RECENT JAPANESE RESEARCH ON OROGRAPHIC SNOW CLOUD MODIFICATION FOR WATER RESOURCES AUGMENTATION

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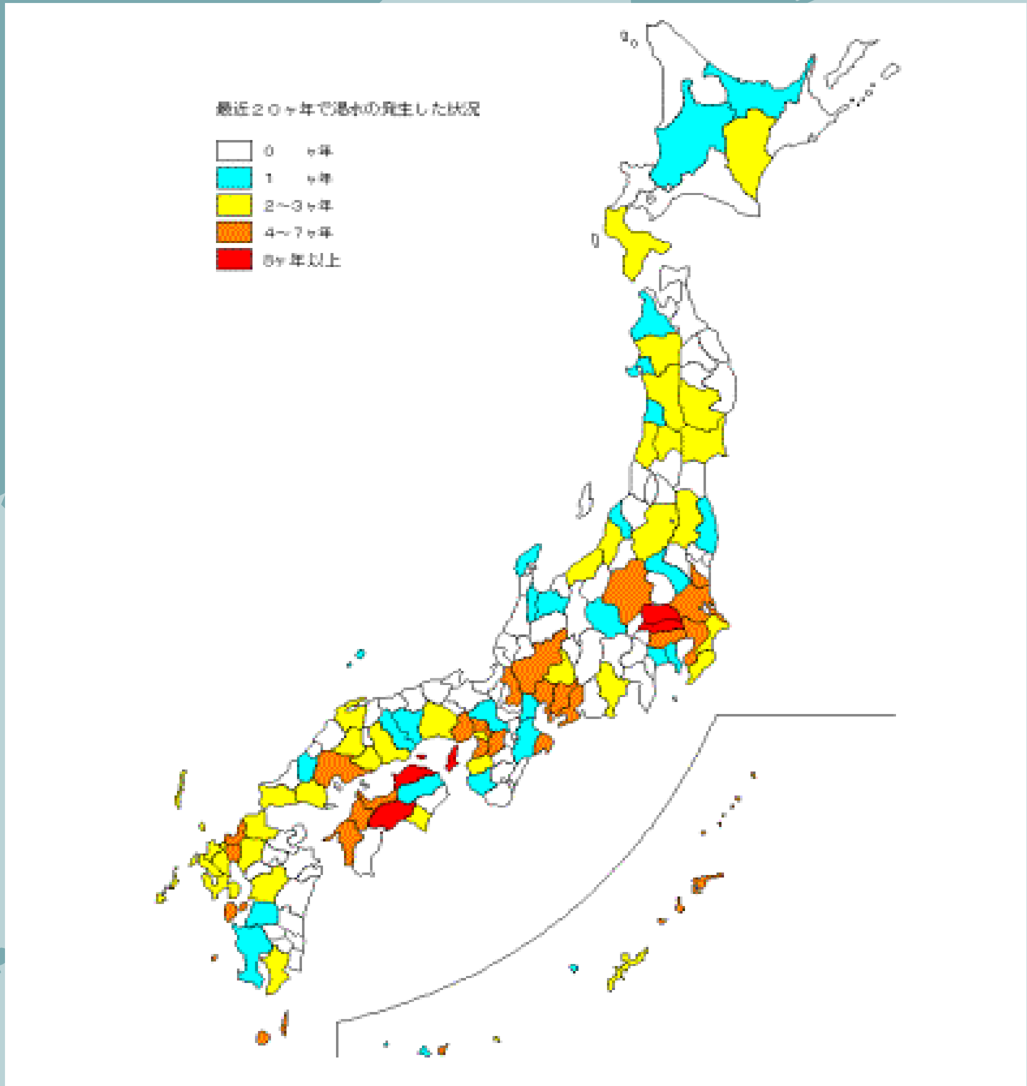
***Idea Co., LTD.

Occurrence frequency of water shortage in Japan　(1983-2002)



昭和58年から平成14年の間で、上水道について減断水のあった年数を図示したもの。

Orographic Snow Cloud Modification Project

(MRI, Tone River Dams Integrated Control Office)

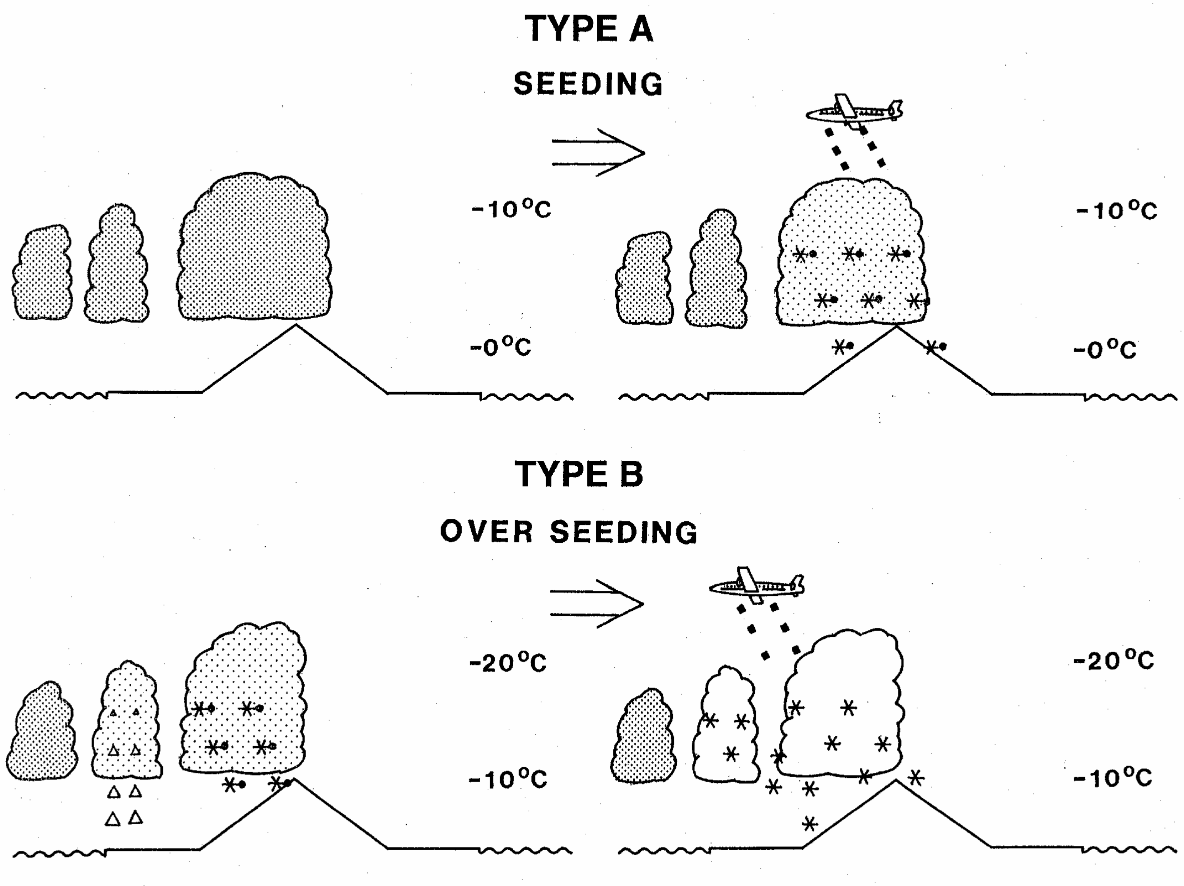
Feasibility Study (1990-1994)
Routinely available data, microwave radiometer

PHASE I (1994-1997)
HYVIS, rawinsonde, X-band Doppler radar,
ground-based microphysical obs. & microwave radiometer
Microphysical structures and seedability, No cloud seeding

PHASE II (1997-2000)
An instrumented aircraft (B200), HYVIS, X-band Doppler radar
Ka-band, instrumented 4-wheel drive van,
ground-based microphysical obs. & microwave radiometer
Small scale cloud seeding

PHASE III (2000-2003)
An instrumented aircraft (C404), a seeding aircraft, HYVIS,
X-band Doppler radar, Ka-band,
ground-based microphysical obs. & microwave radiometer
Small scale, repeated cloud seeding (still research basis)

Hypotheses of Snow Cloud Modification



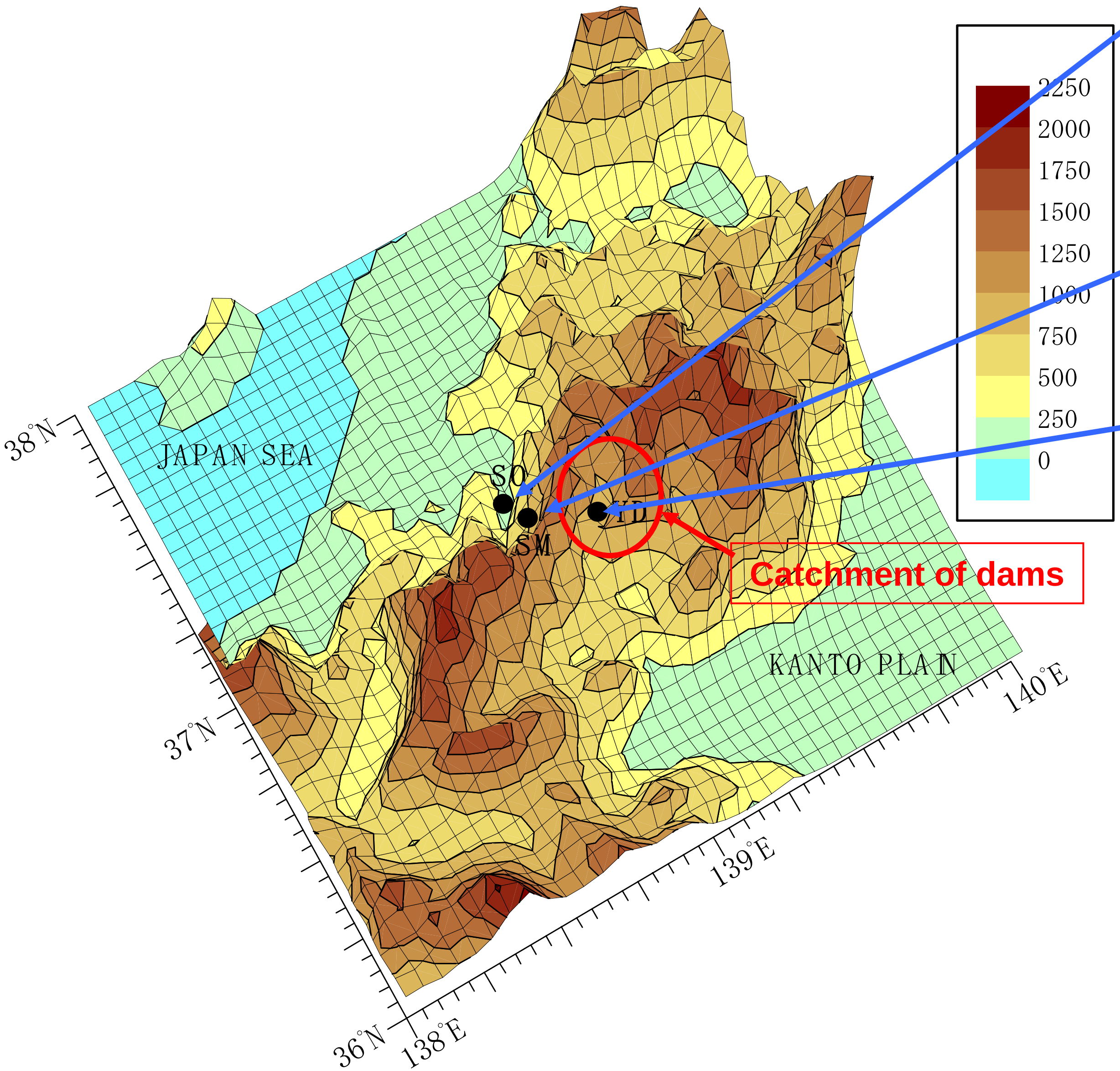
To seed snow clouds with warm top temp.

