Numerical Method of Microwave Heating to Modified for Lifting Condensation Level of Clouds Formation

Supawat K., Thanaset T., Samran S. and Chanchai T.

Abstract— **This paper introduces a physics-based of clouds dynamics that has been considered to calculate the dynamics of rising air parcels in vertically altitude. It is a novel technique to force the lifting condensation level (LCL) by using microwave heating disturbances method to increase the temperature of air. The natural process of clouds formation are depend on LCL, relative humidity (RH), dew-point temperature, and surface temperature (T). Theoretical analyses investigations were carried out using a microwave heating to increase temperature at surface level for air parcels are upward vertically at condensation level. The calculation of cloud formation, growth, motion and dissipation were performed by using commercial software, MATLAB. The initial condition of terrain barrier equal to 3 km. Considering an air parcels as energy absorption load and calculate by using RH are equal to 40%, 60%, 80% and 100%, respectively. The advantage of the LCL algorithm and temperature results at various time by microwave heating is that it can be applied to modified equilibrium of condensation level for warm cloud formation.**

Index Terms— **Clouds precipitation, topographic barrier, lifting condensation levels.**

I. Introduction

CLOUDS are the mere results of the condensation of vapor in the masses of atmosphere which occupy, the variations are produced by the movements of the atmosphere. Clouds are also an integral factor on Earth's climate systems. Consider a temperature changes below which clouds formation influence. The vicissitudes of temperature and humidity that create clouds also results in tempestuous rain [1]. Recently, the study investigates the effects of turbulence-induced collision enhancement (TICE) on warm clouds and precipitation by changing the cloud condensation nuclei (CCN) number concentration using a two-dimensional dynamic model with microphysics has been studied. Therefore, the thermodynamic sounding used in this case is characterized by a warm and humid atmosphere with a capping inversion layer, which is suitable for simulating warm clouds [2]. Furthermore, the response of clouds and precipitation to changes in aerosol properties is variable with the ambient meteorological conditions, which is important for the distribution of water resources, especially in mountain regions. A detailed model to investigate how orographic clouds and precipitation respond to changes in aerosols under different thermodynamic profiles [3].

Nevertheless, clouds can either cause warming or cooling at the Earth's surface. So far, clouds are not well treated in global climate models because of uncertainties concerning the properties of clouds. In additional, orographic precipitation is produced when the air raises over a topographic barrier. Some people say that orographic precipitation is related to mountains [4], but that is not entirely correct, for sometimes even small hills are enough to provide a lift for precipitation to occur. The side of a mountain or hill that receives the prevailing wind is known as the windward side. As air strikes that side it rises, which causes it to come under less air pressure, it to expand, its temperature, raises its relative humidity, clouds to form at the LCL and precipitation if enough condensation occurs [5]. In other words, as the air rises on the windward side it cools adiabatically to help produce orographic precipitation. As the air descends on the leeward side of the mountain the whole process essentially works in reverse. The air descends, which causes it to come under more air pressure, it to contract, raises its temperature, lowers its relative humidity, clear skies and produce drought [6]. As air descends on the leeward side it warms adiabatically to help produce arid region. Many arid regions on Earth are located on the leeward side of mountains and they are known as rain shadow regions [7]. The interest in such clouds precipitation at LCL are considered.

The aim of this paper is presented here, we demonstrate that it is possible to use a microwave heating disturbances method to increase the air temperature for modification LCL, and that the attractive features of rising windward side air level is known as convectional precipitation. This method uses with clouds and precipitation in order to expect for lifting of the clouds over terrain. The dynamics of cloud formation, growth, motion and dissipation are complex. In the development of a cloud calculation, it is important to understand these dynamics so that good approximations can be chosen that allow efficient implement without sacrificing realism. The mathematics of cloud dynamic and propose some useful simplifications that enable modification LCL to climate control and modified equilibrium of condensation level for rain making.

