

「국가 지구환경시스템 및 대기과학 분야 연구활성화」를 위한
2015년도 슈퍼컴퓨터 공동활용 지원 성과 보고

【 2016. 7. 8. (금) / 국가기상슈퍼컴퓨터센터 】

□ **배경 및 목적**

- (배경) 「국가 초고성능컴퓨터 활용 및 육성에 관한 법률」에 따른 지구환경시스템 및 대기과학 분야 슈퍼컴퓨터 공동활용 활성화 및 관련분야 전문인력 양성

< 관련 법령 >

법 제9조 (분야별) 국가초고성능 컴퓨터센터 지정
 법 제12조 전문인력의 양성
 법 제17조 초고성능컴퓨팅자원의 공동활용 활성화

- (목적) 기상청 슈퍼컴퓨터 자원 공동활용을 통한 국가 대기과학 분야 연구 활성화 및 연구 성과 정리

□ **추진경과**

- 슈퍼컴 3호기 해남 자원 한국형수치예보모델개발사업단 지원(11.6)
- 슈퍼컴 3호기 해빛 공동활용 환경 구축 및 지원(12.1)
- 국가 대기과학분야 기상청 슈퍼컴 공동활용 지원 계획 수립(12.6)
- 공동활용 시스템 I/O성능 보강 및 외부 FTP 서비스 제공(13.3)
 - ※ 공동활용 기관 수 : '12년(8개/80명)→13년(10개/91명)→14년(12개/108명)→15년(13개/125명)
- 공동활용 시스템 성능보강 및 사용자 지원 강화(3호기→4호기 초기분)(16.5)

□ **공동활용 시스템 지원 현황**

- 공동활용 시스템 현황(2015년, 3호기 초기분)

구분	해남	해빛
기종	XE6	XT5
코어 수	2,112 개	3,392 개
이론성능	17.7 TF	36.6 TF
용도	한국형수치예보모델 개발	지구/대기과학분야 연구
사용기관	한수예사업단	대학 등 12개 기관

○ 공동활용 사용자 현황(2015년 12월 기준)

- 슈퍼컴퓨터 3호기 초기분(해남, 해빛) 사용자(13개 기관 125명)

시스템	기관	인원	합계
해남(Haenam)	한국형수치예보모델개발사업단	50	50명
해빛(Haebit)	APEC 기후센터	10	75명
	차세대도시농림융합기상사업단	20	
	이화여자대학교	1	
	경북대학교	4	
	연세대학교	2	
	부경대학교	5	
	공주대학교	3	
	부산대학교	13	
	서울대학교	2	
	울산과학기술대학교	3	
	전북대학교	2	
수문기상협력센터	10		
총계(기관수/인원수)		13개 기관	125명

□ 주요 연구 실적

기관	연구내용	연구실적
한 수 예	한국형수치예보모델 개발	국내외 논문 7 학술 발표 40 기타 6 (첨부 참고) 총 53건
APEC 기후센터	기후모델링 및 앙상블 기후예측을 위한 모델구동	
차세대도시농림융합기상사업단	고해상도 도시미기상 모델개발 및 실험 WRF 모델을 이용한 우리나라 집중호우 모의 결과 연구	
이화여자대학교	지역별 기후자료분석, 장기에보 기초자료 생산 및 분석	
경북대학교	레이더/위성자료를 활용한 자료동화 기법 연구	
연세대학교	앙상블 기법을 이용한 토양 수분 섭동 민감도 실험	
부경대학교	계절 및 해양 예측 분석, 대기환경 및 오염확산 분석	
공주대학교	대기 오염물질 확산 및 배출량 시뮬레이션 분석	
부산대학교	중규모 기상 및 대기화학 모델링 동북아시아 지역 미세먼지 농도장 모사 및 연구	
서울대학교	구름미세물리과정이 접합된 고해상도 전지구모형 개발	
UNIST	전지구 계절 예측시스템 지면 초기화 기법 개선 연구	
전북대학교	대기 기후-화학물질 및 해양 생지화학 연구	
수문기상협력센터	수치예보 결과자료를 강우-유출모형 입력자료로 활용	

