Impact of WRF-3DVAR for heavy snowfall simulations over the region of 2018 Pyeongchang Olympic and Paralympic Winter Games

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❖ Introduction

- KISTI is participating in International Collaborative Experiments for Pyeongchang 2018 Olympic and Paralympic winter games (ICE-POP 2018) project. This project is supported by World Meteorological Organization (WMO) World Weather Research Program (WWRP) and allows us to better understand winter storm and snowfall over the mountainous area (around Pyeongchang in South Korea).
- In this study we examine the impact of 3DVAR on a high-resolution WRF simulation for the heavy snowfall event occurred over the Korean Peninsula on 13 December 2016.

❖ Case overview – 2016 heavy snowfall

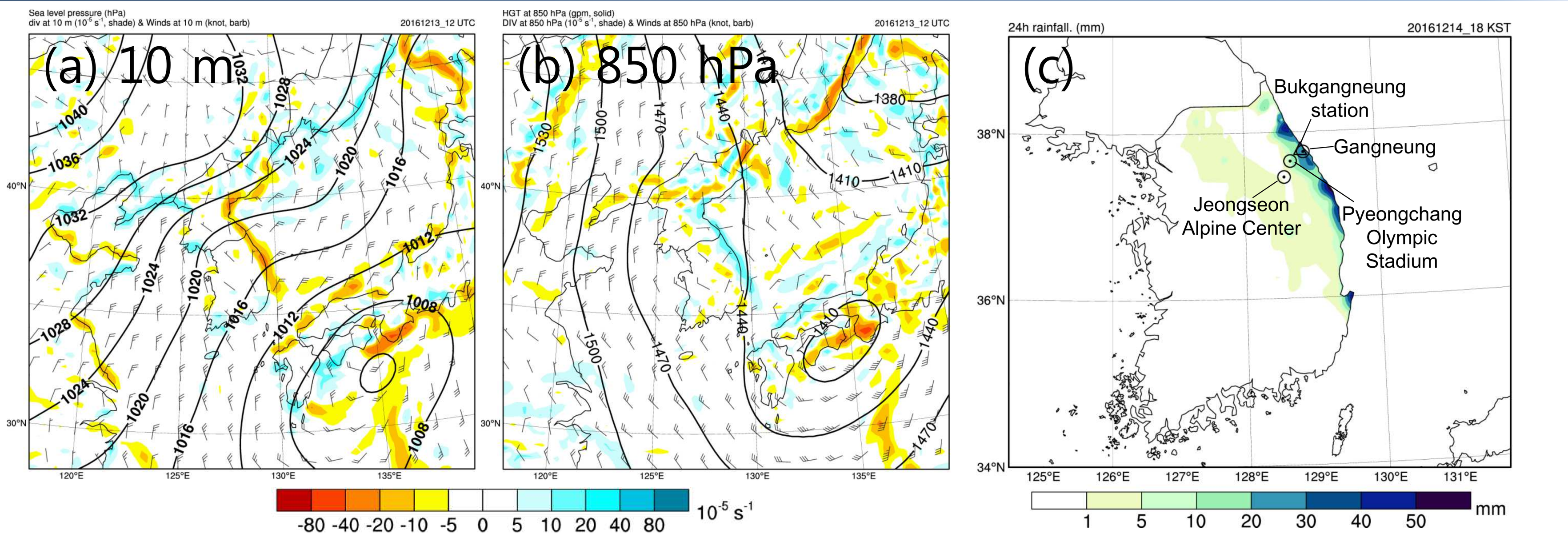

Fig. 1. Divergence (shade, 10^{-5} s^{-1}) and wind fields (barbs, knot) from NCEP FNL data at (a) 10-m and (b) 850 hPa level for 12 UTC 13 December 2016, and (c) 1-day accumulated precipitation observed by automatic weather stations (AWSs) from 09 UTC 13 December 2016. Solid lines in (a) and (b) indicate sea-level pressure (hPa) and geopotential height (gpm), respectively.

- North-westerly winds enhanced between the Siberian High and north-eastward propagating synoptic Low.
- Strong surface convergence line was maintained along the Taebaek mountain range (in the east of the Korean Peninsula)
- The vertical scale of the snow storms were limited below 850 hPa.
- Large accumulated precipitation occurred over the windward slope of the mountain range
- Weak snowfall was also found over the inland of the Korean Peninsula in the NNW-SSE direction.

