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Summary of Priority Project POMPA

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(for the whole project team)

Colleagues (Thanks!)

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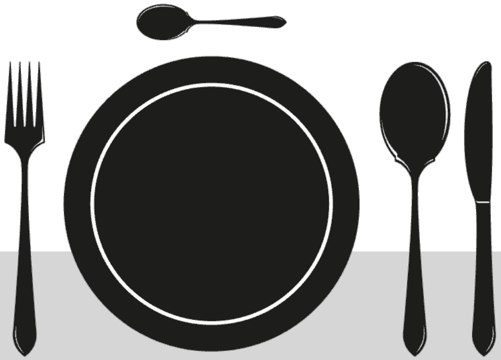
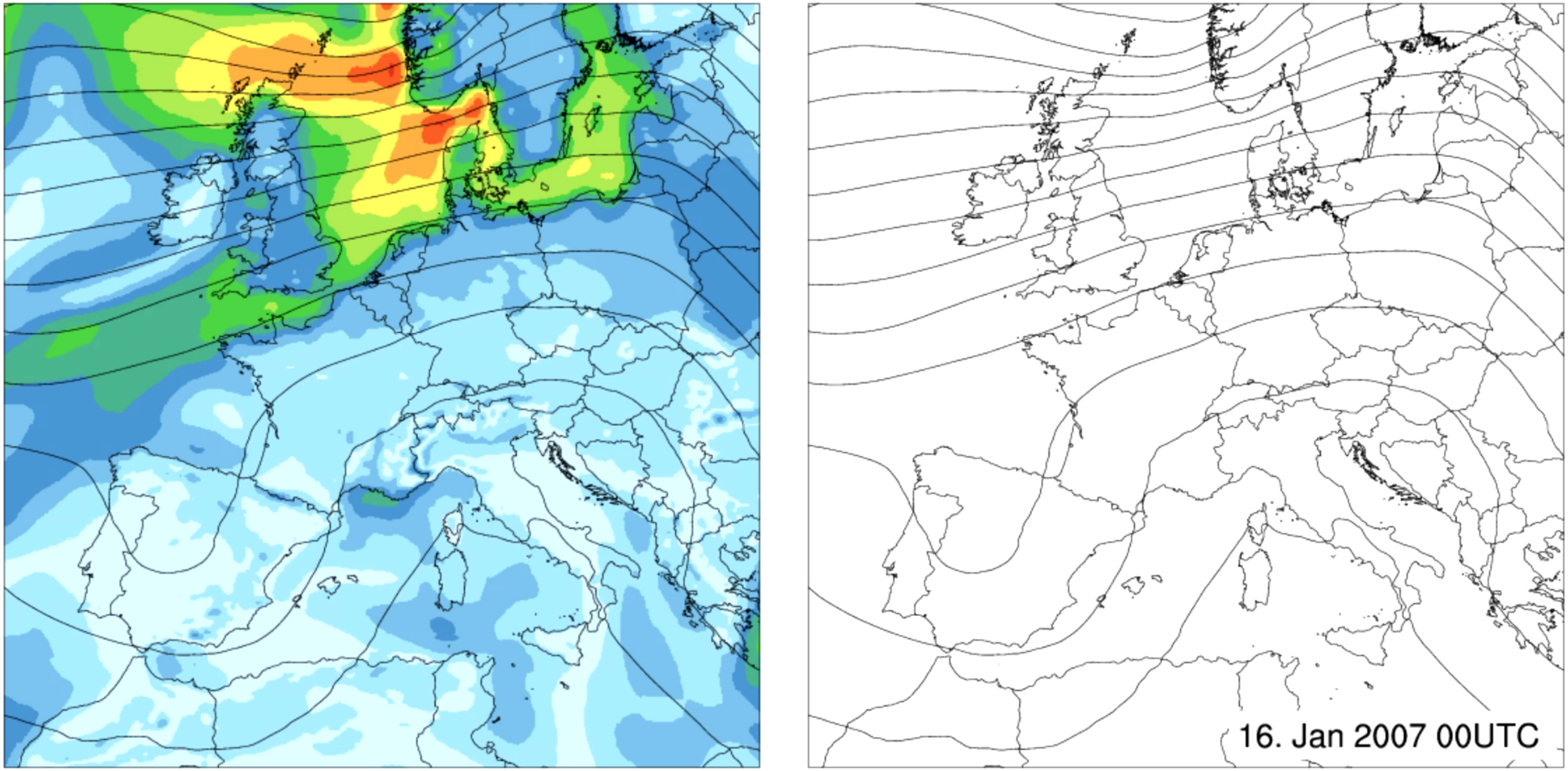
Michael Baldauf
Peter Messmer
Stefan Rüdisühli
Tobias Gysi
Ulrich Schättler
Xavier Lapillonne

Menu



- Highlight
- Specific tasks
  - Single precision
  - Performance profiling of 5.1
  - COSMO 5.X on GPU
  - STELLA developments & discussion
- Outlook

Climate Simulations on GPU (ETH)

