Schweizerische Eidgenossenschaft
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Swiss Confederation

Federal Department of Home Affairs FDHA
Federal Office of Meteorology and Climatology MeteoSwiss

CONSORTIUM FOR SMALL SCALE MODELING
COSMO

Performance on massively parallel architectures: Status of COSMO priority project

The COSMO model on GPU accelerators

X. Lapillonne, O. Fuhrer, P. Steiner

EWGLAM 2016

The COSMO priority project
Performance On Massively Parallel Architectures

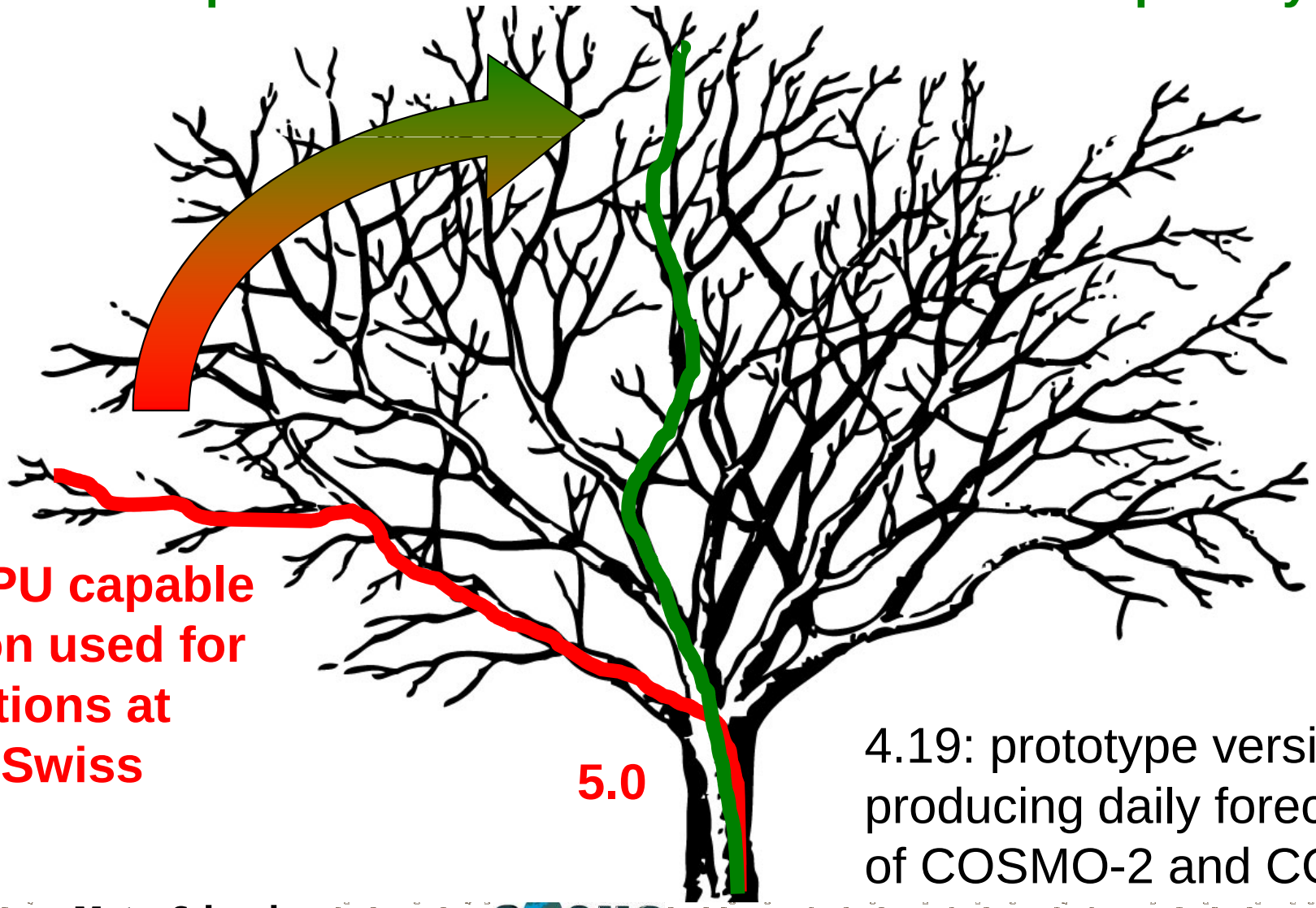
- **Started in 2010 – end of project planned in 2017**

- **Current project leader: X. Lapillonne (MeteoSwiss)**

- **Main outcomes :**
- Performance portable dynamical core: Rewrite using a domain specific library STELLA (C++)
- GPU capable version of the numerical weather prediction model COSMO
- Possibility to run in single precision

History and current task of the project: merge developments into official version

