

IFCES2 SCALEXA

Functional concurrency for ICON`s atmospheric transport and radiation schemes

Fabian Senf, Panagiotis Adamidis, Estela Suarez, Nobert Eicker,
Daniel Klocke, Carsten Clauss, Matthias Lieber, Wolfgang E. Nagel

Roxana Cremer, Jens Stoll, Xingran Wang, Manoel Römmer, Fatemeh Chegini,
Simon Pickartz, Sonja Happ, Xu Huang, Johann Biedermann

*ICON Working Group meeting on
"Radiation, Clouds, Aerosols and Chemistry" @ 3rd September 2024*



MAX-PLANCK-INSTITUT
FÜR METEOROLOGIE

SPONSORED BY THE



Federal Ministry
of Education
and Research



Funded by the
European Union
NextGenerationEU



TECHNISCHE
UNIVERSITÄT
DRESDEN

TROPOS

Motivation

Vision

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

Motivation

Vision

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

Climate modeling needs to become more flexible!

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



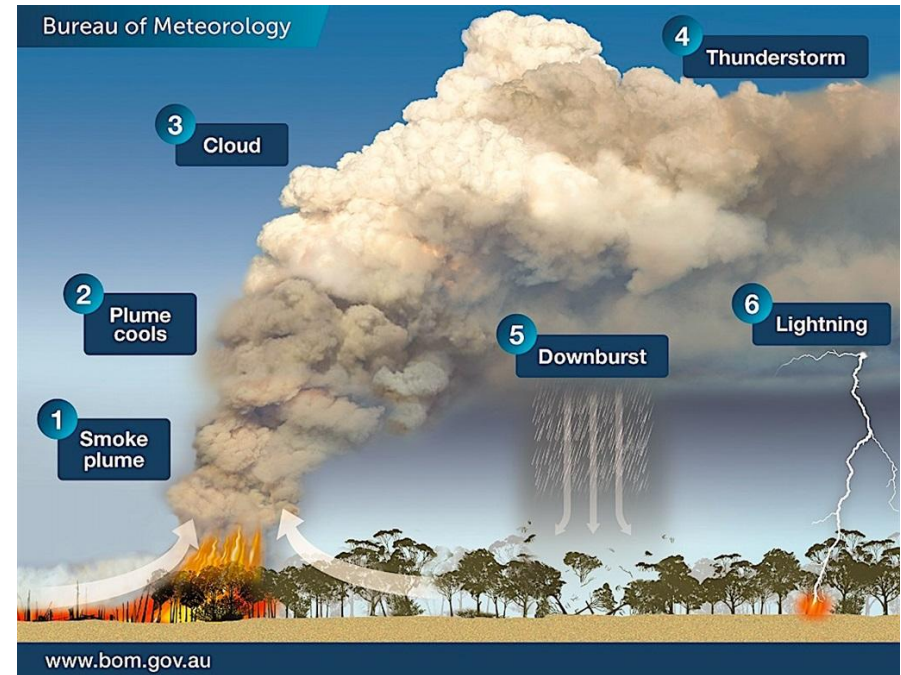
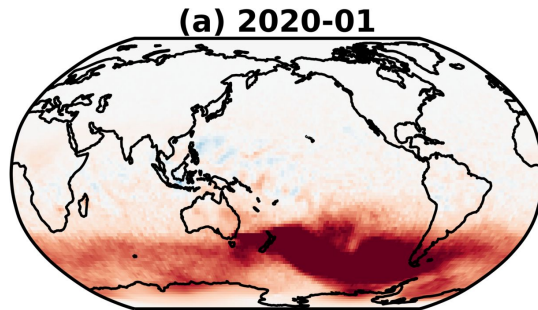
<https://www.fz-juelich.de/en/ias/jsc/jupiter>

