Sensitivity test and validation of Polar WRF at the Antarctic Peninsula during an austral winter

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Introduction

As most of the surface in polar regions is covered with snow and ice, surface characteristics such as albedo, surface temperature, and roughness are very different from those in low to mid-latitudes. Absorbed solar energy is very small so turbulent mixing is limited compared to lower latitudes. In geographical sense, Antarctica is covered with massive ice sheet and surrounded by cold ocean, which makes the Antarctica different from the Arctic. And the circumpolar trough around Antarctica is one of the most active cyclonic regimes on Earth. More than half of the extra-tropical cyclonic systems in the Southern Hemisphere form in the circumpolar trough around. Thus, numerical models reflecting the features of Antarctica are necessary for accurate weather forecasting in the Antarctica. In this study, we used a regional numerical model (Polar WRF V3.3.1) reflecting characteristic of polar regions to simulate weather over the Antarctic peninsula where the Korean King Sejong Station (62˚13'S, 58˚47' W) is located. We conducted sensitivity experiments of physical processes. And, to evaluate the simulated results, we used the surface meteorological observations of King Sejong Station.

Model experiment design

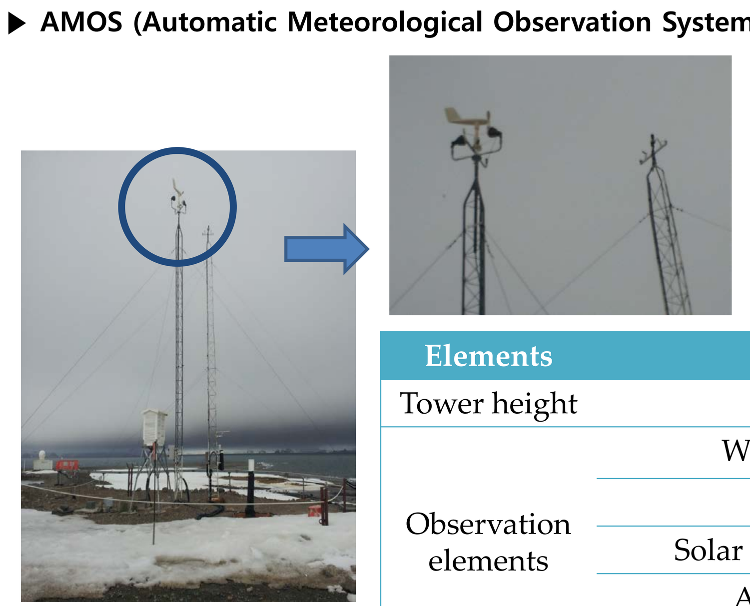
Model & Observation data

❖ WRF vs Polar WRF

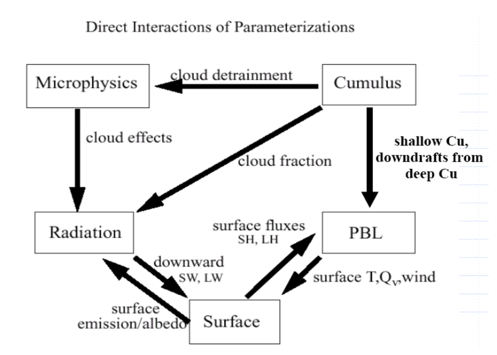
WRF is high resolution regional-scale model.
Polar-WRF is modified from WRF for the Polar regions.
1) Fractional sea ice (ice and water within the same grid box).
2) Microphysics considering 2-moment for both ice and liquid.
3) Noah LSM modifications
- Heat transfer for snow and ice based upon Antarctic snow firn.
- Surface energy balance emissivity, snow/ice albedo skin temperature equation.

