Benefits of dynamically modelled river discharge input for ocean and coupled systems

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Motivations

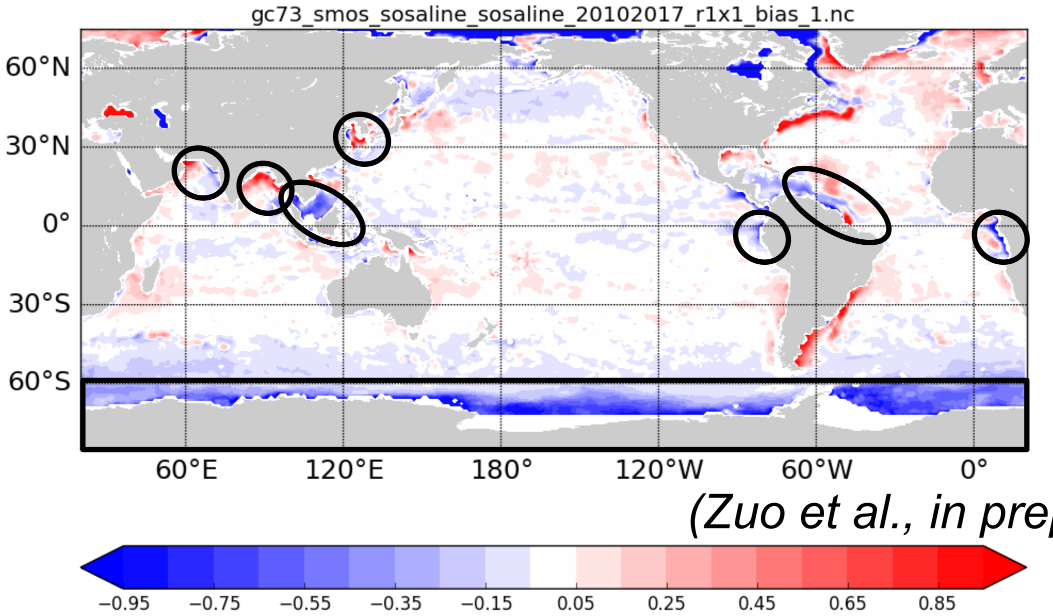
River freshwater input is crucial in modelling global ocean, i.e. coastal and off-shore ocean salinity, near-surface mixing, freshwater transport, regional sea-level changes, global climate, etc. Most current ocean and climate model rely on river discharge data with various deficiencies, which can lead to biased simulated ocean states.

Many climate models use river discharge data from climatology, e.g. monthly mean climatology of Bourdalle and Treguier, 2006 (BT06), which is based on data from Dai and Trenberth, 2002.

Issues

- Overly simplistic discharge data: Climatology with no inter-annual variations
- Not the discharge at river mouths
- Inconsistent forcing: between atmospheric and hydrologic, and between different systems

Mean bias in ORAS5 Sea Surface Salinity



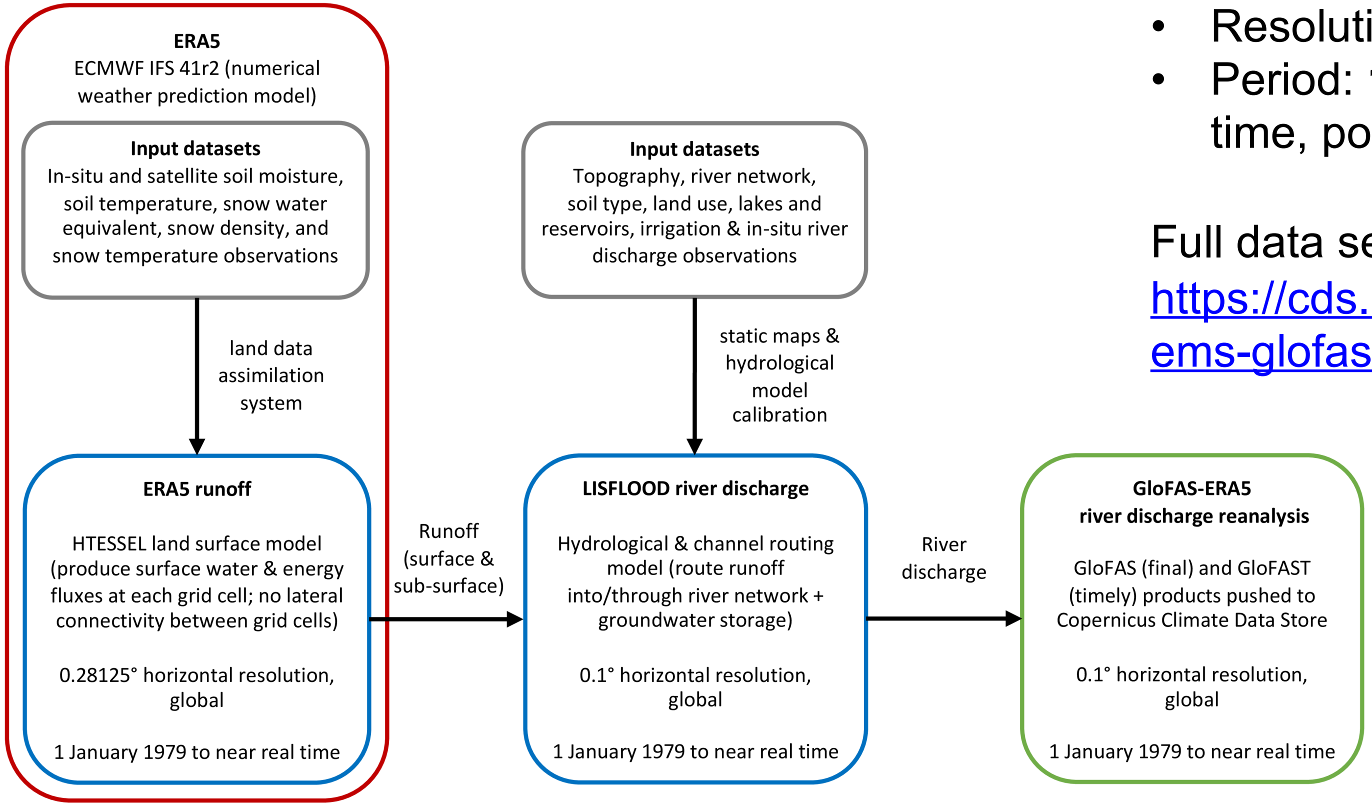
(Zuo et al., in preparation)