□ 2015년 주요 지원 내용

○ 전문인력 양성

- 포트란 프로그래밍 초급교육 실시(4월)
 - 한국형수치모델개발사업단, APCC 등 4개 기관 33명 수료
- 슈퍼컴퓨터 사용자 워크숍 개최(8월)
 - KBS, 국립해양조사원, APCC 등 21개 기관 101명 참가
- 슈퍼컴퓨터 공동활용 사용자 교육 실시(10월)
 - 한수예, 국립해양조사원, WISE 사업단 등 10개 기관 25명 수료
- 병렬 프로그래밍 초급교육 실시(12월)
 - APCC, 서울대 등 3개 기관 26명 수료



포트란 프로그래밍 교육



슈퍼컴퓨터 사용자 워크숍



슈퍼컴퓨터 공동활용 사용자 교육



병렬 프로그래밍 교육

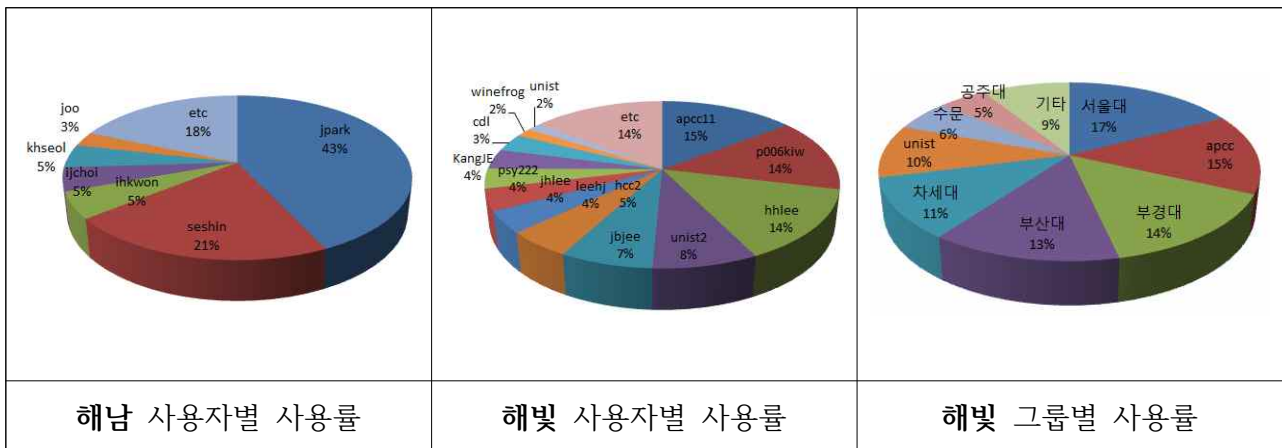
○ 공동활용 사용자 기술지원(8건)

- WRF3.6, WPS3.6 설치 및 NCL 설치(수문기상협력센터)
- 모델 개발을 위한 소프트웨어 설치(7종)(한수예)
- python paramiko module 설치(한수예)

- WRF3.6.1 및 WPSV3.6.1 설치(수문기상협력센터)
- GSM 포팅(부경대)
- netCDF4/1.1.9 설치(한수예)
- GSM 전처리과정 및 유틸리티 디버깅(부경대)
- NCL, CDO 최신버전 라이브러리 설치(부경대)

□ 공동활용 시스템 활용도

- 사용자별 사용률 및 그룹별 사용률



□ 향후계획

- 2016년도 공동활용 사용자 교육 개최(7월)
- 2016년도 슈퍼컴퓨터 사용자 워크숍 개최(8월)
- 2016년도 병렬프로그래밍 교육 개최(10월)
- 2016년도 슈퍼컴퓨터 공동활용 사용자 연구 실적 조사 실시(2017년 상반기)

□ 사용자 의견

- 모델결과 및 입력자료의 원활한 전송을 원함
- 기상청에서 사용하는 다양한 관측자료를 시스템에서 쉽게 사용 원함

첨 부 주요 연구실적

○ 국내 학술지 논문 게재(4건)

『 대기지 』

- 김세현, 김현미, 계준경, 이승우, 2015: 기상청 고해상도 국지 앙상블 예측 시스템 구축 및 성능 검증. 대기지, 25(1), 67-83.
- 조영순, 강지순, 권하택, 2015: KIAPS 앙상블 자료동화 시스템을 이용한 GPS 차폐자료 연직 국지화 규모 최적화. 대기지, 25(3), 529-541.
- 이재형, 장임석, 이상현, 2015: WRF-Chem 모형을 이용한 한반도 대기질 모의: 화학 초기 및 측면 경계 조건의 영향. 대기지, 25(4), 639-657.

