AN ATMOSPHERE-LAND COUPLING IN TERRSYSMP

SEP 23, 2020

Slavko Brdar, Cunbo Han, Stefan Kollet,

Stefan Poll, Ilya Zhukov, Klaus Goergen

OUTLOOK

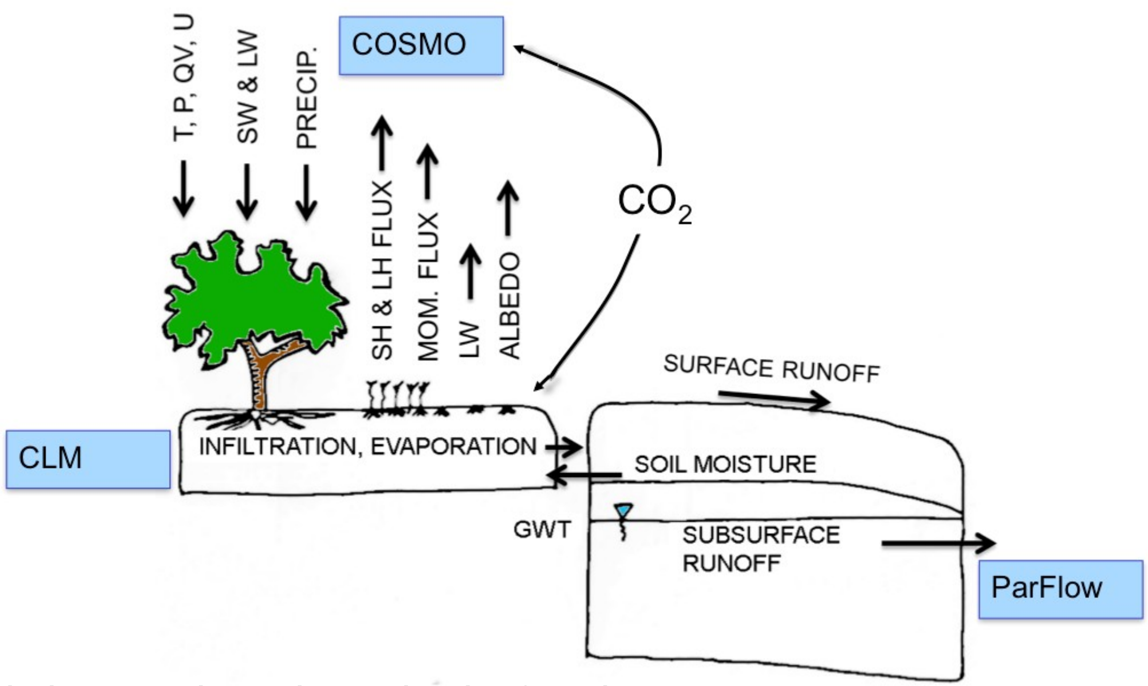
- TerrSysMP (atmo + CLM3.5 + ParFlow)

- Coupling ICON + CLM3.5

OUR FOCUS

- Physically-based representation of transport processes of mass, energy and momentum across scales down to sub-km resolutions, explicit feedbacks between compartments (focus: terrestrial hydrological cycle)

- Holistic representation of complex interactions among the compartments in the geo-ecosystem

