



DIMENSIONAL AND SCALE ANALYSIS IN FOREST FIRES MODELING

Yolanda Pérez, Alba Àgueda, Elsa Pastor & Eulàlia Planas

Vigo, November 29th 2007



1. Introduction

2. Dimensional and scale analysis

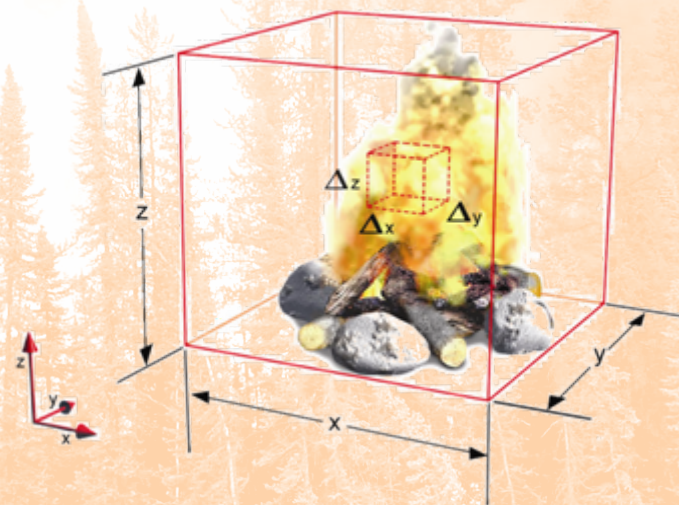
- General concepts
- Previous work
- Forest fires modeling

3. Example

- Methods
- Preliminary results

4. Data Base – DB FOC

5. Conclusions



- **Forest fires spread nonuniformly and nonsteady over nonhomogenous fuels**
- **Limitations to obtain data during real emergencies owing to technical, economical and safety constrains.**
- **Scale model experiments (lab and field) play an important role in forest fires research**



- **Are Scale models able to provide significant information to the full-scale phenomena?**



Source: GRAF – Generalitat de Catalunya

The aim of this work is to discuss about the use of Dimensional and Scale Analysis in forest fires modeling

GENERAL CONCEPTS

▪ Dimensional Analysis

Any phenomenon can be described by a dimensionally homogenous equation containing the minimum characteristic variables

▪ Dimensionless products π_i Selection / Formulation

- Pi Theorem
- Governing equations
- Identification and equating of Energy, forces, and mass rates

▪ Scale analysis – Scaling laws

Similarity theory states that dimensionless products have the same value in different scales

$$\pi_{if} = \pi_{im}$$

$i=1, 2, \dots$
f: full-scale
m: model scale


Scaling laws

 Construct
experimental model (or test)

FOREST FIRES MODELING

- Application of dimensional analysis to forest fires

 $> 30 \pi_i$ 

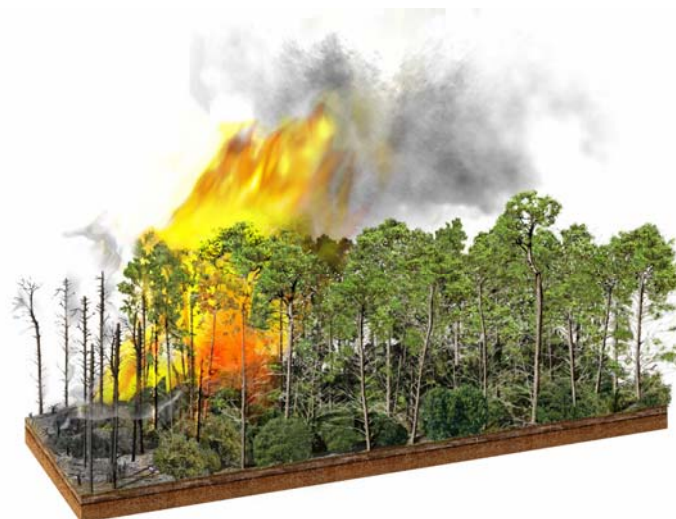
Complete scaling is
not possible

- Hypothesis to omit some π_i groups



Partial Scaling

- Test hypothesis
- Different strategies for modeling



FOREST FIRE MODELLING

▪ Froude Modeling

Same ambient conditions in model scale and full-scale
Re and Fr cannot be both retained

$$Re = \frac{L \cdot V \cdot \rho}{\mu}$$

$$Fr = \frac{V^2}{g \cdot L}$$



$$V \sim L^{-1}$$

≠

$$V \sim L^{1/2}$$

Scaling contradiction



Omit

Re or Fr

L: Characteristic linear dimension

L_i : Linear dimensions

V: Velocity

Q: Heat flux

$$L_i \sim L$$

$$V \sim L^{1/2}$$

$$Q \sim L^{3/2}$$

FOREST FIRE MODELING

Advantages:

- The **generality of dimensional analysis** permits to use it without a **wide knowledge** on the phenomenon
- **Quantitative results** can be produced at an advantage of scale and cost.
- **Useful correlations** can be provided
- Some of the important **phenomena of large-scale** fire spread **can be captured**

Drawbacks:

- It is necessary to **know enough** about the phenomenon of interest **to identify the main variables** that control it
- It **doesn't exist standard definitions** for characteristic parameters
- **Scale effects** can be found and should be avoided
- **Data** from **different scales** are needed to test the modeling hypothesis

PREVIOUS WORK

- **Dimensional and scale analysis have demonstrated their potential in other fire research areas**

(Hottel, 1959; de Ris, Kanury & Yuen, 1972; Quintiere, 1988; Thomas, 2000)

- **Some works using dimensional and/or scale analysis**

- Thomas (1963) – **Model flames length**
- Byram (1966) – **Formulate scaling laws for modeling mass fires**
- Williams (1969) – **Partial scaling mass fires**
- Lee (1972) – **Test scaling laws of Byram (1966) in smaller size models**
- Emori and Saito (1982) – **Model a real fire to replicate its behavior**
- Emori and Saito (1983, 1988) – **Formulate scaling laws for different models**
- Nelson and Adkins (1988) – **Correlate data to model wind aided fires**
- Raupach (1990) – **Similarity analysis of the interaction of fire plume and wind**

METHODS

- Dimensional and Scale analysis have been used for planning forest fires lab experiments
- Tests have been performed in geometrically similar fuel beds
- Tests specifications:
 - No wind, no slope
 - Same fuel: Wheat straw
 - Dried fuel
 - Constant bulk density

Fuel bed width [x10 ⁻² m]	Fuel bed height [x10 ⁻² m]	Fuel load [kg/m ²]	Bulk density [kg/m ³]
25	2,0	0,15	7,5
50	4,0	0,30	7,5
100	8,0	0,60	7,5



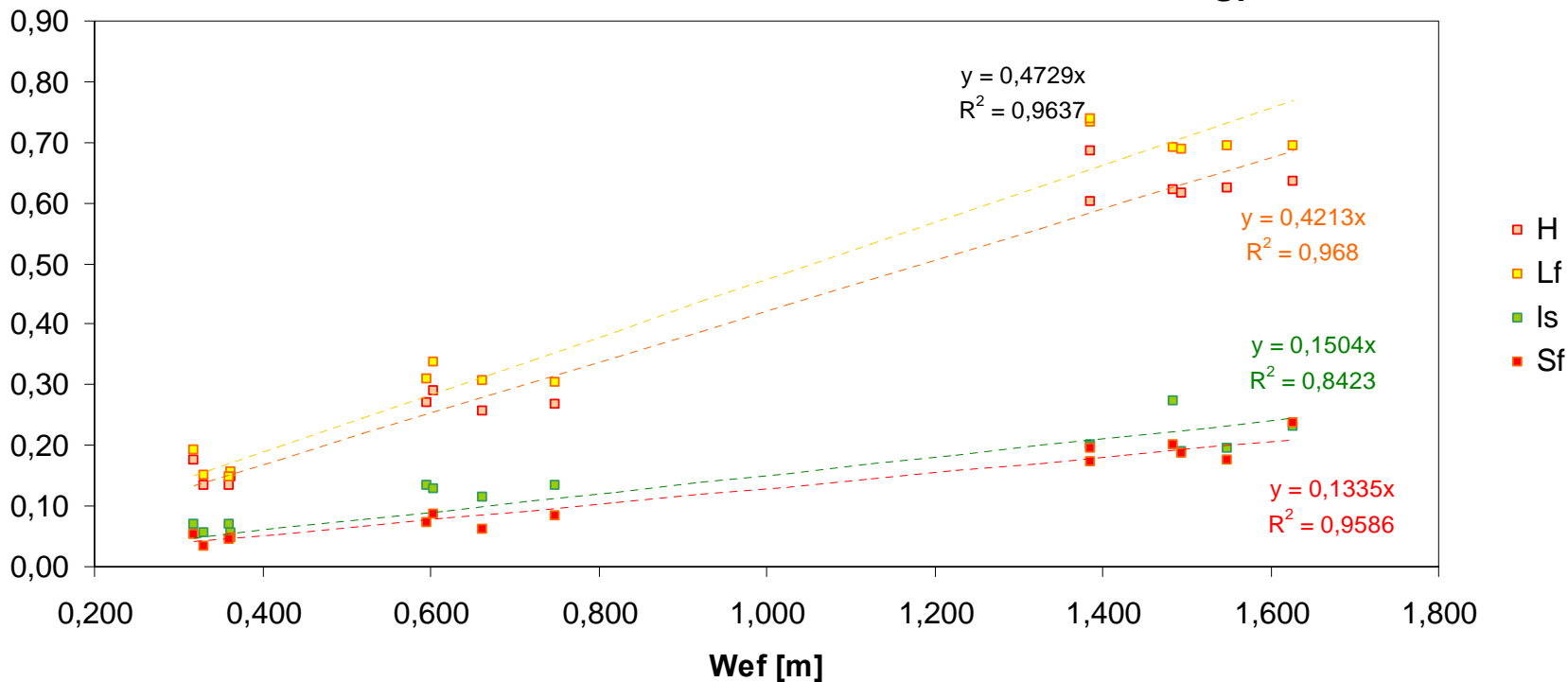
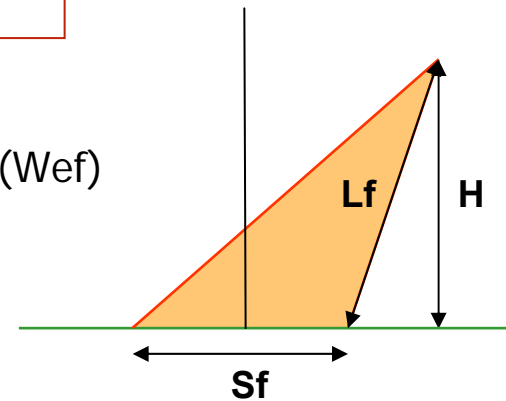
3. EXAMPLE