『 한국지구과학회지 』

- 임아영, 노준우, 지준범, 최영진, 2015. 수도권 지역의 고해상도 WRF 모델 기반 연직 해상도 및 경계층 모수화 방안 민감도 실험. 한국지구과학회지, 36, 553-566.

<p>Development and Evaluation of the High Resolution Limited Area Ensemble Prediction System in the Korea Meteorological Administration</p> <p>Suhng Eun Lee, Seung-Min Kim[*], Jaehyung Lee[*], and Seung-Yong Lee[*]</p> <p>[*]Department of Atmospheric Science, Seoul National University, Seoul, Korea</p> <p>[*]Korea Meteorological Administration, Seoul, Korea</p> <p>(Manuscript received 14 November 2014, in final form 10 December 2014, accepted 22 January 2015)</p> <p>Abstract. Prediction, Re-forecast, and intensity of precipitation still remains a main issue in numerical weather prediction (NWP). Resolution is a key important component of weather forecast in NWP. Compared with a lower resolution model, higher resolution model can predict small scale precipitation and precipitation intensity more precisely. In addition, an ensemble technique can be used to improve the precipitation forecast because it can capture uncertainties in meteorological forecast. WRF-Ens has a higher resolution model and ensemble technique to capture inherent uncertainties of convective scale model better and to improve forecast. In this study we used an ensemble prediction system for the convection-scale (i.e., high-resolution operational limited model) (HRES) in Korea Meteorological Administration (KMA) to develop and evaluate the ensemble forecast during August 2012. The model domain covers the Korean peninsula over the Korean Peninsula. The high resolution limited area ensemble prediction system developed here will aid in predicting precipitation, wind, and temperature at a vertical as well as a horizontal scale of 100 and 50 km. To evaluate the quality of simulation of horizontal resolution and ensemble forecast to see a difference, the system was run with three different horizontal resolution, 10, 50, and 100 km, and ensemble members (i.e., 20, and 100, and 500 members) of the system. The precipitation forecast for one-hour interval using the daily model output is used for the forecast. RMSE, Correlation (COR), and skill score (SS) were used. The RMSE showed an obvious increase in the intensity of precipitation and the SS was effective in verifying the precipitation forecast in the high-resolution limited area ensemble prediction system in KMA.</p> <p>Key words: The high resolution limited area ensemble prediction system of the Korea Meteorological Administration, ensemble forecast, precipitation forecast, forecast, high resolution model.</p> <p>Corresponding author address: Dr. Seung-Min Kim, Department of Atmospheric Science, Seoul National University, 51-52 Shinrim, Seoul 151-747, Korea. E-mail: seungmin@plaza.snu.ac.kr</p> <p>© 2015 Korean Meteorological Society 47</p>	<p>기상청 고해상도 국지 앙상블 예측 시스템 구축 및 성능 검증</p> <p>김세현[*], 김현미[*], 계준경[*], 이승우[*]</p> <p>[*]국립기상연구소, 대기과학국, 대기과학 연구소, 기상청 수리모델연구소 (당일, 2014년 11월 14일; 수정판, 2015년 12월 10일; 게재확정일, 2015년 1월 22일)</p> <p>Development and Evaluation of the High Resolution Limited Area Ensemble Prediction System in the Korea Meteorological Administration</p> <p>Suhng Eun Lee, Seung-Min Kim[*], Jaehyung Lee[*], and Seung-Yong Lee[*]</p> <p>[*]Department of Atmospheric Science, Seoul National University, Seoul, Korea</p> <p>[*]Korea Meteorological Administration, Seoul, Korea</p> <p>(Manuscript received 14 November 2014, in final form 10 December 2014, accepted 22 January 2015)</p> <p>Abstract. Prediction, Re-forecast, and intensity of precipitation still remains a main issue in numerical weather prediction (NWP). Resolution is a key important component of weather forecast in NWP. Compared with a lower resolution model, higher resolution model can predict small scale precipitation and precipitation intensity more precisely. In addition, an ensemble technique can be used to improve the precipitation forecast because it can capture uncertainties in meteorological forecast. WRF-Ens has a higher resolution model and ensemble technique to capture inherent uncertainties of convective scale model better and to improve forecast. In this study we used an ensemble prediction system for the convection-scale (i.e., high-resolution operational limited model) (HRES) in Korea Meteorological Administration (KMA) to develop and evaluate the ensemble forecast during August 2012. The model domain covers the Korean peninsula over the Korean Peninsula. The high resolution limited area ensemble prediction system developed here will aid in predicting precipitation, wind, and temperature at a vertical as well as a horizontal scale of 100 and 50 km. To evaluate the quality of simulation of horizontal resolution and ensemble forecast to see a difference, the system was run with three different horizontal resolution, 10, 50, and 100 km, and ensemble members (i.e., 20, and 100, and 500 members) of the system. The precipitation forecast for one-hour interval using the daily model output is used for the forecast. RMSE, Correlation (COR), and skill score (SS) were used. The RMSE showed an obvious increase in the intensity of precipitation and the SS was effective in verifying the precipitation forecast in the high-resolution limited area ensemble prediction system in KMA.