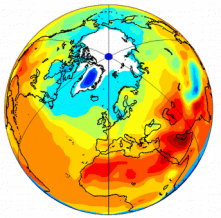
A European community Earth System Model

Ralf Döscher*, Uwe Fladrich*, Kim Serradell**
(* = SMHI, ** = BSC)

- EC-Earth is a community earth system model (ESM) inspired by the approach to use the ECMWF atmosphere model IFS as climate model
- 24 members
- 8 core members (1 per country)
  - SMHI, KNMI, ISAC-CNR, FMI, DMI, AEMET, Met Eireann, IPMA

GCM

EC-EARTH 3



Sea ice
LIM3

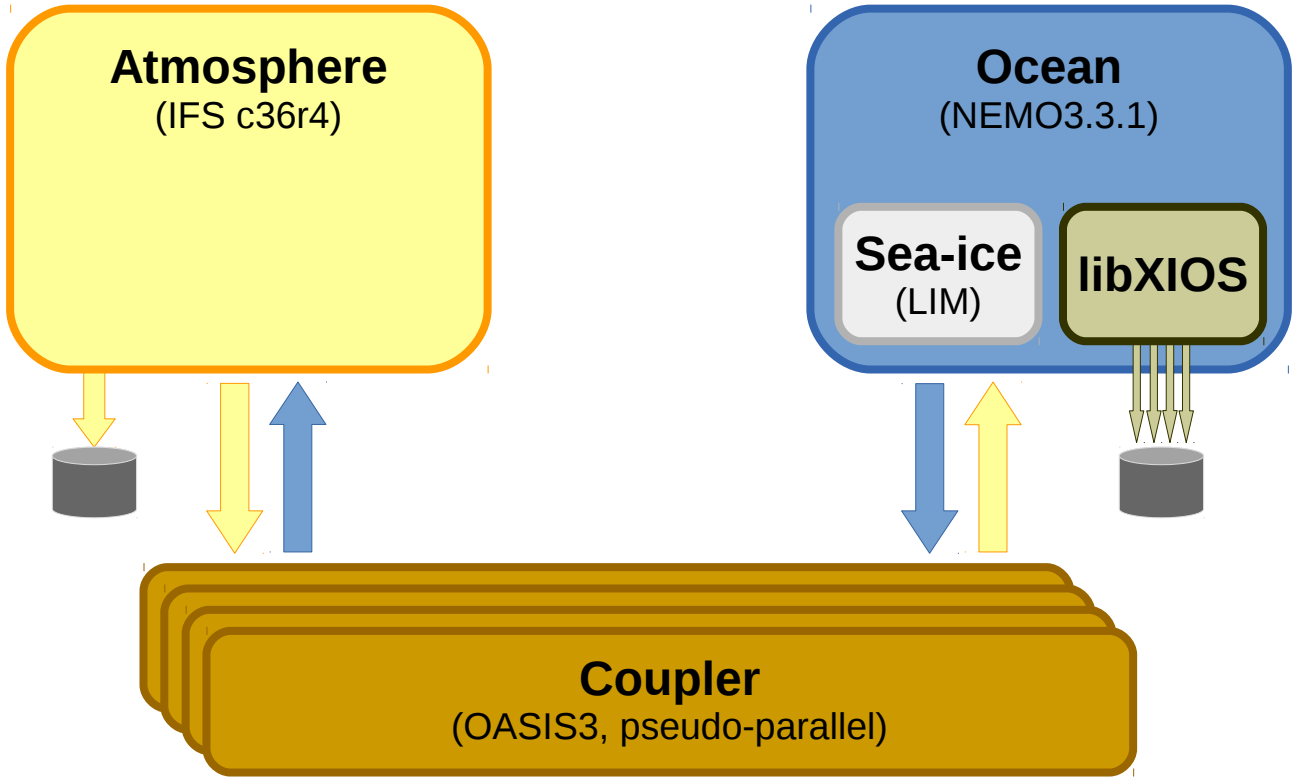
Atmosphere and Surface
IFS and H-Tessel

Coupling
OASIS-MCT

Ocean
NEMO 3.6

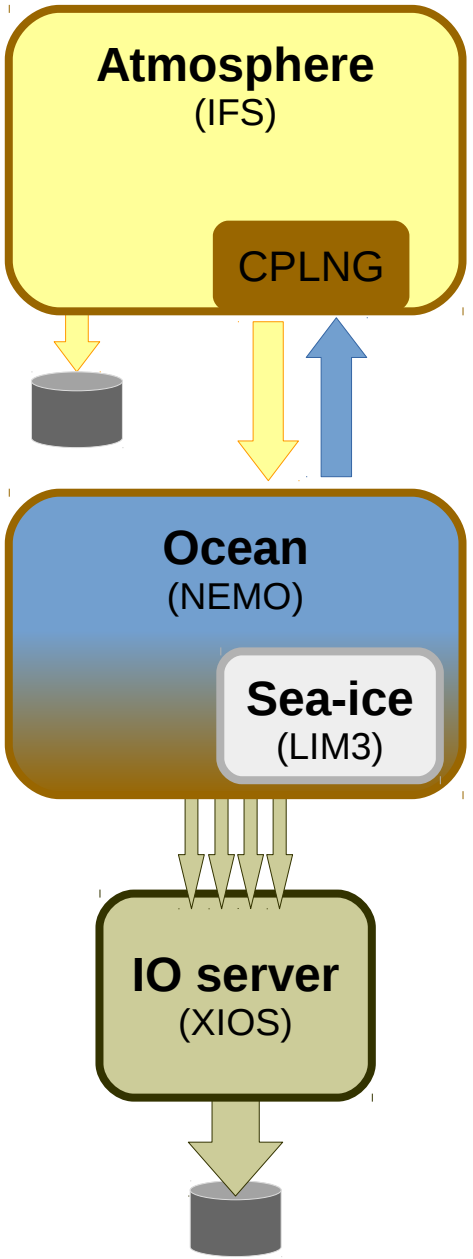
EC-Earth 3.0 + 3.1

Status prior to CMIP6 development:



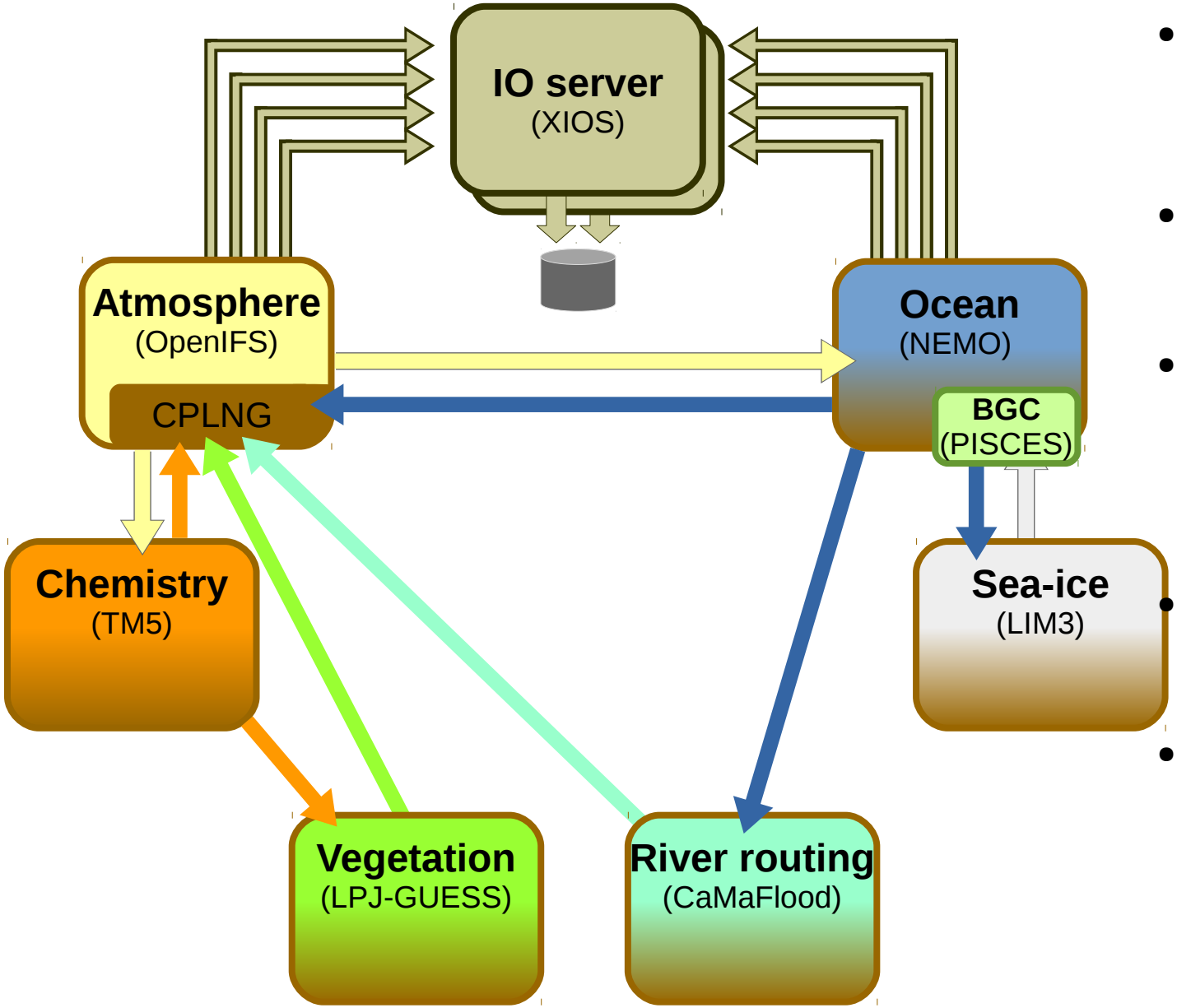
- New component versions available
- Coupling architecture more or less fixed at atm-oce

CMIP6: EC-Earth 3.2 (GCM)



- Current development
- New IFS coupling interface (CPLNG)
- OASIS3-MCT
- New NEMO/LIM version 3.6
- New XIOS version 1.0
- New runtime system
- ESM infrastructure

Beyond EC-Earth 3.2



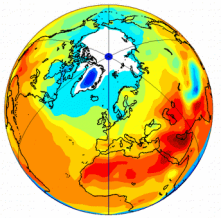
- ESM infrastructure

  To be used ...
- ...in many different experiments
- ...by many different groups
- ...on many different platforms
- ...with even more components?

Uwe Fladrich, SMHI

GCM

EC-EARTH 3



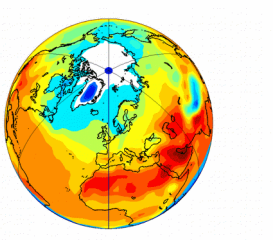
Sea ice
LIM3

Atmosphere and Surface
IFS and H-Tessel

Coupling
OASIS-MCT

Ocean
NEMO 3.6

EC-EARTH 3, the maximum system



Atmosphere chemistry
TM5

Greenland ice sheet

Sea ice
LIM3

Atmosphere and Surface
IFS and H-Tessel

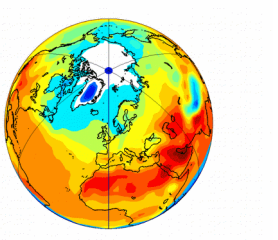
Coupling
OASIS-MCT

Ocean
NEMO 3.6

Dynamic vegetation
LPJ-GUESS

Ocean bio-geo-chemistry
PISCES

EC-EARTH 3 Greenland?



