IFCES2 SCALEXA

Exploring Functional Concurrency and Load Balancing for ICON

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ParTec MODULAR SUPERCOMPUTING
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Leibniz Association
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TECHNISCHE UNIVERSITÄT DRESDEN
TROPOS Leibniz Institute for Tropospheric Research

Motivation

Vision

- **Is current ESM ready for upcoming hardware heterogeneity?**
- **Can ESM deal with adaptive process complexity?**

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Motivation

Vision

- Is current ESM ready for upcoming hardware heterogeneity?
- Can ESM deal with adaptive process complexity?

Climate modeling needs to become more flexible!

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Motivation

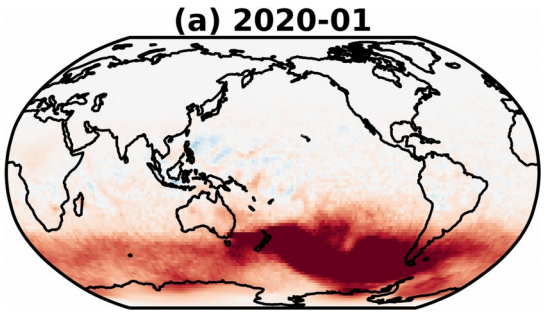
Hardware heterogeneity

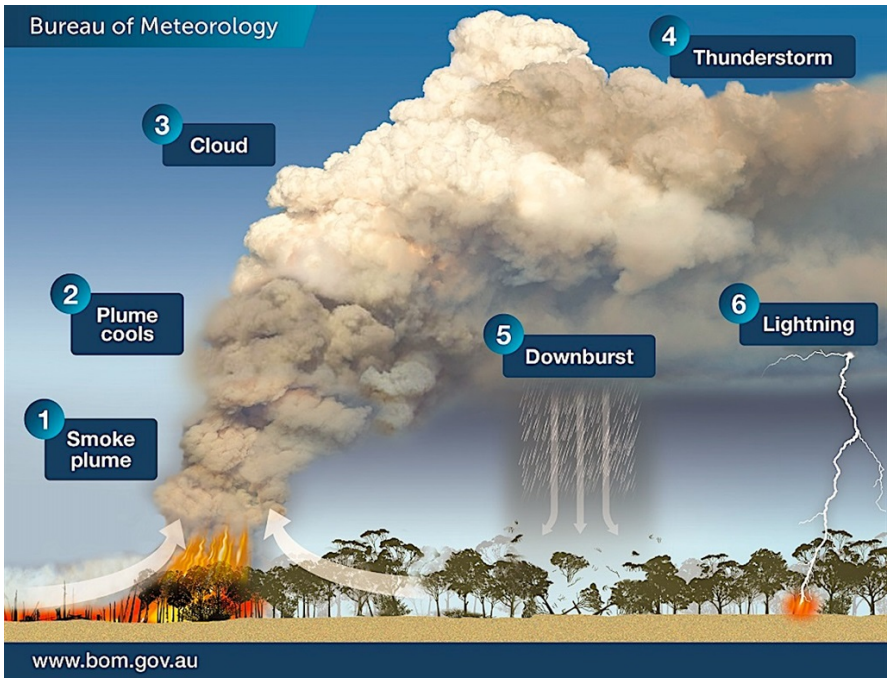
- Jülich will build the **first exascale system**
  - JUPITER: Europe‘s first exascale computer
  - target applications: KI, medicine, material science, physics and climate modeling
  - modular architecture with cluster and booster modules

Motivation

Arguments for adaptive process complexity

- E.g. we do not know how the **threat of extreme wildfires** will change in the future.
  - explosive pyro-convection needs localized description with high process detail
  - global impacts due to long-range smoke transport





Senf et al. (2023). **How the extreme 2019–2020 Australian wildfires affected global circulation and adjustments**, ACP, https://doi.org/10.5194/acp-23-8939-2023