PRELIMINARY RESULTS AND DISCUSSION

$H, L_f, S_f, I_s \sim L$

L (characteristic length scale) = Flames front length (W_{ef})

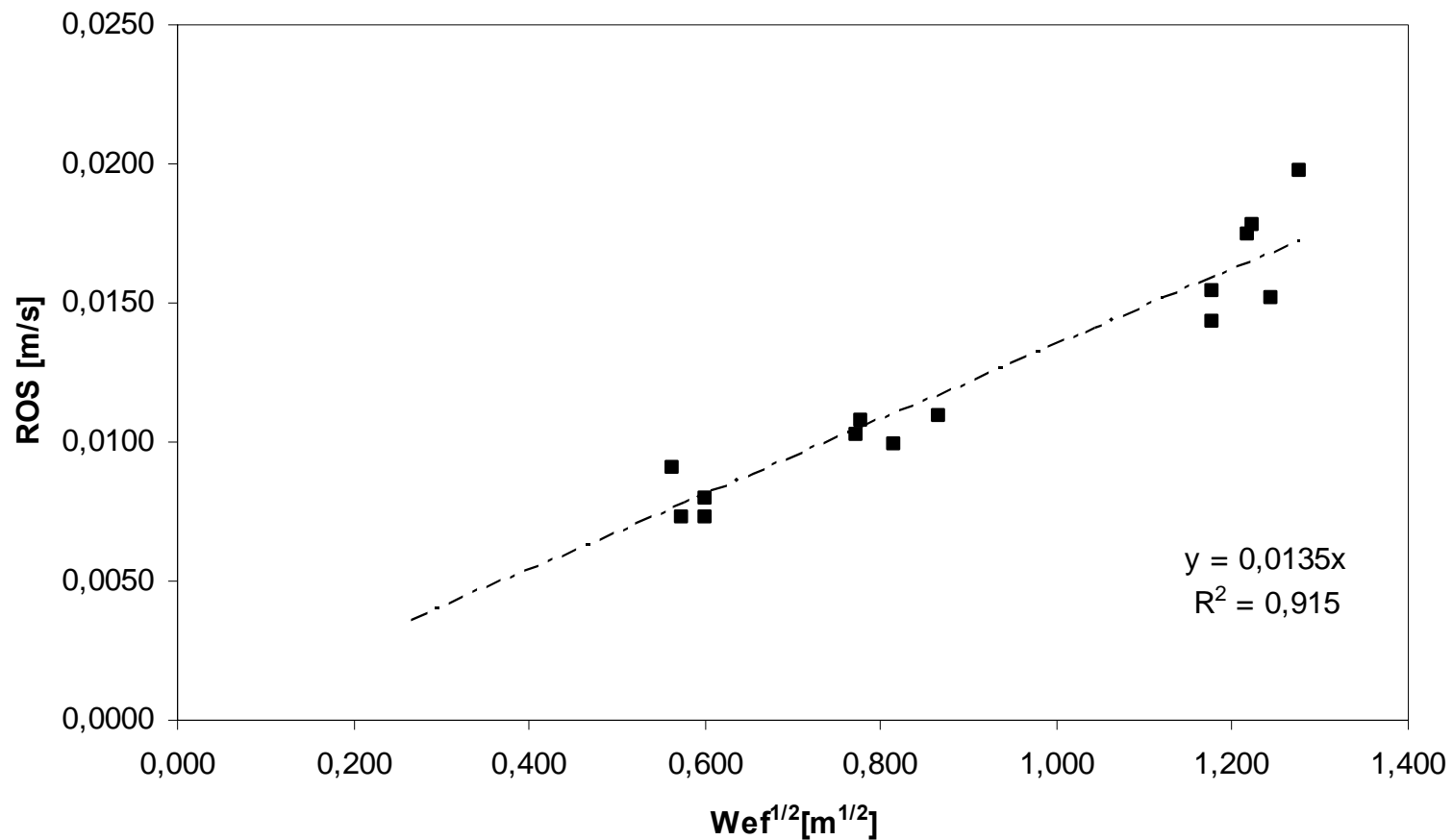
I_s : Preheating fuel bed length



3. EXAMPLE

