ICE-POP2018 Science Plan

Research & Development Project and Forecast Demonstration Project for PyeongChang 2018 Winter Olympic Games

1. Introduction

The 23rd Olympic Winter and the 13th Paralympic Winter Games will be held in PyeongChang, Korea on February 9-25 and March 9-18 respectively, 2018. The Winter Games are great opportunities to understand severe winter weather over complex terrain areas and to improve the predictability of nowcasting and very-short range forecasting. The World Weather Research Programme (WWRP) of the World Meteorological Organization (WMO) has approved and supported several international projects such as Forecast Demonstration Project (FDP) and Research and Development Project (RDP) to enhance the capability of member countries in the area of convective scale numerical weather prediction modeling, and to understand the high impact weather systems.

SNOW-V10 (Science of Nowcasting Olympic Weather for Vancouver 2010) was carried out for the observation monitoring and demonstration of nowcasting systems with the goals of development of a winter nowcasting system over complex terrain. FROST-2014 (Forecast and Research: the Olympic Sochi Testbed 2014) FDP/RDP applied a mesoscale ensemble prediction technique to winter weather over complex terrain and demonstrated winter nowcasting and high resolution numerical weather prediction.

These projects left several issues. The high spatial and temporal observation is essential to obtain good measurements and prediction of severe weather elements over complex terrain. The development or decay of precipitation due to terrain influences needs to be considered to improve the predictability of a winter nowcasting system based on radar echo extrapolation. There are still difficulties for verifying non-traditional variables (visibility and precipitation type, etc) despite of advances in forecast of these variables from high resolution models over complex terrain. Some verification results showed that high resolution was better than lower resolution but was sometimes worse.

KMA (Korea Meteorological Administration) and NIMS (National Institute for

Meteorological Science) have a responsibility to provide weather information for the management of the Games and the safety of the public. To accomplish this mission, NIRM will carry out RDP/FDP for PyeongChang 2018 Winter Olympic Game. These projects are named as ICE-POP2018, which stands for International Collaborative Experiments for Pyeongchang Olympic & Paralympic 2018. These projects focus on intensive observation campaigns to understand severe winter weathers over the PyeongChang region, and the research results from RDP will be used to improve the accuracy of nowcasting and very-short-range forecast systems, which will be run in real time and the forecast will be provided to forecasters during the Games.

The goals of ICE-POP2018 are:

a. Improvement of our understanding on severe weathers (snowfalls, visibility, rapid wind changes and gusts,) over complex terrain

- Specially focus on the microphysical processes over complex terrain as well as the impact of the ocean on snow to extend the experience from SNOW-V10 and FROST- 2014.

b. Improvement of the predictability of nowcasting and very-short-range forecasting with a few kilometer horizontal resolution

- Development of NWP-based nowcasting, multi-scale data assimilation and time-lagged ensemble for VSRF, and radar reflectivity and visibility data assimilation

c. Improvement of verification and evaluation methods for high resolution model considering complex terrain

- Development of verification methods for high spatial and temporal variables with remote-sensing observation and non-traditional variables (visibility and precipitation type, etc) to consider benefit for social and economic effect

2. Venues

The PyeongChang 2018 Winter Olympic and Paralympic Games will be hosted in two clusters (Fig. 1). The snow sports will be enjoyed in PyeongChang, nestled in mountains blanketed with snow where bracing winters are relished. The ice sports will be enjoyed in Gangneung, where the Korean peninsula faces the East Sea (The Sea of Japan). The competition venues consist of snow venues (in Alpensia, Yongpyong, Jeongseon, Jungbong, and Bokwang) and ice venues (Gangneung). A total of 13 competition venues will be in operation. Snow venues consist of six existing venues (Alpine Skiing Slalom/Giant Slalom, Cross Country Skiing, Ski Jumping, Biathlon, Freestyle Skiing, Snowboard) and two new venues (Alpine Skiing Downhill/Super-G, Bobsleigh/Luge/Skeleton). Ice venues consist of one existing venue), and four new venues (Speed Skating, Figure Skating/Short Track Speed Skating, Ice Hockey I, Ice Hockey II).

Figure 1. Maps of Venues for PyeongChang 2018 Winter Olympic Games

PyeongChang Mountain Cluster is characterized by an alpine climate due to its location in the eastern alpine region, more than 700 meters above the sea level, For the past 30 years, average air temperature has been recorded as -5.5℃ in February and -0.5℃ in March, average low air temperature -10.5℃ in February and -5.2℃ in March, and average precipitation 53.6mm in February and 75.6mm in March. It has the optimum weather conditions to hold the Winter Olympics and Paralympics with a high level of precipitation and low temperature, and also for the last 3years

During February-March 2011-2013, the average air temperature was –5.3℃ ~ -0.1℃, and average low temperature ranged –11.6℃ to –5.5℃; the annual precipitation recorded 44mm~55mm; snow falls on 9.7~12.7 days per year; maximum new snowfall(???) was 19.8cm~18.5cm; average wind speed was 3.6m/s~4.3m/s, becoming stronger entering into March.

Gangneung Coastal Cluster is located on the east coast of the peninsula and adjacent to the Taebaek Mountains to its west. This location gives Gangneung the coastal climate. For the past 30 years, the annual average air temperature was recorded as 2.2℃ in Feb. and 6.3℃ in March; the low average temperature was -1.6℃ in February, and 2.0℃ in Mar.; precipitation was 68.9mm in February, and 49.6mm in March.

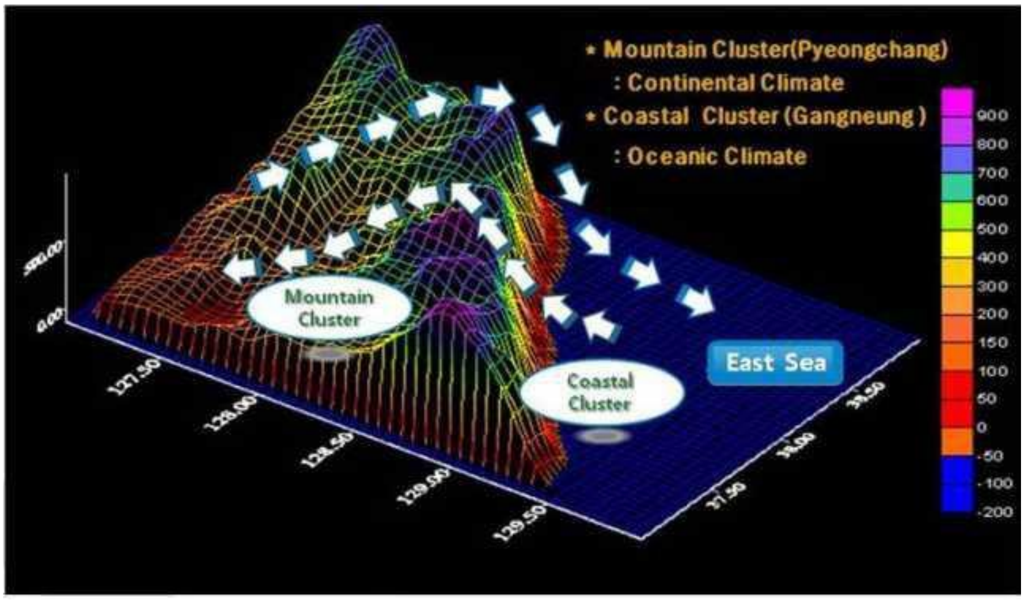


Figure 2. Topography characteristics of the PyeongChang Olympic Region

It is usual to have temporary heavy snow in February and March in Gangneung. Also, for the past 3 years (February-March, 2011-2013), average temperature was 1.6~6.2 ; the average low temperature ranged between –2.5℃ and 1.9℃; the annual (???) precipitation recorded 60.2mm~78.3mm; the snow falls on 6.7~5.3 days per year; the maximum new snowfall was 31.9~11.6cm; and average wind speed was 2.6 ㎧~2.8 ㎧.

