Introduction of the NIMS/KMA Research Aircraft

Preliminary Result of Snow Enhancement Experiment in Pyeongchang region

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7 August 2018

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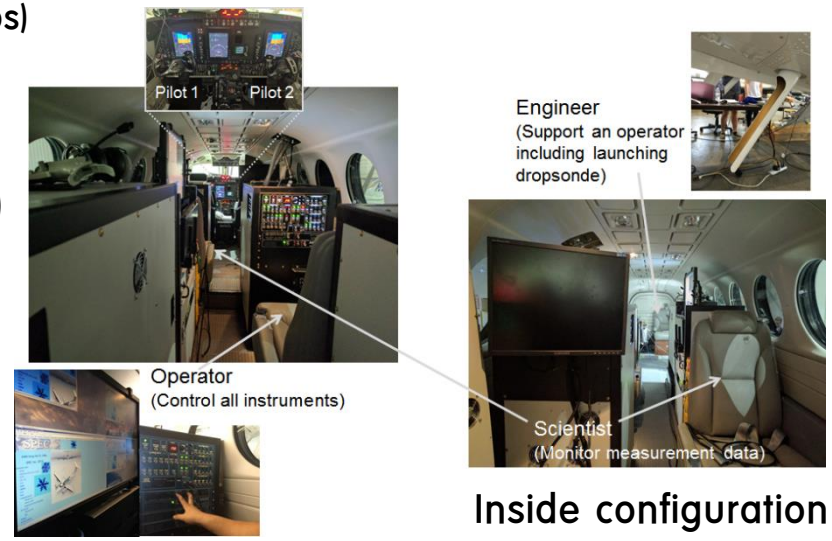
Introduction

- The NIMS/KMA can be limited to improve understanding of meteorological phenomenon and improvement of numerical model performance because of the lack of atmospheric observation data compared to the ground-based observation network.
- In addition, there is a demand for practical application technology of national weather modification to cope with climate change due to global warming and to secure water resources that are getting scarce.

