



A Language-Interoperable C++-Based Memory-Manager for the ICON Climate and Weather Prediction Model

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Find out more:
<https://warmworld.de>

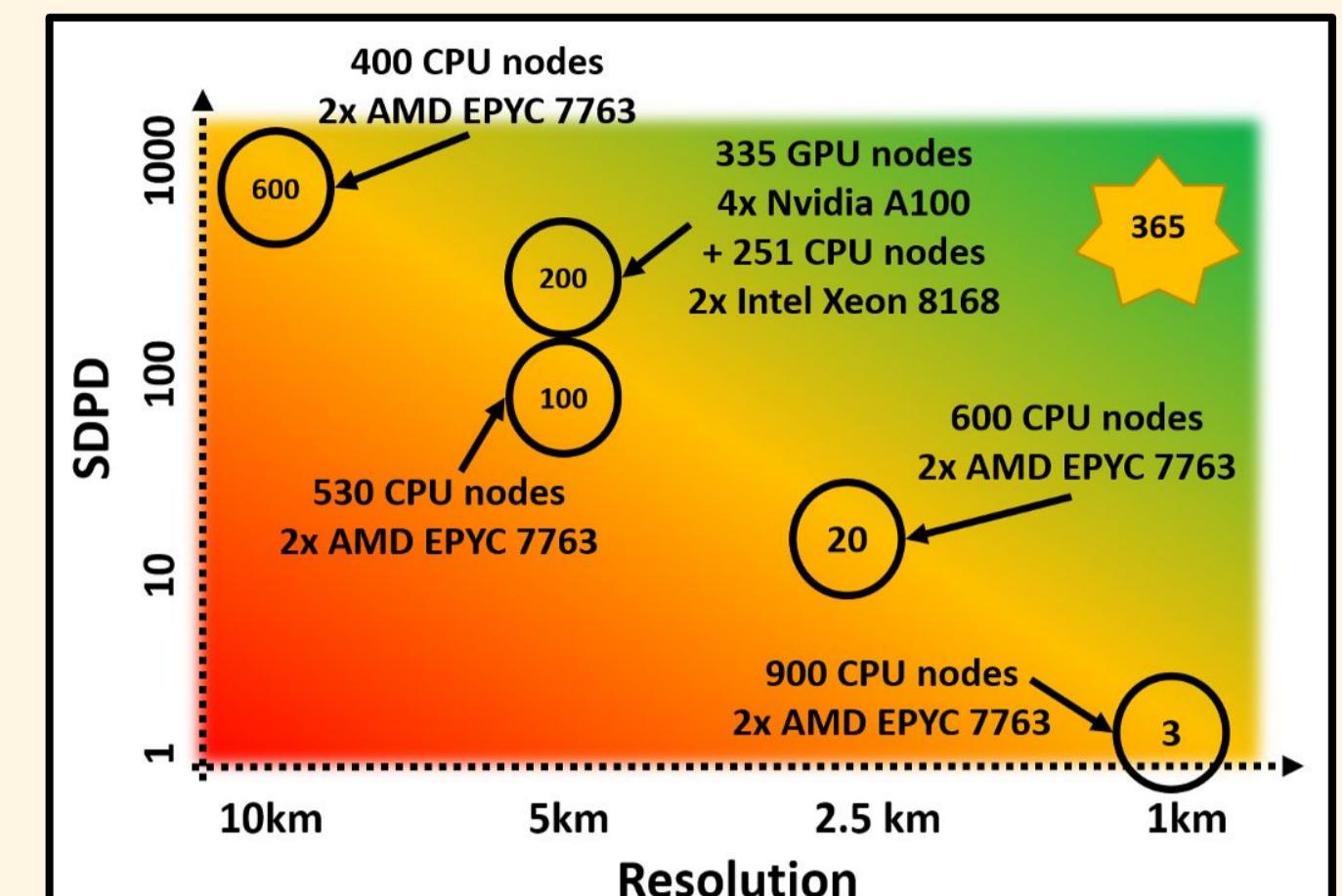
Climate modeling in the exascale era - New possibilities and challenges

- Exascale supercomputers's high performance allows climate simulations to target **high-resolution simulations** (e.g. 2.5 km) for longer simulation times
- But **heterogeneous hardware architectures** (CPU+GPU, vector systems, ...) are a challenge for scientific software development
- WarmWorld is a German national project that aims to use **advances in information technology to compute and evaluate climate warming trajectories**.

