Weather Modification Program using Flare Technique at South Sulawesi, Indonesia – A Technology Transfer

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1. Introduction

To preserve water resource within Larona Catchments Area, located in the District of East Luwu, South Sulawesi Province holds a key role. The reason is that the production process of PT International Nickel Indonesia (PT. INCO) depends strongly on the electric hydro power plant of Batubesi. Water supply of the PLTA Batubesi is coming from the three lakes, namely Matano, Mahalona and Towuti. These lakes are located in Larona Catchments Area (LCA). The electric hydropower of Batubesi is the only source of electric power for PT. INCO. Therefore, to maintain the water storage is the critical factor in yearly nickel production of PT INCO. Accordingly, PT INCO has utilized cloud seeding program to enhance rainfall in the LCA in order to maitain the availability of water resource. If water level of lakes of Matano and Towuti decrease, cloud seeding activity is be carried out. Cloud seeding using flare in South has started since 1998.

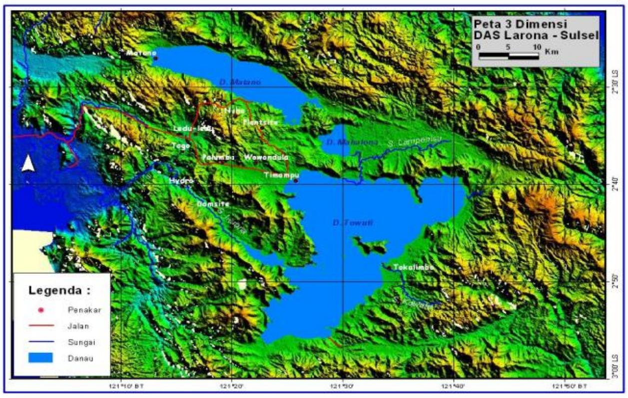

Figure 1. Map of Larona Catchment Area.

The total area of Larona Catchments Area, as the target area for cloud seeding program, is of about 2,477 km^2. There are three lakes in the Larona, namely Matano, Mahalona and Towuti. The Map of Larona Catchments Area can be seen in figure 1. The target area is the watershed of the three lakes (Matano, Mahalona, and Towuti) that feed the two power stations at Larona and Balambano.

Geographical position of LCA, in which close to equator and located between Bone Gulf at west side and Tolo Gulf at east side, causes in unique rain characteristic. Rain might occur in either wind condition, westerlies or easterlies. Larger water body (3 lakes) inside the catchments area causes in local dynamic circulation influences weather pattern and rain occurrence in this area significantly. The effect of lake's breeze and topographical terrain towards air circulation is that subsidence will prevail over the major part of catchments area. Therefore, clouds develop in the catchments area slightly later than those outside. Cloud seeding using flare technique has been conducted when seedable clouds are available in the target area and the vicinity.

Some institution who participate in this program are:

- PT International Nickel Indonesia (INCO), Soroako, Sulawesi, Indonesia.
- Weather Modification Technology Center (WMTC), Agency for the Assessment and Application of Technology (BPPT), Jakarta, Indonesia.
- Atmospherics Inc. (AI), Fresno, California, USA.
- Weather Modification Inc. (WMI), Fargo, North Dakota, USA.
- National Center for Atmospheric Research – Research Applications Laboratory (NCAR/RAL), Boulder, Colorado, USA.

2. Facilities and Instrumentation

Operations Center

The radar and operations control center are located at the Soroako airport (2.53 °S, 121.35 °E) at an elevation of 1388 feet MSL (423 m). Radar data from the WMI weather radar were accessible at this office. The Operations Director performed his duties from the airport. Forecasting and nowcasting tools were available via Internet and local area network (LAN) lines. These tools included access to the MM5 and other real-time forecasts, weather station information via the internet, satellite imagery, and radar data.

The airport facilities included fuel, hangar space, a dedicated tug, flare storing facilities, and office space. Communications with the aircraft were conducted from this location. Aircraft tracks were displayed at the Operations Center, along with real-time temperature and pressure data from the aircraft.

