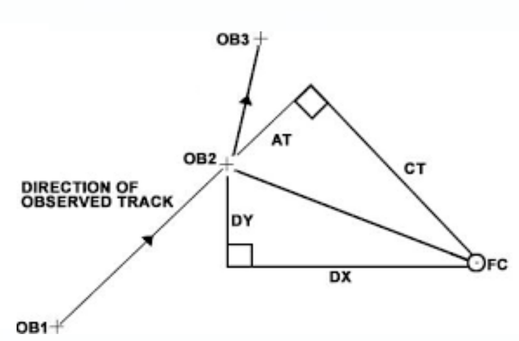
- Typhoon Fanapi is one of the perfect case for this study with high precipitation, stable track and normal intensity.
- According to the CWB heavy rainfall area was recorded on southern plain of taiwan:
  - Majia Village (Pingtung County) :**1,126mm**
  - Gangshan Township (Kaohsiung County): **942 mm**.



Best track of Typhoon Fanapi (CWB)

Tracking analysis

- OB1-3: Observed positions
- FC: Forecast position: verifying against observation OB2
- DPE: Direct positional error; distance from FC to OB2
- DX: Error in the East-West direction
- DY: Error in the North-South direction
- AT: Error in the Along Track direction
- CT: Error in the Cross Track direction



Land use (LU) and roughness (Zo) length issues in Taiwan

- The default LU and Zo data employed in the WRF model is from the U.S. Geological Survey (USGS), which classifies most of Taiwan as cropland and forest.
- In general this is outdated and does not include the urbanization process over recent decades. (Cheng et al. 2012)
- Moreover, the forest area has been erroneously located. MODIS data can correct most LU-type distributions.
- Data retrieved from the 2001 MODIS satellite products were used for the WRF model released after version 3.1.

Land Use classification

Land Type	USGS(%)	MODIS(%)
Urban	0.158	16.895
Dry cropland	8.171	
Irrigated cropland	56.458	
Mixed dry–irrigated		13.073
Evergreen broadleaf	2.609	42.462
Evergreen needleleaf	2.478	4.823
Mixed forest	18.608	18.872
Other	11.518	3.875

Summary

- Four simulation using USGS data were set up during a time of high precipitation with four CPSs: the Kain–Fritsch (KF), Betts–Miller–Janjic (BMJ), Grell–Devenyi ensemble (GD), Grell three-dimension ensemble (G3D), and a no-scheme (NC).
- Each CPSs have there pros and cons. But after analysis KF was chosen as Control run.
- Sensitive point is 12 hours after typhoon hits Taiwan, also is the peak of raining time.
- Simulation surface wind field is too rough on Taiwan inland area.
- By updating LU and Zo we can improve the performance in this case.
- The objective of this reseach is to help predict similar TCs, not to judge which CPS is better or worse for all TC systems. Update LU and Zo also may not work for other case.

Tracks results of difference

A

Along Track Error

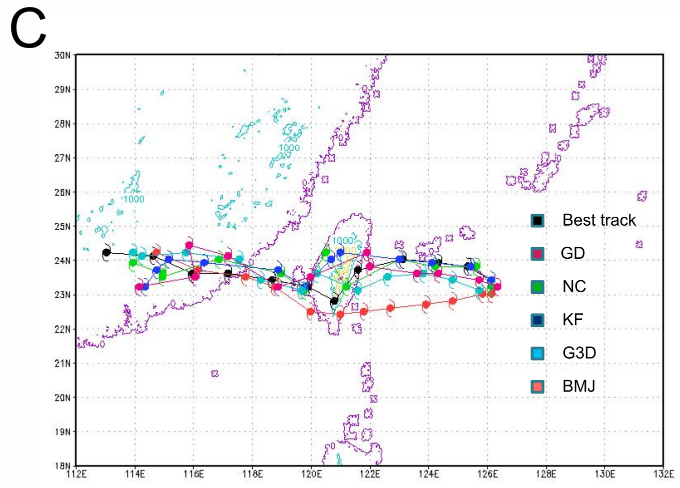
AT (km)	time	06h	12h	18h	24h	30h	36h	42h	48h	54h	60h	66h	72h
	NC	-10	-15	7	11	30	-82	12	-17	19	101	-37	-60
	KF	-2	-9	19	17	35	-70	9	-22	78	84	-34	-103
	GD	-17	-21	-4	-53	-68	-49	-12	-96	-175	-109	-80	-62
	G3D	23	28	27	33	13	25	11	28	-18	22	21	-88
	BMJ	-14	-71	-75	-95	-88	-45	-112	-154	-156	-167	-152	-161
	NC	-10	-15	7	11	30	-82	12	-17	19	101	-37	-60