5.6: planed official version with full GPU-capability



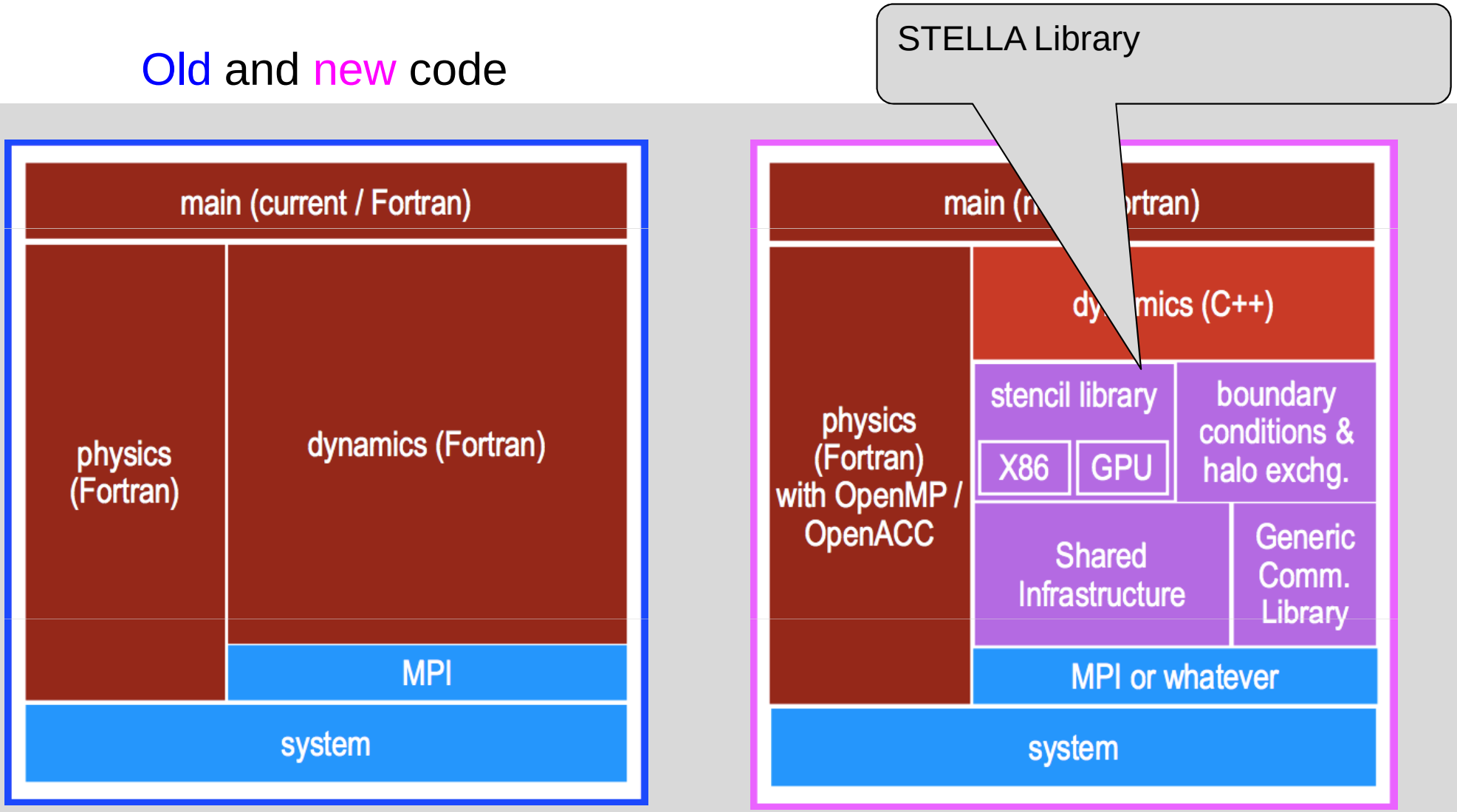
5.0+
full GPU capable version used for operations at MeteoSwiss

5.0

4.19: prototype version producing daily forecasts of COSMO-2 and COSMO-7

COSMO on GPU

Old and new code



adapted from Fuhrer et al. 2014

Performance improvements

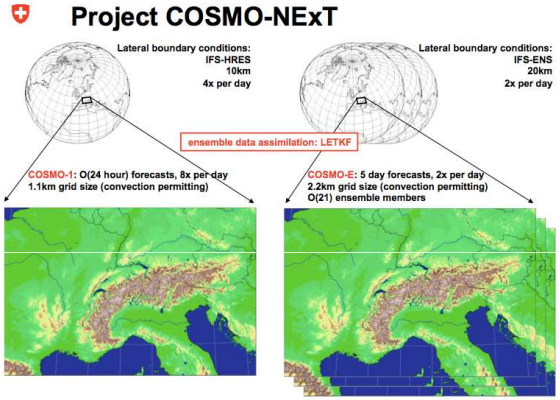
„Old“ = no STELLA dycore, double precision (DP)
„New“ = with STELLA dycore, Single (SP) or double precision (DP)

	Speed up with respect to reference base (“old”) code
Old code CPU, DP	x 1
New code CPU, DP	x 1.46
New code GPU, DP	x 2.63
New code GPU, SP	x 3.89

Results for 1 COSMO-E member using 8 GPU sockets (4 K80 Nvidia cards) or 8 CPU sockets (8 Intel Haswell CPUs with 12 cores each) – Measured on the Piz Kesch System at CSCS

Applications

- MeteoSwiss

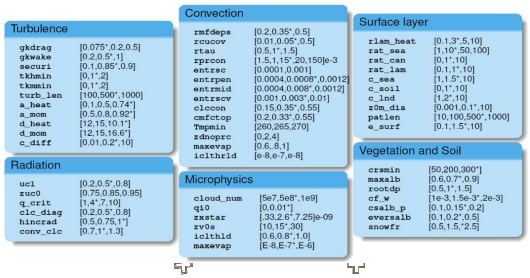


Operational forecast on GPU-based HPC system

- ReMet/CoMet

New HPC system installed with many GPUs
- 102 dual GPUs K80
- #300 TOP500 worldwide
- #5 in Italy
- #1 in Italy with GPUs
- to be operational end of 2016