❖ Observation data

▶ AMOS (Automatic Meteorological Observation System)



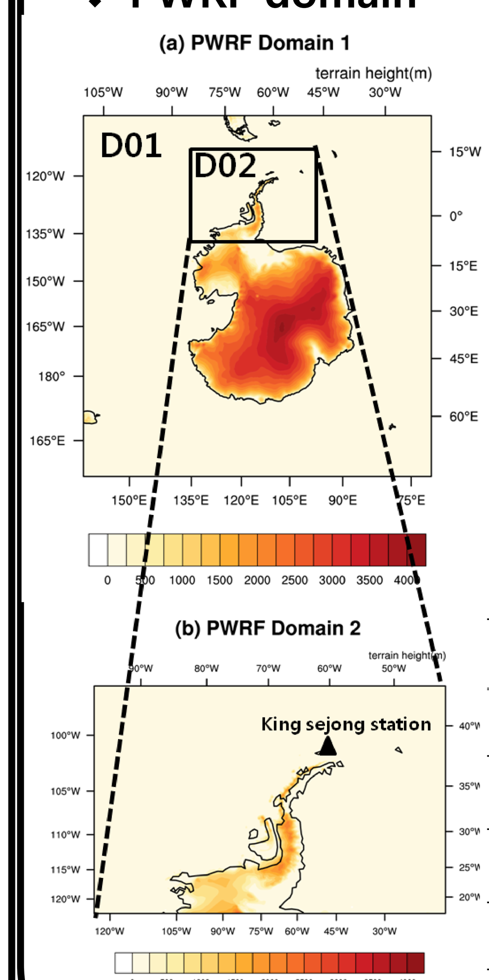
▶ WRF (Weather Research and Forecasting model)



Elements	AMOS
Tower height	10m
Observation elements	Wind speed/direction (ms⁻¹/º)
	Pressure (hPa)
	Solar radiation/Net radiation (Wm^{-2})
	Air temperature/RH(℃/ %)
	Precipitation (mm)

Model experiment

❖ PWRF domain



❖ Design for PWRF model V 3.3.1 experiments.