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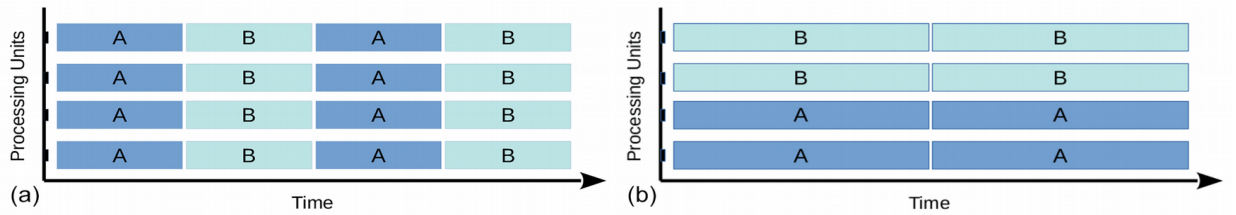
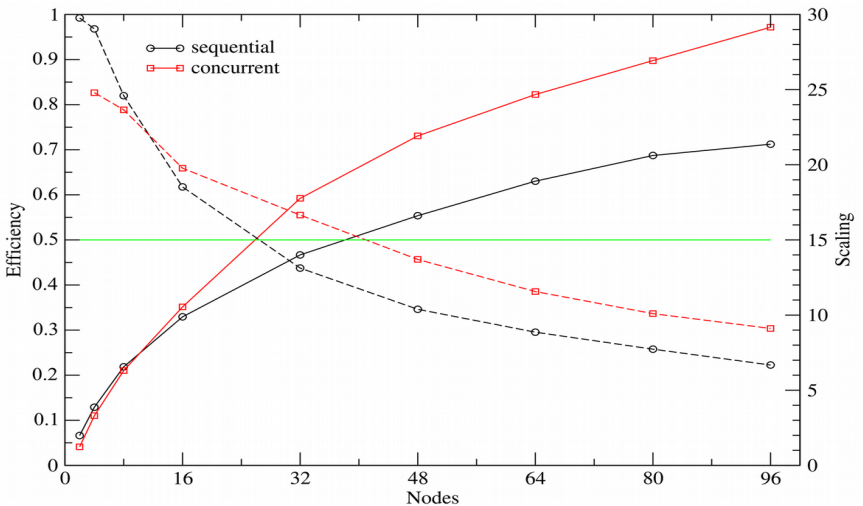
Concepts

Functional Concurrency





Scaling (solid line) and efficiency (dashed line) for the 160 km sequential and concurrent setups.

- **multi-level and multi-dimensional parallelism**
  - coarse-grained component concurrency as additional parallelism dimension
  - complements methods such as domain decomposition and loop-level shared-memory approaches
  - a function-parallel technique

Linardakis et al.: **Improving scalability of Earth system models through coarse-grained component concurrency – a case study with the ICON v2.6.5 modelling system**, GMD, https://doi.org/10.5194/gmd-15-9157-2022, 2022.

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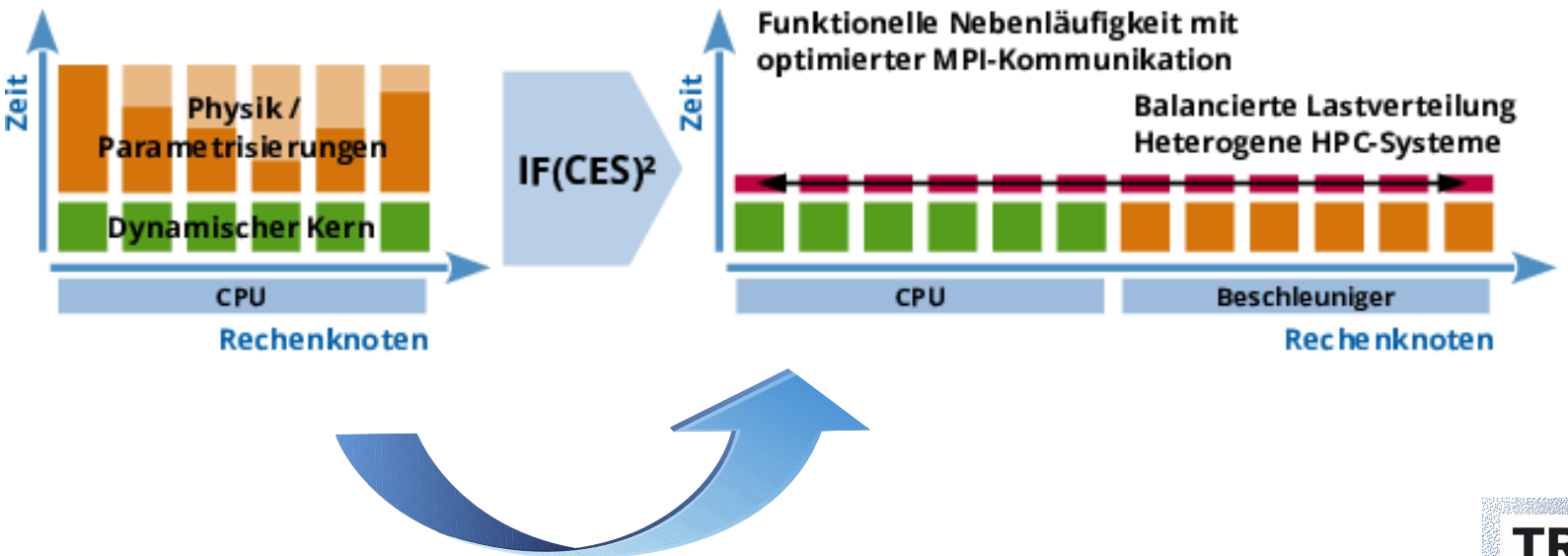
Concepts

