PHOENICS 2019

PHOENICS was the first commercial Computational Fluid Dynamics (CFD) code offered to a market which today is worth some £2.5 billion sterling worldwide (excluding R&D work carried out in government departments, academe, etc).

PHOENICS was, and is, available from CHAM the first consulting company to offer CFD services. Thus PHOENICS is the most established software of its kind, based on a lifetime of the scientific knowledge of Professor Brian Spalding, FRS FREng; Founding Father of CFD.

PHOENICS is reliable, cost effective, extensively validated and, we believe, the only independent commercial CFD software currently available.

Professor Spalding's team, at CHAM, continues his work - updating PHOENICS to incorporate features requested by Users, suggested by advances in technology, or related to current environmental and industrial issues.

Our team works to ensure that our software is easy to use, economic, and optimizes simulations.

We provide expert assistance to those who do their own modelling and those who prefer simulations performed for them or as part of a cooperative effort. Send us your problems - we will provide solutions.

Contact phoenics@cham.co.uk or ring +44 208 947 7651 for help and information.

Introduction

General

PHOENICS is the first, and the most established, commercial CFD Software available. It is reliable, cost effective and has a proven track record. It can simulate scenarios involving fluid flow, heat and mass transfer, combustion and chemical reactions for a wide range of applications in industry and the built environment.

PHOENICS can be used for a wide range of applications in the general environment, the built environment, relating to sewage disposal and green energy and in industry; it can simulate scenarios involving fluid flow, heat and mass transfer, chemical reaction and combustion.

Contact us by telephone, email or via the website to obtain assistance with any and all fluid-flow problems you may be facing.

PHOENICS-2019

PHOENICS-2019 features, designed to assist in modelling a variety of scenarios with greater efficiency and speed, include:

1) Incorporation of additional linear equation solvers and pre conditioners including several from the HYPRE suite
2) Extensions to the Volume-of-Fluid (VOF) Method
3) PARSOLI Upgrade
4) New P1-T3 Radiation Model
5) Solar Illumination Model Upgrade
6) Improved treatment of Angled-In Objects by SPARSOL
7) CVD Upgrade
8) Simplified Menus
9) Iso-Surface Upgrade
10) Improved Surface Contours

Upgrades to the Earth Solver

Additional Linear Equation Solvers

PHOENICS-2019 incorporates additional linear-equation solvers and pre-conditioners, including several from the HYPRE suite. The new solvers, especially those from HYPRE, are less affected by grid refinement, and should prove superior for fine grids, especially when many blocked cells are present.
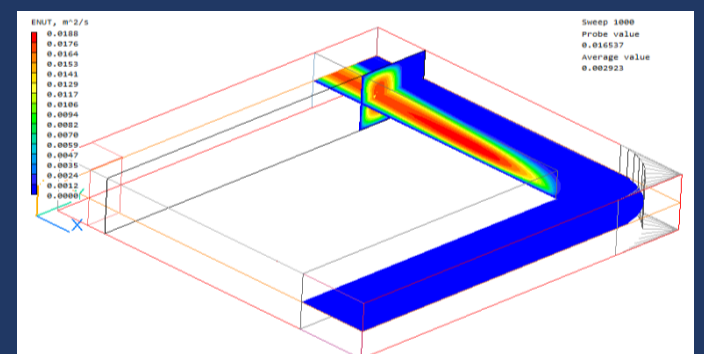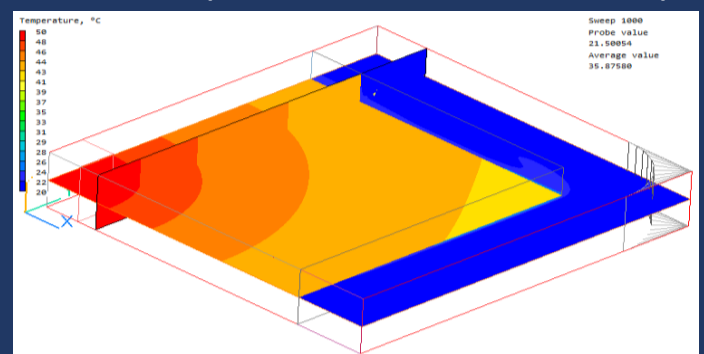
Use of the HYPRE BoomerAMG Solver

