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MODIS and Determination the Threshold of Cloud Seeding in Kermanshah

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Abstract: The present study was carried out within four-years period covering from 2000 to 2003 where the amount of rainfall in Western Iran (Kermanshah) was recorded by precipitation stations. PW was calculated using the data obtained through MODIS satellite. Using the curve and upon choosing the fittest index PW as independent variable and the rainfall average precipitation (P) as dependent variable, from among the PW, the suitable cloud seeding threshold was estimated. The thresholds obtained through MODIS for cloud seeding and PW were compared across 17 cases. This method employed showed high correlation. The thresholds obtained was 12 mm. With this factors (PW and P) we can study on threshold of cloud seeding.

Key words: Cloud seeding, MODIS, precipitable water

INTRODUCTION

In this study, the Precipitation Water (PW) was compared against the actual Precipitation (P) obtained through field stations and satellite images to achieve a reliable cloud seeding threshold model. Gao and Goetz (1990) studied the PW through remote instrument. In the convective cloud seeding projects (PACE), the P augmentation for crops experiments, carried out successfully by Czys and Scott (1993). The PW and buoyancy potential in 500 millibar were determined as suitable factors in cloud seeding and the PW for 26 mm was found to be the optimal p threshold in conducting convective cloud seeding activities. Costa *et al.* (2001) calculated the instability indices for tornado, hail storm and heavy rainfall in northern Italy and introduced the suitable indices to identify the rainfalls. Simoenov and Georgiev (2003) computed the instability indices through studying sever wind/hail storm over Sofia, Bulgaria to obtain the cloud seeding threshold and hail suppression. In this study the CAPE was found to be 3785 J kg^{-1}, the vertical wind velocity of 21.9 m sec^{-1} and PW of 12.9 J kg^{-1}. Manzato and Morgan (2003) studies the regional thunderstorms over Venice, Italy during a 7 year period whereby they found the most suitable forecast indices of thunderstorms and their strength to be the vertical wind velocity, PW, CAPE and KI (K Index). Platnich *et al.* (2003) studied the clouds' temperature qualities, microphysical parameters and PW through the 5 min data obtained from the MODIS satellite over South American coast.

Gao and Kaufman (2003) reviewing the methods used in finding the PW through MODIS satellite, came to the conclusion that the MODIS is capable of providing global coverage. MODIS is the first space device used for recovering general P. The quality control is also performed for both geographical and climatological studies, as well as statistical analysis. King and Bock (2003) while emphasizing the importance of satellite in research, introduced the band limits of 129 for studying the atmospheric characteristics like cloudage, the vertical profile of atmosphere, aerosol and the general PW and managed to find two different patterns of PW in polar clouds. Krauss and Santos (2004) obtained some instability indices through performing hail suppression activities over Alberta, Canada, employing the cloud seeding operations on hailstorms for 82 days in the summers of 2001 and 2002. The indices were as follows: the average PW (18.8 mm), Shulter index (-1.3°C), set of sets index (TT) (54°C), vertical index (-3) and convective available potential energy (781 J kg^{-1}). Sajjadi (2008) studied on calculating PW with thermodynamic graphs and MODIS satellite and calculated PW with thermodynamic graphs and MODIS satellite in Tabriz and compared two method with together.

The study was performed within 4 years (2000-2003) where the PW, as registered by P stations, were determined and through MODIS satellite over Kermanshah and selecting the fittest variables, ground P and PW, the suitable threshold for cloud seeding was estimated.

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MATERIALS AND METHODS

The areas under study (Kermanshah) the amount of PW with Eq. 1 on rainy days in 2000-2003. The increase in convectional movements and heat transfer follows the increase in age and thickness of clouds. The upward movements of the cloud drops by the base are slower than, but they take more speed due to increase in instability produced by the release of the latent heat of drops condensation as the cloud thickness increases and so does the PW, Rogers and Yau (1996). The upward movements and drops growth, as shown in Fig. 1 and 2, reach the maximum in 3/4 of the cloud base. The drops, around the peak and brims of cloud, then vaporize as the surrounding dry and cold air intermingle, in other words, the process causes the temperature decrease rapidly and consequently, the floating forces and upward movement speed decrease as well. Moreover, the amount of water in clouds decreases as the drops vaporize and the air gets cold in the cloud peak when the dry and cold airs intermingle.

