Some Innovation and Ideas From Wildkatze CFD Software

Wildkatze

Finite Volume Utilities and Solvers

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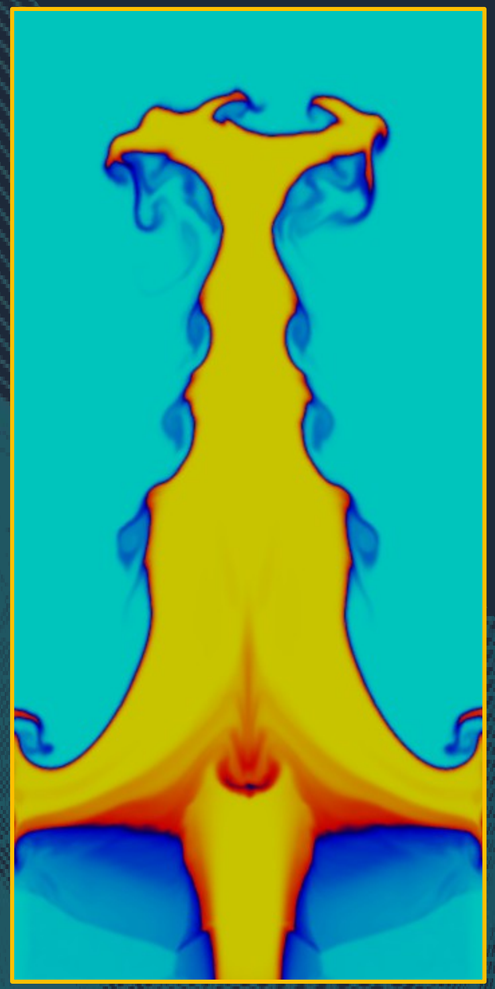
15 April 2026

Development

2015 - Now



Goals and Motivation

- **Solver for Industry**
- **Should welcome innovation and new ideas**
- **Very rapid development and easy to expand the software by multiple developers**

Design and Concepts

Core Concept of Wildkatze

Region Set

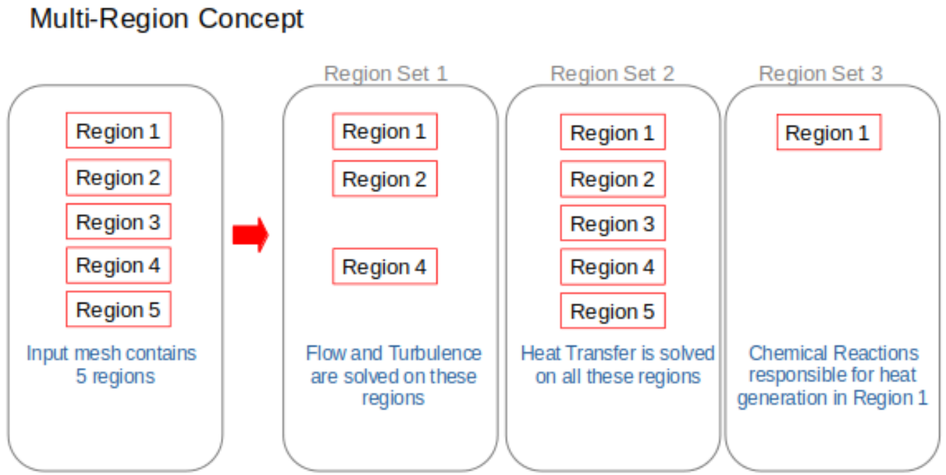
+

Phase Set

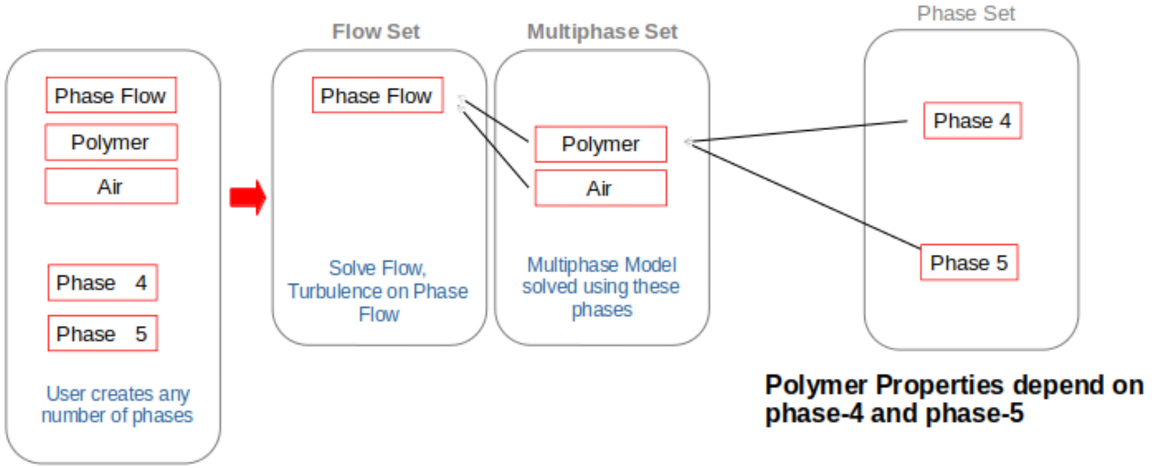
Physics Models

- **Boundary Models**
- **Feature Sub-Models**

Multi-Region Concept

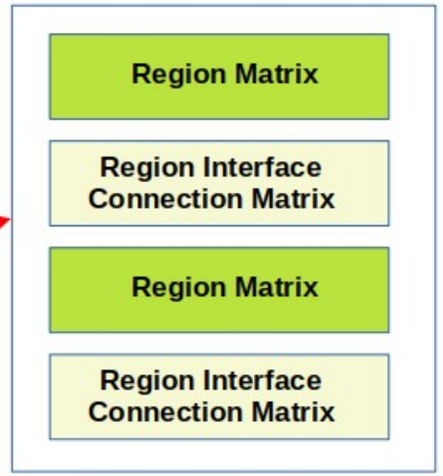


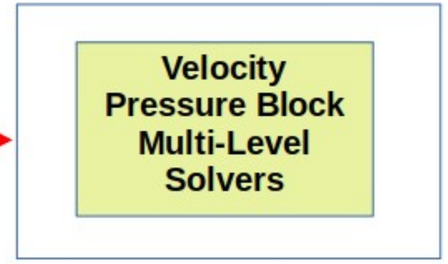
Multi-Phase Concept



Some Experiments with Pressure Based Coupled Solver

WkAmg Library





Coarsening and Multi-level Construction

Fine Matrix

Only Non Zero elements are stored

$$\begin{bmatrix} A_u^k & & & G_u^k \\ & A_v^k & & G_v^k \\ & & A_w^k & G_w^k \\ D_u^k & D_v^k & D_w^k & A_P^k \end{bmatrix} \begin{bmatrix} u^k \\ v^k \\ w^k \\ p^k \end{bmatrix} = \begin{bmatrix} b_u^k \\ b_v^k \\ b_w^k \\ b_p^k \end{bmatrix}$$

Restriction

Prolongation

$$\begin{bmatrix} A_u^{k+1} & & & G_u^{k+1} \\ & A_v^{k+1} & & G_v^{k+1} \\ & & A_w^{k+1} & G_w^{k+1} \\ D_u^{k+1} & D_v^{k+1} & D_w^{k+1} & A_P^{k+1} \end{bmatrix} = \begin{bmatrix} R_u^k & & & \\ & R_v^k & & \\ & & R_v^k & \\ & & & R_p^k \end{bmatrix} \begin{bmatrix} A_u^k & & & G_u^k \\ & A_v^k & & G_v^k \\ & & A_w^k & G_w^k \\ D_u^k & D_v^k & D_w^k & A_P^k \end{bmatrix} \begin{bmatrix} P_u^k & & & \\ & P_v^k & & \\ & & P_v^k & \\ & & & P_p^k \end{bmatrix}$$

$$\begin{bmatrix} A_u^{k+1} & & & G_u^{k+1} \\ & A_v^{k+1} & & G_v^{k+1} \\ & & A_w^{k+1} & G_w^{k+1} \\ D_u^{k+1} & D_v^{k+1} & D_w^{k+1} & A_P^{k+1} \end{bmatrix} = \begin{bmatrix} R_u^k A_u^k P_u^k & & & R_u^k G_u^k P_p^k \\ & R_v^k A_v^k P_v^k & & R_v^k G_v^k P_p^k \\ & & R_w^k A_w^k P_w^k & R_w^k G_w^k P_p^k \\ R_p^k D_u^k P_u^k & R_p^k D_v^k P_v^k & R_p^k D_w^k P_w^k & R_p^k A_p^k P_p^k \end{bmatrix}$$

Coarse Matrix

WkAmg Library

Integration into OpenFOAM

```
std::vector < double >   compressiblityFactors;

compressiblityFactors.push_back( 1E-5 );
compressiblityFactors.push_back( 1E-5 );
compressiblityFactors.push_back( 1E-5 );
compressiblityFactors.push_back( 1E-8 );


std::unique_ptr<WkAmg> wkAmg (new WkAmg(   4 ,
                               Pstream::myProcNo(),
                               Pstream::nProcs  () ,
                               MPI_COMM_WORLD)
                             );


registerMeshRegion                ( mesh,    wkAmg  );

registerMatrixAtDiagonalBlock     ( mesh,    wkAmg, compressiblityFactors,  0,UEqn    );
registerMatrixAtDiagonalBlock     ( mesh,    wkAmg, compressiblityFactors,  3,pdEqn    );

insertBlockCouplingWkMatrix(0, 3, pInU, true,  mesh, wkAmg);
insertBlockCouplingWkMatrix(3, 0, UInp, false, mesh, wkAmg);

insertSolutionWk   (           mesh,    wkAmg,0, U.internalField()      );
insertSolutionWk   (           mesh,    wkAmg,3, pd.internalField()     );


wkAmg   ->  assembleGlobalMatrix        ();
wkAmg   ->  coarsentAMG                 ();

wkAmg   ->  transferRegionSourcePhiToAMG();
```

