POLLUTION DISPERSION PREDICTION FOR THE MUST WIND TUNNEL EXPERIMENT WITH ANISOTROPIC ALGEBRAIC MODELS FOR TURBULENT SCALAR FLUXES

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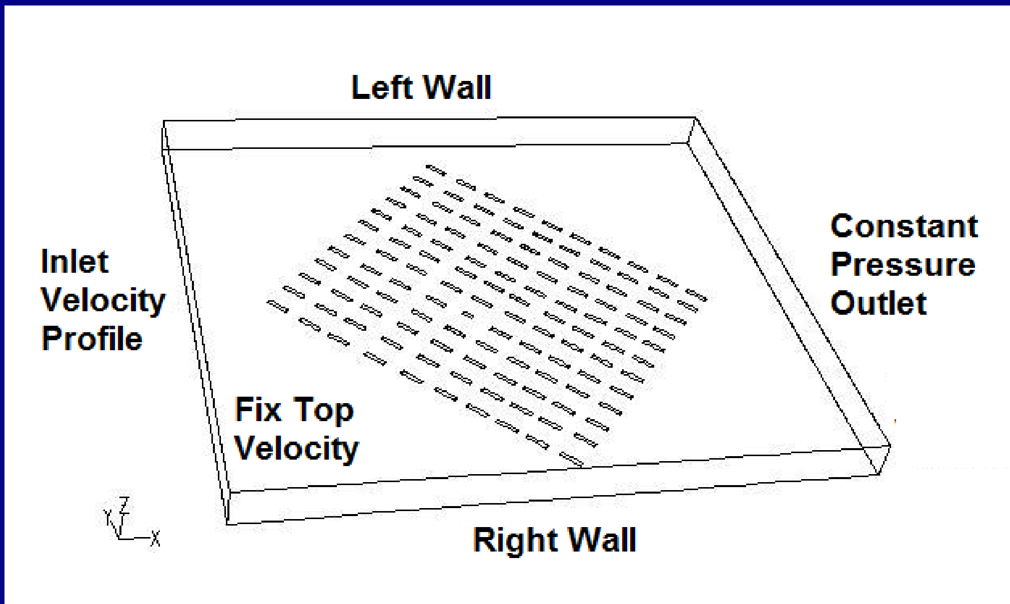
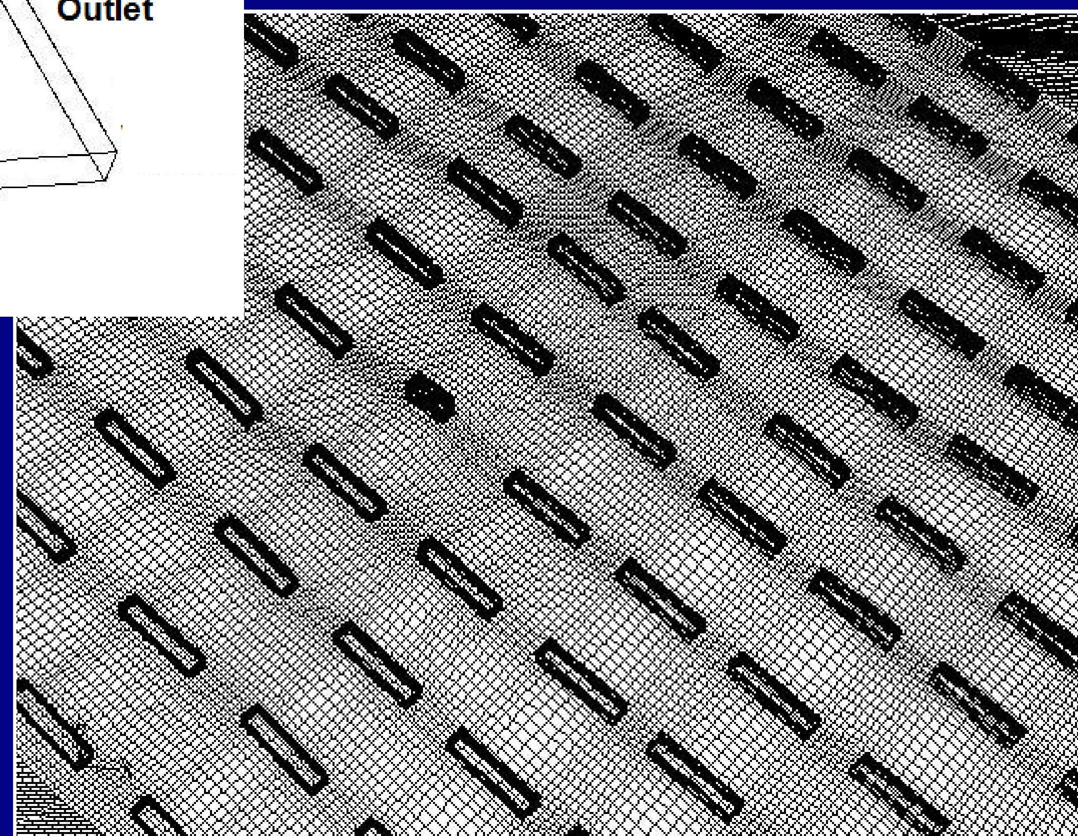
INTRODUCTION AND JUSIFICATION

