Welcome to the 7th Basilisk (Gerris) Users' Meeting!

What's new and future plans

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New features (in src/) 2023–2025

- 456 patches, $\approx$ +24 230 lines
- Patch contributors:

  Clément Robert, Nicolas Fintzi, Daniel Fuster, Youssef Saadeh, Antoon van Hooft, Alexandre Limare
- New "run" server for the wiki: 5 times faster machine, 2 RTX4090 GPUs
- New `src/NEWS` file for release documentation
- Bug fixes: at least one important

```
Date:   Sun Nov 24 18:02:47 CET 2024
  * Important memory bug fix for MPI and multigrid
```

- *Mostly "structural/infrastructure" changes*

- **Dimensional analysis**

  A way to test the correctnes of the Abstract Syntax Tree (AST) grammar parser and type declaration system

  A way to check that everybody is comfortable with dimensional analysis... (answer: no)

```
#include "layered/hydro.h"
...
double G = 9.81 [1,-2], H0 = 10. [1];
double c = G*H0;
...
foreach()
  u.x[] = c;
...

qcc -source -dimensions test15.c
test15.c:10: error: the dimensional constraints below are not
compatible
test15.c:10: 'u.x[]': [u.x[]] = [1,-1]
test15.c:10: 'c':         [c] = [2,-2]
```

A way to catch difficult bugs e.g. is this code correct?

(from the relaxation function of the implicit multilayer solver)

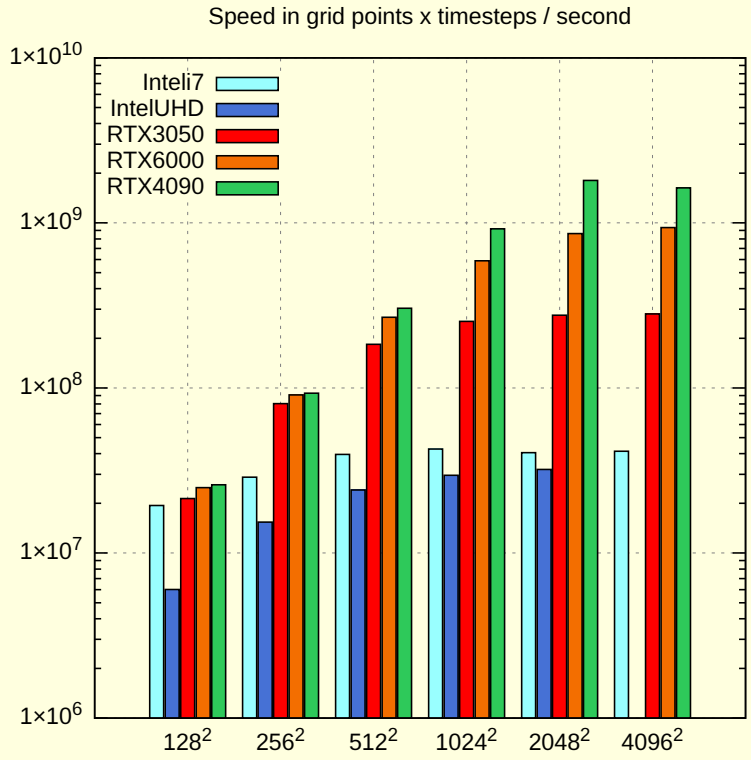
```
foreach_dimension() {
  double s = Delta*slope_limited((dz.x - h[0,0,m] + h[-1,0,m])/
Delta);
  double sp = Delta*slope_limited((dzp.x - h[1,0,m] + h[0,0,m])/
Delta);

  d[l] -= a*(gmetric(0)*(h[-1,0,m] - s)*phi[-1,0,m] +
gmetric(1)*(h[1,0,m] + sp)*phi[1,0,m] + 2.*theta_H*Delta*(hf.x[0,0,
m]*a_baro (eta, 0) - hf.x[1,0,m]*a_baro (eta, 1)));
  H[l*nl + l] -= a*(gmetric(0)*(h[0,0,m] + s) + gmetric(1)*(h[0,0,
m] - sp));
}
```