ECMWF

GloFAS-ERA5 river discharge reanalysis

Emergency Management Service

The Copernicus Emergency Management Service (CEMS) Global Flood Awareness System (**GloFAS**) provides state-of-the-art global flood forecasts and downstream river discharge. Using land runoff input from **ECMWF's** (European Centre for Medium- Range Weather Forecasts) atmospheric reanalysis **ERA5**, a **GloFAS-ERA5** global river discharge reanalysis dataset has been produced and can provide land freshwater input for global ocean and coupled models.



- Resolution: **0.1** degree and **daily**
- Period: **1979 onwards** (within 7 days behind real time, potential to go RT).

Full data set can be downloaded via **CDS** at https://cds.climate.copernicus.eu/cdsapp#!/dataset/cems-glofas-historical?tab=overview

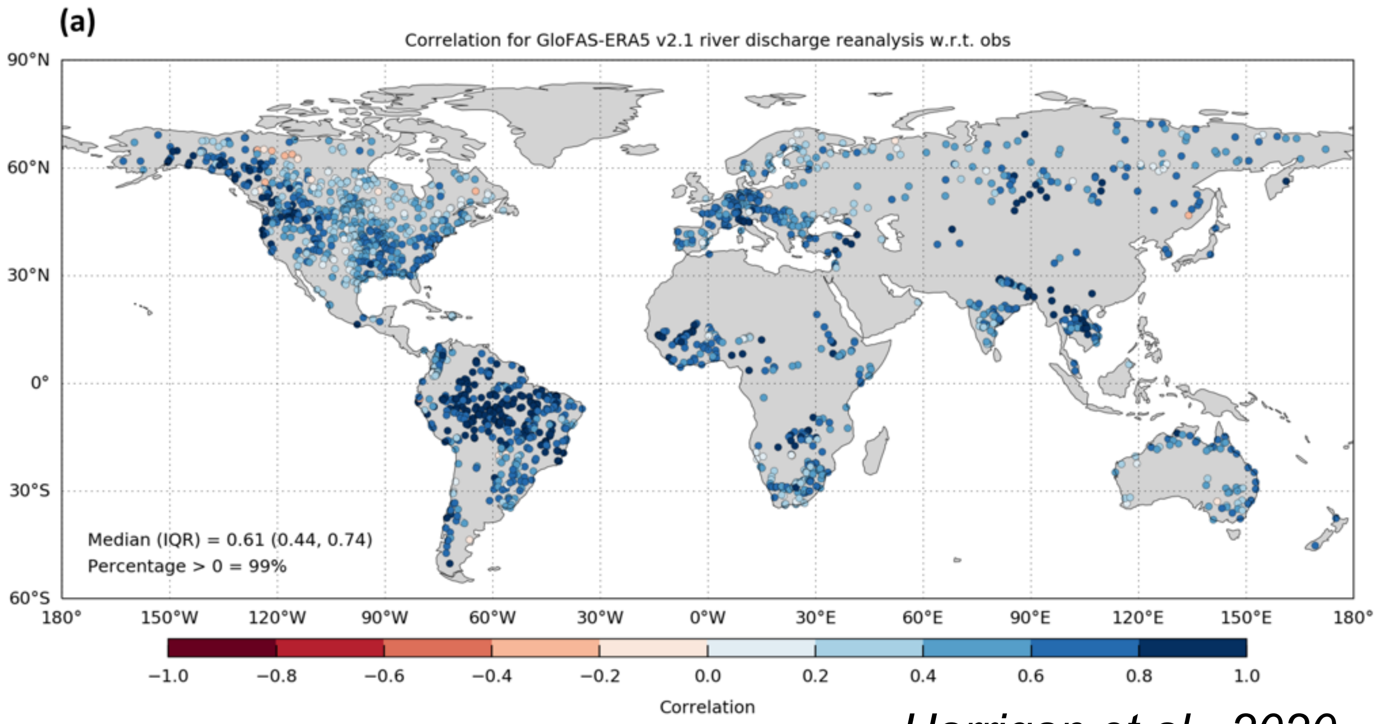
Harrigan et al., 2020

Evaluation of GloFAS-ERA5 data set against in-situ stations

The vast majority of catchments (98 %) show positive correlation with a global median Pearson correlation coefficient of 0.6.