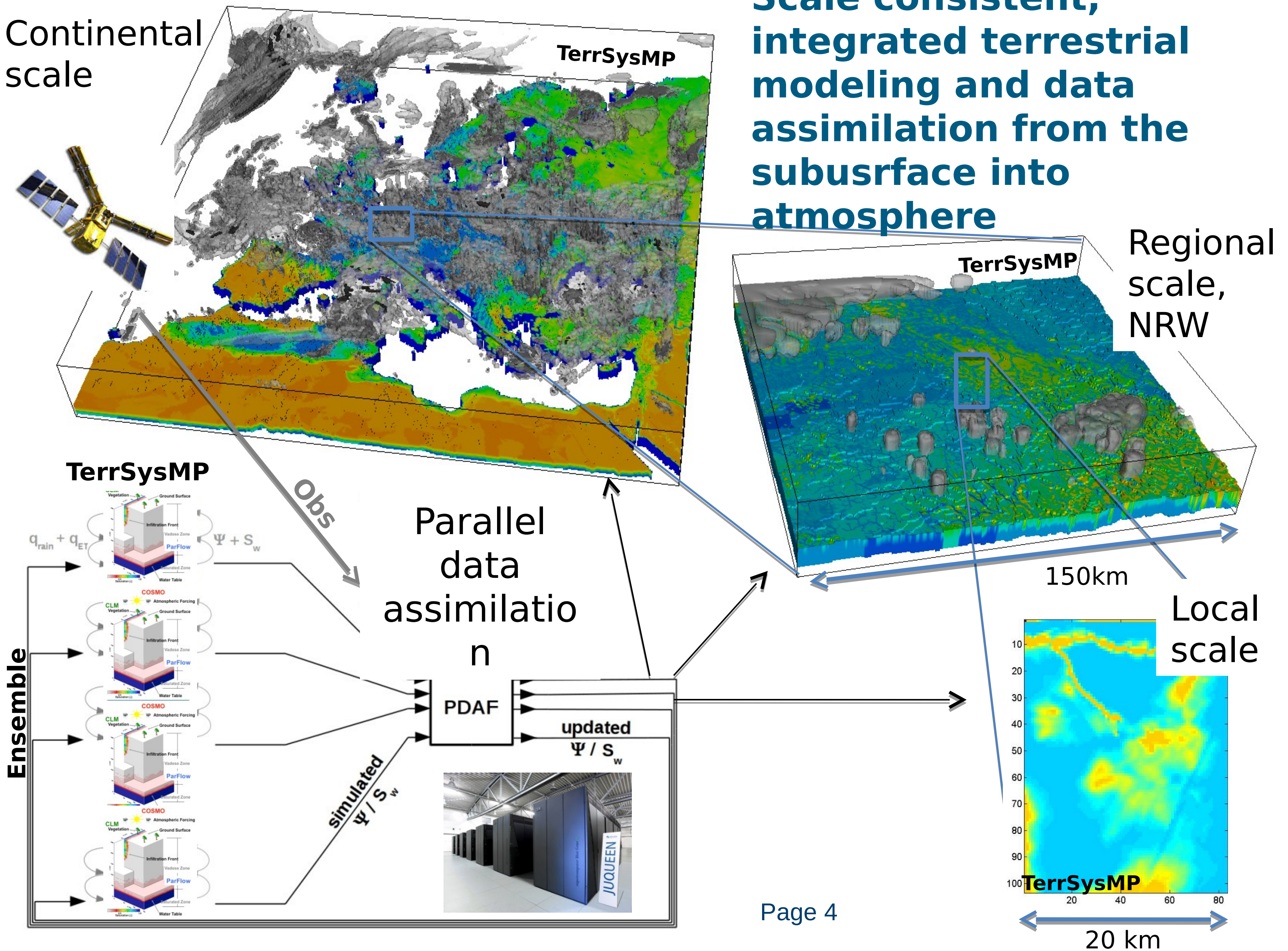


Development:

Transregional Collaborative Research Centre 32 (TR32, “Patterns in Soil-Vegetation-Atmosphere-Systems”)

OPERATIONAL RUNS

Scale consistent, integrated terrestrial modeling and data assimilation from the subusrface into atmosphere

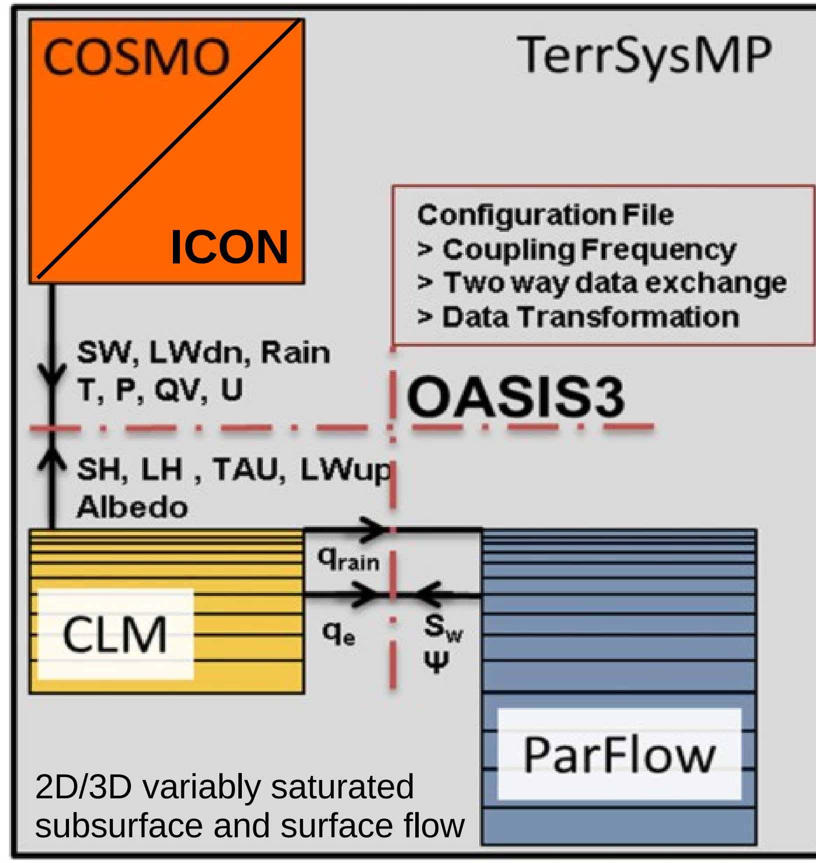


COUPLED SYSTEM

TerrSysMP

Coupling interface: OASIS3 / OASIS3-MCT (driver)

- MPMD execution model
- Suitable for independently developed codes
- Implementation is less code-intrusive
- Component models can have **different** spatio-temporal resolution
- OASIS3-MCT creates MPI_COMM_WORLD
- Various configuration options (component models standalone and combinations)
- Modular coupling design



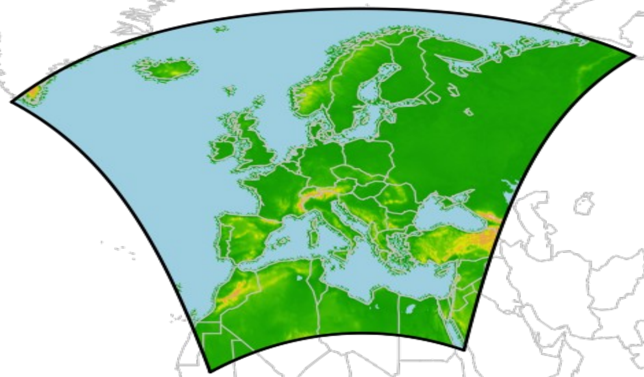
Shrestha et al. (2014, Mon. Weather Rev)