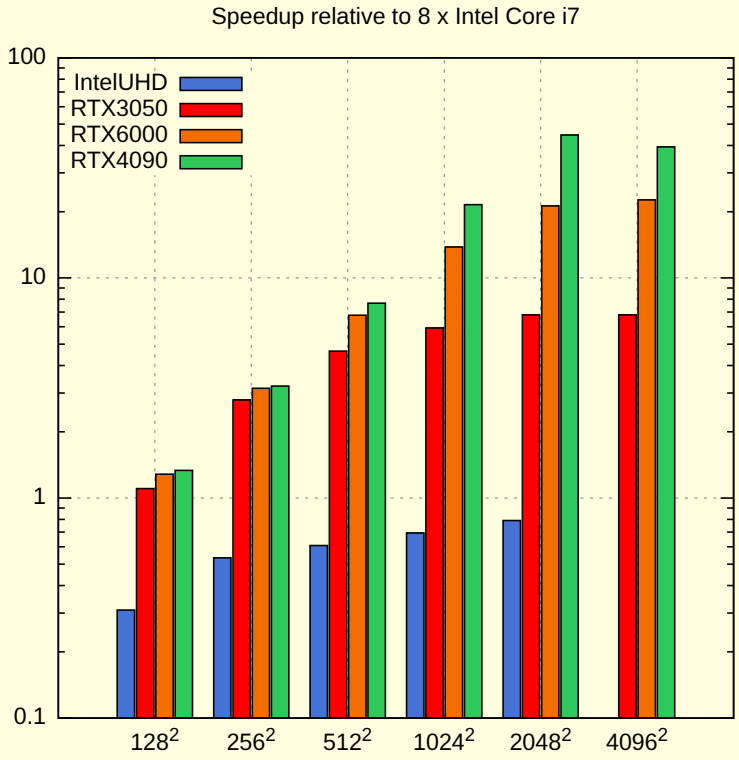
- **GPUs:** src/grid/gpu/grid.h

  Make heavy use of the AST and type system: why?

```
double a;  // CPU "external" variable
...
foreach() {
  double b; // GPU local variable
  ...
  s[] += a + b;  // GPU kernel uses "external" variables
}
```

Two-dimensional turbulence benchmark: `src/grid/gpu/Benchmarks.md`





- Also relies heavily on Automatic Boundary Conditions (from 2023)

```
foreach()
  s[] = x + y;
/* boundary ({s}); // obsolete */
foreach()
  g.x[] = (s[1] - s[-1])/(2.*Delta);
```

`boundary_flux()` is obsolete too...

... but `boundary_level()` is not obsolete (yet...)

- New macro system: src/ast/macro.h

```
macro iterator (int start, int end, int index) {
  for (int index = start; index <= end; index++)
    {...}
  printf ("do␣something␣after␣the␣loop\n");
}

int main() {
  iterator (0, 10, i)
    printf ("%d\n", i);
}
```

The implementations in `src/grid` have been rewritten

Used heavily in `src/grid/gpu/grid.h`

- Einstein summation notation: src/ast/einstein_sum.h

  Done by Nicolas Fintzi during his PhD (already in his sandbox in 2023)

  Example:

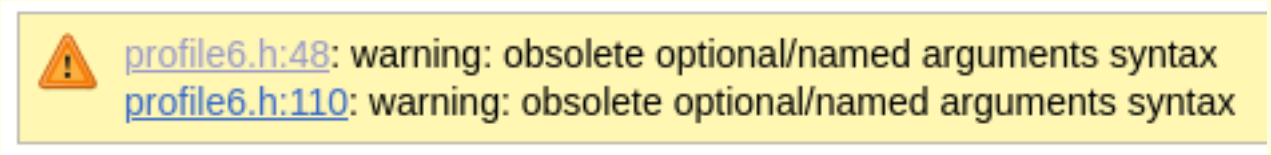
```
einstein_sum(i,j,k)
  C.i.j = A.i.k*B.k.j;
```

- Optional arguments in function calls

```
void example (float f = 0, double d = 0);
...
example (f = 2); // d = 0
example (d = 4, f = 1.2);
```

Note that the old "trick" with structures is deprecated e.g. from Antoon's sandbox

```
struct ob_av {
  scalar * list;  // List of scalar fields (mandatory)
  double * v;     // array for the values (mandatory)
  ...
};
...
double interface_average (struct ob_av oa){
...
```