❖ Data assimilation system

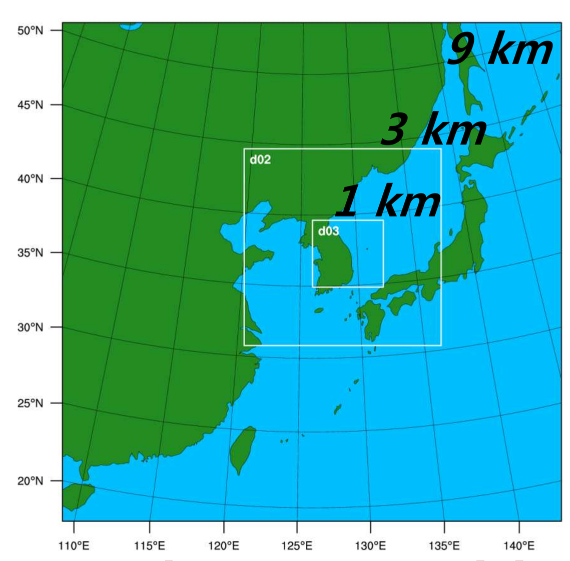

Fig. 2. The experimental domains

Table 1. Configurations for numerical simulations.

WRFV3	d01	d02	d03
△x	9 km	3 km	1 km
H. Grids	424×424	502×502	541×511
V. Levels		41	
MP		WDM6	
CP	Kain-Fritsch	noCP	noCP
PBL		YSU	
LW & SW		RRTMG	
LSM		Noah	
Period		00 UTC 13 – 06 UTC 14 December 2016	

Table. 2. Description of WRF-3DVAR settings

Period	00 UTC 10 – 06 UTC 14 December 2016
OBS data	NCEP PrepBUFR
BEC	CV5 background error covariance with WRF forecasts during 2015 winter season
BC update	GFS forecasts from 00 UTC 10 December 2016

- WRF-3DVAR is applied to domain 1 only and the high-resolution simulation is conducted using 1-way nesting technique.

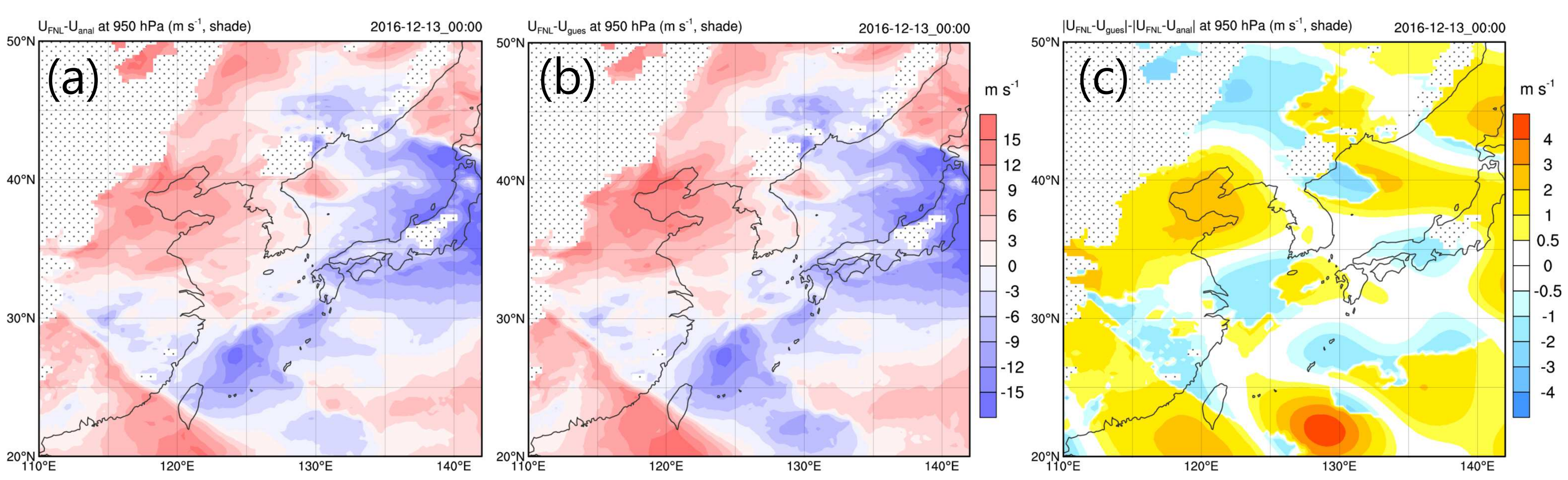

Fig. 3. (a) Analysis and (b) background errors from the NCEP FNL data for zonal wind component (m s^{-1}) at 950 hPa and (c) error reduction due to 3DVAR.