USAGE

ESM Frontier Simulations

TerrSysMP in HGF-ESM

- **Goal**:
  analyse hydrometeorological extreme events
- EURO-CORDEX
- EUR-11 domain, 0.11° resolution, 436 x 424
- Simulation period:
  Spinup: 1989-1995
  Analysis: 1996-2017



© Carina Furusho, FZJ

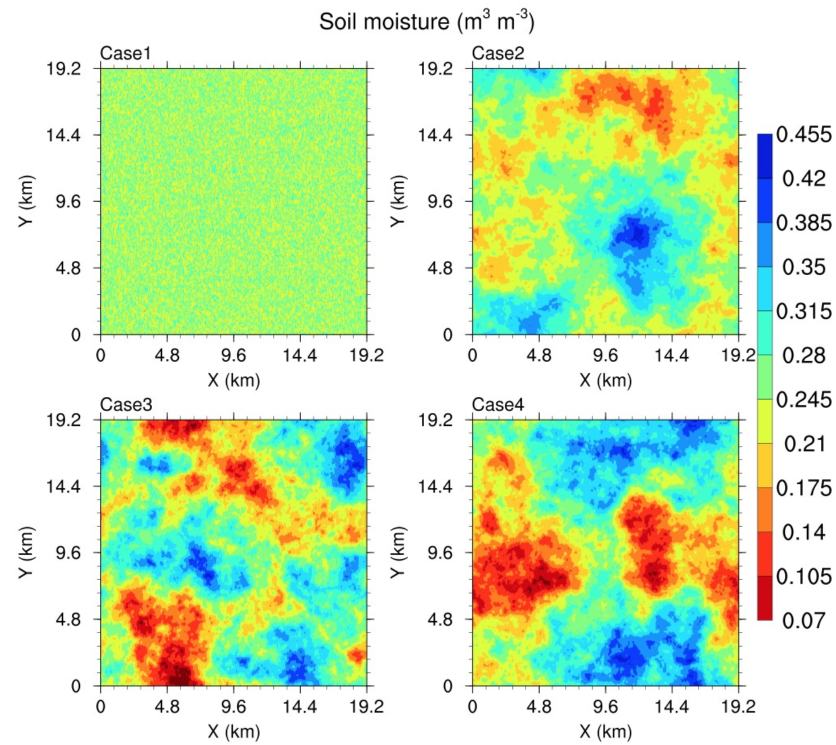
Model	Vertical levels	Time-steps	Input data (Keune et al., 2016)
COSMO	50	60 s	ERA-Interim (ECMWF)
CLM	10	900 s	MODIS data
ParFlow	15	900 s	FAO soil types data

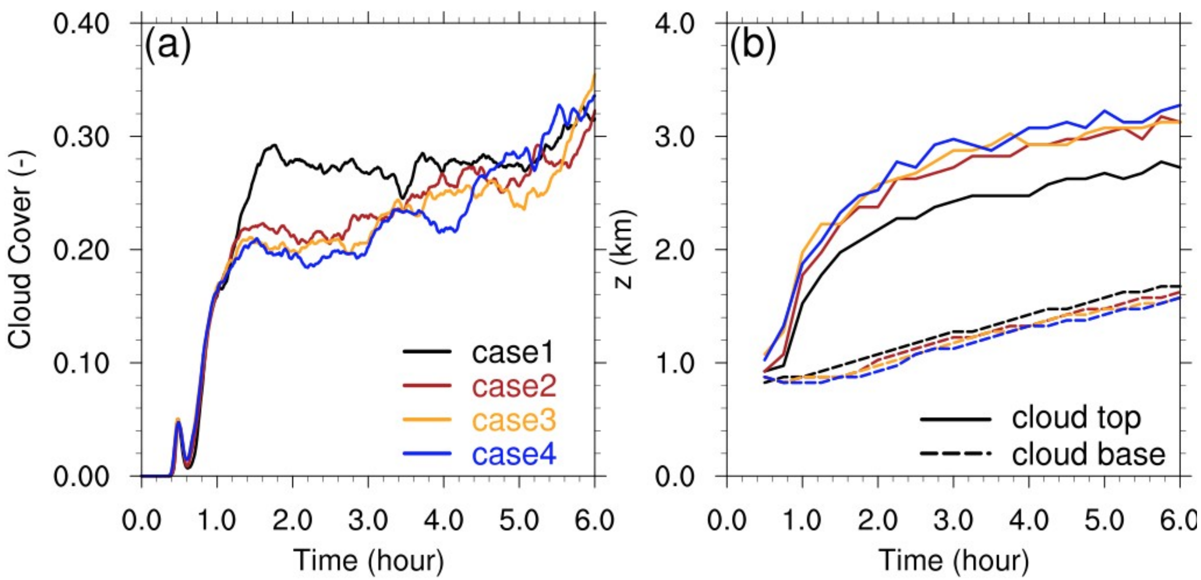
USAGE

HD(CP)² project, Cunbo Han

Work package 3: Catchment scale circulations

- **Goal**:
  How and to what extent do soil moisture distribution and induced circulation impact ABL development and shallow cumulus clouds