WarmWorld Faster

Target Global Objectives

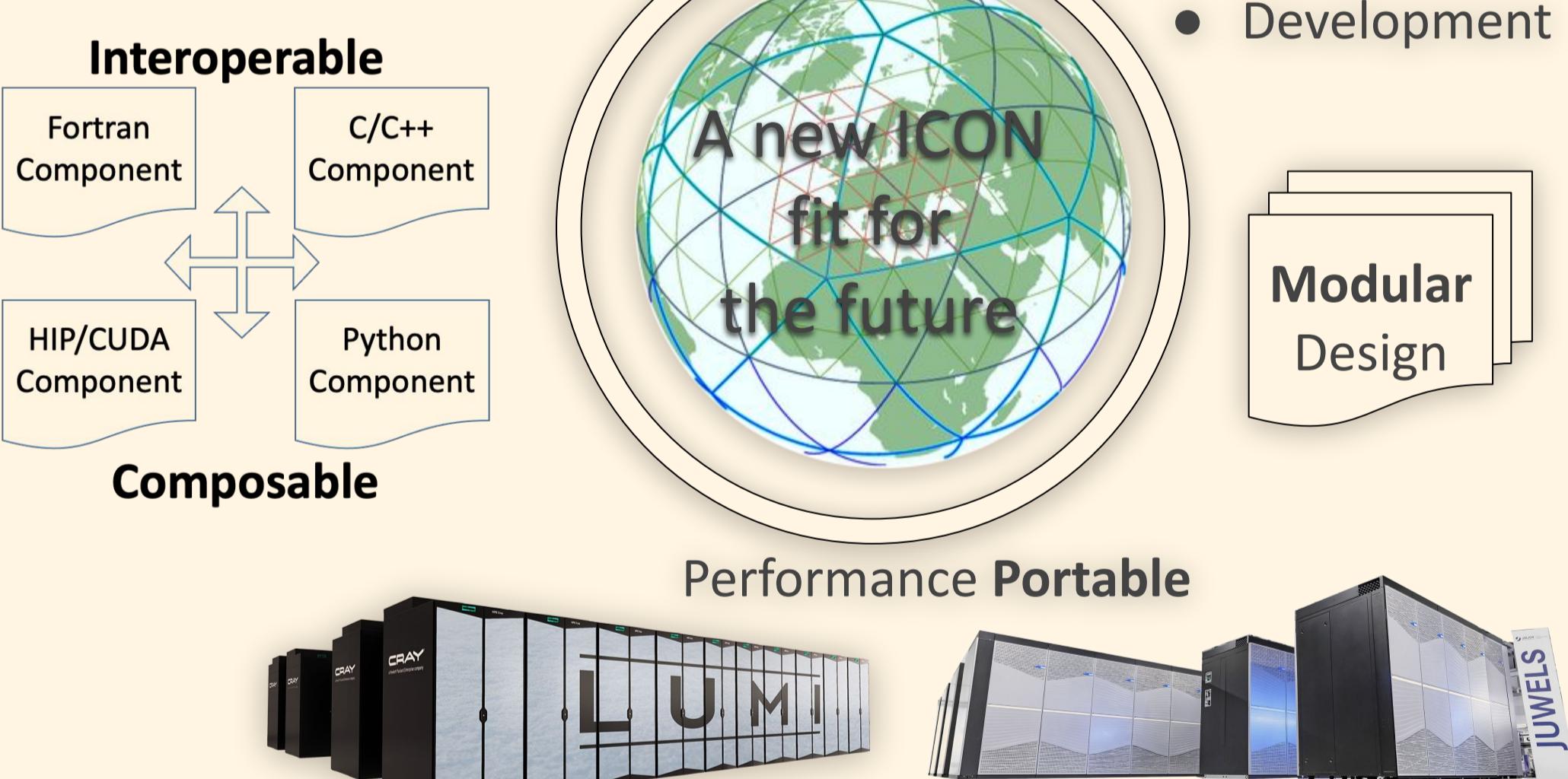
- Enable portable performance improvement with scalable development
- Free, Open Source, refactored ICON for scalable development
- Over 0.5 simulated years per day (SYPD) on $\leq 2.5\text{km}$ grid



A language-interoperable and platform portable memory-manager

Challenge of Language Interoperability

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| <ul style="list-style-type: none"> Challenges <ul style="list-style-type: none"> The memory manager has to register various fields Many ICON components touches the fields Most vendor are C++ based while ICON is Fortran based (Kokkos, RAJA,...) Fortran - C++ interface is not fully supported | <ul style="list-style-type: none"> Opportunities <ul style="list-style-type: none"> Modularize the code Easy extension Favor relying on existing building blocks Better GPU support for a C++ front end than the legacy fortran code |
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Memory Manager Design

Idiomatic interface, e.g. Fortran

```
interface
  function register_real32(ctx, desc_c, &
                           & num_elem) &
                           & result(err) bind(c)
    ...
  end function register_real32
end interface
contains
  function register_real(ctx_id, desc, &
                        & kind, num_elem) &
                        & result(err)
    ...
    select case(kind)
      ...
      err = register_real32(get_ctx(ctx_id), &
                            & to_c_desc(desc), &
                            & int(num_elem, &
                                  & kind=c_int))
    ...
  end select
end function
```

C for ABI

```
struct ctx;
struct var_descriptor;

int register_real32(
  struct ctx* device,
  struct var_descriptor* desc,
  const size_t num_elem);
```

