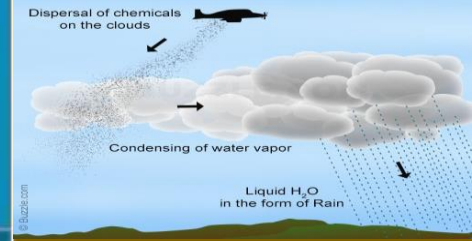
PAGASA
Philippine Atmospheric Geophysical and Astronomical Services Administration



WEATHER MODIFICATION in the PHILIPPINES

(A Country Report)

By:

ROBERT Z. QUINTO
Sr. Weather Specialist

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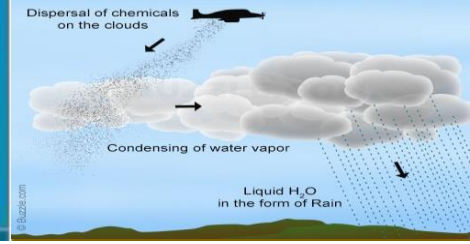
Weather Specialist I



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III
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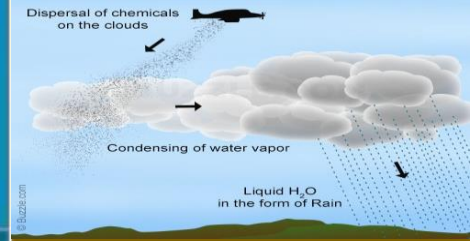
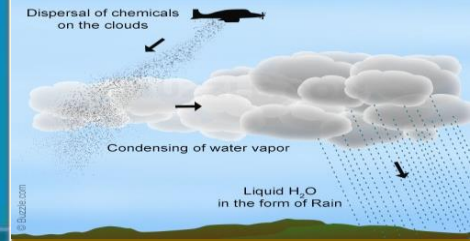


History of Weather Modification in the Philippines

1950's - cloud seeding for rainfall enhancement has been conducted

- This was carried out by the Philippine Air Force
- One of the major efforts was GroMet II which was rain-making project geared to alleviate the dry spells experience in 1968-69.
- This is through the assistance of the US Government which provided two (2) C-130s and technical expertise.
- National Artificial Rainfall Stimulation Committee (NARSC) primarily for sugar producers who were threatened by drought
- No efforts has been done exerted towards the objective evaluation of the results.

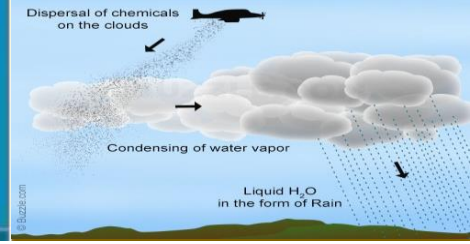


Presidential Decree 1152 of the Philippines – Philippine Environmental Code

Section 13: Weather Modification

"The Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA) shall monitor regularly meteorological factors affecting environmental conditions in order to effectively guide air pollution monitoring activities.

Activities relating to *weather modification* such as rainfall stimulation and storm seeding experiments shall be undertaken in consultation or coordination with the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA)."



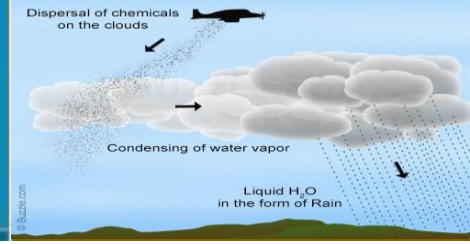
History of Weather Modification in the Philippines

1972's – Typhoon Moderation Research and Development Council (TMRDC) was established and was tasked with the overall coordination of weather modification activities.

1975 - 1st scientific evaluation of cloud modification operations was conducted:

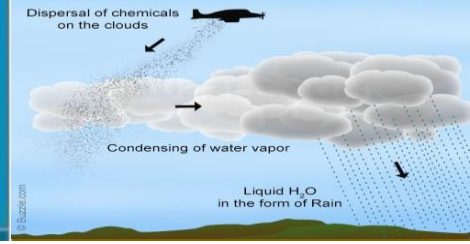
Weather Modification Experiment I or WEMEX I - Controlled experiment in Cumulus scale weather over the Central Visayan Region (Bohol). This was designed to quantify the results of cloud seeding

WEMEX II - another experiment was conducted the following year over the Central Luzon Area. A number of research projects were started in conjunction with these experiments.



Objectives of the project and the establishment of the WEMEX rainfall network:

1) To provide a dense rainfall data which will be beneficial to agro-climatic researches,
2) To provide the necessary data for the furtherance of analytical researches in cloud micro-physics and dynamics,
3) To provide important data necessary for scientific evaluation procedures in any weather modification activity, and
4) To provide opportunity to coordinate weather modification activities with the agricultural sector in particular to a more efficient use of the technology in food production.



WEMEX Experiment

Sodium Chloride (NaCl) - the primary chemical used for warm cloud seeding while AgI for cold cloud seeding.

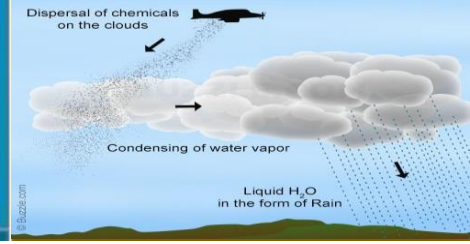
Calcium Chloride and dry ice – occasionally used.

The amount of chemicals used vary with each operation depending on the target cloud characteristics.

Full use were made of the meteorological data coming from various sources.

Experimental sites were chosen on the basis of proximity to radar and radiosonde installation

A dense raingauge network composed of 283 standard raingauges and 62 automatic recorder in Central Luzon was utilized.



WEMEX Experiment

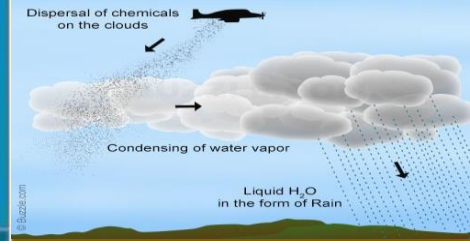
The part-time observers are composed of farmers, government retirees, homemakers and out of school community folks.

They were trained on the proper use of the 8-inch rain gauge and on rainfall measurements.

Daily observations are taken and collected from each of these stations.

The data are archived for utilization in research studies.

The special dispensers for seeding operations were installed on board the aircrafts.



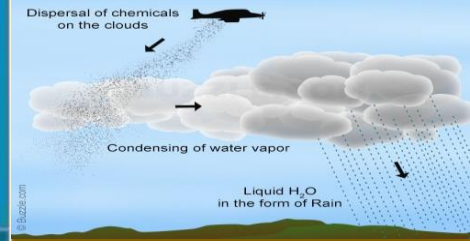
WEMEX Experiment – Rainmaking Operations Component

Pilot, co-pilot, cloud seeding officer and crew

Meteorological support - responsible for meteorological data, analysis and forecasts

Field operations group – responsible for field raingauges and facilities including communications

Research Group – involved in the various connected researches of the project.



WEMEX Experiment: Outcome of the Operations

Generally observed that the *seeded clouds grew* and *became bigger* in dimension, horizontally and vertically with some cloud merging.

When rain came after seeding, *rain usually came about 15 – 20 minutes after seeding*.

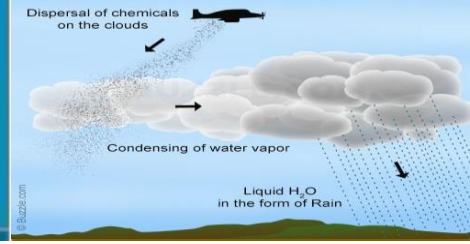
There were varied operations and as such, rainfall durations were also varying.

The *area coverage was not too large* as dictated by the criterion of the experiments and requests for operations (usually in the order of 100 sq. kms.).

The number of operations vary from year to year depending on the meteorological condition (about 10/yr).

Unfortunately, there were not enough seeding operation performed that would warrant statistical evaluation

Overall the rainmaking on an operational basis would be considered as *fairly successful.*



Major Agencies Involved

Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA) – provided the expert, trained meteorological personnel and responsible for the operations and maintenance of pertinent meteorological facilities and equipment;

Philippine Air Force (PAF) – performed air operations requirement of the project;

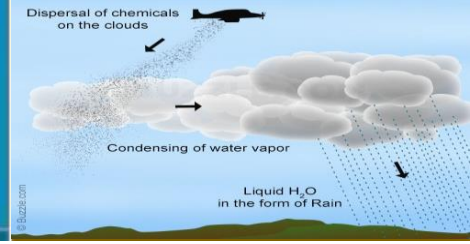
University of the Philippines (UP) – provided the scientific expertise for the experiments.

Civil Aeronautics Administration – reserved the air space above the experimental area on specified dates and hours

National Media Production Center – managed the documentation of the experiment

Local Governments – provided organizational support

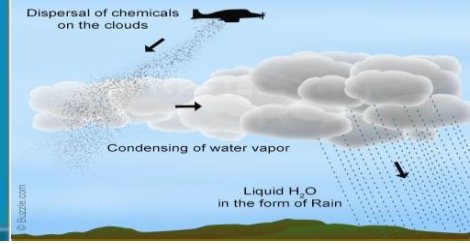
Other government agencies such as the *National Irrigation Administration*, *Bureau of Public Information*, *Bureau of Public Works*, *National Food and Agricultural Commission*, *Philippine Sugar Institute*, *Bureau of Forest development* – assisted in the coordination of field activities and other requirements.



EXECUTIVE ORDER NO. 116, January 30, 1987

RENAMING THE MINISTRY OF AGRICULTURE AND FOOD AS **MINISTRY OF AGRICULTURE,** Reorganizing its units; integrating all offices and agencies whose functions relate to agriculture and fishery into the ministry and for other purposes.

(d) **Bureau of Soils and Water Management (BSWM):** The Bureau of Soils and Water Management shall advise and render assistance on matters relative to the utilization and management of soils and water as vital agricultural resources; formulate measures and guidelines for effective soil, land, and water resource utilization, as well as soil conservation in croplands and other agricultural areas; undertake oil research programs; coordinate with the relevant government agencies in resettlement areas and prepare the necessary plans for the provision of technical assistance in solving of oil impounding and prevention of soil erosion, fertility preservation, and other related matters; *engaged in rainmaking projects for agricultural areas and watersheds to solve the problem of prolonged droughts and minimize their effects on standing agricultural crops, for its own sector recommend plans, programs, policies, rules and regulations to the Minister and provide technical assistance in the implementation of the same.*



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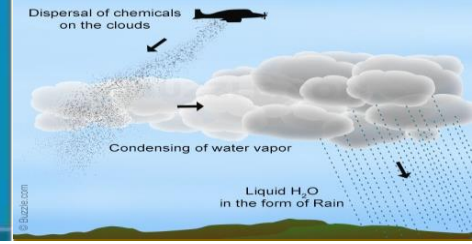
Philippine Air Force (PAF) – performed air operations requirement of the project;

BSWM- assisted in the coordination of field activities and other requirements.

Civil Aeronautics Administration (CAAP)– reserved the air space above the experimental area on specified dates and hours

Local Government Units (LGUs) – provided organizational support



Project Structure

Project Management

. PAGASA
. Partner Agencies (PAF, BSWM, CAAP, LGU)

Project Consultants

Operations
Research
- Cloud Modeling Group
- Seeding Evaluation Group

Airborne Crew

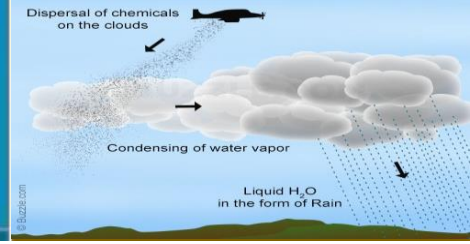
- Pilots
- Cloud Seeding Officers
- Documentation officers

Ground support crew

- Aircraft Maintenance
- Supply Officer (cloud seeding materials)

Technical Support Group

- Meteorologist-in-charge
- Doppler Radar data analyst
- Radiosonde sounding analyst
- Satellite imagery analyst
- NWP model output analyst
- Cloud model output analyst



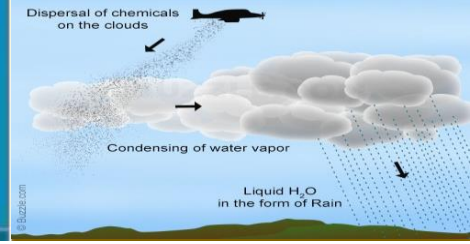
Cloud Seeding Operations Component

Meteorological support - responsible for meteorological data, analysis and forecasts.

Pilot, co-pilot, cloud seeding officer and crew.

Field operations group – responsible for field raingauges and facilities including communications.

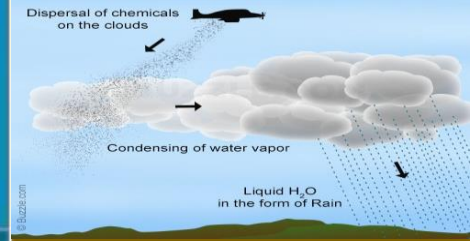
Research Group – involved in the various connected researches of the project.



Cloud Seeding 'In Situ' Experiment, *Operation and Evaluation of Results*

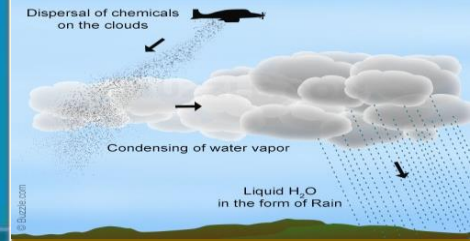
Cloud Seeding 'In-Situ' EXPERIMENTS

- Identify priority cloud seeding areas in Luzon, Visayas, and Mindanao field experiments on cloud seeding involving the use of aircraft to deliver the appropriate seeding materials into the cloud;
- Test the effectiveness of various size-categories (80μ, 40μ, 20μ) of the fine, powdered salt for cloud seeding through field experiments and cloud modelling.
- Observing the cloud before and after seeding by means of radar, radiosonde, satellite, NWP models, etc.,
- Evaluate the successor failure of the experiments/operation of the cloud seeding operations.
- Application of cloud seeding technology to drought/near-drought conditions.



Impact and risk assessments of cloud seeding target areas:

The impact/effect of cloud seeding and seeding materials on vegetation and the environment will be assessed, *together with* The risk involved, through hazard and vulnerability analysis, disaster risk assessment and disaster risk reduction process.