- Performance is best in Brazil (particularly the Amazon basin), central Europe, and eastern and western regions of the US.
- Worst performing catchments are in dryer rivers of Central US, Africa, eastern Brazil, as well as the western coast of South America.

*Pearson correlation, verified against a global network of **1801** discharge observation stations between 1979-2017*



Harrigan et al., 2020

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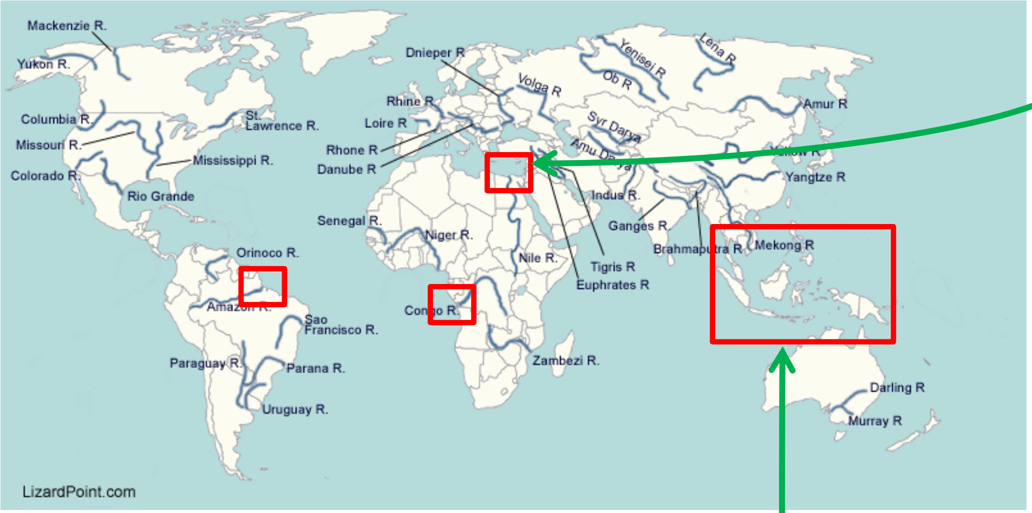
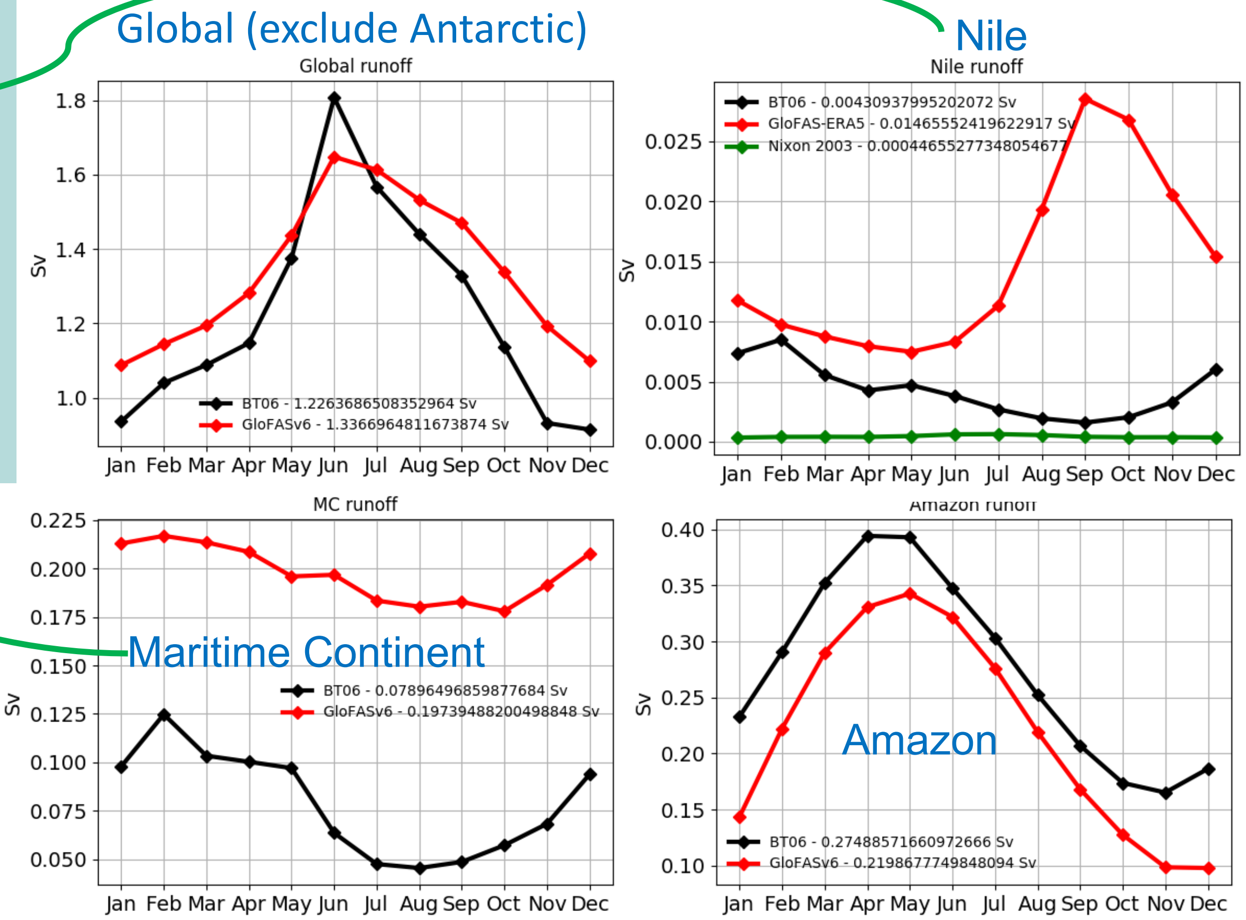
Evaluation of GloFAS-ERA5 against other data sets