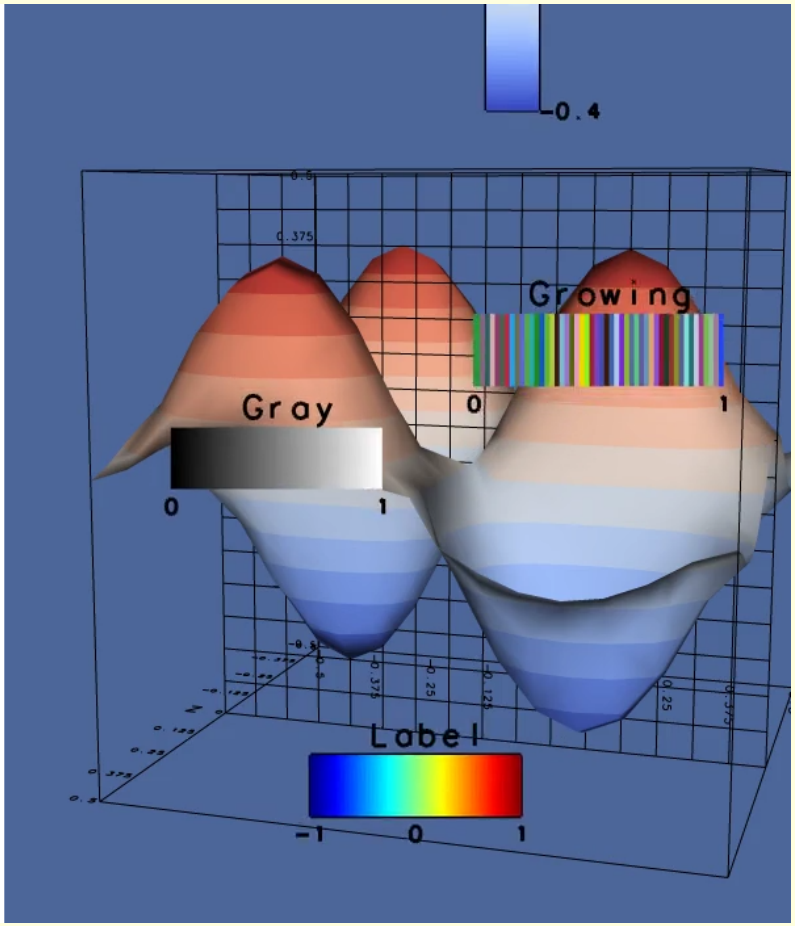


- Non-square/cubic boxes with `grid/multigrid.h` in serial, MPI and GPU

  src/Tips#non-cubic-domains

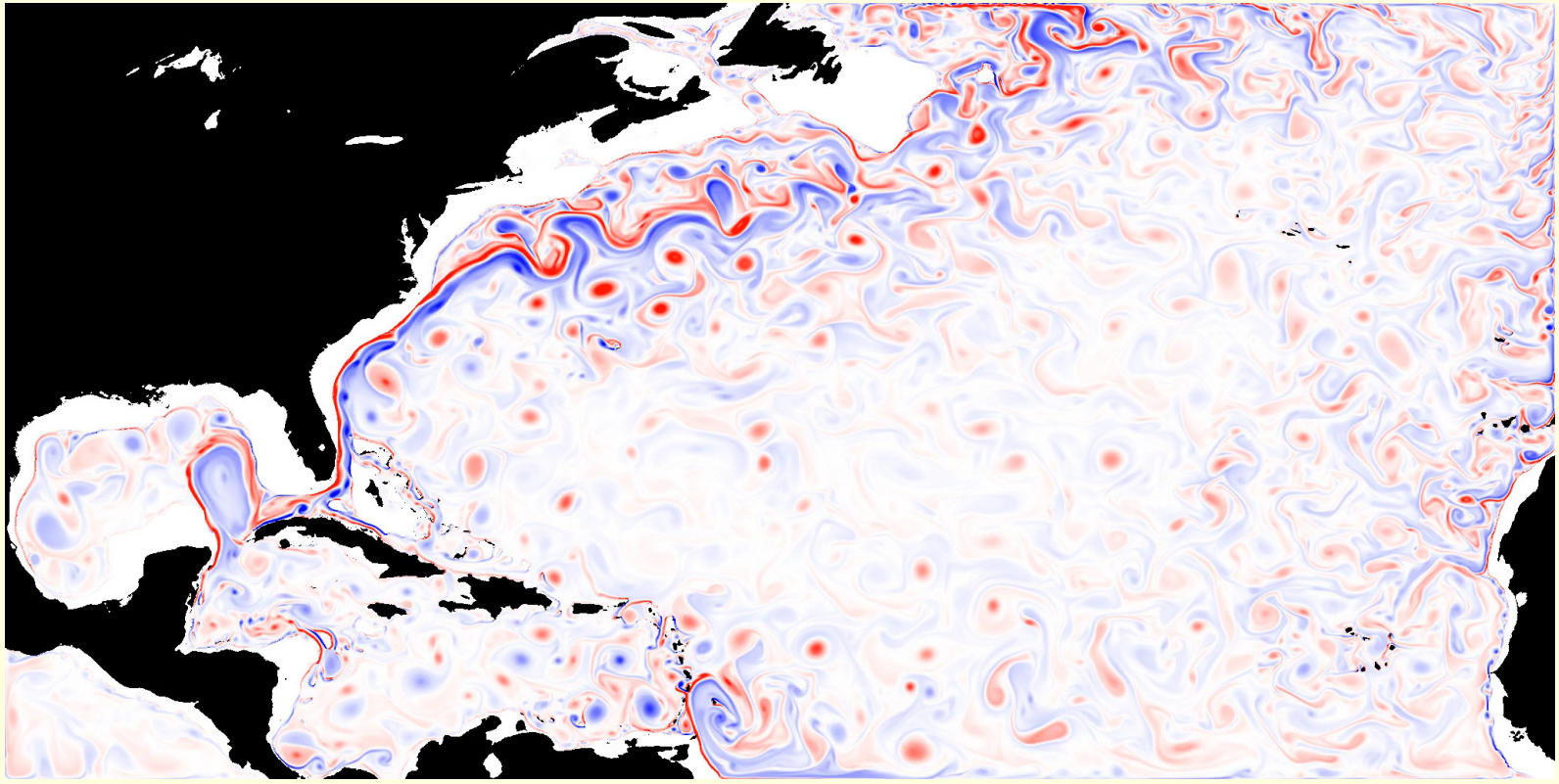
- The long-awaited colorbar for bview (Antoon)