Functional Concurrency

- **extending** functional concurrency for high-resolution simulation and for different platforms (hardware heterogeneity)
- **invent** new functionalities to deal with inbalances



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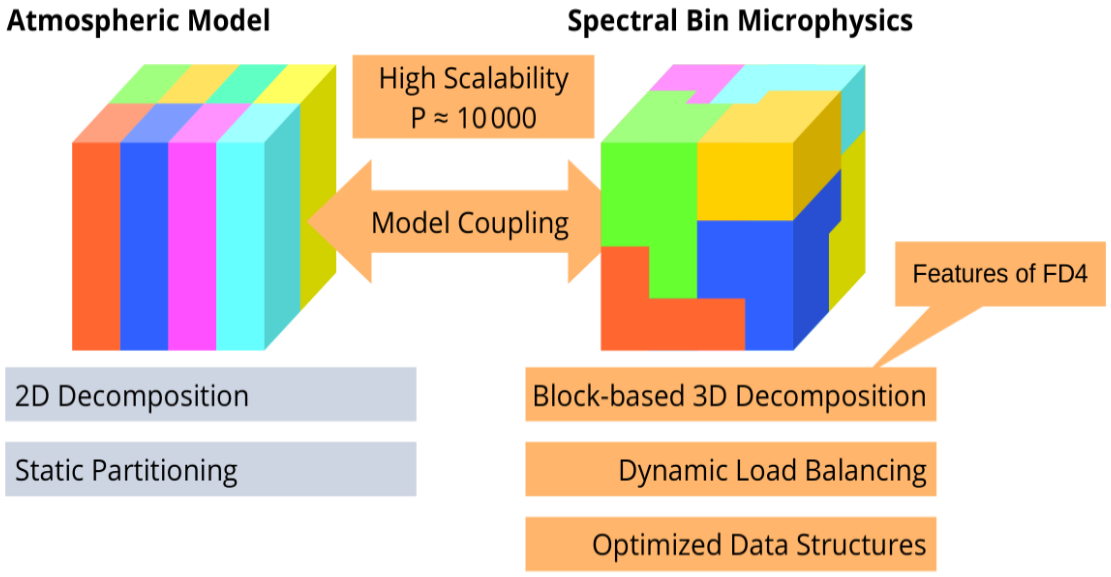
Concepts

Load Balancing

FD4 Concept: Load-balanced Coupling



- **flexibility via load balancing**
  - revises grid decomposition based on dynamical load calculations
  - optimized data structures
  - needs smart and efficient communication

M. Lieber, W.E. Nagel, and H. Mix, **Scalability Tuning of the Load Balancing and Coupling Framework FD4**, in "NIC Symposium 2014", NIC Series, Vol. 47, pp. 363-370, 2014 (full paper, full proceedings)