Greenland ice sheet

Sea ice
LIM3

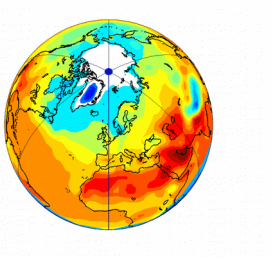
Atmosphere and Surface
IFS and H-Tessel

Coupling
OASIS-MCT

Ocean
NEMO 3.6

For ???MIP

EC-EARTH 3



Atmosphere chemistry
TM5

Atmosphere and Surface
IFS and H-Tessel

Dynamic vegetation
LPJ-GUESS

Coupling
OASIS-MCT

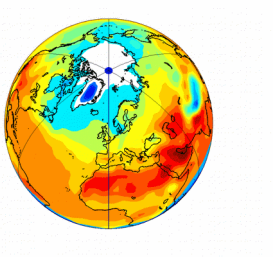
Sea ice
LIM3

Ocean
NEMO 3.6

Ocean bio-geo-chemistry
PISCES

for AerChemMIP

EC-EARTH 3 CC



Atmosphere chemistry
TM5, carbon only

Atmosphere and Surface
IFS and H-Tessel

Dynamic vegetation
LPJ-GUESS

Coupling
OASIS-MCT

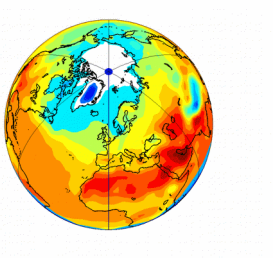
Sea ice
LIM3

Ocean
NEMO 3.6

Ocean bio-geo-chemistry
PISCES

for C4MIP

EC-EARTH 3 CONC



Prescribed CO2 concentrations

Atmosphere and Surface
IFS and H-Tessel

Dynamic vegetation
LPJ-GUESS

Coupling
OASIS-MCT

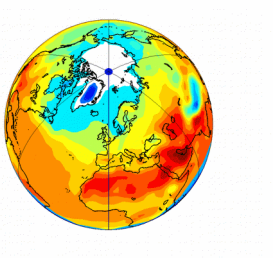
Sea ice
LIM3

Ocean
NEMO 3.6

Ocean bio-geo-chemistry
PISCES

for ScenarioMIP

EC-EARTH 3 VEG



Prescribed CO2 concentrations

Atmosphere and Surface IFS and H-Tessel

Dynamic vegetation LPJ-GUESS

Coupling OASIS-MCT

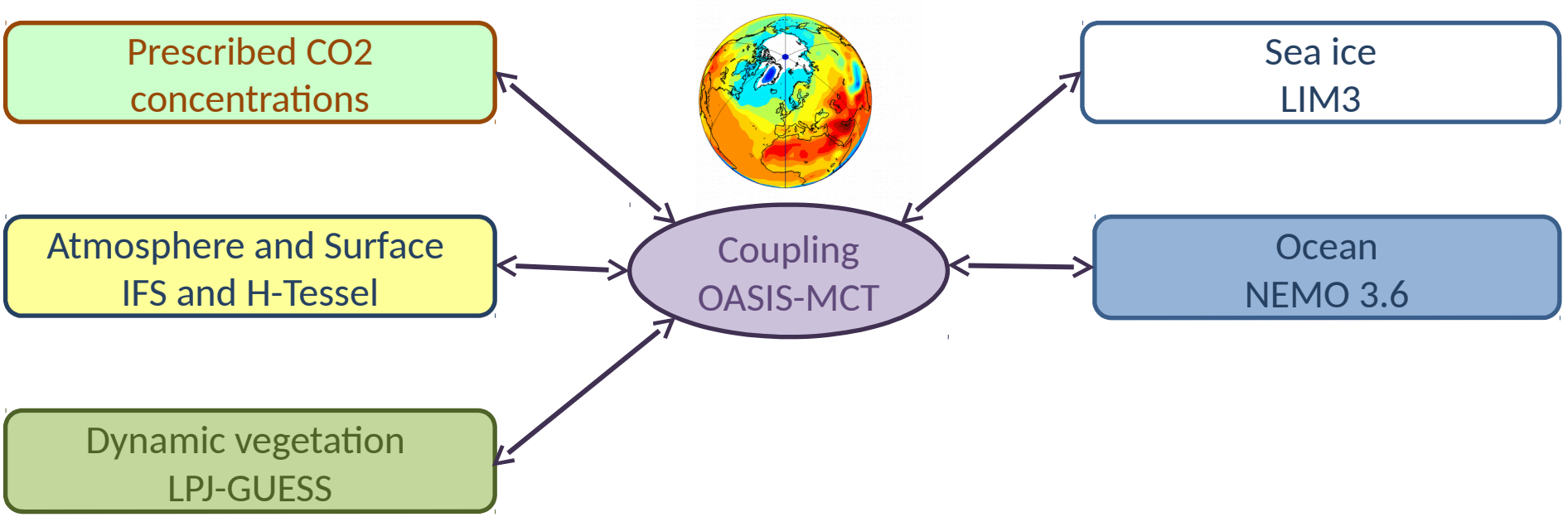
Sea ice LIM3

Ocean NEMO 3.6

for LUMIP

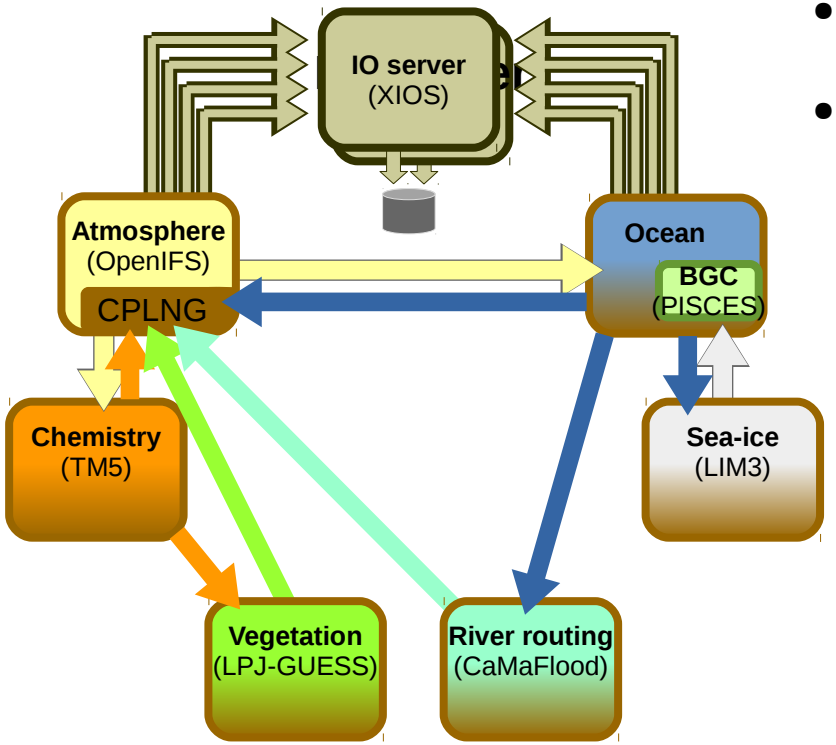
ESM

EC-EARTH 3 VEG



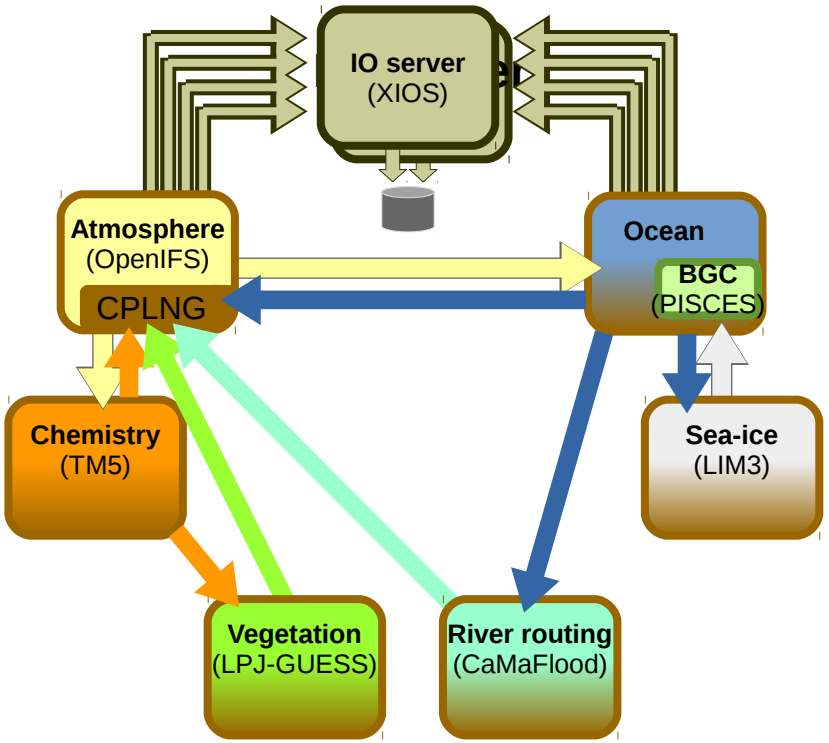
for LuMIP

CPLNG: Objectives



- Simpler to use, more robust, more flexible for multi-component configurations
- Support new components (LIM3, TM5, LPJ-GUESS)
- Support different coupling configurations
- Support for multi-category and 3D fields
- Improve computational performance/scaling

CPLNG: Concepts



- Set of Fortran modules
  - Abstract data type for coupling fields
  - Data and implementation hiding
- Centralised coupling configuration
- Consistent data access
- Support for grid point and spectral fields

Status

- **EC-Earth branches for CMIP6**
  - 3.2.1 for atm-only tuning
  - 3.2.2 for coupled GCM tuning
  - 3.2.3 for ESM configurations
    - Current issues: CMIP6 forcing, Arctic sea ice, ocean too cold, ocean bio-geo-chemistry
- **Resolutions**
  - Standard GCM T255-ORCA1
  - High res GCM T511-ORCA025 (HighResMIP and PRIMAVERA)
  - Low res GCM T156-ORCA1(PMIP)

Resolutions in European ESMs

Model	"Higher" resolution models		"Lower" resolution models	
	Atmosphere	*Ocean*	*Atmosphere*	*Ocean*
CNRM-ESM	T359	0.25°	T127	1°
CMCC-ESM	1°	0.25°	1°	1°
EC-Earth	T255	1°	T159	1°
IPSL-ESM	1.3°x 0.65°	0.25°	2.5°x 1.25°	1°
MPI-ESM	T127/T63	0.4°/1.5°	T31	3°
NorESM	0.9°x 1.25°	0.25°	1.9°x 2.5°	2°
UKESM	0.6°	0.25°	1.5°	1°

Tuning

- present day GCM tuning
  - atm-standalone, coupled
- preindustrial GCM spin-up
- transient GCM tuning
- ESM testing based on the GCM tuning

Status of ESM configurations

- **Components**:
  - GCM: systematic tuning starting
  - LPJ_GUESS (dynamic vegetation, land use and C-N cycling, ...): spin-up is running
  - PISCES (ocean bio-geo-chemistry): problems with BGC-NEMO physics interaction, no spin-up yet
  - TM5: working in full and carbon-only configurations, interacting well with IFS
- **Coupling**
  - GCM: technically running
    - issues: CMIP6 forcing, Arctic sea ice, ocean too cold
  - IFS+NEMO+PISCES is technically up and running
  - IFS+NEMO+LPJ-GUESS is technically up and running
  - IFS+TM5+LPJ-GUESS coming soon