Improvement of information on clouds and development of cloud seeding techniques

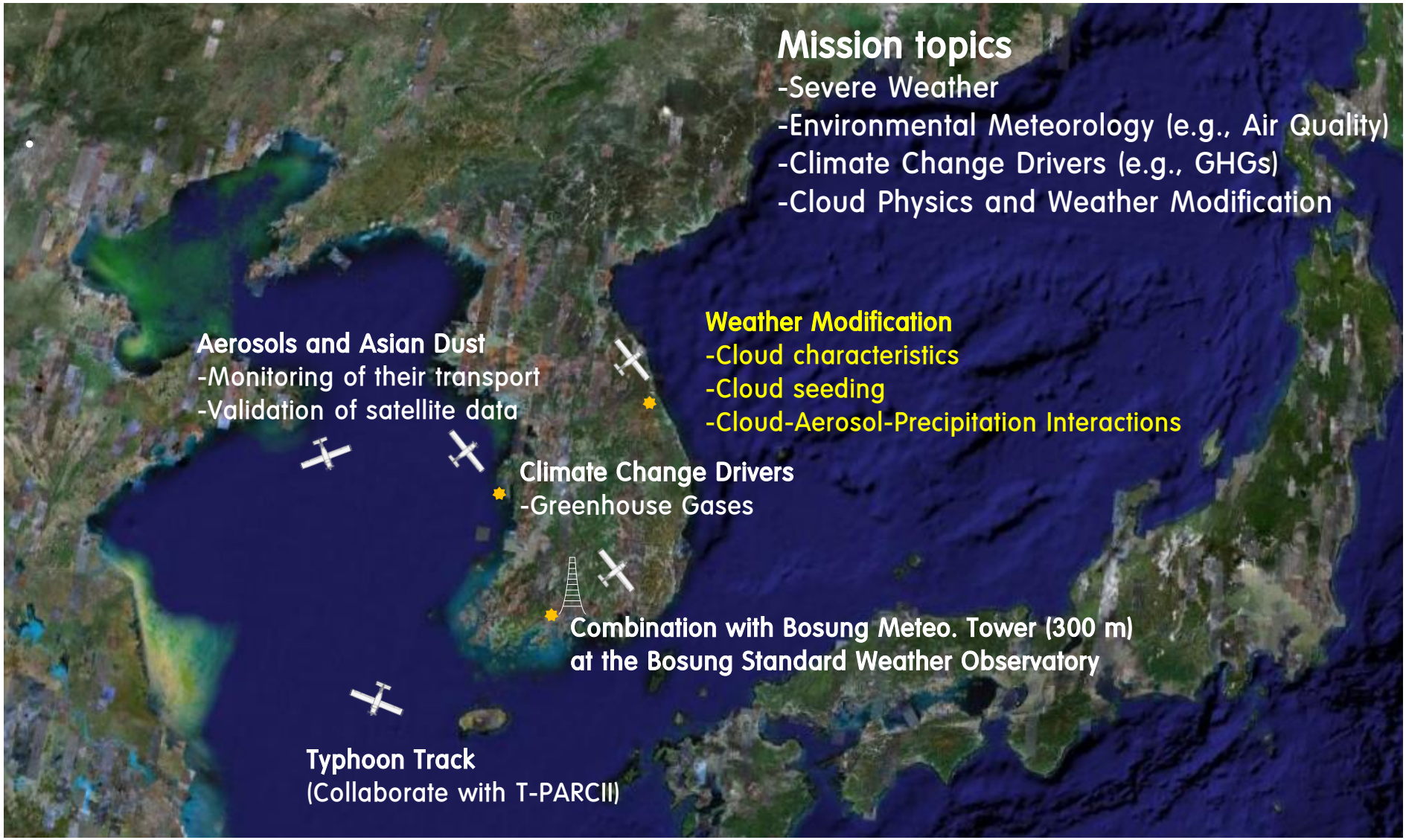
Aircraft Specifications

- **Identification**
  - Type: KingAir 350HW
  - Manufacturer: Beechcraft(USA)
  - Engine category: Turbo-prop
- **Flying performance**
  - Size (L/W/H) : 14.22 / 17.65 / 4.37 m
  - Max ceiling(altitude)
    - 35,000ft (~10.7km)
    - 25,000ft (~7.6km) with maximum payload(3,611lbs)
  - Maximum take-off payload: 16,500lbs(7,425kg)
  - Scientific payload: 3,410lbs (1,534kg)
  - Maximum speed : 312 KTAS (578 km/h at no payload)
  - Range: 1,550nm (2,871km at maximum payload)
  - Endurance(Max): 7.2hrs (with 45min. reserve fuel)
- **Crew and scientists on board**
  - Pilot(2), Operator(1), Engineer(1), Scientist(1)



