

# Simulazione di un incendio ferroviario in galleria

*Perugia, 20 marzo 2013*

*Nuovi metodi per la pianificazione dell'emergenza e la prevenzione incendi nei luoghi chiusi. Le gallerie ferroviarie in provincia di Perugia.*

Luca Nassi

Corpo Nazionale dei Vigili del  
Fuoco



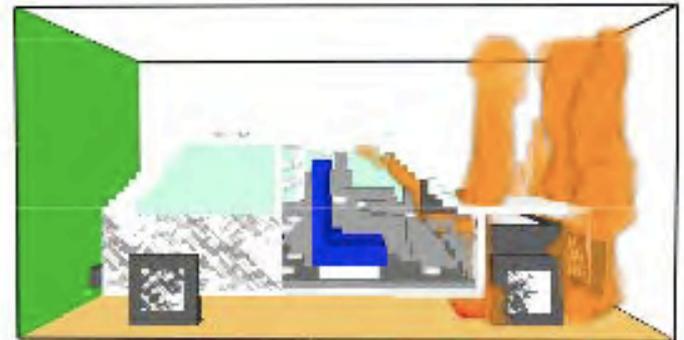
## Nella mia presentazione....

- Le problematiche ed un (possibile) aiuto..... CFD
- parametri interni ed esterni CFD
- Alcuni esempi..
  
- Alcune referenze:
- *The handbook of tunnel fire safety - Alan Beard and Richard Carvel - TT 2005*
- *Kai Kang - Daniel McNamee - Passenger rail vehicle fire models - Fire&Safety magazine - fall 2010*
- *Dr. Anja Hofmann - BAM - Five - fire in Vehicles proceedings - 09-2010- Gotheburg*
- *Dalmarnock fire tests proceedings- University of Edinburgh 2006-2007*
- *David Tonegran, Marcus Ryber - Increased quality and reduced uncertainty when using FDS.*

*E' opinione comune che:  
- Nessuno creda alle analisi numeriche,  
tranne gli analisti che le hanno svolte.....*



Snobview 5.1.3 May 3 2000



Frame: 29  
Time: 1:25

0.621 (34683)

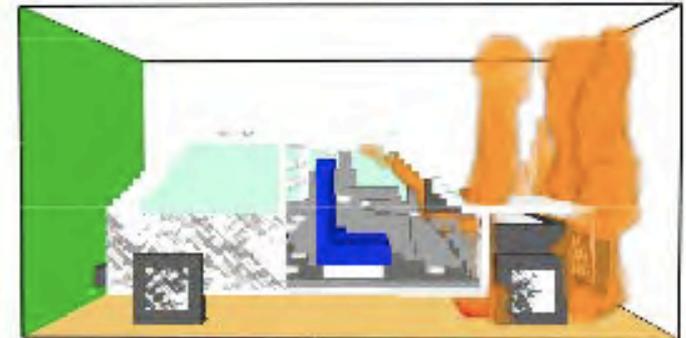
*- E che tutti credano alle analisi sperimentali*

.....

*.....tranne gli sperimentatori.....*



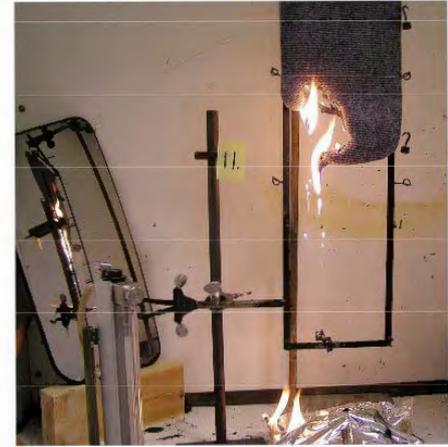
Smokeview 5.1.5 May 9 2000



Frame: 29  
Time: 1.275

0.001 (44000)

ISO 6941 (ECE Reg No 118 annex 8), vertical burning rate



Test of Product No.11, polypropylene needle felt, according to ISO 6941.  
SP Sveriges Tekniska Forskningsinstitut



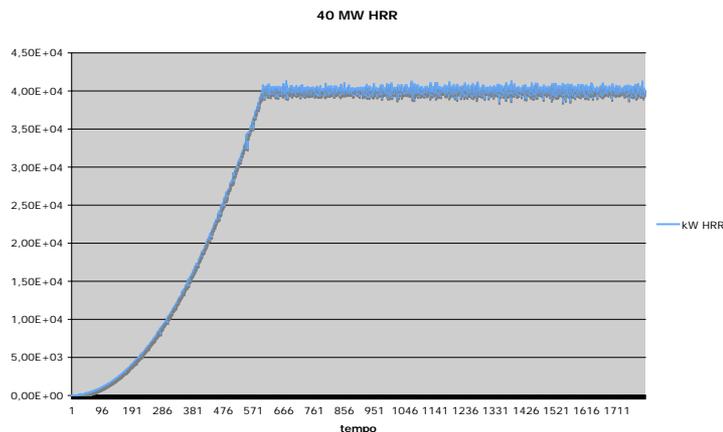
# fire safety vehicle modelling - differenti prospettive

- *Evacuazione sicura dei passeggeri a bordo*
- *Impatto dell'incendio (tunnel, stazione..) durante l'evacuazione dei passeggeri*
- *Impatto strutturale dell'incendio (tunnel, stazione..)*

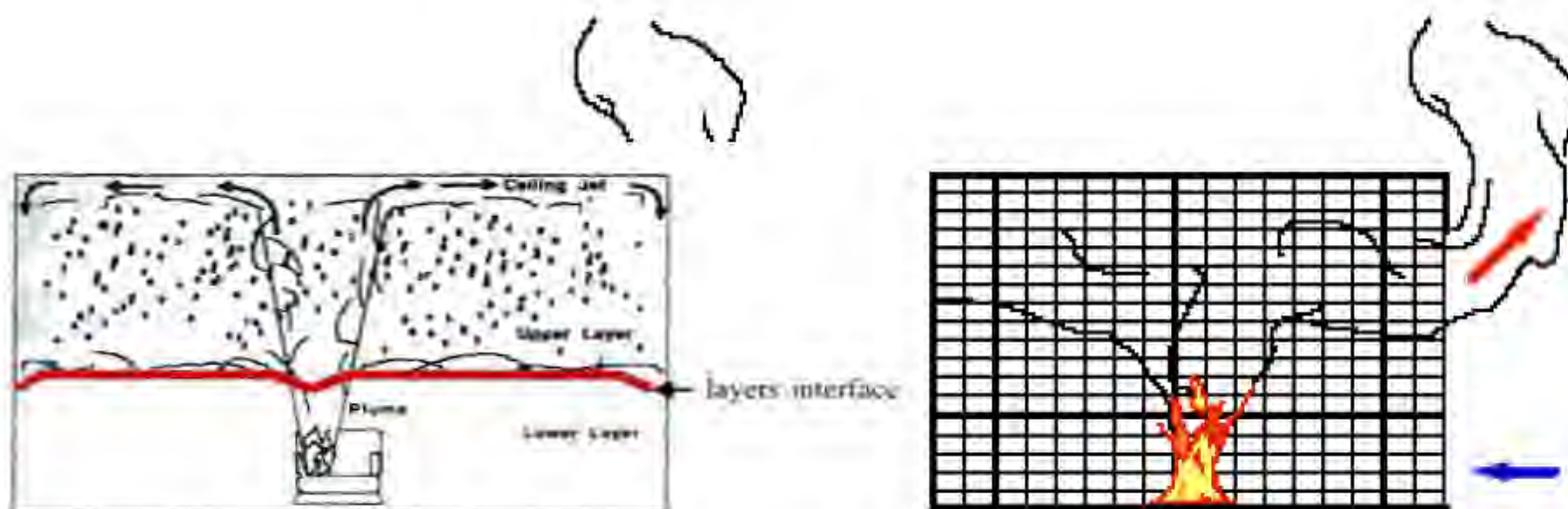


# Esempi di modellazioni - FDS5 - NIST

- caso 1 - galleria di 800 mt con incendio da 10 Mw di picco
- caso 2 - come sopra ma con presenza di Jet fans
- caso 3/4 - come sopra ma con immissione ed estrazione aria
- caso 5 - galleria di 800 mt con incendio da 40 Mw di picco
- caso 6 - galleria da 2.000 mt con vento su di un portale



# Zone to Field Models



**NIST**

National Institute of Standards and Technology  
Technology Administration, U.S. Department of Commerce

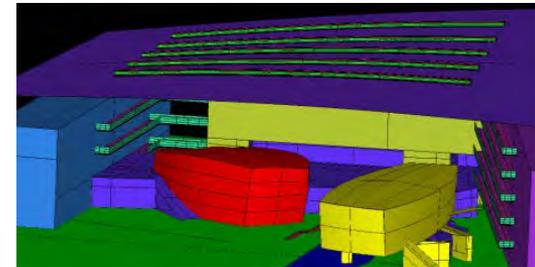
# CFD Modeling

CFD = Computational Fluid Dynamics

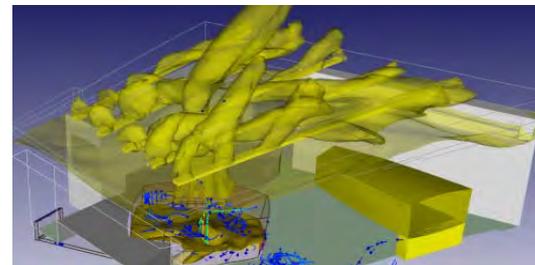
- **Geometry** model with details
- Generation of calculation **mesh**  
(e.g. 500'000 – 5'000'000 cells)
- Transport **equations** are solved
- Initial and boundary **conditions specified**
- **Interpretation** of results
- Make **recommendations** for end-user



Geometry



Grid generation, boundary conditions



Result

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**Labels**  
VTT, NIST, Fire, Simulation, Chemistry, Physics, Combustion, 3D, Visualization, FDS, Smokeview, CFD, FluidDynamics, Thermodynamics, OSX

**Members**  
[mcgra...@gmail.com](#), [gfor...@gmail.com](#),  
[dift...@gmail.com](#), [stuart...@gmail.com](#)

**Fire Dynamics Simulator (FDS)** is a large-eddy simulation (LES) code for low-speed flows, with an emphasis on smoke and heat transport from fires.

**Smokeview (SMV)** is a visualization program used to display the output of FDS and [CFAST](#) simulations.

**FDS+Evac** is the evacuation simulation module for FDS.

### Download FDS-SMV for Windows, Mac, and Linux

[Download FDS and Smokeview](#)

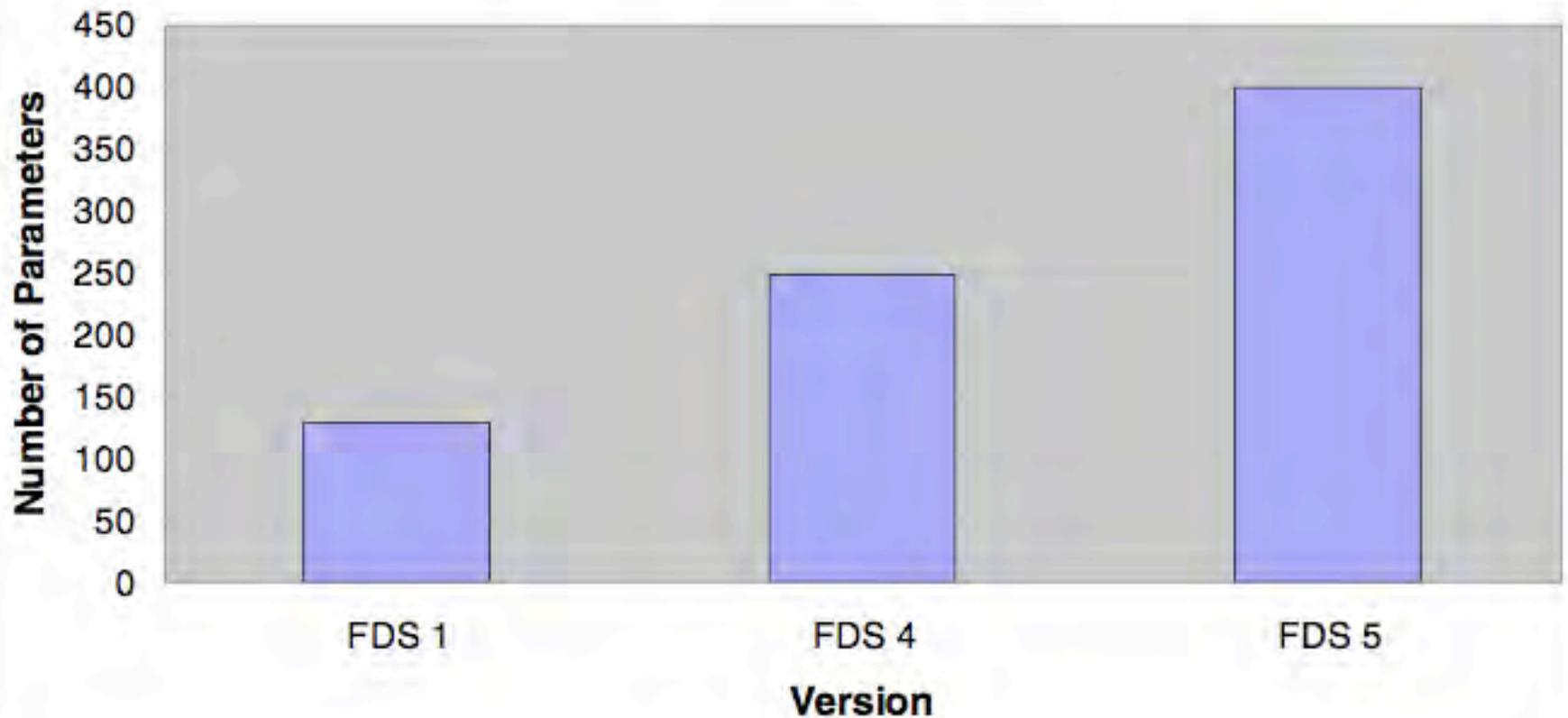
# Parametri INTERNI dei modelli CFD

- Metodo di calcolo numerico
- convergenza
- stabilità - robustezza - sensitive analysis
- mesh - dimensione delle celle
- .....
  
- Validazione (ex. FDS)
- creato per edifici industriali
- Incendi ben ventilati
- Modello di pirolisi (??) (ex FDS)
- SOLO un combustibile gassoso - mixture fraction model

# Parametri ESTERNI dei modelli CFD

- Geometrici
- dimensioni
- ventilazione
- boundary conditions
  
- parametri termofisici
- conduttività
- densità
- Calore specifico .... Etc...
  
- Definire l'incendio (ex FDS)
- HRR, definizione del combustibile, mass loss,.....

## Possible User Defined Inputs



*Fig 1 – Increase of possible user defined variables in recent versions of FDS*

Ogni nuova versione di FDS diventa più sofisticata... e maggiore esperienza e conoscenza è richiesta all'utente del software...

# Burning process and fire

- Volumetric fires
- prescribing a date HRR released by a burner
- experimental curves

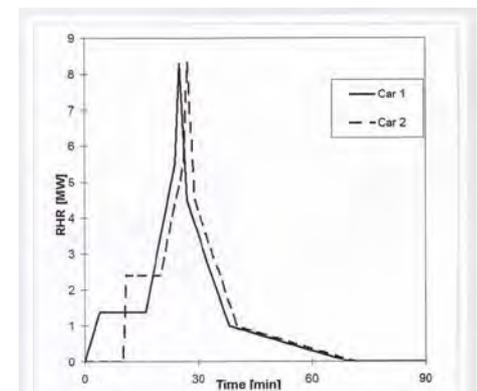
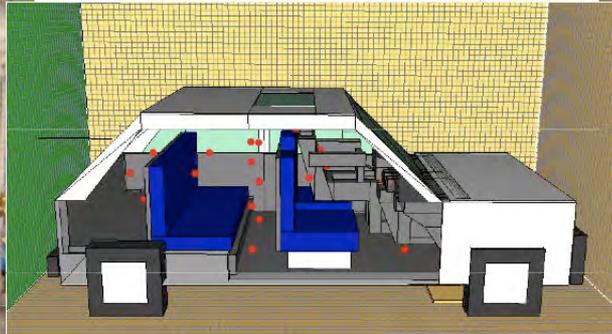


Figure 1. Typical heat release rates for a car initially on fire (car 1) and a car that is ignited by the first car about 10 minutes later

# Burning process and fire

- FDS Pyrolysis model - specify thermophysical properties of solid fuel materials and let them pyrolyze if ignited. The HRR curve is not defined a-priori by the user.