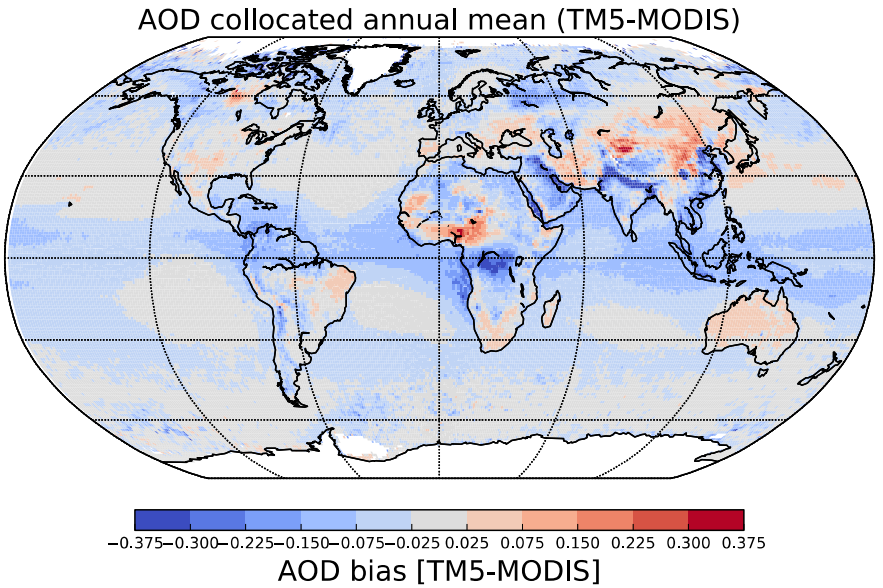
Collocated AOD bias in TM5

TM5 vs MODIS

Annual means

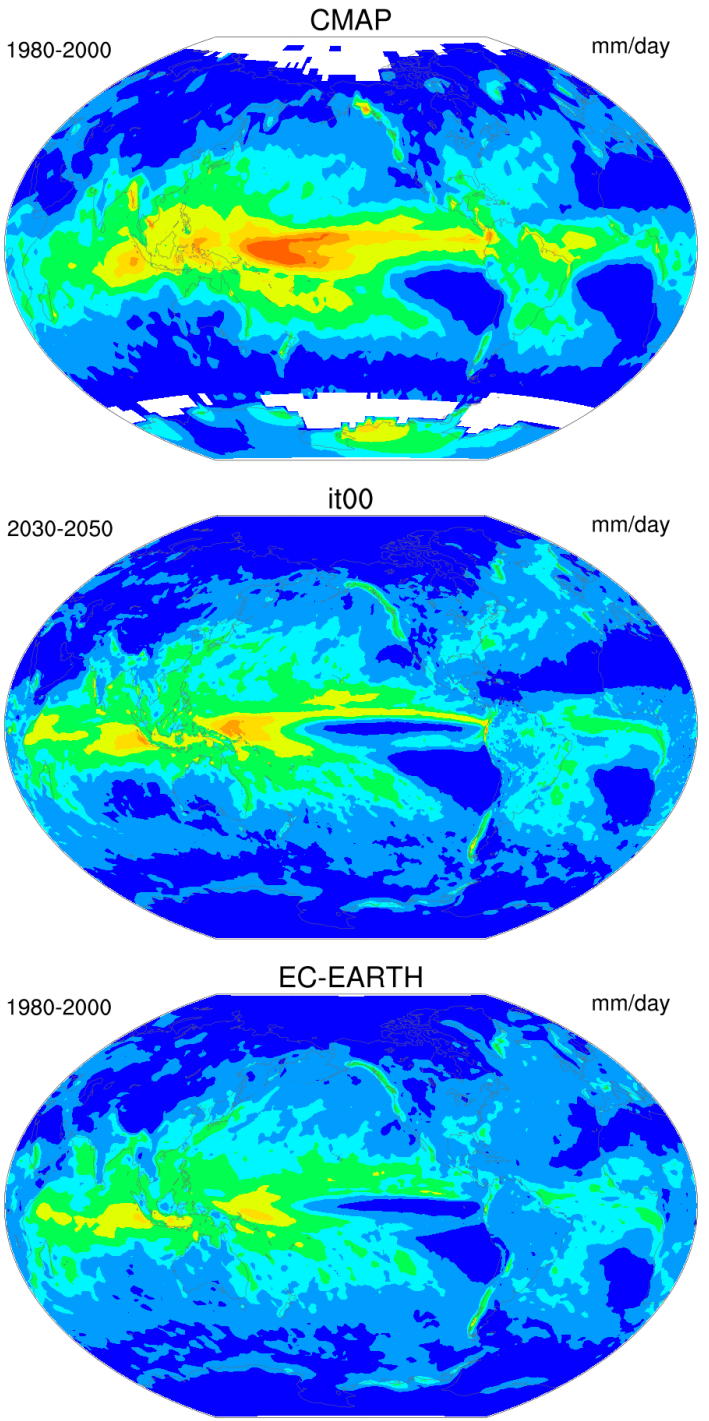
MODIS 0.16

TM5 0.12



Variability

PR Standard Deviations (Annual)



Obs

EC-Earth 3.2 GCM

EC-Earth 2, CMIP5

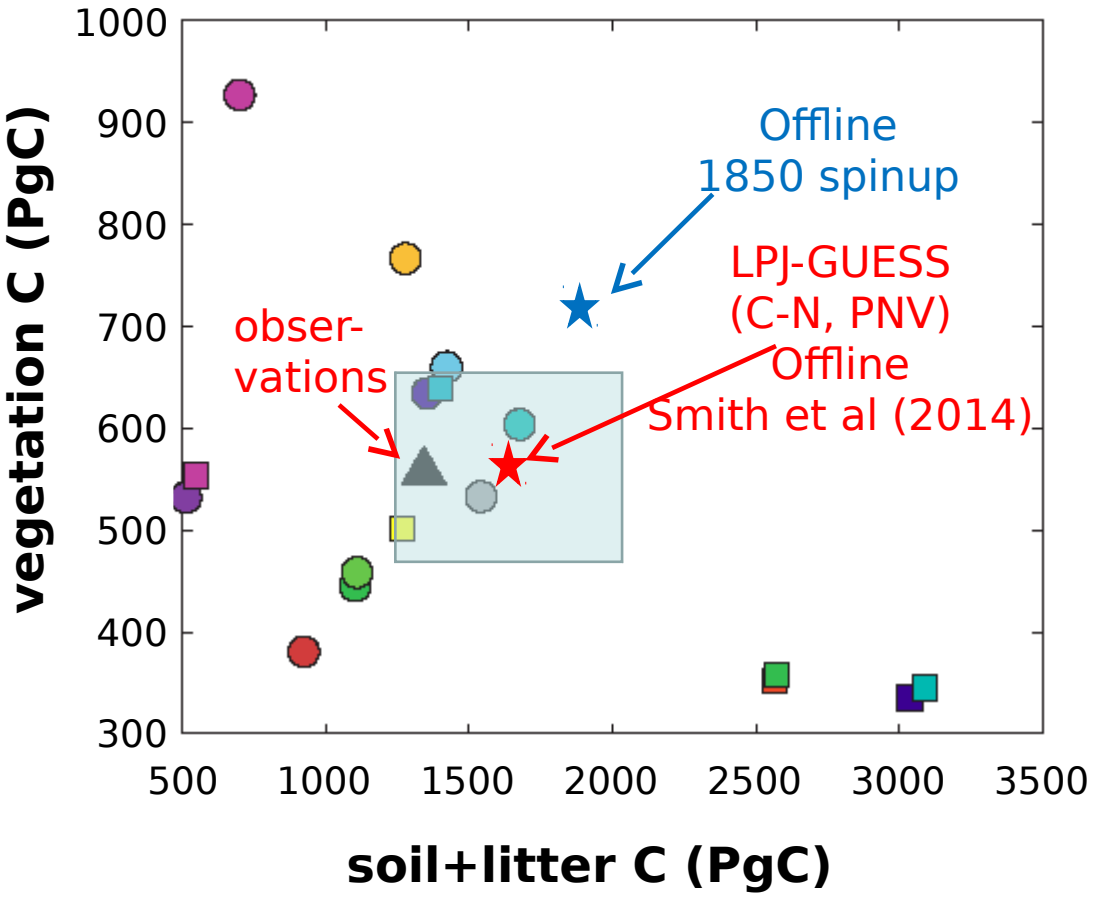
It00 = EC-Earth 3.2.1 recent 80 year run, constant year 2000 forcing

