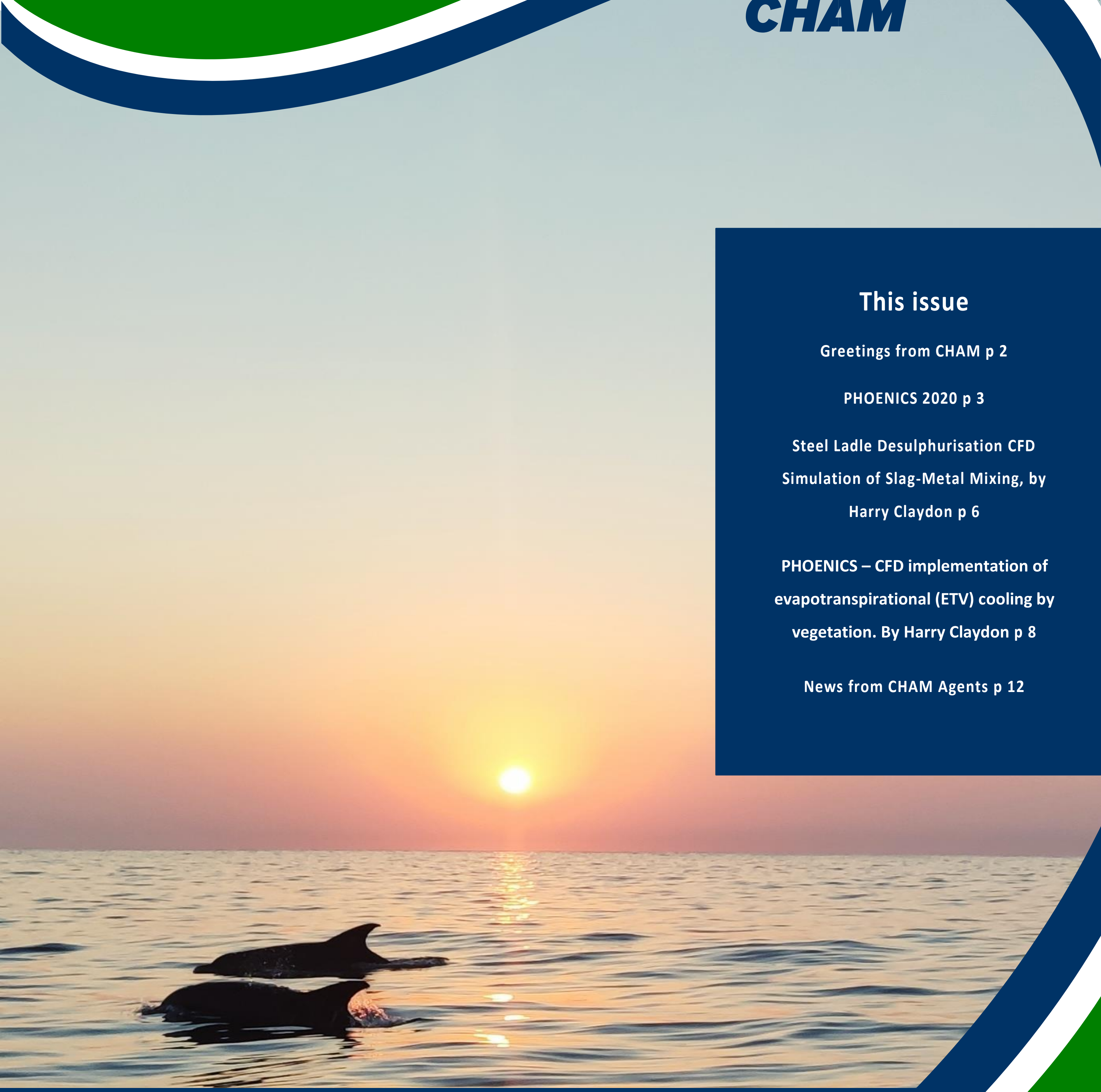
PHOENICS Newsletter

CHAM



This issue

Concentration, Heat and Momentum Limited (CHAM)
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Summer 2020

Welcome to our Summer Newsletter and Greetings from CHAM

It has been an interesting time for CHAM, and for most of the world, as individuals, companies, countries and continents tried to come to terms with the new reality of a global pandemic.

The UK locked down late. CHAM's offices closed, as predicated by the government, from end March to July. During this time we were able to work remotely because of a system that Steve Mortimore put in place and we learned to opeate within – it might be slow but working was, and is, possible.

This meant that CHAM did not furlough any staff but, instead, some staff worked to create new materials, others upgraded PHOENICS, provided support to users and carried out new and ongoing consultancy contracts.

In June we were advised that a return to the office was possible and most of us took advantage of the opportunity. Staff safety is paramount so CHAM personnel were divided into two teams to enable suitable distancing. One team is in the office on Monday and Tuesday, the second on Thursday and Friday The office was deep cleaned before our return, as it is every Wednesday. Hand sanitisers and other accoutrements to ensure staff had access to means of hygiene, were put in place.

It is good to be back, to work within the professional and business environment, albeit in unusual conditions. Hopefully, before long, it will be possible for everyone to work together for the entire week under one roof. We have sufficient space to ensure that staff can be the requisite distance from each other for as long as this is deemed necessary.

Please note that CHAM is still unlocking PHOENICS for use at home. To avail yourself of this facility please contact phoenics@cham.co.uk.

We trust that PHOENICS Clients, Agents, all we have known over the years, have remained healthy throughout this period. With regard to Clients and Agents, we would much like to hear how the pandemic is affecting you, your company, and your country.

We look forward to hearing from you, and working with you, in whatever the new normality may be.

Best wishes.

Colleen Spalding

Contact Us

Should you require any further information regarding our offered products or services please give us a call on +44 (20) 89477651; alternatively you can email us on sales@cham.co.uk.

Visit our website at www.cham.co.uk; we are also on the following social media sites:

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We thank Brett Louw, of South Africa, for letting us use the image on the front cover.

CHAM when first in Wimbledon Village

PHOENICS 2020

PHOENICS, the original commercial CFD Code, was brought to the market by Professor D Brian Spalding FRS, FREng in 1981. It has been regularly upgraded over the last 39 years with the latest release, PHOENICS 2020, being issued in July by the CHAM team based in Wimbledon Village. The release contains useful updates required, or requested, by PHOENICS Users and improvements which the team consider beneficial.

