A study of aerosol dynamics in the cloud area

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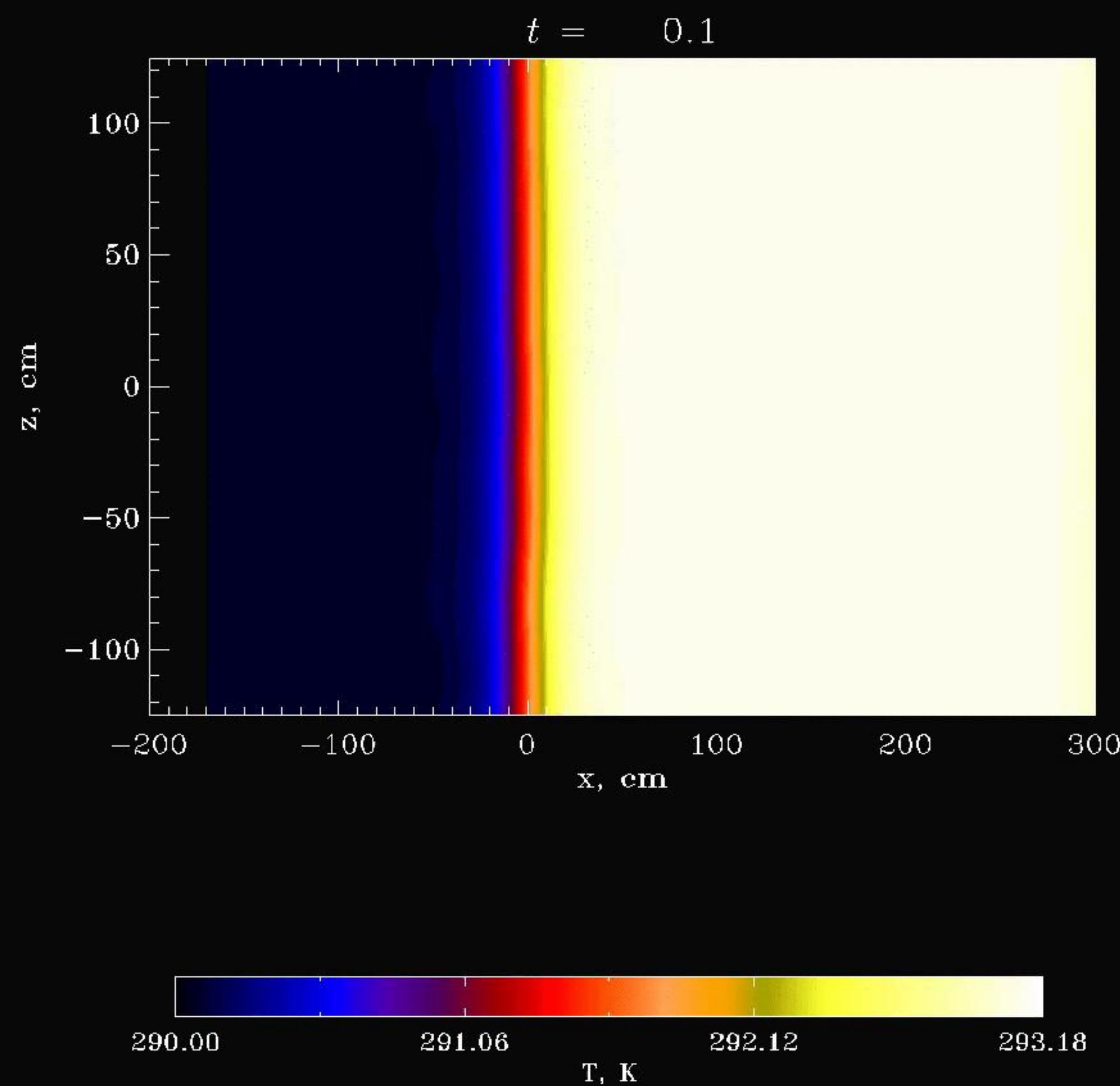
Objectives and motivation

- Studying the influence of turbulence on the aerosol dynamics and vice versa inside a cloud
- Comparing models with different resolutions to answer the principal question about the necessary resolution for the correct description of aerosol dynamics.
- Comparing 2D and 3D approaches. Is it possible to use 2D approach for description of aerosol dynamics?