EC-EARTH = CMIP5 version (v2.3, T159L62-ORCA1L46, historical forcing)

Std of precipitation is a measure of variability. The new version (3.2) is much better in the tropics, South America, ITCZ and in warm pool regions

LPJ-GUESS dynamic vegetation spinup

1850 spinup pools & baseline (1986-2005) ecosystem C pools in IPCC-AR5 ESMs



GPP: 132 GtC yr-1
NPP: 62 GtC yr-1
Forested area: 4.35 million km²

Anav et al. 2013
J. Climate 26: 6801

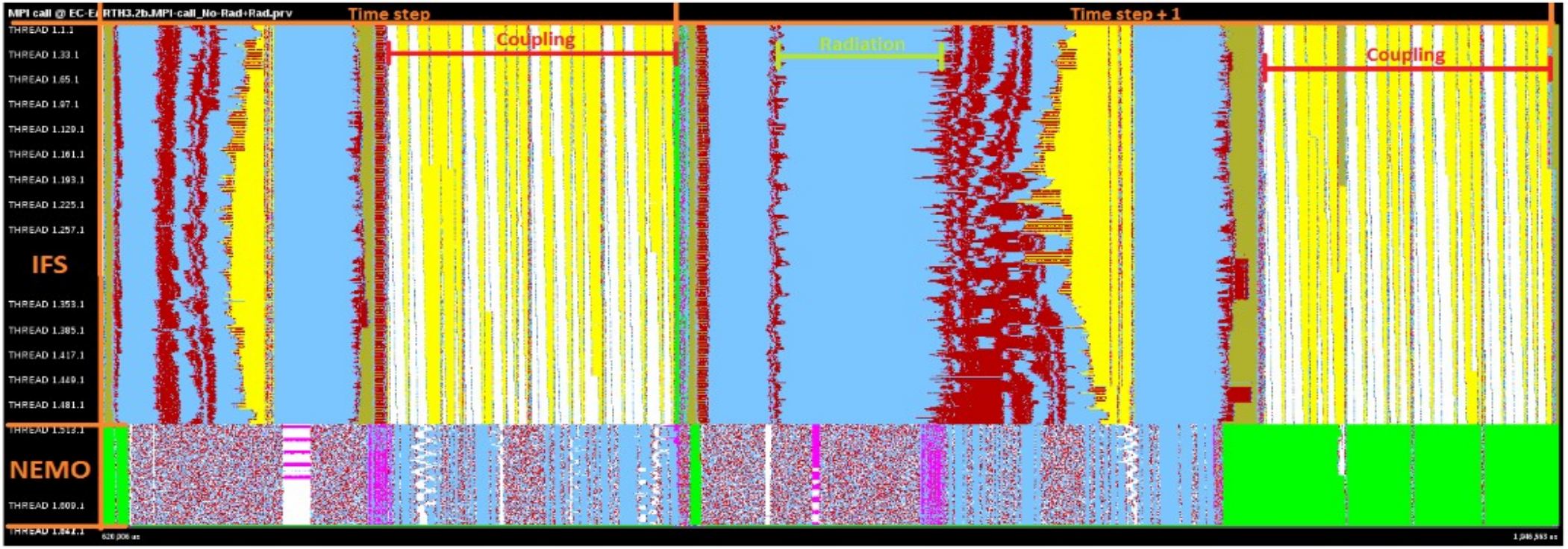
Karlsruhe Institute of Technology

Time lines of EC-Earth for CRESCENDO and CMIP6

- GCM tuning by end 2016
- GCM DECK runs start by early 2017
- ESM DECK starting by May 2017
- First ScenarioMIP runs by late 2017

Performance analysis

- Using BSC performance tools, we can trace an execution



- We see the coupling is taking a important percentage of a time step

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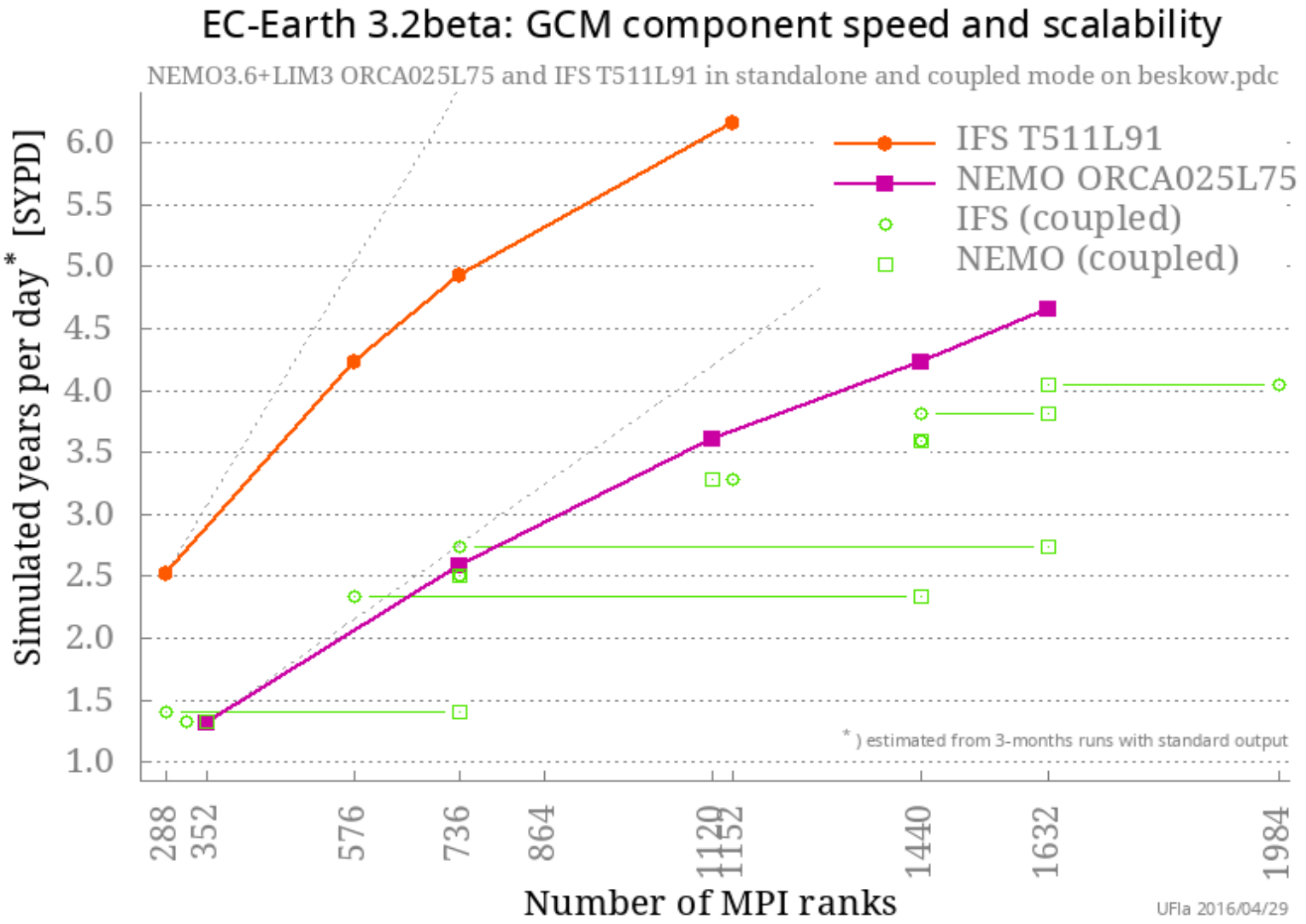
Scaling