→ Augmentation of precip. (Type A)

To overseed graupel-forming snow clouds

→Shift the precip. area downwind (Type B)

Topography and Observation Facilities



Shiozawa site (SO)
- Microwave radiometer
- HYVIS
- x-band Doppler radar
- ka-band Doppler radar

Shimizu site (SM)
- Microwave radiometer
- Microphysical measurement

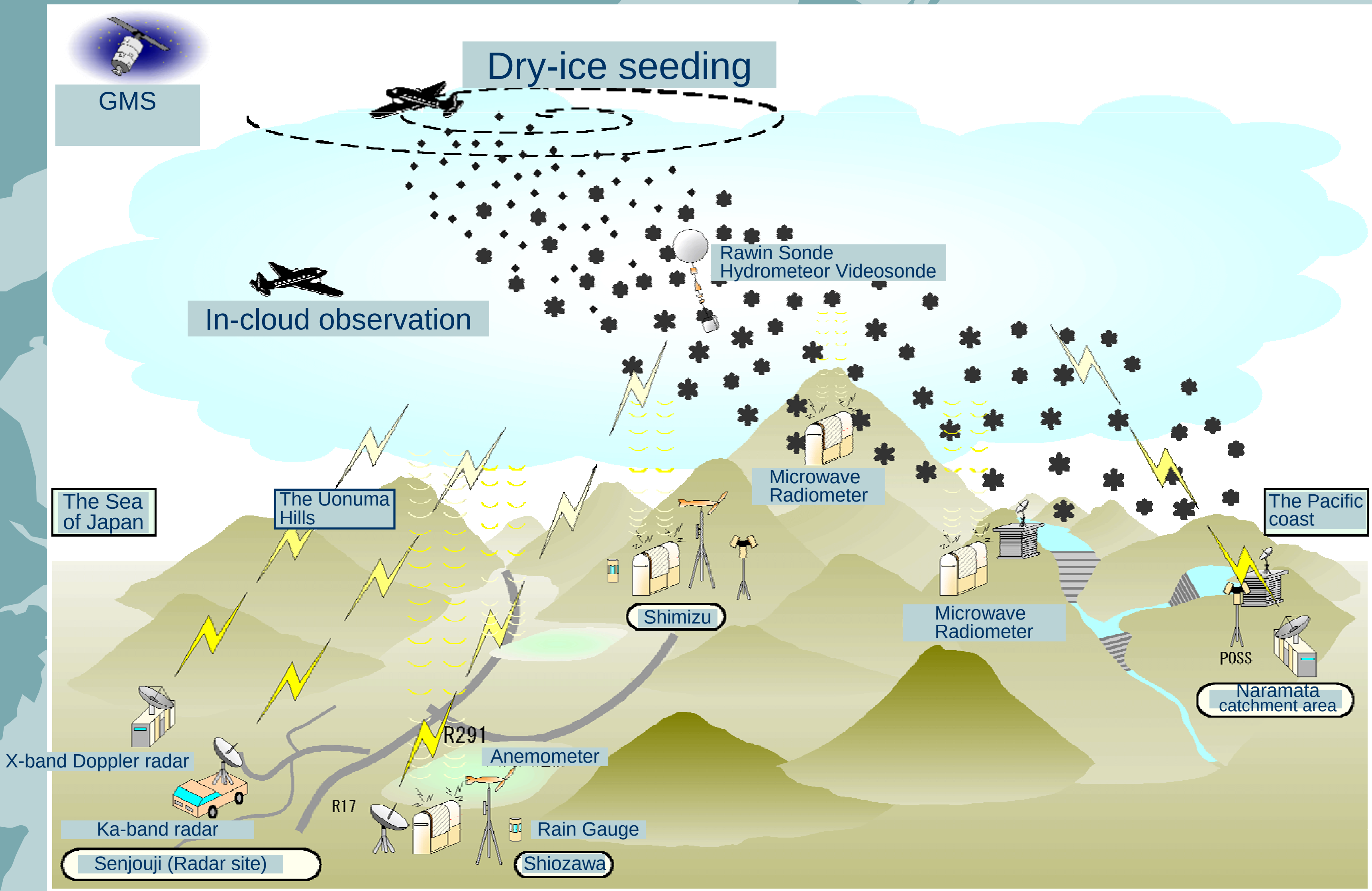
Yagisawa dam site (YD)
- Microwave radiometer
- x-band Doppler radar (2001)
- ka-band Doppler radar (2001)
- Microphysical measurement

Aircraft for in-situ measurement

(operated from Niigata AP)

Aircraft for cloud seeding
(operated from Nagoya AP)

Orographic Snow Cloud Modification Project
(MRI, Tone River Dams Integrated Control Office)



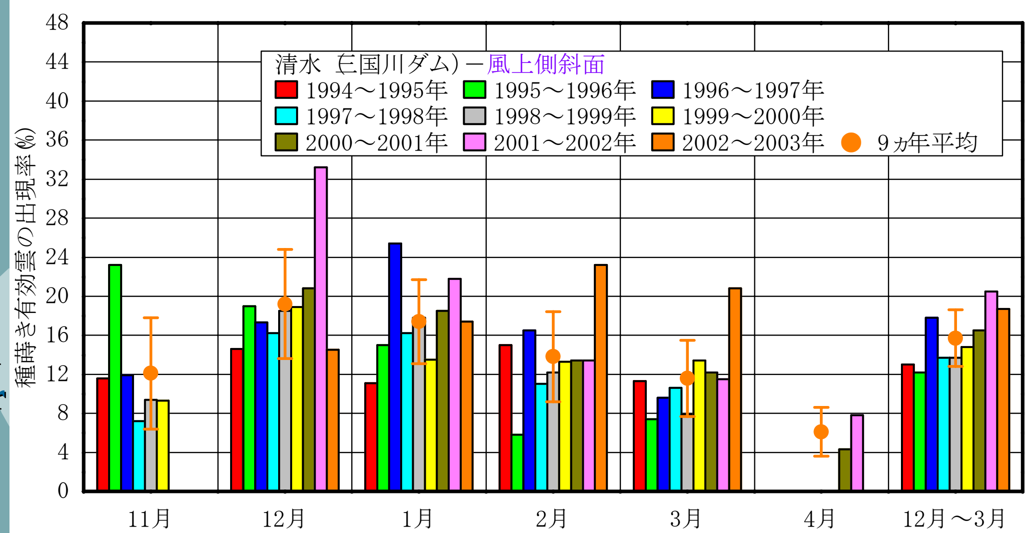
Observation Facilities

INNER STRUCTURES OF OROGRAPHIC SNOW CLOUDS (HYVIS Obs.)

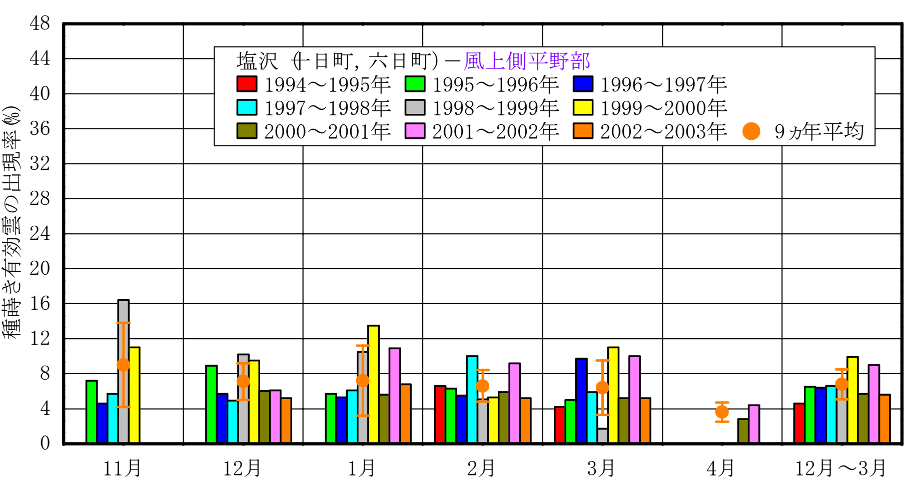
Monthly appearance Freq. of Clouds with High Seedability

DEFINITION
Ttop: －5～－25℃
Htop > 2.5km
Cloud amount > 9/10
1hr ave. LWP > 0.2mm

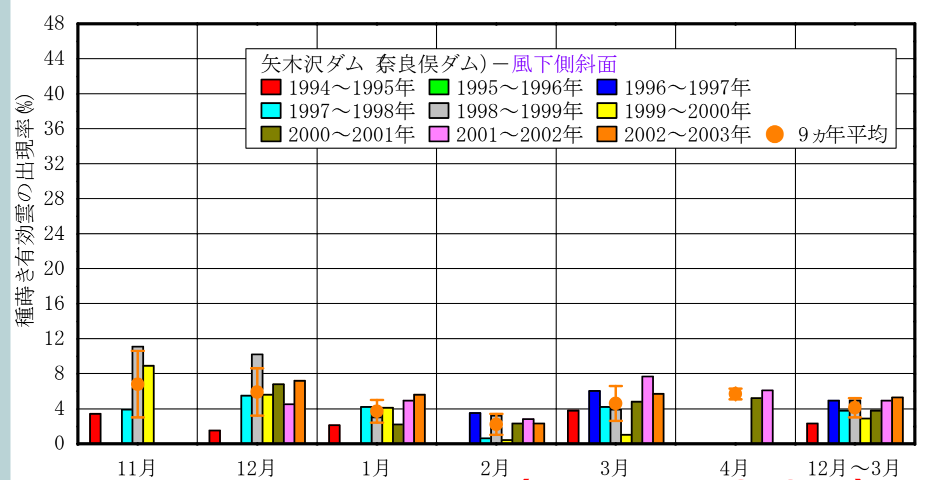
METHOD
Ttop,Htop,CA < GMS IR data
LWP < Microwave radiometer



SM (WINDWARD SLOPE)



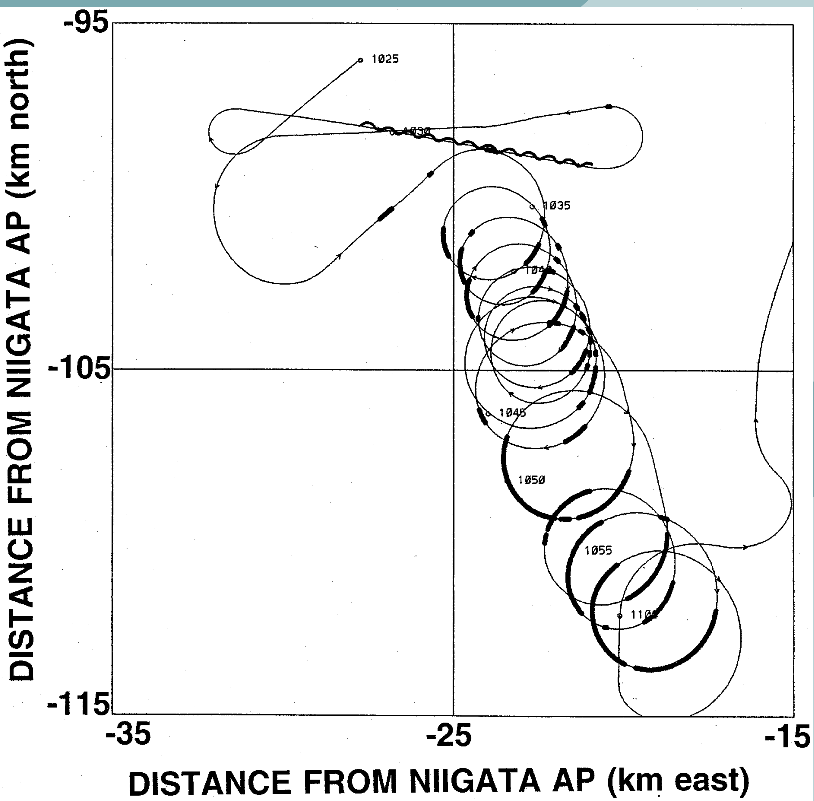
SO (WINDWARD FOOT)

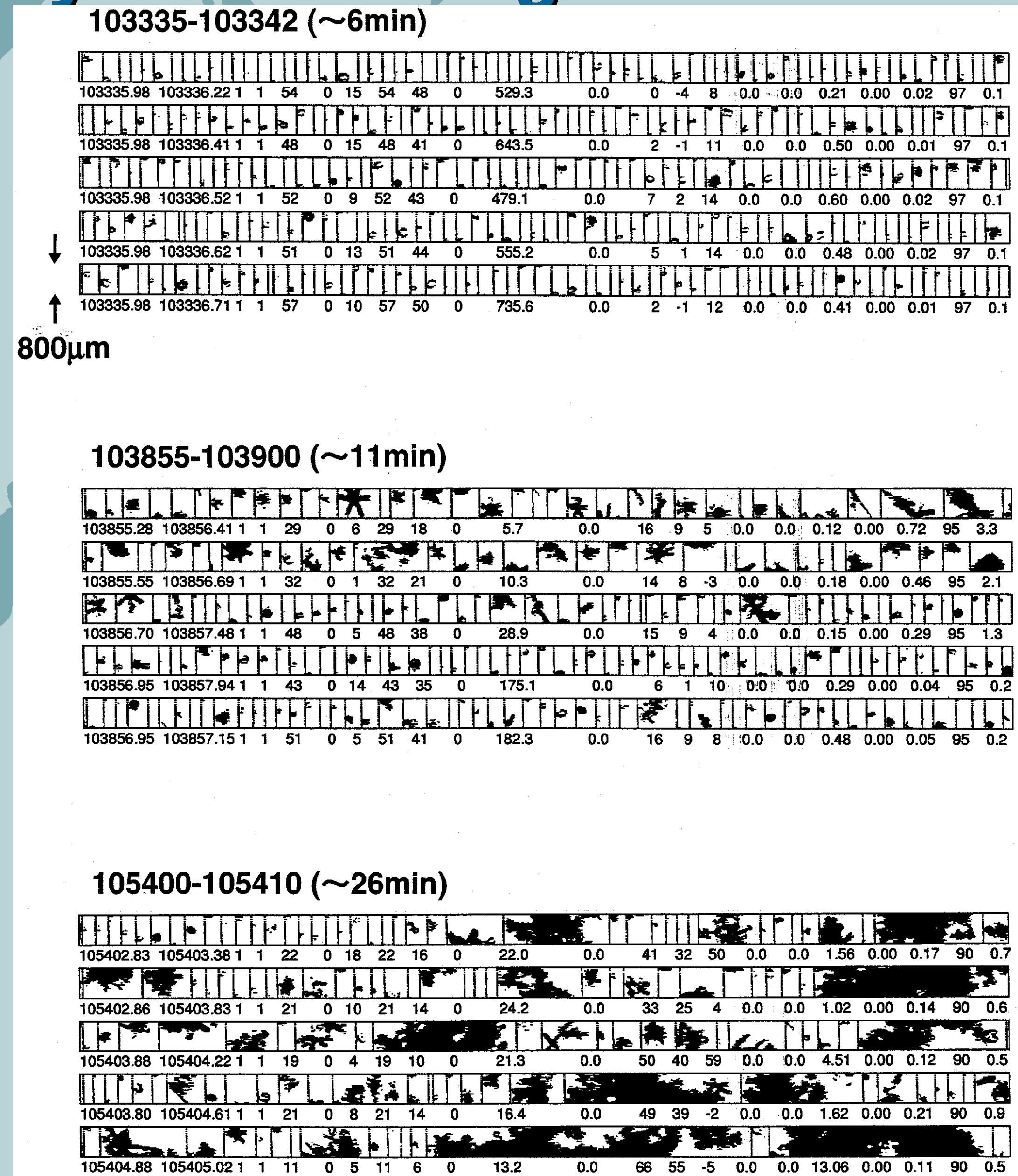


YD (LEEWARD SLOPE)

