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Choosing an I/O approach for Earth system models: lessons learned from a modular I/O servers for MESSy

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1. Introduction

- Modern Earth system models increasingly hit **I/O limits** - not only in performance, but also in reproducibility, maintainability, and developer productivity. As data volumes and workflows evolve, tightly coupled, file-centric I/O approaches can become hard both to scale and to extend.
- The Modular Earth Submodel System (**MESSy**), provides a middleware for connecting atmospheric legacy models (e.g., ICON, ECHAM, COSMO) and specialized ESM components, the so-called submodels [1] (e.g., physical parameterizations, chemistry packages, diagnostics) via generalized interfaces for standardized control and coupling.
- MESSy's I/O operations were detached from the **Fortran-based** scientific core and implemented as separate **Python services**. Communication among the three externally coupled components - MESSy, the input service, and the output service - was implemented using the Yet Another Coupler (YAC) library [2].

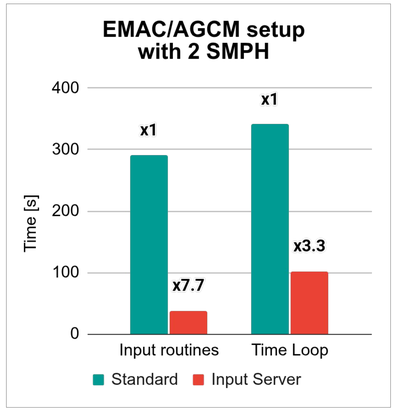
2. Methodology

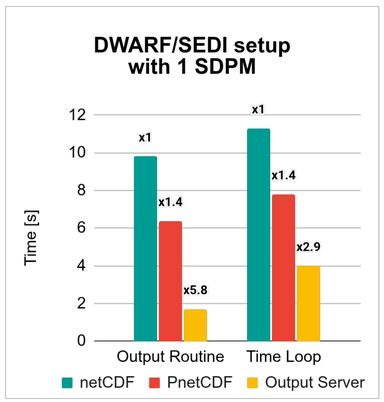
- **Isolate** the I/O processes from worker groups
- Utilize features of **YAC**: Asynchronous communication, regridding and re-partitioning.
- An MPI intercommunicator creation between components for non-gridded fields exchange.
- Implement I/O **time management** for data exchange between components.

MPI & YAC (Yet Another Coupler)

3. Results

- The performance analysis of newly developed I/O components were performed on the DKRZ supercomputer **Levante**, on a single compute node.
- In the MESSy's time loop profile, we compare the timings between the standard input routines and the new **input server** process.
- EMAC was setup in T42L90MA resolution (128x64x90 grid-boxes).
- The default EMAC/AGCM (global circulation model) number of input files are **12**, while the server was reading **48 netCDF** files.





- In the performance profile of the MESSy DWARF setup, timings were measured between the serial and parallel netCDF writing and the **output server** [3].
- The setup included the full MESSy infrastructure and the submodel SEDI. The employed grid consisted of 10848 horizontal grid boxes and 40 vertical layers. 13 artificial gas (6) and aerosol (7) phase tracers were defined, of which only four aerosol phase tracers were subject to sedimentation [4].
- **15** different output files were written to a disk.

4. Key findings

Dedicated I/O processes	• Reduced impact of I/O on model runtime • Improved simulation time
Asynchronous I/O	• Better overlap of computation and data handling • Reduced blocking of compute ranks
The Python-based I/O	• Increased portability • Flexible interface development
A key practical lesson	• **Legacy MPI setup must be adapted to include I/O ranks** • **Spatial interpolation handled by YAC; temporal interpolation by model**

5. Future work

- Assess **exascale scalability**, by further optimizations of output strategies.
- **Parallelize I/O servers** further using YAC-enabled features, by introducing domain decomposition and exploring shared memory approaches.
- Add **ICON model** support, including the configuration of nested domains for input server.
- Making the code more robust to different data read and write file structures.

References

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