</p> <p>Key words: The high resolution limited area ensemble prediction system of the Korea Meteorological Administration, ensemble forecast, precipitation forecast, forecast, high resolution model.</p> <p>Corresponding author address: Dr. Seung-Min Kim, Department of Atmospheric Science, Seoul National University, 51-52 Shinrim, Seoul 151-747, Korea. E-mail: seungmin@plaza.snu.ac.kr</p> <p>© 2015 Korean Meteorological Society 47</p>	<p>Optimization of the Vertical Localization Scale for GPS-RO Data Assimilation within KIAPS-LETKF System</p> <p>Yongwon Joo[*], Jihoon Kim[*], and Frank Keim[*]</p> <p>[*]Korea Institute of Atmospheric Prediction System, Seoul, Korea</p> <p>[*]Korea Institute of Space Technology and Aeronautics, Taejeon, Korea</p> <p>[*]Korea Polar Research Institute, Incheon, Korea</p> <p>(Manuscript received 22 April 2015, in final form 10 August 2015, accepted 11 August 2015)</p> <p>Abstract. Korea Institute of Atmospheric Prediction System (KIAPS) has been developing a global reanalysis prediction model and data assimilation system. In the operational LETKF (Local Ensemble Transform Kalman Filter; Han et al., 2011) data assimilation system, the National Center for Environmental Prediction Center for Atmospheric Research Community Atmospheric Model with Special Transport Operational Core, Dvoros et al., 2012) has been used as the grid. However, as the use and number of KIAPS Integrated Global Observation (IGO) data assimilation systems is increasing, an optimization of the vertical localization scale for GPS-RO data assimilation is required. In this study, we have conducted a sensitivity analysis of the vertical localization scale for GPS-RO data assimilation. The data assimilation system was run with different vertical localization scales (i.e., 100, 50, and 20 km) to see the effect of the vertical localization scale on the forecast accuracy. The results show that the forecast accuracy is improved by the use of the smaller vertical localization scale for GPS-RO data assimilation. However, with a smaller vertical localization scale, the localization scale is bounded to the nearest grid. Therefore, with a smaller vertical localization scale, we have conducted experiments to search for the best vertical localization scale in the GPS-RO data assimilation system. In this study, we found the optimal value of the vertical localization scale for the GPS-RO data assimilation. We also optimized the vertical localization scale for the LETKF system implemented in KMA which is applied to the initial localization of GPS-RO data assimilation data assimilation system. The results show that the forecast accuracy is improved by the use of the smaller vertical localization scale for GPS-RO data assimilation.</p> <p>Key words: GPS-RO, vertical localization scale, GPS-RO, vertical localization scale, GPS-RO</p>	<p>WRF-Chem 모형을 이용한 한반도 대기질 모의: 화학 초기 및 측면 경계 조건의 영향</p> <p>이재형[*], 장임석[*], 이상현[*]</p> <p>[*]국립기상연구소, 대기과학국, 대기과학 연구소, 기상청 수리모델연구소 (당일, 2014년 11월 14일; 수정판, 2015년 12월 10일; 게재확정일, 2015년 1월 22일)</p> <p>Simulation of Air Quality Over South Korea Using the WRF-Chem Model: Impacts of Chemical Initial and Lateral Boundary Conditions</p> <p>Jae-Hyung Lee[*], Eun-Sook Chang[*], and Seung-Yong Lee[*]</p> <p>[*]Department of Atmospheric Science, Seoul National University, Gyeonggi, Korea</p> <p>[*]Korea Institute of Environmental Research, Global Environment Research Institute, Incheon, Korea</p> <p>(Manuscript received 30 July 2015, in final form 10 December 2015, accepted 10 December 2015)</p> <p>Abstract. There is an increasing need to improve the air quality over South Korea to protect public health from both ozone and anthropogenic pollutant emissions that are on an increasing trend. Here, we explore the performance of the WRF-Chem (Weather Research and Forecasting/Chemistry) model in simulating near-surface air quality of major Korean cities, and investigate the impacts of initializing chemical initial and lateral boundary conditions (ICL) on the air quality simulation using a chemical transport model. The model domain was configured over the East Asian region, and anthropogenic, natural, marine, and biogenic emissions were specified over the domain. The WRF-Chem model was applied to the domain. ICLs were specified over the domain. The model results were compared with the observed data. The model results show that the WRF-Chem model is able to simulate the air quality over South Korea. However, the model results show that the WRF-Chem model is not able to simulate the air quality over South Korea. Therefore, we have conducted experiments to search for the best ICL conditions for the WRF-Chem model. We also optimized the ICL conditions for the WRF-Chem model. The results show that the forecast accuracy is improved by the use of the smaller ICL conditions for the WRF-Chem model.</p> <p>Key words: WRF-Chem, MSAQRTM, chemical ICBC, vertical localization, South Korea</p>
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○ 국외 학술지 논문 게재(3건)