Inside configuration

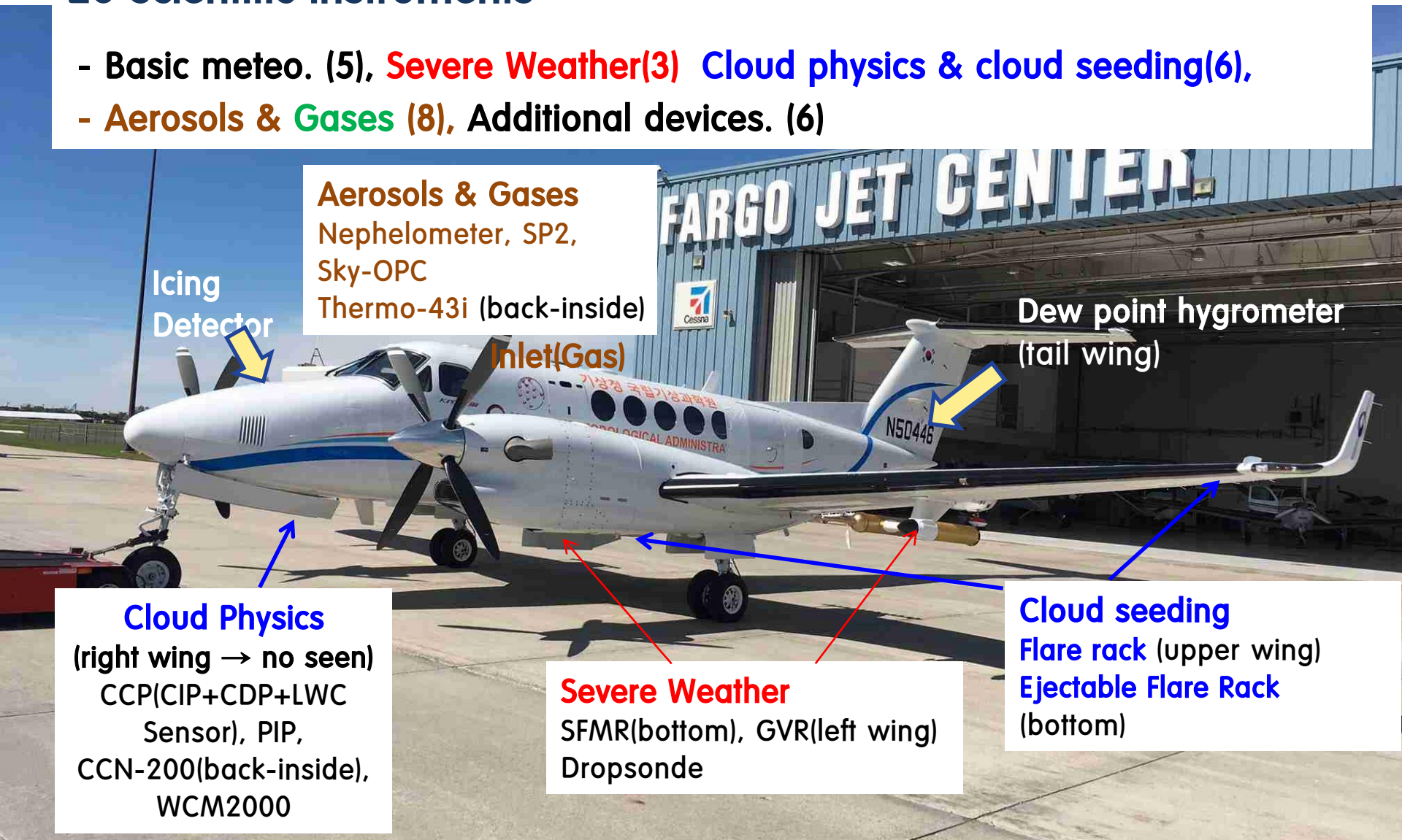
Missions: Overall



Deployment of scientific instruments

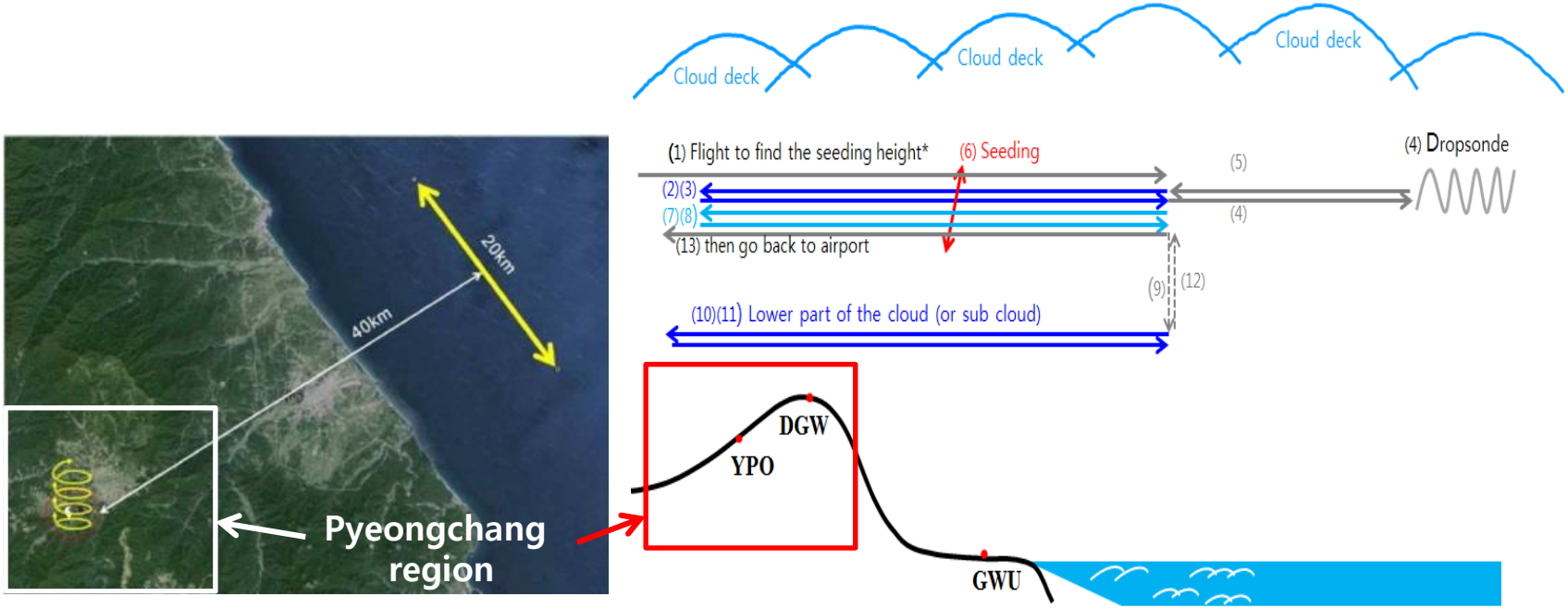
28 scientific instruments

- Basic meteo. (5), Severe Weather(3) Cloud physics & cloud seeding(6),
- Aerosols & Gases (8), Additional devices. (6)



Method

- **Target area**: Pyeongchang region (mountain area in northeast of South Korea)
- **Seeding process** : Weather condition monitoring → Design of seeding path → Seeding
  -perpendicular to wind direction of the upstream area.
  -distance (seeding path ~ target area): considering wind speed, fall velocity of snowfall
  -penetrated into the clouds along the seeding path
  -seeding agent: AgI of burn-in-place flare by ICE Inc. (150g). It was diffused in the clouds



Example of flight pattern for measurements of cloud properties and cloud seeding

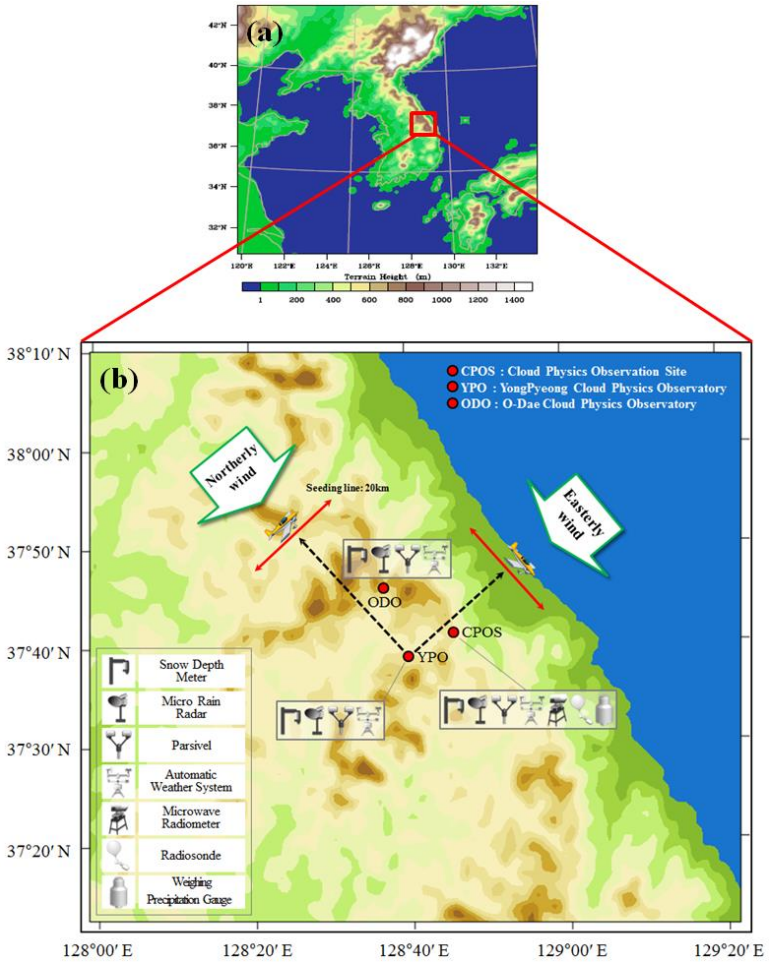
Method

Condition

1) When clouds are on the mountains in the easterly and northerly wind
2) Wind speed: below 20 m/s
   (Gangneung Wind Profiler and Radiosonde)
3) Cloud top Temperature: -5 ~ -10℃
4) Liquid water content: above 0.1 g/m^3

Validation

1) no natural precipitation
2) seeding material remains in the target area during the seeding effect from the diffusion model (WRF V3.5.1)
3) precipitation increases on the ground
4) when additional evidence such as cloud development and precipitation particle number concentration increase on the downwind side to support the increase of precipitation.