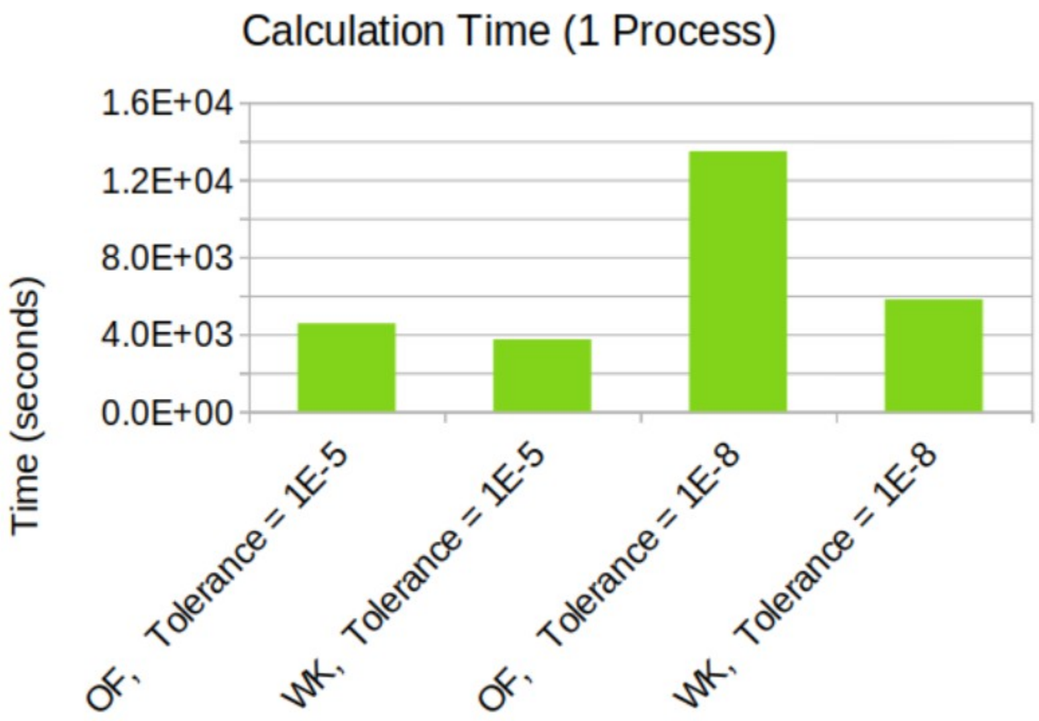
Same as OpenFOAM-Extend

This allows addition of new library easy for already existing code.