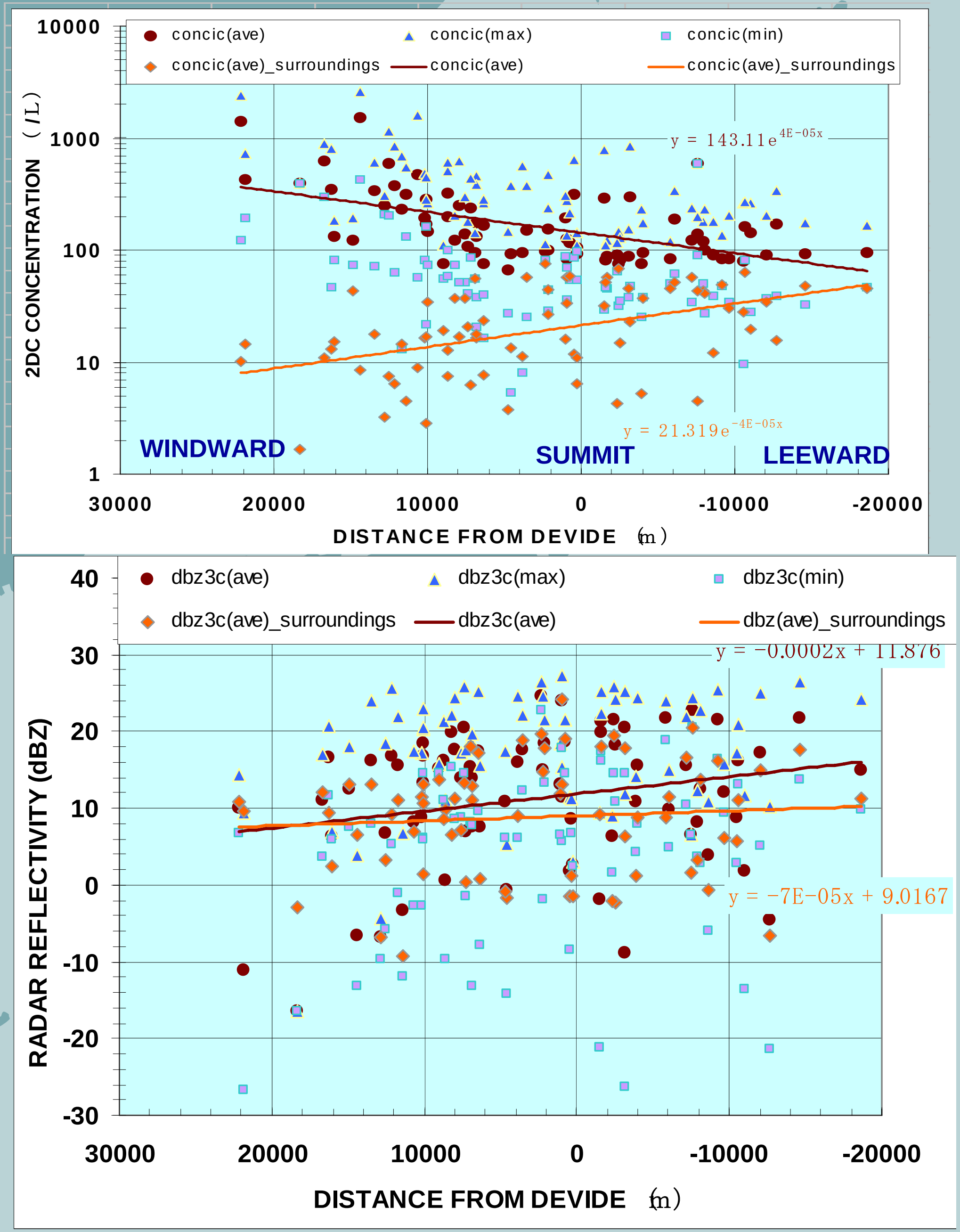
A/C SEEDING EXPERIMENT

Changes in Microphysical Structures Due to Dry-Ice Seeding

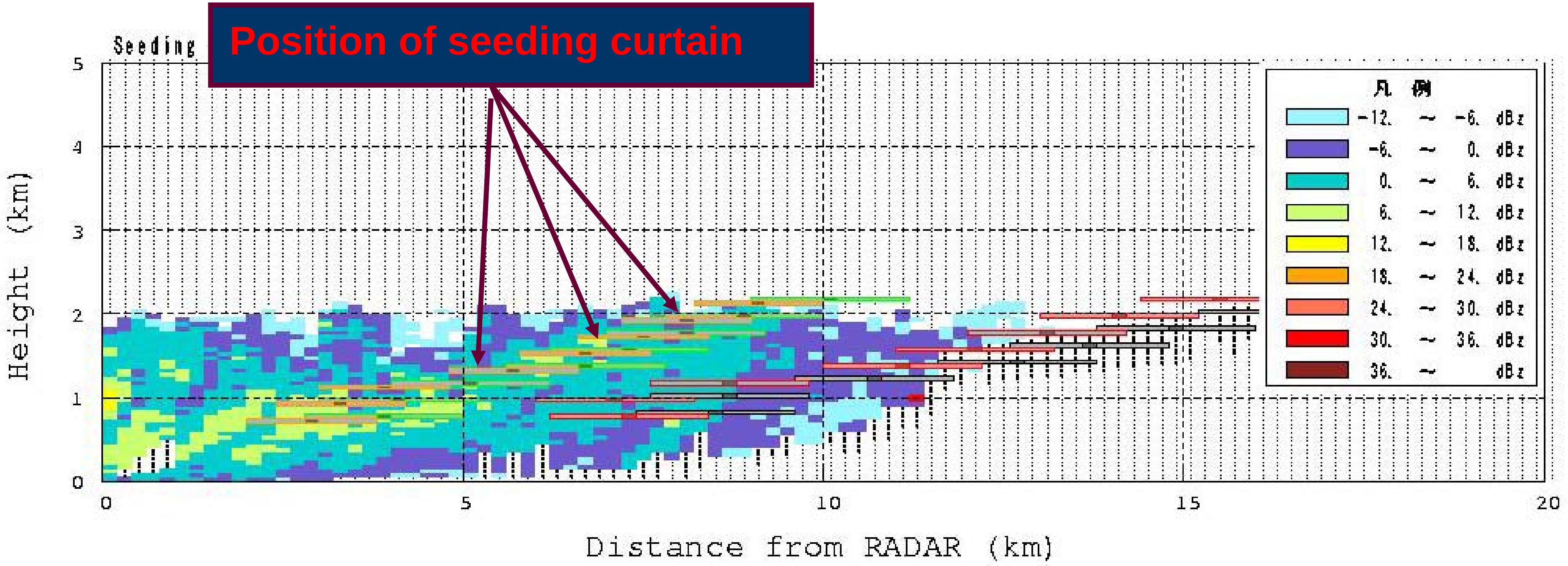




Changes in 2DC Conc. and Reflectivity due to Dry-Ice Seeding



RHI of Ka-band Radar Reflectivity and Expected Position of Seeding Curtains



Model Description

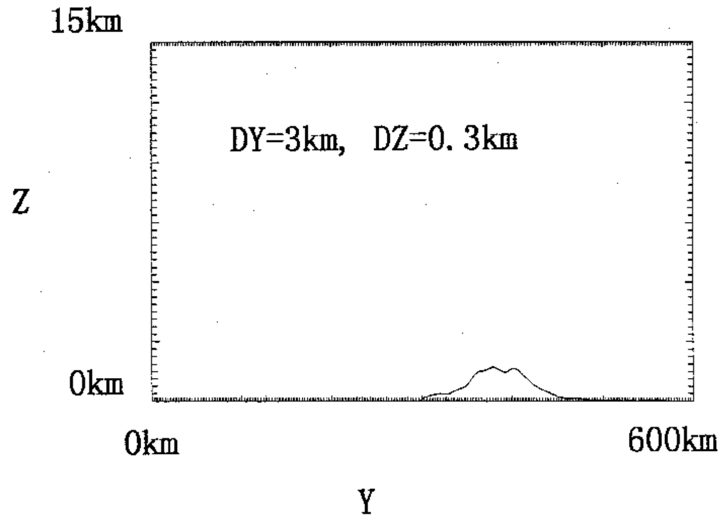
MODEL

Dynamics: 2D version of dynamic cloud model (Clark, 1977)

Microphysics: 2-moment bulk parameterization (Murakami, 1990, 1994)