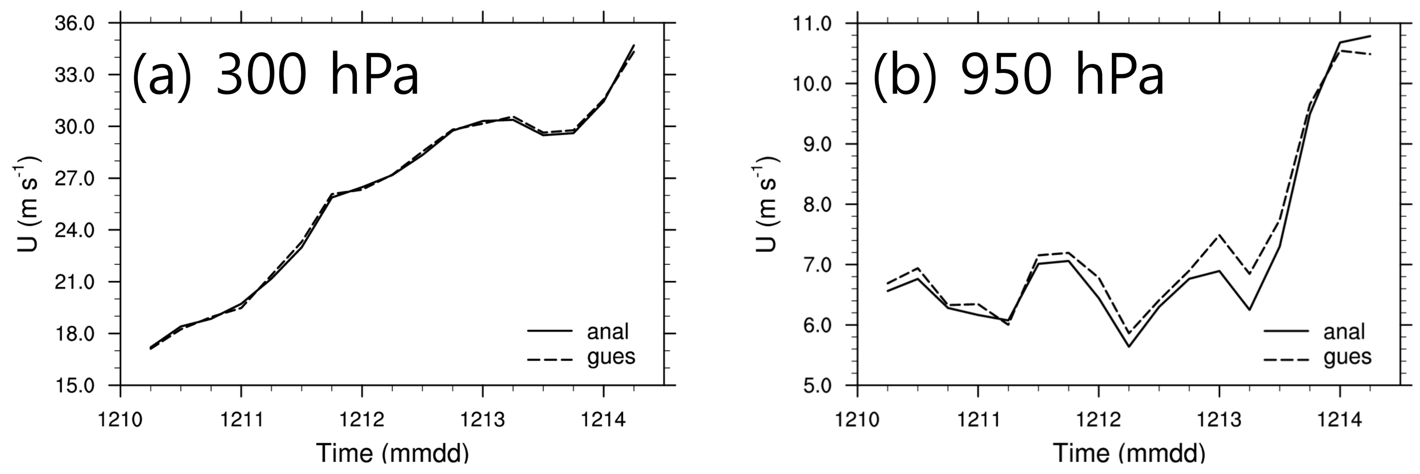

Fig. 4. Time series of analysis (solid line) and background (dashed line) RMSE from the NCEP FNL data for zonal wind component at (a) 300 hPa and (b) 950 hPa.

Table. 3. Summary of averaged RMSE for analysis variables over the period of 00 UTC 13 – 06 UTC 14 December 2016.

Variable		$RMSE_{anal}$	$RMSE_{gues}$	Error Reduction (%)
U (m s^{-1})	300 hPa	30.99	31.01	0.06
	500 hPa	20.81	20.93	0.54
	950 hPa	8.57	8.79	**2.57**
V (m s^{-1})	300 hPa	26.57	26.38	-0.72
	500 hPa	19.11	19.10	-0.02
	950 hPa	12.09	12.61	**4.14**
T (K)	300 hPa	7.35	7.26	-1.31
	500 hPa	12.84	12.85	0.05
	950 hPa	12.08	12.07	-0.08
Psfc (hPa)		50.70	50.59	-0.22

- As shown in Figs. 3-4, and Table 3, 3DVAR gives positive impact on the low-level wind fields.
- However, the improvement is insignificant at middle- and upper troposphere.
- Impact of 3DVAR on temperature and surface pressure is a little negative.

❖ High resolution forecast

Table 4. Summary of the numerical experiments.

Name	Description
CNTL	Downscaling from d01 to d03 (IC/BC for d01 was provided from GFS forecast.)
DA	Downscaling from 3DVAR analysis of d01 to d03