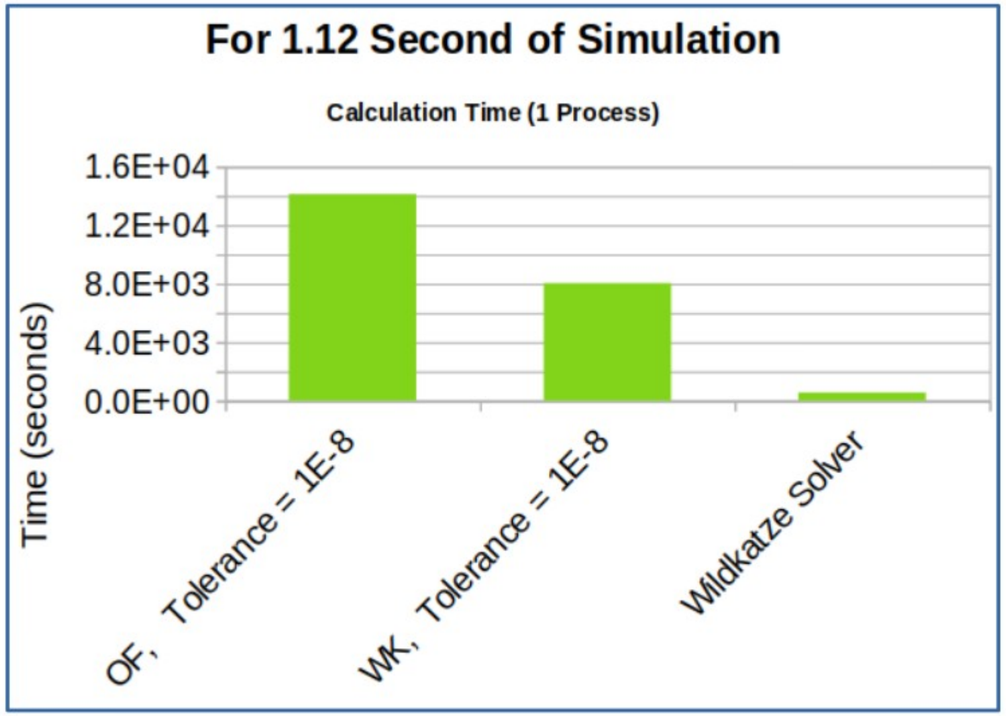
WkAmg Library

Integration into OpenFOAM

DegassingTest

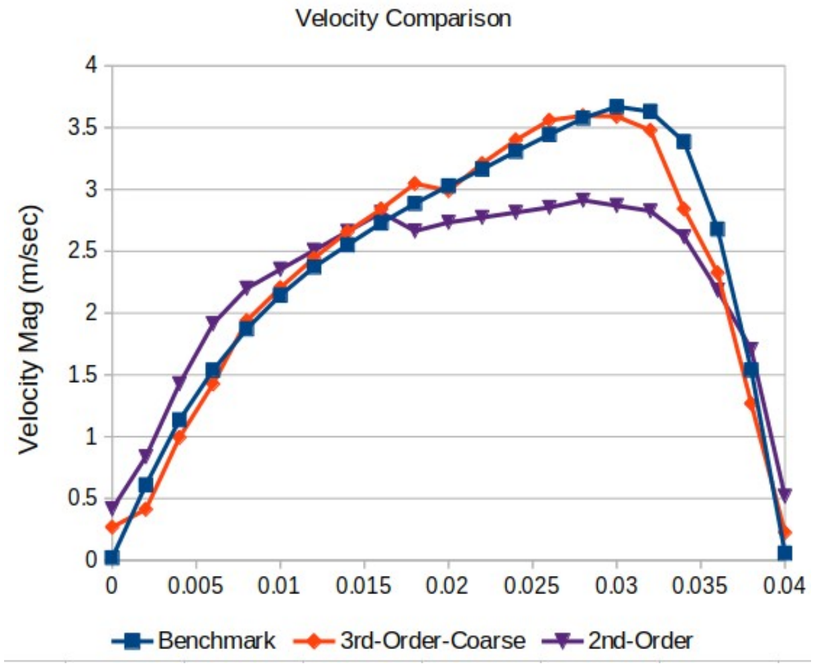


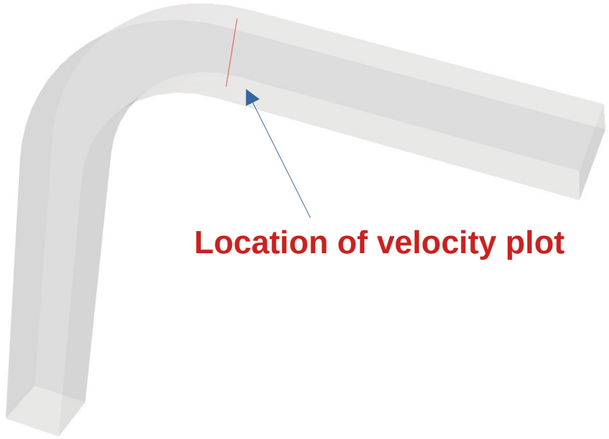
Mold Filling Simulation



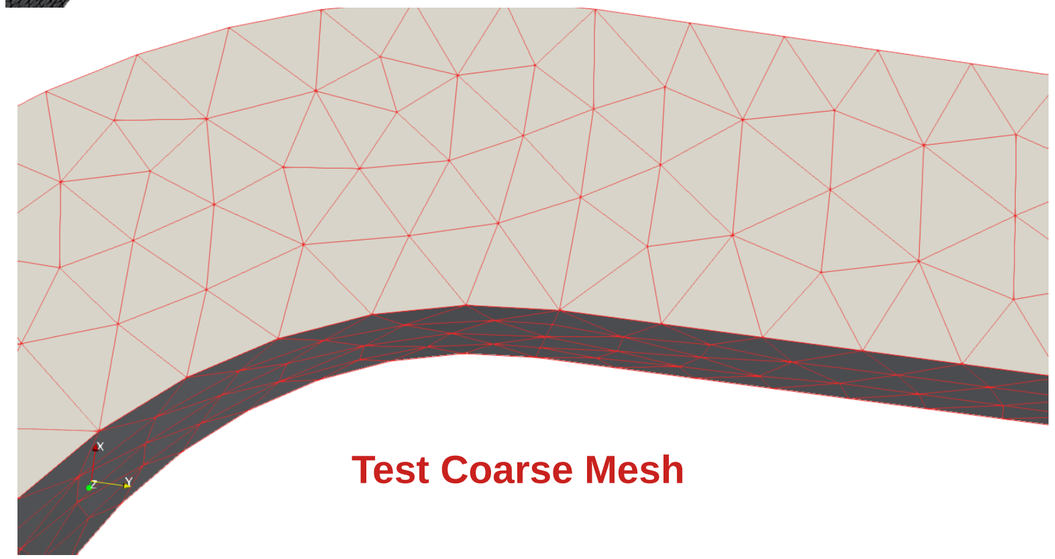
Innovation to be more accurate

Higher Order SIMPLE

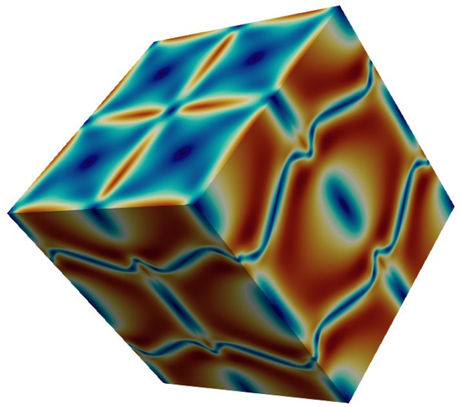




Benchmark Mesh



Test Coarse Mesh

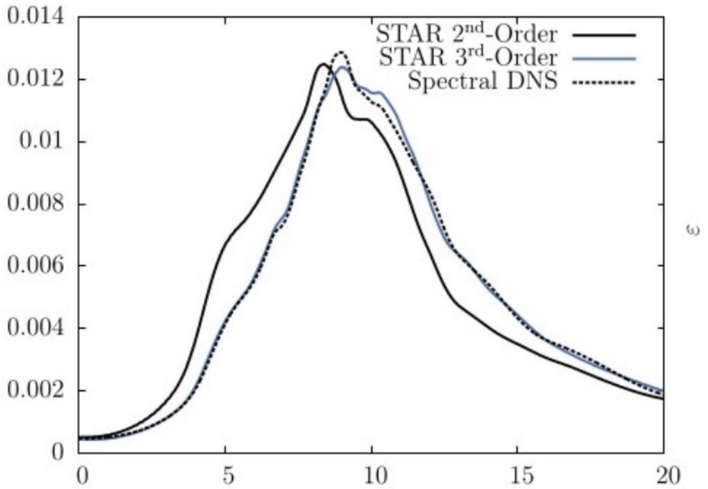


Higher Order Comparison with Star-CCM+

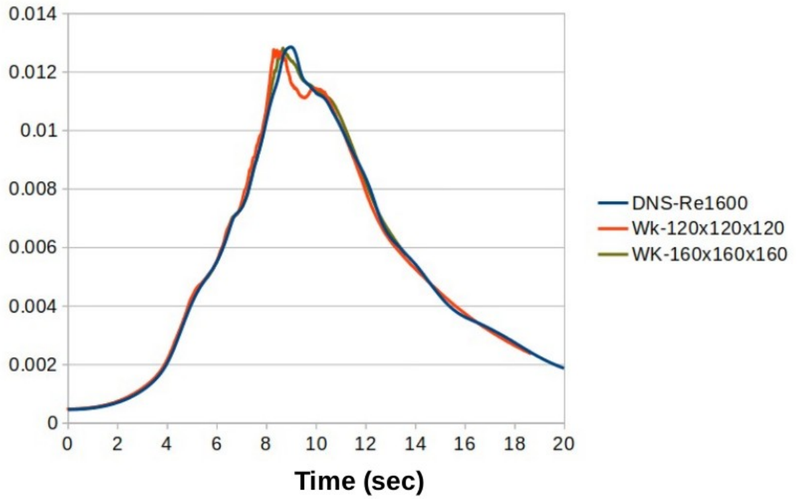
Taylor-Green Vortex decay at Re=1600

Dissipation rate Comparison

StarCCM+ mesh 256x256x256



Wildkatze mesh 120x120x120 and 160x160x160



Reference:

On the utility of GPU accelerated high-order methods for unsteady flow simulations: A comparison with industry-standard tools

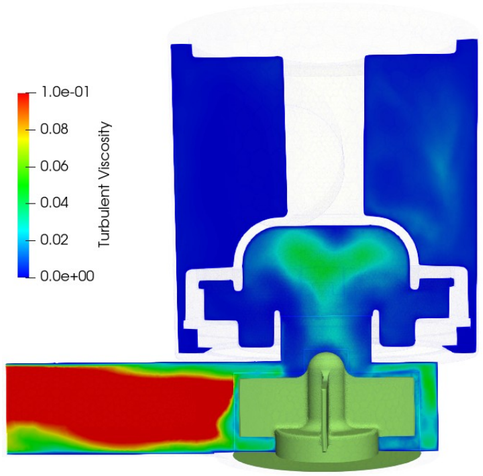
B.C. Vermeire, F.D. Witherden, P.E. Vincent

Higher Order SIMPLE

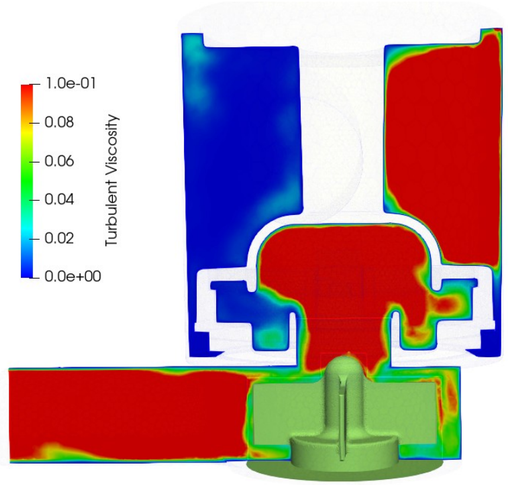
Higher Order is not for Industry?

Pump Simulation

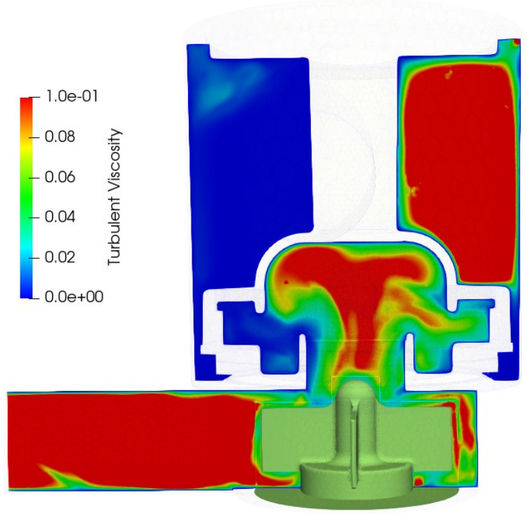
1.5 Million Cells – Second Order



1.5 Million Cells – Third Order



8.8 Million Cells – Third Order

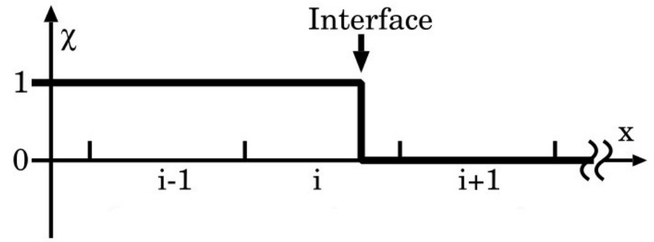


Note: **Polyhedral Mesh is used here.**

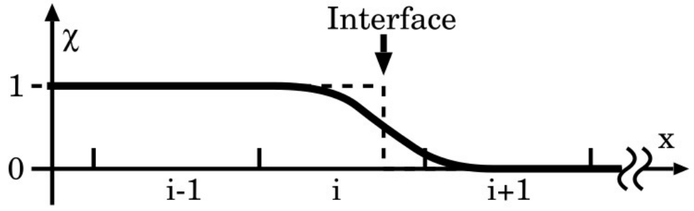
MaxGBCA
Interface Capturing

MaxGBCA Core Concept

- **A sharp fluid-fluid interface remains sharp after reasonably small movement in space.**



- **A sharp fluid-fluid interface that is represented by a mathematical profile remains sharp after reasonably small movement in space and could still be represented by a mathematical profile.**



Interpolation using the gradient. For **beta > 1** the scheme is **compressive**.

$$\alpha_f = \alpha_u + \beta \nabla \alpha_u \cdot \vec{r}_f$$

Use the profile to calculate the gradient limiter.

$$\beta_{MaxGBCA} = \frac{\alpha_{f,THINC} - \alpha_u}{\alpha_{CD} - \alpha_u}$$

$$\alpha_f^* = \alpha_u + \beta_{MaxGBCA} \nabla \alpha_u \cdot \vec{r}_f$$

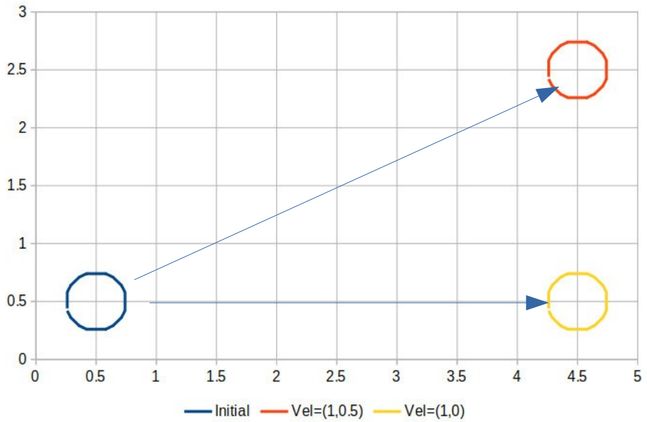
Final Form

$$\tilde{\alpha}_{f(MaxGBCA)} = \tilde{\alpha}_f^* \gamma_{maxgbca} + \tilde{\alpha}_{f(SISP)} \left(1 - \gamma_{maxgbca}\right)$$

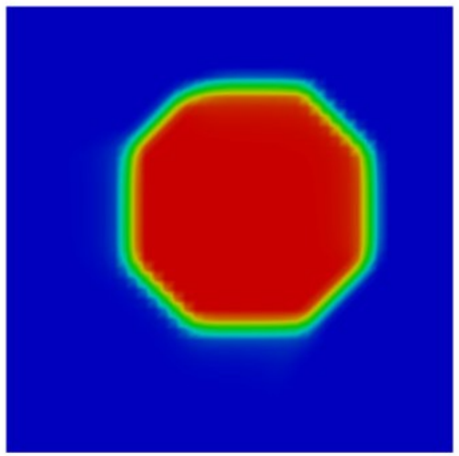
Advection of Disk

Disc in steady uniform two-dimensional flow

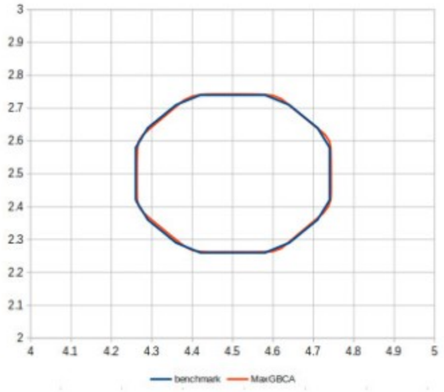
A circular region of fluid of radius **R = 0.25** moving in a constant and uniform velocity field, **v = (1,0)** and **v = (1,0.5)** for 4 seconds.