- Main observational sites : Daegwallyeong (CPOS), Yongpyong (YPO), Odaesan (ODO)
- Instruments: Snow depth meter, Optical disdrometer (Parsivel), X-band radar, etc

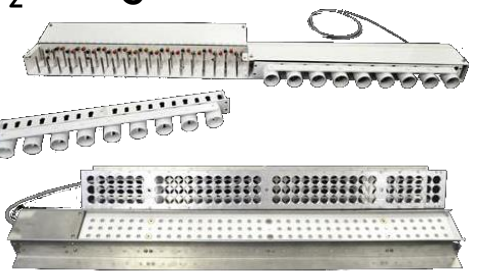
Instruments in the aircraft

*ADPAA
(Airborne Data Processing Analysis) software (Delene, 2011).

CCN-200
Number conc. of cloud condensation nuclei
- 0.75~10 μm (20bins)
Super sat. range: 0.07~2%

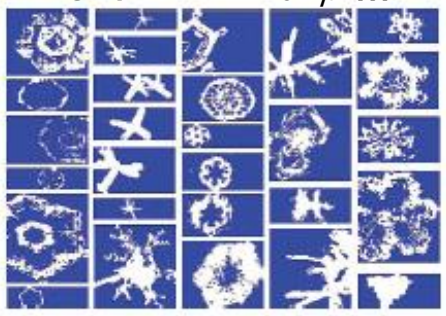
WCM-2000
LWC, TWC

Flares
24 burn-in-place flares ($CaCl_2$ or AgI)

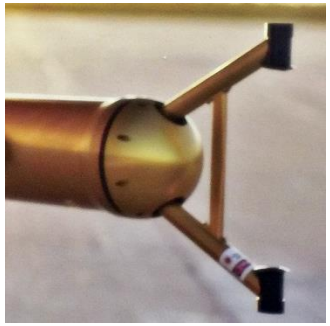


102 Ejectable flares (AgI)

CCP
Size distribution of cloud & ice particles
- CIP : 7.5 ~ 930 μm
- CDP : 2 ~ 50 μm

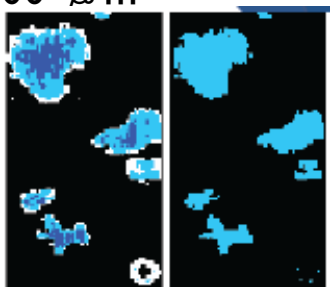


Channels	Size Range	Res.
CIP	12.5~1,550 μm	25 μm
	7.5~930 μm	15 μm
CDP	2~50 μm	
LWC	0~3 g/m3	



PIP
SD of large-size cloud particles & raindrops
- 100 ~ 6,200 μm

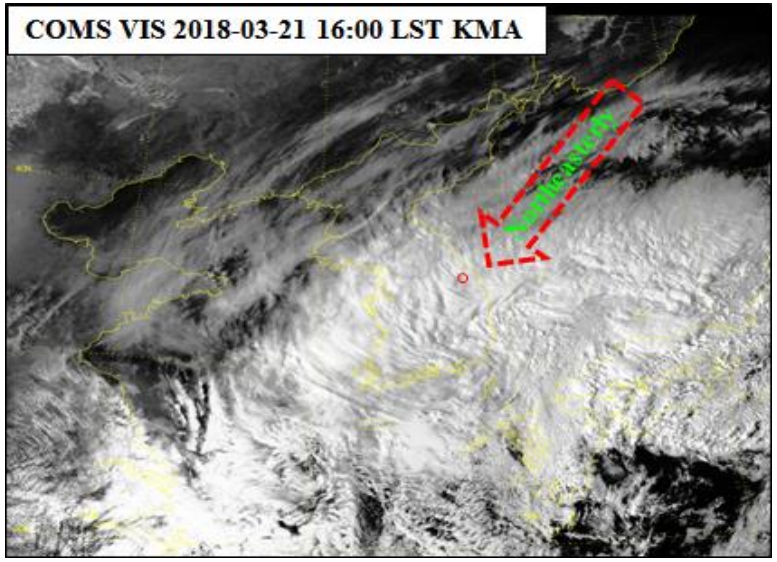
rain, snow, graupel and hail



Airborne Cloud Seeding and Observation

Mission	No. Flight	Date	Time (LST)	Region	Weather condition
Snow Enhancement	SE01	1.30	16:15~19:00 (02:45)	Pyeongchang	Snowfall Cloud altitude: ~2.1km
	SE02	3.21	14:44~18:13 (03:29)	Pyeongchang	Cloud altitude: 2.1~4.0km WD: Southern, WS: 15m/s
Cloud Physics observation and/or Drop-sonde launch	CP01	2.28	13:55~16:44 (02:49)	From Pyeongchang to east sea	Cloud altitude: 0.9~8.8km (almost flight in the clouds) WD: Southwest/ WS: 28m/s at 6.1km altitude Icing and turbulence at < 2.4km
	CP02	3.08	13:39~16:58 (03:19)	From Pyeongchang to east sea	Cloud altitude: 9.1~9.4km (a little icing) WD: South, / WS: 40m/s at 6.1km altitude, WD: western, / WS: 50m/s at 8.8km altitude
	CP03	3.15	12:53~15:16 (02:23)	Pyeongchang	Cloud altitude: 0.2~3.0km (moderately flight in the clouds) WD: western, / WS: 15m/s