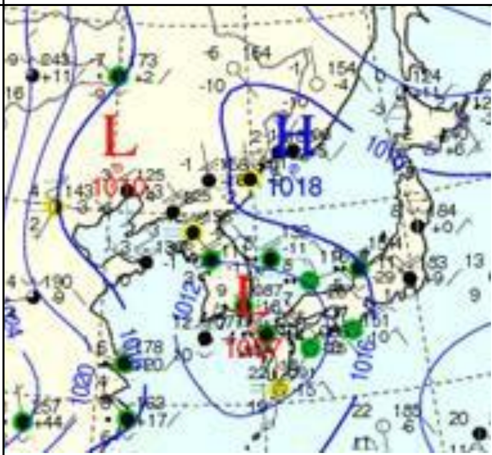
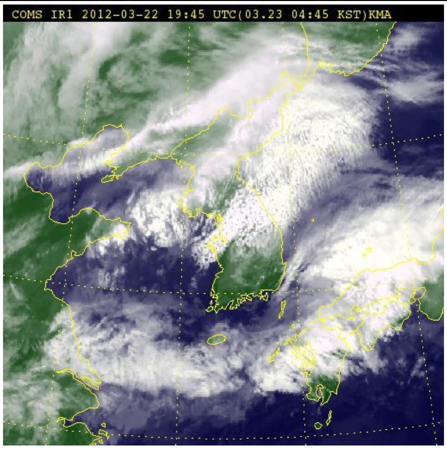
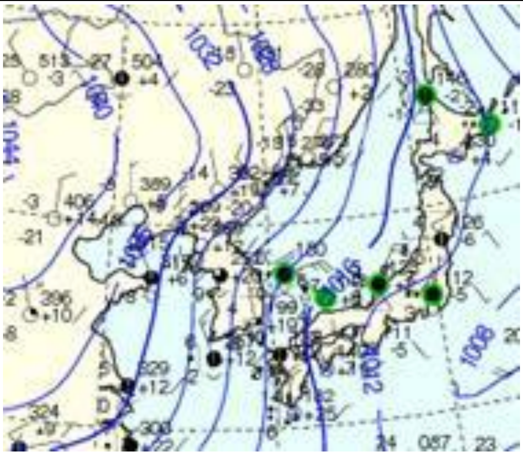
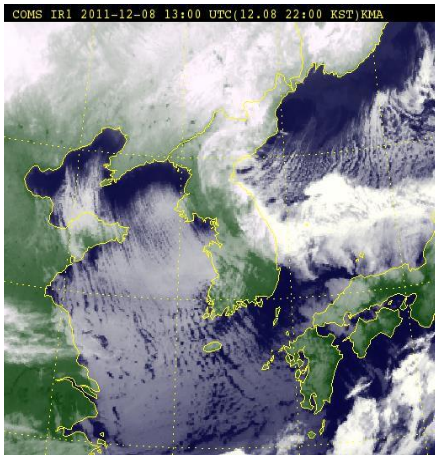
Table 1. Meteorological mean at two major sites on Pyeongchang area

Meteorological Element (2011-2013)	Mountain Cluster (Pyeongchang) 773 m above sea level		Coastal Cluster (Gangneung) 26m above sea level	
	Feb	Mar	Feb	Mar
Avg. Monthly Temperature(℃)	-5.3	-0.1	1.6	6.2
Min. Temperature(℃)	-11.6	-5.5	-2.6	-1.9
Max. Temperature(℃)	0.2	4.9	6.2	10.6
Avg. Monthly Relative Humidity(%)	63	62	49	51
Avg. Monthly Rainfall Amount(mm)	44	55	60	78
Avg. Monthly No. of Snow Day	9.7	12.7	7	5
Avg. Wind Speed(m/s)	3.6	4.3	2.6	2.8
Max. Wind Speed(m/s)	12.4	14.2	8.6	10.5

3. Science Challenges

1) Precipitation types and amounts

Table 2. Conceptual model for snow over PyeongChange regions

	Surface map	Satellite image
Low pressure from west (29% in ten-year snowfall records)		
High pressure(Cold air mass) from east (22% in ten-year snowfall records)		

2) Oceanic and orographic effects on snow

The cold air moving over the relatively warm sea surface is heated and moistened, so that the boundary layers in the lower troposphere become unstable. The snow clouds first formed over the ocean and further developed by the mountains, because the updrafts forced by convergence induced by the frictional differences between land and sea.

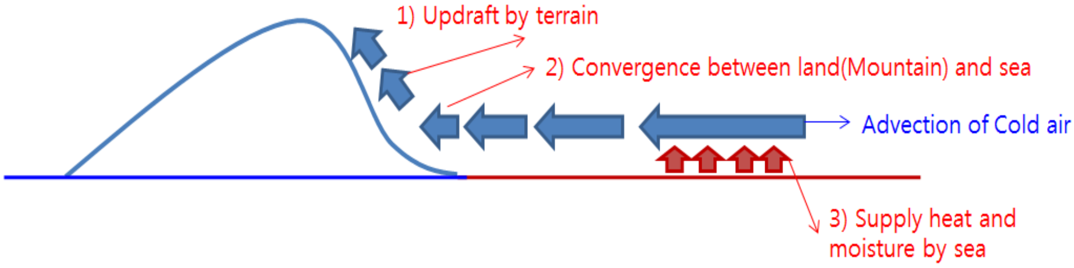


Figure 3 Updraft induced by the friction differences between land and sea

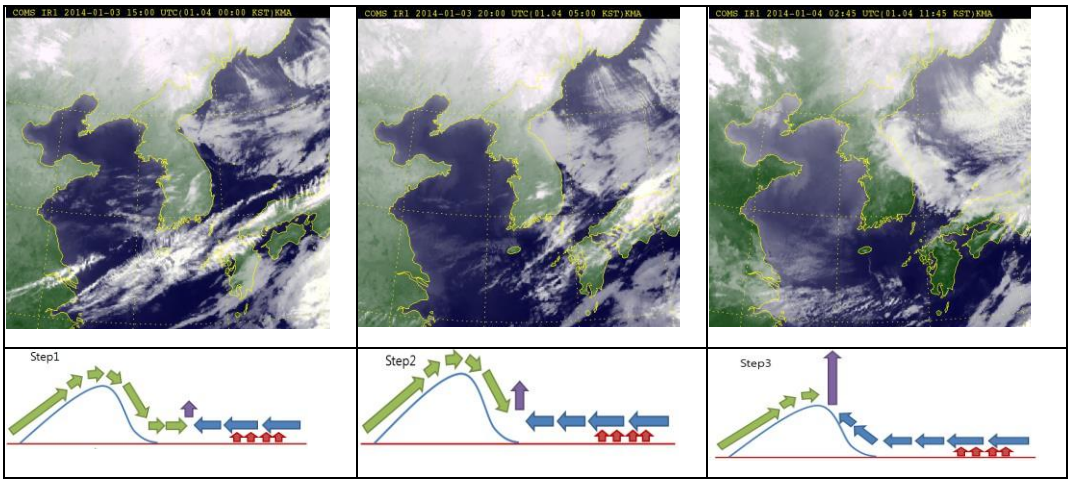


Figure 4. Horizontal roll vortices and Convergence

3) Observations

The intensive observation campaign is planned to characterize the effects of the ocean and opography on the evolution of snow clouds which produce snowfall over PyeongChang. Beside synoptic observations, radars shown in Fig. 5, windprofilers, mobile observation system, observing ship and multi-purpose weather observation aircraft will also participate in this campaign (Appendix 1).