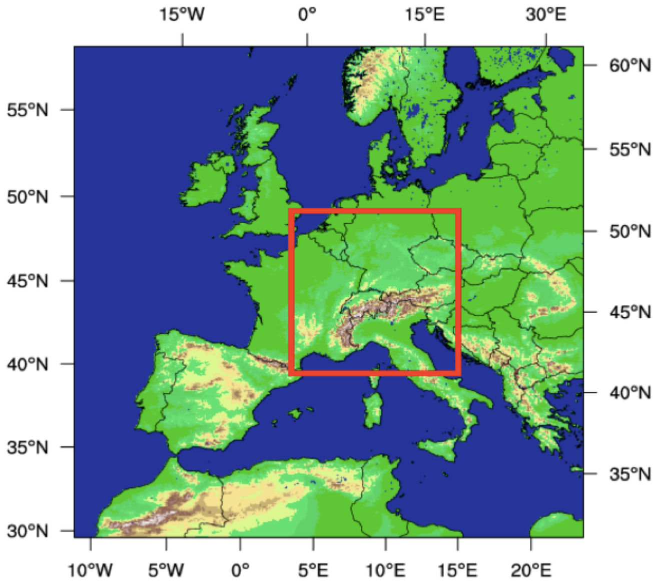


16. Jan 2007 00UTC

(courtesy of David Leutwyler)

Climate Simulations on GPU

- Cray XC30 @ CSCS
  each node has one GPU and one CPU
- COSMO 4.18 + modifs
- European Domain @ 2.2 km
  Size 1536 x 1536 x 60
- 144 nodes (only GPU used)
  40% of DWD's XC30
- Time-to-solution is roughly 0.2 SYPD
  ~2 months for 10 years
- Allocation for ~50 years
  1.1 million nodehours



Third-party funding

Finished

- HP2C COSMO-CLM (June 2010 – June 2013, 1 MCHF)
- HP2C OPCODE (July 2011 – June 2013, 0.5 MCHF)
- HP2C COCoNet (January 2012 – June 2013, 0.2 MCHF)

New

- **PASC GridTools** (January 2014 – June 2017, 0.7 MCHF)
- **SNF Sinergia** (May 2015 – April 2018, 1.5 MCHF)

Planned

- PASC Focused
- H2020 (ECMWF)

Single precision (1/2)

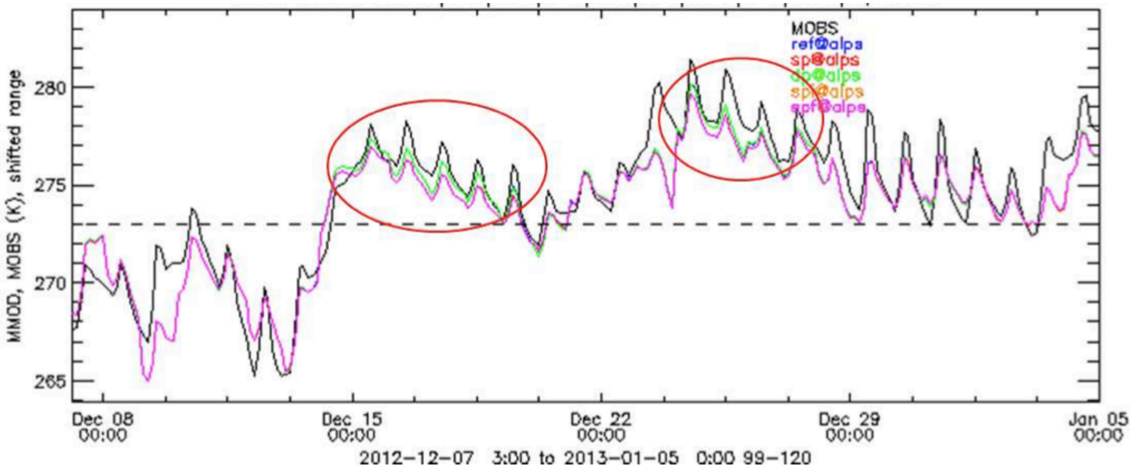
- Will be in official version 5.1, activate with `-DSINGLEPRECISION`
- Runtime & memory consumption decreases significantly (~ 60% of double precision)
- Tested for COSMO-E

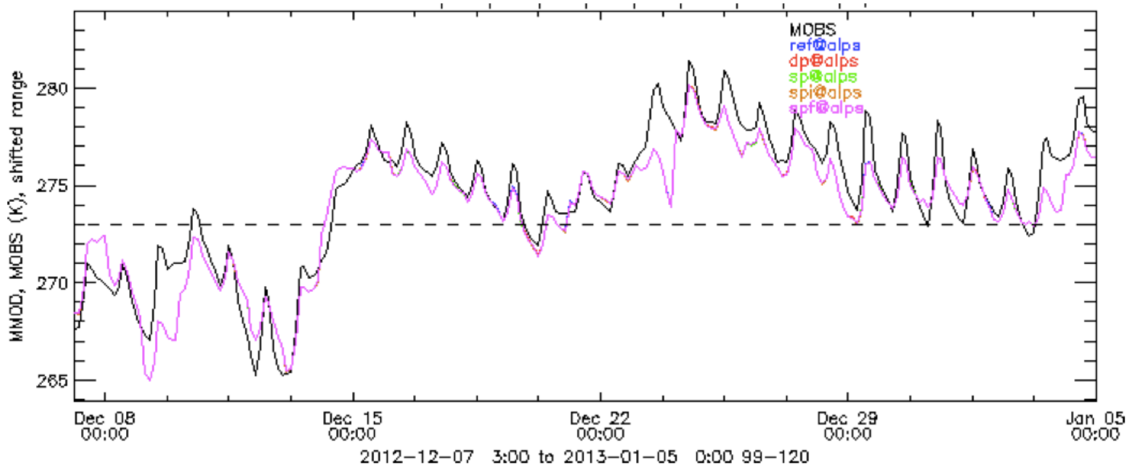
- **But…**
  - Some parts don't work yet (e.g. assimilation) or haven't been tested (e.g. seaice)
  - Developer behavior has to change
  - Developers currently don't run single precision