Mitglied

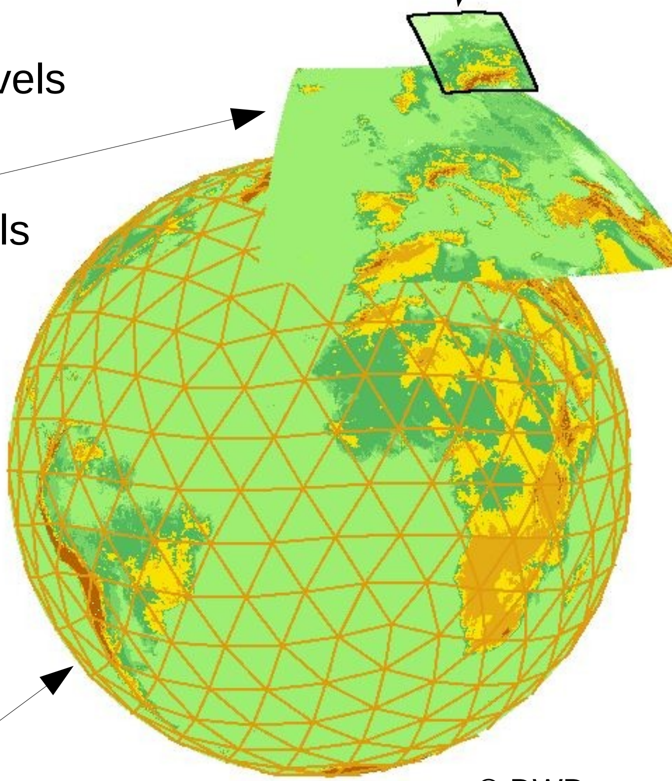
WHY ICON?

- Better dynamical core:
  mass conservation properties,
  grid elements almost same
- Proven to work
  on very high resolutions
- Scales very well
- Static mesh refinement with 1-way or 2-way nesting
- ICON will replace current operational model of German weather service

COSMO-DE
2.8 km, 50 vert. levels
9.7 mil. grid cells
@ 00, 03, ..., 21:
27 h forecast

ICON-EU
6.5 km, 60 vert. levels
42 mil. grid cells

COSMO-EU
7 km, 40 vert. levels
17.5 mil. grid cells
@ 00, 06, 12, 18:
3-day forecast



ICON
13 km, 90 vert. levels
265 mil. grid elements
@ 00, 12 UTC: 180 h forecast
@ 06, 18 UTC: 120 h forecast

WHY ICON?

ICON for LES simulations:

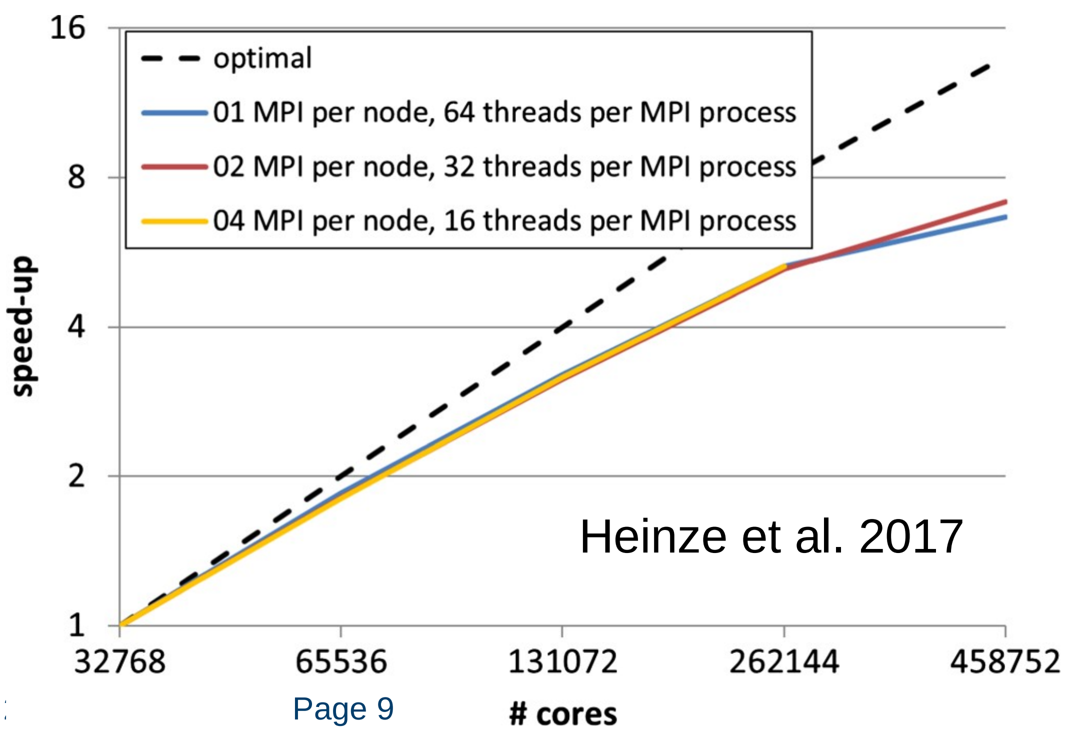
- Improve understanding of moist processes
- Derive parametrization of moist processes for climate models
- Realistic turbulence profiles match well with observations
- Fairly good agreement with observations in Heinze et al. (2017, QJRMS):

Near-surface temp., humidity, winds
Thermodynamical profiles,
Energy balance and spectra