PHOENICS is used worldwide for a range of applications relating to CFD which has become an essential tool for Engineers working in the general environment, the built environment, green energy and industry and many other fields; as well as those involved in research and academe.

The Software models and simulates fluid flow, heat and mass transfer, chemical reaction and combustion in a way that we endeavour to keep easy-to-use and up-to-date.

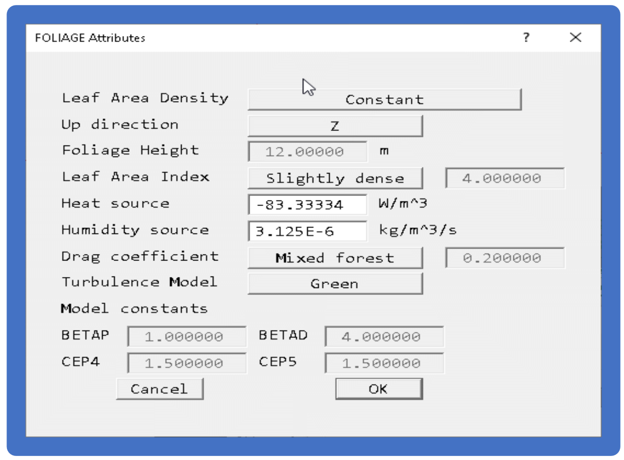
CHAM's expert Consultancy team can assist those with CFD needs *but have neither the expertise*, nor desire, to carry out modelling themselves. Send us your problems and we will work with you to provide optimum, and economically viable, solutions. For general assistance and information contact phoenics@cham.co.uk or telephone +44 208 947 7651.

This article outlines some features of PHOENICS 2020. For more information visit our website (www.cham.co.ik) or telephone the above number and ask for a descriptive leaflet to be sent electronically or in hard-copy format.

Improved foliage model – evaporation and mass transfer

CHAM has implemented a new system for analysing cooling and humidity effects from vegetation which will assist Urban Planners, Architects and Civil Engineers to determine urban vegetation impact on pedestrian comfort.

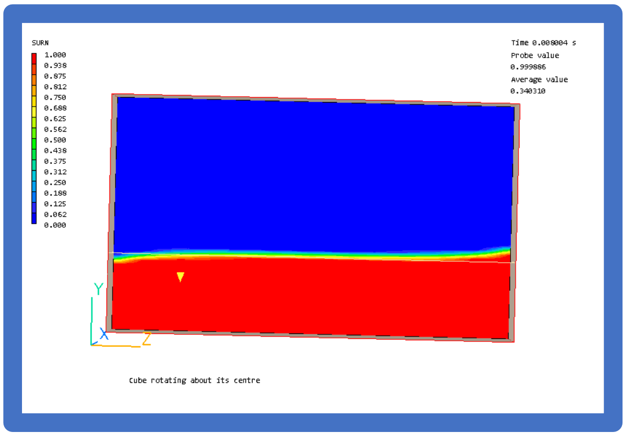
Previously, the PHOENICS "Foliage" object could specify resistance of trees and bushes to the prevailing wind. It now has the additional, optional, capability of specifying, within the defining attributes of the object, the EVT mass transfer rate of moisture from leaves to air, and accompanying (negative) heat source. This means that, for given species of tree, water supply and world location, architects and planners can simulate different arrangements of greenery within a site and determine the resulting impact on the urban environment. (See article on page 8 for further information).

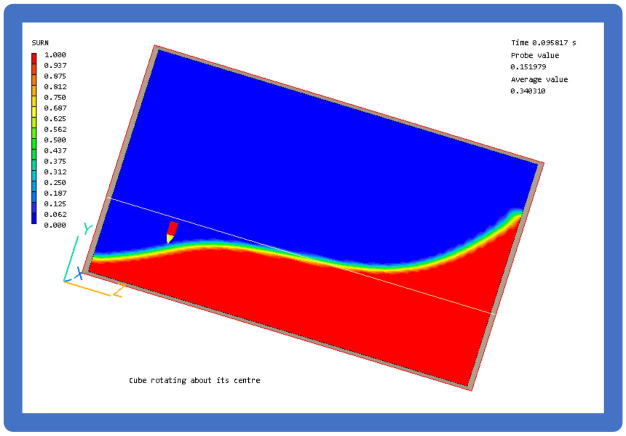


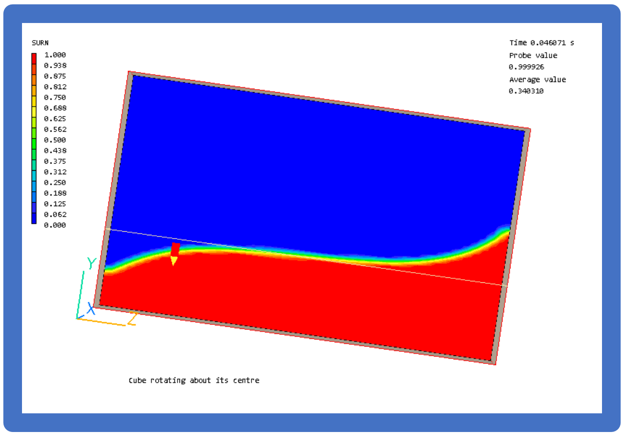
The foliage object represents a group of trees or other vegetation which absorb heat and release water vapour. A pair of input boxes has been added to the foliage object to allow the entry of the cooling rate in W/m3 and water vapour release rate in kg/m3/s. The 'Heat source' box should be set to cooling power of the foliage (typically 250 W/m^2) multiplied by Leaf Area Density. The 'Humidity source' box (available only in FLAIR) should be set to moisture source in $kg/m^2/s$ (of the order 810 $g/m^2/d$), also multiplied by Leaf Area Density.