- **Recommendation**
  - Read CNL!
  - Validate your setup before using SP!
  - Talk to us!

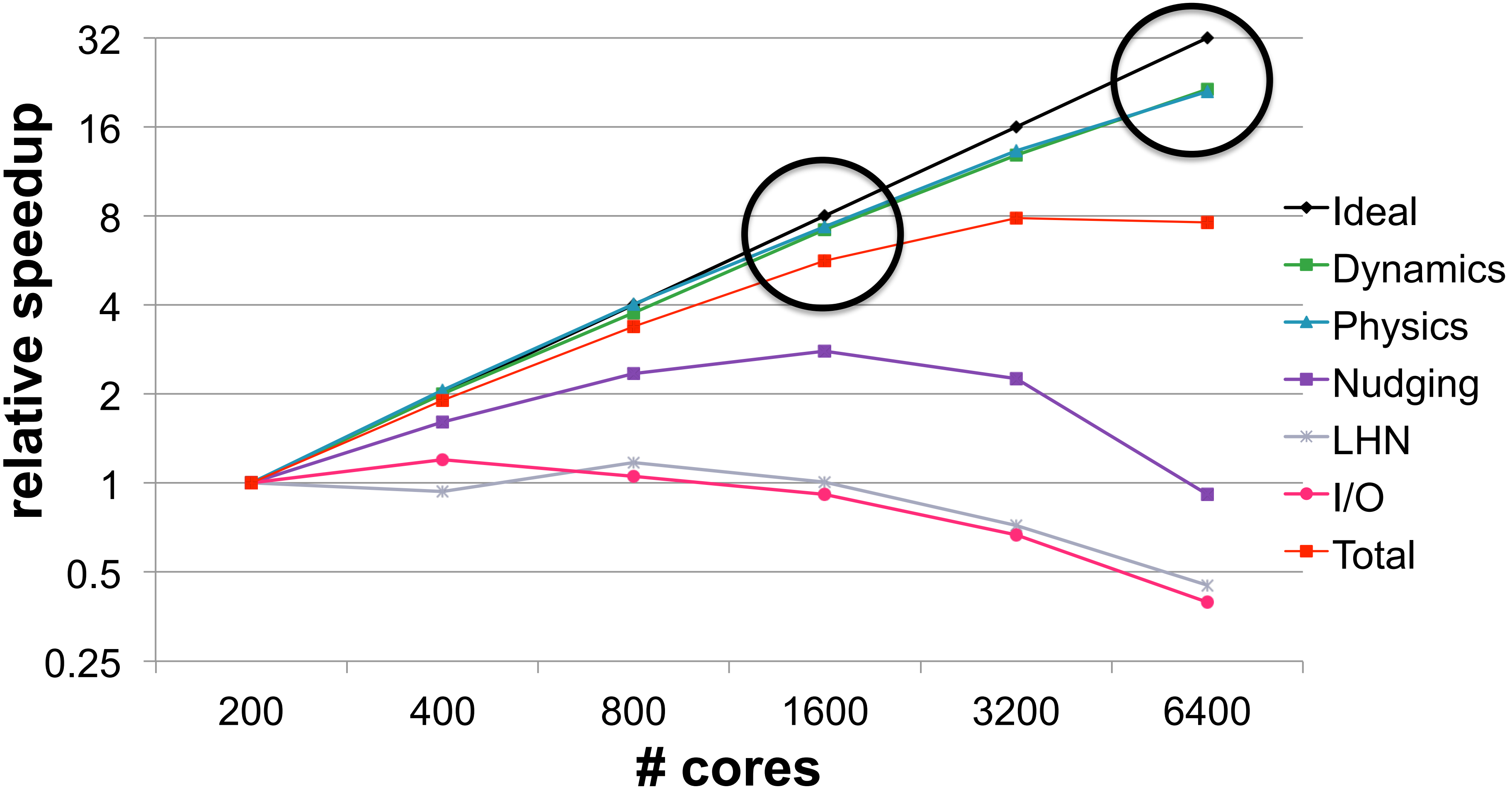
Single precision (2/2)

- Verification of T2m at +5 days (1 month COSMO-E)





