The Modular Earth Submodel System MESSy

developed by the MESSy consortium:

www.messy-interface.org

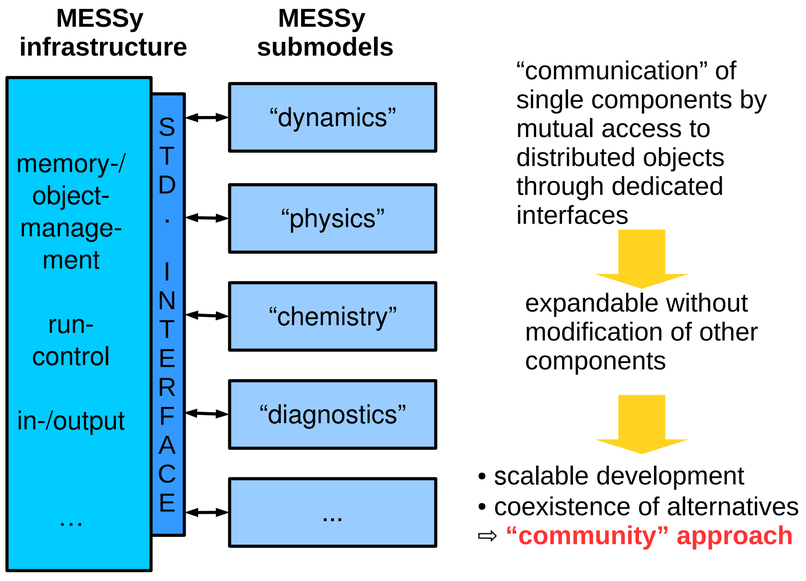
contact: messy_admin@lists.mpic.de

Abstract:

The Modular Earth Submodel System (MESSy) is a ***software*** providing a ***framework*** for a standardised, ***bottom-up*** implementation of Earth System Models (or parts of those) with flexible complexity.

"Bottum-up" means, the MESSy software provides an ***infrastructure*** with generalized ***interfaces*** for the standardised control and interconnection (=coupling) of "low-level ESM components" (dynamical cores, physical parameterisations, chemistry packages, diagnostics etc.) which are called submodels.

MESSy comprises currently ~60 submodels (i.e., coded MESSy conform):
- infrastructure (= the framework) submodels
- diagnostic submodels
- atmospheric chemistry related submodels
- model physics related submodels



What is achieved by MESSy?

- **flexibility** through **modularity** (we want a ***research tool*** for a ***large community*** serving a wide ***variety of scientific needs***!)
- minimum overhead ("software engineering does not spoil HPC")
- plug&play / code sharing largely facilitated
- **scalable model development** (well defined interfaces!)
- new scientific possibilities:
  - previously separated approaches can now be easily combined

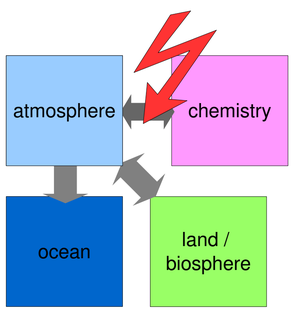
Coupling procedures

External versus internal coupling

External (domain) coupling:

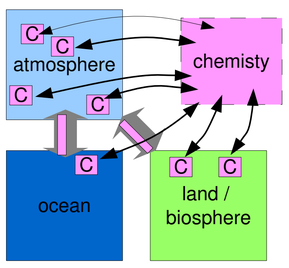
Often used as easiest way to couple independently developed domain models.

BUT:
chemistry is not a domain model ...

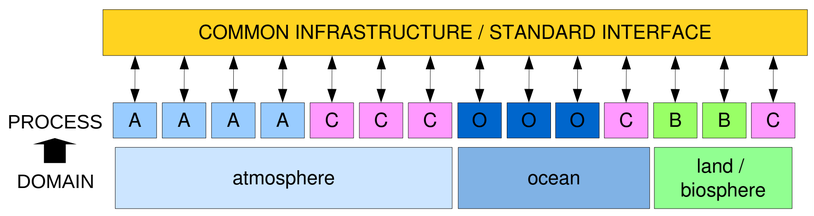


…chemistry comprises a multitude of processes describing the material cycles throughout ALL domains

other examples: diagnostics



Internal (process) coupling:



Design concepts of MESSy:

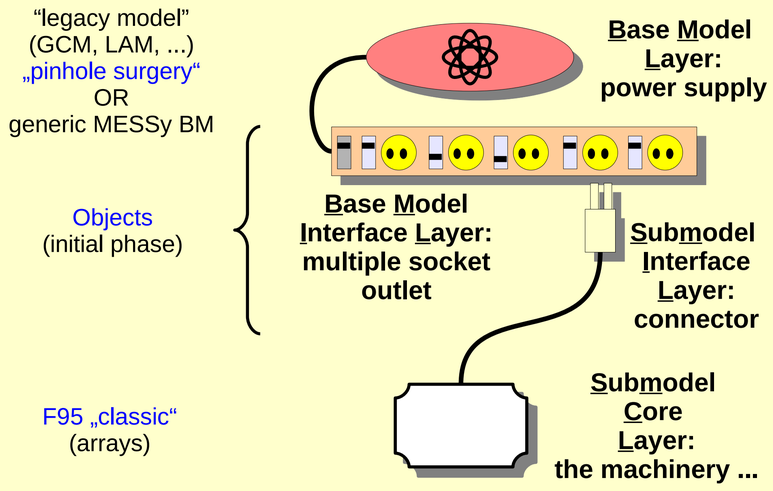
strict separation of
model-infrastructure[1)] and process-description