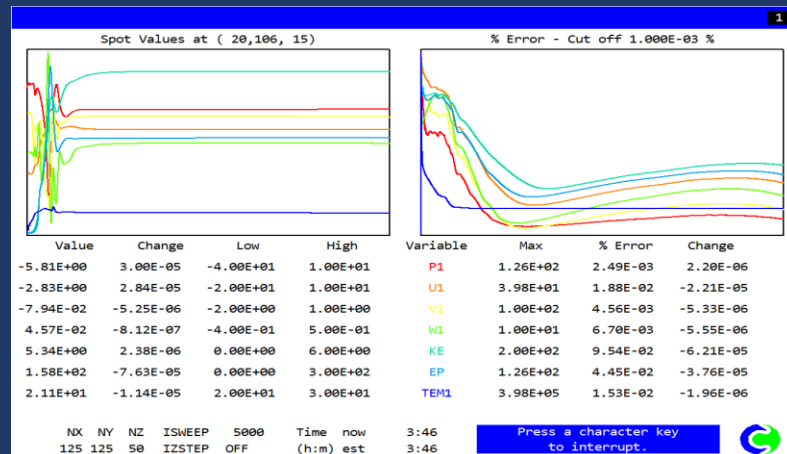This shows the effect of one new solver for flow in an L-shaped duct:
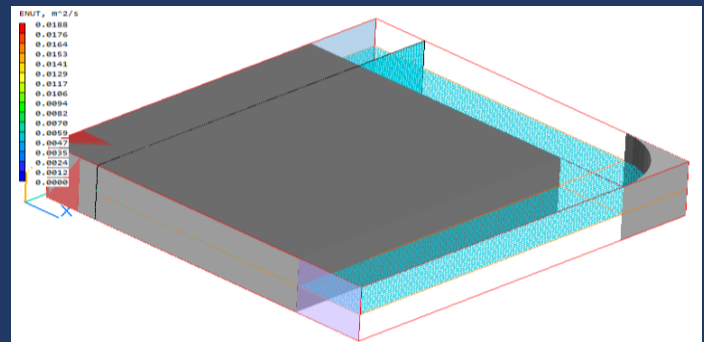
Flow Field
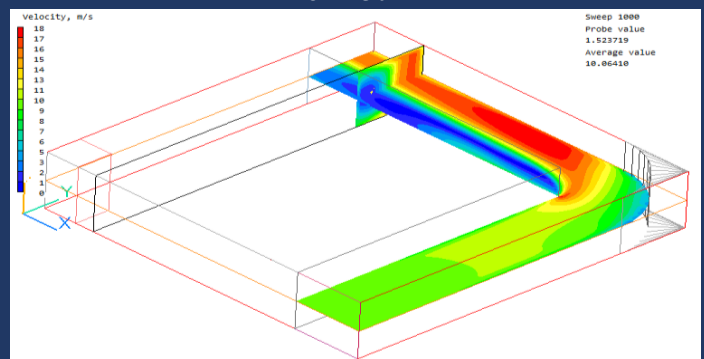
The blockage is participating; red in the corner is a fixed temperature region. The overall grid is 125*125*50; that in the open part of the duct is 50*50; and the blocked part is 75*75*50. The solution is as expected:
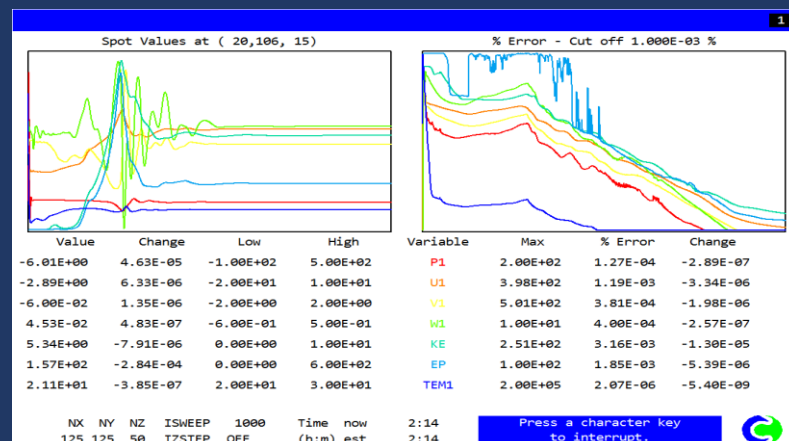
Using default solvers, a 5000 sweep run takes 3:45 hrs, and convergence is:

Value	Change	Low	High	Variable	Max	% Error	Change
-5.81E+00	3.00E-05	-4.00E+01	1.00E+01	P1	1.26E+02	2.49E-03	2.20E-06
-2.83E+00	2.84E-05	-2.00E+01	1.00E+01	U1	3.98E+01	1.88E-02	-2.21E-05
-7.94E-02	-5.25E-06	-2.00E+00	1.00E+00	V1	1.00E+02	4.56E-03	-5.33E-06
4.57E-02	-8.12E-07	-4.00E-01	5.00E-01	W1	1.00E+01	6.70E-03	-5.55E-06
5.34E+00	2.38E-06	0.00E+00	6.00E+00	KE	2.00E+02	9.54E-02	-6.21E-05
1.58E+02	-7.63E-05	0.00E+00	3.00E+02	EP	1.26E+02	4.45E-02	-3.76E-05
2.11E+01	-1.14E-05	2.00E+01	3.00E+01	TEM1	3.98E+05	1.53E-02	-1.96E-06

NX NY NZ ISWEEP 5000 Time now 3:46
125 125 50 IZSTEP OFF (h:m) est 3:46
Press a character key to interrupt.

Residuals initially decrease rapidly, level off, and then start to increase again before reducing towards the end of the run. Using the AMG solver for P1 and TEM1, and CGRS+PBP (Conjugate-Gradient-Residual Solver with Point-By-Point pre-conditioner), a 1000 sweep run takes 2:15 hrs, and convergence is:

Value	Change	Low	High	Variable	Max	% Error	Change
-6.01E+00	4.63E-05	-1.00E+02	5.00E+02	P1	2.00E+02	1.27E-04	-2.89E-07
-2.89E+00	6.33E-06	-2.00E+01	1.00E+01	U1	3.98E+02	1.19E-03	-3.34E-06
-6.00E-02	1.35E-06	-2.00E+00	2.00E+00	V1	5.01E+02	3.81E-04	-1.98E-06
4.53E-02	4.83E-07	-6.00E-01	5.00E-01	W1	1.00E+01	4.00E-04	-2.57E-07
5.34E+00	-7.91E-06	0.00E+00	1.00E+01	KE	2.51E+02	3.16E-03	-1.30E-05
1.57E+02	-2.84E-04	0.00E+00	6.00E+02	EP	1.00E+02	1.85E-03	-5.39E-06
2.11E+01	-3.85E-07	2.00E+01	3.00E+01	TEM1	2.00E+05	2.07E-06	-5.40E-09

NX NY NZ ISWEEP 1000 Time now 2:14
125 125 50 IZSTEP OFF (h:m) est 2:14
Press a character key to interrupt.

Pressure and temperature residuals are below cut-off and others are not far behind. The run converges better in less time. The TEM1 residual reduces to a low value because the AMG run was performed with the double-precision solver. With single-precision the TEM1 residual stalls as in the default run.

For a full list of available linear equation solvers and pre-conditioners go to: (www.cham.co.uk/phoenics/d_polis/d_enc/solvers.htm).

Not all pre-conditioners are available for all solvers. HYPRE solvers use only PBP or HYPRE pre-conditioners. Stone, MSIP and AMG do not require pre-conditioners All Solvers and pre-conditioners can be activated on a pre-variable basis from the Main Menu – Models – Solution control / Extra variables panel.