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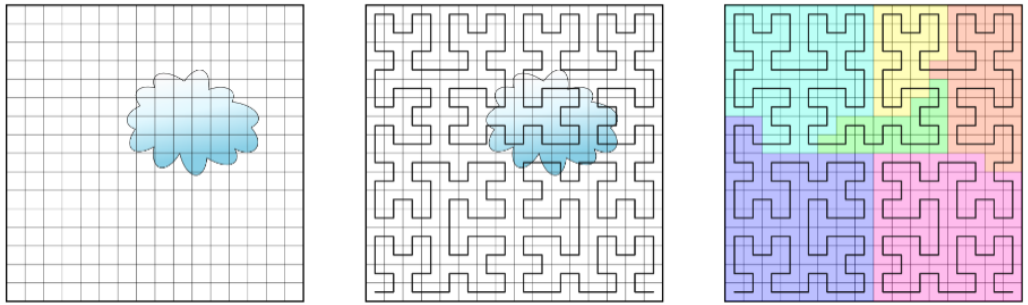
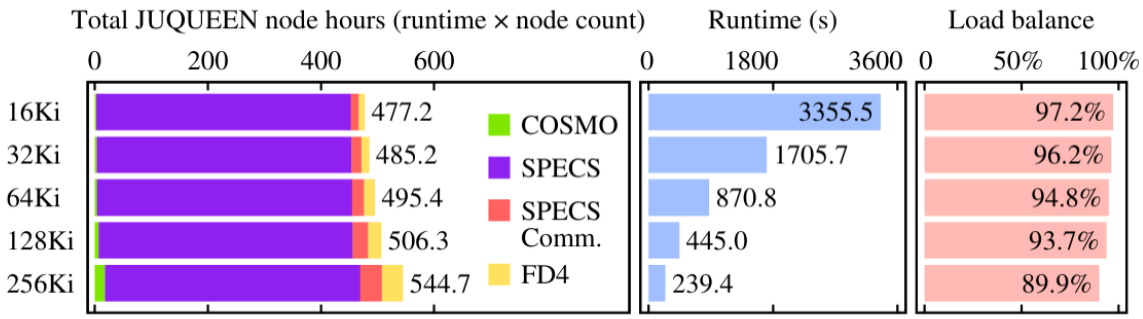
Concepts

Load Balancing



- **space-filling curve (SFC) for partitioning**
  - need to be extended to triangular ICON grid

- **scaling**
  - exceptional performance of predecessor library FD4
  - challenge for new ICON infrastructures



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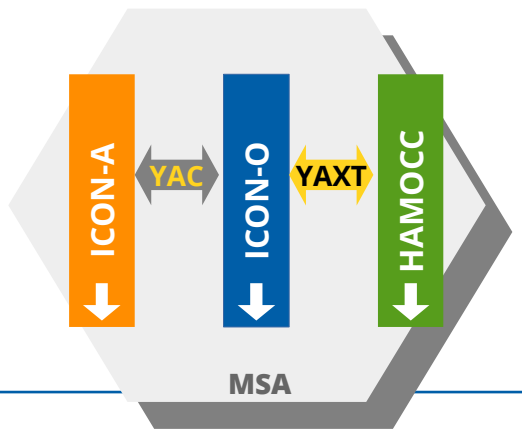
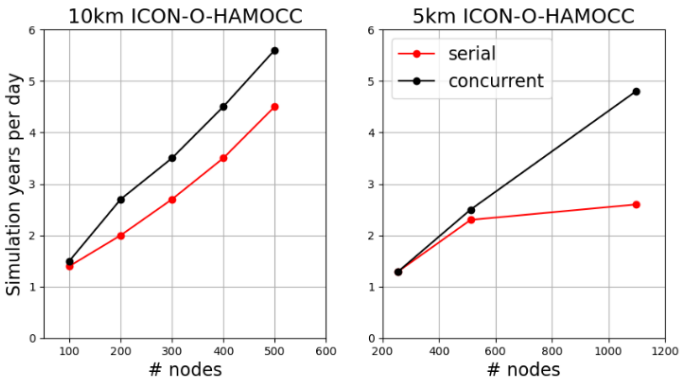
First Successes