- Reduce prediction uncertainties product of the different numerical parameter selection in the simulation of pollution dispersion.

- Improve the modeling capabilities of common practice modeling setup through the implementation and comparison of standard and advance scalar flux models.

COMPUTATIONAL DOMAIN, BC AND GRID





- Structured hexahedral grid
- 3.2 MM (fine), 1.6 MM (middle) and 0.8 MM (coarse) cells
- Min. wall cell size 1e-01 m
- Expansion ratio r≤1.3

GOVERNING EQUATIONS

- **RANS approach (Fluent V6.3)**
- **DSM (LRR-IP) and 2 Eq. turbulence model (Realizable k-ε)**
- **Pollutant Transport Equation**

$$\frac{\partial}{\partial x_j}\left(\rho \bar{u}_j \bar{\phi}\right) - \frac{\partial}{\partial x_j}\left(\Gamma_\phi \frac{\partial \bar{\phi}}{\partial x_j}\right) = S_\phi - \frac{\partial}{\partial x_j}\left(\rho \overline{u'_j \phi'}\right)$$

$$\overline{u'_i \theta'} = F\left(\begin{matrix} \overline{u'_i u'_j}, S_{i,j}, W_{i,j}, \bar{\phi}_{,j}, \rho, \\ \varepsilon, \phi, g_i, \overline{\phi^2}, \frac{\partial P}{\partial x_j}, \frac{\partial \rho}{\partial x_j}, Ma \end{matrix}\right)$$

- **General Scalar Flux Models**

$$-\overline{u'_i \theta'} = \alpha_1 \frac{\partial \bar{\phi}}{\partial x_i} + \alpha_2 \overline{u'_i u'_j} \frac{\partial \bar{\phi}}{\partial x_j} + \alpha_3 \overline{u'_i u'_k}\,\overline{u'_k u'_j} \frac{\partial \bar{\phi}}{\partial x_i}$$

	α1	α2	α3
SED	$\mu_t . Sc_t^{-1}$	0	0
GGDH	0	0.3τ	0
ABE-SUGA	0	0	$0.45\tau k^{-1}$
ABE	0	0.22τ	$0.45\tau k^{-1}$

$\tau = \mathrm{Max}\,[k\varepsilon^{-1}, 6 \cdot (\mu_L (\varepsilon^* \rho)^{-1})^{1/2}]$;

MODEL EVALUATION METRICS

FRANKE ET. AL. (2007)

Factor of two FAC2
(FAC2>0.5)

$$FAC2 = \text{fraction of data with } 0.5 \le \frac{C_p^*}{C_o^*} \le 2$$

Fractional Bias
(|FB|<0.3)

$$FB = \frac{\overline{C_o^*} - \overline{C_p^*}}{0.5\left(\overline{C_o^*} + \overline{C_p^*}\right)}$$

Normalized Mean Square Error
(NMSE < 4)

$$NMSE = \frac{\overline{\left(C_o^* - C_p^*\right)^2}}{\overline{C_o^*} \cdot \overline{C_p^*}}$$