- COSMO PP CALMO

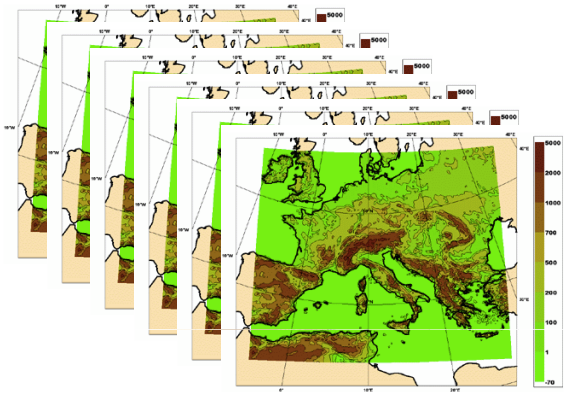


Calibration of COSMO
7.1 M core hours on GPU machine Piz Daint

- COSMO PP T2(RC)2 → tuning of radiation using CALMO strategy

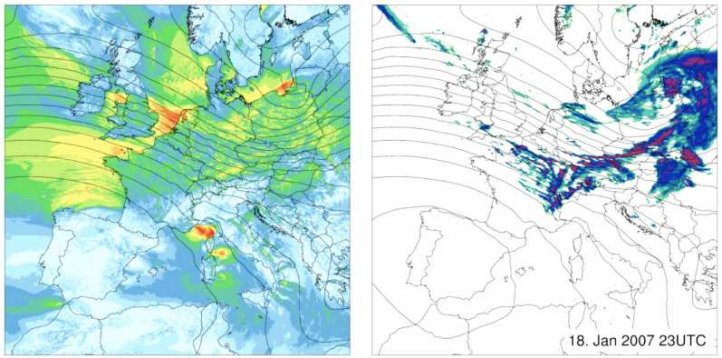
Applications

- COSMO-LEPS



Switch to single precision
- 30% gain in BUs
- 30 → 21 minutes
- 16 → 20 members

- ETH-Zurich



Project crClim (SNF)
PhD David Leutwyler
Project CLAW (PASC)

- CSCS

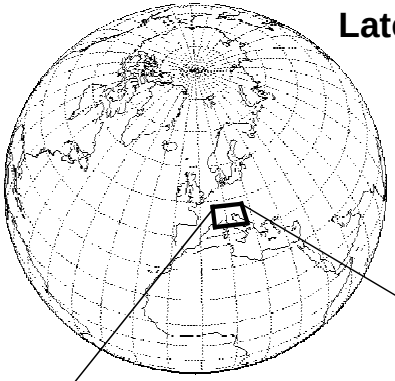
Exa2Green
energy-aware numerics

GPU version and C++ dycore for COSMO-ART

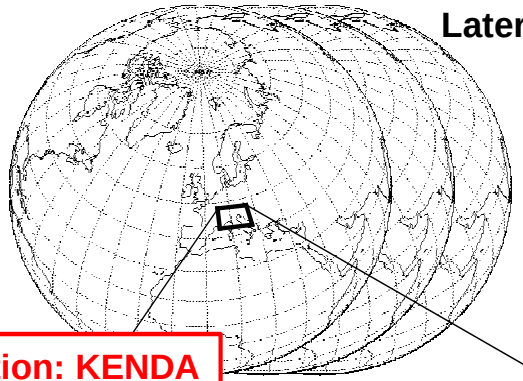
- H2020 ESCAPE (ECMWF)

STELLA DSL
GridTools DSL

Application: new model chain at MeteoSwiss running operationally on GPUs



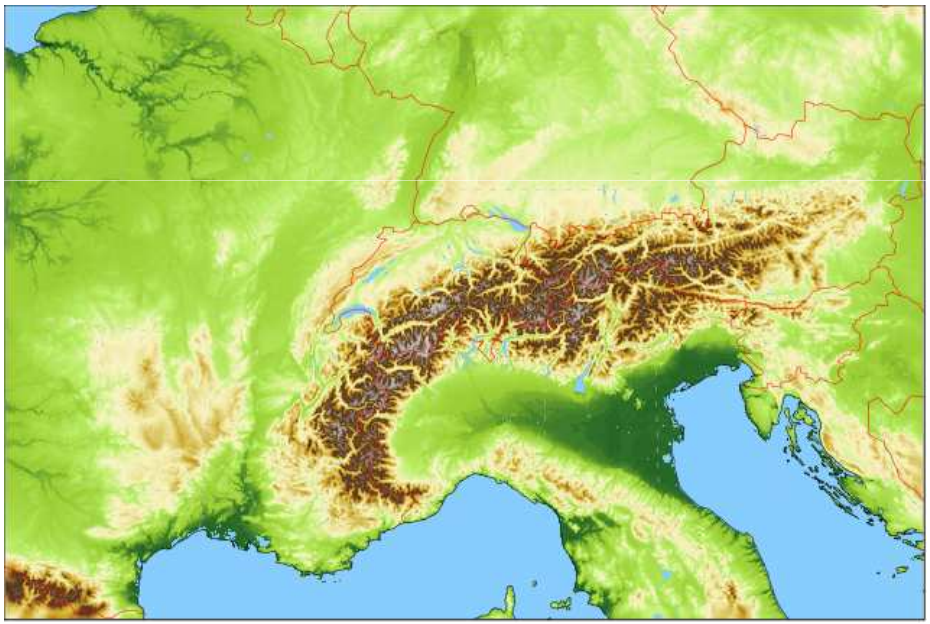
Lateral boundary conditions:
IFS-HRES
9km / 0.1°
4x per day