  sandbox/Antoonvh/tcbar.c



- **New examples for the (implicit) multilayer solver**

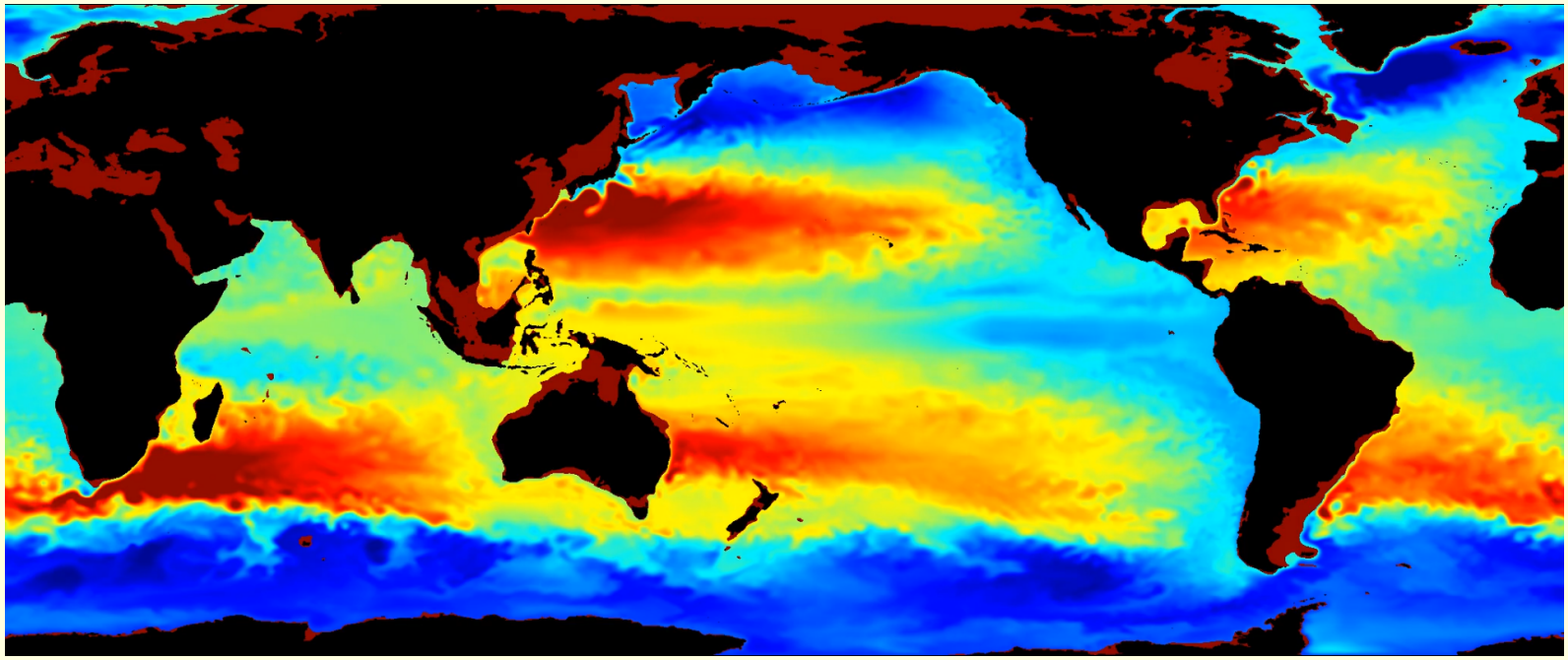
  The Gulf Stream: src/examples/gulf-stream.c



  Runs on the RTX4090 GPU card as fast as on 768 AMD MPI cores

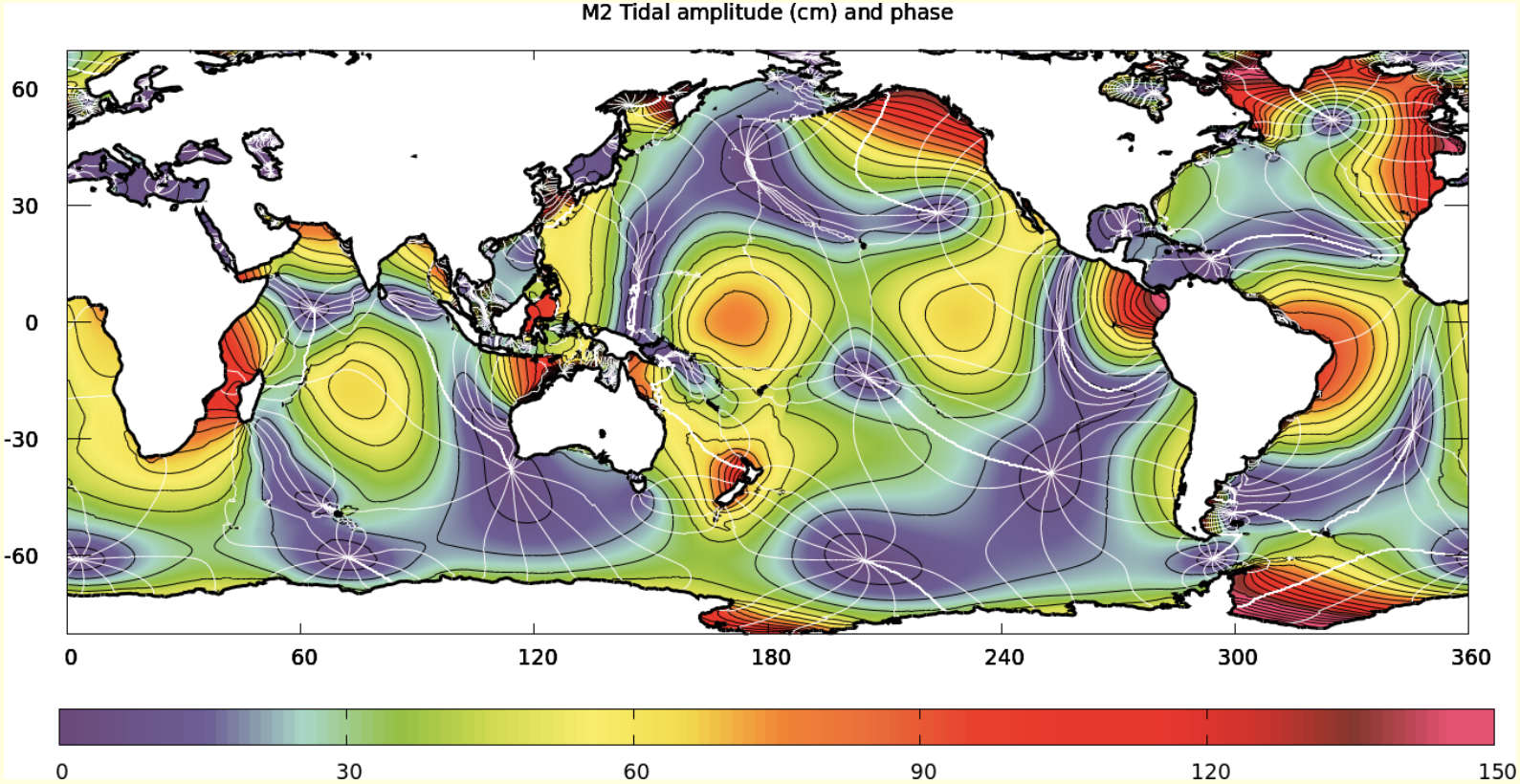
  Power consumption is at least 10 times lower