	Domain 1	Domain 2
Horizontal grid	331 x 315	288 x 381
Horizontal resolution	27 km	9 km
Nested grid	2-way nested	
Vertical resolution	44 Layers	
Initial, Lateral boundary data	ERA Interim reanalysis data (6-hour intervals with a spatial resolution of 1.5°×1.5°)	
Time period	2011. 06. 20. 0000 UTC ~ 2011. 07. 01. 0000 UTC	

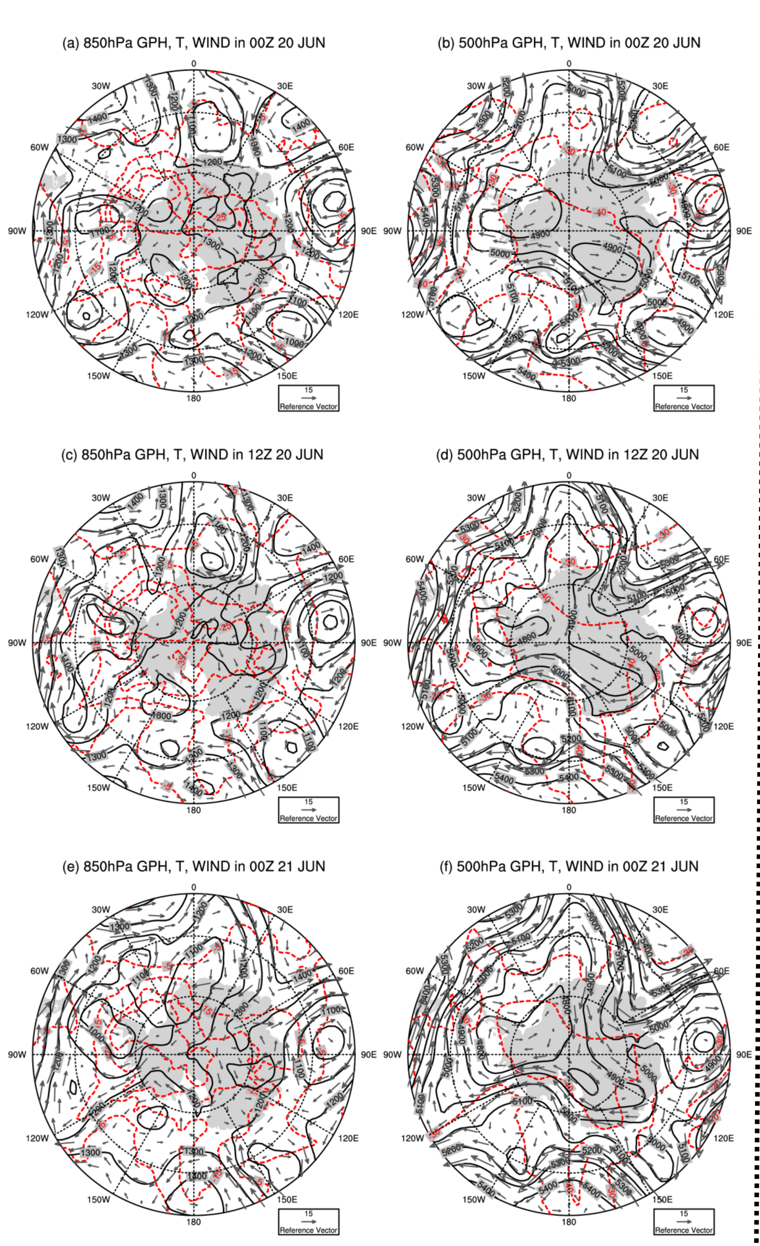
❖ Physics schemes description of PWRF model experiments.