DOMAIN

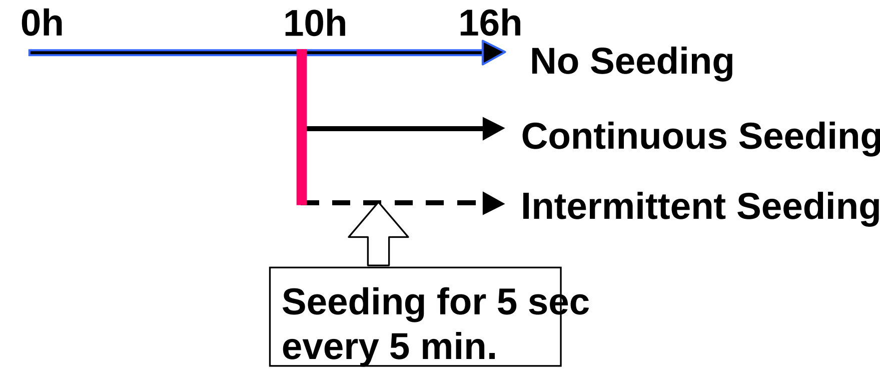
NW-SE cross section passing through SD

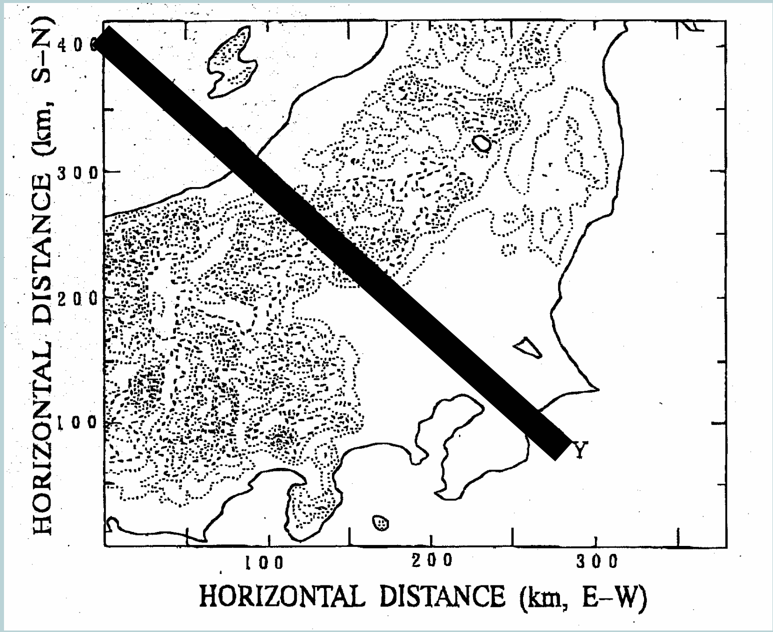


INITIAL

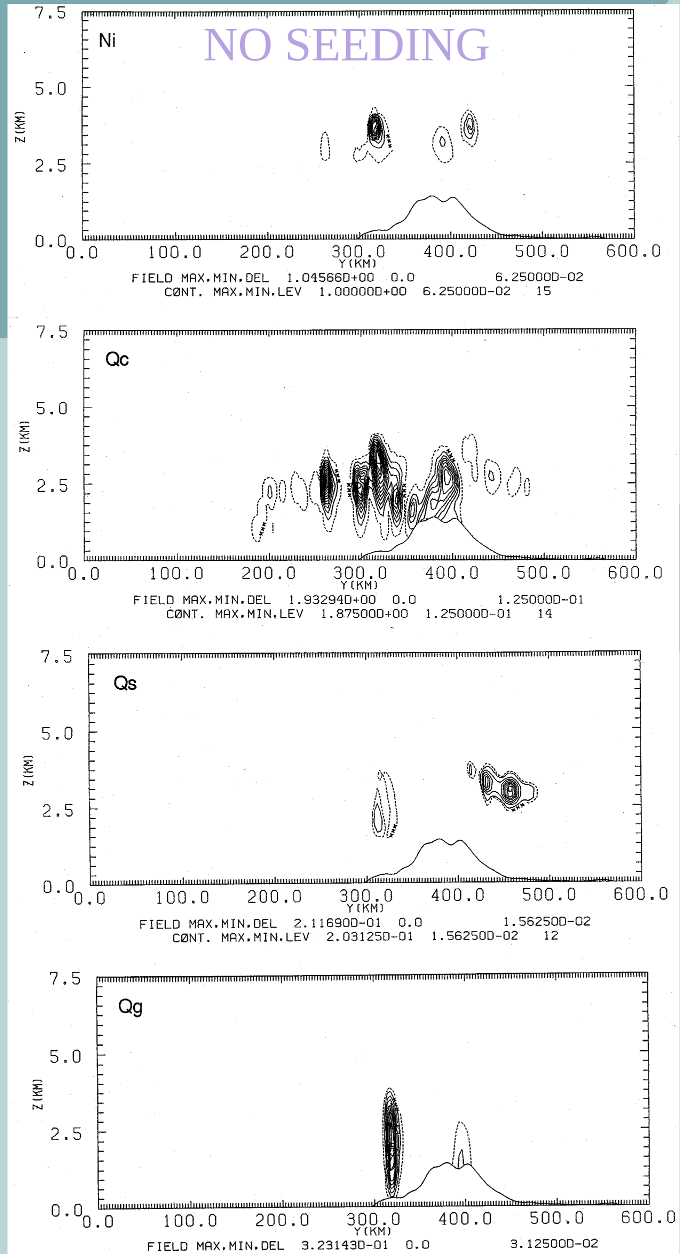
1500 JST on 11 Dec. 1996 (GANAL by JMA)

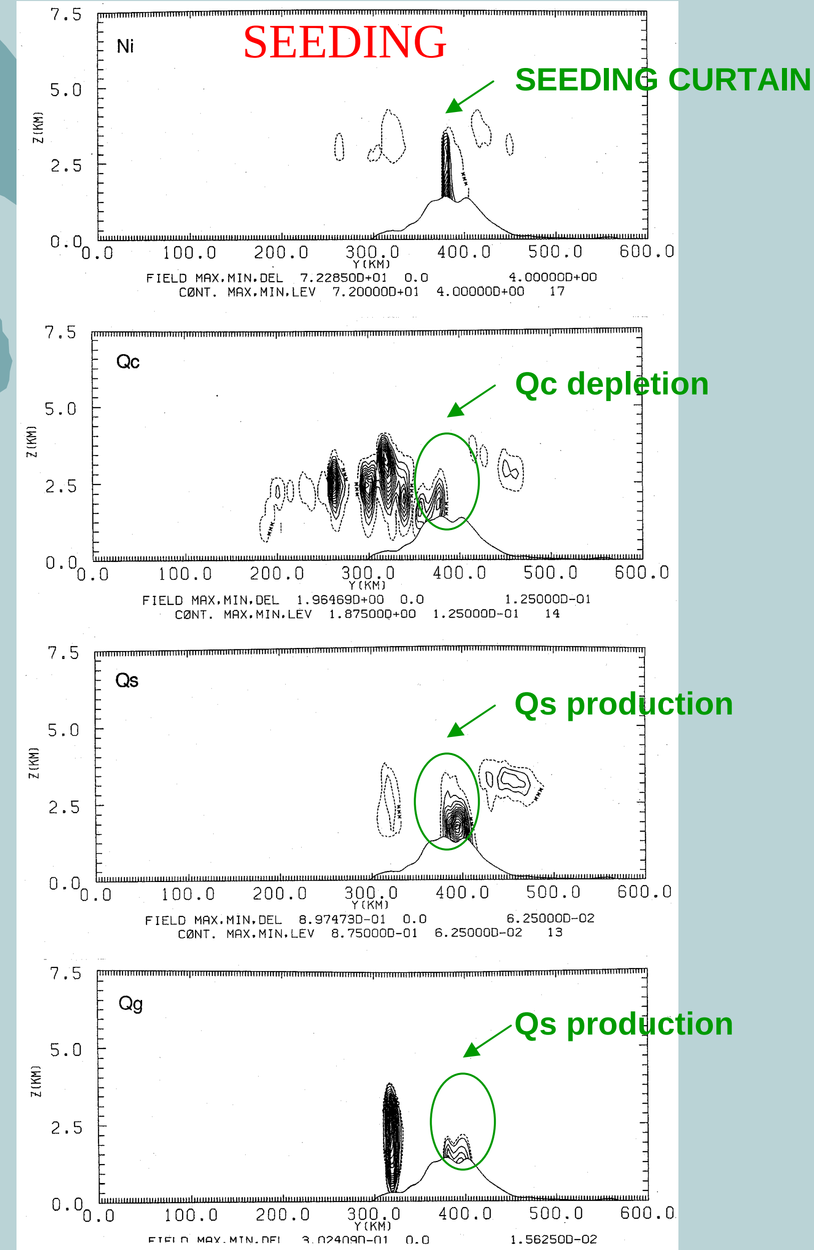
EXPERIMENT



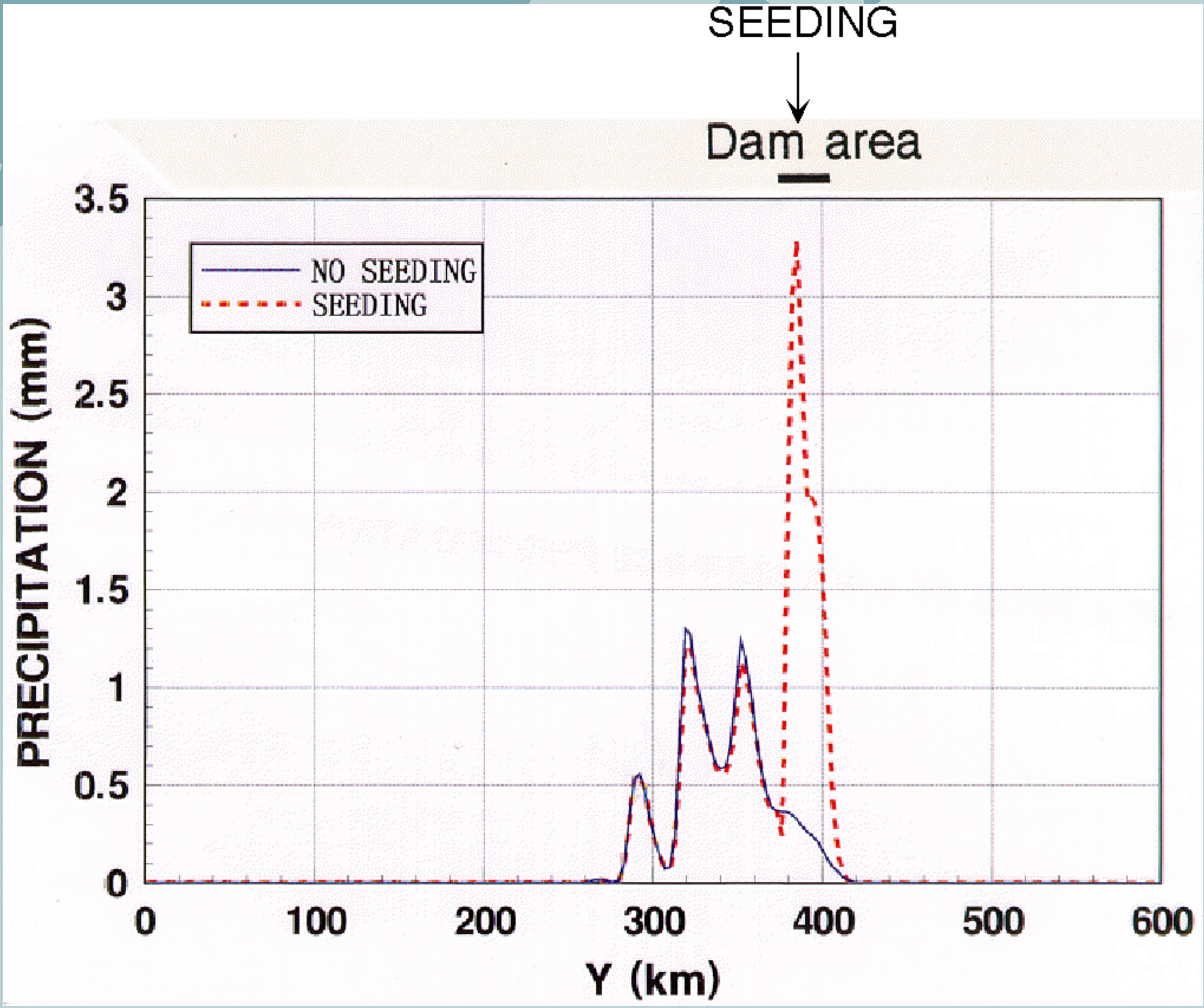


Vertical Cross Section of Snow Clouds





Seeding Effects on Surface Precip.



Sensitivity Experiments

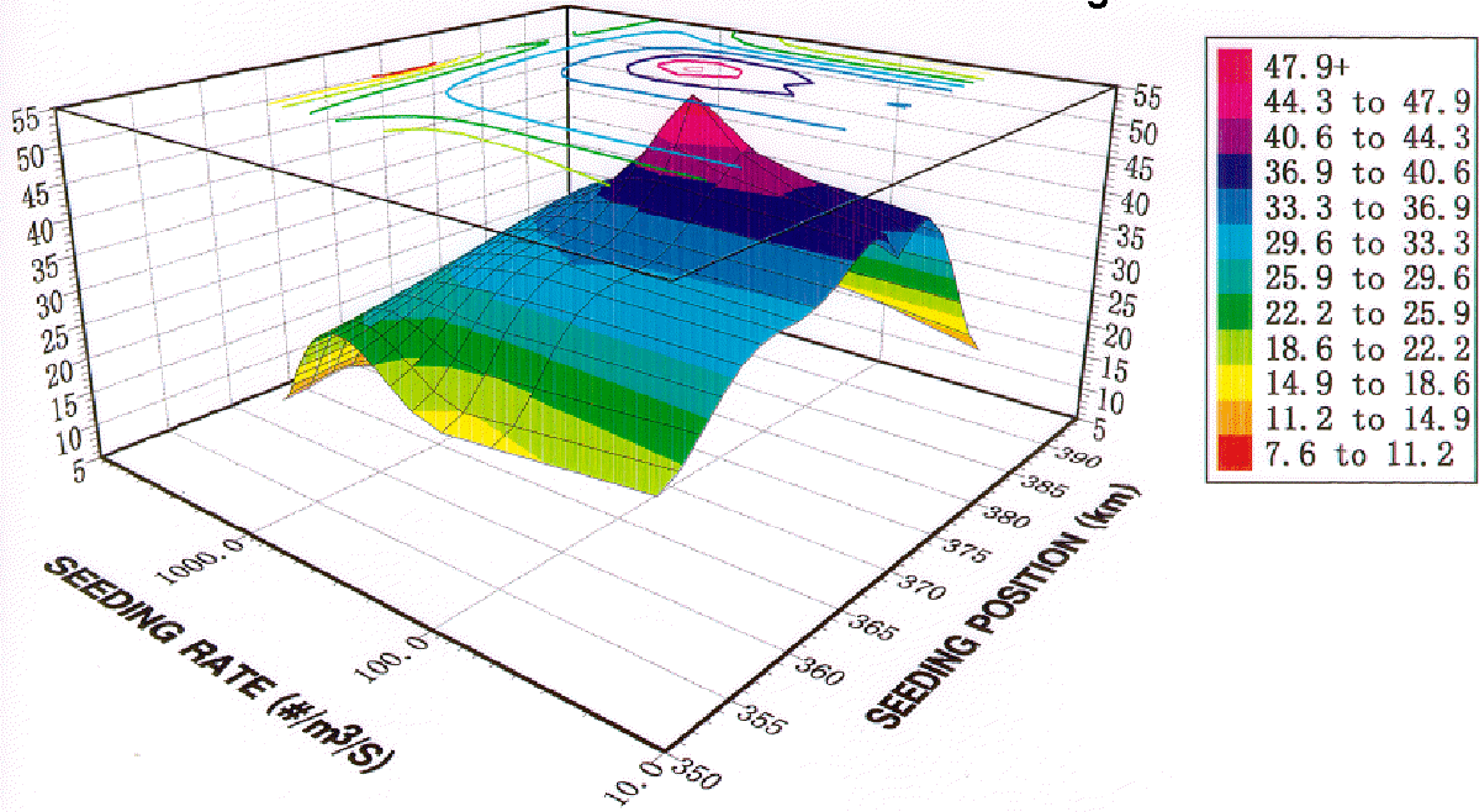
PRECIPITATION AMOUNT (×10^4 tons/4hr)
OVER THE CATCHMENT (21 km×10 km)