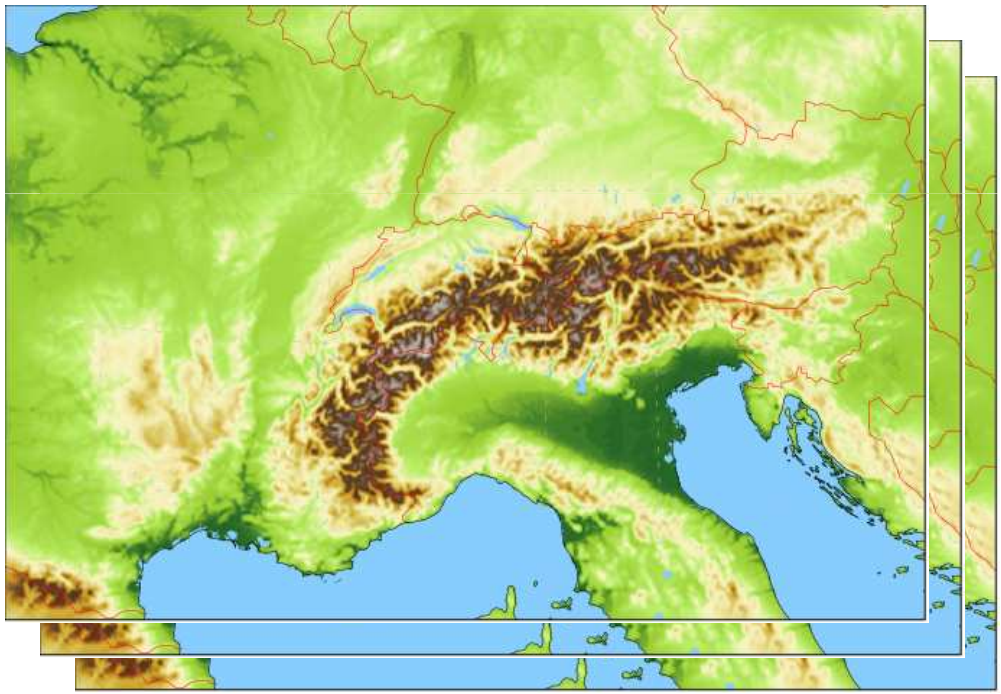
Lateral boundary conditions:
IFS-ENS
18km / 0.2°
4x per day

ensemble data assimilation: KENDA

COSMO-1: 33+ hour forecasts, 8x per day
1.1km grid size



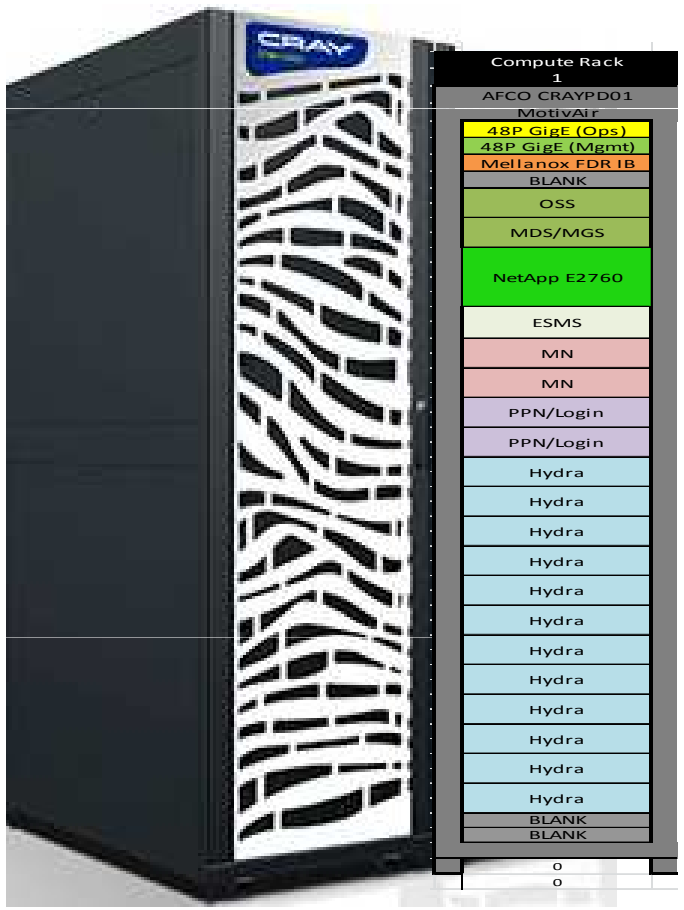
COSMO-E: 5 day forecasts, 2x per day
2.2km grid size, 21 ensemble members



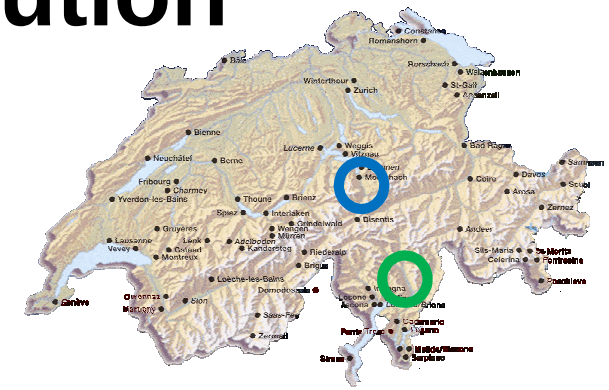
New MeteoSwiss supercomputer at CSCS

Piz Kesch (Cray CS Storm)