『 Monthly Weather Review 』


- 송효중, 권인혁, 2015: Spectral Transformation Using a Cubed-Sphere Grid for a Three-Dimensional Variational Data Assimilation System. Mon. Wea. Rev., 2581-2599

『 Journal of Geophysical Research: Atmospheres 』

- 최현주, 홍성유, 2015: An updated subgrid orographic parameterization for global atmospheric forecast models. J. Geophys. Res. Atmos., 120, 12,445-12,457, doi:10.1002/2015JD024230.

『 Atmospheric Measurement Techniques 』

- 권하택, 강지순, 조영순, 강전호, 2015: Implementation of a GPS-RO data processing system for the KIAPS-LETKF data assimilation system. Atmospheric Measurement Techniques, 8, 1259-1273.



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Spectral Transformation Using a Cubed-Sphere Grid for a Three-Dimensional Variational Data Assimilation System

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DOI: <http://dx.doi.org/10.1175/MWR-D-14-00089.1>
Received: 13 March 2014
Final Form: 12 March 2015
Published Online: 9 July 2015



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Journal of Geophysical Research: Atmospheres

RESEARCH ARTICLE

Updated subgrid orographic parameterization for global atmospheric forecast models

*Yun-Geun Cheol and Dong-Yu Hong**
Korea Institute of Atmospheric Prediction Systems, Seoul, South Korea

Abstract A subgrid orographic parameterization (SGP) is updated by including the effects of orographic windward and flow-blocking drag (FBD). The impact of the updated SGP on short-range forecasts is investigated using a global atmospheric forecast model applied to a heavy rainfall event over Korea on 2 January 2010. When the SGP is updated, the orographic drag in the lower troposphere noticeably increases owing to the additional FBD over mountainous regions. The enhanced drag directly weakens the ascending air flow in the low troposphere and indirectly improves the temperature and mass fields over East Asia. In addition, the snowfall concentration over Korea is improved by the reduced heat fluxes from the surface. The forecast improvements are robust regardless of the horizontal resolution of the model between T126 and T510. The parameterization is statistically evaluated based on the skill of the reanalysis forecasts for February 2014. For the reanalysis forecasts, the skill improvement of the wind speed and temperature in the low troposphere are observed globally and for East Asia, while both positive and negative effects appear indirectly in the mid-troposphere. The statistical skill for the precipitation is mostly improved due to the improvements in the synoptic fields. The improvements are also found for seasonal simulation throughout the troposphere and stratosphere during boreal winter.

