Japanese Cloud Seeding Experiments for Precipitation Augmentation (JCSEPA)

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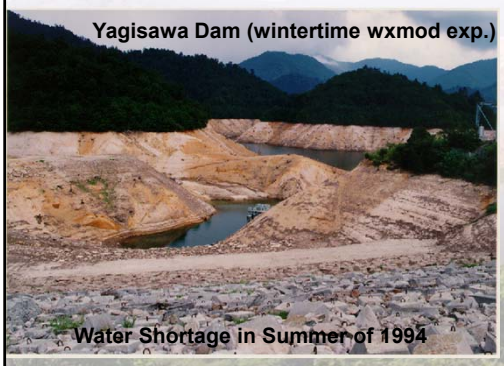
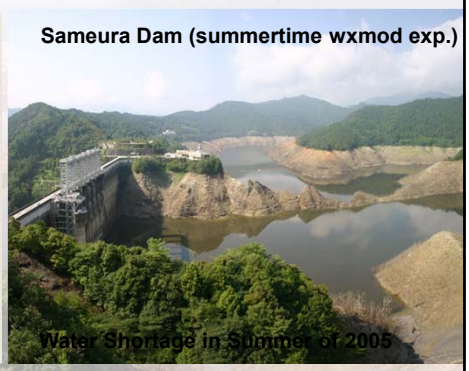
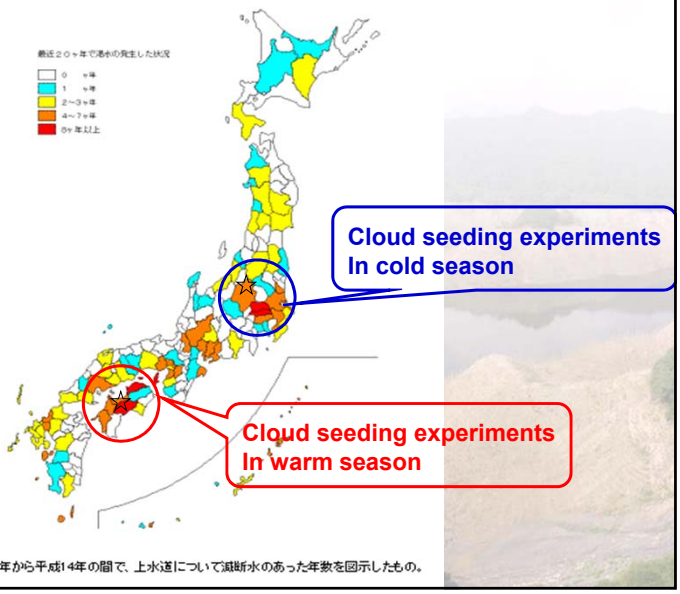
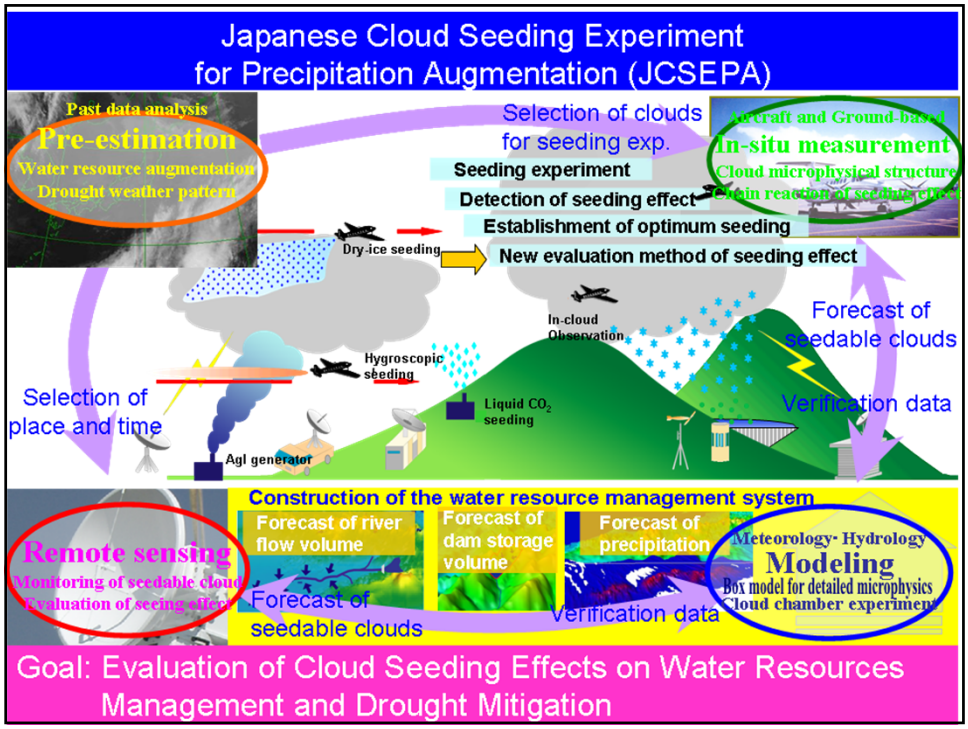




2013 10 7, Taipei, Taiwan
The Workshop of Artificial Rain Enhancement

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





Objectives 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 for quantitative evaluation of seedable clouds
    (synergy technique to estimate microphysical structures of clouds)
  - Physical & statistical evaluation techniques of seeding effects
  - Evaluating the possibility of ground-based seeding
- Investigate the possibility of rain enhancement in warm season
  - Clarification of giant CCN activation processes
  - Monitoring technique of clouds with high seedability
  - Appearance frequency of clouds with high seedability
  - Possibility of glaciogenic seeding
  - Possibility of hygroscopic seeding

Objectives of JCSEPA (cont.)