- Installed at CSCS in July 2015
- Hybrid system with a mixture of CPUs and GPUs
- “Fat” compute nodes with
  2 Intel Xeon E5 2690 (Haswell) and
  8 Tesla K80 (each with 2 GK210)
- Fully redundant (failover for research and development)
- Only 12 out of 22 possible compute nodes



Benefit of the higher resolution

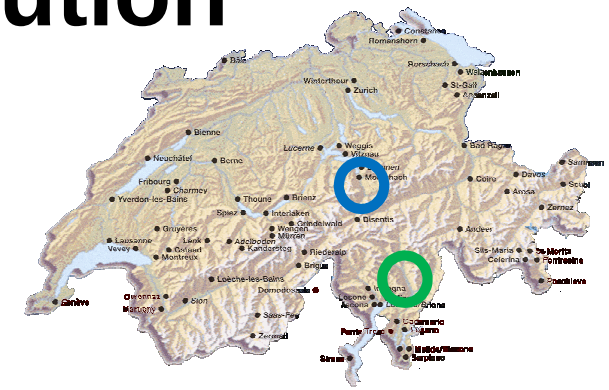


Altdorf (Reuss valley)

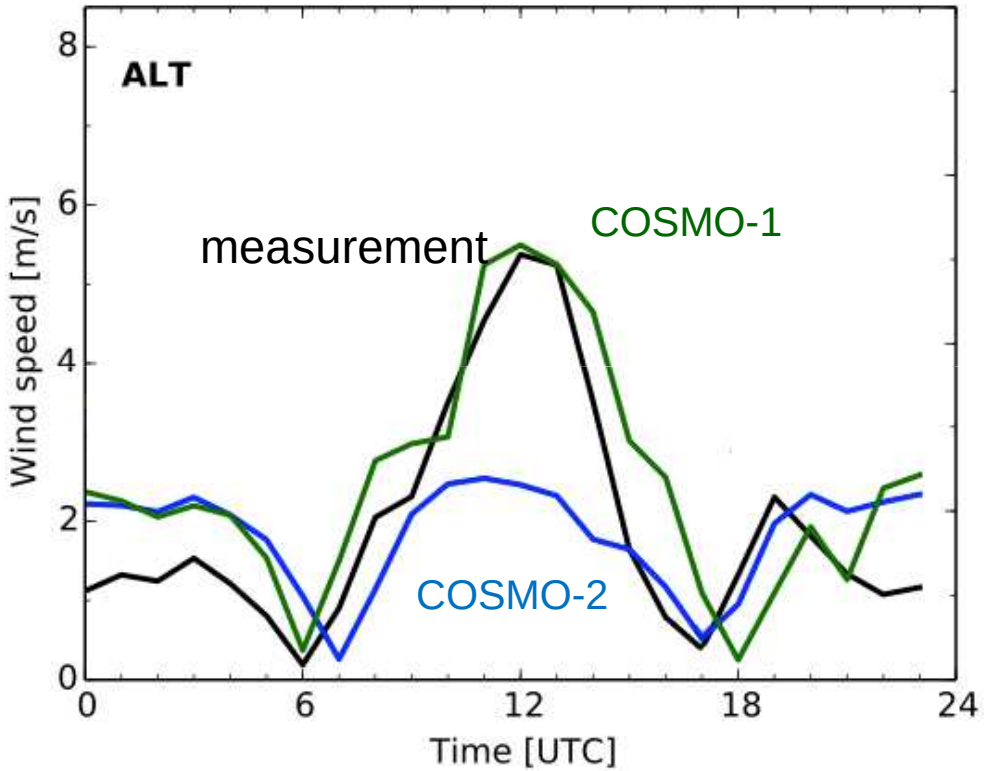
Lodrino (Leventina)

Benefit of the higher resolution

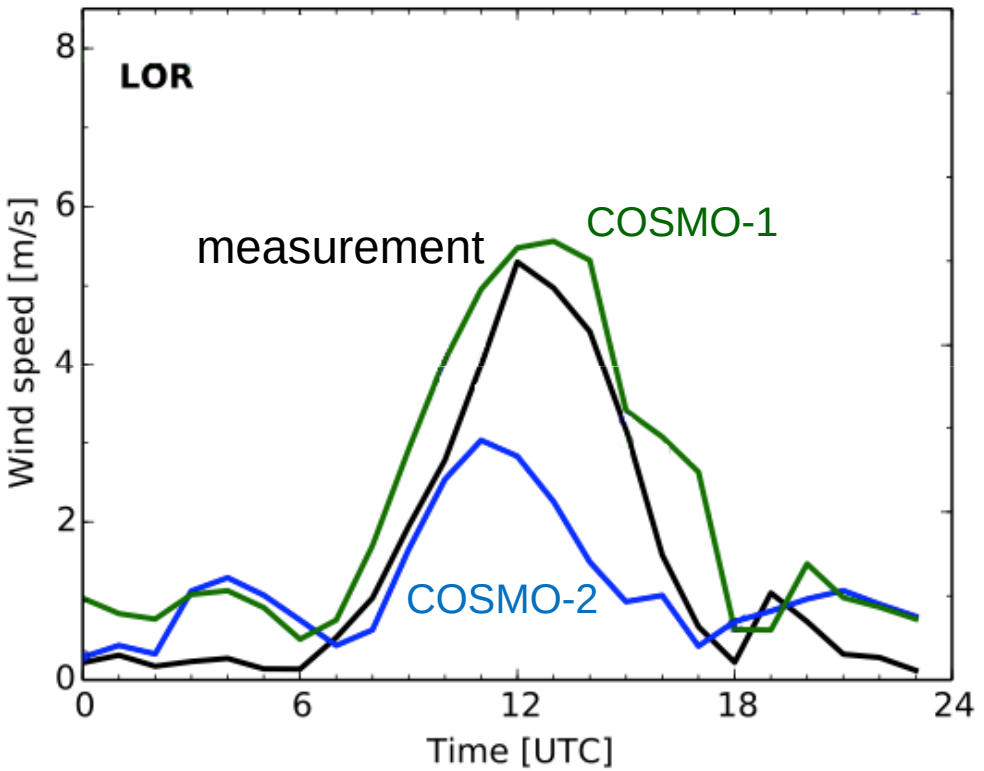
(18 days: 9. – 27.7.2006)