To understand the initiation, formation, and decaying of snow clouds due to easterly flows moving from relatively warm ocean to mountains, observing systems are designed to be aligned along from the east to west, that is, from the east sea to PyeongChang

The observations systems should be placed carefully. To fill the observation gaps, which is very common in complex topography of the PyeongChang area, x-band radars will be placed. The web servers to collect and distribute observation data will be set up for participants in 2016.

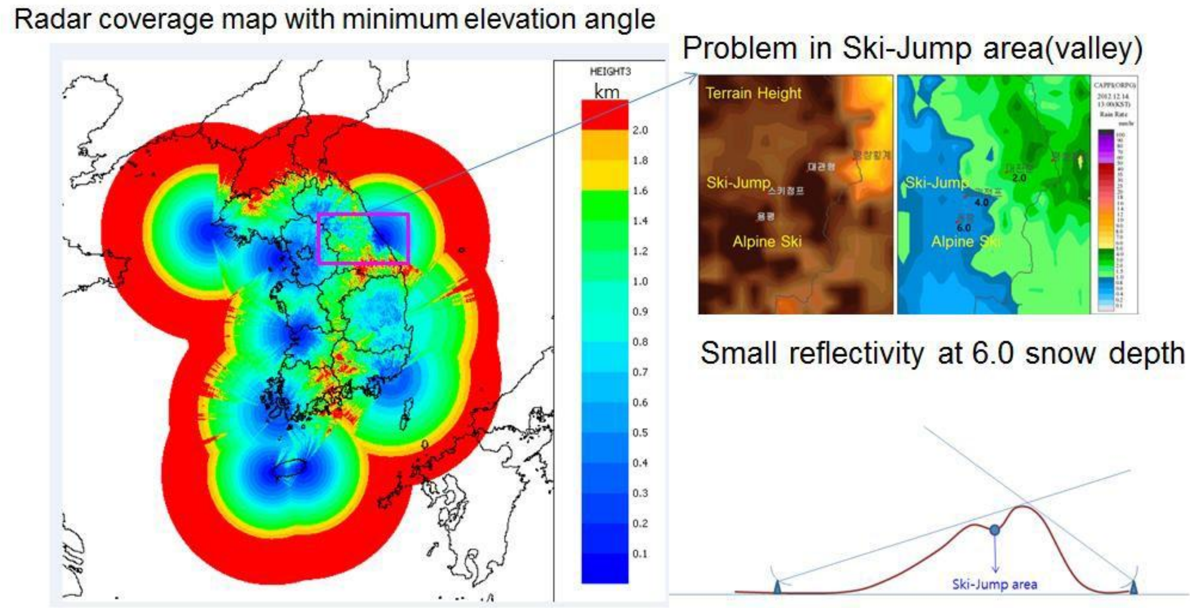


Figure 5 Radar data coverages and gaps

4) Predictability improvement of convective scale NWP forecasts

The physical parameteration shcems should be optimized to apply to higher resolution NWP. One of the goals of the intensive observations is to provide basic statistical information about high-resolution physical processes, which will be used to improve parametrization schemes of high reoslution NWP

The data assimilation of high resolution NWP should be able to assimilate observations with various scales weather information. KMA/NIMS has a plan to develop multi-scale data assimilation using multi-grids for currently developing a very-short-range forecasting system. One of the main complains from forecasters for the high resolution NWP is the inconsistency in forecasts from one cycle to the other cycle. To overcome such inconsistent forecast jumps, NIMS is also considering to develop time-lagged ensembles

4. Projects overview

The RDP and FDP are not separated but blended each other. Research based on intensive observations becomes the basis for the development and advancements of nowcasting and short-range forecasting models. Observations from the intensive observation campaign will be provided for NWP assimilation.

NWP plays a key role in RDP, NWP forecasts are used for quality control of observations data, and retrieval processes. NWP based OSE and OSSE also provide information for the optimal displacements of observation systems. To address the goals of ICE-POP, it is categorized by three sub-projects which consist of observation, modeling and evaluation.

Intensive observation campaign (see Appendix)

Intensive observation to improve our understanding of severe weather over mountainous terrain will be carried out during winter from 2016 to 2018.

○ Specifics provided by KMA/NIMS for any participant agency

- Provision of shipping fee, location, electric power, network for obs. Instrument
- Provision of lodging, meal, transportation for staffs

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○ List of participant agency and instruments for intensive observation campaign

Table 3, Tentative agencies and instruments

Agency		Instruments	
KMA	Observation policy Division	AWS(10), WX sensor(22), Road WX(3) CCTV(10)	
	Radar Center	X-band radar(1)	
NIMS	Observation Based Research Division	Micro-Rain Radar(1), Optical Rain Guage(1), Parsivel(1), GNSS(1), Aircraft(1), Cloud radar(1)	
		aircraft	Hawkeye Spectrometer(1), HVPS Spectrometer(1), 2D-128 Spectrometer(1), CCNC-200(1), Radiometer(1)
	Global Environment System Research Division	Ship	AWS(1), Radio-Sonde(1),PM-10(1), Marine Radar Wave Extractor(1), Acoustic Doppler Current Profiler(1), Percision deepsea recorder(1), Waverider Buoy(1)
	Applied Meteorology Research Division	AWS, Ceilometer(1), Micro Rain Radar(1), Image Snow depth meter(1), Ultrasonic snow depth meter(1), Fog monitor(1), Meteorological Particle Spectrometer(1), Lase Snow depth meter(1), Sky Imager(1), Disdrometer(1), Microwave radiometer(1), Visibility(1)	
EC(Canada)		Ka-band Cloud radar(1) X-band dual-polarimetric radar (2) Doppler lidar(7) Integrated WX sensor(44)	

Forecast demonstration

- ○ Nowcasting, very-short rage NPW for PyeongChang
- ○ Ensemble prediction of nowcasting and very-short-range forecasting systems
- ○ Radar reflectivity and visibility data assimilation
- ○ Specifications provided by KMA/NIMS for any participant agency
- \- Provision of initial static data(terrain height, land use, etc) for high resolution model
- \- Provision of lateral boundary data from KMA Global Model
- \- Provision of observation data to set up data assimilation
- \- Provision of lodging, meal, transportation for expert
- ✓ Providing data format will be discussed in workshop
- ○ Specifics provided by KMA/NIMS for any participant agency
- \- Provision of initial static data(terrain height, land use, etc) for high resolution model
- \- Provision of lateral boundary data from KMA Global Model
- \- Provision of observation data to set up data assimilation
- \- Provision of lodging, meal, transportation for experts
- ✓ Providing data format will be discussed in workshop

Table 4. Tentative list of agencies and models participating in FDP

country (organi.)	**model**	**res/cycle**	**lead time**	**outputs**
Austria (ZAMG)	INCA	1km or higher/ 15min	0-6h (48h)	precip(intensity,type) temp, humidity, visibility, snowfall line, zero degree line
China (CMA)	GRAPES	3-1km/1h	12h	all NWP variables
EC (Canada)	INTW	single/10min		temp, Wind(direction,speed), windgust, RH, pressure,visibility, ceiling
	GEM-LAM	15,2.5,1km/ ??	6h	all NWP variables
Russia (Roshydromet)	COSMO	2.2, 0.55km/ 1hour	24h	all NWP variables postprocessed NWP
USA (NCAR)	FINECAST	1km/ 15min	~2h	wind, temp, precip
	WRF	15,3,1km/ 1h	~12h	all NWP variables
USA (ESRL/NOAA)	HRRR	3km/1H	~18h	all NWP variables
	V-Cloud	500m/ 15min(analysis) Hourly(forecasts)	~6h	cloud analysis
FMI				