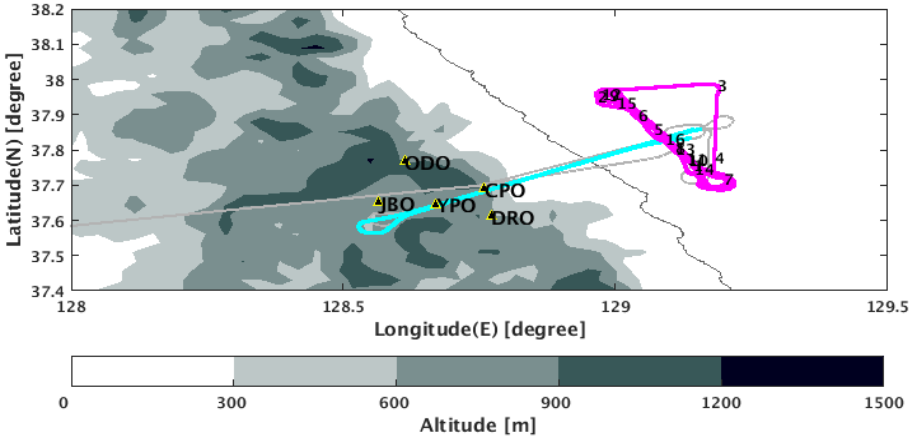
A Case study (2018. 3. 21): Snow Enhancement Exp.



Seeding
(16:50:27 LST)

After seeding
(17:29:36 LST)

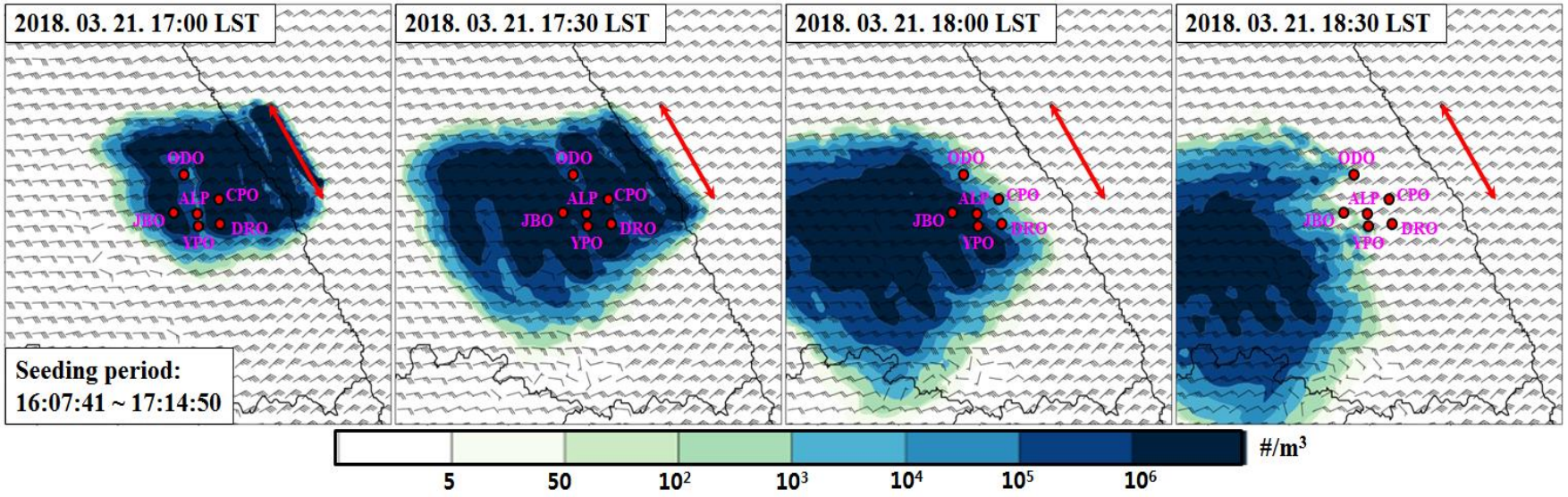
- Weather condition
  - Cloud type : Stratus
  - Wind : Northeasterly wind, 12 m/s
  - Temperature : -9 ℃ at seeding height
  - Cloud top height : 8.0 km
  - LWC at seeding height : ≥ 0.5 g/m^3
  - Seeding height (mean) : 2.1 km



- *Linear seeding repetition (AgI Burn-in-place, 16 times seeding) at 2 km altitude and straight observation to the downwind side after seeding*