Optimum seeding condition

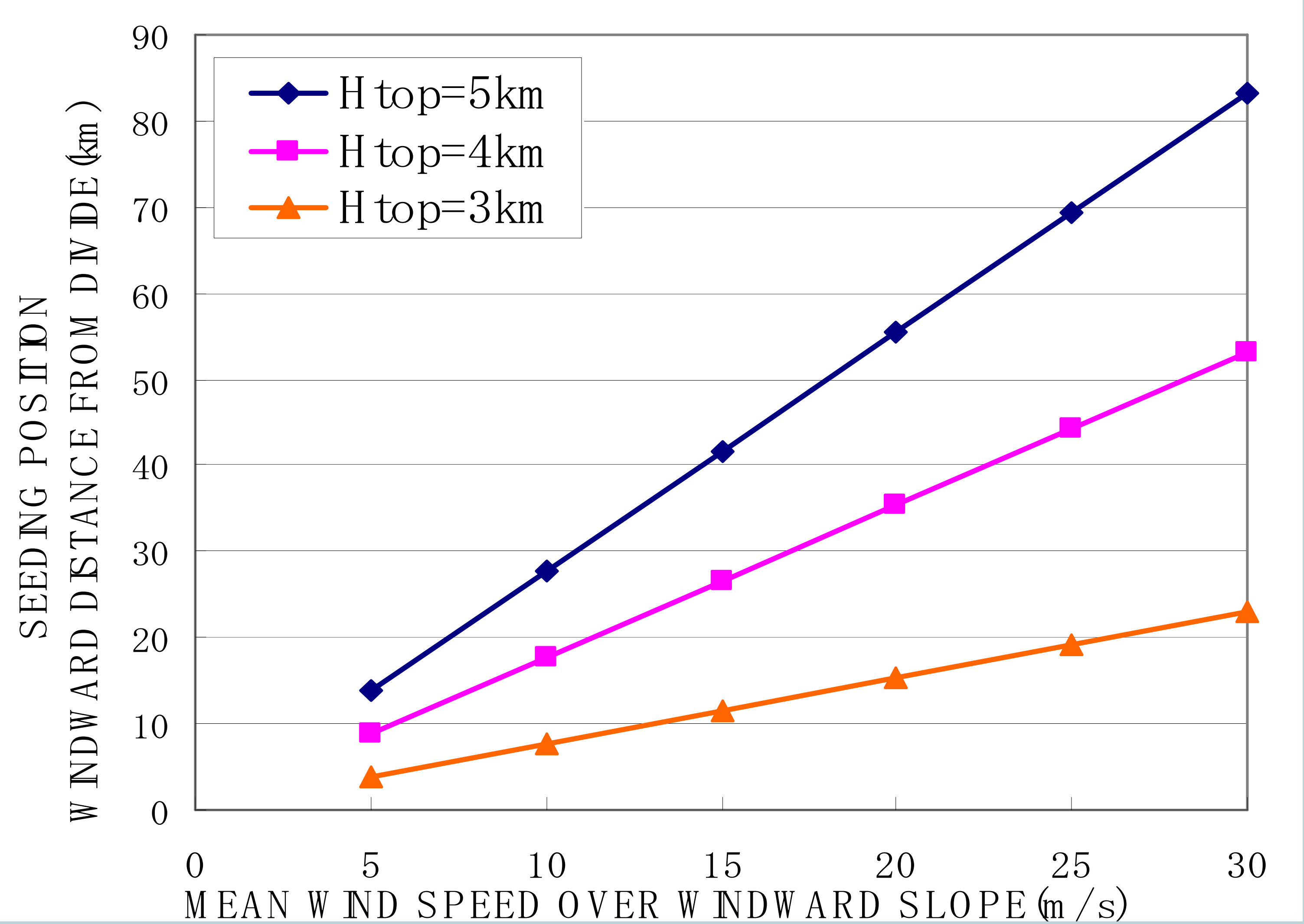
Y = 382.5 km

SR = 300 #/m^3/s

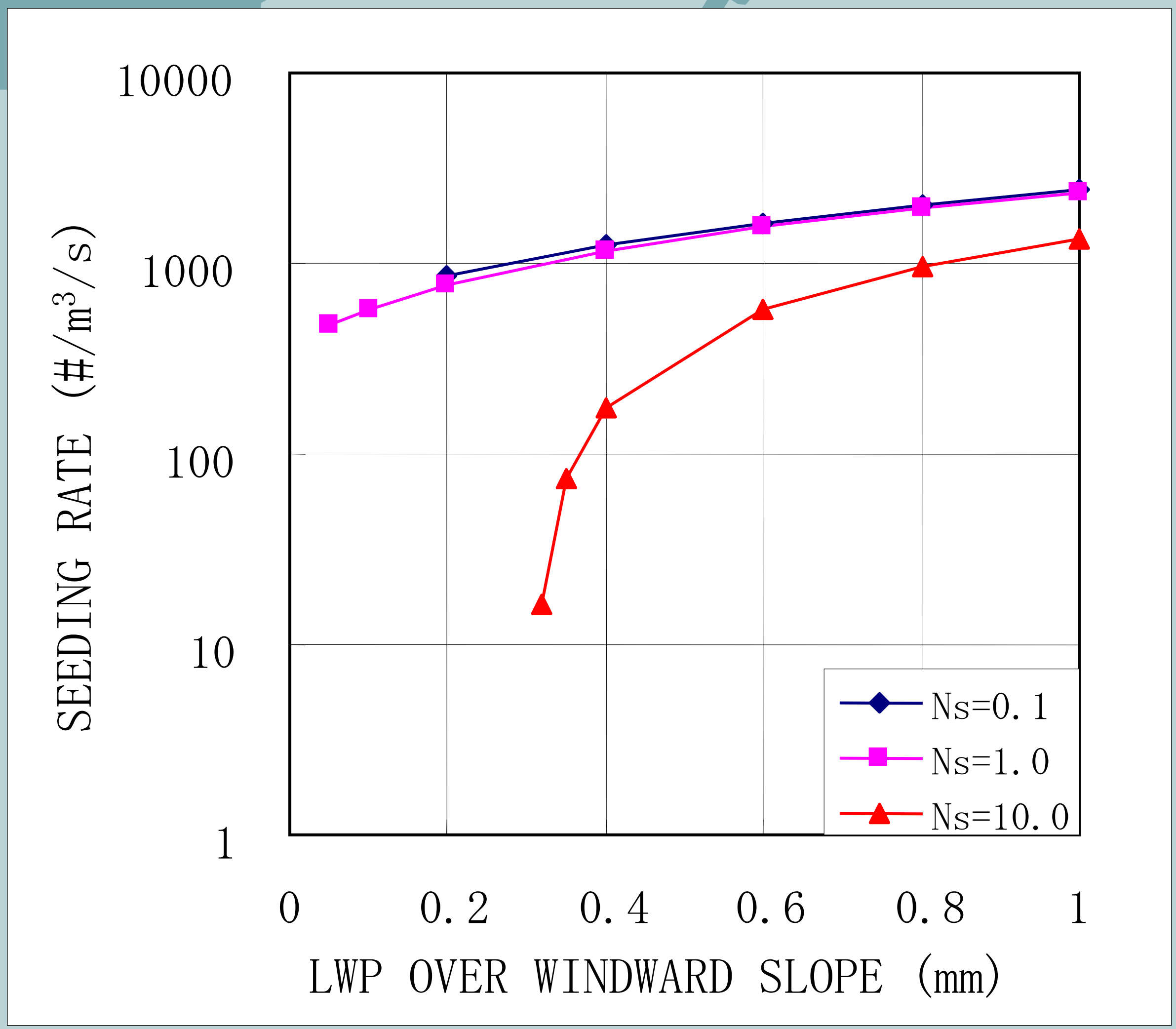
No seeding case: 6.6×104 tons



OPTIMAL SEEDING POSITION



OPTIMAL SEEDING RATE



2D Seeding Experiments
(Winter of 1996-1997)

GANALの風 風向>40および風向<220)の場合

年	1996年							
月	12月							
時	3		9		15		21	
	風上	ダム	風上	ダム	風上	ダム	風上	ダム
1日					-0.3	1.0	-1.2	0.0
2日	-1.8	0.5	-1.9	2.9	-0.4	1.6	-0.7	3.7
3日	0.3	4.4	0.1	2.1				
4日					0.0	0.4		
5日					0.0	0.0	0.1	0.0
6日	0.3	0.3	-3.6	7.9				
7日					0.0	0.1	0.4	1.4
8日	-1.9	1.5					0.2	3.0
9日	0.0	1.9						
10日								
11日	0.3	1.6	0.3	3.6	0.7	4.8	0.6	2.2
12日	0.3	2.3	0.6	2.4	0.2	1.4	0.4	4.7
13日	0.4	3.4						
14日			0.3	0.9	0.3	6.6	0.9	3.4
15日								
16日								
17日								
18日	1.4	7.6	-3.1	7.7	-1.8	6.1	-0.1	0.6
19日	0.3	0.3	1.0	0.6	-1.4	-1.0	-6.7	2.3
20日								
21日								
22日								
23日	1.5	2.6	-1.1	2.5	-1.3	6.8	0.2	6.3
24日								
25日			0.0	2.8	-0.1	5.1	-0.6	3.5
26日	-0.1	5.4	-0.7	5.1	-0.8	3.9	0.5	4.1
27日								
28日			-1.1	4.4	-0.7	4.6	0.3	8.0
29日								
30日			0.5	1.0				
31日								

年	1997年							
月	1月							
時	3		9		15		21	
	風上	ダム	風上	ダム	風上	ダム	風上	ダム
1日								
2日			0.0	0.0	-2.3	2.5	-2.1	4.9
3日	-1.0	4.7	-0.9	2.1	-0.8	4.1	-0.5	4.4
4日	-0.5	4.6	-0.5	5.1				
5日								
6日					0.2	0.5		
7日			-0.6	2.5	-0.7	2.7	0.0	1.8
8日	-0.2	0.8	0.0	0.6			-0.4	3.7
9日	0.3	2.3	0.3	1.4	0.2	1.3	-0.1	0.6
10日	-0.1	2.7	-0.2	1.0	-0.3	2.4	0.5	1.8
11日	0.5	1.9	0.1	3.1				
12日	0.0	0.1	0.3	1.0	0.4	0.9		
13日								
14日					0.1	4.8	-0.6	5.0
15日	-0.1	4.1	0.2	4.3				
16日					0.3	2.1	0.5	1.3
17日								
18日			-0.2	2.4	-0.5	4.9	-0.2	4.4
19日	0.0	5.7						
20日	-0.4	0.8	0.1	2.4				
21日	0.4	1.0						
22日	1.3	-0.5	-1.5	1.7	-1.2	2.0	-0.6	5.2
23日	0.7	2.7	0.8	4.9			0.9	3.3
24日	0.1	1.4	0.5	2.2	0.1	0.1		
25日			-1.1	1.6	-1.2	5.0	-1.3	3.1
26日	-0.6	3.6	-1.3	4.0	-1.6	3.5	-0.3	5.5
27日	0.0	2.4	-0.4	4.9	-0.1	3.7		
28日								
29日	-0.7	1.9	-1.5	1.7				
30日					-0.2	2.2	0.2	3.4
31日	0.6	1.7						

年	1997年							
月	2月							
時	3		9		15		21	
	風上	ダム	風上	ダム	風上	ダム	風上	ダム
1日	-0.4	1.3	0.1	0.9	-1.1	0.9	0.0	1.3
2日	0.1	0.3						
3日					-1.2	2.1	-0.8	2.6
4日	-1.3	0.7	-1.7	3.0	-0.7	4.9	0.7	3.0
5日								
6日					0.0	1.1	-0.9	2.3
7日	0.3	1.6	0.5	2.8				
8日								
9日								
10日								
11日							0.3	1.0
12日	-0.8	1.9	-0.7	2.6	-1.2	1.8	-0.9	3.9
13日			-0.4	2.6	0.0	0.0	0.1	0.7
14日					-0.2	2.0		
15日								
16日					-0.5	5.4	0.8	5.4
17日	0.0	4.1					0.3	1.7
18日	0.3	1.8						
19日	-1.4	-1.5	-0.6	2.1				
20日								
21日	-0.1	0.2	-0.5	1.7	-0.6	1.7	-0.6	0.9
22日	-0.6	0.2	-1.1	2.2	-0.6	3.8	0.4	3.1
23日	0.6	2.2	0.7	1.7	0.4	0.9	0.3	0.9
24日								
25日								
26日	1.5	5.4					0.2	1.9
27日								
28日								
29日								
30日								
31日								