Geometric Mean:
(0.7 < MG < 1.3)

$$MG = \exp\left(\overline{\ln C_o^*} - \overline{\ln C_p^*}\right)$$

Geometric Variance VG
(VG < 1.6)

$$VG = \exp\left[\overline{\left(\ln C_o^* - \ln C_p^*\right)^2}\right]$$

Hit Rate
(q≥0.66)

$$q = \frac{1}{N}\sum_{n=1}^{N} i_n \quad , \quad i_n = \begin{cases} 1 & \text{if } \left|\left(O_n - P_n\right)/O_n\right| \le D \text{ or } \left|O_n - P_n\right| \le W \\ 0 & \text{otherwise} \end{cases}$$

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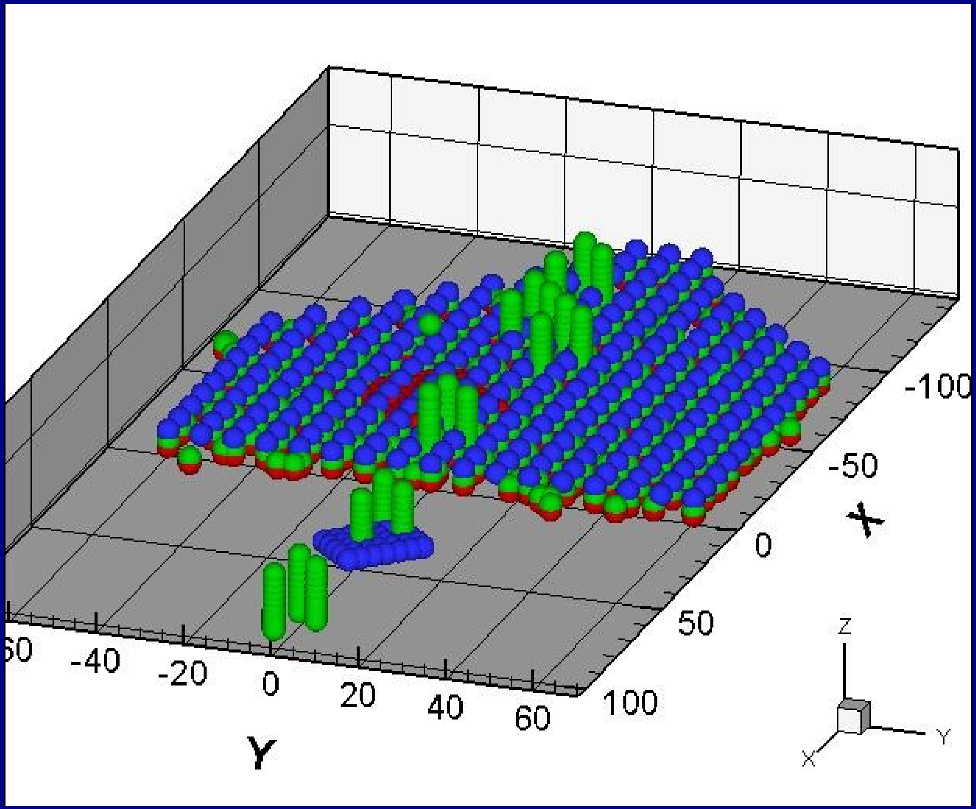
RESULTS: VELOCITY FIELD

HIT RATE (q)

	LRR-IP	RKE
U	0.94	0.86
V	0.37	0.39
W	0.15	0.16
Urms	0.71	0.46
Vrms	0.64	0.58
Wrms	0.72	0.94
u'v	0.20	0.41
u'w'	0.12	0.47
k(u'v')	0.48	0.20
k((u'w')	0.41	0.31