of the current version

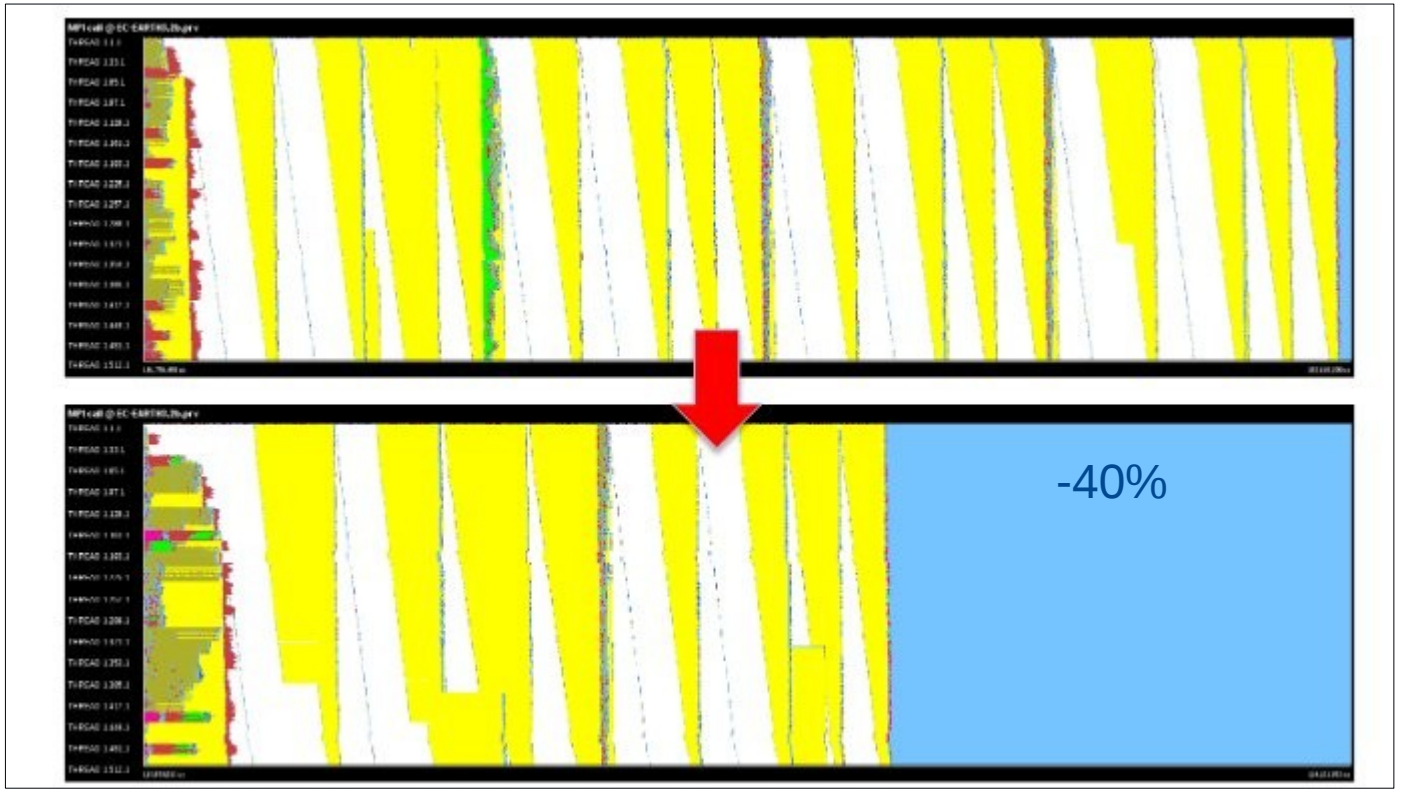


Uwe Fladrich, SMHI

Performance analysis

Analyzing coupling strategy between IFS and NEMO

- Message and calculations aggregation (by default IFS passes variables to NEMO in several times)



Top: using default namcouple file
Bottom: using an optimized namcouple file (pack variable groups with similar type of coupling together)

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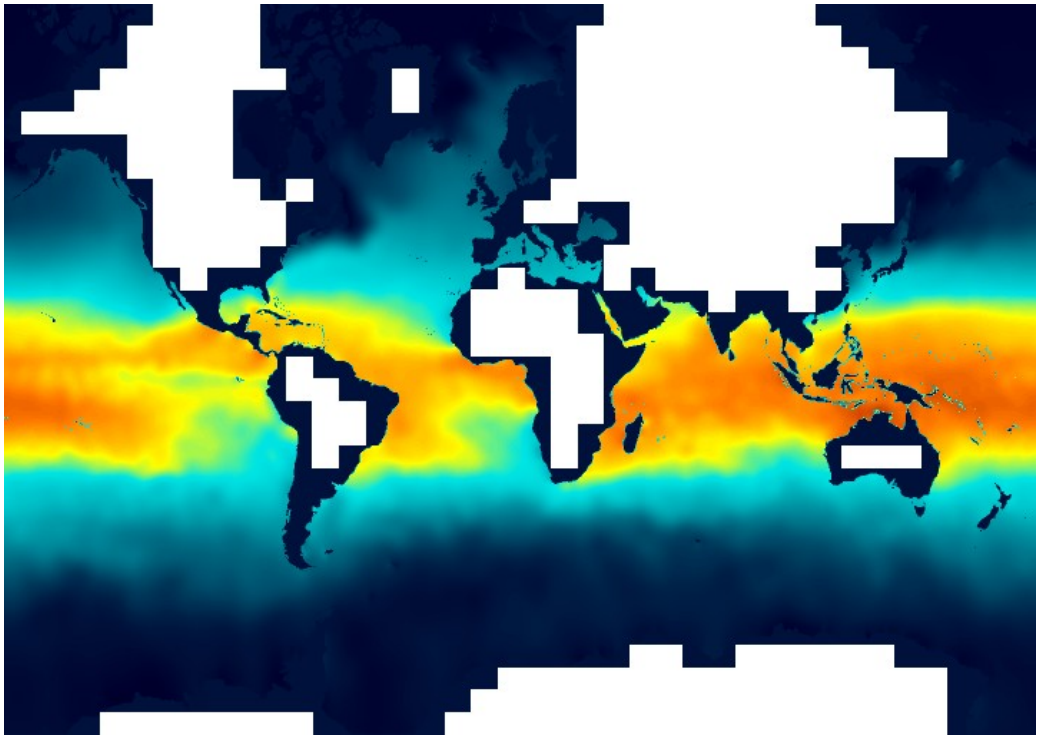
ELPin

- A tool that allow to find proper namelist parameters to exclude land-only processes in NEMO simulations
- NEMO decomposes automatically the domain:
  - Computes and communicates in land-only processes and then discards the result ⇨ waste of resources
- Currently performing an evaluation of the results produced



- ORCA025 domain decomposed in 1287 sub-domains
- 312 are land-only and therefore removed (24% of the total grid)