- Evaluate the effects of cloud seeding on drought mitigation and water resource management by using a combination of NHM and hydrological model.
  - Sophisticated 2-moment bulk microphysics parameterization scheme with seeding materials as prognostic variables
    A/C seeding (solid CO2), Ground-based seeding (liquid CO2, AgI)
  - New bin microphysics scheme with aerosol (CCN) as prognostic variable for hygroscopic seeding experiments
    A/C seeding (hygroscopic flare, salt micro-powder)

JCSEPA Ground-Based Cloud Observation

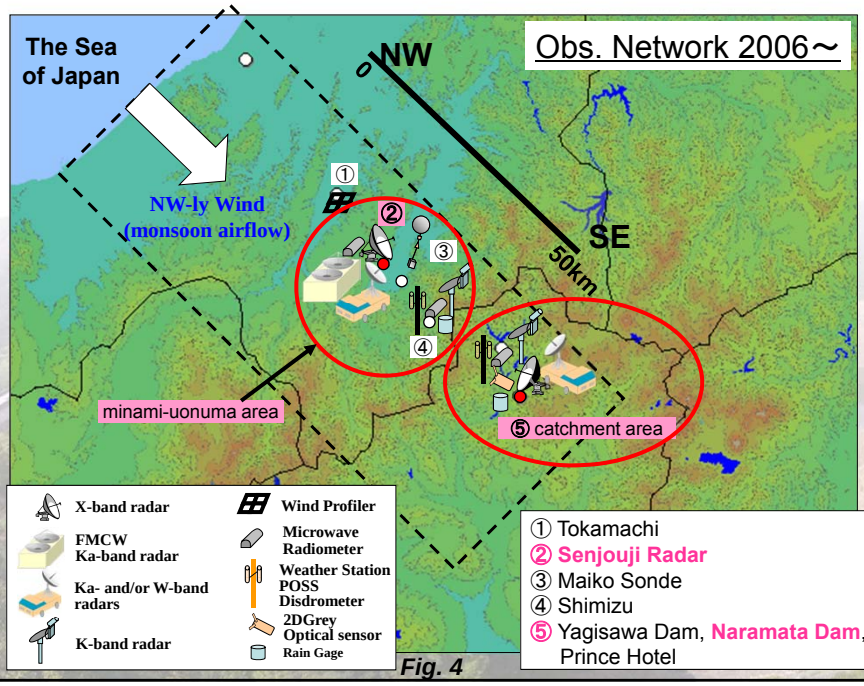
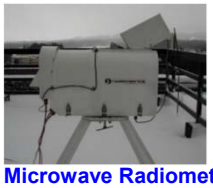


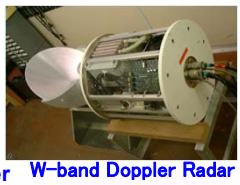
Fig. 4

REMOTE SENSING MEASUREMENTS

For cloud monitoring


MRR (K-band Radar)


Microwave Radiometer


W-band Doppler Radar


FMCW Ka-band Doppler Radar


X-band Doppler Radar (EL 90deg)


Dual Wavelength Lidar
(Summertime only)