Altdorf (Reuss valley)



Lodrino (Leventina)



Benefit of ensemble for warnings

Example: Landslide affecting railway in the Alps, 13.8.2014

RhB-Zug entgleist wegen Erdrutsch – 11 Verletzte

Am Liveticker waren Florian Frey und Norbert Kurz

136 73 39 262

11 Kommentare

In Graubünden ist ein Personenzug der Rhätischen Bahn (RhB) entgleist. Ursache war ein Erdrutsch. Fünf Passagiere wurden schwer verletzt, sechs weitere leicht. Die 140 Passagiere konnten bis zum späten Nachmittag alle geborgen werden.

1/11 Drei Waggons entgleisten, keiner stürzte aber in die Schinschlucht. KAPO GR

Mehr zu Schweiz


Zu warm oder schmutzig: Lebensmittel-Kühltransporte mangelhaft
Heute, 12:50 Uhr


Zwölf Jahre Haft für «ungeheuerlichen Gewaltakt»
Heute, 12:42 Uhr


Die verzweifelte Suche nach Massnahmen für den Tourismus
19.1.2015


Dieudonné darf in der Schweiz auftreten – unter Polizeiaufsicht

Schweiz ›

11 injured persons, 5 heavily

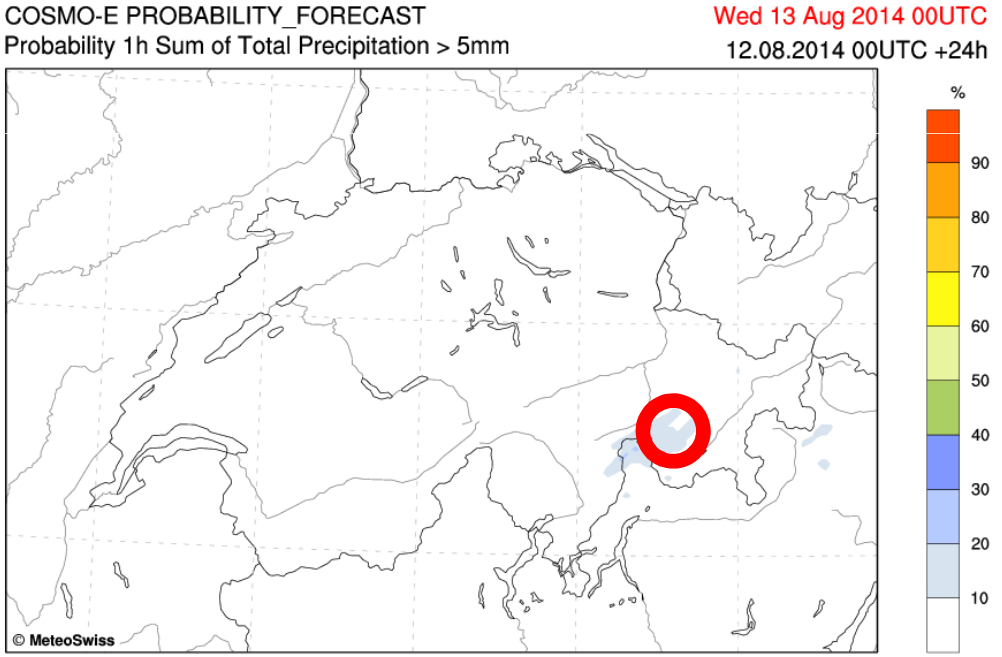
Correct level 3 warning issued the day before at 16:51