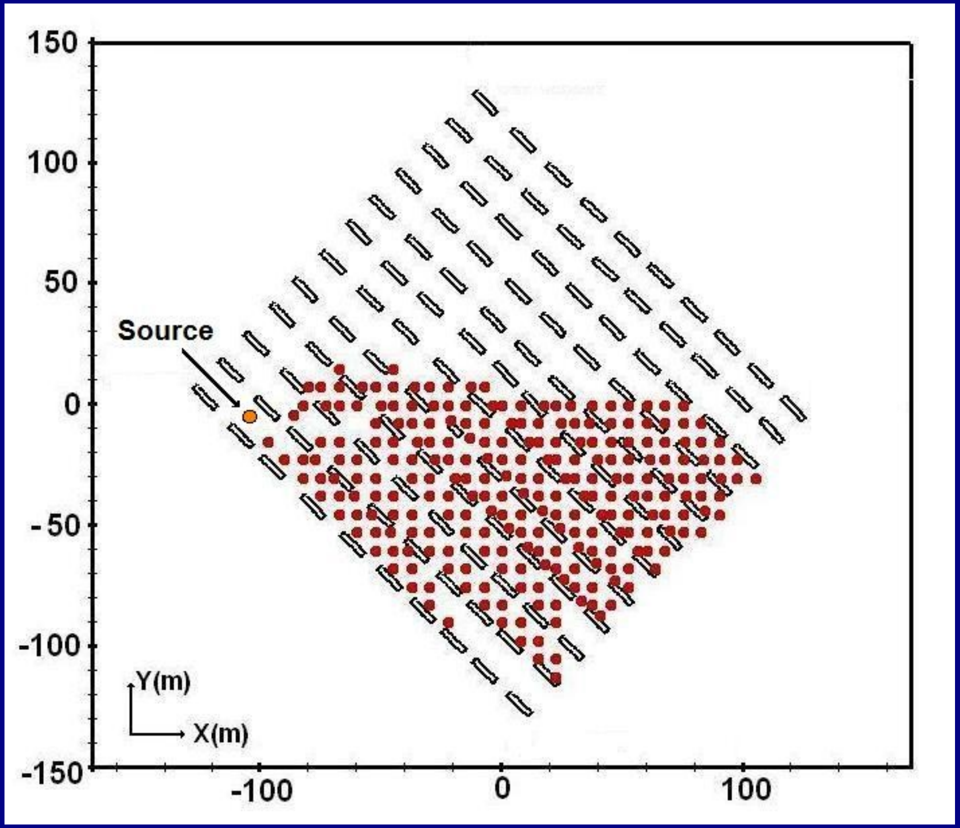
Flow Field Measurement Points

CONCENTRATIONS

Non-dimensional concentration (C*)