For 3D Scanning


W-, Ka-band Doppler & Polarimetric Radar


Ka-band Doppler Radar


X-band Doppler Radar

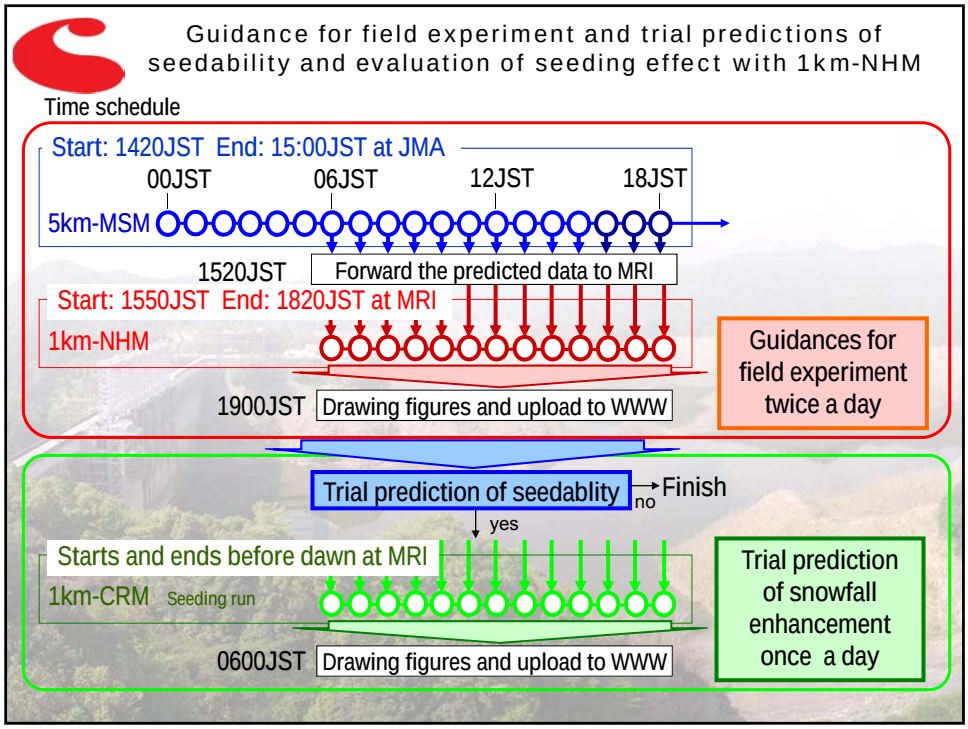
CATCHMENT AREA

YAGISAWA DAM SITE

NARAMATA DAM SITE

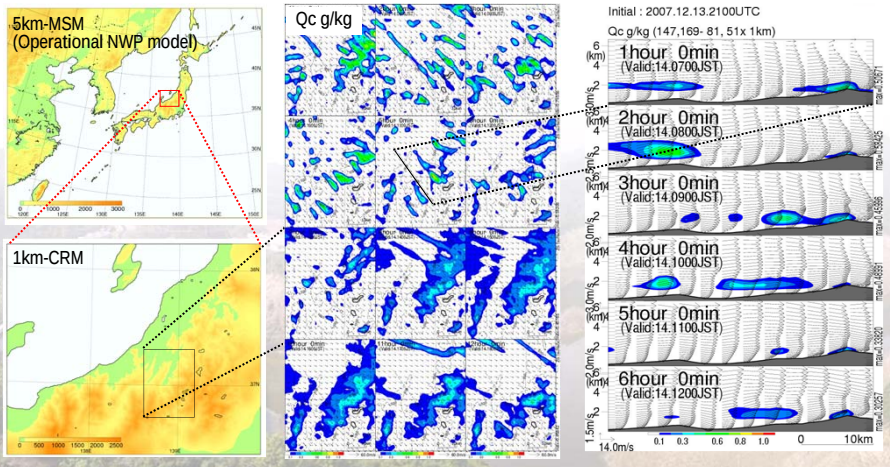
MINAKAMI PRINCE HOTEL RADAR SITE


MINAMI-UONUMA SITES
SENJOUJI RADAR SITE
MAIKO SONDE SITE
SHIMIZU SITE
TOKAMACHI
WIND PROFILER SITE


Guidance for field experiment and trial predictions of seedability and evaluation of seeding effect with 1km-NHM
Time schedule
Start: 1420JST End: 15:00JST at JMA
00JST
06JST
12JST
18JST
5km-MSM
1520JST
Forward the predicted data to MRI
Start: 1550JST End: 1820JST at MRI
1km-NHM
1900JST
Drawing figures and upload to WWW
Guidances for field experiment twice a day
Trial prediction of seedablity
no
Finish
yes
Starts and ends before dawn at MRI
1km-CRM Seeding run
0600JST
Drawing figures and upload to WWW
Trial prediction of snowfall enhancement once a day

Guidance for field experiment

Forecast of seedable clouds, twice a day

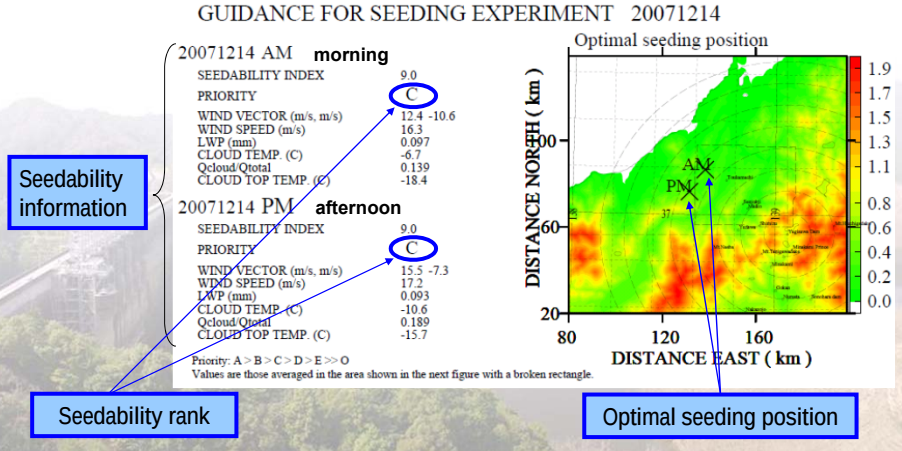


Prediction of cloud water distribution

Surface precipitation, LWP,IWP, mixing ratio and number concentration of liquid and solid hydrometeors, and wind field are also available.