C++ based core backend written in a generic fashion

```
template<typename Storage, typename T>
uuid_t Registry::register_var(T& value);

template<typename K, typename... T>
class KeyedRegistries;

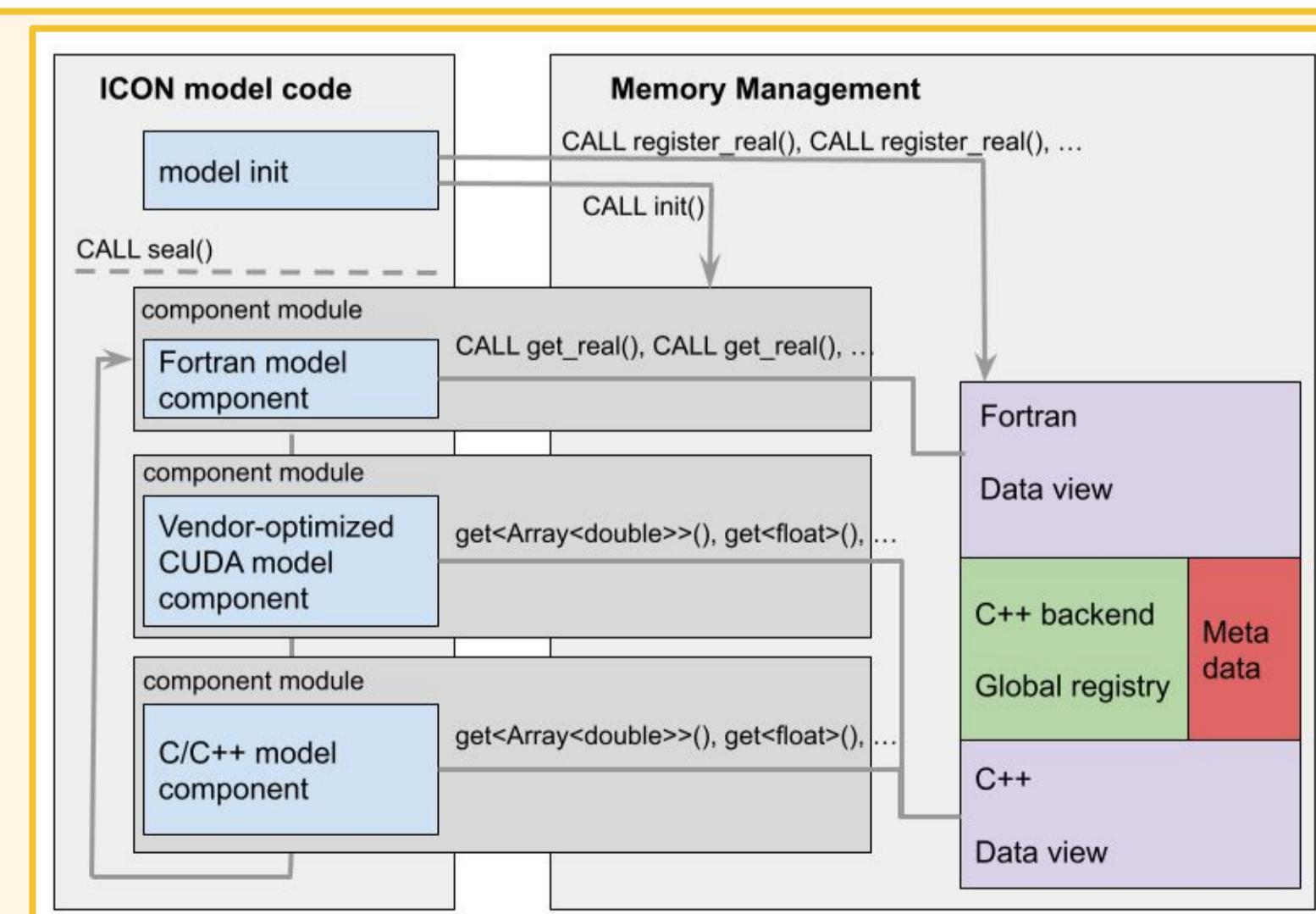
template<typename K, typename... Store, typename... T>
class KeyedRegistries<K, Registry<Store,T>...> {
  std::unordered_map<K, uuid_t> index;
  std::variant<Registry<Store,T>...> regs;
public:
  // Access / Insertion / Manipulation / Deferred Allocation
};
```

Towards sustainable software development of the ICON Climate and Weather Prediction Model

Leveraging the memory-manager for sustainable development

Integrating the memory-manager within the ICON climate and weather prediction model allows to bring sustainable development and to introduce further optimizations:

- Iterative modularization to generate independent model components
- Well-defined interfaces allows to replace components by e.g. vendor-optimized code or third-party components
- Allows easy serialisation of data, eases component testing
- Abstraction allows reuse by other projects
- Towards a data-driven control flow of the ICON code base



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