STANDARD OPERATING PROCEDURE

DETERMINING CLOUD SEEDING POTENTIAL USING PAGASA FACILITIES

PAGASA Facilities/Expertise

OBSERVATIONS

- Satellite (Infrared & Visible) Wx maps
- Doppler Radar
- Radiosonde Sounding

PREDICTIONS

- NWP Numerical weather prediction
- Cloud models

Group Decision

DECISION TIME: GO-SEED, NO-GO, OR STANDBY (BEFORE 10 AM)

PRE-FLIGHT BRIEFING OF AIRBORNE AND GROUND CREW

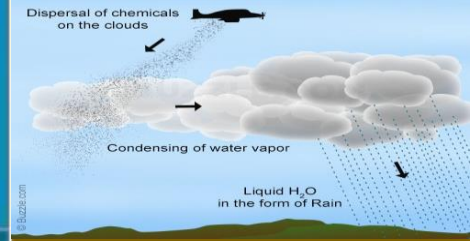
STANDBY ? **NO-GO**

GO-SEED DAY

Activate/Update decision making tools.
Conduct cloud seeding sorties –
Airborne crew performs cloud seeding
Coordinate/Monitor cloud seeding operations

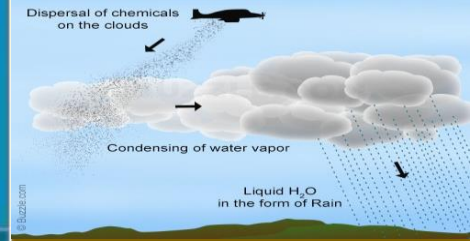
- **DEBRIEFING**
- **PLANNING (FORECAST) FOR NEXT DAY CLOUD SEEDING OPERATIONS**

END

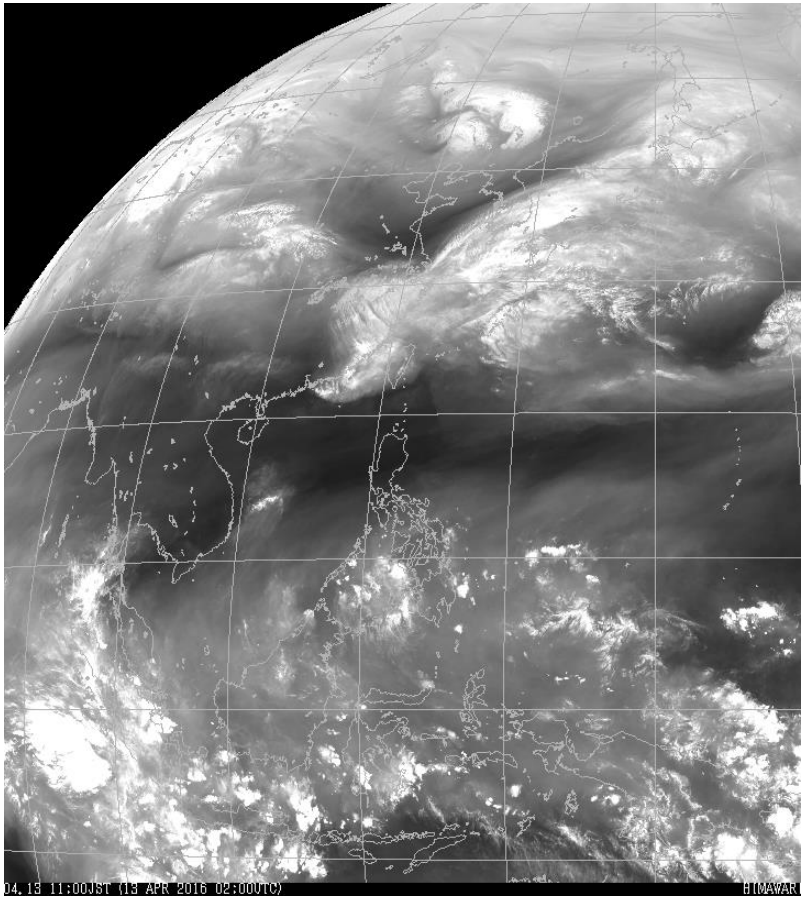


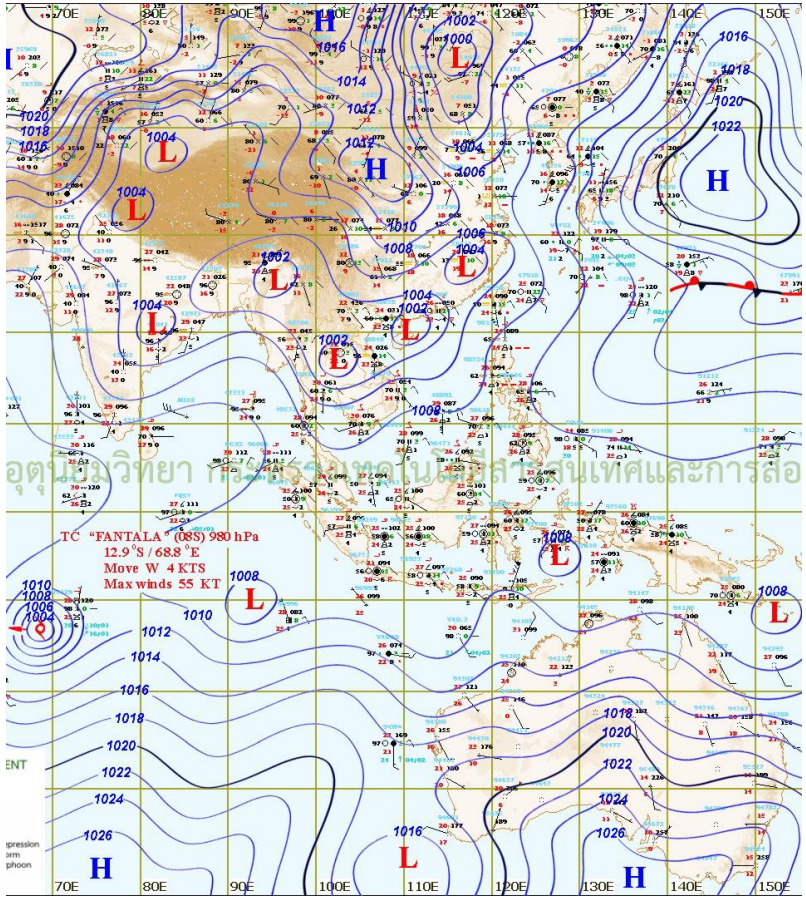
Results of Recent Cloud Seeding Operations

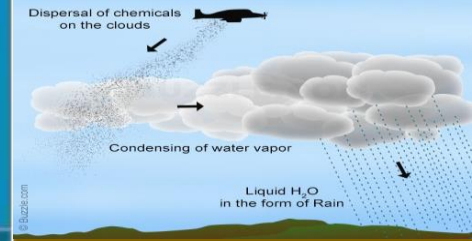
Batangas Province
(Sugar Regulatory Association)
April 13-22, 2016



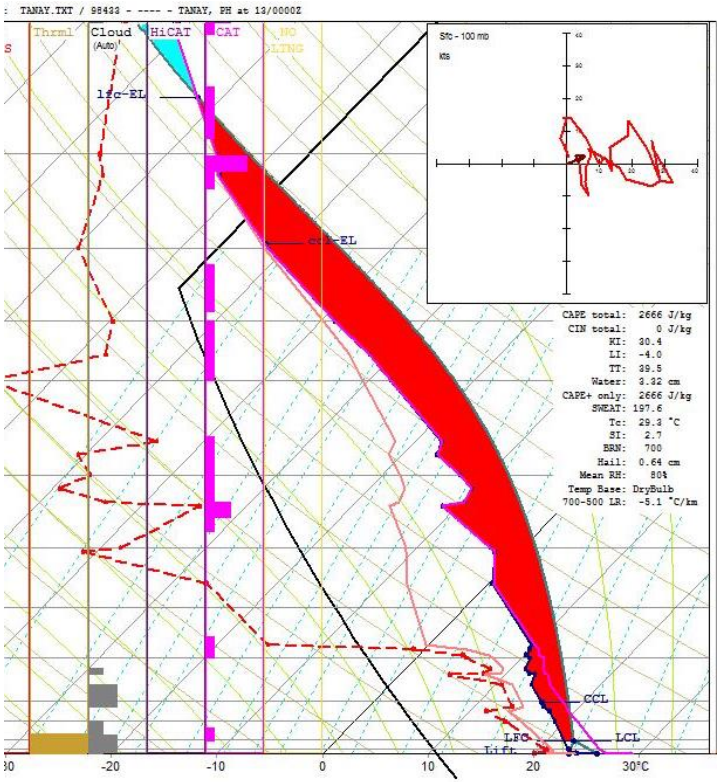
Synoptic Situation

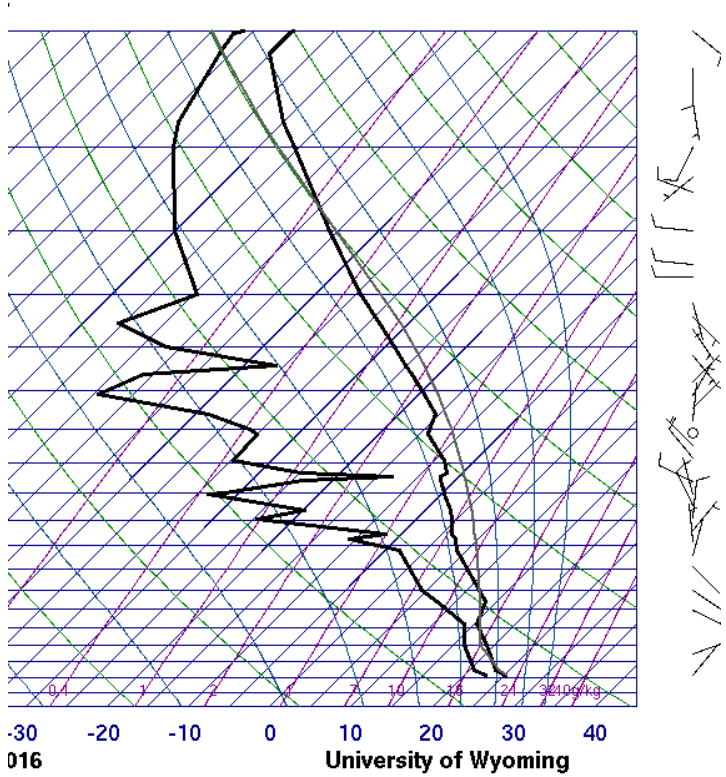


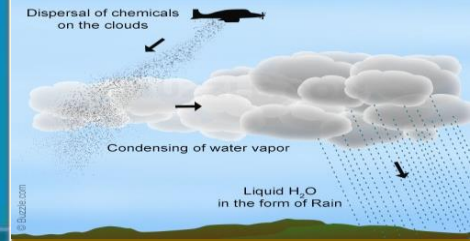




Atmospheric Sounding

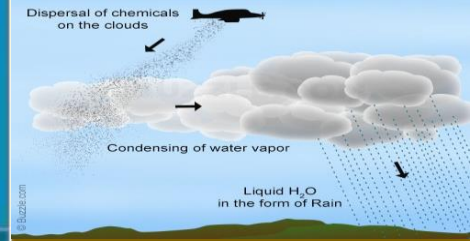






NWP Forecast (GFS Model)

GFS								
Precipitable Water (kg/m²;g/m²)	Relative Humidity (%)				Wind Shear @ (850-500hPa)	Wind direction/speed (km/hr)@		
	SFC (1000 hPa)	850 hPa	700 hPa	500 hPa		850 hPa	700 hPa	500 hPa
						700-500hPa (>70kph)		
>41	>80	>80	>70	>60				
46.987	69%	89%	87%	9%		140/6	170/17	260/23
47.105	54%	92%	79%	10%		135/13	180/17	255/23
46.637	46%	79%	71%	12		155/12	190/15	250/22



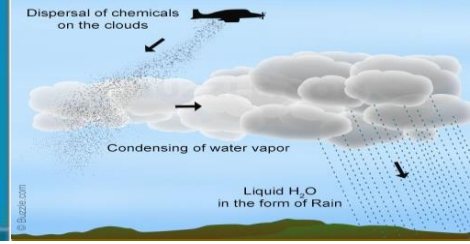
OPLAN BATANGAS – 13 April 2016 (8am – 11am)

Summary: Based on Tanay Rsonde (130000 UTC); GFS Model fcst (130000 UTC; Satellite imagery (130200 UTC)/Wx map (121800 UTC)

Synopsis:
Satellite IR 130200UTC– Upper ITZC over Mindanao
Satellite WV 130200UTC – low level moisture over target area
Map 121800UTC – trough of LPA Thailand; cold front from Japan

Radiosonde: Tanay 130000 UTC
RH – moist up to 694.0 hPa (3198m= 10,490 ft) – 83%-66%
RH – 500hPa and above – dry (< 10%)
Wind – SSE to SE up to 3500m; SW up to 2000m; SE up to 3500m
Indices – Unstable (5Yes - 2No); CAPE = 2666
PW = 33.2cm

NWP Fcst (GFS) 8am 11am 2pm



Decision Time: 8AM, April 13

Relative Humidity – moist up to 10,000ft) – favorable for LOW cloud (CL_2) development

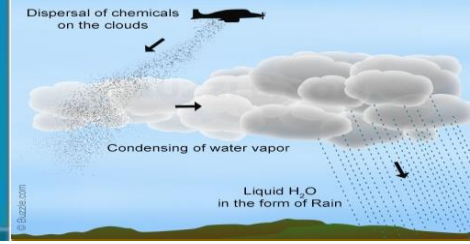
Indices – Unstable - favorable for cloud development

Precipitable Water – 33.2 Tanay; 45 Fcst- favorable for cloud development

Wind – SE-S-WSW - favorable for cloud development (seeding from the South)

Decision: GO SEED DAY

CSO sorties conducted in the morning and afternoon



Decision Time: 8AM, April 19

Analysis:

RH - Sfc to 795hPa (2104m – 6900ft)- relatively moist at 60% to 90% - ***marginally favorable*** for cloud (CL_2) development

Instability – Mostly Stable up to 700 hPa – ***not favorable*** for cloud growth and development

PW – 30cm Tanay; Fcst- 45cm **-** ***marginally favorable*** for cloud development