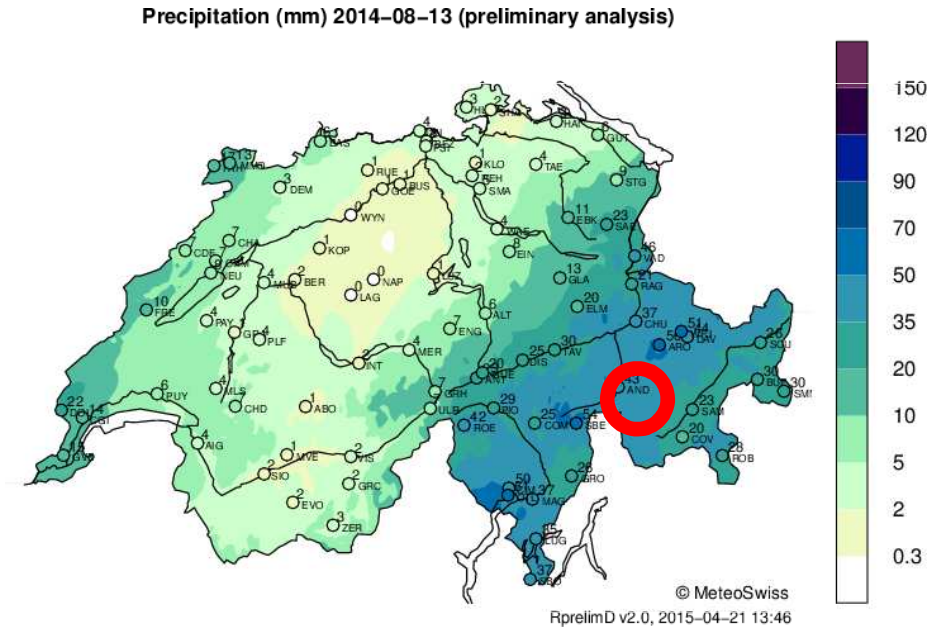
Warnung MeteoSchweiz, Stufe 3

Betroffene Regionen:	Albulatal, Bivio-Avers, Brigels, Davos, Domleschg, Flims-Laax, Lugnez-Valsertal, Rheinwald, Riein-Safiental, Savognin, Schams, Schanfigg, Val Medel-Sumvitg
Warnereignis:	**Intensiver Dauerregen mit 50 bis 80 mm** Mit kräftigen südwestlichen Höhenwinden wird warme, aber auch sehr feuchte Luft zur Schweiz geführt. In den gewarnten Gebieten ist mit 50 bis 80 mm Regen zu rechnen. Die Schneefallgrenze liegt zwischen 2800 und 3400 Metern. Am Mittwochabend erfolgt eine Beruhigung. Weitere Informationen zum Warnereignis sind im Unwetterbulletin auf unserer Internetseite oder auf der ELD der NAZ zu finden.
Ausgabezeit:	Dienstag, 12.08.2014 16:51 Uhr
gültig von:	Mittwoch, 13.08.2014 00:00 Uhr
bis:	Mittwoch, 13.08.2014 18:00 Uhr
Bulletin Nr.:	2
Nächstes Bulletin:	Mittwoch, 13.08.14 18:00 Uhr
Ausgabestelle:	Bundesamt für Meteorologie und Klimatologie, MeteoSchweiz

