Coupling of the global hydrodynamic CaMa-Flood model with the ECMWF land surface model HTESSEL

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ECMWF

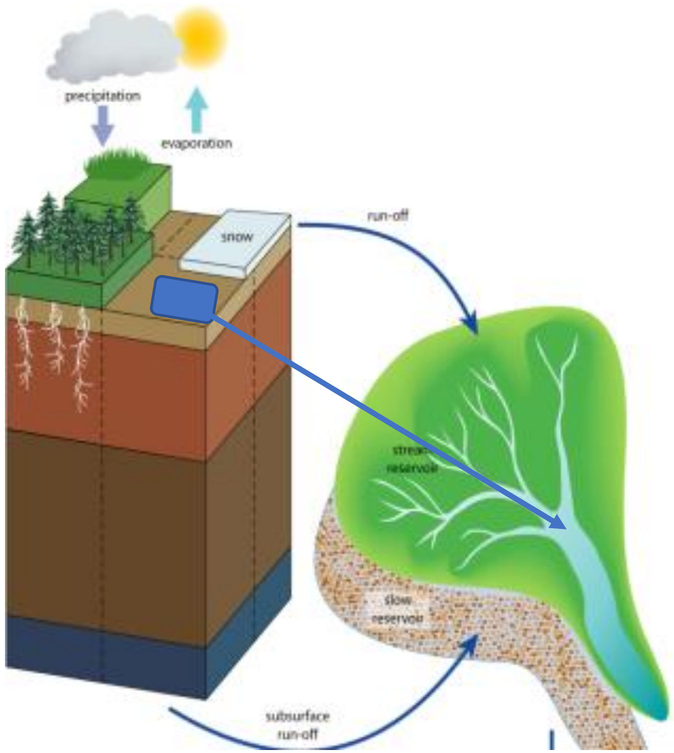
Overview

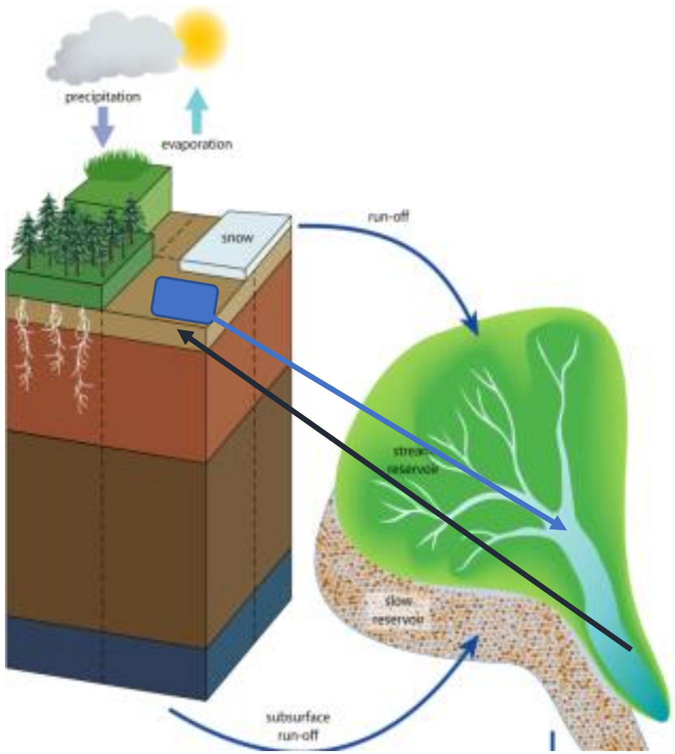
- Technical developments of the 1-way & 2-way coupling
- Inland water vs floodplains : water budget closure
- Model performance;

- Why coupling ?
  - Closing of the water budget over land in ECMWF model
    - Currently inland water (lakes) do not conserve water;
    - Provide freshwater input to coupled ocean model;
    - Investigate the potential for 2-way coupling (variable inland water – inundation);
  - Allow for routine evaluation of discharge of the coupled model.