New solvers and pre-conditioners load only 'live' cells into the solver matrix. This can greatly reduce the solver workload, at the expense of having to copy coefficients into the solver matrices, and then to copy the solution out. There is also a load balancing algorithm for parallel operation which ensures that all processors solve approximately the same number of equations regardless of blockage distribution.

Historically, PHOENICS solvers, in sequential and parallel mode solved over all cells in the domain regardless of cell blockages. Blockages in a large proportion of cells may be adversely affected. In parallel, load balancing may be hard to achieve as some processors may have few or no active cells.

New Boundary Conditions for Non-Participating Blockages

Users can set a range of heat and scalar boundary conditions on the outer surface of a faceted non-partietcipating blockage (ie one using material 198 and not using a geometry starting 'cube').
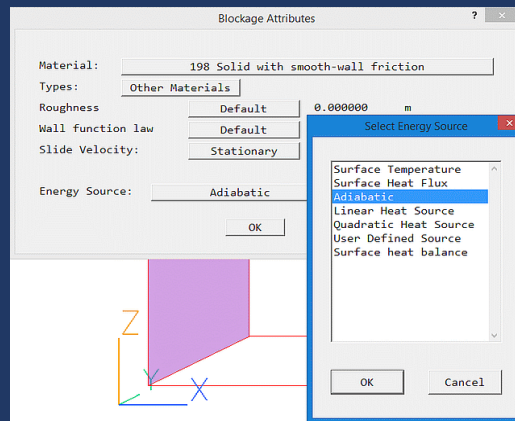
When IMMERSOL or P1-T3 radiation models are active, the 'adiabatic' condition is implemented as at adiabatic plates - the sum of convective and radiative fluxes is zero rather than each flux being zero. Surface temperature (stored in TWALL) is deduced and used as the thermal and radiative boundary condition. Images below show Temperature and T3 contours for flow past two adiabatic blocks, from PHOENICS 2018 and PHOENICS 2019.

Tem 1 Contours PHOENICS 2018

Tem 1 Contours PHOENICS 2019

Tem 3 Contours PHOENICS 2018

Tem 3 Contours PHOENICS 2019
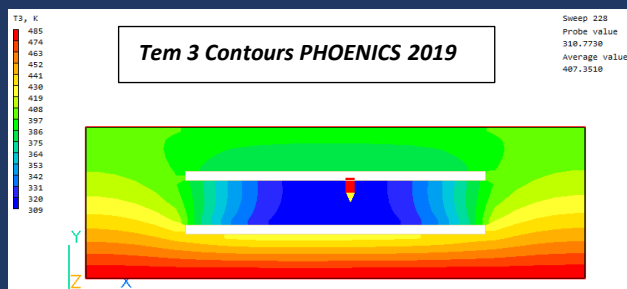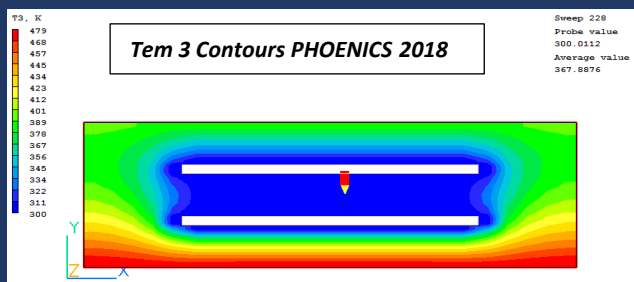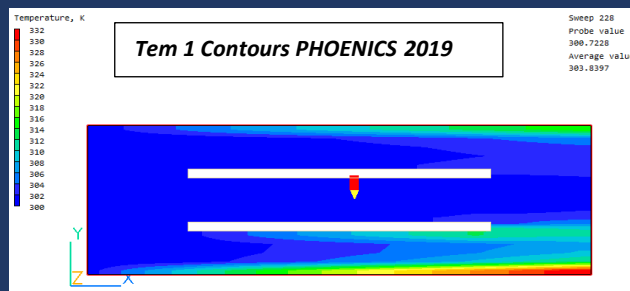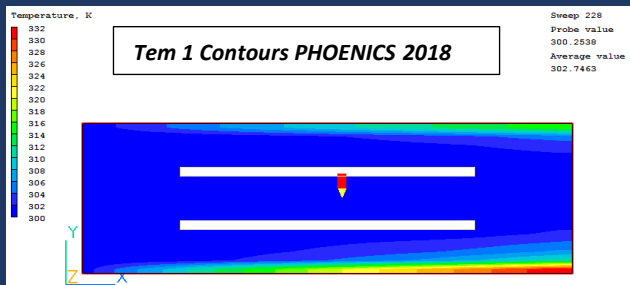
The 'surface heat balance' option is new. Surface temperature is deduced from a heat balance between fluid temperature in the cell adjacent to the surface and a fictitious, user-set, internal temperature and internal resistance. The heat flux is computed based on surface temperature and an external heat transfer coefficient obtained from the wall function, or user-set constant.

Extensions to Volume-Of-Fluid Method (VOF)

THINC-WLIC is implemented as an additional VOF method. THINC (Tangent of Hyperbola for INterface Capturing) uses hyperbolic tangent functions to devise a conservative, oscillation-less, smearing-less scheme which is competitively accurate compared to most existing methods with no geometry reconstruction. Multi-dimensional computing is conducted by the WLIC (Weighted Line Interface Calculation) method.

All VOF methods can solve temperature-dependent cases, with proper treatment of temperature in each phase and in immersed solids. The images show a drop of hot fluid falling over a solid obstacle.