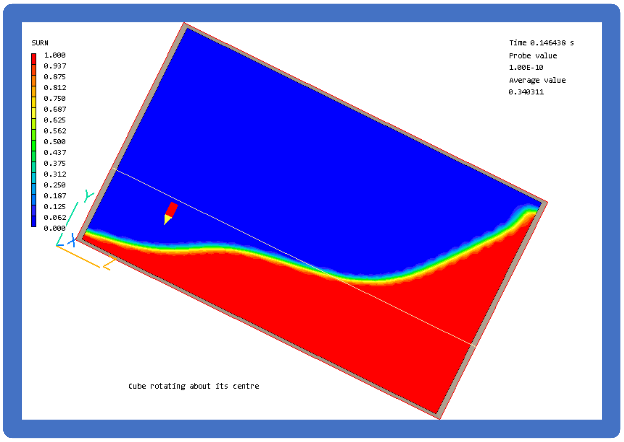
Display of Moving Domain

MOFOR, the moving-objects option in PHOENICS, has been able to impart motion to the entire domain for some time. For example it was possible to model an oscillating tank. The solutions were correct but it could be difficult to display them in the correct orientation. This is resolved. Viewer will automatically display moving domains in their correct position. The following images show time steps from a VOF simulation of an oscillating tank.



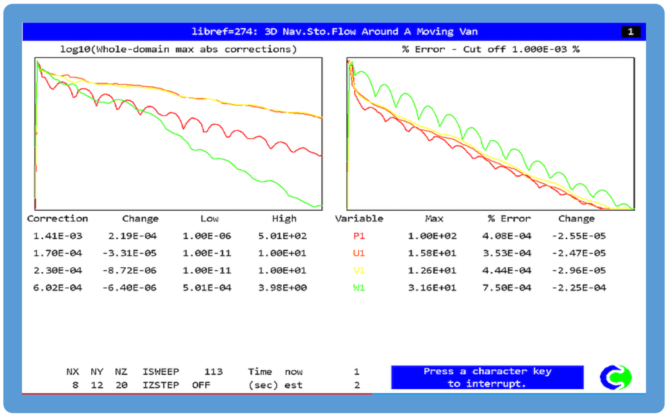






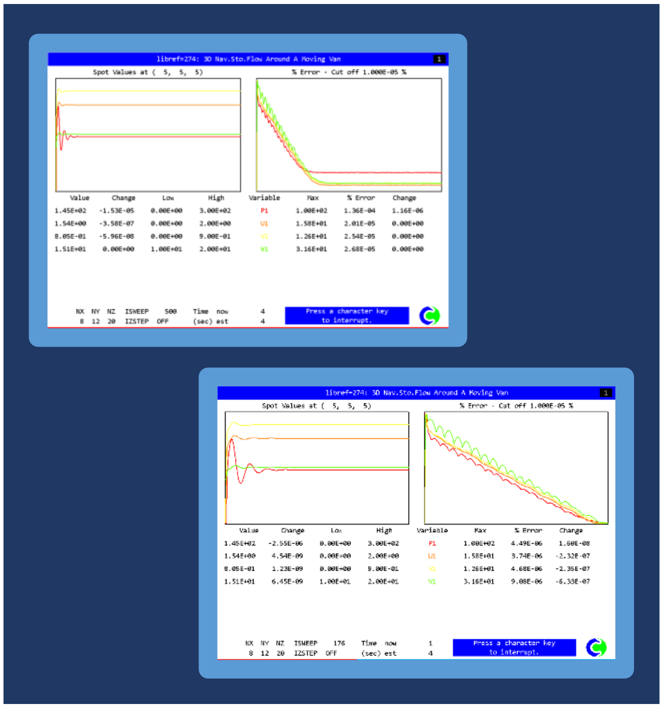
GXMONI – A new combination of monitor graphs added

A fourth monitor-screen option has been added showing maximum absolute correction (left) and logarithmic plot of residuals (right). The option can be activated from VR-Editor 'Options – Solver monitor options' or from the Q1 by setting ISG52=3. All four monitor screens are dumped at run end; the display can be switched between any screen during a run.



Double Precision

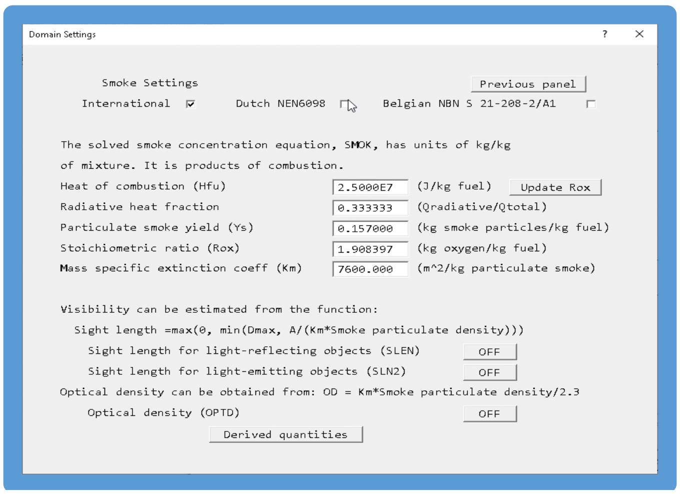
Experience has shown that, in many cases, the use of double-precision can result in smaller residuals, with some cases reaching cut-off level. In VR-Editor 'Options – Solver Precision' is now defaulted to 'Double Precision'. This setting is held in the PHOENICS.CFG file. When restarting a pre-2020 case in PHOENICS 2020, it is advisable to delete any local PHOENICS.CFG (and CHAM.INI) files to take advantage of new default settings.



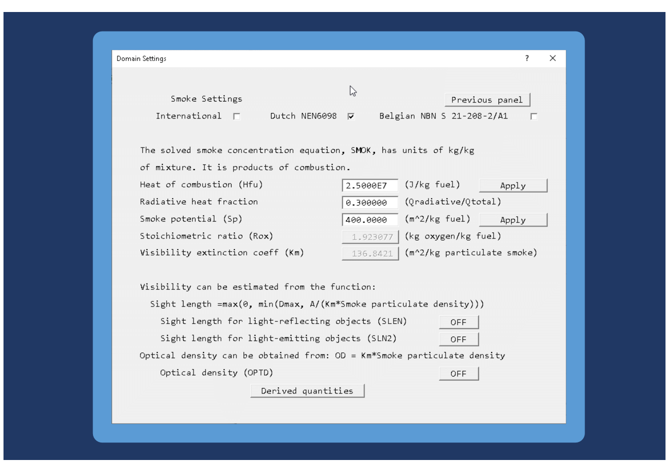
On the left (above), the single-precision solver reaches round-off error in the residuals but continues to solve for all sweeps as cut-off has not been reached. On the right, the double-precision solver reaches cut-off residual value and terminates. This occurs roughly after the same number of sweeps at which the single-precision solver reached round-off.