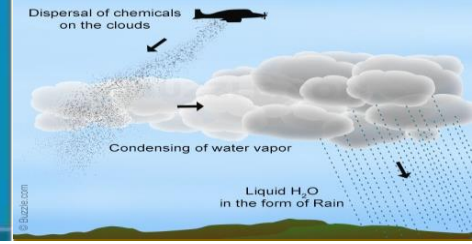
Wind – E-NE (>10kts) **-** ***not favorable*** for cloud development at east coast

Forecast (8am-2pm): PW & RH – ***marginal for RH*** (Sfc to 700mb; OK for PW)- ***marginally favorable*** for cloud development

Temperature inversion @ 2,800 to 4,500 ft could be ***hindrance to further growth*** of clouds; should be overcome by cloud seeding

Decision: STANDBY

(Wait for cloud development thru RADAR and SPOTTERS)



Decision Time: 8AM, April 21

Analysis:

RH - Sfc to 824hPa (1801m=5907ft) – 68%-94% (moist) ***- favorable for fair weather cloud*** (CL_1) development

Instability – ***Stable*** (900 – 650hPa) – ***unfavorable for cloud development***

PW – 27.4cm Tanay; Fcst-31-34cm – ***marginally favorable for cloud development***

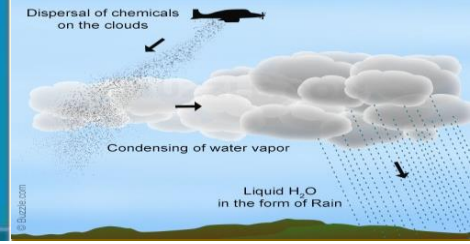
Wind – ENE-NE (15 -30kts);

Forecast (8am-2pm): PW & RH – marginal RH (Sfc to 700mb; OK for PW)- ***marginally favorable for cloud development***)

Temperature inversion @ 824hPa to 746hPa(1800m to 2647m) – ***hindrance to further growth of clouds***; ***may not be overcome by cloud seeding (thick layer ~ 850m)***

Decision: NO GO SEED DAY

… For documentation and forecast (decision) verification…, watch out for cloud developments over target areas - thru RADAR and Ground SPOTTERS



Actual CSO (13 Apr '16)– PAF Report
(First Sortie)

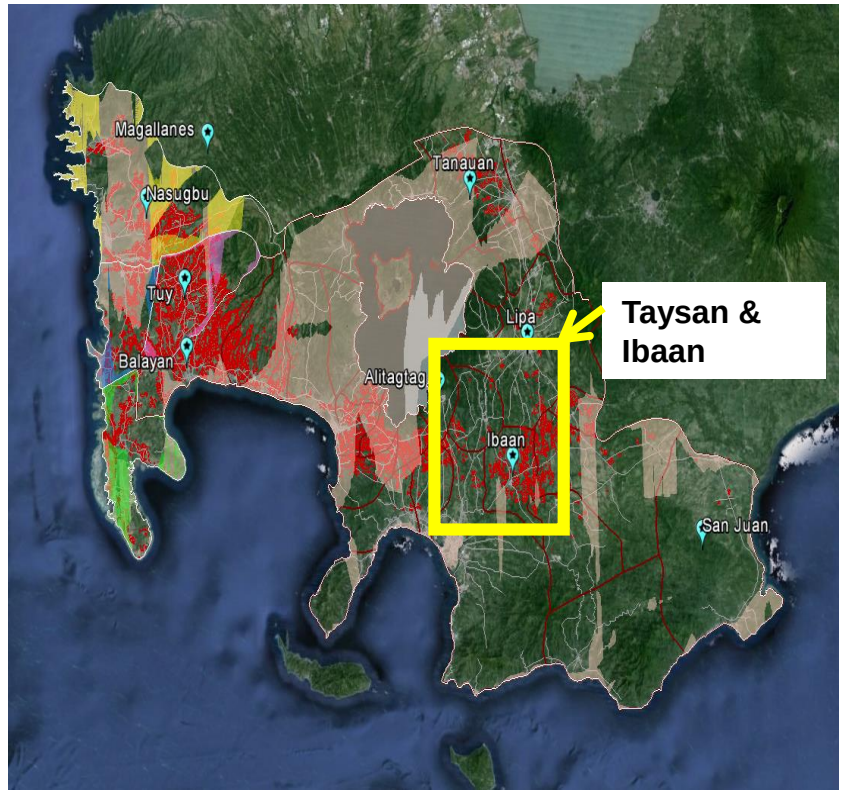
Take off TIME: 09:24 AM from Fernando Air Base Lipa, Batangas

Seeding Time: **09:33 AM to 09:45 AM** (12min)

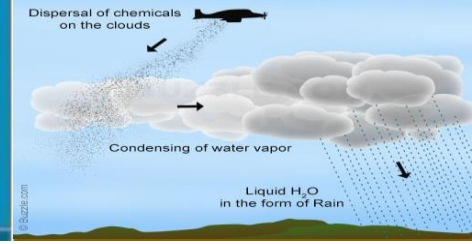
No. of Bags Dispense: 5 Bags

Landing: 09:56 AM

SEEDING AREA	
LAT	**LONG**
13°49.53'	121°10.52'
13°51.417'	121°08.511'

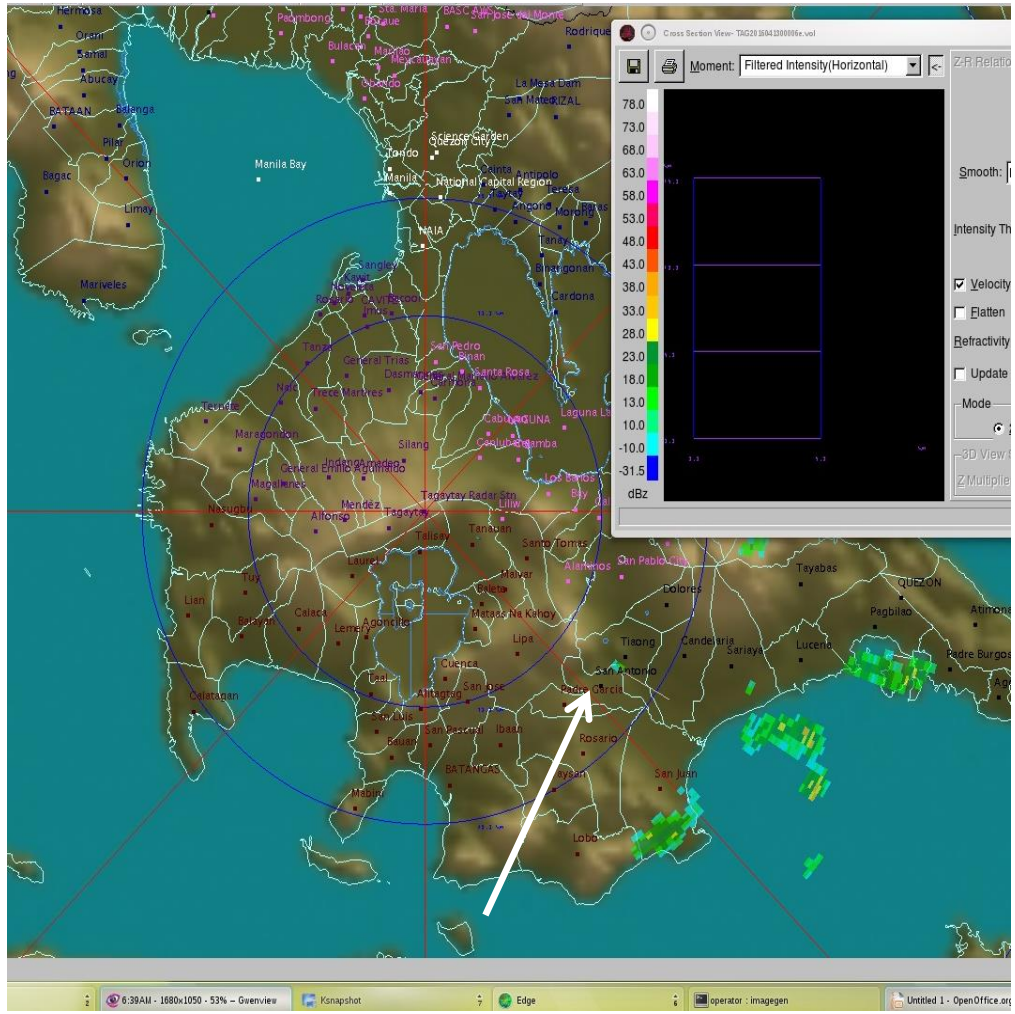


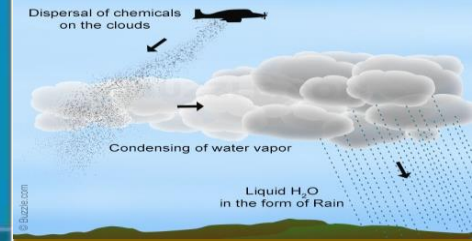
Remarks: Light rains over **Taysan** and **Ibaan.** **(11:30AM to 11:54AM)**



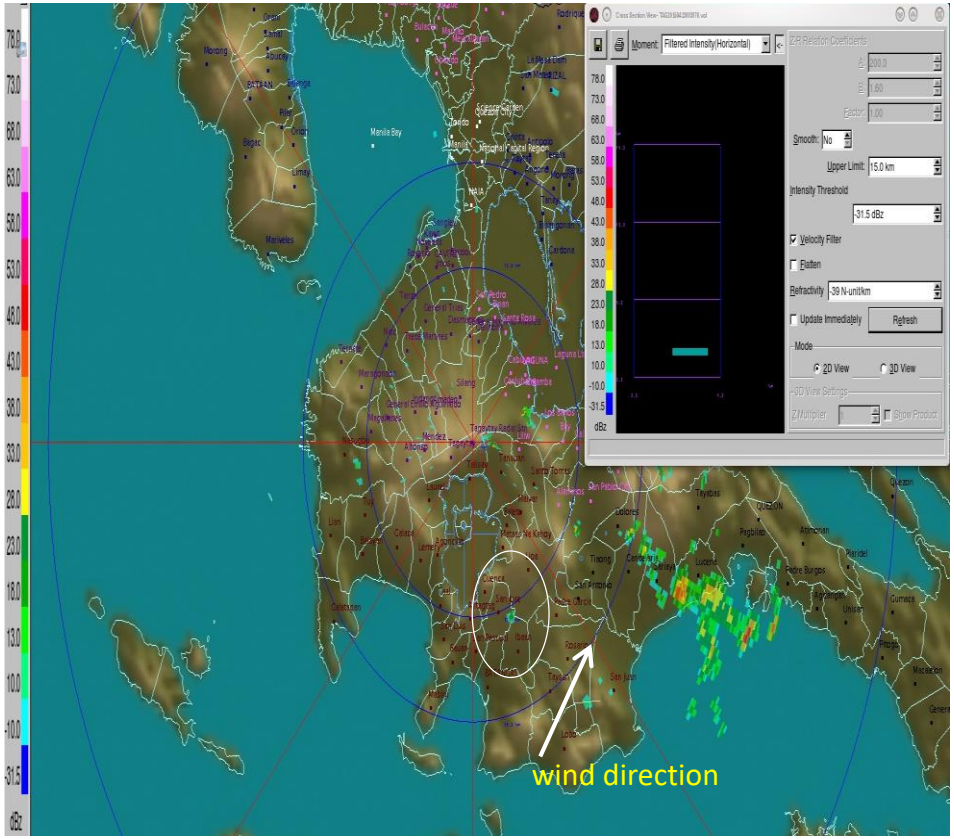
TAGAYTAY Doppler Radar (C-Band)