Airborne instrumentation

An instrumented Piper Cheyenne II twin engine turboprop was used for cloud seeding experiments and microphysical measurements of clouds and aerosols. An array of instrumentation (figure 2) was installed during the evaluation and assessment phase of the field project and included:

- Particle Measuring System [PMS] Forward Scattering Spectrometer Probe [FSSP] (able to detect cloud droplets between 2 and 47 µm diameter)
- PMS Passive Cavity Aerosol Spectrometer Probe [PCASP] (able to measure concentrations and sizes of aerosol particles between 0.1 and 3.0 µm diameter)
- PMS 2D-C Optical Array Imaging Probe (able to detect cloud and precipitation particles between 25 to 800 µm diameter)
- Cloud Liquid Water (CLW) sensor
- Cloud Condensation Nuclei counter (CCNC)
- Cloud seeding racks for 24 hygroscopic flares
- Glaciogenic Cloud seeding material (up to 24 BIP and 306 ejectables)
- GPS system for determining position, ground speed and for estimating winds
- Temperature, pressure and dewpoint sensors
- Data recording system

The data from all of the instruments was recorded every second during flight and select variables were telemetered (radioed) to the operations center in Soroako for real-time data display to aid in the training and direction of flight operations from the ground. The aircraft was capable of carrying only two microphysical measurement probes at a time. Consequently, probes were alternated depending on the mission objectives (aerosol-cloud interactions or precipitation development in clouds) for the day. The FSSP was used for large aerosol and cloud droplets (usually mounted all the time), the PCASP for aerosol characterization (concentrations and sizes) for aerosol-cloud interactions, and the 2D-C for precipitation development studies.

Aircraft analysis software, both commercial and NCAR-developed, was used to examine and summarize the aerosol characteristics, cloud droplet characteristics and precipitation formation processes in clouds in the Soroako region. The measurements obtained with these instruments in combination with radar, satellite and numerical modeling simulations, will be discussed in subsequent sections of this report.

Figure 2. The Piper Cheyenne equipped for seeding and cloud physics measurements.

This instrument package has been designed such that all parameters related to evaluating the seeding potential for Soroako, Indonesia clouds could be assessed. These include microphysical instruments to characterize the natural and seeded precipitation processes, and instruments to characterize the local thermodynamic structure of the atmosphere in which clouds develop.

Radar

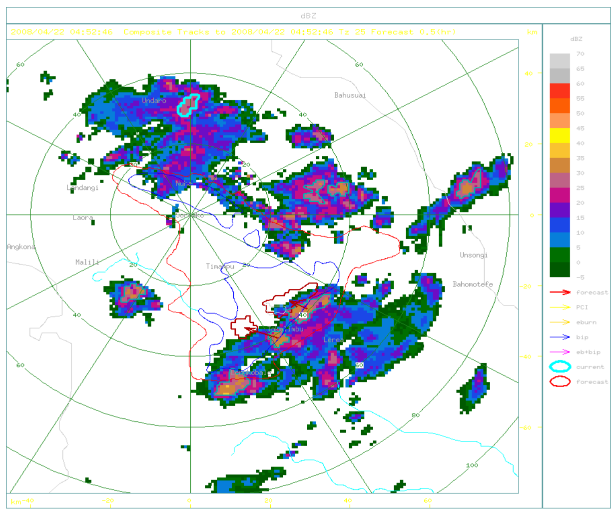

Figure 3. Radar display of precipitation's reflectivity on 22 April 2008, at 12:52 LT.

One of the primary evaluation tools for the Soroako rainfall enhancement project was the WMI C-band weather radar installed at the Soroako airport. The WR-100 radar manufactured by Enterprise Electronics Corporation was located 2.53° S, 121.35° E at an elevation of 423 meters (MSL). The radar was calibrated at the beginning of operations in March and again at the end of May, with regular calibration checks conducted during the operational period to ensure proper performance during the season.

The TITAN software (Dixon and Weiner, 1993) provided the capability of data display and archival of radar data. With TITAN, the characteristics of rainstorms are capable of being monitored to understand: 1) the large-scale organization of the storms, 2) their frequency of occurrence, 3) their spatial distribution in the area of study and, 4) their history of size and intensity. Figure 3 shows an example of radar display.

3. Feasibility Study

In order to assess the feasibility of any future precipitation enhancement potential in clouds in the Soroako region, it is extremely important to obtain observations in a well-designed measurement program. The aerosol and microphysical measurements determines if seeding could be beneficial and help determine what the optimal seeding method would be that may have potential for enhancing precipitation in clouds in the region. The potential for such manmade increases is strongly dependent on the natural microphysics and dynamics of the clouds that are being seeded (in this case microphysics means the size and concentration of water droplets and ice inside clouds). These factors can differ significantly from one geographical region to another, and even during and between seasons in the same region. In some instances, clouds may not be suitable for seeding, or the frequency of occurrence of suitable clouds may be too low to warrant the investment in a cloud seeding program. Both factors need to be evaluated in a climatological sense. It is therefore important to conduct preliminary studies on the microphysics and dynamics of the naturally forming clouds prior to commencing a larger, operational experiment. It is also important to conduct hydrological studies relating rainfall with river flows and reservoir levels, and to determine hydrological regions where reservoir catchments are most efficient. Seeding could then be optimized by preferentially targeting these more efficient watersheds.

