FDS 6 and Beyond

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Fire Modeling Workshop
BFRL Annual Fire Conference
April 29, 2009

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

&MISC FDS6=.TRUE.

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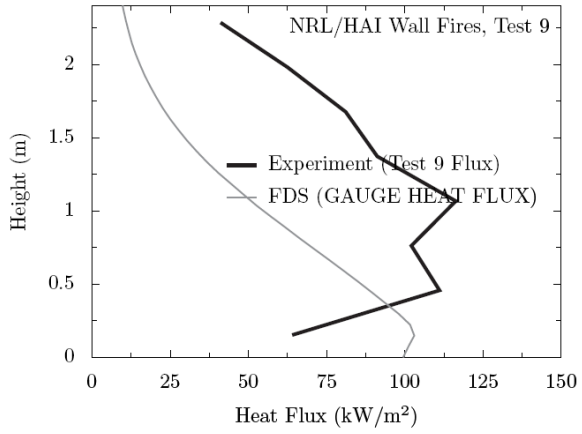
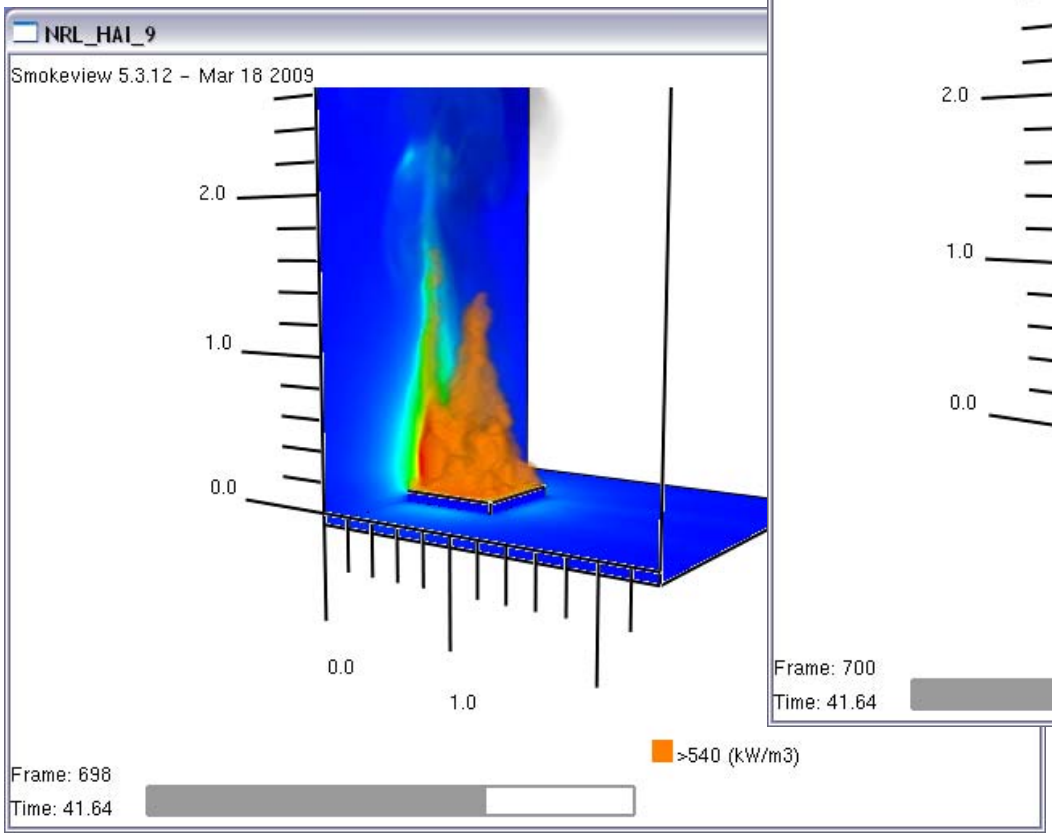
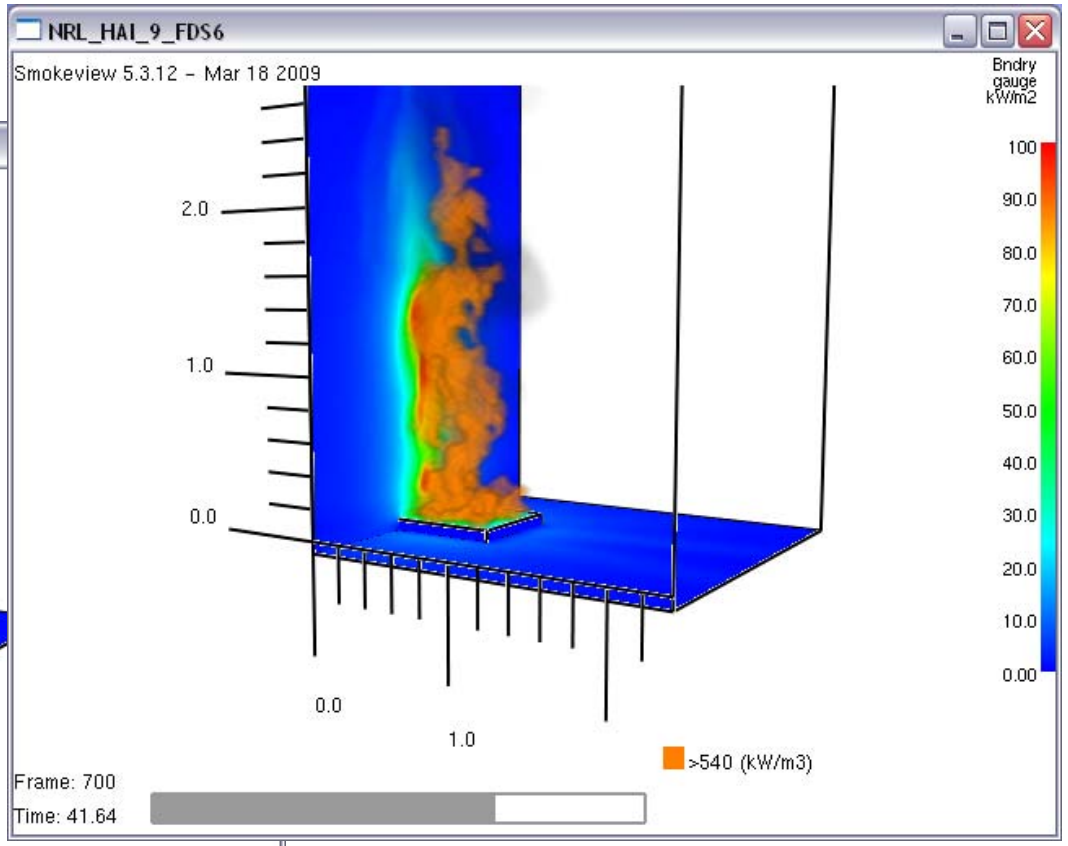
DYNSMAG=.TRUE.