$$C^* = \frac{C_{mean} \cdot U_{ref} \cdot H^2}{Q_S}$$

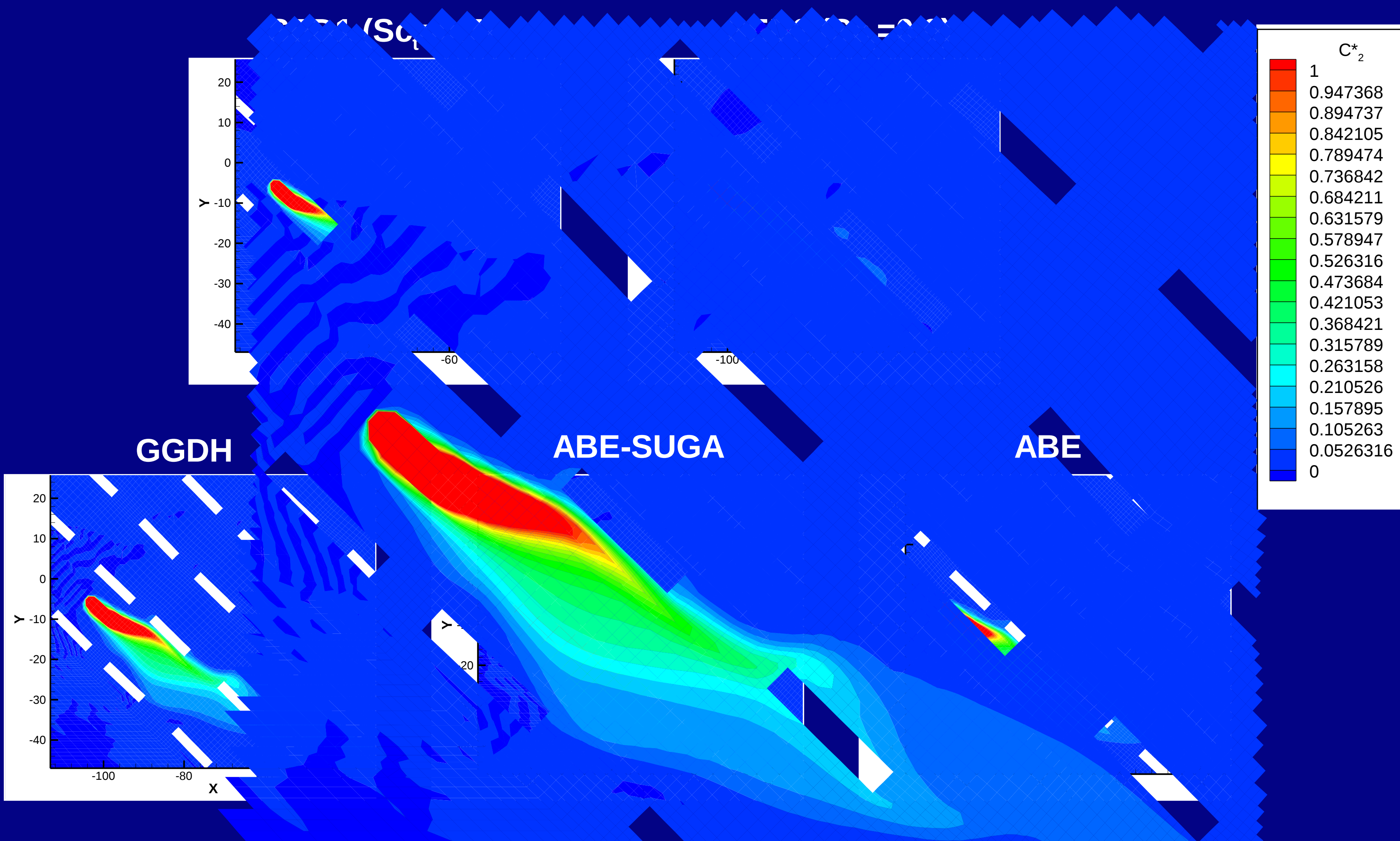
- C_{mean} (ppm)
- U_{ref} (m/s)
- H (m)
- Q_S (m^3/s)