Models and coupling

HTESSEL: ECMWF land-surface model
CaMa-Flood: Global hydrodynamic model





1-way coupling:
HTESSEL -> CaMa: Surface & sub-surface runoff
& potential inland water evaporation

2-way coupling:
HTESSEL -> CaMa: Surface & sub-surface runoff
& potential inland water evaporation
CaMa-HTESSEL -> Flooded area fraction

Singe executable coupling

HTESSEL CaMa-Flood Coupling

- Initialization
- CaMa-Flood initialization
- DO it=1,NT
    - HTESSEL calculations
    - Accumulate coupling fluxes (sro,ssro, evaow)
    - IF COUPLING TIME STEP
        - Send Fluxes
        - Advance Cama Integration
        - Receive flood fraction
- Finalize CaMa
- Finalize

CaMa-Flood library surf/module/cmflood

Initialization

Receive driving data

Advance temporal integration Handling of Output

Send coupling data

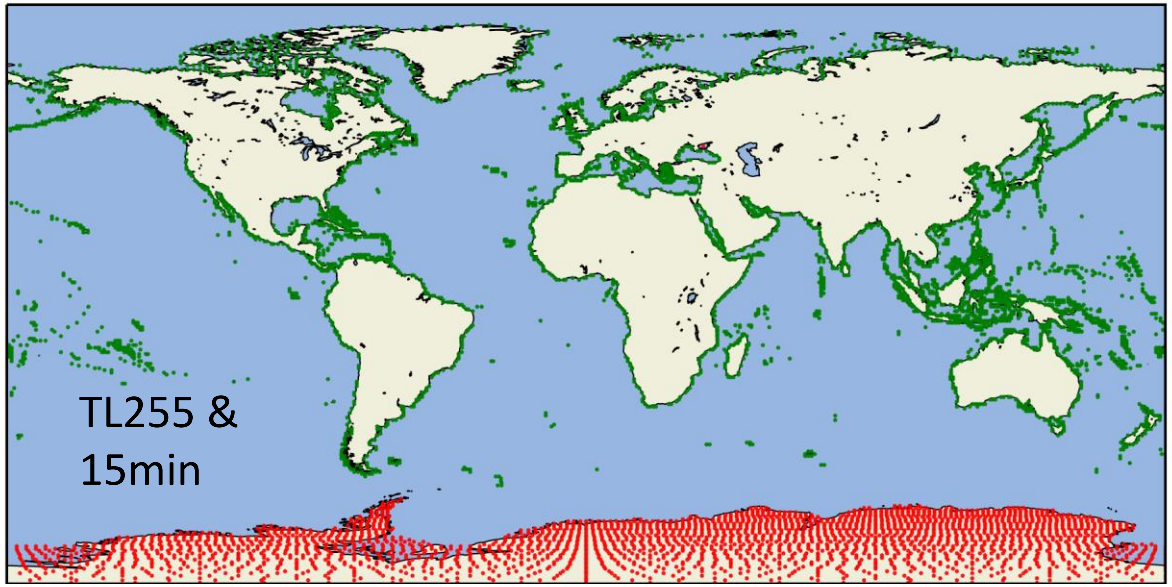
Finalize

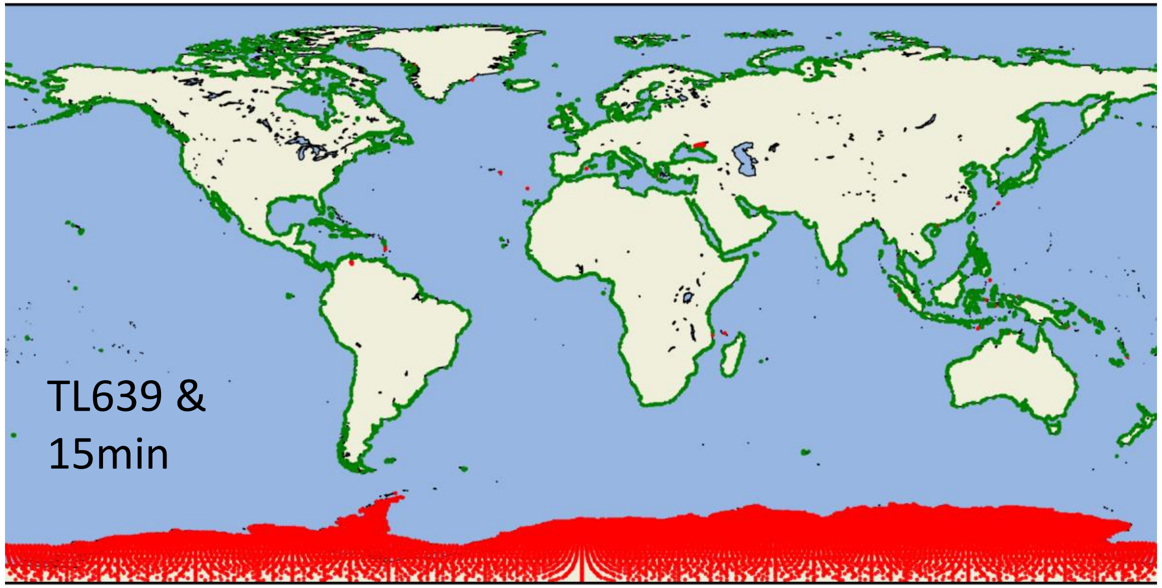
CaMa-Flood stand-alone

- CaMa-Flood initialization
- DO it=1,NT (frequency of driving data)
    - Read netcdf with driving data
        - Code in cama-flood library
    - Send Fluxes
    - Advance Cama Integration
- Finalize CaMa

- Generic coupling infrastructure can be extended to other fields or used in other models. Receive/send data routines handle the grids interpolations (pre-computed);
- No MPI : send/receive of global fields

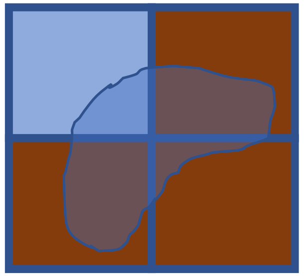
Grids consistency





Red dots indicate land/lake grid-points that do not have any associated river cell at 15min. (Antarctica, Azov sea, some islands)