WERNER_WENGLE_WALL_MODEL=.TRUE.

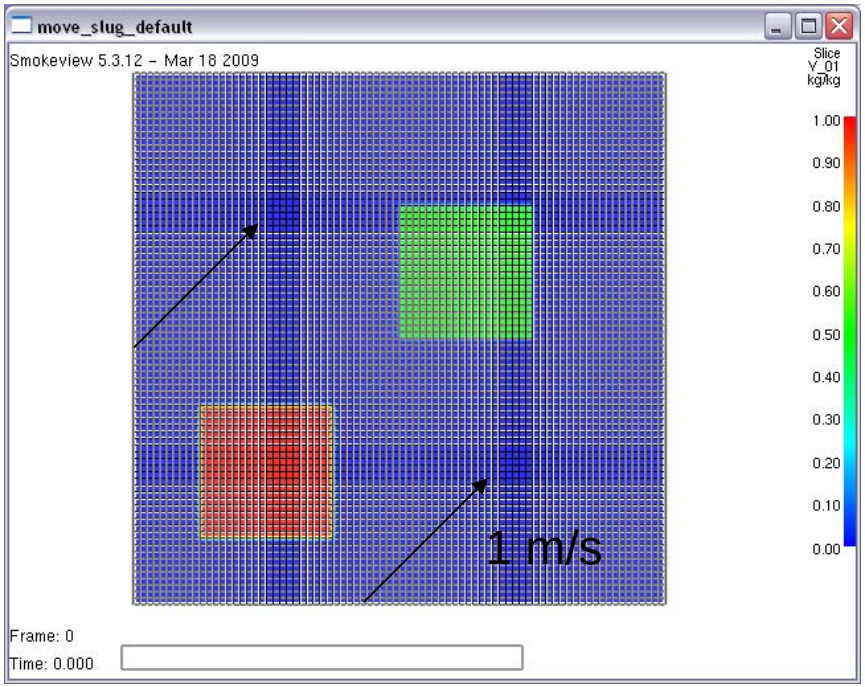


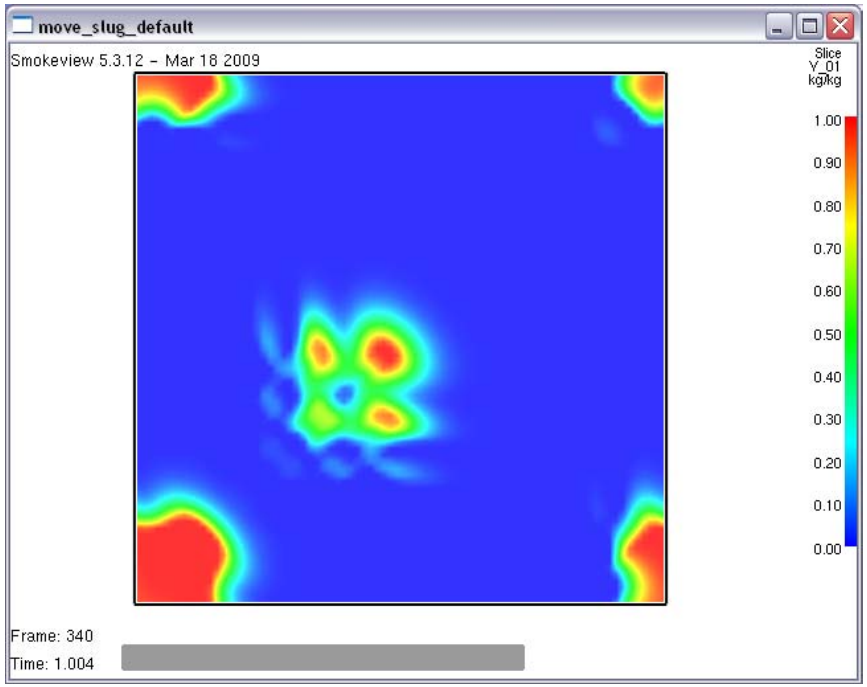




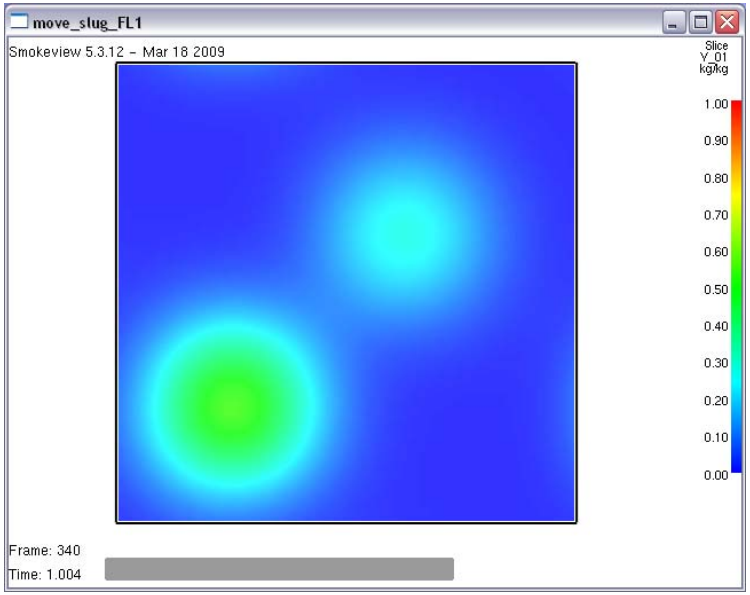
Scalar transport

$$\frac{\partial \rho Y_\alpha}{\partial t} + \frac{\partial \rho Y_\alpha U_j}{\partial x_j} = \frac{\partial}{\partial x_j}\left(\rho D \frac{\partial Y_\alpha}{\partial x_j}\right) + \dot{m}_\alpha'''$$