Fluid is red

Contour of Temperature in the fluid and solid
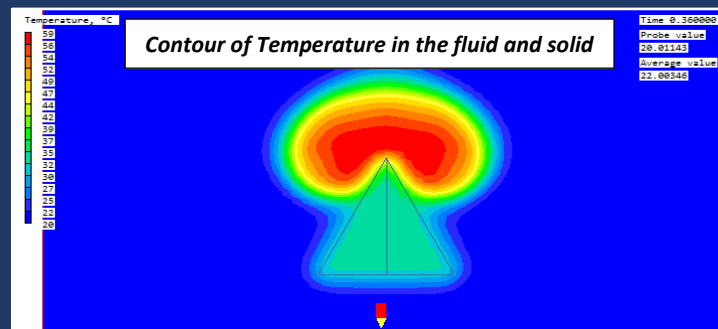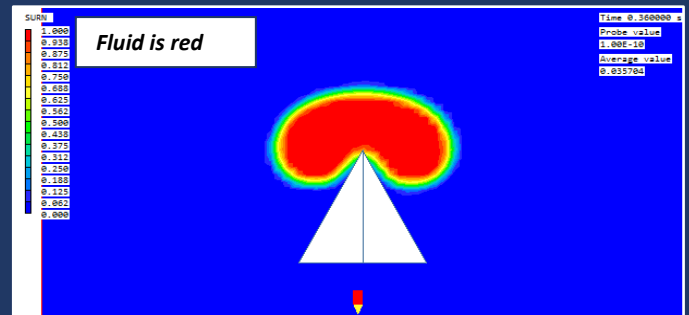
Options have been added to make surface tension a linear function of temperature, or to use the Langmuir equation of state which includes a scalar as well as temperature. A constant static contact angle can be specified to model wall adhesion effects.

PARSOL Upgrade

In PHOENICS 2019 SPARSOL remains the default cut-cell method. PARSOL, the alternative, has been rewritten and detection quality improved. The images show property-marker PRPS fields produced for flow in a channel carved from a solid block (Library case 627) by PHOENICS 2018 and PHOENICS 2019. The new PRPS fields are smoother and fit the geometry better
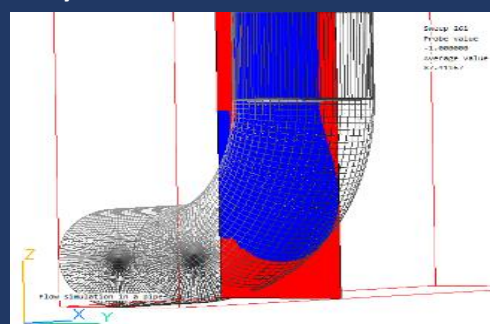
PHOENICS 2018
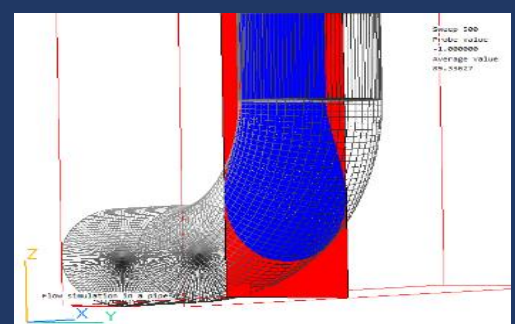
PHOENICS 2019
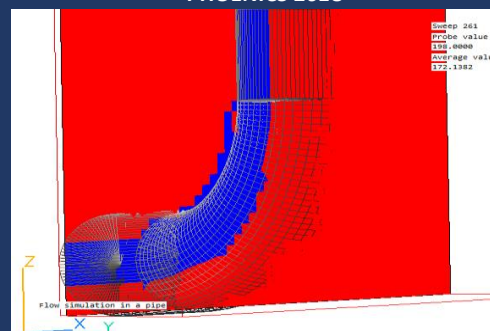
PHOENICS 2018
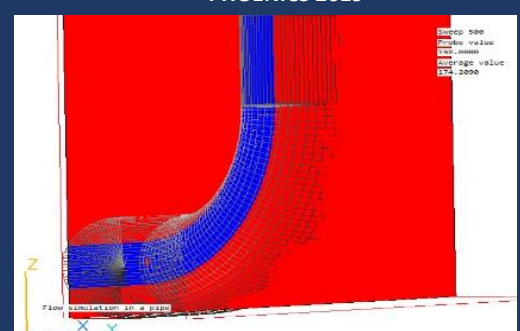
PHOENICS 2019

Choosing 'Old-PARSOL' as the cut-cell method on 'Grid mesh settings' dialog allows Users who wish to reproduce previous results as closely as possible to do so by causing Earth to use the 2018 Parsol. This can also be achieved by adding ISG60=1 in group 19 of the Q1.

New P1-T3 radiation model

Radiation model P-1 T3 is a simplified form of IMMERSOL that ignores the inter-wall distance term. It is, therefore, essentially the same as the composite-radiosity model, but with the radiant temperature T_3 as dependent variable, rather than the radiosity R.

P1-T3 can be used for conjugate-heat-transfer applications; the composite radiosity model cannot.

P1-T3 is applicable to optically-thin and thick media, typically when optical thickness $\tau > 1$, but especially when it is large, ie $\tau \gg 1$. If τ is small or the media are transparent, IMMERSOL is recommended. Here $\tau = a*L \gg 1$, where L is the characteristic dimension of the solution domain, such as width or height of a duct, or diameter of a combustion chamber.

Upgrade to solar illumination model

The shading algorithm used by the SUN object has been rewritten and is considerably faster. The shading shown in the next image was calculated in under a minute

The illumination is calculated for each cell in the air space, not just on the object surfaces. This would have been impractical using the previous method.

SPARSOL - Angled-In Objects

SPARSOL Treatment of ANGLED-IN has been improved as illustrated the following images which show an ANGLED-IN acting on the surface of a wedge blockage in PHOENICS 2018 and 2019.
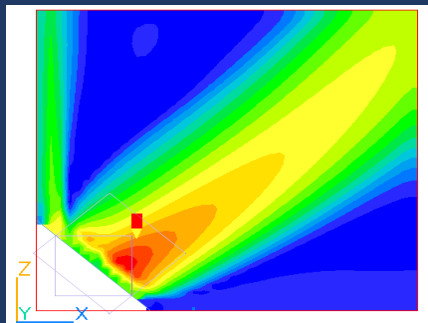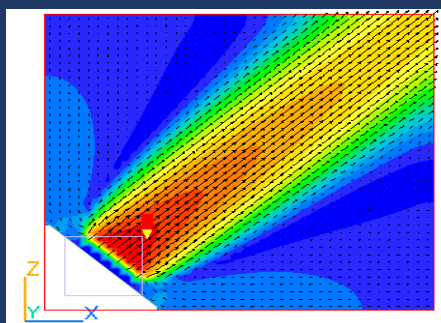
PHOENICS 2018   *PHOENICS 2019*

CVD upgrade

The number of gas species has been increased to 100 and surface reactions to 150. Error messages issued for errors in reaction database files have been made more informative.