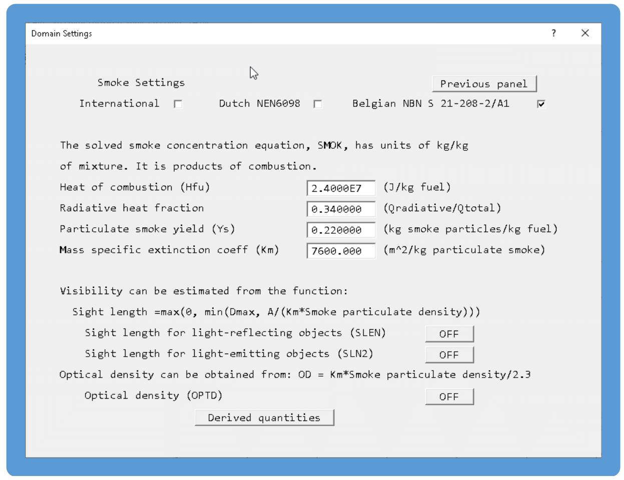
Dutch and Belgian Fire Standards

The FLAIR FIRE object and Smoke solution panels are extended to include Dutch NEN 6098 and Belgian NBN S 21-208-2/A1 Standards. The ’International’ fire and smoke model used in FLAIR for many years is suitable for most cases where rates of production of heat and mass can be prescribed. Dutch and Belgian models are designed to simulate car fires in parking garages and hence are more prescriptive in values used for heat of combustion and heat release rate.

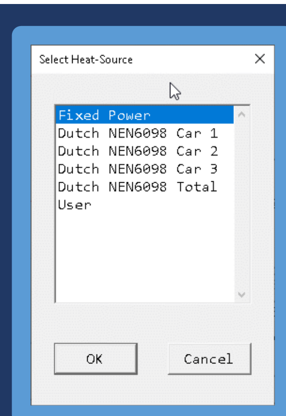


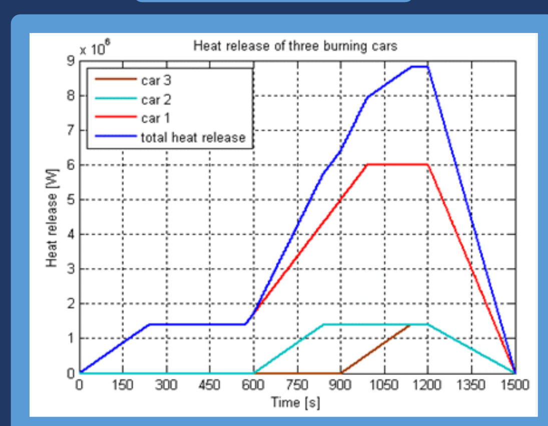
The International model can accommodate the form required by Dutch or Belgian Standards by setting parameters and heat release rates appropriately; this does require some user knowledge of fire and smoke models. Selecting Dutch or Belgian model automatically sets all parameters according to the chosen standard, and displays them in the form used.





For example, to calculate visibility through smoke, the International and Belgian standards use a ‘Mass specific extinction coefficient’, with a default value of 7600m^2/kg. The Dutch standard uses a ‘Smoke Potential’ with a default value of 400m^2/kg. Heat and mass-release options for the FIRE object are also restricted to those described.





The Dutch Standard specifies heat release curves for 1, 2 or 3 cars on fire, with a time delay between the second and first, and third and second cars catching alight. The Belgian Standard is similar, but for one or two cars.

Steel Ladle Desulphurisation CFD Simulation of Slag-Metal Mixing, communicated by Harry Claydon, CHAM, May 2020.

A major steel manufacturer requested CHAM's support in applying a PHOENICS-based CFD model they had developed for simulating a gas-stirred steel ladle to investigate the slag-metal mixing which controls desulphurisation in the production of ultra-low sulphur (ULS) grade steels. Enhanced slag-metal mixing is required at the top interface of the ladle to induce faster refining reactions for reducing sulphur in the melt.

This is achieved by injecting Argon gas through plug locations in the bottom of the ladle. For the production of ULS grade steels, typically, a gas flow rate of 50 SCFM is required per plug to melt the flux powder, and cause sufficiently intense metal-slag mixing at the interface.

An unsteady, three-dimensional, two-phase PHOENICS CFD model was used to evaluate the difference in mixing between using a single plug and two plugs.

The following plug designs were considered in the CFD study:

Case A: The base case of a single 5"-diameter plug injecting 50 SCFM of argon, and located roughly 60% radius at the ladle bottom.

Case B: As Case A, but with a 7" diameter plug.

Case C: Two plugs at the same radial location as Case A, but displaced some 60 degrees from each other; and each with a 5" diameter plug and a gas injection rate of 50 SCFM.

Case D: As Case C, but with 7" diameter plugs.

In this study, mixing time is determined by solving for a passive concentration C2 (tracer), which is injected through the plugs at time zero. Actual mixing time is defined as time required to attain 90% homogenisation throughout the molten steel.

The geometry of the CFD model was created by using only PHOENICS principal objects, without the need for a proprietary piece of CAD software.

This model consists of a ladle with a height of ~3 m and a diameter of ~3 m; only half of the ladle was modelled to exploit symmetry.

Within the ladle there is an inlet of argon (the plug), modelled as air in this simulation, with an inlet velocity of ~1 m/s. As the reaction is unimportant for the simulation purposes, using air is a valid modelling assumption. The domain fluid was set to the density of molten steel. Temperature effects were not considered in this simulation because the aim was to investigate the degree of mixing produced by various gas-injection designs. The standard k-ε turbulence model was used.

In reality the top surface of the ladle is covered with a layer of slag, which can deform as the argon bubble plume strikes and breaks through the free surface. For the purposes of the present study, it is acceptable to ignore the slag layer and model the free surface as a rigid lid through which gas is allowed to escape into the atmosphere.

The model was run as a transient simulation without scalar injection until the hydrodynamics reached a quasi-steady state. After this the tracer was injected and the transient run was continued using a time step of 25 ms for a total duration of 120 s. Below, Figure 1 and Figure 2 show the predicted contour plots of the tracer concentration results 0.5 s into the simulation. As the run progresses, the entire domain gradually turns red, indicating higher tracer concentration and a homogenised mixture.