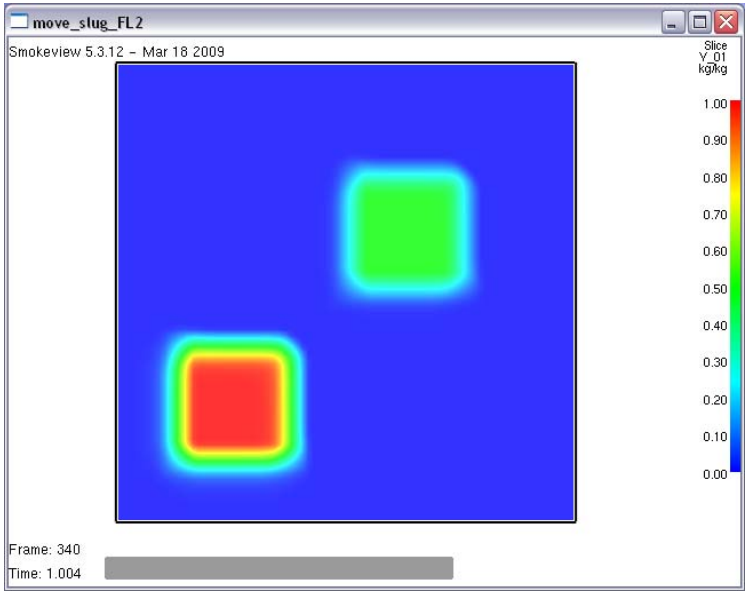




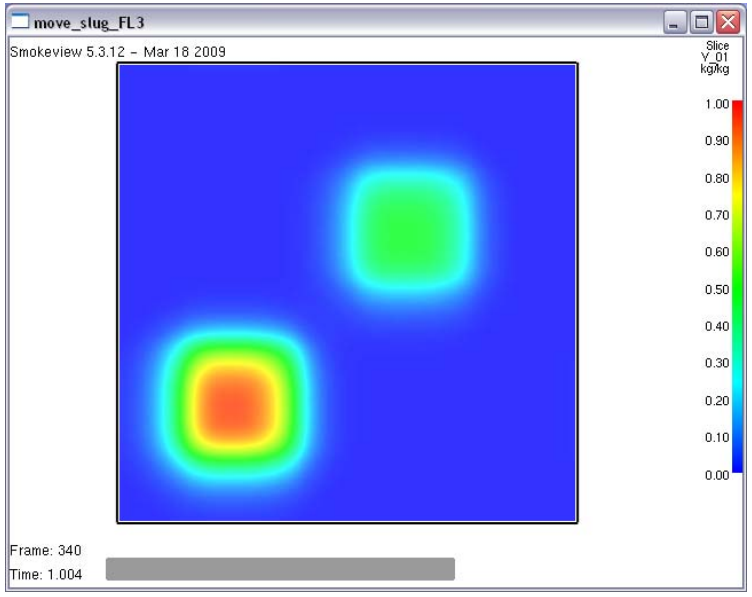
FLUX_LIMITER=1 (first order upwinding)



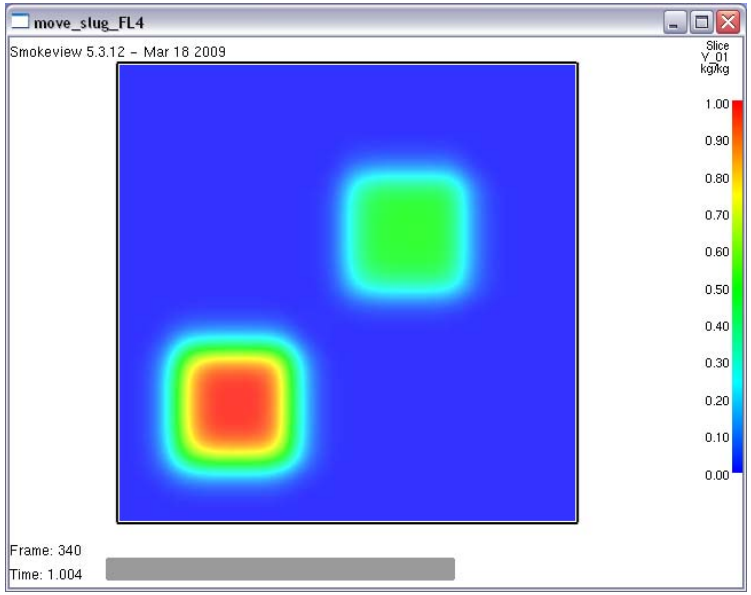
FLUX_LIMITER=2 (Superbee)



FLUX_LIMITER=3 (MINMOD)



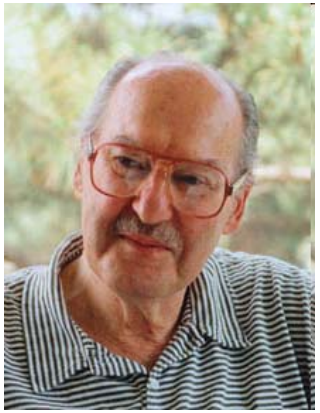
FLUX_LIMITER=4 (CHARM)