Benefit of ensemble for warnings

Example: Landslide affecting railway in the Alps, 13. 8. 2014





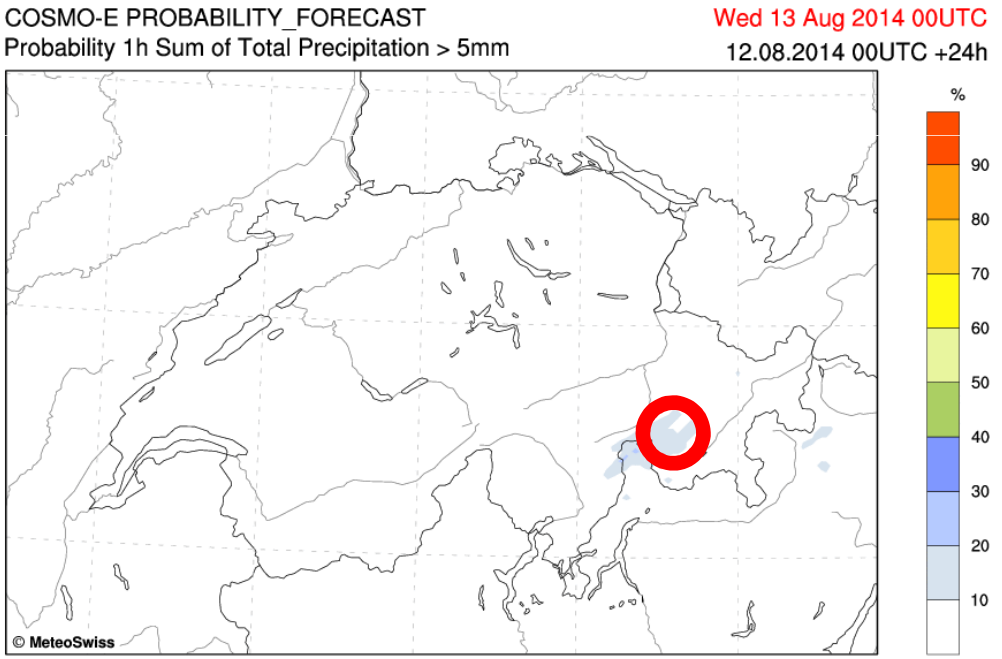
Probabilistic rain forecast

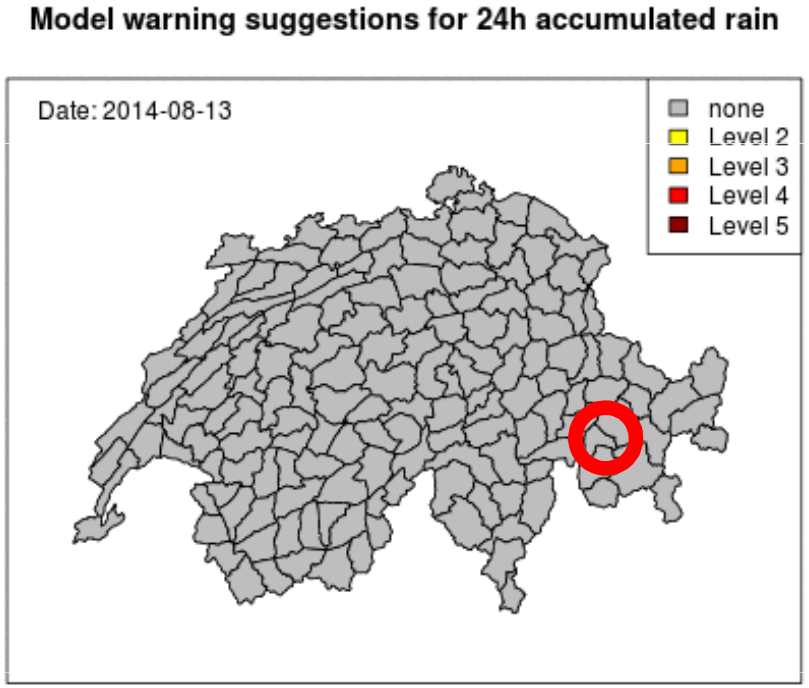
1h Sum > 5mm Modell COSMO-E

24h rain measurement

Benefit of ensemble for warnings

Example: Landslide affecting railway in the Alps, 13. 8. 2014





Probabilistic rain forecast
1h Sum > 5mm from COSMO-E

Automatic warning proposals derived from COSMO-E
(currently in preoperational tests)

Conclusions for Meteoswiss:

- New models operational at MeteoSwiss using GPUs and single precision
- 40x more complex chain at similar costs
- Migration completed
- Old machines turned off

Finalist of Swiss ICT Award 2016!

Related project: CLAW (PASC)

CLAW provides high-**L**evel **A**bstractions for **W**eather and climate models

- Goal: Provide language abstraction for performance portability in climate and weather model
- Directives with code transformation

```
SUBROUTINE inv_th(pclc,pca1, …)
  INTEGER:: ki1sd

  !$acc parallel
  !$acc loop collapse(3)
  !$claw loop-interchange (k,i,j)
  DO i=istart,iend
    DO j=jstart,jend
      DO k=kstart,kend
        ! Computation is done here
      END DO
    END DO
  END DO
  !$acc end parallel

END SUBROUTINE inv_th
```

CLAW

- Code manipulation with AST
- Based on the OMNI compiler
- Transformed code can be compile with standard compiler

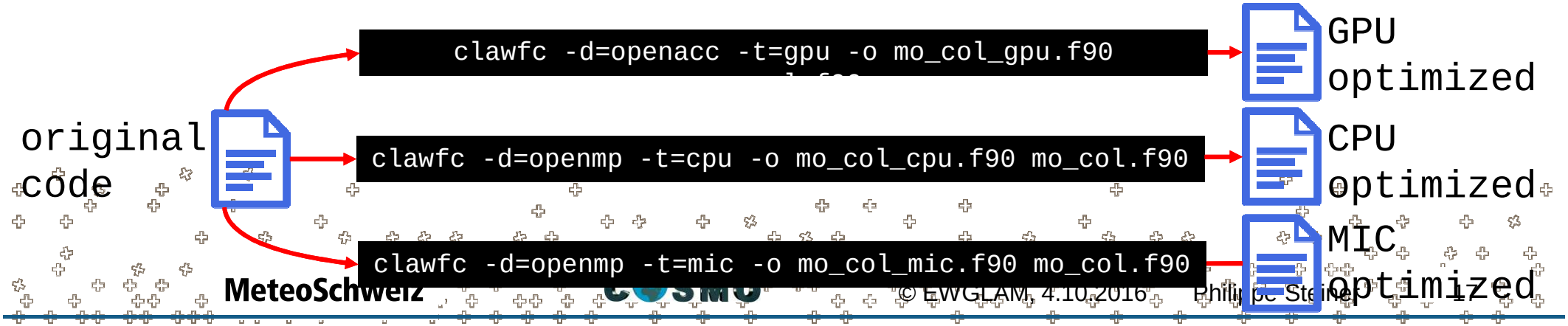
CLAW language definition are available on github :

https://github.com/C2SM-RCM/claw-language-definition

CLAW abstraction column/box model

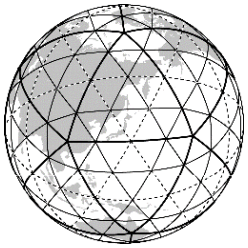
```
SUBROUTINE compute_col(q,t,nz)
  INTEGER, INTENT(IN) :: nz
  REAL, INTENT(INOUT) :: q(:),t(:)
  INTEGER             :: k
  REAL                :: c

!$claw define dimension j(1:nproma) &
!$claw parallelize

c = 5.345
DO k = 1, nz
  t(k) = c * k
  q(k) = t(k) * c
END DO
END SUBROUTINE column_model
```

- Column model code encapsulated in a subroutine
- Agnostic of any architecture
- Let CLAW manage the parallelization over the domain



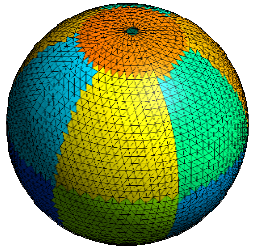
Related project: GridTools (PASC)

- New library to replace STELLA supporting global models (IFS, ICON,…) and additional functions
- New DSL constructs for stencils on global grids



Icosahedral

Cubed sphere



Octahedral

GridTools: Collaborations

- ESCAPE Project with ECMWF
  - Use GridTools data storage in Atlas library
  - Apply DSL for octahedral grids

- Prototype study for RIKEN
  - Implement several stencils from NICAM with GridTools
  - Compare to other approaches (e.g. OpenACC)

Conclusions and outlook:

- Possibility to run COSMO in single precision
- GPU capable version of the COSMO model available
- Already use in different applications
- Used for the new operational models at MeteoSwiss

- Official accelerator-capable version of COSMO available for COSMO member and licensees beginning of 2017

- Project CLAW improves performance portability of Fortran code
- Project GridTools develops a new stencil library also for global models (e.g. IFS, ICON)

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