The Global Oceanic Circulation: src/examples/global.c



Instantaneous sea surface elevation

Global Tides: src/examples/global-tides.c



Harmonic decomposition: src/harmonic.h

$$Z + \sum_i a_i \cos(\omega_i t) + b_i \sin(\omega_i t)$$

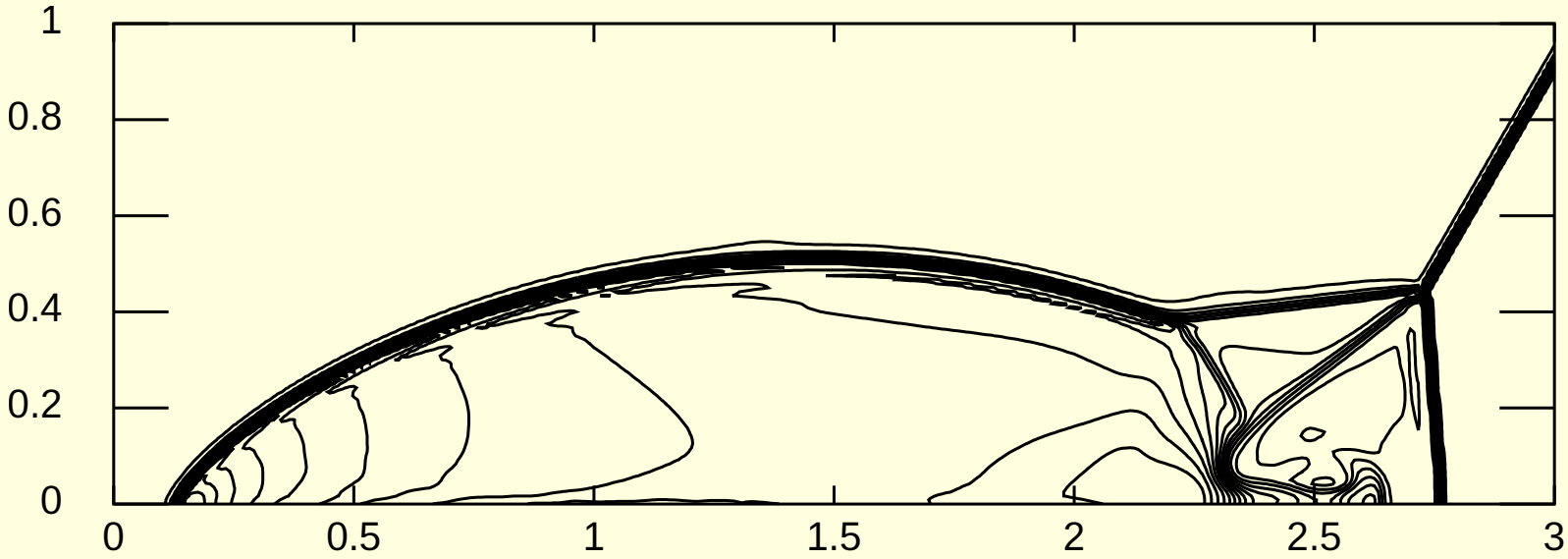
Merged in src/

Code review, bug fixes and automated test cases

- The "All Mach" solver of Daniel and Youssef (thermal effects)