TROPOS

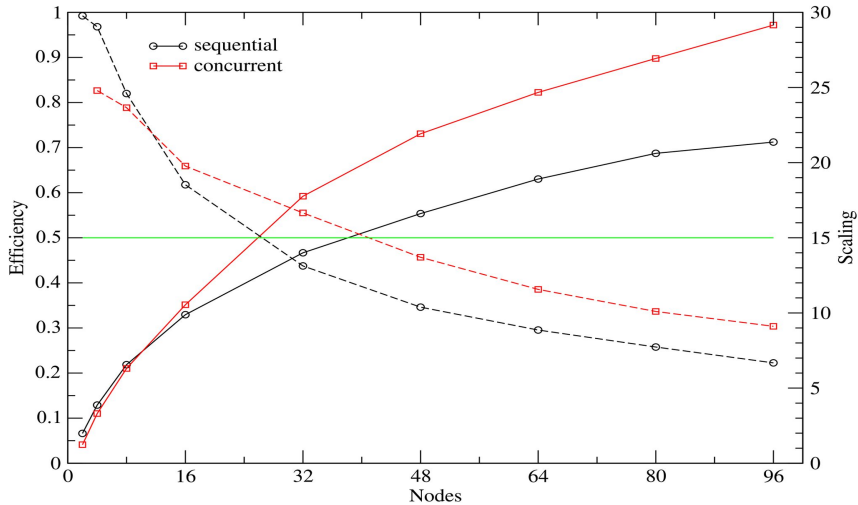
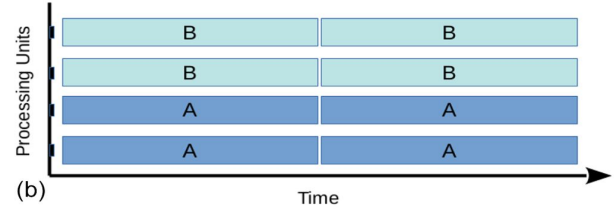
Motivation

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



Functional Concurrency



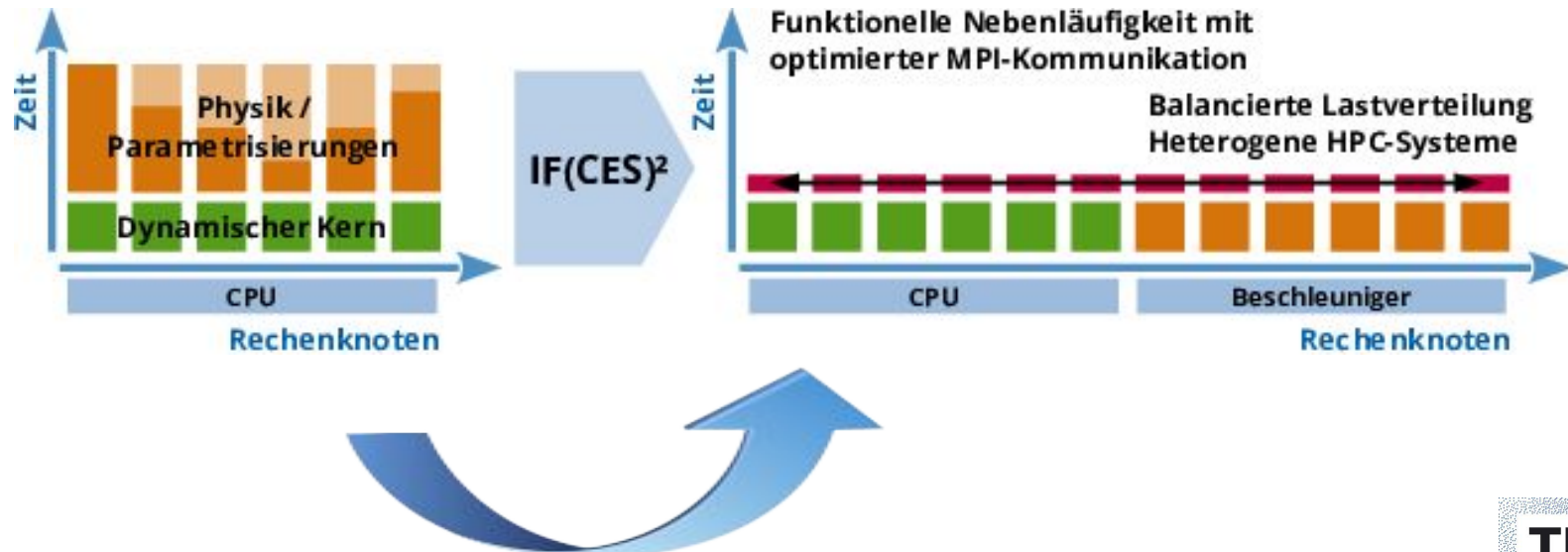
Scaling (solid line) and efficiency (dashed line) for the 160 km sequential and concurrent setups.