Dispersion Measurement Points (z=1.275m)

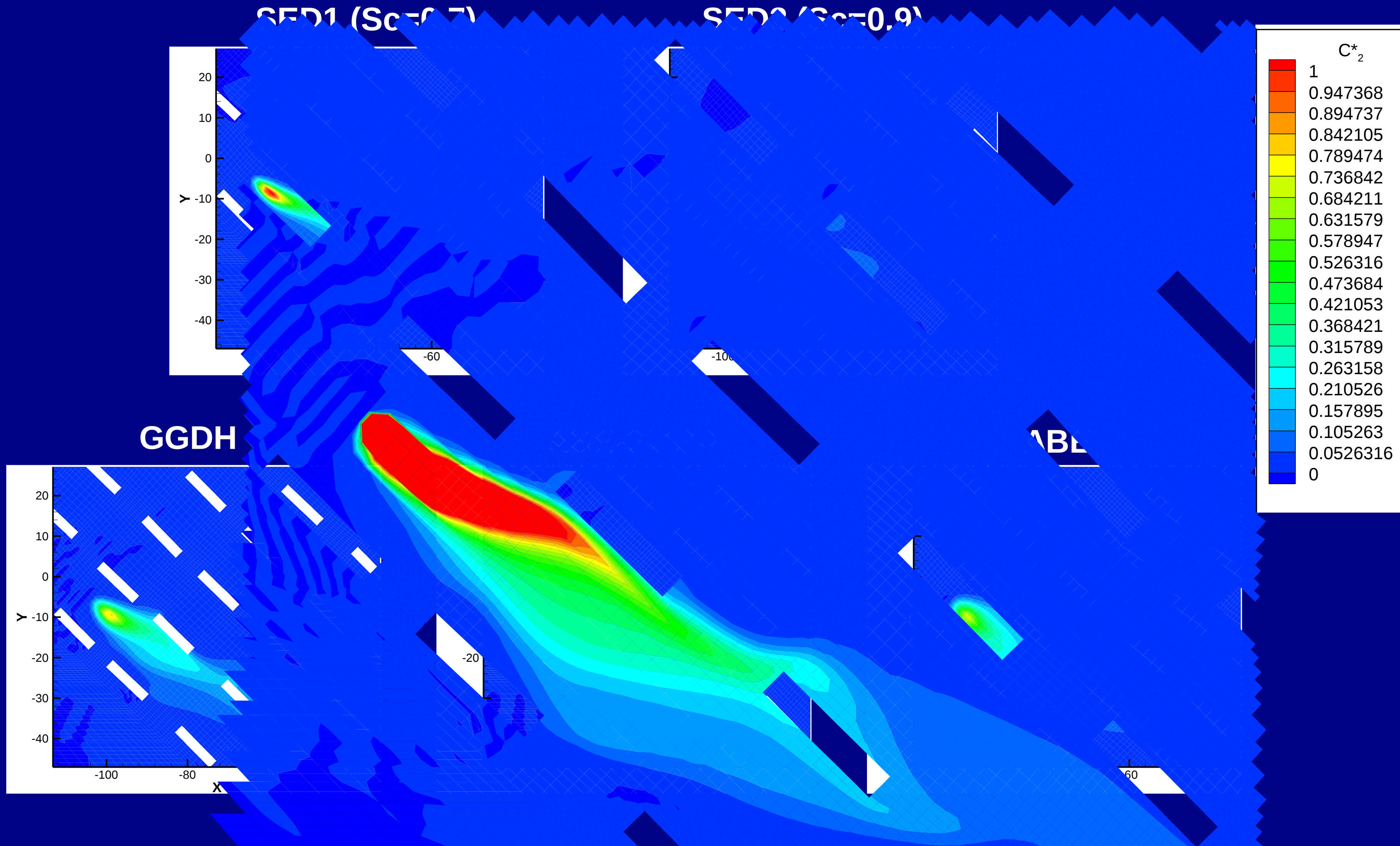
RESULTS: POLLUTION DISPERSION

PLANE Z=0.175m



RESULTS: POLLUTION DISPERSION

PLANE Z=1.275m



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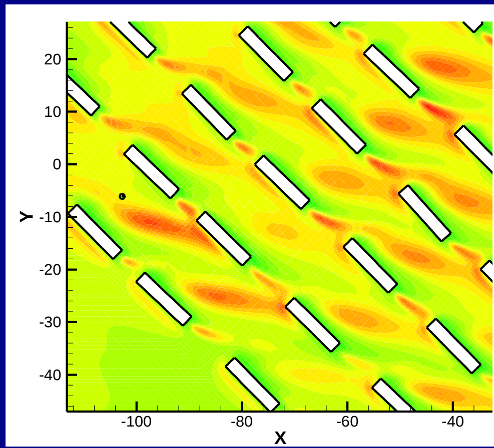
RESULTS: REYNOLDS STRESSES

PLANE Z=1.275m

uu



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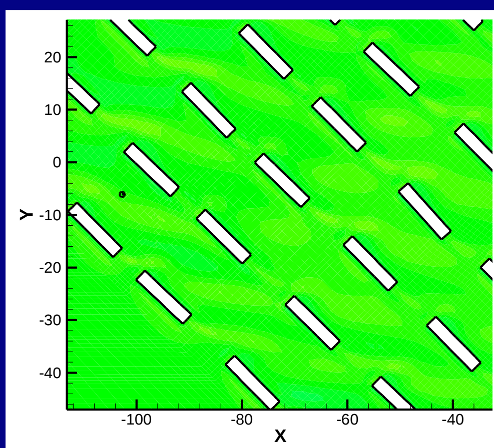