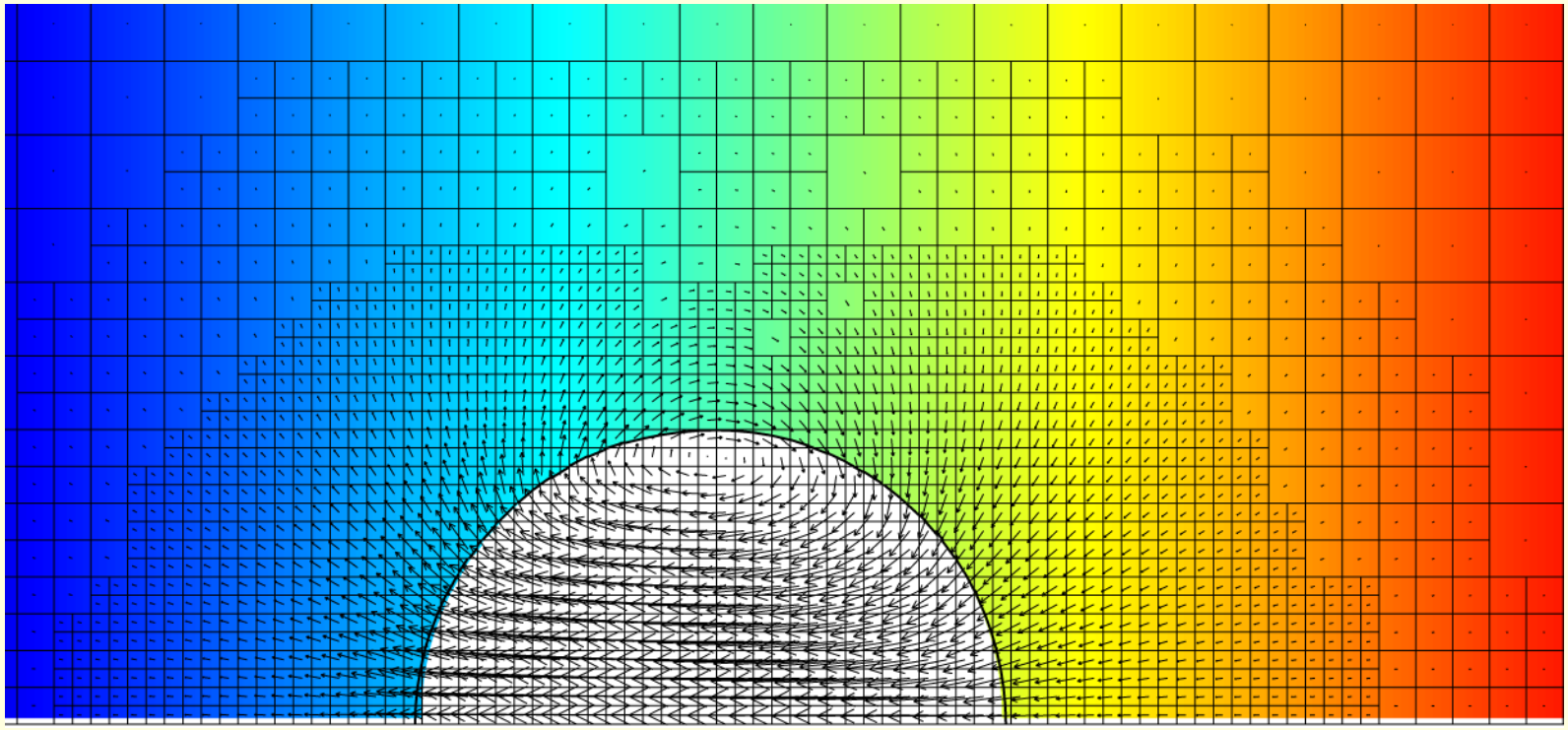
  src/all-mach.h

  src/test/README#compressible-two-phase-flows



- New levelset, CLSVOF and integral surface tension formulation (in 2D)