- **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

Concepts

Functional Concurrency

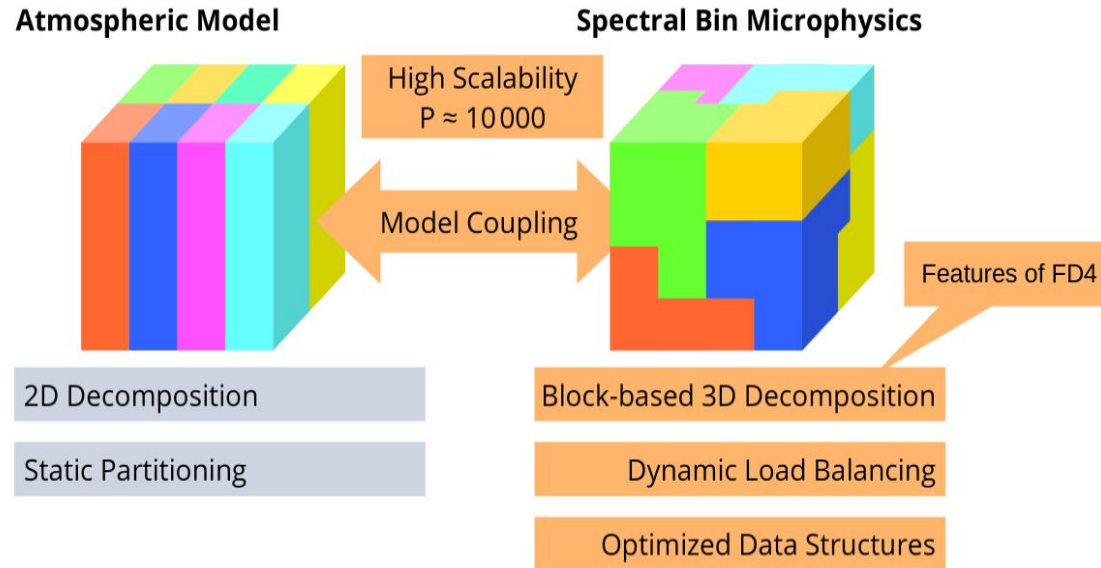
- **extending** functional concurrency for high-resolution simulation and for different platforms (hardware heterogeneity)
- **invent** new functionalities to deal with imbalances