In case it happens, the cloud temperature decreases sharply and the upward movement, too, become downward gradually. To determine the cloud seeding threshold. The information in the Fig. 1 and 2 shows the cloud seeding threshold of the region where the P recorded by the stations remains stable while the PW are increased, also, as shown in the Fig. 5, the clouds' age and thickness are not suitable for seeding. At this stage, any attempt for cloud seeding would result in decrease of P potential, but if the indices exceed the threshold, the P increases, which can be claimed to be the right index for

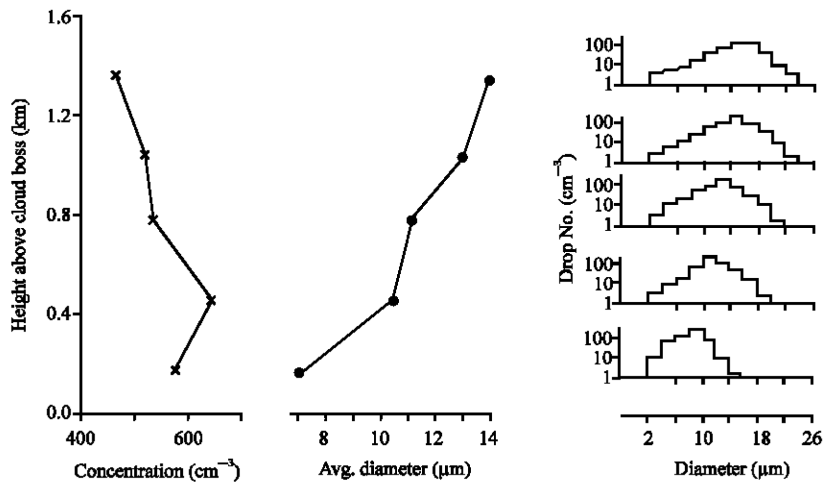

Fig. 1: Differences in density and size of droplets by altitude and their spectrums in each altitude (Rogers and Yau, 1996)

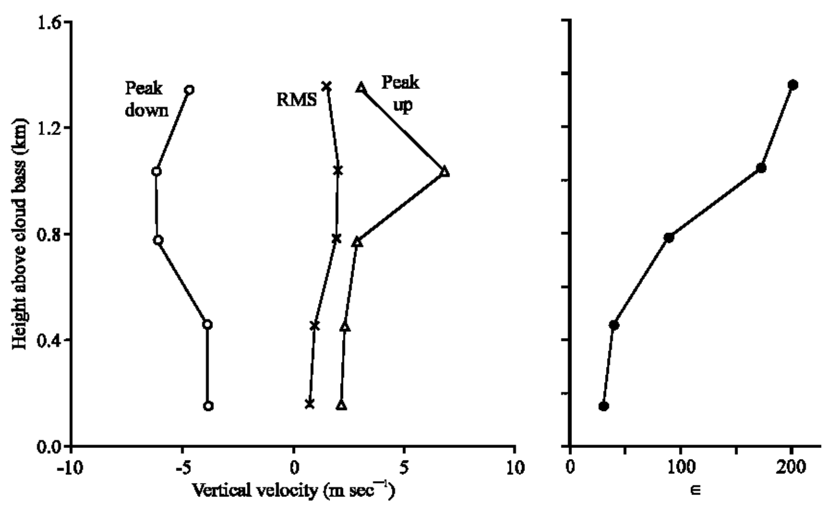

Fig. 2: Maximum differences in upward and downward movements and the average amount of square root of vertical velocity and the turbulent energy differences based on the altitude from the cloud base (Rogers and Yau, 1996)