Diffusion simulation results

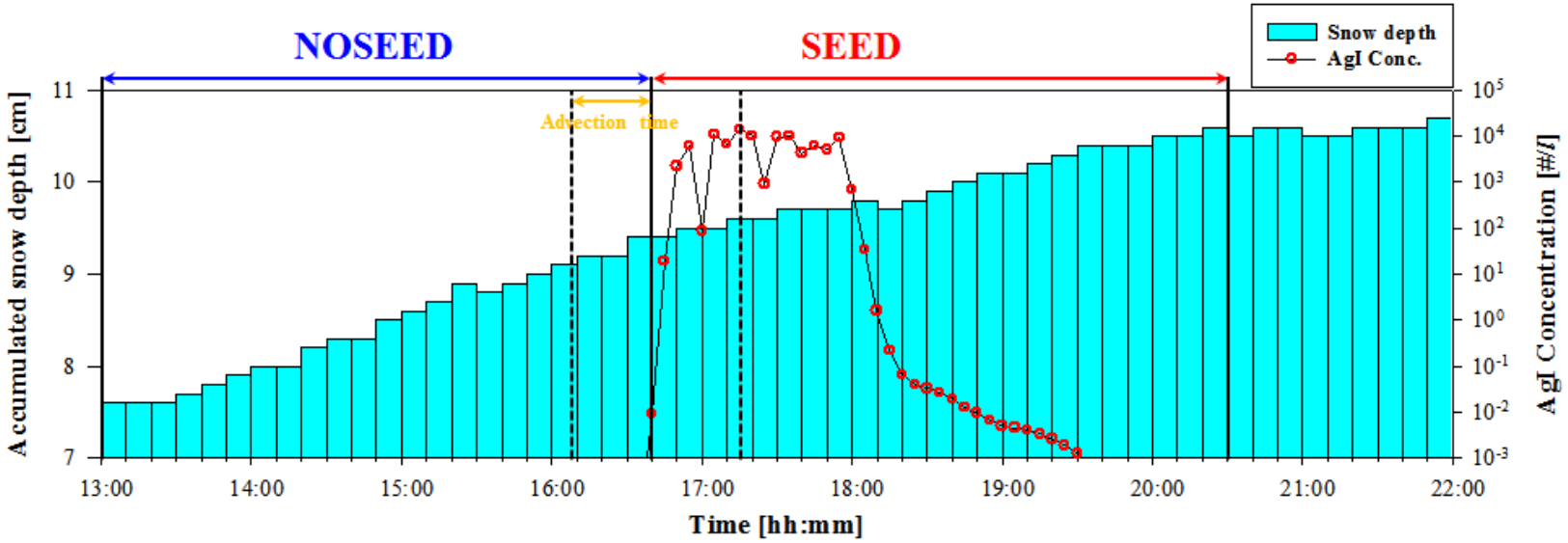
Seeding line (red arrow line) and ground observation site (red dots)



- ***After seeding, moving and passing seed material to the downwind side target area by NE wind***
  -the presence of seeding material in the downstream area, 19:50(LST)

Time series of

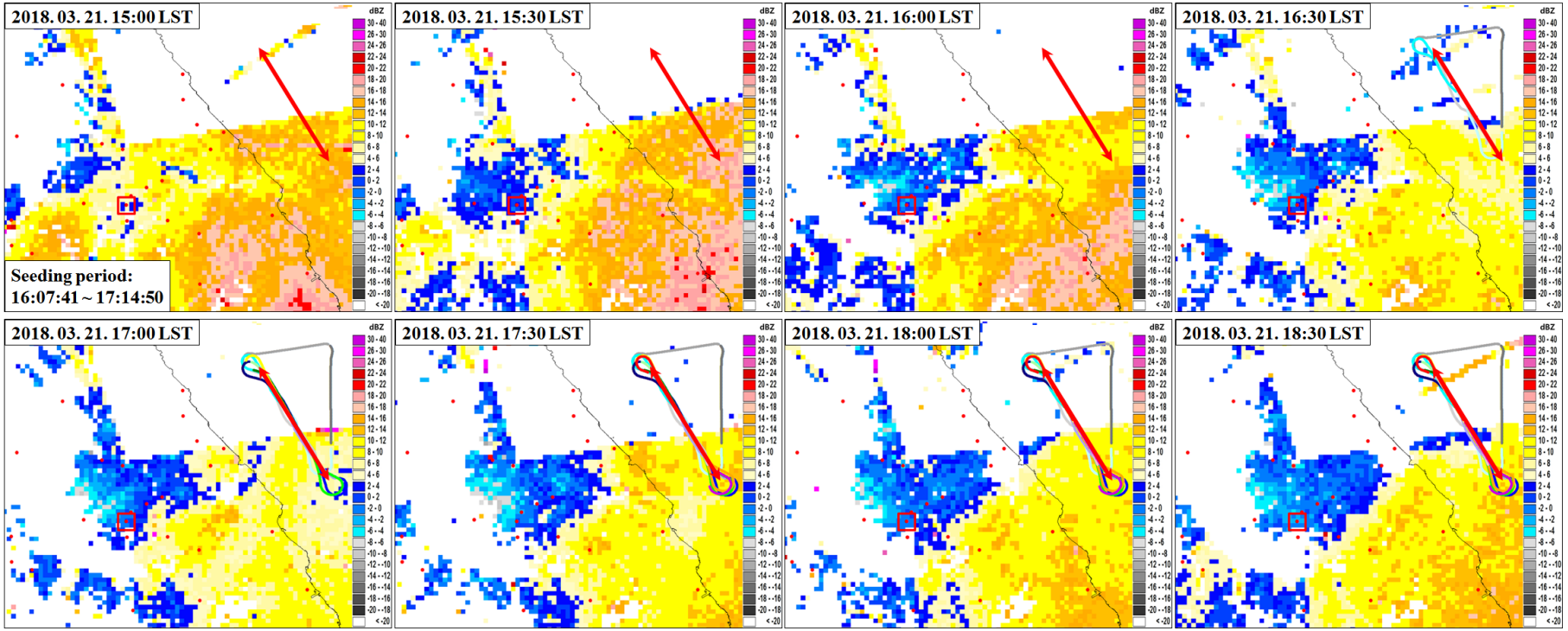
Amount of snowfall and the numerical simulated AgI concentration at target area



- *Increase of 1.2cm snowfall in target area within the time of seeding material effect*

