AN ESTIMATION OF THE GUST PHENOMENON AND THE SPOTTING DISTANCE PRODUCED BY FOREST FIRES

Jin Xiaozhong, Wang Anming, Cheng Banyu
(Forest Protection Institute, Harbin, China 150040)

ABSTRACT

In this paper, avoiding the abstruse equations, a simple model is considered. Althongh the model perhaps exists some discrepancies with actual condition, the result of estimation can explain some characteritics of fire gust phenomenon during the large forest fires.

The paper also introduces some rules of fireband spotting which are being studied and presents a method to predict the spotting distance. To illustrate how to use the method, some examples are given. The calculating results tally with some observations in large fires and provide a supplement or reference to the forest fire management.

INTRODUCTION

At present, the theories related to forest fire behavior are not perfect. One attachs much attention to some researches of fire[1]. According to the analysis for fire behavior of the greatest fire and author's experiences in firefighting, this paper discusss the phenomenon of fire–induced wind and the fire spotting.

THE GUST PHENOMENON

The men who had challenged to forest fires or joined in surpression in person, have such experiences that wind increases fire spread rate and fire causes windspeed increasing during great fires. Sometime this phenomenon is very surprising. In China the "5.6" large forest fire had induced the gust which carried sand and small stone at some place in a short time.

Refered to the meteorological materials at that time, the wind field of large–scale weather systerm did not appear such a great wind[2]. It is no dobut that the wind increase was caused by fire's passing. In the open nature, it is a complex problem that large fires interact with their ambient atomspheric enviroment. It is propablly impossible to describe and analysize strictly the problem with now avialable knowledge, although some scientists such as P. Murgg[3], Lee. S. L had investigated [4] and studied such a complicated problem.

In great fire's course the windspeed increased is due to natural convection above a fire and fire whirles which can be caused by unstability of thermal force of fire surroundings. A simple model, which is perhaps far from the actuality, is adapted to interpret the gust phenomenon produced by forest fire.

The air heated above the large firefront in size raises upward and flows out of convection zone at a height, and the ambient air in low atomsphere flows into the convection zone. It is possible to image that a small vertical circulation is formed in the ahead of firefront as illustrated in fig.1

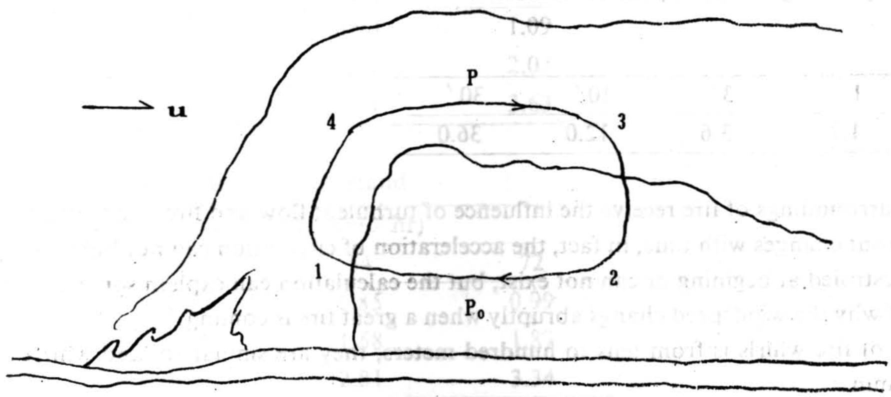

Fig.1 The simple circulation model in ahead of forest firefront

If the temprature of air above fire is T_f, the ambient is T_o. Their difference at some hundreds of height above fire is estimated[5]

$$\triangle T_1 = T_f - T_o = 3.9I^{\frac{2}{3}} / h \tag{1}$$

where I is mean fire intensity (kw / m), h is the height above the fire (m)

If the length of fireline in main spread direction is a few kilometers. The firefront could be considered a line thermal source and showed at Fig.1 (2 point)

$$\triangle T_2 = 3.9I^{\frac{3}{2}} h^{-\frac{5}{3}} \tag{2}$$

considering the change of circulation along the L (1,4,3,2,1), we can write

$$\frac{dr}{dt} = \int_L \frac{dv}{dt} dr = \frac{R}{2}(\triangle T_1 + \triangle T_2) ln \frac{p_o}{p} \tag{3}$$

where r is the quantity of circulation, $\frac{dv}{dt}$ is flow acceleration, R is gas constant (286 $m^2 sec^{-2} deg^{-1}$), Po and P are lower and higher atmospheric presutres respectively. If the following parameters are selected for the "5.6" largest fire:

