Improved Representation of River Runoff in Estimating the Circulation and Climate of the Ocean (ECCO) Simulations

Yang Feng[1,2,5], Dimitris Menemenlis[2], Huijie Xue[1,3,5], Hong Zhang[2], Dustin Carroll[4,2], Yan Du[1,5]

1. State Key Laboratory of Tropical Oceanography, South China Sea Institute of Oceanography, Chinese Academy of Science, Guangzhou, China
2. Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California, USA
3. School of Marine Sciences, University of Maine, Orono, Maine, USA
4. Moss Landing Marine Laboratories, San José State University, Moss Landing, California, USA
5. Southern Marine Science and Engineering Guangdong Laboratory, Guangzhou, China

Introduction

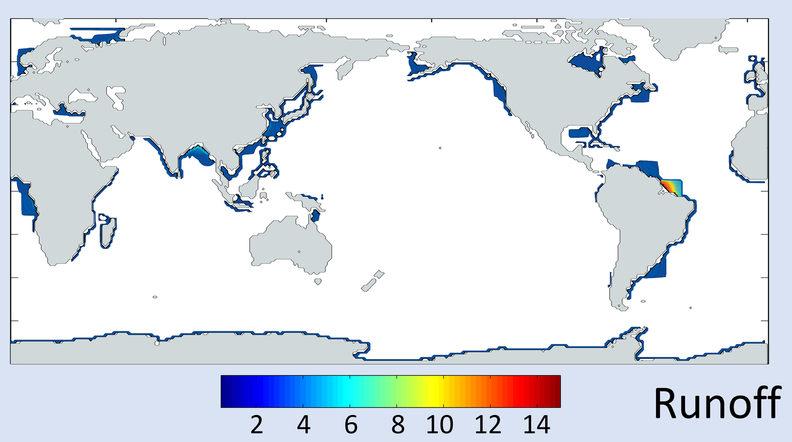
Rivers deliver freshwater, nutrients, carbon, and pollutants to coastal regions, with consequences for marine habitats, primary production, eutrophication, hypoxia, and the global carbon cycle. Here, and in the companion presentation PL24A-2647, we describe the first steps towards improving the representation of river runoff in Estimating the Circulation and Climate of the Ocean (ECCO) global-ocean state estimates.

Methods and Results

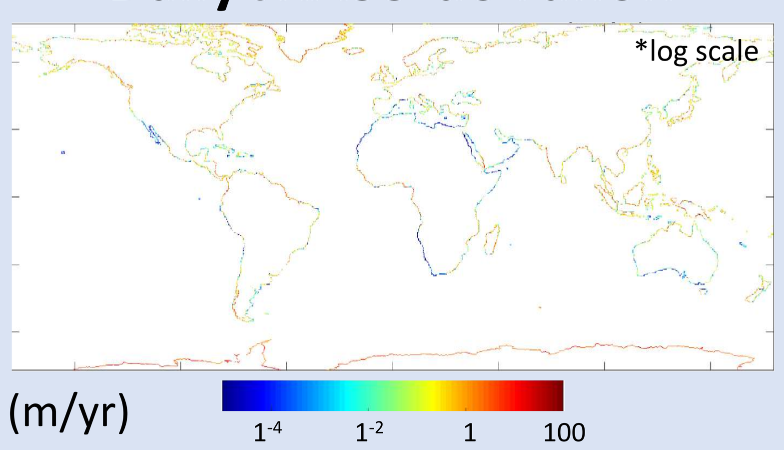
Model and Representation of River Runoff

We use the Massachusetts Institute of Technology general circulation model (MITgcm) in several global configurations that have been previously developed and used by ECCO. We compared the impact of daily, localized JRA55-do runoff (Tsujino et al. 2018) to diffuse, climatological runoff that has been previously been used by ECCO (Stammer et al. 2004; Forget et al. 2015).

