799 *FREQUENCY ANALYSIS ON SUITABLE CONVECTIVE CLOUDS FOR ARTIFICIALLY INCREASING RAINFALL IN THE NORTHERN PART OF KYUSHU, JAPAN, USING METEOROLOGICAL SATELLITE (GMS-5)*

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1. INTRODUCTION

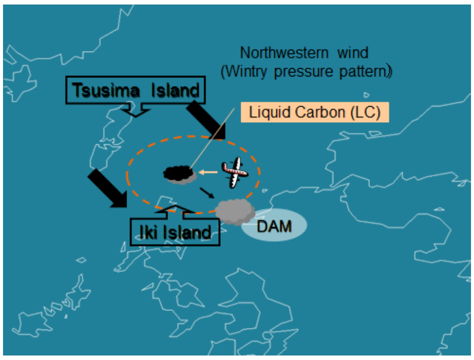
Many droughts (shortage of water) have broken out by extreme small amount rainfall in recent Japan. So far,in order to prevent these droughts, artificial rainfall methods with 'AgI' or 'dry ice' have been widely used in Japan. However, these methods have many problems, which a large amount of overcooling liquid in the cumulus clouds was not able to be converted into precipitation efficiently. So as to solve these problems, new artificial rainfall method using liquid carbon dioxide (LC) was proposed by Fukuta.

This new method is called 'Low-Level Penet -ration Seeding of Homogeneous Ice Nucleant '(LOLEPSHIN) ; this induces a 'Roll-up Expansion of Twin Horizontal Ice-crystal Thermals' (RETHIT) and a subsequent 'Falling growth-Induced Lateral Air Spreading' (FILAS).

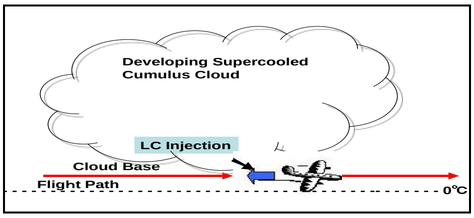
This LC method was applied to the super-cooled cumulus clouds in Northern Kyushu on Februay 2,1999 (Fukuta,Wakimizu etc.,2000). As a result, these experiments succeeded, and the total amount of estimated radar precipitation of the seeded cumulus cloud was approximately 1 million ton (Fig.1).

It turned out that many super-cooled cumulus clouds generated in Japan Sea in winter- time are best clouds to be able to secure a large amount of water resource from these experiment results.

First, this paper will give the simple summary of the new LC seeding method. Next, based on the frequency analysis on suitable convective clouds for artificially increasing rainfall in the northern part of Kyushu, Japan, using meteoro-logical satellite (GMS-5) will be discussed.



(a) Experimental area



(b) LOLEPSHIN (Low Level Penetration Seeding of Homogeneous Ice Nucleant)

Fig.1 Experiment of artificial rainfall in the northern Kyushu, Japan (a) and LOLEPSHIN (b)

2. New method of artificial rainfall using LC

The injection of LC materials into super -cooled convective cloud (cumulus) cause strong evaporative particles per gram of LC materials by homogeneous nucleation (Fig.2a). The number of artificially formed ice particles keeps approximately constant after the injection of LC rials during the ascent of an artificially formed thermal (Fig.2b). No competition process for limited super-cooled liquid water among ice particles in thermal provides an important advantage for effective growth of ice particles (Fig.2c-f).

From this point of view, LC seeding method is still more advantageous than AgI seeding method, which causes competition process due to drastic increase in the number of ice particles in low temperature. In addition, in order to enhance the efficiency of seeding, the seeding operation by an aircraft is designed to be carried out at a low super-cooled portion near 0 ℃ in a young developing cumulus so that ice particles effectively grow into enough size to fall out within a limited lifetime of a cumulus.