8:00AM, 1hr & 30mins before seeding

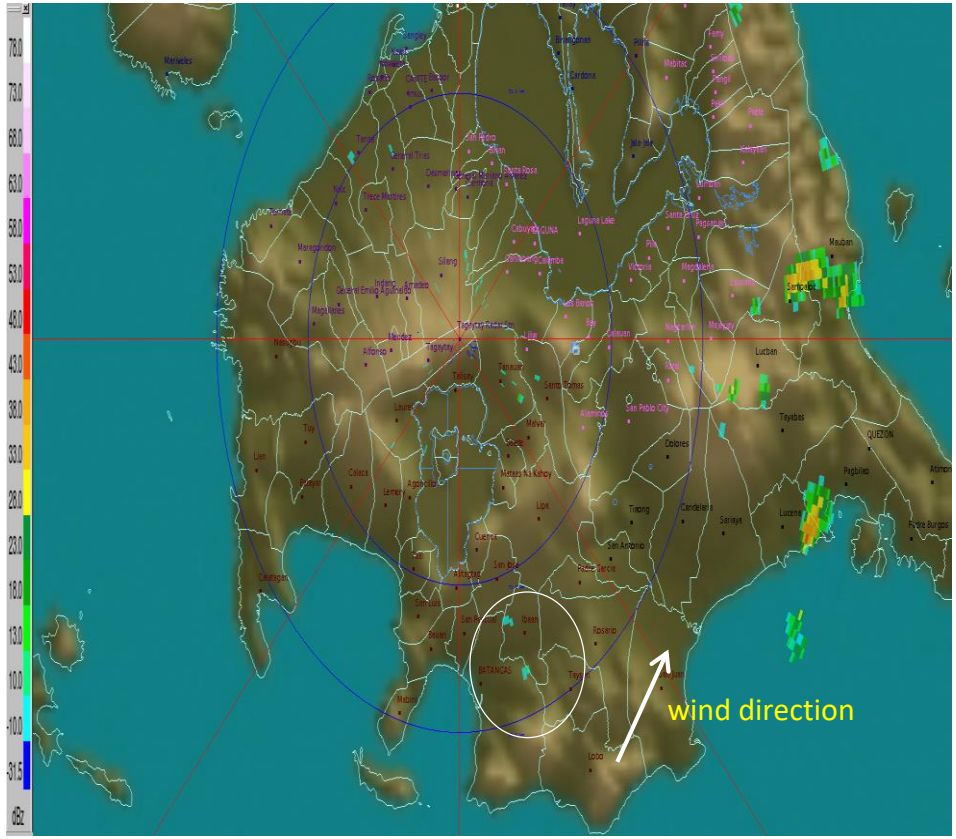


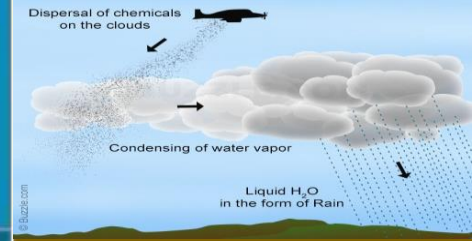


8:45AM, 51mins before seeding

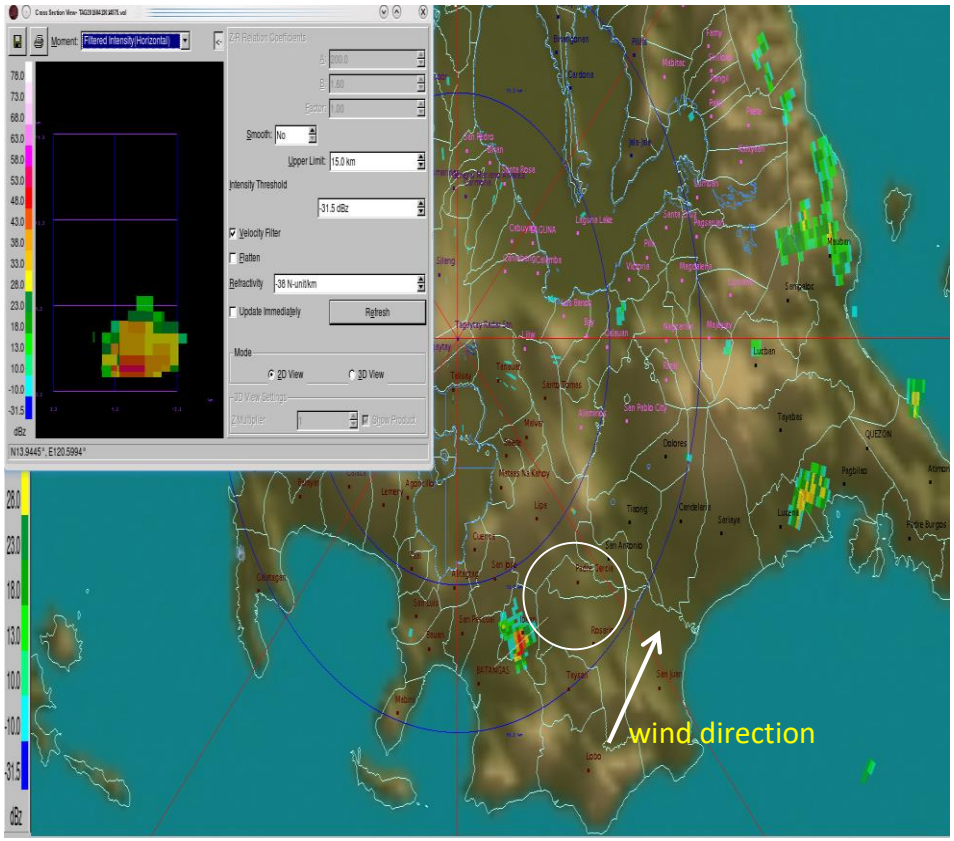


9:30AM, 3mins before seeding

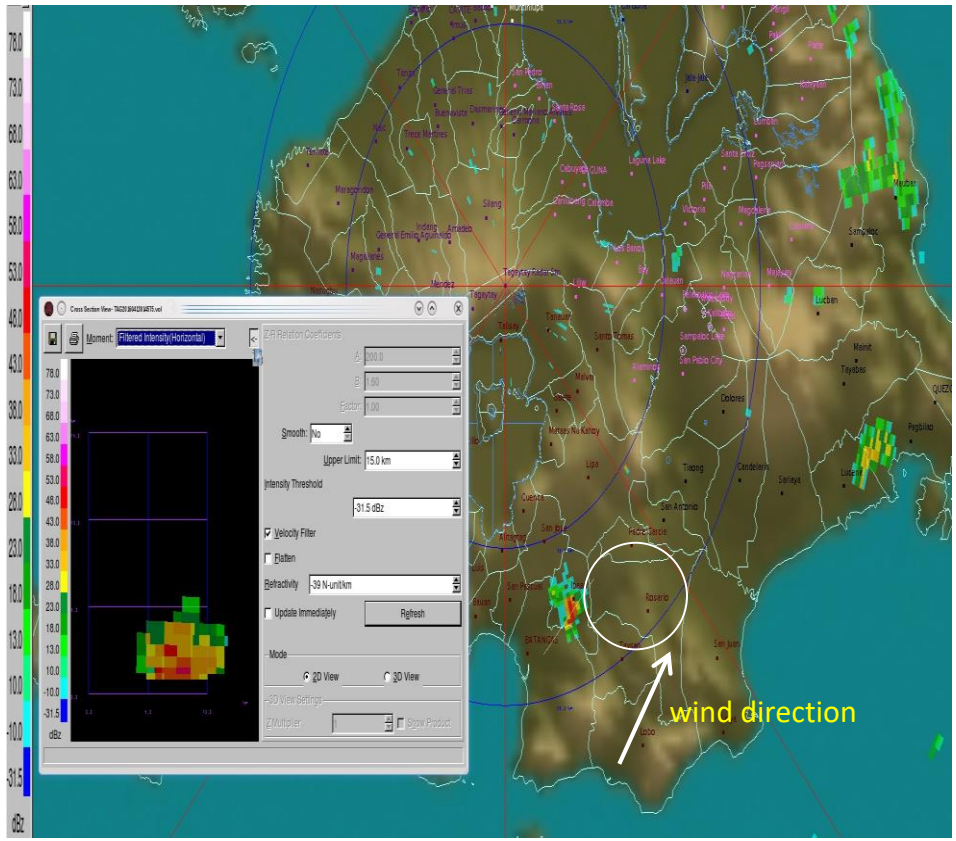


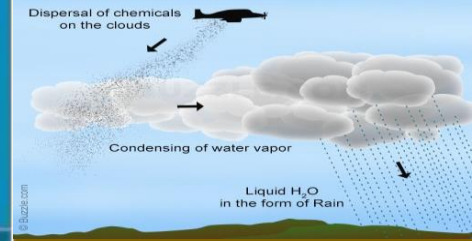


9:45AM, 12mins after seeding

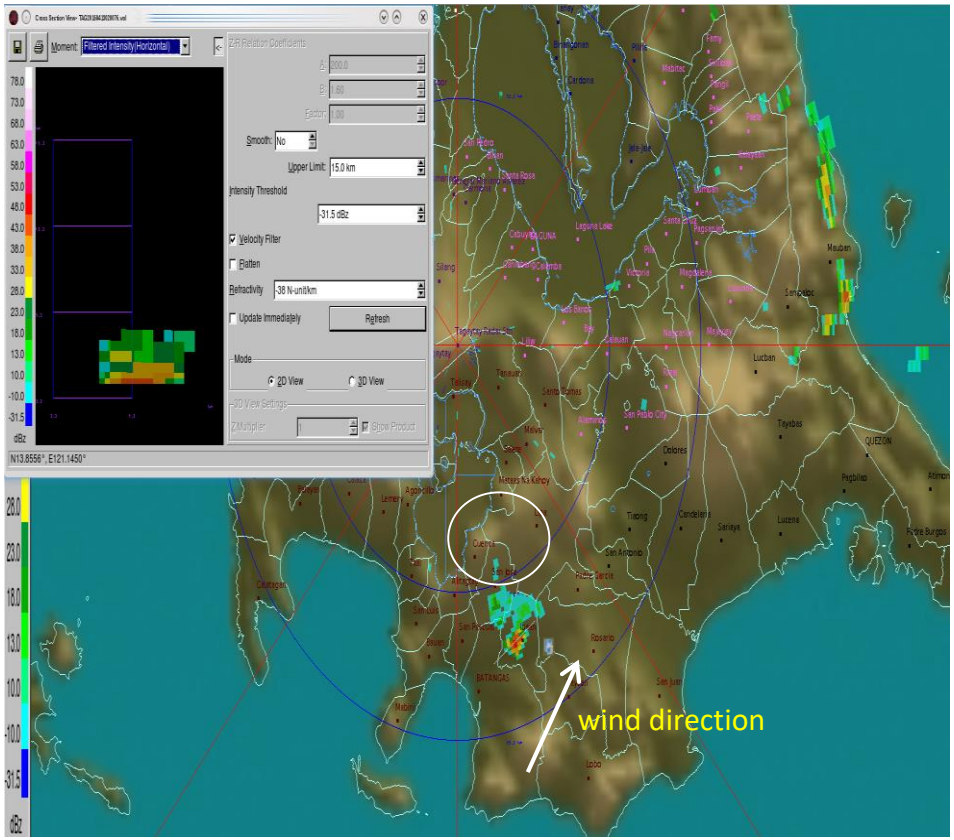


9:57AM, 24mins after seeding

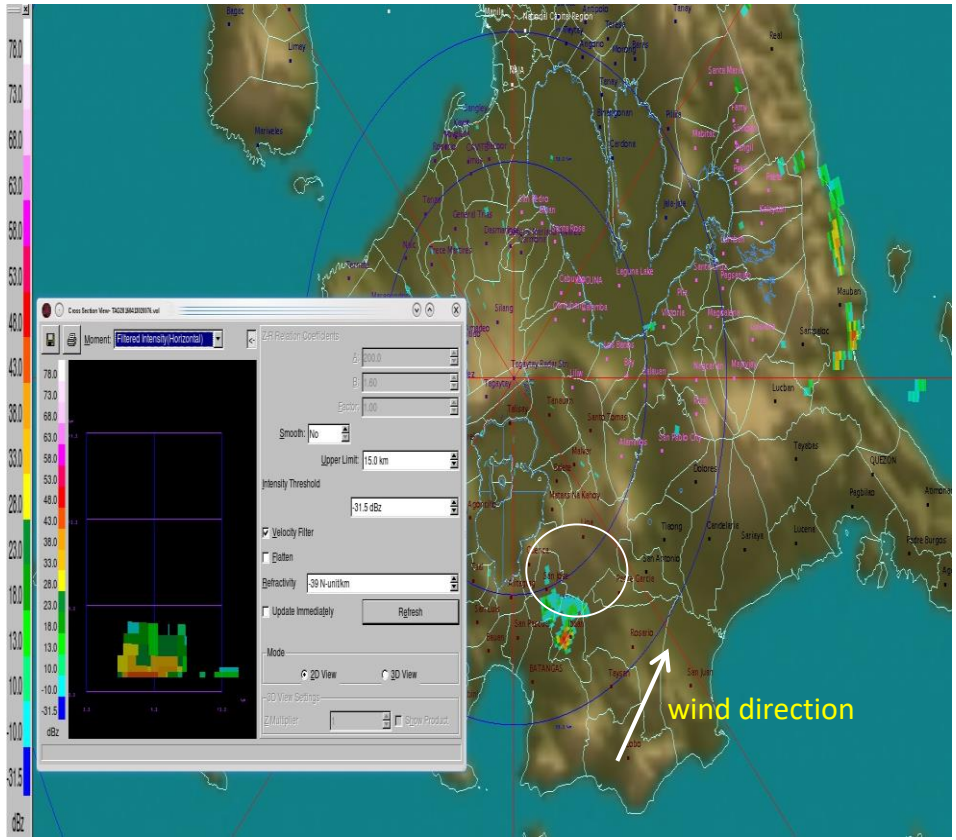


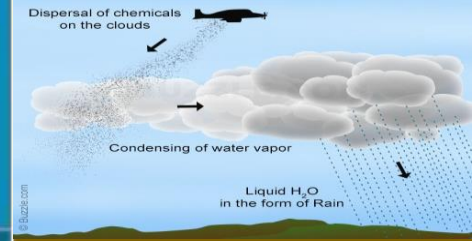


10:00AM, 27mins after seeding

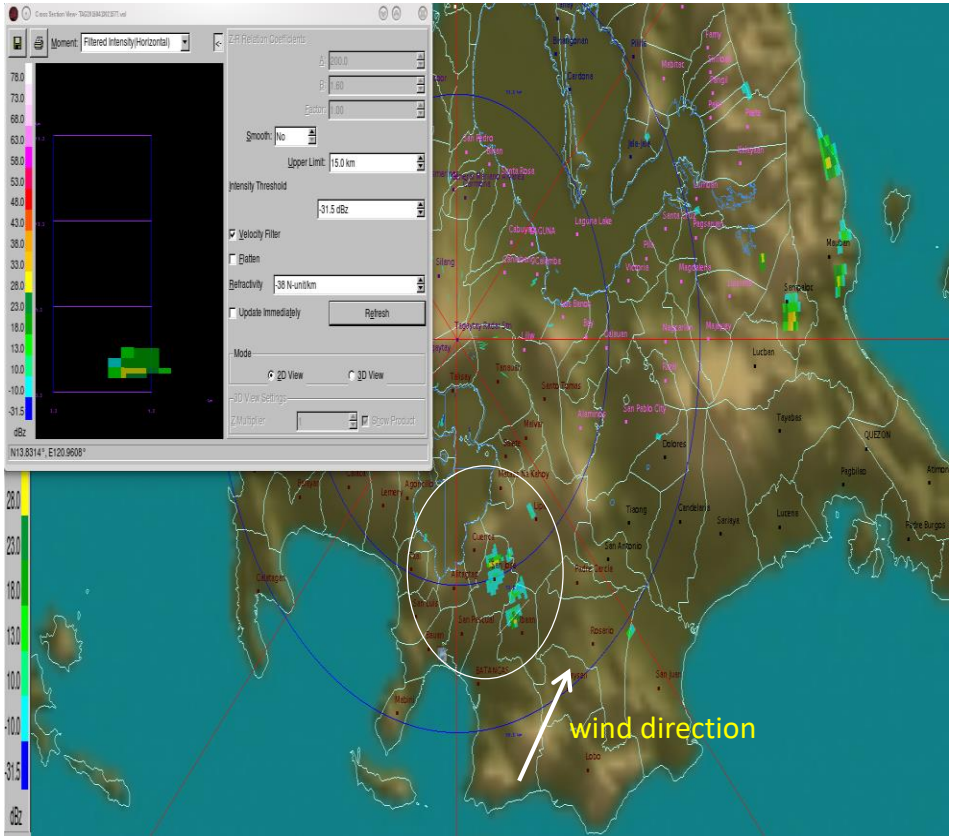


10:12AM, 39mins after seeding

