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Modelling of local air quality for stationary sources: simple tests

Emissions do not display yet total character and level of aircraft impact on air quality. Currently CAEP/12-MDG-FESG/1/WP/13 initiated a feasibility study to test how LAQ dispersion calculations for individual airports can be set up and carried out within MDG in order to provide a quantity that is based on near-ground concentration at and around airports caused by aircraft traffic. PolEmiCa model was involved in the LAQ feasibility study towards a concentration-based LAQ metric.

Local Air Quality.

Key variable of local air quality (LAQ and related impact considerations is the pollutant concentration (quantity of a pollutant per volume of ambient air), for which national and global regulations specify limit values.

Spatial and temporal dispersion and distribution of air pollutants is the basis of unbiased assessment of the present position and future trends of air pollution and of the development of cost-effective strategies to improve air quality and to meet regulatory requirements.

The major objective of air pollutant forecasting is usually the determination of the pollutant in the atmospheric layer 50-100 meters above the surface acquires special importance. As shown by many investigations this layer is considerable changes of wind speed, temperature and turbulence with height. Likewise, the atmospheric stability effect directly related to temperature stratification is very distinct. Thus, the models of spatial and temporal dispersion of air pollutants should include affects of mentioned meteorological parameters in boundary layer.

ICAO Doc 9889 [1] recommends few tools for air quality analysis – to model emission inventory from every character groups of the spatially distributed sources as well as atmospheric concentrations resulting from emission dispersion: EDMS is based on Gaussian plume model (AERMOD) [2]; LASPORT is based on Lagrangian particle model (LASAT) [2]; PolEmiCa is based on Eulerian approach [8]: ALAQS–AV provides to use both Gaussian and Langrangian approaches for dispersion calculations [2].

Aircraft in operation (during approach, landing, taxiing, take-off and initial climb – landing-takeoff cycle or LTO-cycle) and maintenance (aircraft engine run-ups) is a dominant source of impact on LAQ in vicinity of the airport in most cases under consideration. Key variable of local air quality (LAQ) and related impact assessment is the pollutant concentration (not emission) for which national and global regulations specify limits. Although concentration is proportional to emission, it is in general not possible to deduce from LTO emission a concentration.

Emissions do not display yet total character and level of aircraft impact on air quality. The factors, which may provide a difference between emission level and air pollution concentrations, are following:

- *type of the engine in aircraft power unit;*
- *height of the engine installation at power unit;*
- *the dynamic of engine exhaust gases depending on operation mode;*
- *character of an aircraft movement (parking, taxing, accelerating on the runway);*
- *meteorological parameters, as wind velocity and atmospheric stability.*

Currently CAEP/12-MDG-FESG/4/WP/09 [3] initiated a feasibility study to test how LAQ dispersion calculations for individual airports can be set up and carried out within MDG in order to provide a quantity that is based on near-ground concentration at and around airports caused by aircraft traffic. Complex model PolEmiCa [4] was involved in the LAQ feasibility study towards a concentration-based LAQ metric.

Results and discussion

In order to obtain a better understanding of possible systematic differences between the LAQ models that take part the feasibility study, a set of simple test cases were run. All test cases assume flat, homogeneous terrain and stationary meteorological conditions with neutral stratification. In case geographic latitude, pressure or temperature enters the applied meteorological boundary layer model, latitude between 40 and 50 deg and standard ISA conditions are assumed. The x-axis is oriented west/east, the y-axis south/north. SI units only are applied.

Test case 1 - elevated, passive point source

- Passive point source at 60 m height above ground
- Emission rate 1 g/s NOx, no chemical conversion and deposition
- Wind speed at source exit 10 m/s
- Obukhov length infinity (neutral stratification)
- Surface roughness length 0.7 m, no displacement height
- Stationary concentration distribution at 1.5 m height above ground

Concentration distribution C $(x; y ;z)$ were assessed by method OND-86 [7], which provides for this situation a reasonable description of the plume.

For this case the effluent parameters were obtained as $f = 0.00031$, $v' = 0.00024$, m = 4.26368, d=2.48, u_l=0.7 m/s, C_{max}= 1.468 mg/cub.m, X_{max}=148.89 m. The cross-integrated concentration and the results of the dispersion calculation for the receptor points (extent -100 m<x<4000 m, -2000 m<y<2000 m with horizontal resolution at least 30 m) are presented correspondingly in fig. 1 and fig.2.

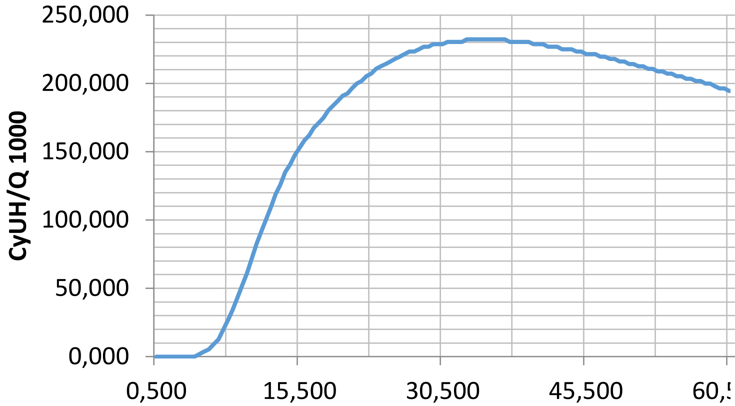

Figure 1. Cross-integrated concentration for elevated stationary source (Test1)