Concurrent HAMOCC

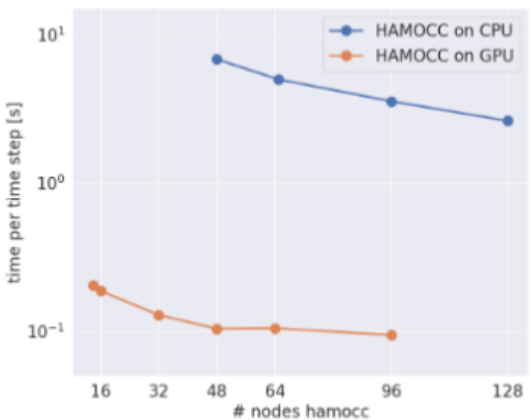
- **functional concurrency**
  - HAMOCC coupled to ICON-O with YAXT
  - across CPU - GPU concurrency





- **concurrency on Levante**
  - esp. beneficial for high resolutions

- **concurrency on JUWELS**
  - porting is promising



work by Manoel Römmer & Fatemeh Chegini

many thanks to Leonidas Linardakis and to natESM for sprint support

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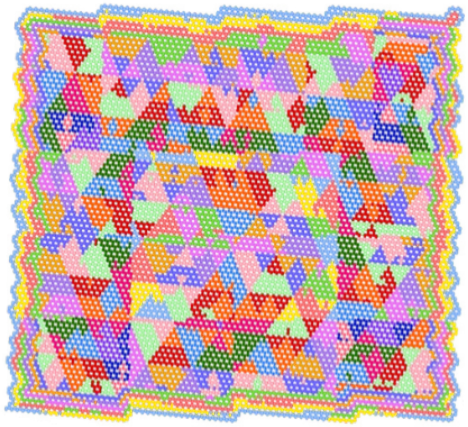
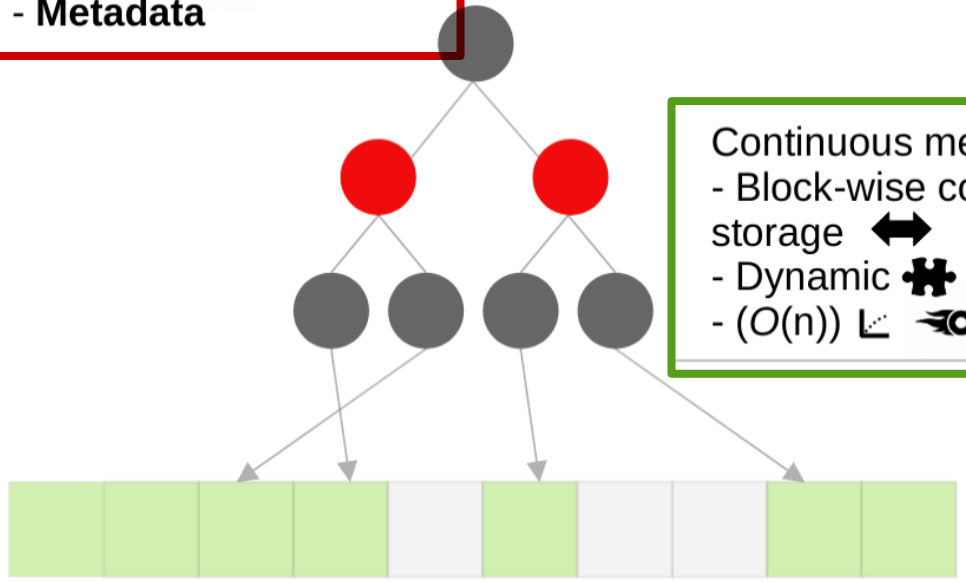
First Successes

LOBSTR



- **explore new flexible data structures for ICON**
  - small blocks
  - vertical decomposition

Red Black Tree
- *O*(log n) search
- Scattered in Memory
- Dynamic
- Iterable
- **Metadata**