Climatological runoff



Daily JRA55-do runoff



Runoff (m/yr)

Sensitivity Experiments

Experiment	Grid Type	Runoff Forcing	Grid spacing
CS510C	Cube-Sphere	Climatological	~19 km
CS510R	Cube-Sphere	JRA55-do	~19 km
LLC90C	Lat-Lon-Cap	Climatological	55–110 km
LLC90R	Lat-Lon-Cap	JRA55-do	55–110 km
LLC270C	Lat-Lon-Cap	Climatological	18–36 km
LLC270R	Lat-Lon-Cap	JRA55-do	18–36 km
LLC540R	Lat-Lon-Cap	JRA55-do	9–18 km

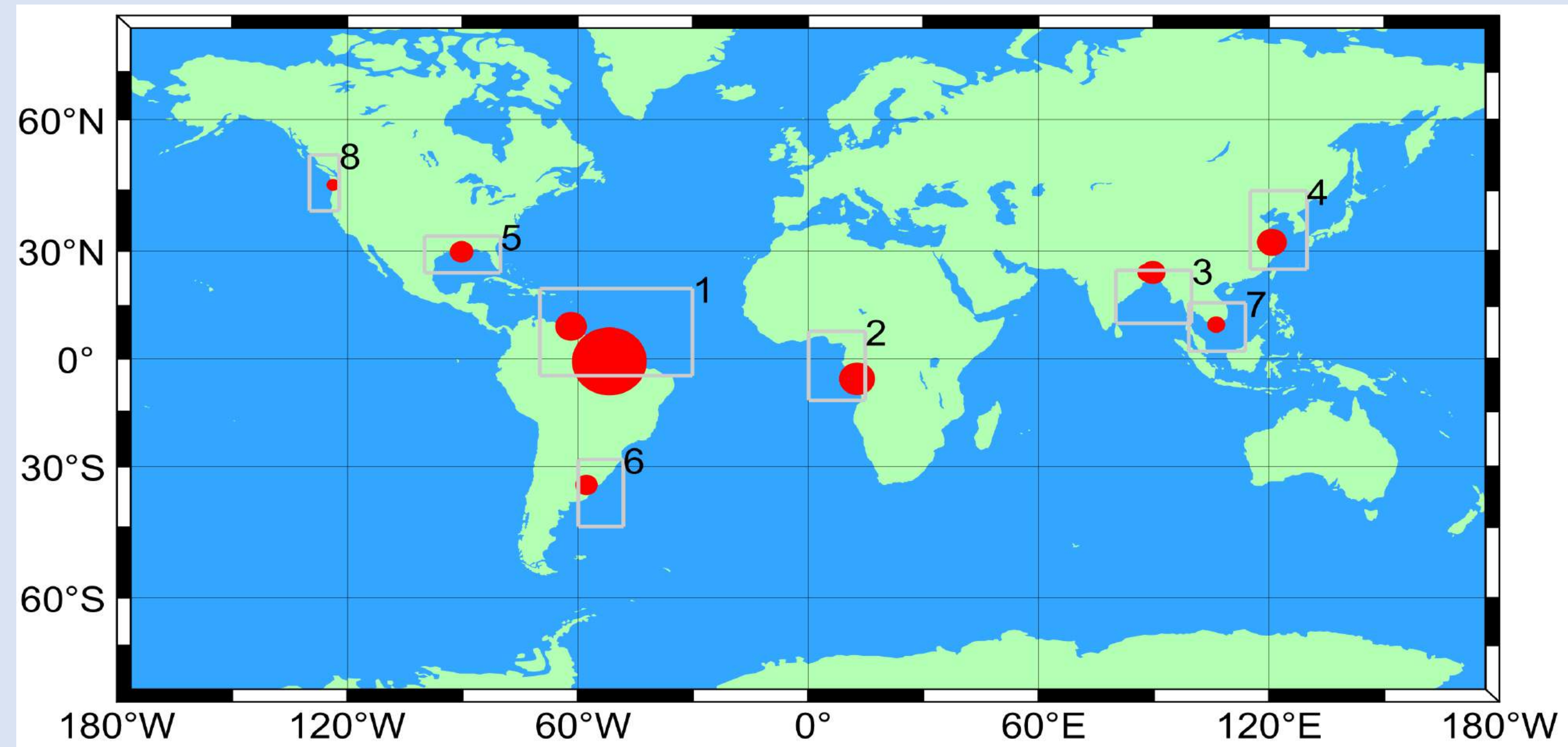
The sensitivity experiments can be divided in three groups:

Group 1: Sensitivity to realistic river forcing
CS510C, LLC90C, and LLC270C use climatological runoff while CS510R, LLC90R, LLC270R, and LLC540R use realistic runoff.