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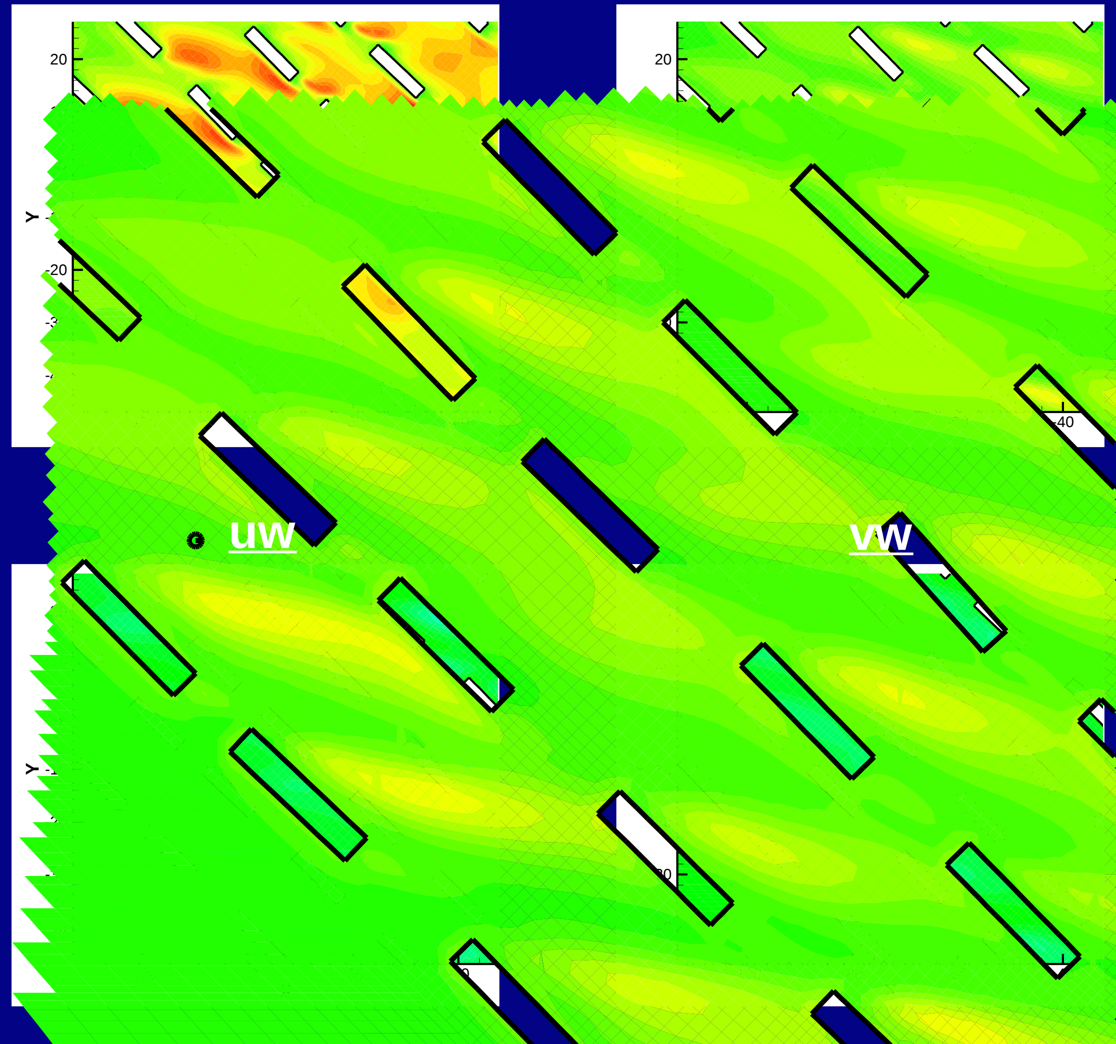
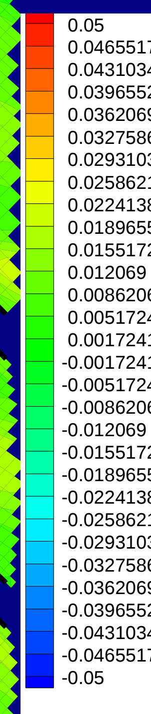
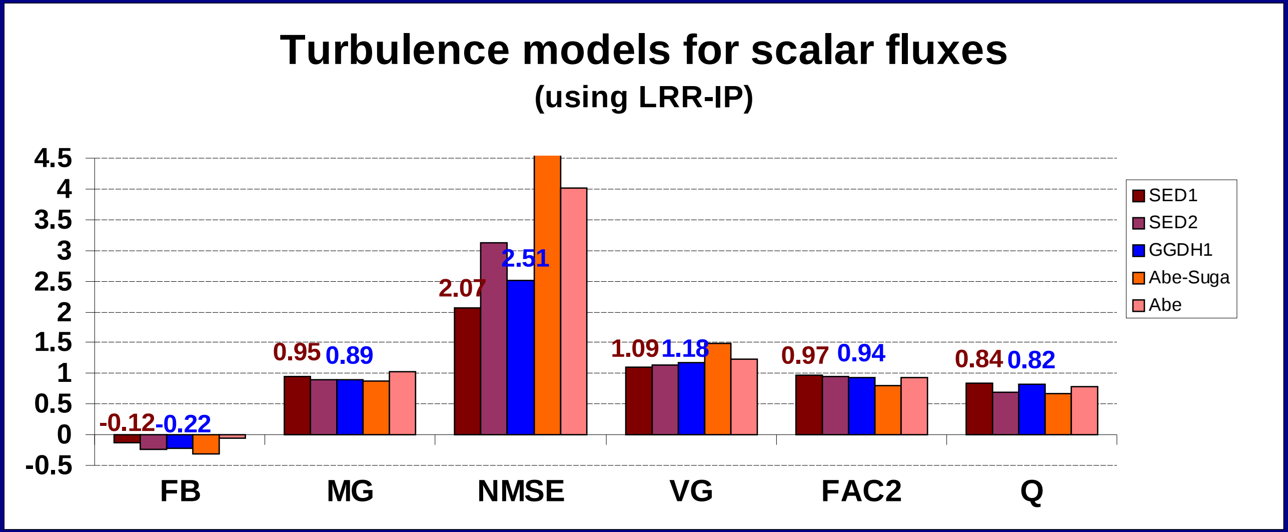