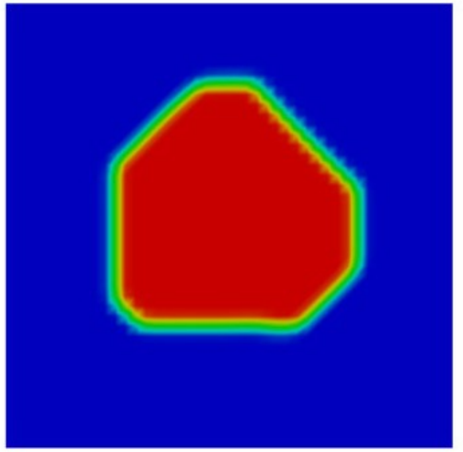


- **Time-step by Max-Courant = 0.2**

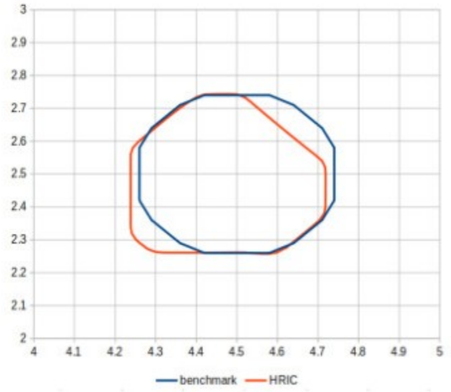


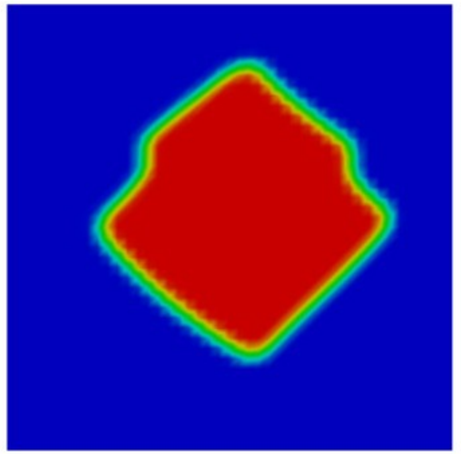
MaxGBCA
Wildkatze



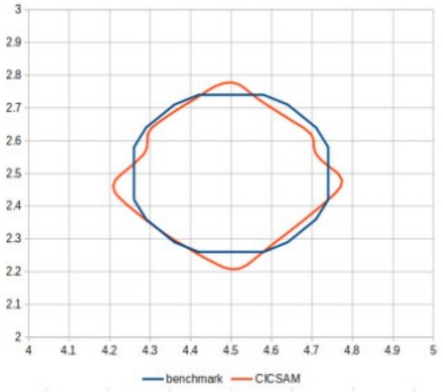


HRIC
StarCCM+





CICSAM
OpenFOAM



Advection of Disk

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Research

Article submitted to journal

Subject Areas:
Computational Fluid Dynamics, Multiphase flows, Numerical methods, Two phase flows, Free

A Computational Method for Sharp Interface Advection*

Johan Roenby[1], Henrik Bredmose[2] and Hrvoje Jasak[3,4]

[1]DHI, Department of Ports & Offshore Technology, Agern Allé 5, 2970 Hørsholm, Denmark
[2]Department of Wind Energy, Technical University of Denmark, 2800 Kgs. Lynbgy, Denmark
[3]University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture, Ivana Lučića 5, Zagreb, Croatia
[4]Wikki Ltd, 459 Southbank House, SE1 7SJ, London, United Kingdom

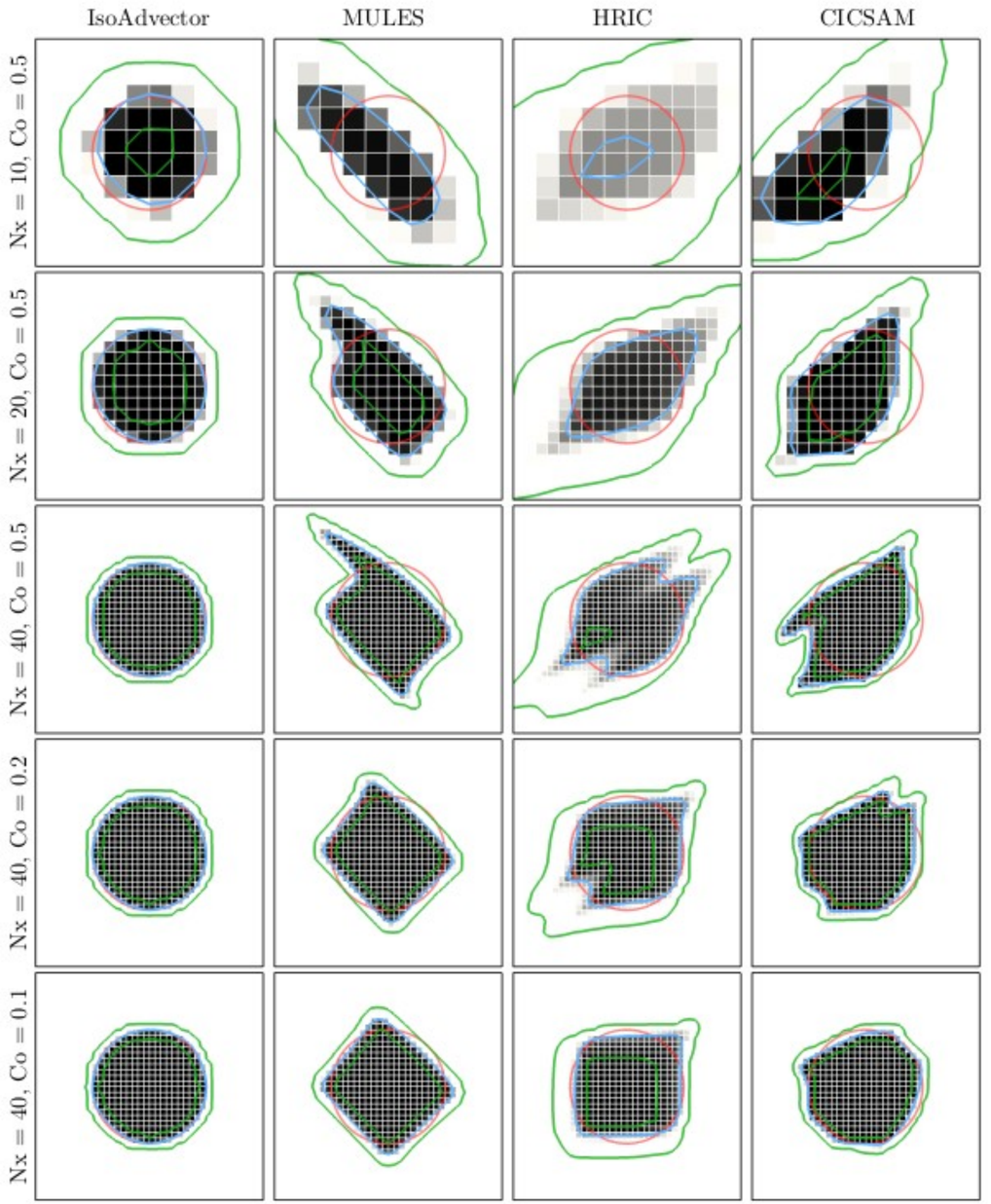
Co = 0.5

Co = 0.5

Co = 0.5

Co = 0.2

Co = 0.1

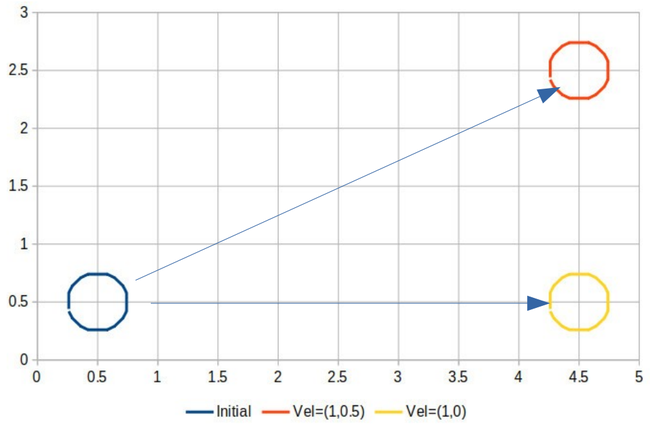


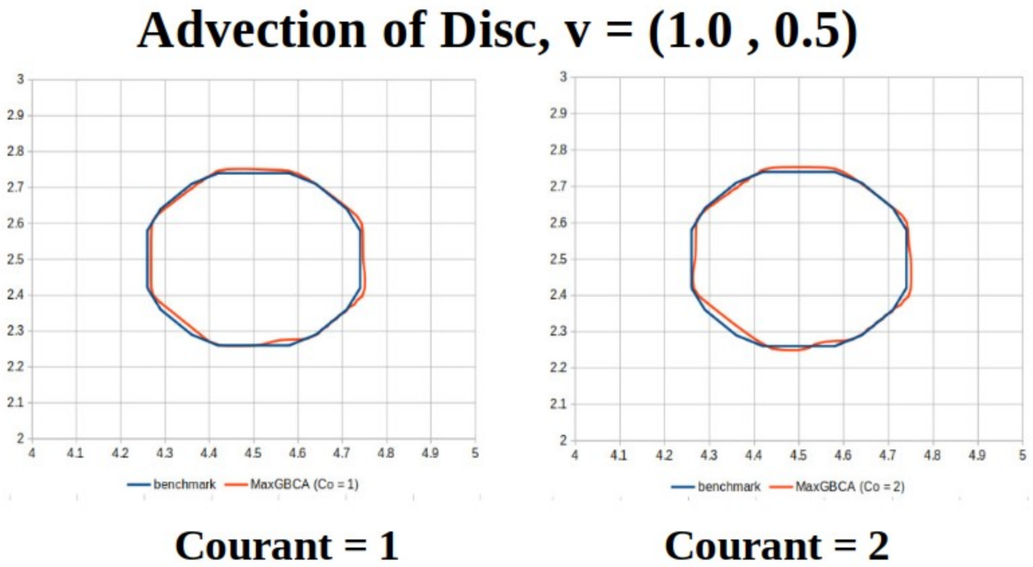
Iso Advector has problems going above 0.5 (now 1.0) Courant numbers