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II. EQUATION

A. Environmental Lapse Rate

The Earth's atmosphere is in static equilibrium. The so-called hydrostatic balance of the opposing forces of gravity and air pressure results in an exponential decrease of pressure with altitude [8-9]

$$p(z) = p_0\left(1-\frac{z\Gamma}{T_0}\right)^{g/\Gamma_d} \qquad (1)$$

Here, z is altitude in kilometers, g is gravitational acceleration, 9.81 m·s^{-2}, p_0 and T_0 are the pressure and temperature at the base altitude. Typically, p_0 = 101.352 *kPa* and T_0 is in the range 280−310 *K*. The lapse rate Γ is the rate of decrease of temperature with altitude. Therefore, I assume that $\Gamma = \Gamma_d$. For dry air, Γ_d is the gas constant (287 J·kg^{-1}·K^{-1}).

B. Dry Adiabatic Lapse Rate

For the special case of humid air with no liquid water or ice carried with the parcel (and no water phase changes; hence, a "dry" process) [10], gives

$$\frac{\Delta T}{\Delta z} = -\left(\frac{|g|}{c_p}\right) = -9.8K\cdot km^{-1} \qquad (2)$$

Recalling that the lapse rate is the negative of the vertical temperature gradient, we can define a dry adiabatic lapse rate Γ_d as in Eq.(3).

$$\Gamma_d = 9.8K\cdot km^{-1} = 9.8°C\cdot km^{-1} \qquad (3)$$

(Degrees *K* and °C are interchangeable in this equation for this process lapse rate, because they represent a temperature change with height.)

C. Mixing ratio

The ratio of mass *m* of water vapor to mass of dry air is called the mixing ratio [10], *r*

$$r = \frac{m_{watervapor}}{m_{dryair}} \qquad (4)$$

The saturated mixing ratio: r_s

$$r_s = \frac{\varepsilon\cdot e_s}{p-e_s} \qquad (5)$$

Where $\varepsilon = \Re_d/\Re_v = 0.622$, $e_0 = 0.611kPa$, $e_s = 4.367kPa$

Although units of mixing ratio are g/g (i.e., grams of water vapor per gram of dry air), it is usually presented as g/kg (i.e., grams of water vapor per kilogram of dry air) by multiplying the g/g value by 1000. By convention in meteorology we don't reduce the ratio g/g to 1, because the numerator and denominator represent masses of different substances that must be discerned in mass budgets.

D. Relative Humidity

The ratio of the actual amount of water vapor in the air compared to the equilibrium (saturation) amount at that temperature is called the relative humidity [10], *RH*

$$\frac{RH\%}{100\%} = \frac{r}{r_s} \qquad (6)$$

E. Dew-Point temperature

The temperature to which air must be cooled in order to become saturated at constant pressure is called the dew-point temperature, T_d (also known as the dew-point) [10].

$$T_d = \left[\frac{1}{T_0} - \frac{\Re_v}{L}\cdot\ln\left(\frac{r\cdot P}{e_0\left(r+e_0\right)}\right)\right]^{-1} \qquad (7)$$

Where $T_0 = 273K$, $\Re_v/L_v = 1.844\times10^{-4}K^{-1}$. The saturation (equilibrium) with respect to a flat surface of liquid water occurs at a slightly colder temperature than saturation with respect to a flat ice surface. With respect to liquid water, use $L = L_v$ in the equation above, where T_d is called the dew-point temperature. With respect to ice, $L = L_d$, and T_d is called the frost-point temperature.

F. Saturation Level or Lifting condensation Level (LCL)

When unsaturated air is lifted, it cools at the dry adiabatic lapse rate. If lifted high enough, the temperature will drop to the dew-point temperature, and clouds will form. Dry air (air of low relative humidity) must be lifted higher than moist air. Saturated air needs no lifting at all. Hence, LCL is a measure of humidity. When lifting on cloudy air, the height at which saturation just occurs (with no super saturation) is the saturation level or the lifting condensation level (LCL). For convective (cumuliform) clouds, cloud base occurs there. LCL height (distance above the height where T and T_d are measured) for cumuliform clouds is very well approximated as follows [10].

$$z_{LCL} = a\cdot\left(T - T_d\right) \qquad (8)$$

Where a = 0.125 km/°C.

$$P_{LCL} = P\cdot\left[1-b\cdot\left(\frac{T-T_d}{T}\right)\right]^{C_p/\Re} \qquad (9)$$

Where $b = a\cdot\Gamma_d = 1.225$ (dimensionless), $C_p/\Re = 3.5$ (dimensionless), and P is the pressure at the initial height where temperature, T, and dew-point, T_d are measured, such as at the surface. Don't forget to use Kelvin for the T in the denominator.