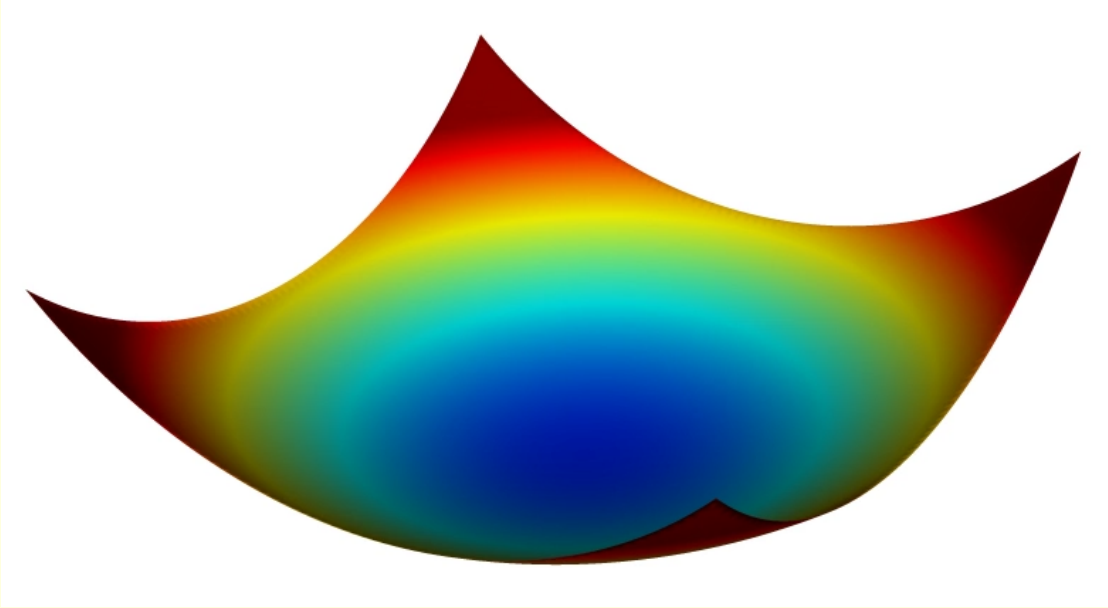
  src/test/marangoni.c



  Also runs on GPUs

- Implicit surface tension in the multilayer solver

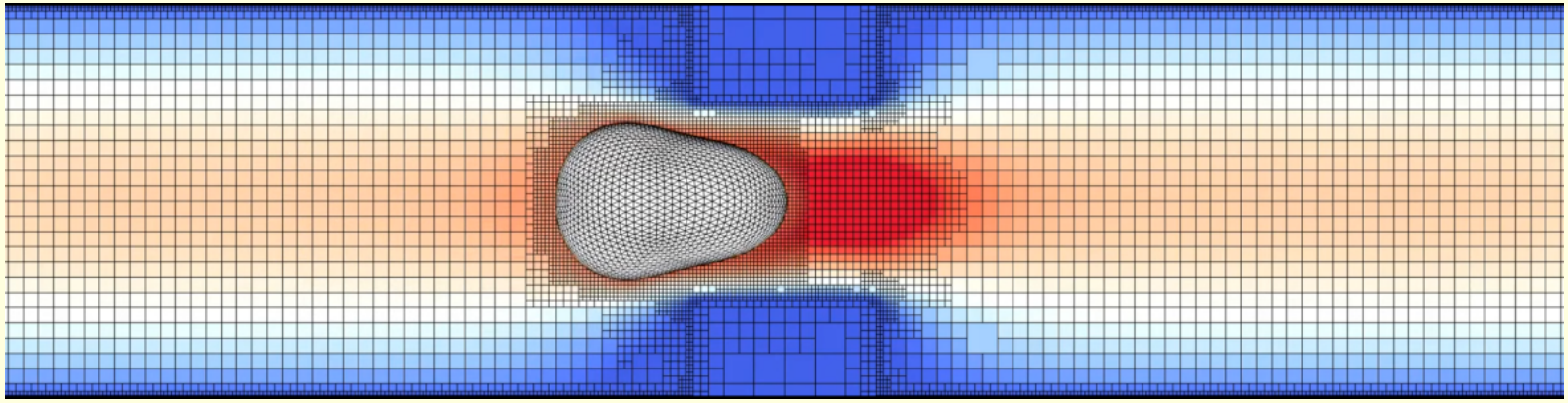
  src/test/meniscus3D.c



- No-coalescence VOF algorithm (Mani and Nicolas)

Codes in `sandbox/` waiting for integration

- Mathilde's (and others) contact angles on embedded solids
- Elasto-visco-plastic materials (Pepe, Vatsal, Lucas, etc...)
- Surfactants (from Palas and others)
- Anton's fourth-order Navier–Stokes solver (since 2023)
- Several phase change / evaporation implementations: Gabriele, Eduardo, Palas, Bradley etc. (since 2023)
- Moving solids (Arthur, UBC): using embedded boundaries (since 2019)
- Coupled fluid/capsule mechanics (Damien Huet) (since 2023)



- Adaptive Lattice Boltzmann (Zihao) (since 2023)
- Phase change / solidification / melting (Alexandre): using embedded boundaries and levelset (since 2023)

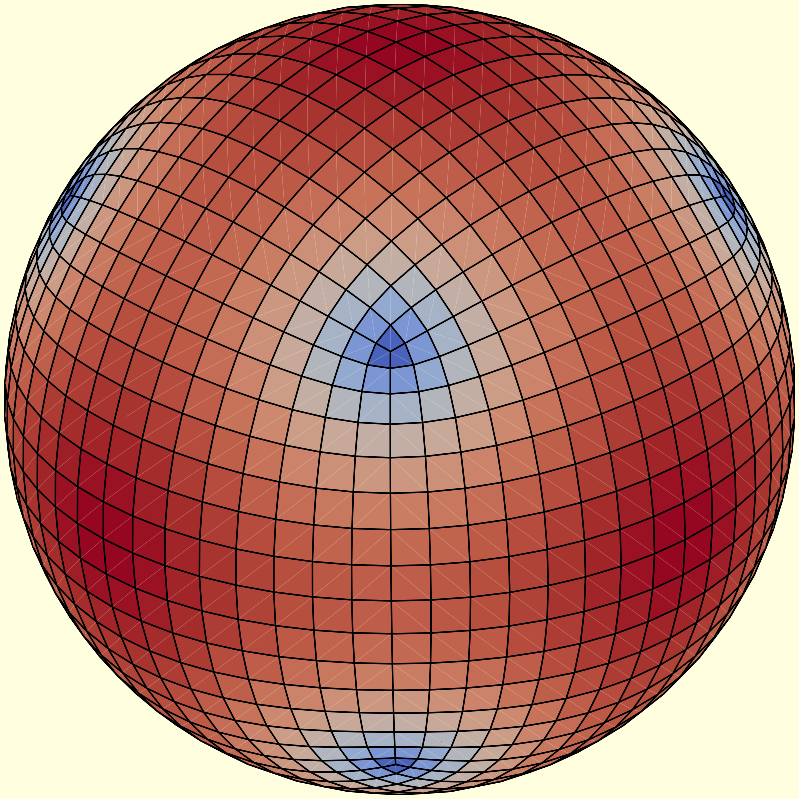
Short-term development priorities

- 3D multigrid and tree grids on GPUs
- Adaptivity for the multilayer solver (e.g. for adaptive ocean models)
- More general storage for cell data

  MPI-parallel STL geometries $\rightarrow$ New MPI-parallel "particule" data structure (from 2019)
- `mask()` will go... and be replaced (to some degree) by "multi-box" topologies (à la Gerris) (from 2019)
- Re-implementation of `adapt_wavelet()` (from 2019)
- Improved documentation / workshops (continued...)