- „generic" submodels
- process- / diagnostic submodels

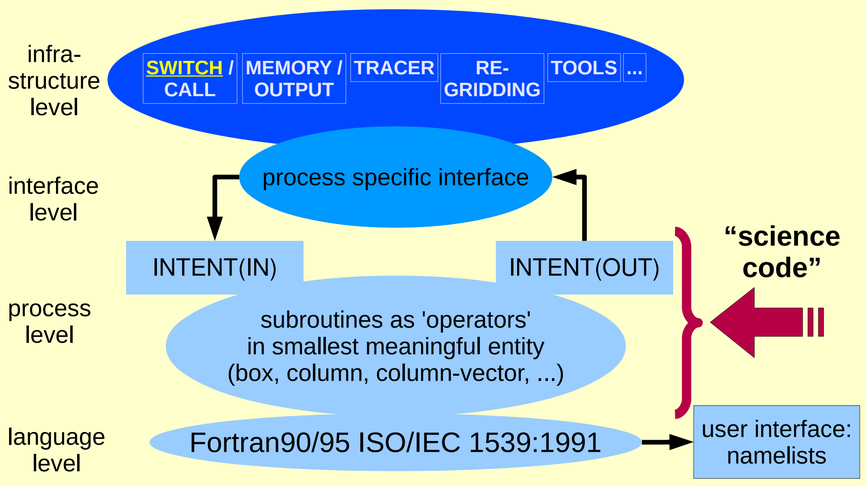
⇨ consequent formalisation of „operator splitting" concept
→ ***modularisation***
⇨ organisation of code in a 4 – layer structure
incl. "low-level" standardisation
→ strict compliance with language standard (F95)
→ simple coding-standard
⇨ object-oriented approach (as far as possible in F95)
⇨ "wireless connections" between different operators

1) memory management, input/output, flow control, grid-transformations, ...

Coupling (I): 4 – layer structure



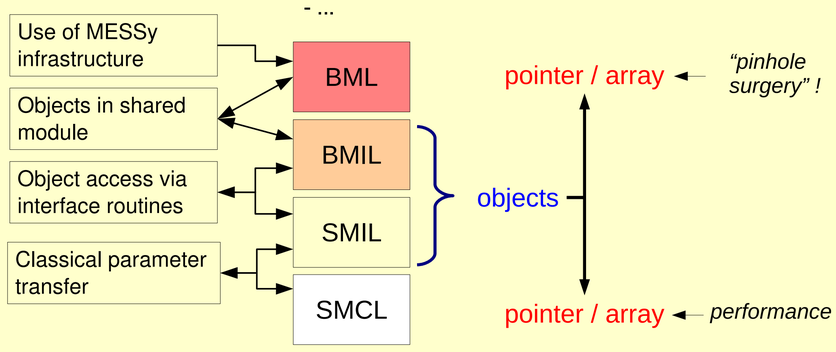
Coupling (II): Operators



Coupling (III): Objects

Fortran variable (array)

"channel object"
(nested F95 structures)
- data (pointer to memory)
- geometry + parallel decomp. (*representation*)
- meta-data (*attributes*)
- output (incl. simple statistics w.r.t. time)
- restart facility
- ...



MESSy infrastructure (generic) submodels

CHANNEL	memory & object management; output; restart (check-pointing)
GRID	grid definitions and transformations
IMPORT	data input (gridded data, time series)
RND	pseudo random number generators
QTIMER	CPU-time measurement, restart trigger
SWITCH	switch & control of all submodels
TENDENCY	trace process-based tendencies of prognostic variables
TIMER	run-time control, event management
TOOLS	shared tools (e.g. sort-algorithms etc.)
TRACER	data & meta-data management of prognostic variables

MESSy process- / diagnostic submodels

Physics:
A2O, AEROPT, CLOUD, CLOUDOPT, CONVECT, CVTRANS, GWAVE, H2O, H2OISO,HD, MLOCEAN, MMFORCE, MXL, QBO, RAD, RAD_FUBRAD, SURFACE, VAHR, VERTDIFF, ...

Chemistry:
Kinetics: CH4, E4CHEM, MECCA, MSBM, SCAV, (MTSKIP)
Photolysis: DISSOC, JVAL, PHOTO, ...
Emissions: AIRSEA, BIOBURN, LNOX, MEGAN, OFFLEM, ONLEM, ORACLE, SPACENOX, SPE, TNUDGE, TREXP, ...
Aerosols: GMXE, M7, MADE, MADE3, ...
Sinks: SCAV, DDEP, SEDI, ...