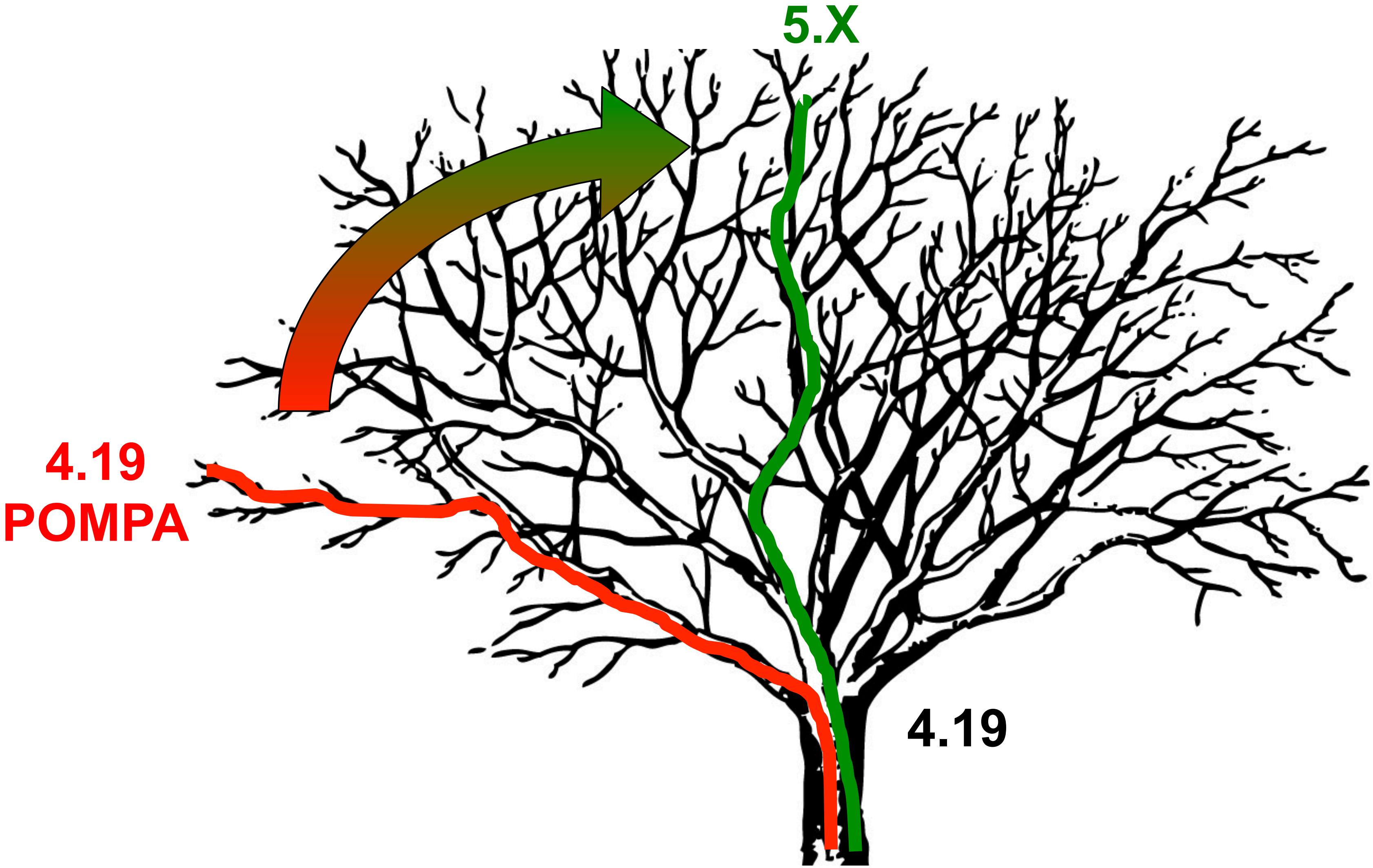
Scalability of COSMO Components (incl. Comm.)



First Conclusions

- ➔ Scalability of COSMO-Model for COSMO-DE65 domain size is reasonably well up to 1600 cores. Dynamics and Physics also scale beyond up to 6400 cores.
- ➔ Operational requirements for COSMO-DE65 ensemble can currently not be met
- ➔ This is not a problem of the scalability, but of some expensive components!
- ➔ Expensive Components:
  - ➔ New fast-waves solver is more expensive than old one (40-50% of dynamics time; but not investigated further up to now)
  - ➔ Communication in the Latent Heat Nudging
  - ➔ Additional Computations: is almost only in RTTOV10
    - ➔ factor of about 10-15 compared to RTTOV7

Summary of POMPA



POMPA developments

- C++ Dycore
- Changes and bugfixes in Fortran dycore
- Static memory allocations
- **Block module**
- **Bl**ock physics
- Serialization
- **Single precision**
- New communication interfaces
- New BC module
- Changes in BCs inside and after dynamics

- Code refactorings
- OpenACC directives
- Tracking and copying of boundary fields
- Re-ordering of microphysics
- Re-ordering of assimilation / relaxation
- Change of application domain in relaxation
- **NetCDF I/O**
- …

Strategy

- **Goal** GPU capable COSMO version 5.X delivered to SCA by December 2014
- **Guideline** COSMO Coding Standards
- **Path** WG chairs → SMC → SCA → Trunk
- Many changes to a large part of the code
- Keeping in sync with the latest repository head is an effort

Conclusion

- In order to make this happen…

  We are dependent on code owners, SCA, WG chairs and SMC for their time and support!
- Bring changes back step-by-step
- Thanks to Uli (block, microph) and Christoph (assimilation)!