Qced PPI 0.7 image from ground X-band Radar

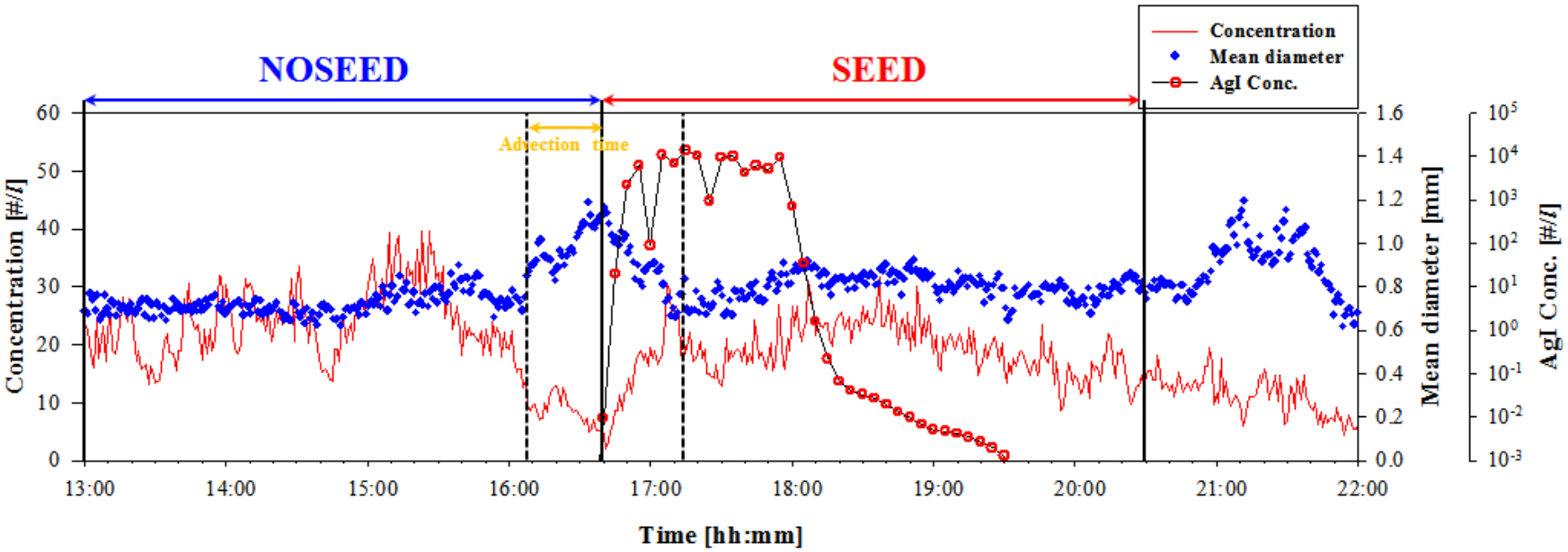
seeding line (red arrow line), target area (red box)



- ***No influx of natural precipitation into the target area before and after seeding***
  - *No increase in radar reflectivity over 4dBZ continuously over target area within the impact time of seeding material after seeding*
  - *After 5 hours after seeding (21:20 (LST)), natural precipitation has flowed in.*

Time series of

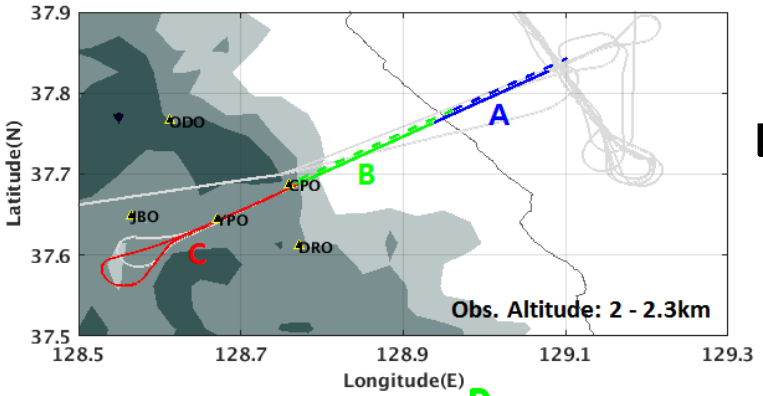
Total number concentration, Average diameter, and vertical total concentration of simulated AgI from ground to 2 km (MSL) at the target area



- *(Additional evidence) Increase in the number concentration of small precipitation particles of 1 mm or less in seeding material effect time after seeding*

Cloud and Precipitation particle size distribution

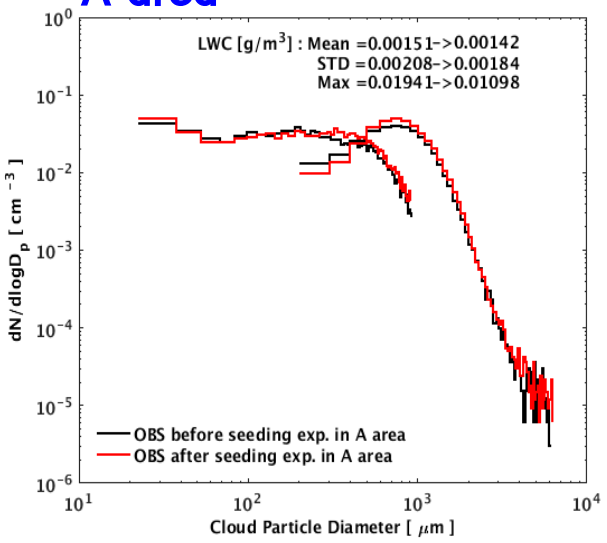
from CIP, PIP during straight line obs. before and after seeding