	CTR	EXP1	EXP2	EXP3
Microphysics	WSM 6 (WRF Single-Moment 6-class)			
Long Radiation	RRTMG	RRTM	RRTMG	RRTMG
Short Radiation	RRTMG	Dudhia	RRTMG	RRTMG
PBL	MYNN	MYNN	YSU	MYNN
Surface layer	MM5 similarity	MM5 similarity	MM5 similarity	MYNN

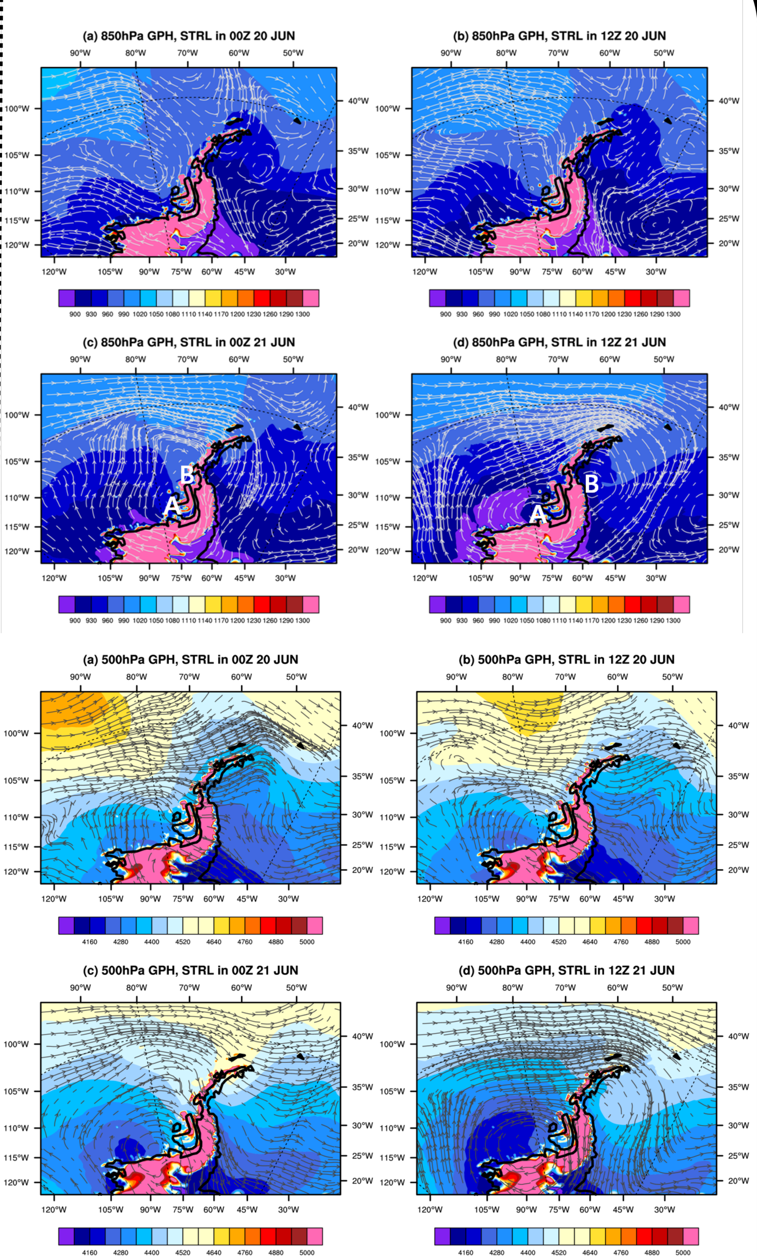
We simulated sensitivity experiments during the austral winter of 2011 using the Polar WRF v3.3.1. Spatial domains are 27km, 9km, respectively, for the two 2-way nested domains. Initial, boundary conditions were provided at 6-hour intervals with a spatial resolution of 1.5°×1.5° ERA Interim data. The control experiment (CTR) in the sensitivity experiments was set for long wave radiation scheme, short wave radiation scheme, planetary boundary layer (PBL) scheme, and surface layer schemes. Experiment 1 (EXP1) was changed to RRTM, long wave radiation scheme and Dudhia, short wave radiation scheme of CTR. Experiment 2 (EXP2) and Experiment 3 (EXP3) were shuffled to YSU, PBL scheme and MYNN, surface layer scheme, respectively.

Results: Synoptic background & Model sensitivity test

Synoptic background



❖ 850 hPa (a, c, and e) and 500 hPa (b, d, and f) weather charts; geopotential heights (black solid lines; [gpm]), temperature (red dotted lines) and wind vectors.