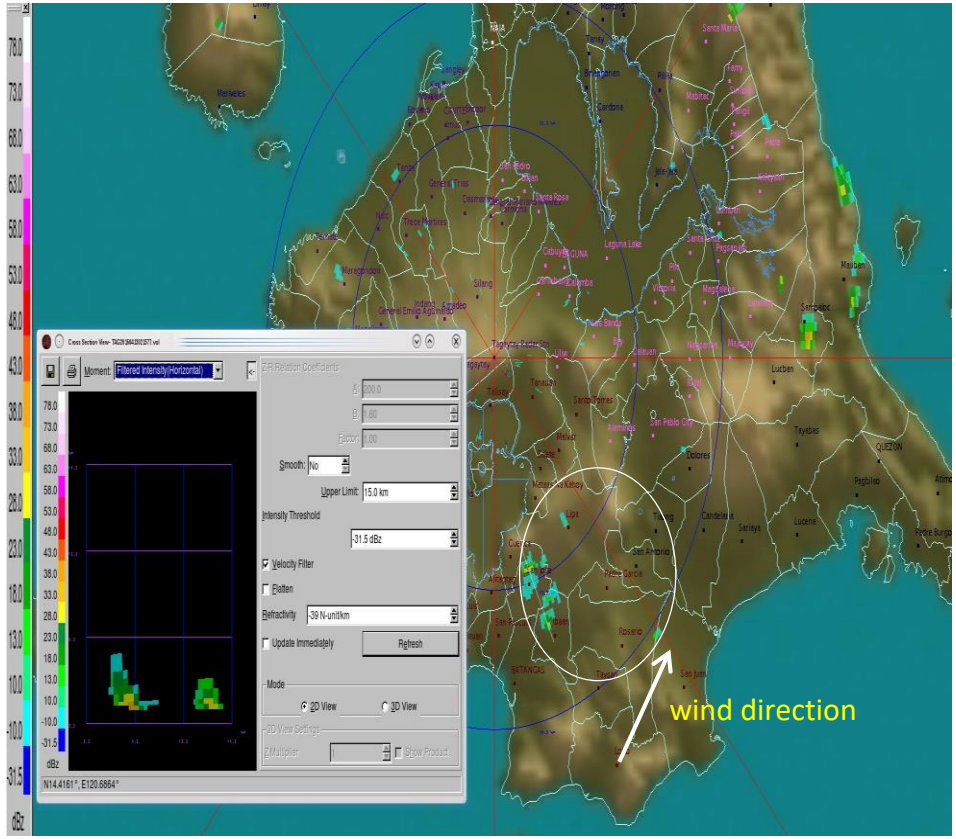


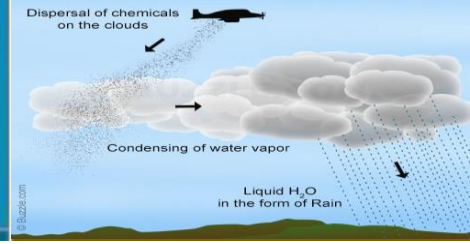


10:15AM, 42mins after seeding



10:27AM, 54mins after seeding





Actual Cloud Seeding Operation - PAF (Second Sortie)

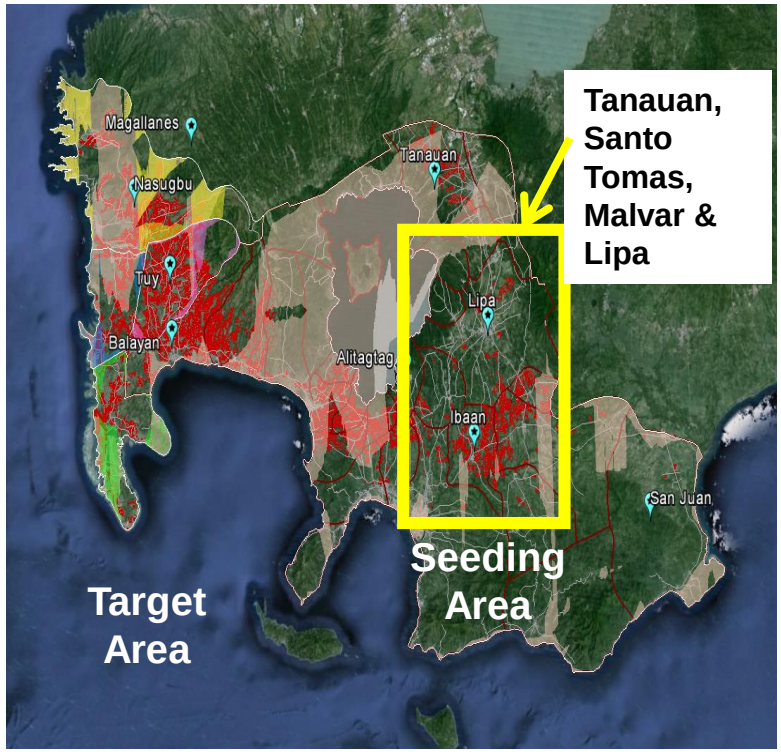
Take off TIME: 01:01 PM from Fernando Air Base Lipa, Batangas

Seeding Time: 01:11 PM to 01:27 PM (16min)

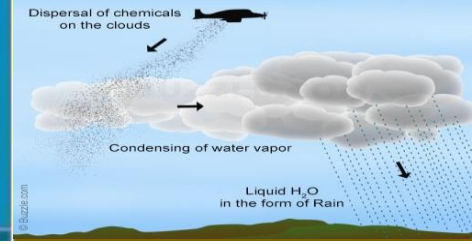
No. of Bags Dispense:

5 Bags

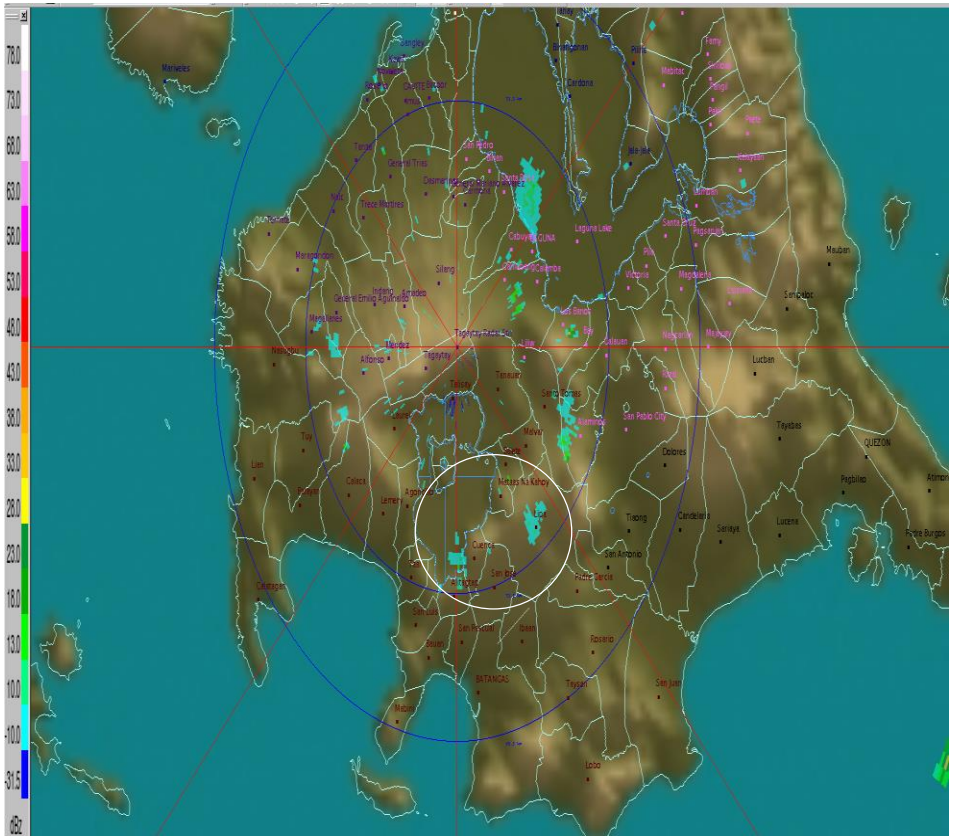
Landing: 01:37 PM



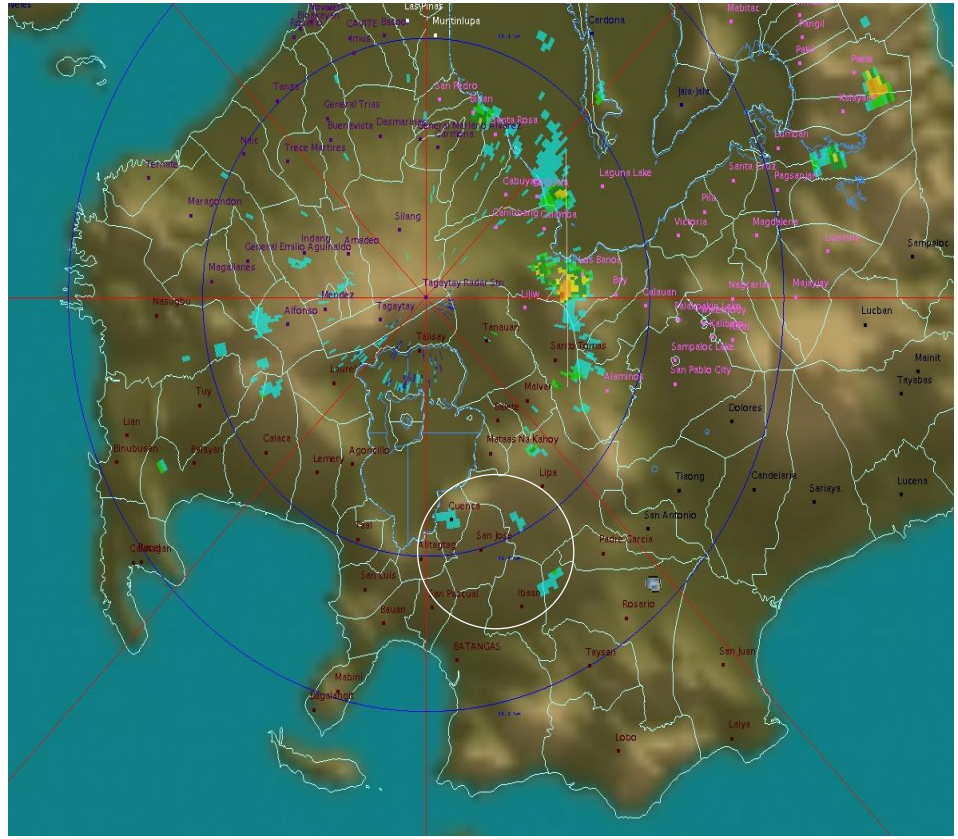
Remarks: Heavy rains over **Tanauan, Sto. Tomas**, **Lipa** and **Malvar. (02:15PM to 03:40PM)**