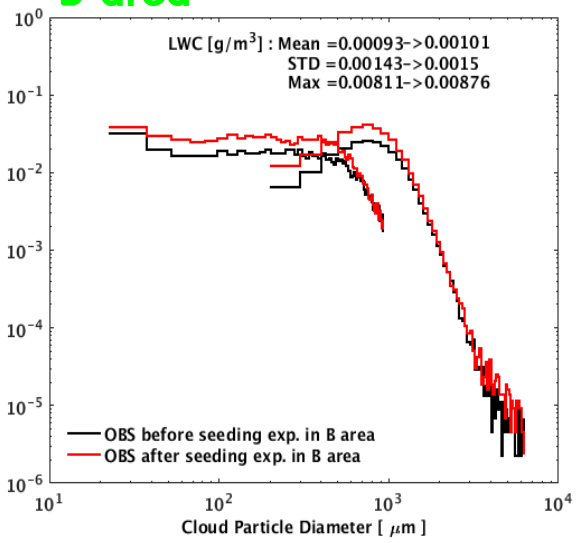
Linear observation Path

- Solid line : Before seeding
- Dotted line : After seeding

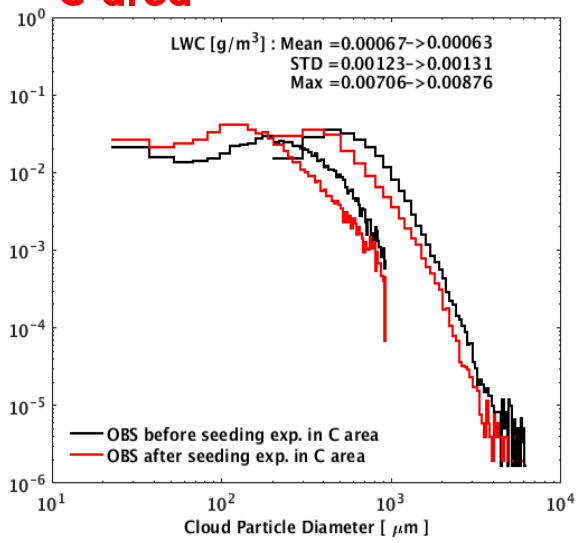
A area



B area



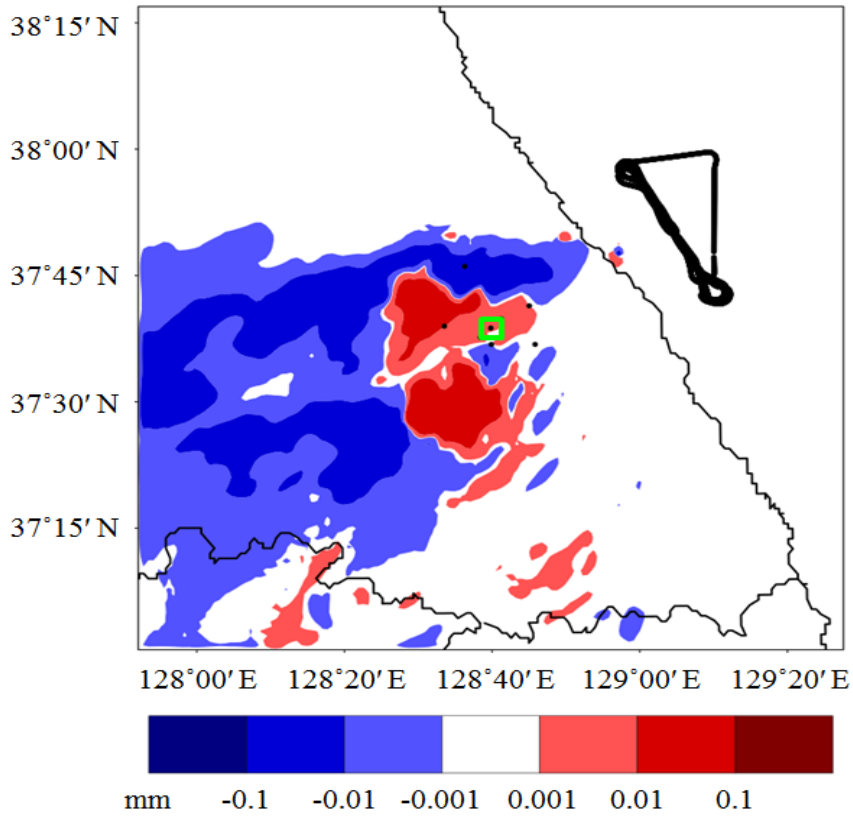
C area



- *(Additional evidence) Increase in the number concentration of small precipitation particles between 100 and 1000 ㎛ at a linear observation altitude after seeding*

Precipitation change simulation results

during 16:00 ~ 21:00 (LST) / Green box: Target area



- *(Additional evidence) Simulation results confirm the increase in precipitation near the target area (about 0.06 mm)*

Summary

- The weather aircraft on NIMS was introduced at the end of 2017 for missions on severe weather study, cloud physics & weather modification experiments, air quality monitoring, and greenhouse gas monitoring.

- We are focusing on the improvement of information on clouds and the development of cloud seeding techniques.

- We analyzed a case study of snow enhancement experiment in March 21, 2018. We seeded 16 times at 2 km altitude using a burn-in-place AgI Flare in the stratus over the east sea.

- The seeding effect was verified by WRF model, in-situ observation using the cloud probes of aircraft and ground-based remote sensing instruments. As a result, it was confirmed that snowfall increased 1.2 cm in Pyeongchang region

Thank you ;)

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