Guidance for A/C seeding experiments

Trial of seedability prediction, twice a day

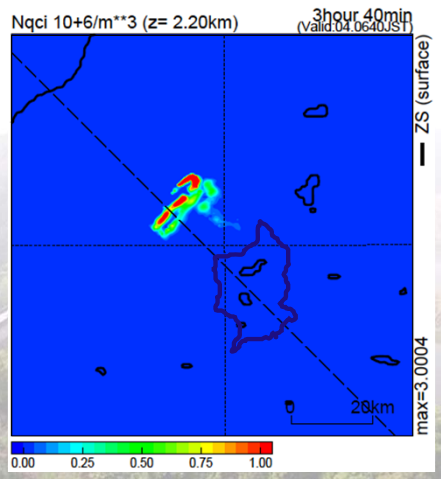


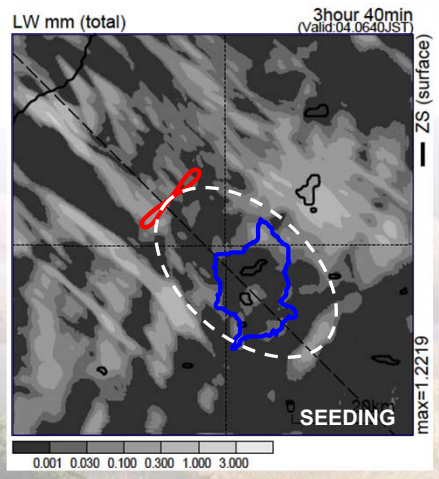
Seedability information

Seedability rank

Optimal seeding position

Dry Ice Pellet Seeding in NHM

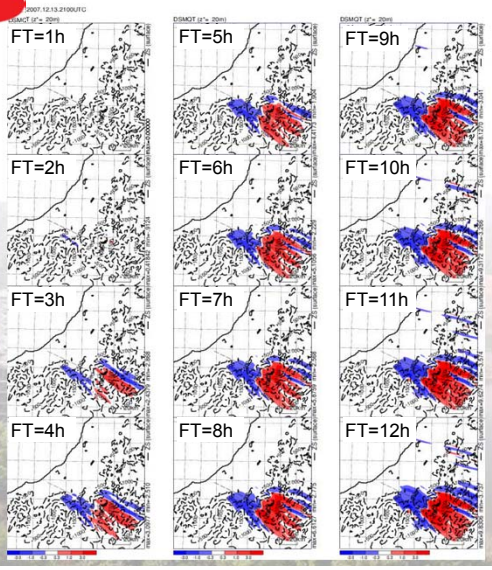




Number conc. of cloud ice produced by dry ice pellet seeding

Depositional growth of ice & snow crystals
↓
Depletion of cloud water

Guidance for A/C seeding experiments



Trial prediction of seeding effects, once a day

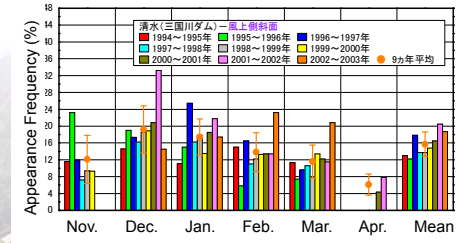
Seeding rate : 3 kg/min
Seeding position : determined from meteorological parameters predicted in control run
Seeding material : dry ice pellet
Flight speed : 100 m/s
Flight level : 2600 m

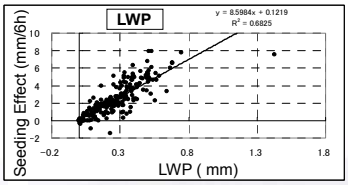
Differences in accumulated surface precipitation (mm) (seeding run minus control run). Red and blue indicate the increase and decrease due to cloud seeding, respectively.

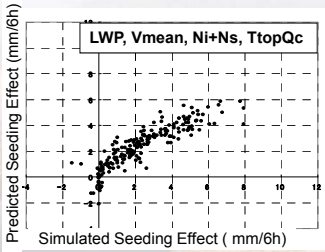
Quantitative evaluation of seedable clouds

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

Microwave radiometer, Satellite IR data, Agrological data, AMeDAS

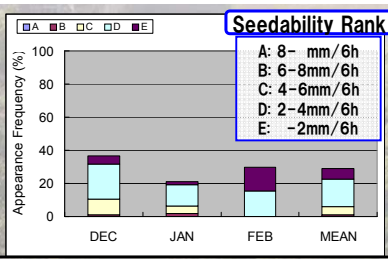




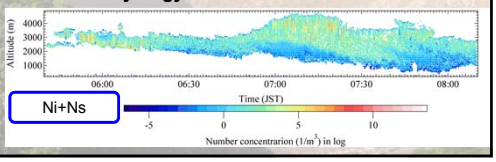


Seedability Rank

A: 8- mm/6h
B: 6-8mm/6h
C: 4-6mm/6h
D: 2-4mm/6h
E: -2mm/6h

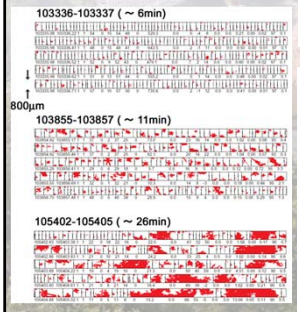


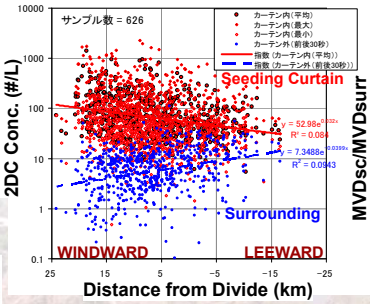
Synergy Observation

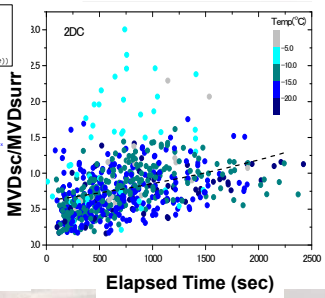


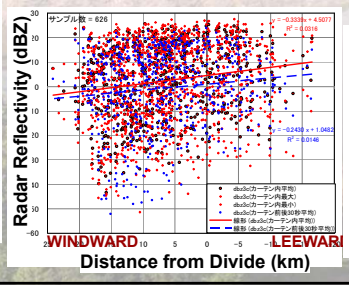
Physical Evaluation Techniques of Seeding Effects **(A/C In-situ Measurements)**

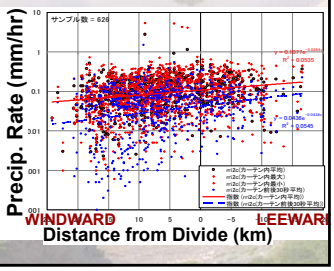
Instrumented aircraft (MU-2)