PRELIMINARY RESULTS AND DISCUSSION

ROS $\sim L^{1/2}$ (L = Wef: Flames front length)

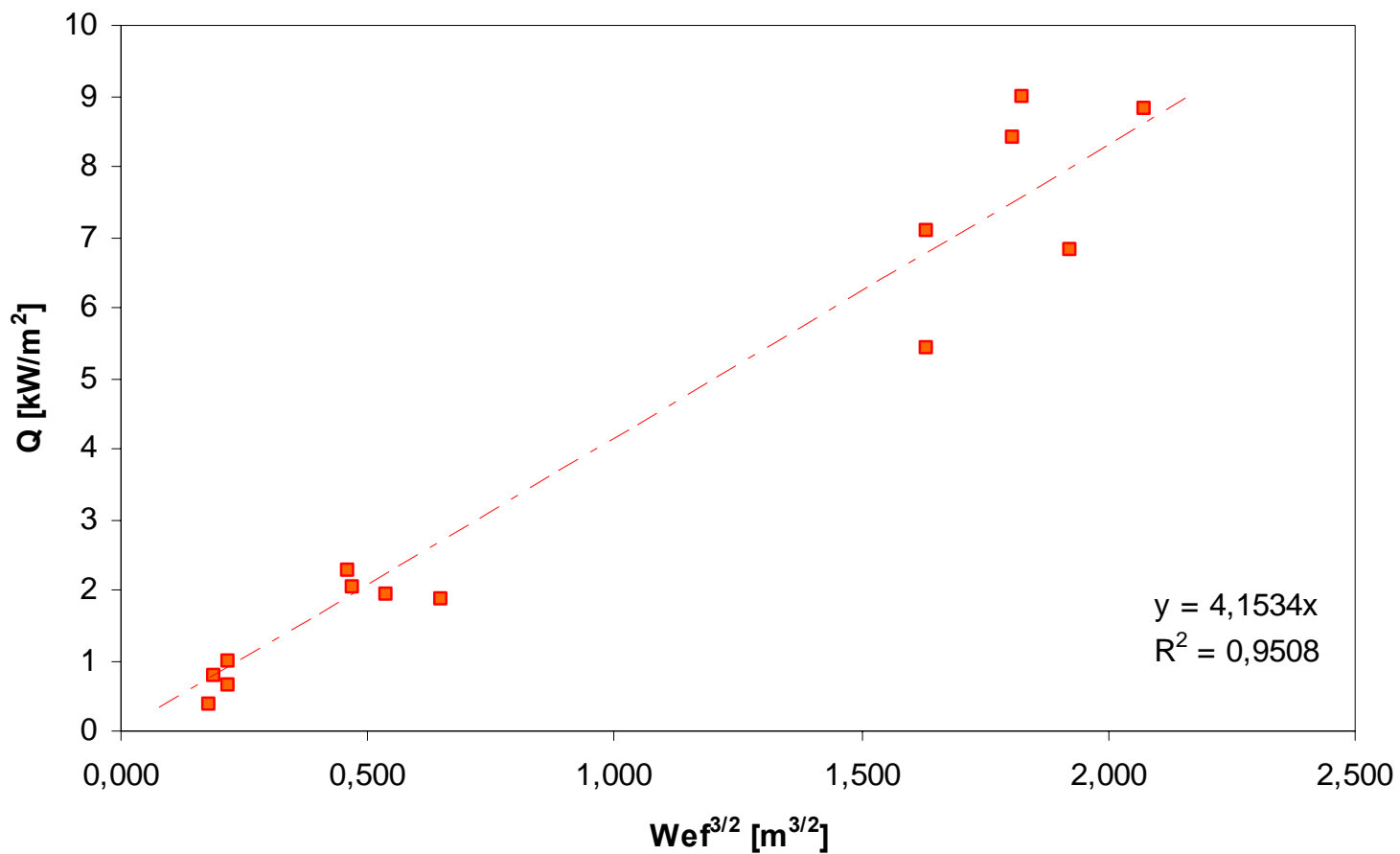


3. EXAMPLE

PRELIMINARY RESULTS AND DISCUSSION

$$Q \sim L^{3/2}$$

(L = Wef: Flames front length)