Evaluation

○ New method of verification for high resolution model

○ Method to use remote-sensing data for verification

○ Specifications provided by KMA/NIMS for any participant agency

- Provision of observation data for verification
- Provision of lodging, meal, transportation for experts

✓ Providing data format and domain for verification will be discussed in workshop

Table 5. List of variables to be evaluated

	Nowcasting	Very-short range forecst	Short range forecast	Digital village forecast	Ensemble
Sky condition	O	O	O	O	O
Precipitation amount	O	O	O	O	O
Precipitation type	O	O	O		
Wind gust		O	O		
Wind speed/dir		O	O	O	O
Freezing level		O	O		
hydrometeo r		O	O		
Simulated reflectivity		O	O		

Supports for FDP s

NWP models participating in FDP are expected to run with the domain covering PyeongChang. The performances of FDP participants will be evaluated and the results will be shared in real time. The data required to run FDP participants models will be provided from KMA/NIMS. All available observations including the intensive observation campaigns will be collected and distributed. The operational NWP forecasts at KMA/NIMS are also provided for data assimilation. KMA/NIMS is operating global, regional, local, and ensemble systems as shown in Fig. 6.

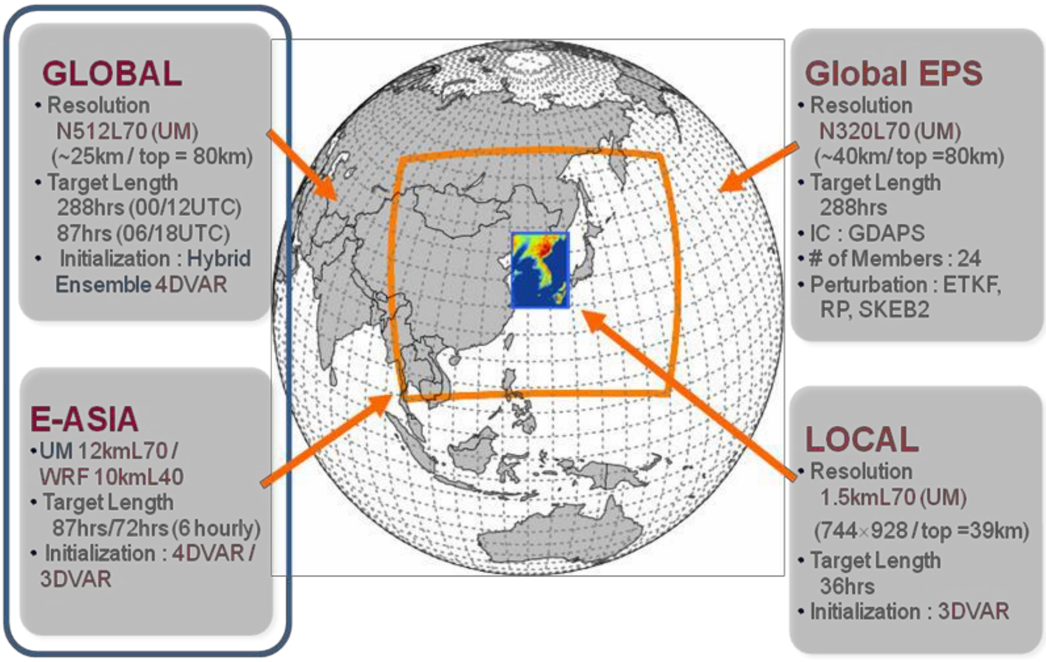


Figure 6. Operational NWP systems of KMA

KMA/NIMS is also developing a very-short-rage forecasting system (VDAPS, Very-short- range Data assimilation and Prediction System) and a NWP -based nowcasting system

(HDAPS, High-frequency Data Assimilation and Prediction System). VDAPS will be run in real time with 1 hour cycling interval and up to12 hour forecasts, while HDAPS with 15 minute cycling interval and 2 hour forecasts. In 2015, VDAPS is expected to be developed with 1hour cycling interval, 1.5km domain covering Korean Peninsular and surrounding seas (Figure 7). Radar reflectivity data assimilation with RH nudging will be implemented in 2016. Data assimilation will be 3DVAR until 2016, and will be tested with 4DVAR in 2017. The final decision for operating a variational method during PyeongChang winter Games will be made based on performances and computational costs. The boundary conditions and background from VDAPS will be available according to the needs of participants.

The computer resources will be available with the services/helps for the implementation and operation, but due to the limitation of the computing resources, services may not be available for all participant systems. KMA/NIMS runs Global NWP daily twice up to 288 hours forecasts, Regional NWP daily four times up to 72 hours forecasts, and High resolution model daily eight times up to 36 hours. Global Ensemble Prediction System with 24 members runs daily twice up to 288 hours.

Table 6. The configurations of VDAPS and HDAPS

	Resolution	Cycling interval	Grids (vertical layer)	Forecast length
HDAPS	1.5 km	1 hour		12 hour
VDAPS	500 m	15 min	360x324 (70)	2 hour

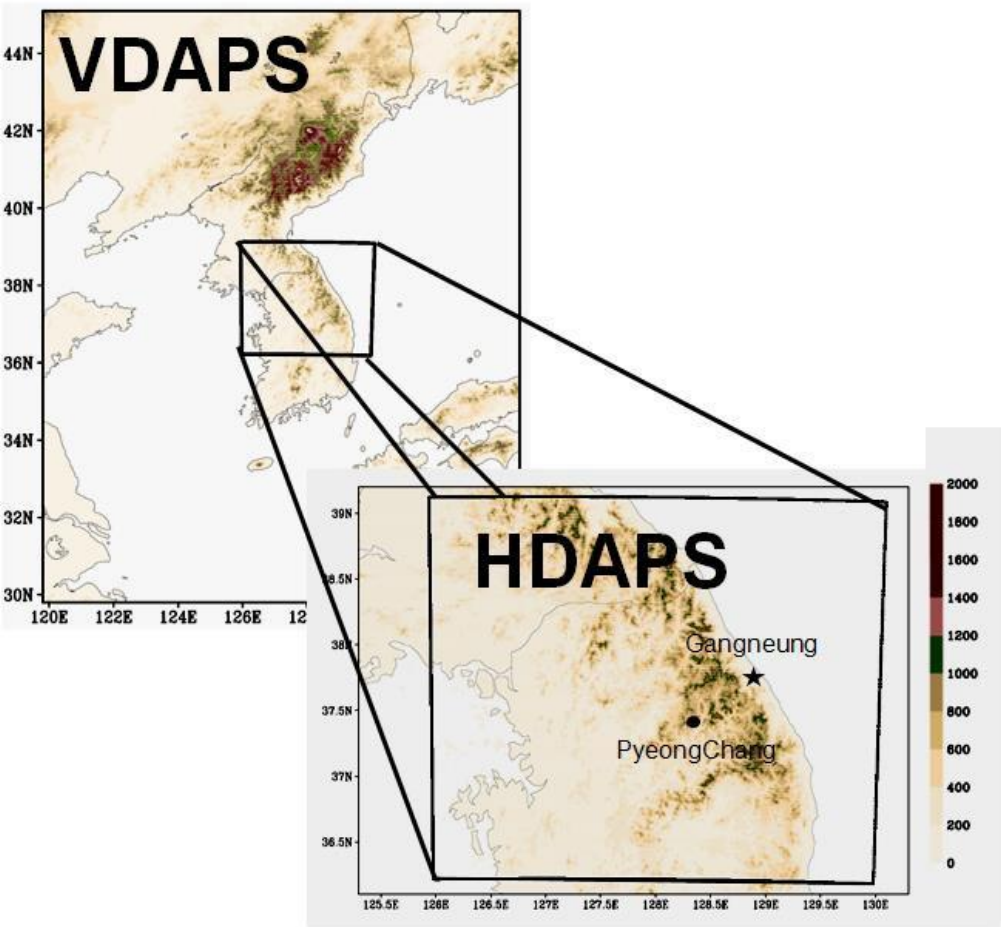


Figure. 7 Domains of VDAPS (Very-short-range Data Assimilation and Prediction System) and HDAPS (High-frequency Data Assimilation and Prediction System)