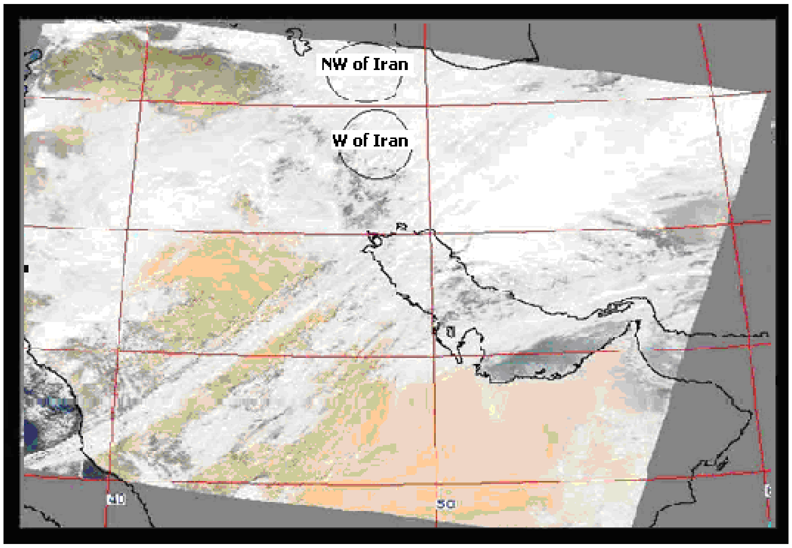

Fig. 3: Cloud coverage of the zone under the study obtained in Jan the 11th, 2003

cloud seeding. By definition, the condensed water in a humid air column is referred to as PW, as shown on centimeter or millimeter scale. Manzato (2003) has used the following simple relation to calculate the PW as an index for the P of conversion activity, the Eq. 1:

$$PW = \left(\frac{1}{g}\int r dp\right) \times 10 \quad (1)$$

where, r is the average amount of mixing between the pressure levels of the cloud base and peak.

To calculate the PW through the Skew-T the following is done.

MODIS is one of the five instruments in TERA satellite. Water vapor (W) in atmosphere has different absorption proportion on the MODIS channels passages in the vicinity of 0.935, 0.94 and 0.905 µm consequently, these three channels have different sensitivities to the water vapor in similar atmospheric conditions. The average W is obtained by the Eq. 2.

$$W = F_1 w_1 + F_2 w_2 + F_3 w_3 \quad (2)$$

Where:

w_1, w_2 and w_3 = The amounts of water vapor in channels 0.935, 0.94 and 0.915 µm
F_1, F_2 and F_3 = Functions of weight

The satellite pictures of MODIS evaluator in the region and the dates stated and the information related to the PW was obtained. The data of PW by the MODIS included the vertical profile of water vapor present in the atmosphere through using the infrared algorithm during the day. Its position dissociation power is one kilometer during the day which is obtained after receiving the temperature bands data and applying it to the estimation model of output PW. A model of the pictures related to the cloud coverage and PW obtained from the region under the study is presented. The required output was obtained as Fig. 3 ([W of Iran] where the weather condition is simply indicative of the presence of cirrus clouds and a jet from the southwest). In the west of the country and within the zone [W of Iran], the clouds are a combination of high, middle and low levels. Then the temperature band enter the estimation model of PW. The obtained output in pictorial mode is grey in context. In case a color picture is needed in distance evaluation software the favorite color codes are defined for it. As an example the average amount of precipitation in ranking (Fig. 4) based on centimeter and geographical region is clarified from which the average PW for example was obtained in the present pixels in 2002/1/11.

The output of PW is in centimeter and in the calculations is in millimeter.

Output:
Date; 2002/1/11 code; 34.9857 47.1867 PW; 1.65
Date; 2002/1/11 code; 34.9781 47.2428 PW; 1.98
Date; 2002/1/11 code; 34.9705 47.2539 PW; 1.47
Date; 2002/1/11 code; 34.9705 47.2988 PW; 2.05
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And finally the average of PW for all points in 2002/1/11 is 2 mm.

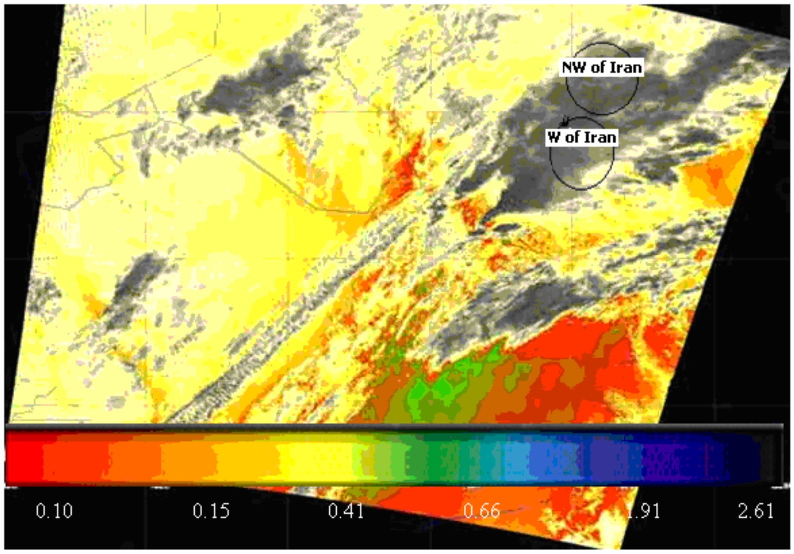

Fig. 4: Precipitable Water (PW) obtained of the zone under the study by MODIS in Jan the 11th, 2003