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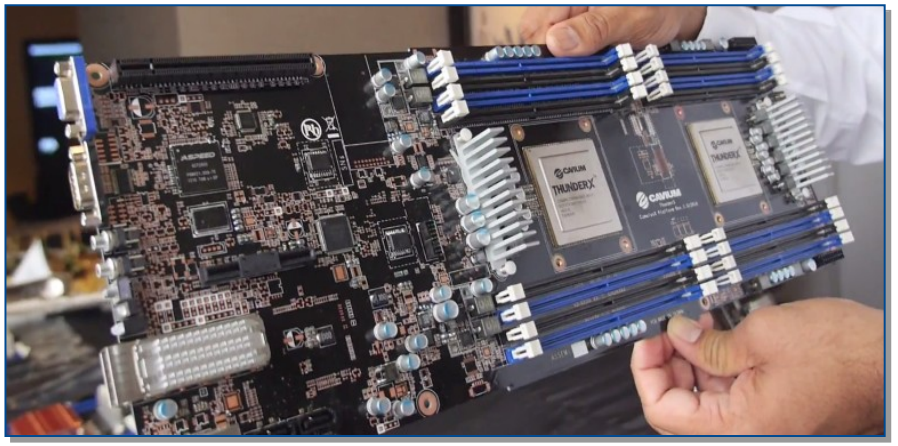
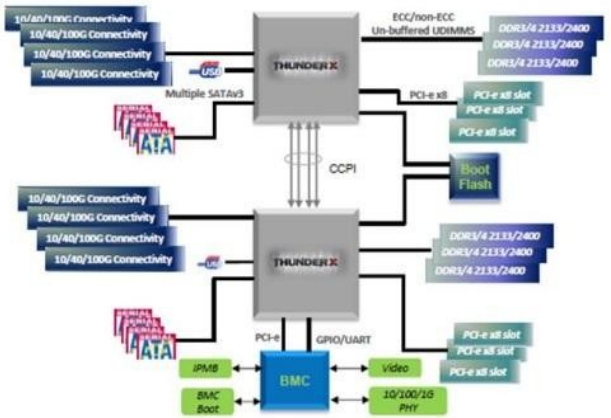
EC-Earth on ThunderX

- One of the Mont-Blanc mini-clusters.
  - Low energy cluster
  - Small clusters including ARMv8 (64 bit) platforms.





- 4 nodes devoted to computation, each equipped with:
  - 2x sockets Cavium ThunderX
    - 48x ARMv8-A cores each (i.e. 96 cores with shared mem each node) @ 1.8 GHz
  - 128 GB memory
  - 128GB SSD

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EC-Earth on ThunderX

- EC-Earth 3.2 build with:
  - GCC 4.8.4, SZIP 2.1, OPENMPI 1.10.2, NETCDF 4.4.0, HDF5 1.8.17, LAPACK 3.6.0
  - T255L91-ORCA1 configuration
- Successful run of one month of simulation (output included)
- First execution times needs to be improved
  - 10.508 seconds using 258 cores (128 IFS, 128 NEMO, 1 XIOS, 1 runoff)
  - 923 seconds using the same number of cores in MN3
  - Work and tunning required to improve this numbers

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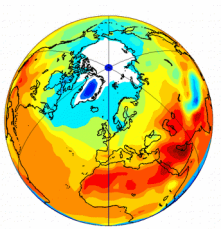
ESM

EC-EARTH 3



Atmosphere chemistry
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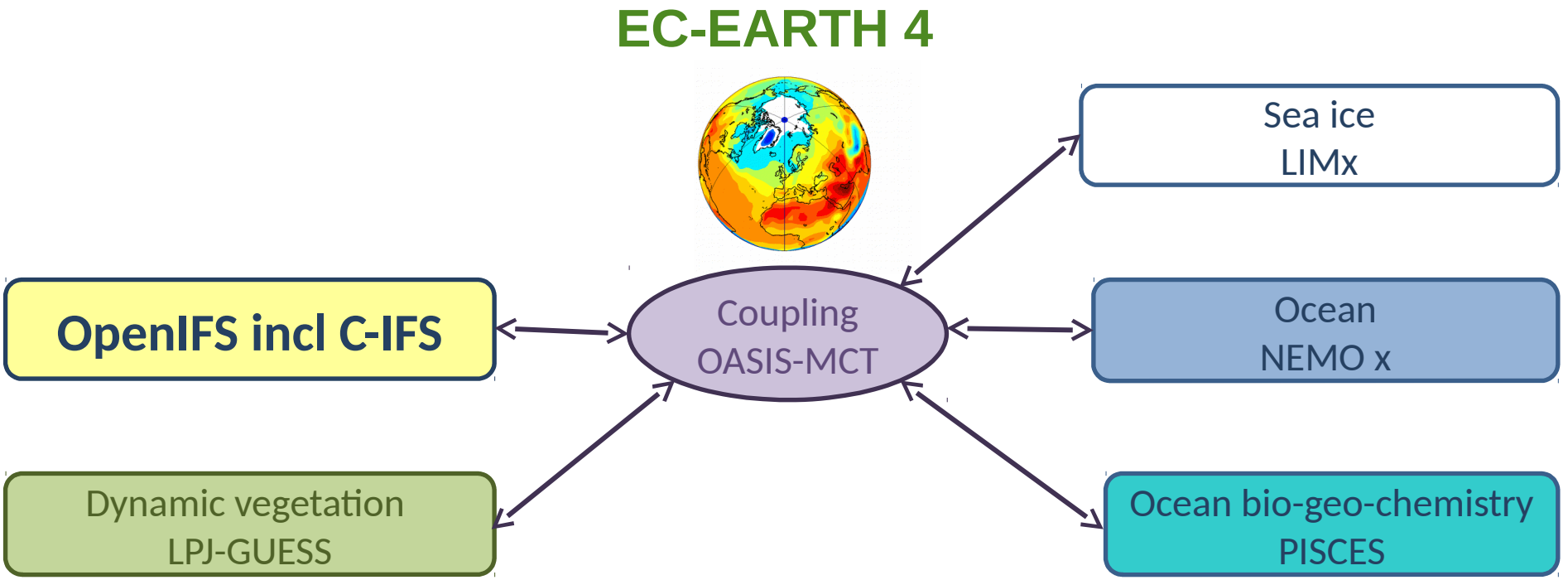
for AerChemMIP

Future: EC-Earth with OpenIFS



Future: EC-Earth with OpenIFS

- First tests with the coupled version (oifs40r1+nemo+lim3 via oasis3-mct) have been carried out at SMHI (Uwe Fladrich).
  - Early version (with it's issues), this allows us to discuss further implementation strategy.
- Strong interest in the EC-Earth community
  - Coupled configuration in standard and very high resolution
  - Performance analysis
  - Education at universities
  - Atmospheric chemistry and aerosol
  - Ocean waves
  - ...

To take home

- EC-Earth is a community model
  - An open community, contributions welcome
- EC-Earth provides a flexible coupling framework with multiple flexible configurations
- The EC-Earth community brings together climate science with expertise on integrating model components
- The future
  - A more efficient ESM coupling framework
  - OpenIFS
  - A collection of different configurations and resolutions for climate process studier, climate projections and predictions