Global mean land freshwater input in GloFAS-ERA5 is ~1.33 Sv (excluding Antarctic)

- ~9% higher than that of BT06
- has reduced seasonal variation
- Nile's discharge is too strong compared to Nixon (2003)
- Discharges in the Maritime Continent (MC) region could be overestimated (due to ERA5)

Seasonal cycle of monthly mean land freshwater input (in Sv) in GloFAS-ERA5 (red line) and BT06 (black line)

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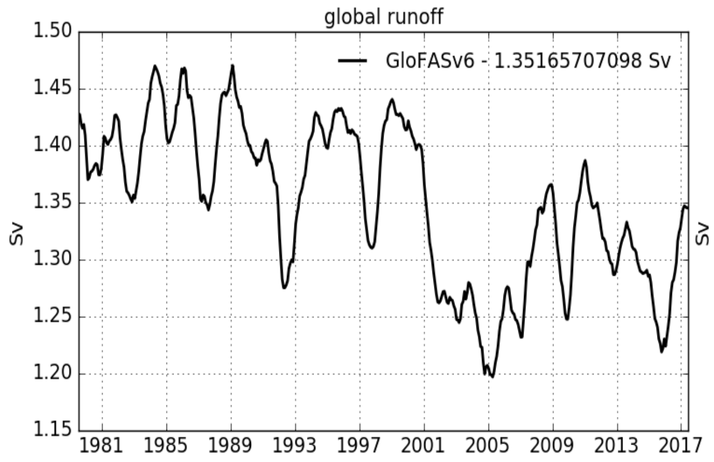
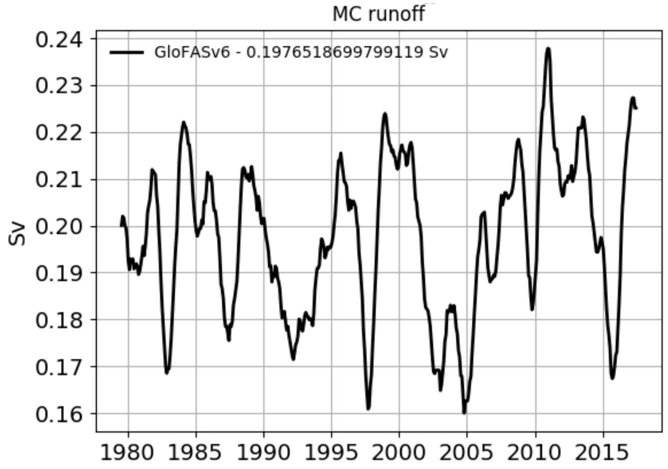
Evaluation of GloFAS-ERA5 against other data sets

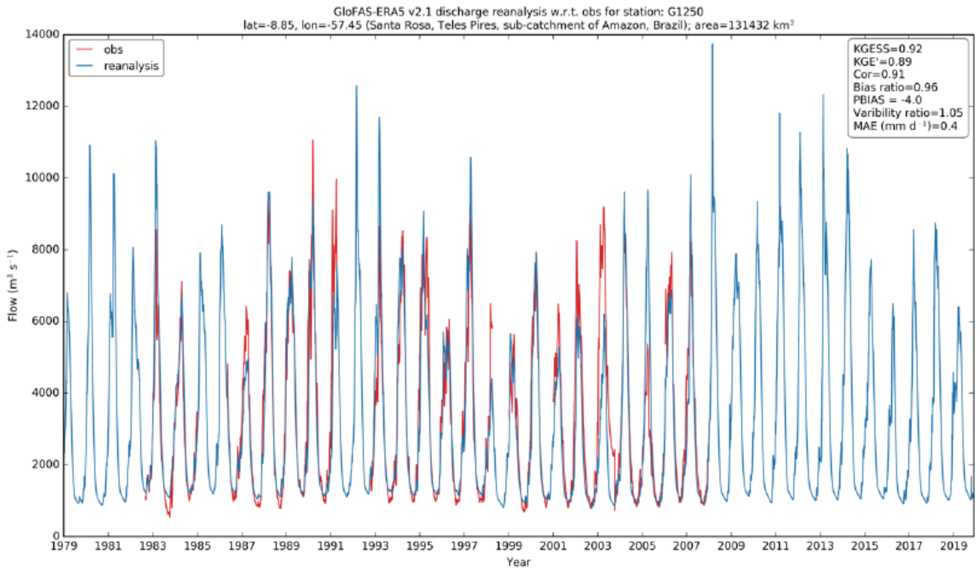
A negative trend in global river discharge exists in GloFAS-ERA5 reanalysis, which is associated with ERA5 precipitation and snow melt over the the 40 years period.