Table 7. Participants needs for FDP

country (organi.)	model	needs
Austria (ZAMG)	INCA	VDAPS outputs, Real time surface observation data, radar, satellite, do not need compuater resources, but a data exchange platform (e.g. ftp) should be provided
China (CMA)	GRAPES	Observations IC, LBC (VDAPS at KMA)
EC (Canada)	INTW	observations(radar, AWS), NWP productions
	GEM-LAM	Observations IC, LBC (VDAPS at KMA)
Russia (Roshydromet)	COSMO	Observations, IC, LBC (VDAPS at KMA), computer resources (before upgrade of the HPC facilities at the Hydrometcentre of Russia (planned for the end of 2016) Output of other participating NWP systems is of interest for multi-model postprocessing
USA (NCAR)	FINECAST	observations(radar, AWS), NWP productions
	WRFDA	local observations do not need LBC computing resources may needed
USA (ESRL/NOAA)	V-Cloud	observations(radar, satellite, celiometer.. etc), NWP products (VDAPS), LBC, Backgroud computing resources needed form 2nd year
	HRRR	NWP products, Observations for DA computing resources needed form 2nd year
FMI		

Future activities

- A Kick-off meeting on October, 2015
- One or two workshops in 2016, 2017, and 2018
- 1st International collaborative observation on 2016-2017(winter season)
- 2nd International collaborative observation on 2017-2018(winter season)

Table 8. Implementation/operation plan

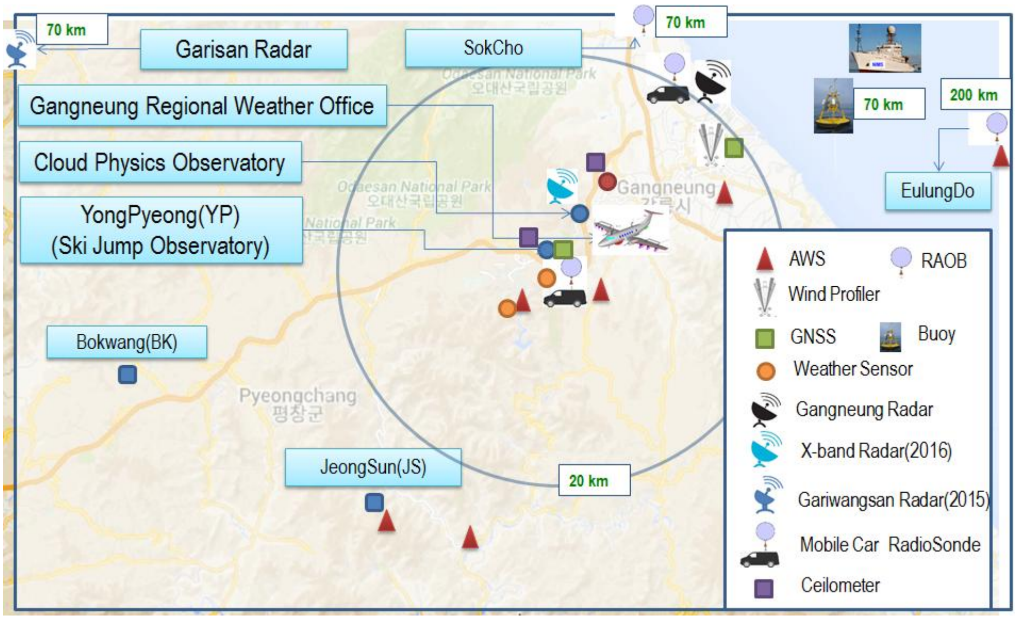
country (organi.)	model	2015~2016	2017	2018
		RDP Phase set-up hindcast	**FDP-phase real-time operation**	**support winter games**
Austria (ZAMG)	INCA	set up system test (hindcast /reanalysis)	Scientific development Real-time	Real-time
	AROME			
China (CMA)	GRAPES	set up system test (hindcast)	near-realtime	Real-time
EC (Canada)	INTW	set up system test (hindcast)	Real-time	Real-time
	GEM-LAM	set up system test (hindcast)	Real-time	Real-time
Russia (Roshydromet)	COSMO	Set up system test	Real-time	Real-time 2.2km for FDP 0.55km for RDP
USA (NCAR)	FINECAST	set up system test (hindcast)	Real-time	Real-time
	WRFDA	set up system test (hindcast)	Real-time	Real-time
USA (ESRL/NOAA)	V-Cloud	set up system test (hindcast)	set up at KMA supercomputer for real-time operation	Real-time
	HRRR	set up system test (hindcast)	set up at KMA supercomputer for real-time operation	Real-time
FMI				