GPU Acceleration (1/2)

- On track
- Not all namelist options will be supported for 5.X version (current focus COSMO-1)
- Not all output fields will be supported for 5.X version (e.g. CAPE)
- You require C++ dynamical core based on STELLA in order to run on GPU

Conclusion

- Tell us your requirements!
- Send us your YUSPECIF!
- Talk to us!

GPU Acceleration (2/2)

Parts	Status	Delivery / Required work	Remark
Physics	On-going	18/09/2014	Only turbulence and radiation still on-going.
Fortran-C++ interface	On-going	05/09/2014	First version working. Modifications on-going.
Dynamical core	On-going	18/09/2014	Working. Including new FW solver. Some features for C-1 still missing.
Assimilation	Ready to merge	1 day. On-demand	Tested with Cray, problem with PGI No LHN
Communication	Ready		Use GCL for GPU
Structure code (e.g. initialization, lmorg.f90, …)	On-going	18/09/2014	Mostly in lmorg.f90 + some utility functions
Diagnostics	Not started	2 days (for minimal set)	Minimal set sufficient for standard verification (also for CALMO)
Output	Not started	30/09/2014	Port already available, only need to be merged into 5.0
Single precision	On hold		Doesn't work for assimilation

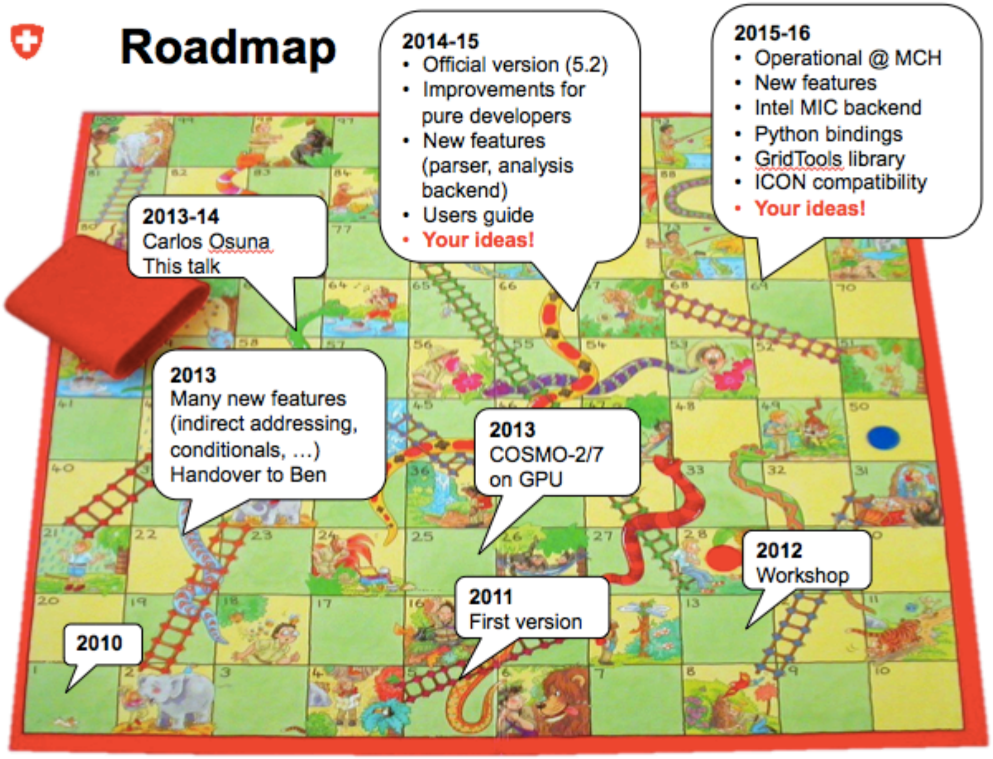
Documentation

- **Existing**
  - Stencil library workshop material
  - Stencil library (implementation)
  - GCL documentation
  - Communication framework
  - Serialization framework
  - C++ style-guide
  - Single precision CNL
  - Block structure API + users guide
  - OpenACC (implementation)

- **Incomplete or Missing**
  - Stencil library (users guide)
  - Parallel NetCDF I/O (users guide)

STELLA developments

- STELLA = Stencil Loop Language
- Generic C++ library for stencils on structured grids
- Still young, but evolving rapidly…



Roadmap

2010

2011
First version

2012
Workshop

2013
COSMO-2/7 on GPU

2013
Many new features (indirect addressing, conditionals, …)
Handover to Ben

2013-14
Carlos Osuna
This talk

2014-15
- Official version (5.2)
- Improvements for pure developers
- New features (parser, analysis backend)
- Users guide
- Your ideas!

2015-16
- Operational @ MCH
- New features
- Intel MIC backend
- Python bindings
- GridTools library
- ICON compatibility
- Your ideas!