B

Cross Track Error

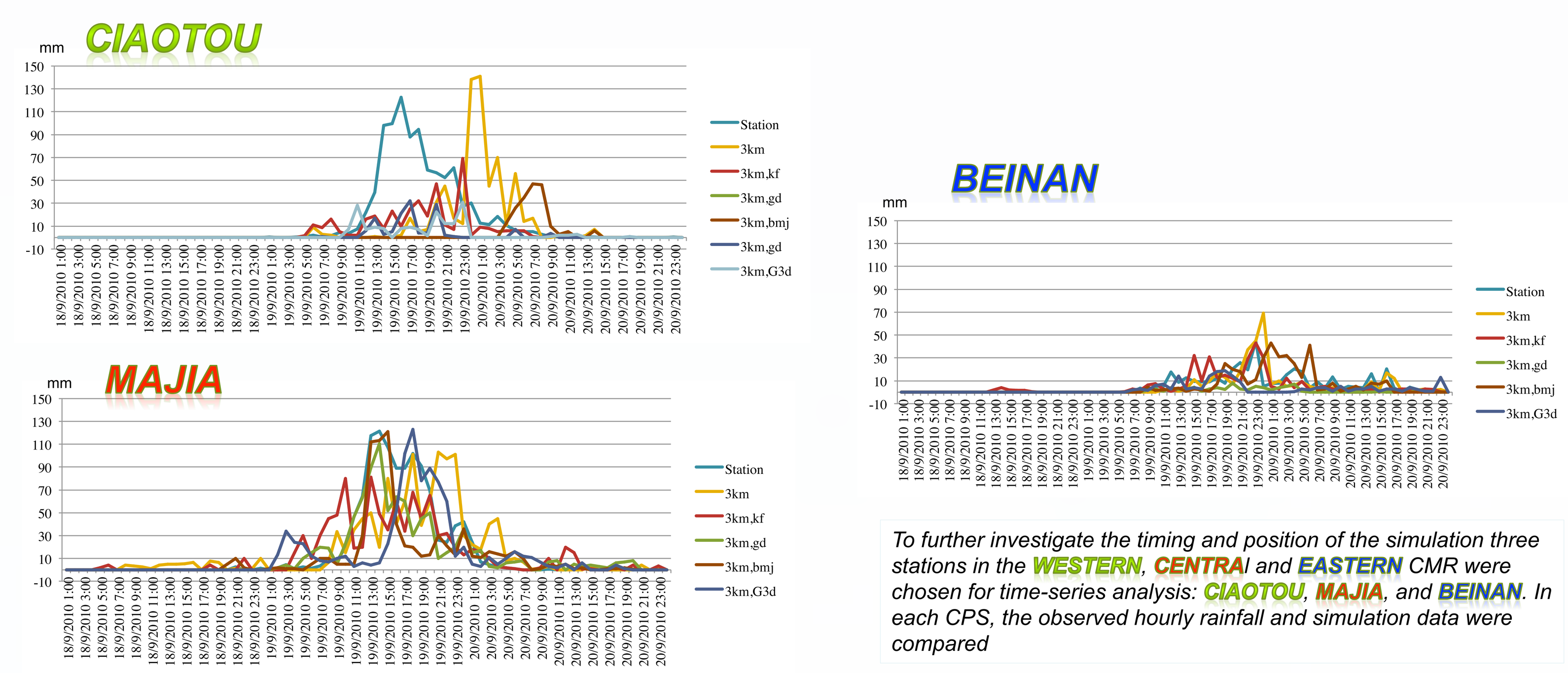
CT (km)	time	06h	12h	18h	24h	30h	36h	42h	48h	54h	60h	66h	72h
	NC	-15	13	-8	9	-37	98	-13	21	29	-20	-46	-56
	KF	-2	8	3	-2	34	100	-8	20	60	52	-34	-90
	GD	-22	-46	-53	-49	-29	-50	15	56	50	74	70	138
	G3D	-31	-33	-27	-32	-36	98	-15	-13	38	48	-20	35
	BMJ	-40	-49	-75	-104	-119	-93	-60	-85	-65	-41	43	44
	NC	-15	13	-8	9	-37	98	-13	21	29	-20	-46	-56