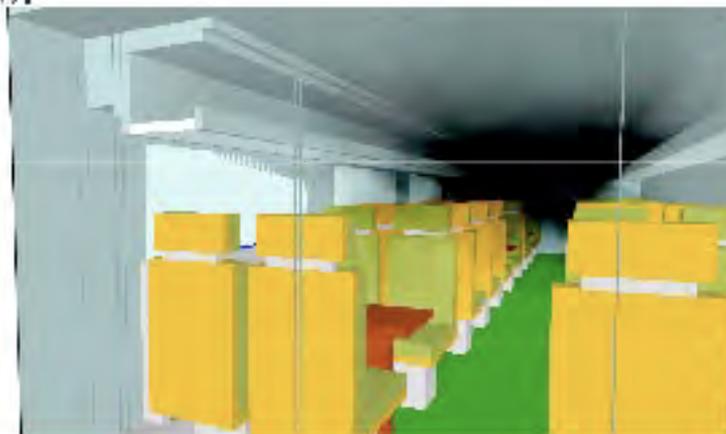
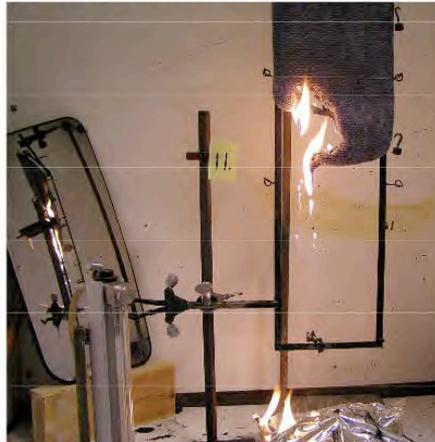
ISO 3795 (ECE Reg No 118 annex 6), horizontal burning rate



ISO 5658-2 (IMO Res A.643(16), CEN/TS 45545-2), Spread of fire



ISO 6941 (ECE Reg No 118 annex 8), vertical burning rate



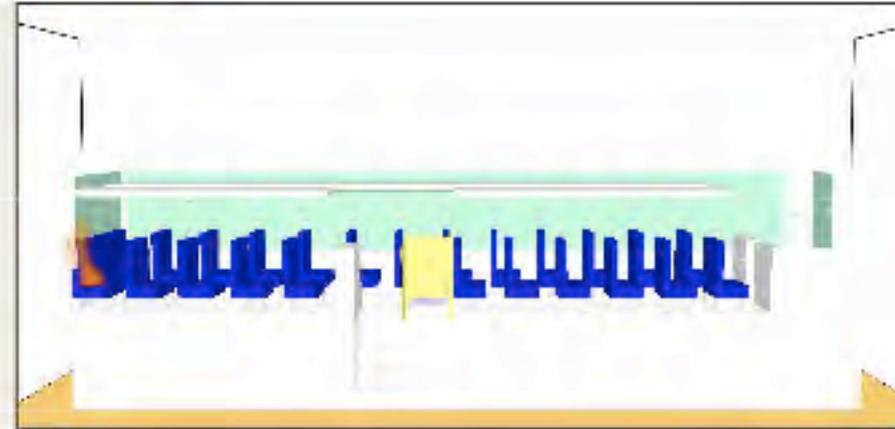
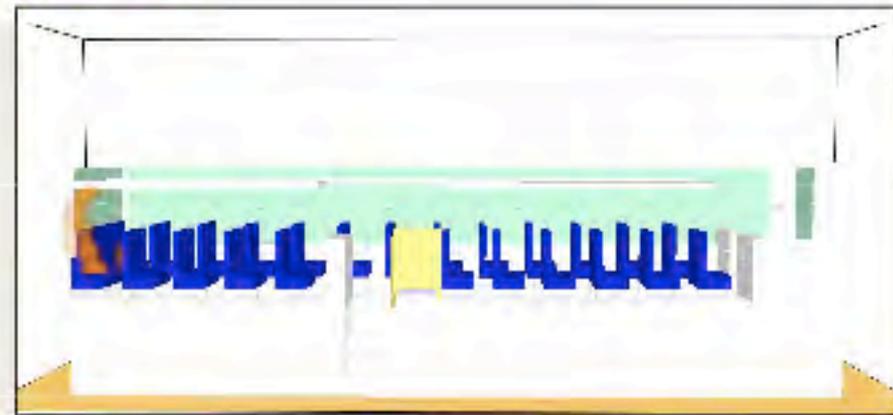
ling to ISO 5658-2.

*Bus upholstered seat*

*Railway upholstered seat*

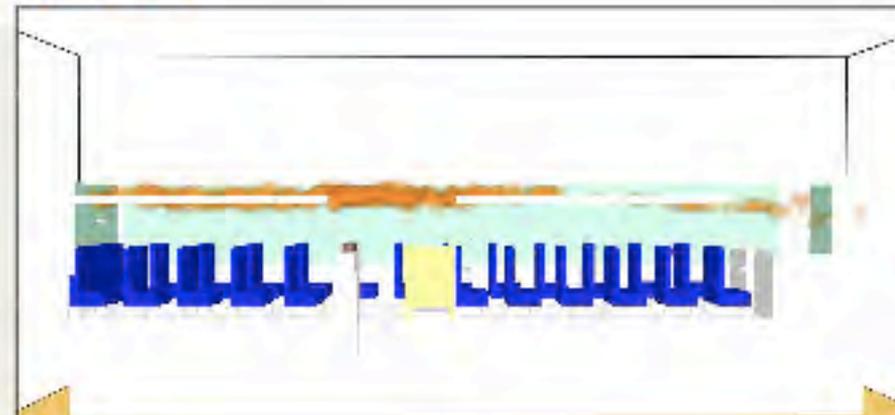
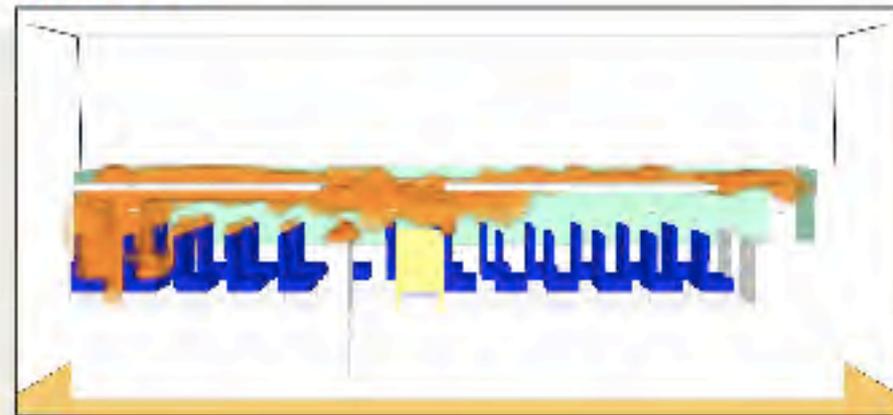
*After 40 s*

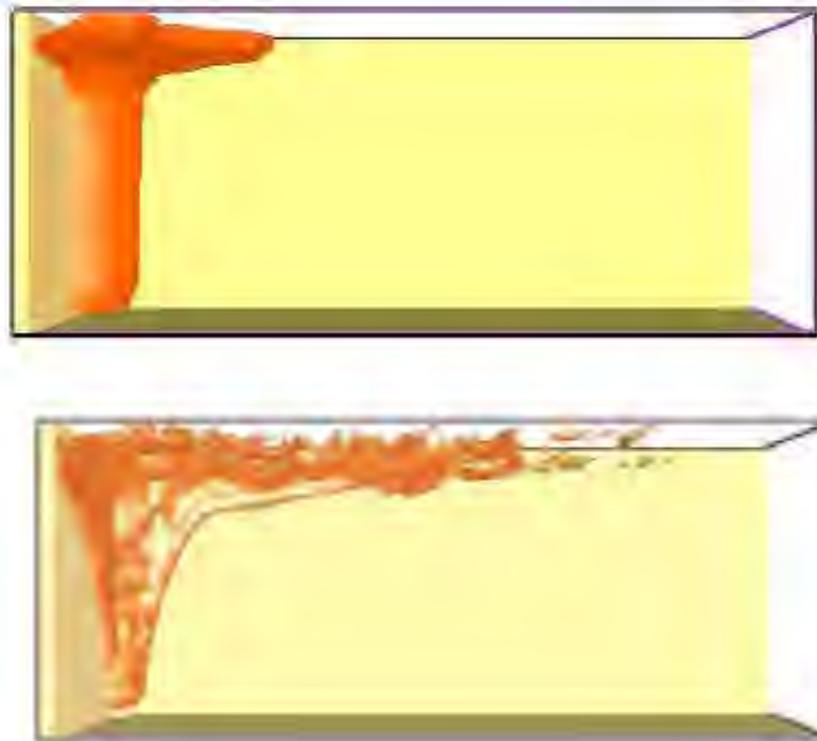
*After 40 s*



*After 66 s*

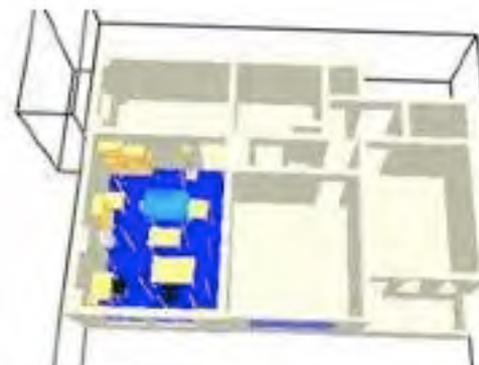
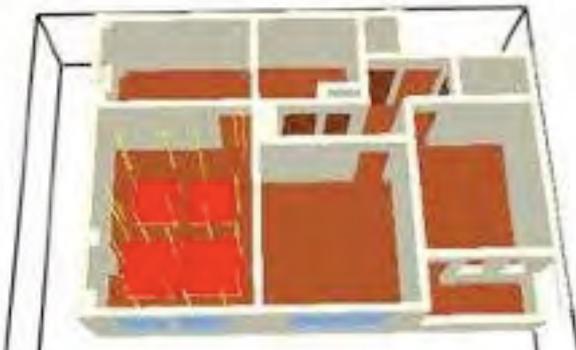
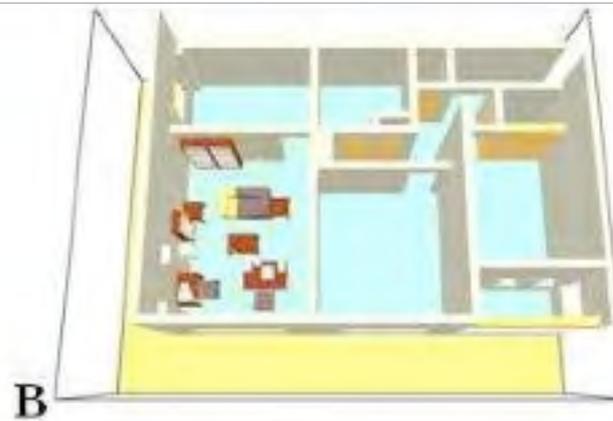
*After 66 s*





The upper image is a corner burn showing the flame spread over a layered paint surface. The cell size is 10 cm. In the lower image the fire is the same size, the surface properties are the same and the images are captured at the same time in the simulation. The only difference is that the cell size is 2.5 cm. As you can see, the scenario with the higher resolution displays greater fire spread.

# Dalmarnock fire tests - University of Edinburgh 2006-2007



Combustible furniture modeled

# Dalmarnock fire tests - A priori and a posteriori analysis

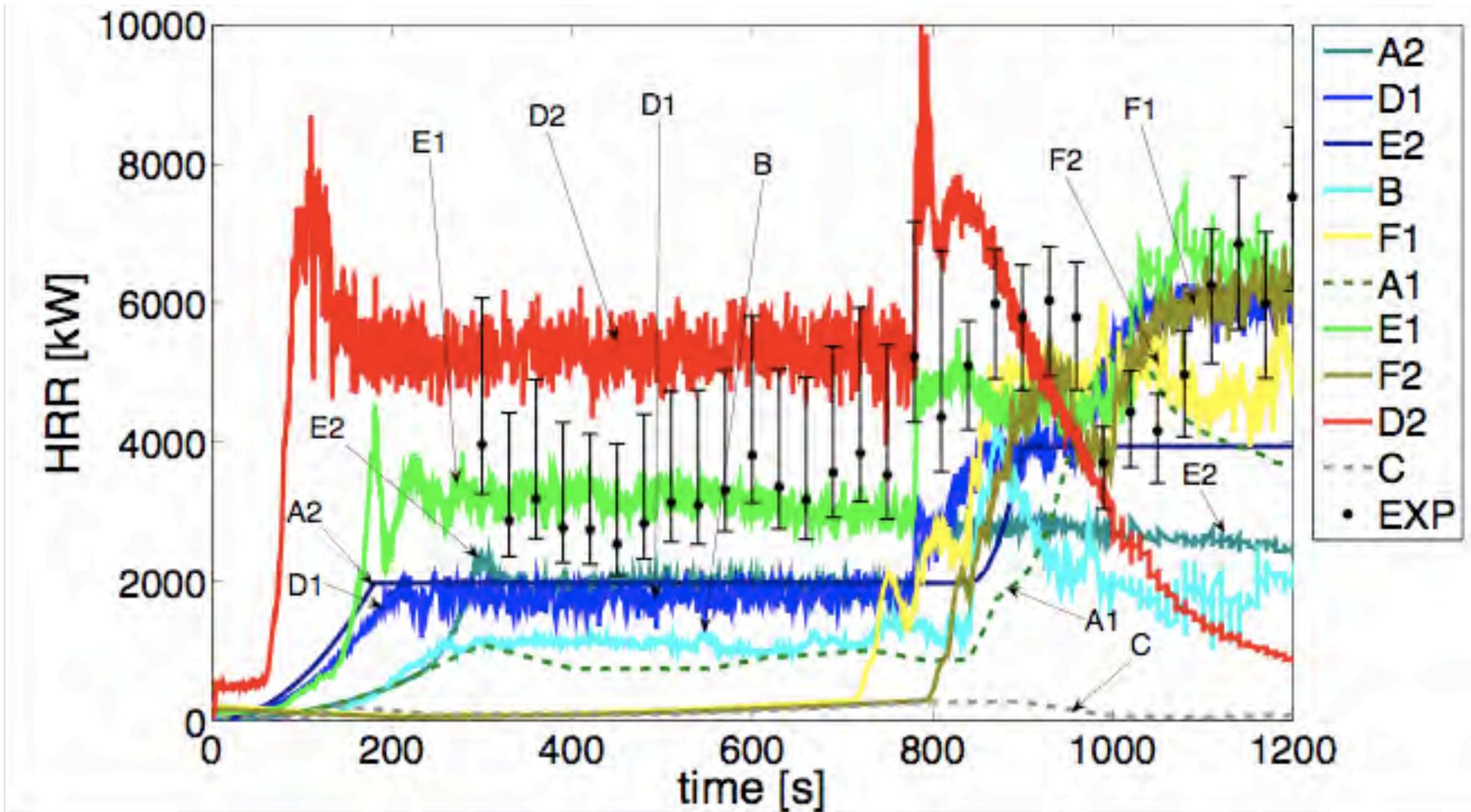
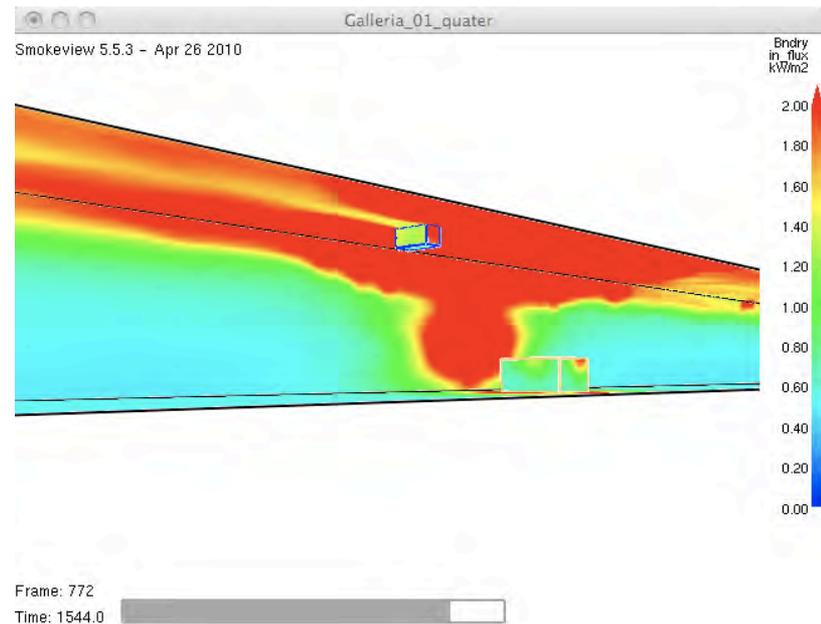
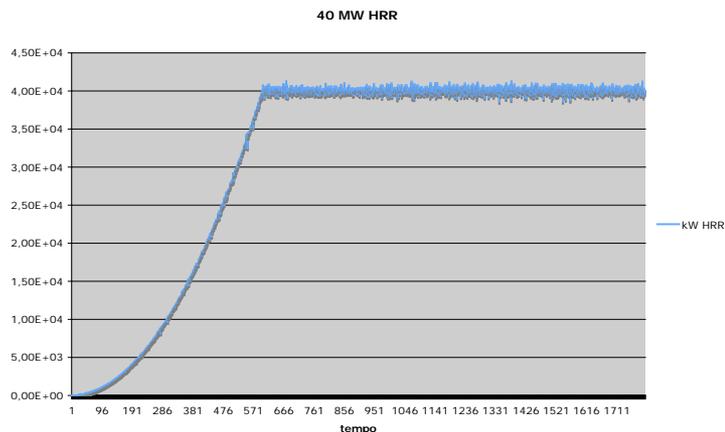