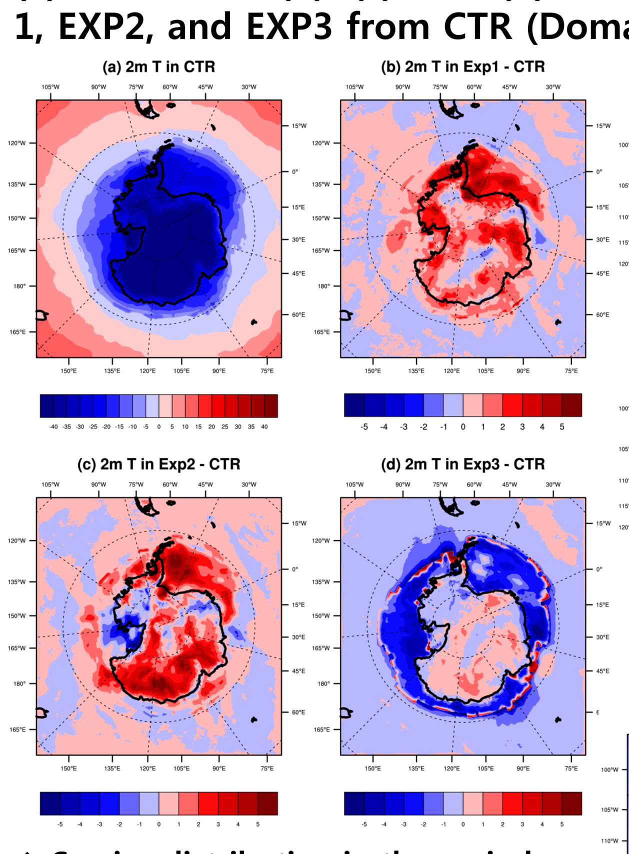


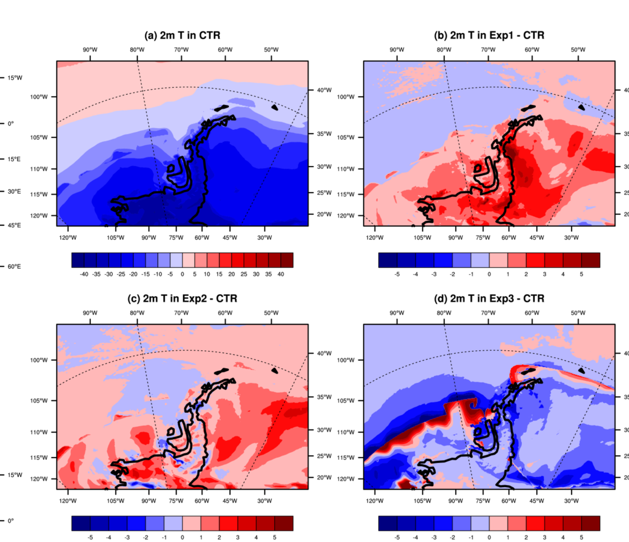
❖ 850 hPa and 500 hPa geopotential height (shaded; [gpm]) and streamline (vector) in the domain 2 of CTR.

More than half of the extra-tropical cyclonic systems in the Southern Hemisphere form in the circumpolar trough around Antarctica. A case of cyclonic system over the Antarctic Peninsula was investigated. The low system over the King Sejong station in June 21 0000 UTC is seen to a binary interaction system among 2-3 lows over the Antarctic peninsular and blocking high over the Weddell Sea.

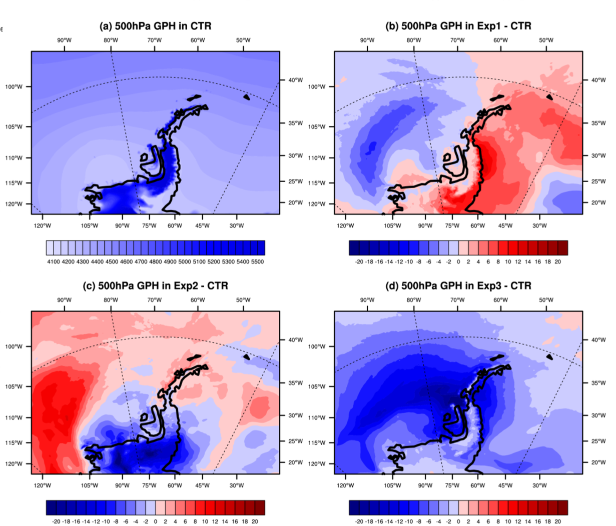
Model sensitivity test

❖ Averaged 2m temperature (℃) for all period in 4 experiments. (a) is CTR and (b), (c), and (d) are respectively difference to EXP 1, EXP2, and EXP3 from CTR (Domain1, Domain2).