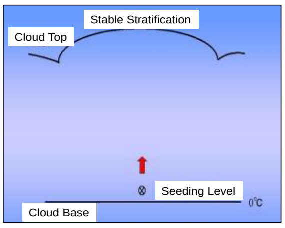


Fig.2a

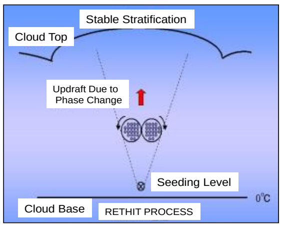


Fig.2b

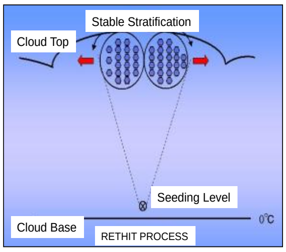


Fig.2c

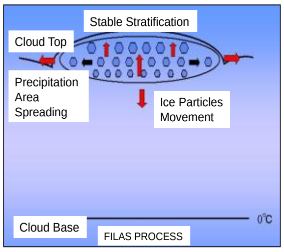


Fig.2d

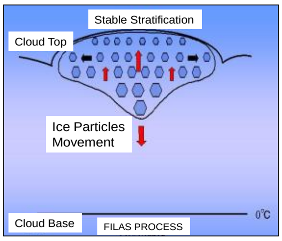


Fig.2e

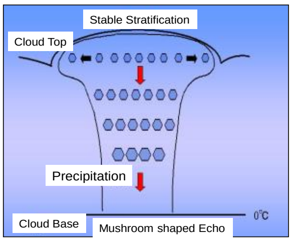
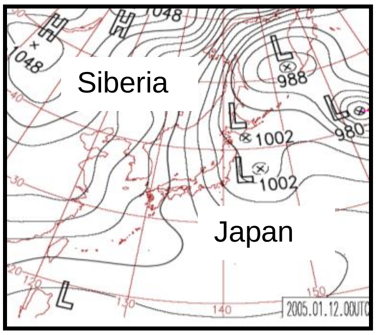


Fig.2f

Fig.2 RETHIT process and FILAS process

3. Wintry-pattern day

Wintry pressure pattern occur in Japan, when the high-pressure is in west of Japan and the low-pressure in east of Japan (Fig.3). When it is a wintry pressure pattern in Japan, with cold dry wind from the Siberia and the warmly wet air of the Sea of Japan, a line-formed clouds occurs in the Sea of Japan (Fig.4,5).



. Fig.3 Surface weather map on birthday of wintry pressure pattern in Japan

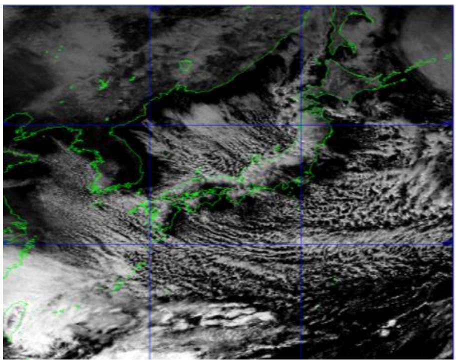


Fig.4 Weather satellite visible image of a line - formed cloud on wintry-pattern day.

Fig.5 Picture of a line-formed cloud from Kyushu University on wintry-pattern day..

4. The weather conditions for the artificial rainfall experiment to succeed

The most important weather conditions so as to succeed artificial rainfall are to find the suitable convective cloud (cumulus cloud) on the seeding area. In order to succeed the artificial rainfall experiment need following 4 conditions.

1) The cloud for the artificial rainfall must be the convective cloud.
2) The thickness of the cloud must be 2000m or more.
3) The temperature of the cloud must be 0℃ or less.
4) The wind direction of the ground is from northwest to north.

5. Method of finding suitable convective clouds for artificial rainfall

These suitable convective clouds occur in winter season in Japan, because the cold dry air moves from Siberia to Japan Sea. The resultant wind flows strongly in these regions (Fig.6).

1) The convective clouds are judged from a visible image of the meteorological satellite (GMS-5 Fig.7).
2) The cloud-top's altitude is estimated from the air temperature of aerological observation data and the luminance temperature of the infrared data obtained from GMS-5 (Fig.8). And, the cloud-top's altitude is calculated with the following two numerical formuras.

$$LCL = 128(T - T_d)$$

$$T' = T - LCL \times \gamma_\alpha - CD \times \gamma_w$$

Where,

LCL: level of cloud-bottom, *T*: ground temperature, *T´*: luminance temperature, γ_α: dry adiabatic lapse rate, γ_w: wet adiabatic lapse rate, *CD*: thickness of cloud

3) The cloud-bottom's altitude is estimated from the air temperature and the dew point temperature of aerological observation data.
4) The thickness of the cloud is estimated from the difference between the height of cloud-top and the height of cloud-bottom.

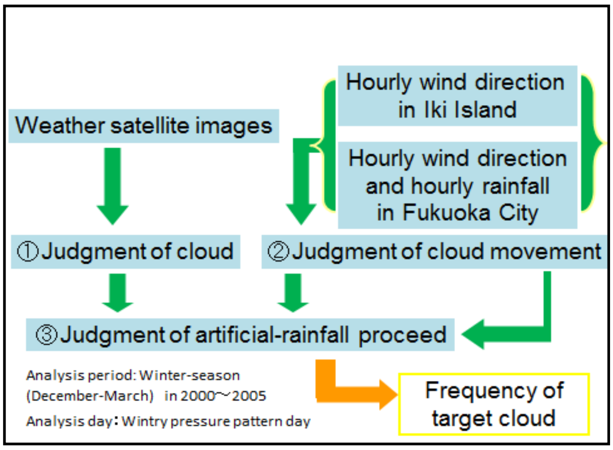


Fig.6 Method of analysis

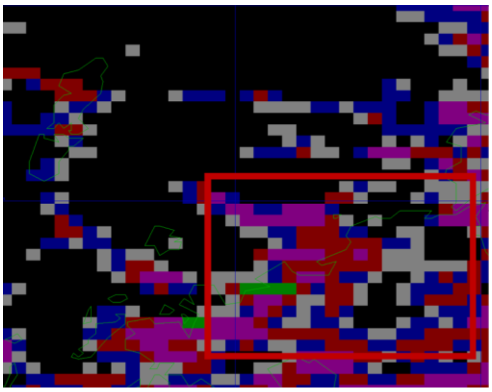


Fig.7 Infrared image of weather satellite (GMS-5)