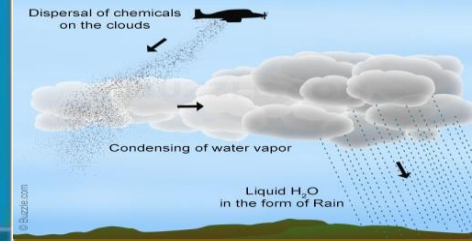


1:00PM, 11mins before seeding

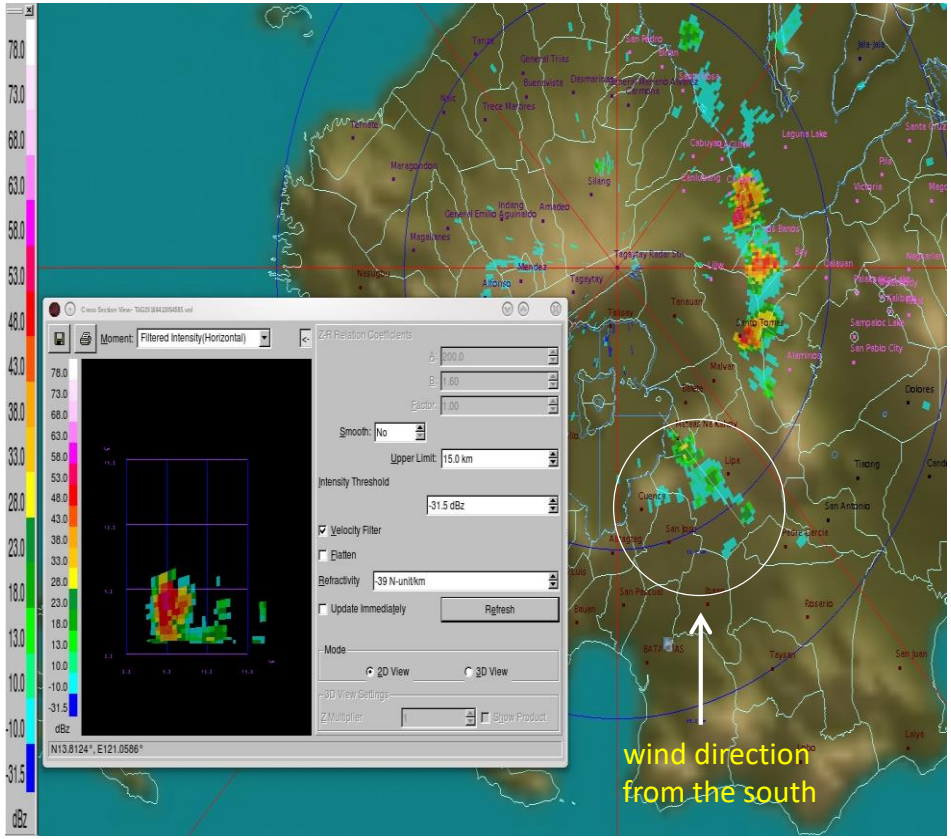


3:30AM, 19mins after seeding

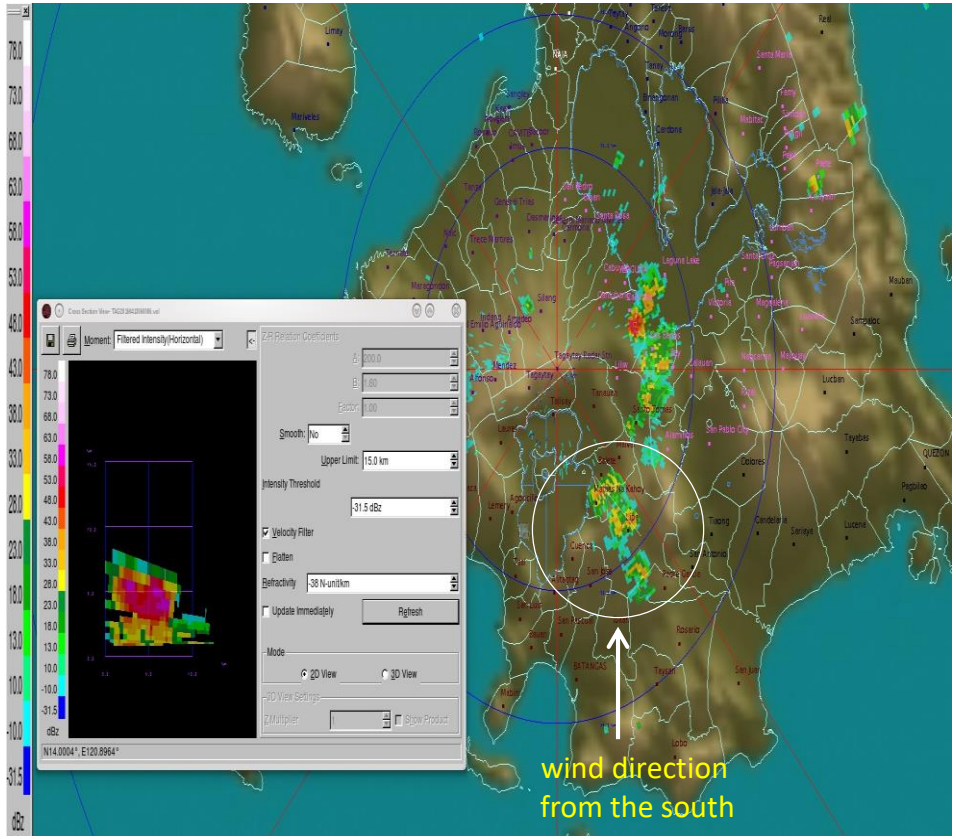


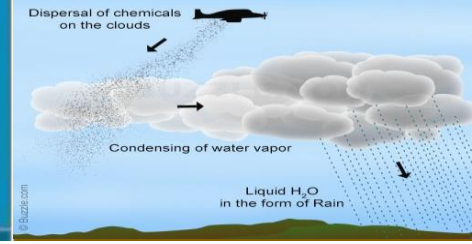


1:45PM, 34mins after seeding

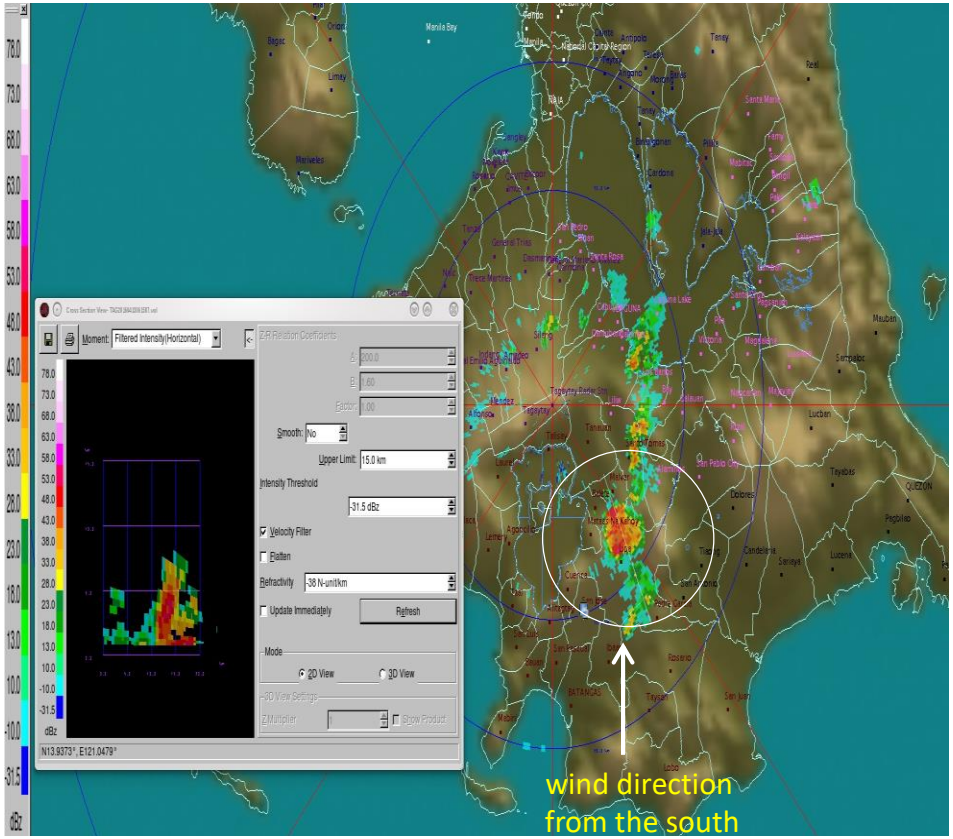


2:00PM, 49mins after seeding

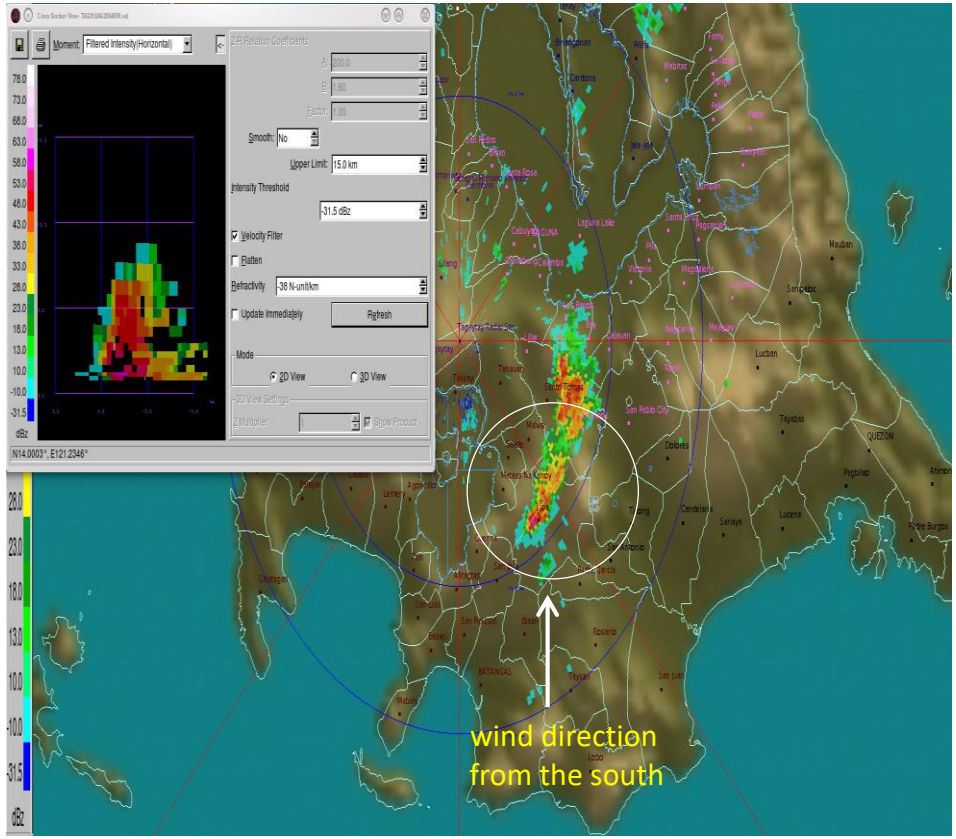


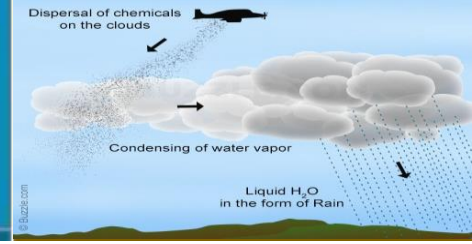


2:15PM, 1 hr & 4mins after seeding

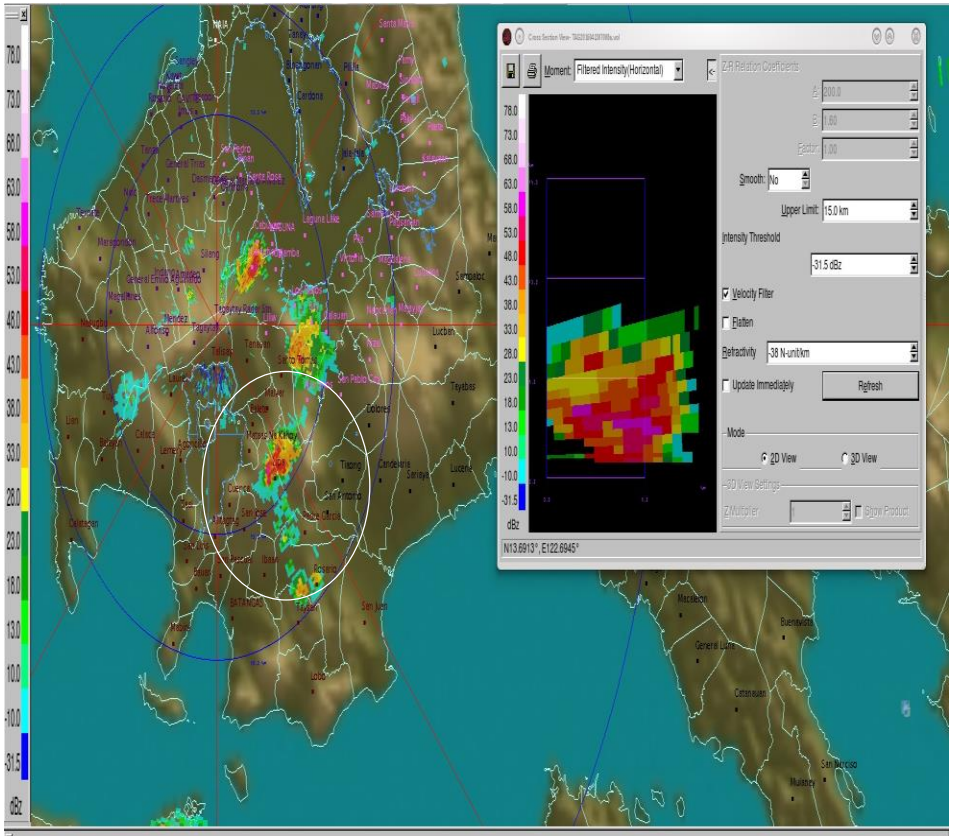


2:45PM, 1 hr & 34mins after seeding

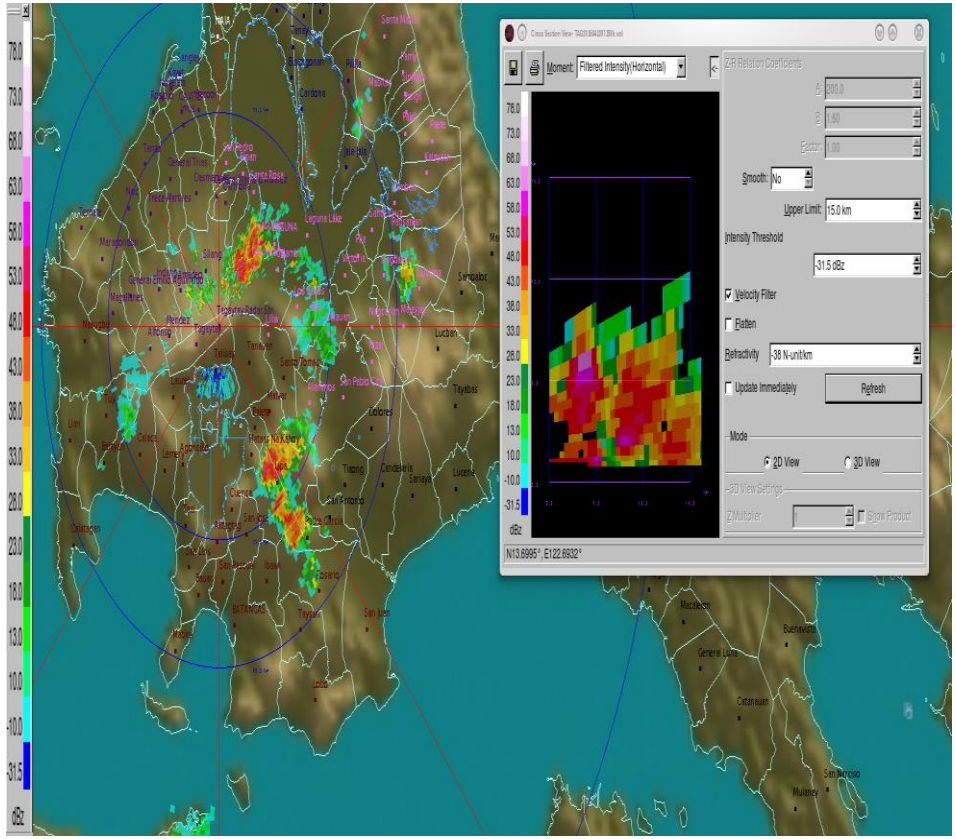


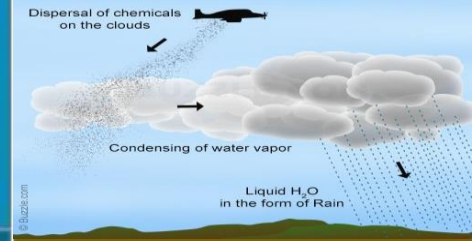


3:00PM, 1 hr & 45mins after seeding

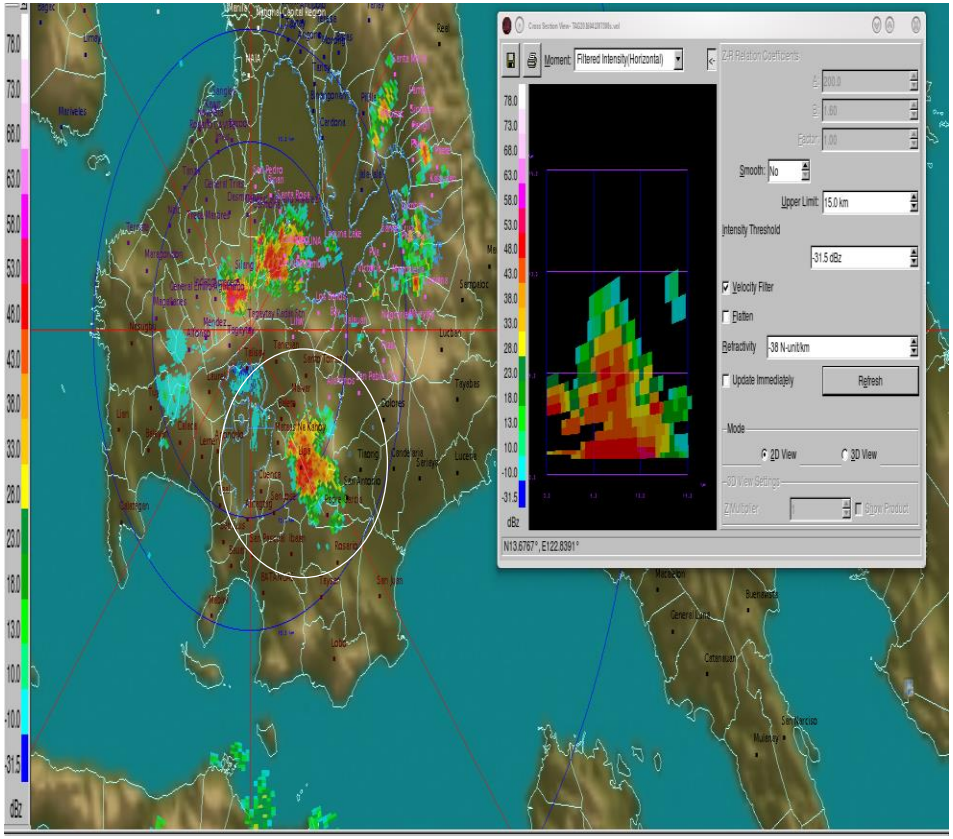


3:15PM, 2 hrs & 4mins after seeding

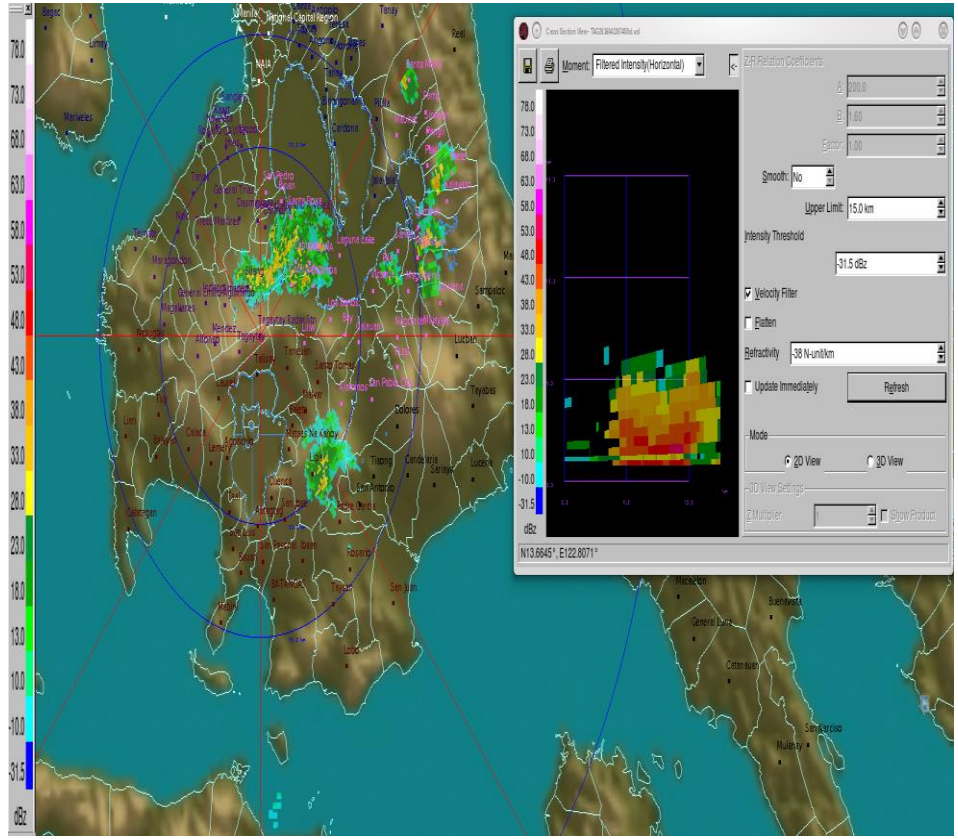


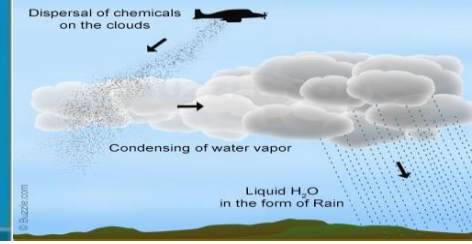


3:30PM, 2 hrs & 19mins after seeding



3:45PM, 2 hrs & 32mins after seeding





Batangas CSO

Day 1 (Apr 13) – GO Seed Day

Day 2 (Apr 14) – GO Seed Day

Day 3 (Apr 15) – GO Seed Day

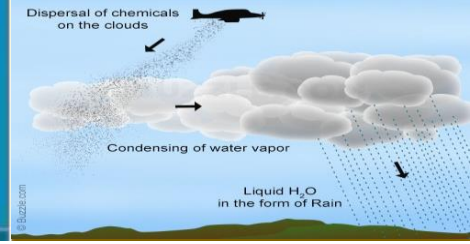
Day 4 (Apr 18) – GO Seed Day

Day 5 (Apr 19) – STANDBY/NO GO SEED

Day 6 (Apr 20) – GO Seed Day

Day 7 (Apr 21) – NO GO Seed Day

Day 8 (Apr 22) – STANDBY/GO Seed Day