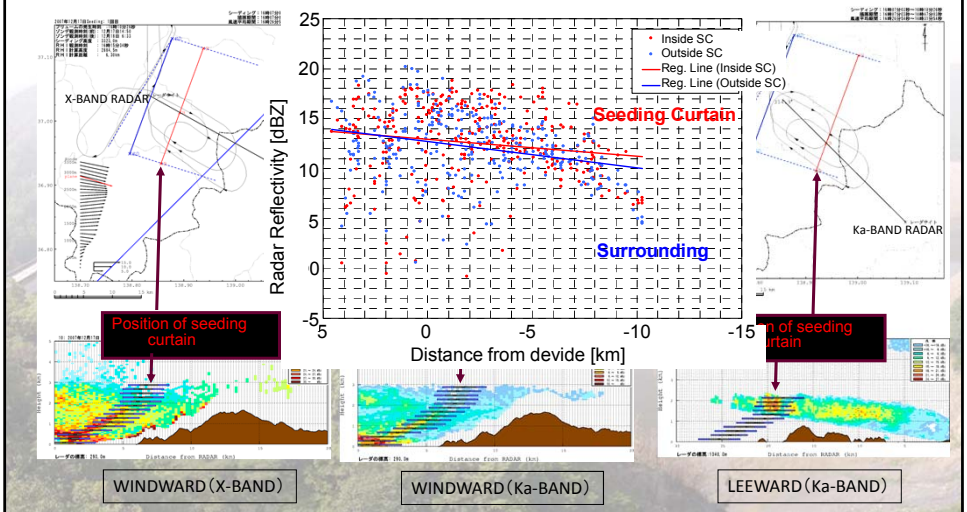






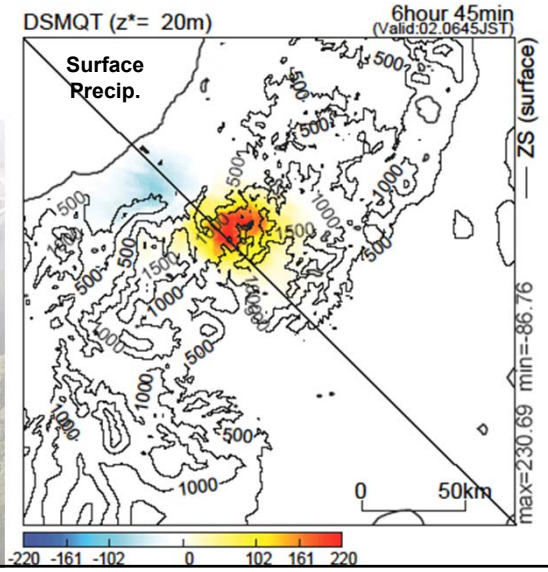


Physical Evaluation Techniques of Seeding Effects (cont.)



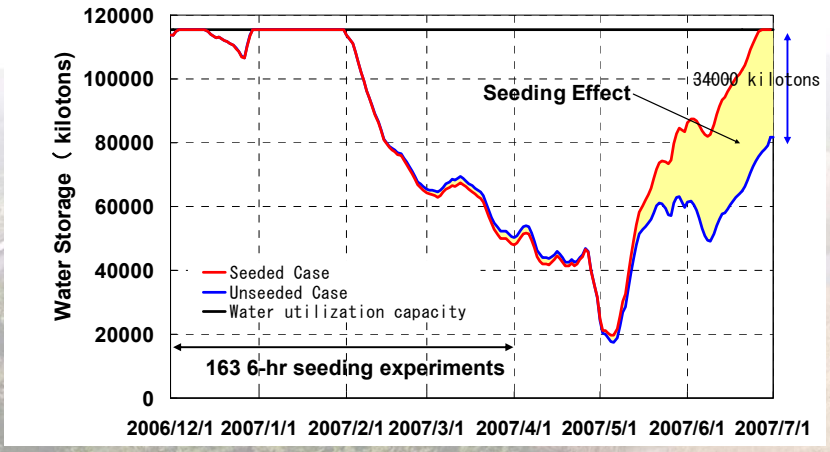
Seeding Effects on Seasonal Precip.(163 cases)

（NHM simulation: Under winter monsoon conditions: Dec. 2006-Mar. 2007）



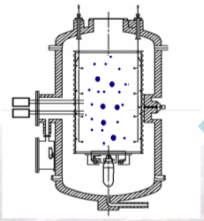
Seeding Effect on Dam Water Storage

(Numerical simulation with a combination of NHM and land surface model)



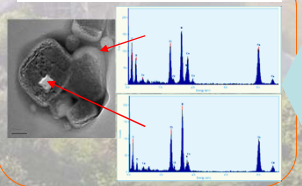
Hygroscopic seeding experiment

MRI CLOUD SIMULATION CHAMBER

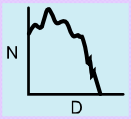


Hygroscopic seeding experiment

Sample analysis using Electron microscope



Background CCN



+

cloud seeding materials

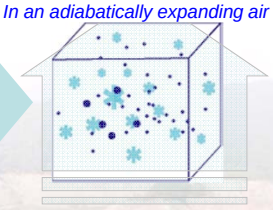
Hygroscopic Flare

Micro-Powder

⋮

Improvement of Box-type cloud model

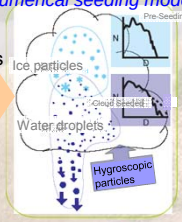
Growth of cloud droplets In an adiabatically expanding air



Bin-type cloud physics + Seeding processes

Quantification of the hygroscopic seeding effects

Development of numerical seeding model

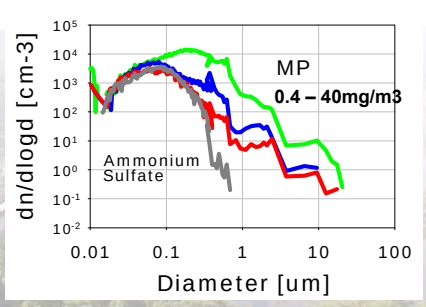


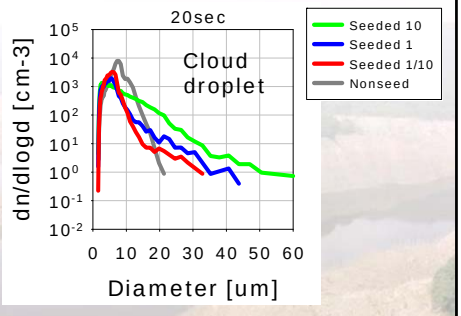
Identification of physico-chemical properties of optimal seeding material
Evaluation of hygroscopic seeding effect