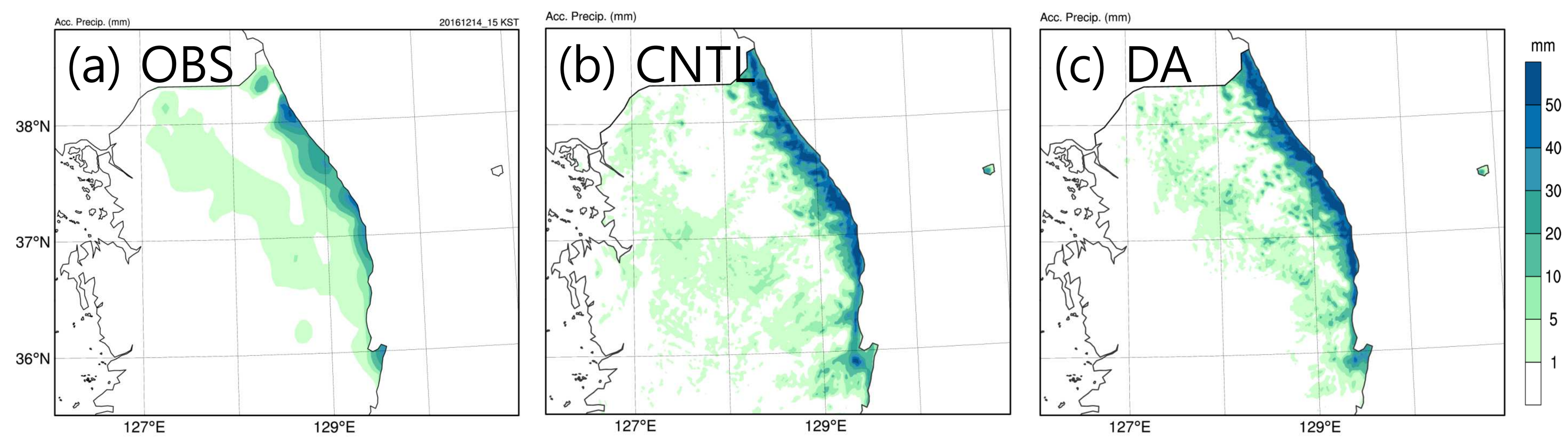

Fig. 5. One-day accumulated precipitation from (a) AWSs, (b) CNTL, and (c) DA experiments during 06 UTC 13 – 06 UTC 14 December 2016.

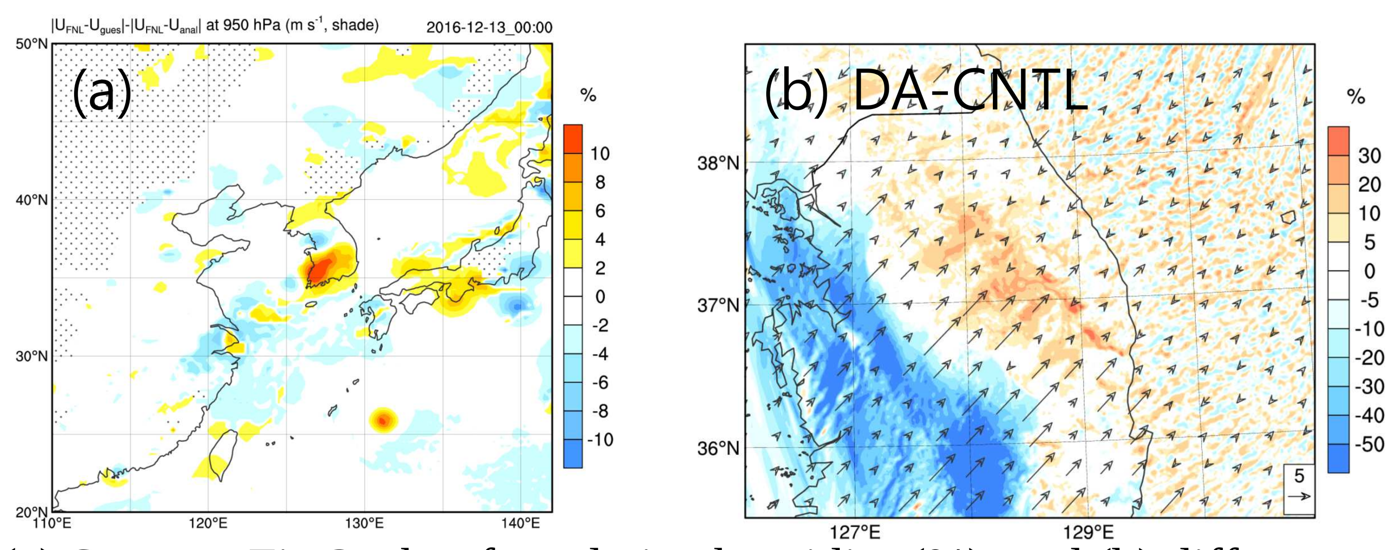

Fig. 6. (a) Same as Fig 3c, but for relative humidity (%), and (b) difference of relative humidity (shade, %) and horizontal winds (vector, m s^{-1}) between DA and CNTL experiments at z=5 (about 0.5 km) for 00 UTC 14 December 2016.

- In both experiments, the heavy snowfall over the windward slope of the Taebaek mountain range is well captured because of the orographic effect.
- In DA experiment, the weak snowfall over the inland of the Korean Peninsula is considerably well simulated than that of CNTL due to the modification of initial low-level wind and moisture fields.

❖ Summary & Future plan

- Data assimilation improves the predictability of high-resolution forecast for heavy snowfall over the Korean Peninsula.
- The improvement of snowfall prediction is induced by low-level wind and moisture analysis fields.
- To assess the sensitivity of different data assimilation techniques, we have performed WRF-LETKF system (Miyoshi and Kunii, 2012) and the results are under investigation.

❖ References

Miyoshi, T and M. Kunii, 2012: The Local Ensemble Transform Kalman Filter with the Weather Research and Forecasting Model: Experiments with Real Observations. *Pure Appl. Geophys.*, **169**, 321-333, doi:10.1007/s00024-011-0373-4

Barker, D., and Authors, 2012: The Weather Research and Forecasting Model's Community Variational/Ensemble Data Assimilation System: WRFDA. *Bull. Amer. Meteor. Soc.*, **93**, 831-843, doi:10.1175/BAMS-D-11-00167.1

❖ Acknowledgment

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