Model

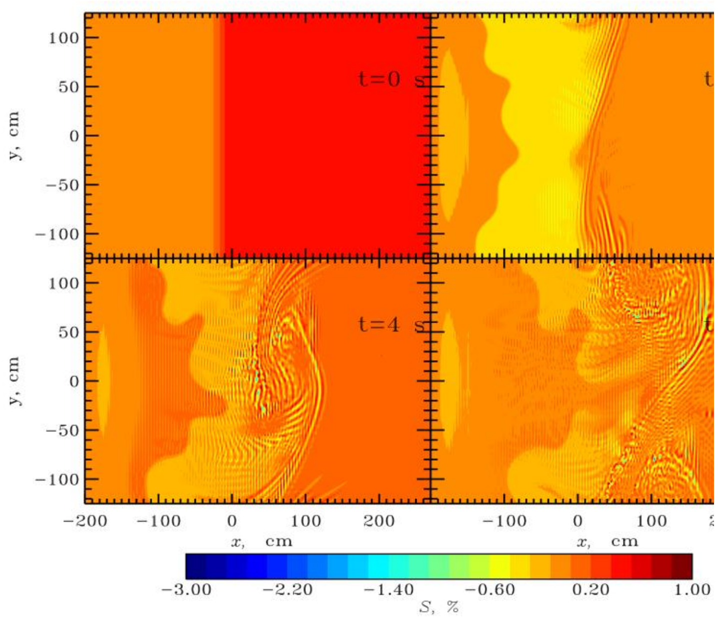
- Dustdensity + Chemistry modules
- Cloud area
- Air composition: $N_2+O_2+H_2O$
- Aerosol particles: solid core + liquid water envelope
- Aerosol dynamics: evaporation + activation
- Particle distribution function



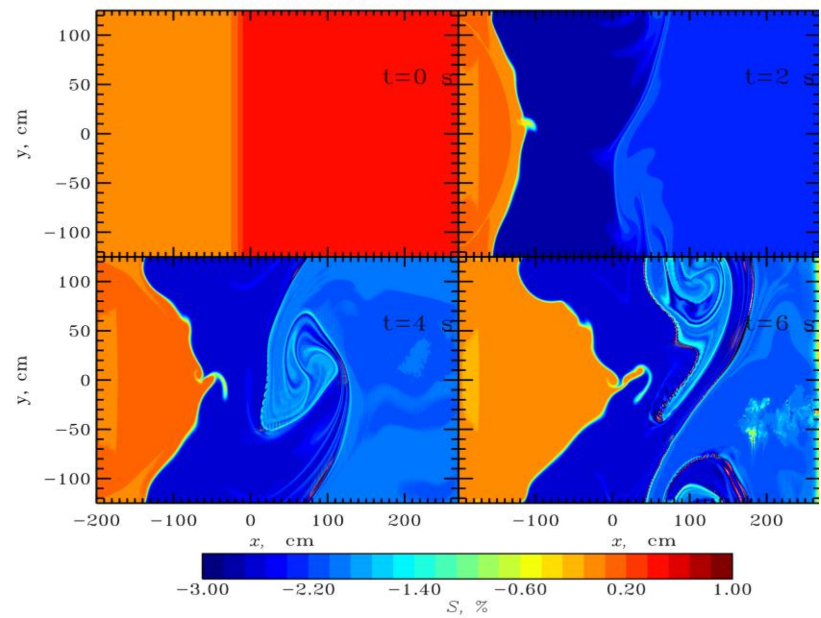
t = 0.1
100
50
0
−50
−100
z, cm
−200
−100
0
100
200
300
x, cm
290.00
291.06
292.12
293.18
T, K