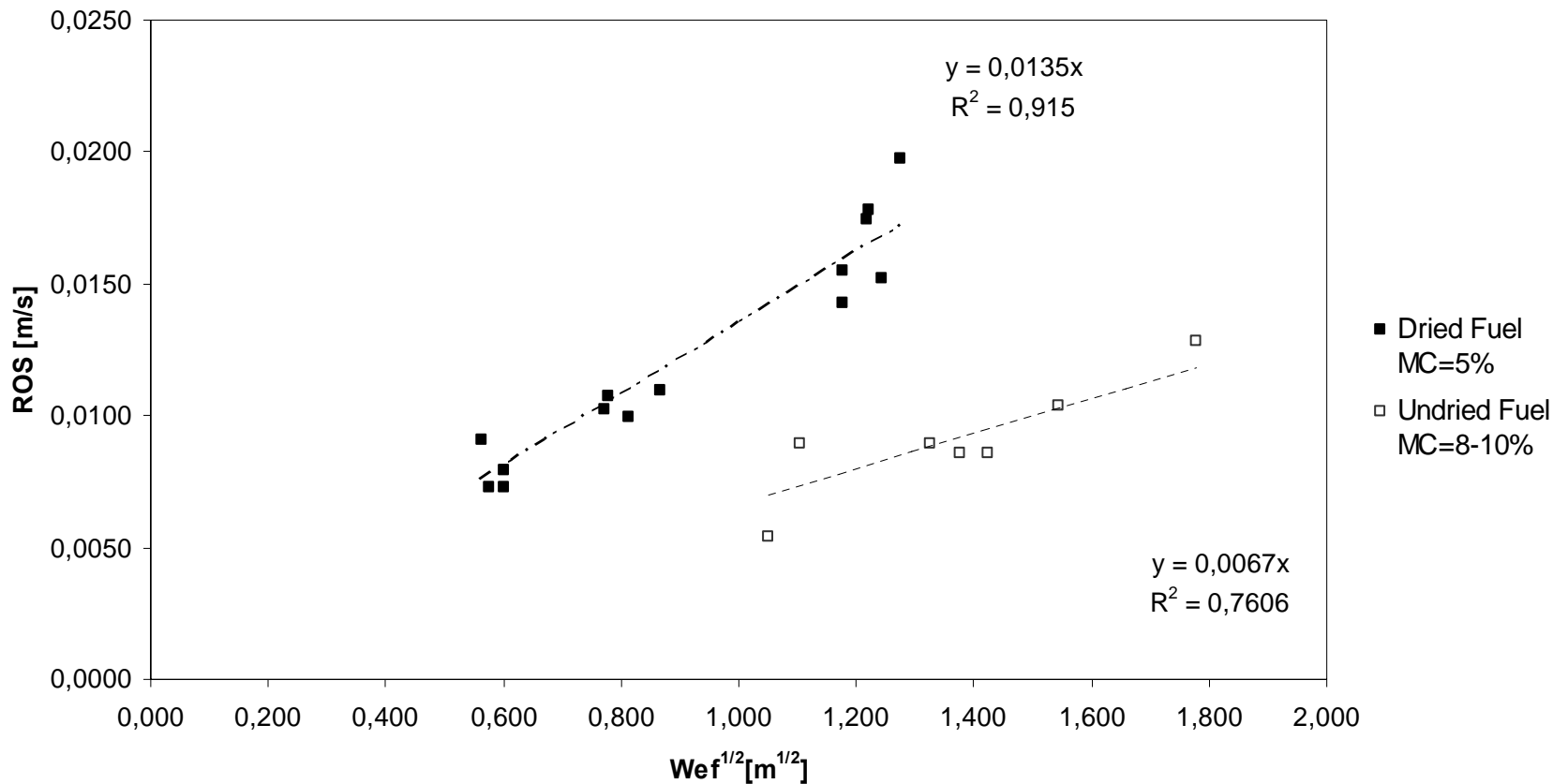


3. EXAMPLE

PRELIMINARY RESULTS AND DISCUSSION

Undried fuel

ROS $\sim L^{1/2}$ (L = Wef: Flames front length)