C



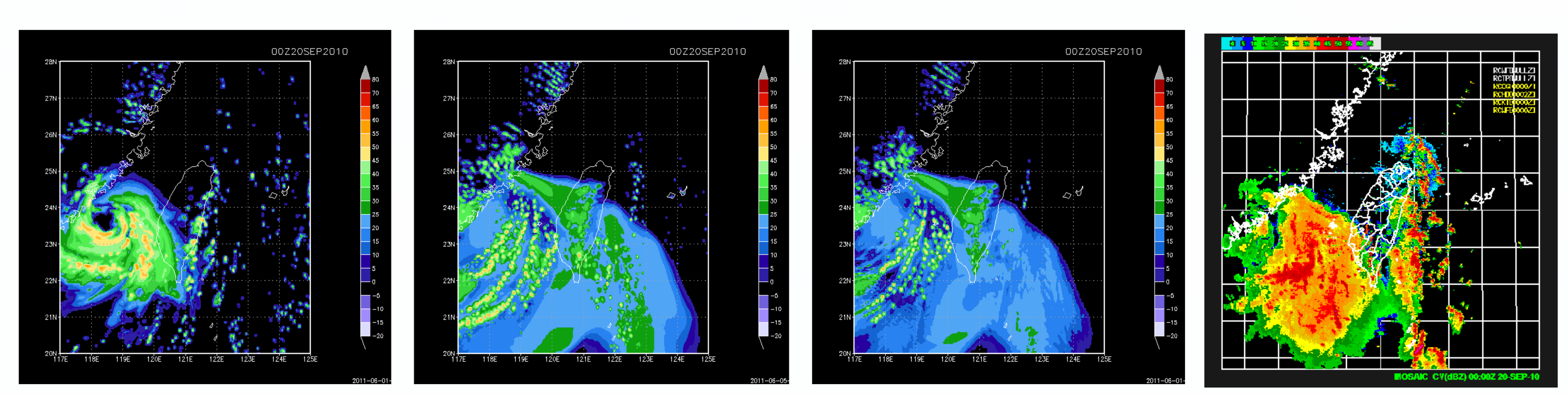
Along Track direction (AT) is positive if the forecast position lies ahead of the observed position along the track. Cross Track direction (CT) is positive if the forecast position lies right of the observed track in the northern hemisphere and left of the observed track in the southern hemisphere.