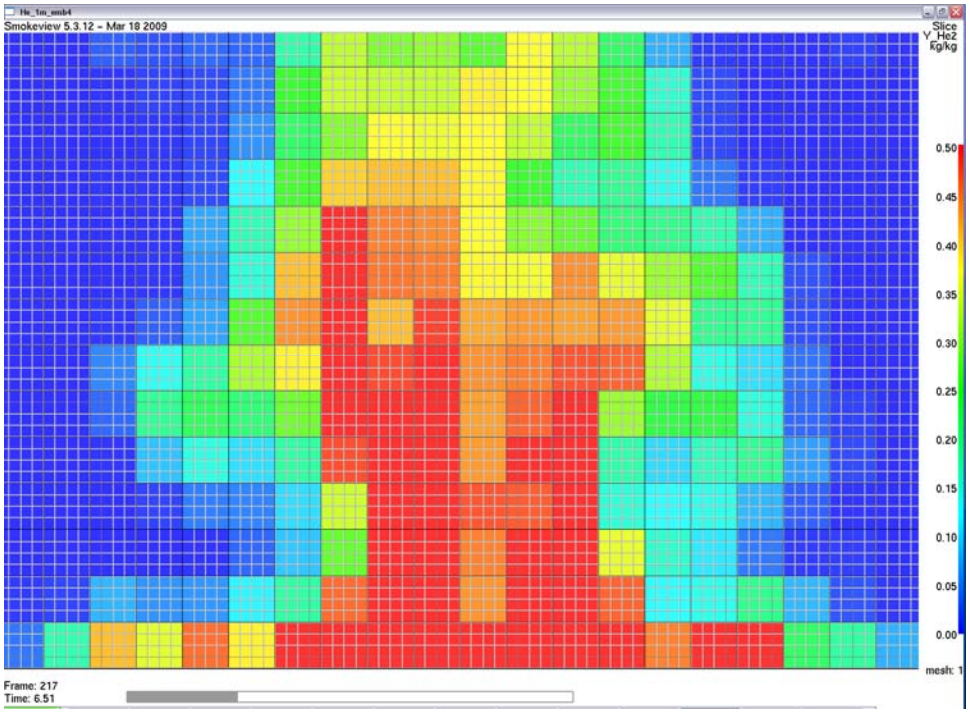
Dynamic Smagorinsky

$$\frac{\mu_{turb}}{\overline{\rho}} = (C_s[\mathbf{x}, t]\Delta)^2 |\tilde{S}|$$

Professor Massimo Germano
Department of Aerospace Engineering
Politecnico di Torino



Joseph Smagorinsky (1924-2005)

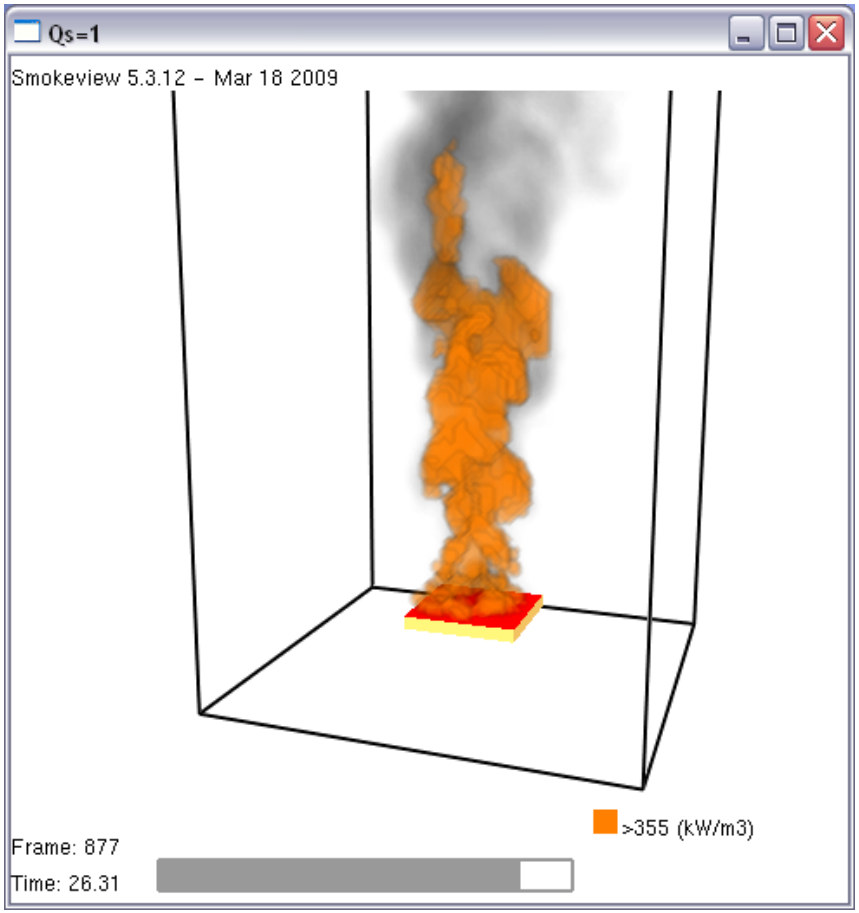


Big whorls have little whorls
Which feed on their velocity,
And little whorls have lesser whorls,
And so on to viscosity!

~ Lewis Fry Richardson

http://en.wikipedia.org/wiki/Lewis_Fry_Richardson

Germano, M., Piomelli, U., Moin, P., and Cabot, W. (1991): A dynamic subgrid-scale eddy viscosity model. Phys. Fluids A, Vol. 3, No. 7, pp. 1760-1765.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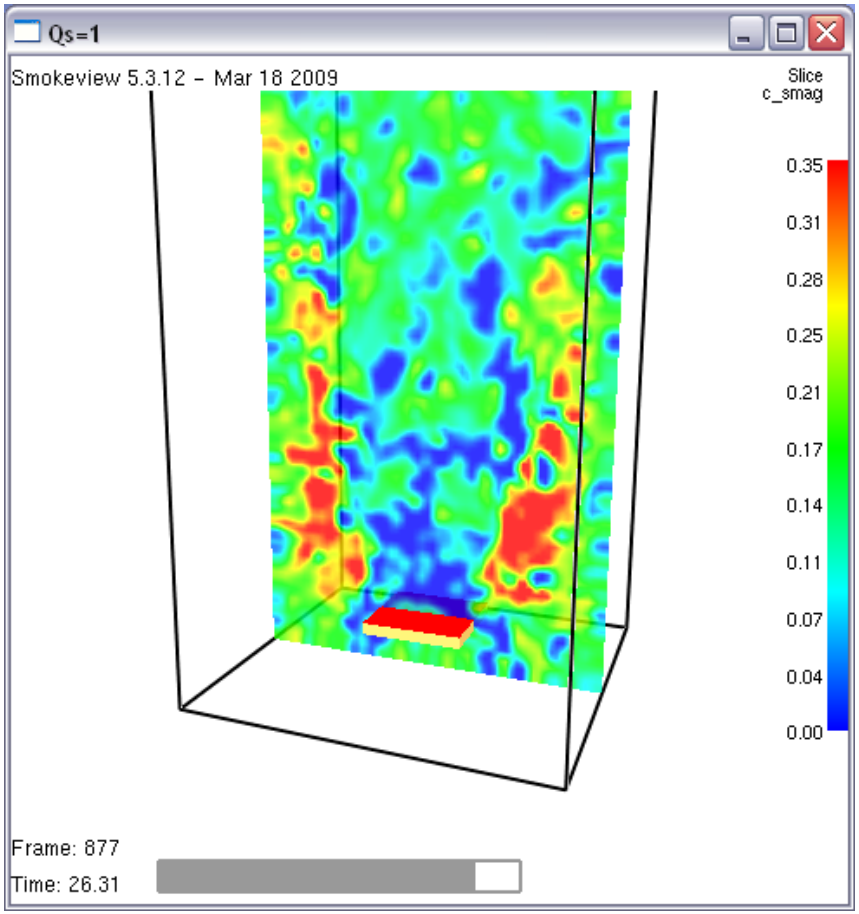
Time: 26.31