Figure 6: Evolution of the global heat release rate within the compartment. Legend for the different curves: continuous line for CFD simulations; dashed line for zone model simulations; and dotted for the experiment data with error bars.

# Esempi di modellazioni - FDS5 - NIST

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- caso 5 - galleria di 800 mt con incendio da 40 Mw di picco
- caso 6 - galleria da 2.000 mt con vento su di un portale



# Galleria di 800 mt - incendio 10 Mw

Galleria\_01\_bis

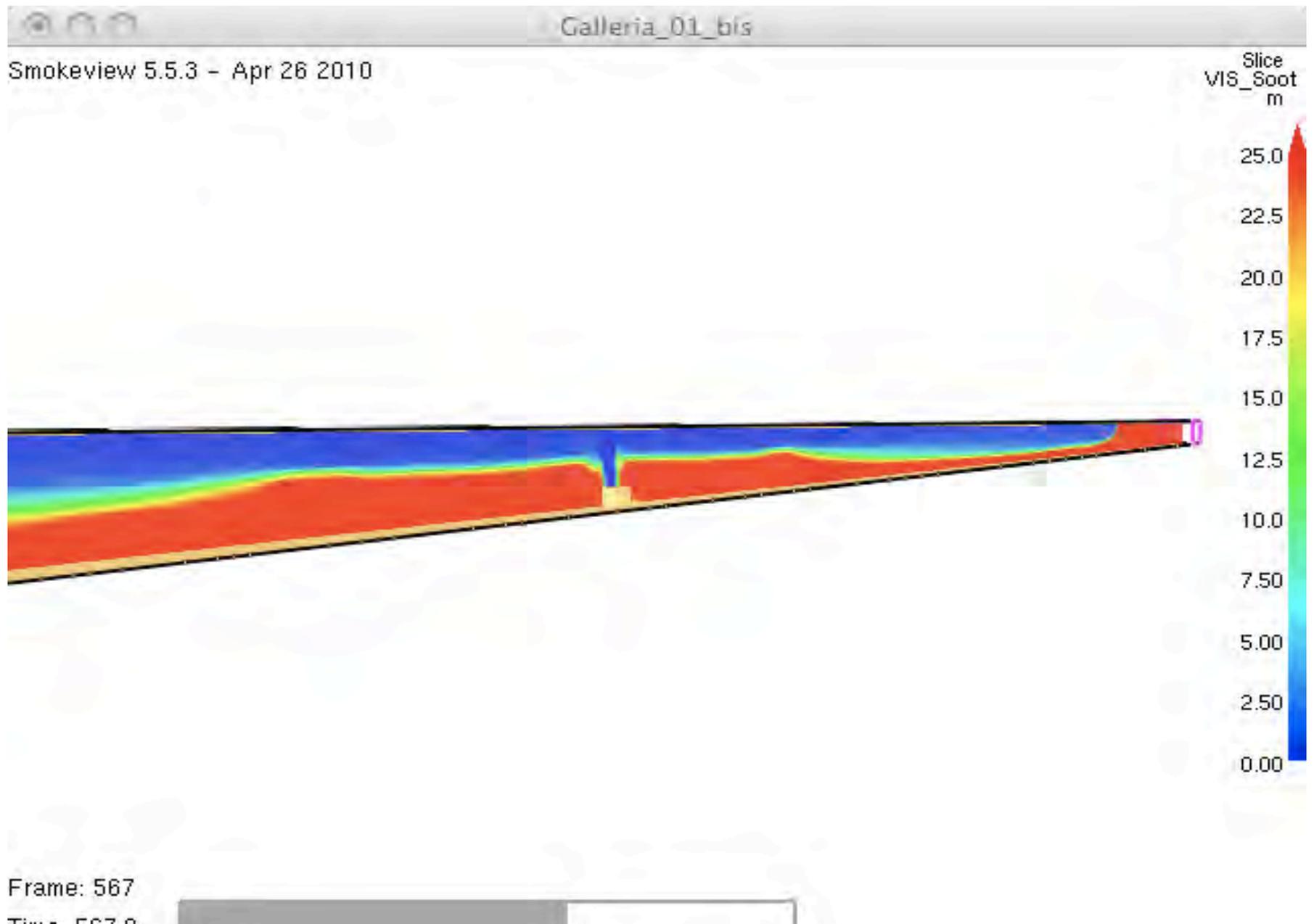
Smokeview 5.5.3 - Apr 26 2010