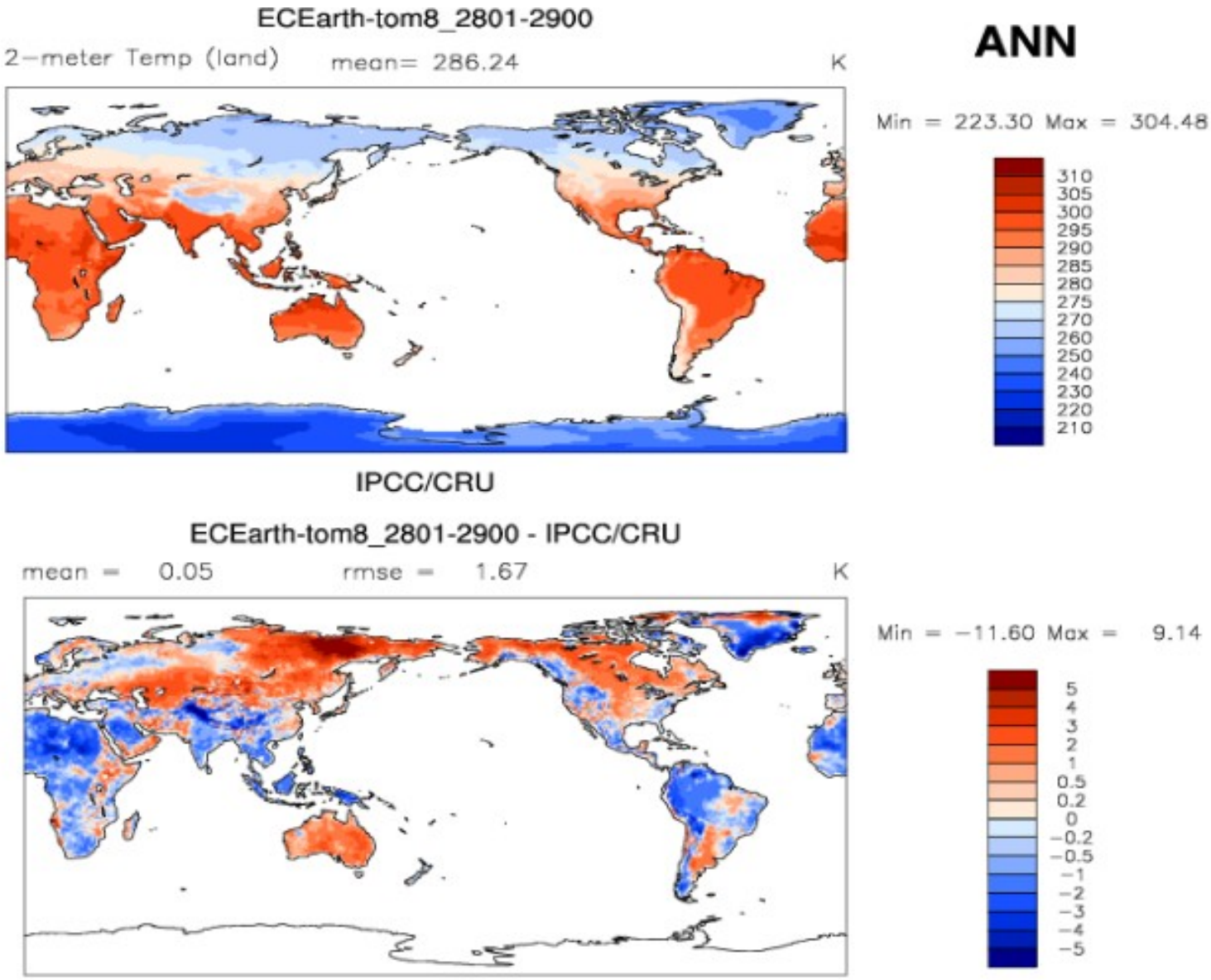
END

EC-Earth surface temperature

Surface temperature mean climatology for ECE3.1 (top),

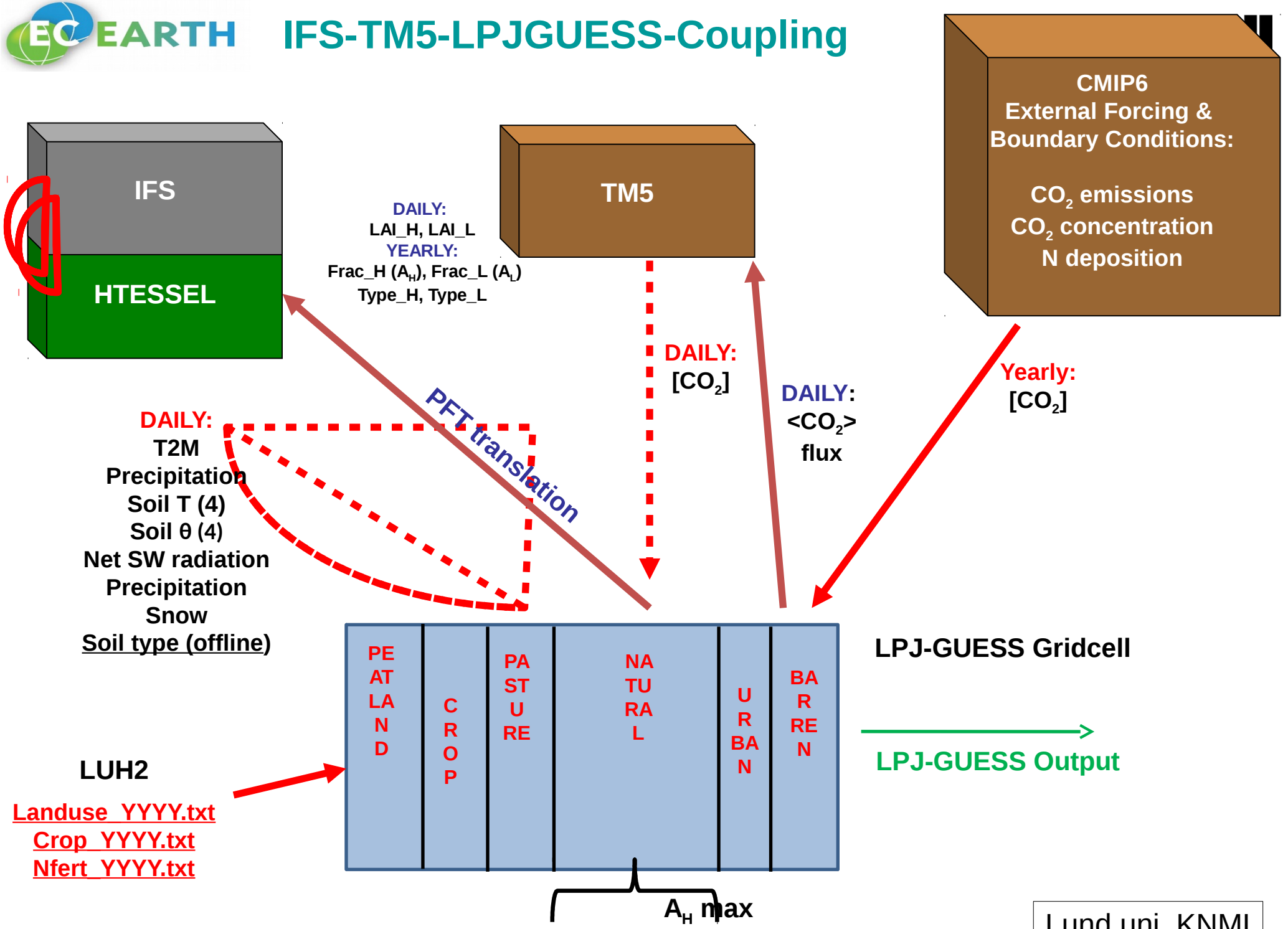
Run is performed under perennial year 2000 GHGs and aerosol forcing (applied for 810 years) and the last 100 years of each run are considered.

its biases with IPCC/CRU (1961-1990)



(Davini and von Hardenberg, CNR-ISAC)

IFS-TM5-LPJGUESS-Coupling



Lund uni, KNMI

Metrics

EC-Earth 3.1

Table 1: Main global averages of some selected fields for the two different versions of EC-Earth. In red we report the values closer to observations (where possible).

Field	*EC-EARTH 3.0.1 (io03)*	*EC-EARTH 3.1 (tom8)*	*OBSERVATIONS*
TOA	-0.43 W/m^2	-0.91 W/m^2	Should be 0
SFC	2.03 W/m^2	0.15 W/m^2	Should be 0
TOA-SFC	-2.46 W/m^2	-1.07 W/m^2	Should be 0
P-E	0.031 mm/day	-0.016 mm/day	Should be 0
SST	17.69 °C	18.71 °C	18.41 (Hadisst 1990-2010)
T2M	286.39 K	287.56 K	287.58 (ERAI 1990-2010)

Table 2: Main Performance Indices for the two different versions of EC-Earth. In red we reported the lower values.

Field	*EC-EARTH 3.0.1*	*EC-EARTH 3.1*
T2M	33.35	13.10
MSL	2.21	1.72
QNET	19.10	21.28
TP	22.34	26.80
SST	13.07	14.97
T-zonal	25.58	10.71
U-zonal	1.97	1.82
V-zonal	1.63	1.43
Q-zonal	23.85	16.55
Total PI	0.83	0.72

Reichler and Kim (2008) metric