SCALING

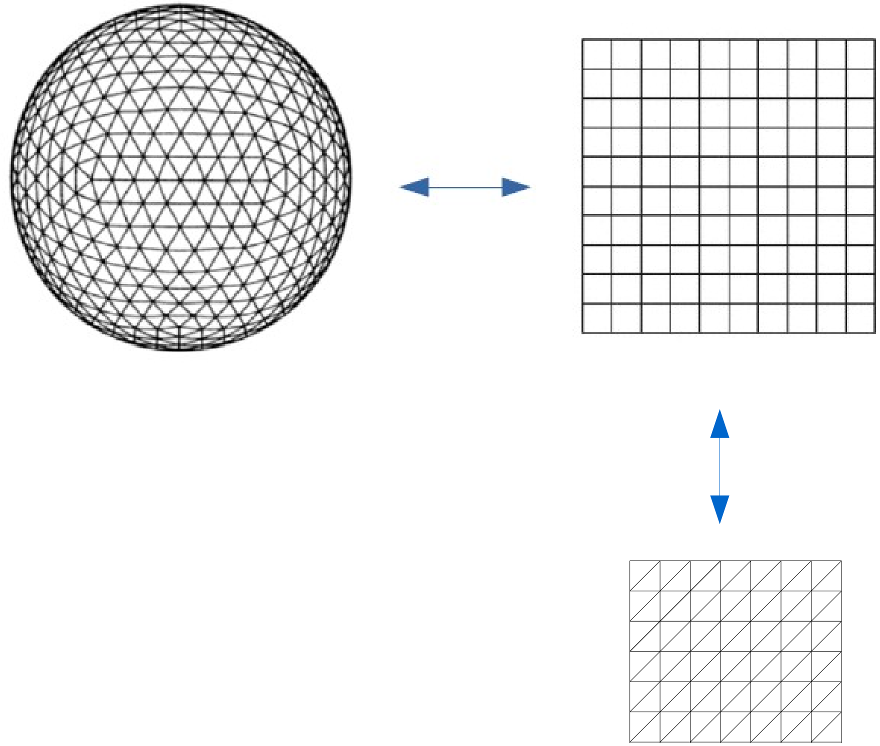
BlueGene/Q JUQUEEN in Juelich
120m spatial resolution
6.7 billion grid cells

No output



HOW COUPLING WAS DONE...

Unstructured grids of ICON



OASIS3-MCT can handle unstructured □-grids (natively)

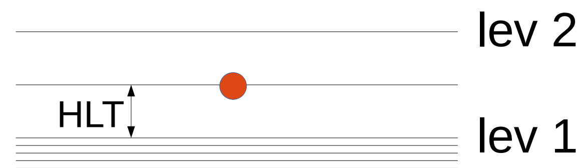
Given weight factors between grids, OASIS3-MCT can handle unstructured Δ-grids

Climate Data Operators (CDO) provides the weight factors between grids:

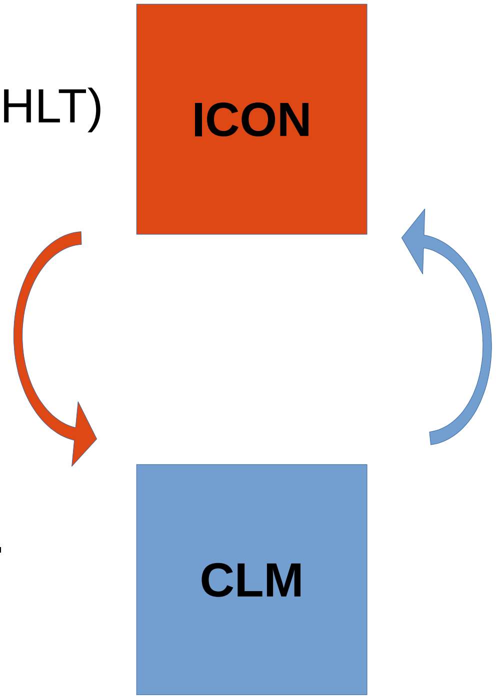
```
cdo gendis,clmgrid.nc icongrid.nc rmp_gclm_to_gicon_DISTWGT.nc
cdo gendis,icogrid.nc clmgrid.nc  rmp_gicon_to_gclm_DISTWGT.nc
```

HOW COUPLING WAS DONE...

Variables exchanged



1. half layer thickness (HLT)
2. temperature
3. zonal wind
4. meridional wind
5. water vapor content
6. pressure
7. dir. short-wave rad.
8. dif. short-wave rad.
9. long-wave down rad.
10. convective precip.
11. gridscale precip.



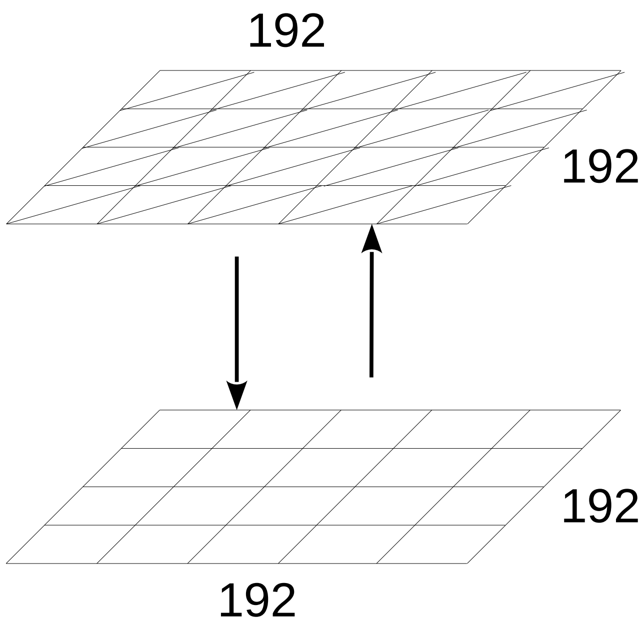
1. ground temp.
2. ground emission
3. direct albedo
4. diffuse albedo
5. zonal wind shear
6. meridional wind shear
7. sensible heat flux
8. latent heat flux