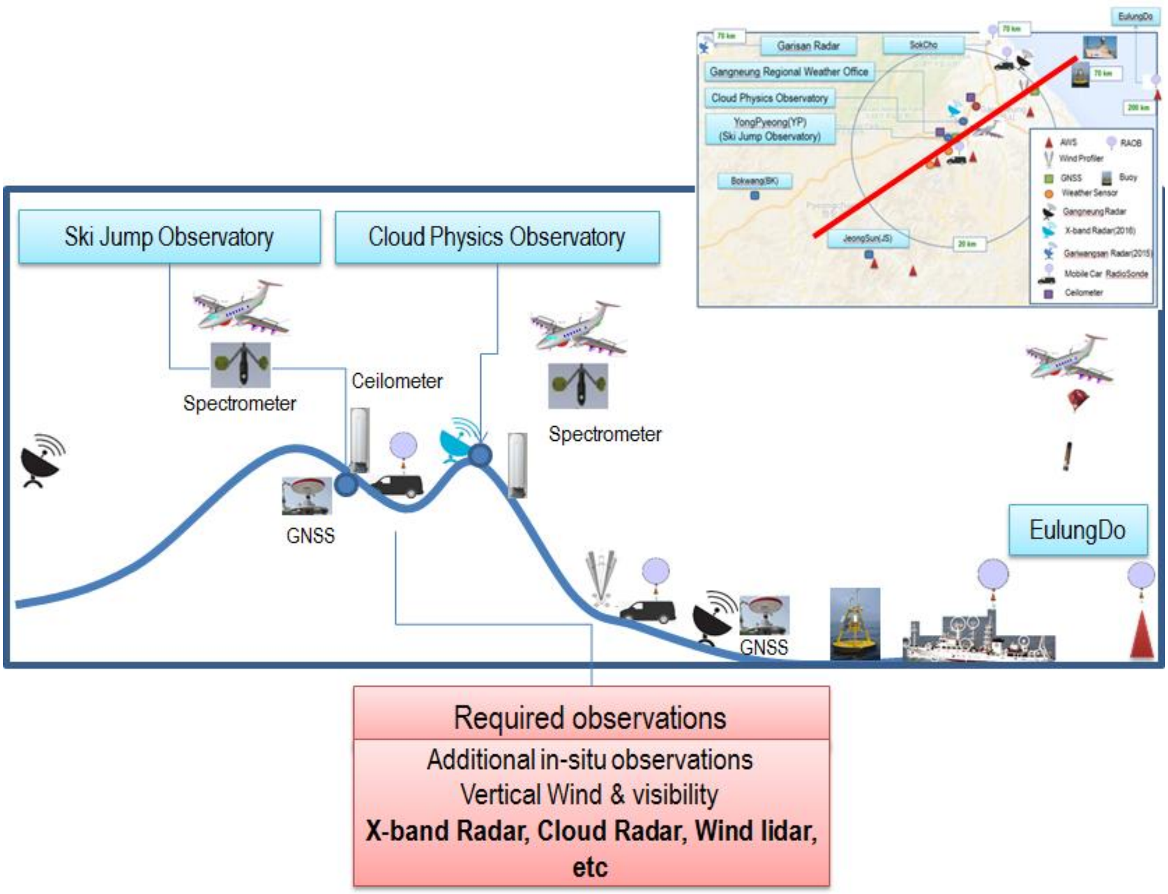
Table 9. work timeline

	2015					2016		2017		2018	
						1st half	2nd half	1st half	2nd half	1st half	2nd half
Science plan											
Advisory board meeting							Sep		Sep.	Sep.	
Workshop							Oct.		Oct	June	
Final report											Nov
Observation instruments											
Intensive observation campaign											
Observation data analysis											
Optimize physical processes of NWP											
Design of nowcasting/VSRF system											
upgrade HDAPS											
upgrade VDAPS											
Development of Multi-scale data assimilation											
Development of multi-model/time-lagged ensemble system											
Support test events / winter Olympics											
Implementation and operation of data sharing system											
Implementation and operation of verification system											
Implementation and operation of Graphic display system											
Transfer to operation											

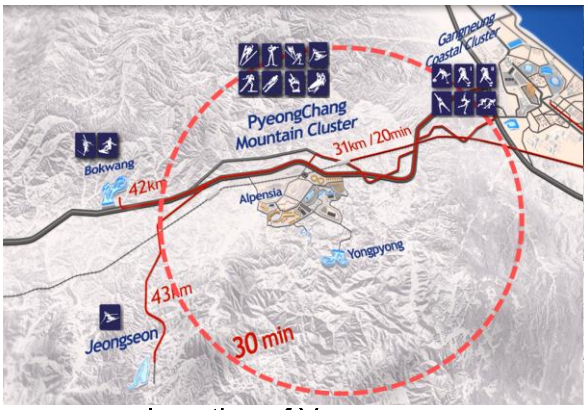
Appendix Observation Network

Observation design (Figure1)



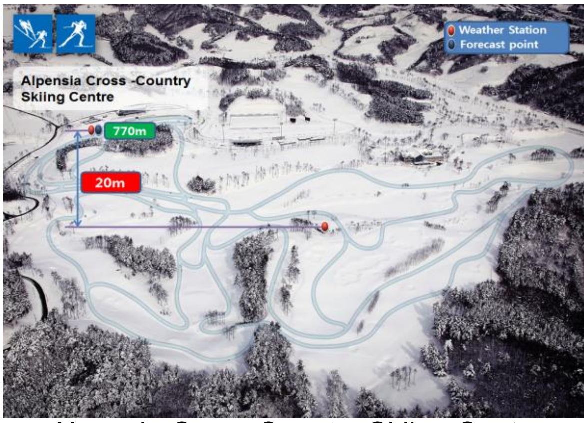


Weather stations(red) and forecast points(blue) (Figure 2)



Location of Venues

Alpensia Biathlon Centre



Alpensia Cross-Country Skiing Centre

Alpensia Ski Jumping Centre

Yongpyong Alpine Centres

Bokwang Snow Park

Alpensia Sliding Centreues

Jeongseon Alpine Centre

Surface Observation

There are operational 728 automatic weather system (AWS) sites and 80 automated surface observing system (ASOS) over Korea peninsula. New surface observation sites(45 points) established over PyeongChang region from 2012 to 2013. These new sites are 10 AWS same as operational AWS and 22 Special Weather Sensors(SWS) on venues.

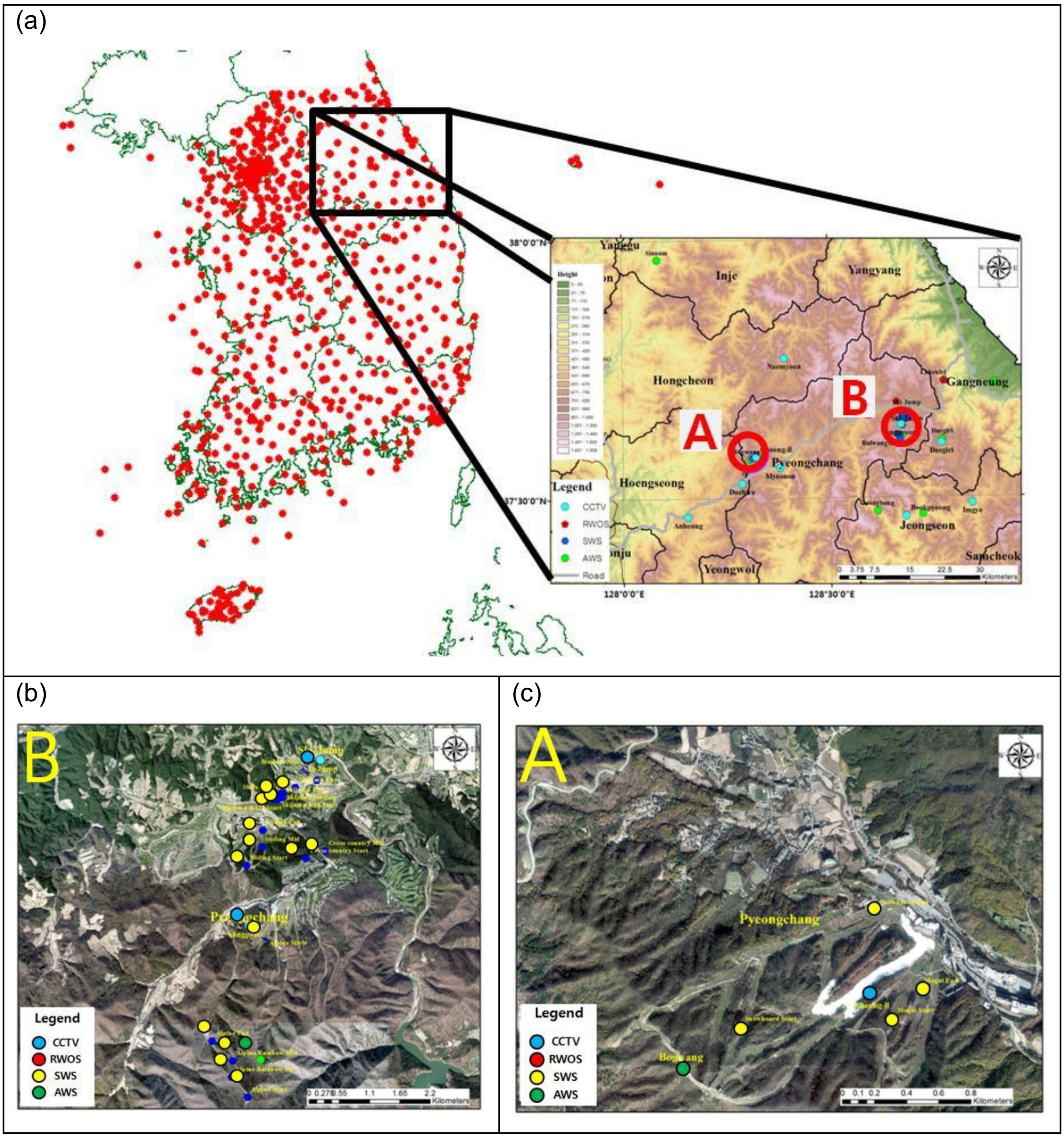


Figure 3. The site map of (a) AWS/ASOS sites over Korea peninsula and (b) new established surface observation sites over venue area. The map of automatic weather system of (b) and (c) is A and B in (a) respectively. The picture of observation systems are (e) AWS and (f) Special Weather Sensor(SWS).