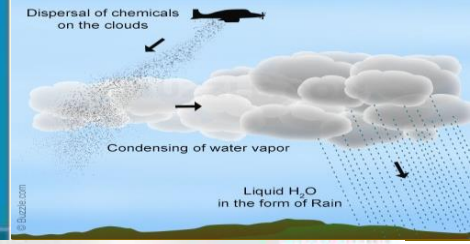


ANGAT DAM Cloud Seeding Operations (CSO)

November 4 – 6, 2015

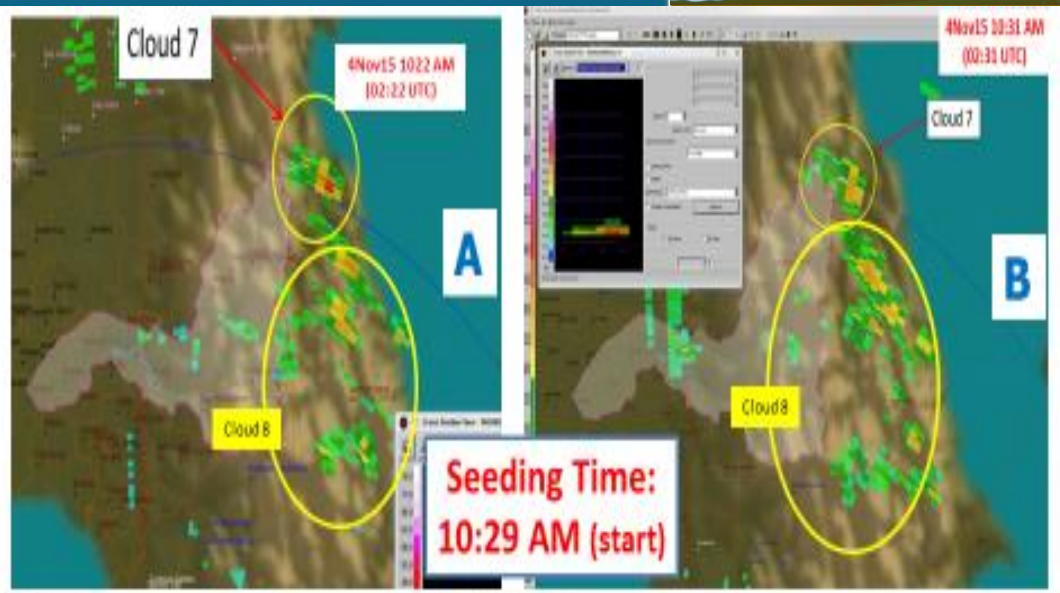
PAGASA's Mobile Radar

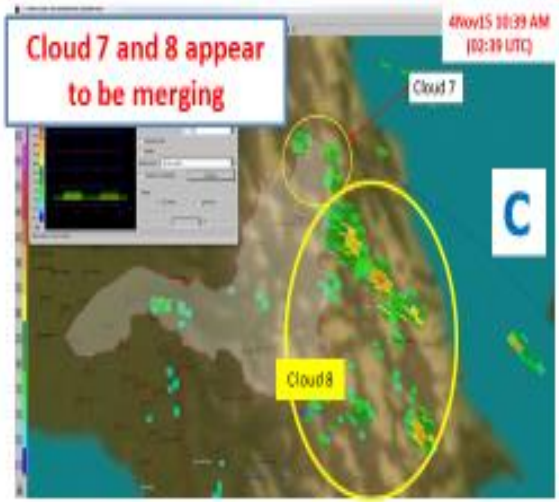
The Team recognizes the ***"Primacy of the Radar"*** in its decision-making … to SEED or Not to Seed



Day 1: Nov. 4, 2015

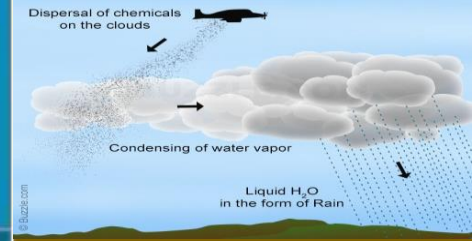
- Cloud seeding was effective in changing the characteristics of clouds and in producing rain
- Changes in cloud growth and development were apparent, mostly pointing towards more rains falling in the target area.



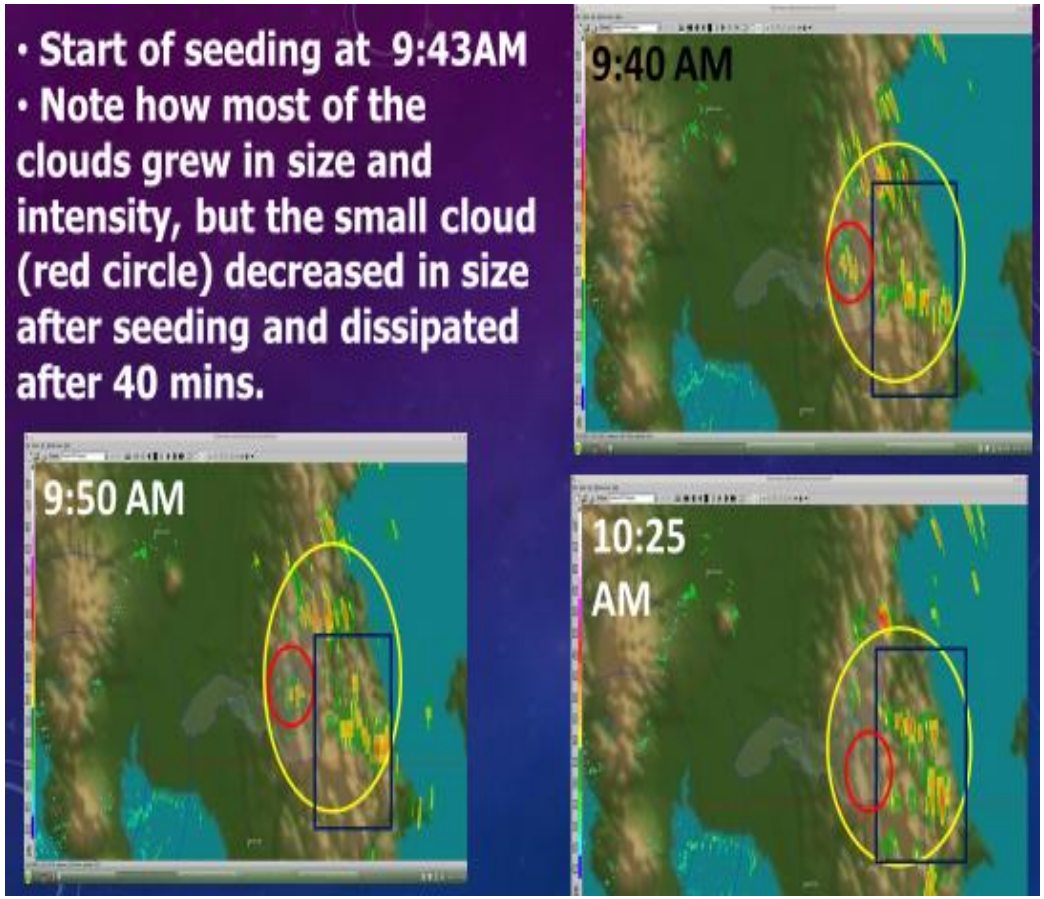


Cloud 7 and Cloud 8 were seeded from 10:29 AM to 11:12 AM (43 mins) with 16 sacks of salt (25kg/sack)

- Note how cloud 7 and 8, specially **cloud 8 grew in size and intensity, two (2) minutes after seeding (10:31AM) –** (Figure B)
- **Cloud intensity grew further after 10 min (10:39AM)** but some clouds started to **rain-out, thinned, and, ultimately, dissipated** (Fig. C)

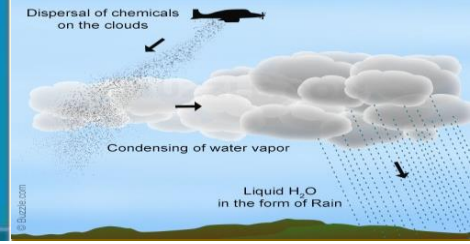


Day 2: Nov. 5, 2015

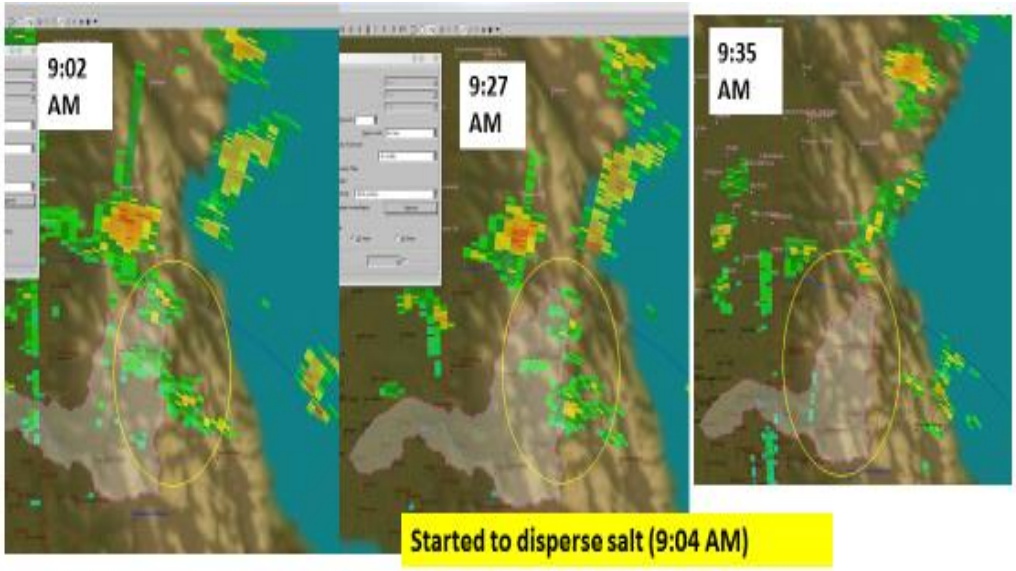


However, the rains fall out earlier and of shorter duration than expected, probably due to the coarseness of the seeding material (salt).