FIRST TEST CASE

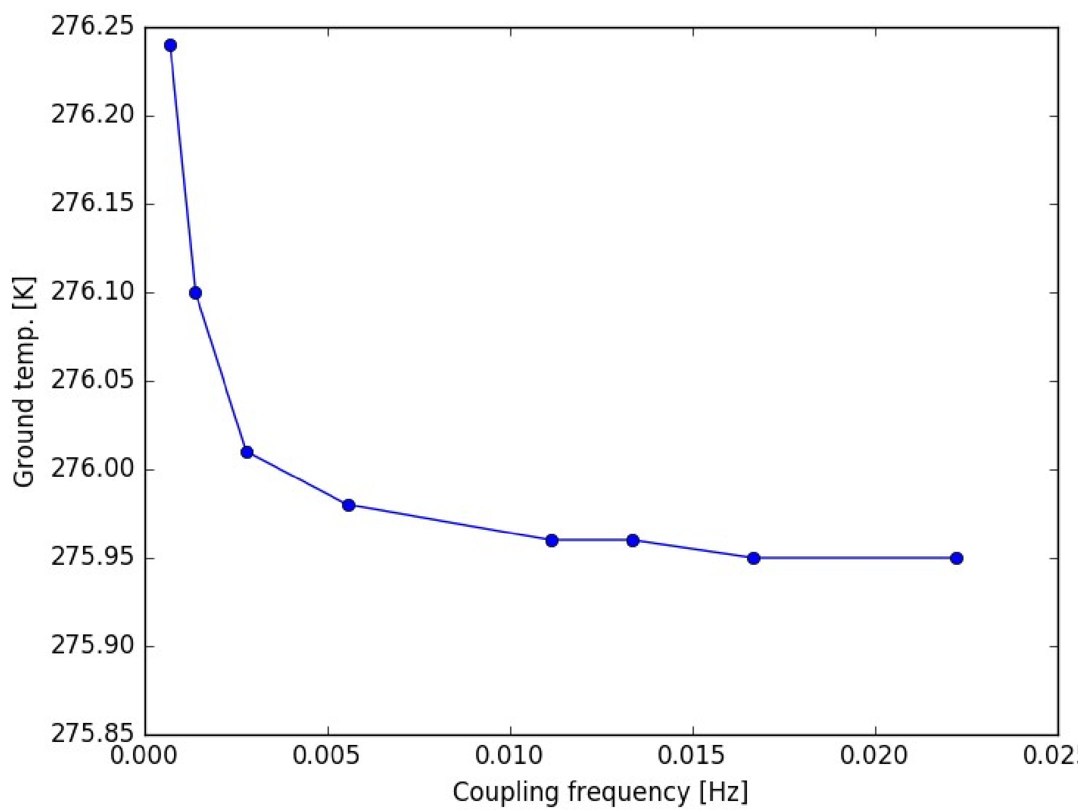
ICON + CLM

	CLM	ICON
Time step	15 sec	0.5 sec
End time	2 hours	
Vert. levels	10	64

ICON setup:
Dipankar et al. (2014)