Time-series of GloFAS-ERA5 NEMO coastal discharges





Amazon: GloFAS-ERA5 reanalysis (blue) and observation at Santa Rosa gauging station (red)



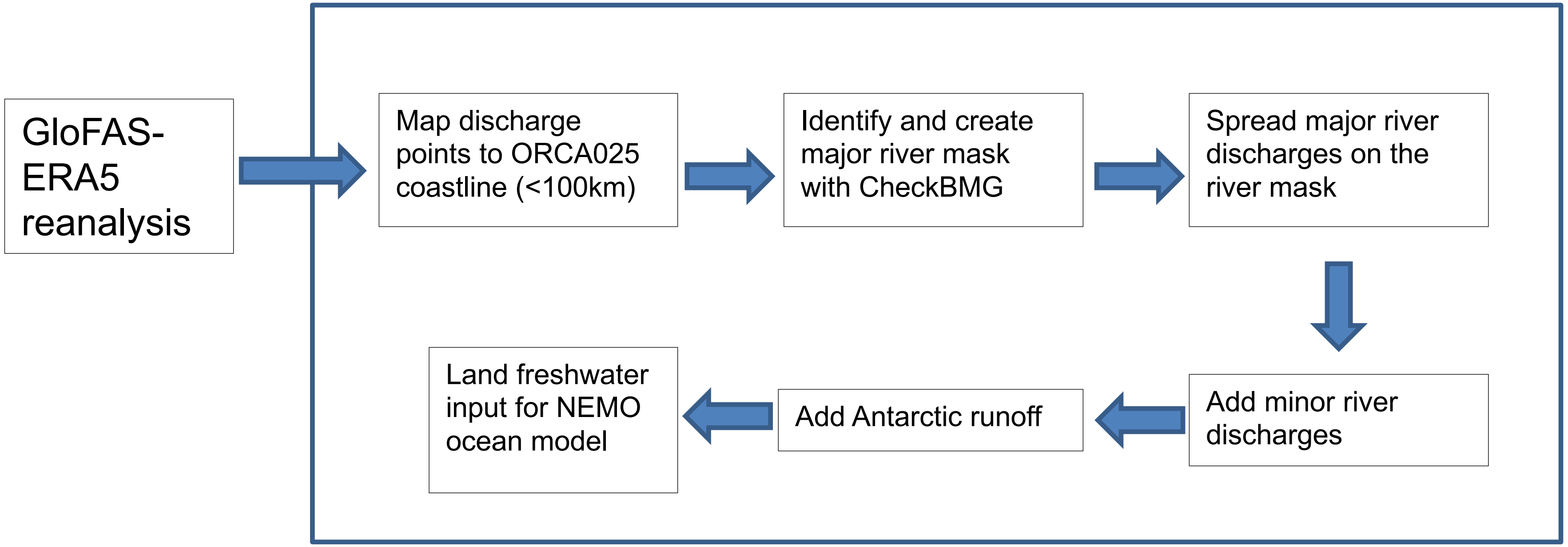
Harrigan et al., 2020

Implementation of GloFAS-ERA5 reanalysis in the NEMO ocean model

A new method has been developed for conversion of the GloFAS-ERA5 reanalysis data into land freshwater input for the NEMO ocean model.

- This method has been tested in NEMO ORCA025.L75 configuration, between 1979-2017.
- Most parts of this conversion method are generic, can be adapted for different configurations of NEMO model (global or regional).

Flow chart of conversion steps



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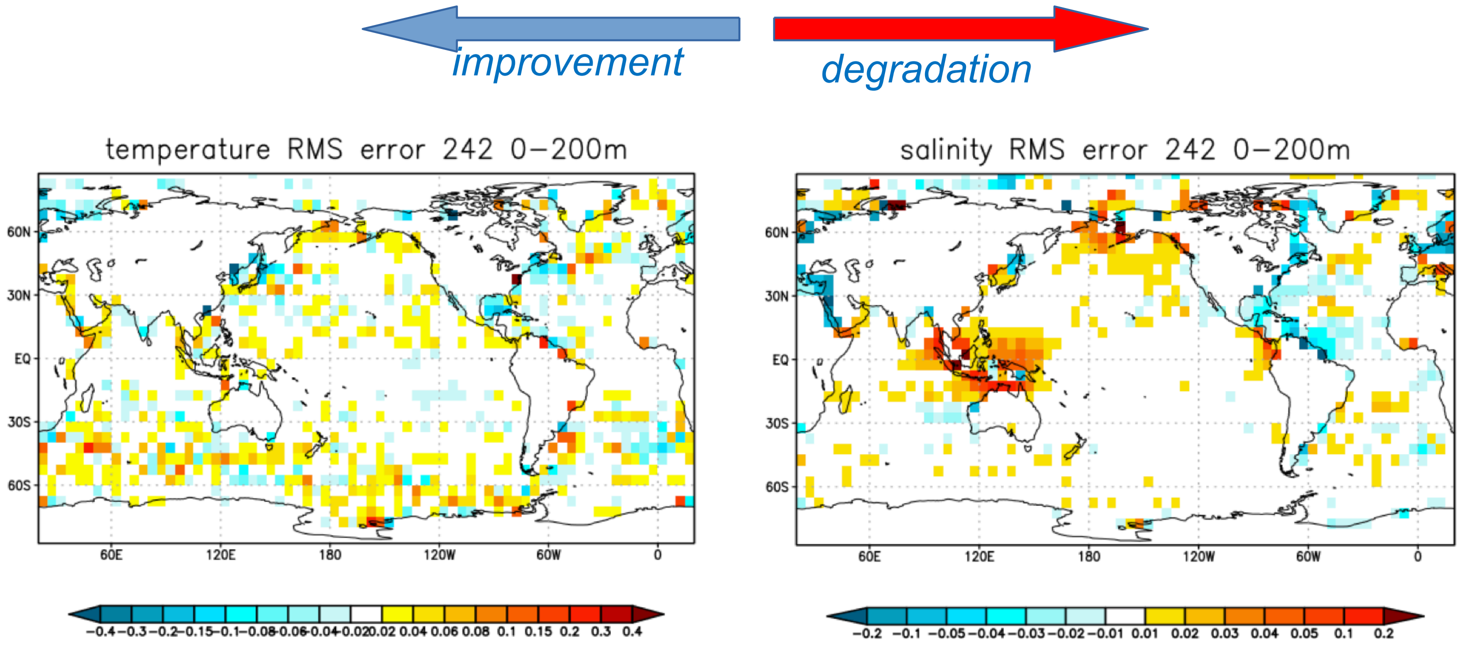
Evaluation of GloFAS-ERA5 reanalysis in the NEMO ocean model