Qs=1
Smokeview 5.3.12 - Mar 18 2009
Slice
c_smag
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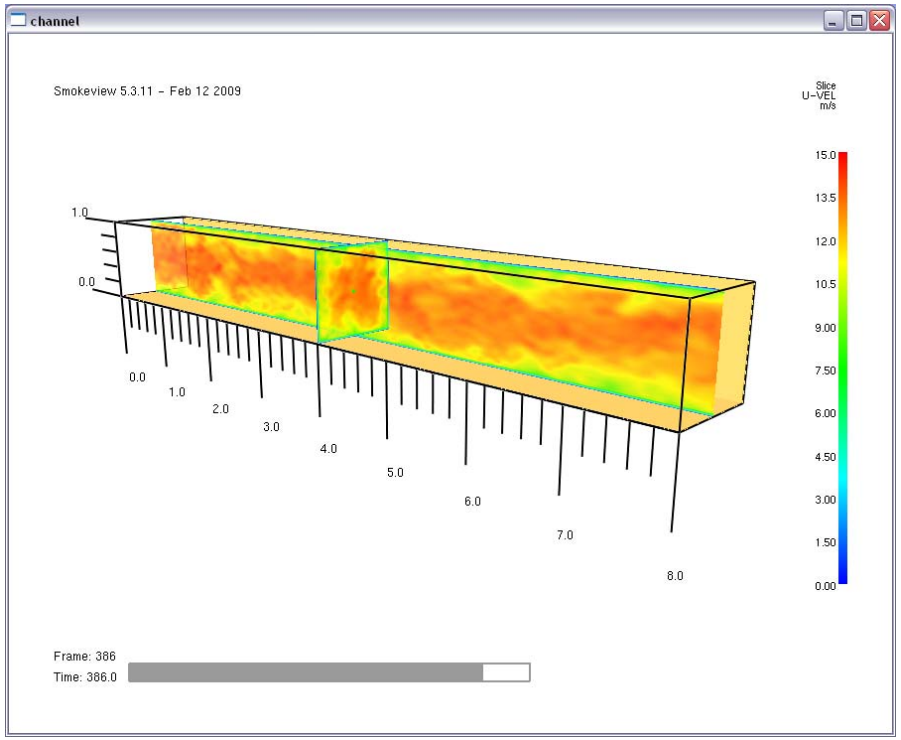
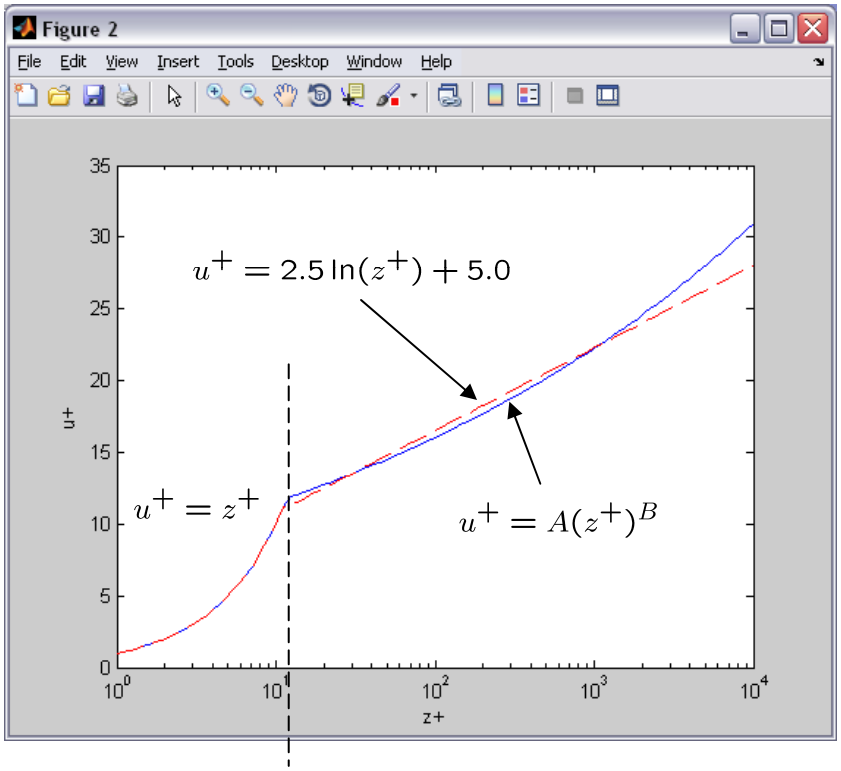
0.31
0.28
0.25
0.21
0.17
0.14
0.11
0.07
0.04
0.00
Frame: 877
Time: 26.31