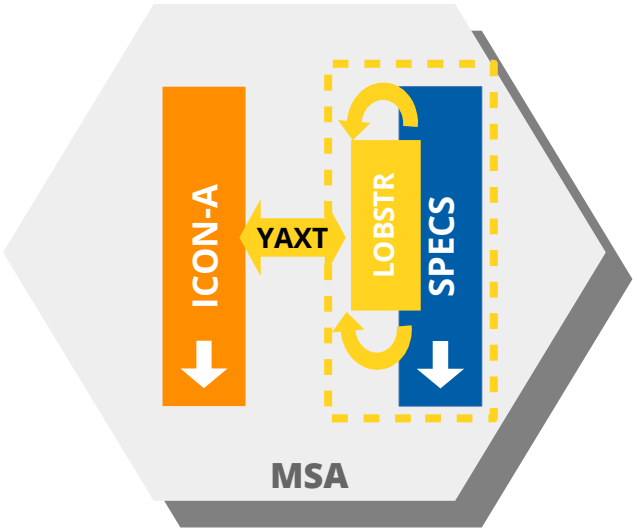


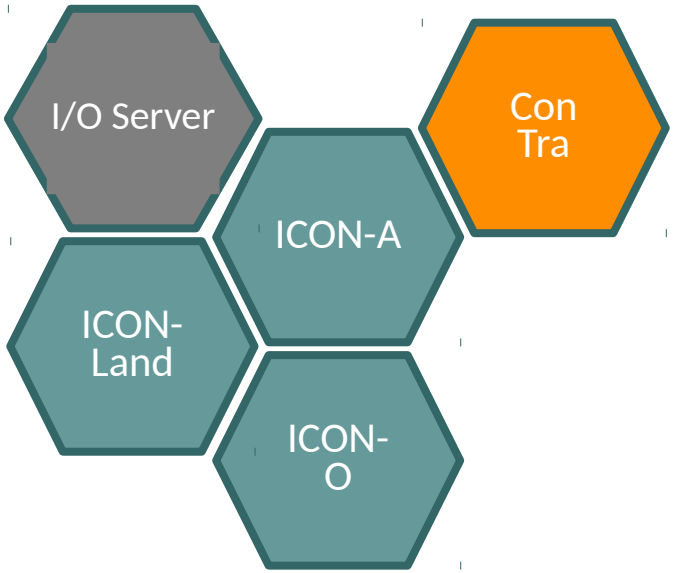
Continuous memory
- Block-wise continuous **Data storage**
- Dynamic
- (*O*(n))