Chamber Experiment on Hygroscopic Seeding

Salt Micro-Powder Seeding

Initial Size Distribution of CCN



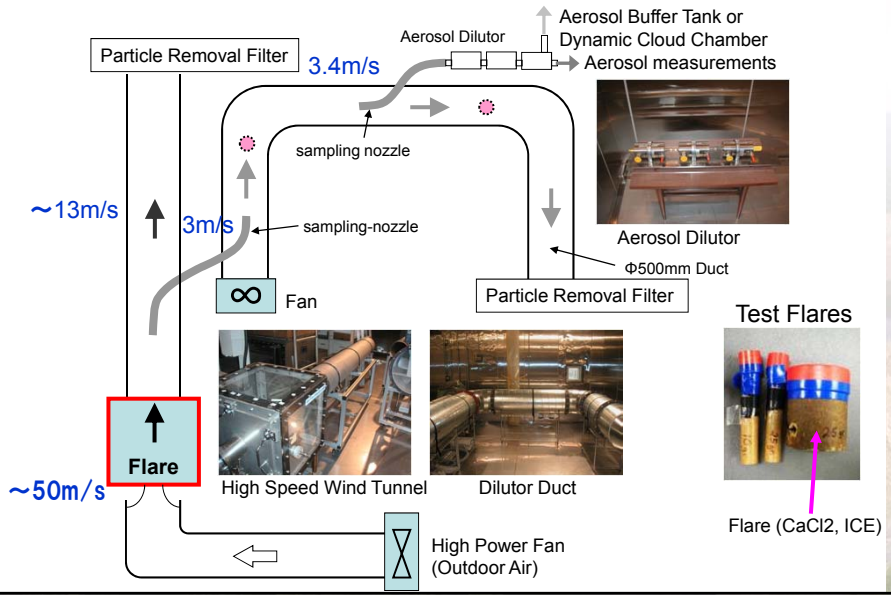


Number of large droplets increases and total number of droplets decreases with increasing the total mass of seeding materials...

Chamber Experiment on Hygroscopic Seeding

Hygroscopic Flare Seeding

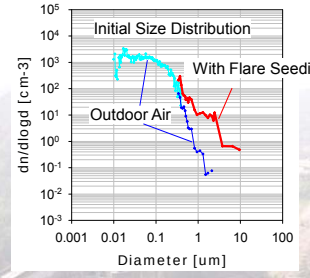
Flare Test System



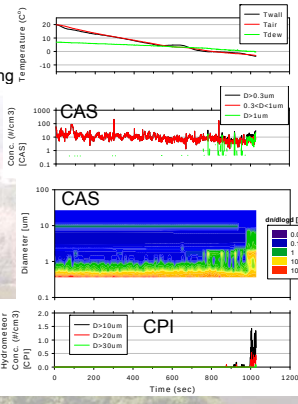
Chamber Experiment on Hygroscopic Seeding

Hygroscopic Flare Seeding

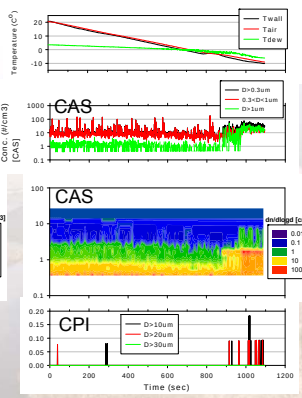
Initial Aerosol Size Distributions



Outdoor Air



Outdoor Air＋Flare



Experimental Conditions

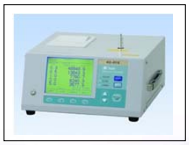
	Outdoor	Outdoor＋Flare
Updraft[m/s]	3	3
Init. Temp.[C]	19.9	20.5
Init. Press.[hPa]	999.85	999.93
Init. Tdp[°C]	6.9	3.6

Hygroscopic flare seeding causes a slight increase in the number of large droplets, but more significant increase in total droplet concentrations..

Instrumentation for Observation and Seeding A/C


CCN Counter (SSw 0.1～2%)


SMPS (DMA+CPC) (0.01～0.45μm)

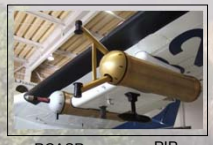

OPC (>0.3, >0.5, >1, >3, >5μm)


Sampling Impactor for EM mesh

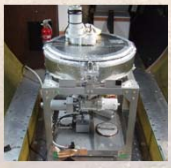

Salt Micro-powder Dispenser


Hygroscopic Flare Rack

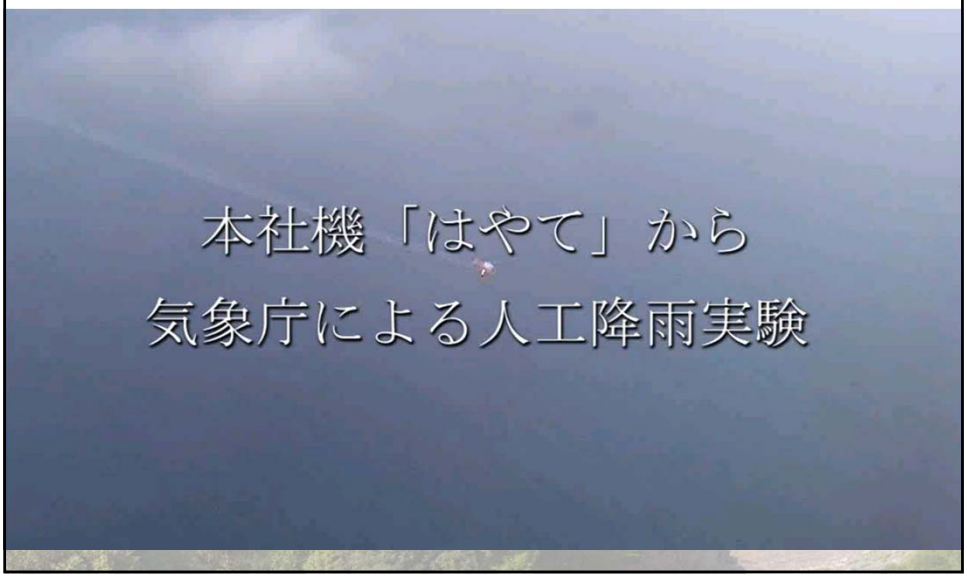

CFDC INC


PCASP (0.1～3μm)

PIP (0.1～6.4mm)