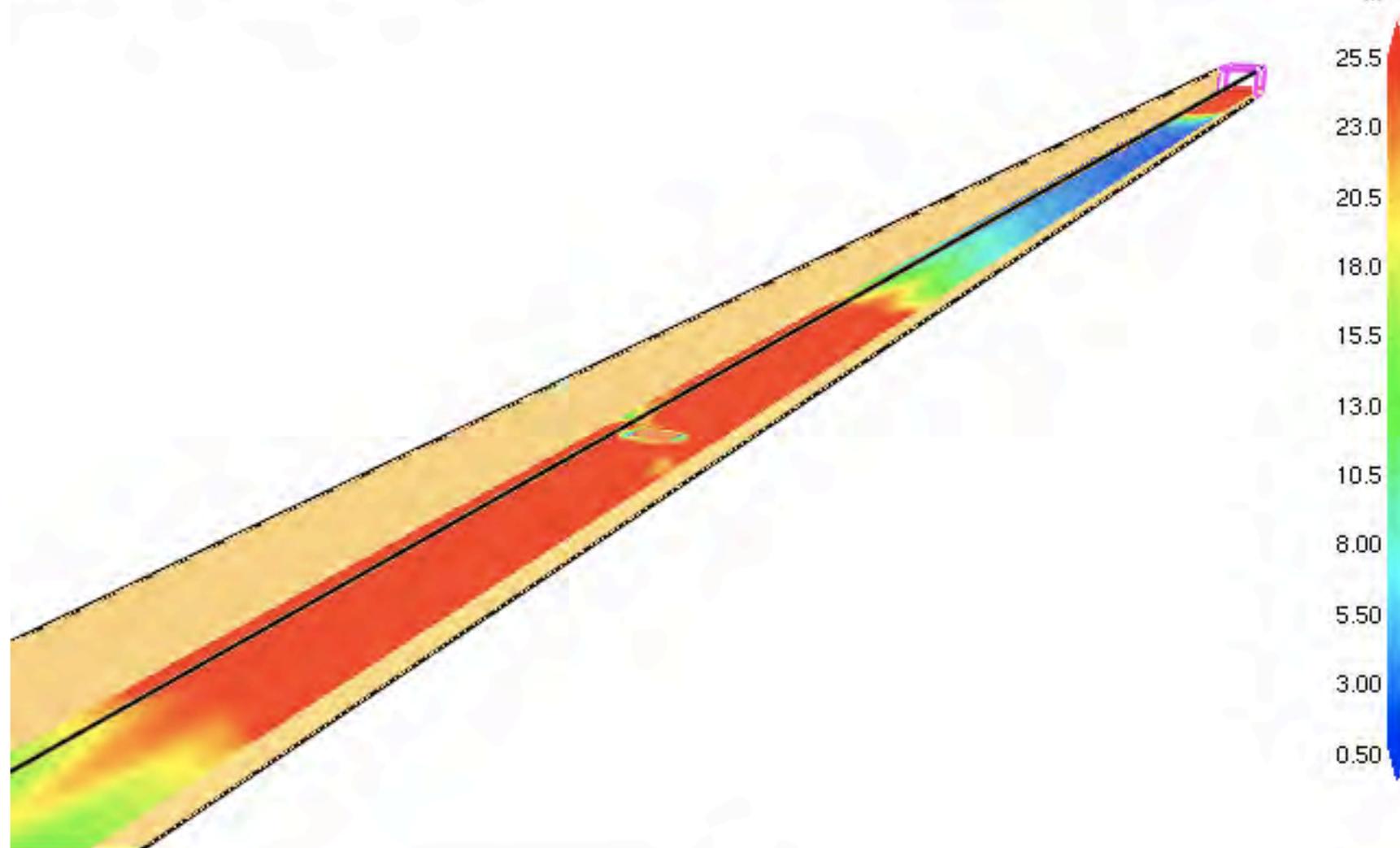
Frame: 178

Time: 178.0

# Galleria di 800 mt - incendio 10 Mw

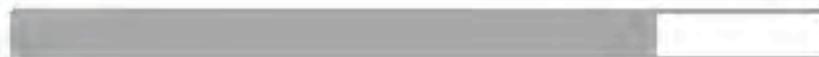


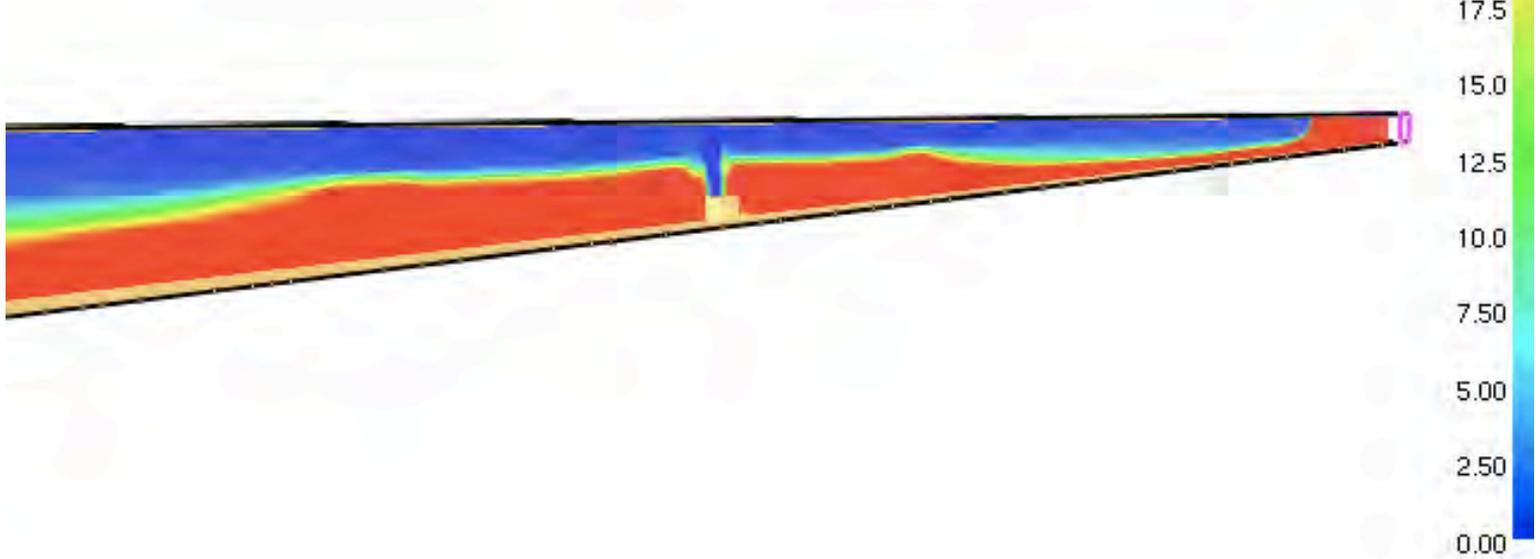
Slice  
VIS\_Soot  
m



Frame: 712

Time: 712.0

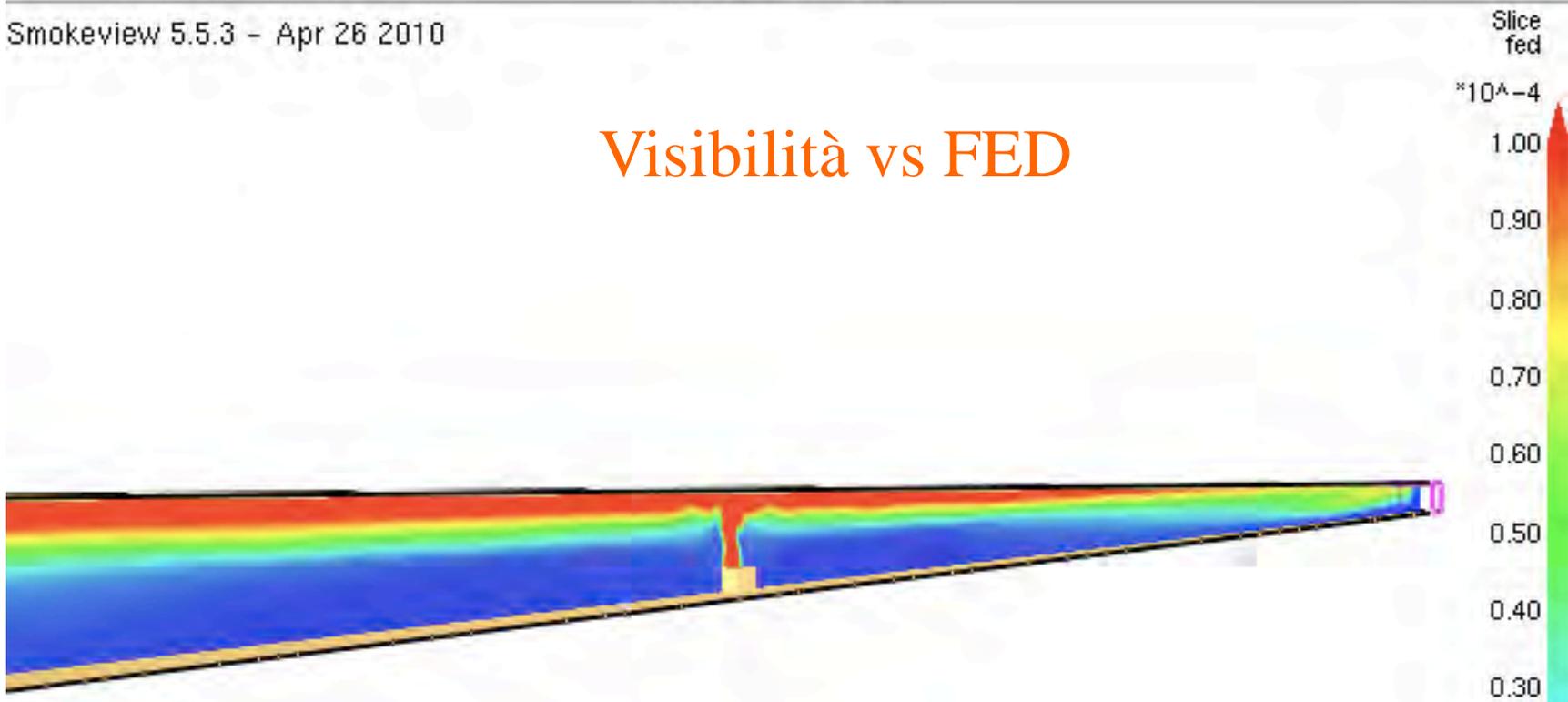




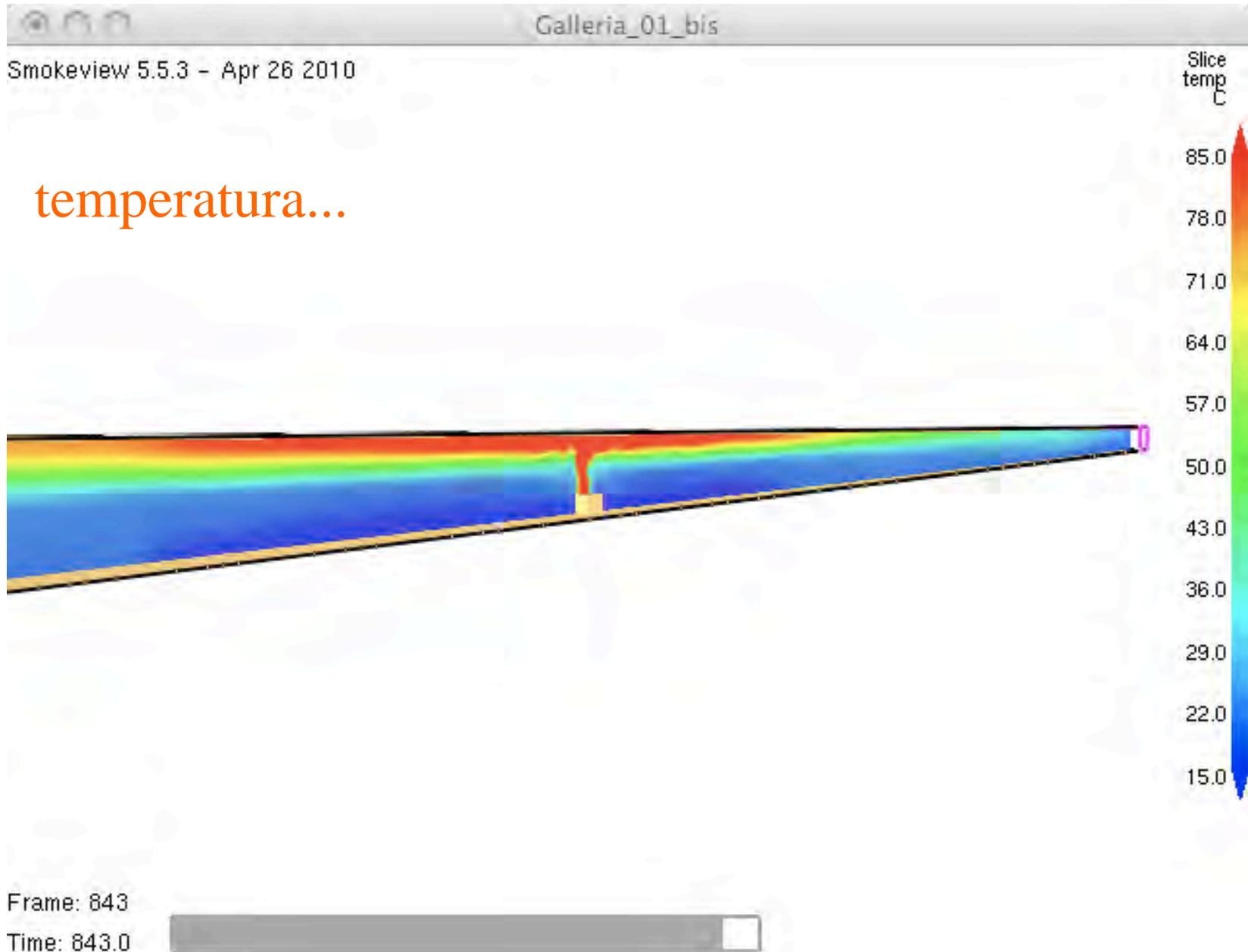
Galleria\_01\_bis

Smokeview 5.5.3 - Apr 26 2010

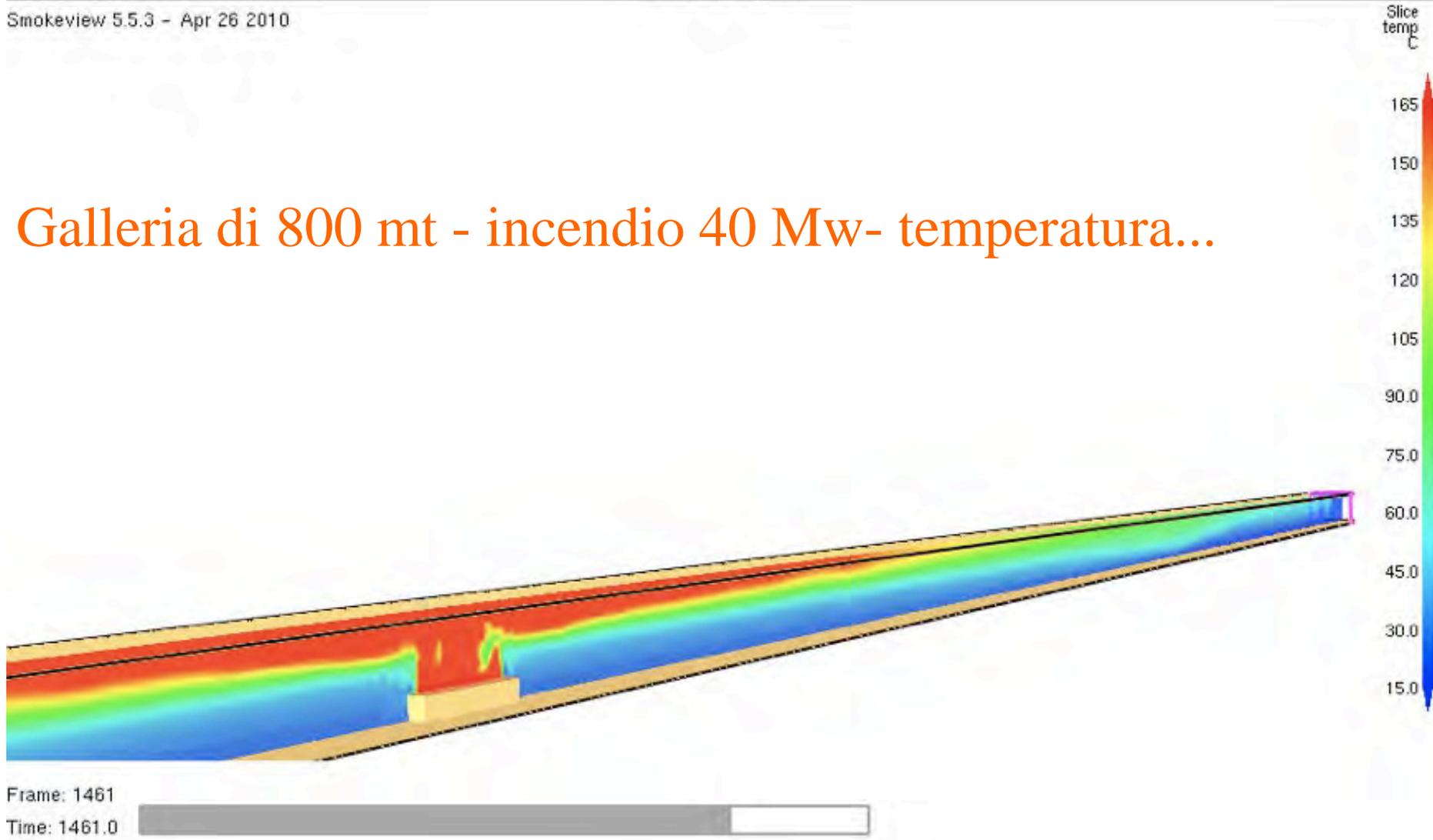
## Visibilità vs FED



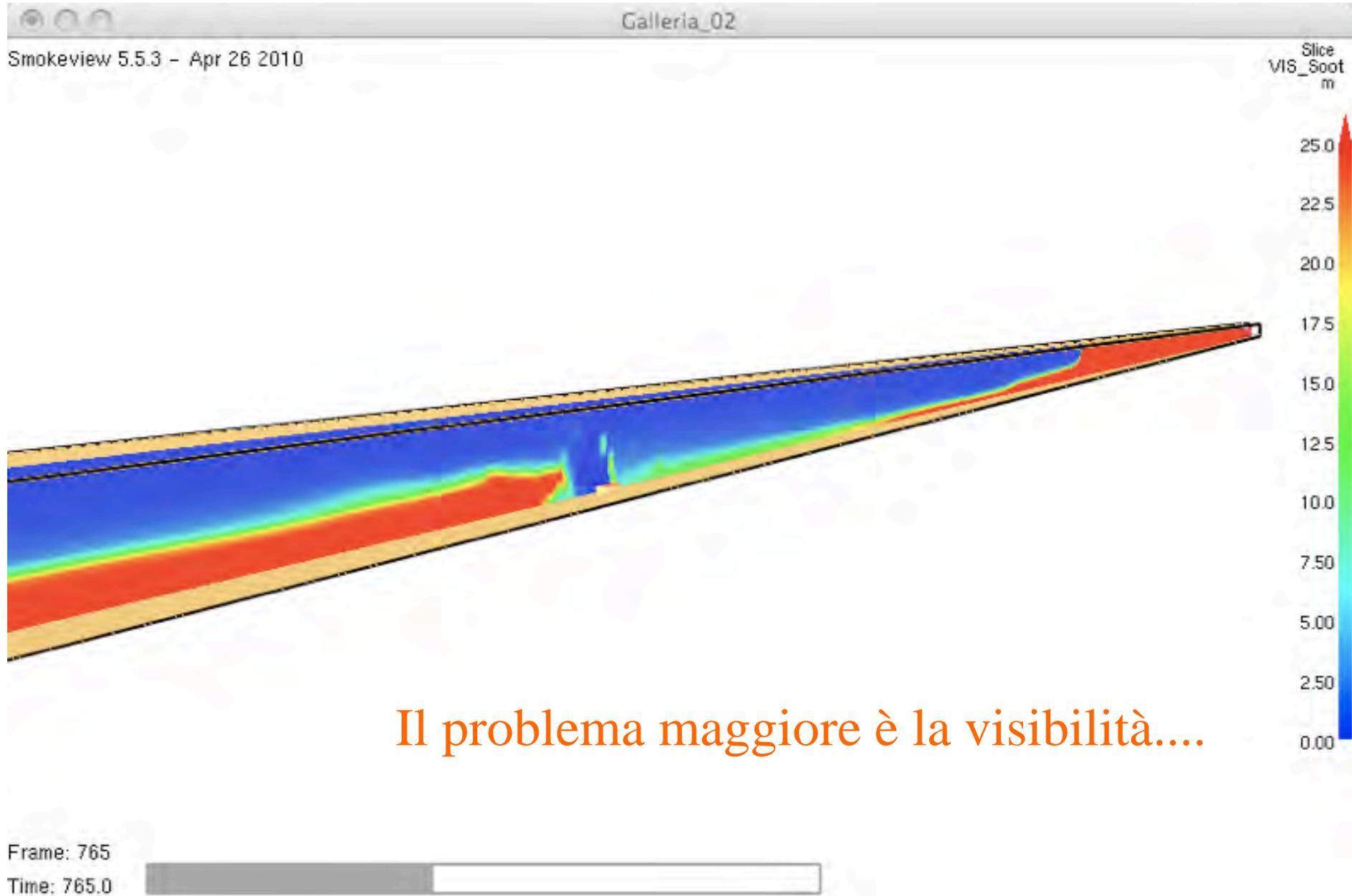
# Galleria di 800 mt - incendio 10 Mw



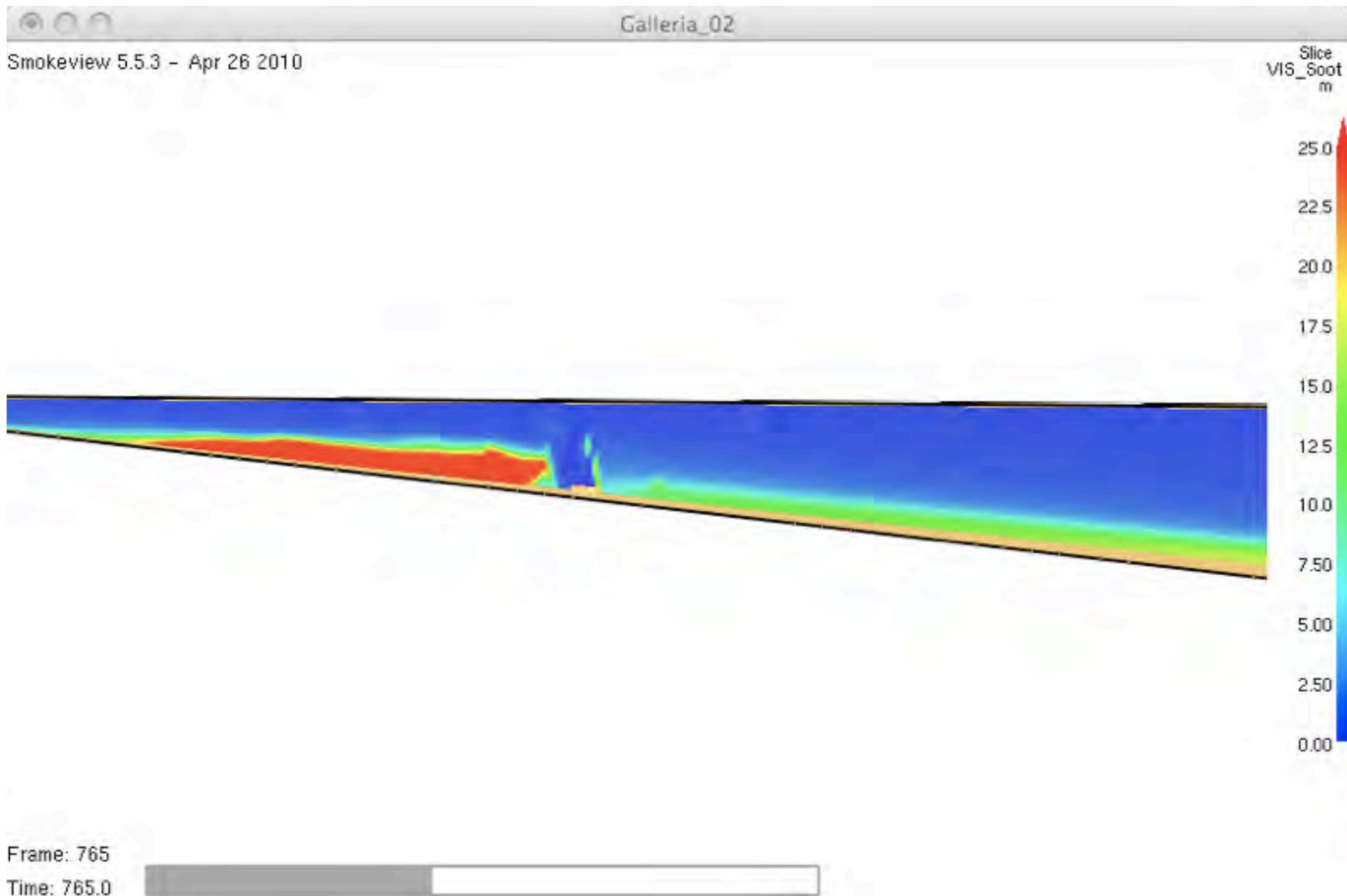
# Galleria di 800 mt - incendio 40 Mw- temperatura...