Time Series Analysis



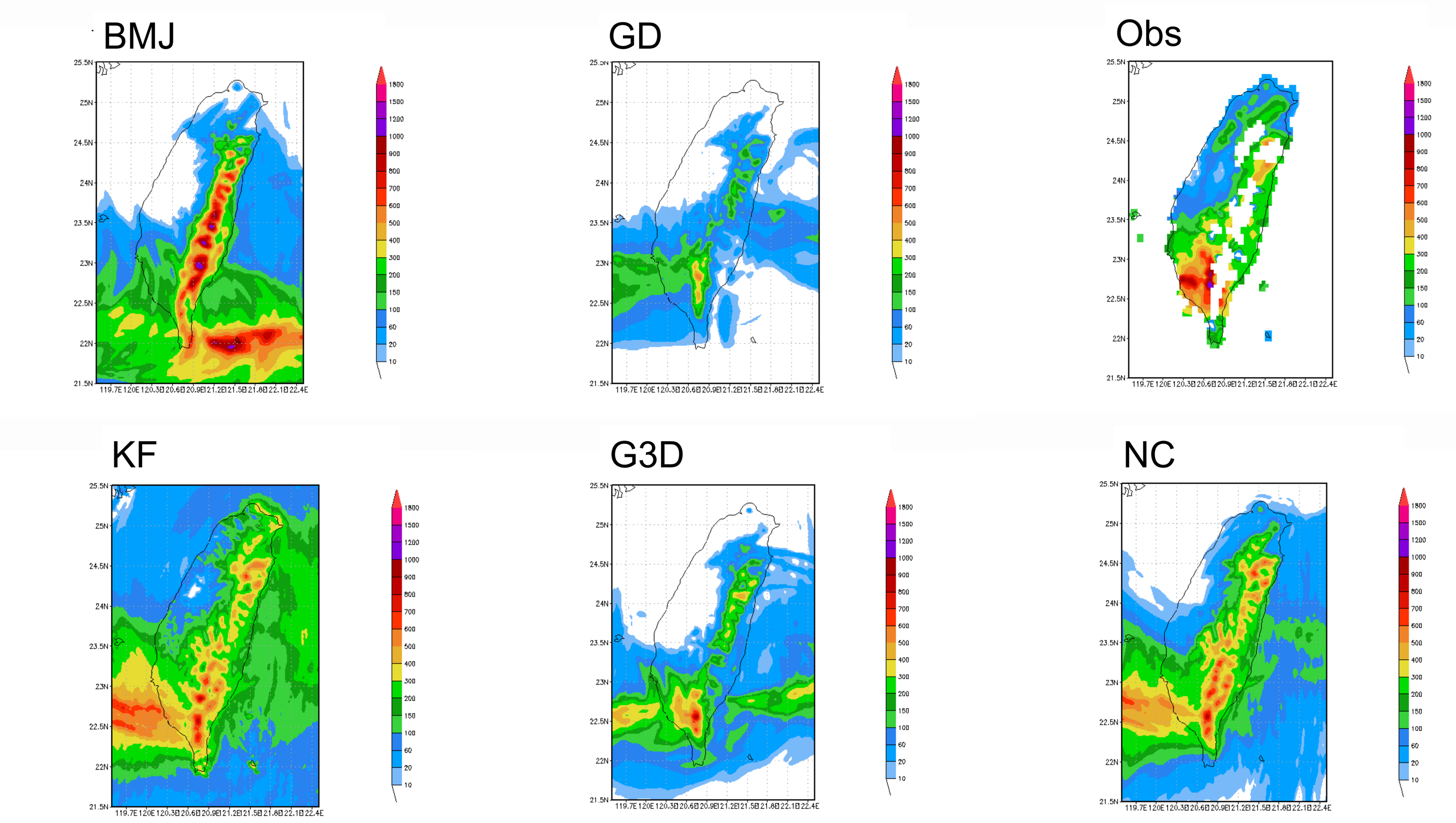
*To further investigate the timing and position of the simulation three stations in the **WESTERN**, **CENTRAL** and **EASTERN** CMR were chosen for time-series analysis: **CIAOTOU**, **MAJIA**, and **BEINAN**. In each CPS, the observed hourly rainfall and simulation data were compared*

Land use and Roughness Length



Maximum radar reflectivity (dBz) of observation data (Obs), no CPS (NC) and Kain-Fritsch scheme (KF) and update LU and ZO for Kain-Fritsch scheme simulation (LU,Zo-KF) at 12 September 18th, 2010

Total Precipitation



Total rainfall (mm) of difference CPSs and observation precipitation from 00UTC September 18 to 00UTC September 21

Conclusions

- For all experiments design, the model is capable of simulating heavy torographic precipitation over southern Taiwan.
- However, with a better track and circulation forecast, Kain-Fritsch scheme simulates the high-reflectivity band associated with the convergence zone. Especially after TC pass through CMRs and go to the SW of Taiwan.
- By updating Land Use and Roughness Length inland wind field result is improve. Leading to better local convection and precipitation.

Future Directions

- In the future, running more TCs are necessary, to further investigate the effect of CPSs in sub-grid scale.
- In my opinion, with longer data set classifying typhoon case by intensity or other indexes can help to get better analyzing of CPSs effect.

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Literature Cited

(1) Cheng, F.Y. Y.C. Hsu, P. L.Lin, and T. H. Lin, Investigation of the Effects of Different Land Use and Land Cover Patterns on Mesoscale Meteorological

(2) Chiao, S. and Y. L. Lin, Numerical modeling of an orographically enhanced precipitation event associated with Tropical Storm Rachel over Taiwan. *Weather Forecast.*, **18**, 325-344, 2003.

(3) Lee, Chia-Ying, Shuyi S. Chen, Stable Boundary Layer and Its Impact on Tropical Cyclone Structure in a Coupled Atmosphere–Ocean Model. *Mon. Wea. Rev.*, **142**, 1927–1944, 2014.

(4) Wu, C.-C., and Y. Kurihara, A numerical study of the feedback mechanisms of hurricane–environment interaction on hurricane movement from the potential