If shown to be feasible, the cloud seeding technique should then be evaluated using a randomization procedure to demonstrate statistically that the seeding method works, and to quantify the increase in rainfall achieved. This approach is similar, for example, to what is commonly done in medical trials with a new drug. Such a randomized statistical experiment would become the second phase of a future program.

Scientists from the Research Applications Laboratory (RAL) of NCAR, in collaboration with WMI of Fargo, North Dakota in the U.S. and WMTC in Indonesia, assisted PT INCO by conducting a feasibility study for rainfall enhancement via cloud seeding in the Soroako region. The feasibility study included the latest technologies that have been developed in this field combining an airborne laboratory with surface weather radar to evaluate and assess seeding operations. The collaborative work entailed all aspects of the project, including cloud physics and radar meteorology, and built on the experience obtained in programs in other parts of the world.

4. Seeding Activities

Flight activities for cloud seeding were carried out based on the availability of cumulus clouds observed by weather radar installed at the Sorowako airport. If radar display showed some cumulus clouds that are able to develop into a storm in target area, seeding aircraft would be taking off to seed the clouds. Before 2009 there were three types of flares mounted on aircraft on each flight. There were hygroscopic flare which ignited at just below of cloud base, AgI Burn in Place flare that ignited at the level of about – 6^0 C isotherms (middle of the cloud) and AgI Ejectable flare which ignited at top cloud level when needed. Cloud seeding flights were ended at about 18:00 pm daily.

Before take off, the pilots, flight scientist and the weather observer, held a meeting to discuss cloud development and movement. We then decided which clouds to be seeded within the region. The pilots and an observer at radar site kept communicating to up date radar observation. The observer would guide which could is better to be seeded based on radar reflectivity. The observer on the radar site also had to observe weather condition over the run way to be informed to the pilots. This was to avoid the run way was closed by incoming clouds.

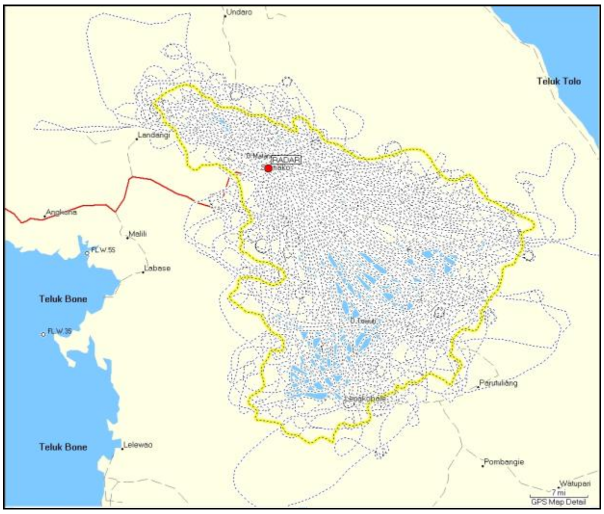

Figure 4. Superimposed flight seeding tracks for the period of January – May 2008.

When the aircraft reaching cloud base of intended cloud to be seeded, a BIP-CN was burn as seen on Figure 10. This burning may continue as needed. While BIP-IN and ejectable flares would be used if the clouds were deep and had strong up draft. Seeding activity, mostly was about one and a half hours. Figure 4 shows a sample of flight track. Table 1 shows the amount of flares used and result in lake inflow in each cloud seeding program.

Year	Flare used	Result (million m^3)	Flight sorties
1998	496 HBIP, 235 EBIP, 150 EJ	230.84	89
1999	480 HBIP, 366 EBIP, 1025 EJ	1818.13	**
2000	539 AI, 120 BPPT	2250.5	71
2008	704 HBIP-12, 90 EBIP-77, 159 EJ-300	246.2	138
2009 - 2010	1313 HBIP-12, 1 AgI	297.2	112

Table 1. Flare used and result from cloud seeding program in South Sulawesi

Note: HBIP: Hygroscopic Burn in Place Flare
EBIP: AgI Burn in Place Flare
EJ: AgI Ejectable Flare
For year 2000, all using HBIP, with 120 flare made by BPPT

5. Summary

- As one of the largest and most cost-eficient nickel producers in the entire world, PT International Nickel Indonesia (PT INCO) has low-cost electricity which is received from the hydro-power facilities that it owns, which provide approximately 80 percent of electric energy needed..
- To preserve water resource at Larona catchment area, PT INCO carried out weather modification to enhance rainfall since 1998.
- Under colaboration with international some institutions, weather modification program at Larona catchment area has been conducted using some modern equipmments to introduce both of glaciogenic and hygroscopic seeding agent.
- This program also improves the capability WMTC in cloud seeding program using flare technique and weather observation using radar especially for cloud seeding activity.

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