The green points indicate IFS grid-points that should provide runoff to the 15min river network but are ocean points (coastal regions)



There is a reduction of grid-points that do not provide runoff to the river catchments from 1.5% of global land in TL255 to 0.46% in TL639

Some inconsistencies are unavoidable without a close development of IFS and CaMa grids (huge effort). Binary land/ocean in IFS responsible for part of the problems. Activating sub-grid land not allowed in IFS, would be a significant effort.

Global water budget

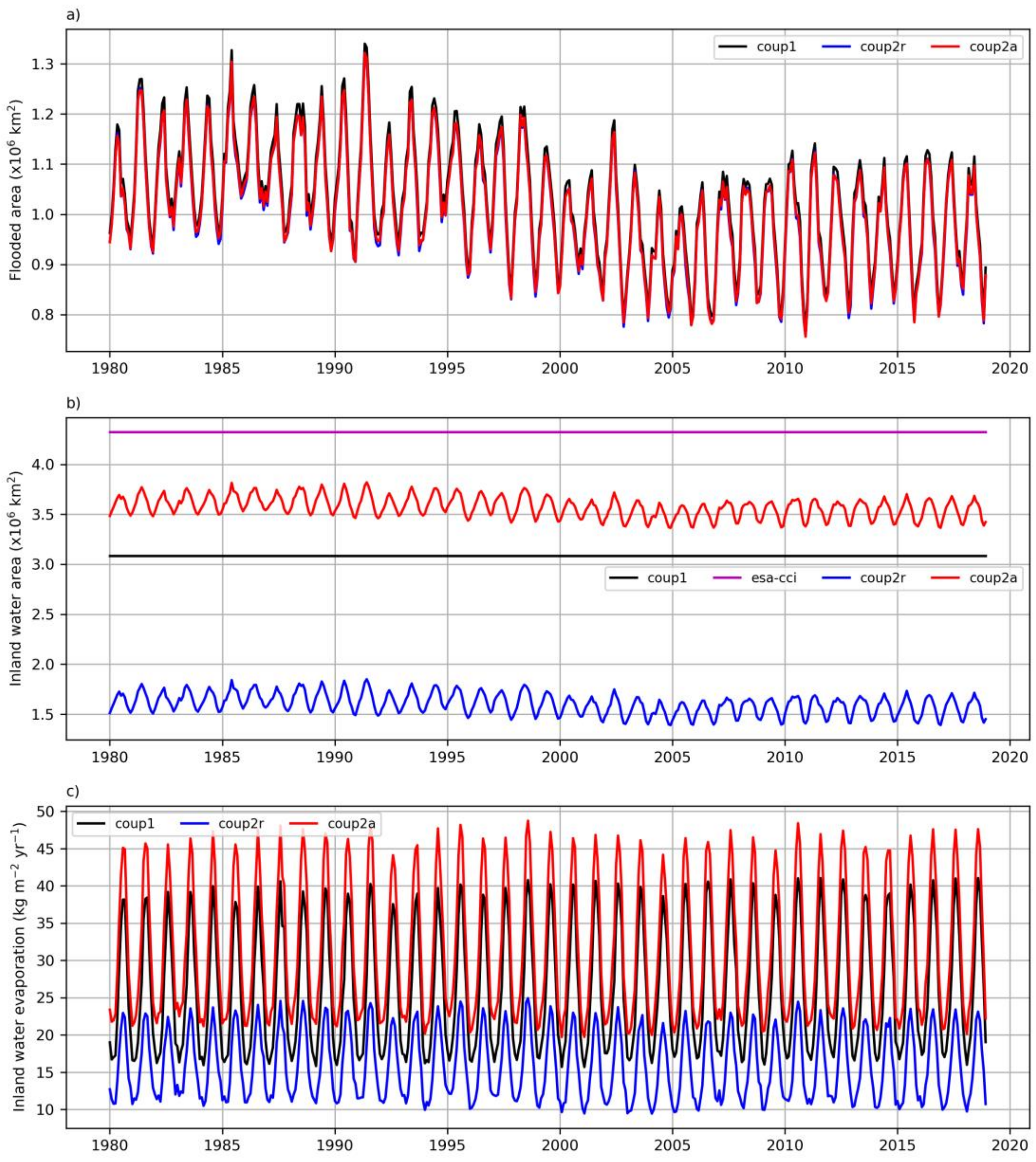
$$P - E - R - \Delta S_L = e_l \qquad (1)$$
$$R - E_W - D - \Delta S_R = e_r \qquad (2)$$
$$P - E - D - \Delta S_L - \Delta S_R = e \qquad (3)$$