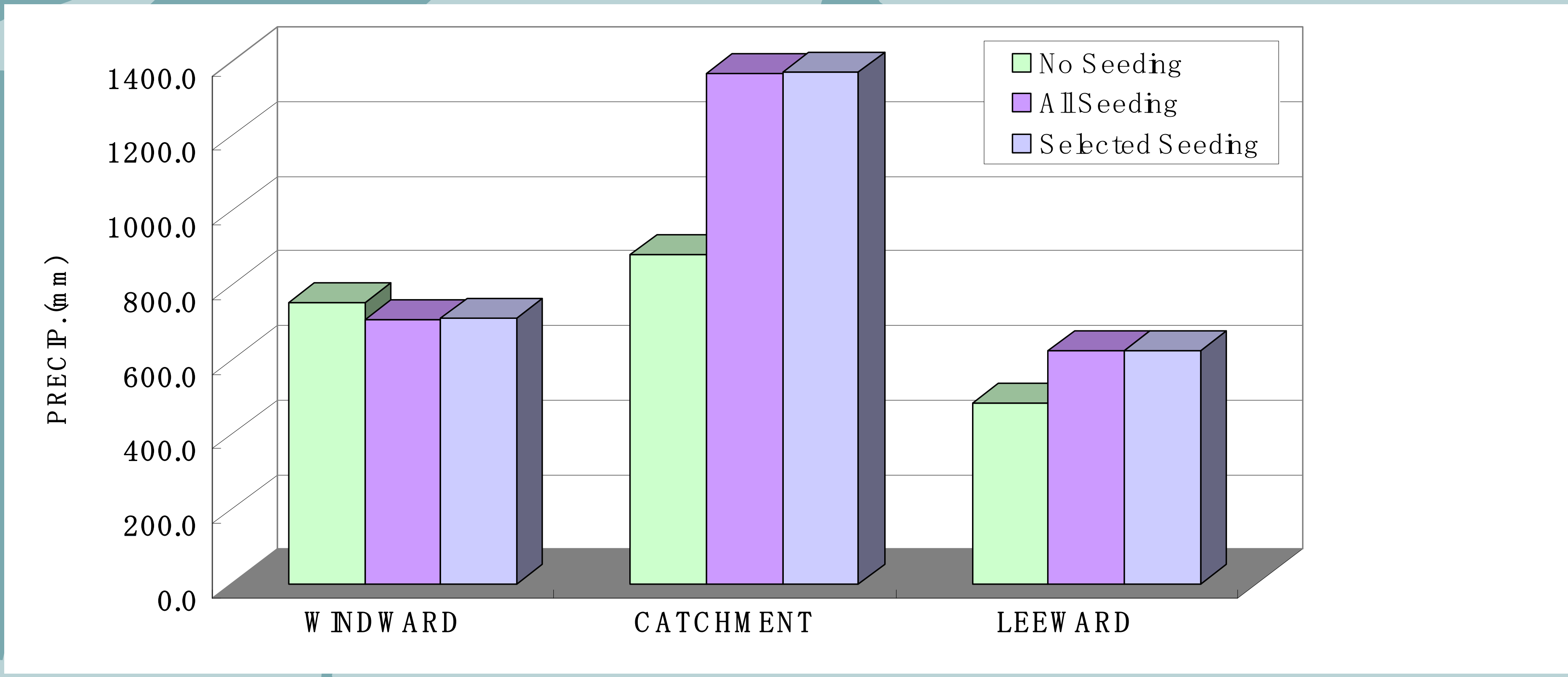
年	1997年							
月	3月							
時	3		9		15		21	
	風上	ダム	風上	ダム	風上	ダム	風上	ダム
1日								
2日								
3日								
4日			0.1	3.7	0.7	5.6		
5日	0.3	1.7	1.0	4.7				
6日								
7日							0.3	2.2
8日	0.0	0.0	0.2	2.3				
9日	0.1	4.0	0.2	5.1				
10日								
11日								
12日								
13日								
14日								
15日								
16日								
17日								
18日								
19日								
20日								
21日								
22日							0.2	0.5
23日					0.0	0.0	-0.2	2.7
24日								
25日								
26日	0.1	0.0						
27日								
28日								
29日								
30日			0.4	6.5	-1.1	6.0	5.1	2.3
31日			0.4	1.2	0.4	2.7		

凡例

- Value＞4
- 2<Value≦4
- 0<Value≦2
- Value＝0 or Seeding実験なし
- 0>Value≧－2
- －2>Value≧－4
- －4>Value

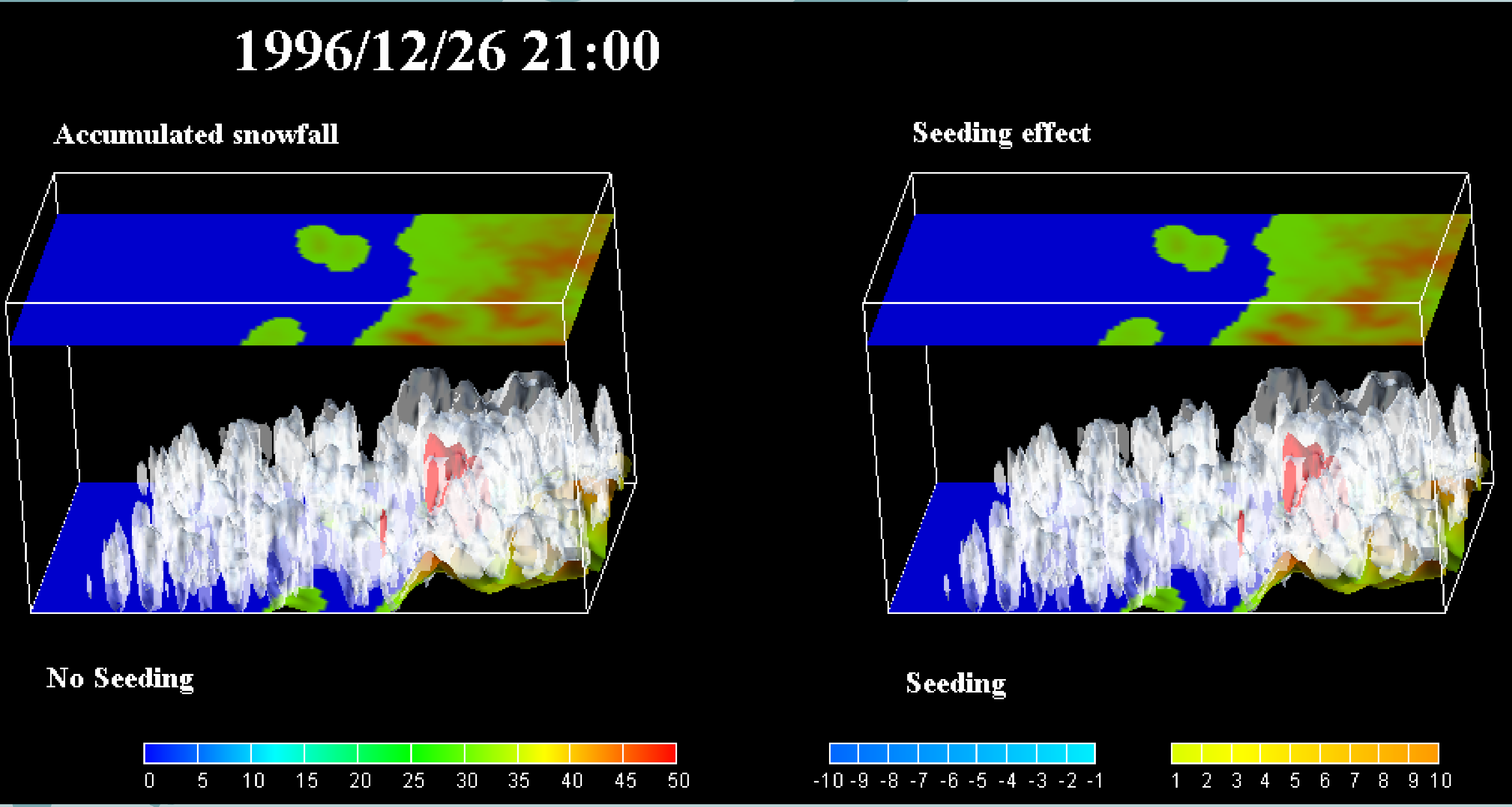
Seeding Effects on Seasonal Precip.

(Under winter monsoon conditions: Nov. 1994-Mar. 1995)



3D Seeding Experiments

(Qc + Ni + Qs + Qg)



CONCLUSIONS

HYVIS observations showed the existence of two types of snow clouds with high seedability.

Snow clouds of type A : Seeding is likely to result in an enhancement of precipitation efficiency.

Snow clouds of type B : Overseeding is likely to result in the shift of precipitation area downwind.

Ttop (GMS IR data) & 1-hr ave. LWP (microwave radiometers) showed that:

Snow clouds of type A appeared in Nov., Dec. and Mar.

Snow cloud of type B appeared in Dec., Jan. and Feb.

The total appearance freq. (A+B) reached 15-20 % of the time

A/C seeding experiments demonstrated:

Generation of numerous tiny crystals by dry-ice seeding

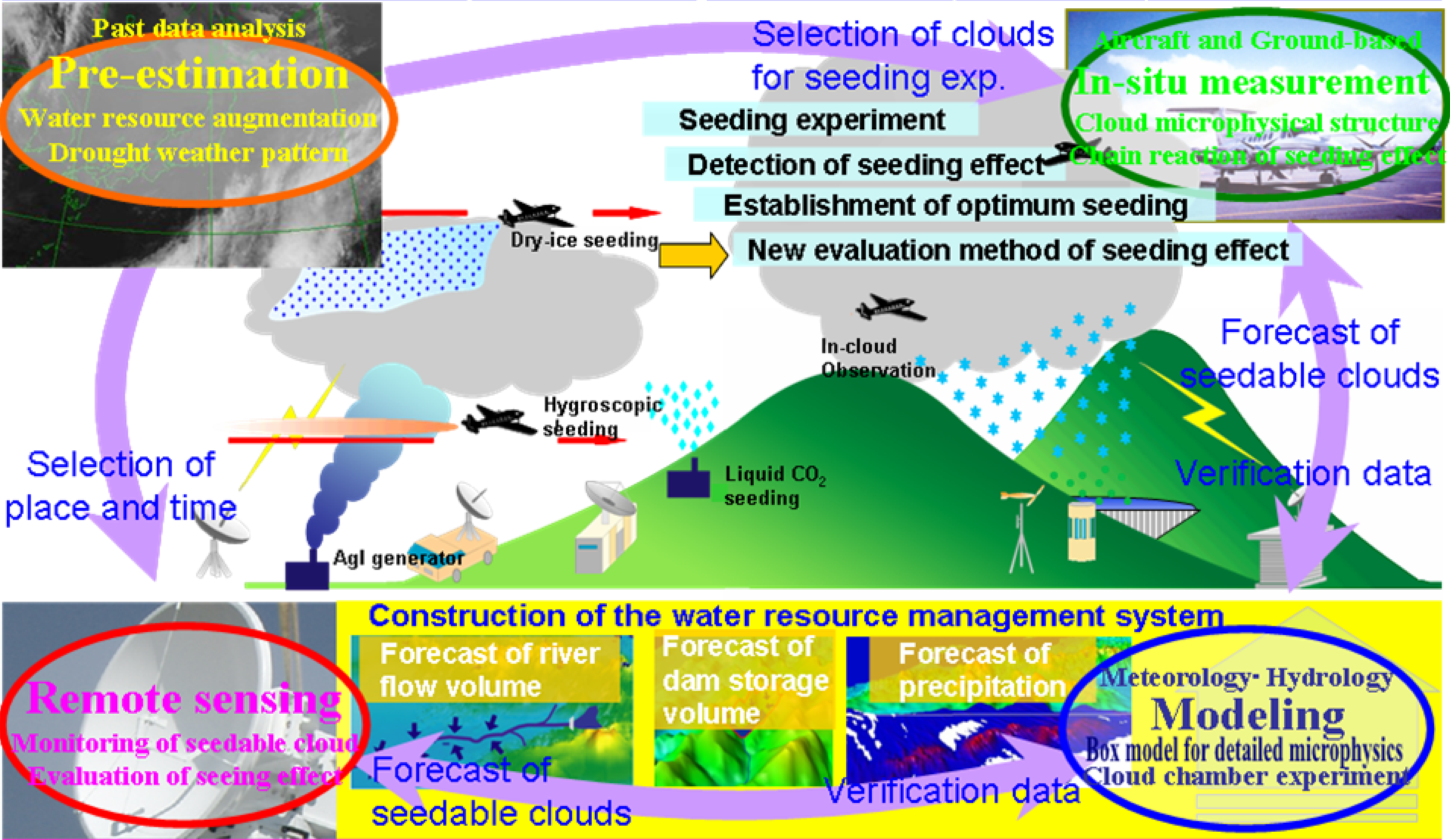
Subsequent growth of ice crystals up to mm-size precipitation particles.