Werner Wengle Wall Model

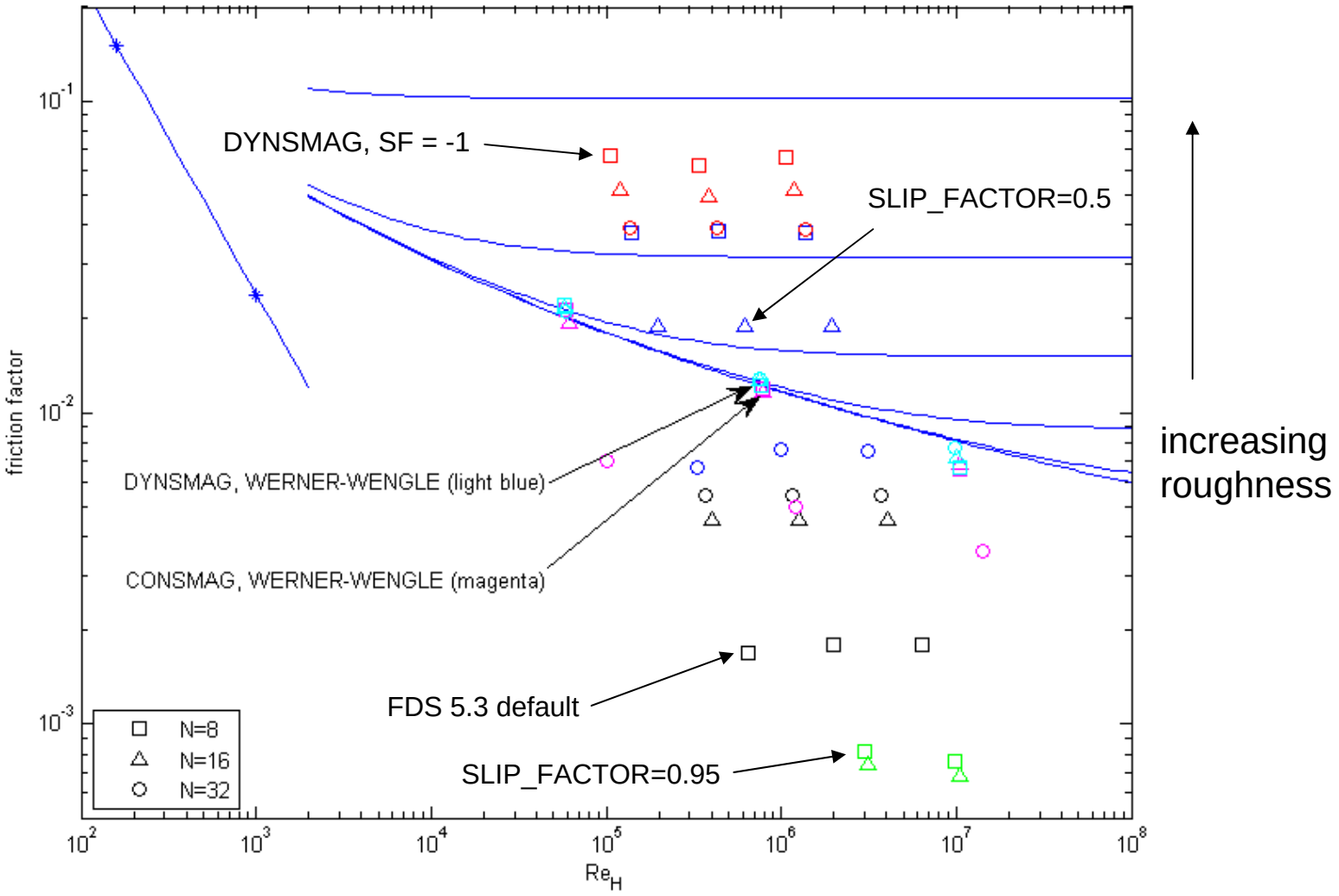
$$\tau_w = \overline{\rho}\left[\frac{1-B}{2}A^{\frac{1+B}{1-B}}\left(\frac{\mu}{\overline{\rho}\Delta z}\right)^{1+B} + \frac{1+B}{A}\left(\frac{\mu}{\overline{\rho}\Delta z}\right)^{B}\tilde{U}\right]^{\frac{2}{1+B}}$$





Werner, H., Wengle, H. (1991): Large-eddy simulation of turbulent flow over and around a cube in a plate channel. (8th Symposium on Turbulent Shear Flows, Munich, Germany).

FDS Moody Chart



On the drawing board…

- Fuel element formulation (WFDS)
- Scalable global pressure solver (Kilian)
- ALMS (Autonomous Linked Mesh Solver) – A poor man's parallel pressure solver
- OpenMP (Rogsch)
- LES quality and reliability measures
- Embedded Mesh Methods

LES Quality: Measure of Turbulence Resolution

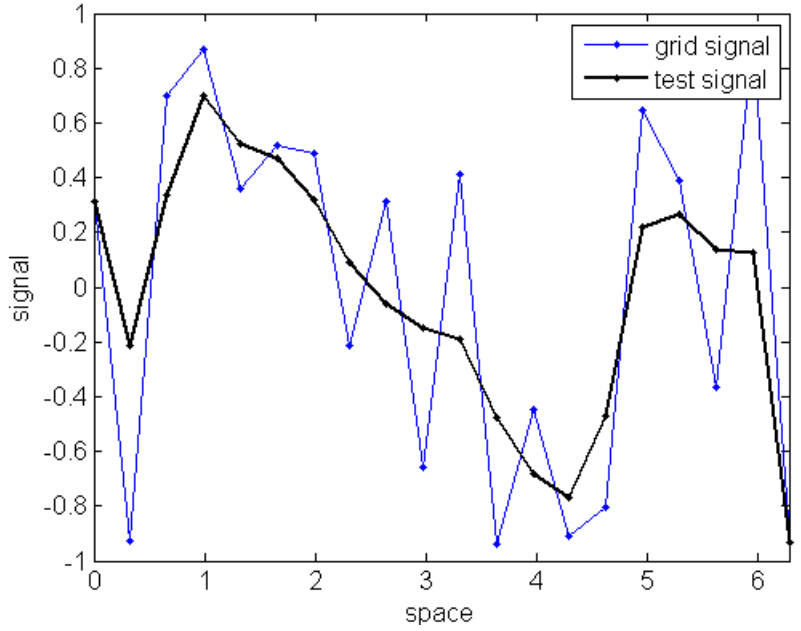
$$\mathrm{MTR}(\mathbf{x},t) = \frac{k_{sgs}}{k_{les} + k_{sgs}}$$