Advection of Disk, MaxGBCA

Disc in steady uniform two-dimensional flow

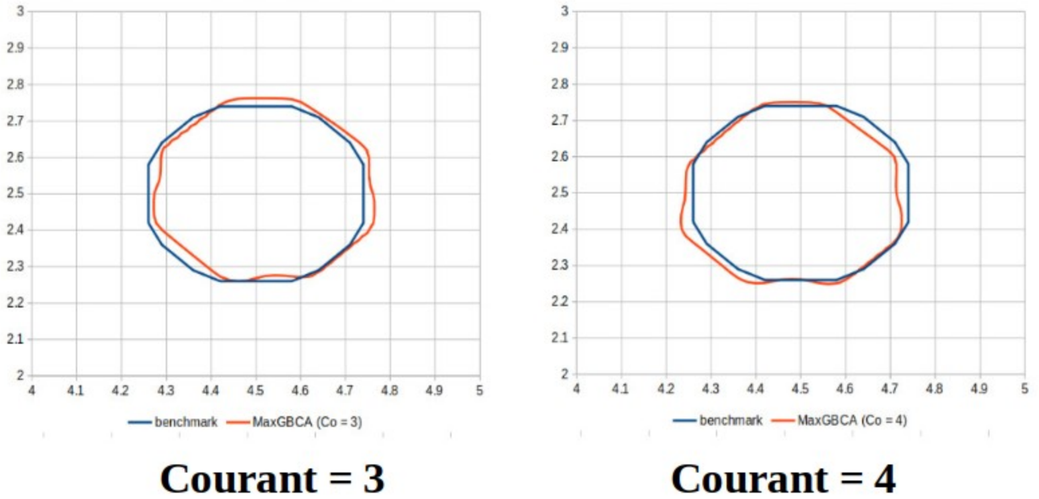
A circular region of fluid of radius **R = 0.25** moving in a constant and uniform velocity field, **v = (1,0)** and **v = (1,0.5)** for 4 seconds.





Courant = 1

Courant = 2

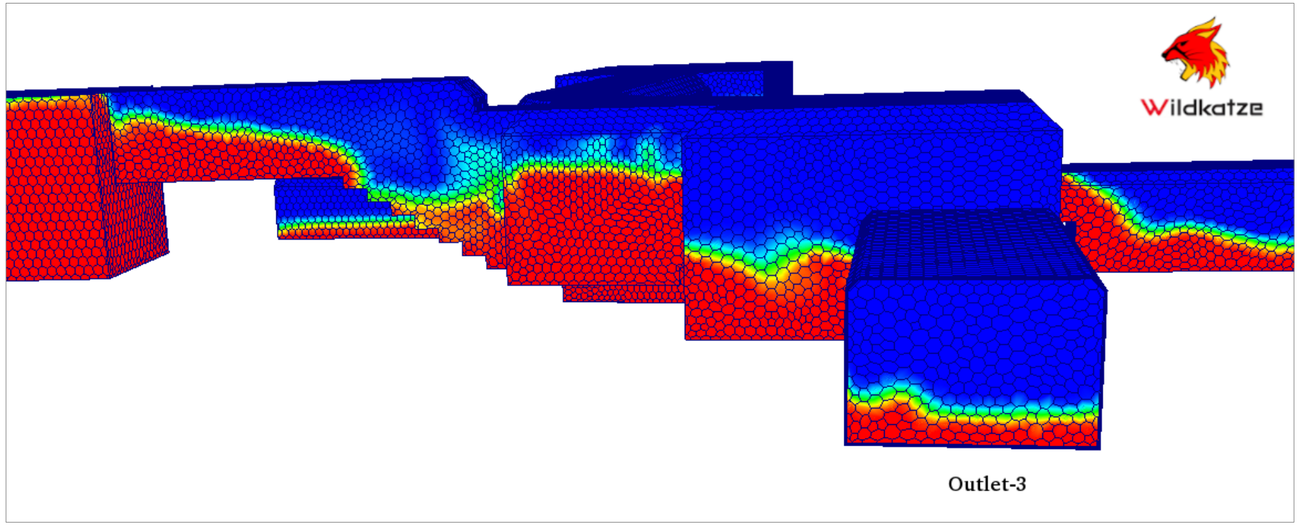


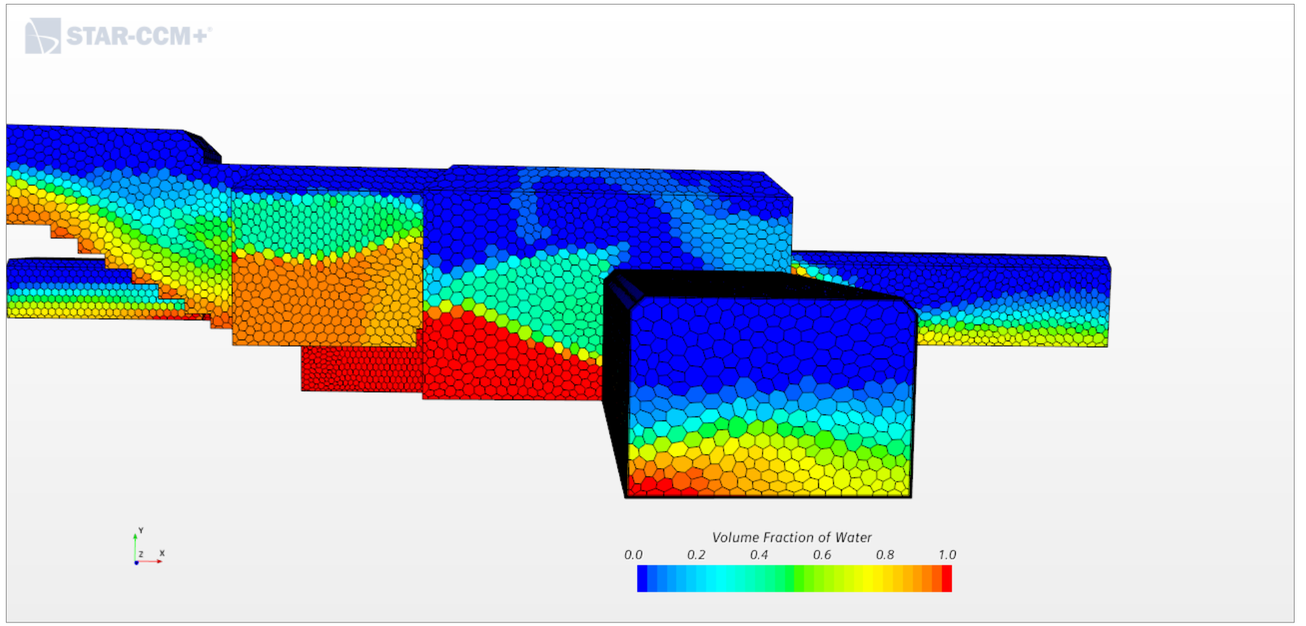
Courant = 3

Courant = 4

Interface Tracking at Higher Time Step-Sizes

- **Both solvers are run on exact same settings**
- **Only difference is interface tracking algorithm**