Group 2: Sensitivity to the model grid spacing
LLC90R, LLC270R, and LLC540R have nominal horizontal grid spacing of 1°, 1/3°, and 1/6°, respectively.

Group 3: Sensitivity to the model grid type
CS510R uses a cube-sphere grid (Menemenlis et al. 2005), while LLC540R uses a latitude-longitude-polar cap grid (Forget et al. 2015).

Regional Analysis



We focus on 10 large rivers (flowing into 8 coastal regions): 1) Amazon and Orinoco, South America, 2) Congo, Africa, 3) Changjiang, Asia, 4) Ganges and Brahamptura, Asia, 5) Mississippi, North America, 6) Parana, South America, 7) Mekong, Asia, 8) Columbia, North America. Red circles are scaled by net river discharge.

RMSD between simulated and observed (SMAP) Sea Surface Salinity (SSS)

	CS510R		CS510C		LLC270R		LLC270C		LLC90R		LLC90C		LLC540R	
	RM	PE	RM	PE	RM	PE	RM	PE	RM	PE	RM	PE	RM	PE
Amazon / Orinoco	5.6	1.8	14.5	2.0	4.3	1.6	9.2	1.6	12.4	1.4	12.7	1.6	6.7	1.7
Congo	3.0	0.9	4.4	0.8	4.0	0.9	4.1	0.8	3.2	0.9	4.2	0.8	3.9	0.9
Changjiang	4.2	0.9	8.6	1.1	5.1	1.5	7.9	1.6	5.8	1.9	8.3	1.9	4.0	1.5
Ganges / Brahamptura	6.6	3.5	8.4	3.4	6.1	3.2	7.9	2.9	5.6	3.7	8.8	3.6	5.0	3.3
Mississippi	2.9	1.3	3.4	1.3	2.3	1.3	3.3	1.2	2.3	1.3	3.3	1.3	3.0	1.2
Parana	4.2	2.5	8.1	4.7	5.7	3.7	5.5	3.2	6.3	3.9	7.9	4.5	4.2	2.7
Mekong	5.2	1.4	1.5	1.2	4.7	1.9	1.6	1.2	1.4	0.9	1.5	0.8	1.7	0.9
Columbia	3.1	0.9	3.9	1.2	2.9	0.6	3.3	0.6	3.1	0.9	3.5	0.9	2.9	0.8

Model-data Root Mean Square Difference (RMSD) is computed for 9 model grid cells near the River Mouth (RM) and eight model grid cells in the Plume Extension (PE).