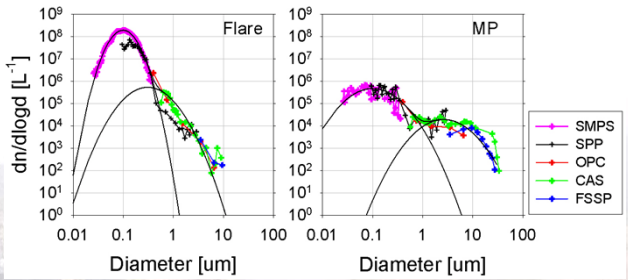

Dry Ice Pellet Dispenser

A/C Measurement of Seeding Particles



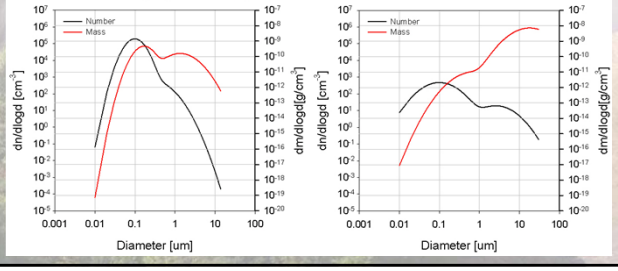
Size Distributions of Hygroscopic Flare & Salt Micro-powder Particles

2010/06/05



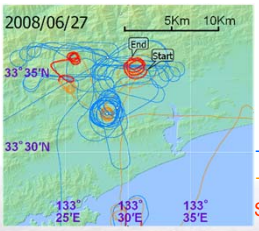
Seeding Plume; 10~20 m dia.
Mass Conc.; 333 µg/m3
No. Conc.; 89514 /cm3

Seeding Plume; 10~20 m dia.
Mass Conc.; 4,595 µg/m3
No. Conc.; 432 /cm3

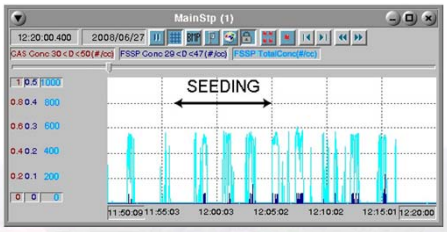


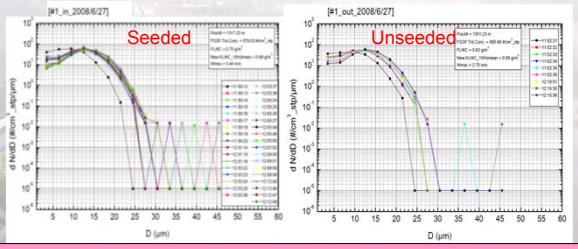
A/C Seeding Experiments

Flare Seeding



Track of KingAir
Track of Helicopter
Seeding track





A few min. after seeding, droplets larger than 30 um were measured just above cloud base.

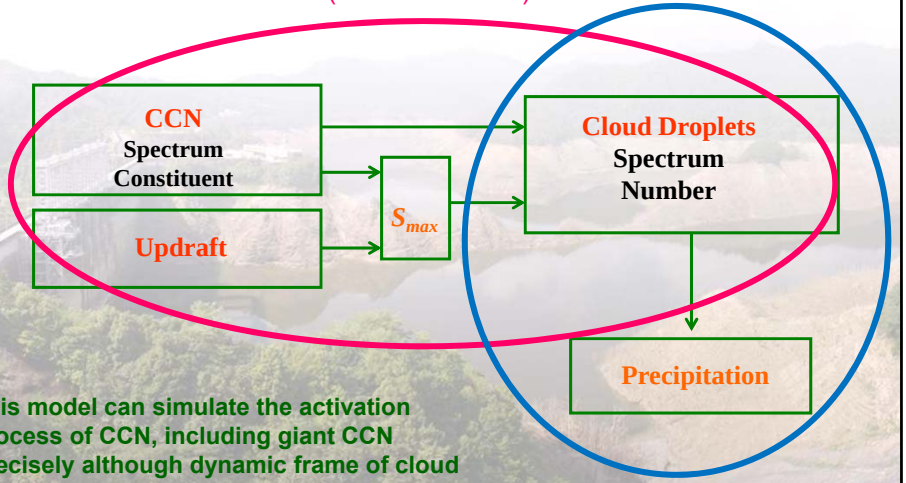
Regarding hygroscopic seeding in real clouds, what we can do at present is to detect a broadening of cloud droplet size distribution toward larger sizes, sometimes but not every time.
Only from aircraft seeding experiments, it is rather difficult to trace a chain reaction of microphysical processes, leading to an additional raindrop formation,

Numerical Experiment on Hygroscopic Seeding

Hybrid Cloud-Microphysics Model ((Kuba and Murakami 2010, ACP)

Parcel model (Particle method)

Grid model (Bin method)

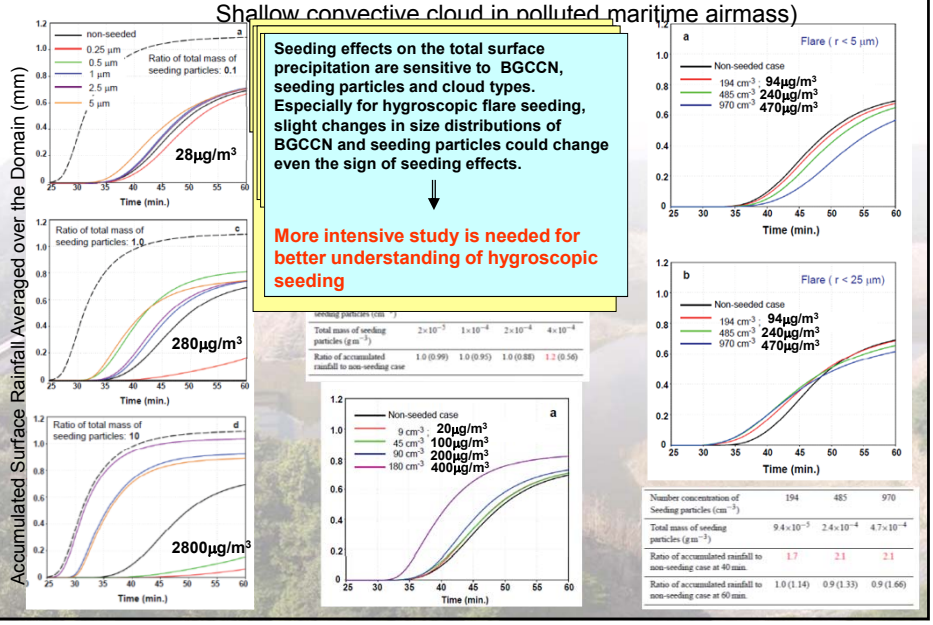


This model can simulate the activation process of CCN, including giant CCN precisely although dynamic frame of cloud model is prescribed.

