**Advanced Computation and I/O Methods for Earth-System Simulations**

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**Motivation**

- Several groups work on icosahedral grid-based climate/weather models
- Obstacles for Exascale simulations - too small on small scale
- Code is very complex and difficult to refactor
- Climate prediction creates huge data volumes

**Existing Domain-Specific Languages**

- May create optimized code for different architectures
- Technical languages with limited relation to scientific domain
- Typically require language-specific paradigm shift for scientists
- Unclear future of the framework/tool

**Goals**

- Enhance programmability and performance-portability
- Overcome storage limitations
- Provide a common benchmark for icosahedral models

**ICON**

**DYNAMICO**

**NICAM**

**GGDML Domain-Specific Language**

- **GGDML**: the General Grid Definition and Manipulation Language
- Abstracted scientific-domain based constructs for:
  - Data types reflecting "grid" concepts
  - Field declaration
  - Iterators to traverse and update fields
  - Named neighbours in different grids
- Developed in co-design with domain scientists

**Coding with GGDML**

```c
// GGDML code

class field { ... };
field f;
field g;
field h;

// Nesting and passing as parameters
field *f,*g,*h;

// For loop with indexed and range
for ( int i = 0; i < 10; i++) {
    for ( int j = i; j < 20; j++) {
        ...;
    }
}
```

**Scientific Work Packages: Objectives and Tasks**

**WP 1: Towards higher-level code design**

- Foster separation of concerns: Domain scientists, scientific programmer and computer scientists
- High level of abstraction, reflects domain science concepts
- Independence of hardware-specific features, e.g., memory layout
- Convertible into existing languages and DSLs
- Develop/refactorize key parts of models into DSL-dialects

**WP 2: Massive I/O**

- 2.1 Optimize file formats for icosahedral data
- 2.2 Data reduction concepts
- 2.3 API for user-defined variable accuracy
- 2.4 Identifying required variable accuracy
- 2.5 Lossy compression

**WP 3: Evaluation**

- 3.1 Selection of representative test cases
- 3.2 Construction of simple kernels
- 3.3 Common benchmark package (mini-GCMx)
- 3.4 Benefit of the DSL for kernels (mini-GCMx)
- 3.5 Estimating benefit for full-featured models
- 3.6 I/O advances for full models

**Project Key Facts**

- Started March 2016, with three year plan
- Achieved main deliverables:
  - DSL language definition
  - Source-to-source translation tools development
  - SCIL compression library development
  - Icosahedral benchmarks and mini-applications

**Architectures and Programming Models**

- **GGDML** code is translated into different targets
  - Multi-core processors (with OpenMP)
  - Vector engines (with OpenMP)
  - GPU-accelerated machines (with OpenACC)
  - Multi-node (OpenMP/OpenACC+MPI)

**WP 1: Higher-Level Code**

- **Milestones**:
  - Development: delivered May 2017
  - The development of the DSL, delivered March 2018
  - The source-to-source translation tool: continuing

**WP 2: Compression**

- **Development of Scientific Compression Library**
- Users define the required accuracy
- In terms of relative/absolute precision...
- In terms of required performance
- The library picks a fitting algorithm
- Full value integration into existing algorithms
- Testing with different models: Isabel, EXAAM, NICAM
- WP 2 status:
  - Extended compression library with new algorithms: delivered 2017
  - Definition of all quantities: delivered 2017
  - Integration into HDF5/NetCDF4: delivered Jan. 2018

**WP 3: Benchmarking**

- **WP 3 status**:
  - IcoAtmosBenchmark v1 (kernel-suites): March 2018
  - IcoAtmosBenchmark v2 (mini-apps): in progress

**Acknowledgement**

This work was supported by the German Research Foundation (DFG) through the Priority Programme 1489 "Software for Exascale Computing" (SPECA).