Exp	P	E	E_W	R	D	ΔS_L	ΔS_R	e_l	e_r	e	e(%)
coup1	883.4	-554.7	-26.2	356.7	349.4	-0.6	0.0	-27.5	-18.8	**-20.2**	**-2.3**
coup2r	883.4	-547.5	-15.7	353.5	345.3	-0.6	0.0	-17.1	-7.5	**-8.9**	**-1,0**
coup2a	883.4	-557.2	-31.5	359.6	347.8	-0.5	0.0	-32.9	-19.7	**-21.1**	**-2.4**

coup1 – 1 way coupling
coup2r – 2-way coupling replacing lake fraction in htessel by flooded area of CaMa-Flood
coup2a – 2-way coupling adding flooded area of CaMa-Flood to lake fraction in htessel
e(%) is the total water budget residual normalized by total precipitation

Due to the different representation of surface water in HTESSEl & CaMa-Flood, and different simulation grids, it is not possible to “force” a full closure of the water budget;

1-way vs 2-way: Global statistics



Global evolution of flooded area (top), inland water fraction (middle) and inland water evaporation (bottom)

coup1

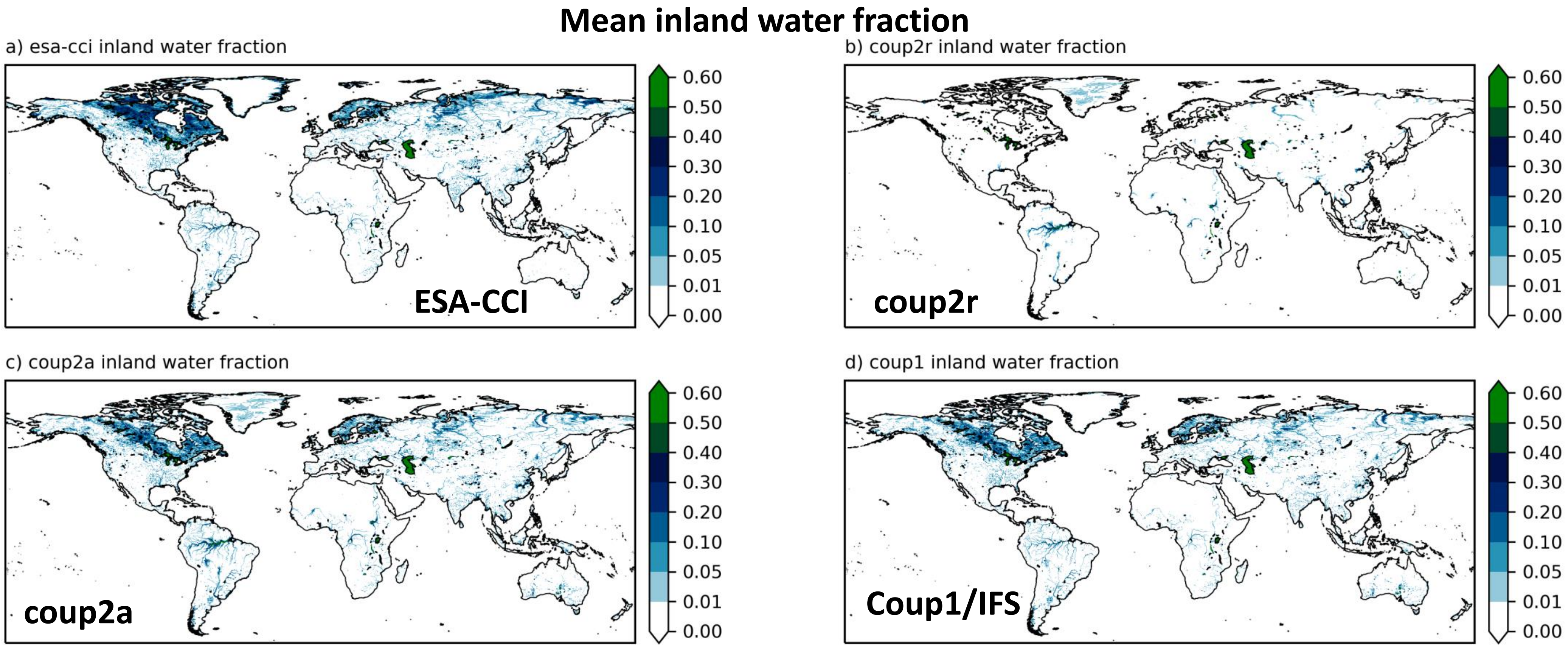
coup2r

coup2a

esa-cci (only inland water fraction)

- Consistent evolution of flooded area in all simulations (2-way coupling is stable);
- Large differences in inland water fraction in coup2r, what's a good dataset to verify ?
- Changes in inland water fraction reflected in inland water evaporation (reach about 5% of total global evaporation)

Global inland water fraction



- Nothing done on resolved lakes in IFS (CL>0.5)
- Coup2r : almost no inland water in northern regions: no inundation from main channel.
- Coup2a: keeps the northern areas adding some seasonality.