Wind Attenuation Coefficient (WAT) for FLAIR

WAT is defined as modelled speed divided by speed in absence of geometry minus 1.

```
WAT = (absolute velocity / wind speed at local height) -1
```

The derivation of this coefficient is activated from the WIND object dialog, and the values are placed in the 3D store WAT for display in the Viewer.

## AIRVOL as synonym for ROOM object

The existing ROOM object is used to define a volume of space. The Earth solver calculates object volume, excluding solid obstructions, and sums up volumetric inflow rate across the object boundary, including internal air supply. It prints, into the RESULT file, Air Changes per hour for the object-defined volume object. This is calculated from 3600.0*(sum of volumetric inflows) / (room volume). The ROOM object has no effect on the solution. As this function can apply to any open or closed volume, not just a room, the synonym AIRVOL has been introduced to make this clearer to Uers.

# Improvements to the Editor

Simplified menus

VR-Editor Main Menu panels operate in two modes, (show) Less and (show) More. (Show) Less is equivalent to previous versions in that all available options are presented. The (show) More mode displays only the most commonly used options. The first image shows Main Menu Models panel in default (show) Less mode. The mode is recorded in the Q1 file saved at the end of the session, and will be used next time the Q1 is loaded.
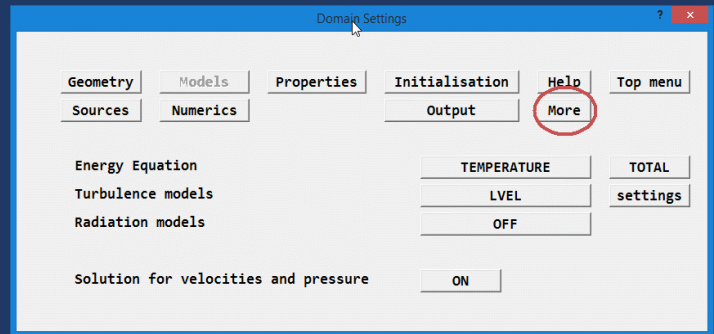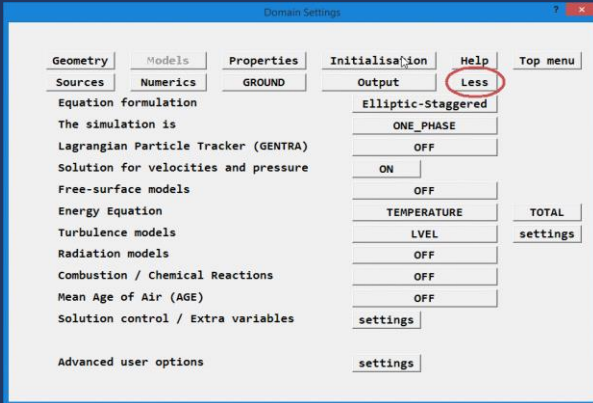
Full Menu – pressing 'Less' changes dialogue to that on the right.

Reduced Menu – pressing 'More' restores full menu shown left.

Panels have been modified to reduce the use of 'jargon' or command language:
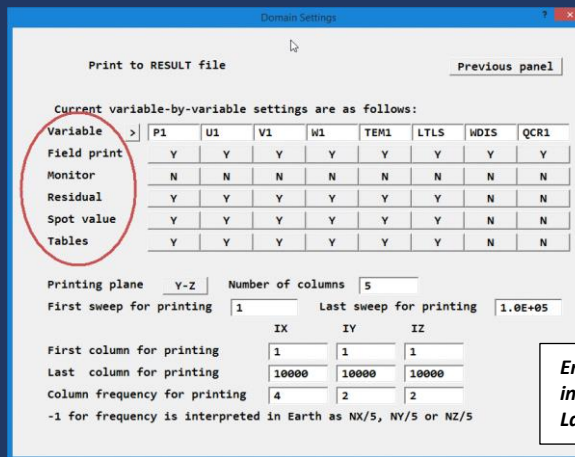
English description of menu items instead of PHOENICS Input Language variables

Menu selection of solver / pre-conditioner pairs
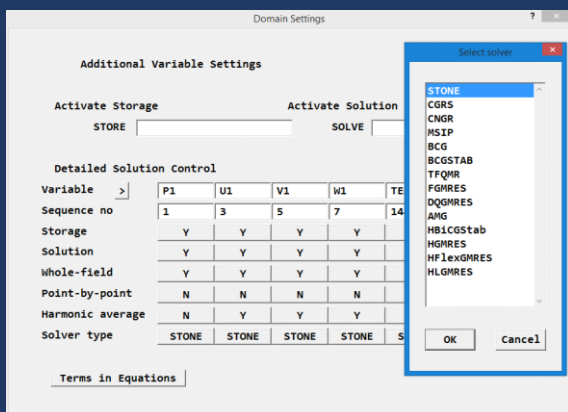
Selection of Solvers
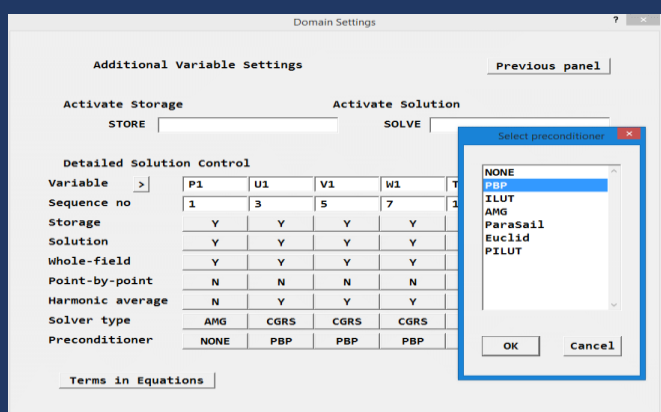
Selection of Pre-conditioners