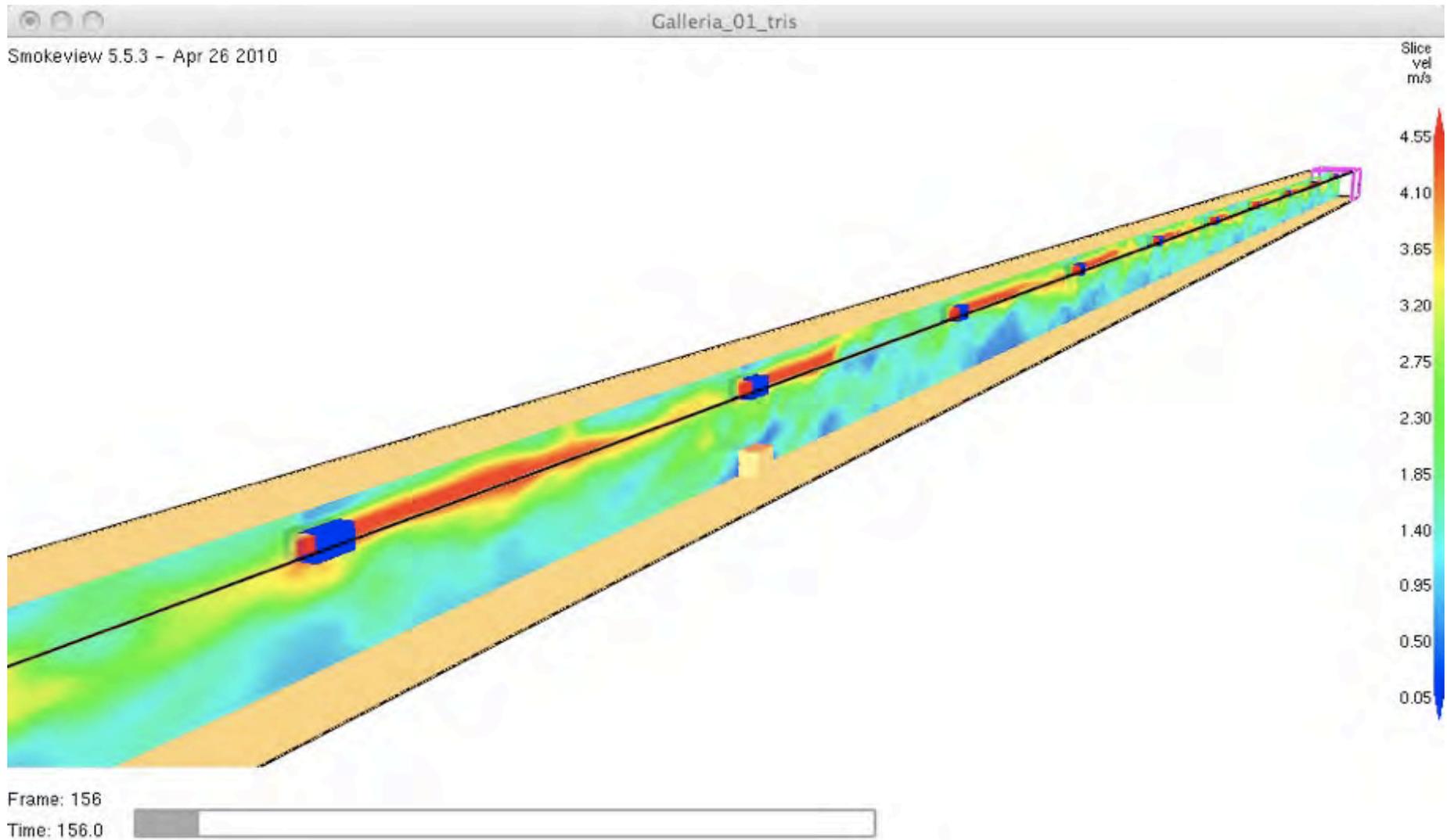
# Galleria di 2.000 mt - incendio 10 Mw- vento laterale



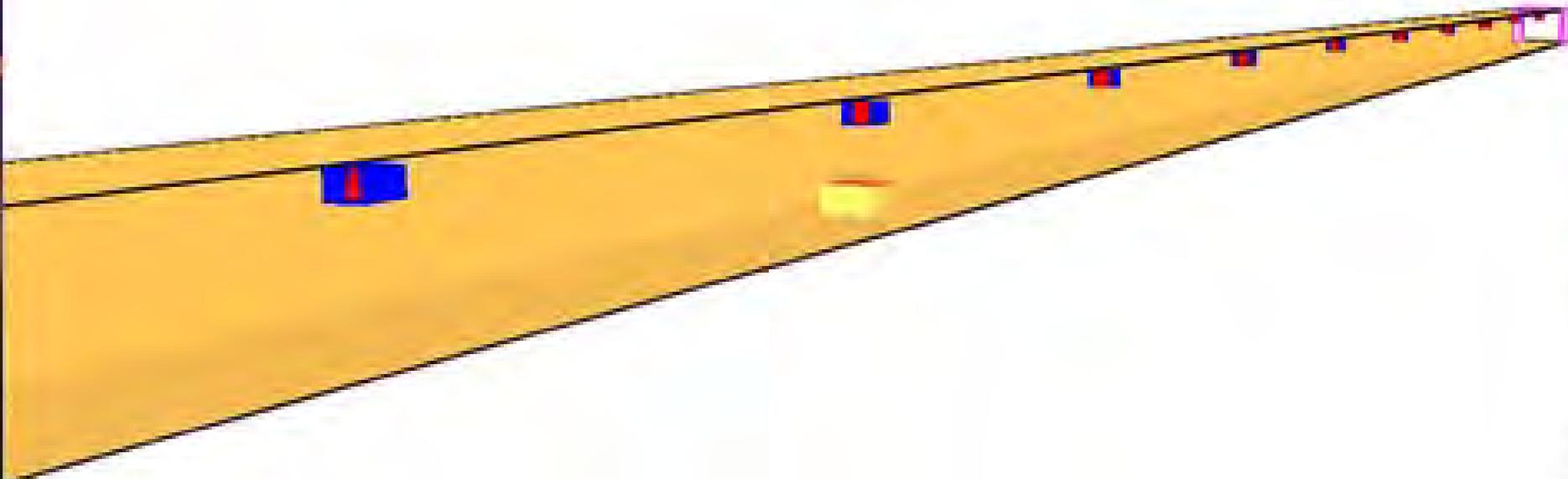
# Galleria di 2.000 mt - incendio 10 Mw- vento laterale



# Galleria di 800 mt - incendio 10 Mw



Smokeview 3.5.3 - Apr 26 2010



>40 (kW/m3)