The Team is experimenting on the use of finely pulverized salt as cloud seeding agent

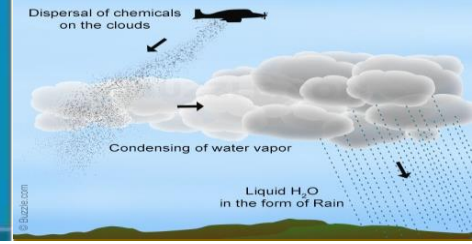


Day 3: Nov. 6, 2015



The growth of clouds and development of rains before, during and after seeding can be monitored by the Doppler Radar

- As early as 8AM, clouds were streaming into the target area from the east coast, through the Sierra Madre mountains. The cloud area was still increasing before the start of seeding at 9:04AM
- Six minutes after seeding (9:10AM), there were increases in intensity (rainfall) in some areas, but decrease in cloud area in others. About 30 minutes after seeding the cloud was completely gone



Cost benefit of water produced based on increase in dam elevation

Date	Dam Elevation (meters)	Dam Elevation (MCM)	Difference (MCM)	Cost at P28.29/m³
Nov. 3	205.08	780.9		
Nov. 4	205.39	786.6	5.7	161,253,000.00
Nov. 5	205.46	787.55	0.95	26,875,500.00
Nov. 6	205.79	794.2	6.65	188,128,500.00
Totals				376,257,000.00

Cost-Benefit Analysis

Assuming a very conservative estimate of 5% of the total rainfall due to cloud seeding:

a) BASED on dam elevation increase
= P18.8M

b) Based on average rainfall @ watershed =P17M

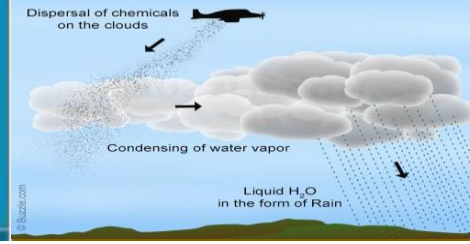
At an esimated. cloud seeding operations cost of P1.5M

COST OF CLOUD SEEDING OPERATION

Cost of Aircraft Operation(Nov 4-6)	621,791.21
Cost of Seeding Salt	19,600.00
Estimated Other Costs	900,000.00
Estimated cost of 3-days cloud seeding operations	1,541,391.21

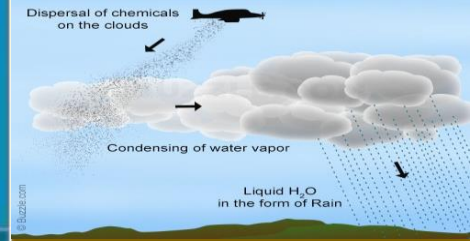
Cost benefit of water produced based on rainfall amount analysis

Average Rainfall (mm)	VOLUME (MCM)	Cost at P28.29/m3
9	5.112	144,618,480.00
8.3	4.6	130,134,000.00
3.8	2.3	65,067,000.00
		339,819,480.00



Way Forward

1. Employment of Hygroscopic Flares
2. Installation of high-end Sensors in the Cloud Seeding aircraft such as Cloud Water Inertial Probe (CWIP)
3. Acquisition of aircraft solely for cloud seeding operations purposes.
4. Strengthen linkages and partnership with other agencies, both local and international, to improve cloud seeding operations.
5. Publish journals and/or papers relating to cloud seeding operations in the Philippines.

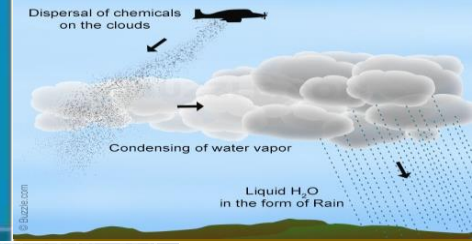


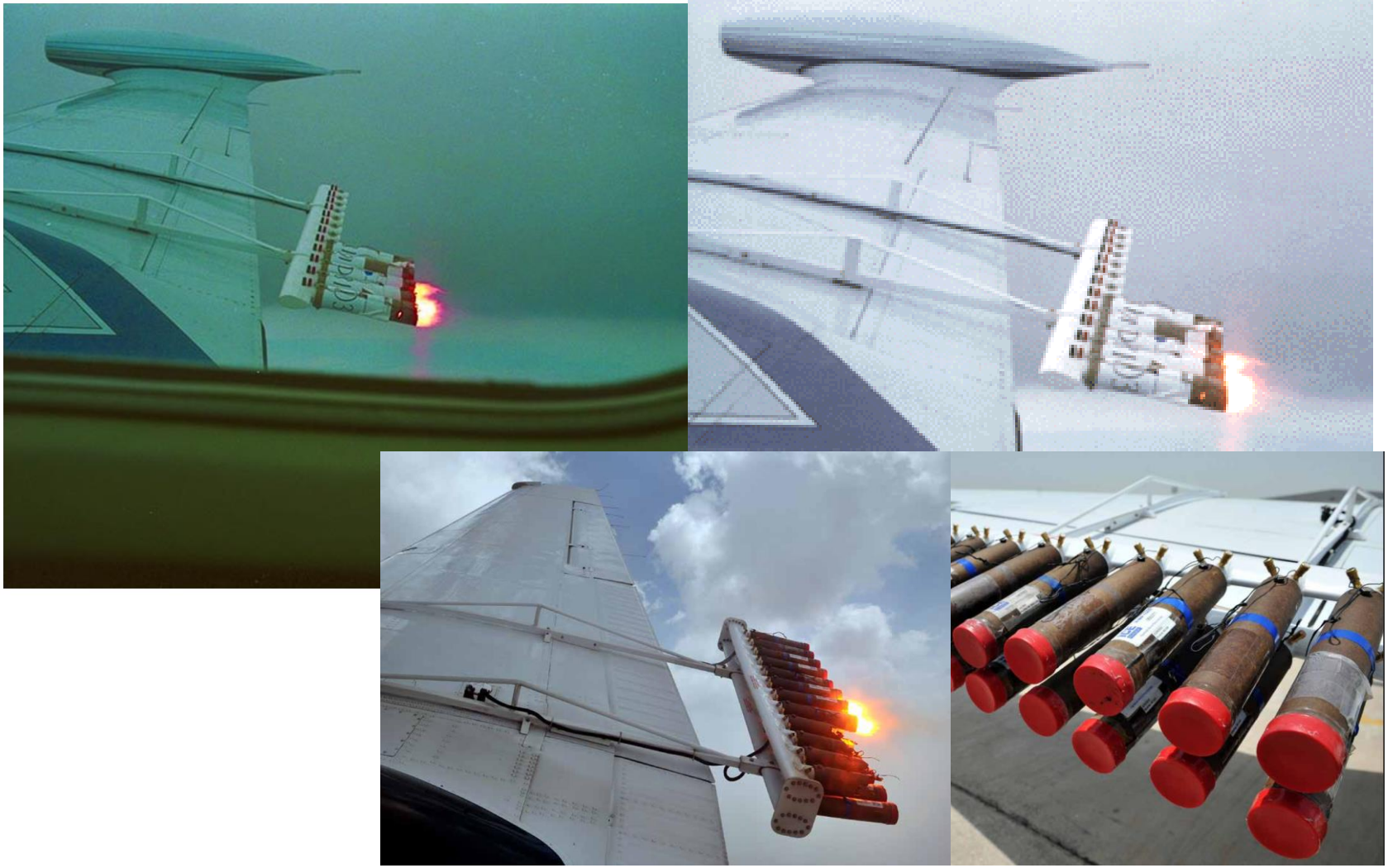
Cloud Seeding Agents –New Technologies

Rain Enhancement Flares
(Hygroscopic Flares)

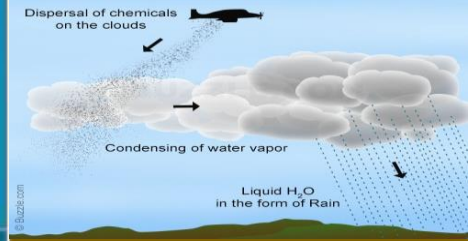
Rain enhancement Pyrotechnic flares
(Ice Crystal Engineering)

AgI Ejectable Cloud
Cold Cloud Seeding Flares





Photograph of burning hygroscopic flares during a seeding experiment in Coahuila, Mexico.

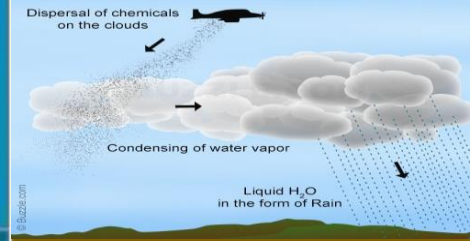


For general atmospheric measurement and characterization:

- **Total temperature**
- **Dew point**
- **Pressure/pressure altitude**
- **3-D winds**
- **GPS position**
- **Vertical acceleration**

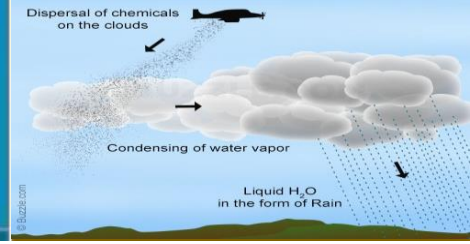
For the measurement of cloud hydrometeors:

- Cloud liquid water content (LWC)
- Cloud droplets (sizes and numbers)
- Cloud images (sizes, shapes, and numbers; small particles)
- Precipitation images (sizes, shapes, and numbers, precipitation-sized particles)



• A forward scattering spectrometer probe (FSSP-SPP-100) is an optical particle counter, suitable for counting and sizing particles in the size range of 0.5 - 47 micron diameter (collect size distributions of airborne particulates).
• For ease of service and compatibility the probe mounts in the 7-inch OD cylinder as a plug-in assembly with two internal connectors at 90° to each other allowing the probe light tubes to be oriented either perpendicular or parallel to the mounting pad.

- The DMT Cloud Imaging Probe (CIP) is very similar in technical operation to the 2D-OAP developed by PMS. A linear array of laser beams is focused on a sampling area where the particles' shadows are optically magnified to provide the imaging data.
- The data output is distributed in 62 channels making the minimum detectable particle size at 12.5 µm and the largest particle at 1562.5 µm.
- The CIP incorporates a Liquid Water Content (LWC) detector.



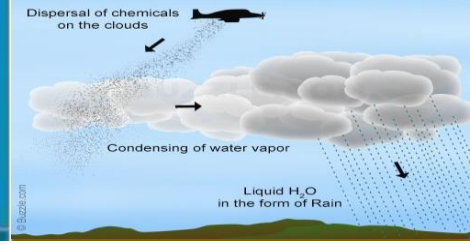
Cloud Water Inertial Probe (CWIP)

CWIP features

1. Developed to help the pilot make informed seeding decisions.
2. Single instrument for easy installation on seeding aircraft.
3. Combines altitude, temperature, humidity, airspeed, angle of attack, updraft speed and liquid water content data for cloud seeding pilots in a single display.
4. EFIS style display.
5. Dfault or user defined algorithms for cloud base and cloud top seeding.
6. Gives the pilot an indication of when seeding conditions are suitable.
7.-Guides the pilot to previous seed location.

Measurement capabilities

1.-ambient temperature
2.-relative humidity
3.-atmospheric pressure
4.-cloud liquid water content
5.-true airspeed
6.-angle of attack
7.-GPS latitude and longitude
8.-GPS altitude
9.-GPS groundspeed, GPS track
10.-velocity and acceleration in x, y and z axis
11.-magnetic heading, true heading
12.-turn rate, yaw angle, pitch angle, roll angle
13.-wind speed and direction
14.-air vertical velocity



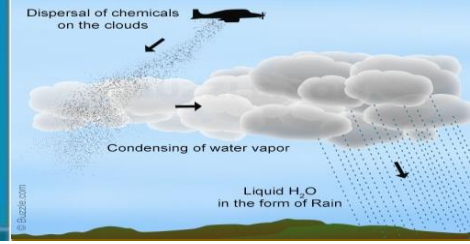
Summary

Weather Modification activities in the Philippines are centered mainly on **rain enhancement** and has been involved since the early 1950's.

Rainmaking activities must be carried out by **different agencies**.

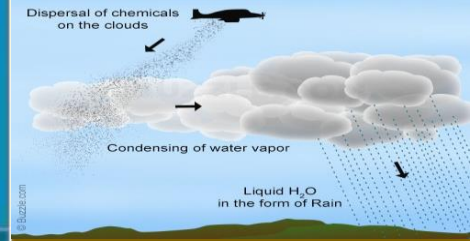
The need to design and implement a sustained national weather modification program for the country

Serious efforts must be exerted to study/assess the socio-economic as well as the ecological effects of weather modification.



SIGNIFICANT OUTCOME OF THE CLOUD SEEDING OPERATION PROJECT

The results of these experimentations, together with the cloud seeding operational procedures formulated, could be the **legacy of this project** to present and future cloud seeding operations in the country…


Dispersal of chemicals
on the clouds
Condensing of water vapor
Liquid H_2O
in the form of Rain

Thank you!