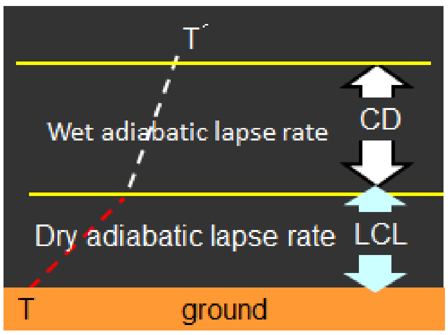


Fig.8 Cloud-top's altitude estimated by satellite image data

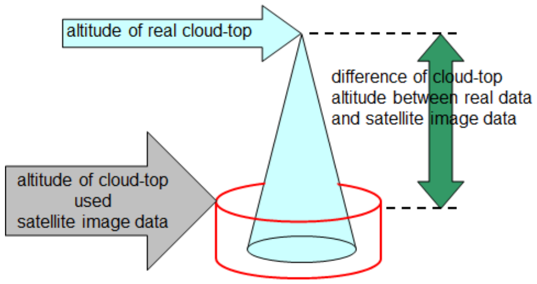


Fig.9 Mean of cloud-top's altitude estimated by weather satellite image data

Table.1 Past experiment of artificial rainfall's data

Feb.2,1999	Thickness of Cloud	Image
Echo B	780m	-12.4℃
Echo C	1181m	-15.6℃

The altitude of real cloud-top observed data by airplane are about 1000m than satellite image data. Because, 1pixel observed data by satellite is mean of area (25km × 25km).

6. Results

6.1 Frequency distribution of winter-season rainfall

Judgment of artificial-rainfall proceed were used visible images and infrared images of the weather satellite image at every hour for day-time (0600-1800) on wintry pressure pattern days.

The number of rainy days is 2269 in winter-time of the 15 years (1990 to 2004) (flg.10).

62. Possible days of artificial rainfall

The possible days of artificial rainfall are 9 days in winter season in Fukuoka City (Fig.11).

1) The number of rainy days is 2269 in winter-time of the 15 years (1990 to 2004).

2) The number of wintery pressure pattern precipitation is the biggest (28%).

3) The number of suitable convective cloud in January is the biggest (38%) in winter-time of the 6 years (1999 to 2004).

4) The possible days of artificial rainfall are 9 days in winter season in Fukuoka City .

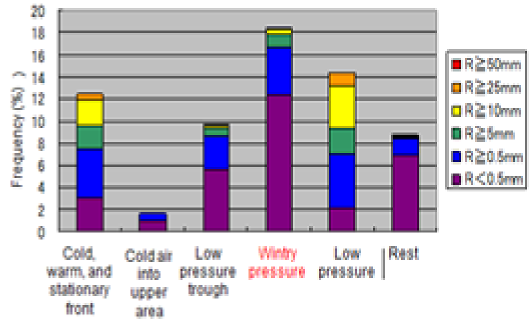


Fig.10 Frequency distribution of winter-season rainfall in Fukuoka City in winter-season (1990 -2004)

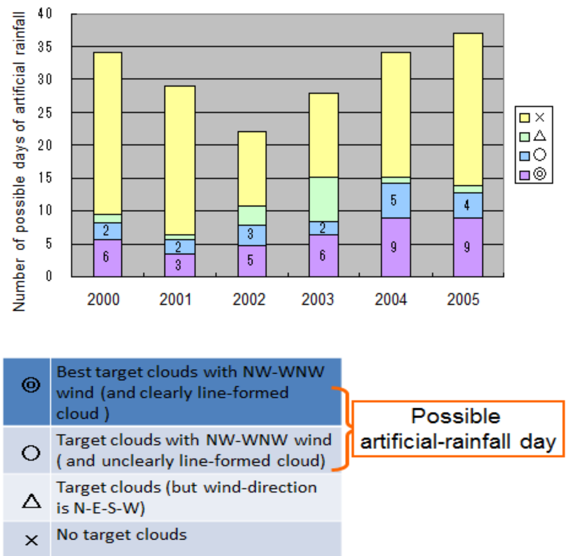


Fig.11 Number of possible days of artificial rainfall

REFERENCE

Fukuta N.,Wakimizu K., Nishiyama K. Suzuki Y. and Yoshikoshi H., 2000: Large unique radar echoes in a new, self-enhancing cloud seeding, Atmos. Res., 55, 271-273.