G. Microwave Heating

The purpose of our investigation is to obtain a model heat diffusion equation of the form [11].

$$\rho C_p\frac{\partial T}{\partial t} = k\nabla^2 T + I_v(x,y,z,t) \qquad (10)$$

When ρ is the density 1.225 kg·m^{-3}, C_p is the specific heat at constant pressure 1007 J· kg^{-1}·K^{-1}, k is the thermal conductivity (W· m^{-1}·K^{-1}), $\partial T/\partial t$ is the change in temperature over time, and I_v is the power absorbed in the load over volume (W). For the system under consideration, the boundary condition is relatively simple and is prescribed by the heat balance through into the environment.

$$-k\hat{n}\cdot\nabla T = \varepsilon_s\sigma_s\left(T^4 - T_\infty^4\right) \qquad (11)$$

Where ε_s is the surface emissivity, σ_s is the Stefan-

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Boltzmann constant (5.670 × 10^{-8} J·s^{-1}·m^{-2}·K^{-4}), and T_∞ is the ambient temperature K. Typically, the convective effect is ignored because the thermally induced free convection inside the microwave cavity is negligible.

III. Calculation And Results

The example topographic barrier scenario was constructed by diagram in Fig. 1.

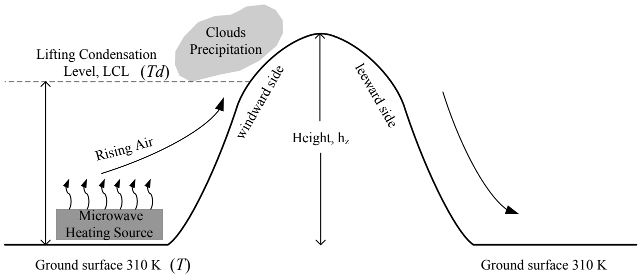

Fig. 1. Orographic precipitation model.

Rising air on the windward side of the mountain cools adiabatically. Clouds form as the air rise above the LCL. This can lead to the formation of precipitation [4]. The cooling or warming of air as a result of changing its air pressure is known as the adiabatic process [12]. The air is not heated or cooled directly, but its temperature changes because its pressure changes [13-14]. If a rising parcel of unsaturated air has a surface temperature (T) of 310 K (37°C), and hot air at the surface might have a relative humidity of 60%, but as it raises the adiabatic process causes it to cool through expansion, so its relative humidity increases. The relative humidity keeps going up as the air continues to rise, 70%, 80%, 90%, and at 100%, the dew point has been reached [15]. The elevation in the atmosphere where rising air reaches 100% relative humidity is known as the lifting condensation level (LCL) [5]. In this context, this terrain altitude (h_z) about 3 km, and the condensation level less than two kilometers.

A. Heat Convective Models

Applied microwave heating is converted into power based on the power distribution at a surface location. The absorbed power term is considered a source term in heat transfer equations to calculate transient temperature profile. According to Fig. 1. The microwave heating has been used for air temperature disturbances by following Eq. (10). Now, consider the special case where the entire material is being heated homogenously. Determined ambient temperature is negligible, we set $\nabla T = 0$ in Eq. (11), to obtain, According to Eq. (10).

$$\rho C_p \frac{\partial T}{\partial t} = I_v(x,y,z,t) \tag{12}$$

We can convert Eq. (12) to integral form as follows Eq. (13).

$$\Delta T = \frac{1}{\rho C_p}\int_0^t I_v(x,y,z,t)dt = \frac{I_v(t)\cdot t}{\rho C_p} \tag{13}$$

In calculation by using MATLAB, provide intensity power per volume equal to 10 W/m^3, 100 W/m^3, 300 W/m^3, 500 W/m^3, and 1000 W/m^3, respectively. Considering the air parcel load as a cube unit will move through the atmosphere relative to the ground surface, shown in Fig. 2.