First Successes

ICON ConTra

- **flexible tracer infrastructure**
  - unites concurrency with load balancing





- **ConTra design**
  - treated as separate MPI groups

work by Panos Adamidis, Xingran Wang & Jens Stoll

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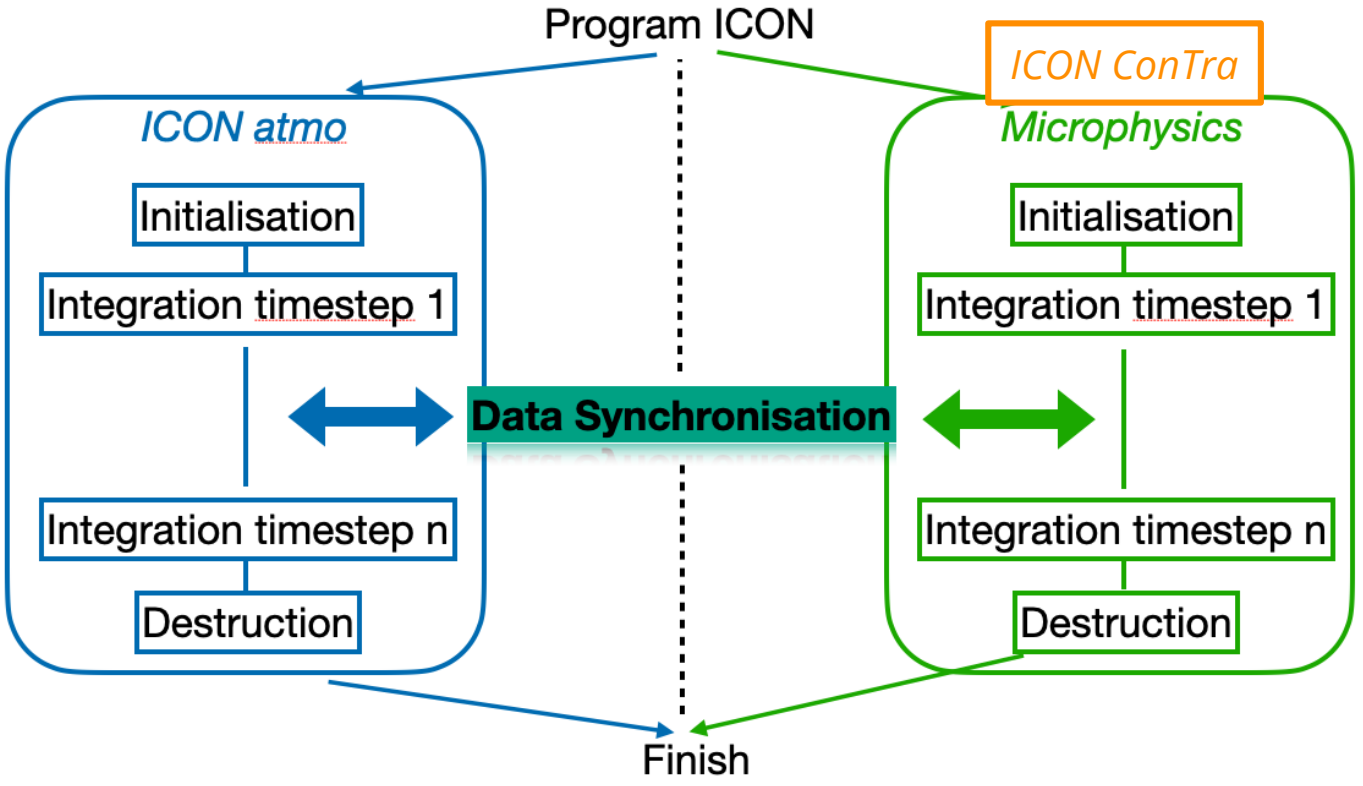
First Successes

ICON ConTra



work by Panos Adamidis, Xingran Wang & Jens Stoll

Outlook

- **Concurrency**
  - improve scalability of concurrent HAMMOC at JSC
  - further develop the concurrent tracer abstraction layer **`ConTra`**
- **Load Balancing**
  - finalize new data handling
  - solve vertical decomposition challenge
- **Use Cases**
  - hires hurricane with complex cloud microphysics
  - hires coupled ICON-A/O/HAMOCC

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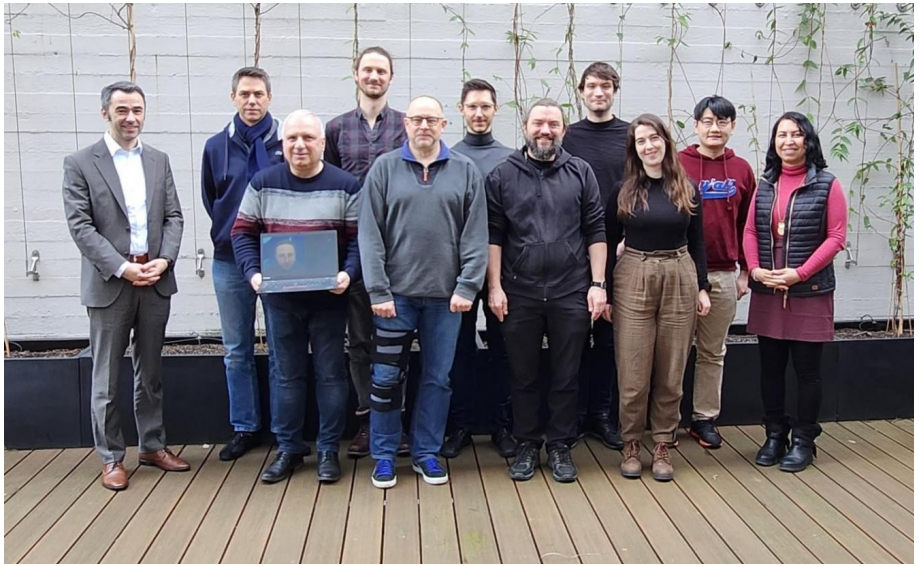

A big thank you to the team!

Interest ? → Get in touch!

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