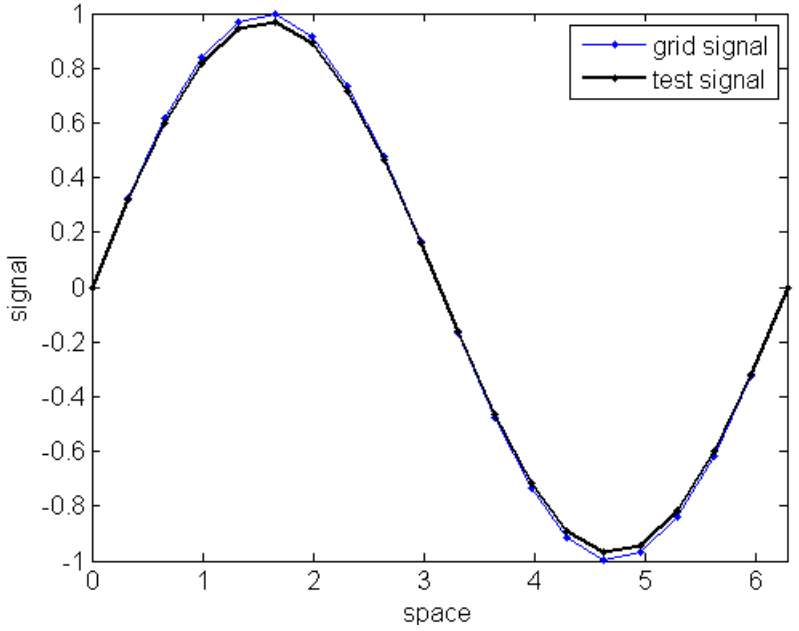
$$k_{sgs} \approx \left(\tilde{U}_i - \hat{\tilde{U}}_i\right)\left(\tilde{U}_i - \hat{\tilde{U}}_i\right)$$

test signal

grid signal

$\langle \mathrm{MTR} \rangle < 0.2 \longrightarrow$ Good LES??

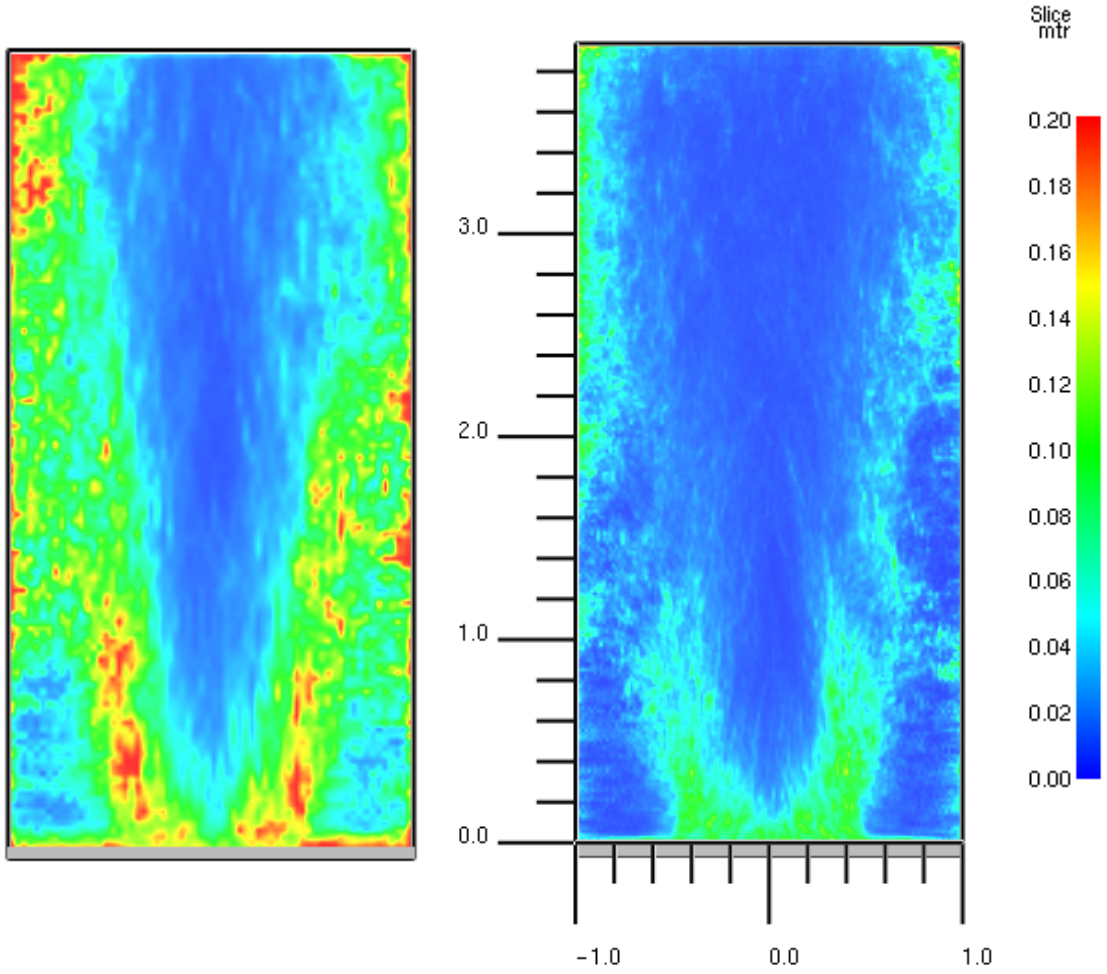




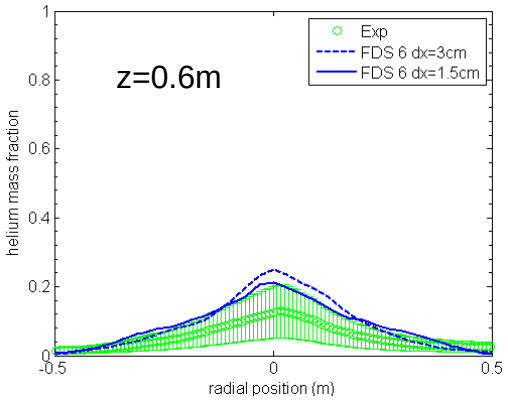
Time average of MTR
Sandia 1 m helium plume