Scientific evaluation of this GloFAS-ERA5 land freshwater input has been carried out with the operational ECMWF ocean analysis system-OCEAN5 (Zuo et al., 2019), driven by the same ERA5 atmospheric forcing.

RMSE differences in simulated ocean states: GloFAS-ERA5 – BT06
(verified against EN4 in-situ obs between 2010-2017)



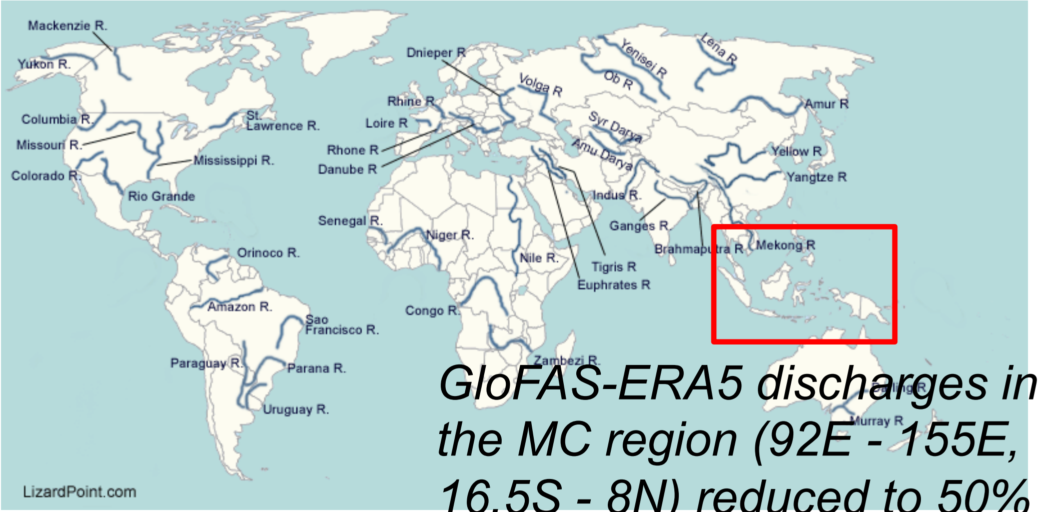
Model runs with climatological river discharge input, and without data assimilation

- Improvements: *Tropic and North Atlantic Ocean, Red sea and Mediterranean Sea, North Sea, Baltic Sea, Baffin Bay*, due to reducing a negative sea surface salinity bias
- Negative impact is visible in the Maritime Continent, west coast of central America and Gulf of Alaska, which is associated with a positive bias in the GloFAS-ERA5 river discharge
- Performance degradation can be mitigated by applying bias-correction to the GloFAS-ERA5 input, and/or by adding extra vertical mixing near the river mouths

Bias-correction of GloFAS-ERA5

Salinity performance degradation in the Tropics (MC, eastern tropical Pacific …) could be associated with bias in GloFAS-ERA5 reanalysis, which is likely inherited from ERA5 precipitation.

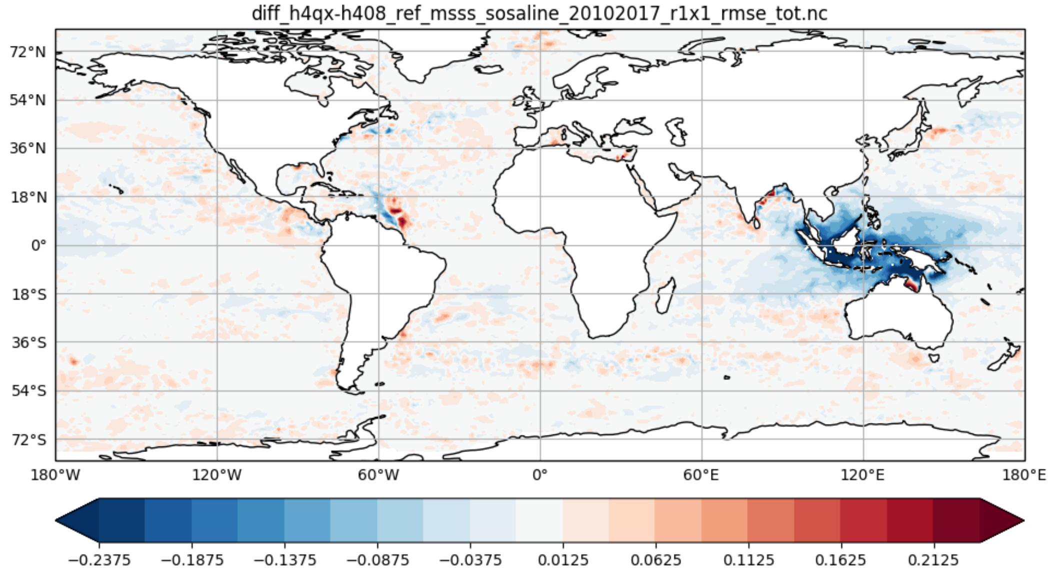
NEMO simulation driven by a bias-corrected GloFAS-ERA5 data set fits much better to observations in the MC region, where a 50% reduction is applied to GloFAS-ERA5 discharges