Concepts

Load Balancing

FD4 Concept: Load-balanced Coupling

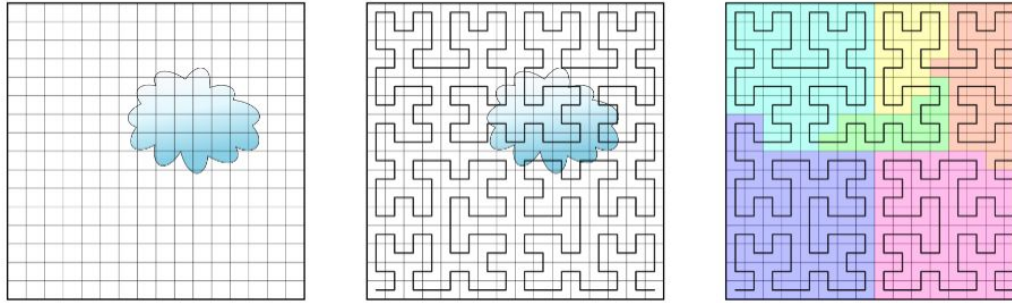


- **flexibility via load balancing**

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

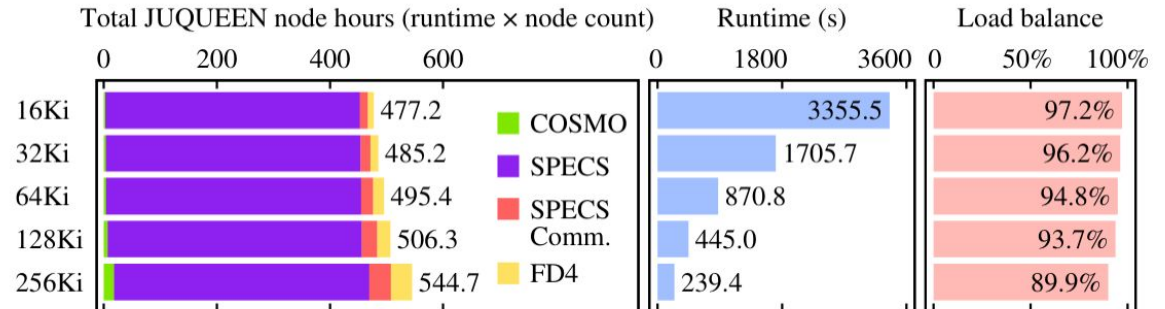
Concepts

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

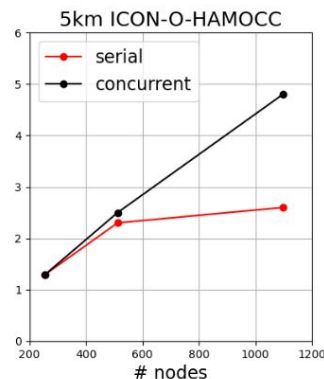
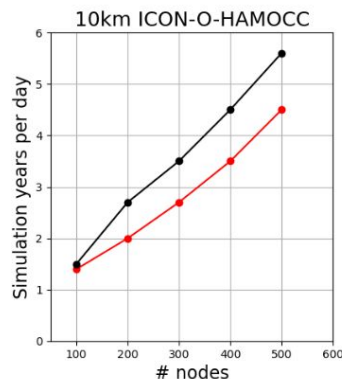
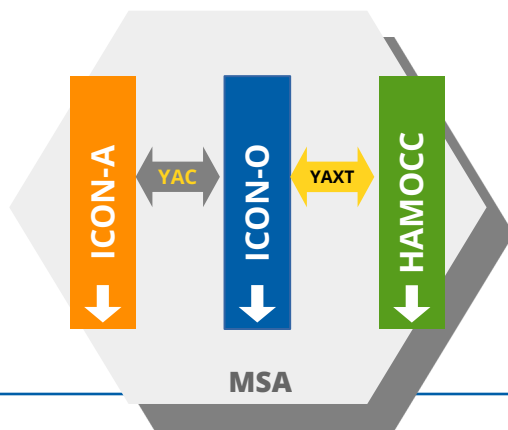