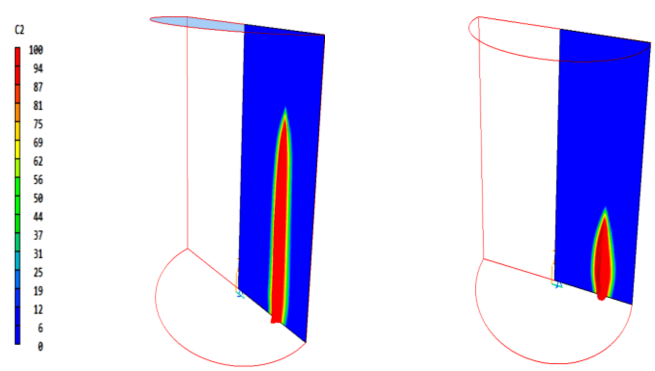


Figure 1: Single-plug Design: Contour plots of C2 scalar (tracer) concentration along plane of injection at 0.5 s. This also shows the 90% tracer iso-surface. Case A, left and case B, right.

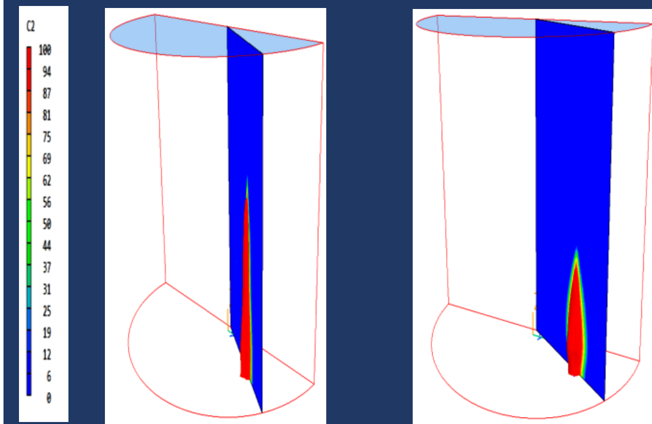


Figure 2: Two-plug Design: Contour plots of C2 scalar (tracer) concentration along plane of injection at 0.5 s. This also shows the 90% tracer iso-surface. Case C, left and case D, right.

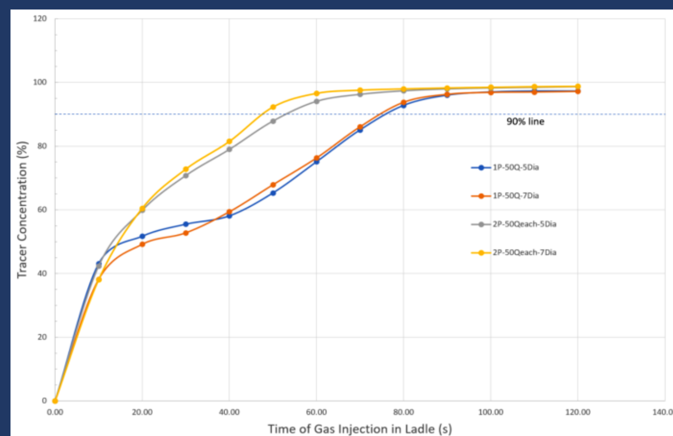


Figure 3: Graph showing the volume-averaged tracer concentration over time for each case, including the 90% concentration threshold line. Case A, blue; case B, red; case C, grey; case D, yellow.

Mixing time curves in Figure 3 show that:

a. The 2 plug cases achieve 90% homogenization much sooner (~50 sec) than the 1 plug cases (~75 sec).
b. There is not much difference in mixing behaviour between 5” and 7” diameter plugs.

The researchers’ results showed that:

a. Use of 2 plugs with 50 SCFM flow causes intense stirring and mixing of the steel in the ladle required for achieving low sulphur level in steel.
b. Mixing time is not very sensitive to plug design, as long as the desired 50 SCFM flowrate can be achieved.
c. For the 2 plug cases, the tracer homogenisation is effectively complete in less than 1 minute, indicating a higher degree of turbulent mixing in the ladle.

The researchers’ conclusion was that, for faster sulphur removal and shorter processing times, the 2-plug design is desirable for use on this steel ladle. The simulations also identified further modelling studies to investigate the possibility of steel splashing and spillage from the top tip of the ladle (freeboard). Such studies will extend the CFD model to allow for a deformable free surface, so as to predict the dome height where the gas plume breaks through the steel surface, and also the accompanying surface waves produced during bottom gas stirring.

These simulations helped the manufacturer to investigate and visualise the melt mixing of the various design cases, and to create a proposal for improving the equipment. In addition, they also led to ideas for further simulations and investigation, which may be used to update and improve the proposed design.

PHOENICS – CFD implementation of evapotranspirational (ETV) cooling by vegetation, by Harry Claydon, CFD Engineer, CHAM.

CHAM has recently implemented a new technique for analysing cooling and humidity effects from vegetation. This capability has been in demand and will help Urban Planners, Architects and Civil Engineers determine the impact of urban vegetation on pedestrian comfort.

The PHOENICS "Foliage" object has provided a means of specifying resistance of trees and bushes to prevailing wind. It now has the additional optional capability of specifying, within the defining attributes of the object, the EVT mass transfer rate of moisture from the leaves to the air, and the accompanying (negative) heat source. This means that for given species of tree, water supply and world location, architects and planners can simulate different arrangements of greenery within a site and determine the resulting impacts on the urban environment.

This article presents an example case to demonstrate the capabilities of the new feature, utilising values for heat and moisture sources taken from the literature. The Urban Heat Island (UHI) is the heating effect of man-made structures, such as buildings and roads, hindering ventilation and trapping solar radiation. It is well known that the heating effect of the UHI can be ameliorated by greenery. The main mechanism for vegetation's role in cooling air temperatures has been identified as having two aspects: shading and evapotranspiration, see Zhang (2019) [1]. The present simulation concerns evapotranspiration effects only. Solar shading is handled separately by PHOENICS.

Figures 1 and 2 show the layout of the model used. Detached houses on the street are modelled as cubes with triangular roofs; for simplicity detailed window and terrace geometry is not modelled in the simulation. Tree canopies on either side of the street are shown in Figure 1 as stylised trees, representing the real-life scenario and modelled for simplicity as continuous rectangular blocks of foliage.

Each house is approximately an 18 m cube and is a standard PHOENICS blockage object with friction and with no heat transfer. The setup is based on the model in figure. 2 of Xue and Li (2017) [2].