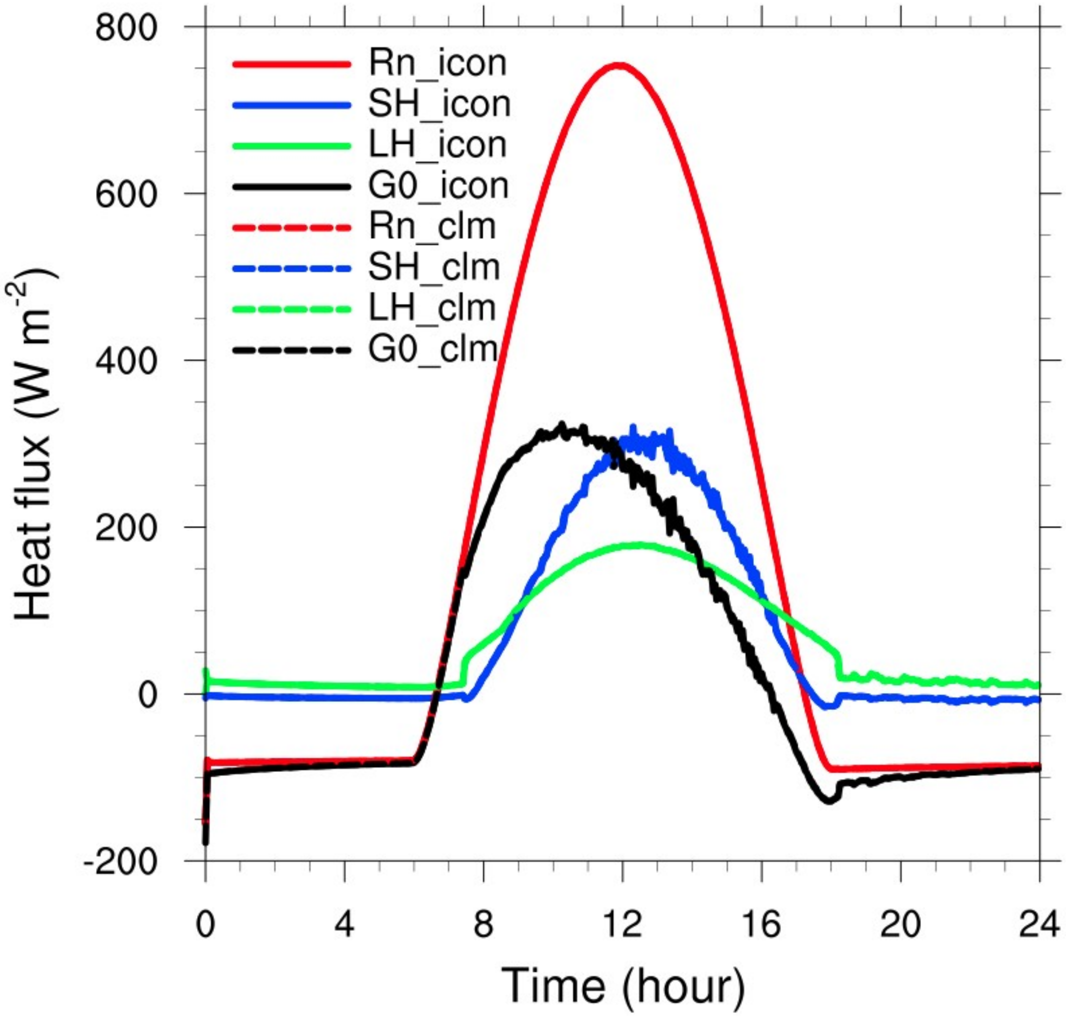


CLM setup:
TerrSysMP/ideal300150



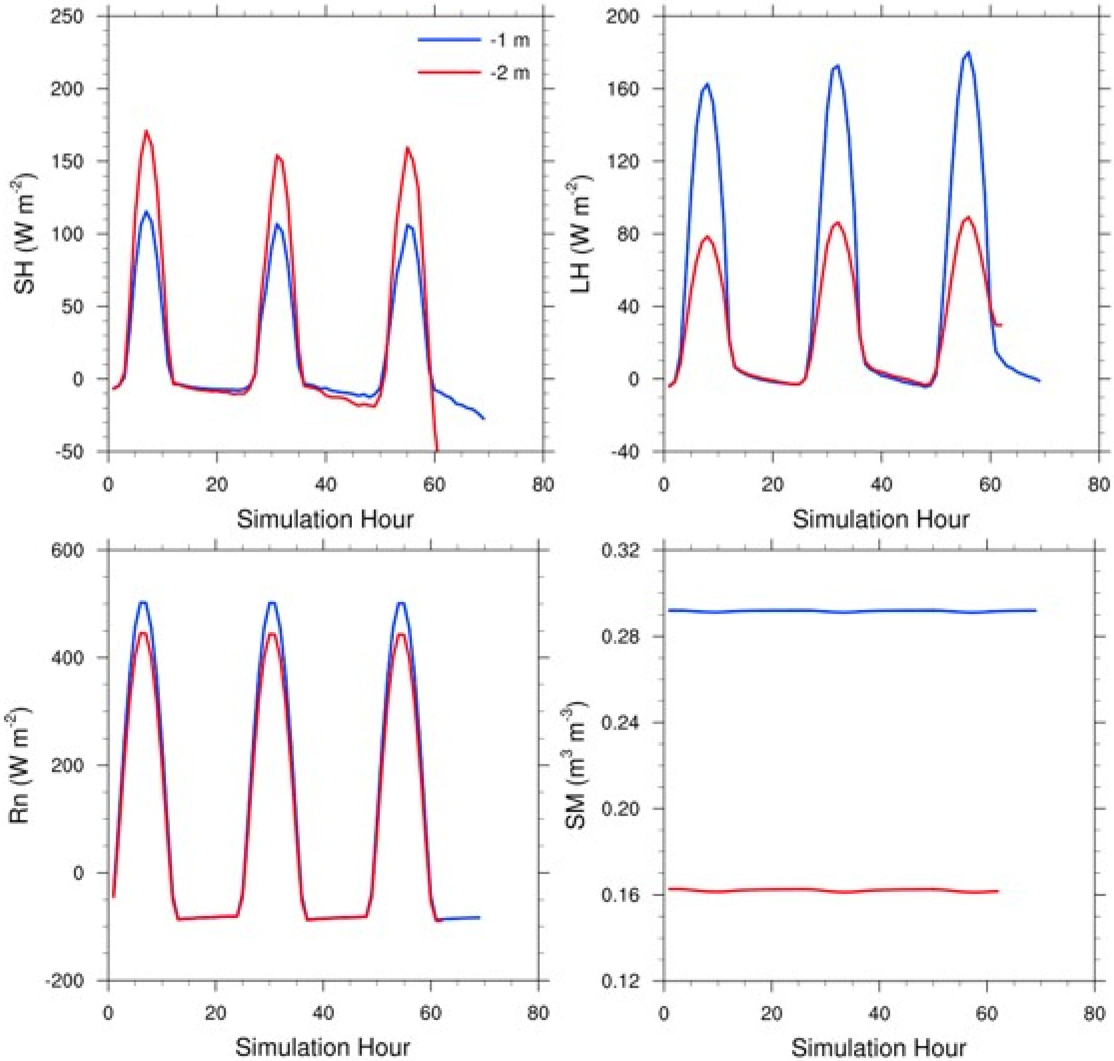
ENERGY BUDGET

Between ICON and CLM



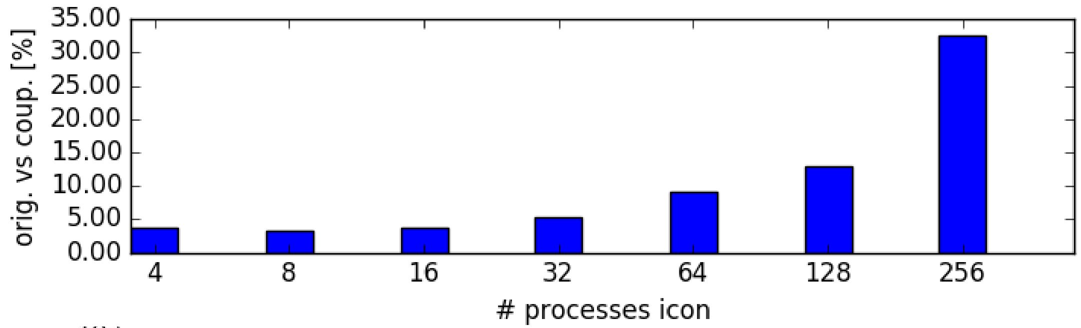
JÜLICH Forschungszentrum

ENERGY BUDGET

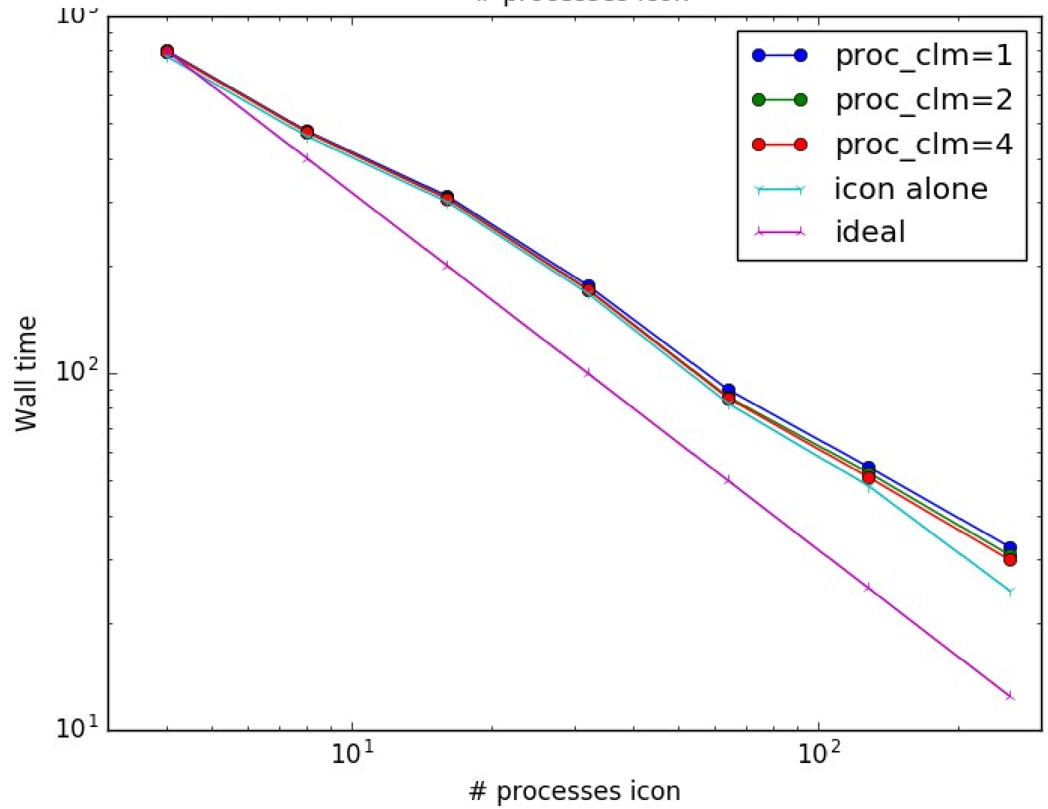


SCALING

ICON + CLM



	CLM	ICON
Time step	15 sec	0.5 sec
End time	1 hours	
Coupl. step	45 sec	
Vert. levels	10	64



PERFORMANCE

ICON + CLM + ParFlow

Intel® VTune™ Amplifier

Application Performance Snapshot

Application: *icon*
Report creation date: *2019-02-22 11:12:56*
Number of ranks: *384*
Ranks per node: *24*
OpenMP threads per rank: *1*
HW Platform: *Intel(R) Xeon(R) E5/E7 v3 Processor code named Haswell*
Logical Core Count per node: *48*
Collector type: *Driverless Perf system-wide counting*

176.17s
Elapsed Time

0.74
CPI
(MAX 0.82, MIN 0.00)

Your application is memory bound.