First Successes

Concurrent HAMOCC

- **functional concurrency**

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

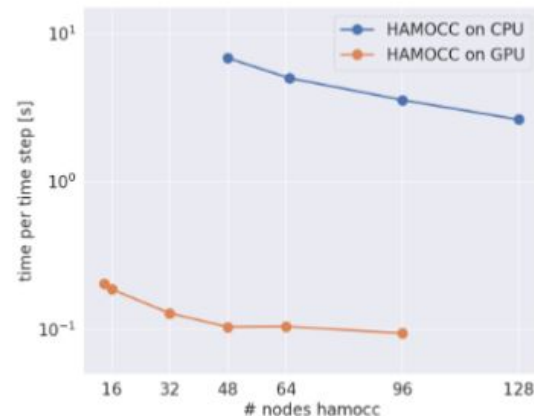


- **concurrency on Levante**

- ▶ esp. beneficial for high resolutions

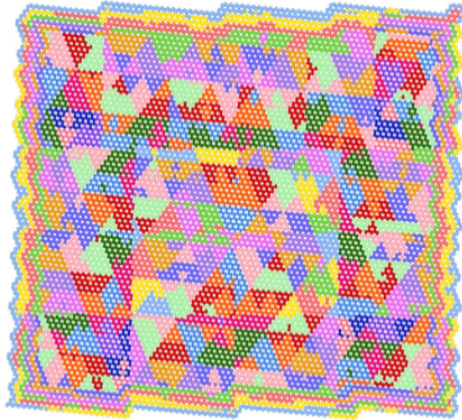
- **concurrency on JUWELS**

- ▶ porting is promising



First Successes

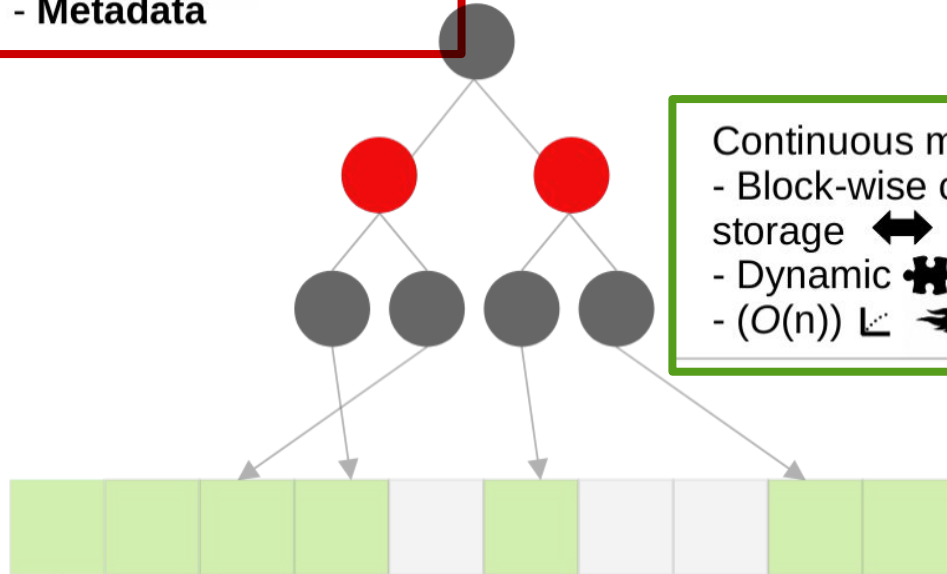
LOBSTR



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

Red Black Tree

- $O(\log n)$ search 🔍 ⚡
- Scattered in Memory
- Dynamic 🧩
- Iterable 🔍
- **Metadata**



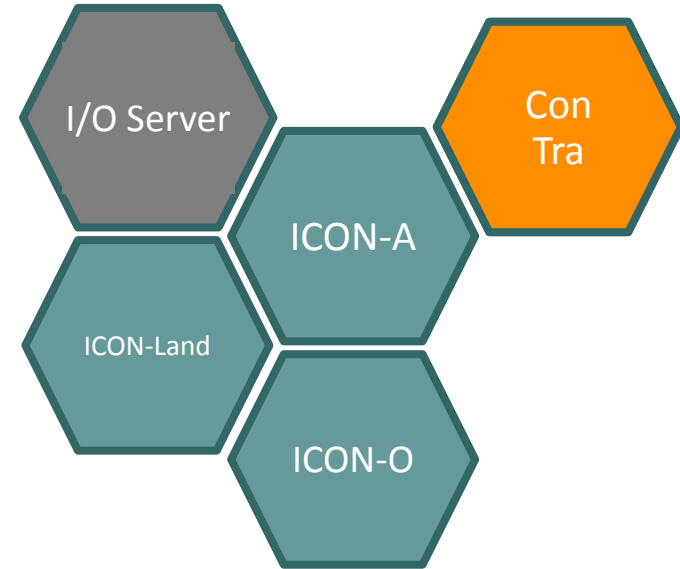
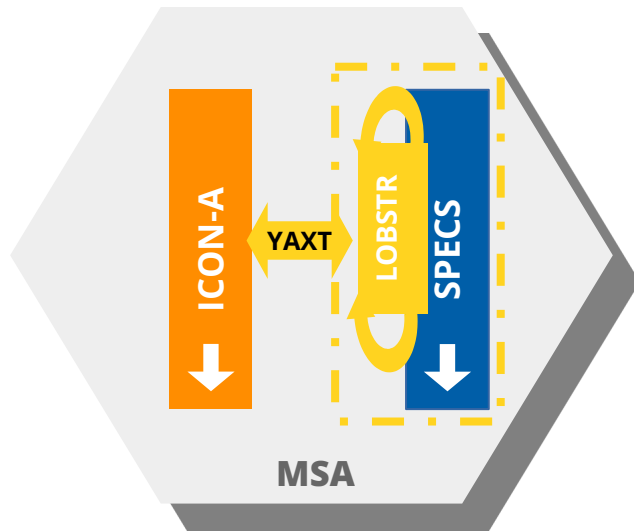
Continuous memory