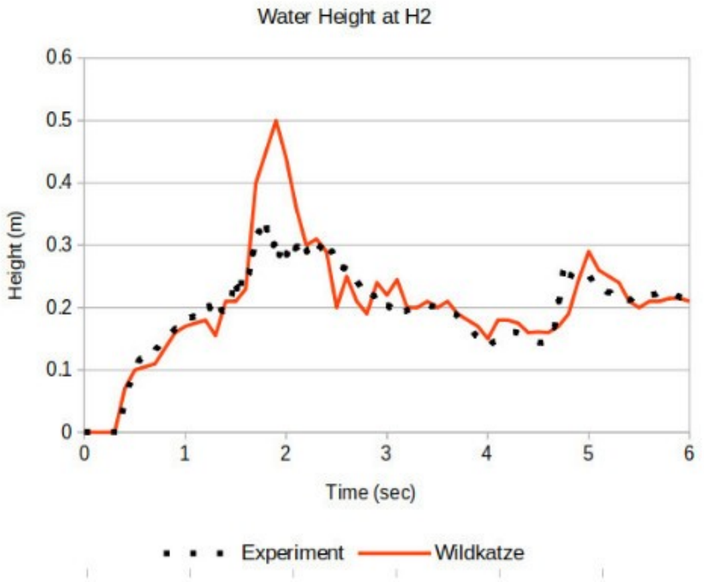


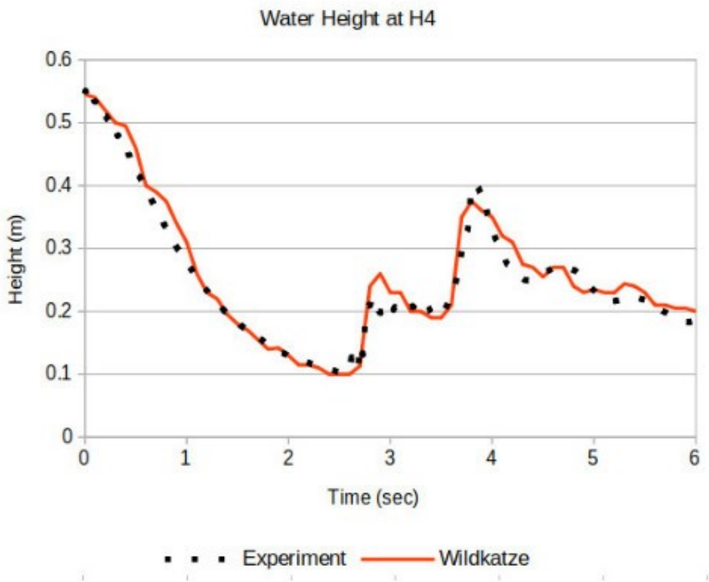


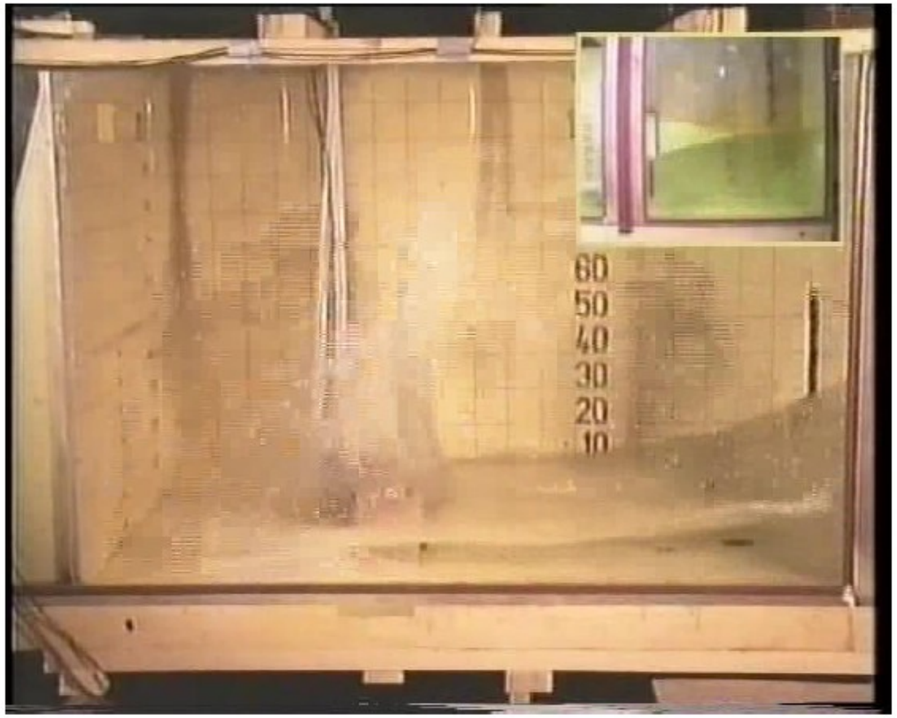
This comparison was done in 2021. Wildkatze has improved VOF a lot since that time

Interface Tracking at Higher Time Step-Sizes

Dam-break Case







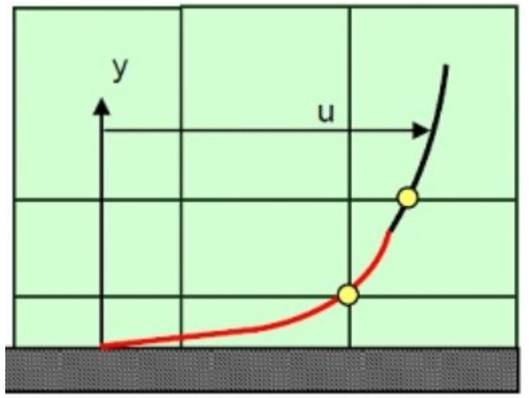
- **Calculation was done with time step size based on maximum Courant number of 10.**

Better Wall Functions

```
solveSteadyTBLENonUniform( kappa2,  wwB,  K_1,  K_2,  K_3,
                 nfaces,
                 distToWall,
                 velParToWall, viscAtWall, denAtWall, dPdnWall,
                 0,strainCAtWall, tbleShearRate1
                );

solveSteadyTBLENonUniform( kappa2,  wwB,  K_1,  K_2,  K_3,
                 nfaces,
                 distToWall2,
                 velParToWall2, viscAtWall, denAtWall, dPdnWall2,
                 0,strainCAtWall2, tbleShearRate2
                );


calculateKWWall(
         kappa,  E,
         b,  valC,  valD,
         ypLower,  ypMid,  ypHigh,
         minLamWeight,
         ReFactor,
         tw0Weight,
          nfaces,  CL,  CR,  CL2Own,
          ax,  ay,  az
         ,  xc,  yc,  zc
         ,  distToWall   ,   distToWall2
         ,  viscosity,  density
         ,  xVel,  yVel,  zVel
         ,  k_kw
         ,  betaStar
         ,  tbleShearRate1,  tbleShearRate2
         ,  Yplus ,   TW,  UStarWW,  blendingFactor
         ,  UStar ,  Uplus,  ReTurb
         ,  TWX
         ,  TWY  ,  TWZ,   RatioTw_Up
         ,  WallTBLEOmega
         ,  TPW,TWtW
         );
```

Solution of Turbulent Boundary Layer (Second cell to wall)

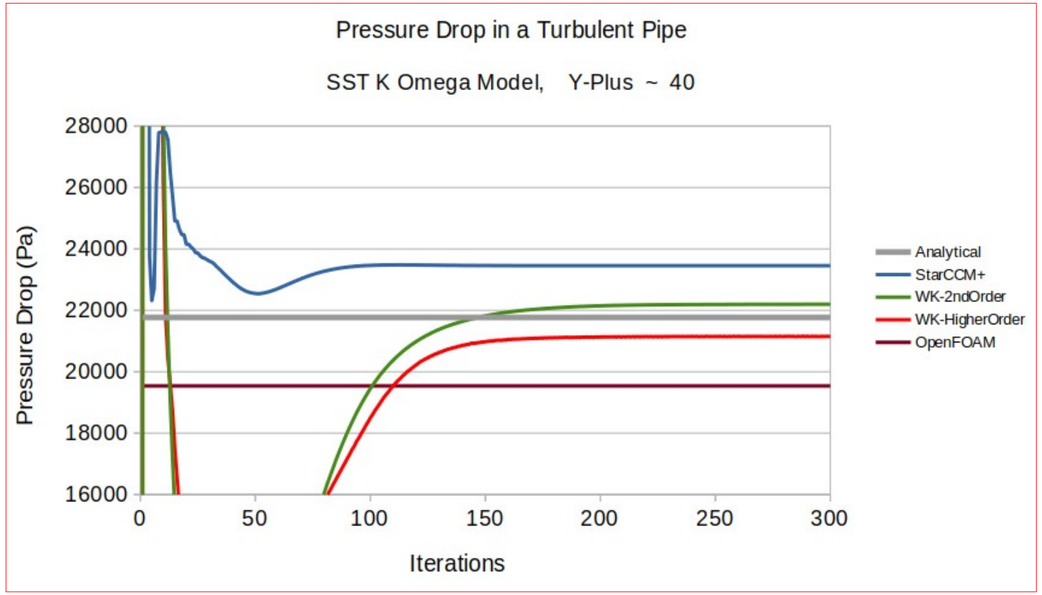
Solution of Turbulent Boundary Layer (First cell to wall)



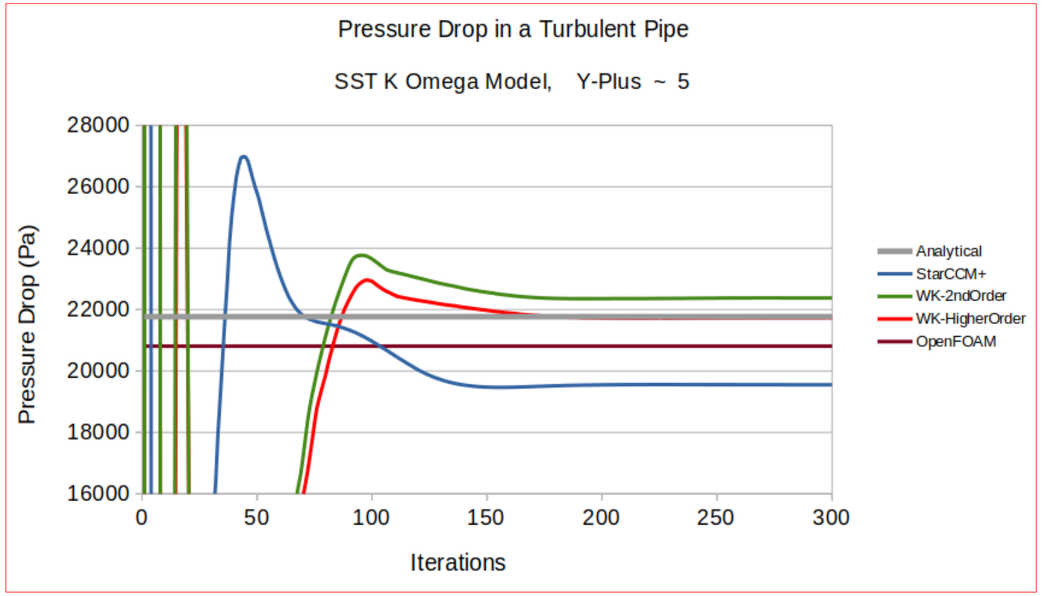
Finally solve for wall functions using the information from first 2 cells from wall

Better Wall Functions

High Re Mesh



Low Re Mesh



Turbulent Flow in a Pipe

Target	[Pa]		21744	Difference [%]
OpenFOAM	HighRe		19538	**-10.1453**
OpenFOAM	LowRe		20808	**-4.30464**
StarCCM+	HighRe		23453	**7.85964**
StarCCM+	LowRe		19552	**-10.0809**
WK	HighRe	**2nd**	22197	**2.08333**
WK	HighRe	**3rd**	21148	**-2.74099**
WK	LowRe	**2nd**	22378	**2.91575**
WK	LowRe	**3rd**	21728	**-0.07358**

Split Smoother for AMG

$$M = (A - N)$$

$$M^{-1} = (A - N)^{-1}$$

$$M^{-1} = \left(I - A^{-1}N\right)^{-1} A^{-1}$$

$$M^{-1} = \left\{ I + \alpha \left(A^{-1}N + \left(A^{-1}N\right)^2 + \left(A^{-1}N\right)^3 + \left(A^{-1}N\right)^4 + \ . \ . \ . \right) \right\} A^{-1}$$