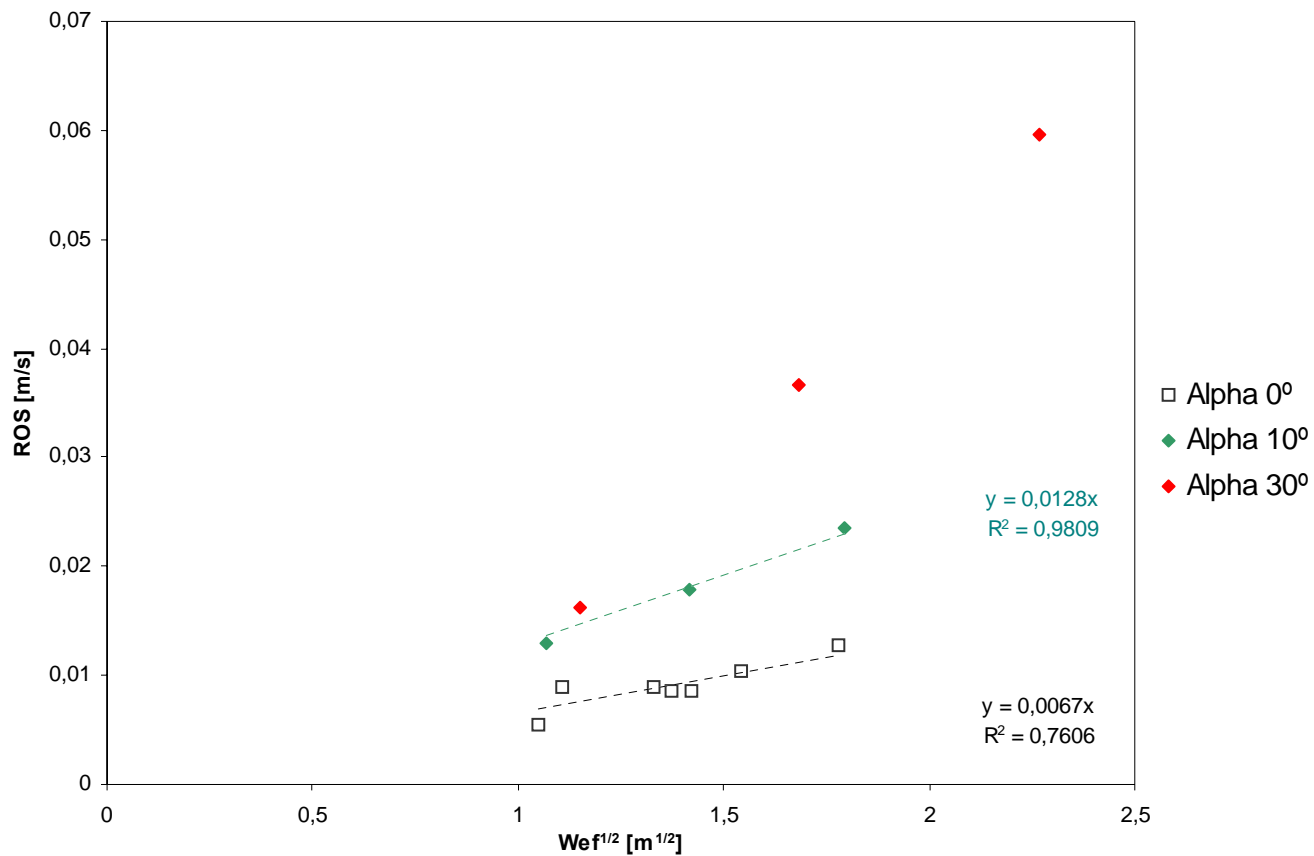


3. EXAMPLE

PRELIMINARY RESULTS AND DISCUSSION

Undried fuel + slope

$ROS \sim L^{1/2}$ (L = Wef: Flames front length)