Numerical Experiment on Hygroscopic Seeding

(Hybrid Cloud-Microphysics Model;

Shallow convective cloud in polluted maritime airmass)

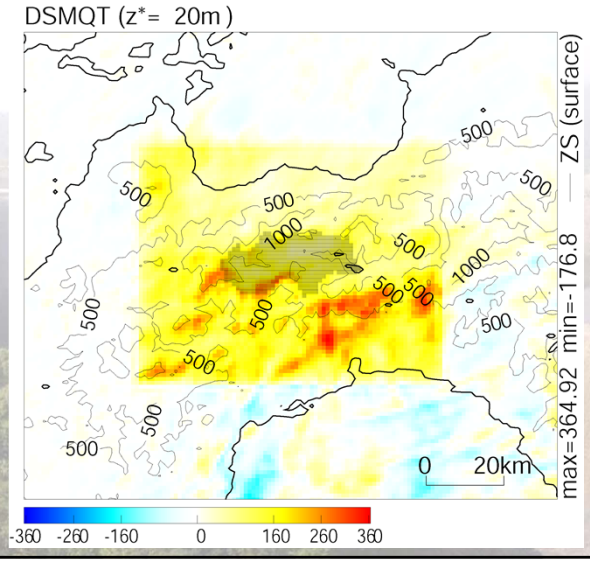


Japanese Cloud Seeding Experiment for Precipitation Augmentation (JCSEPA)

Seeding Effects on Seasonal Precip.

(93 6-hr MP seeding experiments)

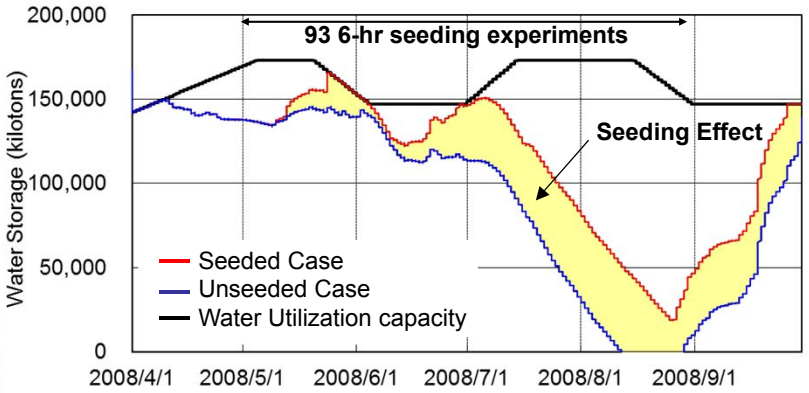
Simplified seeding method: May 2008-Aug. 2008）



Japanese cloud seeding Experiment for Precipitation Augmentation

Seeding Effect on Dam Water Storage

(Numerical simulation with a combination of NHM and land surface model)



Ground-based Observation Facilities(2008)

Obs. Period: May-July
(IOP: June)

Ehime Pref.

Tokushima Pref.

Obs. Site A
(Sameura Dam)

Obs. Site B

Kouchi Pref.

Obs. Site C

Kouchi City

Tosa City

Obs. Site E

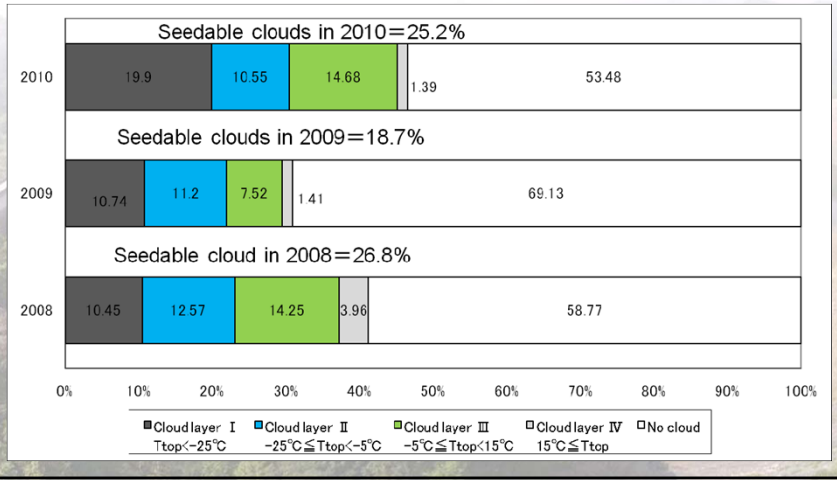
Obs. Site F

Obs. Site D

Appearance Frequency of Seedable Clouds

Cloud type 1 : Ttop < -25 C
unsuitable for cloud seeding
Cloud type 2 : -5 C > Ttop > -25 C
suitable for glaciogenic seeding

Cloud type 3 : 15 C > Ttop > -5 C
suitable for hygroscopic seeding
Cloud type 4 : Others
unsuitable for cloud seeding?



CONCLUDING REMARKS

- Glaciogenic seeding of mixed-phased orographic clouds is effective
- Hygroscopic seeding of warm clouds may be effective under limited conditions
- Hygroscopic seeding of cold, convective clouds is reported to be effective. But many argument about the effectiveness
  - Need more intensive study
- Weather modification study is indispensable for the understanding of aerosol indirect effect