Where

$$\alpha \in \{-\infty, \infty\}$$

Gauss – Siedel AMG

```
       Iteration update :: CartEnergyModel
   26518011 -> 8842318 -> 2914977 -> 854530 -> 281133 -> 92224 -> 29464 -> 9502 -> 3062 -> 968 -> 319 -> 114 -> 46 -> 24

       Linear system 0 :: 1.571258322302630113e+05 -> 1.571209779092473036e+05 ratio  =  1.000308954353536l7e+00
       Linear system 1 :: 1.571258322302630113e+05 -> 1.571282248893555079e+05 ratio  =  9.999847725697010858e-01
       Linear system 2 :: 1.571258322302630113e+05 -> 1.571295194107088901e+05 ratio  =  9.999765341327351287e-01
       Linear system 3 :: 1.571258322302630113e+05 -> 1.571297660753481323e+05 ratio  =  9.999749643547281019e-01
       Linear system 4 :: 1.571258322302630113e+05 -> 1.571298148327803065e+05 ratio  =  9.999746540621744506e-01

                Linear system solution time , Time = 3.442487239837646484e+00(sec)
Residuals for model-set:       Model-Set-1
```

Split Smoother AMG

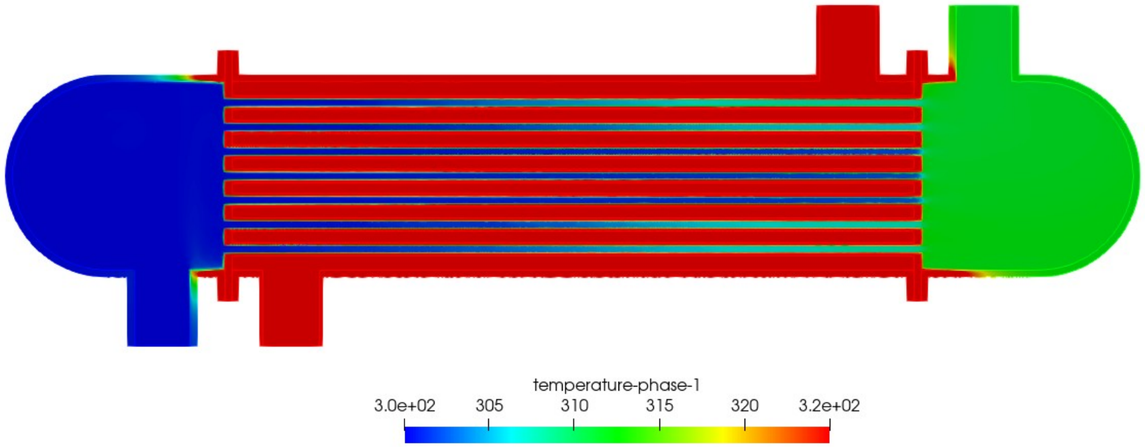
```
       Iteration update :: CartEnergyModel
   26518011 -> 6692716 -> 1659111 -> 410732 -> 101462 -> 25178 -> 6257 -> 1576 -> 404 -> 111 -> 40 -> 24

       Linear system 0 :: 3.865970501108931785e+04 -> 1.620000802588337501e+04 ratio  =  2.386400361612242449e+00
       Linear system 1 :: 3.865970501108931785e+04 -> 9.286467329652850822e+03 ratio  =  4.163015239136635515e+00
       Linear system 2 :: 3.865970501108931785e+04 -> 5.810074725668397150e+03 ratio  =  6.653908398164683824e+00
       Linear system 3 :: 3.865970501108931785e+04 -> 3.789699105317338308e+03 ratio  =  1.020125976673075918e+01

                Linear system solution time , Time = 8.940152168273925781e+00(sec)
```

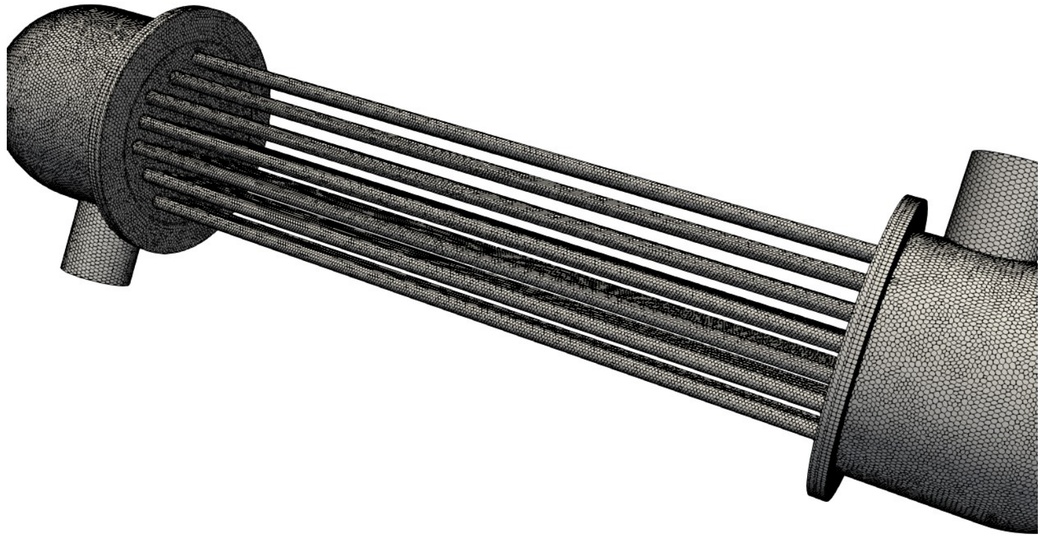
Automated Set Up

Year 2018 onwards ….

Heat Exchanger from Command Prompt

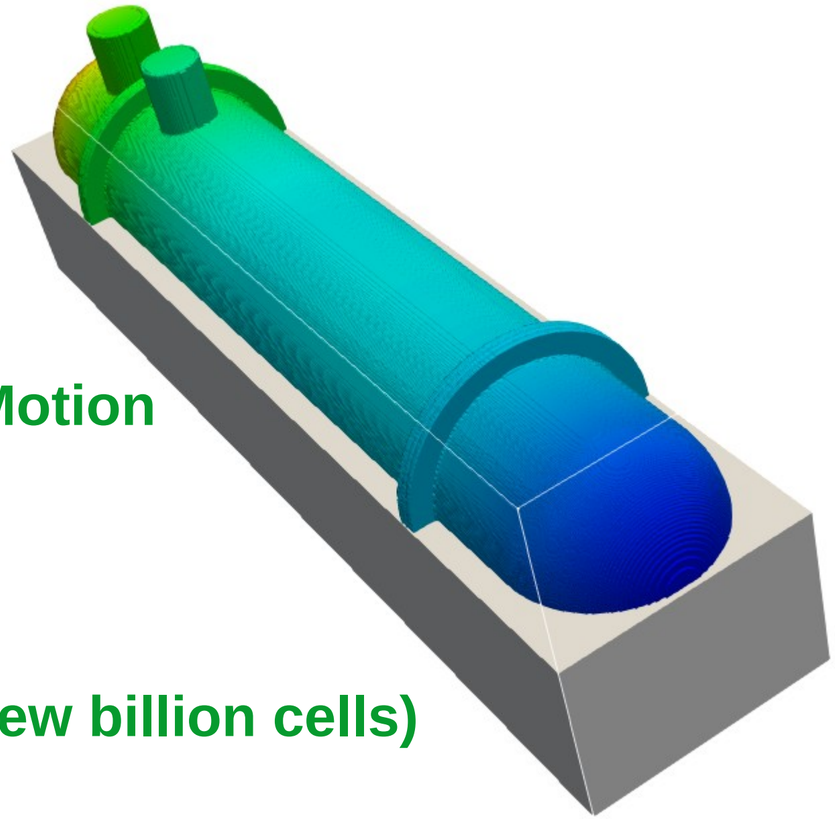
whac12.sh -lc **flow-conf** **shelltube** **-conf** **shelltube0.info.conf** **-pre-init-file oAdd.txt** -lc **pf** **o.txt** -lc **iterate 200** -lc **export-ensight Results**