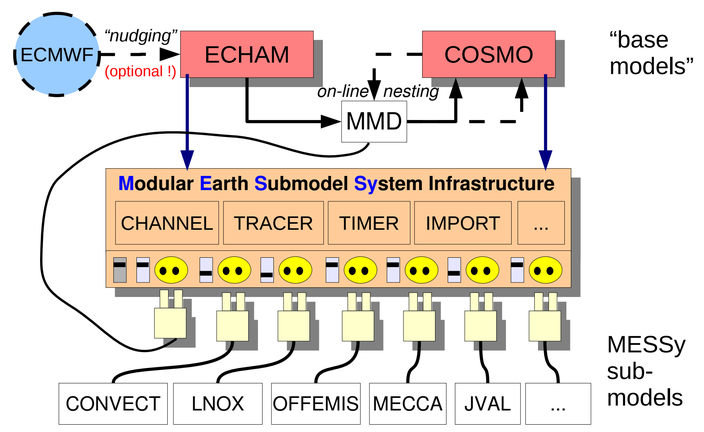
Diagnostics:
CONTRAIL, D14CO, DRADON, GEC, O3ORIG, PTRAC, PTRACINI, SATSIMS, SCALC, TAGGING, TBUDGET, MYTOY, S4D, SCOUT, SORBIT, TIMEPOS, TROPOP, VISO, ...

Basemodels equipped with MESSy

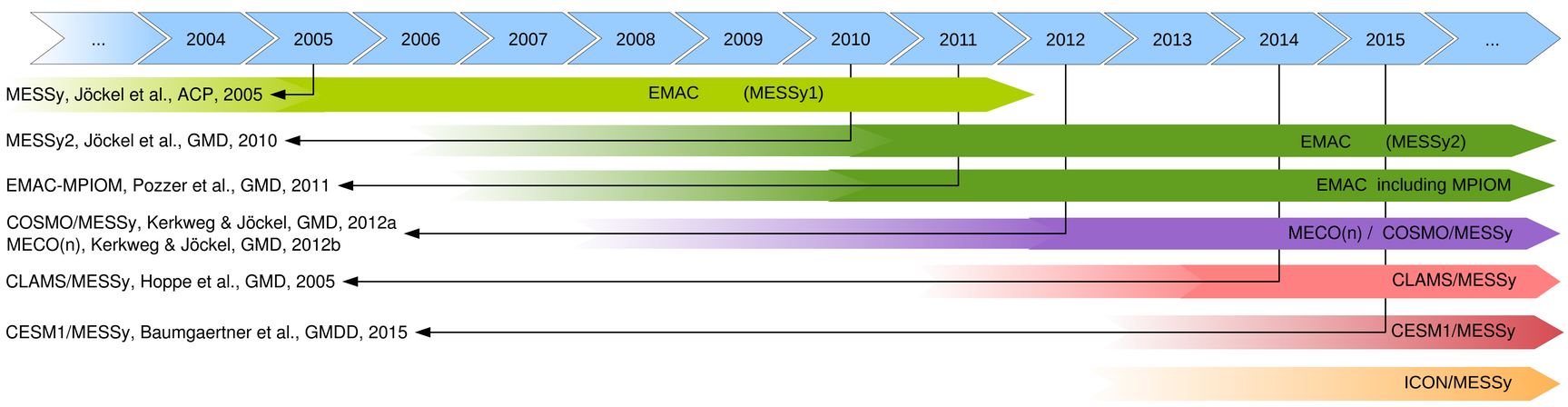
- **ECHAM5**: EMAC (ECHAM/MESSy Atmospheric Chemistry)
  - ECHAM5 "physics" transformed into MESSy submodels
  - including the coupling of MPIOM/HAMOCC/HD as MESSy submodels
- **COSMO-CLM**: COSMO/MESSy
  - since COSMO v5.0 the MESSy infrastructure entry points are part of the official DWD release
  - online-nesting of COSMO/MESSy (into itself and) into EMAC via the MESSy infrastructure (*MECO(n)*)
- **CLaMS/MESSy**:
  - CLaMS implemented bottom-up based on MESSy infrastructure
  - includes the on-line coupling of CLaMS/MESSy to EMAC
- **CAABA/MECCA**: a widely used chemistry box model
  - (has been developed within the MESSy framework)
- **CESM1/MESSy** (work in progress)
- **ICON**
  - within the HD(CP)^2 project: infrastructure for on-line diagnostics

Example for external coupling: MECO(n) - MESSy-fied ECHAM and COSMO models nested n times

The key is the modular approach (and the strict separation of process / diagnostic implementations from model infrastructure) ⇨ high flexibility



Global / regional chemistry climate modelling (methodological milestones)



The consortium – organisational structure