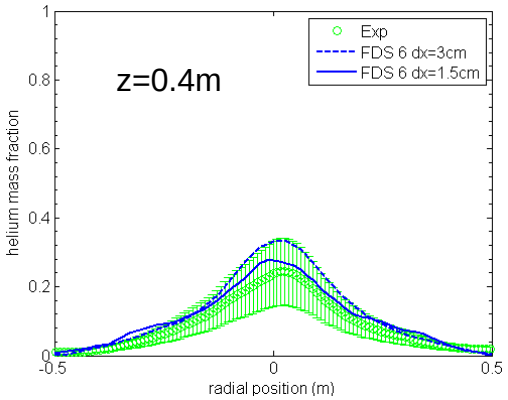
dx = 3 cm

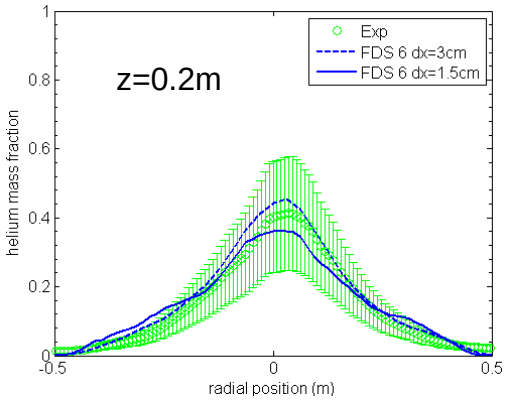
dx = 1.5 cm



helium mass fraction

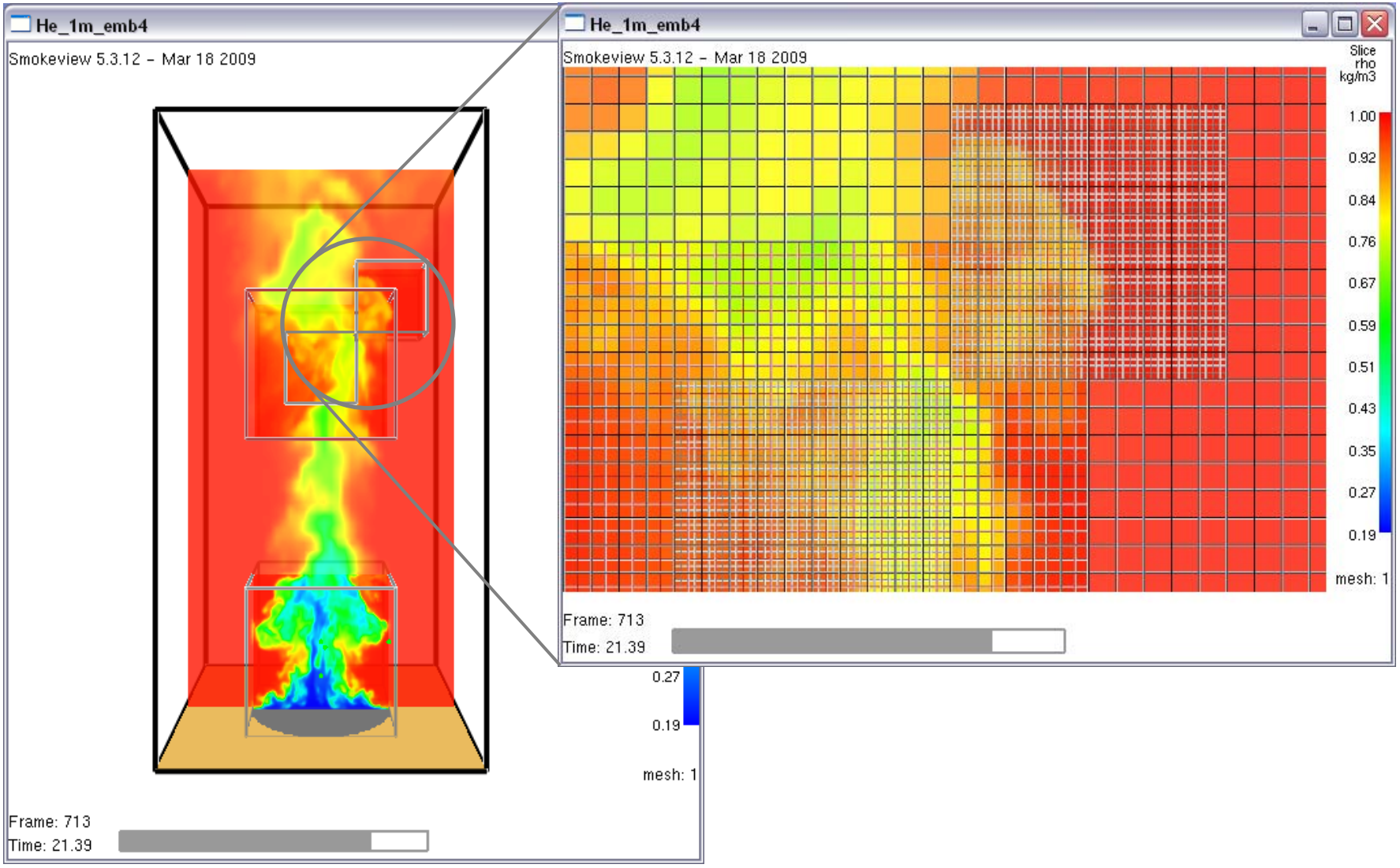






O'Hern, T.J., Weckman, E.J., Gerhart, A.L., Tieszen, S.R., and Schefer, R.W., (2005): Experimental study of a turbulent buoyant helium plume, J. Fluid Mech., Vol. 544, pp. 143-171.

Embedded Mesh Method



A glimpse of the future…

- Adaptive Mesh Refinement
- Material Point Methods for complex geometry and fluid/structure interaction
- Parameterized lookup tables for turbulence/chemistry/radiation interactions
- Turbulent inflow conditions

Arthur C. Clarke on the perception of progress:

People tend to overestimate what can be accomplished in the short run, but to underestimate what can be accomplished in the long run.