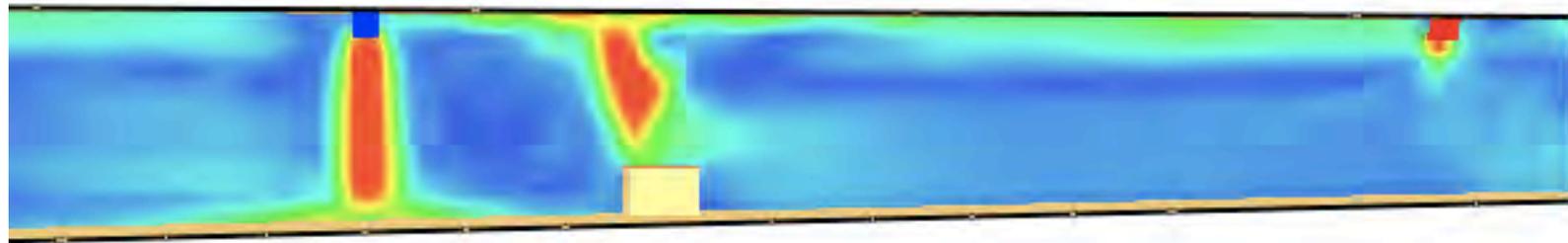
Frame: 13  
Time: 13.0





Smokeview 5.5.3 - Apr 26 2010

Slice  
vel  
m/s

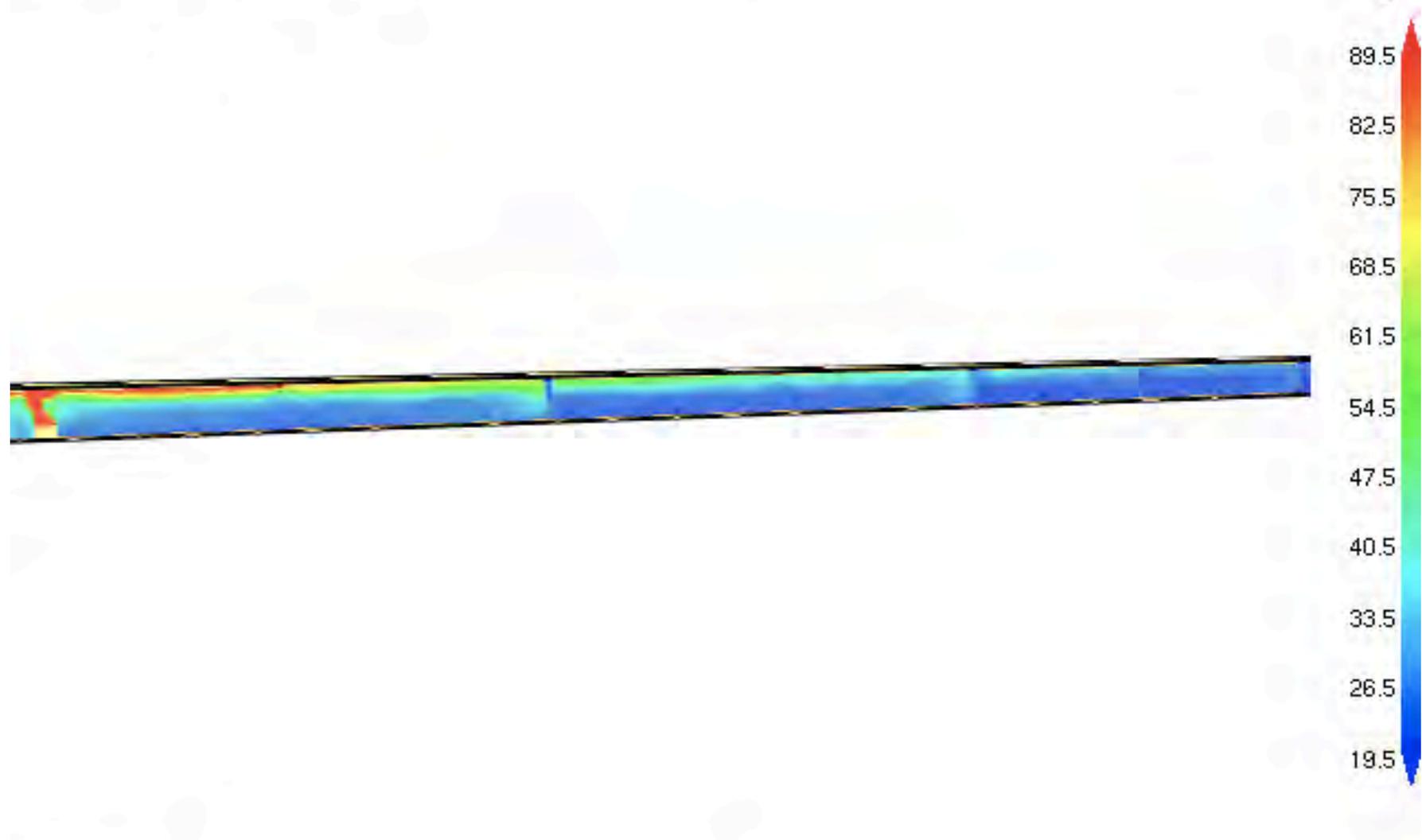


Frame: 190

Time: 190.1



Smokeview 5.5.3 - Apr 26 2010



Frame: 1419

Time: 1419.0

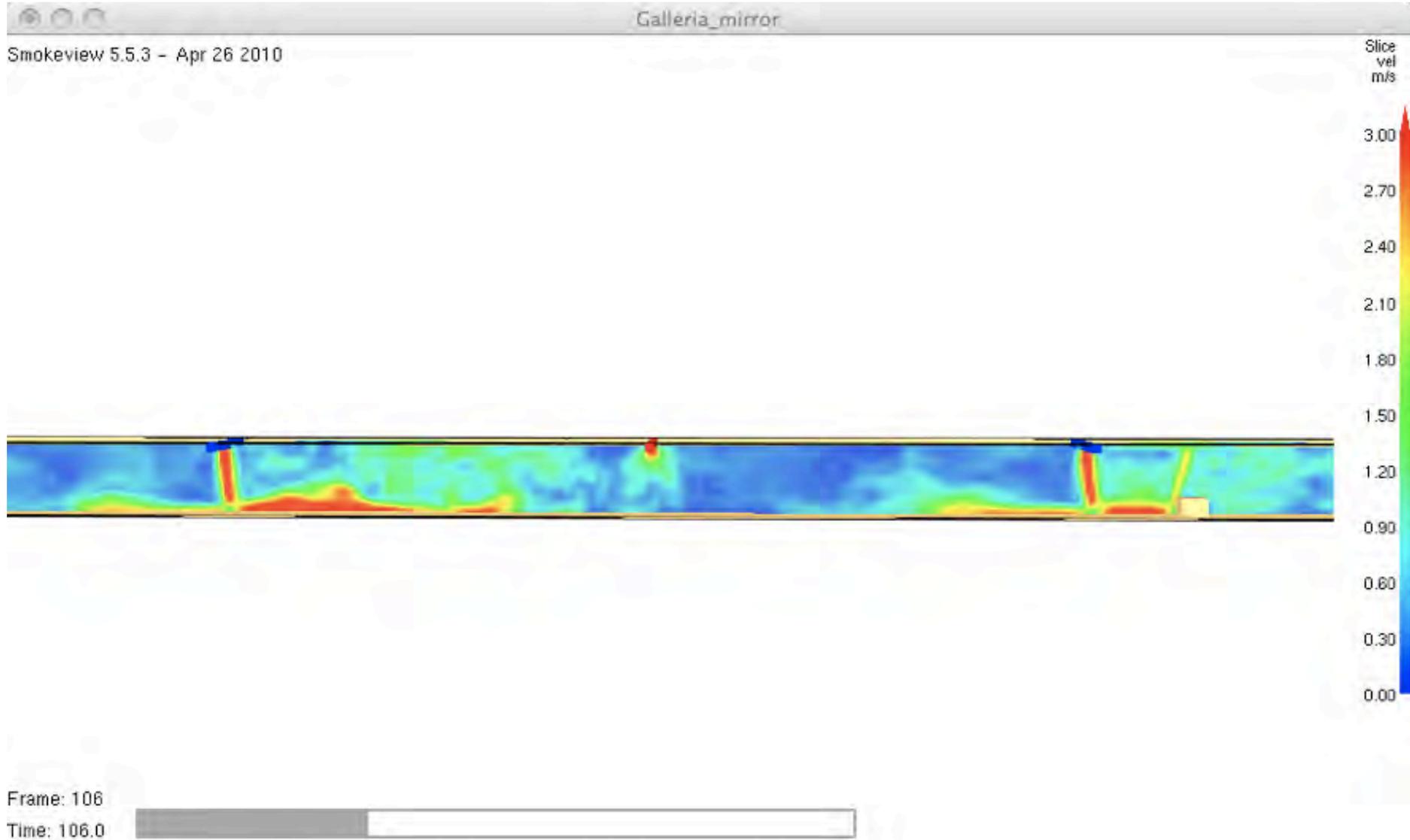


Smokeview 5.5.3 - Apr 26 2010



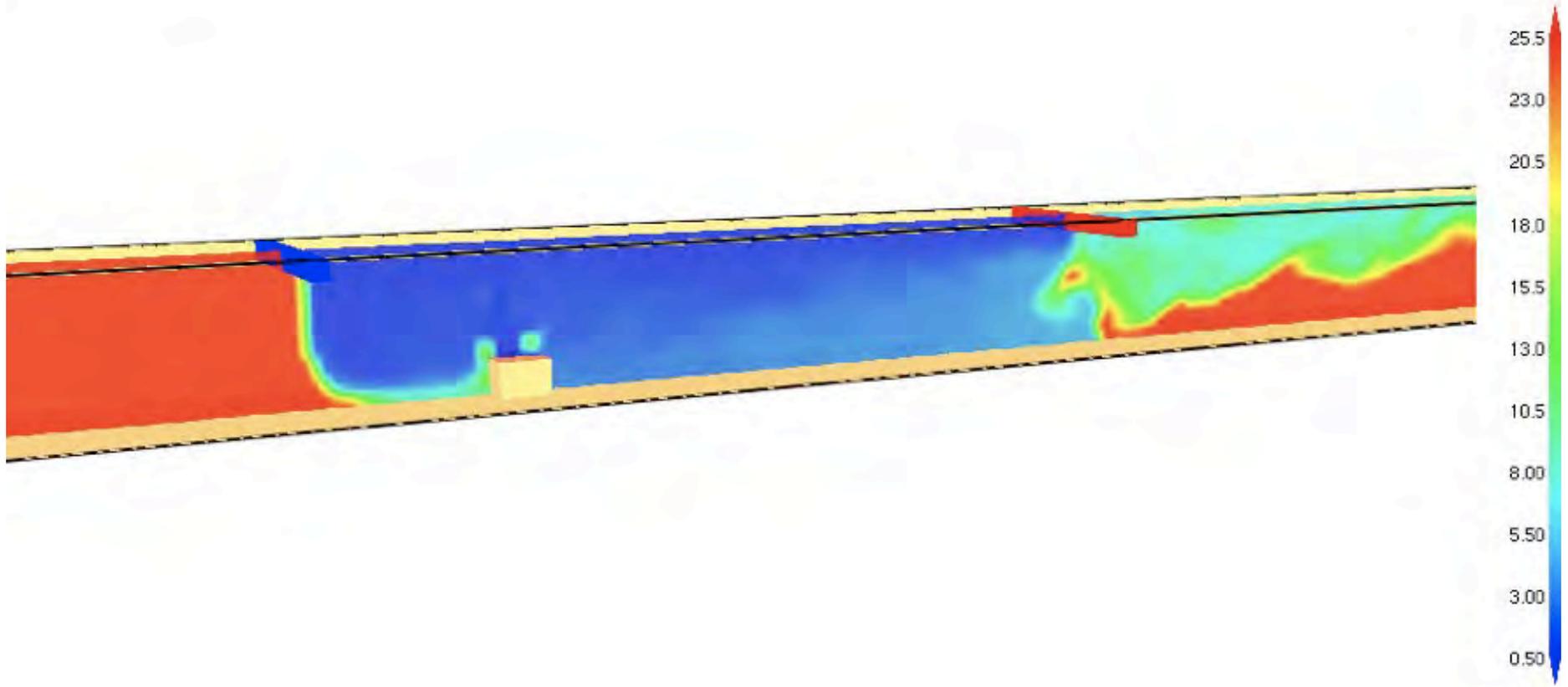
Frame: 1681

Time: 1681.0



Incrementiamo il rateo di aspirazione ed immissione aria

Slice  
VIS\_Soot  
m



Frame: 312

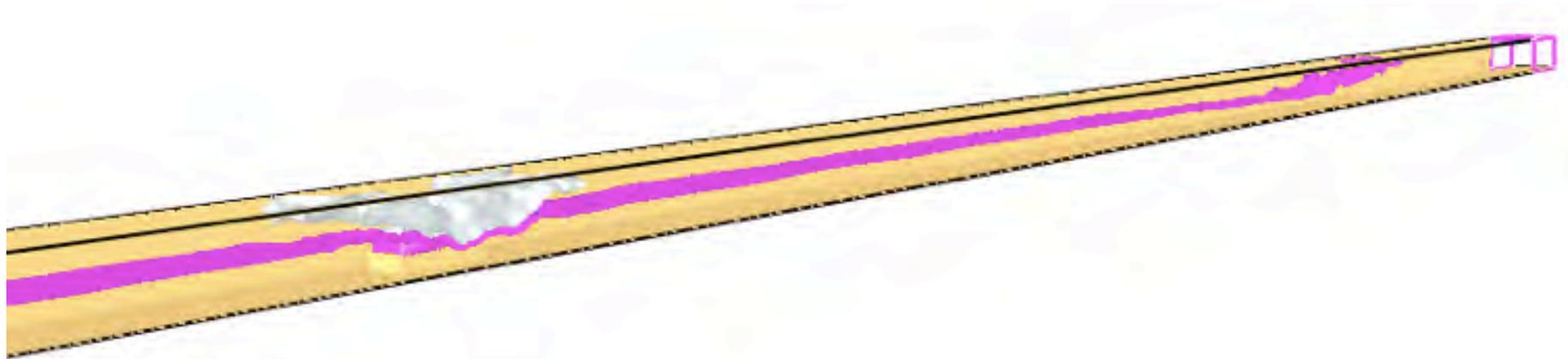
Time: 312.0



QuickTime™ e un  
decompressore H.264  
sono necessari per visualizzare quest'immagine.