GUIs for service programs phisum, phidiff and pho2vtk
Use Main Menu - Run – Utilities to access.
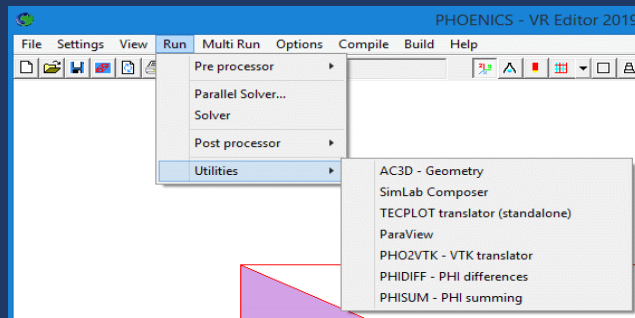
To produce interfaces like this (for PHIDIFF) the utility subtracts field values in file 2 from those in file 1 and creates a new file containing the differences.
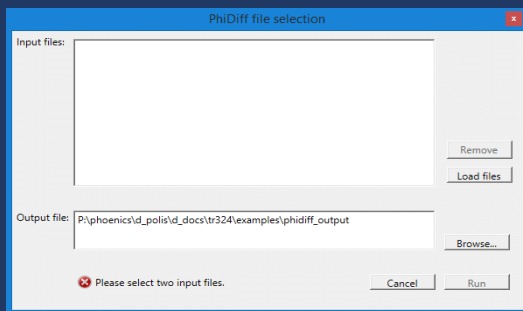

Extended GUI for new P1-T3 radiation model
The new P1-T3 radiation model is under Main menu - Models – Radiation
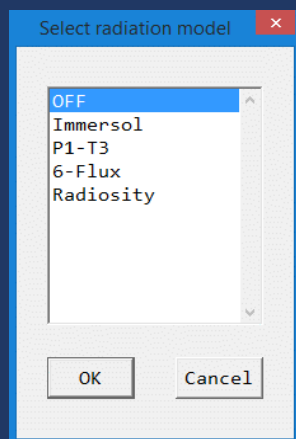
Calculation of Q-Criterion and Vorticity
Main Menu - Output - Derived Variables panel has been updated to allow activation of calculation and storage of Q-criterion and Vorticity. The following images show Q-criterion and Vorticity contours during vortex shedding from a square block:
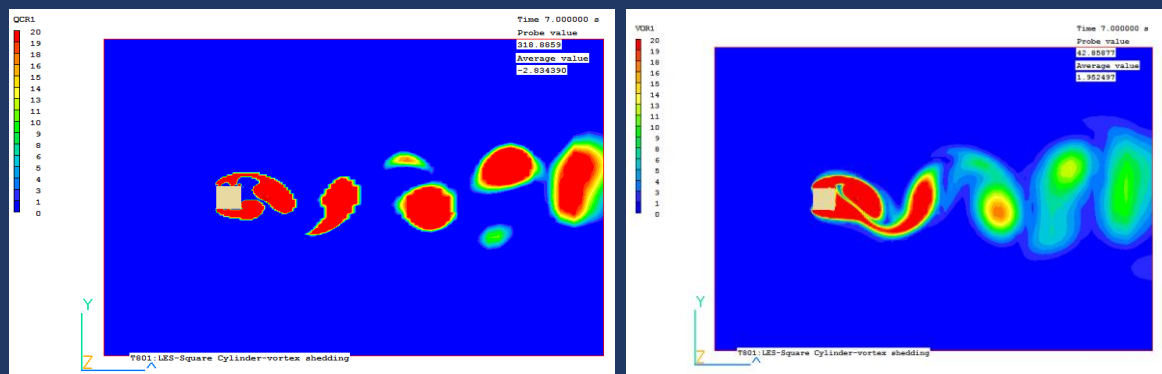
Improvements to Viewer