Table 1. The list of surface station over venue

Classification	quantity	Located point	Observation Elements
Automatic Weather System(AWS) (10 point)	10	Bangsan, Sinnam, Sabuk, Balwangsan, Eoheul-ri, Daegi-ri, Ski jumping Damsan, Jungbong(Finish area), Bogwang	Wind dir., Wind Spd., Temp., RH, Precp., Pres.
Independent sensor in the competition venue (22 point)	22	Ski jumping(2), Biathlon(2), Sliding Centre(2), Alphine ski(3), Cross country(1) Ski jumping(4), Mogul(2), Snowboard(2), Alphine ski(2), Cross country(1), Sliding Centre(1)	Wind dir., Wind Spd., Temp., RH, Precp., Pres., Visibility, Sky condition
Road Weather Information System (3 point)	3	Sapgyo-ri, Yucheon-ri, Eoheul-ri	Road condition, Visibility, Sky condition
Snowfall monitoring CCTV (10 point)	10	Yongpyeong, Myeonon, Nae-myeon, Daehwa, Bukpyeong, Daegiri, Anheung, Imgye, Cheongil AWS, Ski jumping	-

Upper-Air Observation

The upper-air observation sites are 5 radio-sonde and 10 windprofiler sites by KMA, and 2 radio-sonde and 1 windprofiler by airforces. The site closest to venue is Gangneung wind profiler near coast.

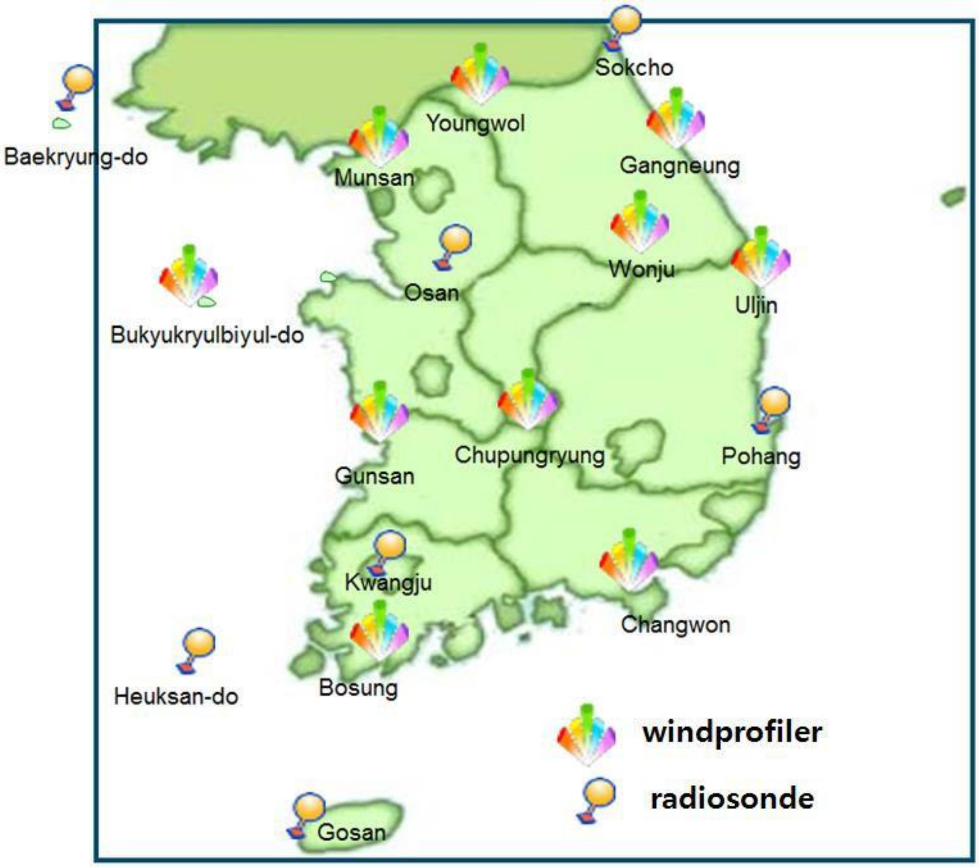


Figure 4. The upper air observation sites of 11 wind profiler and 7 radio-sonde sites.

Weather Radar network

The operational radar networks covering PyeongChang region. Four radars of KMA (green), and two radars from Ministry of land, infrastructure and transport (red). X-band radar will be operating during the intensive observation campaign to fill the gap in YongPyeong due to the complex terrain.

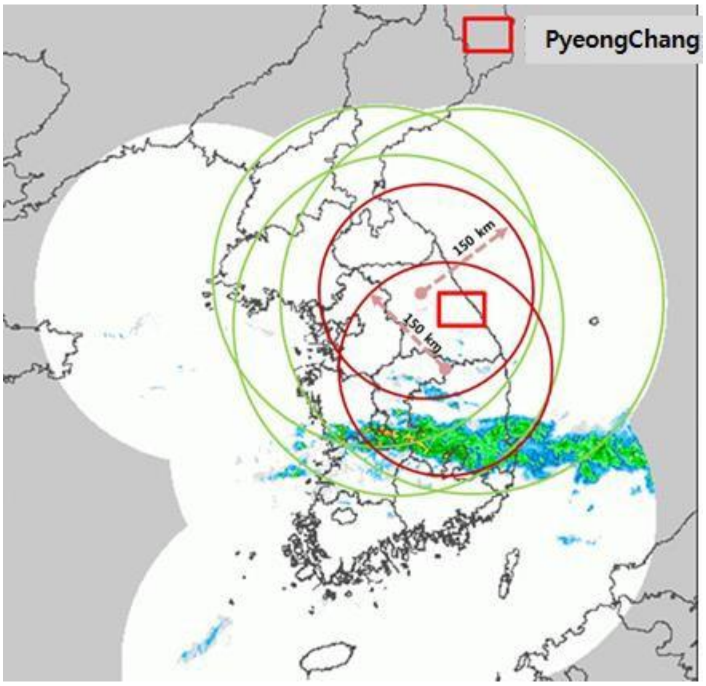


Figure 5. The 6 radars covering PyeongChang region.