Numerical simulations:

Seeding would result in a significant increase of surface precipitation over the catchment area.

With an ideal seeding method, total precipitation during winter months could be augmented by 30 – 40 %.

Japanese Cloud Seeding Experiment for Precipitation Augmentation (JCSEPA)



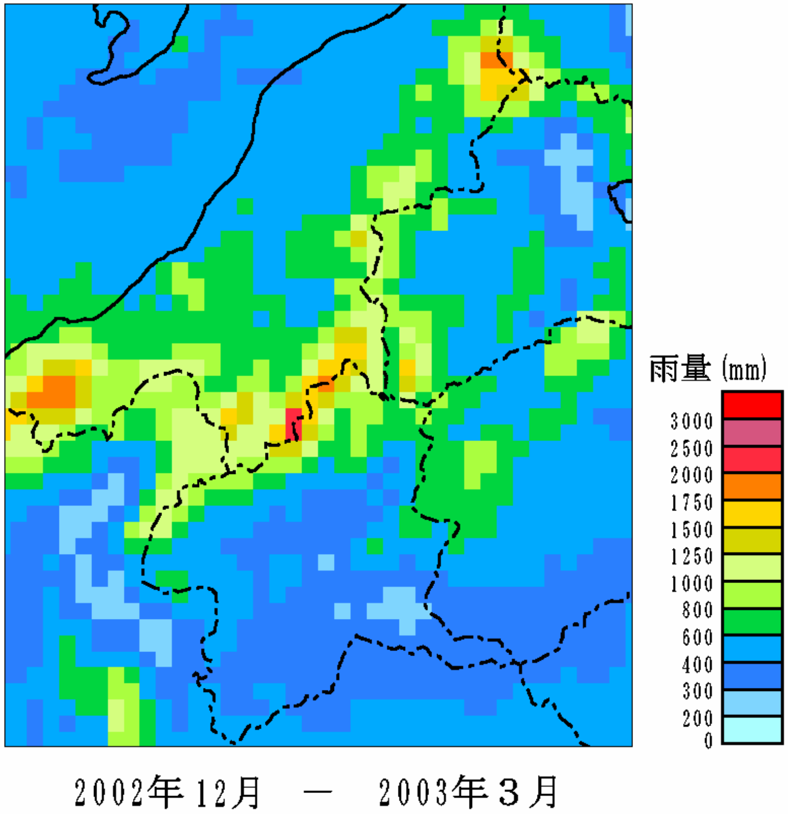
Goal: Evaluation of Cloud Seeding Effects on Water Resources Management and Drought Mitigation

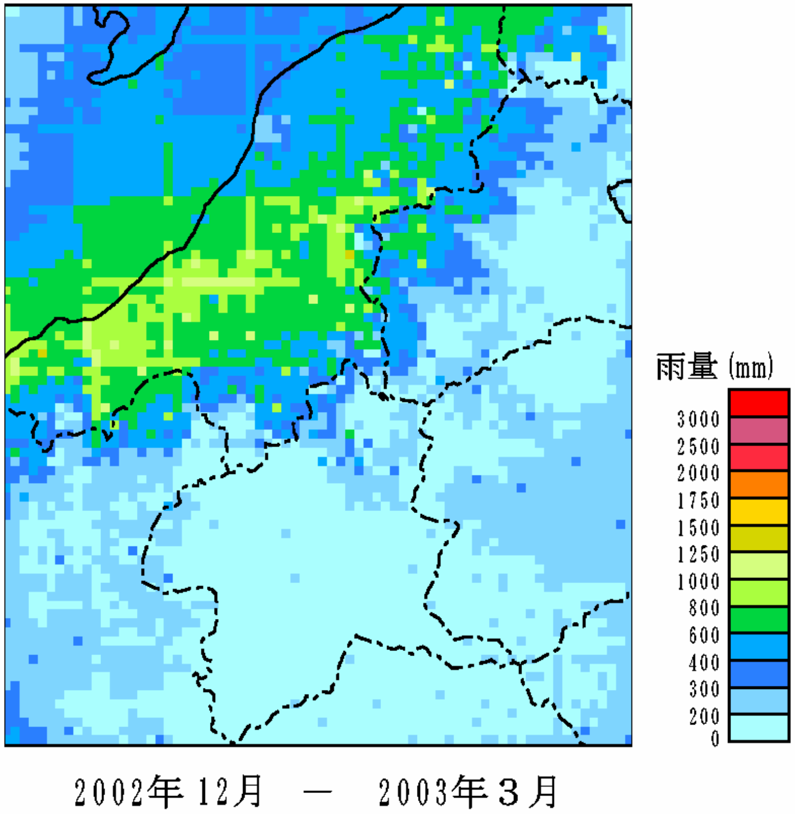
Plan of JCSEPA

- Investigate the causes of drought at different areas in Japan by analyzing past meteorological and hydrological data
- Sophisticate WM technology for orographic snow clouds
  - Monitoring technique of clouds with high seedability
  - Physical & statistical evaluation techniques of seeding effects
  - Evaluate the possibility of ground-based seeding
- Investigate the possibility of rain enhancement in warm season
  - Monitoring technique of clouds with high seedability
  - Appearance frequency of clouds with high seedability
  - Possibility of glaciogenic seeding
  - Possibility of hygroscopic seeding
- Evaluate the effects of cloud seeing on drought mitigation and water resource management by using a combination of NHM and hydrological model.
  - Sophisticated 2-moment bulk microphysics parameterization with seeding materials as prognostic variable
  - New bin microphysics scheme with aerosol (CCN) as prognostic variable for hygroscopic seeding experiments

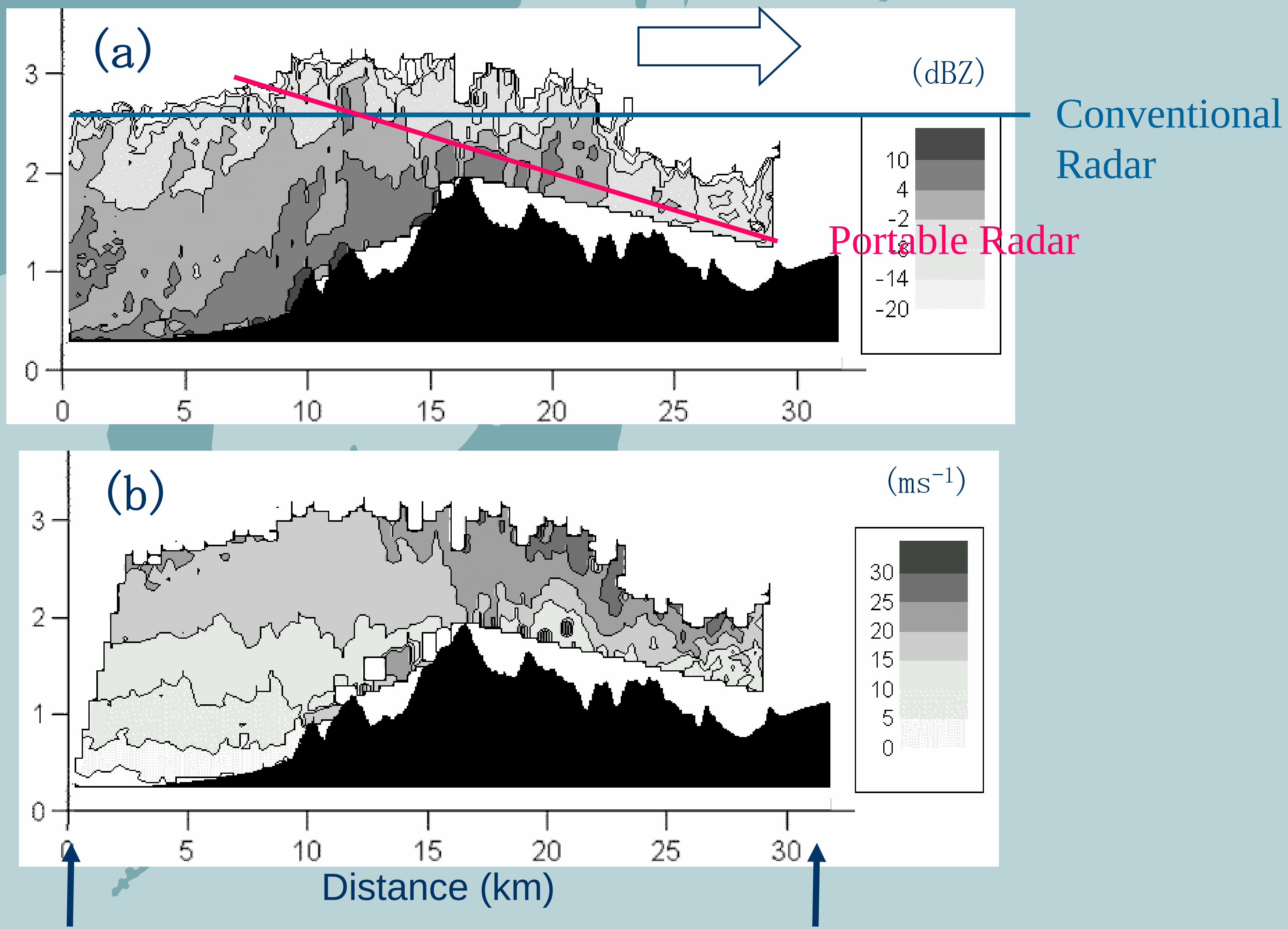
Thank you for your attention !

COMPARISON OF WINTER PRECIPITATION FROM NHM SIMULATION AND RADAR OBSERVATION





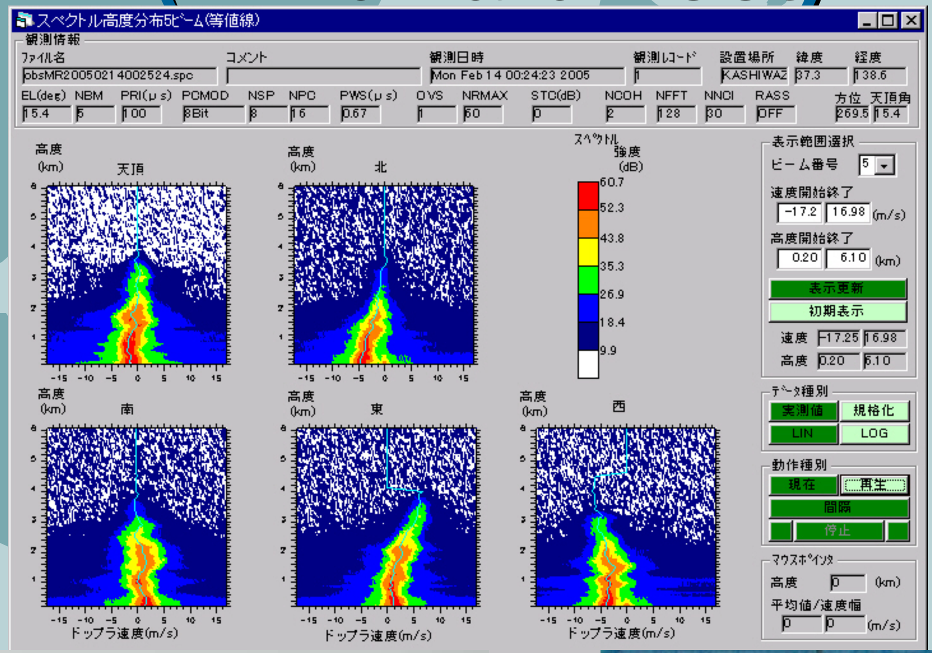
Vertical cross section of orographic snow cloud

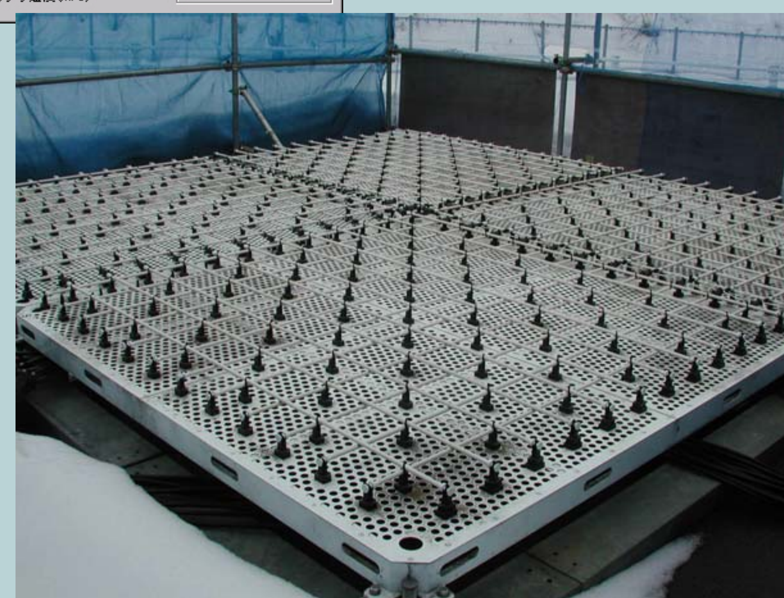


:Radar positions

Mean wind direction :