Conclusions

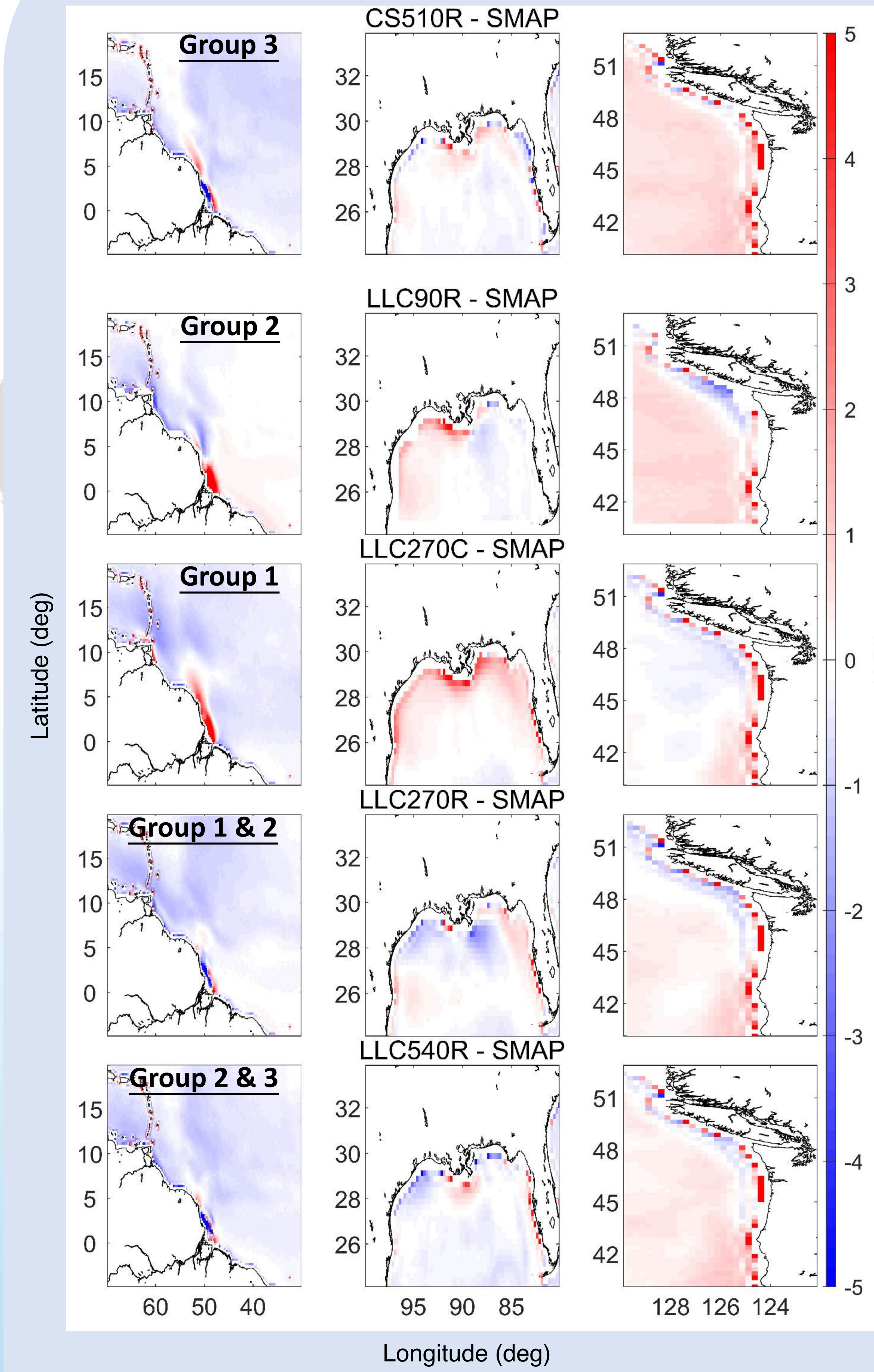
We explored the sensitivity of modeled river plumes to: 1) realistic runoff, 2) model grid spacing, and 3) model grid type. For all sensitivity experiments, the impacts are primarily local. When compared with the Soil Moisture Active Passive (SMAP) satellite observations from Apr. 2015 to Dec. 2017, we found that:

- SSS near the mouth of large rivers improved greatly when using realistic river forcing
- SSS improved greatly when decreasing nominal grid spacing from 1° to 1/3°, but there was minimal improvement when further decreasing grid spacing to 1/6°
- Model grid type had a negligible impact on SSS for coastal rivers in tropical and temperate zones.

These results are an important first step towards predicting land-ocean-atmosphere feedbacks seamlessly in next-generation earth system models.

References:
Menemenlis, D. et al. (2005). Mon. Weather Rev., doi:10.1175/MWR2912.1
Stammer, D. (2004). J. Geophys. Res-Oceans, doi:10.1029/2003JC002082
Forget, G. (2015). Geosci. Model Dev., doi:10.5194/gmd-8-3071-2015
Tsujino (2018). Ocean Modelling, doi:10.1016/j.ocemod.2018.07.002

Models vs. Observations



Sea Surface Salinity (SSS) difference between model simulations and Soil Moisture Active Passive (SMAP) observations for large (Amazon, left column), middle (Mississippi, middle column), and small (Columbia, right column) rivers.

Group 1 experiments: LLC270C SSS is higher than SMAP, but lower in LLC270R for the Amazon and Mississippi. The RMSD near river mouths is smaller when using realistic forcing, where runoff exceeds precipitation as the dominant freshwater source.
Group 2 experiments: Results improve greatly when increasing grid spacing from LLC90 to LLC270; however, no further improvement is obtained when using LLC540;
Group 3 experiments: No substantial difference between the two runs. The model grid type may impact Arctic and Antarctic rivers; further analysis is needed to quantify this effect.