Distribution of the supersaturation

2 cm grid cell



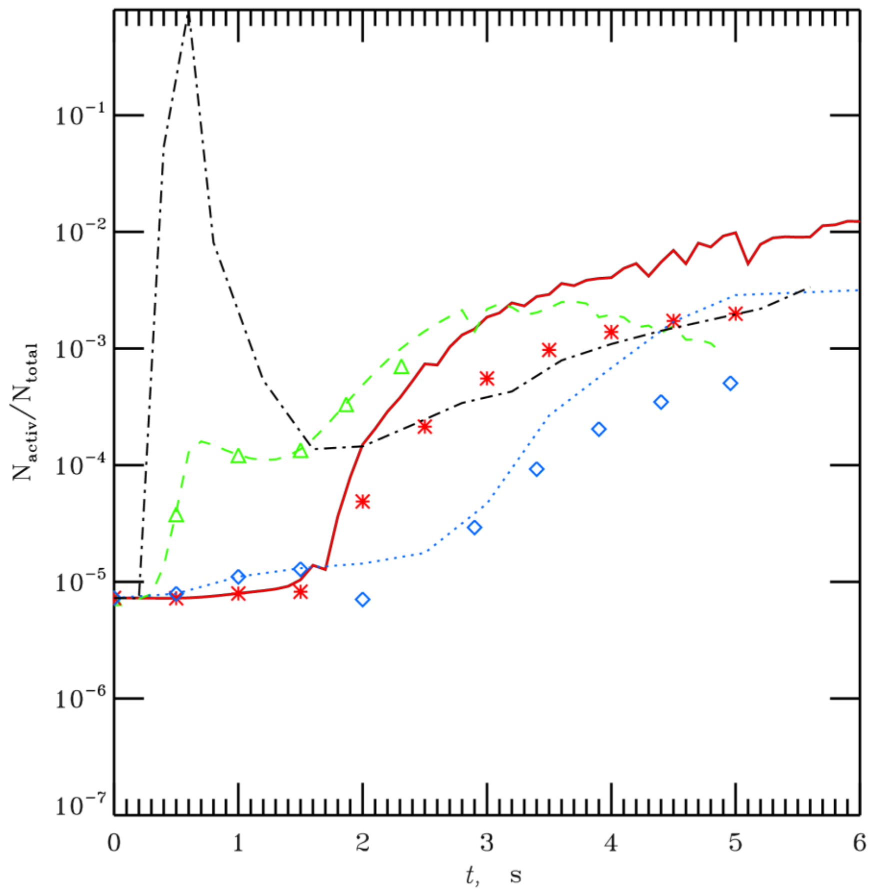
0.5 cm grid cell



A ratio of a number of activated particles to the total number as a function of time

2D: curves
3D: dotts

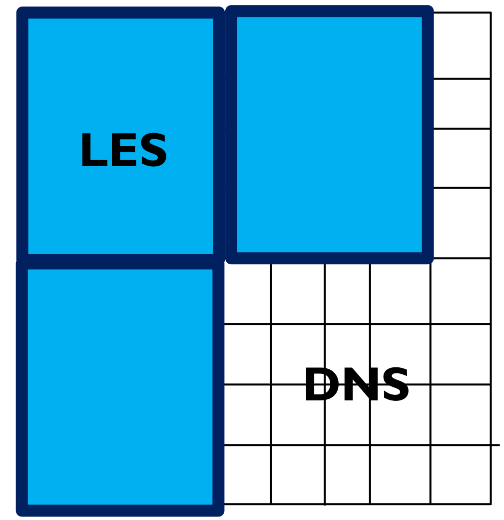
Red: 4 cm
Blue: 2 cm
Black: 0.5 cm



Objectives and motivation

- Improving the parameterization of LES with DNS
- PEEX (Pan-Eurasian Experiment)
  https://www.atm.helsinki.fi/peex/

LES: Basic equations



$$\frac{\partial \tilde{u}_i}{\partial xi} = 0$$

$$\frac{\partial \tilde{u}_i}{\partial t} + \frac{\partial (\widetilde{u_i u_j})}{\partial xj} = -\frac{\partial}{\partial xj}\left(\frac{\tilde{p}}{\rho}\right) + \nu_{air}\frac{\partial^2 \tilde{u}_i}{\partial xj^2}$$