Wind Profiler (1.3 GHz)
(Windward Foot)



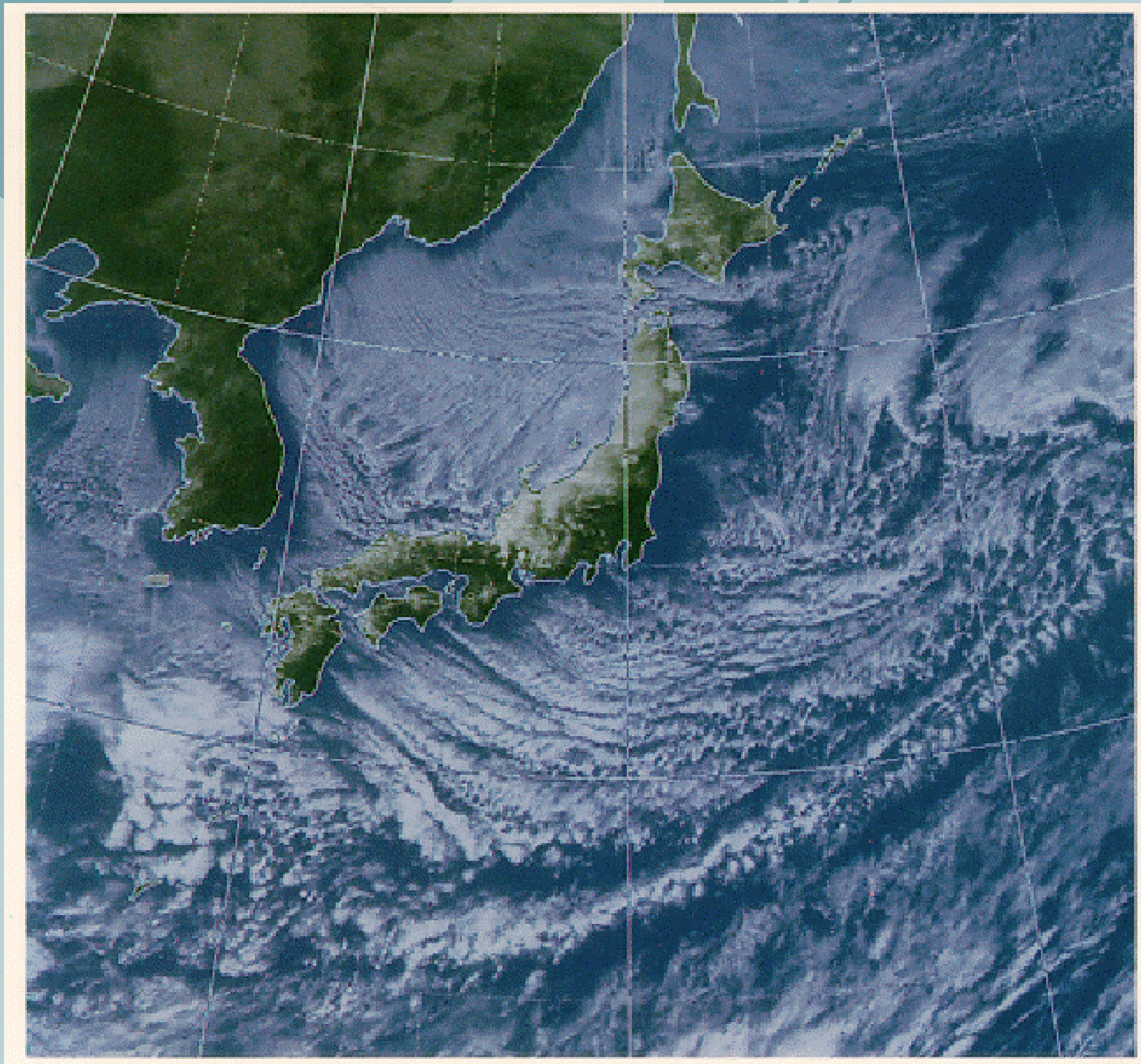


Microwave radiometer & MRR(24GHz) (Windward slope)

MRR, Optical Disdrometer & POSS (10.5GHz) (Catchment)

Precip. Gauge (Tipping-bucket, Electric balance), 2D Grey probe

Snow Clouds during Cold Airmass Outbreaks



Orographic Snow Cloud Modification Project
(PHASE IV: 2003-2006)
(PHASE V: 2006-2009)

(MRI, Tone River Dams Integrated Control Office)

PROBLEMS TO BE SOLVED
FOR OPERATIONAL CLOUD SEEDING

Water shortage (drought) in Japan is transient, but not chronic.

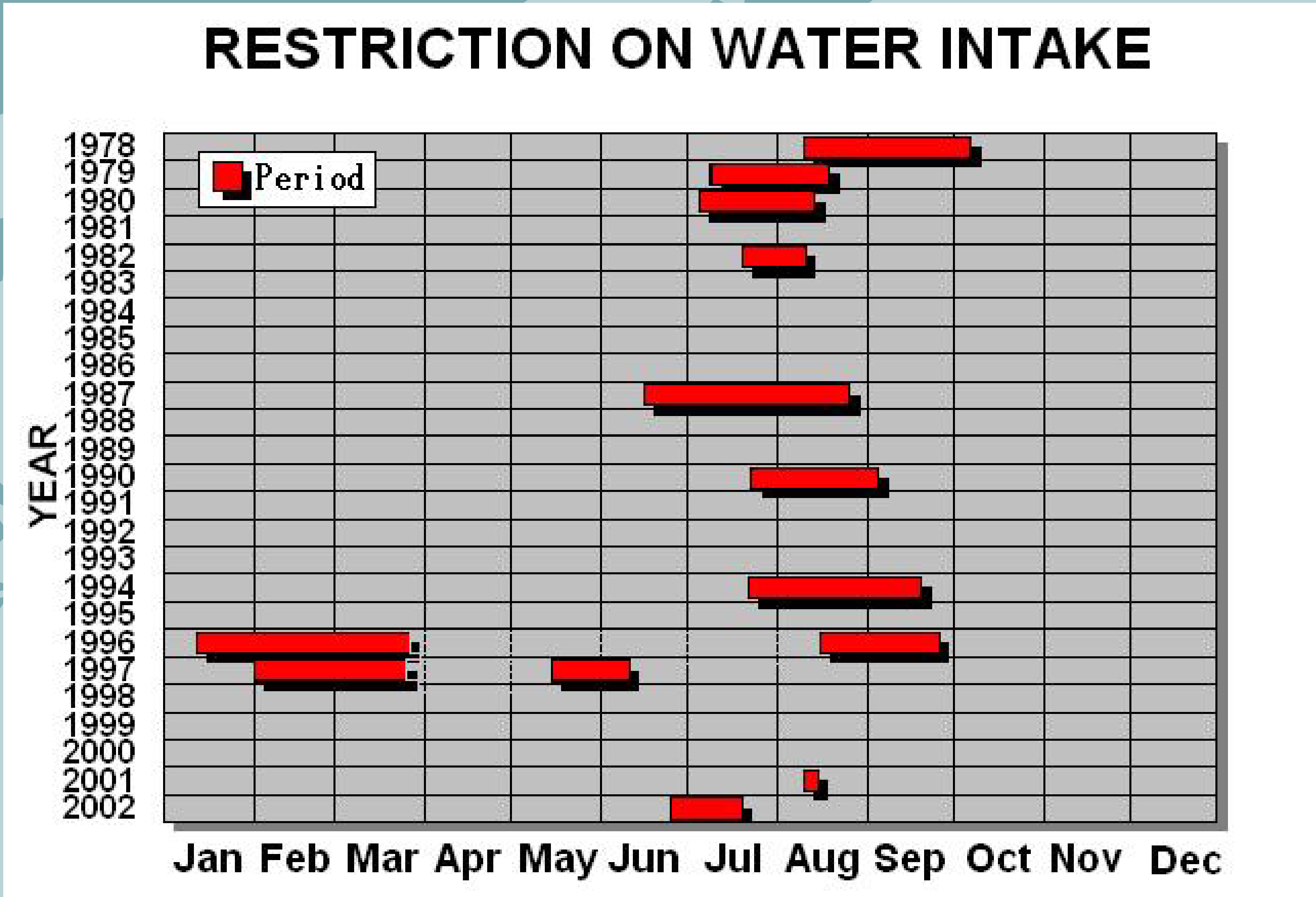
Keep the snowfall amount just more than usual (the average).
(People do not want to have too much snow by cloud seeding)

To do so, need accurate measurements of snowfall in deep mountain areas (catchment).

To accurately estimate snowfall in deep mountain areas;

- **improve radar observation techniques (detect the echoes near surface, Z-R relation)**
- **validate NHM with observation data and improve NHM**

Water rationing periods in Kanto Area



Field Campaign In Dec. 2001

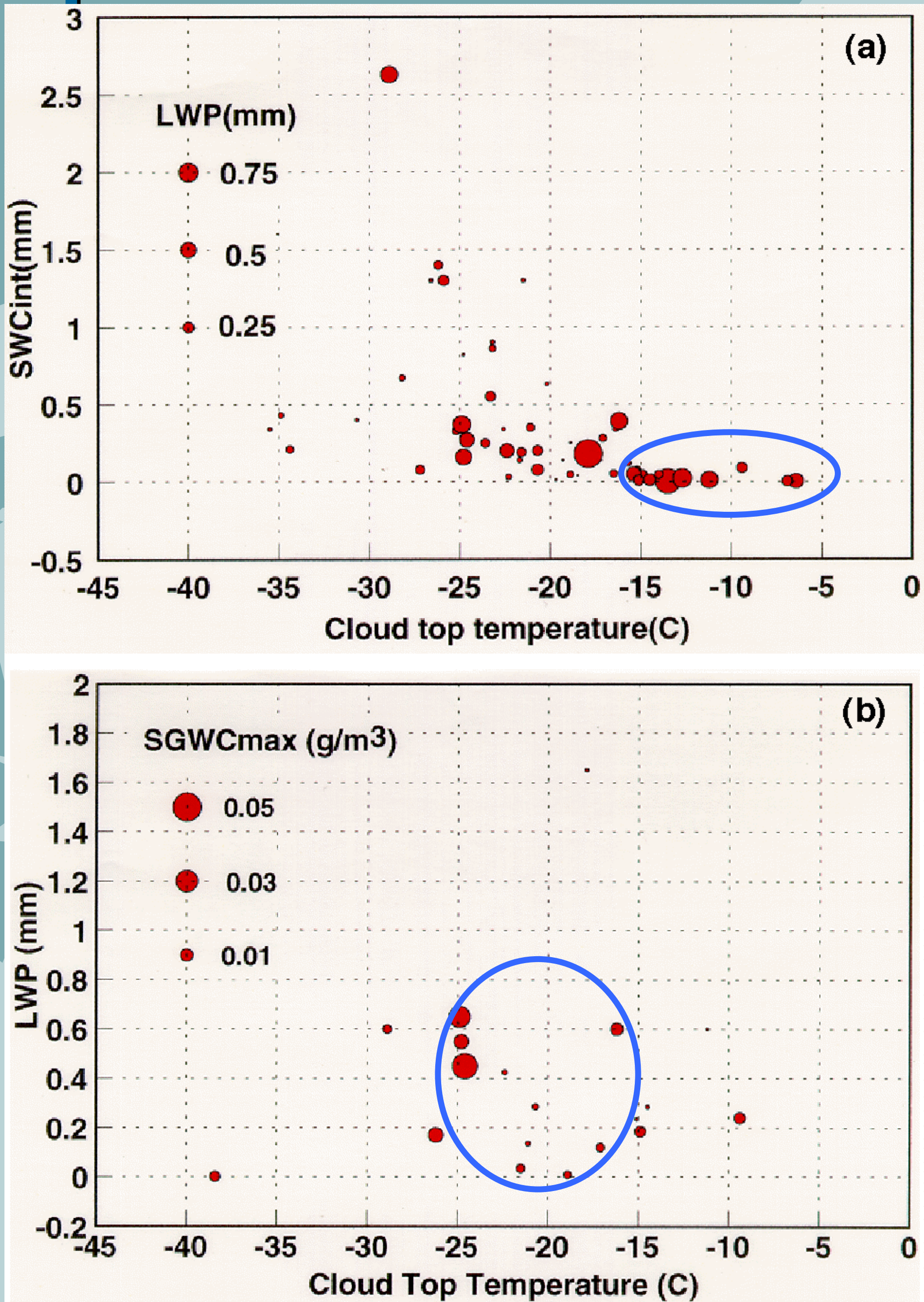

WINDWARD PLAINS


LEEWARD CATCHMENT


LEEWARD CATCHMENT


LEEWARD CATCHMENT

Requisites for clouds with high seedabilities



For precip. enhancement

For shift of precip. area