Iso-surface Upgrade

The iso-surface contour feature has been extended to allow an iso-surface of one variable to be coloured by the contour map of another. This is activated from the 'Surface' tab of the 'Viewer Options' dialog.
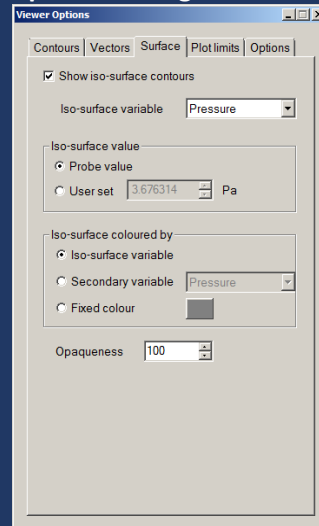
The 'secondary' variable can be any SOLVEd or STOREd variable. The image below shows an iso-surface of P1 coloured by Velocity:
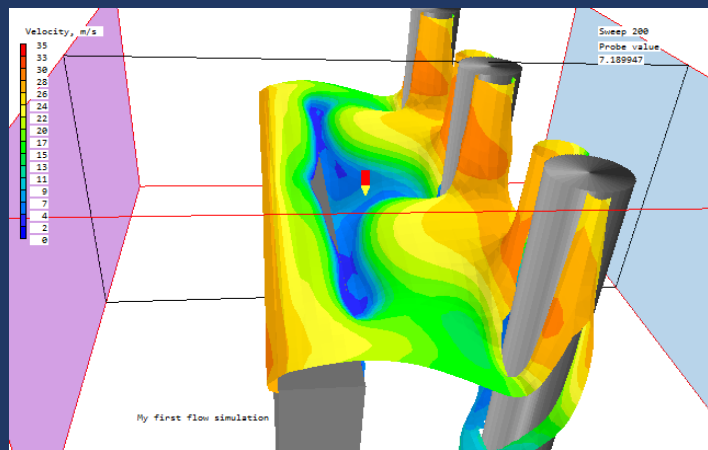
The 'Fill', 'Lines' and 'Fill and lines' options on the 'Contour' tab also operate on the iso-surface contour map.
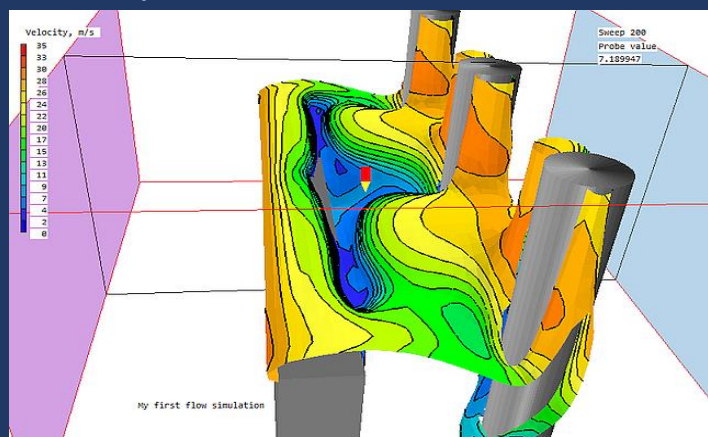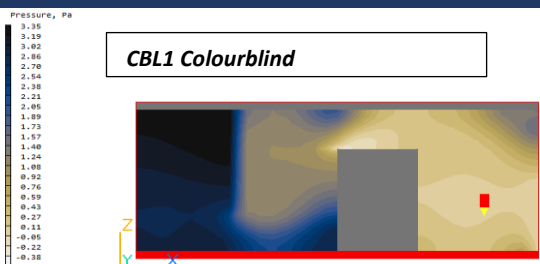
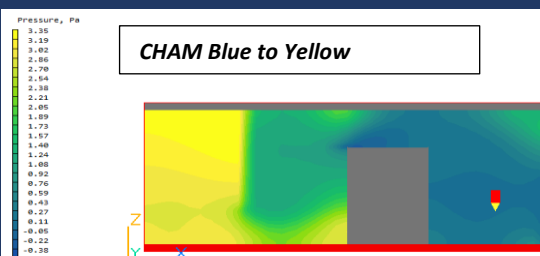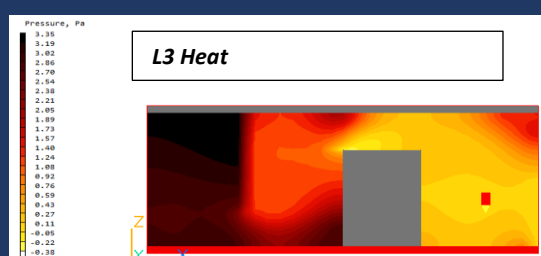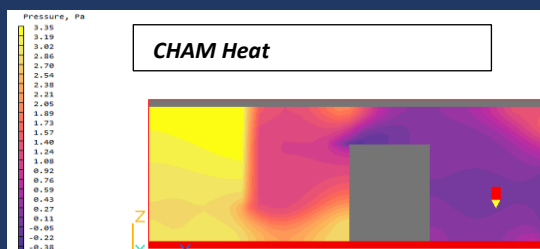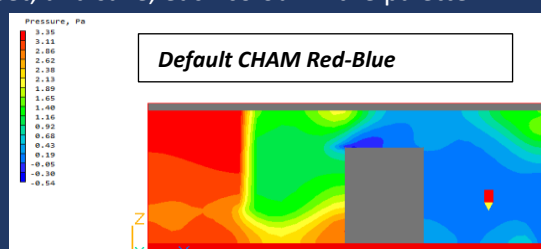# Auto update of display when Earth dumps new file

Clicking F9 leads Viewer to refresh screen images from the latest solution file Earth writes. Right-click automates the process; screen images refresh each time the Earth solver writes a solution file.

Choice of colour maps

Pre-set colour maps are available which are selected from the 'Update palette' button on the 'Contours' tab of the Viewer Options dialog.
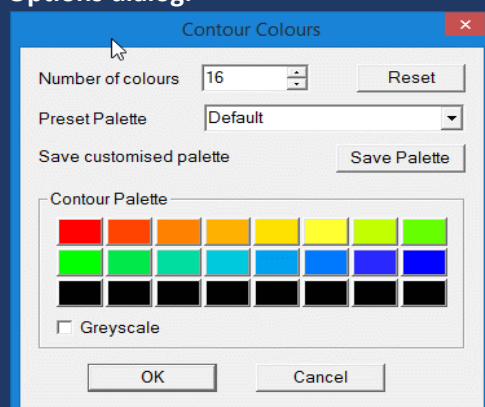
The dialog allows one pre-set colour palette to be loaded with a 'Custom' option whereby Users can set, and save, each colour in the palette.