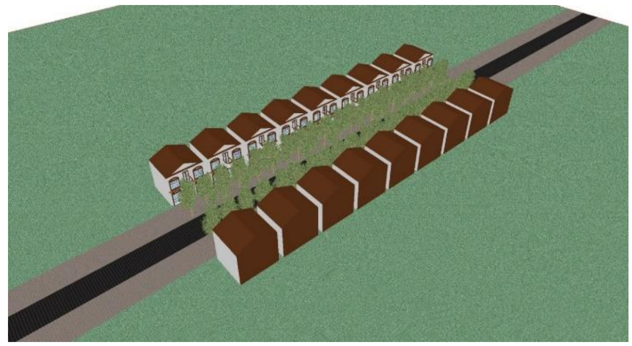


Figure 1: Street setup based on the model in Xue and Li (2017, Figure.1) Two rows of detached houses are separated by a central road and two rows of trees.

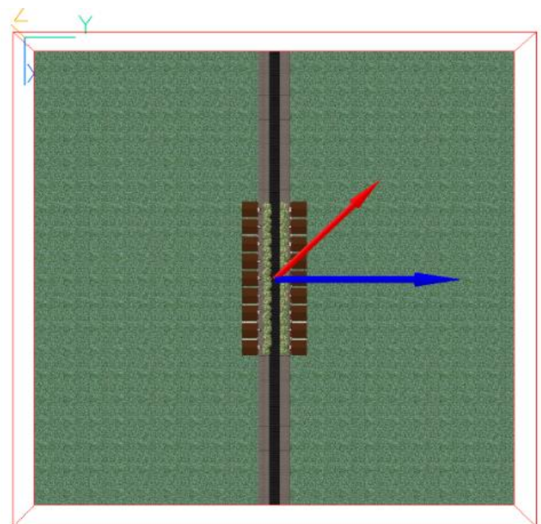
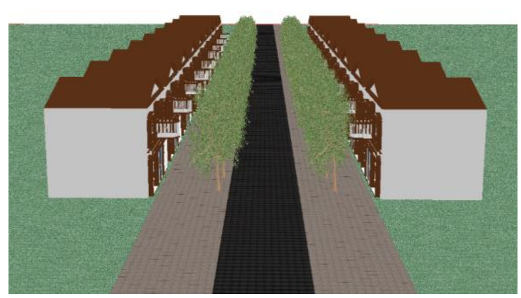


Figure 2: Plan view showing the prevailing wind direction at 45° to the North (+Y) direction.

Side view showing the view down the street.



The Leaf Area Density (LAD) used in this model is from the Leaf Area Index (LAI) divided by average foliage height. LAI was set as "slightly dense", a value of 4, to represent a typical urban tree. LAD was therefore calculated as 0.33, based on a foliage height of 12 m.

The cooling power of the foliage object was set to 250 $W \cdot m^{-3}$ multiplied by LAD. This standard value of cooling power was taken from a paper by Zhang (2019) [1] and was validated using data by Gromke (2015) [3]. The moisture source was set to 810 $g \cdot m^{-2} \cdot d^{-1}$ or 9.375e-6 $kg \cdot m^{-2} \cdot s^{-1}$ multiplied by the LAD; this was also taken from Zhang (2019) [1]. More values for specific species can be found in Mo et al (2007) [4].

It may be helpful to note that more plant-specific parameters are available in Breuer (2003) [5] for LAI, and for stomatal conductance, which is used to calculate the moisture source. More complex equations are available in Gkatsopolous (2017) [6] for specific tree species to calculate more appropriate values for height/spread ratios, along with data for crop coefficients and stomatal conductance. Stomatal conductance is the measure of the rate of passage of carbon dioxide entering, or water vapour exiting, through the stomata of a leaf.

The prevailing wind was set to have a relative humidity of 50 %, ambient temperature of 20 °C, and speed of 4.7 $m \cdot s^{-1}$ at an 18 m reference height at a direction of 45 ° to the +Y direction.

Figures 3, 4, 5, 6 and 7 show results of the simulation. As the wind blows through the trees there is seen to be a decrease in temperature of up to 3 °C along the street at pedestrian level and an increase of up to 10% in relative humidity. The majority of the street experiences at least 1 °C of cooling (Figure 5 & 7) and 3% increase in humidity (Figure 4) due to EVT effects. The "apparent temperature" is approximately 18 °C along the street due to the wind speed remaining quite high (Figure 3 & 6). However, on the leeward side of the buildings, the apparent temperature increases due to stagnating air and lower wind speeds (Figure 6).

Apparent Temperature is a general term for the perceived outdoor temperature caused by the combined effects of air temperature, relative humidity, radiation and wind speed. The formulae for the Apparent Temperature used in PHOENICS-FLAIR are those used by the Australian Bureau of Meteorology. They are an approximation of the value provided by a mathematical model of heat balance in the human body.

Two forms are given by the Australian Bureau, one including radiation (suitable for the working condition of people in direct sunlight) and one without (suitable for the working condition of people walking in the shade). The Apparent Temperature (TAPP) used here is the non-radiation version.

These results are in line with previous studies regarding vegetation's cooling effect; Zhang (2019) [1] and Gerogi et al (2010) [7] show that the amount of maximum temperature reduction was similar at ~3 °C reduction through plant evapotranspiration.

Gromke (2015) [3] found that avenue-trees (as simulated here) were the most effective measure for reducing air temperatures. Cooling by facade greening was noticeable but less strong than by avenue-trees. Roof greening did not result in noticeable air temperature reductions in the canyon. It was found, also, that cooling effects were restricted to the vicinity (≤ 10 m) of the vegetative measures as confirmed by the results of the present simulation.