I	4×10^4	kw / m
Po	1000	mb
P	900	mb
h	800	m
$L_{1,4,3,2,1}$	7600	m

using(3), we can obtain

$$\frac{dr}{dt} = 76.6M^2 / sec^2$$

$$\frac{dv}{dt} = 2 \times 10^{-2} m / sec^2$$

If $\frac{dv}{dt}$ is constant, the circulation velocity is increased to 6 scales of wind during 10 min. and to hurricane's velocity during 1 hour as pointed in table 1.

table 1

t(s)	1′	3′	10′	30′
V(m / s)	1.2	3.6	12.0	36.0

Because the surroundings of fire receive the influence of turbulent flow and fire intensity and the position of firefront changes with time, in fact, the acceleration of circulation can not hold a long time, propably is destroied at begining or can not exist, but the calculation can explain some fire behavior mechanism of why the windspeed changs abruptly when a great fire is coming.

The diameter of fire whirls is from tens to hundred meters, they are similar to land whirls and appear in a few min.

THE SPOTTING DISTANCE

Spotting is an important fire behavior. It occurs frequently in great forest fires and makes a new fire in ahead of main firefront[6]. It induces fire spread from continusely to jumply and makes fire spread rate increaing.

It is generally agreed that when fire intensity exceeds 500kw / m, fuel moisture content is less than 15% and windspeed more than 9m / s, spotting likely occurs[8]. According to Albin's works, spotting distance prelimarily depend on the lofting height of firebrand. It has the following form

$$H = 0.173E^{\frac{1}{2}} \tag{3}$$

where H is firebrand's lofting height (m) and E is thermal strength (KJ / m)

$$E = If(u) \tag{4}$$

where I is mean fire intensity (KW / m), f(u) is a function of the mean windspeed

$$f(u) = A(0.295U)^B \tag{5}$$

where A and B are fuel model–dependent parameters, U is wind speed at 6m height (km / hr). If A, B and U are given, the following equation can be used to estimate the spotting distance for the most serious surface fire.

$$S = 1.30 \times 10^{-3} Uh^{\frac{1}{2}} \left\{ 0.362 + \left(\frac{H}{h}\right)^{\frac{1}{2}} \left(\frac{1}{2}\right) ln\left(\frac{H}{h}\right) \right\} + 5.03 \times 10^{-4} UH^{0.643}$$

where s is the spotting distance (km) h is the mean height of trees. For example, it can be used to calculate the spotting distance of the "5.6" greatest fire. When the fire blew up in logging slash and supermature stand and the following parameters are adapted

logging slash A = 170 B = −0.79
supermature stand A = 301 B = −1.05
mean hight of trees h (m) 20
windspeed U (km / hr) 36, 54, 72
mean fire intensity I (kw / m) 8.7×10^3, 4.0×10^4, 1.8×10^5

Tab.2 and Tab.3 present the calculating results of its spotting distance.

Tab.2 Spotting distance in logging slash

I(kw / m)	U (km / hr)		
	36	54	72
8.7×10^3	0.69	0.90	1.09
4.0×10^4	1.26	1.67	2.03
1.8×10^5	2.23	2.97	3.63

Tab.3 Spotting distance in supermature stand

I(kw / m)	U (km / hr)		
	36	54	72
8.7×10^3	0.68	0.85	0.99
4.0×10^4	1.24	1.58	1.87
1.8×10^5	2.19	2.81	3.34

Rerfered to the tab.2 in logging slash when windspeed is 36 km / hr and fire intensity 8.7×10^3kw / m (flame height 5m), the predicted spotting distance is about 600–700m. The "5.6" greatest fire occurred at the time when windspeed was over the range 36km / hr to 72km / hr, its fireline intensity was approximate $4.0\times10^4\sim1.8\times10^5$kw / m. The spotting distance is predicted over the range of 2 to 3.5km and is agreed with the observation results of witness[7].

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