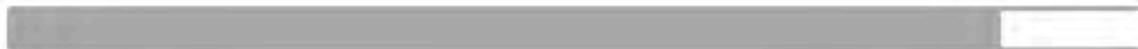


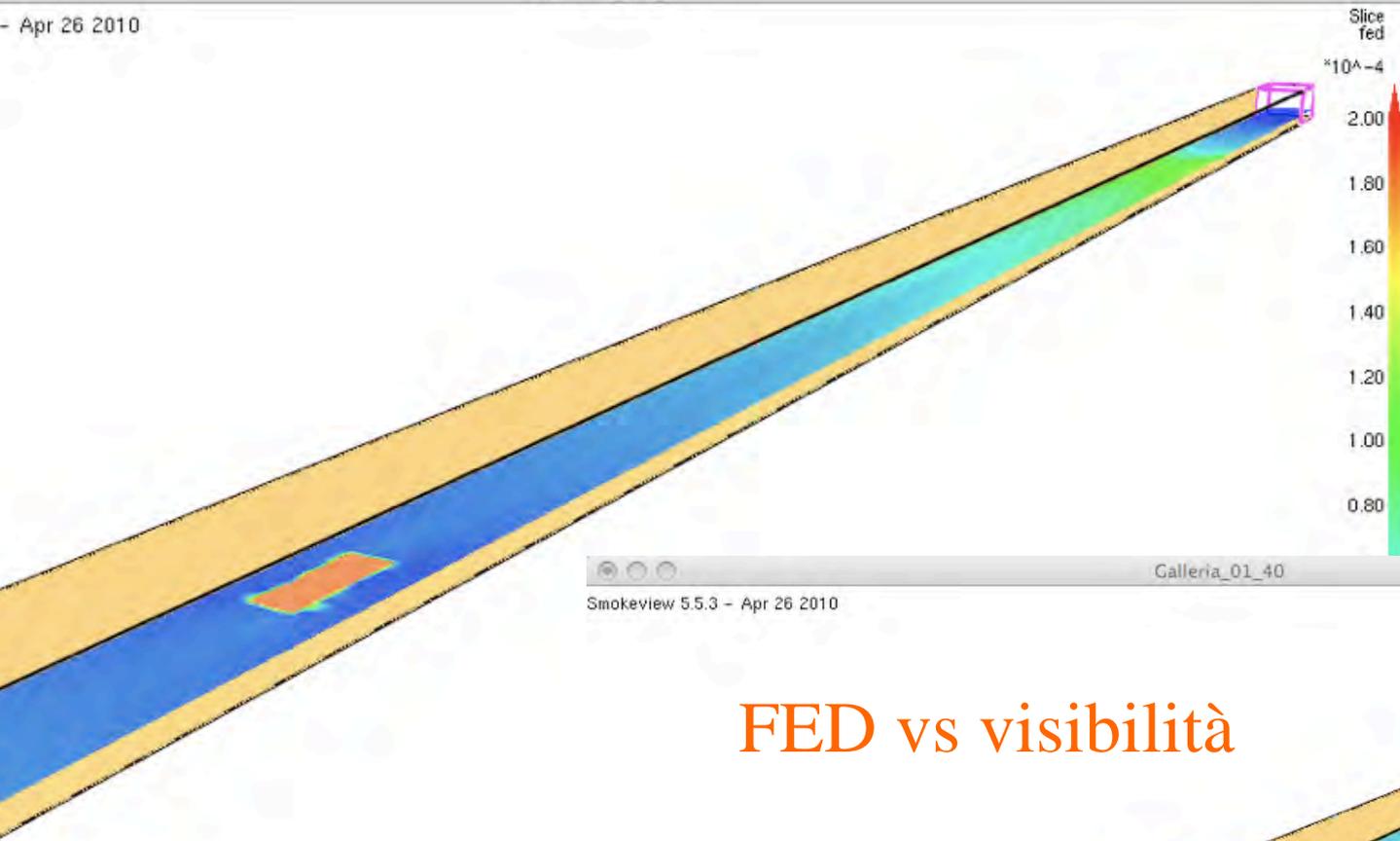
# Galleria di 800 mt - incendio 40 Mw



Frame: 1569

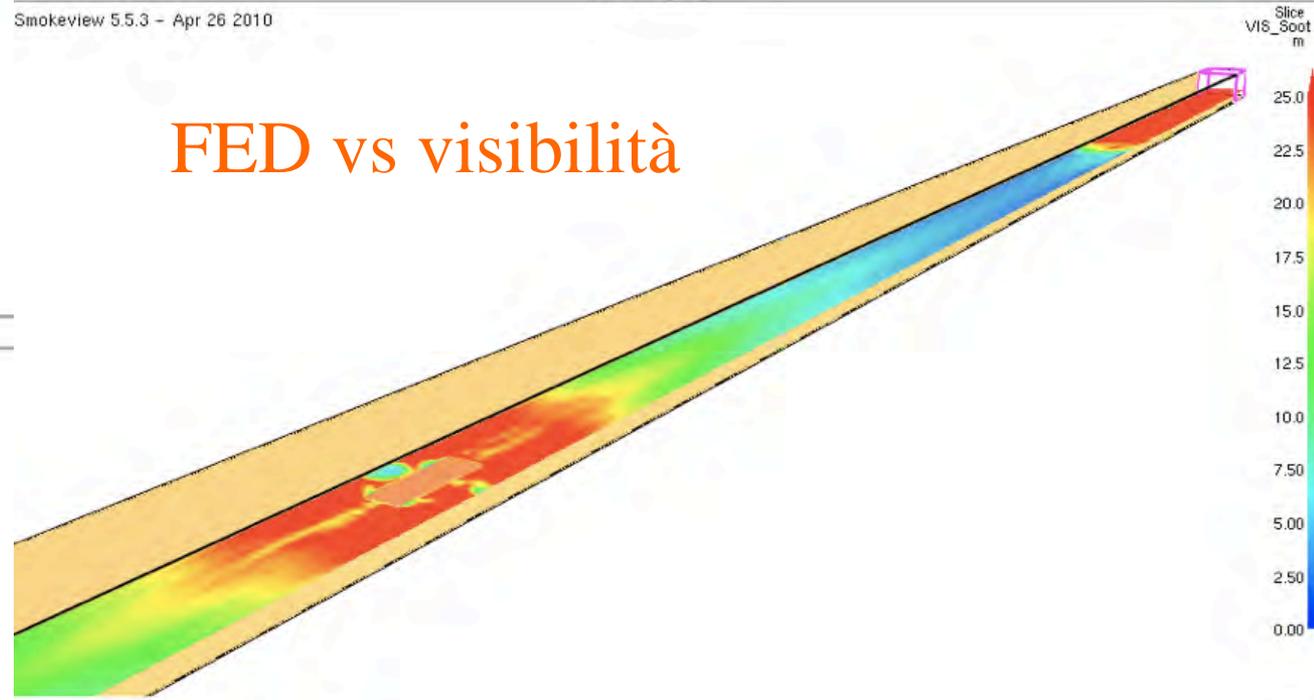
Time: 1569.0





Galleria\_01\_40  
Smokeview 5.5.3 - Apr 26 2010

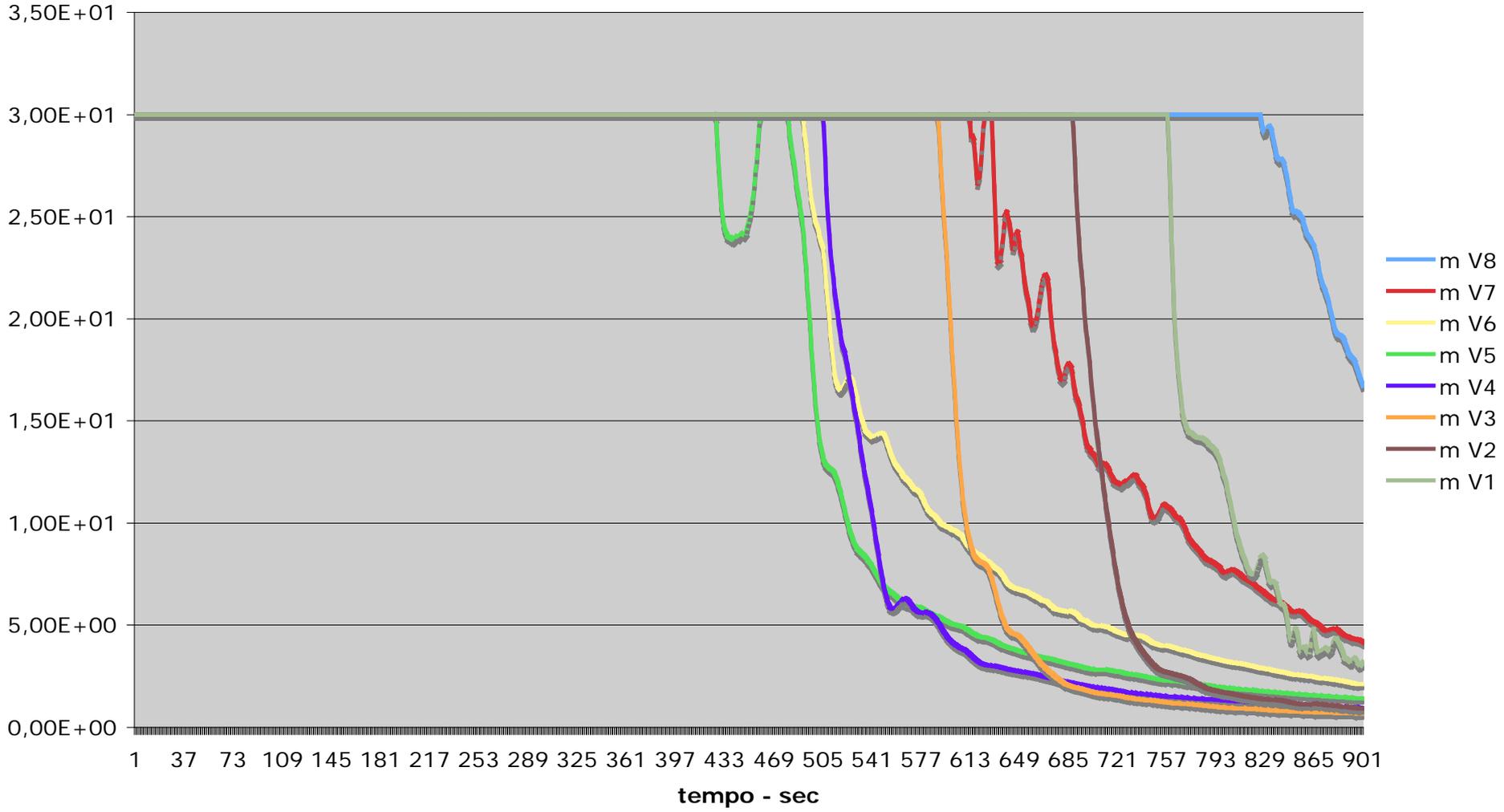
# FED vs visibilità



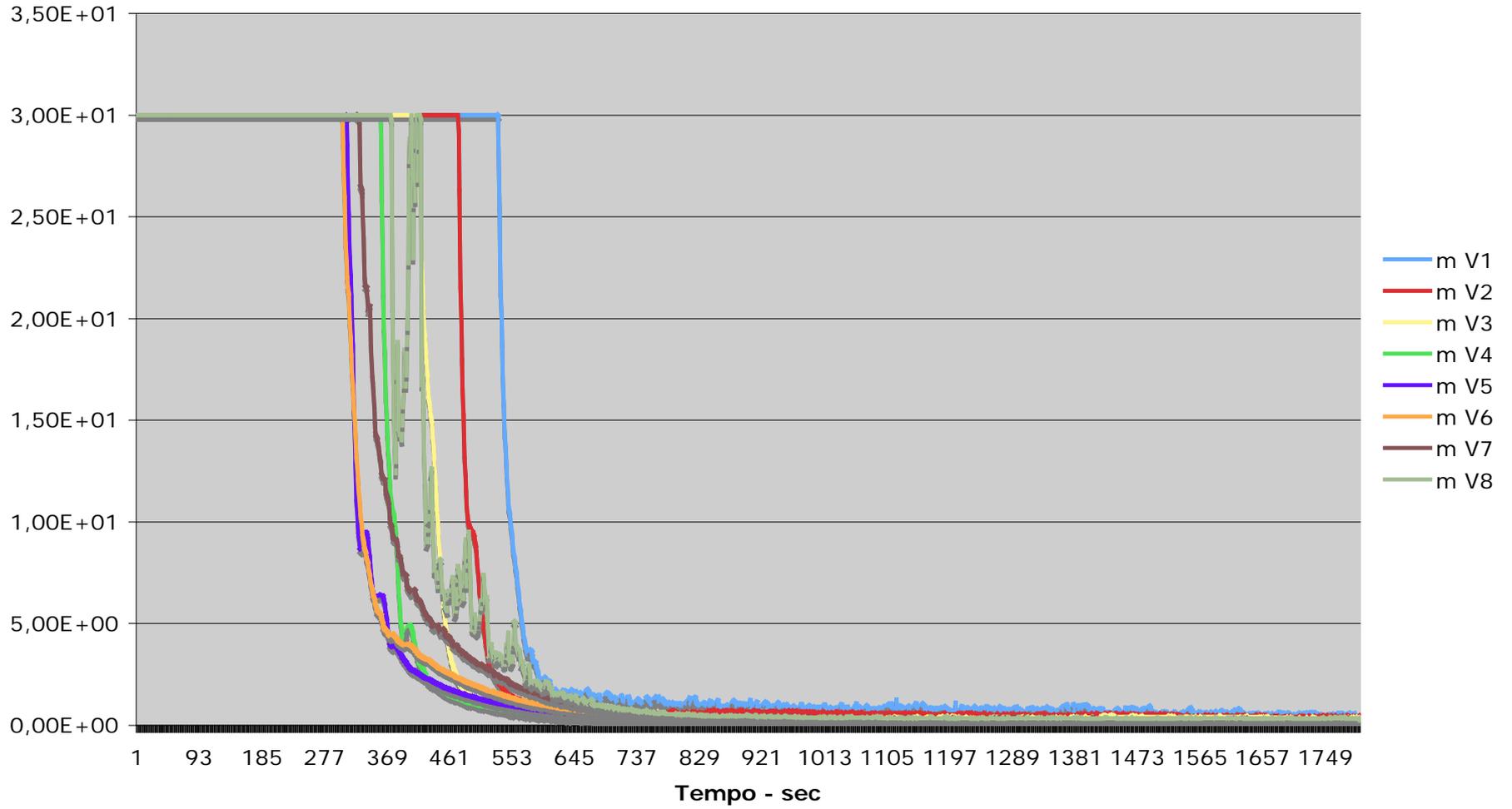
Frame: 423  
Time: 423.0

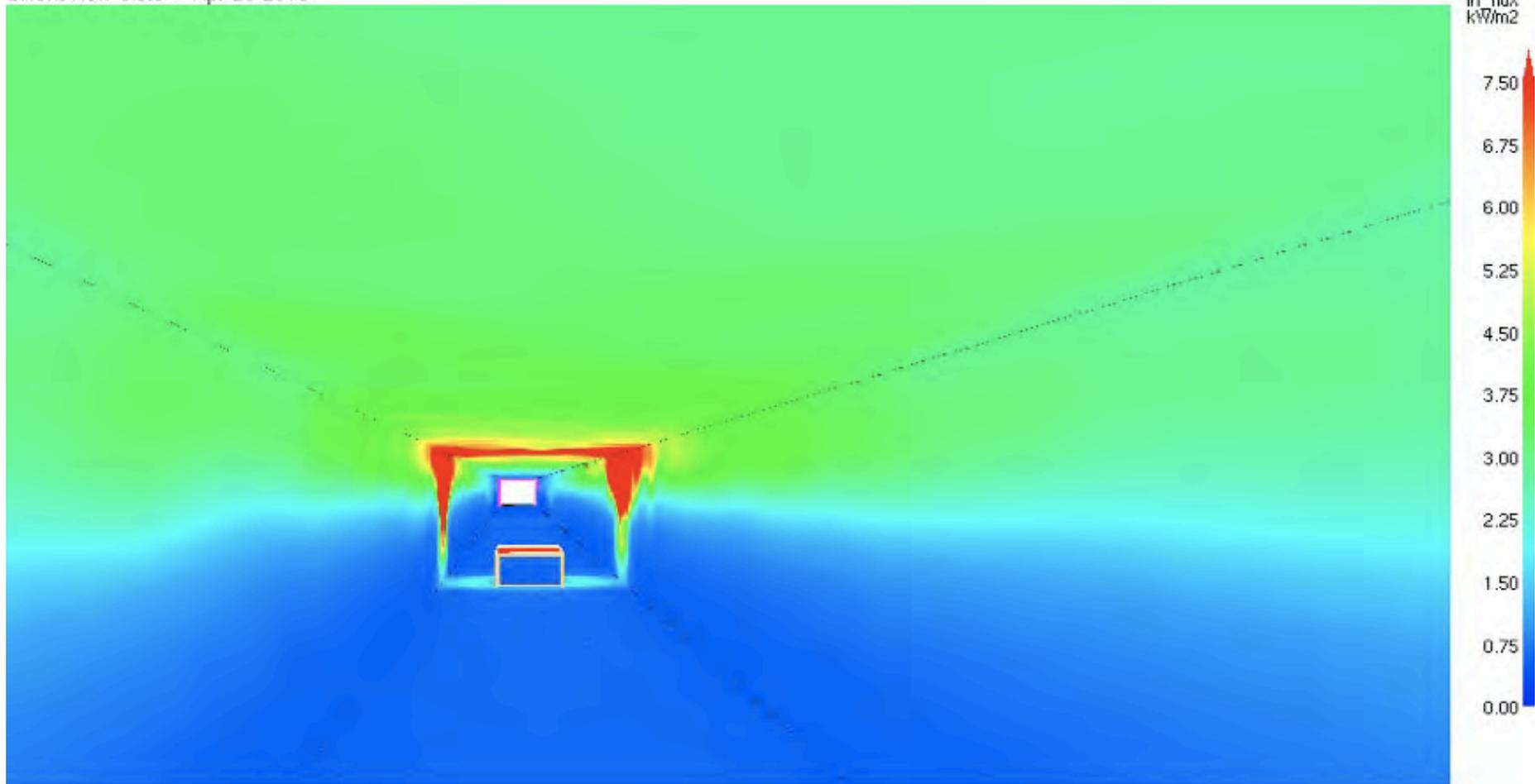
QuickTime™ e un  
decompressore H.264  
sono necessari per visualizzare quest'immagine.