STELLA as a language

Language elements

- Declaration
- Loops (k, ij)
- Conditions (switch/ case, if)

Keywords

- **Base language**
  StencilCompiler, Param, StencilConfiguration, define_loops, define_sweep, define_stages, StencilStage, IJRange, Krange, define_switch, define_case, define_if

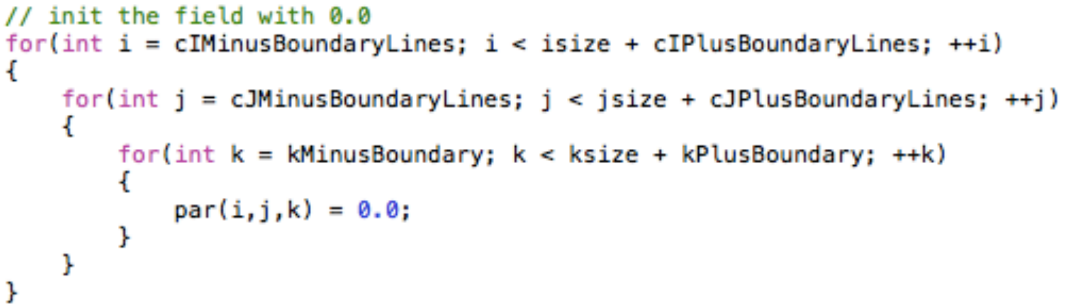
- **Optimization**
  define_temporaries, StencilBuffer, StageVariable, define_caches, IJCache, KCache, IJKCache, KWindow

- **Qualifiers**
  - FullDomain, FlatCoordinates, TerrainCoordinates
  - KMinimumCenter, KMaximumCenter, …
  - cKIncrement, cKDecrement, cKParallel
  - cFillAndFlush, cFill, cFlush, cLocal

STELLA / C++ interoperability

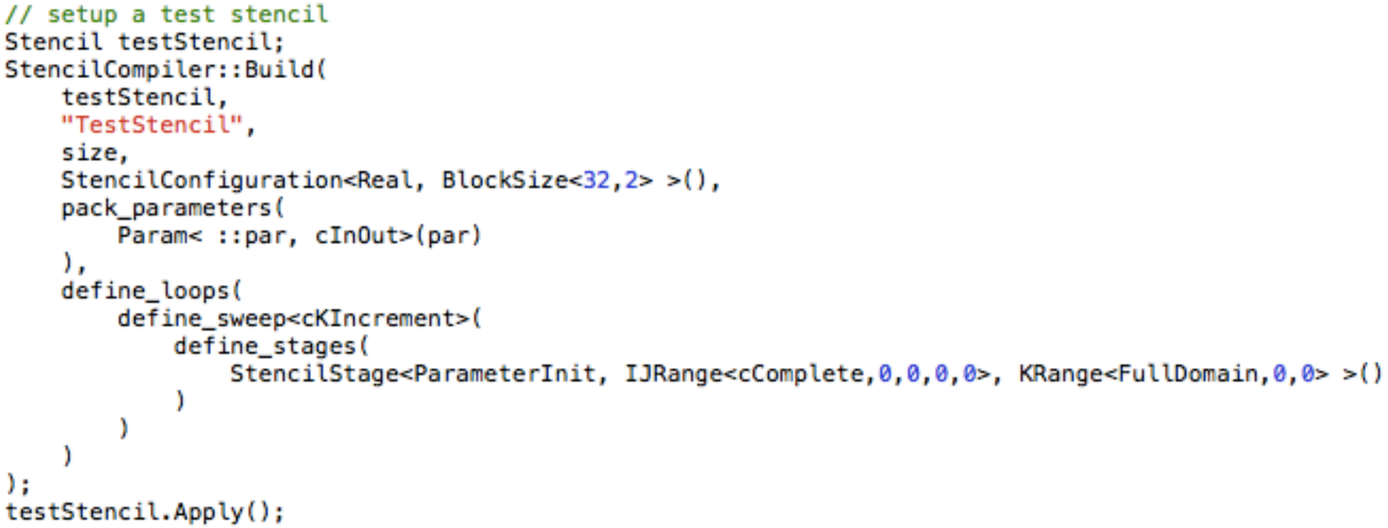
- We do it all the time (for testing)!

C++ code



```
// init the field with 0.0
for(int i = cIMinusBoundaryLines; i < isize + cIPlusBoundaryLines; ++i)
{
    for(int j = cJMinusBoundaryLines; j < jsize + cJPlusBoundaryLines; ++j)
    {
        for(int k = kMinusBoundary; k < ksize + kPlusBoundary; ++k)
        {
            par(i,j,k) = 0.0;
        }
    }
}
```

“STELLA code”