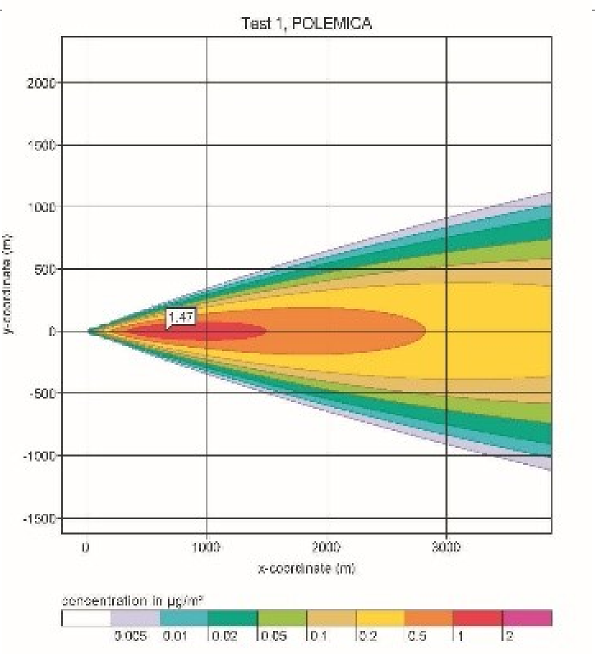

Figure 2. Concentration distribution at the ground for elevated stationary source (Test1)

Test case 2 - elevated, passive point source
Test 2, point source near ground

- Passive point source at 0.4 m height above ground at x=0 m/y=0 m
- Emission 1 g/s SO2, no chemical conversion
- Calculation without dry deposition
- Wind speed at 2 m height above ground 6.2 m/s
- Obukhov length 248 m, friction velocity 0.38 m/s
- Surface roughness length 0.008 m, no displacement height
- Stationary concentration distribution at 0.5 m height above ground
- Extent -100 m<x<1000 m, -500 m<y<500 m
- Horizontal resolution at least 10m

Concentration distribution C *(x; y; z)* were also assessed by method OND-86 [7], which provides for this situation a reasonable description of the plume.

For this case the effluent parameters were obtained as f = 0.00031, v' = 0.00073, m = 4.11485, d=2.53, C_{max}= 11.018 mg/cub.m, X_{max}=29.32 m. The cross-integrated concentration and the results of the dispersion calculation for the receptor points (extent -100 m<x<1000 m, -500 m<y<500 m with horizontal resolution at least 10 m) are presented correspondingly in fig. 3 and fig.4.

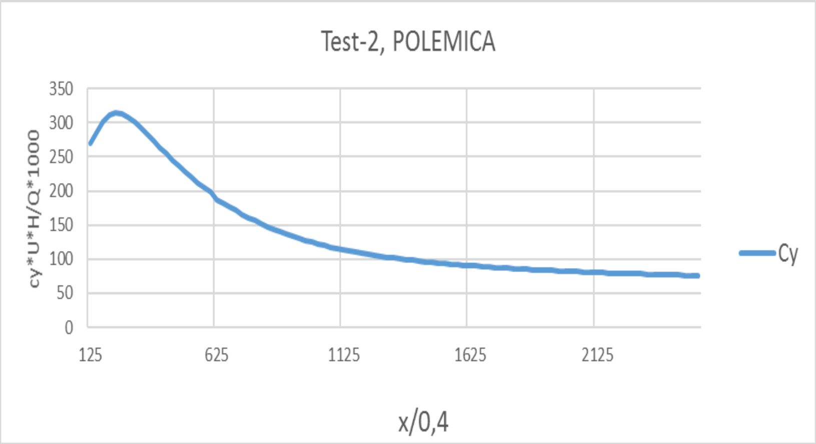

Figure 3: Scaled, cross-integrated concentration for point source near (Test 2)

LAQ metric. The paper demonstrated the calculation results obtained for first simple test under condition of neutral atmospheric stratification. PolEmiCa includes the impact meteorological conditions, as wind distribution with altitude, atmospheric turbulence and stratification.

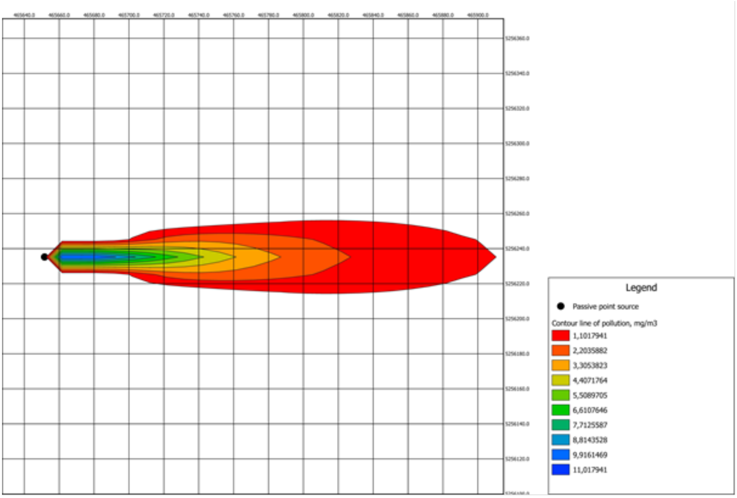

Figure 4. Concentration distribution at the ground for near ground stationary source (Test1)

References

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2. ICAO Doc 9889. Airport Ait Quality. 1st ed 2011 200 p
3. CAEP/12-MDG-FESG/4-WP/09 LAQ Dispersion Feasibility Study. CAEP fourth virtual meeting, 15 to 19 June 2020 (CAEP/12-MDG-FESG/4)
4. Zaporozhets O. Synylo K. Improvements on aircraft engine emission and emission inventory asesessment inside the airport area // Journal of Energy. – 2017. – Volume 140. – P.1350-1357.