- Block-wise continuous **Data** storage ↔
- Dynamic 🧩
- $O(n)$ 🔍 ⚡

First Successes

ICON ConTra

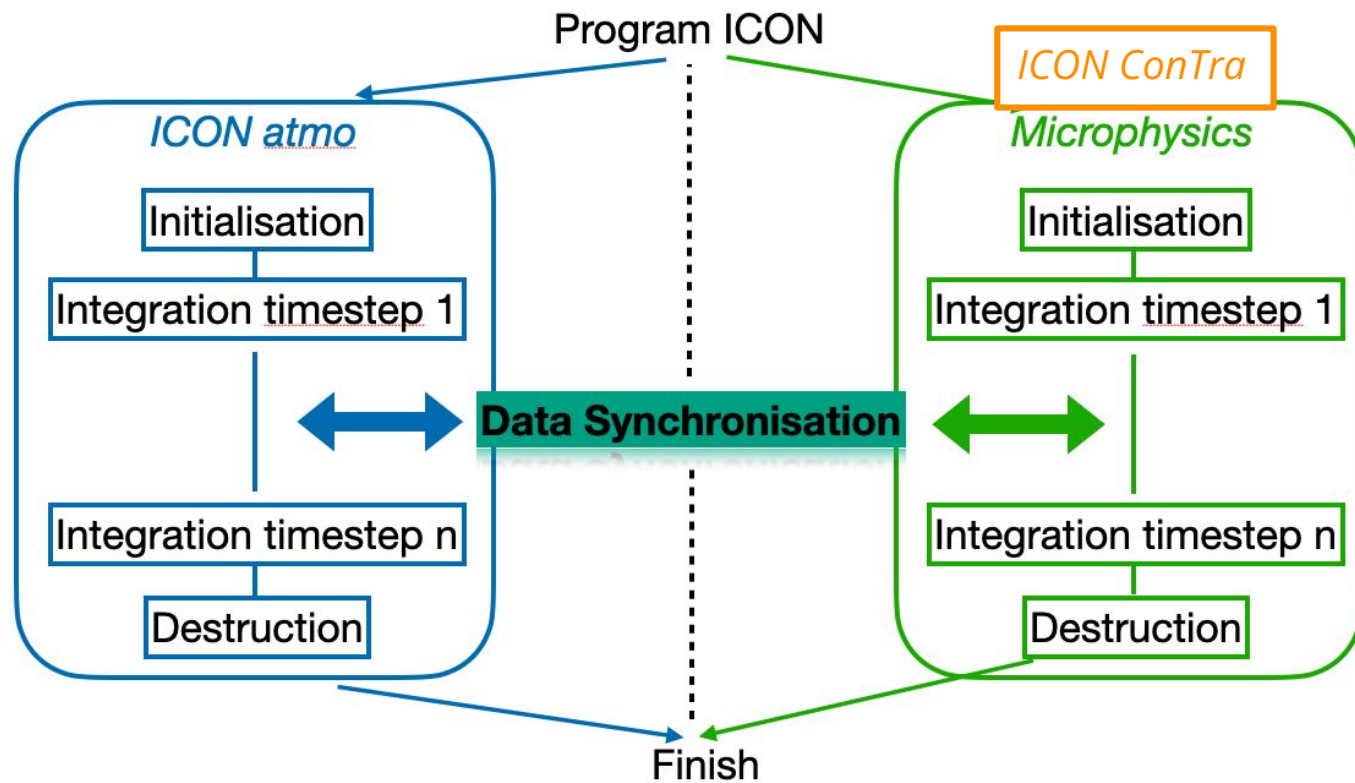
- **flexible tracer infrastructure**
 - unites concurrency with load balancing



