CrClim: bit-reproducibility

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Me !

- Me
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  - Scientific programmer for the CrClim project
    - since August 2015

The CrClim project

- The CrClim project
  - **C**loud-**r**esolving **Clim**ate modeling on future supercomputing platforms
  - From a computer science perspective:
    - Climatology: long term simulation
    - Computational resolution increase: **huge** volume of data
    - Heterogeneous multi-core architecture: **bit-reproducibility!**

Bit-reproducibility

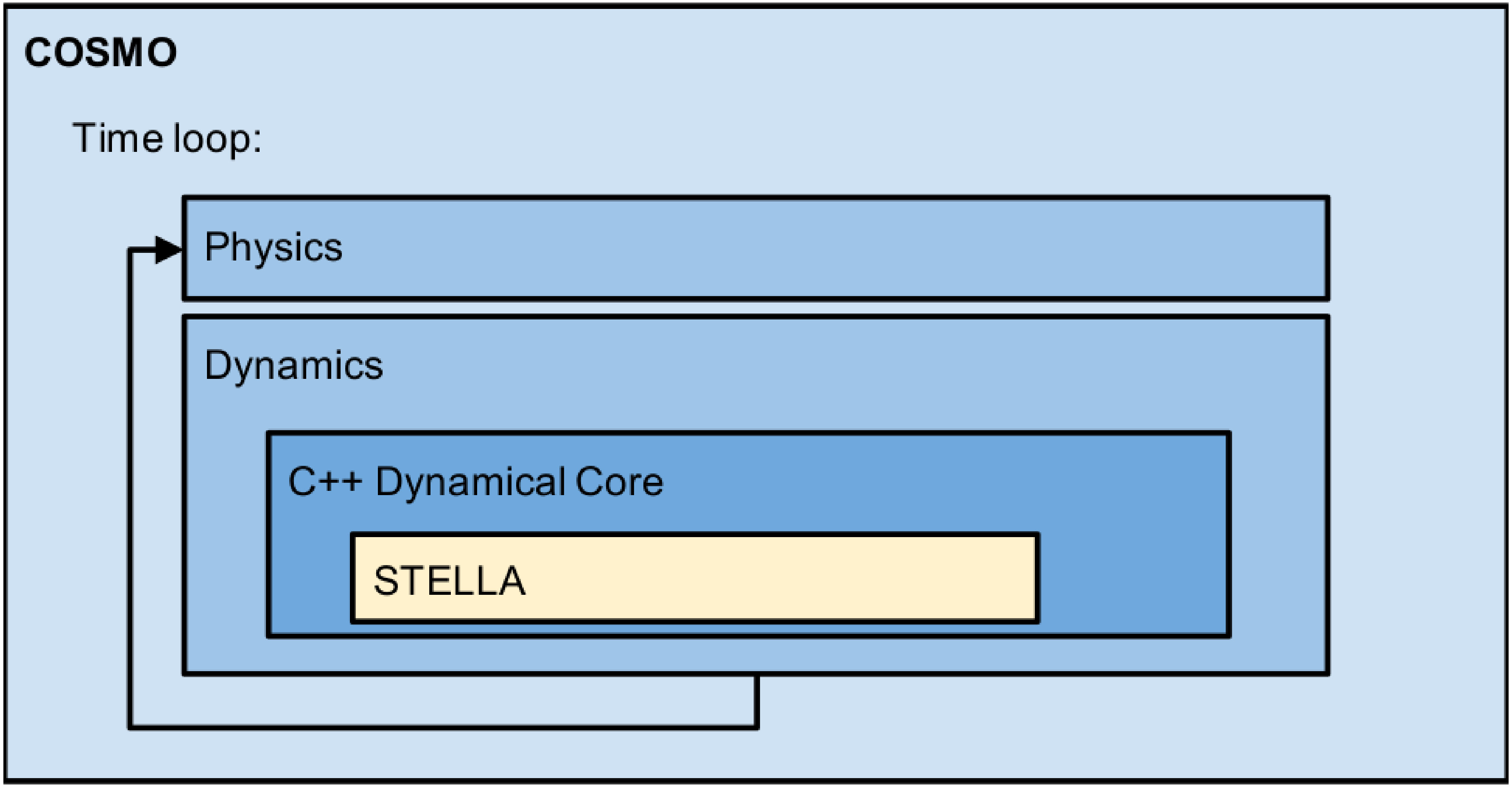
- Make the C++ Dycore and COSMO bit-reproducible
- Why not reproducible?
  - Computation transcendental functions and intrinsic operators
  - Reassociation
  - Floating point optimization (i.e. FMA)
- Drawback
  - Hard to prove
    - Pragmatic approach, we need to run tests
  - Deactivation of compiler optimization
    - Huge performances loss (?)

Thank you

for your attention

Supplementary slides

COSMO architecture



P. Spörri

Current status

- Dycore
  - The only problem are the transcendental functions
- COSMO
  - Call a C function from Fortran OpenACC: done but not very well documented (Cray)
  - Replace the transcendental functions: by shadowing
  - Reassociation
    - Can be controlled by compilation flags
    - May have no effect on the generated PTX by Cray or on the Cuda/LLVM generated by PGI
- Next
  - Tests (our approach is pragmatic and it's hard to prove that it's reproductible)
  - Evaluate performance loss

Representation of real numbers

- For any base *K*:

$$\text{+/-}\ D.FF\cdots FF\cdot K^{e}$$

$$1\leqslant D\leqslant K-1 \text{ and } 0\leqslant F\leqslant K-1$$

- Example in base 10:

$$+99.99=+9.999\cdot 10^{1}$$

$$+0.1615=+1.615\cdot 10^{-1}$$

- Example in base 2 (half-precision):

$$+3.3\approx +1.1010011010\cdot 2^{1}=+3.380$$

Example of arithmetic issues

- We want to sum two real values (4 digits)

  $9.999 \cdot 10^{1}$ and $1.615 \cdot 10^{-1}$

  - Align the decimal point of the value with the smallest exponent

    $$1.615 \cdot 10^{-1} = 0.01615 \cdot 10^{1}$$

  - Apply the sum and the rounding function:

$$\begin{array}{r} 9.999 \quad \cdot 10^{1} \\ +\ 0.01615 \cdot 10^{1} \\ \hline 10.01515 \cdot 10^{1} \end{array} \rightarrow 1.001515 \cdot 10^{2} \rightarrow 1.002 \cdot 10^{2}$$