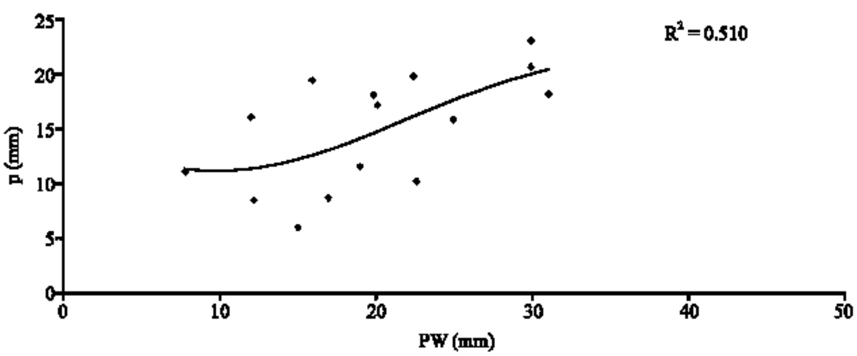

Fig. 5: Precipitable water (PW) fitting obtained by MODIS on average precipitation (p) in Kermanshah, curve (R^2 = 0.51) is the best PW fitting by MODIS

RESULTS AND DISCUSSION

Czys and Scott (1993) determined the threshold of cloud seeding with p and instability indices, also Gao and Goetz (1990), Costa *et al*. (2001), Simoenov and Georgiev (2003), Manzato and Morgan (2003) and Krauss and Santos (2004) studied on instability indices (CAPE, KI, SI,TT, PW), Platnich *et al*. (2003), Gao and Kaufman (2003) and King and Bock (2003) have studied on MODIS data and Sajjadi (2008) introduced the suitable factor (PW) for cloud seeding.

In this study after obtaining the amounts of PW by MODIS in the rainy days (17 cases) and the amount of ground P on these days by PW fitting index on the average of P, the appropriate threshold of cloud seeding was obtained in each case. The amounts for PW and the average of P were calculated as 25, 50 and 75%. Using these amounts, it can be calculated that the index amount is indicative of how much the downpour of the different regions are. The best PW fitting obtained by MODIS on P average in Kermanshah (17 cases of study) is shown in Fig. 5. The appropriate threshold for cloud seeding of the index of PW measured by the MODIS in Kermanshah based on the curve, the best fitting in Fig. 5 is almost 12 mm. Based on Table 1 the amount of first quarter of PW and average P are 16 and 9 mm. As it is clear from Table 2 when the PW is 32 mm, the amount of expected P is 25 mm although Data by MODIS is related to the water vapor absorption in thick clouds.

Table 1: The amount of precipitable water (PW, mm) by MODIS and the average precipitation (P, mm) in Kermanshah of specific percentages

Percentages	PW	P
25	16	9
50	11	12
75	10	15

Table 2: The relationship between the precipitation water (PW, mm) by MODIS and probability of different precipitations (P, mm) in Kermanshah

PW	P<9	9≤P<15	15≤P<25	25≤P
PW≥32	Nearly 0	8%	24%	66%
32>PW≥11	39%	Nearly 0	58%	Nearly 0
11>PW≥10	Nearly 0	97%	Nearly 0	Nearly 0
PW<10	Nearly	98%	Nearly 0	Nearly 0

The greatest source of error is due to the uncertainty of the spectrum of reflections on the surface targets and the unclear amount of fog Fraser and Kaufman (1985).

CONCLUSION

The amounts of PW in Kermanshah was obtained by MODIS 12 mm.

The proportion of P obtained from the PW in Kermanshah: 20 by MODIS. MODIS itself shows a 5 to 15% of error, in the amounts obtained is due to some reasons: Information by the PW in MODIS were obtained while passing the region and in limited dates when the cloud may not have enough thickness for the droplets to grow or have passed that stage, also in foggy weather there may be more errors. The information on water vapor absorption by MODIS in thick clouds is valid.

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