$$\tau_{ij} = \widetilde{u_i u_j} - \tilde{u}_i \tilde{u}_j$$

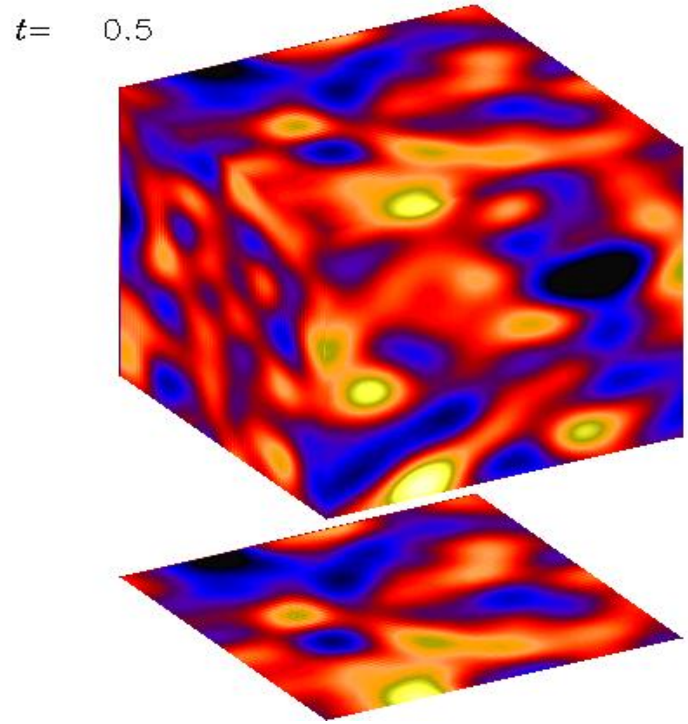
$$\frac{\partial \tilde{u}_i}{\partial t} + \frac{\partial}{\partial xj}(\tilde{u}_i \tilde{u}_j) = -\frac{\partial}{\partial xj}\left(\frac{\tilde{p}}{\rho}\right) + \nu_{air}\frac{\partial^2 \tilde{u}_i}{\partial xj^2} - \frac{\partial \tau_{ij}}{\partial xj}$$

Smagorinski model:

$\tau_{ij} = 2\nu_t \tilde{S}_{ij}$, where $\nu_t = C_s(\Delta)^2 |\tilde{S}_{ij}|$

Formulation of the problem

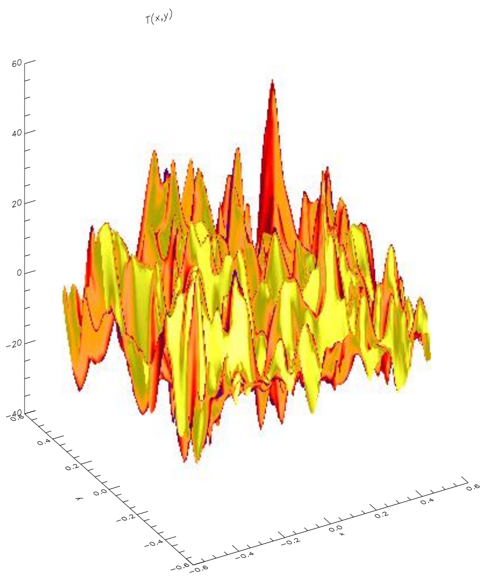
- Domain 20 cm x 20 cm x 20 cm
- Generation of the turbulence for the first 0.5 s
- Periodic BC in x - and z - direction
- At y=y0 Ux=20 cm/s, at y=Ly Ux=-20 cm/s



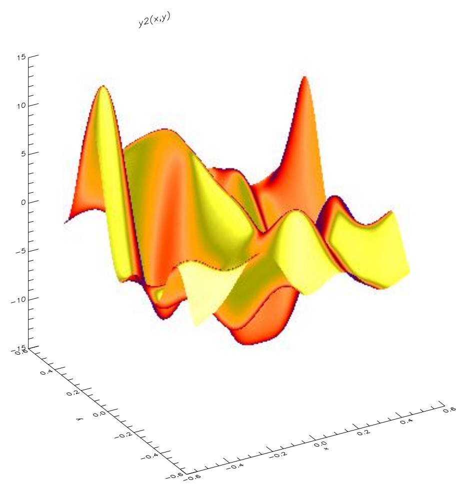
Method

- Get DNS results
- Filtering Ui, UiUj with FFT
- Calculate $\tau_{ij}=\widetilde{u_i u_j} - \tilde{u}_i \tilde{u}_j$
- Extract ν_t and Cs, using $\tau_{xy}=2\nu_t \tilde{S}_{xy}$ and $\nu_t=C_s(\Delta)^2\,|\tilde{S}_{ij}|$
- Choose Δ=10 cm, 5 cm