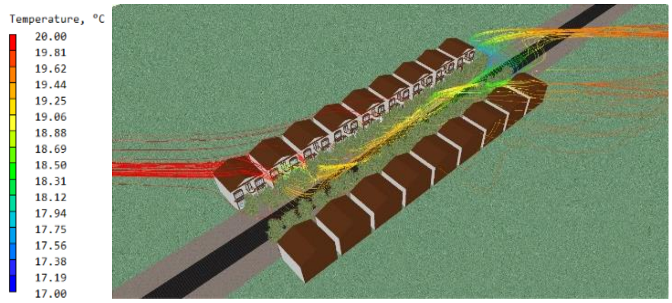


Figure 3: Streamline plot, coloured by temperature, showing the origin and destination of flow along the centre of the street at pedestrian level. Scale: Red – 20 °C; Blue – 17 °C

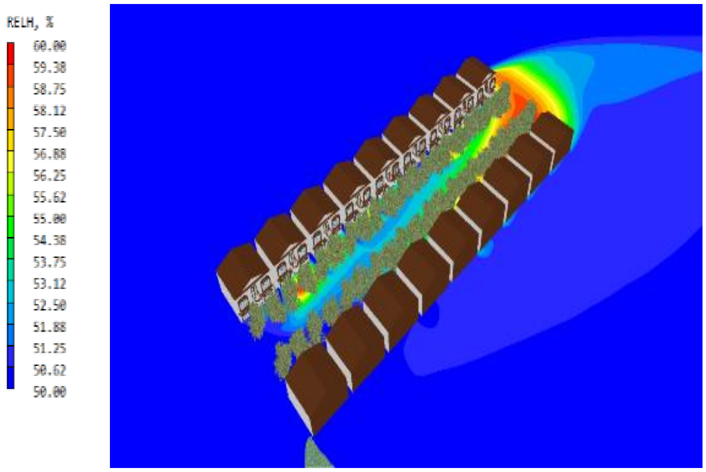


Figure 4: Contour plot of relative humidity at pedestrian level showing up to an increase of 10% humidity towards the leeward end of the street. Scale: Red – 60 %; Blue – 50 %

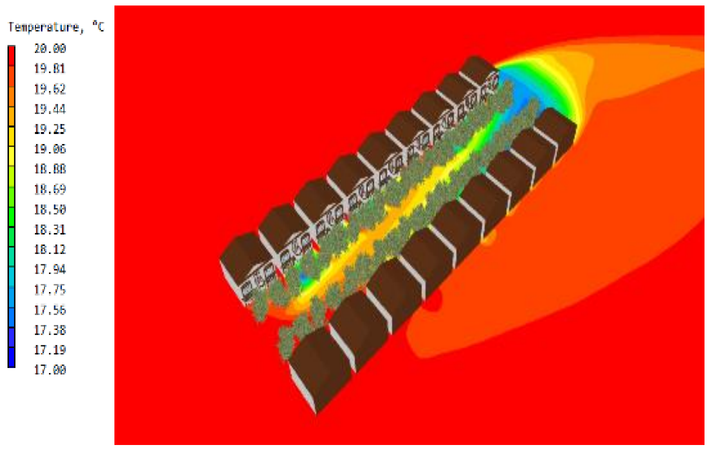
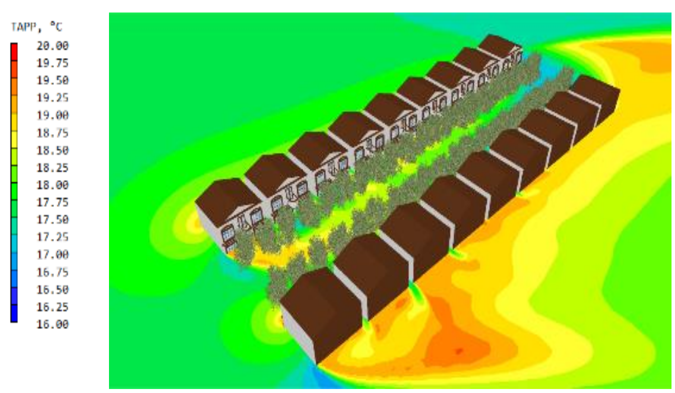


Figure 5: Contour plot of temperature at pedestrian level showing up to 3 °C of cooling towards the leeward end of the street. Scale: Red – 20 °C; Blue – 17 °C

Konarska (2015) [8] states that transpiration of trees is "controlled mainly by the evaporative demand of air, soil water supply and the stomatal control of water loss". In the present simulation it is assumed that there is no lack of water which might hinder transpiration. Konarska also states that "transpiration in darkness is often assumed to be negligible due to stomatal closure. However, several studies have reported non-negligible night-time stomatal conductance and transpiration of trees in natural stands". The present simulation is run assuming the maximum stomatal conductance and transpiration rate at midday (as imposed by the figures taken from Zhang (2019)), but this is variable depending on weather conditions and time of day.

Figure 6: Contour plot of apparent temperature at pedestrian level showing up to 3 °C of cooling towards the leeward end of the street. Scale: Red – 20 °C; Blue – 16 °C



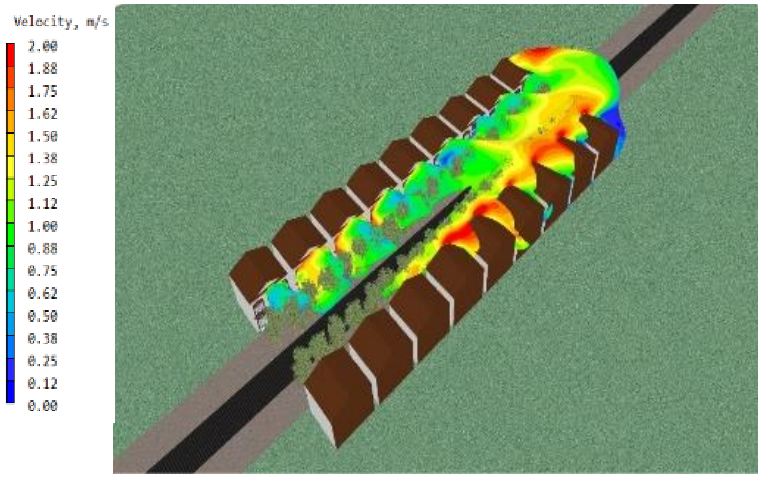


Figure 7: Iso-surface plot of temperature at 19 °C, coloured by velocity, demonstrating that the majority of the street experiences at least 1 °C of cooling due to evapotranspiration.

The paper by Zhang [1] examines how the arrangement of vegetation affects microclimate air temperatures in an apartment housing complex, for various wind flows. It was found that a given total area of vegetation was more effective at reducing the air temperature when divided into smaller units, rather than being concentrated in one place; placing small vegetation spaces close to buildings was better than locating them centred between buildings which are further apart.

To conclude, this model has helped to illustrate how the new EVT feature embodied in the foliage object of PHOENICS can be used to simulate realistic effects of vegetative cooling.