GloFAS-ERA5 discharges in the MC region (92E - 155E, -16.5S - 8N) reduced to 50%

Improvements in sea surface salinity (SSS) with bias-corrected GloFAS-ERA5 discharges

(Changes in RMSE, verification against CMEMS SSS product)



Impact from long time-series of GloFAS-ERA5 discharges

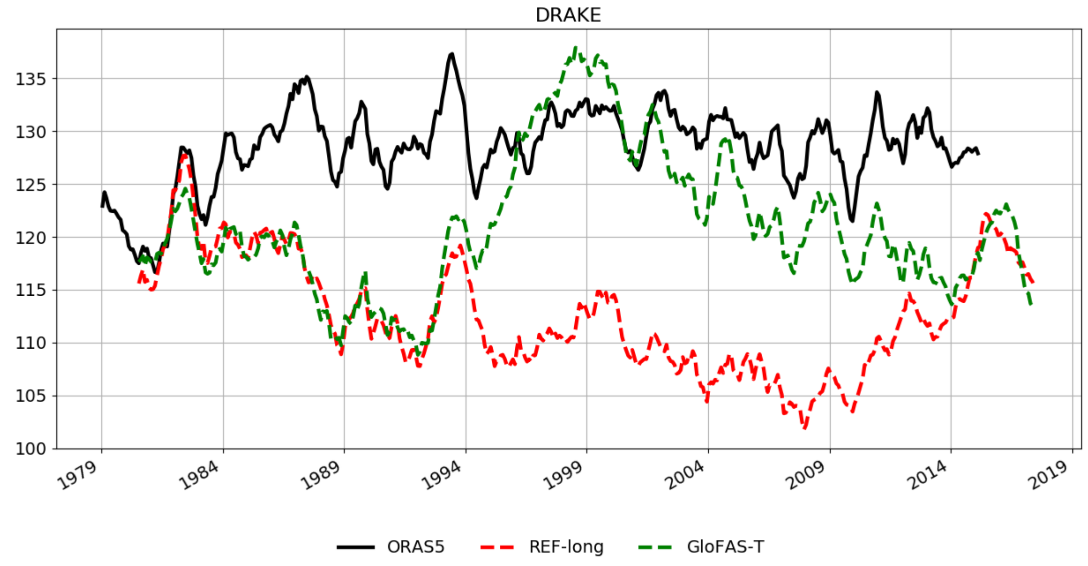
Improvements in large-scale ocean circulations like the Atlantic Meridional Overturning Circulation (AMOC) and Antarctic Circumpolar Current (ACC) are also noted after decadal integration of the ocean models with the full time-series of GloFAS-ERA5 land freshwater input

Time-series of large-scale ocean circulations

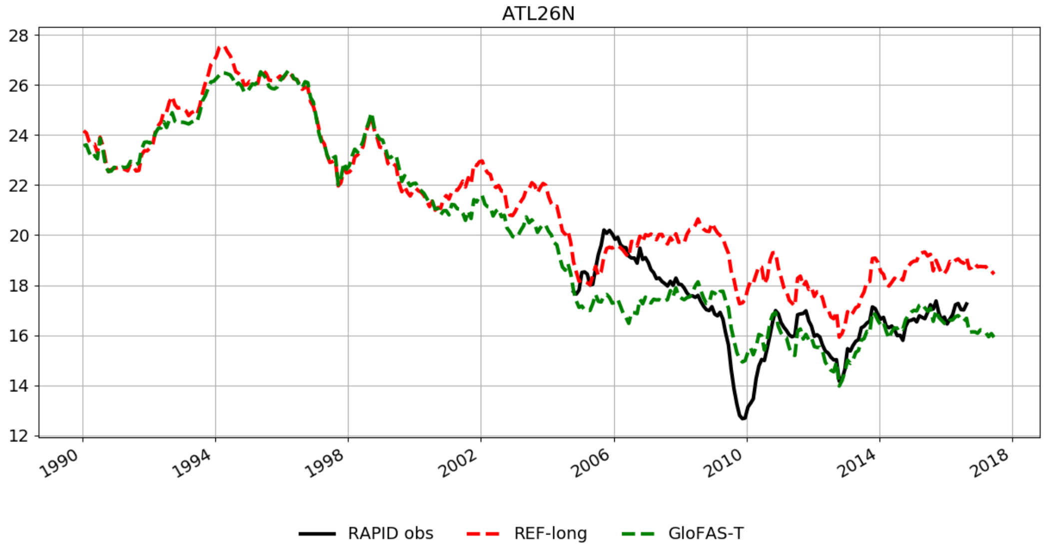
(black = ocean reanalysis/observations, green=GloFAS-ERA5, red=BT06)