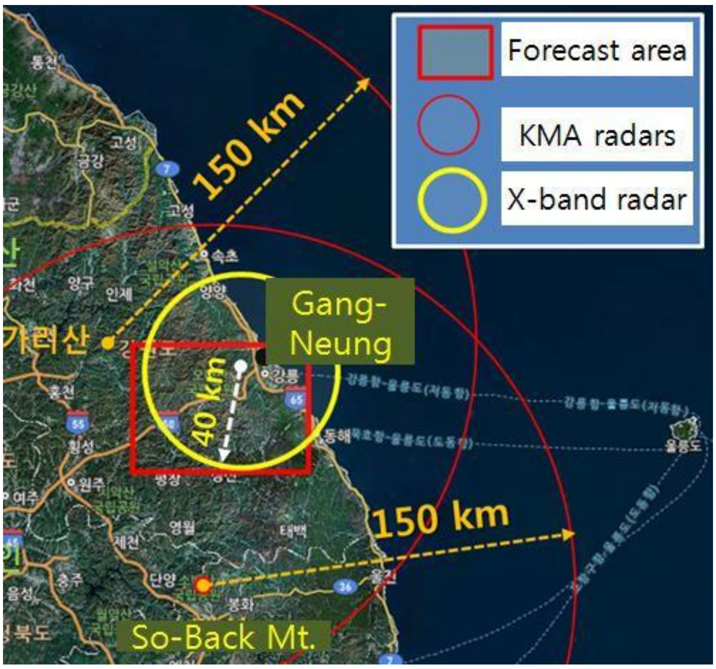


Figure 6. X-band radar coverage (Yellow)

Airborne Instrument

NIMS will launch airplane end of 2015. The radiometer and high volume precipitation spectrometer are installed on airplane.

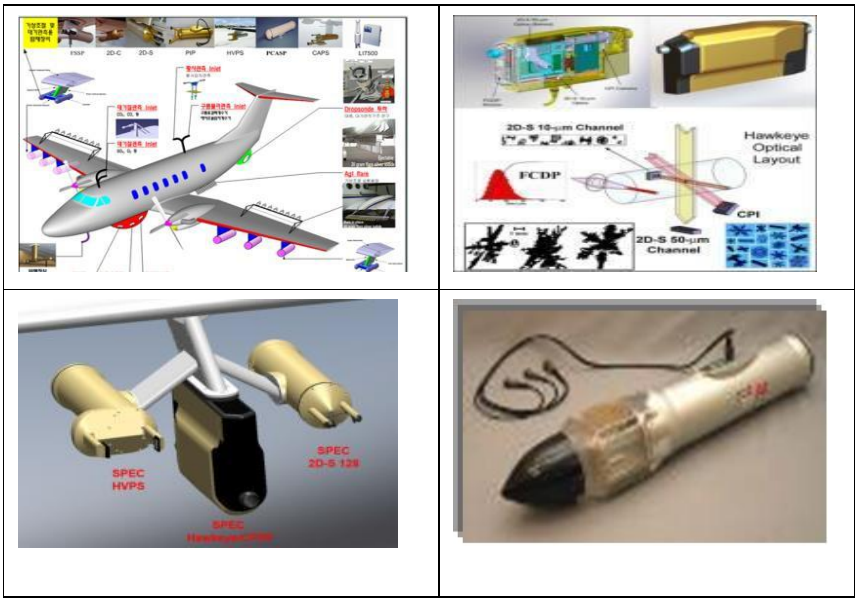


Figure 7. The picture of airplane (upper left) and airborne instrument with (upper right) Hawkeye Spectrometer(lower left) installed all spectrometer and (lower right) radiometer.

Table 2. The list of spectrometer on airplane

Hawkeye (SPEC)	· FCDP: 0.5~70 ㎛ (resol. 1 ㎛) · 2D-S (ch.1): 10~1280 ㎛ (10 ㎛) · 2D-S (Ch.2): 50~6400 ㎛ (50 ㎛) · CPIP: 50~6400 ㎛ (2.3 ㎛)
HVPS (SPEC)	150~19200 ㎛
2D-S128 (SPEC)	20~2560 ㎛
CCNC-200 (DMT):	0.75~10 ㎛ (20 bins)

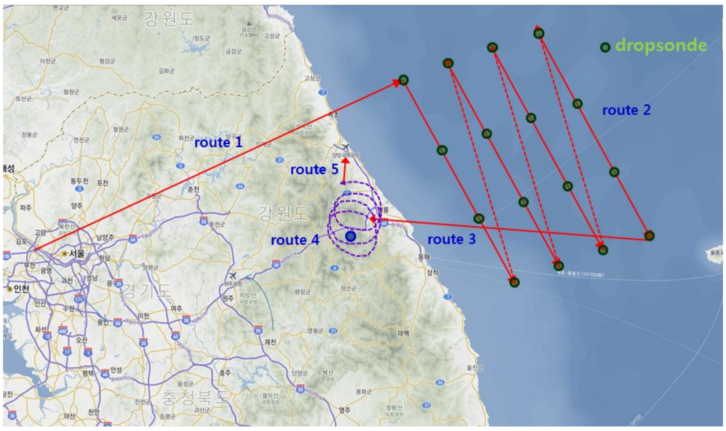


Figure 8. Strategy for the deployment of dropsonde and upper air observation

Marine Weather Observing Ship

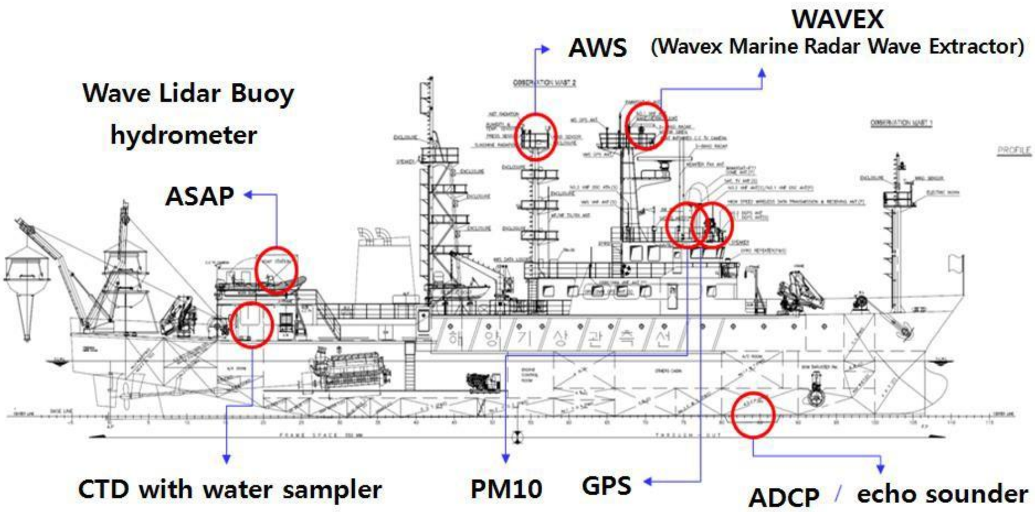
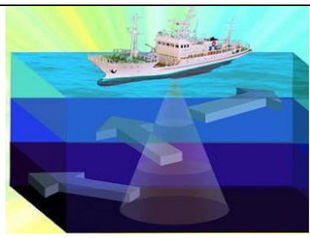


Figure 9. Blue print and instruments of marine weather observing ship of NIMS

Table 3. Instruments and pictures of Marine Weather Observing ship

 AWS	 PM10	 ADCP/PDR
 ASAP	 CTD	 DCS
 WAVEX	 Wave-Rider Buoy	 Visibility sensor

Mobile Observation Vehicle

NIMS/KMA developed the mobile observation systems on which observations instruments installed. All mobile observation vehicles have sensors for wind, temperature and humidity. Two have radiosonde and GNSS receiver, and the other one have lidar observing system.

Figure 10. The mobile observation vehicles to support Pyeongchang 2018 winter games

Non-synoptic observation(Research) sites

The cloud physics observatory near Ski jump venue are managed by many remote-sensing instruments (Micro Rain Radar(MRR), Optical Rain Guage (ORG), Ceilometer, Microwave Radiometer, etc., see Figure 8). New research site on Ski jump venue is established with remote sensing instruments(MRR, ORG, Parsivel-2, GNSS) on Mar. 2015.

Figure 11. Observation Instruments on Cloud Physics Observatory(CPO)