Future plans

- Periodic boundary conditions and more general topologies e.g. cubed sphere (for geophysical fluid dynamics) (since 2017)



"Multi-boxes" but more flexible than Gerris (2:1 box connections)

- Automated dimensional analysis
- Automatic differentiation?
- Other ideas?

Important non-technical issues

- Merging sandbox contributions in /src

  Why this is **very important**!

  delegate code review (volunteers?)

  "public consultation" on what to merge

- "Forks" in the sandbox/ and on github

  Read carefully Help#How to re-use, modify or fix codes in the `sandbox`

- Attribution / Authorship

- Communication / Training

Some statistics

927 members in basilisk-fr google group (197 in 2017, 328 in 2019, 730 in 2023)

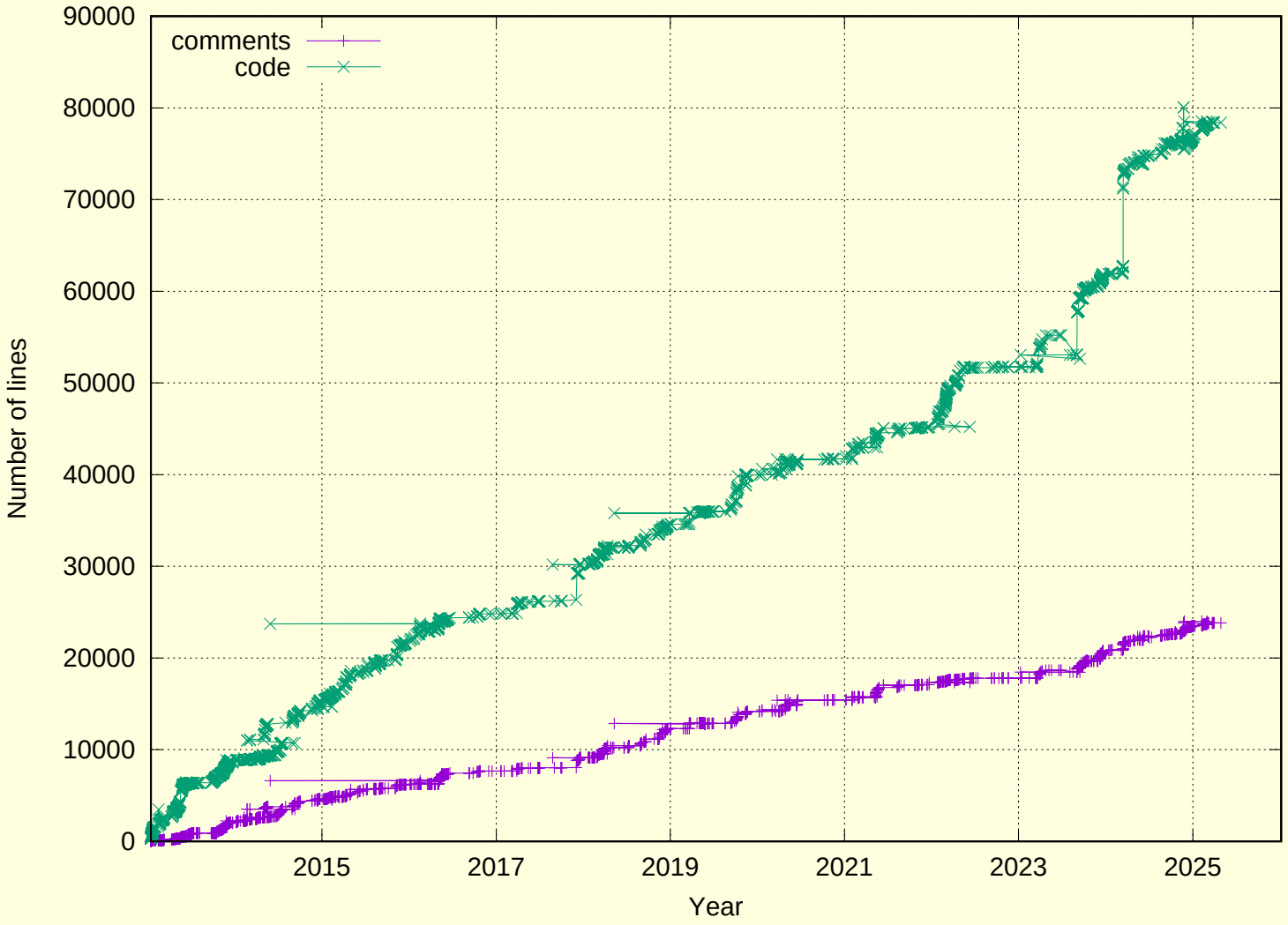
Published papers or PhD manuscripts: `basilisk.fr/Bibliography`

24 in 2025, 40 in 2024, 43 in 2023, 34 in 2022, 39 in 2021, 30 in 2020, 12 in 2019 etc...

Journal of Non-Newtonian Fluid Mechanics, *Physical Review Fluids*, *Journal of Fluid Mechanics*, *Ocean Modelling*, *Natural Hazards and Earth System Sciences*, *Nuclear Science and Engineering*, *International Journal of Multiphase Flow*, *Journal of Computational Physics*, *Chemical Engineering Science*, *Agricultural and Forest Meteorology*, *Journal of Geophysical Research*, *Geophysical Research Letters*, *Physical Review Letters*, etc...

Several covers of *Journal of Fluid Mechanics*.

Lines of code (in /src)



Number of patches (in /src)