Model runs without data assimilation, no bias correction go GloFAS-ERA5

ACC transport across Drake passage



Maximum AMOC transport at 26.5 N

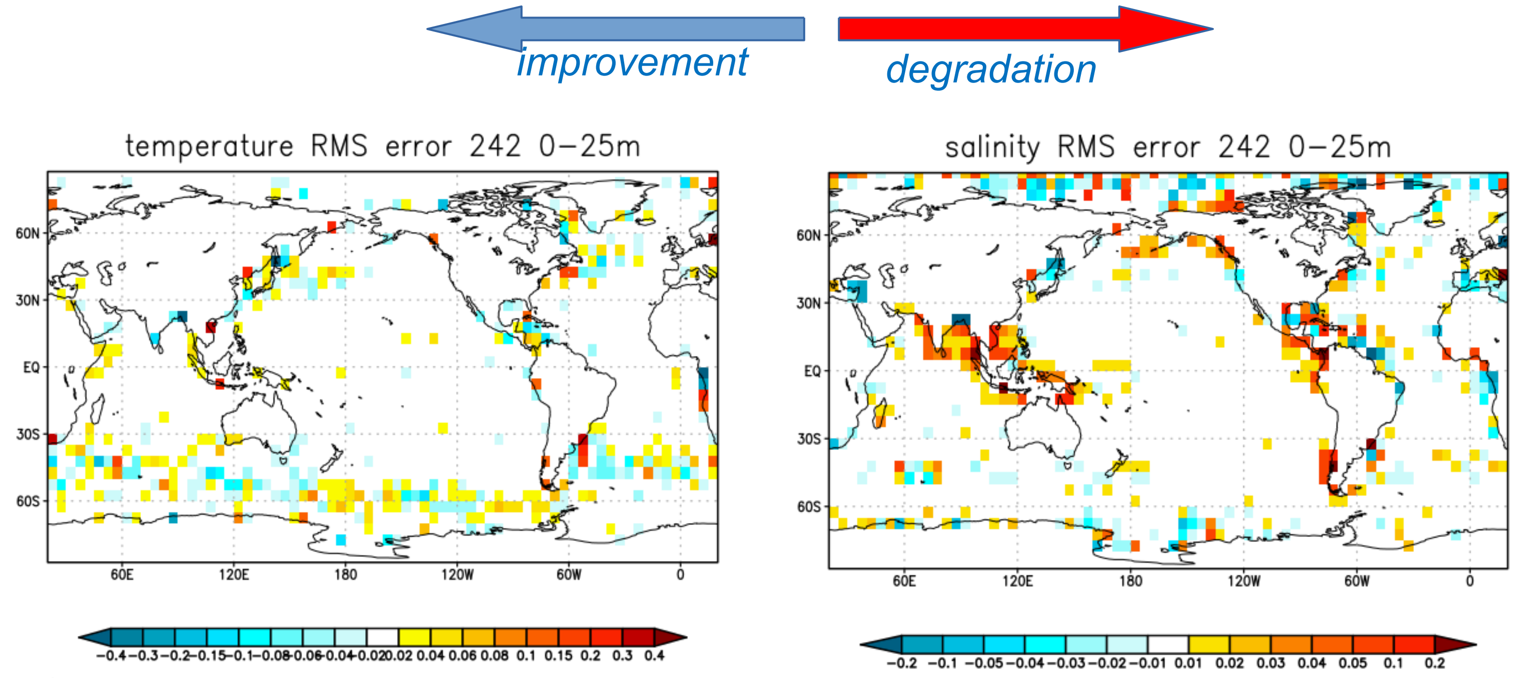


ECMWF

Impact of GloFAS-ERA5 input in the ocean reanalysis

Impact from switching land freshwater input has reduced over time and with ever increasing global network of ocean observations. This is expected since ocean reanalysis is better constrained by data assimilation of ocean in-situ and surface observations.

RMSE differences in ocean reanalyses: GloFAS-ERA5 – BT06
(verified against EN4 in-situ obs between 2005-2013)



Data assimilation was activated in both runs, no bias correction to GloFAS-ERA5

- Impact from switching river discharge product remains localized on the main river mouths
- Satellite data and ocean in-situ observations (Argo, ship-based, moored buoys etc) were assimilated in ocean reanalysis, leading to a well constrained ocean state that is less susceptible to river freshwater input

Conclusion

GloFAS-ERA5 is a new data set that provides improved and reliable river discharge data set over the ERA5 periods (1979 onwards)

- Unprecedented temporal (daily) and spatial resolution (0.1 degree) with realistic variability
- Consistent atmospheric boundary conditions in both the hydrology and ocean components
- Homogenised river forcing approaches in global, regional and coastal model
- Overall good performance when verified against a global network of discharge observations.

A new conversion method has been developed to implement GloFAS-ERA5 river discharges into the NEMO model. This method can be adapted for other model configurations. Evaluation with the ECMWF's OCEAN5 system suggests that simulated ocean state can be improved in many regions with this new data set. However, bias-correction in the MC region is still required to mitigate local performance degradation.

The development presented here is the first step towards an improved connection and coupling between ocean and land surface and hydrological models. it is desirable to carry out further works in the future to achieve an improved GloFAS-ERA5 reanalysis and, eventually towards an operational implementation in the NWP system