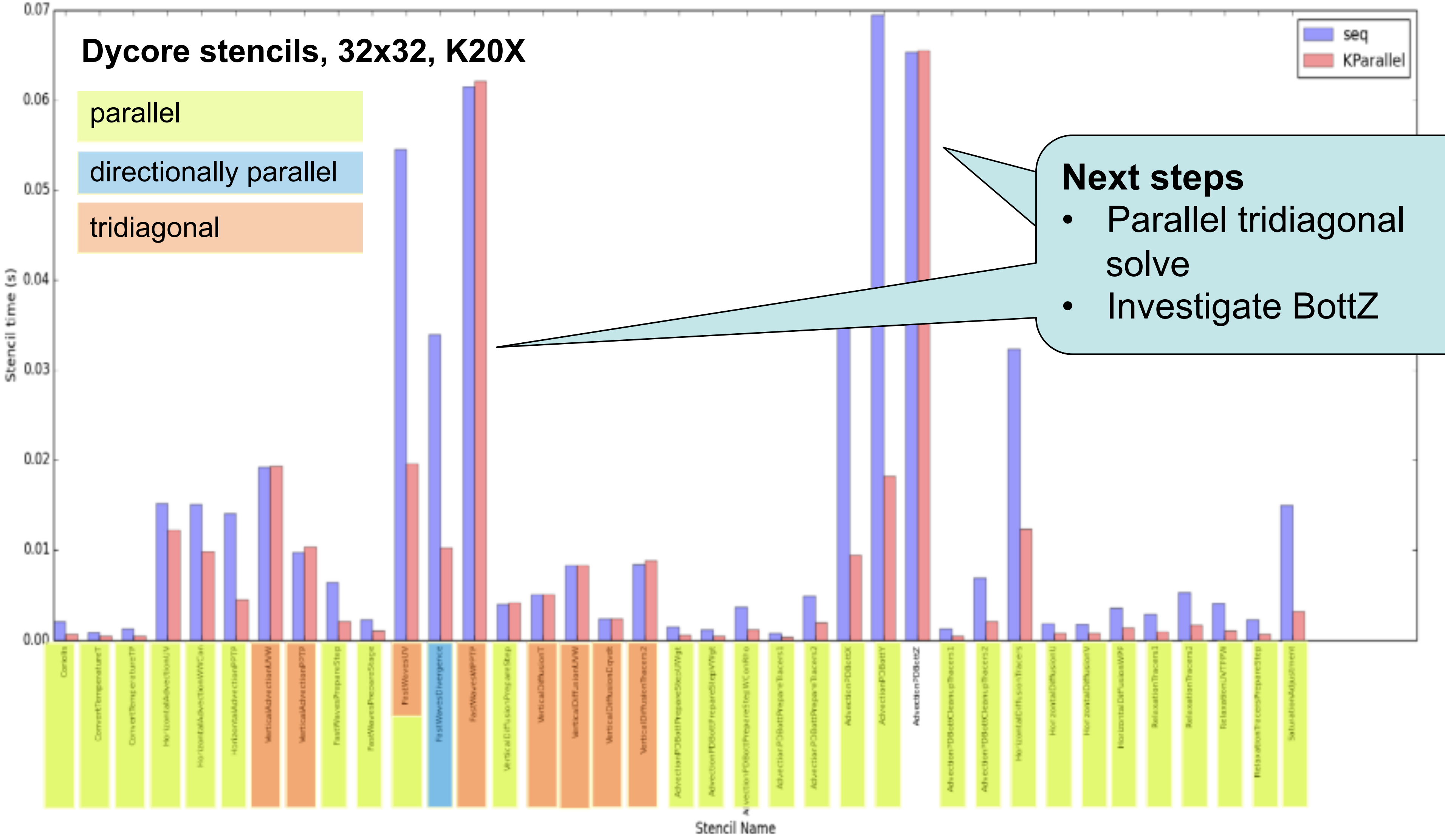


```
// setup a test stencil
Stencil testStencil;
StencilCompiler::Build(
    testStencil,
    "TestStencil",
    size,
    StencilConfiguration<Real, BlockSize<32,2> >(),
    pack_parameters(
        Param< ::par, cInOut>(par)
    ),
    define_loops(
        define_sweep<cKIncrement>(
            define_stages(
                StencilStage<ParameterInit, IJRange<cComplete,0,0,0,0>, KRange<FullDomain,0,0> >()
            )
        )
    )
);
testStencil.Apply();
```

STELLA developments

- **Syntax features**
  - flexible runtime / compile time options
  - flexible if and switch/case statements
- **Performance features**
  - vertical parallelization
  - improved caching on GPU
- **Debugging features**
  - Unified compile time errors
  - Parser
- **Standalone usage features**
  - Debugging features
  - Logging / verbose mode
  - Python interface

Vertical parallelization



Next steps

- Parallel tridiagonal solve
- Investigate BottZ

Review by Michael Baldauf

- We take the feedback **very** seriously

- Summary of (negative) feedback
  - It is hard to learn a new language (→ help, docu)
    - switch imperative → declarative is hard
    - STELLA is harder than C++
  - Productivity is low (factor 5-10)
    - it get's better over time
    - performance portable code
    - coding is typically fraction of working time
  - No advantages of DSEL, use source-to-source translator? (→ evaluation)