### visibilità - 10 Mw



### visibilità - 40 Mw



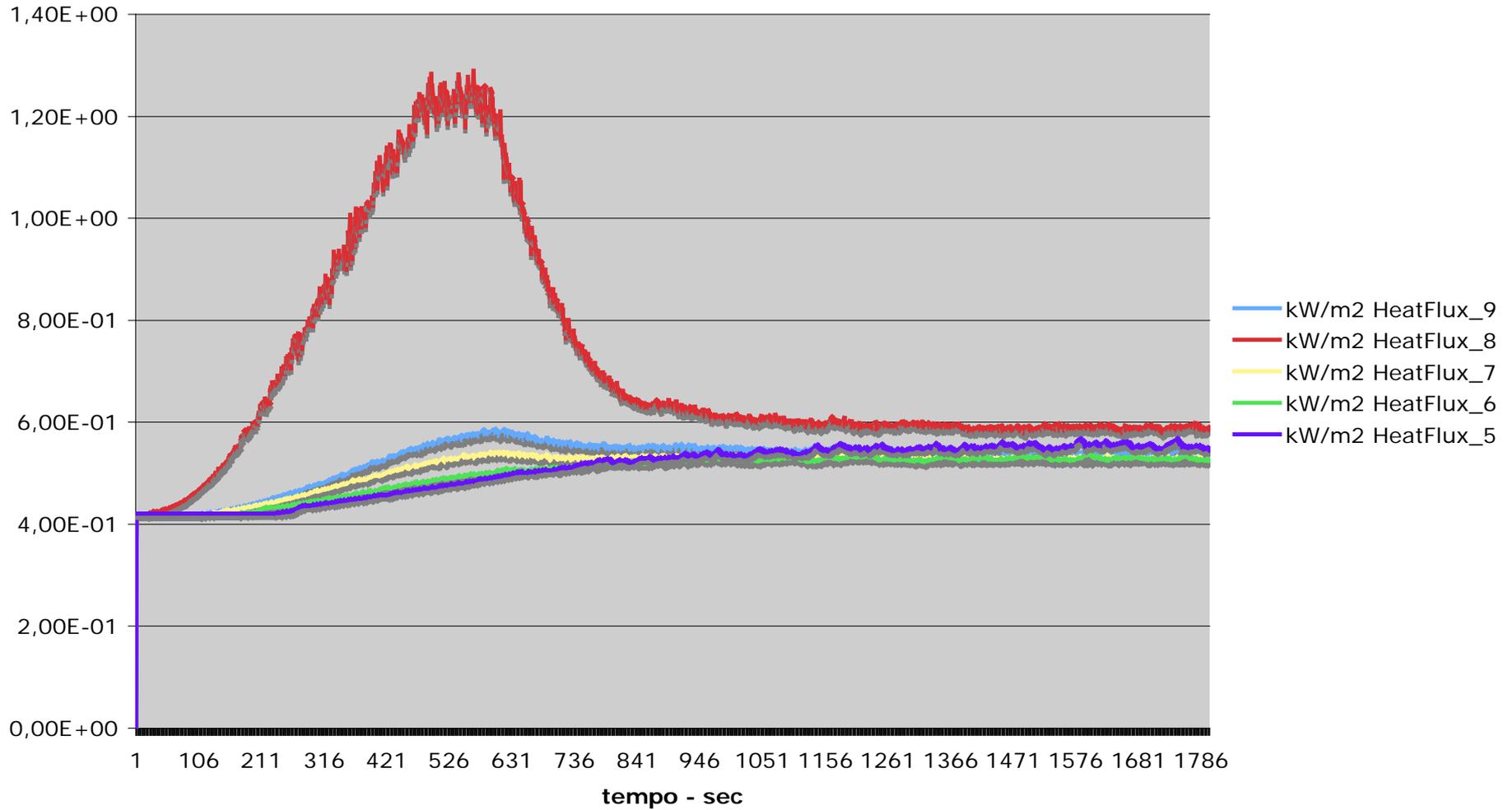


Frame: 730

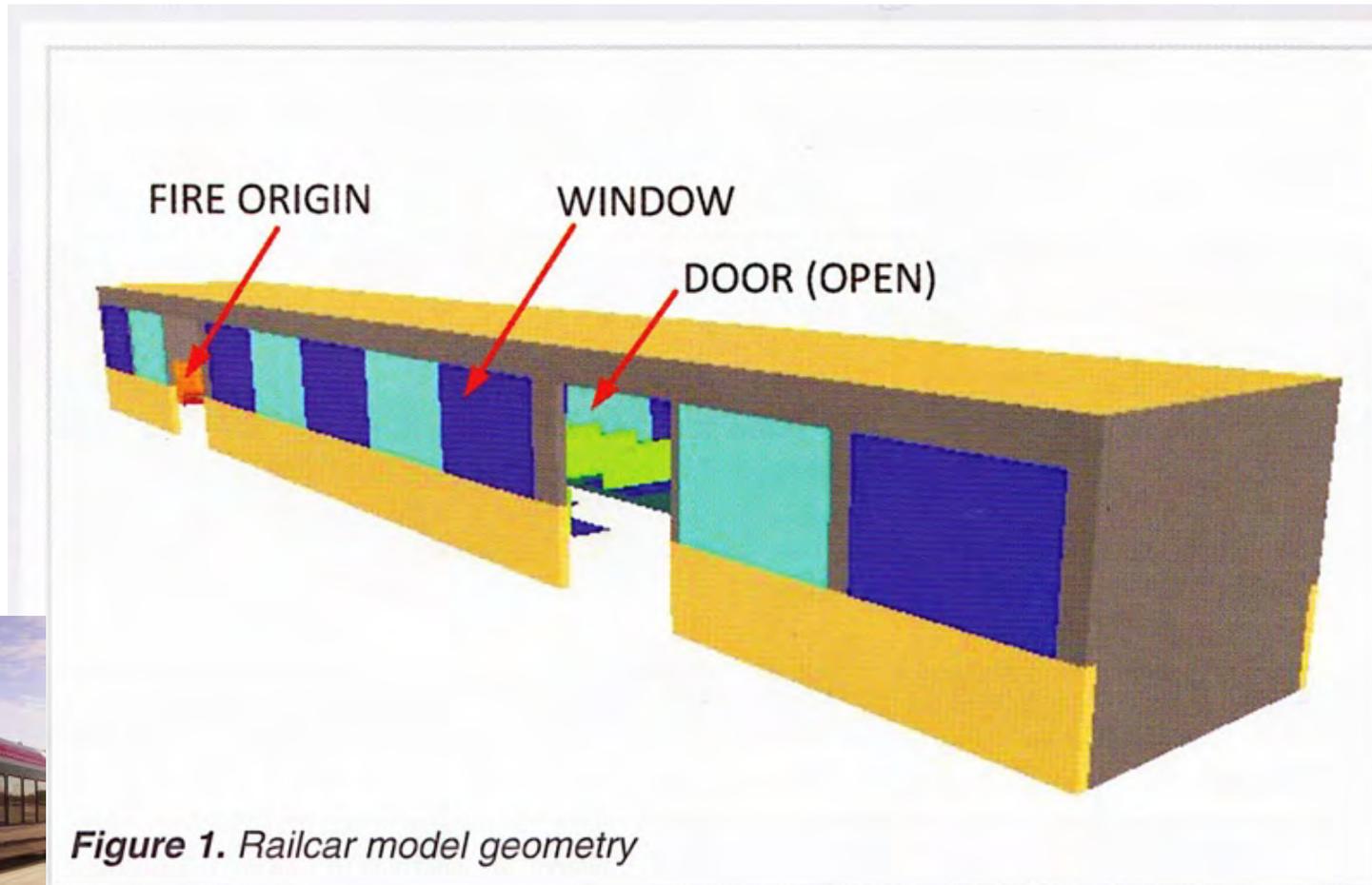
Time: 1460.0

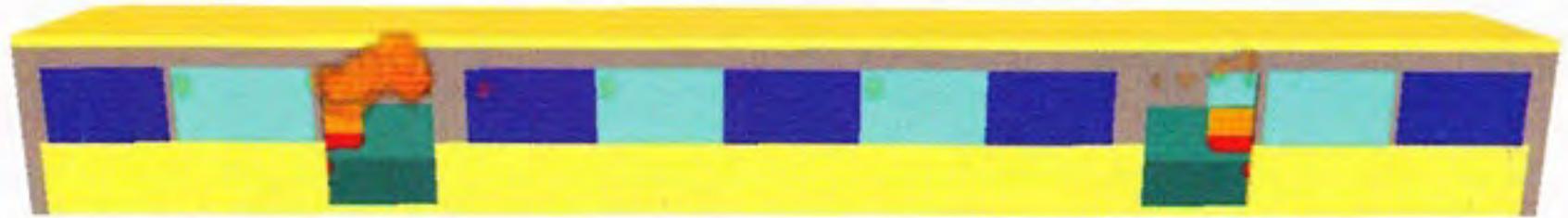


### irraggiamento - 40 Mw

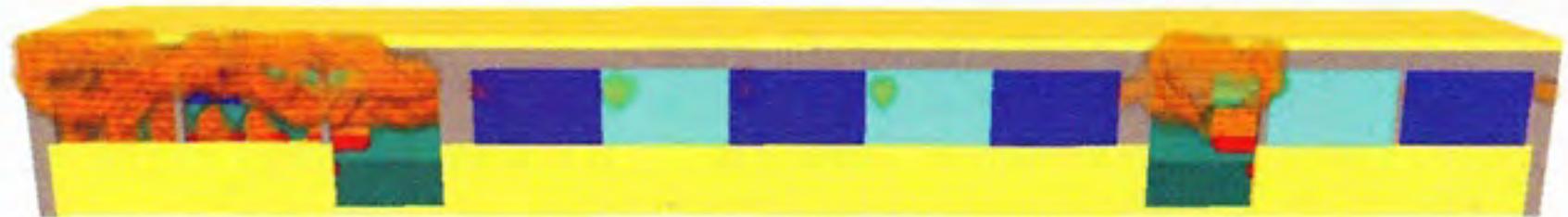


# Working on uncertainties - FDS (modified) Parametric study on window glass breakage and fallout.

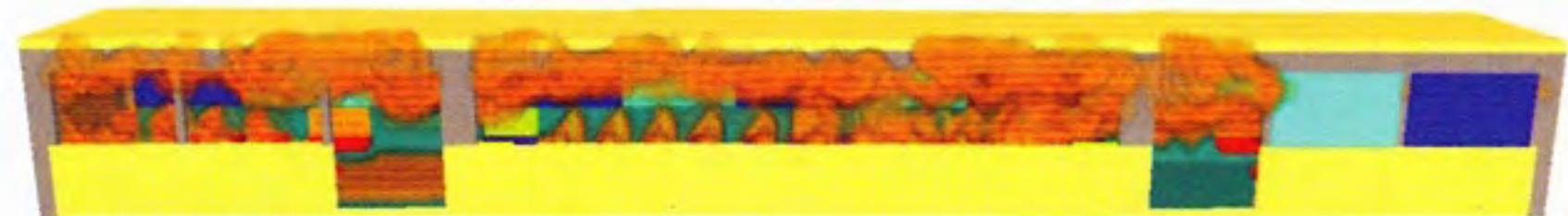




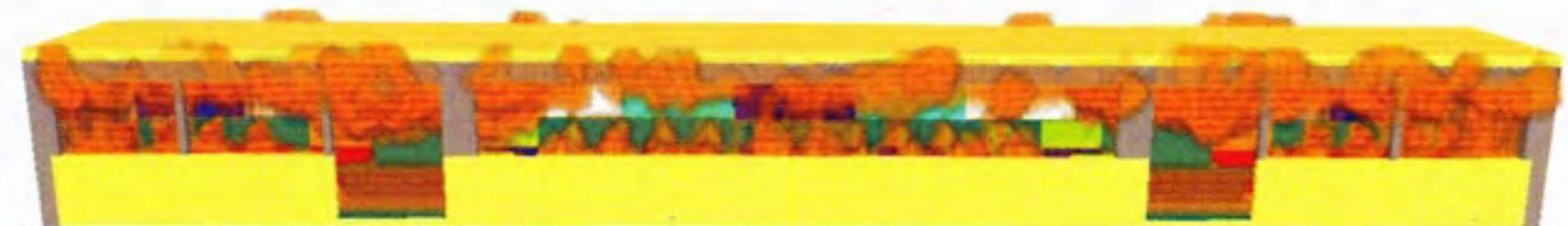
(a)  $t = 410 \text{ s}$



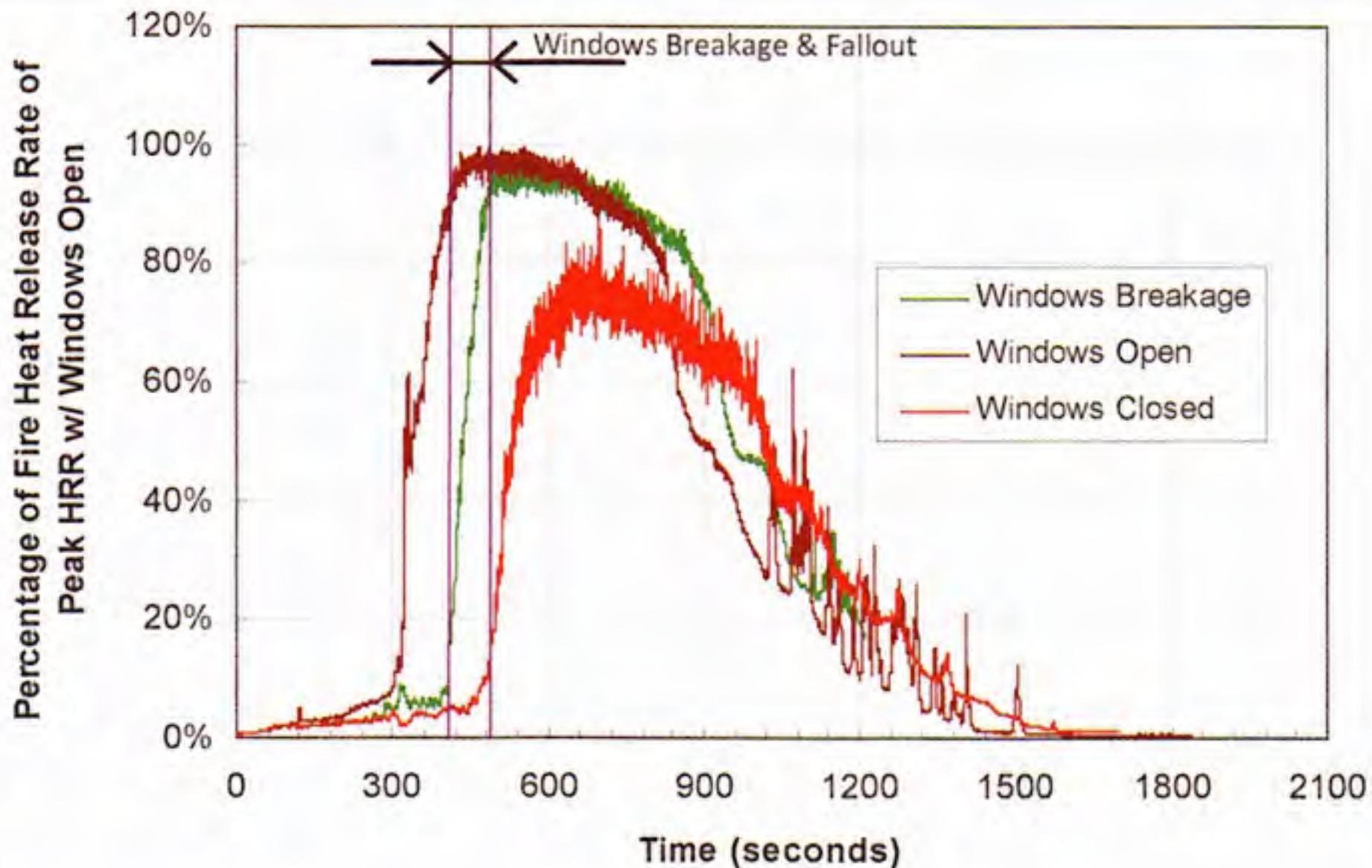
(b)  $t = 427 \text{ s}$



(c)  $t = 444 \text{ s}$



(d)  $t = 498 \text{ s}$



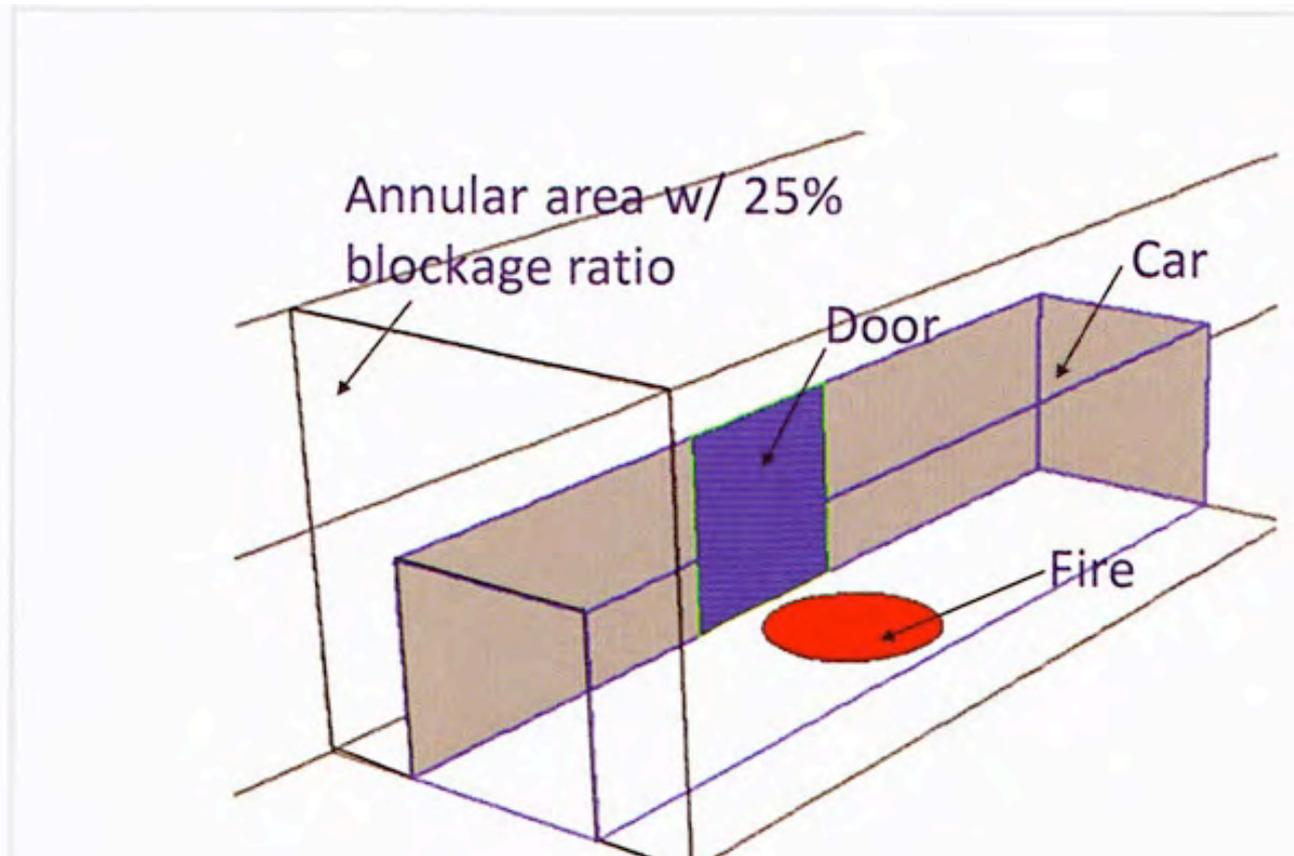
*Figure 3. Comparison of predicted fire HRR as a function of time at different ventilation conditions due to windows fallout*

# Working on Uncertainties - Geometric Impact - the fire is affected by the environment



Small scale model used to simulate a fire in a tunnel under a longitudinal air flow.

The combustion reaction rate is modeled as dependent on turbulent mixing of the fuel and oxygen.



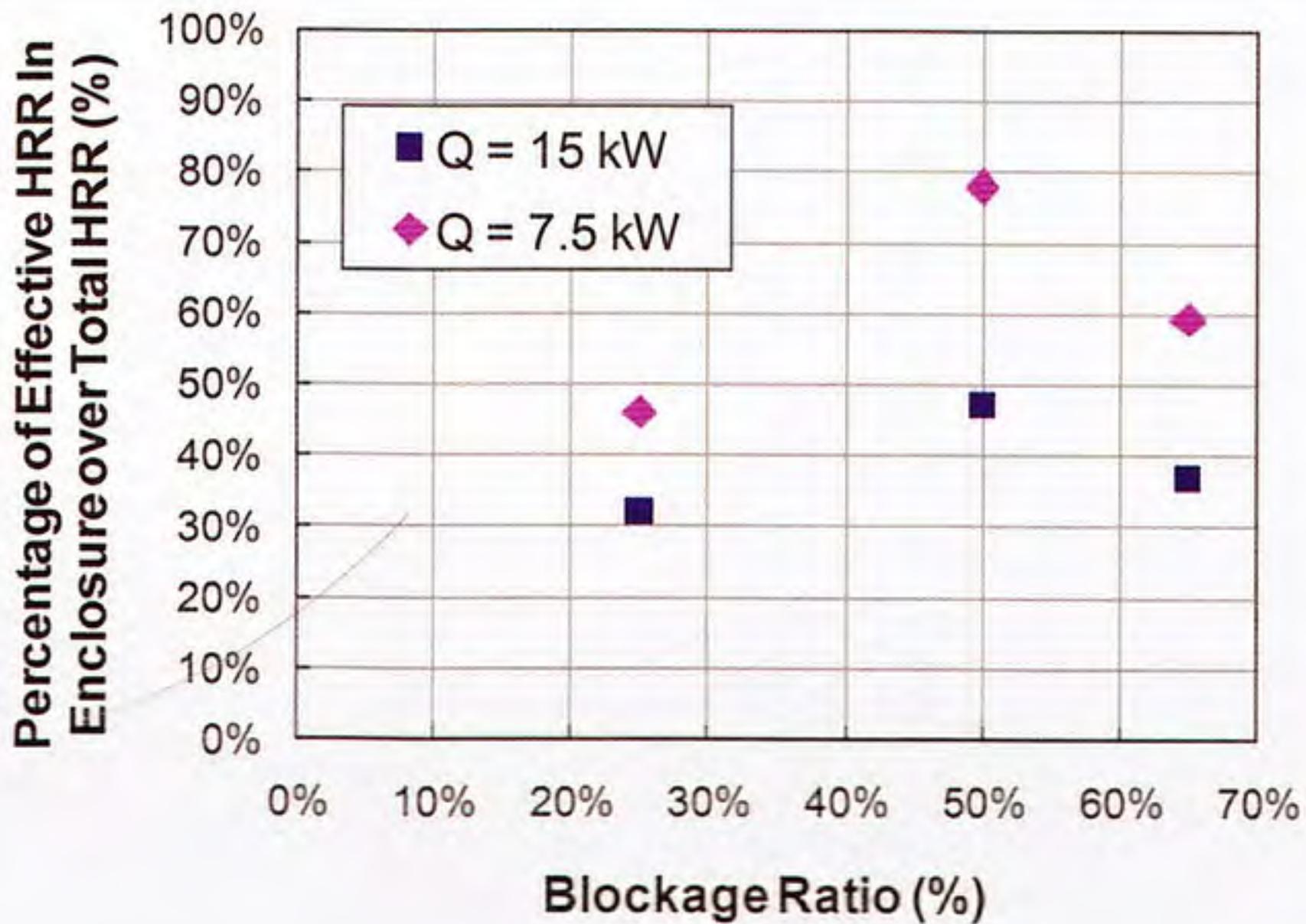


Figure 4. (b) percentage of effective HRR in the compartment vs. blockage ratio



*- Problemi complessi....CFD può dare accurate soluzioni per incendi modellati con bruciatore volumetrico, in un caso specifico, con specifici parametri*

*- Dobbiamo tenere presenti i molti parametri che presentano incertezze...Analisti esperti e full scale test*

*- Simulare la combustione di oggetti e la propagazione dell'incendio aggiunge **ULTERIORI** incertezze.....*

*- Forse meglio cercare di semplificare al massimo, investendo in un numero maggiore di simulazioni*

**Grazie, e non  
dimentichiamo  
le soluzioni  
SEMPLICI !!!!**