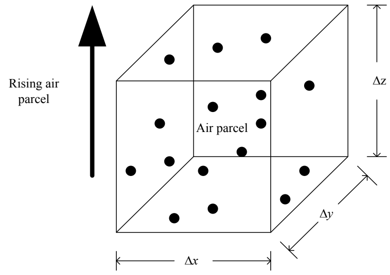

Fig. 2. Air parcel load as a unit box.

The power distribution from the microwave to affect on the volume of air parcel load. When the power intensity at different power, considering at time varying. Hence, it can show that graph of the relationship between time and temperature absorption, and the results of heat rate will be explained in the form of temperature changes as follows Fig. 3. Determined the volume of air parcel load equal 1 m^3 (Δx= Δy= Δz=1). The results of temperature are converted to °C.

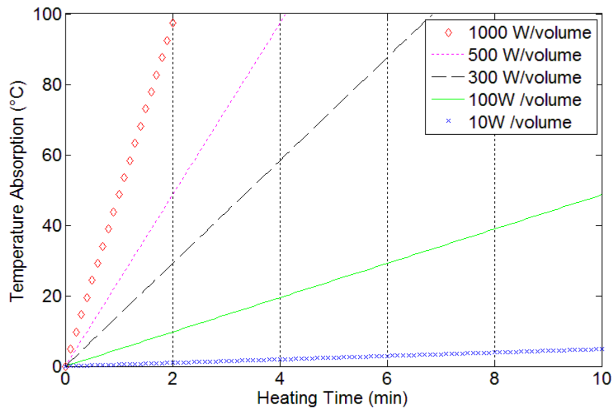

Fig. 3. The relationship between time and temperature absorption (ΔT) are incresed on the air parcel box, 1 m^3.

According to Fig. 3. The temperatures are increased from surface temperature. The final temperatures of air box are equal to summing of surface temperature (T) and (ΔT)

B. Advection of Air Parcel Box above Horizontally in the Atmosphere

Cloud formation are developed in a predominantly vertical direction (cumuliform). Clouds start to form as warm air continues to raise up and above the LCL, for the air has reached its dew-point so water vapor starts to condense forming cumulus clouds. We consider that the microwave heating can be raised the LCL in a vertical direction. The LCL can be calculated according to Eq. (8), includes Eq. (1), Eq. (3), Eq. (5), Eq. (6), Eq. (7). The solutions are calculated that explain the mechanism of the rising air box vertically. Which involved with dew-point temperature, altitude pressure, and surface temperature. Provide intensity power per volume equal to 100 W/m^3. For Eq. (6), determined the mixing ratio (r) is based on the relative humidity (RH), such as 40%, 60%, 80%, 100%, respectively. We set an initial condition of (h_z) equal to 3 km. The dew-point temperature under pressure equal 80 kPa at terrain altitude about 3 km, which can be calculated according to Eq. (7). Results are describe the relationship between heating time and lifting condensation level at different relative humidity and time various shown as follows Fig. 4.

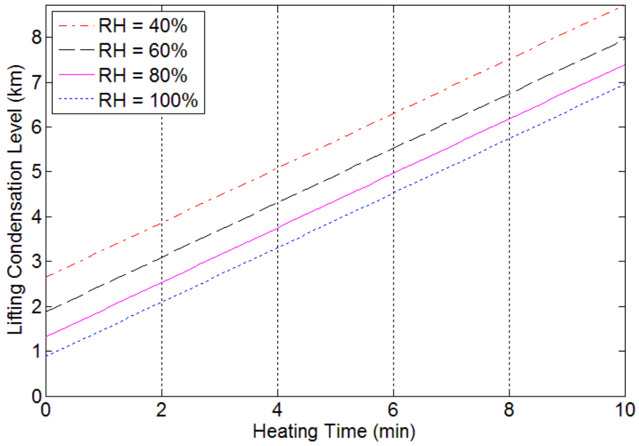

Fig. 4. The air parcels box (volume = 1 m^3) was urged by microwave heating at time various.