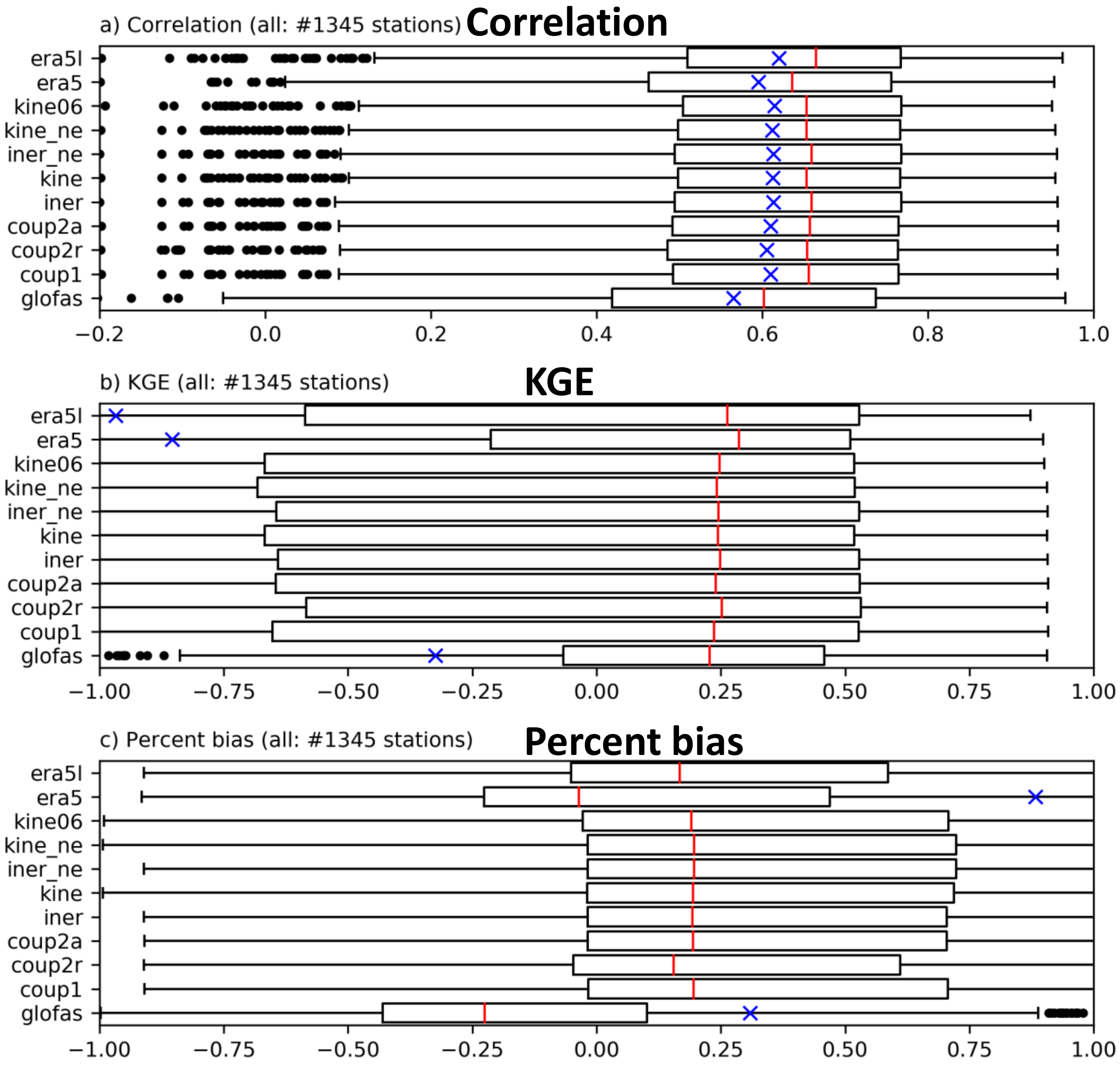
Test Cases overview

- Set of experiments with different HTESSEL and CaMa-Flood configurations. Mainly TL639 in HTESSEL (like ERA5) and 15min CaMa-Flood. Also driving CaMa-Flood directly with ERA5 and ERA5L runoff.
- The discharge simulations were evaluated against GRDC stations for the period 1982-2017 for all datasets, including only stations with at least 5 years of data, resulting in a total of 1345 stations.
  - No manual checking – there are stations that should be discarded
- GLOFAS simulations driven by ERA5 were also used as benchmark;

Test Cases: Computational runtime

Exp	Runtime (1 year)	Details
OSM	47 minutes	OSM only TL639 OMP=16 (time step = 1hour)
coup1	92 minutes	OSM+CMF TL639, 15min, OMP=16 (tstep=5.4min)
iner	40 minutes	CMF 15min OMP=16 (adptstp=5.4min)
kine	7.8 minutes	CMF 15min OMP=4 (tstep=1hour) kinematic wave
kine06	25 minutes	CMF 06min OMP=8 (tstep=1hour) kinematic wave
iner06	8,5 hours	CMF 06min OMP=36 (tstep=2.5min)
iner03	3.2 days	CMF 03min OMP=36 (tstep=1.2 min)
iner01	~182 days (estimated) 30min/hour cannot run monthly chunks	CMF 01min OMP=36 (tstep=24 s

Test Cases: Global overview



- Very small differences among different coupled and stand-alone CaMa-Flood simulations (iner vs kine, 15min vs 06min, coup1 vs coup2)
- Larger differences induced by input runoff (ERA5, ERA5L)
- Larger pbias differences with GLOFAS

Final remarks

- Single executable coupling between HTESSEL and CaMa-Flood allowing both models to run with different spatial grids (HTESSEL – regular lat/lon or gaussian reduced , CaMa-Flood : 15min, 06min, 05min, 03min, 01min);
- Generic coupling interface in CaMa-Flood: could be used to couple to other land-surface models ;
- Flexibility of running the models with different grids limits further coupling (e.g. infiltration of floodplains water);
- Different representation of inland water (lakes) and floodplains : no “forced” consistency between the models and resolved vs unresolved lakes in HTESSEL limit the full closure of the water budget ;
- Large regional differences in performance between GLOFAS and CaMa-Flood. Despite these differences, overall performance of CaMa-Flood is comparable to that of GLOFAS, considering that CaMa-Flood was not calibrated;