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

First Successes

ICON ConTra

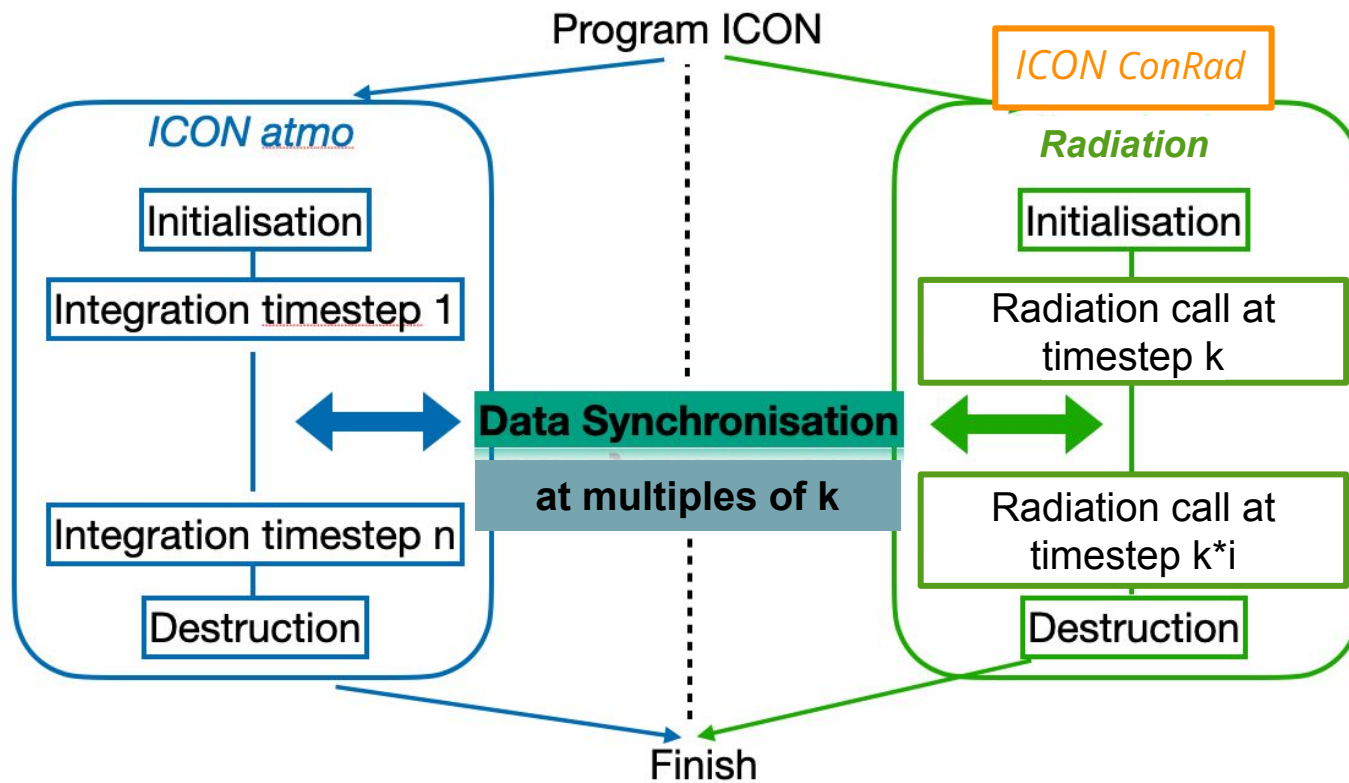


work by Panos Adamidis, Xingran Wang & Jens Stoll

TROPOS

First Successes

ICON Concurrent Radiation



Outlook

- **Concurrency**

- ▶ improve scalability of concurrent HAMMOC at JSC
- ▶ further develop the concurrent tracer abstraction layer **ConTra**

- **Load Balancing**

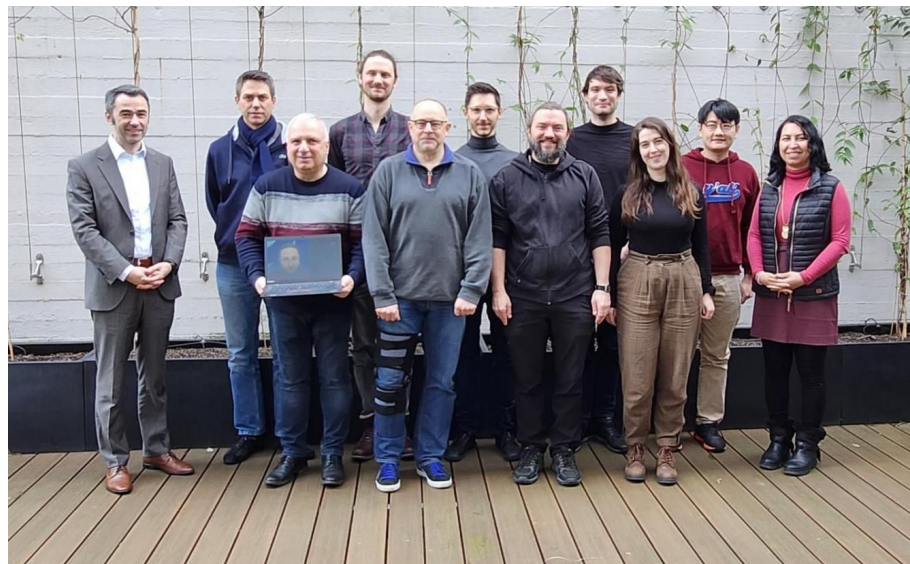
- ▶ finalize new data handling
- ▶ solve vertical decomposition challenge

- **Use Cases**

- ▶ hires hurricane with complex cloud microphysics
- ▶ hires coupled ICON-A/O/HAMOCC

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



A big thank you to the team!

Interest ? → Get in touch!

TROPOS



BACKUP

TROPOS