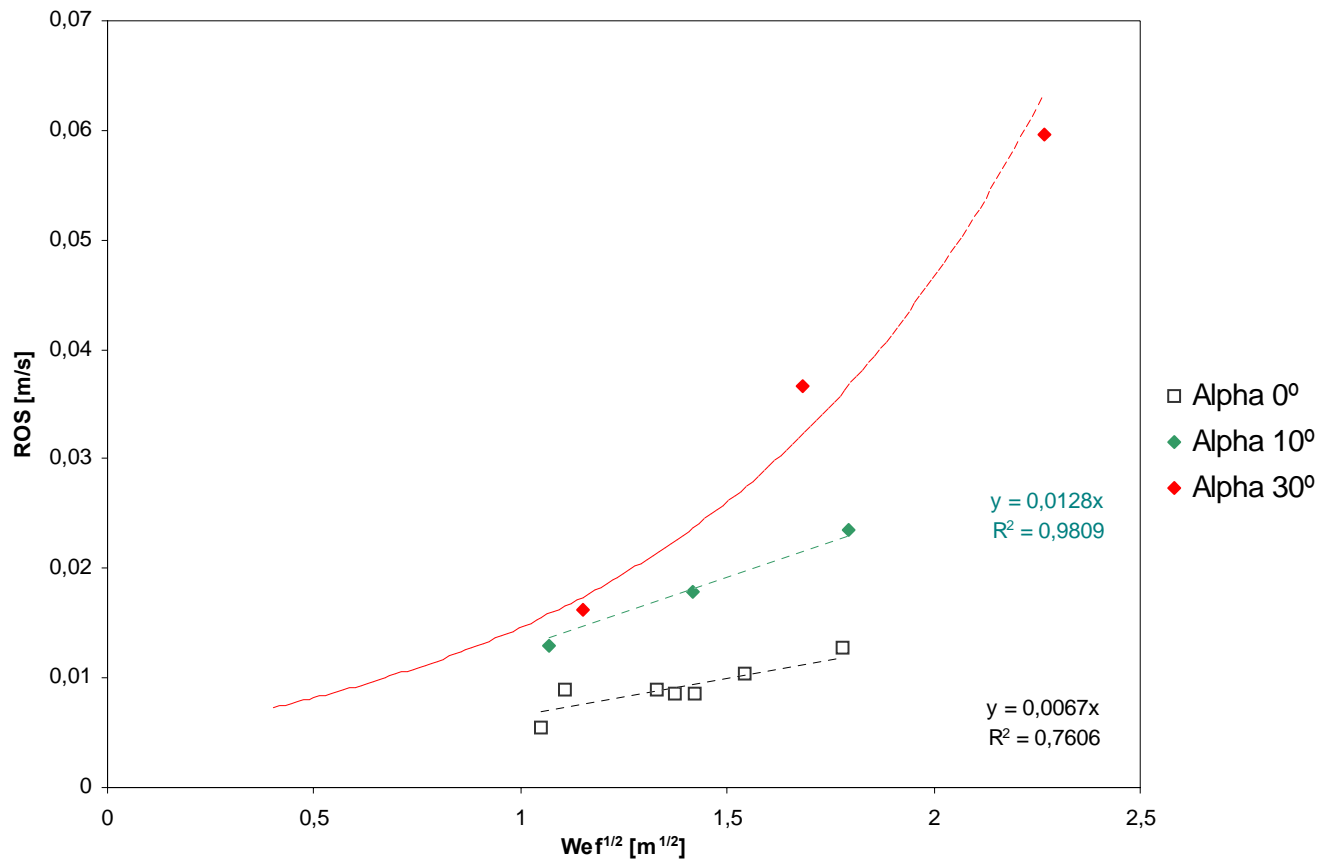


3. EXAMPLE

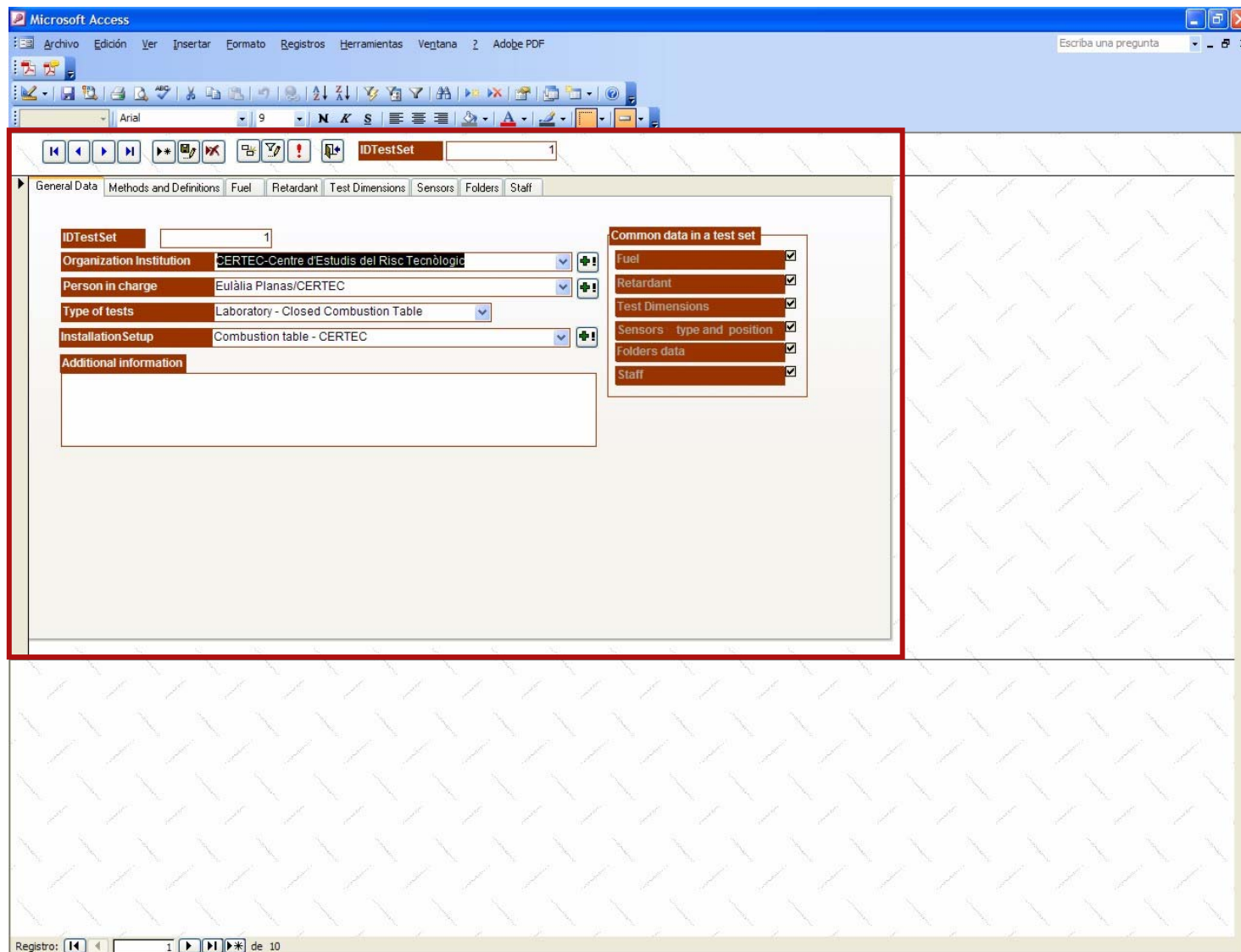
PRELIMINARY RESULTS AND DISCUSSION

Undried fuel + slope

$ROS \sim L^{1/2}$ (L = Wef: Flames front length)



DB FOC – Data base on forest fire lab and field experiments



The screenshot displays the Microsoft Access interface for the DB FOC database. The form is titled "IDTestSet" and is currently showing record 1. The form is divided into several sections:

- General Data:** This section contains the following fields:
 - IDTestSet: 1
 - Organization Institution: CERTEC-Centre d'Estudis del Risc Tecnològic
 - Person in charge: Eulàlia Planas/CERTEC
 - Type of tests: Laboratory - Closed Combustion Table
 - Installation Setup: Combustion table - CERTEC
 - Additional information: (Empty text box)
- Common data in a test set:** This section contains a list of checkboxes for data categories:
 - Fuel:
 - Retardant:
 - Test Dimensions:
 - Sensors type and position:
 - Folders data:
 - Staff:

The status bar at the bottom indicates "Registro: 1 de 10".

DB FOC – Data base on forest fire lab and field experiments

Navigation icons: Home, Previous, Next, First, Last, Refresh, Print, Save, Warning, Help, IDTestSet: 1

General Data | Methods and Definitions | Fuel | Retardant | Test Dimensions | Sensors | Folders | Staff

IDTestSet: 1

Organization Institution: CERTEC-Centre d'Estudis del Risc Tecnològic [+!]

Person in charge: Eulàlia Planas/CERTEC [+!]

Type of tests: Laboratory - Closed Combustion Table

Installation Setup: Combustion table - CERTEC [+!]

Additional information

Common data in a test set

- Fuel