Use memory access analysis tools like Intel® VTune™ Amplifier for a detailed metric breakdown by memory hierarchy, memory bandwidth, and correlation by memory objects.

	Current run	Target	Delta
MPI Time	45.74%	<10%	
Memory Stalls	60.48%	<20%	
I/O Bound	0.00%	<10%	

MPI Time

80.59s
45.74% of Elapsed Time

MPI Imbalance
N/A
0.00% of Elapsed Time

TOP 5 MPI Functions	%
Waitall	35.43
Send	5.44
Init	1.55
Finalize	0.69
Barrier	0.52

Memory Stalls

60.48% of pipeline slots

Cache Stalls
50.95% of cycles of cycles

DRAM Bandwidth
AVG 53.71 GB/s

NUMA
0.51% of remote accesses

I/O Bound

0.00%
(AVG 0.00, PEAK 0.01)

Read
AVG 938.1 KB, MAX 139.5 MB

Write
AVG 1.5 MB, MAX 428.2 MB

Memory Footprint

Resident	PEAK	AVG
Per node:	9026.81 MB	8560.43 MB
Per rank:	585.14 MB	356.68 MB

Virtual	PEAK	AVG
Per node:	13755.06 MB	13633.49 MB
Per rank:	712.27 MB	568.06 MB

SUMMARY

- TerrSysMP has two atmo models: COSMO and ICON
- Energy conservation at atmo-land interface
- InterVTune, Scalasca/Score-P used on ICON/TerrSysMP