POMPA Conclusions

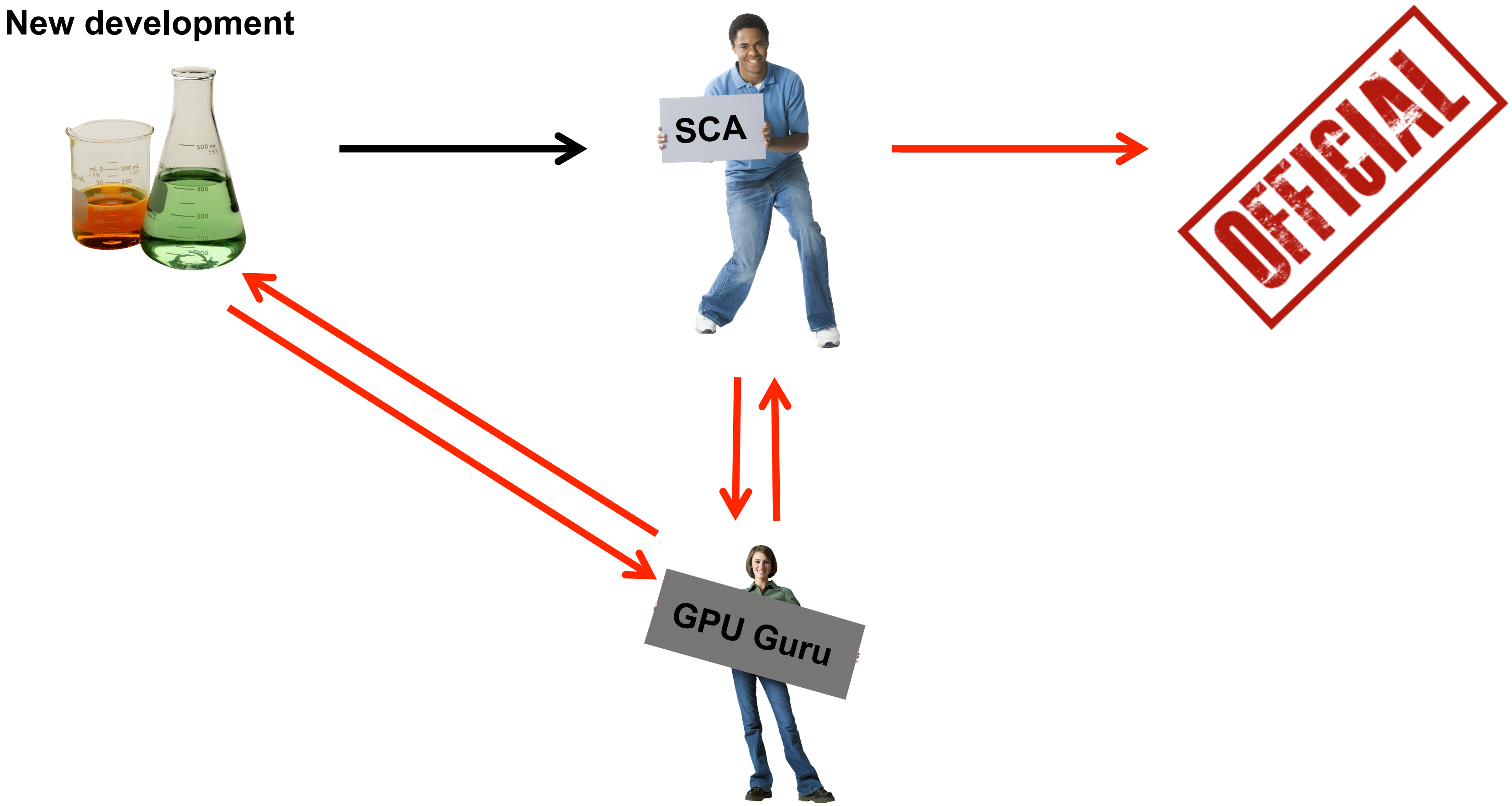
- **Retain the Fortran code, but re-evaluate this decision regularly**
  - Situation is evolving rapidly
  - Extra effort carried by COSMO consortium

- **Synchronization of Fortran with C++ code has to be organized**
  - This can not be **only** done by the **dynamics** developers
  - But, interaction is critical for efficiency and knowhow transfer

- **Involve developers in design and implementation next version of stencil library**
  - Via a joint research project?
  - Especially also from the ICON team

- **Focus more on usability features of C++ code in standalone mode**
  - Try a new development using STELLA

Coordination of new versions



New development

SCA

GPU Guru

We would not recommend delivering a version which is out-of-synch to the users

Coding standards

Coding standards require adaption / extension

- **C++ code**
  - Coding conventions of Fortran don’t apply (e.g. naming)
  - Integrate POMPA project coding conventions?
- **OpenACC / GPU**
  - Changes for good practices
- **Conflicting interests**
  - Performance on CPUs / GPUs / other hardware
  - Memory usage vs. efficiency
- License for STELLA and C++ Dycore?

Knowhow Transfer

- Stencil workshop
- OpenACC tutorial
- Documentation + Presentations + Publications + Newsletters
- **What else? Your suggestions?**

Project extension

- **POMPA project extension proposed until 09.2015 (according to project plan v5.0)**
- **Main reasons**
  - Integration into 5.X will require further work with code responsibles, SCA, and working group chairs
  - Further GPU porting work required/requested (physical parametrizations, LHN)
  - Work to keep C++ version of dycore synchronized
  - Support, training and documentation
  - Assimilation does not work in single precision
  - Open tasks (hybrid OpenMP/MPI, new halo-update, …)
  - Ongoing related activities (e.g. PASC GridTools project)

Thank you!