According to Fig. 4. The air parcels box (volume = 1 m^3) was urged by microwave heating at time various. If air humidity is high, air raising less than air with low humidity, considering with lifting condensation level 3 km. Therefore, air with high humidity must be used time more than air with low humidity. Which it means that air if the humidity is high, must be used higher power. Likewise, if volume of air with more than 1 m^3 must be used higher power or long times as well.

IV. Conclusion

In this paper, we have tried to implement dynamic calculation for explanation the raising process of air. According to the principle of heat transfer. Which it is possible to use a microwave heating disturbances method to increase the temperature of air for modification lifting condensation level. This will make the clouds formation can move up over terrain altitude. Factors that are important such as relative humidity, volume of air parcels, and heating time. However, the formation is complex, and in this context was calculated by conditions limited area and without interference of the environment such as ambient temperature, wind effect, and provides surface temperature is constant. At the first stage, we calculate by using MATLAB and describe rendering in 1 dimension. Nevertheless, it is possible to use microwave heating for disturbances of the lifting condensation level. The advantage of the LCL algorithm and temperature results at various time by microwave heating is that it can be applied to modified equilibrium of condensation level for warm cloud formation. In addition, this work will be developed to climate control such as rain making by using knowledge of the microwave engineering.

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References

[1] R. M. Ramirez and J. F. Kasting, “Could cirrus clouds have warmed early Mars,” Icarus, vol. 281, pp. 248-261, 2017.
[2] H. Lee, J.-J. Baik, and J.-Y. Han, “Effects of turbulence on warm clouds and precipitation with various aerosol concentrations,” Atmospheric Research, vol. 153, pp. 19-33, 2015.
[3] H. Xiao, Y. Yin, Q. Chen, and P. Zhao, “Impact of aerosol and freezing level on orographic clouds: A sensitivity study,” Atmospheric Research, vol. 176-177, pp. 19-28, 2016.
[4] G. H. Roe, “Orographic Precipitation,” Annual Review of Earth and Planetary Sciences, vol. 33, pp. 645-671, February 2005.
[5] M. G. Lawrence, “The Relationship between Relative Humidity and the Dewpoint Temperature in Moist Air: A Simple Conversion and Applications,” Bulletin of the American Meteorological Society, vol. 86, pp. 225-233, February 2005.
[6] H. Guan, C. T. Simmons, and A. J. Love, “Orographic controls on rain water isotope distribution in the Mount Lofty Ranges of South Australia,” Journal of Hydrology, vol. 374, pp. 255-264, 2009.
[7] J. Houston, and A. J. Hartley, “The central Andean west-slope rainshadow and its potential contribution to the origin of hyper-aridity in the Atacama Desert,” International Journal of Climatology, vol. 23, pp. 1453-1464, May 2003.
[8] D. G. Andrews. An Introduction to Atmospheric Physics, Cambridge University Press, Cambridge, 2000.
[9] R. R. Rogers and M.K. Yau, A Short Course in Cloud Physics, Third Edition, International Series in Natural Philosophy, Bytterworth Heinemann, Burlington, 1989.
[10] R. Stull, Practical Meteorology: An Algebra-based Survey of Atmospheric Science, Univ, of British Columbia. 2015.
[11] J. M. Hill, M. J. Jennings, “Formulation of model equations for heating by microwave radiation,” Applied Mathematical Modelling, vol. 17, pp. 369-379, July 1993.
[12] J. Marshall, and R. A. Plumb, Atmosphere, Ocean and Climate Dynamics: An Introductory Text, International Geophysics Series , Academic Press, vol. 93, 2008.
[13] M. Engström, and B. Nordell, “Temperature-driven groundwater convection in cold climates,” Hydrogeology Journal, vol. 24, pp. 1245-1253, 2016.
[14] R. A. Houze, Cloud Dynamics, International Geophysics Series, Academic Press, vol. 104, 2014.
[15] J. E. Castillo, J. A. Weibel, and S. V. Garimella, “The effect of relative humidity on dropwise condensation dynamics,” International Journal of Heat and Mass Transfer, vol. 80, pp. 759-766, 2015.