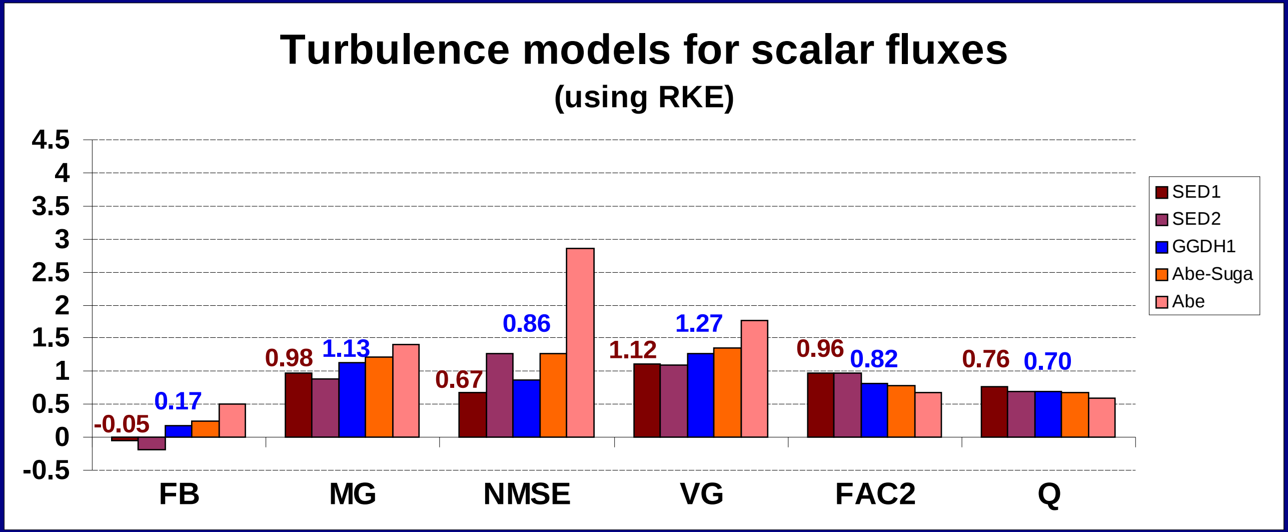


RESULTS: CONCENTRATION METRICS

RECOMMENDED RANGE:
(Chang & Hanna 2004)

|**FB**|<0.3
0.7 < **MG** < 1.3
NMSE < 4
VG < 1.6
FAC2>0.5
Q>0.66





Metrics Tolerance:
D=25%
W=0.003

CONCLUSIONS

- Statistical metrics are a useful tool to quantify the prediction capability of different scalar flux models for the evaluation of the MUST wind tunnel test experiment.

- As was expected, the dispersion predictions using SED model gives satisfactory results for most of the metrics for an given specific Sc_t(=0.7). However, the performance is highly dependent of the selected Sc_t.

- It was found that the modeling of turbulent scalar fluxes by anisotropic models is highly related to the prediction accuracy of the Reynolds stresses.

- Better model does not means always better metrics.

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THANK YOU

FOR YOUR ATTENTION