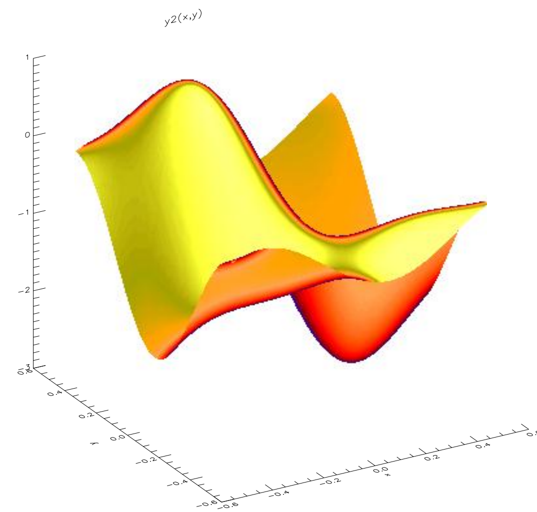
Original



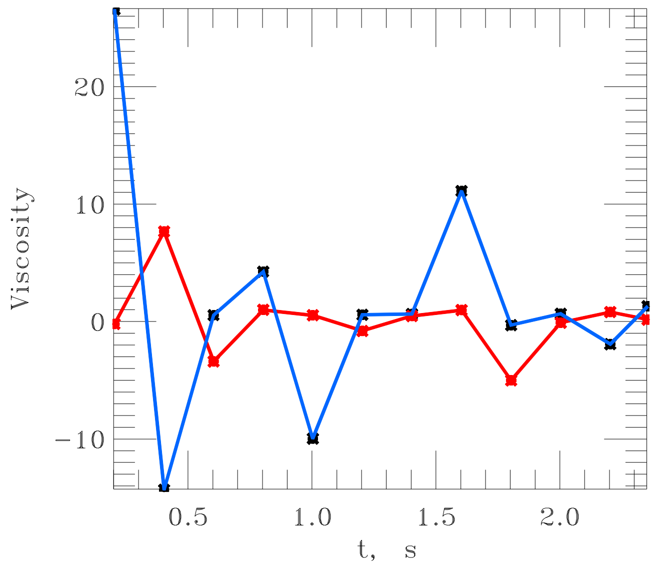
Δ=5 cm

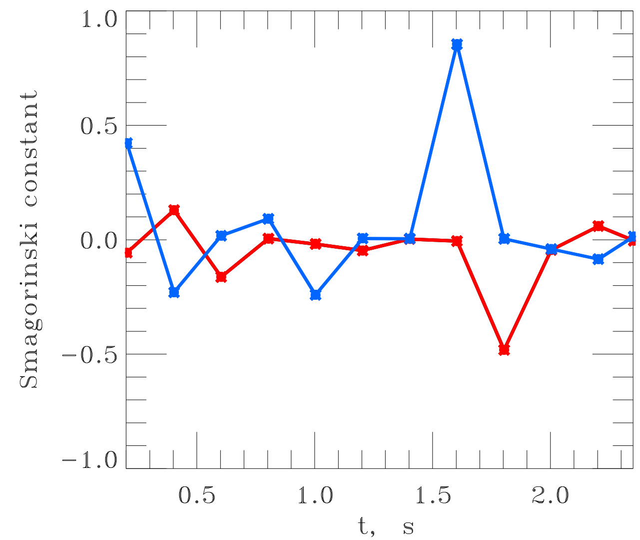


Δ=10 cm



Results





Filters size: Δ=10 cm, Δ=5 cm,

Averaged values : Cs=-0.048, Cs=0.071

ν_t =0.25 cm²/s, ν_t =1.666 cm²/s

$\tau_{ij}=2\nu_t\tilde{S}_{ij}$,

$\nu_t=C_s(\Delta)^2\,|\tilde{S}_{ij}|$

Commonly used value Cs=(0.15)² =0.0225

ν_{air} =1.8 10⁻² cm²/s

Questions

- How general are the conclusions?
- How sensitive this result to the BC and initial conditions?
- Do the results depend on the size of the domain?
- Is it possible to propose the universal parameters?
- What is better to use: Smagorinski constant (Cs) or turbulent viscosity (ν_t)?
- How to apply this result to real LES grid cell (10 m – 1 km)?
- What is the correct way of averaging?
- How important this correction of parameters for LES?
- How this result effect on aerosol?
- How this result effect on energy transportation?
- Has anybody else checked Smagorinski model?
- ????????