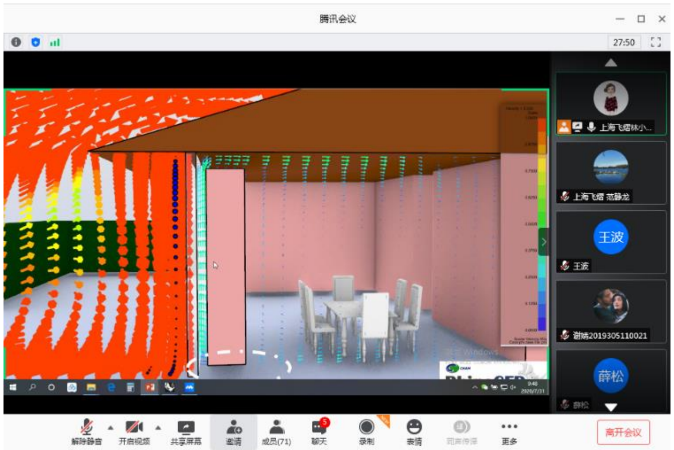
It also provides a brief review of some of the literature around the subject, which should provide a good starting point to help architects and urban planners who wish to model EVT in PHOENICS simulations

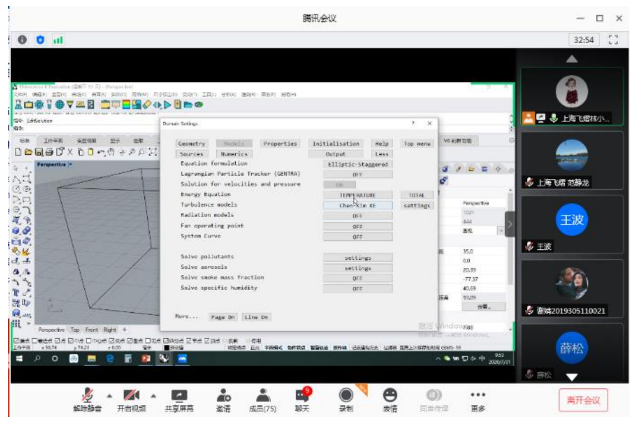
References

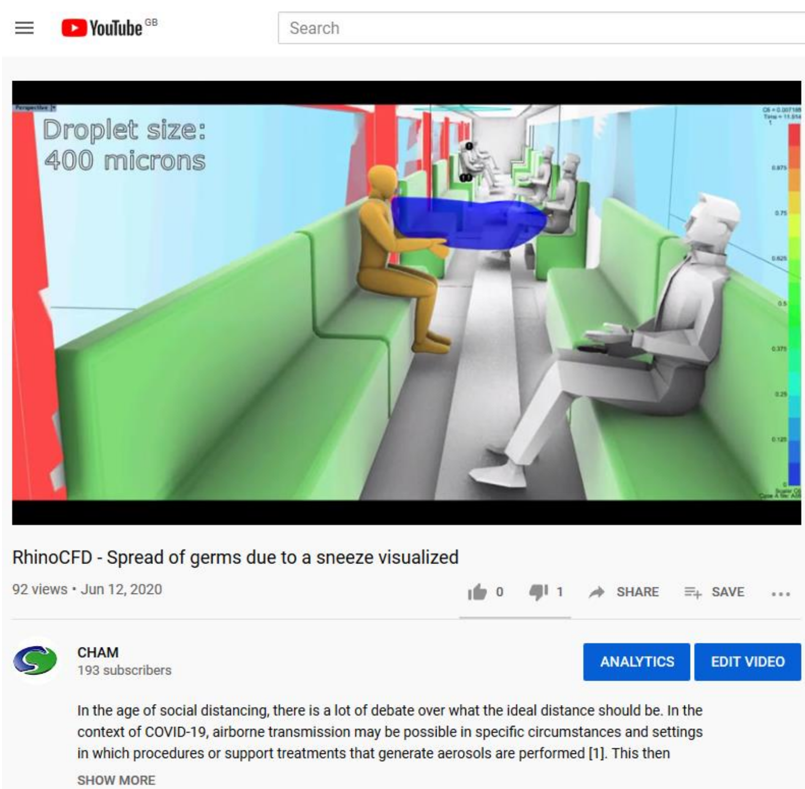
1. Zhang,M., et al, "*The Effects of the Layouts of Vegetation and Wind Flow in an Apartment Housing Complex to Mitigate Outdoor Microclimate Air Temperature*", Sustainability 11(11), 3081 (2019)
2. Xue,F. and Li,X., "*The impact of roadside trees on traffic released PM10 in urban street canyon: Aerodynamic and deposition effects*", Sustainable Cities and Society 30, pp195–204 (2017)
3. Gromke,C., et al, "*CFD analysis of transpirational cooling by vegetation: Case study for specific meteorological conditions during a heat wave in Arnhem, Netherlands*", Building and Environment 83, pp11—26 (2015)
4. Mo, J.B.; Wang, L.M.; Qin, J.; Huang, J.; Hu, Y.H.; "*Study on temperature decreasing and humidification of ornamental plants in Shanghai.*", J. Anhui Agric. Sci. 35, 9506–9507. (In Chinese) (2007)
5. Breuer,L., et al, "*Plant parameter values for models in temperate climates*", Ecological Modelling 169 pp237–293 (2003)
6. Gkatsopoulos,P., "*A Methodology for Calculating Cooling from Vegetation Evapotranspiration for Use in Urban Space Microclimate Simulations*", Procedia Environmental Sciences 38, pp477–484 (2017)
7. Georgi, J.N.; Dimitriou, D. "*The contribution of urban green spaces to the improvement of environment in cities: Case study of Chania, Greece.*" Build. Environ. (2010), 45, 1401–1414.
8. Konarska,J., et al, "*Transpiration of urban trees and its cooling effect in a high latitude city*", Int J Biometeorol 60, pp159–172 (2016)

News from CHAM Agents

Shanghai Feiyi held an online RhinoCFD seminar on July which attracted 75 attendees. The material used was taken from the RhinoCFD Section of the CHAM website www.cham.co.uk.







CHAM has modelled the spread of a sneeze of varying droplet size using RhinoCFD. This can be viewed at https://www.youtube.com/channel/UCYD-5MDLuOS8RRbI5-53Xsg.