Default CHAM Red-Blue

CHAM Heat

L3 Heat

CHAM Blue to Yellow

L9 Blue to Yellow

CHAM Diverging

D1 Diverging

CBL1 Colourblind

R1 Rainbow with Pink


R1 Rainbow without Pink
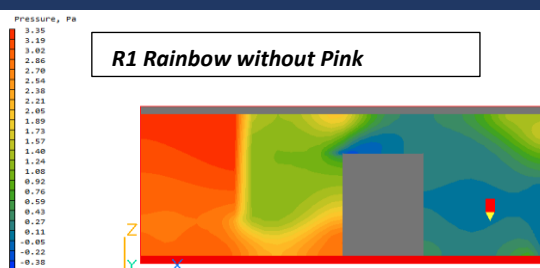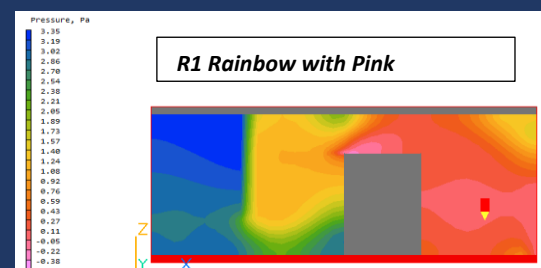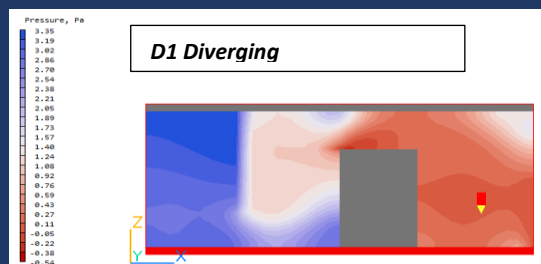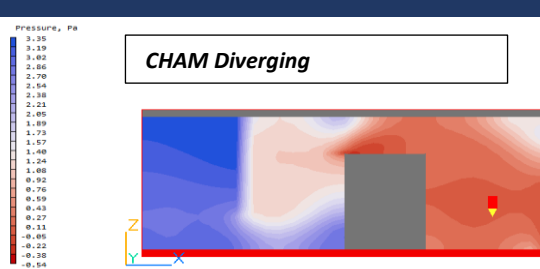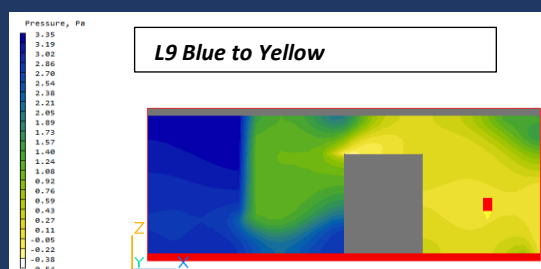
Improved surface contours

To plot contours on the surface of an object, the surface the contour is plotted on must be offset slightly from the actual surface of the body. The algorithm for offsetting the plotting surface has been improved, leading to better surface contours.

The image on the left shows surface contours not matching the in-plane contours whilst that on the right shows the same plot after correction. The mis-alignment is much reduced.
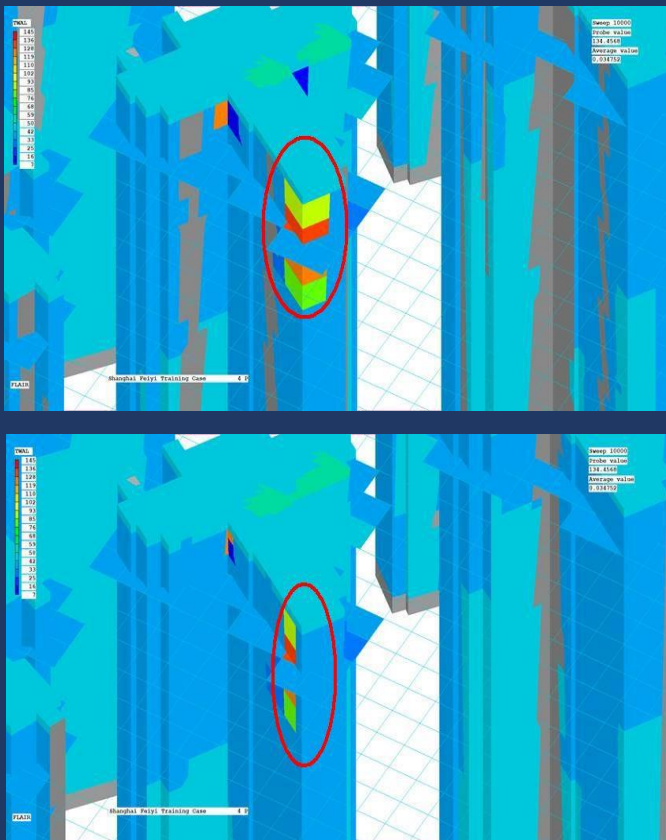
Stopping an Animation

Users reported that it can be difficult to stop an animation early especially if solution files are large and it takes a long time to read each file.

The mechanism to check for an interrupt (pressing the animation toggle again) has been rewritten to make the process more reliable.

In addition, if VR-Viewer finds a file called 'stopit' or 'stopit.txt' in the working folder during an animation, it will stop the animation and delete the file.

Generic

Directory Structure

In addition to existing d_win32 and d_win64 directories, which contain single-precision 32-bit and 64-bit code, there are d_windble directories containing the 64-bit double-precision code. No provision has been made for 32-bit double-precision.

Activation of Double-Precision

Activation and implementation of double-precision has been changed. Selection of single or double-precision is on the VR-Editor Options menu:
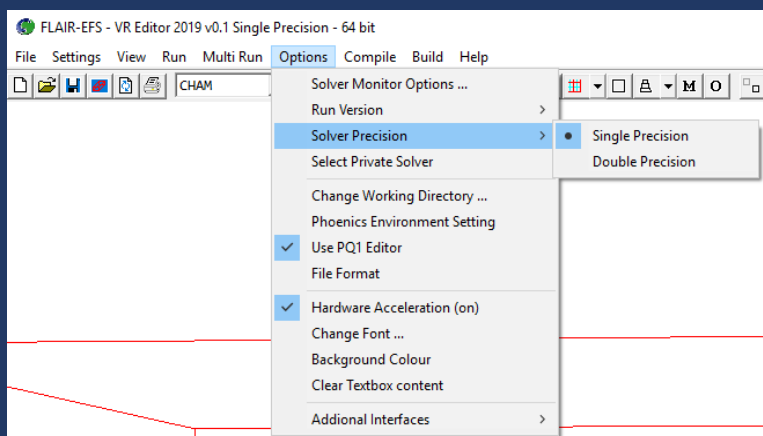
Once Double precision is selected, 'Compile' and 'Build' commands compile/build double-precision solver versions.

Unlocking

Error messages relating to problems with unlocking are captured in the text file unlock_error.txt so that Users do not have to rely on screen-grabbing the error message.

Installation

The installer for PHOENICS 2019 performs a pre-requisite check to ensure that items needed to run PHOENICS are present. This will eliminate the problem some users may have encountered if some Microsoft DLL files are missing.

Parallel

PHOENICS 2019 is shipped with MS-MPI rather than the MPICH2 software used in previous versions. MPICH2 is quite old and, due to changes made by Microsoft to the Windows Registry, cannot be installed on new Windows 10 machines.

Contact:

Contact phoenics@cham.co.uk or ring +44 208 947 7651 for help and information. We look forward to hearing from you.