- Retardant
- Test Dimensions
- Sensors type and position
- Folders data
- Staff

DB FOC – Data base on forest fire lab and field experiments

The screenshot shows the DB FOC software interface. At the top, there is a toolbar with navigation and action icons. Below the toolbar is a tabbed menu with the following tabs: General Data, Atmospheric Conditions, Fuel bed properties, Fire Behavior, Flame geometry, and CG properties. The 'Atmospheric Conditions' tab is currently selected and highlighted with an orange box.

The main content area is divided into two columns. The left column contains data entry fields:

- ID Test: 1
- Date / Hour: 10/11/2006 14:22:00
- Ignition type: Line
- PropagationType: headfire
- Additional information: (empty text area)

The right column contains an 'Available Data' list with the following items, each with a checked checkbox:

- Atmospheric conditions
- Fuel
- Fuel Bed Properties
- Test Dimensions
- Retardant
- Sensor's type and position
- Fire Behavior
- Flame geometry
- Combustion gases properties
- Folders data
- Staff

Orange ovals highlight the 'Atmospheric conditions', 'Fuel Bed Properties', 'Fire Behavior', and 'Combustion gases properties' items in the 'Available Data' list.

- **Dimensional and scale analysis seem to be very useful tools in forest fire modeling**
- **Data from different scales are essential for the assessment of forest fires models.**
- **Data base DBFOC has been developed to collect and manage field and lab data**
- **Next step... other conditions in lab and field assessment of scaling laws**



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