1. Introduction
The parameterization of the effects of subgrid-scale orography in global numerical weather prediction and climate models is crucial for accurate weather and climate prediction (e.g., Miller et al. 1986; Miller et al. 1989). Subgrid orographic parameterizations (SGP) describe the transport of momentum induced by subgrid-scale orography to large-scale flow. Considerable efforts have been made to more realistically parameterize this orography-induced flow in a subgrid orographic drag in a vertical, see (e.g., 2002) and Anagnostou et al. (2010).

Atmospheric Measurement Techniques

Implementation of a GPS-RO data processing system for the KIAPS-LETKF data assimilation system

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Received: 31 October 2014 – Published in Atmos. Meas. Tech. Discuss.: 28 November 2014
Revised: 17 February 2015 – Accepted: 17 February 2015 – Published: 16 March 2015

Abstract. The Korea Institute of Atmospheric Prediction Systems (KIAPS) has been developing a new global numerical weather prediction model and an advanced data assimilation system. As part of the KIAPS package for observation processing (OPOP) system for data assimilation, preprocessing, and quality control modules for bending-angle measurements of global positioning system radio occultation (GPS-RO) data have been implemented and executed. The GPS-RO data processing system is composed of several steps for checking observation locations, missing values, physical values for Earth radius of curvature, and geodetic coordinates. An observation minus background check is implemented by use of a one-dimensional observational bending-angle operator, and target great circles are established in the quality control process. We have used GPS-RO observations utilized by the Korea Meteorological Administration (KMA) within R20P, based on both the KMA global model and the National Center for Atmospheric Research Community Atmosphere Model with Spectral Element Approximation (CAM-SE) as a model background. Background fields from the CAM-SE model are incorporated for the preparation of assimilation experiments with the KIAPS local ensemble transform Kalman filter (LETKF) data assimilation system, which has been recently implemented by a cubed-sphere model with unstructured quadrilateral meshes. As a result of data processing, the bending-angle dependent criterion between observations and background shows significant improvement. Also, the first experiment in assimilating GPS-RO bending angle from R20P within KIAPS-LETKF shows encouraging results.

1 Introduction
Global positioning system radio occultation (GPS-RO; Kovacs et al. 1997) is a high-precision remote-sensing technique whereby the time delay of GPS radio signals that have passed through the limb of the Earth's atmosphere are used to determine vertical profiles of atmospheric refractive index. GPS satellites transmit two microwave signals (1.2 and 1.5 GHz) to receivers on low Earth orbit (LEO) satellites. An occultation occurs when the microwave signals transmitted by one of the GPS satellites, as it rises or sets past the Earth's atmosphere. During an occultation, the ray connecting the GPS and LEO satellites passes the atmosphere, providing vertical information of the atmosphere from the refraction of the GPS radio signals as measured by the receiver in a low Earth orbit. The raw measurements of radio occultations are the phase and magnitude of radio signals transmitted by the GPS satellites. Based on these measurements and knowledge of the precise position and velocity of the GPS and LEO satellites, vertical profiles of bending angle and atmospheric refractivity are derived by use of the least-squares symmetry assumption and the Abel inversion (Flanagan and Anderson, 1988). The observations have high vertical resolutions (0.1 km near surface to 1 km toposphere) and global coverage, even though the horizontal resolution is relatively poor (hundreds of kilometers). Also, they show high accuracy (repeatability: ± 1.0 K, average accuracy: ± 0.1 K) and precision (0.02–0.05 K) (Lambert, 2013) for a frequency in the vertical range of 10–40 km and equal accuracy over either land or ocean (Cornwall et al., 2013). The most powerful benefit of the GPS-RO measurements are on suitable bias and minimal effect on the data by

Published by Copernicus Publications on behalf of the European Geosciences Union.

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