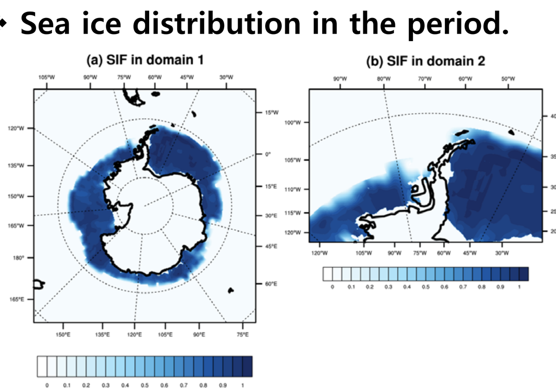




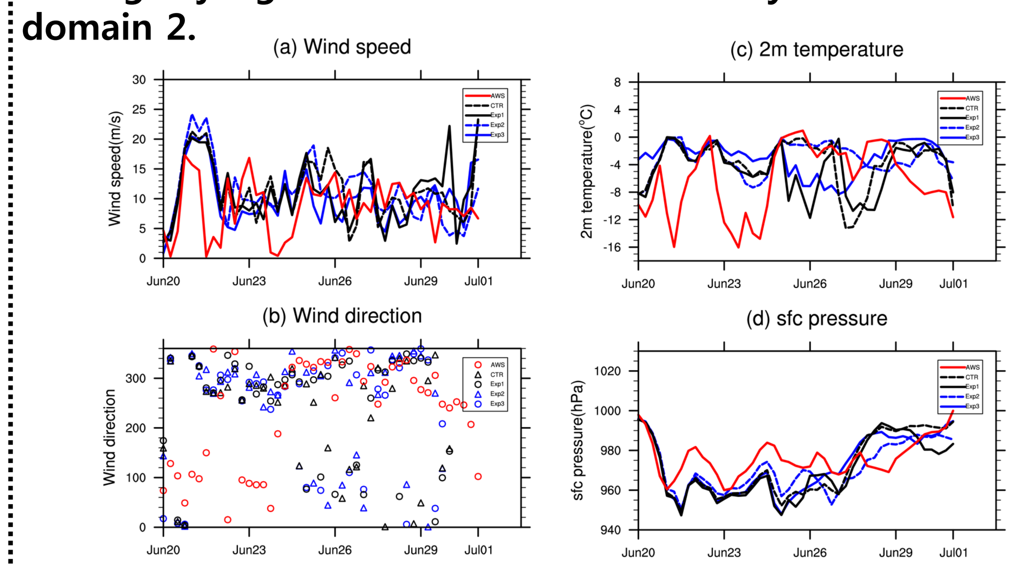
<500 hPa geopotential height (gpm) >



❖ Sea ice distribution in the period.



❖ Time series of the 4 experiments and the AMOS data in King Sejong station from June 20 to July 1 2011 in domain 2.



❖ Correlation, mean bias, rmse of simulated meteorological elements compared to amos data in King sejong station (domain2).

Variables		CTR	Exp1	Exp2	Exp3
Wind speed (m/s)	Correlation	0.23	0.11	0.18	0.10
	Mean bias	2.69	2.41	2.42	1.25
	RMSE	6.50	6.92	6.52	6.12
Surface pressure (hPa)	Correlation	0.64	0.52	0.72	0.62
	Mean bias	-3.97	-6.13	-4.76	-4.24
	RMSE	12.48	13.88	9.65	12.12
2m Temperature (℃)	Correlation	0.15	-0.19	0.43	-0.34
	Mean bias	2.35	1.53	3.00	3.16
	RMSE	6.03	6.66	5.38	6.91

Summary

To test sensitive of physics process in PWRF during a case of cyclones approaching the Antarctic Peninsula region, we conducted simulations of the Polar WRF over the Antarctica including King Sejong Station. Through the ECMWF reanalysis data and PWRF simulations, two or three cyclones located near the Antarctic Peninsula show interaction with each other. While low pressure has stagnated in Antarctica, cyclone is rapidly moving in the vicinity of the Antarctic Peninsula. As the cyclones was blocked by the high pressure near Weddell Sea, pressure gradient increased near King Sejong station.

Though short period modelling in winter, we found distinctive features between the schemes in atmosphere-surface interactions and boundary layer structures. When simulated PWRF results compared to surface meteorological observations of King Sejong Station, correlation of surface pressure is from 0.52 to 0.72, mean bias is from -6.13 to -3.97 as physical scheme. Correlation of 2m temperature is from -0.34 to 0.43, mean bias is from 1.53 to 3.16. And correlation of wind speed is from 0.10 to 0.23, mean bias is from 1.25 to 2.69. According to this case, EXP2 physical scheme description is well simulated overall.

References

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Acknowledgements

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