WkNext

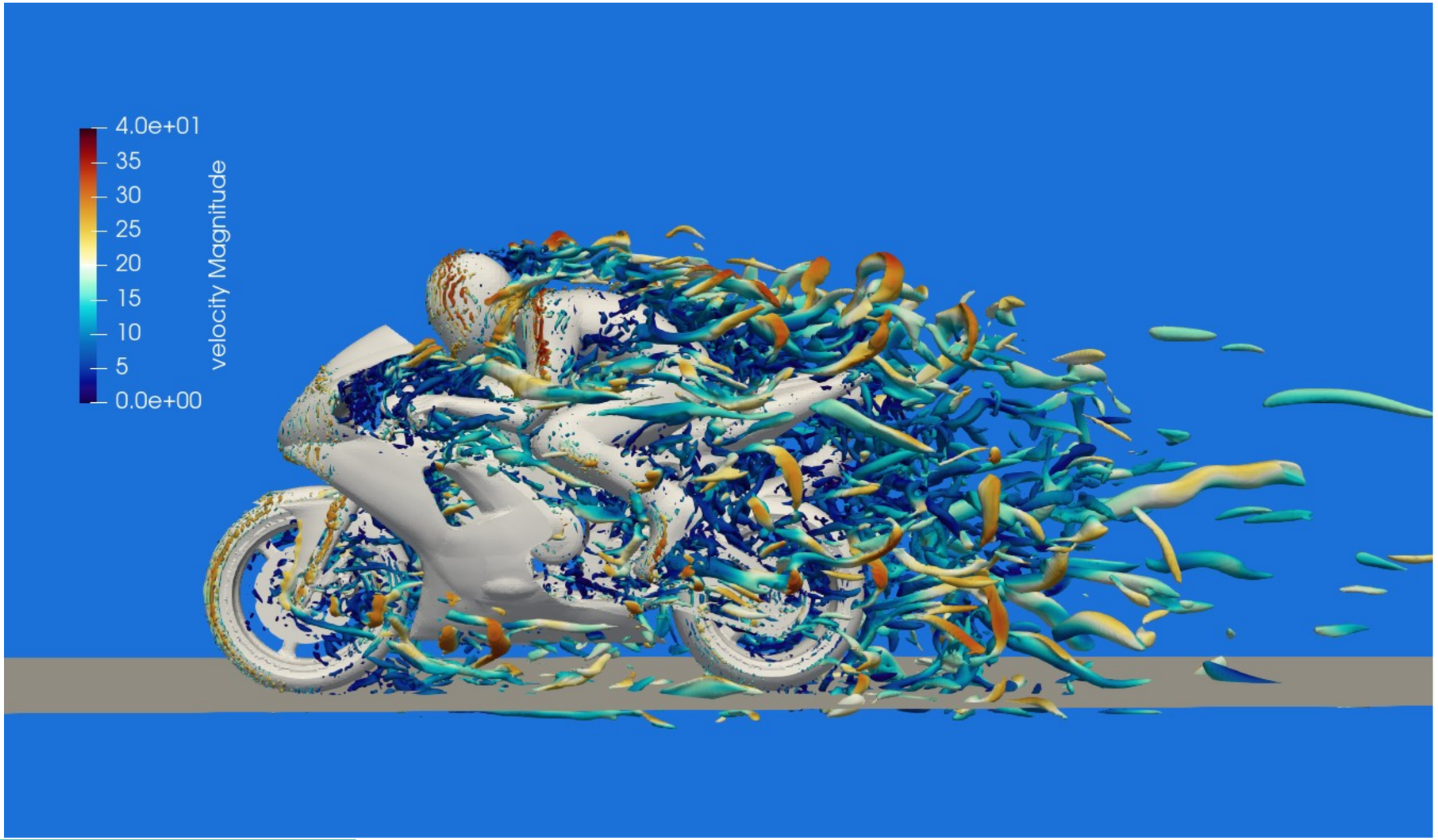
Cartesian High Accuracy Solver



- **Not just simple Cartesian grid solver**
- **Allows combination of Immersed Boundary and Overset Motion**
- **Can apply higher order solvers (4th, 6th or higher)**
- **Should allow extremely large calculations (500 million to few billion cells)**
- **Large meshes plus higher order is unbeatable in accuracy**

Cartesian Solver

for utmost accuracy

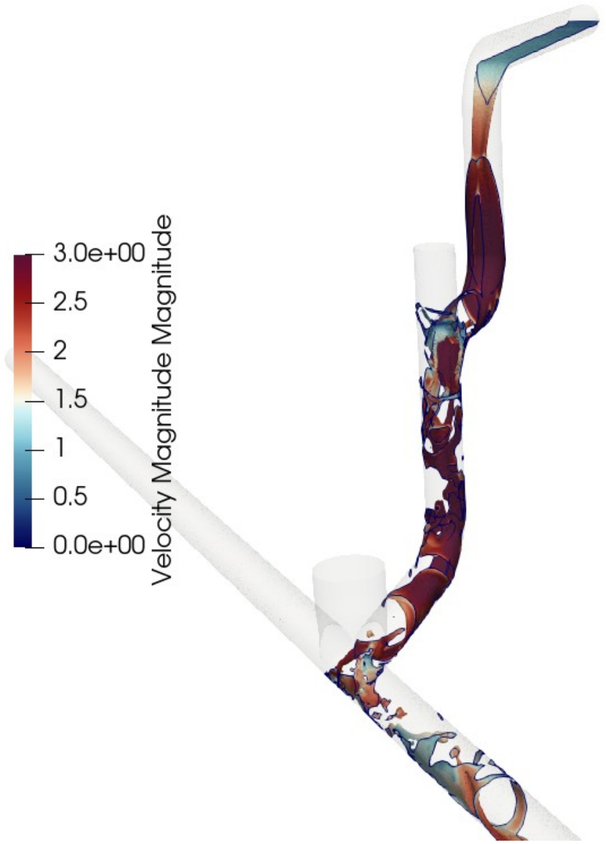


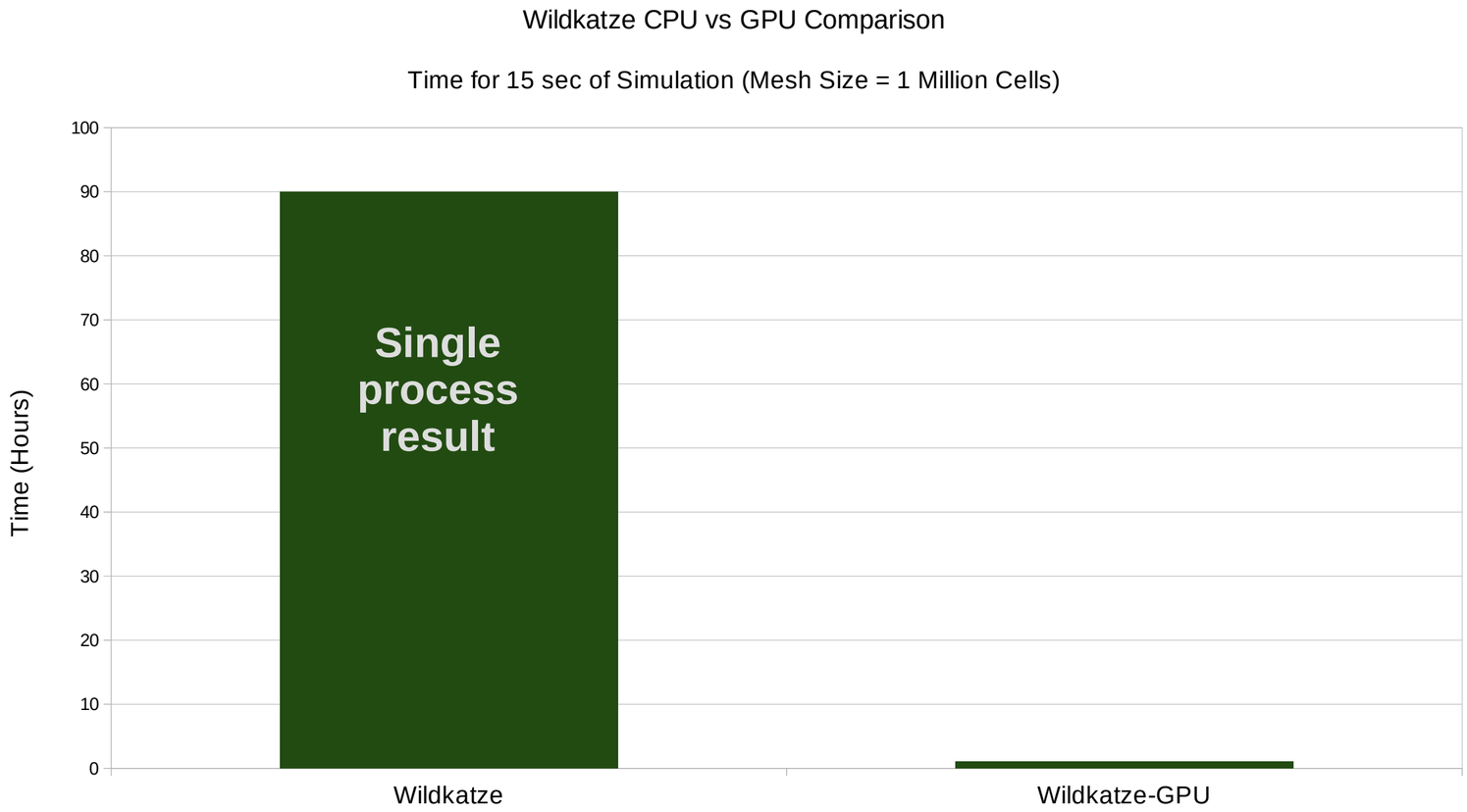
WkNext
Multi-GPU

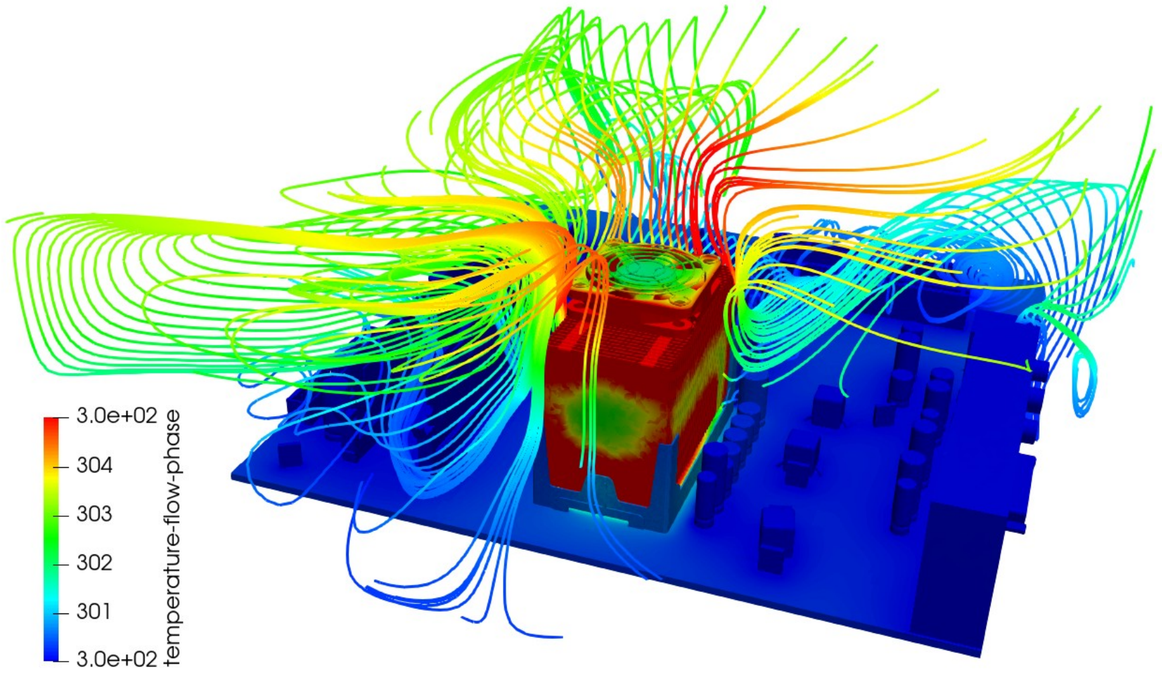
Wildkatze GPU

Development of Multi GPU from 2025

Two Phase flow in a Pipe







Thank You